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Title : **Calibration Test Sites Selection and Characterisation**
WP 230 - Site characterisation from climatological dataset

Abstract : This document describes the geophysical properties relevant to vicarious calibration.

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GLOSSARY

The Glossary contains definitions of acronyms, abbreviations and terms used throughout the document.

AAOT	Acqua Alta Oceanographic Tower
BOUSSOLE	BOUée pour l'acquiSition de Séries Optiques à Long termE
BRDF	Bi-directional Reflectance Distribution Function
BRF	Bi-directional Reflectance Function
Cal/Val	Calibration and Validation
CEOS	Committee on Earth Observation Satellites
ENVISAT	ENVIronment SATellite
EO	Earth Observation
ESA	European Space Agency
ITT	Invitation To Tender
IVOS	Infrared and Visible Optical Sensors
LES	Land Equipped Site
LNES	Land Non Equipped Site
MAVT	MERIS & AATSR Validation Team
MERIS	Medium Resolution Imaging Spectrometer
MOBY	Marine Optical Buoy
PMP	Project Management Plan
Q1, Q2,Q3, Q4	Quarter 1, 2, 3 and 4
RMS	Root Mean Square
RT	Radiative Transfer
RTC	Radiative Transfer Code
Sentinel	Family of ESA spacecrafts
SES	Sea Equipped Site
SNES	Sea Non Equipped Site
SOW	Statement Of Work
TBC	To Be Confirmed
TBD	To be Defined
TOA	Top Of Atmosphere
VIS	Visible
VOS	Visible Optical Sensors
WGCV	Working Group on Calibration and Validation
WP	Work Package

AMENDMENT POLICY

This document shall be amended by releasing a new edition of the document in its entirety. The Amendment Record Sheet below records the history and issue status of this document.

AMENDMENT RECORD SHEET

ISSUE	DATE	DCI No	REASON
A	10 Feb 2009	N/A	Initial Issue
B	30 April 2009		Final version

1. INTRODUCTION

1.1 Overview of the project: purpose and scope

This study is part of the ESA strategy for ensuring the quality (calibration, validation and operational quality) of data developed for current and future missions within the Explorers and GMES framework.

The scope of the project is to select, identify and characterise reference test sites that will be used for the calibration and characterisation of different sensor types. The characteristics of the sites that will be provided at the end of this study will be incorporated in the Cal/Val portal.

The project is composed of four tasks.

- The first task (WP100) aims at identifying the needs per sensors in terms of external (vicarious) calibration.
- The second task (WP200) aims at identifying and, characterising remote test sites that can be used for external calibration according to the needs previously described in WP 100.
- The third task (WP300) will perform the synthesis adapted to Sentinels satellites. The output of this task will help ESA in the definition of the strategy for external calibration of Sentinel instruments.
- The fourth task aims at giving ESA the support for the integration of identified sites into the ESA Cal/Val portal.

WP 100 is achieved and documented in RD.18. This document is a part of WP 200.

1.2 Objectives of the WP 200: “Identification and characterisation of remote test sites”

WP 200 aims at identifying and characterising the reference test sites used for vicarious calibration of sensors belonging to the sensor class 2 or 3[1], which are defined in RD.18.

For this, several steps are chaining in order to affine the characterisation, then the choice of reference test sites.

- In WP 210, the reference test sites used for vicarious calibration have been identified, and classified based on their intrinsic properties.
- WP 220 reviews the calibration methods used and identifies the appropriate sites, respectively for the radiometric (WP 221), geometric (WP 222), spectral (WP 223) and image quality (WP 224) aspects.
- WP 230 assesses the adequacy of the choice criteria of the sites in order to identify sites that minimize the source of errors in the calibration process.
- The objective of WP 240 is to collect information about available site equipment and required auxiliary data to lead correct calibration processes.
- WP 250 objective is to study the interest of grouping some sites presenting same characteristics in order to answer to technical requirements, limit efforts of coordination or ensure homogenised maintenance …

[1] *Class 2 is low spatial resolution sensors, class 3 is high spatial resolution sensors.*

- An error budget for four calibration sites is made in WP 260, accounting for surface and parameters.

Output of WP 200 will be used in WP 300 in order to define a strategy for vicarious calibration of the Sentinel mission (Figure 1).

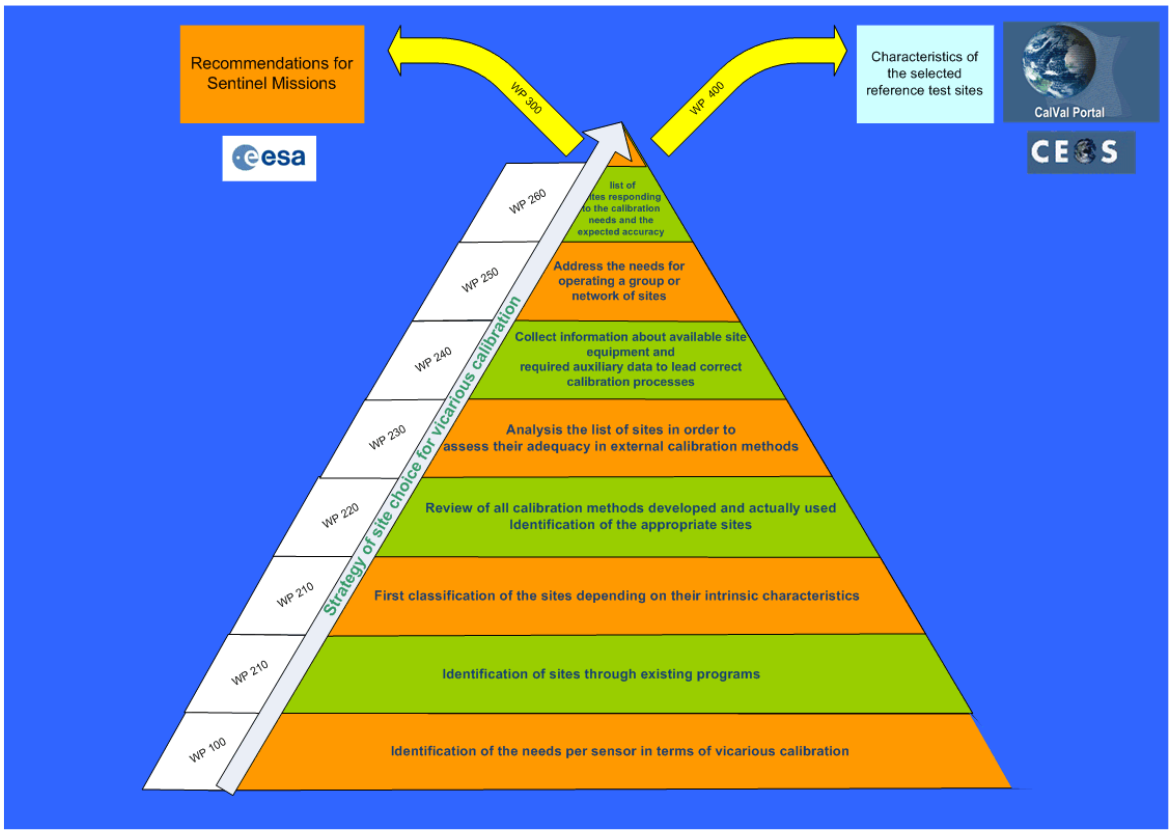


Figure 1: WP 200 activities for defining the vicarious calibration strategy used for S2/S3 sensors.

1.3 Objectives of the WP 230: Analysis of the sites in order to assess their adequacy in external calibration methods

The objectives of the Work Package are to characterise the calibration sites in order to assess their adequacy in external calibration methods. This adequacy is analysed with respect to selection criteria, based on the analysis of the spatial and temporal variability of the atmospheric constituents and their optical properties, as well as the spatial and temporal variability of surface properties. Both land and ocean sites are analysed. At the end, a classification is done, in order to select the sites which minimize the source of errors in the calibration process.

2. SITE EVALUATION

2.1 Introduction

In WP210 and WP 220, we have identified four classes of sites and defined the calibration method to be used for each of them.

For reminder, the sites have been classified in fours classes, which are:

- LES : Land Equipped Sites,
- LNES : Land Non Equipped Sites,
- SES : Sea Equipped Sites,
- SNES : Sea Non Equipped Sites.

The location in latitude and longitude of the sites has been provided for each of the classes in the RD.19. Site location is displayed on Figure 2.

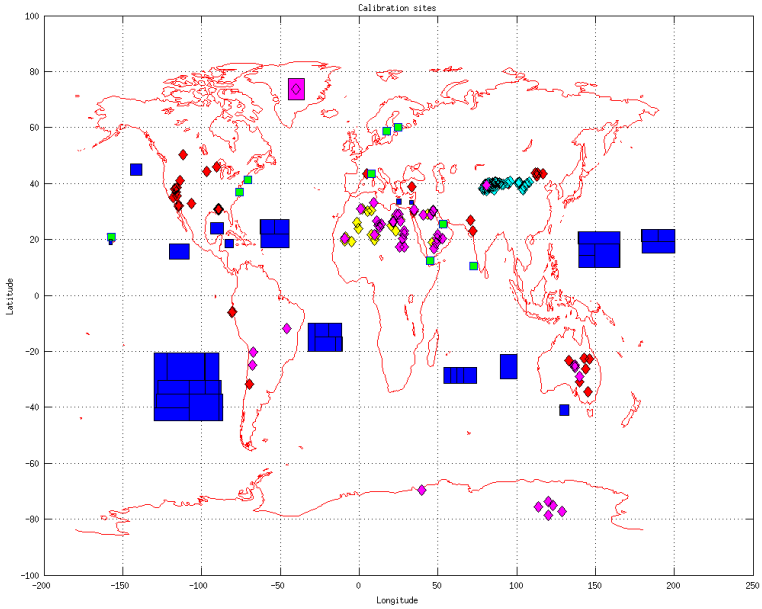


Figure 2: Site location. Oceanic sites (SES and SNES) are represented with green and blue squares, Land sites (LNES and LES) are represented with diamonds. Yellow, pink, and cyan colors are for the sub group of LNES[2]: desert, china, others respectively, red color is for LES.

All the sites identified in this study have been used temporary for the time of calibration campaign or are used routinely for sensor vicarious calibration. We saw that there are sites or group of sites that are **systematically** used, either they are equipped or not, over land or ocean, and that there are sites that are used **occasionally**, or sites that have been listed as potential sites.

The analysis made in the WP aims at being independent of these uses. The classification is based only on statistical analysis.

[2] Sub classes have been defined for the LNES corresponding to the 20 desert sites (Cosnefroy et al., 1998, RD.25), the 38 sites identified in china (Wu and Zhong, 1999, RD.20), the others.

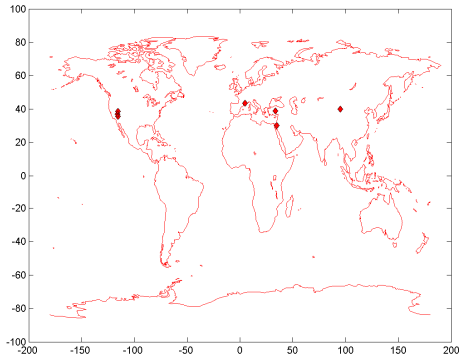
2.1.1 LES

2.1.1.1 CEOS reference test sites

Table 1: CEOS reference test site

List	Location

LES	Site Name	Country
CEOS site	La Crau	France
CEOS site	Railroad Valley Playa	USA
CEOS site	Ivanpah playa	USA
CEOS site	Frenchman Flat	USA
CEOS site	Negev	Israel
CEOS site	Tuz Gulu	Turkey
CEOS site	Dunhuang	China
CEOS site	Dome C cnes	Antarctica

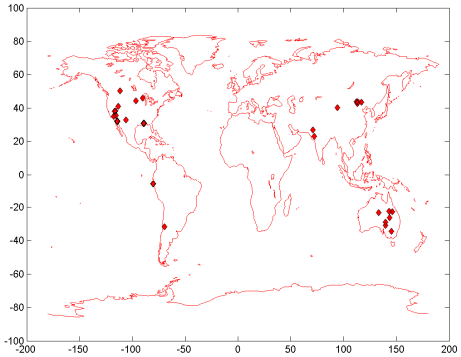


2.1.1.2 Other LES

Table 2: Other LES test site list

List	Location

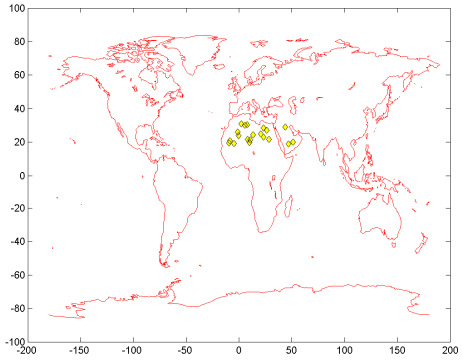
LES Site Name	Country
Lunar playa	USA
White Sands	USA
Roger Dry Lake	USA
Bonneville Salt Flats	USA
Brookings	USA
Lake Frome	Australia
Tinga Tingana	Australia
Dunrobin	Australia
Warrabin	Australia
Winton	Australia
Amburla	Australia
Barreal Blanco	Argentina
Sonoran desert	USA
Sechura desert	Peru
Hay _Uardry	Australia
Perkingston, Gravel Pits MS, USA	USA
Park Falls, WI, USA	USA
Jaisalmer, Inde	India
Chhrodi (Tarp) India	India
RoachLakePlaya	USA
Mud_Lake	USA
Gongger	China
Erlian	China
Zuoqi	China
Youqi	China
Wiggins- Gravel pits - USA	USA
Wiggins- Rye Field - USA	USA
Wiggins- Cut Grass - USA	USA
Newell, Canada	Canada
Wiggins West tarp	USA
Yuma (Sonoran)	USA
Sonoran_RAL	USA
Brookings_2	USA
Sechura_RAL	Peru
Dunhuang_RAL	China



2.1.2 LNES

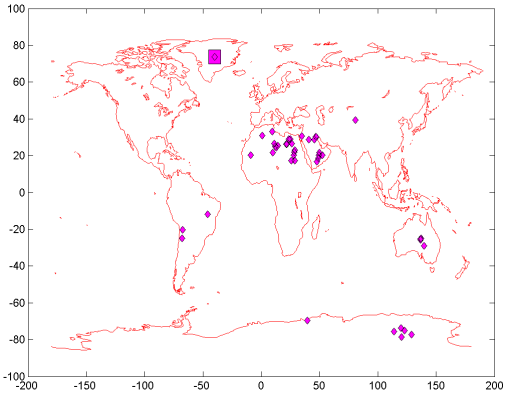
2.1.2.1 LNES included in CNES SADE database

Table 3: SADE test site

List			Location
Label	**Site Name**	**Country**	
SADE	**Algeria 1**	Algeria	
	Algeria 2	Algeria	
	Algeria 3	Algeria	
	Algeria 4	Algeria	
	Algeria 5	Algeria	
	Arabia 1	Arabia	
	Arabia 2	Arabia	
	Arabia 3	Arabia	
	Egypt 1	Egypte	
	Libya 1	Lybia	
	Libya 2	Lybia	
	Libya 3	Lybia	
	Libya 4	Lybia	
	Mali 1	Mali	
	Mauritania 1	Mauritania	
	Mauritania 2	Mauritania	
	Niger 1	Niger	
	Niger 2	Niger	
	Niger 3	Niger	
	Sudan 1	Sudan	

2.1.2.2 LNES others

Table 4: Others LNES test sites

List			Location
Label	**Site Name**	**Country**	
Desert	**Algeria 5 -RAL**	Algeria	
	Libya 1 RAL	Lybia	
	Libya 2 RAL	Lybia	
	Sudan RAL	Sudan	
	Libya _1_NOAA (Site 1)	Lybia	
	Libya _1_NOAA (site 2)	Lybia	
	Egypt1_NOAA	Egypte	
	Lybia 4 NOAA	Lybia	
	Mauritania_3 (Landsat)	Mauritania	
	Lybie2_USGS (Site1)	Lybia	
	Irak_USGS (Site1)	Irak	
	Tunisia_MSG	Tunisia	
	Lybie2_USGS (Site2)	Lybia	
	Irak_USGS (Site2)	Irak	
	Egypt_2	Egypte	
	Yemen 1	Yemen	
	Mahktesh_Ramon	Israel	
	Lybie	Libya	
	Australia_1	Australia	
	Australia_2	Australia	
	Australia_3	Australia	
	Australia_4	Australia	
	Taklamakan	China	
	Arabia 4	Arabia	
	Arabia 5	Arabia	
	Arabia 7	Arabia	
	Arabia 8	Arabia	
	Arabia 9	Arabia	
	UAE 1	Arabia	
	Sudan 2	Sudan	
	Sudan 3	Sudan	
	Sudan 4	Sudan	
	Niger 4	Niger	
Label	**Site Name**	**Country**	
Snow/Ice	**Dome_1**	Antarctica	
	Dome_2	Antarctica	
	Dome_3	Antarctica	
	Dome CAATSR	Antarctica	
	Greenland	Danemark	
	Antarctica	Antarctica	
Salar	**Salar de Uyuani**	Bolivia	
	Salar de Arizaro	Argentina	
Crop	**Brazil Bahia site**	Brazil	

2.1.2.3 LNES china group of sites

Table 5: China potential LNES test site

List	Location

Label	Site Name	Country
China 38 sites	China_1	China
	China_2	China
	China_3	China
	China_4	China
	China_5	China
	China_6	China
	China_7	China
	China_8	China
	China_9	China
	China_10	China
	China_11	China
	China_12	China
	China_13	China
	China_14	China
	China_15	China
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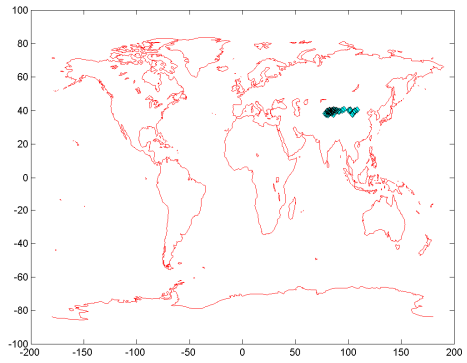
	China_37	China
	China_38	China

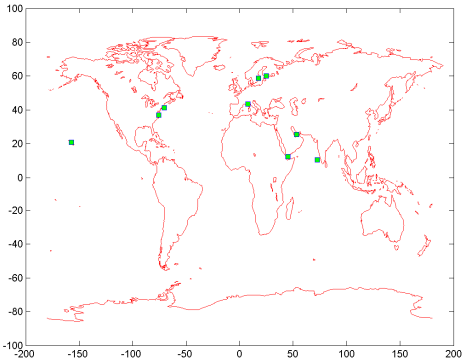


2.1.3 SES

Table 6: SES test site

List	Location

Site Name	Ocean
Boussole	Mediterannée
MOBY	Pacific
Venice (Aeronet_AC)	Mediterannée
Abu_Al_Bukhoosh (Aeronet_AC)	Oman
COVE_SEAPRISM (Aeronet_AC)	Atlantique
Gustav_Dalen_Tower (Aeronet_AC)	
Helsinki_Lighthouse (Aeronet_AC)	
MVCO (Aeronet_AC)	Atlantic
Kavaratti OCM	Indian

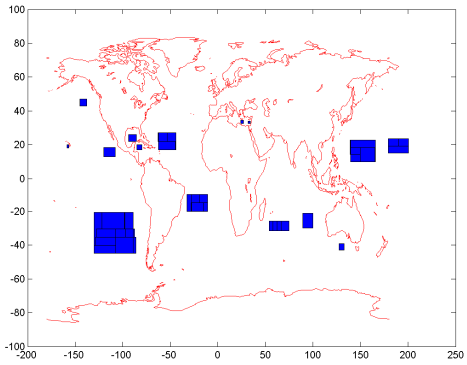


2.1.4 SNES

Table 7: SNES test site

List	Location

Site Name	Ocean
PacSE	Pacific
PacSE-0	Pacific
PacSE-1	Pacific
PacSE-2	Pacific
PacSE-3	Pacific
PacSE-4	Pacific
PacSE-5	Pacific
PacSE-6	Pacific
PacSE-7	Pacific
PacNW	Pacific
PacNW-0	Pacific
PacNW-1	Pacific
PacNW-2	Pacific
PacNW-3	Pacific
PacN	Pacific
PacN-0	Pacific
PacN-1	Pacific
PacN-2	Pacific
Hawai	Pacific
GuAlas	Pacific
AtlN	Atlantique
AtlN-0	Atlantique
AtlN-1	Atlantique
AtlN-2	Atlantique
AtlS	Atlantique
AtlS-0	Atlantique
AtlS-1	Atlantique
AtlS-2	Atlantique
AtlS-3	Atlantique
AtlS-4	Atlantique
MedCr	Mediterannée
MedCy	Mediterannée
GuMex	GulfeMexico
GuYuc	GulfeMexico
IndS	Indian
MadE	Indian
MadE-0	Indian
MadE-1	Indian
MadE-2	Indian
MadE-3	Indian
DoCoRi	Pacific



2.2 Data

The site classification is based on the site climatologic properties. For the analysis, we used global monthly dataset (level 3 data), i.e. gridded point geophysical products on a multi-pass basis, or resampled products.

These dataset used for the characterisation are listed in Table 8. They are classified in three groups:

- Dataset characterising the atmosphere that are common to land and ocean,
- Dataset characterising the ocean,
- Dataset characterising the land.

Table 8: Source and list of data used in the analysis. Crosses indicate that the variables has been analysed, pink cases indicate that the content origin is not climatological (see questionnaires), grey cases indicate that the data analysis is not relevant.

	Data Name	LES	LNES	SES	SNES	Data Source
Atmosphere	Cloud cover	x	x	x	x	MODIS L3
	Optical depth at 550 nm		x		x	MODIS L3
	Angstroem exponent over Land 0.47-0.66		x			MODIS L3
	Angstroem exponent over Ocean 0.55-0.865		x		x	MODIS L3
	Ozone O3	x	x	x	x	MODIS L3
	Water vapour H20	x	x	x	x	MODIS L3
	Precipitation	x	x			GPCP
	Wind Speed			x	x	Quicksat
Land	Altitude	x	x			Google earth
	Black Sky Albedo BSA		x			MODIS L3
	White Sky Albedo WSA		x			MODIS L3
	NDVI		x			MODIS L3
	BSA/WSA		x			MODIS L3
	Size	x	x			Literature
Ocean	Normalised Radiance 412 nm				x	MERIS L3
	Normalised Radiance 443 nm				x	MERIS L3
	Normalised Radiance 490 nm				x	MERIS L3
	Normalised Radiance 510 nm				x	MERIS L3
	Normalised Radiance 560 nm				x	MERIS L3
	Chlorophyll-a content				x	MERIS L3
	Attenuation 490 nm				x	MODIS L3
	Size			x	x	Literature

2.3 Method

2.3.1 Statistics

A number of statistical parameters is computed from the analysis of the climatological data.

This includes:

- Mean,
- Standard deviation,
- Minimum,
- Maximum,
- Difference (Maximum-Minimum), used for analysing the dynamics over the season
- Ratio of normalised difference (Maximum-Minimum)/Mean,
- Coefficient of variation (CV). CV is a normalised measure of the dispersion.

The statistical analysis is conducted on a set of data characterising the surface and atmosphere state in order to classify the sites according to established criteria and assess the impact of the temporal, spatial or spectral variability of the variables.

The retained criteria are explained in the next sections for each of the studied variables.

The analysis is conducted for each class of sites, and the results are analysed and reported for each variables.

2.3.2 Example of data analysis

2.3.2.1 Step 1: Analysis of the spatial variability of the products

We provided an example of the method used to analyse the spatial and temporal variability of each dataset. The analysis is conducted on Chlorophyll-a content extracted from MERIS Level 3 products. The site chosen is PacSE area.

For each site and for each month, standard statistics are computed for the area. For instance, Chlorophyll-a content for the PacSE zone in January is represented in Figure 3 and the temporal variability of the area for 2007 represented in Figure 4. A latitudinal gradient is observed, with higher values in the south. White areas are areas where no valid pixels are available over the month, probably due to a permanent cloud presence.

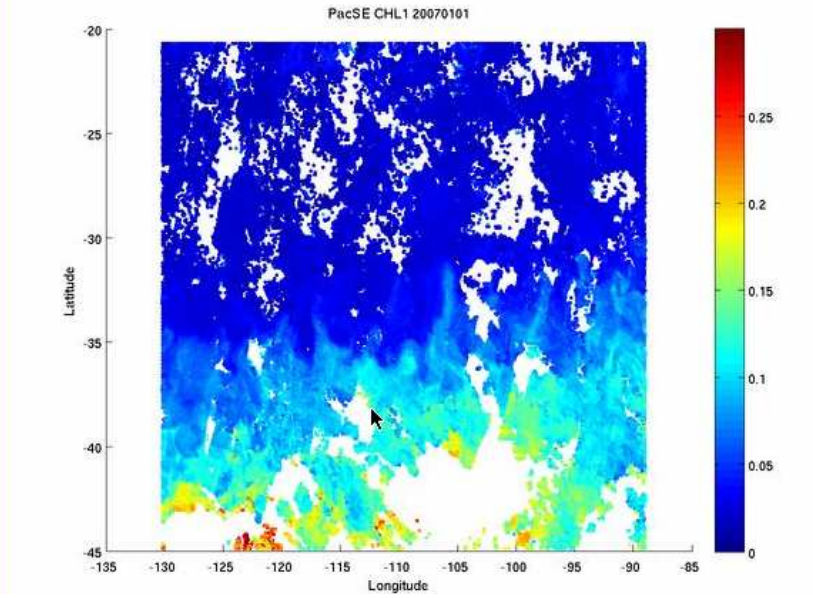


Figure 3: Chlorophyll-a content in January 2007. Units mg/m3.

The gradient is observed over the twelve months, with lower values in the north of the area (0.05 mg/m3), and highest values in the south (0.1mg/m3). North east part of the site is the most stable.

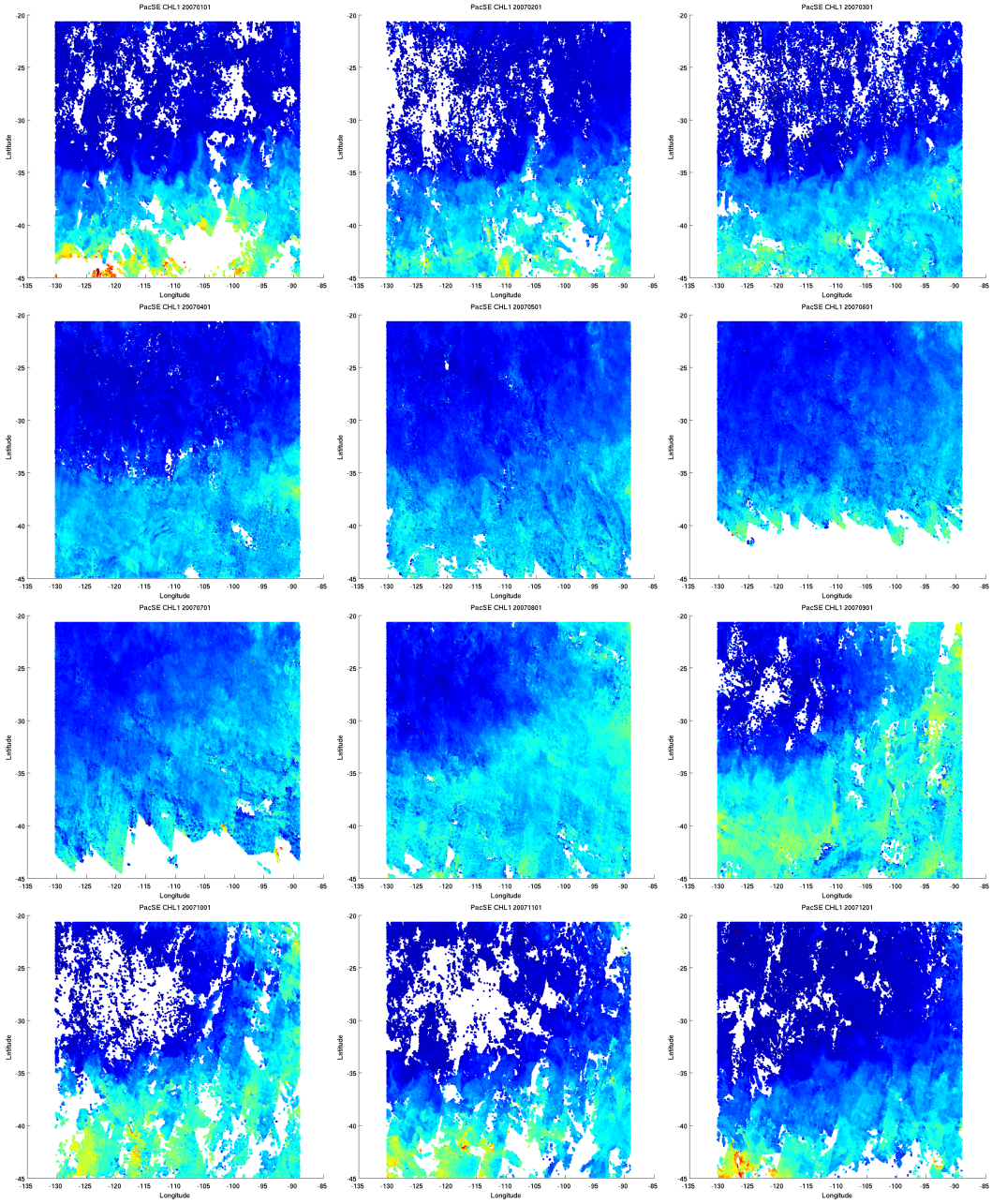


Figure 4: Temporal variability of chlorophyll a content for PacSE zone. Line of images corresponds to Q1, Q2, Q3, and Q4 respectively.

The standard statistics associated to images are compiled in a one table (Table 9 is an example for this site).

Table 9: Statistics for chlorophyll a products for 2007

Month	Year	Number of pixels	Mean	Standard deviation	Minimum	Maximum
1	2007	120046	5.6508e-02	4.4309e-02	1.00e-02	3.3687
2	2007	120046	5.8969e-02	3.7545e-02	1.00e-02	0.6503
3	2007	120046	6.6133e-02	3.6350e-02	1.00e-02	0.2431
4	2007	120046	5.8365e-02	3.3025e-02	1.00e-02	3.2158
5	2007	120046	6.1555e-02	2.8008e-02	1.00e-02	1.4702
6	2007	120046	6.3073e-02	2.5930e-02	1.00e-02	1.1456
7	2007	120046	7.2441e-02	2.9448e-02	1.00e-02	3.3745
8	2007	120046	8.1662e-02	3.1382e-02	1.00e-02	0.7497
9	2007	120046	9.0712e-02	1.0423e-01	1.00e-02	30.221
10	2007	120046	8.2247e-02	4.2860e-02	1.00e-02	0.3030
11	2007	120046	6.1368e-02	4.4081e-02	1.00e-02	2.5447
12	2007	120046	5.1153e-02	7.2596e-02	1.00e-02	10.0863

A histogram of the data distribution are computed and conserved for each site (Figure 5).

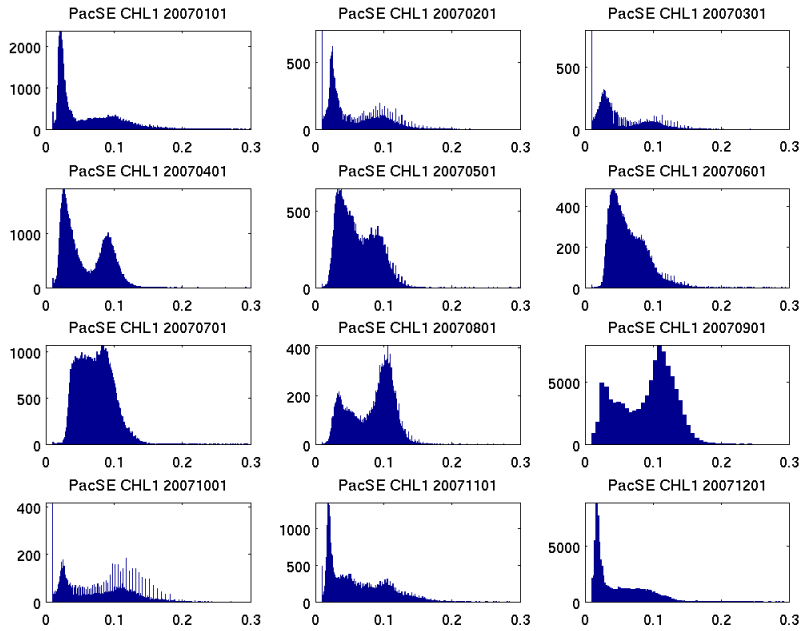


Figure 5: Histogram of CHL1 products for each month. X scale is set to [0-0.3] mg/m3.

2.3.2.2 Step 2: Analysis of temporal variability

For each site, the annual variability is analysed. The mean of monthly values is computed and the associated statistics (standard deviation, etc) are derived around the mean value. This monthly variability is represented for each site (Figure 6).

For this site, the variability is low, and the standard deviation almost at the same level, except for one month (September) where the standard deviation is high due to an observed maximum of 30 mg/m3 in the area (cf Table 9).

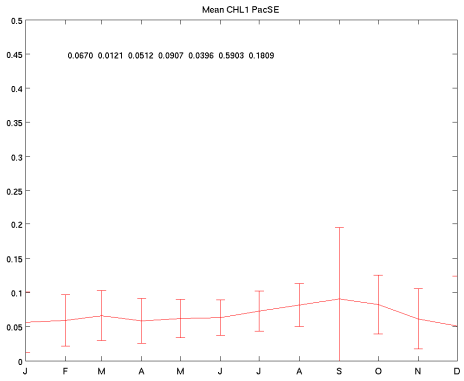


Figure 6: Monthly variability of mean CHL1 product for PacSE site. Bars represent the standard deviation around the mean for the specific date (Table 9). Numbers at the top represent: the mean of the monthly values, the standard deviation of this mean, the minimum and the maximum of the mean value, the difference normalised to the mean, and the coefficient of variation.

Table 10 provides the standard statistics for all sites.

Table 10: Statistics for monthly mean of chlorophyll a data

Site name	Annual Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
PacSE	0.0670	0.0121	0.0512	0.0907	0.0396	0.5903	0.1809

2.3.2.3 Step 3: Analysis for all sites

The temporal variability of all SNES is represented on Figure 7. Most of sites are contained in one envelop around 0.1 mg.m^{-3}, except a few sites for which the mean level is higher or sites with a pronounced seasonal cycle.

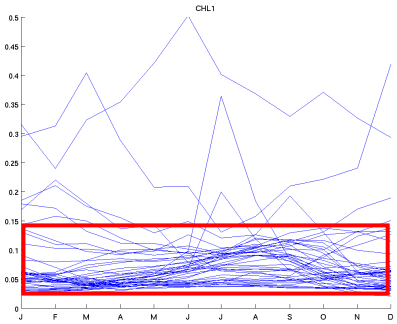


Figure 7: Superimposed temporal profiles of chlorophyll content for the SNES.

Figure 8 provides the seasonal variations of chlorophyll–a content site by site. The two sites that have the highest chlorophyll content are the Gulf Alaska and the Australian site. The maximum of chlorophyll content is around 0.5 $mg.m^{-3}$, reached in summer for Alaska site (North hemisphere) and winter in south hemisphere. The AtlN-0 site has a peak of chlorophyll content in summer, around 0.35 $mg.m^{-3}$. The other sites have a seasonal cycle less marked.

Figure 8: Temporal variability of chlorophyll content for the SNES. X axis scale is one year, from January to December. Y axis scale is 0.5.

The distribution of the chlorophyll-a content is represented on the following histograms (Figure 9) for each site.

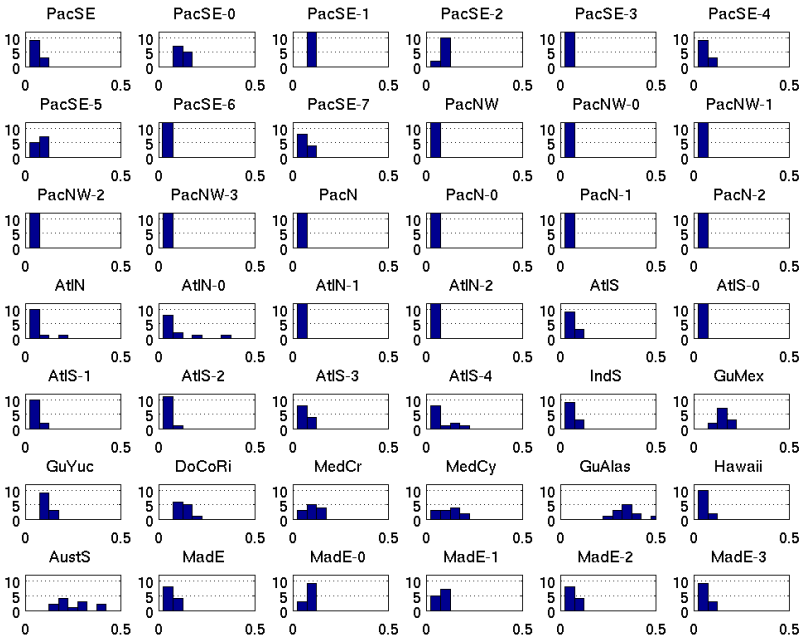


Figure 9: Histogram of the monthly mean chlorophyll content for the SNES.

2.3.2.4 Step 4: Site classification

The classification is based on the mean value of chlorophyll -1 content.

Table 11: Site classification based on the mean of CHL1

Rank	Site name	Mean		Rank	Site name	Mean
1	PacNW-1	0.0357		22	PacSE-4	0.0668
2	PacSE-6	0.0364		23	PacSE	0.0670
3	PacNW-0	0.0392		24	MadE	0.0678
4	PacNW	0.0397		25	Hawaii	0.0682
5	PacNW-3	0.0426		26	AtlS-3	0.0706
6	AtlS-0	0.0448		27	AtlN	0.0726
7	PacNW-2	0.0449		28	MadE-1	0.0761
8	PacSE-3	0.0451		29	AtlS-4	0.0791
9	AtlN-2	0.0462		30	PacSE-5	0.0838
10	PacN-0	0.0467		31	MadE-0	0.0864
11	PacN-1	0.0477		32	PacSE-2	0.0869
12	AtlS-1	0.0490		33	AtlN-0	0.0976
13	AtlN-1	0.0494		34	PacSE-1	0.1017
14	PacN	0.0508		35	GuYuc	0.1087
15	AtlS-2	0.0512		36	MedCr	0.1091
16	AtlS	0.0548		37	PacSE-0	0.1160
17	PacN-2	0.0550		38	MedCy	0.1192
18	MadE-3	0.0556		39	DoCoRi	0.1257
19	IndS	0.0564		40	GuMex	0.1545
20	PacSE-7	0.0618		41	AustS	0.2579
21	MadE-2	0.0647		42	GuAlas	0.3536

3. ANALYSIS OF ATMOSPHERE DATASET

The criteria used for the characterisation of the atmosphere are shared by the land and oceanic sites. The spatial and temporal variability of the atmospheric variables is analysed in order to assess the adequacy in terms of external calibration methods: The analysis is based on the following parameters:

- cloud cover,
- aerosol optical thickness,
- aerosol type,
- water vapour content,
- ozone content,
- precipitation,
- wind speed

3.1 Magnitude of Cloud cover

The analysis aims at quantifying the cloud cover over calibration sites (Table 12), knowing that the lower probability of cloud coverage the higher probability of the satellite instruments imaging the test site at the time of overpass.
The criterion defined here is to find the sites which to minimize the probability of cloudy weather.

Table 12: Criterion for cloud cover

Retained criteria	Studied parameters	Site type
Site visibility from space	Cloud cover	▪ LES ▪ SES ▪ LNES ▪ SNES

3.1.1 Dataset description

3.1.1.1 Dataset identification

Level-3 MODIS Atmosphere Monthly Global Product, MOD08_M3

3.1.1.2 Spatial Characteristics

3.1.1.2.1 Spatial Coverage

Coverage of the data sets is global, land and ocean surface.

3.1.1.2.2 Spatial Coverage Map

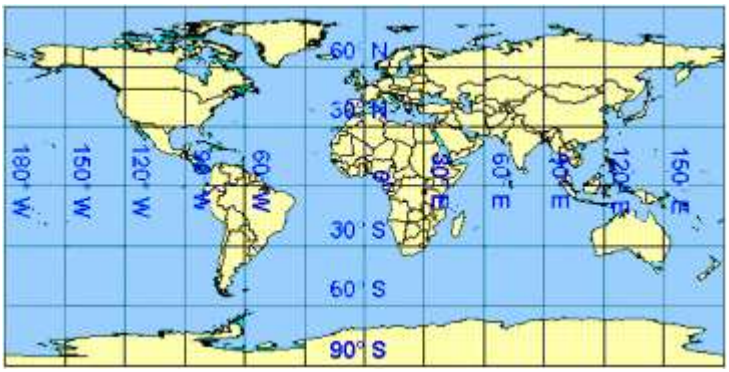


Figure 10: Spatial coverage map of MODIS level 3

3.1.1.2.3 Spatial Resolution

The MODIS Level 3 Atmosphere Products data set has been produced at a resolution of 1 degree in latitude and longitude. The grid cells are 1 degree by 1 degree, which means the output grid is always 360 pixels in width and 180 pixels in length.

3.1.1.3 Projection

The MODIS Level 3 Atmosphere Products data set has been produced on an equal angle lat-lon grid.

3.1.1.4 Temporal Characteristics

3.1.1.4.1 Temporal Coverage

Data sets cover January 2007 to December 2007.

3.1.1.4.2 Temporal Resolution

The Level 3 Monthly data set is available at a resolution of one month.

3.1.1.5 Data Characteristics

3.1.1.5.1 Parameter/Variable

Monthly cloud fraction is extracted from the Level-3 MODIS Atmosphere Monthly Global product (Hubanks et al., 2008, RD.30).

The product analysed is: **Cloud_Fraction_Day_Mean**

3.1.1.5.2 Variable Description/Definition

Statistics in the Monthly files are based on the set of L3 Daily pixels read from the L3 Daily input product files that cover the time period being summarized (1 month). Daily Cloud fraction at L3 is the number of cloudy L2 pixels divided by the total number of non-fill L2 pixels within a 1°× 1°L3 grid box.

The product is based on daytime retrieval only. Statistics are computed over a 1-degree equal-angle lat-lon. The simple statistics for monthly quantities include mean, standard deviation, and minimum and maximum values of the corresponding daily means (i.e., daily mean, daily QA mean).

3.1.1.5.3 Unit of Measurement

No units

3.1.1.5.4 Data Source

Product is derived from the Level-3 MODIS Atmosphere Daily Global Product.

3.1.1.5.5 Data Range

Cloud fraction varies between 0 and 1.

3.1.1.6 Sample Data Record

Dataset format is HDF. The specifications are provided at: http://modis-atmos.gsfc.nasa.gov/MOD08_M3/spec_c5.html

3.1.2 Analysis

3.1.2.1 Variability at global scale

Global temporal variations of monthly mean cloud fraction are represented on Figure 11. The maximum and the minimum of the mean are represented on Figure 12 and Figure 13.

Blue values indicate areas where the cloud fraction is lower than 50%. Yellow and red values indicate the areas where the cloud fraction is higher than 50%. Large areas over land and ocean have monthly cloud fraction less than 50%. These areas are quite stable and well located (Saharan desert, south Africa, West part of Australia, west part of South pacific).

Figure 11 confirms globally that the mean cloud fraction is less than 30 % over desert areas (Sahara, South Africa, Australia) and in a large area located in South Pacific. There is some seasonal variability, but cloud fraction seems to be the lowest over the year in these areas.

Figure 12 represents the maximum of the cloud fraction observed over each month. As expected, we can see that the maximum of the cloud fraction (blue part of the images) located over Sahara desert reaches 20-30 %, confirming that the areas are low cloudy. This maximum (blue task) lasts from June to December. On the contrary, Figure 13 highlights the areas that are never clear over a month period. These areas do not concern the calibration sites.

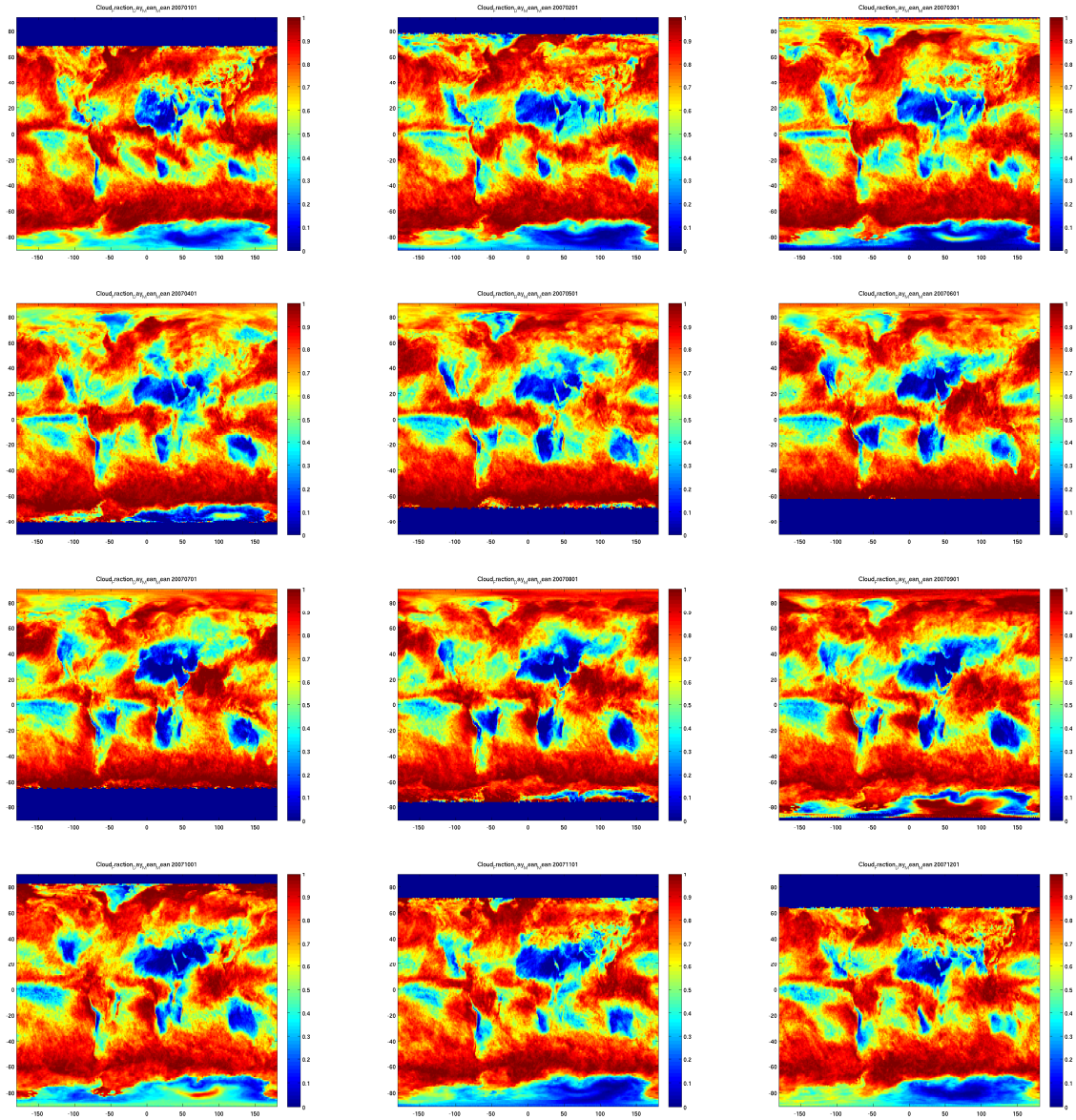


Figure 11: Monthly mean of cloud fraction (MOD08_M3). Line of images corresponds to Q1, Q2, Q3, and Q4 respectively. No Units.

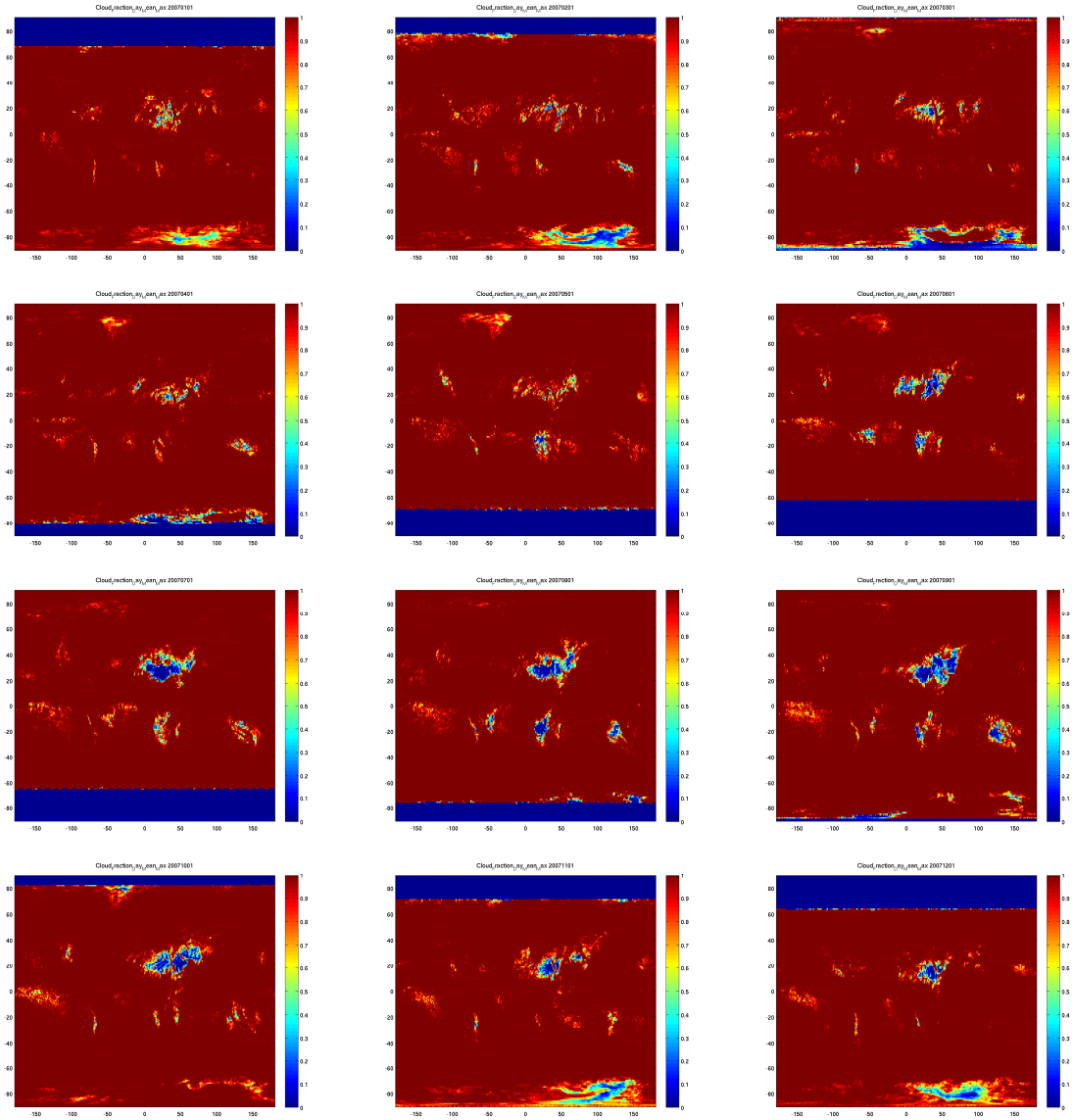


Figure 12: Maximum of monthly mean cloud fraction (MOD08_M3). Line of images corresponds to Q1, Q2, Q3, and Q4 respectively. No units.

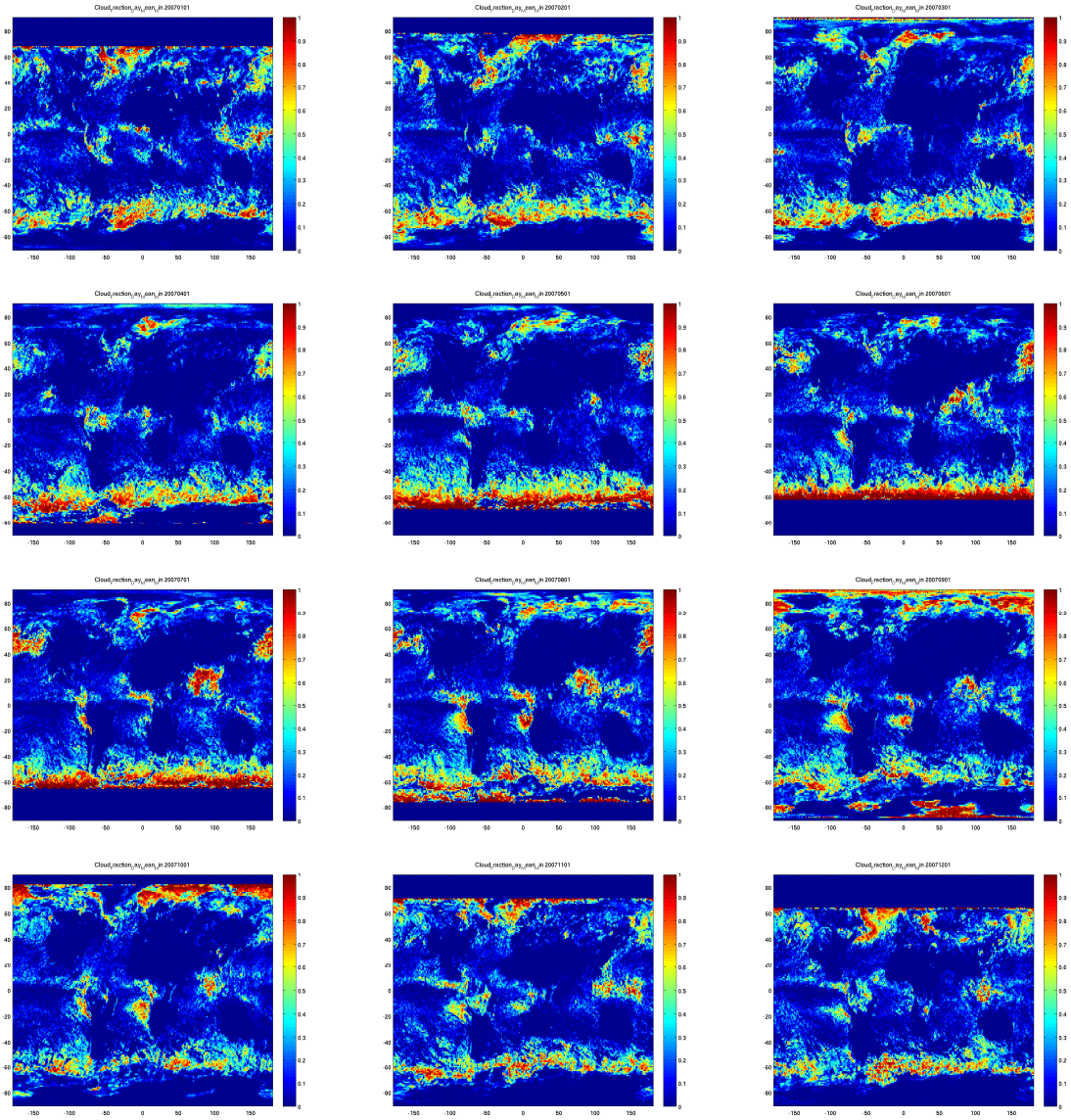


Figure 13: Minimum of monthly mean cloud fraction (MOD08_M3). Line of images corresponds to Q1, Q2, Q3, and Q4 respectively. No units.

3.1.2.2 Temporal variability over LNES

3.1.2.2.1 Statistics

Figure 14 represents the temporal variability of the mean cloud fraction of the 20 desert sites, and Figure 15 provides the temporal variability for each site. The annual mean varies between 5.8% (Soudan_1) and 27.6% (Mauritanie_1), indicating that the cloud fraction is low over the group of sites, even some seasonal variability appears (the maximum could reach 73% and the minimum 0%, Table 13. Figure 16 presents the distribution of cloud fraction over the year for each site. As expected, the two first bins of the histograms concentrate 75% of the data.

Two groups of sites are identified. The first one has the minimum cloud fraction between June and October whereas the second one (Mauritania, Mali) highlights the maximum in the period.

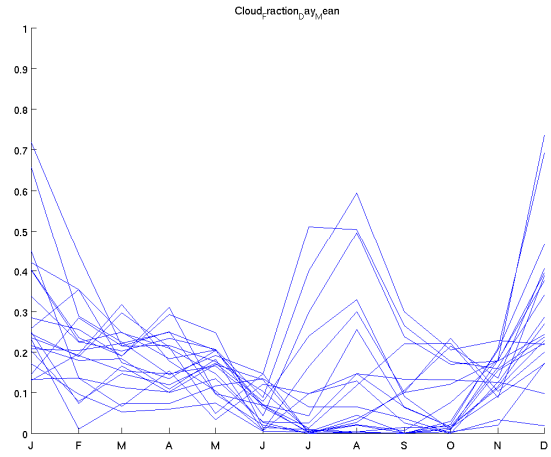


Figure 14: Superimposed temporal profiles of mean monthly cloud fraction for the LNES.

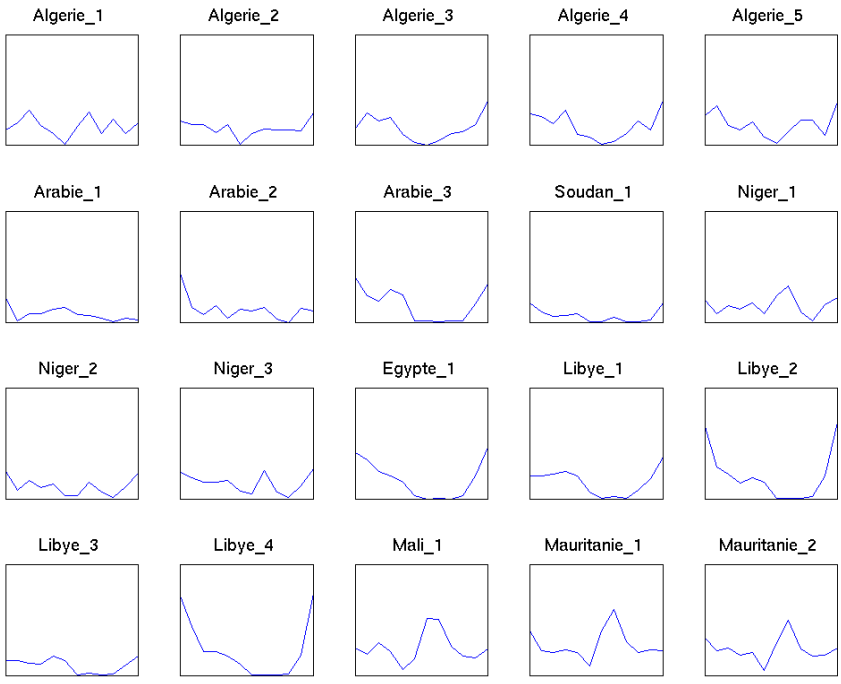


Figure 15: Temporal variability of monthly cloud fraction for the LNES. X axis scale is one year, from January to December. Y axis scale is 0-1.

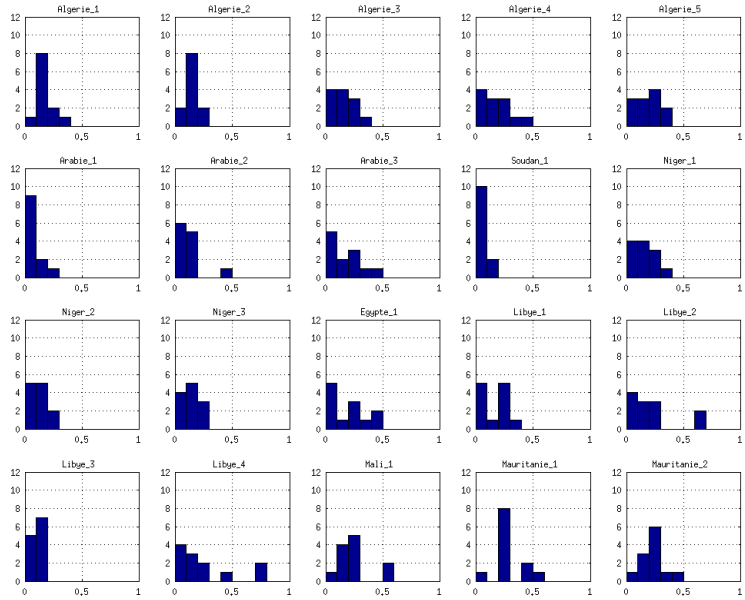


Figure 16: Histogram of monthly cloud fraction

Table 13: Statistics for cloud fraction products

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Algerie_1	0.1696	0.0883	0.0071	0.3167	0.3096	1.8259	0.5208
Algerie_2	0.1496	0.0691	0.0055	0.2859	0.2804	1.8737	0.4616
Algerie_3	0.1535	0.1177	0.0000	0.3954	0.3954	2.5753	0.7666
Algerie_4	0.1746	0.1234	0.0002	0.4052	0.4050	2.3189	0.7064
Algerie_5	0.1869	0.1119	0.0136	0.3880	0.3744	2.0035	0.5987
Arabie_1	0.0715	0.0648	0.0009	0.2324	0.2315	3.2355	0.9051
Arabie_2	0.1197	0.1152	0.0000	0.4513	0.4513	3.7700	0.9621
Arabie_3	0.1610	0.1461	0.0035	0.4046	0.4011	2.4907	0.9074
Soudan_1	0.0586	0.0616	0.0006	0.1727	0.1721	2.9373	1.0505
Niger_1	0.1536	0.0867	0.0095	0.3288	0.3193	2.0788	0.5645
Niger_2	0.1119	0.0770	0.0161	0.2504	0.2343	2.0929	0.6878
Niger_3	0.1437	0.0847	0.0154	0.2701	0.2547	1.7718	0.5894
Egypte_1	0.1757	0.1703	0.0000	0.4660	0.4660	2.6524	0.9695
Libye_1	0.1512	0.1161	0.0030	0.3761	0.3731	2.4672	0.7676
Libye_2	0.2149	0.2369	0.0001	0.6930	0.6929	3.2242	1.1025
Libye_3	0.0898	0.0648	0.0001	0.1706	0.1705	1.8990	0.7221
Libye_4	0.2337	0.2640	0.0001	0.7363	0.7362	3.1505	1.1298
Mali_1	0.2492	0.1366	0.0488	0.5108	0.4620	1.8537	0.5482
Mauritanie_1	0.2755	0.1327	0.0876	0.5937	0.5061	1.8369	0.4815
Mauritanie_2	0.2389	0.1089	0.0436	0.4962	0.4526	1.8943	0.4559

3.1.2.2.2 Results

Table 14 provides a classification of the sites based on the observed mean cloud fraction. Fourth column indicates the number of months where the cloud fraction is less than 20%.

Except Mali and Mauritania sites, the cloud fraction is very low for 6 months of the year, from May to October, indicating the good adequacy of the sites to monitor the sensor stability.

Table 14: Rank of sites based on the mean cloud fraction

Rank	Site name	Mean of monthly Cloud fraction	Number of months where CF < 20%
1	Soudan_1	0.0586	12
2	Arabie_1	0.0715	11
3	Libye_3	0.0898	12
4	Niger_2	0.1119	10
5	Arabie_2	0.1197	11
6	Niger_3	0.1437	9
7	Algerie_2	0.1496	10
8	Libye_1	0.1512	6
9	Algerie_3	0.1535	8
10	Niger_1	0.1536	8
11	Arabie_3	0.1610	7
12	Algerie_1	0.1696	9
13	Algerie_4	0.1746	7
14	Egypte_1	0.1757	6
15	Algerie_5	0.1869	6
16	Libye_2	0.2149	7
17	Libye_4	0.2337	7
18	Mauritanie_2	0.2389	4
19	Mali_1	0.2492	5
20	Mauritanie_1	0.2755	1

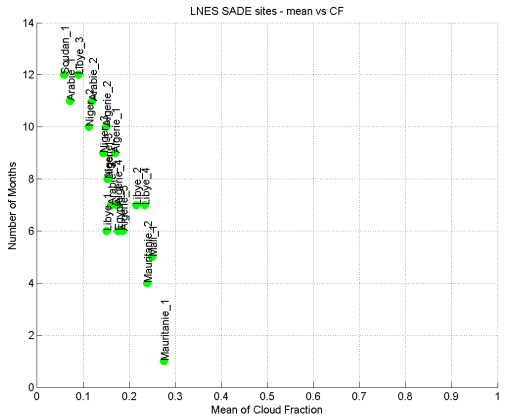


Figure 17 : Mean of CF versus number of months for which cloud fraction is lower than 20%

3.1.2.3 Temporal variability over LNES- others

3.1.2.3.1 Statistics

Five groups of sites with different characteristics are listed in Table 15, and analysed regards to their location. There are the sites covered by snow or ice, located in Antarctica and Greenland, the salars of South America, the sites used for CBERS calibration, desert sites of Taklamantan, another group of desert sites located in Saharan desert and Arabic desert, and small sites in Australia.

Antarctic sites have low cloud fraction in winter months (4 to 6 months where cloud fraction is lower than 10%), indicating the good visibility of the sites during winter period.

Desert sites have the same variability of the sites belonging to the SADE database, with a low minimum in summer, a low temporal variability

Two groups of sites are identified. The first one has the cloud fraction which reaches the minimum between June and October and the second one (Sudan sites and both salars) where the cloud fraction highlights a maximum during summer time.

Table 15: Statistics for cloud fraction products for LNES others group site

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Dome_1	0.2553	0.2476	0.0192	0.7560	0.7368	2.8857	0.9696
Dome_2	0.2760	0.2835	0.0172	0.7798	0.7626	2.7628	1.0270
Dome_3	0.2288	0.1998	0.0287	0.6413	0.6126	2.6780	0.8733
DomeC_AATSR	0.3198	0.3096	0.0259	0.9872	0.9613	3.0057	0.9681
Antarctica	0.6041	0.1115	0.3482	0.7210	0.3728	0.6172	0.1845
Greenland	0.4277	0.0928	0.2985	0.5302	0.2317	0.5417	0.2170
Salar_de_Uyuani	0.3633	0.2128	0.1297	0.6712	0.5415	1.4903	0.5856
Salar_de_Arizaro	0.1582	0.0765	0.0896	0.3353	0.2457	1.5530	0.4833
Brazil Bahia	0.4301	0.3218	0.0046	0.8686	0.8640	2.0088	0.7481
Taklamakan	0.5505	0.2205	0.2660	0.9433	0.6773	1.2303	0.4006
Algeria5-RAL	0.1831	0.0896	0.0310	0.2934	0.2624	1.4328	0.4892
Libya1-RAL	0.1512	0.1161	0.0030	0.3761	0.3731	2.4672	0.7676
Libya2-RAL	0.1241	0.0991	0.0021	0.2795	0.2774	2.2351	0.7988
Sudan-RAL	0.0712	0.0822	0.0003	0.2407	0.2404	3.3753	1.1540
Libya_1_NOAA	0.1523	0.1088	0.0147	0.3236	0.3090	2.0289	0.7144
Libya_1b_NOAA	0.1629	0.1228	0.0009	0.3807	0.3798	2.3313	0.7535
Egypt1_NOAA	0.1779	0.1829	0.0001	0.5069	0.5068	2.8489	1.0283
Lybia4_NOAA	0.2352	0.2497	0.0001	0.6607	0.6606	2.8087	1.0618
Mauritania_3	0.2359	0.1349	0.0306	0.5728	0.5422	2.2982	0.5719
Lybie2_USGS	0.1734	0.1650	0.0001	0.4801	0.4800	2.7679	0.9517
Irak_USGS	0.3036	0.2713	0.0037	0.7113	0.7076	2.3304	0.8935

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Tunisia_MSG	0.3043	0.1972	0.0210	0.6307	0.6097	2.0038	0.6480
Lybie2_USGS	0.1734	0.1650	0.0001	0.4801	0.4800	2.7679	0.9517
Irak_USGS	0.3036	0.2713	0.0037	0.7113	0.7076	2.3304	0.8935
Egypt_2	0.0839	0.1036	0.0000	0.3094	0.3094	3.6885	1.2347
Yemen_1	0.0635	0.0429	0.0000	0.1501	0.1501	2.3632	0.6755
Mahktesh_Ramon	0.2724	0.2737	0.0001	0.7145	0.7144	2.6230	1.0048
Lybie	0.2337	0.2640	0.0001	0.7363	0.7362	3.1505	1.1298
Arabia4	0.1656	0.1572	0.0004	0.4803	0.4799	2.8984	0.9492
Arabia5	0.2425	0.2680	0.0018	0.7928	0.7910	3.2617	1.1052
Arabia7	0.0943	0.0557	0.0000	0.1881	0.1881	1.9942	0.5904
Arabia8	0.1049	0.1032	0.0000	0.4057	0.4057	3.8663	0.9834
Arabia9	0.1125	0.0795	0.0000	0.3093	0.3093	2.7499	0.7068
UAE1	0.1082	0.1203	0.0000	0.4426	0.4426	4.0912	1.1120
Sudan2	0.0943	0.1096	0.0052	0.3860	0.3808	4.0400	1.1626
Sudan3	0.1202	0.1777	0.0000	0.4981	0.4981	4.1434	1.4783
Sudan4	0.0523	0.0531	0.0027	0.1385	0.1358	2.5945	1.0154
Niger4	0.1321	0.0709	0.0268	0.2390	0.2122	1.6061	0.5366
Australia_1	0.1841	0.1598	0.0064	0.6061	0.5997	3.2570	0.8681
Australia_2	0.1853	0.1640	0.0013	0.5779	0.5766	3.1119	0.8852
Australia_3	0.1853	0.1640	0.0013	0.5779	0.5766	3.1119	0.8852
Australia_4	0.3139	0.1172	0.0913	0.4758	0.3845	1.2250	0.3735

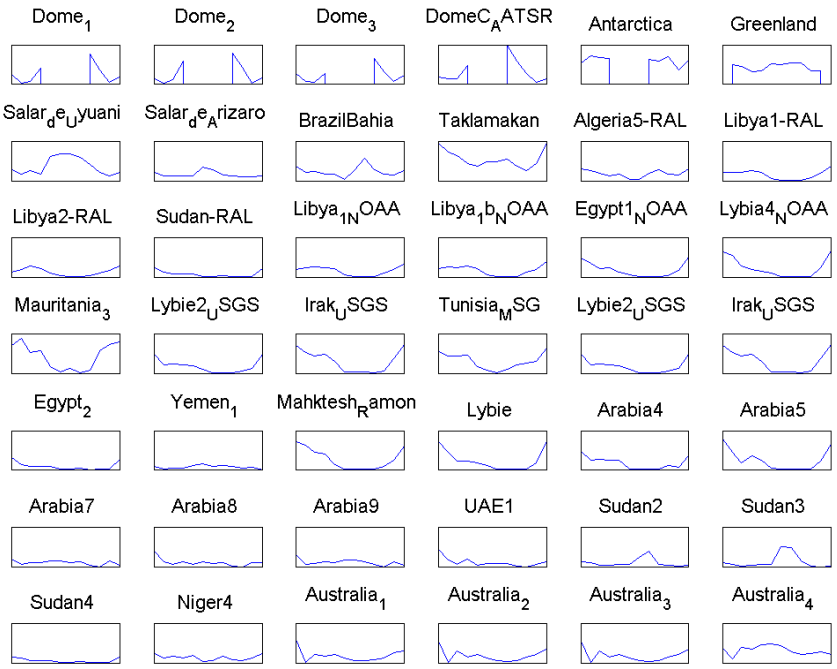


Figure 18: Temporal variability of monthly cloud fraction for the LNES-Others. X axis scale is one year, from January to December. Y axis scale is 0-1.

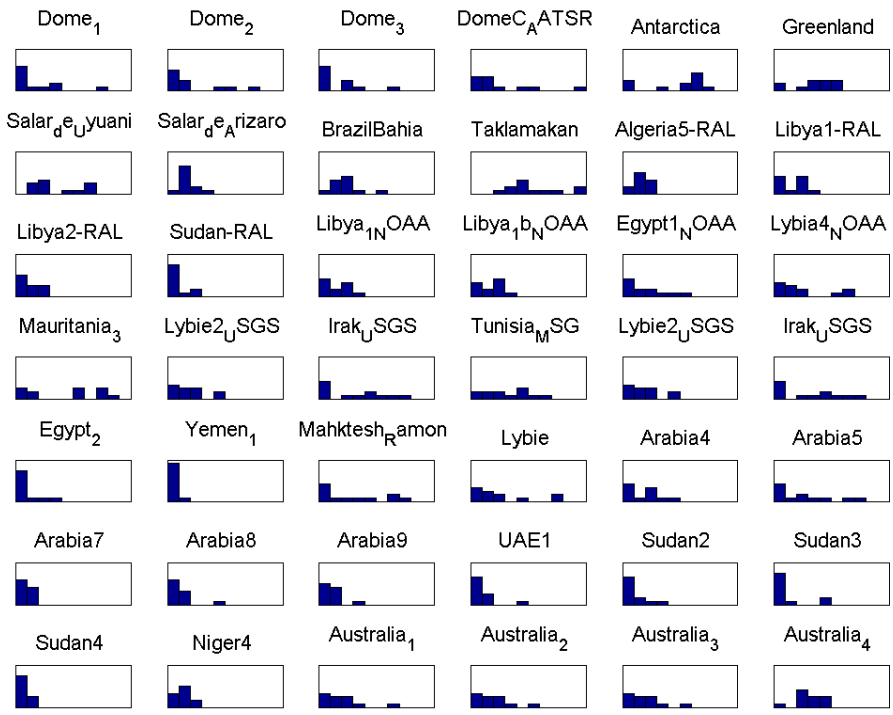


Figure 19: Histogram of monthly cloud fraction for the LNES-Others

3.1.2.3.2 Results

Table 16 provides a classification of the sites based on the observed mean cloud fraction. Fourth column indicates the number of months where the cloud fraction is less than 20%.

Except a few sites, the cloud fraction is less than 30 % in mean over the year, and the number of months where it is lower than 20 % varies between 6 and 12 from May to October.

Table 16: Rank of sites based on the mean cloud fraction

Rank	Site name	Mean of monthly Cloud fraction	Number of months where CF < 20%
1	Sudan4	0.0523	12
2	Yemen_1	0.0635	12
3	Sudan-RAL	0.0712	10
4	Egypt_2	0.0839	10
5	Sudan2	0.0943	10
6	Arabia7	0.0943	12
7	Arabia8	0.1049	11
8	UAE1	0.1082	11
9	Arabia9	0.1125	11
10	Sudan3	0.1202	10
11	Libya2-RAL	0.1241	9
12	Niger4	0.1321	10
13	Libya1-RAL	0.1512	6
14	Libya_1_NOAA	0.1523	7
15	Salar_de_Arizaro	0.1582	9
16	Libya_1b_NOAA	0.1629	6
17	Arabia4	0.1656	6
18	Lybie2_USGS	0.1734	7
19	Lybie2_USGS	0.1734	7
20	Egypt1_NOAA	0.1779	7
21	Algeria5-RAL	0.1831	8
22	Australia_1	0.1841	7
23	Australia_2	0.1853	7
24	Australia_3	0.1853	7
25	Dome_3	0.2288	7
26	Lybie	0.2337	7
27	Lybia4_NOAA	0.2352	7
28	Mauritania_3	0.2359	5
29	Arabia5	0.2425	6
30	Dome_1	0.2553	8

Rank	Site name	Mean of monthly Cloud fraction	Number of months where CF < 20%
31	Mahktesh_Ramon	0.2724	6
32	Dome_2	0.2760	9
33	Irak_USGS	0.3036	5
34	Irak_USGS	0.3036	5
35	Tunisia_MSG	0.3043	4
36	Australia_4	0.3139	1
37	DomeC_AATSR	0.3198	8
38	Salar_de_Uyuani	0.3633	3
39	Greenland	0.4277	2
40	Brazil Bahia	0.4301	5
41	Taklamakan	0.5505	0
42	Antarctica	0.6041	3

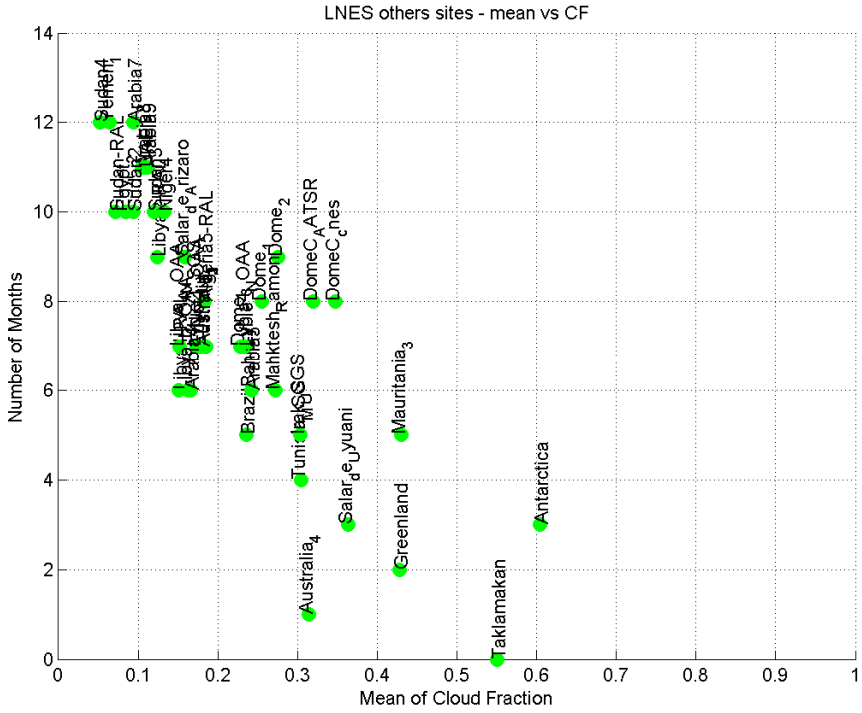


Figure 20 : Mean of CF versus number of months for which cloud fraction is lower than 20%

3.1.2.4 Temporal variability over LNES- China

3.1.2.4.1 Statistics

Figure 21 represents the temporal variability of the mean cloud fraction of the china sites, and Figure 22 provides the temporal variability for each site. The variations are very similar, with two minima in spring and fall, and two maxima in winter and summer.

The annual mean is high between 50% and 60%, with a minimum which is never lower than 20%. Seasonal variability appears with minima in spring and fall.

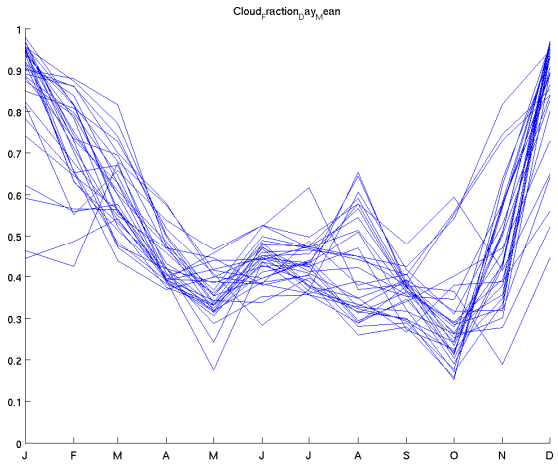


Figure 21: Superimposed temporal profiles of mean monthly cloud fraction for the LNES china sites.

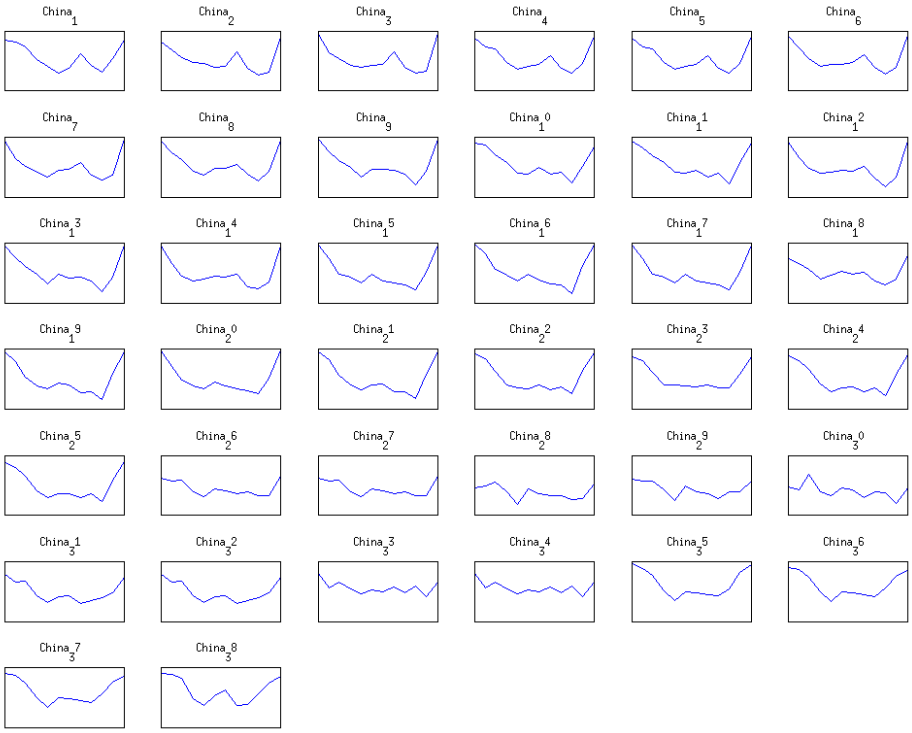


Figure 22: Temporal variability of monthly cloud fraction for the LNES-china sites. X axis scale is one year, from January to December. Y axis scale is 0-1.

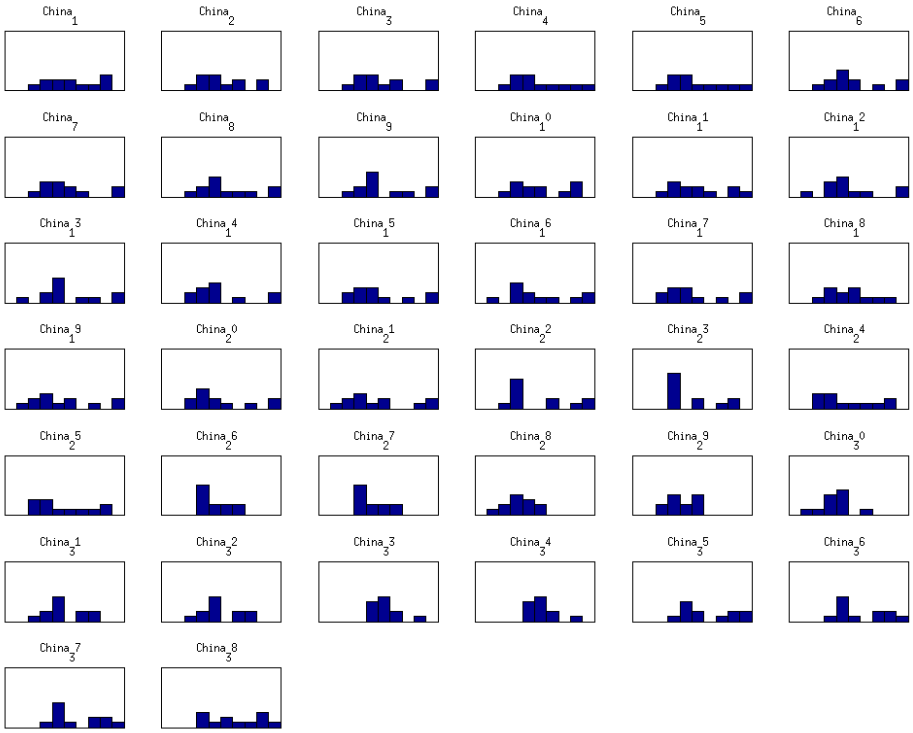


Figure 23: Histogram of monthly cloud fraction for China sites

Statistical parameters are reported in Table 17.

Table 17: Statistics for cloud fraction products for the LNES-china sites

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
China_1	0.5553	0.2078	0.2835	0.8499	0.5664	1.0200	0.3742
China_2	0.5191	0.2039	0.2525	0.8942	0.6417	1.2362	0.3929
China_3	0.5312	0.2274	0.2840	0.9654	0.6814	1.2828	0.4281
China_4	0.5469	0.2108	0.2788	0.9068	0.6280	1.1483	0.3855
China_5	0.5469	0.2108	0.2788	0.9068	0.6280	1.1483	0.3855
China_6	0.5398	0.2140	0.2629	0.9330	0.6701	1.2415	0.3966
China_7	0.5220	0.2247	0.2879	0.9671	0.6792	1.3011	0.4304
China_8	0.5505	0.2205	0.2660	0.9433	0.6773	1.2303	0.4006
China_9	0.5408	0.2381	0.2036	0.9677	0.7641	1.4128	0.4402
China_10	0.5544	0.2170	0.2343	0.8908	0.6565	1.1841	0.3913
China_11	0.5548	0.2327	0.2121	0.9370	0.7249	1.3067	0.4194
China_12	0.5010	0.2295	0.1709	0.9324	0.7615	1.5201	0.4580
China_13	0.5276	0.2427	0.1898	0.9550	0.7652	1.4504	0.4600
China_14	0.4957	0.2368	0.2264	0.9551	0.7287	1.4699	0.4777
China_15	0.5069	0.2509	0.2209	0.9711	0.7502	1.4800	0.4951
China_16	0.5304	0.2669	0.1520	0.9803	0.8283	1.5616	0.5032
China_17	0.5069	0.2509	0.2209	0.9711	0.7502	1.4800	0.4951
China_18	0.5134	0.1542	0.2908	0.8006	0.5098	0.9930	0.3004

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
China_19	0.5003	0.2657	0.1578	0.9511	0.7933	1.5856	0.5311
China_20	0.5023	0.2489	0.2426	0.9699	0.7273	1.4478	0.4955
China_21	0.5086	0.2672	0.1760	0.9577	0.7817	1.5368	0.5254
China_22	0.5285	0.2506	0.2441	0.9304	0.6863	1.2985	0.4740
China_23	0.5266	0.2086	0.3462	0.8738	0.5276	1.0020	0.3961
China_24	0.5045	0.2457	0.2169	0.8947	0.6778	1.3435	0.4870
China_25	0.5045	0.2457	0.2169	0.8947	0.6778	1.3435	0.4870
China_26	0.4432	0.1240	0.3057	0.6420	0.3363	0.7587	0.2797
China_27	0.4432	0.1240	0.3057	0.6420	0.3363	0.7587	0.2797
China_28	0.3783	0.1121	0.1759	0.5425	0.3666	0.9692	0.2964
China_29	0.4325	0.1198	0.2424	0.5916	0.3492	0.8073	0.2770
China_30	0.4001	0.1174	0.1895	0.6771	0.4876	1.2187	0.2935
China_31	0.4933	0.1697	0.2940	0.7826	0.4886	0.9906	0.3441
China_32	0.4933	0.1697	0.2940	0.7826	0.4886	0.9906	0.3441
China_33	0.5643	0.1074	0.4151	0.8165	0.4014	0.7113	0.1903
China_34	0.5643	0.1074	0.4151	0.8165	0.4014	0.7113	0.1903
China_35	0.6341	0.2212	0.3535	0.9556	0.6021	0.9495	0.3488
China_36	0.6085	0.1996	0.3376	0.9046	0.5670	0.9318	0.3279
China_37	0.6085	0.1996	0.3376	0.9046	0.5670	0.9318	0.3279
China_38	0.6212	0.2055	0.3673	0.9019	0.5346	0.8606	0.3309

3.1.2.4.2 Results

Table 18 provides a classification of the sites based on the observed mean cloud fraction. Fourth column indicates the number of months where the cloud fraction is less than 20%.

Except a few sites, the cloud fraction is never less than 40 % in mean over the year.

Table 18: Rank of sites based on the mean cloud fraction

Rank	Site name	Mean of monthly Cloud fraction	Number of months where CF < 20%
1	China_28	0.3783	1
2	China_30	0.4001	1
3	China_29	0.4325	0
4	China_26	0.4432	0
5	China_27	0.4432	0
6	China_31	0.4933	0
7	China_32	0.4933	0
8	China_14	0.4957	0
9	China_19	0.5003	1
10	China_12	0.5010	1
11	China_20	0.5023	0

Rank	Site name	Mean of monthly Cloud fraction	Number of months where CF < 20%
12	China_24	0.5045	0
13	China_25	0.5045	0
14	China_15	0.5069	0
15	China_17	0.5069	0
16	China_21	0.5086	1
17	China_18	0.5134	0
18	China_2	0.5191	0
19	China_7	0.5220	0
20	China_23	0.5266	0
21	China_13	0.5276	1
22	China_22	0.5285	0
23	China_16	0.5304	1
24	China_3	0.5312	0
25	China_6	0.5398	0
26	China_9	0.5408	0
27	China_4	0.5469	0
28	China_5	0.5469	0
29	China_8	0.5505	0
30	China_10	0.5544	0
31	China_11	0.5548	0
32	China_1	0.5553	0
33	China_33	0.5643	0
34	China_34	0.5643	0
35	China_36	0.6085	0
36	China_37	0.6085	0
37	China_38	0.6212	0
38	China_35	0.6341	0

3.1.2.5 Temporal variability over LES

3.1.2.5.1 Statistics for CEOS Reference Standard Test Sites

Figure 24 provides the temporal variability for each site. Statistics are reported in Table 19. The annual mean is higher than for the desert sites (greater than 24 %) and varies between 24.26% (Frenchman Flats) and 42% (Tuz Gulu, La Crau). Negev, Frenchman Flats and Tuz Gulu sites have a low cloud fraction in summer as indicated by the observed minimum which is 0%, 5%, 5% for the three sites respectively. The maximum of cloud fraction is high in winter for Negev (more than 70%) and Tuz Gulu. A seasonal variability of the cloud cover is observed.

Table 19: Statistics for cloud fraction products

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
LaCrau	0.4221	0.1109	0.2681	0.6248	0.3567	0.8451	0.2628
RailroadValley	0.3516	0.1862	0.1215	0.6505	0.5290	1.5044	0.5295
Ivanpahplaya	0.2739	0.1576	0.0866	0.5354	0.4488	1.6383	0.5754
FrenchmanFlat	0.2426	0.1447	0.0577	0.4682	0.4105	1.6922	0.5964
Negev	0.2724	0.2737	0.0001	0.7145	0.7144	2.6230	1.0048
TuzGulu	0.4265	0.2674	0.0475	0.7565	0.7090	1.6623	0.6269
Dunhuang	0.4080	0.1247	0.1830	0.5964	0.4134	1.0132	0.3055
Dome C_cnes	0.3470	0.3472	0.0081	0.9792	0.9710	2.7984	1.0007

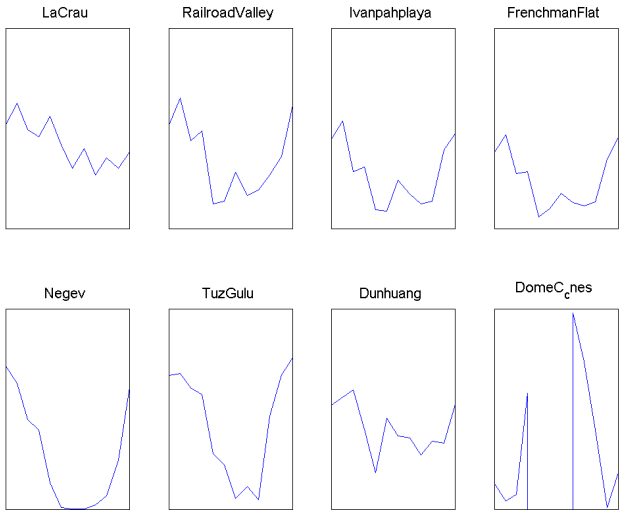


Figure 24: Temporal variability of cloud fraction for the CEOS - LES. X axis scale is one year, from January to December. Y axis scale is 0-1.

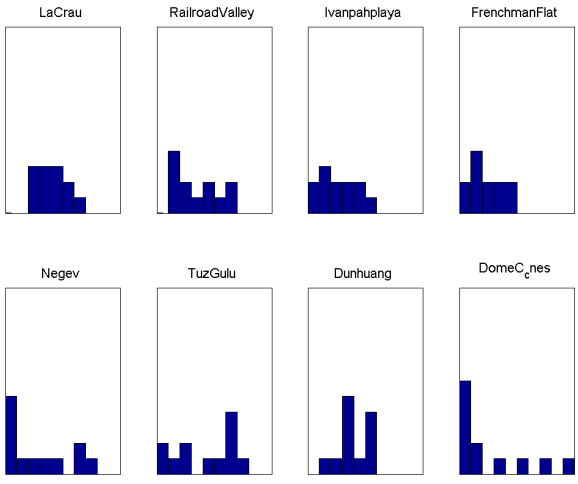


Figure 25: Histogram of monthly cloud fraction

3.1.2.5.2 Statistics for temporary equipped sites

Concerning the other sites, sites located in Northern hemisphere present a minimum of cloud cover in summer (Figure 26), except sites located in India (Jaisalmer, Chhrodi) and Barreal Blanco. Cloud cover over Australian sites is low. The maximum is about 50% during one or two months.

Sechura desert cloud fraction is never lower than 50%, (mean at 70%) indicating the low probability to observe the site from space.

Table 20: Statistics for cloud fraction products

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Lunarplaya	0.3516	0.1862	0.1215	0.6505	0.5290	1.5044	0.5295
WhiteSands	0.3001	0.1504	0.0649	0.6110	0.5461	1.8198	0.5013
RogerDryLake	0.2462	0.1528	0.0626	0.5062	0.4436	1.8019	0.6207
BonnevilleSaltFlats	0.4575	0.1995	0.2280	0.8427	0.6147	1.3435	0.4360
LakeFrome	0.3286	0.1152	0.1177	0.5202	0.4025	1.2251	0.3505
BarrealBlanco	0.2386	0.1587	0.0811	0.4949	0.4138	1.7345	0.6653
RoachLakePlaya	0.2739	0.1576	0.0866	0.5354	0.4488	1.6383	0.5754
Mud_Lake	0.2787	0.1651	0.0747	0.5597	0.4850	1.7399	0.5924
Brookings	0.5810	0.1462	0.3663	0.7982	0.4319	0.7434	0.2517
TingaTingana	0.3139	0.1172	0.0913	0.4758	0.3845	1.2250	0.3735
Dunrobin	0.2995	0.1773	0.0340	0.6099	0.5759	1.9229	0.5919
Warrabin	0.2173	0.1451	0.0471	0.4823	0.4352	2.0031	0.6678
Winton	0.2542	0.1867	0.0248	0.6481	0.6233	2.4517	0.7342
Amburla	0.1871	0.1786	0.0204	0.5301	0.5097	2.7237	0.9545
Sonoran_desert	0.3438	0.2302	0.0446	0.7269	0.6823	1.9846	0.6697
Sechura_desert	0.7944	0.0972	0.6452	0.9415	0.2963	0.3730	0.1224
Hay_Uardry	0.3998	0.0771	0.3159	0.5927	0.2768	0.6923	0.1930
Perkingston	0.5479	0.1011	0.3621	0.7557	0.3936	0.7184	0.1844
ParkFalls	0.6613	0.1724	0.4061	0.9254	0.5193	0.7853	0.2607
Jaisalmer	0.2903	0.2843	0.0005	0.8437	0.8432	2.9047	0.9793
Chhrodi	0.3695	0.3547	0.0561	0.9227	0.8666	2.3452	0.9598
Gongger	0.5169	0.1398	0.2973	0.6961	0.3988	0.7716	0.2706
Erlian	0.5303	0.1712	0.3192	0.7851	0.4659	0.8785	0.3229
Zuoqi	0.4905	0.1522	0.2650	0.7797	0.5147	1.0494	0.3104
Youqi	0.6088	0.1955	0.3349	0.8915	0.5566	0.9142	0.3212
Wiggins_Gravelpits	0.5479	0.1011	0.3621	0.7557	0.3936	0.7184	0.1844
Wiggins_RyeField	0.5479	0.1011	0.3621	0.7557	0.3936	0.7184	0.1844
Wiggins_CutGrass	0.5479	0.1011	0.3621	0.7557	0.3936	0.7184	0.1844
Newell	0.6849	0.1991	0.2822	0.9192	0.6370	0.9301	0.2907
WigginsWesttarp	0.5479	0.1011	0.3621	0.7557	0.3936	0.7184	0.1844

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Yuma	0.2818	0.1559	0.0549	0.5489	0.4940	1.7530	0.5533
Sonoran_RAL	0.2818	0.1559	0.0549	0.5489	0.4940	1.7530	0.5533
Brookings_2	0.5810	0.1462	0.3663	0.7982	0.4319	0.7434	0.2517
Sechura_RAL	0.7130	0.1369	0.4717	0.9265	0.4548	0.6378	0.1920
Dunhuang_RAL	0.3783	0.1121	0.1759	0.5425	0.3666	0.9692	0.2964

Figure 26: Temporal variability of cloud fraction for the LES. X axis scale is one year, from January to December. Y axis scale is 0-1.

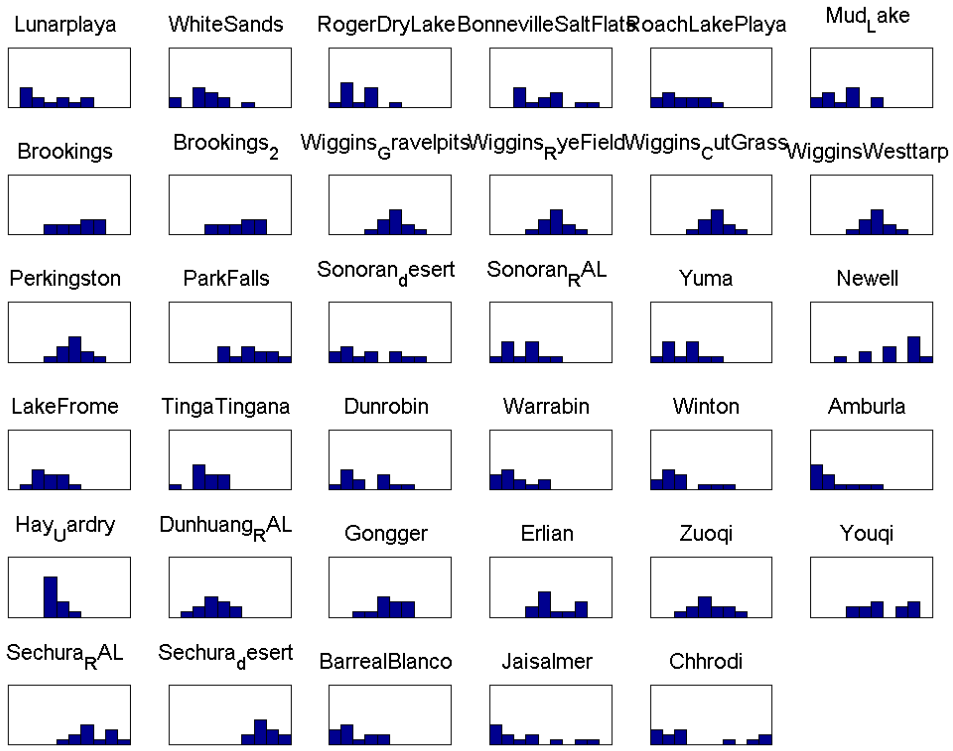


Figure 27: Histogram of monthly cloud fraction

3.1.2.5.3 Results

Table 21 and Table 22 provide a classification of the sites based on the observed mean cloud fraction for CEOS reference standard sites and the others. Fourth column indicates the number of months where the cloud fraction is less than 20%. At maximum, cloud cover is very low only a few months for this class of sites.

Except La Crau, these sites are used or have been used the time of a calibration campaigns for duration of a few days only. This is why it is possible to find a period to use the sites, even if the cloud cover is higher than the cloud cover over desert sites.

Cloud cover for the CEOS reference test sites is given in Table 21. Negev and Frenchman flats sites are the sites where cloud cover is the lowest over the longest period.

Table 21: Rank of CEOS Reference Standard Test Sites based on the mean cloud fraction

Rank	Site name	Mean of monthly Cloud fraction	Number of months where CF < 20%
	Frenchman Flat	0.2426	6
	Negev	0.2724	6
	Ivanpah playa	0.2739	5
	Railroad Valley	0.3516	4
	Dunhuang	0.4080	1
	La Crau	0.4221	0
	Tuz Gulu	0.4265	3
	Dome C	0.3470	8

Observed cloud cover for the Non CEOS LES sites is given in Table 22. It varies from 20% to 70%. The twenty first listed sites have a mean cloud fraction less than 40%, including periods where the cloud fraction is low. It includes the Australian sites, the lake playa and salt lakes which are often used for external calibration. On the other hand, sites ranked from 26 to 42 are often cloudy, and their use for external calibration seems dependant from weather. These sites are however used for punctual campaigns, based on tarp use (Wiggins and Brookings sites) for High spatial resolution sensors. Note that the four china sites are often cloudy.

Table 22: Rank of sites based on the mean cloud fraction

Rank	Site name	Mean of monthly Cloud fraction	Number of months where CF < 20%
1	Amburla	0.1871	8
2	Warrabin	0.2173	7
3	Barreal Blanco	0.2386	7
4	Roger Dry Lake	0.2462	6
5	Winton	0.2542	6
6	Roach Lake Playa	0.2739	5
7	Mud_Lake	0.2787	5
8	Yuma	0.2818	5
9	Sonoran_RAL	0.2818	5
10	Jaisalmer	0.2903	6
11	Dunrobin	0.2995	5
12	WhiteSands	0.3001	2
13	TingaTingana	0.3139	1
14	LakeFrome	0.3286	1
15	Sonoran_desert	0.3438	5
16	Lunarplaya	0.3516	4
17	Chhrodi	0.3695	5
18	Dunhuang_RAL	0.3783	1
19	Hay_Uardry	0.3998	0
20	BonnevilleSaltFlats	0.4575	0
21	Zuoqi	0.4905	0
22	Gongger	0.5169	0
23	Erlian	0.5303	0
24	Perkingston	0.5479	0
25	Wiggins_Gravelpits	0.5479	0
26	Wiggins_RyeField	0.5479	0
27	Wiggins_CutGrass	0.5479	0
28	WigginsWesttarp	0.5479	0
29	Brookings	0.5810	0
30	Brookings_2	0.5810	0
31	Youqi	0.6088	0

Rank	Site name	Mean of monthly Cloud fraction	Number of months where CF < 20%
32	ParkFalls	0.6613	0
33	Newell	0.6849	0
34	Sechura_RAL	0.7130	0
35	Sechura_desert	0.7944	0

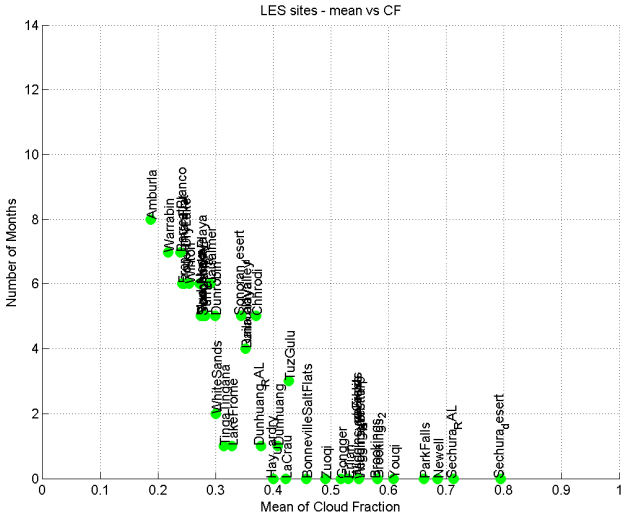


Figure 28: Sites ranking versus the number of months where cloud fraction is less than 20%.

3.1.2.6 Temporal variability over SNES

3.1.2.6.1 Statistics

Figure 29 represents the temporal variability of the mean cloud fraction of the 42 oceanic sites, and Figure 30 provides the temporal variability for each site. The annual mean varies between 42% (MedCr) and 95% (GulfAls), indicating that the cloud fraction is high, most of time greater than 40% for the whole group of sites, Table 23.

Table 23: Statistics for cloud fraction products

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
PacSE	0.7426	0.0537	0.6556	0.8058	0.1502	0.2023	0.0723
PacSE-0	0.8495	0.0236	0.8016	0.8813	0.0797	0.0939	0.0278
PacSE-1	0.8320	0.0428	0.7170	0.8747	0.1577	0.1896	0.0515
PacSE-2	0.8037	0.0581	0.6662	0.8665	0.2003	0.2492	0.0723
PacSE-3	0.7309	0.0918	0.5715	0.8498	0.2783	0.3808	0.1255
PacSE-4	0.7290	0.1238	0.4949	0.8736	0.3786	0.5194	0.1698
PacSE-5	0.7402	0.0788	0.5736	0.8614	0.2878	0.3889	0.1065
PacSE-6	0.6345	0.0758	0.4853	0.7463	0.2610	0.4114	0.1195
PacSE-7	0.7067	0.0886	0.5008	0.8004	0.2997	0.4240	0.1253
PacNW	0.6134	0.1213	0.4632	0.8167	0.3536	0.5764	0.1978

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
PacNW-0	0.7513	0.1485	0.5397	0.9540	0.4143	0.5514	0.1977
PacNW-1	0.6163	0.1361	0.4405	0.8166	0.3761	0.6102	0.2209
PacNW-2	0.6410	0.1585	0.4218	0.9022	0.4804	0.7495	0.2473
PacNW-3	0.5424	0.1107	0.4116	0.7400	0.3284	0.6055	0.2040
PacN	0.5177	0.0571	0.4606	0.6468	0.1862	0.3596	0.1104
PacN-0	0.5213	0.0727	0.4159	0.6690	0.2531	0.4855	0.1395
PacN-1	0.5202	0.0556	0.4451	0.6359	0.1908	0.3667	0.1068
PacN-2	0.5099	0.0580	0.4458	0.6206	0.1747	0.3426	0.1138
AtlN	0.5518	0.0635	0.4171	0.6302	0.2131	0.3862	0.1150
AtlN-0	0.5405	0.0858	0.4023	0.6408	0.2385	0.4413	0.1587
AtlN-1	0.5715	0.0832	0.4281	0.7484	0.3203	0.5606	0.1455
AtlN-2	0.5533	0.0727	0.4287	0.6534	0.2247	0.4061	0.1314
AtlS	0.5869	0.1184	0.4278	0.7650	0.3372	0.5746	0.2017
AtlS-0	0.5095	0.0643	0.4212	0.6186	0.1974	0.3874	0.1263
AtlS-1	0.5652	0.1198	0.3987	0.7117	0.3129	0.5537	0.2119
AtlS-2	0.5814	0.1299	0.4173	0.8083	0.3910	0.6726	0.2235
AtlS-3	0.6663	0.1709	0.4190	0.9253	0.5063	0.7598	0.2565
AtlS-4	0.6660	0.1312	0.4694	0.8416	0.3723	0.5589	0.1970
IndS	0.6935	0.0481	0.6066	0.7620	0.1554	0.2241	0.0694
GuMex	0.5861	0.0709	0.4859	0.7023	0.2163	0.3691	0.1210
GuYuc	0.6286	0.1387	0.3619	0.8499	0.4880	0.7763	0.2206
DoCoRi	0.7145	0.0767	0.5860	0.8422	0.2561	0.3585	0.1073
MedCr	0.4268	0.2211	0.0900	0.7770	0.6870	1.6096	0.5180
MedCy	0.4492	0.1468	0.2372	0.6769	0.4397	0.9789	0.3268
GuAlas	0.8851	0.0608	0.7876	0.9553	0.1677	0.1895	0.0687
Hawaii	0.4859	0.0645	0.4208	0.6466	0.2258	0.4647	0.1327
AustS	0.8168	0.0427	0.7244	0.8692	0.1448	0.1773	0.0523
MadE	0.6038	0.0604	0.4655	0.6788	0.2133	0.3532	0.1000
MadE-0	0.6082	0.0457	0.5303	0.6852	0.1549	0.2547	0.0751
MadE-1	0.5888	0.0571	0.4917	0.6778	0.1861	0.3161	0.0970
MadE-2	0.6022	0.0806	0.4500	0.7088	0.2588	0.4298	0.1339
MadE-3	0.6093	0.0854	0.4112	0.7070	0.2958	0.4855	0.1402

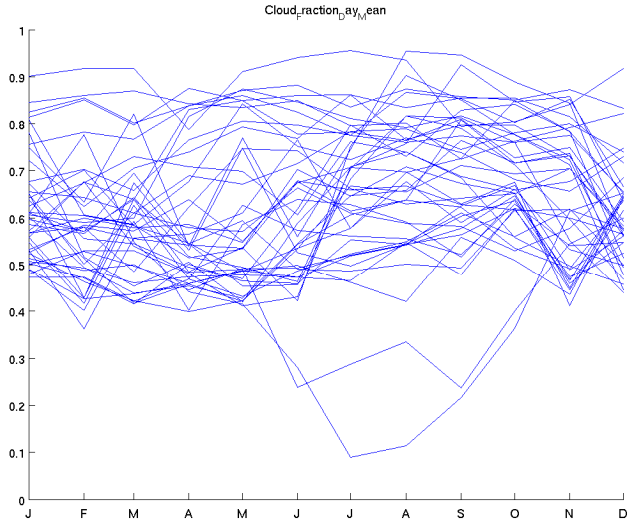


Figure 29: Superimposed temporal profiles of monthly cloud fraction for the SNES.

Figure 30: Temporal variability of monthly cloud fraction for the SNES. X axis scale is one year, from January to December. Y axis scale is 0-1.

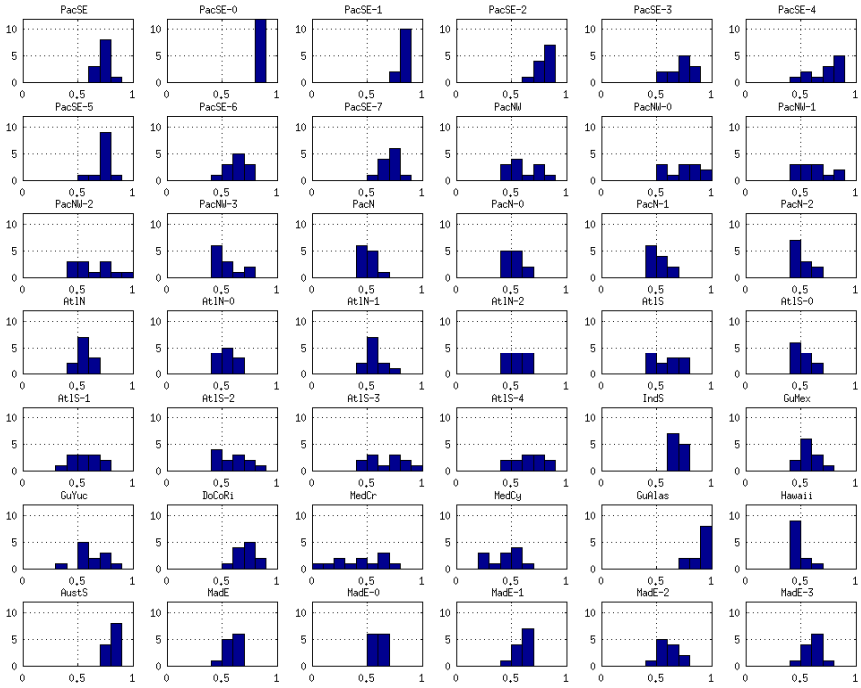


Figure 31: Histogram of monthly cloud fraction

3.1.2.6.2 Results

Table 24 provides a classification of the sites based on the observed mean cloud fraction. Fourth column indicates the number of months where the cloud fraction is less than 50%.

Table 24: Rank of sites based on the mean cloud fraction

Rank	Site name	Mean of monthly Cloud fraction	Number of months where CF < 50%		Rank	Site name	Mean of monthly Cloud fraction	Number of months where CF < 50%
1	MedCr	0.4268	7		22	MadE-3	0.6093	1
2	MedCy	0.4492	7		23	PacNW	0.6134	3
3	Hawaii	0.4859	9		24	PacNW-1	0.6163	3
4	AtlS-0	0.5095	6		25	GuYuc	0.6286	1
5	PacN-2	0.5099	7		26	PacSE-6	0.6345	1
6	PacN	0.5177	6		27	PacNW-2	0.6410	3
7	PacN-1	0.5202	6		28	AtlS-4	0.6660	2
8	PacN-0	0.5213	5		29	AtlS-3	0.6663	2
9	AtlN-0	0.5405	4		30	IndS	0.6935	0
10	PacNW-3	0.5424	6		31	PacSE-7	0.7067	0
11	AtlN	0.5518	2		32	DoCoRi	0.7145	0
12	AtlN-2	0.5533	4		33	PacSE-4	0.7290	1
13	AtlS-1	0.5652	4		34	PacSE-3	0.7309	0

Rank	Site name	Mean of monthly Cloud fraction	Number of months where CF < 50%		Rank	Site name	Mean of monthly Cloud fraction	Number of months where CF < 50%
14	AtlN-1	0.5715	2		35	PacSE-5	0.7402	0
15	AtlS-2	0.5814	4		36	PacSE	0.7426	0
16	GuMex	0.5861	2		37	PacNW-0	0.7513	0
17	AtlS	0.5869	4		38	PacSE-2	0.8037	0
18	MadE-1	0.5888	1		39	AustS	0.8168	0
19	MadE-2	0.6022	1		40	PacSE-1	0.8320	0
20	MadE	0.6038	1		41	PacSE-0	0.8495	0
21	MadE-0	0.6082	0		42	GuAlas	0.8851	0

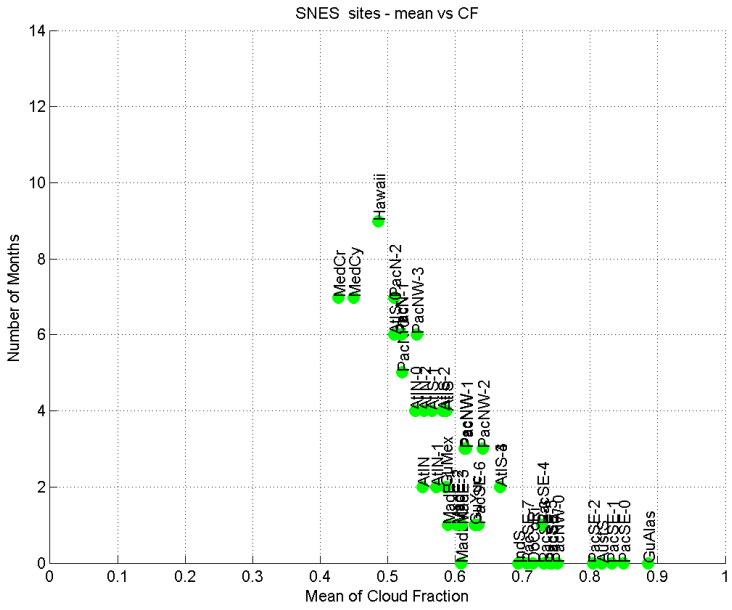


Figure 32: Sites ranking versus the number of months where cloud fraction is less than 50%.

3.1.2.7 Temporal variability over SES

3.1.2.7.1 Statistics

Figure 33 represents the temporal variability of the mean cloud fraction of the 9 identified SES test sites. The histograms of monthly cloud fraction are represented in Figure 34.

MOBY has the lowest monthly mean cloud fraction (36%), with a low standard deviation (8%), indicating constant cloud fraction over the year. A maximum of cloud fraction during summer is visible for AAOT (85%), with a minimum at 23%. Boussole has a minimum in summer but a mean around 50%. The sites at high latitude have a high cloud fraction.

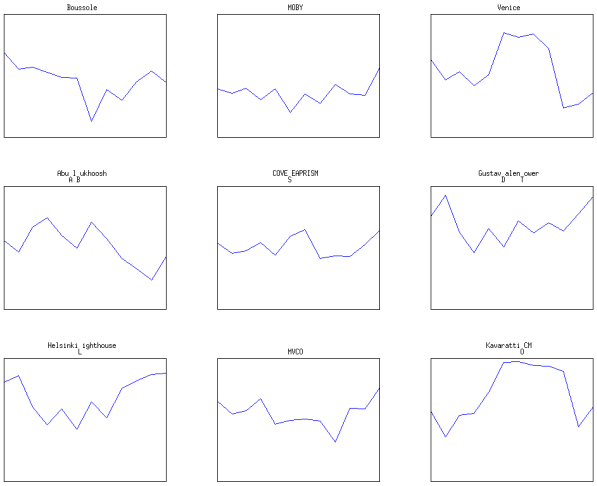


Figure 33: Temporal variability of monthly cloud fraction for the SES. X axis scale is one year, from January to December. Y axis scale is 0-1.

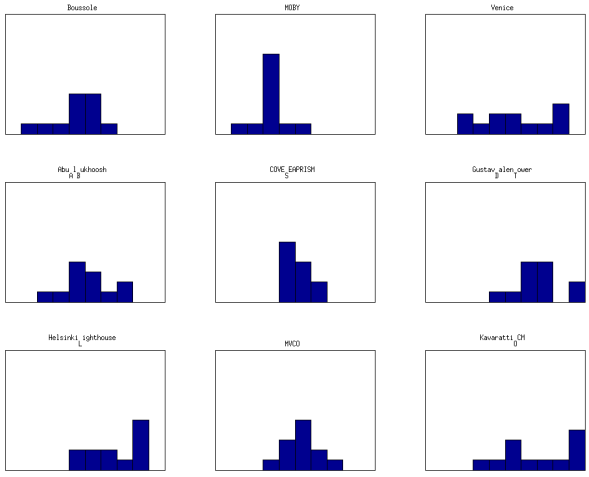


Figure 34: Histogram of monthly cloud fraction

Table 25: Statistics for cloud fraction products over SES

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Boussole	0.4609	0.1427	0.1294	0.6873	0.5579	1.2105	0.3097
MOBY	0.3610	0.0886	0.1973	0.5603	0.3630	1.0055	0.2453
Venice/AAOT	0.5521	0.2167	0.2338	0.8477	0.6139	1.1120	0.3926
Abu_Al_Bukhoosh	0.5171	0.1532	0.2340	0.7424	0.5084	0.9832	0.2962
COVE_SEAPRISM	0.5102	0.0837	0.4124	0.6455	0.2331	0.4569	0.1641
Gustav_Dalen_Tower	0.6899	0.1403	0.4595	0.9239	0.4644	0.6732	0.2033
Helsinki_Lighthouse	0.6839	0.1656	0.4245	0.8794	0.4549	0.6651	0.2421
MVCO	0.5549	0.1132	0.3195	0.7573	0.4378	0.7890	0.2040
Kavaratti_OCM	0.7076	0.2237	0.3579	0.9698	0.6119	0.8648	0.3162

3.1.2.7.2 Results

Table 26 provides a classification of the sites based on the observed mean cloud fraction. Fourth column indicates the number of months where the cloud fraction is less than 50%.

Table 26: Rank of SES Test Sites based on the mean cloud fraction

Rank	Site name	Mean of monthly Cloud fraction	Number of months where CF < 50%
1	MOBY	0.3610	11
2	Boussole	0.4609	7
3	COVE_SEAPRISM	0.5102	6
4	Abu_Al_Bukhoosh	0.5171	6
5	Venice	0.5521	5
6	MVCO	0.5549	4
7	Helsinki_Lighthouse	0.6839	1
8	Gustav_Dalen_Tower	0.6899	1
9	Kavaratti_OCM	0.7076	2

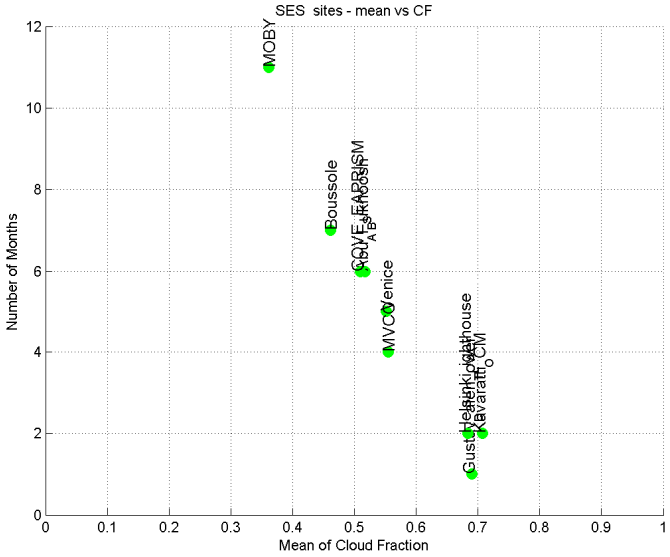


Figure 35: Sites ranking versus the number of months where cloud fraction is less than 50%.

3.2 Variability of Aerosol

Most of the calibration methods are based on the knowledge of the optical properties of the surface. Therefore the role of the aerosols is bias which minimized by high meteorological visibilities. The aerosol load is described by the solar extinction measurements. The link between extinction and scattering is ensured through the knowledge of the absorbing properties of the aerosols. Some aerosols are known to absorb (Asian dust …) and in contaminated areas, the absorption properties of the aerosols have to be known.

Table 27: Criterion for aerosol characterisation

Retained criteria	Studied parameters	Site type
Aerosol characterisation	▪ Aerosol optical thickness ▪ Angstrom exponent ▪ Atmosphere type	▪ LNES ▪ SNES

3.2.1 Dataset description

3.2.1.1 Dataset identification

Level-3 MODIS Atmosphere Monthly Global Product, MOD08_M3

3.2.1.2 Spatial Characteristics

See section 3.1.1.2.

3.2.1.3 Projection

See section 3.1.1.3.

3.2.1.4 Temporal Characteristics

See section 3.1.1.4.

3.2.1.5 Data Characteristics

3.2.1.5.1 Parameter/Variable

Aerosol is extracted from the Level-3 MODIS Atmosphere Monthly Global (Hubanks et al., 2008, RD.30). This product is derived from the Level-3 MODIS Atmosphere Daily Global Product. The specifications are provided at: http://modis-atmos.gsfc.nasa.gov/MOD08_M3/spec_c5.html

The products analysed are:

- **Optical_Depth_Land_And_Ocean,**
- **Angstrom_Exponent_Land,**
- **Angstrom_Exponent_1_Ocean.**

3.2.1.5.2 Variable Description/Definition

Optical_Depth_Land_And_Ocean is the mean of daily mean L3 aerosol Optical Thickness at 0.55 microns for both Ocean (best) and Land (corrected)

Angstrom_Exponent_Land is the mean of daily mean L3 angstrom exponent over Land between 0.47 and 0.66 µm. It varies between -0.5 and 5.

Angstrom_Exponent_1_Ocean is the mean of daily mean L3 Angstrom Exponent (0.550 and 0.865 micron.

Statistics are based on the daily statistics with the assumption that the daily statistics from retrieved pixels can represent the statistics of the "populations" of each 1° x 1° grid cell. The simple statistics for monthly quantities include mean, standard deviation, and minimum and maximum values of the corresponding daily means (i.e., daily mean, daily QA mean).

3.2.1.5.3 Unit of Measurement

No units for the three datasets.

3.2.1.5.4 Data Source

Product is derived from the Level-3 MODIS Atmosphere Daily Global Product.

3.2.1.5.5 Data Range

Optical_Depth_Land_And_Ocean varies between -0.1 and 5.

Angstrom_Exponent_Land varies between -0.5 and 5.

Angstrom_Exponent_1_ varies between -0.5 and 5.

3.2.1.6 Sample Data Record

Dataset format is HDF. The specifications are provided at: http://modis-atmos.gsfc.nasa.gov/MOD08_M3/spec_c5.html

3.2.2 Analysis

3.2.2.1 Variability at global scale

Global temporal variations of the monthly optical depth, the Angstroem exponent over land and ocean are represented on Figure 36, Figure 37, Figure 38 respectively.

The MODIS aerosol optical thickness exhibits strong seasonal variation essentially due to the biomass burning events occurring in South America in autumn (from August to October) , in central Africa in winter, or dust events occurring in spring in Asia.

No retrieval is available over deserts areas. Except in the strong events where it exceeds 1, the AOT is less than 0.3.

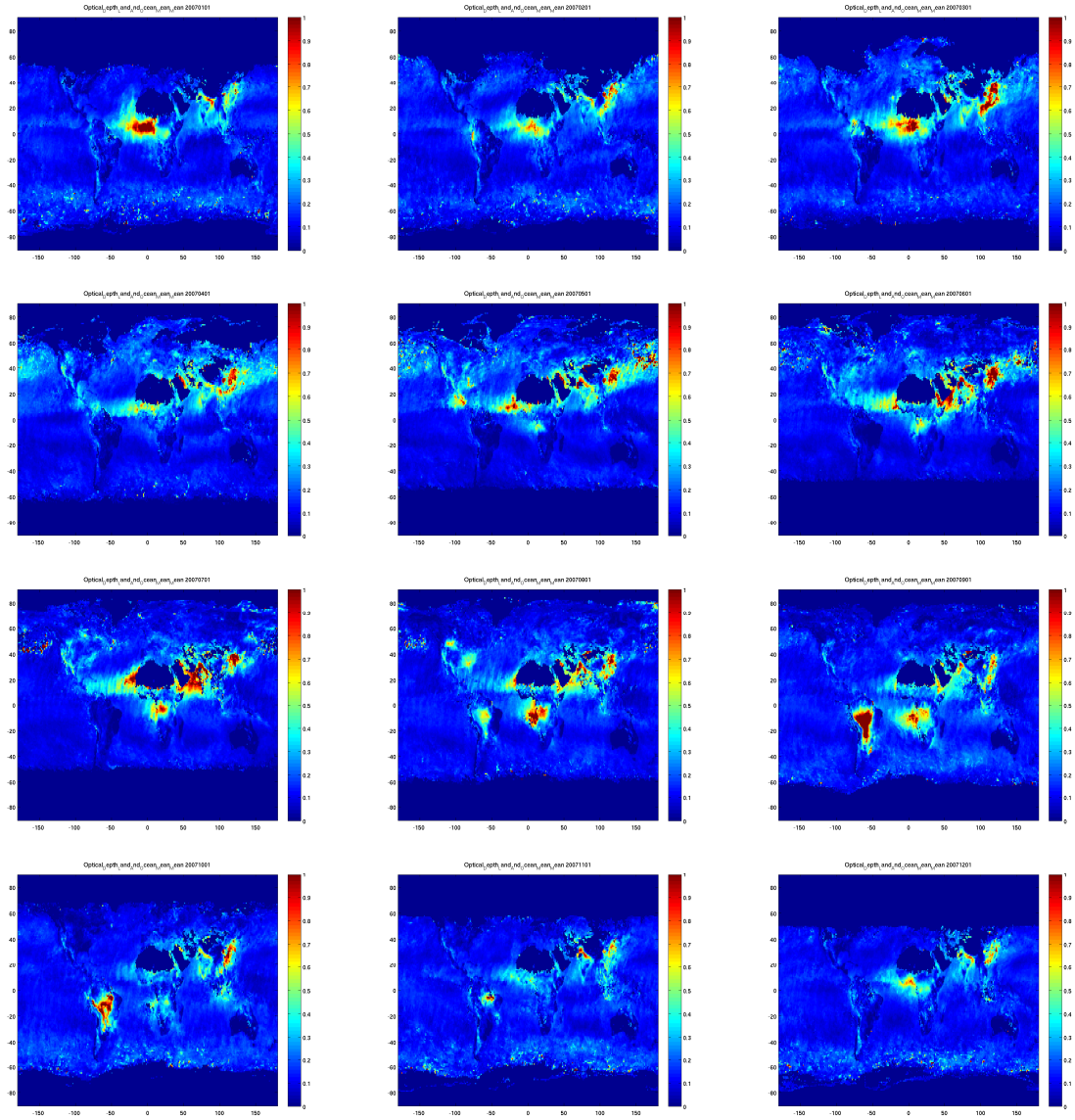


Figure 36: Monthly mean of aerosol optical thickness at 550 nm (MOD08_M3). Line of images corresponds to Q1, Q2, Q3, and Q4 respectively. No units.

Angstroem exponent exhibits also a strong seasonal variability. Higher variations are seen in the Northern hemisphere from spring to summer, where the angstrom exponent varies from 0.5 to 1.5 and more.

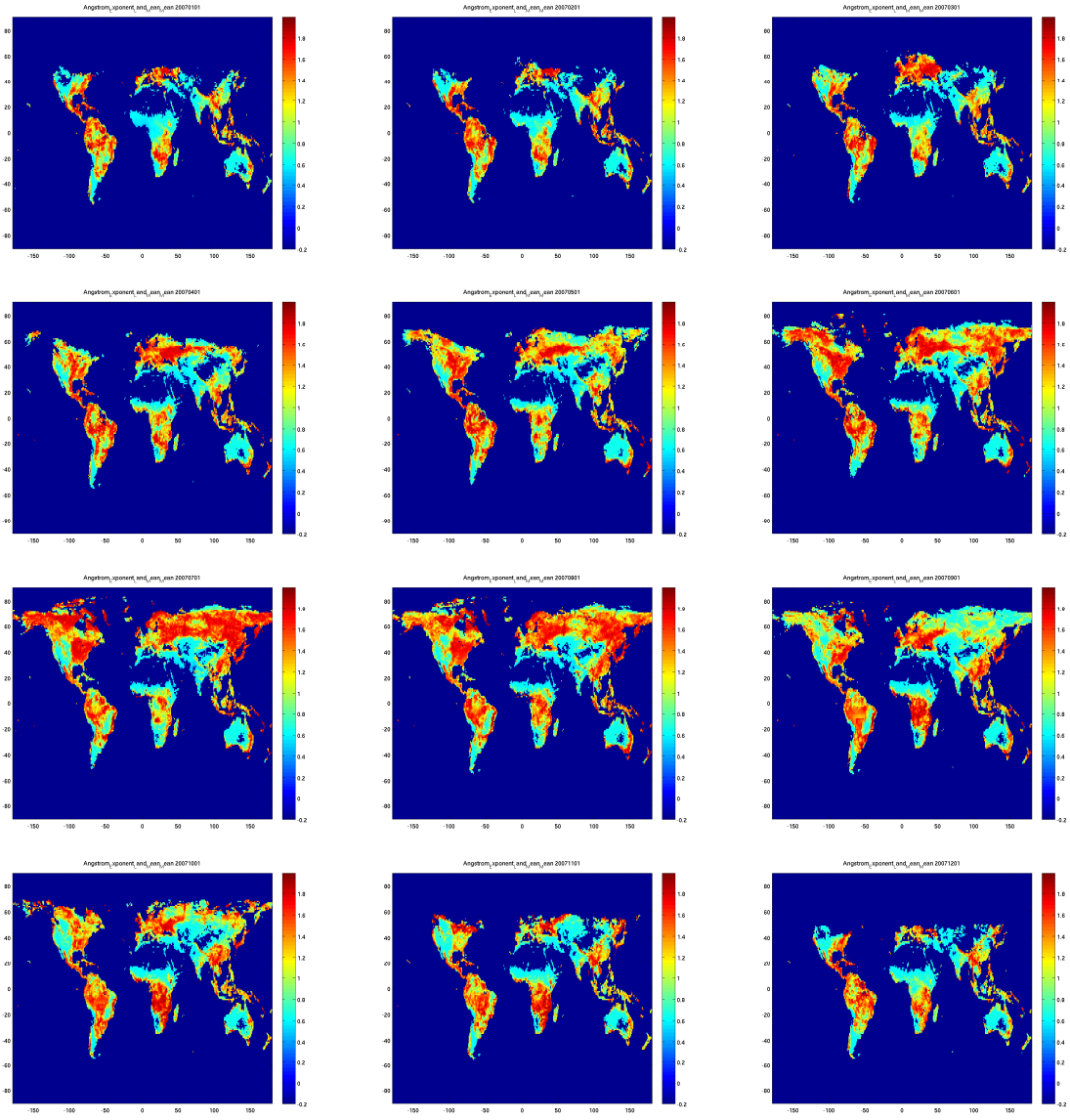


Figure 37: Monthly mean of Angstroem exponent over land (MOD08_M3). Line of images corresponds to Q1, Q2, Q3, and Q4 respectively. No units.

The Angstroem exponent exhibits latitudinal variations in the ocean. It varies between 0.5 and 1-1.2 , except along the coast where it is higher because aerosol type is different over land and ocean.

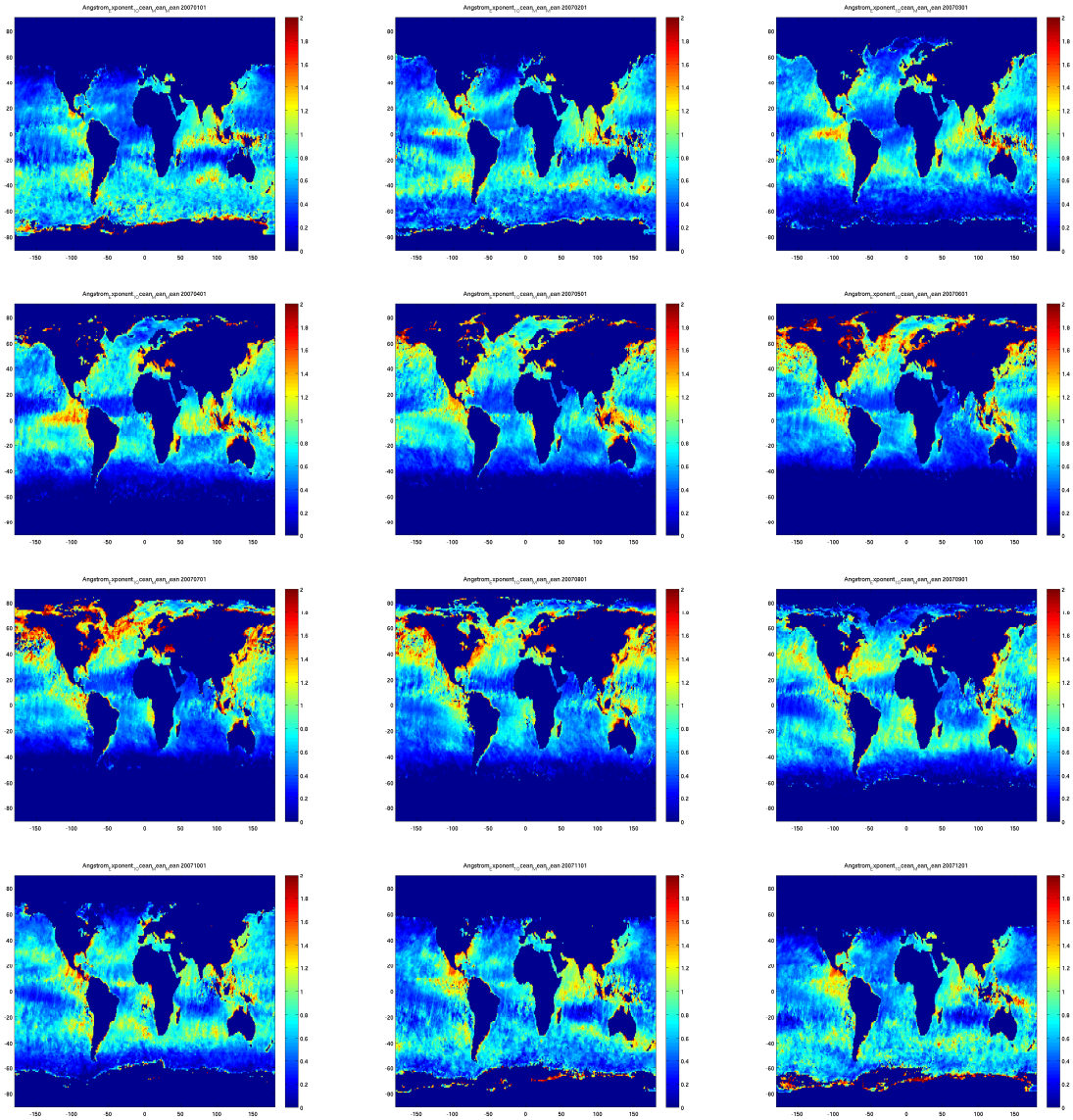


Figure 38: Monthly mean of Angstroem exponent over ocean (MOD08_M3). Line of images corresponds to Q1, Q2, Q3, and Q4 respectively. No units.

3.2.2.2 Temporal variability over LNES

3.2.2.2.1 Aerosol Optical thickness

No data

3.2.2.2.2 Angstroem coefficient

No data

3.2.2.3 Temporal variability over SNES

3.2.2.3.1 Aerosol Optical thickness

3.2.2.3.1.1 Statistics

Figure 39 represents the temporal variability of the monthly mean AOT for each site.

Lowest values (0.07) are observed for PacSE sites, and the maximum is observed for the Mediterranean sites (0.4). No strong seasonal cycles is observed for the Pacific sites whereas a maximum is observed in the Atlantic sites, in fall in the southern hemisphere, summer in the northern hemisphere. This maximum is around 0.4 (AtlS-3), and 0.2-0.25 for the others. Statistics are reported in Table 28.

Table 28: Statistics for AOT products

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
PacSE	0.1037	0.0164	0.0783	0.1324	0.0541	0.5211	0.1580
PacSE-0	0.1264	0.0366	0.0607	0.1824	0.1217	0.9627	0.2893
PacSE-1	0.1178	0.0283	0.0666	0.1606	0.0940	0.7983	0.2407
PacSE-2	0.1129	0.0272	0.0733	0.1651	0.0918	0.8128	0.2409
PacSE-3	0.1007	0.0170	0.0760	0.1279	0.0519	0.5154	0.1690
PacSE-4	0.0974	0.0225	0.0639	0.1418	0.0780	0.8006	0.2315
PacSE-5	0.0890	0.0235	0.0651	0.1408	0.0757	0.8509	0.2644
PacSE-6	0.0906	0.0085	0.0778	0.1059	0.0281	0.3097	0.0934
PacSE-7	0.0851	0.0121	0.0629	0.1026	0.0398	0.4676	0.1418
PacNW	0.1179	0.0236	0.0916	0.1691	0.0775	0.6575	0.2000
PacNW-0	0.1136	0.0385	0.0464	0.1735	0.1270	1.1182	0.3388
PacNW-1	0.1229	0.0208	0.0990	0.1655	0.0665	0.5410	0.1692
PacNW-2	0.1169	0.0337	0.0665	0.1976	0.1311	1.1211	0.2886
PacNW-3	0.1129	0.0288	0.0826	0.1813	0.0987	0.8745	0.2553
PacN	0.1333	0.0214	0.1021	0.1868	0.0847	0.6351	0.1607
PacN-0	0.1423	0.0221	0.1146	0.1956	0.0810	0.5689	0.1551
PacN-1	0.1221	0.0228	0.0919	0.1796	0.0877	0.7182	0.1867
PacN-2	0.1302	0.0227	0.0909	0.1804	0.0895	0.6875	0.1740
AtlN	0.1570	0.0615	0.0858	0.2632	0.1774	1.1298	0.3919
AtlN-0	0.1764	0.0823	0.0932	0.3300	0.2368	1.3424	0.4663
AtlN-1	0.1330	0.0385	0.0795	0.2068	0.1272	0.9567	0.2895
AtlN-2	0.1410	0.0484	0.0754	0.2171	0.1417	1.0048	0.3430
AtlS	0.1263	0.0485	0.0813	0.2567	0.1754	1.3882	0.3835
AtlS-0	0.1184	0.0369	0.0771	0.2009	0.1237	1.0446	0.3120
AtlS-1	0.1076	0.0371	0.0661	0.1860	0.1199	1.1144	0.3447
AtlS-2	0.1350	0.0459	0.0928	0.2636	0.1709	1.2660	0.3403

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
AtlS-3	0.1570	0.0845	0.0972	0.4088	0.3116	1.9850	0.5379
AtlS-4	0.1223	0.0588	0.0597	0.2782	0.2185	1.7867	0.4809
IndS	0.0938	0.0138	0.0757	0.1177	0.0420	0.4480	0.1471
GuMex	0.1934	0.0607	0.1195	0.3079	0.1885	0.9746	0.3140
GuYuc	0.1979	0.0606	0.1199	0.3152	0.1953	0.9869	0.3062
DoCoRi	0.1354	0.0299	0.1056	0.2182	0.1126	0.8313	0.2210
MedCr	0.2229	0.0858	0.1292	0.4112	0.2820	1.2649	0.3849
MedCy	0.2374	0.0836	0.1288	0.4130	0.2843	1.1974	0.3523
GuAlas	0.2544	0.2482	0.1064	1.0186	0.9122	3.5862	0.9759
Hawaii	0.1518	0.0285	0.1165	0.2038	0.0873	0.5751	0.1876
AustS	0.1301	0.0328	0.0619	0.1763	0.1144	0.8794	0.2519
MadE	0.0994	0.0203	0.0659	0.1440	0.0780	0.7848	0.2043
MadE-0	0.1129	0.0217	0.0624	0.1499	0.0874	0.7746	0.1922
MadE-1	0.1043	0.0217	0.0655	0.1570	0.0915	0.8765	0.2081
MadE-2	0.0968	0.0254	0.0633	0.1487	0.0854	0.8821	0.2623
MadE-3	0.0925	0.0204	0.0653	0.1334	0.0681	0.7367	0.2209

Figure 39: Temporal variability of aerosol optical thickness for the SNES. X axis scale is one year, from January to December. Y axis scale is 0-0.4. No units.

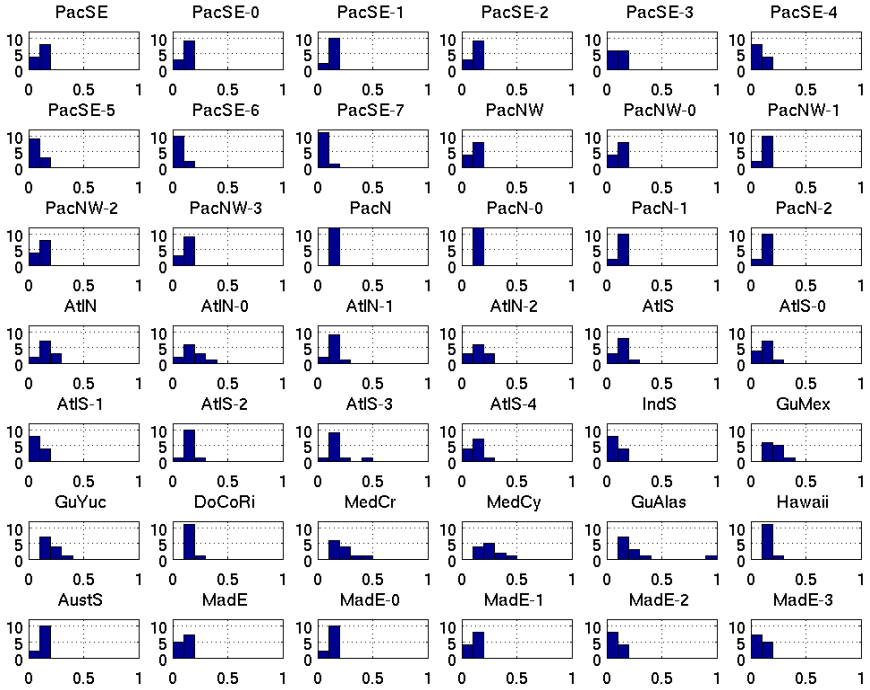


Figure 40: Histogram of AOT

3.2.2.3.1.2 Results

Table 29 provides a classification of the sites based on the mean level of the AOT over one year. Fourth column indicates the number of months where AOT is less than 0.1.

The first ten sites listed in the table have in mean, an AOT less than 0.1 for long period of time 6 to 10 months). For these sites, the standard deviation is low (0.01 to 0.02), indicating the low variability of AOT and stability with time.

Table 29: Rank of sites based on the AOT mean

Rank	Site name	Mean of monthly AOT	Number of months where AOT < 0.1		Rank	Site name	Mean of monthly AOT	Number of months where AOT < 0.1
1	PacSE-7	0.0851	11		22	AtlS-4	0.1223	4
2	PacSE-5	0.0890	9		23	PacNW-1	0.1229	2
3	PacSE-6	0.0906	10		24	AtlS	0.1263	3
4	MadE-3	0.0925	7		25	PacSE-0	0.1264	3
5	IndS	0.0938	8		26	AustS	0.1301	2
6	MadE-2	0.0968	8		27	PacN-2	0.1302	2
7	PacSE-4	0.0974	8		28	AtlN-1	0.1330	2
8	MadE	0.0994	5		29	PacN	0.1333	0
9	PacSE-3	0.1007	6		30	AtlS-2	0.1350	1
10	PacSE	0.1037	4		31	DoCoRi	0.1354	0
11	MadE-1	0.1043	4		32	AtlN-2	0.1410	3
12	AtlS-1	0.1076	8		33	PacN-0	0.1423	0

Rank	Site name	Mean of monthly AOT	Number of months where AOT < 0.1		Rank	Site name	Mean of monthly AOT	Number of months where AOT < 0.1
13	PacNW-3	0.1129	3		34	Hawaii	0.1518	0
14	PacSE-2	0.1129	3		35	AtlS-3	0.1570	1
15	MadE-0	0.1129	2		36	AtlN	0.1570	2
16	PacNW-0	0.1136	4		37	AtlN-0	0.1764	2
17	PacNW-2	0.1169	4		38	GuMex	0.1934	0
18	PacSE-1	0.1178	2		39	GuYuc	0.1979	0
19	PacNW	0.1179	4		40	MedCr	0.2229	0
20	AtlS-0	0.1184	4		41	MedCy	0.2374	0
21	PacN-1	0.1221	2		42	GuAlas	0.2544	0

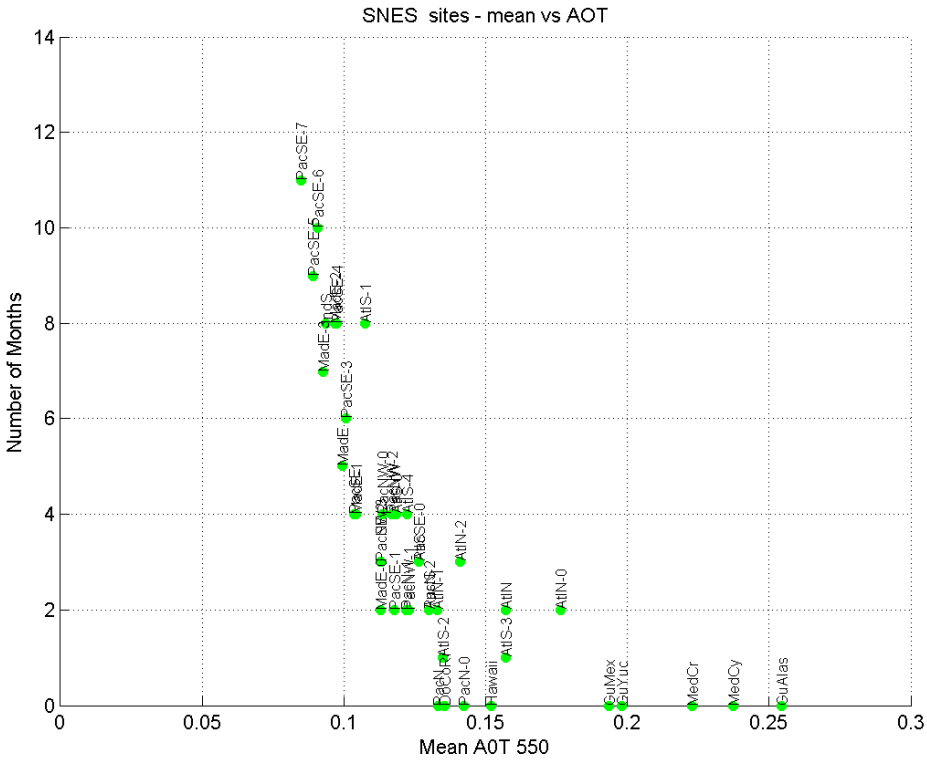


Figure 41: Sites ranking versus the number of months where AOT is less than 0.1.

3.2.2.3.2 Angstroem coefficient

3.2.2.3.2.1 Statistics

Figure 42 represents the temporal variability of the monthly Angstroem coefficient for the 42 sites. The coefficient varies around 0.4 to 0.8. A very low Angstroem coefficient is observed for PacSE sites in May to June (summer), and at the opposite, low values are observed in winter for Alaska site.

Statistics are reported in Table 30.

Table 30: Statistics for Angstroem products

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
PacSE	0.5520	0.2280	0.1720	0.8333	0.6613	1.1980	0.4131
PacSE-0	0.3854	0.3123	-0.0675	0.8766	0.9441	2.4499	0.8104
PacSE-1	0.4786	0.3093	0.0030	0.8642	0.8611	1.7994	0.6464
PacSE-2	0.4892	0.2971	0.0282	0.8755	0.8472	1.7320	0.6074
PacSE-3	0.5174	0.2195	0.1221	0.8455	0.7235	1.3984	0.4242
PacSE-4	0.6474	0.2631	0.2856	1.0207	0.7351	1.1354	0.4063
PacSE-5	0.7621	0.2716	0.3064	1.1305	0.8241	1.0814	0.3563
PacSE-6	0.6263	0.1777	0.3395	0.8972	0.5576	0.8904	0.2837
PacSE-7	0.7284	0.2000	0.4109	1.0262	0.6153	0.8447	0.2746
PacNW	0.5344	0.1335	0.3479	0.7447	0.3968	0.7426	0.2499
PacNW-0	0.5017	0.1865	0.3174	0.8623	0.5449	1.0862	0.3718
PacNW-1	0.4652	0.1381	0.2362	0.6631	0.4269	0.9177	0.2969
PacNW-2	0.5926	0.1852	0.3743	0.9662	0.5919	0.9988	0.3126
PacNW-3	0.6035	0.1406	0.3513	0.8519	0.5006	0.8295	0.2330
PacN	0.5373	0.0796	0.4149	0.6373	0.2223	0.4138	0.1481
PacN-0	0.5037	0.0818	0.3087	0.5819	0.2732	0.5424	0.1624
PacN-1	0.5667	0.1085	0.3629	0.6983	0.3355	0.5919	0.1915
PacN-2	0.5602	0.0997	0.3621	0.7173	0.3553	0.6342	0.1779
AtlN	0.6259	0.1388	0.4441	0.8351	0.3910	0.6248	0.2217
AtlN-0	0.5727	0.1483	0.3704	0.7608	0.3904	0.6817	0.2589
AtlN-1	0.6889	0.1591	0.4888	1.0250	0.5362	0.7784	0.2310
AtlN-2	0.6705	0.1923	0.4359	1.0597	0.6238	0.9303	0.2868
AtlS	0.6057	0.1304	0.4220	0.8443	0.4223	0.6972	0.2152
AtlS-0	0.5745	0.1344	0.4134	0.7410	0.3276	0.5701	0.2340
AtlS-1	0.6247	0.1679	0.4220	0.8945	0.4724	0.7562	0.2688
AtlS-2	0.5603	0.1076	0.4311	0.7801	0.3490	0.6229	0.1920
AtlS-3	0.6304	0.1375	0.4002	0.8907	0.4906	0.7782	0.2181
AtlS-4	0.6595	0.1643	0.3867	0.9627	0.5759	0.8733	0.2491
IndS	0.6210	0.2106	0.2781	0.8935	0.6154	0.9910	0.3392

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
GuMex	0.8821	0.1833	0.5742	1.2827	0.7084	0.8031	0.2078
GuYuc	0.6673	0.1668	0.4268	0.9643	0.5375	0.8054	0.2500
DoCoRi	0.9010	0.1441	0.6375	1.1490	0.5116	0.5678	0.1599
MedCr	0.8019	0.1263	0.6668	1.0668	0.4000	0.4988	0.1576
MedCy	0.8597	0.1064	0.6820	1.0757	0.3937	0.4580	0.1238
GuAlas	0.5694	0.3853	0.0343	1.1913	1.1571	2.0322	0.6768
Hawaii	0.6977	0.1249	0.5418	0.9223	0.3805	0.5453	0.1790
AustS	0.4614	0.3231	-0.0021	1.0475	1.0496	2.2748	0.7003
MadE	0.6228	0.2091	0.3250	0.9469	0.6219	0.9986	0.3357
MadE-0	0.5845	0.1948	0.3464	0.9331	0.5867	1.0036	0.3332
MadE-1	0.6064	0.2000	0.3590	0.9169	0.5579	0.9199	0.3298
MadE-2	0.6280	0.2136	0.3207	0.9428	0.6221	0.9906	0.3401
MadE-3	0.6448	0.2374	0.2620	0.9969	0.7349	1.1397	0.3682

Histograms of Angstroem coefficients are represented in Figure 43. PacN sites have the lowest variability, and the (maximum-minimum) difference the lowest. The Others sites have a variability more extended.

Figure 42: Temporal variability of Angstroem exponent for the SNES. X axis scale is one year, from January to December. Y axis scale is 0-2.

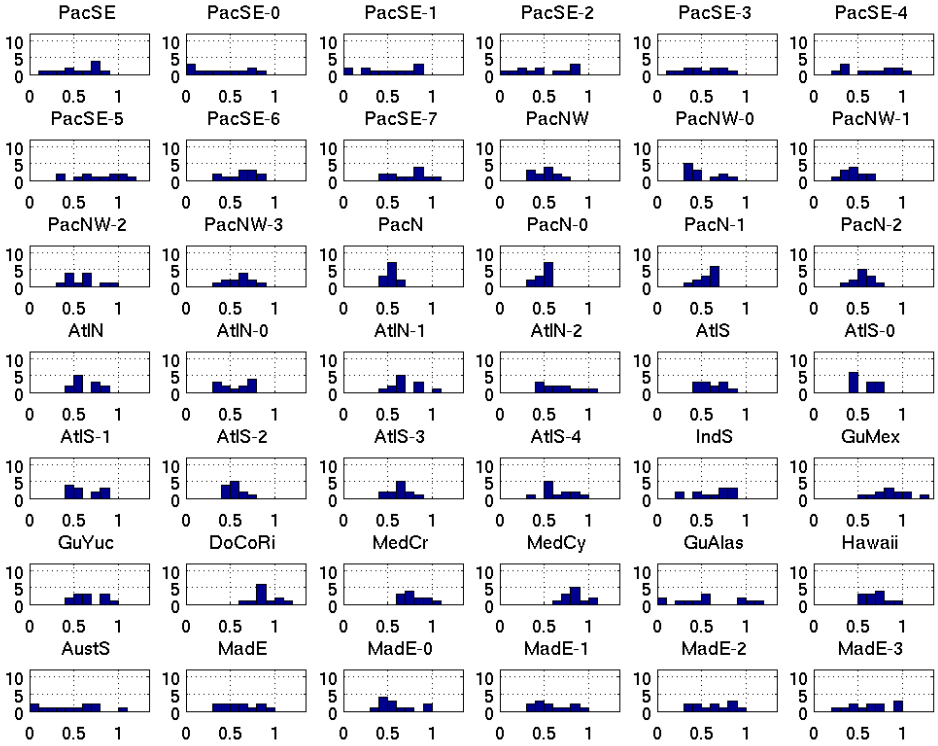


Figure 43: Histogram of Angstroem coefficient

3.2.2.3.2.2 Results

Table 31 provides a classification of the sites based on the lowest dynamics observed over one year, meaning that the aerosol type is probably the same over the year.

Table 31: Rank of sites based on the minimum of dynamics of Angstroem coefficient

Rank	Site name	Min of dynamics		Rank	Site name	Min of dynamics
1	PacN	0.2223		22	PacSE-6	0.5576
2	PacN-0	0.2732		23	MadE-1	0.5579
3	AtlS-0	0.3276		24	AtlS-4	0.5759
4	PacN-1	0.3355		25	MadE-0	0.5867
5	AtlS-2	0.3490		26	PacNW-2	0.5919
6	PacN-2	0.3553		27	PacSE-7	0.6153
7	Hawaii	0.3805		28	IndS	0.6154
8	AtlN-0	0.3904		29	MadE	0.6219
9	AtlN	0.3910		30	MadE-2	0.6221
10	MedCy	0.3937		31	AtlN-2	0.6238
11	PacNW	0.3968		32	PacSE	0.6613
12	MedCr	0.4000		33	GuMex	0.7084
13	AtlS	0.4223		34	PacSE-3	0.7235
14	PacNW-1	0.4269		35	MadE-3	0.7349

Rank	Site name	Min of dynamics		Rank	Site name	Min of dynamics
15	AtlS-1	0.4724		36	PacSE-4	0.7351
16	AtlS-3	0.4906		37	PacSE-5	0.8241
17	PacNW-3	0.5006		38	PacSE-2	0.8472
18	DoCoRi	0.5116		39	PacSE-1	0.8611
19	AtlN-1	0.5362		40	PacSE-0	0.9441
20	GuYuc	0.5375		41	AustS	1.0496
21	PacNW-0	0.5449		42	GuAlas	1.1571

3.3 Variability of water vapour content

Data are analysed to estimate the variability of the water vapour content over all sites.

Table 32: Criterion for Water vapour absorption

Retained criteria	Studied parameters	Site type
Water vapour absorption	Water vapour content	▪ LNES ▪ LES ▪ SNES ▪ SES

3.3.1 Dataset description

3.3.1.1 Dataset identification

Level-3 MODIS Atmosphere Monthly Global Product, MOD08_M3

3.3.1.2 Spatial Characteristics

See section 3.1.1.2.

3.3.1.3 Projection

See section 3.1.1.3.

3.3.1.4 Temporal Characteristics

See section 3.1.1.4.

3.3.1.5 Data Characteristics

3.3.1.5.1 Parameter/Variable

The MODIS Precipitable Water product consists of column water-vapor amounts over clear land areas of the globe. Water vapour content is extracted from the Level-3 MODIS

Atmosphere Monthly Global (Hubanks et al., 2008, RD.30). This product is derived from the Level-3 MODIS Atmosphere Daily Global Product. The specifications are provided at: http://modis-atmos.gsfc.nasa.gov/MOD08_M3/spec_c5.html.

The products analysed is: **Atmospheric_Water_Vapor_Mean**

3.3.1.5.2 Variable Description/Definition

Atmospheric_Water_Vapor_Mean is mean of Daily mean of Precipitable Water Vapor (IR Retrieval) Total Column.

Statistics are based on the daily statistics with the assumption that the daily statistics from retrieved pixels can represent the statistics of the "populations" of each 1° x 1° grid cell. The simple statistics for monthly quantities include mean, standard deviation, and minimum and maximum values of the corresponding daily means (i.e., daily mean, daily QA mean).

3.3.1.5.3 Unit of Measurement

Unit is cm (equivalent to g/cm^2).

3.3.1.5.4 Data Source

Product is derived from the Level-3 MODIS Atmosphere Daily Global Product.

3.3.1.5.5 Data Range

Atmospheric_Water_Vapor_Mean varies between 0 and 20.

3.3.1.6 Sample Data Record

Dataset format is HDF. The specifications are provided at: http://modis-atmos.gsfc.nasa.gov/MOD08_M3/spec_c5.html

3.3.2 Analysis

3.3.2.1 Variability at global scale

Global temporal variations are represented on Figure 44. The highest contents are observed at the equator, with latitudinal variations depending on the season. The water vapour content ranges from 1 to 2 g/cm2 above 40 ° of latitude Nor th and South. Between these latitudes, the content varies between 2 and 7 g/cm2, reaching 10 g/cm2 in the Indian Ocean and Pacific.

The variability is analysed for all the NES.

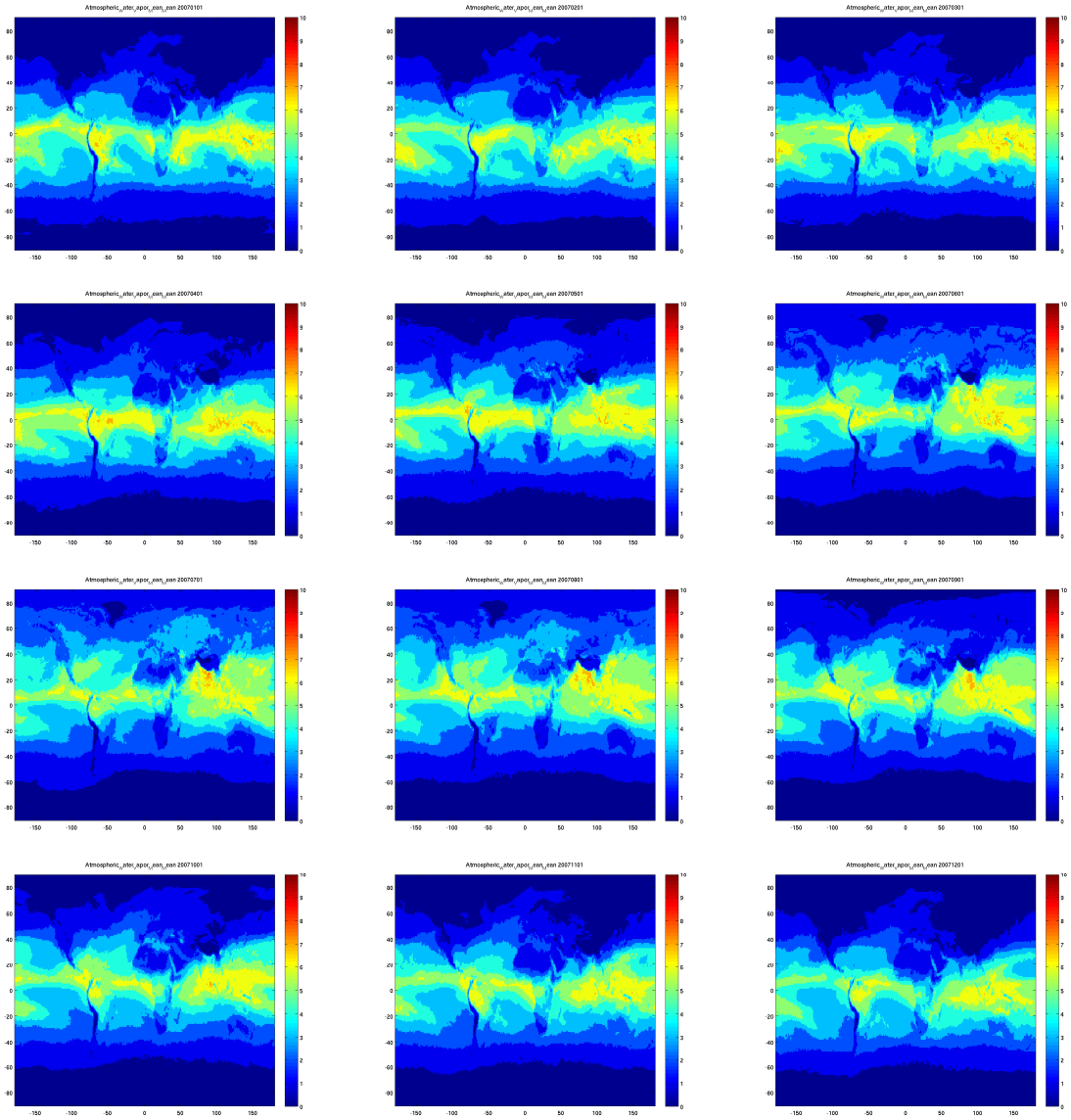


Figure 44: Monthly mean of water vapour content (MOD08_M3). Line of images corresponds to Q1, Q2, Q3, and Q4 respectively. Units : g/cm2.

3.3.2.2 Temporal variability over LNES

3.3.2.2.1 Statistics

Figure 45 represents the temporal variability of the water vapour content of the 20 desert sites, and Figure 46 provides the temporal variability for each site. Water vapour content varies between 0.5 and 1 in summer, and increases up to 3 g/cm^2 in summer (the maximum is in August for all the sites). Annual mean ranges between 0.98 and 1.5 g/cm2, but the difference between the observed maximum and minimum could be higher(0.67(Egypt) to 2.22)Mauritania.

Sites in the East Africa (Libya, Egypt) have the lowest temporal variability (the mean is around 1 g/cm^2 with a low standard deviation (0.25g/cm^2) whereas the maximum is observed in Mauritania and is around 3 g/cm^2. Statistics are reported in Table 33. The distribution of water content for the 20 sites is represented on Figure 47.

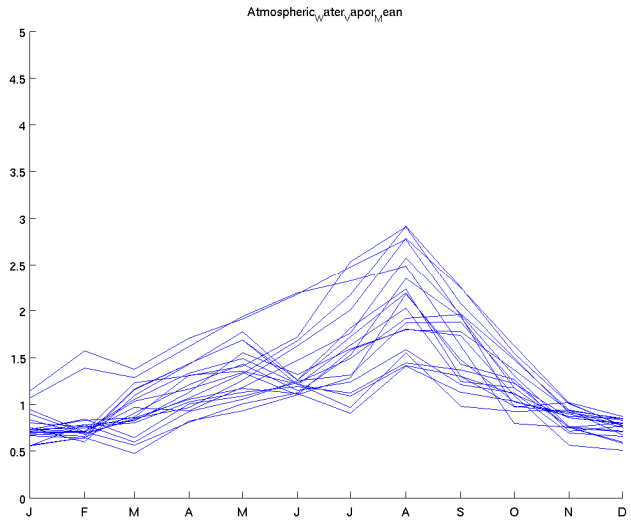


Figure 45: Superimposed temporal profiles of water vapour content for the LNES.

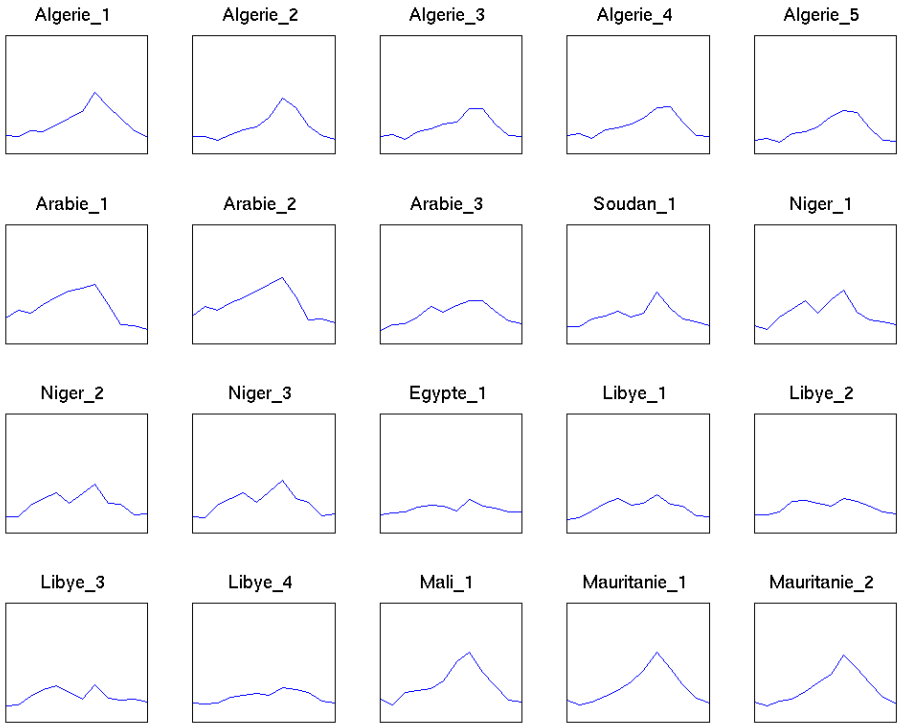


Figure 46: Temporal variability of Water vapour content for the LNES. X axis scale is one year, from January to December. Y axis scale is 0-5 g/cm^2.

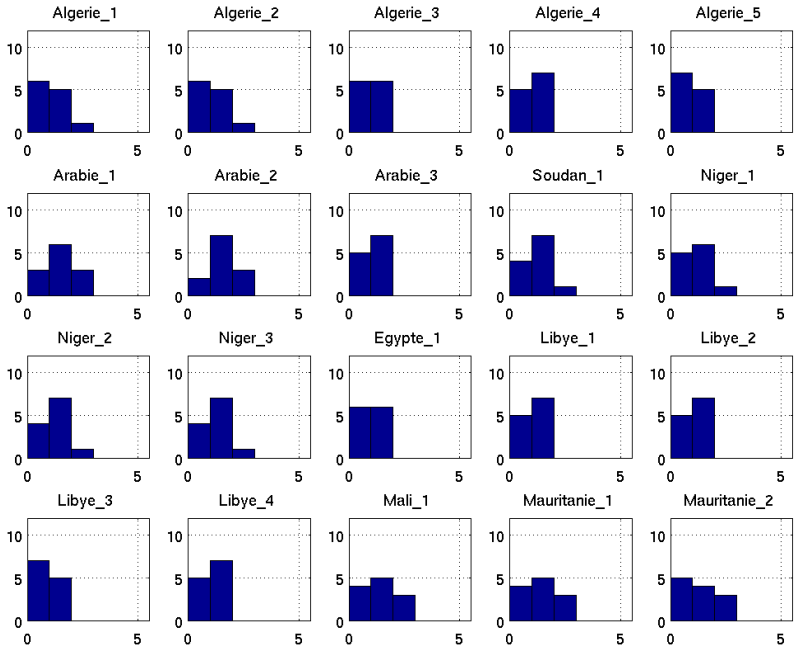


Figure 47: Histogram of water vapour content

Table 33: Statistics for water vapour products

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Algerie_1	1.2823	0.5872	0.6750	2.5730	1.8980	1.4802	0.4580
Algerie_2	1.1046	0.5654	0.5640	2.3500	1.7860	1.6169	0.5118
Algerie_3	1.0888	0.4366	0.5940	1.8770	1.2830	1.1784	0.4010
Algerie_4	1.1407	0.4557	0.6430	1.9590	1.3160	1.1536	0.3994
Algerie_5	0.9855	0.4865	0.4770	1.8020	1.3250	1.3445	0.4937
Arabie_1	1.5055	0.6404	0.5860	2.4890	1.9030	1.2640	0.4253
Arabie_2	1.6618	0.6179	0.8690	2.7730	1.9040	1.1457	0.3718
Arabie_3	1.2056	0.4211	0.5520	1.7960	1.2440	1.0319	0.3493
Soudan_1	1.1380	0.4128	0.6970	2.1770	1.4800	1.3005	0.3627
Niger_1	1.2445	0.4969	0.5940	2.2360	1.6420	1.3194	0.3993
Niger_2	1.2072	0.4354	0.6600	2.0320	1.3720	1.1365	0.3607
Niger_3	1.2441	0.4880	0.6350	2.1960	1.5610	1.2547	0.3923
Egypte_1	0.9952	0.1900	0.7320	1.4060	0.6740	0.6772	0.1909
Libye_1	1.0343	0.3359	0.5600	1.5890	1.0290	0.9948	0.3247
Libye_2	1.0664	0.2549	0.7300	1.4160	0.6860	0.6433	0.2391
Libye_3	1.0559	0.2858	0.6710	1.5520	0.8810	0.8343	0.2707
Libye_4	1.0430	0.2393	0.7600	1.4450	0.6850	0.6568	0.2295
Mali_1	1.5062	0.6930	0.7090	2.9100	2.2010	1.4612	0.4601
Mauritanie_1	1.4315	0.7040	0.6900	2.9150	2.2250	1.5543	0.4918
Mauritanie_2	1.3887	0.6756	0.6760	2.7880	2.1120	1.5209	0.4865

3.3.2.2.2 Results

Table 34 provides a classification of the sites based on the minimum of the dynamics of the water vapour content. Indeed, the mean values are almost the same, with the same variability. This is the strong variability in the summer month that is characterised.

Table 34: Rank of sites based on the dynamics of Water vapour content

Site score	Site name	Max -Min
1	Egypte_1	0.6740
2	Libye_4	0.6850
3	Libye_2	0.6860
4	Libye_3	0.8810
5	Libye_1	1.0290
6	Arabie_3	1.2440
7	Algerie_3	1.2830
8	Algerie_4	1.3160
9	Algerie_5	1.3250
10	Niger_2	1.3720
11	Soudan_1	1.4800
12	Niger_3	1.5610
13	Niger_1	1.6420
14	Algerie_2	1.7860
15	Algerie_1	1.8980
16	Arabie_1	1.9030
17	Arabie_2	1.9040
18	Mauritanie_2	2.1120
19	Mali_1	2.2010
20	Mauritanie_1	2.2250

3.3.2.3 Temporal variability over LNES- others

3.3.2.3.1 Statistics

Figure 48 provides the temporal variability of all of sites. A seasonal cycle is observed with a maximum in north hemisphere in summer and a minimum in south hemisphere in winter. Antarctica sites have very low values. Statistics are reported in Table 35.

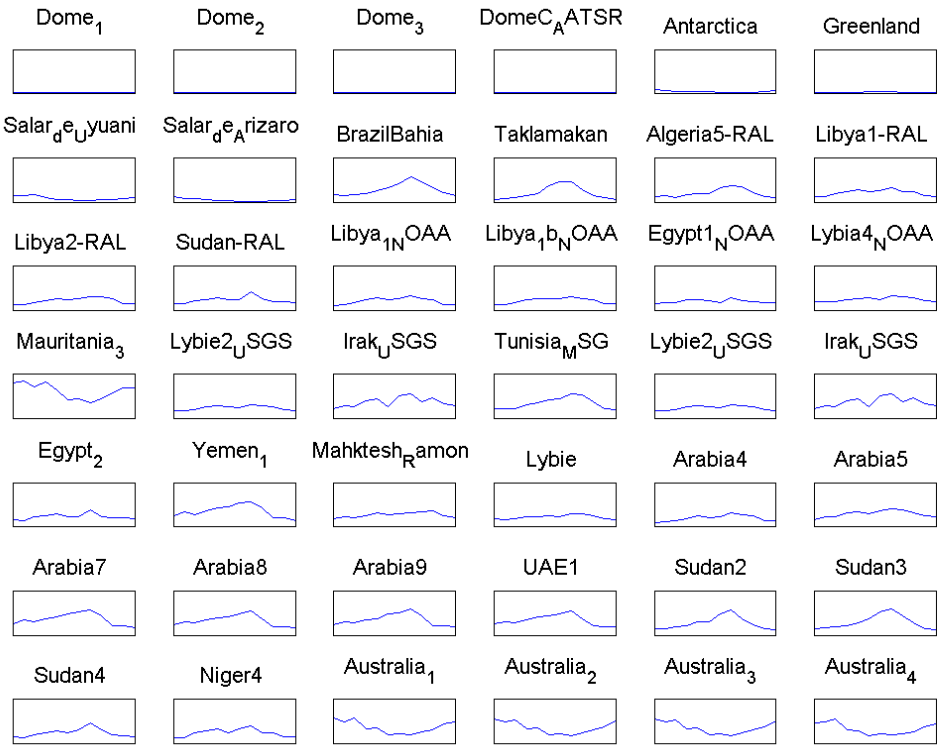


Figure 48: Temporal variability of Water vapour content for the LNES-Others. X axis scale is one year, from January to December. Y axis scale is 0-5 g/cm^2.

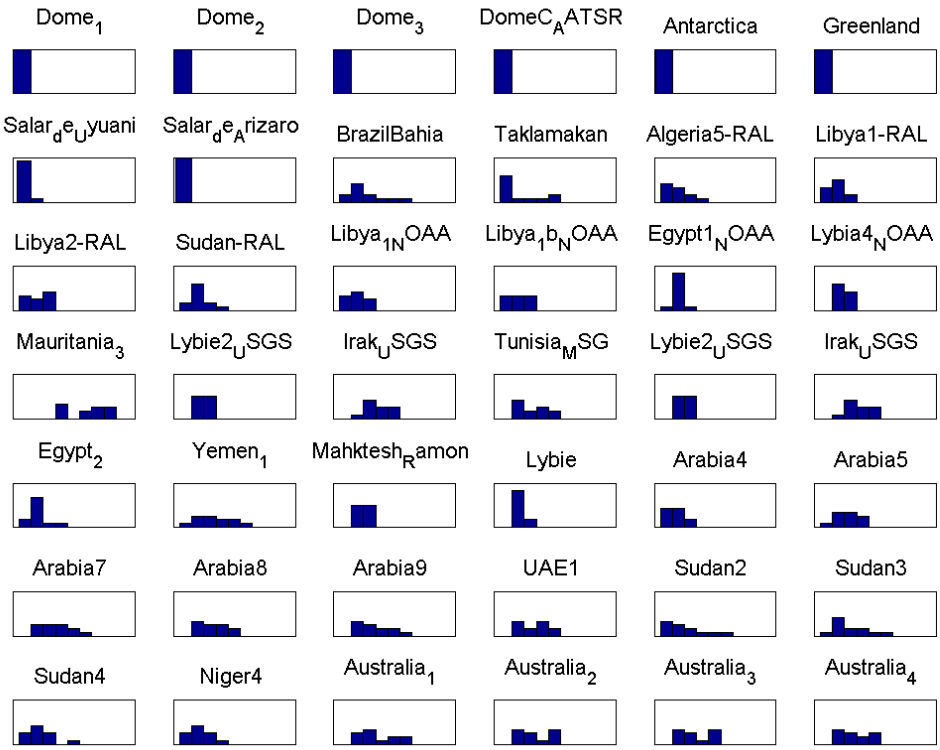


Figure 49: Histogram of water vapour content for the LNES-Others

Table 35: Statistics for water vapour content products for LNES others group site

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Dome_1	0.0142	0.0087	0.0060	0.0350	0.0290	2.0471	0.6130
Dome_2	0.0129	0.0079	0.0060	0.0320	0.0260	2.0129	0.6091
Dome_3	0.0157	0.0095	0.0070	0.0380	0.0310	1.9683	0.6061
DomeC_AATSR	0.0145	0.0084	0.0070	0.0340	0.0270	1.8674	0.5793
Antarctica	0.1608	0.0851	0.0650	0.3470	0.2820	1.7543	0.5293
Greenland	0.0825	0.0712	0.0224	0.2174	0.1950	2.3642	0.8635
Salar_de_Uyuani	0.4283	0.2134	0.1810	0.8260	0.6450	1.5058	0.4982
Salar_de_Arizaro	0.2391	0.1410	0.0830	0.5720	0.4890	2.0453	0.5900
Brazil Bahia	3.0364	0.8471	1.7700	4.2030	2.4330	0.8013	0.2790
Taklamakan	1.0169	0.7544	0.2620	2.3110	2.0490	2.0149	0.7418
Algeria5-RAL	0.9835	0.4943	0.4680	1.8520	1.3840	1.4072	0.5025
Libya1-RAL	1.0343	0.3359	0.5600	1.5890	1.0290	0.9948	0.3247
Libya2-RAL	1.0593	0.3433	0.5670	1.5440	0.9770	0.9223	0.3241
Sudan-RAL	1.1074	0.3675	0.6800	2.0395	1.3595	1.2276	0.3319
Libya_1_NOAA	1.0195	0.3536	0.5110	1.5753	1.0642	1.0439	0.3468
Libya_1b_NOAA	1.0469	0.3218	0.5820	1.5335	0.9515	0.9089	0.3074
Egypt1_NOAA	0.9698	0.1843	0.7300	1.3550	0.6250	0.6445	0.1900
Lybia4_NOAA	1.1972	0.2407	0.9035	1.6065	0.7030	0.5872	0.2011
Mauritania_3	1.3807	0.6878	0.6720	2.7920	2.1200	1.5354	0.4981
Lybie2_USGS	1.1324	0.2695	0.7790	1.5190	0.7400	0.6535	0.2380
Irak_USGS	1.7959	0.5213	1.0800	2.6960	1.6160	0.8998	0.2903
Tunisia_MSG	1.6458	0.6349	0.9540	2.7040	1.7500	1.0633	0.3858
Lybie2_USGS	1.1324	0.2695	0.7790	1.5190	0.7400	0.6535	0.2380
Irak_USGS	1.7959	0.5213	1.0800	2.6960	1.6160	0.8998	0.2903
Egypt_2	1.0768	0.3315	0.6630	1.9020	1.2390	1.1506	0.3079
Yemen_1	1.7032	0.6861	0.6450	2.7750	2.1300	1.2506	0.4028
Mahktesh_Ramon	1.2945	0.2965	0.8020	1.7120	0.9100	0.7030	0.2290
Lybie	1.0430	0.2393	0.7600	1.4450	0.6850	0.6568	0.2295
Arabia4	0.8952	0.3577	0.3800	1.4800	1.1000	1.2287	0.3996
Arabia5	1.3984	0.3894	0.7320	1.9530	1.2210	0.8731	0.2784
Arabia7	1.7804	0.6348	0.8860	2.8340	1.9480	1.0941	0.3566
Arabia8	1.6234	0.6011	0.8360	2.6790	1.8430	1.1353	0.3703
Arabia9	1.7173	0.6541	0.9640	2.9460	1.9820	1.1541	0.3809
UAE1	1.6708	0.5881	0.9240	2.7360	1.8120	1.0845	0.3520
Sudan2	1.3186	0.7132	0.5580	2.8250	2.2670	1.7193	0.5409

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Sudan3	1.4489	0.7979	0.6420	2.9930	2.3510	1.6226	0.5507
Sudan4	1.1468	0.4716	0.6630	2.2780	1.6150	1.4082	0.4112
Niger4	1.1689	0.4340	0.6280	1.9770	1.3490	1.1541	0.3713
Australia_1	1.8003	0.6929	0.9440	2.8020	1.8580	1.0321	0.3849
Australia_2	1.7476	0.6710	0.8850	2.6930	1.8080	1.0346	0.3840
Australia_3	1.7476	0.6710	0.8850	2.6930	1.8080	1.0346	0.3840
Australia_4	1.6237	0.6473	0.8220	2.6830	1.8610	1.1462	0.3987

3.3.2.3.2 Results

Table 36 provides a classification of the sites based on the minimum of the dynamics of the water vapour content.

Table 36: Rank of sites based on the dynamics of Water vapour content

Rank	Site name	Max –Min of Water vapour content		Rank	Site name	Max -Min of Water vapour content
1	Dome_2	0.0260		22	Niger4	1.3490
2	DomeC_AATSR	0.0270		23	Sudan-RAL	1.3595
3	Dome_1	0.0290		24	Algeria5-RAL	1.3840
4	Dome_3	0.0310		25	Sudan4	1.6150
5	Greenland	0.1950		26	Irak_USGS	1.6160
6	Antarctica	0.2820		27	Irak_USGS	1.6160
7	Salar_de_Arizaro	0.4890		28	Tunisia_MSG	1.7500
8	Egypt1_NOAA	0.6250		29	Australia_2	1.8080
9	Salar_de_Uyuani	0.6450		30	Australia_3	1.8080
10	Lybie	0.6850		31	UAE1	1.8120
11	Lybia4_NOAA	0.7030		32	Arabia8	1.8430
12	Lybie2_USGS	0.7400		33	Australia_1	1.8580
13	Lybie2_USGS	0.7400		34	Australia_4	1.8610
14	Mahktesh_Ramon	0.9100		35	Arabia7	1.9480
15	Libya_1b_NOAA	0.9515		36	Arabia9	1.9820
16	Libya2-RAL	0.9770		37	Taklamakan	2.0490
17	Libya1-RAL	1.0290		38	Mauritania_3	2.1200
18	Libya_1_NOAA	1.0642		39	Yemen_1	2.1300
19	Arabia4	1.1000		40	Sudan2	2.2670
20	Arabia5	1.2210		41	Sudan3	2.3510
21	Egypt_2	1.2390		42	BrazilBahia	2.4330

3.3.2.4 Temporal variability over LNES- China

3.3.2.4.1 Statistics

Figure 50 represents the temporal variability of the water vapour content of the china sites, and Figure 51 provides the temporal variability for each site. The variations are very similar, with a minimum in winter and a maximum in summer. The maximum is around 3g /cm2.

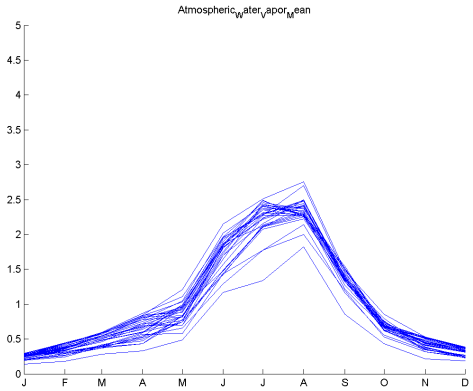


Figure 50: Superimposed temporal profiles of water vapour content for the LNES china sites.

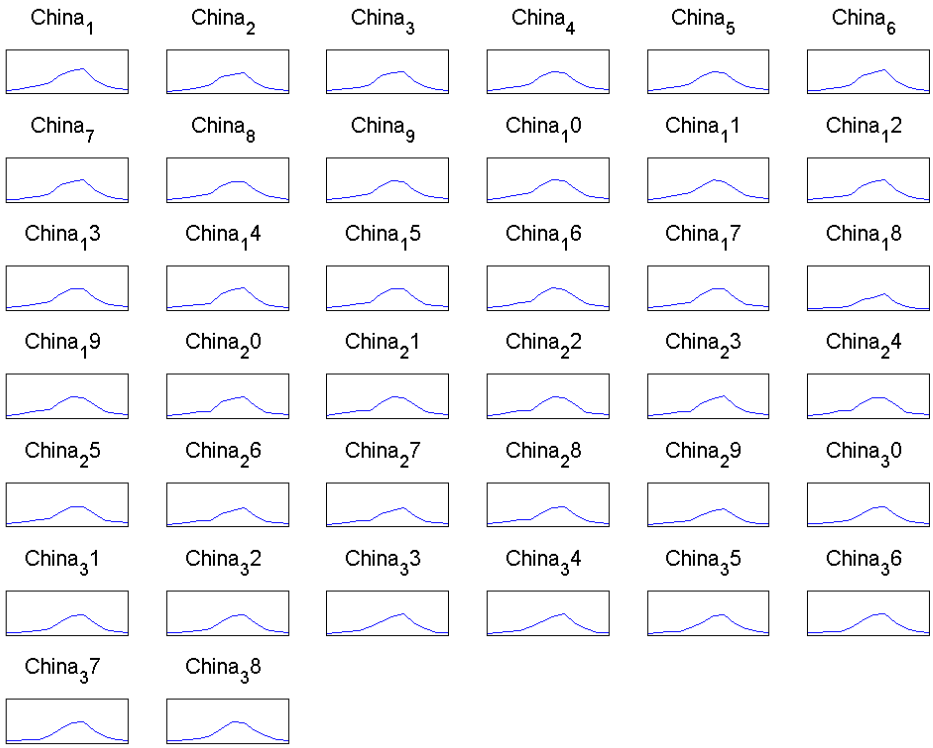


Figure 51: Temporal variability of water vapour content for the LNES-china sites. X axis scale is one year, from January to December. Y axis scale is 0-6 g/cm2.

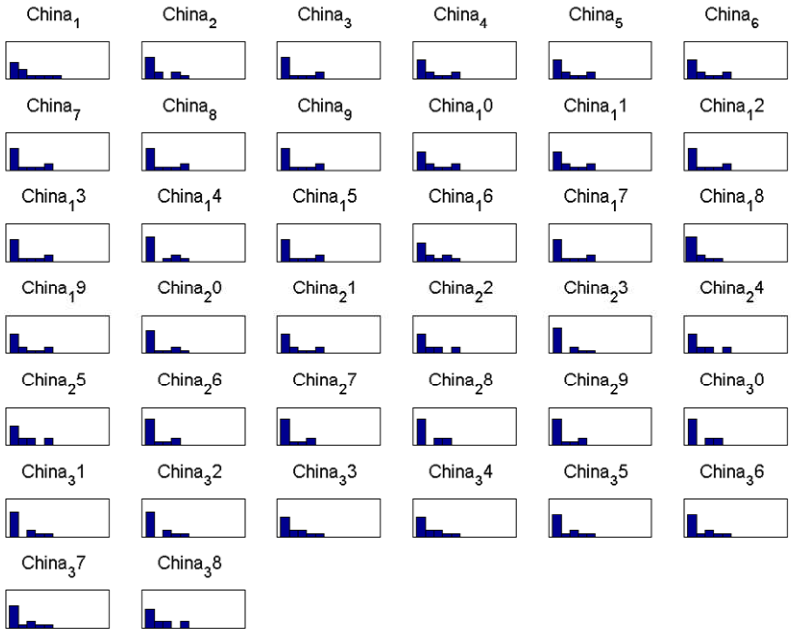


Figure 52: Histogram of water vapour content for China sites

Statistical parameters are reported in Table 37.

Table 37: Statistics for water vapour content products for the LNES-china sites

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
China_1	1.1679	0.8671	0.2930	2.7540	2.4610	2.1072	0.7424
China_2	0.9359	0.7674	0.2000	2.3060	2.1060	2.2502	0.8200
China_3	1.0192	0.7999	0.2530	2.4440	2.1910	2.1498	0.7848
China_4	1.0744	0.7913	0.2830	2.4130	2.1300	1.9825	0.7365
China_5	1.0744	0.7913	0.2830	2.4130	2.1300	1.9825	0.7365
China_6	1.0405	0.8510	0.2420	2.7040	2.4620	2.3662	0.8179
China_7	1.0196	0.8046	0.2540	2.4900	2.2360	2.1931	0.7891
China_8	1.0169	0.7544	0.2620	2.3110	2.0490	2.0149	0.7418
China_9	1.0083	0.7605	0.2560	2.3530	2.0970	2.0797	0.7542
China_10	1.1010	0.7856	0.2730	2.4590	2.1860	1.9855	0.7135
China_11	1.0711	0.7689	0.2780	2.4850	2.2070	2.0605	0.7178
China_12	0.9878	0.7947	0.2480	2.4750	2.2270	2.2546	0.8045
China_13	1.0131	0.7797	0.2640	2.3740	2.1100	2.0828	0.7696
China_14	0.9739	0.7959	0.2450	2.5000	2.2550	2.3154	0.8172
China_15	1.0118	0.7864	0.2620	2.4020	2.1400	2.1150	0.7772
China_16	1.0541	0.7833	0.2590	2.4900	2.2310	2.1165	0.7431
China_17	1.0118	0.7864	0.2620	2.4020	2.1400	2.1150	0.7772
China_18	0.6188	0.5513	0.1380	1.8230	1.6850	2.7229	0.8909
China_19	1.0553	0.7603	0.2940	2.4110	2.1170	2.0060	0.7204
China_20	0.9931	0.7624	0.2700	2.4110	2.1410	2.1559	0.7677
China_21	1.0471	0.7494	0.2920	2.4000	2.1080	2.0132	0.7157

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
China_22	1.0402	0.7594	0.2890	2.4350	2.1460	2.0631	0.7301
China_23	0.9825	0.7608	0.2620	2.4870	2.2250	2.2646	0.7743
China_24	1.0004	0.7331	0.2790	2.2700	1.9910	1.9902	0.7328
China_25	1.0004	0.7331	0.2790	2.2700	1.9910	1.9902	0.7328
China_26	0.8036	0.6591	0.1960	2.1430	1.9470	2.4229	0.8202
China_27	0.8036	0.6591	0.1960	2.1430	1.9470	2.4229	0.8202
China_28	0.9212	0.7014	0.2890	2.2480	1.9590	2.1267	0.7614
China_29	0.7834	0.6253	0.2060	2.0010	1.7950	2.2912	0.7982
China_30	0.8809	0.7123	0.2650	2.2220	1.9570	2.2215	0.8086
China_31	0.8934	0.7322	0.2520	2.2800	2.0280	2.2699	0.8195
China_32	0.8934	0.7322	0.2520	2.2800	2.0280	2.2699	0.8195
China_33	0.9143	0.7574	0.1980	2.4140	2.2160	2.4238	0.8284
China_34	0.9143	0.7574	0.1980	2.4140	2.2160	2.4238	0.8284
China_35	0.8745	0.7458	0.2040	2.3240	2.1200	2.4242	0.8529
China_36	0.9278	0.7830	0.2220	2.4200	2.1980	2.3690	0.8439
China_37	0.9278	0.7830	0.2220	2.4200	2.1980	2.3690	0.8439
China_38	0.9534	0.7995	0.2310	2.4350	2.2040	2.3117	0.8386

3.3.2.4.2 Results

Table 38 provides a classification of the sites based on the minimum of the dynamics of the water vapour content

Table 38: Rank of sites based on the dynamics of Water vapour content

Rank	Site name	Max –Min of Water vapour content		Rank	Site name	Max –Min of Water vapour content
1	China_18	1.6850		20	China_15	2.1400
2	China_29	1.7950		21	China_17	2.1400
3	China_26	1.9470		22	China_20	2.1410
4	China_27	1.9470		23	China_22	2.1460
5	China_30	1.9570		24	China_10	2.1860
6	China_28	1.9590		25	China_3	2.1910
7	China_24	1.9910		26	China_36	2.1980
8	China_25	1.9910		27	China_37	2.1980
9	China_31	2.0280		28	China_38	2.2040
10	China_32	2.0280		29	China_11	2.2070
11	China_8	2.0490		30	China_33	2.2160
12	China_9	2.0970		31	China_34	2.2160
13	China_2	2.1060		32	China_23	2.2250
14	China_21	2.1080		33	China_12	2.2270
15	China_13	2.1100		34	China_16	2.2310
16	China_19	2.1170		35	China_7	2.2360

Rank	Site name	Max –Min of Water vapour content		Rank	Site name	Max –Min of Water vapour content
17	China_35	2.1200		36	China_14	2.2550
18	China_4	2.1300		37	China_1	2.4610
19	China_5	2.1300		38	China_6	2.4620

3.3.2.5 Temporal variability over LES

3.3.2.5.1 Statistics for CEOS Reference Standard Test Sites

Figure 53 provides the temporal variability for each CEOS site. Statistics are reported in Table 39. The maximum in La Crau is around 3.5 g/cm2. All sites present a maximum in summer.

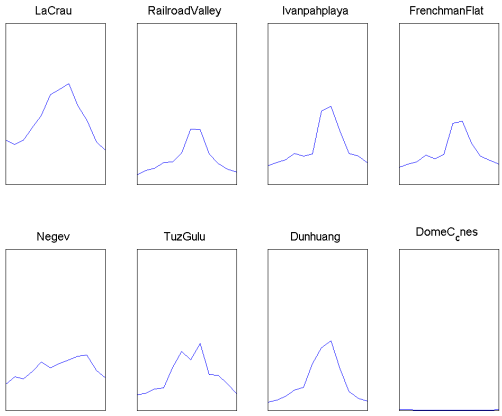


Figure 53: Temporal variability of water vapour content for the LES. X axis scale is one year, from January to December. Y axis scale is 0-6 g/cm2.

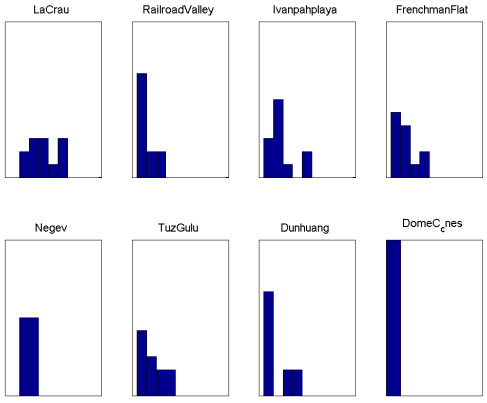


Figure 54: Histogram of water vapour content

Table 39: Statistics of water vapour content over CEOS LES

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
LaCrau	1.9630	0.7208	1.0600	3.1170	2.0570	1.0479	0.3672
RailroadValley	0.7856	0.4760	0.3030	1.7160	1.4130	1.7987	0.6060
Ivanpahplaya	1.1353	0.6241	0.5820	2.4110	1.8290	1.6110	0.5497
FrenchmanFlat	0.9927	0.4795	0.5240	1.9640	1.4400	1.4506	0.4831
Negev	1.2945	0.2965	0.8020	1.7120	0.9100	0.7030	0.2290
TuzGulu	1.0582	0.5416	0.4850	2.0730	1.5880	1.5007	0.5118
Dunhuang	0.8692	0.6696	0.2490	2.1530	1.9040	2.1906	0.7704
Dome C_cnes	0.0125	0.0073	0.0055	0.0297	0.0243	1.9432	0.5830

3.3.2.5.2 Statistics for temporary equipped sites

Concerning the other sites, sites located in Northern hemisphere present a maximum of water vapour content in summer (Figure 55),

Table 40: Statistics for water vapour content over Non CEOS LES

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Lunarplaya	0.7856	0.4760	0.3030	1.7160	1.4130	1.7987	0.6060
WhiteSands	1.3781	0.9218	0.5050	3.0710	2.5660	1.8620	0.6689
RogerDryLake	1.3747	0.5856	0.7810	2.6350	1.8540	1.3486	0.4260
BonnevilleSaltFlats	0.8772	0.5916	0.2720	2.0190	1.7470	1.9916	0.6745
LakeFrome	1.7849	0.6502	0.9370	2.9040	1.9670	1.1020	0.3643
BarrealBlanco	0.4574	0.2315	0.1970	0.9710	0.7740	1.6921	0.5061
RoachLakePlaya	1.1353	0.6241	0.5820	2.4110	1.8290	1.6110	0.5497
Mud_Lake	0.8430	0.4501	0.3890	1.7330	1.3440	1.5943	0.5339
Brookings	1.4372	0.9436	0.3600	2.8790	2.5190	1.7527	0.6565
TingaTingana	1.6237	0.6473	0.8220	2.6830	1.8610	1.1462	0.3987
Dunrobin	2.9016	1.0305	1.4440	4.6980	3.2540	1.1215	0.3552
Warrabin	2.1428	0.8367	1.1670	3.3860	2.2190	1.0355	0.3904
Winton	2.7703	1.0062	1.4550	4.4060	2.9510	1.0652	0.3632
Amburla	1.9667	0.8381	0.8540	3.5150	2.6610	1.3530	0.4261
Sonoran_desert	1.6375	0.9830	0.8540	3.7200	2.8660	1.7502	0.6003
Sechura_desert	4.6396	0.6589	3.5850	5.6250	2.0400	0.4397	0.1420
Hay_Uardry	1.8275	0.5684	1.1360	2.7210	1.5850	0.8673	0.3111
Perkingston	3.0402	1.2570	1.5680	5.1390	3.5710	1.1746	0.4135
ParkFalls	1.3638	0.9193	0.3020	2.8020	2.5000	1.8332	0.6741
Jaisalmer	2.6313	1.6932	1.1080	5.2640	4.1560	1.5795	0.6435
Chhrodi	3.5946	2.0161	1.9390	6.7790	4.8400	1.3465	0.5609

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Gongger	0.8522	0.8005	0.1400	2.3620	2.2220	2.6075	0.9394
Erlian	0.8402	0.7214	0.1960	2.3460	2.1500	2.5590	0.8587
Zuoqi	0.8432	0.7388	0.1740	2.3700	2.1960	2.6045	0.8763
Youqi	0.8176	0.7225	0.1850	2.3020	2.1170	2.5893	0.8836
Wiggins_Gravelpits	3.0402	1.2570	1.5680	5.1390	3.5710	1.1746	0.4135
Wiggins_RyeField	3.0402	1.2570	1.5680	5.1390	3.5710	1.1746	0.4135
Wiggins_CutGrass	3.0402	1.2570	1.5680	5.1390	3.5710	1.1746	0.4135
Newell	1.0628	0.6990	0.2860	2.4570	2.1710	2.0427	0.6577
WigginsWesttarp	3.0402	1.2570	1.5680	5.1390	3.5710	1.1746	0.4135
Yuma	2.0247	0.9688	1.1570	3.9430	2.7860	1.3760	0.4785
Sonoran_RAL	2.0247	0.9688	1.1570	3.9430	2.7860	1.3760	0.4785
Brookings_2	1.4372	0.9436	0.3600	2.8790	2.5190	1.7527	0.6565
Sechura_RAL	4.5166	0.5984	3.6280	5.4960	1.8680	0.4136	0.1325
Dunhuang_RAL	0.9212	0.7014	0.2890	2.2480	1.9590	2.1267	0.7614

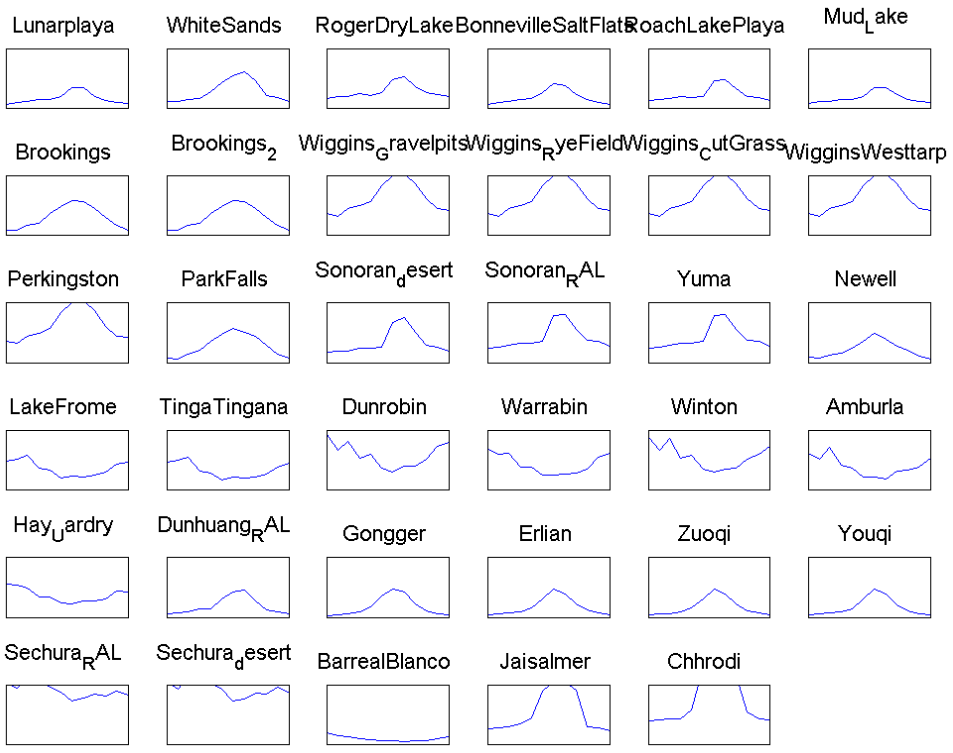


Figure 55: Temporal variability of water vapour content for the LES. X axis scale is one year, from January to December. Y axis scale is 0-6 g/cm2.

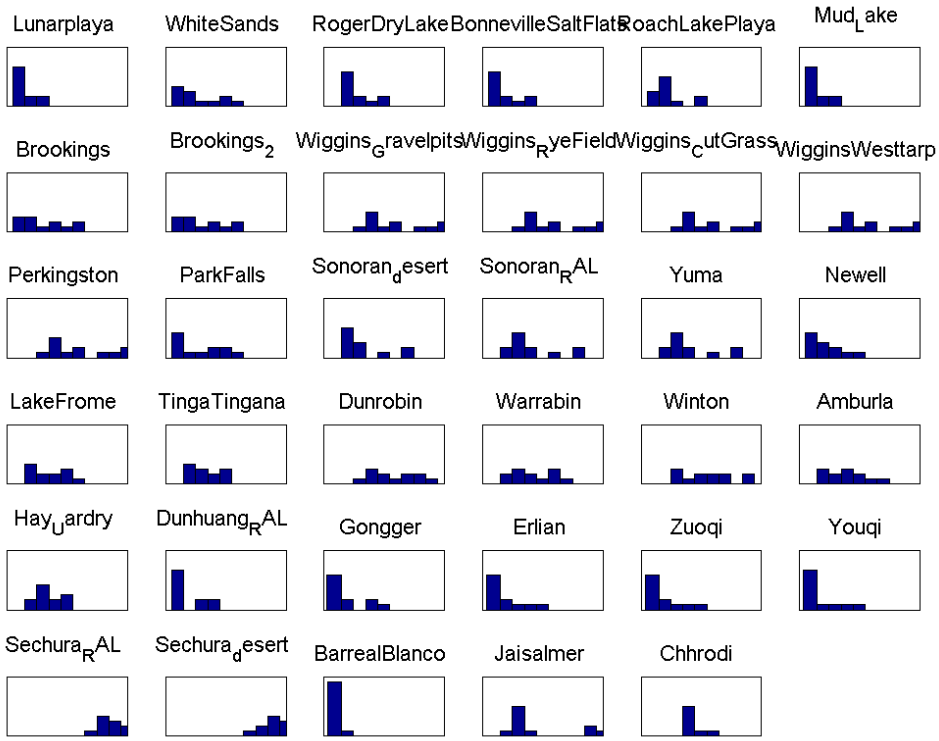


Figure 56: Histogram of water vapour content

3.3.2.5.3 Results

The classification is reported in the following table.

Table 41: Rank of CEOS Reference Standard Test Sites based on the dynamics of Water vapour content

Rank	Site name	Max –Min of Water vapour content
	DomeC_cnes	0.0243
	Negev	0.9100
	RailroadValley	1.4130
	FrenchmanFlat	1.4400
	TuzGulu	1.5880
	Ivanpahplaya	1.8290
	Dunhuang	1.9040
	LaCrau	2.0570

Table 42: Rank of sites based on the dynamics of Water vapour content

Rank	Site name	Max –Min of Water vapour content		Rank	Site name	Max –Min of Water vapour content
1	BarrealBlanco	0.7740		19	ParkFalls	2.5000
2	Mud_Lake	1.3440		20	Brookings	2.5190

Rank	Site name	Max –Min of Water vapour content		Rank	Site name	Max –Min of Water vapour content
3	Lunarplaya	1.4130		21	Brookings_2	2.5190
4	Hay_Uardry	1.5850		22	WhiteSands	2.5660
5	BonnevilleSaltFlats	1.7470		23	Amburla	2.6610
6	RoachLakePlaya	1.8290		24	Yuma	2.7860
7	RogerDryLake	1.8540		25	Sonoran_RAL	2.7860
8	TingaTingana	1.8610		26	Sonoran_desert	2.8660
9	Sechura_RAL	1.8680		27	Winton	2.9510
10	Dunhuang_RAL	1.9590		28	Dunrobin	3.2540
11	LakeFrome	1.9670		29	Perkingston	3.5710
12	Sechura_desert	2.0400		30	Wiggins_Gravelpits	3.5710
13	Youqi	2.1170		31	Wiggins_RyeField	3.5710
14	Erlian	2.1500		32	Wiggins_CutGrass	3.5710
15	Newell	2.1710		33	WigginsWesttarp	3.5710
16	Zuoqi	2.1960		34	Jaisalmer	4.1560
17	Warrabin	2.2190		35	Chhrodi	4.8400
18	Gongger	2.2220				

3.3.2.6 Temporal variability over SNES

3.3.2.6.1 Statistics

Figure 57 represents the temporal variability of the water vapour content of the 42 oceanic sites, and Figure 58 provides the temporal variability for each site. The temporal variability is different and opposite in the Northern Hemisphere and the Southern Hemisphere. For sites in the Southern Hemisphere, the maximum ranges from 2 to 4 g/cm^2, and the minimum ranges from 1 to 3 g/cm^2. For sites in the Northern hemisphere, the minimum ranges from 3 to 4 g/cm^2 in winter, and reaches 4 to 6 g/cm^2 in summer (August and September). The maximum is observed for the PacNW sites.

Statistics are reported in Table 43. The distribution of water content for the 42 sites is represented on Figure 59.

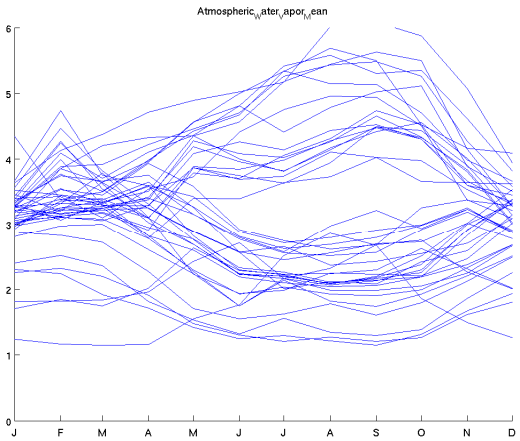


Figure 57: Superimposed temporal profiles of water vapour content for the SNES.

Figure 58: Temporal variability of Water vapour content for the SNES. X axis scale is one year, from January to December. Y axis scale is 0-5 g/cm2.

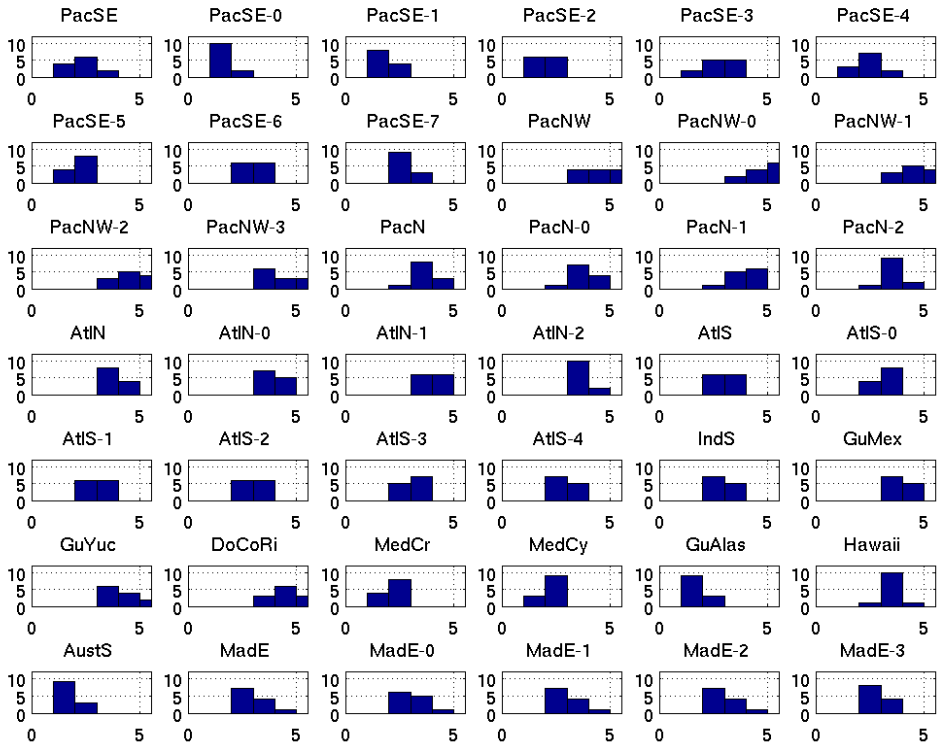


Figure 59: Histogram of water vapour content for SNES

Table 43: Statistics for water vapour products

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
PacSE	2.4209	0.4782	1.9065	3.1082	1.2017	0.4964	0.1975
PacSE-0	1.6193	0.4064	1.1541	2.3083	1.1542	0.7128	0.2510
PacSE-1	1.8053	0.4645	1.3000	2.5131	1.2131	0.6720	0.2573
PacSE-2	2.1156	0.5079	1.5517	2.8814	1.3297	0.6285	0.2401
PacSE-3	2.6503	0.6150	1.9369	3.7829	1.8460	0.6965	0.2321
PacSE-4	2.4607	0.5379	1.7501	3.3622	1.6121	0.6551	0.2186
PacSE-5	2.3095	0.4653	1.7368	2.9995	1.2627	0.5467	0.2015
PacSE-6	3.0116	0.5292	2.3719	3.7546	1.3827	0.4591	0.1757
PacSE-7	2.6094	0.4253	2.1061	3.2304	1.1243	0.4309	0.1630
PacNW	4.4772	0.7510	3.2782	5.4771	2.1990	0.4911	0.1677
PacNW-0	4.9093	0.8059	3.6337	6.0823	2.4485	0.4987	0.1642
PacNW-1	4.4630	0.8410	3.0873	5.6287	2.5414	0.5694	0.1884
PacNW-2	4.5364	0.7575	3.3113	5.5820	2.2707	0.5005	0.1670
PacNW-3	4.3034	0.6916	3.3331	5.3388	2.0057	0.4661	0.1607
PacN	3.7017	0.4972	2.9931	4.4693	1.4762	0.3988	0.1343
PacN-0	3.7509	0.5518	2.9965	4.7350	1.7385	0.4635	0.1471
PacN-1	3.8036	0.5448	2.9259	4.5234	1.5974	0.4200	0.1432
PacN-2	3.5315	0.4234	2.9093	4.1040	1.1947	0.3383	0.1199
AtlN	3.7543	0.5079	3.1242	4.4881	1.3639	0.3633	0.1353
AtlN-0	3.8167	0.5048	3.0621	4.5517	1.4897	0.3903	0.1322
AtlN-1	3.7878	0.5587	3.0090	4.6517	1.6427	0.4337	0.1475
AtlN-2	3.6168	0.5049	3.0348	4.4917	1.4569	0.4028	0.1396
AtlS	3.0682	0.3071	2.6211	3.5779	0.9569	0.3119	0.1001
AtlS-0	3.1962	0.4035	2.6134	3.9321	1.3187	0.4126	0.1262
AtlS-1	2.9564	0.3034	2.5152	3.4042	0.8890	0.3007	0.1026
AtlS-2	3.1294	0.3058	2.7130	3.5954	0.8824	0.2820	0.0977
AtlS-3	3.1470	0.3217	2.5736	3.6493	1.0757	0.3418	0.1022
AtlS-4	2.8798	0.2899	2.4487	3.2521	0.8033	0.2789	0.1007
IndS	2.8176	0.6176	2.0097	3.8480	1.8383	0.6524	0.2192
GuMex	3.9505	0.7045	3.0970	4.9573	1.8603	0.4709	0.1783
GuYuc	4.1975	0.6673	3.2038	5.1135	1.9097	0.4550	0.1590
DoCoRi	4.5012	0.7513	3.3751	5.6818	2.3067	0.5125	0.1669
MedCr	2.2292	0.3544	1.8128	2.7553	0.9425	0.4228	0.1590
MedCy	2.1632	0.3052	1.7085	2.6305	0.9220	0.4262	0.1411
GuAlas	1.7247	0.6266	1.1529	2.8606	1.7077	0.9902	0.3633
Hawaii	3.4632	0.3241	2.7843	4.0233	1.2390	0.3578	0.0936

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
AustS	1.6529	0.4312	1.2072	2.3241	1.1168	0.6757	0.2608
MadE	2.8505	0.7075	2.0644	4.2699	2.2055	0.7737	0.2482
MadE-0	3.0351	0.8249	2.0800	4.7325	2.6525	0.8739	0.2718
MadE-1	2.9422	0.7685	2.0802	4.4679	2.3877	0.8115	0.2612
MadE-2	2.8457	0.6936	2.0907	4.2407	2.1500	0.7555	0.2437
MadE-3	2.7297	0.6437	2.0388	3.9893	1.9505	0.7145	0.2358

3.3.2.6.2 Results

Table 44 provides a classification of the sites based on the minimum of the mean

Table 44: Rank of sites based on the mean of Water vapour content of SNES

Rank	Site name	Mean		Rank	Site name	Mean
1	PacSE-0	1.6193		22	AtlS	3.0682
2	AustS	1.6529		23	AtlS-2	3.1294
3	GuAlas	1.7247		24	AtlS-3	3.1470
4	PacSE-1	1.8053		25	AtlS-0	3.1962
5	PacSE-2	2.1156		26	Hawaii	3.4632
6	MedCy	2.1632		27	PacN-2	3.5315
7	MedCr	2.2292		28	AtlN-2	3.6168
8	PacSE-5	2.3095		29	PacN	3.7017
9	PacSE	2.4209		30	PacN-0	3.7509
10	PacSE-4	2.4607		31	AtlN	3.7543
11	PacSE-7	2.6094		32	AtlN-1	3.7878
12	PacSE-3	2.6503		33	PacN-1	3.8036
13	MadE-3	2.7297		34	AtlN-0	3.8167
14	IndS	2.8176		35	GuMex	3.9505
15	MadE-2	2.8457		36	GuYuc	4.1975
16	MadE	2.8505		37	PacNW-3	4.3034
17	AtlS-4	2.8798		38	PacNW-1	4.4630
18	MadE-1	2.9422		39	PacNW	4.4772
19	AtlS-1	2.9564		40	DoCoRi	4.5012
20	PacSE-6	3.0116		41	PacNW-2	4.5364
21	MadE-0	3.0351		42	PacNW-0	4.9093

3.3.2.7 Temporal variability over SES

3.3.2.7.1 Statistics

The temporal variability of the water vapour content over the SES is represented in Figure 60. The highest values are observed during the summer months, except for MOBY and Venice site where the mean is high and the temporal variability low. The water vapour content of the site located in India (Karavatti) is high (mean around 4.4 g/cm2), and the maximum reach 5.5 g/cm2 in summer during the monsoon months.

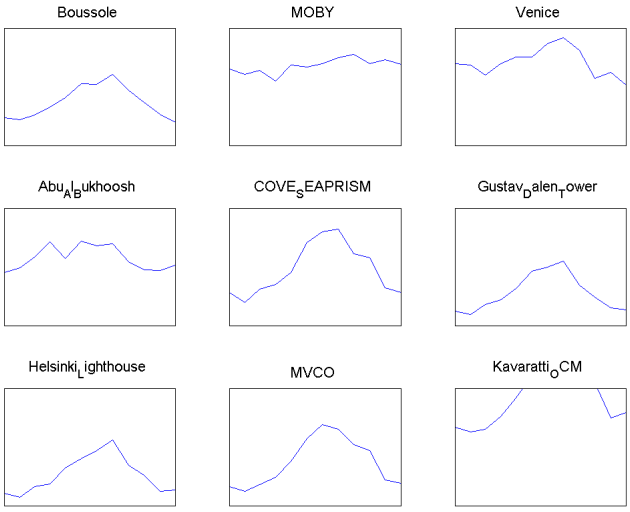


Figure 60: Temporal variability of water vapour content for the SES. X axis scale is one year, from January to December. Y axis scale is 0-5 g/cm2.

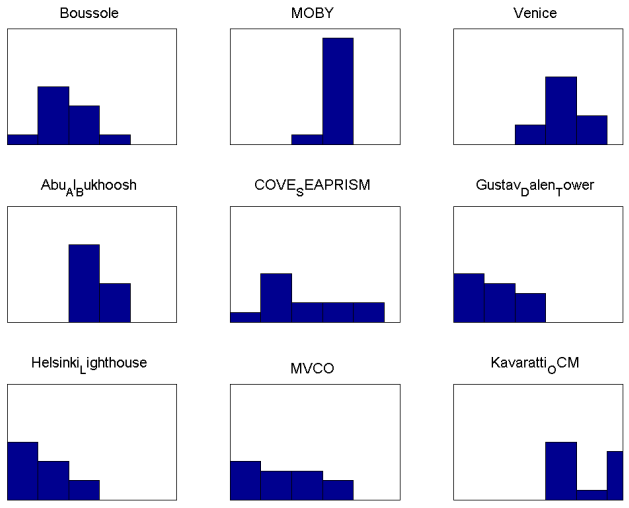


Figure 61: Histogram of water vapour content

Statistics are reported in Table 45.

Table 45: Statistics for water vapour content over SES

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Boussole	1.8272	0.6921	0.9680	3.0350	2.0670	1.1313	0.3788
MOBY	3.3880	0.3119	2.7380	3.8750	1.1370	0.3356	0.0921
Venice/AAOT	3.5336	0.5992	2.5830	4.5810	1.9980	0.5654	0.1696
Abu_Al_Bukhoosh	2.8763	0.5076	2.2550	3.5880	1.3330	0.4634	0.1765
COVE_SEAPRISM	2.3817	1.0958	0.9710	4.1090	3.1380	1.3176	0.4601
Gustav_Dalen_Tower	1.3781	0.7785	0.4760	2.7300	2.2540	1.6356	0.5649
Helsinki_Lighthouse	1.3060	0.7852	0.3680	2.7960	2.4280	1.8591	0.6013
MVCO	1.8282	1.0331	0.6060	3.4620	2.8560	1.5622	0.5651
Kavaratti_OCM	4.4225	0.9812	3.1440	5.6960	2.5520	0.5770	0.2219

3.3.2.7.2 Results

Table 26 provides a classification of the sites based on the observed mean water vapour content.

Table 46: Rank of SES Test Sites based on the mean of water vapour content

Rank	Site name	Mean of water vapour content
1	Helsinki_Lighthouse	1.3060
2	Gustav_Dalen_Tower	1.3781
3	Boussole	1.8272
4	MVCO	1.8282
5	COVE_SEAPRISM	2.3817
6	Abu_Al_Bukhoosh	2.8763
7	MOBY	3.3880
8	Venice	3.5336
9	Kavaratti_OCM	4.4225

3.4 Variability of Precipitation

This criterion is only valid for land sites. The impact of precipitation on reflectance ground is related to the change in soil moisture, thus the soil brightness.

Cosnefroy et al. 1996 (RD.25) compiled precipitation data from the Global Historical Climatology Network database (Vose et al., 1992, RD.26), from which it is possible to extract monthly precipitation estimates recorded in a network of local stations neighbouring our sites in Sahara and Saudi Arabia, averaged over long periods of time (from 40 years to 100 years). The sites of Sudan, Egypt, Libya, and Niger are dry all year long, with average monthly precipitation from 0.1 mm/month to 1.9 mm/ month depending on the site.

Table 47: Criterion for precipitation

Retained criteria	Studied parameters	Site type
Change in surface state	Precipitation	▪ LES ▪ LNES

3.4.1 Dataset description

3.4.1.1 Dataset identification

The data set is referred to as the "GPCP Version 2 Combined Precipitation Data Set": Monthly Means from combined satellite/station data. The dataset filename is **precip.mon.statistic.nc**

3.4.1.2 Spatial Characteristics

3.4.1.2.1 Spatial Coverage

Coverage of the data set is global over land surface.

3.4.1.2.2 Spatial Coverage Map

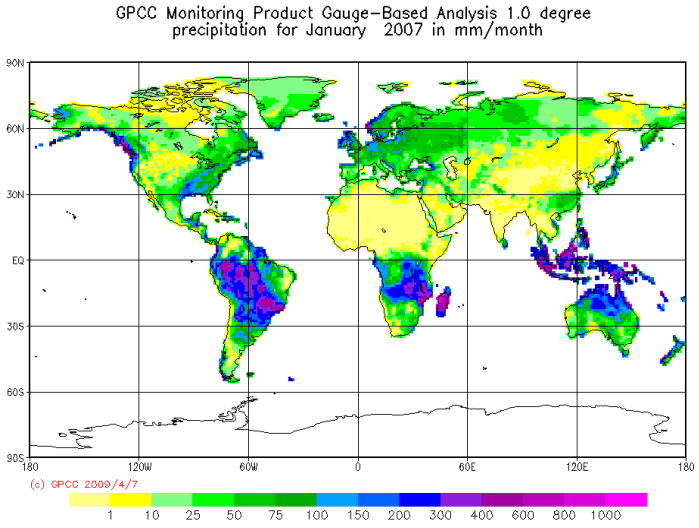


Figure 62: Spatial coverage map of GPCC monthly mean precipitation

3.4.1.2.3 Spatial Resolution

2.5 degree latitude x 2.5 degree longitude global grid. Image size is (144x72).

Range of latitude is 88.75N - 88.75S. Range of longitude is 1.25E - 358.75E.

3.4.1.3 Projection

3.4.1.4 Temporal Characteristics

3.4.1.4.1 Temporal Coverage

Temporal coverage is monthly values 1979/01 through Apr 2008. The data sets analysed covers January 2007 to December 2007.

3.4.1.4.2 Temporal Resolution

The data set is available at a resolution of one month.

3.4.1.5 Data Characteristics

3.4.1.5.1 Parameter/Variable

The current data set provides two final products, the combined satellite-gauge (SG) precipitation estimate and the combined satellite-gauge precipitation error estimate.

The product analysed is: **precip.mon.statistic.nc**

3.4.1.5.2 Variable Description/Definition

This data set consists of monthly means of precipitation derived from satellite and gauge measurements. From the documentation, "The work is being carried out as part of the Global Precipitation Climatology Project (*GPCP*), an international project of the WMO/WCRP/GEWEX designed to provide improved long-record estimates of precipitation over the globe. The GPCP home page is located at http://precip.gsfc.nasa.gov/

3.4.1.5.3 Unit of Measurement

Unit is mm/day

3.4.1.5.4 Data Source

The Version 2 Data Set contains data from several contributing centers:

- GPCP Polar Satellite Precipitation Data Centre - Emission (SSM/I emission estimates),
- GPCP Polar Satellite Precipitation Data Centre - Scattering (SSM/I scattering estimates),
- GPCP Geostationary Satellite Precipitation Data Centre (GPI and OPI estimates and rain gauge analyses),
- NASA/GSFC Satellite Applications Office (TOVS estimates), and
- GPCP Global Precipitation Climatology Centre (rain gauge analyses),

3.4.1.5.5 Data Range

Precipitation varies between 0 and 10 mm/day.

3.4.1.6 Sample Data Record

Dataset format is netcdf. The specifications are provided at: http://precip.gsfc.nasa.gov/gpcp_v2_data.html

3.4.2 Analysis

3.4.2.1 Variability at global scale

Global temporal variations of monthly mean precipitation are represented on Figure 63. Maximum of variations are located around the ITCZ in Africa in the summer period.

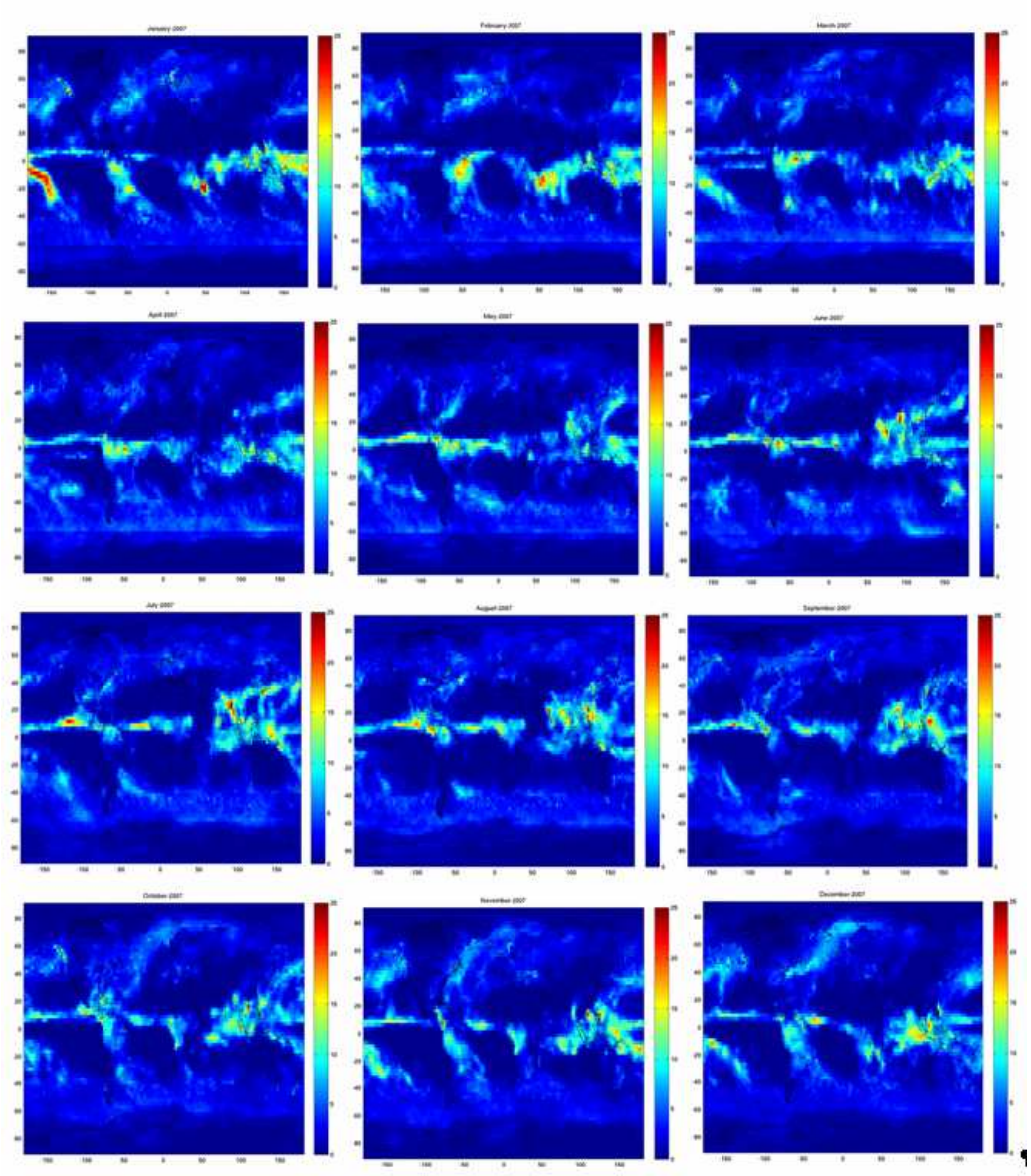


Figure 63: Monthly mean of precipitation (GPCP). Line of images corresponds to Q1, Q2, Q3, and Q4 respectively. Units : mm/day.

3.4.2.2 Temporal variability over LNES

3.4.2.2.1 Statistics

Figure 64 represents the temporal variability for each site. For all sites, the precipitation is low for a period of the year. Sites low in latitudes are subject to the variations of ITCZ (Mauritania_1, Mali_1, Niger_1), meaning a period where the precipitations are important.

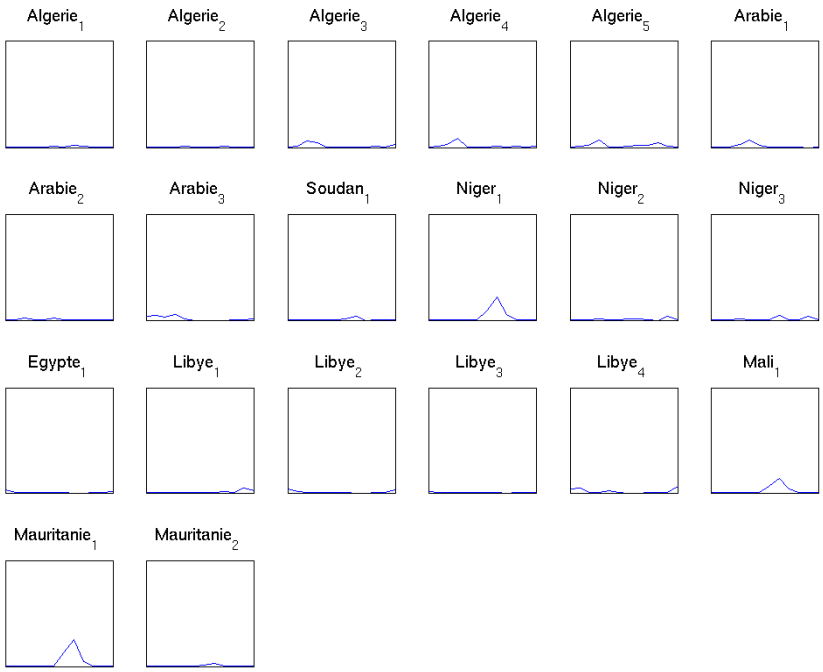


Figure 64: Temporal variability of precipitation level for the LNES. X axis scale is one year, from January to December. Y axis scale is 0-10 mm/day.

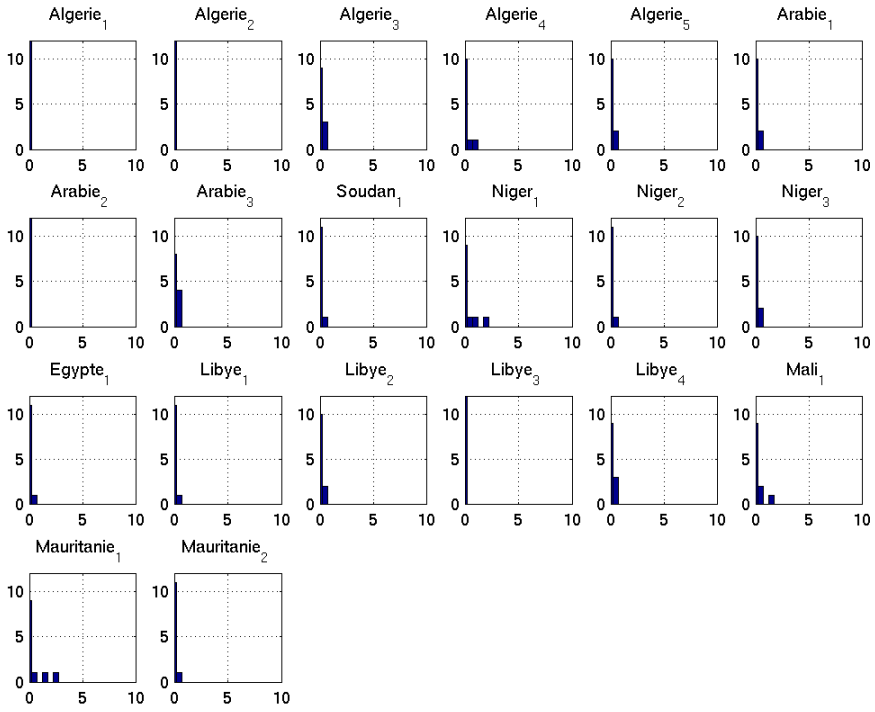


Figure 65: Histogram of monthly precipitation level

Statistics are reported in Table 48. The minimum of precipitation is very low for all sites (0 for 11 sites). The maximum is high (2.53 for Mauritania_1 site).

Table 48: Statistics for precipitation products

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Algerie_1	0.0546	0.0582	0.0003	0.1755	0.1752	3.2069	1.0657
Algerie_2	0.0493	0.0376	0.0002	0.1214	0.1211	2.4566	0.7631
Algerie_3	0.1541	0.2100	0.0063	0.6512	0.6449	4.1851	1.3632
Algerie_4	0.1444	0.2312	0.0027	0.8283	0.8256	5.7184	1.6014
Algerie_5	0.1945	0.1856	0.0282	0.6656	0.6374	3.2780	0.9547
Arabie_1	0.1049	0.2024	0.0000	0.6886	0.6886	6.5639	1.9289
Arabie_2	0.0393	0.0693	0.0001	0.1914	0.1913	4.8734	1.7661
Arabie_3	0.1602	0.2104	0.0000	0.5737	0.5737	3.5800	1.3132
Soudan_1	0.0474	0.1054	0.0000	0.3624	0.3624	7.6392	2.2211
Niger_1	0.3067	0.6448	0.0000	2.1507	2.1507	7.0133	2.1025
Niger_2	0.0663	0.1069	0.0000	0.3797	0.3797	5.7302	1.6126
Niger_3	0.1003	0.1598	0.0000	0.4845	0.4845	4.8330	1.5939
Egypte_1	0.0488	0.0834	0.0000	0.2664	0.2664	5.4596	1.7085
Libye_1	0.0894	0.1353	0.0000	0.4839	0.4839	5.4137	1.5140
Libye_2	0.0778	0.1350	0.0000	0.4057	0.4057	5.2179	1.7361
Libye_3	0.0243	0.0385	0.0000	0.1189	0.1189	4.8890	1.5848
Libye_4	0.1392	0.2239	0.0000	0.6545	0.6545	4.7020	1.6086
Mali_1	0.2083	0.4240	0.0014	1.4038	1.4023	6.7321	2.0355
Mauritanie_1	0.3625	0.7738	0.0034	2.5329	2.5295	6.9787	2.1347
Mauritanie_2	0.0729	0.0452	0.0061	0.2667	0.2606	5.7602	1.6108

3.4.2.2.2 Results

Table 49 provides a classification of the sites based on the observed mean cloud fraction.

Table 49: Rank of sites based on the mean of precipitation

Rank	Site name	Mean of precipitation
1	Libye_3	0.0243
2	Arabie_2	0.0393
3	Mauritanie_2	0.0452
4	Soudan_1	0.0474
5	Egypte_1	0.0488
6	Algerie_2	0.0493
7	Algerie_1	0.0546
8	Niger_2	0.0663
9	Libye_2	0.0778

Rank	Site name	Mean of precipitation
10	Libye_1	0.0894
11	Niger_3	0.1003
12	Arabie_1	0.1049
13	Libye_4	0.1392
14	Algerie_4	0.1444
15	Algerie_3	0.1541
16	Arabie_3	0.1602
17	Algerie_5	0.1945
18	Mali_1	0.2083
19	Niger_1	0.3067
20	Mauritanie_1	0.3625

3.4.2.3 Temporal variability over LNES- others

3.4.2.3.1 Statistics

Statistics are reported in Table 48. The minimum of precipitation is very low for all sites, except for the site located in Brazil (Bahia) where both the minimum and the maximum are high.

Table 50: Statistics for cloud fraction products for LNES others group site

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Dome_1	0.0380	0.0364	0.0002	0.1279	0.1277	3.3649	0.9599
Dome_2	0.0624	0.0491	0.0010	0.1313	0.1303	2.0896	0.7871
Dome_3	0.0458	0.0401	0.0002	0.1136	0.1134	2.4784	0.8756
DomeC_AATSR	0.0897	0.0814	0.0139	0.2237	0.2098	2.3376	0.9068
Antarctica	1.2128	0.7633	0.0581	2.5081	2.4500	2.0202	0.6294
Greenland	0.2433	0.2902	0.0165	1.0587	1.0422	4.2830	1.1926
Salar_de_Uyuni	1.1974	1.4000	0.0103	4.4068	4.3966	3.6719	1.1692
Salar_de_Arizaro	0.1849	0.1831	0.0183	0.5190	0.5007	2.7076	0.9901
Brazil Bahia	2.7591	3.6156	0.0127	12.4726	12.4600	4.5159	1.3104
Taklamakan	0.2605	0.2842	0.0634	1.0728	1.0094	3.8743	1.0910
Algeria5-RAL	0.1945	0.1856	0.0282	0.6656	0.6374	3.2780	0.9547
Libya1-RAL	0.0894	0.1353	0.0000	0.4839	0.4839	5.4137	1.5140
Libya2-RAL	0.1233	0.1943	0.0000	0.5791	0.5791	4.6974	1.5761
Sudan-RAL	0.0474	0.1054	0.0000	0.3624	0.3624	7.6392	2.2211
Libya_1_NOAA	0.1233	0.1943	0.0000	0.5791	0.5791	4.6974	1.5761
Libya_1b_NOAA	0.0696	0.1012	0.0000	0.3090	0.3090	4.4401	1.4543

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Egypt1_NOAA	0.0488	0.0834	0.0000	0.2664	0.2664	5.4596	1.7085
Lybia4_NOAA	0.1392	0.2239	0.0000	0.6545	0.6545	4.7020	1.6086
Mauritania_3	0.0452	0.0729	0.0061	0.2667	0.2606	5.7602	1.6108
Lybie2_USGS	0.0778	0.1350	0.0000	0.4057	0.4057	5.2179	1.7361
Irak_USGS	0.5431	0.5788	0.0024	1.4234	1.4210	2.6164	1.0657
Tunisia_MSG	0.4789	0.5036	0.0238	1.7205	1.6967	3.5426	1.0515
Lybie2_USGS	0.0778	0.1350	0.0000	0.4057	0.4057	5.2179	1.7361
Irak_USGS	0.5431	0.5788	0.0024	1.4234	1.4210	2.6164	1.0657
Egypt_2	0.0113	0.0262	0.0000	0.0913	0.0913	8.0924	2.3248
Yemen_1	0.3529	0.3862	0.0361	1.2901	1.2540	3.5531	1.0942
Mahktesh_Ramon	0.4009	0.3751	0.0362	0.9307	0.8945	2.2311	0.9356
Lybie	0.1392	0.2239	0.0000	0.6545	0.6545	4.7020	1.6086
Arabia4	0.1164	0.1506	0.0000	0.4185	0.4185	3.5943	1.2936
Arabia5	0.3136	0.4009	0.0066	1.2857	1.2790	4.0781	1.2783
Arabia7	0.0823	0.1417	0.0001	0.4134	0.4133	5.0215	1.7224
Arabia8	0.0521	0.0820	0.0000	0.2246	0.2246	4.3084	1.5731
Arabia9	0.0637	0.1046	0.0025	0.3349	0.3324	5.2210	1.6438
UAE1	0.0521	0.0820	0.0000	0.2246	0.2246	4.3084	1.5731
Sudan2	0.4083	0.9289	0.0000	3.1777	3.1777	7.7824	2.2749
Sudan3	0.4261	0.8390	0.0000	2.5612	2.5612	6.0111	1.9691
Sudan4	0.0474	0.1054	0.0000	0.3624	0.3624	7.6392	2.2211
Niger4	0.1003	0.1598	0.0000	0.4845	0.4845	4.8330	1.5939
Australia_1	0.4872	0.6953	0.0022	2.1386	2.1365	4.3850	1.4270
Australia_2	0.4872	0.6953	0.0022	2.1386	2.1365	4.3850	1.4270
Australia_3	0.4872	0.6953	0.0022	2.1386	2.1365	4.3850	1.4270
Australia_4	0.3536	0.4022	0.0050	1.3006	1.2956	3.6637	1.1374

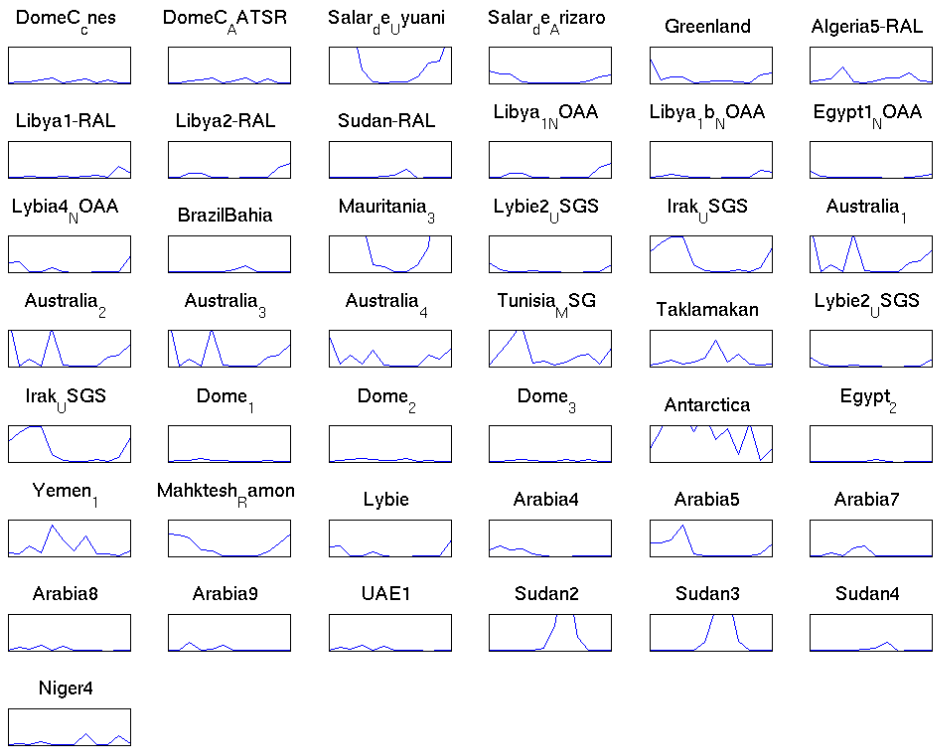


Figure 66: Temporal variability of precipitation for the LNES-Others. X axis scale is one year, from January to December. Y axis scale is 0-1.

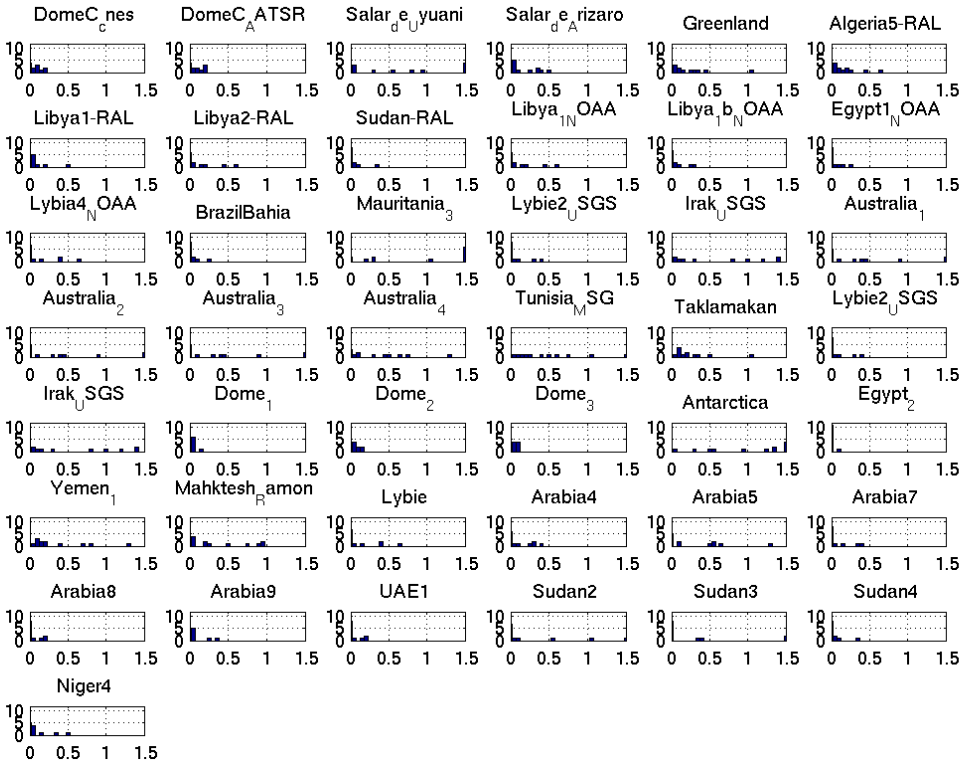


Figure 67: Histogram of precipitation for the LNES-Others

3.4.2.3.2 Results

Table 51 provides a classification of the sites based on the precipitation level.

Table 51: Rank of sites based on the mean precipitation

Rank	Site name	Mean		Rank	Site name	Mean
1	Egypt_2	0.0113		22	Lybia4_NOAA	0.1392
2	Dome_1	0.0380		23	Lybie	0.1392
3	Mauritania_3	0.0452		24	Salar_de_Arizaro	0.1849
4	Dome_3	0.0458		25	Algeria5-RAL	0.1945
5	Sudan-RAL	0.0474		26	Greenland	0.2433
6	Sudan4	0.0474		27	Taklamakan	0.2605
7	Egypt1_NOAA	0.0488		28	Arabia5	0.3136
8	Arabia8	0.0521		29	Yemen_1	0.3529
9	UAE1	0.0521		30	Australia_4	0.3536
10	Dome_2	0.0624		31	Mahktesh_Ramon	0.4009
11	Arabia9	0.0637		32	Sudan2	0.4083
12	Libya_1b_NOAA	0.0696		33	Sudan3	0.4261
13	Lybie2_USGS	0.0778		34	Tunisia_MSG	0.4789
14	Lybie2_USGS	0.0778		35	Australia_1	0.4872
15	Arabia7	0.0823		36	Australia_2	0.4872
16	Libya1-RAL	0.0894		37	Australia_3	0.4872
17	DomeC_AATSR	0.0897		38	Irak_USGS	0.5431
18	Niger4	0.1003		39	Irak_USGS	0.5431
19	Arabia4	0.1164		40	Salar_de_Uyuani	1.1974
20	Libya2-RAL	0.1233		41	Antarctica	1.2128
21	Libya_1_NOAA	0.1233		42	BrazilBahia	2.7591

3.4.2.4 Temporal variability over LNES- China

3.4.2.4.1 Statistics

The precipitation for this set of sites varies in summer and reaches almost 2mm/day. Varaitions are the same for all the sites.

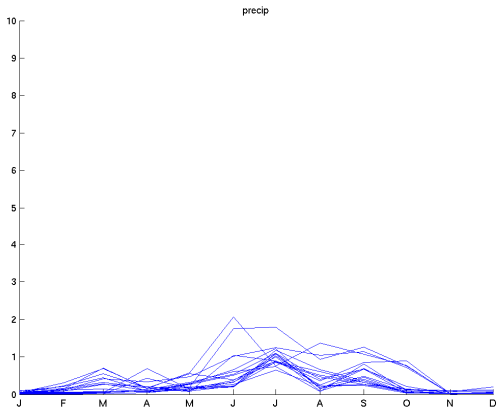


Figure 68: Superimposed temporal profiles of mean monthly cloud fraction for the LNES china sites.

Figure 69: Temporal variability of daily cloud fraction for the LNES-china sites. X axis scale is one year, from January to December. Y axis scale is 0-1.

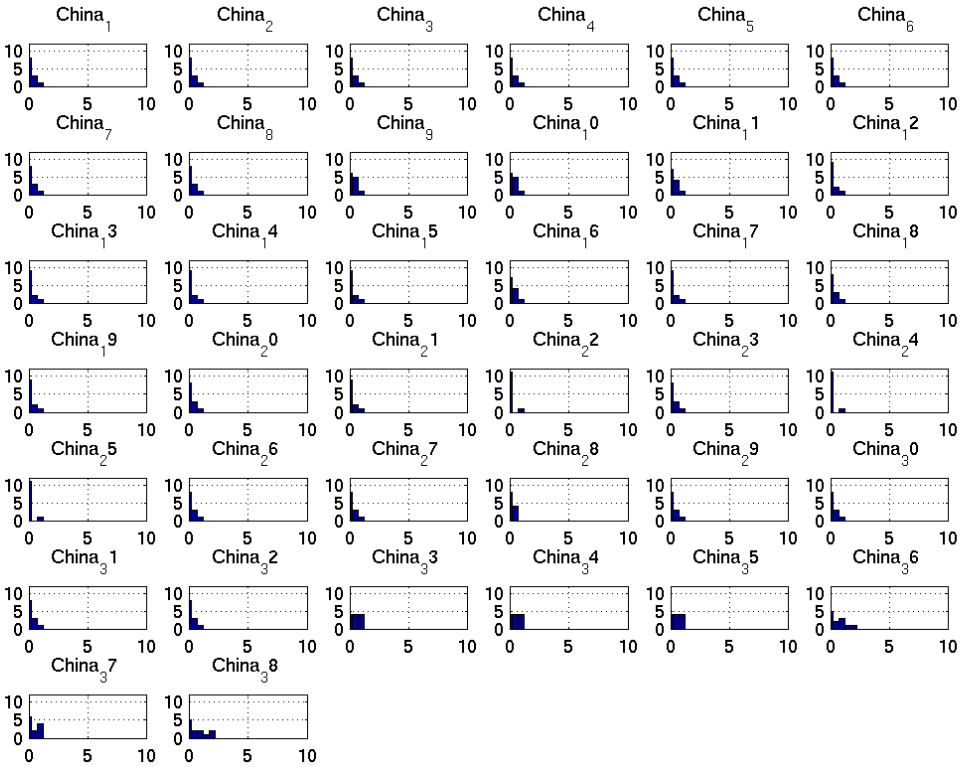


Figure 70: Histogram of monthly cloud fraction for China sites

Statistical parameters are reported in Table 52.

Table 52: Statistics for cloud fraction products for the LNES-china sites

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
China_1	0.2869	0.2619	0.0823	0.8859	0.8037	2.8015	0.9130
China_2	0.2869	0.2619	0.0823	0.8859	0.8037	2.8015	0.9130
China_3	0.2869	0.2619	0.0823	0.8859	0.8037	2.8015	0.9130
China_4	0.2869	0.2619	0.0823	0.8859	0.8037	2.8015	0.9130
China_5	0.2605	0.2842	0.0634	1.0728	1.0094	3.8743	1.0910
China_6	0.2605	0.2842	0.0634	1.0728	1.0094	3.8743	1.0910
China_7	0.2605	0.2842	0.0634	1.0728	1.0094	3.8743	1.0910
China_8	0.2605	0.2842	0.0634	1.0728	1.0094	3.8743	1.0910
China_9	0.3067	0.2269	0.0717	0.8479	0.7762	2.5306	0.7397
China_10	0.3067	0.2269	0.0717	0.8479	0.7762	2.5306	0.7397
China_11	0.2562	0.2735	0.0197	0.8742	0.8545	3.3354	1.0674
China_12	0.2049	0.2887	0.0283	1.0072	0.9789	4.7779	1.4092
China_13	0.2049	0.2887	0.0283	1.0072	0.9789	4.7779	1.4092
China_14	0.2049	0.2887	0.0283	1.0072	0.9789	4.7779	1.4092
China_15	0.2049	0.2887	0.0283	1.0072	0.9789	4.7779	1.4092
China_16	0.2562	0.2735	0.0197	0.8742	0.8545	3.3354	1.0674
China_17	0.2049	0.2887	0.0283	1.0072	0.9789	4.7779	1.4092
China_18	0.2359	0.3181	0.0263	1.0985	1.0723	4.5444	1.3480

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
China_19	0.2437	0.3490	0.0242	1.1733	1.1491	4.7152	1.4320
China_20	0.2359	0.3181	0.0263	1.0985	1.0723	4.5444	1.3480
China_21	0.2437	0.3490	0.0242	1.1733	1.1491	4.7152	1.4320
China_22	0.1705	0.2846	0.0142	1.0332	1.0189	5.9747	1.6689
China_23	0.2717	0.3815	0.0131	1.2142	1.2011	4.4208	1.4041
China_24	0.1705	0.2846	0.0142	1.0332	1.0189	5.9747	1.6689
China_25	0.1705	0.2846	0.0142	1.0332	1.0189	5.9747	1.6689
China_26	0.2419	0.3021	0.0111	0.8098	0.7988	3.3023	1.2491
China_27	0.2419	0.3021	0.0111	0.8098	0.7988	3.3023	1.2491
China_28	0.1836	0.1988	0.0075	0.6511	0.6436	3.5059	1.0827
China_29	0.2969	0.3497	0.0051	1.0968	1.0917	3.6767	1.1778
China_30	0.2264	0.2485	0.0153	0.8696	0.8543	3.7731	1.0976
China_31	0.2264	0.2485	0.0153	0.8696	0.8543	3.7731	1.0976
China_32	0.2264	0.2485	0.0153	0.8696	0.8543	3.7731	1.0976
China_33	0.5482	0.4662	0.0185	1.2399	1.2213	2.2277	0.8504
China_34	0.5482	0.4662	0.0185	1.2399	1.2213	2.2277	0.8504
China_35	0.5482	0.4662	0.0185	1.2399	1.2213	2.2277	0.8504
China_36	0.6396	0.6309	0.0116	2.0661	2.0545	3.2121	0.9865
China_37	0.4285	0.3957	0.0145	1.0428	1.0282	2.3999	0.9236
China_38	0.6659	0.6491	0.0236	1.7897	1.7661	2.6521	0.9748

3.4.2.4.2 Results

Table 53: Rank of sites based on the mean precipitation

Rank	Site name	Mean of precipitation		Rank	Site name	Mean of precipitation
1	China_22	0.1705		20	China_16	0.2562
2	China_24	0.1705		21	China_5	0.2605
3	China_25	0.1705		22	China_6	0.2605
4	China_28	0.1836		23	China_7	0.2605
5	China_12	0.2049		24	China_8	0.2605
6	China_13	0.2049		25	China_23	0.2717
7	China_14	0.2049		26	China_1	0.2869
8	China_15	0.2049		27	China_2	0.2869
9	China_17	0.2049		28	China_3	0.2869
10	China_30	0.2264		29	China_4	0.2869
11	China_31	0.2264		30	China_29	0.2969
12	China_32	0.2264		31	China_9	0.3067
13	China_18	0.2359		32	China_10	0.3067

Rank	Site name	Mean of precipitation		Rank	Site name	Mean of precipitation
14	China_20	0.2359		33	China_37	0.4285
15	China_26	0.2419		34	China_33	0.5482
16	China_27	0.2419		35	China_34	0.5482
17	China_19	0.2437		36	China_35	0.5482
18	China_21	0.2437		37	China_36	0.6396
19	China_11	0.2562		38	China_38	0.6659

3.4.2.5 Temporal variability over LES

3.4.2.5.1 Statistics for CEOS Reference Standard Test Sites

Figure 71: Temporal variability of precipitation for the LES. X axis scale is one year, from January to December. Y axis scale is 0-1.

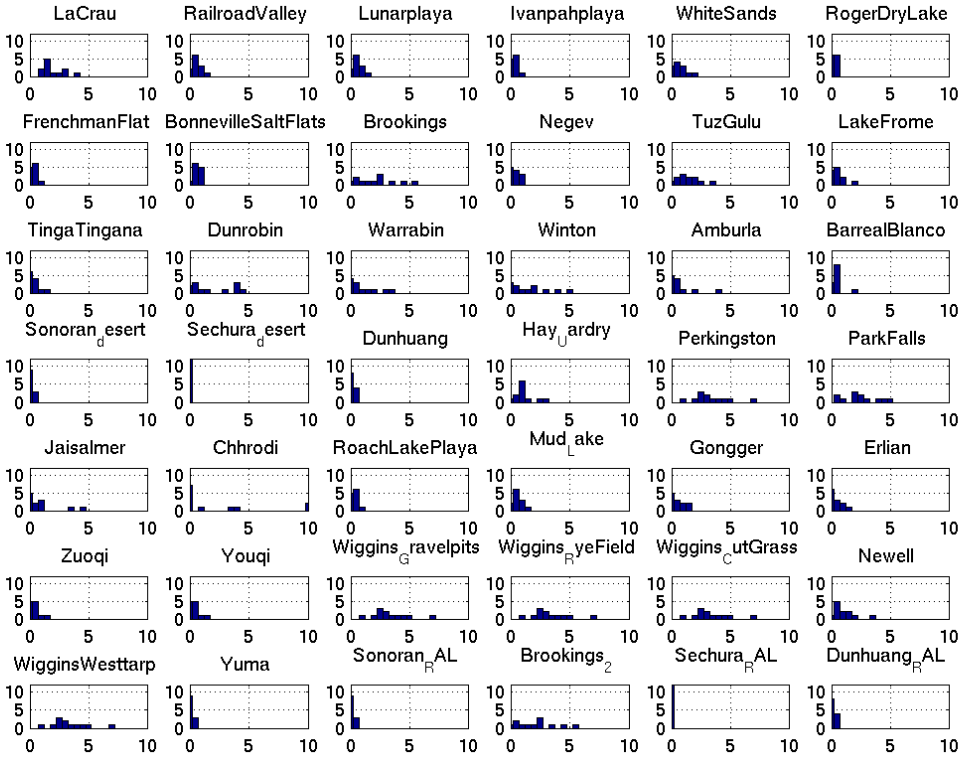


Figure 72: Histogram of precipitation

Table 54: Statistics for precipitation

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
LaCrau	1.9201	0.9153	1.0297	4.0797	3.0500	1.5885	0.4767
RailroadValley	0.6137	0.3891	0.2230	1.4190	1.1961	1.9489	0.6341
Ivanpahplaya	0.3343	0.2334	0.0502	0.7723	0.7221	2.1597	0.6980
FrenchmanFlat	0.3343	0.2334	0.0502	0.7723	0.7221	2.1597	0.6980
Negev	0.3869	0.3875	0.0181	1.1247	1.1065	2.8603	1.0017
TuzGulu	1.4171	0.9679	0.0940	3.4676	3.3736	2.3806	0.6830
Dunhuang	0.1836	0.1988	0.0075	0.6511	0.6436	3.5059	1.0827
Dome C_cnes	0.0806	0.0725	0.0080	0.2090	0.2010	2.4947	0.8995

3.4.2.5.2 Statistics for temporary equipped sites

Table 55: Statistics for precipitation

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Lunarplaya	0.6137	0.3891	0.2230	1.4190	1.1961	1.9489	0.6341
WhiteSands	0.7906	0.5754	0.0813	1.8211	1.7398	2.2007	0.7279
RogerDryLake	0.3001	0.2653	0.0100	0.7335	0.7235	2.4113	0.8841
BonnevilleSaltFlats	0.6232	0.3422	0.2395	1.1654	0.9258	1.4857	0.5491
LakeFrome	0.5369	0.5464	0.0243	2.0606	2.0363	3.7927	1.0177
BarrealBlanco	0.4933	0.4335	0.1537	1.7872	1.6335	3.3116	0.8788
RoachLakePlaya	0.3343	0.2334	0.0502	0.7723	0.7221	2.1597	0.6980
Mud_Lake	0.6137	0.3891	0.2230	1.4190	1.1961	1.9489	0.6341
Brookings	2.1979	1.6703	0.0483	5.3852	5.3369	2.4282	0.7600
TingaTingana	0.3536	0.4022	0.0050	1.3006	1.2956	3.6637	1.1374
Dunrobin	1.9964	1.7931	0.0244	4.6966	4.6722	2.3403	0.8982
Warrabin	1.0609	1.1579	0.0000	3.5465	3.5465	3.3430	1.0914
Winton	1.6334	1.6734	0.0176	5.0372	5.0196	3.0731	1.0245
Amburla	0.7450	1.1848	0.0001	4.1139	4.1138	5.5217	1.5903
Sonoran_desert	0.2039	0.2499	0.0036	0.7367	0.7331	3.5956	1.2255
Sechura_desert	0.0908	0.0810	0.0025	0.2275	0.2250	2.4791	0.8922
Hay_Uardry	1.1658	0.8938	0.1031	3.1347	3.0316	2.6006	0.7667
Perkingston	3.4291	1.5910	0.9267	7.0686	6.1419	1.7911	0.4640
ParkFalls	2.4434	1.4963	0.3286	5.0682	4.7397	1.9398	0.6124
Jaisalmer	1.0093	1.4794	0.0031	4.3576	4.3545	4.3146	1.4658
Chhrodi	2.5708	4.1024	0.0433	11.6774	11.6341	4.5255	1.5958
Gongger	0.6026	0.5396	0.0533	1.5946	1.5413	2.5577	0.8955
Erlian	0.3871	0.4002	0.0372	1.2884	1.2512	3.2319	1.0338
Zuoqi	0.4637	0.4881	0.0426	1.6073	1.5647	3.3747	1.0527
Youqi	0.4637	0.4881	0.0426	1.6073	1.5647	3.3747	1.0527
Wiggins_Gravelpits	3.4291	1.5910	0.9267	7.0686	6.1419	1.7911	0.4640
Wiggins_RyeField	3.4291	1.5910	0.9267	7.0686	6.1419	1.7911	0.4640
Wiggins_CutGrass	3.4291	1.5910	0.9267	7.0686	6.1419	1.7911	0.4640
Newell	1.0427	0.9556	0.2031	3.3385	3.1354	3.0070	0.9164
WigginsWesttarp	3.4291	1.5910	0.9267	7.0686	6.1419	1.7911	0.4640
Yuma	0.2039	0.2499	0.0036	0.7367	0.7331	3.5956	1.2255
Sonoran_RAL	0.2039	0.2499	0.0036	0.7367	0.7331	3.5956	1.2255
Brookings_2	2.1979	1.6703	0.0483	5.3852	5.3369	2.4282	0.7600
Sechura_RAL	0.0908	0.0810	0.0025	0.2275	0.2250	2.4791	0.8922
Dunhuang_RAL	0.1836	0.1988	0.0075	0.6511	0.6436	3.5059	1.0827

Figure 73: Temporal variability of precipitation for the LES. X axis scale is one year, from January to December. Y axis scale is 0-1.

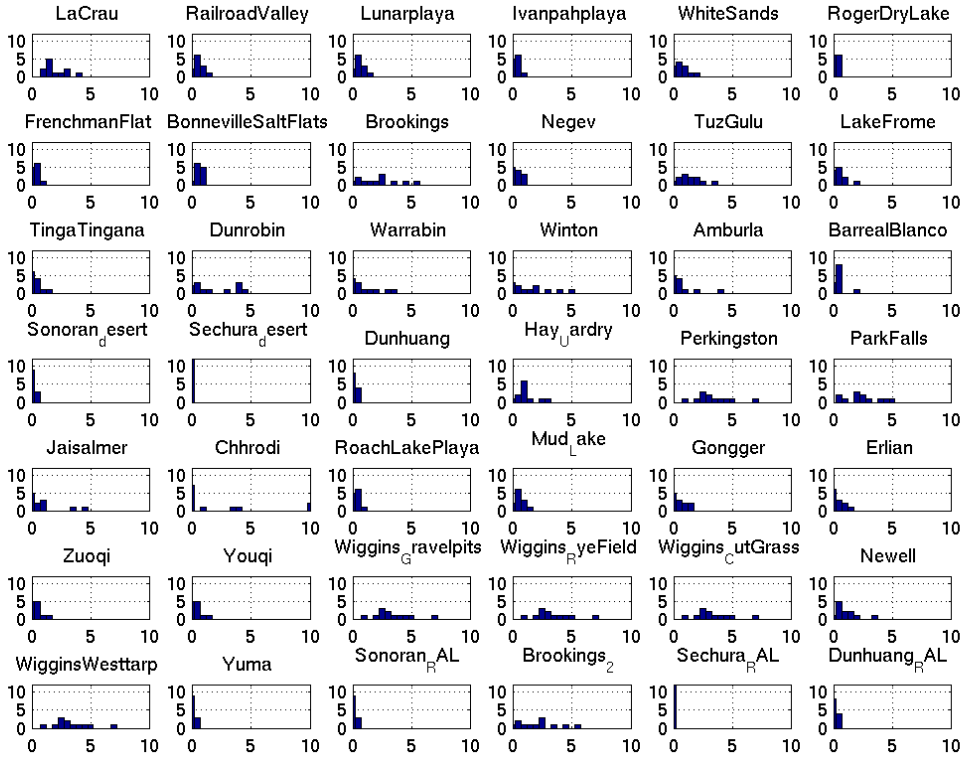


Figure 74: Histogram of precipitation

3.4.2.5.3 Results

Table 56 and Table 57 provide a classification of the sites based on the observed mean cloud fraction for CEOS reference standard sites and the others. Fourth column indicates the number of months where the cloud fraction is less than 10%. At maximum, cloud cover is very low only a few months for this class of sites.

Except La Crau, these sites are used or have been used the time of a calibration campaigns for duration of a few days only. This is why it is possible to find a period to use the sites, even if the cloud cover is higher than the cloud cover over desert sites.

Cloud cover for the CEOS reference test sites is given in Table 21. Negev site is the site where cloud cover is the lowest over the longest period.

Table 56: Rank of CEOS Reference Standard Test Sites based on the mean precipitation

Rank	Site name	Mean of precipitation
	DomeC_cnes	0.0806
	Dunhuang	0.1836
	Ivanpahplaya	0.3343
	FrenchmanFlat	0.3343
	Negev	0.3869
	RailroadValley	0.6137
	Lunarplaya	0.6137
	LaCrau	1.9201

Table 57: Rank of sites based on the mean precipitation

Rank	Site name	Mean of monthly Cloud fraction				
1	Sechura_desert	0.0908		19	WhiteSands	0.7906
2	Sechura_RAL	0.0908		20	Jaisalmer	1.0093
3	Dunhuang_RAL	0.1836		21	Newell	1.0427
4	Sonoran_desert	0.2039		22	Warrabin	1.0609
5	Yuma	0.2039		23	Hay_Uardry	1.1658
6	Sonoran_RAL	0.2039		24	TuzGulu	1.4171
7	RogerDryLake	0.3001		25	Winton	1.6334
8	RoachLakePlaya	0.3343		26	Dunrobin	1.9964
9	TingaTingana	0.3536		27	Brookings	2.1979
10	Erlian	0.3871		28	Brookings_2	2.1979
11	Zuoqi	0.4637		29	ParkFalls	2.4434
12	Youqi	0.4637		30	Chhrodi	2.5708
13	BarrealBlanco	0.4933		31	Perkingston	3.4291
14	LakeFrome	0.5369		32	Wiggins_Gravelpits	3.4291
15	Gongger	0.6026		33	Wiggins_RyeField	3.4291
16	Mud_Lake	0.6137		34	Wiggins_CutGrass	3.4291

Rank	Site name	Mean of monthly Cloud fraction				
17	BonnevilleSaltFlats	0.6232		35	WigginsWesttarp	3.4291
18	Amburla	0.7450				

3.5 Variability of Ozone content

Data are analysed to estimate the variability of the ozone content over LNES and SNES.

Table 58: Criterion for ozone absorption

Retained criteria	Studied parameters	Site type
Ozone absorption	Ozone content	▪ LNES ▪ SNES

3.5.1 Dataset description

3.5.1.1 Dataset identification

Level-3 MODIS Atmosphere Monthly Global Product, MOD08_M3

3.5.1.2 Spatial Characteristics

See section 3.1.1.2.

3.5.1.3 Projection

See section 3.1.1.3.

3.5.1.4 Temporal Characteristics

See section 3.1.1.4.

3.5.1.5 Data Characteristics

3.5.1.5.1 Parameter/Variable

The MODIS Ozone product is an estimate of the total-column tropospheric and stratospheric ozone content. Ozone content is extracted from the Level-3 MODIS Atmosphere Monthly Global (Hubanks et al., 2008, RD.30). This product is derived from the Level-3 MODIS Atmosphere Daily Global Product. The specifications are provided at: http://modis-atmos.gsfc.nasa.gov/MOD08_M3/spec_c5.html.

The products analysed is: **Total_Ozone_Mean_Mean**

3.5.1.5.2 Variable Description/Definition

Total_Ozone_Mean_Mean is mean of Daily mean of Ozone content.

Statistics are based on the daily statistics with the assumption that the daily statistics from retrieved pixels can represent the statistics of the "populations" of each 1° x 1° grid cell. The simple statistics for monthly quantities include mean, standard deviation, and minimum and maximum values of the corresponding daily means (i.e., daily mean, daily QA mean).

3.5.1.5.3 Unit of Measurement

Unit is Dobson.

3.5.1.5.4 Data Source

Product is derived from the Level-3 MODIS Atmosphere Daily Global Product.

3.5.1.5.5 Data Range

Total_Ozone_Mean_Mean varies between 0 and 500 Dobson.

3.5.1.6 Sample Data Record

Dataset format is HDF. The specifications are provided at: http://modis-atmos.gsfc.nasa.gov/MOD08_M3/spec_c5.html

3.5.2 Analysis

3.5.2.1 Variability at global scale

The global spatial distribution of ozone content and its temporal variability is represented on Figure 75.

The spatial distribution varies with latitude. The highest values are observed in North Polar zones from January to June, whereas a minimum is observed from July to December in the South polar zones.

The variability is analysed for all the NES.

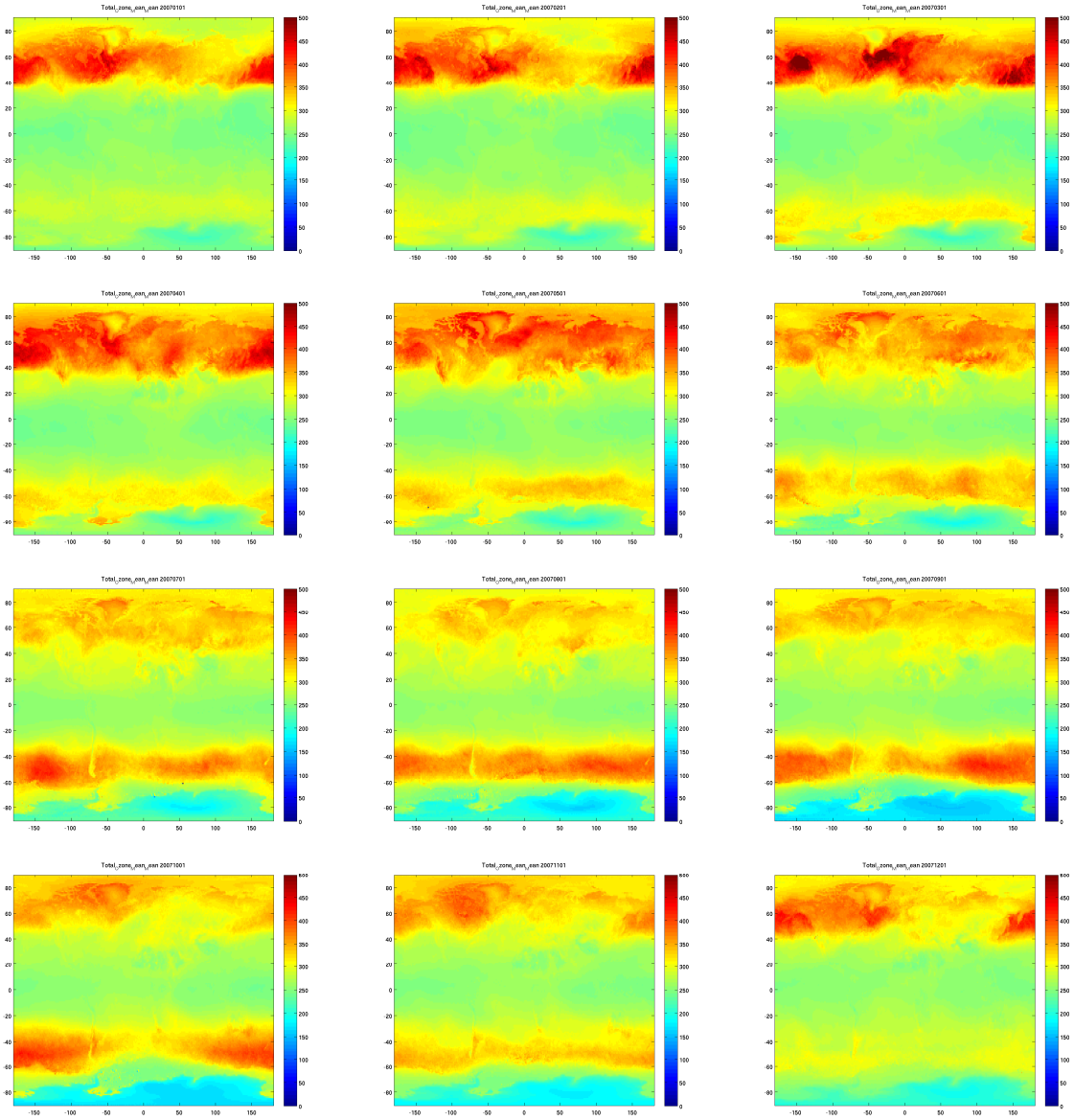


Figure 75: Monthly mean of ozone content (MOD08_M3). Line of images corresponds to Q1, Q2, Q3, and Q4 respectively. Units: Dobson.

3.5.2.2 Temporal variability over LNES

3.5.2.2.1 Statistics

Figure 76 represents the temporal variability of the ozone content of the 20 desert sites, and Figure 77 provides the temporal variability for each site.

Ozone content varies between 250 and 300 Dobson with low variations over the year. Statistics are reported in Table 59. The distribution of ozone for the 20 sites is represented on Figure 88.

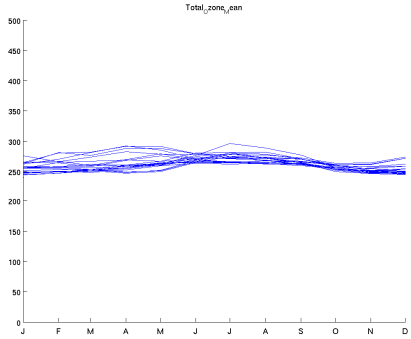


Figure 76: Superimposed temporal profiles of ozone content for the LNES.

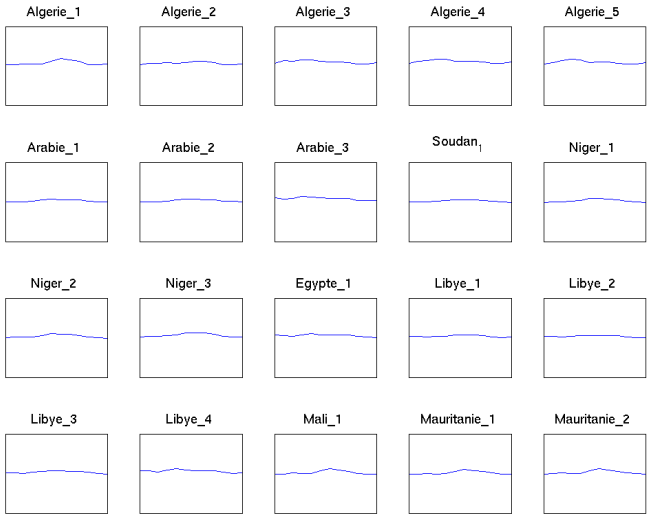


Figure 77: Temporal variability of ozone content for the LNES. X axis scale is one year, from January to December. Y axis scale is 0-500 Dobson.

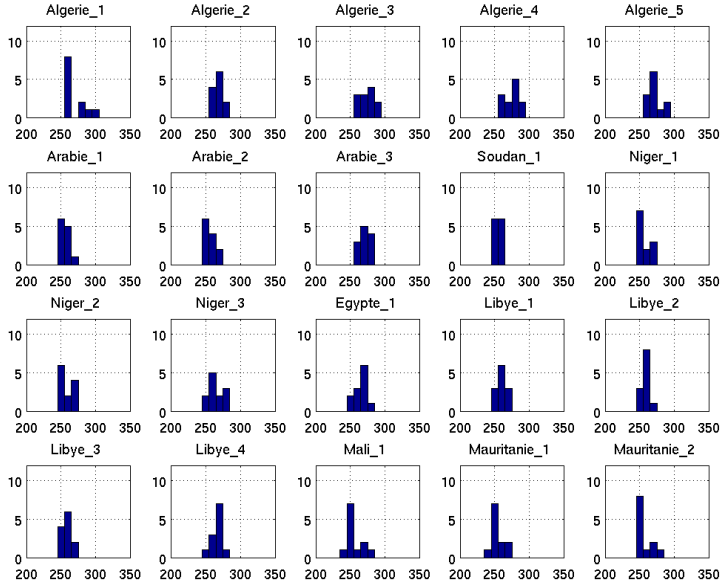


Figure 78: Histogram of ozone content

Table 59: Statistics for ozone content

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Algerie_1	267.5750	13.8974	255.5000	296.70	41.20	0.1540	0.0519
Algerie_2	266.8917	7.6007	255.70	280.50	24.80	0.0929	0.0285
Algerie_3	274.3417	9.0922	261.70	288.20	26.50	0.0966	0.0331
Algerie_4	276.5167	9.3601	263.50	291.30	27.80	0.1005	0.0338
Algerie_5	272.4833	9.6025	261.50	292.20	30.70	0.1127	0.0352
Arabie_1	256.6583	6.5500	248.90	266.20	17.30	0.0674	0.0255
Arabie_2	257.1667	7.0135	248.80	266.70	17.90	0.0696	0.0273
Arabie_3	270.8250	8.2933	257.70	282.80	25.10	0.0927	0.0306
Soudan_1	255.2333	6.4120	246.40	263.70	17.30	0.0678	0.0251
Niger_1	257.3667	9.4429	246.80	272.60	25.80	0.1002	0.0367
Niger_2	259.4333	9.3672	247.30	274.40	27.10	0.1045	0.0361
Niger_3	265.0083	11.0738	252.80	281.80	29.00	0.1094	0.0418
Egypte_1	263.7083	7.1836	250.80	275.70	24.90	0.0944	0.0272
Libye_1	259.4750	5.6591	251.10	269.30	18.20	0.0701	0.0218
Libye_2	258.5667	5.9166	248.30	265.10	16.80	0.0650	0.0229
Libye_3	258.0083	6.5333	246.10	265.40	19.30	0.0748	0.0253
Libye_4	264.9583	7.3391	252.10	279.50	27.40	0.1034	0.0277
Mali_1	256.1000	12.0933	244.50	280.50	36.00	0.1406	0.0472
Mauritanie_1	254.6667	10.1152	245.00	275.00	30.00	0.1178	0.0397
Mauritanie_2	256.8833	10.9064	247.10	278.90	31.80	0.1238	0.0425

3.5.2.2.2 Results

Table 60 provides a classification of the sites based on the mean.

Table 60: Rank based on Mean of ozone content of LNES

Rank	Site name	CV
1	Mauritanie_1	254.6667
2	Soudan_1	255.2333
3	Mali_1	256.1000
4	Arabie_1	256.6583
5	Mauritanie_2	256.8833
6	Arabie_2	257.1667
7	Niger_1	257.3667
8	Libye_3	258.0083
9	Libye_2	258.5667
10	Niger_2	259.4333
11	Libye_1	259.4750

Rank	Site name	CV
12	Egypte_1	263.7083
13	Libye_4	264.9583
14	Niger_3	265.0083
15	Algerie_2	266.8917
16	Algerie_1	267.5750
17	Arabie_3	270.8250
18	Algerie_5	272.4833
19	Algerie_3	274.3417
20	Algerie_4	276.5167

3.5.2.3 Temporal variability over LNES- others

3.5.2.3.1 Statistics

Figure 79 provides the temporal variability of ozone content for each site. As expected, no strong variations are observed, except in the high latitude (Antarctica) in winter. Ozone content varies between 250 and 300 Dobson. The distribution of ozone for all 20 sites is represented on Figure 80.

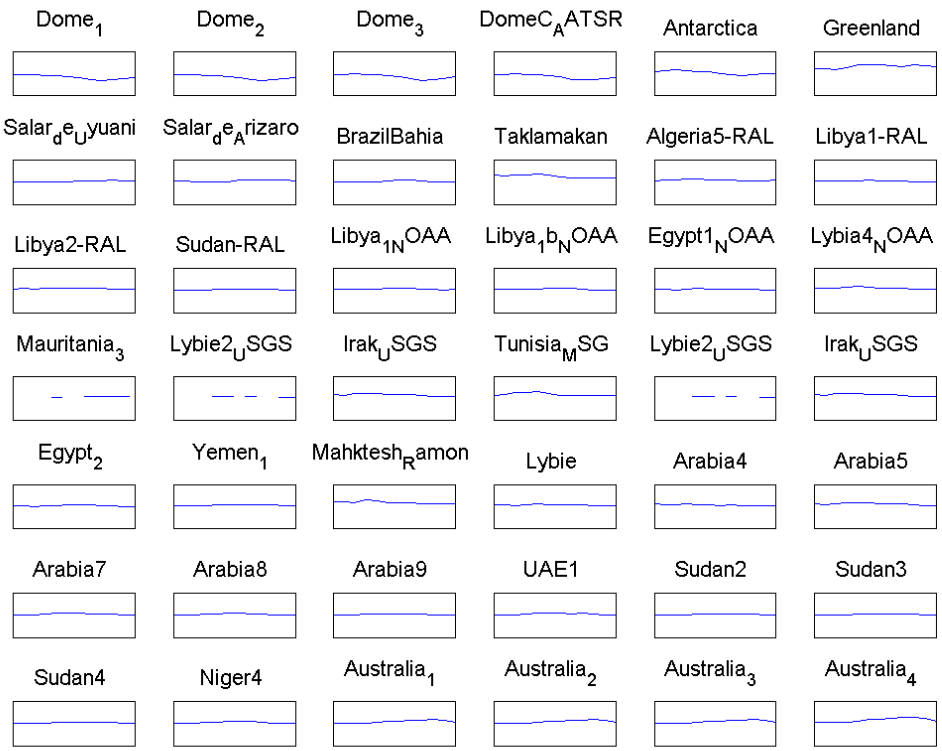


Figure 79: Temporal variability of ozone content for the LNES-others. X axis scale is one year, from January to December. Y axis scale is 0-500 Dobson.

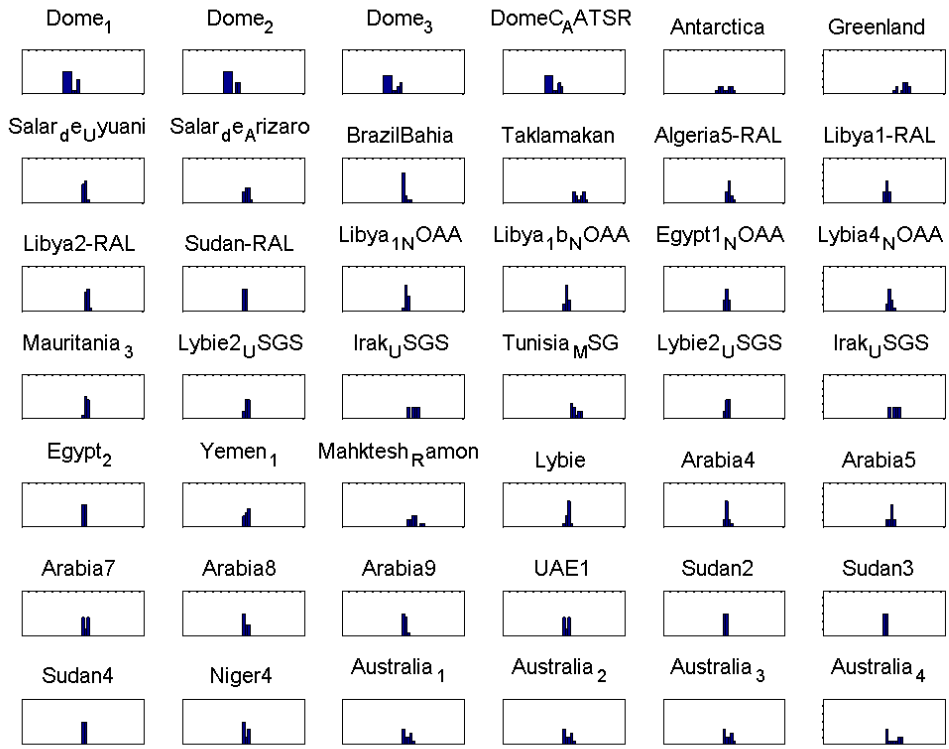


Figure 80: Histogram of ozone content

Statistics are reported in Table 61.

Table 61: Statistics for ozone content products for LNES others group site

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Dome_1	205.9750	25.0062	165.6000	234.0000	68.4000	0.3321	0.1214
Dome_2	205.3000	24.2219	167.2000	233.5000	66.3000	0.3229	0.1180
Dome_3	211.2250	26.3218	168.6000	241.7000	73.1000	0.3461	0.1246
DomeC_AATSR	210.8750	25.3922	171.8000	240.9500	69.1500	0.3279	0.1204
Antarctica	255.8500	23.4448	220.1000	286.6000	66.5000	0.2599	0.0916
Greenland	326.3073	19.7924	292.6500	347.9375	55.2875	0.1694	0.0607
Salar_de_Uyuani	256.9750	6.2446	245.3000	267.1000	21.8000	0.0848	0.0243
Salar_de_Arizaro	262.5500	9.1862	250.1000	276.3000	26.2000	0.0998	0.0350
Brazil Bahia	255.8167	10.0268	247.0000	276.3000	29.3000	0.1145	0.0392
Taklamakan	313.1583	18.8974	289.2000	340.8000	51.6000	0.1648	0.0603
Algeria5-RAL	270.2917	8.3681	261.0000	287.6000	26.6000	0.0984	0.0310
Libya1-RAL	259.4750	5.6591	251.1000	269.3000	18.2000	0.0701	0.0218
Libya2-RAL	267.5167	6.6229	256.9000	276.5000	19.6000	0.0733	0.0248

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Sudan-RAL	255.4750	6.4121	245.9000	263.8000	17.9000	0.0701	0.0251
Libya_1_NOAA	262.9354	5.6475	254.0500	272.5000	18.4500	0.0702	0.0215
Libya_1b_NOAA	261.2917	5.7119	252.1500	270.7000	18.5500	0.0710	0.0219
Egypt1_NOAA	260.3667	6.2660	248.6500	269.1000	20.4500	0.0785	0.0241
Lybia4_NOAA	272.0833	9.2810	256.5000	289.7750	33.2750	0.1223	0.0341
Mauritania_3	262.8417	6.4023	254.2000	272.0000	17.8000	0.0677	0.0244
Lybie2_USGS	261.3083	6.7737	250.4000	270.4000	20.0000	0.0765	0.0259
Irak_USGS	292.4917	13.7711	271.7000	310.4000	38.7000	0.1323	0.0471
Tunisia_MSG	295.7417	16.9932	278.6000	323.5000	44.9000	0.1518	0.0575
Lybie2_USGS	261.3083	6.7737	250.4000	270.4000	20.0000	0.0765	0.0259
Irak_USGS	292.4917	13.7711	271.7000	310.4000	38.7000	0.1323	0.0471
Egypt_2	255.7167	6.4408	245.4000	263.9000	18.5000	0.0723	0.0252
Yemen_1	261.9833	7.3983	251.4000	272.7000	21.3000	0.0813	0.0282
Mahktesh_Ramon	292.3167	16.3611	273.2000	327.0000	53.8000	0.1840	0.0560
Lybie	264.9583	7.3391	252.1000	279.5000	27.4000	0.1034	0.0277
Arabia4	262.8250	8.0344	252.5000	281.4000	28.9000	0.1100	0.0306
Arabia5	275.9000	9.5889	260.5000	287.4000	26.9000	0.0975	0.0348
Arabia7	260.6000	7.6571	250.9000	272.6000	21.7000	0.0833	0.0294
Arabia8	257.6167	7.2912	248.9000	267.8000	18.9000	0.0734	0.0283
Arabia9	256.5333	6.4608	247.5000	266.2000	18.7000	0.0729	0.0252
UAE1	259.8250	8.1381	249.8000	270.7000	20.9000	0.0804	0.0313
Sudan2	253.8250	5.7783	246.7000	261.0000	14.3000	0.0563	0.0228
Sudan3	256.5250	6.5642	248.4000	264.3000	15.9000	0.0620	0.0256
Sudan4	255.0333	6.1559	247.4000	263.3000	15.9000	0.0623	0.0241
Niger4	259.8250	9.1487	248.6000	273.7000	25.1000	0.0966	0.0352
Australia_1	266.0500	15.5410	248.5000	289.4000	40.9000	0.1537	0.0584
Australia_2	266.8167	15.4396	249.3000	289.1000	39.8000	0.1492	0.0579
Australia_3	266.8167	15.4396	249.3000	289.1000	39.8000	0.1492	0.0579
Australia_4	285.5750	22.9002	256.7000	318.4000	61.7000	0.2161	0.0802

3.5.2.3.2 Results

Table 62 provides a classification of the sites based on the mean of the ozone content.

Table 62: Rank of sites based on the mean of ozone content

Rank	Site name	Mean of Ozone content		Rank	Site name	Mean of Ozone content
1	Dome_2	205.3000		22	Lybie2_USGS	261.3083
2	Dome_1	205.9750		23	Yemen_1	261.9833
3	DomeC_AATSR	210.8750		24	Salar_de_Arizaro	262.5500
4	Dome_3	211.2250		25	Arabia4	262.8250
5	Sudan2	253.8250		26	Mauritania_3	262.8417
6	Sudan4	255.0333		27	Libya_1_NOAA	262.9354
7	Sudan-RAL	255.4750		28	Lybie	264.9583
8	Egypt_2	255.7167		29	Australia_1	266.0500
9	BrazilBahia	255.8167		30	Australia_2	266.8167
10	Antarctica	255.8500		31	Australia_3	266.8167
11	Sudan3	256.5250		32	Libya2-RAL	267.5167
12	Arabia9	256.5333		33	Algeria5-RAL	270.2917
13	Salar_de_Uyuani	256.9750		34	Lybia4_NOAA	272.0833
14	Arabia8	257.6167		35	Arabia5	275.9000
15	Libya1-RAL	259.4750		36	Australia_4	285.5750
16	UAE1	259.8250		37	Mahktesh_Ramon	292.3167
17	Niger4	259.8250		38	Irak_USGS	292.4917
18	Egypt1_NOAA	260.3667		39	Irak_USGS	292.4917
19	Arabia7	260.6000		40	Tunisia_MSG	295.7417
20	Libya_1b_NOAA	261.2917		41	Taklamakan	313.1583
21	Lybie2_USGS	261.3083		42	Greenland	326.3073

3.5.2.4 Temporal variability over LNES- China

3.5.2.4.1 Statistics

Figure 81 represents the variability of the ozone content of the 38 desert sites and Figure 82 provides the temporal variability of ozone content for each site. As the sites are located over the same latitude, the temporal variability of the ozone content is almost the same. The ozone content varies between 300 and 350 Dobson. The distribution of ozone for all 38 sites is represented on .

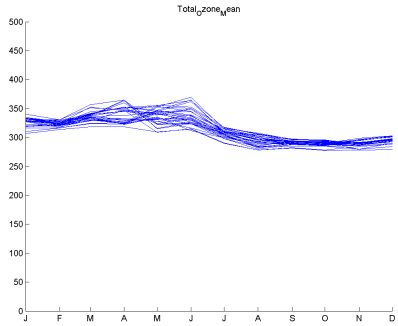


Figure 81: Superimposed temporal profiles of ozone content for the LNES-china.

Figure 82: Temporal variability of ozone content for the LNES-china. X axis scale is one year, from January to December. Y axis scale is 0-500 Dobson.

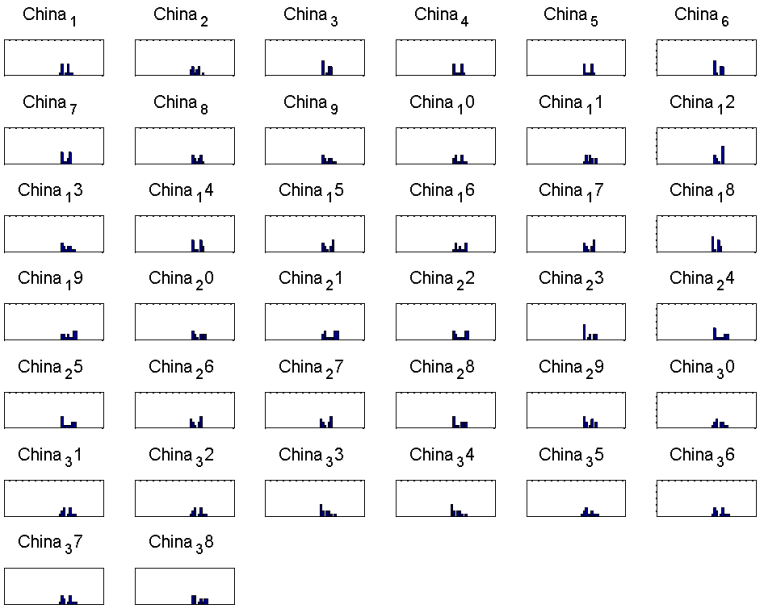


Figure 83: Histogram of ozone content

Statistical parameters are reported in Table 37.

Table 63: Statistics for ozone content products for the LNES-china sites

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
China_1	309.2250	19.8933	279.6000	343.4000	63.8000	0.2063	0.0643
China_2	303.9750	18.4900	279.8000	335.2000	55.4000	0.1823	0.0608
China_3	310.6083	18.8986	287.9000	333.2000	45.3000	0.1458	0.0608
China_4	312.1167	19.0844	286.2000	342.2000	56.0000	0.1794	0.0611
China_5	312.1167	19.0844	286.2000	342.2000	56.0000	0.1794	0.0611
China_6	308.3250	19.0987	286.1000	334.8000	48.7000	0.1580	0.0619
China_7	311.0917	18.7436	288.8000	334.9000	46.1000	0.1482	0.0603
China_8	313.1583	18.8974	289.2000	340.8000	51.6000	0.1648	0.0603
China_9	315.2750	19.8547	290.3000	345.6000	55.3000	0.1754	0.0630
China_10	315.8667	21.5275	287.1000	353.6000	66.5000	0.2105	0.0682
China_11	317.6417	21.4030	289.9000	352.2000	62.3000	0.1961	0.0674
China_12	313.3083	18.8996	290.8000	334.6000	43.8000	0.1398	0.0603
China_13	316.0333	19.6796	290.6000	346.1000	55.5000	0.1756	0.0623
China_14	313.2333	19.9514	289.6000	338.4000	48.8000	0.1558	0.0637
China_15	317.5000	21.9115	291.2000	344.7000	53.5000	0.1685	0.0690
China_16	320.8333	24.1226	289.3000	356.1000	66.8000	0.2082	0.0752
China_17	317.5000	21.9115	291.2000	344.7000	53.5000	0.1685	0.0690
China_18	297.1167	17.6376	277.8000	318.5000	40.7000	0.1370	0.0594
China_19	322.6750	26.2149	290.8000	363.9000	73.1000	0.2265	0.0812
China_20	317.8583	23.2452	291.5000	348.8000	57.3000	0.1803	0.0731
China_21	322.5917	27.2699	291.6000	369.8000	78.2000	0.2424	0.0845
China_22	319.7583	26.7891	290.1000	364.9000	74.8000	0.2339	0.0838
China_23	314.6083	24.6407	287.0000	349.2000	62.2000	0.1977	0.0783
China_24	319.0417	26.3616	290.2000	361.8000	71.6000	0.2244	0.0826
China_25	319.0417	26.3616	290.2000	361.8000	71.6000	0.2244	0.0826
China_26	307.4917	21.0959	283.7000	333.1000	49.4000	0.1607	0.0686
China_27	307.4917	21.0959	283.7000	333.1000	49.4000	0.1607	0.0686
China_28	317.9000	23.9233	290.8000	351.1000	60.3000	0.1897	0.0753
China_29	314.5333	23.7274	286.8000	352.3000	65.5000	0.2082	0.0754
China_30	313.2333	23.0442	284.1000	352.3000	68.2000	0.2177	0.0736
China_31	314.3333	23.9842	283.3000	359.9000	76.6000	0.2437	0.0763
China_32	314.3333	23.9842	283.3000	359.9000	76.6000	0.2437	0.0763
China_33	303.5583	22.7932	278.2000	347.2000	69.0000	0.2273	0.0751
China_34	303.5583	22.7932	278.2000	347.2000	69.0000	0.2273	0.0751
China_35	312.9583	25.4067	279.7000	364.5000	84.8000	0.2710	0.0812
China_36	313.8083	24.9097	281.9000	363.7000	81.8000	0.2607	0.0794
China_37	313.8083	24.9097	281.9000	363.7000	81.8000	0.2607	0.0794
China_38	318.7583	26.5175	285.4000	364.5000	79.1000	0.2482	0.0832

3.5.2.4.2 Results

Table 64 provides a classification of the sites based on the mean of the ozone content

Table 64: Rank of sites based on the mean of ozone content

Rank	Site name	Mean of Ozone content		Rank	Site name	Mean of Ozone content
1	China_18	297.1167		20	China_31	314.3333
2	China_33	303.5583		21	China_32	314.3333
3	China_34	303.5583		22	China_29	314.5333
4	China_2	303.9750		23	China_23	314.6083
5	China_26	307.4917		24	China_9	315.2750
6	China_27	307.4917		25	China_10	315.8667
7	China_6	308.3250		26	China_13	316.0333
8	China_1	309.2250		27	China_15	317.5000
9	China_3	310.6083		28	China_17	317.5000
10	China_7	311.0917		29	China_11	317.6417
11	China_4	312.1167		30	China_20	317.8583
12	China_5	312.1167		31	China_28	317.9000
13	China_35	312.9583		32	China_38	318.7583
14	China_8	313.1583		33	China_24	319.0417
15	China_14	313.2333		34	China_25	319.0417
16	China_30	313.2333		35	China_22	319.7583
17	China_12	313.3083		36	China_16	320.8333
18	China_36	313.8083		37	China_21	322.5917
19	China_37	313.8083		38	China_19	322.6750

3.5.2.5 Temporal variability over LES

3.5.2.5.1 Statistics for CEOS Reference Standard Test Sites

Table 65: Statistics of ozone content over CEOS LES

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
LaCrau	328.5250	33.0497	292.1000	414.6000	122.5000	0.3729	0.1006
RailroadValley	313.9000	24.5506	284.5000	368.3000	83.8000	0.2670	0.0782
Ivanpahplaya	319.3917	30.6037	283.2000	375.8000	92.6000	0.2899	0.0958
FrenchmanFlat	322.4333	30.2985	285.5000	381.9000	96.4000	0.2990	0.0940
Negev	292.3167	16.3611	273.2000	327.0000	53.8000	0.1840	0.0560
TuzGulu	322.8667	29.3840	290.2000	381.5000	91.3000	0.2828	0.0910
Dunhuang	316.7750	24.2629	289.0000	349.1000	60.1000	0.1897	0.0766
Dome C_cnes	207.2875	24.0393	169.2500	235.5250	66.2750	0.3197	0.1160

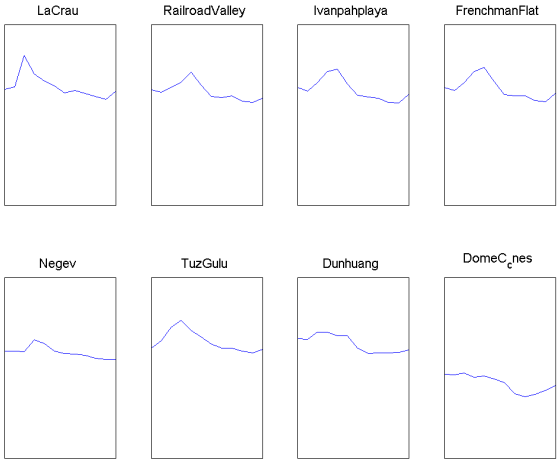


Figure 84: Temporal variability of ozone content for the CEOS - LES. X axis scale is one year, from January to December. Y axis scale is 0-500 Dobson.

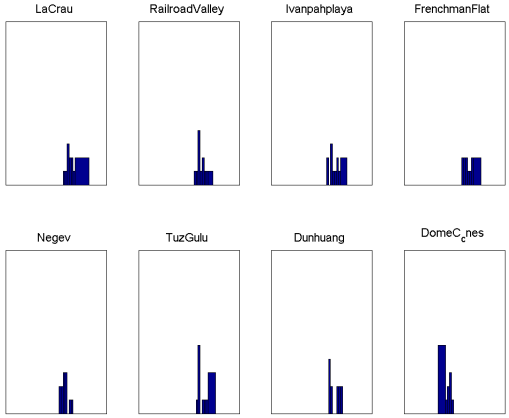


Figure 85: Histogram of ozone content

3.5.2.5.2 Statistics for temporary equipped sites

Table 66: Statistics for ozone content over Non CEOS LES

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Lunarplaya	313.9000	24.5506	284.5000	368.3000	83.8000	0.2670	0.0782
WhiteSands	297.3583	18.8582	271.0000	327.5000	56.5000	0.1900	0.0634
RogerDryLake	312.5917	22.4055	283.3000	351.3000	68.0000	0.2175	0.0717
BonnevilleSaltFlats	315.1500	22.7779	282.1000	358.4000	76.3000	0.2421	0.0723
LakeFrome	319.3917	30.6037	283.2000	375.8000	92.6000	0.2899	0.0958
BarrealBlanco	319.0333	25.9392	286.8000	371.9000	85.1000	0.2667	0.0813
RoachLakePlaya	326.3333	31.7519	287.5000	373.1000	85.6000	0.2623	0.0973
Mud_Lake	326.3333	31.7519	287.5000	373.1000	85.6000	0.2623	0.0973
Brookings	284.2583	12.3370	269.2000	313.9000	44.7000	0.1573	0.0434

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
TingaTingana	284.2583	12.3370	269.2000	313.9000	44.7000	0.1573	0.0434
Dunrobin	284.2583	12.3370	269.2000	313.9000	44.7000	0.1573	0.0434
Warrabin	284.2583	12.3370	269.2000	313.9000	44.7000	0.1573	0.0434
Winton	284.2583	12.3370	269.2000	313.9000	44.7000	0.1573	0.0434
Amburla	329.6417	34.1250	290.5000	388.3000	97.8000	0.2967	0.1035
Sonoran_desert	305.0833	25.1805	272.1000	351.5000	79.4000	0.2603	0.0825
Sechura_desert	298.3667	16.7962	272.2000	328.2000	56.0000	0.1877	0.0563
Hay_Uardry	298.3667	16.7962	272.2000	328.2000	56.0000	0.1877	0.0563
Perkingston	340.3917	31.0245	301.6000	382.5000	80.9000	0.2377	0.0911
ParkFalls	295.2667	27.5801	260.3000	337.2000	76.9000	0.2604	0.0934
Jaisalmer	285.5750	22.9002	256.7000	318.4000	61.7000	0.2161	0.0802
Chhrodi	270.6083	13.7890	255.0000	294.5000	39.5000	0.1460	0.0510
Gongger	281.2917	20.2372	257.2000	315.1000	57.9000	0.2058	0.0719
Erlian	273.0083	14.8511	255.7000	296.5000	40.8000	0.1494	0.0544
Zuoqi	270.9667	14.0368	254.0000	293.6000	39.6000	0.1461	0.0518
Youqi	307.6333	35.4768	266.2000	364.6000	98.4000	0.3199	0.1153
Wiggins_Gravelpits	317.9000	23.9233	290.8000	351.1000	60.3000	0.1897	0.0753
Wiggins_RyeField	330.6333	30.2844	297.9000	380.7000	82.8000	0.2504	0.0916
Wiggins_CutGrass	334.5417	29.2089	303.8000	383.8000	80.0000	0.2391	0.0873
Newell	333.1917	28.9532	303.1000	380.3000	77.2000	0.2317	0.0869
WigginsWesttarp	328.0250	27.0933	297.1000	373.4000	76.3000	0.2326	0.0826
Yuma	253.5000	4.9249	247.8000	261.8000	14.0000	0.0552	0.0194
Sonoran_RAL	255.4667	4.3425	249.1000	262.4000	13.3000	0.0521	0.0170
Brookings_2	292.4833	23.4869	267.6000	334.0000	66.4000	0.2270	0.0803
Sechura_RAL	275.2333	8.7775	264.0000	294.1000	30.1000	0.1094	0.0319
Dunhuang_RAL	272.7500	8.9117	261.1000	291.7000	30.6000	0.1122	0.0327

Figure 86: Temporal variability of ozone content for the non CEOS - LES. X axis scale is one year, from January to December. Y axis scale is 0-500 Dobson.

Figure 87: Histogram of ozone content

3.5.2.5.3 Results

The classification is reported in the following tables.

Table 67: Rank of CEOS Reference Standard Test Sites based on the mean of ozone content

Rank	Site name	Mean of ozone content
1	DomeC_cnes	207.2875
2	Negev	292.3167
3	RailroadValley	313.9000
4	Dunhuang	316.7750
5	Ivanpahplaya	319.3917
6	FrenchmanFlat	322.4333
7	TuzGulu	322.8667
8	LaCrau	328.5250

Table 68: Rank of sites based on the mean of ozone content

Rank	Site name	Max –Min of Water vapour content		Rank	Site name	Max –Min of Water vapour content
1	Sechura_RAL	253.5000		19	Yuma	298.3667
2	Sechura_desert	255.4667		20	Sonoran_desert	305.0833
3	Dunrobin	270.6083		21	Hay_Uardry	307.6333
4	Amburla	270.9667		22	RogerDryLake	312.5917
5	Chhrodi	272.7500		23	Lunarplaya	313.9000
6	Winton	273.0083		24	BonnevilleSaltFlats	315.1500
7	Jaisalmer	275.2333		25	Dunhuang_RAL	317.9000
8	Warrabin	281.2917		26	Mud_Lake	319.0333
9	Wiggins_Gravelpits	284.2583		27	RoachLakePlaya	319.3917
10	Wiggins_RyeField	284.2583		28	Brookings	326.3333
11	Wiggins_CutGrass	284.2583		29	Brookings_2	326.3333
12	WigginsWesttarp	284.2583		30	Youqi	328.0250
13	Perkingston	284.2583		31	ParkFalls	329.6417
14	TingaTingana	285.5750		32	Gongger	330.6333
15	BarrealBlanco	292.4833		33	Zuoqi	333.1917
16	LakeFrome	295.2667		34	Erlian	334.5417
17	WhiteSands	297.3583		35	Newell	340.3917
18	Sonoran_RAL	298.3667				

3.5.2.6 Temporal variability over SNES

3.5.2.6.1 Statistics

Figure 88 represents the temporal variability of the ozone content of the 42 oceanic sites, and Figure 89 provides the temporal variability for each site.

A seasonal variability is observed for the sites located in the southern hemisphere, where the maximum ranges between 250 and 350 Dobson. Three sites located in Northern hemisphere (GuAlas and the Mediterranean sites have their maximum in winter (February and March), around 300 Dobson. The difference between the maximum and the minimum is the lowest for sites located between the latitude -30 S and 30 °N Pac-NW, Pac-N and Atl-Nand Atl-S sites.

Statistics are reported in Table 69. The distribution of ozone content for the 42 sites is represented on Figure 90.

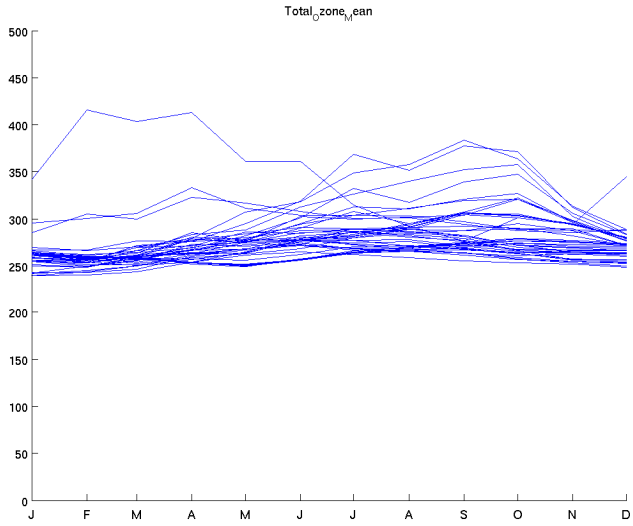


Figure 88: Temporal variability of ozone content for the SNES.

Figure 89: Temporal variability of ozone content for the SNES. Y axis scale is 0-500 Dobson.

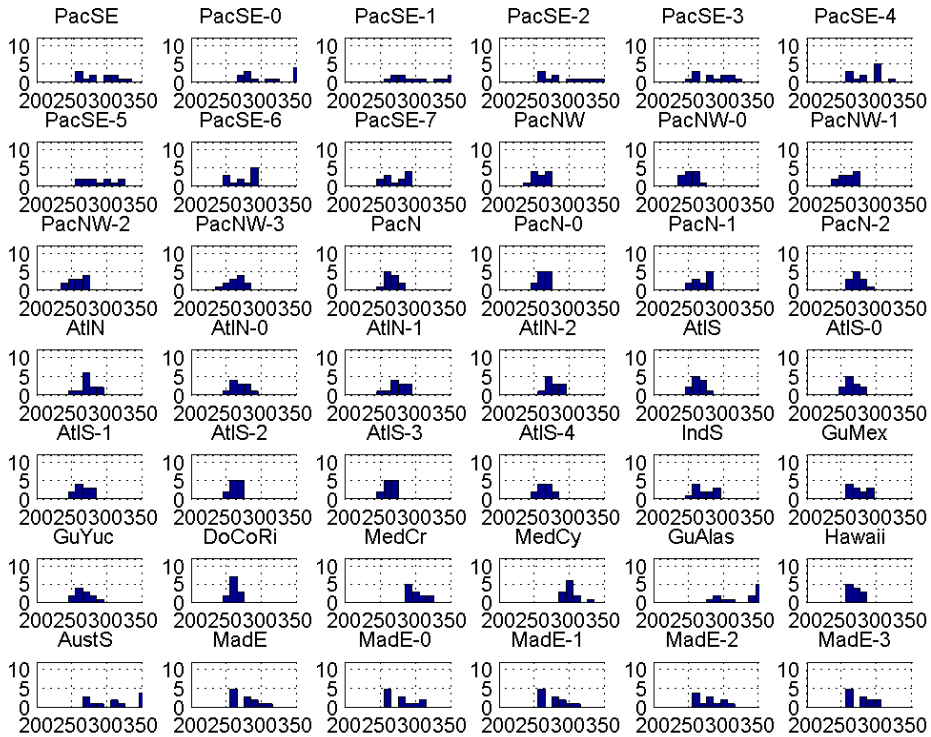


Figure 90: Histogram of Ozone content

Table 69: Statistics for ozone products

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
PacSE	288.6584	25.0609	258.7164	327.1640	68.4477	0.2371	0.0868
PacSE-0	313.8063	42.8778	267.1227	377.2618	110.1391	0.3510	0.1366
PacSE-1	303.1137	34.5017	261.2459	357.9368	96.6909	0.3190	0.1138
PacSE-2	297.4622	31.1706	262.0857	347.4133	85.3276	0.2869	0.1048
PacSE-3	284.4677	22.1674	254.1990	322.3290	68.1300	0.2395	0.0779
PacSE-4	285.8017	21.2444	256.4818	320.6164	64.1345	0.2244	0.0743
PacSE-5	287.9685	22.7854	258.5927	320.7018	62.1091	0.2157	0.0791
PacSE-6	273.2610	16.0499	250.8482	294.7662	43.9181	0.1607	0.0587
PacSE-7	272.7234	16.1928	251.4012	291.9852	40.5840	0.1488	0.0594
PacNW	258.9688	10.0736	242.0484	272.7293	30.6809	0.1185	0.0389
PacNW-0	252.8656	8.5159	239.6975	265.3250	25.6275	0.1013	0.0337
PacNW-1	257.5699	9.6787	242.8867	271.5956	28.7089	0.1115	0.0376
PacNW-2	257.9447	10.4980	239.6527	272.4782	32.8255	0.1273	0.0407
PacNW-3	263.3022	11.3331	242.7111	277.2963	34.5852	0.1314	0.0430
PacN	266.9362	8.2501	253.0869	278.6677	25.5808	0.0958	0.0309
PacN-0	263.4776	7.7343	249.7488	274.4559	24.7071	0.0938	0.0294
PacN-1	268.6383	9.6444	253.2509	280.4691	27.2182	0.1013	0.0359
PacN-2	270.7356	8.2195	258.1146	285.3091	27.1945	0.1004	0.0304
AtlN	272.2533	10.1348	254.1184	287.1558	33.0374	0.1213	0.0372
AtlN-0	269.1432	9.9208	253.5278	285.2856	31.7578	0.1180	0.0369
AtlN-1	274.8852	10.8506	253.7580	288.9700	35.2120	0.1281	0.0395
AtlN-2	275.8477	10.7235	255.3120	290.7360	35.4240	0.1284	0.0389
AtlS	264.4145	8.7842	250.5100	276.6324	26.1224	0.0988	0.0332
AtlS-0	264.6417	9.3615	249.1750	276.6125	27.4375	0.1037	0.0354
AtlS-1	265.5106	9.7039	250.8769	279.1815	28.3046	0.1066	0.0365
AtlS-2	263.4865	8.1010	249.8089	273.9489	24.1400	0.0916	0.0307
AtlS-3	263.1821	7.3951	251.4350	274.3675	22.9325	0.0871	0.0281
AtlS-4	264.9508	9.2643	251.7150	278.9550	27.2400	0.1028	0.0350
IndS	271.8892	13.9586	252.6111	289.8990	37.2879	0.1371	0.0513
GuMex	273.3880	12.3279	256.1469	289.2875	33.1406	0.1212	0.0451
GuYuc	265.8244	11.8054	249.1133	286.5533	37.4400	0.1408	0.0444
DoCoRi	259.8857	7.4248	248.8667	271.8683	23.0017	0.0885	0.0286
MedCr	299.7653	12.0844	285.5667	322.8333	37.2667	0.1243	0.0403
MedCy	301.6542	12.4988	287.6250	333.1250	45.5000	0.1508	0.0414

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
GuAlas	343.3214	49.0962	276.5250	415.8250	139.3000	0.4057	0.1430
Hawaii	267.4681	7.7290	256.1667	278.9000	22.7333	0.0850	0.0289
AustS	313.9833	40.9525	266.3833	383.6625	117.2792	0.3735	0.1304
MadE	278.7015	16.9284	258.0457	305.6638	47.6181	0.1709	0.0607
MadE-0	279.3175	17.5797	257.1350	306.0300	48.8950	0.1751	0.0629
MadE-1	279.2088	17.5268	257.2600	306.9100	49.6500	0.1778	0.0628
MadE-2	278.8679	17.0860	258.0350	306.0600	48.0250	0.1722	0.0613
MadE-3	278.1283	16.3431	258.8044	304.7711	45.9667	0.1653	0.0588

3.5.2.6.2 Results

Table 70 provides a classification of the sites based on the mean of the ozone content

Table 70: Rank of sites based on the mean of ozone content

Rank	Site name	Mean		Rank	Site name	Mean
1	PacNW-0	252.8656		22	PacSE-7	272.7234
2	PacNW-1	257.5699		23	PacSE-6	273.2610
3	PacNW-2	257.9447		24	GuMex	273.3880
4	PacNW	258.9688		25	AtlN-1	274.8852
5	DoCoRi	259.8857		26	AtlN-2	275.8477
6	AtlS-3	263.1821		27	MadE-3	278.1283
7	PacNW-3	263.3022		28	MadE	278.7015
8	PacN-0	263.4776		29	MadE-2	278.8679
9	AtlS-2	263.4865		30	MadE-1	279.2088
10	AtlS	264.4145		31	MadE-0	279.3175
11	AtlS-0	264.6417		32	PacSE-3	284.4677
12	AtlS-4	264.9508		33	PacSE-4	285.8017
13	AtlS-1	265.5106		34	PacSE-5	287.9685
14	GuYuc	265.8244		35	PacSE	288.6584
15	PacN	266.9362		36	PacSE-2	297.4622
16	Hawaii	267.4681		37	MedCr	299.7653
17	PacN-1	268.6383		38	MedCy	301.6542
18	AtlN-0	269.1432		39	PacSE-1	303.1137
19	PacN-2	270.7356		40	PacSE-0	313.8063
20	IndS	271.8892		41	AustS	313.9833
21	AtlN	272.2533		42	GuAlas	343.3214

3.5.2.7 Temporal variability over SES

3.5.2.7.1 Statistics

The temporal variability of the ozone content over the SES is represented in Figure 91. The highest values are observed during the winter months an for the sites located at high latitudes. Statistics are reported in Table 71. The distribution of ozone content for the 42 sites is represented on Figure 92.

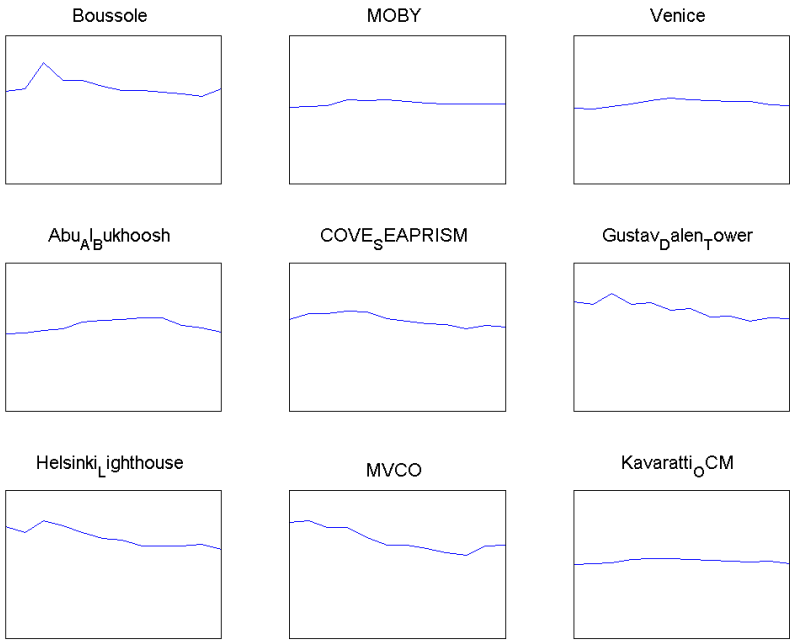


Figure 91: Temporal variability of ozone content for the SES. X axis scale is one year, from January to December. Y axis scale is 0-500 Dobson.

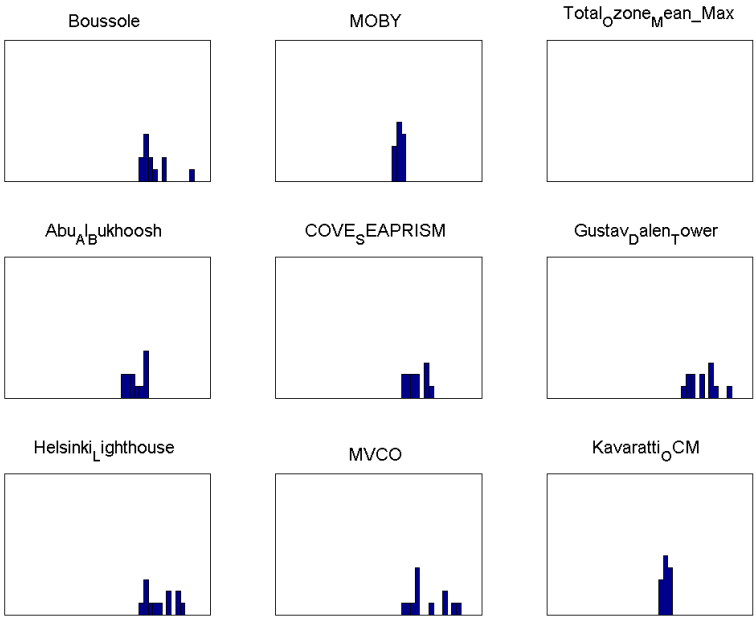


Figure 92: Histogram of ozone content. X axis scale is 250-450 Dobson

Table 71: Statistics of ozone content over SES

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Boussole	326.1583	30.3910	295.1000	408.9000	113.8000	0.3489	0.0932
MOBY	270.3500	8.4341	257.4000	284.0000	26.6000	0.0984	0.0312
Venice/AAOT	270.8167	12.0657	252.8000	288.8000	36.0000	0.1329	0.0446
Abu_Al_Bukhoosh	287.0833	20.0003	260.8000	313.6000	52.8000	0.1839	0.0697
COVE_SEAPRISM	306.2417	20.9174	277.1000	337.0000	59.9000	0.1956	0.0683
Gustav_Dalen_Tower	340.9750	29.1685	301.4000	396.6000	95.2000	0.2792	0.0855
Helsinki_Lighthouse	340.1833	31.9585	299.3000	394.9000	95.6000	0.2810	0.0939
MVCO	332.8000	40.2739	281.1000	396.1000	115.0000	0.3456	0.1210
Kavaratti_OCM	259.8000	6.6542	248.8000	268.6000	19.8000	0.0762	0.0256

3.5.2.7.2 Results

Table 72 provides a classification of the sites based on the observed mean ozone content.

Table 72: Rank of SES Test Sites based on the mean of ozone content

Rank	Site name	Mean of ozone content
1	Kavaratti_OCM	259.8000
2	MOBY	270.3500
3	Venice	270.8167
4	Abu_Al_Bukhoosh	287.0833
5	COVE_SEAPRISM	306.2417
6	Boussole	326.1583
7	MVCO	332.8000
8	Helsinki_Lighthouse	340.1833
9	Gustav_Dalen_Tower	340.9750

3.6 Variability of Windspeed

Data are analysed to estimate the variability of the Windspeed over SNES. The Windspeed is used as input to estimate the glitter and the foam reflectance.

Table 73: Criterion for Windspeed analysis

Retained criteria	Studied parameters	Site type
Glitter Foam	Windspeed	▪ SNES

3.6.1 Dataset description

3.6.1.1 Dataset identification

QuikSCAT Mean Wind Fields

3.6.1.2 Spatial Characteristics

The QuikSCAT mean wind fields are provided on a rectangular 0.5°x0.5° resolution grid.

3.6.1.2.1 Spatial Coverage

The QuikSCAT mean wind fields cover global oceans from 80° North to 80° South in latitude, and 180° West to 180° East in longitude.

3.6.1.2.2 Spatial Coverage Map

The data are projected on a 0.5° rectangular grid of 720 columns and 320 lines. A grid cell spans 0.5° in longitude and 0.5° in latitude. Latitude and longitude of each grid cell refers to its centre. The origin of each data grid is the grid cell defined by 179.75° West in longitude and 79.75° North in latitude. The last grid cell is centered at 79.75° South and 179.75° East.

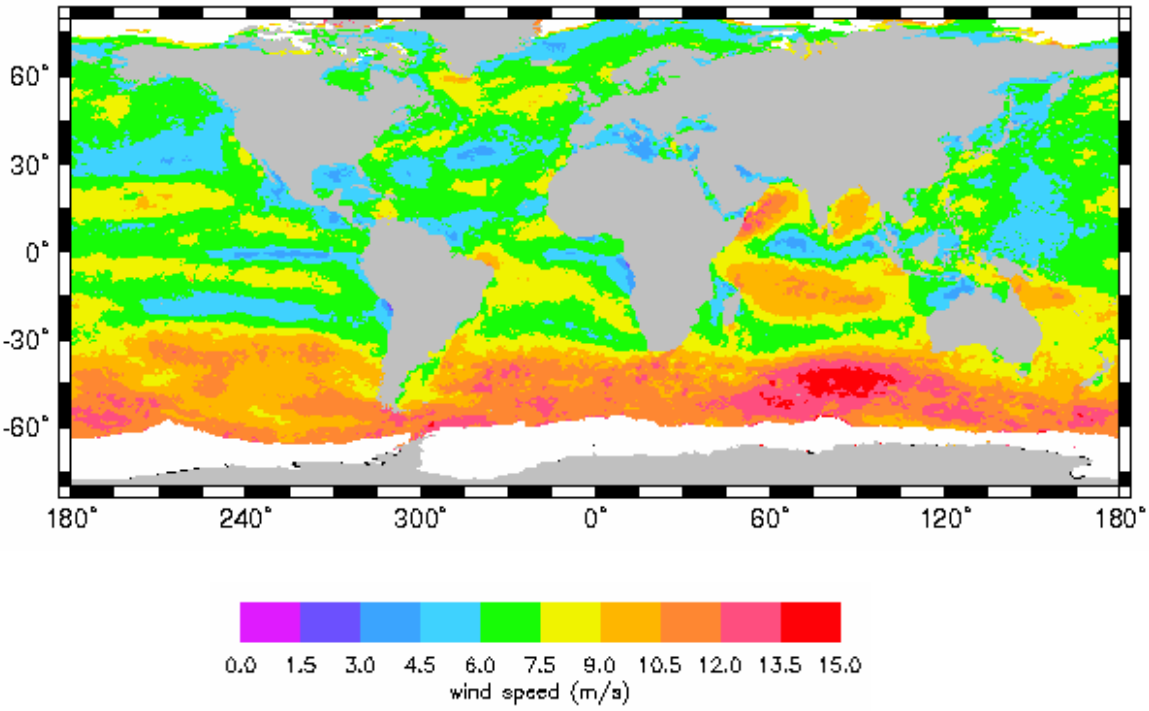


Figure 93: Spatial coverage map of Quicksat level 3 data

3.6.1.2.3 Spatial Resolution

The QuikSCAT mean wind fields are provided on a rectangular 0.5°x0.5° resolution grid.

3.6.1.3 Projection

The data are projected on a 0.5° rectangular grid.

3.6.1.4 Temporal Characteristics

Mean winds fields are available from 20 July 1999 to present. They are continually completed.

3.6.1.5 Data Characteristics

3.6.1.5.1 Parameter/Variable

The following parameters are available.

- Wind speed modulus: 0 – 60 m/s
- Zonal wind component: -60 – 60 m/s
- Meridional wind component: -30 – 30 m/s
- Wind stress modulus: 0 – 2.5 Pa
- Zonal wind stress component: - 2.5 – 2.5 Pa
- Meridional wind stress component: - 2.5 – 2.5 Pa
- Wind vector divergence: - 10-3 – 10-3 s-1
- Wind stress curl: -2.5 – 2.10-5

The estimated error of each at the above parameters is provided with the same unit.

The products analysed is: **Windspeed**

3.6.1.5.2 Variable Description/Definition

This product provides the scientific community with easy-to-use synoptic gridded fields of wind parameters as retrieved from the NASA SeaWinds scatterometer, onboard QuikSCAT. This Ku-Band active microwave instrument provides radar backscatter (sigma0), from which wind speed and direction can be retrieved over oceans. The product provides daily, weekly and monthly wind fields over global 0.5°x5° resolut ion geographical grids. the main parameters include wind speed module and components, wind stress magnitude and components. In order to reconstruct gap-filled and averaged synoptic fields from discrete observations (available in JPL/PO.DAAC Level 2B product) over each time period, a statistical interpolation is performed using an objective method; the standard errors of the parameters estimated by this method are also computed and provided as complementary gridded fields. Wind divergence and stress curl are also derived respectively from wind and stress grids and included in the dataset. The dataset covers the whole QuikSCAT mission and is regularly updated..

3.6.1.5.3 Unit of Measurement

Unit is m/s.

3.6.1.5.4 Data Source

http://www.ifremer.fr/cersat/en/data/overview/gridded/mwfqscat.htm#diffusion.

3.6.1.5.5 Data Range

Windspeed varies between 0 and 60m/s.

3.6.1.6 Sample Data Record

Dataset format is netcdf.

3.6.2 Analysis

3.6.2.1 Variability at global scale

The global spatial distribution of wind speed and its temporal variability is represented on Figure 94. Strong variations are observed in the south between 40 et 60 °south.

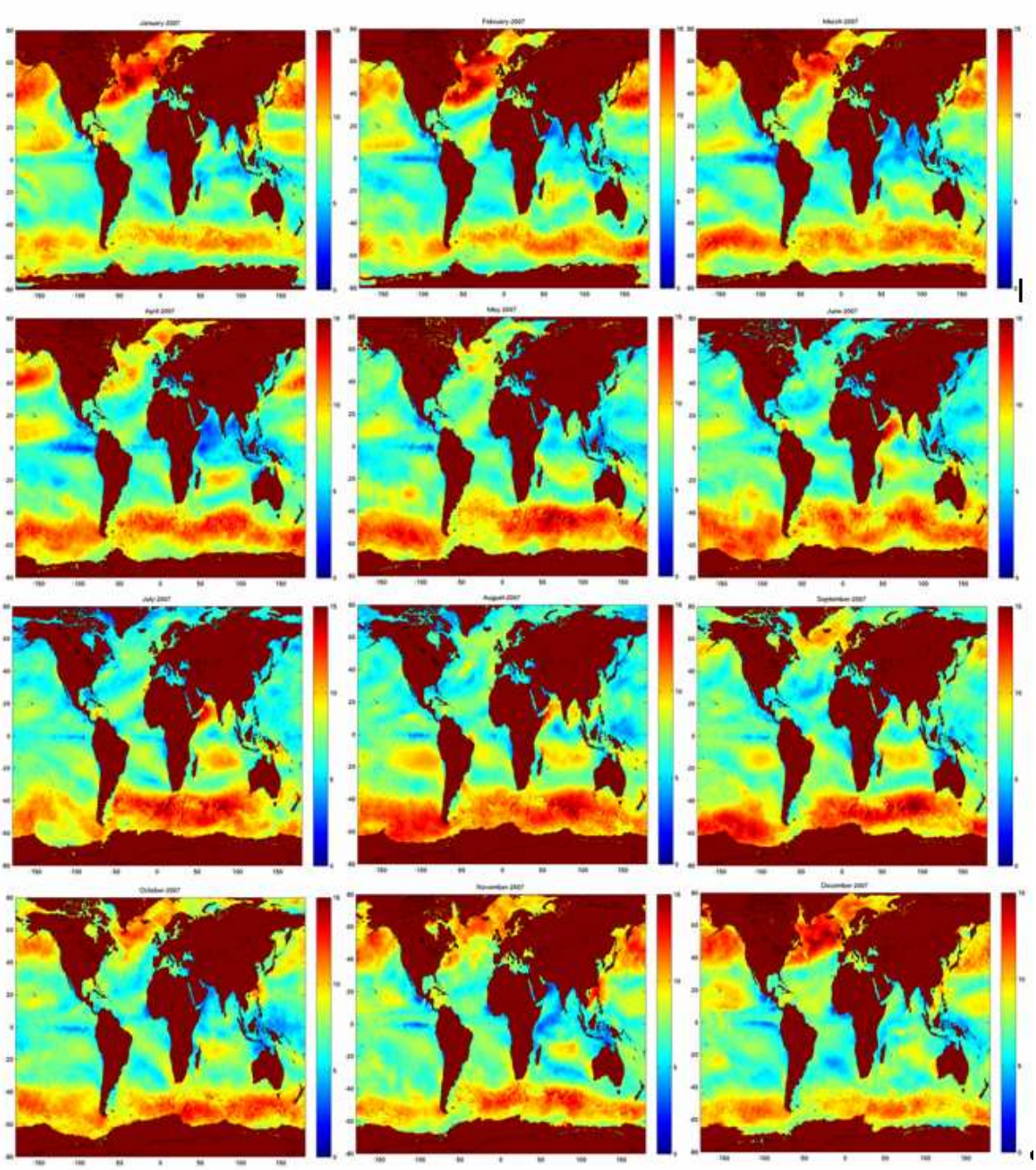


Figure 94: Monthly mean of Windspeed (Quicksat). Line of images corresponds to Q1, Q2, Q3, and Q4 respectively. Units: m/s.

3.6.2.2 Temporal variability over SNES

3.6.2.2.1 Statistics

Figure 95 represents the temporal variability of the mean Windspeed of the 42 oceanic sites. Windspeed ranges from 6 to 8 m/s, with a low dynamics. Sites in high latitude (south or North have the highest values, with maximum which are greater than 11m/s.

Statistics are reported in Table 69. The distribution of Windspeed for the 42 sites is represented on Figure 90.

Figure 95: Temporal variability of Windspeed for the SNES. Y axis scale is 0-12 m/s.

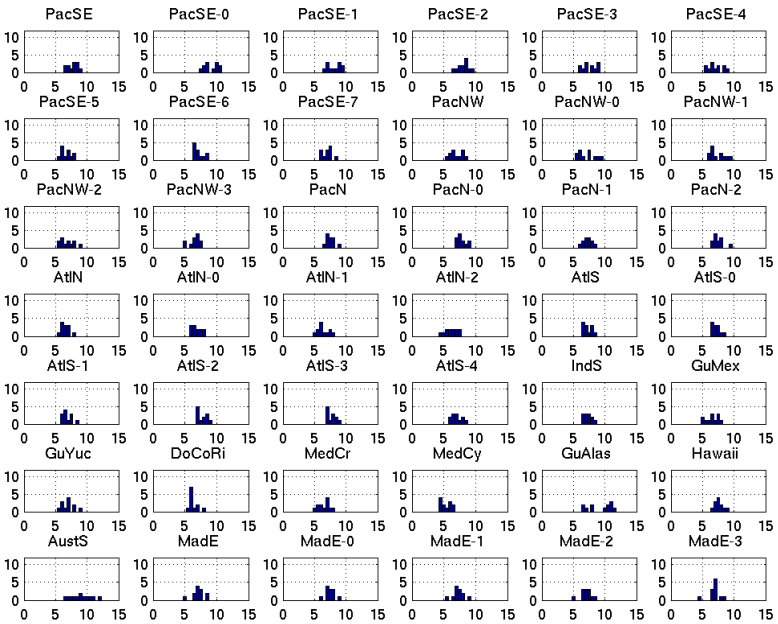


Figure 96: Histogram of Windspeed

Table 74: Statistics for windspeed

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
PacSE	7.6567	0.7507	6.5426	8.7516	2.2090	0.2885	0.0980
PacSE-0	9.0318	1.0292	7.3642	10.3710	3.0068	0.3329	0.1139
PacSE-1	8.1810	1.1081	6.6456	9.7427	3.0971	0.3786	0.1355
PacSE-2	8.0236	0.9364	6.3729	9.5666	3.1937	0.3980	0.1167
PacSE-3	7.6445	1.1086	6.0475	9.1492	3.1017	0.4057	0.1450
PacSE-4	7.0056	1.1351	5.3412	8.9869	3.6458	0.5204	0.1620
PacSE-5	6.7271	0.9034	5.2736	8.2252	2.9516	0.4388	0.1343
PacSE-6	7.1465	0.8468	6.2677	8.6968	2.4291	0.3399	0.1185
PacSE-7	6.9172	0.7869	5.7794	8.5418	2.7624	0.3994	0.1138
PacNW	6.9767	0.9721	5.7418	8.7198	2.9780	0.4269	0.1393
PacNW-0	7.0482	1.3956	5.2828	9.5657	4.2829	0.6077	0.1980
PacNW-1	7.3024	1.2356	5.7574	9.6533	3.8959	0.5335	0.1692
PacNW-2	6.8524	1.0701	5.5837	8.9549	3.3712	0.4920	0.1562
PacNW-3	6.5723	0.8516	4.8992	7.5286	2.6295	0.4001	0.1296
PacN	7.5322	0.6441	6.5626	8.8741	2.3115	0.3069	0.0855
PacN-0	7.7495	0.6795	6.9058	8.9524	2.0466	0.2641	0.0877
PacN-1	7.2474	0.6763	6.1035	8.3029	2.1994	0.3035	0.0933
PacN-2	7.4217	0.7749	6.2910	9.2880	2.9970	0.4038	0.1044
AtlN	6.5584	0.7221	5.6676	7.9746	2.3070	0.3518	0.1101
AtlN-0	6.8006	0.7685	5.8607	8.2203	2.3596	0.3470	0.1130
AtlN-1	6.3736	0.8920	5.0082	7.7674	2.7592	0.4329	0.1400
AtlN-2	6.2522	0.9856	4.6072	7.7320	3.1248	0.4998	0.1576
AtlS	7.2804	0.7328	6.4550	8.7055	2.2505	0.3091	0.1007
AtlS-0	7.1358	0.7057	6.3092	8.6166	2.3073	0.3233	0.0989
AtlS-1	6.8997	0.7757	6.0492	8.4874	2.4382	0.3534	0.1124
AtlS-2	7.7697	0.8125	6.8220	9.2115	2.3895	0.3075	0.1046
AtlS-3	7.6496	0.7639	6.7635	8.7921	2.0286	0.2652	0.0999
AtlS-4	7.0188	0.7756	5.9636	8.3555	2.3919	0.3408	0.1105
IndS	7.2851	0.6659	6.3334	8.3069	1.9734	0.2709	0.0914
GuMex	6.5792	0.9924	5.1581	8.1906	3.0325	0.4609	0.1508
GuYuc	6.8717	0.9726	5.4695	8.7683	3.2988	0.4801	0.1415
DoCoRi	6.3215	0.7594	5.3550	8.1785	2.8234	0.4466	0.1201
MedCr	6.5424	0.8328	5.0467	7.8192	2.7725	0.4238	0.1273
MedCy	5.3854	0.8609	4.2660	6.6413	2.3753	0.4411	0.1599
GuAlas	9.2767	1.9066	6.2851	11.5976	5.3125	0.5727	0.2055

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Hawaii	7.5872	0.5853	6.5325	8.7737	2.2412	0.2954	0.0771
AustS	9.0377	1.6100	6.7122	11.7591	5.0469	0.5584	0.1781
MadE	7.1197	0.8348	5.1916	8.4003	3.2087	0.4507	0.1173
MadE-0	7.4532	0.7170	6.1892	9.1225	2.9333	0.3936	0.0962
MadE-1	7.3205	0.8435	5.4925	8.9280	3.4355	0.4693	0.1152
MadE-2	7.0963	0.8649	5.1217	8.4449	3.3232	0.4683	0.1219
MadE-3	6.8657	0.9666	4.5816	8.7435	4.1618	0.6062	0.1408

3.6.2.2.2 Results

Table 75 provides a classification of the sites based on the mean of the Windspeed.

Table 75: Rank of sites based on the mean Windspeed

Rank	Site name	Mean		Rank	Site name	Mean
1	MedCy	5.3854		22	AtlS-0	7.1358
2	AtlN-2	6.2522		23	PacSE-6	7.1465
3	DoCoRi	6.3215		24	PacN-1	7.2474
4	AtlN-1	6.3736		25	AtlS	7.2804
5	MedCr	6.5424		26	IndS	7.2851
6	AtlN	6.5584		27	PacNW-1	7.3024
7	PacNW-3	6.5723		28	MadE-1	7.3205
8	GuMex	6.5792		29	PacN-2	7.4217
9	PacSE-5	6.7271		30	MadE-0	7.4532
10	AtlN-0	6.8006		31	PacN	7.5322
11	PacNW-2	6.8524		32	Hawaii	7.5872
12	MadE-3	6.8657		33	PacSE-3	7.6445
13	GuYuc	6.8717		34	AtlS-3	7.6496
14	AtlS-1	6.8997		35	PacSE	7.6567
15	PacSE-7	6.9172		36	PacN-0	7.7495
16	PacNW	6.9767		37	AtlS-2	7.7697
17	PacSE-4	7.0056		38	PacSE-2	8.0236
18	AtlS-4	7.0188		39	PacSE-1	8.1810
19	PacNW-0	7.0482		40	PacSE-0	9.0318
20	MadE-2	7.0963		41	AustS	9.0377
21	MadE	7.1197		42	GuAlas	9.2767

3.6.2.3 Temporal variability over SES

3.6.2.3.1 Statistics

The temporal variability of the Windspeed for the 9 SES is represented in Figure 97. A seasonal cycle is observed for MVCO, Helsinki , and karavatti Islands. Windspeed in MOBY sites is almost constant over the year. No climatological data has been computed for Gustav Tower sites.

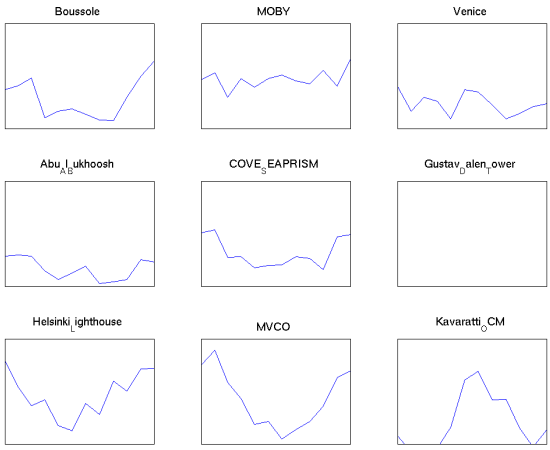


Figure 97: Temporal variability of windspeed for the SES. X axis scale is one year, from January to December. Y axis scale is 0-10 m/s.

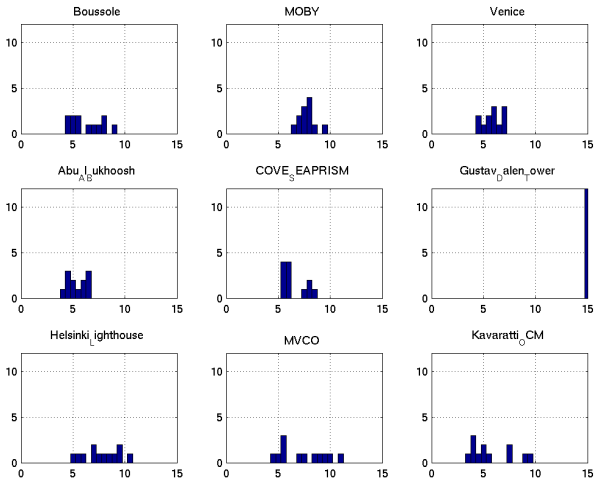


Figure 98: Histogram of windspeed

Table 76: Statistics of windspeed over SES

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Boussole	6.3017	1.5148	4.6200	9.1200	4.5000	0.7141	0.2404
MOBY	7.7583	0.7331	6.4000	9.3300	2.9300	0.3777	0.0945
Venice/AAOT	5.8842	0.8364	4.7200	7.2200	2.5000	0.4249	0.1421
Abu_Al_Bukhoosh	5.3350	0.8177	4.1800	6.3600	2.1800	0.4086	0.1533
COVE_SEAPRISM	6.5600	1.1251	5.2700	8.3100	3.0400	0.4634	0.1715
Gustav_Dalen_Tower	-	-		-	-	-	-
Helsinki_Lighthouse	7.7475	1.7320	5.0000	10.3900	5.3900	0.6957	0.2236
MVCO	7.4200	2.2137	4.3600	11.1200	6.7600	0.9111	0.2983
Kavaratti_OCM	5.6650	2.1078	3.3500	9.5200	6.1700	1.0891	0.3721

3.6.2.3.2 Results

Table 77 provides a classification of the sites based on the Windspeed.

Table 77: Rank of SES Test Sites based on the mean of Windspeed

Rank	Site name	Mean of ozone content
1	Abu_Al_Bukhoosh	5.3350
2	Kavaratti_OCM	5.6650
3	Venice	5.8842
4	Boussole	6.3017
5	COVE_SEAPRISM	6.5600
6	MVCO	7.4200
7	Helsinki_Lighthouse	7.7475
8	MOBY	7.7583
9	Gustav_Dalen_Tower	-

4. ANALYSIS OF LAND SITE

4.1 Altitude of the sites

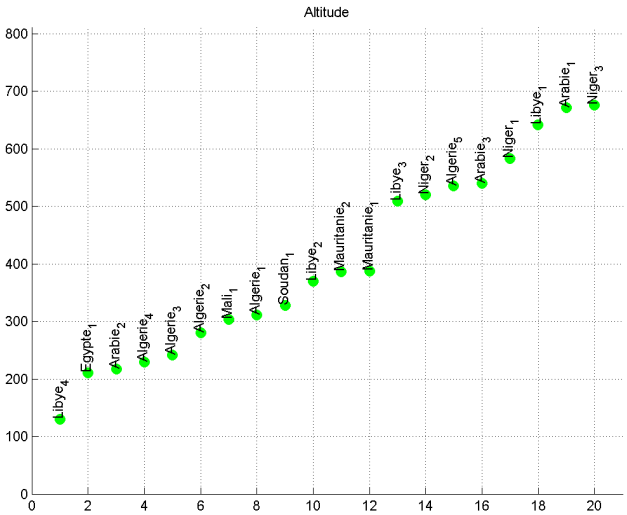
The site should be located at high altitude (to minimize aerosol loading and the uncertainties due to unknown vertical distribution of aerosols and water vapour), far from the ocean (to minimize the influence of atmospheric water vapour), and far from urban and industrial areas (to minimize anthropogenic aerosols).

Table 78: Criterion for site altitude

Retained criteria	Studied parameters	Site type
Minimisation of aerosol scattering	MNT (Altitude)	▪ LES ▪ LNES

4.1.1 Altitude of LNES

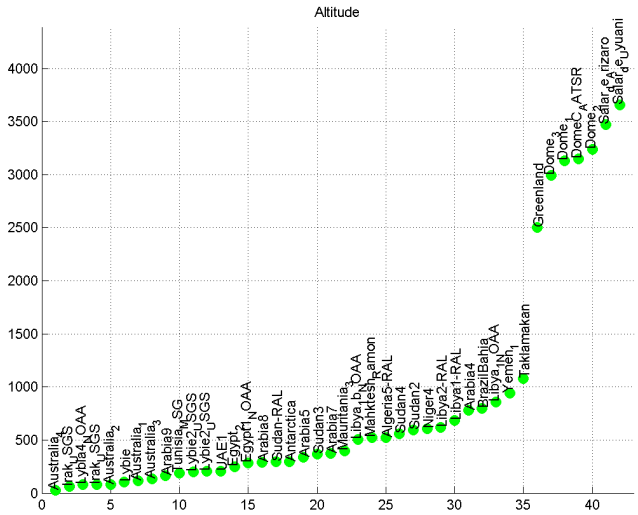
Table 79: Site elevation for the LNES-SADE test sites

Site name	Mean	
Algerie_1	311	
Algerie_2	280	
Algerie_3	242	
Algerie_4	229	
Algerie_5	536	
Arabie_1	671	
Arabie_2	217	
Arabie_3	540	
Soudan_1	328	
Niger_1	583	
Niger_2	520	
Niger_3	676	
Egypte_1	210	
Libye_1	642	
Libye_2	370	
Libye_3	509	
Libye_4	130	
Mali_1	303	
Mauritanie_1	387	
Mauritanie_2	386	

4.1.2 Altitude of LNES- others test sites

Table 80: Site elevation for the LNES-others test sites

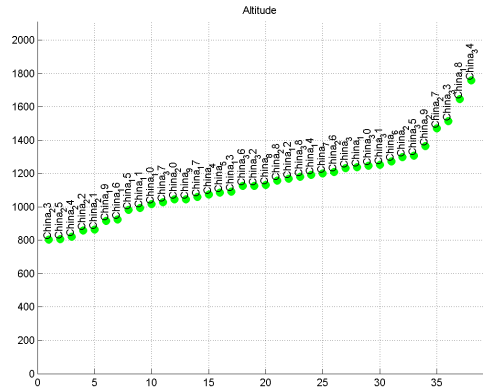
Site name	Mean	
Dome_1	3128	
Dome_2	3240	
Dome_3	2992	
DomeC_AATSR	3150	
Antarctica	298	
Greenland	2500-2950	
Salar_de_Uyuani	3658	
Salar_de_Arizaro	3470	
Brazil Bahia	800	
Taklamakan	1080	
Algeria5-RAL	526	
Libya1-RAL	683	
Libya2-RAL	616	
Sudan-RAL	296	
Libya_1_NOAA	860	
Libya_1b_NOAA	506	
Egypt1_NOAA	283	
Lybia4_NOAA	78	
Mauritania_3	399	
Lybie2_USGS	204	
Irak_USGS	65	
Tunisia_MSG	186	
Lybie2_USGS	202	
Irak_USGS	78	
Egypt_2	249	
Yemen_1	942	
Mahktesh_Ramon	522	
Lybie	107	
Arabia4	779	
Arabia5	339	
Arabia7	376	
Arabia8	291	
Arabia9	166	
UAE1	208	
Sudan2	598	
Sudan3	370	
Sudan4	558	
Niger4	608	
Australia_1	115	
Australia_2	78	
Australia_3	136	
Australia_4	26	



4.1.3 Altitude of LNES- China

Table 81: Site elevation for the LNES-china sites

Site name	Mean Altitude (m)	Site name	Mean Altitude (m)	Site name	Mean Altitude (m)
China_1	1238	China_14	1192	China_27	1472
China_2	1298	China_15	983	China_28	1157
China_3	1232	China_16	924	China_29	1365
China_4	1074	China_17	1059	China_30	1247
China_5	1085	China_18	1646	China_31	1253
China_6	1274	China_19	916	China_32	1127
China_7	1201	China_20	1046	China_33	1514
China_8	1131	China_21	866	China_34	1760
China_9	1047	China_22	859	China_35	1308
China_10	1017	China_23	804	China_36	1126
China_11	993	China_24	822	China_37	1030
China_12	1171	China_25	807	China_38	1180
China_13	1093	China_26	1210		



4.1.4 Altitude of LES

Table 82: Altitude for CEOS sites

Site name	Altitude (m)	
LaCrau	18	
RailroadValley	1436	
Ivanpahplaya	795	
FrenchmanFlat	1195	
Negev	340	
TuzGulu	905	
Dunhuang	1355	
Dome C_cnes	3264	

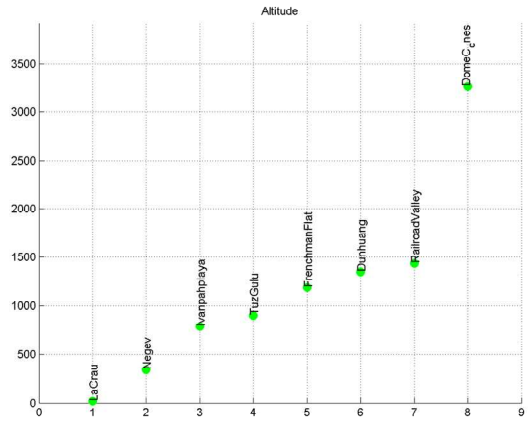
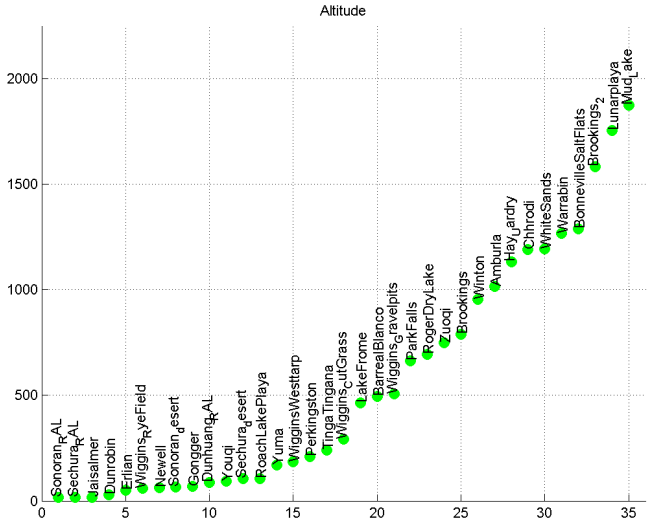


Table 83: Altitude for LES sites (except CEOS)

Site name	Mean	
Lunarplaya	1755	
WhiteSands	1193	
RogerDryLake	694	
BonnevilleSaltFlats	1289	
LakeFrome	106	
BarrealBlanco	1875	
RoachLakePlaya	790	
Mud_Lake	1582	
Brookings	506	
TingaTingana	59	
Dunrobin	292	
Warrabin	185	
Winton	209	
Amburla	665	
Sonoran_desert	66	
Sechura_desert	17	
Hay_Uardry	170	
Perkingston	64	
ParkFalls	463	
Jaisalmer	242	
Chharodi	28	
Gongger	1268	
Erlian	954	
Zuoqi	1017	
Youqi	1134	
Wiggins_Gravelpits	87	
Wiggins_RyeField	69	
Wiggins_CutGrass	50	
Newell	751	
WigginsWesttarp	92	
Yuma	17	
Sonoran_RAL	105	
Brookings_2	496	
Sechura_RAL	17	
Dunhuang_RAL	1191	



4.2 Morphology of the terrain

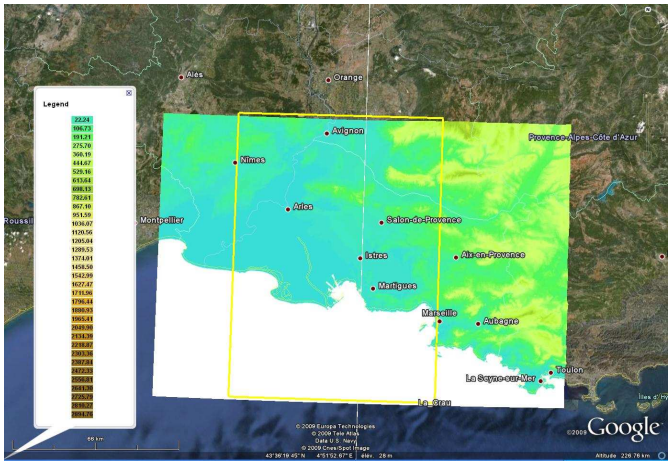
The surface of the site should be flat to minimize slope-aspect effects.

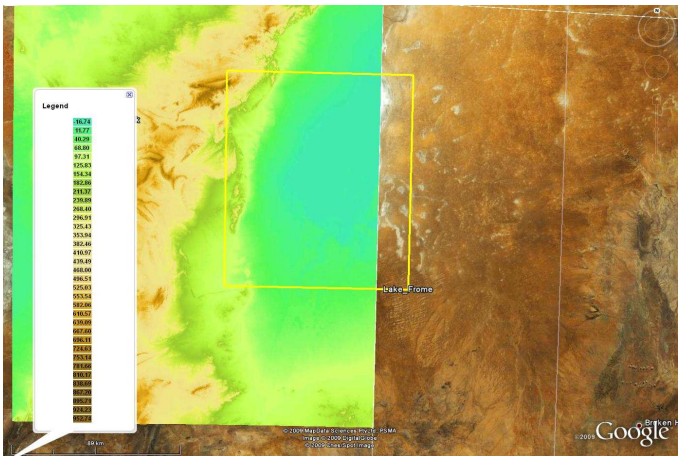
Table 84: Criterion for site relief

Retained criteria	Studied parameters	Site type
Relief	Slope, orientation	▪ LES ▪ LNES

Cosnefroy et al. 1996 (RD.25) have studied the geomorphology of desert sites. According to existing sand dune classifications (Cooke et al., 1993; RD.27, Mainguet, 1984, RD.28), the sand dunes of Algeria 2, Egypt 1, and Libya 1, Niger 2, and Algeria 3 may be classified as linear, transverse and star dunes, respectively. The interdune distance varies from a few hundred meters (Niger 2) to 2-3 km (Algeria 2, for example). The longitudinal dimension of linear dunes can be quite large, from several kilometers to several tens of kilometers. The transverse dimension of dunes varies from typically 100 m (Niger 2 and Libya 1) to 1 km (Algeria 2 and Algeria 3). The height of dunes cannot be directly inferred from the Spot images, but is known to vary typically from about 10 m (Libya 1 and Niger 2) to 100 m (Algeria 2 and Algeria 3)

STRM maps have been extracted over a few sites.





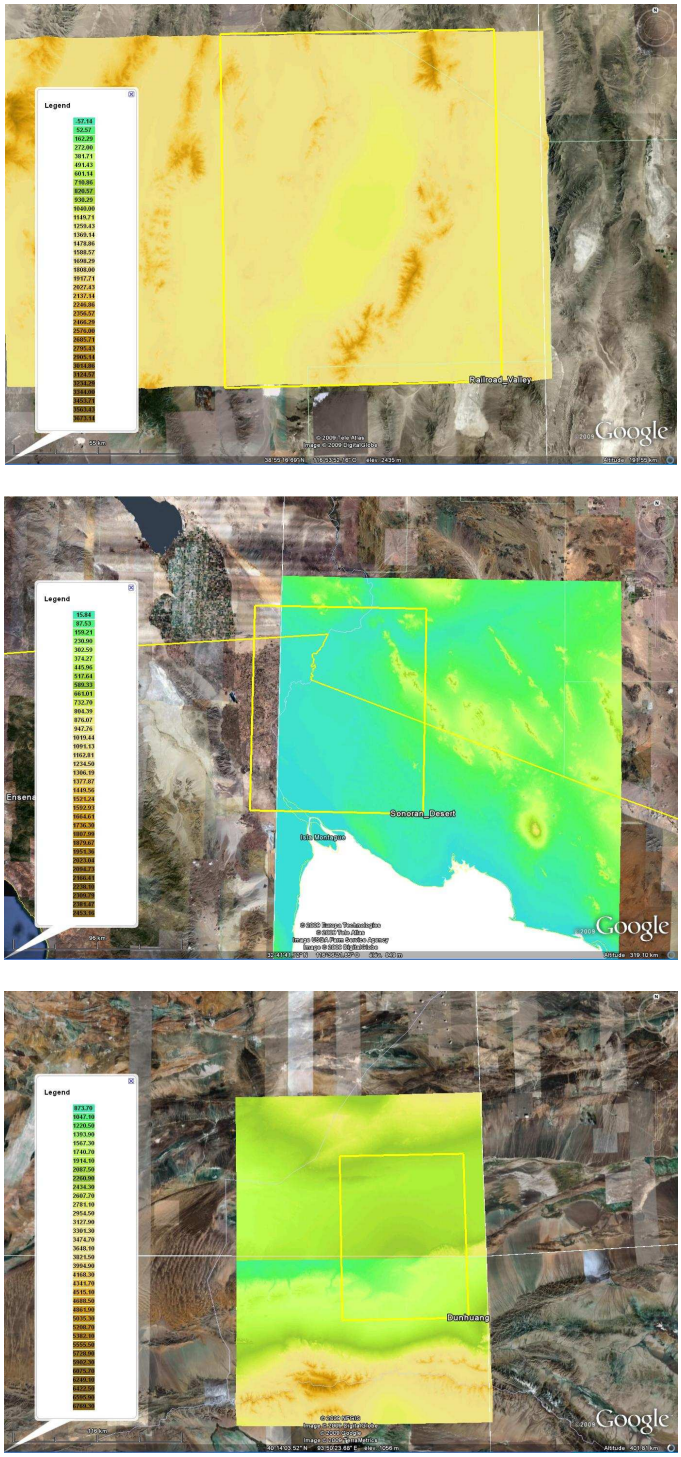


Figure 99: SRTM map for Dunhuang, La Crau, lake Frome, RRVP, and Sonoran sites.

4.3 Surface reflectance analysis

4.3.1 Invariance of spectral and radiometric properties

The surface properties of the site (reflectance, BRDF, spectral) should be temporally invariant. Otherwise, adequate accuracy would be obtained only if these properties were measured for every calibration. This implies that the site should have little or no vegetation.

Table 85: Criterion for temporal invariance of reflectance

Retained criteria	Studied parameters	Site type
Invariance of spectral and radiometric surface properties	Temporal series of : ▪ BRDF ▪ Albedo ▪ Vegetation indices ▪ Surface classification	▪ LES ▪ LNES

4.3.2 Spectral variability of the surface albedo

The surface of the site should have flat spectral reflectance. This becomes important if the multiple instruments involved in cross-calibration have spectral bands with different response profiles.

Table 86: Criterion for spectral reflectance variability

Retained criteria	Studied parameters	Site type
Spectral variability	Variation of the spectral reflectance	▪ LNES

4.3.3 Surface reflectance Level

The analysis aims at quantifying the level of the surface albedo for calibration sites (Table 87), knowing that it is required (Teillet et al., 2007, RD.21) that the terrestrial site should have a surface reflectance greater than 0.3 in order to provide higher signal-to-noise ratio (SNR) and reduce the impact of atmospheric errors.

Surfaces with high level of reflectance such as desert or playas may be interesting to reduce atmospheric contribution to the TOA signal. Moreover, constant spectral response may be interesting in case of cross-calibration of sensors having slightly different spectral band responses.

Table 87: Criterion for surface reflectance level

Retained criteria	Studied parameters	Site type
Atmospheric signal minimisation	▪ Surface reflectance level	▪ LES ▪ LNES

4.3.4 Dataset description

4.3.4.1 Dataset identification

MODIS Terra+Aqua BRDF/Albedo 16-Day L3 Global 0.05Deg CMG V005 (MCD43C3)

4.3.4.2 Spatial Characteristics

4.3.4.2.1 Spatial Coverage

Coverage of the data sets is global over land surface.

4.3.4.2.2 Spatial Coverage Map

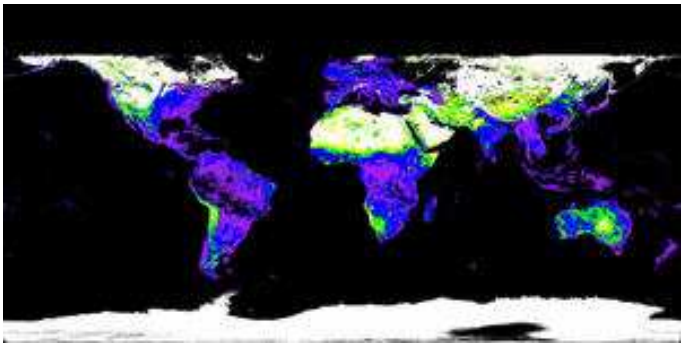


Figure 100: Spatial coverage map of MODIS level 3

4.3.4.2.3 Spatial Resolution

0.05 x 0.05 degrees

4.3.4.3 Projection

The MODIS Level 3 Albedo Products data set has been produced on an equal angle lat-lon grid, CMG (Climate Modeling Grid).

4.3.4.4 Temporal Characteristics

4.3.4.4.1 Temporal Coverage

Data sets cover January 2007 to December 2007.

4.3.4.4.2 Temporal Resolution

The Level 3 data set is produced every 8 days with 16 days of acquisition.

4.3.4.5 Data Characteristics

4.3.4.5.1 Parameter/Variable

The MODerate-resolution Imaging Spectroradiometer (MODIS) Albedo product (MCD43C3) provides data describing both directional hemispherical reflectance (black-sky albedo) and bihemispherical reflectance (white-sky albedo). MCD43C3 data are 16-day composites provided as a level-3 product projected to a 0.05 degree (5600-meter) latitude/longitude Climate Modeling Grid.

Both Terra and Aqua data are used in the generation of this product, providing the highest probability for quality input data and designating it as an "MCD," meaning "Combined," product.

4.3.4.5.2 Variable Description/Definition

Albedo is defined as the ratio of upwelling to downwelling radiative flux at the surface. Downwelling flux may be written as the sum of a direct component and a diffuse component. Black-sky albedo (directional hemispherical reflectance) is defined as albedo in the absence of a diffuse component and is a function of solar zenith angle. White-sky albedo (bihemispherical reflectance) is defined as albedo in the absence of a direct component

when the diffuse component is isotropic. Black-sky albedo and white-sky albedo mark the extreme cases of completely direct and completely diffuse illumination, (http://www-modis.bu.edu/brdf/userguide/albedo.html, RD.33).

The MCD43C3 Albedo Product (MODIS/Terra/Aqua Albedo 16-Day L3 Global 1km SIN Grid) provides both the white-sky albedos and the black-sky albedos (at local solar noon) for MODIS bands 1-7 as well as for three broad bands (0.3-0.7µm, 0.7-5.0µm, and 0.3-5.0µm).

Table 88: MCD43C3 products

MODIS band	Spectral Bandwidth	Black Sky Albedo product	White Sky Albedo product	Quality product
1	0.659	Albedo_BSA_Band_1	Albedo_WSA_Band_1	BRDF_Quality
2	0.858	Albedo_BSA_Band_2	Albedo_WSA_Band_2	Local_Solar_Noon
3	0.470	Albedo_BSA_Band_3	Albedo_WSA_Band_3	Percent_Inputs
4	0.555	Albedo_BSA_Band_4	Albedo_WSA_Band_4	Percent_Snow
5	1.24	Albedo_BSA_Band_5	Albedo_WSA_Band_5	
6	1.64	Albedo_BSA_Band_6	Albedo_WSA_Band_6	
7	2.10	Albedo_BSA_Band_7	Albedo_WSA_Band_7	
	0.3-0.7	Albedo_BSA_Band_vis	Albedo_WSA_Band_vis	
	0.3-5	Albedo_BSA_Band_nir	Albedo_WSA_Band_nir	
	0.7-5	Albedo_BSA_Band_shortwave	Albedo_WSA_Band_shortwave	

The table below lists the four Science Data Sets representing Quality in the Albedo, with applicable QC bit legends. Note that Local_Solar_Noon, Percent_Inputs, and Percent_Snow do not utilize their full 0–254 range (see below).

Table 89: MCD43C3 quality flag

Bit Comb.	BRDF_Albedo_Quality
0	best quality, 75% or more with best full inversions
1	good quality, 75% or more with full inversions
2	Mixed, 75% or less full inversions and 25% or less fill values
3	All magnitude inversions or 50% or less fill values
4	50% or more fill values
255	FillValue
	Local_Solar_Noon
0–254	Zenith Angle at local solar noon (0–180 degrees)
255	FillValue
	Percent_Inputs
0–254	Percent of the processed finer resolution data which contributed to this CMG pixel (0–100%)
255	FillValue
	Percent_Snow

Bit Comb.	BRDF_Albedo_Quality
0–254	Percent of underlying data flagged as snow (0–100%)
255	FillValue

4.3.4.5.3 Unit of Measurement

No units

4.3.4.5.4 Data Source

N/A

4.3.4.5.5 Data Range

Albedo varies between 0 and 1.

4.3.4.6 Sample Data Record

Dataset format is HDF. The specifications are provided at: ftp://modular.nascom.nasa.gov/pub/LatestFilespecs/collection5/MCD43C3.fs

4.3.5 Variability at global scale

Global temporal variations of WSA are represented on Figure 101. The maximum is observed in the polar zone, north in winter (Boreal and arctic), south in summer (Antarctic). WSA varies strongly in the northern hemisphere, due the presence of snow in winter. Deserts have also high values of albedo.

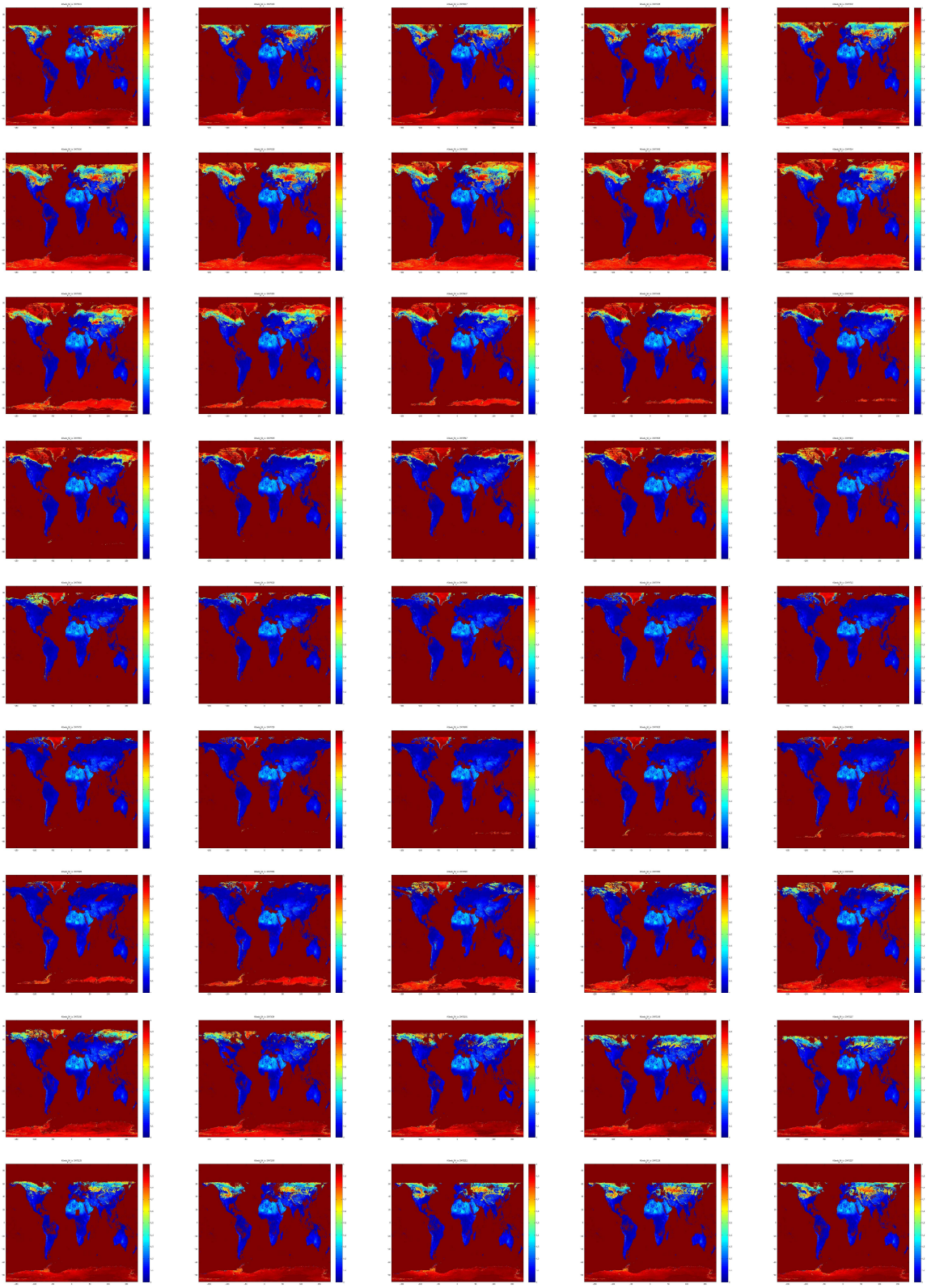


Figure 101: Temporal variability of the WSA vis Albedo. One image represents the albedo for a period of 16 days. First line represents the five first period. Line 2 represents period 6 to 10 etc. No Units. Blue colours represent low albedo, red colours represent high albedo. Colour Scale varies between 0 and 1.

4.3.6 Temporal variability over LNES

4.3.6.1 Statistics

Figure 102 provides the temporal variability for all sites and each MODIS channel. The temporal stability is observed, with different levels of albedo. Depending on the channel, a difference of 10% to 15% is observed between the darkest site and the brightest sites.

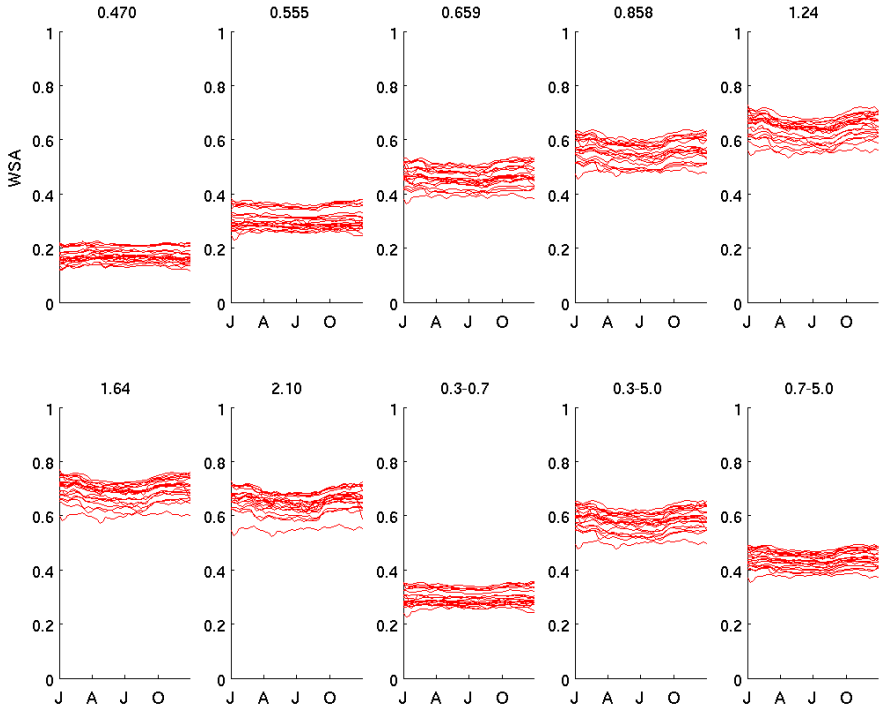


Figure 102: WSA variability for all sites. Spectral band is indicated at the top of each subplot.

The temporal variability for each site is represented for channel B1 (0,659 µm) and B2 (0,858 µm) hereafter. The mean values of the albedo ranges between 0.4 and 0.5 for MODIS B1 and 0.5 to 0.6 for MODIS B2 channels. Libye_1 and Libye_2 are the brightest sites with an albedo around 0.5 in the Vis channel and 0.6 in the NIR channels. Arabia_3 site has the lowest albedo. The difference between the highest value and the lowest value over the year is around 2-3 % in B1 and 3-4 % in B2.

Statistics are reported only for channel B1 (Table 90) and B2 (Table 91).

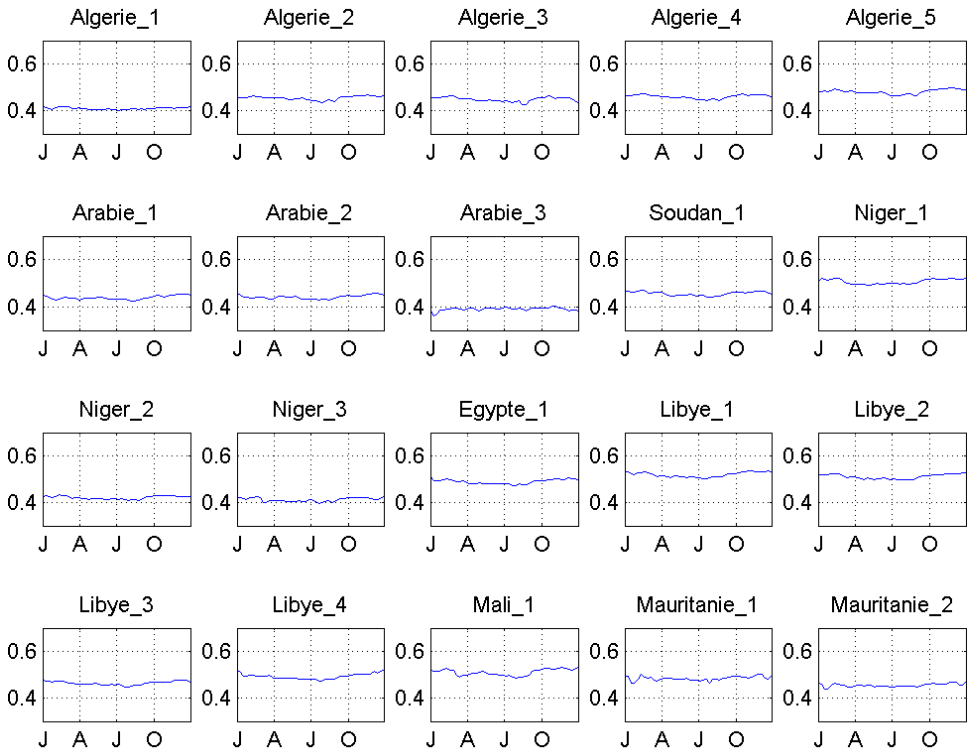


Figure 103: Temporal variability of WSA for VIS channel (B1). X axis scale is one year, from January to December. Y axis scale is 0.3-0.7.

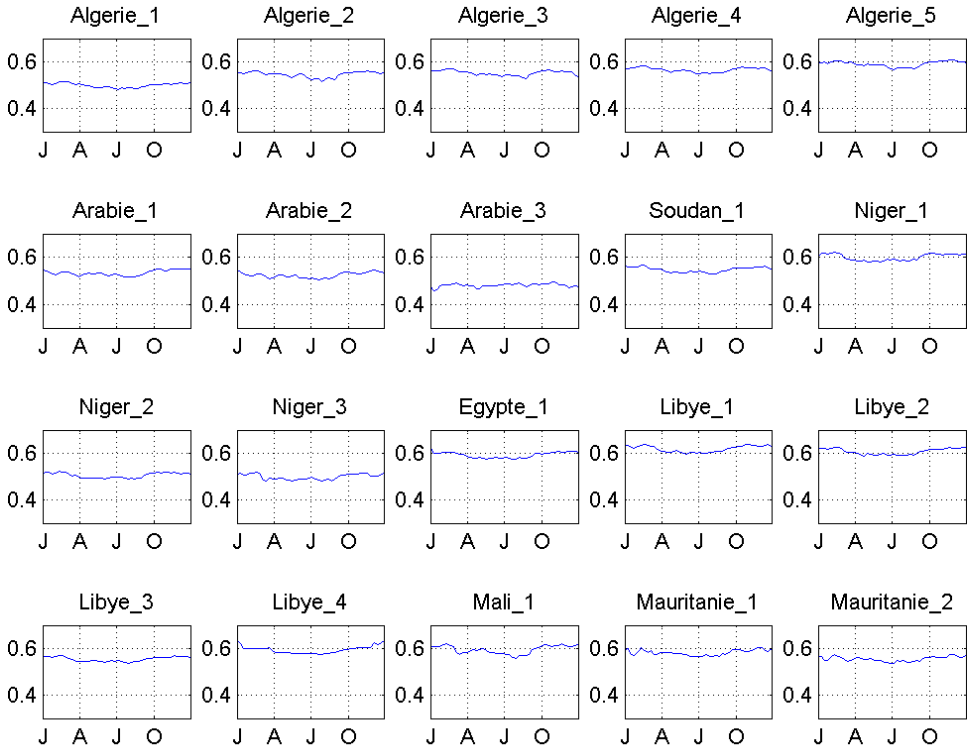


Figure 104: Temporal variability of WSA for NIR channel (B2). X axis scale is one year, from January to December. Y axis scale is 0.3-0.7.

Table 90: Statistics for WSA B1 products

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Algerie_1	0.409224	0.004836	0.398700	0.418505	0.019805	0.048396	0.011817
Algerie_2	0.454119	0.008161	0.434355	0.466135	0.031780	0.069982	0.017971
Algerie_3	0.448459	0.009507	0.423690	0.463348	0.039658	0.088431	0.021199
Algerie_4	0.459416	0.007956	0.443252	0.471303	0.028050	0.061056	0.017319
Algerie_5	0.481008	0.009711	0.463093	0.496910	0.033818	0.070306	0.020188
Arabie_1	0.439050	0.008197	0.423265	0.453572	0.030307	0.069030	0.018670
Arabie_2	0.441816	0.008051	0.427130	0.459335	0.032205	0.072892	0.018222
Arabie_3	0.390616	0.007257	0.361875	0.403168	0.041293	0.105711	0.018577
Soudan_1	0.456367	0.008483	0.440900	0.469073	0.028172	0.061732	0.018589
Niger_1	0.507275	0.010419	0.493022	0.522197	0.029175	0.057513	0.020539
Niger_2	0.421648	0.006848	0.409272	0.432140	0.022868	0.054234	0.016242
Niger_3	0.412081	0.007988	0.397292	0.426380	0.029087	0.070587	0.019385
Egypte_1	0.490093	0.009843	0.472957	0.516138	0.043180	0.088106	0.020084
Libye_1	0.519901	0.010470	0.502663	0.536667	0.034005	0.065407	0.020139
Libye_2	0.511761	0.009985	0.496725	0.527720	0.030995	0.060565	0.019511
Libye_3	0.463735	0.007873	0.447313	0.476957	0.029645	0.063927	0.016978
Libye_4	0.492420	0.011899	0.472370	0.521665	0.049295	0.100108	0.024163
Mali_1	0.510279	0.013670	0.484285	0.532455	0.048170	0.094399	0.026790
Mauritanie_1	0.484525	0.009036	0.464600	0.503093	0.038493	0.079444	0.018649
Mauritanie_2	0.454729	0.007296	0.437795	0.470640	0.032845	0.072230	0.016046

Table 91: Statistics for WSA B2 products

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Algerie_1	0.499790	0.009582	0.481335	0.516765	0.035430	0.070890	0.019172
Algerie_2	0.545732	0.012152	0.516410	0.559917	0.043507	0.079723	0.022267
Algerie_3	0.552149	0.011060	0.529035	0.571335	0.042300	0.076610	0.020031
Algerie_4	0.565823	0.009869	0.547405	0.582860	0.035455	0.062661	0.017441
Algerie_5	0.591384	0.011653	0.566595	0.607345	0.040750	0.068906	0.019705
Arabie_1	0.534052	0.011601	0.516160	0.552628	0.036468	0.068284	0.021723
Arabie_2	0.524151	0.011806	0.502210	0.547395	0.045185	0.086206	0.022525
Arabie_3	0.481280	0.007639	0.455830	0.495443	0.039612	0.082307	0.015873
Soudan_1	0.547788	0.010981	0.530145	0.566255	0.036110	0.065920	0.020046
Niger_1	0.600347	0.014086	0.580135	0.622378	0.042243	0.070364	0.023464
Niger_2	0.505566	0.011115	0.489397	0.522282	0.032885	0.065046	0.021985

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Niger_3	0.498696	0.012254	0.479982	0.517415	0.037432	0.075061	0.024573
Egypte_1	0.592817	0.012607	0.574260	0.629460	0.055200	0.093115	0.021266
Libye_1	0.618994	0.013590	0.597720	0.636805	0.039085	0.063143	0.021955
Libye_2	0.607610	0.012905	0.588503	0.626422	0.037920	0.062408	0.021239
Libye_3	0.554490	0.009939	0.536663	0.569163	0.032500	0.058612	0.017925
Libye_4	0.594381	0.015937	0.573342	0.635485	0.062142	0.104550	0.026813
Mali_1	0.595233	0.017553	0.558260	0.620672	0.062412	0.104854	0.029489
Mauritanie_1	0.582693	0.012102	0.564905	0.606032	0.041127	0.070582	0.020769
Mauritanie_2	0.555508	0.010576	0.534162	0.573425	0.039262	0.070679	0.019038

4.3.6.2 Results

The classification of the sites based on the level of the albedo is reported in Table 92.

Table 92: Classification of the sites based on the level of WSA in B1 and B2 MODIS channels

rank	Site name	B1		Site name	B2
1	Libye_1	0.519901		Libye_1	0.618994
2	Libye_2	0.511761		Libye_2	0.607610
3	Mali_1	0.510279		Niger_1	0.600347
4	Niger_1	0.507275		Mali_1	0.595233
5	Libye_4	0.492420		Libye_4	0.594381
6	Egypte_1	0.490093		Egypte_1	0.592817
7	Mauritanie_1	0.484525		Algerie_5	0.591384
8	Algerie_5	0.481008		Mauritanie_1	0.582693
9	Libye_3	0.463735		Algerie_4	0.565823
10	Algerie_4	0.459416		Mauritanie_2	0.555508
11	Soudan_1	0.456367		Libye_3	0.554490
12	Mauritanie_2	0.454729		Algerie_3	0.552149
13	Algerie_2	0.454119		Soudan_1	0.547788
14	Algerie_3	0.448459		Algerie_2	0.545732
15	Arabie_2	0.441816		Arabie_1	0.534052
16	Arabie_1	0.439050		Arabie_2	0.524151
17	Niger_2	0.421648		Niger_2	0.505566
18	Niger_3	0.412081		Algerie_1	0.499790
19	Algerie_1	0.409224		Niger_3	0.498696
20	Arabie_3	0.390616		Arabie_3	0.481280

4.3.7 Spectral variability

4.3.7.1 Over LNES

The reflectance spectrum for all sites and all dates is represented in Figure 105 and Figure 106 for each site. The same spectral variability is observed and is typical of soil reflectance spectrum, only the level differs. .

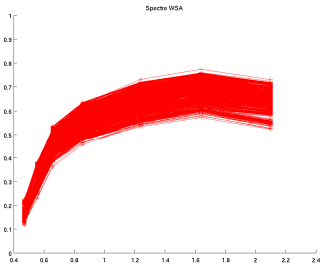


Figure 105: Spectral variability of WSA for the LNES for all sites and all dates.

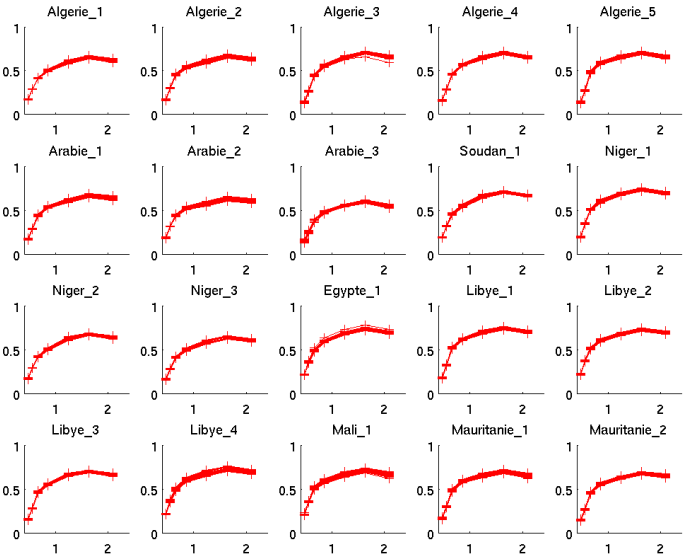


Figure 106: Spectral variability for LNES

The slope variability (B1/B2) is represented on the next figure. This ratio is constant with time, expressing the invariance of the surface properties for these sites.

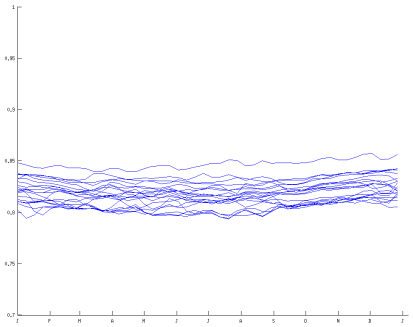


Figure 107: Slope variability (B1/B2)

4.3.7.2 Over LNES others

The spectra of reflectances are represented for 5 dates (2007/01/01, 2007/03/30, 2007/06/26, 2007/09/22, 2007/12/19) for all sites in Figure 108. The spectral variability is different for sites located over ice (Dome C sites, Greenland), Sites located over salaar (Uyuni and arizaro), and deserts.

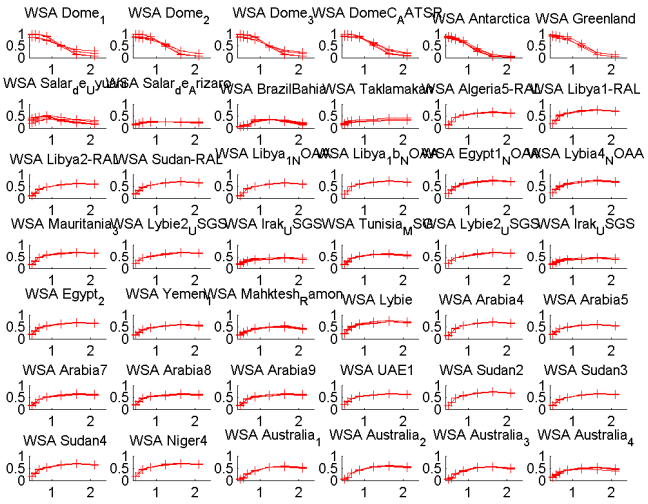


Figure 108: Spectral variability for LNES

4.3.7.3 Over LNES china

The spectra of reflectances are represented for 5 dates (2007/01/01, 2007/03/30, 2007/06/26, 2007/09/22, 2007/12/19) for all sites in Figure 109. The spectral variability is very similar for all sites. Snow impact in winter can be observed for some sites (China_35 for instance), with an albedo in short wavelength which is high.

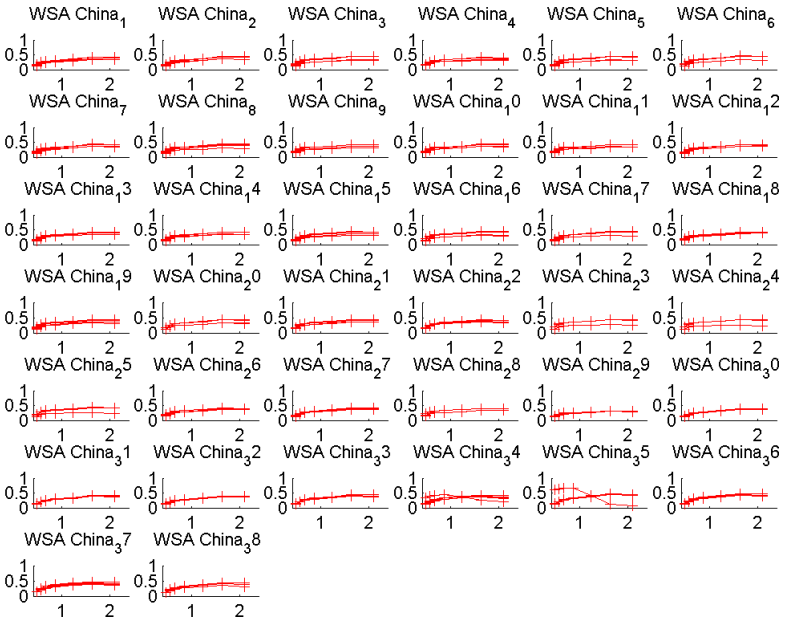


Figure 109: Spectral variability for LNES

4.3.7.4 Over CEOS LES

The spectral variability in this case is interested for the largest sites (RRVP and Tuz Gulu). For RRVP, the site is covered by snow in winter. The spectrum has high value in the shortwave and lower value in the short infrared. For the others period, a spectrum typical for a salt surface is observed.

For Tuz Gulu, a decreasing of the shortwave signal is observed in winter, whereas the site is bright in summer. The decrease is probably due to the flood lake.

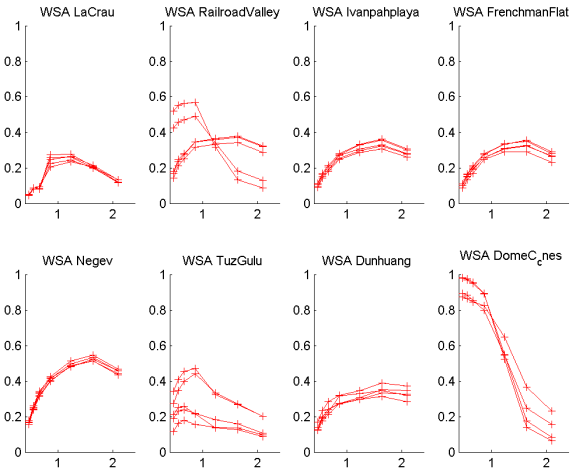


Figure 110: Spectral variability for LNES

4.3.7.5 Over LES Non CEOS

Impact of snow is observed for Chinese sites, and site located in mountains (Lunar lake), or Great Plains of USA (Brookings). Desert site have no temporal variability.

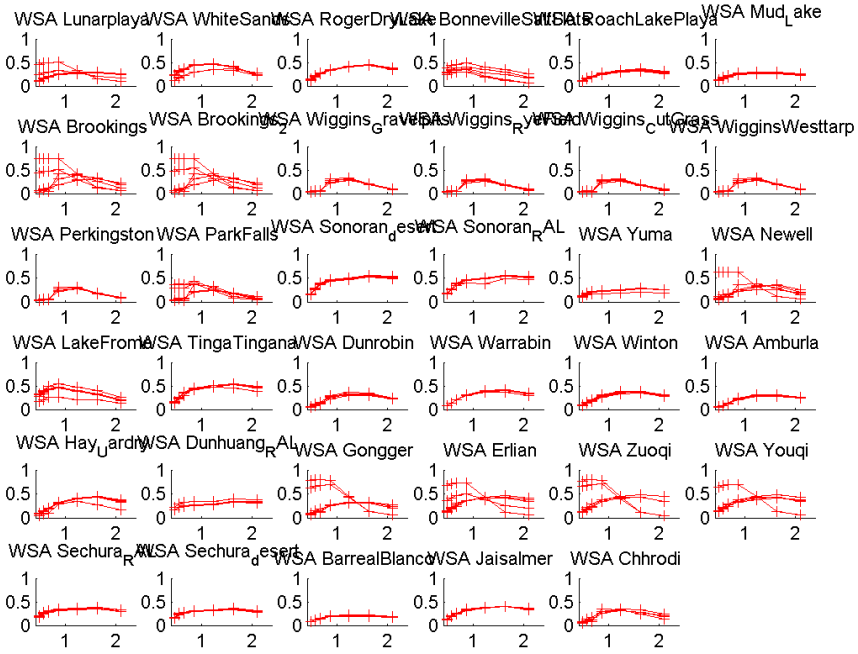


Figure 111: spectral variability for LNES

4.3.8 Vegetation indices (NDVI)

Vegetation indices variability could be an indicator of site variability (if vegetation or crops are developed). The NDVI is computed from B1 and B2 channels (NDVI=(B2-B1)/(B1+B2))

4.3.8.1 Temporal variability over LNES

As expected, no variation is observed in the NDVI for all sites.

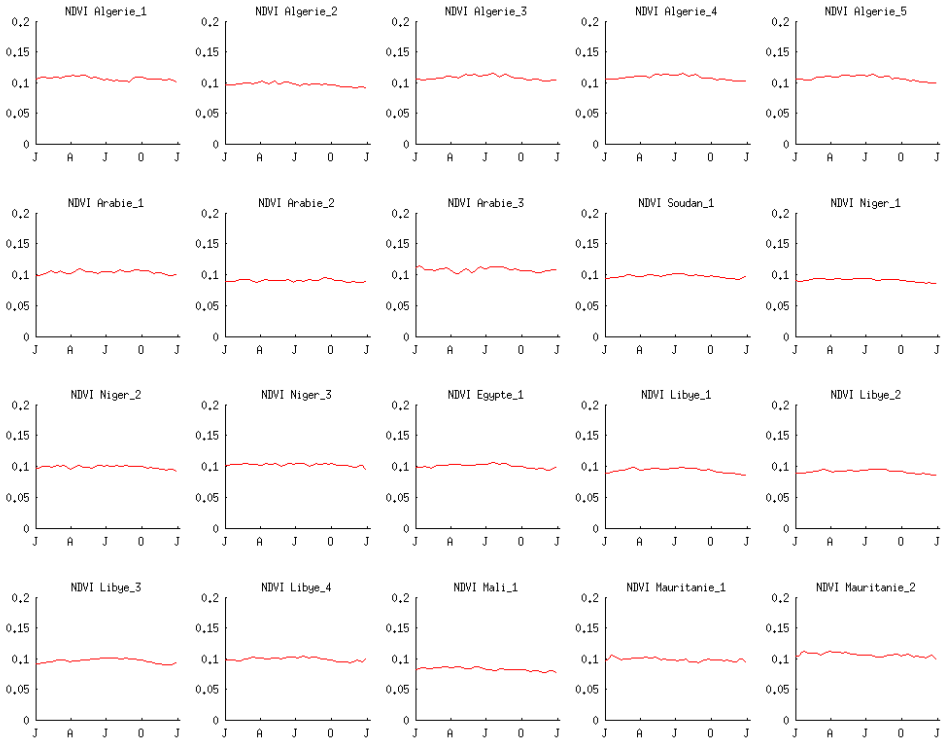


Figure 112: Variability of NDVI

4.4 Magnitude of directional effects

The surface of the site should be horizontal and have nearly Lambertian reflectance to minimize uncertainties due to differences in solar illumination and observation geometries. It should also be flat to minimize slope-aspect effects.

Table 93: Criterion for site anisotropy

Retained criteria	Studied parameters	Site type
Anisotropy	▪ Ratio Black albedo/White Albedo	▪ LES ▪ LNES

The ratio BSA/WSA is computed from MODIS data.

4.4.1 Analysis

4.4.1.1 Temporal variability over LNES

The ratio BSA/WSA is computed for all sites and all dates. Figure 113 represents these variations for all the channels. The ratio can be greater of lower than 1 depending on the spectral band. In general, variations are lower than 5%, except in the blue channel (B3) where it can reach 8 %. The ratio is stable in B1 and B2. The temporal variability can be due to a residual variation in solar zenith angle.

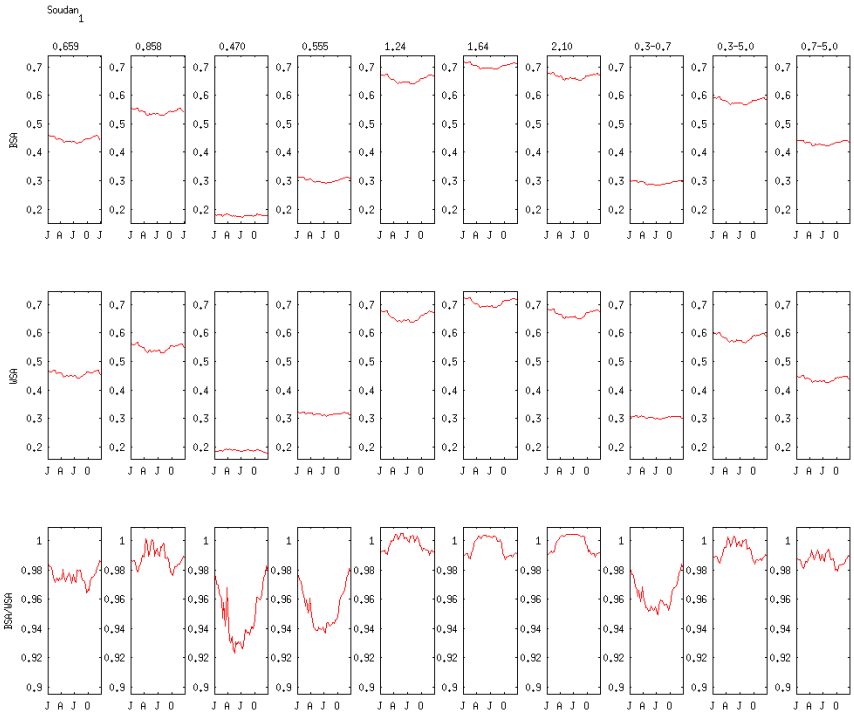


Figure 113: BSA (first line), WSA (middle line), and ratio BSA/WSA (Third line) for Soudan_1 site. Spectral band is indicated at the top of the first line of plot.

Table 94 and Table 95 report the statistics for the ratio BSA/WSA for B1 and B2 channels. The ratio is close to 1, and ranges from 0;96 to 0.97 for B1 and 0.97 to 0.98 for B2. No classification is made because results are close together.

Table 94: Statistics for BSA/WSA B1 products

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Algerie_1	0.964701	0.009788	0.949364	0.982641	0.033277	0.034495	0.010146
Algerie_2	0.964298	0.012208	0.943977	0.987856	0.043879	0.045503	0.012660
Algerie_3	0.969162	0.016145	0.946677	0.998989	0.052312	0.053977	0.016658
Algerie_4	0.968526	0.015776	0.946984	0.998592	0.051608	0.053285	0.016289
Algerie_5	0.970018	0.016552	0.948270	1.001450	0.053179	0.054823	0.017064
Arabie_1	0.963962	0.008238	0.947306	0.975810	0.028504	0.029569	0.008546
Arabie_2	0.964689	0.007622	0.943622	0.978949	0.035327	0.036620	0.007901
Arabie_3	0.962449	0.017155	0.937520	0.992703	0.055182	0.057335	0.017824

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Soudan_1	0.975996	0.004972	0.964652	0.986613	0.021961	0.022501	0.005094
Niger_1	0.970178	0.008021	0.955245	0.987293	0.032047	0.033032	0.008268
Niger_2	0.968027	0.006808	0.955506	0.981051	0.025545	0.026389	0.007033
Niger_3	0.963748	0.008675	0.948953	0.978322	0.029369	0.030474	0.009001
Egypte_1	0.973625	0.008746	0.962514	0.990272	0.027758	0.028510	0.008983
Libye_1	0.973266	0.007573	0.961877	0.985682	0.023805	0.024459	0.007781
Libye_2	0.972966	0.008138	0.958925	0.987678	0.028753	0.029551	0.008364
Libye_3	0.967100	0.009020	0.954046	0.984422	0.030377	0.031410	0.009327
Libye_4	0.972593	0.009865	0.960576	0.992401	0.031825	0.032721	0.010143
Mali_1	0.975649	0.005911	0.964541	0.988007	0.023466	0.024052	0.006059
Mauritanie_1	0.969316	0.011365	0.918339	0.987698	0.069359	0.071554	0.011725
Mauritanie_2	0.966291	0.008527	0.951961	0.986180	0.034220	0.035413	0.008825

Table 95: Statistics for BSA/WSA for B2 products

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Algerie_1	0.978573	0.007872	0.964014	0.997993	0.033979	0.034723	0.008044
Algerie_2	0.974221	0.010056	0.956736	0.991119	0.034383	0.035293	0.010322
Algerie_3	0.977620	0.010858	0.963481	0.999052	0.035572	0.036386	0.011107
Algerie_4	0.977541	0.010433	0.961240	0.998560	0.037320	0.038178	0.010673
Algerie_5	0.978335	0.011683	0.960112	1.001213	0.041100	0.042011	0.011942
Arabie_1	0.976531	0.006891	0.958635	0.990299	0.031665	0.032426	0.007057
Arabie_2	0.974674	0.006172	0.961461	0.988837	0.027376	0.028087	0.006333
Arabie_3	0.969993	0.012566	0.951361	0.993093	0.041732	0.043023	0.012955
Soudan_1	0.988626	0.006474	0.976539	1.001465	0.024926	0.025213	0.006549
Niger_1	0.984326	0.009040	0.968709	1.002170	0.033461	0.033994	0.009184
Niger_2	0.984178	0.007796	0.971573	1.000963	0.029390	0.029862	0.007922
Niger_3	0.978485	0.008390	0.964302	0.995951	0.031649	0.032345	0.008574
Egypte_1	0.984727	0.005055	0.974366	0.993870	0.019504	0.019806	0.005133
Libye_1	0.986379	0.006744	0.975727	0.999420	0.023693	0.024020	0.006837
Libye_2	0.984609	0.006175	0.972814	1.000091	0.027277	0.027703	0.006272
Libye_3	0.980991	0.005653	0.970810	0.993830	0.023020	0.023466	0.005763
Libye_4	0.982657	0.005160	0.969914	0.992647	0.022733	0.023134	0.005251
Mali_1	0.987646	0.007839	0.974427	1.002437	0.028010	0.028360	0.007937
Mauritanie_1	0.981926	0.011773	0.924347	1.000488	0.076141	0.077542	0.011990
Mauritanie_2	0.978963	0.007415	0.967478	1.000063	0.032585	0.033285	0.007575

4.5 Spatial uniformity

The site should have high spatial uniformity, relative to the pixel size, to minimize the effects of scaling radiometric data to the size of the entire test site. This is especially important for cross-calibration between instruments because it minimizes the effects of misregistration. The site should also be centred in an area large enough to accommodate the sampling of a large number of pixels and to minimize atmospheric adjacency effects due to light scattered from outside the target region (Teillet et al., 2007, RD.21).

Bannari et al., 2005 (RD.22), analysed two indicators to study the radiometric spatial uniformity and temporal stability of the Lunar Lake Playa calibration site. The computed the spatial autocorrelation coefficient and the coefficient of variation expressed by the ratio of the standard deviation over the average. This is illustrated in the site description.

Cosnefroy et al., 1993 (RD.25) investigated the potential of desert sites for the calibration of space instruments, 20 desertic zones have been selected in Saharian North Africa and Saoudi Arabia, using a criterion of spatial uniformity in a multitemporal series of cloud-free METEOSAT-4 visible images, and it has been verified that the temporal stability of these sites at hourly and seasonal time scales has a satisfactory level. Sites are characterised by less than 3 % of relative spatial uniformity. The coefficient of variation $\sigma(\rho)/\rho$ has been used

A threshold of 3% is set to declare the spatial uniformity of a site.

Table 96: Criterion for site spatial uniformity

Retained criteria	Studied parameters	Site type
Size	▪ Size, surface	▪ LES ▪ LNES
Spatial uniformity	▪ Variation of surface reflectance on the site (coefficient of variation) ▪ Low Horizontal Gradients	

LNES site size is 1 x 1 degrees.

4.5.1 Analysis

4.5.1.1 Variability of the albedo inside the site

Figure 114 represents the variability of the BSA, WSA, and anisotropy factor (BSA/WSA) for one site (soudan_1 for the period December, 27, 2007). The variability is low. The coefficient of variation for all sites has been computed and is reported in Table 99. The Cv is lower than 3%, meaning that the sites are spatially uniform.

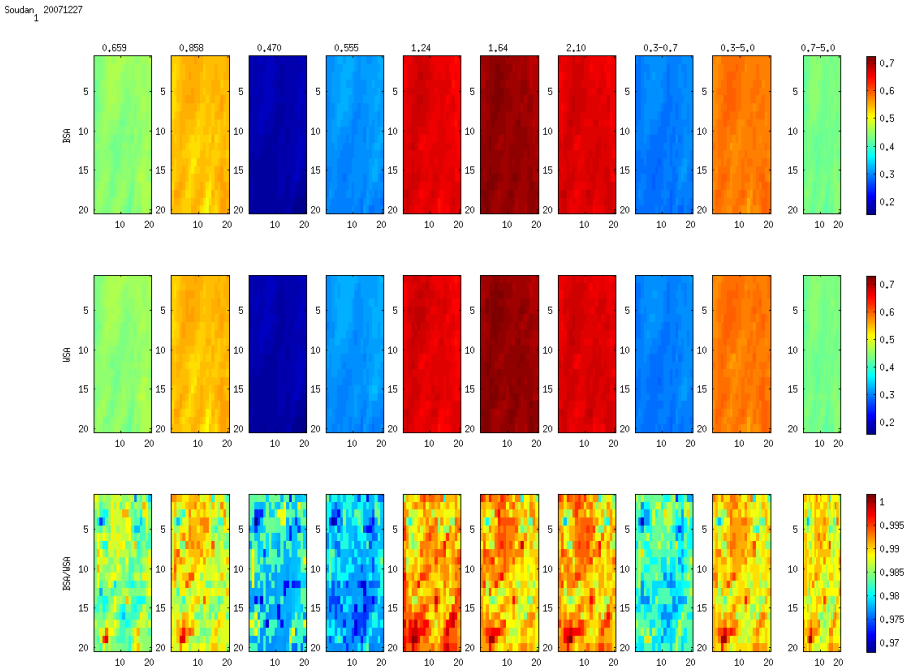


Figure 114: Spatial variability of BSA, WSA and BSA/WSA ratio for one site, all wavelengths

Table 97: Coefficient of variation for B1 and B2 channels

Site name	B1	B2
Algerie_1	0.011817	0.019172
Algerie_2	0.017971	0.022267
Algerie_3	0.021199	0.020031
Algerie_4	0.017319	0.017441
Algerie_5	0.020188	0.019705
Arabie_1	0.018670	0.021723
Arabie_2	0.018222	0.022525
Arabie_3	0.018577	0.015873
Soudan_1	0.018589	0.020046
Niger_1	0.020539	0.023464
Niger_2	0.016242	0.021985
Niger_3	0.019385	0.024573
Egypte_1	0.020084	0.021266
Libye_1	0.020139	0.021955
Libye_2	0.019511	0.021239
Libye_3	0.016978	0.017925
Libye_4	0.024163	0.026813
Mali_1	0.026790	0.029489
Mauritanie_1	0.018649	0.020769
Mauritanie_2	0.016046	0.019038

5. ANALYSIS OF SEA SITE

5.1 Characterisation of water mass type

The minimum is to classify the type of water between class 1 and class 2. With class 1, for method such as the Rayleigh method, you need oligotrophic or mesotrophic waters. The bathymetry is a required information as well as the type of sea bottom surface. It is the case for SES on platform for which it is required to know the possible contribution from the sea bottom.

The hydrodynamic is an issue during match-ups if you want to relate non simultaneous measurements.

Table 98: Criterion for site characterisation

Retained criteria	Studied parameters	Site type
Water class	▪ Characterize Physical, Biological, & Optical ▪ Depth ▪ Hydrodynamic	▪ SES ▪ SNES

The apparent optical properties of the water in the satellite geometrical conditions are the key parameter. For case 1 water, the second order parameter (BRDF) is computed from the chlorophyll content estimates from the optical measurements or from the analysis of water samples.

- Deep water mask: where water depth is greater than 1000m.
- Shallow water mask: where water depth is between 30m and 1000m.

All sites are deep water.

5.2 Analysis of temporal variability of variables characterising the site

The surface properties of the site (reflectance, BRDF, spectral) should be temporally invariant. Otherwise, adequate accuracy would be obtained only if these properties were measured for every calibration. This implies that the site is oligotrophic, poor in phytoplankton.

Table 99: Criterion for invariance of site properties

Retained criteria	Studied parameters	Site type
Oligotrophic Waters -Stable Target	▪ Chlorophyll concentration and variability ▪ Surface reflectance ▪ Turbidity	▪ SES ▪ SNES

A eutrophication scale (Table 100) has been defined by Karydis et al., 1995, RD.34, for the categorisation of the chlorophyll a concentrations to four eutrophication levels: oligotrophic, lower-mesotrophic, upper mesotrophic and eutrophic.

Table 100: Eutrophication scale for chlorophyll a concentrations

Chlorophyll a (mg m^{-3})	Eutrophication Level
0.000 – 0.084	Oligotrophic
0.084 – 0.359	Lower-mesotrophic
0.359 – 0.793	Upper-mesotrophic
> 0.793	Eutrophic

5.2.1 Dataset description

5.2.1.1 Dataset identification

MERIS Level 3 products

5.2.1.2 Spatial Characteristics

5.2.1.2.1 Spatial Coverage

Coverage of the data sets is global over ocean.

5.2.1.2.2 Spatial Coverage Map

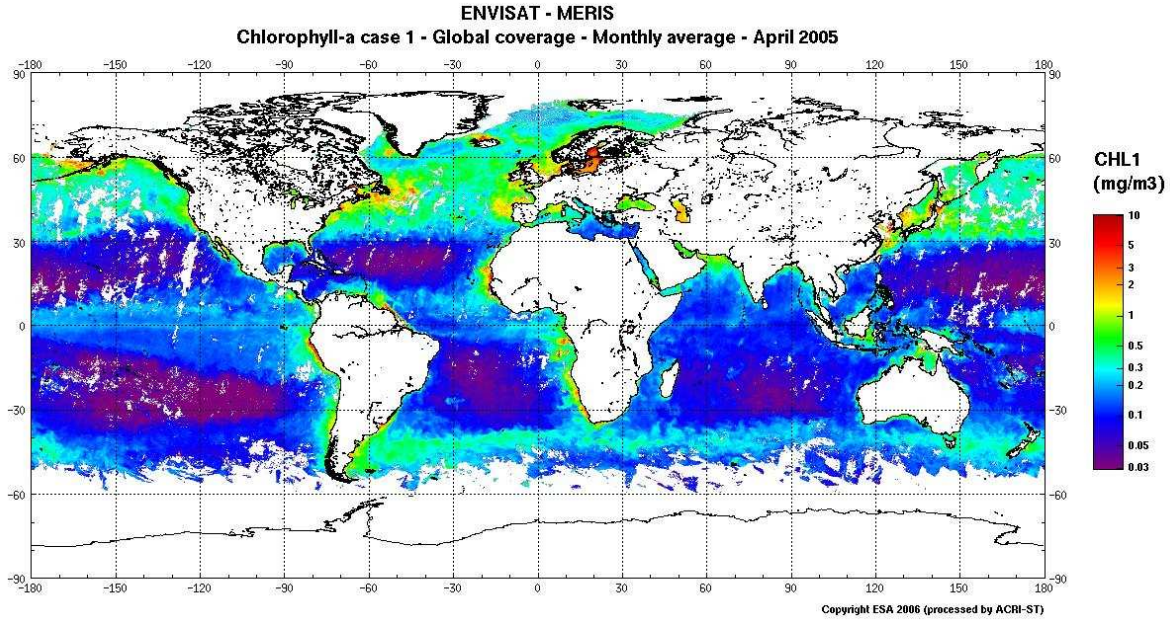


Figure 115: Spatial coverage map of MERIS level 3

5.2.1.2.3 Spatial Resolution

The MERIS level-3 binned data are specified on a global sinusoidal grid (ISIN), with a spatial resolution of 1/12°(roughly 9.277 km) i.e. 4320 bi ns at the equator.

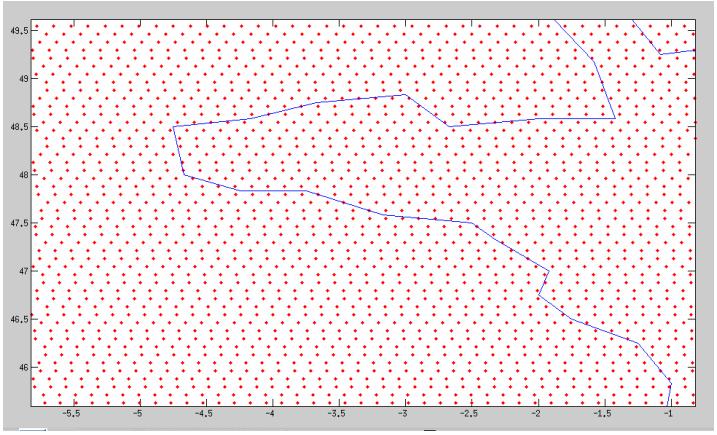


Figure 116: Grid extract over Britain

5.2.1.3 Projection

This grid is the sinusoidal equal-area grid on which the MERIS level 2 products are spatially binned (ISIN grid). The average size of the grid bins is equal to 1/12°, leading to 2160 rows in latitude, i.e. 1080 latitude rows in each hemisphere (the equatorial line is located between two rows of bins). This discretisation corresponds to roughly 9.277 km. Just below and above the equatorial line, the rows have 4320 bins. This number decreases regularly from the equator to the poles where the last latitude rows have only 3 bins.

For each row, the left side of the first bin is always aligned with longitude -180° while the right side of the last bin is aligned with longitude +180°, covering all the latitude row area. The number of bins per row is always an integer number, computed in order to have the bin cell size as close as possible to 9.277 km, so that the effective longitudinal bin size may vary from one row to the next one.

Applying these simple rules from South to North Pole leads to a total of 5,940,422 bins.

5.2.1.4 Temporal Characteristics

5.2.1.4.1 Temporal Coverage

Data sets cover January 2007 to December 2007.

5.2.1.4.2 Temporal Resolution

The Level 3 Monthly data set is available at a resolution of one month.

5.2.1.5 Data Characteristics

5.2.1.5.1 Parameter/Variable

Product analysed are:

- Chlorophyll Concentration for the open ocean (case I): Chlorophyll concentration is a very convenient measure of abundance of phytoplankton biomass, which has an important role in fixing CO2 through photosynthesis.
- Water leaving radiances at 412, 443, 490, 510 and 560 nm.

5.2.1.5.2 Variable Description/Definition

- CHL1 is the chlorophyll-a concentration for case 1 water. Case 1 waters are defined as waters for which phytoplankton and their associated materials (such as debris, heterotrophic organisms and bacteria, excreted organic matter) control the optical properties (Morel and Prieur, 1977; Gordon and Morel 1983).
- The normalized water-leaving radiance, [Lw]N, was defined by Gordon and Clark [1981] through:

$$L_w(\lambda) = [L_w(\lambda)]_N \cdot \cos(\theta_S) \cdot t_d(\theta_S, \lambda)$$

where Lw(λ) is the radiance backscattered out of the water at a wavelength λ, and t_d the diffuse transmittance of the atmosphere. θ_S is the solar zenith angle.

5.2.1.5.3 Unit of Measurement

Chlorophyll-a concentration is expressed in mg/m3.

Normalised radiance is expressed in mW/cm2/µm/sr.

5.2.1.5.4 Data Source

The MERIS level-3 binned data products consist of the accumulation of MERIS level-2 data (MER_RR_2P) corresponding to a month.

5.2.1.5.5 Data Range

Chlorophyll content varies from 0 to 10 mg/m^3.

Normalised radiance varies from 0 to 5 mW/cm^2/µm/sr.

5.2.1.6 Sample Data Record

Dataset format is HDF or netcdf. The specifications are provided at: http://envisat.esa.int/level3/meris/docs/mkl3_product_handbook_is1r0.pdf and described in RD.31.

The MERIS level-3 products are available at http://www.enviport.org/meris or at http://envisat.esa.int/level3/meris/

5.2.2 Variability of Chlorophyll concentration

5.2.2.1 Variability at global scale

The global variations of the monthly mean chlorophyll a concentration are represented in Figure 117.

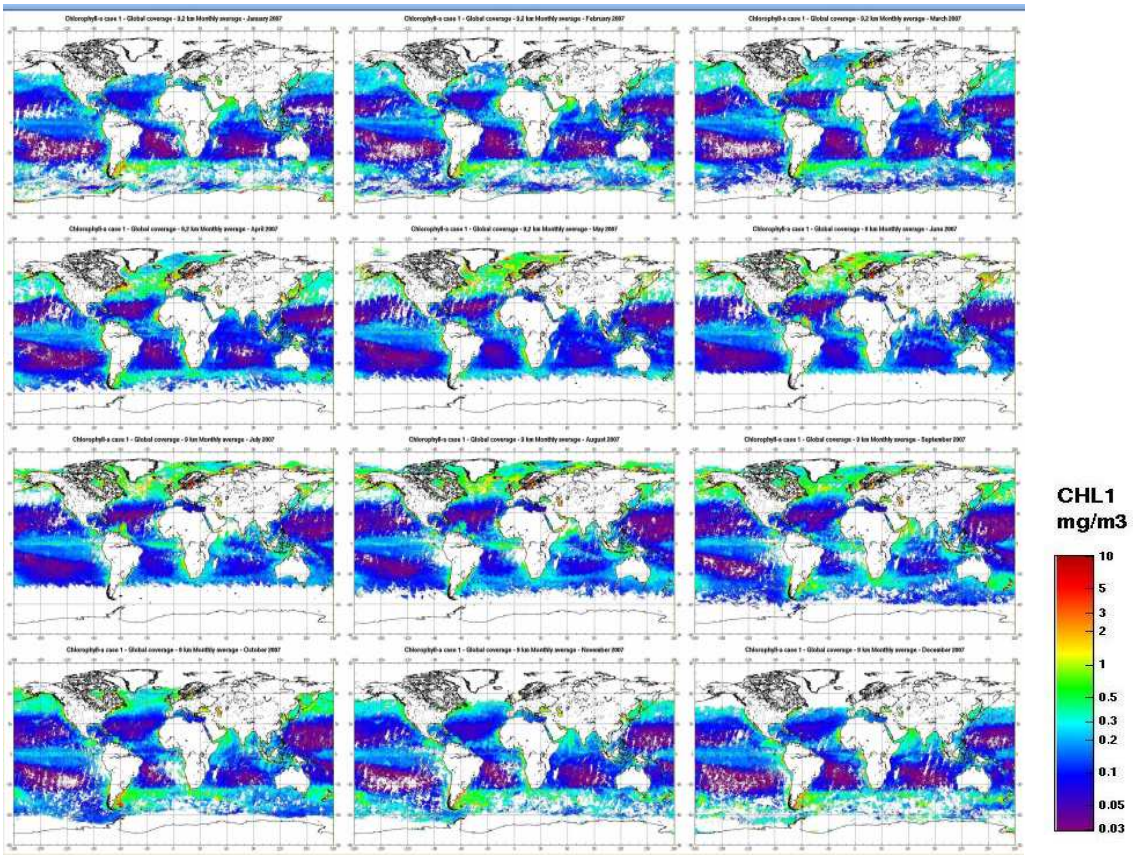


Figure 117: Monthly mean of chlorophyll a (MERIS L3). Units ($mg.m^{-3}$)

5.2.2.2 Temporal variability over SNES

The temporal variability of all SNES is represented on Figure 118. Most of sites are contained in one envelop around 0.1 $mg.m^{-3}$, except a few sites for which the mean level is higher or sites with a pronounced seasonal cycle.

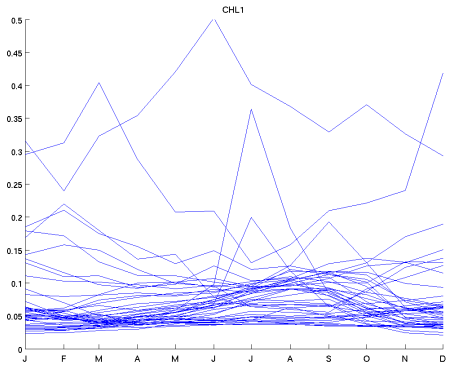


Figure 118: Superimposed temporal profiles of chlorophyll content for the SNES.

Figure 119 provides the seasonal variations of chlorophyll–a content site by site. The two sites that have the highest chlorophyll content are the Gulf Alaska and the Australian site. The maximum of chlorophyll content is around 0.5 $mg.m^{-3}$, reached in summer for Alaska site (North hemisphere) and winter in south hemisphere. The AtlN-0 site has a peak of chlorophyll content in summer, around 0.35 $mg.m^{-3}$. The other sites have a seasonal cycle less marked.

Figure 119: Temporal variability of chlorophyll content for the SNES. X axis scale is one year, from January to December. Y axis scale is 0.5.

The distribution of the chlorophyll-a content is represented on the following histograms (Figure 120) for each site.

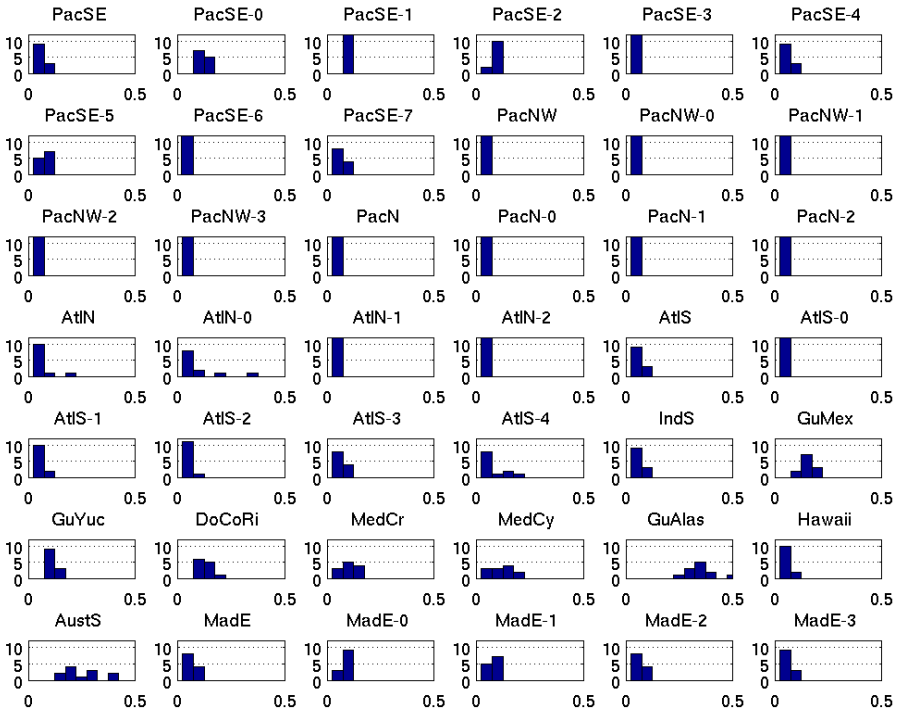


Figure 120: Histogram of the monthly mean chlorophyll content for the SNES.

Table 101 provides the standard statistics for all sites. The minimum of site variable is highlighted in bold blue; the maximum is highlighted in bold red.

Table 101: Statistics for monthly mean of chlorophyll a data

Site name	Annual Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
PacSE	0.0670	0.0121	0.0512	0.0907	0.0396	0.5903	0.1809
PacSE-0	0.1160	0.0146	0.0934	0.1374	0.0440	0.3796	0.1258
PacSE-1	0.1017	0.0089	0.0911	0.1167	0.0256	0.2516	0.0879
PacSE-2	0.0869	0.0136	0.0640	0.1132	0.0491	0.5657	0.1572
PacSE-3	0.0451	0.0172	0.0250	0.0712	0.0462	1.0251	0.3809
PacSE-4	0.0668	0.0238	0.0366	0.1087	0.0721	1.0795	0.3564
PacSE-5	0.0838	0.0232	0.0546	0.1179	0.0633	0.7552	0.2763
PacSE-6	0.0364	0.0134	**0.0208**	0.0568	0.0361	0.9915	0.3691
PacSE-7	0.0618	0.0312	0.0270	0.1165	0.0895	1.4484	0.5049
PacNW	0.0397	0.0040	0.0352	0.0486	0.0134	0.3381	0.1013
PacNW-0	0.0392	0.0048	0.0322	0.0473	0.0152	0.3863	0.1229
PacNW-1	**0.0357**	0.0031	0.0321	**0.0438**	**0.0116**	0.3264	**0.0865**
PacNW-2	0.0449	0.0057	0.0373	0.0556	0.0182	0.4058	0.1258
PacNW-3	0.0426	0.0061	0.0346	0.0512	0.0166	0.3906	0.1433
PacN	0.0508	0.0075	0.0401	0.0633	0.0232	0.4564	0.1478
PacN-0	0.0467	0.0077	0.0361	0.0632	0.0271	0.5808	0.1653
PacN-1	0.0477	0.0061	0.0385	0.0578	0.0193	0.4055	0.1277
PacN-2	0.0550	0.0081	0.0440	0.0710	0.0270	0.4906	0.1476
AtlN	0.0726	0.0448	0.0411	0.1994	0.1583	2.1794	0.6163
AtlN-0	0.0976	0.0922	0.0426	0.3639	**0.3213**	3.2933	**0.9448**
AtlN-1	0.0494	0.0091	0.0398	0.0634	0.0236	0.4771	0.1839
AtlN-2	0.0462	0.0122	0.0359	0.0723	0.0365	0.7906	0.2639
AtlS	0.0548	0.0219	0.0340	0.0915	0.0576	1.0507	0.3997
AtlS-0	0.0448	0.0156	0.0298	0.0674	0.0377	0.8401	0.3483
AtlS-1	0.0490	0.0230	0.0280	0.0902	0.0623	1.2703	0.4695
AtlS-2	0.0512	0.0174	0.0331	0.0754	0.0423	0.8262	0.3395
AtlS-3	0.0706	0.0285	0.0445	0.1201	0.0755	1.0690	0.4034
AtlS-4	0.0791	0.0484	0.0375	0.1930	0.1555	1.9656	0.6114
IndS	0.0564	0.0234	0.0315	0.1029	0.0714	1.2662	0.4154
GuMex	0.1545	0.0313	0.1141	0.2102	0.0961	0.6218	0.2025
GuYuc	0.1087	0.0161	0.0920	0.1366	0.0447	0.4111	0.1479
DoCoRi	0.1257	0.0285	0.0938	0.1791	0.0854	0.6790	0.2267
MedCr	0.1091	0.0343	0.0638	0.1581	0.0943	0.8645	0.3148
MedCy	0.1192	0.0526	0.0558	0.2202	0.1644	1.3787	0.4415

Site name	Annual Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
GuAlas	**0.3536**	0.0672	**0.2398**	**0.5021**	0.2623	0.7417	0.1900
Hawaii	0.0682	0.0107	0.0499	0.0915	0.0416	0.6098	0.1567
AustS	0.2579	0.0892	0.1306	0.4185	**0.2879**	1.1163	0.3458
MadE	0.0678	0.0185	0.0445	0.0976	0.0531	0.7843	0.2730
MadE-0	0.0864	0.0178	0.0573	0.1098	0.0525	0.6072	0.2065
MadE-1	0.0761	0.0181	0.0497	0.1049	0.0552	0.7250	0.2376
MadE-2	0.0647	0.0178	0.0441	0.0912	0.0471	0.7277	0.2754
MadE-3	0.0556	0.0206	0.0336	0.0911	0.0575	1.0346	0.3715

5.2.2.3 Results

The classification is based on the mean value of chlorophyll -a content.

Table 102: Site classification based on the mean of CHL1

Rank	Site name	Mean		Rank	Site name	Mean
1	PacNW-1	0.0357		22	PacSE-4	0.0668
2	PacSE-6	0.0364		23	PacSE	0.0670
3	PacNW-0	0.0392		24	MadE	0.0678
4	PacNW	0.0397		25	Hawaii	0.0682
5	PacNW-3	0.0426		26	AtlS-3	0.0706
6	AtlS-0	0.0448		27	AtlN	0.0726
7	PacNW-2	0.0449		28	MadE-1	0.0761
8	PacSE-3	0.0451		29	AtlS-4	0.0791
9	AtlN-2	0.0462		30	PacSE-5	0.0838
10	PacN-0	0.0467		31	MadE-0	0.0864
11	PacN-1	0.0477		32	PacSE-2	0.0869
12	AtlS-1	0.0490		33	AtlN-0	0.0976
13	AtlN-1	0.0494		34	PacSE-1	0.1017
14	PacN	0.0508		35	GuYuc	0.1087
15	AtlS-2	0.0512		36	MedCr	0.1091
16	AtlS	0.0548		37	PacSE-0	0.1160
17	PacN-2	0.0550		38	MedCy	0.1192
18	MadE-3	0.0556		39	DoCoRi	0.1257
19	IndS	0.0564		40	GuMex	0.1545
20	PacSE-7	0.0618		41	AustS	0.2579
21	MadE-2	0.0647		42	GuAlas	0.3536

5.2.3 Water leaving radiance or surface reflectance at 443 nm

5.2.3.1 Variability at global scale

The global variations of the water leaving radiance are represented in Figure 121. As expected, the areas with the highest level are the areas with the lowest chlorophyll content.

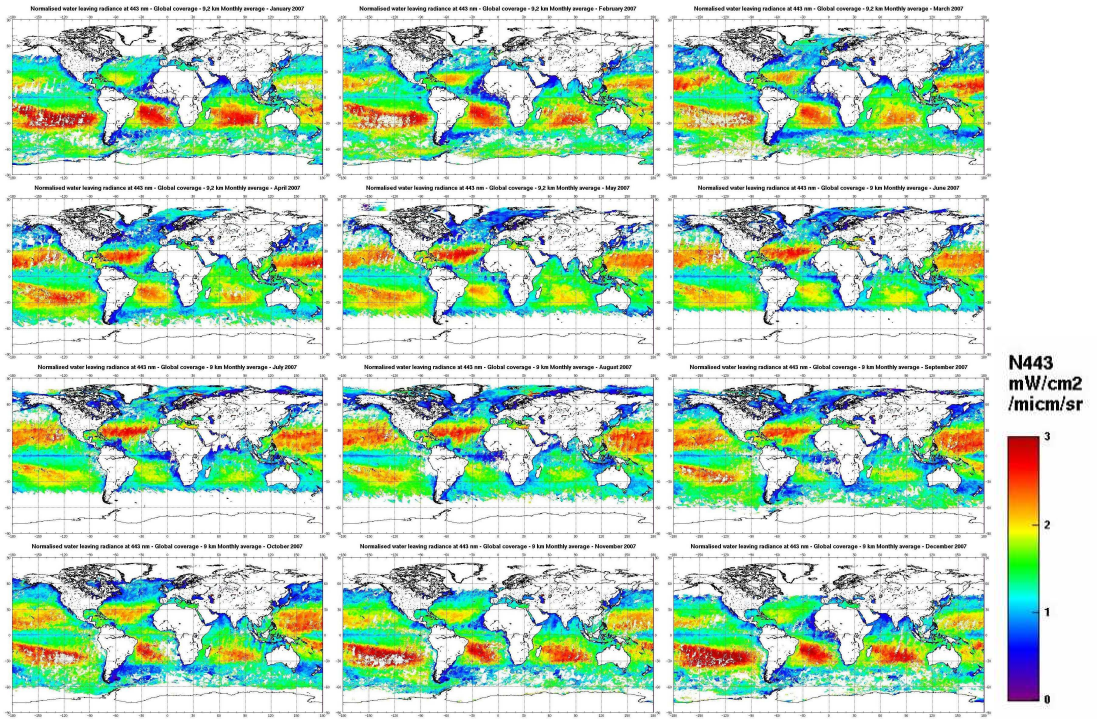


Figure 121: Monthly mean of water leaving radiance at 443 nm.

5.2.3.2 Temporal variability over SNES

5.2.3.2.1 Statistics

The temporal variability of all SNES is represented on Figure 122. Two types of profiles are superimposed: those which have a maximum in summer (located in North hemisphere) and those which have a maximum of water leaving radiances in winter (located in south hemisphere). Means varies from 1 to 3 $mW/cm^2/\mu m/sr$, with a difference between the minimum and the maximum which is around 1.

Figure 123 provides the seasonal variations of $L_w(443)_N$ site by site. The two sites that have the minimum of $L_w(443)_N$ are the Gulf Alaska and the Australian site.

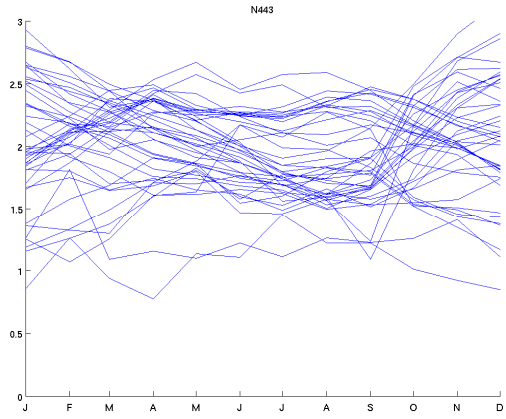


Figure 122: Superimposed temporal profiles of water leaving radiance at 443 nm for the SNES. Units: mW/cm^2/µm/sr.

Figure 123: Temporal variability of for the SNES. X axis scale is one year, from January to December. Y axis scale is 0-3. Units: mW/cm^2/µm/sr

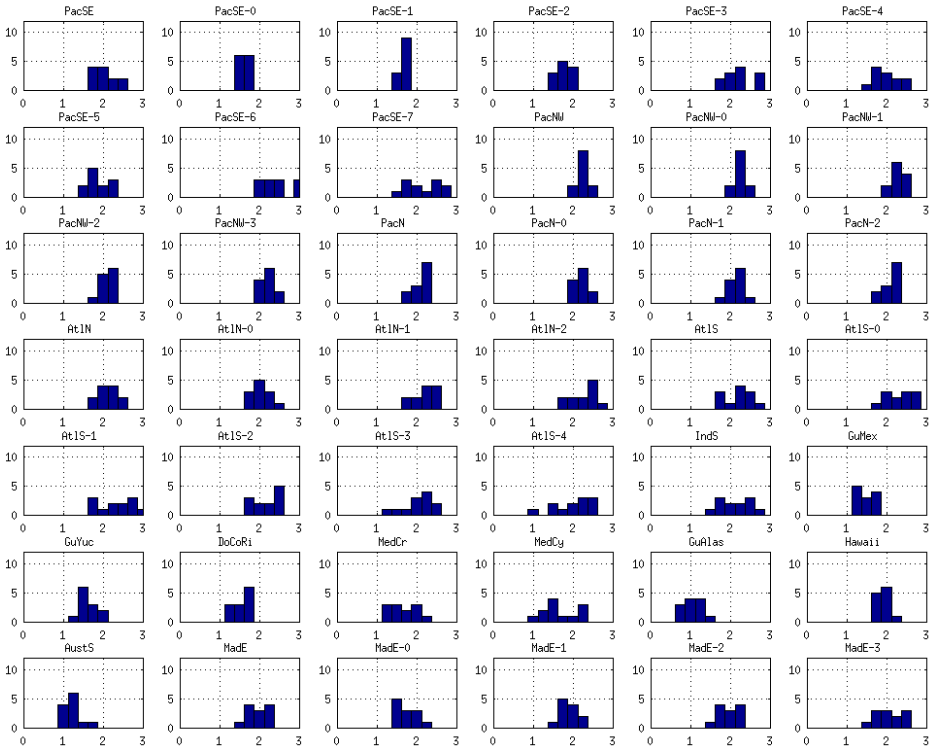


Figure 124: Histogram of the monthly mean L433N for the SNES.

Table 103 provides the standard statistics for all sites.

Table 103: Statistics for L443N products

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
PacSE	2.0595	0.2657	1.7553	2.5384	0.7831	0.3802	0.1290
PacSE-0	1.6212	0.1112	1.4600	1.8002	0.3402	0.2098	0.0686
PacSE-1	1.6913	0.1120	1.4870	1.8491	0.3621	0.2141	0.0662
PacSE-2	1.7725	0.2013	1.5146	2.1241	0.6094	0.3438	0.1136
PacSE-3	2.2142	0.3500	1.8003	2.8602	1.0600	0.4787	0.1581
PacSE-4	2.0098	0.3232	1.5988	2.5910	0.9923	0.4937	0.1608
PacSE-5	1.8895	0.2566	1.5340	2.2423	0.7083	0.3748	0.1358
PacSE-6	2.4109	0.4139	1.9072	3.1531	1.2459	0.5168	0.1717
PacSE-7	2.1547	0.4171	1.5875	2.7996	1.2121	0.5625	0.1936
PacNW	2.2360	0.1339	1.9720	2.4262	0.4542	0.2031	0.0599
PacNW-0	2.2467	0.1493	1.9770	2.4749	0.4979	0.2216	0.0664
PacNW-1	2.2936	0.1367	2.0757	2.4912	0.4155	0.1812	0.0596
PacNW-2	2.1457	0.1340	1.8681	2.3594	0.4913	0.2290	0.0624
PacNW-3	2.1982	0.1789	1.9239	2.4417	0.5178	0.2356	0.0814
PacN	2.1523	0.1835	1.8473	2.3682	0.5208	0.2420	0.0853
PacN-0	2.2202	0.1743	1.8988	2.4641	0.5653	0.2546	0.0785

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
PacN-1	2.1692	0.1779	1.8098	2.3788	0.5690	0.2623	0.0820
PacN-2	2.0854	0.2033	1.6886	2.2771	0.5885	0.2822	0.0975
AtlN	2.1337	0.1881	1.8195	2.4469	0.6274	0.2941	0.0882
AtlN-0	2.0181	0.2079	1.6856	2.4140	0.7284	0.3609	0.1030
AtlN-1	2.2223	0.2462	1.8150	2.5725	0.7575	0.3409	0.1108
AtlN-2	2.2812	0.3208	1.7023	2.6713	0.9690	0.4248	0.1406
AtlS	2.2158	0.3571	1.6700	2.6318	0.9618	0.4341	0.1612
AtlS-0	2.3044	0.3238	1.8469	2.7120	0.8651	0.3754	0.1405
AtlS-1	2.3102	0.4310	1.6854	2.9014	1.2160	0.5264	0.1866
AtlS-2	2.2051	0.2995	1.7698	2.5913	0.8215	0.3725	0.1358
AtlS-3	2.0435	0.3806	1.2354	2.5131	1.2777	0.6252	0.1862
AtlS-4	2.0329	0.4553	1.0892	2.5569	1.4677	0.7220	0.2239
IndS	2.1421	0.3454	1.6204	2.6727	1.0523	0.4913	0.1612
GuMex	1.5110	0.2459	1.1573	1.8291	0.6718	0.4446	0.1628
GuYuc	1.6450	0.1864	1.3749	1.9102	0.5353	0.3254	0.1133
DoCoRi	1.5775	0.2080	1.1869	1.8314	0.6445	0.4086	0.1318
MedCr	1.6609	0.3042	1.3005	2.1710	0.8705	0.5241	0.1832
MedCy	1.6646	0.4026	1.0712	2.2725	1.2013	0.7217	0.2418
GuAlas	1.0630	0.2036	0.7770	1.4508	0.6738	0.6339	0.1915
Hawaii	1.9542	0.1630	1.6554	2.1563	0.5009	0.2563	0.0834
AustS	1.2521	0.2008	1.0906	1.8166	0.7260	0.5798	0.1604
MadE	1.9620	0.2636	1.5715	2.3399	0.7684	0.3916	0.1344
MadE-0	1.7539	0.2037	1.4975	2.1312	0.6338	0.3613	0.1161
MadE-1	1.8593	0.2290	1.5050	2.2041	0.6991	0.3760	0.1232
MadE-2	1.9865	0.2690	1.6142	2.3449	0.7307	0.3678	0.1354
MadE-3	2.1061	0.3154	1.6201	2.5193	0.8991	0.4269	0.1498

5.2.3.2.2 Results

Table 104 provides the classification of the sites based on the mean of radiance, from highest to lowest radiance at 443 nm

Table 104: Rank based on the mean

Rank	Site name	Mean		Rank	Site name	Mean
1	PacSE-6	2.4109		22	PacSE	2.0595
2	AtlS-1	2.3102		23	AtlS-3	2.0435
3	AtlS-0	2.3044		24	AtlS-4	2.0329

Rank	Site name	Mean		Rank	Site name	Mean
4	PacNW-1	2.2936		25	AtlN-0	2.0181
5	AtlN-2	2.2812		26	PacSE-4	2.0098
6	PacNW-0	2.2467		27	MadE-2	1.9865
7	PacNW	2.2360		28	MadE	1.9620
8	AtlN-1	2.2223		29	Hawaii	1.9542
9	PacN-0	2.2202		30	PacSE-5	1.8895
10	AtlS	2.2158		31	MadE-1	1.8593
11	PacSE-3	2.2142		32	PacSE-2	1.7725
12	AtlS-2	2.2051		33	MadE-0	1.7539
13	PacNW-3	2.1982		34	PacSE-1	1.6913
14	PacN-1	2.1692		35	MedCy	1.6646
15	PacSE-7	2.1547		36	MedCr	1.6609
16	PacN	2.1523		37	GuYuc	1.6450
17	PacNW-2	2.1457		38	PacSE-0	1.6212
18	IndS	2.1421		39	DoCoRi	1.5775
19	AtlN	2.1337		40	GuMex	1.5110
20	MadE-3	2.1061		41	AustS	1.2521
21	PacN-2	2.0854		42	GuAlas	1.0630

5.2.4 Water leaving radiance or surface reflectance at 560 nm

5.2.4.1 Variability at global scale

The global variations of the water leaving radiance are represented in Figure 125. As expected, the areas with the highest level are the areas with the lowest chlorophyll content.

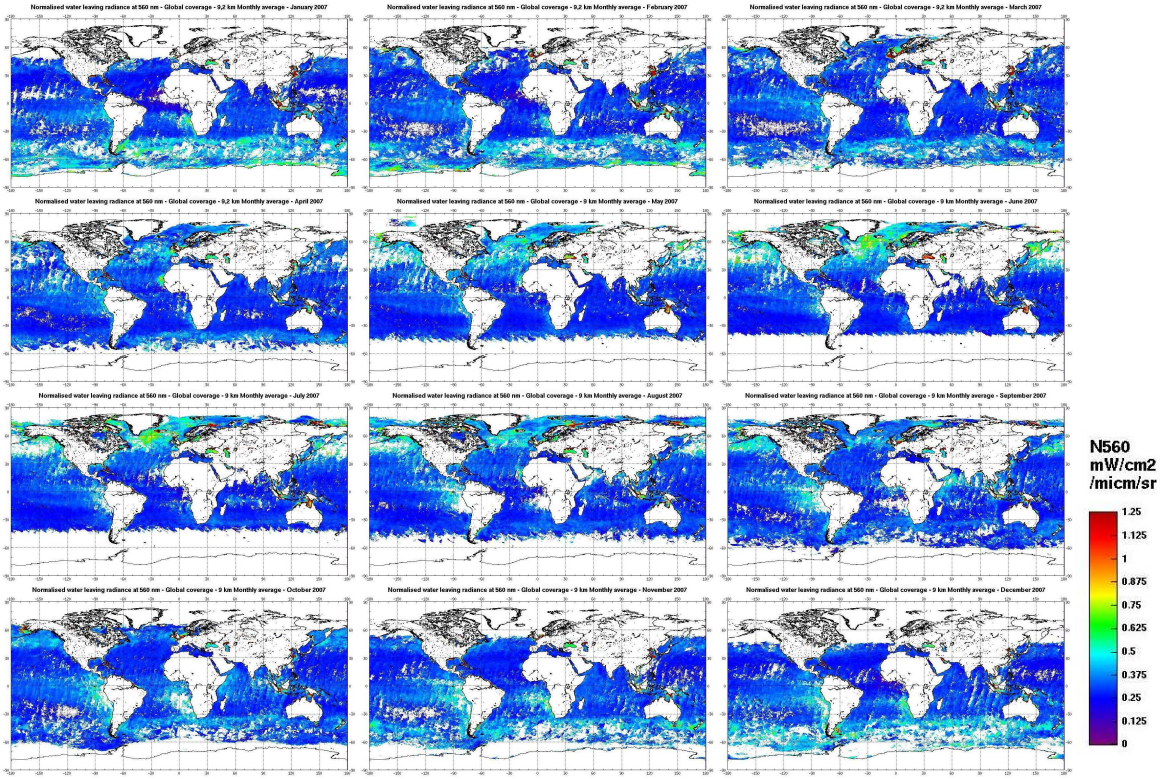


Figure 125: Monthly mean of water leaving radiance at 560 nm.

5.2.4.2 Temporal variability over SNES

5.2.4.2.1 Statistics

The temporal variability of all SNES is represented on Figure 126. The temporal profiles are stable, around 0.3 mW/m^2/sr/µm, except for three sites which have values higher than 0.3. Two profiles are superimposed: those which have a maximum in summer (located in North hemisphere) and those which have a maximum of water leaving radiances in winter (located in south hemisphere). Figure 127 provides the seasonal variations of $L_w(560)_N$ site by site.

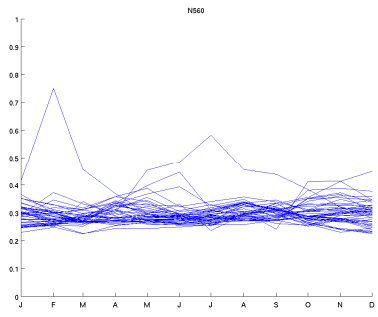


Figure 126: Superimposed temporal profiles of water leaving radiance at 560 nm for the SNES. Units: mW/cm^2/µm/sr.

Figure 127: Temporal variability of $L_w(560)_N$ for the SNES. X axis scale is one year, from January to December. Y axis scale is 0-1. Units: mW/cm^2/µm/sr.

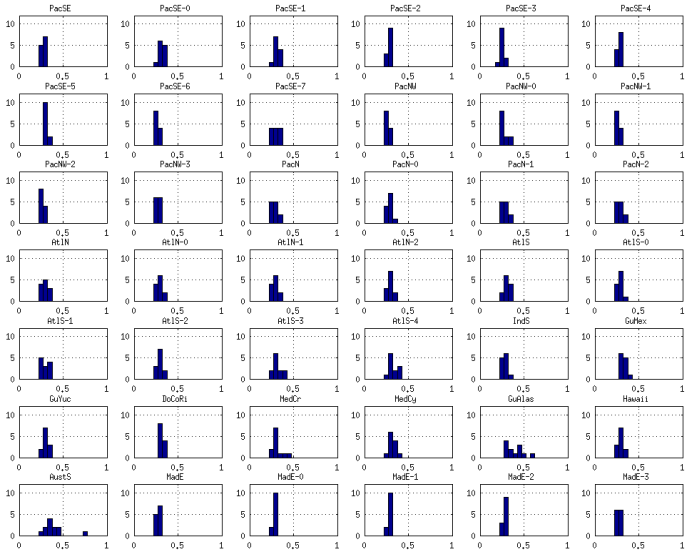


Figure 128: Histogram of the monthly mean L560N for the SNES.

Table 105 provides the standard statistics for all sites.

Table 105: Statistics for L560N products

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
PacSE	0.2875	0.0219	0.2630	0.3182	0.0552	0.1920	0.0762
PacSE-0	0.3152	0.0245	0.2670	0.3516	0.0847	0.2686	0.0778
PacSE-1	0.3086	0.0251	0.2566	0.3509	0.0943	0.3056	0.0814
PacSE-2	0.2930	0.0207	0.2530	0.3177	0.0647	0.2209	0.0708

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
PacSE-3	0.2631	0.0163	0.2246	0.2828	0.0581	0.2210	0.0619
PacSE-4	0.2887	0.0183	0.2621	0.3135	0.0514	0.1779	0.0633
PacSE-5	0.3060	0.0170	0.2830	0.3342	0.0513	0.1675	0.0555
PacSE-6	0.2684	0.0286	0.2259	0.3161	0.0902	0.3360	0.1067
PacSE-7	0.3016	0.0356	0.2553	0.3544	0.0991	0.3284	0.1181
PacNW	0.2705	0.0247	0.2332	0.3057	0.0725	0.2682	0.0912
PacNW-0	0.2711	0.0372	0.2264	0.3404	0.1140	0.4205	0.1371
PacNW-1	0.2676	0.0266	0.2283	0.3113	0.0830	0.3101	0.0994
PacNW-2	0.2711	0.0263	0.2300	0.3188	0.0888	0.3276	0.0970
PacNW-3	0.2729	0.0274	0.2343	0.3139	0.0796	0.2917	0.1003
PacN	0.2887	0.0266	0.2566	0.3350	0.0784	0.2715	0.0922
PacN-0	0.2892	0.0259	0.2663	0.3449	0.0787	0.2720	0.0895
PacN-1	0.2851	0.0288	0.2398	0.3291	0.0893	0.3132	0.1009
PacN-2	0.2885	0.0298	0.2464	0.3351	0.0887	0.3074	0.1035
AtlN	0.2953	0.0275	0.2609	0.3366	0.0757	0.2564	0.0931
AtlN-0	0.2963	0.0241	0.2697	0.3345	0.0648	0.2188	0.0815
AtlN-1	0.2939	0.0341	0.2527	0.3548	0.1021	0.3475	0.1160
AtlN-2	0.2955	0.0315	0.2520	0.3441	0.0921	0.3117	0.1066
AtlS	0.3030	0.0362	0.2699	0.3713	0.1013	0.3344	0.1193
AtlS-0	0.2915	0.0271	0.2610	0.3482	0.0871	0.2989	0.0929
AtlS-1	0.3002	0.0380	0.2618	0.3614	0.0996	0.3320	0.1267
AtlS-2	0.2982	0.0325	0.2621	0.3663	0.1042	0.3494	0.1089
AtlS-3	0.3170	0.0558	0.2402	0.4141	0.1739	0.5486	0.1760
AtlS-4	0.3193	0.0447	0.2693	0.3877	0.1184	0.3708	0.1401
IndS	0.2892	0.0239	0.2620	0.3279	0.0659	0.2280	0.0827
GuMex	0.3320	0.0283	0.2881	0.3881	0.1000	0.3012	0.0852
GuYuc	0.3057	0.0282	0.2702	0.3577	0.0875	0.2862	0.0923
DoCoRi	0.3176	0.0173	0.2918	0.3465	0.0547	0.1721	0.0544
MedCr	0.3139	0.0556	0.2563	0.4465	0.1902	0.6059	0.1770
MedCy	0.3172	0.0388	0.2554	0.3932	0.1378	0.4344	0.1225
GuAlas	0.3917	0.0925	0.2820	0.5817	0.2997	0.7651	0.2363
Hawaii	0.2953	0.0223	0.2700	0.3300	0.0600	0.2032	0.0756
AustS	0.3916	0.1312	0.2365	0.7513	0.5149	1.3146	0.3351
MadE	0.2832	0.0110	0.2728	0.3038	0.0310	0.1096	0.0387
MadE-0	0.2869	0.0122	0.2685	0.3128	0.0443	0.1544	0.0425
MadE-1	0.2857	0.0118	0.2700	0.3071	0.0371	0.1300	0.0413

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
MadE-2	0.2837	0.0123	0.2711	0.3060	0.0349	0.1231	0.0435
MadE-3	0.2798	0.0115	0.2678	0.2989	0.0312	0.1113	0.0409

5.2.4.2.2 Results

Table 106 provides the classification of the sites based on the mean of radiance at 560 nm

Table 106: Rank based on the mean radiance at 560 nm

Rank	Site name	Mean		Rank	Site name	Mean
1	PacSE-3	0.2631		22	AtlN-1	0.2939
2	PacNW-1	0.2676		23	Hawaii	0.2953
3	PacSE-6	0.2684		24	AtlN	0.2953
4	PacNW	0.2705		25	AtlN-2	0.2955
5	PacNW-2	0.2711		26	AtlN-0	0.2963
6	PacNW-0	0.2711		27	AtlS-2	0.2982
7	PacNW-3	0.2729		28	AtlS-1	0.3002
8	MadE-3	0.2798		29	PacSE-7	0.3016
9	MadE	0.2832		30	AtlS	0.3030
10	MadE-2	0.2837		31	GuYuc	0.3057
11	PacN-1	0.2851		32	PacSE-5	0.3060
12	MadE-1	0.2857		33	PacSE-1	0.3086
13	MadE-0	0.2869		34	MedCr	0.3139
14	PacSE	0.2875		35	PacSE-0	0.3152
15	PacN-2	0.2885		36	AtlS-3	0.3170
16	PacN	0.2887		37	MedCy	0.3172
17	PacSE-4	0.2887		38	DoCoRi	0.3176
18	PacN-0	0.2892		39	AtlS-4	0.3193
19	IndS	0.2892		40	GuMex	0.3320
20	AtlS-0	0.2915		41	AustS	0.3916
21	PacSE-2	0.2930		42	GuAlas	0.3917

5.2.5 Temporal variability of Turbidity

5.2.5.1 Dataset description

5.2.5.1.1 Dataset identification

Level-3 Aqua MODIS Ocean Monthly Global Product, MYDK490

5.2.5.1.2 Spatial Characteristics

9km global

5.2.5.1.3 Projection

Plate-carrée

5.2.5.1.4 Temporal Characteristics

2007

5.2.5.1.5 Data Characteristics

5.2.5.1.5.1 Parameter/Variable

The diffuse attenuation coefficient at band 3 (K490) indicates the turbidity of the water column (how visible light in the blue-green regions of the spectrum penetrates within the water column. It is directly related to the presence of scattering particles in the water column.

$$K(490) = K_W(490) + A\left[\frac{L_W(\lambda_1)}{L_W(\lambda_2)}\right]^B$$

Where $K_w(490)$ is the diffuse coefficient of pure water (0.016 m^{-1}), from Mueller 2000 and Smith and Baker (1981)

$\lambda 1$=488/490, $\lambda 2$=551/555, A=0.15645, B=-1.5401

The products analysed is: **Attenuation at 490 nm**

5.2.5.1.5.2 Variable Description/Definition

The diffuse attenuation coefficient in water indicates how strongly light intensity at a specified wavelength is attenuated within the water column. This parameter has wide applicability in ocean optics, as it is directly related to the presence of scattering particles in the water column, either organic or inorganic, and thus is an indication of water clarity.

The diffuse attenuation coefficient at 490 nm (K490) indicates the turbidity of the water column - how visible light in the blue to green region of the spectrum penetrates within the water column. The value of K490 represents the rate which light at 490 nm is attenuated with depth. For example a K490 of 0.1/meter means that light intensity will be reduced one natural log within 10 meters of water. Thus, for a K490 of 0.1, one attenuation length is 10 meters. Higher K490 value means smaller attenuation depth, and lower clarity of ocean water.

5.2.5.1.5.3 Unit of Measurement

Unit is m-1

5.2.5.1.6 Data Source

Ocean Color Web (http://oceancolor.gsfc.nasa.gov/)

5.2.5.1.7 Data Range

[0 -1] m^{-1}

5.2.5.2 Sample Data Record

Dataset format is HDF. The specifications are provided at: http://seadas.gsfc.nasa.gov/

5.2.5.3 Analysis

5.2.5.3.1 Variability at global scale

Global temporal variations are represented on **Error! Reference source not found.**. The highest contents are observed at the equator, with latitudinal variations depending on the season. The water vapour content ranges from 1 to 2 g/cm2 above 40 °of latitude North and South. Between these latitudes, the content varies between 2 and 7 g/cm2, reaching 10 g/cm2 in the Indian Ocean and Pacific.

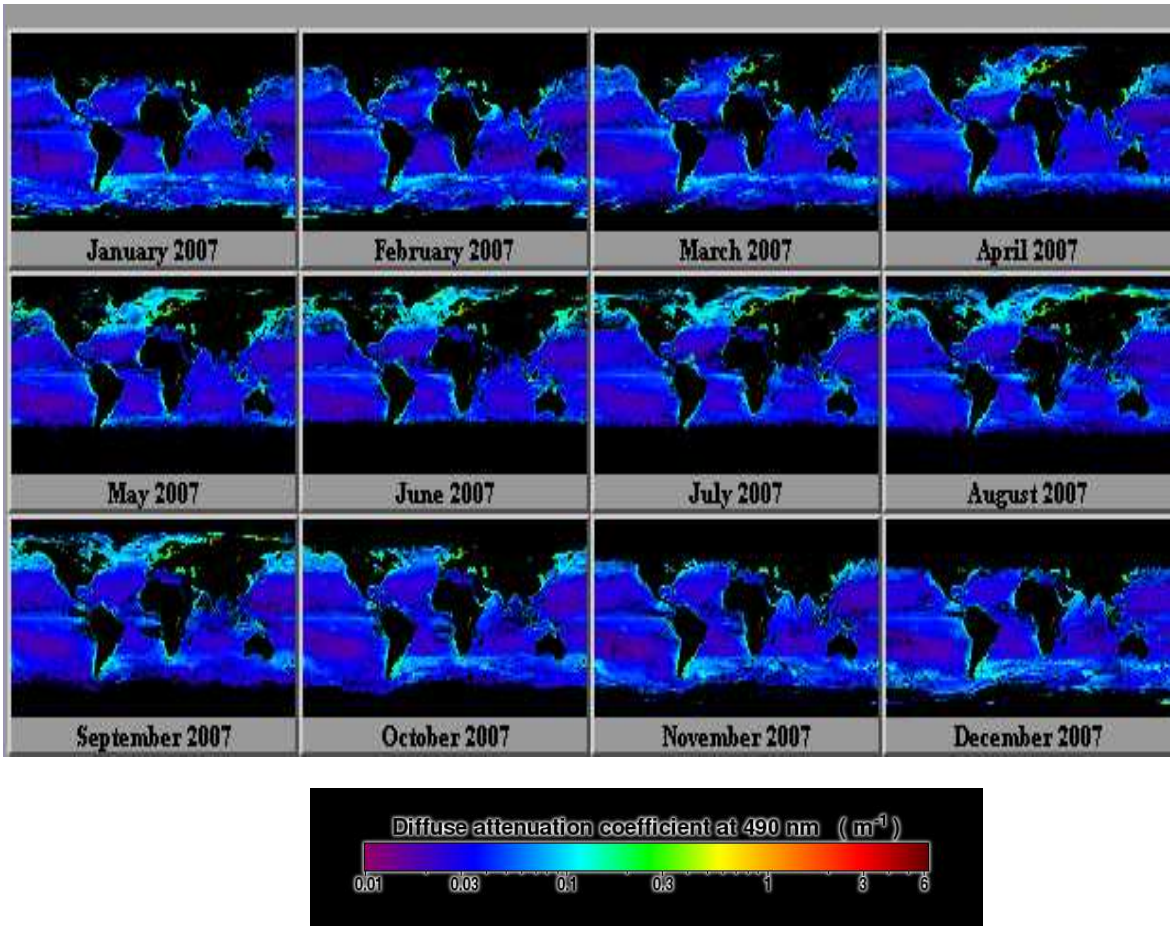


Figure 129: Variability of the attenuation coefficient at global scale

5.2.5.3.2 Temporal variability over SNES

5.2.5.3.2.1 Statistics

Figure 130 represents the temporal variability of the attenuation coefficient of the 42 sites, and Figure 131 provides the temporal variability for each site.

The coefficient varies between 0.02 and 0.1 m^{-1} with low variations over the year, except for the site located in the Gulf of Alaska.

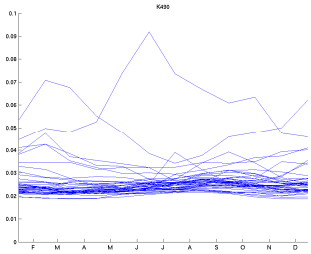


Figure 130: Superimposed temporal profiles of K490 for the SNES.

Figure 131: Temporal variability of attenuation coefficient K490 for the SNES. X axis scale is one year, from January to December. Y axis scale is 0-0.1 m^{-1}.

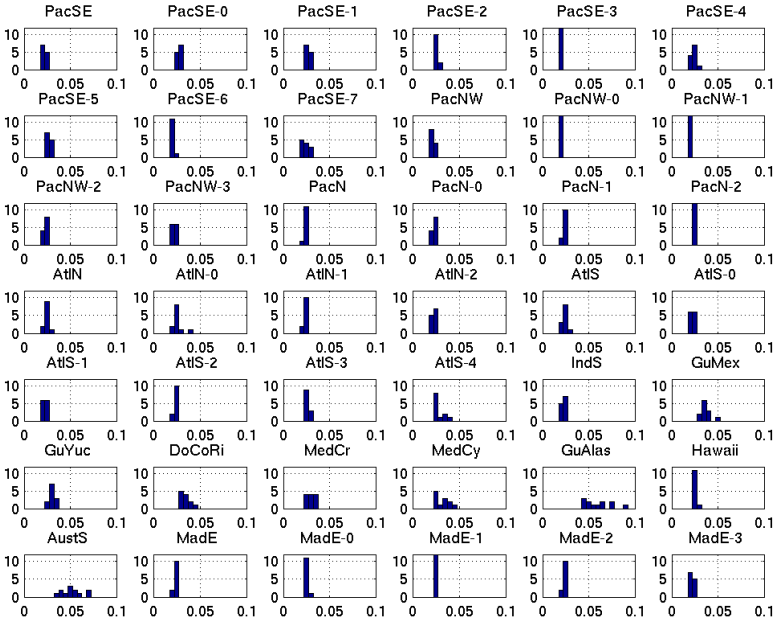


Figure 132: Histogram of attenuation coefficient for SNES

Table 107 provides the standard statistics for all sites.

Table 107: Statistics for coefficient of attenuation

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
PacSE	0.0224	0.0012	0.0210	0.0248	0.0037	0.1667	0.0538
PacSE-0	0.0277	0.0028	0.0236	0.0313	0.0077	0.2788	0.1011
PacSE-1	0.0267	0.0019	0.0227	0.0293	0.0066	0.2451	0.0700
PacSE-2	0.0257	0.0012	0.0235	0.0282	0.0047	0.1813	0.0487
PacSE-3	0.0200	0.0012	0.0187	0.0215	0.0029	0.1433	0.0594
PacSE-4	0.0237	0.0020	0.0209	0.0276	0.0067	0.2812	0.0824
PacSE-5	0.0269	0.0020	0.0246	0.0304	0.0058	0.2159	0.0745
PacSE-6	0.0202	0.0013	0.0190	0.0229	0.0039	0.1924	0.0643
PacSE-7	0.0245	0.0037	0.0205	0.0312	0.0108	0.4395	0.1492
PacNW	0.0220	0.0006	0.0209	0.0229	0.0020	0.0903	0.0289
PacNW-0	0.0213	0.0006	0.0200	0.0223	0.0023	0.1082	0.0280
PacNW-1	0.0212	0.0007	0.0201	0.0222	0.0020	0.0966	0.0347
PacNW-2	0.0226	0.0006	0.0217	0.0235	0.0018	0.0802	0.0266
PacNW-3	0.0225	0.0008	0.0214	0.0237	0.0023	0.1032	0.0342
PacN	0.0239	0.0011	0.0218	0.0257	0.0039	0.1643	0.0464
PacN-0	0.0232	0.0011	0.0213	0.0251	0.0038	0.1647	0.0495
PacN-1	0.0235	0.0011	0.0211	0.0247	0.0036	0.1552	0.0450
PacN-2	0.0253	0.0013	0.0230	0.0275	0.0045	0.1757	0.0511
AtlN	0.0245	0.0022	0.0214	0.0294	0.0080	0.3272	0.0912
AtlN-0	0.0261	0.0048	0.0214	0.0391	0.0176	0.6761	0.1846
AtlN-1	0.0236	0.0012	0.0215	0.0256	0.0041	0.1734	0.0505
AtlN-2	0.0233	0.0016	0.0210	0.0258	0.0048	0.2055	0.0685
AtlS	0.0240	0.0021	0.0217	0.0278	0.0061	0.2544	0.0854
AtlS-0	0.0229	0.0015	0.0212	0.0253	0.0041	0.1813	0.0664
AtlS-1	0.0233	0.0021	0.0211	0.0274	0.0063	0.2687	0.0919
AtlS-2	0.0241	0.0015	0.0217	0.0259	0.0042	0.1733	0.0639
AtlS-3	0.0263	0.0027	0.0234	0.0312	0.0078	0.2955	0.1010
AtlS-4	0.0277	0.0054	0.0232	0.0392	0.0160	0.5775	0.1935
IndS	0.0234	0.0020	0.0206	0.0272	0.0066	0.2823	0.0836
GuMex	0.0367	0.0042	0.0324	0.0475	0.0151	0.4123	0.1156
GuYuc	0.0295	0.0030	0.0254	0.0349	0.0095	0.3222	0.1024
DoCoRi	0.0350	0.0047	0.0295	0.0425	0.0130	0.3715	0.1336
MedCr	0.0308	0.0037	0.0261	0.0354	0.0094	0.3034	0.1212
MedCy	0.0316	0.0060	0.0253	0.0426	0.0172	0.5465	0.1886
GuAlas	0.0599	0.0147	0.0446	0.0919	0.0473	0.7894	0.2447

Site name	Mean	Standard deviation	Minimum	Maximum	Max-Min	(Max-Min)/ Mean	CV
Hawaii	0.0260	0.0010	0.0241	0.0277	0.0036	0.1385	0.0372
AustS	0.0509	0.0116	0.0343	0.0708	0.0364	0.7161	0.2277
MadE	0.0241	0.0014	0.0220	0.0263	0.0043	0.1792	0.0596
MadE-0	0.0260	0.0014	0.0234	0.0282	0.0048	0.1848	0.0531
MadE-1	0.0248	0.0015	0.0226	0.0272	0.0047	0.1881	0.0586
MadE-2	0.0238	0.0014	0.0219	0.0260	0.0041	0.1713	0.0586
MadE-3	0.0229	0.0016	0.0211	0.0253	0.0042	0.1837	0.0706

5.2.5.3.2.2 Results

Table 108 provides a classification of the sites based on the mean of the coefficient of attenuation.

Table 108: Rank of sites based on the mean of attenuation coefficient of SNES

Rank	Site name	Mean		Rank	Site name	Mean
1	PacSE-3	0.0200		22	MadE	0.0241
2	PacSE-6	0.0202		23	PacSE-7	0.0245
3	PacNW-1	0.0212		24	AtlN	0.0245
4	PacNW-0	0.0213		25	MadE-1	0.0248
5	PacNW	0.0220		26	PacN-2	0.0253
6	PacSE	0.0224		27	PacSE-2	0.0257
7	PacNW-3	0.0225		28	MadE-0	0.0260
8	PacNW-2	0.0226		29	Hawaii	0.0260
9	AtlS-0	0.0229		30	AtlN-0	0.0261
10	MadE-3	0.0229		31	AtlS-3	0.0263
11	PacN-0	0.0232		32	PacSE-1	0.0267
12	AtlN-2	0.0233		33	PacSE-5	0.0269
13	AtlS-1	0.0233		34	AtlS-4	0.0277
14	IndS	0.0234		35	PacSE-0	0.0277
15	PacN-1	0.0235		36	GuYuc	0.0295
16	AtlN-1	0.0236		37	MedCr	0.0308
17	PacSE-4	0.0237		38	MedCy	0.0316
18	MadE-2	0.0238		39	DoCoRi	0.0350
19	PacN	0.0239		40	GuMex	0.0367
20	AtlS	0.0240		41	AustS	0.0509
21	AtlS-2	0.0241		42	GuAlas	0.0599

5.3 Analysis of site homogeneity

Fougnie et al, 2002 (RD.29) identified stable and homogeneous oceanic sites, and characterized them in terms of marine and atmospheric properties. The first goal was reached through detailed statistical analyses of elementary parcels (about 500*500 km²), a priori selected according to oceanographic considerations. For all elementary parcels, statistics were established for each month, mean value and spatial standard deviation over the parcel for chlorophyll a concentration, R(443) and R(555). Then, these parcels were agglomerated in order to create larger 'fusion' respecting to a typical 10% spatial variation criterion for R(443). As results, selected sites are located in the main subtropical gyres (S- and N- Atlantic ocean, S- and N- Pacific ocean, and S-Indian ocean). Seasonal variations are also analysed.

Table 109: Criterion for site homogeneity

Retained criteria	Studied parameters	Site type
Size	▪ Size, surface	▪ SNES
Spatial uniformity	▪ Variation of surface reflectance on the site (coefficient of variation) ▪ Low Horizontal Gradients	

5.3.1 Site size

The site size is expressed in km^2.

Table 110: Site size (km^2)

	Site name	Site size
1	PacSE	10160022
2	PacSE-0	981882
3	PacSE-1	1948005
4	PacSE-2	1014356
5	PacSE-3	1004021
6	PacSE-4	504977
7	PacSE-5	500000,6
8	PacSE-6	2577839
9	PacSE-7	963124,8
10	PacNW	3934993
11	PacNW-0	516716,2
12	PacNW-1	1581155
13	PacNW-2	528200,2
14	PacNW-3	1281104
15	PacN	1959362

	Site name	Site size
16	PacN-0	951513,2
17	PacN-1	525903,4
18	PacN-2	525010,2
19	AtlN	2105464
20	AtlN-0	1052190
21	AtlN-1	530305,6
22	AtlN-2	524436
23	AtlS	2528777
24	AtlS-0	523160
25	AtlS-1	759092,4
26	AtlS-2	515504
27	AtlS-3	506316,8
28	AtlS-4	253796,4
29	IndS	1029923
30	GuMex	362511,6
31	GuYuc	170601,2
32	DoCoRi	786654
33	MedCr	58951,2
34	MedCy	34834,8
35	GuAlas	249202,8
36	Hawaii	44532,4
37	AustS	207924,2
38	MadE	1269684
39	MadE-0	255710,4
40	MadE-1	249649,4
41	MadE-2	255774,2
42	MadE-3	505615

5.3.2 Spatial uniformity

5.3.2.1 Spatial variability over SNES for chlorophyll content

The spatial uniformity is estimated by computing the coefficient of variation for a tile containing 5 x 5 pixels (around 50 km^2) shifting from one pixel to the next. Areas where the gradient is high are represented by a high coefficient of variation (red colours).

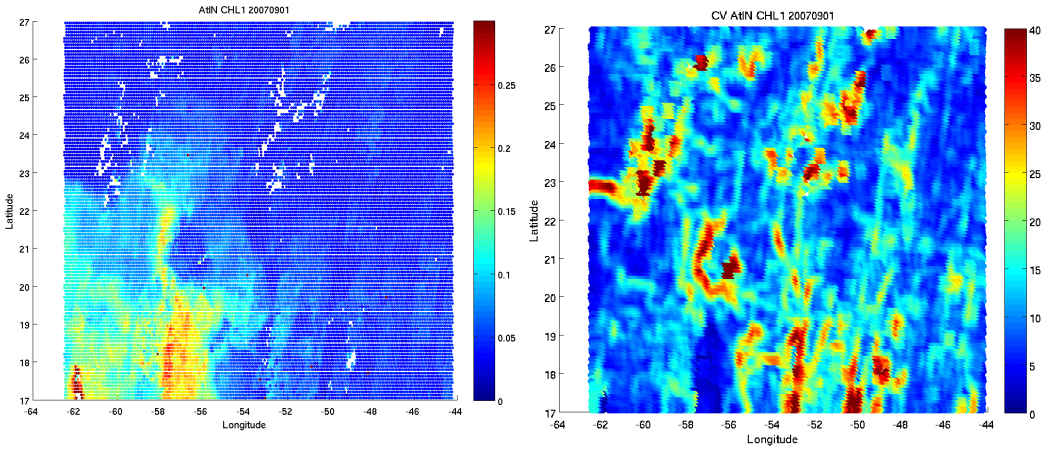


Figure 133: Chlorophyll map and its spatial coefficient of variation

The mean CV for each area is computed for each month, and is represented for all sites on the next figure. The mean CV for each site varies from 5% to 45%. The minimum is never lower than 5% whereas the maximum is reached at some specific months, meaning that chlorophyll-a content varies strongly in some part of the sites. The variations of CV are represented in Figure 134 for each site. The histogram of CV (Figure 135) allows to count the number of months where CV is less than 10%.

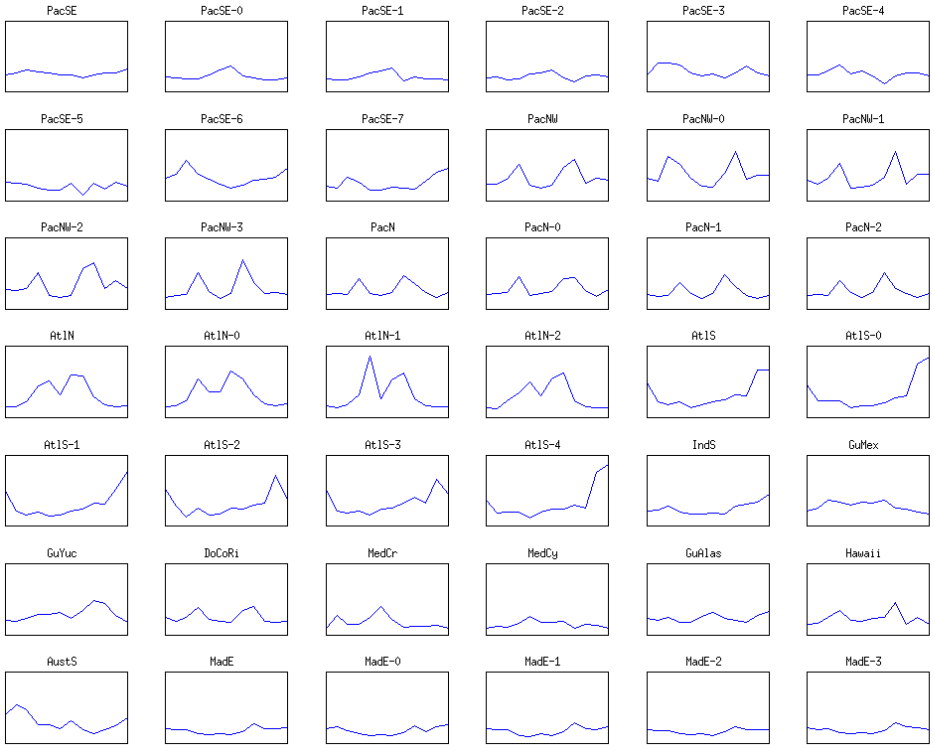


Figure 134: Temporal variability of CV(CHL1) for the SNES. X axis scale is one year, from January to December. Y axis scale is 0-0.5. No Units.

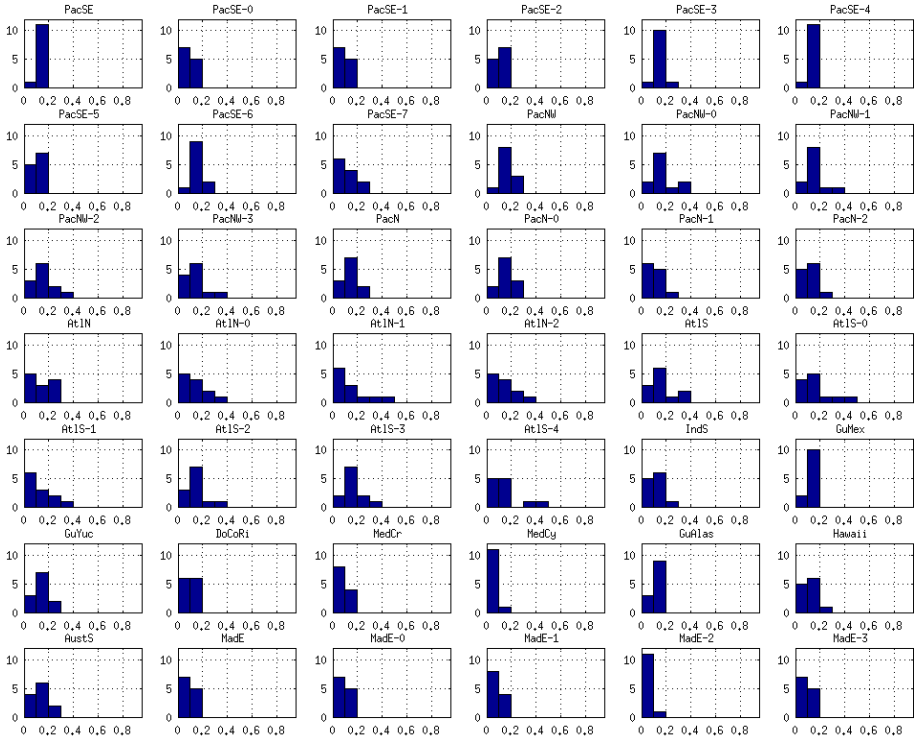


Figure 135: Histogram of the monthly mean CV(CHL1) for the SNES.

Table 111 reports the classification of the sites based on the mean value of the coefficient of dispersion.

Table 111: Mean of coefficient of variation of SNES

Site score	Site name	CV	Number of time where CV < 10%
1	MedCy	0.0725	11
2	MadE-2	0.0826	11
3	MedCr	0.0852	8
4	MadE-1	0.0870	8
5	MadE-0	0.0871	7
6	MadE	0.0888	7
7	MadE-3	0.0930	7
8	PacSE-5	0.1000	5
9	PacSE-1	0.1025	7
10	PacSE-2	0.1058	5
11	PacSE-0	0.1060	7
12	Hawaii	0.1145	5
13	GuAlas	0.1169	3
14	PacN-1	0.1180	6
15	IndS	0.1204	5
16	DoCoRi	0.1216	6

Site score	Site name	CV	Number of time where CV < 10%
17	PacSE-7	0.1216	6
18	PacSE-4	0.1223	1
19	PacN-2	0.1230	5
20	PacSE	0.1275	1
21	PacN	0.1298	3
22	GuMex	0.1358	2
23	PacN-0	0.1364	2
24	PacNW-3	0.1409	4
25	AtlN-2	0.1420	5
26	PacSE-3	0.1429	1
27	GuYuc	0.1430	3
28	AustS	0.1468	4
29	AtlS-2	0.1516	3
30	AtlS-1	0.1520	6
31	AtlN	0.1541	5
32	AtlN-1	0.1565	6
33	PacNW	0.1568	1
34	AtlS	0.1579	3
35	AtlN-0	0.1588	5
36	AtlS-4	0.1603	5
37	PacNW-1	0.1613	2
38	AtlS-3	0.1615	2
39	PacSE-6	0.1625	1
40	AtlS-0	0.1655	4
41	PacNW-2	0.1678	3
42	PacNW-0	0.1866	2

5.3.2.2 Spatial variability over SNES for L_N443

Figure 136 represents the radiance at 443 nm and the coefficient of dispersion for the same area and same month as the one represented in Figure 133. The area where the chlorophyll content is high (South East part of the image) are correlated to the area where the radiance at 443 nm is the lowest. Large part of this site has a coefficient of variation less than 10%, which is the criterion to estimate the spatial homogeneity of the site.

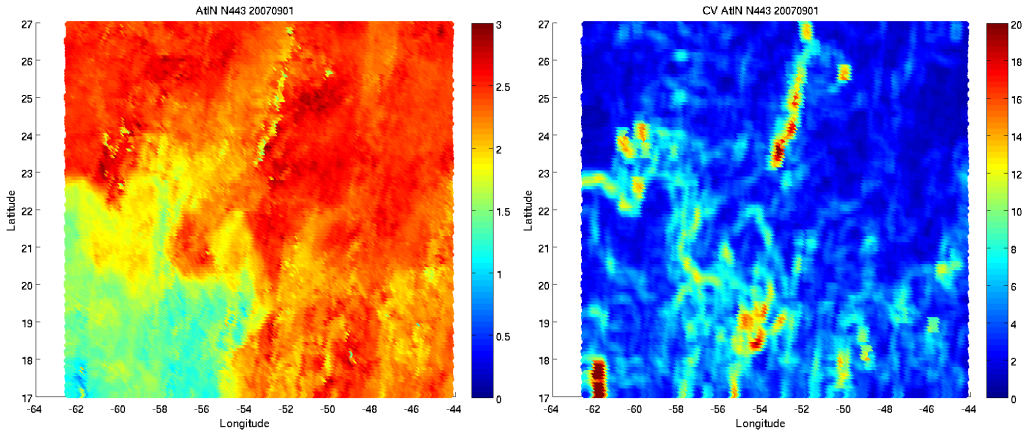


Figure 136: Normalised radiance at 443 nm and its spatial coefficient of variation

The mean CV for L_N443 is represented for all sites in Figure 137. It is highly correlated to the CV computed for the chlorophyll-a concentration, but with lowest values.

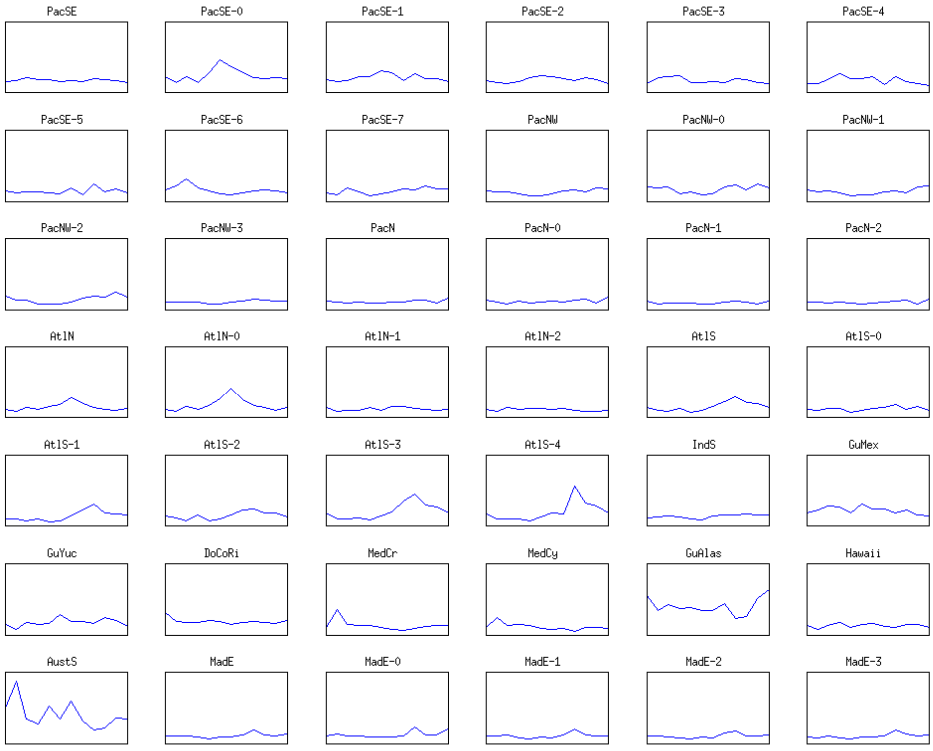


Figure 137: Temporal variability of CV(L_N 443) for the SNES. X axis scale is one year, from January to December. Y axis scale is 0-0.25. No Units.

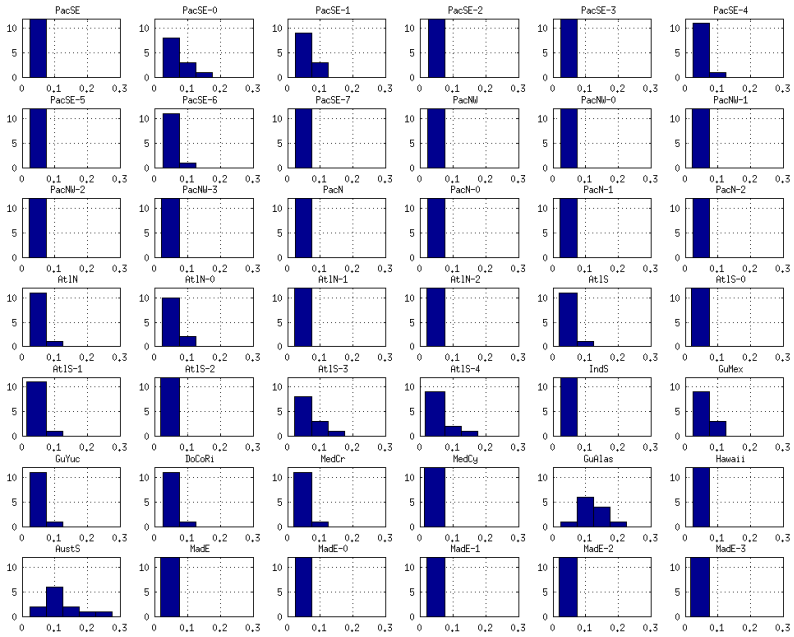


Figure 138: Histogram of the monthly mean CV(L_N443) for the SNES.

Table 112 reports the classification of the site based on the coefficient of dispersion. The fourth column indicates the number of months where the CV is lower than 10%, indicating the good level of spatial homogeneity of the sites. Only the sites located in high latitudes have a mean CV greater than 10%. The cloud coverage over these two sites is high (greater than 80%, see Table 23), the chlorophyll content is also high (0.35 and 0.25, see Table 101) and variable along the year. As results, the coefficient of variation is high.

Table 112: Mean of coefficient of variation of SNES

Site score	Site name	CV	Number of time where CV < 10%
1	PacN-1	0.0287	12
2	MadE-3	0.0307	12
3	MadE-2	0.0307	12
4	AtlN-2	0.0309	12
5	PacN-2	0.0309	12
6	PacNW-3	0.0321	12
7	MadE	0.0324	12
8	MadE-1	0.0325	12
9	AtlN-1	0.0327	12
10	PacN	0.0327	12
11	AtlS-0	0.0335	12
12	MedCy	0.0339	12
13	PacN-0	0.0346	12
14	MadE-0	0.0371	12

Site score	Site name	CV	Number of time where CV < 10%
15	IndS	0.0377	12
16	MedCr	0.0389	11
17	Hawaii	0.0390	12
18	PacNW	0.0392	12
19	AtlS-1	0.0400	11
20	PacNW-1	0.0408	12
21	AtlN	0.0411	11
22	AtlS-2	0.0415	12
23	PacSE-5	0.0420	12
24	PacSE-7	0.0431	12
25	PacNW-2	0.0436	12
26	AtlS	0.0438	11
27	PacSE-6	0.0479	11
28	PacSE-3	0.0488	12
29	PacSE-4	0.0490	11
30	PacSE	0.0502	12
31	AtlN-0	0.0504	10
32	PacSE-2	0.0513	12
33	PacNW-0	0.0515	12
34	GuYuc	0.0526	11
35	AtlS-4	0.0563	9
36	DoCoRi	0.0572	11
37	AtlS-3	0.0603	8
38	PacSE-1	0.0617	9
39	GuMex	0.0636	9
40	PacSE-0	0.0725	8
41	AustS	0.1206	2
42	GuAlas	0.1208	1

5.3.2.3 Spatial variability over SNES for L_N560

Figure 139 represents the radiance at 560 nm and the coefficient of dispersion for the same area and same month as the one represented in Figure 133. The radiance is more homogeneous than the one at 443 nm, ranging from 0.2 to 0.4 mW/cm^2/µm/sr.

Figure 140 represents the mean CV for L_N560 for all sites, and Figure 141 represents the distribution of CV.

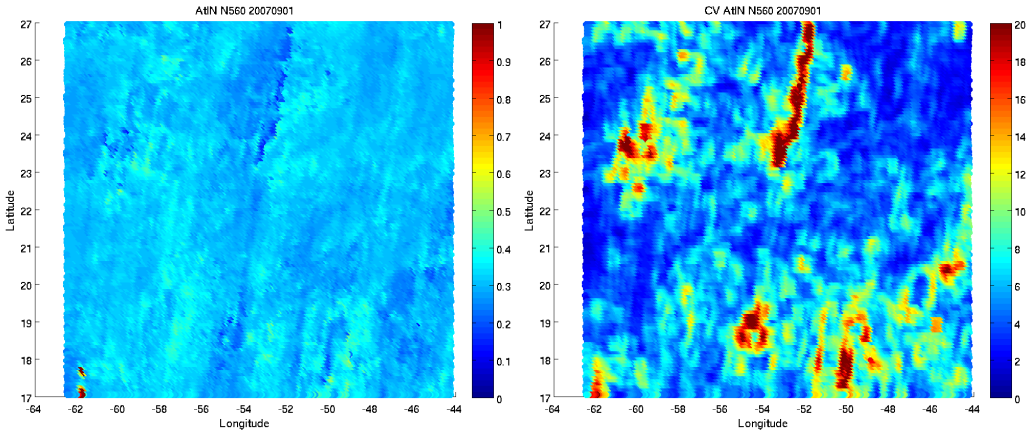


Figure 139: Normalised radiance at 560 nm and its spatial coefficient of variation

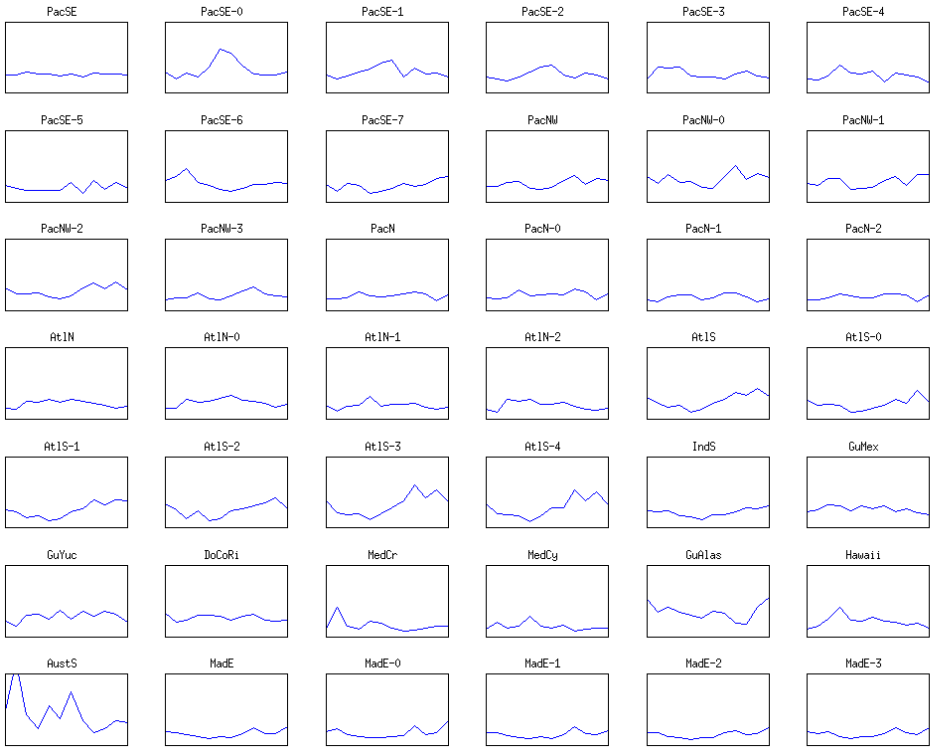


Figure 140: Temporal variability of CV(L560N) for the SNES. X axis scale is one year, from January to December. Y axis scale is 0-0.25. No Units.

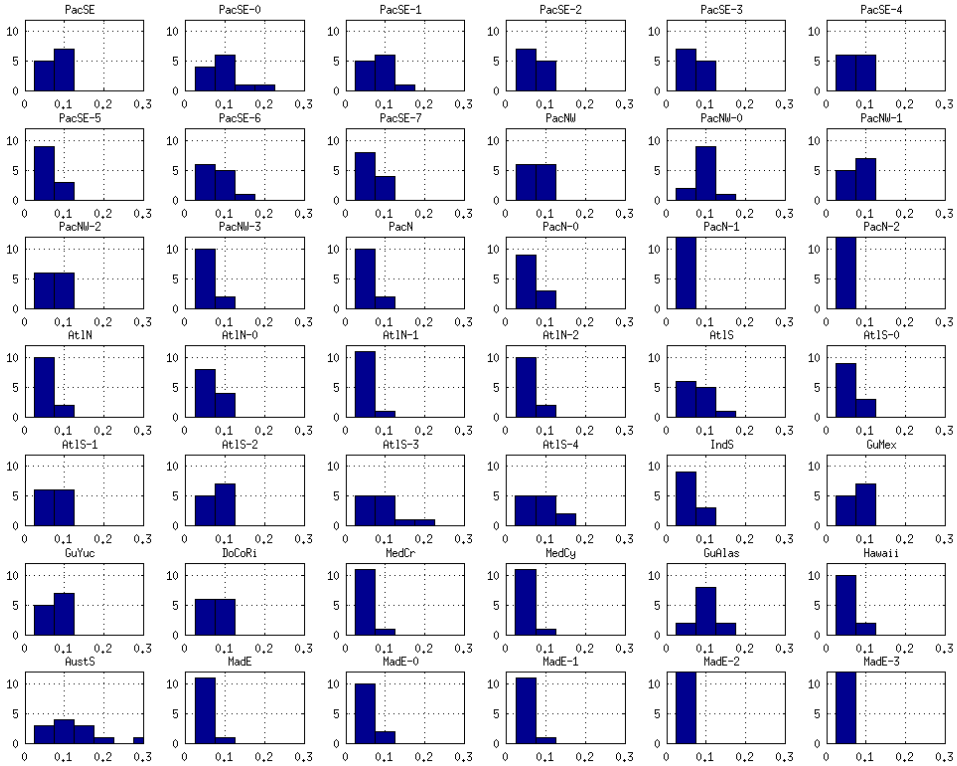


Figure 141: Histogram of the monthly mean CV(L_N 560) for the SNES.

Table 113 reports the classification of the site based on the coefficient of dispersion. The fourth column indicates the number of months where the CV is lower than 10%, indicating the good level of spatial homogeneity of the sites. Once again, only the sites located in high latitudes have a mean CV greater than 10%.

Table 113: Mean of coefficient of variation of SNES

Site score	Site name	CV	Number of time where CV < 10%
1	MedCy	0.0422	11
2	MadE-2	0.0441	12
3	MadE-1	0.0454	11
4	MedCr	0.0470	11
5	MadE	0.0478	11
6	MadE-3	0.0488	12
7	MadE-0	0.0513	10
8	PacN-1	0.0542	12
9	AtlN-1	0.0556	11
10	AtlN-2	0.0557	10
11	PacN-2	0.0563	12
12	PacSE-5	0.0594	9
13	PacN	0.0606	10
14	PacNW-3	0.0616	10

Site score	Site name	CV	Number of time where CV < 10%
15	AtlN	0.0619	10
16	IndS	0.0621	9
17	AtlS-0	0.0623	9
18	Hawaii	0.0624	10
19	PacN-0	0.0650	9
20	AtlN-0	0.0683	8
21	PacSE-7	0.0683	8
22	PacSE-4	0.0711	6
23	AtlS-1	0.0729	6
24	AtlS-2	0.0743	5
25	PacSE-2	0.0750	7
26	GuMex	0.0755	5
27	AtlS	0.0756	6
28	PacSE	0.0763	5
29	PacNW	0.0772	6
30	PacSE-3	0.0776	7
31	PacSE-6	0.0785	6
32	DoCoRi	0.0790	6
33	PacNW-2	0.0813	6
34	GuYuc	0.0828	5
35	PacNW-1	0.0833	5
36	AtlS-4	0.0849	5
37	PacSE-1	0.0874	5
38	AtlS-3	0.0948	5
39	PacNW-0	0.0961	2
40	PacSE-0	0.0975	4
41	GuAlas	0.1045	2
42	AustS	0.1331	3

6. SYNTHESIS

6.1 Introduction

In this WP, an analysis of the temporal and spatial variability of different data has been made in order to address the adequacy of the use of the site as reference test site into vicarious calibration methods. The spatial variability has been statistically analysed, allowing to classify the sites, for all surface and atmosphere properties, from the one which has the lowest variability to the ones which has the greatest. However, this criteria is not the only one according the selection criteria. The temporal variability is addressed in terms of period (several months) for which the sites could be chosen for calibration.

Each class of sites has its representatives (Table 114):

Table 114: Representatives of site classes

LES	LNES	SES	SNES
Salt lake	Desert	Buoy	Ocean
Playa	Snow	Platform	Clouds
Sand		Boat	Glitter

Methods used for vicarious calibration using these sites are summarised in Table 115 for channels located in the main domain of the solar spectrum (Blue, Red, Near Infra red and Middle infra red), and to the class of sensor (Class 2 or Class 3). The site usage is indicated by the following colour table. Yellow indicates that the site is used in a nominal way, Purple indicates that specific instrumentation is needed for such a calibration, Red colour indicates the non applicability of methods over specific sites, and the green one indicates that under specific conditions, the calibration can be conducted using specific sites.

Nominal	Specific instrumentation	N/A	Potential

Table 115: Sites used in vicarious method

Method acronym		LES	LES	LES	LES	SES buoy	SES buoy	SES buoy	SES	SES	SES	SES	LNES				SNES			
		Bo	Ro	NIRo	SWIRo	Bo	Ro	NIRo	Bo	Ro	NIRo	SWIRo	Bo	Ro	NIRo	SWIRo	Bo	Ro	NIRo	SWIRo
Absolute	Class 2					Buoy	Buoy		Platform Boat	Platform Boat	Platform Boat	Platform Boat					Ocean			
Absolute	Class 3	Saltlake Playa Sand	Saltlake Playa Sand	Saltlake Playa Sand	Saltlake Playa Sand															
ITVC	Class 2												Desert Snow	Desert Snow	Desert Snow	Desert Snow				
ITVC	Class 3												Desert Snow	Desert Snow	Desert Snow	Desert Snow				
ISVC-band	Class 2																	Clouds Glitter	Clouds Glitter	Clouds Glitter
ISVC-band	Class 3	Saltlake Playa Sand	Saltlake Playa Sand	Saltlake Playa Sand	Saltlake Playa Sand													Clouds Glitter	Clouds Glitter	Clouds Glitter
ISVC	Class 2												Desert Snow	Desert Snow	Desert Snow	Desert Snow				
ISVC	Class 3	Saltlake Playa Sand	Saltlake Playa Sand	Saltlake Playa Sand	Saltlake Playa Sand								Desert Snow	Desert Snow	Desert Snow	Desert Snow				

The characteristics of the sites have been addressed in :

- Questionnaires for LES and SES;
- Technical note (RD – SES);
- This report for LNES and SNES, and LES and SES for the description of the site climatology.

As results, we have compiled into the following tables the mean level (annual mean) of the studied variables for the overall sites, class by class. The mean level has been assessed together with the temporal variability.

The criteria associated to each variables are the following :

- Altitude: High altitude minimizes aerosol loading and the uncertainties due to unknown vertical distribution of aerosols
- Cloud cover: Low cloud coverage increase the site visibility from space
- AOT: Sites with low AOT are prefereed
- Angstroem : Sites with no change in AOT type are preferred
- Water vapour content: Sites with low Water vapour content are preferred
- Ozone content: Sites with low ozone temporal variability are preferred
- Precipitation: precipitation could change the surface state (vegetation growth), and surface reflectance
- Albedo: surface reflectance greater than 0.3 in order to provide higher signal-to-noise ratio (SNR) and reduce uncertainties due to the atmospheric path radiance.
- Chlorophyll content: Sites with low temporal chlorophyll content variability are preferred
- Windspeed: impact on glitter reflectance computation
- Attenuation coefficient: indicator of water transparency
- Water leaving radiance: Sites with high water leaving radiance in the blue are preferred

6.2 Climatological data analysis summary

A color is assigned to the quality of the sites according to the criterion analysed.

Table 116: Correspondence with the criteria

Good	Good over a determined period	Mean level high

6.2.1 LES

Climatological properties of LES sites are reported in Table 117.

Table 117: mean of geophysical properties of CEOS LES

Site name	Altitude (m)	Cloud Fraction	Aerosol optical Thickness	Angstroem exponent	Water vapour content (g/cm2)	Ozone content (Dobson)	Precipitation (mm/j)	Albedo VIS (0.685µm)	Albedo NIR (0.865 µm)
LaCrau	18	0.4221	0.15	1.4	1.9630	328.52	1.9201	0.0870	0.2460
RailroadValley	1436	0.3516	0.08	1.4	0.7856	313.90	0.6137	0.2883	0.3466
Ivanpah playa	795	0.2739			1.1353	319.39	0.3343	0.1968	0.2678
FrenchmanFlat	1195	0.2426	0.08	0.875	0.9927	322.43	0.3343	0.1968	0.2667
Negev	340	0.2724	0.2	1	1.2945	292.31	0.3869	0.3296	0.4111
TuzGulu	905	0.4265	0.2	1.44	1.0582	322.86	1.4171	0.3217	0.3150
Dunhuang	1355	0.4080	0.5	0.135	0.8692	316.77	0.1836	0.2384	0.2926
Dome C_cnes	3264	0.3470	0.03	1.74	0.0125	207.28	0.0806	0.9225	0.8647

Table 118: mean of geophysical properties of LES

Site name	Altitude (m)	Cloud Fraction	Aerosol optical Thickness	Angstroem exponent	Water vapour content (g/cm2)	Ozone content (Dobson)	Precipitation (mm/j)	Albedo VIS (0.685µm)	Albedo NIR (0.865 µm)
Lunarplaya	1755	0.3516	0.15	1.2	0.7856	313.90	0.6137	0.2147	0.2674
WhiteSands	1193	0.3001	0.157	1.158	1.3781	297.35	0.7906	0.3253	0.7
RogerDryLake	694	0.2462			1.3747	312.59	0.3001	0.2675	0.3438
BonnevilleSaltFlats	1289	0.4575			0.8772	315.15	0.6232	0.3663	0.3867
LakeFrome	106	0.3286			1.7849	319.39	0.5369	0.4009	0.5
BarrealBlanco	1875	0.2386			0.4574	319.03	0.4933	0.1477	0.1921
RoachLakePlaya	790	0.2739			1.1353	326.33	0.3343	0.1956	0.2676
Mud_Lake	1582	0.2787			0.8430	326.33	0.6137	0.2141	0.2618
Brookings	506	0.5810			1.4372	284.25	2.1979	0.2607	0.4235
TingaTingana	59	0.3139	0.08	1	1.6237	284.25	0.3536	0.3391	0.4472
Dunrobin	292	0.2995			2.9016	284.25	1.9964	0.1360	0.2674
Warrabin	185	0.2173			2.1428	284.25	1.0609	0.2074	0.3049
Winton	209	0.2542			2.7703	284.25	1.6334	0.1905	0.2934
Amburla	665	0.1871			1.9667	329.64	0.7450	0.1286	0.2206
Sonoran_desert	66	0.3438			1.6375	305.08	0.2039	0.3604	0.4342
Sechura_desert	17	0.7944			4.6396	298.36	0.0908	0.2697	0.3099
Hay_Uardry	170	0.3998			1.8275	298.36	1.1658	0.1702	0.3134
Perkingston	64	0.5479			3.0402	340.39	3.4291	0.0477	0.2672
ParkFalls	463	0.6613			1.3638	295.26	2.4434	0.1312	0.3078
Jaisalmer	242	0.2903			2.6313	285.57	1.0093	0.2575	0.3383
Chharodi	28	0.3695			3.5946	270.60	2.5708	0.1320	0.2946
Gongger	1268	0.5169			0.8522	281.29	0.6026	0.3273	0.4141
Erlian	954	0.5303			0.8402	273.00	0.3871	0.3410	0.4160
Zuoqi	1017	0.4905			0.8432	270.96	0.4637	0.3718	0.4621
Youqi	1134	0.6088			0.8176	307.63	0.4637	0.3386	0.4166
Wiggins_Gravelpits	87	0.5479			3.0402	317.90	3.4291	0.0504	0.2730
Wiggins_RyeField	69	0.5479			3.0402	330.63	3.4291	0.0456	0.2636
Wiggins_CutGrass	50	0.5479			3.0402	334.54	3.4291	0.0451	0.2625
Newell	751	0.6849			1.0628	333.19	1.0427	0.2068	0.3300
WigginsWesttarp	92	0.5479			3.0402	328.02	3.4291	0.0504	0.2730
Yuma	17	0.2818			2.0247	253.50	0.2039	0.2119	0.2305
Sonoran_RAL	105	0.2818			2.0247	255.46	0.2039	0.3748	0.4496
Brookings_2	496	0.5810			1.4372	292.48	2.1979	0.2598	0.4212
Sechura_RAL	17	0.7130			4.5166	275.23	0.0908	0.2932	0.3306
Dunhuang_RAL	1191	0.3783			0.9212	272.75	0.1836	0.2586	0.2693

6.2.2 LNES

Table 119: mean of geophysical properties of LNES

Site name	Altitude (m)	Cloud Fraction	Aerosol optical Thickness	Angstroem exponent	Water vapour content (g/cm2)	Ozone content (Dobson)	Precipitation (mm/j)	Albedo VIS (0.685µm)	Albedo NIR (0.865 µm)
Algerie_1	311	0.1696			1.2823	267.5750	0.0546	0.409224	0.499790
Algerie_2	280	0.1496			1.1046	266.8917	0.0493	0.454119	0.545732
Algerie_3	242	0.1535			1.0888	274.3417	0.1541	0.448459	0.552149
Algerie_4	229	0.1746			1.1407	276.5167	0.1444	0.459416	0.565823
Algerie_5	536	0.1869			0.9855	272.4833	0.1945	0.481008	0.591384
Arabie_1	671	0.0715			1.5055	256.6583	0.1049	0.439050	0.534052
Arabie_2	217	0.1197			1.6618	257.1667	0.0393	0.441816	0.524151
Arabie_3	540	0.1610			1.2056	270.8250	0.1602	0.390616	0.481280
Soudan_1	328	0.0586			1.1380	255.2333	0.0474	0.456367	0.547788
Niger_1	583	0.1536			1.2445	257.3667	0.3067	0.507275	0.600347
Niger_2	520	0.1119			1.2072	259.4333	0.0663	0.421648	0.505566
Niger_3	676	0.1437			1.2441	265.0083	0.1003	0.412081	0.498696
Egypte_1	210	0.1757			0.9952	263.7083	0.0488	0.490093	0.592817
Libye_1	642	0.1512			1.0343	259.4750	0.0894	0.519901	0.618994
Libye_2	370	0.2149			1.0664	258.5667	0.0778	0.511761	0.607610
Libye_3	509	0.0898			1.0559	258.0083	0.0243	0.463735	0.554490
Libye_4	130	0.2337			1.0430	264.9583	0.1392	0.492420	0.594381
Mali_1	303	0.2492			1.5062	256.1000	0.2083	0.510279	0.595233
Mauritanie_1	387	0.2755			1.4315	254.6667	0.3625	0.484525	0.582693
Mauritanie_2	386	0.2389			1.3887	256.8833	0.0729	0.454729	0.555508

Table 120: mean of geophysical properties of LNES - others

Site name	Altitude (m)	Cloud Fraction	Aerosol optical Thickness	Angstroem exponent	Water vapour content (g/cm2)	Ozone content (Dobson)	Precipitation (mm/j)	Albedo VIS (0.685µm)	Albedo NIR (0.865 µm)
Dome_1	3128	0.2553			0.0142	205.9750	0.0380	0.9072	0.8482
Dome_2	3240	0.2760			0.0129	205.3000	0.0624	0.9158	0.8535
Dome_3	2992	0.2288			0.0157	211.2250	0.0458	0.9046	0.8357
DomeC_AATSR	3150	0.3198			0.0145	210.8750	0.0897	0.9197	0.8637
Antarctica	298	0.6041			0.1608	255.8500	1.2128	0.7855	0.6703
Greenland	2500-2950	0.4277			0.0825	326.3073	0.2433	0.8494	0.7859
Salar_de_Uyuani	3658	0.3633			0.4283	256.9750	1.1974	0.4331	0.4597
Salar_de_Arizaro	3470	0.1582			0.2391	262.5500	0.1849	0.2204	0.2457
Brazil Bahia	800	0.4301			3.0364	255.8167	2.7591	0.1021	0.2957
Taklamakan	1080	0.5505			1.0169	313.1583	0.2605	0.2934	0.3198
Algeria5-RAL	526	0.1831			0.9835	270.2917	0.1945	0.4442	0.5518
Libya1-RAL	683	0.1512			1.0343	259.4750	0.0894	0.5270	0.6313
Libya2-RAL	616	0.1241			1.0593	267.5167	0.1233	0.3769	0.4716
Sudan-RAL	296	0.0712			1.1074	255.4750	0.0474	0.4632	0.5525
Libya_1_NOAA	860	0.1523			1.0195	262.9354	0.1233	0.4040	0.5005
Libya_1b_NOAA	506	0.1629			1.0469	261.2917	0.0696	0.5000	0.6001
Egypt1_NOAA	283	0.1779			0.9698	260.3667	0.0488	0.4939	0.5967
Lybia4_NOAA	78	0.2352			1.1972	272.0833	0.1392	0.4941	0.5999
Mauritania_3	399	0.2359			1.3807	262.8417	0.0452	0.4724	0.5711
Lybie2_USGS	204	0.1734			1.1324	261.3083	0.0778	0.4392	0.5308
Irak_USGS	65	0.3036			1.7959	292.4917	0.5431	0.3407	0.3996
Tunisia_MSG	186	0.3043			1.6458	295.7417	0.4789	0.4349	0.5405
Lybie2_USGS	202	0.1734			1.1324	261.3083	0.0778	0.4392	0.5308
Irak_USGS	78	0.3036			1.7959	292.4917	0.5431	0.3407	0.3996
Egypt_2	249	0.0839			1.0768	255.7167	0.0113	0.4600	0.5487
Yemen_1	942	0.0635			1.7032	261.9833	0.3529	0.3833	0.4625
Mahktesh_Ramon	522	0.2724			1.2945	292.3167	0.4009	0.3325	0.4218
Lybie	107	0.2337			1.0430	264.9583	0.1392	0.4964	0.6000
Arabia4	779	0.1656			0.8952	262.8250	0.1164	0.4387	0.5566
Arabia5	339	0.2425			1.3984	275.9000	0.3136	0.4105	0.4920
Arabia7	376	0.0943			1.7804	260.6000	0.0823	0.4165	0.5131
Arabia8	291	0.1049			1.6234	257.6167	0.0521	0.4480	0.5307
Arabia9	166	0.1125			1.7173	256.5333	0.0637	0.4204	0.5253
UAE1	208	0.1082			1.6708	259.8250	0.0521	0.4399	0.5297
Sudan2	598	0.0943			1.3186	253.8250	0.4083	0.4648	0.5623
Sudan3	370	0.1202			1.4489	256.5250	0.4261	0.4038	0.4949
Sudan4	558	0.0523			1.1468	255.0333	0.0474	0.4402	0.5261
Niger4	608	0.1321			1.1689	259.8250	0.1003	0.4503	0.5379
Australia_1	115	0.1841			1.8003	266.0500	0.4872	0.2596	0.3946
Australia_2	78	0.1853			1.7476	266.8167	0.4872	0.2924	0.4225
Australia_3	136	0.1853			1.7476	266.8167	0.4872	0.2541	0.3853
Australia_4	26	0.3139			1.6237	285.5750	0.3536	0.3167	0.4253

Table 121: mean of geophysical properties of Chinese LNES

Site name	Altitude (m)	Cloud Fraction	Aerosol optical Thickness	Angstroem exponent	Water vapour content (g/cm2)	Ozone content (Dobson)	Precipitation (mm/j)	Albedo VIS (0.685µm)	Albedo NIR (0.865 µm)
China_1	1238	0.5553			1.1679	309.2250	0.2869	0.2817	0.3098
China_2	1298	0.5191			0.9359	303.9750	0.2869	0.2880	0.3211
China_3	1232	0.5312			1.0192	310.6083	0.2869	0.2982	0.3336
China_4	1074	0.5469			1.0744	312.1167	0.2869	0.2872	0.3221
China_5	1085	0.5469			1.0744	312.1167	0.2605	0.3008	0.3271
China_6	1274	0.5398			1.0405	308.3250	0.2605	0.3098	0.3427
China_7	1201	0.5220			1.0196	311.0917	0.2605	0.2882	0.3167
China_8	1131	0.5505			1.0169	313.1583	0.2605	0.2996	0.3254
China_9	1047	0.5408			1.0083	315.2750	0.3067	0.2991	0.3204
China_10	1017	0.5544			1.1010	315.8667	0.3067	0.2994	0.3206
China_11	993	0.5548			1.0711	317.6417	0.2562	0.2986	0.3220
China_12	1171	0.5010			0.9878	313.3083	0.2049	0.2876	0.3168
China_13	1093	0.5276			1.0131	316.0333	0.2049	0.2863	0.3171
China_14	1192	0.4957			0.9739	313.2333	0.2049	0.2899	0.3210
China_15	983	0.5069			1.0118	317.5000	0.2049	0.2964	0.3323
China_16	924	0.5304			1.0541	320.8333	0.2562	0.3006	0.3312
China_17	1059	0.5069			1.0118	317.5000	0.2049	0.2923	0.3255
China_18	1646	0.5134			0.6188	297.1167	0.2359	0.2904	0.3151
China_19	916	0.5003			1.0553	322.6750	0.2437	0.3001	0.3281
China_20	1046	0.5023			0.9931	317.8583	0.2359	0.2925	0.3217
China_21	866	0.5086			1.0471	322.5917	0.2437	0.2992	0.3294
China_22	859	0.5285			1.0402	319.7583	0.1705	0.2969	0.3267
China_23	804	0.5266			0.9825	314.6083	0.2717	0.3235	0.3511
China_24	822	0.5045			1.0004	319.0417	0.1705	0.3166	0.3418
China_25	807	0.5045			1.0004	319.0417	0.1705	0.3166	0.3418
China_26	1210	0.4432			0.8036	307.4917	0.2419	0.2720	0.2977
China_27	1472	0.4432			0.8036	307.4917	0.2419	0.2569	0.2873
China_28	1157	0.3783			0.9212	317.9000	0.1836	0.2590	0.2739
China_29	1365	0.4325			0.7834	314.5333	0.2969	0.2261	0.2505
China_30	1247	0.4001			0.8809	313.2333	0.2264	0.2424	0.2779
China_31	1253	0.4933			0.8934	314.3333	0.2264	0.2644	0.3010
China_32	1127	0.4933			0.8934	314.3333	0.2264	0.2596	0.2933
China_33	1514	0.5643			0.9143	303.5583	0.5482	0.2651	0.3156
China_34	1760	0.5643			0.9143	303.5583	0.5482	0.2470	0.3240
China_35	1308	0.6341			0.8745	312.9583	0.5482	0.2954	0.3505
China_36	1126	0.6085			0.9278	313.8083	0.6396	0.3080	0.3602
China_37	1030	0.6085			0.9278	313.8083	0.4285	0.3225	0.3778
China_38	1180	0.6212			0.9534	318.7583	0.6659	0.2805	0.3337

6.2.3 SES

Table 122: mean of geophysical properties of Chinese SES

Site name	Cloud Fraction	Aerosol optical Thickness (550nm)	Angstroem exponent	Water vapour content (g/cm2)	Ozone content (Dobson)	LNW440	LNW560	Chl-a	k490	Windspeed
Boussole	0.4609	0.2	1.5	1.8272	326.1583					6.3017
MOBY	0.3610	0.076 (500)	0.705	3.3880	270.3500					7.7583
OC_Aeronet : AAOT	0.5521	0.06	0.7	3.5336	270.8167	1.606	1.929			5.8842
OC_Aeronet : Abu_Al_Bukhoosh	0.5171	0.437	0.896	2.8763	287.0833	0.463	0.532			5.3350
OC_Aeronet : COVE_SEAPRISM	0.5102	0.146	1.414	2.3817	306.2417	0.321	0.142			6.5600
OC_Aeronet : Gustav_Dalen_Tower	0.6899	0.062	1.257	1.3781	340.9750	0.183	0.533			-
OC_Aeronet : Helsinki_Lighthouse	0.6839	0.125	1.44	1.3060	340.1833	0.142	0.532			7.7475
OC_Aeronet : MVCO	0.5549	0.094	1.743	1.8282	332.8000	0.534	0.921			7.4200
Kavaratti OCM	0.7076			4.4225	259.8000					5.6650

6.2.4 SNES

Table 123: mean of geophysical properties of Chinese SNES

Site name	Cloud Fraction	Aerosol optical Thickness	Angstroem exponent	Water vapour content (g/cm2)	Ozone content (Dobson)	LNW440	LNW560	Chl-a	k490	Windspeed
PacSE	0.7426	0.1037	0.5520	2.4209	288.6584	2.0595	0.2875	0.0670	0.0224	7.6567
PacSE-0	0.8495	0.1264	0.3854	1.6193	313.8063	1.6212	0.3152	0.1160	0.0277	9.0318
PacSE-1	0.8320	0.1178	0.4786	1.8053	303.1137	1.6913	0.3086	0.1017	0.0267	8.1810
PacSE-2	0.8037	0.1129	0.4892	2.1156	297.4622	1.7725	0.2930	0.0869	0.0257	8.0236
PacSE-3	0.7309	0.1007	0.5174	2.6503	284.4677	2.2142	0.2631	0.0451	0.0200	7.6445
PacSE-4	0.7290	0.0974	0.6474	2.4607	285.8017	2.0098	0.2887	0.0668	0.0237	7.0056
PacSE-5	0.7402	0.0890	0.7621	2.3095	287.9685	1.8895	0.3060	0.0838	0.0269	6.7271
PacSE-6	0.6345	0.0906	0.6263	3.0116	273.2610	2.4109	0.2684	0.0364	0.0202	7.1465
PacSE-7	0.7067	0.0851	0.7284	2.6094	272.7234	2.1547	0.3016	0.0618	0.0245	6.9172
PacNW	0.6134	0.1179	0.5344	4.4772	258.9688	2.2360	0.2705	0.0397	0.0220	6.9767
PacNW-0	0.7513	0.1136	0.5017	4.9093	252.8656	2.2467	0.2711	0.0392	0.0213	7.0482
PacNW-1	0.6163	0.1229	0.4652	4.4630	257.5699	2.2936	0.2676	0.0357	0.0212	7.3024
PacNW-2	0.6410	0.1169	0.5926	4.5364	257.9447	2.1457	0.2711	0.0449	0.0226	6.8524
PacNW-3	0.5424	0.1129	0.6035	4.3034	263.3022	2.1982	0.2729	0.0426	0.0225	6.5723
PacN	0.5177	0.1333	0.5373	3.7017	266.9362	2.1523	0.2887	0.0508	0.0239	7.5322
PacN-0	0.5213	0.1423	0.5037	3.7509	263.4776	2.2202	0.2892	0.0467	0.0232	7.7495
PacN-1	0.5202	0.1221	0.5667	3.8036	268.6383	2.1692	0.2851	0.0477	0.0235	7.2474
PacN-2	0.5099	0.1302	0.5602	3.5315	270.7356	2.0854	0.2885	0.0550	0.0253	7.4217
AtlN	0.5518	0.1570	0.6259	3.7543	272.2533	2.1337	0.2953	0.0726	0.0245	6.5584
AtlN-0	0.5405	0.1764	0.5727	3.8167	269.1432	2.0181	0.2963	0.0976	0.0261	6.8006
AtlN-1	0.5715	0.1330	0.6889	3.7878	274.8852	2.2223	0.2939	0.0494	0.0236	6.3736
AtlN-2	0.5533	0.1410	0.6705	3.6168	275.8477	2.2812	0.2955	0.0462	0.0233	6.2522
AtlS	0.5869	0.1263	0.6057	3.0682	264.4145	2.2158	0.3030	0.0548	0.0240	7.2804
AtlS-0	0.5095	0.1184	0.5745	3.1962	264.6417	2.3044	0.2915	0.0448	0.0229	7.1358
AtlS-1	0.5652	0.1076	0.6247	2.9564	265.5106	2.3102	0.3002	0.0490	0.0233	6.8997
AtlS-2	0.5814	0.1350	0.5603	3.1294	263.4865	2.2051	0.2982	0.0512	0.0241	7.7697
AtlS-3	0.6663	0.1570	0.6304	3.1470	263.1821	2.0435	0.3170	0.0706	0.0263	7.6496
AtlS-4	0.6660	0.1223	0.6595	2.8798	264.9508	2.0329	0.3193	0.0791	0.0277	7.0188
IndS	0.6935	0.0938	0.6210	2.8176	271.8892	2.1421	0.2892	0.0564	0.0234	7.2851
GuMex	0.5861	0.1934	0.8821	3.9505	273.3880	1.5110	0.3320	0.1545	0.0367	6.5792
GuYuc	0.6286	0.1979	0.6673	4.1975	265.8244	1.6450	0.3057	0.1087	0.0295	6.8717
DoCoRi	0.7145	0.1354	0.9010	4.5012	259.8857	1.5775	0.3176	0.1257	0.0350	6.3215
MedCr	0.4268	0.2229	0.8019	2.2292	299.7653	1.6609	0.3139	0.1091	0.0308	6.5424
MedCy	0.4492	0.2374	0.8597	2.1632	301.6542	1.6646	0.3172	0.1192	0.0316	5.3854
GuAlas	0.8851	0.2544	0.5694	1.7247	343.3214	1.0630	0.3917	0.3536	0.0599	9.2767
Hawaii	0.4859	0.1518	0.6977	3.4632	267.4681	1.9542	0.2953	0.0682	0.0260	7.5872
AustS	0.8168	0.1301	0.4614	1.6529	313.9833	1.2521	0.3916	0.2579	0.0509	9.0377
MadE	0.6038	0.0994	0.6228	2.8505	278.7015	1.9620	0.2832	0.0678	0.0241	7.1197
MadE-0	0.6082	0.1129	0.5845	3.0351	279.3175	1.7539	0.2869	0.0864	0.0260	7.4532
MadE-1	0.5888	0.1043	0.6064	2.9422	279.2088	1.8593	0.2857	0.0761	0.0248	7.3205
MadE-2	0.6022	0.0968	0.6280	2.8457	278.8679	1.9865	0.2837	0.0647	0.0238	7.0963
MadE-3	0.6093	0.0925	0.6448	2.7297	278.1283	2.1061	0.2798	0.0556	0.0229	6.8657

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