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HYPERNETS Vicarious calibration feasibility study

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IVOS meeting 29/09/2023

HYPERNETS in a single slide

2023-2027

INSTRUMENTS

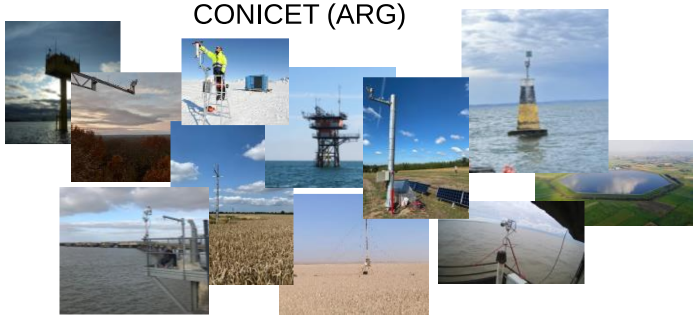
Automated hyperspectral measurements

PANTHYR system
[Vansteenwegen et al, 2019]
400-900nm, 10nm FWHM

HYPSTAR® system
[https://hypstar.eu/]
380-1700nm, 3-10nm FWHM

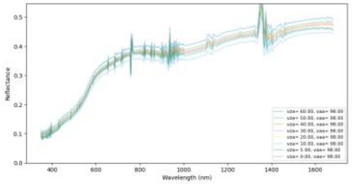
NETWORK

RBINS (BE, coordinator)
+ VLIZ (BE), CNR (IT), LOV (FR), NPL (UK), GFZ (D), TARTU (ES), CONICET (ARG)



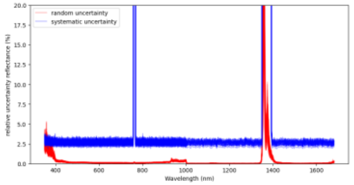
8 water and 8 land sites operating/ed
+7 water +4 land by April 2023
Many international requests to join in 2023

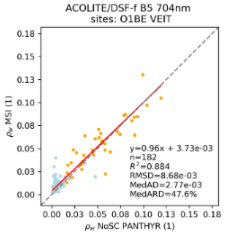
DATA PROCESSING and ANALYSIS



e.g. reflectance

uncertainties





one band (S2/704nm), many matchups

First data publicly available on Zenodo:

https://zenodo.org/search?page=1&size=20&q=HYPERNETS

Prototype network has provided validation data and information to:

Sentinel-2A&B, Sentinel-3A&B/OLCI, Landsat-8&9, Planetscope Doves and Superdoves, PRISMA, Pléiades, ENMAP, MODIS-A&T, VIIRS-1&2,...

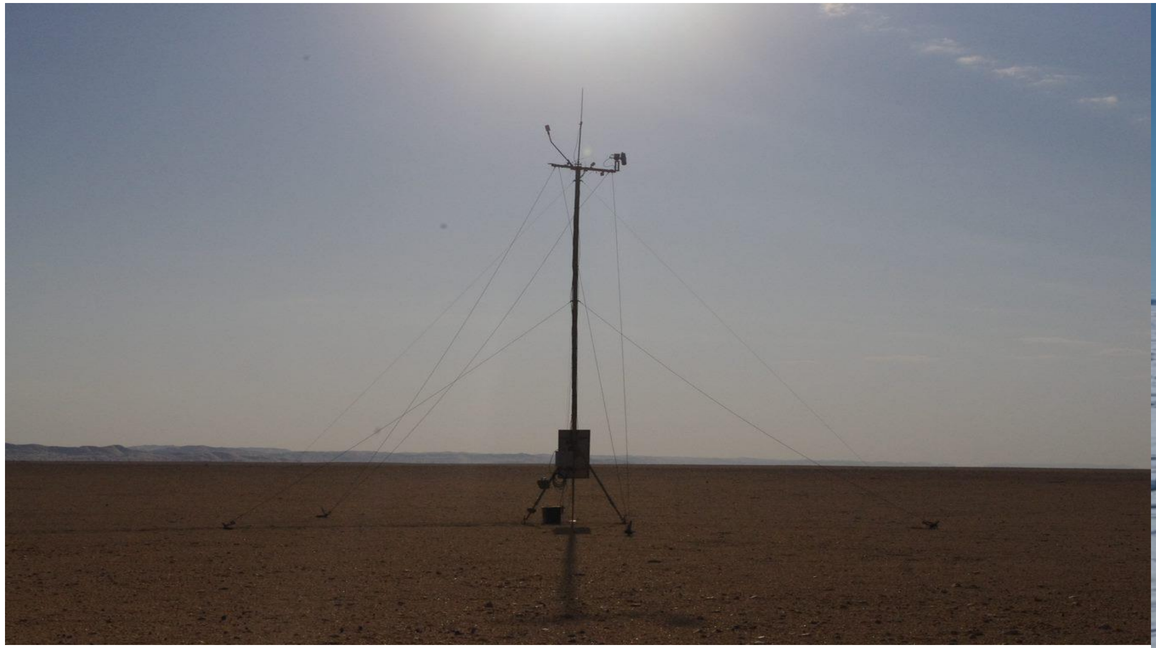
and preparing for:

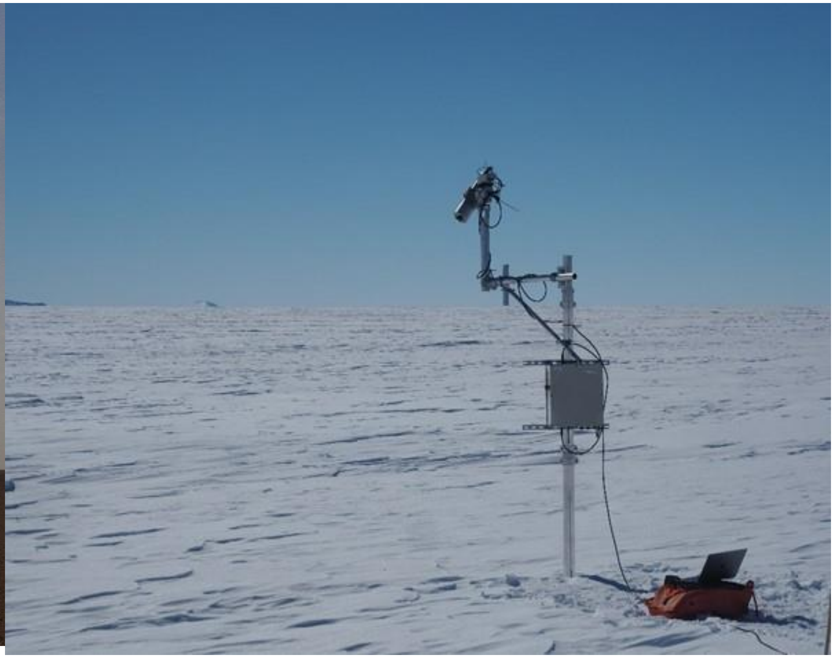
ACIX, DESIS, MTG and SEVIRI, EMIT, CHIME, LSTM, PACE, GLIMR, SBG, PROBAV-CC, GOCI, SABIAMAR, various Newspace, ... (national hyperspectral imagers from Canada, Norway, Australia, ...)

OBJECTIVE: To validate **all** VIS/NIR spectral bands (400-1700nm, @3-10nm FWHM) for **all** satellite missions measuring water or land surface reflectance

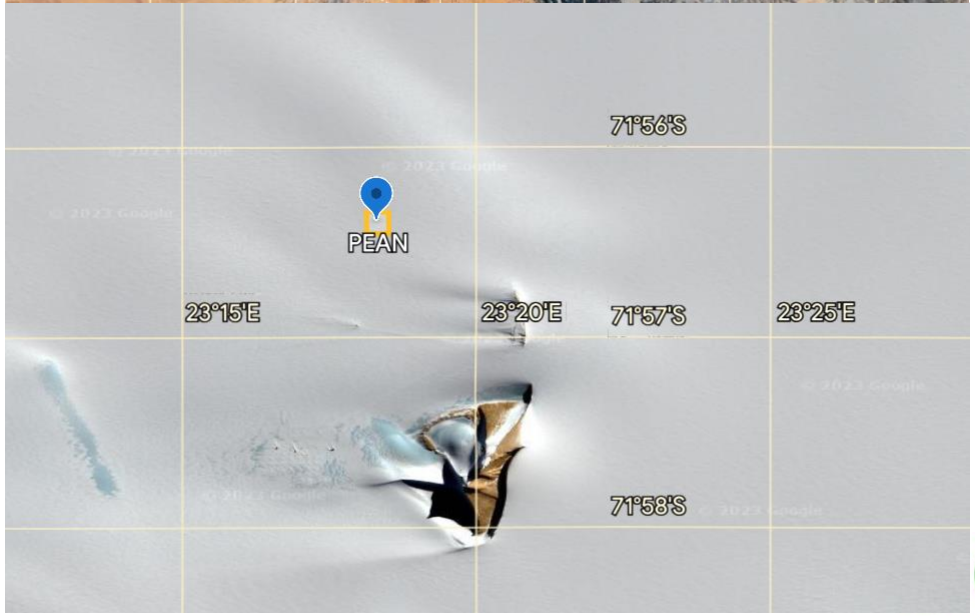
HYPERNETS vicarious calibration study

- As a network of continuously measuring hyperspectral instruments, HYPERNETS is ideally suited to multi-mission vicarious calibration.
- GHNA (Gobabeb, Namibia) is ideal site for vicarious calibration due to spatial and temporal stability – DOI: 10.5281/zenodo.8039303
- PEAN (Princess Elisabeth, Antarctica) also has good potential, but is more affected by shadowing due to low sun and uneven surface





Satellite data used



Google Earth Images

- Matchups with HYPERNETS found and downloaded using automated system
    - Download of PRISMA is manual
    - Compare to RadCalNet when also available

- 200 m cutout over HYPERNETS location used

- Good quality matchups for GHNA over 5 month period:
    - Sentinel-2 (A&B): 9 (5 with RadCalNet)
    - Landsat-8/9: 6 (3 with RadCalNet)
    - PRISMA: 4 (2 with RadCalNet)

TOA processing overview

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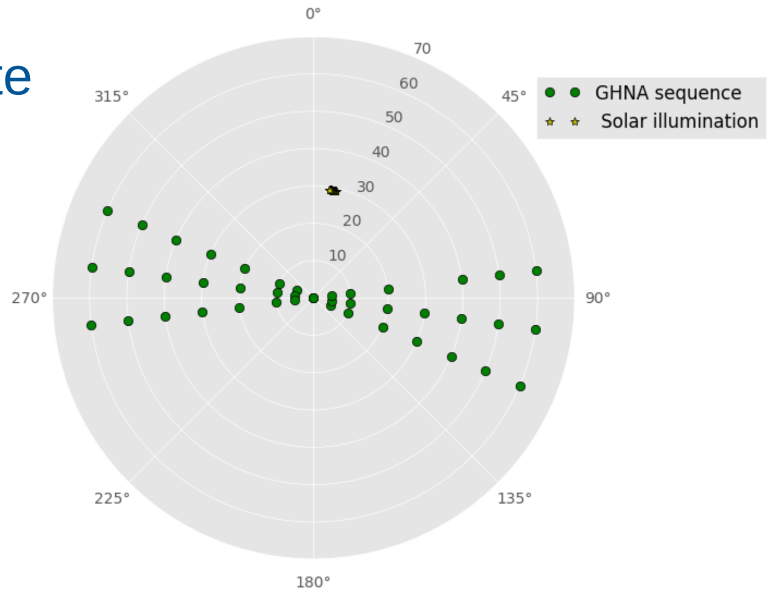
Before the HYPERNETS data can be compared to satellite observations, the following steps need to be applied:

- Read/select satellite data and HYPERNETS data for appropriate angle
- Apply the atmospheric correction based on radiative transfer modelling
  - Atmospheric parameters at time of overpass
    - taken from RadCalNet for GHNA when available
    - For PEAN, and when RadCalNet data is unavailable: ERA5 reanalysis + AERONET
- Convolve the TOA spectrum with the satellite SRF
- Propagate uncertainties
- Compare



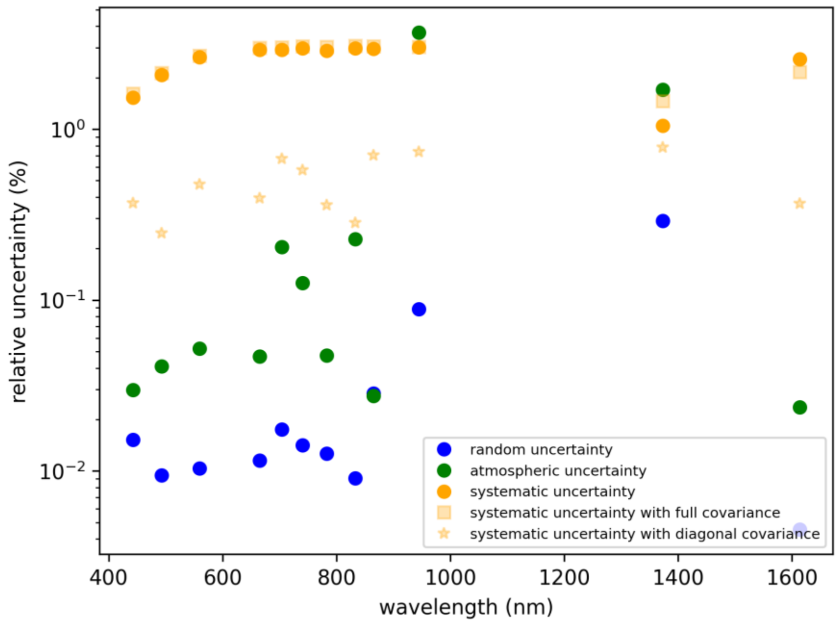
Uncertainties

- Metrological approach is used to propagate uncertainties through a given measurement function using MC.

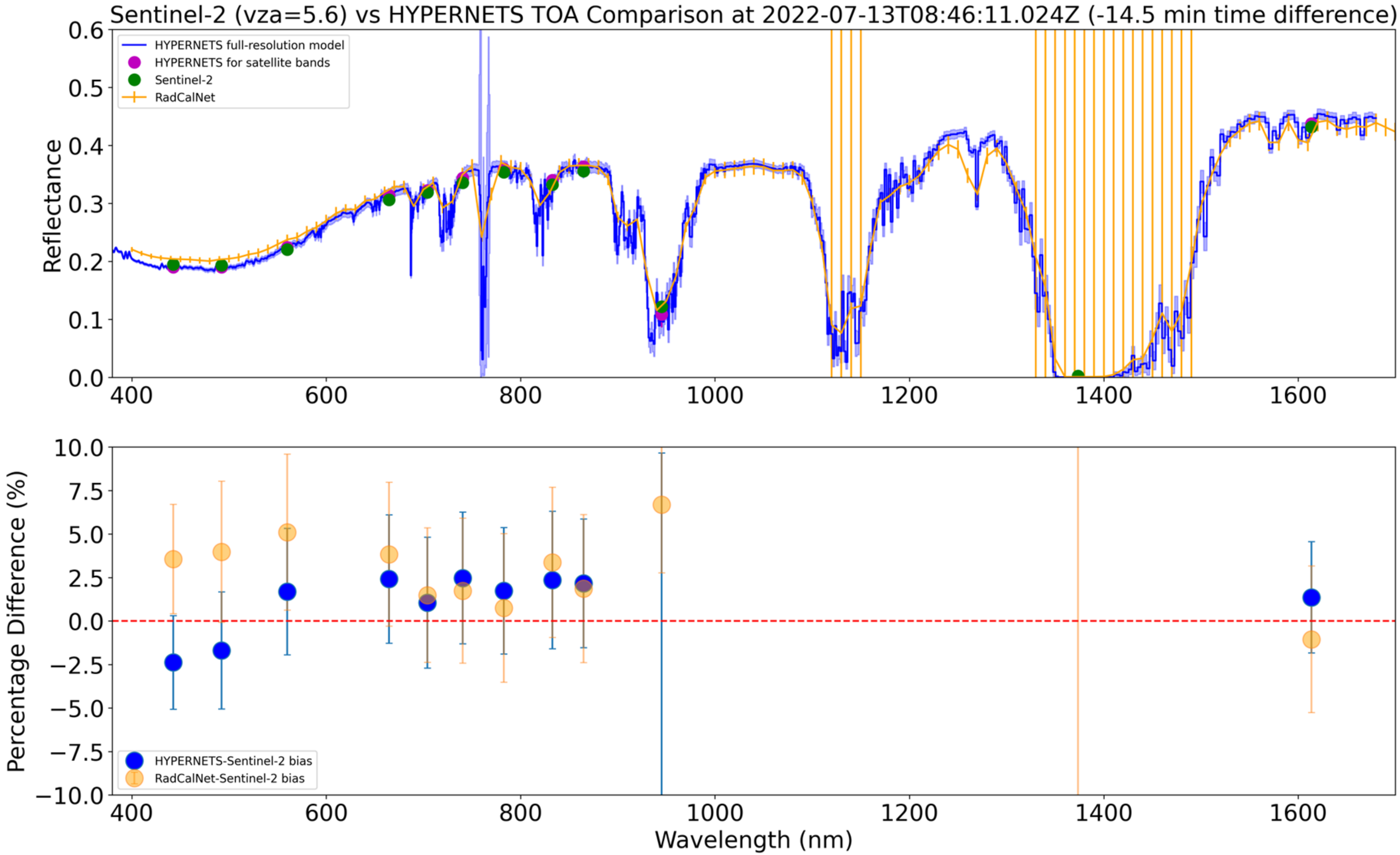
- CoMet toolkit (punpy) is used to propagate uncertainties through python measurement function
  - Random uncertainties from L2A product
  - Systematic uncertainties from L2A product (including covariance matrix)
  - Uncertainties on atmospheric parameters

- Satellite uncertainties from std between pixels
  + 2% systematic uncertainty

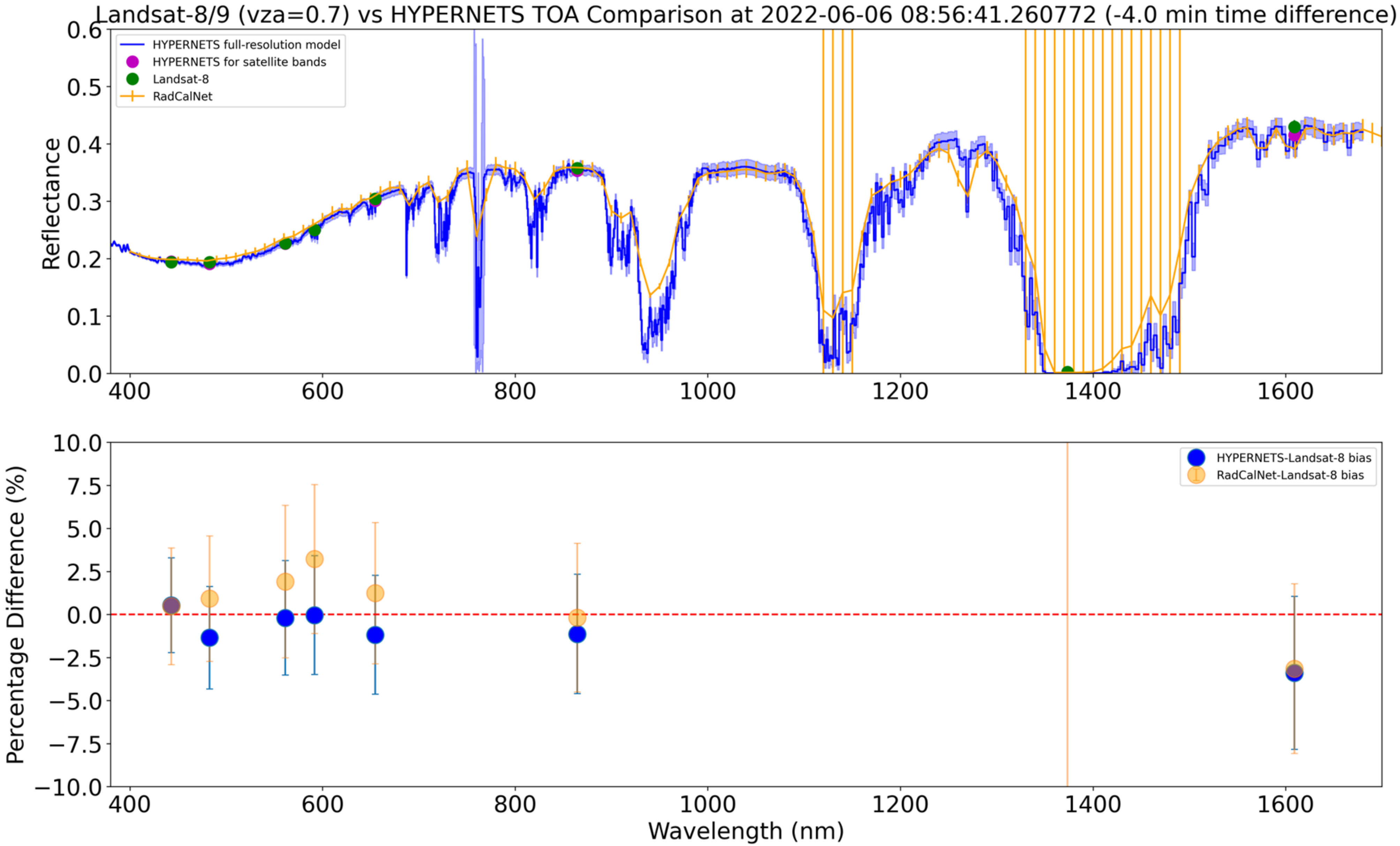
- Error-correlation information taken into account



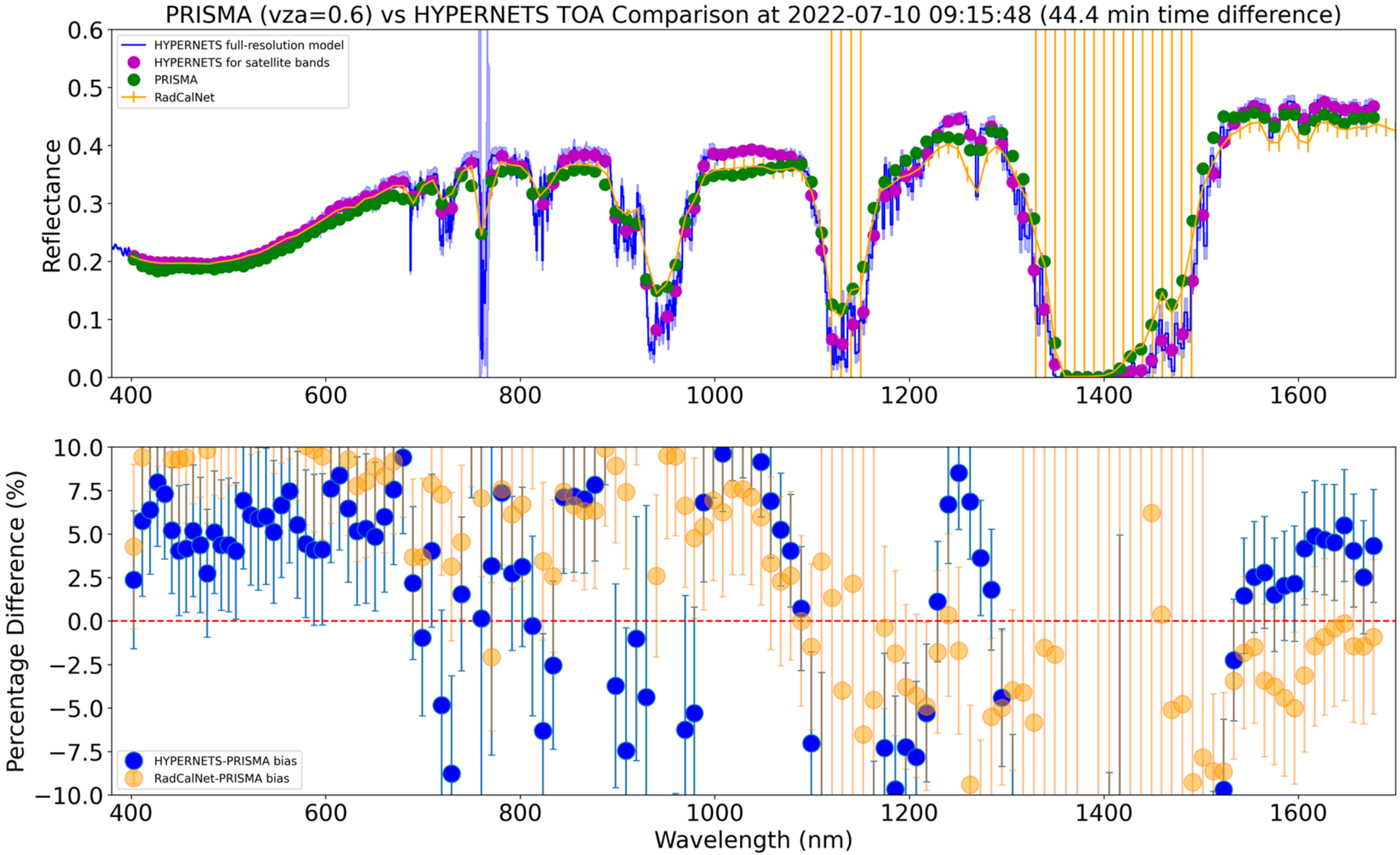
Comparing S2B, HYPERNETS & RadCalNet



Comparing L8, HYPERNETS & RadCalNet

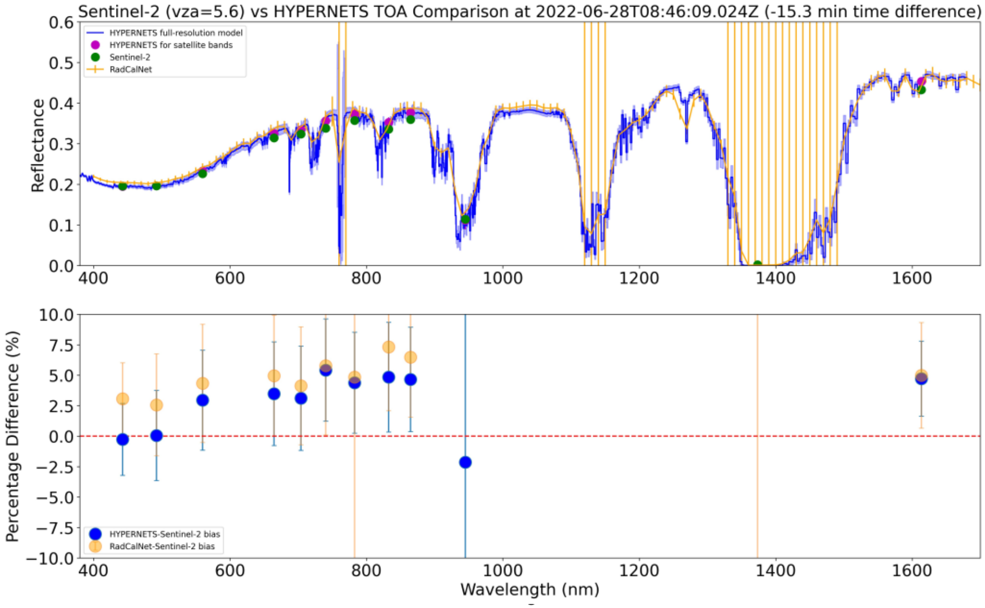


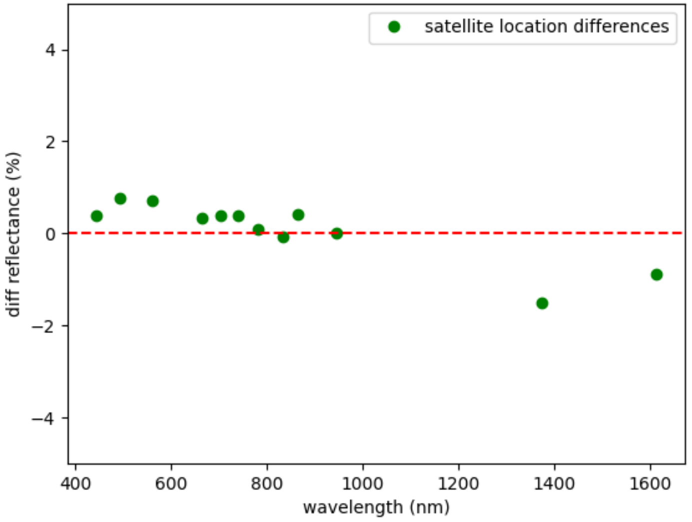
Comparing PRISMA, HYPERNETS & RadCalNet



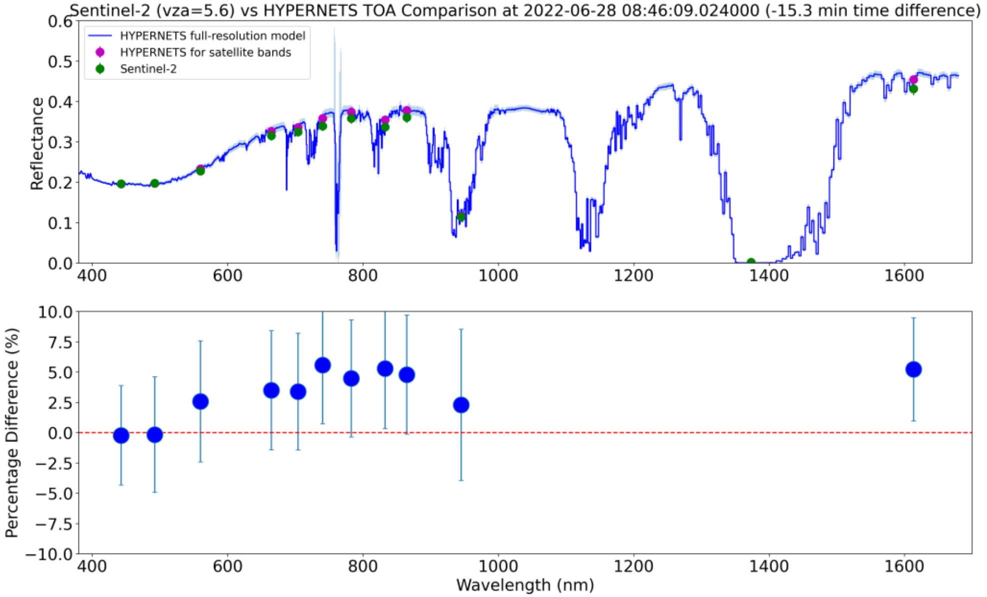
Differences between GHNA and GONA

- Sites are located 700 m from each other & differ < 2%
- Results differ by few percent due to small differences in atmospheric properties
  - RadCalNet parameters used when available
  - If not, AERONET + ERA5 data is used
- RadCalNet uses nadir, HYPERNETS results use nearest vza
- Results differ due to different RT code used



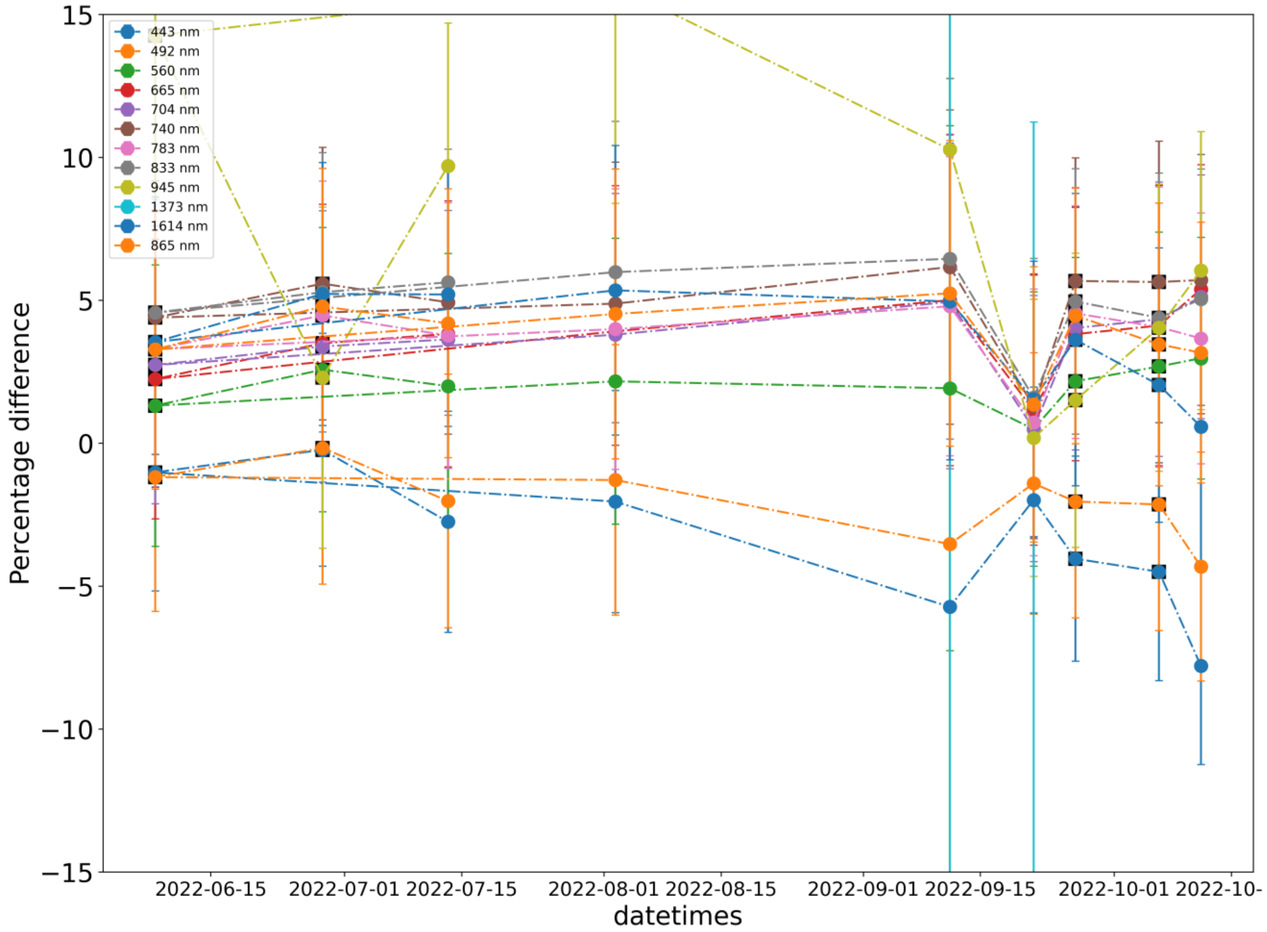


parameter	GHNA	GONA
AOD	0.0454	0.062
angstrom	1.05	0.983
H2O (mm)	13.0	13.8
O3 (DU)	269	261
Pressure (hPa)	967	960

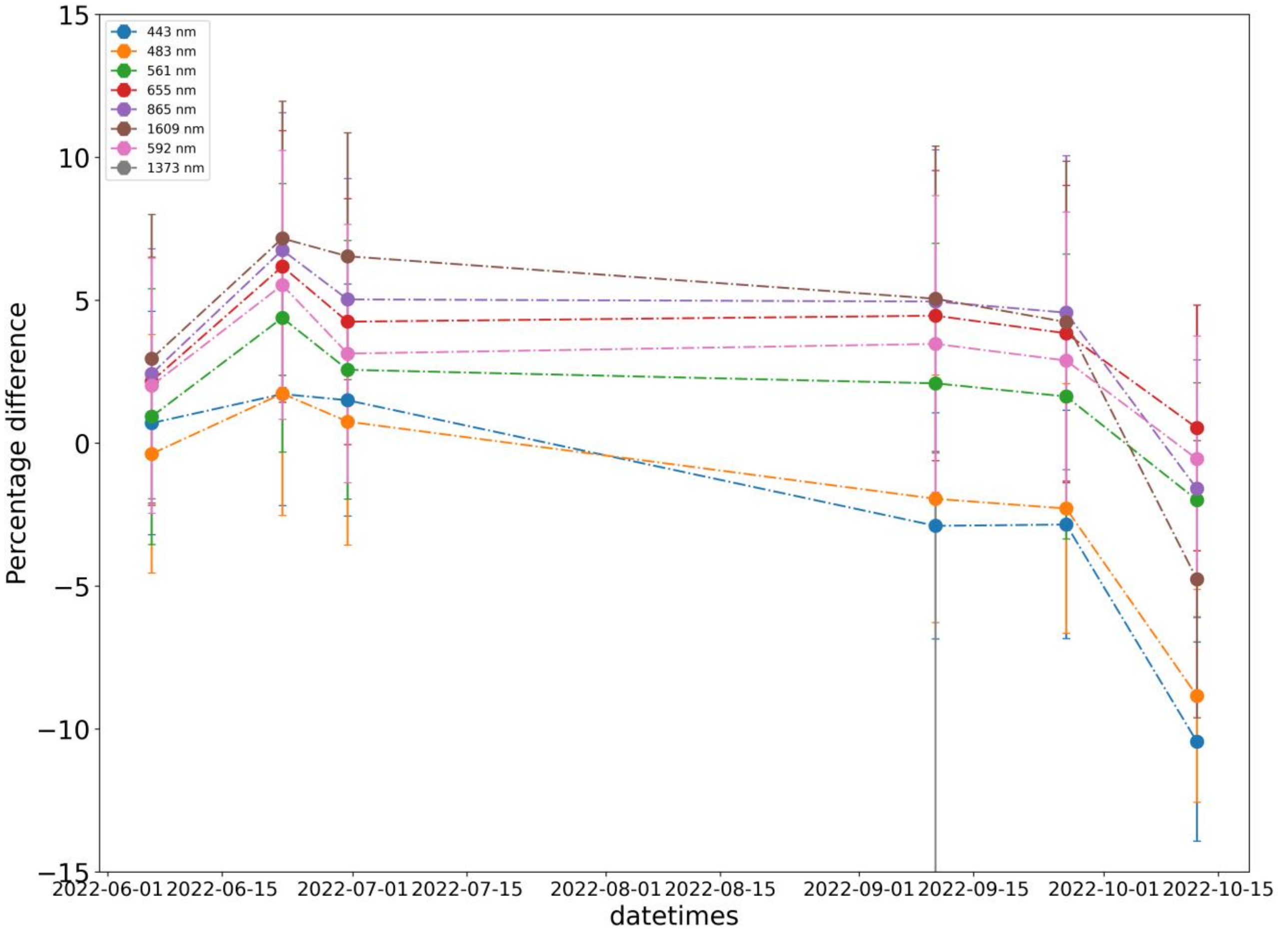


GHNA bias time-series

Sentinel-2



Landsat-8



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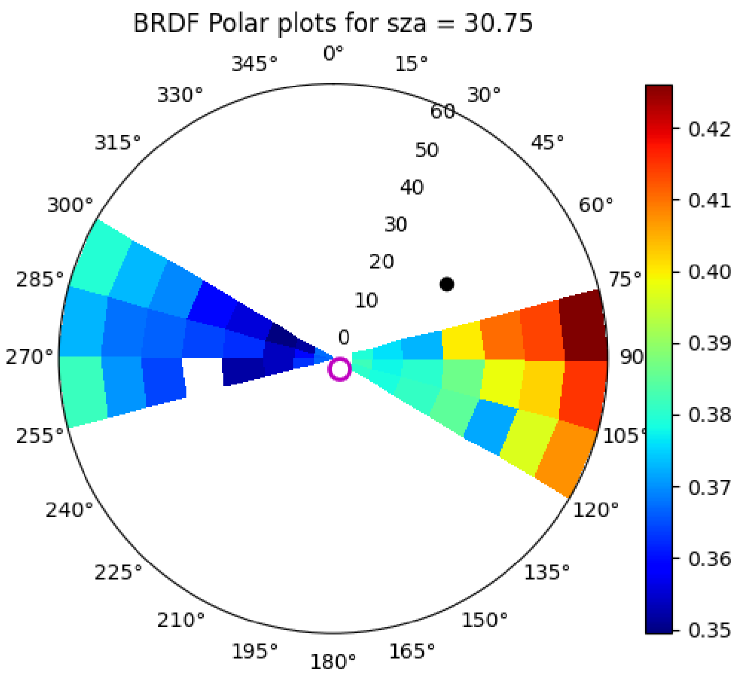
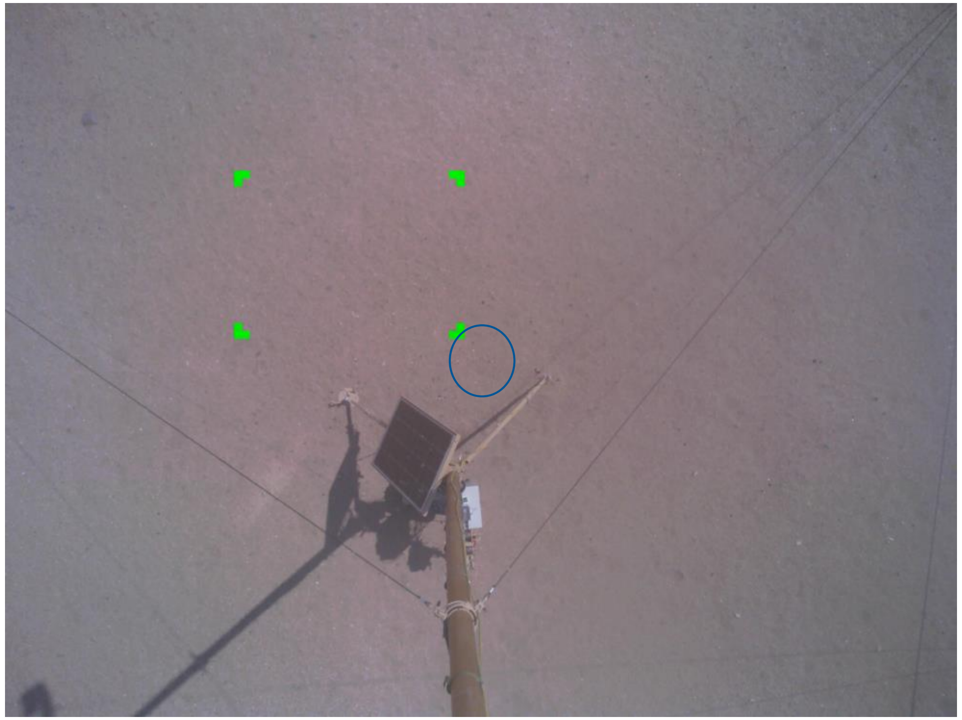
GHNA Caveat

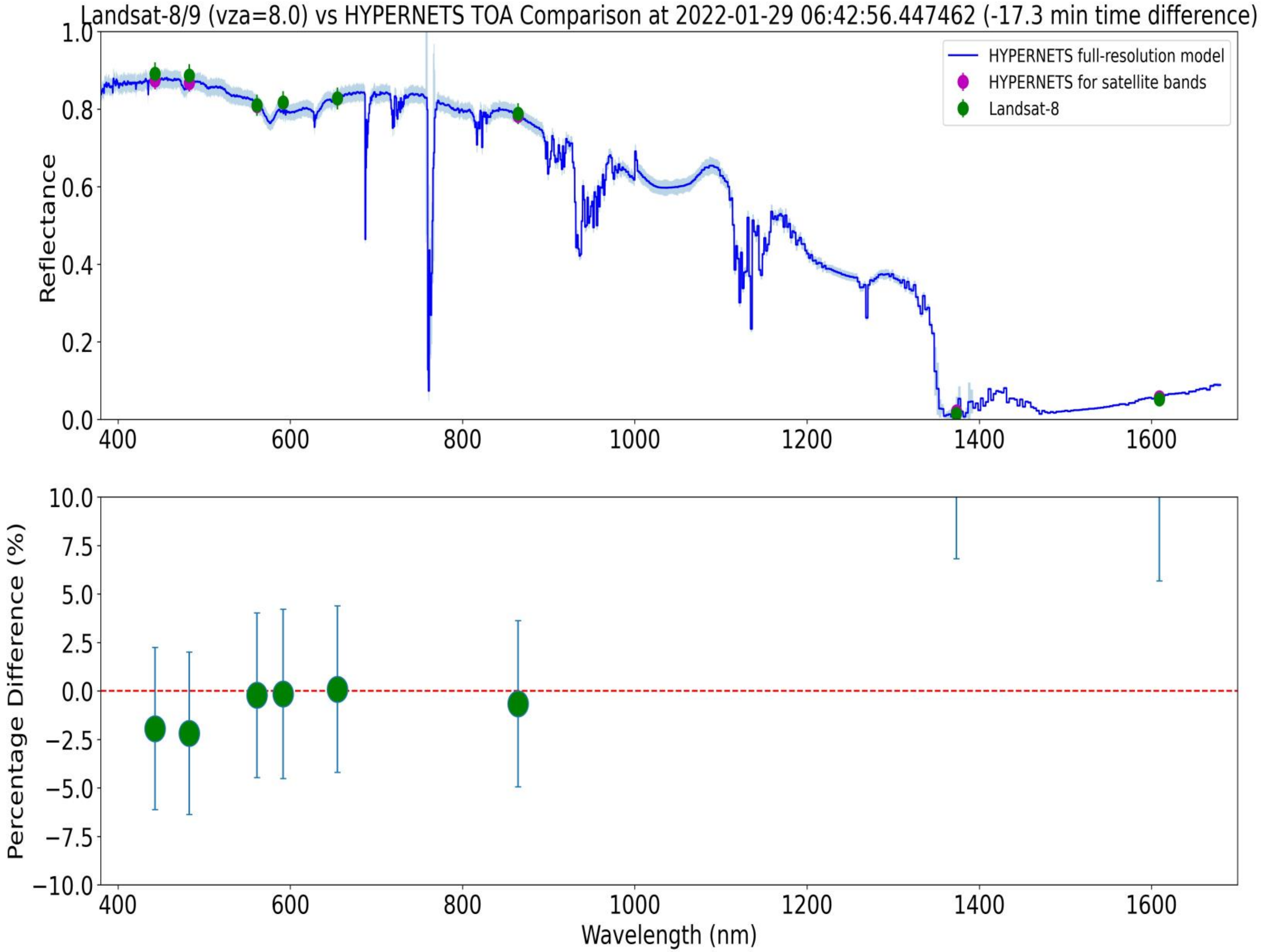
- Due to limited size of boom (~1m) compared to field of view of instrument (~ 0.5m radius), there is a risk of contamination of field of view by mast legs and solar panels.

- BRDF model can be fitted to identify outliers relative to model, and interpolate over masked values



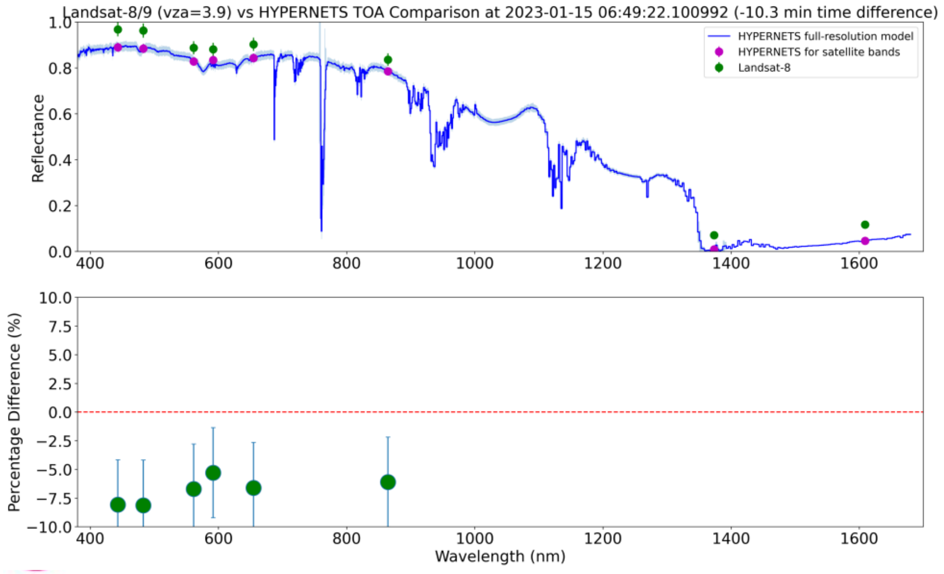


PEAN vs Landsat 8



Good example shown, but most matchups are significantly worse.

Many matchups are significantly underestimated/overestimated due to uneven surface & shadowing

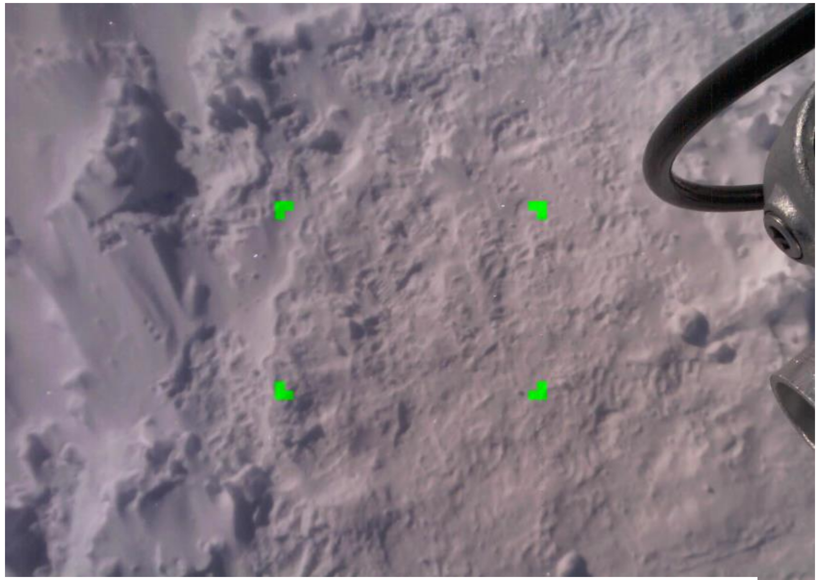


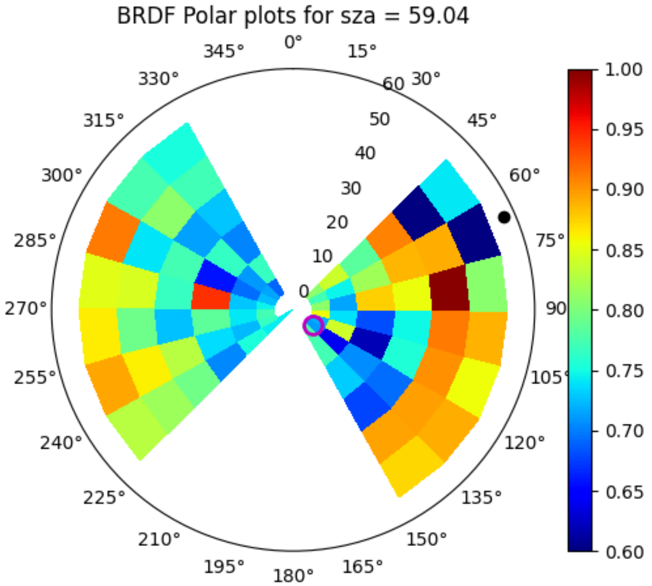
Difficult PEAN surface

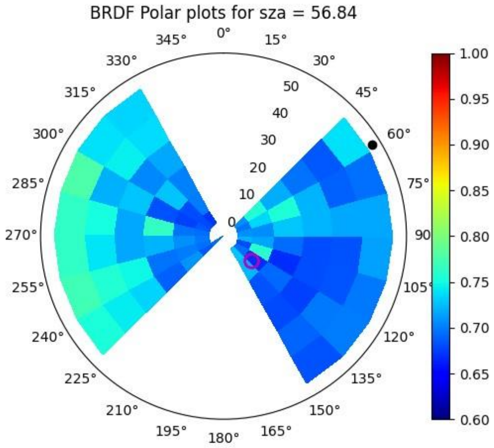
- Even though at large spatial scales, the surface is homogeneous, it is heterogeneous at small scale (~0.2 m FOV) due to shadowing (typically low sun)

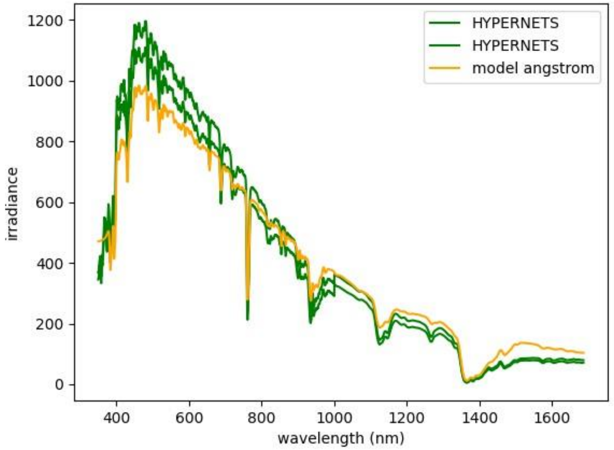
- Either the instrument should be placed significantly higher or BRDF model should be fitted and used to smooth the data

- Cloudy scenes show much less variability, but still have high irradiance.









Avenues for future work

- Fitting BRDF models to the HYPERNETS data and identify outliers with respect to the BRDF

- Fit atmospheric parameters to HYPERNETS irradiance data so that self-consistent atmospheric params are always available (as opposed to needing to use reanalysis data).

- Mitigate the effects of angular alignment, contamination by mast in field of view, surface disturbances (especially when combined with low solar zenith angle for PEAN),

Conclusions

- GHNA site performs well for vicarious calibration, with biases <5% for both S2 and L8/9
- GHNA has similar performance to GONA
- PEAN has good potential for vicarious calibration, but is significantly affected by heterogeneity due to surface shadowing
- Improvements expected from longer time-series, fitting BRDF, masking outliers (e.g. contamination from mast) and having consistently derived atmospheric params
- See De Vis et al. (in prep.)