



Results of Sensor comparison using Tuz Gölü salt lake, Ankara, Turkey

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Objective

- The objective is to compare the satellite data using a methodology (Mackin, et. al., 2010) that removes biases due to sun-target-sensor geometry and atmospheric effects, so that different sensors with different overpass times and different spatial and spectral characteristics collected on different days over the same site can be directly compared.

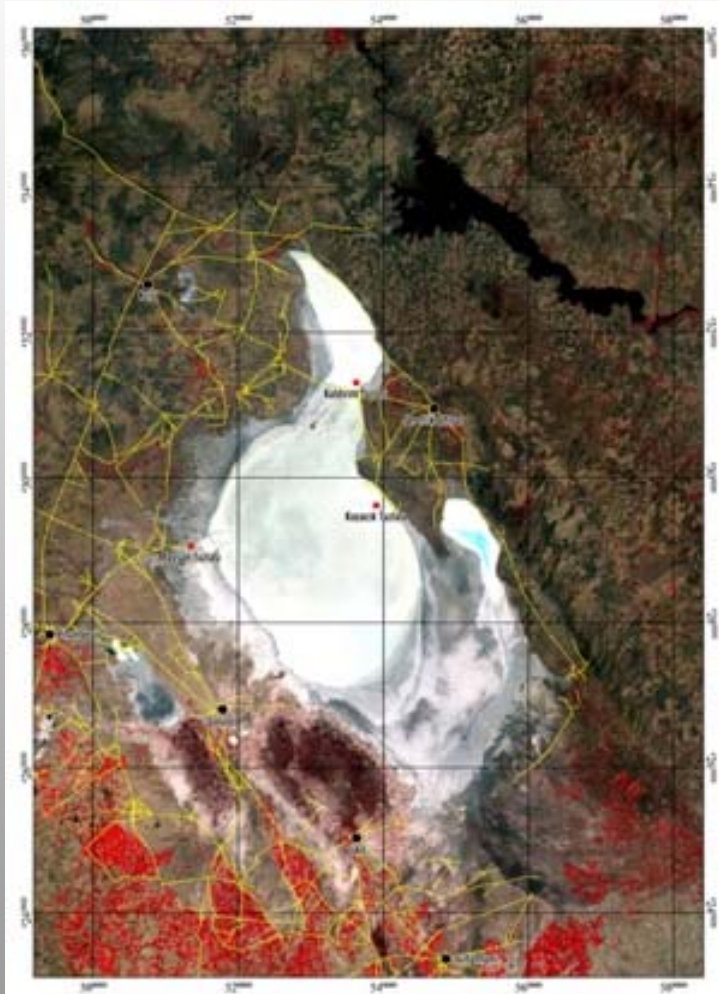


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Site Description

- Landnet Site: Tuz gölü salt lake



DMC-UK image (24.08.2008)

Location: 38 50'N, 33 20'E
Central Anatolia, Turkey

Elevation: 907 m

Total area: 1964 km²

Surface type: Salt lake

Atmospheric conditions: Sunny and mostly cloud-free in dry season (July-August). Low aerosol loading.

Properties: A bright natural target, free of vegetation.

It is extremely saline and during the summer %95 of water in the lake dries up and exposes an average of 30-80 cm thick salt layer.



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SENSOR COMPARISON STUDY



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Sensor Comparison Study

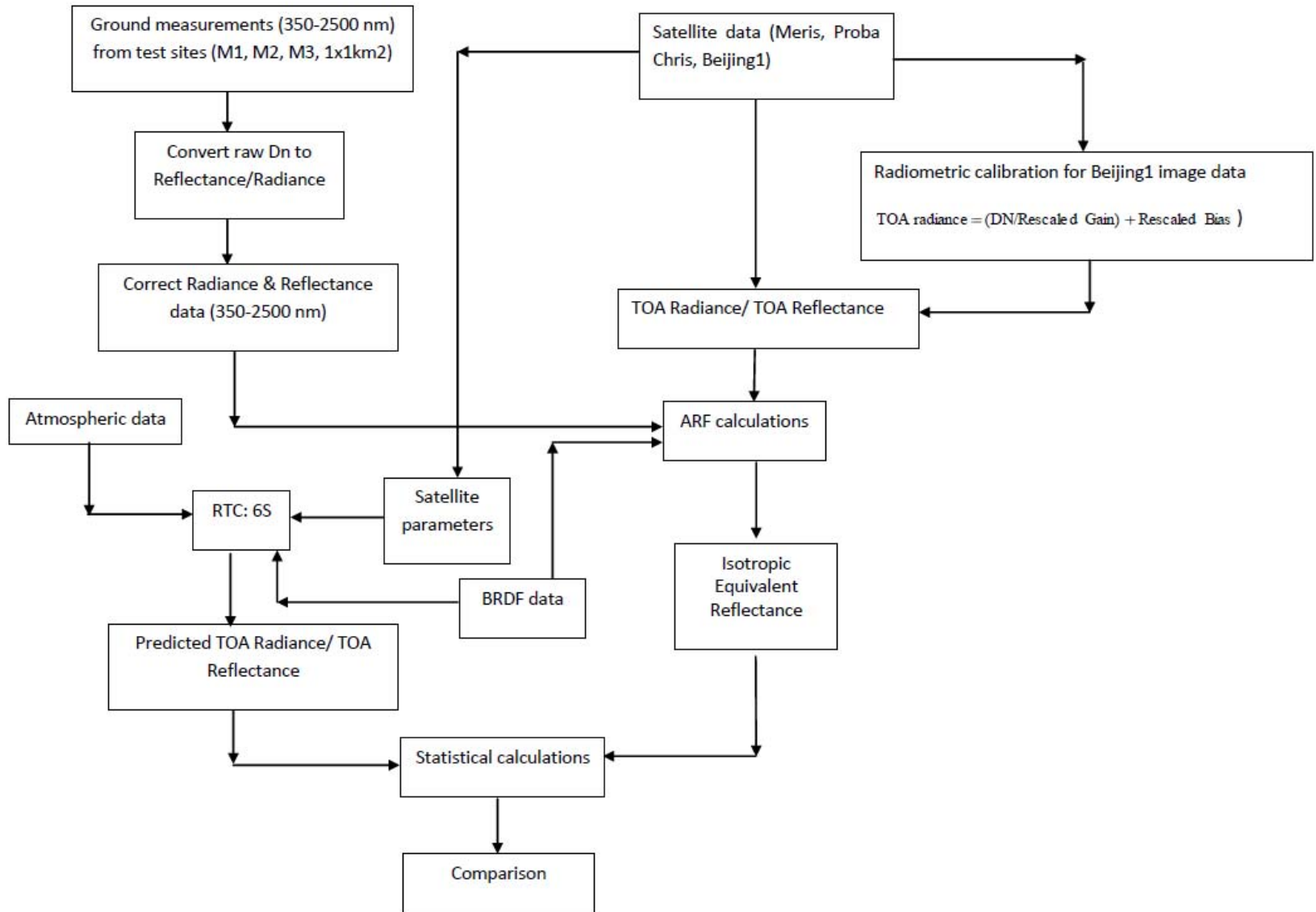
- Ground-based spectral measurements collected during the field measurement campaign in August 2009 at the Tuz Gölü, calibration test site in Turkey, are compared with satellite data of low and medium resolution sensors using a methodology (Mackin, et. al., 2010) that removes biases due to sun-target-sensor geometry and atmospheric effects.



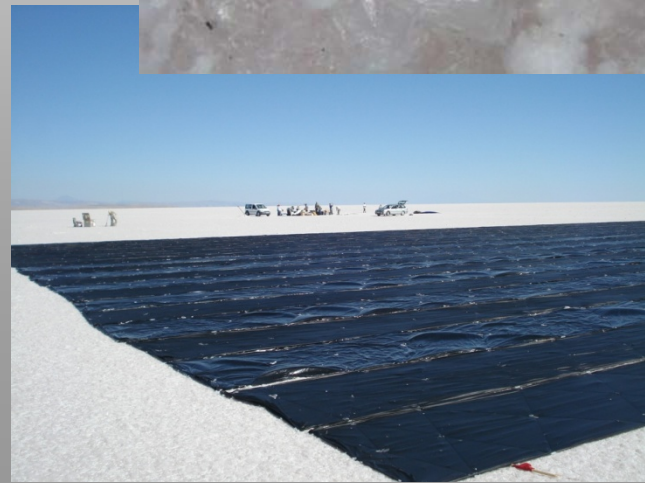
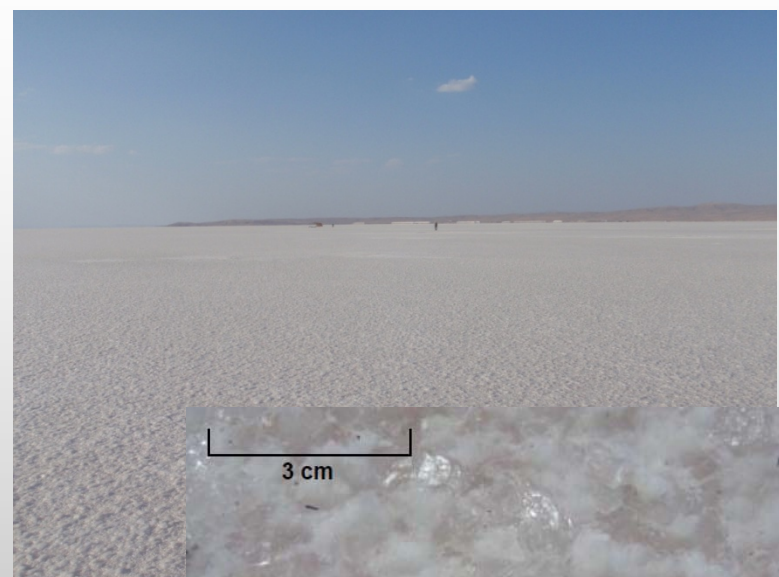
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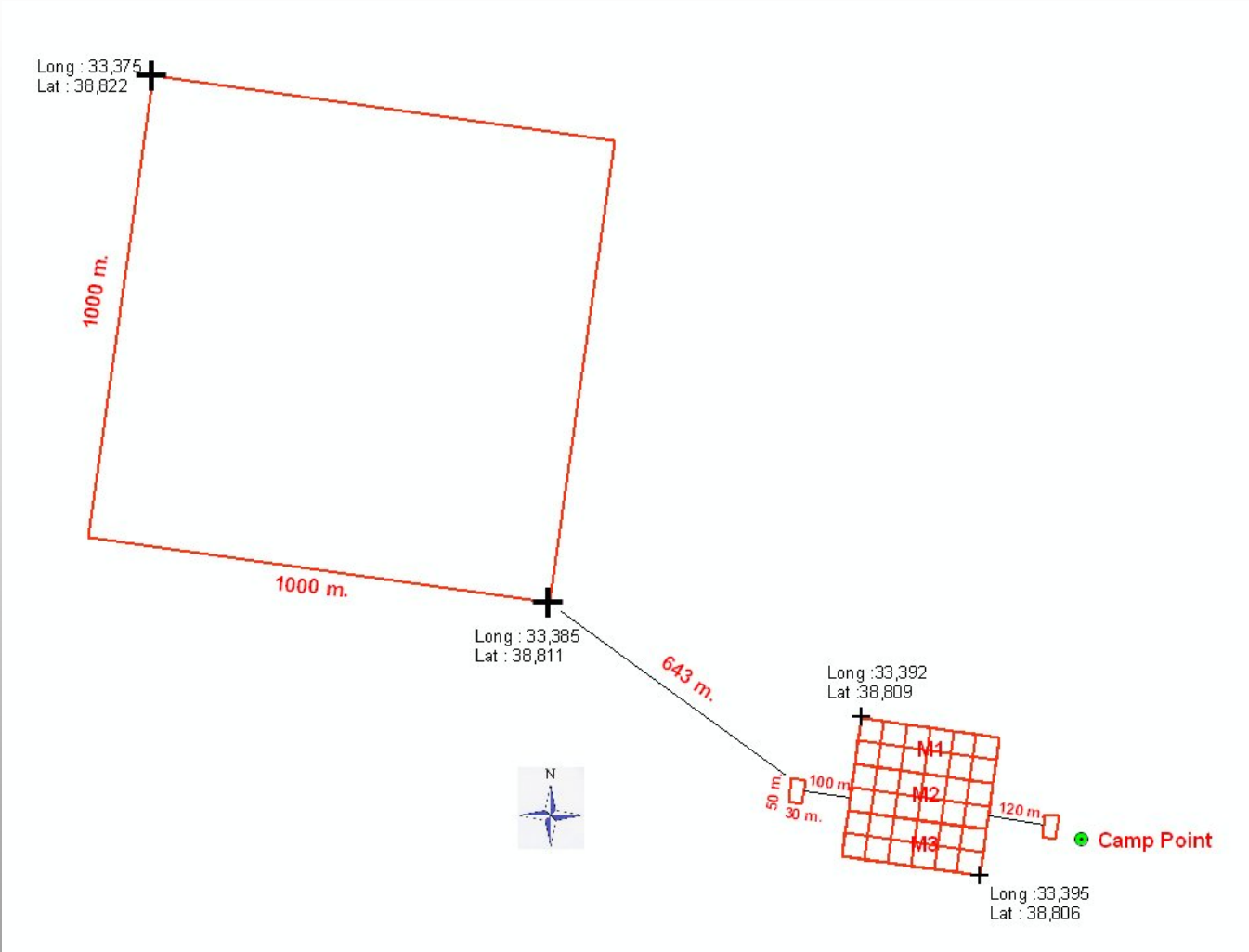
Comparison Methodology



Measurement Site of 2009 Campaign



Measurement Site of 2009 Campaign



- Three areas of 100 m x 300 m and one area of 1 km x 1km nearby
- Tarpaulins are 100 m and 120 m away from the sites of 100 m x 300 m
- The measurement site is located 8 degrees from North

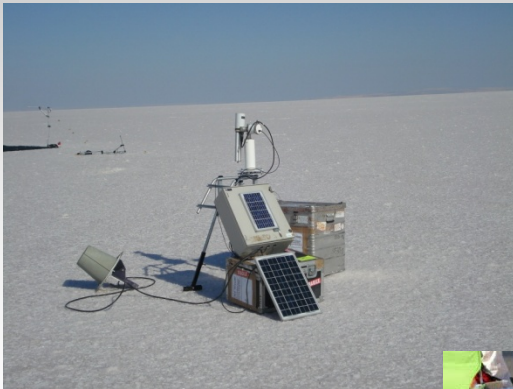
Sensor Comparison Study

- The ground reflectance values were obtained with the ASD Fieldspec3 spectroradiometer during 25th August– 01st September 2009 field campaign

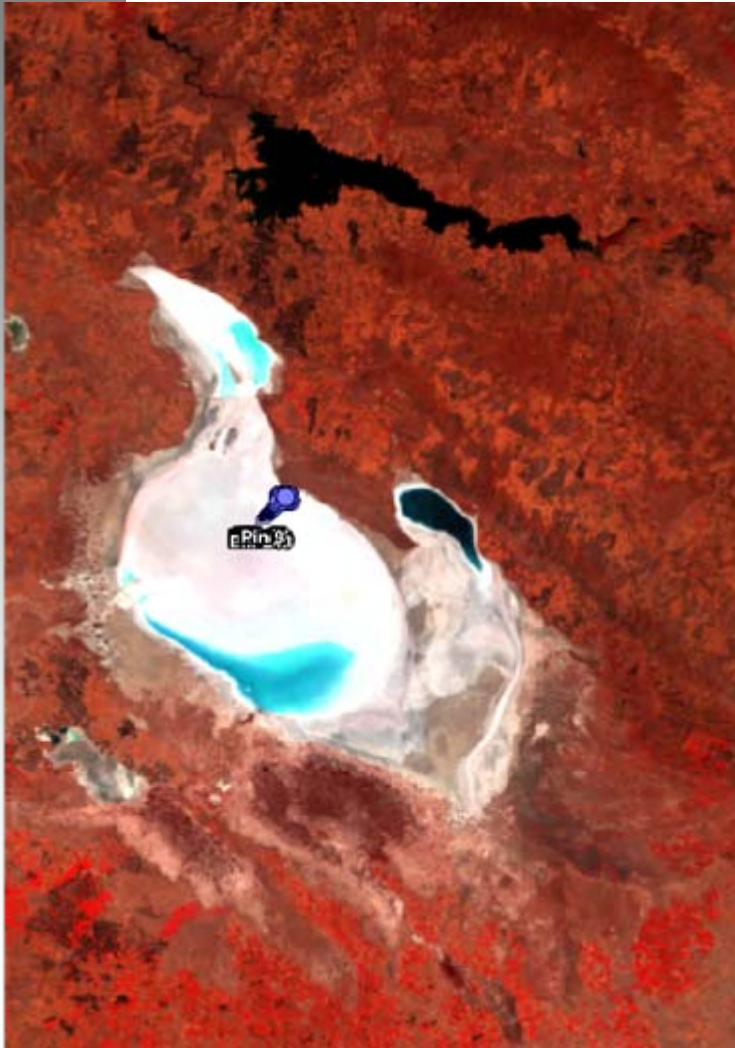


Sensor Comparison Study

- BRDF measurements are done by the GRASS instrument (NPL)
- Atmospheric data has been collected with the CIMEL (CNES) and MICROTOPS (DLR) sunphotometers

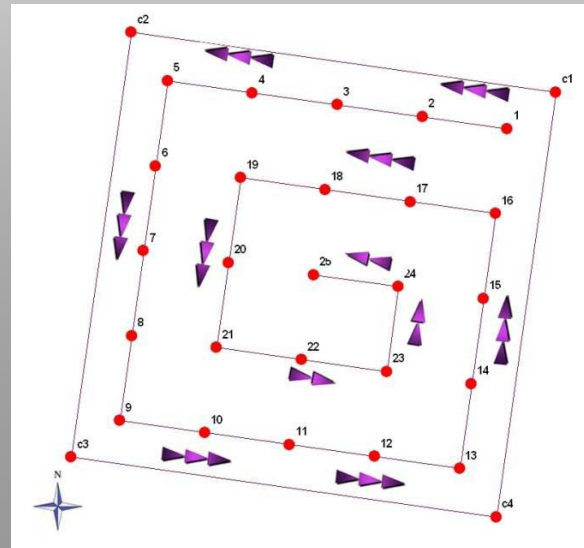


Satellite Data: MERIS



| | |
|------------------------|----------------|
| Acquisition Date | 29 August 2009 |
| Acquisition Time (UTC) | 08:17 |
| Solar zenith angle | 35,85° |
| Solar azimuth angle | 139,49° |
| View zenith angle | 4,59° |
| View azimuth angle | 284,4° |
| Measurement site | 1kmx1km |

| | |
|-----------------------------|----------------------------|
| Spectral Conditions: | 0.39 - 1.04 mm |
| Green | 0.55µm - 0.57µm (b5) |
| Red | 0.655µm - 0.688µm (b7-b8) |
| NIR | 0.763µm - 0.91µm (b12-b15) |

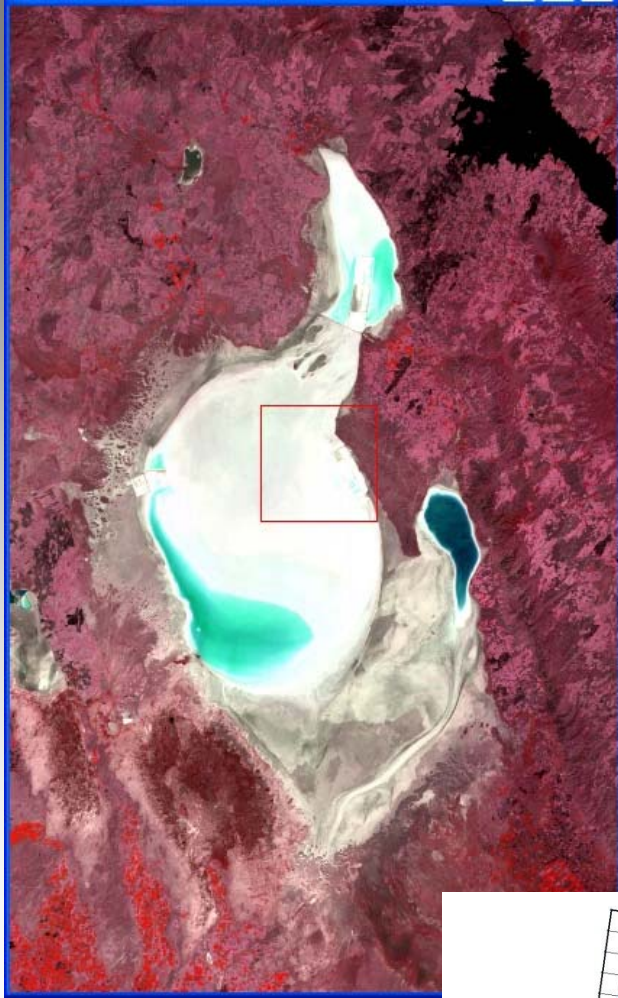


Meris FR1 P TOA radiance data¹



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Satellite Data: Beijing1

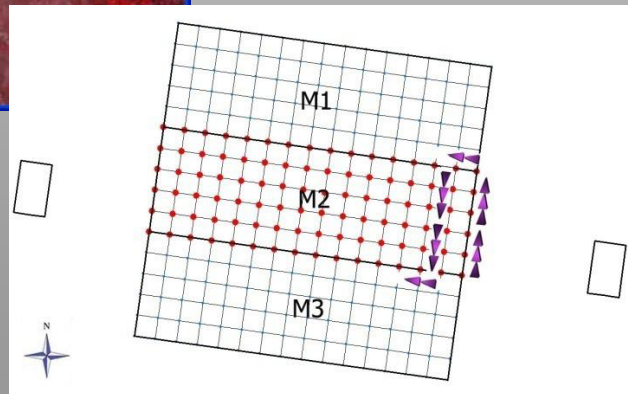


| Geometrical Conditions: | | |
|-------------------------|----------------|----------------|
| Acquisition Date | 25 August 2009 | 30 August 2009 |
| Acquisition Time (UTC) | 07:22 | 07:26 |
| Solar zenith angle | 42,92° | 43,36° |
| Solar azimuth angle | 121,02° | 124,18° |
| View zenith angle | 11,12° | 3,91° |
| View azimuth angle | 79,27° | 79,45° |
| Measurement site | M2 | M3 |

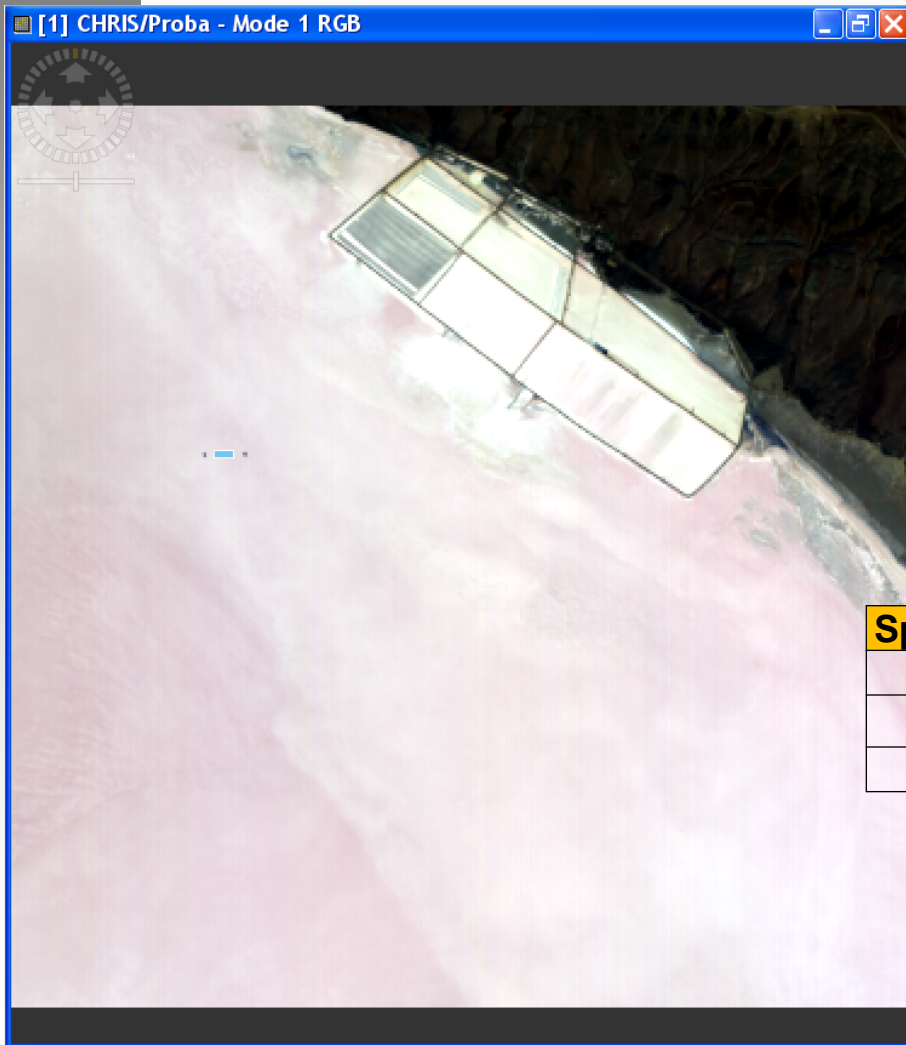
| Spectral Conditions: | |
|----------------------|----------------------|
| Green | 0.52µm - 0.60µm (B1) |
| Red | 0.63µm - 0.69µm (B2) |
| NIR | 0.77µm - 0.90µm (B3) |

The DMC Beijing1 data are converted to a radiance image using the formula below:

$$\text{RADIANCE} = \left[\frac{\text{DN}}{\text{RESCALE GAIN}} \right] + \text{RESCALE BIAS}$$

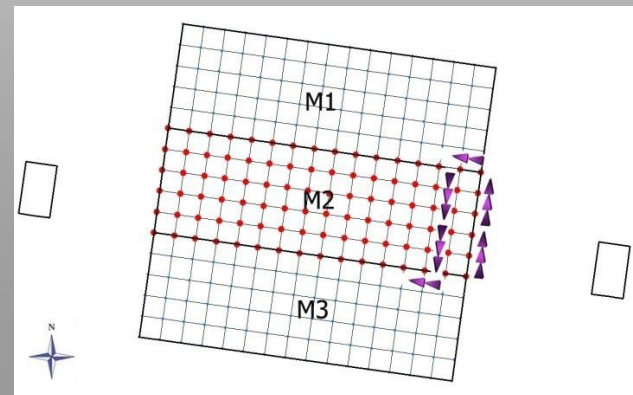


Satellite Data: Proba CHRIS



| | |
|-------------------------------|----------------|
| Acquisition Date | 25 August 2009 |
| Acquisition Time (UTC) | 07:46 |
| Solar zenith angle | 39,00° |
| Solar azimuth angle | 127,78° |
| View zenith angle | 4,20° |
| View azimuth angle | 196,94° |
| Measurement site | M2 |

| Spectral Conditions: | 0.41 - 0.99 mm |
|-----------------------------|---|
| Green | 0.515 μ m - 0.609 μ m (b10-b18) |
| Red | 0.627 μ m - 0.694 μ m (b21-b28) |
| NIR | 0.766 μ m - 0.91 μ m (b40-b54) |



Anisotropic Reflectance Factor

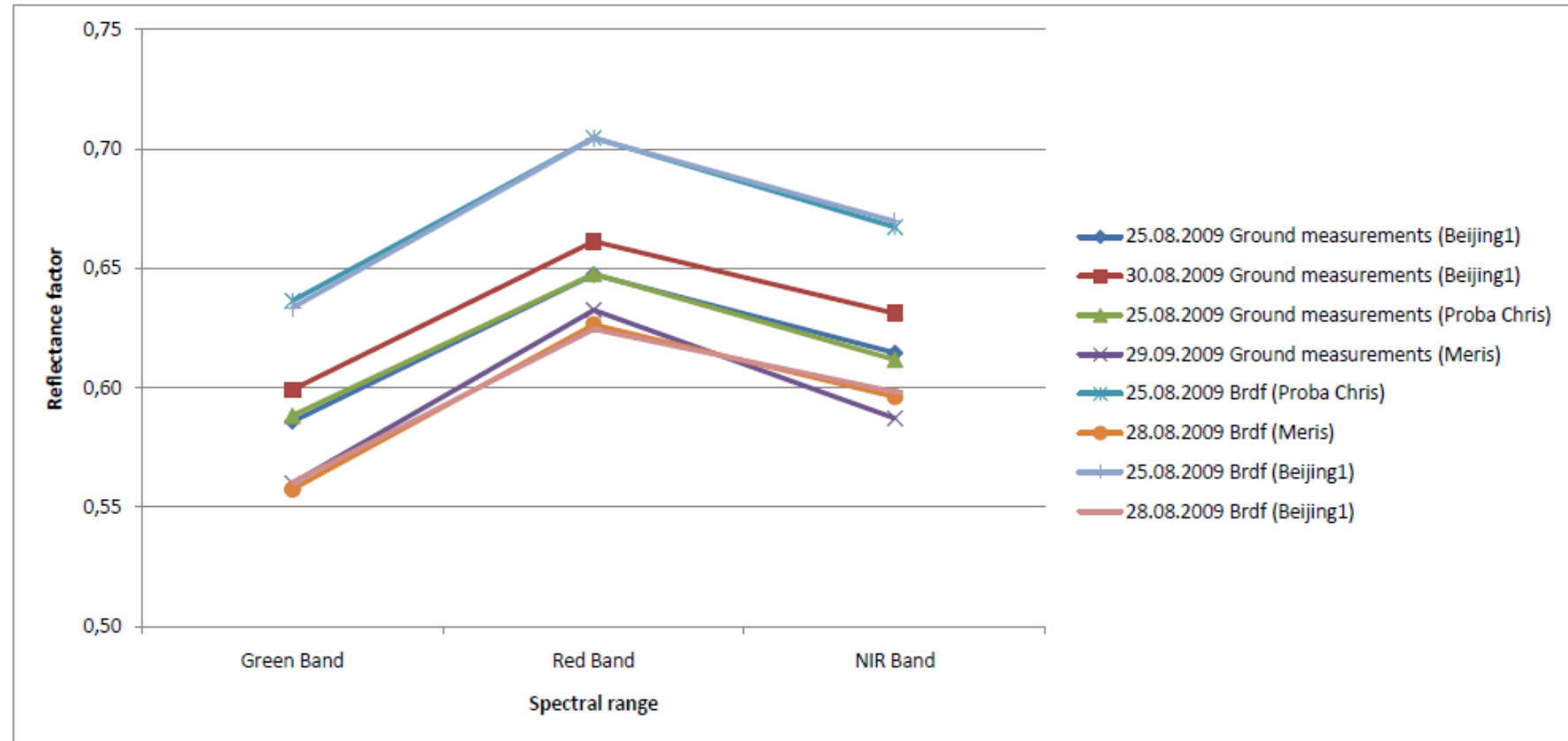
- ARF is a ratio of the average reflectance across the whole hemisphere for that particular spectral band, divided by the nadir measured reflectance for that particular band.
- The aim of this calculation is to convert from the measured TOA Reflectance which suffers from BRDF effects to an Isotropic Equivalent Reflectance (IER).



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A Non-lambertian Surface



If the surface was lambertian nadir measured reflectance and the BRDF values would be equal, but most surfaces are not lambertian, hence there is a need to generate the ARF values and apply them.

Sensor Comparison Study

- TOA reflectances and TOA radiances of each satellite image are acquired from the sample measurement areas of the Tuz Gölü test site using the radiative transfer code 6S (Second Simulation of a Satellite Signal in the Solar Spectrum).



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Input for 6S* Radiative Transfer Code

| Satellite | Beijing 1 | Proba CHRIS | Meris | Beijing 1 |
|---|--------------------------------------|--------------------------------------|-----------------------------------|--------------------------------------|
| Acquisition Date | 25.08.2009 | 25.08.2009 | 29.08.2009 | 30.08.2009 |
| Acquisition Time (UTC) | 07:22:44 M2 AREA 07:00 - 08:00 | 07:46:26 M2 AREA 07:00 - 08:00 | 08:17:32 1km*1km AREA | 07:26:39 M3 Area 07:05 - 08:16 |
| Ground measurements test site and duration (UTC) | | | | |
| Geometrical Conditions: | | | | |
| month | 8 | 8 | 8 | 8 |
| day | 25 | 25 | 29 | 30 |
| solar zenith angle (deg) | 42,92 | 39,00 | 35,85 | 43,3558 |
| solar azimuthal angle (deg) | 121,02 | 127,78 | 139,49 | 124,18 |
| view zenith angle (deg) | 11,12 | 4,20 | 4,59 | 3,906 |
| view azimuthal angle (deg) | 79,27 | 196,94 | 284,4 | 79,45 |
| BRDF: | | | | |
| Relative azimuth (deg) | 41,75 | -69,16 | -144,91 | 44,73 |
| BRDF data file | 25.08.2009, 08:09 file | 25.08.2009, 08:09 file | 28.08.2009, 06:29 file | 28.08.2009, 06:29 file |
| Camera | 2,1 | 4,0 | 4,0 | 4,0 |
| Atmospheric Model: | | | | |
| water content | 1.45 cm | 1.45 cm | 1,13 g/cm2 (25,27,28.08.09) | 1,13 cm |
| ozone content | 0.29 cm-atm /290 DU | 0.29 cm-atm /290 DU | 0.29 cm-atm /290 DU | 0.29 cm-atm /290 DU |
| aerosols model | Continental | Continental | Continental | Continental |
| aerosol optical depth (550 nm) | 0.14 | 0.14 | 0,1 (25,27,28.08.09) | 0.1 |
| Spectral Conditions: | | | | |
| Green | 0.52µm - 0.60µm | 0.515µm - 0.609µm (b10-b18) | 0.55µm - 0.57µm (b5) | 0.52µm - 0.60µm |
| Red | 0.63µm - 0.69µm | 0.627µm - 0.694µm (b21-b28) | 0.655µm - 0.688µm (b7-b8) | 0.63µm - 0.69µm |
| NIR | 0.77µm - 0.90µm | 0.766µm - 0.91µm (b40-b54) | 0.763µm - 0.91µm (b12-b15) | 0.77µm - 0.90µm |
| Sensor and Target Altitude: | | | | |
| Sensor Altitude [km] | 686 | 547 | 800 | 686 |
| Target Altitude [km] | 0.907 | 0.907 | 0.907 | 0.907 |
| Ground Reflectance: | | | | |
| Reflectance (Uniform Lambertian surface) | M2 Area data | M2 Area data | Ground data 27.08.09 of 1km2 Area | M3 Area Data |



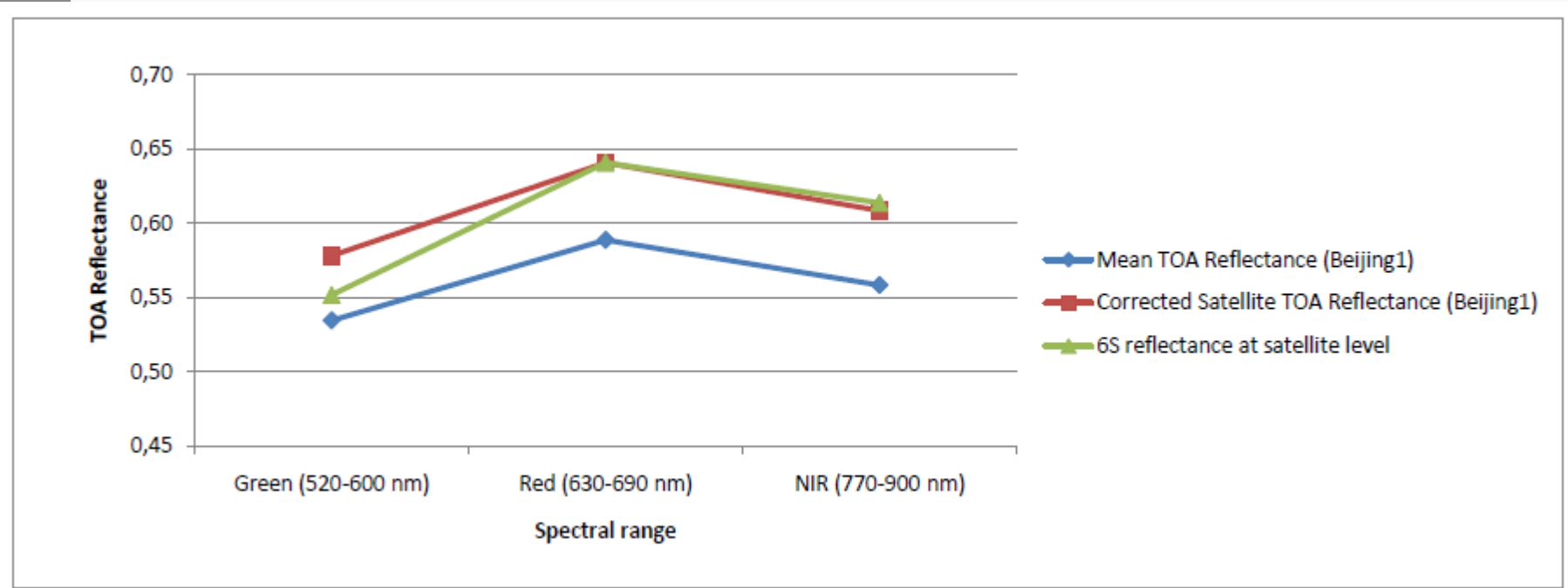
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• <http://6s.ltdri.org/index.html>

Results

Beijing1, 25.08.2009



25.08.2009

Satellite data Arf corrected

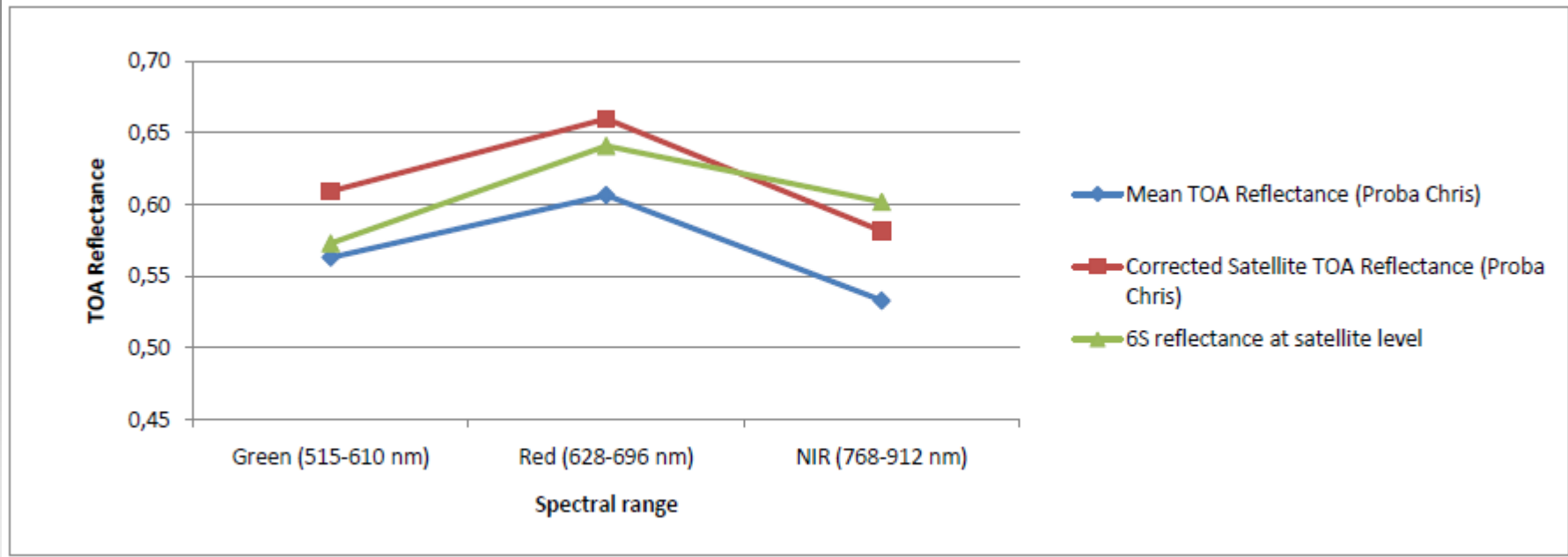
Satellite data Arf corrected Non Arf corrected

| Wavelength (nm) | Ground measurements | Brdf | Mean TOA Reflectance | Corrected Satellite TOA Reflectance | 6S reflectance at satellite level | 6S rad at satel. level (w/m2/sr/mic) | Mean TOA Radiance | % Difference | % Difference |
|-----------------|---------------------|--------|----------------------|-------------------------------------|-----------------------------------|--------------------------------------|-------------------|--------------|--------------|
| Green (520-600) | 0,5858 | 0,6335 | 0,5348 | 0,5783 | 0,5520 | 164,6160 | 216,3568 | 4,55 | -3,23 |
| Red (630-690) | 0,6474 | 0,7046 | 0,5890 | 0,6410 | 0,6410 | 228,0640 | 206,9850 | 0,00 | -8,84 |
| NIR (770-900) | 0,6145 | 0,6697 | 0,5585 | 0,6087 | 0,6140 | 148,1540 | 133,1193 | -0,87 | -9,93 |



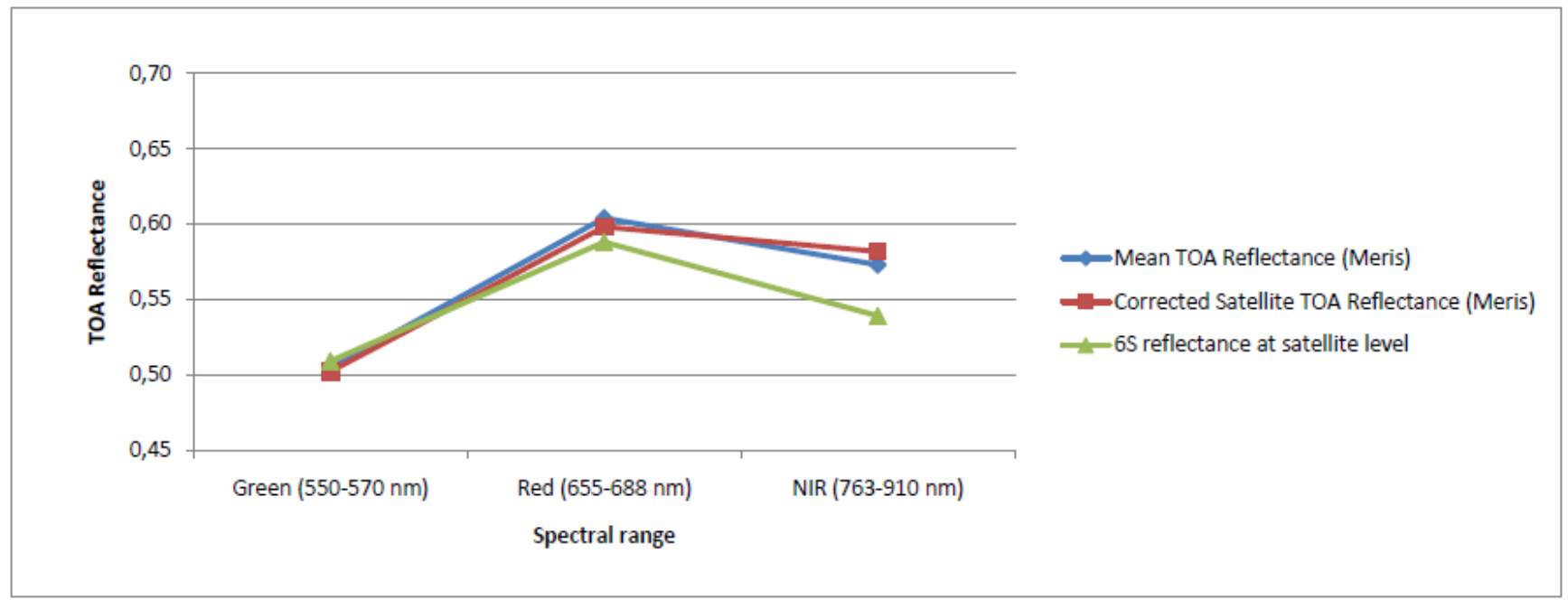
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Proba Chris, 25.08.2009



| 25.08.2009 | | | Satellite data | Arf corrected | | | Satellite data | Arf corrected | Non Arf corrected |
|-----------------|---------------------|--------|----------------------|-------------------------------------|-----------------------------------|--------------------------------------|-------------------|---------------|-------------------|
| Wavelength (nm) | Ground measurements | Brdf | Mean TOA Reflectance | Corrected Satellite TOA Reflectance | 6S reflectance at satellite level | 6S rad at satel. level (w/m2/sr/mic) | Mean TOA Radiance | % Difference | % Difference |
| Green (515-610) | 0,5883 | 0,6364 | 0,5632 | 0,6092 | 0,5730 | 254,576 | 246,7853 | 5,95 | -1,75 |
| Red (628-696) | 0,6476 | 0,7046 | 0,6065 | 0,6599 | 0,6410 | 241,425 | 224,3355 | 2,87 | -5,68 |
| NIR (768-912) | 0,6117 | 0,6672 | 0,5331 | 0,5815 | 0,6020 | 153,737 | 133,8734 | -3,53 | -12,92 |

Meris, 29.08.2009



29.09.2009

Satellite data

Arf corrected

Satellite data

Arf corrected

Non Arf corrected

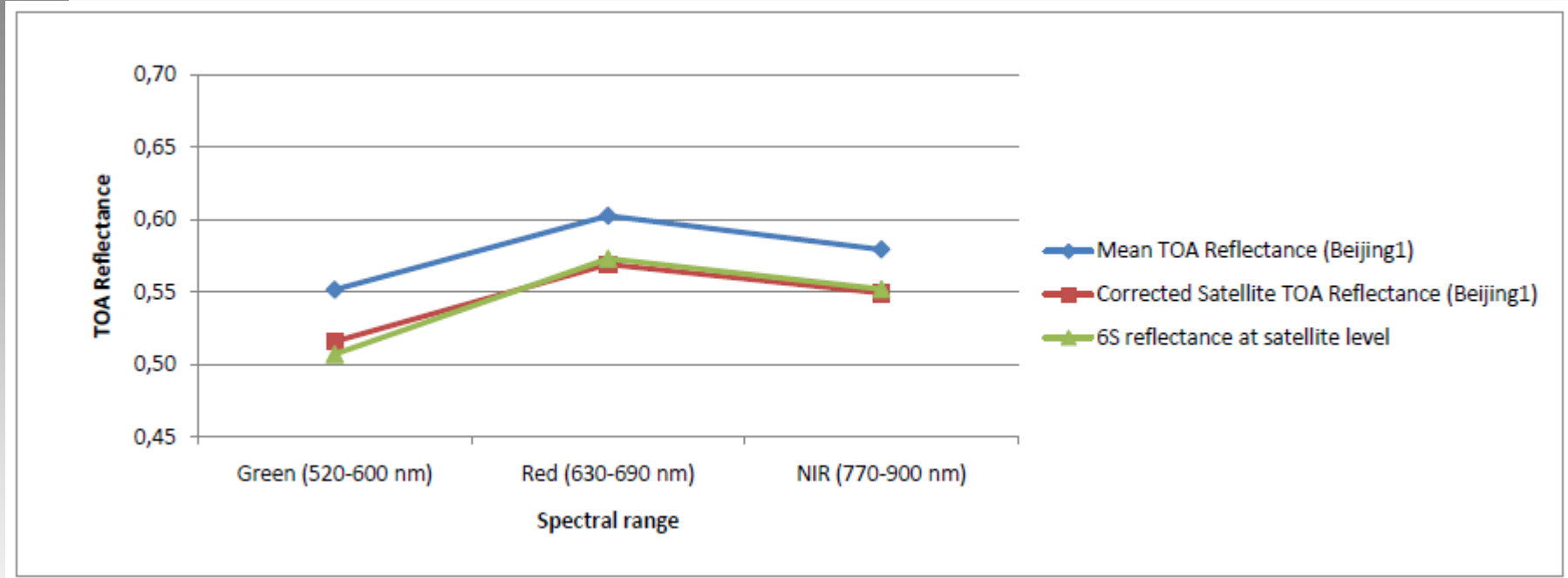
| Wavelength (nm) | Ground measurements | BRDF | Mean TOA Reflectance | Corrected | | | Mean TOA Radiance | % Difference | % Difference |
|-----------------|---------------------|--------|----------------------|---------------------------|-----------------------------------|--------------------------------------|-------------------|--------------|--------------|
| | | | | Satellite TOA Reflectance | 6S reflectance at satellite level | 6S rad at satel. level (w/m2/sr/mic) | | | |
| Green (550-570) | 0,5599 | 0,5574 | 0,5044 | 0,5021 | 0,5090 | 238,572 | 229,6771 | -1,37 | -0,91 |
| Red (655-688) | 0,6325 | 0,6264 | 0,6039 | 0,5981 | 0,5880 | 226,058 | 229,3080 | 1,69 | 2,64 |
| NIR (763-910) | 0,5872 | 0,5961 | 0,5730 | 0,5818 | 0,5390 | 144,283 | 135,4177 | 7,35 | 5,93 |



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Results

Beijing1, 30.08.2009



30.08.2009

Satellite data Arf corrected

Satellite data Arf corrected Non Arf corrected

| Wavelength (nm) | Satellite data | | | 6S rad at satel. level | | | Non Arf corrected | | |
|-----------------|---------------------|--------|----------------------|-------------------------------------|-----------------------------------|---------------|-------------------|--------------|--------------|
| | Ground measurements | Brdf | Mean TOA Reflectance | Corrected Satellite TOA Reflectance | 6S reflectance at satellite level | (w/m2/sr/mic) | Mean TOA Radiance | % Difference | % Difference |
| Green (520-600) | 0,5992 | 0,5603 | 0,5515 | 0,5157 | 0,5070 | 212,493 | 221,4450 | 1,70 | 8,08 |
| Red (630-690) | 0,6613 | 0,6244 | 0,6026 | 0,5690 | 0,5730 | 202,645 | 210,7648 | -0,70 | 4,92 |
| NIR (770-900) | 0,6311 | 0,5983 | 0,5794 | 0,5493 | 0,5520 | 132,671 | 137,1157 | -0,49 | 4,72 |

Discussion

- Comparison of ground based measurements with satellite images
 - The differences of satellite derived TOA values from 6S predicted are less than 8%. In case of DMC images even less than 5%. (ARF applied)
 - The differences of satellite derived TOA values from 6S predicted are less than 13%. In case of DMC images even less than 10%. (Non ARF applied)



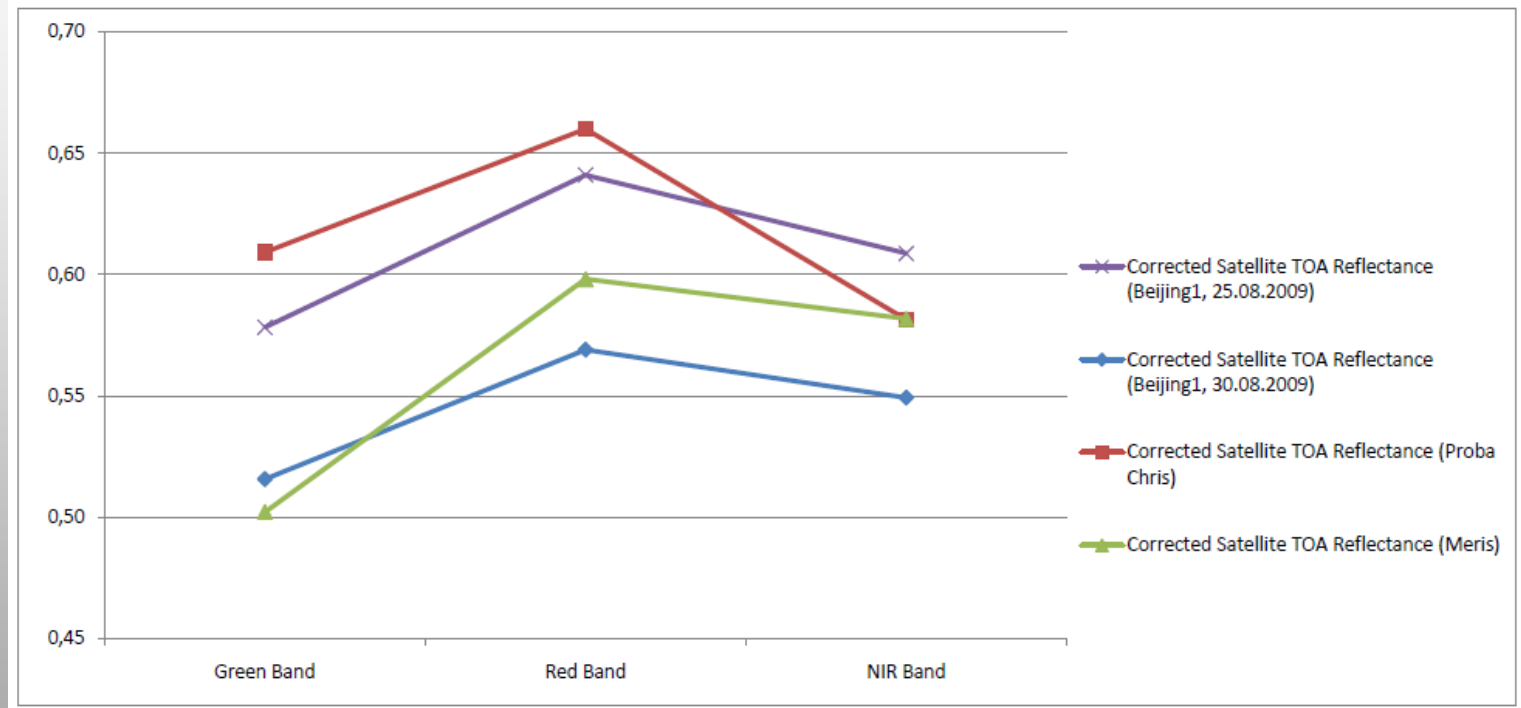
Discussion

- Although the ARF application removed biases due to sun-target-sensor geometry and atmospheric effects, in this study the advantage of the method is not clear to see for Meris data.
- This could be due to:
 - low resolution of the satellite
 - there is no BRDF data (28.08.2009) for the day of Meris data (29.08.2009) acquisition
 - the ground measurement data is collected on the 27.08.2009
- Again this method did not work well for the green bands of Proba Chris and Meris data.



Results

- Isotropic equivalent reflectances of different sensor:



25.08.2009

30.08.2009

25.08.2009

29.08.2009

| Spectral range | Corrected Satellite TOA Reflectance (Beijing1) | Corrected Satellite TOA Reflectance (Beijing1) | Corrected Satellite TOA Reflectance (Proba Chris) | Corrected Satellite TOA Reflectance (Meris) | Mean | St.dev | % St. Dev |
|----------------|--|--|---|---|--------|--------|-----------|
| Green Band | 0,5783 | 0,5157 | 0,6092 | 0,5021 | 0,5513 | 0,0509 | 9,23 |
| Red Band | 0,6410 | 0,5690 | 0,6599 | 0,5981 | 0,6170 | 0,0411 | 6,67 |
| NIR Band | 0,6087 | 0,5493 | 0,5815 | 0,5818 | 0,5803 | 0,0243 | 4,19 |



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Conclusion

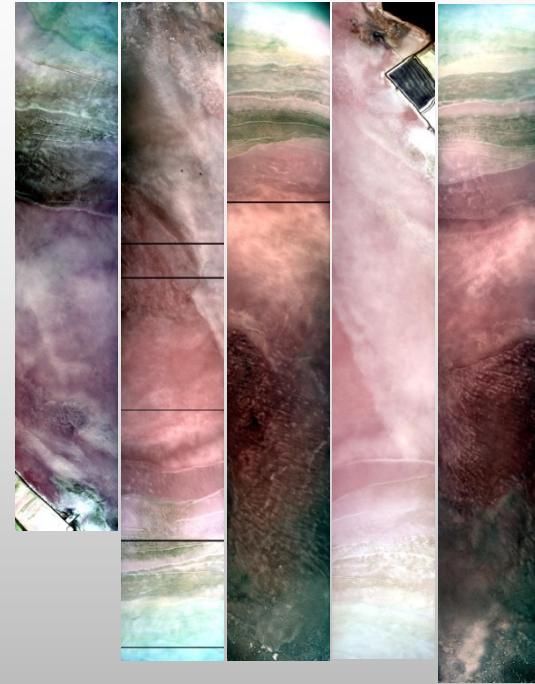
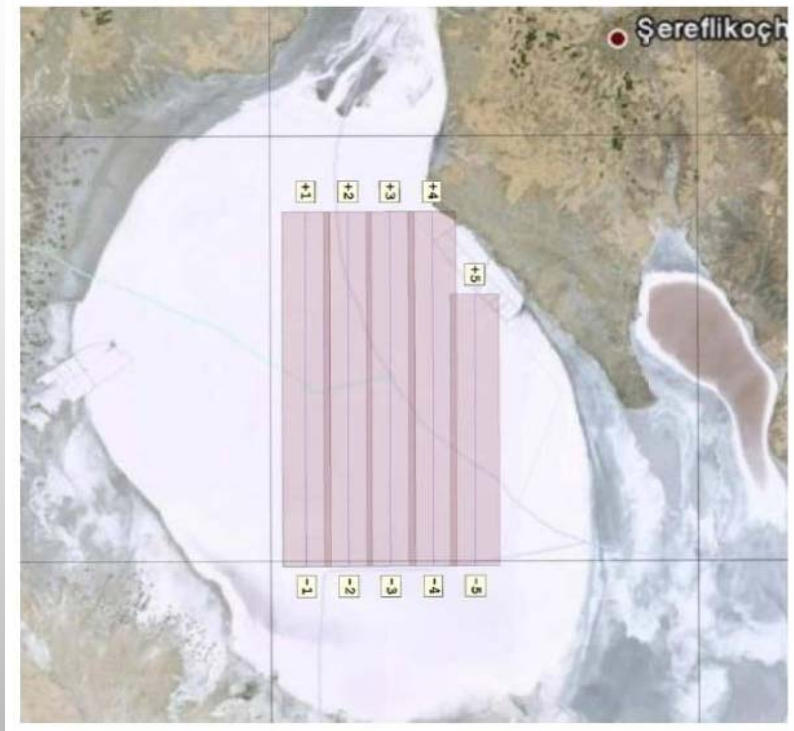
- For a non-lambertian surface, in all likelihood the nadir reflectance will be less than expected and be dependent on the solar zenith and relative azimuth and the view zenith.
- The best way is to convert the values to an Anisotropic Reflectance Factor and then determine the scaling factor to the TOA Reflectance to be applied to each data set.
- This removes biases due to sun-target-sensor geometry and atmospheric effects up to 5%.



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Aircraft Data: HYMAP



Tuz Gölü HyMap campaign 01.09.2010

| Line-# | Time (UTC) | Flight azimuth (0° =N, 180°=S) | Flight altitude (asl) | Solar zenith | Solar azimuth |
|--------|------------|--------------------------------|-----------------------|--------------|---------------|
| 1 | 8:54 | 359° | 3600 m | 23.9° | 146.4° |
| 2 | 9:14 | 0° | 3600 m | 21.8° | 158.0° |
| 3 | 8:46 | 179° | 3600 m | 24.9° | 142.3° |
| 4 | 9:04 | 179° | 3600 m | 22.7° | 152.0° |
| 5 | 8:35 | 0° | 3600 m | 26.4° | 137.1° |



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References

1. MERIS Products and Algorithms:
<http://envisat.esa.int/handbooks/meris/CNTR2.htm>.
2. <http://6s.ltdri.org/>
3. Gary Crowley, DMC-GSCDA FREQUENTLY ASKED QUESTIONS, DMC report, January 2010.
4. Steve Mackin, Irina Behnert, Dale Plotts, Nigel Fox, CEOS inter-comparison of TOA Radiance and Reflectance over the DOME-C site (2008-2009), NPL report, March 2010.
5. Irina Behnert, Andrew Deadman, Nigel Fox, Peter Harris, Selime Gürol, Hilal Özen, Martin Bachmann, Yannick Boucher, Sophie Lachérade; Measurement Report CEOS WGCV pilot Comparison of techniques/instruments used for the vicarious calibration of Land surface imaging through a ground reference standard test site 2009, NPL report, March 2010.



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A sunset scene over the ocean. The sun is a large, bright white circle in the center, surrounded by a glowing orange and red aura. The sky is filled with scattered, dark clouds, some of which are illuminated from below by the setting sun, giving them a reddish-orange glow. The horizon line is visible at the bottom, showing the dark water of the ocean and some distant, low mountains or hills.

Thank you for your patience!