
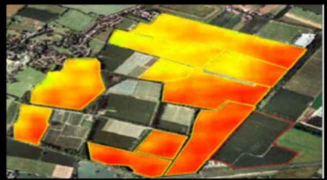

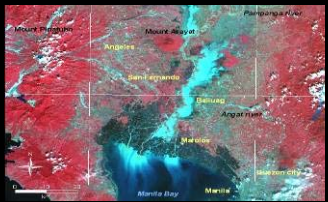

Cross-Calibration of Landsat 7 and the Disaster Monitoring Constellation satellites

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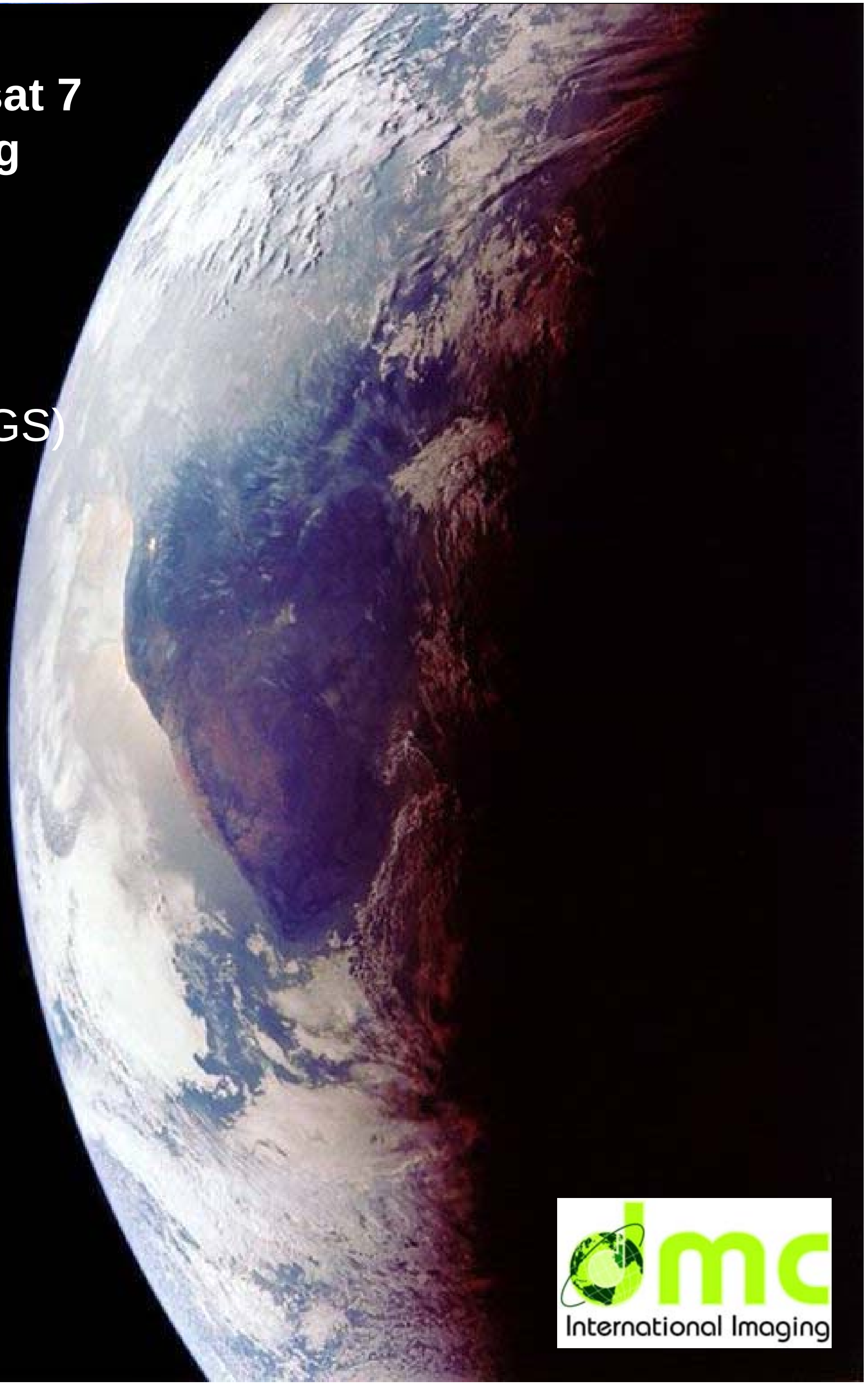


DMC International Imaging

Overview

- We have been working with the USGS (Chander) for several years, developing methods to cross-calibrate Landsat 7 ETM+ and the DMC satellites (UK-DMC-1 and UK-DMC-2).
- Two very different key sites. Dome-C (instrumented) and Libya 4 (non-instrumented).
- I want to briefly show the methods and highlight some issues of applying the methods.

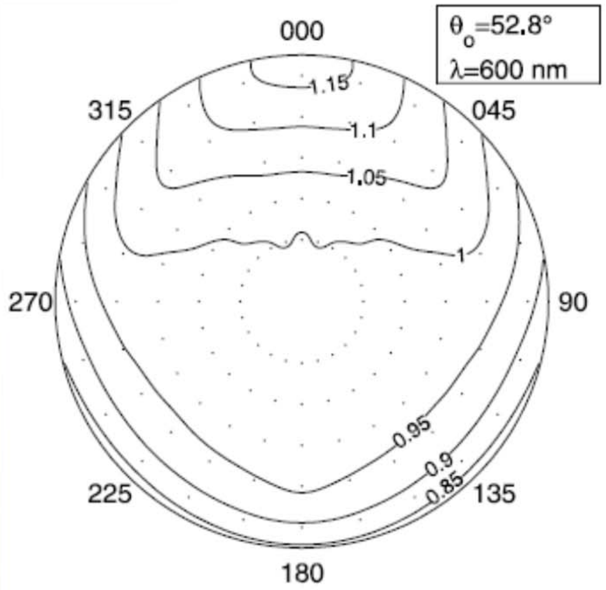
Procedure

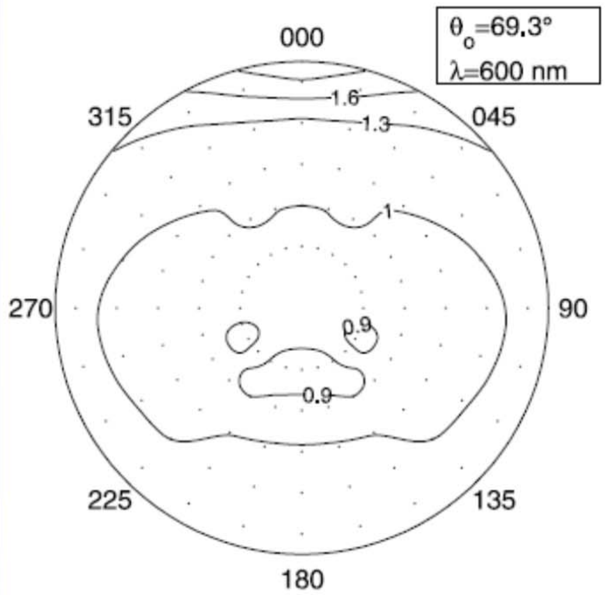
- Dark images collected over the Pacific at Night.
- Cross-calibration over Dome-C in Antarctica against Landsat 7 ETM+
  - Correction for nadir viewing BRDF
  - Correction for Ozone (green and red bands)
  - Correction for water vapour variations (NIR)
- Cross-Calibration over Libya 4 against Landsat 7 ETM+
  - Correction of nadir viewing BRDF
  - Correction for view angle variation
  - Atmospheric variations are considered noise

Intercomparison Study Site – Dome C

- 75° 06'S , 123° 23'E
- Flat plateau at 3200m a.s.l.
- Used in past (DMCii since late 2003), AVHRR, SPOT
- Franco-Italian base. Sun photometer, ozone, radiosondes daily and BRDF measurements of surface from past campaigns.

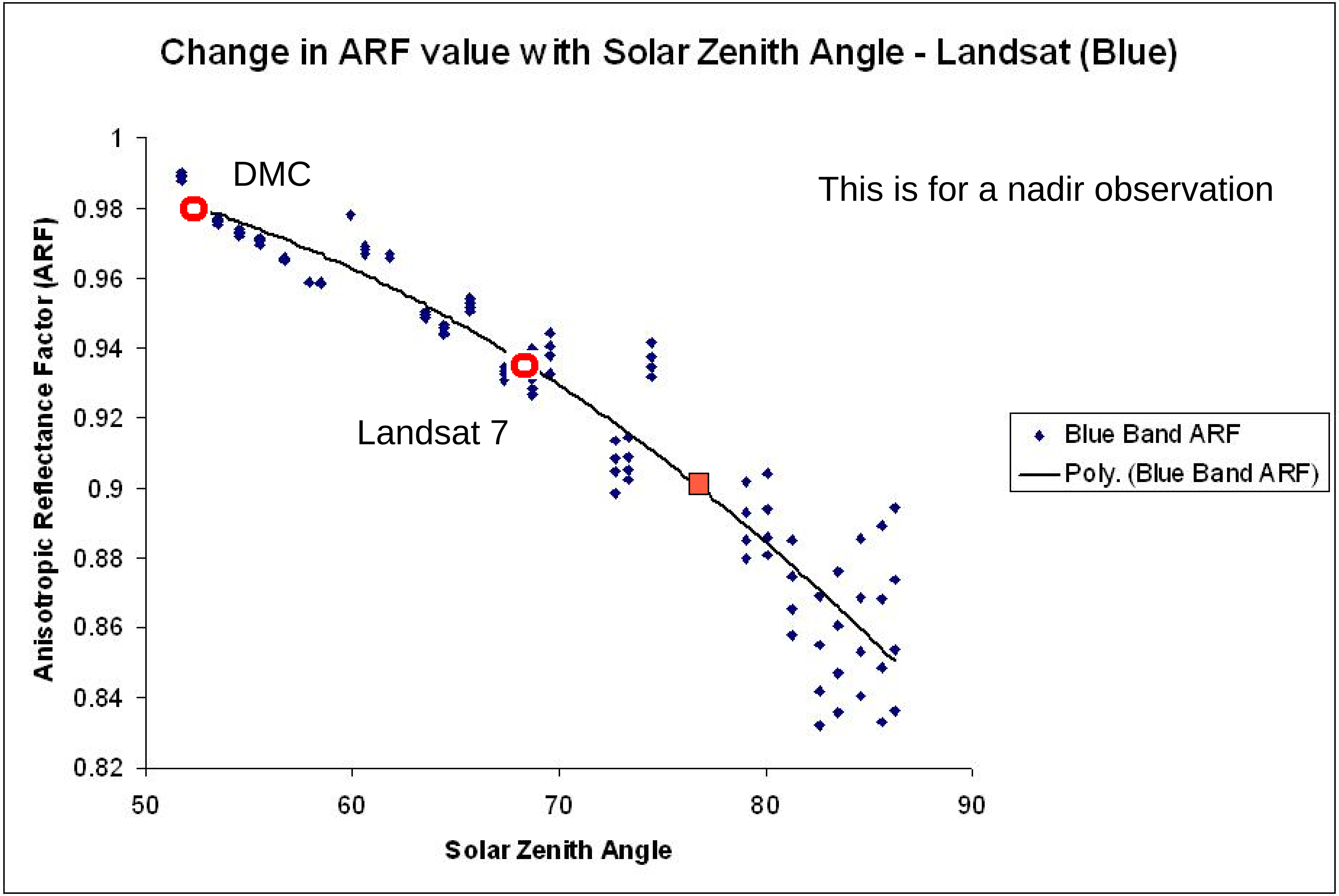
BRDF – Dome C





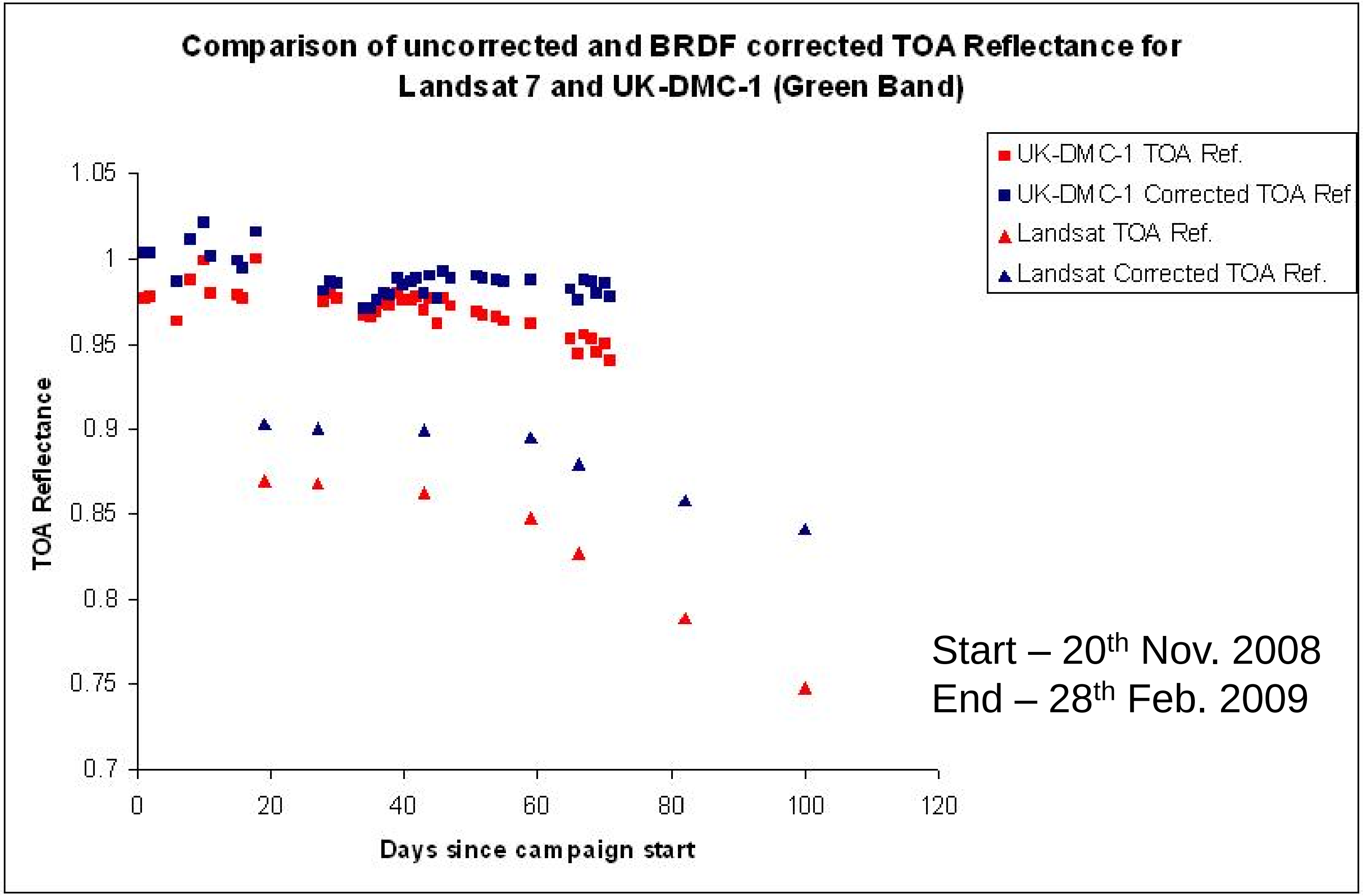
- The Anisotropic Reflectance Factor (ARF) shows the normalised variation of reflectance across the entire hemisphere. Based on studies by the University of Washington (2003-2004)
- The top plot is for a DMC like overpass solar zenith angle, while the bottom plot is an end of season LANDSAT overpass solar zenith angle
- Wavelength in the plots is located at the red/green band boundary
- If we cross-compare **nadir** images from LANDSAT and DMC (or any other satellite) without correcting for these BRDF effects then we are inducing an error of several percent.
- Note that there is a suggestion that there is little or no variation when the view angular range is small. Recent tests suggest this is not the case.
- Current model has problems at low sun angles (can we model this out?)

BRDF – Dome C



Change in ARF value with Solar Zenith Angle - Landsat (Blue)
DMC
This is for a nadir observation
Landsat 7
Anisotropic Reflectance Factor (ARF)
1
0.98
0.96
0.94
0.92
0.9
0.88
0.86
0.84
0.82
50
60
70
80
90
Solar Zenith Angle
Blue Band ARF
Poly. (Blue Band ARF)

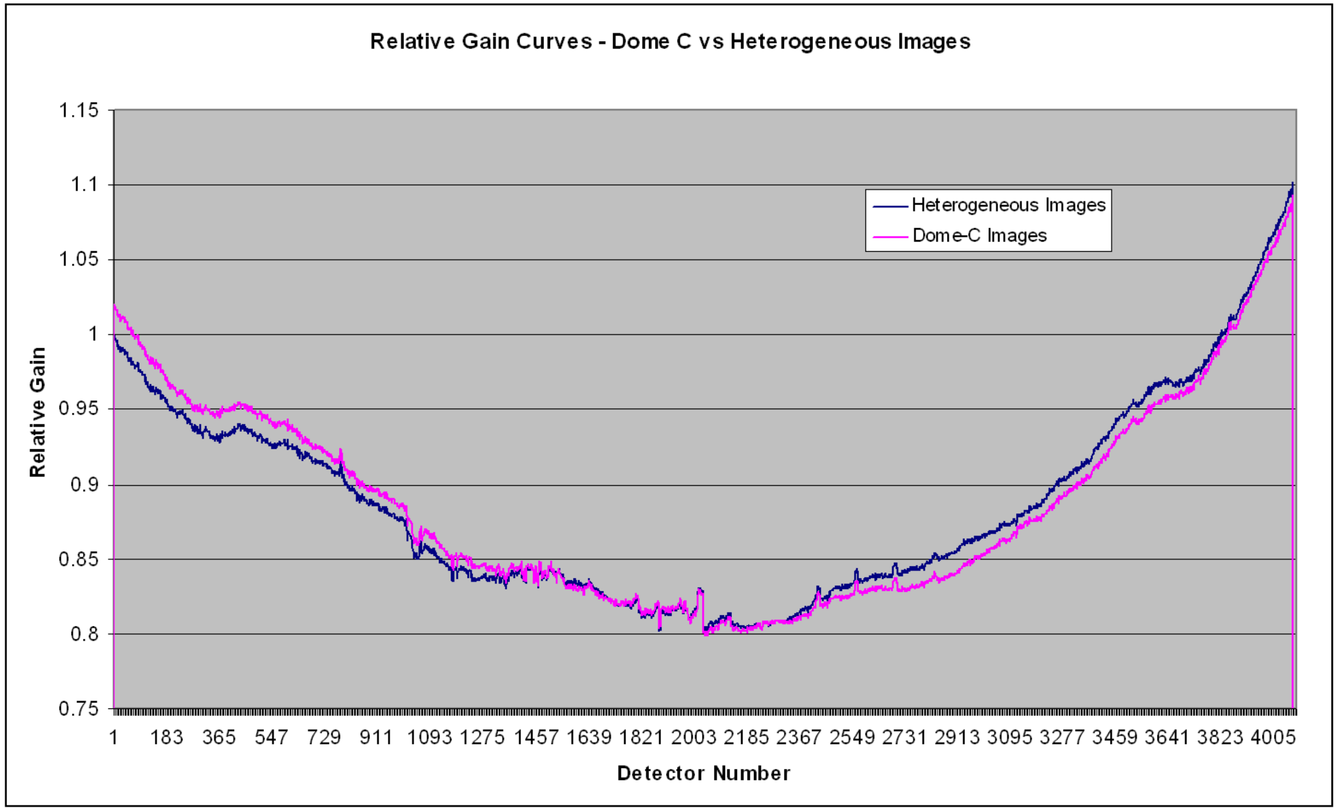
BRDF Comparison



Start – 20th Nov. 2008
End – 28th Feb. 2009

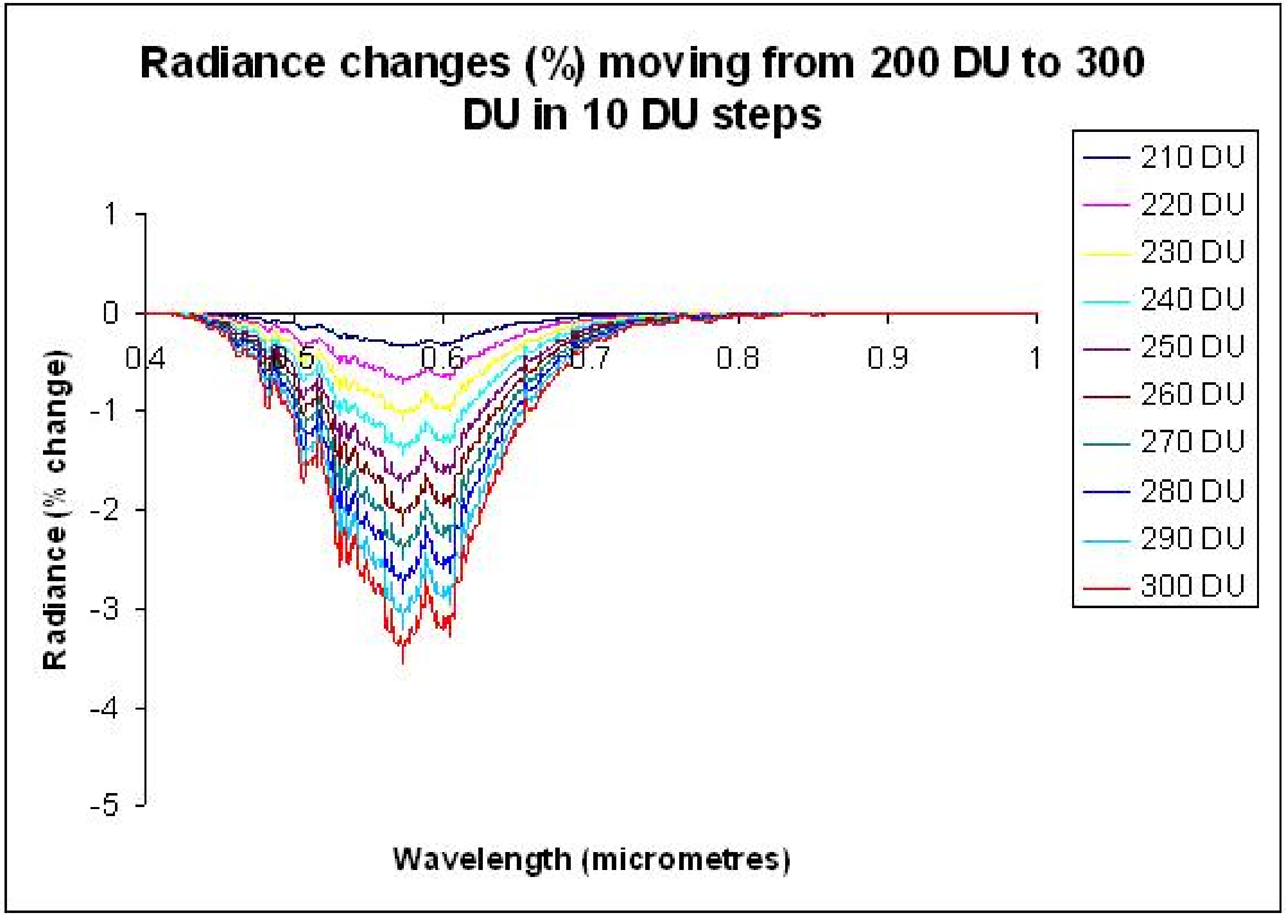
White Images – Equalisation (Relative)

- Dome-C
  - Comparison of both pre-launch and heterogeneous image averages, show a distinct BRDF effect in a Dome-C image captured by NigeriaSat-2. The magnitude is the order of 2% but this is for a 1.67 degree FOV. So significant effects close to nadir. Solar elevation is typical for that of Landsat 7 in this example.



Ozone

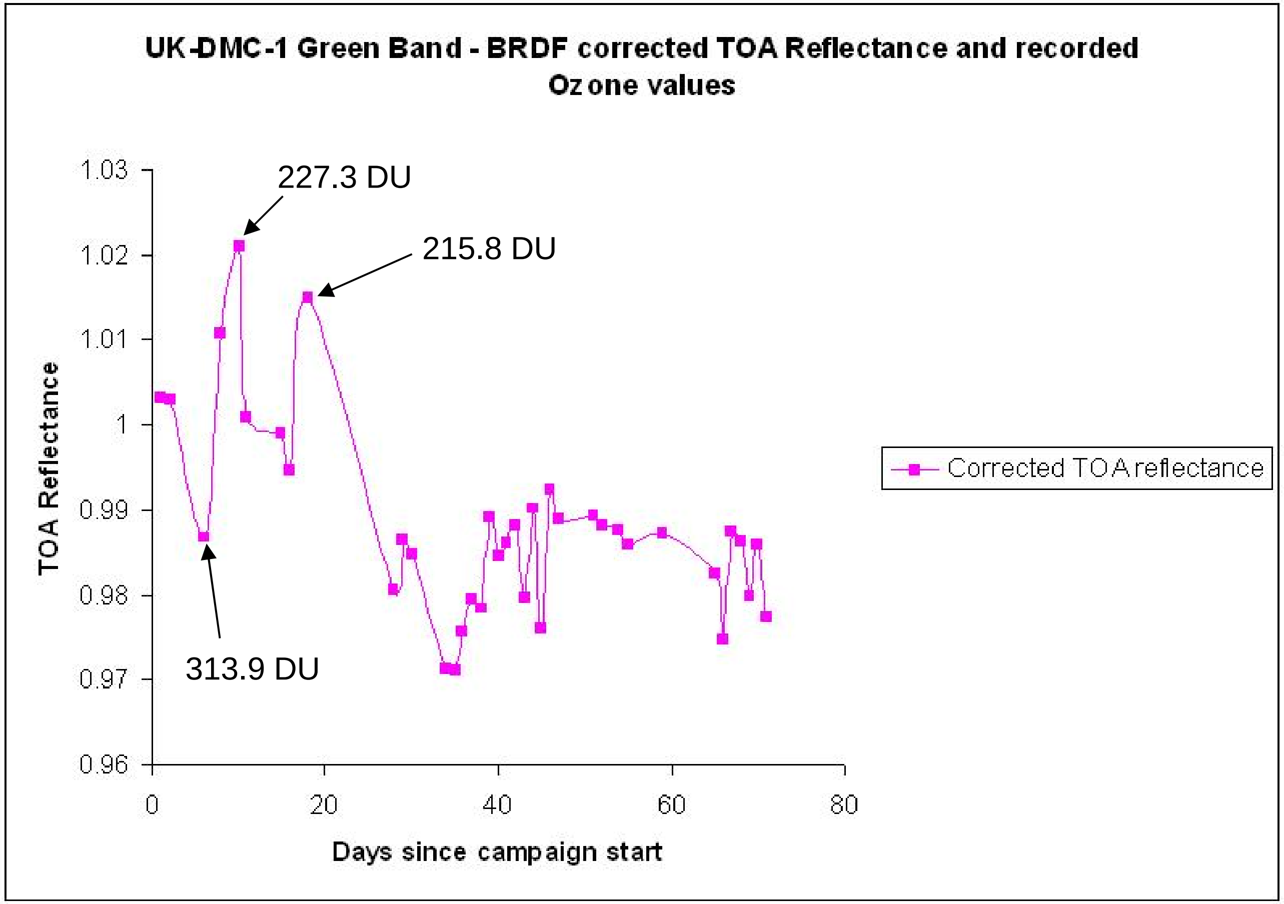
- Ozone absorption in the VNIR



Known as the Chappius absorptions, the peak absorption is near the green / red boundary

Ozone values cover a range from about 210 DU to over 310 DU in the data collected during the CEOS intercomparison.

Ozone Correction



The pink line is the BRDF corrected TOA Reflectance, the large spikes on the left of the plot show acquisitions with extreme ozone variations (either very low or very high)

Ozone Variability

INDIAN J RADIO & SPACE PHYS, AUGUST 2006

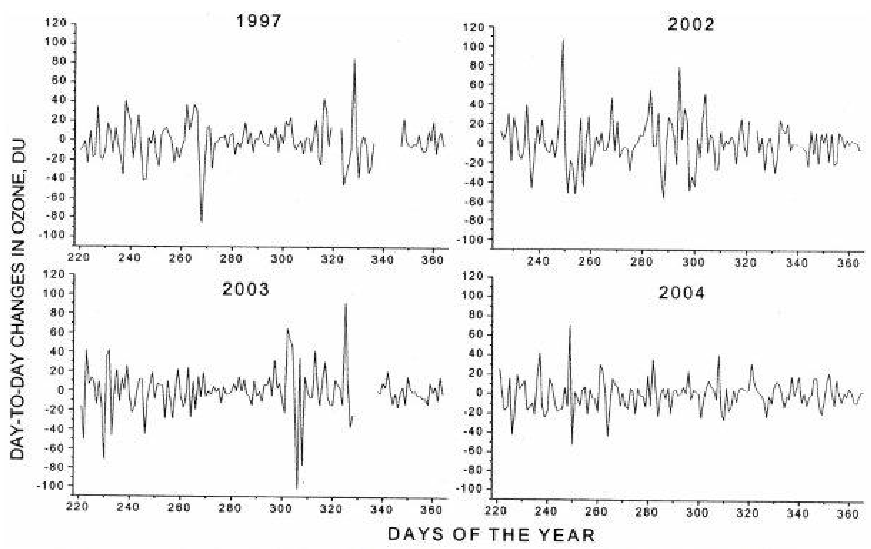
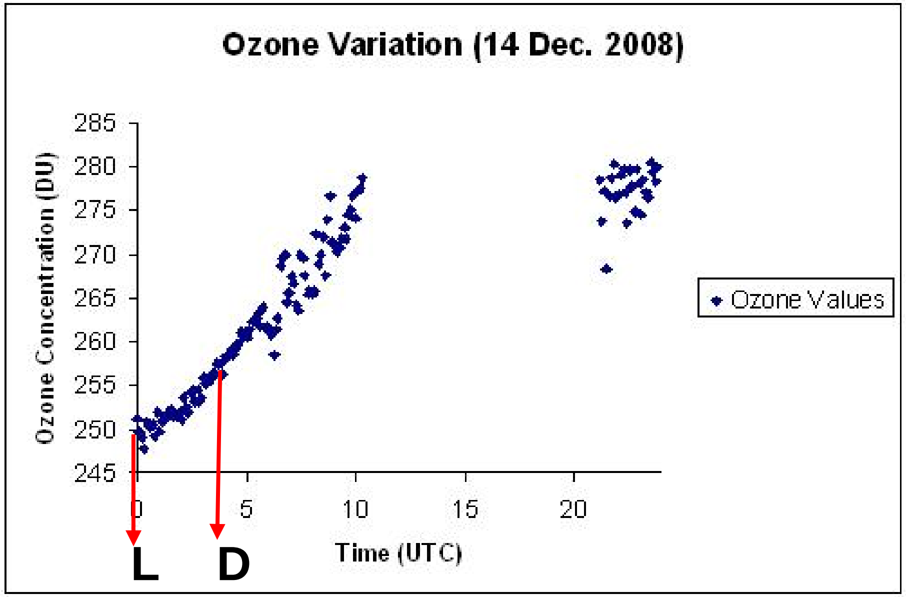


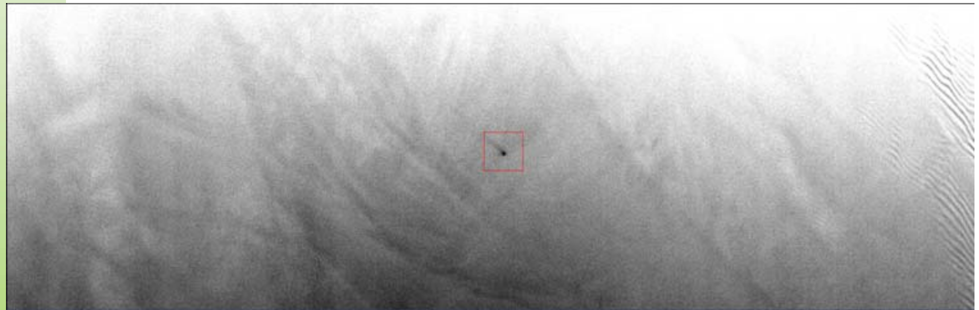
Fig. 3—Day-to-day change of daily total ozone during ozone hole periods of 1997, 2002, 2003 and 2004



- Ozone can vary dramatically from day to day, so two acquisitions separated by one day could have an ozone difference of 100 DU equivalent to a radiance change of 3.5% at 600nm
- Even within a single day the recorded ozone can vary greatly. Note on the lower figure the L and D for Landsat and DMC overpasses (0.25% radiance difference at 600nm).
- Ozone profile temporally is not consistent. So can we use satellite data taken in one time on images taken from a different time slot.
- Need to correct for path length and view angle due to wide FOV of DMC satellites. (Drifting ground track)
- Disparity between ground data and that from satellite sensors.

Other Factors – Surface Variability

Figure 3.12: View from an airplane near Siple Dome, West Antarctica (82°S, 150°W), November 1994. The surface elevation is about 500 m. The streaks which appear dark in this photograph were later identified (on an oversnow traverse by snowmobile) as surface frost; viewed from the opposite direction they instead appear brighter than the intervening regions of snow. (The frost therefore probably has little effect on the albedo.) Photo by Nadine Nereson.



15f

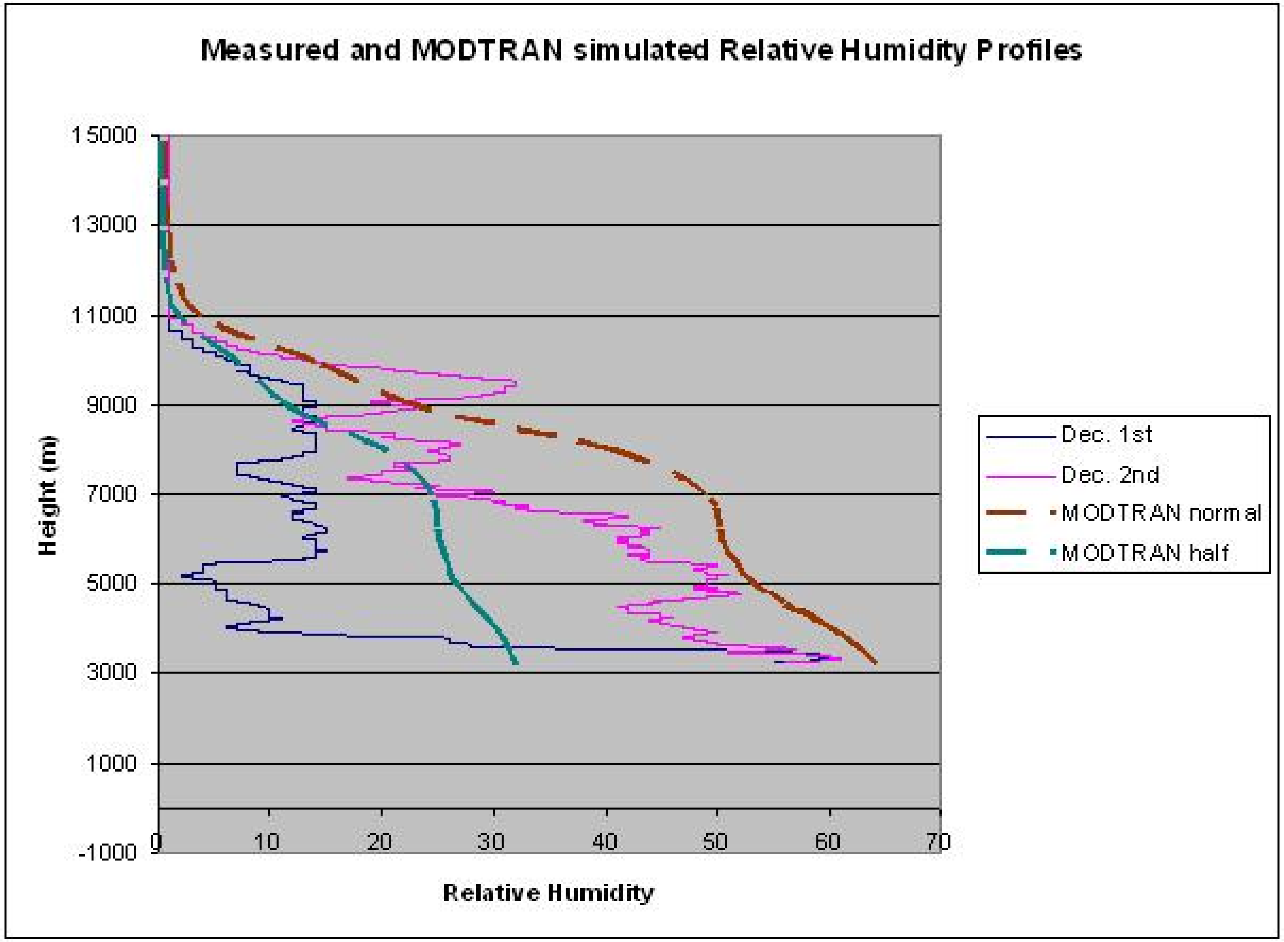
205

The upper image was taken on the 4th December 2011, while the lower image was taken late in the season on the 5th February 2012.

Hoar frost effects are clearly visible in the lower image and can cause variability in response of up to 4% in some cases.

Other Factors

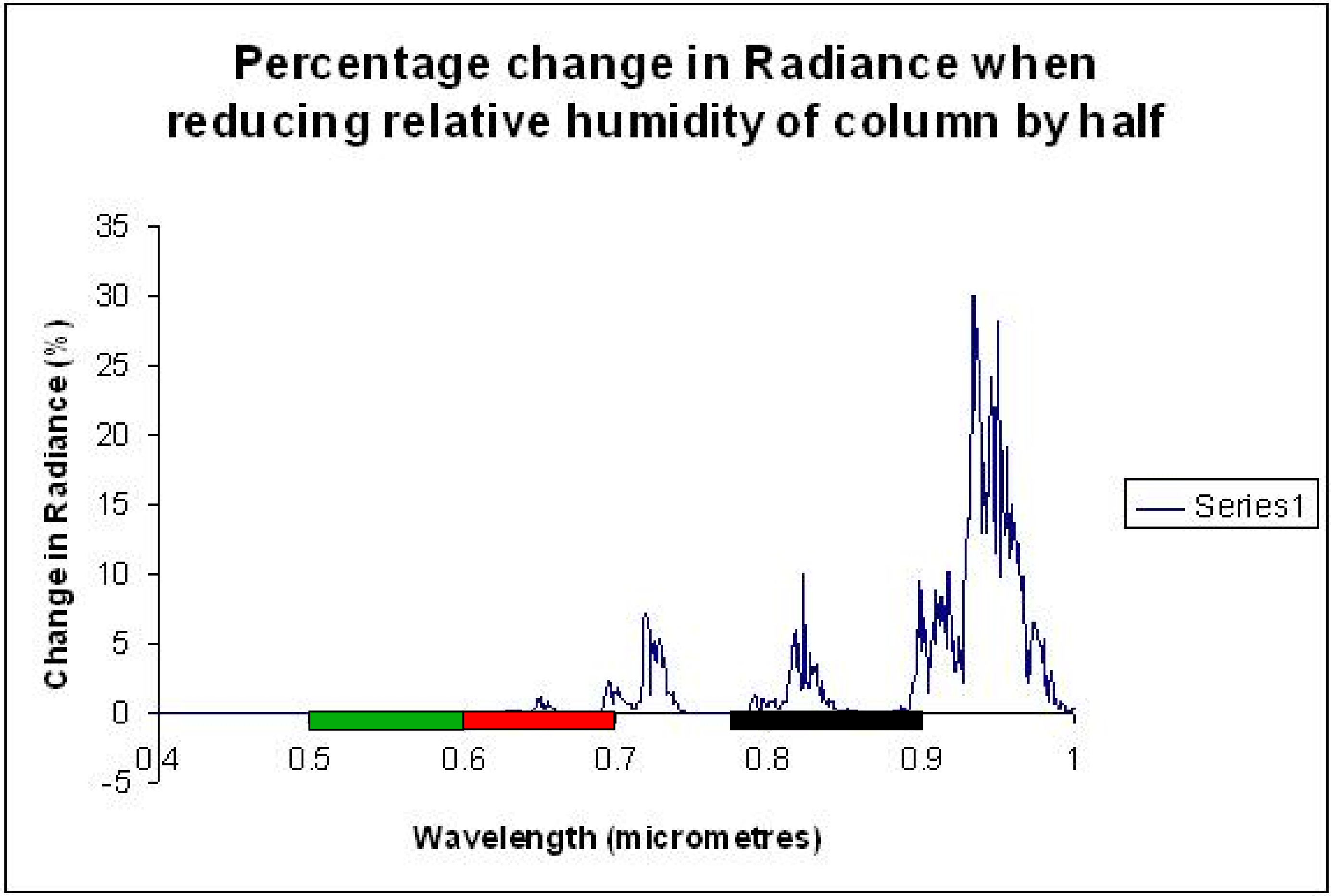
- Water Vapour



- Two radiosonde relative humidity profiles (Dec. 1st and 2nd are compared to MODTRAN simulations with the "normal" relative humidity profile and that with half of the water in the column

Other Factors

- Water Vapour

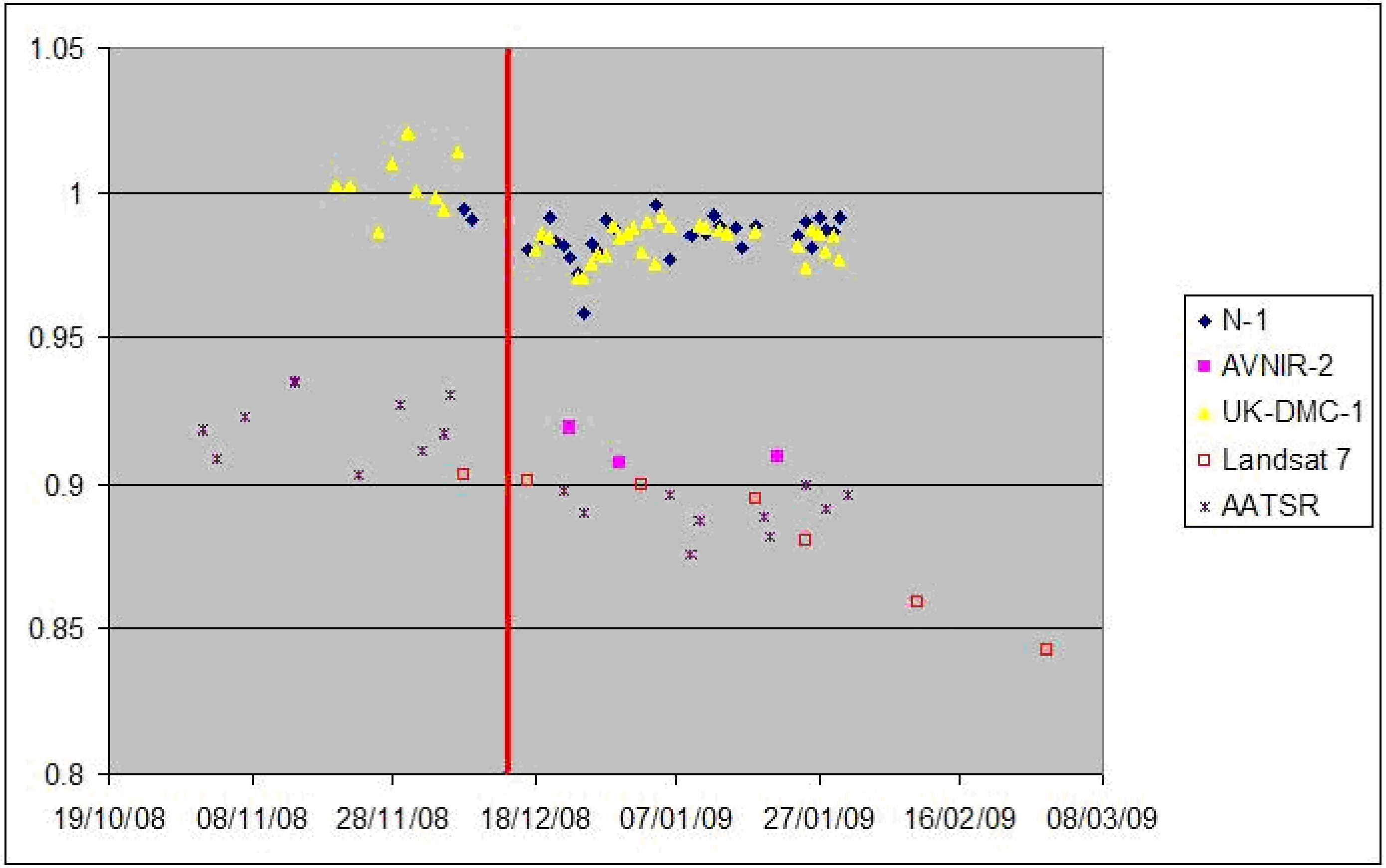


Water vapour effects have a larger impact in the NIR spectral band (black bar in diagram) with smaller effects in the red.

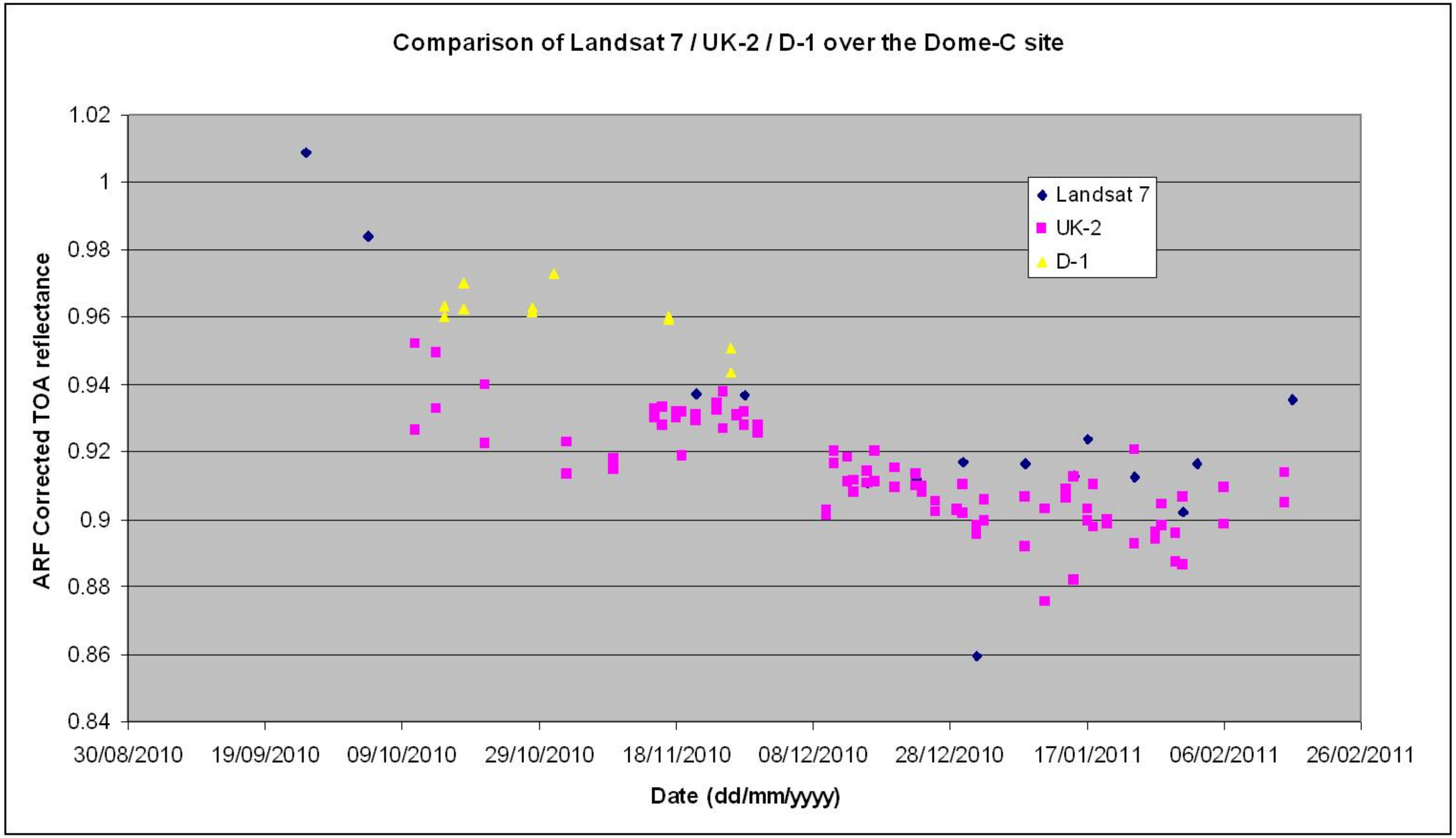
No real effects in the green spectral band.

Dome-C Cross-Calibration (2008-2009)

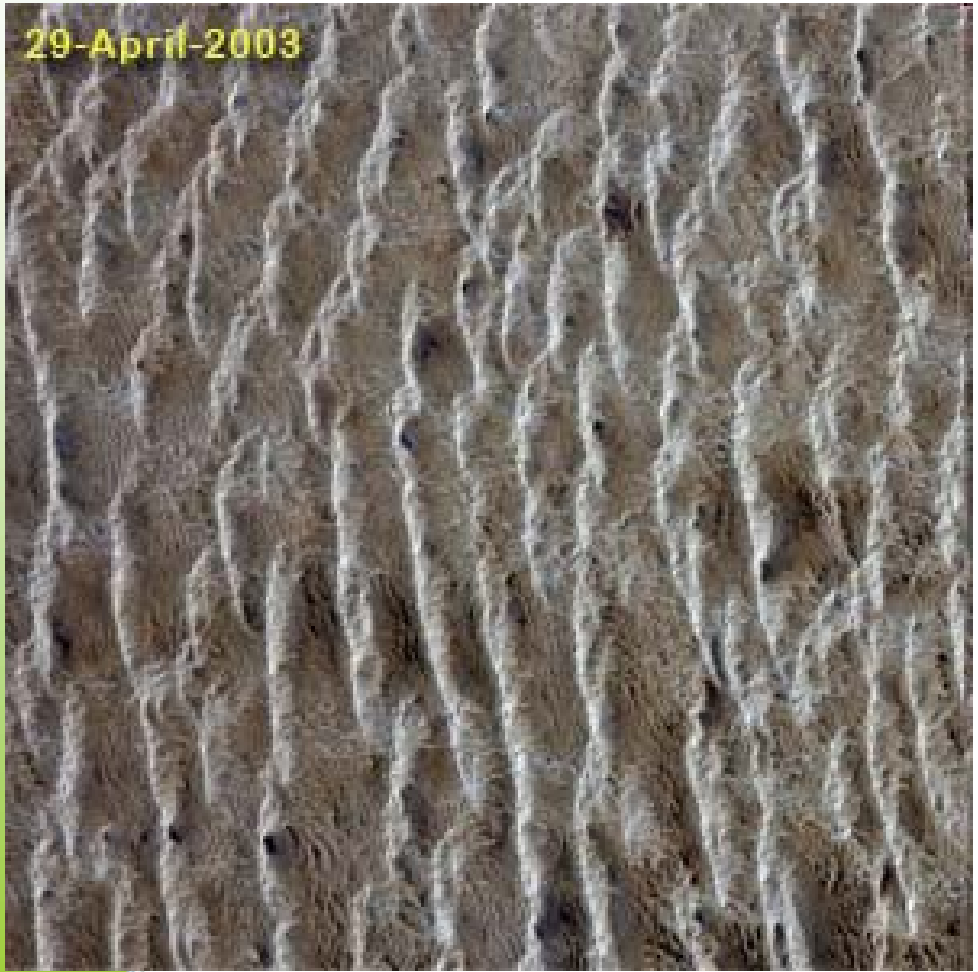
- Note the step in the data in December 2008
- Step clearly seen in AATSR and DMC satellite data
- What causes it ?



Dome C – Cross Calibration (2010-2011)



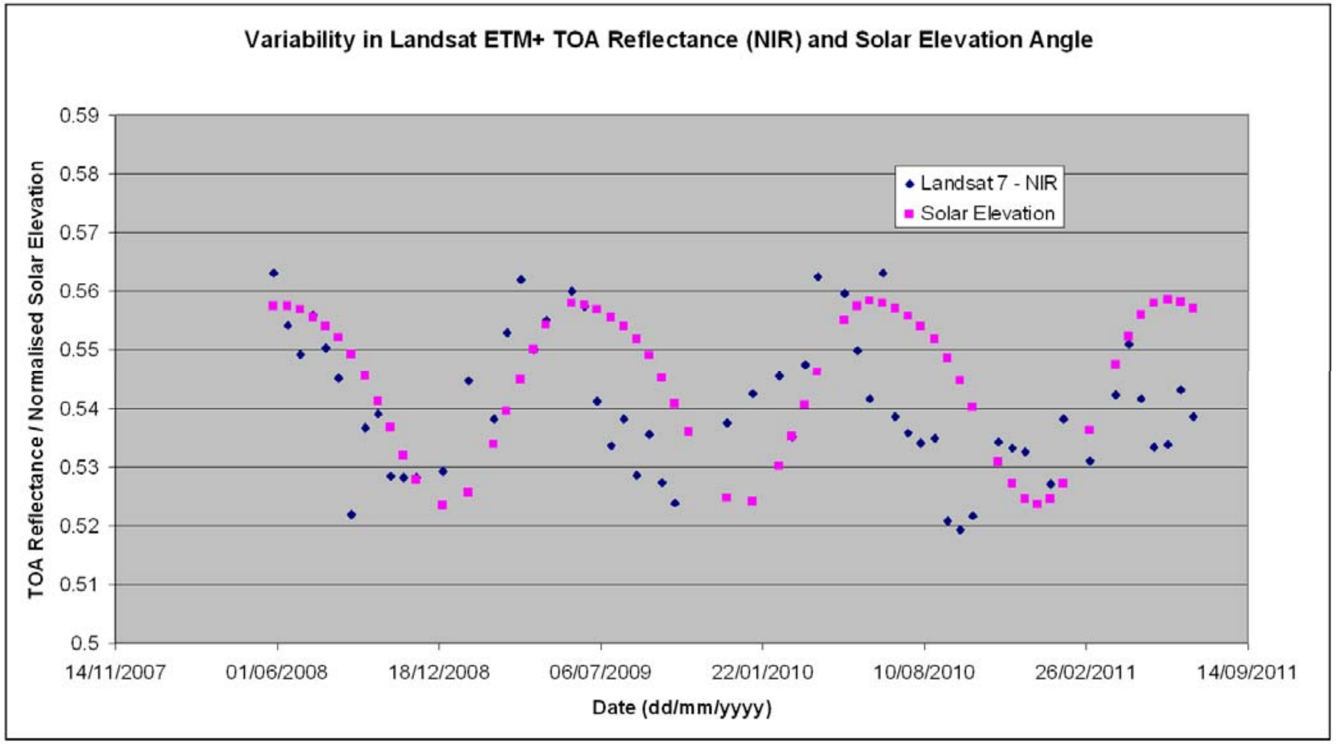
Cross-Cal other sites



- Libya 4 site (CEOS reference)
- Detailed work began in 2009, cross-comparing data from Landsat 7
- The cross-comparison is based on the data alone (no in-situ data)

http://calval.cr.usgs.gov/sites_catalog_template.php?site=lib4

Cross-Calibration Libya 4 – Nadir Element

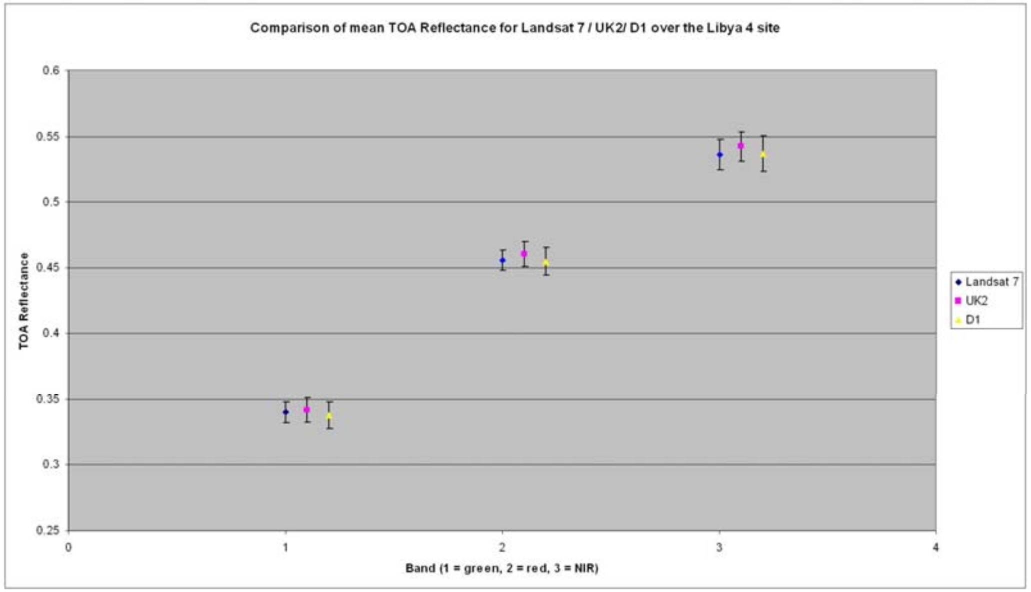


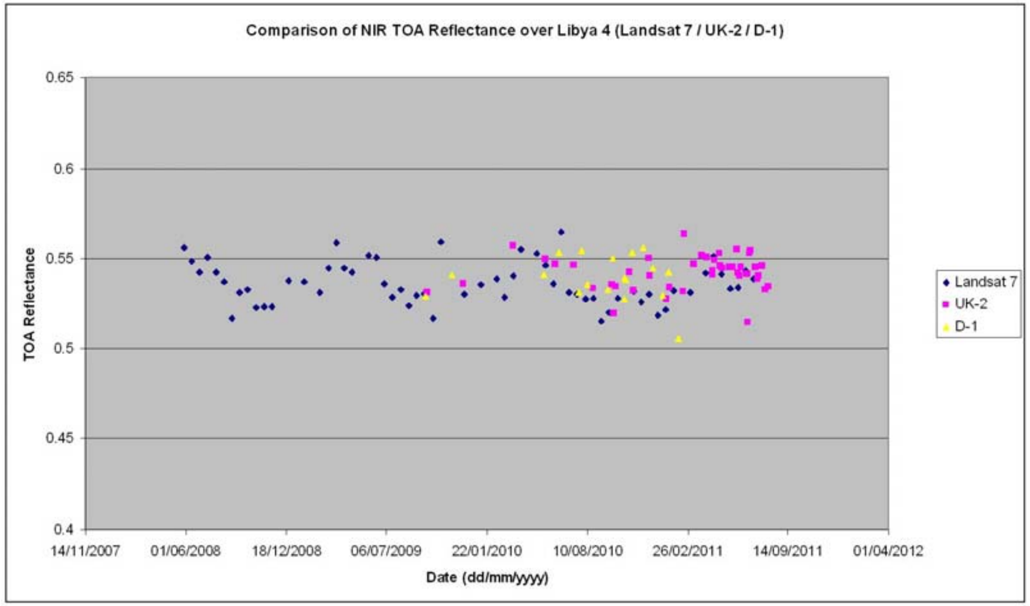
As solar elevation and azimuth changes the TOA reflectance follows a distinct pattern, with low values in the winter and high in the summer when looking at nadir, but out of sync. Is this a different result to Dennis Helder at SDSU

The differences may be related to the complex surface and solar azimuth variations during the year.

Libya 4

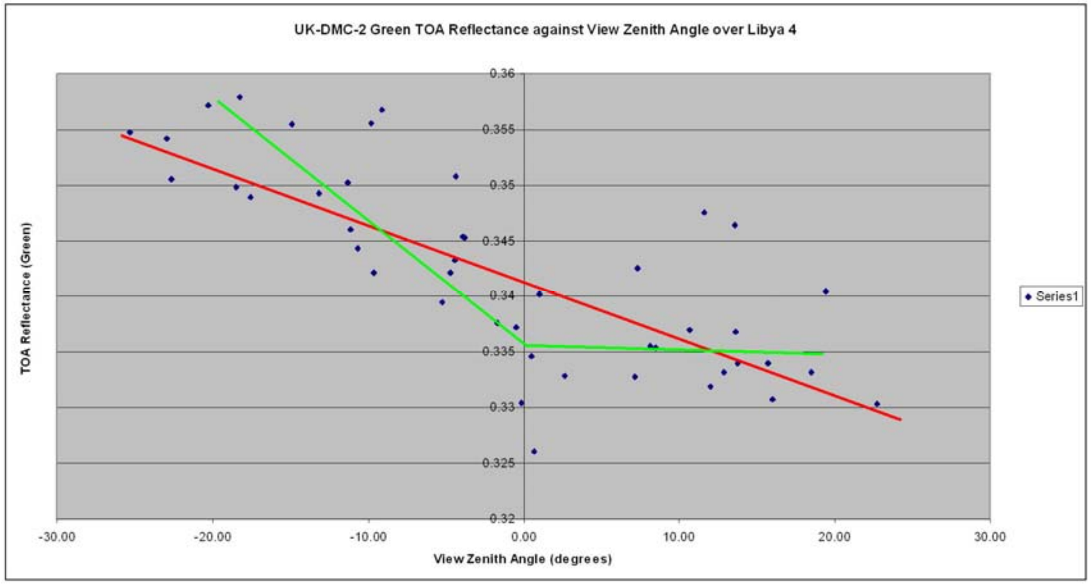
- Cross-Calibration over Libya 4 with Landsat 7 has continued.
- Now collecting more intensively at all view angles so 6-8 images per month for UK-2
- Using images to assess uncertainty related to the surface variability.
- Further work underway to fully understand causes of variability over the Libya 4 site

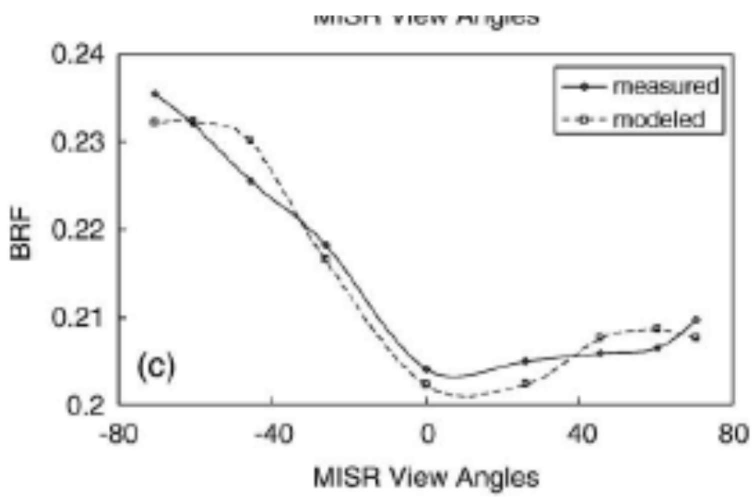




Libya 4

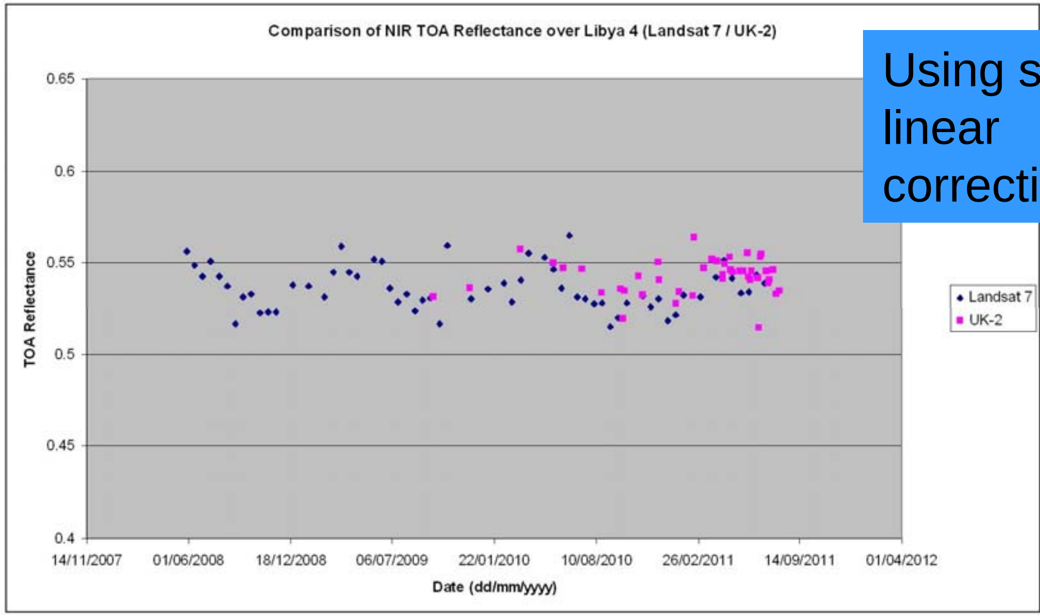
- Initially not enough points to define relationship between TOA reflectance and view zenith angle, so used linear (red line).
- Relationship is not a linear as first used, but follows green line. Similar profiles have been observed by MISR over similar desert forms in China. (diagram below)
- Simple correction is to use the inflexion at nadir to give the reference value for comparison with Landsat 7. This will tend to drop the values.



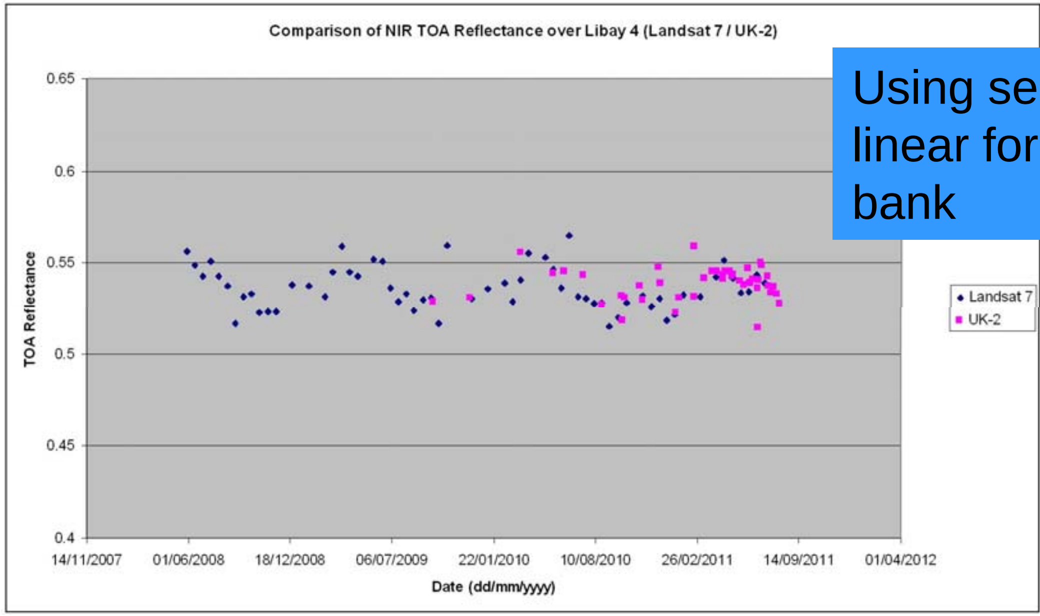


Libya 4

- Solar zenith variations seem to cause the sinusoidal oscillation seen in the data.
- Biggest effect is view angle variation, which is corrected in the lower diagram.
- Compensate for these effects to get better overall fit for trending purposes.
- Should improve with physical modelling of the site.



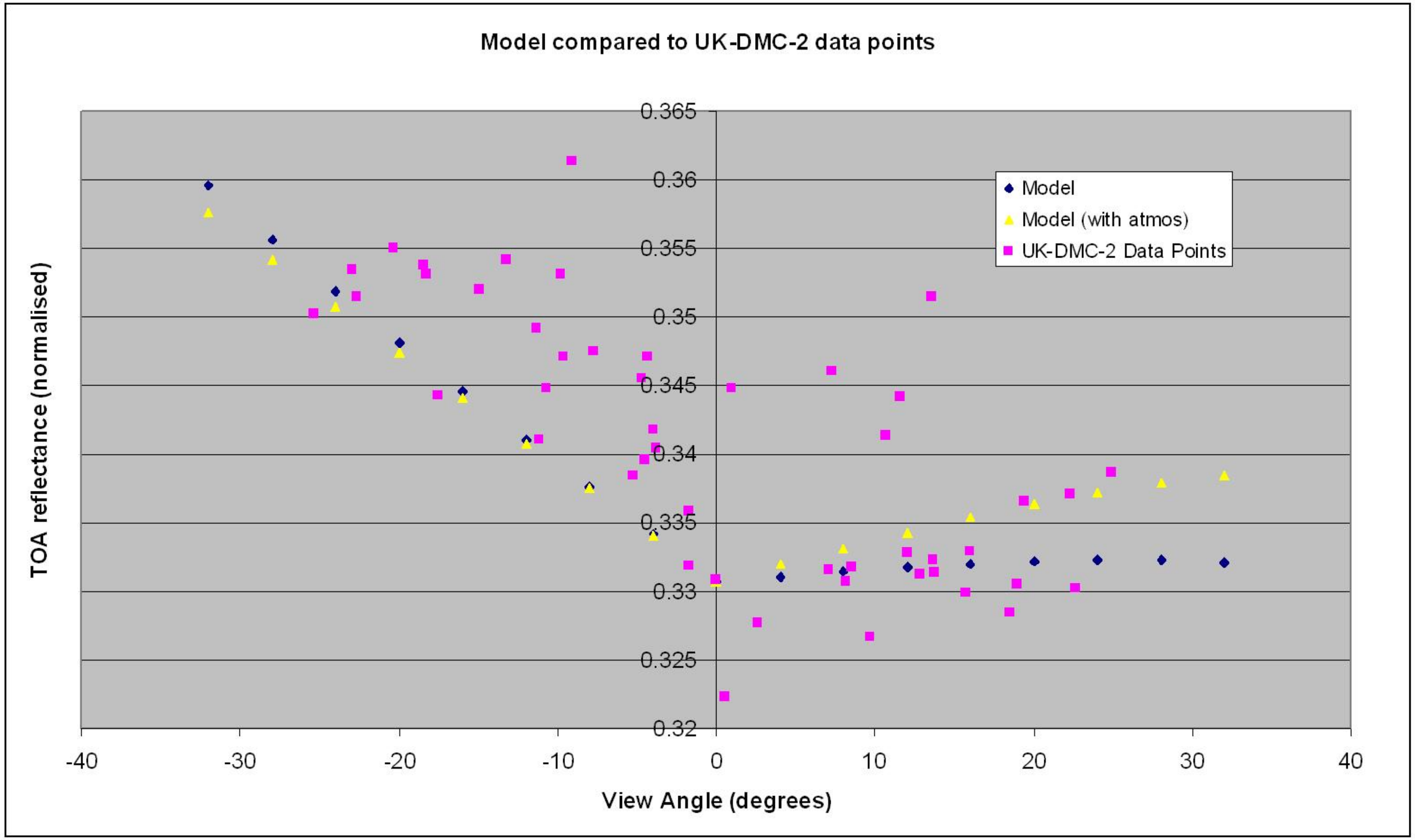
Using simple linear correction



Using separate linear for each bank

Libya 4 – Step 3

- Developing model of the surface is next step



Future

- Needs these techniques for Virtual Constellations with different Equatorial Crossing times (different LTAN's or LTDN's)
- Allows cross-calibration with temporal gaps not SNO.
- DMC constellation plan to tie to Landsat 7 for now
- Also looking at Sentinel – 2 from the European Space Agency as a "Gold" Standard (possible to use multiple tracking)
- Ultimately looking at the "TRUTHS" calibration laboratory in space as the "Gold" standard, guaranteeing an absolute uncertainty lower than 0.5%. **http://www.npl.co.uk/optical-radiation-photonics/environment-climate-change/research/truths**