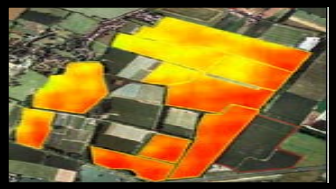
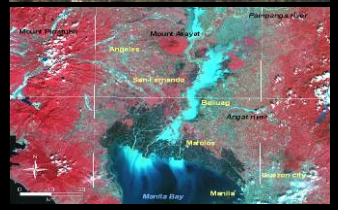




Comparison of the radiometry of Landsat 7 and the Disaster Monitoring Constellation (DMC) satellites over the Dome-C Calibration site in Antarctica

Steve Mackin (DMCii)
Gyanesh Chander (SGT/USGS)
contractor to the USGS EROS, Sioux Falls, SD, 57198 USA
*Work performed under USGS contract 08HQCN0005

International Imaging

Presentation

- Introduction to the study (Dec 2008 – Jan 2009)
  - Dome C
  - Sensors taking part
- TOA Reflectance a standard measurement ?
  - BRDF
  - Ozone
  - Water Vapour
- Cross-Calibration using Dome-C
- Cross-Calibration using CEOS reference sites
- Virtual Constellations and “Gold” standards

Intercomparison Study Site – Dome C

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

Sensors taking part

- From many agencies with different spectral and spatial resolutions and including
  - Landsat 7 ETM+
  - SPOT 5 HRG
  - ALOS AVNIR-2
  - UK-DMC-1 SLIM6
  - NigeriaSat-1 SLIM6
  - PROBA CHRIS
  - TERRA and AQUA MODIS
  - ENVISAT MERIS
  - OrbView-2 SeaWiFS
  - EO-1 Hyperion, AVHRR, AATSR….etc…
- We will concentrate primarily on UK-DMC-1, Landsat 7 with selected results from AVNIR-2 and NigeriaSat-1.

TOA Reflectance – A standard measurement ?

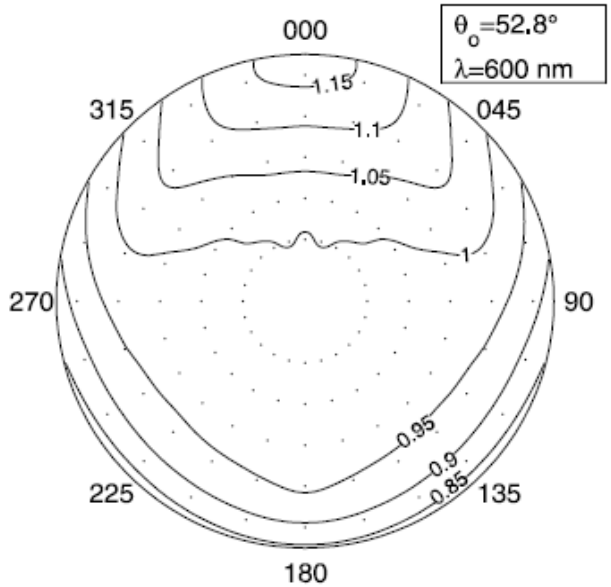
$$\rho_P = \frac{\Pi \cdot L_\lambda \cdot d^2}{\mathrm{ESUN}_\lambda \cdot \cos\theta_s}$$

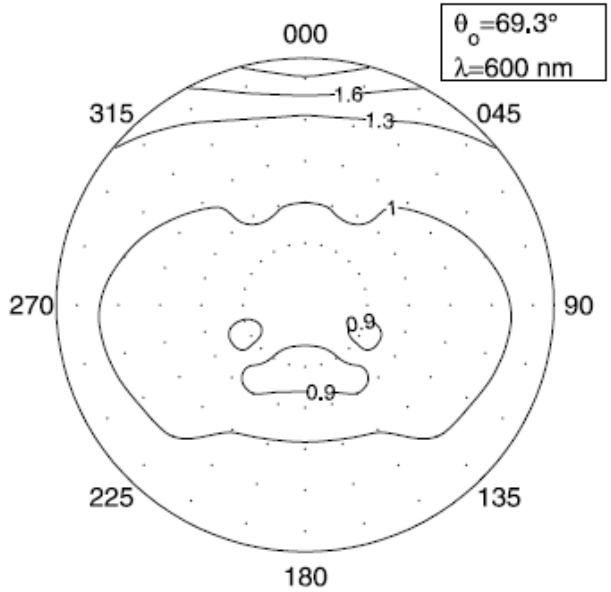
where

ρ_P	unitless planetary reflectance;
L_λ	spectral radiance at the sensor's aperture;
d	earth–sun distance in astronomical units;
ESUN_λ	mean solar exoatmospheric irradiances;
θ_s	solar zenith angle in degrees.

- Problems
  - BRDF
  - Atmosphere (ozone, water vapour, aerosols)
  - Surface variability

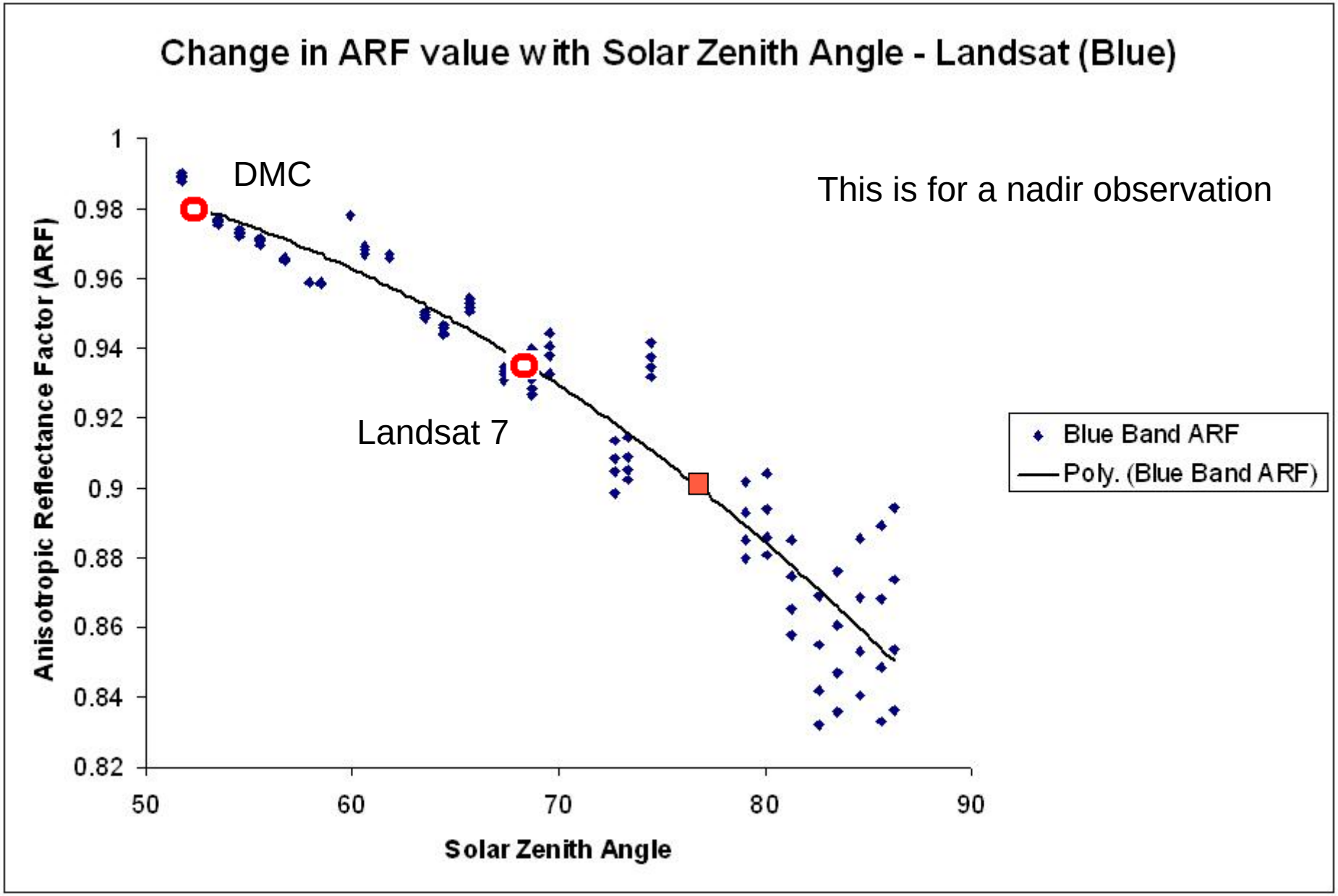
BRDF



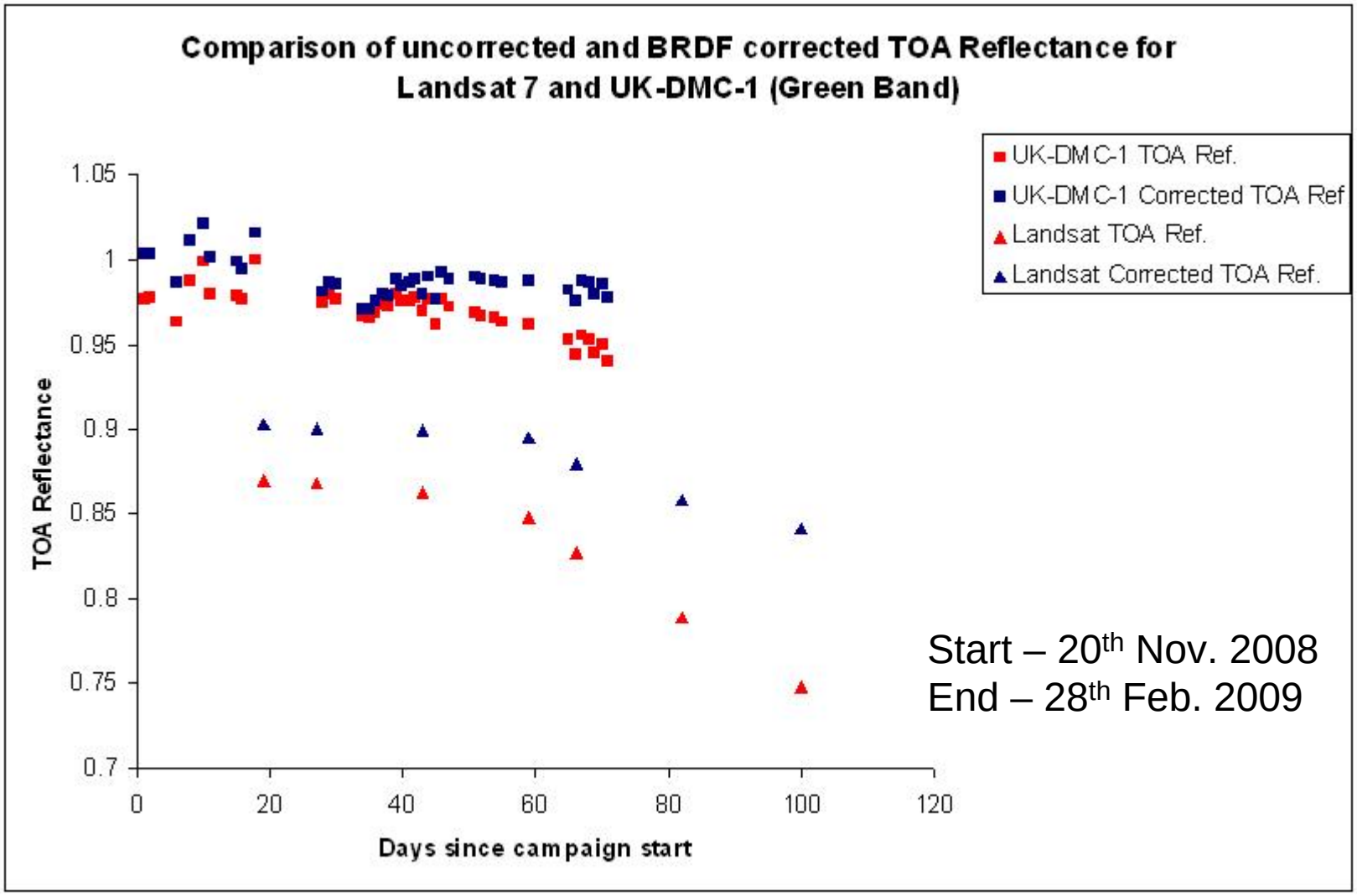


- The Anisotropic Reflectance Factor shows the normalised variation of reflectance across the entire hemisphere.
- The top plot is for a DMC like overpass solar zenith angle, while the bottom plot is an end of season LANDSAT overpass solar zenith angle
- Wavelength located at the red/green band boundary
- 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

BRDF

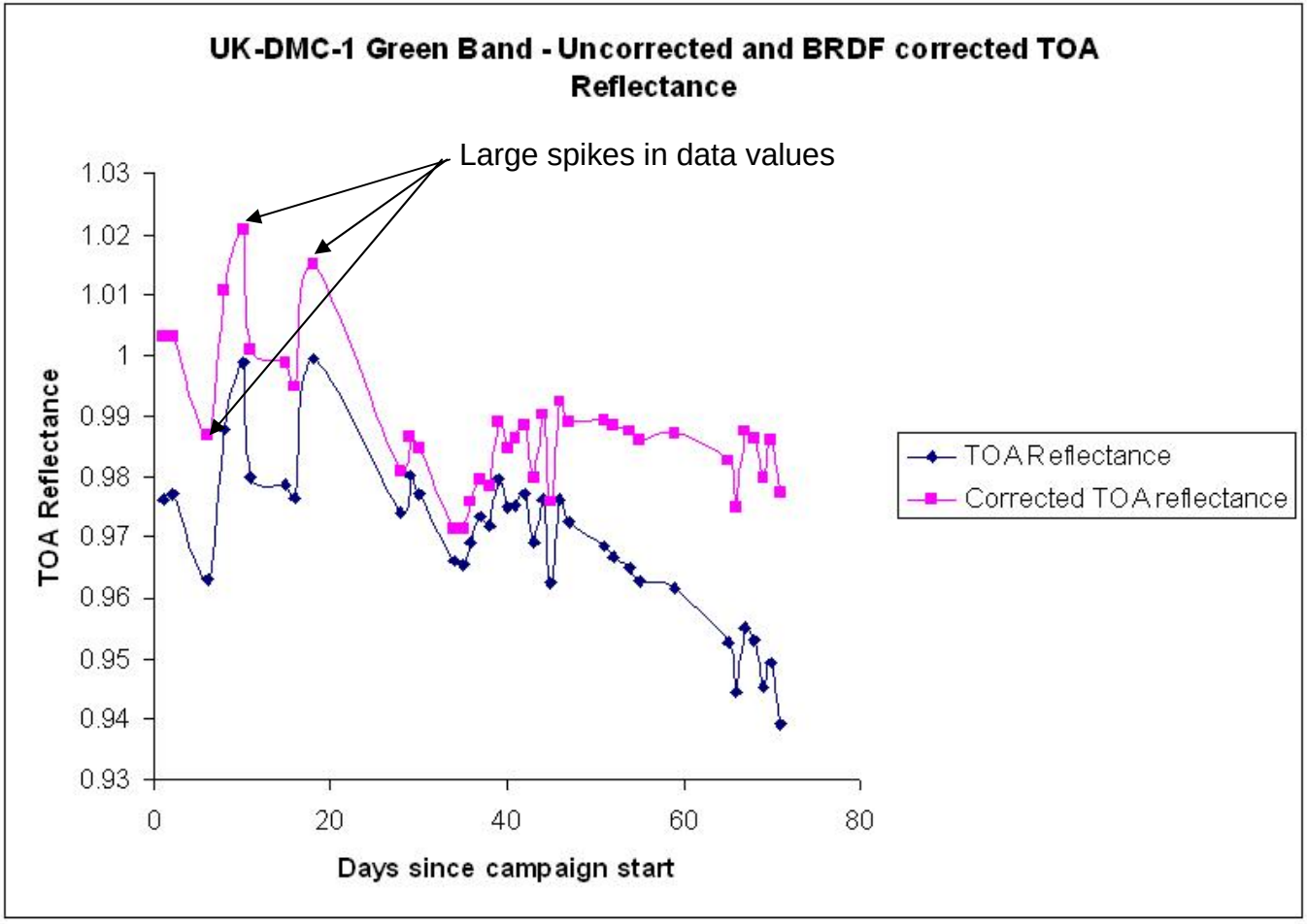

Change in ARF value with Solar Zenith Angle - Landsat (Blue)
DMC
This is for a nadir observation
Landsat 7
Anisotropic Reflectance Factor (ARF)
1
0.98
0.96
0.94
0.92
0.9
0.88
0.86
0.84
0.82
50
60
70
80
90
Solar Zenith Angle
Blue Band ARF
Poly. (Blue Band ARF)

BRDF Comparison



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

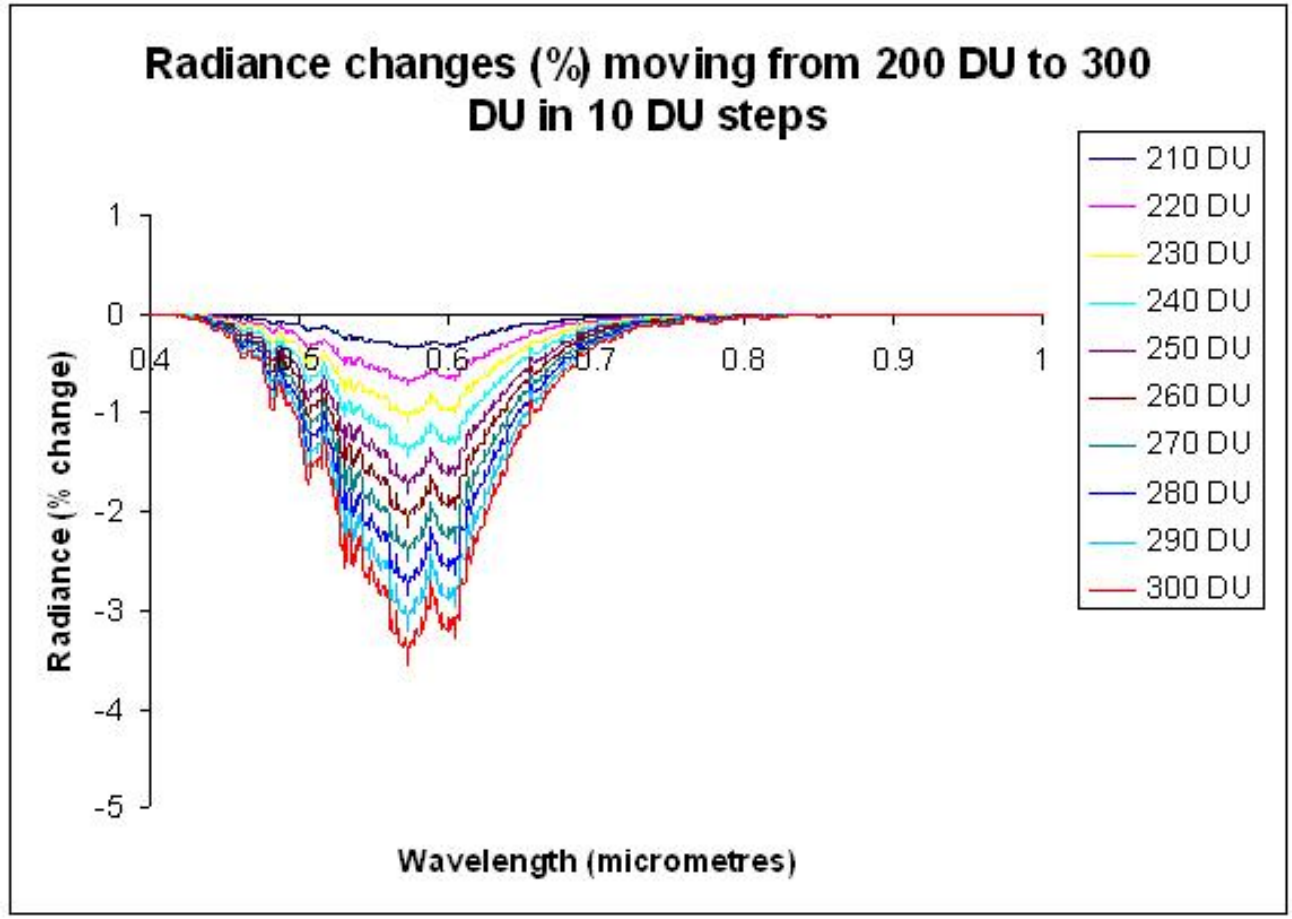
Other Factors



- Correction works well from day 25 onwards
- Features in data prior to this (spikes)

Ozone

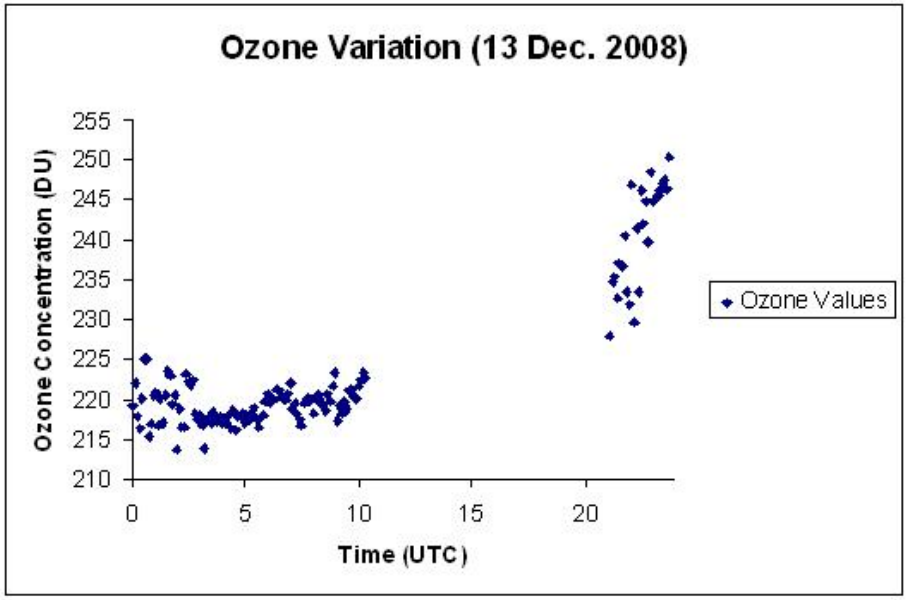
- Ozone absorption in the VNIR

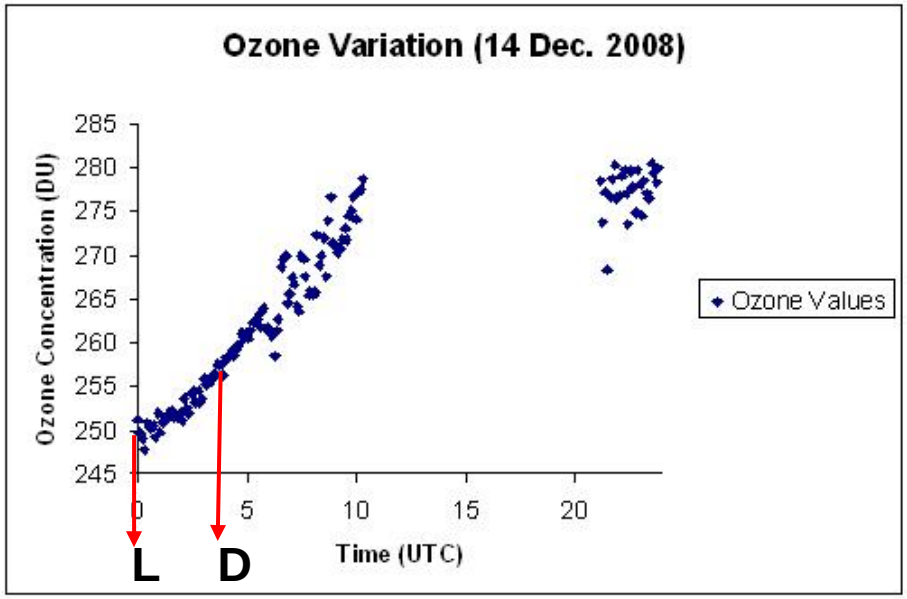


Known as the Chappius absorptions, the peak absorption is near the green / red boundary

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

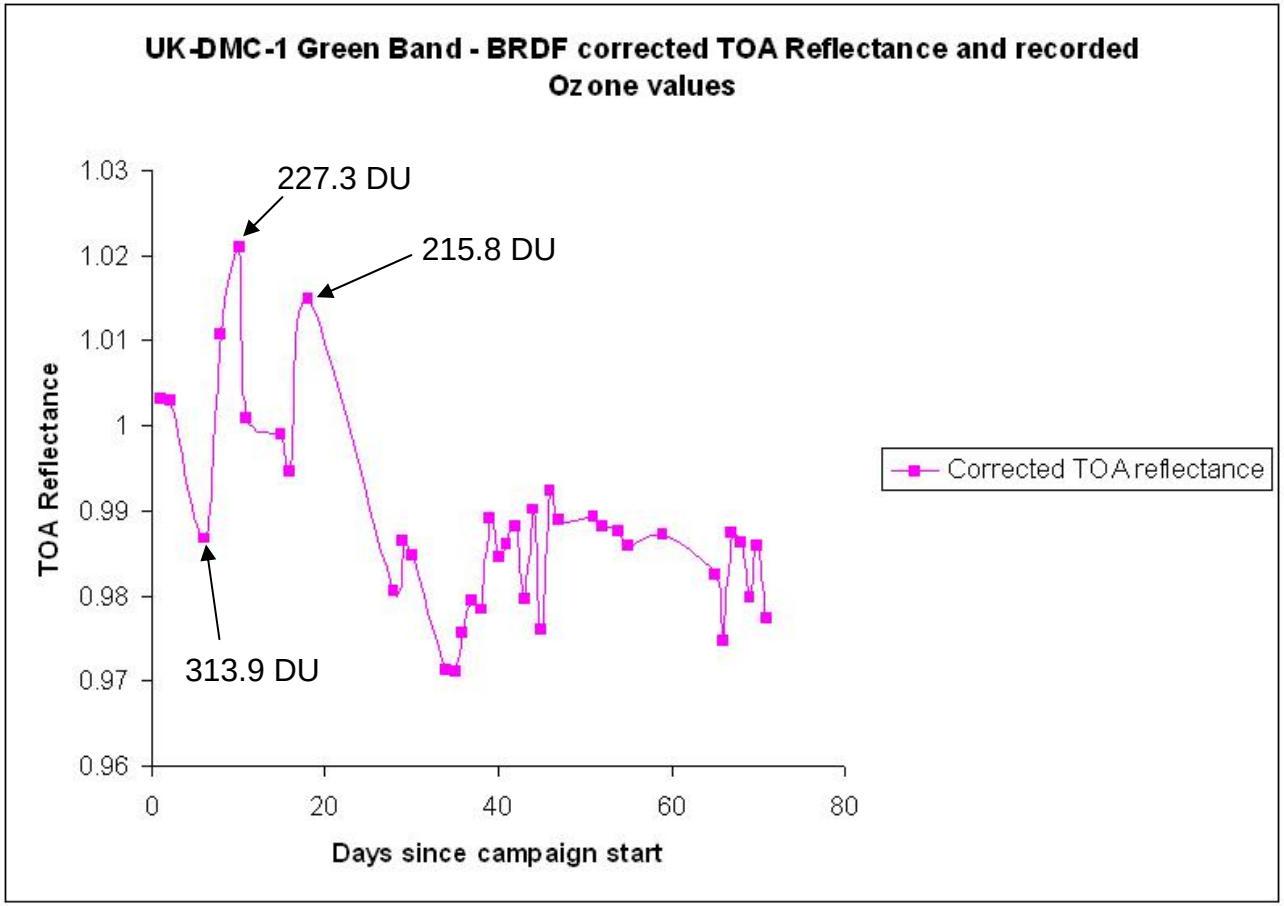
Ozone Variability





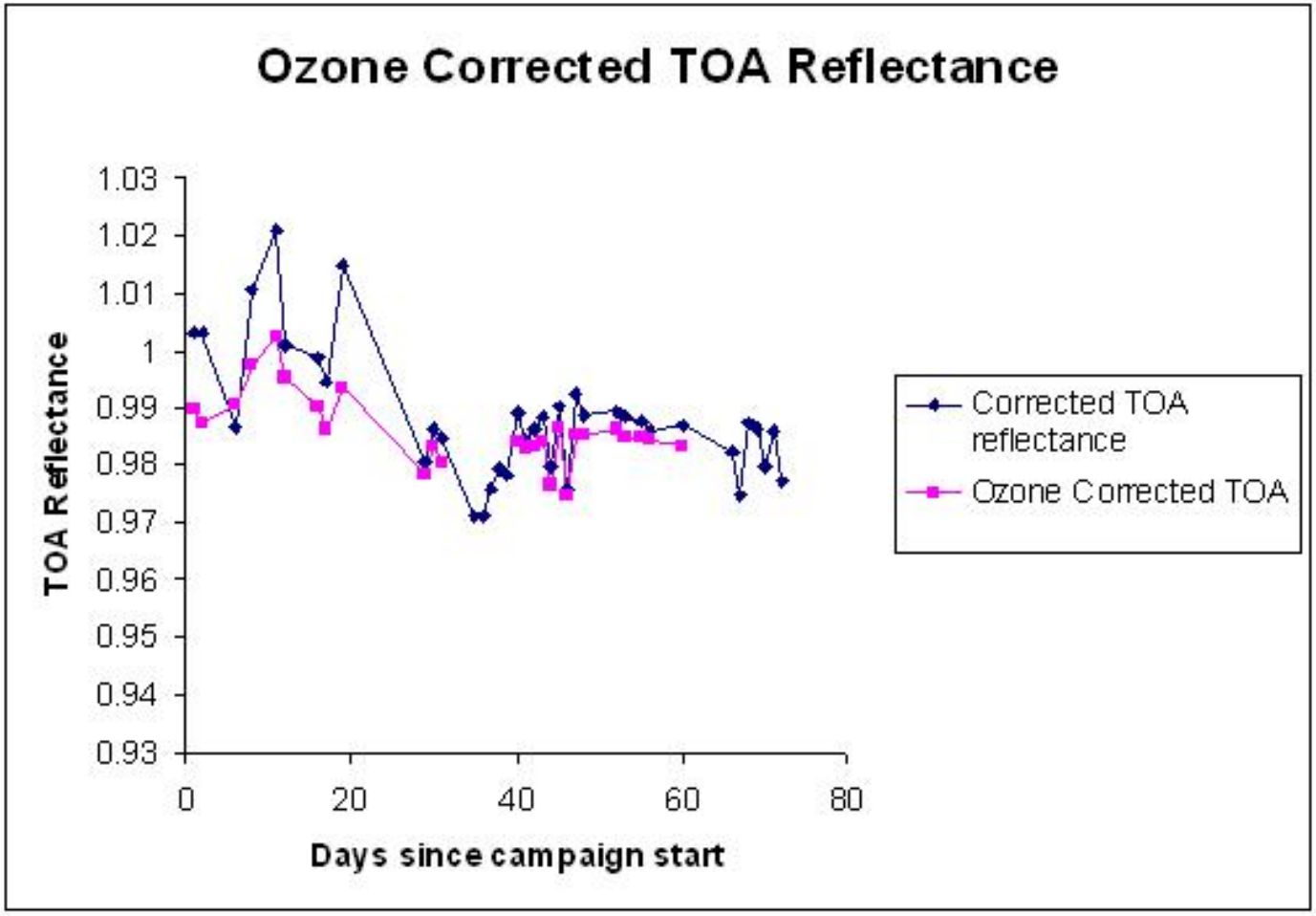
- Ozone can vary dramatically from day to day, so two acquisitions separated by one day could have an ozone difference of 50 DU equivalent to a radiance change of 1.75% at 600nm
- Even within a single day the recorded ozone can vary greatly. Note on the lower figure the L and D for Landsat and DMC overpasses (0.25% radiance difference at 600nm).
- Ozone profile temporally is not consistent.
- Some days missing from records.

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)

Example of ozone correction of UK-DMC-1



- The overall correction for some points is of the order of 2% (in radiance or reflectance terms (green band)
- Large reduction in the variability of the TOA Reflectance
- Some small residuals seem to be present

Other Factors – Surface Variability

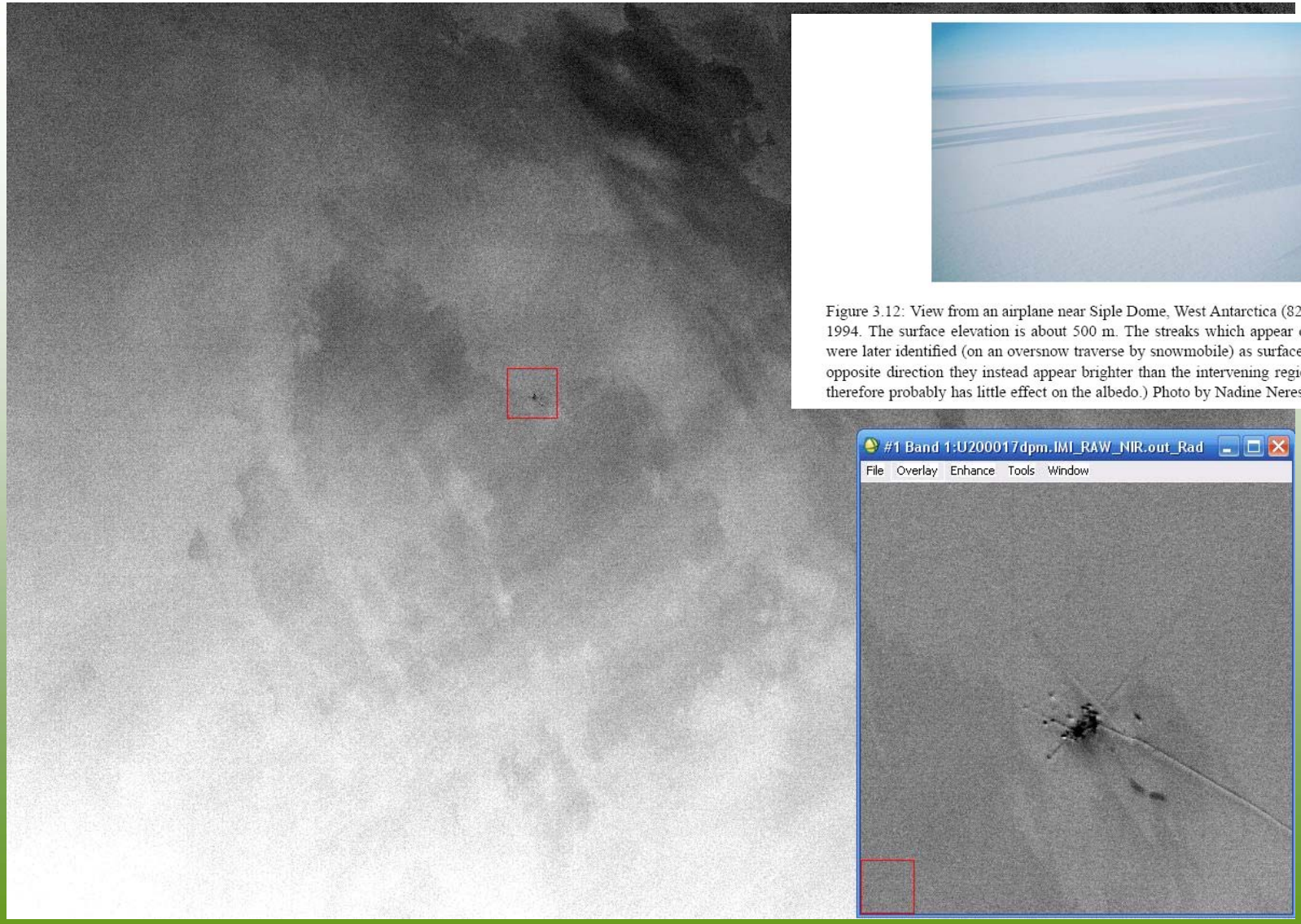
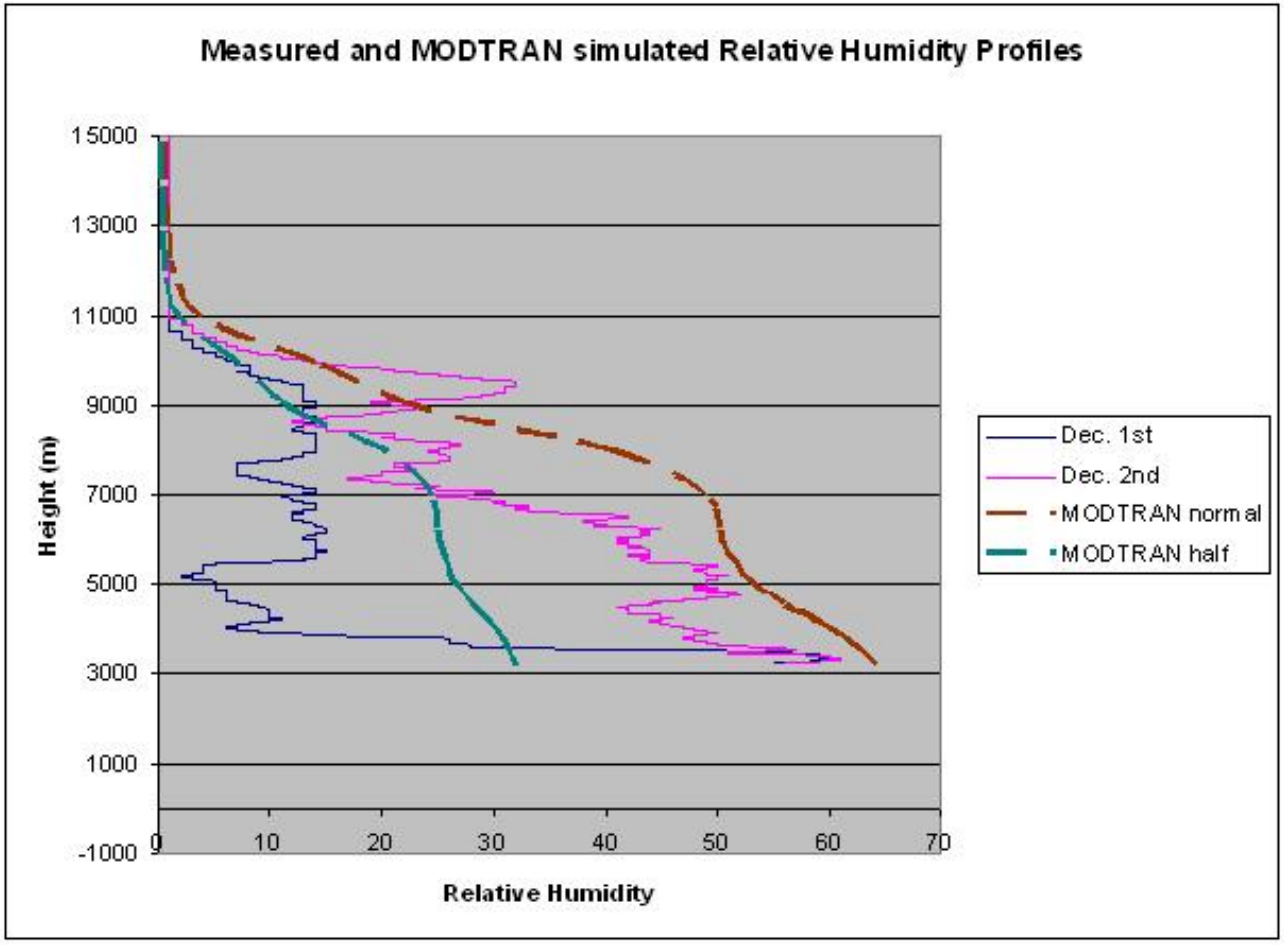


Figure 3.12: View from an airplane near Siple Dome, West Antarctica (82°S, 150°W), November 1994. The surface elevation is about 500 m. The streaks which appear dark in this photograph were later identified (on an oversnow traverse by snowmobile) as surface frost; viewed from the opposite direction they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

Other Factors

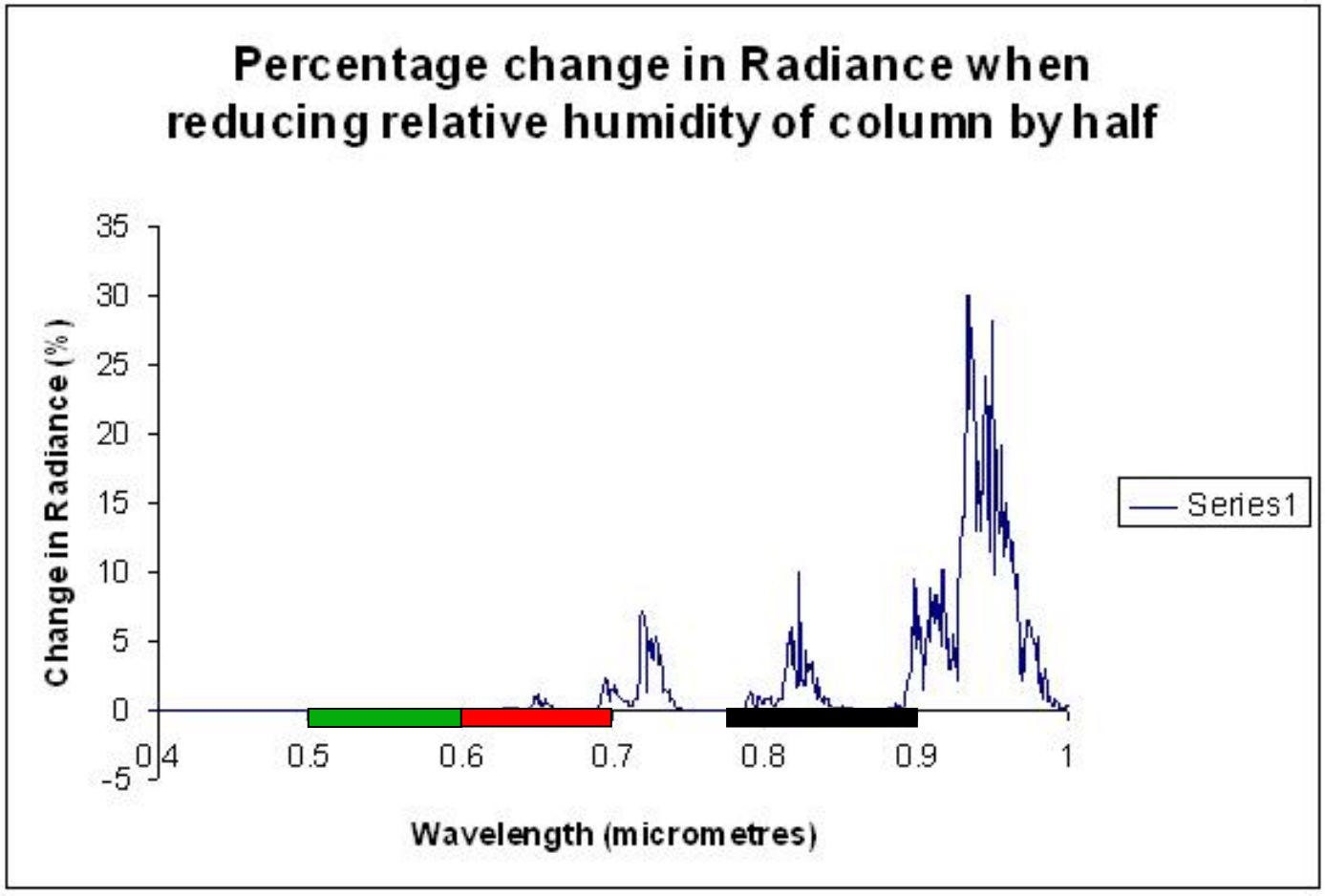
- Water Vapour



- 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

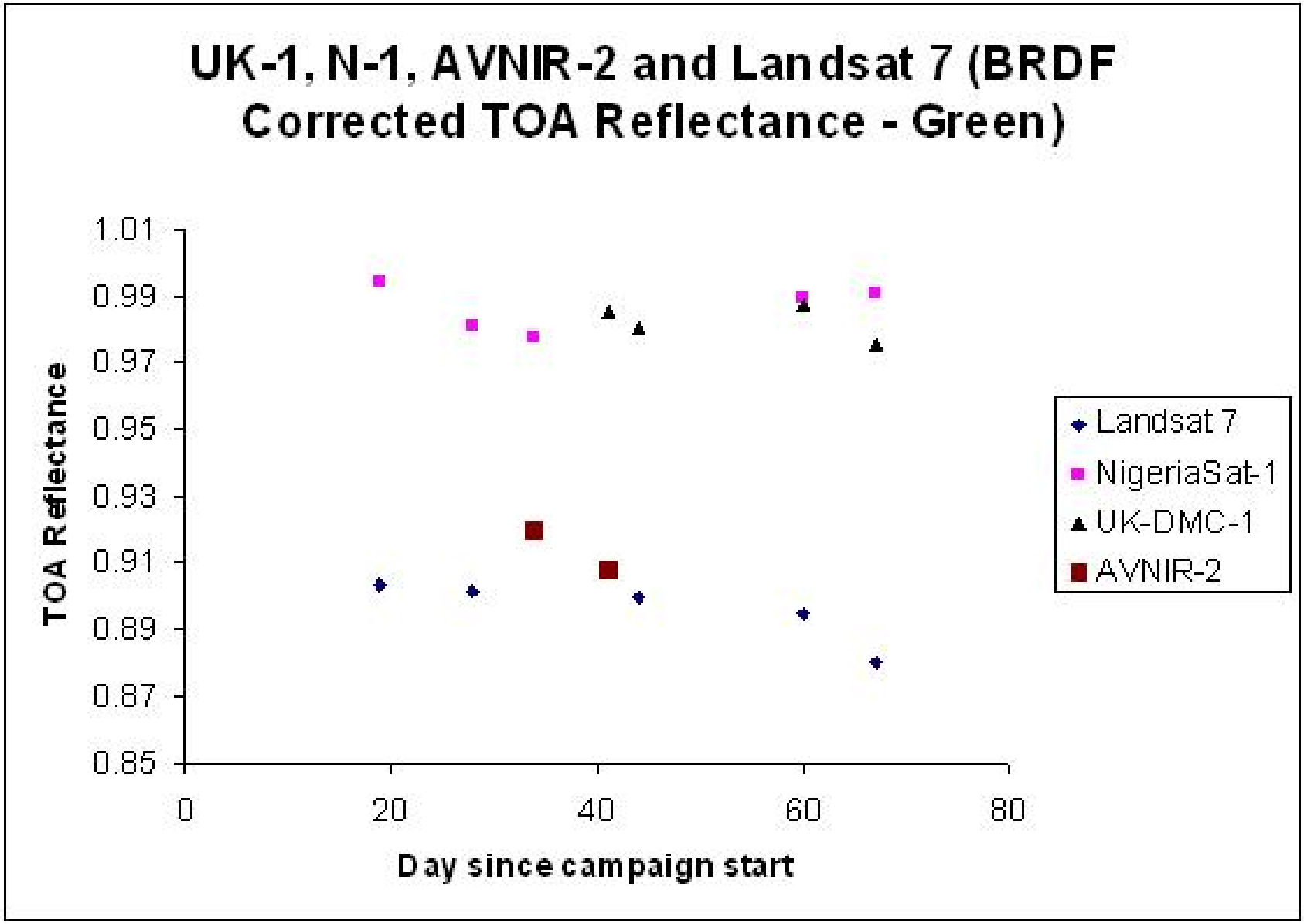
- Water Vapour



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.

Cross Calibration Dome-C (2008-2009)



Cross Calibration Dome-C (2008-2009)

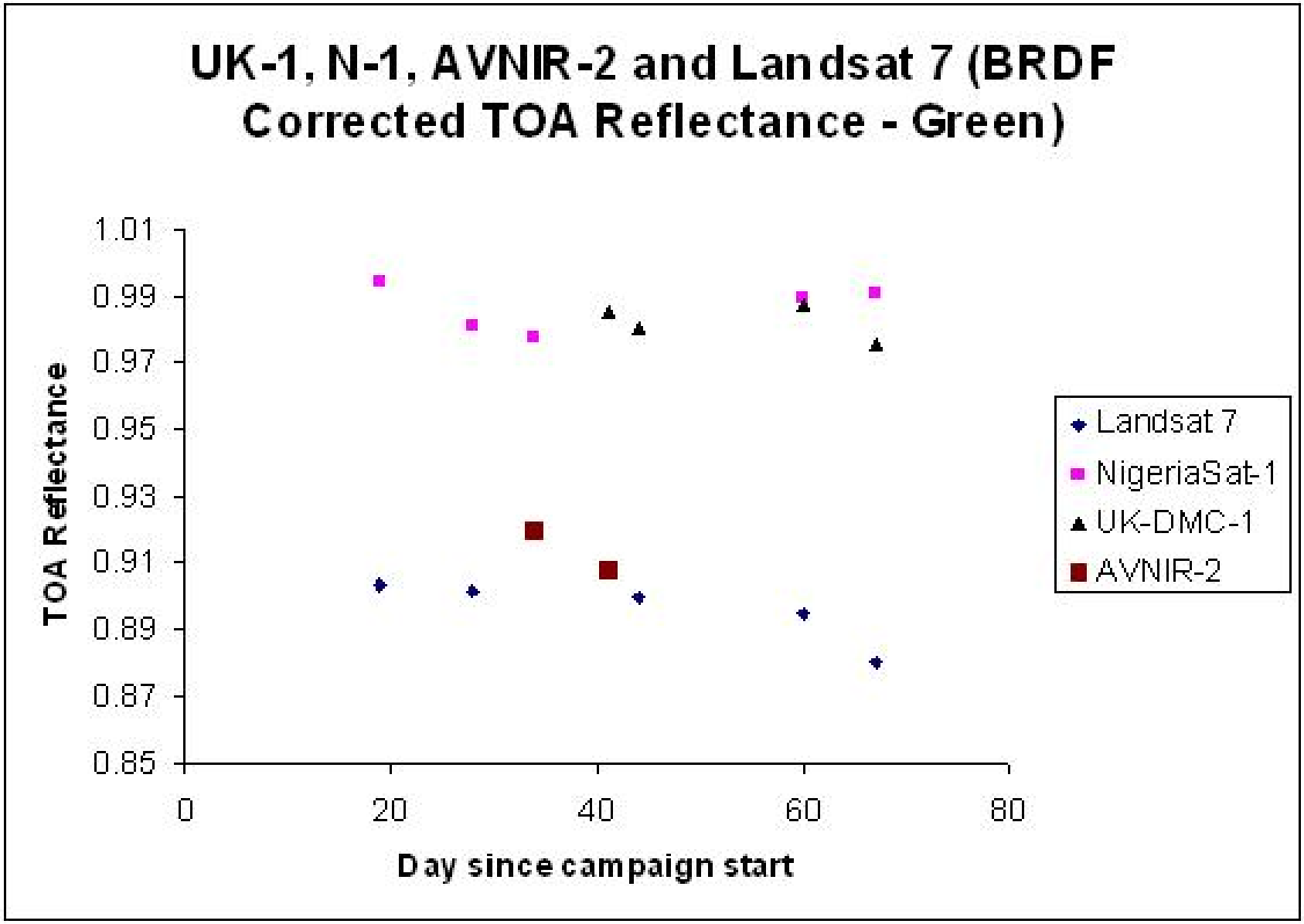
Satellite	Diff from Landsat (G)	Diff from Landsat (R)	Diff from Landsat (N)
Landsat	0	0	0
NigeriaSat-1	+ 9.07%	+ 7.79%	+ 9.77%
UK-DMC-1	+ 8.59%	+ 7.44%	+ 9.36%
AVNIR-2	+ 1.75%	- 0.12%	- 6.32%

Overall the DMC values were over 7% higher than Landsat in all bands

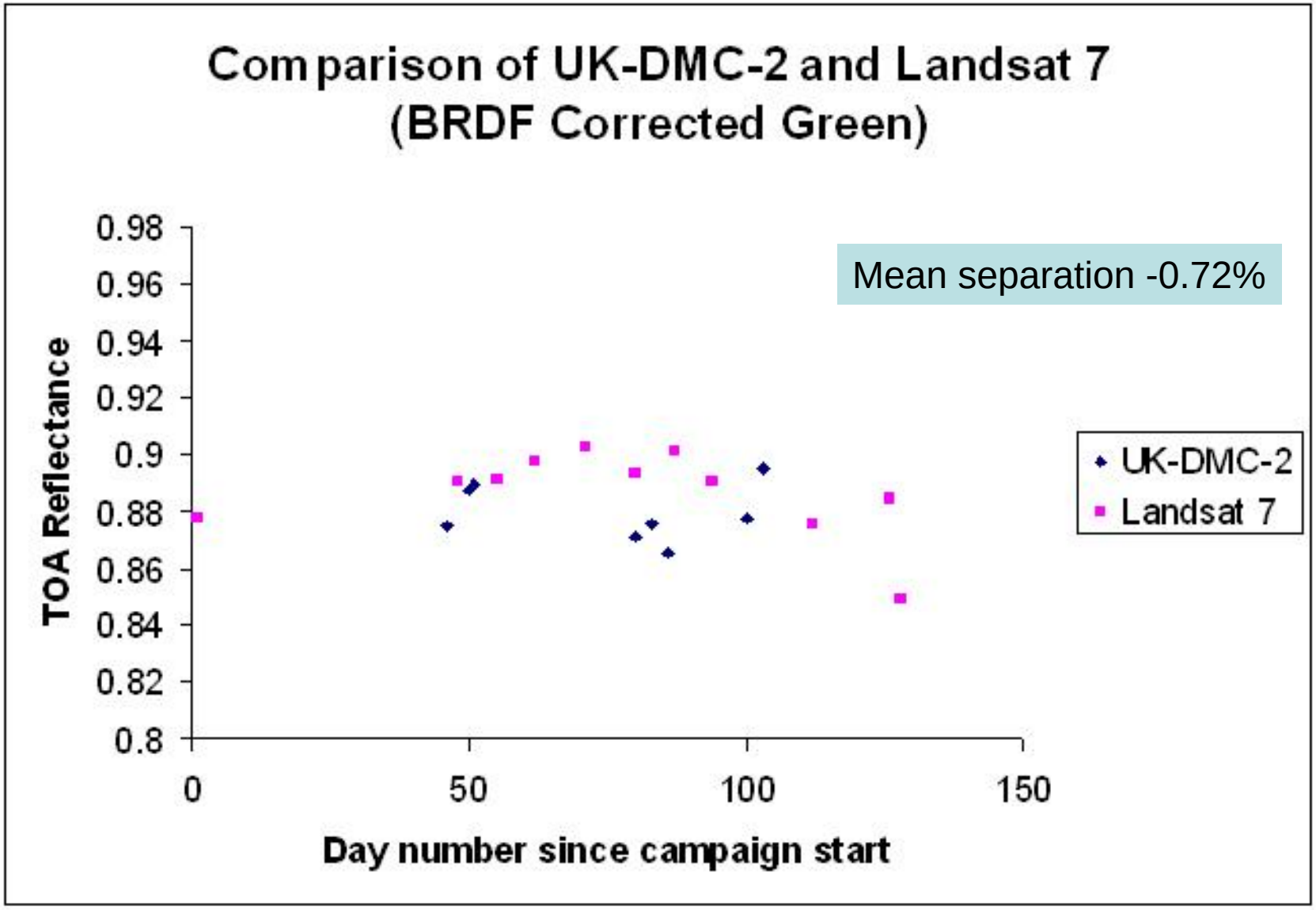
Between DMC satellites the values were within 1%.

Landsat shows a drop off in TOA Reflectance not seen in the DMC satellites (BRDF model ?)

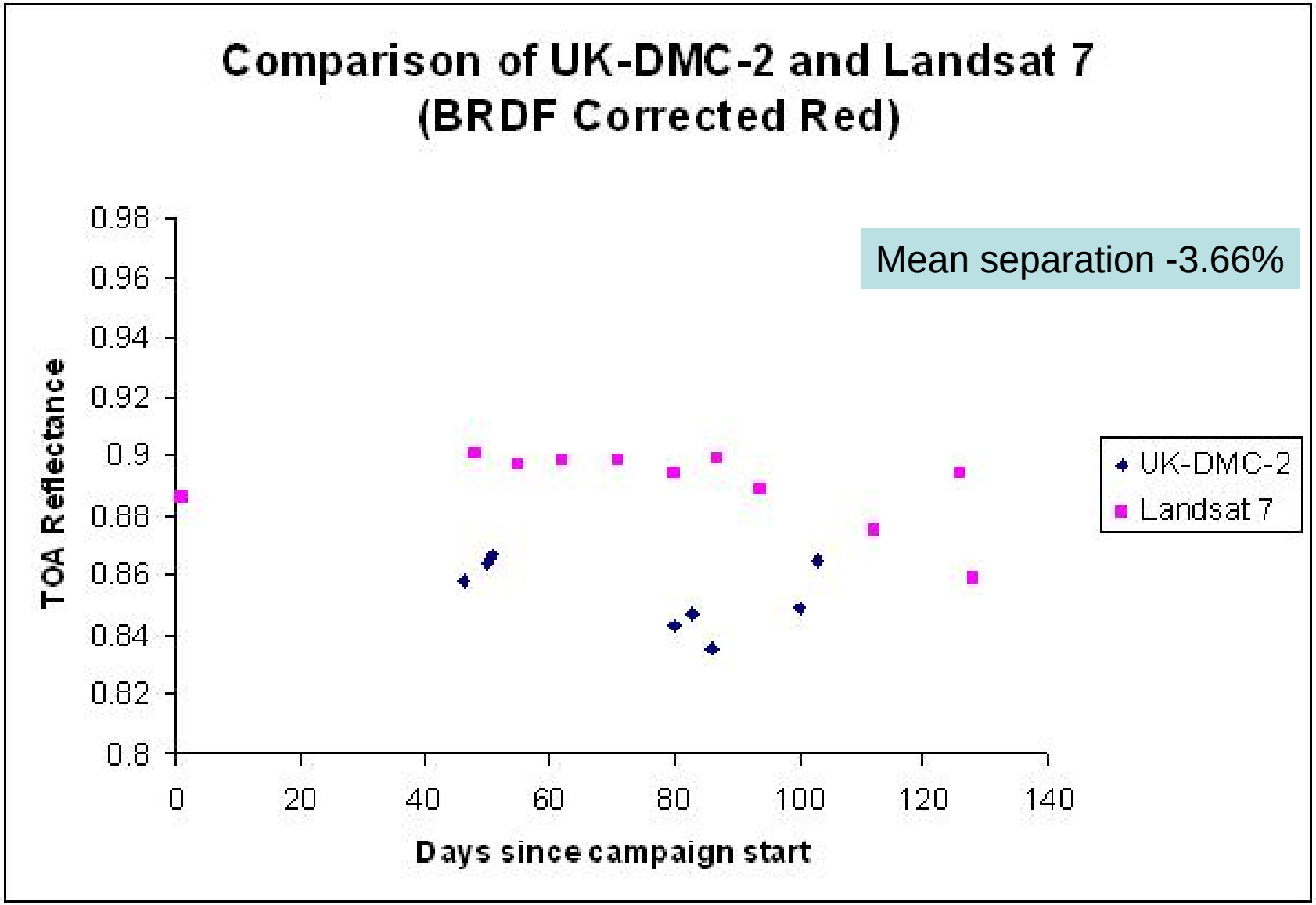
Cross Calibration Dome-C (2008-2009)



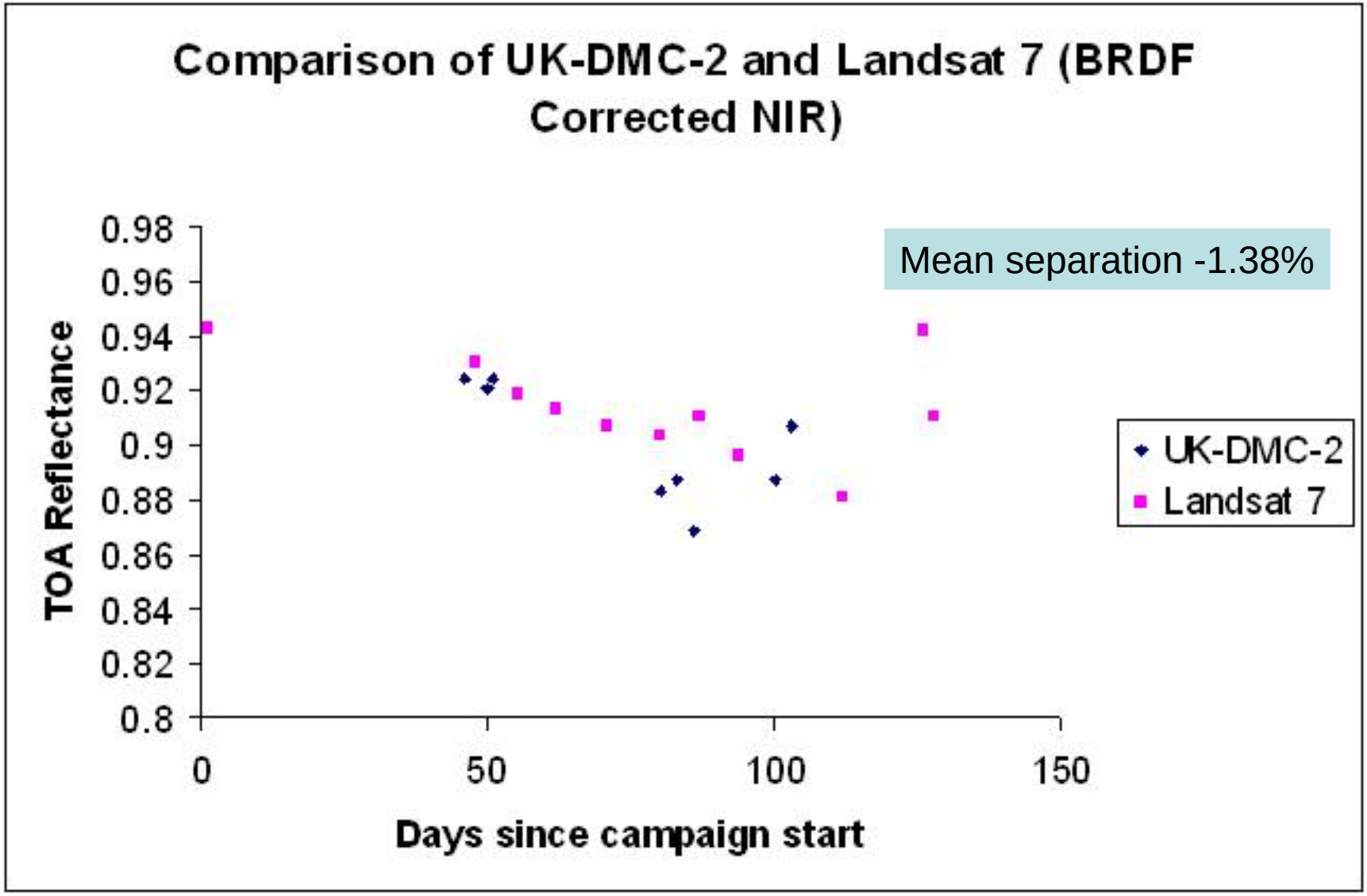
Cross Calibration Dome-C (2009-2010)



Cross Calibration Dome-C (2009-2010)



Cross Calibration Dome-C (2009-2010)



Cross-Cal other sites

- Libya 4 site (CEOS reference)
- Need detailed BRDF (MISR, CHRIS, ground ?)
- Need atmospheric measurements (aerosols, water vapour and ozone)

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

Future

- Needs these techniques for Virtual Constellations with different Equatorial Crossing times (different LTAN's or LTDN's)
- Allows cross-calibration with temporal gaps
- 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 uncertainty lower than 0.5%. **http://www.npl.co.uk/optical-radiation-photonics/environment-climate-change/research/truths**

Thank You!

- www.dmcii.com
- www.sstl.co.uk

Sustainable Earth Observation