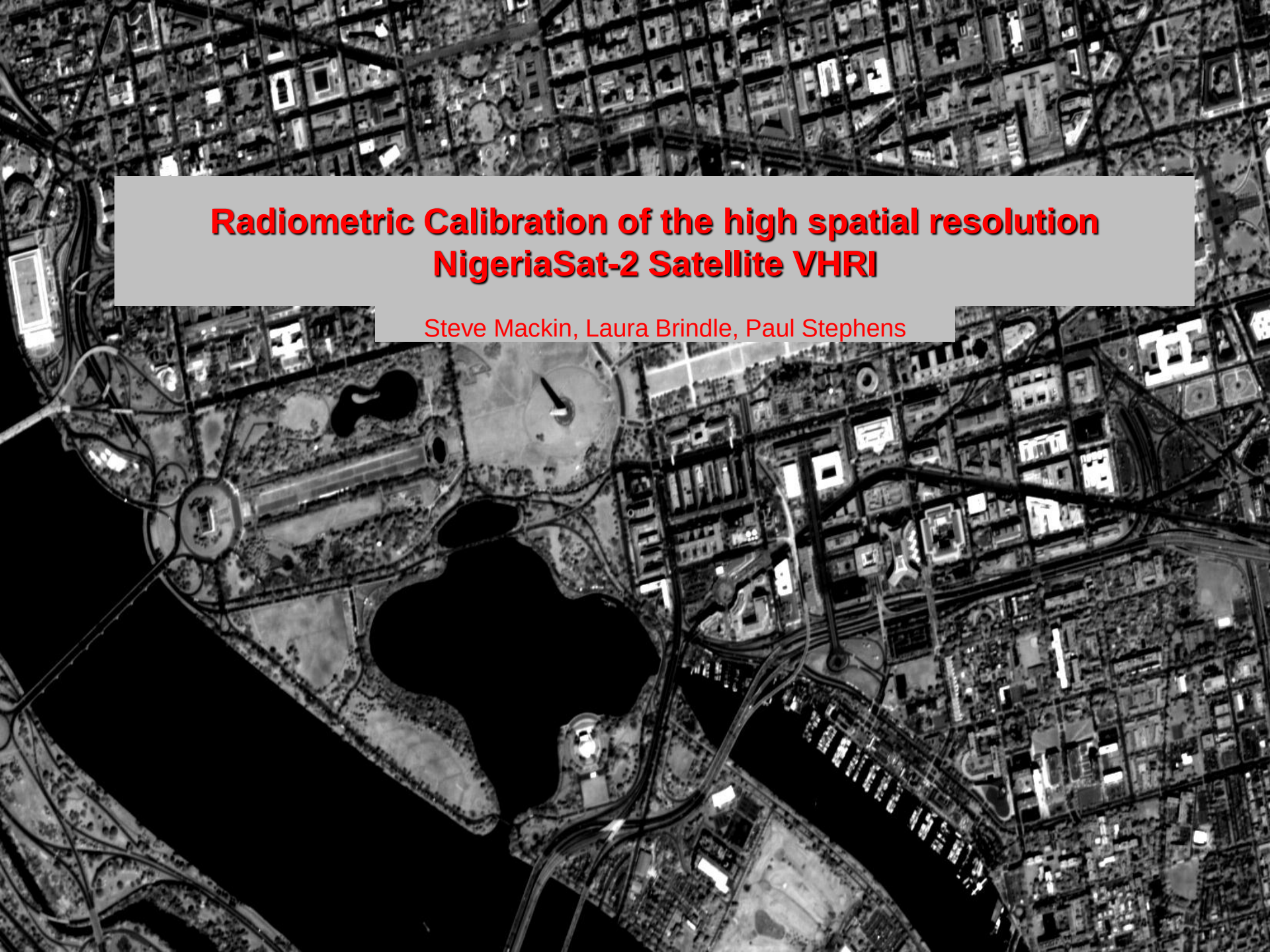


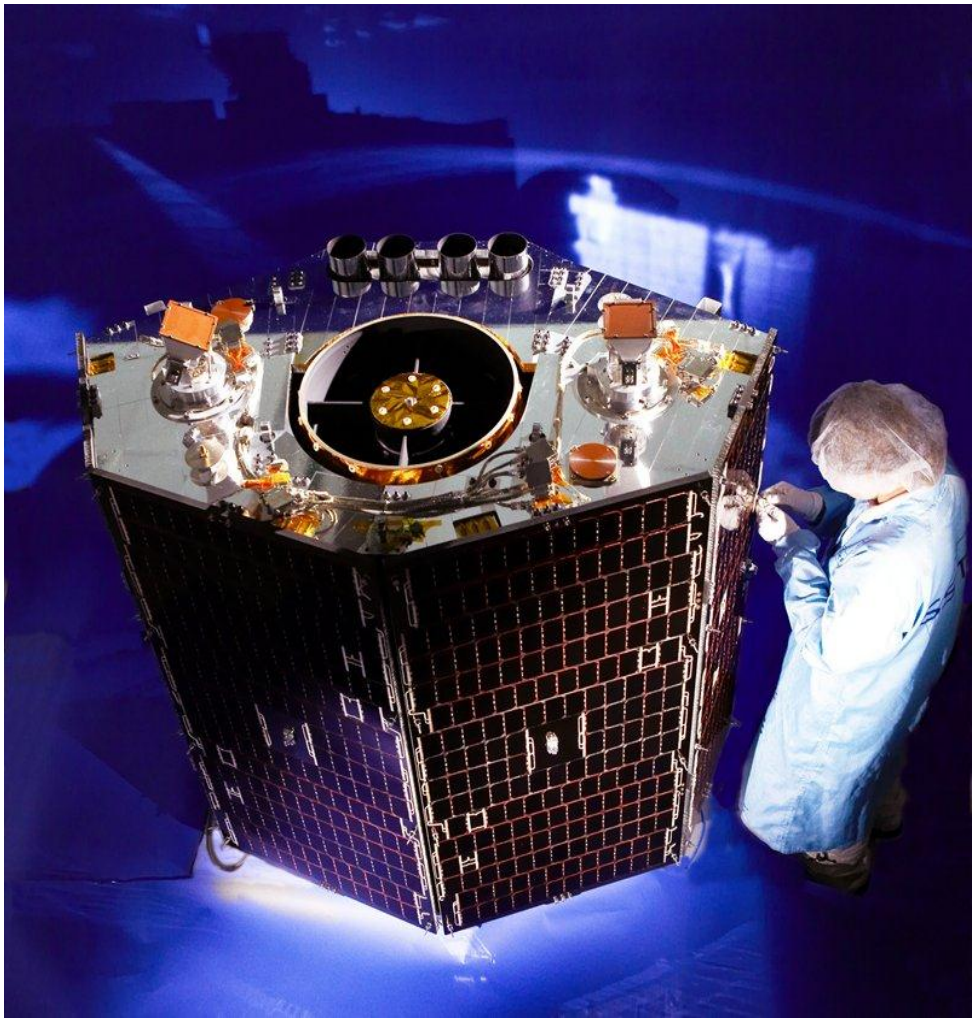
Radiometric Calibration of the high spatial resolution NigeriaSat-2 Satellite VHRI

Steve Mackin, Laura Brindle, Paul Stephens

NigeriaSat-2 (N2)

- Agile small satellite weighing 268 kg
- Two sensors
  - 32m GSD four band multispectral instrument
  - 5m GSD four band multispectral with 2.5m PAN band

Band	Wavelengths
Blue	448 – 517 nm
Green	527 – 606 nm
Red	630 – 691 nm
NIR	776 – 898 nm
PAN	520 – 898 nm

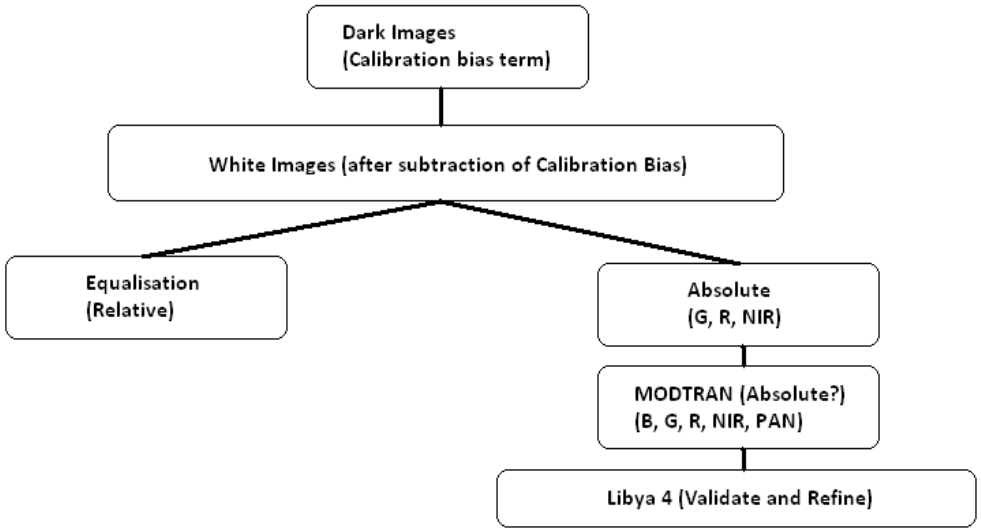


NigeriaSat-2

- Agile
- Stereo Modes
- Area Modes
- 20km swath

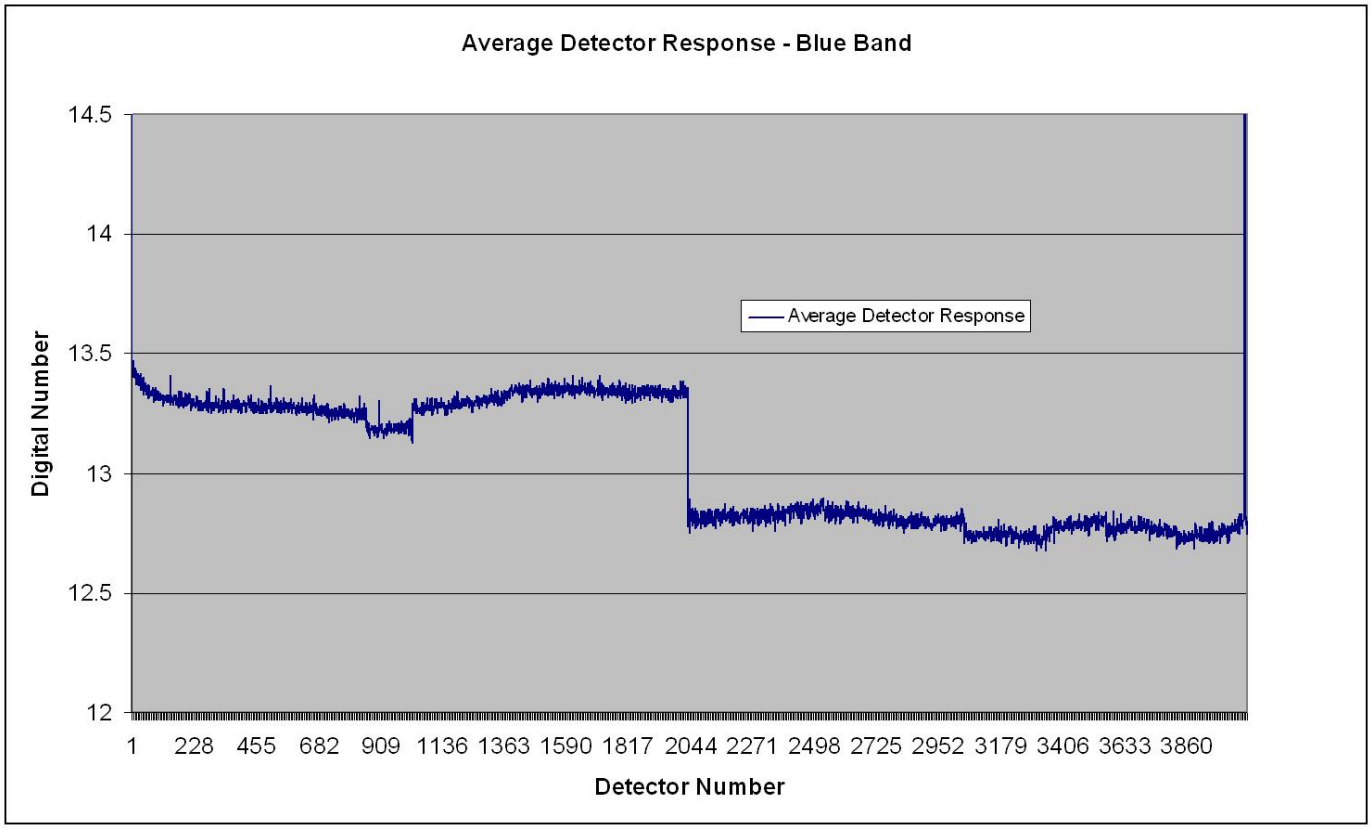
Calibration Steps

- Dark Images (Pacific Ocean at Night)
- White Images (Dome-C Antarctica)
  - Equalisation (no yaw)
  - Cross-calibration – UK-2
  - Use of MODTRAN modelling
- Libya 4
  - Cross-calibration – Landsat 7



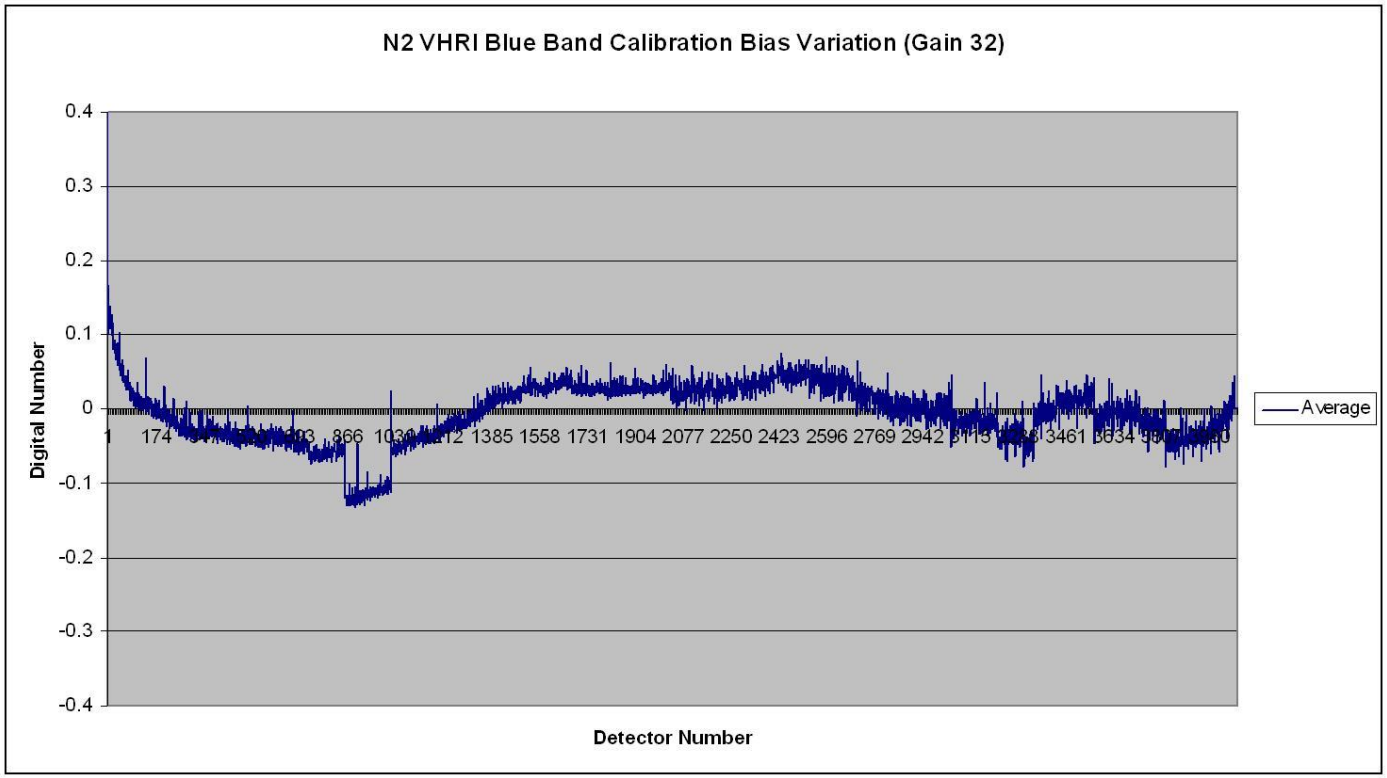
Dark Images

- Collect dark images (4 CCD segments)

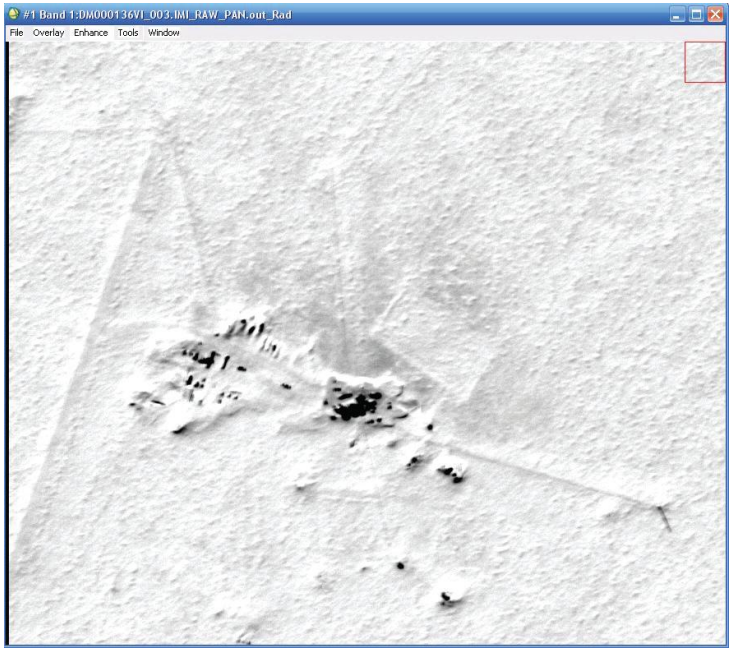


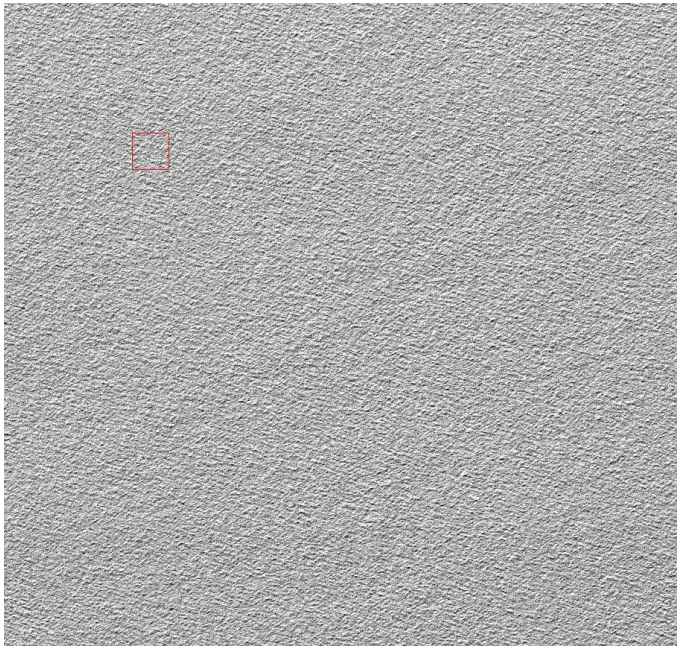
Dark Images

- Subtract reference pixel values per segment
  - Residual values form calibration bias terms



White Images - Equalisation (Relative)





- Instrumented Franco-Italian base, 3.2km above sea level on a very flat plateau.

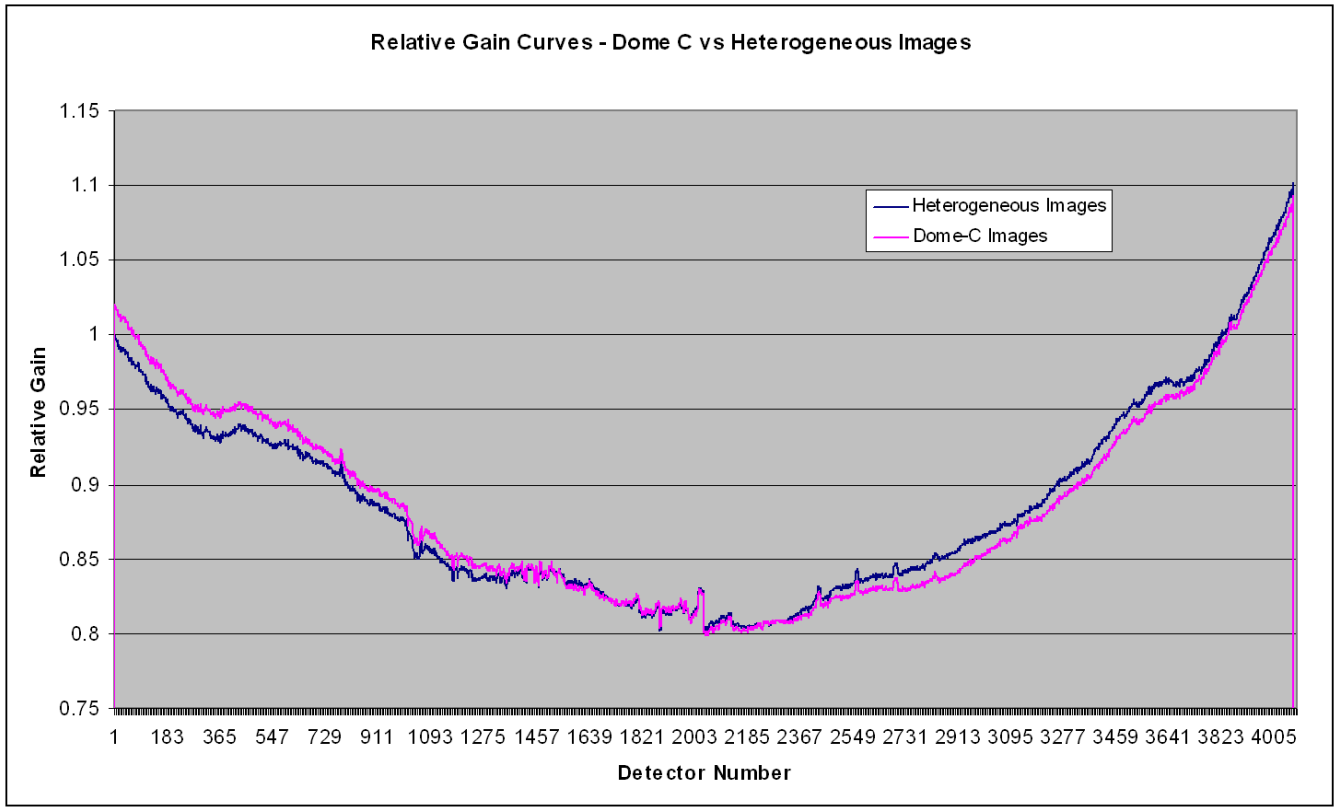
- Temperatures below -40C, so stable all year round, with minimum of recrystallisation

White Images - Equalisation (Relative)

- Dome-C
  - In the past DMC sensors yawed across the principal plane to the sun to reduce illumination and BRDF effects.
  - Nigeriasat-2 has a Field Of View (FOV) of 1.67 degrees (20km) – Landsat 7 ETM+ has an FOV of approximately 15 degrees.
  - We assumed that 1.67 degrees was not a problem in terms of illumination and BRDF effects.

White Images – Equalisation (Relative)

- Dome-C
  - Alternative method, from our automatic processing using heterogeneous images shows a distinct BRDF signature (Dome-C captured in descending node) with left side of plot looking towards the sun.



White Image – Issues (Absolute)

- Ozone effects (up to 3% at 600nm)

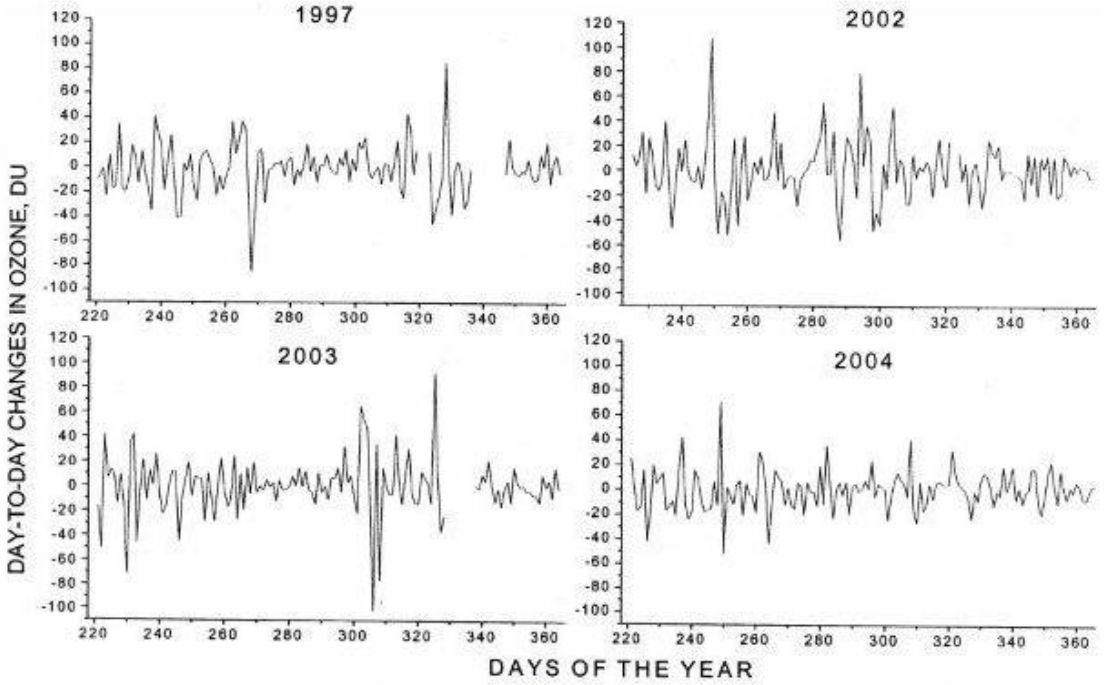
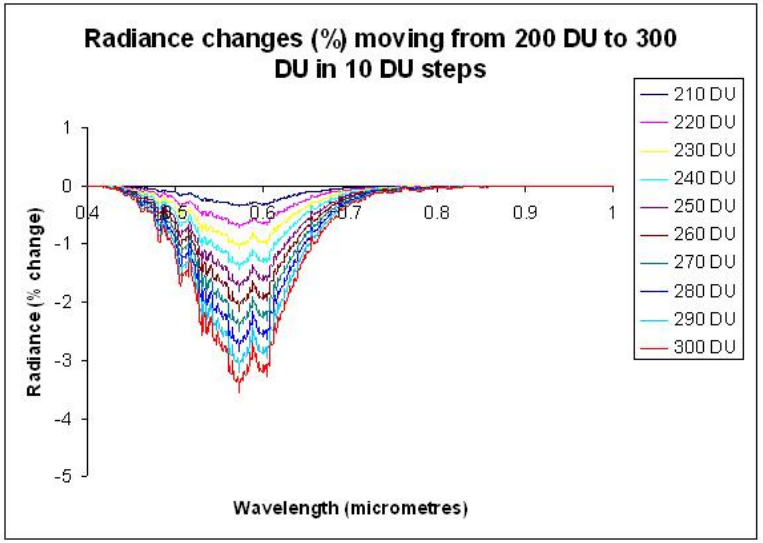


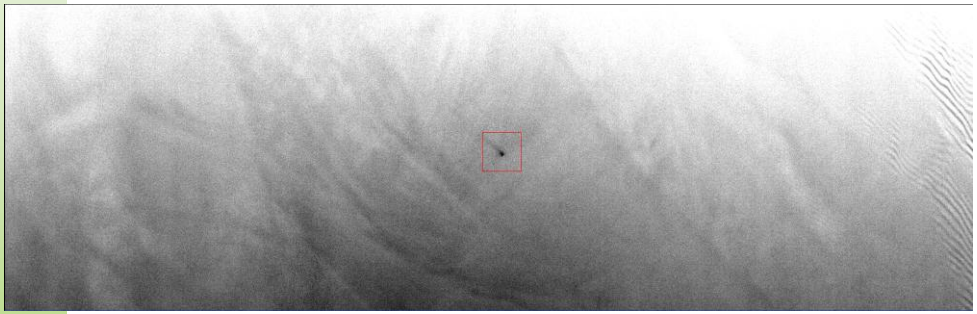
Fig. 3—Day-to-day change of daily total ozone during ozone hole periods of 1997, 2002, 2003 and 2004



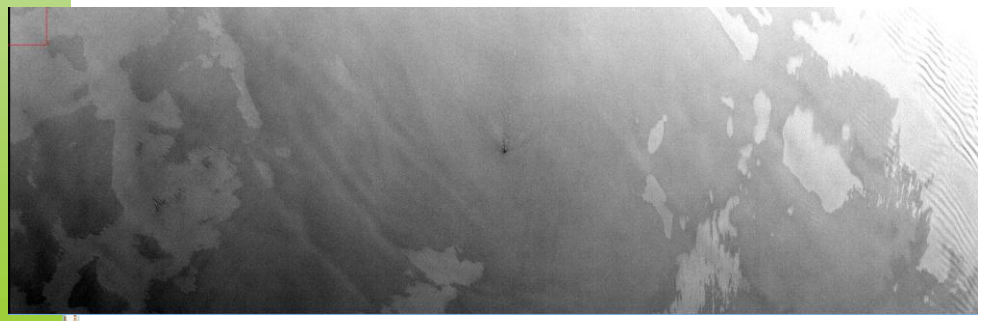
INDIAN J RADIO & SPACE PHYS, AUGUST 2006

White Image – Issues (Absolute)

- Water Vapour (effects up to 1% in the NIR)
- Surface Variability effects.



15f



205

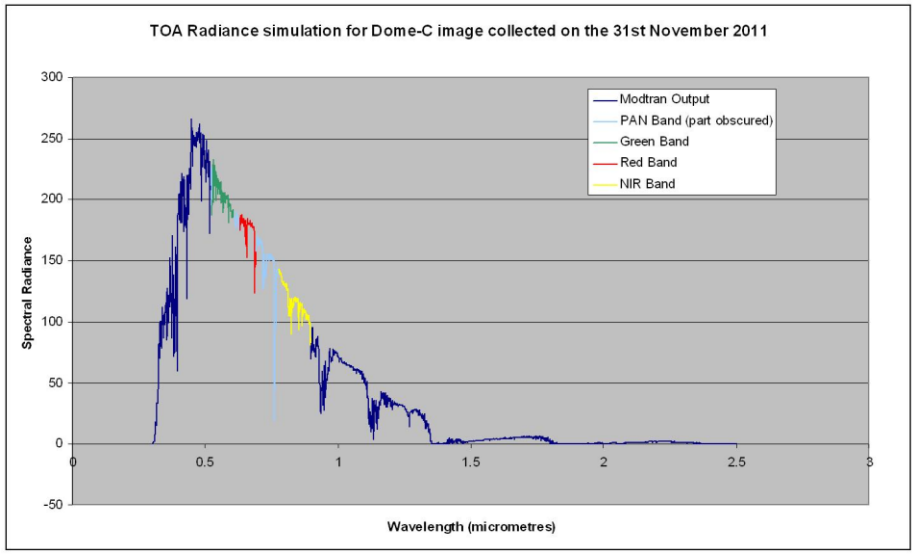
The upper image was taken on the 4th December 2011, while the lower image was taken late in the season on the 5th February 2012.

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

Absolute Calibration (Blue and PAN bands)

- Only able to calibrate the green, red and NIR bands.

UK-DMC-2		MODTRAN	
		Blue	238.50 W
Green	203.78 W	Green	206.34 W
Red	179.83 W	Red	176.62 W
NIR	119.93 W	NIR	115.15 W
		PAN	156.57 W

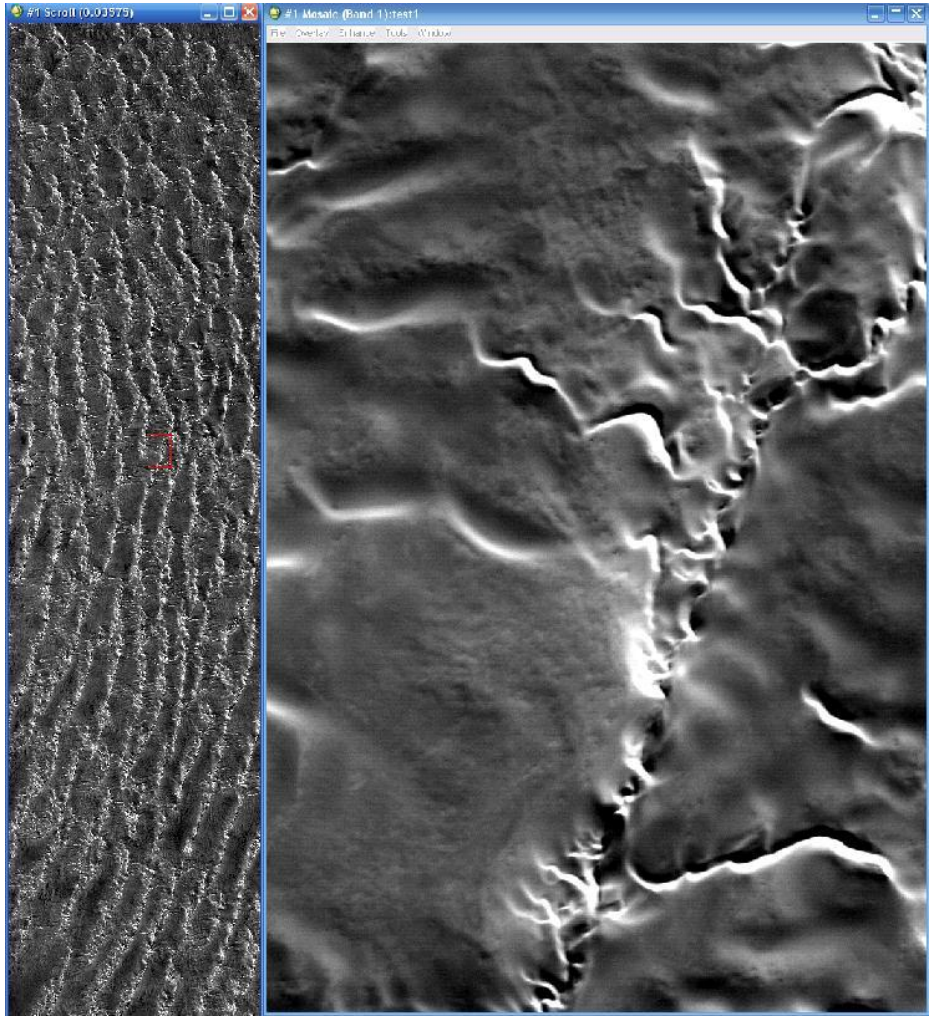


- Use MODTRAN to simulate the spectral bands of NigeriaSat-2 (blue and PAN)

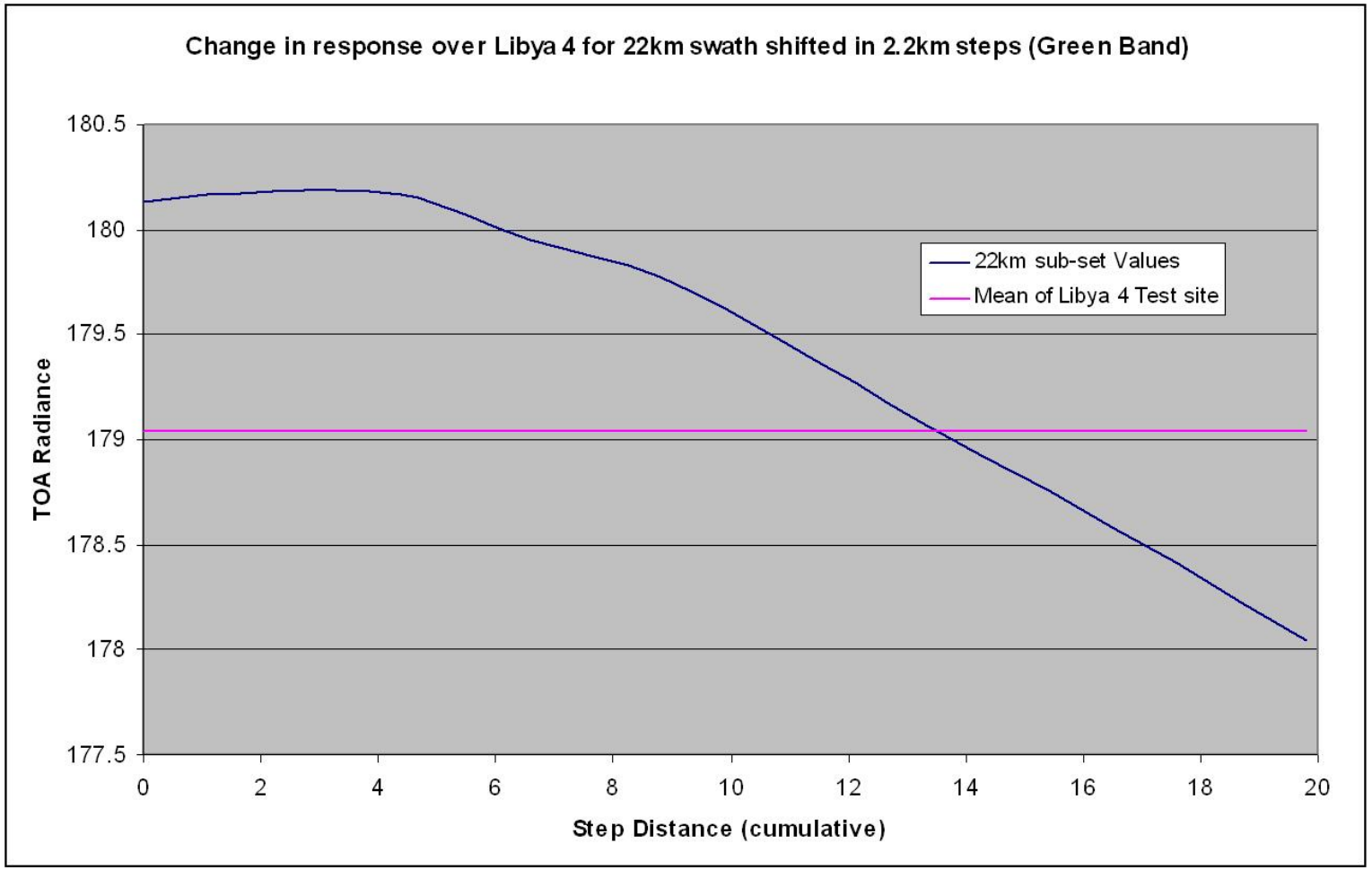
- Indicative values. Revised using the Libya 4 data.

Cross-Calibration Libya 4

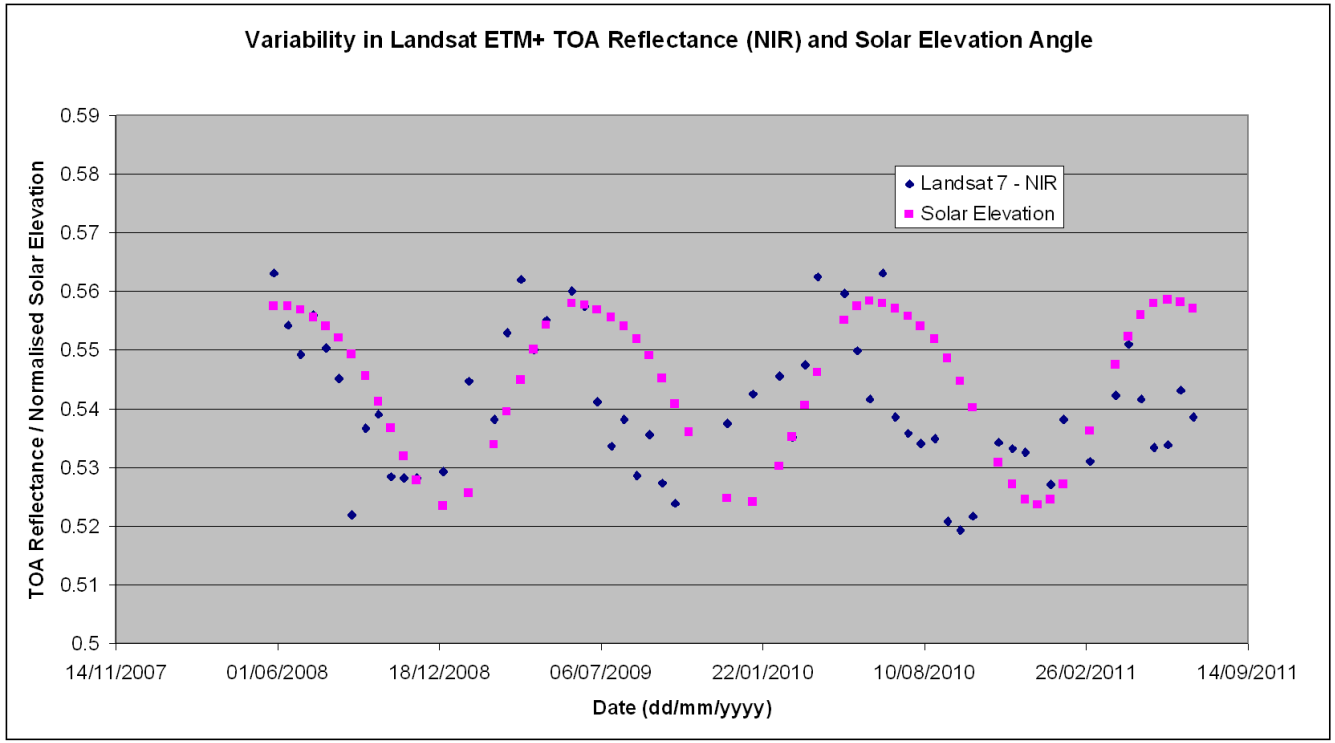
- Compared NigeriaSat-2 to Landsat 7 ETM+
- Site is not instrumented and consists of sand-dunes, so strong BRDF component.
  - Nadir viewing element
  - Off-pointing viewing element
- Water vapour variations affect the NIR spectral band.
- NigeriaSat-2 only looks at part of the site, the impact on the calculation of the TOA Radiance is small the maximum variation seen is 0.6%.



Cross-Calibration Libya 4



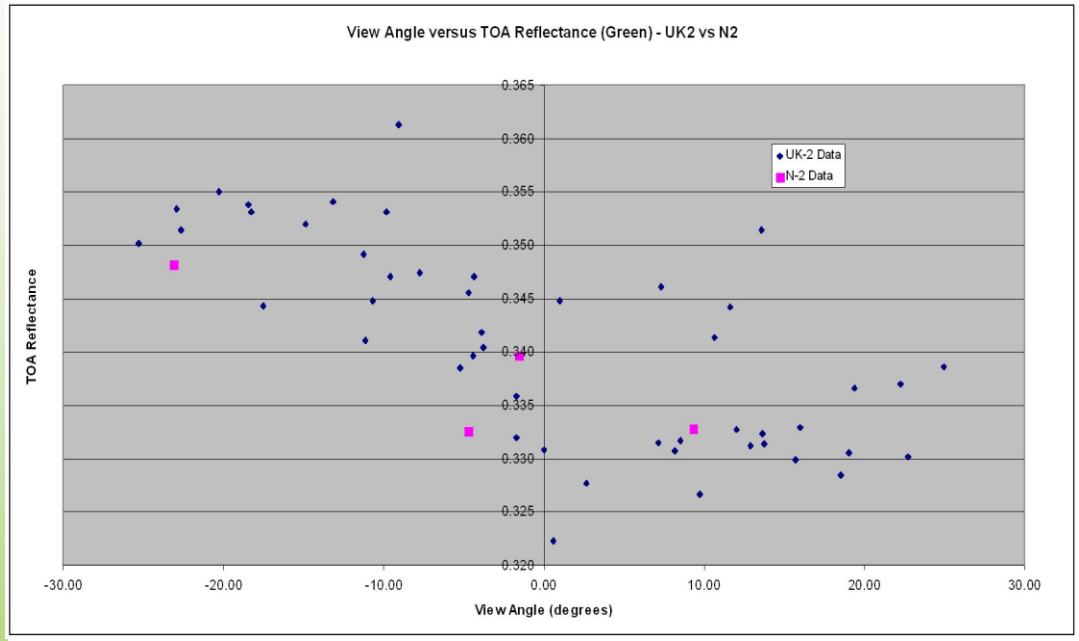
Cross-Calibration Libya 4 – Nadir Element



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.

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

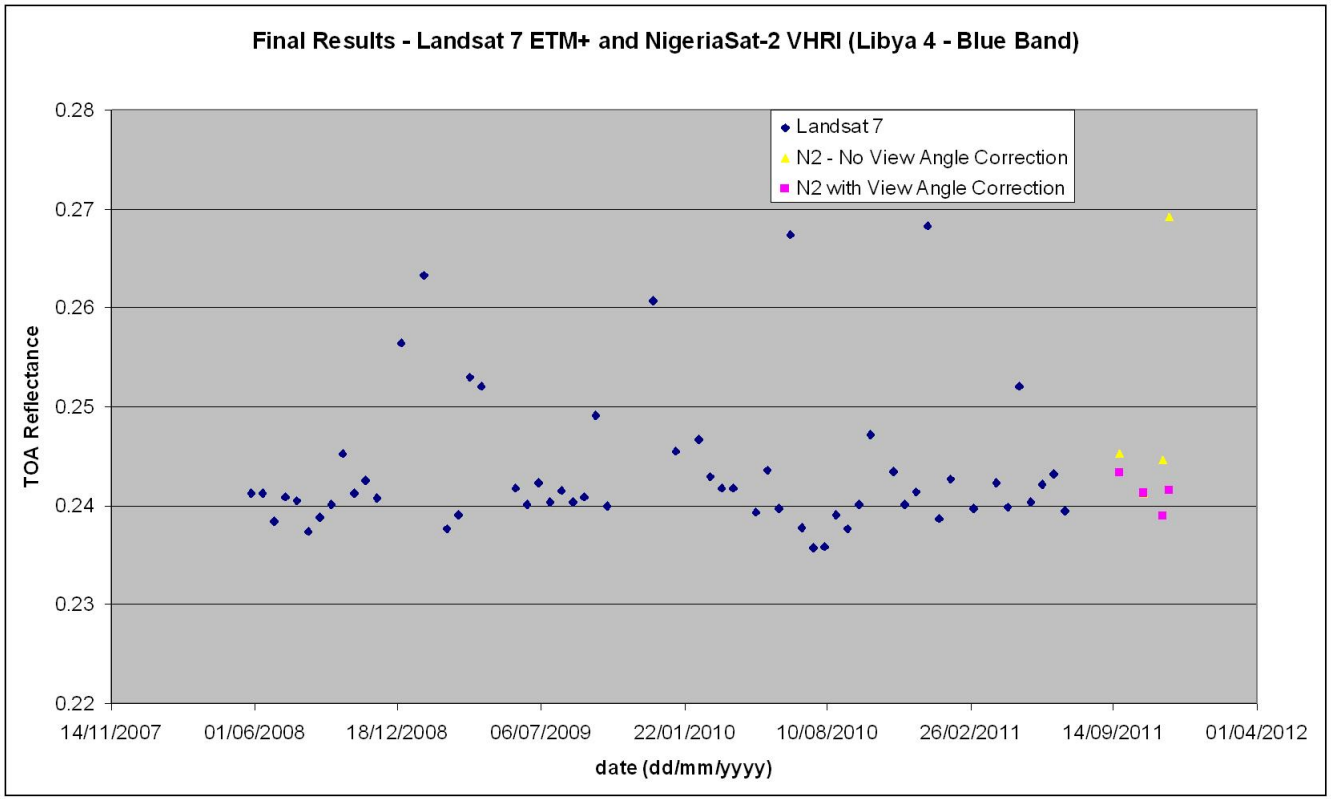
Cross-Calibration Libya 4 – View Angle Effects



- View Angle profile (after removal of the seasonal element) generated using UK-DMC-2 data.
- N2 data points (only four) fit pattern. Many more needed.

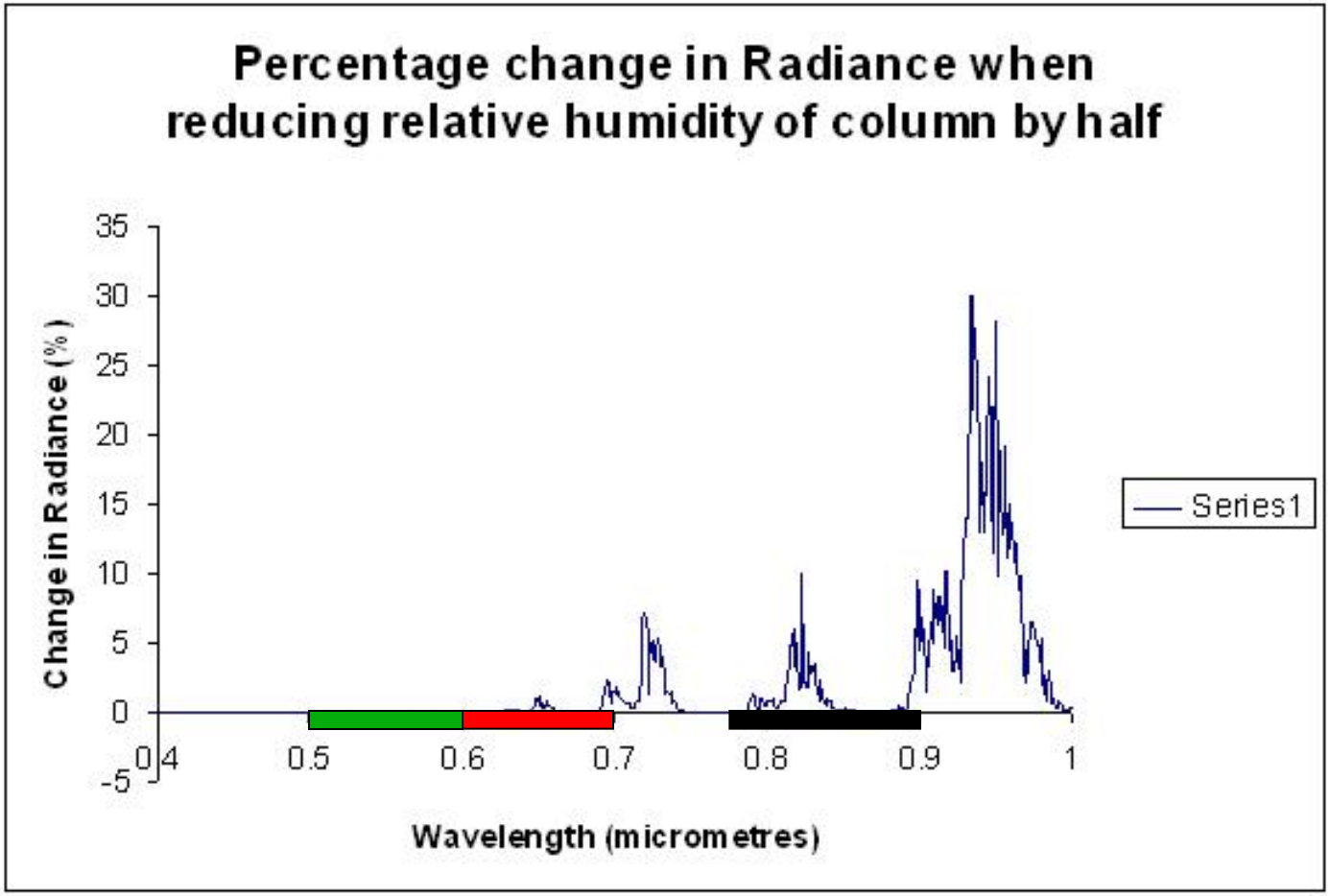
Final Calibration results – Libya 4

- Data corrected iteratively
  - Removal of seasonal trend
  - Removal of view angle effects
  - Calculation of differences when compared to Landsat 7 data
  - Adjustment of coefficients to approach Landsat 7 more closely



Final Calibration results – Libya 4

- NIR spectral band shows more variability
  - Effect is due to the small water absorption feature centred on 830nm.
  - Compounded due to off-pointing and hence longer path-length through the atmosphere



Final Calibration results – Libya 4

- NIR spectral band shows more variability
  - Effect is smaller in Landsat 7 data which is nadir viewing, while NigeriaSat-2 off-points at large angles.
  - Looking at relationships between bands to identify the presence of large water vapour changes to reduce scatter

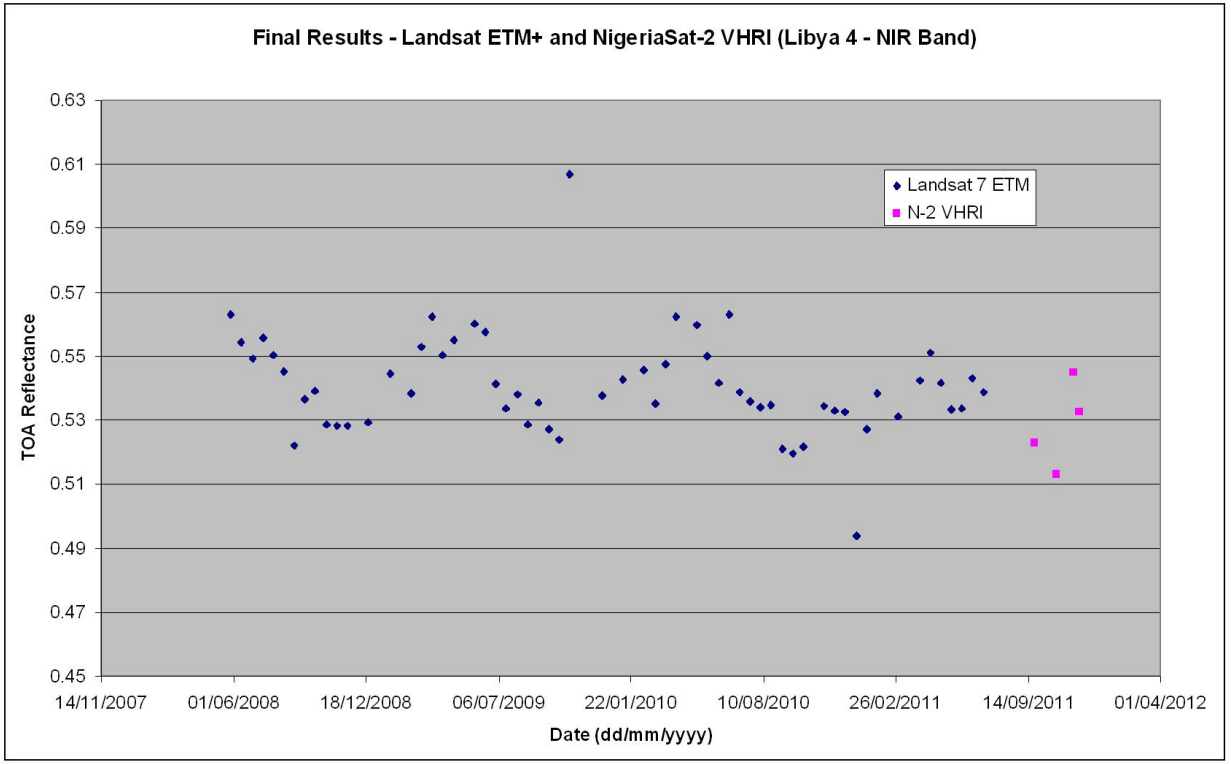


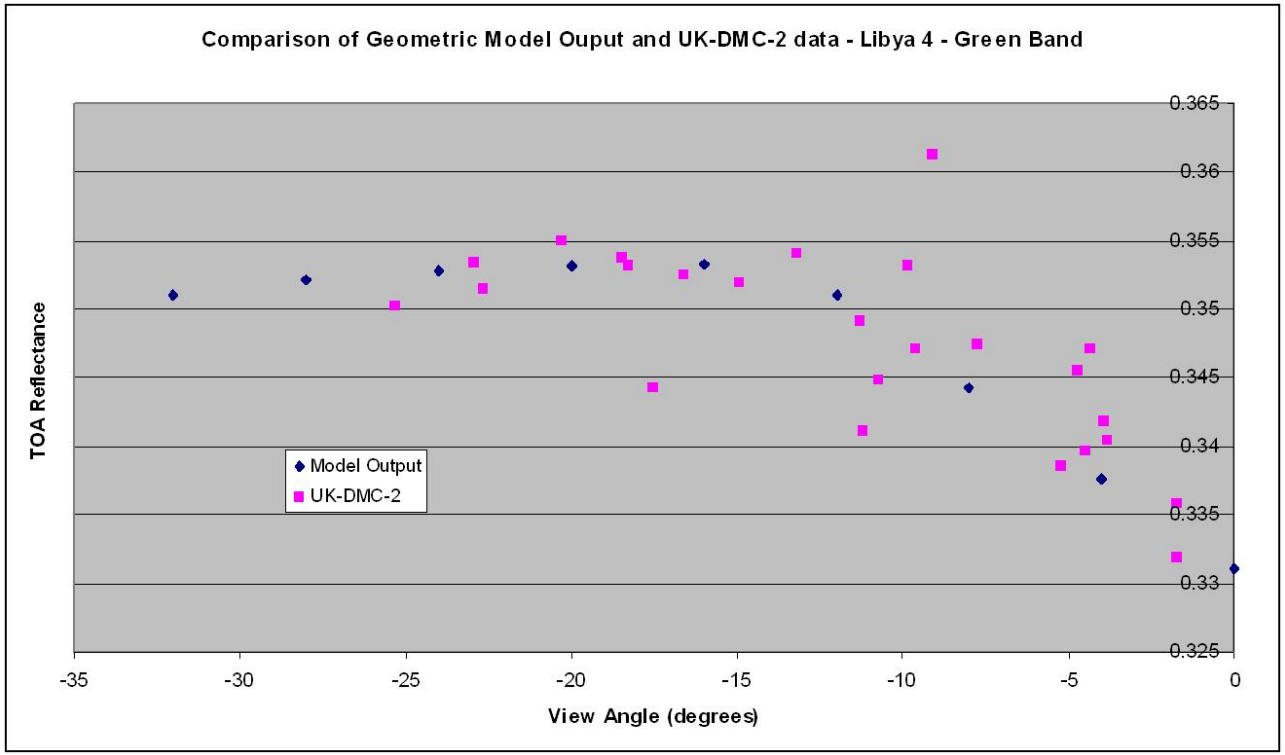
Table of results and summary

Band	Absolute Calibration Uncertainty
Blue	4.1%
Green	4.1%
Red	4.1%
NIR	6.3%
PAN	8.6%

- The major sources of uncertainty are
  - Related to the original reference satellite (assume 3.5% for Landsat 7)
  - The large standard deviation of the results, especially in the NIR band (assumed due to water vapour variations)
  - Surface variability (assume 0.6% worst case) for using only part of the test site.
- BRDF effects have been reduced significantly in the analysis
- More data points are required to reduce the uncertainty (four points is far too low).

Future Developments

- Modelling of site is major emphasis in 2012
- Example shown assumes
  - 50 degrees solar elevation
  - Asymmetric dunes
  - Forward scattering profile
  - Relative view azimuth of zero



Modelling is a very powerful tool in terms of predicting the nadir observation for the cross-calibration, but the models need to be sophisticated to help reduce the uncertainties induced in the calibration process due to the geometry.

Future Developments

- Lots of satellites, three high-resolution already being built, DMCii considering a 3 to 5 satellite always on constellation (1 day repeat). Data volumes huge.
- Impossible to check everything manually.
- Automated calibration and data quality checks. Changes in individual detectors, changes in groups of detectors or overall calibration curve, changes in absolute calibration.
- More will be revealed on Thursday afternoon.

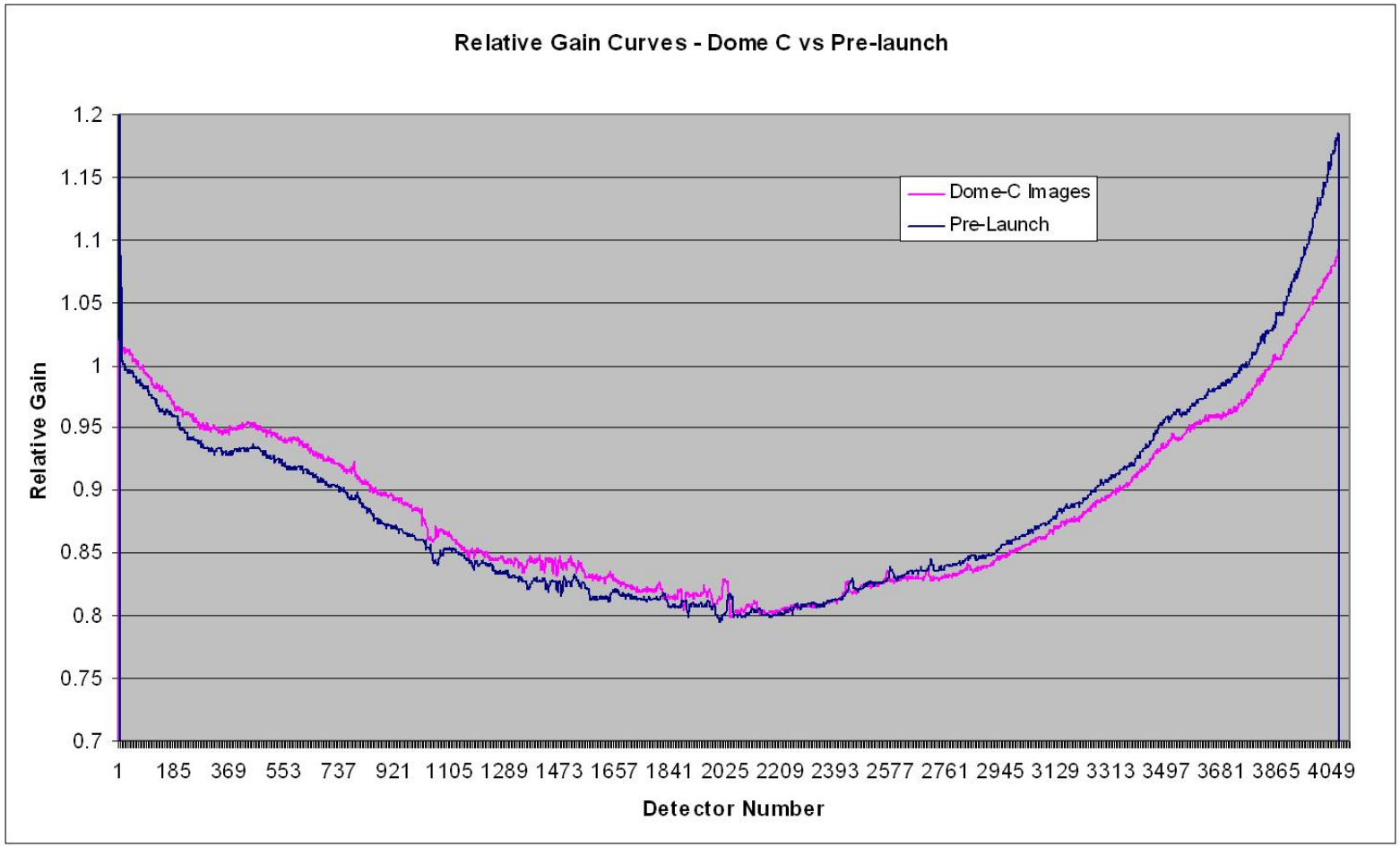
Thank you

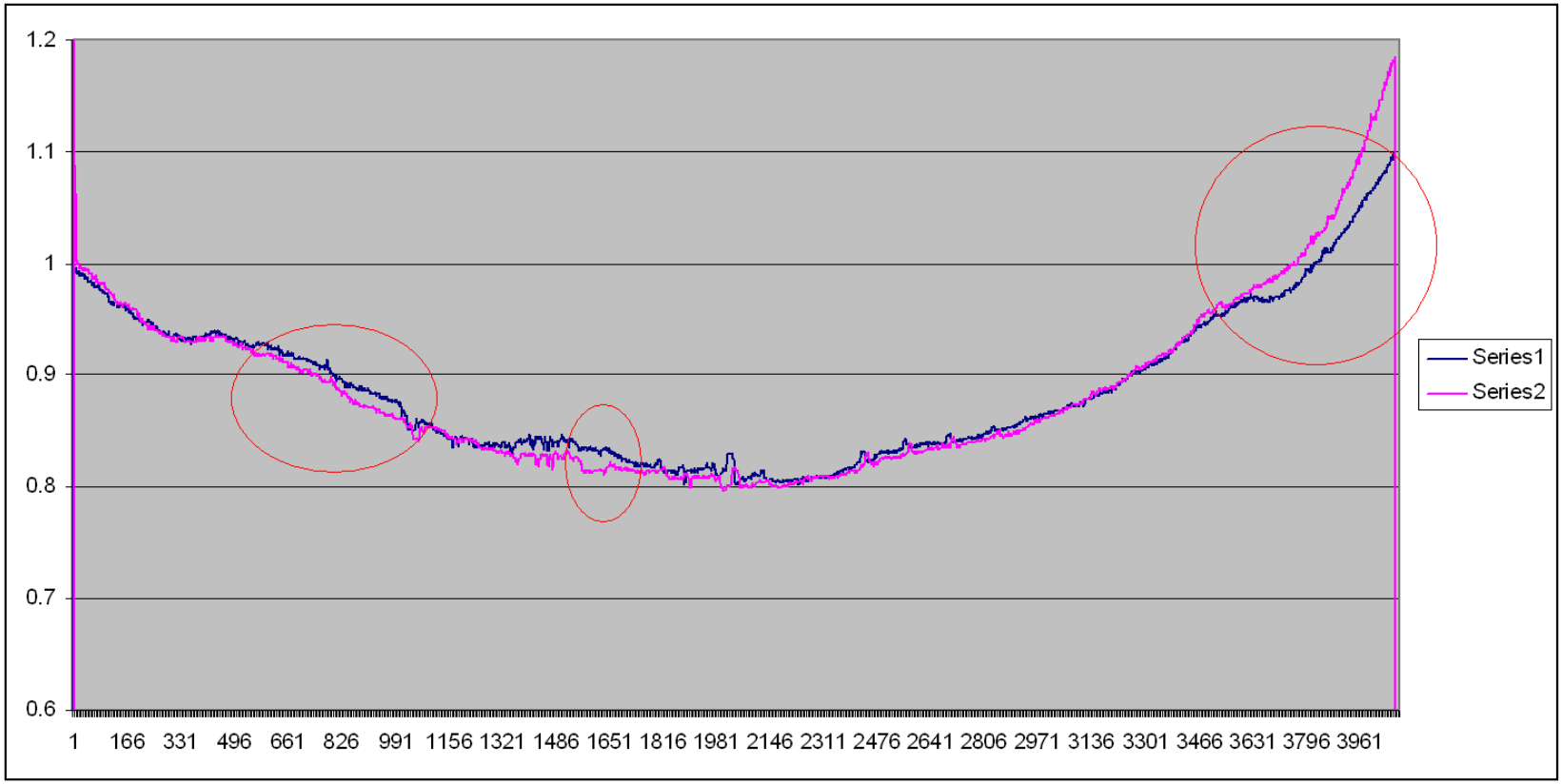
Cross-Cal UK-2 and MODTRAN

- Only able to calibrate the green, red and NIR bands.

Image	Date	Green	Red	NIR	PAN	Est. Pan	Diff %
DM0000ab	31/10/11	212.55	178.86	120.32	157.75	161.76	2.54
DM00015f	04/12/11	267.18	227.35	153.4	200.2	204.92	2.36
DM000122	21/11/11	237.12	203.2	139.63	179.95	185.82	2.15
DM000136	27/11/11	260.55	221.4	148.4	194.35	199.22	2.50
DM000205	05/02/12	197.17	168.9	113.73	148.05	151,74	2.49

- Use MODTRAN to simulate the spectral bands (blue and PAN)


Relative Gain Curves - Dome C vs Pre-launch
Relative Gain
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
Dome-C Images
Pre-Launch
1
185
369
553
737
921
1105
1289
1473
1657
1841
2025
2209
2393
2577
2761
2945
3129
3313
3497
3681
3865
4049
Detector Number


1.2
1.1
1
0.9
0.8
0.7
0.6
1 166 331 496 661 826 991 1156 1321 1486 1651 1816 1981 2146 2311 2476 2641 2806 2971 3136 3301 3466 3631 3796 3961
Series1
Series2