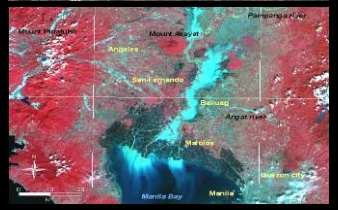
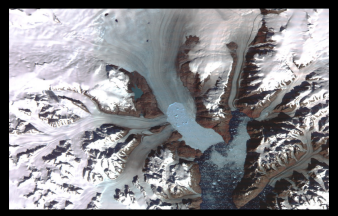
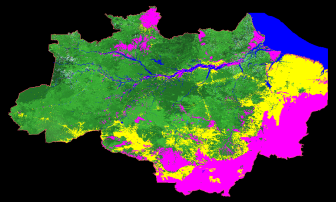




Constellation Calibration for Commercial Application support

Stephen Mackin
Paul Stephens
Gary Crowley
Dave Hodgson

DMC International Imaging



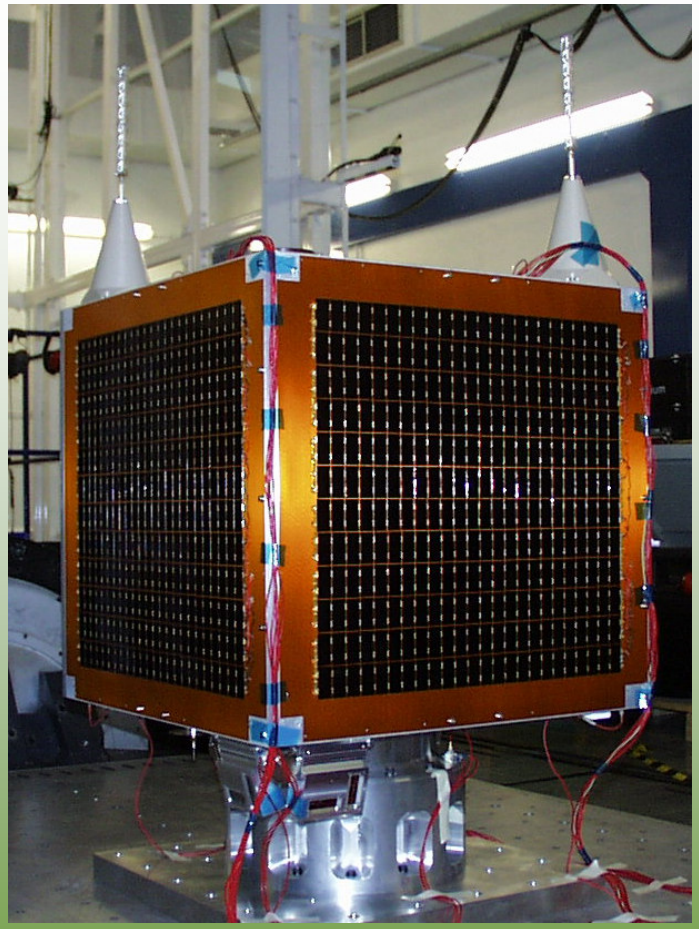
JACIE
March 2008

International Imaging

Overview of Presentation

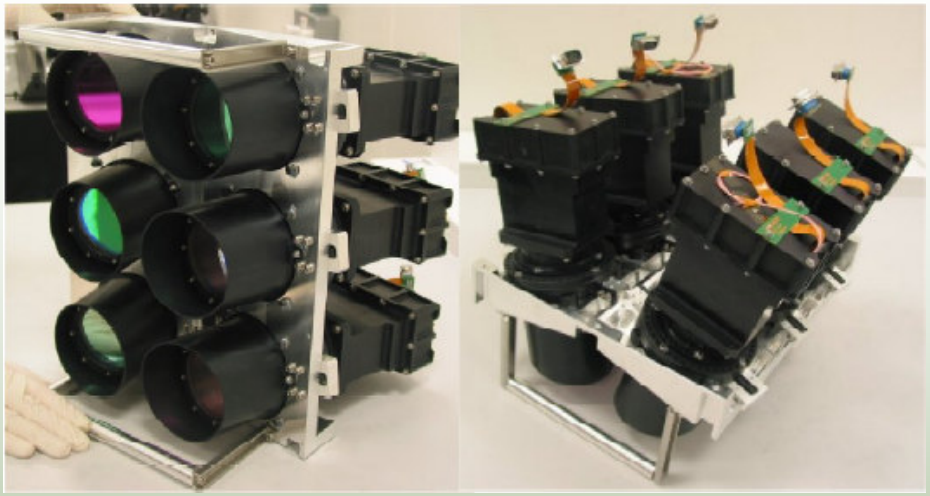
- DMC satellite and its applications
- Current calibration methodology
- Planned Constellation cross-calibration
- Proposed QA/QC for the DMC satellite systems
- Future plans

DMC Satellite



- Sub 100 kg
- Three spectral bands (equivalent to bands 2,3 and 4 of Landsat but 32m GSD)
- Currently four in orbit (three in one plane and fourth is second plane)
- Three more DMC satellites under construction (22m GSD)

DMC Satellite



Three bands per bank

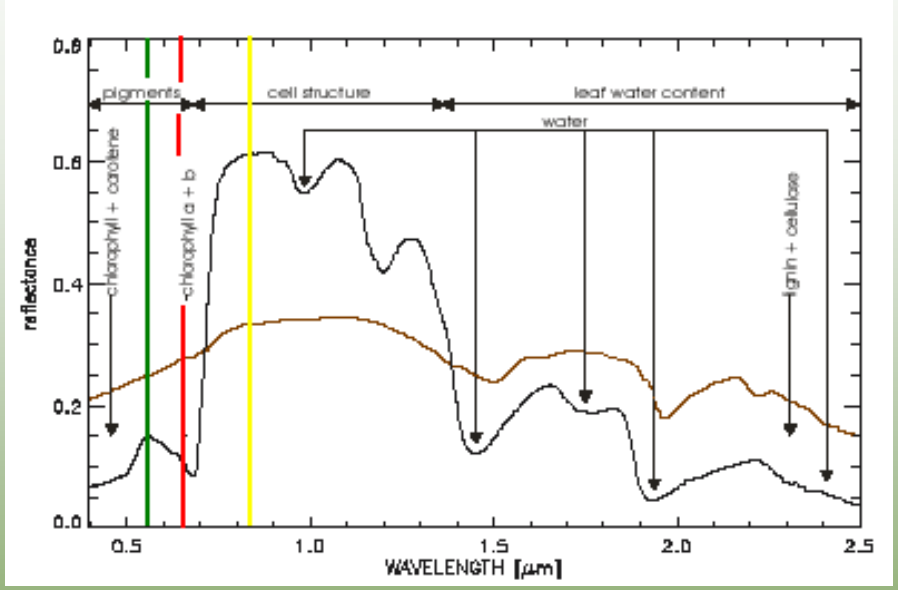
Two banks (starboard and port)

10, 000 active detectors per band

Band	Channel	Bank	Common	Bandwidth (nm)	IFOV (m)	Sub Satellite GSD (m)	Closest Landsat
0	1	1 (Starboard Ground)	NIR	0.77 to 0.90 um	46.388	31.822	ETM+4
	4	0 (Port Ground)	NIR	0.77 to 0.90 um	46.388	31.822	ETM+4
1	2	1 (Starboard Ground)	Red	0.63 to 0.69 um	46.388	31.822	ETM+3
	5	0 (Port Ground)	Red	0.63 to 0.69 um	46.388	31.822	ETM+3
2	3	1 (Starboard Ground)	Green	0.52 to 0.60 um	46.388	31.822	ETM+2
	6	0 (Port Ground)	Green	0.52 to 0.60 um	46.388	31.822	ETM+2

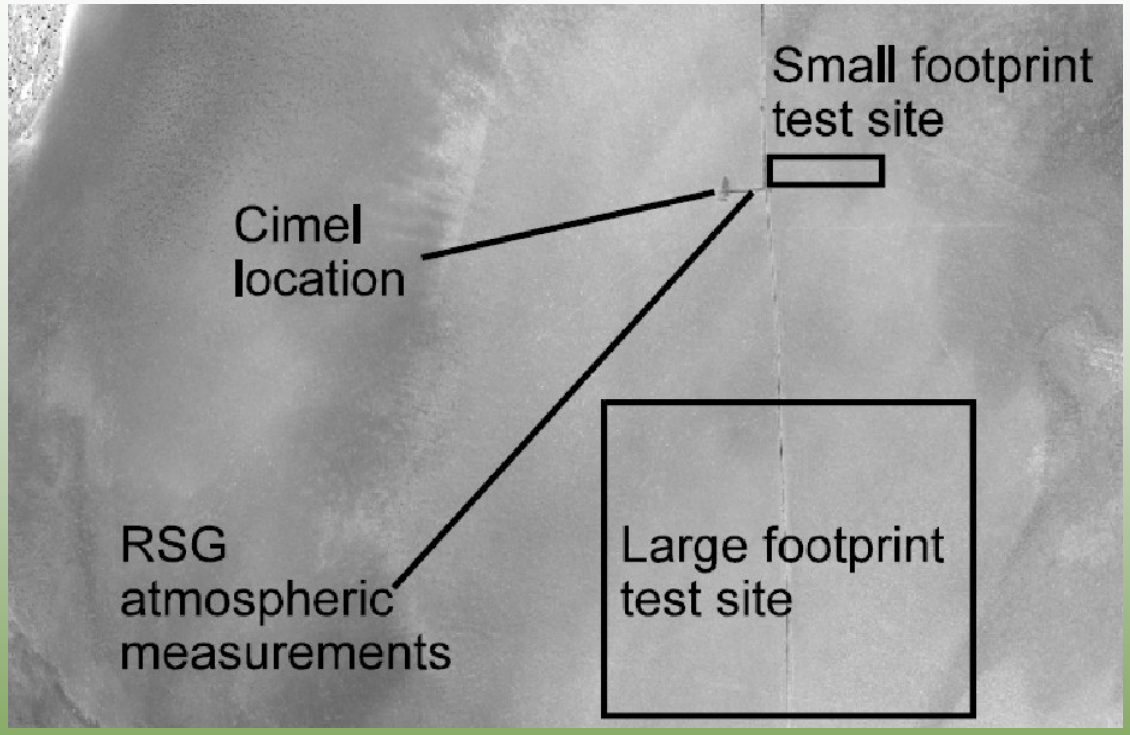
Absolute and Relative Calibration

- Most applications based on red / NIR relationship either as NDVI or derived product, so band to band stability and absolute calibration important



- However, relative satellite to satellite calibration even more important than absolute so consistent results from use of all constellation members

Absolute Calibration Images



- Railroad Valley, Nevada
- Carried out by RSG from Arizona
- All processing carried out by Arizona team up to derivation of TOA radiances
- Uses reflectance method

Difficulties in Current Calibration

- Difficult to maintain the calibration across many satellites owned by different agencies (management of process)
- Too many acquisitions required for each satellite over RRV (cost element with ground teams, time taken, images acquired, processing). Landsat say 4-6 required. We prefer 6-10.
- Even with acquisitions, given the error bars there are slight differences from satellite to satellite in terms of absolute calibration.

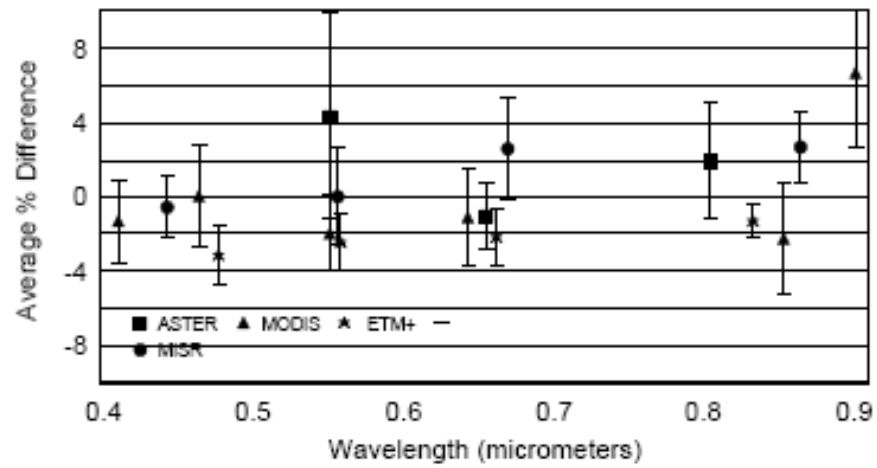
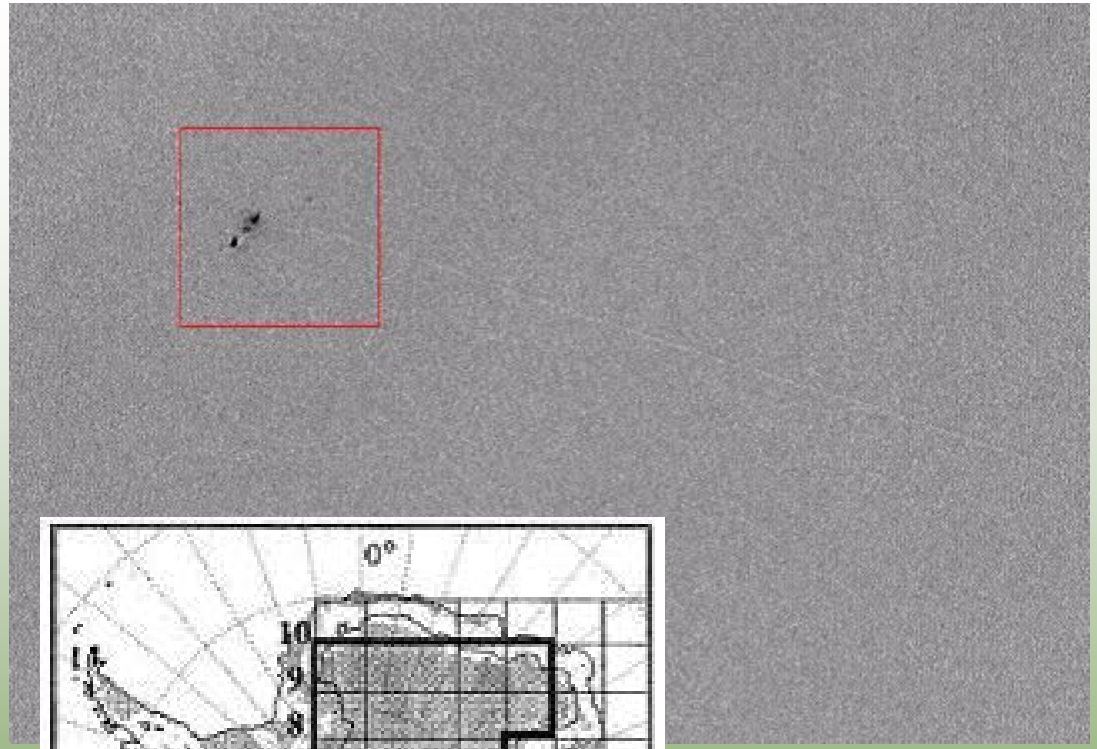


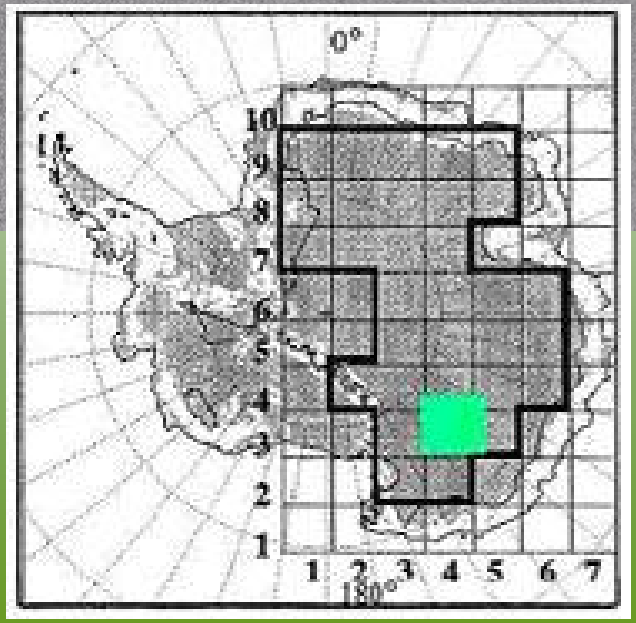
Figure 3. Percent difference between reflectance-based results using 1-km^2 site for all four sensors in this work for the VNIR bands

Cross-Calibration

- Best way of ensuring relative accuracy is through cross-calibration
- Standard “Gold” well-calibrated primary satellite (6-10 absolute calibration exercises per year over RRV)
- Intersecting with other satellites over same site (so different orbital planes)
- Needs target that has many intersections (high latitude)

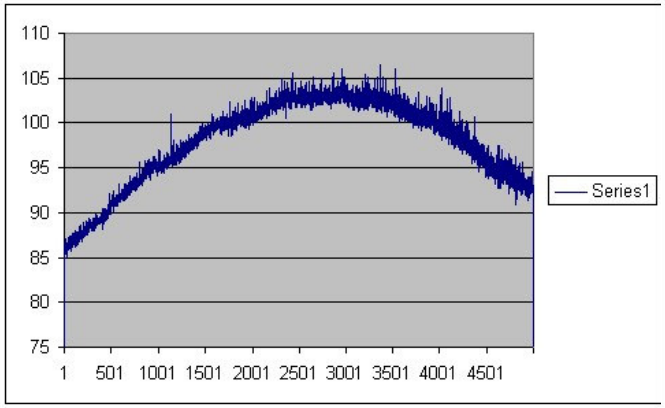
Dome-C

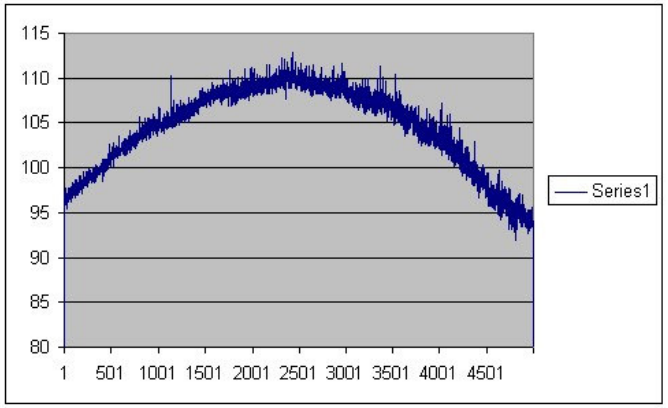




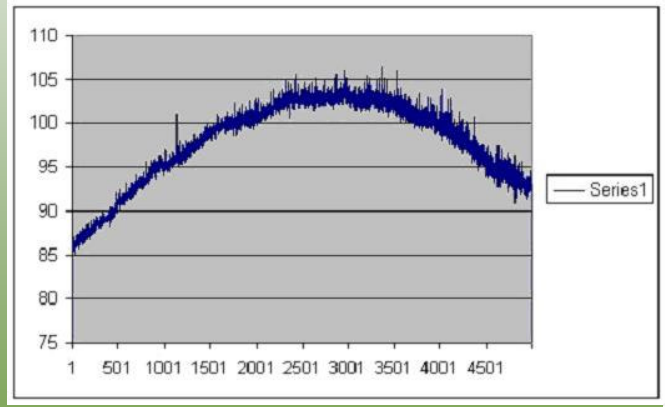
- Need homogeneous scene over 600 km + wide with good temporal stability at high latitudes
- DOME-C site in Antarctica (75 S), very high, flat plateau, stable snow conditions
- Instrumented year round, some BRDF studies
- Used by AVHRR, SPOT-VEG

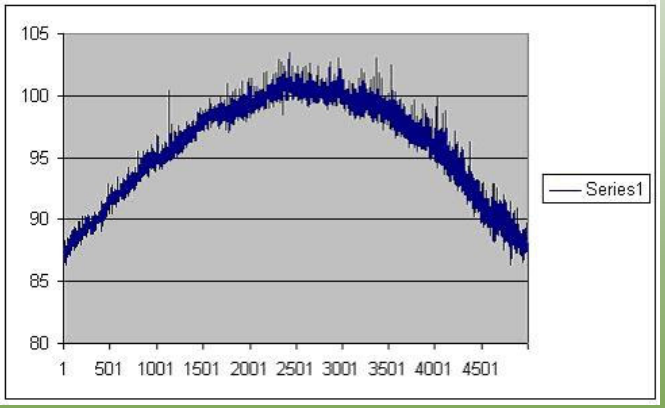
Dome-C Images





Asymmetry normal (left), Yaw 180 degrees (right)





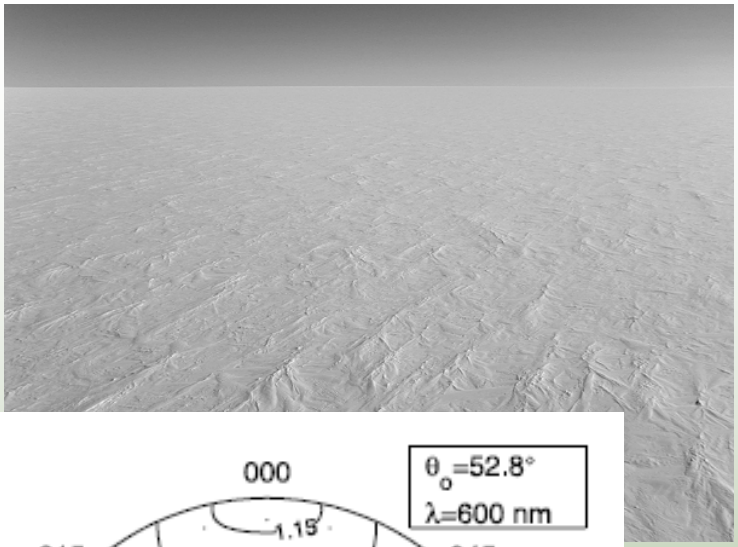
Asymmetry normal (left), Aligned across principal plane

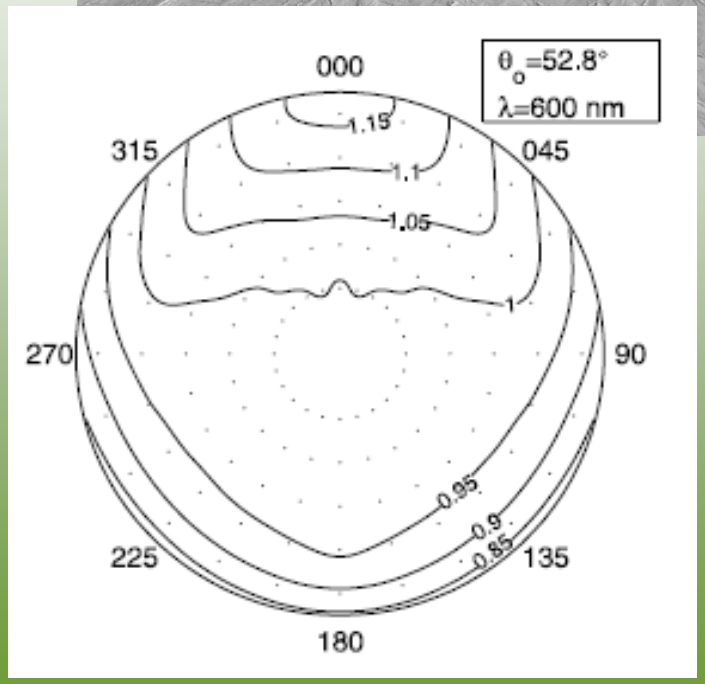
- Original images showed asymmetry due to variable illumination across swath.
- Reversing flight direction confirmed this
- Yawing spacecraft across principal plane eliminated the effect
- Residual geometry error due to earth curvature
- BRDF effects

Dome-C Other Issues

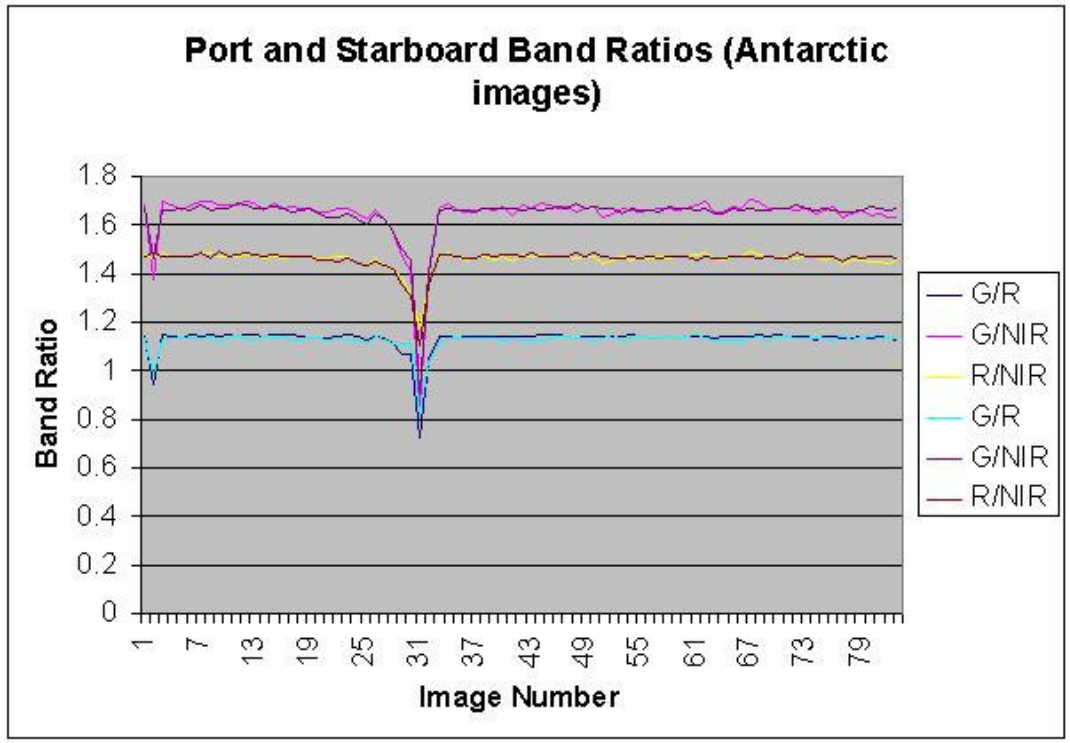
- Wide swath produces uneven illumination (even after Yaw) but small effect (< 0.11% variation across array)

- BRDF is a problem, but minimised (across array) by Yaw manoeuvre





Calibration Stability



- Over 100 scenes analysed (cloud free selected)
- Monitored band ratios. Consistent for three years across both image banks
- Variation of less than 0.34% r.m.s. across three years
- Odd feature around Scene 31. Coincided with very high snowfall conditions and low sun angle

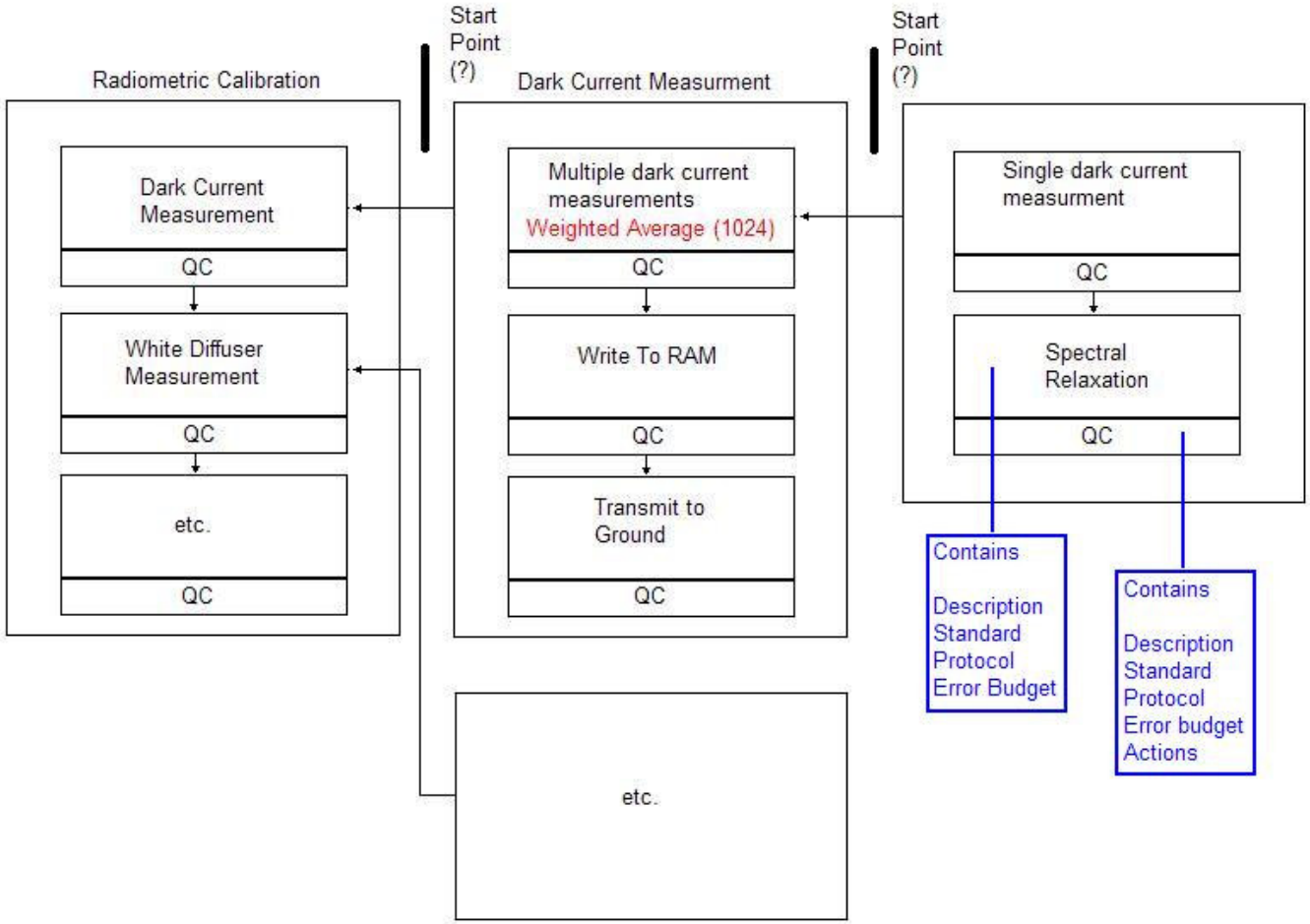
Calibration - Conclusions

- Cross-calibration provides a means of providing consistent calibration across large constellations
  - Requires well characterised and very stable “Gold” satellite
  - High latitude site for multiple intersections
  - Satellites in different orbital planes to maximise overlaps and minimise temporal separation
  - Minimisation of sources of uncertainty over transfer target

Related Tasks

- Measurement uncertainty in process will be quantified as part of modular QA/QC system being developed for ESA by NPL.
- Modular system will allow uncertainty of all processing and analysis steps (including level products) to be determined, a total end-to-end system
- Working through CEOS WGCV to guarantee it will meet international guidelines and standards.
- Unique system that can be also used for system simulation, process control and QC monitoring

Overview - Example



Overview – Main Points (1)

- Provides a **generic** "thin" framework for building new processing and QA/QC procedures rapidly and in a systematic manner
- Can be easily translated to corresponding **physical** implementation structures with addition of instrument specific modules as required
- Each module has a defined **protocol** which encapsulates best practice in terms of operation
- Each module has a defined **error budget** for quantitative estimation within a structured QA/QC scheme
- Modules use defined reference **standards** to evaluate uncertainty (quantified error)

Overview – Main Points (2)

- As each module has an error budget, the overall **quantified error** can be traced throughout all operations
- Out of bounds conditions or trends leading to out of bounds conditions can be identified and localised easily within the structure
- Remedial QC can be performed to reduce the effects of instrumental ageing without human intervention or re-processing (in some cases)
- Modules can be simply replaced by updated modules as required (with improved protocols or QC) without affecting the rest of the processing chain.
- Additional modules can be added to deal with unusual system behaviours without affecting the rest of the system
- Modular structures can be created rapidly using a point and click interface
- By adding simulation elements (instrument parameter files, scenario files) it is possible to populate the modular structure and assess errors prior to launch or to simulate changes in procedures.

The Future

- Cross-calibration 2007/2008 in progress
- Use of well-calibrated “Gold” standard based on 6-10 vicarious calibrations over RRV per year of a stable satellite (UK-DMC) from 2008
- Four new satellites being launched in 2008/2009
- Cross-calibration over Antarctica (especially of satellites launched in October 2008)
- Implementation of total end-to-end QA/QC system to trace uncertainty from pre-launch through level products and including the data validation