Geostationary Earth Radiation Budget (GERB) Lessons learned

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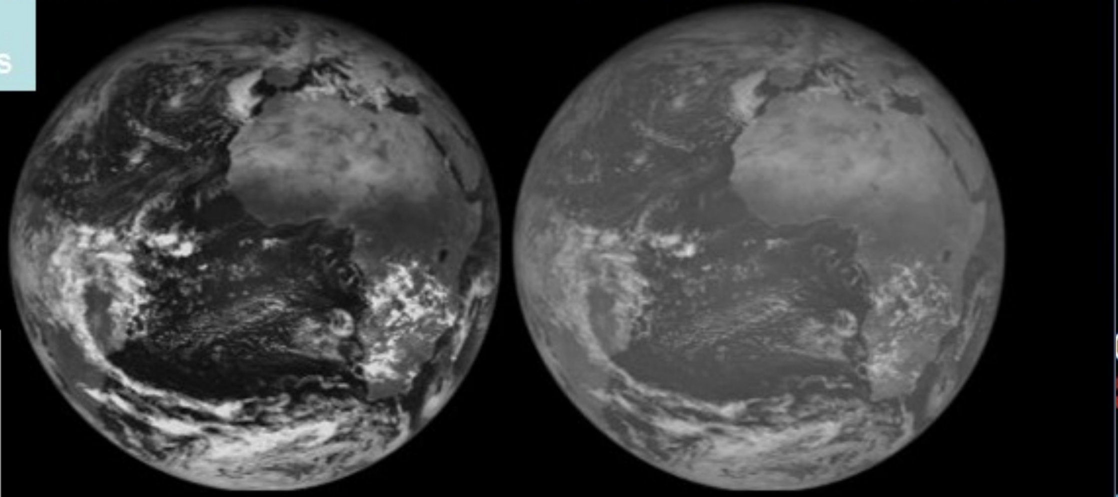
Talk Outline

- GERB measurements and onboard calibration
- Onboard calibration, some strengths and some limitations
- Unexpected signals and instrument / satellite effects
- The power and difficulties of inter-instrument & in-orbit comparisons and checks

GERB observations: outside view

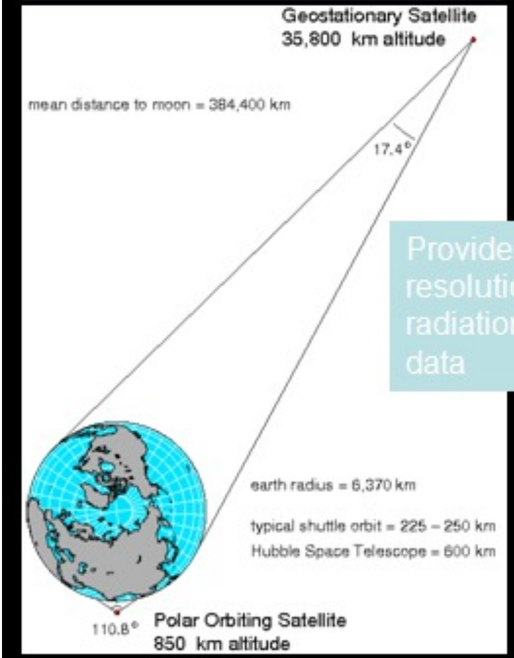
Shortwave channel (λ=0.3-4.0µm): reflected solar energy

Total channel (λ=0.3->100µm): reflected solar + emitted thermal energy

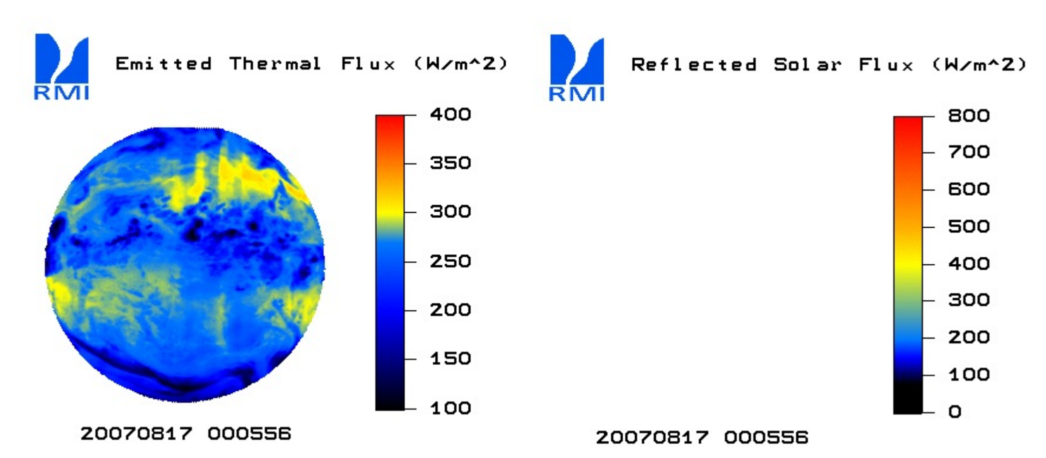


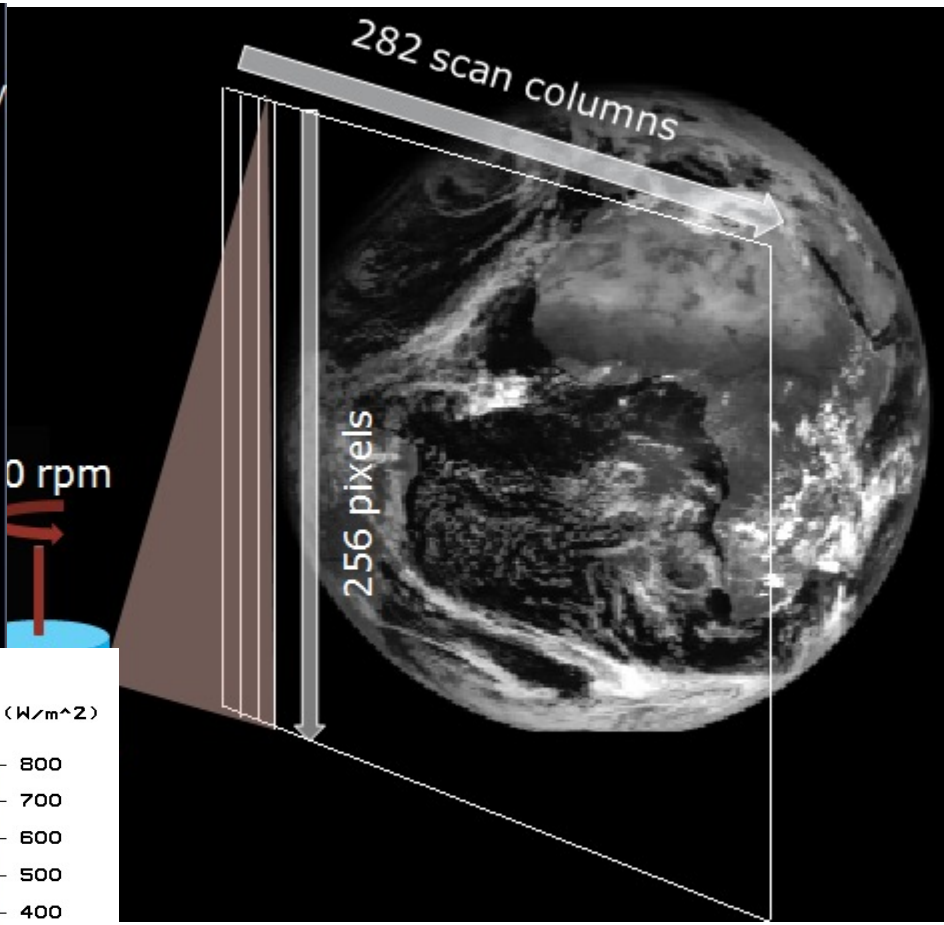
GERB observes the Earth in two channels

GERB is the first and only geostationary broadband radiometer

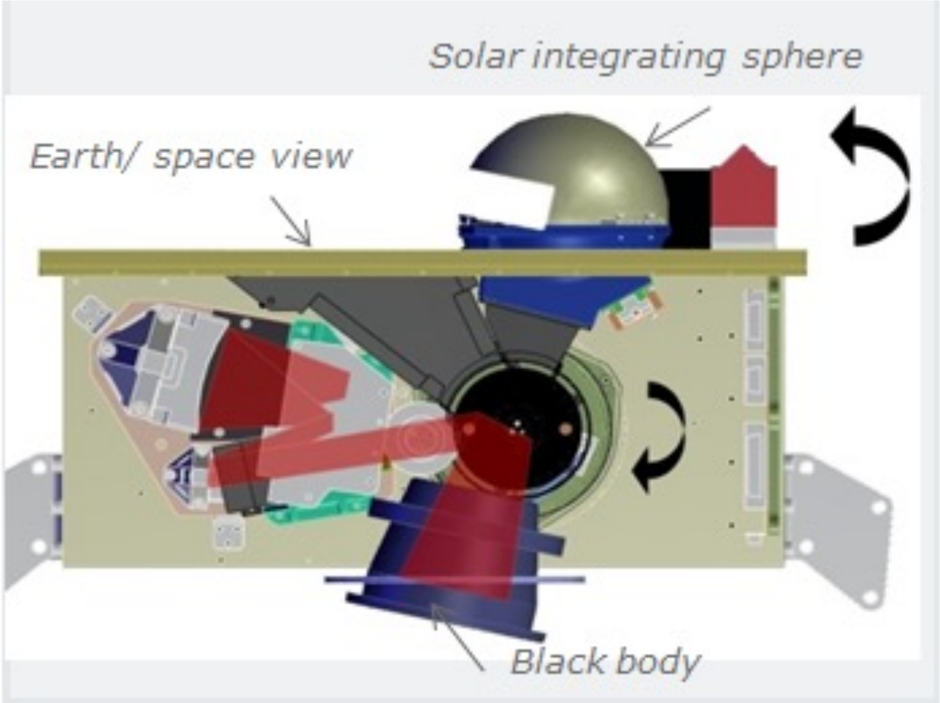


Provides high time resolution (15min) radiation budget data





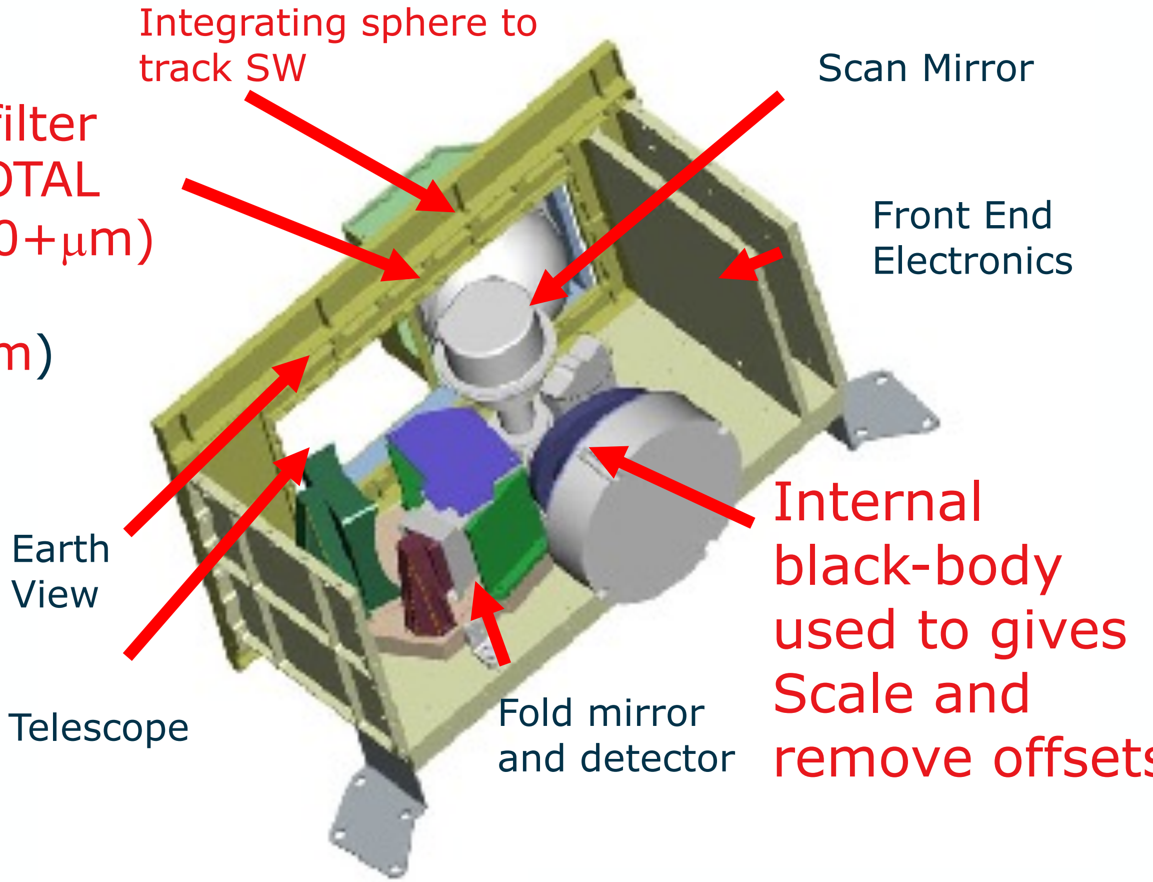
GERB observations on the inside



Blackbody & deep space enable two point calibration to determine gain for LW scenes
Multiplied by a ground calibration factor ‘B’ (ratio of SW to LW responses) to determine SW gain

Solar integrating sphere onboard to enable SW gain to be tracked

Quartz filter turns TOTAL (0.3-100+μm) into SW (0.3-4μm)



Measurements of space obtained every scan to give zero

GERB observations, from the inside out

Internal black body is used to remove offsets and calibrate the counts to SW and TOTAL filtered radiances

LW is obtained by subtraction, accounting for the effect of the quartz filter

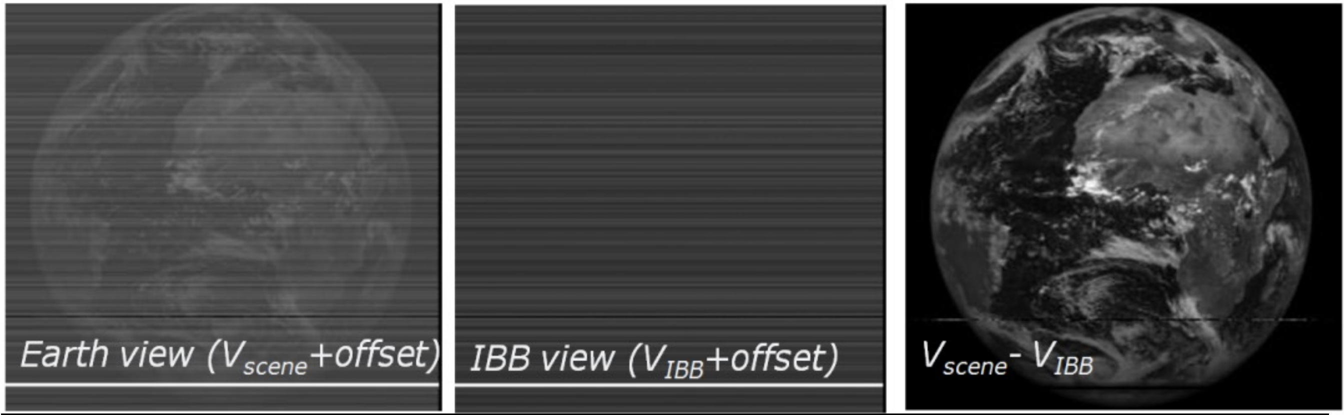
$$\text{Gain (TOT)} = \frac{V(BB) - V(space)}{\text{BB radiance}}$$

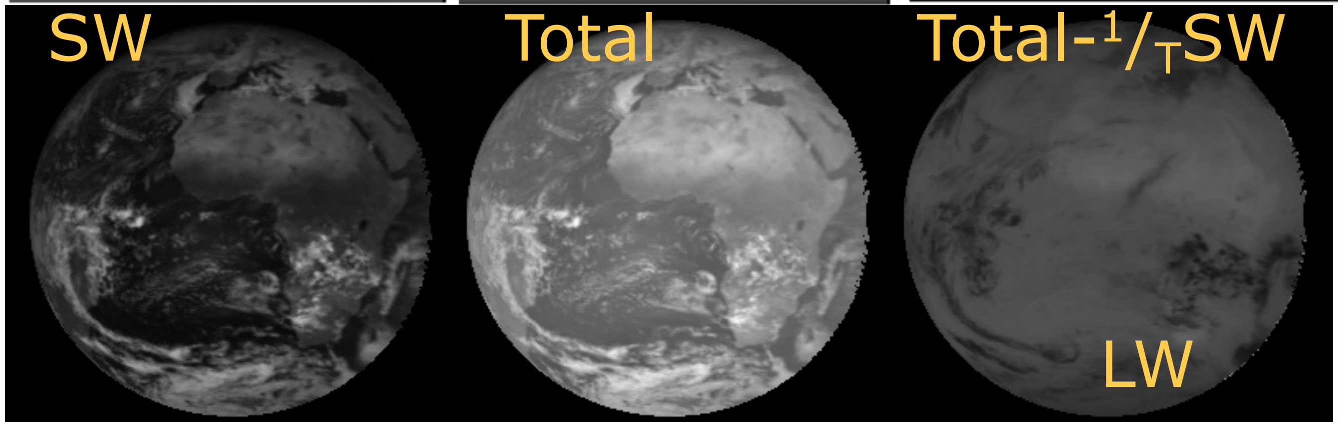
$$\text{Gain (SW)} = B \times \text{Gain (TOT)}$$

$$\text{Scene radiance} = \frac{V(Scene) - V(BB)}{\text{Gain}} + \text{BB radiance}$$

CALIBRATION PARAMETERS:

- Internal black body output,
- Quartz filter transmission
- Instrument spectral response
- SW/TOTAL gain ratio (B)





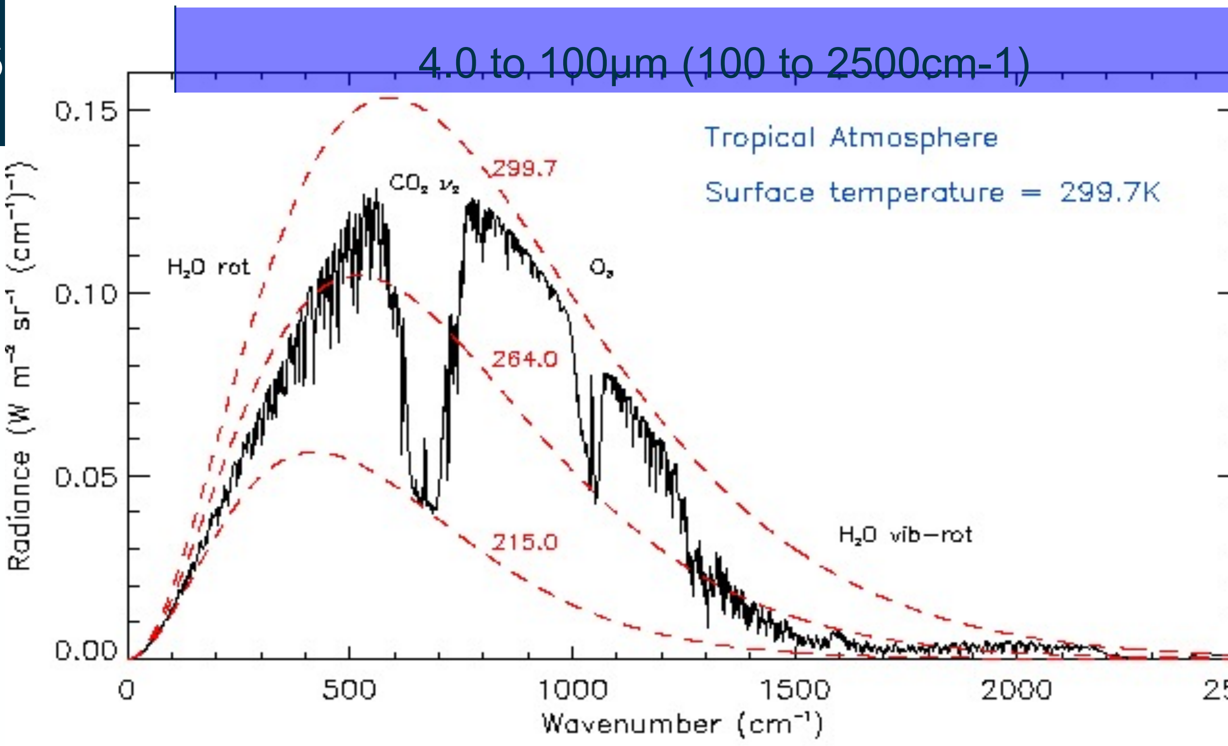
TOTAL (0.3 to beyond 100μm)
SW (0.3 to ~4μm) with the addition of quartz filter
Longwave is obtained by subtraction

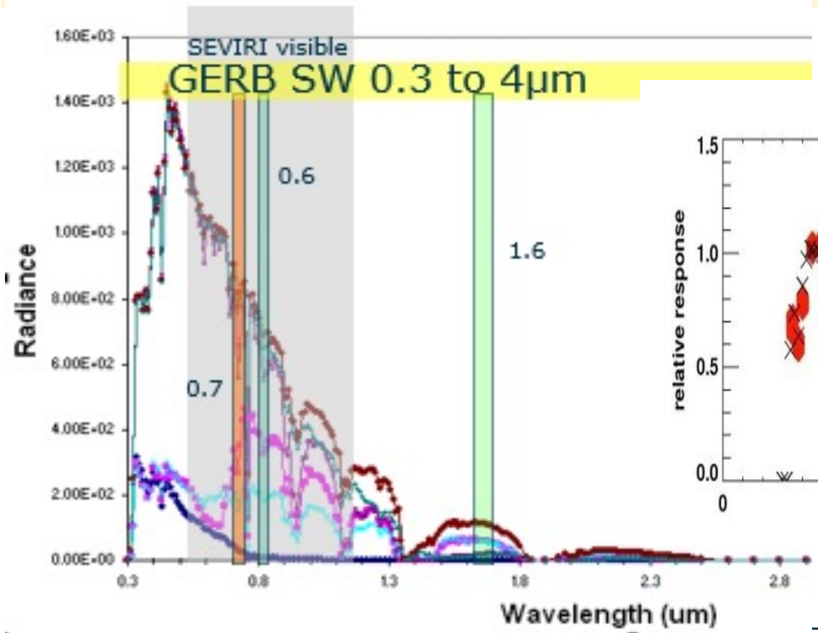
Radiances are unfiltered (corrected for instrument spectral response) using spectral information from the SEVIRI imager

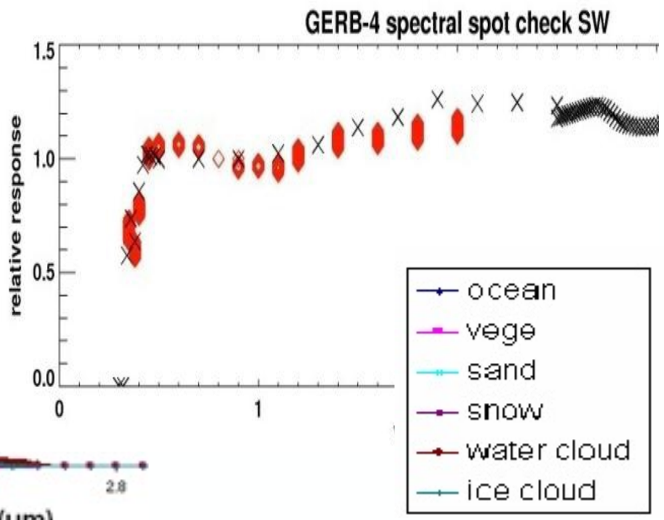
GERB observation characteristics

- 256 individually calibrated pixels
- Same telescope both TOTAL and SW by swapping in a quartz filter
- Offsets removed every 0.3s, Gain updated every 6 minutes
- Solar diffuser sphere to track ratio of response to SW vs LW sources

- 5 mirrors (2 sides of scan mirror)
- Wide field of view
- Broad spectral range
- 256 pixesl







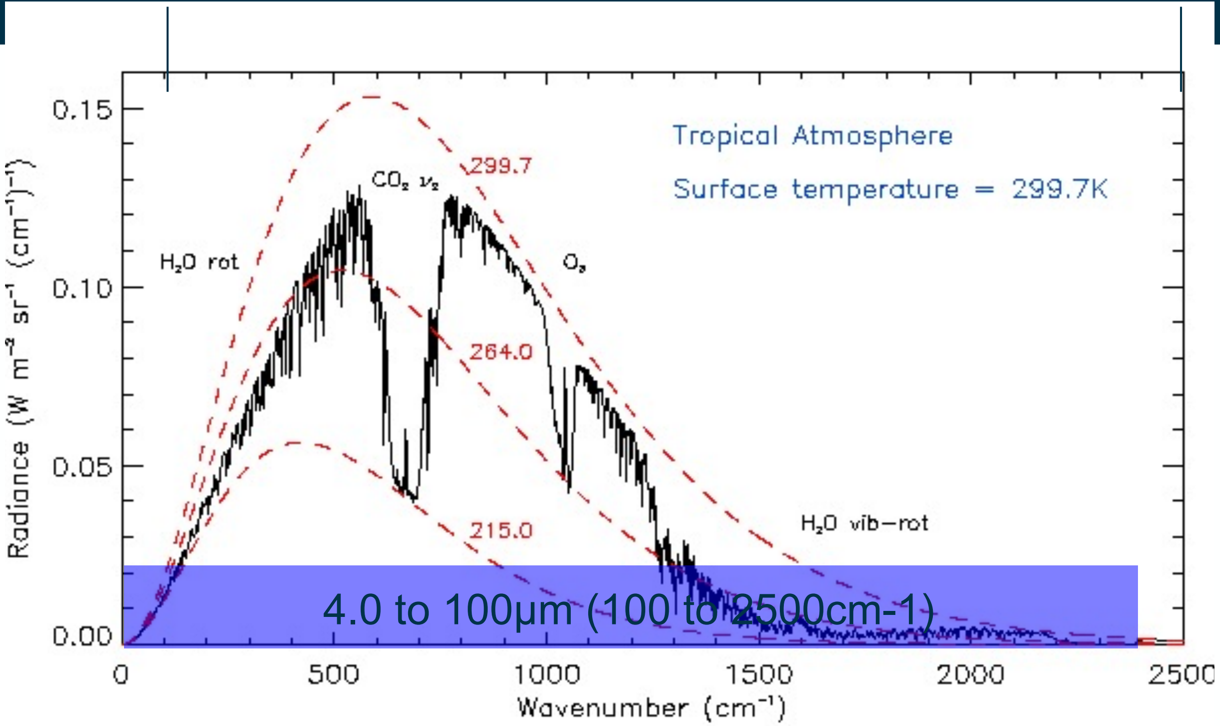
TOT:0.32 µm - 100.0+ µm
SW: 0.32 µm - 4.0 µm
LW: 4.0 µm - 100.0+ µm

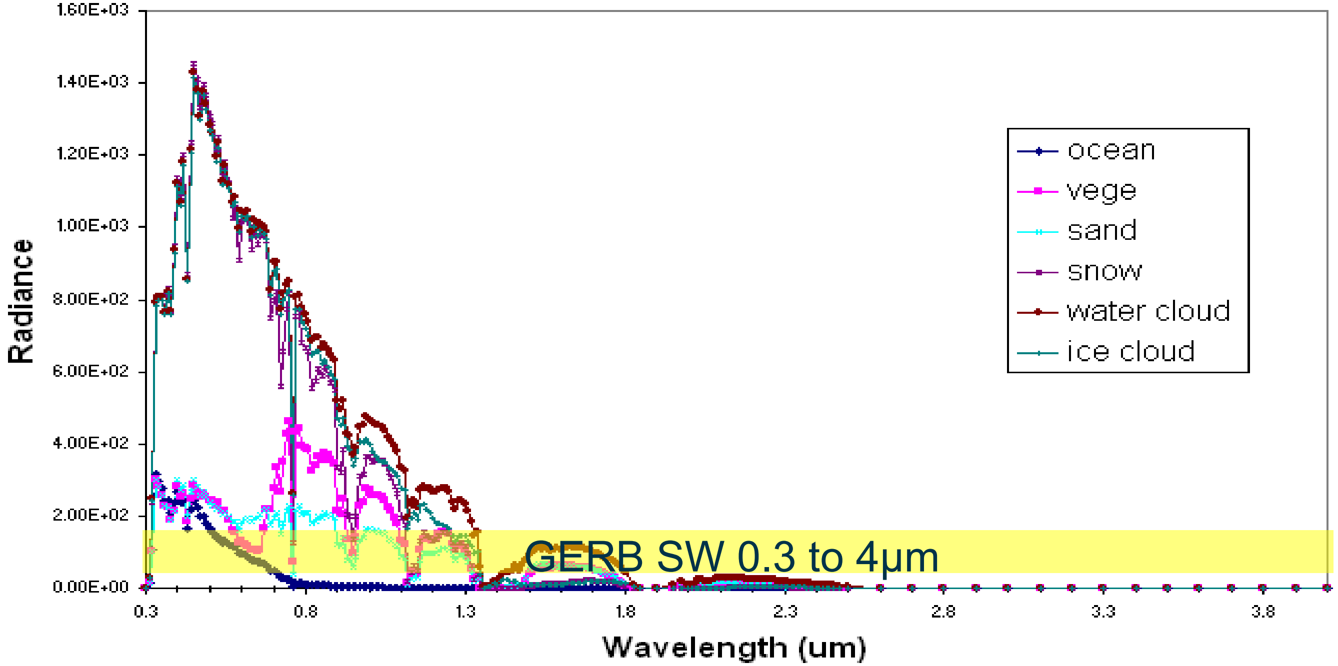
Absolute Accuracy: 1.0 %
Signal/Noise: 1250 (SW) 400 (LW)
Dynamic Range: 0-380 (SW) 0-90 (LW) W m-2 sr-1
SPATIAL SAMPLING 44.6 × 39.3 km (NS × EW)
TEMPORAL SAMPLING 15 minute SW and LW fluxes
CYCLE TIME Full Earth disc, both channels in 5 minutes

GERB onboard calibration

LW

- Black bodies provide very good tracking of response to longwave scenes
- Similar spectral distribution to longwave Earth scenes mean changes/errors in spectral response partly compensated for
- Instrument gain more stable than expected (noise on gain can be reduced by averaging)

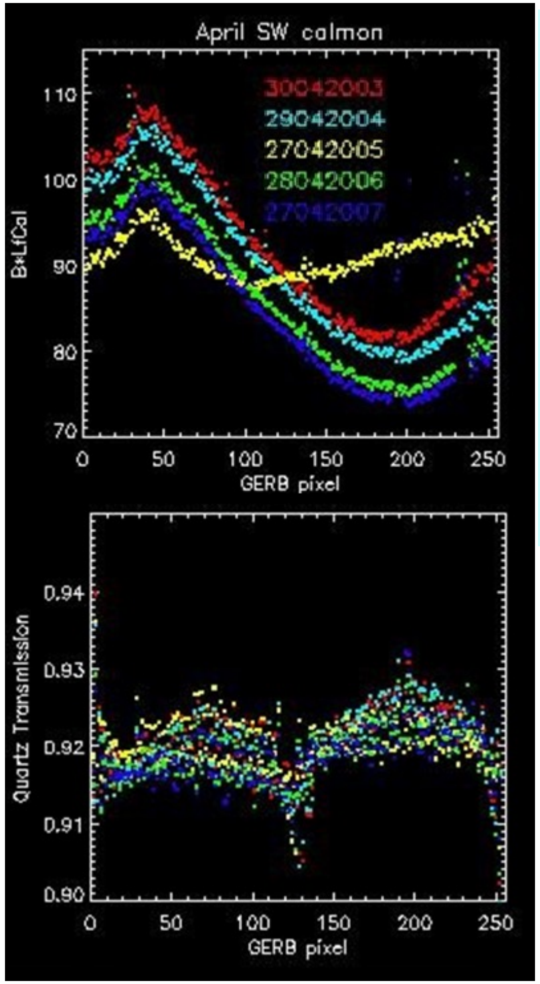




SW

- Solar diffuser can track filter changes well & some differences
- Doesn't give a similar response to the variety of Earth scenes
- Can't diagnose spectral effects
- Isn't an absolute source
- Changes with time
- Not sensitive enough to changes at blue/UV end

Solar Diffuser Sphere: strengths & weaknesses



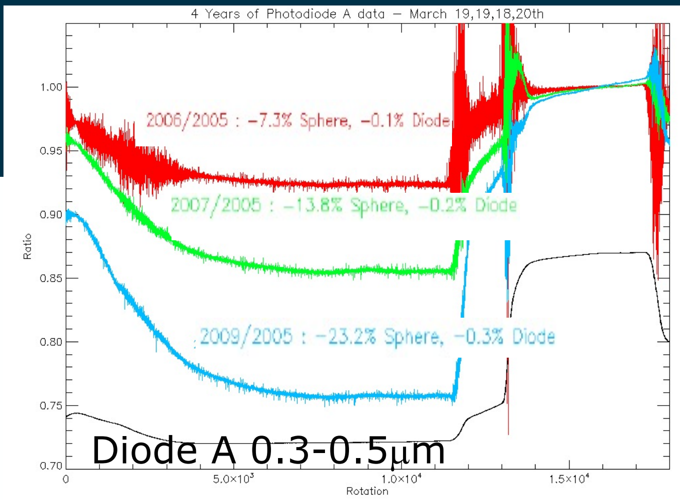
The integrating sphere observations can:

- verify the stability of quartz filter transmission
- evidence differential changes to the two sides of the scan mirror

CAN NOT

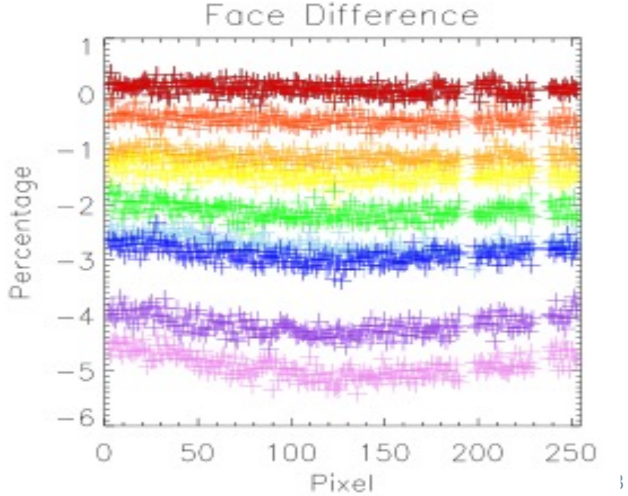
- Provide absolute in-orbit calibration
- diagnose spectrally varying changes to the shortwave response
- Track changes that occur equally to both sides of the scan mirror

Considerable degradation has been observed in the sphere's reflectance at some wavelengths, making less and less similar to Earth scenes and further compromising its sensitivity to shorter wavelengths



Relative change in diodes monitoring sphere over 2005-2009. Periods of both diffuse (reflected from sphere) and direct (to monitor diode response) illumination shown

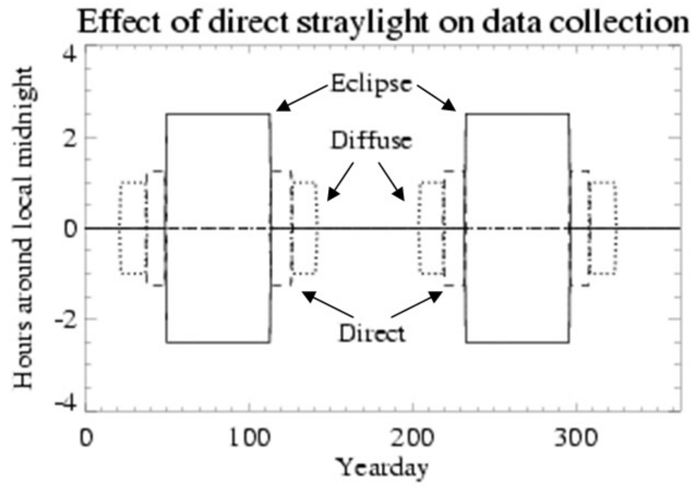
Diode output and sphere reflectance is changing most significantly at shortest wavelengths



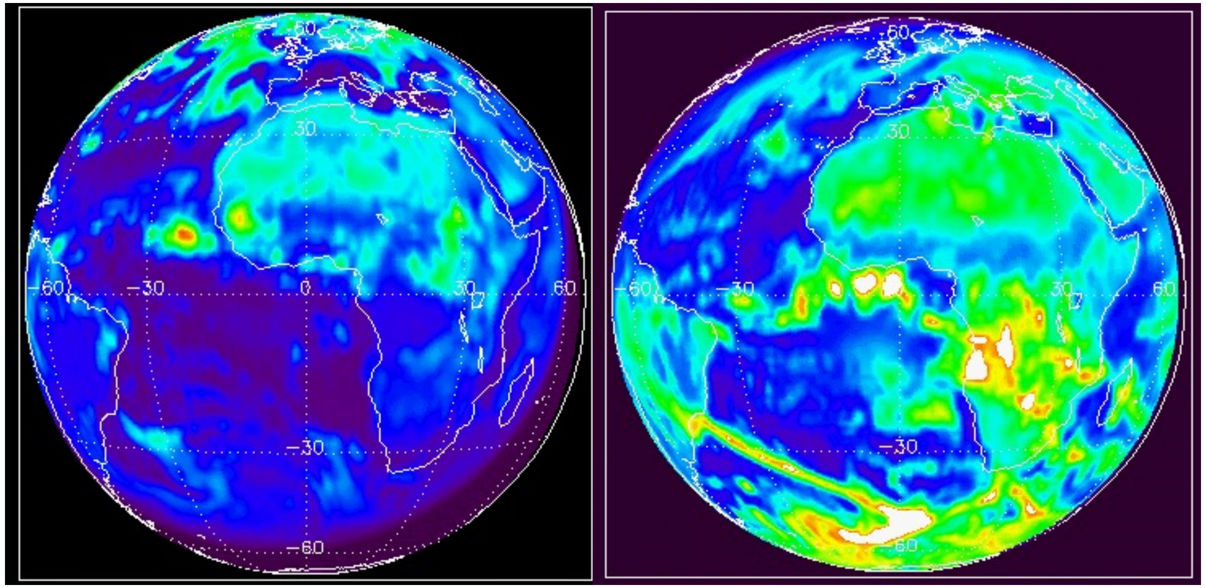
Differential aging of the two sides of the scan on the first GERB 2003-2015 mirror diagnosed by the CALMON due to exposure in the park position.

$$T(CALMON) = \frac{\{[V_{sw}(CALlight) - V_{sw}(ibb)] - [V_{sw}(CALdark) - V_{sw}(ibb)]\}}{\{[V_{tot}(CALlight) - V_{tot}(ibb)] - [V_{tot}(CALdark) - V_{tot}(ibb)]\}}$$

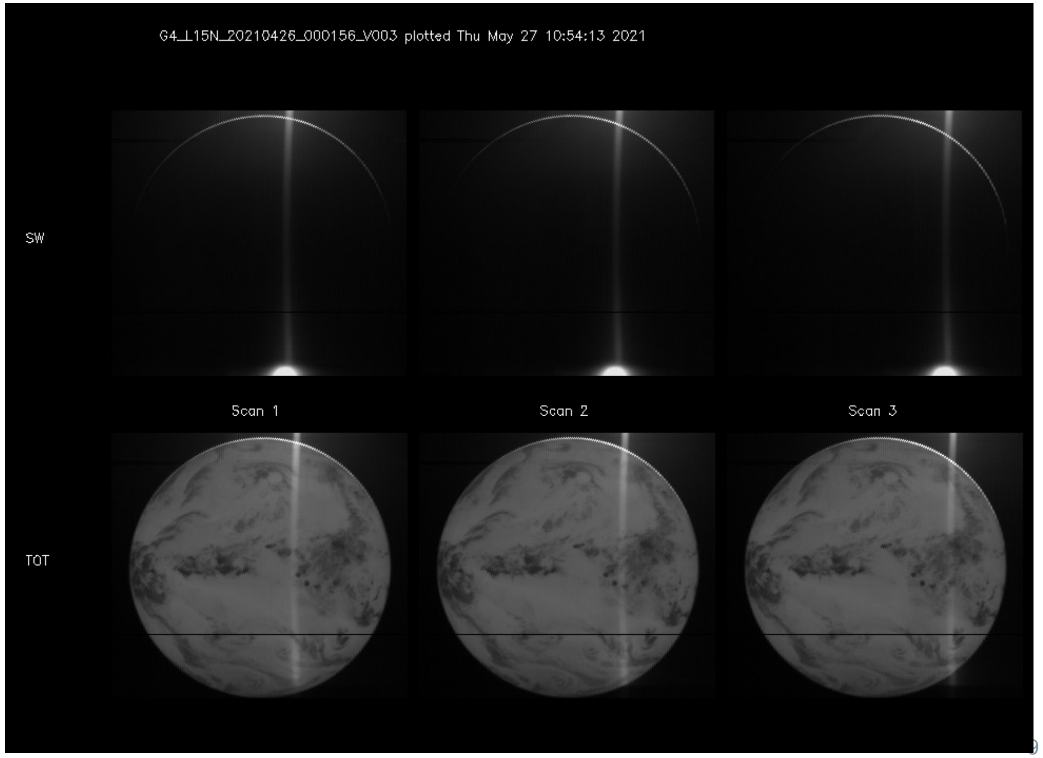
Expect: Unexpected effects & Stray signals



Some early surprises in early results that required **changes to operation and process**: geolocation & straylight

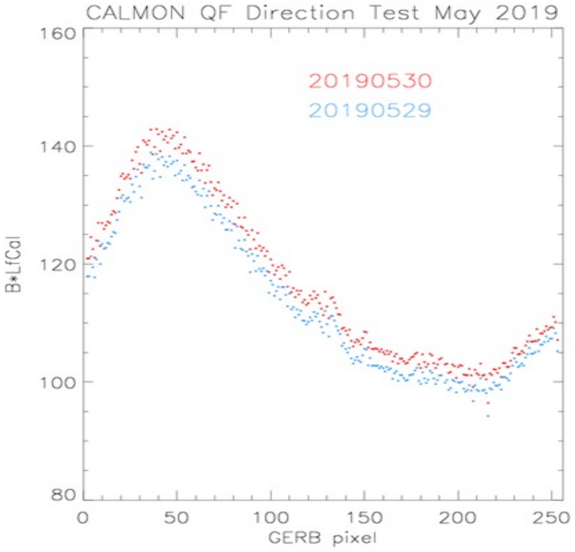


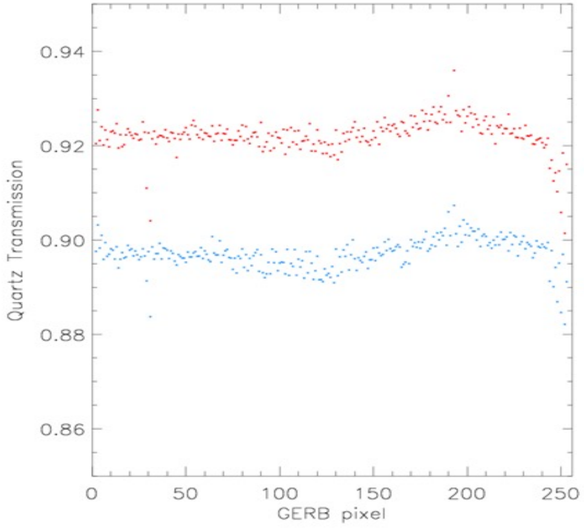
Geolocation errors May & June 2003

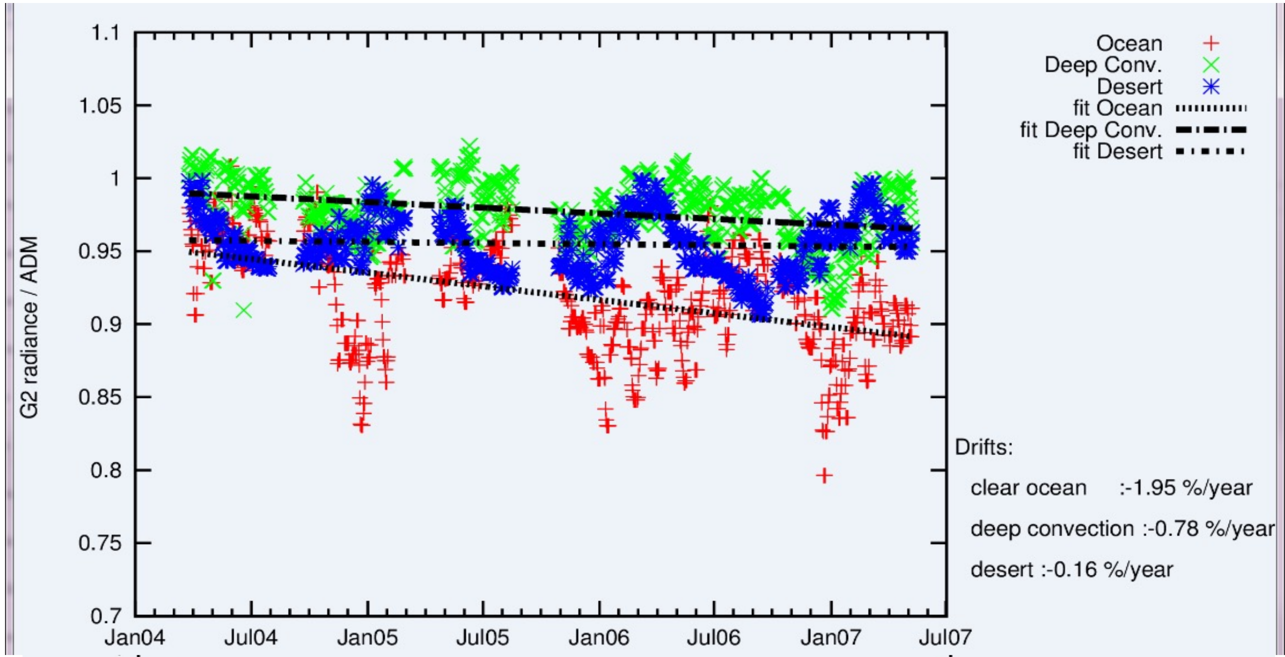


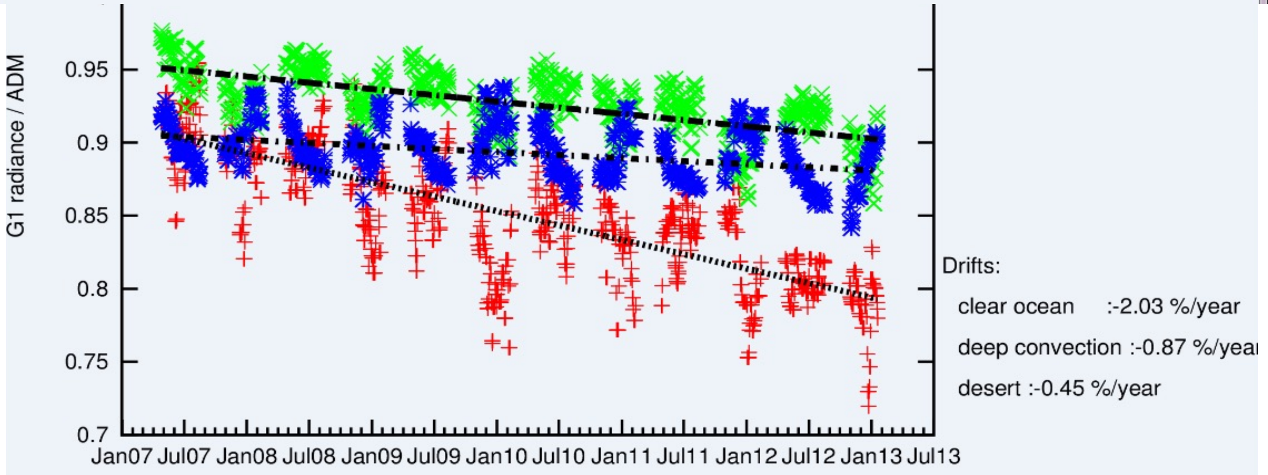
Continue to expect: Unexpected effects & change

Some effects that only occur or become apparent over time, **that require calibration updates and reprocessing** like differential aging of the mirror, mispositioning of the quartz filter and aging in the instrument response

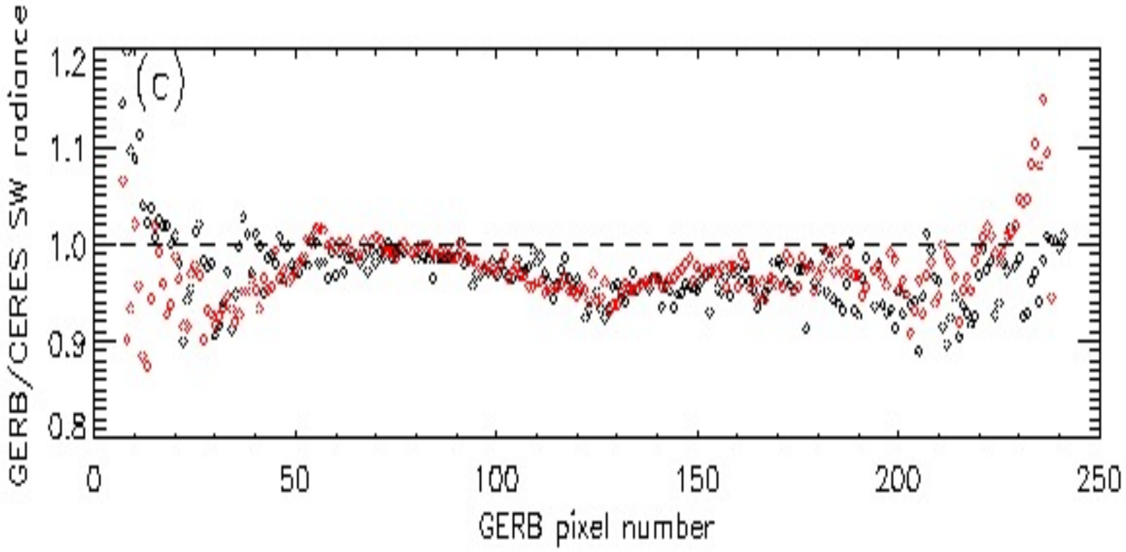




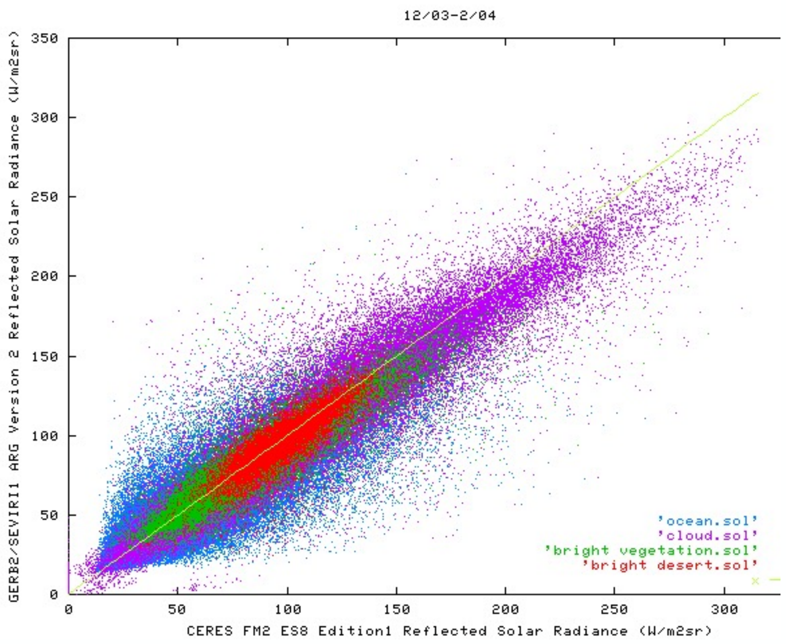


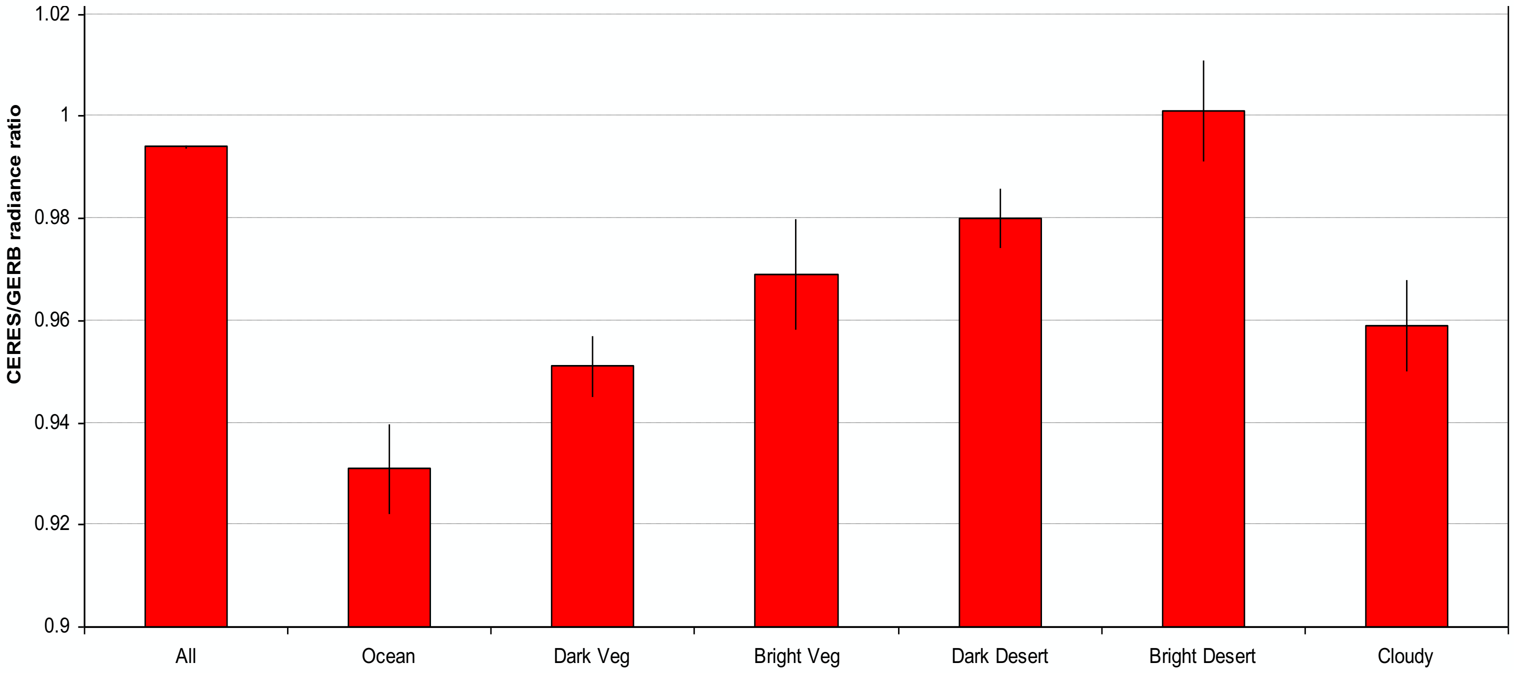


Inter-instrument comparisons: Powerful & difficult

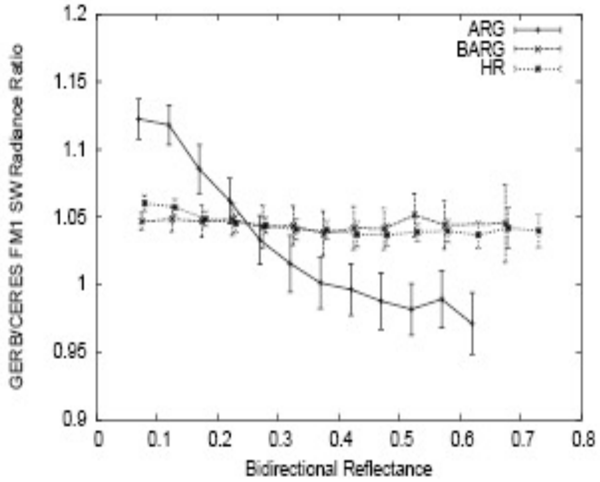


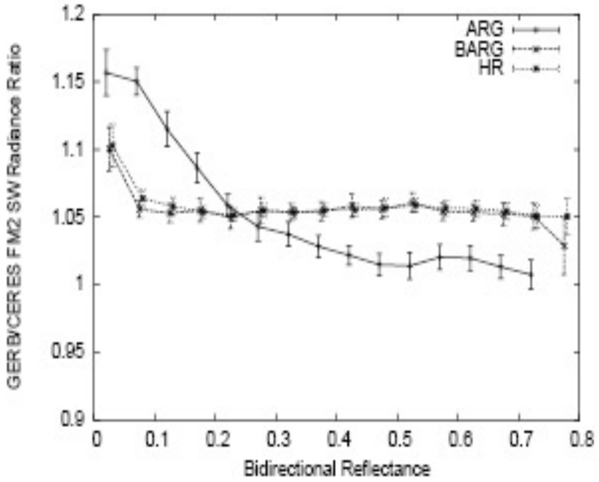
Untangling pixel & scene dependence of differences requires **a lot of matches** to untangle differences

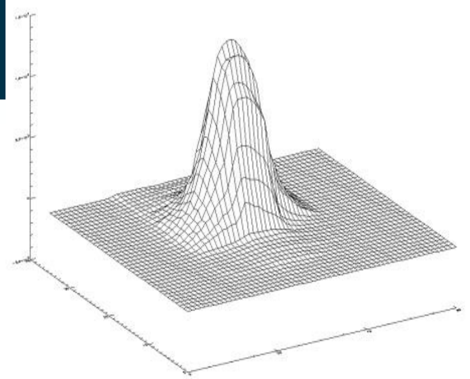


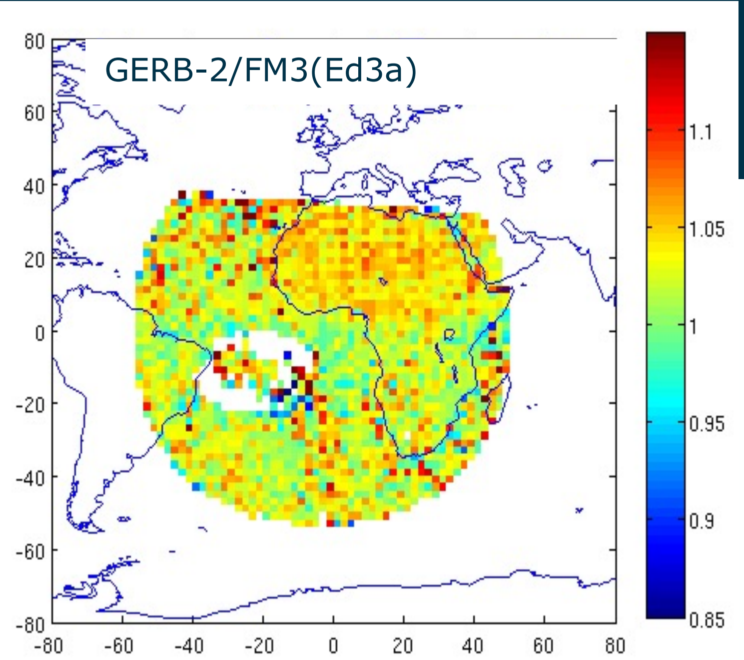


GERB/CERES comparisons





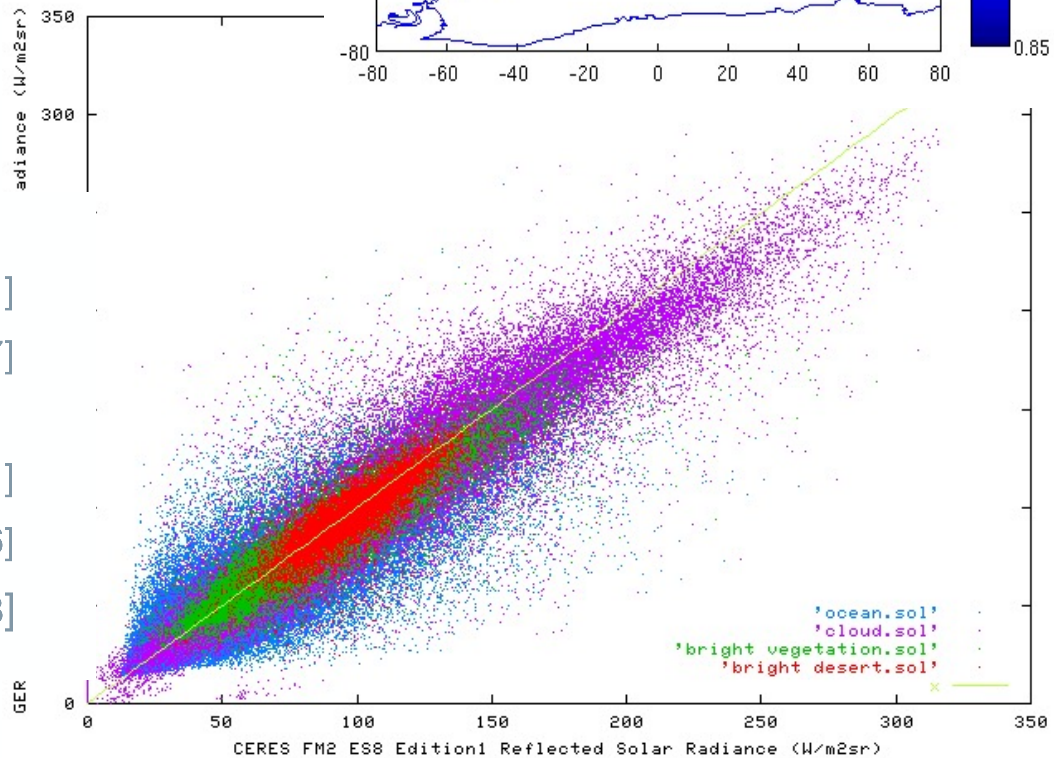




Spatial matching can introduce systematic effects that look like scene dependent effect, and untangling processing vs instrument bias is complex

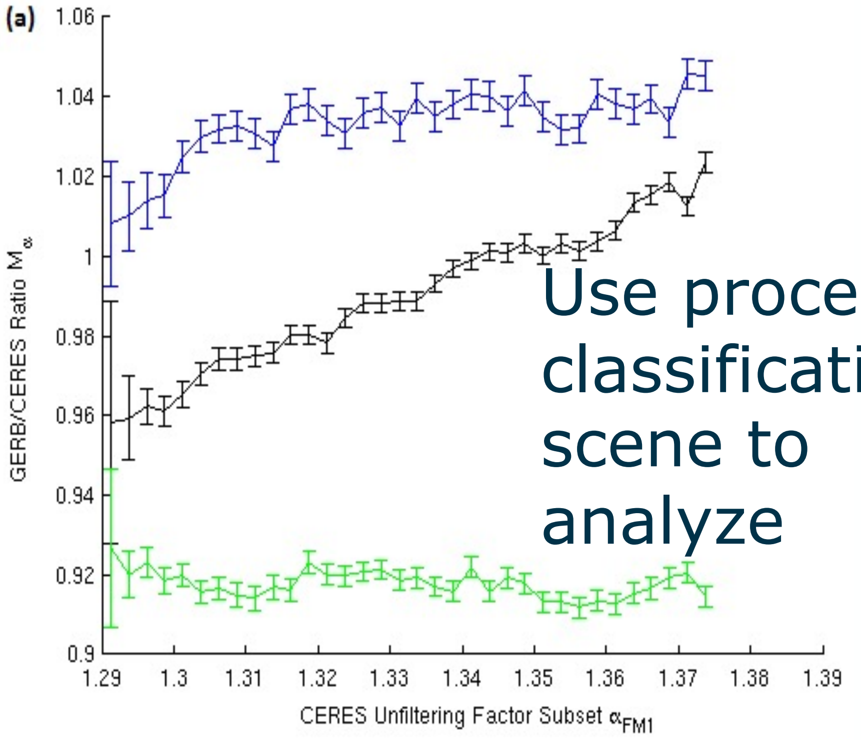
GERB /CERES reflected solar radiance

Ocean:	0.931+/-0.009=[0.922-0.941]
Dark veg.:	0.951+/-0.006=[0.944-0.957]
Bright veg.:	0.969+/-0.011=[0.958-0.980]
Dark desert:	1.001+/-0.010=[0.991-1.011]
Bright desert:	0.980+/-0.006=[0.974-0.986]
Clouds:	0.959+/-0.009=[0.950-0.968]



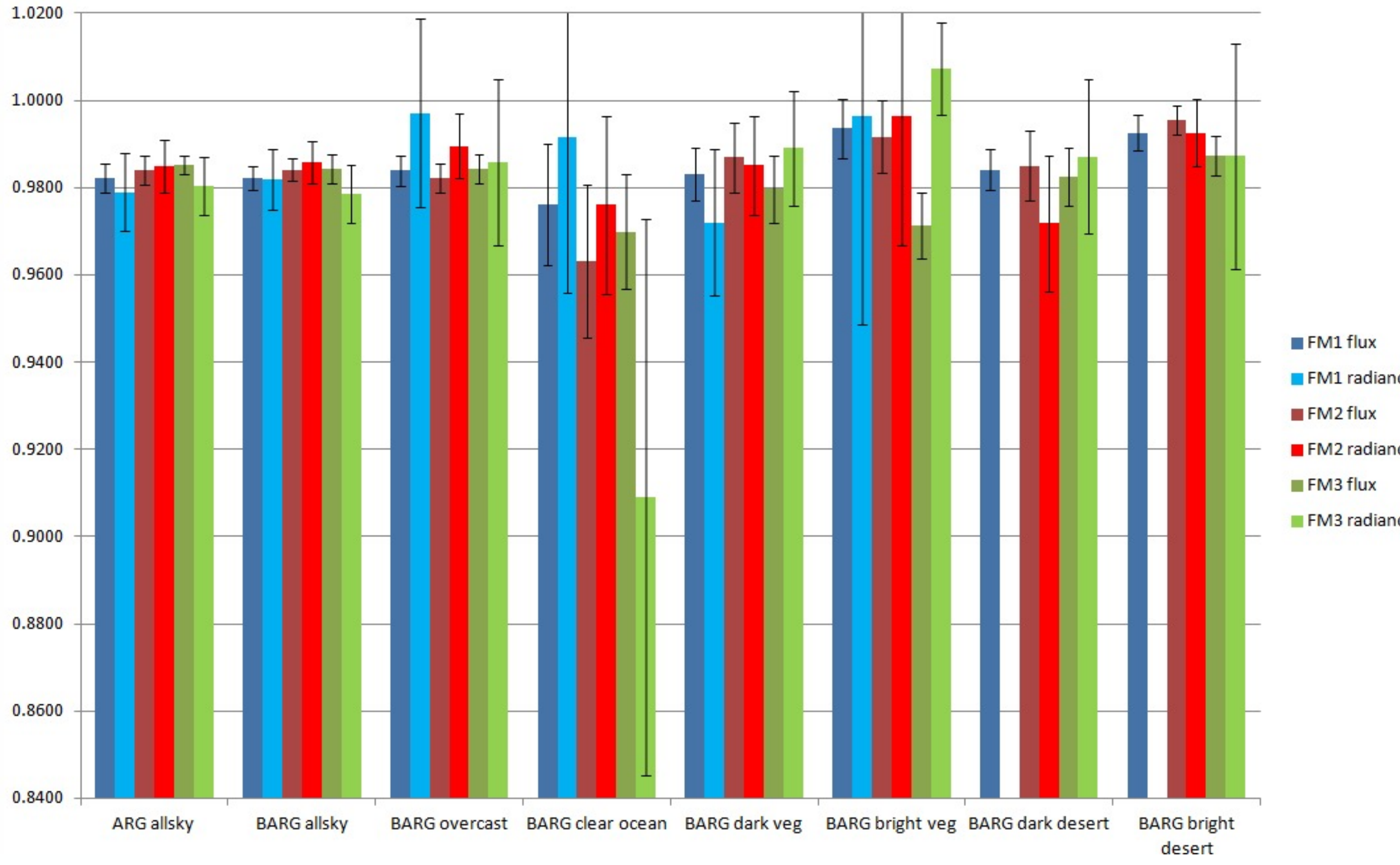
Seeing things change: GERB/CERES comparisons over time

To diagnose change during instrument life using comparisons, the problems are similar but even more involved

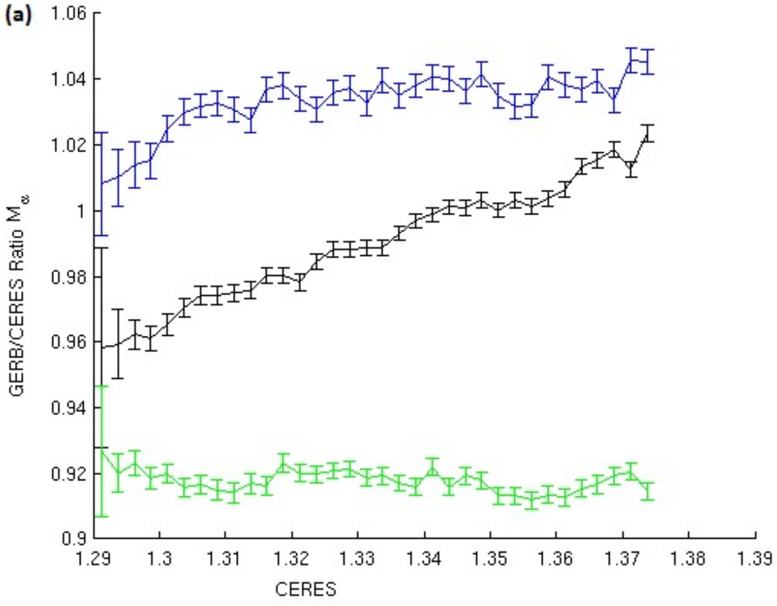


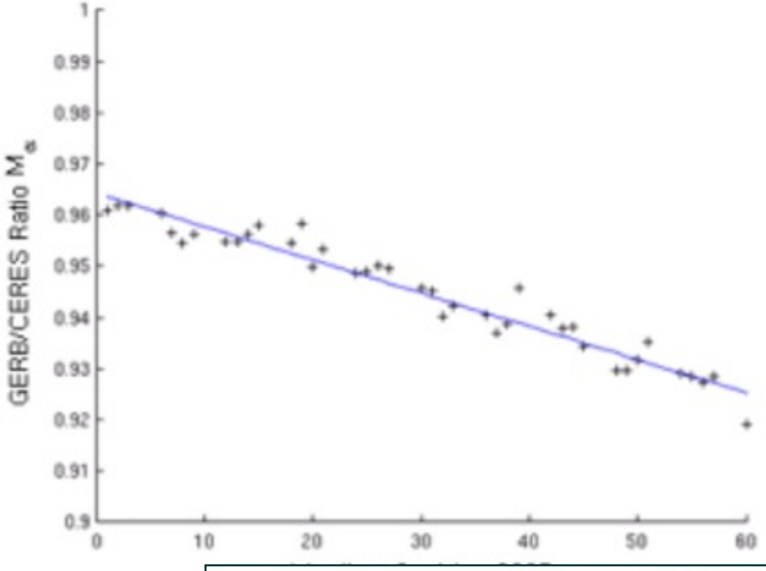
Use processing classification of scene to analyze

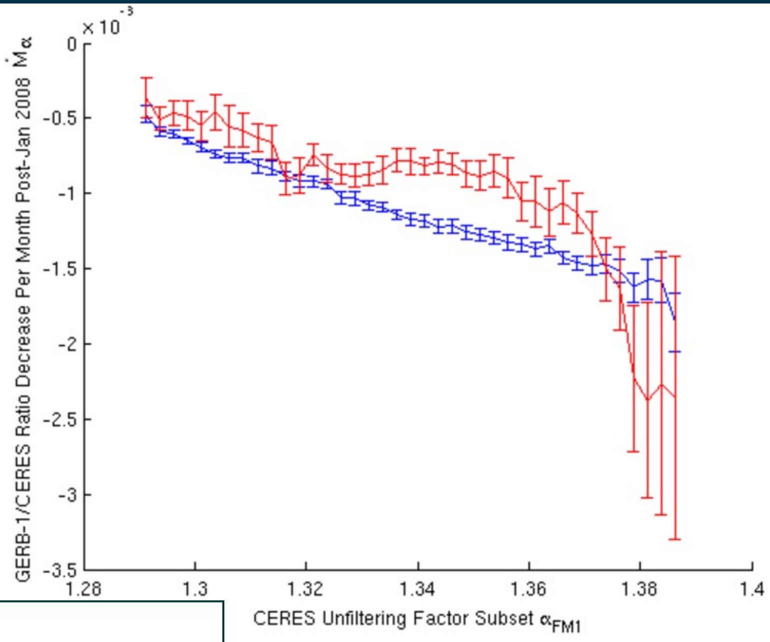
2004 to 2007 GERB 2 / CERES



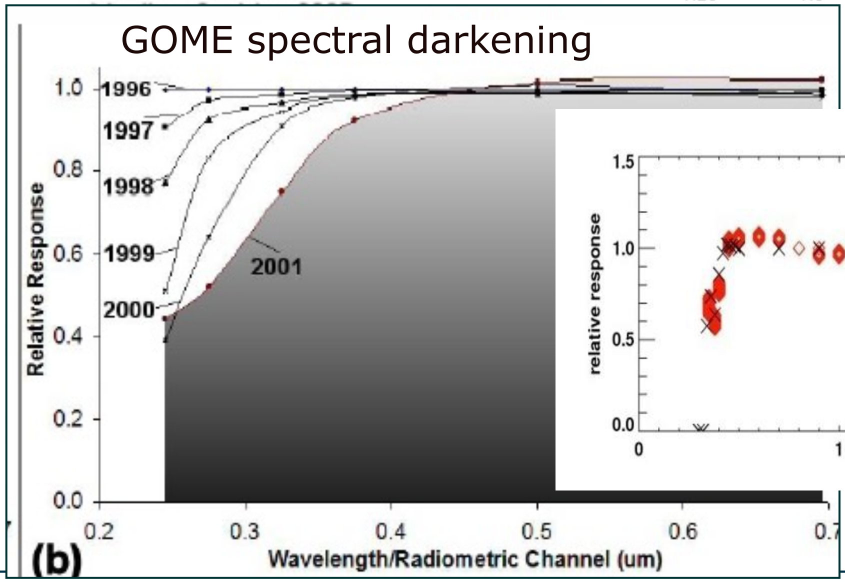
Quantify the change: GERB / CERES comparisons over time

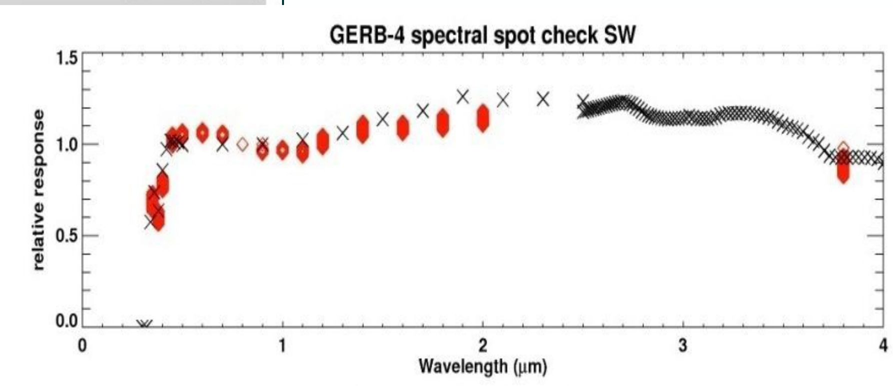




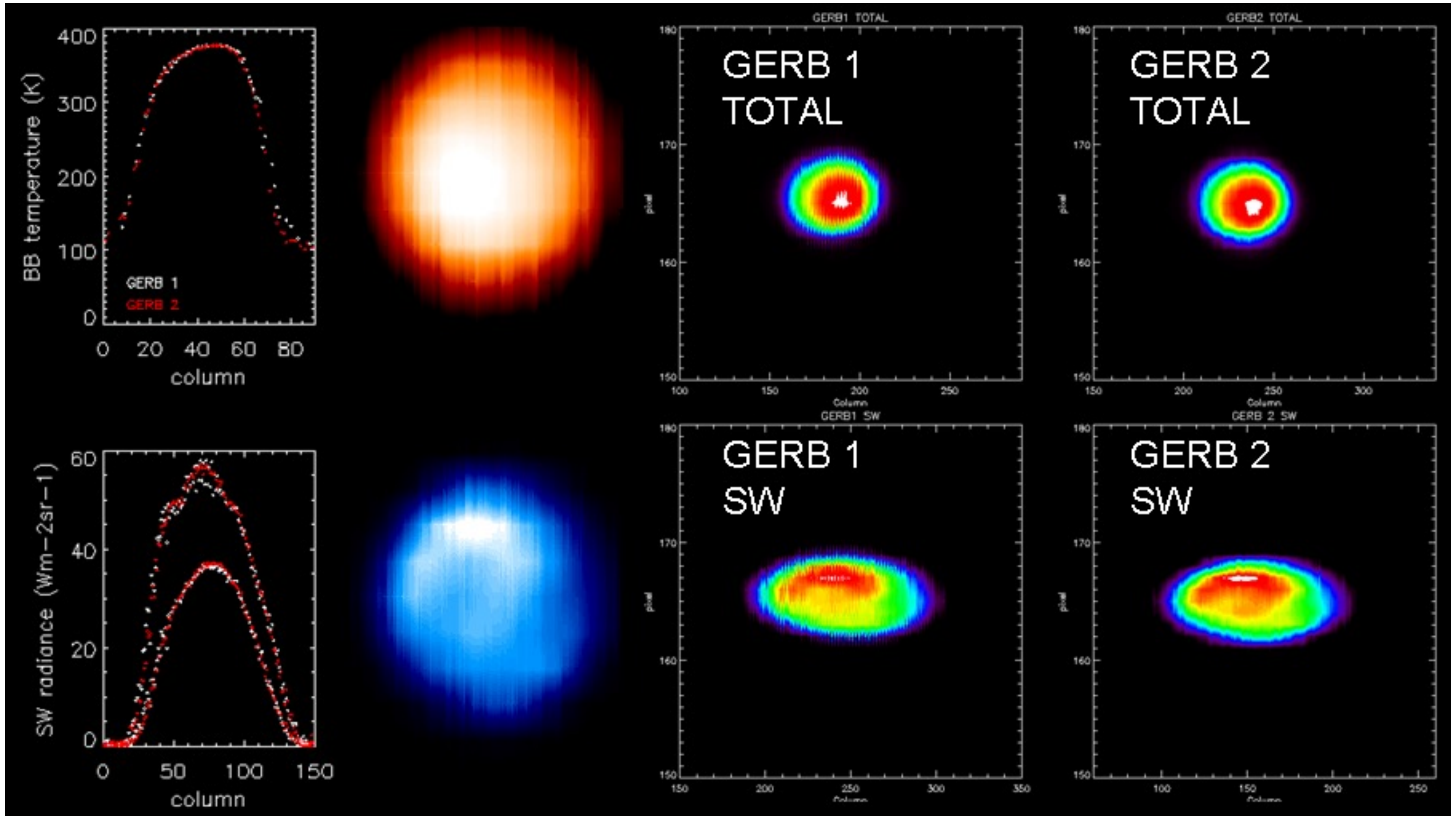


Difference between instrument and the rate of change in the difference varies with spectral distribution of energy in the scene





Vicarious comparison can lead to traceable updates



Peak LW and TOTAL radiances agree to with 0.5 and 0.2% respectively

Disk integrated LW and TOTAL radiances within, 1.8 and 1.6% respectively or to within 1% if disk edge defined by threshold on SW radiance

Peak SW agrees to within 1.3% and disk integrated SW to within 0.3%

GERB 1 & 2 lunar observations

Applying full calibration knowledge would alter LW < 0.3%, but would give a 5% offset in SW

NPL re-checked SW cal source absolute level

Ssimilarly day/night consistency checks between narrowband-broad band and GERB observed thermal radiances led to an error in the quartz filter calibration parameter normalisation being discovered

Summary

- Instruments and satellites don’t behave as expected
  - Flexibility and revisiting processing may be necessary
- Inter-instrument in-orbit comparisons
  - Extremely useful although not definitive, differences in processing and footprint can lead to systematics, whilst temporal and angular matches are more likely to be noise
- Tracking SW aging is not straightforward
  - Expect change and allow for adaptations in processing to deal with these
- Ground to orbit calibration transfer is difficult (particularly in the SW)
  - But in orbit tests for consistency can be sufficient to indicate that ground calibration analysis needs to be revisited
- Vicarious targets and qualities checks are important throughout the mission life
  - Useful to evaluating processing and providing inter instrument comparison for ideal cases, identifying systematic changes and gross offsets

Lessons

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- There will be things you don’t expect
  - Communication with instrument team likely to be needed to understand and solve some issues
  - Expect to need to update processing to cope and revisit your plans
- Some errors and effects only get highlighted by use or time
  - Maintain communication with instrument team and enable baseline values to be revisited
- There will be changes to the instrument over time you have to deal with to maintain data quality
  - Expect to have to keep checking, and update your processing and revisit your plans
- Some artefacts you never expects can occur years into a mission
  - Continuous quality monitoring is important and updates to processing and reprocessing will likely be needed

Lessons

THOUGHOUT THE MISSION LIFE (and probably after)

Maintain communication with instrument Engineers
Retain ability to adapt processing
Expect to have to update and reprocess data

Also think about how you communicate issues and uncertainties to users best (and then tell me)