Providing Consistent Solar Channel Radiometry for the ATSR series

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VIS-SWIR Channels on ATSR Series

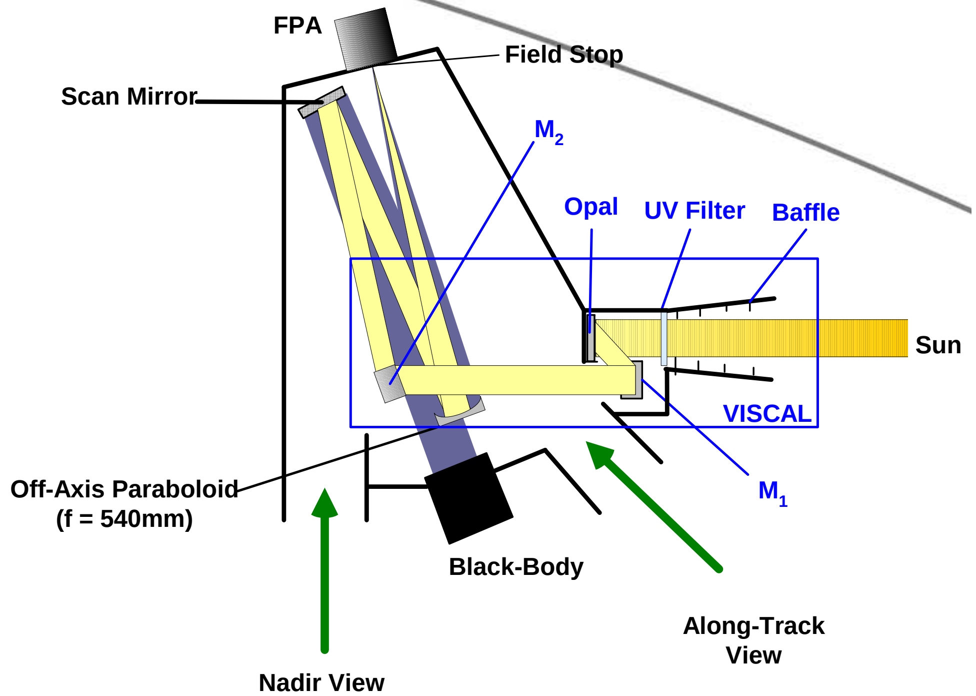
Band Centre	Bandwidth	Function	ATSR-1	ATSR-2	AATSR
555nm	20nm	Chlorophyll	N	Y	Y
659nm	20nm	Vegetation Index	N	Y	Y
870nm	20nm	Vegetation Index	N	Y	Y
1600nm	60nm	Clouds	Y	Y	Y
VISCAL			N	Y	Y

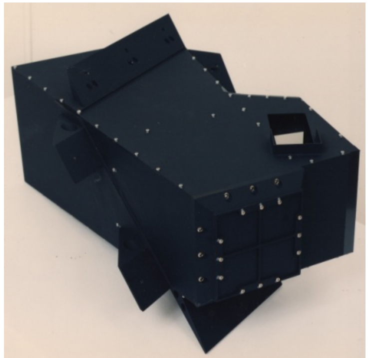
VISCAL System

- ATSR-2 introduced a prototype VISCAL system which provides a calibration reference proportional to the solar irradiance, so

$$R_{scene}\cos\theta_0 = R_{viscal}\frac{(C_{scene} - C_{dark})}{(C_{viscal} - C_{dark})}$$

- AATSR has a developed version of the VISCAL system
  - Improved stray light baffling
  - Wider field of view for diffuser





Calibration Budget

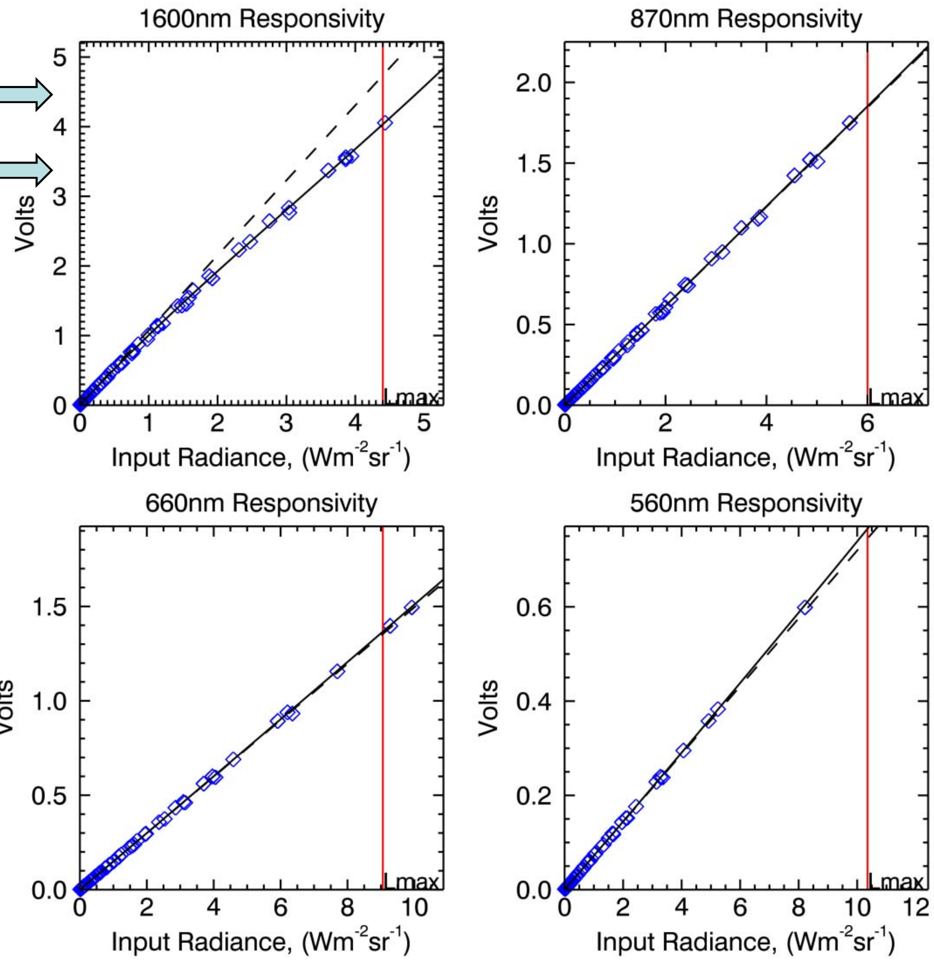
Component	Expression	Source	Uncertainty
Reflectance Factor For VISCAL	Δr_{viscal}	Pre-Launch Calibration Diffuser BRDF Relay Mirror Reflectances UV window transmission VISCAL geometry	3%
Degradation of VISCAL Reflectance Factor	Δr_{drift}	Post-Launch Vicarious Calibration	1%
Orbital Gain Stability	Δr_{orbit}	By design & Pre-Launch Testing	0.1%
Signal Channel Noise (VISCAL Source Signal)	$\Delta r_{noise,viscal}$	Measured from On-Board Sources	<0.01%
Signal Channel Noise (VISCAL Dark Signal)	$\Delta r_{noise,dark}$	Measured from On-Board Sources	<0.01%
Signal Channel Noise (Scene Signal)	$\Delta r_{noise,scene}$	Measured from On-Board Sources	<0.01%
Signal Channel Noise (Dark Signal)	$\Delta r_{noise,dark}$	Measured from On-Board Sources	<0.01%
Non-Linearity	Δr_{nonlin}	Pre-Launch Calibration	1%
Total Uncertainty	$\mathbf{\Delta r_{scene}}$		

Solar Irradiance Error	ΔI_0	Solspec Reference Spectrum Spectral Response (Pre-Launch)	2%
Total Uncertainty	$\mathbf{\Delta L_{scene}}$		

Pre-Launch Calibration (AATSR)

- Spectral Response
- Radiometric Response
- Linearity
- Noise Performance
- Polarisation Sensitivity
- Variation around scan
- VISCAL Reflectance Factor

	Expected	Measured
1600nm	0.192±0.005	0.192±0.006
870nm	0.156±0.004	0.154±0.005
659nm	0.163±0.003	0.163±0.005
555nm	0.165±0.003	0.165±0.005



Calibration over stable targets

- ATSR-2 and AATSR carry in-flight systems for calibrating the VIS-SWIR channels.

- Quasi stable desert and ice targets allow monitoring of long-term stability and comparisons between sensors (e.g. AATSR, MERIS, MODIS)

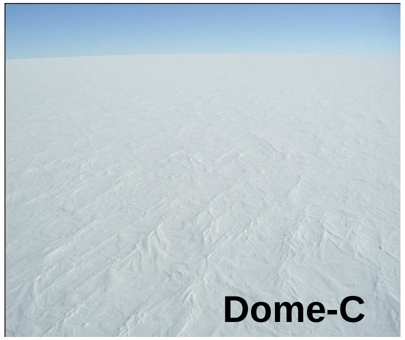
Site selection criteria:

Uniform reflectance over large area

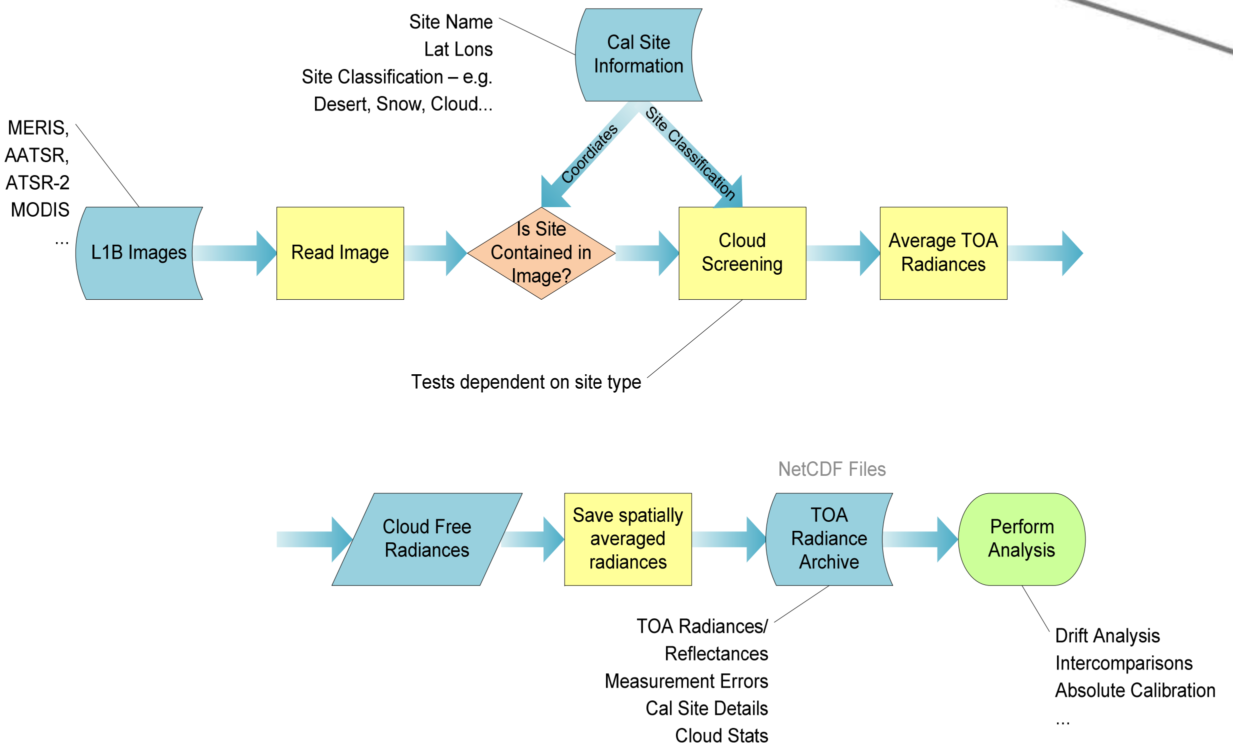
Long term-radiometric stability of the calibration sites

Ensures long-term stability of the top-of-the atmosphere (TOA) albedo (and of seasonal variations, if any) or reflectance over large spatially uniform areas.

High surface reflectance to maximise the signal-to-noise and minimise atmospheric effects on the radiation measured by the satellite



Site Data Extractions



No of extractions

- AATSR – 7782
- ATSR-2 – 1562
- ATSR-1 – 1267
- MERIS - 16050 (Desert sites provided by ACRI using METRIC)
  1359 (Dome-C and Greenland from L1b products)
- MODIS-A – 11149 (Dome-C and Libya 4 only!)

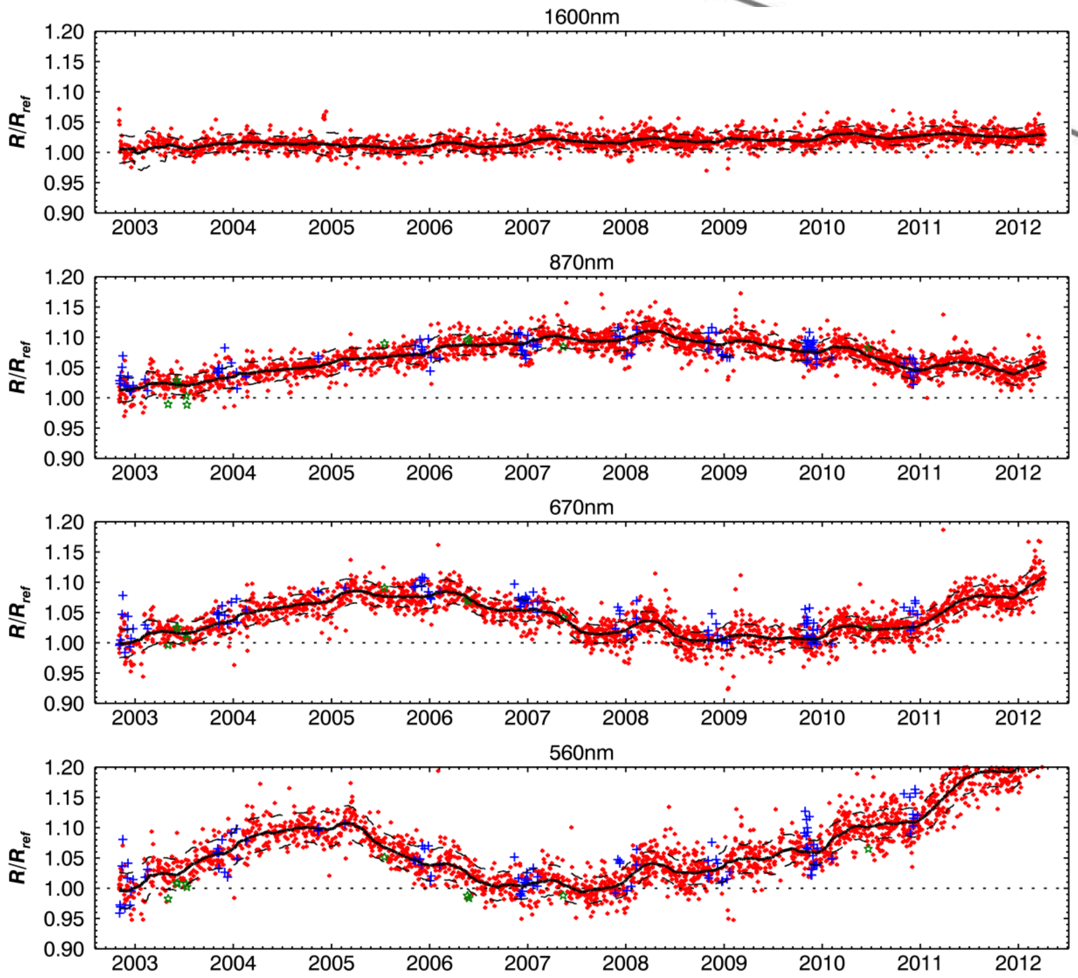
AATSR Drift Analysis

To obtain drift we compare measured BRF against reference BRF for all sites

Trend is obtained by averaging drift for all sites of 90day window filtering for values <2sigma from mean.

AATSR drift does not follow linear trend as originally expected – suggests a more complex model for drift

Results provide input to drift correction look-up-table



AATSR Drift Corrections

- For AATSR L1b images it is advised to remove existing drift corrections (based on early analysis) and use the drift correction look-up-table and tools available on-line to users via CEOS cal-val portal

  http://calvalportal.ceos.org/cvp/web/guest/aatsr-envisat

- IDL tools have been developed to identify and implement appropriate corrections to L1B products

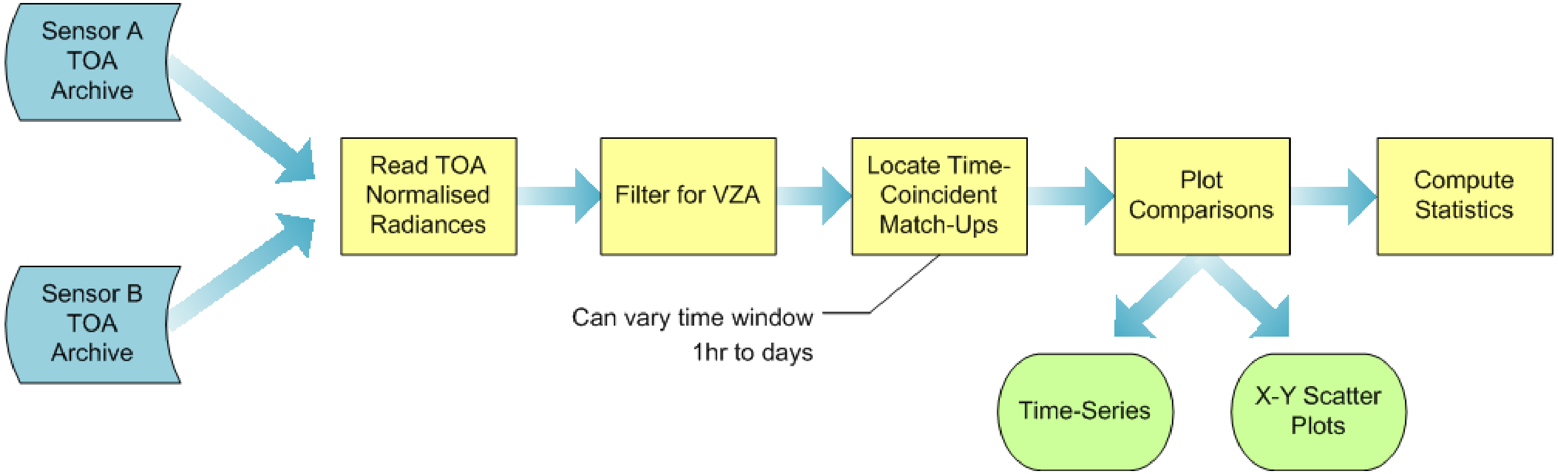
  – AATSR_CORRECT_V16_NONLINEARITY.PRO
    – corrects 1.6um nonlinearity if not already implemented.
  – AATSR_REMOVE_DRIFT_CORRECTION.PRO
    – removes existing drift correction to allow the latest and best drift corrections to be applied
  – AATSR_APPLY_DRIFT_CORRECTION.PRO
    – Applies the drift correction using a look up-table containing the measured drift for each channel

- These correction tools have also been implemented as BEAM extensions.

- Next AATSR L1b reprocessing will include ‘best’ drfit correction factors

Intercomparison Methodology – Direct comparisons

Approach works for sensors at similar local time and view geometry – e.g. MERIS and AATSR



Provides Limited number of coincidences

No good for sensors at different crossing times – e.g. EOS-A/ENVISAT

Restricted to near nadir observations

Atmospheric corrections are needed where spectral bands are not coincident

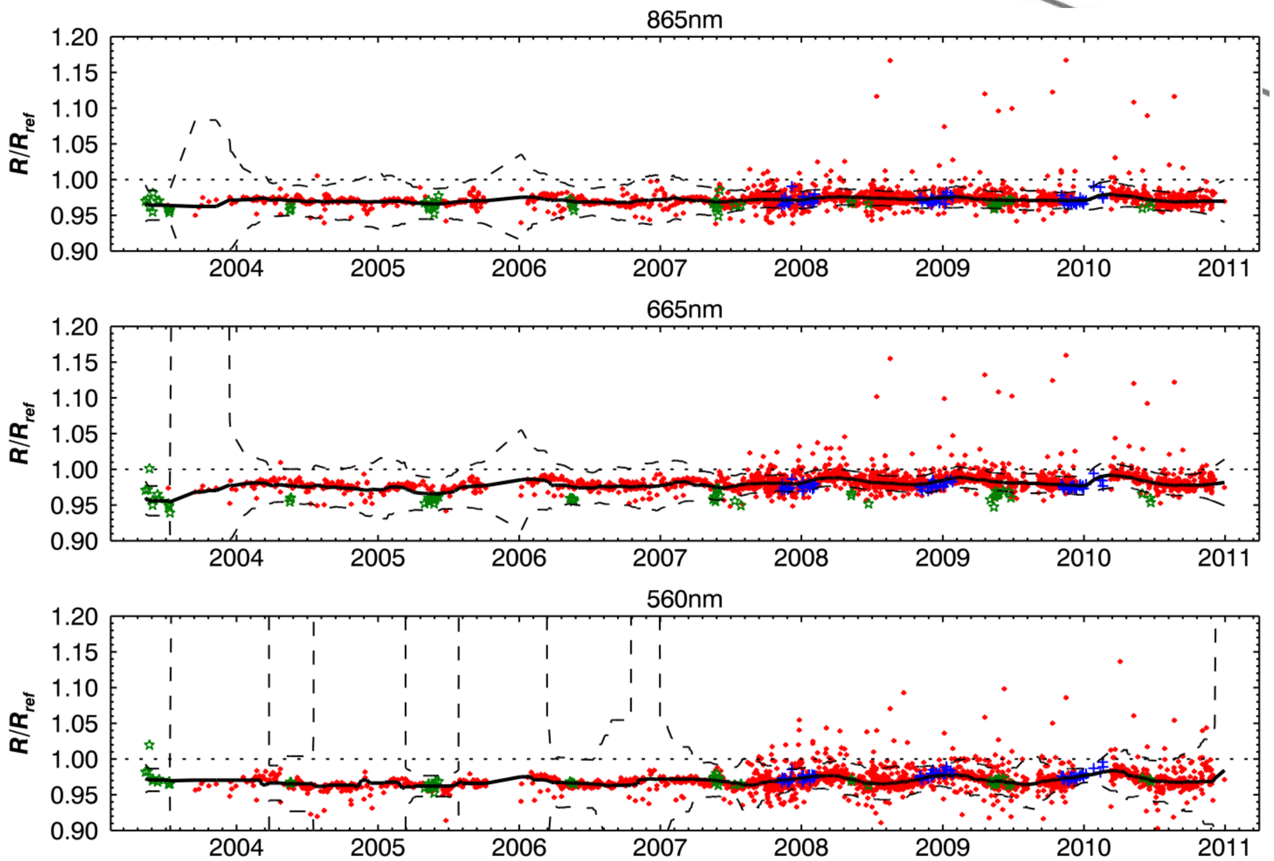
Direct comparison MERIS vs. AATSR

AATSR and MERIS share same platform hence direct comparisons are possible

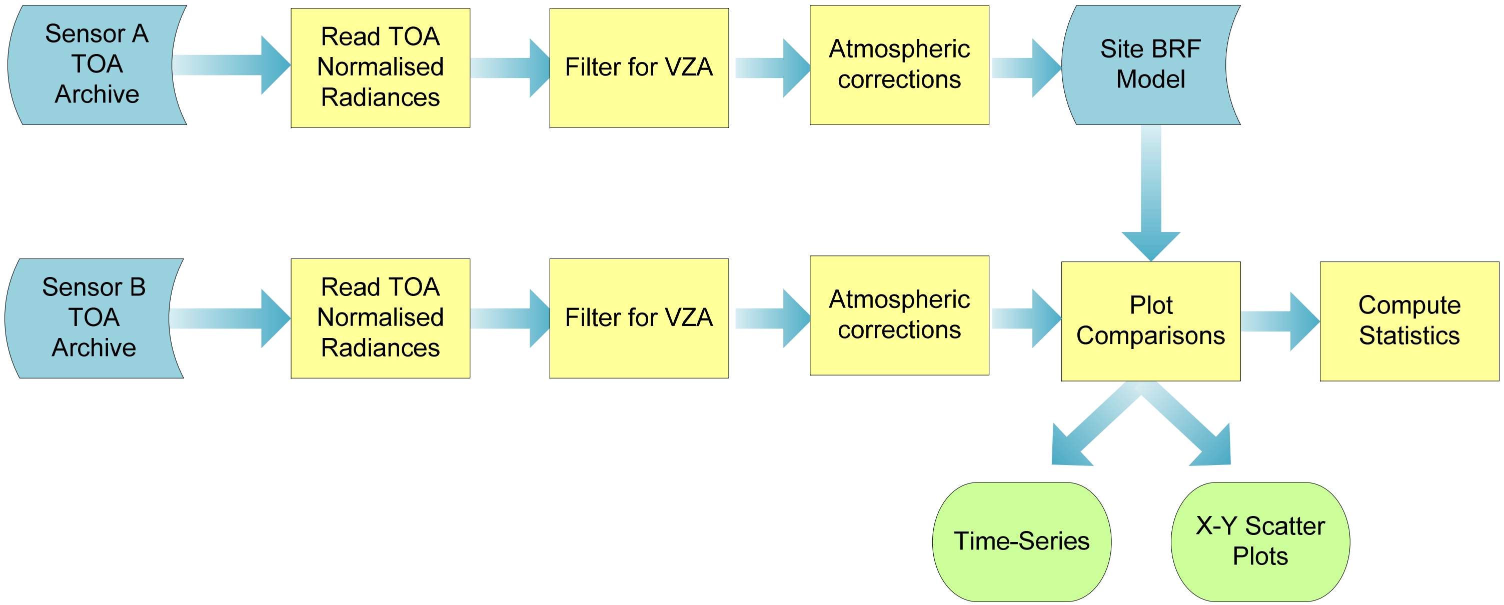
Corresponding channels at 865nm, 660nm and 555nm

Matchups at VZA <10°

AATSR drift corrections applied



Intercomparison Methodology – Via reference BRF



Extends range of possible cross-calibrations

- Sensors at different overpass times – e.g. EOS-A/ENVISAT
- Sensors where no direct comparisons possible – e.g. AATSR/ATSR-2

Atmospheric adjustments needed where bands are not coincident

Reference BRF (Updated Model)

- For a given view zenith angle , $\theta \pm 5^\circ$ we treat the BRF as polynomial function of the solar zenith angle, θ_0

- Assumes correlation between solar zenith and relative azimuth is >0.9.

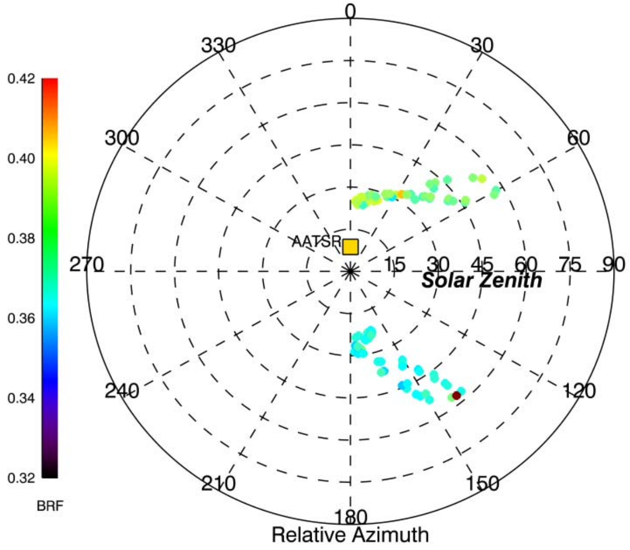
- The function is obtained by fitting to data measured early in the mission where the drift is assumed to be low compared to the surface anisotropy, Smith et al 2002.

- The uncertainty in the BRF, $u(R)$ is taken from the co-variance matrix generated by the function.
  - Dependent on the measurement errors provided to the model. For this analysis we assume the standard deviation of the average reflectance measurements over the site.

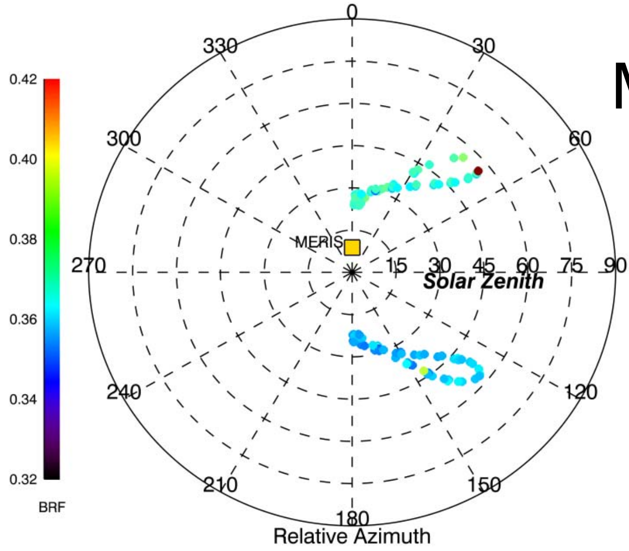
- For each band and view angle, model provides coefficents, co-variance matrix, sza-relaz correlation, rss of residuals and validity range.

Solar Zenith and Relative Azimuth Correlation

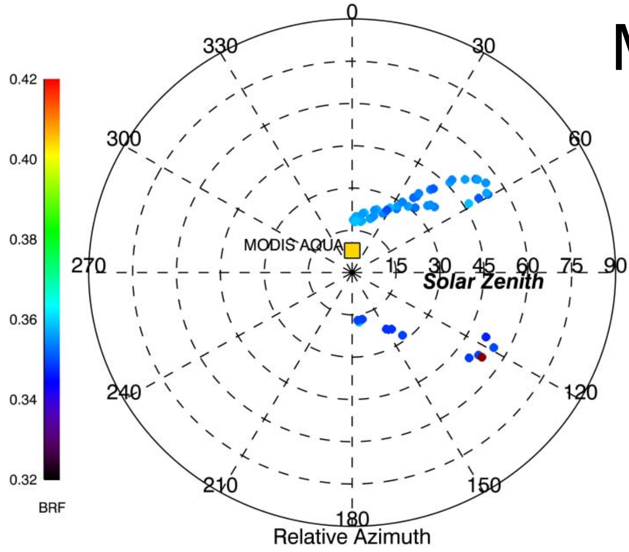
AATSR



MERIS



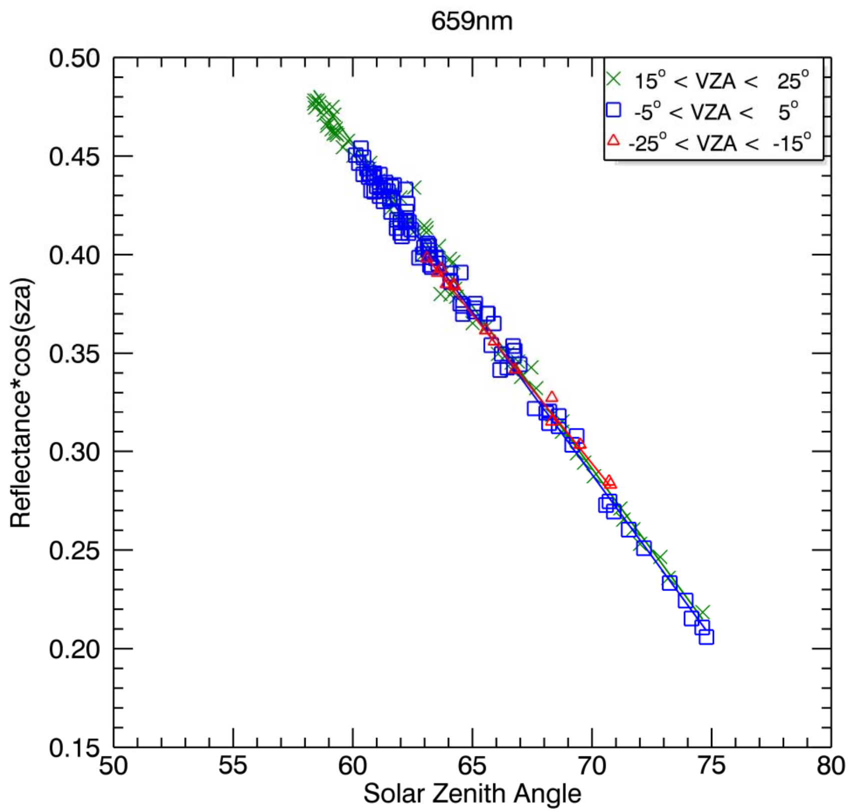
MODIS



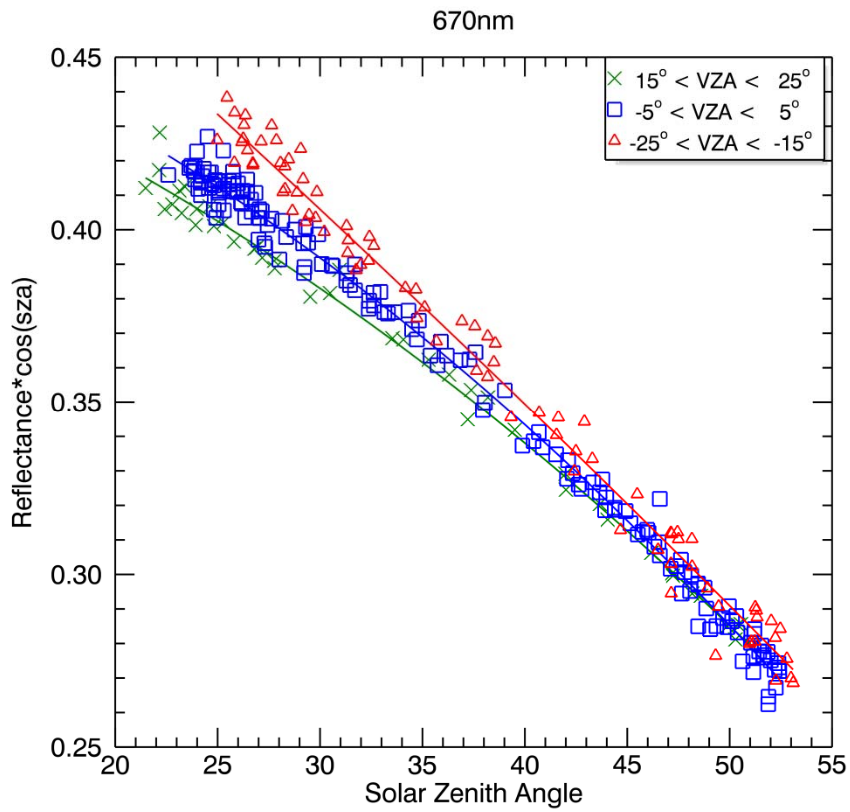
555nm BRF for Libya-4

5º < view zenith < 15º

Site BRF Model



DOME-C 660nm



Sudan-1 660nm

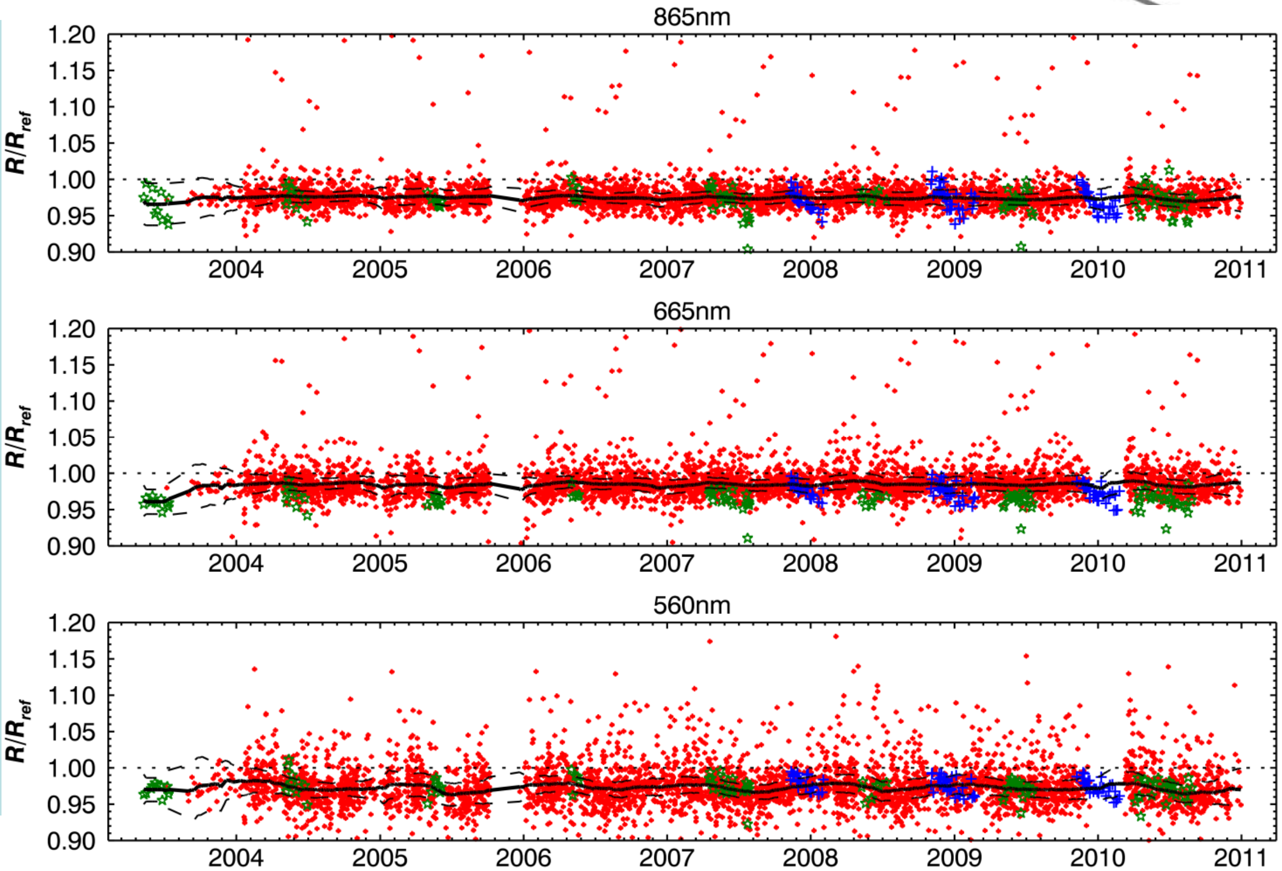
Corrections for Rayleigh, O_3 and H_2O applied before fitting model

MERIS vs. AATSR BRF

Using BRF model provides more comparisons

Results are in agreement with direct comparisons

Improvements to MERIS cloud screening could reduce scatter



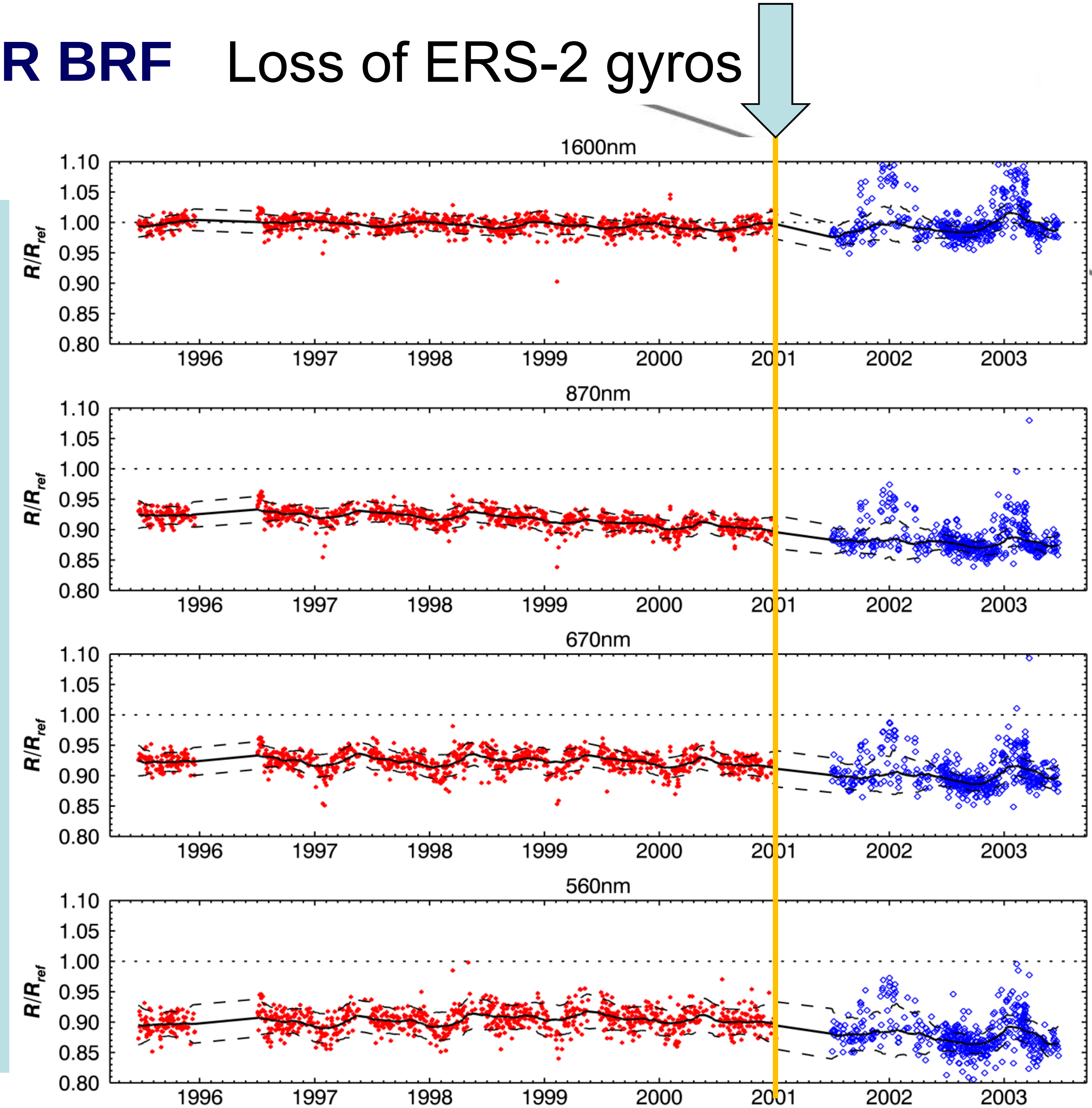
ATSR-2 vs. AATSR BRF

Loss of ERS-2 gyros

Direct comparisons with AATSR or MERIS not possible before 2002 – hence comparisons with BRF model is only method available

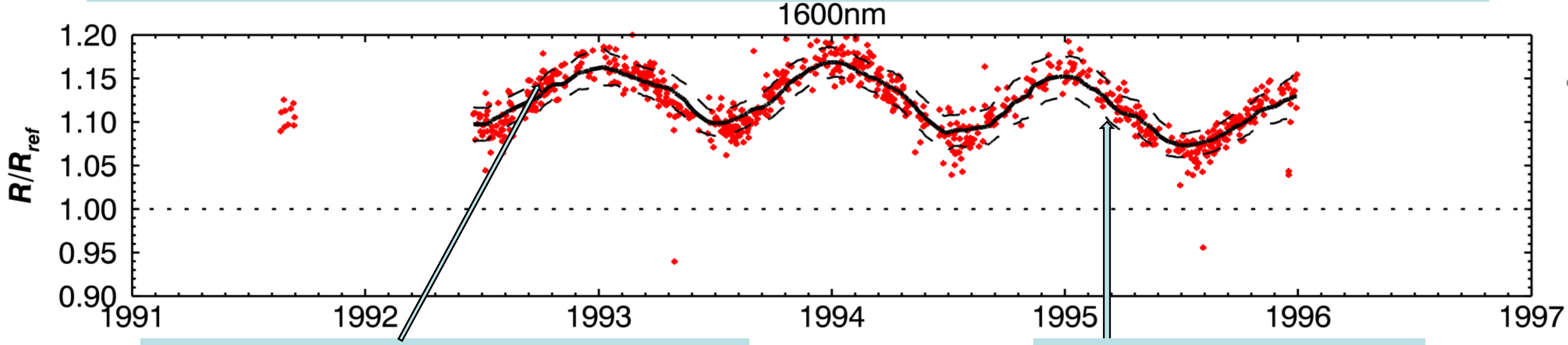
Results show systematic bias between AATSR and ATSR-2

Small correction for ATSR-2 long-term drift is needed at 870nm



ATSR-1 vs AATSR BRF

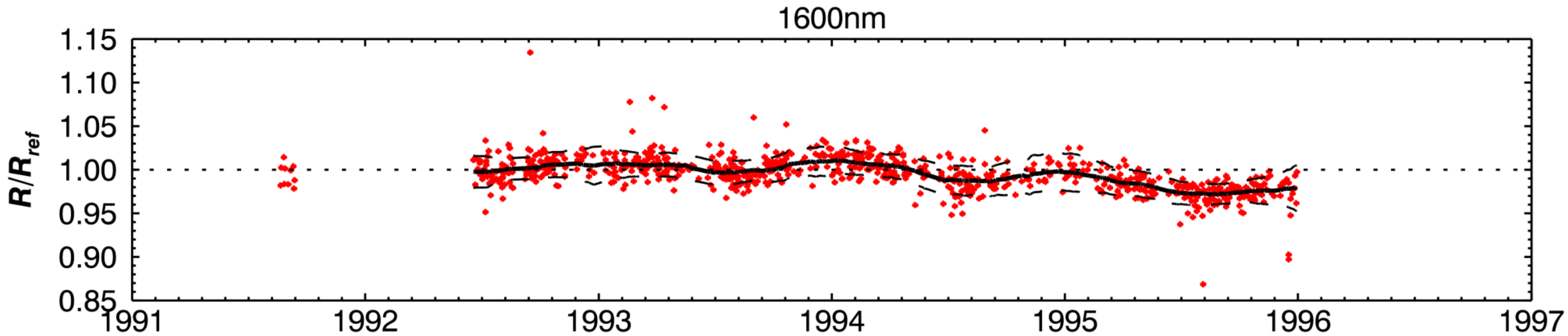
As processed - note ATSR-1 has no on-board calibration for SWIR



ATSR-1 L1 processor does not account for sun-earth distance scaling factor

13% systematic bias relative to AATSR

1st Order Corrections applied

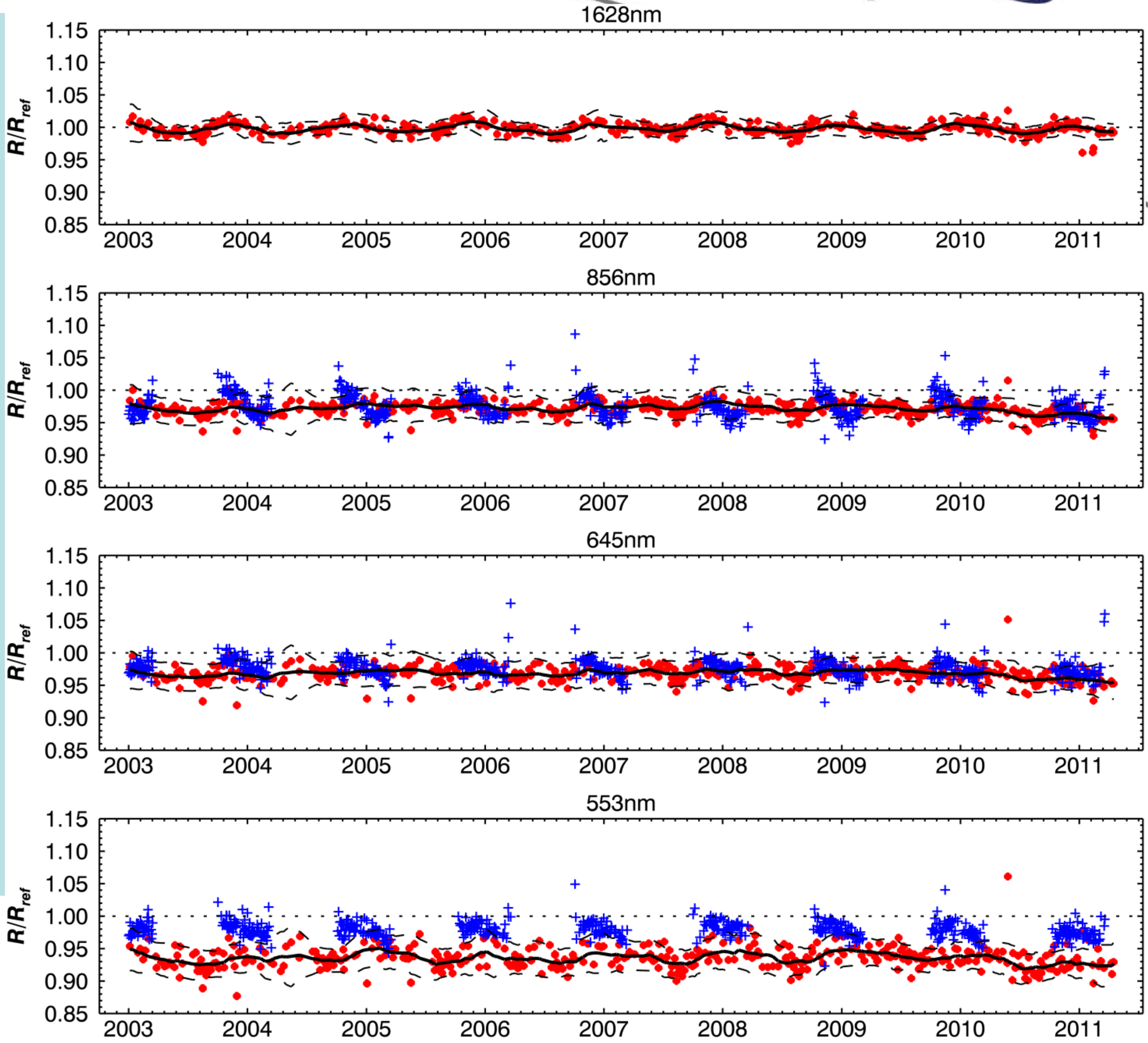


MODIS-A vs. AATSR BRF

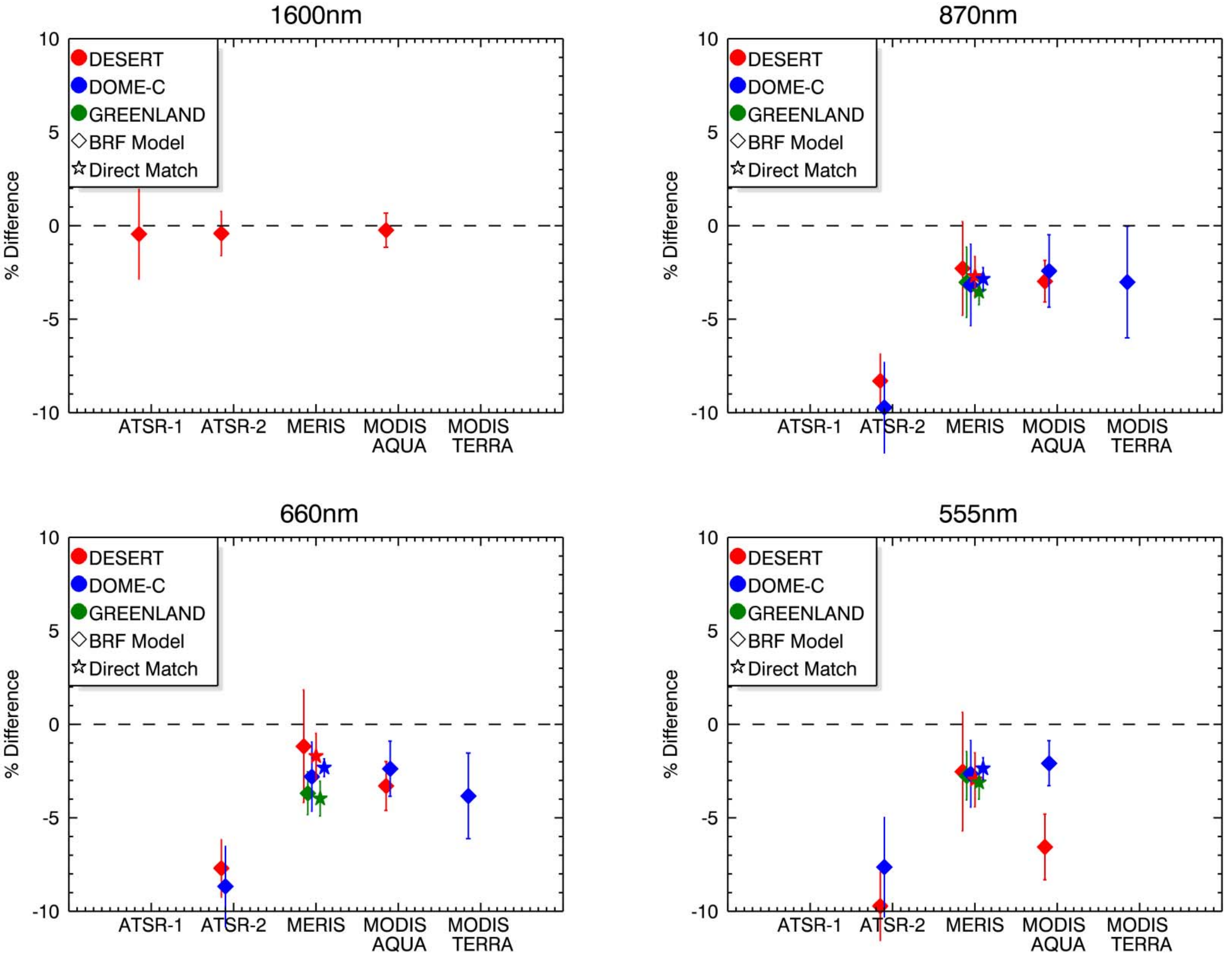
Direct comparisons between MODIS-A and AATSR are not possible due to orbit differences

Differences between Desert and Dome-C are apparent – due to spectral variation in site reflectance

Improvements to cloud screening, spectral corrections should reduce differences



Intercomparison summary
As measured

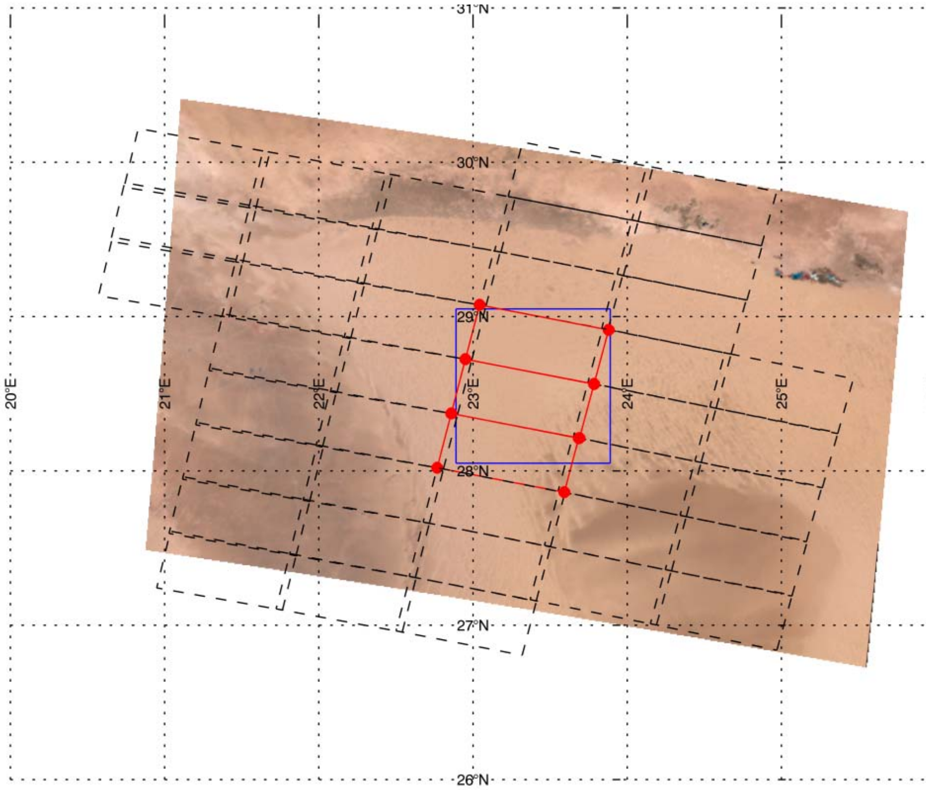


How to account for spectral Variations

- Even after accounting for atmosphere – we still need to address spectral variations of site BRF
- Use MERIS profile
  - OK as a rough approximation
  - Spectral resolution not fine enough to account for absorption lines
- Use Simulations
  - MODTRAN
  - Corrections to atmosphere only - site spectral variations not specific enough
  - Need spectra for sites
- Use Spectrometer Data
  - GOME-2
    - Nadir View
    - Bands up to 800nm
  - SCIAMACHY
    - Alternate Limb/Nadir view
    - Bands up to 2200nm

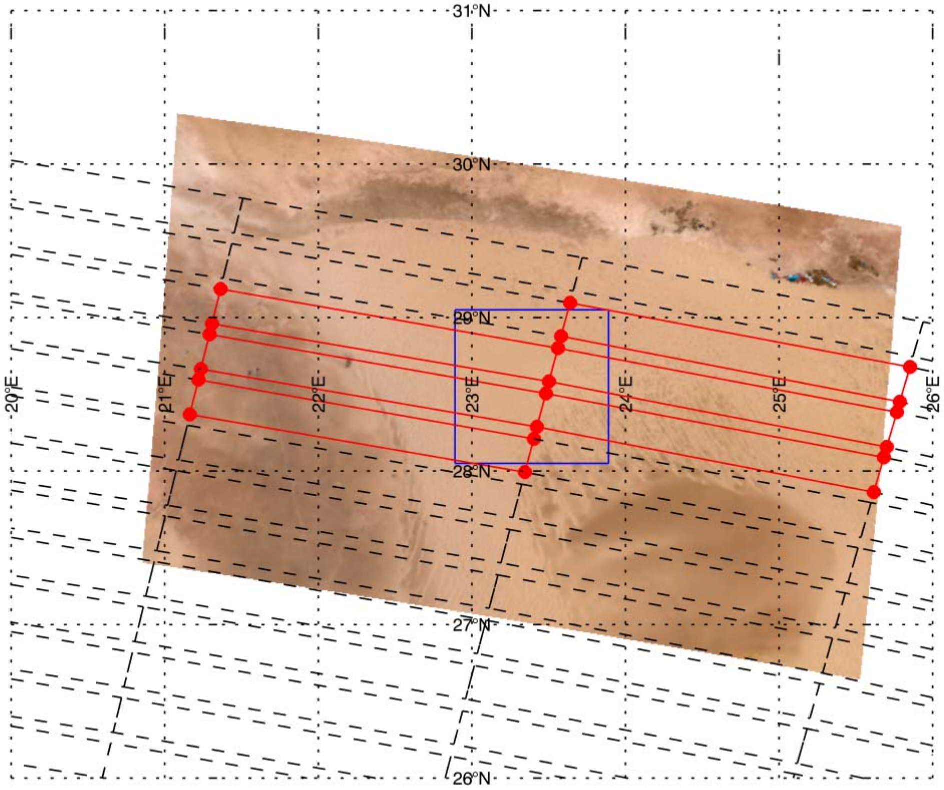
Spectrometers

GOME-2 Over Libya-4



Good temporal coverage
Spatial resolution within Libya-4 site
Spectral range up to 800nm
Co-registered with METOP-AVHRR

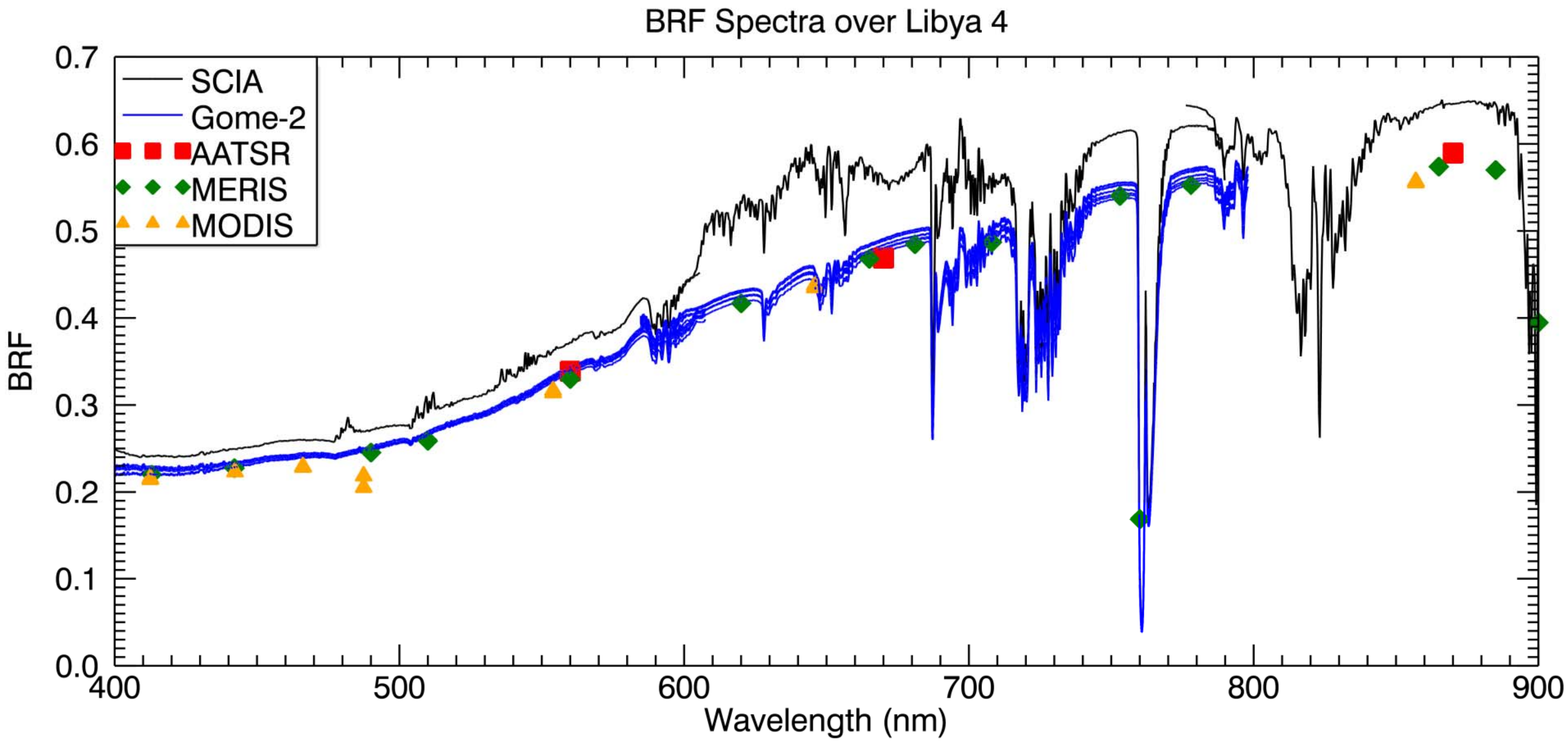
SCIA Over Libya-4



Poor temporal coverage (for Nadir)
Spatial resolution larger than site
Spectral range up to 2000nm
Co-Registered with AATSR/MERIS

Site Spectral Variations

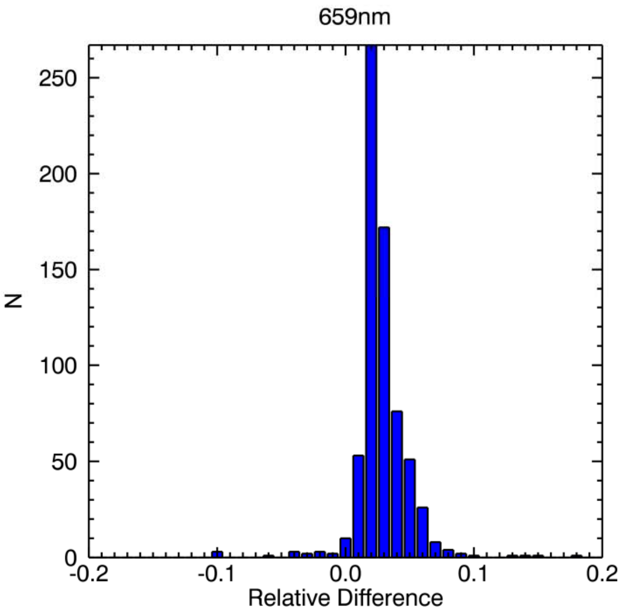
Comparison of SCIA, GOME-2, AATSR, MERIS and MODIS-A measured BRF over Libya-4

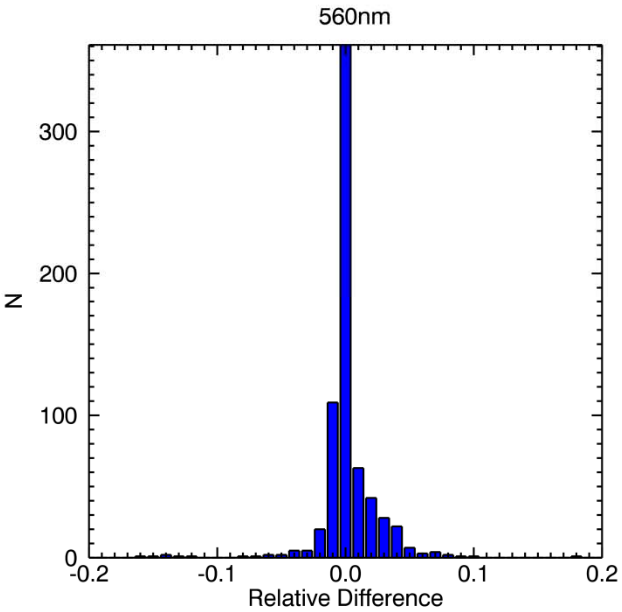


GOME-2 shown for August 2007
All data are assumed to be cloud free

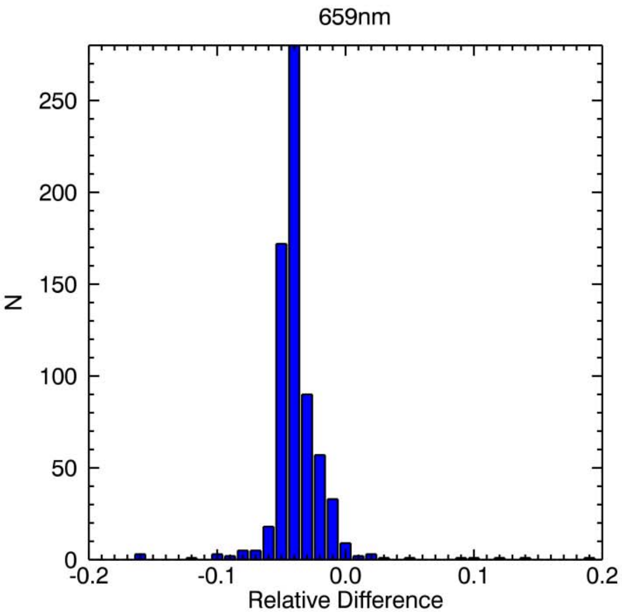
Systematic bias estimates using GOME-2

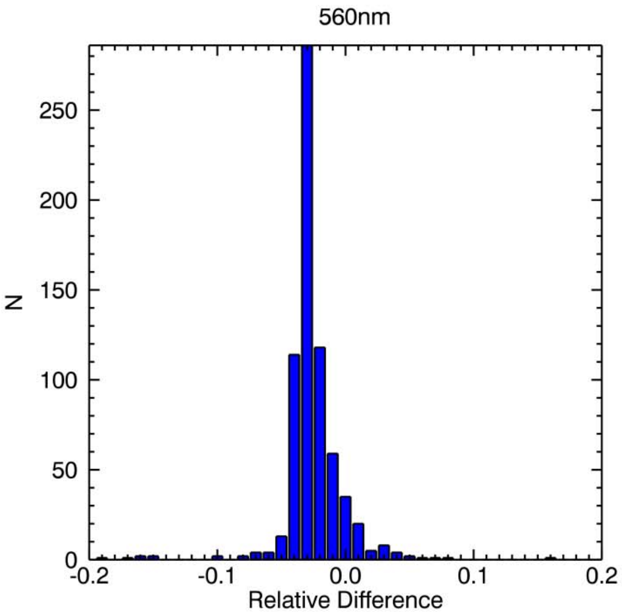
MERIS vs. AATSR





MODIS vs. AATSR

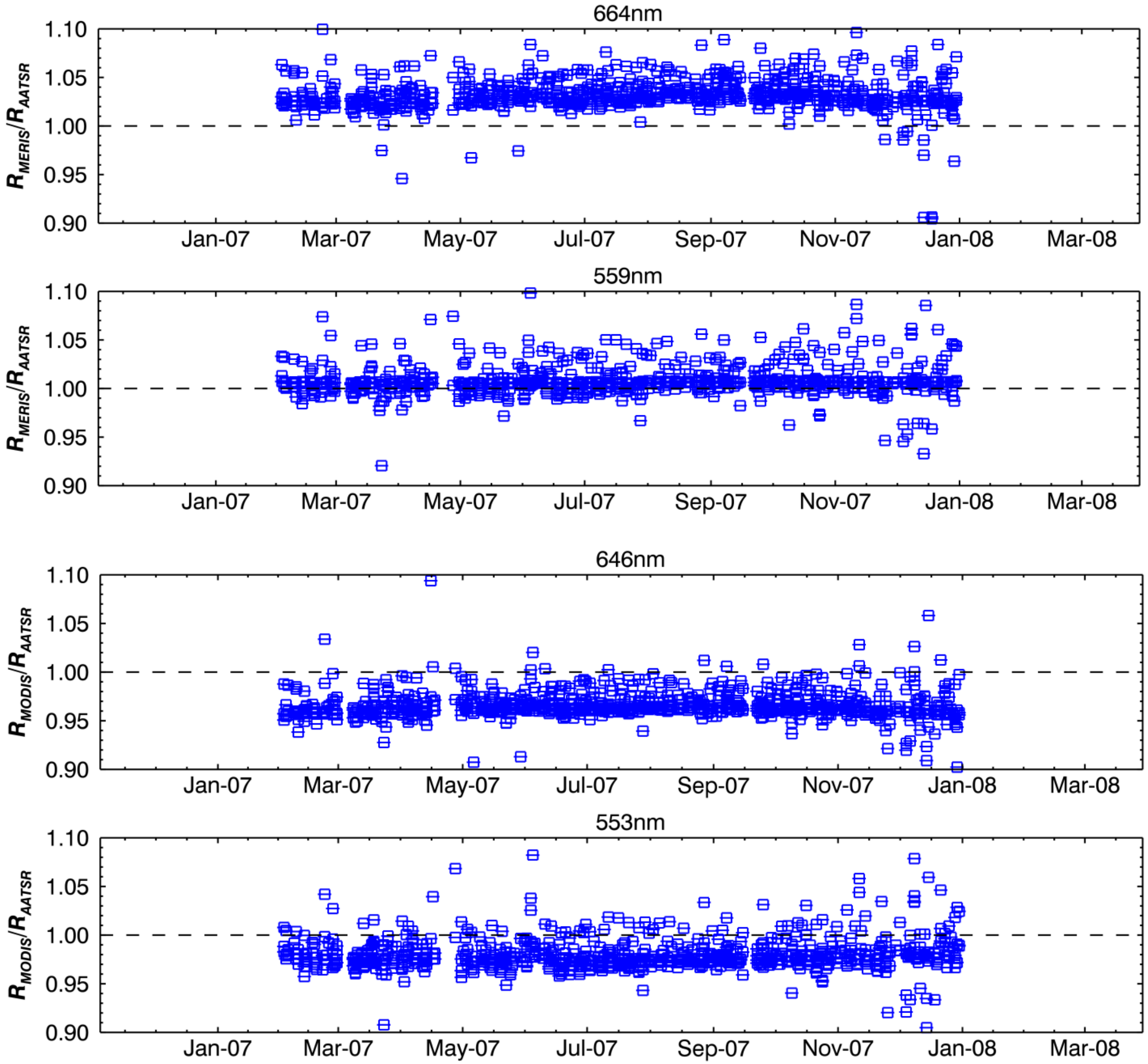




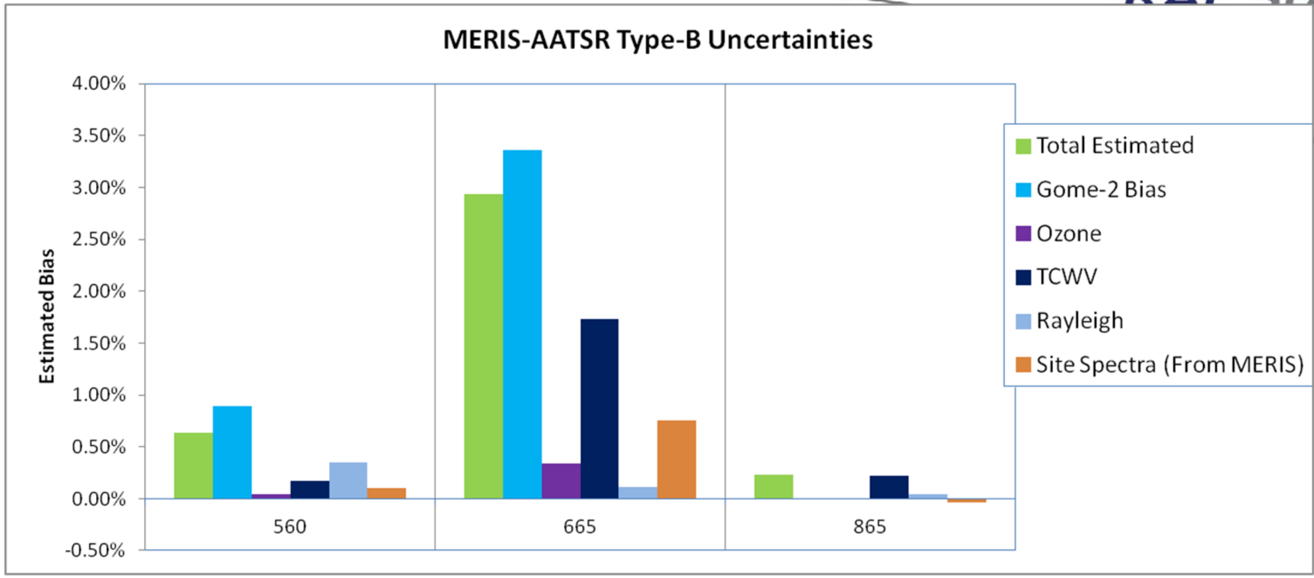
Systematic bias estimates using GOME-2

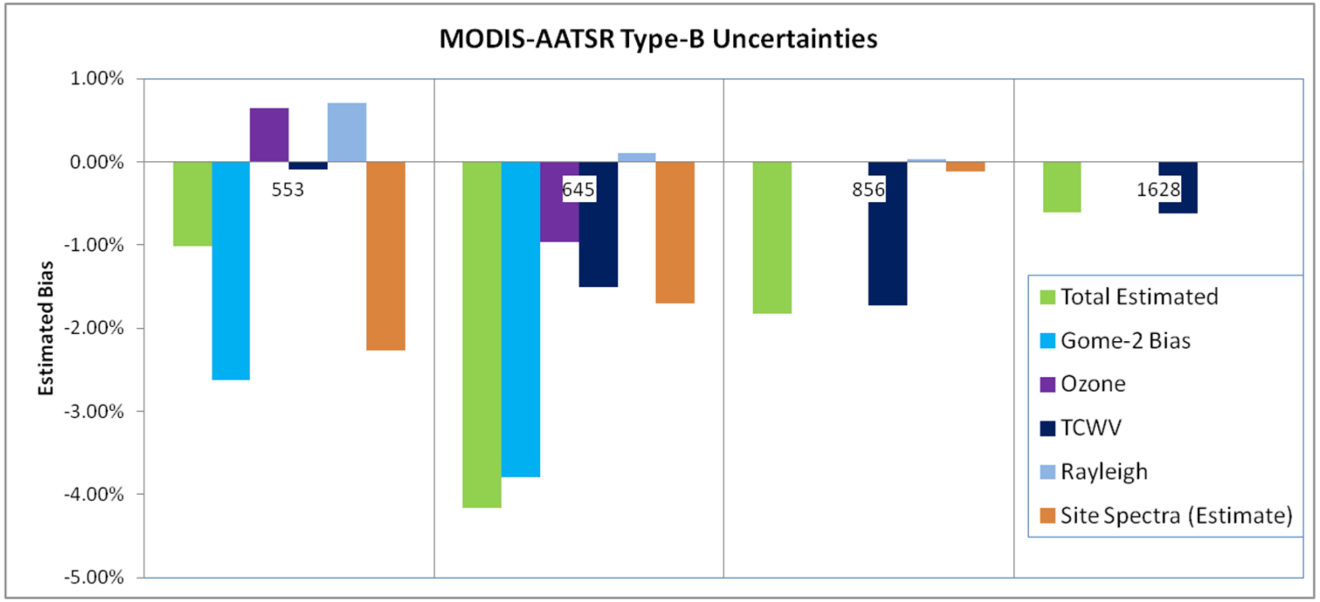
MERIS vs. AATSR

MODIS vs. AATSR

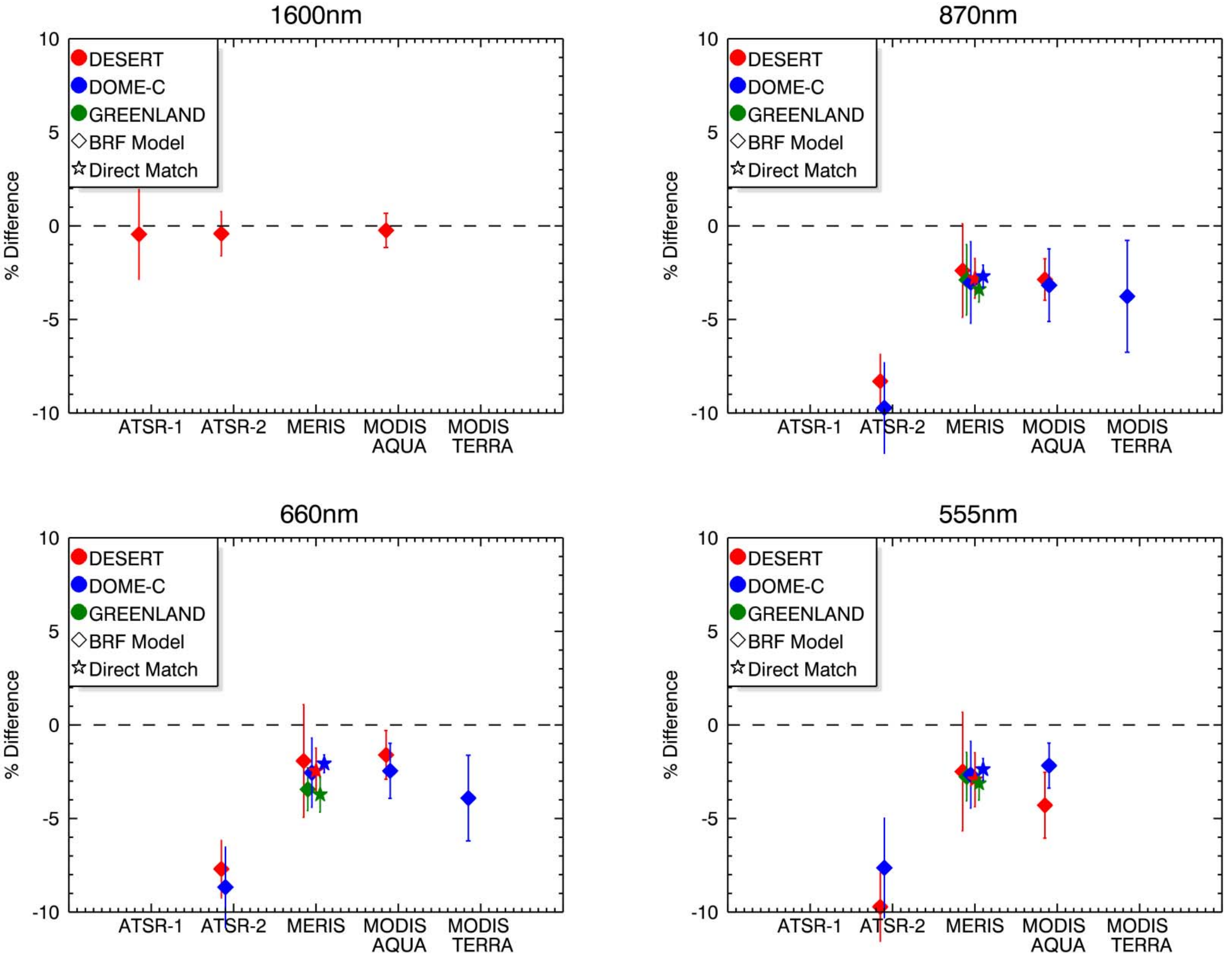


Systematic Errors



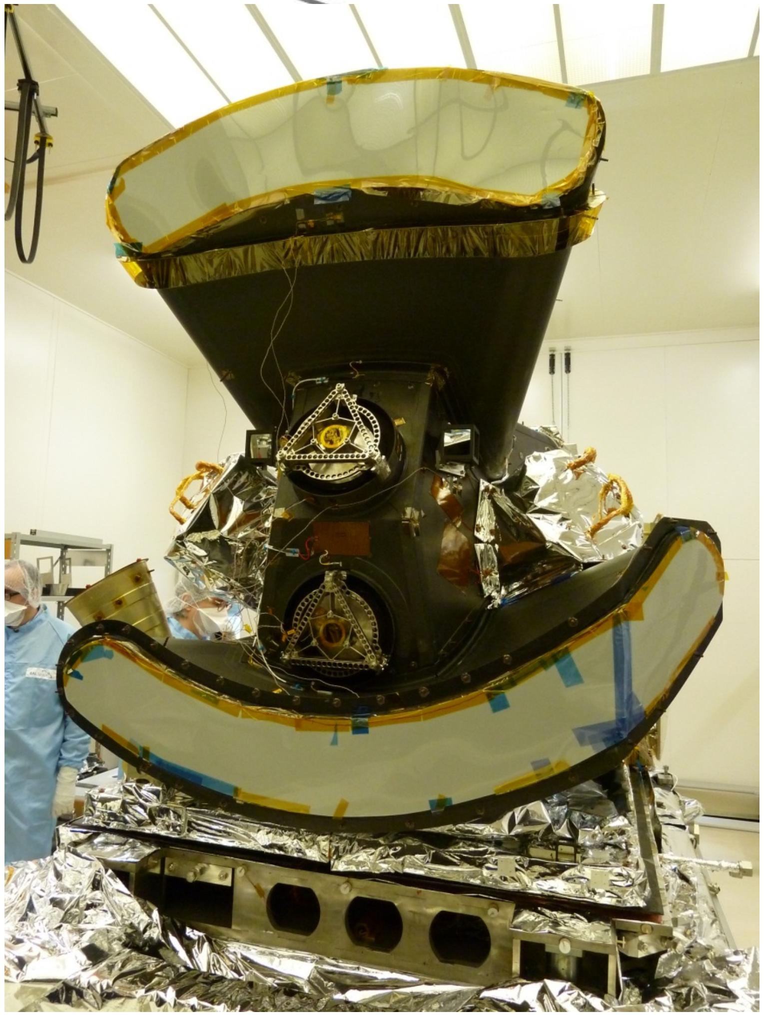


Intercomparison summary
Adjusted for estimated spectral errors



Sea and Land Surface Temperature Radiometer

Nadir swath	>74°	(1300 km min up to 1800 km)
Dual view swath	49°	(750 km)
Two telescopes	Φ110 mm / 600mm focal length	
Spectral bands	TIR : 3.74µm, 10.85µm, 12µm SWIR : 1.38µm, 1.61µm, 2.25 µm VIS: 555nm, 659nm, 859nm	
Spatial Resolution	1km at nadir for TIR, 0.5km for VIS/SWIR	
Radiometric quality	NEΔT 30 mK (LWIR) – 50mK (MWIR) SNR 20 for VIS - SWIR	
Radiometric accuracy	0.2K for IR channels 2% for Solar channels relative to sun	



AATSR Performance is Maintained!

Issues for Sentinel-3 SLSTR

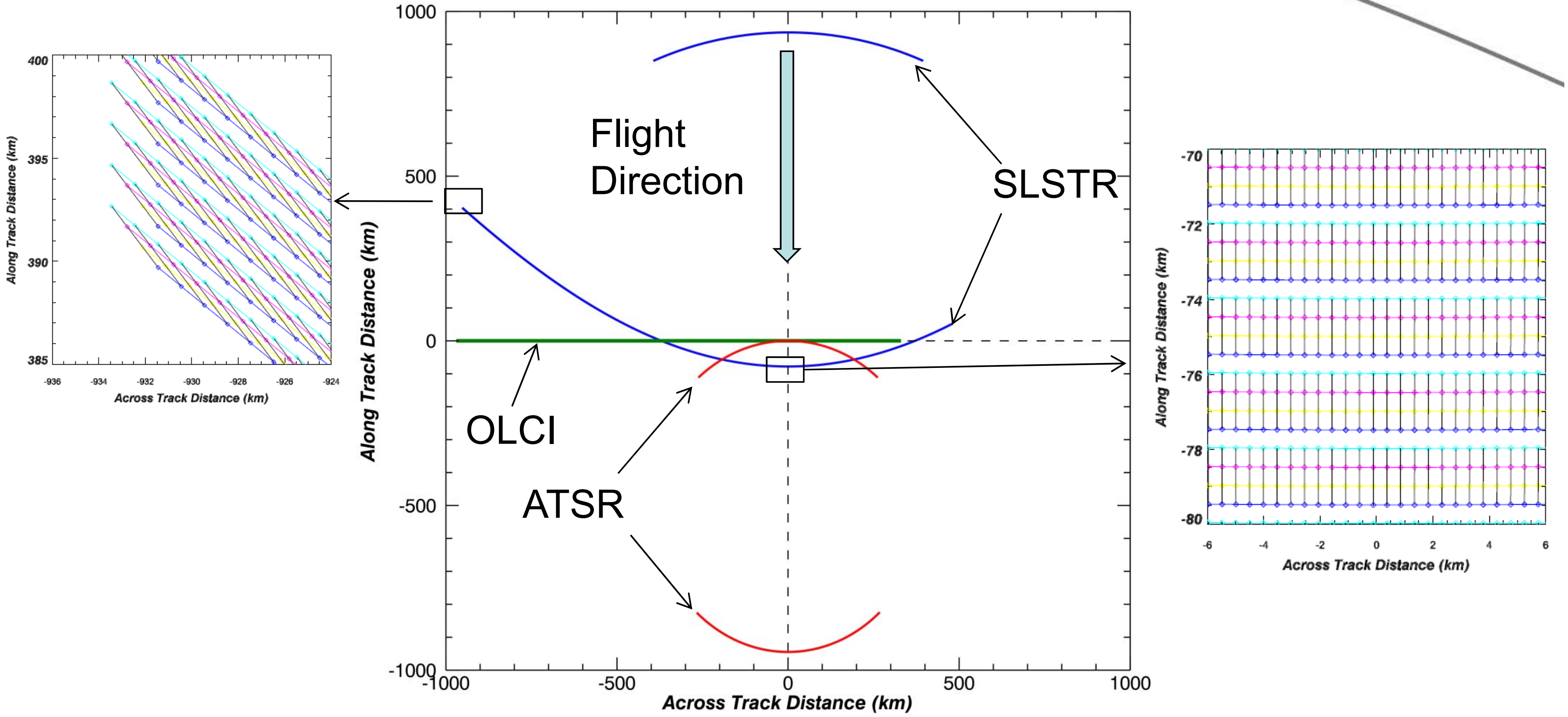
- Bands at 1375nm and 2250nm
  - Use MODIS-A for reference BRF
  - Spectral matching?

- SLSTR has significantly wider FOV – 1500km compared to 500km

- Nadir pixel is offset by -5º
  - Not exact coincidence with OLCI at Nadir
  - Matching geometry at swath edges

- Inclined view in opposite direction to (A)ATSR
  - Hence in backscatter direction in northern hemisphere
  - Good for match-ups with GEO sensors

SLSTR v AATSR Swath



Conclusions

- Results allow us to provide a consistent and stable calibration across all ATSR sensors
- ATSR-1 and ATSR-2 will be recalibrated to AATSR in next reprocessing and include improved drift corrections
- AATSR Long term drift measurements will be included in the 3rd reprocessing.
  - Will not be adjusted to align with MERIS/MODIS calibrations
- Improvements to site BRF modelling to allow for dependency with view zenith angles and spectral differences.
- Techniques will be adapted for Sentinel-3 sensors (SLSTR and OLCI) and allow cross calibrations with ENVISAT (AATSR and MERIS) despite mission gap.