In-flight Calibration Techniques Using Natural Targets

CNES Activities on Calibration of Space Sensors

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In-flight Calibration using Natural Targets

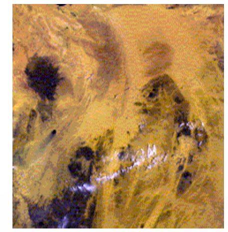
- Historically, methods using natural targets were developed in order to validate/adjust the pre-flight calibration of instruments
  - including sensors equipped with on-board calibration device

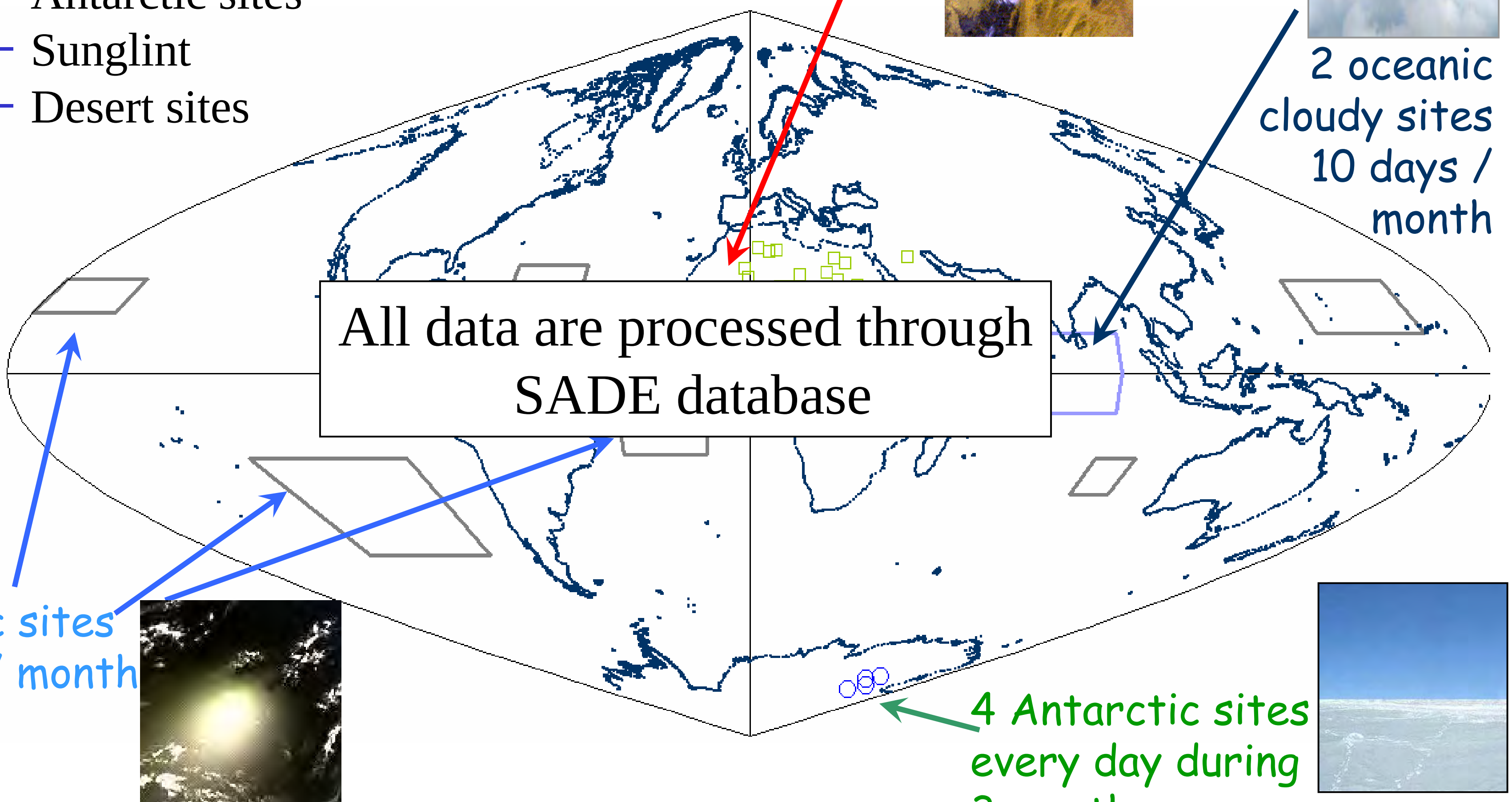
- Main aspects of in-flight calibration are :
  - absolute calibration : bias in interpretation
  - interband calibration : error on spectral ratio
  - multi-temporal calibration : error in temporal trends
  - multi-angular calibration : noise on synthesis
  - cross-calibration : biased analysis and comparison

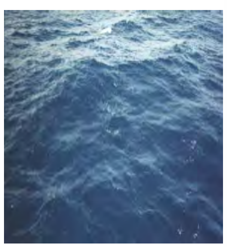
- Methods using acquisitions over selected natural targets were developed to assess these aspects

In-flight Calibration using Natural Targets

- <u>The Arsenal</u> :
  - Rayleigh Scattering
  - Deep Convective Clouds
  - Antarctic sites
  - Sunglint
  - Desert sites

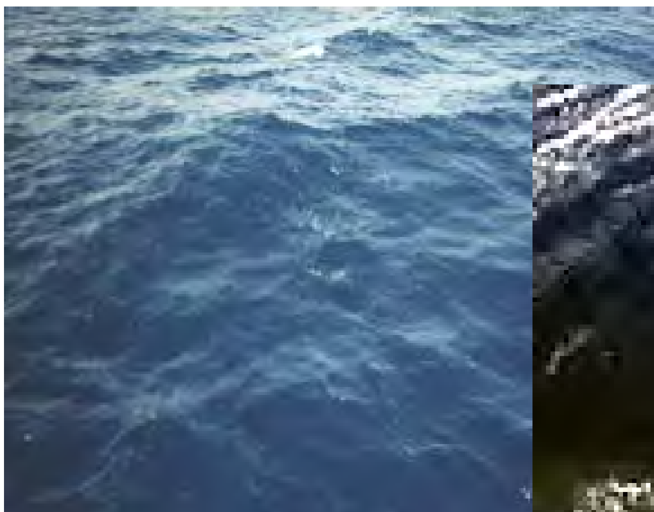




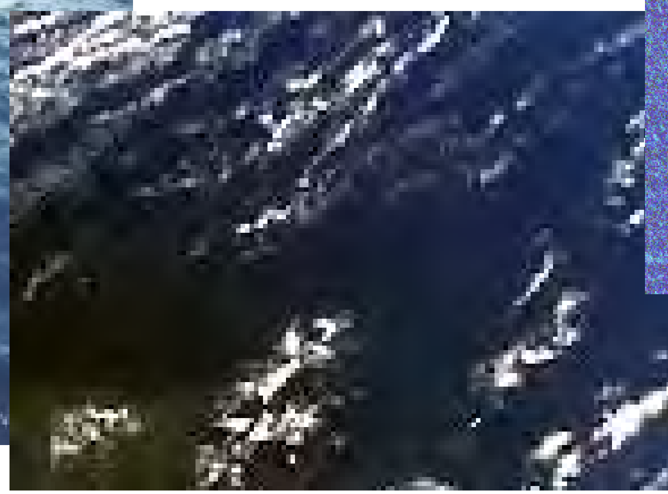


In-flight Calibration using Natural Targets

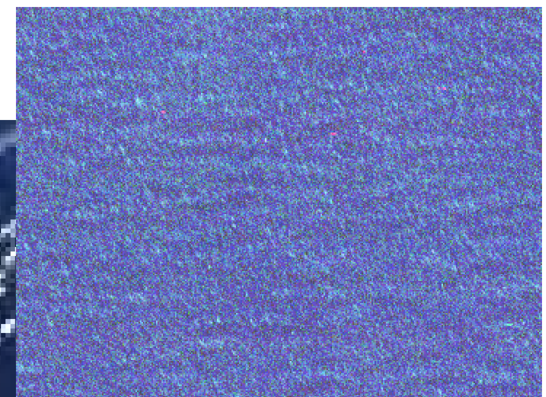
Calibration over Rayleigh Scattering



In-situ view



PARASOL view



SPOT view

Calibration over Rayleigh Scattering : method

- <u>Statistical approach</u> over molecular scattering (Rayleigh) :
  - observe the atmosphere above ocean surface (= dark surface)
  - calibration from blue to red <u>443nm to 670nm</u>
  - contributions to the TOA signal
    - Rayleigh molecular scattering : accurately computed (SOS code)
      - main contributor : ~85/90% of the TOA signal
    - ocean surface : prediction through a climatology
      - no foam because of threshold on wind speed
    - aerosols : rejected using threshold + corrected
      - background residue using 865nm band + Maritime-98 model
      - ideal criteria : <τa> = 0.025 and max(τa) = 0.05
    - gaseous absorption : O3 (TOMS), NO2 (climato), H20 (meteo)

Rayleigh

ocean

aerosols

	molecular	aerosol	marine	gaseous	I_mean
443	**84.25**	**1.25**	**14.48**	**-0.56**	**0.1177**
490	**85.25**	**1.98**	**12.75**	**-1.84**	**0.0842**
565	**90.56**	**3.76**	**5.67**	**-8**	**0.04456**
670	**90.23**	**7.5**	**2.25**	**-3.67**	**0.02308**

Main contributors to TOA reflectance (in %)

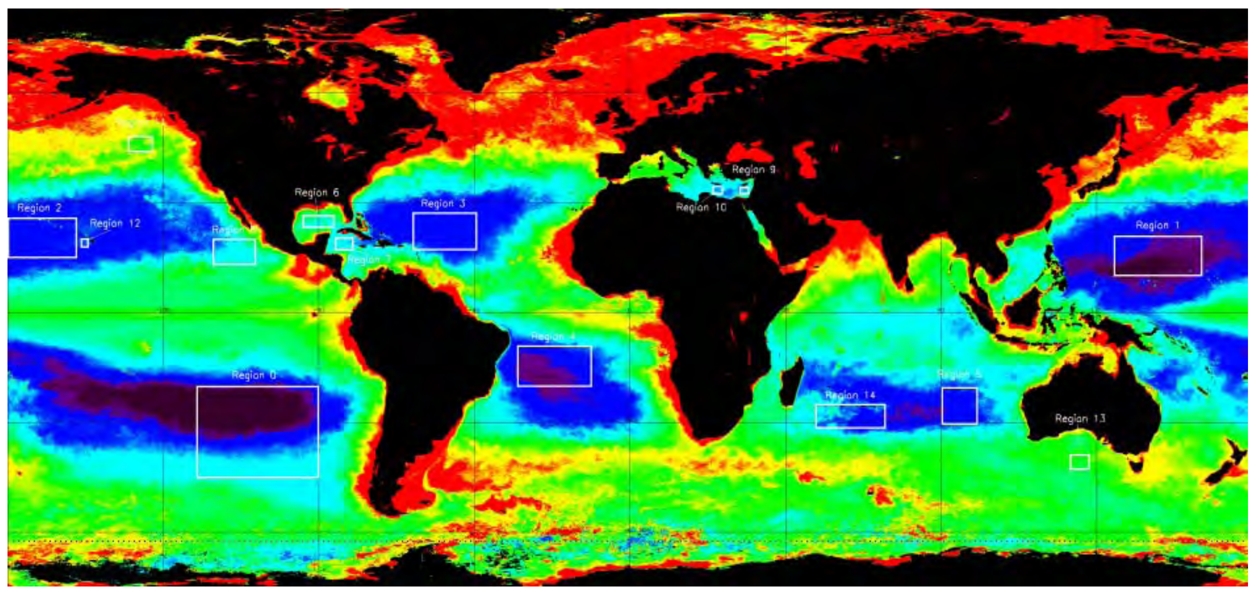
  - accuracy : typically 2% (3% in blue)

Calibration over Rayleigh Scattering : method

- **analysis over predefined and characterized oceanic sites**
  - selected sites for spatial homogeneity and limited seasonal variation
  - benefit to calibrate over various oceanic sites
    - 1 site = still a small possible bias due to exact knowledge of ρw
    - statistical approach : distinguish sensor from sites behaviors

- ClimZOO :

Climatology of
Oligotrophic
Oceanic Zones

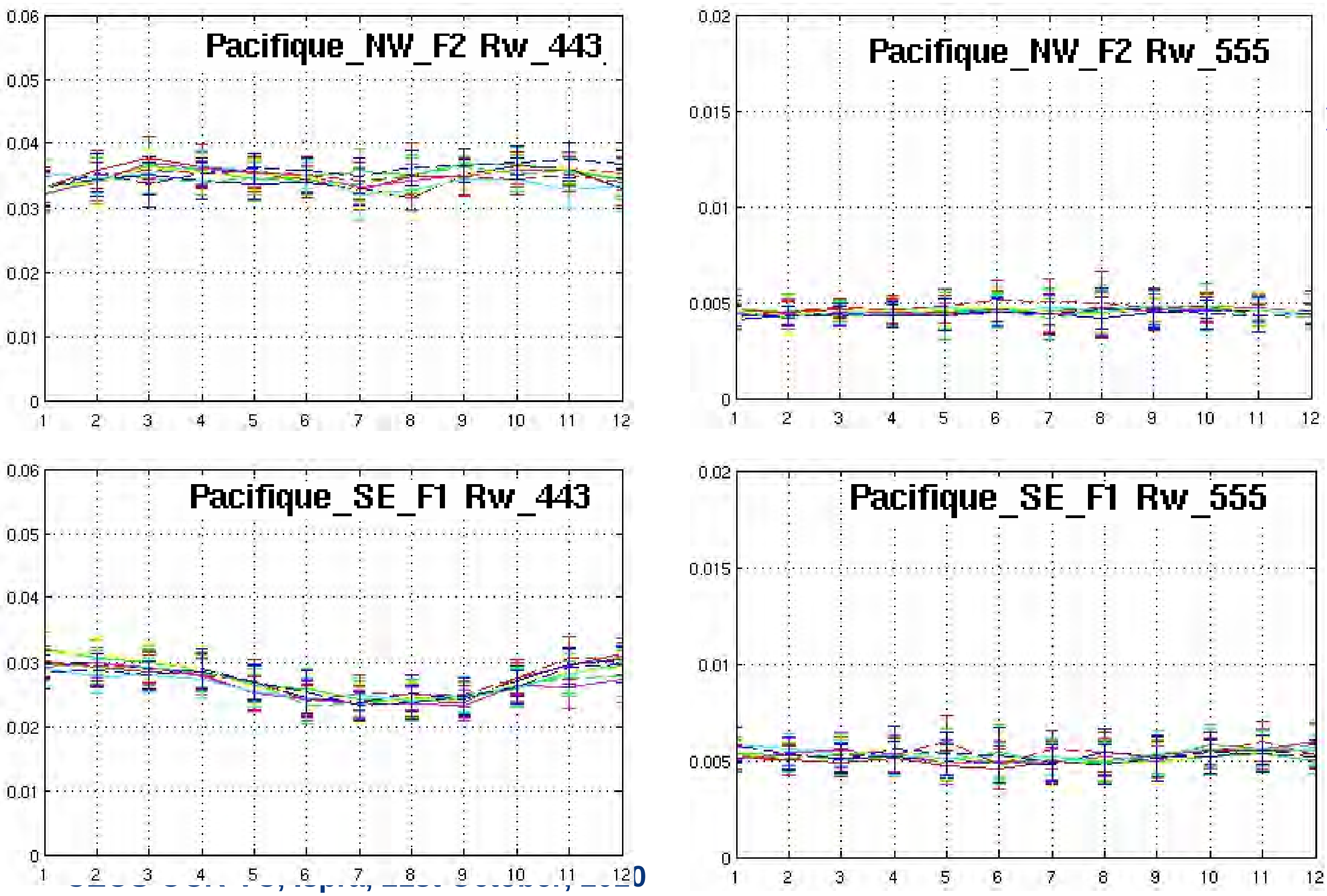


(from Fougnie et al., 2002)

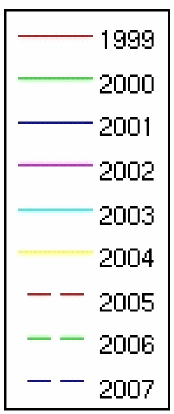
Calibration over Rayleigh Scattering : method

- ClimZOO : Climatology of Oligotrophic Oceanic Zones – 9 years of SeaWiFS data

  2 examples : very good sites in Northern and Southern hemispheres



marine reflectance versus month

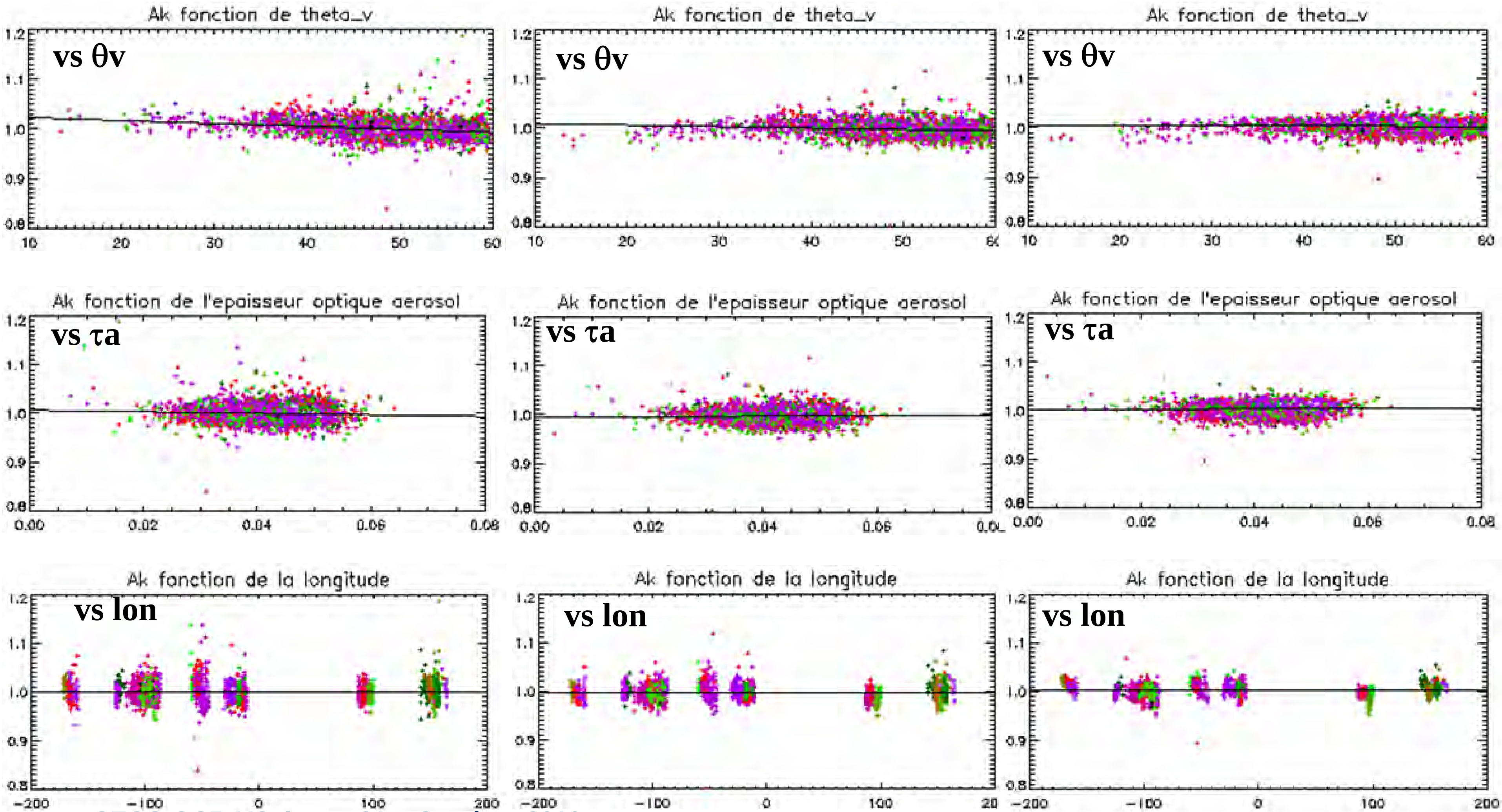


(from Fougnie et al., 2010)

Calibration over Rayleigh Scattering : results

PARASOL

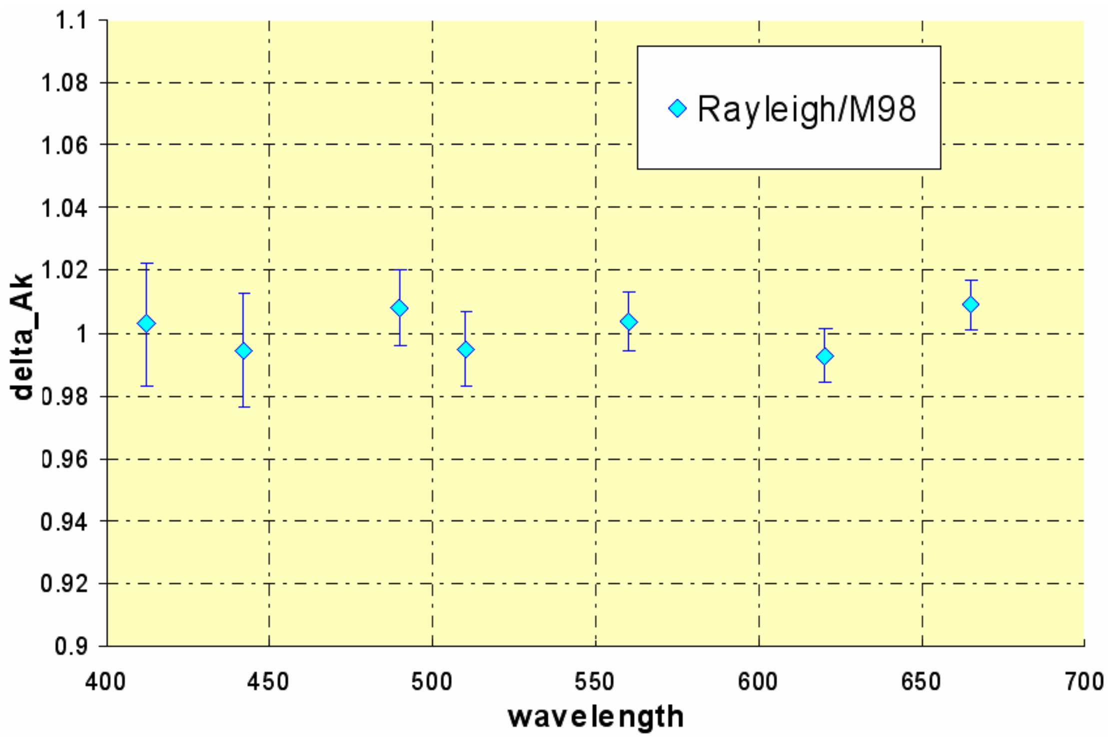
670 Ak=0.999 σ=0.022 | **565 Ak=0.997 σ=0.014** | **490 Ak=1.003 σ=0.011**



(from Fougnie et al. 2007)

Calibration over Rayleigh Scattering: results

- Absolute calibration for all the visible range
  - MERIS example from 412 to 670 nm (using 15,000 measurements in 2003)
    very good accordance with the official calibration



  - Results being updated

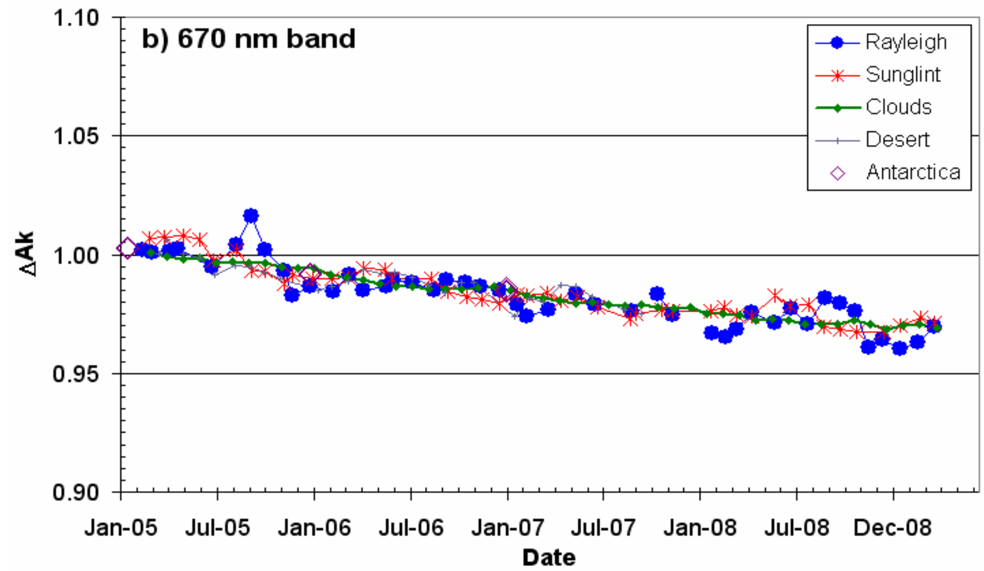
(from Hagolle et al. 2006)

Calibration over Rayleigh Scattering: results

- Valuable for multi-temporal monitoring validation :
  - PARASOL example

    validation of the operational method using DCC

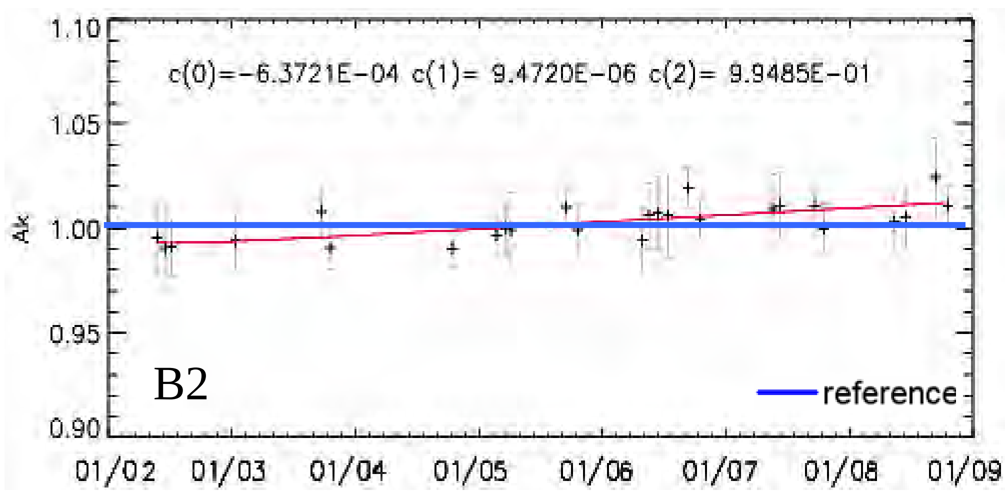
    The red band



  - Végétation-2 example

    comparison to official calibration

    The red band



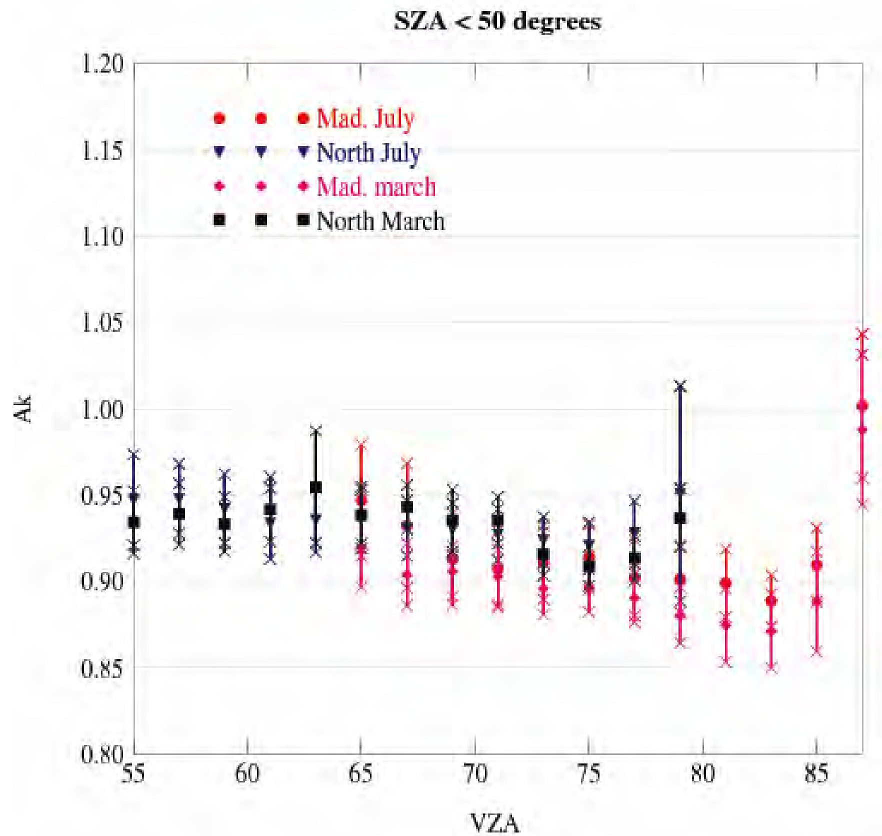
(from Fougnie et al. 2009)

Calibration over Rayleigh Scattering: results

- Applicable for geostationary missions :
  - Example with SEVIRI

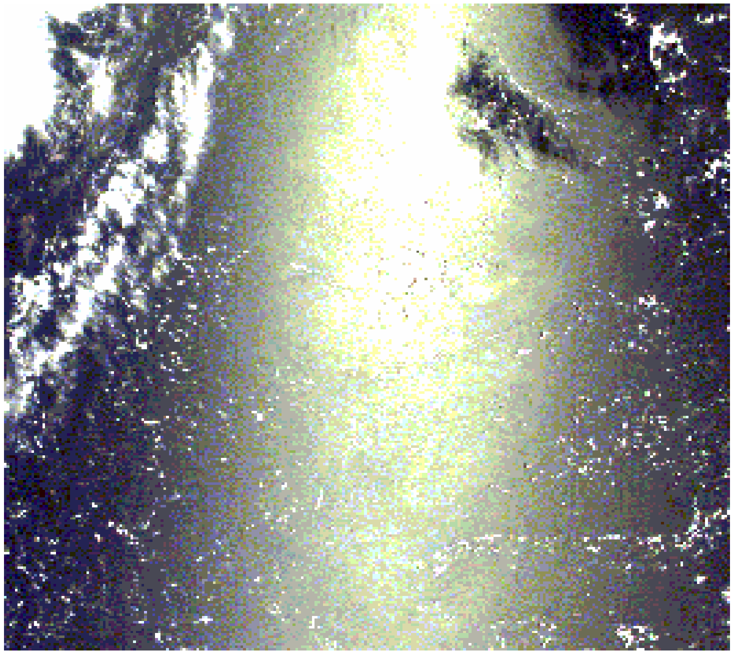
    For band 670nm

    method extended for very large airmass (improved radiative transfer computation)

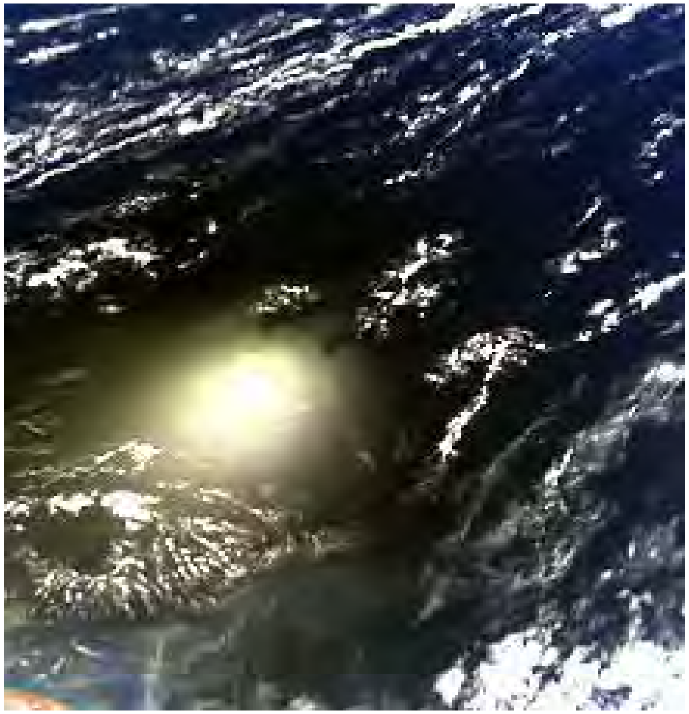


(from Jolivet et al., 2009 [Hygeos])

Calibration over Sunglint (+Rayleigh)



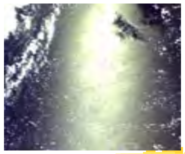
Pushbroom view



2D sensor view

Interband calibration over sunglint : method

- Interband method
  - observe the “white” reflection of the sun over the ocean surface
  - inter-calibration of blue to SWIR bands (440 to 1600nm) with a reference band : red band (670) usually adopted as reference & calibrated over Rayleigh
  - accurate computation of the 2 main contributors :
    - Rayleigh scattering
    - sunglint strongly depend on the wind speed estimated using a reference band
      - both computed using Successive Order of Scattering code
      - use of a spectral refraction index of water (not constant) + Cox and Munk model
  - other minor contributions :
    - ocean surface : predicted using climatology
    - aerosol : threshold + correction
      - threshold using another viewing direction or exogenous data (SeaWiFS)
      - background correction considering Maritime-98 with aot of 0.05
    - gaseous absorption : O3 (TOMS), NO2 (climato), H20 (meteo)
  - dedicated selection

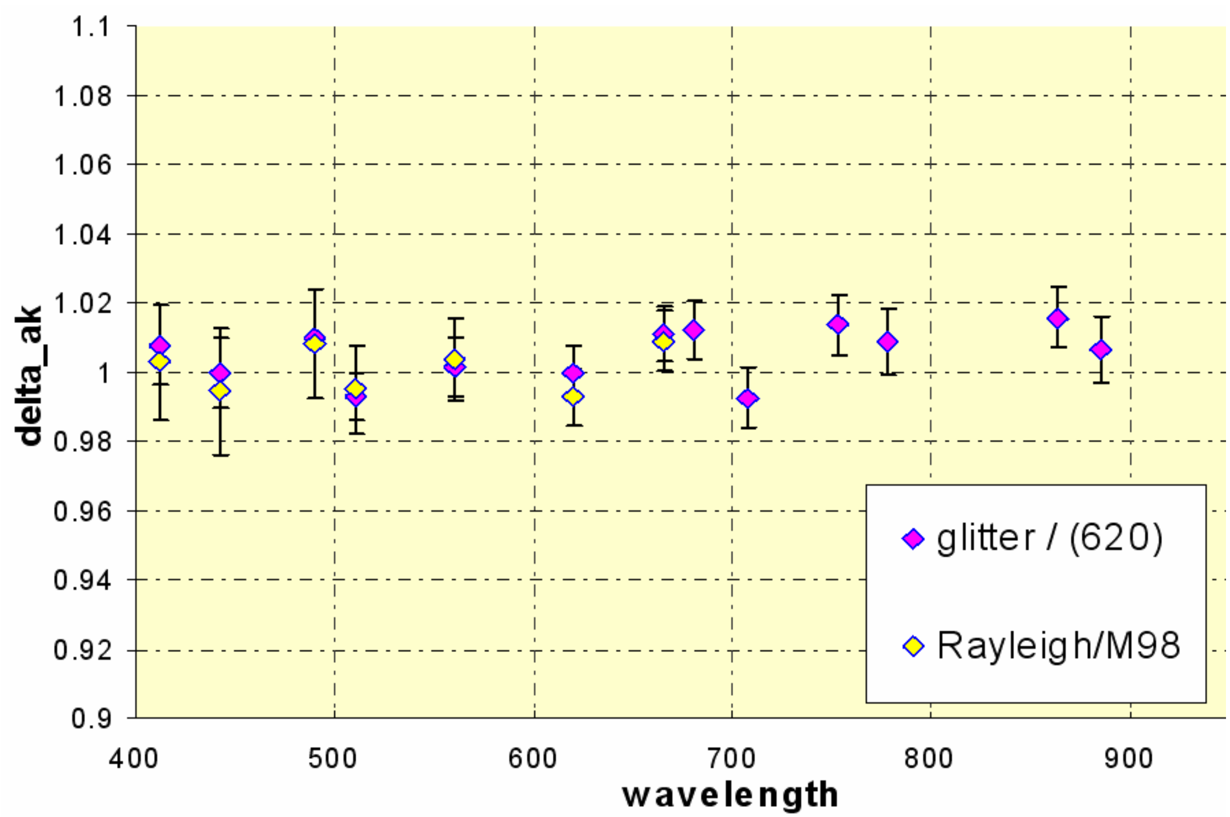


Interband calibration over sunglint : results

- Interband calibration efficiency :

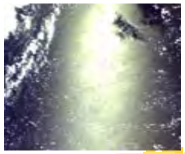
  ex : MERIS calibration for NIR bands

  – Dispersion very low for bands close to 620 (reference)



  – Results being updated

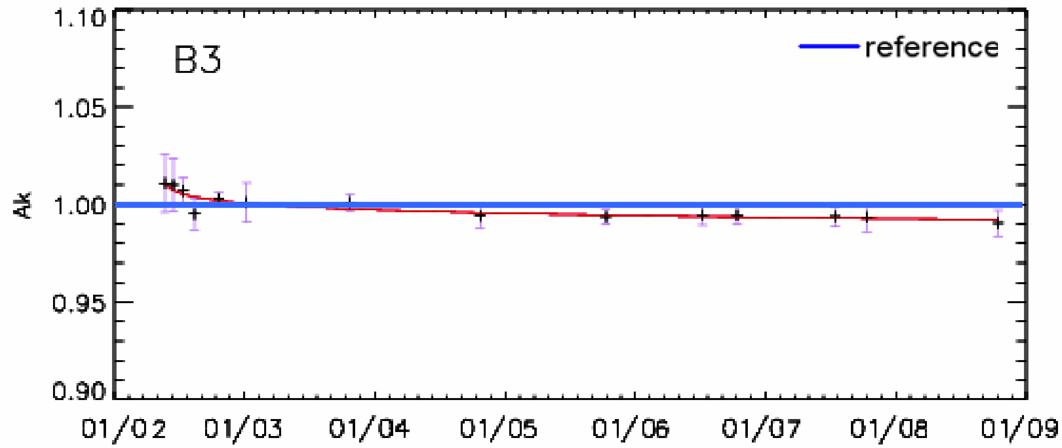
(from Hagolle et al. 2006)



Interband calibration over sunglint : results

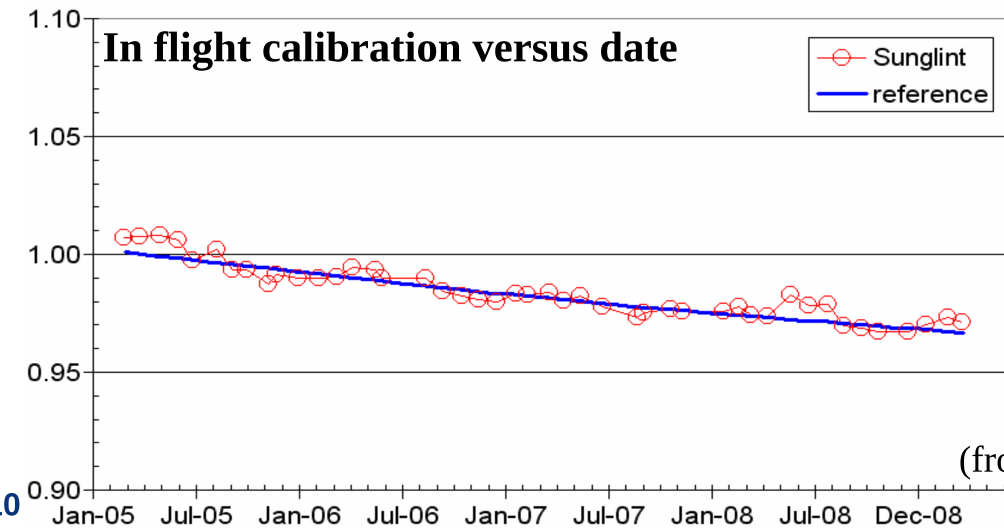
- Multi-temporal survey :
  - efficiency depending on sampling (geographic and temporal)

Absolute calibration versus date



***Végétation*-2**
B3 NIR band

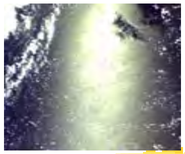
Temporal decrease in fact due to a drift of the reference band B2



PARASOL
670nm band

Reference band = 765
Temporal decrease confirmed by all other methods

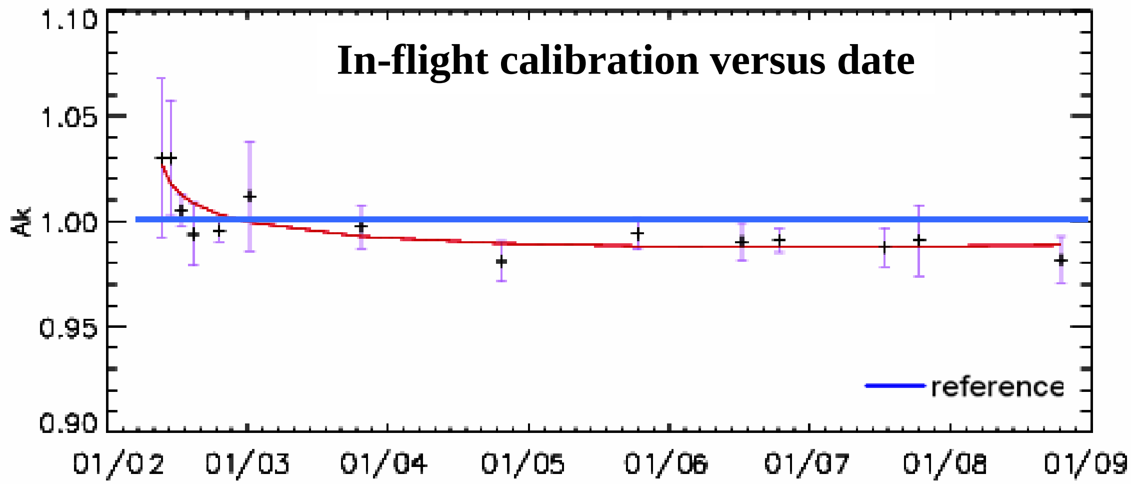
(from Fougnie et al. 2009)



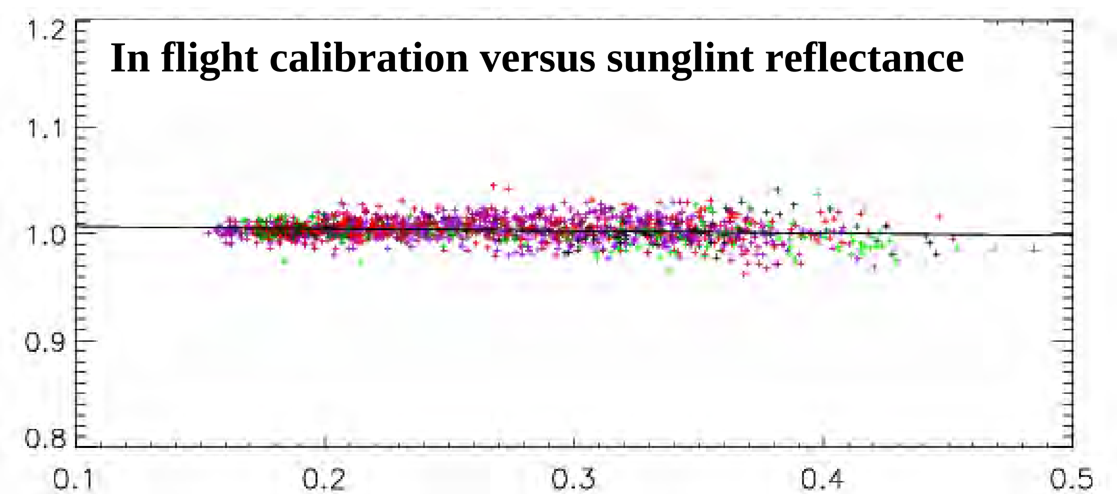
Interband calibration over sunglint : results

- Valuable for SWIR band calibration :

Végétation
SWIR-1600nm band

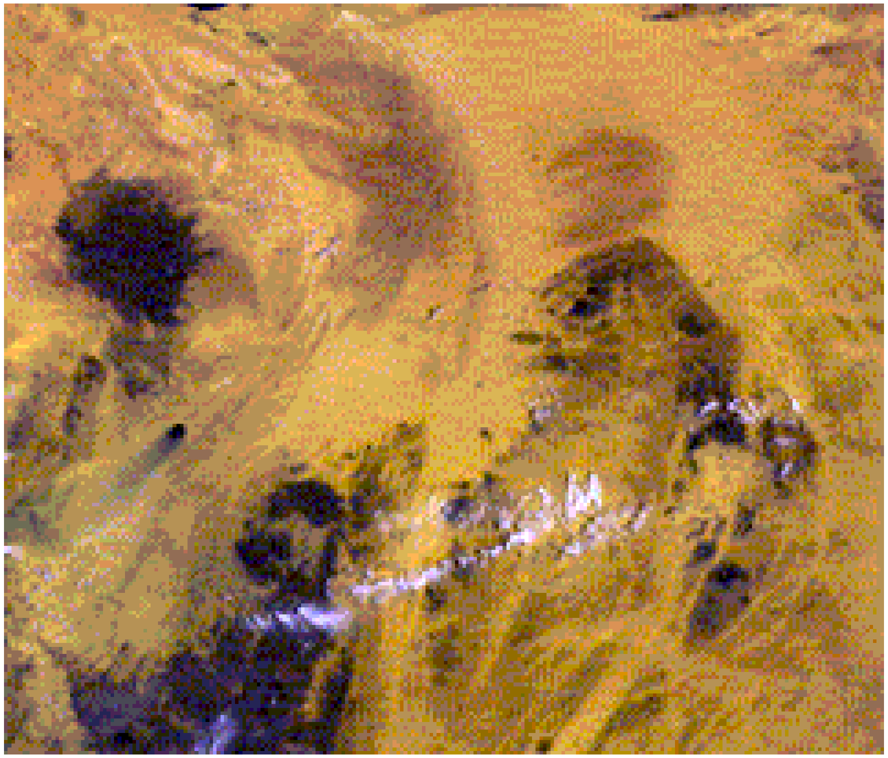


PARASOL
1020nm band

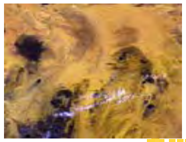


In-flight Calibration using Natural Targets

Calibration over Desert Sites

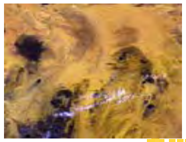


CEOS-OCR-VC, Ispra, 21st October, 2010



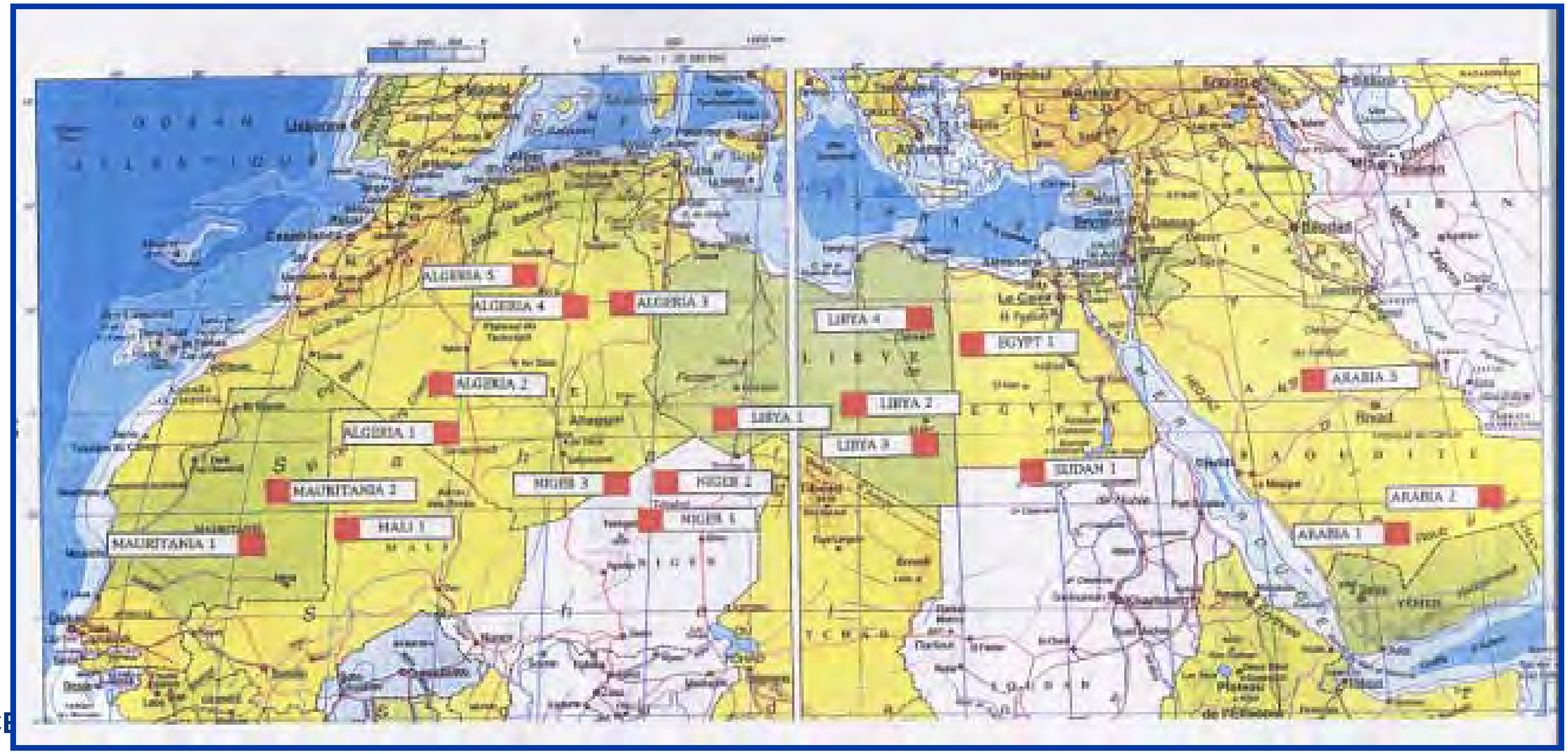
Calibration over desert sites

- This method use acquisitions over desert sites is used to
  - Cross-calibrate a sensor to a reference sensor
  - monitor multi-temporal evolution referring to this sensor
- Efficiency for wavelength inside the spectral range of the reference sensor, typically from 443 to 865nm
- Selection of the same acquisition geometry for both sensors
- Atmospheric correction include gaseous absorption but do not integrate aerosol correction (limitation in the blue)
- Accuracy
  - about 1% in multi-temporal (nearly 2% for blue bands)
  - better than 2% for cross-calibration (3% in blue band)
  - better when spectral bands of the 2 sensors are close
- limitation for sensor with band saturating over bright scene



Calibration over desert sites

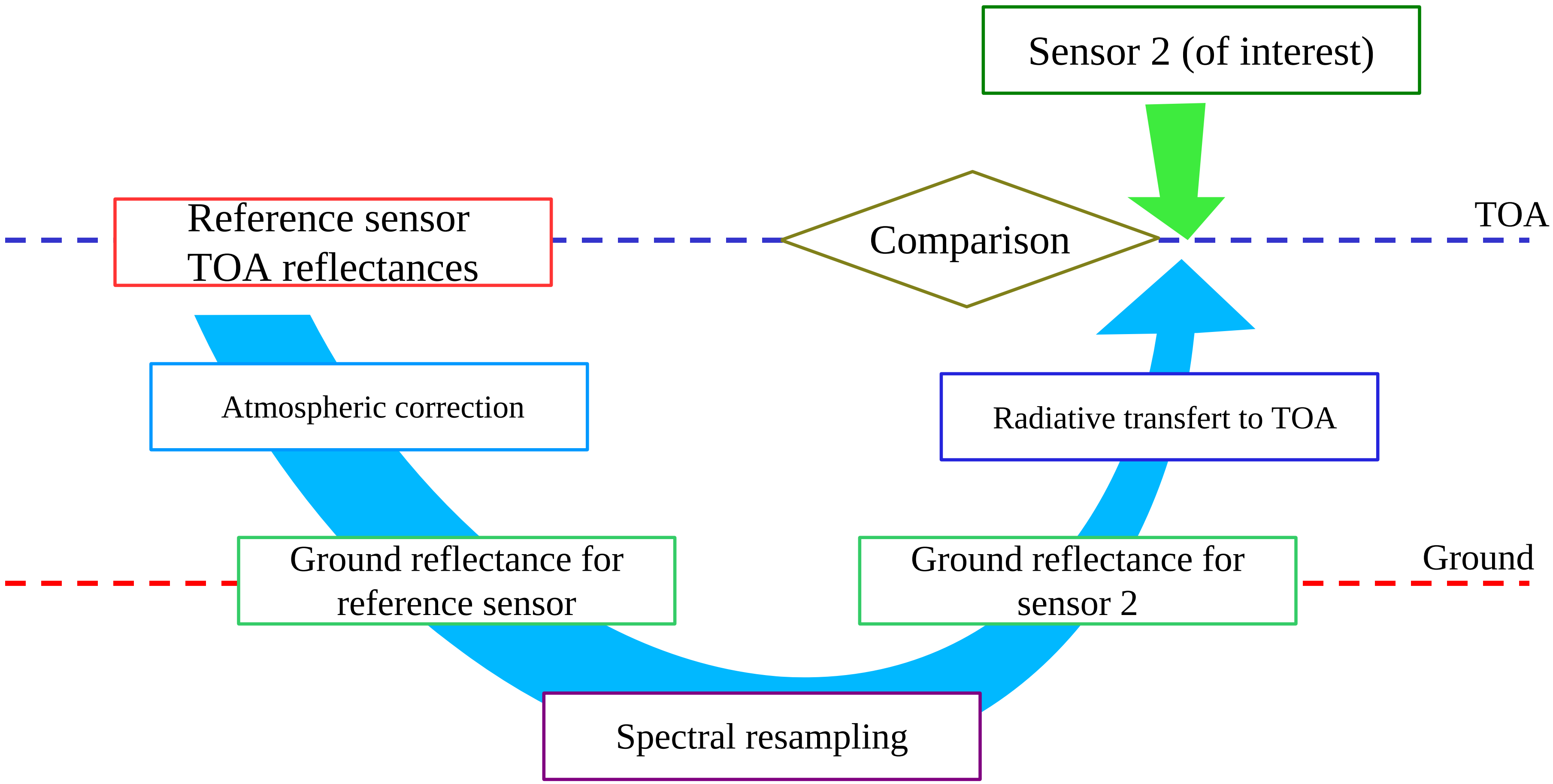
- 20 desert sites were selected in North Africa and Arabia :
  - statistical analysis of Meteosat data (1y) completed by AVHRR data (1m)
  - sites are 100*100 km²
  - accessibility in term of cloud coverage
  - spatial uniformity : better than 2%
  - low directional effect : less than 15%

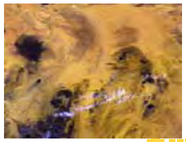


Calibration over desert sites

- Principle :

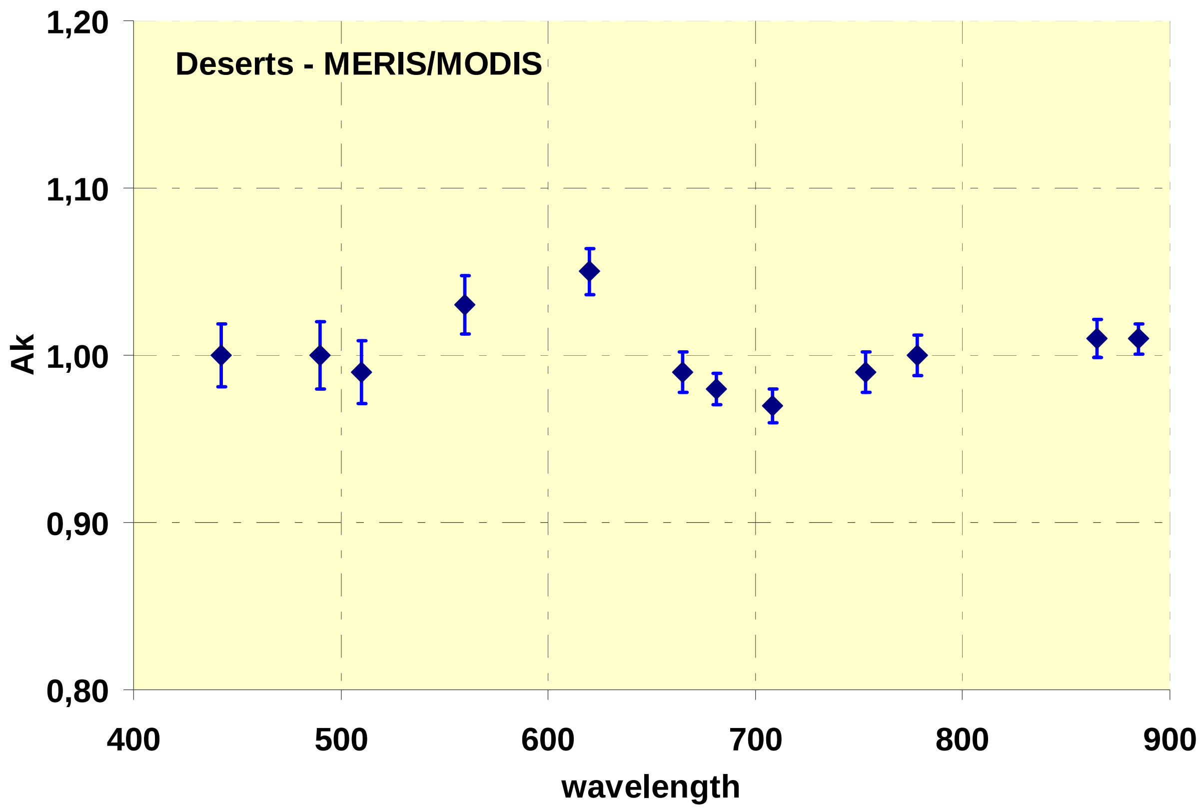
  use of a reference sensor to simulate the TOA reflectance observed by the sensor of interest

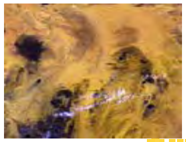




Calibration over desert sites

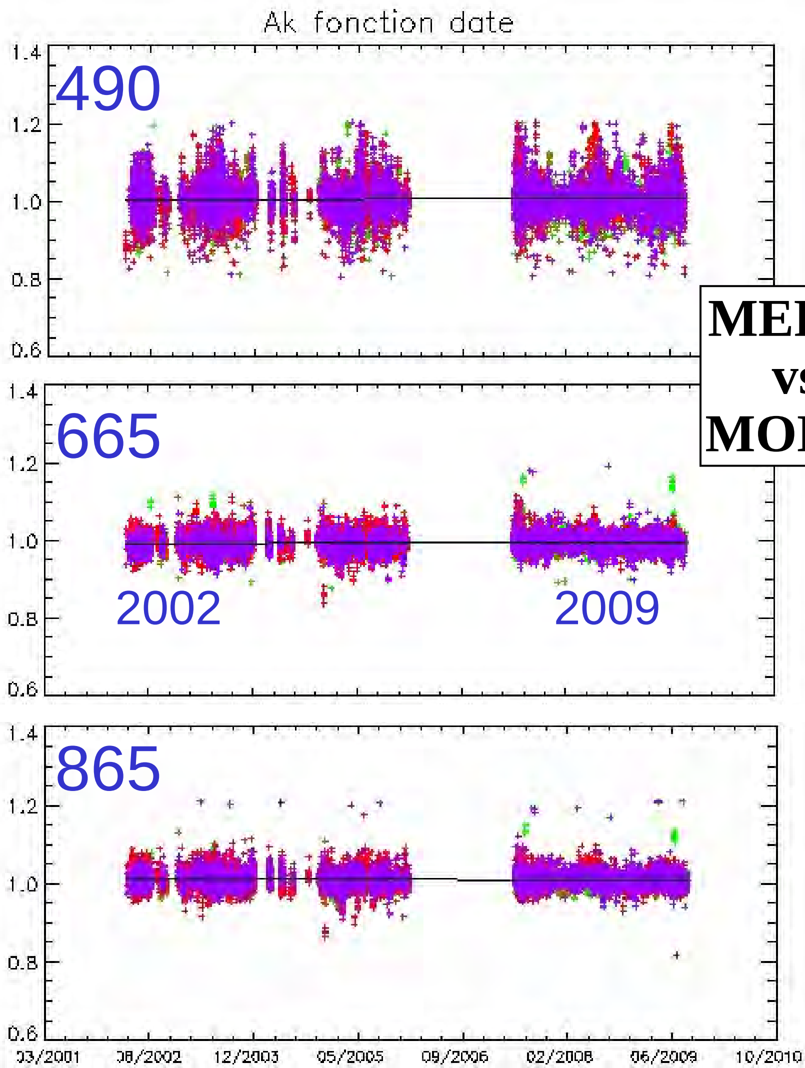
- Cross-calibration MERIS-MODIS (land bands)

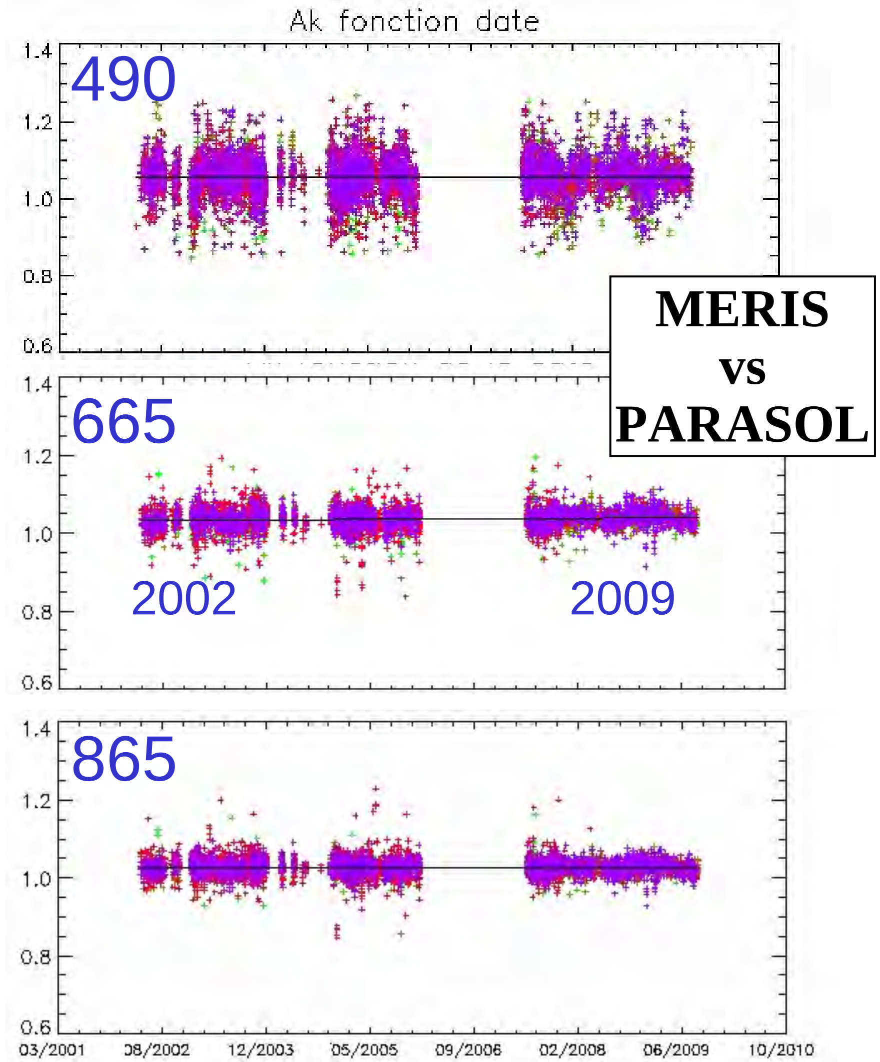




Calibration over desert sites

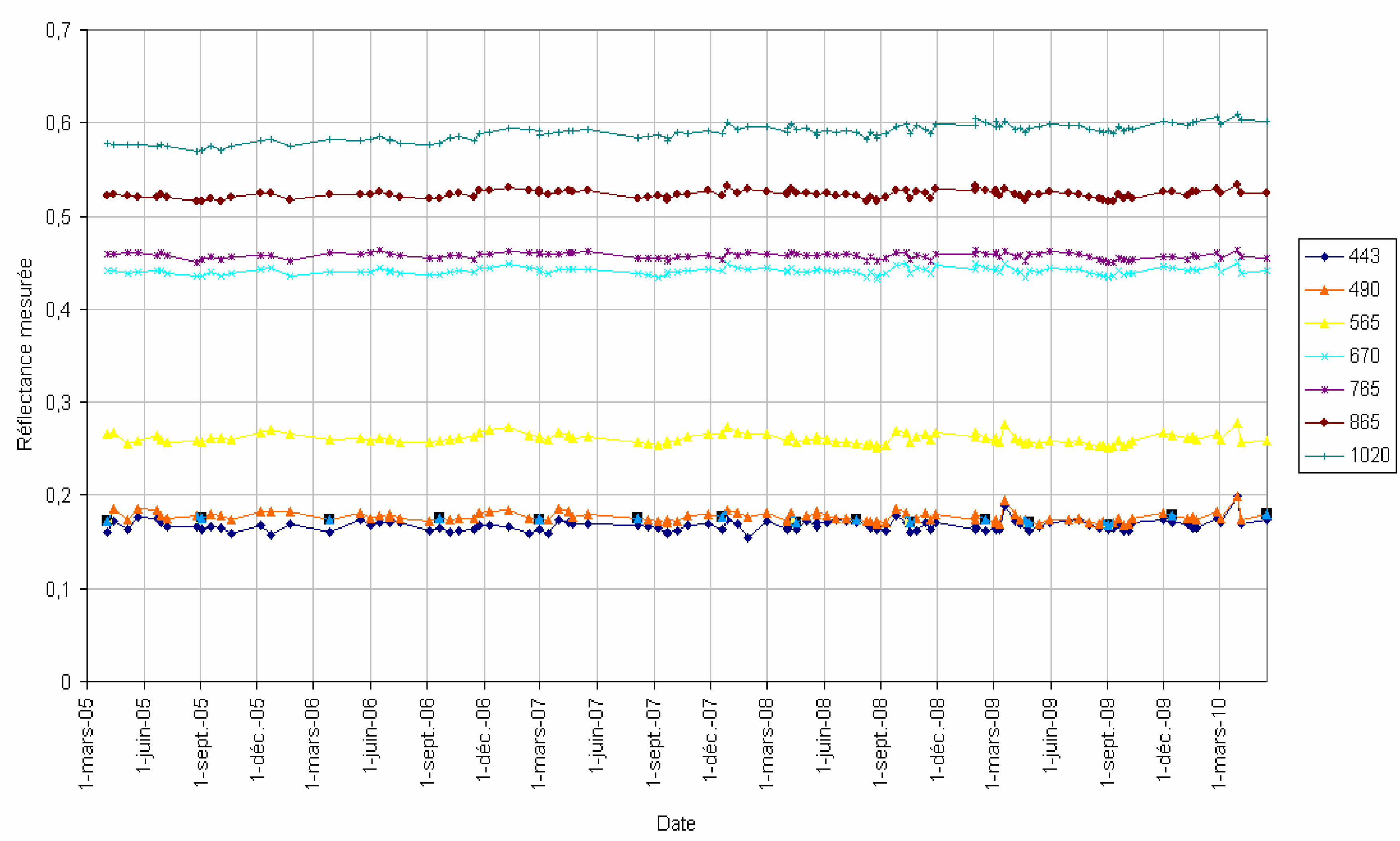
- Validation of the MERIS calibration with time

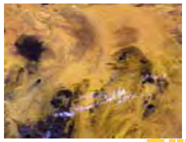




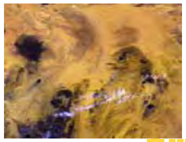
Calibration over desert sites

- Validation of PARASOL calibration with time
  - through the absolute reflectance over Lybia 3 for θv=30°





Discussion - Conclusion



Discussion - Conclusion

- Why deploy such calibration methods while a vicarious method adjusts [cal+atmosph-algo] at the end for OC applications ?
  - CI = predicted radiance →calibration method
  - MI = measured radiance → radiometric model
- A standard calibration method assumes that $\Delta A_k^{estimé} = \frac{MI}{CI} = \frac{Ak.X}{CI}$
  - the difference between MI and CI is only due to the A calibration

$$X^a_{lp} = \left(\frac{Es}{\pi}.G.t\right).A.T^a.g^a_{lp}.SL^a_{Xlp}.NL.\left[P1^a_{lp}.I^a + P2^a_{lp}.Q^a + P3^a_{lp}.U^a\right] + SL^a_{\Sigma Xlp} + C_{lp}$$

- ***Absolute Calibration*** (A)
- ***Equalization Variation in fov*** (T^a)
- ***Straylight Correction (proportional)*** ($g^a_{lp}.SL^a_{Xlp}$)
- ***Non-linearity correction*** (NL)
- ***Polarization correction*** (P1, P2, P3)
- ***Straylight Correction (additive)*** ($SL^a_{\Sigma Xlp}$)
- ***Dark current correction*** (C_{lp})

- To cross different methods provides a powerful diagnostic before the final vicarious adjustment

Références :

Fougnie et al., 2002, Identification and Characterization of Stable Homogeneous Oceanic Zones : Climatology and Impact on In-flight Calibration of Space Sensor over Rayleigh Scattering, *Ocean Optics XVI Proceedings*

Fougnie et al., 2007, PARASOL In-flight Calibration and Performance, *Applied Optics*

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Fougnie B., 2010, Temporal Decrease of the PARASOL Radiometric Sensitivity : In-flight Characterization of the Multi-angular Aspect, *Earth Observing Systems XV*, SPIE Optics & Photonics

Fougnie et al., 2010, Climatology of Oceanic Zones Suitable for In-flight Calibration of Space Sensors, *Earth Observing Systems XV*, SPIE Optics & Photonics

Hagolle et al., 2006, Meris User Meeting

Jolivet et al., 2009, In-flight Calibration of Seviri Solar Channels on board MSG Platforms, Eumetsat User Meeting

Llido et al., 2010, Climatology of Oceanic Zones Suitable for In-flight Calibration of Space Sensors, Rapport d'étude CNES

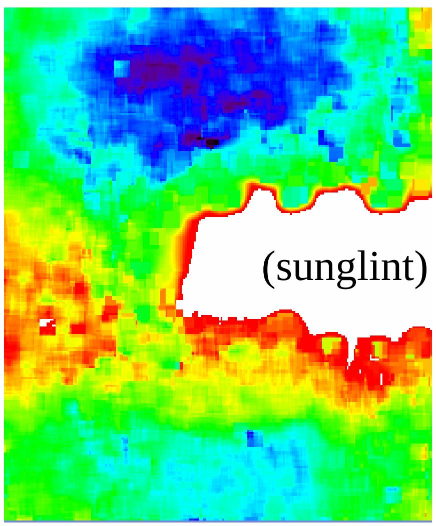
Additional Slides

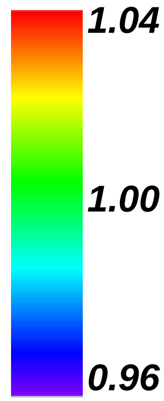
Calibration over Rayleigh Scattering: results

- Potentiality for multi-angular calibration :
  - Example with PARASOL

    Evolution of the calibration in the field of view after 2 years in orbit for band 490

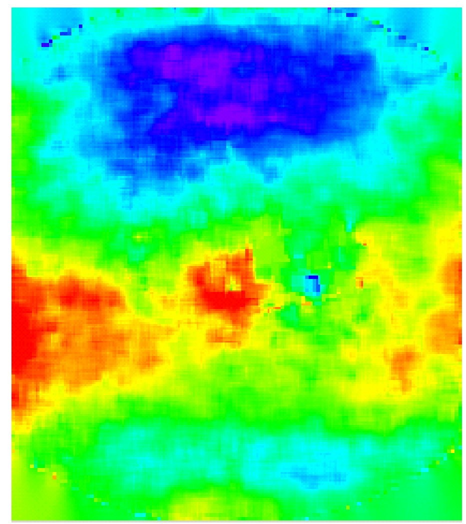
Calibration over Rayleigh Scattering





derived using acquisitions over ocean

Calibration over Clouds



derived using acquisitions over Deep Convective Clouds

(from Fougnie et al. 2010)