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In-flight Spectral Calibration of MERIS/OLCI

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MERIS Instrument

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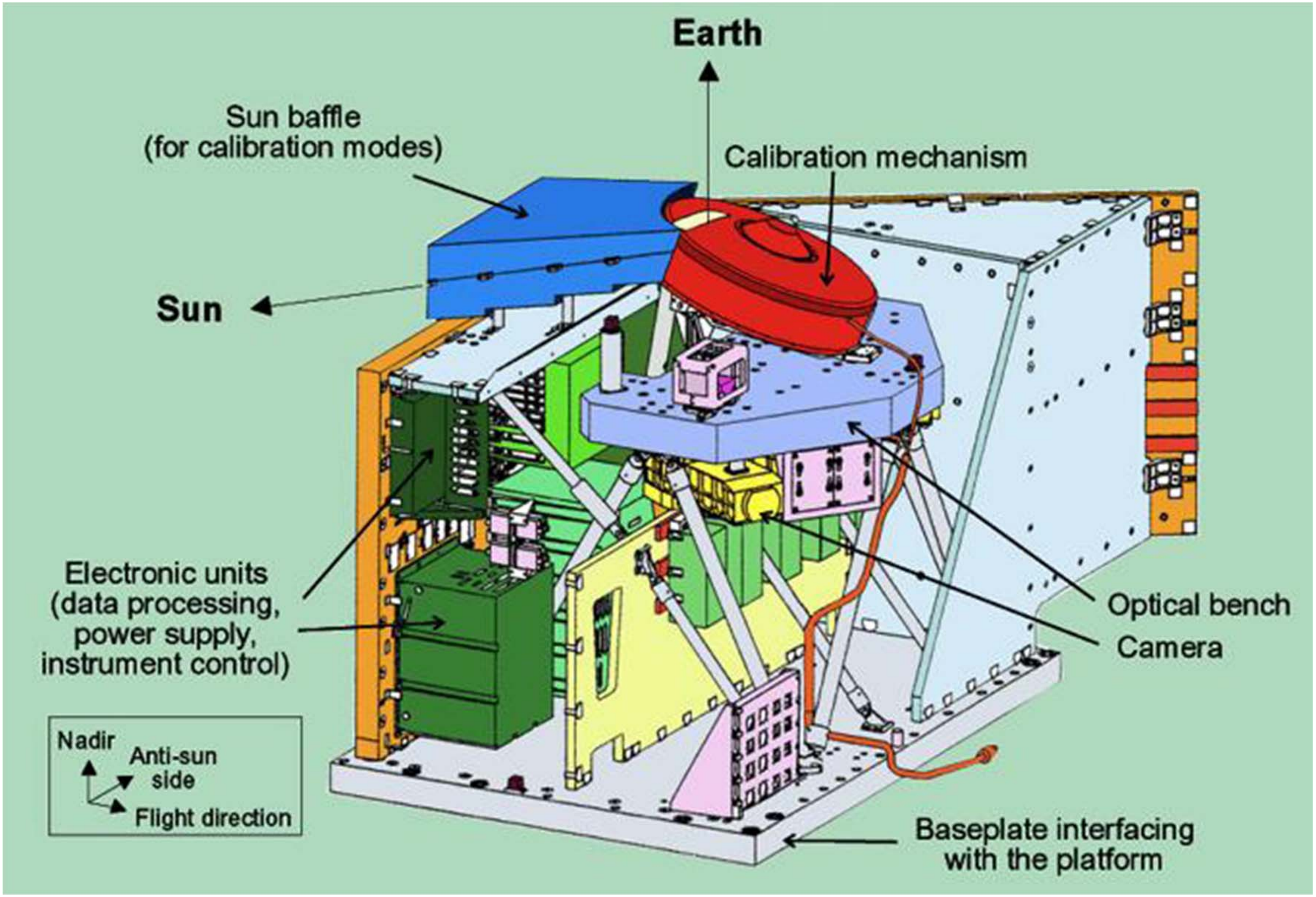
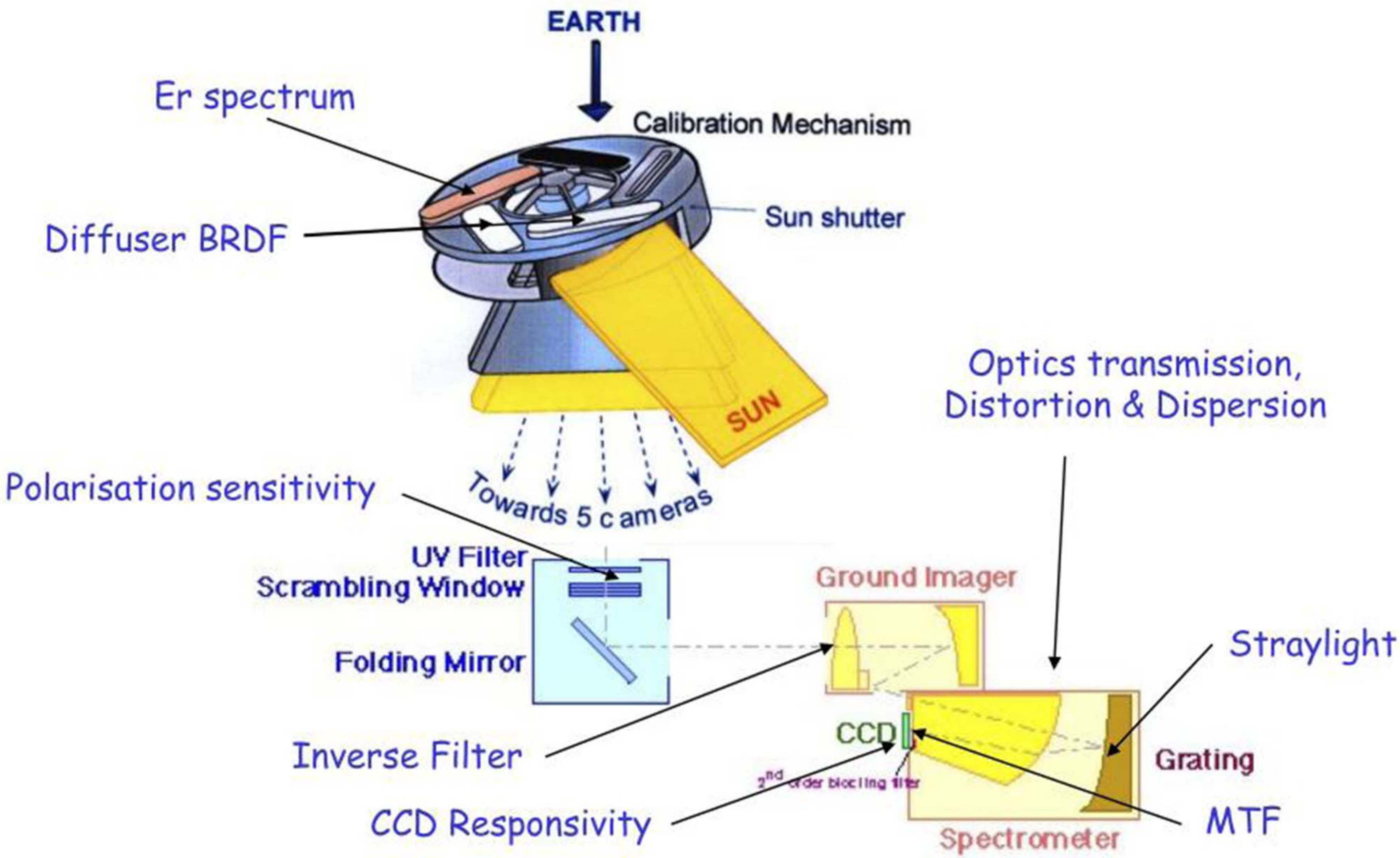


MERIS Instrument Concept



MERIS Operation

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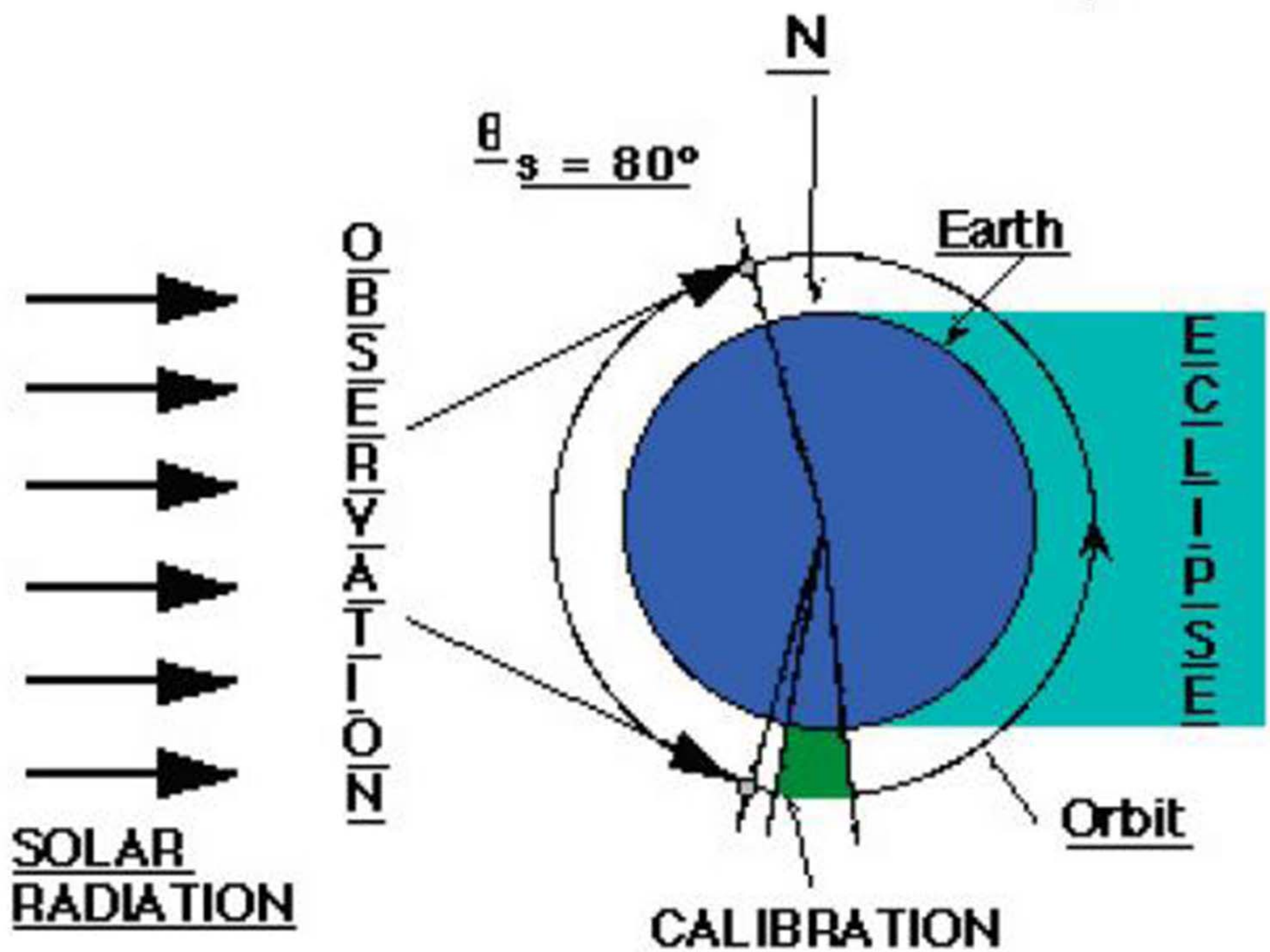

Bourg & Delwart, 2011

MERIS Calibration (Bourg &Delwart, 2011)

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Radiometric Calibration, executed every two weeks, starts with a **Dark Calibration (**shutter) followed by **Radiometric Calibration** with the frequently illuminated diffuser centered when the solar illumination angle on the diffuser is at 65.5° .

Diffuser Aging Calibration sequence, is executed every three months.

Spectral Calibration, executed every three months, is performed on two consecutive orbits with the instrument spectral band setting (with $\Delta\lambda$=1.25 nm) centered around Erbium spectral features at 410 nm and 520 nm.

MERIS Calibration Process (Bourg &Delwart, 2011)

1. **Radiometric calibration** measurement provides instrument numerical counts $X_{cal}(\square,k)$, where $\square$ stands for the spectral channel and *k* for the spatial position.

2. **Instrumental corrections** (non-linearity, dark offset, smear) yields *corrected counts*, $X'_{cal}(\square,k)$, considered as perfectly proportional to the radiance at instrument entrance, including the **straylight** contribution.

3. **Instrument Inverse Gain Coefficients** A^0 are then computed such as

$$X'_{cal}(b,k,m) = A^0(b,k,m) * L_{cal}(b,k,m)$$

where

$$X'_{cal}(b,k,m,t) = N\ L^{-1}(X_{cal}(b,k,m,t) - C^0_{b,k,m} - Sm(b,k,m,t)$$

are the calibration counts corrected for non-linearity, dark offset and smear.

4. ***L_{cal}*** is estimated from *E_0(□)*, the Sun extraterrestrial irradiance at the MERIS channel wavelength, illumination and viewing geometry and the diffuser BRDF.

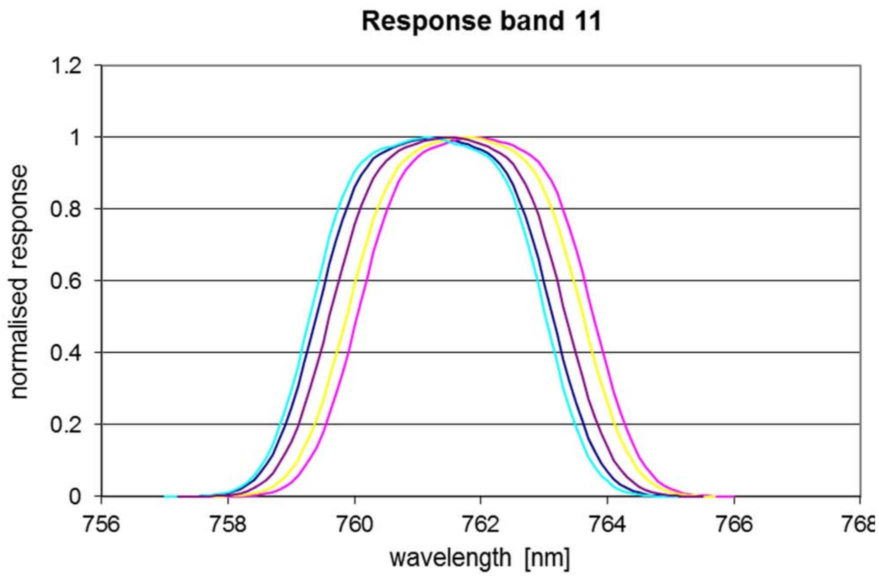
Straylight contribution is computed and added to the calibration radiance before use. This process includes an iterative loop: as the straylight contribution is estimated from the corrupted signal, the corrected signal allows deriving a better estimate of the straylight contribution that in turn allows computing a better corrected signal.

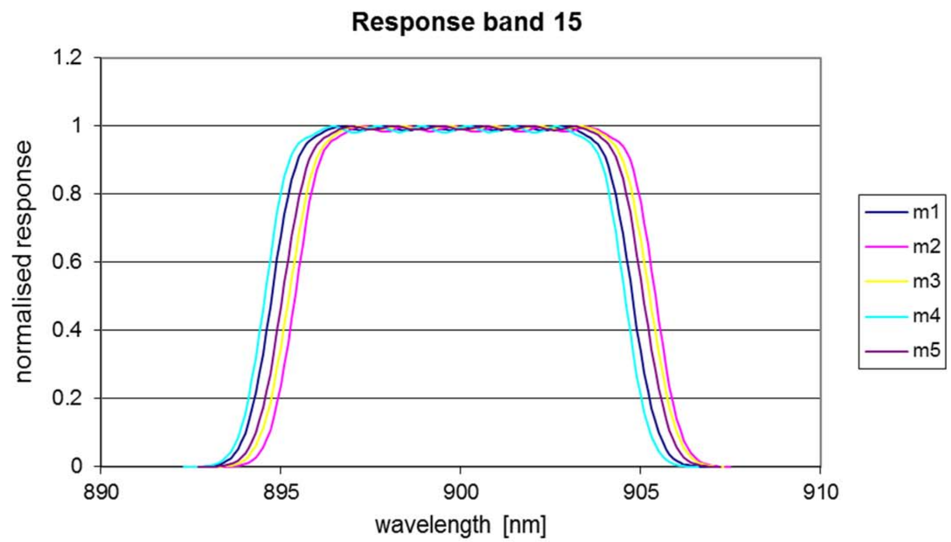
5. The diffuser BRDF has been characterised on-ground and is corrected for the diffuser ageing when used on on-orbit data.

6. *E_0* is derived from a model, the seasonal variation of the Sun-Earth distance, and the **instrument spectral characterization** (channels central wavelengths and spectral response curves);

7. Geometry is derived from satellite position and attitude computations and instrument pointing characterisation.

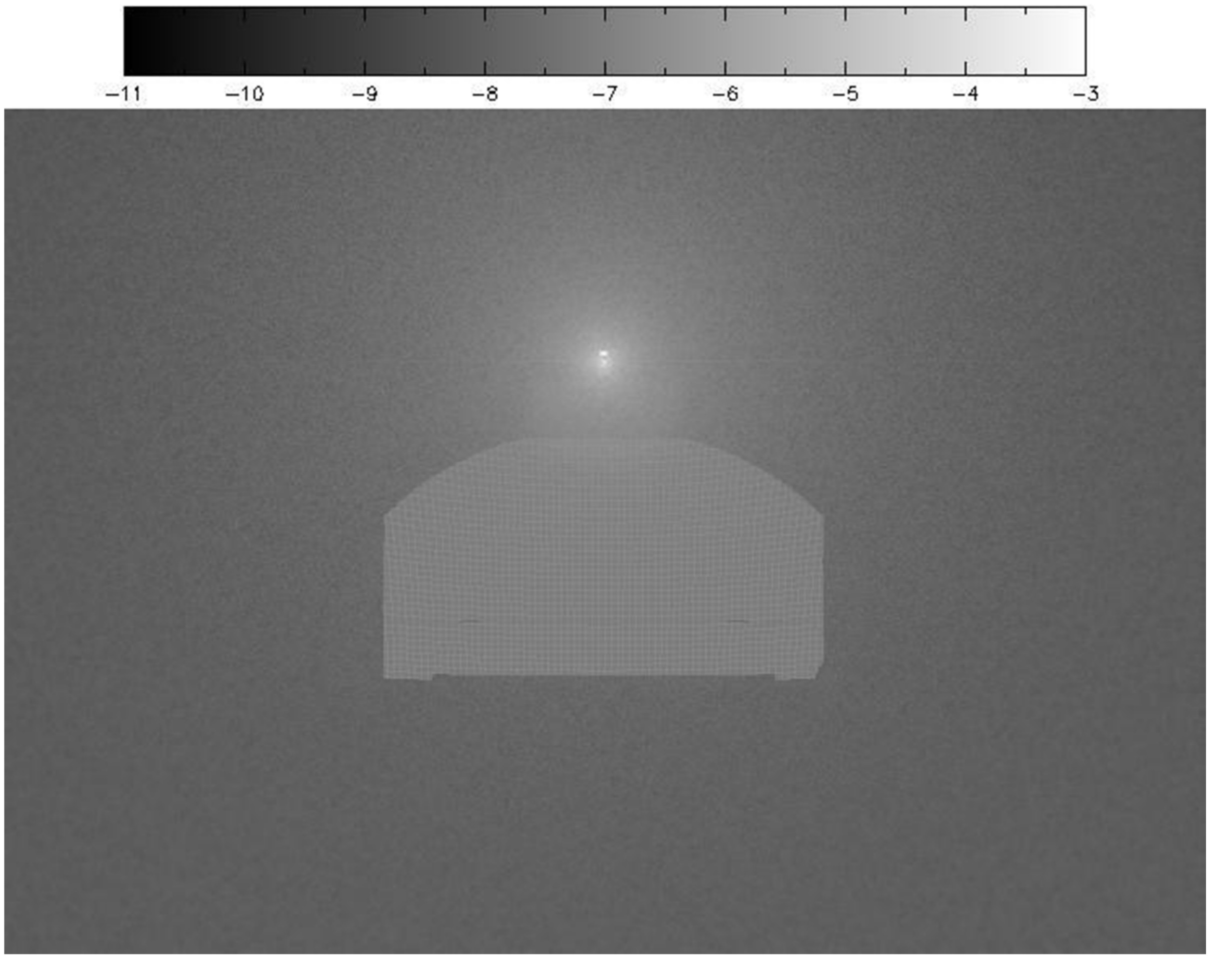
MERIS response functions





Modeled band 11 Line shape (3 spectral pixels) (left) and band 15 line shape (16 spectral pixels) for the central pixel of the five cameras.

MERIS Straylight



Straylight convolution kernel in log scale (generated for FM1 – or camera 4 – at 715 nm and FOV centre)

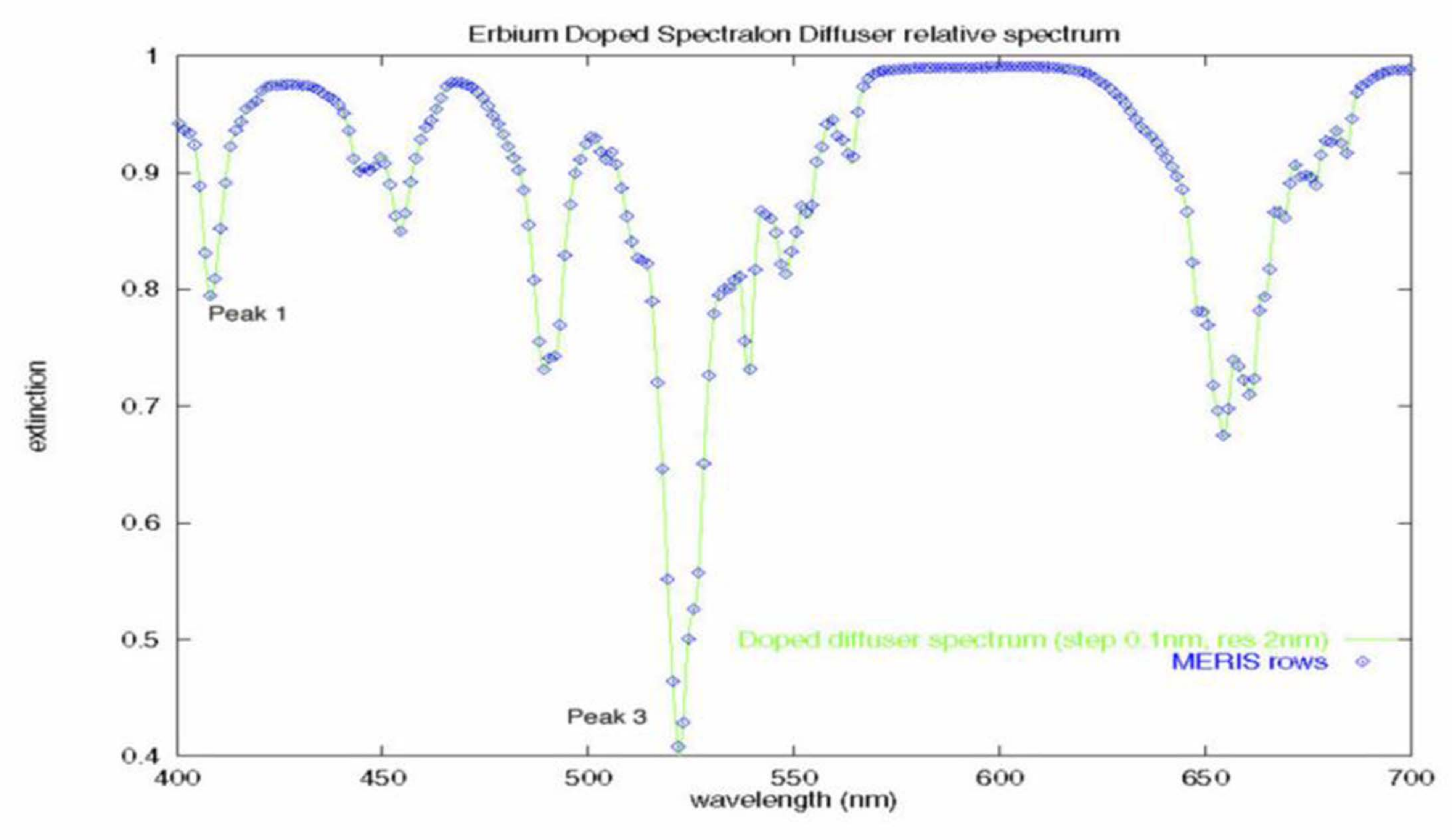
BASIS of Spectral Calibration

Spectral Calibration of MERIS uses the ability to program the 15 channels around spectral features such as

1. *Erbium doped Spectralon diffuser absorption spectrum*
2. Fraunhofer lines
3. atmospheric absorption bands (O2A).

The micro-bands have a bandwidth of
1.7nm (fwhm)
and a sampling of
1.25nm

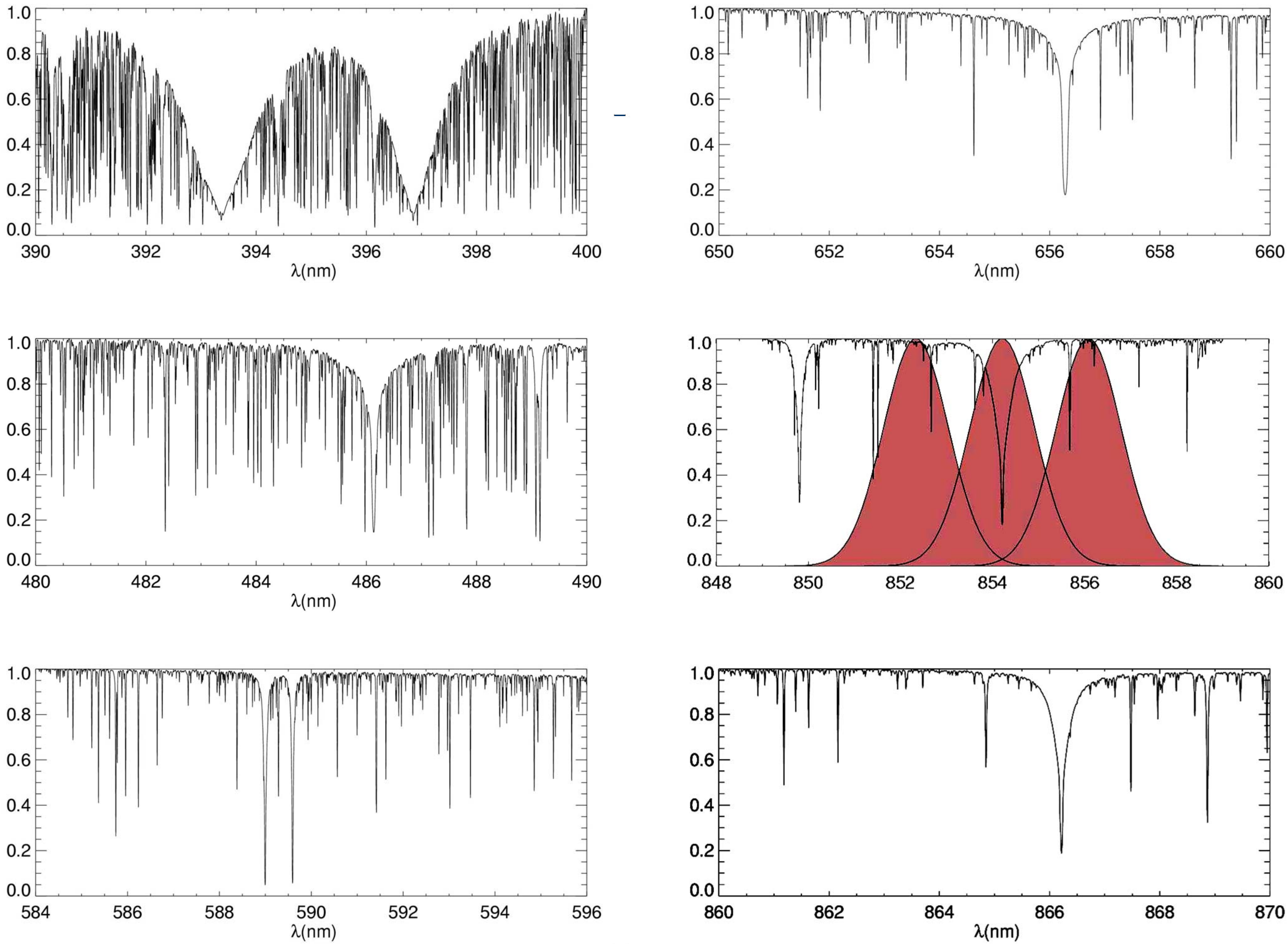
Erbium doped Spectralon diffuser absorption spectrum



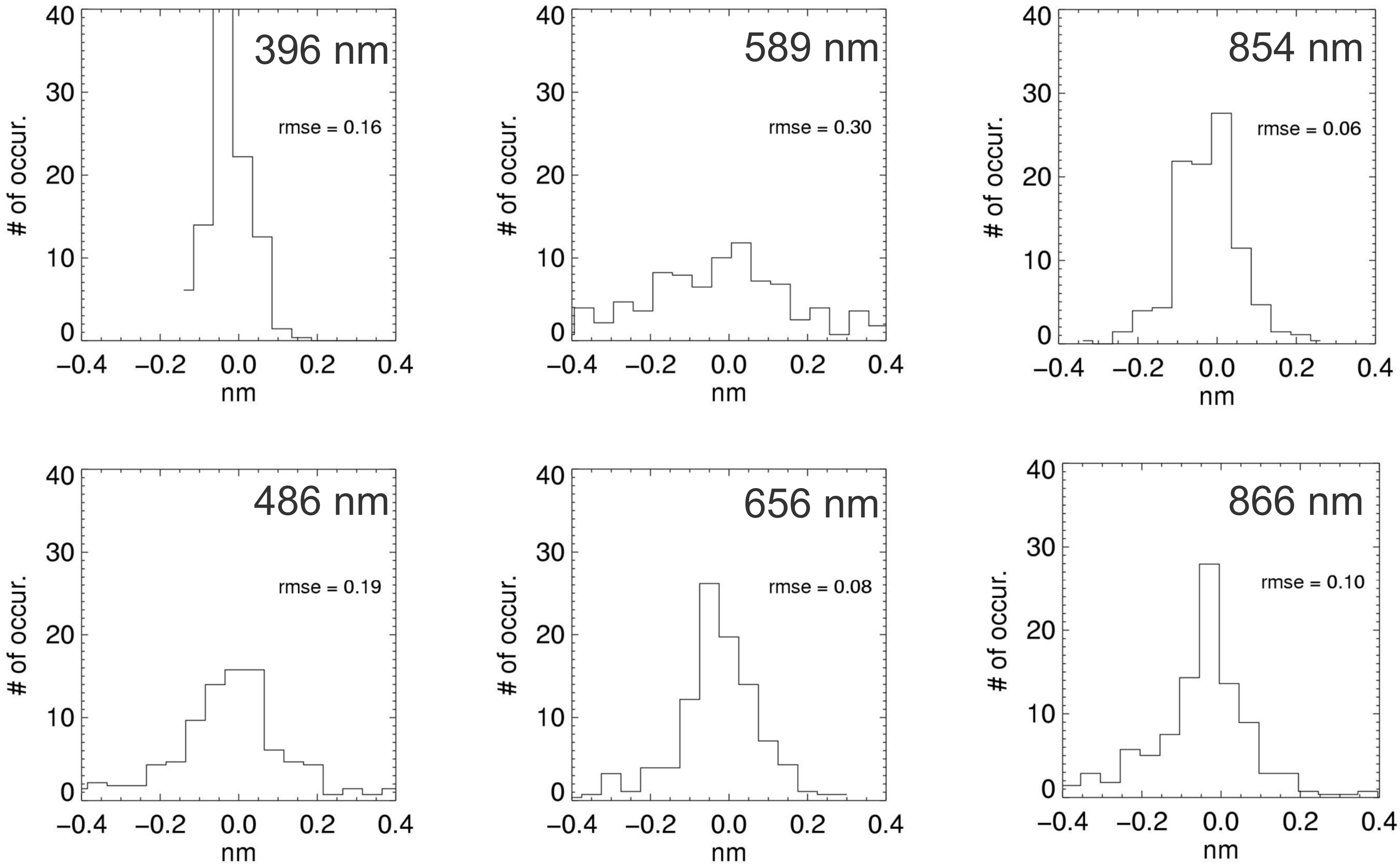
Fraunhofer method

- Prerequisites:
  - The spectral channels of MERIS are placed around the Fraunhofer lines
  - A database of simulated MERIS measurements in the range of the Fraunhofer lines.

- Spectral calibration by finding the best LUT entry


λ(nm)
λ(nm)
λ(nm)
λ(nm)
λ(nm)
λ(nm)

Theoretical accuracy for **4 micro-channels** around the Fraunhofer lines:



Theoretical accuracy for **6 micro-channels** around the Fraunhofer lines :

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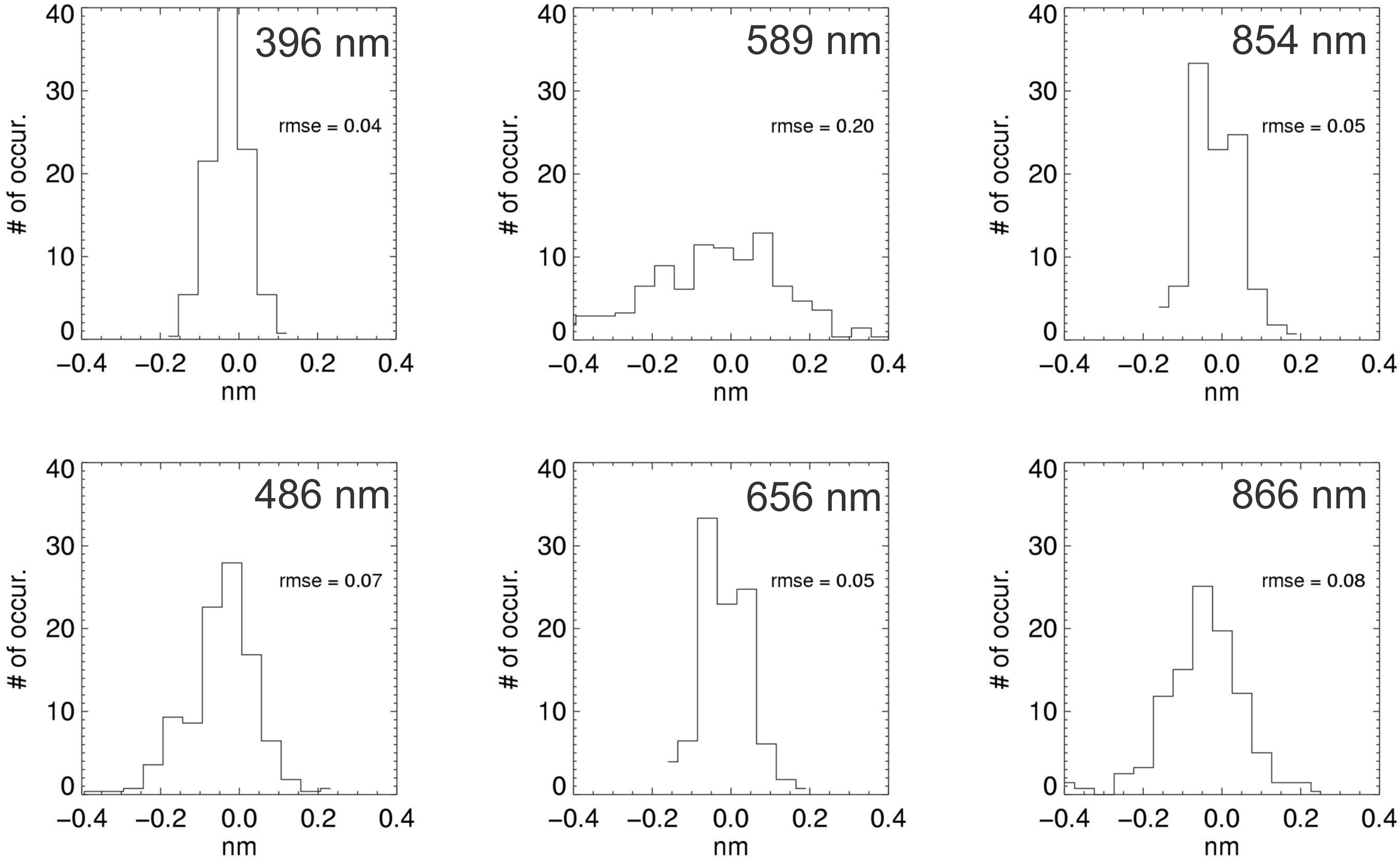
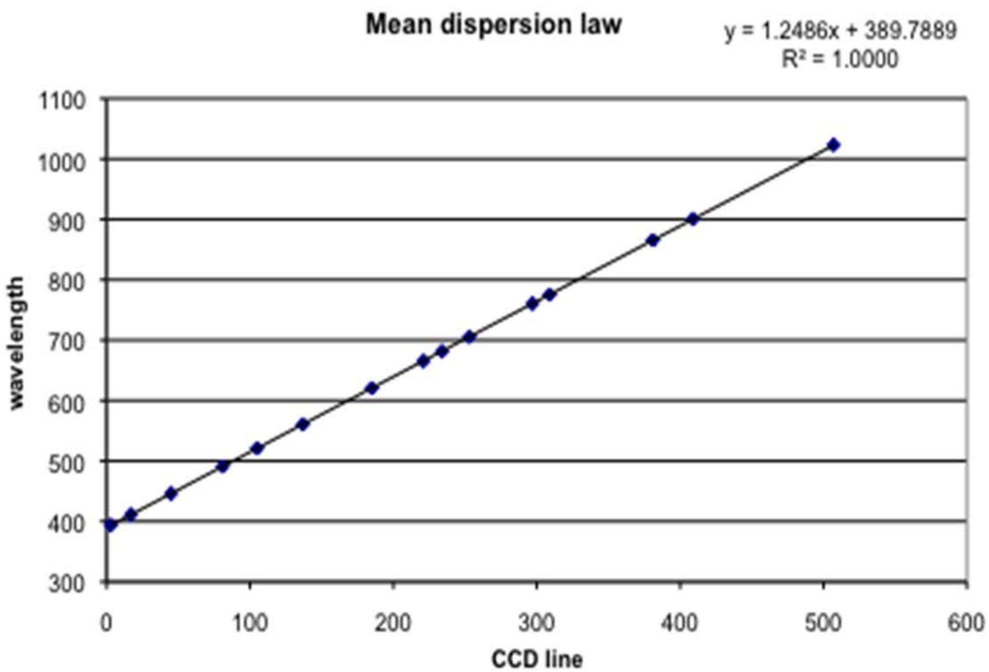
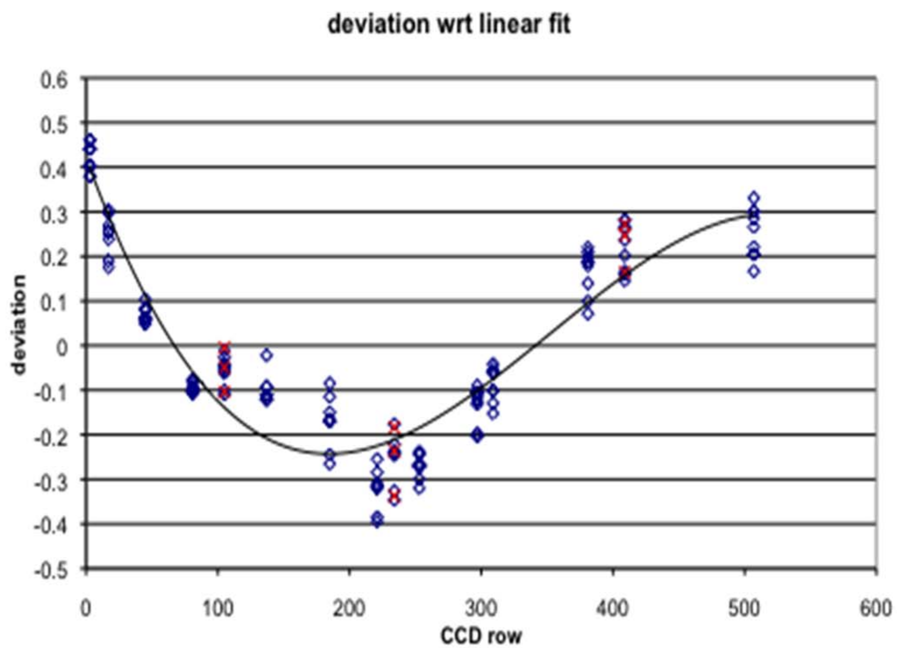


MERIS RADIOMETRIC CALIBRATION PRINCIPLE





Characterised central wavelength for Camera 4. Left: Wavelengths (nm) as a function of CCD line number; right: Deviation from linear trend [nm] as a function of line number. (Line 1 = 390nm, Line 520 = 1040 nm)

O2A Method

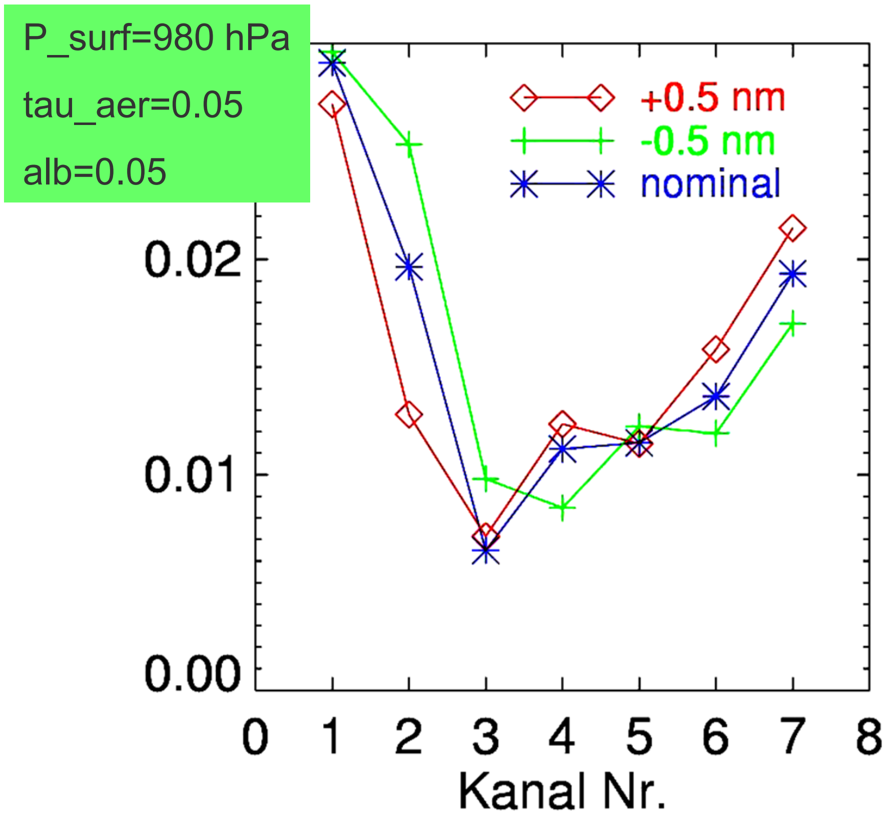
- Prerequisite:

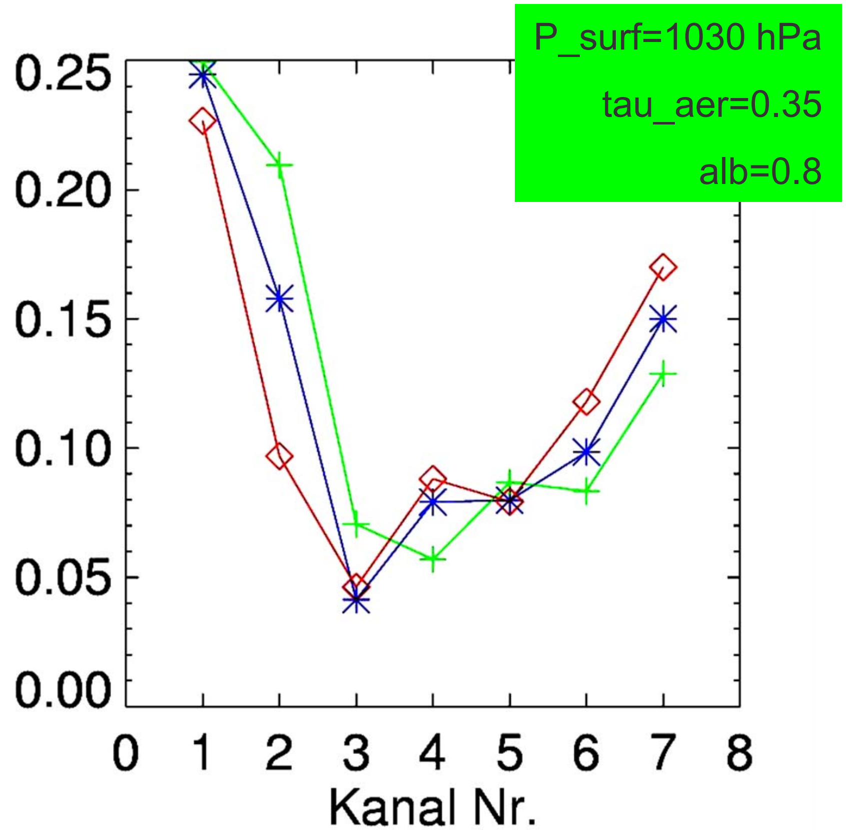
  The measured „shape" S of the oxygen A band is a function of spectral position of the channels and almost independent on surface and atmospheric conditions.

$$S(\lambda_i) = \frac{1n\left(I(\lambda_i)\right) - \ln(I_0)}{1n(I_{\min}) - 1n(I_0)} \approx 1 - \frac{k_{eff}(\lambda_i)}{k_{eff}(\lambda_{\min})}$$

- Usage of a compressed LUT (NN) of simulated O2A measurements for a huge variety of surface and atmospheric conditions.

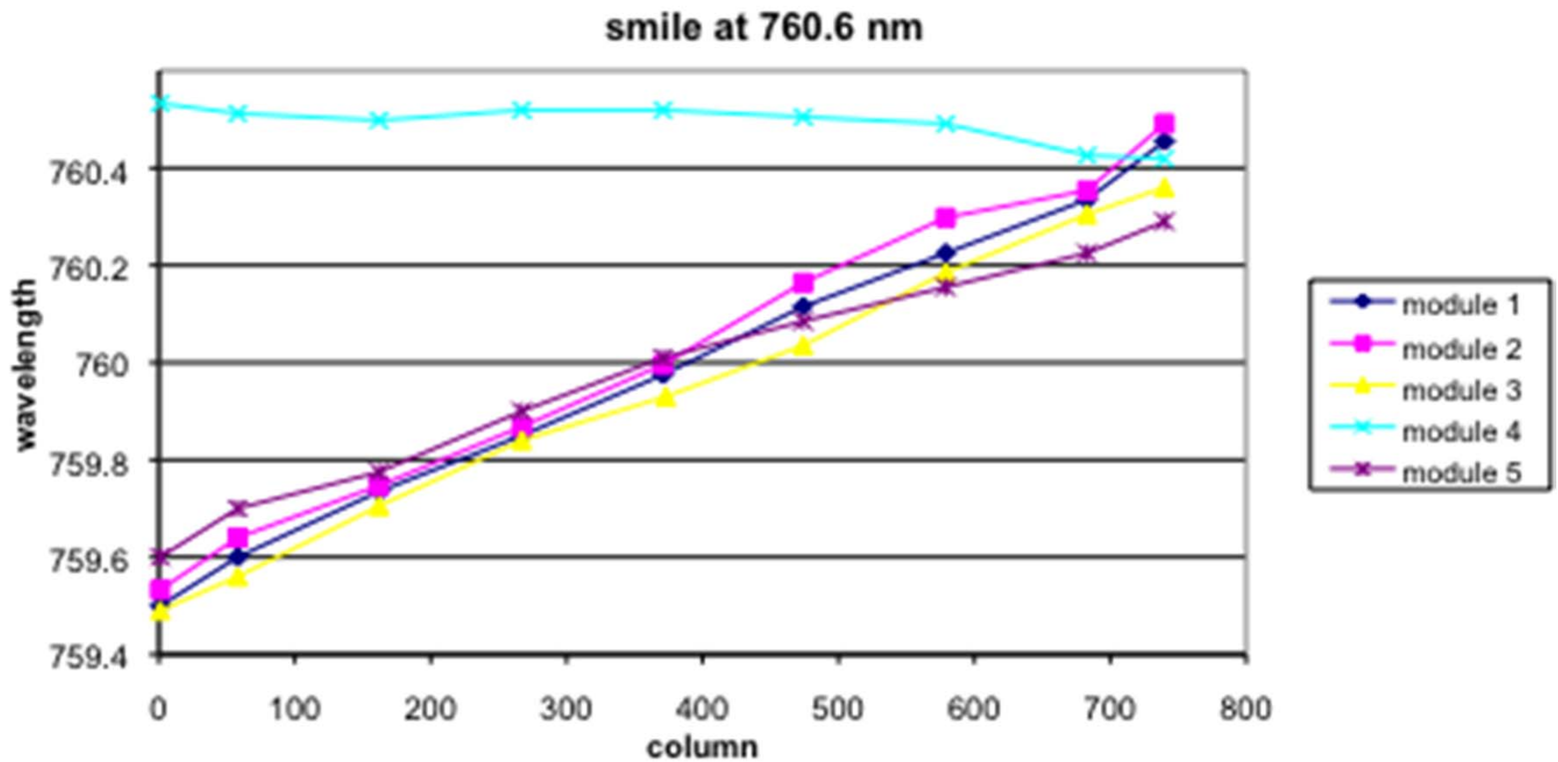
Example:





Simulated radiance for the sub-channels for different situations: absolute values differ, shape is constant for the same spectral position

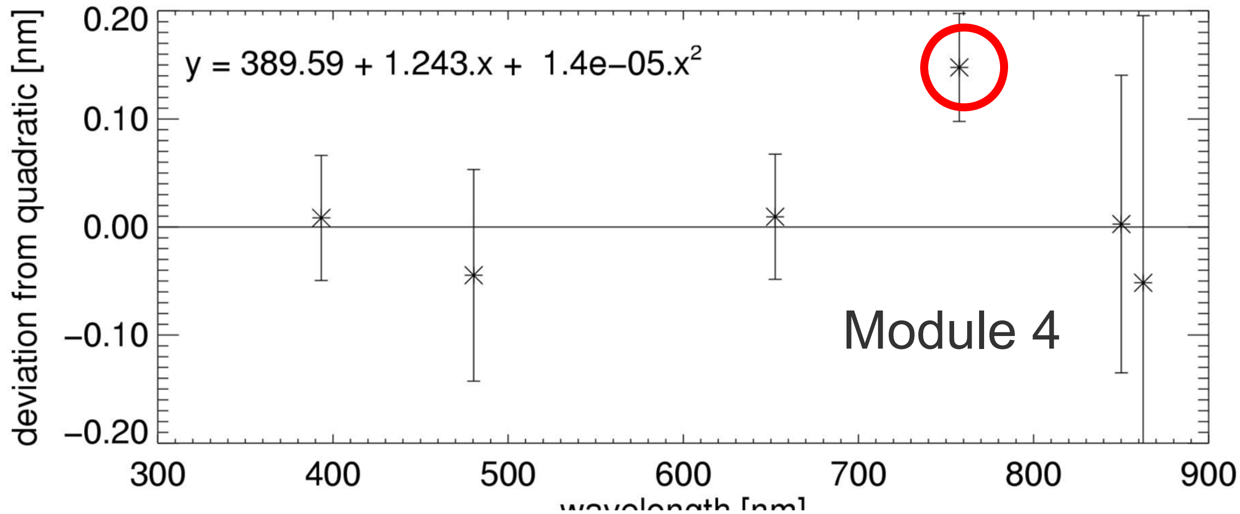
Spectral calibration

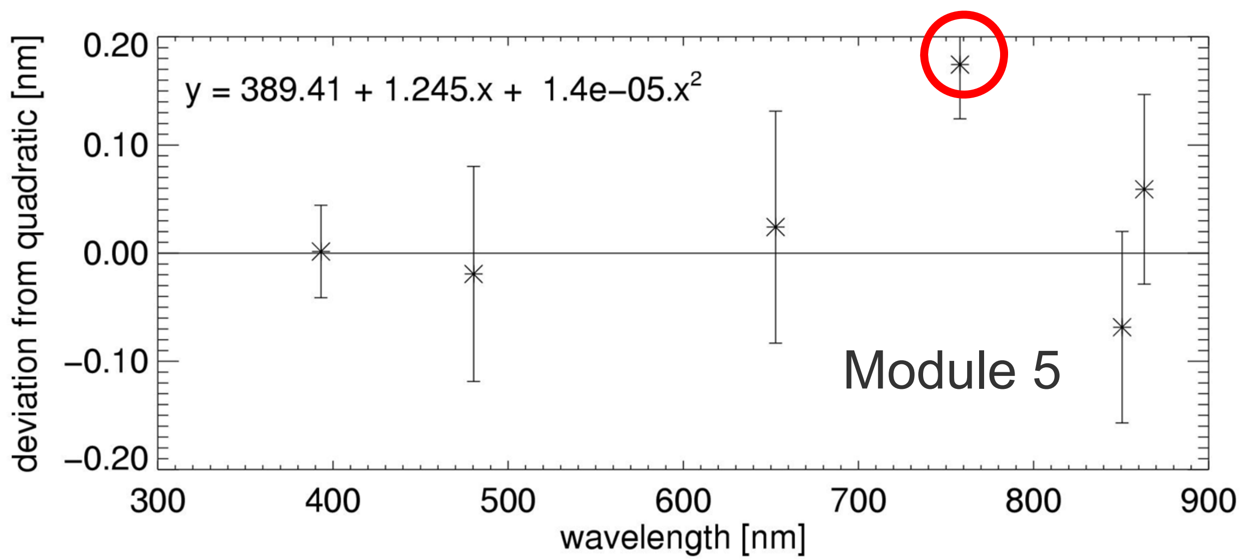


Characterised central wavelength for all MERIS cameras as a function of field of view (column #) for line 297 centred at 760 nm (Bourg and Delwart, 2011)

Consistency of Fraunhofer and oxygen calibration

For almost all cases the oxygen calibration results had an offset between 0.05 and 0.15nm!





Empirical correction of straylight

- Problem
  - Prominent camera boundaries
  - Pressure jumps at boundaries depend on brightness and height (pressure) of the scene
- Strategy
  - Stray light model
  - Spectral model
- Tools
  - Surface pressure ANN: SP_{FUB}
  - Cloud-top pressure ANN: CTP_{FUB}
  - Reference data:
    - SP: Digital elevation models: GTOPO, GLAS/ IceSAT + ECMWF
    - CTP: MSG brightness temperature
- Data
  - MERIS Scenes
- Results

Idea

- Optimize coefficients of simple stray-light model by fitting SP- and CTP-retrieval to ‘accurate’ reference data.

- First approach:
  - As spectral misalignment (smile) and stray-light cause highly correlated errors, both were adjusted simultaneously.
  - Results are purely artificial.

- Second approach:
  - We assume that spectral Fraunhofer calibration is accurate within ± 0.1nm.
  - Limit spectral adjustment, optimize stray light coefficients
  - More physical results.

Stray light model

Assumptions:

• Stray-light is proportional to brightness in window channel:

$$s = f * rad10$$

•Quartic dependence of f on detector index x:

$$f = a + bx + cx^4$$

$$rad11\_corr = rad11 + f * rad10$$

Spectral model

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Assumptions:

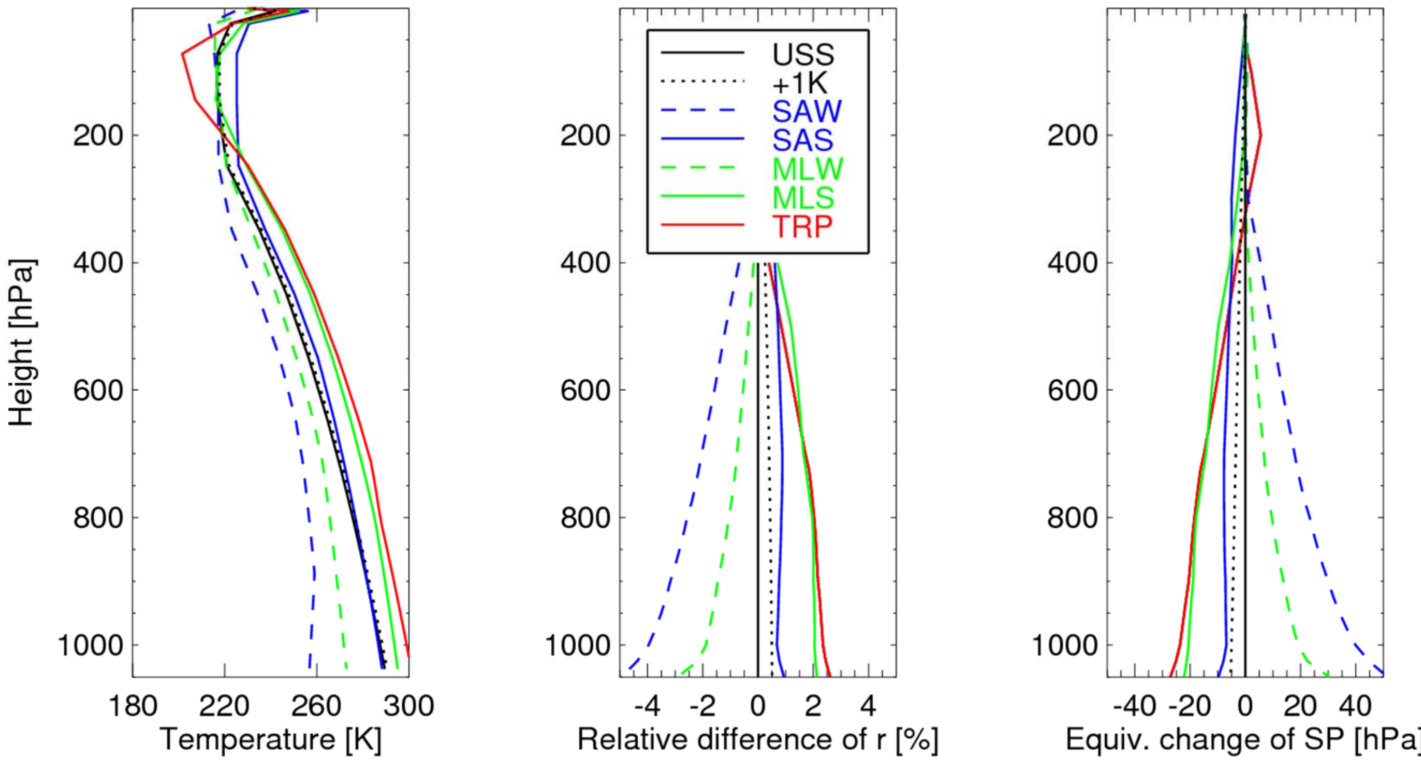
• Spectral Fraunhofer calibration is valid in the O_2 *A* band.

• Difference of spectral misalignment from Fraunhofer calibration is constant for each camera:

$$\Delta\lambda = d$$

• In the optimization *d* was restricted to ± 0.1nm (Fraunhofer calibration accuracy)

Sensitivity of channel ratio to temperature profile



Impact of temperature profile (relative to US standard atmosphere) on channel ratio r (middle) and retrieved surface pressure (right), depending on surface elevation.

Used data - desert

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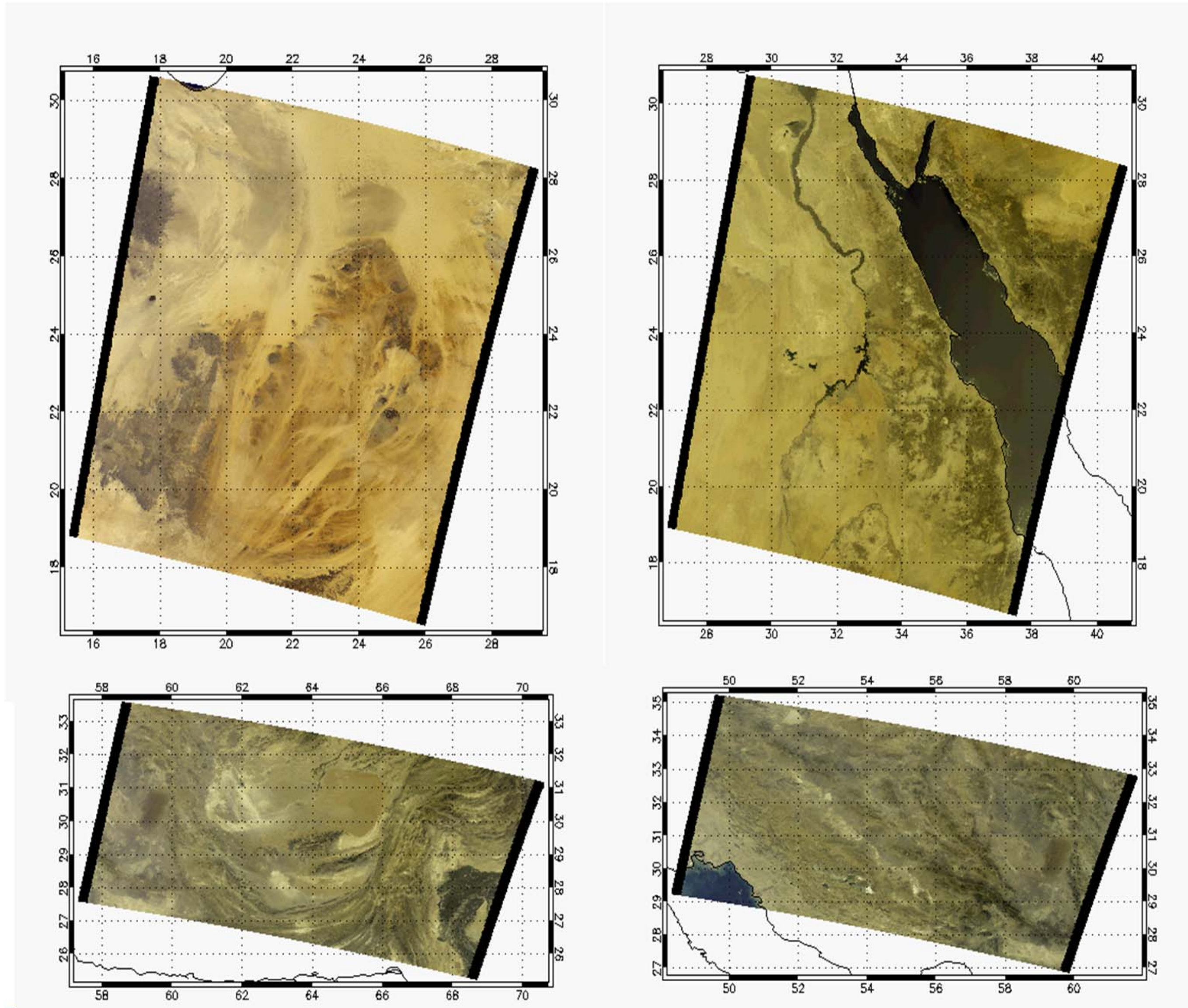
4 desert scenes:

• 20050920, orbit 18598, Libyan desert

• 20051001, orbit 18755, Egypt desert

• 20051011, orbit 18897, Iran / Pakistan

• 20051013, orbit 18926, Iran



Used data - Greenland

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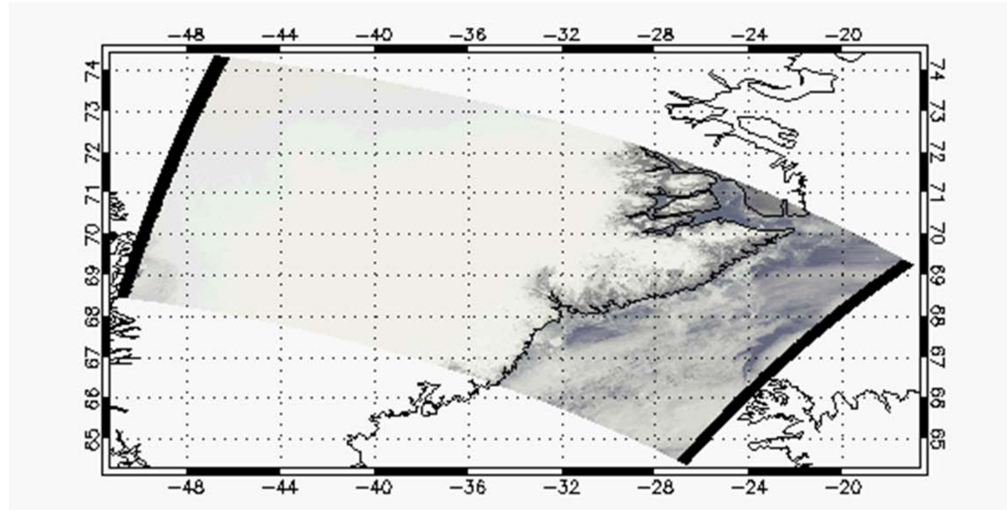
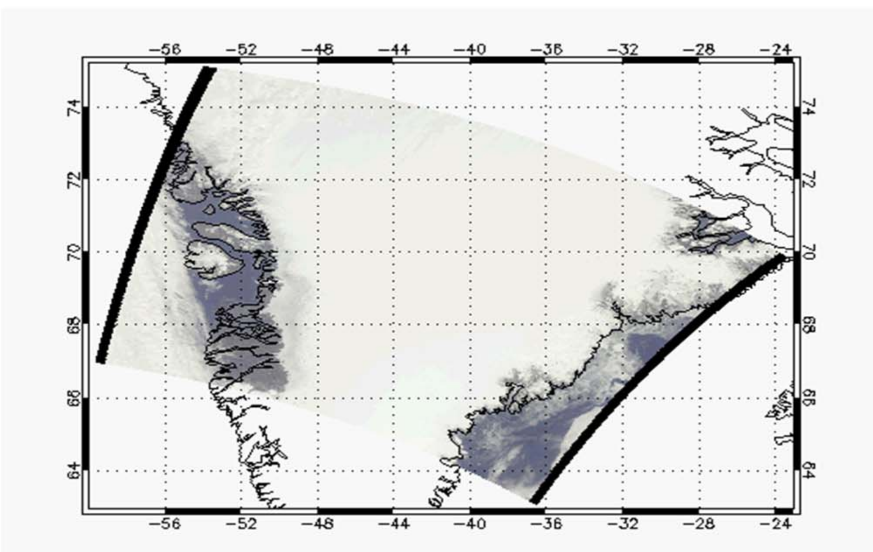
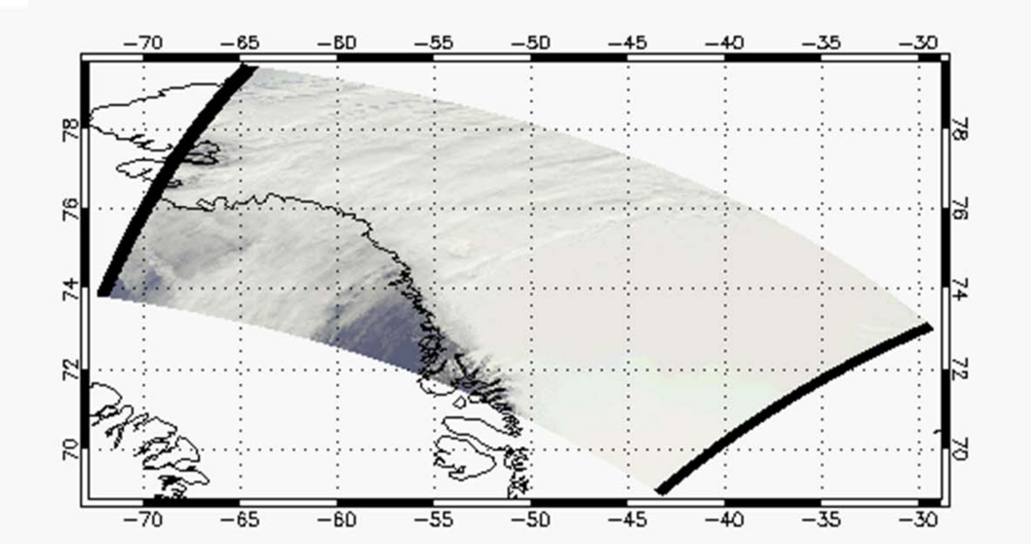
3 Greenland scenes:
- 20050720, orbit 17714
- 20050721, orbit 17728
- 20050721, orbit 17729







Used data - Clouds

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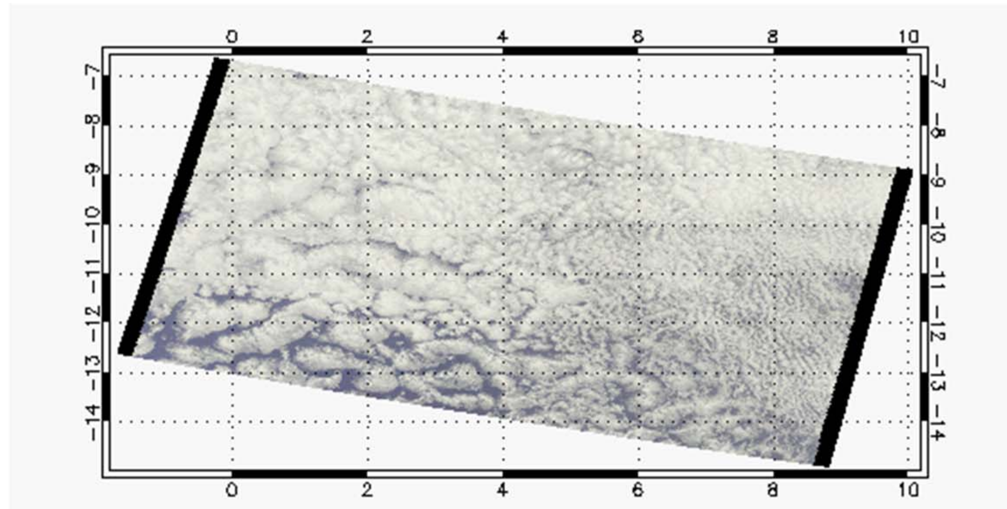
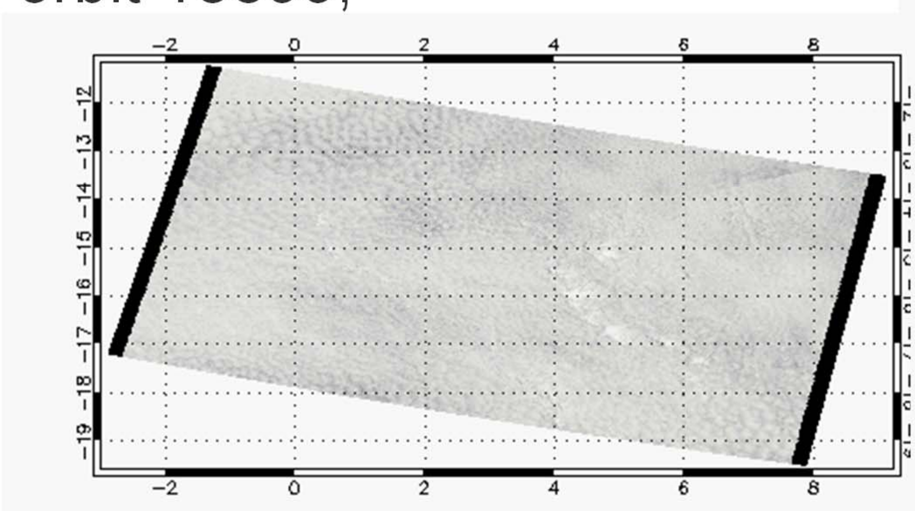
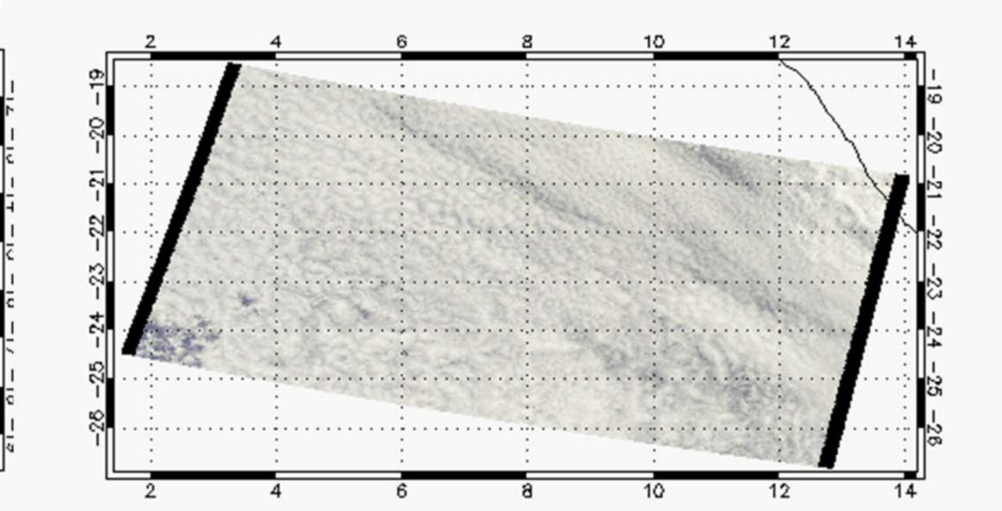
3 cloud scenes:

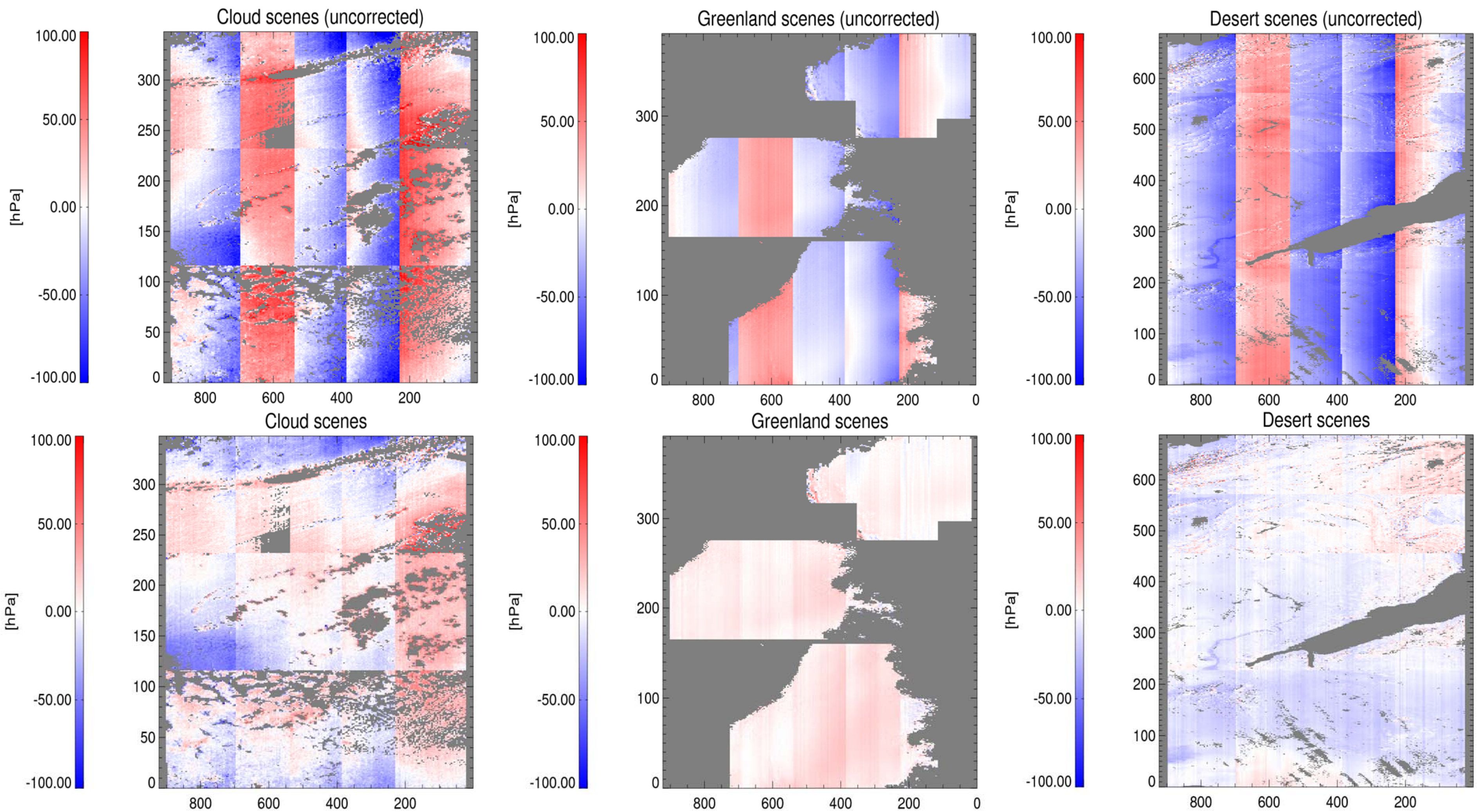
- 20050419, orbit 16394, Benguela current
- 20051011, orbit 18899,







Results



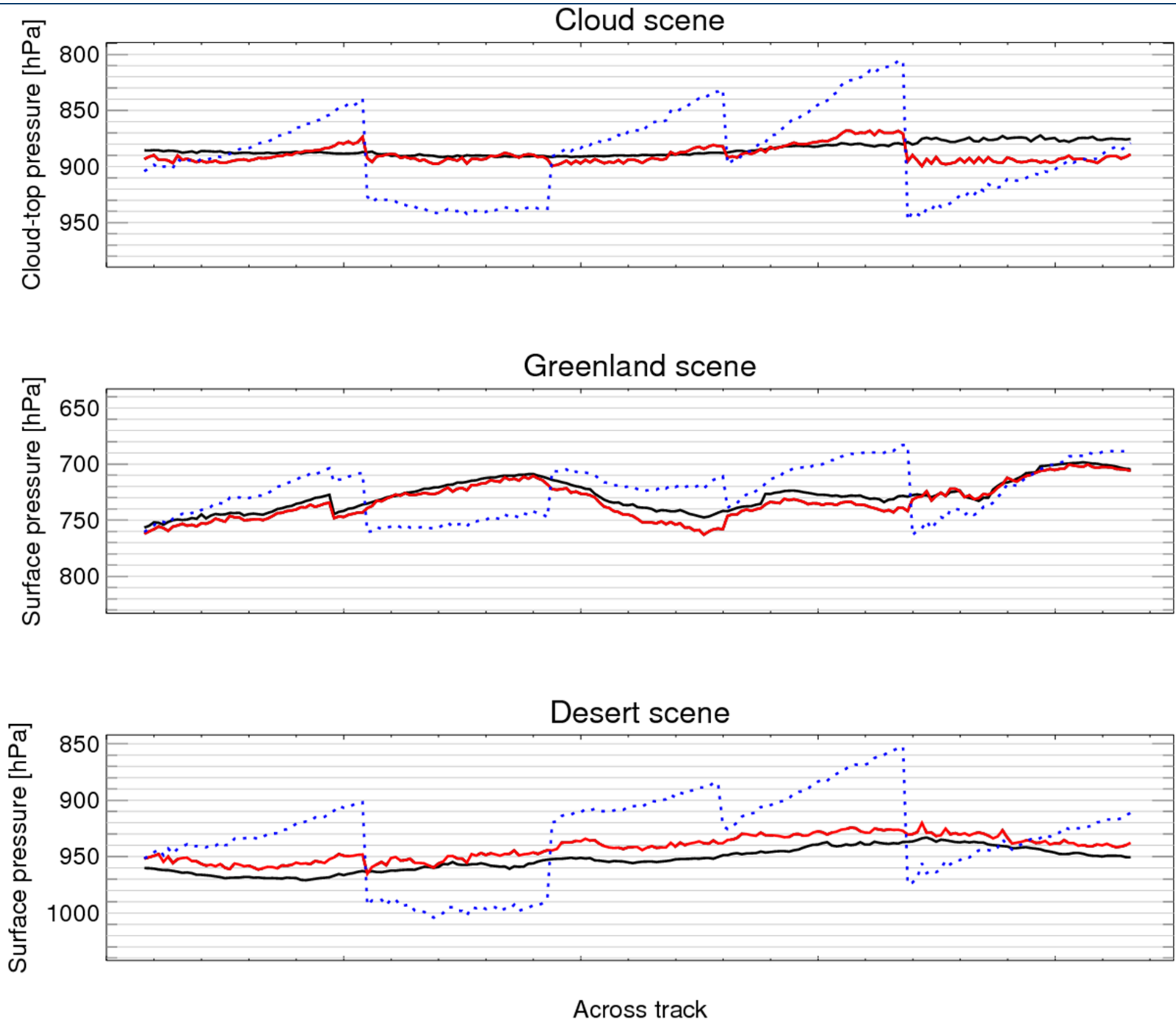
Cloud scenes (uncorrected)
Greenland scenes (uncorrected)
Desert scenes (uncorrected)
Cloud scenes
Greenland scenes
Desert scenes
[hPa]
100.00
50.00
0.00
-50.00
-100.00

Results

Black: Reference pressure

Red: Corrected pressure

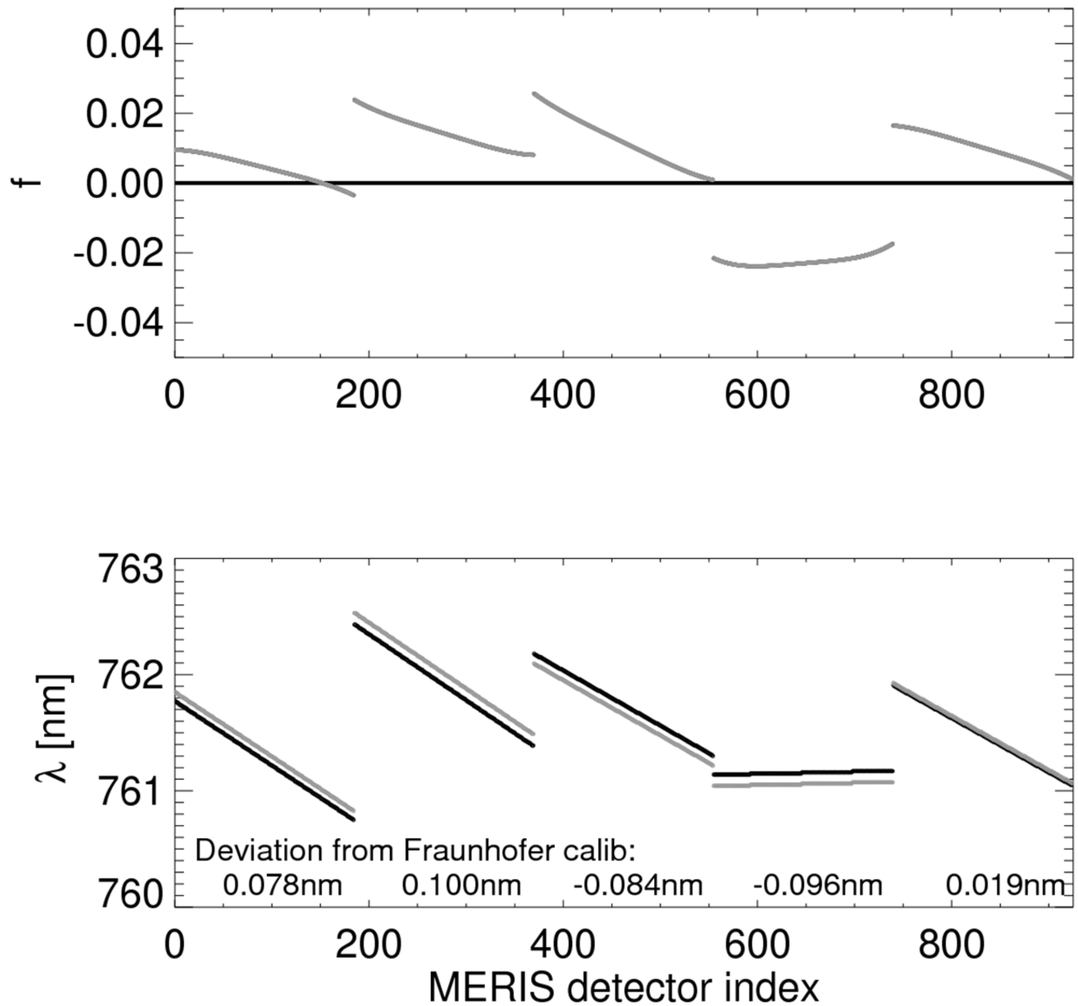
Blue: Uncorrected pressure



Surface pressure – SP_{FUB} / „stray-light" factor

- Resulting stray light factor f:

- Center wavelength band 11 (black: Fraunhofer calib, red optimized)



Summary:

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- Both algorithms are working
- Individual accuracy is better than 0.1nm
- Inconsistency between Fraunhofer data based spectral model and O2A method – still not solved.

→Has to be examined in more detail !

Candidates for failure:

1. Pressure and temperature dependence of O2A absorption lines
2. Spectroscopy of the O2A band
3. Insufficient stray-light model

OLCI (Ocean & Land Color Instrument)

OLCI:

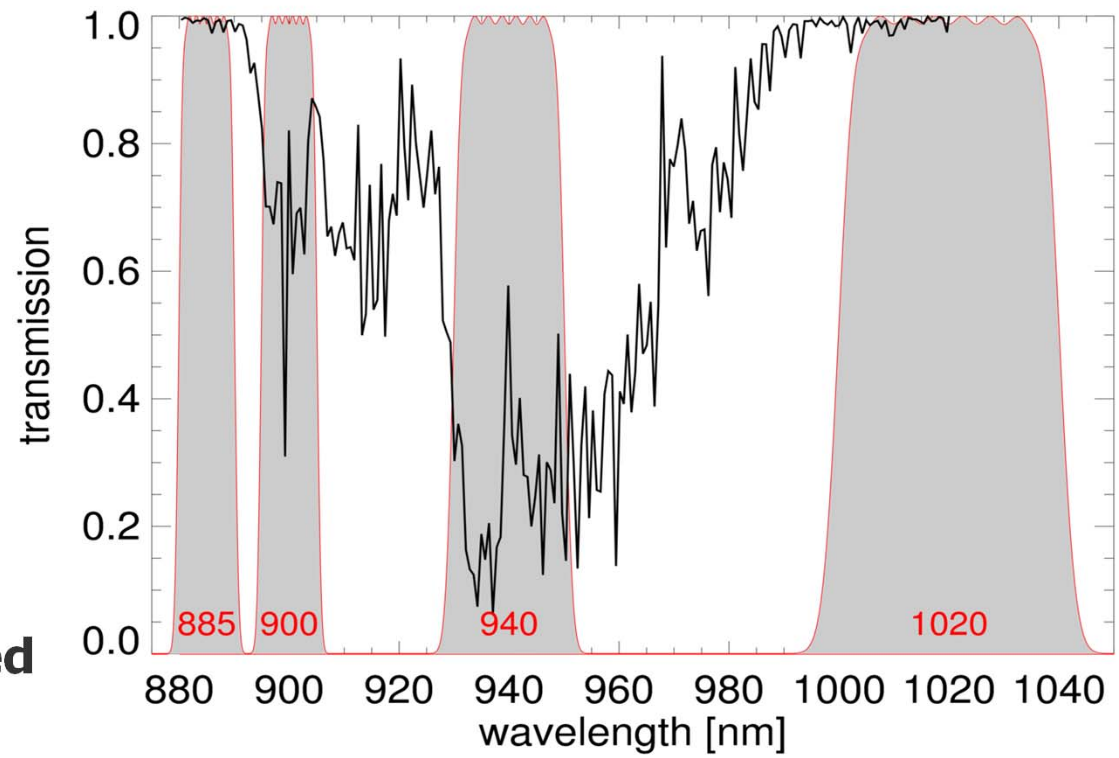
-Swath ≈ 1300km

-21 channels [0.4-1.02µm]

- Wider spectral range

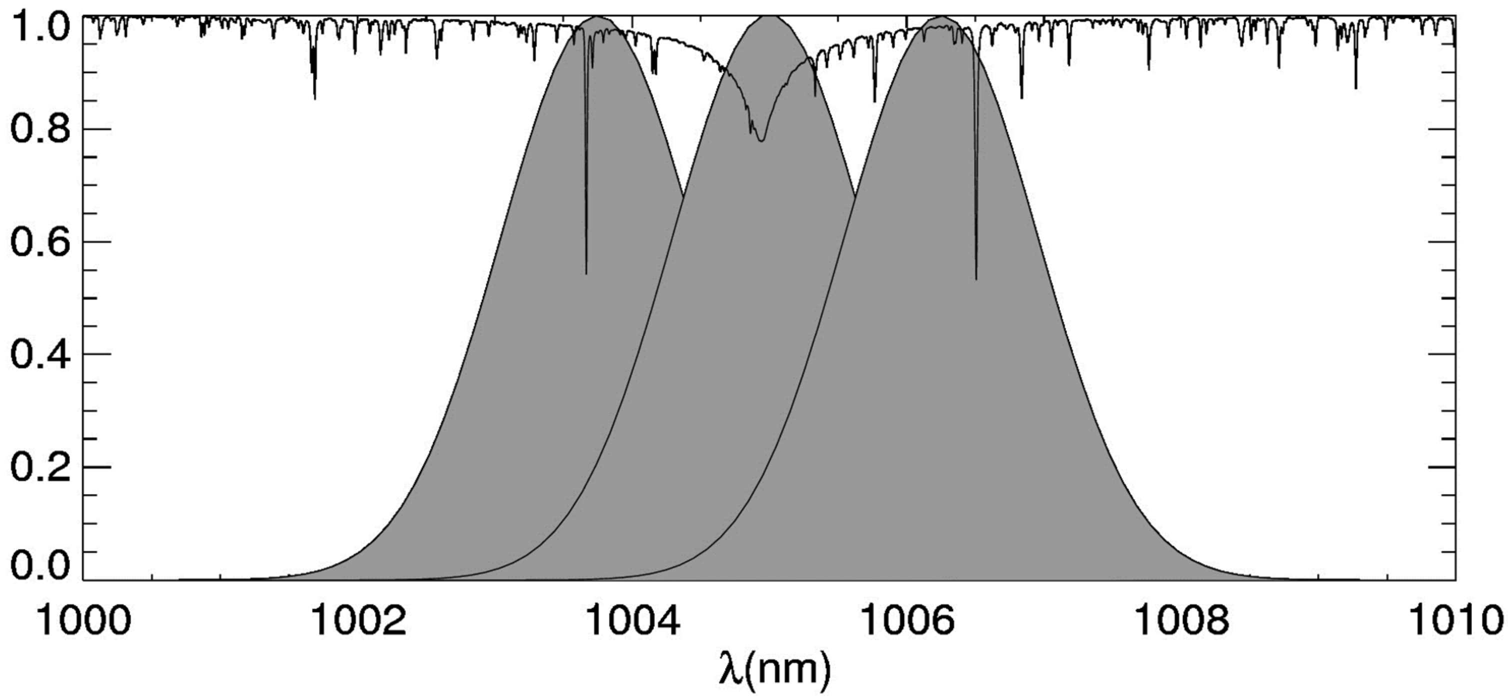
Additional use of

H_20 ρστ-aborption band



Identification of optimal channels is needed

OLCI (Ocean & Land Color Instrument)



Additional use of Ca Fraunhofer-line

Recommendation for OLCI spectral calibration

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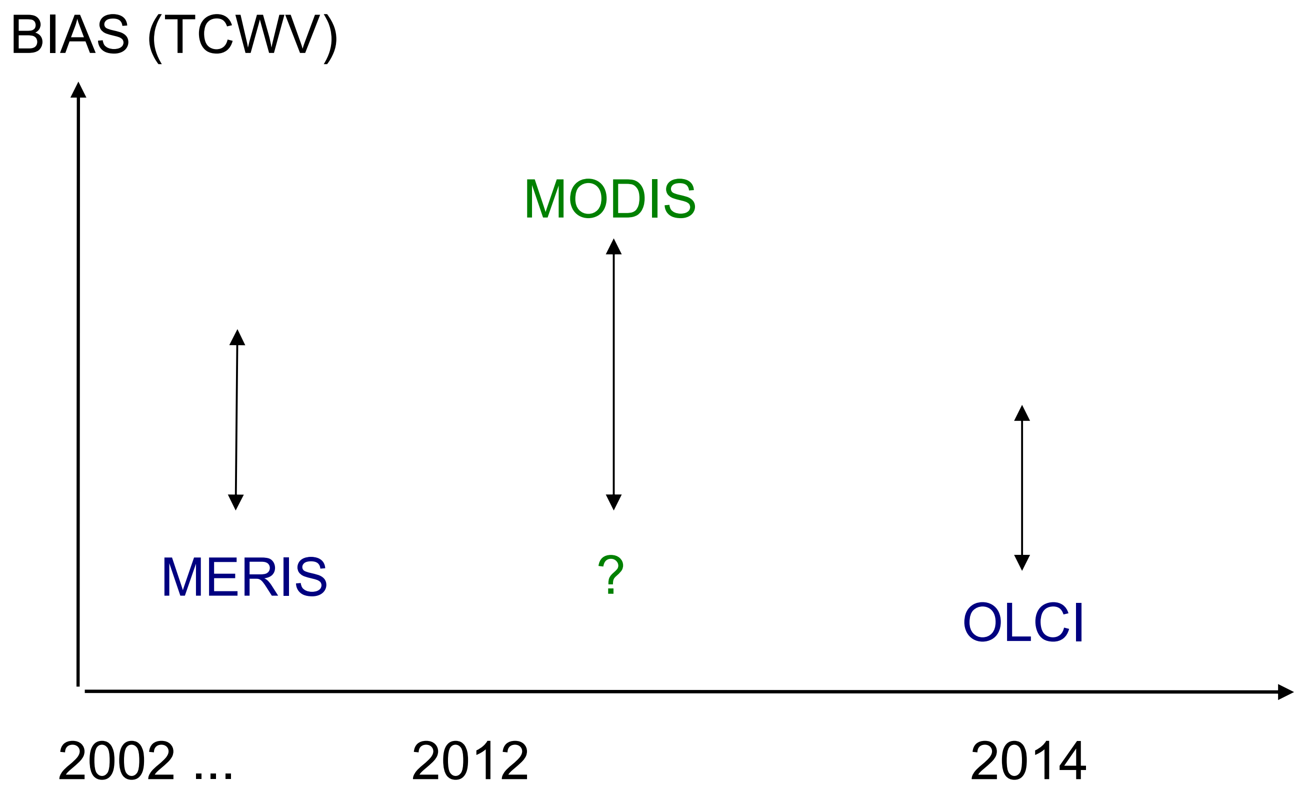
- Spectral calibration
  - Use additional Fraunhofer Ca-line (λ=1005 nm)
  - Use of $H_2$0 $\rho\sigma\tau$-aborption lines between 920 nm and 970 nm
  - Analyse camera boundaries

- Spectral correction factor / “stray-light” correction
  - Derive via surface pressure and digital height model
  - Use 3 O_2 A-band channels
  - Perform bias-monitoring

- Rayleigh correction above dark ocean surfaces
  - Use improved radiative transfer in ocean and atmosphere (polarisation)
  - Use of complex refractive index as function of wavelength, temperature and salinity

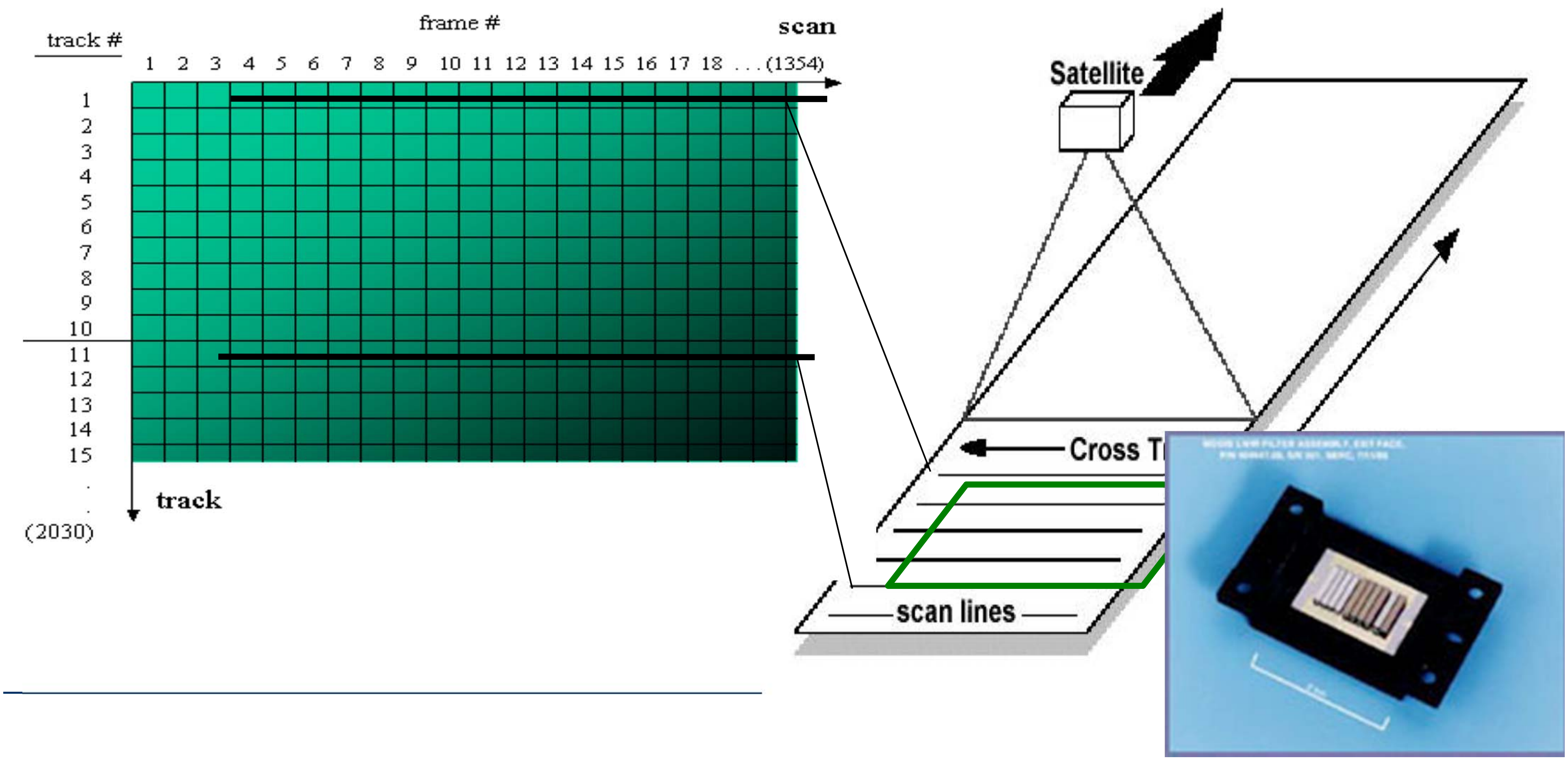
Multi-satellite observations

Filling the ENVISAT – Sentinel-3 gap
and extending the global water vapour data set



MODIS scanning scheme

10 detectors for each channel (1km resolution)



MODIS channel characterisation - TERRA

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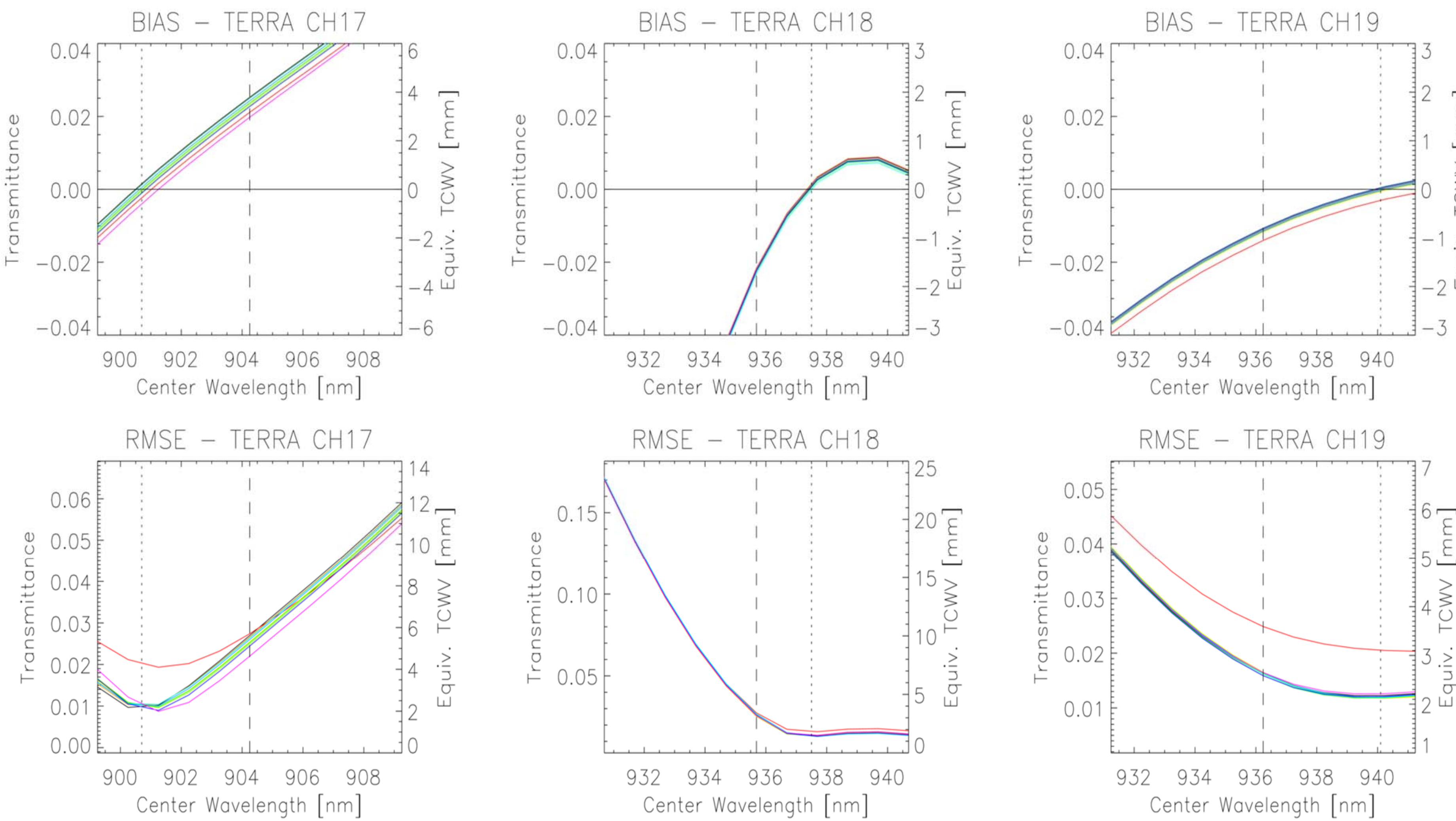

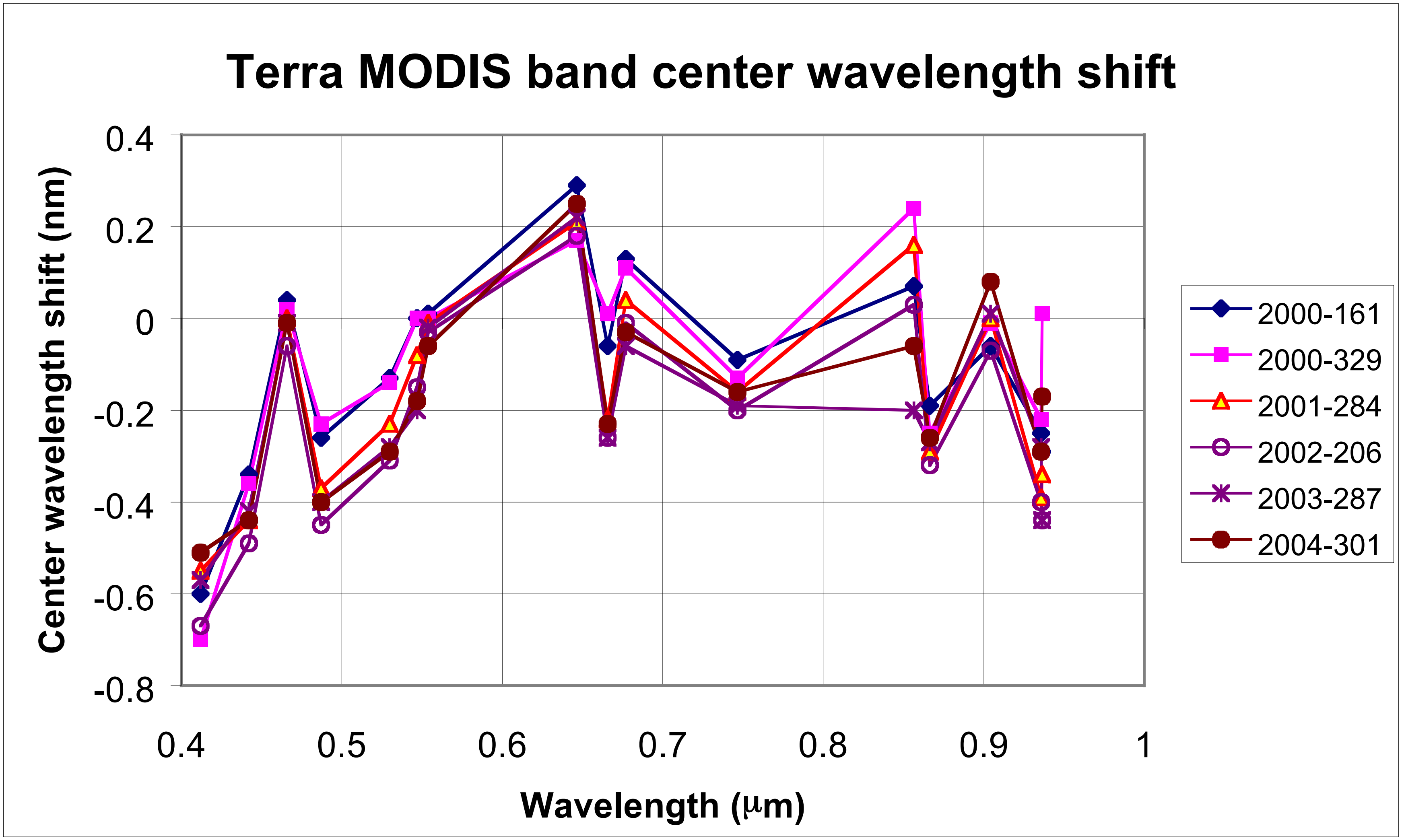

(Salomonson et al, 2004)