MERIS US Workshop

Instrument Calibration Methods and Results

Steven Delwart

Presentation Overview

1. Instrument overview
2. Radiometric equation
3. Radiometric calibration method
4. Radiometric calibration results
5. Instrument degradation
6. Diffuser aging
7. Spectral calibration methods
8. Spectral calibration results
9. Spectral stability
10. Instrument Spectral Model

Acknowledgement

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For doing all the work
Richard Santer
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Rene Preuske
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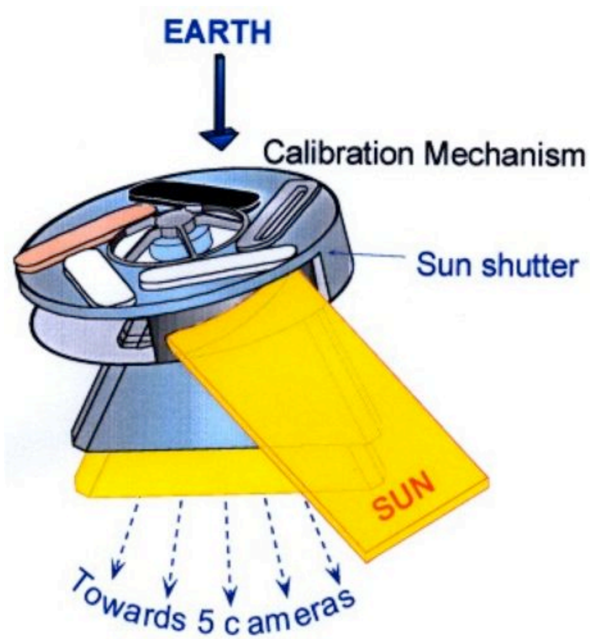
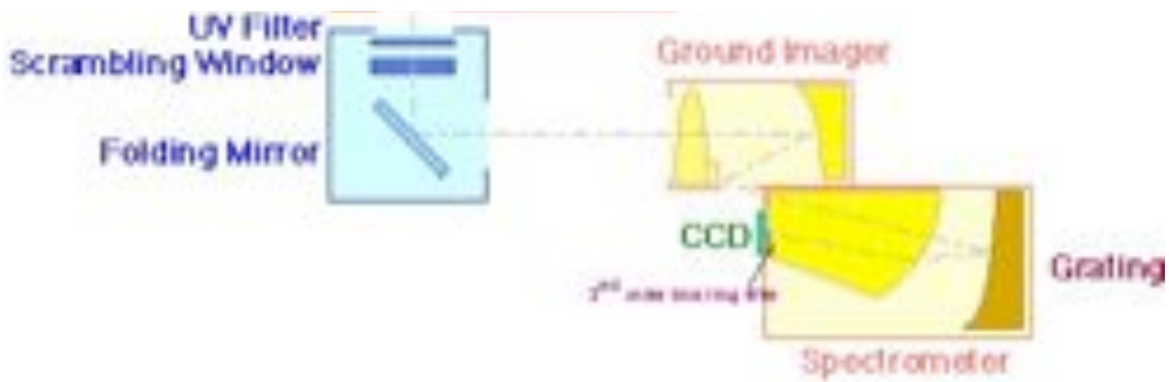
Radiometric Calibration



- Radiometric Calibration based on in-flight measurements
- Relies on Spectralon diffuser charateristion (pre-launch)
- Thuillier Solar Spectrum
- Uses the same radiometric model as in the L1 data processing



Calibration frequency

Diffuser-1: 15 days

Diffuser-2: 3 months

Diffuser-Er: 3 months peak 3

Diffuser-Er: 6 months peak 1

Radiometric Equation

$$X_{b,k,m,f} = NonLin_{b,m}\left[g(T_f^{VEU}).\left[A_{b,k,m}.\left(L_{b,k,m,f} + G_{b,k,m}(L_{*,*,*,f}) \right) + Sm_{b,k,m,f}(L_{b,k,m,*}) \right] + g_c(T_f^{CCD}).C^0_{b,k,m} \right].$$

$X_{b,k,m,f}$ is the MERIS raw sample
$NonLin_{b,m}$ is a non-linear function,
T_f^{VEU} is the amplification unit temperature,
T_f^{CCD} is the sensor temperature,
g(T) and **g_c(T)** are temperature dependent gain terms
$A_{b,k,m}$ the "absolute radiometric gain";
$L_{b,k,m,f}$ the spectral radiance distribution in front of MERIS;
$Sm_{b,k,m,f}$ the smear signal, due to continuous sensing of light by MERIS;
$G_{b,k,m}$ a linear process representing the stray light contribution to the signal. For a given sample, some stray light is expected from all the other simultaneous samples in the module, spread into the sample by specular (ghost image) or scattering processes.
$C^0_{b,k,m}$ the dark signal (corrected on board for temperature effects by the Offset Control Loop);

Radiometric Calibration

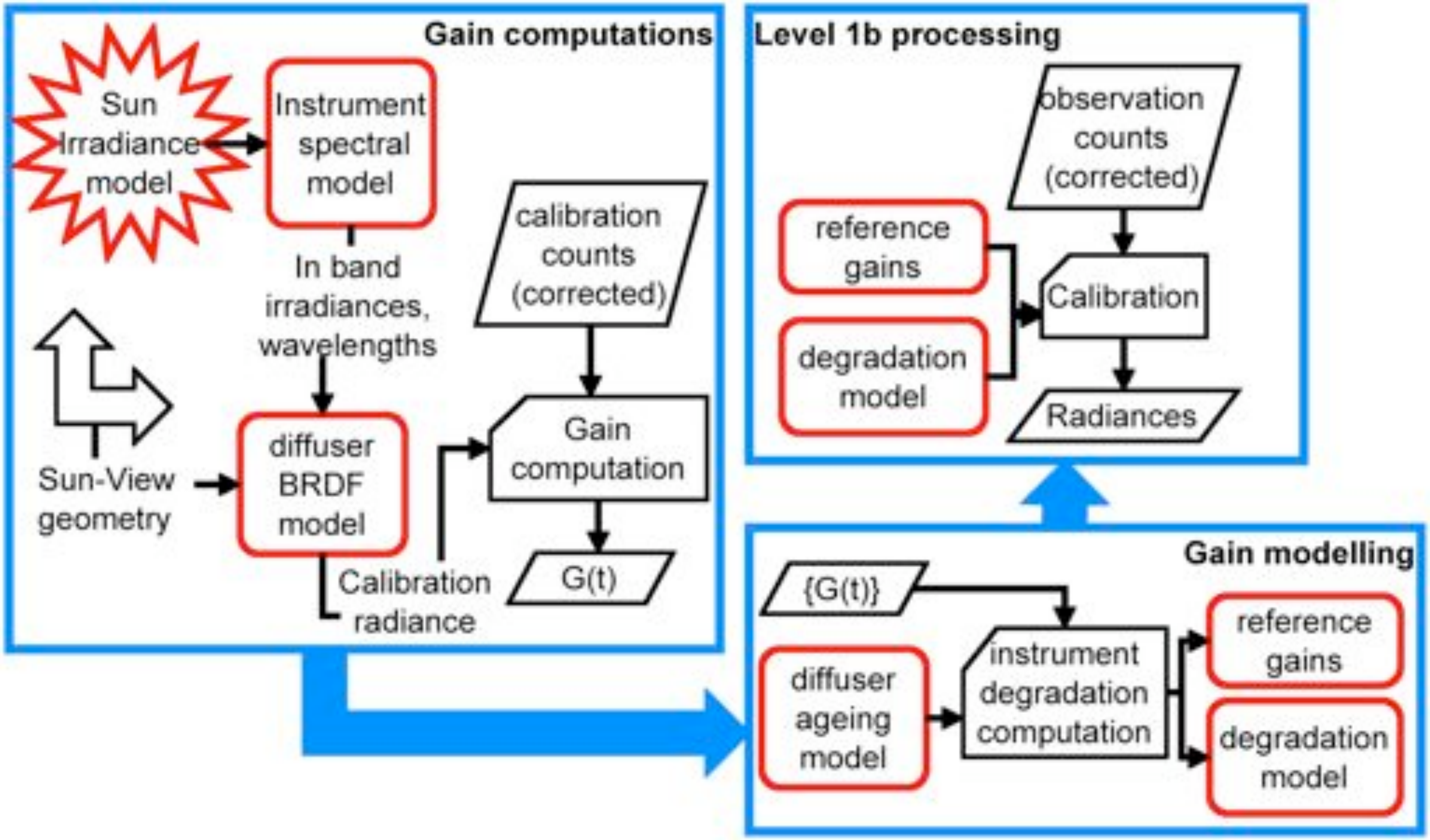
Principle

- Calibration provides instrument numerical counts $X_{cal}(l,k)$
- Instrumental corrections (non-linearity, dark offset, smear) yields $X'_{cal}(l,k)$
- Instrument Gain such as $X'_{cal}(l,k) = G(l,k).L_{cal}(l,k)$
- L_{cal} computed from $E_0(l)$, geometry and diffuser BRDF
  - Diffuser BRDF characterised on-ground
  - $E_0(l)$, from a model + seasonal variation
  - Geometry from orbitography and instrument pointing characterisation

- Space environment implies **ageing** of Diffuser and Optics
  - 2nd diffuser to monitor diffuser-1 BRDF ageing
    => Diffuser Aging model
  - frequent calibration to monitor Instrument degradation
    => instrument degradation model

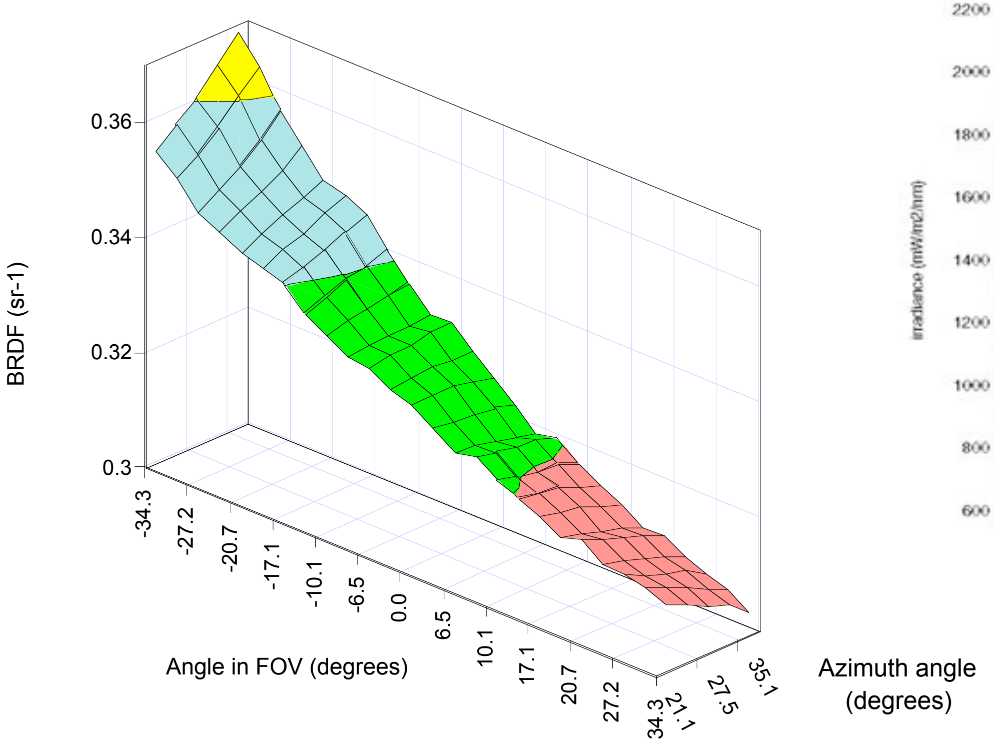
Radiometric Calibration

Method

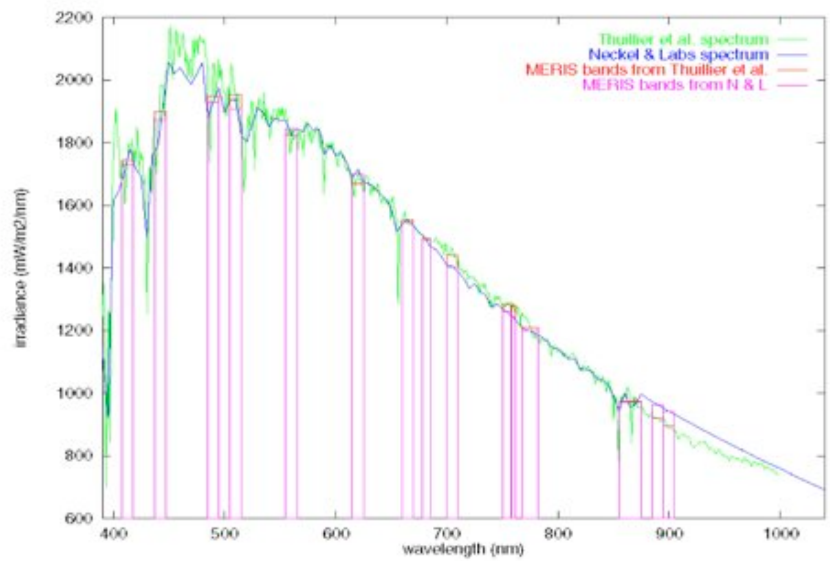


Radiometric Calibration

Key Inputs



On-ground characterisation of diffuser-1 @ 410nm

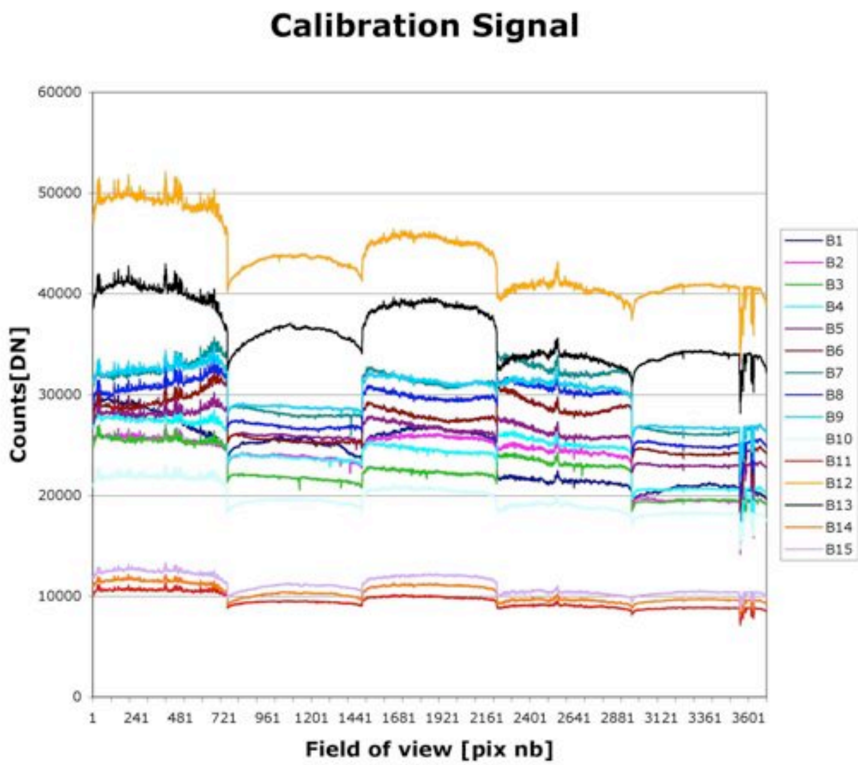


Comparison of in-band Extra terrestrial solar irradiance between Neckel & Labs and Thuillier et al.

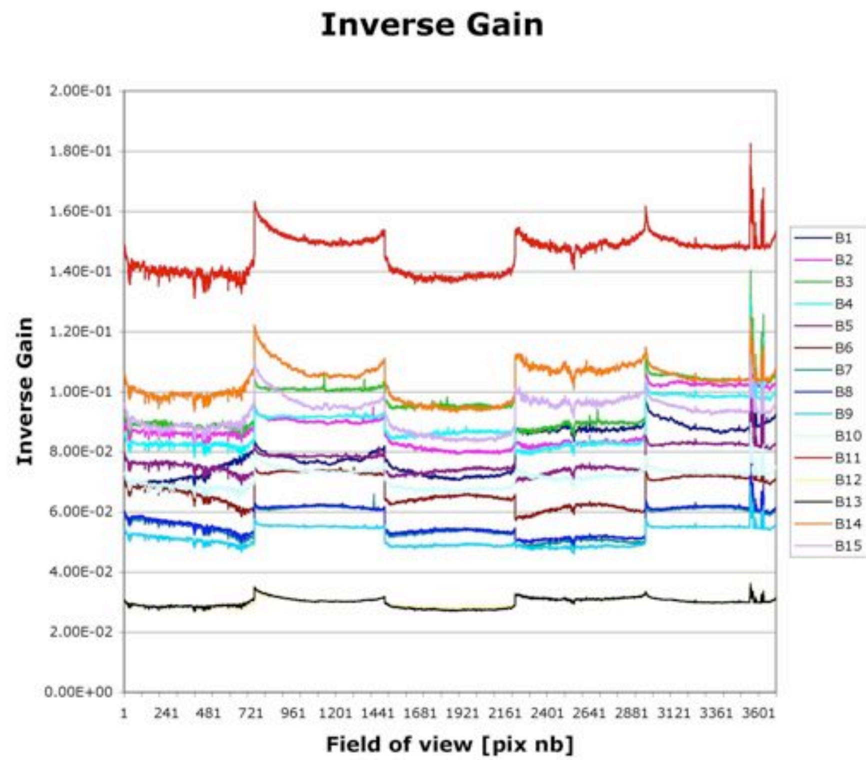
Details of the spectral model available in later slides

Radiometric Calibration

Results

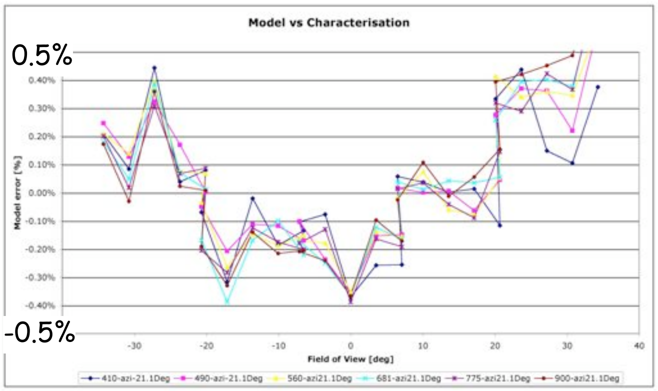


Radiometric Calibration raw digital counts

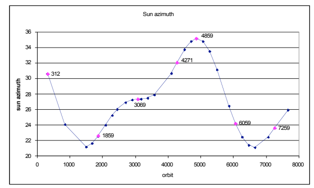


Corresponding Radiometric Gain Coefficients

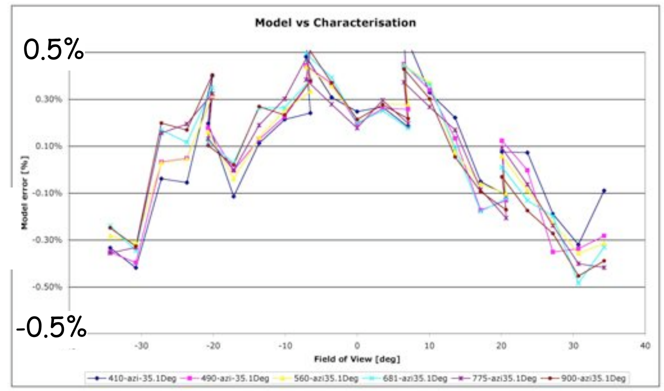
Diffuser Model Error



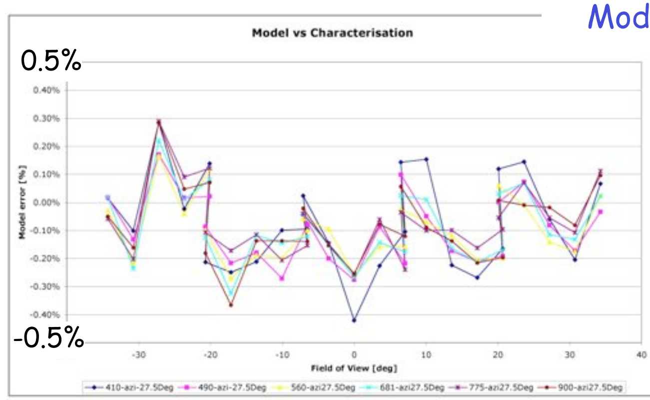
Model error at 21.1 deg azimuth



Azimuth illumination angle during calibration



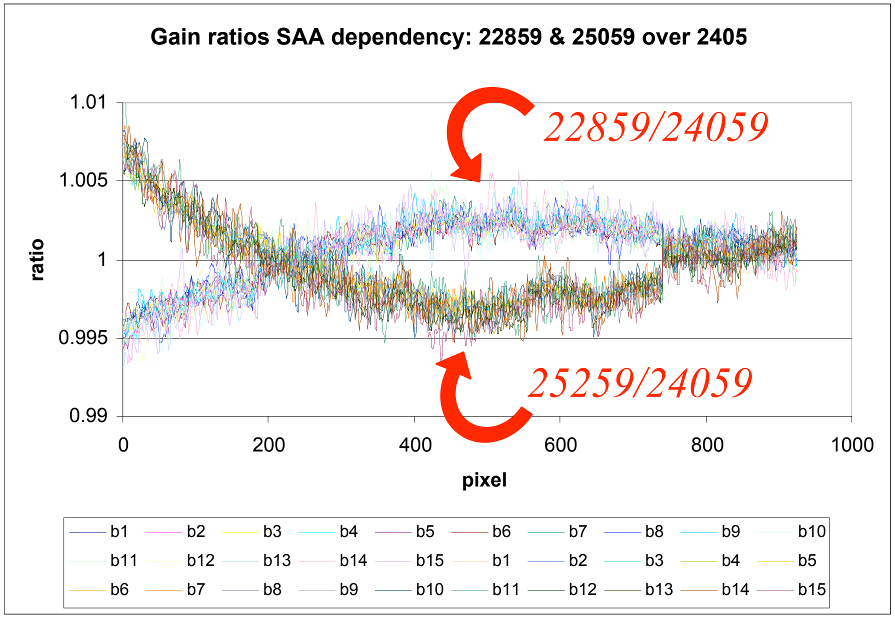
Model error at 35.1 deg azimuth



Model error at reference azimuth (27.5 deg)

Rahman H., Pinty B., Verstraete M.Couple surface-atmosphere model (CSAR) 2. Journal of Geophysical Research, D18, 20: pp455-468

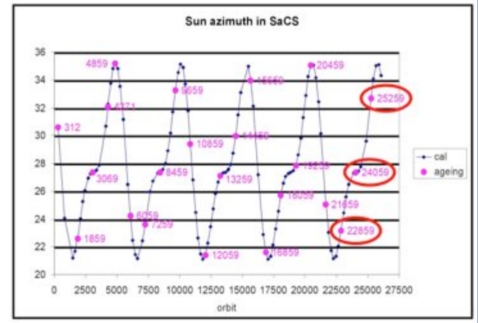
Characterisation Accuracy



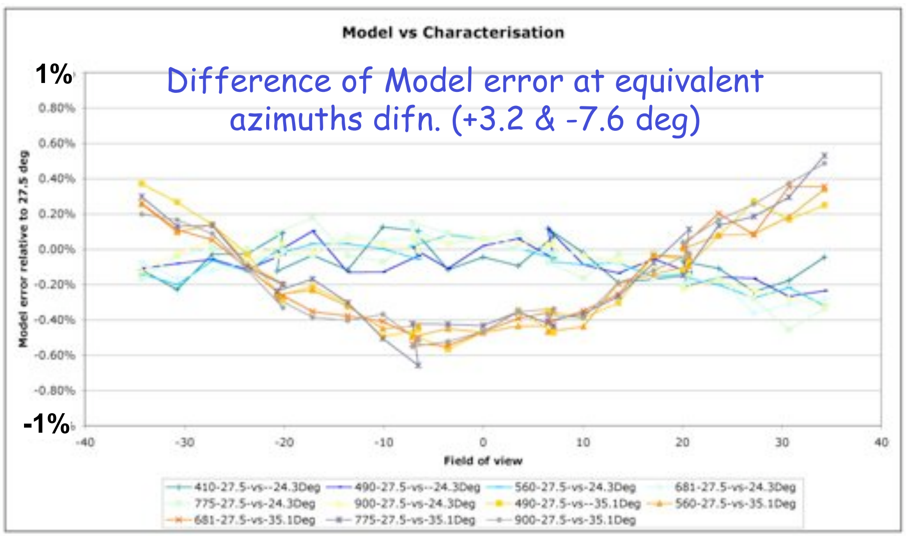
Azimuth differences

22859 to 24059 = +4.2deg

25259 to 24059 = -5.3 deg

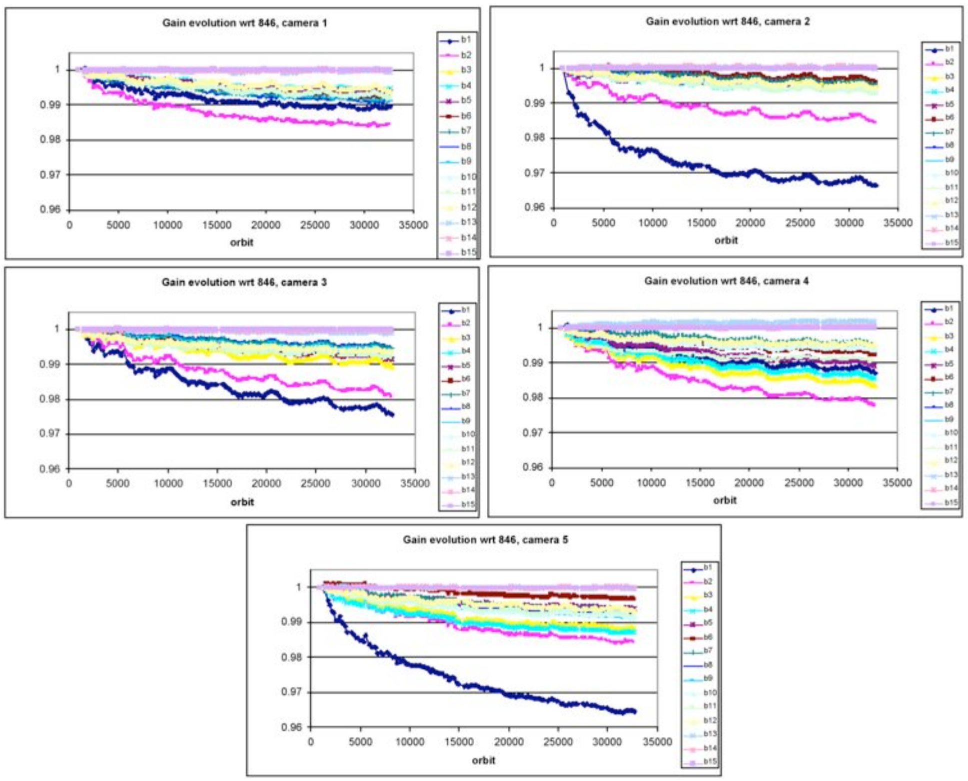


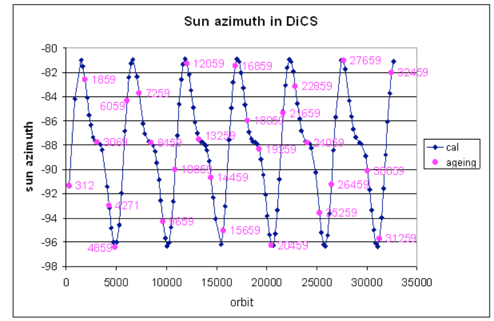
The ratio of gains computed at extreme azimuth illumination direction to that computed at the nominal azimuth illumination direction, show the limitation of the diffuser model to resolve the exact diffuser's BRDF azimuth dependence.



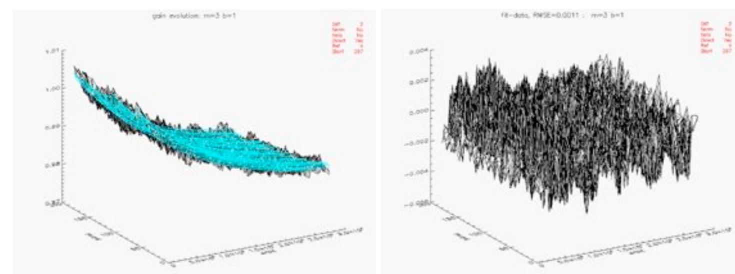
A very similar signature is seen when comparing model error relative differences using the most similar azimuth angular spreads available from the diffuser characterisation data set. This indicates that the BRDF measured on-ground, better capture the actual BRDF of the diffuser than the model used.

Instrument Degradation

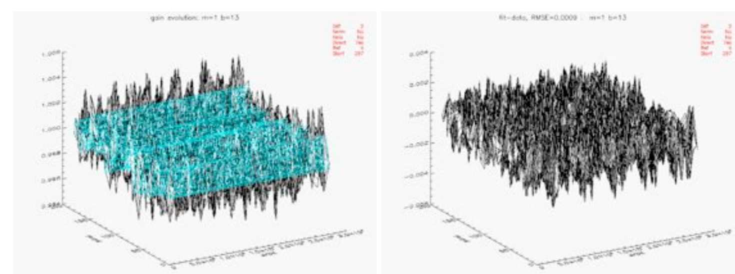




Diffuser illumination



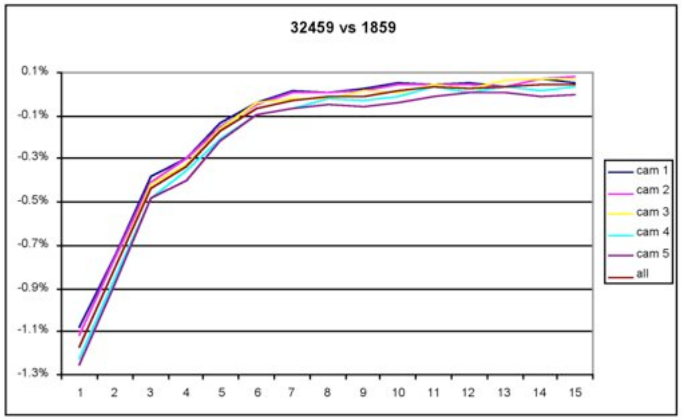
$$G(t) = G(t_0)\cdot\left(1-\beta\cdot\left(1-\gamma\cdot e^{-\delta t}\right)\right)$$



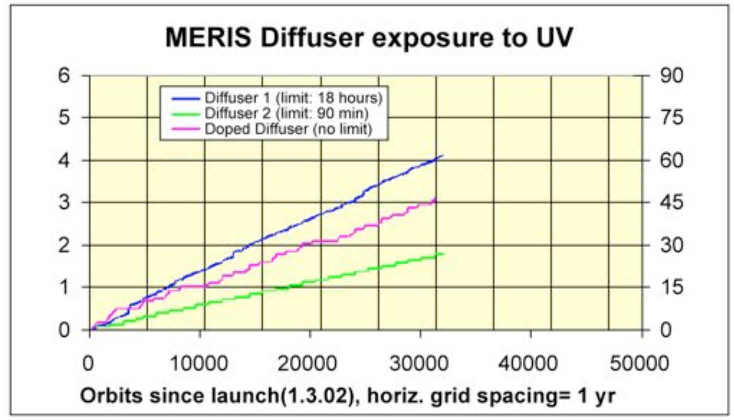
Maximum degradation of 3%
after more than 6 years in space

Degradation Model based
on the SeaWifs model (Barnes et al.)

Diffuser Aging



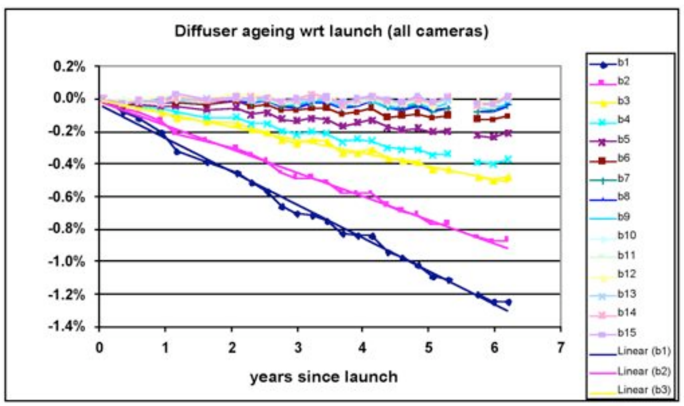
Degradation of Diffuser-1 vs Diffuser-2



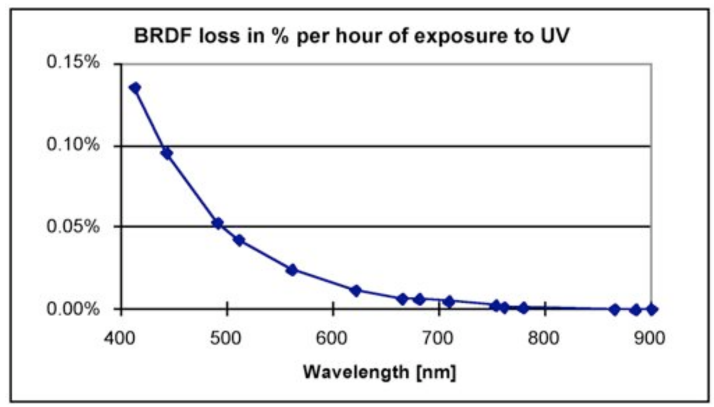
Diffuser's UV exposure

(Dif-1 [hrs], Dif-2 & doped[min])

Diffuser aging is <1.2 % after 6 years in space



Diffuser Degradation process is linear



Spectral behaviour of diffuser aging
(65 deg illumination)

Spectral Calibration

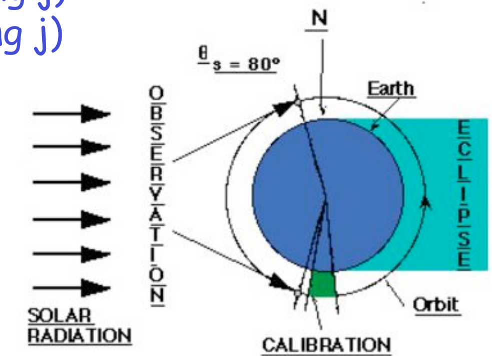
Overview

1. Diffuser based Spectral Calibration
   a) Spectral Features of Erbium doped diffuser
   b) Fraunhofer Lines on white diffuser

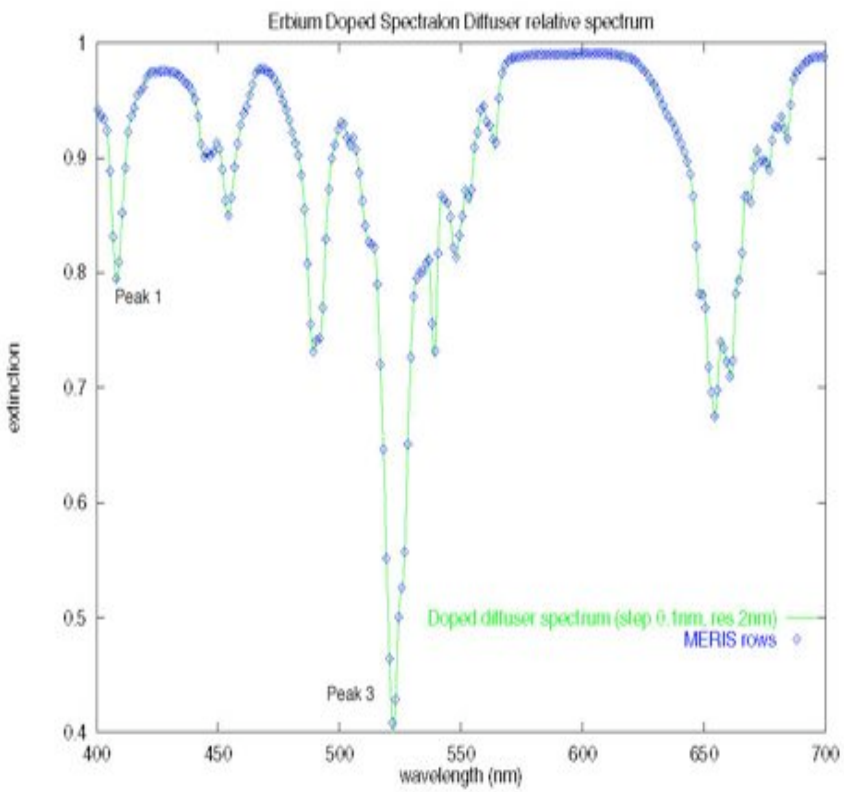
2. O2-A Spectral Campaigns
3. Spectral Stability
4. Instrument spectral model

Erbium Doped Diffuser

Acquisitions scenario:
Orbit n = Diffuser-1 Cal (Band setting j)
Orbit n+1 = Diffuser-Er (Band setting j)



"Pink" Diffuser Measurements

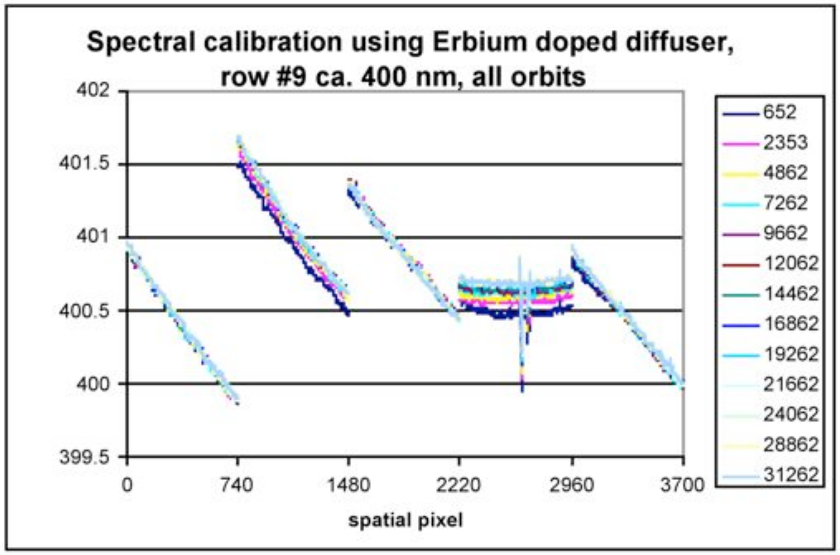


Erbium absorption spectrum

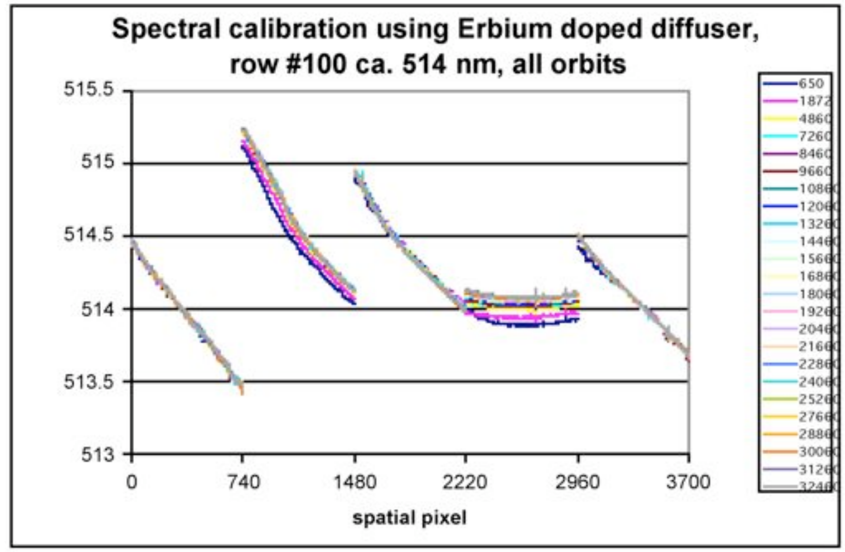
centre	width (nm)	centre	width (nm)
400.625	1.25	514.375	1.25
401.875	1.25	515.625	1.25
403.125	1.25	516.875	1.25
404.375	1.25	518.125	1.25
405.625	1.25	519.375	1.25
406.875	1.25	520.625	1.25
408.125	1.25	521.875	1.25
409.375	1.25	523.125	1.25
410.625	1.25	524.375	1.25
411.875	1.25	525.625	1.25
413.125	1.25	526.875	1.25
414.375	1.25	528.125	1.25
415.625	1.25	529.375	1.25
416.875	1.25	530.625	1.25
418.125	1.25	531.875	1.25

Band settings j

Erbium Results



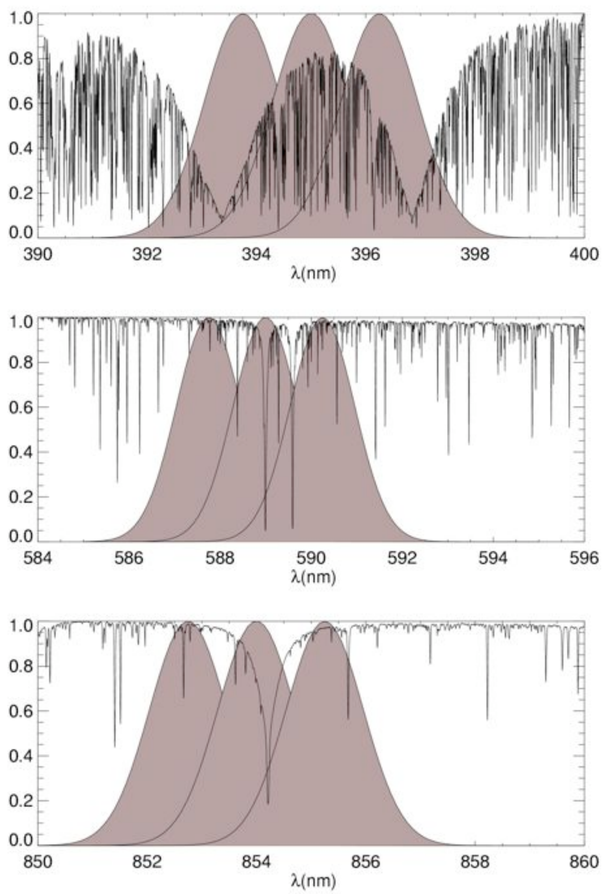
Erbium absorption peak 1



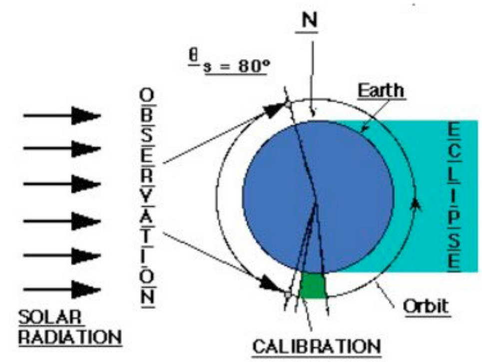
Erbium absorption peak 3

Method: Correlate measurements with reference spectrum, corrected for Air-Vacuum changes (Edlen law)

Fraunhofer Lines



Examples of Fraunhofer absorption spectrum
With MERIS spectral response overlay



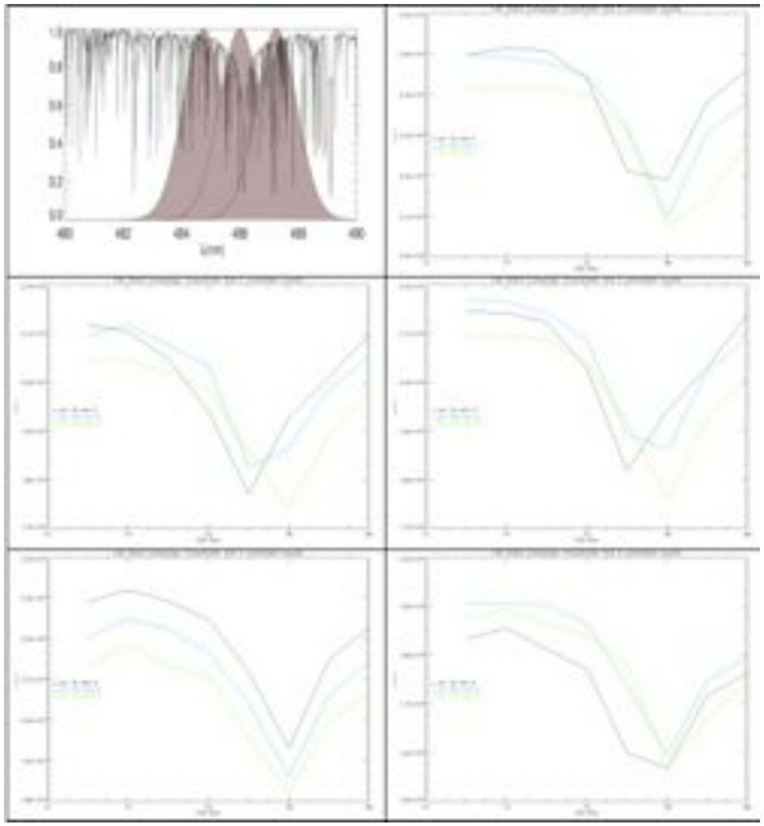
White diffuser-1 measurement

line 1 (393nm)	line 2 (485nm)	line 3 (588nm)	line 4 (655nm)	line 5 (855nm)	line 6 (867nm)
393.125	480.625	584.375	653.125	850.625	863.125
394.375	481.875	585.625	654.375	851.875	864.375
395.625	483.125	586.875	655.625	853.125	865.625
396.875	484.375	588.125	656.875	854.375	866.875
398.125	485.625	589.375	658.125	855.625	868.125
399.375	486.875	590.625	659.375	856.875	869.375
400.625	488.125	591.875	660.625	858.125	870.625
	489.375	593.125			

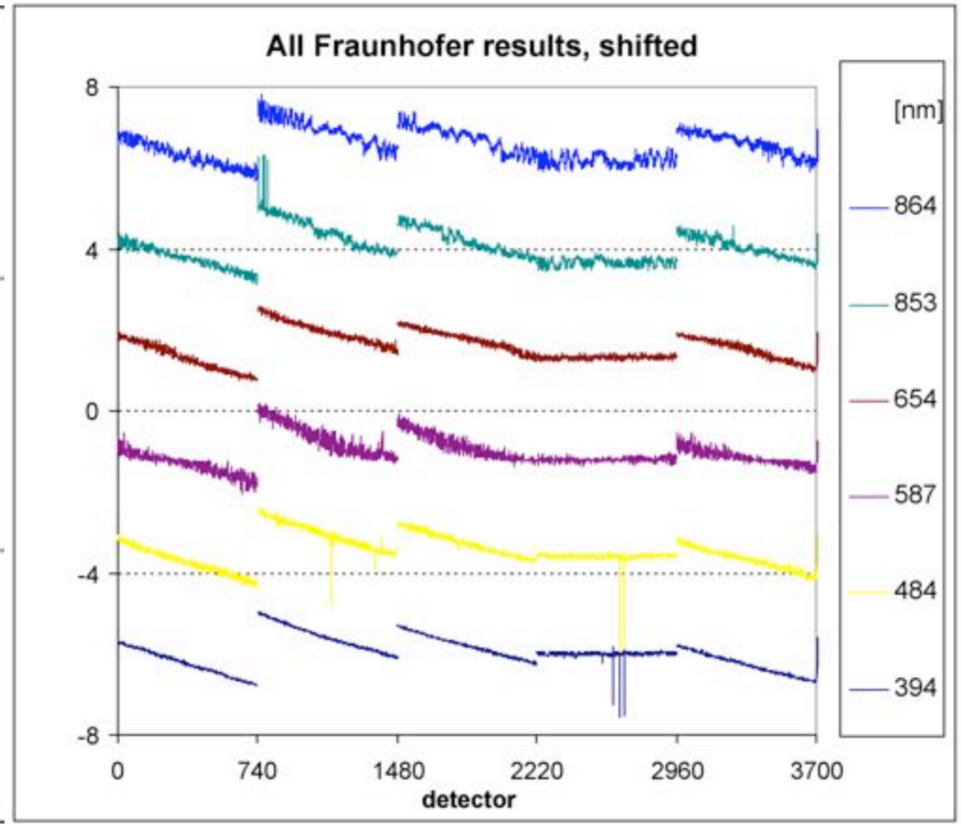
Band settings (3 configurations)

Fraunhofer Results

Line 2 Raw data: 5-cameras, 3 Fov



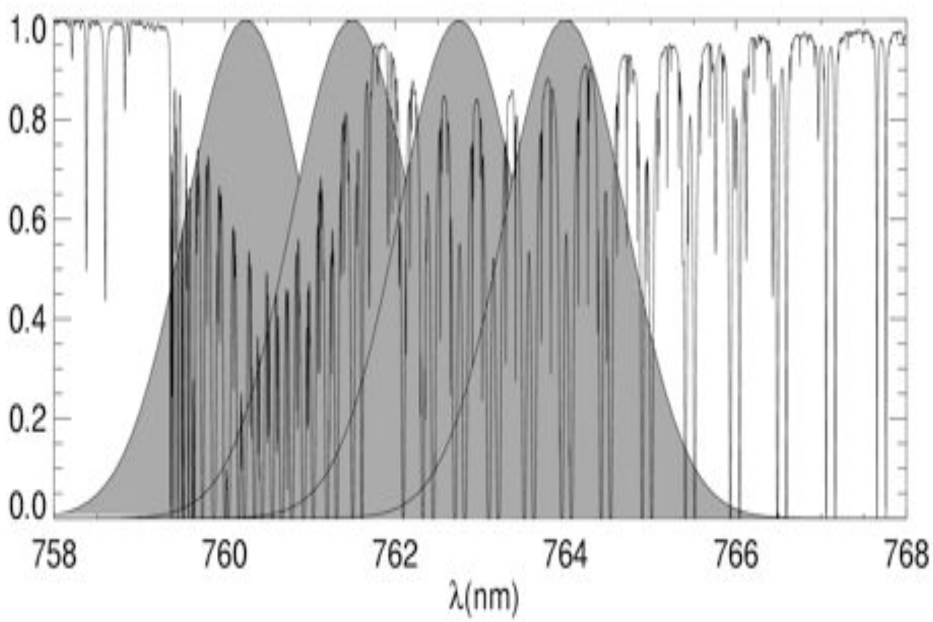
Results all Fraunhofer lines



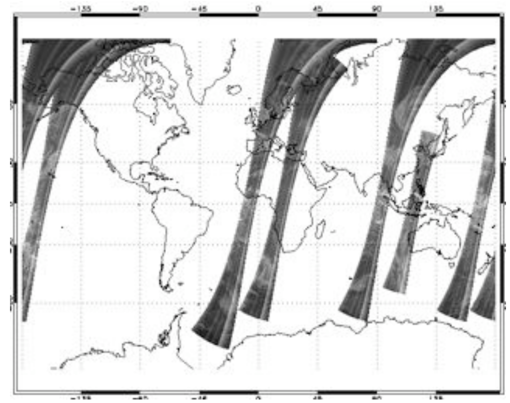
Method: Spectrum-matching, with correction for Air-Vacuum (Edlen)

Oxygen O2A

For three orbits every six months, MERIS is configured to observe in detail the O2A absorption features



Oxygen O2A absorption spectrum
MERIS spectral response overlay



Measurements over Natural target

name	centre	width (nm)
blue-2	442.5	10
red-1	665	10
ref-1	753.125	6.25
O2-0	758.125	1.25
O2-1	759.375	1.25
O2-2	760.625	1.25
O2-3	761.875	1.25
O2-4	763.125	1.25
O2-5	764.375	1.25
O2-6	765.625	1.25
O2-7	766.875	1.25
O2-8	768.125	1.25
O2-9	769.375	1.25
ref-2	778.75	7.5
IR-1	865	10

O2A Campaign Band setting

Oxygen O2A Results

2 Methods

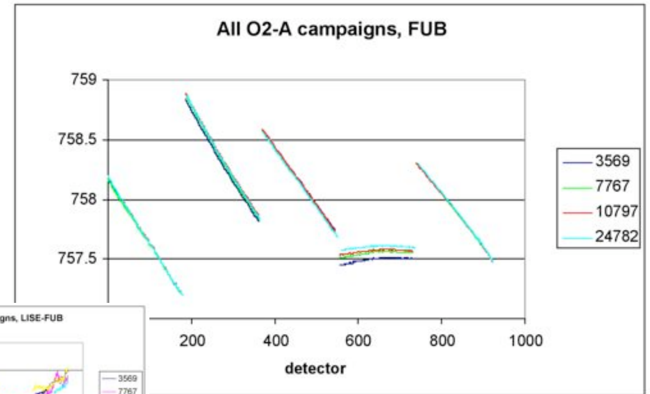
- A pressure minimization (LISE)

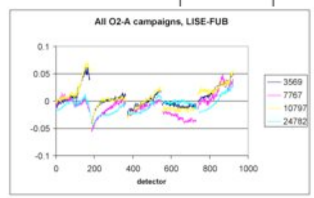
  Find the wavelength shift that minimises the dispersion in surface pressure retrieved from 7 O2A-campaign channels

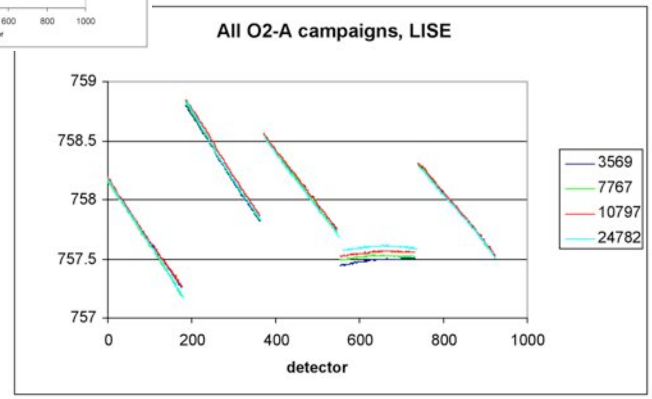
- Spectrum-matching (FUB)

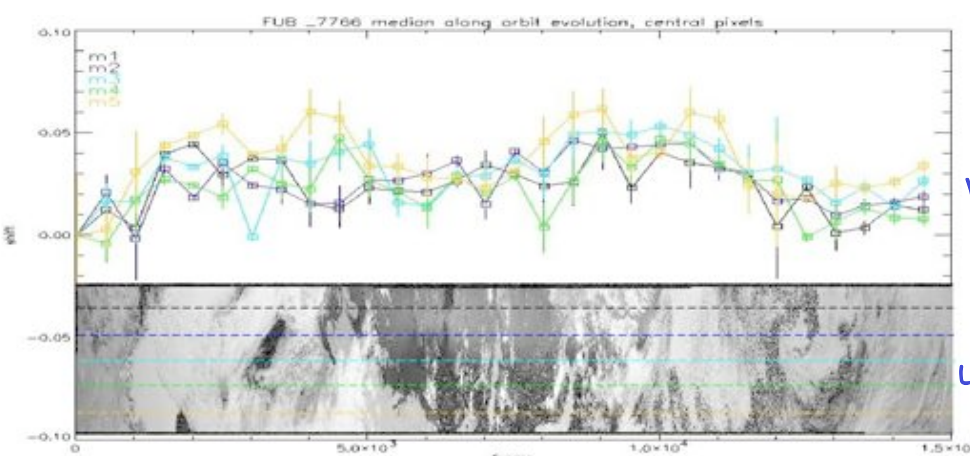
  Uses a neural net trained on a large number of radiative transfer computations

- Methods agree to better than 0.05nm)



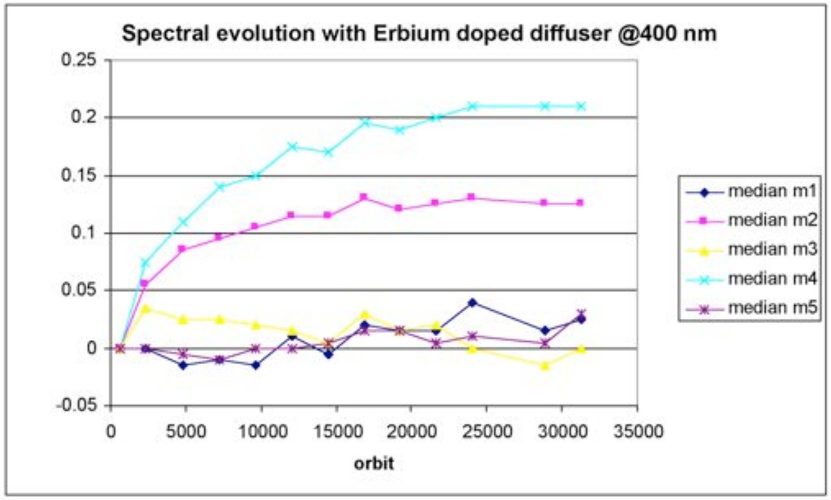


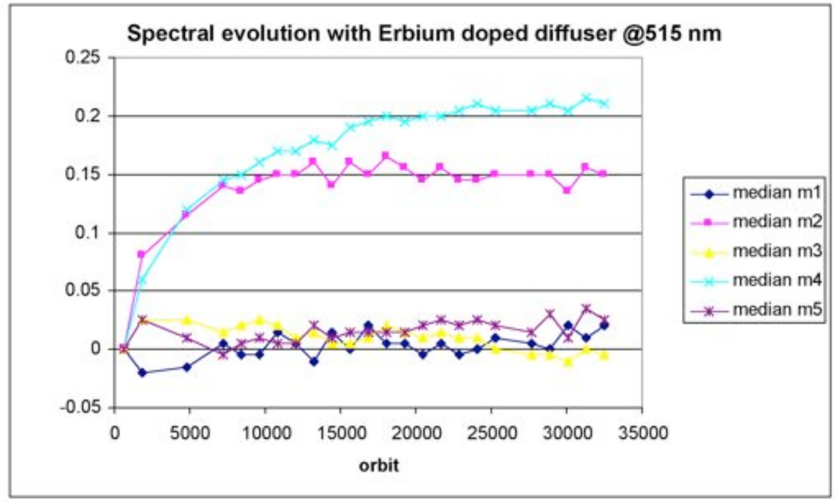




When using O2A results for absolute spectral calibration, great care should be taken in the selection of the scene to be analyzed as the absorption spectrum is very sensitive to the underlying surface and "air-mass" seen. Desert targets have been selected for MERIS.

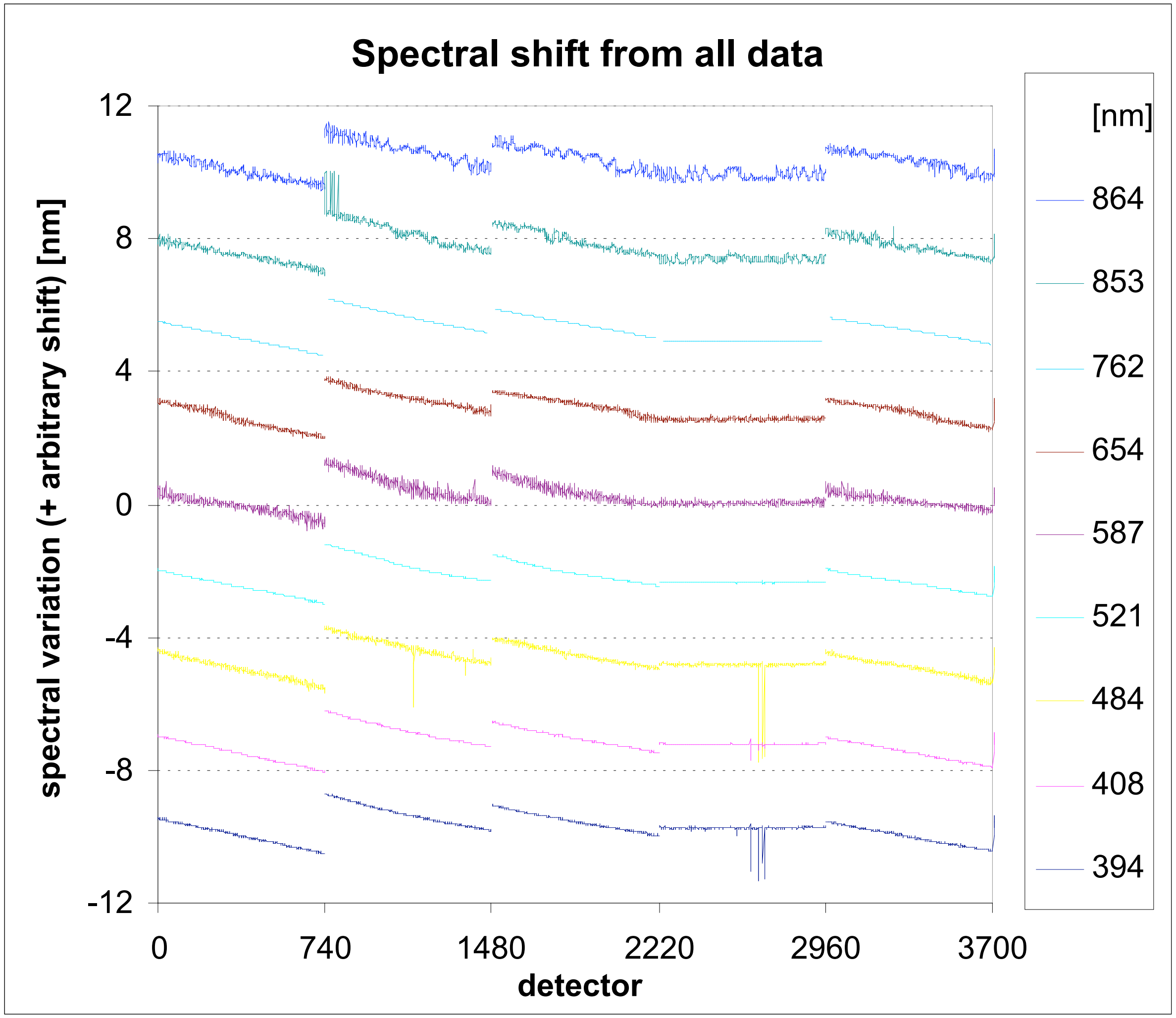
Spectral Stability



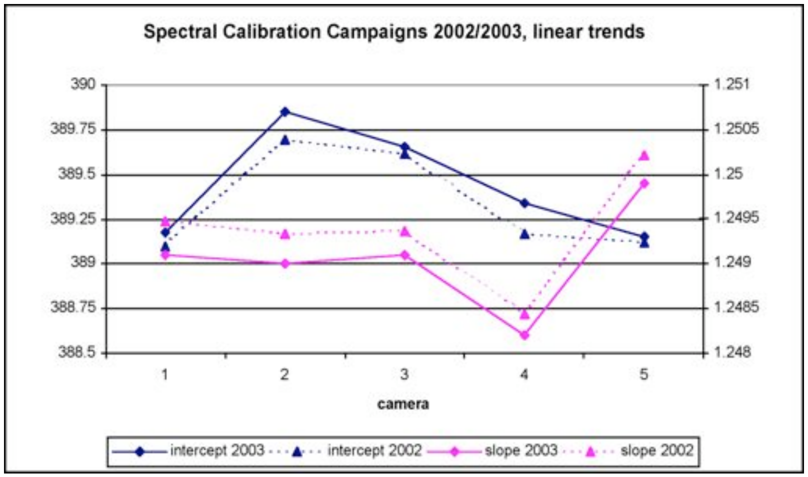


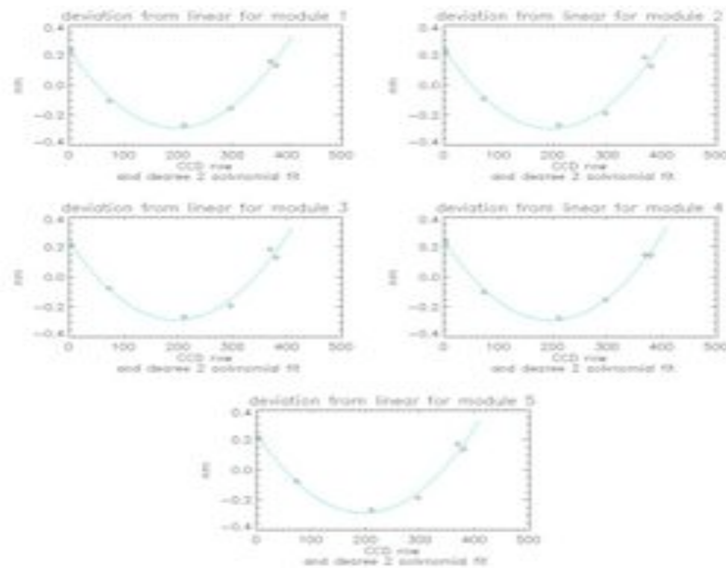
Camera 4 has stabilised with a spectral shift of 0.2 nm
Camera 2 has stabilised with a spectral shift of 0.14 nm
Similar results available using the O2A and Fraunhofer lines data
The shift is mainly wavelength independent
No spectral shift measured for Cameras 1,3,5 (all methods)

Results All Methods



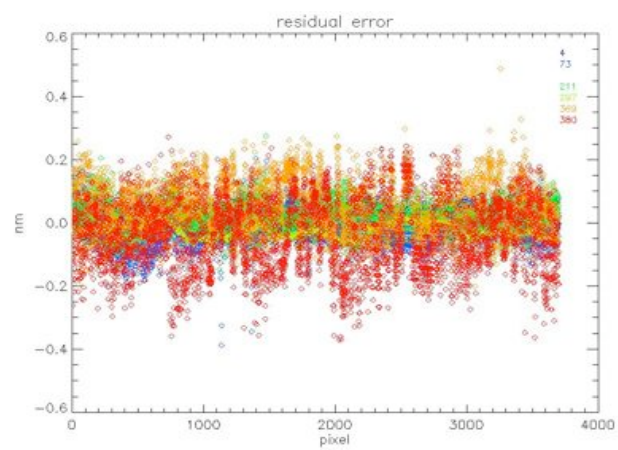
Instrument Model





$$\lambda(k,l) = \overline{\lambda}(l) + \Delta\lambda(k)$$

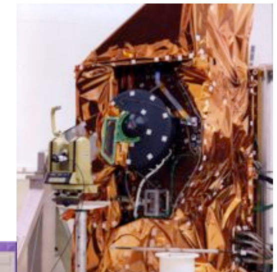
Simple instrument model where *k* and *l* stand for the spatial and spectral co-ordinates of a given detector respectively , the mean dispersion law –mainly linear– is a polynomial of order 3 (best fit), and, the across-track variation term, is a linear fit of the data at 395, 656 and 671nm expressed relative to its mean value



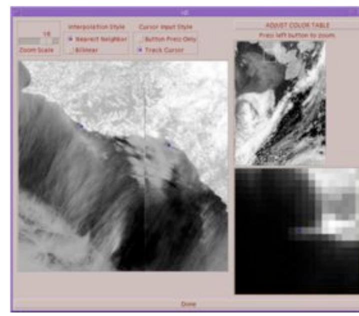
Geolocation Accuracy

ENVISAT
CARING FOR THE EARTH

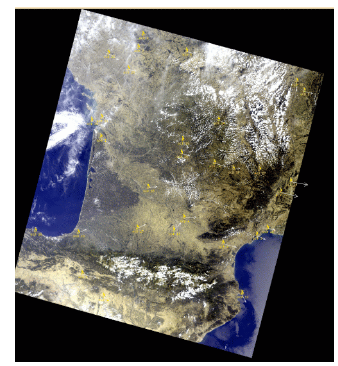
- On-Ground Charaterisation (Theodolite)
  Camera pointing - Instrument cube - s/c Cube



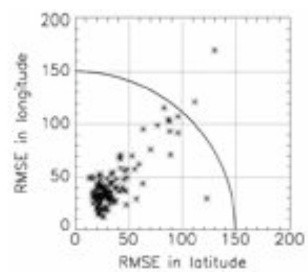
- On-Orbit Characterisation (GCP)
  Update of the rotation matrix (Ins-s/c)
  => Accuracies of ± 132m (Lat) and ± 165 m (lon).
  => RMS 212 ± 22 meters (incl. nearest neighbourg)



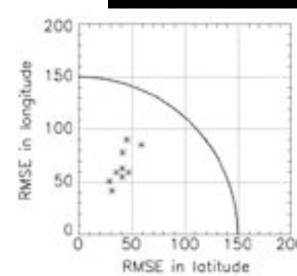
80 Targets over UK & Netherlands
- Roll mispointing = 0.0251 deg
- Pitch mispointing = -0.0022 deg
- Yaw mispointing = 0.0247 deg



- GCP on orthogeolocated data:
  Update of camera pointing
  => Orthogeolocated absolute geolocation accuracy 77.1 m
  => Scene to scene co-registration 51.6 m
  (Globecover paper IGARSS 2007)



Relative RMS errors [m]



Absolute RMS errors [m]

Full Resulution Full Swath

Orthogeolocated products

New Product to be available …
See H. Laur presentation