OZONE MONITORING INSTRUMENT (OMI) IN-FLIGHT CALIBRATION AND PERFORMANCE

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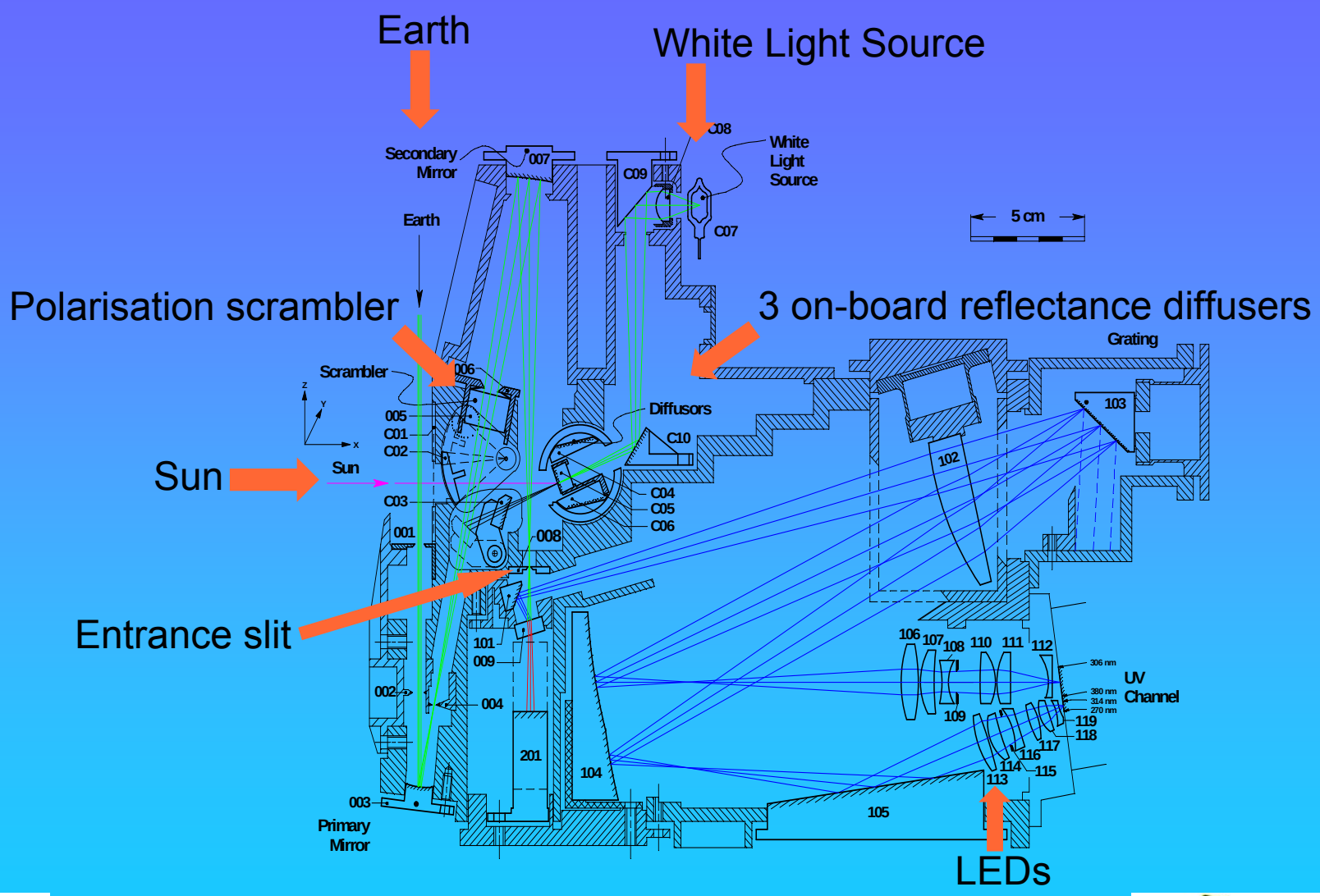
Contents of the presentation

- OMI instrument
- In-flight performance and calibration results:
  - Radiometric calibration:
    - Solar irradiance
    - Optical stability
  - Spectral calibration
- Conclusions

The OMI Instrument

- Telescope with 115 degrees cross-flight-direction field of view
- CCD's → small ground pixels of 13×12 km^2
- Daily global coverage with high spatial resolution
- Wavelength range 264-504 nm

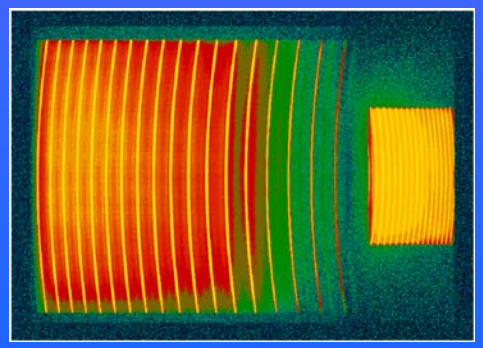
OMI optics: UV channels and telescope



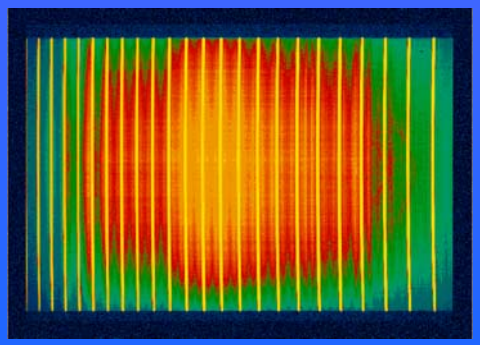
OMI instrument characteristics

	Wavelength range (nm)	Resolution / sampling (nm)	Global (binning 8) (km^2)	Spatial zoom-in (binning 4) (km^2)
UV1	264-311	0.63 (0.33)	13 × 48	13 × 24
UV2	307-383	0.42 (0.14)	13 × 24	13 × 12
VIS	349-504	0.63 (0.21)	13 × 24	13 × 12

Dimensions of each CCD detector: 580 rows x 814 columns
Rows binned to 60 image rows (binning factor 8)
In-flight temperature of optical bench and CCD detectors: 265 K



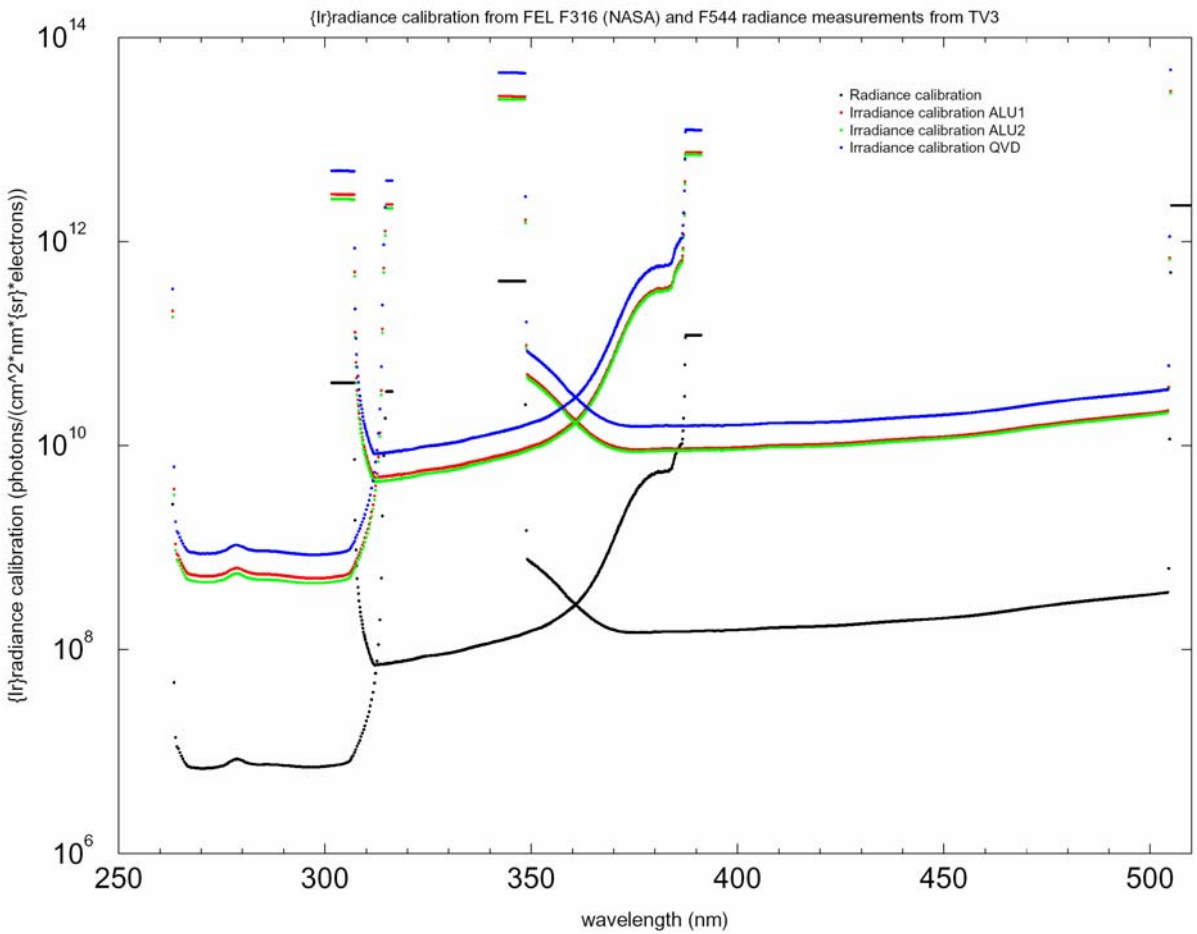
UV



VIS

OMI in-flight calibration and performance

Pre-launch (Ir)radiance calibration results nadir viewing



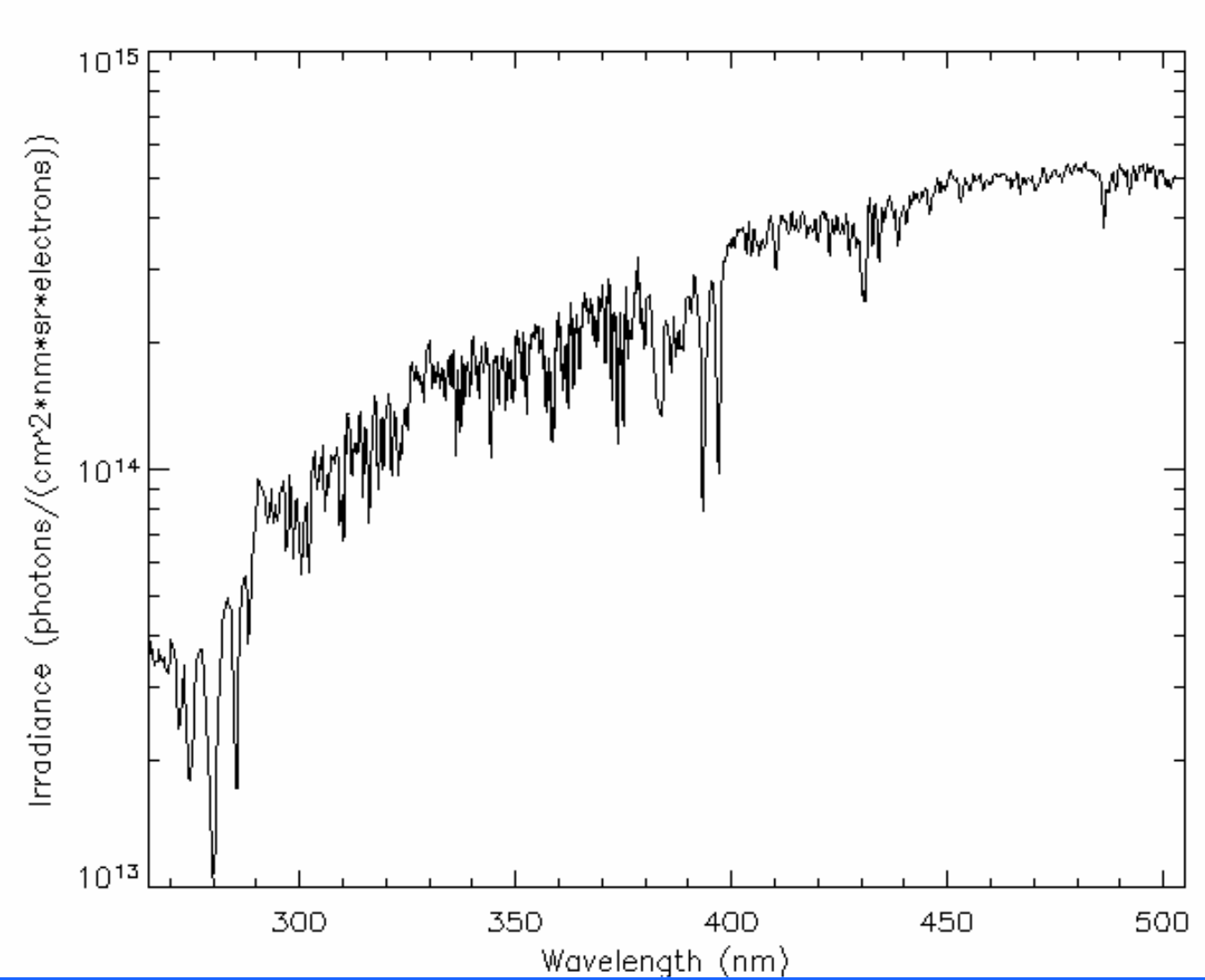
Irradiance calibration

- Comparison measured in-flight irradiance with literature high-resolution solar spectrum convolved with spectral slit functions.

- Spectral slit functions have been accurately calibrated on the ground as a function of viewing angle and wavelength.

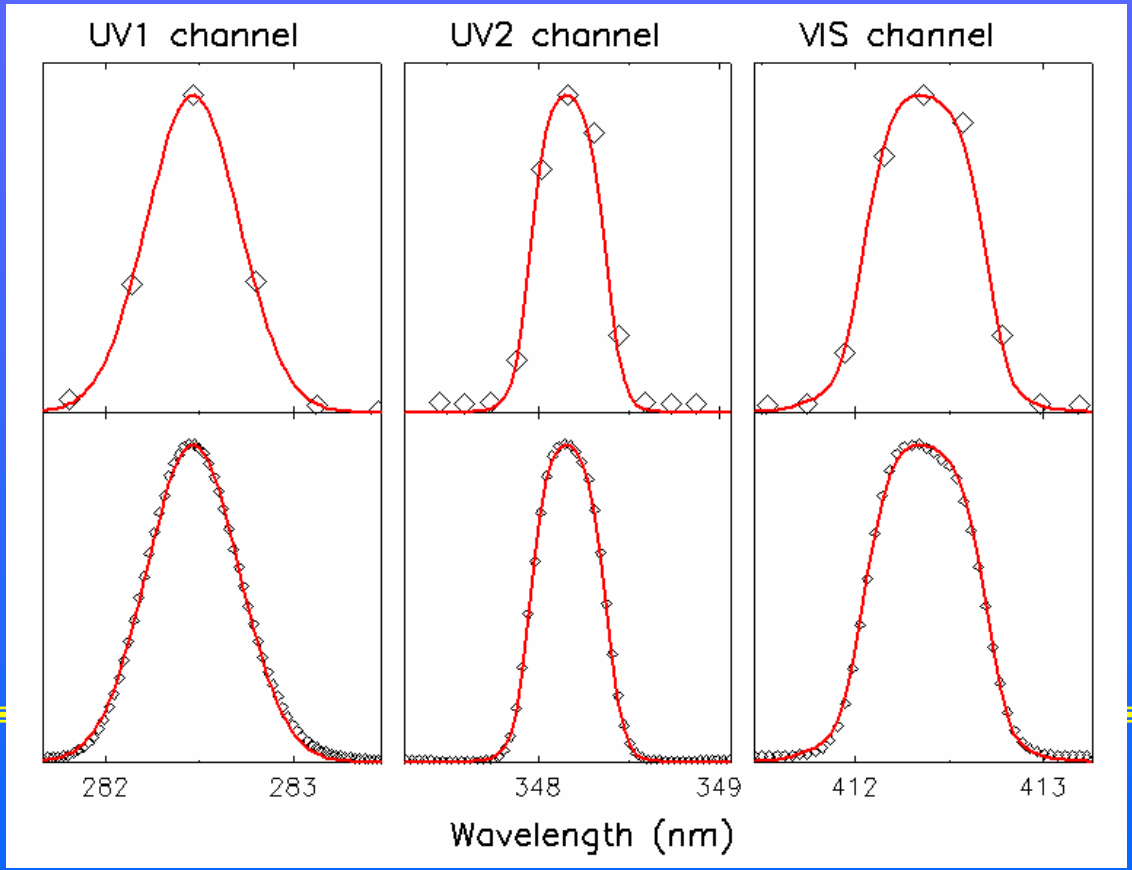
- Residual structure may be due to errors in:
  - OMI radiometric (irradiance) calibration.
  - Spectral calibration.
  - Spectral slit functions.
  - Literature high-resolution solar spectrum.

Irradiance example measured by OMI



Spectral slit functions

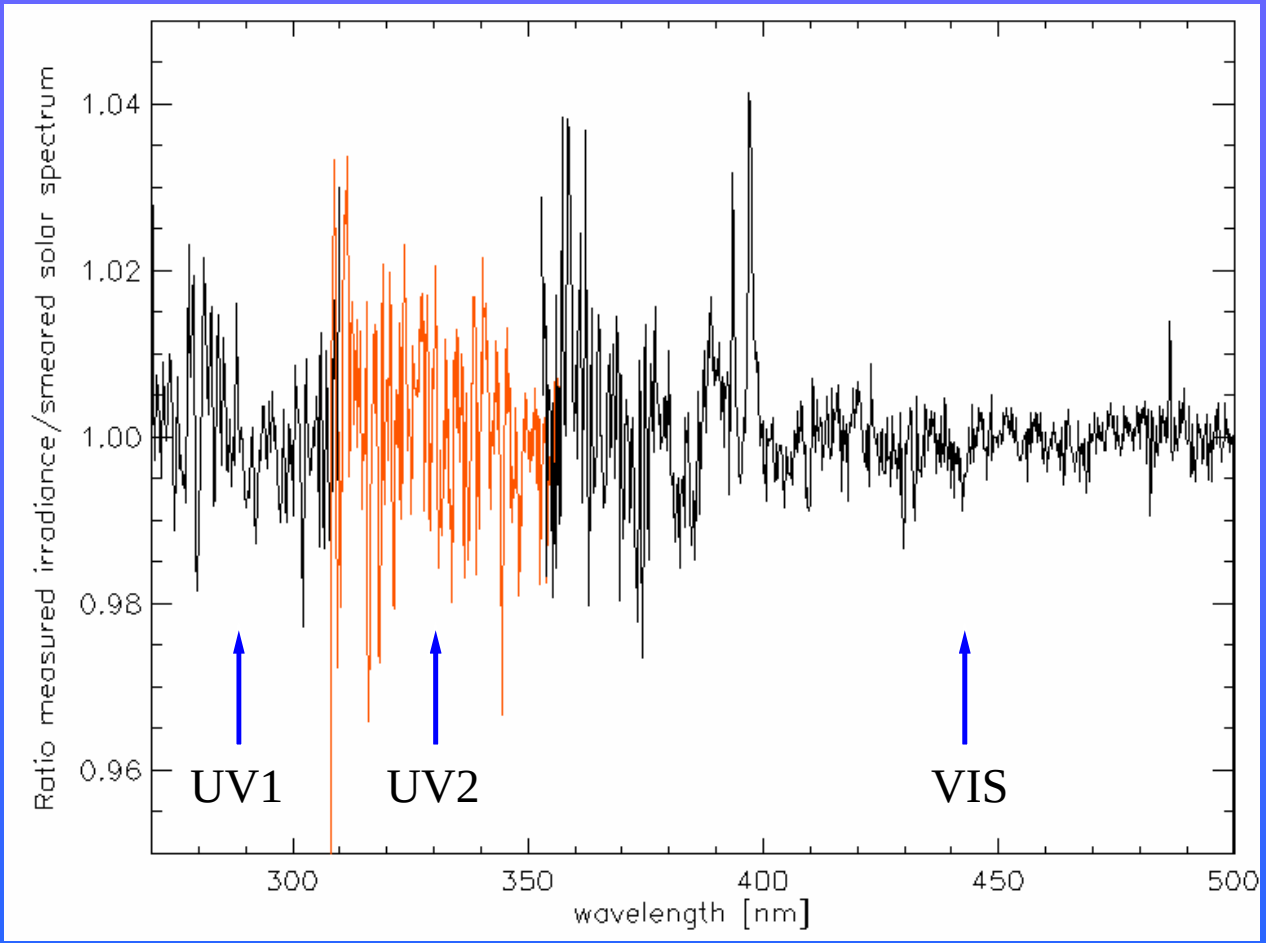
- OMI's spectral slit functions have been accurately calibrated on the ground, as function of wavelength and viewing angle.
  - Using dedicated echelle grating optical stimulus.
  - Necessary for DOAS type instrument (trace gas retrievals).
  - Necessary for accurate in-flight calibration.



Sampling of OMI instrument

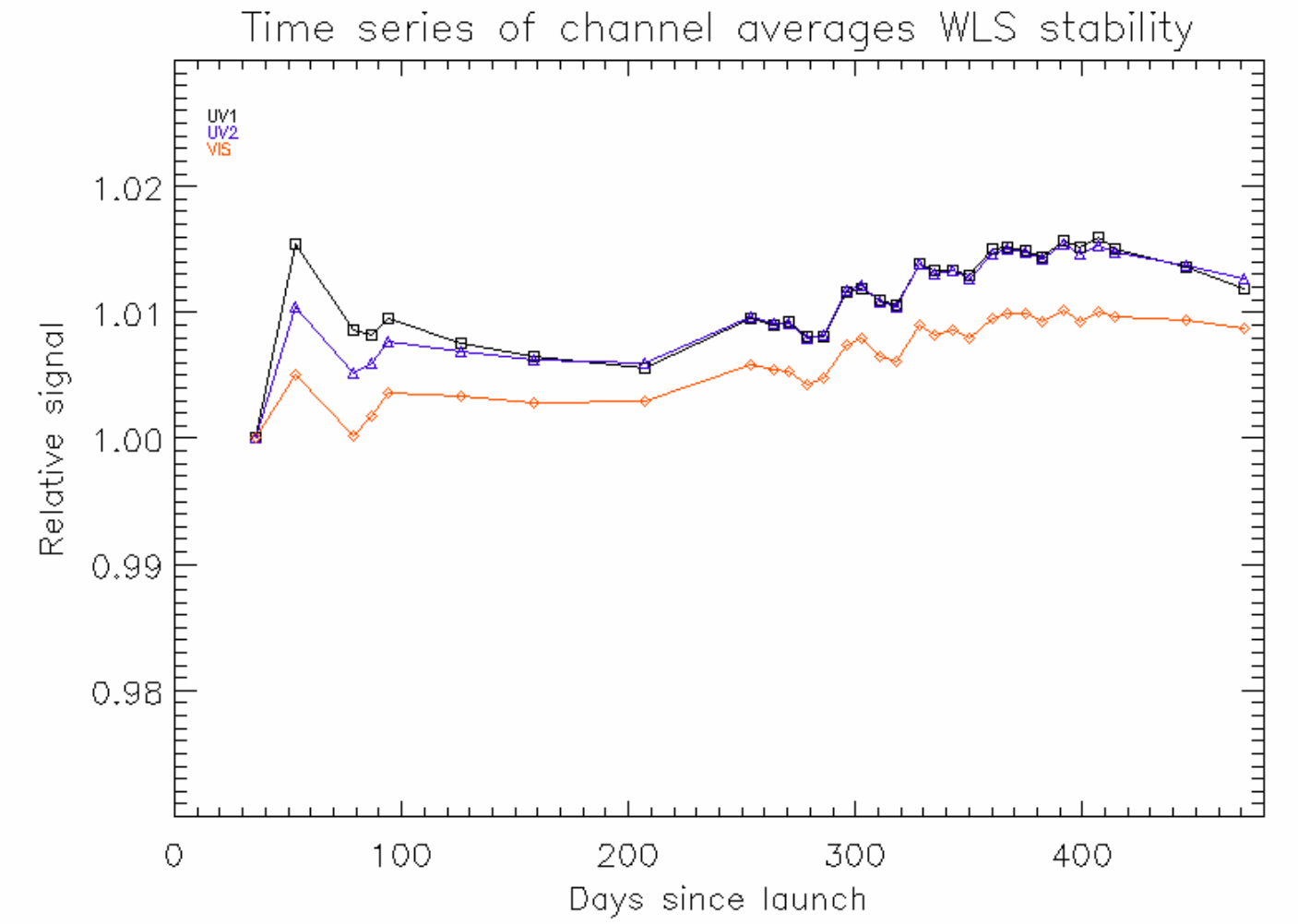
Sampling of slit function measurements

Irradiance calibration



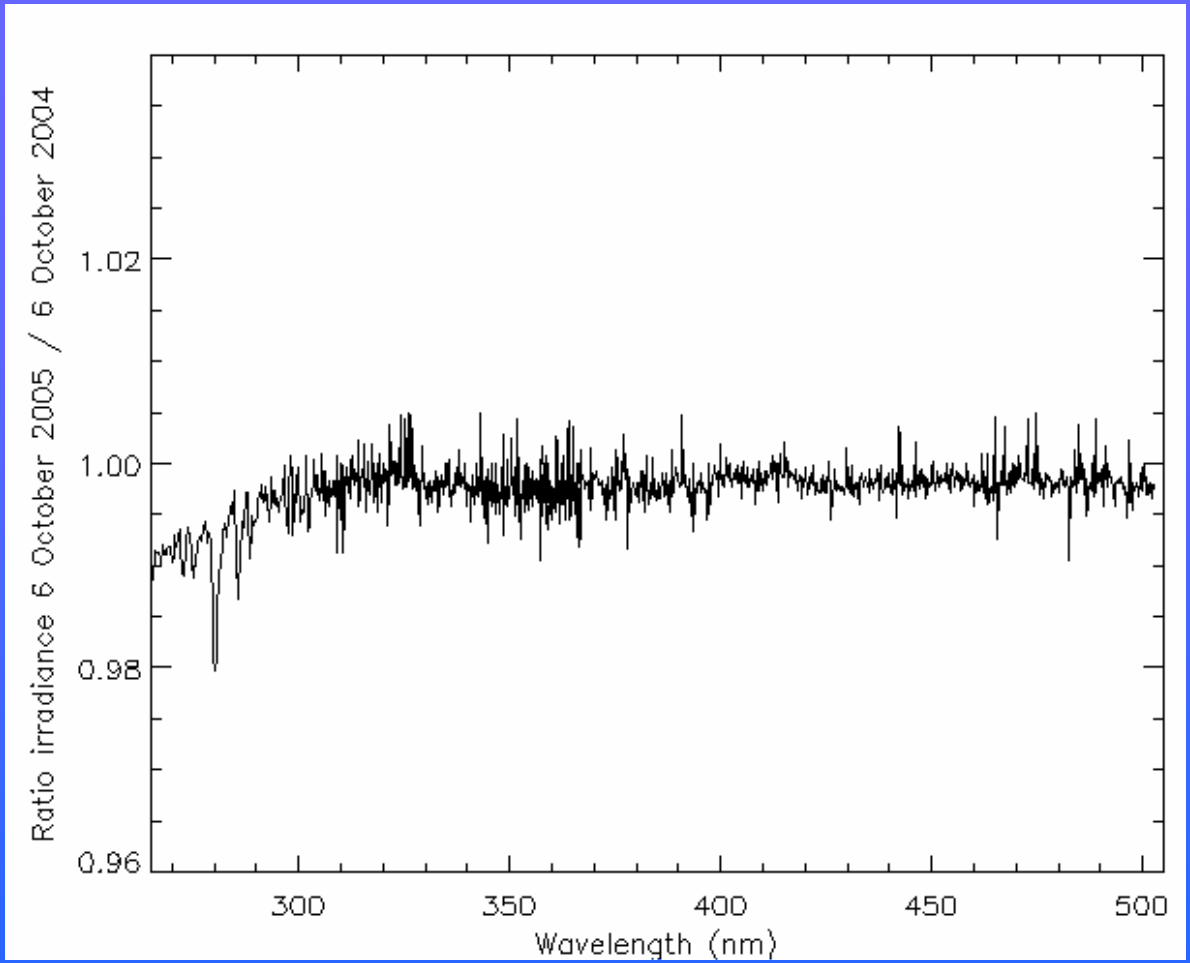
Measured irradiance from orbit 2465, 31 December 2004.

Optical stability from WLS



- From launch to launch + 15 months.

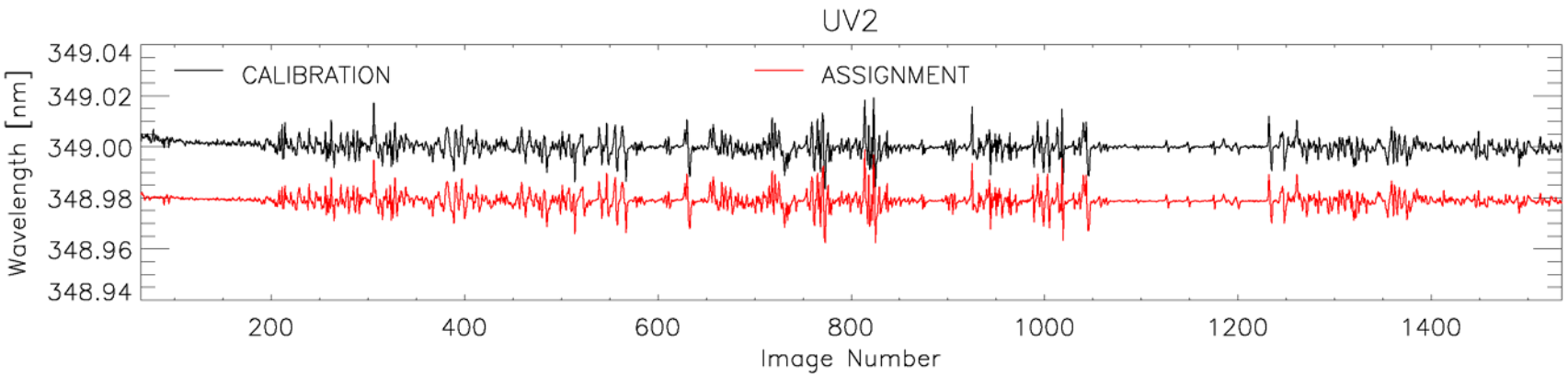
Optical stability from irradiance



Spectral stability (long-term and within one orbit) is very good.

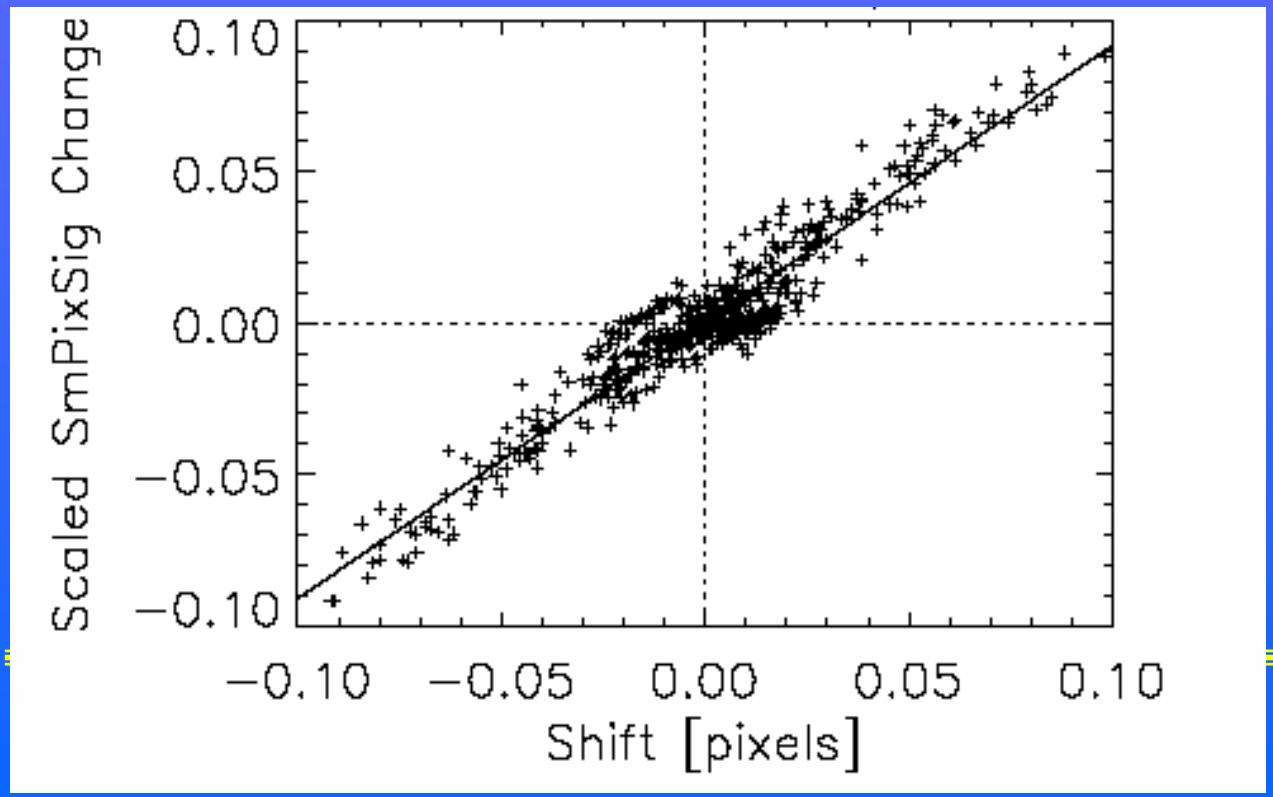
Spectral calibration: problem

- Shifts of up to 0.5 px are observed in the in-flight spectral calibration for Earth measurements.
- Goal accuracy for spectral calibration is 0.01 px.
- Shifts are correlated with inhomogeneous filling of the spectrometer's entrance slit, resulting from observation of inhomogeneous ground scenes (e.g. clouds).



Spectral calibration: solution

- Small-pixel columns are read out at a 4-5 times higher frequency than the complete images.
- One small-pixel column per CCD.
- Correlation between wavelength calibration and small-pixel signals.
- Use this correlation to improve spectral calibration accuracy to the goal accuracy of about 0.01 px (about 0.002 nm).



Calibration keydata, status level-1B products

- Improved calibration keydata starting and 0-1 data processing from 7 October 2005:
  - Absolute radiometric (ir)radiance calibration
  - Irradiance goniometry
  - Spectral calibration / assignment
  - Spectral slit functions
  - Electronic non-linearity (using in-flight LED measurements)
  - Transient pixel flagging

- Provisional release of level-1B radiance and irradiance data for validation in November 2005.

Conclusions

- OMI is working well and stable in flight.
- OMI in-flight performance and calibration is as expected from pre-launch testing.
- For new features discovered in flight, corrective measures have been (are being) defined and implemented.
  - Variation in detector dark current.
  - Improve dark signal correction using dark measurements from same orbit as light measurements.
  - Swath angle dependency of irradiance.
  - Instrument response at low signals.
  - Etc.

OMI calibration team

• Quintus Kleipool	KNMI
• Ruud Dirksen	KNMI / SRON
• Robert Voors	KNMI
• Werner Dierssen	KNMI / TriopSys
• Johan de Vries	DS
• Glen Jaross	NASA / SSAI
• Matt Kowalewski	NASA / SSAI
• Marcel Dobber	KNMI

More information:

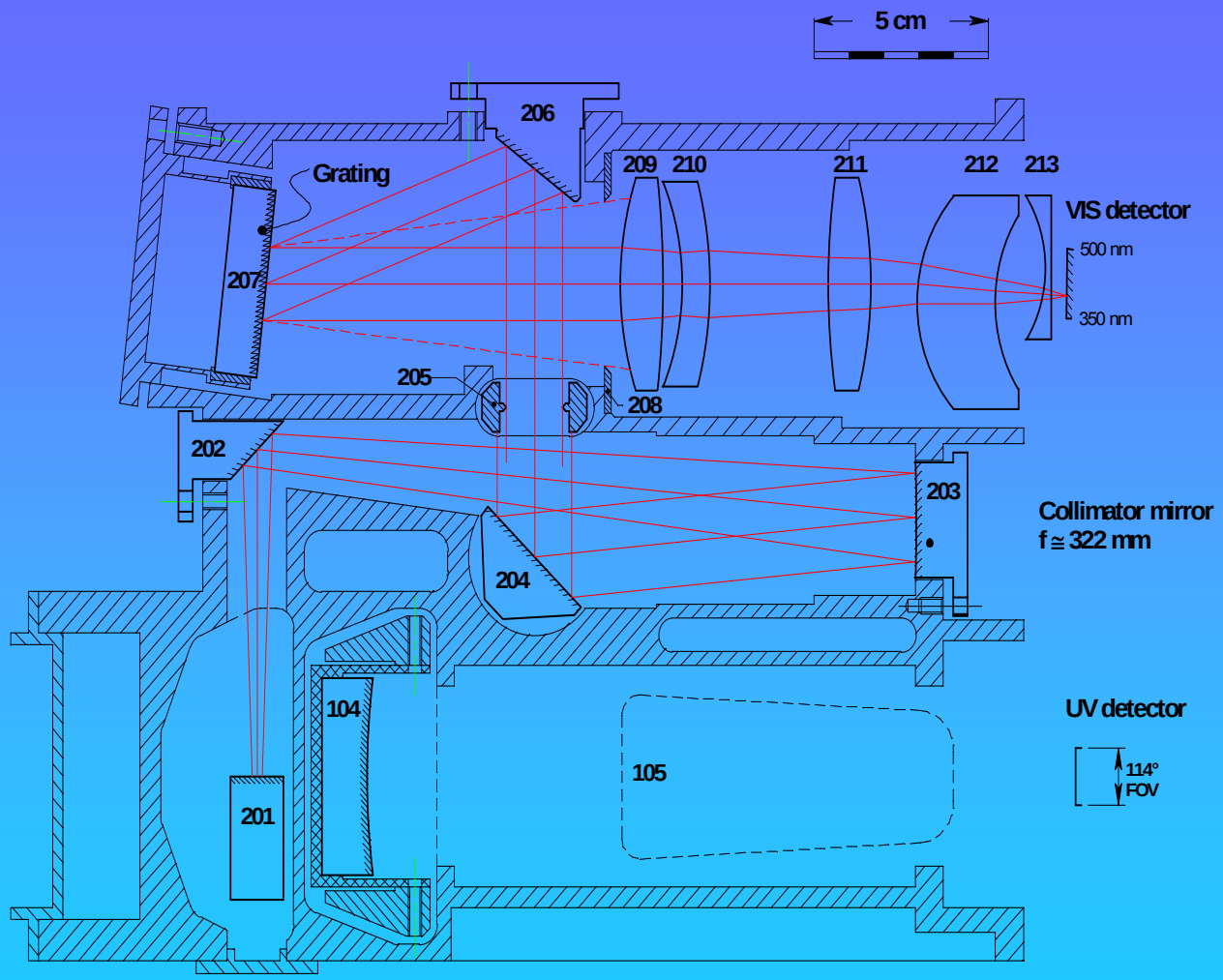
Links:

OMI http://www.knmi.nl/omi/

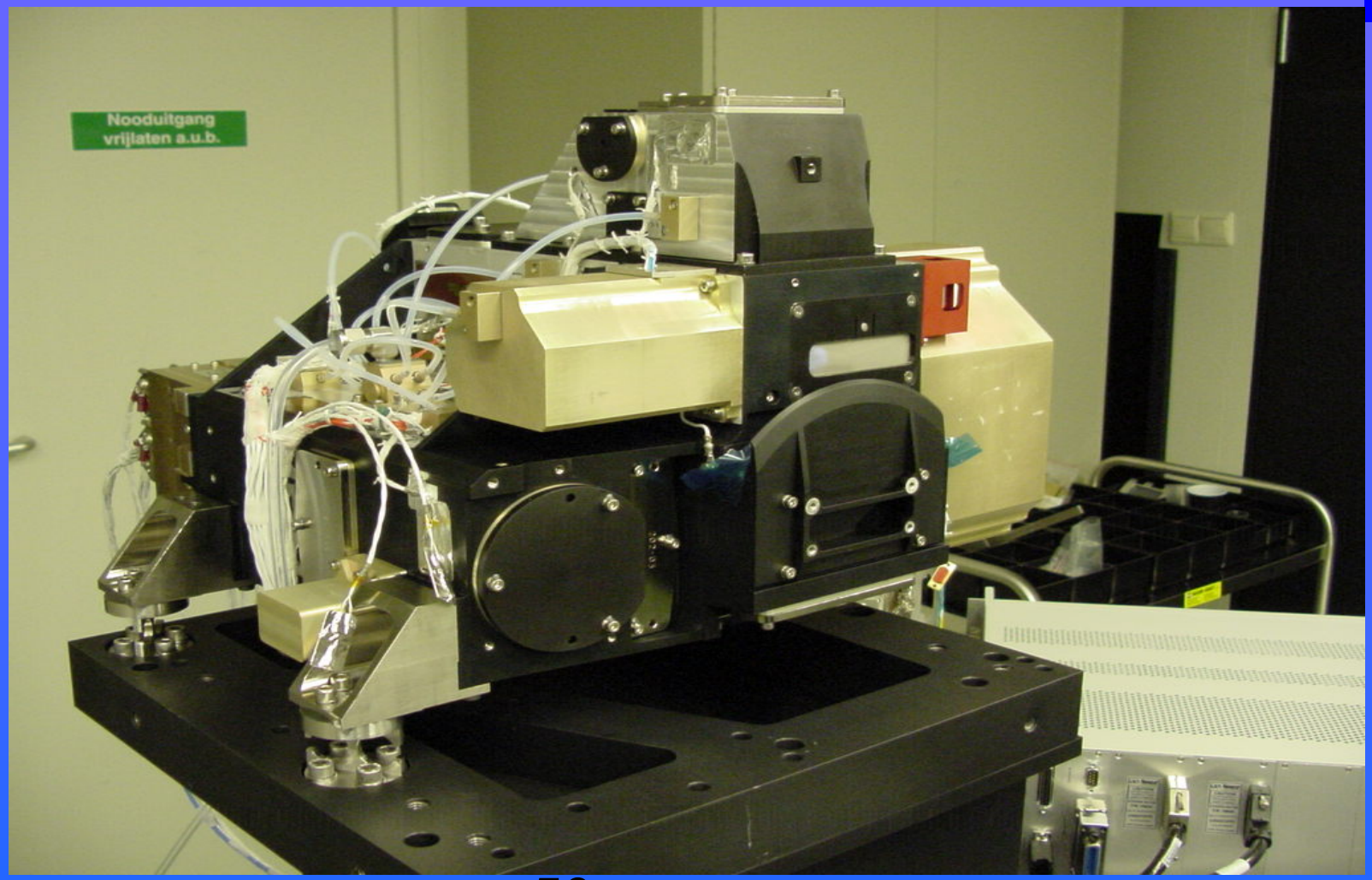
EOS-AURA http://aura.gsfc.nasa.gov

Backup slides

OMI optics: visible channel



OMI flight model optical bench



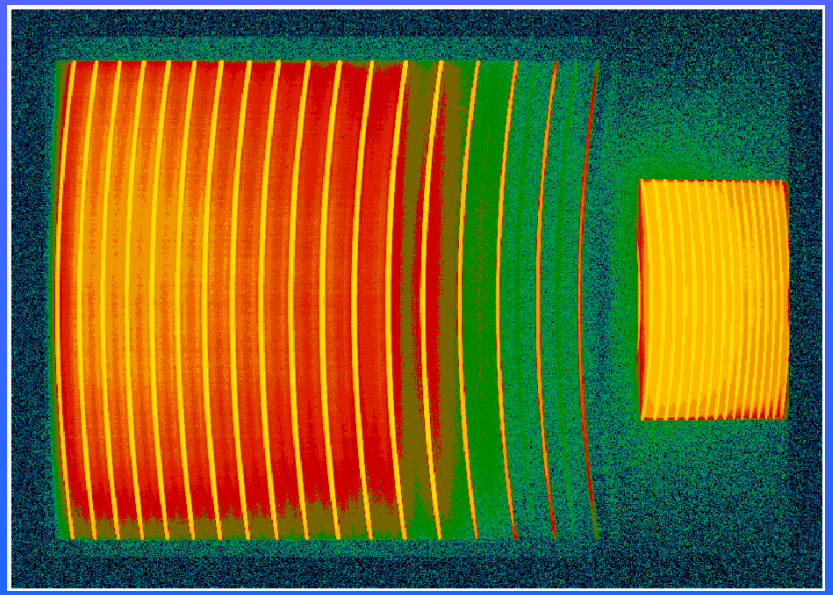
50 cm

Slit function: Instrument spectral response

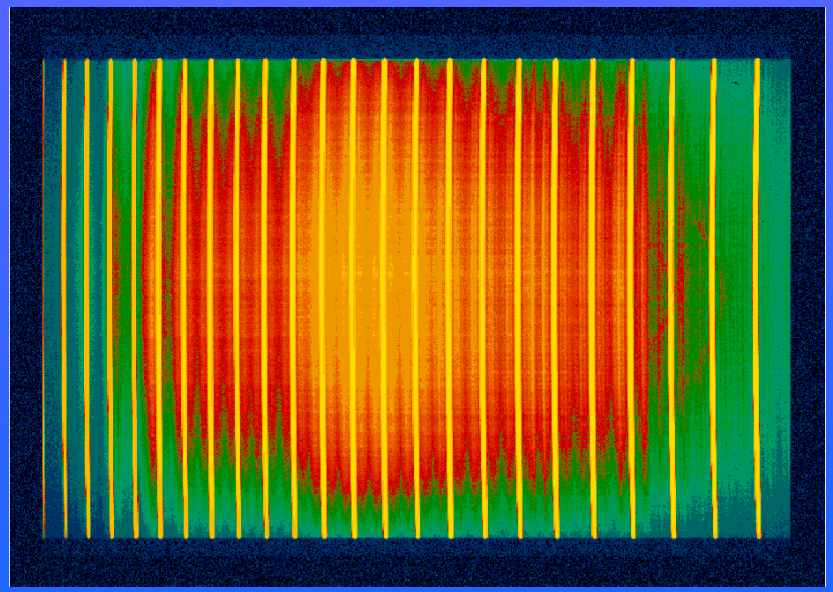
Spectral ‘smile’.

Calibrating spectral slit function accurately is crucial for accurate atmospheric gas retrieval.

UV



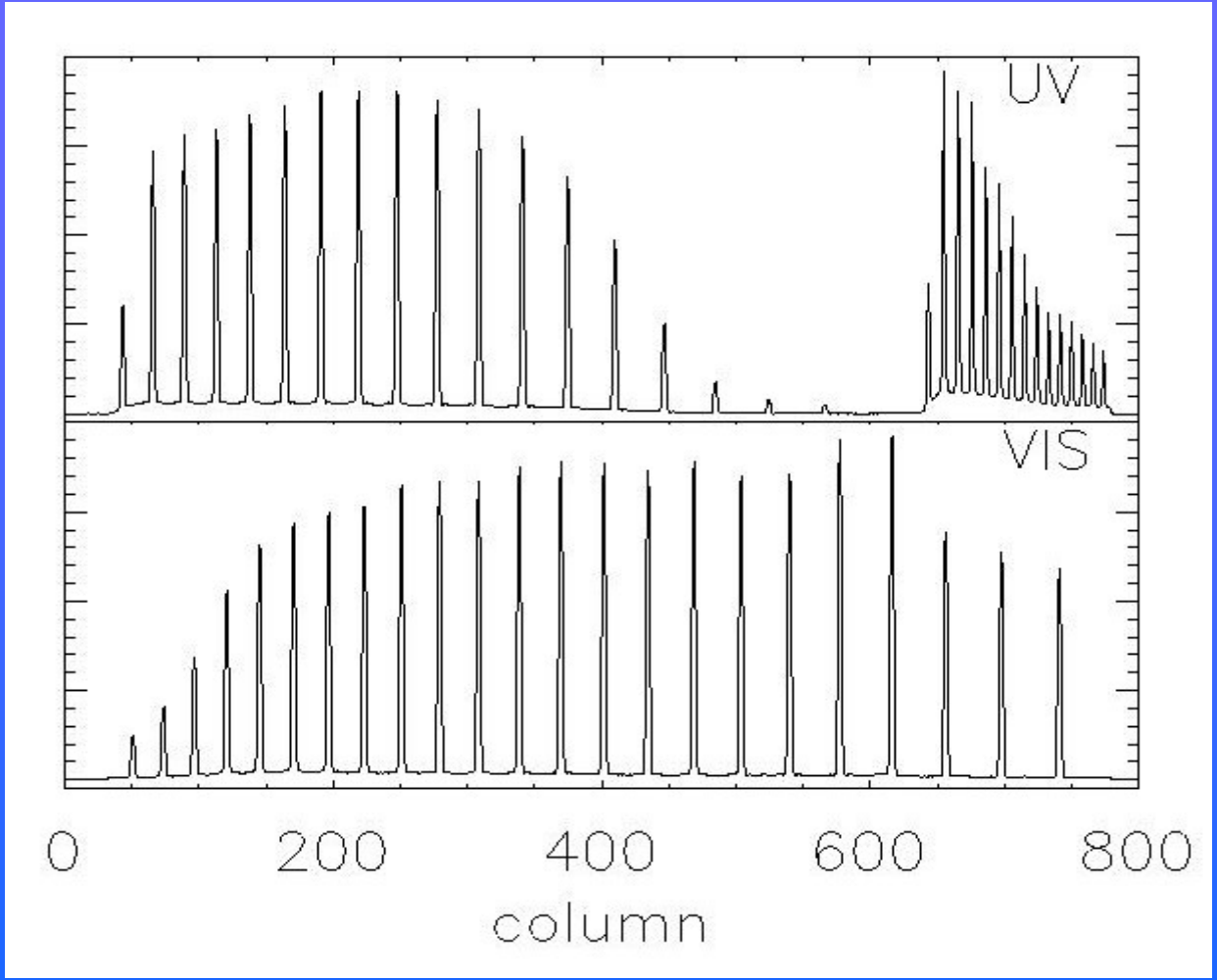
VIS



Instrument spectral response for central row

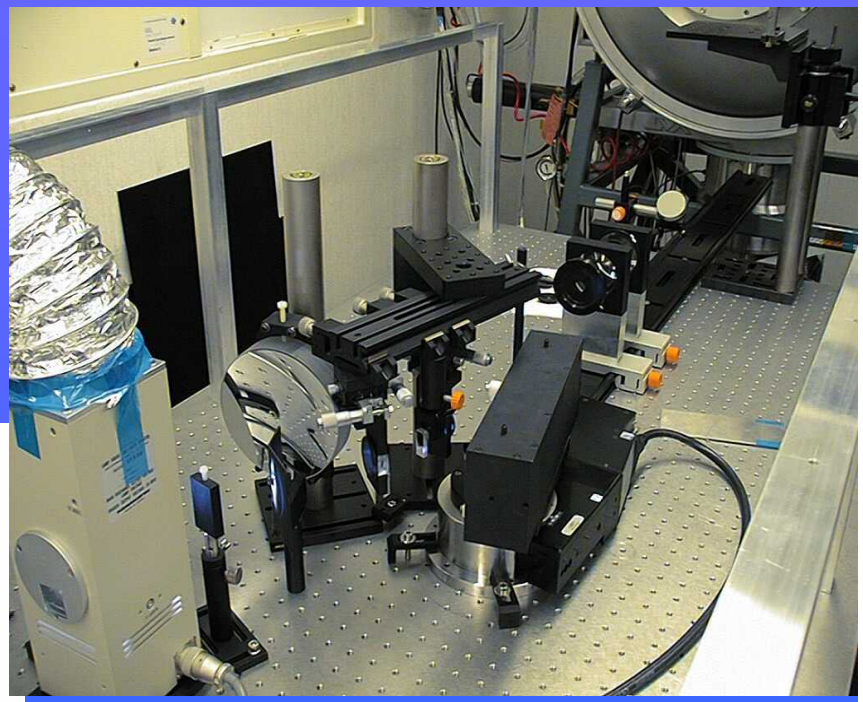
UV

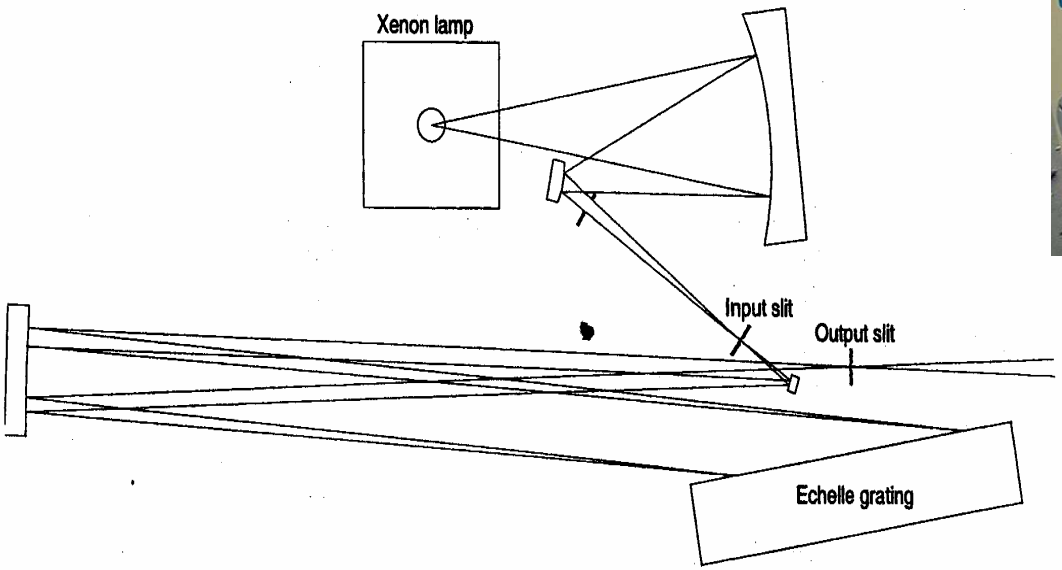
VIS



Slit function echelle grating optical stimulus developed for the OMI project

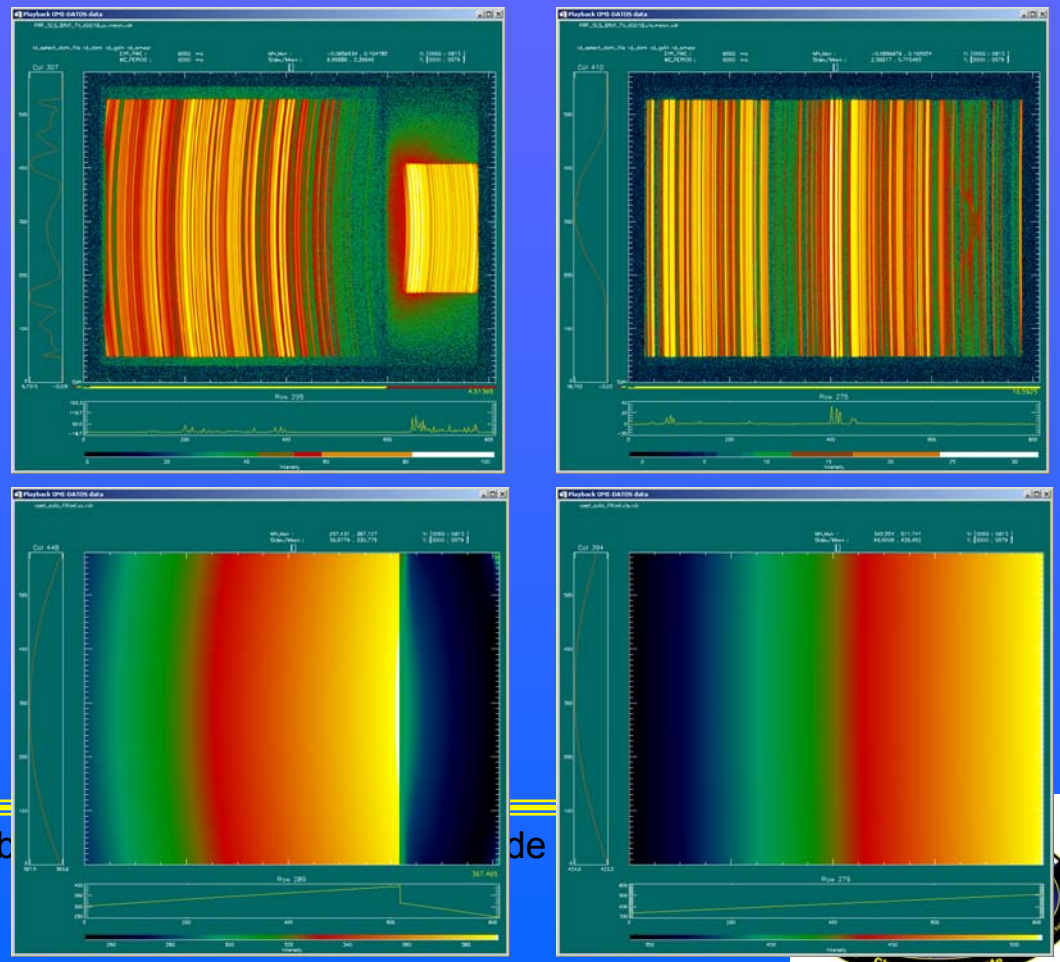
- Turnable echelle grating
- ~15 peaks in each sub-channel (UV1, UV2, VIS).
- Peaks narrow compared to spectral resolution.





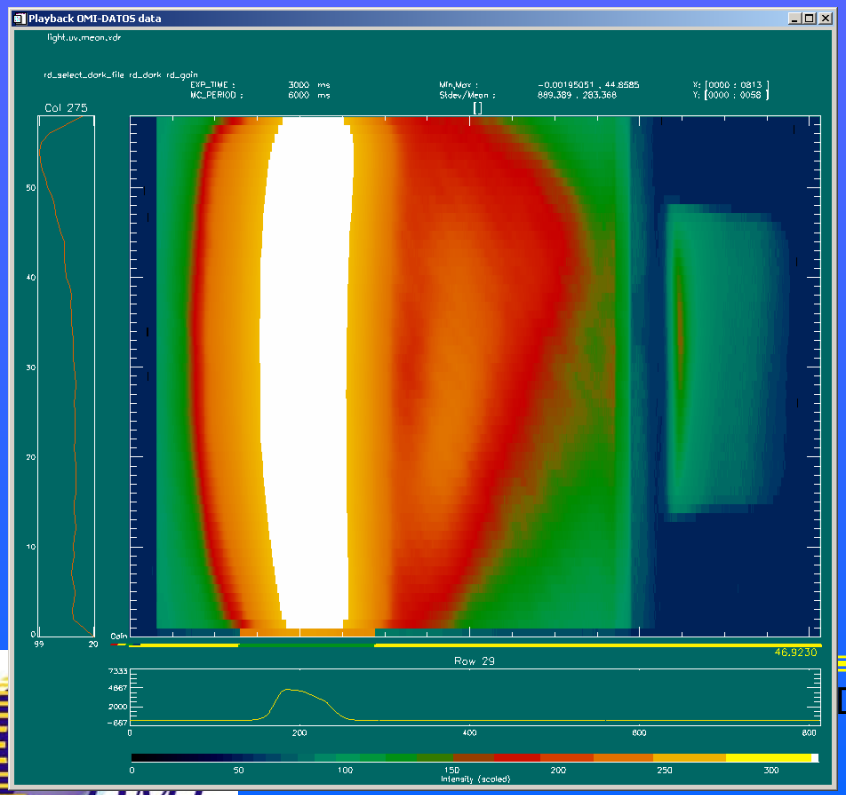
Spectral calibration

- Spectral ‘smile’.
- Based on PtCrNe(Ar) spectral lamp measurements and on slit function echelle optical stimulus measurements.
- Relative accuracy on ground about 0.05 px.
- Absolute accuracy on ground worse, about 0.5 px.
- Accuracy from in-flight algorithm using solar Fraunhofer lines expected to be better than 0.01 px.



Spectral stray light

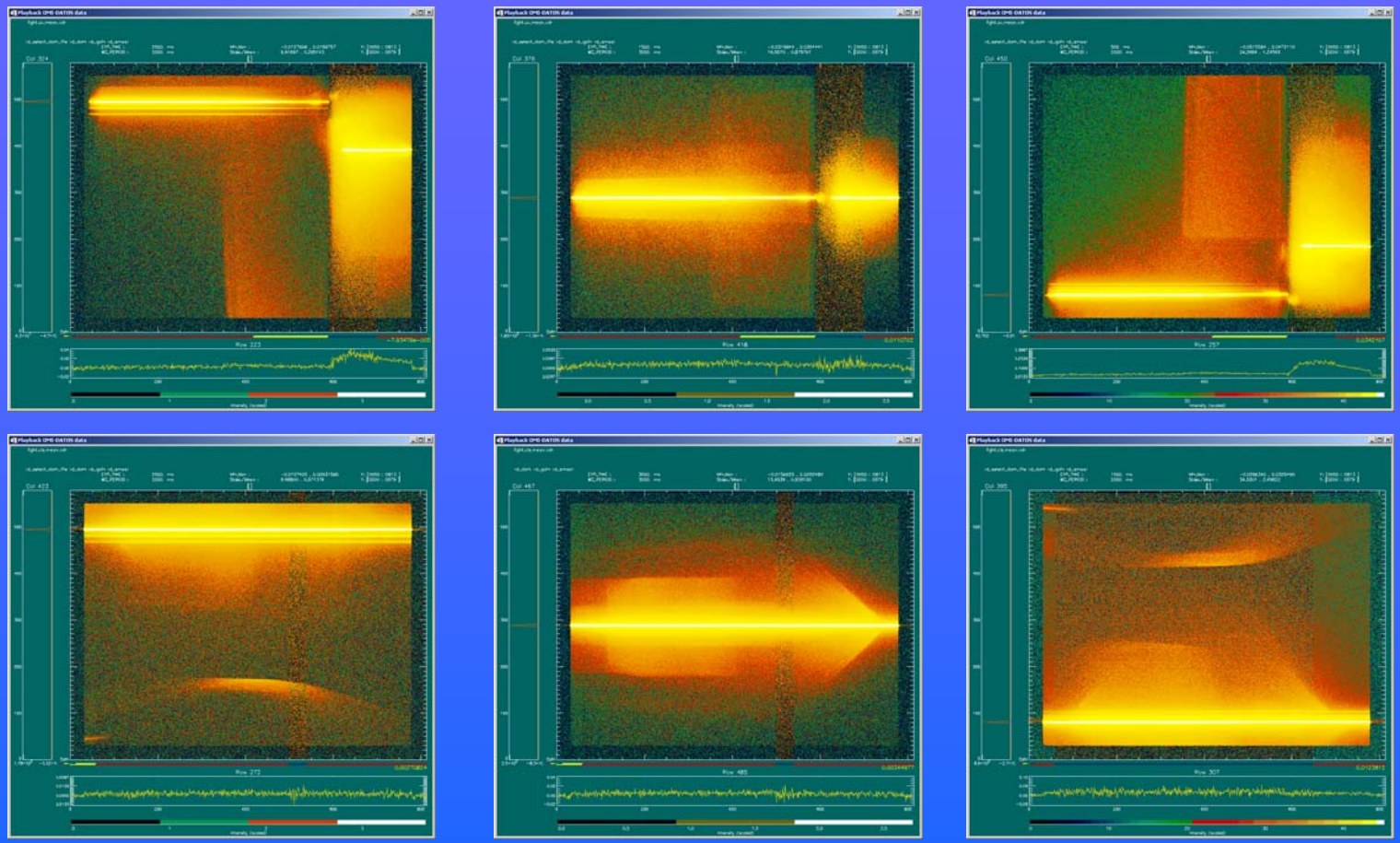
- Spectral stray light in UV1 <3% of useful signal before correction.
- Expected to be <0.5% after correction.
- Correction algorithm in GDPS, calibration parameters measured.



Bandpass 320 nm + WG 320
UV channel

Spatial stray light

Swath –50 degrees | Swath 0 degrees | Swath +50 degrees



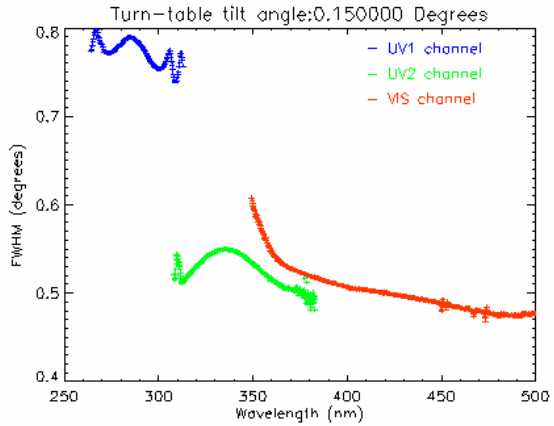
UV

VIS

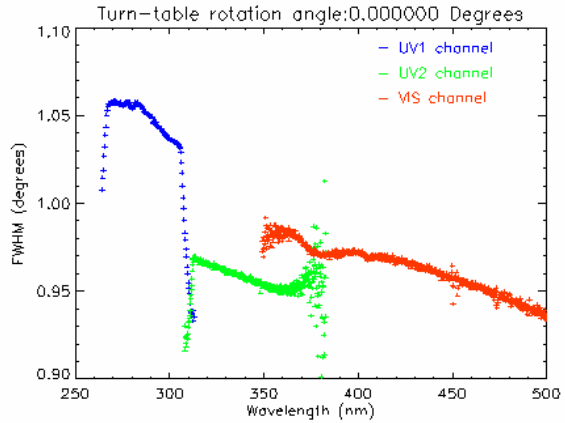
Geometry calibration

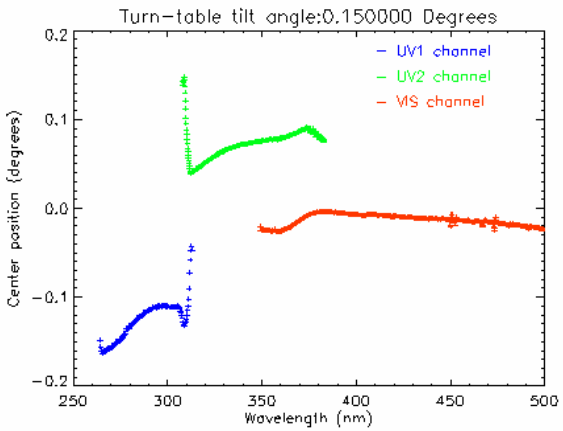
Swath direction

Flight direction

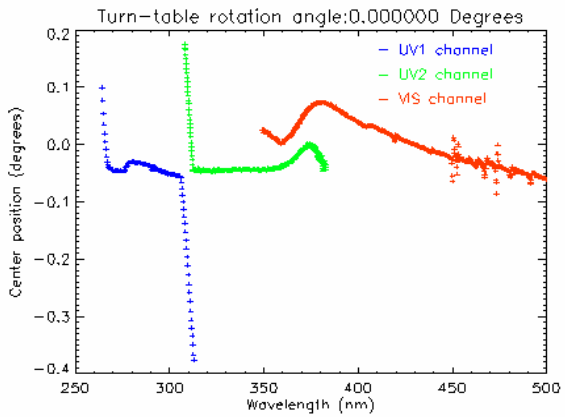


FWHM

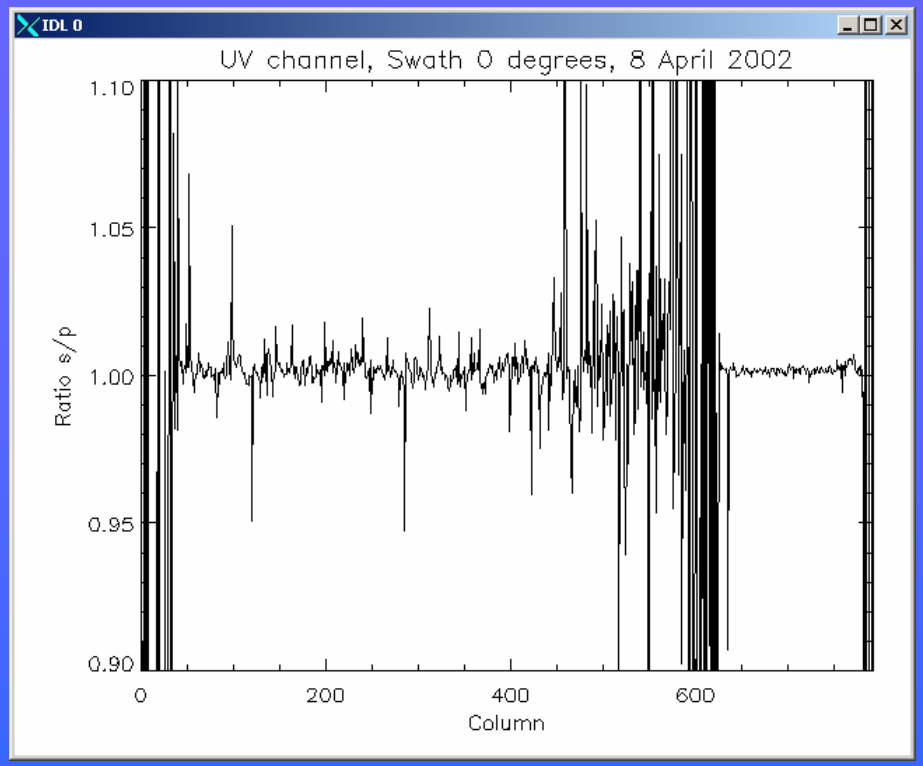


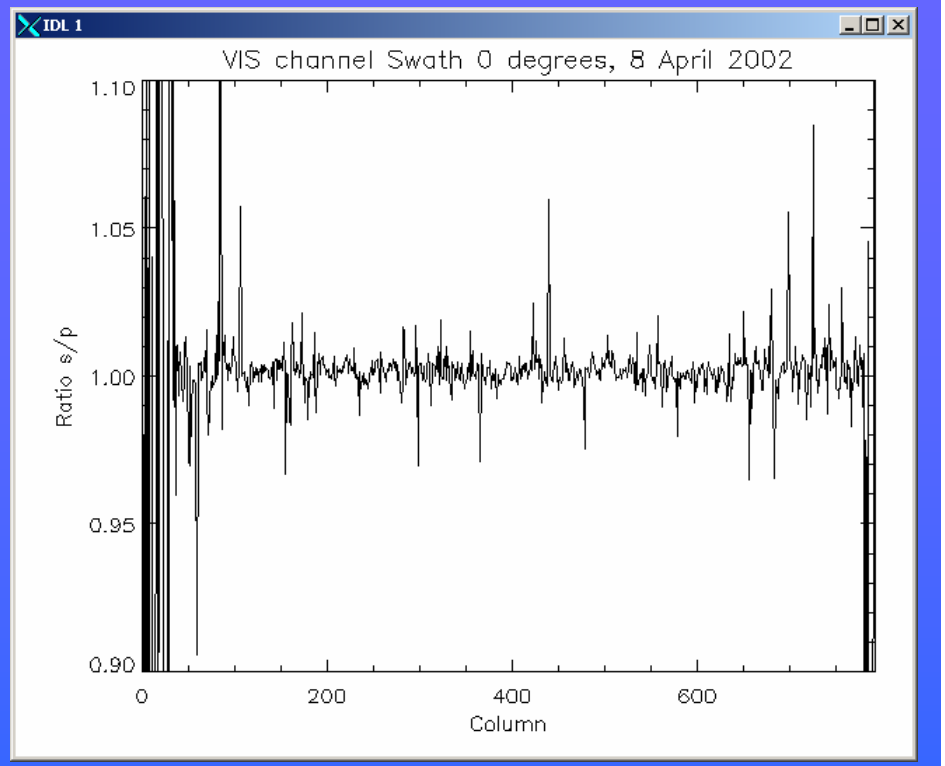


Coregistration



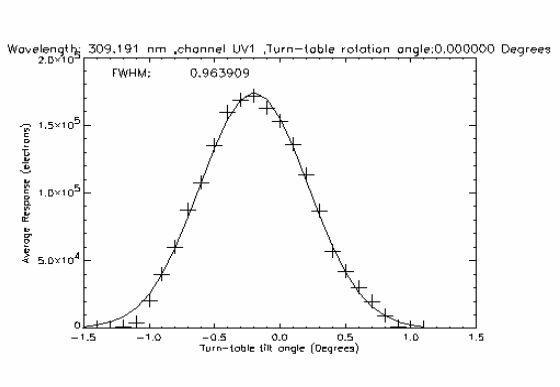
Polarisation scrambler performance



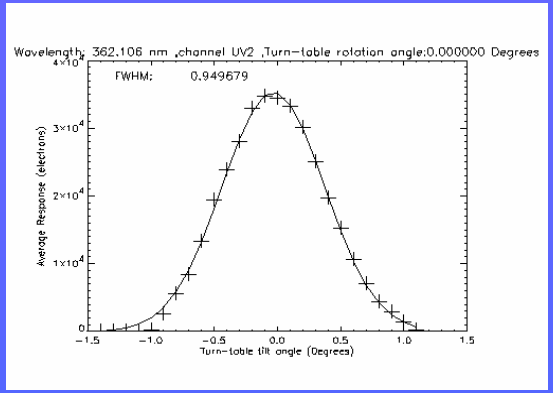


Ratio of measured response to polarised light parallel and perpendicular to the entrance slit, UV and VIS, nadir viewing direction.

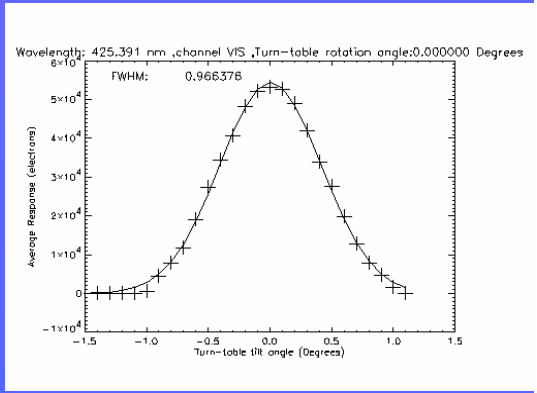
Geometry calibration (ILOS)



309 nm, UV1, flight direction

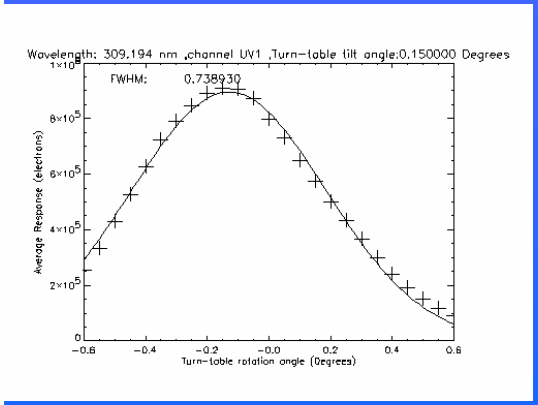


362 nm, UV2, flight direction

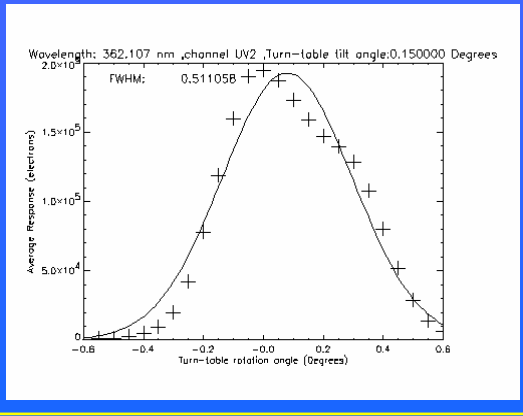


425 nm, VIS, flight direction

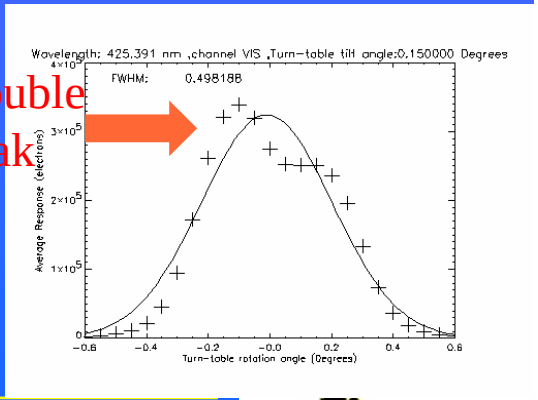
309 nm, UV1, swath direction



362 nm, UV2, swath direction

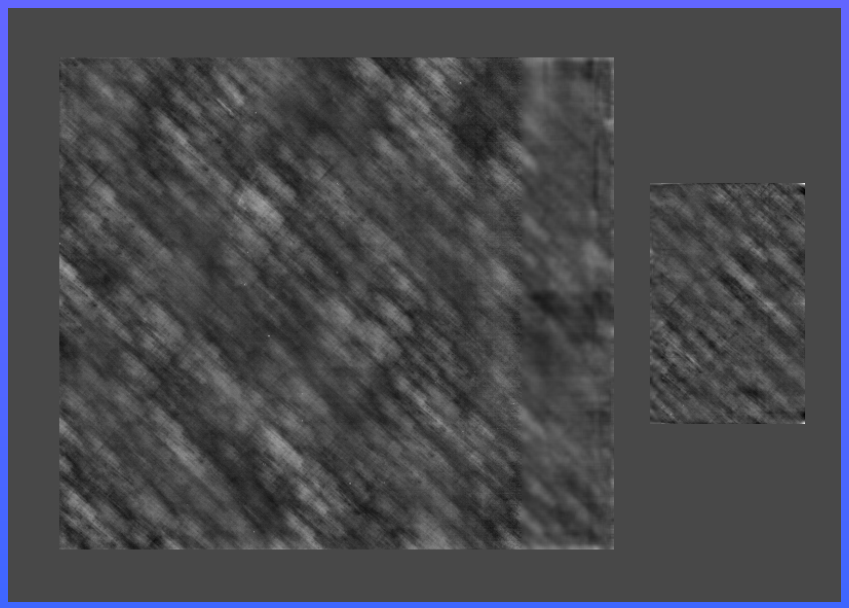


425 nm, VIS, swath direction

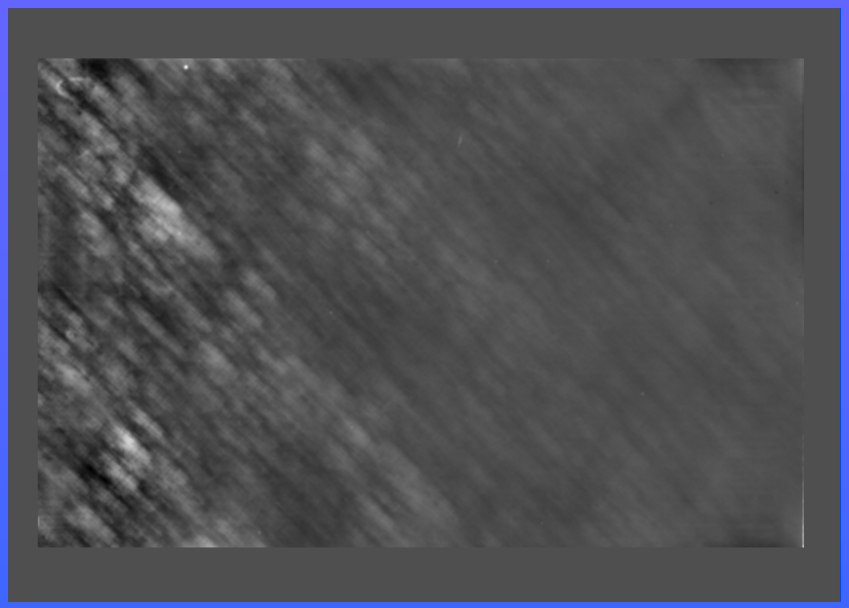


Detector Pixel Response Non-Uniformity (PRNU) in Thermal-Vacuum

Pixel-to-pixel sensitivity maps of the UV1, UV2 and VIS channel in thermal vacuum.

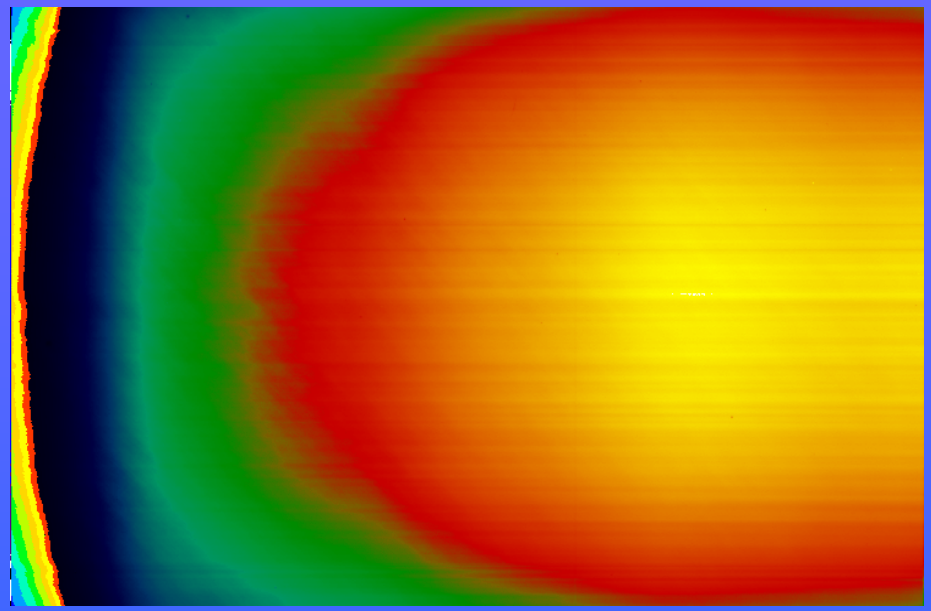


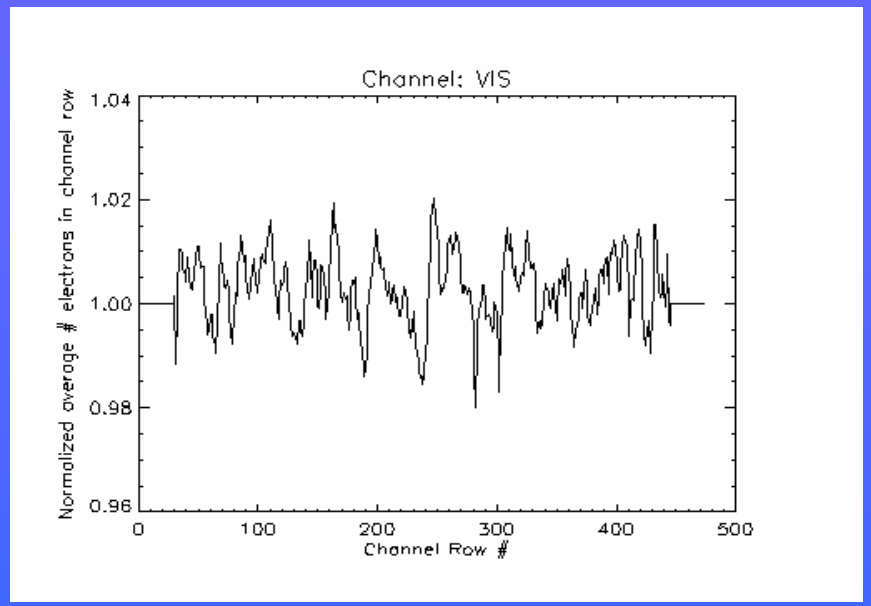
UV

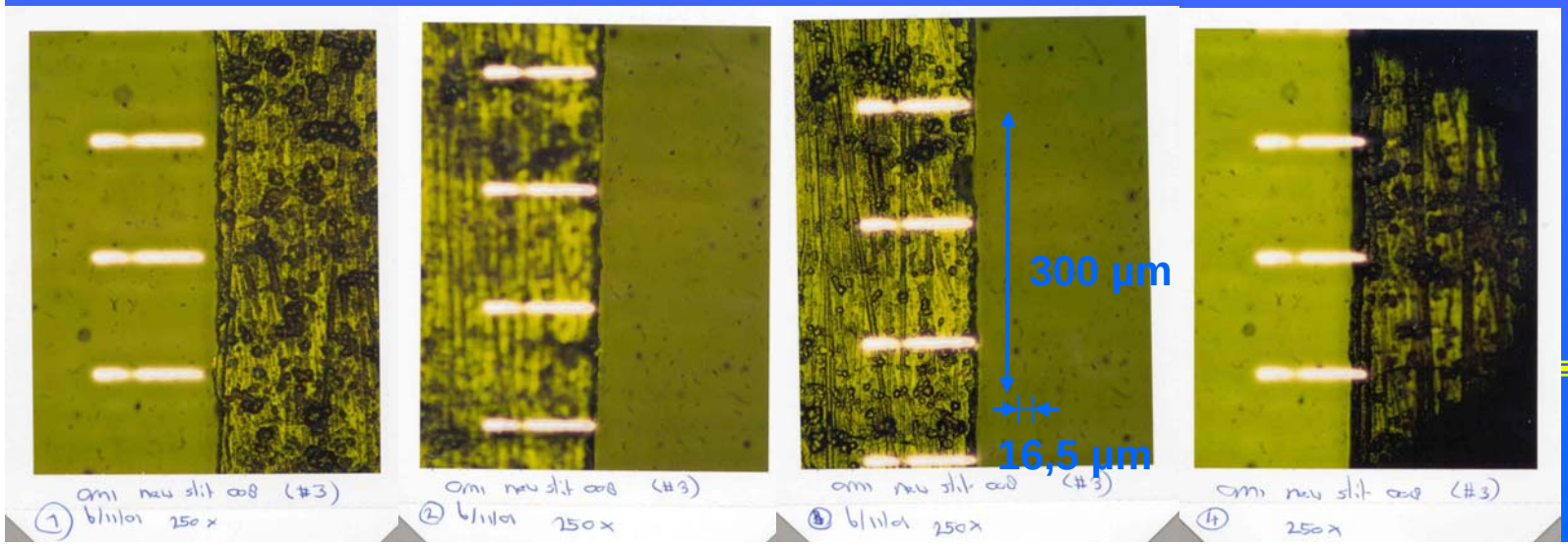


VIS

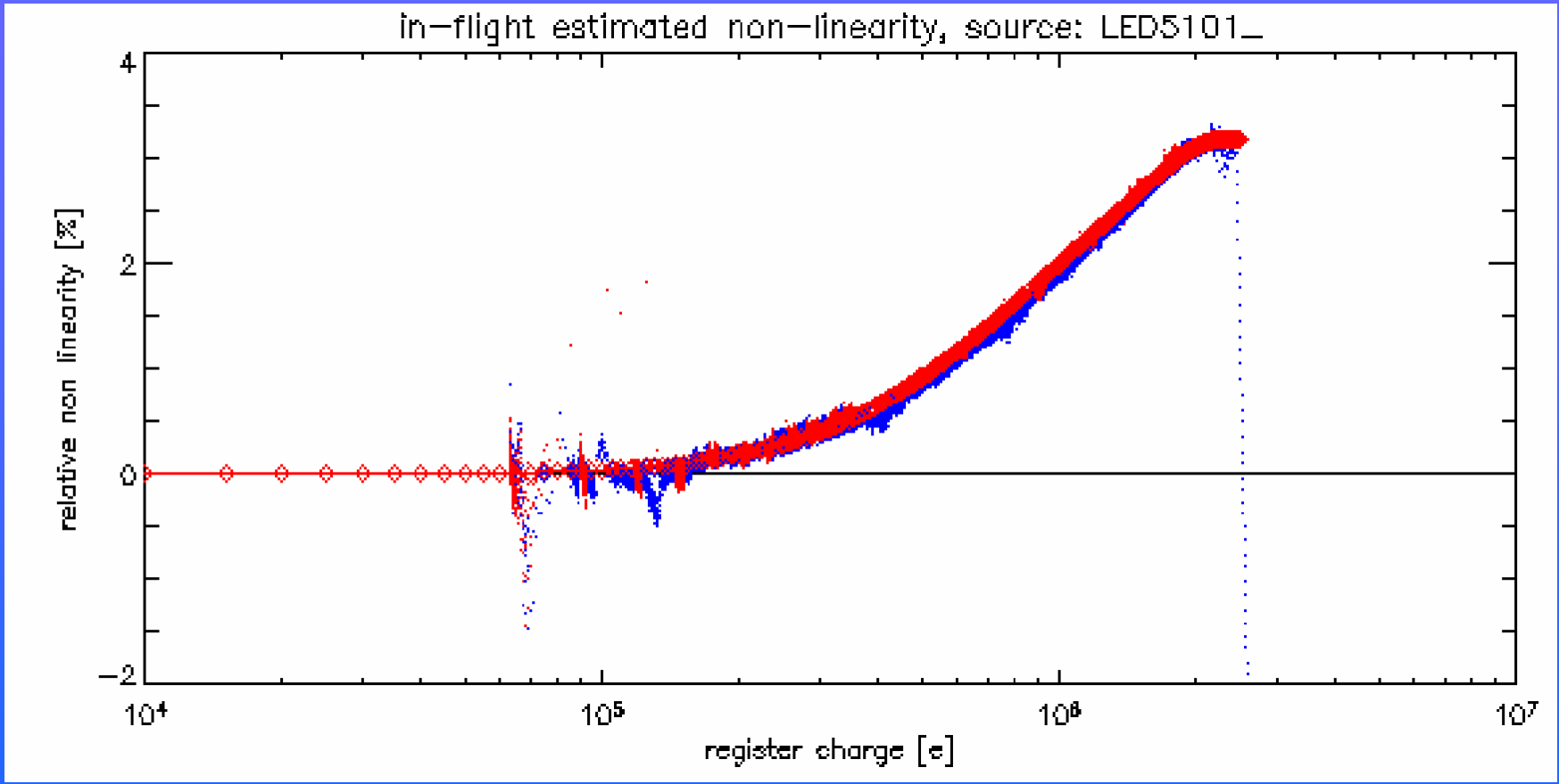
Slit irregularity







Electronics non-linearity

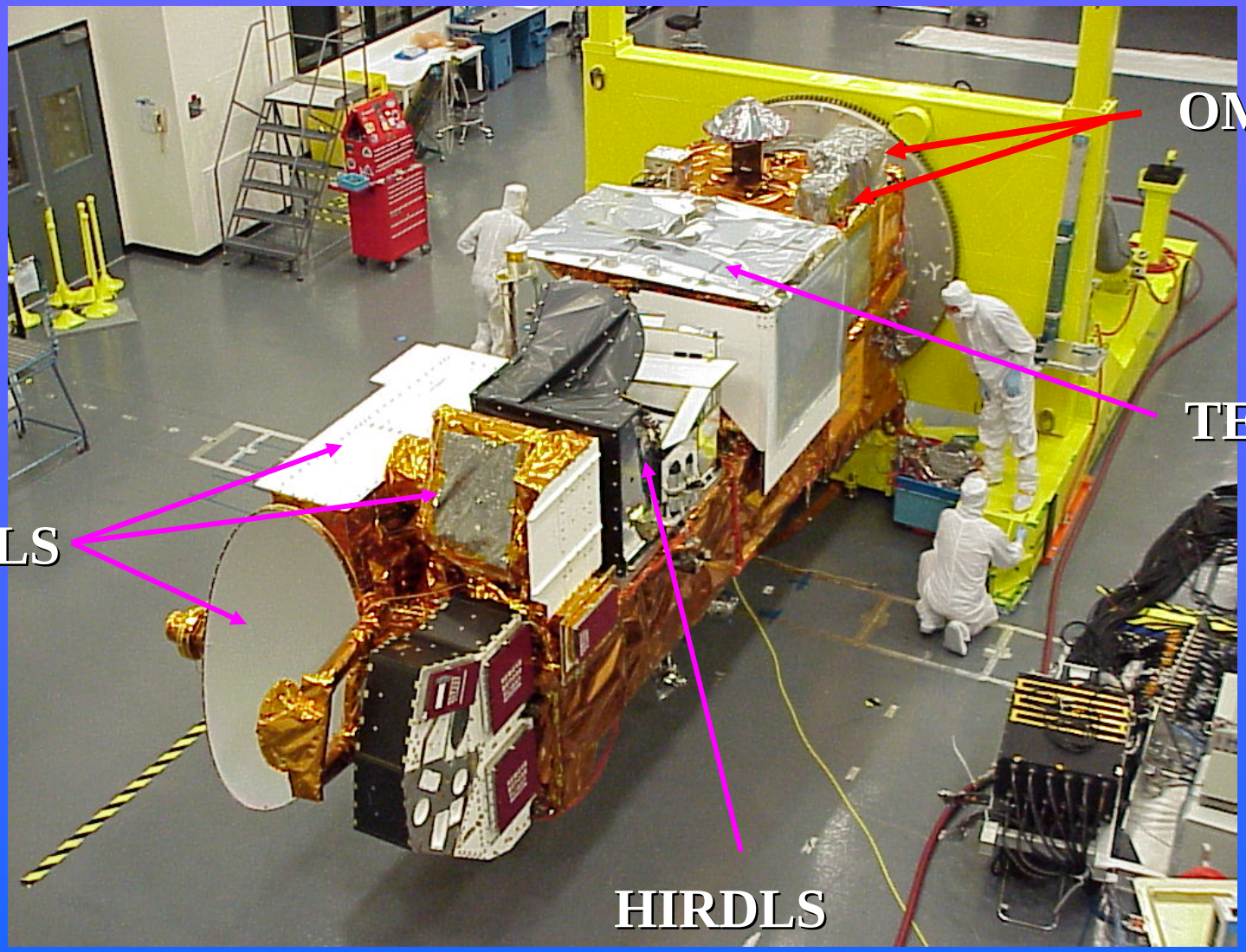


BSDF in-flight

- In-flight calibration of absolute radiance and absolute reflectance, including swath angle dependency:
  - Antarctica and Greenland ice for all wavelengths >300 nm
  - Clouds in UV2 channel
  - Clouds in VIS channel
  - Low-reflectance scenes over land in UV2

- Ongoing work.

NASA EOS Aura spacecraft



NASA EOS Aura spacecraft launch

Successfully launched from Vandenberg with Delta II carrier on 15 July 2004.

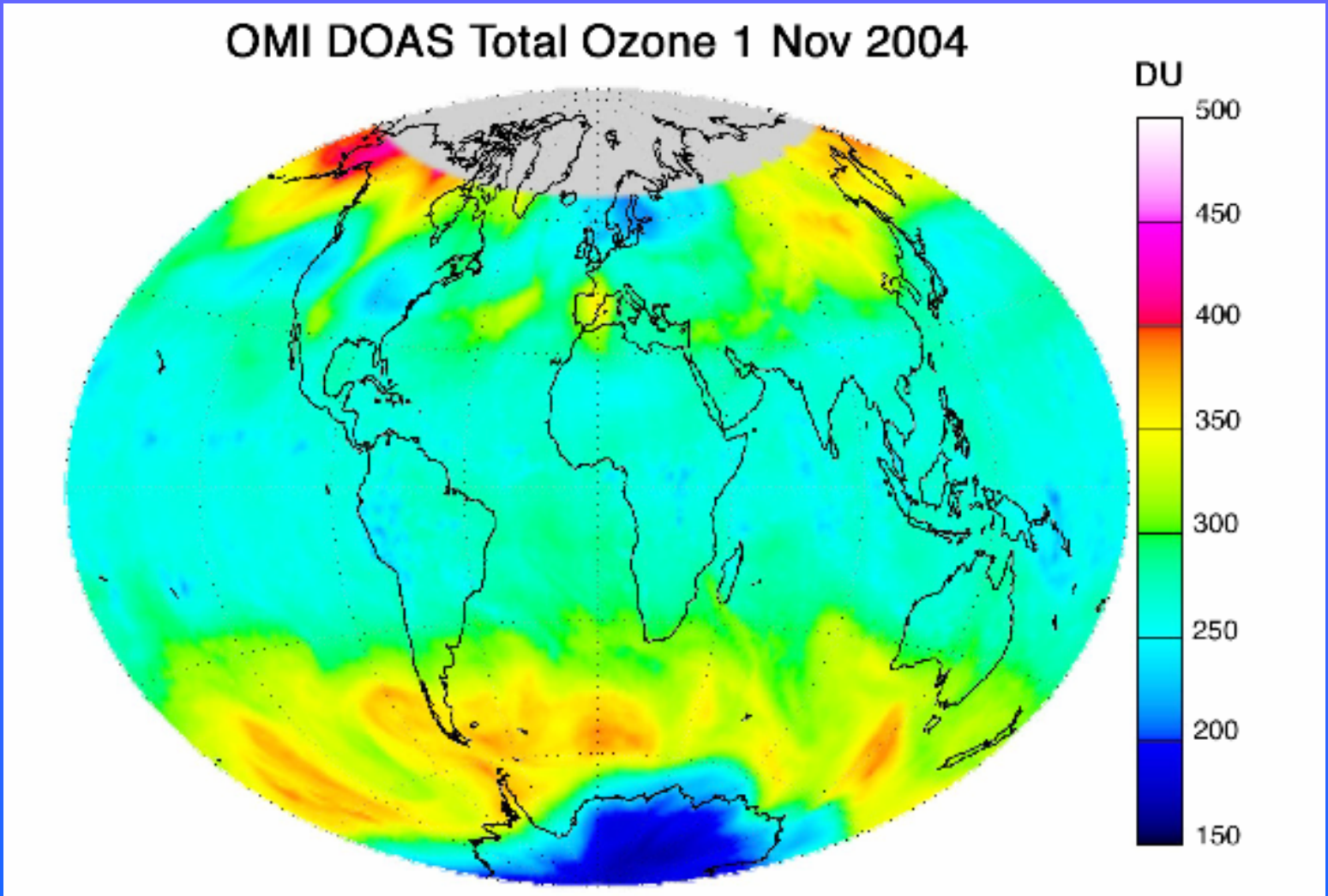
OMI data products

- OMI will provide continuation of US-TOMS ozone record

- Level 1 data products:
  - Absolute earth radiance
  - Absolute solar irradiance
- Level 2 data products:
  - Total column ozone (tropospheric ozone)
  - Ozone vertical profile
  - Total column NO_2 (tropospheric NO_2)
  - Aerosols, including absorbing aerosols
  - Cloud properties from O_2-O_2 absorption (470 nm)
  - Trace gases:
    - SO_2
    - BrO
    - HCOH
    - OClO

Differential Optical Absorption Spectroscopy (DOAS) products in yellow

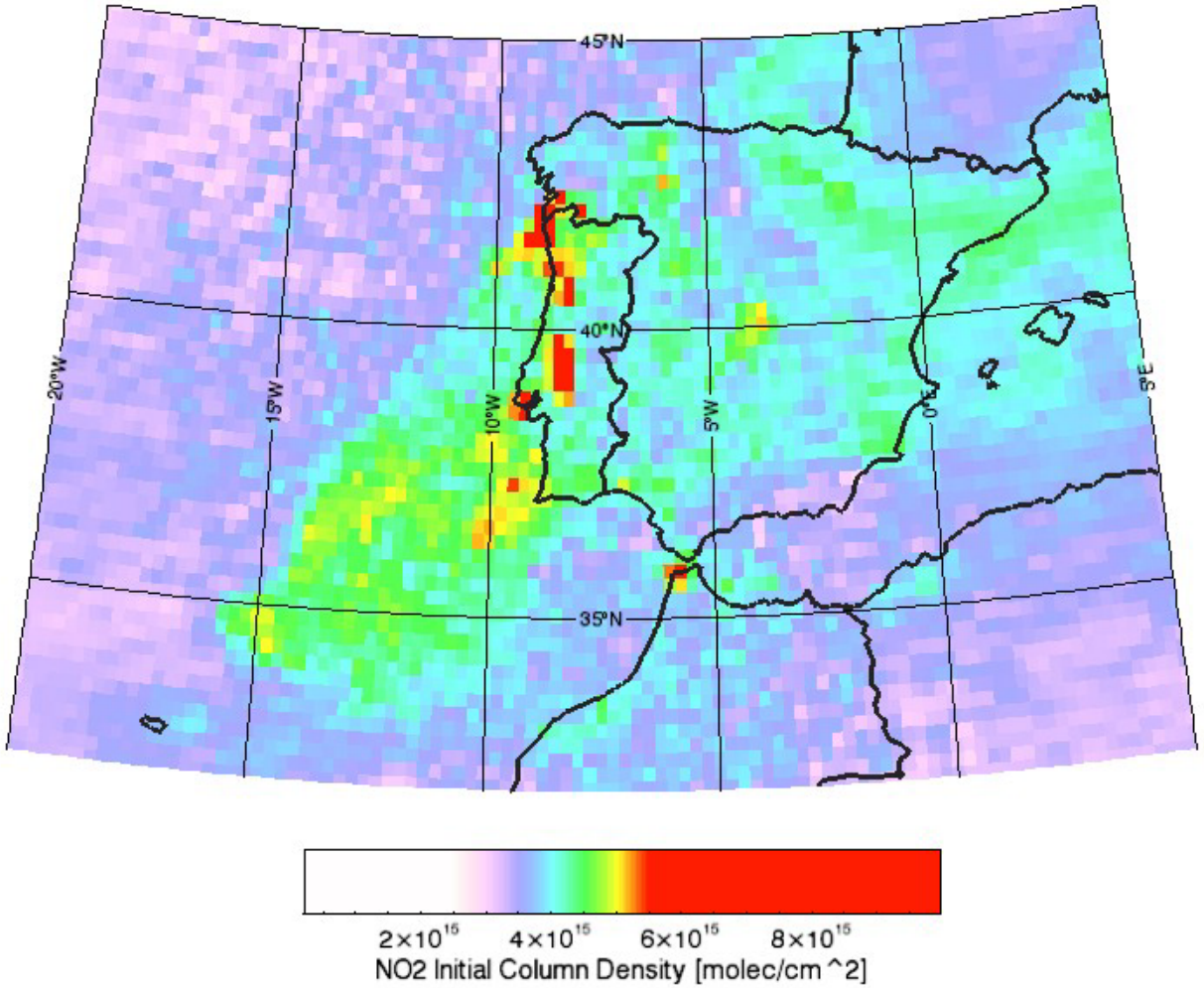
Ozone hole 2004



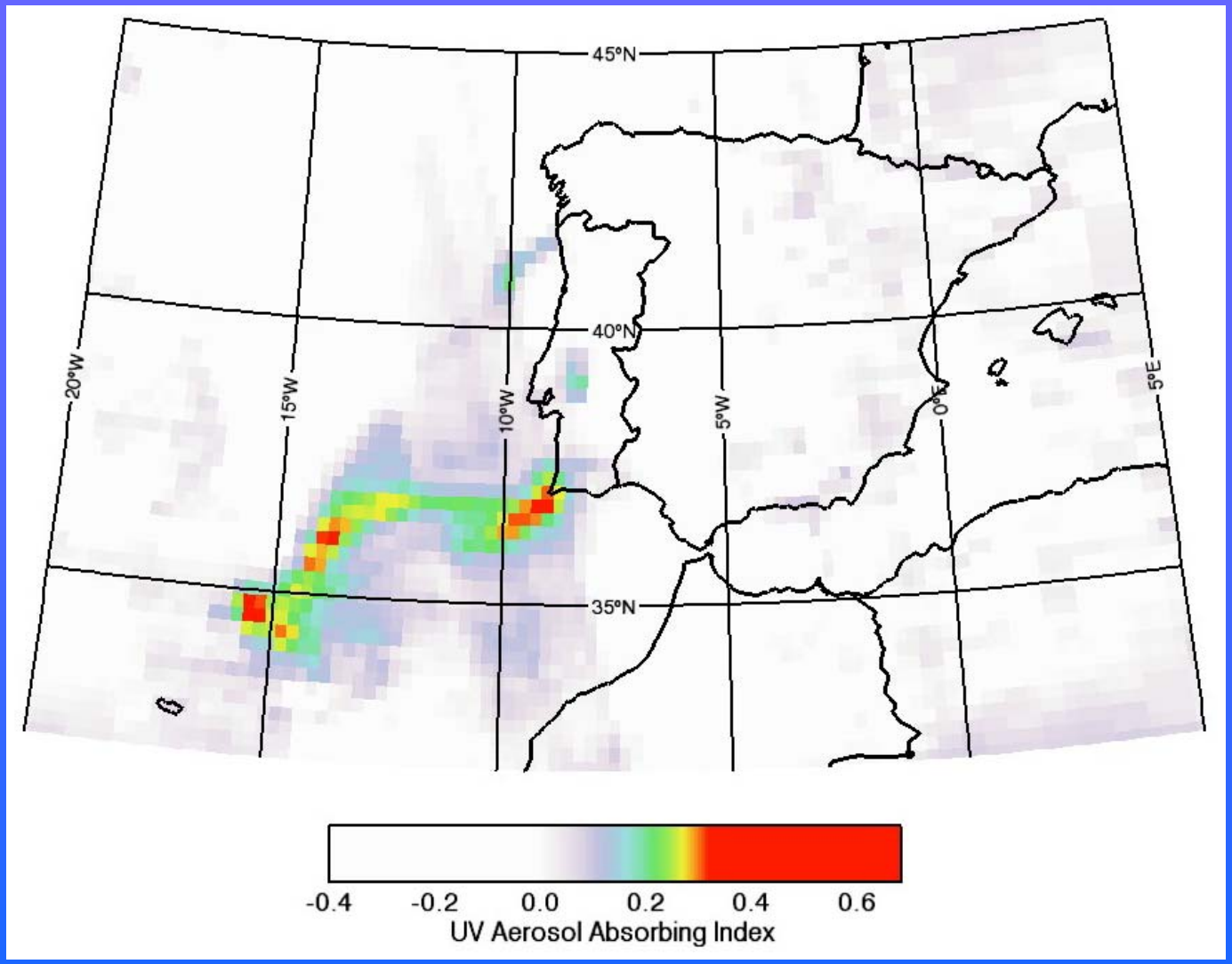
Fires in Portugal, 21 August 2005

Modis Aqua, 21 August 2005 13:16 h, RGB from Channels 1,4,3
Image from the Dundee Satellite Receiving Station Archive

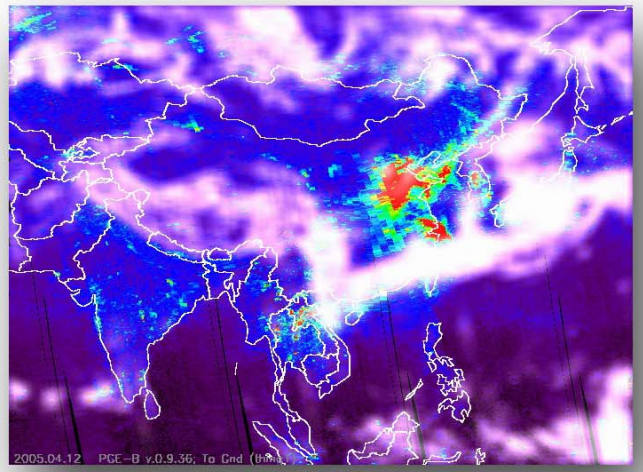
OMI NO_2, 21 August 2005



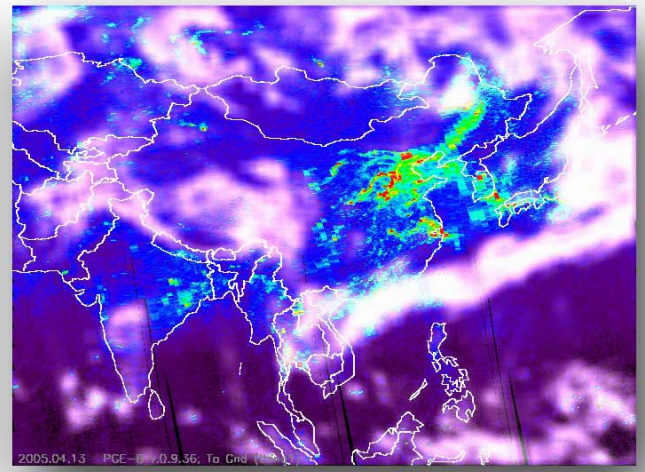
OMI Aerosol Absorbing Index, 21 August 2005



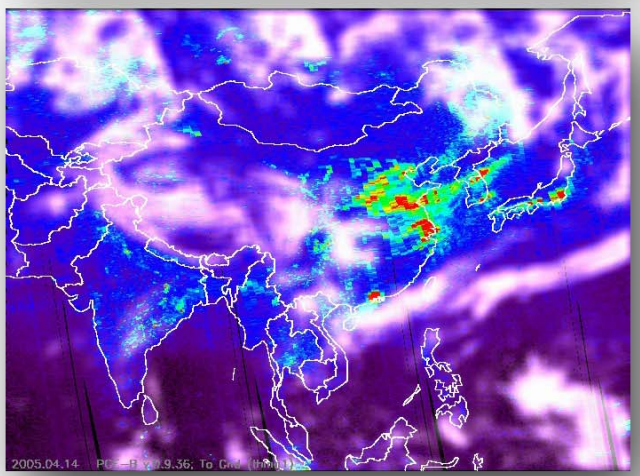
OMI NO_2, Asia, 11-15 April 2005



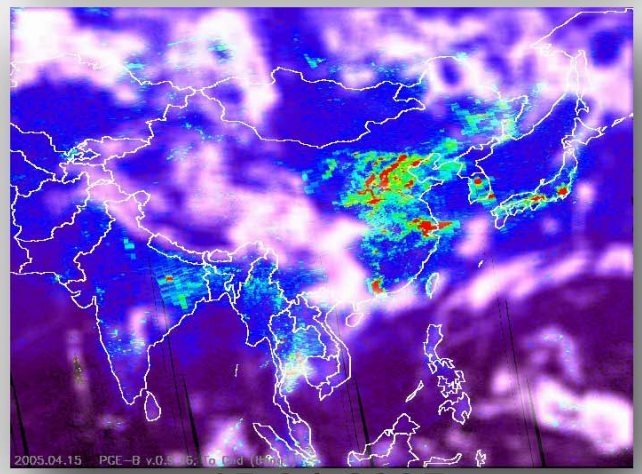
12-04-2005



13-04-2005

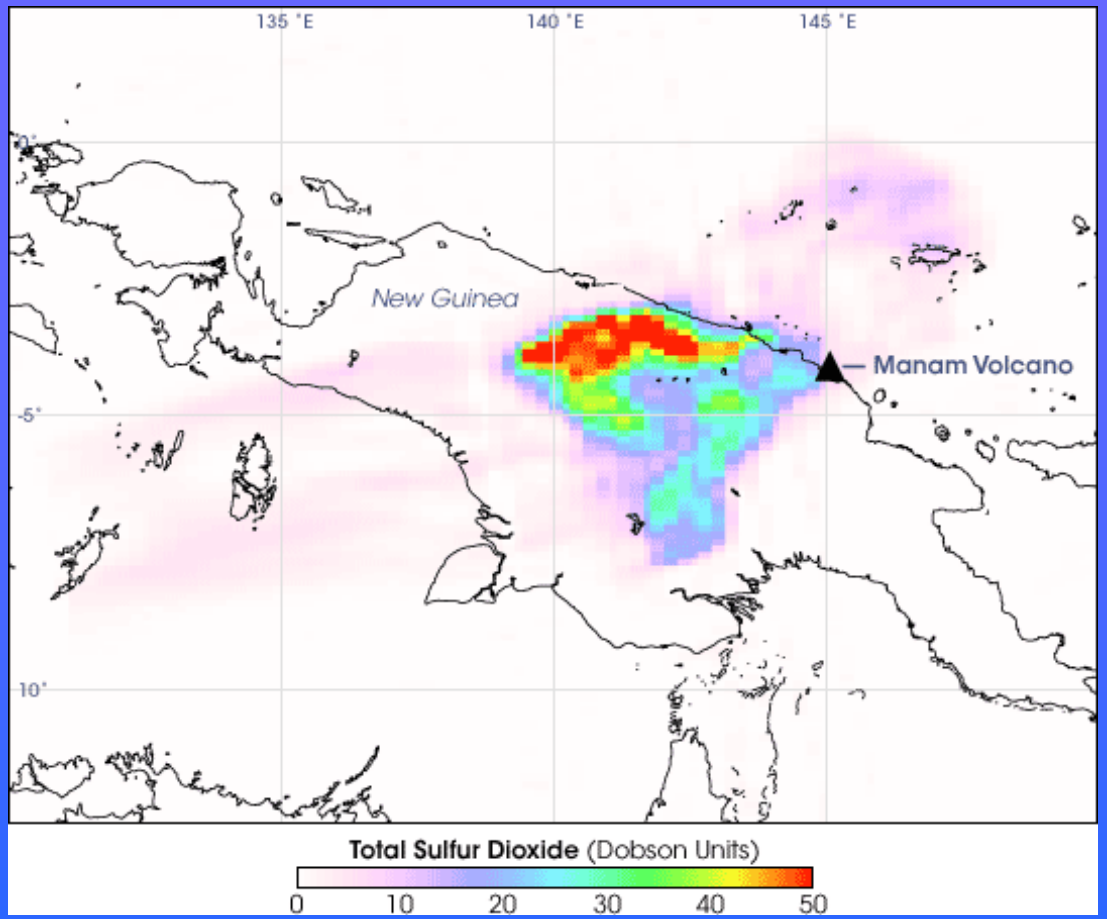


14-04-2005



15-04-2005

Volcanic SO_2

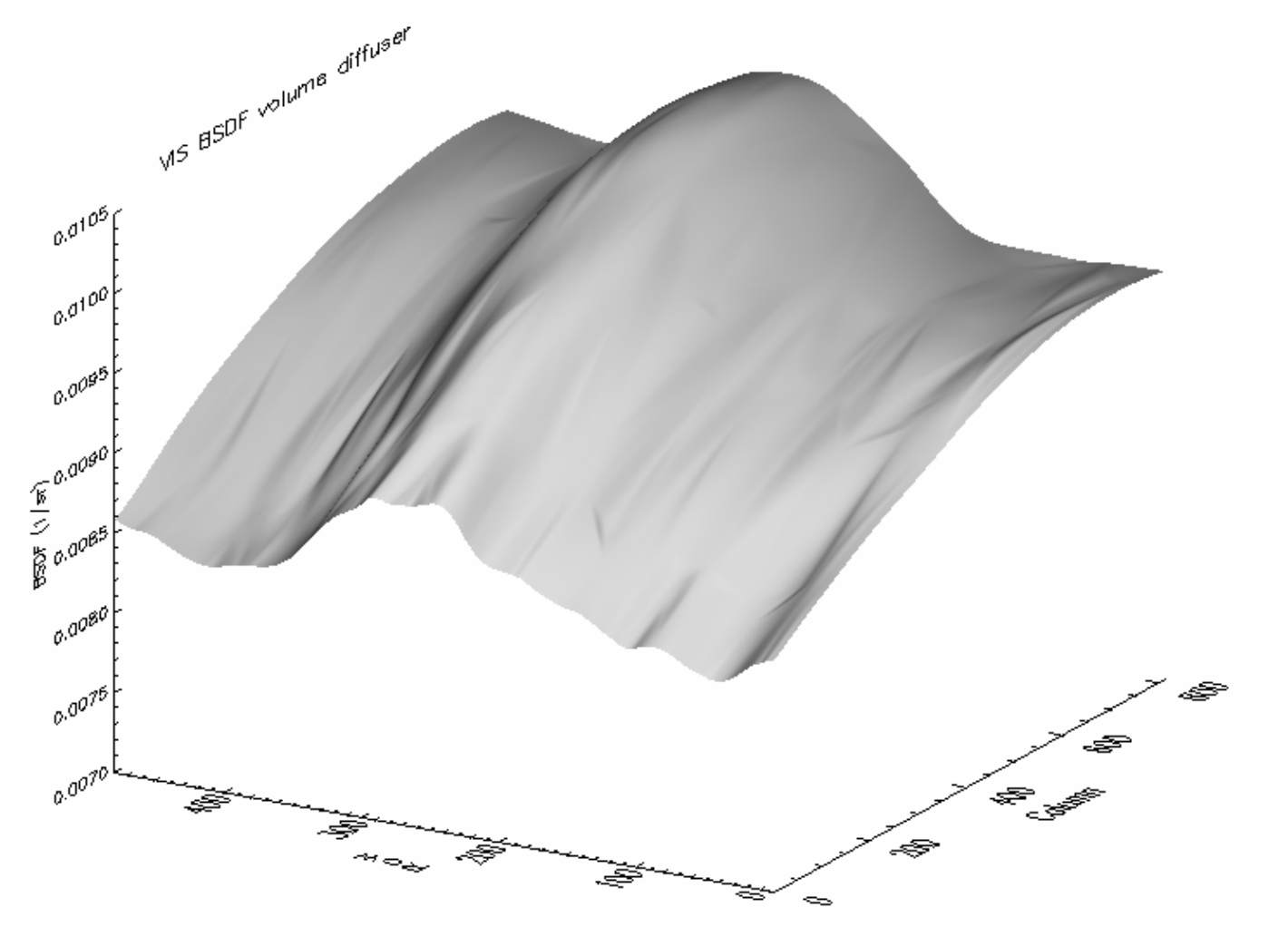


Continued eruption of Manan volcano
Image courtesy Simon Carn, JCET & UMBC

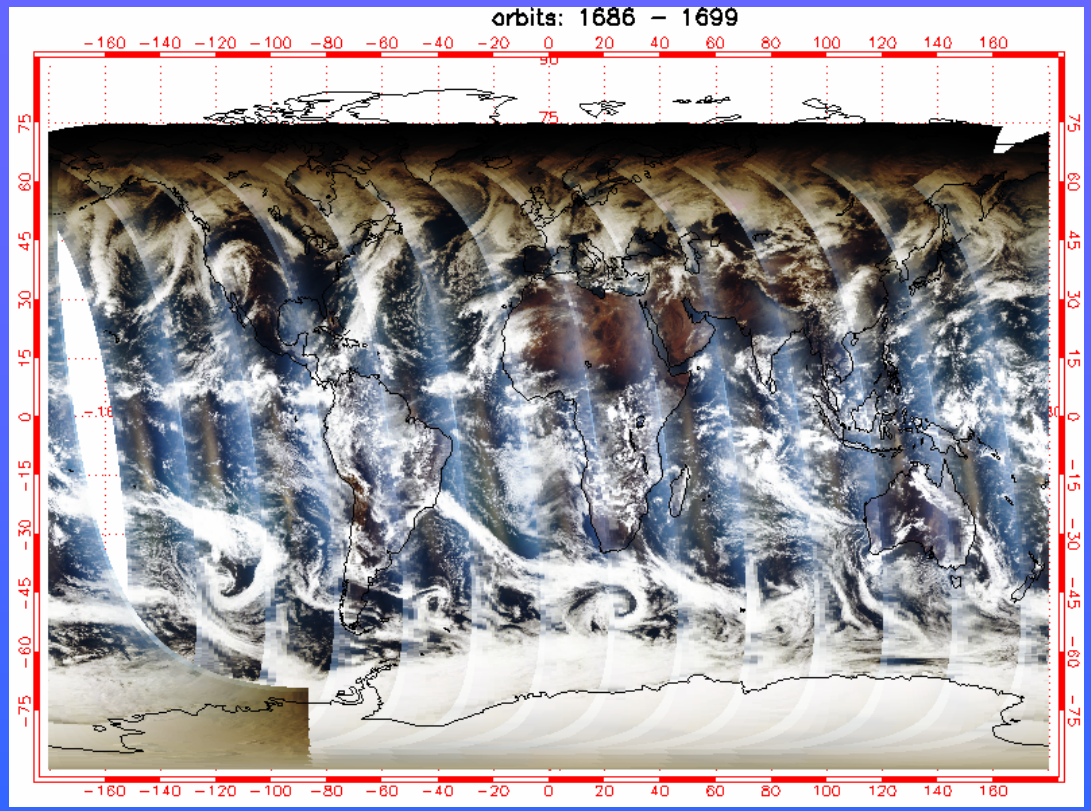
OMI instrument reflectance calibration results

- OMI instrument Bidirectional Scattering Distribution Function (BSDF) describes the absolute Earth reflectance calibration → starting point for nearly all level 1 – level 2 data retrieval algorithms.
- Absolute reflectance = Earth Radiance / Sun Irradiance
- BSDF = Radiance calibration / Irradiance calibration.
- All common path elements cancel.
- BSDF is a (smooth) function of azimuth and elevation angles (irradiance), swath angle and wavelength.

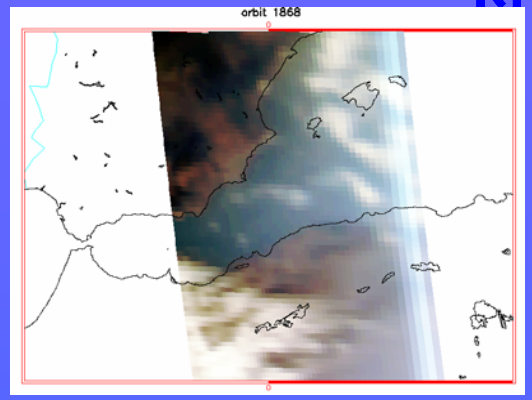
OMI instrument BSDF for VIS (on-ground)



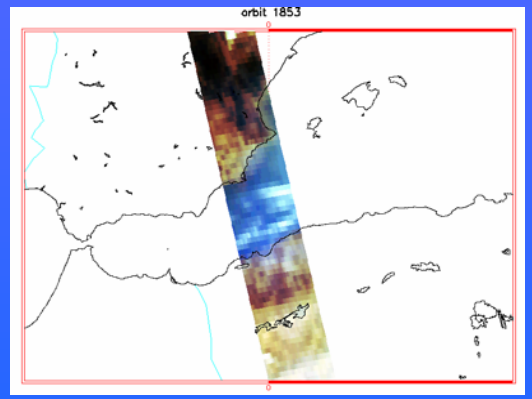
Viewing properties



One day of OMI global measurements.

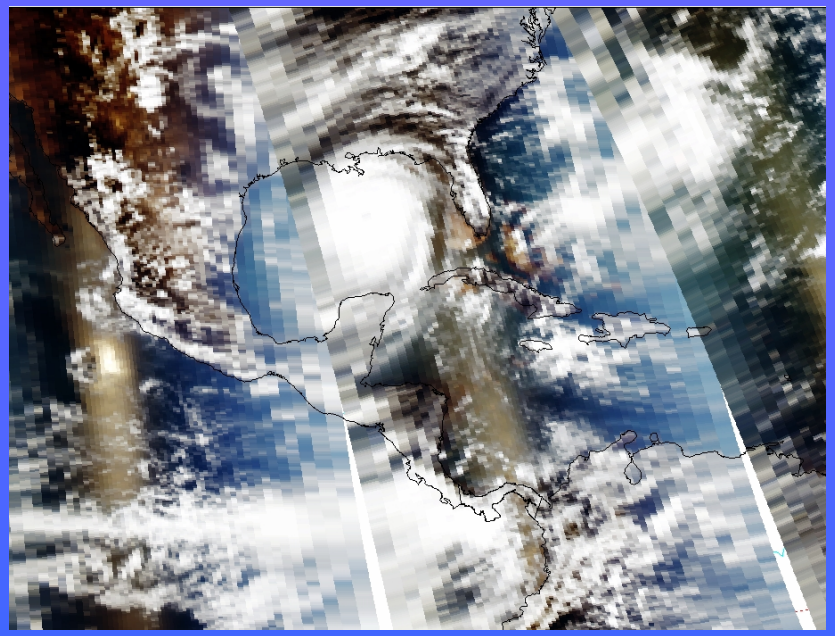


Southern Spain, global mode (binning factor 8)

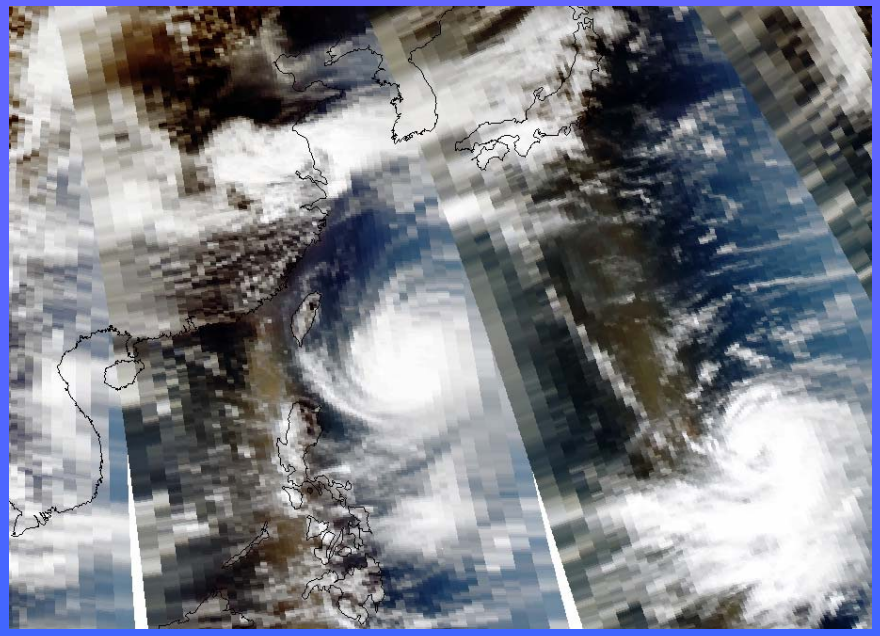


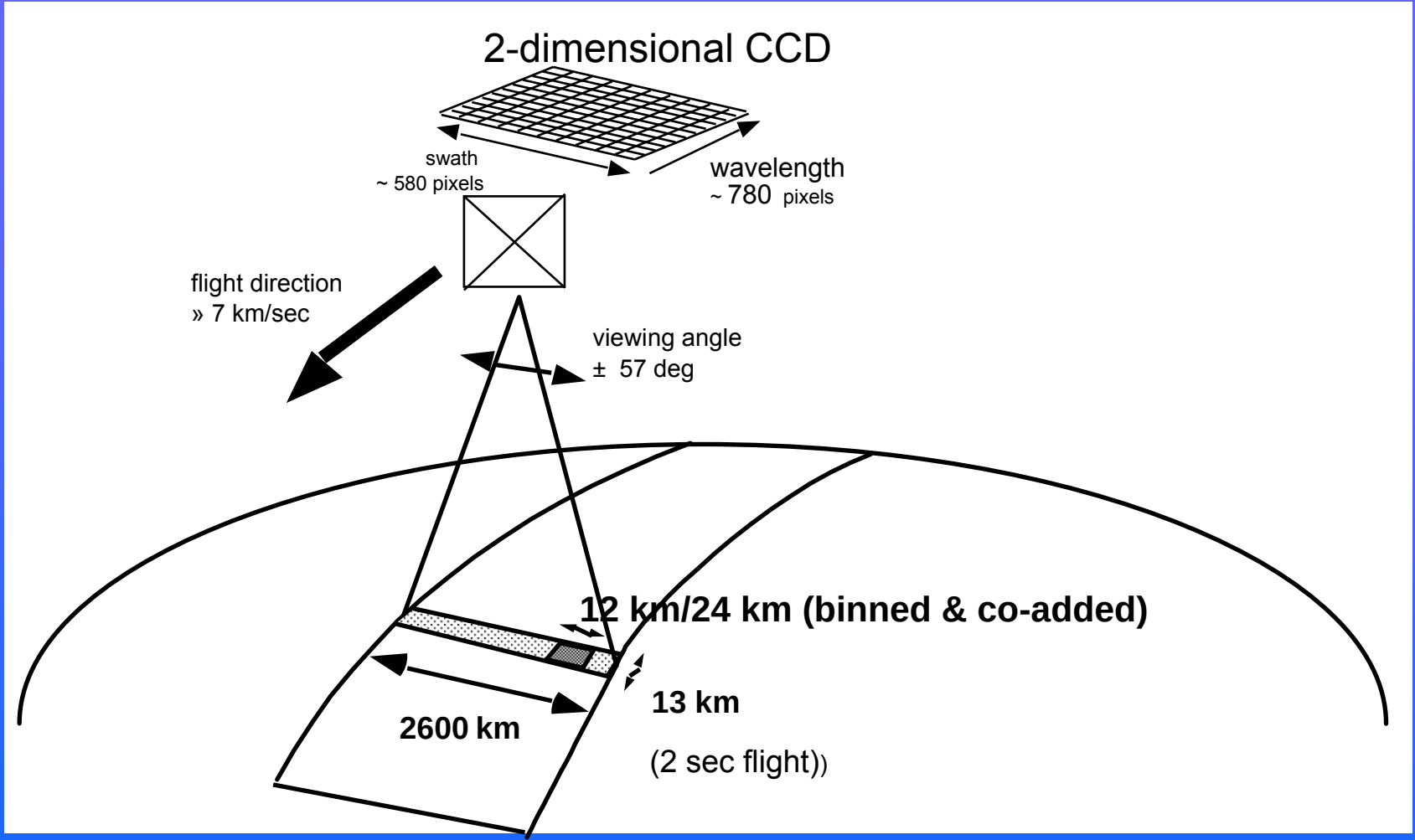
Southern Spain, superzoom mode (unbinned)

Viewing properties



Hurricane Katrina, 28 August 2005



Typhoons Talim and Nabi, 30 August 2005

OMI measurement principle