SCIAMACHY/GOME experiences and lessons learned

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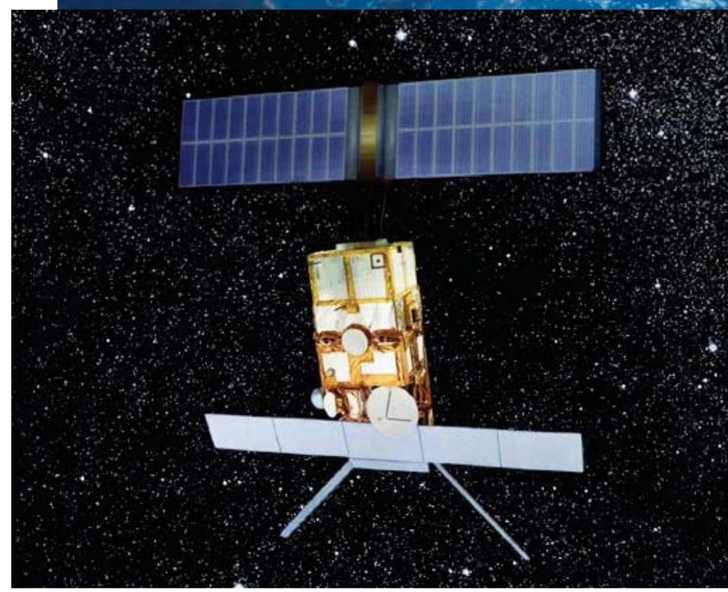
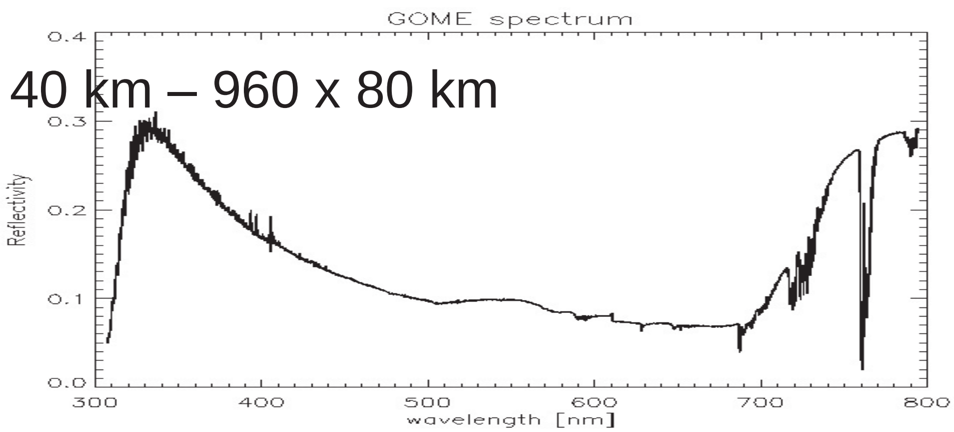
Overview

- Quick Instrument Intro
  - GOME
  - SCIAMACHY
- GOME/SCIAMACHY surprises
- ...and the lessons learned
- Experiences from day-to-day work
- ...and the lessons learned
- Other „common sense“ points
- Open Points



GOME – Instrument Description

- 4 spectrally resolved channels UV/VIS (237-793nm) with 1024 pixels
  - 4 UV/VIS Reticon Si photo diode arrays
- Spectral resolution depending on channel between 0.2 and 0.33 nm
- 3 broadband Polarisation Measurements Devices (PMDs)
- Nadir Earth observation mode
- Additionally: Sun and Moon observation modes + internal white light source (WLS) and spectral lines source (SLS) + LED
- Mirrors are plane (Al) and coated (MgF_2) and scan the Total Clear Field of View (TCFoV)
- Telescope: 2.8 deg x 0.14 deg
- Typical Ground Pixel Nadir: 80 x 40 km – 960 x 80 km



SCIAMACHY – Instrument Description

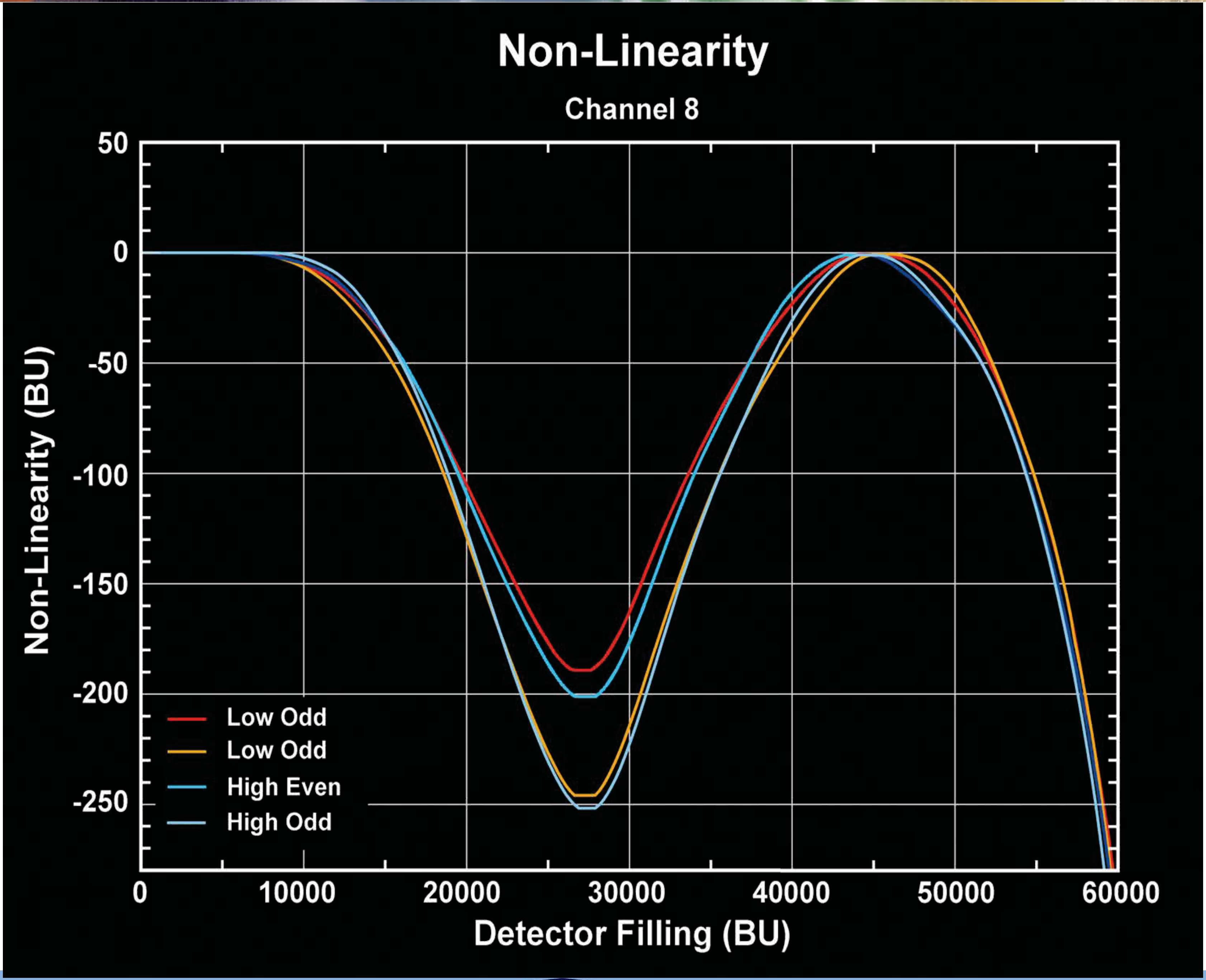
- 8 spectrally resolved channels from UV/VIS to **SWIR** with 1024 pixels
  - 5 UV/VIS Si photo diode arrays, 3 IR InGaAs arrays with varying doping
- Spectral resolution depending on channel between 0.2 and 1.24 nm
- 7 Polarisation Measurements Devices (PMDs), 6 measuring p-direction, one **+45°**
- Two Earth observation modes: **Limb** and Nadir
- Additionally: Sun and Moon observation modes + internal white light source (WLS) and spectral lines source (SLS)
- Mirrors are plane and not coated (Al) and scan the Total Clear Field of View (TCFoV)
- Telescope: 32 mm, Slit: 7.7 x 0.19 mm = 1.8 x 0.045 deg
- IfoV: 25 x 0.6 km (Nadir), 105 km x 2.5 km (Limb)
- Typical Ground Pixel:
  - Nadir: 26 x 30 km - 32 x 233 km
  - Limb: 230 x 2.6 km - x 1060 x 3.6 km

SCIAMACHY surprises (I)

- Memory effect (UV/VIS) needed re-analysis:
  - Insufficient measurements on-ground could be compensated by internal WLS measurements in-flight
- Non-Linearity was (wrongly) assumed to be negligible:
  - Corrections calculated from on-ground measurements (in-flight not possible due to life limit on internal WLS)
  - Used on-ground measurements were not scheduled, but done one evening in spare time, therefore the correction is not optimal
- Light Leak in channel 7:
  - Light tightness could only checked in ambient were SWIR channels have not enough S/N
  - No in-flight correction found yet
- Ice in channels 7&8:
  - Combination of not enough venting + carbon fibre structure of ENVISAT
  - Leads to loss of S/N and slit function changes
  - Level 2 retrievals were adjusted

Memory Effect: Measurement & Fit
Channel 3
Memory Effect (BU)
200
100
0
-100
-200
0
10000
20000
30000
40000
50000
60000
70000
Detector Filling (BU)

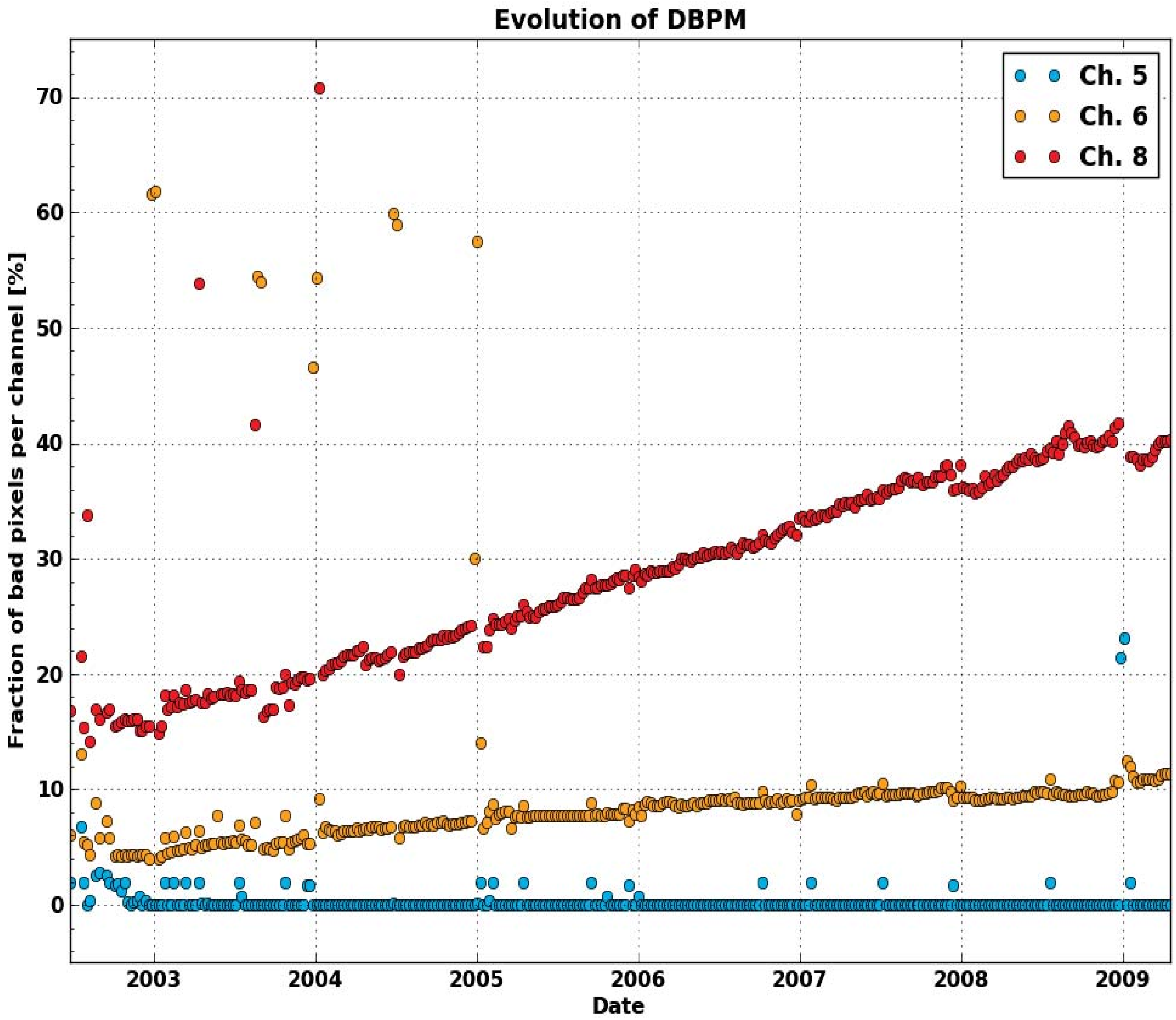
SCIAMAC


Non-Linearity
Channel 8
Non-Linearity (BU)
50
0
-50
-100
-150
-200
-250
0
10000
20000
30000
40000
50000
60000
Detector Filling (BU)
Low Odd
Low Odd
High Even
High Odd

SCIAMAC

SCIAMACHY surprises (II)

- Number of “bad pixels” increases in SWIR
  - Is monitored in-flight
  - Difficult to foresee, since the detectors were never used before in space
- Polarisation:
  - Unexpected sensitivity to 45 deg polarised light
  - Made the addition of PMD 45 and additional measurements necessary
- Spectral features of ESM diffuser
  - Additional diffuser added “in the last minute”

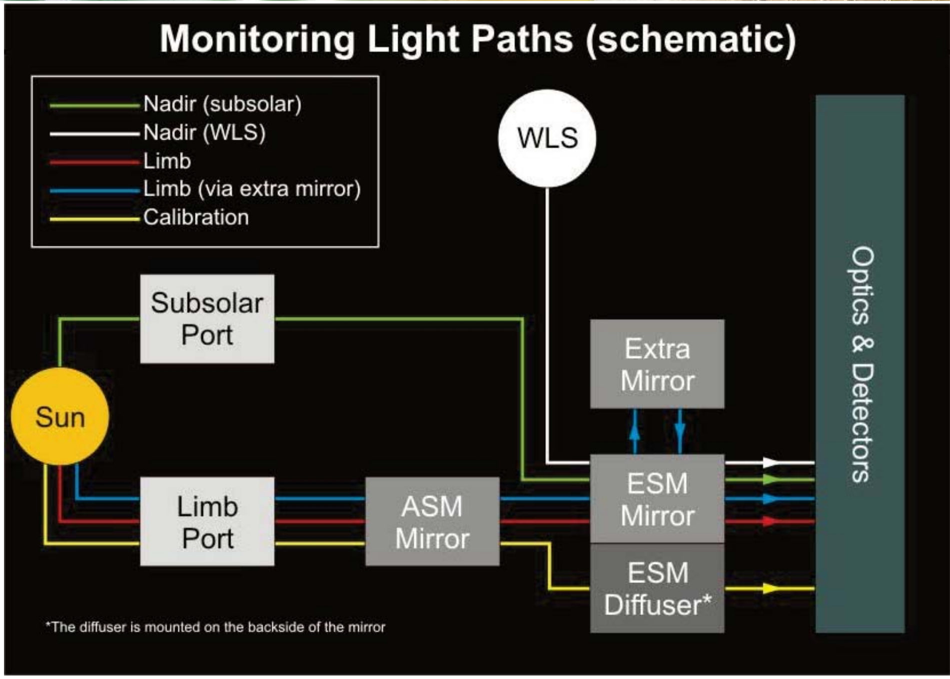


Evolution of DBPM
Ch. 5
Ch. 6
Ch. 8
Fraction of bad pixels per channel [%]
0
10
20
30
40
50
60
70
2003
2004
2005
2006
2007
2008
2009
Date

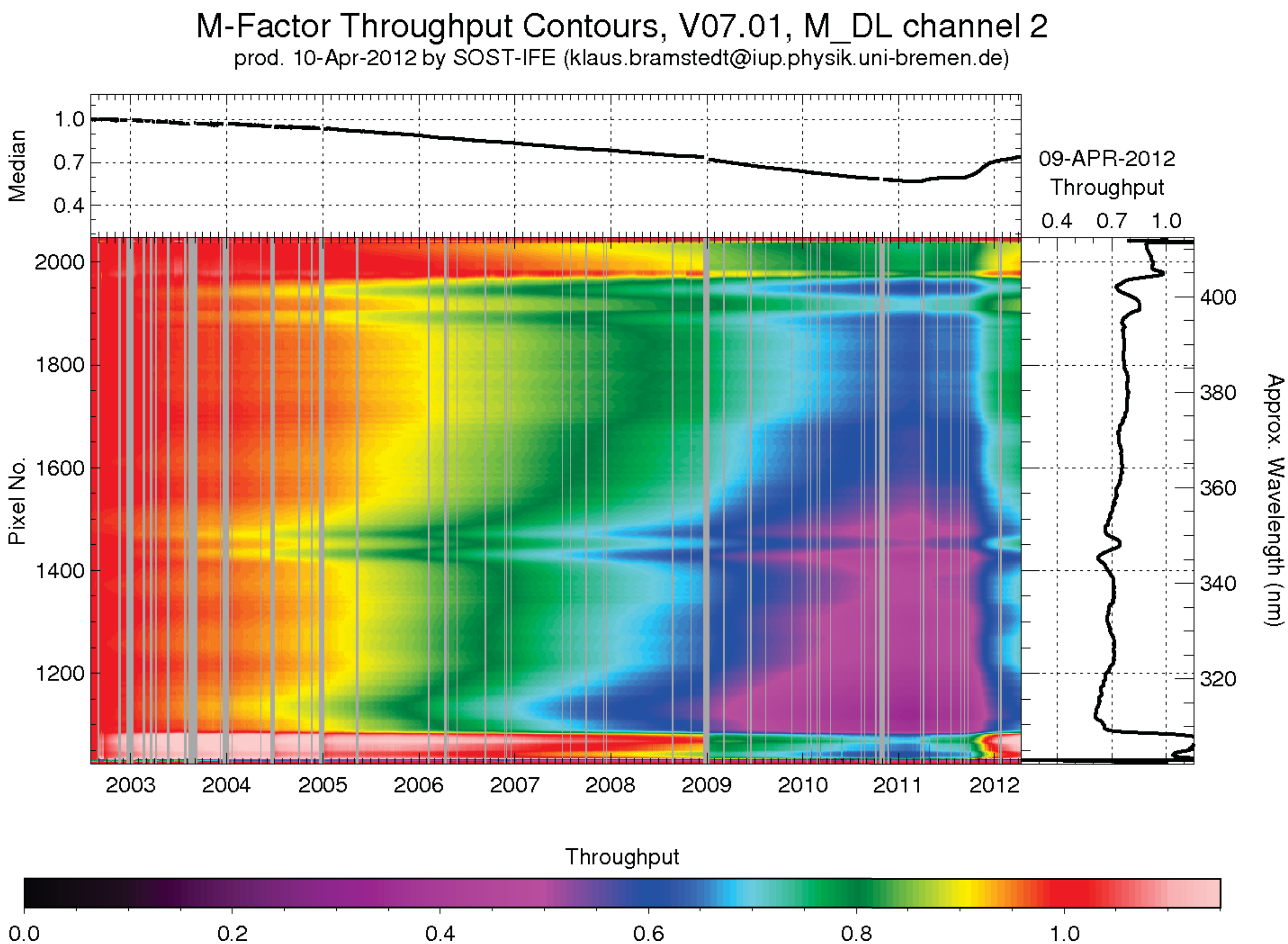
SCIAMACHY surprises (III)

- Initial Radiometric & polarisation correction showed not the expected quality in orbit:
  - Complete re-analysis of on-ground data is on-going
- Degradation showed unexpected scan angle dependence:
  - New approach to degradation correction (contaminated mirror model)
- Degradation showed not the expected behaviour in orbit (recovery)
  - Complete re-analysis of in-flight data is on-going

Instrument monitoring (SCIAMACHY)

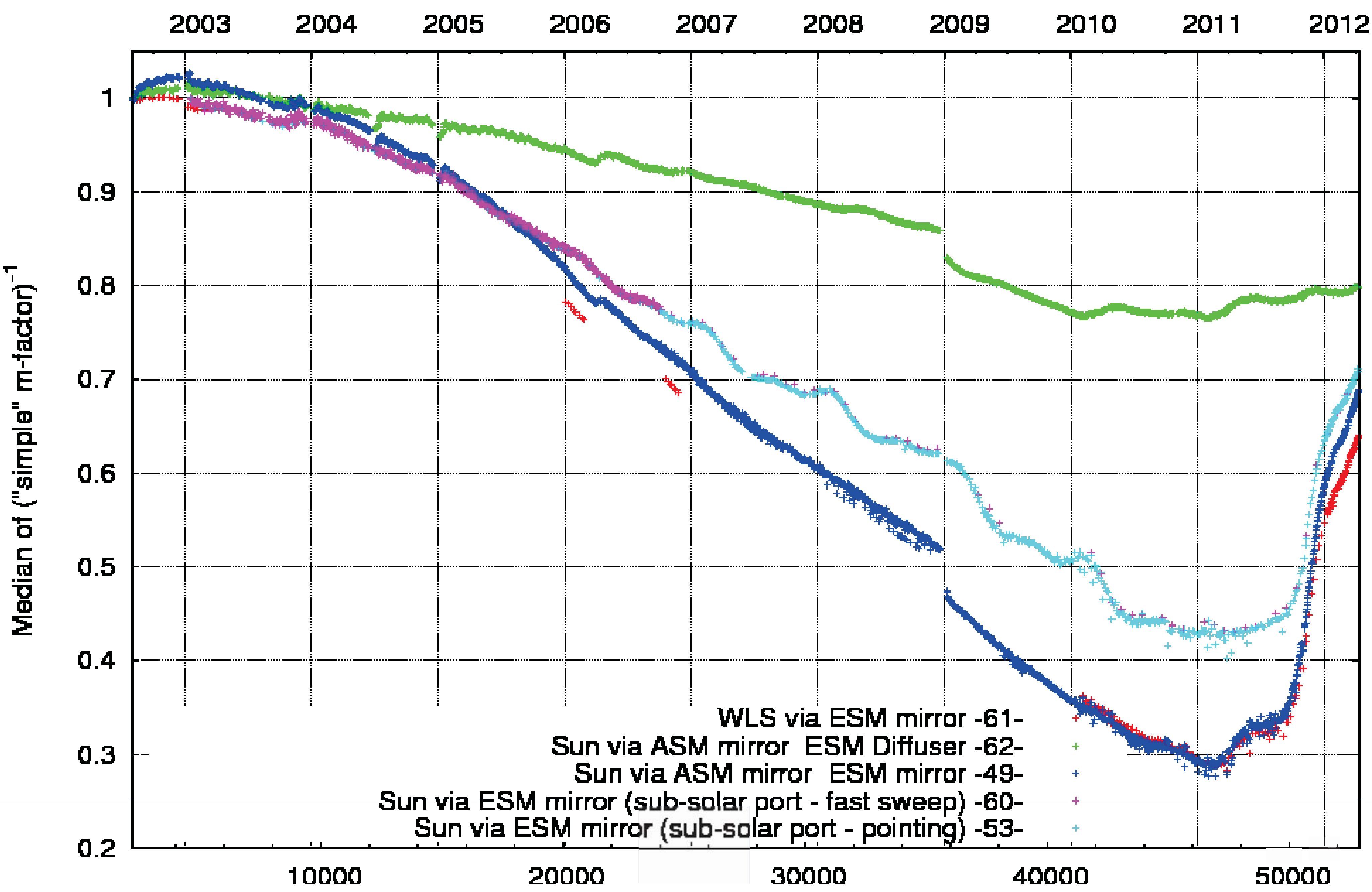


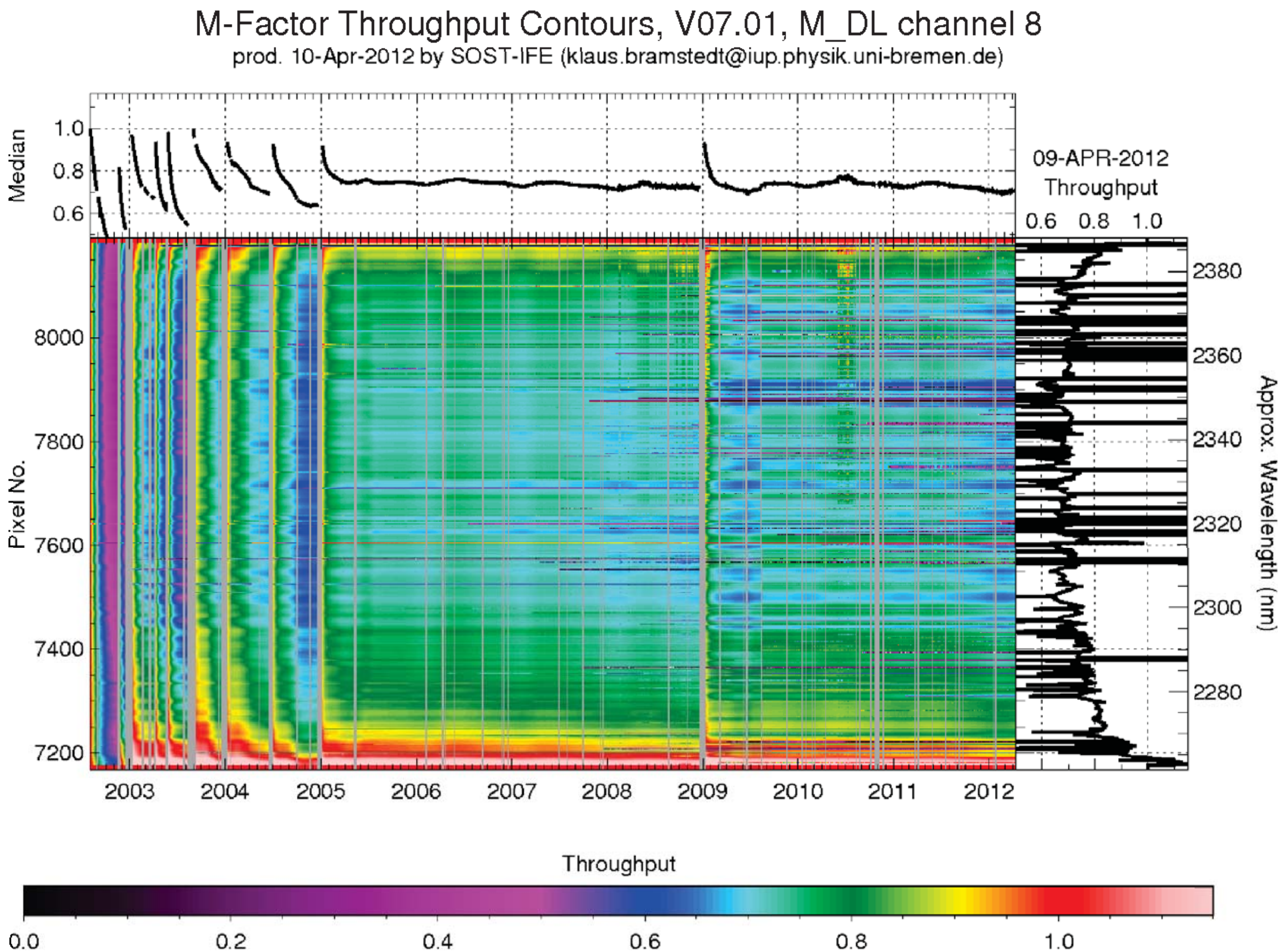
- Optical performance of the instrument is degrading/changing with time.
- Monitoring concept (radiometric calibr.):
  - Regular end-to-end measurements of a “constant” light source:
    - SubSolar / WLS (Nadir light path)
    - Solar occultation (Limb light path)
    - Sun over diffuser (Sun over diffuser light path)
- Degradation correction (L1B V6 / V7):
  - “m-factors”: End-to-end correction factors
    - ratio actual to reference measurement of the constant light source
    - separate per light path



- SCIAMACHY ch. 2 (UV) throughput loss
- Limb light path
- Unexpected recovery since March 2011

Sciamachy Light Path Monitoring with L1b M-factors: Ch. 1





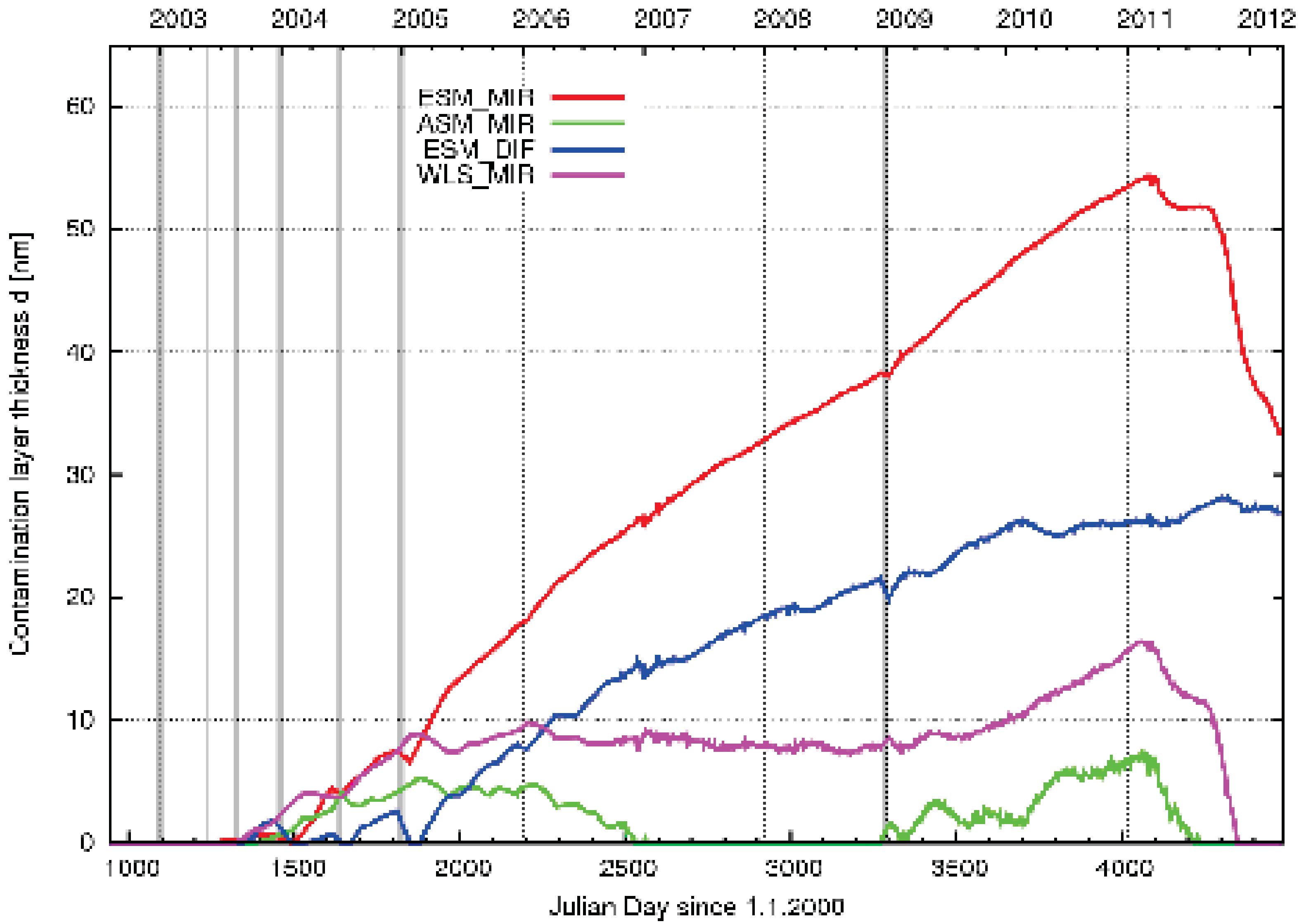
- SCIAMACHY ch. 8 (NIR) throughput loss
- Limb light path
- Icing visible: Decontaminations with short recovery of throughut
- Bad/dead pixels

Scanner model approach

- New degradation correction concept for L1B V8.
- Physical model of the scanner unit (mirrors/diffusers) developed.
- Full Mueller matrix approach.
- Contamination layers on top of the optical surfaces included.
- Thicknesses of the contimation layers are fitted:
  - Same monitoring measurements as before.
  - Thicknesses describe large part of degradation.
- Advantage: Valid degradation correction for **all** scan angles.

- Principle can be used for other instruments:
  - GOME, GOME-2, ….

Thicknesses derived for SCIAMACHY



… and the lessons Learned

- T/V measurements are a must
- At least quick look of calibration measurements *during the calibration* to detect anomalies early (and before the instrument is gone)
- Identify instrument characteristics that can only be measured on-ground, make these a top priority and do redundant measurements (the latter must be part of the calibration planning)
- If you expect cold temperatures, put a cold finger somewhere that is colder than your detector and the optical surfaces
- Extra measurements! Do them!

Experiences from day-to-day work

- Testing algorithms with the L1b processor were very difficult, since the processor was originally not required and intended to read on-ground data.
- Documentation & traceability was insufficient for SCIA:
  - It took years to reconstruct reference frames used for polarisation and re-construct the radiometric measurements after the fact (reasonable guesses had to be used for some details)
  - It took 2 years to clear all the formalities until the science institutes got all the measurements & software that we used for the on-ground calibration.

...and the lessons learned

- Immediate, thorough documentation and traceability is essential (not only measurement logs but higher level documents): If you do not do it you pay a factor more later to get the knowledge back
- Involvement of scientists/users is essential
- The entity responsible for the operation of the instrument must have all the measurements, S/W and documentation from the on-ground calibration. Contracts have to be set up this way.
- On-ground characterisation, in-flight calibration and mission concept are interdependent
- Data Formats and L0-1 data processor should be compatible, so it is easily possible to feed the processor with on-ground data

Other common sense points

- “Real” target measurements are very useful (sky, surface etc.)
- Automate as far as possible the logging of your on-ground calibration
- Use *one* interface to save on-ground measurements and results, if possible the same should be used in-flight (database)
- Science institute should accept that the 100% solution is not always possible. Industrial companies should not slavishly cling to the letters of the contract, but show some initiative on their own.
- Learn the lessons from your project. All partners should sit together after the project and compile the lessons they learned

...and the lessons learned

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Data Formats

- Envisat L1b and L2 data formats were a nightmare.
- Recommendations:
  - Use standard formats for L1b onwards (netCDF, HDF, HF5-EOS, ...)
  - Define standards for dataset annotations:
    - Within ESA for all (similar) instruments.
    - Ideally also with EUMETSAT, NASA, JAXA, ...
  - Foresee and allow extensions in format/content in the course of the mission.
  - Provide non-graphical reading tools
    - EnviView was useless
    - BEAT is a good starting point

Open Points – Is there work done on these? Would they be useful?

- Consequences of using models as basis for calibration:
  - Spectral calibration uses Earth (or sun) signal and compares to RTM models/solar spectra derived from different sources
  - What are the consequences for the retrieved geophysical parameters? What if the model used there is different? In how far do we put information into the calibration that we want to retrieve in the first place?
- On-ground measurements with spectral resolution/range comparable to the spectral imagers
  - Typically measurements are done for imagers broadband channels (e.g. DOME-C)
  - Would higher resolution measurements be useful for spectral imagers?

Concluding remarks

- Sh... happens, so plan in extra time
- SCIAMACHY is a somewhat special case:
  - Several adjustments could be made during the instrument, we had 5 calibration campaigns (not all of them for everything). It is unlikely that this happens again under conditions today, so planning must be extra thourough
  - Together with GOME it was the first instrument of its kind in Europe, so experience was not there and had to be gained => If you build instruments using new concepts, expect more extra time is needed
- In S4-UVN study, a detailled TN with calibration recommendation based experience with GOME, SCIAMACHY, GOME-2 and OMI was prepared: *Sentinel-4 instrument calibration: recommendations on requirements and principles, IUP-S4UVN-TN-09, Feb 2010*

Additional slides

SCIAMACHY Calibration&Characterisation - Concept

- Ideally measurements should be done under the same conditions as in space, i.e. in a tank with thermal vacuum conditions, but tank size did not allow rotation for all necessary angles (scan mirrors!)
- Combination of measurements was used:
  - Thermal Vacuum (T/V):
    - One scan angle only, full instrument (Science channels and PMD) and full spectral resolution
    - Measurements with a calibrated light source to calculate the radiometric sensitivity
    - Measurements with s, p, +/- 45° polarised light and unpolarised light
  - Ambient:
    - On component level, i.e. only mirrors and diffuser (combinations)
    - Only for selected wavelengths and angle (combinations)

  - => Scan Angle Correction: In-flight measurements with different incidence angles than the T/V measurements are corrected using the ambient measurements

SCIAMACHY Ambient Calibration

- Performed in CR100 environment
- Only scanner modules (with instrument mirror/diffuser) mounted on a two-axis trolley to allow for the measurement of desired scan angles
- Lightsources:
  - 300 W Xe lamp for UV/VIS
  - 250 W QTH lamp for UV – SWIR (low signal in UV)
- Monchromator produces line widths between 1.8 and 22 nm, depending on wavelength
- Polariser and analyser were used to determine polarisation characteristics
- Detectors: 200 – 1050 nm: Silicon, 1050 – 2400 nm : Lead Sulphide (PbS)
- Measurement set-up was intended for relative measurements only (using a signal detector and a reference detector)

In-Flight Calibration – Flow diagram