Improved pointing knowledge for SCIAMACHY

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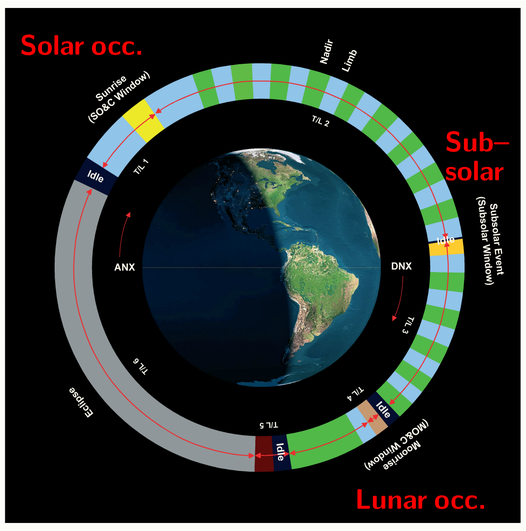
1 SCIAMACHY

Satellite measurements in limb and occultation provide altitude resolved information about Earth's atmosphere. SCIAMACHY (SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY) on-board ESA's Envisat (2002-2012) is a passive remote sensing moderate-resolution imaging UV-Vis-NIR spectrometer (nadir / limb / occultation).
Precise pointing knowledge is needed, because the pointing defines the viewing direction and therefore the observed tangent height and altitudes of the retrieved profiles.

2.1 Measurements used in pointing investigations

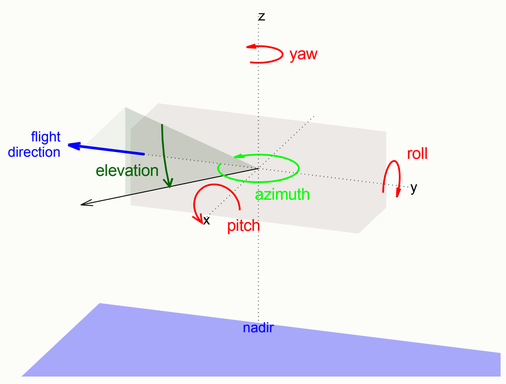
- Solar occultation:
  - Northern hemisphere.
  - Once per orbit.
- Sub–solar:
  - Monitoring measurement.
  - Equator region.
  - Monthly calibration.
- Lunar occultation:
  - Southern hemisphere.
  - Once per orbit, if moon is in FOV
  - 1 week per month
  - ∼6 month per year



2.2 Angles and pointing

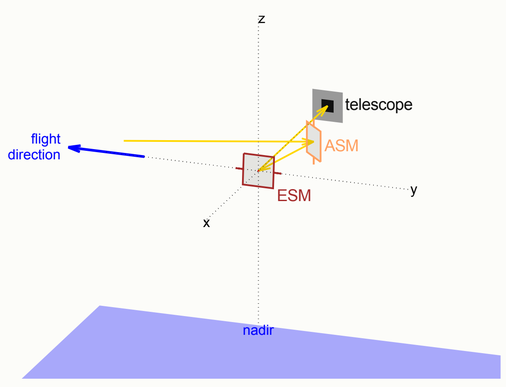
Viewing directions:
- Elevation
  - Perpendicular to the horizon, positive downwards.
- Azimuth
  - In plane parallel to horizon.

Platform mispointing angles are offsets to
- Pitch / Roll / Yaw



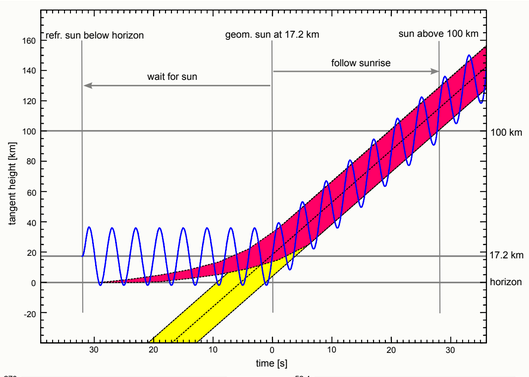
2.3 SCIAMACHY's scanner unit

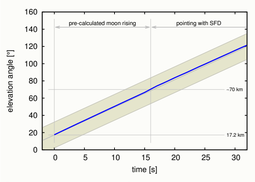
Sketch optical parts:
- Telescope: Further optics + detectors.
- Two scanners:
  - Elevation Scan Mechanism (ESM)
  - Azimuth Scan Mechanism (ASM)



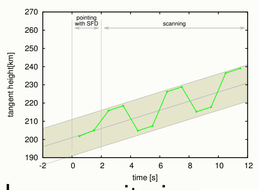
2.4 Measurement sequences

Solar occultation:
- Scanning solar disk up to 290 km or 110 km.

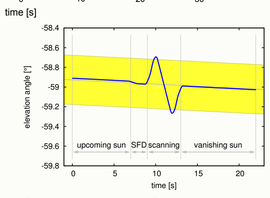




Lunar occultation: Pointing up to 380 km / 140 km.



Lunar monitoring: 2 s pointing + scanning.



Sub–solar: One scan over solar disk.

2.5 Mispointing determination

Calculated viewing direction:
- Calculate elevation and azimuth of target, using attitude knowledge!
- ⇒ *product geolocation!*

Measured viewing direction:
- Get mirror positions, when SCIAMACHY points to target.
- Translate mirror position to elevation and azimuth.

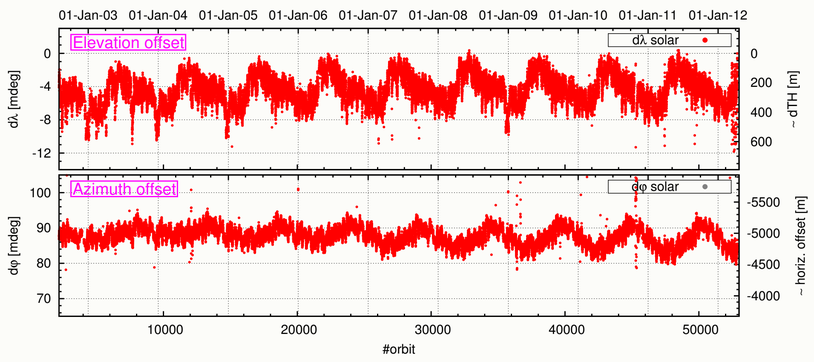
Difference *calculated – measured* viewing direction is mispointing.

Measuring the viewing direction:

Scan over solar disk:
- Fit maximum intensity to get solar center.
  - Solar occultation (elevation).
  - Sub–solar (elevation).

Pointing to sun / moon:
- Sun Follower (SF) adjusts towards brightness center.
  - Solar occ. (azimuth)
  - Lunar occ. (elevation + azimuth)

3 Solar occultation elevation / azimuth offsets



Elevation Angle Offset (EAO):
- Overall mean 266m.
- Seasonal cycle: ±114 m.

Azimuth Angle Offset (AAO):
- Large horizontal offset!
- Overall mean: 4955 m.
- Amplit. seasonal cycle: 127 m.

Note: Remaining uncertainty of tangent height for individual solar occultation measurements is ± 26 m!

4.1 Moon as target

Lunar disk is highly variable:
- Lunar phase.
- Lunar libration:
  - Longitude: orbit eccentricity.
  - Latitude: axis inclination.

Sun Follower (SF) target:
- *Gravity center of brightness*!
- This is not the center of the moon!

Task:
- Determine for each measurement the *center of brightness*!
- Simulate SF adjustment on appropriate reference images.
- Libration and phase at measurement time and for the reference image must closely match!

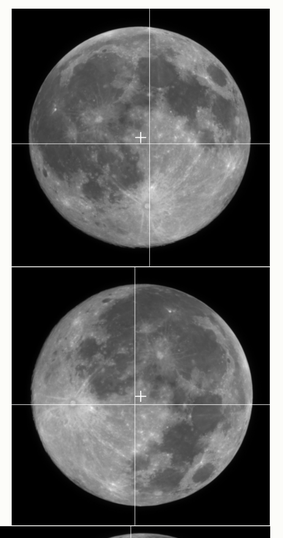
4.2 Lunar reference images from ROLO

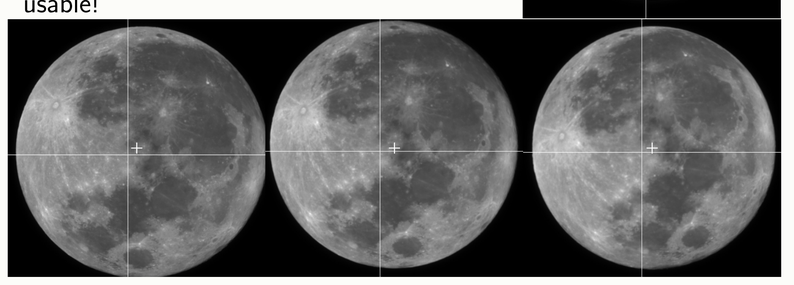
USGS Robotic Lunar Observatory (ROLO)

- 6 years of automatic lunar images (1997 - 2003).
- Absolutely calibrated instrument, here 550 nm channel is used.
- Similar to SCIAMACHY's sun follower sensitivity (∼500 nm).

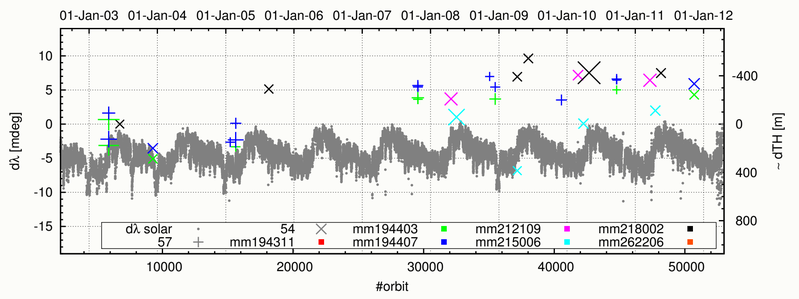
4.3 SF adjustment simulation:

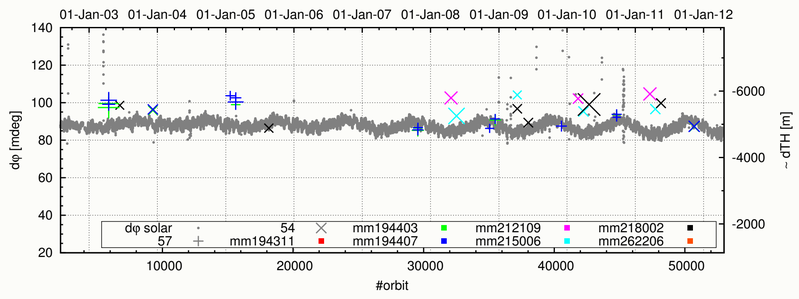
- Moon image is mapped onto the 4 quadrants of the SF.
- After adjustment, the 4 quadrants receive same amount of light.
- Simulated using ROLO reference images.
- Thick small cross: center of moon.
- Found center of brightness is marked by the cross-hair. ⇒ Lunar Target!
- 5 ROLO images used here (more will be added).
- Limited to full moon.
- Close match of phase + libration needed!
- Limited number of lunar measurement usable!





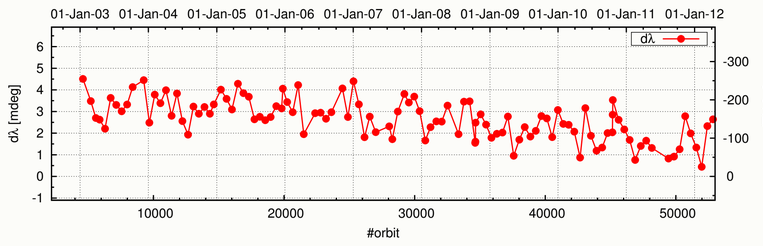
4.4 Lunar Angle Offsets





- Only best matches with reference images *(colors indicate images)*!
- Larger cross ⇒ better match.
- Grey points: solar occultation offsets for comparison.
- Preliminary results! More reference images needed for better statistics.

5 Sub–solar elevation angle offset



- Sun via subsolar port, elevation mirror only.
- Mean elevation angle offset: 3 mdeg.

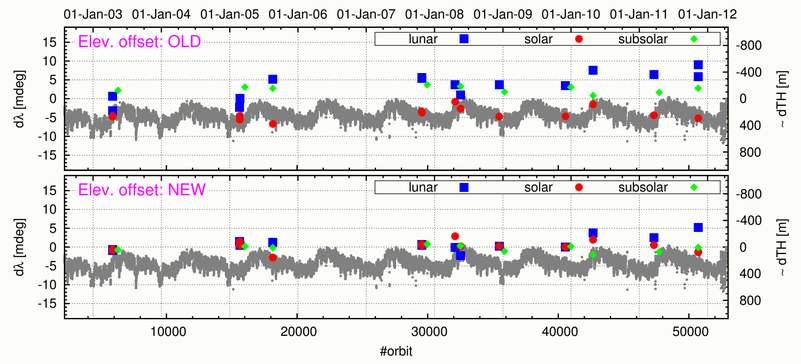
6.1 Mispointing analysis

Platform misalignment:
- SCIAMACHY may not exactly aligned with the platform.
- Misalignment is described with pitch / roll / yaw mispointing angles.
- First set determined in 2007 (Gottwald et. al).

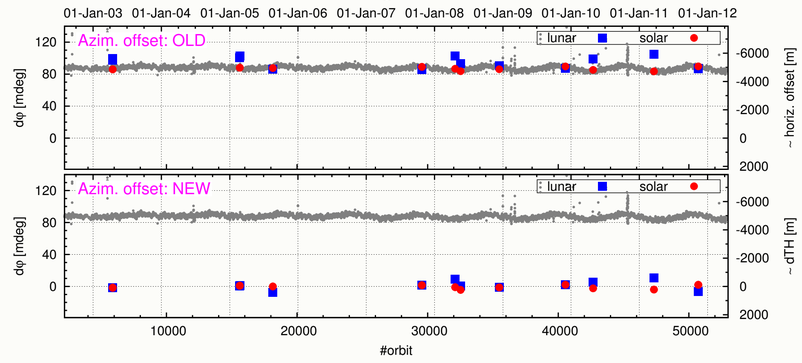
Scanner offsets:
- Scan mirrors zero positions might have an offset.
- ASM mirror offset:
  - Rotation around yaw axis!
  - Not distinguishable from yaw mispointing – ignored.
- ESM mirror offset, corresponds
  - to roll offset for nadir/subsolar,
  - to pitch in limb/occultation (ASM mirror reflection!).

⇒ Four mispointing parameters: pitch, roll, yaw, ESM offset.
- Non-linear Levenberg-Marquad fit: minimize offsets in elevation and azimuth.
- 15 lunar occultations with best matches to reference images.
- Selected close in time: 14 solar occult. + 10 subsolar measurements.

6.2 Fit results



- Elevation angle offset (EAO) minimized for all measurement types.
- Note: Solar and lunar EAO changed in different direction!



- Azimuth angle offset (AAO) minimized for all measurement types.
- Large AAO offset removed.

6.3 Summary fitted mispointing parameters:

	Old(2007) [mdeg]	New(fit) [mdeg]	error [mdeg]
pitch	-25.4	-12.7	± 1.6
roll	-18.3	-26.6	± 1.2
yaw	-218.5	-124.2	± 0.9
esmpos	0.0	-11.2	± 1.4

Main effects of mispointing change:
- Yaw: ⇒ Azimuth offset fixed!
- Roll: Fixes elevation offset with opposite signs for occultation:
  - Solar occ: ∼-30° azim. angle
  - Lunar occ: ∼+40° azim. angle
- Pitch: Overall adjustment of elevation offset.

Preliminary results!
- Extend number of ROLO images (better lunar statistics).
- Preliminary set of improved mispointing parameters fitted.
- Foreseen for use in the SCIAMACHY Level 0 - 1 processor Version 9.
- Improved geolocation for all SCIAMACHY measurements.

Selected references

Bramstedt et al, Precise pointing knowledge for SCIAMACHY solar occultation measurements, Atmos. Meas. Tech., 5, 2867-2880, 2012.

Gottwald et al, The Status of the SCIAMACHY Line-of-Sight Pointing Knowledge, Proc. ESA Living Planet Symposium, Bergen, 2010.

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SCIAMACHY is a national contribution to the ESA ENVISAT project, funded by Germany, The Netherlands, and Belgium. SCIAMACHY Level 1 data have been provided by ESA. This work has been funded by DLR-Bonn, by ESA in the framework of the SCIAMACHY Quality Working Group (SQWG) and by the University of Bremen.

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