Study on validation of spectral band adjustment factors using lunar hyperspectral measurements

Activity 4: GOME2

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EARTH SPACE SOLUTIONS

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THE GOME-2 LUNAR OBSERVATIONS

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Teaser
Lunar Irradiance
Lunar Reflectance

65 Degrees Phase

Reflectance vs. Wavelength (nm)

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Content

• GOME2
• GOME2 Lunar observations
• Lunar Irradiance derivation
• Lunar variation model
• Issues
• Results
• Comparison GIRO
SCIAMACHY

Ratio measurement / GIRO, phase angle = 50 deg

EARTH SPACE SOLUTIONS
Objective Activity 4

- Derive stable lunar irradiance from GOME2
GOME2
The GOME-2 UVN instrument on Metop
Measuring atmospheric composition

GOME-2:
- series of 3 instruments on Metop (Metop A launched in 10/2006)
- sun-synchronous orbit, 09:30
- 412 orbits (29 days) repeat cycle
- Global coverage 1.5 days
- 240 nm to 800 nm
- 0.25 to 0.5 nm spectral resolution (FWHM)
- 4 channels with 4098 energy measurements of polarisation corrected radiances (40 x 80 km²)
- 2 channels with 512 energy measurements of linear polarised light in perpendicular direction (S/P) (40 x 10 km²)

Orbit file sizes
- GOME-2 L1B ~ 1GB
- IASI L1C ~ 2GB
Sun Mode

NOTE:
“Irradiance” is Lunar Irradiance not solar irradiance unless explicit
Earth Mode
Lunar Mode

Fixed Mirror

GOME2
Lunar Mode

Moon motion

Moon

IFOV
Nominal Lunar Measurement

Scan ID: 304

Radiance

Time [sec]

nm

737

613

549

445

390

332

309
Measurements
Irradiance Derivation

- (all per nm per m^2)
- \( R = \text{#photons/sec/sr} \)
- \( S = \text{#photons} = R \times (L \times B) \times T \)
- Sum Scan \( \Sigma R \)
- \( I = \text{#photons/sec} \)
- \( I = \frac{\Sigma S}{B/V} \)
- \( I = \frac{\Sigma R \times L \times B \times T}{B/V} \)
- \( I = \Sigma R \times L \times V \times T \)
Modelling Lunar Variation
4 Models

- GOME2 Irradiance
- GOME2 Reflectance
- GOME2/GIRO Irradiance
- GOME2/GIRO Reflectances
Model
(for each wavelength)

- $P[0]*$
- $1+P[1]^*\left(\sqrt{\text{lunar\_phase}}-\sqrt{65^\circ}\right)$
- $1+P[2]^*\text{Libration\_latitude}$
- $1+P[3]^*\text{Libration\_longitude}$
- $1+P[4]^*\text{Solar\_longitude}$

- $\text{Distance\_sun\_moon}^P[8]$
- $\text{Distance\_sat\_moon}^P[9]$
Fitting

- Weight invalid measurements to zero
- Fit degradation relative to GIRO (seed)
- Fit model (incl degradation) relative to GIRO
- Add distance dependence ($P[8:9]=-2$)
- Fit model (incl degradation) to data
- Remove channel overlaps

Both for Reflectance and Irradiance
P[0]

MJD 4720, No libration, Phase 65°
Issues

- Degradation
- Missing Data
- Pointing
- Duration
- Background
- Straylight
Degradation
Conclusion: Degradation is there, but can be fitted
Model as verification

Max lunar signal

Lunar Slit Model
Sample contaminated Lunar measurement

Channel averages
Signal as function of solar position relative to satellite
Straylight Spectra compared to known sources

- Not Earth
- Looks like sun
- Incorrect background
- Not Moon

Outside

Central
Impact estimate

Conclusion: Straylight will impact relative accuracy
Note: Straylight not random error!
Results
Model
(for each wavelength)

- $P[0]*$
- $1+P[1]* (\sqrt{\text{lunar\_phase}}- \sqrt{65^\circ})$ [radians]
- $1+P[2]*\text{Libration\_latitiude}$ [degrees]
- $1+P[3]*\text{Libration\_longitude}$ [degrees]
- $1+P[4]*\text{Solar\_longitude}$
- $\exp(MJD*P[5]+MJD^2*P[6]*MJD^3*P[7])$
- $\text{Distance\_sun\_moon}^P[8]$ Fixed
- $\text{Distance\_sat\_moon}^P[9]$ Fixed

Reproduces GIRO

MJD-4720 (Dec 2012)
Lunar Reflectance

Lunar Irradiance

Dec 2012, No libration, Phase 65°
Compare to GIRO
SCIAMACHY vs GOME2

Libration

Lunar phase

550nm
GOME2 very small phase and libration range compared SCIAMACY
Conclusions

• Issues
  – Degradation
  – Missing Data
  – Pointing
  – Duration
  – Background
  – Straylight

• Stable lunar irradiance derived

• Differences relative GIRO due limited geometries
Thank you!
Extra Slides
Channel Edges
Figure 8: Geometry for lunar observations. Elevation and azimuth angles in the Satellite Relative Actual Reference CS are calculated for the four points HJKL delimiting the illuminated part of the lunar surface as seen from the satellite, and for point M, the centre of the moon.
**Geometries provided in the L1B product**

**MDR-1B-Moon / GEO_MOON**

<table>
<thead>
<tr>
<th>Geometries</th>
<th>Definition</th>
<th>Units</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>(d_{Moon})</td>
<td>Azimuth of lunar points HJKLM (Satellite Relative Actual Reference CS)</td>
<td>deg o</td>
<td>A2.23.1</td>
</tr>
<tr>
<td>(E_{Moon})</td>
<td>Elevation of lunar points HJKLM (Satellite Relative Actual Reference CS)</td>
<td>deg o</td>
<td>A2.23.1</td>
</tr>
<tr>
<td>(D_{Sun-Moon})</td>
<td>Distance between sun and moon</td>
<td>d m o</td>
<td>A2.23.1</td>
</tr>
<tr>
<td>(D_{Sat-Moon})</td>
<td>Distance between satellite and moon</td>
<td>d m o</td>
<td>A2.23.1</td>
</tr>
<tr>
<td>(\omega)</td>
<td>Lunar phase angle (geometrical)</td>
<td>d deg o</td>
<td>A2.23.1</td>
</tr>
<tr>
<td>(A_{Moon})</td>
<td>Illuminated fraction of lunar disc (sunlit moon area divided by total moon area as seen from the satellite)</td>
<td>d o</td>
<td>A2.23.1</td>
</tr>
</tbody>
</table>
GOME-2 optical layout
Scanning grating spectrometer with a random-access linear silicon photodiode array

Earthshine

Sun $I_0$ (daily)
Solar diffuser
White Light Source
WLS (daily)
Spectral Light Source
SLS (daily)

Scan Mirror

Calibration Unit
Common (Earth/Solar/Cal) path
Spectral variation

Date: 04 March 2005
Satellite: Rosetta
Depicts: Three lunar spectra
Copyright: ESA

Three spectra of three different regions on the Moon:

- Blue = Kepler crater
- Green = Mare Humorum
- Red = Oceanus Procellarum
GOME2A

• Simular results (not shown here)
• Additional uncertainty
  – Step-function degradation (2\textsuperscript{nd} Throughput test)
  – Calibration problem early mission
Recommendations

• Degradation
  – Fact of life
• Missing Data
  – Check Lv0/1 for missing data
• Pointing
  – Check Flight Dynamics
• Duration
  – Extend lunar measurement by 30-60sec both direction
• Background
  – Investigate background from Lv0 (not Lv1)
• Straylight
  – Investigate straylight at Lv0