Water vapor measurements in the stratosphere at 936 nm by stellar occultations with GOMOS/ENVISAT

Jean-Loup Bertaux(1), Alain Hauchecorne (1), Nadège Montoux (1), Francis Dalaudier(1), Laurent Blanot (4), Jean-Claude Lebrun (1) 
Erkki Kyrölä(2), Viktoria Sofieva(2), Didier Fussen(3), Gilbert Barrot (4) 
Thorsten Fehr(5), Lidia Saavedra de Miguel(6) 

bertaux@latmos.ipsl.fr

(1) LATMOS, UVSQ, CNRS, BP3, 91370 Verrières-le-Buisson, France
(2) FMI, Helsinki, Finland
(3) IASB/BIRA, Brussels, Belgium
(4) ACRI-ST, Sophia-Antopolis, France
(5) ESA, Frascati, Italy
(6) Serco, Frascati, Italy
Plan of talk

• Importance of H2O at UTLS: mechanism of injection, trend
• GOMOS principle: star occ at 936 nm HiRes
• modeled transmission HITRAN +LBLRTM
• Limb: solar scattered radiation OK
• First comparison: problems.
• PRNU map. (Pixel to Pixel Response Non-Uniformity)
• Intra pixel PRNU
• New results, comparison with HALOE.
Injection of H$_2$O from troposphere to stratosphere

Brewer-Dobson (BD) general circulation: cold tropopause, $\Rightarrow$ de-hydration
Contribution of cirrus and Cumulo nimbus overshoots (See Pommereau paper)

after Holton, 1995
Stratospheric H2O trend: discrepancy between instruments

HALOE: IR Solar Occultation on UARS:
Frost Point Hygrometers: balloon borne in Colorado

Desirable to have other long series of instruments operating now, with some overlap with previous period 1992-2005

Scherer et al., 2007
CONSEQUENCES OF A TREND OF +0.04 ppmv/yr:

1. Consequences
   - T ↘ stratosphere (-0.35 K/18 ans)
   - T ↗ troposphere (+0.15K/18 ans)
   - total ozone column decrease ↘ (-0.3%/10 yr)
     HOx scavenger
   - delay in the resorption of ozone hole 10 yr

2. Possible Causes:
   - 25-35% linked to ↗ methane
   - Remaining ? Injection from tropo to strato more efficient?
H$_2$O with GOMOS
Primary mission objectives: profiles of ozone, NO2, NO3, temperature, water vapor, air and aerosols; Day- and night-side measurement capability;
Star spectra vs magnitude and temperature

Reference star spectra

Orbit 2155

- **S005**: 0.03, 11000K
- **S013**: 0.87, 3800K
- **S030**: 1.69, 30000K
- **S084**: 2.40, 4500K

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Distance to nearest habitable planet in light years: 760 nm

Water molecule: 

O₂: 936
Brightest stars at 936 nm

9 stars OK for H2O retrieval; -2 = 7 stars
# Name of Gomos stars

<table>
<thead>
<tr>
<th>GOMOS ID number</th>
<th>Name of star</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sirius</td>
<td>α Canis Major</td>
</tr>
<tr>
<td>2</td>
<td>Canopus</td>
<td>α Carinae</td>
</tr>
<tr>
<td>3</td>
<td>Arcturus</td>
<td>α Bootis</td>
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<tr>
<td>4</td>
<td>Rigel</td>
<td>α Centauri</td>
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<tr>
<td>13</td>
<td>Aldebaran</td>
<td>α Tauri</td>
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<td>14</td>
<td>Betelgeuse</td>
<td>α Orionis</td>
</tr>
<tr>
<td>16</td>
<td>Antares</td>
<td>α Scorpii</td>
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<tr>
<td>26</td>
<td>GaCrux</td>
<td>γ Crux</td>
</tr>
<tr>
<td>63</td>
<td></td>
<td>β Gru</td>
</tr>
</tbody>
</table>
GOMOS Latitude coverage of H2O stars
Calculated transmission with LBLRTM and HITRAN 2004 spectral data base for a typical US standard profile.
• **Black**: model, **red**: GOMOS transmission
• Narrow absorption lines are where they should be
• **Additional structure**: instrumental, not spectroscopy
Bright limb measurement with GOMOS (no star)

Blue: GOMOS. Black: HITRAN model transmission at 7 km
GOMOS H2O profiles - S0002 - Tropics

H2O S0002
23°S-5°S  11/09 - 06/10 2003
Gomos H2O : Comparison with HALOE and MLS


This validation exercise tells that there is a problem in H2O GOMOS retrieval!
Pixel to pixel Relative Non Uniformity (PRNU) for B2 spectrometer (926-955 nm)

the raw signal depends on vertical position on the CCD
Star position on tracker and CCD spectro B2 (H2O)

During one occultation, if the star remains exactly at the same place on CCD star tracker, and on B2 CCD, PRNU structure cancels out in the computation of the transmission.
Star position on tracker and CCD spectro B2 (H2O)

SATU (Star Tracker)

Refraction, scintillations, tracking loop: motion of star on SATU and B2 CCD, taken into account in Level1b processing with PRNU map.
Comparison Model-data (transmission)

R04600-S0014 (Alp Ori)

- Black: model, red: GOMOS transmission
- Narrow absorption lines are where they should be
- Additional structure: instrumental, not spectroscopy
-since 2004: A huge effort was undertaken to cure the bias by understanding the source (Quality Working Group)

-we believe it is not a spectroscopic problem, because of very good fit for limb observations

-Level 1b Transmissions: problems associated to a non-perfect correction of PRNU.

-Sub-pixel non-uniformity is suspected (star is too well focused!)

-Construction of sub-pixel maps, difficult to produce, but helped by a technical anomaly of the Front Mirror Steering Assembly which moved the star on the star tracker and CCD spectrometer at high altitude

-work still in progress: example of a sample of occultations with new Level 1B algorithm
GOMOS H$_2$O

V6.0cf with standard PRNU

V7.0bb with sub-pixel PRNU
GOMOS H₂O – V7.0bb with sub-pixel PRNU

Number of occultations

Altitude m

H₂O mixing ratio

Star S063

25%
Median
75%
HALOE
Acknowledgements

- Partial support from EC Scout-O3 programme and from CNES
- Many thanks to ESOC people operating ENVISAT and GOMOS
Conclusions

• Within CCD silicium range, the 936 nm region is the strongest H2O band and is not contaminated by other absorbers.
• The large PRNU of CCD at this wavelength is a problem.
• We think we understand the problem (sub-pixel sensitivity) and the way to overcome
• We wish a new data treatment of GOMOS data with the new algorithms SOON
R03290 D-394 geometrical altitude = -22km
O2 GOMOS compared to ECMWF
H2O: comparison GOMOS-HALOE

- GOMOS
- HALOE
- Tropiques
- Moyennes latitudes
- Hautes latitudes

Altitude en km vs. Vapeur d'eau en ppmv

Altitude en km vs. Variabilité en %
H2O : comparison GOMOS-MLS
Directly From a .pdf
From a .jpg converted from eps to jpg in Graphic converter
H2O
Bauru, February
2004
Comparison, S016 - SDLA
H2O
Aire s Adour ,
September 2003
Comparison, S063 - SDLA
The GOMOS TEAM

SA/CNRS, France: J.L. Bertaux, A. Hauchecorne, F. Dalaudier, C. Cot
FMI, Finland: E. Kyrölä, J. Tamminen, V. Sofieva
IASB/BIRA, Belgium: D. Fussen, F. Vanhellemont
ACRI-ST: O. Fanton d’Andon, G. Barrot, A. Mangin, B. Théodore, M. Guirlet
ESA/ESTEC, Netherlands: P. Snoej
ESA/ESRIN, Italy: R. Koopman, L. Saavedra, M. de Laurentis
Astrium, France: R. Fraisse
Magnitude at 940 nm

9 stars OK for H2O retrieval
SIRIUS REFERENCE SPECTRA IN B2 FROM LEVEL1B with old GOPR version (up spectra) and GOPR_6.0 (bottom spectra)
Transport de $\text{H}_2\text{O}$ entre troposphère et stratosphère

Circulation générale de Brewer-Dobson (BD) induite par le déferlement d’ondes planétaires qui réalisent un pompage de la vapeur d’eau à travers la tropopause froide $\Rightarrow$ déshydratation à la tropopause.

Contribution des overshoots, des cirrus.

Adapté de Holton, 1995

Marcy et al., 2007

MAIS

transport isentrope bidirectionnel.

But de cette thèse : quantification transport isentrope UT$\rightarrow$ LS
1. Contexte
2. Qualité mesures H₂O
3.3 Quantification transport
4. Conclusions

GOMOS H₂O – V7.0bb

Number of occultations

Altitude m

H₂O mixing ratio

70ab Data set - Star S0014
1. Evolution observée par hygromètre à point de condensation sous ballon :
   • 16-28 km : tendance à l’augmentation de 1 à 1,5 %/an (0,05 à 0,07 ppmv/an) à Boulder Colorado entre 1980 et 2000
   • Revue à la baisse récemment :

2. Conséquences de +0,04 ppmv/an :
   • T stratosphère (-0,35 K/18 ans)
   • T troposphère (+0,15K/18 ans)
   • colonne totale d’ozone (-0,3%/décennie)
   • délais dans la résorption du trou d’ozone (+10ans)

3. Causes :
   • 25-34% dû à méthane
   • Reste ? Echanges tropo/strato ?