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Atmospheric Chemistry and Physics Discussions

ACPD
10, C4979–C4987, 2010

Interactive Comment

Interactive comment on "A global climatology of the mesospheric sodium layer from GOMOS data during the 2002–2008 period" *by* D. Fussen et al.

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Answer to Referee #1 (J. Gumbel)

major issue:

——————— However, I have major concerns about the underlying spectral analysis! What bothers me is the validity of the transmittance analysis in the present case of narrow absorption lines and possible Fraunhofer structures in the stellar irradiance. ———————

We thank referee #1 for his accurate reading of the paper and his very pertinent comments. The most critical one concerns the spectral analysis and the issue of Fraunhofer lines. We have to admit that this point was not enough discussed in the paper as we only implicitly suppose that its impact would be minor on the retrieved Na concentrations. This will be corrected in the revised paper. The referee analysis is correct when explaining that a depleted Fraunhofer line would hardly contribute to any atmospheric absorption. And he is also correct when suggesting an explanation for the amazing validity of the retrievals: we always assume that the Doppler shift allows us to consider the star irradiance as roughly constant before atmospheric absorption takes place. Firstly, there is the experimental fact of seeing the D2/D1 doublet spectral signature in the binned GOMOS transmittances with an observed D2/D1 ratio that can be modeled according to the forward model. This evidence suggests that the mean Fraunhofer depletion, if any, is limited (full depletion would mean an undetermined experimental ratio). In a very elementary model we can write that the GOMOS transmittance T averaged over a spectral interval Δ (4 GOMOS pixels) reads:

T=1-$\varepsilon\Gamma$D/Δ

where D is the atmospheric line width, Γ is the true atmospheric Na slant optical thickness and 1-ε is the Fraunhofer depletion (i.e. ε of the star irradiance is left): ε equals 1 when there is no overlap between the stellar Fraunhofer line of width δ and the atmospheric absorption line. We have however to consider this Doppler shift in a geocentric frame (not heliocentric where the star radial velocity can be considered as constant), with an important contribution of the earth's orbital velocity (30 km/s). Also, only a minority of GOMOS stars exhibit a strong Na Fraunhofer depletion and GOMOS is frequently observing hot stars with small δ values. To correct the GOMOS transmittances for this effect turns out to be an almost intractable problem. This is due to the weakness of the observed signal in individual occultations that forced us to use binned transmittances in monthly and 10° latitudinal bins and hence combining different stars. Any correction factor to be applied on an individual occultation has to take into account the geocentric effective radial velocity of the star that varies during the month and should be correctly co-added in the weighted median binning. A major difficulty also arises from the scarcity of high resolution star spectra around 600 nm. However we undertook

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an evaluation of the averaged Fraunhofer depletion for the Jan 2003 bin in the 70°N-80°N latitude band (about 1200 occultations). We spent a lot of time to gather spectra from published and unpublished sources, mostly from ELODIE and UVES databases, sometime using Kurucz synthetic data or estimating ε and δ from the star spectral class when no spectra were available. A full re-computation of the averaged transmittances was carried out in the context of the above-mentioned elementary model, leading to an average underestimation of the complementary transmittance (apparent optical thickness) ranging between 17 % and 26 % depending on the D2/D1 ratio of the stellar Fraunhofer lines. So there is indeed a limited effect, to be considered with respect to the natural Na variability. We have also computed the median radial star velocities for the whole GOMOS data set and we found a value of 18.2 km/s equivalent to a 0.036 nm Doppler shift, showing that the non-overlapping condition is often met.

Minor issues:

——————————— Section 2, paragraph 1: It is stated that the slant path optical thickness is not larger than 0.005. This is confusing.... ———————————

We will speak about "apparent optical thickness" in the revised version

——————————— Section 2, paragraph 2: What is meant by "upper and lower bands"? ———————————

Upper and lower bands of the GOMOS detector, that are used to estimate the straylight contribution to be subtracted from the star signal in the central band. Revised.

——————————— Section 2, after eq. 3: In the definition of U small "t" should be capitol "T". ———————————

"t" was chosen to avoid confusion with transmittance "T"

——————————— Section 2, after eq. 4: It would be instructive to provide some typical values of the line center slant optical thickness (see above). ———————————
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This is exactly the content of Figure 2

—————————— Section 2, paragraph preceeding eq. 5: The D1a/D1b ratio of 1.667 is called the "theoretical value". This is confusing since also the ratios 1.658 and 1.424 are "teoretical". It might be better to call 1.667 for the "optically thin limit". ——————————

We agree. Revised.

—————————— Some resonance lidar references could be given about the depletion of metal atom concentrations in the presence of PMC. ——————————

The reference Plane et al, Science [2004] was given.

—————————— Section 3.2: It is stated that the temperature profile used in the retrieval is fixed at a climatological value.... ——————————

We think that Figure 6 explains that a variation of +100 Kelvins is necessary to show an effect distinguishable from the measurement noise, which is a rather poor sensitivity compatible with the use of a constant climatological value. The impact on the sodium concentration is roughly linear (within the 30 % saturation effect). Solar occultations (even with Fraunhofer lines) should allow for a much more accurate of Na temperatures in the mesosphere.

—————————— Section 5, paragraph 3: It is correct that is has been suggested that PMC may be responsible for the strong sodium decrease in the polar summer mesosphere. However,a more complete reference to Fan et al. (2007) would be . . . ——————————

OK. Revised

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Answer to Referee #2

We than referee #2 for his careful reading of the manuscript major issues:

——————— I am confused by one aspect of the fitting procedure: is the D2/D1 ratio fitted in some way? It is first mentioned when discussing Fig. 6, where it seems to be quite variable. ———————

Yes, the forward model contains both D2 and D1 absorption features that lead, after instrumental convolution, to a bi-gaussian pattern shown in Figure 4. Please consider however the experimental signal (y axis range lies between 0.995 and 1.000) still containing noise, even after binning . This why the experimental D2/D1 ratio is so spread as a quotient of two noisy variables. The inversion is performed however by matching the forward model with the experimental transmittance defined by equation (6) and not with respect to the D2/D1 ratio.

——————— Are all the data presented in the paper diurnal averages? Also, what about the local time of the measurements? ———————

Yes, all presented data are diurnal "averages". The reason is the difficulty to separate the combined latitudinal and possible diurnal effects (as done in our preliminary GRL paper) and the inhomogeneity of available solar zenith angle (sza) in some bins. Hereafter we present the histogram of sza's for Jan 2003 in polar and equatorial bins.

It should be kept in mind that the limited sensitivity of GOMOS reduces the number of observable stars to about 150 and that the ENVISAT orbit (heliosynchroneous with 10 AM at descending node) concentrates the observed local times around roughly 9 am and 11 pm, except during polar night.[see FigHisto1 and FigHisto2 added to this reply]

——————— The authors compare an average 7-year data-set with a 2-year data-set from OSIRIS, and lidar data which was taken for a decade ending 4 years before the GOMOS data begins! ———————

Here we disagree with the referee. Figure 7 explicitly shows two data sets for Fort Collins validation data. The first one (published in GRL) refers indeed to 1990-1999.

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The second one (2002-2006) was dedicated to GOMOS (optimized for local time matching and with error bars) and produced by some co-authors of this paper. Independently of GOMOS data, we estimate that both data sets match, WITHIN the error bars (mostly driven by the natural variability at Fort Collins).

——————— Similarly, at high northern latitudes the data is sparse, but the smoothing seems to have produced averages that don't match the observations of more than 7e9 cm-2. ———————

We agree with this comment but this is not a smoothing procedure (that should be valid locally). It's a global simple fit capable of capturing the principal latitudinal and temporal dependences and also to interpolate in regions of missing data. The fit error is about 0.8e9 cm**-2 to be quadratically added with the natural variability. The latter one (see Figure 7) can easily reach 2e9 cm**-2.

——————— How can the authors be sure that they are observing Na and PMCs in the same air mass, not simply averaging along very long slant columns? The second point is that once PMCs have nucleated, meteoric ablation continues. ———————

We agree with both remarks and we will adapt the manuscript accordingly.

——————— Clearly, meridional transport is an important factor, but the situation is quite complex. Why plot the O3 column between 80 and 100 km? Why not the O3 concentration at the peak of the Na layer? ———————

This procedure was chosen to minimize the effect of the retrieval error (the vertical columns have an accuracy comparable to the measured slant columns, better than the concentration profiles). We also expect to be less sensitive to tidal effects and O3 retrieval errors.

Minor issues:

——————— p. 6098, line 21. Meteorites are stones found on the ground.

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Meteoroids are particles entering the atmosphere. ———————

OK

——————— p. 6099, line 16. Substitute "In brief, ..." for "Shortly" ———————

OK

——————— p. 6101, line 18. split into ———————

OK

——————— p. 6105, line 2. does not exist ———————

OK

——————— Figure 8 - please put tick marks on to show the beginning and end of each month ———————

OK

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Interactive comment on Atmos. Chem. Phys. Discuss., 10, 6097, 2010.

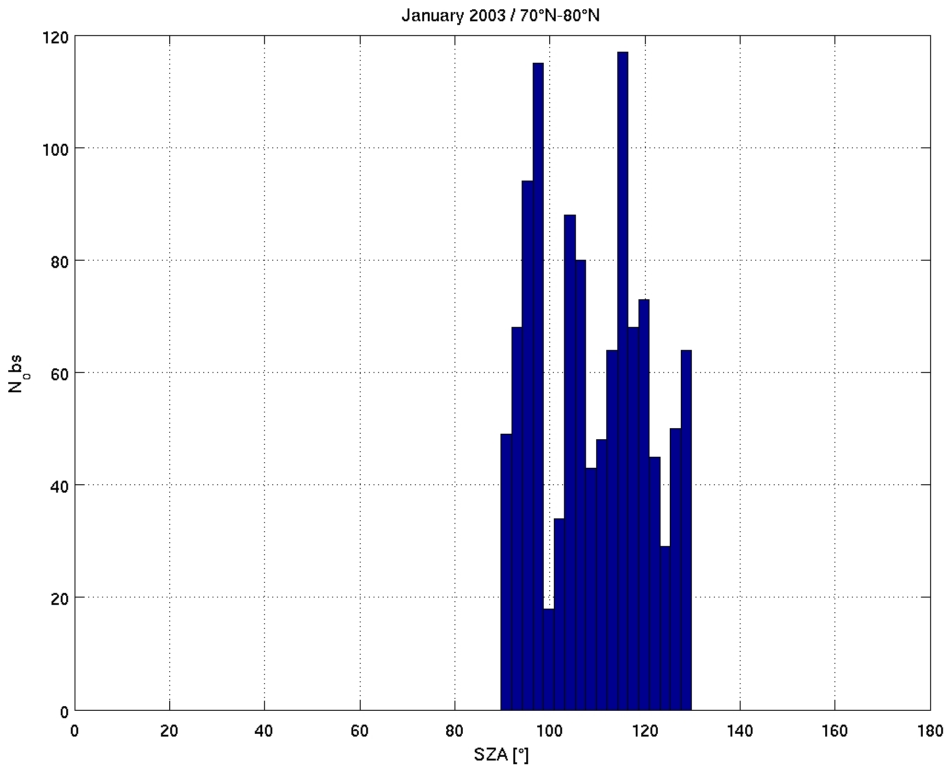

Fig. 1. FigHisto1

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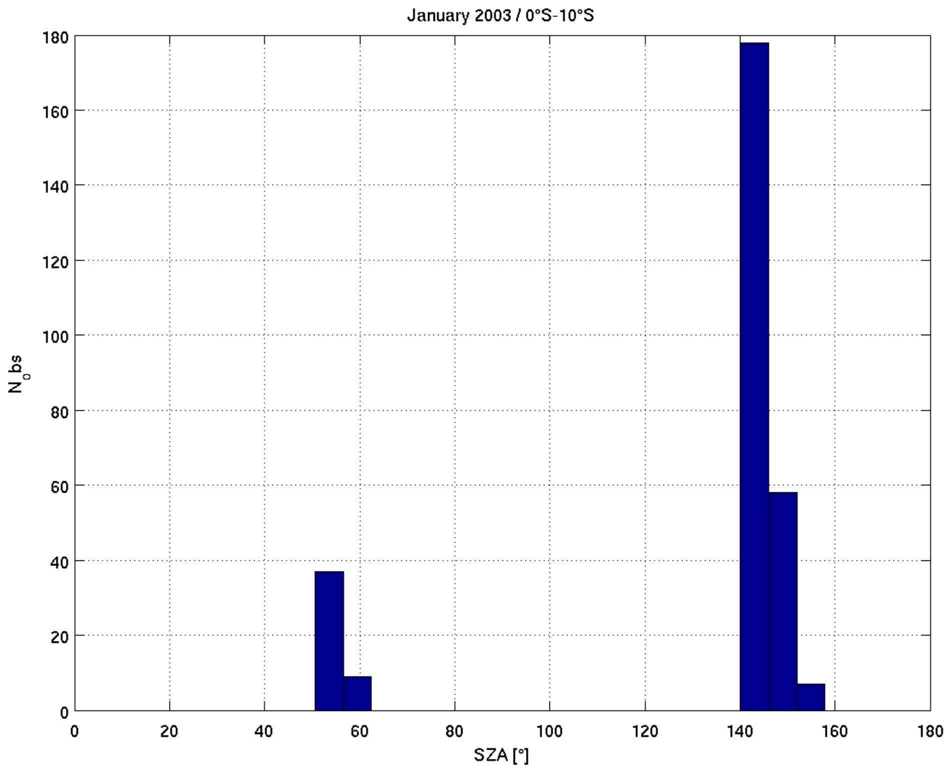

Fig. 2. FigHisto2