MARS MESOSPHERIC WINDS - A SEARCH FOR AN ACCURATE COMPARISON BETWEEN RESULTS FROM ATMOSPHERIC MODELS AND RETRIEVALS FROM GROUND-BASED OBSERVATIONS.

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Introduction

Only few techniques allow remote sensing of the dynamical variables in an atmosphere. One unique possibility is the ground-based observation of Doppler wind velocities by the detection of non-LTE CO_2 emission lines. Over the last years we performed several observing runs with a focus on wind measurements using the Cologne based infrared heterodyne spectrometer THIS [1].

A comprehensive dataset of results is published in Sonnabend et al. [2] including a basic comparison to the Mars Climate Database 4.3 [3, 4, 5]. The validation of the model calculation reaches very quickly its limits. Observational issues like the extended beam volume, the integration time effected by the rotation of the planet or atmospheric variabilities have to be taken into account. In addition the specific nature of non-LTE processes must be incorporated requiring complex radiative calculations. Only if all significant aspects are included the observations can be used for a reliable validation of atmospheric model predictions.

A careful evaluation of misinterpretations and boundary conditions are subject of our coordinated investigations and the presentation within the workshop.

Objectives

For a first approximative comparison of model predictions and observations we extracted wind values from the website of the Mars Climate Database 4.3 (MCD4.3). Corresponding seasons, latitudes/longitudes and Mars universal times were used. The altitudinal distribution followed the peak non-LTE contribution calculated by Lopez-Valverde et al. [6]. Full month standard deviation were used to give uncertainties of the MCD4.3. The results for one specific observing run is shown in Fig.1.

Apart from the high latitudes the predicted values agree with the observations within the errors. This is, as first step, a nice result but the conclusion from this comparison is limited. The observing geometry and the integration time was not taken into account. Wind velocities are averaged over a solar longitude between 30° and 60°. In addition no precise non-LTE weighting functions were used to average the emissions along the LOS mixing nadir and limb portions of the beam.

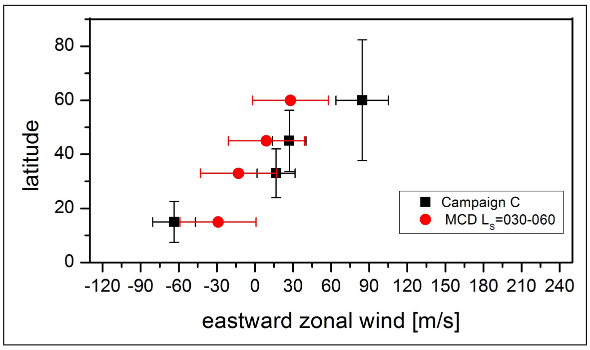

Figure 1: *Comparison of horizontal wind velocities from observations at the IRTF in March 2008 and the MCD4.3 predictions. The figure is taken from Sonnabend et al. [2]*

To perform a profound validation of model predictions is the motivation to accomplish extensive sensitivity studies and to develop a sophisticated methodology of wind extraction from the model taking observational conditions into account.

Methodology

From previous cooperation we developed the following approach for a detailed comparison of Doppler wind observations from CO_2 emission lines at 10 μm and model predictions from the MCD including a full radiative calculation for the non-LTE emission:

step(1) Definition of the observing geometry and conversion into a suitable 3D grid: The sketch in Fig.2 indicates the problem. A 2D grid of the beam cross section is defined by an angle and the altitude from the surface of Mars along the line of sight (LOS).

step(2) Determination of the atmospheric non-LTE emission region for a specific observing situation. An example of the influence on the emitting region is shown in Fig. 3. The weighting functions of a typical emission line of the 10 μm CO_2 band, computed along the LOS for three different tangent altitudes, are shown.

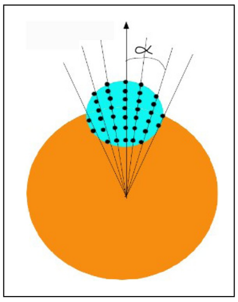

Figure 2: *Definition of the 2D grid perpendicular to the line of sight direction (black) for a given observing beam (turquoise) on the planet (orange)*

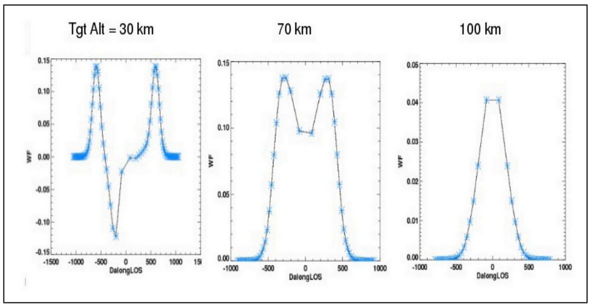

Figure 3: *Atmospheric emitting region of the non-LTE emission line along three different line of sights: 30, 70 and 100 km tangent altitudes.*

step(3) Extraction of wind values from the MCD taking into account the definition of the emitting regions determined by the radiative calculations.

step(4) Projection into the line of sight according to the observing geometry.

step(5) Convolution of the projected wind with the radiative weighting functions and beam shape, and integration over the full 3D field. Fig.4 shows the effect of different pointing on the final averaged wind value. A constant wind of 85 m/s parallel to the surface was assumed and results in a difference up to 6 m/s for the different tangent altitudes given in Fig.3.

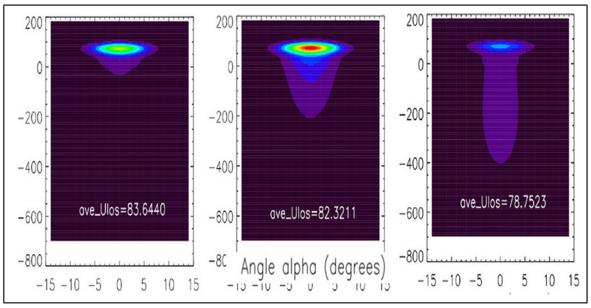

Figure 4: *A constant wind of 85 m/s parallel to the surface was assumed and resulted in a difference up to 6 m/s for different line of sights which are given in Fig.3.*

step(6) Applying the same procedure taking into account variabilities (a) of the atmospheric structure appearing during the integrated time of observation and (b) in the model.

step(7) Comparison of the resulting averaged wind from the model with the observation.

Table 1: *Overview of observing runs dedicated to measure mesospheric wind velocities on Mars for comparison the MCD.*

campaign	A	B	C
year	2005	2007	2008
month	December	Nov.-Dec.	March
telescope	McMath [1]	McMath [1]	IRTF [2]
location	Kitt Peak	Kitt Peak	Mauna Kea
# data points	8	10	5
season	335-336	352-357	41-42

[1] McMath Pierce Solar Telescope, AZ, USA
[2] NASA InfraRed Telescope Facility, Mauna Kea, HI, USA

Preliminary Results and Future Work

In a first approach measurements at three different locations on Mars are included. Limb observations at a latitude of 33°N, 45°N and 57°N from an observing run at the NASA IRTF in March 2008 are taken into account. The comparison is pictured in the Fig. 5 below.

In principle we find the same behavior with latitude in both data and model, but the retrieved values do not agree with each other. The situation is even worse compared to the first more simple approach in Fig.1. From our investigation we found the pointing to be one of the most severe effects for the calculation of the final wind result. We did include the beam size but did not take into account pointing error of the observation itself so far.

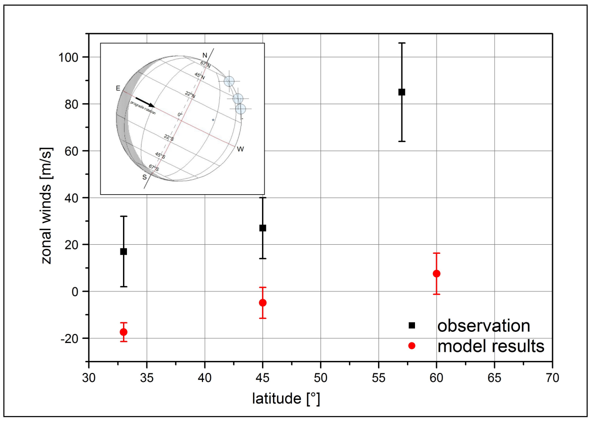

Figure 5: *Comparison of horizontal wind velocities from observations and MCD predictions. The inlet gives the observing geometry for Mars. The field of view was 0.8” given relative to the apparent diameter of Mars with about 9”.*

It is also important to evaluate additional sources of errors and variabilities like natural atmospheric variabilities during integration time. This is work in progress and new results and findings shall be presented during the workshop.

The final goal is to calculate comparable wind velocities from model predictions for the observations given in Tab.1 to provide a reliable verification of the model calculations and, hopefully, to advance our understanding of the dynamics of the Martian mesosphere, a region very unexplored so far [7].

References

[1] G. Sonnabend, M. Sornig, P. Kroetz, D. Stupar, and R. Schieder. Ultra high spectral resolution observations of planetary atmospheres using the Cologne tuneable heterodyne infrared spectrometer. *Journal of Quantitative Spectroscopy and Radiative Transfer*, 109:1016–1029, April 2008.

[2] G. Sonnabend, M. Sornig, P. Kroetz, and D. Stupar. Mars mesospheric zonal wind around northern spring equinox from infrared heterodyne observations of CO_2. *Icarus*, 217:315–321, January 2012. doi: 10.1016/j.icarus.2011.11.009.

[3] F. Forget, F. Hourdin, R. Fournier, C. Hourdin, O. Talagrand, M. Collins, S. R. Lewis, P. L. Read, and J.-P. Huot. Improved general circulation models of the Martian atmosphere from the surface to above 80 km. *Journal of Geophysical Research*, 104:24155–24176, October 1999. doi: 10.1029/1999JE001025.

[4] S. R. Lewis, M. Collins, P. L. Read, F. Forget, F. Hourdin, R. Fournier, C. Hourdin, O. Talagrand, and J.-P. Huot. A climate database for Mars. *Journal of Geophysical Research*, 104:24177–24194, October 1999. doi: 10.1029/1999JE001024.

[5] E. Millour, F. Forget, A. Spiga, S. R. Lewis, L. Montabone, P. L. Read, M. A. López-Valverde, F. González-Galindo, F. Lefèvre, F. Montmessin, M.-C. Desjean, J.-P. Huot, and McD/Gcm Development Team. An improved Mars Climate database. In F. Forget and E. Millour, editors, *Mars Atmosphere: Modelling and observation*, pages 268–271, February 2011.

[6] M. A. Lopez-Valverde, G. Sonnabend, B. Funke, G. Gilli, M. Gracia-Comas, M. Sornig, and P. Kroetz. Modelling the atmospheric CO2 10micron laser emission in Mars and Venus at high spectral resolution. *Planetary and Space Science*, 59:999–1009, August 2011. doi: 10.1016/j.pss.2010.11.011.

[7] M. A. Lopez-Valverde, L. Montabone, and M. Sornig. Mars mesospheric winds: A strategy for the optimal comparisons between ground based observations and GCM models. *in preparation*, 2013.