ATMOSPHERIC THERMAL STRUCTURE AND CLOUD FEATURES OF VENUS AS RETRIEVED FROM VIRTIS/VEX MEASUREMENTS

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1 INTRODUCTION

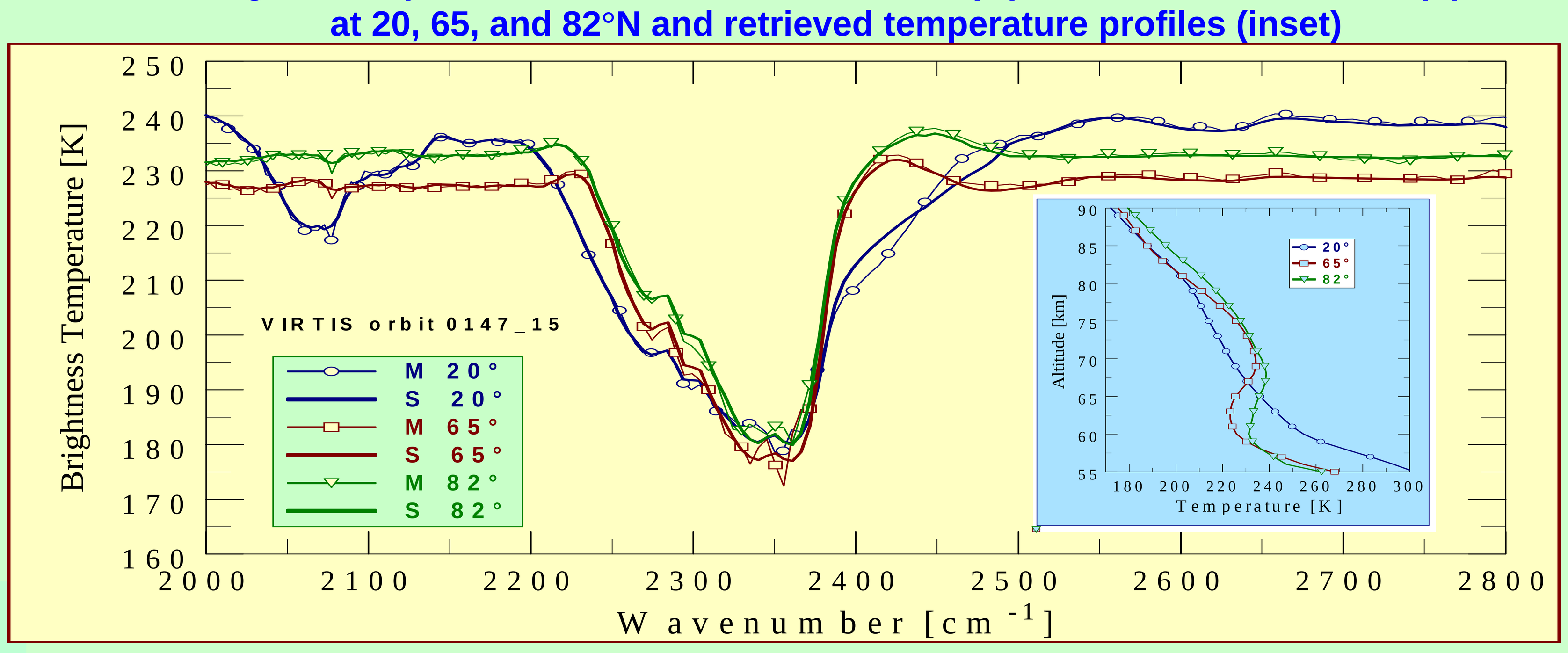
Updated results on mesospheric nightside thermal structure and cloud features of Venus are presented. They were retrieved from spectroscopic data recorded by the Visible and InfraRed Thermal Imaging Spectrometer (VIRTIS-M-IR) on Venus Express during eight Venus solar days between April 2006 and October 2008.

Refinements in the data analyses [Kappel et al., ASR 50(2), 228-255, 2012] and new methodical approaches for self-consistent temperature profile and cloud parameter retrievals [Haus et al., PSS 89, 77-101, 2013; Haus et al., Icarus 232C, 232-248, 2014] were applied where the latter carefully separate the influence of these parameters on measured spectra. This allows for explicit cloud parameter studies. A data selection strategy was developed that is especially useful for statistical exploration of massive data sets. Combined radiative transfer and multi-window retrieval techniques simultaneously process information from different spectral ranges of an individual spectrum.

2 METHOD

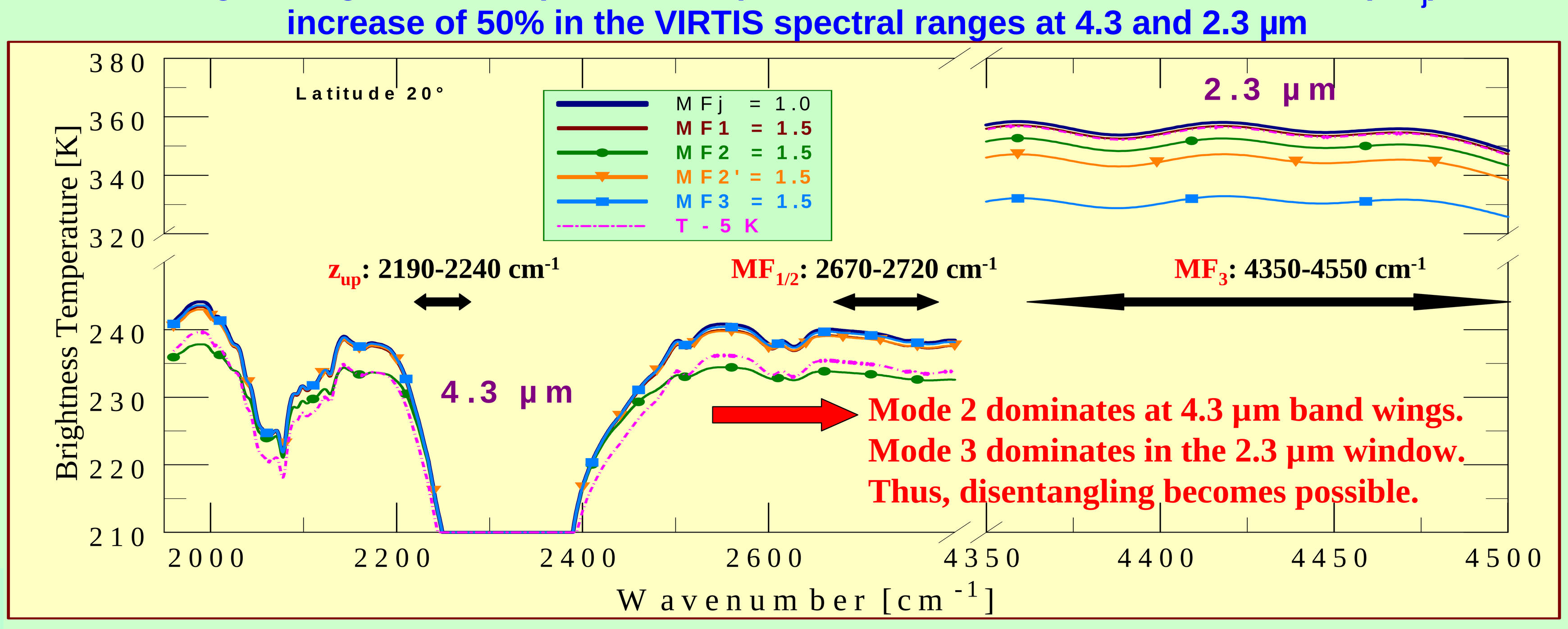
Mesospheric temperature altitude profiles (58-85 km) are determined from 4.3 μm CO_2 absorption band signatures using Smiths relaxation technique.

Fig. 1. Comparison of VIRTIS measurements (M) and simulation results (S) at 20, 65, and 82°N and retrieved temperature profiles (inset)



Specific parts of the 4.3 μm band wings and the 2.3 μm transparency window are utilized to derive cloud parameters. A λ-dependent CO_2 opacity correction is considered at 2.3 μm.

Fig. 2. Brightness temperature response to individual cloud mode factor (MF_j) increase of 50% in the VIRTIS spectral ranges at 4.3 and 2.3 µm



3 TEMPERATURE RESULTS

Fig. 3. Zonal average of mean temperature field [K] as a function of latitude and altitude in both hemispheres

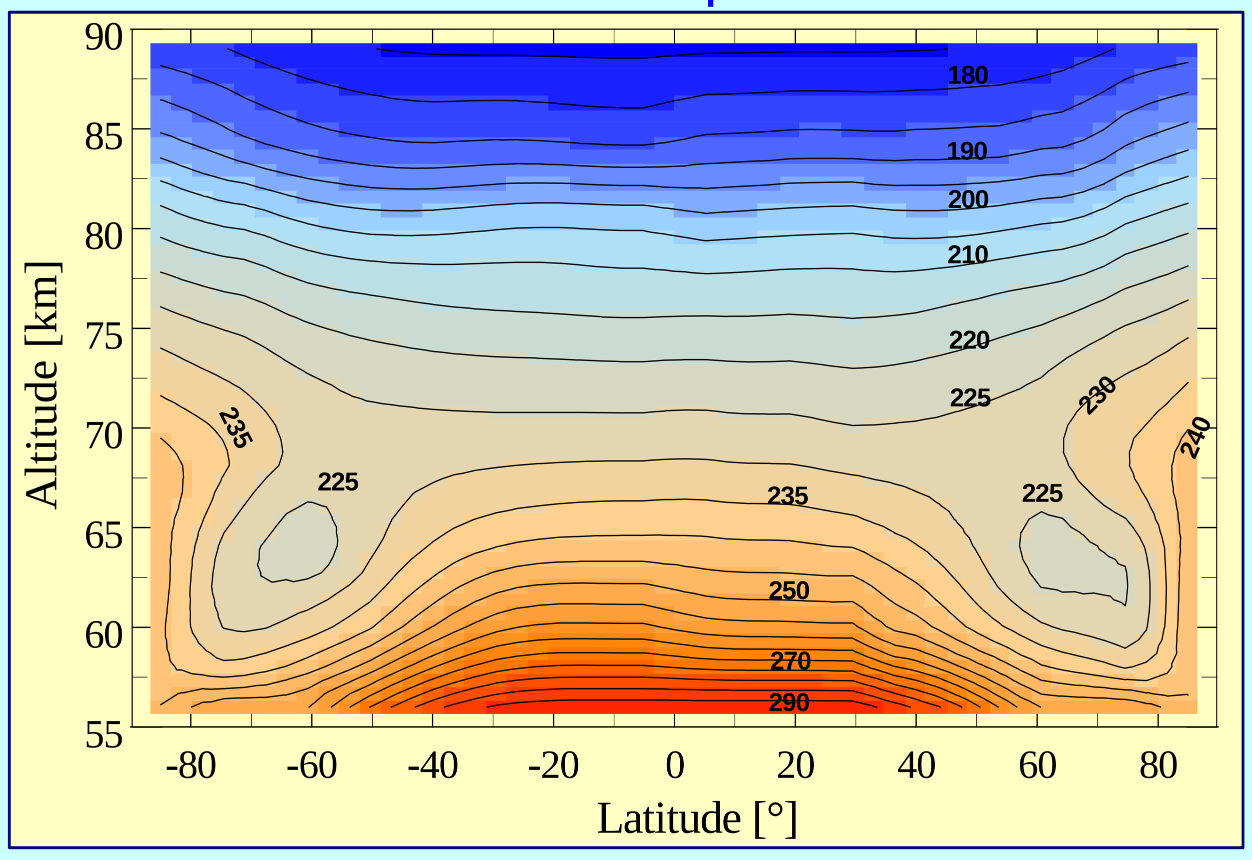


Fig. 4. Zonal average of temperature standard deviations [K] as a function of latitude and altitude (southern hemisphere)

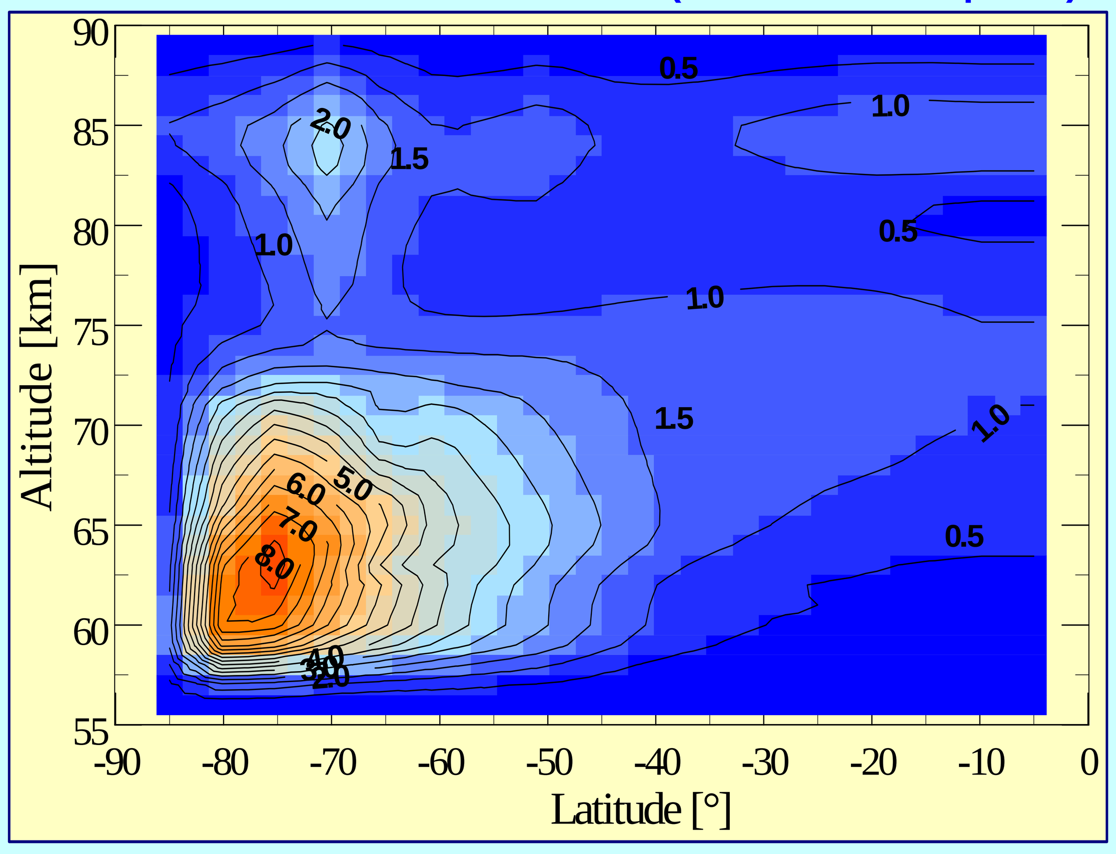
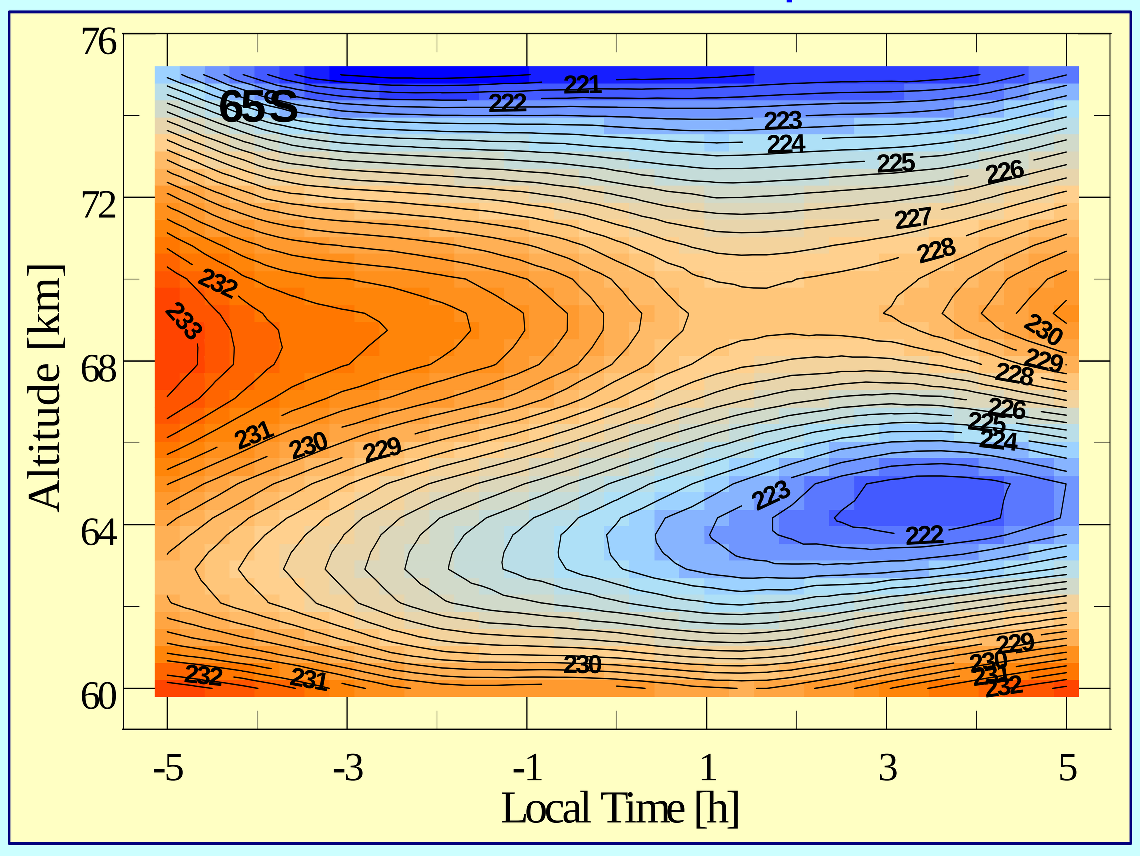


Fig. 5. Mean temperature fields [K] as functions of local time and altitude at 65°S. Local time -5 h corresponds to 19:00 h



4 CLOUD PARAMETER RESULTS

Fig. 6. Particle number density distribution functions of the initial cloud model (Haus et al., 2013)

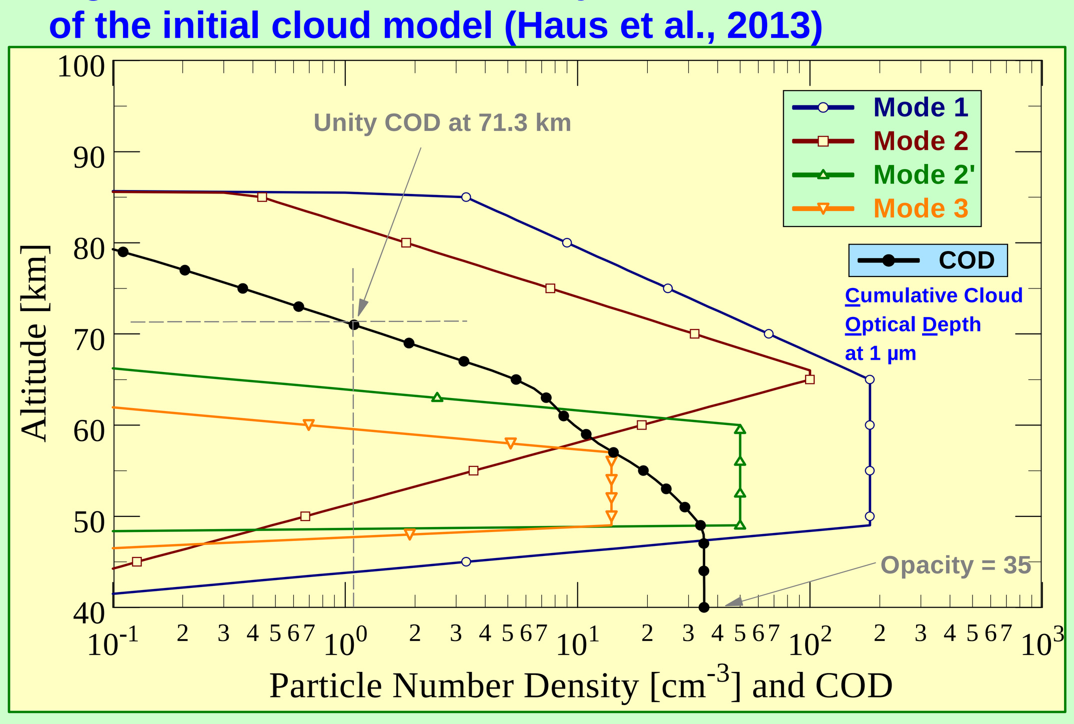


Fig. 7. Zonal average and scatter of mean cloud top altitude at 1 µm as functions of latitude in both hemispheres

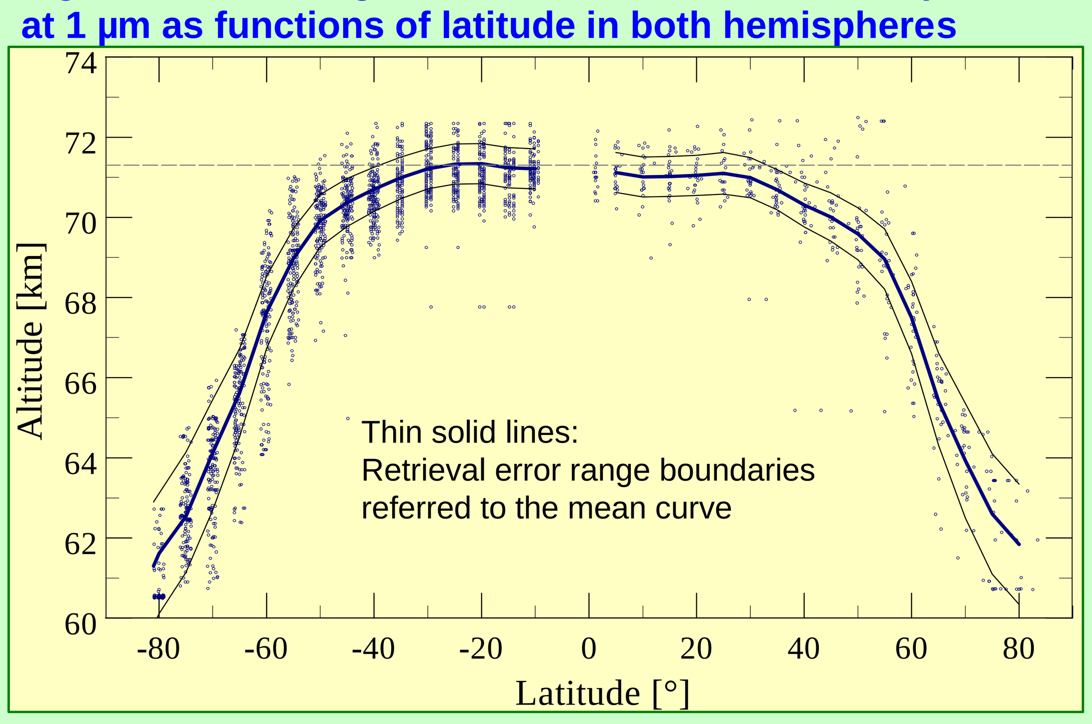


Fig. 8. Zonal averages of cloud mode factors and cloud opacity (1 µm) as functions of latitude in both hemispheres. Numbers: Hemispheric averages, Circles and crosses: Opacity scatter south/north.

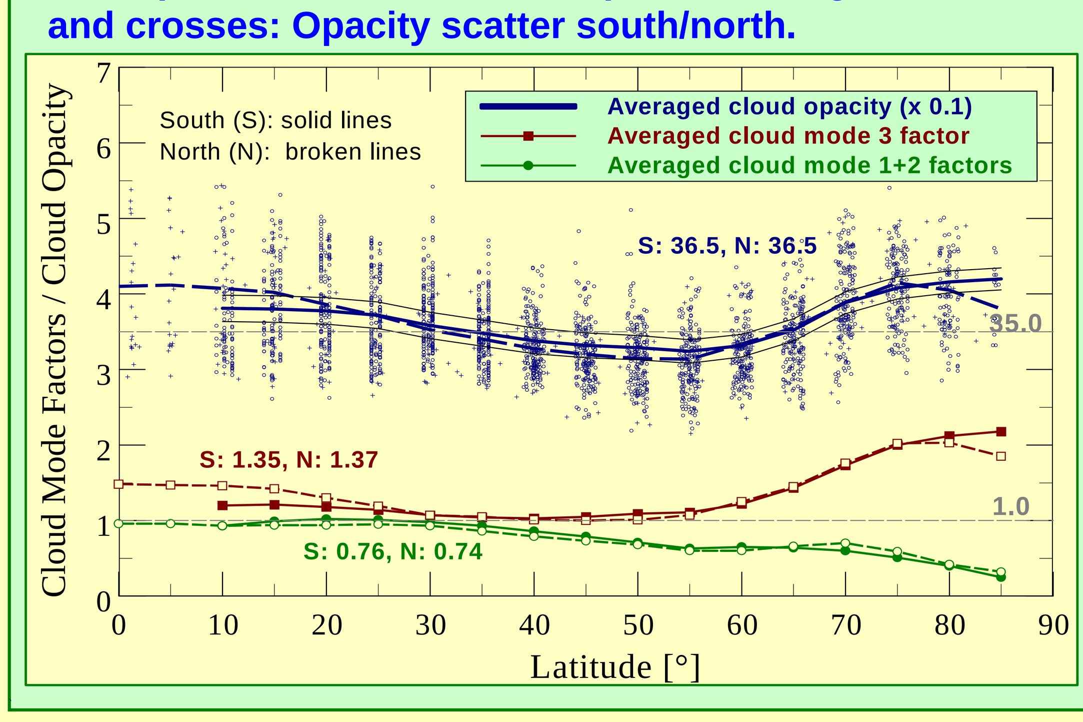
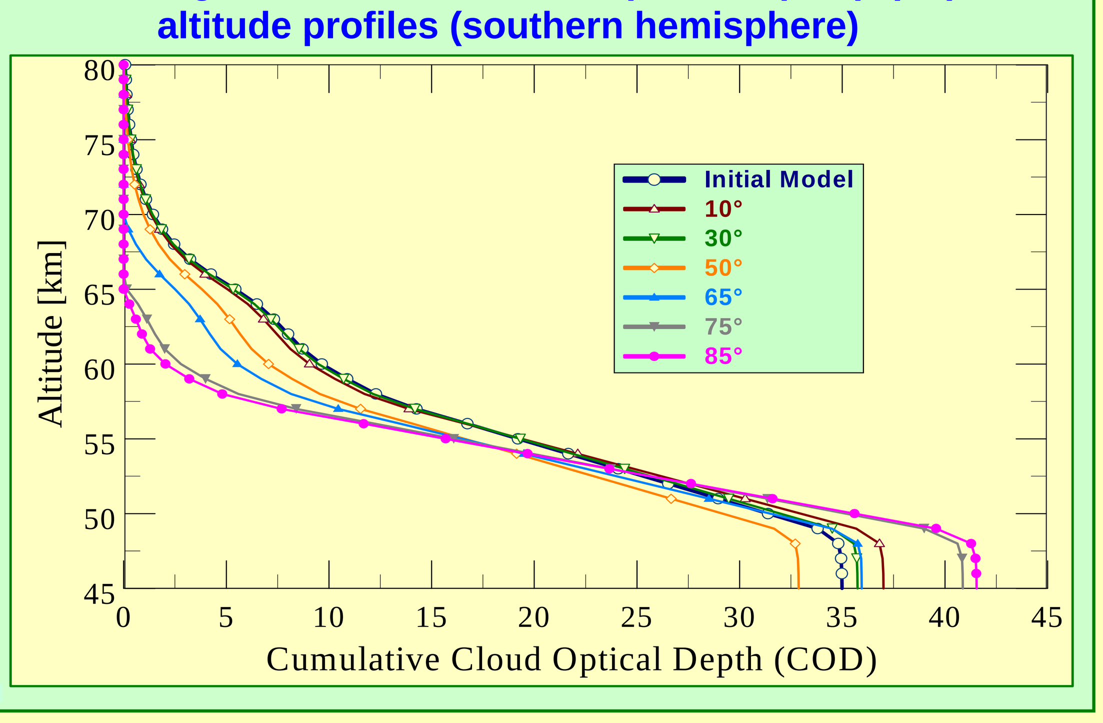


Fig. 9. Cumulative cloud optical depth (1 µm) altitude profiles (southern hemisphere)



5 CONCLUSIONS

- Zonal averages of Venus' mesospheric temperature field are N-S axial symmetric and well correspond to earlier results.
- A strong cold inversion layer at 55-75°N and 58-70 km divides the atmosphere vertically. For fixed altitudes below the 'collar', temperature decreases toward the poles, while it increases above 70 km (Fig.3).
- Warmer and vertically nearly isothermal regions poleward of 75° extend from 58 to 66 km and are associated with a strongly time-dependent bright polar vortex.
- Collar and vortex regions exhibit the strongest zonal average temperature variability with standard deviations up to 8.5 K at 75°S and 63 km altitude compared with 1.0 K at low/mid latitudes above 75 km (Fig.4).
- The mesospheric temperature field strongly depends on local time. At altitudes above about 75 km, the atmosphere is warmer in the second half of night, while the dawn side at lower altitudes is colder than the dusk side by about 8 K. Local minimum temperature of 220 K occurs at 03:30 h local time at 65 km and 65°S (Fig.5). Temperature standard deviation at polar latitudes is particularly large near midnight.
- There are no explicit temperature trends with mission time. The averaged mesospheric thermal structure was essentially stable between 2006 and 2008. The influence of observed cloud parameter changes on retrieved mesospheric zonal average temperature structure is moderate and does not exceed 2-3 K at altitudes between 60 and 75 km.
- The newly proposed initial cloud model (Fig.6) incorporates analytical descriptions of four-modal particle altitude distributions. It enables optimum fits of VIRTIS measurements by retrieval of cloud mode factors and cloud upper altitude boundaries that determine cloud top altitudes.
- Global N-S axial symmetry is also observed in cloud structures. Zonal averages of cloud top altitude at 1 µm slowly decrease from 71 km at the equator to 70 km at 45-50° and rapidly drop poleward of 50°. They reach 62 km over both poles (Fig.7). This result is in good qualitative agreement with earlier findings.
- Average particle size in the vertical cloud column increases from mid latitudes toward the poles and also toward the equator resulting in minimum and maximum zonal average cloud opacities of about 32 and 42 and a planetary average of 36.5 at 1 µm (Figs.8,9). Zonal averages of cloud features are similar at different solar days, but variations with local time are very complex and inseparably associated with the atmospheric super-rotation.
- Present results will be used in the near future as an important prerequisite for sophisticated studies on Venus' radiative energy balance.