Mesospheric CO measured by Aura MLS

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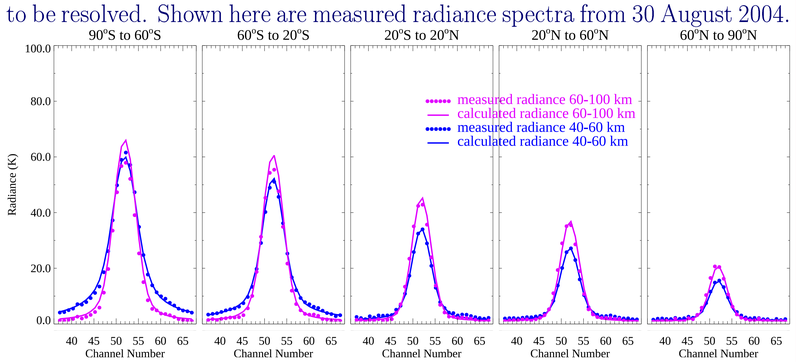
Carbon monoxide (CO) is a useful tracer of atmospheric transport in the upper stratosphere and mesosphere and, because it is a conserved quantity in the polar night, an excellent tracer in the winter polar vortex.
The Microwave Limb Sounder (MLS) launched on Aura in July 2004 has been making global daily measurements of carbon monoxide from the troposphere to the thermosphere since August 2004.

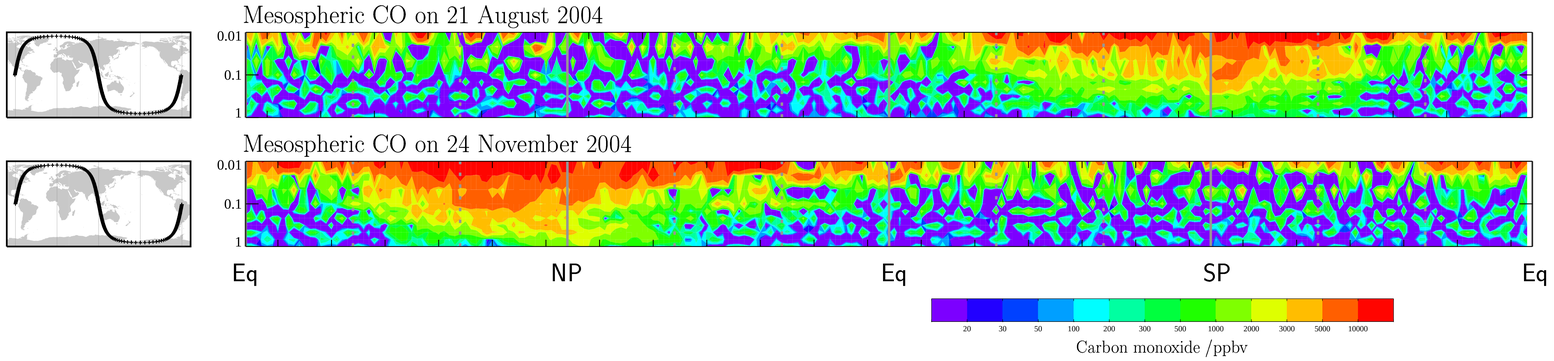
The MLS instrument

MLS measures the thermal emission lines of trace species in the atmosphere, at frequencies ranging from 120 to 2500 GHz. Its antenna is pointed so that its beam is tangential to the Earth's surface, and moved to scan the narrow (∼3 km in the vertical at the tangent point) field-of-view through the atmosphere from the ground to 120 km. It performs one scan every 1.5° of the orbit.
CO is measured from its $J = 2 \rightarrow 1$ transition at 230.538 GHz. The spectral line is analysed with a filter bank (resolution 6–96 MHz) for the stratosphere and troposphere, and a digital autocorrelator spectrometer (129 channels, resolution ∼0.1 MHz) for the mesosphere and upper stratosphere. The ∼0.1 MHz resolution allows the narrow (∼1 MHz) Doppler broadened lines to be resolved. Shown here are measured radiance spectra from 30 August 2004.



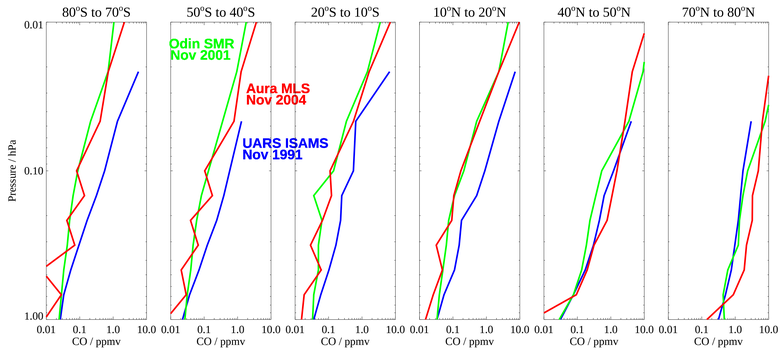
The spectra have been averaged over latitude and height bins. The marked north-south asymmetry is due to descent of CO-rich air into the winter (south) polar mesosphere and ascent of CO-poor air into the summer (north) polar mesosphere. Also note that, since in this Doppler-broadened regime the peak radiance is proportional to concentration, the similar values for the two height bins imply that the *mixing ratio* of CO is much higher in the 60–100 km region, as expected.
The radiance measurements are transformed to species mixing ratios by inverting a forward model using optimal estimation. The radiances calculated (using this forward model) from the retrieved CO mixing ratios are also shown in the figure. There are some residual differences, especially in the winter pole, and these are being investigated.

A slice through the atmosphere



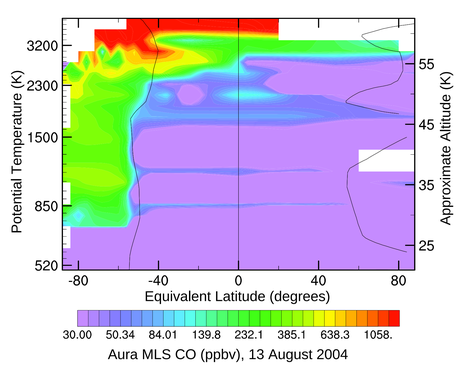
MLS looks forward along the orbit and its antenna scans the atmosphere from the ground to 120 km in the orbit plane, one scan every 1.5° of the orbit. Exploiting this geometry, a tomographic retrieval is made to give a continuous slice through the atmosphere, as shown in these 'curtain' plots of CO in the mesosphere. The upper panel is for late southern winter, the lower for early northern winter. Each is one orbit out of the 14 made per day and the orbit track can be seen on the maps on the left (in fact Aura moves along this track from right to left in this view). The height range in these panels is 1 to 0.01 hPa (∼48 to 80 km) covering the whole mesosphere. In each case the descent of CO rich air from the lower thermosphere can be clearly seen in the winter hemisphere vortex. The speckle is measurement noise but even in this unaveraged data large scale dynamical structures can be seen.

Comparisons



A preliminary comparison has been made between the MLS data for November 2004 and results from Odin-SMR and UARS-ISAMS for the same period in earlier years. SMR is a submillimetre-wave limb sounder very similar to MLS, measuring the $J = 5 \rightarrow 4$ transition of CO at 576.268 GHz. ISAMS is an infra-red limb sounder and measures CO from its vibration-rotation band at 4.6 μm.The MLS CO profiles are close to the SMR results, except in the northern hemisphere, where differences may be due to stronger descent in 2004 than in 2001. Comparisons will continue with more recent Odin-SMR results and with other datasets.
(Figure adapted from Dupuy et al. (2004), Geophys. Res. Lett., 31, L20101, doi:10.1029/2004GL020558.)

Tracing dynamics on different timescales



During the winter at the poles, descent in the vortex brings carbon monoxide rich air from the thermosphere into the stratosphere. There is no hydroxyl radical (OH) in the polar night to destroy the CO, so it acts as a passive tracer of vortex dynamics until spring. The equivalent latitude/height cross-section on the left shows CO-rich air reaching the mid-stratosphere by late southern winter 2004 (the black line is the vortex edge defined by potential vorticity (PV) gradient). The map of the lower mesosphere (∼50 km) on the right shows a more rapid dynamical event. Planetary wave activity has caused a filament of material to be stripped off from the vortex. The white contours are the PV-defined edge of the vortex; this shows good correlation with the carbon monoxide field.