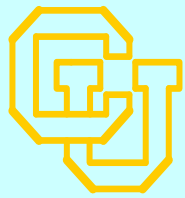




# The Correspondence Between Thin Layers of Ozone Observed by HIRDLS in the Extratropical UTLS and Potential Vorticity



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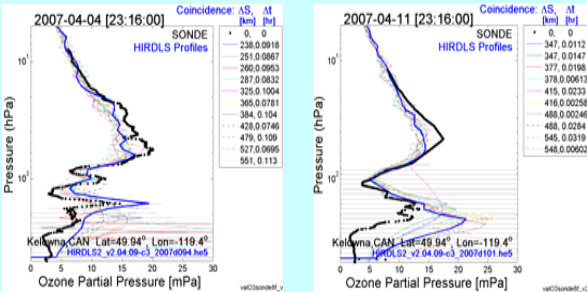
Discussion

## The HIRDLS Experiment

- The High Resolution Dynamics Limb Sounder (HIRDLS)
  - A joint development of the U.S. (NASA) and the U.K. (NERC)
  - Led by the University of Colorado and NCAR in the U.S.
  - Led by Oxford University in the U.K.
  - Principal Investigators:
    - John Barnett (Oxford) and John Gille (University of Colorado)
- Instrument
  - 21 Channel Limb-scanning infrared radiometer
  - Sounds from Upper Troposphere (UT) to Stratosphere
  - 1 km Vertical Resolution
  - Products: (V003) Temperature, Ozone, Nitric Acid
  - Preliminary – Water Vapor

Figure 1. Illustrating HIRDLS Ability to Observe Fine Vertical Structure in Ozone In the Upper Troposphere Lower Stratosphere (UTLS)

Black is ozone profile measured by sonde  
Blue is closest HIRDLS retrieval  
Other lines are other nearby HIRDLS Retrievals



These panels show HIRDLS retrievals of ozone, nitric acid, and temperature along a track across the Eastern Pacific on 21 January 2006.

Note the thin layer or lamina of air with low ozone extending along the 380K isentrope, to the extent of the 5 pvu contour. ( $1 \text{ pvu} = 10^{-6} \text{ m}^2 \text{ s}^{-1} \text{ K kg}^{-1}$ )

The same lamina contains low values of nitric acid. The temperature shows a "Double tropopause" around the lamina.

Figure 2. HIRDLS along-track data

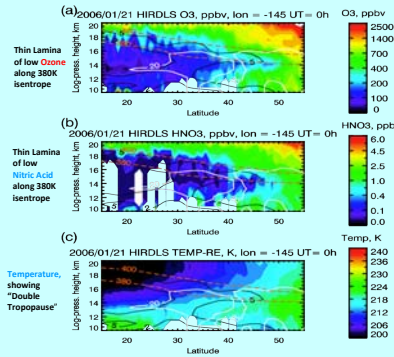


Figure 3. Development and decay of the lamina

Initially a deep layer of air from the tropical Troposphere with low PV (< 5 pvu) and low ozone breaks poleward.

20 January 2006. Deep layer of low ozone extending to ~50° N, following PV.

By 14 hours later (Fig. 2(a)) an intrusion of air with higher stratospheric PV (> 5 pvu) has pushed to nearly 33° near 13 km altitude, with stratospheric levels of ozone. This creates the lamina. By 23 January (Fig. 2 (b)) the PV contour has been eroded back to ~30°, leaving the ozone behind to mix with its surroundings.

23 January (follows Figure 2(a)). Ozone layer in place, but PV contour is back at ~30° at 15 km.

25 January. Ozone has mixed with surroundings, as PV contour has receded further.

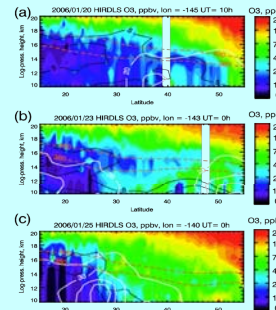
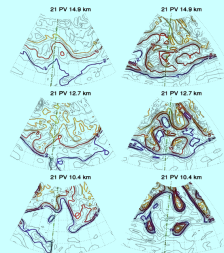


Figure 4. GEOS 5 Potential Vorticity at Several Levels and 2 Longitude Sectors

The left plots show the PV over the Eastern Pacific at 3 levels in the UTLS on 21 January. The green line shows the HIRDLS scan track at this time. The blue contour indicates 2 pvu, the red denotes 5pvu. These show the poleward extension of low PV air at 14.9 km, compared to that at 12.7 km.

The right plots show PV over the Atlantic Sector, with the green line showing another HIRDLS scan track on 21 January. In this case there is a much more complex PV field at the upper levels, although tropical PV extends to high latitudes at 10.4 km. The effects on ozone are shown in Fig. 5.



- Formation of thin layers results from a sequence of atmospheric events. In this case these were a deep poleward motion, followed by replacement of the low altitude air by lower stratospheric air, consistent with the life cycle of a baroclinic wave.
- Following formation of these thin laminae, the PV contours appear to be eroded, presumably by dissipative processes, probably small scale turbulence, breaking the links with the ozone mixing ratios, allowing the ozone to mix with the surrounding air.
- The amount of irreversible mixing cannot be immediately ascertained, but it could be a significant portion of the air in the lamina.
- These features present a possible means for creating the mixing region in the lower stratosphere in which the composition of air parcels is between that of the troposphere and the stratosphere.

## Conclusions

- HIRDLS data are uniquely capable of displaying fine (~ 1 km) vertical scales
- These data show, for the first time, that thin laminae of low ozone (and nitric acid) extend from the UT into the mid-latitude lowermost stratosphere on frequent occasions
- This opens the way for many future studies to elucidate processes in this critical region
- The high resolution is also important for data assimilation studies, a necessary step toward realistic cross-tropopause tracer transport studies with models
- Future versions of HIRDLS data are expected to have improved UT ozone, which will allow more to be said about return transport in tropopause folds and other stratosphere to troposphere flows.
- Future versions are also expected to have additional trace gases, including water vapor and long-lived tracers, which will allow more detailed studies of stratosphere-troposphere exchange processes.

Figure 5. Ozone cross-sections near the Greenwich Meridian

These plots show ozone measured by HIRDLS (upper) and the Microwave Limb Sounder (MLS, lower) along the scan path near the Greenwich meridian shown on Fig. 4.

Although this is a much more complex field, the HIRDLS and MLS both show the lowest ozone characteristic of tropical tropospheric air associated with the low PV.

For the shortest time scales, the ozone and PV are highly correlated.

