HIGH RESOLUTION SOUNDING OF UPPER TROPOSPHERE AND LOWER STRATOSPHERE OZONE, WATER VAPOR AND TEMPERATURE

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1. INTRODUCTION

Sounding the region around the tropopause for water vapor or other trace gases has always been difficult, and at the limits of earlier measurements. For nadir sounders the vertical resolution is insufficient to follow the rapid changes with altitude in this region, and the low optical depth for ozone and water vapor has made it difficult to obtain observations from this region. Limb sounders must look through long stratospheric paths to observe this region, and signals may be saturated. In addition, these have often had vertical resolution that was not sufficient to observe critical features.

The High Resolution Dynamics Limb Sounder (HIRDLS) instrument was designed to avoid these problems. The experiment is described by Gille et al., [1,2]. To address the first problem, it incorporates spectral channels in the wings of the strong bands of CO_2, O_3 and H_2O, where the absorption coefficient is low, allowing signals from the upper troposphere/lower stratosphere (UTLS) to reach space. It has a 1 km vertical field of view, and oversamples by a factor of 5, to address the second difficulty.

Unfortunately, during launch HIRDLS was damaged in such a way that a piece of lining material blocked part of the aperture. Considerable effort has gone into developing algorithms to correct for this [3, 7]. The most difficult, and most recent algorithm is one that improves the correction for the varying signal introduced by the blockage, and is designated the $(ST)^3$ approach. This allows correction to a higher precision, allowing more of the original channels to be used. The approach will be briefly described.

2. APPLICATIONS OF THE DATA

This high resolution sounding of the region around the tropopause opens several areas to study, including the injection of water (and other species) into the stratosphere, its transport and global distribution in the UTLS. Inherent to studies of water vapor injection in the tropics are the temporal and vertical variations known as the tropical tape recorder for which the HIRDLS data provide the highest vertical resolution.

One of the significant questions in this part of the atmosphere is the ease with which important trace-constituents can be exchanged between the troposphere and stratosphere across the extra-tropical tropopause. In this region diabatic processes are slow, with timescales of ~ 10 days. This means that fluid motions are along isentropic surfaces, or surfaces of constant potential temperature, denoted by theta (θ). In this study we have interpolated the HIRDLS data, which is retrieved as a function of pressure, onto θ surfaces every 10K between 350K and 380K, or approximately every 1 km at altitudes of ~ 13-16 km. (The lower limit is set by the present lower limit of the HIRDLS retrievals, limited by channel saturation or clouds, while the tropical tropopause is at 380K.) In this study we have concentrated on the Northern Hemisphere. One salient feature of this representation is the clear presence of thin layers or laminae of low ozone from the low-latitude tropospheric that extend to high latitudes, often overlaying laminae of high ozone from the high-latitude stratosphere that extend to low latitudes. These look like they could be effecting stratosphere-troposphere exchange, as suggested by Holton et al. [5].

However, transport is also affected by requirements for conservation of potential vorticity (PV). Using Nakamura's [6] Lagrangian method, we have calculated the Equivalent Latitude (ϕ_e) for ozone isolines. In this representation, movement across parallels of ϕ_e indicate diffusive mixing. Similarly, we have calculated the Equivalent Diffusivity, which provides an indication of the location and strength of barriers to such mixing. The strongest barriers are seen to be very close to the mid-latitude thermal tropopause in winter, but weaken and move poleward in spring, and remain weak until the barrier begins to reform in the following autumn. This is very similar to that found by Haynes and Shuckburgh [4] from calculations for an idealized tracer. The effects of the barriers are also seen on the latitudinal and seasonal distributions of water vapor and other trace species. The thermal tropopause, based on the Goddard Space Flight Center (GSFC) Modeling and Assimilation Office (GMAO) analyzed meteorological products, also shows the thermal tropopause close to the PV = 4 contour, a higher value than has been suggested in many previous studies.

These high resolution sounding data also provide excellent insight into the role of the Asian monsoon in providing a pathway for stratosphere-troposphere exchange in northern summer. Again, this is a feature that requires high vertical resolution observations in the UTLS region to show and diagnose.

3. REFERENCES

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