Transport and Meteorological Analysis

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The objectives of this work are twofold. First, to provide real-time meteorological satellite guidance to airborne field missions for NASA's Upper Atmosphere Research Program, the Global Tropospheric Experiment, and the Atmospheric Effects of Aviation Project. Extensive meteorological satellite datasets were provided for use by the mission scientist and by the science team. These same data were then archived for postdeployment data analysis by the science team. Second, to provide scientific analysis of the data from the airborne field missions supported. The results of these analyses were made public through peer-reviewed publications.

During FY00, the science field campaigns, for which real-time meteorological support was provided, included the Sage III Ozone Loss and Validation Experiment (SOLVE) mission in Sweden from December 1999 to March 2000, and the Atmospheric Chemistry of Combustion Emissions Near the Tropopause (ACCENT) mission in September 2000. In addition, real-time information on convectively influenced air for mission planning during ACCENT was provided. This technique uses a combination of trajectory modeling and satellite imagery to establish which air masses have been recently influenced by convection. This information is useful for investigating such problems as nitrogen oxides (NO_x) production by lightning, water vapor budgets in the upper troposphere, and emissions by subsonic aircraft in the upper troposphere. This technique for establishing the recent air-mass history is also a useful tool for postprocessing and data analysis in support of other investigators on the missions.

The second objective of this work is scientific analysis of the data from the airborne field missions supported. Data are divided into four basic areas:

- water vapor and subvisible cirrus clouds in the upper tropical troposphere,
- water vapor in the upper winter arctic troposphere and lower stratosphere,
- gravity waves and turbulence, and
- tropospheric chemistry.

The first of these areas is fundamental to the input of water vapor into the stratosphere, which is an important factor in stratospheric gas-phase chemistry and for the formation of Polar Stratospheric Clouds (PSCs). The chemistry of PSCs, in turn, is responsible for much of the ozone loss due to chlorinated hydrocarbons. The second area, water vapor in the arctic upper troposphere and lower stratosphere, is potentially important in the formation of ice clouds that can have similar chemical effects as the PSCs. Gravity waves are important because (a) they produce turbulence, which can affect vertical mixing of stratospheric trace constituents; (b) they transport momentum upward, driving important features of the stratospheric circulation such as the tropical quasi-biennial oscillation; and (c) they produce temperature deviations that can produce subvisible cirrus clouds. The fourth area involves investigating the effects of convection on tropospheric chemical trace constituents, particularly NO_x (via lightning) and water vapor.

To deal with the four areas of scientific analysis, some important analysis tools have been developed. The most novel of these is the so-called "convective influence" calculation, whereby a calculation is done, using a combination of back trajectories and meteorological satellite data, the amount and age of recent "convective influence" on an air parcel. This technique has been used in connection with the first area of scientific analysis indicated previously, namely subvisible cirrus clouds in the upper tropical troposphere. An assessment has been done as to whether subvisible cirrus clouds observed during the 1995-1996 Tropical Ozone Transport Experiment/Vortex Ozone Transport Experiment (TOTE/VOTE) were produced by local cooling and ice nucleation, or were a long-lived outflow from convection. It was found that good correspondence exists between the locations of different types of near-tropopause cirrus and the origins of the air, with smooth laminar cirrus clearly the result of local cooling, and lumpier clouds the apparent outflow of convection. Notably, these calculations indicate that some of this convective outflow can last several days. Also of note is the presence of inertia-gravity waves and their characteristics. These waves have a very good correspondence to the sloping cloud shapes, indicating that the cooling associated with these waves is probably responsible for the clouds.

This last result is significant, since it lends support to a hypothesis that is the result of modeling work. This hypothesis suggests that long-period waves produce cirrus clouds, which are then heated and lofted into the stratosphere. As the clouds grow, large particles fall out, dehydrating the air. In effect, this mechanism will move air into the stratosphere and dehydrate it at the same time, possibly resolving a crucial question of how very dry air gets into the lower tropical stratosphere.

The convective influence technique has also yielded insight into some of the results from the ACCENT experiment. As a result of this technique, it is possible to trace high values of methyl iodide in the upper troposphere over the Gulf of Mexico to convection in the eastern Pacific. The significance of this finding is the ability to understand one component (convection) influencing why air masses have the composition that they do. Developing an understanding of the impact of natural processes (for example, convection) on air masses is certainly a prerequisite for understanding the impact of human influences (for example, aircraft).

With the completion of the SOLVE experiment, some results have been obtained on the second area of scientific analysis, namely water vapor in the lowermost arctic stratosphere. These results, based on observed water vapor and temperature histories, show that during early spring about 15% of air parcels that have ozone values between 300-350 parts per billion by volume (ppbv) (well within the arctic stratosphere) experience ice saturation sometime during a given ten-day period.

This is potentially significant, since ice clouds within the lowermost stratosphere can lead to possible chlorine activation. What may be more significant is that, at the very bottom of the arctic stratosphere (near 100 ppbv of ozone), 30% of parcels in a given ten-day period during early spring experience ice saturation even if their water vapor content is at the prevailing stratospheric value of 5 parts per million by volume (ppmv). This means that the arctic tropopause may act as a major drying mechanism for the upper troposphere during spring, a finding that is important for the Earth's radiation budget.

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