DCOTSS

NASA Earth Venture Suborbital 3
Dynamics and Chemistry of the Summer Stratosphere

Science Questions

The primary goal of the DCOTSS mission is to understand how dynamical and chemical processes interact to determine the composition of the extratropical stratosphere, and how that composition may change in response to ongoing changes in the climate system. The phenomena involved, which range from turbulence and deep convection to the continental- and planetary-scale circulations, require observing systems and models that cover a similarly wide range of space and time scales. DCOTSS will employ a novel combination of airborne in situ instruments, ground and satellite-based remote sensing, meteorological analyses, and dynamical and chemical models to address the specific scientific questions discussed below.

Dynamics Questions

- *How much tropospheric air and water is irreversibly injected into the stratosphere by convection?*

  There are large uncertainties in estimates of the amount of tropospheric air injected into the stratosphere by convection. These uncertainties arise in part from sparse aircraft sampling, and in part from an incomplete understanding of how often the overshooting storms observed by NEXRAD inject significant amounts of water into the lower stratosphere. DCOTSS is expected to transform the observational record of convective plumes in the stratosphere, recording many more profiles in outflow, from a broader range of storm types and environmental conditions, over a larger part of the summer season. The detailed in situ observations from the ER-2 will be combined with regional-scale observations of overshooting frequency and magnitude provided by NEXRAD, GOES, and MLS to estimate the total transport by convection during the summer season.

- *Which convective source regions impact the NAMA?*

  It is not currently known how much of the stratospheric air in the North American Monsoon Anticyclone (NAMA) originates from convection over the U.S., how much comes from convection over the Sierra Madre Occidental of Mexico, and how much is downstream transport from the Asian monsoon circulation. DCOTSS will target convective plumes originating in the U.S. and the Sierra Madre Occidental to determine the altitude of associated convective injection and the magnitude of water inputs through direct measurement. In situ measurements and back trajectories will be used to investigate long distance transport from Asia.

- *What is the residence time for convectively injected air in the NAMA, and how is air from the NAMA exported to the global stratosphere?*

  Some DCOTSS flights will cross the NAMA boundary and observe the transition between the interior and exterior of the anticyclone. DCOTSS offers a unique opportunity to combine in situ measurements of atmospheric composition inside and outside of the NAMA with dynamical and chemical models to quantify the residence time for convectively injected air within the anticyclone.

- *What dynamical mechanisms lead to the irreversible injection of material into the stratosphere by convective storms?*

  In situ observations from the ER-2 will be combined with high-resolution numerical models of convective systems to investigate the mixing processes at the boundaries of overshooting updrafts.

Chemistry Questions

- *How much VSLS chlorine is present in the lower stratosphere over North America in summer?*

  Very short-lived substances (VSLSs) are a broad class of primarily chlorine- and bromine-containing gases that have nonuniform tropospheric abundances and lifetimes less than 6 months. Chlorinated VSLSs predominantly originate from anthropogenic sources, while brominated VSLSs mainly come from natural sources. Due to their short lifetimes, VSLSs release their halogen content shortly after entering the stratosphere and therefore play an important role in lower stratospheric chemistry, leading to increased ozone depletion. Quantification of VSLS halogens has historically been significantly more difficult than for long-lived halogen compounds because of their short lifetimes and atmospheric variability. VSLSs are of particular interest because they represent chlorine and bromine species emitted into the atmosphere that are not controlled under the Montreal Protocol. While total chlorine and bromine entering the stratosphere from long-lived sources is in decline, VSLSs are not. Chlorine-containing VSLSs, which are predominately produced by industry, have shown relatively large increases in recent years.

- *What chemical changes take place in the stratosphere due to convection in the NAMA?*

  Non-catalytic reservoir species (HCl and $ClONO_2$) typically comprise more than 95% of inorganic chlorine (Cl_y) in the mid-latitude LS. However, enhanced water vapor and low temperatures in the NAMA can enable the conversion of Cl_y to free radical form on ubiquitous binary sulfate-water aerosols, and these surfaces also drive the conversion of NO_x into reservoir species (HNO_3, $ClONO_2$). Satellite measurements have provided unprecedented global long-term data sets, but to examine localized chemical changes, targeted, high-resolution, in situ measurements are needed to complement and extend the satellite data.

- *What are the composition and potential sources of aerosol in the lower stratosphere over North America?*

  Very little is known about: (1) the sources and sinks of the organic aerosols in the summer stratosphere, although it is clear that its source must be tropospheric (anthropogenic and natural), (2) the phase of the organic fraction, and (3) the impact of organic aerosol on the chemistry and radiative properties of the stratosphere. DCOTSS observations will significantly advance our understanding of stratospheric aerosol composition and may also provide insight into the potential for aerosols to impact heterogeneous chemical processes.

- *What will be the stratospheric chemical response to volcanic eruption?*

  Large, explosive volcanic eruptions significantly alter the radiative and chemical properties of the lower stratosphere, including column ozone, through large scale, dramatic changes in trace gas composition and aerosol loading. DCOTSS will add to our knowledge of the lower stratospheric base state, and the project is prepared to modify previous mission plans to make the ER-2 scientific payload available to study an active volcano or to add a deployment with quick turnaround if a significant eruption occurs.