Position Paper: Dynamical Considerations in Station Location, Geographical Representation and Variability - Species

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Introduction

Three types of changes in chemical species, particularly ozone, may be considered for the purposes of this exercise:

1) Upper stratospheric changes, induced by photochemical chain reactions.
2) Lower stratospheric changes induced in high latitude winter and spring.
3) Changes in total column abundances induced by a combination of (1) and (2).

It seems unlikely that detection of (3) would provide a better early warning system, at least in principle, than (1) and (2). Accordingly, further consideration is given mostly to these two categories. I am aware that this flies in the face of an obvious lesson from Farman et al.

Upper Stratospheric Changes

One early warning possibility is the change in shape of the waveform of ozone during sunlight hours under a switch from NO_x and HO_x - dominated chemistry to Cl_x - dominated chemistry, as suggested by Pallister and Tuck (1983) and Herman and McQuillan (1985). For ground based measurement, the requirement of 1-2 km resolution at 40-50 km is severe. The maximum calculated amplitude of the diurnal variation tends be in the equatorial regions. What evidence there is suggests that the non-diurnal O_3 variance is also less there, although tidal effects on the equatorial O_3 diurnal waveform remain unexplored. On balance, a lidar technique near the equator would seem to be indicated by these preliminary considerations. It is obvious that for both mechanistic understanding and long term monitoring, concomitant diurnal measurements of O_3, OH, HO_2 and ClO, plus long term measurements of H_2O would add great value. A problem with the tropics is the large intervening tropospheric H_2O column; perhaps a high dry mountain site (in the Andes?) is indicated.

Lower Stratospheric Changes

There are some indications of significant changes in the ozone content of stratospheric air emerging from exposure to the cold temperatures (and possibly the concomitant Polar Stratospheric Clouds) of the Antarctic night. The requisite low temperatures for PSC formation are also intermittently found in the Arctic. Because it seems to be the case that darkness and the return of sunlight to the cold vortical air are involved there is a need to consider monitoring operations at both the preferred locations (if any) of these PSC's and also of any preferred locations for the cold air to leave the vortex. It may therefore be necessary to conduct a design study with diagnosed isentropic potential vorticity maps and/or trajectories, before siting stations. PSC observations and synoptic intuition suggest the Hudson Bay Area, Iceland-Scandinavia and possibly the sea of Okhotsk, in addition to sites at the Centre and periphery of the Antarctic continent.

It is tempting to ask if continuous lengthy periods of darkness are essential from the chemical rather than the radiative point of view. If not, there is a possibility of effects in the lower tropical stratosphere in regions of cumulonimbus penetration, where temperatures of $-90^{\circ}C$ and ice crystals are also observed, but where there is an everpresent 12 hourly switching between dark and sunlit conditions.

Farman, Murgatroyd, Silnickas and Thrush (1985) point out that the decay of total ozone observed at Halley Bay and Argentine Islands during Antarctic summer (fig 1) is a combination between a photochemical sink and downward motion. The smoothness of this decay suggests that stations located inside and just outside the Antarctic circle may be uniquely valuable for testing the photochemical loss of ozone; in particular there should be observable effects at points where, near equinox, very short periods of insolation are experienced, during which some reservoirs may be photodissociated but others may not.

The Aleutian high is another region in which isentropic potential vorticity studies suggest that air may on occasions have a long residence time in a system not subject to much dynamical fluctuation, and which may therefore be suitable for longer term ground based study of photochemical evolution. Such a proposal must be very speculative, however.

Summary

- Upper stratospheric monitoring, possibly via diurnal cycle: best done from a high, dry tropical mountain.
- Lower stratopheric monitoring: best at Antarctic and sub-Antarctic sites, but also possible in the Hudson Bay to Scandinavia sector in the Arctic.
- Long shots: Aleutian high, lower tropical stratosphere at points of ingress of cumulonimbus storms. Also, consider regular flights of an aeroplane with upward pointing instruments, flying above most of the tropospheric water vapour.