erases pre-established LTP. If CO were acting as a retrograde messenger, one might expect its action to be limited to the time shortly after the brief high-frequency stimulus used to induce LTP. The CO released would then trigger some biochemical cascade within proximal presynaptic terminals, leading to increased transmitter release. But Stevens and Wang[3] observed that ZnPP could erase LTP in a potentiated pathway, without affecting a control pathway, even when applied 30 minutes after induction. This remarkable finding means that CO could be enabling some tonically active process that is necessary for the expression of LTP.

Whatever the mechanism, the possibility that LTP can be erased pharmacologically is potentially of considerable value in the analysis of LTP's functional significance. To date, there are two main lines of evidence that the underlying mechanisms of LTP are activated during, and are required for, certain kinds of learning — first, from studies showing that certain physiological properties of LTP (such as decay time course) covary with indices of behavioural learning[13]; and second, that the blockade of hippocampal LTP *in vivo* is associated with a selective impairment of hippocampal-dependent learning[14]. Fresh points of attack would be helpful.

One such approach, suggested by Stevens and Wang's findings, would be to explore whether ZnPP can selectively erase recent memories. Provided ZnPP erased LTP *in vivo*, its application shortly after a learning experience would obviate certain interpretive problems associated with giving drugs before training episodes[15]; that's because there would then be no possibility that the drug was interfering with perceptual or motor processes during learning itself. Finding that ZnPP could cause animals to forget would be memorable, and such a result would further potentiate the hypothesis that LTP underlies learning. □

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ATMOSPHERIC SCIENCE

Ideas flow on Antarctic vortex

William Randel

OZONE destruction within the vortex that forms over the Antarctic during polar winter gives us the all too familiar 'ozone hole'. But if large volumes of air are swept through the vortex, ozone-depleting reactions at the poles could also be affecting mid-latitudes, where most of the world's population lives. New results from the Upper Atmosphere Research Satellite (UARS), presented at a conference in late May*, have rekindled arguments over just how fast material does flow through the stratospheric vortex.

The controversy centres on whether air is effectively contained on seasonal timescales within the vortex, horizontally by the polar night jet stream and vertically by weak vertical velocities[1], or whether there is relatively rapid air transit through the system[2]. High in the atmosphere (more than 40 kilometres up) there appears to be rapid downward motion into the vortex, associated with convergence of the mean summer to winter hemisphere flow in the mesosphere. But as density decreases exponentially with height, this strong inflow can be balanced by modest flow out of the vortex in the lower stratosphere (see figure overleaf).

The degree of flow-through is important for understanding the budgets of trace constituents within and outside the vortex (and its Northern Hemisphere counterpart). Fast flow-through implies continual refreshing of air within the vortex, so that chemical processing (such as that responsible for the Antarctic ozone hole) would be substantially faster than would be the case for isolated air. Moreover, it would mean that air outside the vortex over much of the hemisphere had experienced the intense cold and chemically perturbed conditions within the vortex and the effects would be propagated to middle and low latitudes. In this case, the vortex is termed a 'flowing processor'.

This latter signature is the basis for the suggestion that UARS data show a flowing processor. Observations of water vapour and methane from the Halogen Occultation Experiment (HALOE) on UARS indicate substantial dehydration within the polar vortex (A. Tuck, NOAA Aeronomy Laboratory). This occurs each winter in the Antarctic, as water vapour is frozen out in the intense cold of the vortex interior. The intriguing observation from HALOE is that the dehydration signature extends far into middle and low latitudes, over a deep layer of the lower stratosphere (16–24 kilometres). Because temperatures cold enough to freeze out stratospheric water vapour are found only within the Antarctic vortex and at this time of year, the widespread dehydration suggests that air over much of the hemisphere has recently traversed the vortex interior. The volume of air in the vortex is 10–20 per cent of that for the rest of the dehydrated hemisphere, so it looks like there has been a complete exchange of vortex air several times during the winter; Tuck suggests a timescale of 30 days for 'flushing' the vortex.

Not everyone agrees. Opponents of the flowing processor concept argue that there is little mass transport out of the vortex. They have a formidable body of evidence for this — aircraft and satellite measurements of the dynamical and chemical structure of the vortex, coupled with trajectory and radiative calculations (M. Schoeberl, Goddard Space Flight Centre). Numerical studies of such vortices back the idea that the horizontal boundary is nearly impermeable[3] (as seems intuitively likely from the observed steep gradients of constituents across the edge). Simulations suggest that a small amount of material is peeled off the outer edge of the vortex in narrow tongues or filaments over the course of the winter, and this material is then rapidly mixed over mid-latitudes. High-resolution simulations of this process in the real atmosphere, based on trajectory calculations, agree well with satellite- and aircraft-based constituent measurements, and confirm the earlier findings of low material flux from inside the vortex to outside (D. Waugh and A. Plumb, Massachusetts Institute of Technology, and B. Pierce, NASA Langley Research Center).

Furthermore, analysis of trace constituent fluxes mapped at high resolution from aircraft has shown that horizontal transport across the vortex on smaller spatial scales (down to 10 kilometres) is insignificant[4]. So it appears that net flow through the sides of the vortex is minimal, although there is probably a good deal of mixing between the vortex edge and air well away from the poles.

This leaves transport out of the bottom of the vortex as the other possible mechanism for flushing (although it is not obvious how such transport could be communicated back to the mid-latitude lower stratosphere). To flush the whole of the vortex volume over the 16–24-kilometre layer of the lower stratosphere with a 30-day timescale requires a vertical velocity of about 0.1 cm s^{-1} averaged over the area of the vortex at a height of 16 kilometres. The vertical velocity of air parcels is a difficult quantity to measure. A convenient substitute for height that can be readily measured from aircraft is the 'potential temperature' of the air, which is the air temperature adjusted for adiabatic expansion effects. Recast in these terms, the downward velocity near 16 kilometres is equivalent to a potential temperature increase at a rate of just 1.2–1.4 kelvin per day. In equilibrium,

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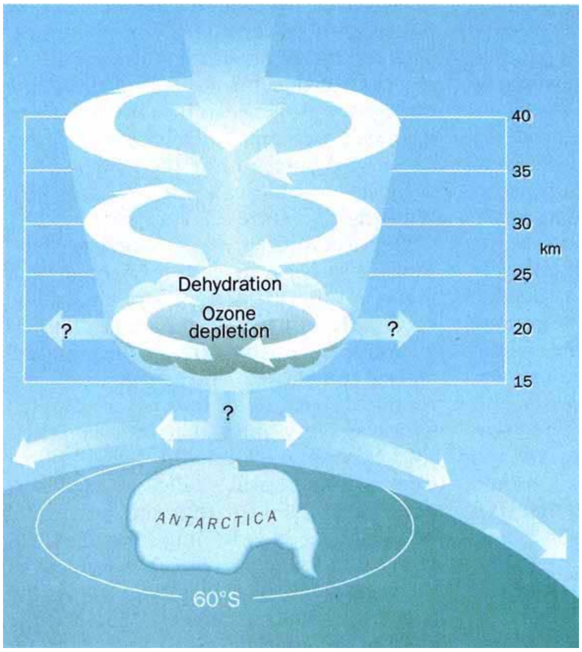

The Antarctic polar stratospheric vortex in middle to late winter; the vertical scale is exaggerated by a factor of about a hundred. The vortex is defined by the stratospheric jet-stream winds circulating about the South Pole (with maximum speeds near 100 m s^{-1} in the upper stratosphere in mid-winter), and by the associated horizontal gradients of potential vorticity[1–3]. Air flows strongly downwards into the vortex above 40 km. The rate of horizontal and vertical flux out of the vortex below 25 km is the focus of the debate over whether the vortex is a 'flowing processor' or a 'containment vessel'. Dehydration and ozone depletion both occur in the lower stratosphere at heights between about 15 and 25 km. Both are ultimately due to the intense cold within the vortex at this height (below −80 °C): dehydration results directly from freeze-out of water vapour, ozone depletion from chlorine-catalysed processes which in turn occur primarily in the presence of polar stratospheric clouds (composed of ice or hydrates of nitric acid).

this tendency would be balanced by infrared radiative cooling of the lower stratosphere.

Do the measurements bear this out? Preliminary estimates of these descent rates from the HALOE data, based on the vertical displacements of the dehydrated region within the vortex during one week in mid-October (after temperatures have risen above the frost point) look promising (1.7±0.3 kelvin per day, near 19 kilometres; Tuck). But extensive aircraft observations of the long-lived tracer N_2O in the Antarctic vortex during August and September 1987 showed little vertical variation with time, suggesting cooling rates less than 0.2 kelvin per day[5,6]. Furthermore, similar small values are derived from independent calculations of the radiative cooling rates in the polar lower stratosphere[7,8] (which, as noted above, must balance the descent rates in equilibrium).

The difference between the rival descent rates may be attributable to the shorter time record analysed by HALOE, together with the fact that vortex descent rates are highest during late spring (October). But it seems difficult to reconcile the earlier N_2O observations and current radiative transfer calculations with the strong flow out of the bottom of the vortex needed throughout the entire winter to produce the mass flux proposed by Tuck.

The HALOE observations of hemispheric-scale dehydration in the Southern Hemisphere present atmospheric scientists with an intriguing problem. Matters may become clearer with further analyses of a new general circulation model simulation of the stratospheric water vapour budget, which shows mid-latitude dehydration in the southern stratosphere similar to that observed by HALOE[9] (although the transport mechanism remains to be established).

Transport of vortex air to mid-latitudes would leave other clues to its presence. Decreasing concentrations of ozone have been observed over mid-latitudes of both hemispheres, and this as yet unexplained observation may be a signature of vortex processing. This may be more likely in the Northern Hemisphere stratosphere[10], where the downward circulation in the vortex is stronger than that in the south. Although dehydration is not widespread in the Northern Hemisphere vortex because the air is too warm, the CLAES and MLS instruments, also on board UARS, have been looking for tell-tale signs of vortex processing in the concentrations of other trace gases. When the results are analysed in detail, we can expect fresh contributions to the debate. □

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DAEDALUS

Outfacing time

'YOUTH'S a stuff will not endure', at least facially. The encroaching lines and wrinkles of maturity fill many of us with dismay. Some of us are so dismayed that we even seek surgical help.

In the standard face-lift, the surgeon removes a chunk of skin and stretches the rest to fill its place, thus ironing out the wrinkles. The procedure may seem rather drastic, but has nature on its side. In the normal process of wound-healing, the dermis contracts around the region of damage; so the surgeon can rely on a useful automatic reduction of skin area. Even so, the removal of one big chunk of skin, and the stretching of the rest, tends to distort the patient's features. One way of avoiding this might be to remove very many small areas of skin, distributed evenly over the region to be smoothed. Daedalus is now taking the idea to extremes. He proposes to remove millions of micron-sized regions of dermis, each too small to see.

He has been inspired by the technology of grit-blasting with solid carbon dioxide. It is surprisingly gentle. The tiny particles chip away dirt and dust from the object to be cleaned, and then evaporate perfectly to leave no residue. Solid carbon dioxide seems a bit drastic as a facial abrasive, but micron-sized pieces of ice (or better, frozen medical saline solution) should do the trick nicely. So the DREADCO Wrinkle Blaster is a sort of small-scale thunderstorm. It grinds ice into many tiny particles, and charges and accelerates them in a big electric field. The resulting miniaturized hailstorm is directed onto the subject's skin. Each particle penetrates a fraction of a millimetre, just sufficient to traverse the epidermis and enter the dermis. (There is a ballistic immunizer that works this way.) The ice melts and the microscopic lesion soon heals, with the normal contraction of dermal healing. The skin is fractionally tightened at that point, and the epidermis reforms scarlessly over the tiny wound. The millions of tiny pinpricks contract the whole region of skin, evenly and strongly.

Thus the facial clock will be put back, and the cruel marks of time erased. Wrinkle Blasting will certainly sting severely, but may not need a local anaesthetic. Daedalus even hopes that the patient can control the whole treatment. DREADCO could then market the Wrinkle Blaster as a consumer product, for private facial maintenance and editing. Wrinkles may best be blasted in many small, controlled stages. The resulting slow and subtle facial rejuvenation will then arouse appreciation but no suspicion in friends, associates and lovers.

David Jones