minent phenomena of Venus's atmosphere, the polar dipole and the circumpolar collar. The true nature of these was hidden from Earth-based observers for decades because they occur at such high latitudes (65–70° and 80–90° respectively) as to be foreshortened beyond recognition to all but the polar-orbiting Pioneer Venus Orbiter. They appear in PVO IR images as a very cold, nearly circular feature about 5,000 km in diameter centred on the pole (the collar) and two hot features, thought to be holes in the otherwise ubiquitous cloud cover, about 1,000 km either side of the pole and rotating around it (the dipole; see *Nature* **279**, 613; 1979). A meridional cross-section of the temperature structure of the middle and upper atmospheres (Fig.3) reveals the collar as an intense, cold planetary-scale wave of long duration. It has been speculated that it is a disturbance produced at the boundary between the 'solid body' rotation of the atmosphere, which is observed in cloud-tracked winds and latitudes equatorwards of the collar, and the regime polewards in which the atmosphere accelerates in the zonal direction as it flows towards the pole, in an attempt to conserve angular momentum. This acceleration is evident in the high rotation rate (every 2.5 to 3 days) of the dipole at the centre of the collar. The dipole is the eye at the centre of the polar vortex on Venus, remarkable for its 'double' appearance. Two clearings in the polar cloud orbit around the pole, rather than the expected one at its centre. The dipole itself is perhaps the biggest mystery of Venus' atmosphere, and a prime target for future missions to the planet. □

Dynamics of the atmosphere

from Lee S. Elson

ATTEMPTS to explain the observation that the entire atmosphere of Venus moves in the same retrograde (westward) direction provided one important focus of the conference. Schubert (University of California, Los Angeles, and see refs 1, 2) described the atmospheric circulation as it is now known from the Pioneer Venus and the Soviet Venera spacecraft. The atmosphere moves westwards at average speeds of up to about 110 m s^{-1} and there is a meridional (north/south) cloud level cell analagous to the terrestrial Hadley cell. As shown in Fig.1 (from Schubert's paper), there is considerable variation in this flow with time. Therefore, the term '4 day wind' used to describe the periodicity of UV features advected by the retrograde winds is a misnomer, because the wind speed corresponds more closely to a 5 day period.

Several suggestions for the possible causal mechanisms of this flow were made in the context of comparative planetary meteorology. Mayr (Goddard Space Flight Center) and Williams (Princeton University) considered the role of meridional cells, viscosity and solar heating of the atmosphere in producing zonal (east/west) jets on Jupiter, Saturn and Venus. Their conclusions and the discussion with the audience indicated that one might expect such jets on Venus if several mechanisms operated simultaneously. However, model calculations are still unable to reproduce exactly the observed flow while simultaneously satisfying heat and momentum conservation constraints. Two papers dealing with the zonal jet above the clouds were also presented. Elson (Jet Propulsion Laboratory) described evidence[3] that the zonal jet dies off with increasing altitude so that it has disappeared entirely above about 80 km altitude (see Fig.2). The jet may reappear above 100 km and, as was discussed by Mayr, it seems to be required at altitudes above 150 km to explain Pioneer observations.

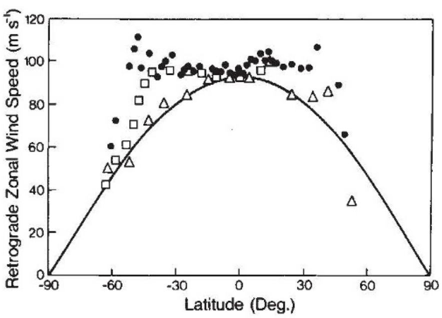

Fig.1 Mean cloudtop westward wind as a function of latitude. Mariner 10 data from 1974 (filled dots) show different structure from that of Pioneer Venus as shown by the open symbols representing UV data presented by Del Genio.

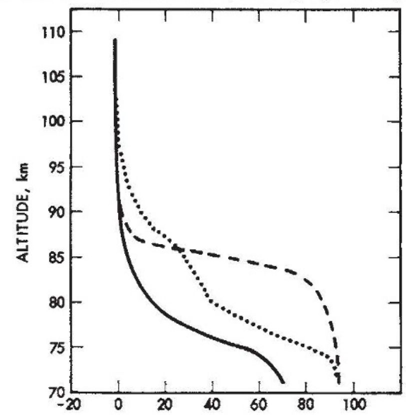

Fig.2 Mean westward wind as a function of altitude above the cloud tops. The solid curve is the best estimate based on a model[4] and the other curves are the results of a study of the model sensitivity to input assumptions.

Atmospheric thermal tides, temperature and wind perturbations caused by solar heating of the atmosphere were addressed by several speakers. Elson discussed them from an observational and diagnostic point of view, suggesting that the temperatures observed by the Pioneer spacecraft are difficult to reconcile with our terrestrial experience, and that model calculations indicate that the tidal winds are probably small in amplitude and dominated by dissipative forces. Pechmann (California Institute of Technology) described theoretical calculations of tidal winds and temperatures using a model. Her results suggest that the tidal response of the atmosphere strongly depends on the mean (zonal and time averaged) zonal wind and static stability. A similar calculation of the tidal fields was made by Fels (Princeton University) but for a very different purpose. Assuming that the unusual observed warming at the poles has a non-radiative source, Fels chose to examine a dynamical forcing mechanism which relies on the interaction between tidally forced waves and the averaged flow whereby the tides force the averaged flow to descend in the polar regions. This descent produces warming at the pole due to adiabatic compression of the atmospheric gas as it moves down to higher pressures. To produce warmings as large as are observed, however, this mechanism must assume that the cloud level winds are much stronger than those observed.

Tides were not the only type of waves to be discussed during the session. Apt (Jet Propulsion Laboratory) reported the presence of waves with periods of 5.3 and 2.9 Earth days over the entire Northern Hemisphere between the cloud tops at about 65 km and 90 km. These waves are thermal perturbations observed at IR wavelengths. Del Genio (NASA Goddard Institute for Space Studies) reported the existence of a 5.2 day wave from UV observations. Perhaps there is a temperature-sensitive UV absorber present. In the area of theoretical wave calculations, a presentation was made concerning results produced by a general circulation model of the type used for comprehensive terrestrial studies. Young (NASA Ames Research Center) described calculations of baroclinically unstable waves whose terrestrial counterparts are responsible for most of what is called weather. As is the case on the Earth, these waves are caused in part by the vertical shear in the zonal wind. Despite this similarity, differences in the rotation rates and atmospheric structures of the two planets appear to produce different wave characteristics. □

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2. Schubert *et al. J. geophys. Res.* **85**, 8007 (1980).
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