NOTES AND CORRESPONDENCE

Mesospheric and Lower Thermospheric Dynamics

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1. Introduction

The region between 60 and 85 km altitude (the mesosphere) has often been referred to as the "ignorosphere," in that it is above the heights sounded by conventional meteorological rockets, and below the E region, which has been monitored for decades using radio techniques.

The advent of the rocket released vapour trail in the late 1950's did little to increase our knowledge of the mesosphere, in that these sodium vapor and trimethyl aluminum releases were concentrated in the 85 to 240 km altitude range, with the exception of a few titanium tetrachloride releases in the mesosphere.

Since the early 1950's, a considerable amount of data on neutral atmosphere motions in the height range 80 to 100 km has come from the meteor radar technique. However, with the notable exception of those stations operated by the Hydrometeorological Service of the U.S.S.R. (which, unfortunately do not routinely measure height, but consider all echoes as coming from a mean echo height near 95 km), the continuous operation needed to infer the synoptic meteorology of the region has been rare. The only attempt at such operation producing height/time profiles of winds between 80 and 100 km has been carried out at Atlanta (34°N, 84°W), and winds from August 1974 through December 1977 have been published by Roper (1978). While these results are valuable, being from a single station they provide only a crude insight into the synoptic meteorology of the meteor region.

2. Prevailing winds

While considerable variability exists in the meteor winds measured by various groups, global circulation systems with seasonal variability, reproducing year after year, have been found. Analysis of several years northern hemisphere radio meteor wind data by Minina, *et al.*, 1977,

and Ilichev and Portnyagin, 1977, shows that the pressure field at meteor heights *in winter* is similar to the baric profile of the underlying atmosphere. During the summer, however, the lower thermosphere differs considerably from the baric profile of the mesosphere, stratosphere, and troposphere. In winter, at high and mid latitudes a cyclonic vortex with its center near the pole is observed; in summer, at latitudes greater than 65°, anticyclonic motion prevails. Cyclonic motions prevail through the year at midlatitudes, with anticyclonic circulations in the subtropics. On the average, the spring reversal of the circulation in the meteor zone occurs before that in the stratosphere—thus continuous monitoring of mesopause circulation can be used as a predictive tool in inferring the circulation of the upper stratosphere.

To date, the meridional circulation, which is of comparable strength to the zonal at meteor heights, has received little detailed attention. However, there does seem to exist a global system of motion from summer to winter pole, which agrees with the warm winter/cold summer mesopause inferred from high latitude rocket grenade temperature soundings.

One outstanding feature of the prevailing wind motions as deduced at midlatitudes (see, for example, Elford, 1974) is the fact that the 85 km (mesopause) level is an obvious boundary between the mesospheric circulation below, and the thermospheric circulation above.

3. Mean vertical motions

One of the most puzzling features of winds measured in the 80 to 100 km height range is the apparently large (meters per second) mean motion which is inferred from both incoherent scatter and radio meteor wind observations. While the large magnitude of these winds is still in question, the sign of these motions, at least as inferred from the quasi-continuous observa-

tions over Atlanta, is consistent with the general circulation (Dolas, 1979).

4. Tidal winds

The most outstanding feature of the motions at meteor heights is the prevalence of solar tidal oscillations. On the average, more wind energy resides in tidal motions than in the prevailing circulation in the lower thermosphere.

While the irregularity of the diurnal tide, particularly in the northern hemisphere, has hampered the investigation of this tide as a global phenomenon, recent work by Mathews (1967) using the Arecibo Observatory incoherent scatter facility, and by the French with their portable meteor wind radar at Ramey, Puerto Rico (results as yet unpublished) has shown the presence of a stable, large amplitude (~ 50 m/sec) diurnal tide at the equinoxes.

In the southern hemisphere (Adelaide, 35°S , 139°E), the diurnal tide has a larger average amplitude than is found at northern hemisphere midlatitudes, but both phase and amplitude are highly variable in both hemispheres.

The semidiurnal tide, by comparison, exhibits relatively constant phase, but, again, great variability in amplitude. This variability can be explained by variations in the stratospheric/mesospheric wind fields through which the tidal energy is propagating to reach the mesopause. The variability has time scales related to the planetary wave time scales in the lower atmosphere, and further understanding of these variations can only come from long period (preferably continuous) observation by a network of stations widespread in both latitude and longitude.

5. Stratospheric warmings

It has been known for some time that the sudden warmings of the polar stratosphere which occur during some northern hemisphere winters affect the circulation at mesopause levels at high latitudes. More recent measurements at midlatitudes (Atlanta, 34°N , 84°W) have shown a direct cause/effect relationship, with major stratwarms causing zonal wind reversals. There are indications from the limited amount of data available from the southern hemisphere that northern hemisphere winter polar stratwarms may be a global phenomenon at the mesopause level.

Stratospheric warmings also affect tidal amplitudes and phases, but with a lack of continuous height/time profiles available globally, reports of

such effects have been for the most part descriptive of particular locations only, and somewhat confusing in their interpretation.

6. Models

Two significant semiempirical models of stratospheric/mesospheric/lower thermospheric winds have emerged in the last decade. Groves (1970) took data from 1000 rocket launches with ejected sensors, 127 rocket grenade experiments, and 230 experiments with rocket released vapor trails and clouds, and constructed monthly mean zonal and meridional circulation patterns. This model, together with monthly mean tropospheric data, upper air global temperature maps, radio meteor winds, and the Jacchia thermospheric model have been incorporated in the Global Reference Atmospheric Model of Justus, *et al.* 1976. This empirical model generates latitude, longitude, and altitude dependent monthly mean values for pressure, density, temperature and winds from surface to orbital altitudes.

Theoretical models of atmospheric tides have recently been reviewed by Forbes and Garrett (1979). While there is a measure of agreement between the latest theoretical models and observational data, since the tides are a global phenomenon, questions as to standing versus travelling waves, and latitudinal variation will not be resolved until a global network of synoptic measurement capability is established.

An additional problem in resolving theory and observation centers around the variability encountered in all meteorological phenomena. The presence of other motions besides those of primary interest, in particular, the aliasing of tidal observational data by long period (planetary) waves, and the interaction between the tides and the shorter period random internal atmospheric gravity waves, makes a widespread, continuously operating monitoring network a necessity. An ideal radar for deployment is that described by Aso, *et al.* (1979).

7. Compatibility of measurement techniques

While early attempts to compare winds measured by different techniques (*e.g.*, rocket released vapor trails, radio meteor winds, airglow drifts, and partial reflections radio observations) were singularly unsuccessful, more recent comparisons, in which allowances were made for sampling differences, in particular integration intervals in both height and time, have resolved these inconsistencies (see, for example, Felgate, *et al.*,

1975; Geller, *et al.*, 1976; Vincent, *et al.*, 1977; and Hernandez and Roper, 1979). As yet unpublished comparisons between the French meteor radar located at Ramey, Puerto Rico, and Arecibo incoherent scatter facility, have shown excellent agreement. One outstanding achievement at Arecibo has been the extension of the lower limit of reliable wind determination by the incoherent scatter radar down to as low as 55 km.

The radio meteor wind technique is capable of continuously monitoring the dynamics of the 80 to 100 km altitude range, with a lower limit of observable variation of a few hours, and a height resolution of some 2 km. Specialized highpowered radars, such as that operated by the University of Illinois, can monitor variability of time constant less than one hour, but the logistics of highpowered operation preclude continuous sampling beyond intervals of a few days. The diurnal variability of meteor influx renders the error of wind determination greater at dusk than at dawn, but most facilities achieve a sufficiently high echo rate at dusk to make these results still statistically significant.

The partial reflections drift experiment is capable of sampling, with a time resolution of minutes, and a height resolution of 3 km, a height range from 60 kilometers to 110 km in daylight hours, but returns are reliably received only from 90 km up at night. The incoherent scatter technique suffers similarly from the diurnal variation of mesospheric ionization.

Rocket vapor techniques, while yielding excellent instantaneous snapshots of the stratosphere/mesosphere/thermosphere (height range governed by type of vapor released, and time of day) are prohibitively expensive if synoptic data is required. Their dependence, together with airglow observations, on cloud cover for observation is also a significant drawback.

Winds can be inferred in the stratosphere, mesosphere, and lower thermosphere by application of the thermal wind equation to satellite temperature soundings. Unfortunately, the large tidal winds at upper mesospheric heights and above, preclude the use of quasi-geostrophic approximations—the inference of viable winds from satellite temperatures at these altitudes is highly doubtful.

A further groundbased technique worthy of mention is the VHF radar technique (Rottger, *et al.*, 1978). While not yet in routine operation, these VHF radars have demonstrated the capa-

bility of measuring winds and turbulence in the troposphere, stratosphere, and upper mesosphere.

Also, the VLF observations of Schminder and Kurschner (1979) warrant further investigation, since they appear to provide continuous, reliable observations of mesopause dynamics.

8. Availability of data

Beginning with the formation of GRMWSP, the Global Radio Meteor Wind Studies Project of IAGA, in 1970, followed by the URSI/IAGA Cooperative Tidal Observations Program (CTOP), which added incoherent scatter radar observations, attempts have been made to coordinate observations (see Roper, 1979). Some of these results were published in the August, 1978, issue of the *Journal of Atmospheric and Terrestrial Physics*.

While data is available from individual observers, as yet formats and analysis techniques have not been standardized, and no central depository exists. The Soviet Union is moving toward having all their radio meteor wind data available through the World Data Center in Moscow. The mechanics of such archiving, both in the Soviet Union and elsewhere, are to be discussed at a meeting of IAGA Division V, Working Group 2 (Meteor Observatories) at the IUGG Assembly in Canberra, Australia, in December 1979.

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中間圏および下部熱圏の力学

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