3.4.1 OBSERVATIONS AND A MODEL OF GRAVITY-WAVE VARIABILITY IN THE MIDDLE ATMOSPHERE

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I. Introduction

The recent recognition of the important role of gravity waves in middle atmosphere dynamics has stimulated renewed interest in their propagation and effects. The most significant effect, perhaps, is the drag that results from a vertical divergence of the gravity-wave momentum flux due to wave saturation. Initial studies of this momentum flux and divergence were performed by VINCENT and REID (1983) and REID (1984). The purpose of this note is to report on a more recent study that addressed the gravity-wave momentum flux, and its variability in space and time, in detail.

II. DATA PRESENTATION AND DISCUSSION

As in the studies cited above, the data used in this study were collected with the HF radar in Adelaide, Australia. The system capabilities and momentum flux measurement technique were described by VINCENT and REID (1983).

A major goal of the present study was to determine what portion of the gravity-wave frequency spectrum accounted for the majority of the momentum flux and divergence, as this has important implications for the middle atmosphere response. It was found that $\sim$70% of the total flux and divergence was due to wave motions with observed periods < 1 hr, consistent with expectations based on the shape of the observed gravity-wave spectrum (FRITTS, 1984). This dominance of the momentum flux and divergence by high-frequency motions implies a potential for the modulation of those quantities by large-amplitude motions at lower frequencies.

A second, striking aspect of the velocity and momentum flux data is its dramatic diurnal variability, particularly at certain levels. This variability is illustrated with the momentum flux, computed in 8-hr blocks, in Figure 1. Note the large negative values occurring at 0000 local time at upper levels and the phase lag at lower levels. As indicated above, the dominant contributions here are due to waves with periods < 1 hr. The variability with height and time of the mean square velocity in the west beam and the momentum flux, averaged over the 3-day period, are illustrated in Figure 2. Note here the rapid growth of wave amplitude (and momentum flux) below 90 km during the 8-hr period centered at 0000 local time.

We have performed a detailed analysis of the various tidal motions present during this data interval and have determined that variations in the zonal wind profile imposed by the diurnal tidal motion likely are responsible for the modulation of the gravity-wave amplitudes and momentum fluxes. The modulation appears to proceed as follows. For most of each 24-hr period, the tidal winds

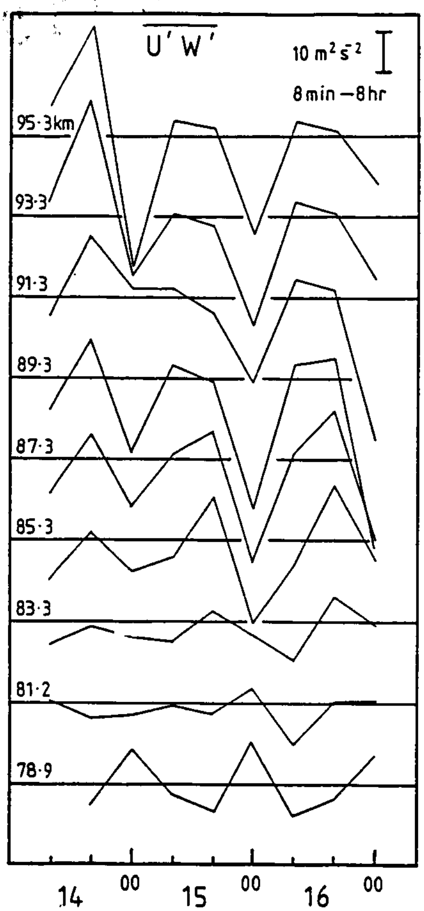

Figure 1. Momentum flux estimates in 8-hr blocks as a function of height for 14-16 June. Note the large diurnal modulation at upper levels and the phase lag at lower levels. Large negative values occur preferentially near 0000 local time.

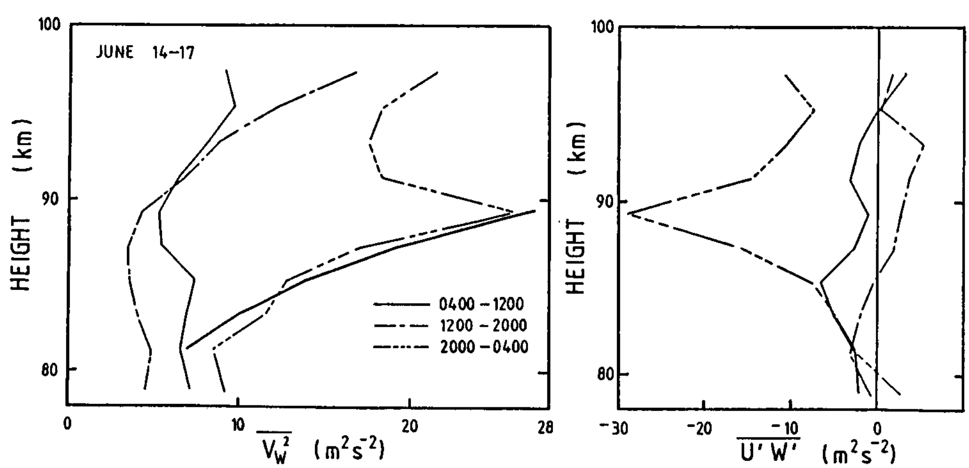

Figure 2. West mean square velocity and momentum flux profiles for 8-hr intervals averaged over the final three days of the observation period.

do not alter substantially the zonal wind shears, which are normally negative, causing a gradual reduction in $\bar{u} - c$ (for westward propagating gravity waves) and a gradual constriction of the momentum flux due to such waves, as shown schematically in Figure 3a. These are the dominant gravity waves as evidenced by the momentum flux data presented by VINCENT and FRITTS (1985). During the interval centered at 0000 local time, however, the tidal winds during this 3-day period acted to reverse (make positive) the vertical shear of the zonal "mean" wind, producing an environment in which high-frequency easterly wave motions experience a considerable increase of $\bar{u} - c$ with height. Because the amplitude needed for saturation scales as $\bar{u} - c$, these waves now propagate upward largely without saturating, resulting in am amplitude and momentum flux as shown in Figure 2 (see Figure 3b). Near 90 km, however, the waves again encounter an adverse shear, causing a rapid amplitude reduction and a large momentum flux divergence.

The implications of this tidal modulation of the high-frequency momentum fluxes are illustrated in Figure 4. The diurnal tidal amplitude at 90 km is shown in Figure 4a and reaches a maximum near 0000 local time, at which time the momentum flux and flux divergence below and at 90 km achieve large values. The strong diurnal variation of the momentum flux divergence results in large, temporarily localized zonal flow accelerations which may themselves alter the

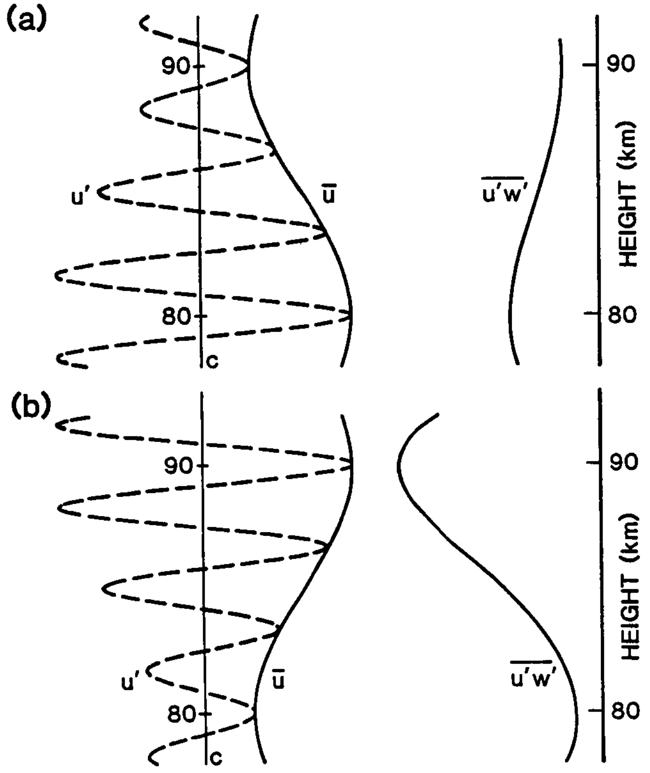

Figure 3. Schematic of saturated gravity-wave amplitude and momentum flux in an environment with $\bar{u}$-c decreasing (a) and increasing (b). Note that the implied zonal drag is very large above 90 km in the lower figure.

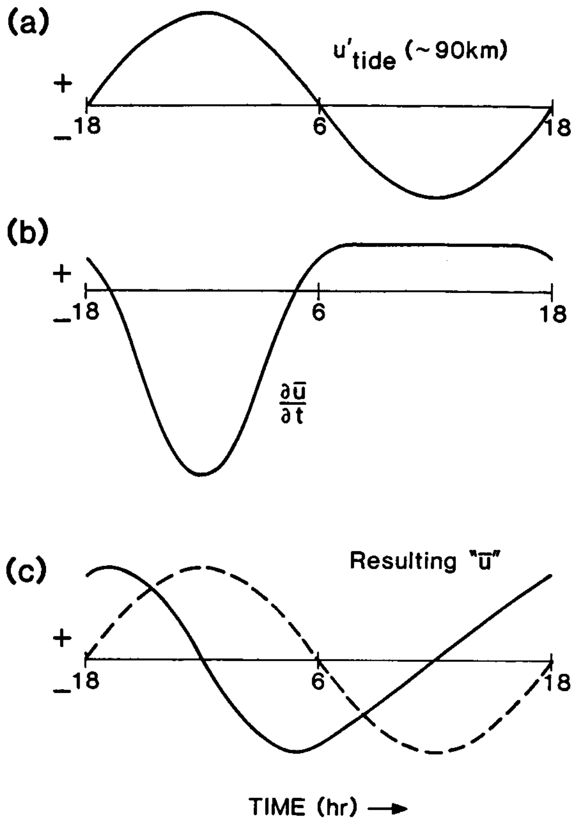

Figure 4. Schematic illustrating the effects of a diurnally varying zonal drag on the inferred tidal structure. The results are an altered amplitude and an advanced phase of the apparent tidal motion.

tidal structures or at least our ability to infer the tidal amplitudes and phases. This mechanism suggests an advance of the phase of the diurnal tidal motion during periods of particularly large diurnal tidal amplitudes, consistent with tidal observations made during this period. This mechanism may also be expected to contribute to the variability of tides and other low-frequency components of the motion spectrum at other locations.

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