Monsoonal Quasi-Stationary Ultralong Waves of the Tropical Troposphere Predicted by a Real Data Prediction Over a Global Tropical Belt

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Abstract – The mechanisms of the maintenance of the tropical upper tropospheric quasi-stationary ultralong waves during the northern hemisphere summer season are briefly reviewed and discussed. Diagnostic and prognostic studies indicate that the waves are maintained by the land–ocean contrast heating. These scales of motion as a whole (sum of the zonal wavenumbers 1, 2 and 3) are considered to supply kinetic energy to all other scales of motion.

The ultralong waves predicted in the real data numerical prediction experiment over the global tropics using a multi-level primitive equation model are examined and compared with the observed climatological waves. The predicted waves are found to have several similarities with the observations. Further investigations of the baroclinic nature of the waves indicate that their thermal structure is essential for understanding their dynamics.

The vorticity budget computations are performed for the predicted ultralong waves at 200 mb and also compared with the climatological observations. It is found that the advection term is one of the leading terms in the vorticity equation.

This study indicates that the tropical quasi-stationary ultralong waves are fully nonlinear, non-geostrophic, three-dimensional waves forced mainly by the convective heating over the monsoon Indian subcontinent.

Key words: Monsoon, Tropical ultralong waves.

1. Introduction

Although the tropical troposphere has long been considered as a primary source region for the general circulation of the atmosphere, studies on the detailed four-dimensional global tropical circulations have not been performed until recently. This was mainly due to the poor observational coverage over the tropics. Research on tropical circulations started from several regional synoptic climatological studies over the area of rich upper air observations (e.g., Riehl, 1954; Koteswaram, 1958; Flohn, 1964). These studies indicated the existence of several typical quasi-stationary upper tropospheric flow patterns. However, these findings had not been combined to give overall global tropical circulations until the recent analyses by Krishnamurti and Rogers (1970) became available. They collected commercial aircraft reports

from the major airports in the various tropical countries, and combining them with standard observations, analyzed 92 days of wind fields at 200 mb during June, July and August of 1967.

Based on these massive analyses, KRISHNAMURTI (1971a,b) made several quantitative and qualitative studies of the tropical upper tropospheric circulations during the northern hemisphere summer season. He showed that the flow fields were characterized by a number of very large scale quasi-stationary cyclonic and anti-cyclonic circulations which were expressed mostly by the zonal wavenumbers 1 and 2. He also pointed out that these ultralong waves (zonal wavenumber 1 and 2) had strong southwest to northeast tilt which effectively transported westerly momentum toward the north pole. KRISHNAMURTI (1971a) and KANAMITSU et al. (1972) computed the barotropic energetics using the 92 days of analyses and found that the ultralong waves acted as a kinetic energy source for smaller scales of motion and also for the zonal motion.

The most comprehensive energetics of the tropical upper troposphere during the northern summer, which were able to be evaluated or be estimated from up-to-date observations, were compiled by KRISHNAMURTI et al. (1973a). Figure 1 shows the estimated direction of the energy exchange/conversion processes. They may be interpreted as follows. The available potential energy (APE) of the ultralong waves, $P_L$, is generated by the land-ocean contrast heating, $H_L$. The kinetic energy (KE) of

![Energy diagram of the tropical upper troposphere estimated from observations during northern hemisphere summer. L stands for ultralong waves, S for other shorter waves and Z for zonal flows. H, P and K express heating, available potential energy and kinetic energy, respectively. A question mark denotes that the process is unknown. (After KRISHNAMURTI et al., 1973a.)](image-url)