Tropical-Extratropical Interactions During the Northern Winter

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ABSTRACT

The basic circulations in the tropics and in the midlatitudes are reviewed. The dynamical mechanisms of tropica-extratropical interactions and low-frequency variability of the atmosphere are discussed. Some preliminary results of using the CWB global data set to study the tropical-extratropical interactions over Asia and the western Pacific during the 1993 northern winter are presented.

I. BASIC CIRCULATIONS IN THE TROPICS AND IN THE MIDLATITUDES

The three-dimensional picture of the tropical circulation did not emerge untill the last two decades. It has become well known that the tropical circulation can be generally decomposed into the monsoonal and the large-scale near-equatorial flow. The monsoon flow may be envisioned as a strong local Hadley circulation with low-level flow out of the cool winter hemisphere across the equator and into the monsoon convection area of the summer hemisphere. Upper-level flow returns to the winter hemisphere. The near-equatorial flow (or "local" Walker circulation) may be thought of as a very deep circulation filling the entire troposphere with low-level air flowing toward the convective regions in an almost zonal direction, rising motion in the convective region and upper tropospheric flow, also almost zonal, away from the convection. In contrast to the monsoonal circulation the near-equatorial flow has little annual variation. The monsoon flow is interhemispheric, while the near-equatorial flow is almost parallel to the equator. In addition to the monsoon activities, a subseasonal-scale atmospheric oscillation known as the "30-60" day oscillation (e.g. Madden and Julian, 1971,1972) has been brought into sharp focus. This oscillation is the strongest signal so far found in the intraseasonal variation of the tropical atmosphere.

The three-dimensional picture of the circulation in midlatitudes is much more complicated than its tropical counterpart. The upper atmosphere of the winter hemisphere is characterized by the wavy polar front where the meridional temperature gradient is large and the westerlies are strong. On the east side of the troughs there are usually upward motions, while on the west side there are downward motions. The east side of a trough is a favorable area for frontogenesis. On the other hand, the lower atmosphere is characterized by anticyclonic circulations over cold continents and cyclonic circulations over warm oceans. Intraseasonal oscillation has also been observed in the extratropics but with a shorter period than the "30-60" day oscillation in the tropics (e.g. Branstator 1987).

II. TROPICAL-EXTRATROPICAL INTERACTION

Tropical-extratropical interaction has been recognized as an important and challenging subject in meterology, particularly, in understanding low-frequency variability of the atmosphere. The low-frequency variability (anomalous circulations) of the atmosphere has been noticed by meteorologists, especially long-range forecasters, for a long time. The present intense interest in this problem was stimulated by the theoretical work of Charney and DeVore (1979). They showed that a low-order nonlinear barotropic system, with forcing and dissipation for certain parameter values, may possess multiple steady states of which several may be stable. Two typical stable steady states are found to be high index state (zonal current is strong and amplitudes of the planetary-scale waves are small) and low index state (zonal current is weak and amplitudes of the planetary-scale waves are large). The bifurcation depends on the strength of the forcing. The low index state generated by their simple model was compared to the most pronounced anomalous midlatitude circulation: the blocking. Interestingly, Murakami and Unninayer (1977) found in their observational study that the winter tropical upper atmosphere can also be categorized into tow distinct states. The low (high) index state or the M (m) period called in their paper is characterized by well above (below) seasonal mean eddy kinetic energy at all latitudinal belt. During the M period the northeast Asia jet stream is extremely strong, the local Hadley cell over eastern Asia more vigorous, and low-level monsoon surges together with the cloudiness over the East and South China are enhanced. On the other hand, during the m period the northeast Asia jet stream and oceanic trough over the central North Pacific are weak. The local Hadley cell and cloudiness over east and southeast Asia are depressed. It has later been suggested by other authors that the tropical-extratropical interaction is more active in the low index state than in the high index state. In the former state the upper troughs over the Pacific can penetrate from winter hemisphere to summer one (Webser and Holten, 1982).

Recurrent spatial patterns (persistent anomalies) is well documented in Wallace and Gutzler (1981). These patterns may be indicative of standing oscillations in the planetary-scale waves during the northern winter with time scales on the order of a month or longer. The Pacific/North American pattern (PNA) is the clearest mode among many others. The recurrent patterns have been explained by the tropical forcing effect. In other words, rotational modes in the subtropics and extratropics are forced by thermal or divergence forcing generated from tropical heat source through dispersing Rossby waves (e.g., Hoskins and Karoly, 1981; Sardeshmukh and Hoskins, 1988). Recurrent patterns manifest rays of the Rossby waves. On the other hand, Lau and Phillips (1986) found that the patterns resembling PNA, the Eurasian pattern and the North Atlantic pattern, in the time scale of 20-70 days, in both 500 hPa geopotential height field and the tropical outgoing longwave radiation (OLR) data. The OLR and height space-time evolution is consistent with normal mode descriptions within the tropics and in the midlatiudes, respectively. They also showed strong phase-locking between tropical convection and extratropical height anomalies which suggests the presence of coupled normal modes between the tropics and midlatitudes.

In addition to the normal mode mechanism, an instability theory has been suggested (Frederiksen, 1982) to explain the generation mechanism of the teleconnection patterns. It has been shown that all the major distrubances in the atmosphere, from cyclogenesis to blocking and teleconnection patterns, can be explained with the individual or combined barotropic and baroclinic instability with three-dimensonal basic state flows (e.g. Frederiksen and Bell, 1987).

III. THE 1993 NORTHERN WINTER

The 1993 northern winter (January, February and March) is characterized by strong local Hadley cell in east Asia and western Pacific, and in south America. The near-equatorial flow which flows from the east to the west Pacific in the lower atmosphere and flows from the west or central back to the east Pacific in the upper part is evident. The intensity of northeast Asia jet stream clearly oscillates with a period of roughly 30 days. The oscillation is particularly clear in January and February. Five "cold surge" events in Taiwan area are observed during these three months. The daily minimum temperature recorded at the Taipei station droped for 7.2° between January 14 and January 16, for 3.7° between January 23 and January 25, for 6.1° between February 21 and February 23, for 4.1° between March 16 and 18, and for 7.4° between March 27 and March 29. We notice that all the five events occured near or after the middle of each month. Does this imply that the "forcing" which triggers the cold surge events somehow oscillates with a period of about 30 days is still being investigated.

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北半球冬季熱帶與副熱帶大氣的交互作用

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摘要

熱帶與副熱帶大氣的交互作用不但是於探討大氣的基本低頻變化性時必要面對的課題，於研判東亞地區天氣型態的維持或轉變上亦不容輕忽。因而，我們得首先回顧熱帶與副熱帶地區的冬季基本環流與低頻變化之特徵，接著回顧在研究熱帶與副熱帶大氣的交互作用與大氣低頻變化性之關係這方面的一些顯著成果。目前我們正利用中央氣象局的全球分析資料針對今年(1993)冬季的台灣天氣型態與大尺度環流關係進行分析研究。有關東亞地區的寒潮暴發件與大氣的低頻變化（如熱帶地區的30至60天振盪，太平洋及大西洋的高壓阻塞等等）的相互關係之初步結果並得提出討論。