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TIME-SPACE CHARACTERISTICS OF ATMOSPHERIC WATER BALANCE IN MONSOON AREAS BASED ON ECMWF REANALYSIS DATA

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1. INTRODUCTION

Precipitation depend upon moisture transport/convergence and evapo-transpiration from the surface. Seasonal and interannual variability of precipitation are determined by the characteristic nature of water vapor transport & convergence and evapotranspiration, and their mutual dependencies. Water vapor transport and covergence in the atmosphere is basically controlled by large-scale atmospheric circulation (e.g, ITCZ, monsoon flow, and extra-tropical westerly flow etc.), whereas evapotranspiration is strongly controlled by surface condition (e.g., sea surface temperature, soil moisture and vegetation etc.) and near-surface atmospheric condition (wind, temperature, stability etc.). The large-scale circulation and surface condition also interact each other, to change convergence (divergence) and evapotranspiration, and as a result, precipitation. The characteristics of interaction should be different from region to region, and/or season to season, depending upon climatological and geographical conditions.

This study aims to understand seasonal and regional dependencies of interannual variability of precipitation in the monsoon regions in the world, as well as in the tropics, on water vapor convergence vs. evapotranspiration, and to assess the relative importance of these two parameters for variability of precipitation of each climatological region.

2. DATA AND METHOD OF ANALYSIS

The fifteen-years (1979-1993) reanalysis data from Europian Center for Medium Range Forecast (ECMWF), i.e., ERA data, are basic data source for computing atmospheric water vapor convergence (C) for some regions of the world. The vertically integrated atmospheric water vapor convergence is computed from the surface to 10 hPa for each specified region based on four times/daily specific humidity, temperature, geopotential height and wind (u, v) field for the 15 years (Yatagai and Yasunari, 1998), and is converted to monthly mean data. Precipitation (P) is adopted from CMAP analysis (Xie and Arkin, 1997), which is a blended product from in-situ raingauge data and satellite-derived rainfall data (from OLR and SSM/I). Evapotranspiration (E) can be evaluated as a residual of the atmospheric column mean water vapor budget, i.e., $E = P - C$, where local time change of colomn water vapor content (precipitable water) is neglected. For the monthly mean product, this assumption is proved to be vaild.

3. SEASONAL MEAN ATMOSPHERIC WATER BALANCE IN MONSOON AREAS

Before we examine the characteristic nature of the interannual variablility, we compared the 15-year mean atmospheric water balance in various regions in monsoon Asia, adding some other regions in the tropics for comparison. The regions selected are, Arabian Sea(AS), Indian subcontinent (IS), Bay of Bengal (BB), Tibetan Plateau (TI), Thailand (TH), South China Sea (SCS), tropical Western Pacific (WP), China Plain in East Asia (CP), Mongolia (MO), Lena River basin in Siberia (LE), and the Amazon river basin (AM) and the Western African monsoon region (WA). Figure 1 shows, as an example, seasonal change of P, C and E in the IS region (8N-30N, 70E-90E), the CP region(25N-35N, 105E-120E), the WP region (5N-15N, 130E-160E) and the AM reigon(5N-15S, 50W-75W). In most of the regions, seasonal cycle of P correspond well to that of C, but in the CP region contribution of E in the season cycle is in the comparable order to C.

Since we focus on the contribution of C and E to P particularly in rainy (or monsoon) season, P, C and E of the peak rainfall month for each region are plotted (with a circle) in the P-C-E diagram as shown in Figure 2. As is clearly shown, P of all the ocean regions except the AS region range at around 400 mm/month, with more than 50% of contribution to the total amount by C. In the AS region, E is a dominant factor of the water balance, which nearly balance divergence (negative C) with small amount of P (50 mm/month or less). Over all the land-based regions in the tropics, P ranges mostly in 200-300 mm/month, but C-E ratio shows a considearble different feature from region to region. In the IS and TI region, C explains most of P (more than 70%), while in WA about 60% of P is occupied by E. In AM and TH regions, C and E occupies nearly the same amount. It is noteworthy to state that in CP, where so-called Meiyu (or Baiu) frontal rain is dominated in the peak rainfall month (June or July), E contributes large amount of P (of about 150 mm/month). In addition, in higher latitudes of Eurasia, i.e., MO and LE, P is nearly balanced by E, though the amount of P (of about 50 mm/month) is very small compared to the other subtropical and tropical regions.

4. INTERANNUAL VARIABILITY OF ATMOSPHERIC WATER BALANCE IN MONSOON AREAS

By using the 15-years monthly water balance components P, C, E, the linear correlations between P and C & E were computed for each region. In most of the regions P and C shows a high linear correlation with more than 1% significant level, but the correlation between P and E is weaker even if the mean contribution of E to P is large, e.g., in the CP region. In addition, a large variety of the gradient (C versus E) of the linear regression is noticed from region to region, which suggests that different physical processes or feedbacks are involved in the P-C-E relations.

In the same P-C-E diagram (Figure 2), the interannual range of the three components are also drawn for each region, based on the linear regressions. Interestingly, the C vs. E gradients for the SCS region and the WP region show some positive values while that for the BB region shows negative values, although these three ocean regions, as warm water pools under the Asian monsoon climate, show nearly the same P and E/C ratio in the climatological mean state. These features may imply that in the SCS and WP regions, a positive feedback processes, e.g., wind-evaporation feedback (Emanuel, 1986), is dominated between C and E, presumably based upon the strong association between wind speed and low-level convergence, whereas in the BB region, a negative feedback between C and E, e.g., cloudiness-insolation (-SST) feedback, may be more effective possibly through strong C vs. cloudiness relation. As a result, in SCS and WP regions, the interannual variability of P appears to be large, while that in the BB region is small irrespective of relatively large variance in C.

In the AS region, C vs. E slope is nearly -1, which implies E contributes mostly to negative C (Divergence) even in the interannual variability under the very stable condition with small P.

In most of the land-based regions, C vs. E gradients are negative, which implies negative feedback between C and E is dominated, e.g., cloudiness-insolation feedback. The range (variance) of C is considerably large in the TH region, while that in the AM and WA region is relatively small. In the CP region, C-E gradient is nearly flat or slightly positive, suggesting some positive feedback or nearly constant E is maintained irrespective of years. We speculate that dominaned water-fed rice paddy field in the CP region may be responsible for this nearly-constant E contribution to P. In the MO and LN region , nearly constant or small varianceof E is also noted, though the interannual range of C and P is also small. The dominant role of the boreal forest Taiga and the steppe on the regulation of constant evapotranspiration is suggested, though further study is needed.

5. SUMMARY AND REMARKS

The interannual variability of atmospheric water balance components (P, C and E) and their mutual relations were investigated for the Asian monsoon regions and other tropical and extra-tropical regions by using the 15-years ECMWF reanalysis data. It has been found that the correlations between P versus C (and E) are different among the convectively active ocean regions in the Asian monsoon area, particularly between the Bay of Bengal and the South China Sea/Western Pacific region. The former region is suggested to be dominated by some negative feedback between C and E, while in the latter region a positive feedback is likely to be dominated. It is interesting that these two ocean regions correspond to the two major "warm water pool" where SST-convection correlation has been noted by many previous studies. This result strongly suggests that the role of these two oceanic regions on the variability of large-scale convection and precipitation could be considerably different each other.

Over the land-based regions, a remarkable different nature of P-C correlation is found in the interannual variabilitybetween the Indian subcontinent and the continental Southeast Asia (represented by Thailand) . However, the ERA data for the latter region seems to have some systematic error due to too strong topographical effect on C. It is also noticed that the regions in monsoon Asia have large variance of C and E compared to the other tropical regions, though the variability of P itself is not so much different. Some of the uncertainties and problems noticed here will hopefully be improved at least partly by the 4DDA reanalysis of GAME/SCSMEX-IOP data in summer of 1998, which contain the enhanced radiosonde observations at more than 110 stations in Asian monsoon/South China Sea region.

6. REFERENCES

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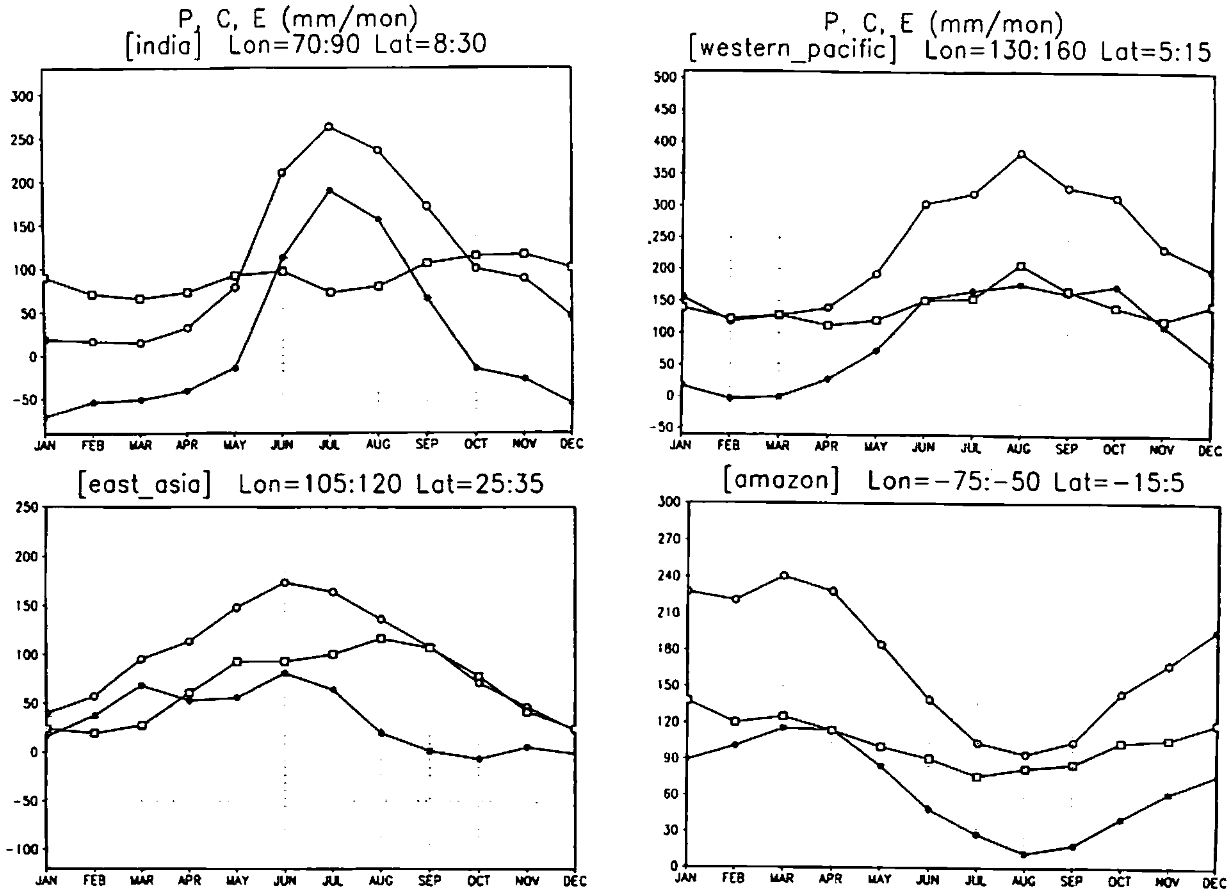

Figure 1: Seasonal cycle of Monthly Mean Precipitation(○), Convergence(●) and Evapotranspiration(□) in India (IS), East Asia (CP), Western Pacific (WP) and Amazon basin (AM).

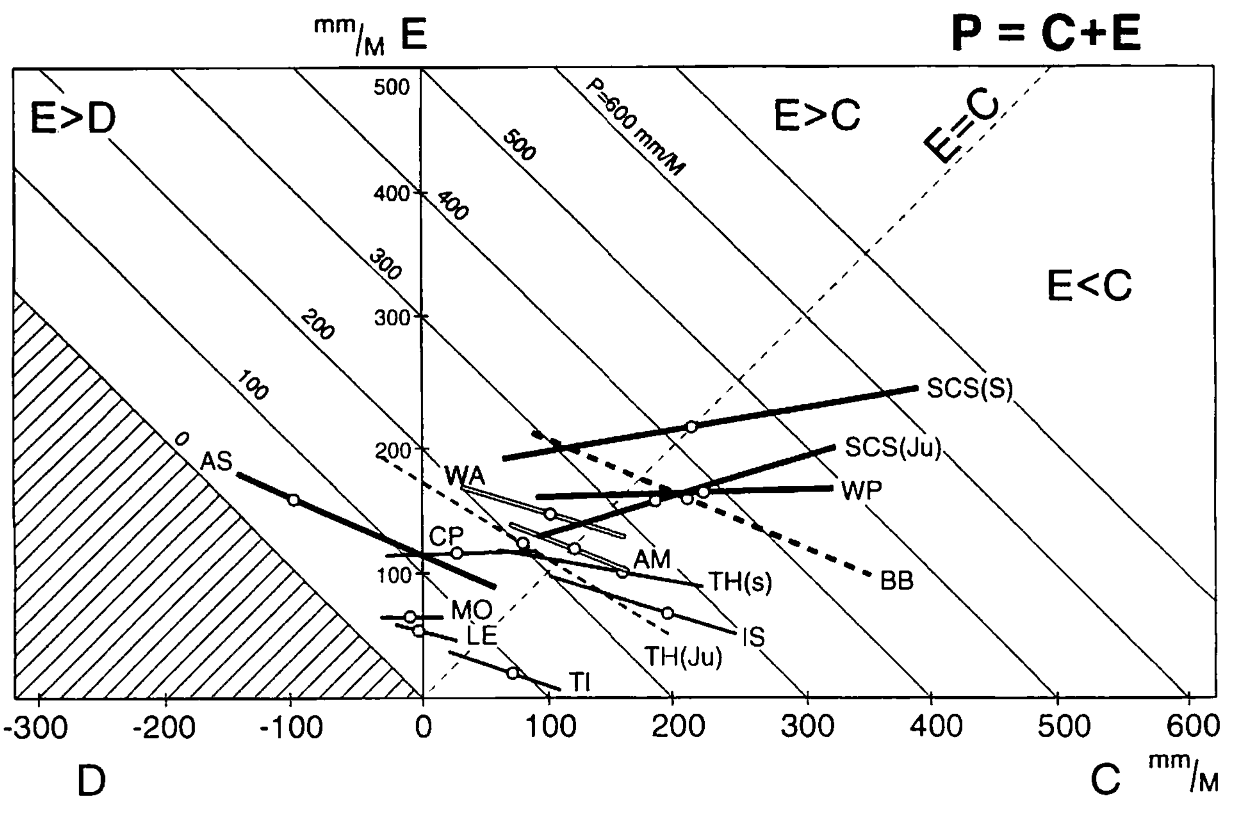

Figure 2: P-C-E diagram for interannual ranges of atmospheric water balance in Asia/Pacific, West Africa and Amazon river regions. 15-year mean values are shown with circles.