General Circulation Model Simulations of East Asia Climate: Regional Climate Characteristics

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Abstract

This paper documents a collaborative study among three institutes, National Taiwan University (NTU), National Taiwan Normal University (NTNU) and State University of New York at Albany (SUNYA) on the GCM simulated seasonal climate characteristics over East Asia. Simulations from four GCMs (NCAR-CCM3, NCAR-CSM, MPI-GCM and NTU-GCM) were used to study the systematic biases of climate parameters over five-regions (Fig. 1): the Bay of Bengal (BoB; 80-100°E; 8-20°N), Indo-China Peninsula (ICP; 100-110°E; 10-21°N), South China Sea (SCS; 110-120°E; 8-21°N), Tropical Western Pacific (TWP; 122-135°E; 5-25°N), and the Tibetan-Plateau (TP; 80-100°E; 28-40°N). These regions are closely related to the monsoon over eastern China. The analyses concentrates on two aspects: the seasonal characteristics of the AMIP model simulations, and the difference in these characteristics between CCM3 and CSM. The latter can be used to identify the effects of air-sea interactions over the oceanic regions.

Climate Data

In the present study, we used four GCMs: NCAR-CCM3 (Hurrell et al., 1998), NCAR-CSM (Boville et al., 1998), MPI-ECHAM4 (Roeckner et al., 1996), and NTU-GCM (Kau, 1998). All four GCMs use T42 resolution. While simulations of CCM3, ECHAM4 and NTU-GCM use prescribed SST for the period 1979-1996 (the AMIP simulations; Gates et al., 1998), CSM is a coupled atmosphere-ocean GCM. In addition, we also used NCEP reanalysis data for comparison. Note however that we consider this data as model simulations, although the wind fields may be more realistic than other fields and can be treated as observations.

Seasonal Characteristics

For the seasonal characteristics, we examine the climate parameters of precipitation, outgoing longwave radiation at the top of the atmosphere, total cloudiness, the 850- and 200-hPa zonal winds, and the surface temperature and energy balance components (sensible, latent and radiative fluxes). In general, the model-to-model and model-to-observation show consistency. But differences exist. For example, Figure 3 shows the comparison of GCM simulated precipitation with the observation (Xie and Arkin, 1997) at the five-regions.

As expected, the observed seasonal precipitation has maximum in summer and minimum in winter (except for TWP where the minimum is in Spring). The summer precipitation peaks in June at the BoB, but is shifted to August at ICP, SCS and TWP. In general, larger peak values, ~11-12 mm/day exist over the oceanic areas while smaller peak value, ~9 mm/day is observed over land area. For ICP and SCS, there exists a second maximum at June, which is in contrast with BoB and TWP where only one maximum occurs. On the other hand, TP is very dry with July maximum of around 2.5 mm/day.

All models show qualitatively similar observed seasonal cycle, although quantitatively the differences among the models are substantial. Several features are noted here. CSM, the coupled atmosphere-ocean GCM, simulate well the seasonal variations at BoB and SCS, but over-estimate the values at TWP and TP. Relatively speaking, MPI-GCM gives the most consistent simulations of the seasonal precipitation among the four models. However, there still exist substantial differences, notably the substantially smaller values during Spring and early Summer at BoB and SCS, and much large values during Summer over ICP. For the Summer precipitation, the NTU model simulates well over SCS, but yields substantially larger values at BoB and smaller values over IDC and TWP. Large differences are also found for other seasons.

But the most interesting characteristics are the large differences between CSM and CCM3, in particular at SCS and TWP where the seasonal variation is weak in CCM3 but strong in CSM. This contrast does not exist at another oceanic region, BoB. As will be shown below, the feature can be attributed to the much smaller latent heat flux associated with the weaker surface wind simulated by CCM3 at SCS and TWP. However, it is not clear why CSM which considers the atmosphere-ocean interactions can simulate much stronger surface wind.

Air-Sea Interactions

Here, we discuss the differences in the climate characteristics between CCM3 and CSM. The comparison is unique in that the atmospheric component of CSM is CCM3. Therefore, the differences in these model characteristics can be attributed to the effect of the air-sea interaction. In the low latitudes, BoB, SCS, and TWP are oceanic regions. However, the contrast in characteristics between CSM and CCM3 show similar features at SCS and TWP, but different at BoB. Therefore, we concentrate on the comparison between CSM and CCM3 at BoB and SCS.

Figure 3 shows the comparison of precipitation, latent heat flux, total cloud, and surface wind between NCEP, CSM and CCM3 at BoB. In general, CSM simulates similar seasonal variations of these parameters as those of NCEP. The notable difference is found in the May-June latent heat flux and the summer surface wind. On the other hand, CCM3 simulates different seasonal characteristics when compared with CSM, in particular the latent heat flux and surface wind. The latter two also show internal consistency, for example, the smaller surface wind is consistent with the smaller latent heat flux. In other words, the prescribed SST appears to limit the variation of the atmospheric responses, in particular the surface wind.

Similar comparisons are shown in Fig. 4 for SCS. In general, CSM also simulate the seasonal variations as demonstrated in the NCEP simulations, although the agreement is not as good as for BoB, in particular during the summer. Although the effect of air-sea interaction appears in the simulations at BoB, but it is much more obvious at SCS. For example, the latent heat flux begins to increase at May and peaks at July, with similar features reflected in the surface wind. However, it is quite clear that CCM3 fails to simulate the summer characteristics and the feature is also shown in the surface wind which remains relatively unchanged throughout the summer.

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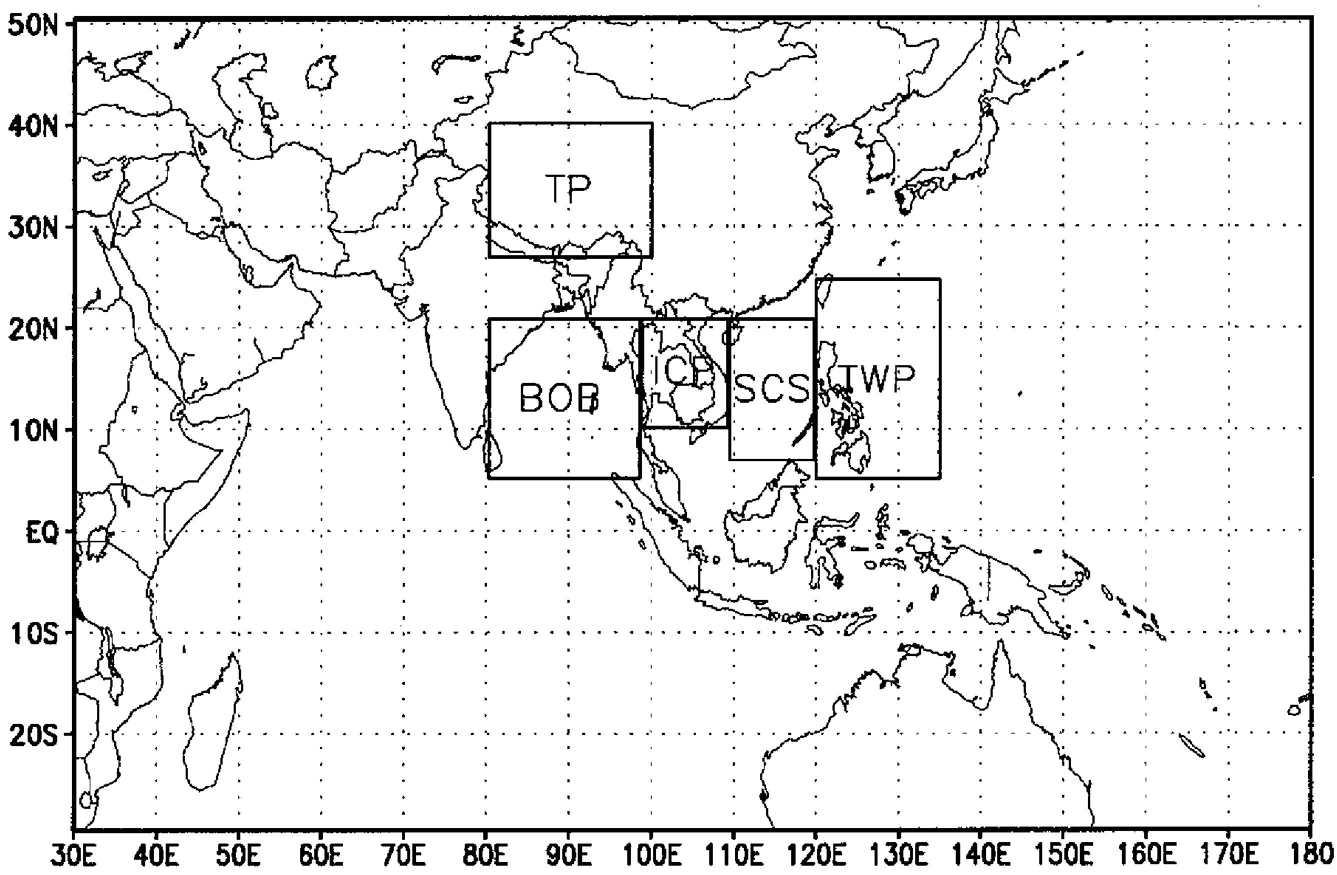

Fig. 1: The five-regions (Tibetan Plateau, TP; Bay of Bengal, BoB; IndoChina Penninsula, ICP; South China-Sea, SCS; and Tropical Western Pacific, TWP) used in studying the seasonal climate characteristics.

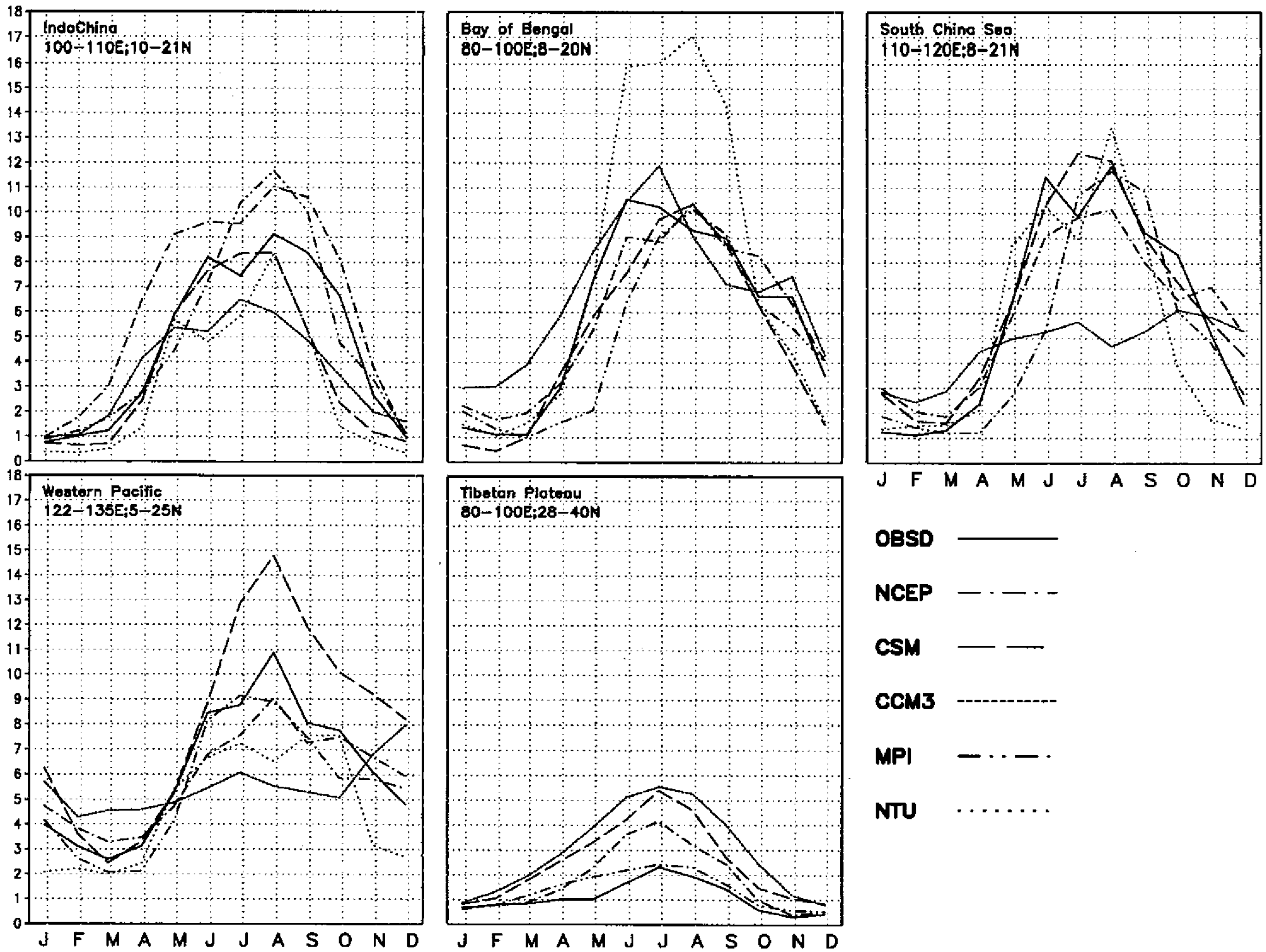

Fig. 2: Model-observations comparison of the 1979-1993 monthly mean precipitation (mm/day) at the five-regions shown in Fig. 1. Observations are taken from Xie and Arkin (1997).

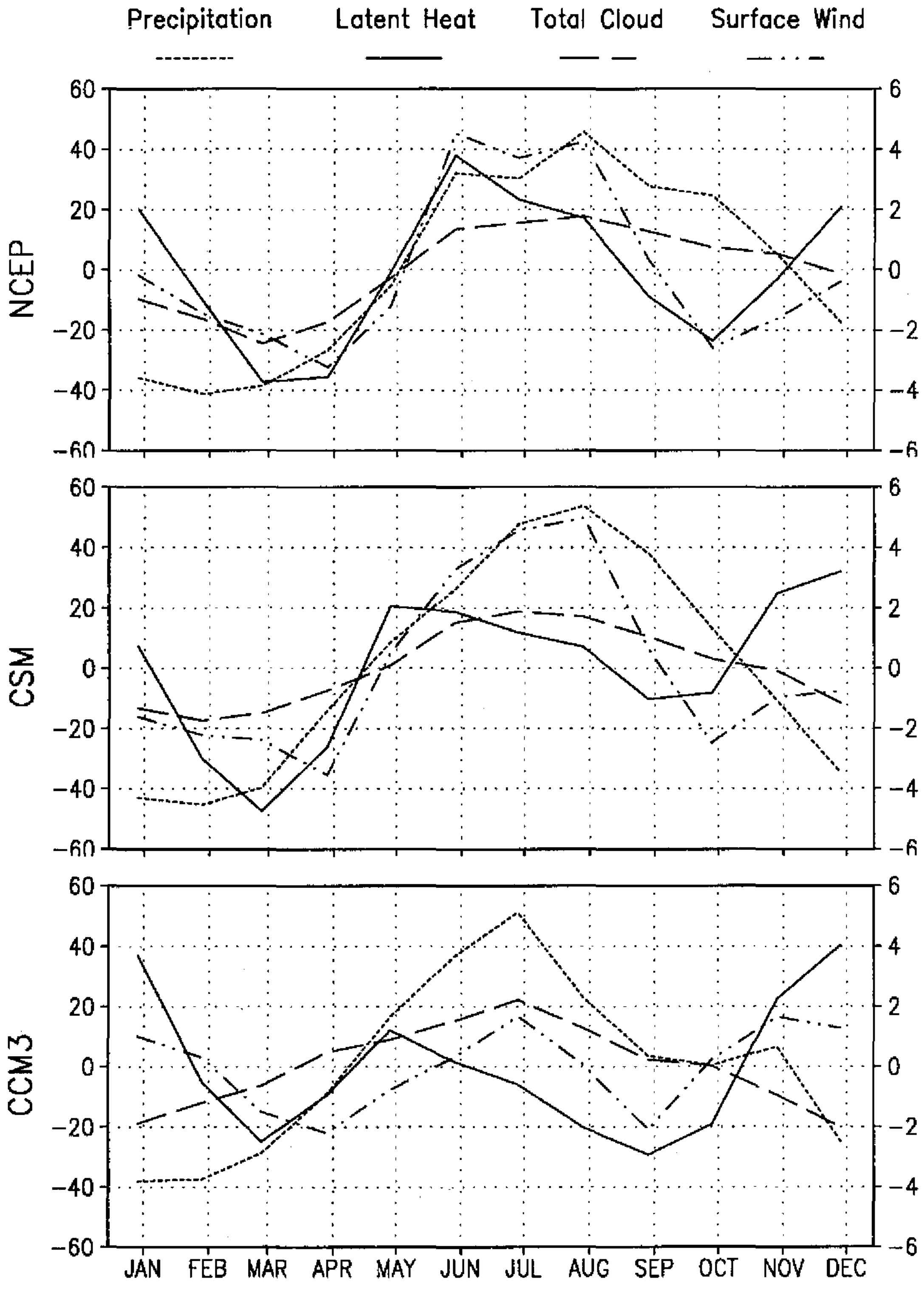

Fig. 3: The monthly mean anomaly of precipitation (mm/day, right scale), latent heat flux (Wm^{-2}, left scale), total cloud (%, left scale), and surface wind (ms^{-1}, right scale) at the Bay of Bengal from NCEP, CSM and CCM3.

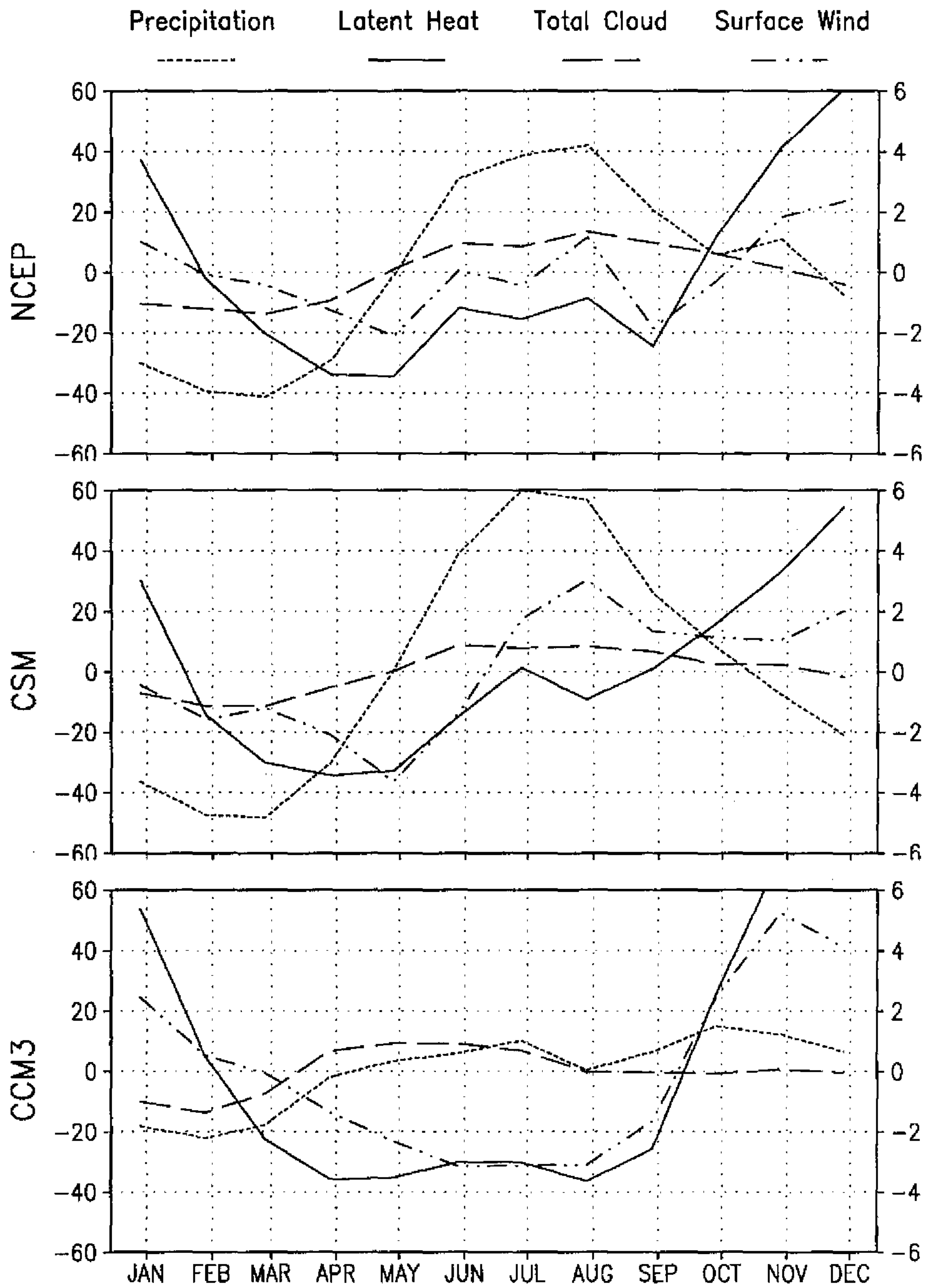

Fig 4: Same as in Fig. 3 except for the South China Sea.