Global Climate Model Projection of the Mediterranean Climate in the 21st Century

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1. Model and experiment

We conducted the simulations under the SRES A2 and B2 scenarios up to 2100 with the MRI coupled ocean-atmosphere GCM (MRI-CGCM2, Yukimoto et al. 2001). The atmospheric part of the model has a horizontal resolution of T42 (about 280km) and 30 vertical levels. The oceanic part adopted variable resolution 0.5°-2.0° for latitudinal direction with finer grid in the tropics and fixed 2.5° for longitudinal direction. Three ensemble runs were performed for each scenario from different initial conditions. Daily precipitation output was analyzed.

In this report, we compare 3 ensemble averages of the mid-21st century 20 yr (2041-2060) simulations (denoted as F) under the SRES-A2 scenario with 3 ensemble averages of the present (1981-2000) simulations (P).

2. Results

Figure 1 shows the annual mean changes (F–P) in total precipitation at mid-21st century. In the tropics, an eastward displacement of major precipitation center was noted associated with El Nino-like background mean SST changes. The Asian summer monsoon rainfall increased while the African monsoon rainfall decreased. In higher latitudes, total precipitation increased, while there is a decrease in precipitation over the subtropical oceans and the Mediterranean.

Figure 2 shows the changes in annual rainy-day frequency. Here we defined the day as rainy when precipitation exceeds 1.0 mm./d. An overall pattern is similar to that in total precipitation, but relatively large changes in frequency can be found in the middle and high latitudes.

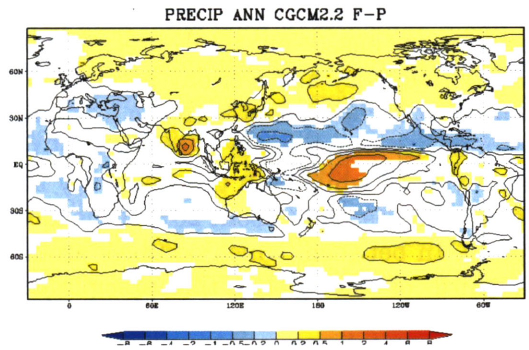

Fig. 1: Annual mean total precipitation difference (F–P).

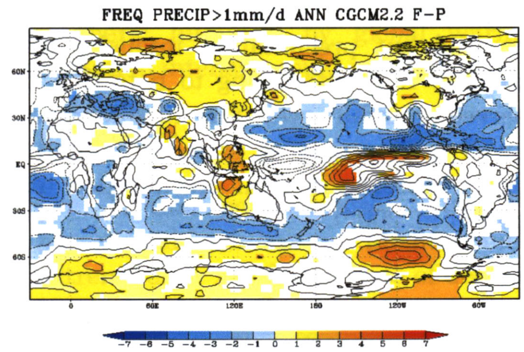

Fig. 2: As in Fig. 1 except for rainy-day frequency.

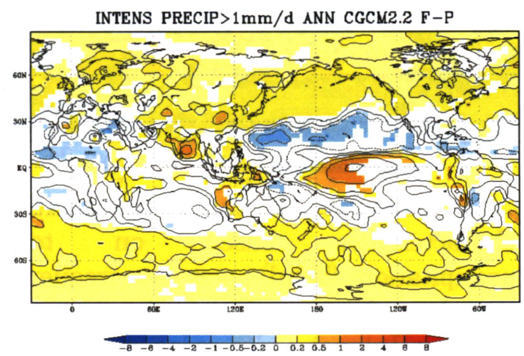

Fig. 3: As in Fig. 1 except for precipitation intensity in rainy day.

Figure 3 shows the intensity of precipitation in rainy days. An overall pattern is similar to Figs. 1 and 2 in the tropics and high latitudes.

However, in the mid-latitudes, there are regions with different signs between intensity and frequency. For example, over the Mediterranean region, frequency change is negative while intensity change is positive.

In order to investigate the relationship among the three characteristics we classified each grid point into 8 categories. Figure 4 shows the changes in three characteristics in precipitation based on total precipitation, wet-day frequency and wet-day precipitation intensity. It is shown that both the frequency and intensity increased in about 40% of the globe (type 1), while both the frequency and intensity decreased in about 20% of the globe (type 8). In between, which occupies around one third of the globe, the precipitation frequency decreased but its intensity increased (type 3 or 7), suggesting a shift toward more intense events by global warming. The Mediterranean and the Middle East is such a region where both total precipitation and number of rainy days decreased but precipitation intensity itself increased. It is interesting to note that the observed rainfall over the Mediterranean showed an increase of extreme rainfall in spite of decrease in total precipitation (e.g., Alpert et al. 2002).

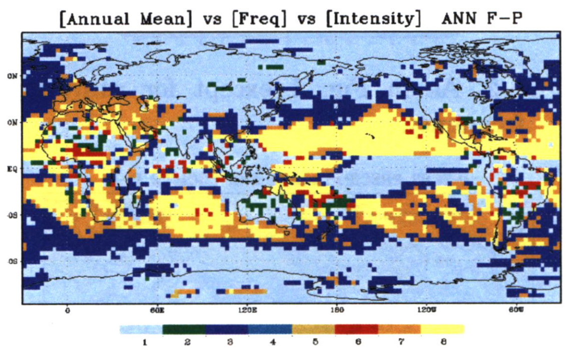

Fig. 4: Changes in three precipitation characteristics based on total precipitation (Total), wet-day frequency (Freq) and precipitation intensity of wet-day (Intens). Color codes of 1–8 are + + +, + + –, + – +, + – –, – + +, – + –, – – + and – – – for Total, Freq and Intens, respectively.

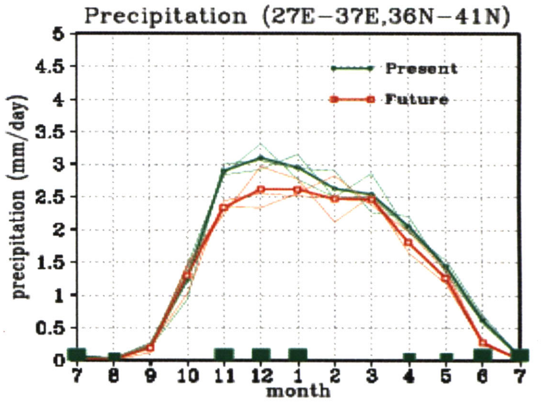

Fig. 5: Monthly mean precipitation averaged for the region 27°–37°E, 36°–41°N. Green (red) line denotes P (F). Thin lines are for each ensemble member and thick lines are for the ensemble mean. Large (small) boxes are plotted when the difference is significant at 90 (70)% level. Green (red) boxes denote that P (F) is larger.

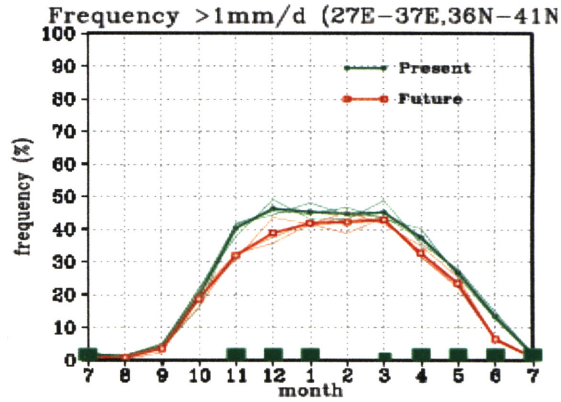

Fig. 6: As in Fig. 5 except for rainy-day frequency.

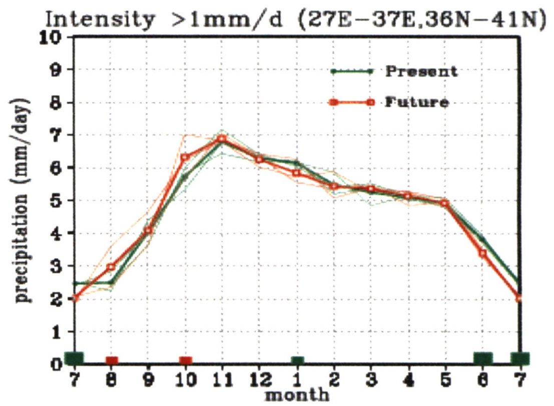

Fig. 7: As in Fig. 5 except for precipitation intensity in rainy day.

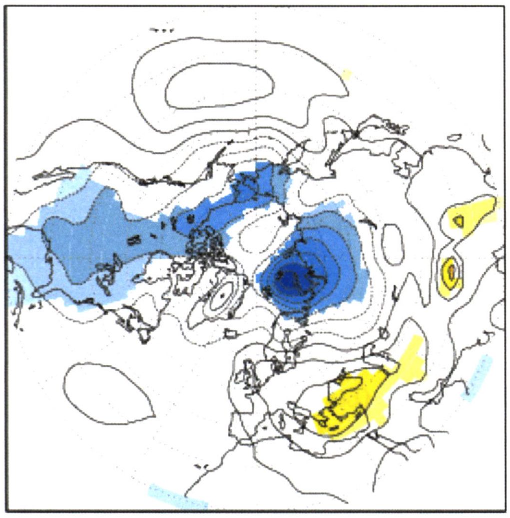

Fig. 8: Changes in Dec–Feb mean sea level pressure (F–P).

Figs. 5–7 show the monthly mean values of total precipitation, wet-day frequency and intensity averaged for the region 27°–37°E, 36°–41°N. It is shown that the total precipitation decreased significantly in F during early winter season (Nov–Jan). Frequency of rainy day events decreased throughout the year, with significant decrease during Nov–Jan and Apr–Jul season. On the other hand, changes in intensity are smaller and there is even a month (Oct) when intensity has increased. Therefore, a decrease in total precipitation mainly comes from a decrease in rainy day.

Figure 8 shows the wintertime (Dec–Feb) sea level pressure (SLP) difference between F and P. There is a significant decrease in SLP in the Arctic region and an increase over the Eurasia with its center around the Mediterranean. The model has produced less cyclonic activity in F compared to P, which is associated with the positive SLP anomaly. This SLP anomaly field is reminiscent of the North Atlantic Oscillation (NAO) pattern or the Arctic Oscillation (AO). This hemispheric change of SLP pattern corresponds to a positive phase of NAO and many climate models have shown to produce a shift towards a stronger NAO index by global warming (Osborn 2002).

3. Summary

The daily precipitation data produced by the MRI-CGCM ensemble runs under the SRES–A scenario are analyzed. In the tropics, eastward displacement of precipitation was noted associated with El Nino-like mean SST changes. A decrease in precipitation around the Mediterranean region is significant. Changes in precipitation characteristics are also analyzed. It is found that both total precipitation and number of rainy days decreased but precipitation intensity itself increased in the Mediterranean region. Over Turkey, a decrease in rainy events resulted in a decrease in total precipitation. A positive phase of North Atlantic Oscillation-like pattern dominates in the mean response of sea level pressure anomaly, which suppresses cyclone activity. However, due to increase in atmospheric humidity by global warming, precipitation intensity could increase more.

4. References

Alpert, P. and collaborators, 2002: The paradoxical increase of Mediterranean extreme daily rainfall in spite of decrease in total values. *Geophys. Res. Lett.*, 29 (11), doi:10.1029/2001GL013554.

Osborn, T.J., 2002: The winter North Atlantic Oscillation: roles of internal variability and greenhouse gas forcing. *CLIVAR Exchanges*, 25, 54-58.

Yukimoto, S and collaborators, 2001: The new Meteorological Research Institute coupled GCM (MRI-CGCM2). *Pap. Meteor. Geophys.* 51, 47-88.