Future Climate Projections around Turkey by Global Climate Models

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1. Introduction

In this report, we compare the future precipitation change obtained by 19 coupled atmosphere-ocean general circulation models (AOGCMs) under the SRES A1B scenario, whose horizontal resolution is about 200 km, and that obtained by a time-slice experiment with an atmospheric general circulation model (AGCM) with a horizontal resolution of about 20 km (TL959 linear Gaussian grid) (Mizuta et al. 2006).

2. Present-day precipitation validation

We first validate model precipitation with two observations. Figure 1a illustrates observed annual precipitation from East Mediterranean 0.05 degree climatology (Yatagai 2006), while Fig. 1b is from the Climate Research Unit (CRU; New et al. 1999). Two observations show areas of large precipitation such as coastal regions and mountainous areas.

Figure 1c shows the ensemble averaged annual precipitation of 19 AOGCMs corresponding to the 1981-2000 period. Here, data are interpolated to common 2.5 degree grids as the models' horizontal resolution varies between 500 km and 100 km. See Nohara et al. (2006) for details of the models used. Due to coarse resolution, the model ensemble reproduces large-scale characteristics of annual precipitation distributions with a north-south contrast within this region and large precipitation at the northeastern part of Turkey, but orographic rainfall pattern and coastal maximum are not visible.

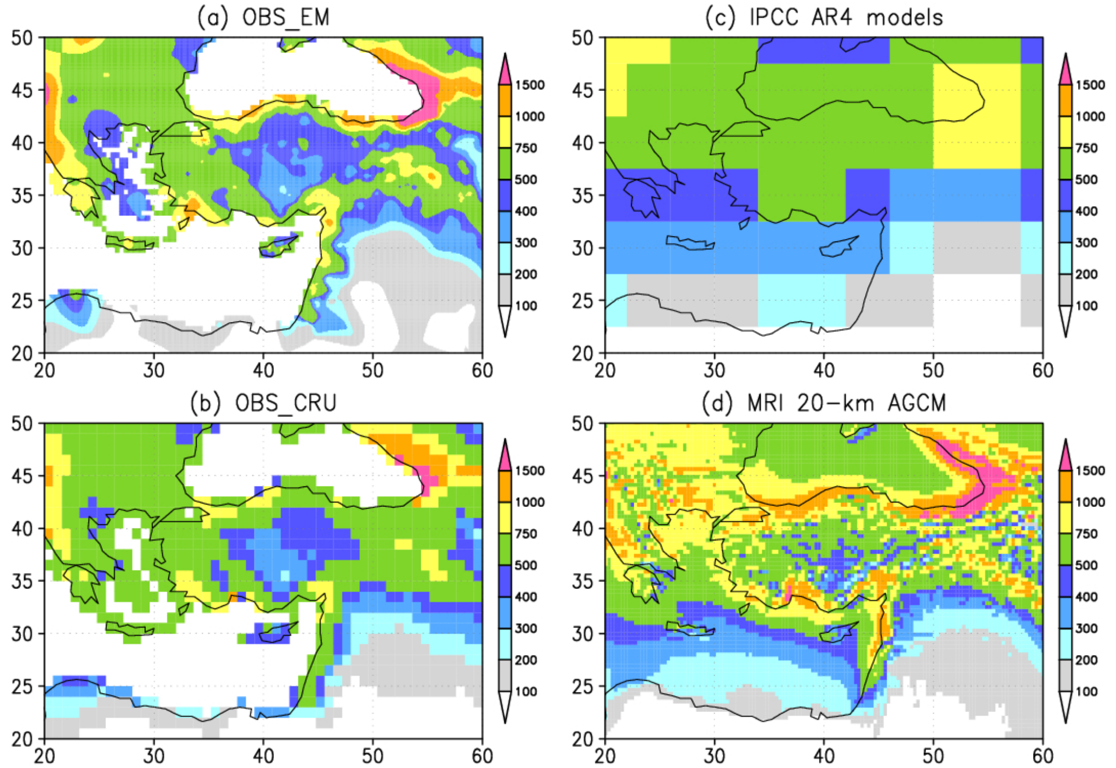

Fig. 1. Annual precipitation. (a) East Mediterranean 0.05 deg climatology (Yatagai 2006). (b) CRU (New et al. 1999). (c) IPCC AR4 model ensemble means. (d) MRI 20-km AGCM.

Figure 1d is the annual precipitation obtained with the 20-km mesh AGCM, which clearly depicts orographic rainfall along the Mediterranean and the Black Sea coast, as well as over the Zagros Mountains. Precipitation maximum over the Adana region is also well reproduced. There also is a hint of "Fertile Crescent"-like precipitation belt, which runs from the Jordan Valley northwards through inland Syria, into southeastern Turkey (Anatolia), eastwards through northern Iraq, and finally southeastward along the Zagros foothills of western Iran. It is apparent that the high-resolution model depicts orographic rainfall very well, and is suitable for regional climate projections.

3. Future projections by AOGCMs

Before discussing future climate projections by the 20-km mesh model, projected precipitation changes by AOGCMs are shown in comparison.

Using daily precipitation data of the MRI AOGCM simulations (Yukimoto et al. 2006), we calculated various statistics of precipitation and their changes (Kitoh et al. 2005). It is found that the Mediterranean region is classified as the region where total precipitation decreases and the precipitation frequency decreases but its intensity increases in the future. Figure 2 shows the monthly mean precipitation averaged for the region 27°–37°E, 36°–41°N. It is shown that the precipitation decreased significantly in the future during early winter season (Nov–Jan). Analysis of frequency of rainy day and intensity (not shown) reveals that the frequency of rainy day events decreased throughout the year, with significant decrease during Nov–Jan and Apr–Jul season, while 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 3 shows the changes in seasonally averaged precipitation between the end of the twenty-first century and the end of the twentieth century of IPCC AR4 model ensemble means. Here model uncertainty is estimated by comparing the ensemble mean change and the model scatter (inter-model standard deviation of the changes). In Fig. 3, lightly and heavily hatched region denotes the grid point where the ensemble mean precipitation change is larger than 0.5 times or 1 times of inter-model standard deviation of the changes, i.e., consistency among model projections. As a large-scale feature, future precipitation in this region will decrease throughout the year. It is noted that future precipitation will significantly decrease over the Mediterranean and the surrounding region including Middle East in winter. A positive phase of North Atlantic Oscillation-like pattern dominates in the mean response of sea level pressure anomaly in the future, which favors to suppress cyclone activity and precipitation in this region. A decrease is also significant in this region among models in spring, although its magnitude is less than in winter. The summertime decrease in precipitation shifts northward toward the Black Sea area.

4. Future projections by 20-km mesh AGCM

Using the 20-km mesh AGCM, we have conducted two “time-slice” 20-year simulations. One is a present-day and the other is a global warming simulation that uses the sea surface temperature (SST) corresponding to the 1981-2000 and 2081-2100 period, respectively, by the MRI-AOGCM simulations.

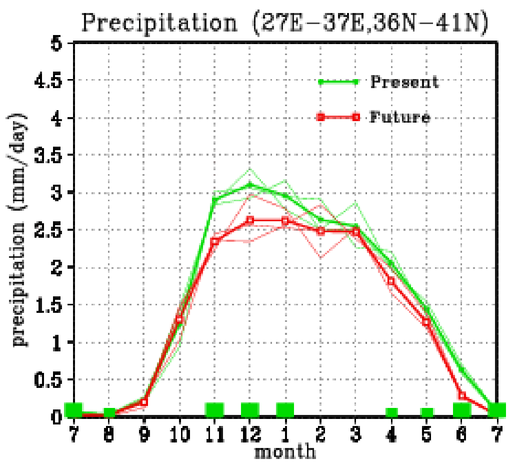

Fig. 2. Monthly mean precipitation averaged over the Turkey (27°–37°E, 36°–41°N) by the MRI-CGCM2 for the present (green line) and the future (red line). Thin lines are for each ensemble member and thick lines are for the ensemble mean. Large (small) boxes are plotted when the difference is significant at 90 (70)% level.

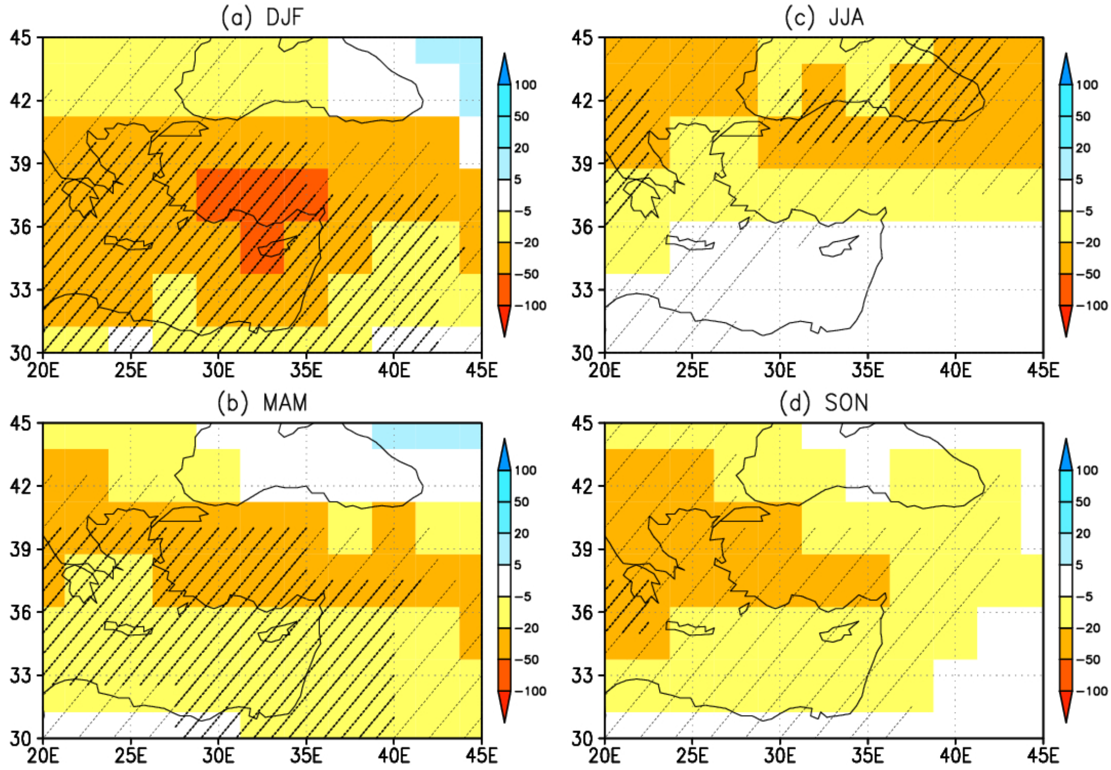

Fig. 3. Seasonal precipitation changes from the present to the future (2081-2100) by the IPCC AR4 model ensemble means. Light and heavy slant lines denote areas where the change is larger than 0.5 and 1.0 times of intermodel standard deviation, respectively.

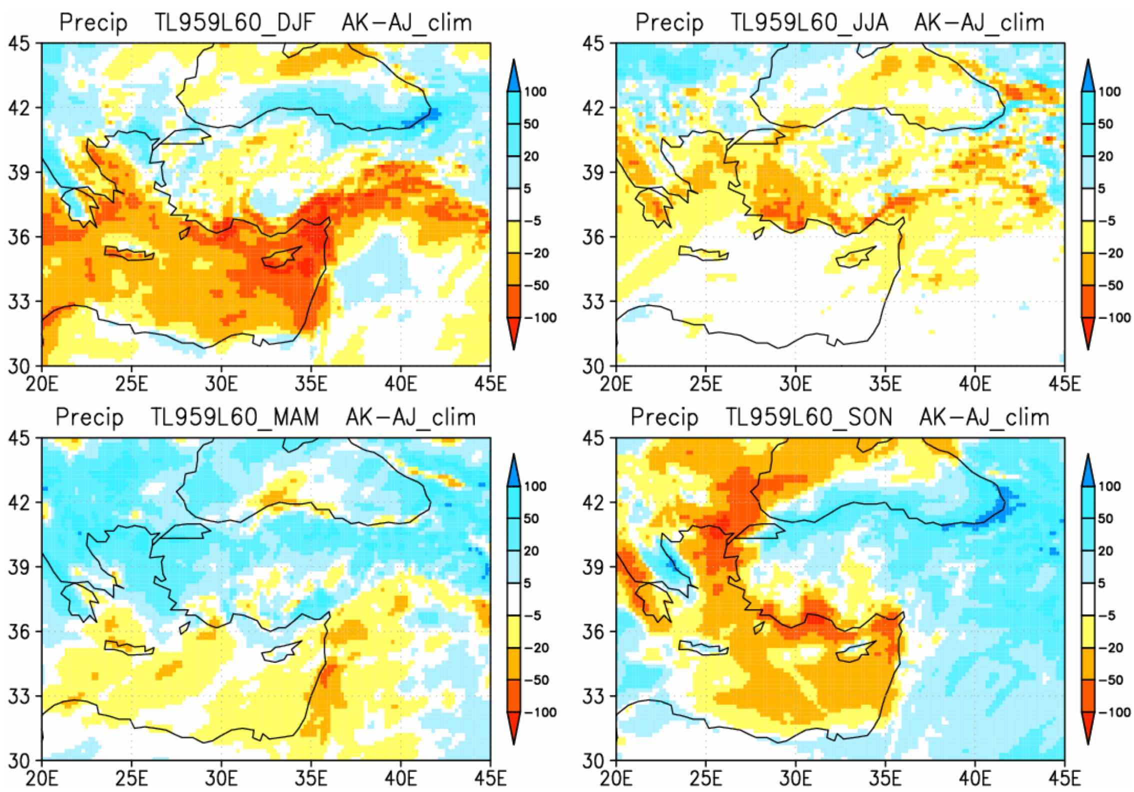

Fig. 4. Seasonal precipitation changes from the present to the future by the 20-km mesh AGCM.

Figure 4 shows the changes in seasonal mean precipitation at the end of the 21st century simulated by the 20-km mesh AGCM. Large decrease in precipitation is found in winter (DJF) around the southern coastal region of Turkey, particularly over the eastern Mediterranean Sea. It is noted that an area of large precipitation decrease is extended into the lower Seyhan River Basin, blocked by the Toros Mountains to the north. There is an increase in precipitation over the northern coastal region in Turkey facing the Black Sea. The pattern is different in spring (MAM), when magnitude in precipitation changes over the Mediterranean Sea becomes smaller, and even a sign of precipitation changes becomes opposite from that in winter in some areas, in particular over the ICCAP region of the lower Seyhan River Basin. The Central Turkey region is projected to have more precipitation in this season. There is a small belt of precipitation decrease over the upper Seyhan River region, where a decrease becomes more evident in summer. In summer (JJA) most of Turkey experiences decreased rainfall in this model projection. In fall (SON), decreased precipitation over the Mediterranean region becomes dominant again with a northern wet and southern dry contrast.

Evaporation generally increases in all seasons, but this field is distinct in a clear contrast between land and the oceans (not shown). There are large evaporation increases over the Mediterranean and the Black Sea in summer, fall and winter seasons, while in spring evaporation increase over land is larger. Large evaporation decreases are only projected over southern part of Turkey in summer and over eastern Mediterranean countries in spring and summer. Decreased evaporation in these regions may be related to soil moisture changes, but further investigation is needed.

Even in areas of increased precipitation, evaporation excess overcompensates and surface runoff has decreased. This is particularly true over the central Anatolia in spring, where precipitation increased but runoff decreased. Over the lower Seyhan River Basin, decrease in runoff is projected in winter but changes its sign in spring. On the other hand, opposite runoff changes are seen over the upper Seyhan River area. In summer, there is little change in surface runoff, although precipitation decreases over the southern Anatolia region. Cancellation between precipitation changes and evaporation changes resulted in little changes in runoff in this season.

5. Concluding remarks

The 20-km mesh global AGCM simulations are performed for the present and future conditions, respectively. Due to increased resolution, synoptic scale atmospheric circulations are very well simulated together with orographic precipitation features. There is a discrepancy between low-resolution AOGCM results and high-resolution AGCM results on the sign in future precipitation change in some areas. Whether this discrepancy comes from different resolution, i.e. how orographic rainfall is resolved in the model, or stems from other reason should be investigated in the future.

These very high resolution model's results would be very useful for regional climate change assessment because the global model has no artificial boundaries that regional models must use. A limitation of time integration due to huge computational resource and non-existence of air-sea interaction are trade-offs.

Acknowledgment

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6. References

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