Development of a daily grid precipitation data in the East Mediterranean and its application for the ICCAP studies

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1. Introduction

Precipitation is a definitely important element to assess the impact of global warming on agricultural production in arid/semi-arid regions. However, it is not easy to obtain reliable simulation results of precipitation comparing to that of temperature by the following two reasons. 1) Precipitation has a localized structure in distribution, and 2) simulated precipitation by climate models depends on a cumulus parameterization scheme that is used in the model. In other words, climate modelers are tuning their precipitation pattern and amounts against the observations.

Therefore, quantified high resolution precipitation dataset based on direct observation is necessary for validation of the simulated value. Recently, it is one of the important topics to simulate the change of extreme events due to global warming. Satellite-estimates have a good special coverage and frequent time intervals, however they are not suitable for validating extreme events. Hence daily grid precipitation dataset based on rain-gauge observation is warranted.

There have been many papers to show gridding algorithms, and recently those for showing daily grid precipitation dataset are indicated (Rajeevan et al., 2005; Xie et al., 2004; 2007). A method that I adapted to the ICCAP project is shown in Yatagai (2006).

Here, additional explanation of our gridding algorithm that was used for the ICCAP studies is displayed in section 2. Validation of model precipitation results those were used for the ICCAP project is shown in section 3. Application studies of using the grid precipitation products, trend analysis and hydrological budget studies are given in section 4 and 5, respectively.

2. Grid Analysis

As written in Yatagai (2005), we created daily grid precipitation dataset over the East Mediterranean by taking a similar method with Xie et al. (2004, 2007) that developed an analysis over East Asia. The differences in method with Xie et al. (2004, 2007) are 1) we did not use PRISM (Daly et al., 1994) because it was not available in this region, and 2) we used Shepard (1968) for interpolation instead of optimum interpolation.

I collected more rain-gauge data over Israel as well as Iran, and the analysis was improved after Yatagai (2005). Here I briefly write about our method and used data to develop the latest version of our precipitation analysis over the Middle East.

2.1 Gauge data

It is undoubtedly very important to collect rain gauge data from as many stations as possible to create a gauge-based analysis data set. To create the monthly climate normal precipitation analysis and the daily climate normal precipitation analysis, we collected monthly and daily precipitation data in the domain 15°E–70°E, 15°N–55°N using the following data sources.

2.1.1 Monthly precipitation

We obtained monthly precipitation data from a total of 1222 stations.

1) Turkey
   Monthly precipitation data from 225 stations for 1975–2004 compiled by the Turkish State Meteorological Service were used to compute the monthly precipitation climatology.
2) Israel
   Monthly precipitation from 19 stations for the 1960s to the present from the Israel Meteorological Service were used to compute the monthly precipitation climatology.
3) Iran
   We obtained two kinds of monthly precipitation data

from the home page of the Islamic Republic of Iran Meteorological Organization. We used data from 154 World Meteorological Organization (WMO) stations and from 183 non-WMO stations. The data coverage period differed among stations, with the longest period from the 1960s to the present. In this version, we used data from stations with more than 5 years of data to compute the monthly climatology.

4) Global Historical Climatological Network

We used the Global Historical Climatological Network ver. 2b data set for countries other than the above three. We used data from stations with more than 5 years of observation records to compute the normal climate.

2.1.1 Daily precipitation

We used daily precipitation data from a total of 2194 stations.

1) Turkey

We used daily precipitation data from 338 stations with observation records covering at least 20 years, compiled by the Turkish State Meteorological Service.

2) Global Telecommunication System (GTS)

We used GTS data from stations with 5 years or more of records during 1978–2004 in the data domain (15°E–70°E; 15°N–55°N), excepting Turkey.

2.2 Analysis

As indicated in Yatagai (2005, 2006), we first defined the monthly climate normal by using the data from 1222 stations. Then, we analyzed the climate normal using the algorithm of Shepard (1968) to interpolate the values into 0.05° grid boxes.

Yatagai (2006) shows January precipitation climatology for a 0.5° grid, and mountain precipitation over the western Zagros Mountains is clearly seen as a result of the addition of the Iranian data compared with the first version (Yatagai, 2005). Also, a precipitation zone south of the Caspian Sea can be clearly observed.

As the next step, we defined daily climate normal for each station by averaging daily precipitation and then truncating the averaged time series after the first six harmonics. Then, we adjusted the daily precipitation climatology by the monthly precipitation climatology. An example of the adjusted daily precipitation climatology is shown in Fig. 1. Patterns of orographically induced precipitation over eastern Anatolia and the coastal areas of Turkey and Israel are shown. October is the most important month for rain-fed agriculture in Turkey and Israel because it is the beginning of the rainy season. A crescent-shaped precipitation zone is observed along the Jordan Valley northward through northwestern Syria into southeastern Turkey (Anatolia), then eastward through northern Iraq, and finally southeastward along the western slope of the Zagros Mountains in western Iran. The pattern is shifted a little northward into Anatolia and eastward into Iran compared with the ancient region known as the “Fertile Crescent” (Bellwood, 2004). In particular, the modern high-precipitation zone is at a higher elevation than the ancient Fertile Crescent was. Observations as well as models clearly show that orographically induced precipitation in Anatolia and the Zagros Mountains is a very important water resource in the Fertile Crescent region.

After defining the daily climatology, we calculated the ratio of the daily observed precipitation at each station to the corresponding daily grid climatology for the target day. Figure 2 shows an analysis of the precipitation on 5 January 2000. Since the analysis used a 0.05° grid, a detailed pattern is seen where rain gauge data are available. Figure 3 shows an enlarged view of the Chukurova basin in south central Turkey. Although the monthly climatology aided the interpolation, in this analysis we could not reproduce an orographic effect where no daily rain gauge data or climatological data were available. Only a few stations are situated in the upper reaches of the Ceyhan and Seyhan rivers, which flow into this basin. Efforts to develop a PRISM-type monthly climatology data set by using Geographic Information System (GIS) data and satellite products are under way and results are expected in the near future.

3. Model Validation

Using the above mentioned monthly and daily climatology dataset, simulated precipitation by both TEAC-RAMS RCM and the MRI 20km mesh GCM, those are used for the ICCAP studies were validated (Yatagai et al., 2006).

The TEAC-RAMS RCM and the MRI 20km mesh GCM successfully simulate precipitation patterns over Turkey presented in our grid precipitation data. The both two models project decrease of precipitation in 2070s (based on SRES A2 or A1B scenario) over the southern part of Turkey including Chukurova basin. According to the MRI 20km AGCM, which simulates precipitation amount and its seasonal change around Adana better, average annual precipitation change for Adana -123 mm/year, which corresponds to around 18% of the present total precipitation. It is inevitably important for projecting the future change of the water resources over a basin to estimate daily precipitation accurately. Representation of precipitation around mountaineous region is one of the challenging subjects for climate system modeling. It is warranted to further development of daily grid precipitation for the past several decades by taking into account of orographic enhancements.

4. Trend Analysis

A trend analysis is done over Turkey based on daily/monthly precipitation data from Turkish State Meteorological Service (Yatagai, 2005). After quality check, a linear trend of monthly precipitation from 1975 – 2004 was computed for each month over Turkey. Result is shown in Fig.1 of Yatagai, 2005. In Yatagai (2004a), trend from 1977 to 2000 using GTS gauges are reported for January, April, July and October over the East Mediterranean. Here we could use much more qualified and consistent data to analyze trend.

Clear decreasing trend in January is observed in Fig.1 of Yatagai (2005) and it is consistent with that is shown Yatagai (2004a). Interestingly, the strong decreasing trend is not observed in other winter months (December and February). In March and April, a decreasing trend is observed around central part of Turkey including Cukurova basin, while other area show increasing trend. The April trend pattern is very different from that shown in Yatagai (2004a). Both May and June show similar decreasing trend overall Turkey, although the value is small due to small amount of precipitation in this season. We will analyze statistical significance of the trend as the next step.

It is stimulus to see increasing trend around Cukurova basin for August and September. It may relate to irrigation system development. We need further investigation on this point.

October shows clear dipole pattern of trend. Increasing trend is observed in the northern part of Turkey, while decreasing trend is observed in the southern part. Further analysis related to regionality of climate change should be done because October rainfall is one of the most important meteorological elements for agricultural activity in Turkey.

Further analysis is necessary to reveal trend in precipitation character such as extreme events.

5. Hydrological Budget Analysis

Yatagai (2003) compared seasonal variation of hydrological budget of Turkey with the same latitude band of Central Asia and China by using a 15-year reanalysis dataset of European Centre for Medium-Range Weather Forecasts (ECMWF, Gibson et al., 1997). The reanalysis datasets made it possible to analyze inter-annual variations.

As described in Yatagai (2004b, 2005), the moisture flux vector (Q_λ, Q_φ) facilitates a computation of atmospheric moisture convergence $-\nabla_H \cdot \mathbf{Q}$. If the time rate of change of liquid and solid water and their horizontal transports are neglected (Peixoto and Oort 1983), then $-\nabla_H \cdot \mathbf{Q} \fallingdotseq$ (Precipitation) – (Evapotranspiration) for spatial and temporal averages over a large area at monthly to seasonal time scales. This equation yields an estimate of evapotranspiration if regional mean precipitation data is available.

We used the CPC Merged Analysis of Precipitation (Xie and Arkin, 1997) and ECMWF 15-year reanalysis (ERA15; Gibson et al., 1997) to assess interannual variability in the hydrologic budget over Turkey for 1979-1993, although more precise estimation is underway by using the new daily precipitation analysis shown in the previous section over Turkey and ERA40 (Simmons et al., 2000) for a longer period. The vapor convergence (C) was computed as described by Yatagai (2003).

Figure 3 of Yatagai (2005) showed preliminary estimates of interannual variability in the hydrologic budget in July over the central part of Turkey. Since July is dry season for Turkey, it is interesting that E is mostly explained by convergence because P is almost zero for summer. Arid regions in China show completely different character in the atmospheric hydrological balance (Yatagai, 2003).

The figure also shows ERA15 evapotranspiration (Ef) computed with a fixed land surface model in the ERA15 assimilation scheme. During the forecast, atmospheric conditions were used at each time step to compute Ef. The magnitude of Ef was almost equal to that of Ea for the first several years; however, Ef did not show a linear trend. Because it was derived from large-scale changes in the atmospheric moisture balance, Ea represents observational values that include changes in surface land/water use. In contrast, Ef includes no surface changes. The ERA15 assimilation scheme and models yielded a Pf that was very close to Pa even though the two values are independent. Even though the land surface model used to compute Ef in ERA15 does not always represent real land use (e.g., irrigation are not represented in the model), the surface parameters were constant over the 15 years. Therefore, the increase in Ea could represent increasing anthropogenic (mostly agricultural) water use that causes increasing evapotranspiration during the summer.

Similar graphs for other part of Turkey, and also those for January are shown Yatagai (2004b). Further analysis is currently in progress to assess the hydrologic budget for all months and over a longer period using ERA40 (Simmons and Gibson, 2000) high-resolution analysis. A grid precipitation with dense precipitation network of Turkey shown above and incorporating mountain effect will give a better estimation of the hydrological budget, especially for the evapotranspiration over the complicated terrain.

6. Concluding Remarks

In order to contribute to the project ICCAP, I did the following things.

1) Development of a daily grid precipitation dataset over the East Mediterranean,

2) Validation of simulated precipitation by the models used for the ICCAP by utilizing 1),

3) Assessment of the precipitation trend over Turkey as well as the East Mediterranean, and

4) Assessment of hydrological budgets and its inter-annual variation over Turkey.

ICCAP project clarified the needs of daily grid precipitation dataset in order to validate the simulated precipitation as well as to investigate the impact of climate changes on the local water resources. The author's proposal to make a grid precipitation dataset for evaluation of the impact of global warming to local water resources over the arid region was funded by the Ministry of Environment for the fiscal year 2005. After one-year feasibility study of the global environmental research fund, we (RIHN and Meteorological Research Institute, Japan Meteorological Agency) got a 3-year's project for development of a daily grid precipitation dataset over Asia from the Ministry of Environment.

Further development of the algorithm shown in this report are underway, especially we are expressing orographic rainfall over the mountaineous regions because it is a very important water resources for the arid/semi-arid regions.

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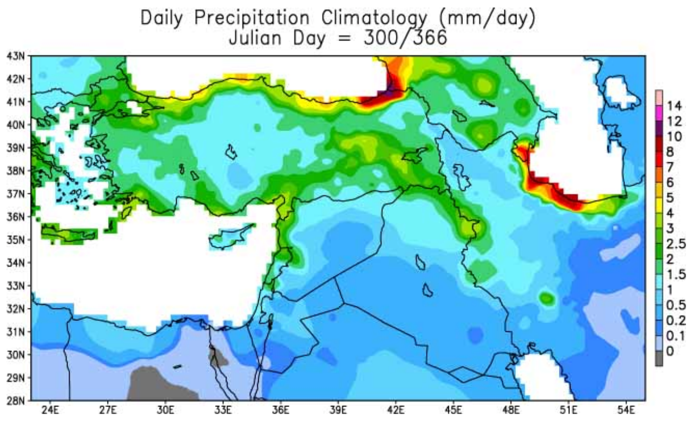

Fig. 1. A sample of daily precipitation climatology from late October (300 Julian day).

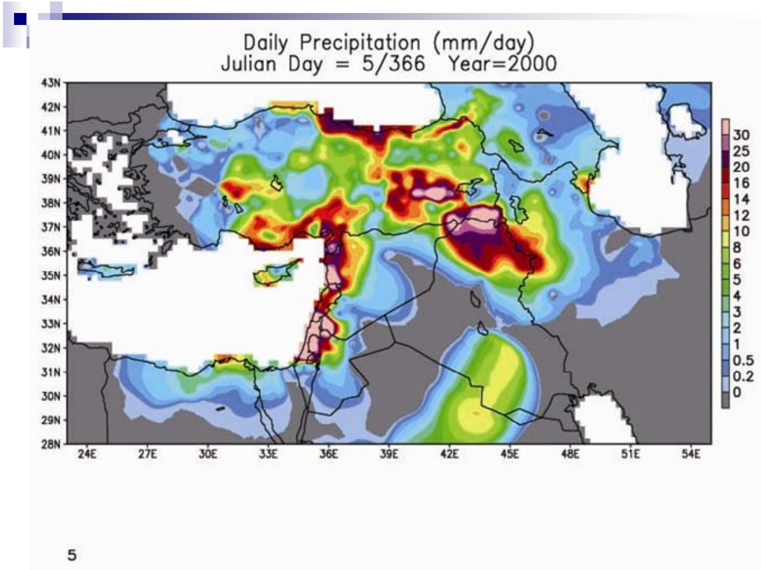

Fig.2. A sample daily gauge-based analysis for 5 January 2000.

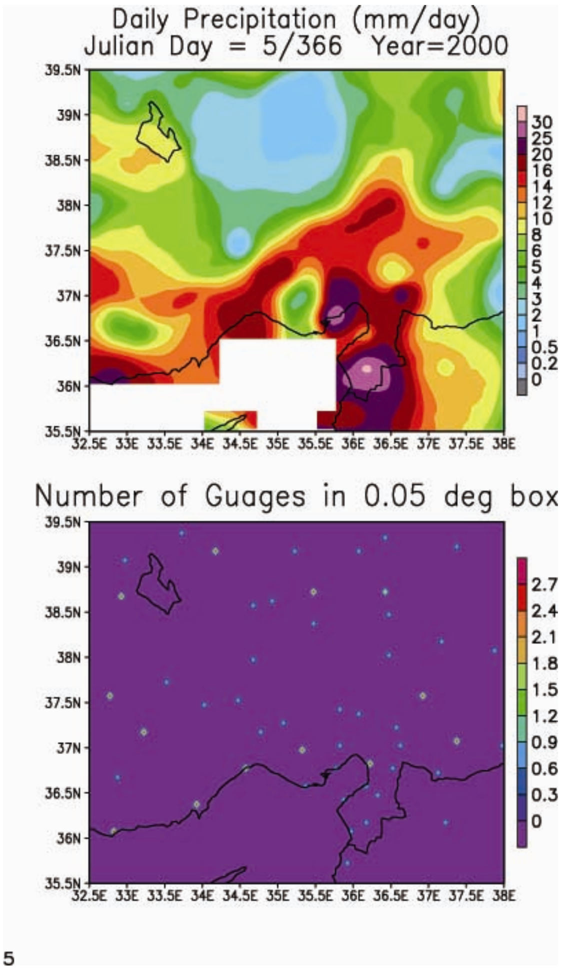

Fig. 3. A sample daily analysis for 5 January 2000 for the Chukurova basin, Turkey. The lower panel shows the number of gauges in each 0.05° grid box.