An Analysis of Observed Precipitation over the Fertile Crescent

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1. Introduction

The Fertile Crescent is a famous region in archaeology where ancient civilization, especially for the transition to agriculture was developed. This region 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 (Bellwood, 2004). Climatic conditions prevailed in those days allowed rain-fed agriculture to develop, but at present, most part of this region requires irrigation systems for sustainable agricultural production. Recent satellite images show that the rich Mesopotamian marshlands known for centuries as the Fertile Crescent have almost completely disappeared (National Geographic News, 2001). The damage is thought to be a result of extensive damming of the two rivers – the Tigris and Euphrates - and heavy draining of the river basin in recent decades.

Thus, the environment and water resource of this region is affected by both global climate changes and regional anthropogenic effect, namely over use of the river water. Recent climatological models project that the East Mediterranean/Mid-East will have less rainfall and less river discharge due to the global warming (IPCC, 2001; Milly et al., 2005; Nohara et al., 2006). Recent high-resolution atmospheric general circulation models, such as 20km resolution model by Japanese Meteorological Research Institute (MRI) can also simulate rainfall pattern over the Fertile Crescent (Yatagai, 2005; Kitoh, 2006). However, current observed precipitation pattern is not well reported due to lack of progress in data assembly.

Therefore, quantitative estimate of observed precipitation and its time-space variability are inevitably important in order to assess the impacts of global warming to local hydrological resources. Hence, an attempt was made to develop daily grid precipitation dataset over the East Mediterranean with explicitly representing orographic effect. Here, advanced methodology followed in constructing daily grid precipitation analysis over the East Mediterranean is reported.

2. Developing daily grid precipitation

2.1 Algorithm

Xie et al. (2004, 2006) developed an algorithm to create daily grid precipitation product based on rain gauge data over East Asia. In this algorithm, orographic effect is considered both implicitly and explicitly. By interpolating daily ratio field separately to the mean field, we can explain orographic effect implicitly (New et al., 1999; Chen et al., 2002). In addition, for the East Asia analysis, monthly mean climatology was adjusted to Parameter-elevation Regressions on Independent Slopes Model (PRISM, Daly et al., 1994).

We are developing similar dataset over the East Mediterranean region. Since PRISM is not currently available for East Mediterranean, we devise interpolation implicitly. The algorithm steps are as follows.

1) Define monthly precipitation climatology
2) Interpolate 1)
3) Define daily precipitation climatology
4) Interpolate 3)
5) Adjust daily precipitation climatology (4) by monthly precipitation climatology (2)
6) Compute analyzed field of ratio of daily observation to daily climatology (5) for the target day

7) Define analysis of daily precipitation by multiplying the daily climatology (5) with the daily ratio (6).

In step 5), we adjust daily precipitation climatology by monthly precipitation climatology, even if PRISM monthly climatology is not available. This is because we have more stations of monthly precipitation data compared to that of daily precipitation, and monthly precipitation data is more reliable because local meteorological agencies check for its quality. Sometimes we cannot make out between missing and 0 mm rainfall while handling the daily precipitation data. The data reported by Global Telecommunication Network (GTS) contains data with this problem, and this leads to underestimation of total rainfall in well-known GPCP or CMAP (Xie and Arkin, 1997) dataset.

2.2 Data

In order to create monthly climate normal precipitation analysis (step 1) and daily climate normal precipitation analysis (step 3), we used the following data source in the current version.

Monthly and daily precipitation data are collected for the domain 15E-70E; 15N-55N.

- Monthly Precipitation

  Totally 1222 station data were used.

1) Turkey

   225 stations monthly precipitation data for 1975-2004 compiled by Turkish State Meteorological Service were used to compute monthly precipitation climatology.

2) Israel

   19 stations monthly precipitation from 1960s to present from Israel Met Service were used to compute monthly precipitation climatology.

3) Iran

   We got two kinds of monthly precipitation data via the home page of Islamic Republic of Iran Meteorological Organization. We used 154 WMO stations, and 183 stations of not WMO stations. Data coverage period is different from station to station. Longer one begins at 1960s till present. In this study, stations with more than 5 years data were used to compute monthly climatology.

4) GHCN

   The Global Historical Climatological Network (GHCN) ver.2b dataset was used for other countries except Turkey, Israel and Iran. Stations that have more than 5 years of observation records were used to compute climate normal.

- Daily Precipitation

  Totally 2194 station daily precipitation data were used.

1) Turkey

   338 stations daily precipitation data compiled by Turkish State Meteorological Service those are available for more than 20 years were used.

2) GTS

   Stations in the data domain (15E-70E; 15N-55N) except for Turkey were used. Stations where daily precipitation data is available for more than 5 years within the time period of 1978-2004 were used.

2.3 Analysis

As detailed in section 2.1, we first define monthly climate normal by using the 1222 station data. Then, climate normal is analyzed (interpolated) by Shepard (1968) algorithm; we interpolated it into 0.05 degree grid box. The analysis domain is 15E-70E, 15-55N.

Figure 1 shows January precipitation climatology on 0.5 degree grid box in order to show the station availability more clearly. Compared to the previous version (Yatagai, 2005), mountaineous precipitation over the western side of the Zagros Mountains clearly appeared. Also, precipitation zone in the south of the Caspian Sea was clearly observed.

As a next step, we defined daily climate normal for each station by averaging daily precipitation and then take the first 6 harmonics to truncate the averaged time series. The reason of compositing the first 6 harmonics is, it could well demonstrate monsoon onset and it turned to be stable by some tests at Climate Prediction Center/NOAA when Xie et al. (2004, 2006) developed daily grid precipitation for East Asia. However, we need to test to understand the best composite of the harmonics for representing the seasonal variation of daily precipitation climatology over the East Mediterranean region in future.

Then, as the step 5), we adjusted daily precipitation climatology by monthly precipitation climatology. An example of the adjusted daily precipitation climatology is shown in Fig. 2. Patterns of orographically induced precipitation over the East Anatolia and the coastal areas of Turkey and Israel are represented. October is most important season for rain-fed agriculture in Turkey and Israel, because it is the beginning of the rainy season. The shape of "Crescent" in precipitation zone is observed along the Jordan Valley northwards through the northwest part of Syria, into southeastern Turkey (Anatolia), then eastwards through northern Iraq, and finally southeastward along the western side of Zagros Mountains of western Iran. The pattern is little bit shifted northward (Anatolia) and eastward (Iran) compared to the ancient "Fertile Crescent" (Bellwood, 2004). This indicates that the present-days precipitation zone is located in the higher elevation place compared to the "Fertile Crescent". Observations as well as models clearly show that orographically induced precipitation along Anatolia and Zagros is very much important water resource for the Fertile Crescent. Efforts of estimating quantitative precipitation and analysis of its year-to-year variability over this region should be beneficial to get reliable future projection of the water resources as well as understanding the past environment.

The results of the daily precipitation analysis and application studies are reported in other places. Efforts for expressing orographic precipitation in monthly climatology by using satellite as well as GIS information are on the way.

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3. References

Bellwood, P. S. 2004: The first farmers: origins of agricultural societies, Blackwell Publishing, 360pp.

Chen, M., P. Xie, J. E. Janowiak, 2002: Global land precipitation: a 50-yr monthly analysis based on gauge observations. *J. Hydrometeor.*, **3,** 249-266.

Daly, C., R.P. Neilson, D.L. Phillips, 1994: A statistical-topographic model for mapping climatological precipitation over mountainous terrain. *J. Appl. Meteor.*, **33**, 140 – 158.

Milly, P.C.D., K.A. Dunne, and A.V. Vecchia, 2005. Global pattern of trends in streamflow and water availability in a changing climate. Nature, 438, 347-350.

National Geographic News, 2001: Ancient Fertile Crescent Almost Gone. Satellite Images Show, news.nationalgeographic.com/news/2001/05/0518_crescent.html

New, M. G., M. Hulme, and P. D. Jones, 1999: Representing twentieth century space-time climate variability. Part I: Development of a 1961-90 mean monthly terrestrial climatology. *J. Climate*, **12**, 829-856.

Nohara, D., A. Kitoh, M. Hosaka, and T. Oki, 2006. Impact of climate change on river discharge projected by multi-model ensemble. J. Hydromet. (in press).

Shepard, D., 1968: A two-dimensionl interpolation function for irregularly spaced data. Proc. 23 ACM Nat'l Conf., Princeton, NJ, Brandon/Systems Press, 517-524.

Xie, P., P. A. Arkin, 1997: Global precipitation: A 17-year monthly analysis based on gauge observations, satellite estimates, and numerical model outputs. *Bull. Amer. Meteorol. Soc.*, **78**: 2539-2558.

Xie, P., A. Yatagai, M. Chen, T. Hayasaka, Y. Fukushima and C. Liu, 2004: Daily precipitation analysis over East Asia: Algorithm, validation and products. *Proceeding for the 2nd Internationl Workshop on Yellow River studies, Nov. 8-10, 2004, Kyoto, Japan*.

Xie, P., A. Yatagai, M. Chen, T. Hayasaka, Y. Fukushima, C. Liu and Y. Song, 2006: An analysis of daily precipitation over East Asia, submitted to J. Hydrometeor.

Yatagai, A. 2005: The preliminary analysis of Turkish Precipitation, ICCAP progress report, 13-18.

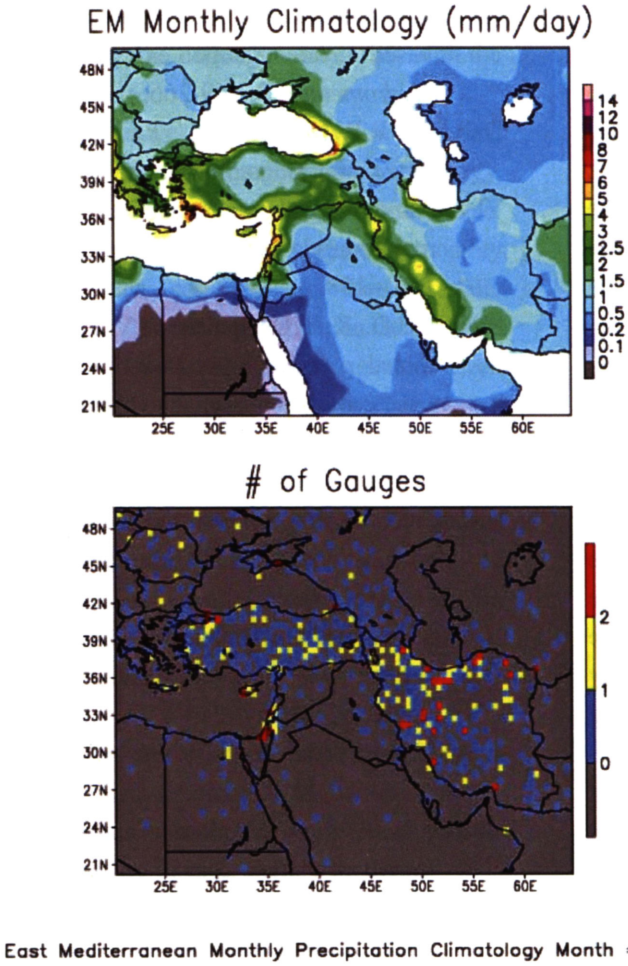

Fig.1 (a) Monthly Precipitation Climatology (mm/day) for January.(b) Number of rain gauges in each 0.5 degree grid box.

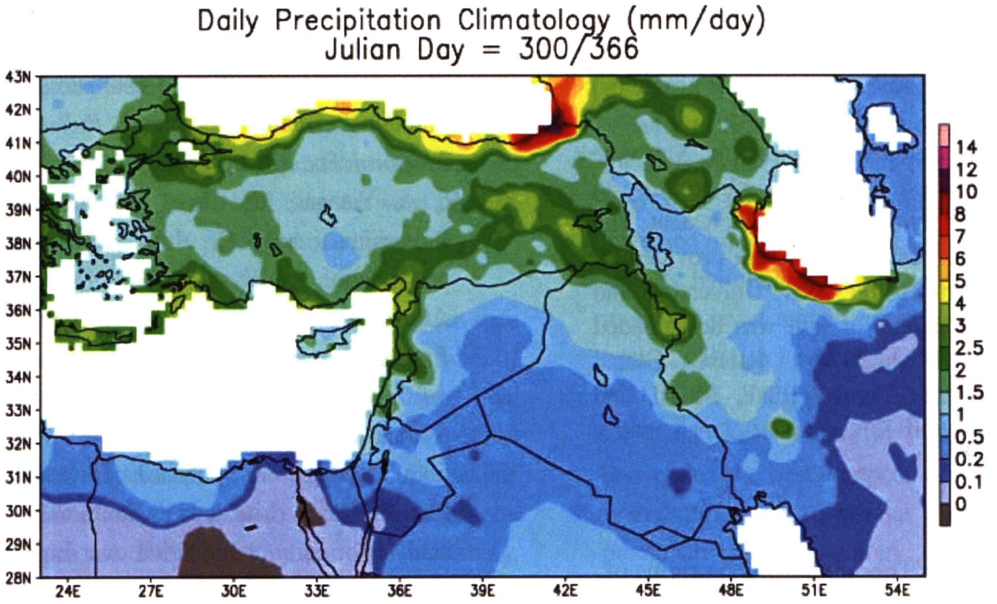

Fig.2 A sample of daily precipitation climatology in late-October (300 Julian day).