Preliminary Analysis of Turkish Precipitation

Akiyo YATAGAI
Research Institute for Humanity and Nature (RIHN),
335 Takashima-cho, Kamigyo-ku, Kyoto 602-0878, JAPAN
e-mail: akiyo@chikyu.ac.jp

1. Introduction

The goal of this study is to create daily grid precipitation dataset over the East Mediterranean with explicitly representing orographic effect. The possible resolution of the new daily precipitation dataset is 0.5 degree grid or finer. This dataset will be used 1) to validate high resolution climate model outputs, 2) to apply statistical downscale method by combining with atmospheric patterns derived from a coarse general circulation model to know the local (e.g. Cukurova basin) impact of global warming, and 3) to diagnose the change of hydrological budget over Turkey in order to assess the impact of both natural and anthropogenic effect to the budget.

During the last fiscal year, efforts have been made to check daily/monthly precipitation data that ICCAP obtained from Turkish State Meteorological Service. Then we prepared for making grid analysis precipitation. Here we show preliminary monthly trend analysis by using the gauge precipitation data from 1975 to 2004 (section 2), and brief algorithm/strategy description for creating daily analysis (section 3). In section 4, an example of hydrological budget analysis is shown using previously available datasets in order to show the plan of 3).

2. Trend Analysis

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. In Yatagai (2004a, interim report of ICCAP), 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, 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.

3. Making grid precipitation

Grid precipitation data is widely used to validate model results and climate diagnostic studies. However, in order to validate high resolution model results, high grid precipitation data set is necessary. Many algorithms to estimate precipitation from satellite images are proposed and several dataset with 1.0 degree dataset is available, however, over land, rain gauge data is more reliable than that of estimated from the space. In addition, long-term consistent product is necessary to diagnose both the past climate and model performance.

Xie et al. (2004,2005) developed an algorithm to create daily grid precipitation product based on rain gauge data over East Asia. In this algorithm, both explain orographic effect 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 PRISM (Daly et al., 1994).

Here we are planning to create similar dataset by using Turkish data with other rain gauge data from other countries than Turkey. Since PRISM is not currently available for East Mediterranean, so far we devise interpolation implicitly.

Although we obtained data for more than 500 stations over Turkey after 1979, we chose stations with high reporting rate. First we defined monthly climate normal by averaging from 1979 to 2002 for such stable ~250 station data. Then, climate normal is analyzed (interpolated) by Shepard (1968) algorithm. A sample pattern of January climate normal is shown in Fig. 2 (lower panel, details of this figure is explained later).

As a next step, we define daily climate normal for each station by averaging the 24 years daily precipitation and take the first 6 harmonics to truncate the averaged time series. Then we define daily precipitation ratio to the daily climate normal. Optimal Interpolation (OI) is applied separately both to daily climatology and daily ratio. After interpolating, we will get daily grid precipitation analysis by multiplying analyzed field of daily climatology and daily ratio.

Figure 2 shows a comparison of January precipitation climate (mm/mon) derived from a time slice experiment of TL959 (approximately horizontally 20km) atmosphere model results estimated from meteorological research institute (MRI), Japan with January precipitation climate normal as descried above.

MRI 20km model simulates overall pattern very well over Turkey. It represents orographic effect appropriately, for example, coastal region has more precipitation than inland areas of Turkey. From Cukurova basin to the southeast part of Turkey, there is a strong precipitation zone, which corresponds to the so-called Fertile Crescent where civilization developed in early times of human history.

It is also said that we were succeeded in representing precipitation analysis based on Turkish and GTS based precipitation gauge dataset. Although the current version of analysis does not include enough rain gauge data over some regions (Iran, Saudi Arabia and Egypt etc), this data set should be used to validate model results as well as used to apply statistical downscale method.

Looking at inside Turkey, MRI 20 km present control a little overestimates precipitation compare to our rain gauge analysis. Validation for other months as well as their seasonal variation are now under investigation.

4. Interannual variability of the hydrological budget

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 1992), 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 shows preliminary estimates of interannual variability in the hydrologic budget in July over the central part of Turkey. The graph is complicated because both forecast (dotted lines) and analysis (solid lines) values of precipitation (P), evapotranspiration (E), and moisture convergence (C) are shown.

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; Yatagai et al., 2004c).

The dotted green line in Fig. 3 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 conclusions arise from comparisons of the two types of convergence (C) in Fig. 3. The dotted red line represents Cf, which can be calculated as Pf-Ef. The solid red line, Ca, was computed from ERA15 analysis data. Cf showed no trends, whereas Ca showed a decrease in moisture convergence. Because the independent Pa did not decrease, the increase in Ea must have been caused by a decrease in Ca. Consistent data sets of both Ca and Pa are vital for assessing hydrological changes in target regions in terms of assessing both natural and anthropogenically-induced changes.

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 trial of making grid precipitation with dense precipitation network of Turkey and incorporating mountain effect (Xie et al., 2004) will give a better estimation of the hydrological budget, especially for the evapotranspiration over the complicated terrain.

4. Summary

A trend analysis is done over Turkey based on daily/monthly precipitation data from Turkish State Meteorological Service. An apparent decreasing trend is observed in January for all over Turkey from 1975 to 2004 (30 years). Interestingly, precipitation in August and September shows increasing trend over the Cukurova basin. Further analysis is necessary to reveal both national and anthropogenesis (agricultural water use) effects to this trend.

In order to estimate the change of evapotranspiration, atmospheric water balance method is one of the best ways to approach if both consistent atmospheric objective reanalysis and precise grid precipitation datasets are available. Using both ECMWF 15 year reanalysis (ERA15) for 1979-1993 and CPC Merged Analysis of Precipitation (CMAP), preliminary assessment of the hydrological budget for the 15 year was done based on 2.5 degree grid (~250 km) resolution. A clear increasing trend of actual evapotranspiration was observed during the 15 years. More detailed analysis is underway by using ERA40 (1957-2002) 1.125 degree grid dataset.

A daily grid analysis by using Turkish State Meteorological Service is created. This data set is used for the above mentioned budget analysis but also for climate/atmospheric model validations and developments.

5. References

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.

Gibson, J.K., P. Kallberg, S. Uppala, A. Nomura, A. Hernandez, E. Serrano, 1997.:ERA Discription. *ECMWF re-analysis project report series*, **1**, 72pp.

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.

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.

Simmons, A.J. and J.K. Gibson, 2000: The ERA-40 Project Plan. ERA-40 Project Report series, No.1, 62pp.

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, 2005: Daily Precipitation Analyses over East Asia:A Gauge-Based Data Set with Orographic Modification. (to be submitted to J. Hydrometeor.)

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.*

Yatagai, A., 2003: Evaluation of hydrological balance and its variability over the arid/semi-arid regions in the Eurasian continent seen from ECMWF 15-year reanalysis data, *Hydrological Processes*, **17**, 2871-2884.

Yatagai, 2004a: Precipitation data availability over the East Mediterranean and their preliminary analysis, Interim report of the ICCAP project.

Yatagai, 2004b: Recent variation int eh hydrological budget over Turkey, Proceedings of the international workshop on ICCAP, November, 2004, Cappadocia, Turkey.

Yatagai, A., P. Xie, M. Chen, 2004c: Recent variations in the atmospheric branch of the hydrological cycle over the Yellow River: Preliminary results for July. *Proceeding for the 2nd Internationl Workshop on Yellow River studies, Nov. 8-10, 2004, Kyoto, Japan .*

Acknowledgment

The author appreciates Dr. Pingping Xie, Climate Prediction Center (CPC)/National Ocean and Atmosphere Administration (NOAA) for kindly provide his program to compute grid precipitation analysis and many precious comments.

The MRI 20km resolution model result is based on a time-slice experiment performed by a Global Modeling Group (T.Matsuo, T.Aoki, A.Noda, S.Kusunoki, A.Kitoh, M.Hosaka, J.Yoshimura, S.Yukimoto, H.Yoshimura, T.Uchiyama, T.Yasuda, K.Shibata, M.Mikami, H.Ichizaki, H.Tsujino, Y.Takeuchi, T.Matsumura, H.Kitagawa, K.Katayama, M.Nakagawa, M.Kyouda, K.Yamada, M.Hirai, T.Hosomi, R.Sakai, S.Murai, M.Yamaguchi, T.Sakashita, A.Narui, T.Kadowaki, M.Kazumori, T.Ose, S.Maeda, C.Kobayashi, H.Kawai, K.Horiuchi, K.Ouchi, R.Mizuta, K.Miyamoto, H.Murakami, K.Fukuda) under the research project "Development of Super High Resolution Global and Regional Climate Models" funded by the Ministry of Education, Culture, Sports, Science and Technology (MEXT).

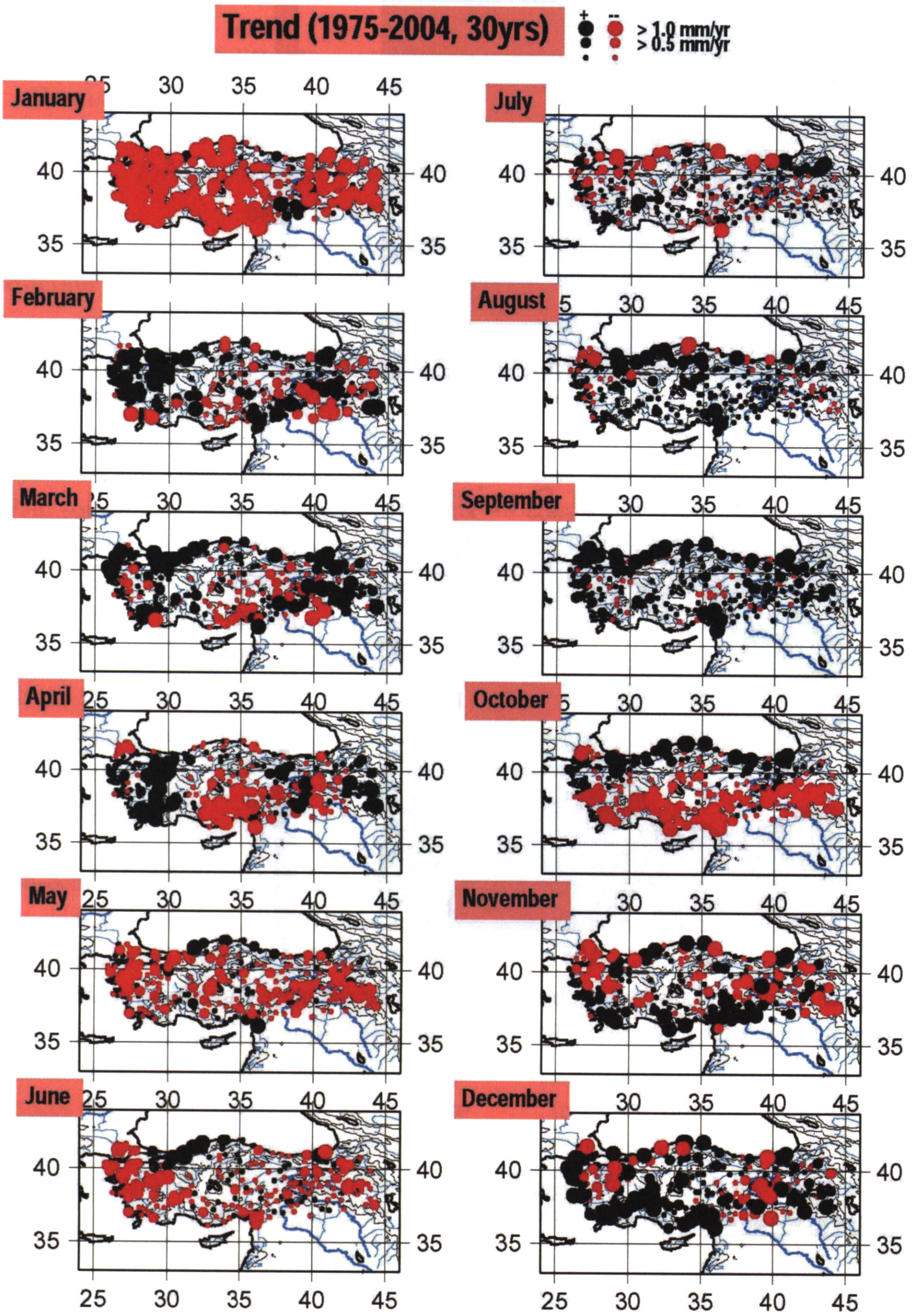

Fig. 1 Linear trends in monthly precipitation from 1975 to 2004. Black shows increases and red shows decreases.

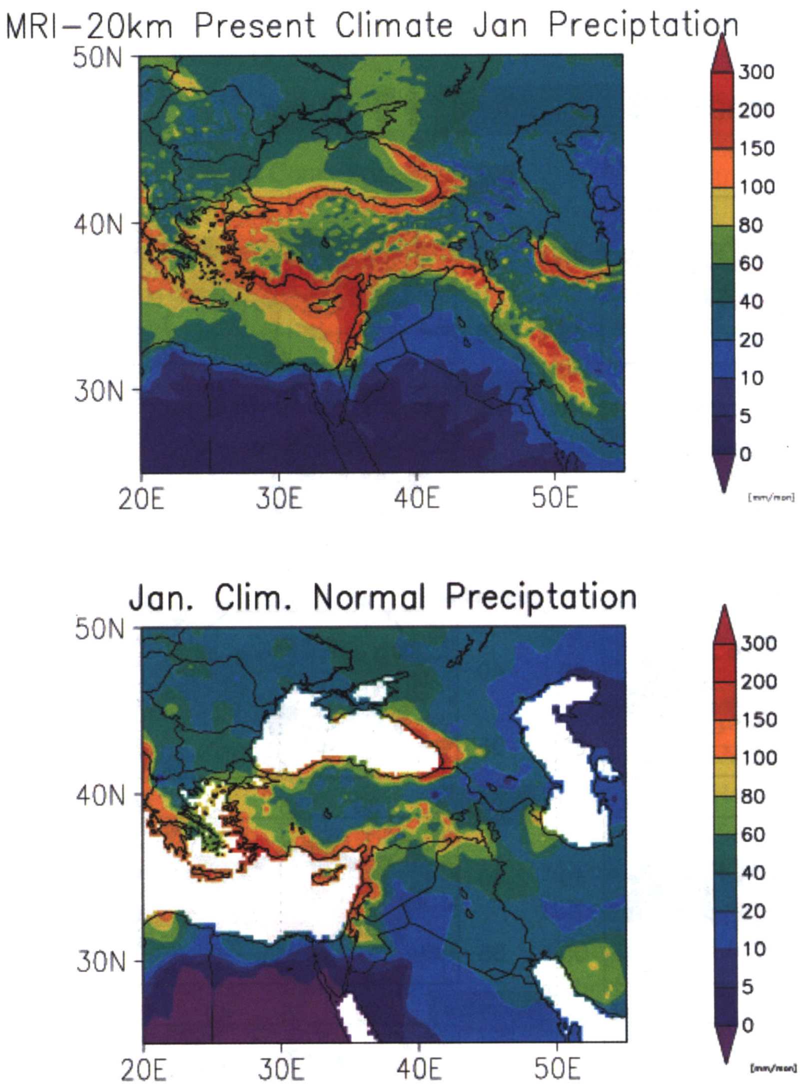

Fig. 2 Upper diagram: Lower diagram: Distribution of January climatology (1975-2004) interpolated by Shehard (1965) algorithm.

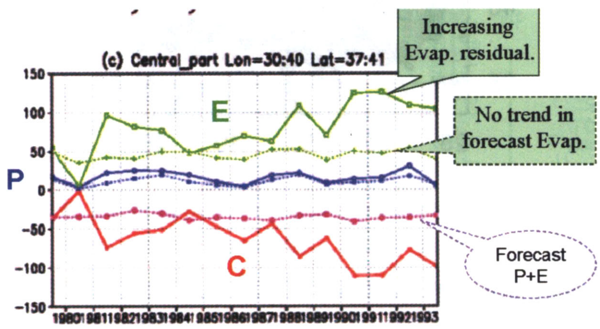

Fig. 3 Variations in the hydrologic budget in July over the central part of Turkey (units in mm/month). Dotted blue line, ERA15 forecast precipitation (Pf); solid bl ue line, CMAP precipitation (Pa); dotted green line, ERA15 forecast evapotranspiration (Ef); solid green line, evapotranspiration estimated as residual (Ea) of Pa-Ca; dotted red line, moisture convergence (Cf) estimated as Pf-Ef; solid red line, moisture convergence (Ca) estimated from ERA15.