Interannual variability in the hydrological budget over the Yellow River

Akiyo Yatagai (Research Institute for Humanity and Nature)

1. Introduction

Since the late 1990s, reanalysis of meteorological data using observations and a data assimilation scheme in a fixed global weather forecasting model has created dynamically consistent sets of historical atmospheric data (Kalnay et al., 1996; Gibson et al., 1997). The European Centre for Medium-Range Weather Forecasts (ECMWF) and National Centers for Environmental Prediction (NCEP) have both produced second generation reanalyses. Reanalysis data were used in this study to investigate interannual variability in the hydrological budget over the Yellow River. Analyses derived from the first ECMWF reanalysis (ERA15) are reported here. Analyses using the ECMWF 40-year reanalysis (ERA40, Simmons and Gibson 2000) are now underway.

2. Atmospheric moisture flux and hydrological budget

Figure 1 shows 15-year averages of atmospheric moisture content (precipitable water) and vertically integrated moisture flux over mid-latitudes of Eurasia. These values were computed using the first ECMWF reanalysis (ERA15). Computation details are in Yatagai (2003). 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

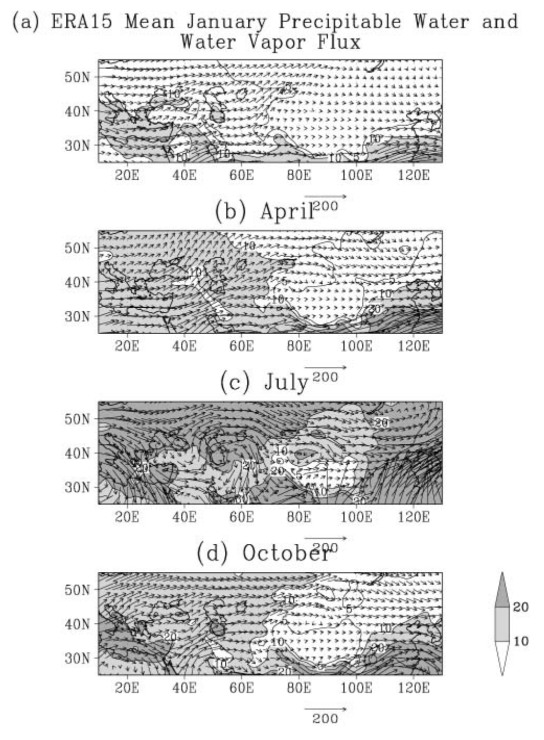

Fig. 1 Climatological mean precipitable water and vertically integrated moisture flux for (a) January, (b) April, (c) July and (d) October.

monthly to seasonal time scales.

This equation yields an estimate of evapotranspiration if regional mean precipitation data are known. Figure 2 shows the annual cycle of $-\nabla_H \cdot \mathbf{Q}$ (moisture convergence) and precipitation (from CPC Merged Analysis of Precipitation (CMAP), Xie and Arkin, 1997) for the large subregions shown in Figure 3 (dotted box). Details are given in Yatagai (2003).

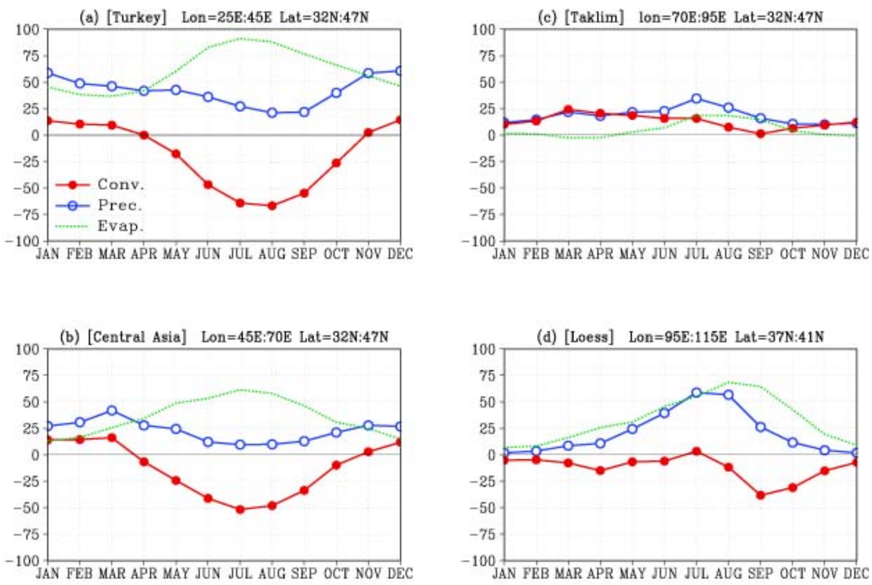

Fig.2 Annual cycle of $-\nabla_H \cdot Q$ and CMAP precipitation for subregions (a) Turkey, (b) central Asia, (c) the Taklimakan Desert, and (d) the Loess Plateau (mm/month).

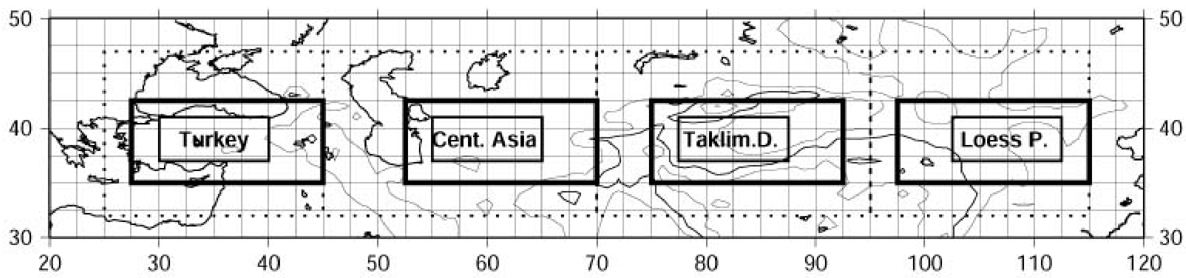

Fig.3 Geographical distribution of the box regions dicussed in Yatagai (2003).

3. Validation of precipitation datasets

Precise grid precipitation datasets as well as an objective (re)analysis dataset are needed to estimate the hydrological balance with the methods described in the previous section. Figure 4 shows July precipitation for the four sub-regions shown in Fig. 5. The precipitation test product (Xie, 2002) was interpolated from Global Telecommunication System (GTS) based precipitation data by Shepherd (1968) (shown in the black lines). This product is compared with CMAP and ERA15 precipitation. The precipitation test product and CMAP (green lines) data are similar except for the years 1979, 1980, and 1981 over the Tibetan Plateau. The ERA15 forecast corresponds well with the other two products over the Loess Plateau. However, it overestimates precipitation over the Tibetan Plateau, which causes an overestimate for the whole domain (Fig. 4a). The few gauge stations that there are on the Plateau are at relatively low altitudes; thus, the two products (test product and CMAP) may underestimate real precipitation amounts. More gauge precipitation data were incorporated for the second product (Xie et al., 2003, in this volume), so the estimates are expected to be better. Consideration of orographical effects on precipitation is an important focus for future study.

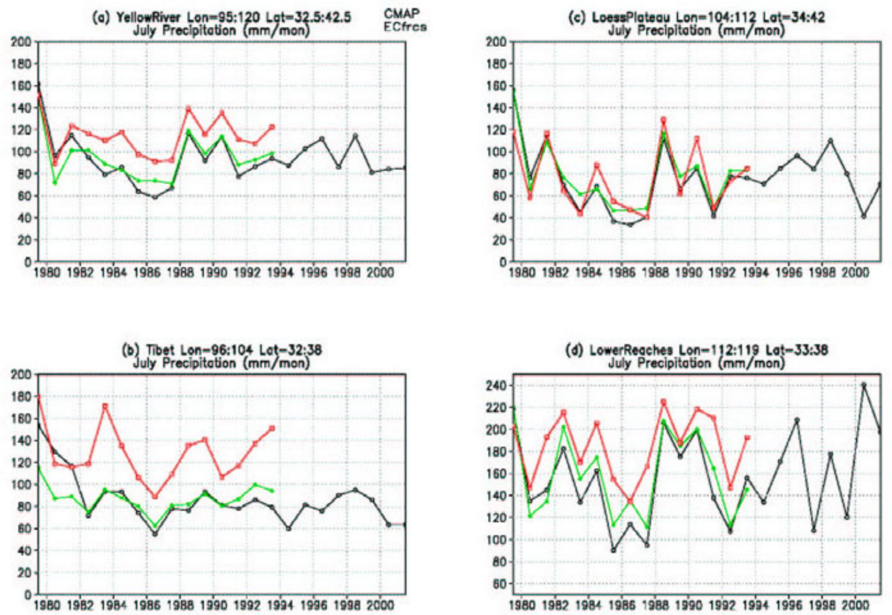

Fig. 4 July precipitation averaged for (a) the Yellow River domain, (b) Tibetan Plateau, (c) Loess Plateau and (d) Lower Reach of the Yellow River. The area is shown at the top of each panel and in Fig.5. Black: Xie (2002, test product), Green: CMAP (Xie and Arkin, 1997), Red: ERA15 forecasted precipitation.

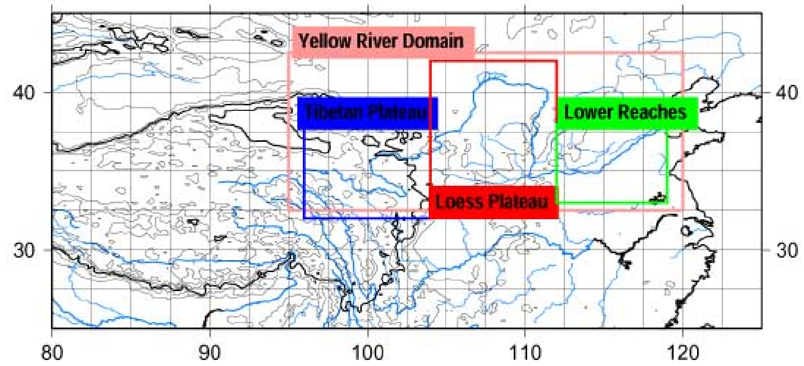

Fig.5 Geographical distribution of the Yellow River domain. (See Fig.4.)

4. Interannual variation of the hydrological budget

Figure 6 shows an example of interannual variability in July precipitation for the test product (black lines) and July moisture convergence derived from the ERA15 data. In general, the time series of convergence correspond to time series of precipitation.

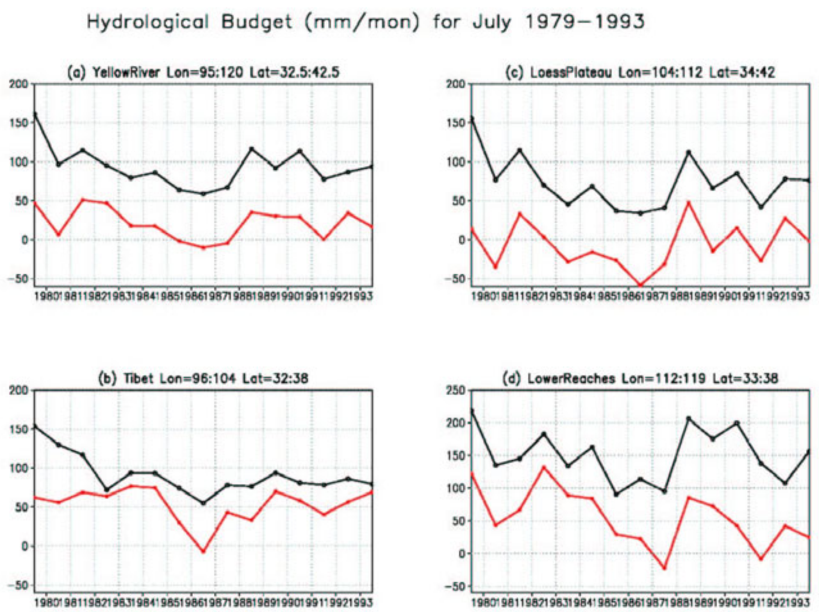

Fig.6 The interannual variations of precipitation (black lines) and atmospheric moisture convergence (red lines) averaged in the each dotted boxed shown in Fig. 5.

Negative convergence suggests that an area has more evaporation than precipitation at the surface. Thus, the difference between the two lines, namely (precipitation) – (convergence), represents the areal averaged evaporation, as shown in Fig. 2. Over the Tibetan Plateau, the areal averaged precipitation and convergence show similar values in 1982 and 1993. As the eastern part of the Tibetan plateau is a moisture source, these values may contain significant errors. Further investigation using better products is warranted.

In this note we showed the preliminary results of averaging precipitation or of convergence in the boxed areas shown in Figure 5. However, if we consider average parameters for a river basin (or sub-basin), convergence values can be compared to runoff if storage is neglected. Furthermore, if high quality datasets for moisture convergence, precipitation, and runoff are available, the average storage of water in a basin can be evaluated (e.g. Oki et al., 1995; Seneviratne et al. 2004; submitted).

References

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

Kalnay E, Kanamitsu M, Kistler R, Collins W, Deaven D, Gandin D, Iredell M, Saha S, White G, Woollen J, Zhu Y, Chelliah M, Ebisuzaki W, Higgins W, Janowiak J, Mo KC, Ropelewski C, Wang J, Leetmaa A, Rdynolds R, Jenne R, Joseph D. 1996. The NCEP/NCAR 40-year reanalysis project, *Bull. Amer. Meteor. Soc.*, **77**: 437-471.

Oki T, Musiake K, Matsuyama H, Masuda K, 1995. Global atmospheric water balance and runoff from large river basins. *Hydrological Processes*, **9**: 655-678.

Seneviratne, S.I., P. Viterbo, D. Luthi and C. Schar (2004) Inferring changes in terrestrial water storage using ERA-40 reanalysis data: The Mississippi River basin (in press).

Simmons, AJ and JK Gibson, 2000: The ERA-40 Project Plan. ERA-40 Project Report series, No.1, 62pp.

Xie P, Arkin PA. 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.

Yatagai, A. (2003): 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.