J8.2

USING MODEL-ASSIMILATED METEOROLOGICAL DATA IN FORECASTING OF SEASONAL RUNOFF BASED ON STATISTICAL MODELS FOR SOME ARAL SEA SUB-CATCHMENTS

Mariya G. Glazirina*, R. Schiemann, J. Gurtz, L. Vasilina, F. Pertziger, S. Dirren, and C. Schär
Institute for Atmospheric and Climate Science, ETH Zürich, Switzerland

1. Introduction

The economy and ecology of the Central Asian region heavily relies on two rivers – Syrdarya and Amudarya and the exploitation of their limited water resources has led to the dramatic dessication of the Aral Sea (Micklin (1988), Glantz (1999)). After the disintegration of the Soviet Union the necessity of dividing the water resources of the region among five independent countries (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan) appeared. In a heaviliy overused system such as the Aral Sea basin, the rational distribution and use of water is one of the most important tasks. Therefore, appropriate seasonal forecasting (for the whole period of vegetation and for single months of this period) is particularly important in order to optimize the complex water management tasks (Baumgartner et al. (2001), Dukhovny (2003)).

The Syrdarya and Amudarya rivers have their source regions in the high mountains of the Tian Shan, Pamir, and Hindukush. Their main source of alimentation is water from melted seasonal snow cover (Shults (1965)) and, thus, the main challenge to seasonal forecasting in the Aral Sea basin is the determination of winter and spring snow accumulation. During the time of the Soviet Union, an extensive monitoring program was in place. Following its disintegration, however, the number of observation points decreased drastically (Borovikova (1997)) and is far too low to support a reliable estimate of snow water equivalent in the whole of the runoff formation region at present. The use of satellite data to provide snow cover maps which is the basis of short-term and seasonal forecasts now (Baumgartner et al. (2000), Kobilov et al. (2001), Pertziger et al. (2002)) allows to determine the spatial and temporal extent of snow-cover, but is not sufficient to derive fully reliable quantitative estimates of snow water equivalent in complex terrain (Schär et al. 2004).

The primary goal of this project is to circumvent the lack of conventional observations from one side and the weakness of satellite data from the other by using model-assimilated meteorological data for the estimation of snow-water equivalent to drive a seasonal runoff forecasting system in the Central Asian region.

2. State of Affairs

Numerical weather prediction models used in the generation of analyses and re-analyses are capable of describing the spatial and temporal evolution of the state of the atmosphere. This is why observations at different times and locations can be ingested during the assimilation process such that re-analysis products do not heavily rely on local observations which is especially important in data sparse regions such as Central Asia.

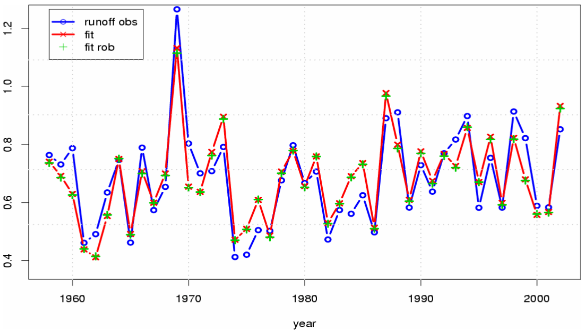

Figure 1. Interannual (year-to-year) summer runoff variations (May-September) in the Syrdarya basin upstream of Chinaz (in mm/d averaged over the catchment area). The blue line shows the observed runoff figures and the red line the fitted observations. The green crosses denote fitted values obtained with a robust regression.

In (Schär et al. (2002)) the suitability of the ERA-15 (available 1979-1993) re-analysis for estimating snow accumulation in the catchment regions of Syrdarya and Amudarya is assessed. Furthermore, these data are used to drive several linear and multi-linear statistical runoff forecast models (Schär et. al (2004)). For the Syrdarya basin, the results of theses studies were very encouraging: correlation coefficients as high as r=0.92 were obtained for the dependence of summer runoff on assimilated spring and winter precipitation. In case of the Amudarya basin, however, the results were not statistically significant. Additionally, it was shown that ERA-15 precipitation data better represents interannual variability of precipitation than rain-gauge-based precipitation products (GPCP, DELAWARE) and is thus more suitable for seasonal runoff forecasting. Furthermore, spring precipitation (in March and April) was shown to

---

* *Corresponding author address*: Mariya Glazirina, Institute for Atmospheric and Climate Science, ETH Zürich, Winterthurerstr. 190, 8057 Zürich, Switzerland; e-mail: mariya.glazirina@env.ethz.ch

be particularly important for summer runoff. Including assimilated surface temperature data (in addition to precipitation) did not yield a significant improvement of the forecast models.

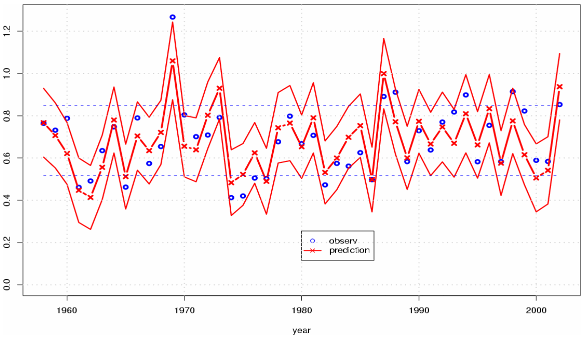

Figure 2. Cross validation for hindcasting of summer runoffs. The thick line represents the runoffs predicted by the model and the thin red lines the 90% forecasting intervals. Also shown is the range of typical observations (dashed blue lines, mean plus/minus one standard deviation).

In a subsequent study (Dirren (2003)), the ERA-40 re-analysis was used for statistical runoff forecasting. The longer period of time (1958-2002) covered by the ERA-40 dataset allowed to include more explanatory variables in the statistical models and to make more accurate predictions. In general, the results of this work confirm those obtained by (Schär et al. (2004)).

One of the statistical models used by Dirren (2003) is a multi-linear regression correlating runoff in the extended summer season (May-September) solely to monthly precipitations from October to April. Fitting runoffs in the Syrdarya with this model (see Fig.1) yields a correlation coefficient of r=0.89, i.e. it accounts for r^2=79% of summer runoff variability. Figure 2 shows the results that were obtained by using the same statistical model for the hindcast of runoffs in the ERA-40 period. In most years the model provides an excellent prediction, with departure from the forecasting interval in only three years (1960, 1990, and 1999, as to be expected for a 90%-prediction interval and 45 data values).

In the case of the Amudarya catchment, significant correlations were obtained, even though they are still much smaller than for the Syrdarya. Finally, a very important finding of this work are the large inhomogeneities that are observed between precipitation data of the ERA-40 and operational ECMWF analysis datasets. A quasi-operational forecast strategy that overcomes these inhomogeneities is proposed and tested successfully by means of cross-validation hindcasting techniques.

3. Ongoing Work

One objective of current research is to ascertain the cause(s) of the considerable differences of the quality of results obtained for the Syrdarya and Amudarya catchments. Possible reasons are the different role of glacier melt for the alimentation of both rivers and the insufficient quality and resolution of model-assimilated precipitation data in highly complex mountain terrain. Consequently, we test the suitability of this data for seasonal forecasting for some (sub-)catchments of both rivers (see Fig.3) and

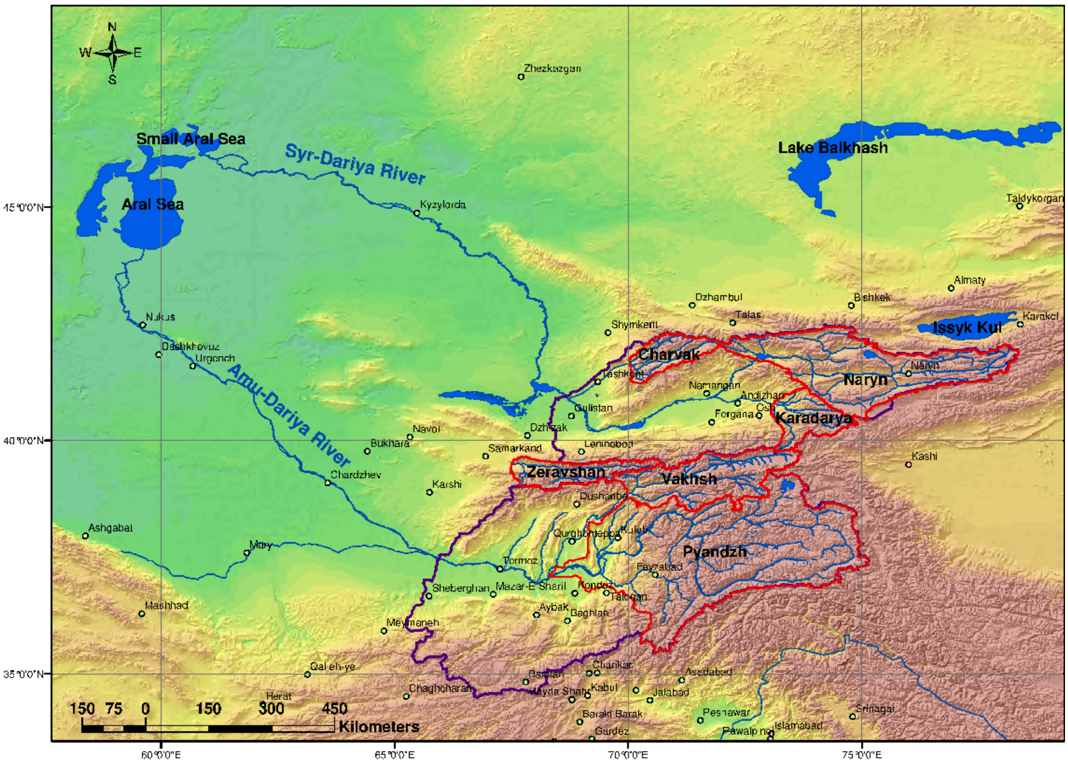

Figure 3. Central Asia: Syrdarya and Amudarya rivers and some of their sub-catchments.

investigate the dependence of the quality of our results on the location and size of considered (sub-) catchments as well as on the extent of glaciations in these basins.

In a future step of work, a distributed hydrological runoff model will be used in order to be able to account explicitly for non-linearities of snow-accumulation and snow-melt processes that cannot be described in terms of linear statistical models. Apart from currently available analysis and re-analysis data (ERA-15, ERA-40, ECMWF-operational) we plan to use precipitation data downscaled by means of a regional climate model which should mitigate the problem of low data resolution. Also, the planned ECMWF interim analysis (scheduled for 2005) will be used in order to bridge the inhomogeneity gap between re-analysis data and operational data.

4. References

Baumgartner, M.F., 2000: Operational snowmelt runoff forecasting in the Central Asian mountains. Proc. Conf. on Remote Sensing and Hydrology, Santa Fe, New Mexico, USA, April 2000; IAHS Publ. 267.

Baumgartner,M.F., M. Spreafico, and H.W. Weiss, 2001: Hydropower and conflicts over water in Central Asia. Mountains of the World. UN Comission on Sustainable Development and its 2001 Spring Session, Mountain Agenda, University of Berne (Switzerland), Dept. of Geography.

Borovikova, L.N., 1997: Description of the state of the National Hydrometeorological Surveys and concept for their future development. Report No. 4, World Bank Program 2.1, Improvement of Hydrometeorological Surveys in Central Asia, 57pp, Tashkent (Uzbekistan).

Dirren, S., 2003: Towards a quasi-operational forecasting system for river discharge in Central Asia using model-assimilated data. Report, Swiss Aral Sea Mission, Tashkent (Uzbekistan).

Dukhovny, V., 2003: The Aral Sea Basin – Rumors, Realities, Prospects. *Irrig. and Drain.*, **52**, 109-120.

Glantz, M.H. (Ed.), 1999: Creeping Environmental Problems and Sustainable Development in the Aral Sea Basin. Cambridge University Press, 304pp.

Kobilov, T., F. Pertziger, L. Vasilina, and M.F. Baumgartner, 2001: Operational technology for snow-cover mapping in the Central Asian mountains by means of NOAA-AVHRR data. Proc. Conf. on Remote Sensing and Hydrology, Santa Fe, New Mexico, USA, April 2000; IAHS Publ. 267.

Micklin, P.P., 1988: Dessication of the Aral Sea: A water management desaster in the Soviet Union. *Science*, **241**, 1170-76.

Pertziger, F., M.F. Baumgartner, T. Kobilov, A. Schultz, and L. Vasilina, 2002: Model of snow cover formation and method for the long-term prediction of inflow into water reservoirs during the flood seasons. Proc. Conv. Flood Forecasting, Bern, Switzerland, 2002.

Schär, C, L. Vasilina, and F. Pertziger, 2002: The use of Numerical Weather Prediction Data to estimate Winter Snow Accumulation in the Aral Sea Basin. Report, Regional Center of Hydrology, Tashkent.

Schär, C, L. Vasilina, F. Pertziger, and S. Dirren, 2004: Seasonal Runoff Forecasting using Model-Assimilated Precipitation Data. *Journal of Hydrometeorology*, **5(5)**, 959-973.

Shults, V.L., 1963: Central Asian Rivers., vol. 1, Gidrometeoisdat (Leningrad), (in Russian).