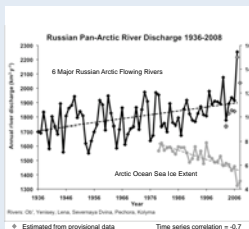


# Hydrologic Variability in Eurasian Pan-Arctic and Future Scenarios

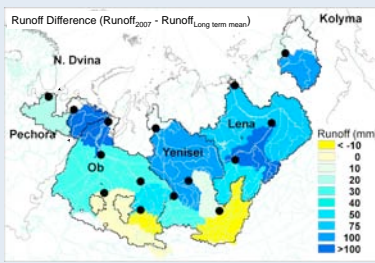
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## Contemporary Hydrology - A Look at the Year 2007



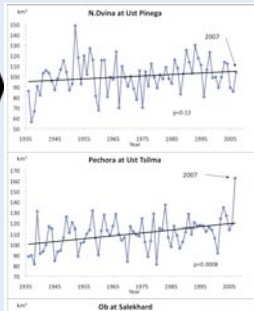
Russian river discharge aggregated from the Pechora, Dvina, Ob, Yenisey, Lena, and Kolyma rivers (upper line) from the Regional Integrated Hydrological Monitoring System for the Pan-Arctic Land Mass (<http://RIMS.unh.edu>). Historical data shown as black diamonds and provisional data shown as gray diamonds. September Arctic Ocean sea ice extent from the National Snow and Ice Data Center (lower line).

Over the historical record from 1936 to 2006, the mean annual river discharge for the six largest Russian rivers was 1796 km<sup>3</sup> y<sup>-1</sup> and the previous record was 2080 km<sup>3</sup> y<sup>-1</sup> in 2002. Our estimates indicate 2007 showed a massive flux of fresh water from the Russian land surface of 2250 km<sup>3</sup> y<sup>-1</sup> (fig. 1). This is an increase of more than 23% over the long term mean which is equivalent to the total annual flow from the Ob basin – the 8th largest basin in the world by drainage area.



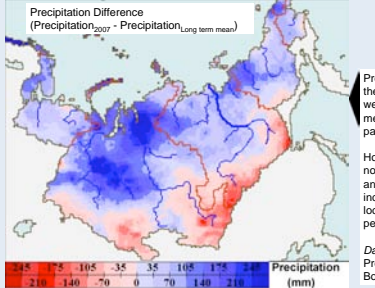
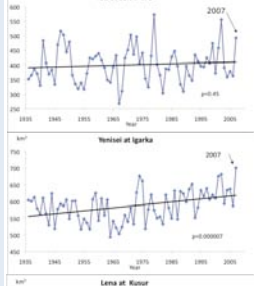
Time series of annual discharge from the downstream river monitoring stations of the 6 largest Russian drainage basins is given.

The year 2007 shows the Pechora and Yenisey with record years, the Lena has its second highest year on record, the Kolyma is high and the Dvina is normal. The large values in the Pechora, Yenisey, and Lena are part of the long term significant upward trends.



Comparing year 2007 runoff with the long term mean (1936 - 2007) shows large contributions from the Pechora, northern Ob, northern Yenisey, and the central Lena. The southern extents of the Ob and the Yenisey basins show a small decrease or no difference relative to the long term mean.

Overall we see increasing river flows in the north and decreasing flows in the south. Dry areas are drier and wet areas are wetter which emphasizes the extremes.



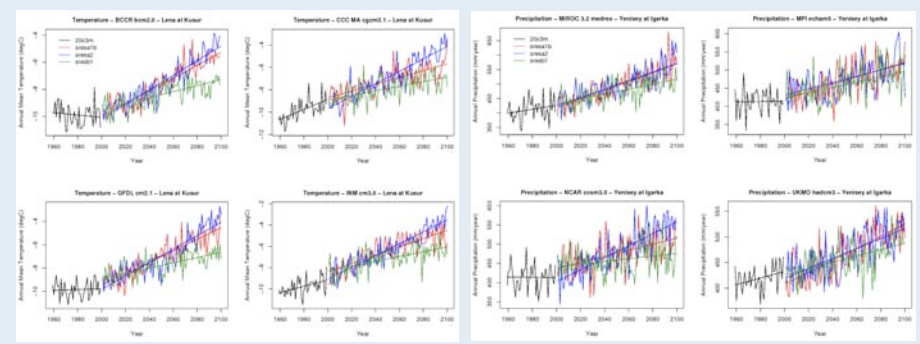
The river discharge change over the long term (1936-2007), based on the linear regression line for each inter-station region, shows similar patterns to the 2007 runoff anomalies. While year 2007 is anomalous in magnitude, the patterns suggest the 2007 anomalies are not unexpected as they are simply an extreme example of the trajectory of the existing long term trend.

Precipitation is the most obvious candidate for the large 2007 river discharge anomaly. When we look at precipitation anomalies (long term mean: 1980-2008) we see a similar overall pattern, a wetter north and a drier south.

However, there are some differences which are not consistent such as the low precipitation anomaly in the southern Lena with large increases in river discharge. This suggests other local hydrological contributions such as permafrost melt.

Data source: ArcticRIMS Reconstructed Precipitation developed by M. Serreze, CU-Boulder (<http://RIMS.unh.edu>)

## Future Scenarios



Summary of Models (col/row)

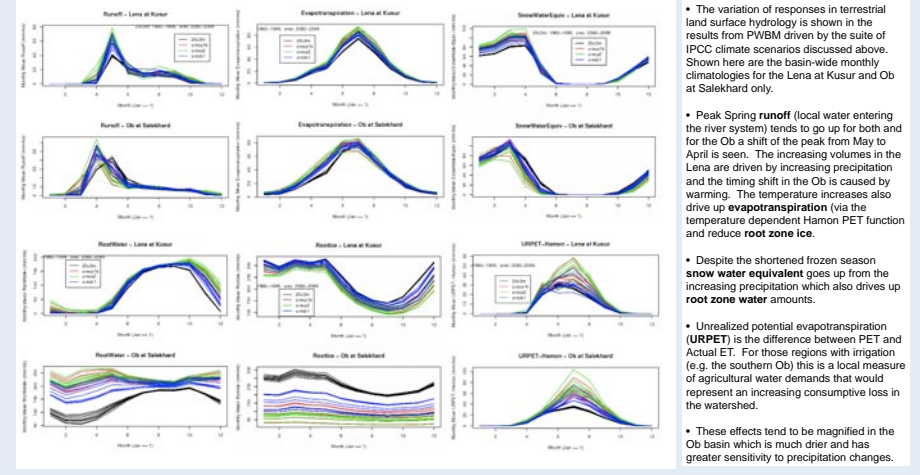
Model Name	Grid & Lon/Lat	Levels	Center	City, Country
bccr_bcm2_0	128 x 64	T63	BCCR	Bergen, Norway
cccma_cgcm3_1	96 x 48	T47 L31	CCC	Victoria, Canada
gfdl_cm2_1	144 x 90	M45 L24	GFDL	Princeton, USA
inmcm3_0	72 x 45	4deg L21	INM	Moscow, Russia
miroc3_2_medres	128 x 64	T42 L20	CCSR	Tokyo, Japan
mri_cgcm2_3_2a	192 x 96	T63 L32	MPI	Hamburg, Germany
ncar_ccsm3_0	256 x 128	T85	NCAR	Boulder, USA
ukmo_hadcm3	96 x 73	2.5deg	UKMO	Exeter, UK

Temperature and precipitation fields from 8 IPCC model data sets were used to drive the UNH Pan-Arctic Water Balance Model (PWBM) for contemporary ("20c3m" 1960-1999) and future runs (2080-2099). Three SRES scenarios, A1b ("sresab1"), A2 ("sresaz2"), and B1 ("sresb1") were used for all models. Lines represent linear regression for each scenario within the temporal range of the displayed data.

Model input fields for are shown for the average annual temperature in the Lena at Kurur drainage basin (above left) and for total annual precipitation in the Yenisey at Igarka watershed (above right). For most regions of the Russian Arctic, temperature is expected to increase throughout the 21st Century and for many regions precipitation is expected to increase.

The 8 models used in this study were selected from a pool of 24 models based on their completeness in availability of all the SRES scenarios and to represent nations with significant Arctic research (the dangerous a priori assumption that nations with a large Arctic research program would have an increased probability of having important high latitude processes within the model).

In the 8 time series above note large inter-model differences in:  
1) Contemporary patterns and trends  
2) Temporal variation



- The variation of responses in terrestrial land surface hydrology is shown in the results from PWBM driven by the suite of IPCC climate scenarios discussed above. Shown here are the basin-wide monthly climatologies for the Lena at Kurur and Ob at Salekhard only.
- Peak Spring runoff (local water entering the river system) tends to go up for both and for the Ob a shift of the peak from May to April is seen. The increasing volumes in the Lena are driven by increasing precipitation and the timing shift in the Ob is caused by warming. The temperature increases also drive up evapotranspiration (via the temperature dependent Hamon PET function and reduce root zone water ice.
- Despite the shortened frozen season snow water equivalent goes up from the increasing precipitation which also drives up root zone water amounts.
- Unrealized potential evapotranspiration (URPET) is the difference between PET and Actual ET. For those regions with irrigation (e.g. the southern Ob) this is a local measure of agricultural water demands that would represent an increasing consumptive loss in the watershed.
- These effects tend to be magnified in the Ob basin which is much drier and has greater sensitivity to precipitation changes.



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