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River Discharge

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Highlights

- In 2014, combined discharge from the eight largest Arctic rivers (2,487 km^3) was 10% greater than average discharge for the period 1980-1989. Values for 2013 (2,282 km^3) and 2012 (2,240 km^3) were 1% greater than and 1% less than the 1980-1989 average, respectively.
- For the first seven months of 2015, the combined discharge for the six largest Eurasian Arctic rivers shows that peak discharge was 10% greater and five days earlier than the 1980-1989 average for those months.

River discharge integrates hydrologic processes occurring throughout the surrounding landscape; consequently, changes in the discharge of large rivers can be a sensitive indicator of widespread changes in watersheds (Rawlins et al. 2010, Holmes et al. 2012). Changes in river discharge also impact coastal and ocean chemistry, biology and circulation. This interaction is particularly strong in the Arctic because rivers in this region transport >10% of global river discharge but the Arctic Ocean contains only ~1% of the global ocean volume (Aagaard and Carmack 1989, McClelland et al. 2012).

Here we report annual river discharge values for the eight largest Arctic rivers since 2011, when river discharge was last featured in the Arctic Report Card (Shiklomanov and Lammers 2011), and compare these recent observations to a 1980-1989 reference period (the first decade with data from all eight rivers). Six of the eight rivers lie in Eurasia, and the other two are in North America. Together, the watersheds of these eight rivers cover 70% of the pan-Arctic drainage area, so the rivers featured here account for the majority of riverine freshwater inputs to the Arctic Ocean (**Fig. 8.1**).

Fig. 8.1. Map showing the watersheds of the eight rivers featured in this report. Together they cover 70% of the 16.8 x 10^6 km^2 pan-Arctic watershed. The red dots show the location of the discharge monitoring stations and the red line shows the boundary of the pan-Arctic watershed.

A long-term increase in Arctic river discharge has been well documented and is primarily a function of increasing precipitation linked to global warming (Peterson et al. 2002, McClelland et al. 2006, Shiklomanov and Lammers 2009, Overeem and Syvitski 2010, Rawlins et al. 2010). The long-term discharge trend is greatest for rivers of the Eurasian Arctic and constitutes the strongest evidence of intensification of the Arctic freshwater cycle (Rawlins et al. 2010).

The results presented here demonstrate that Eurasian Arctic river discharge generally declined between 2007 and 2012 and then began to increase again in 2013 and 2014 (**Fig. 8.2**, **Table 8.1**). The discharge increase seems to be continuing in 2015, as over the first seven months of 2015 the combined discharge of these rivers was 10% greater than the 1980-1989 average for those same months (**Table 8.2**). The short-term variability in Eurasian Arctic river discharge is consistent with previous increases and decreases over 4-6 year intervals in the past (**Fig. 8.2**). Overall, the most recent data indicate a continuing long-term increase in Eurasian Arctic river discharge.

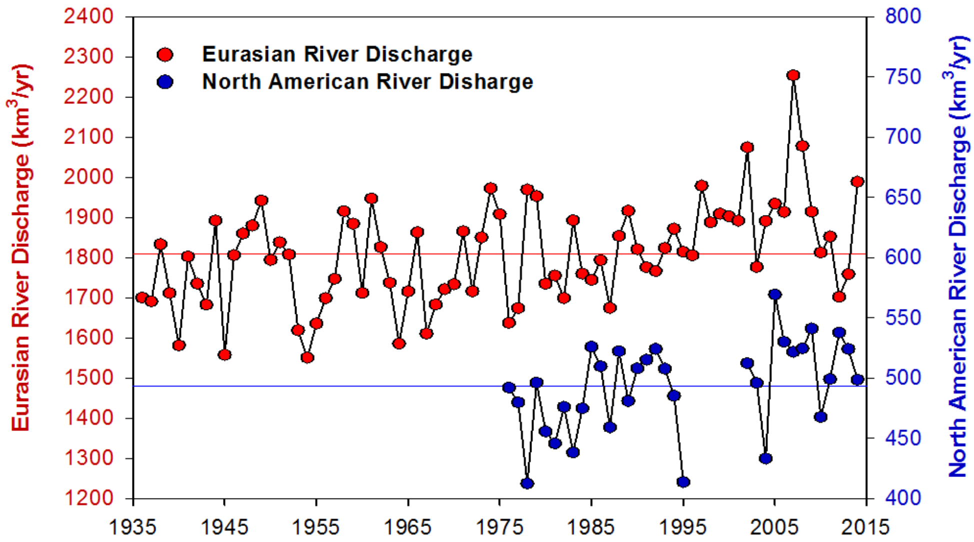

Fig. 8.2. Long-term records of annual discharge for Eurasian and North American Arctic rivers. The Eurasian rivers are the Severnaya Dvina, Pechora, Ob', Yenisey, Lena, and Kolyma. The North American rivers are the Yukon and Mackenzie. Note the different scales for the Eurasian and North American river discharge; discharge from the former is 3-4 times greater than it is from the latter. The horizontal lines show long-term mean discharge values for the Eurasian (1,809 km^3 y^{-1}) and North American (493 km^3 y^{-1}) rivers.

Table 8.1. Annual discharge for 2012, 2013 and 2014 for the eight largest Arctic rivers compared to long-term and decadal averages back to the start of observations. Red values indicate provisional data, which are subject to modification before official data are published. In practice, the modifications usually do not substantially impact annual discharge estimates.

Discharge (km^3/y)									
	Yukon	**Mackenzie**	**Pechora**	**S. Dvina**	**Ob'**	**Yenisey**	**Lena**	**Kolyma**	**Sum**
2014	*227*	272	116	91	448	640	607	86	2487
2013	213	311	82	97	372	527	600	80	2282
2012	232	306	103	117	300	458	665	59	2240
Average 2010-2014	212	293	106	95	385	582	582	74	2329
Average 2000-2009	207	305	124	103	415	640	603	78	2475
Average 1990-1999	217	275	117	111	405	613	532	68	2338
Average 1980-1989	206	273	108	100	376	582	549	68	2262
Average 1970-1979	184	292	108	94	441	591	529	65	2304
Average 1960-1969			112	98	376	546	535	73	
Average 1950-1959			110	108	380	566	511	74	
Average 1940-1949			102	100	424	578	498	72	
Average for Period of Record	206	286	110	100	400	588	539	71	2300

For the North American Arctic rivers considered here (Yukon and Mackenzie), the combined discharge declined each year from 2012 to 2014, yet in each of those years the combined discharge was greater than the long-term average (**Fig. 8.2**, **Table 8.1**). Thus, as discussed for Eurasian rivers, these most recent data indicate a longer-term pattern of increasing river discharge (**Fig. 8.2**). Indeed the overall trends of increasing discharge since 1976 are remarkably similar for the North American and Eurasian rivers. Increases per decade since 1976 were 3.1±2.0% for the Eurasian rivers and 2.6±1.7% for the North American rivers. Increases per decade follow a Mann-Kendall trend analysis; error bounds are 95% confidence intervals for the trend.

Considering the eight Eurasian and North American Arctic rivers together, their combined discharge in 2014 (2487 km^3) was 10% greater than average discharge from 1980-1989. Comparing 2014 to 2012, the combined discharge of these eight rivers was almost 250 km^3 greater in 2014. For perspective, 250 km^3 is approximately 14 times the annual discharge of the Hudson River, the largest river on the East Coast of the United States.

An assessment of the combined daily discharge of Eurasian Arctic rivers for the period January 1 through July 31 2015 reveals an earlier and higher peak discharge compared to the 1980-1989 average (**Fig. 8.3**, **Table 8.2**). The 2015 peak discharge for these six rivers was 10% higher and five days earlier than the 1980-1989 average. The higher and earlier discharge peak is consistent with the early spring melt of deeper snow in Eurasia (see the essay on *Terrestrial Snow Cover*).

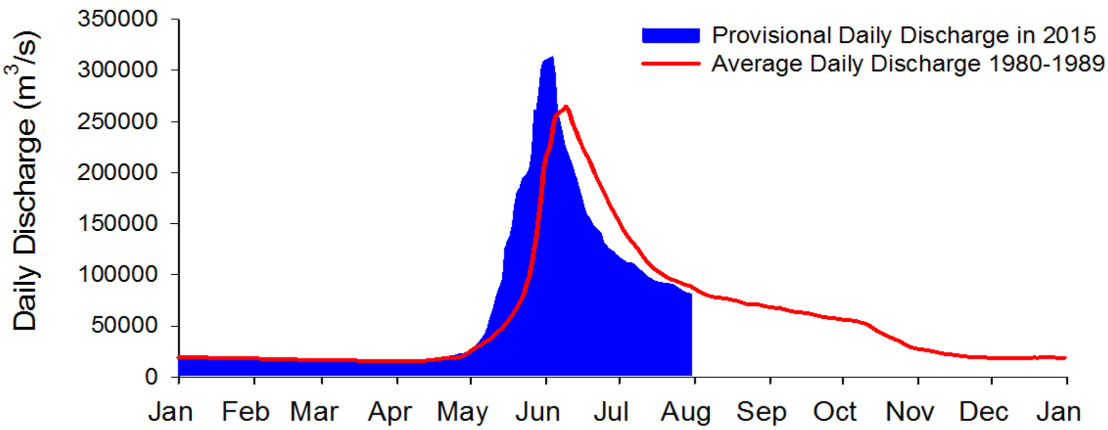

Fig. 8.3. Average combined daily discharge for the six Eurasian Arctic rivers for the period 1 January through 31 July 2015 compared to the 1980-1989 average for those months.

Table 8.2. Cumulative Eurasian river discharge for the first seven months of 2015 compared to the January-July average for 1980-1989. All 2015 data are provisional.

1 January – 31 July Discharge (km^3)							
	Pechora	**S. Dvina**	**Ob'**	**Yenisey**	**Lena**	**Kolyma**	**Sum**
2015	95	51	290	447	421	51	1355
1980-1989 Ave.	82	73	244	426	361	44	1229

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