Decadal-scale predictability of Eurasian summer precipitation: the role of AMV

Dario Nicolì[1,2] (*dario.nicoli@cmcc.it*), Alessio Bellucci[2], Doroteaciro Iovino[2], Paolo Ruggieri[2] and Silvio Gualdi[2,3]

1. Ca' Foscari University, Venice, Italy - 2. CMCC Foundation, Bologna, Italy - 3. INGV, Bologna Italy

Abstract

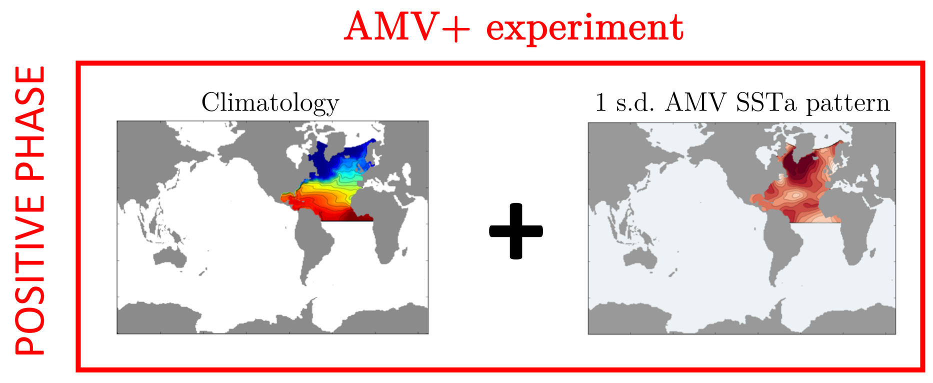
Studies of the Atlantic Multidecadal Variability (AMV) impact on the climate system are severely limited by the lack of sufficiently long observational records (~150 years, at best), leading to a poor constrain of the multi-decadal range of the global climate variability spectrum. Relying on a model-based approach is therefore instrumental to overcome this limitation. In this study, a novel experimental setup, designed in the framework of the CMIP6-endorsed Decadal Climate Prediction Project-Component C effort, is applied in order to analyse the remote impact of the AMV on the Northern Eurasian continent. Model results shows that, during Boreal summer, a positive phase of the AMV induces a hemispheric-scale wave-train over Eurasia, inducing moisture advection from the North Atlantic Ocean, and triggering a meridional moisture flux from the Pacific sector into Eurasia. The convergence of the two anomalous flows leads to intensification of rainfall over Scandinavia and Siberia. Increased Siberian precipitation leads to an intensified river runoff by the major Siberian rivers which accounts for more than half of the Arctic freshwater input provided by terrestrial sources. A decrease of sea surface salinity (about 12% of model climatology), broadly consistent with the changes in the anomalous river discharge, is found in the proximity of the river mouths during positive-AMV years.

Methodology

Following a common experimental protocol, outlined in CMIP6 Decadal Climate Prediction Project (DCPP) – Component C [1], we have performed suites of idealized AMV SST perturbation experiments with regional restoring using CMCC-CM2 fully coupled model, to simulate AMV polarities.

	CMCC-CM2-SR*
Horizontal Res.	1° for all components
Ocean Comp.	NEMO 3.6
Atm. Comp.	CAM 5.2
External Forcings	Pre-industrial values
Ensemble size	32 members
Run Length	10 years

[Cherchi et al. 2018]*



AMV- experiments: thy are analogous to AMV+ but it is considered the negative phase of the AMV (i.e. -1 standard deviation of the AMV pattern).

Results #1

During early summer, a significant increase of decadal rainfall emerges over the northern Eurasia, consistent with [2]: an anomalous meridional dipole characterizes the European continent, with wetter condition over Scandinavia and drier condition over the eastern Europe. Interestingly, the largest signal is found over Siberia, where rainfall increases. Composites of Z300* (departure from the zonal mean of geopotential height at 300 hPa) reveal that the AMV excites an east-west wave train along the Northern Hemisphere. The positive anomaly in the Euro-Mediterranean sector may partially explain the significant decrease of total precipitation in this region. A zonal dipole over Siberia, with positive and negative anomalies centred over the eastern and western part of the region, indicates that the AMV induces a southerly flow in the

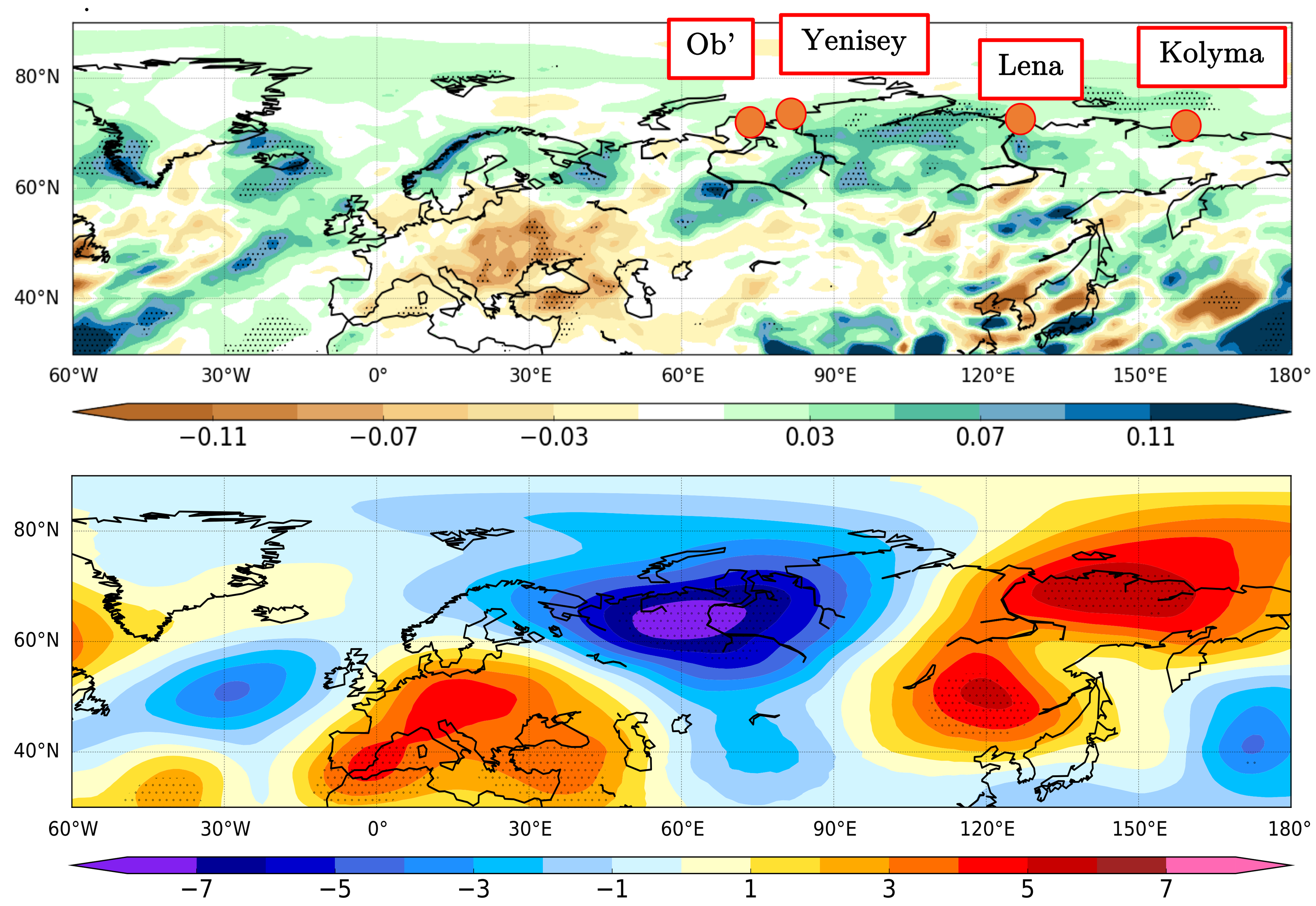


Figure 1: May-to-August (MJJA) difference (AMV+ - AMV- exps.) for total precipitation (top panel, unit is mm/d) and Z300 (bottom panel, unit is m). Dotted regions display non-significant values (below 95% confidence level using a two-sided Student's t test).*

Results #2

The AMV-composite for the vertically-integrated moisture flux shows an eastward wave-like flow from the North Atlantic Ocean towards the western Russia, in agreement with [3], and a second anti-cyclonic flow centred over Mongolia, as detected in [2], both converging over Siberia, around 100°E (fig. 2.a). Moisture flux convergence is found over a zonally elongated belt straddling the Eurasian continent north of 60°N, with local minima over Scandinavia and Siberia, where maximum precipitation anomalies are also found (fig. 1), suggesting a tight relationship between the rainfall enhancement and the increase in moisture convergence over those areas.

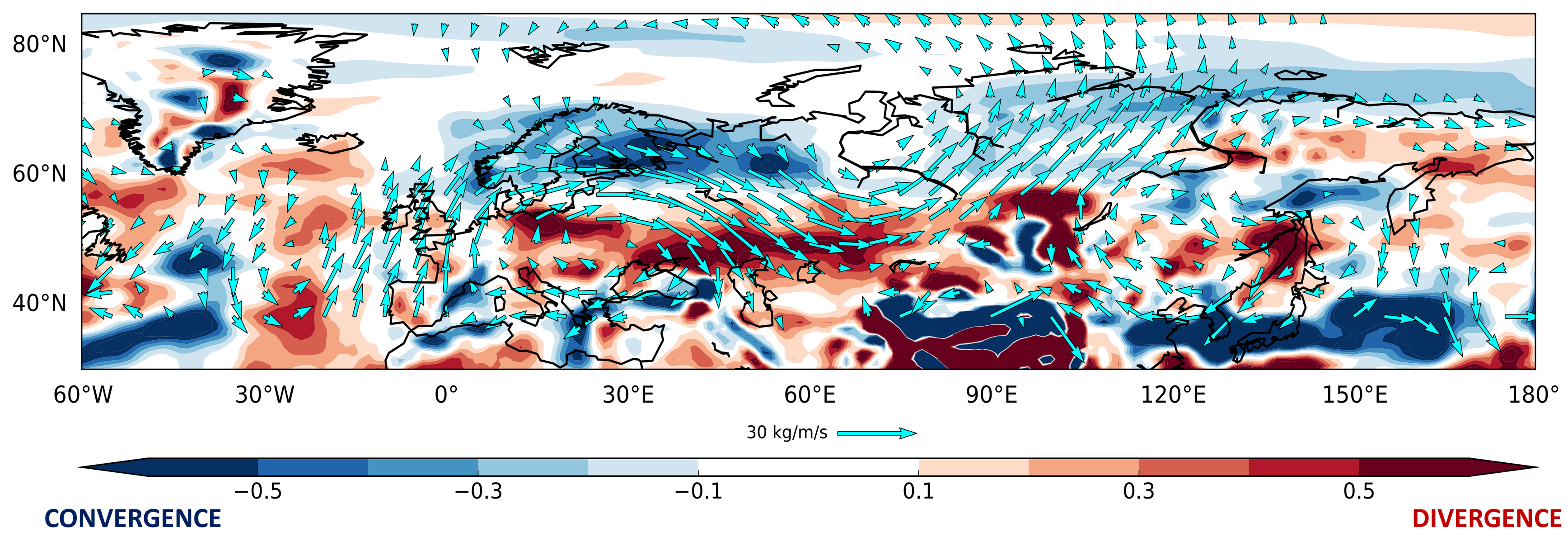


Figure 2.a: MJJA difference (AMV+ - AMV- exps.) for vertically-integrated moisture flux (vectors, unit is kg/m/s, vectors < 4 kg/m/s are not shown) and its divergence (shading, unit is 10^{-3} kg/s).

Positive anomalies of zonal moisture transport prevail over northern Eurasia (fig. 2.b, contours). The anomalous flux injects specific humidity from the North Atlantic Ocean into the continent and is supported by a strengthening of the mean westerlies (fig. 3.b, vectors). On the Pacific side, around 40°N, negative anomalies indicates a sea-to-land moisture transport. Focusing at the meridional moisture flux field, an anomalous seesaw pattern emerges along the Arctic side of the Eurasian continent with the wider anomaly located over Siberia. The maximum latitudinally spans from 40°N to 70°N, implying the poleward recall of moisture from lower latitude, supported by the wind anomalies.

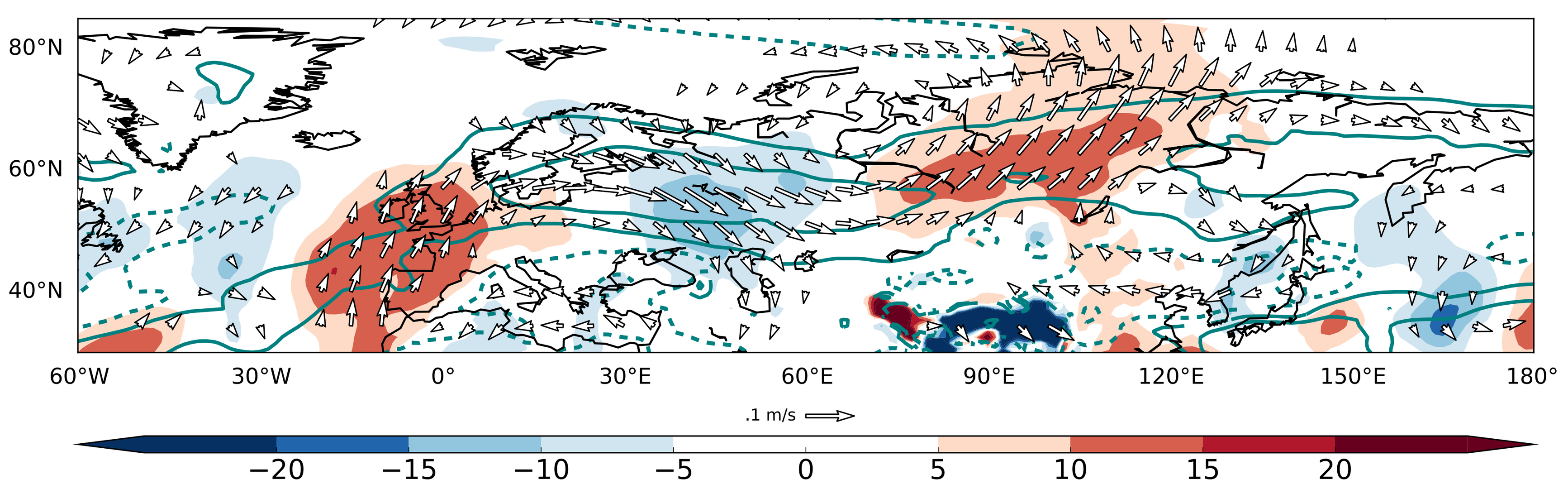


Figure 2.b: MJJA difference (AMV+ - AMV- exps.) for zonal (contours, unit is kg/m²/s, interval between -15 kg/m²/s and 15 kg/m²/s) and meridional (shading, unit is kg/m²/s) vertically-integrated moisture flux and wind anomaly (vectors, unit is m/s, vectors < 0.02 m/s are not shown).

Results #3

The Siberian rivers account for more than 50% of the Arctic freshwater input provided by terrestrial sources and their watersheds cover almost 70% of the catchment areas of all Eurasian Arctic rivers. Therefore, the increased rainfall over East Siberia may play a crucial role in the northern-hemisphere hydrological cycle contributing to a freshening of the Arctic Ocean via an enhanced river discharge. As expected, the detected AMV-related anomalies in Siberian rivers' freshwater inflow affect the sea surface salinity (SSS) of the Arctic Ocean, decreasing SSS along the Arctic coast, with local minima close to the river mouths.

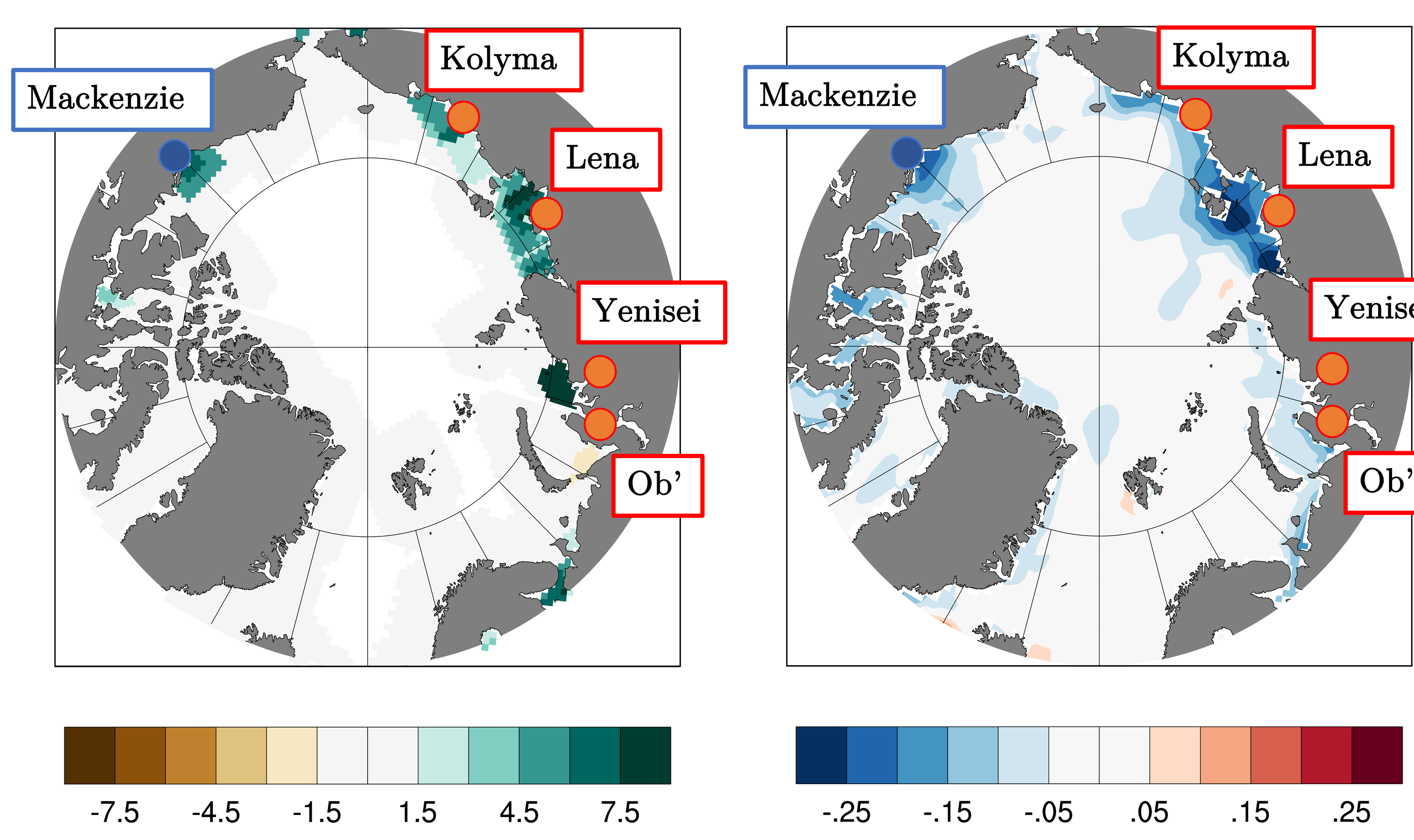


Figure 3: MJJA difference (AMV+ - AMV- exps.) for river runoff (left panel, unit is 10^{-6} kg/m²/s) and sea surface salinity (right panel, unit is PSU).

Essential literature:

[1] Boer, G. J., et al. 'The decadal climate prediction project (DCPP) contribution to CMIP6.' Geoscientific Model Development (Online) 9.10 (2016).

[2] Sun, C., Li, J., & Zhao, S. (2015). Remote influence of Atlantic multidecadal variability on Siberian warm season precipitation. Scientific reports, 5, 16853.

[3] Zhang, X., He, J., Zhang, J., Polyakov, I., Gerdes, R., Inoue, J., & Wu, P. (2013). Enhanced poleward moisture transport and amplified northern high-latitude wetting trend. Nature Climate Change, 3(1), 47.

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