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Emerging climate change signals in the Lena River catchment, Eastern Siberia, Russia

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Climate change is very pronounced in high latitudes and impacts permafrost-underlain landscapes with respect to hydrology, ecosystems and the population's traditional livelihoods. However, a strong spatial and temporal variability in temperature and precipitation records renders the characterization of changes as well as the implementation of mitigation strategies difficult. Here we present an approach to investigate temperature and precipitation time series from observational records, reanalysis, and climate model data in the Lena River catchment, Eastern Siberia, Russia, where significant environmental changes are already apparent. We developed a statistical method to identify the time of emergence (ToE) of climate change signals, i.e. the time when a climate signal permanently exceeds its natural variability. Our method provides more freedom than traditional parametric approaches and allows for a detailed temporal analysis of climate signals. The method is based on the Hellinger distance metric to compare probability density functions between a reference and target periods. We use a reference period common to all tested datasets (1900-1921) to provide an estimate for the natural variability, and target periods with moving windows of 21 years thereafter at annual and seasonal scale. We investigate how and when temperature and precipitation signals have emerged from the original value distribution. The metric describes the overlap of the probability density functions (PDFs) of two periods and is adjusted to yield dissimilarities between them as values ranging from 0% to 100%. A strong onset of emergence is apparent in the 1970s for temperature with a monotonic increase thereafter for observational data. The same evolution is obtained for a collection of 65 climate model projections using the RCP85 emission scenario. At the end of the observational dataset (2016), temperature distributions have emerged by 50% to 60%. Climate model projections suggest 90% emergence by 2040. For precipitation the analysis is less conclusive because of high uncertainties in existing observational datasets that also impede an evaluation of the climate model projections. These suggest hardly any emergence by 2000 but a well-defined emergence thereafter, reaching 60% by 2100. An original strategy to select the most realistic model simulations based on the available observational data significantly reduces the uncertainties resulting from the spread in the 65 climate models used.