The time of emergence of Arctic warming, wettening and sea ice melting

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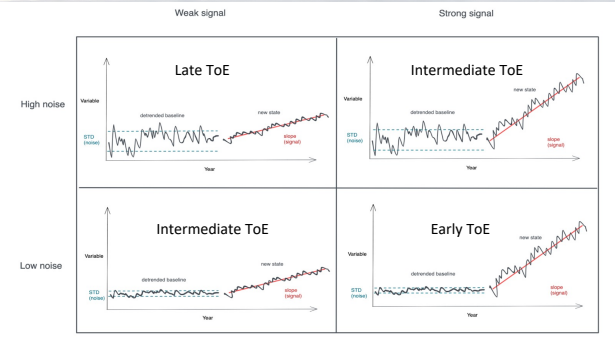
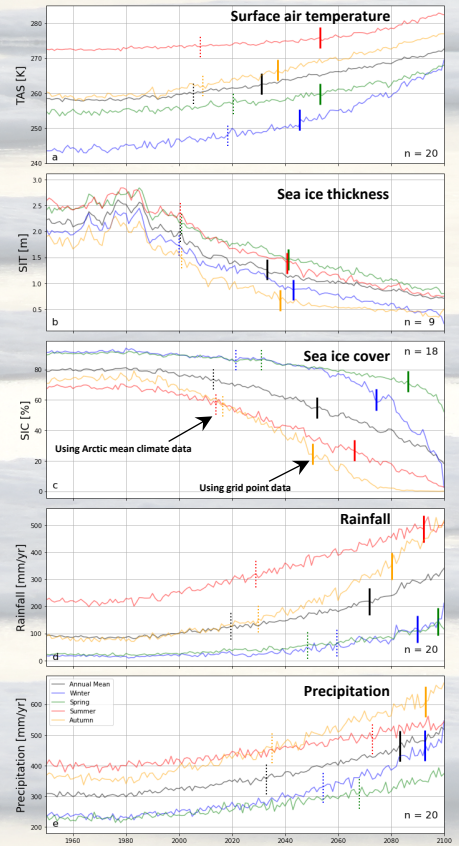
Summary

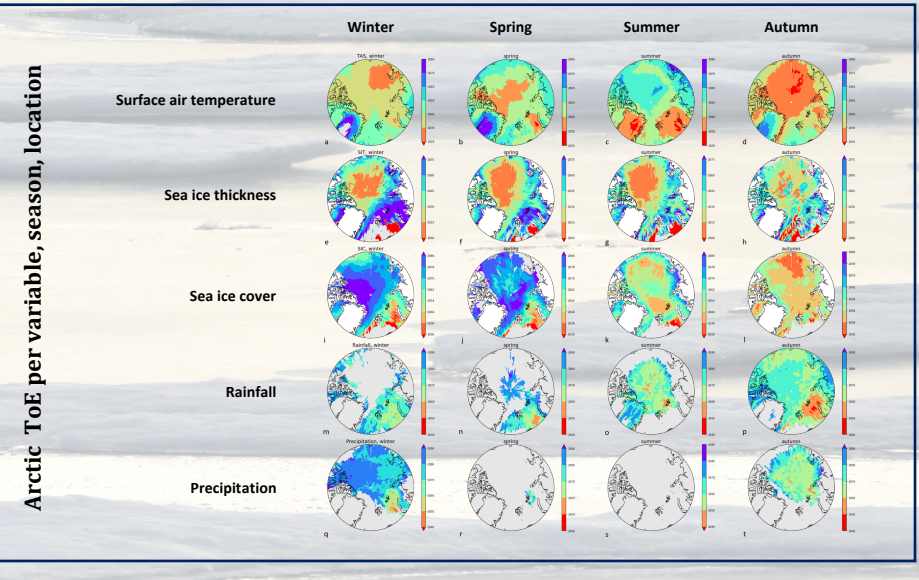
The warming, wettening Arctic exhibits considerable variability (interannual/decadal). The definite transition to a new climate state (time of emergence, ToE) occurs when the trend exceeds natural variability. Uncertainties in climate model projections, variability and ToE-methods resulted in diverging estimates of Arctic ToE. Here we use a new and robust method in conjunction with state-of-the-art climate model projections (CMIP6) to show that, generally, Arctic sea ice thickness emerges first (2038-2043), followed by surface air temperature (2037-2053), sea ice cover (2050-2074), and precipitation/rainfall (after 2080). Autumn generally exhibits the earliest ToE-values due to strong sea ice retreat. The earliest ToE for temperature and sea ice thickness occurs in the Central Arctic, whereas for sea ice cover and rainfall this is primarily the Barents Sea region. Parts of the Arctic are thus close to a new climate state (for temperature and sea ice), with wide-ranging and possibly irreversible consequences for vulnerable Arctic ecosystems and human activities.

The impact of trends and variability on ToE



Arctic changes, ToE per variable and season





Conclusion and discussion

Using a new, robust method and the most recent state-of-the-art global climate model simulations (CMIP6) to evaluate the time of emergence (ToE) of the climate signal in the Arctic region, we found that the emergence of most variables in most seasons and regions has not occurred yet, but will occur in the (near) future. We have consistently incorporated spatial variations in climate variability, which in particular for sea ice cover/thickness result in a more accurate (and much later) estimate of ToE. The earliest Arctic ToE are found for sea ice thickness, owing to its comparatively low variability but strong trend. Interestingly, Arctic sea ice cover emerges later than thickness. Climate trends are not so influenced by spatiotemporal resolution, but variability reduces considerably with spatial and temporal averaging. Consequently, ToE-estimates are crucially dependent on the scale on which variability is evaluated. Moreover, Arctic ToE exhibits strong spatial and seasonal variations, and differences between variables: on average, sea ice thickness emerges around 2040, followed by temperature and sea ice cover (around 2045, 2060) while precipitation and rainfall enter a new state only by the end of the century.

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