Ice Season forecast under Climate Change: Tipping elements approach

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Abstract ID: 20073

EGU2020 OS1.11: Changes in the Arctic Ocean, sea ice and subarctic seas systems: Observations, Models and Perspectives

Sea of Okhotsk

Image Credit: NASA image courtesy LANCE/EOSDIS MODIS Rapid Response Team at NASA GSFC

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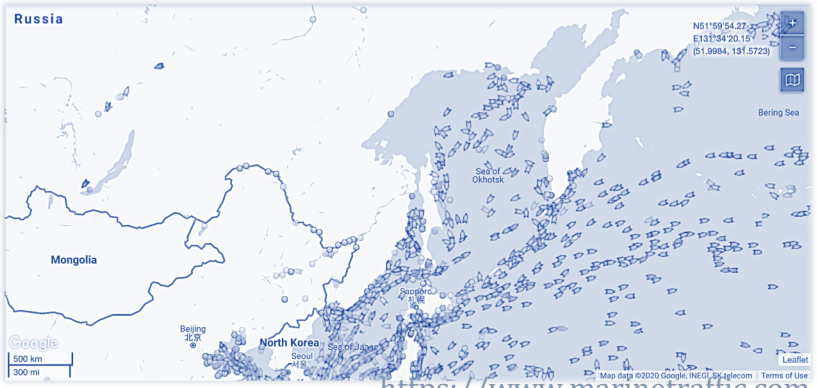
Motivation

The Sea of Okhotsk is a marginal sea of the western Pacific Ocean. It is one of the world's richest in biological resources and famous for the fishing industry.

In winter, navigation on the Sea is difficult, if not impossible, due to the presence of sea ice. The absence of a long-term forecast of the navigational period in the Sea of Okhotsk affects the safety of navigation.



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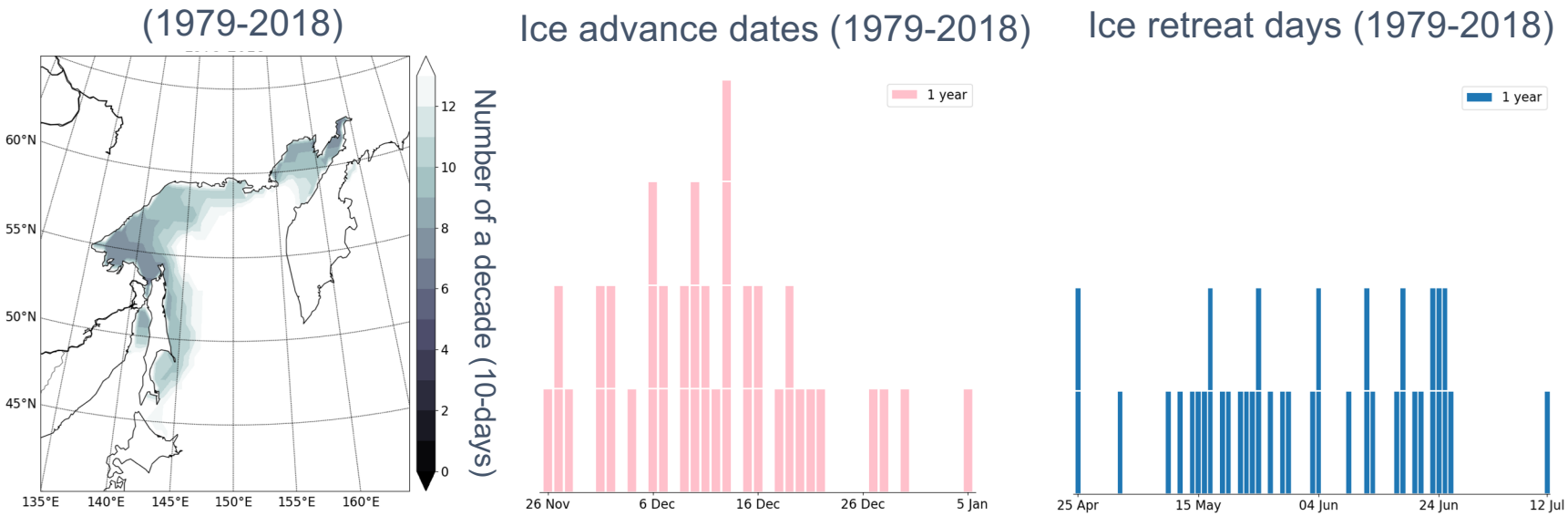
Interannual Variability in the Sea of Okhotsk



On average, the ice-free period lasts from June to November. However, the start and end dates of the ice season vary from year to year within a month and even more. Such variability is impossible to capture by meteorological methods. Currently, there is a only weekly operational forecast, e.g. by "Planet"Roshydromet. Thus, a long-term forecast is desperately needed for navigation planning.

Abstract ID: 20073

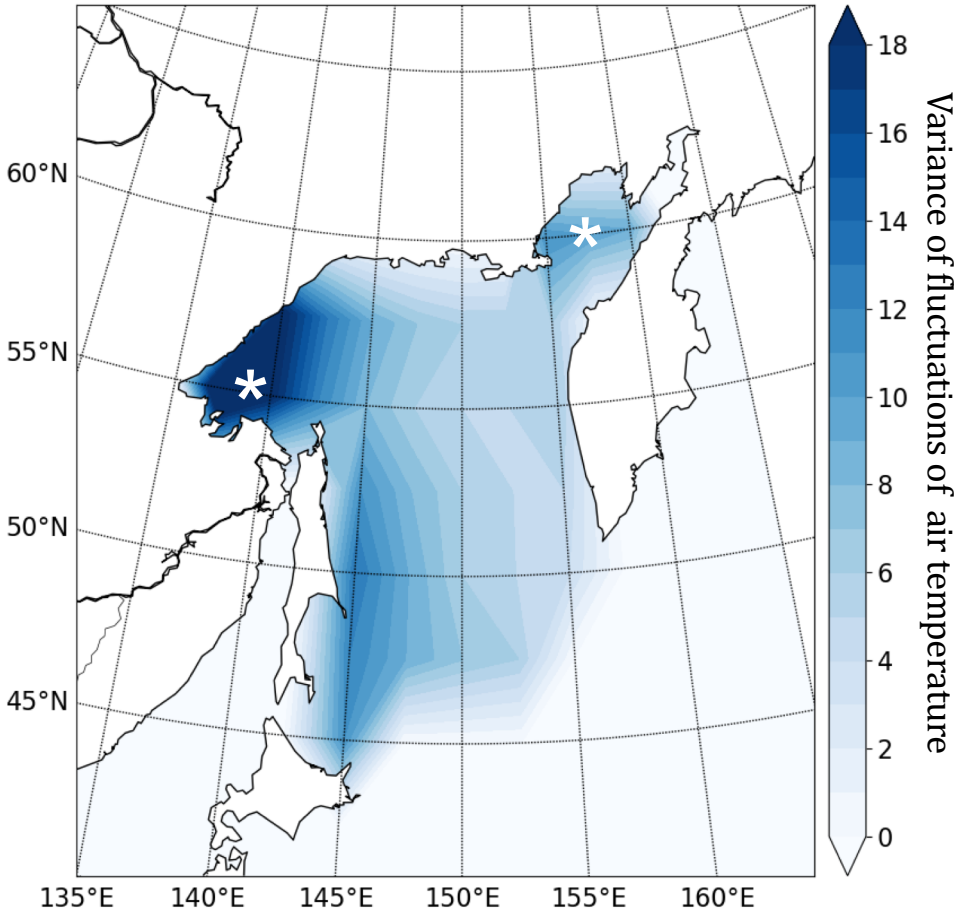
Methods

The Tipping elements approach to forecast ice advance/retreat date is a new methodology based on a newly discovered feature - the spatially organized critical transition in the near-surface atmosphere over the Sea of Okhotsk.

The approach allows

- identification of locations of Tipping Elements using Critical Fluctuations [2],
- revealing regularities between the Tipping Elements (see analogies in [1]),
- developing forecasting scheme (see analogies in [1], [7]).

Tipping Elements



Data source: NCEP/NCAR reanalyzes, daily air temperature at 1000hPa, 2.5°/2.5° resolution, (1949-2019)

Forecasting scheme of sea ice advance date

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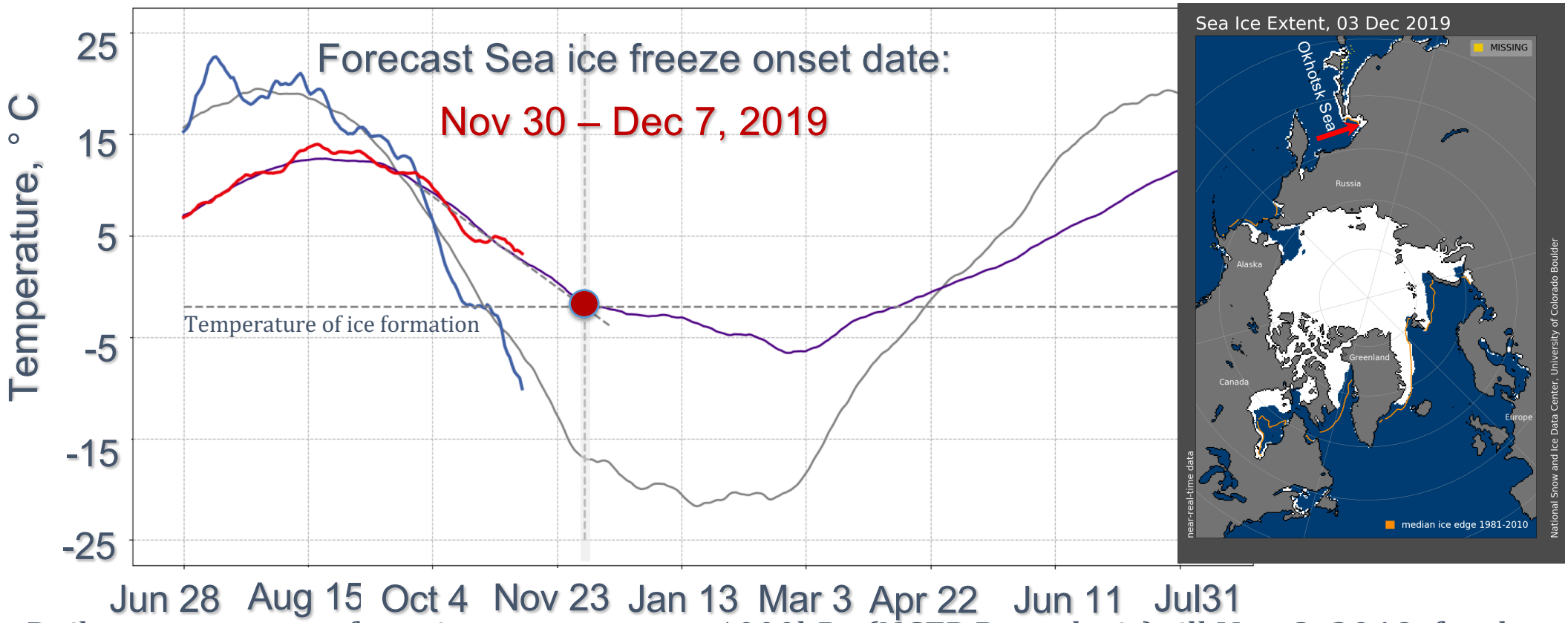
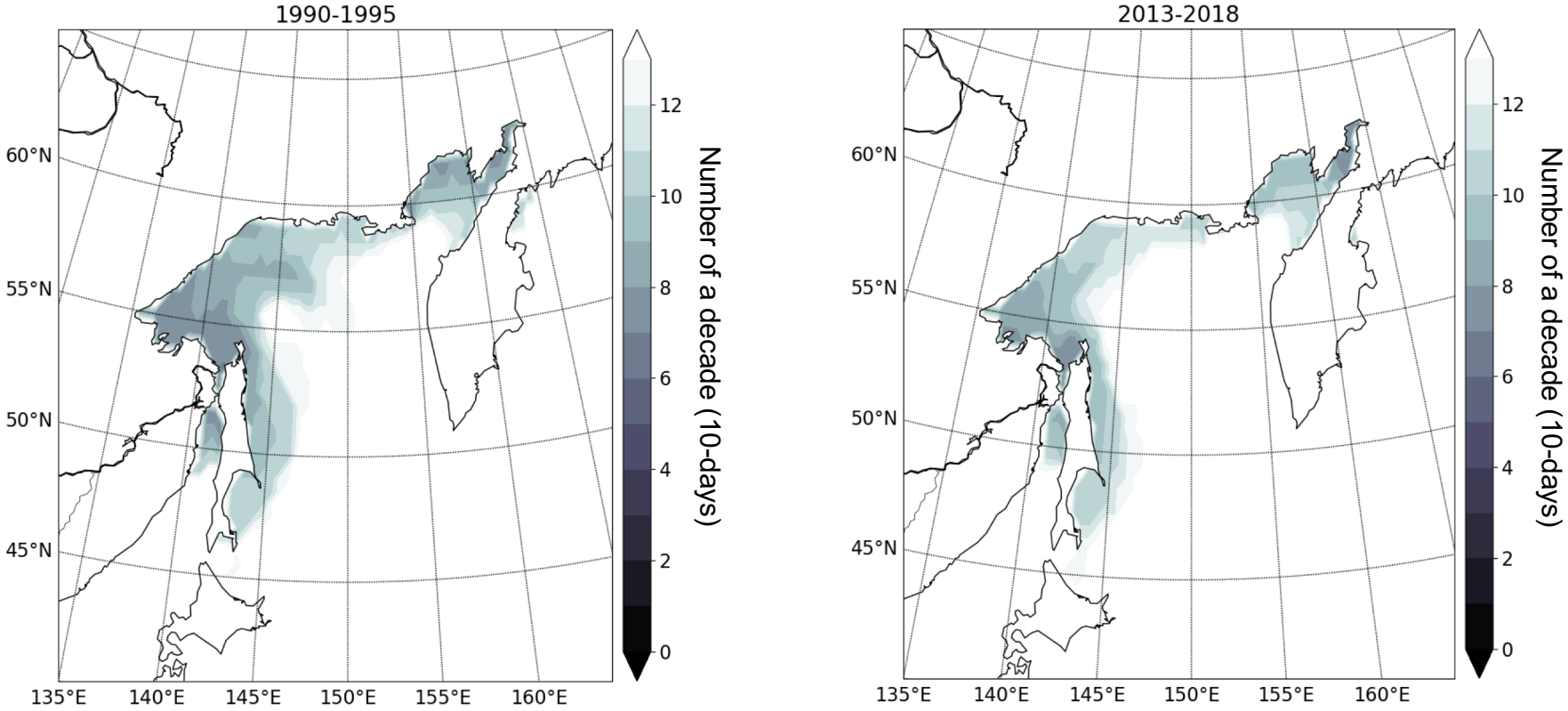
Evidence from observations



Daily mean near-surface air temperature at 1000hPa (NCEP Reanalysis) till **Nov 8, 2019** for the western (red) and eastern parts (blue). Violet and gray lines - past 19-years average for same regions. The tipping point (red) indicates the critical temperature and the forecasted onset date.

Climate change impact in sea ice advance

Abstract ID: 20073



The 10-days ice advance: a number of a decade (10-days) started from 1 October to 31 January. We use Sea Ice Index, Concentration (fraction) with the ice concentrations is greater than 50%. The maps show the expanse covered by ice in 2013-2018 down 27% compared to 1990-1995.

Data source: ERA5, https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels?tab=overview

Conclusions

We propose a new Tipping elements approach to forecasting the ice advance & retreat dates in the Okhotsk See. The new approach offers three key advances in ice season forecasting:

- A prediction of the ice advance & retreat in Okhotsk See where long-term prediction has never been made;
- A prediction of the dates of the advance & retreat for more than one month in advance - which is unprecedently early;
- An ability for accounting for climate change effects: an ice season time-shift, a decrease of expanse covered by ice.

The methodology opens new possibilities for regional ice season forecasting and can be extended around the globe.

References

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Thanks to my co-authors from: