Winter coastal divergence as a predictor for the minimum sea ice extent in the Laptev Sea

Overview
In addition to its downward trend, the minimum sea ice extent (SIE) displays important interannual variability that represents a challenge in terms of predictability of sea ice. We demonstrate feasibility of using late winter coastal divergence as a predictor for the SIE minimum on a seasonal timescale and regional spatial scale. Following Nikolaeva & Sesterikov [1970], we take the Laptev Sea as a first case of study.

Mechanism (idealized)

- (Fig.1a) An initial contour of sea ice on February 1st moves until May 1st for two different years: one with weaker coastal divergence and one year with anomalously high coastal divergence.
- During the winter, new ice formation takes place in the polynyas created by coastal divergence.
- If the new ice forms late in the winter, it does not grow to a sufficient thickness to survive the summer melt. Between February 1st and May 1st, sea ice can freeze up to a thickness of 1 to 1.5 m, which is equivalent to the climatological summer melting (Nikolaeva & Sesterikov [1970]).
- (Fig.1b) Consequently, a larger area of late winter coastal divergence is associated to a low SIE min. anomaly in the following September, a smaller area of coastal divergence to a high SIE min. anomaly (as studied on the pan-Arctic scale by Williams et al. [2016]).

What we find
- (Fig.2) For the Laptev Sea, we present the correlation between anomalies of the September SIE min. and anomalies of coastal divergence area during the previous winter, integrated between the time indicated on the x-axis and the first week of May (Julian week X to May week 18).
- The strongest negative correlation arises when coastal divergence is considered between February and May (r = –0.63).

Method & Results

- To identify areas of coastal divergence, we follow motion of sea ice in the Laptev Sea using the Lagrangian Ice Tracker System (LITS) forced with sea ice drifts from Polar Pathfinder V3 (Tschudi et al. [2016]), for years 1992-2014.
- (Fig.3) Example for 2014. a) Initial position of tracers in the first week of February, in the model domain. b) Position of tracers 14 weeks later, in May. In b), blue points indicate tracers that have drifted away from the coast and red points indicate landfast ice.

- (Fig.5) We compare areas of coastal divergence (red contours) with observed sea ice thickness fields from the merged CS2SMOS product (Ricker et al. [2017]). The last thickness distribution before the summer is available at Julian week 15, coastal divergence is therefore calculated between week 5 and week 15.
- We expect the area of coastal divergence to match regions of thinner ice (<1 m) that formed in the polynyas during the winter. Differences are present and can be partly explained by a low bias in the Polar Pathfinder sea ice drifts.

- (Fig.6) Time series of the SIE min. and area of coastal divergence (from week 5 to week 18) in the Laptev Sea for the years 1992-2014.
- There is a negative trend in the regional SIE min. (-27.1%/decade) while there is a positive trend in the area of coastal divergence (+8.3%/decade).

- (Fig.7) Scatter plot of the SIE min. anomalies (y-axis) against anomalies of coastal divergence (x-axis). The strength of the negative correlation is r = −0.63, therefore close to 40% of the interannual variability of the SIE min. anomalies can be expressed via the proposed mechanism at the regional scale in the Laptev Sea.
- The slope (|m| = 0.3) indicates a threefold amplification of anomalies between coastal divergence and SIE min. Coastal divergence leads to formation of thinner ice which melts earlier in the season, creating areas of open water that have a lower albedo and trigger an ice-albedo feedback. The threefold amplification suggests that sea ice state anomalies at the end of the winter are enhanced during the summer.

Future work

- Application of the method to other peripheral seas of the Arctic Ocean to highlight regional characteristics regarding predictability of sea ice.
- Improving the method by an in-depth assessment of biases in the sea ice drift products.

References