Laptev Sea and East Siberian Sea landfast ice: Mechanism of formation and variability of extent

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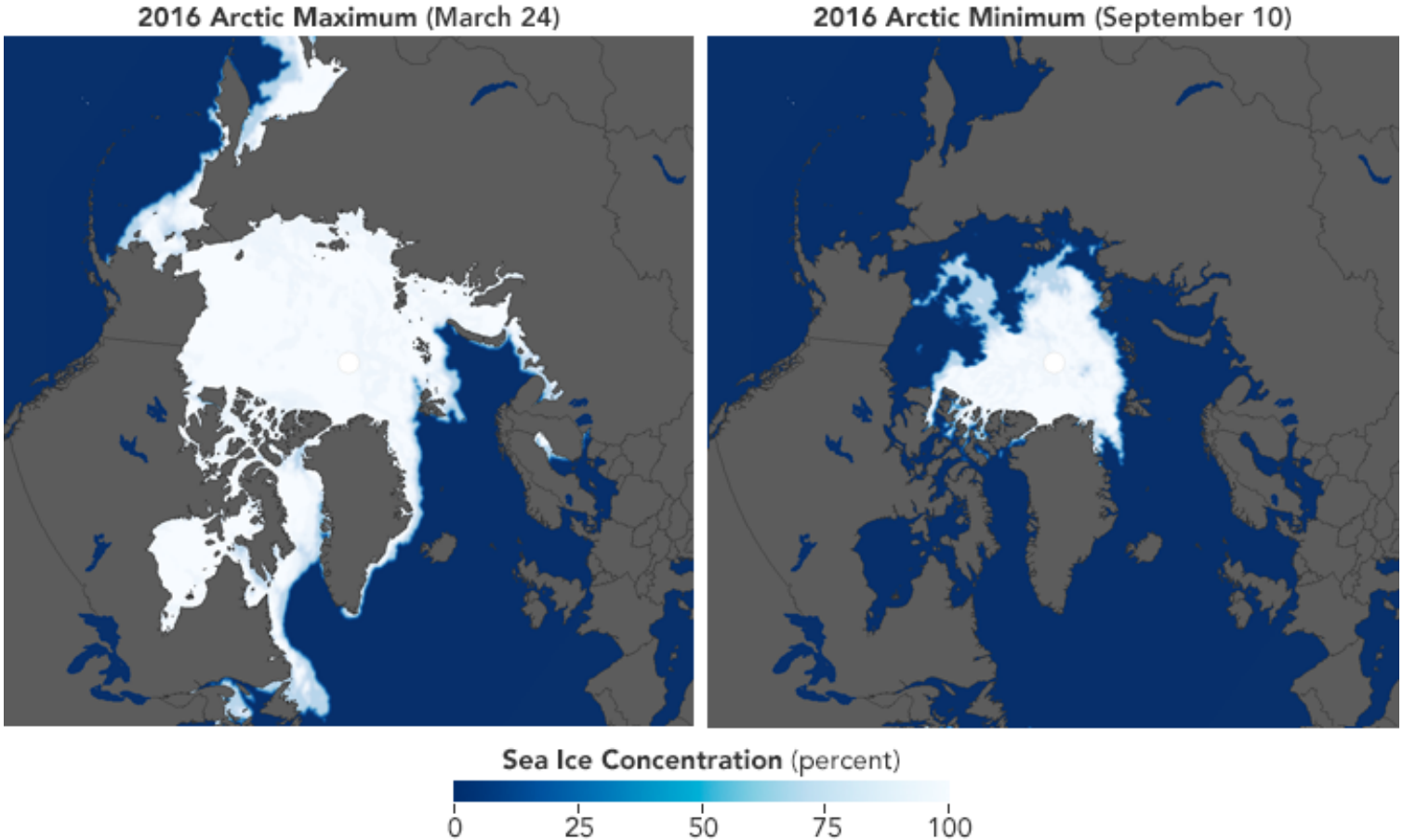
Outline

I. Arctic sea ice



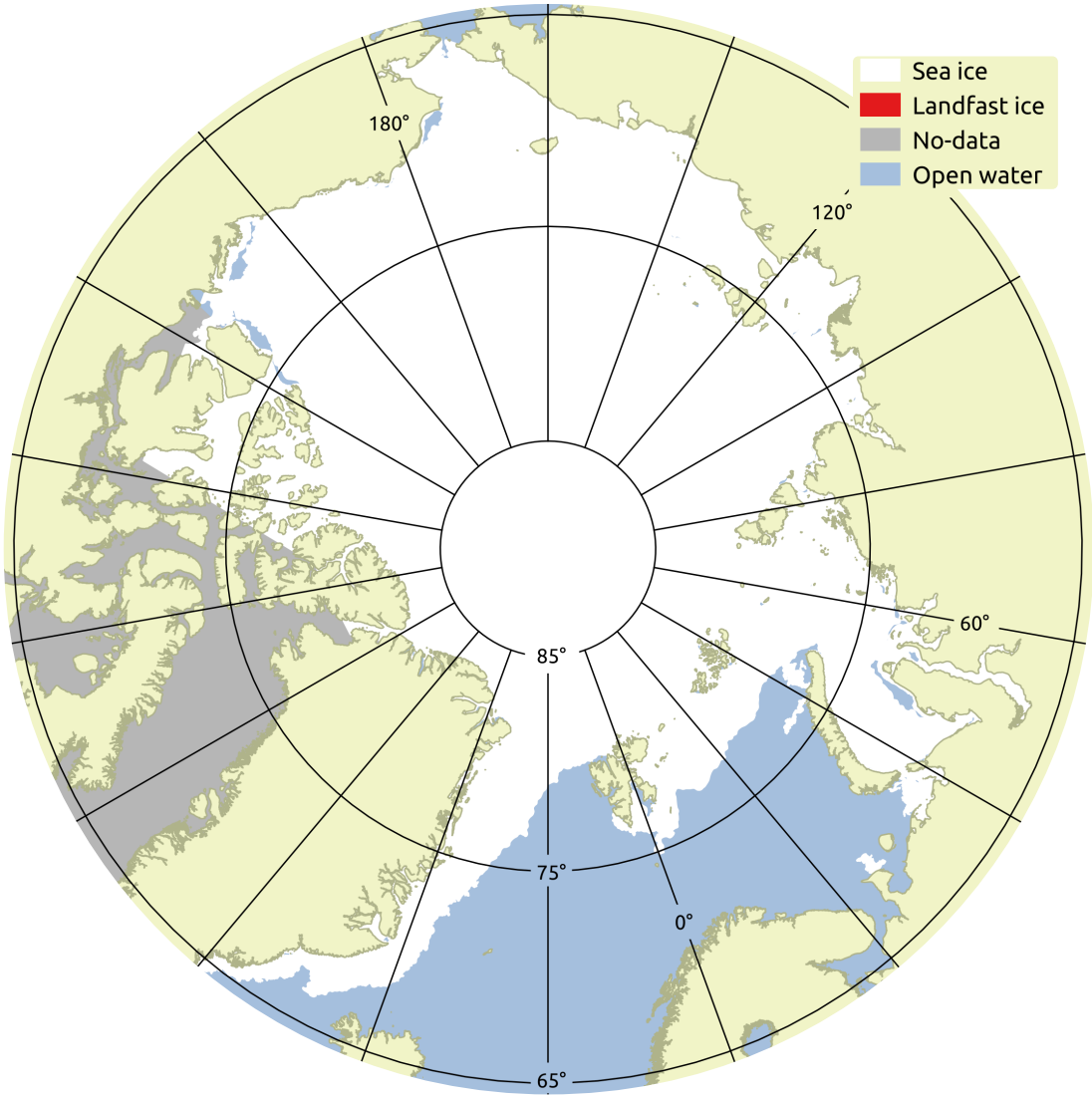
I. The importance of Arctic sea ice

- Sea ice regulates the climate (reflects about 80% of solar radiation)
- Important component of ecological system (provided habitat and hunting platform)
- Impacts human activity (navigation, exploration, indigenous people activity)

I. Forms of sea ice

- Based on stage of development - frazil ice, pancake ice, first-year, multi-year ice
- Based on deformation - level ice, deformed ice
- Based on ability to move - pack ice and landfast ice

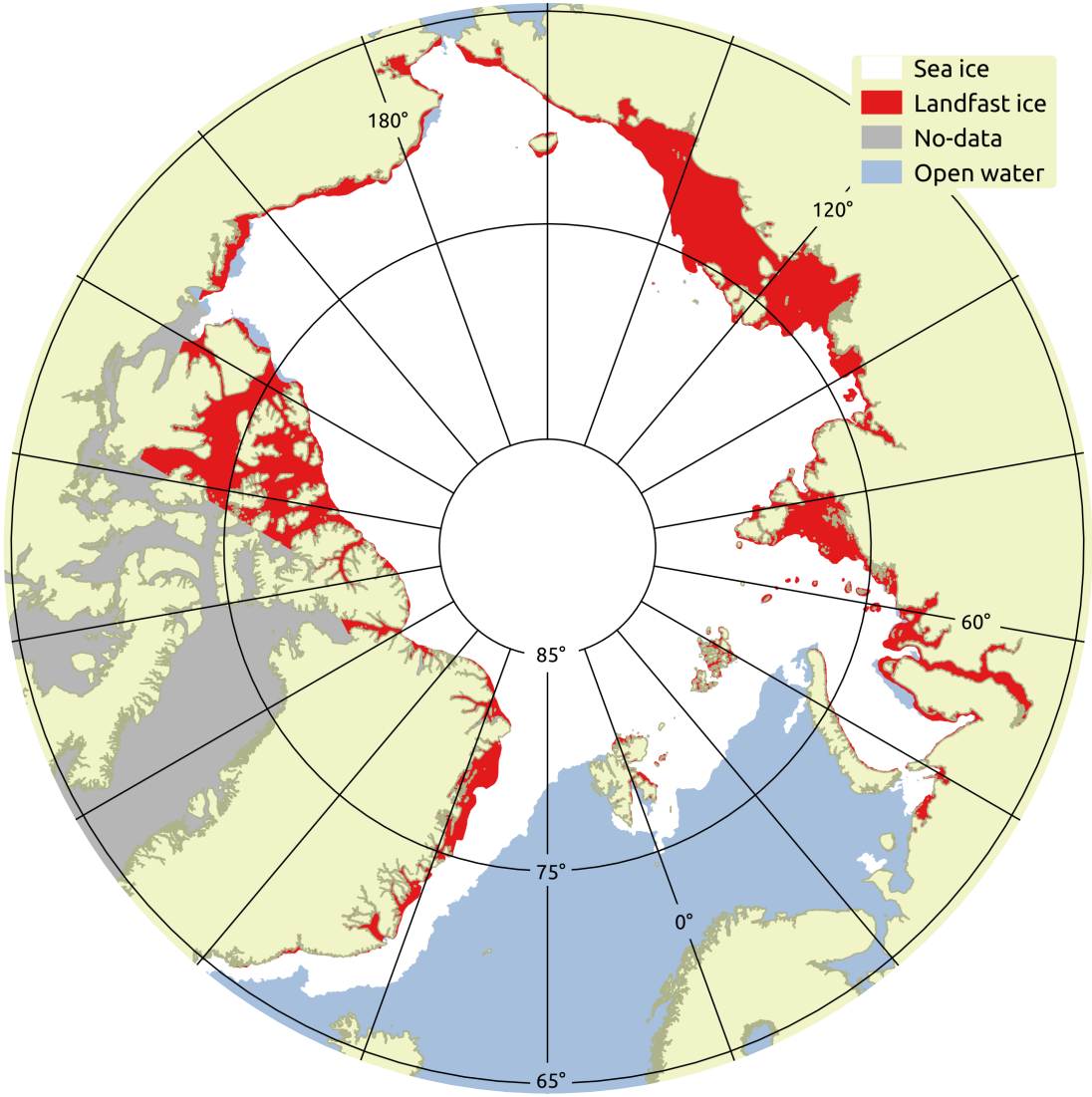
I. Arctic sea ice



May, 5, 2015

based on Operational Sea Ice Charts,
Arctic and Antarctic Research Institute, Russia (**AARI Charts**)

I. Arctic landfast ice



May, 5, 2015

based on AARI Charts

$\sim$ 13% of total sea ice extent

- affects state of the Arctic Ocean [Maqueda et al. 2004, Itkin et al. 2015]
- protects coasts from erosion [Rachold et al. 2000, Eicken et al. 2005]
- helps to maintain submarine permafrost [Rachold et al. 2000]
- affects human activity [Johannessen et al. 2005, Hughes et al. 2011, Weintrit 2013]

I. Landfast ice definition

*'Sea ice which **forms and remains fast along the coast**, where it is attached to the shore, to an ice wall, to an ice front, between shoals or grounded icebergs.'* World Meteorological Organization (WMO)

Operational sea ice mapping

expert's opinion (2-7 days)

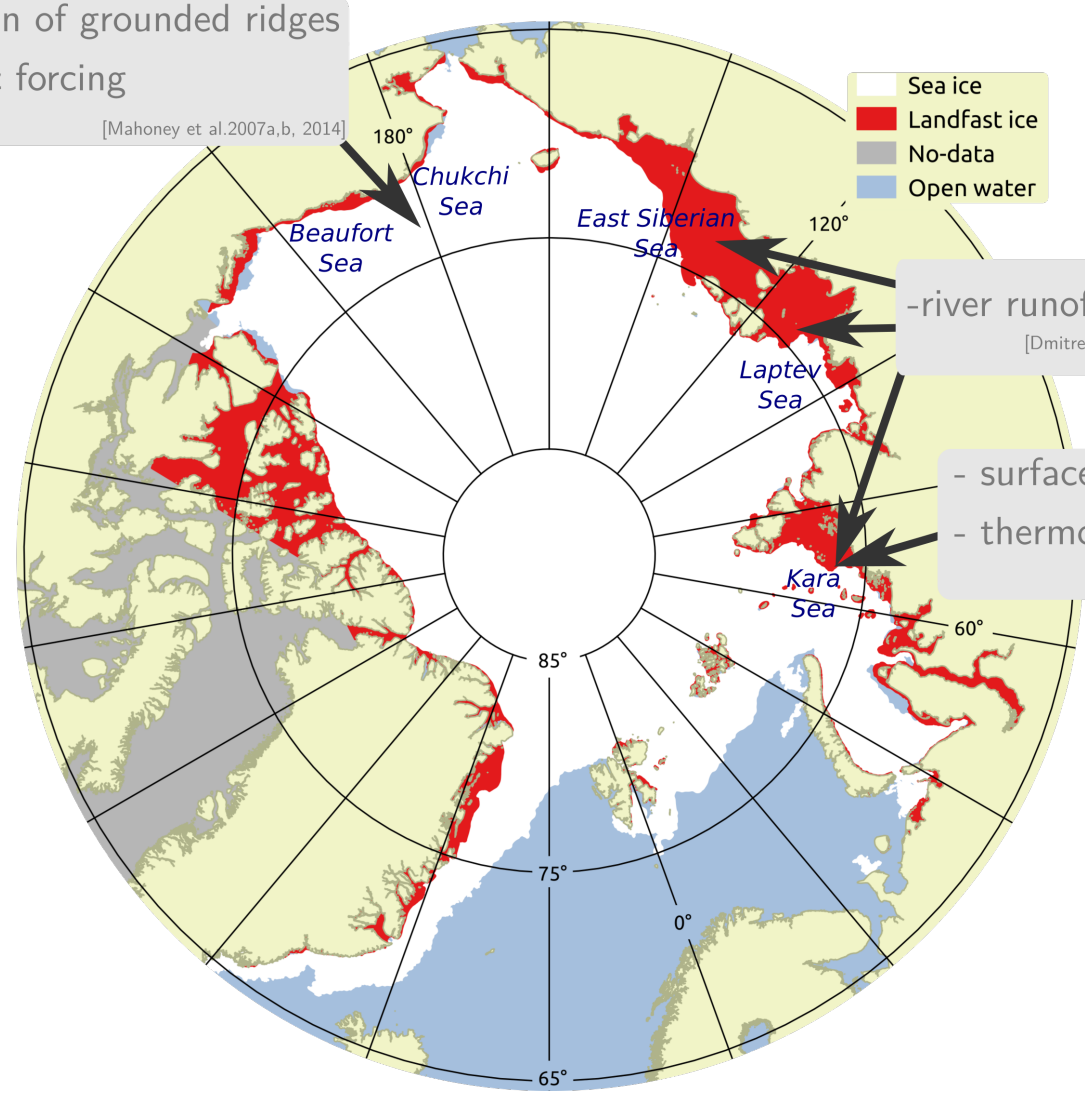
Semi-/automatic mapping

strict definition
(eg. 25 days[Mahoney et al.])

I. Factors controlling landfast ice extent

- alongshore chain of grounded ridges
- thermodynamic forcing

[Mahoney et al.2007a,b, 2014]



-river runoff

[Dmitrenko et al.1999]

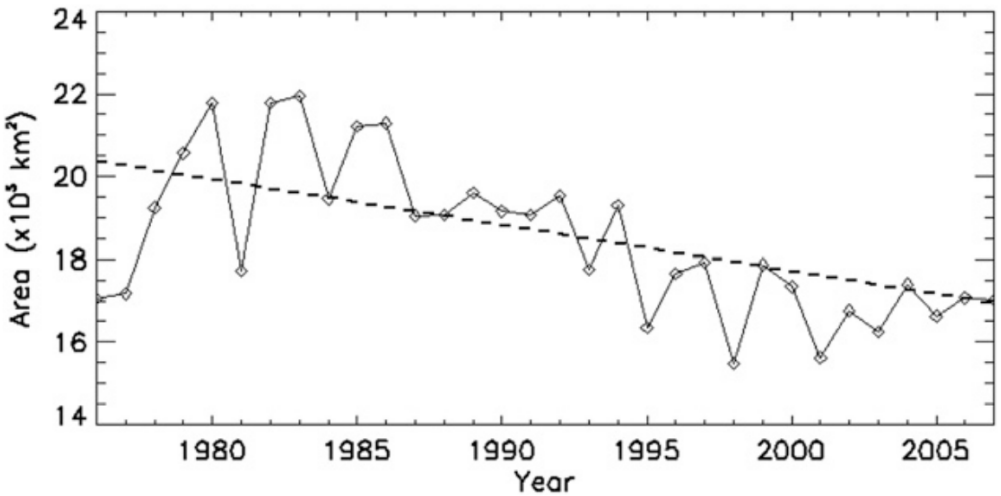
- surface wind
- thermodynamic forcing

[Divine et al.2004, 2005]

May, 5, 2015

based on AARI Charts

I. Changes in Arctic landfast ice



Arctic winter landfast ice extent

[Yu et al.2014]

- decrease in extent
- shorter landfast ice season

I.Objectives

Objective 1 - Annual variability

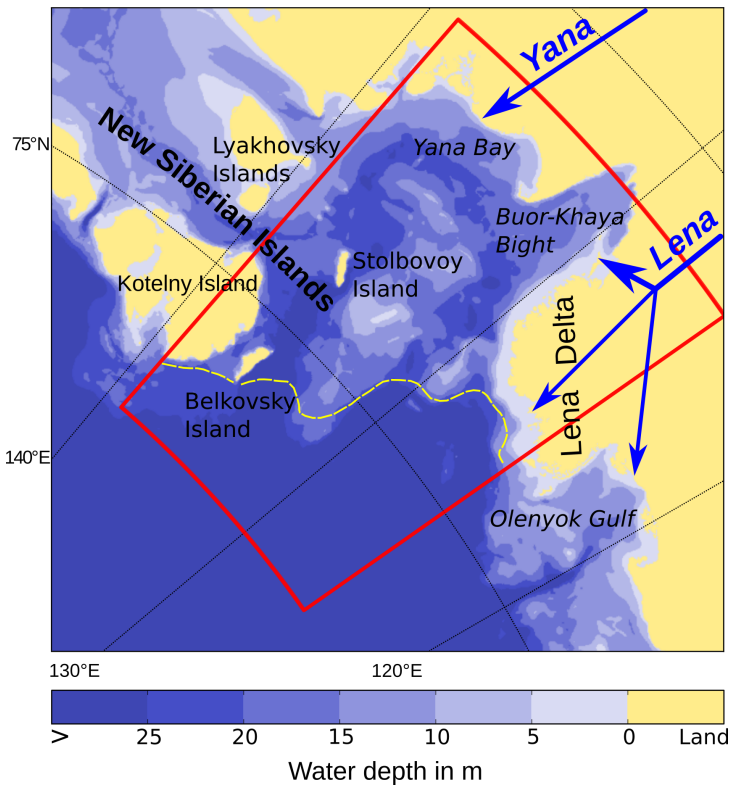
- To describe the **annual fast ice cycle** and reveal the **mechanisms driving the seasonal development** of fast ice.

Objective 2 - Interannual variability and changes

- To evaluate **changes** in fast ice cover **on interannual scales** and link them to climate processes.

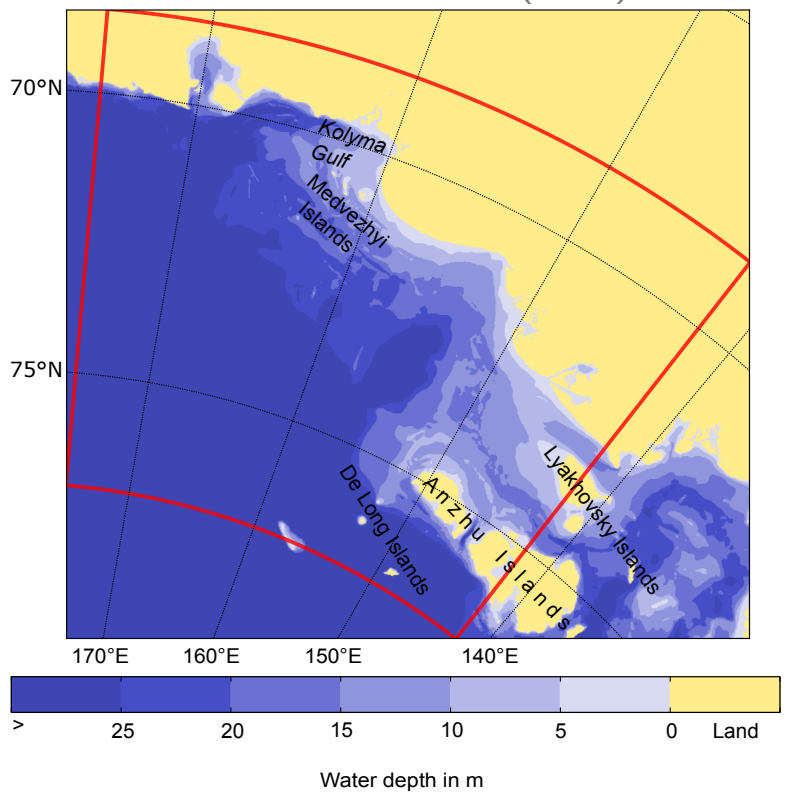
II. Regions of interest and fast ice information

Laptev Sea (LS)



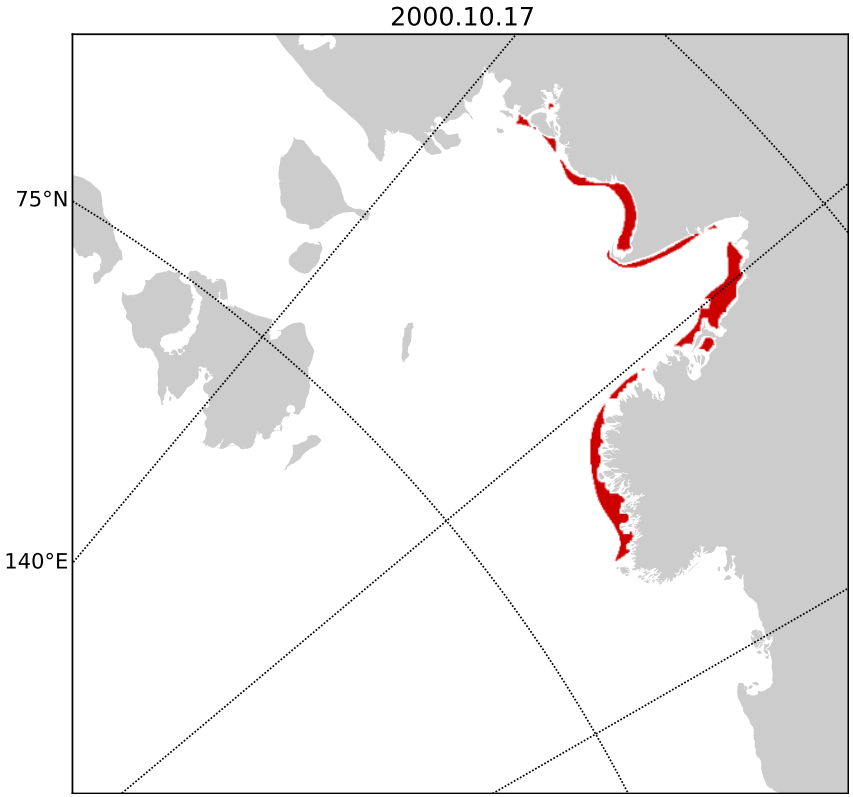
AARI charts, 1999-2013, weekly

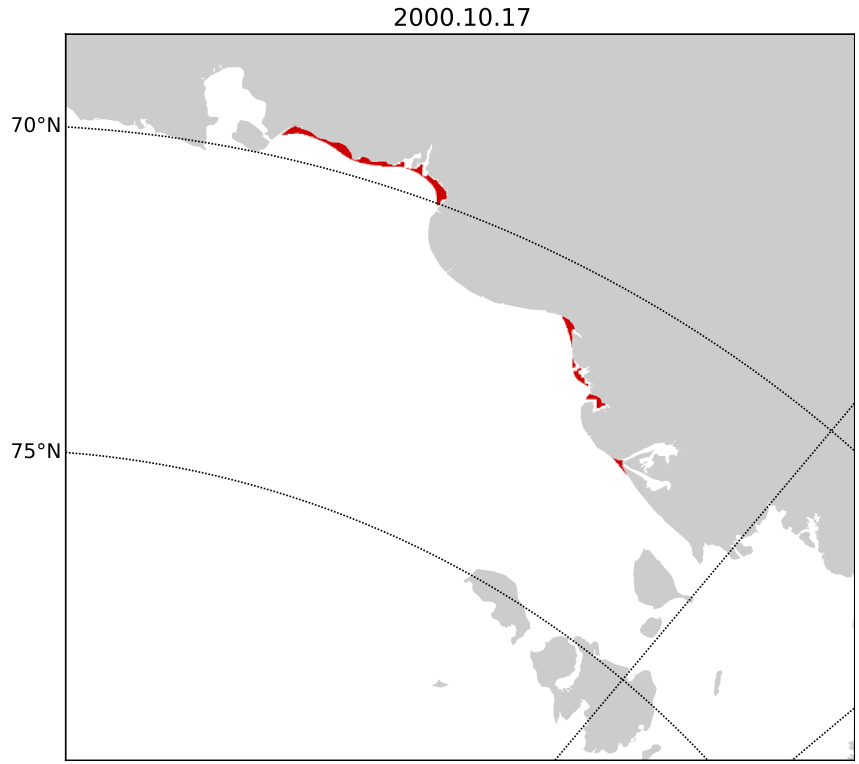
East Siberian Sea (ESS)



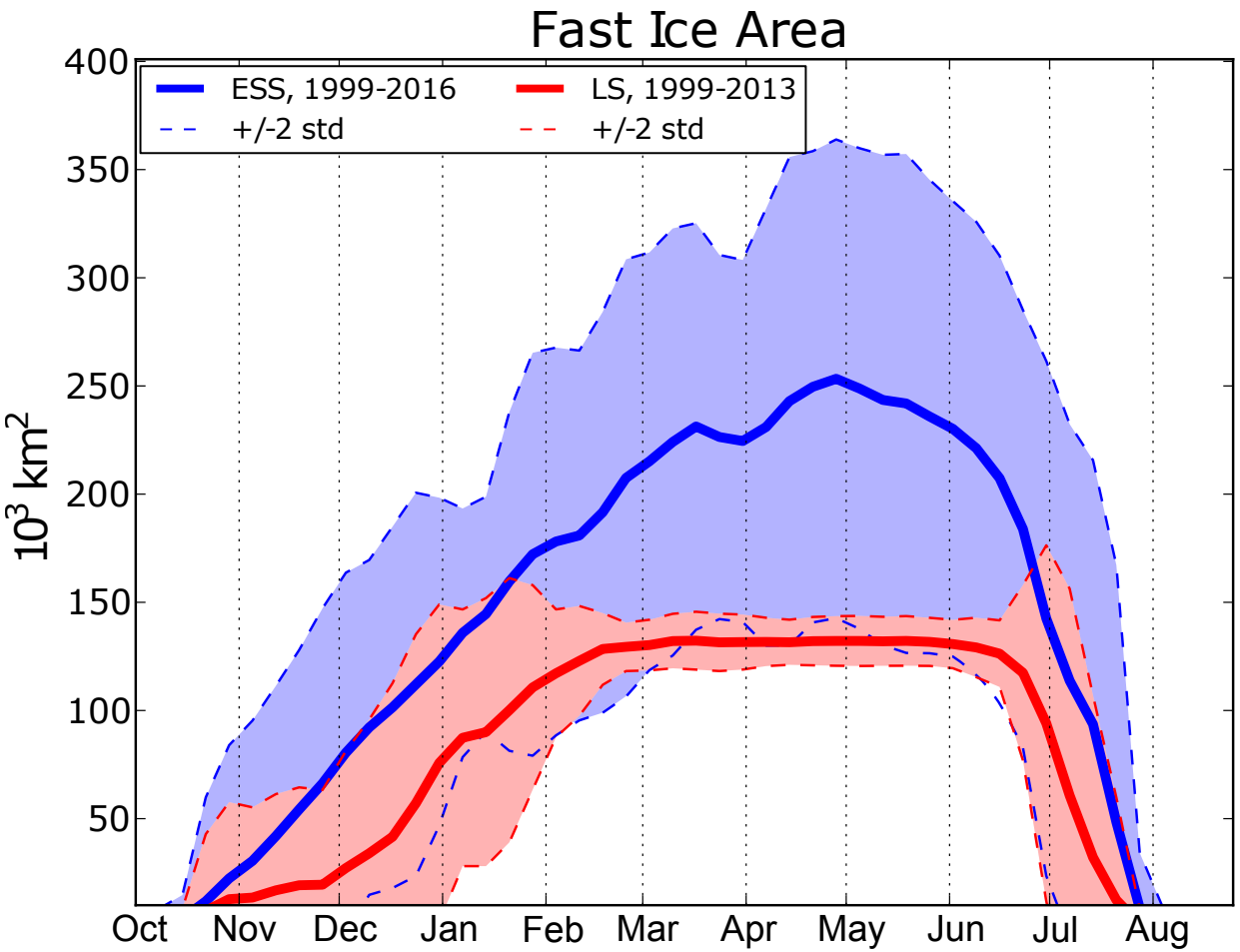
AARI charts, 1999-2013, weekly

II. Annual landfast ice cycle, 2000-2001





II. Mean annual landfast ice cycle



Interannual variability

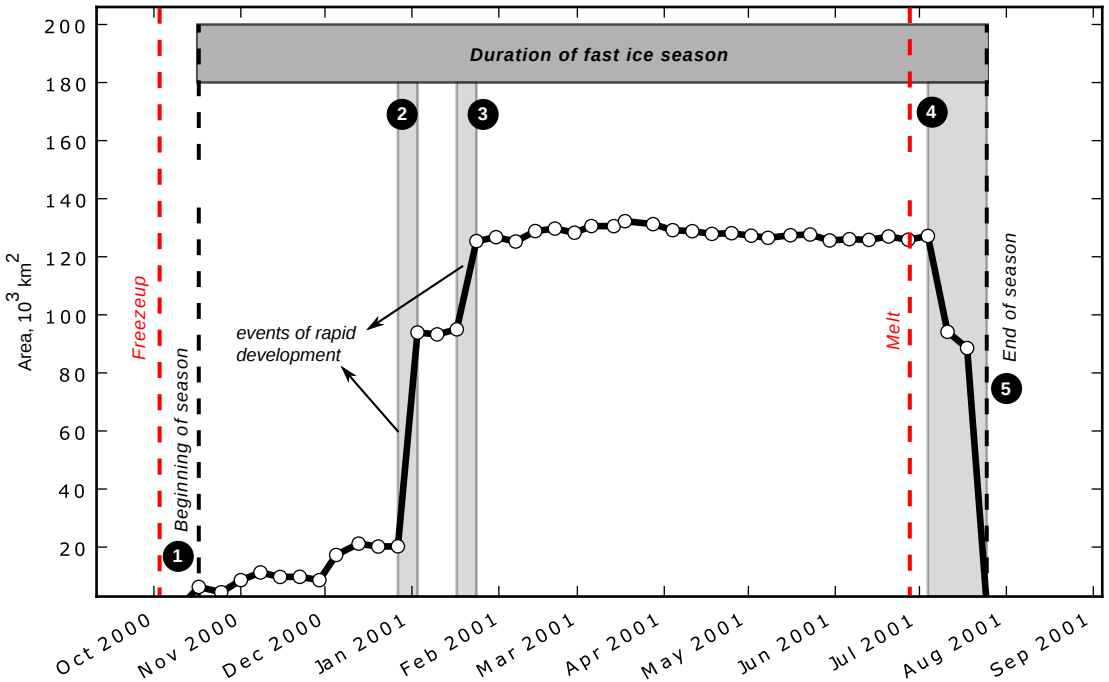
Laptev Sea:

- high in November-February
- low throughout the rest of season
- the lowest in winter

East Siberian Sea:

- the highest in winter

II.Key events of annual cycle



A typical annual landfast ice cycle for the Laptev Sea
[Selyuzhenok et al. 2015]

Laptev Sea,1999-2013

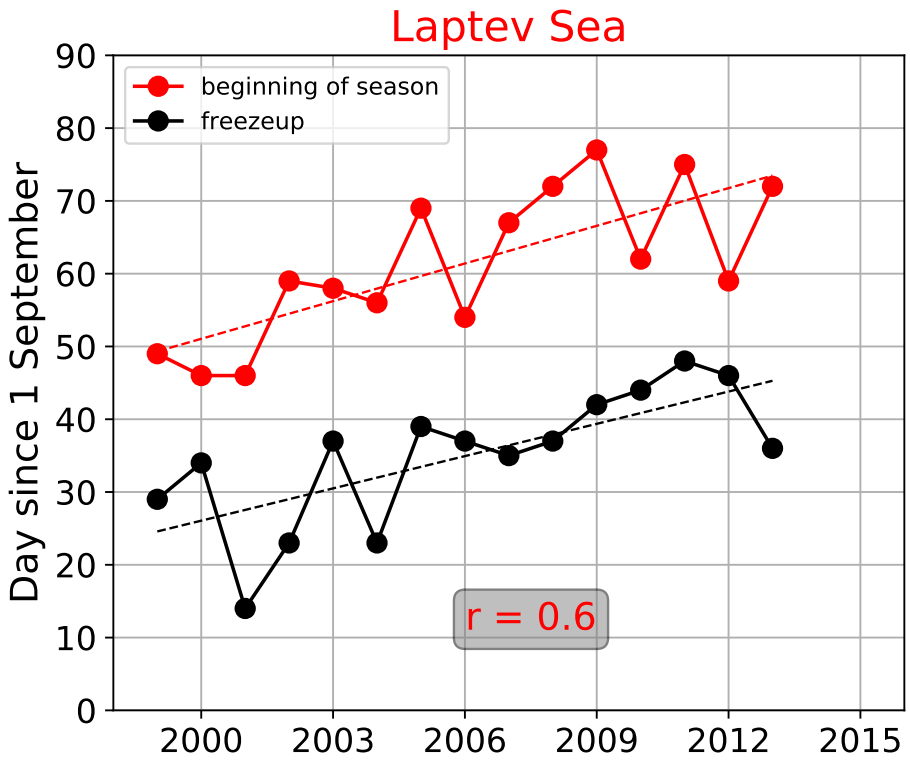
Time series of Key events 1-5

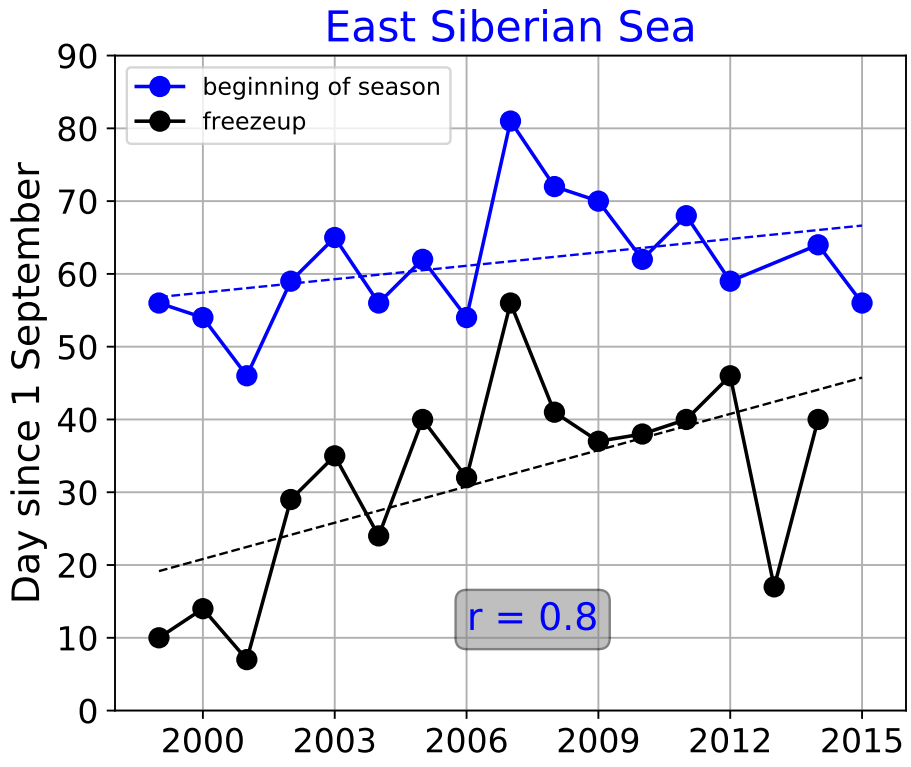
East Siberian Sea, 1999-2015

Time series of Key events 1,5

and Key events 2,3 for some seasons

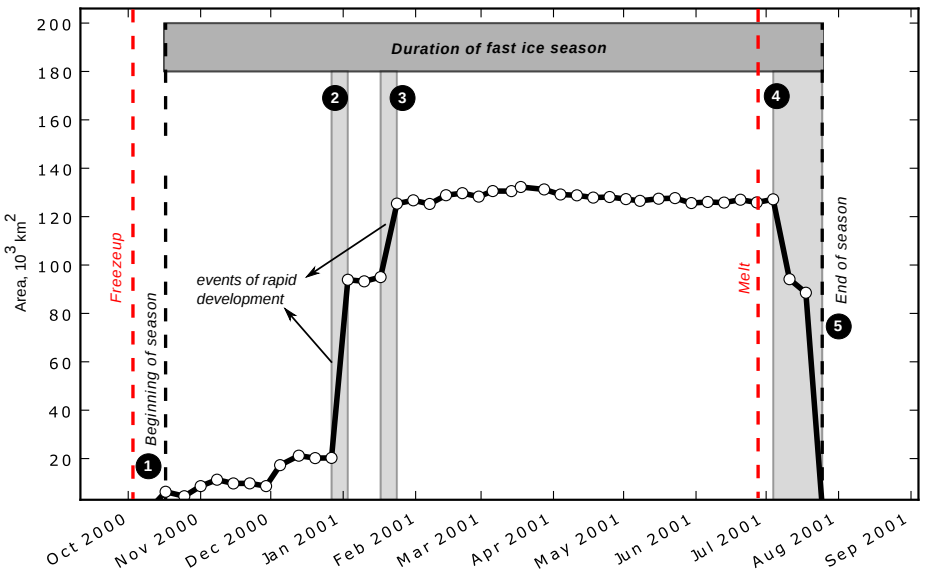
II.Beginning of landfast ice season

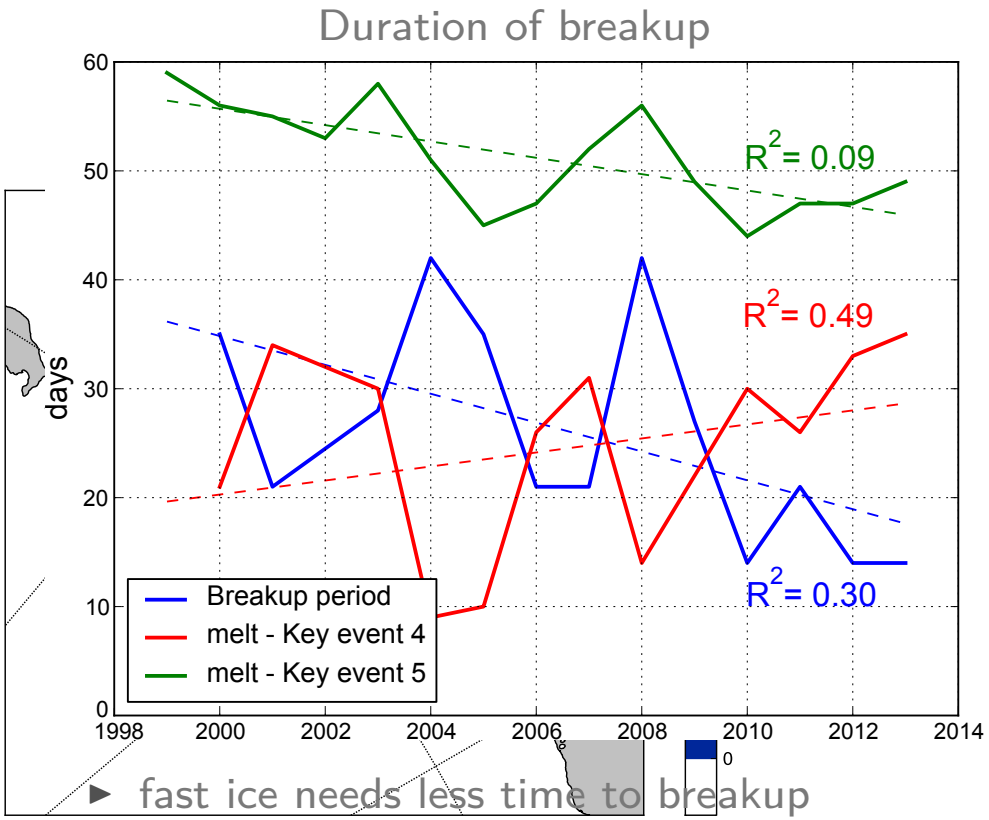




- 1.7 day/year ($p < 0.01$)

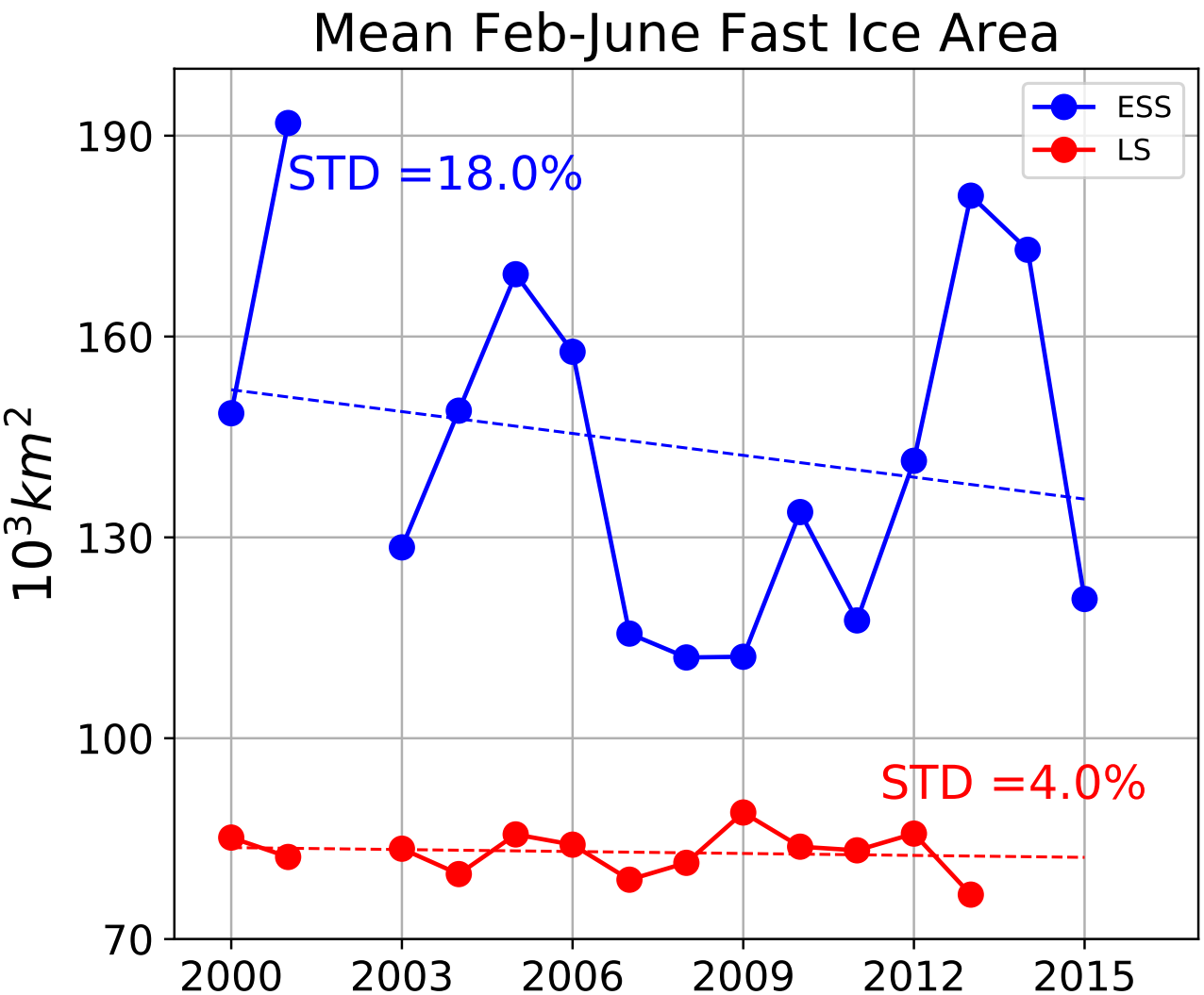
II.Duration of breakup: Laptev Sea





- fast ice needs less time to breakup
- more time between melt onset and beginning of breakup –¿ shorter period of breakup

II.Winter landfast ice extent



- no statistically significant chan
  winter areal extent

II. Annual variability and interannual changes

Laptev Sea

- high variation during fall development
- later formation
- shorter period of breakup
- shorter fast ice season (by 2.8 days/decade)
- no changes in winter extent

East Siberian Sea

- high variability of winter extent
- shorter fast ice season (by 1.5 day/year)

II. Annual variability and interannual changes

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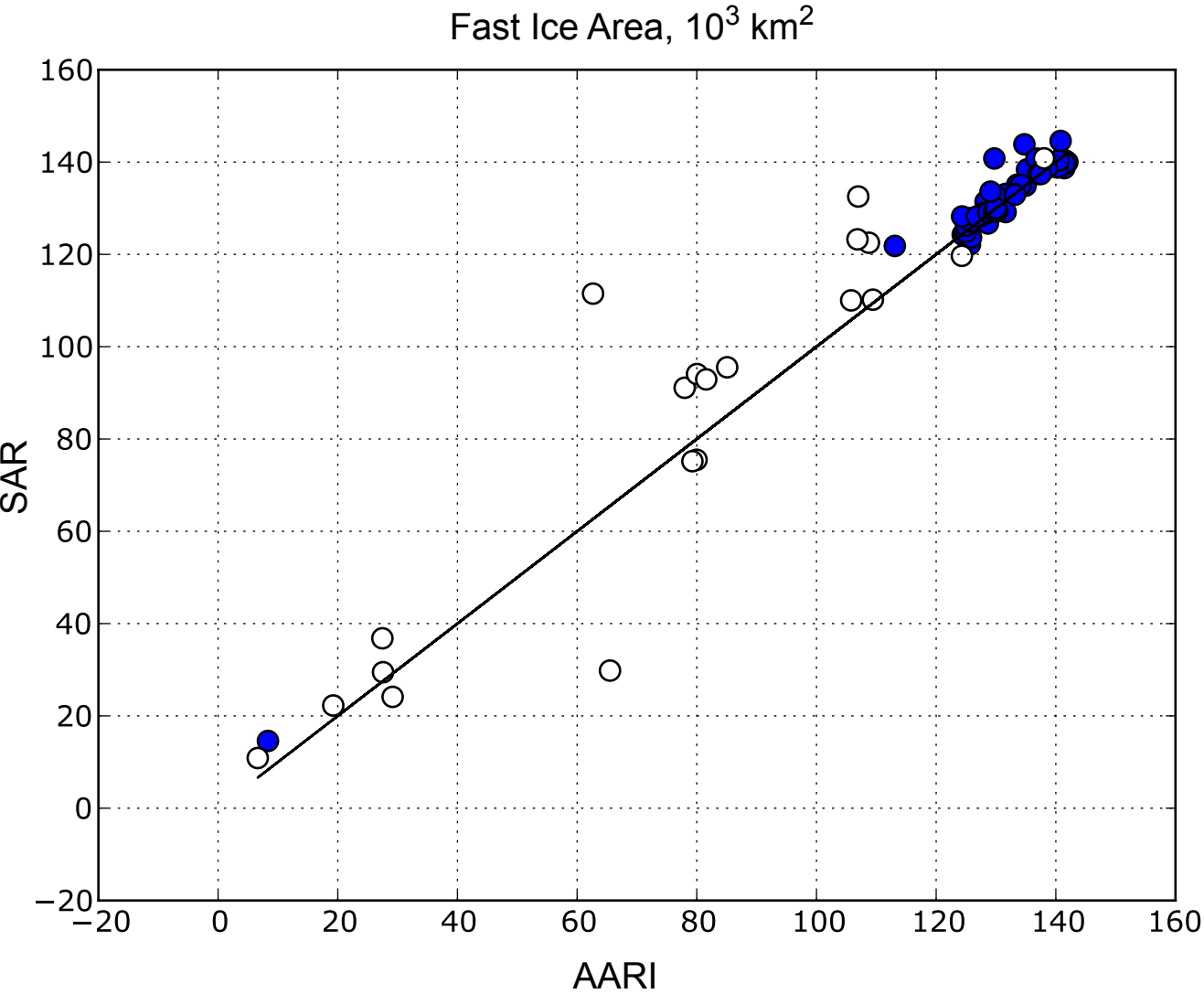
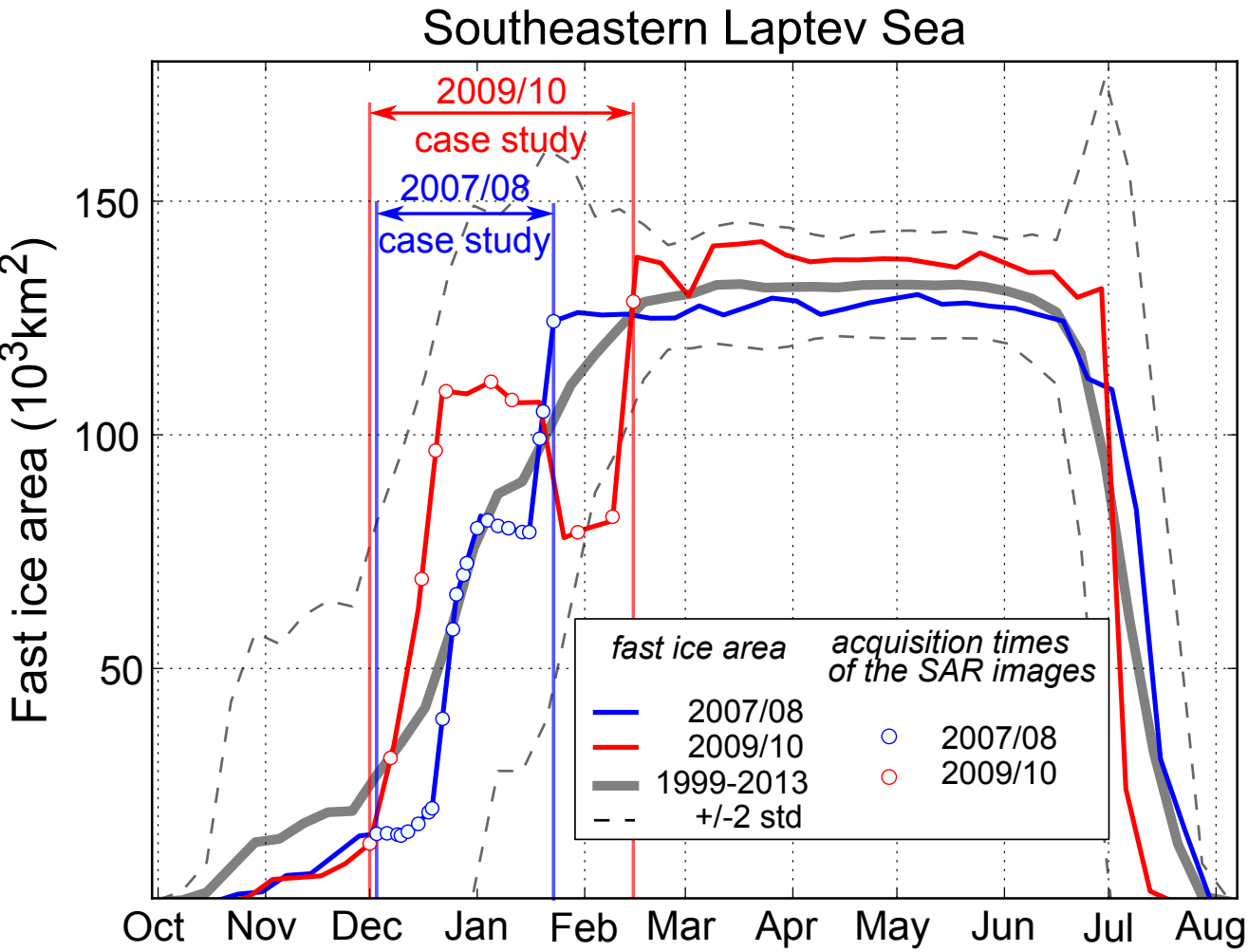
III.Laptev Sea : comparison of landfast ice information



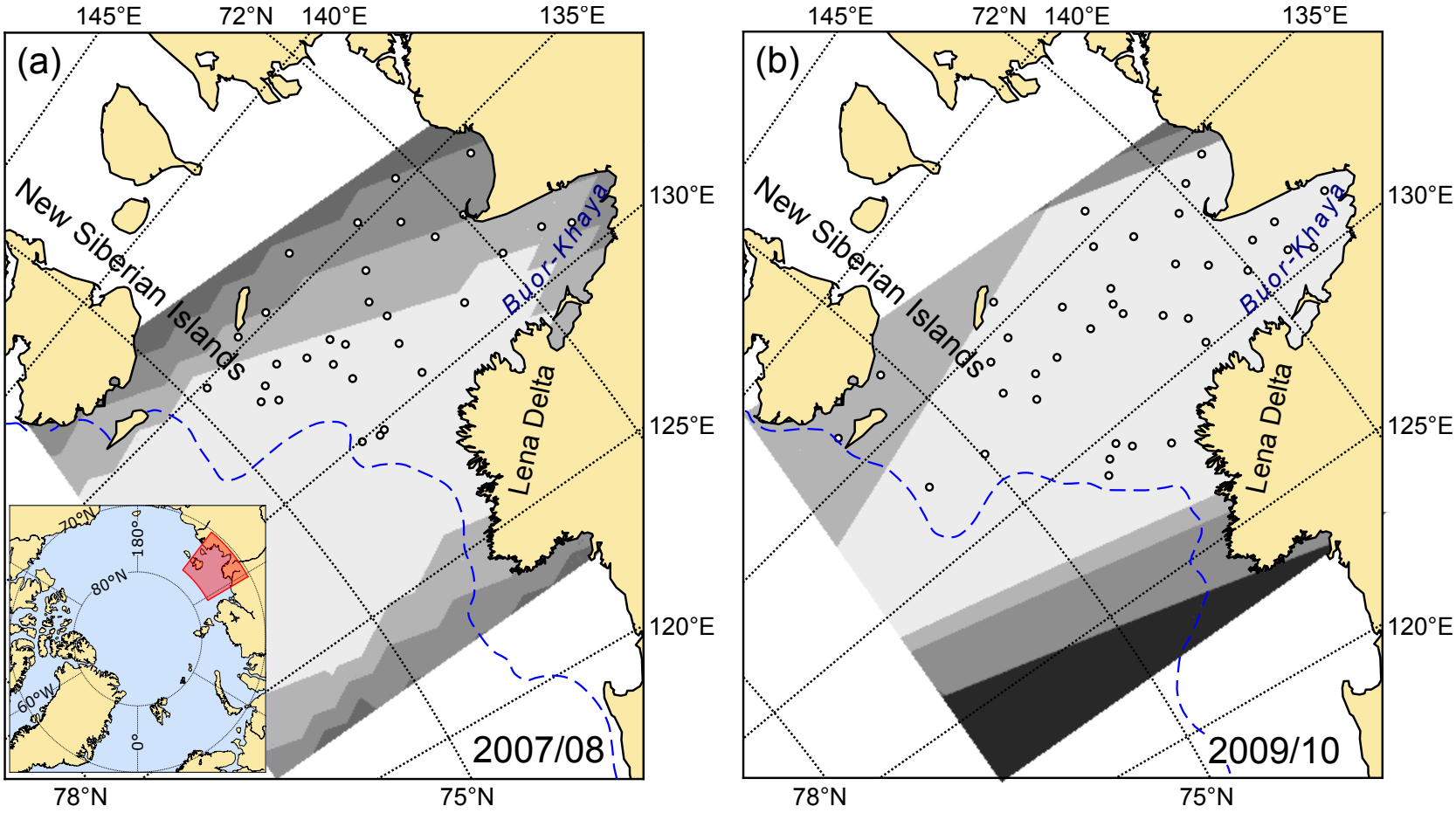
- fast ice mapped by two experts
- high deviations during develop

III.Laptev Sea : Case study of winter 2008/9 and 2009/10



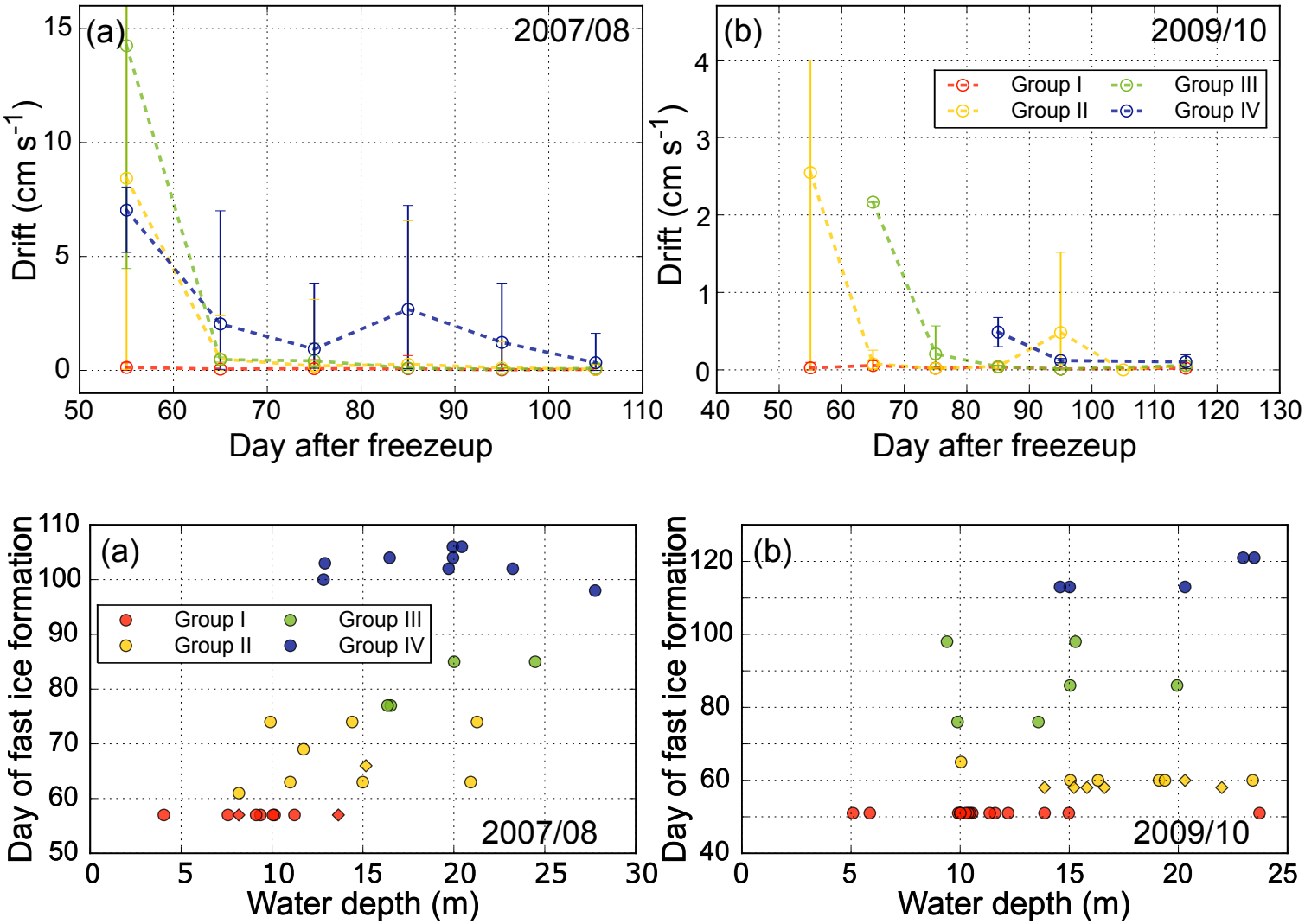
- SAR image every 2-14 days

III. Tracked sea ice features

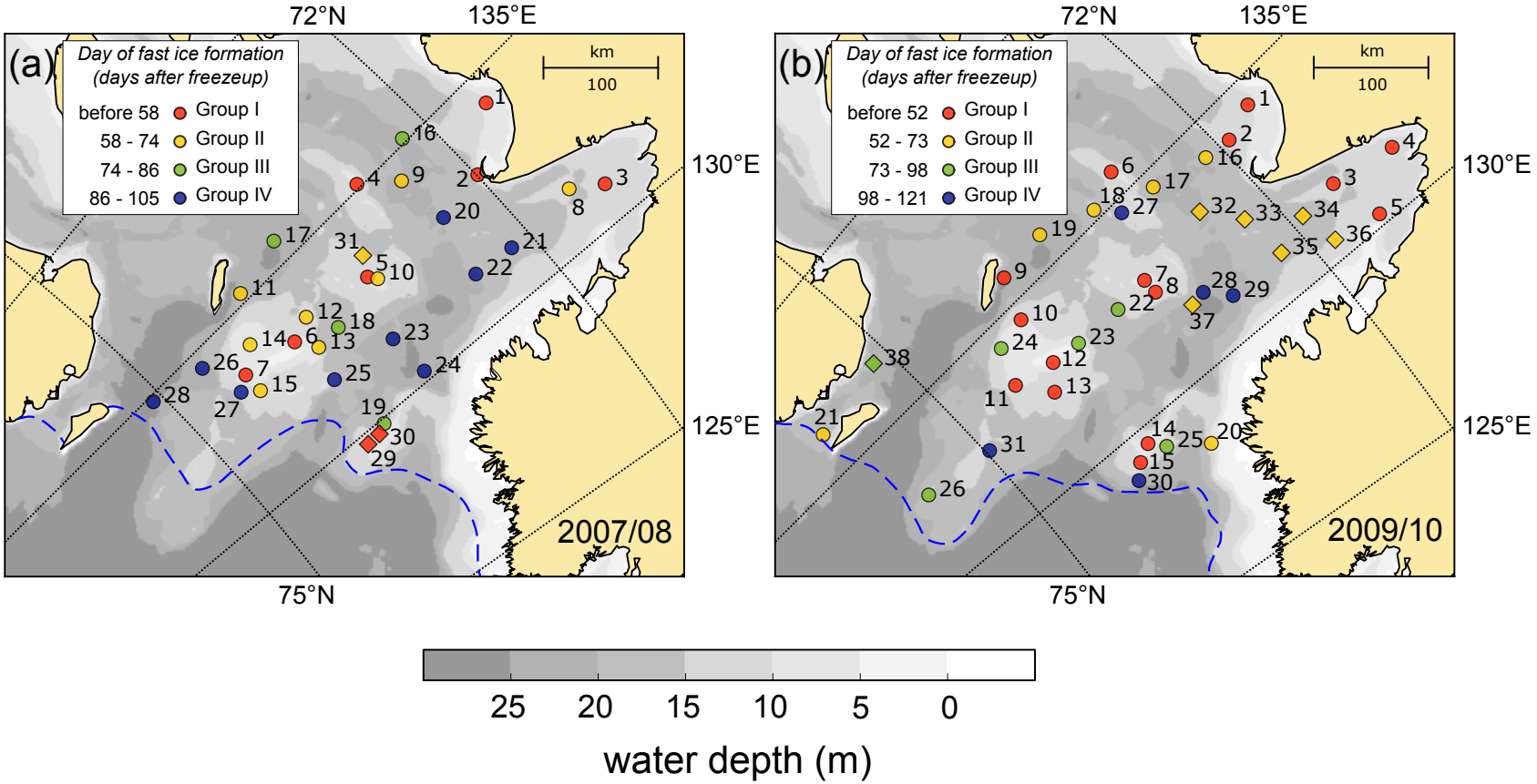


fast ice = drift speed <0 cm/s

III. Patterns of drift



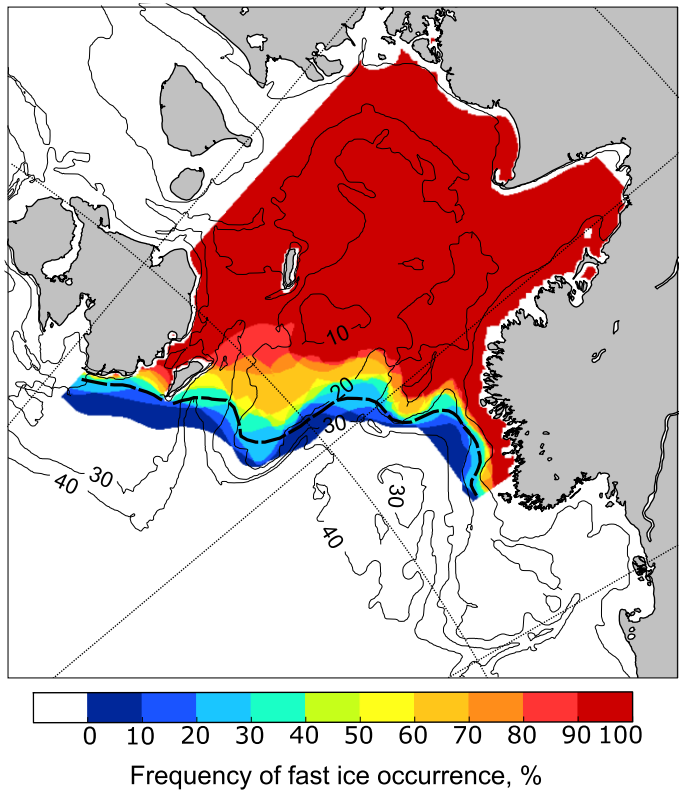
III. Final location of features

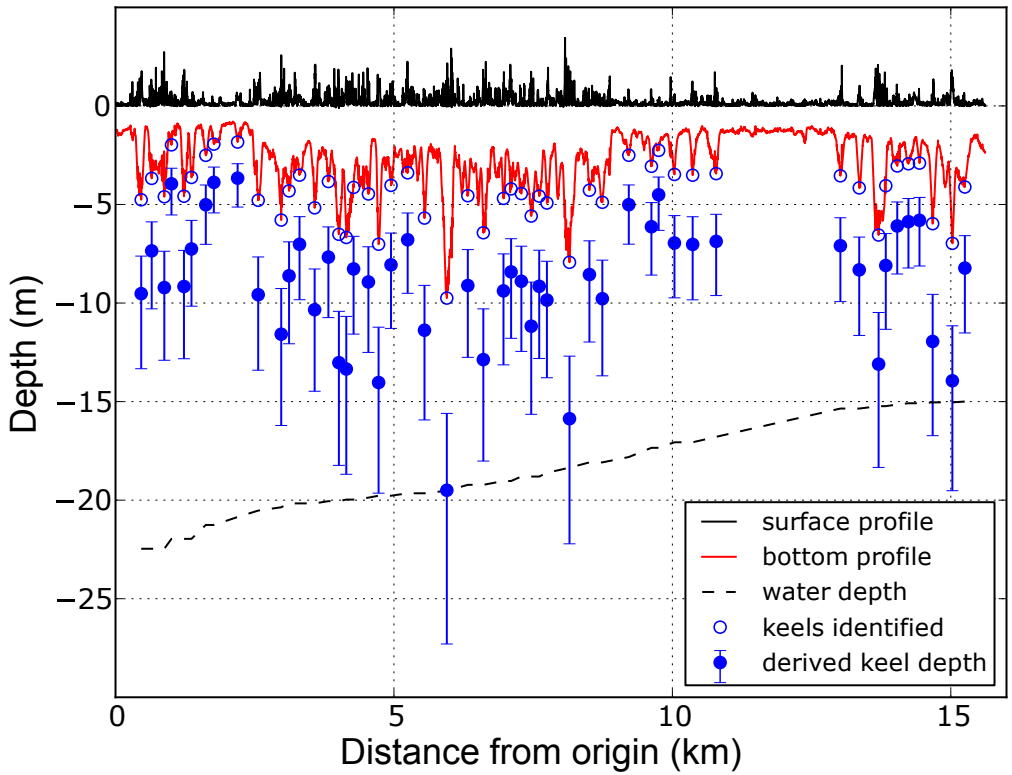


- relatively thin ice becomes grounded over the shoals (red circles)
- it serves as stabilizing points for surrounding sea ice
- low variations in winter extent predefined by the bathymetry

III.Deep sea ice ridges

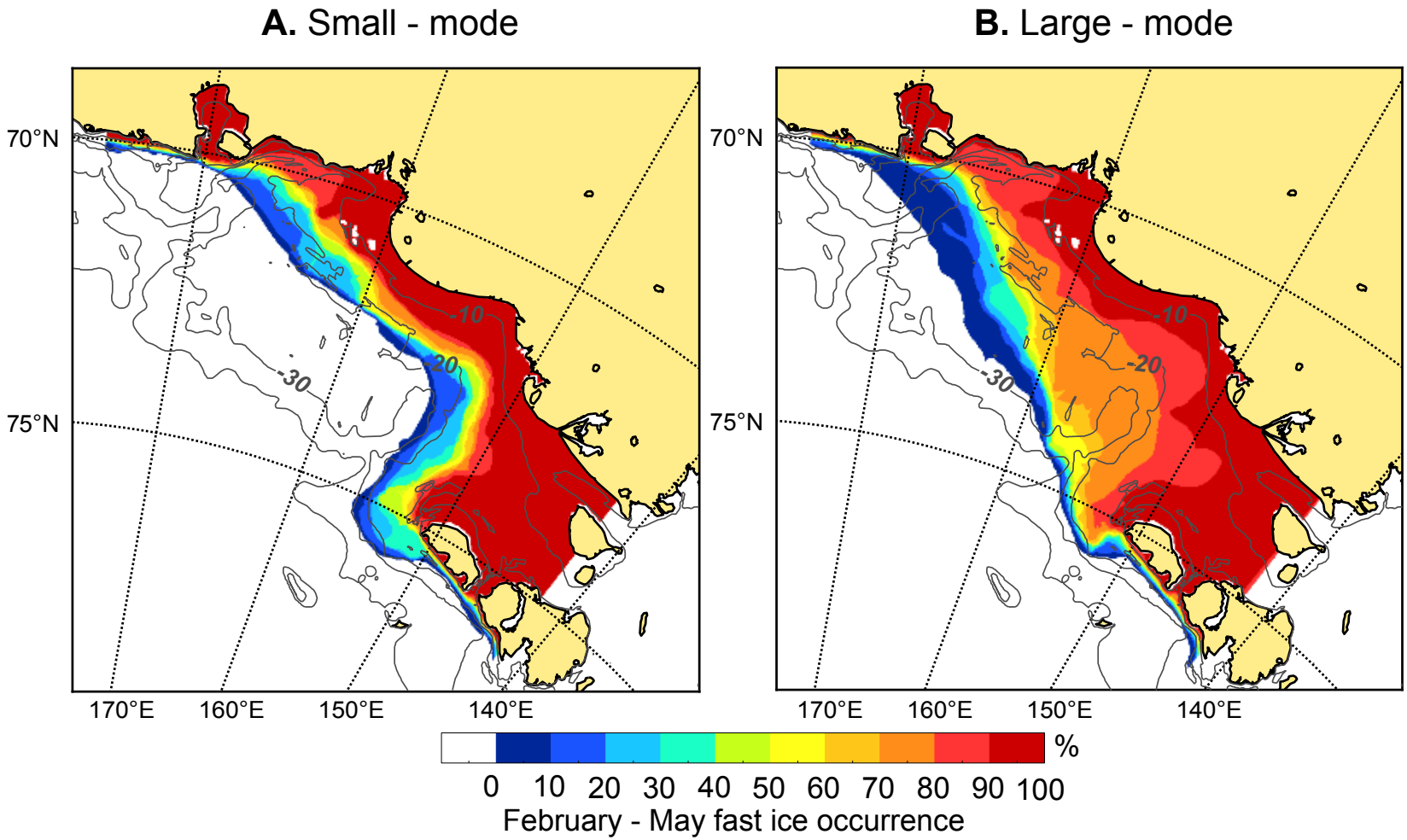
End of Rapid Development





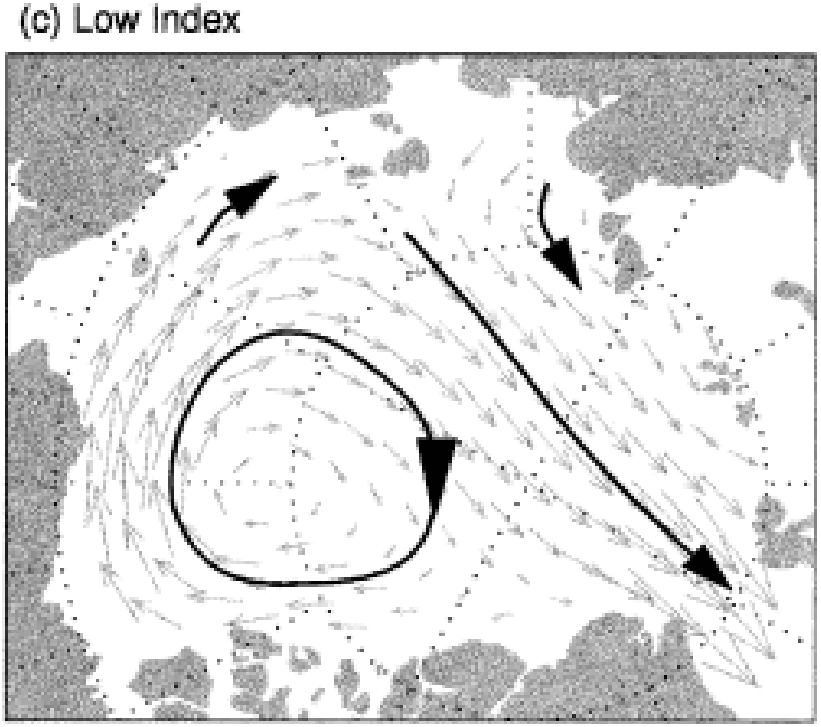
- variations in winter fast ice edge is likely controlled by grounding of deep ice ridges

III.East Siberian Sea Fast ice modes

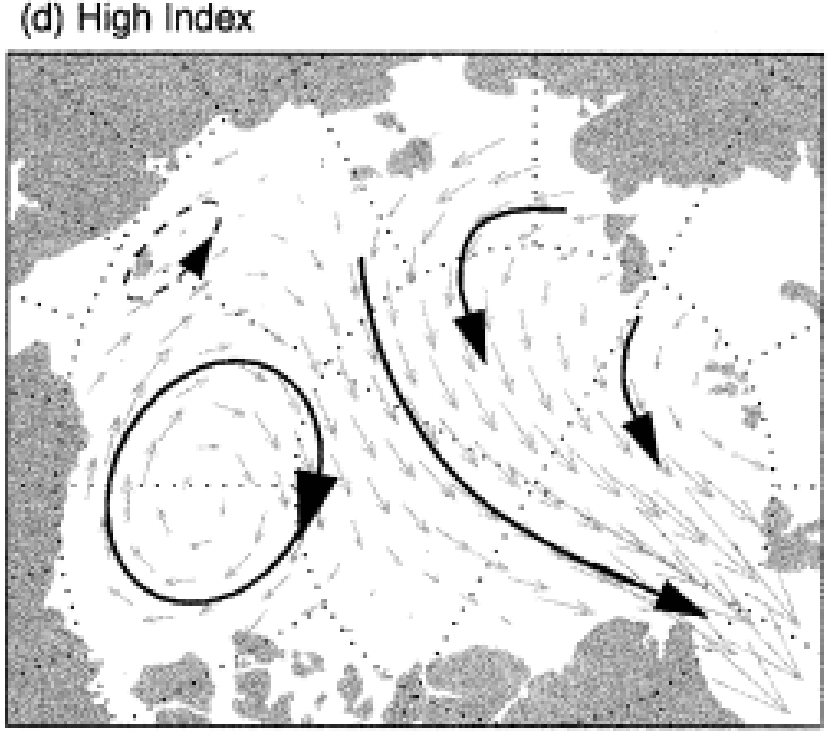


III. Arctic Oscillation index

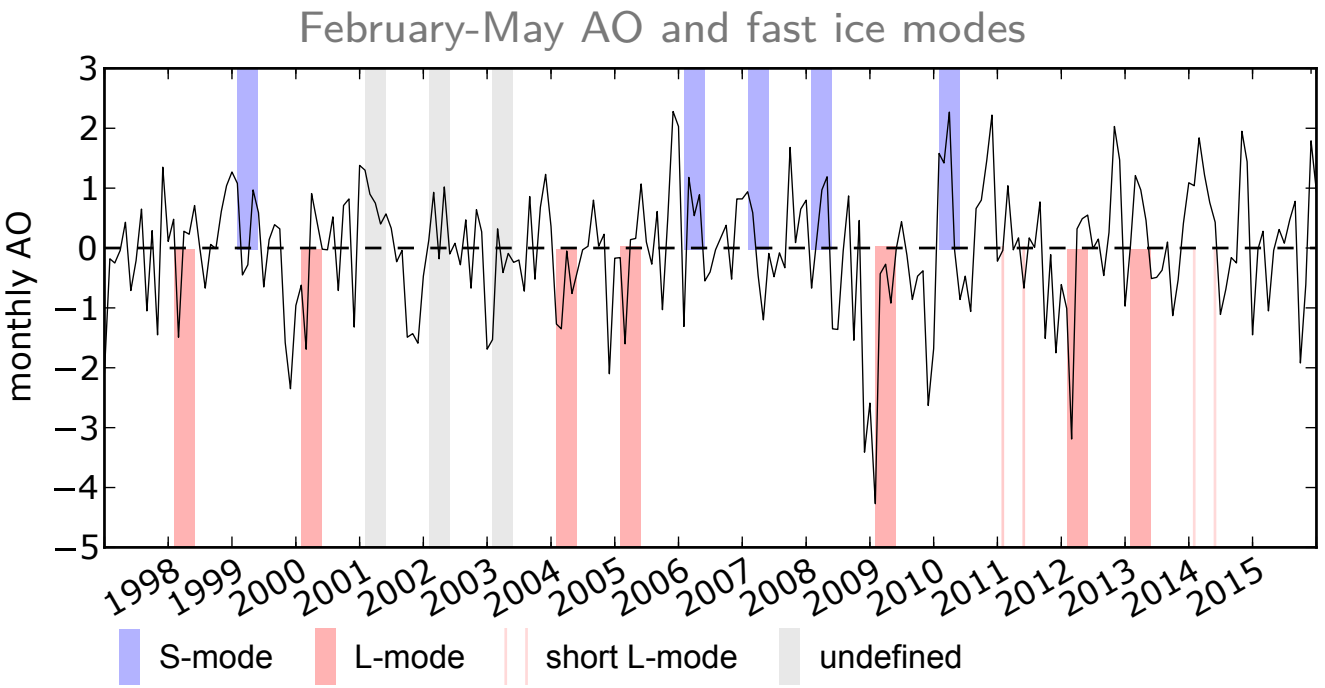
Positive Arctic Oscillation index (AO)



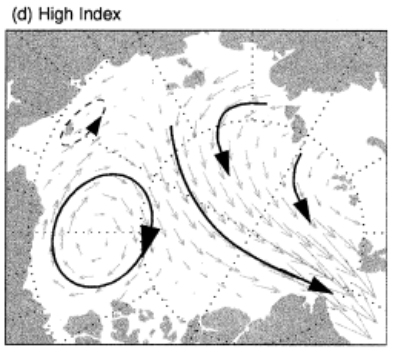
Negative Arctic Oscillation index (AO)



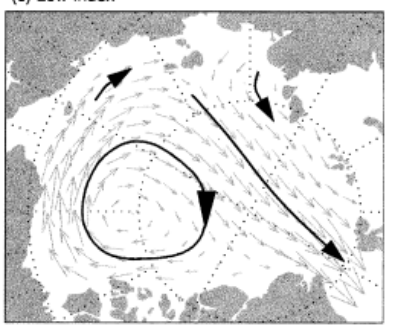
III.East Siberian Sea fast ice modes



Negative AO



Positive AO



Hypothesis

Sea ice import during AO+ leads to formation thick ice ridges, which become grounded and stabilize fast ice in L-mode.

Summary

Objective 1 - Annual variability

- Annual fast ice cycle described with Key events
- Sea ice grounding is a key process in annual fast ice development

Objective 2 - Interannual variability and changes

- Tendency towards shorter fast ice season (LS - 2,8 days/year, ESS - 1.5 days/year)
- No changes in winter fast ice extent
- Shorter time required for fast ice to breakup in summer