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

Valeria Selyuzhenok

Approved Dissertation Committee
Prof. Dr. R"udiger Gerdes
Prof. Dr. Joachim Vogt
Dr. Thomas Krumpen

Jacobs University Bremen

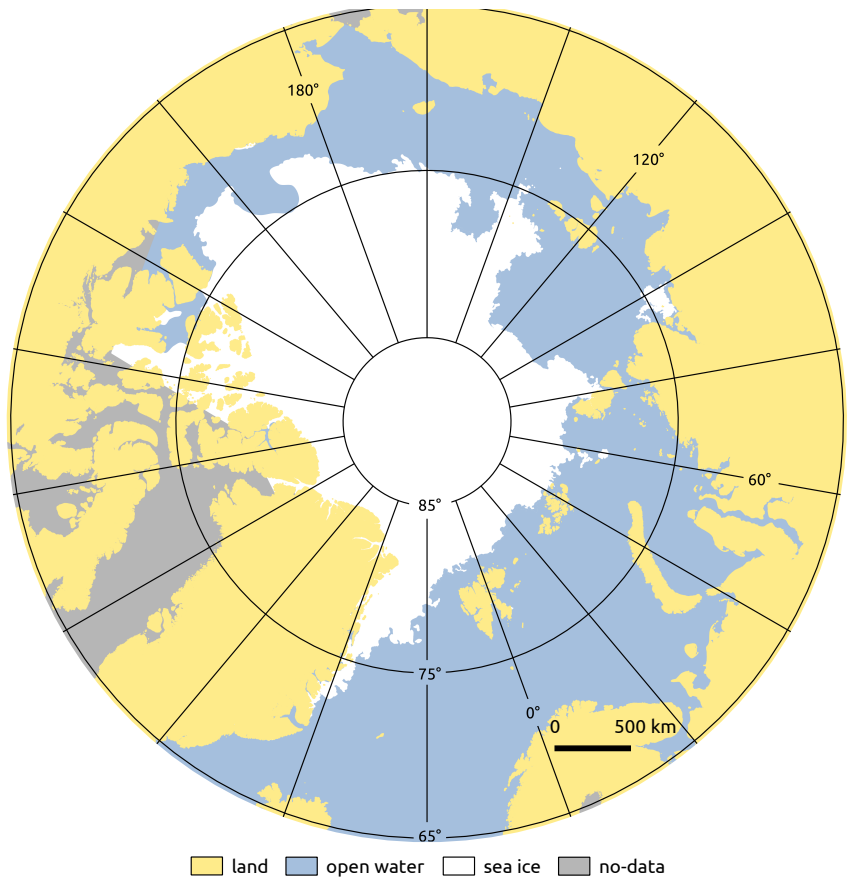
October 3, 2017

Outline

I. Arctic sea ice

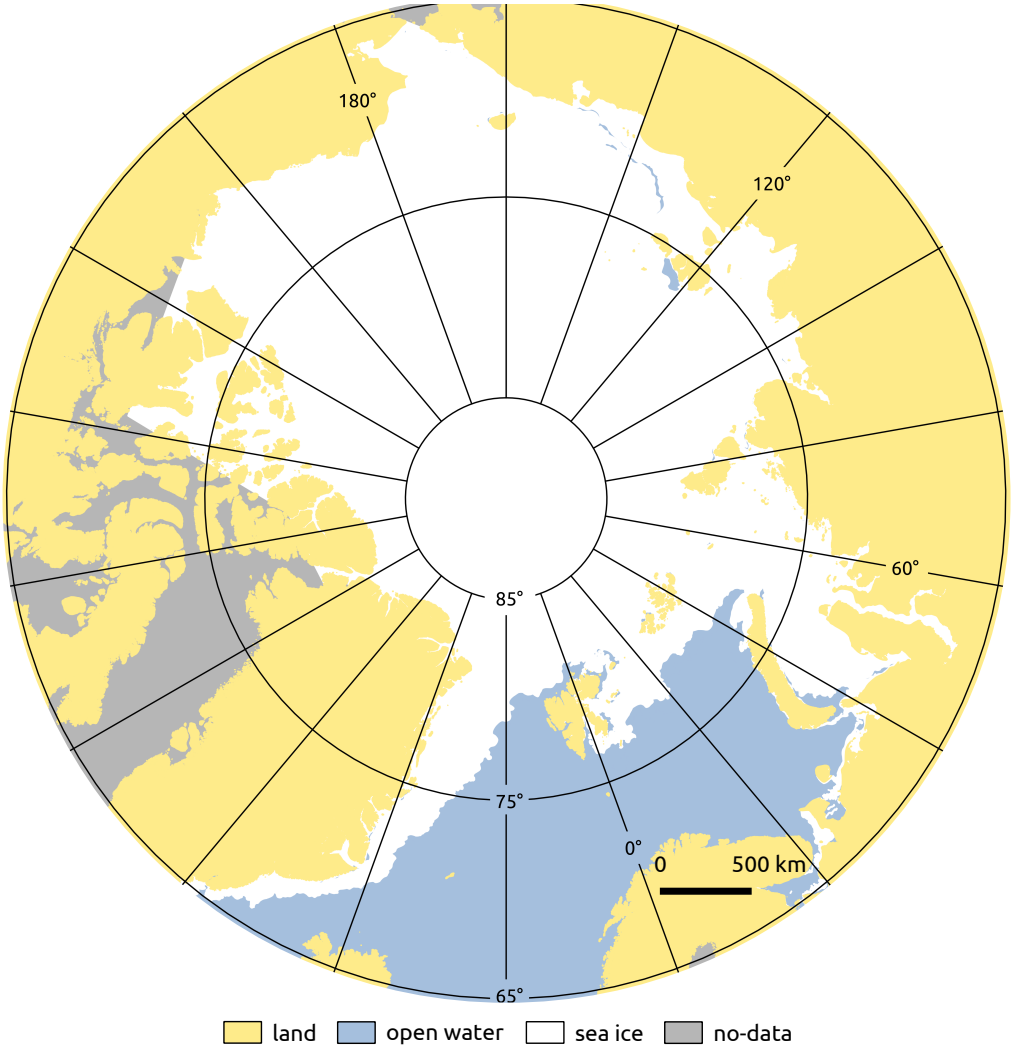
17 March 2015

10 September 2015



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

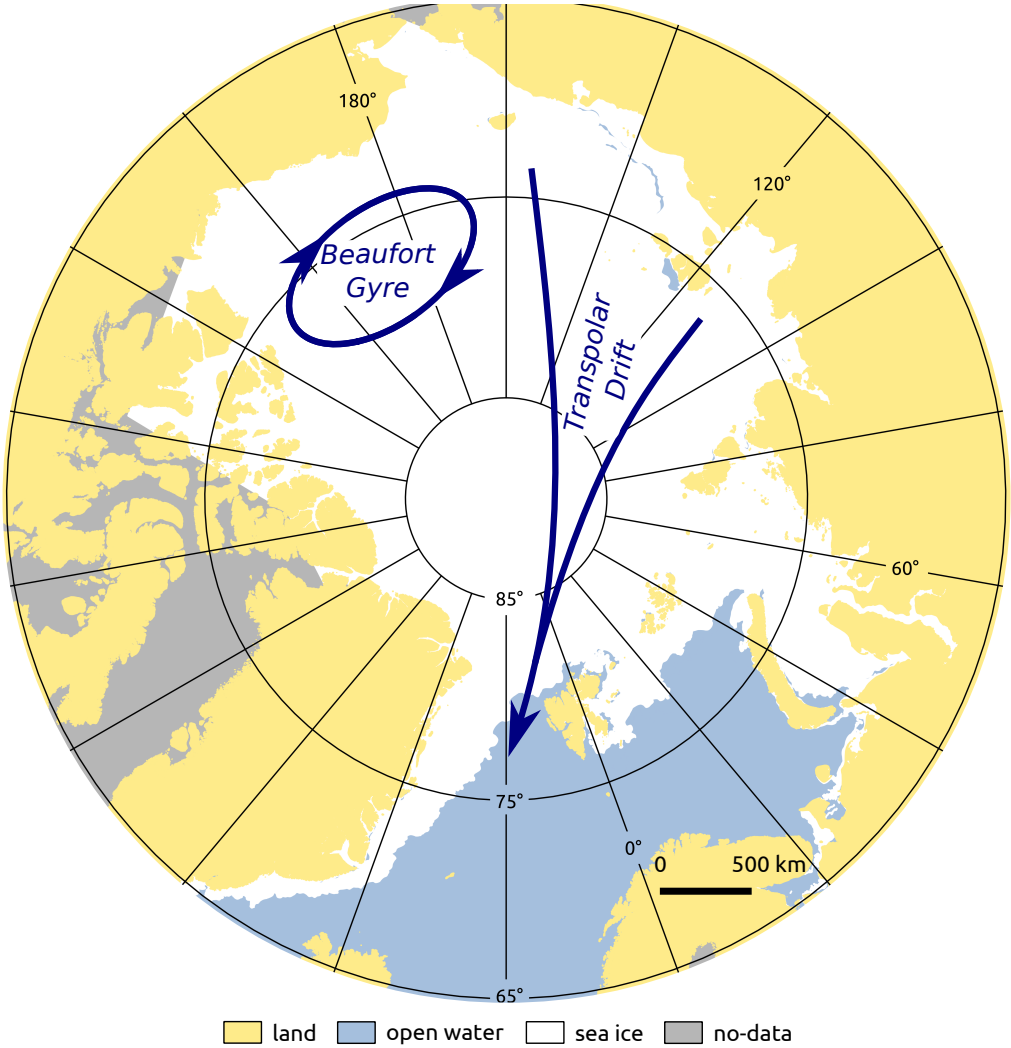
I. The importance of Arctic sea ice



17 March 2015 (AARI Charts)

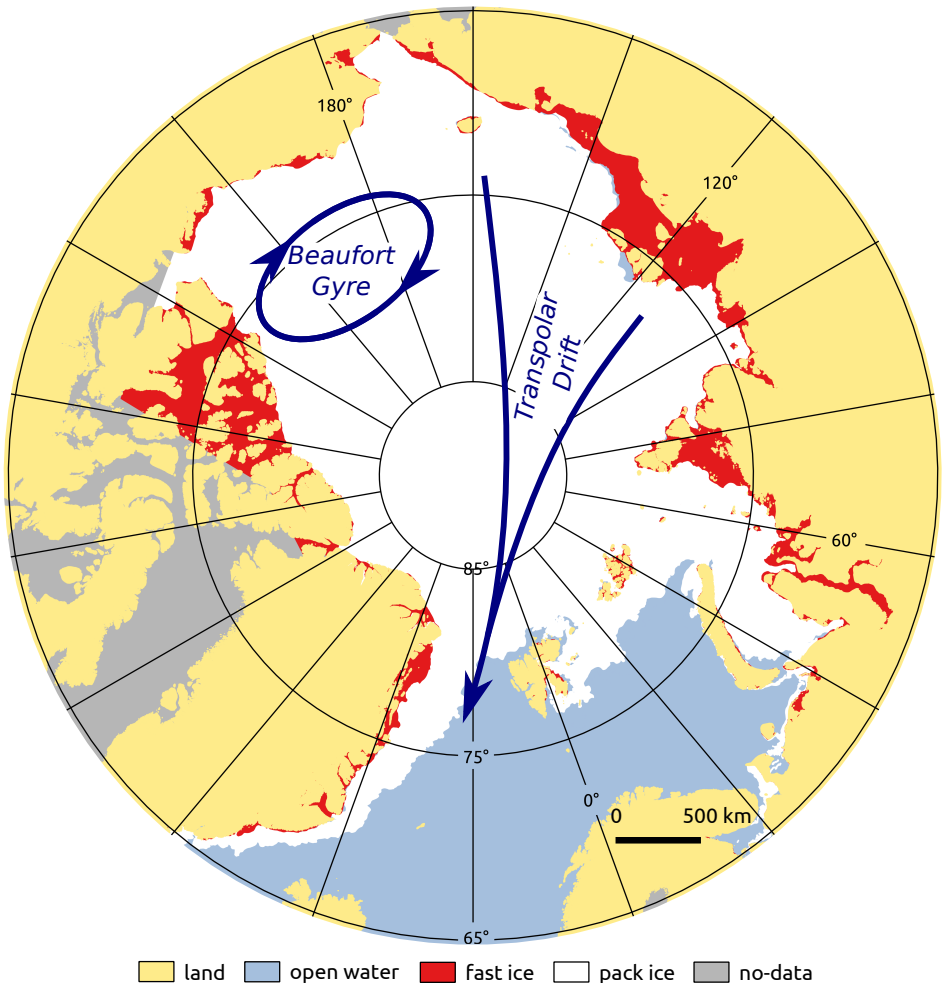
- **Climate system:**
  reflects about 80% of solar radiation
- **Ecosystem:**
  provides habitat and hunting platform
- **Human activity:**
  navigation, exploration, indigenous people activity

I. Arctic fast ice



17 March 2015 (AARI Charts)

I. Arctic fast ice



17 March 2015 (AARI Charts)

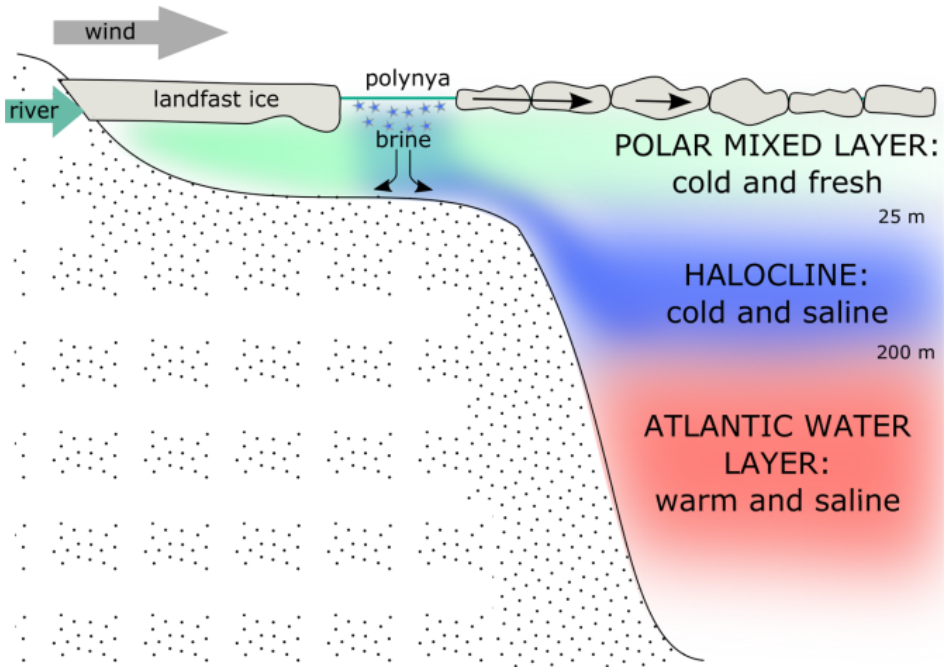
Definition

Motionless and adjustent to the shore

- **Operational charts** - experts opinion (2-7 days, e.g. AARI charts)
- **Remote sensing techniques** - time interval between images (e.g. 25 days - Mahoney et al. 2005)

$\sim$ 13% of total sea ice extent

I.Importance of Arctic fast ice

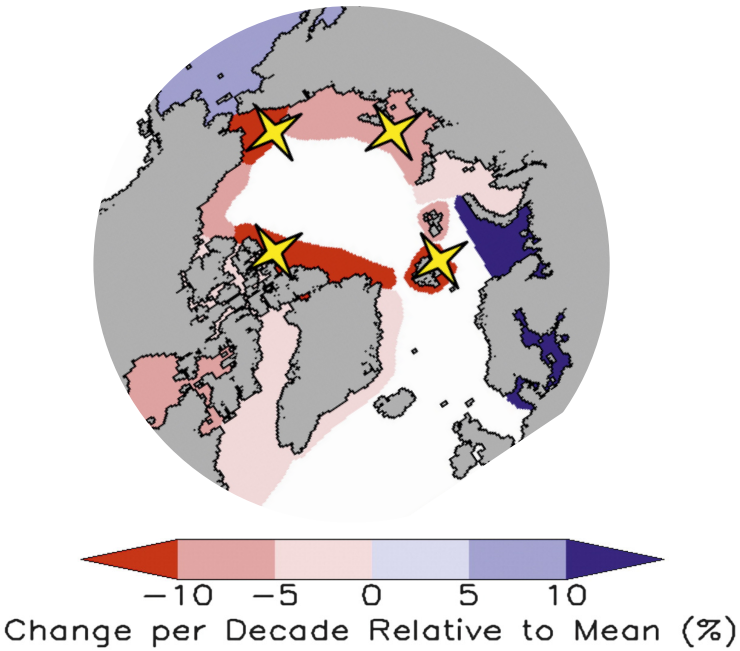


Itkin et al. 2015

- affects state of the Arctic Ocean and atmosphere (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)

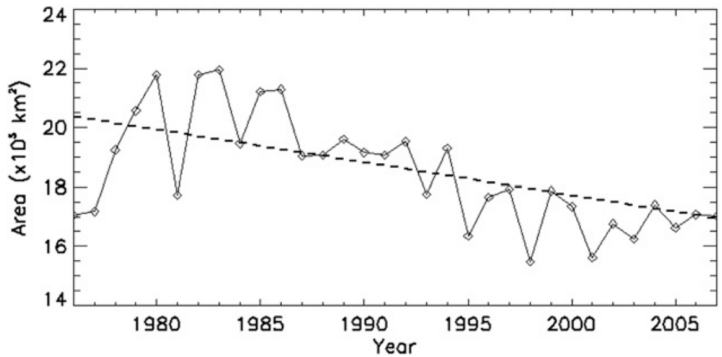
I. Changes in Arctic fast ice, 1976-2007

Changes in fast ice extent



(Yu et al.2014)

Long-term variation of fast ice extent for the Northern Hemisphere

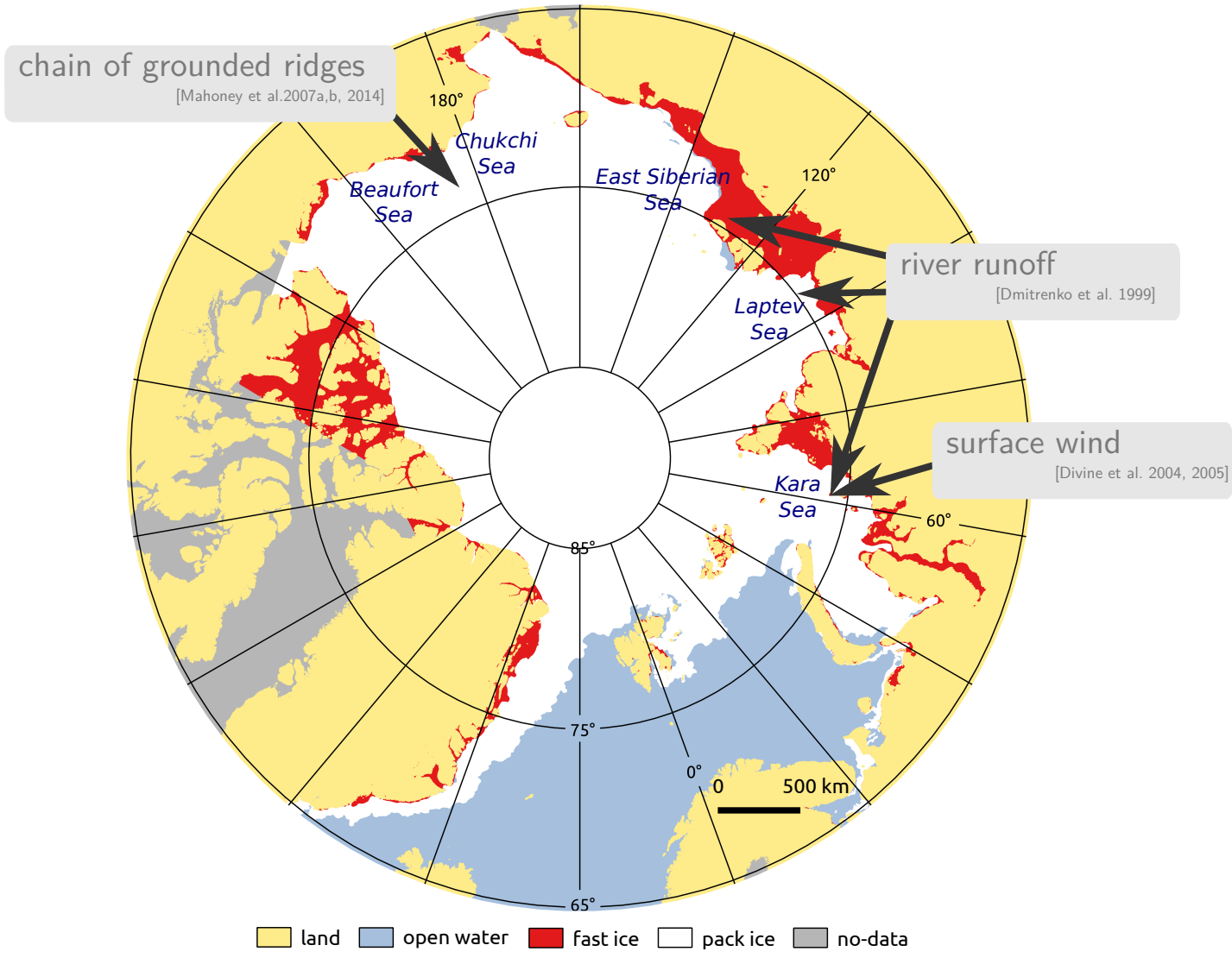


(Yu et al.2014)

overall decrease in extent
LS - 8.4% per decade

shorter landfast ice season LS - 2.5 weeks per decade

I. Factors controlling variability of fast ice winter extent



17 March 2015 (AARI Charts)

I.Objectives

Objective 1 - Annual variability

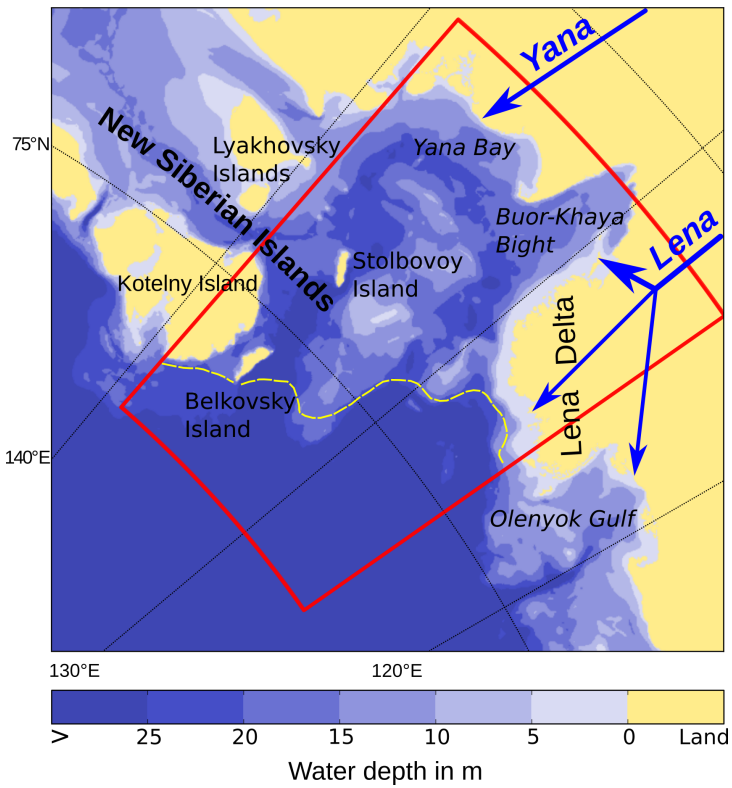
- To describe the **annual fast ice cycle** and reveal the **mechanisms driving the seasonal development** of fast ice.

Objective 2 - Interannual variability and changes

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

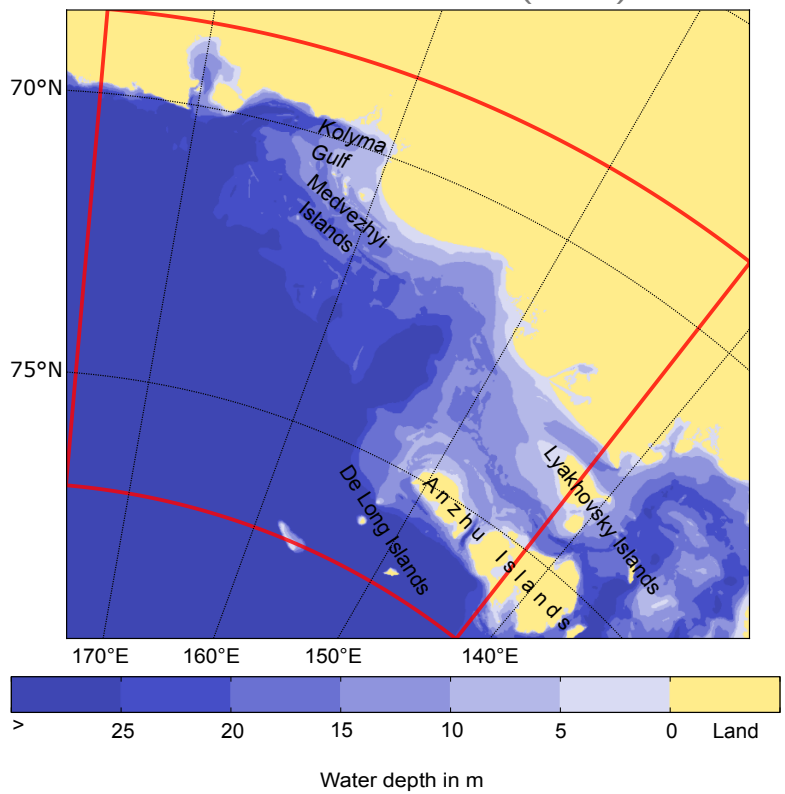
II. Regions of interest and fast ice information

Laptev Sea (LS)



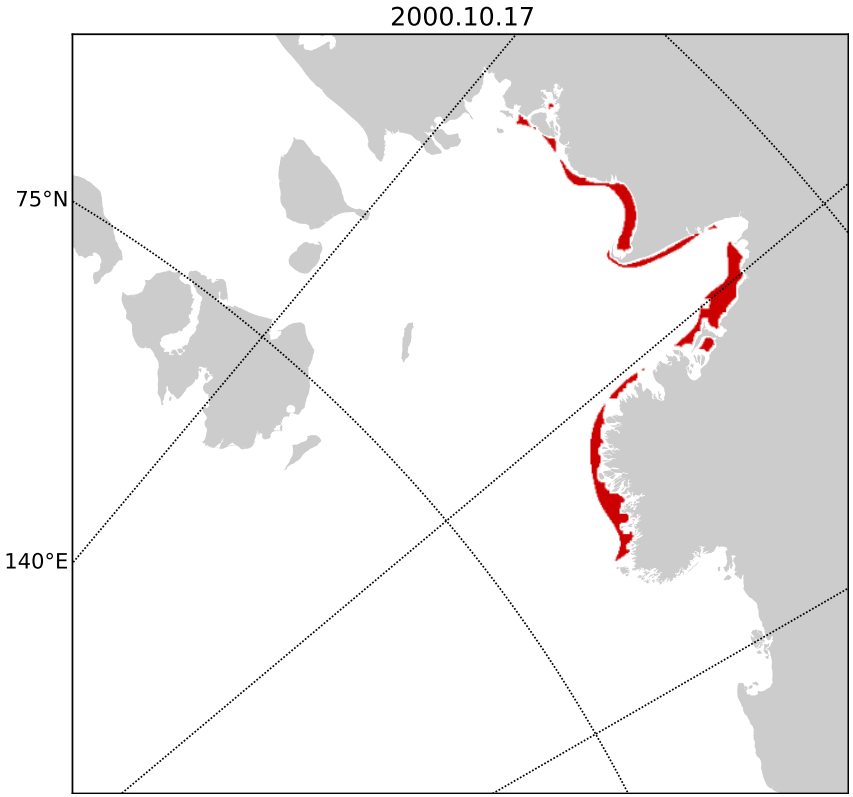
AARI charts, 1999-2013, weekly

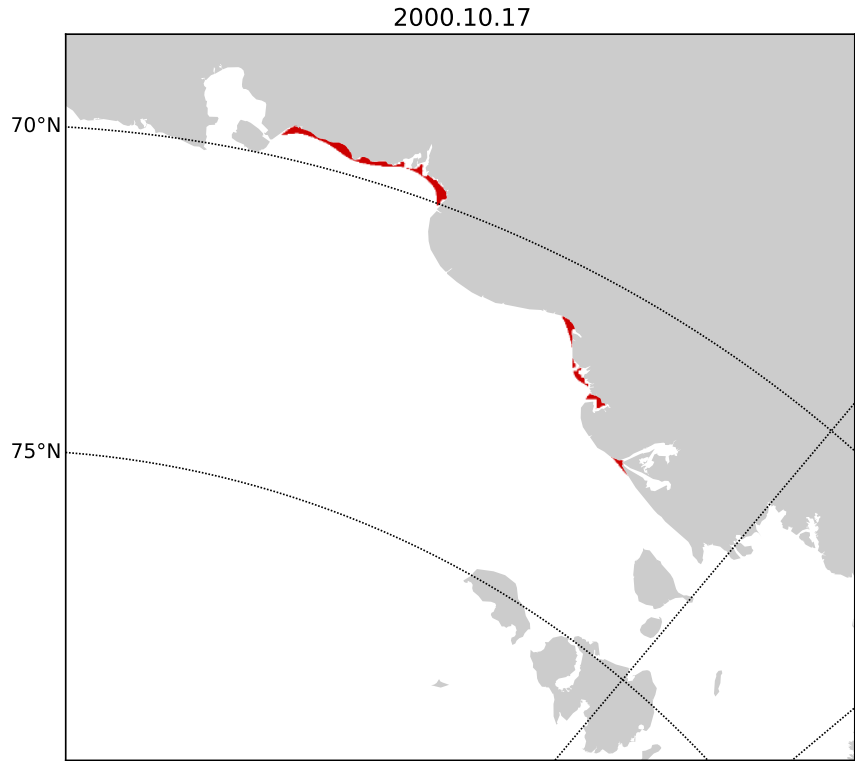
East Siberian Sea (ESS)



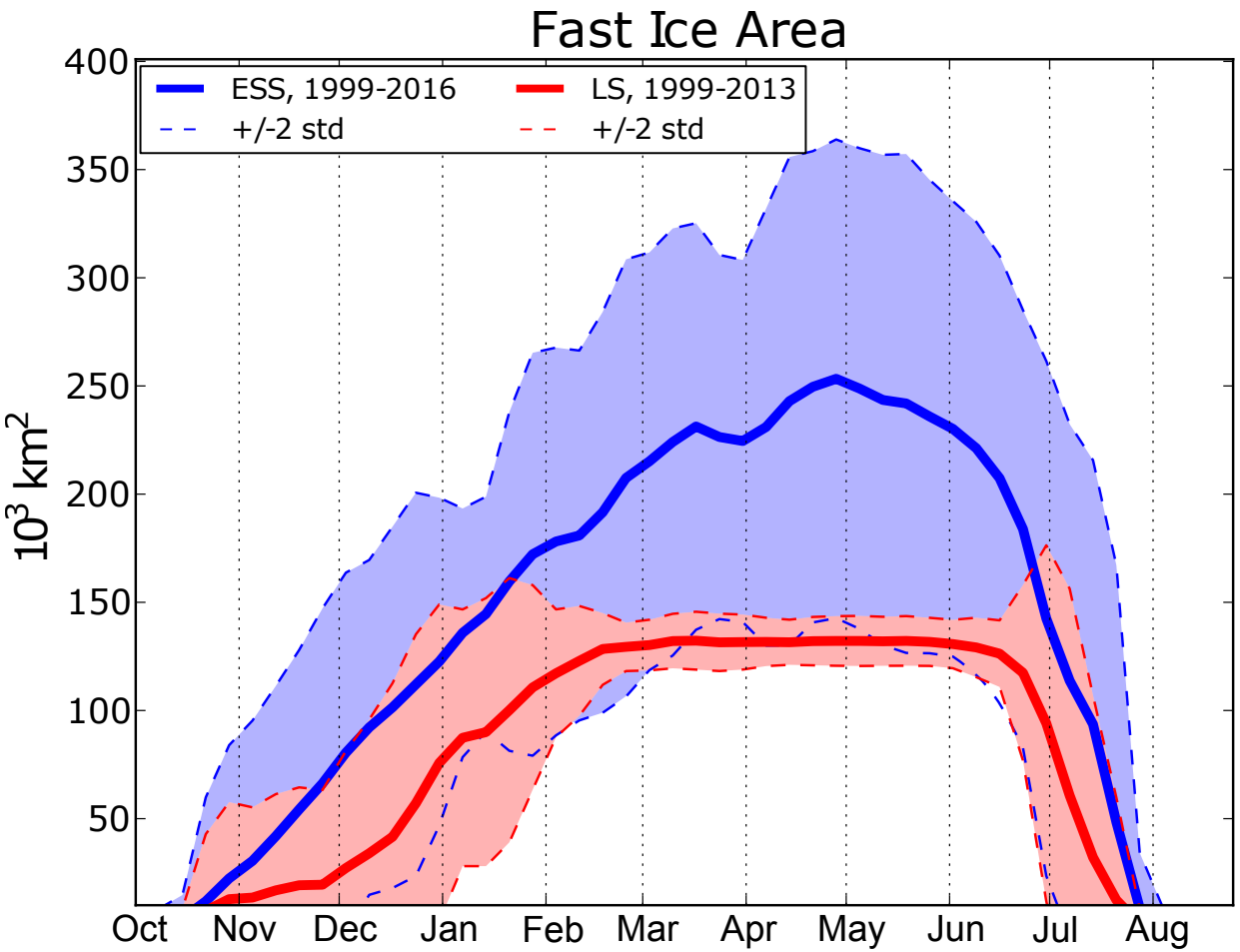
AARI charts, 1999-2013, weekly

II. Annual fast ice cycle, 2000-2001





II. Mean annual fast ice cycle



Interannual variability

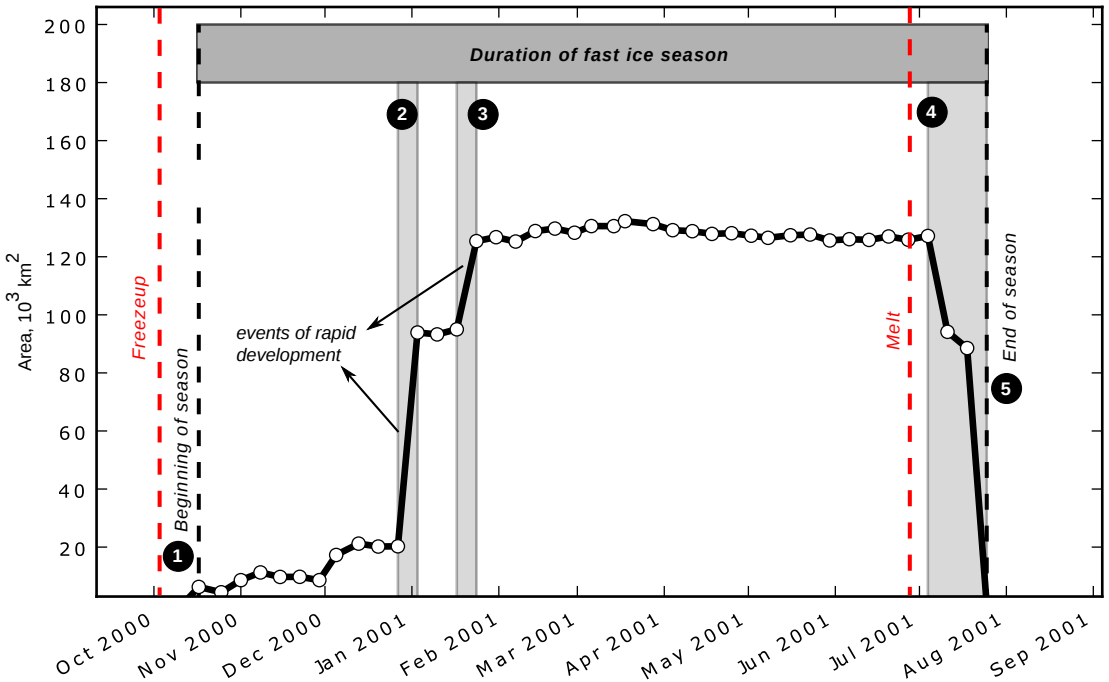
Laptev Sea:

- 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 fast ice cycle for the Laptev Sea
(Selyuzhenok et al. 2015)

Laptev Sea,1999-2013

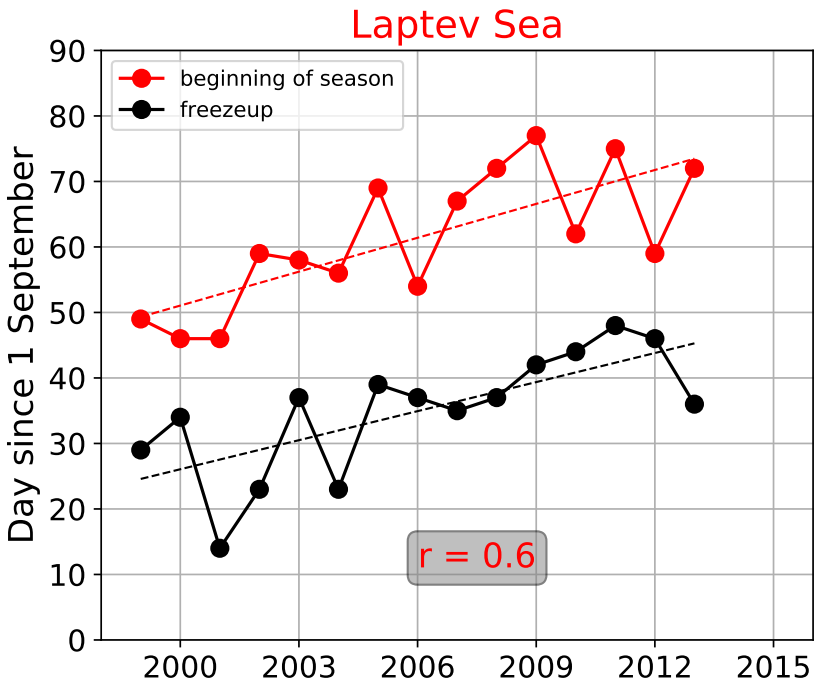
Time series of Key events 1-5

East Siberian Sea, 1999-2015

Time series of Key events 1,5

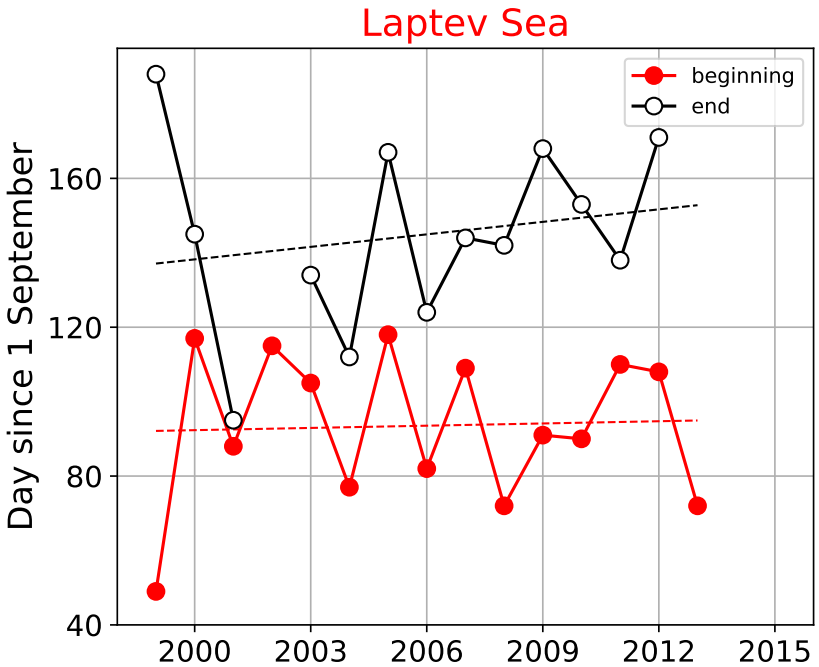
and Key events 2,3 for some seasons

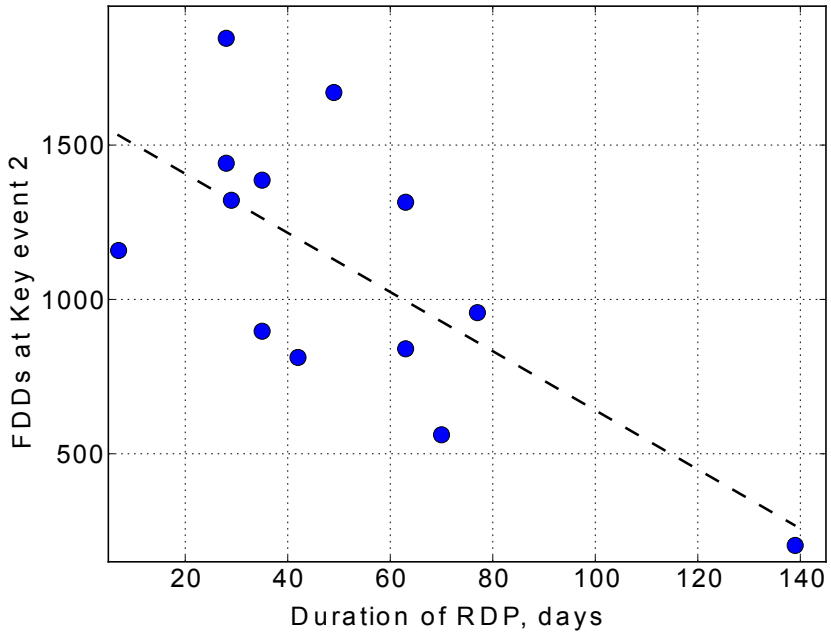
II. Beginning of season



- tendency towards later formation
  1.7 days/year ($p<0.01$)
- partly explained by delay in freezeup
  ($r = 0.6$)

II. Rapid development

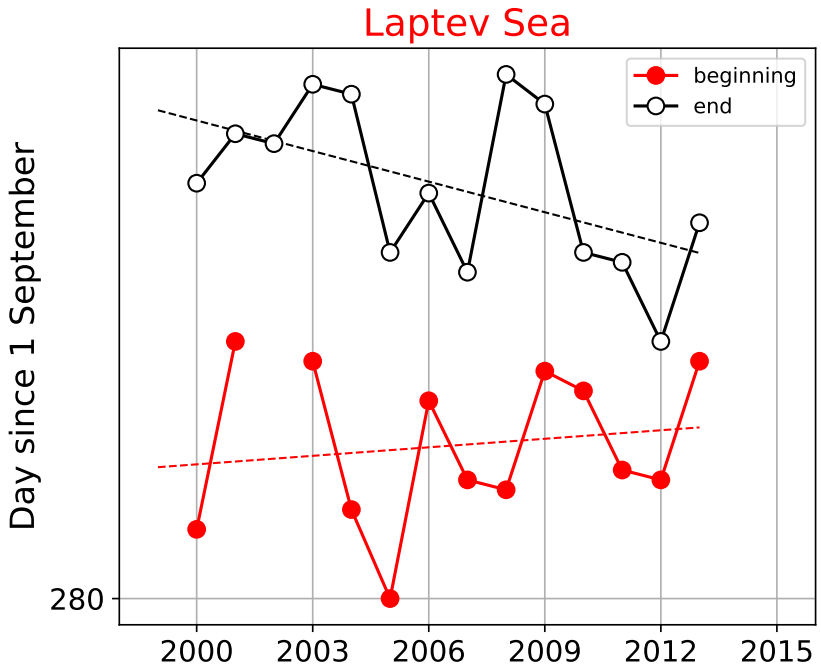


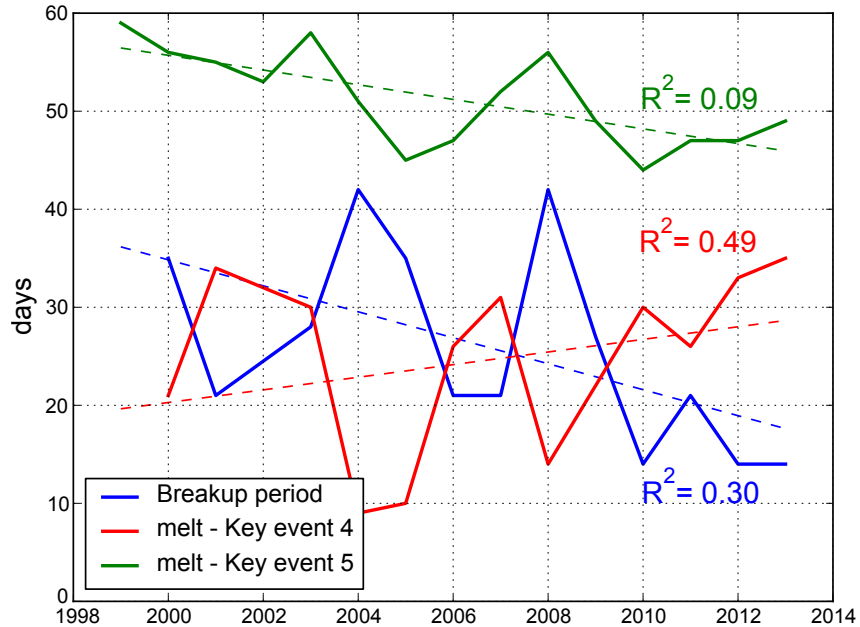


- high variability of dates
- tendency towards later end
  0.4 days/year (p=0.07)

- duration of period depends on accumulated FDD
- there is a critical ice thickness (Hi) required for rapid ice development
  Hi(FDD) = 70-80 cm

II. Breakup

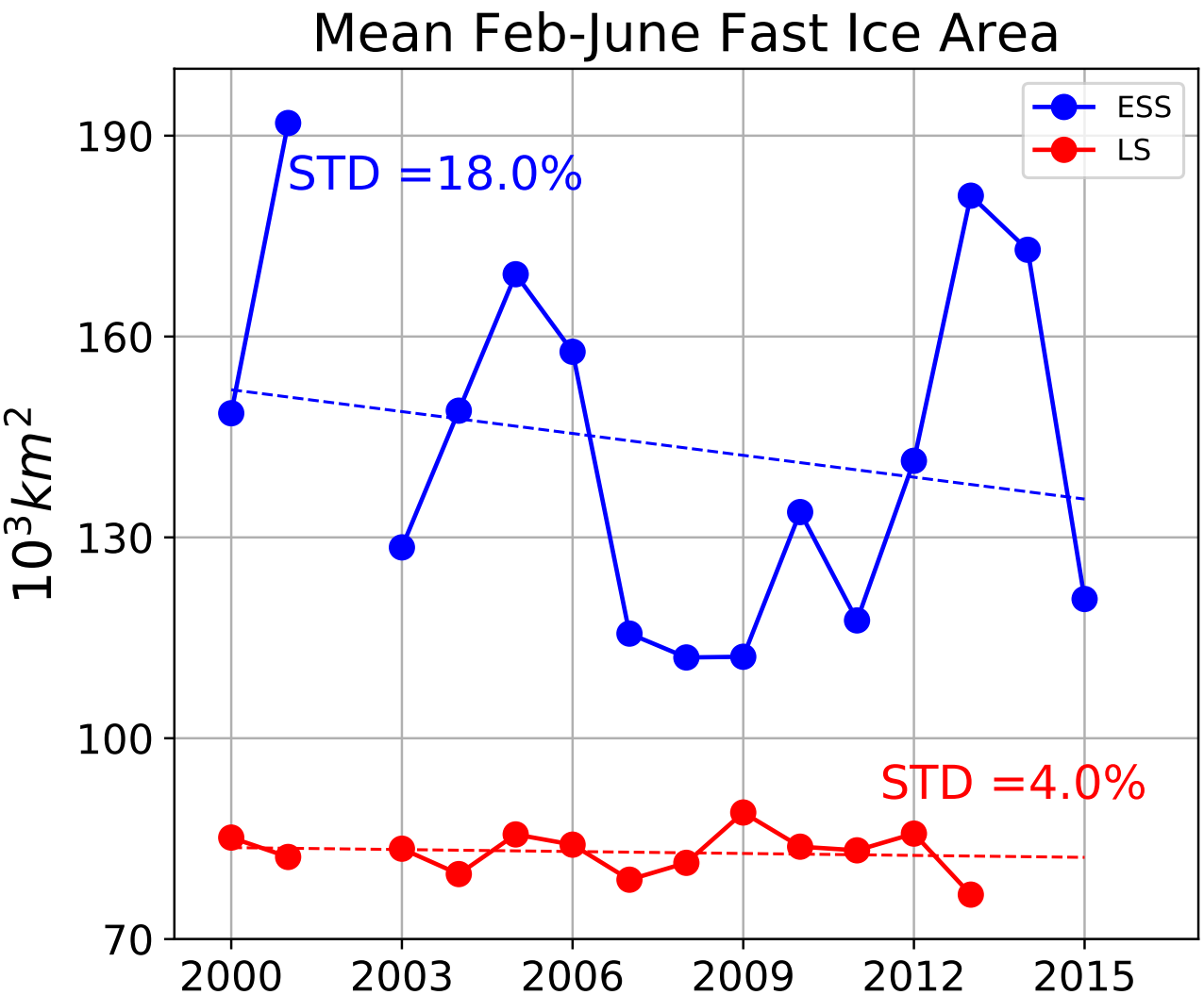




- tendency towards earlier end
  -1.0 days/year (p=0.06)
- no changes in beginning
  0.3 days/year (p=0.63)

- fast ice needs less time to breakup
- duration of breakup depend on TDD acquired prior beginning 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

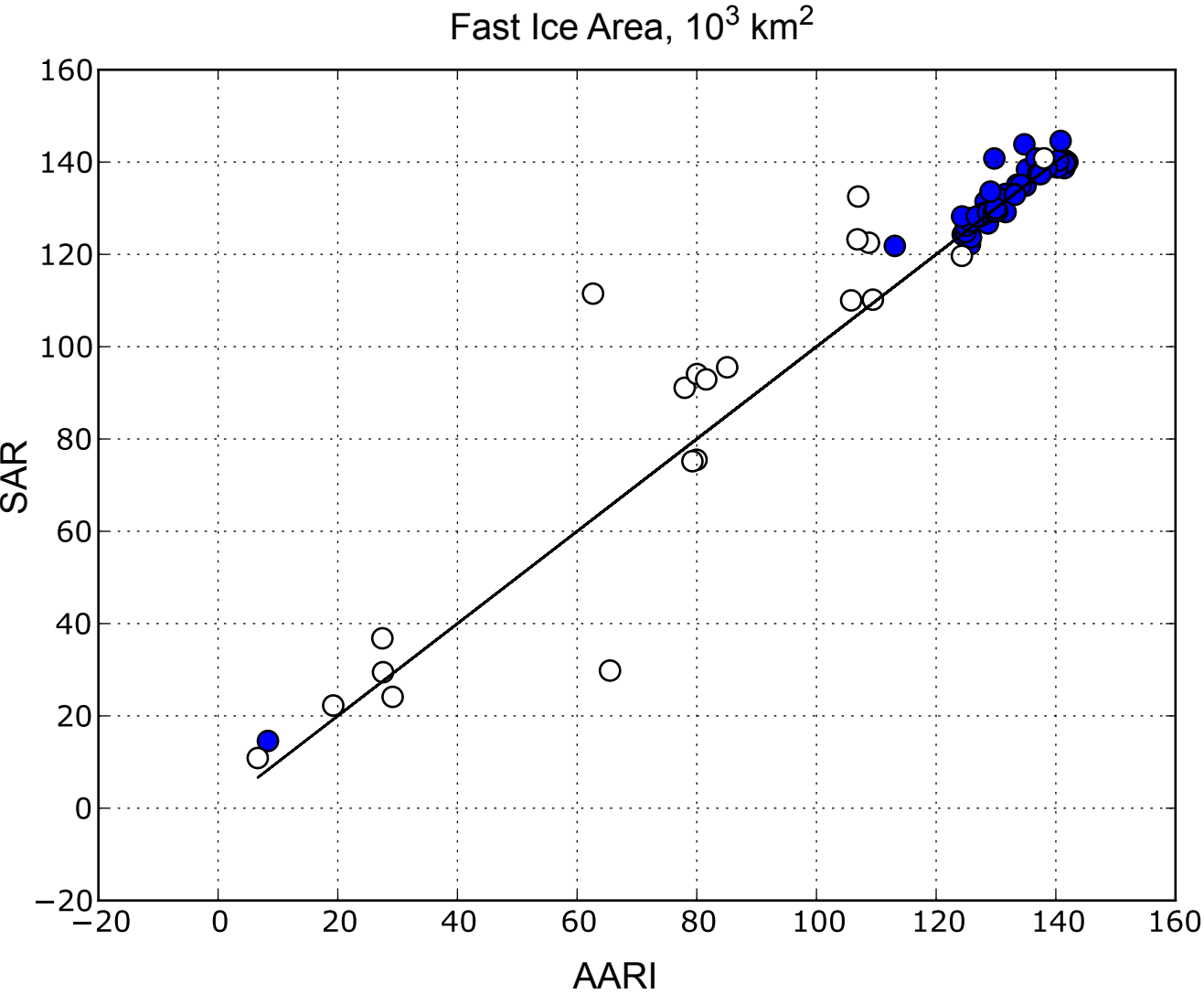
Laptev Sea

- **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

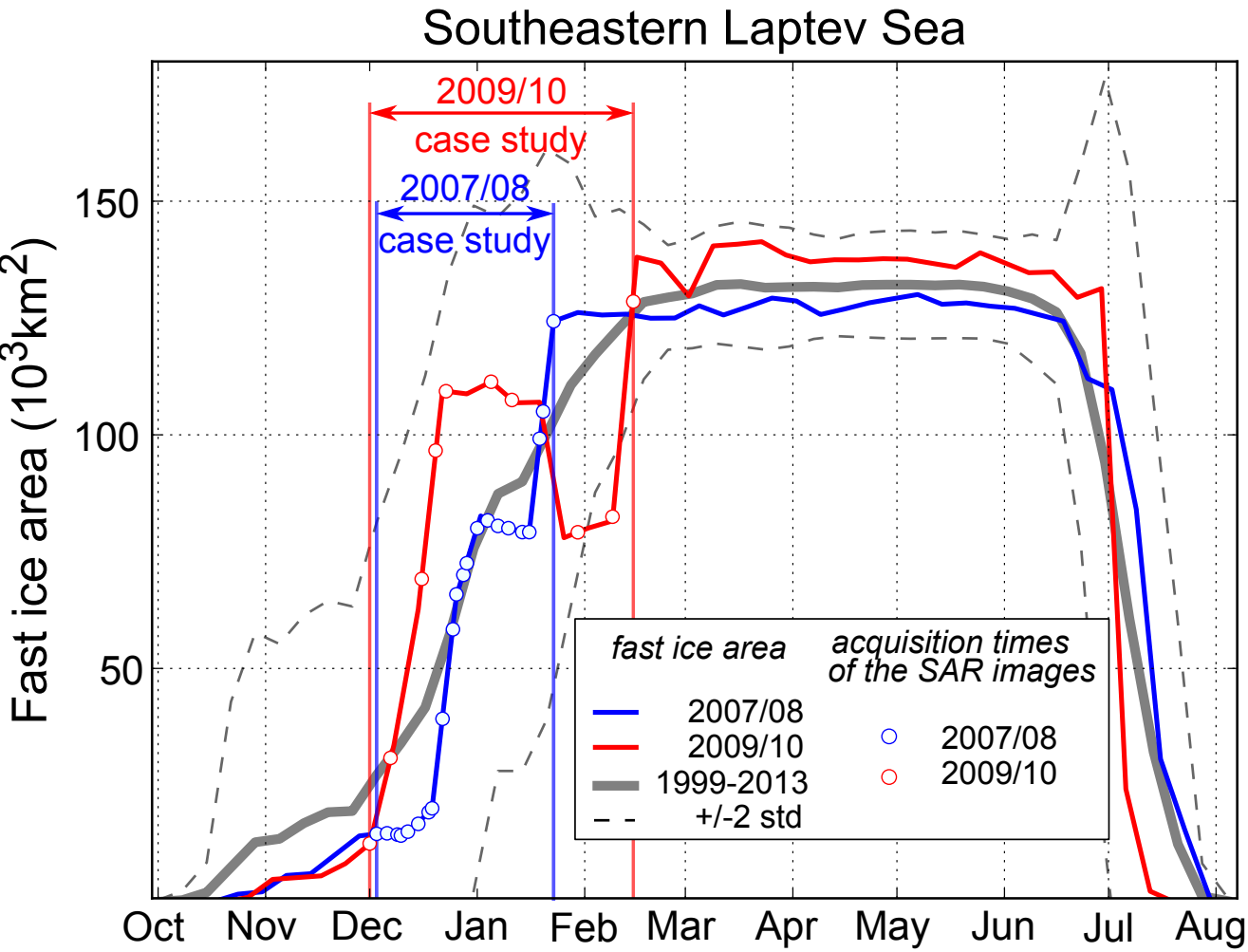
- **high variability of winter extent**
- shorter fast ice season (by 1.5 day/year)

III.Laptev Sea : comparison of landfast ice information



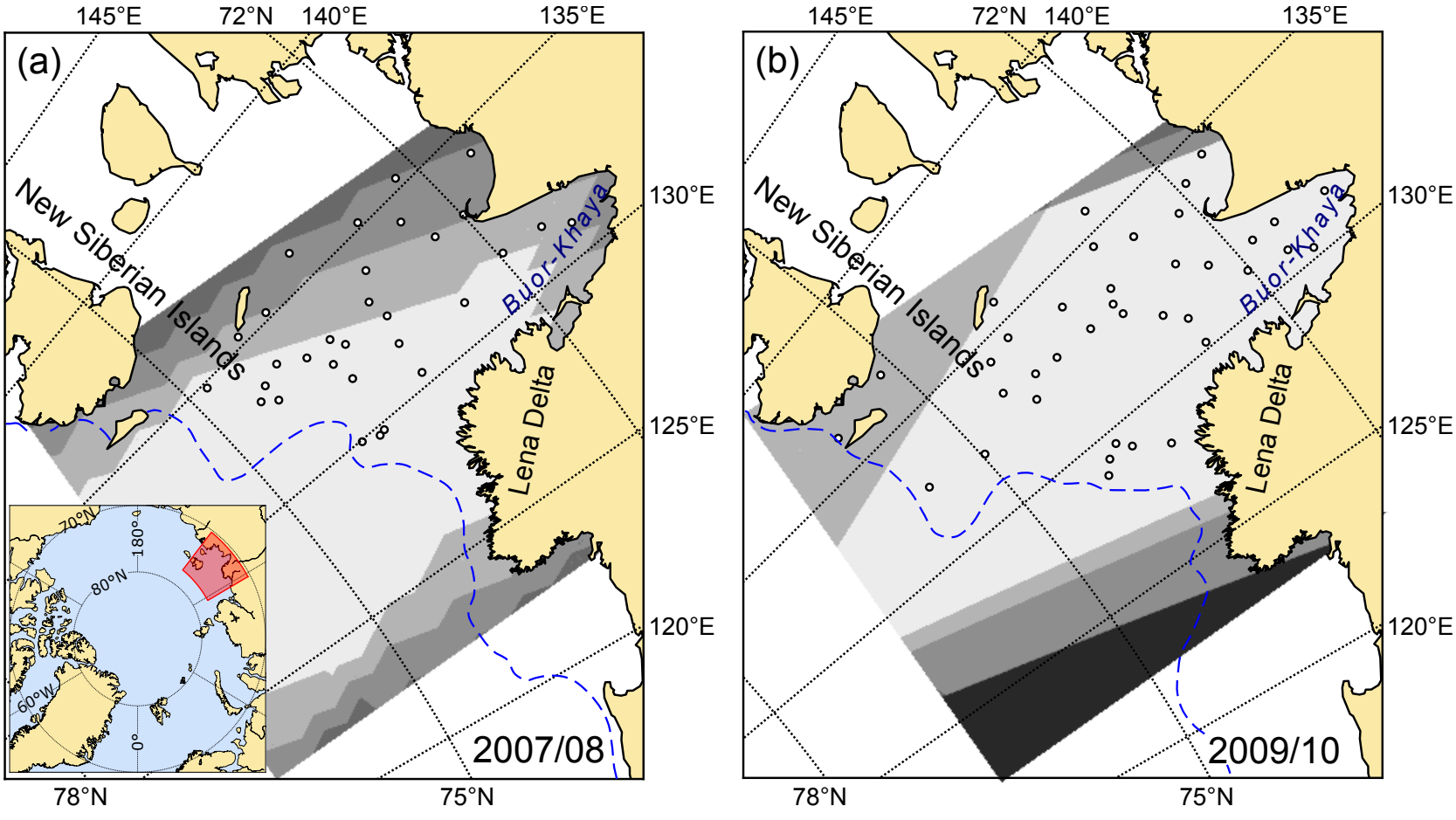
- fast ice mapped by two experts
- high deviations during develop

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



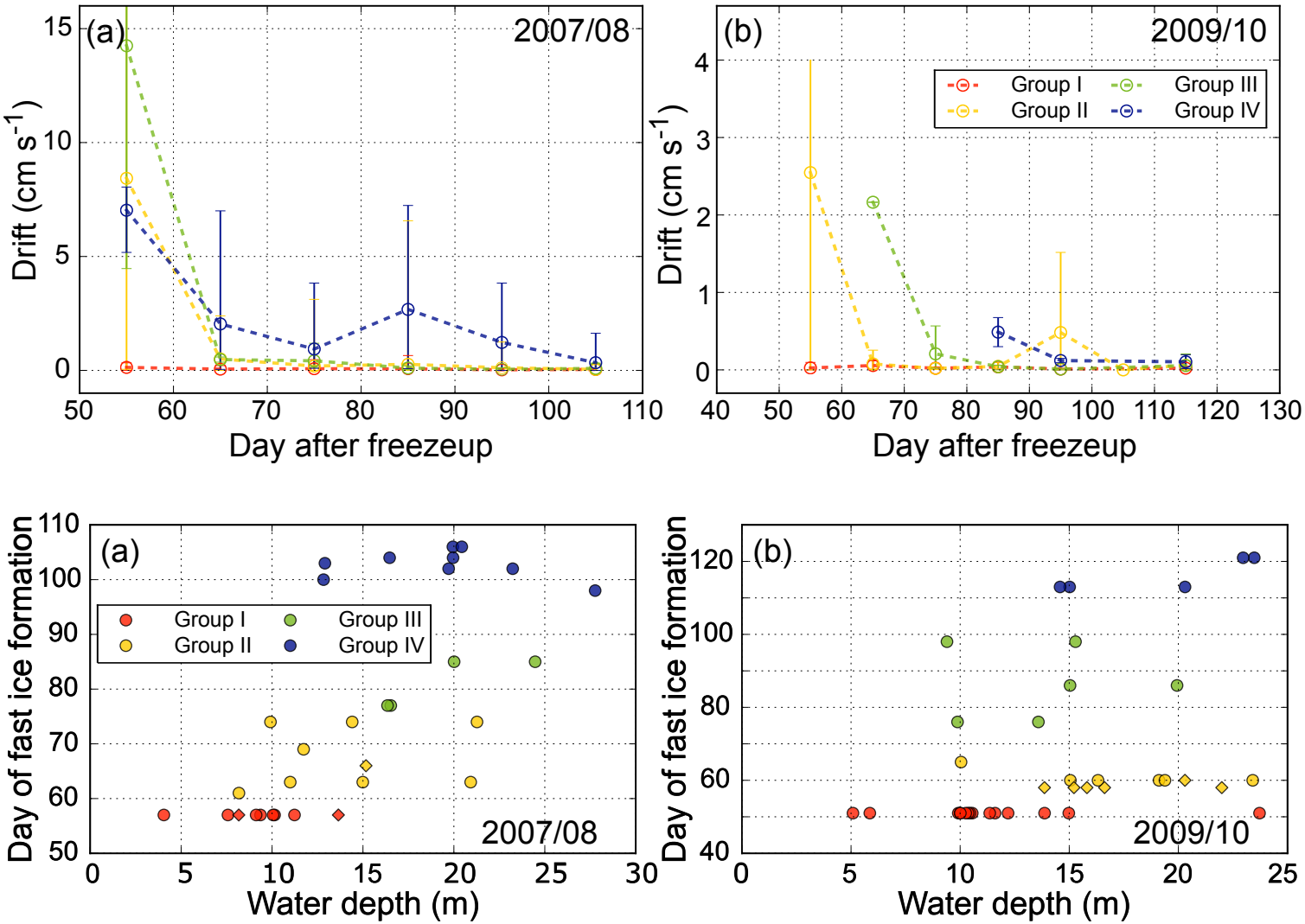
- SAR image every 2-14 days

III. Tracked sea ice features

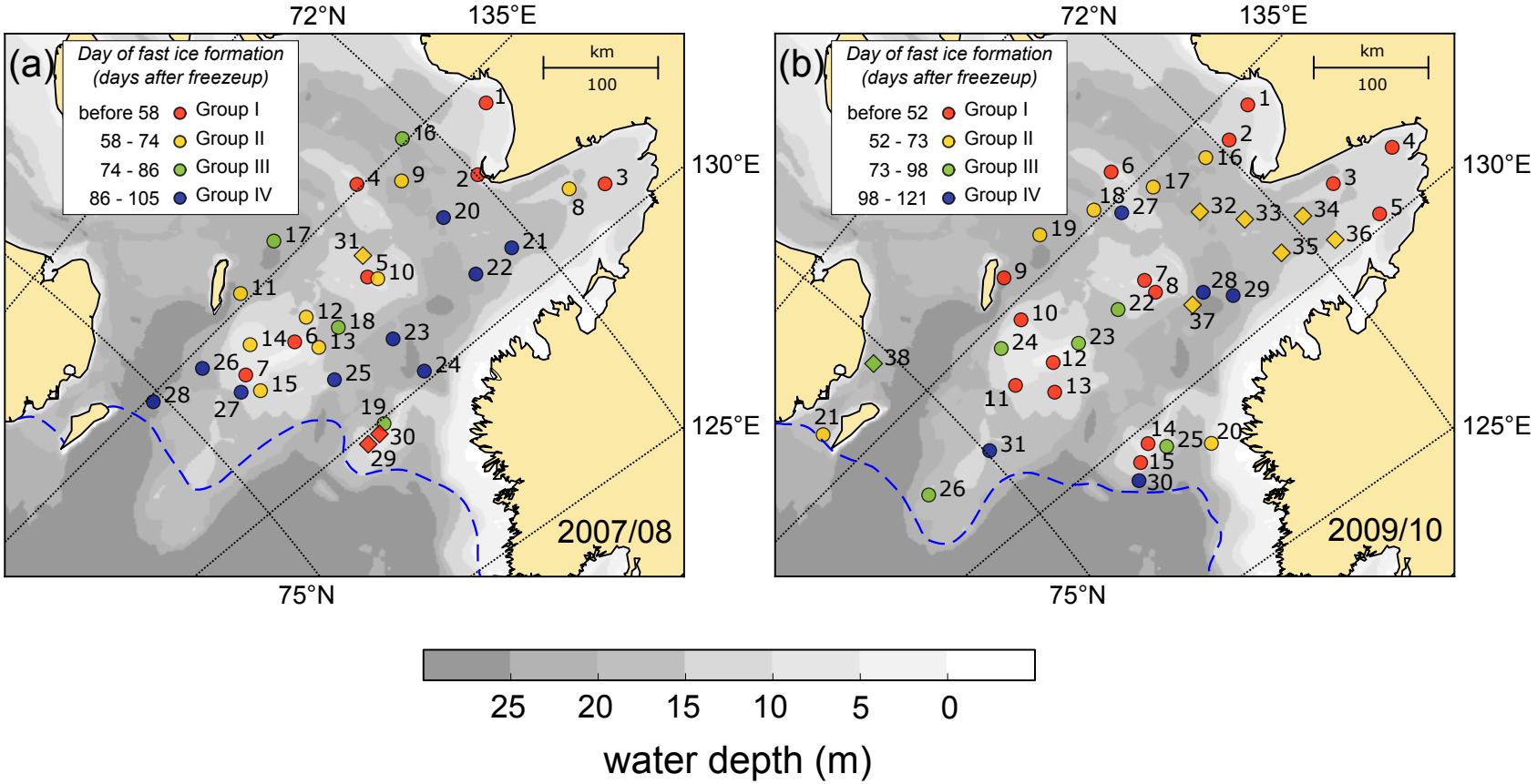


fast ice = drift speed <0 cm/s

III. Patterns of drift



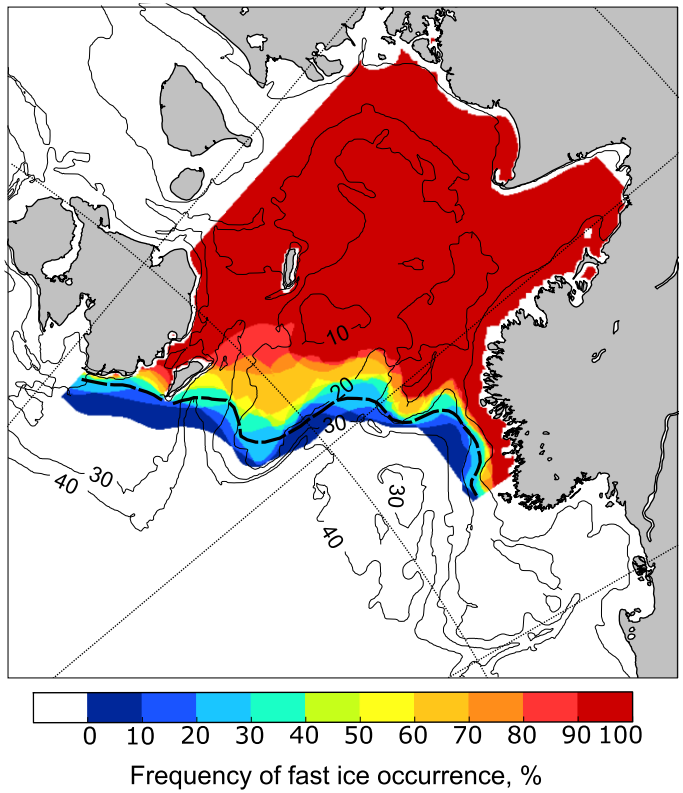
III. Final location of features

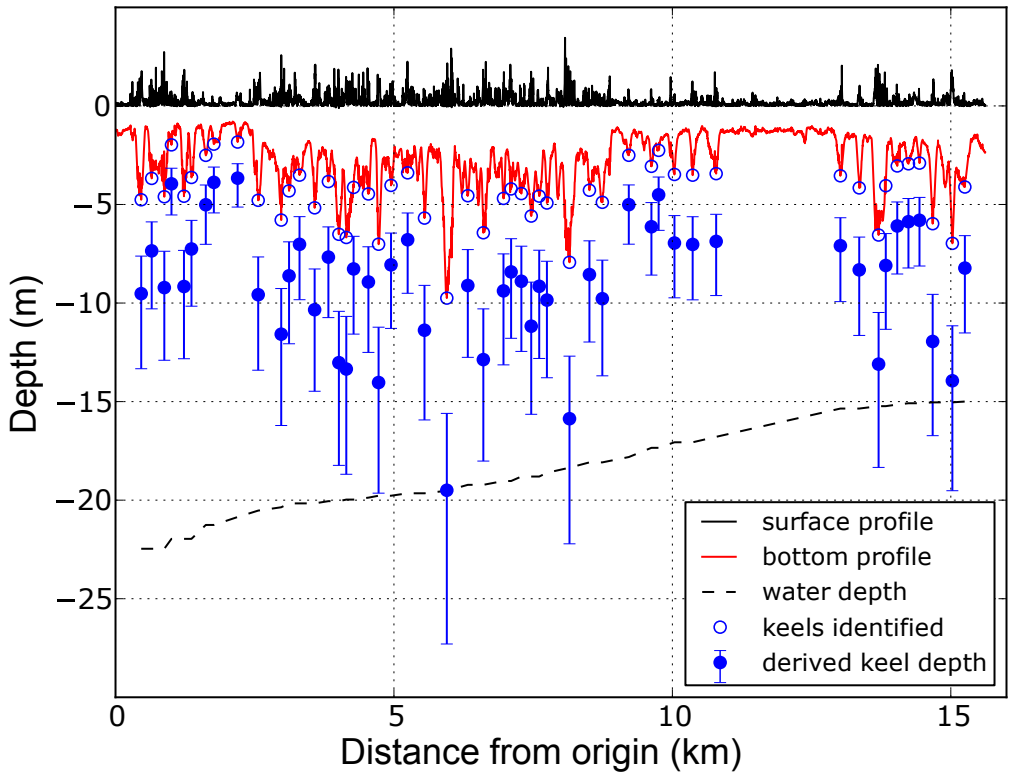


- relatively thin ice becomes grounded over the shoals (red circles)
- it serves as stabilizing points for surrounding sea ice
- low variations in winter extent predefined by the bathymetry

III.Deep sea ice ridges

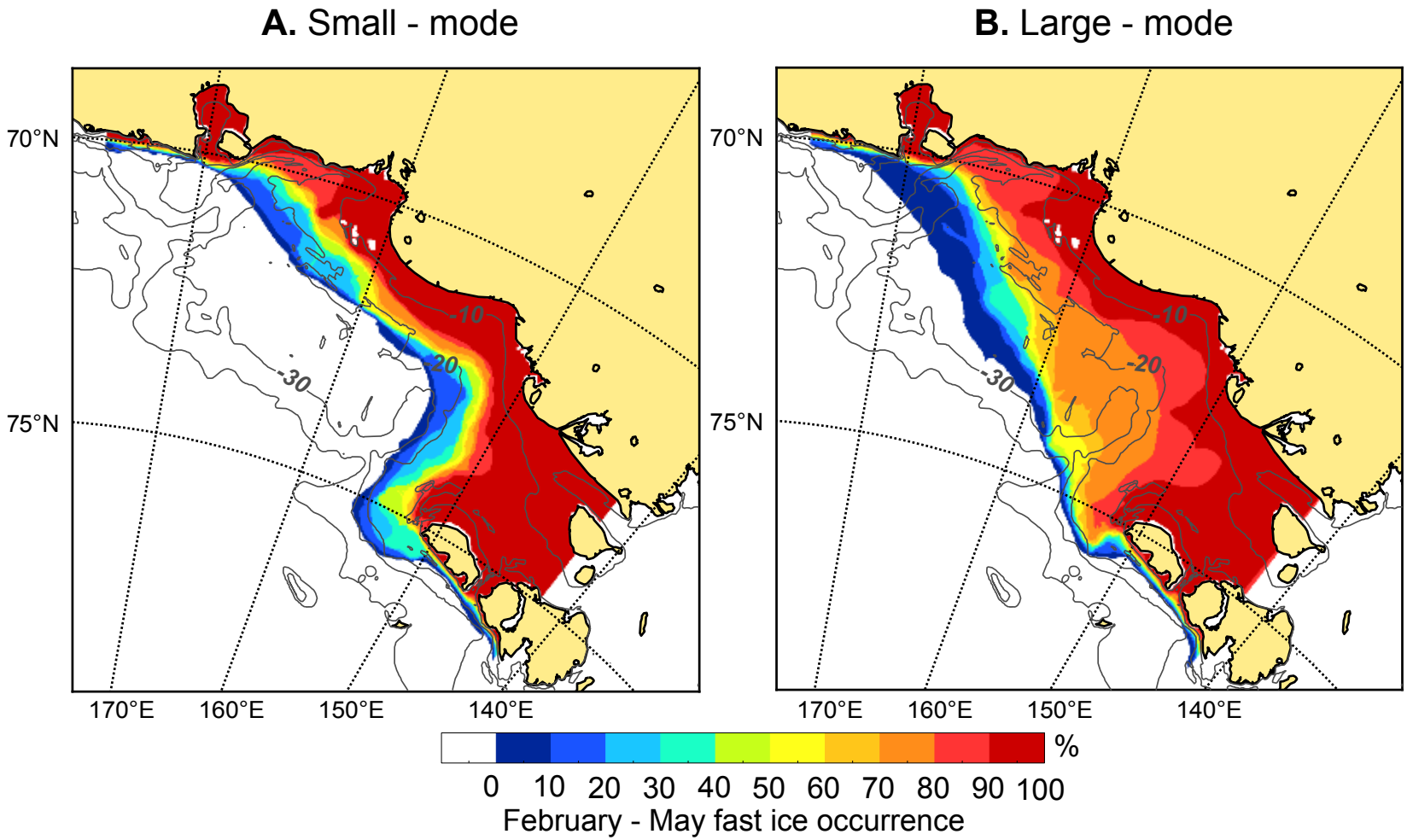
End of Rapid Development





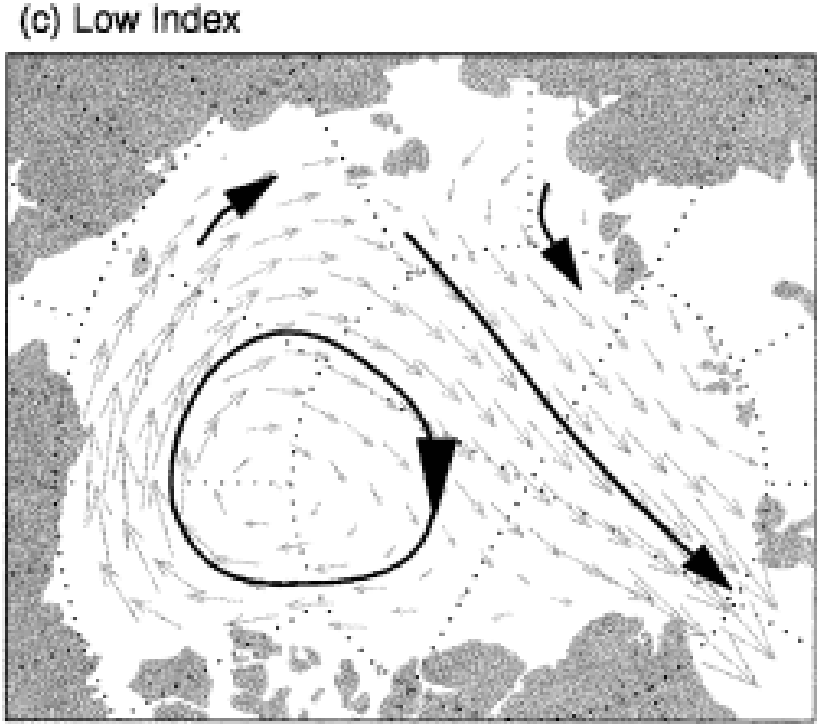
- variations in winter fast ice edge is likely controlled by grounding of deep ice ridges

III.East Siberian Sea Fast ice modes

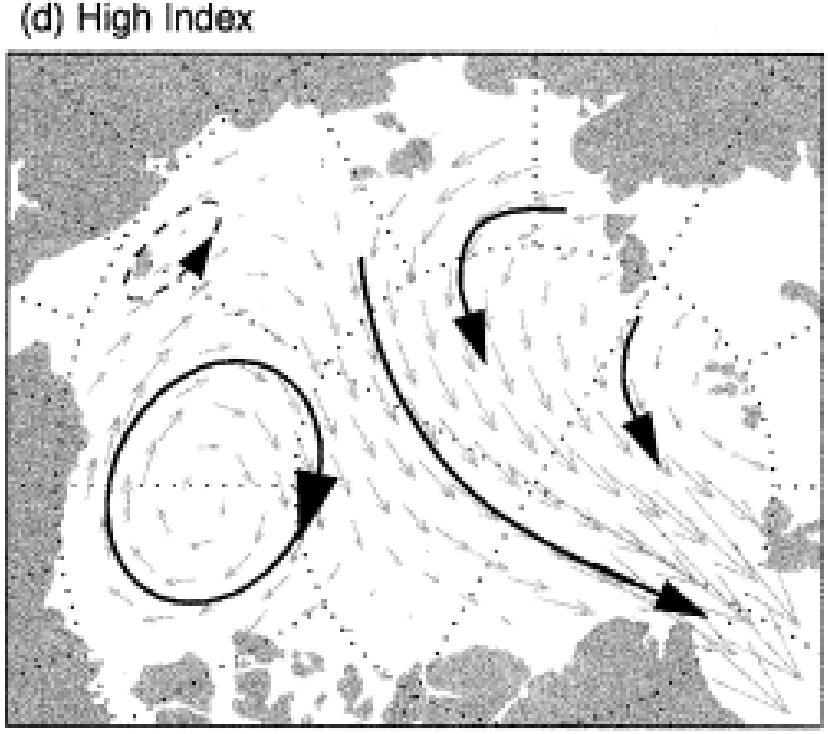


III. Arctic Oscillation index

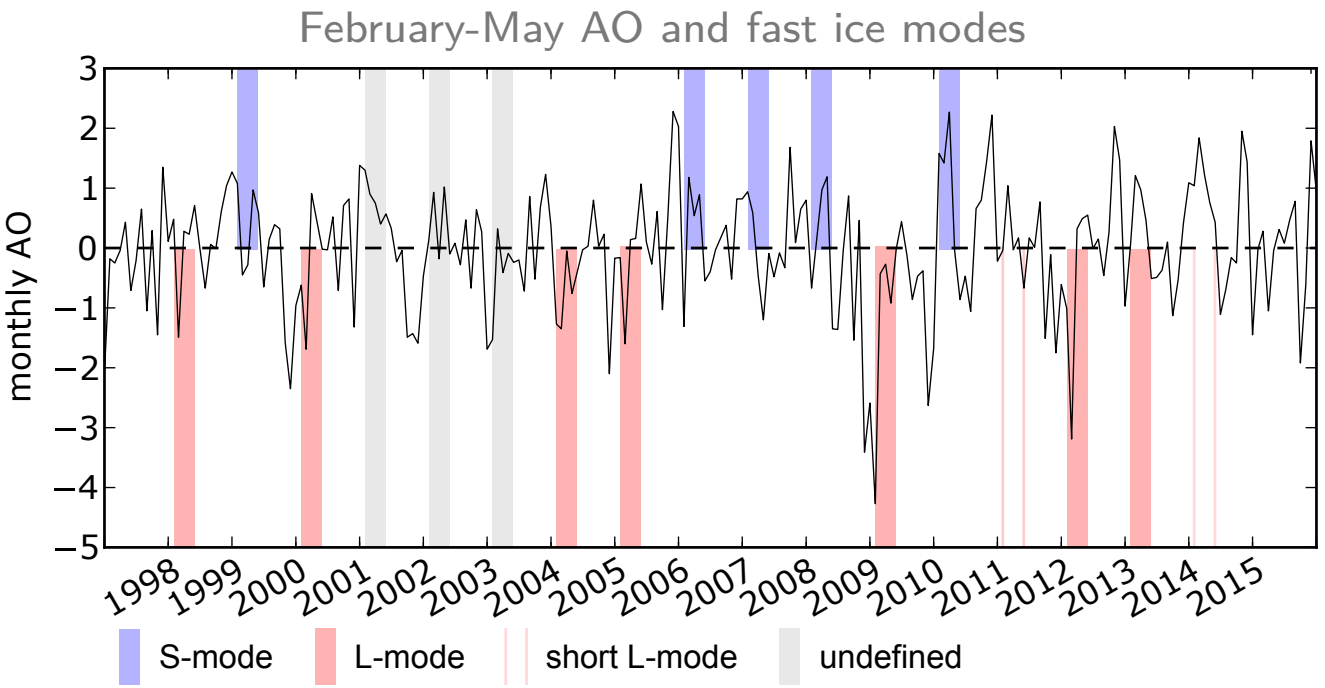
Positive Arctic Oscillation index (AO)



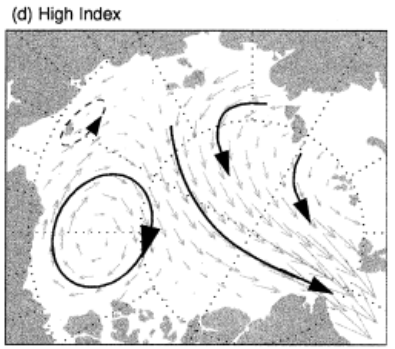
Negative Arctic Oscillation index (AO)



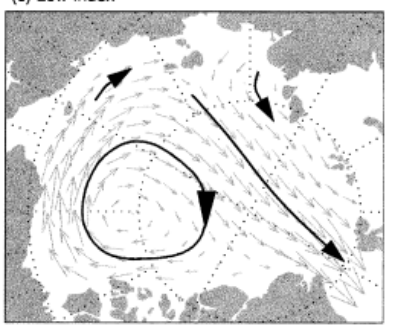
III.East Siberian Sea fast ice modes



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