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

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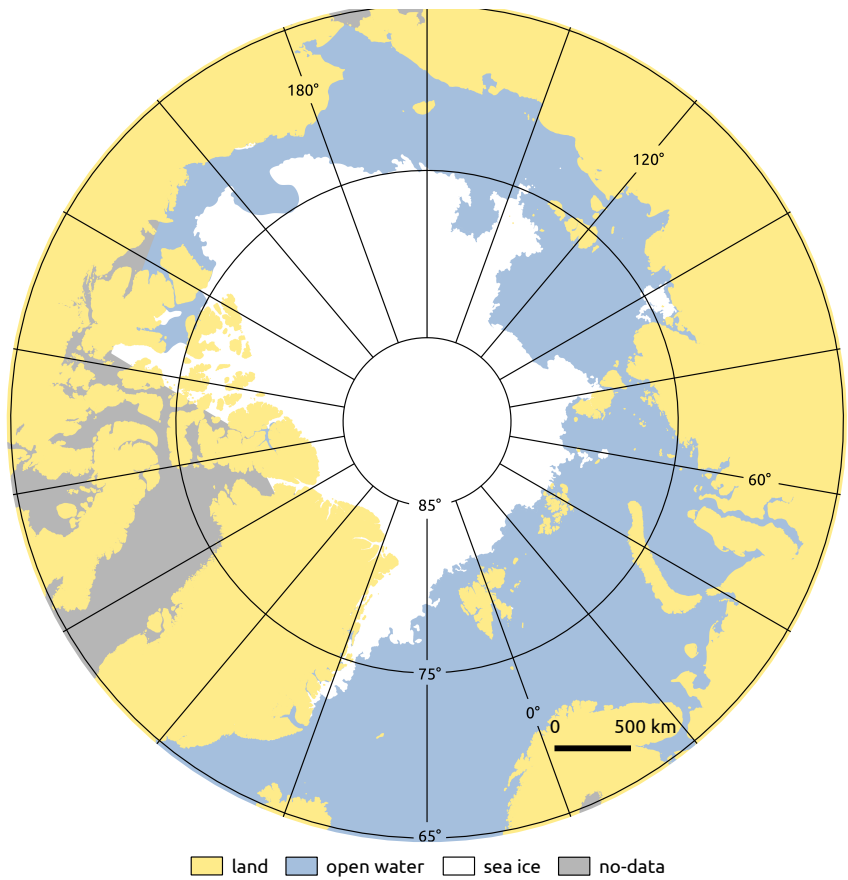
Outline

I. Arctic sea ice

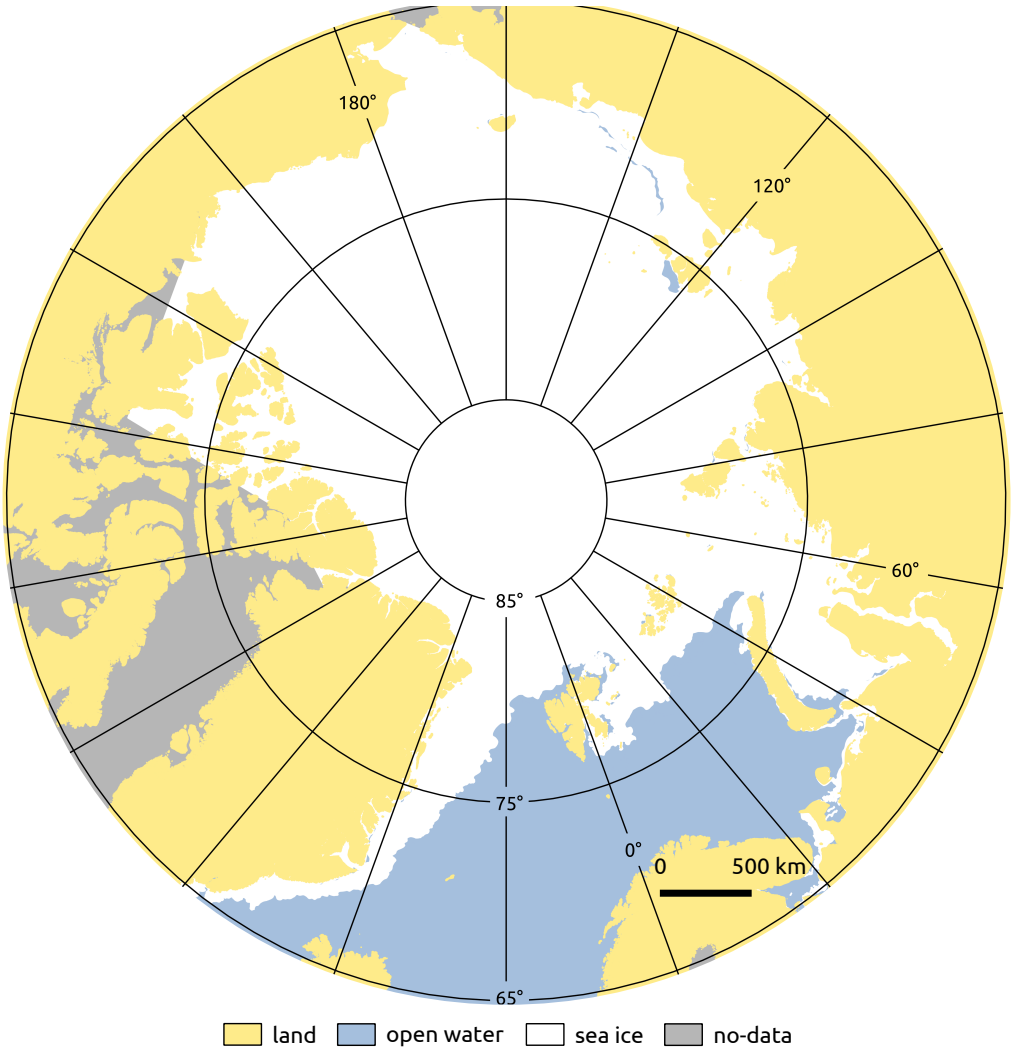
17 March 2015

10 September 2015



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

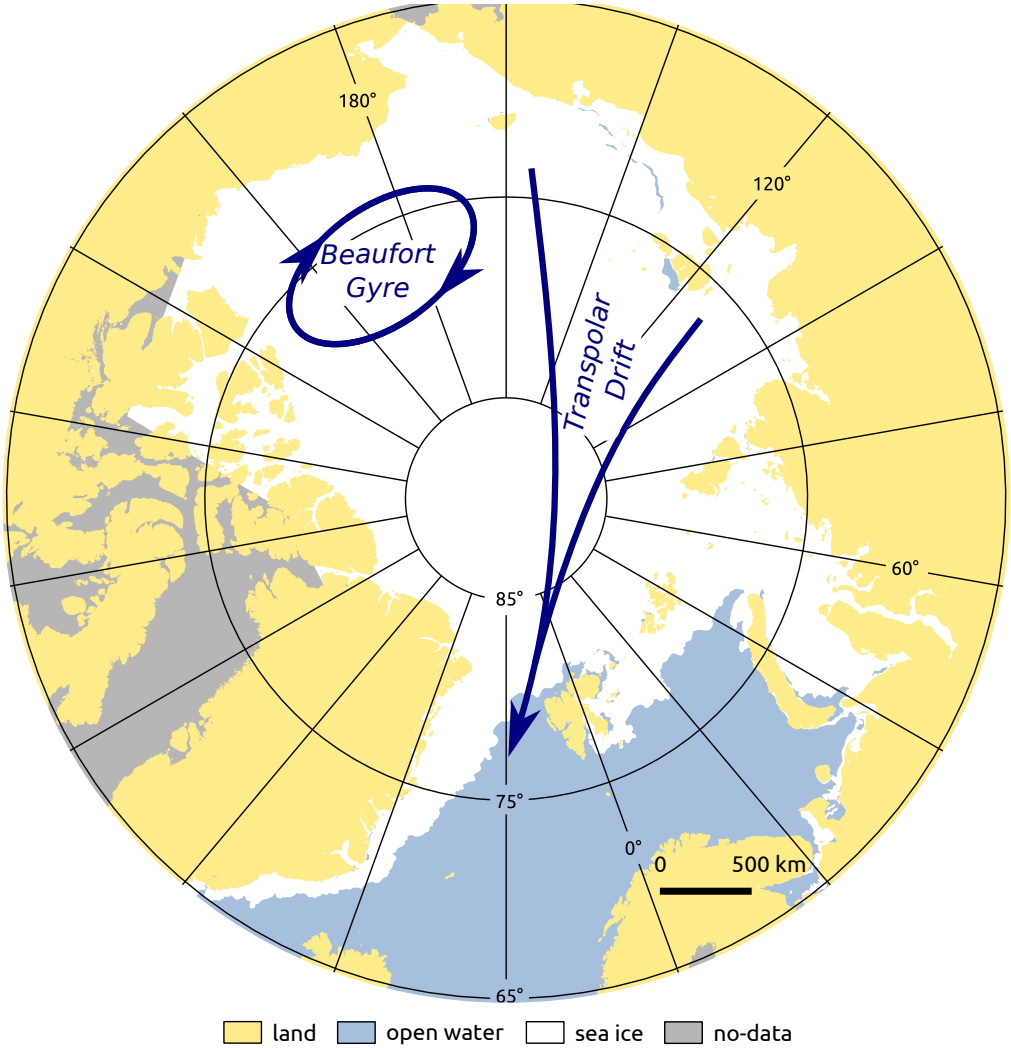
I. The importance of Arctic sea ice



17 March 2015 (AARI Charts)

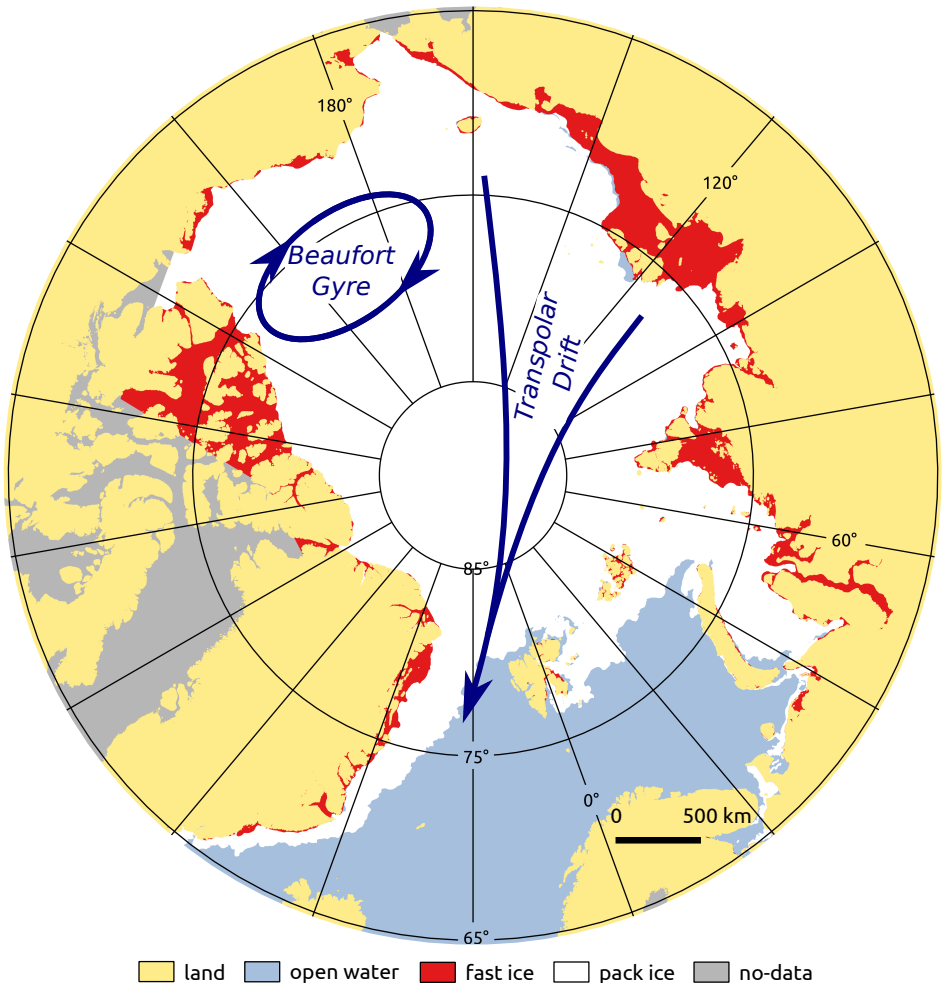
- **Climate system:**
  reflects about 80% of solar radiation
- **Ecosystem:**
  provides habitat and hunting platform
- **Human activity:**
  navigation, exploration, indigenous people activity

I. Arctic fast ice



17 March 2015 (AARI Charts)

I. Arctic fast ice



17 March 2015 (AARI Charts)

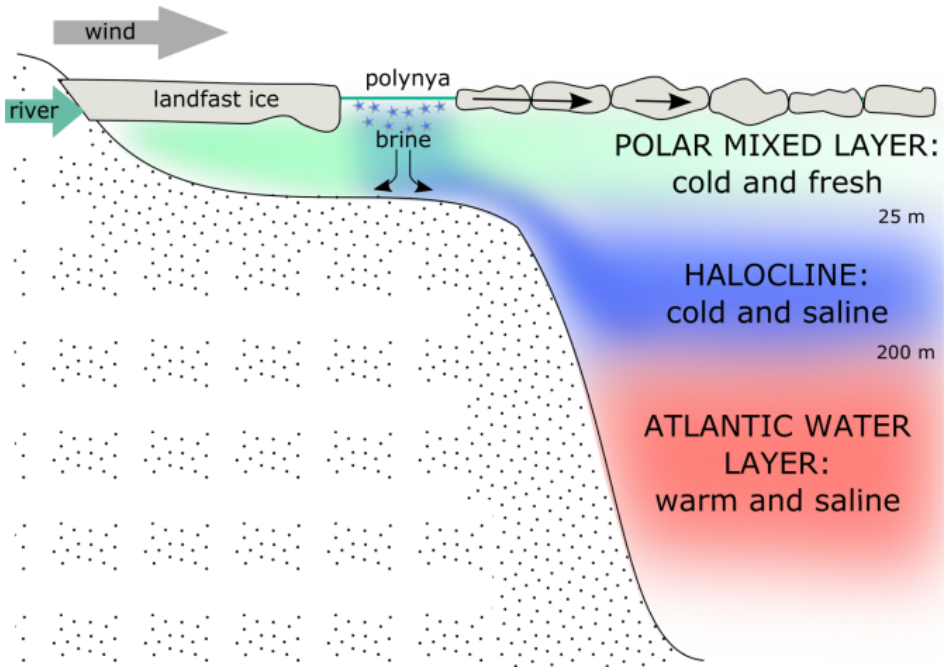
$\sim$ 13% of total sea ice extent

Definition

Motionless and adjacent 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)

I.Importance of Arctic fast ice

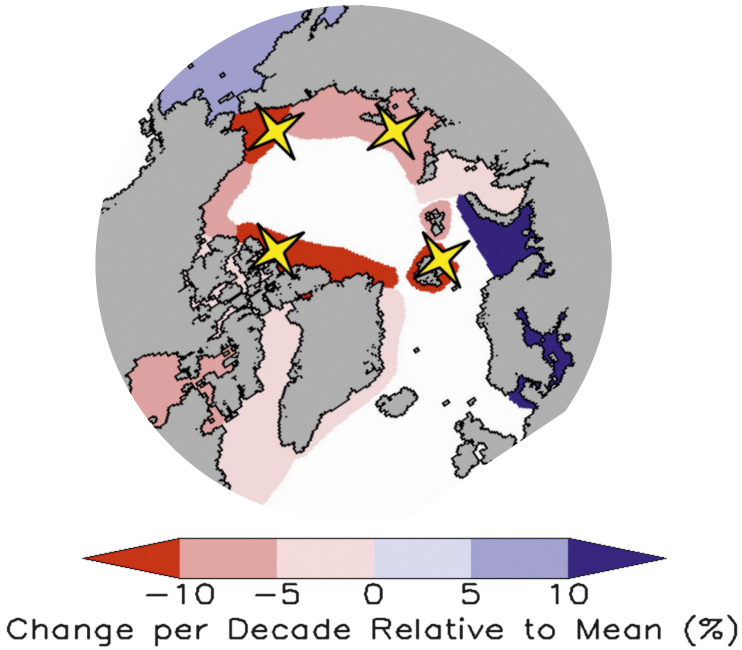


Itkin et al. 2015

- 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)

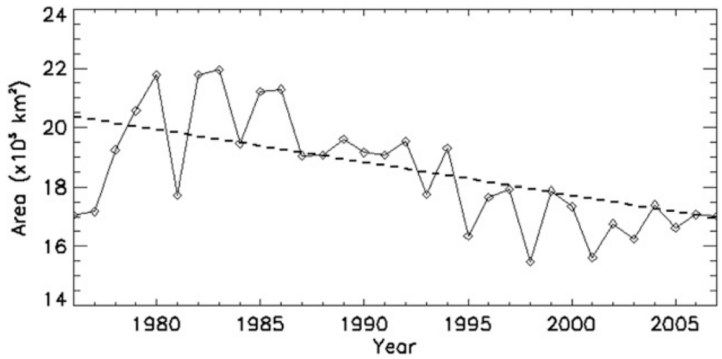
I. Changes in Arctic fast ice, 1976-2007

Changes in fast ice extent



(Yu et al.2014)

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

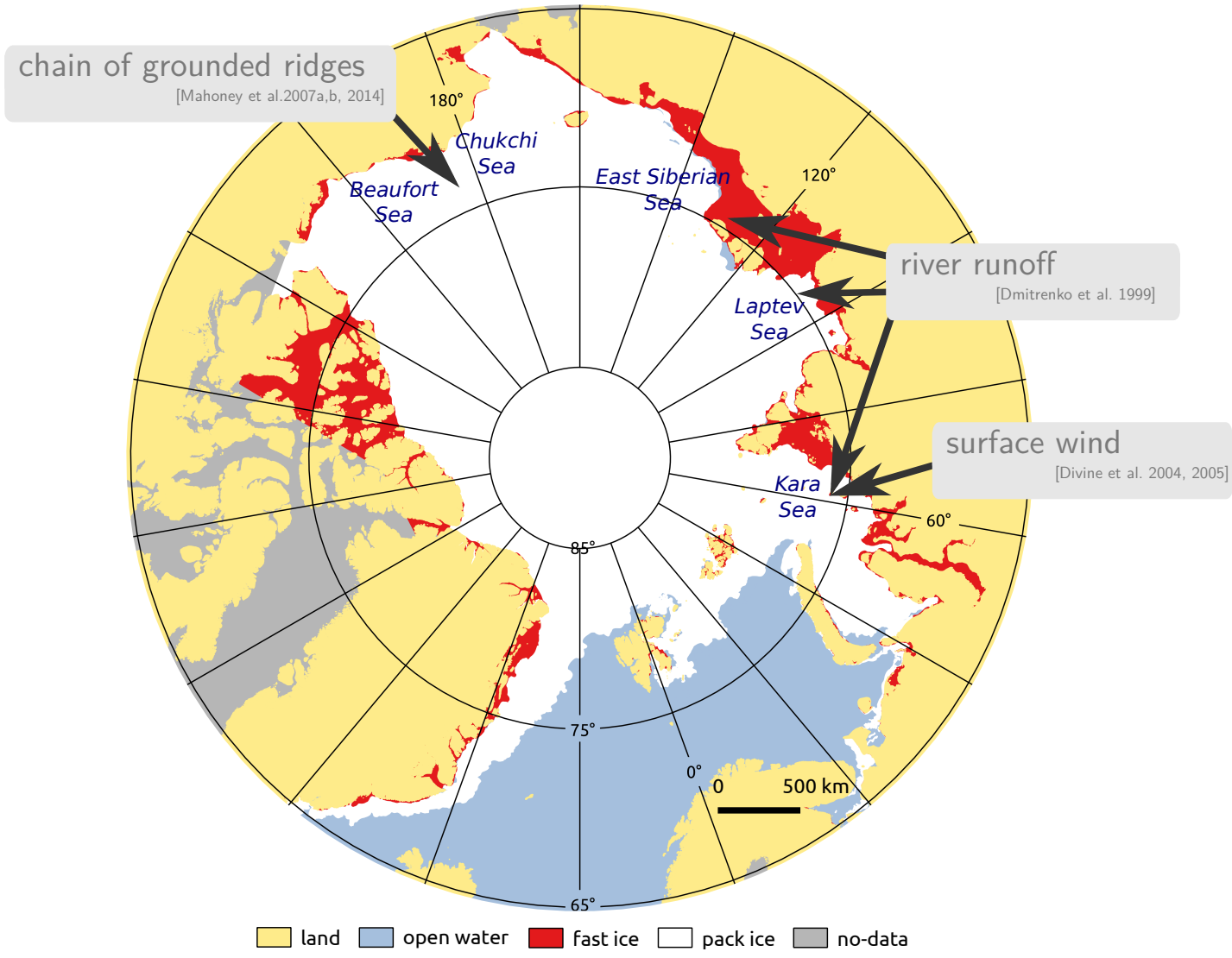


(Yu et al.2014)

overall decrease in extent - 7 % per decade
Laptev Sea - 8.4% per decade

shorter landfast ice season
Laptev and East Siberian Seas - 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

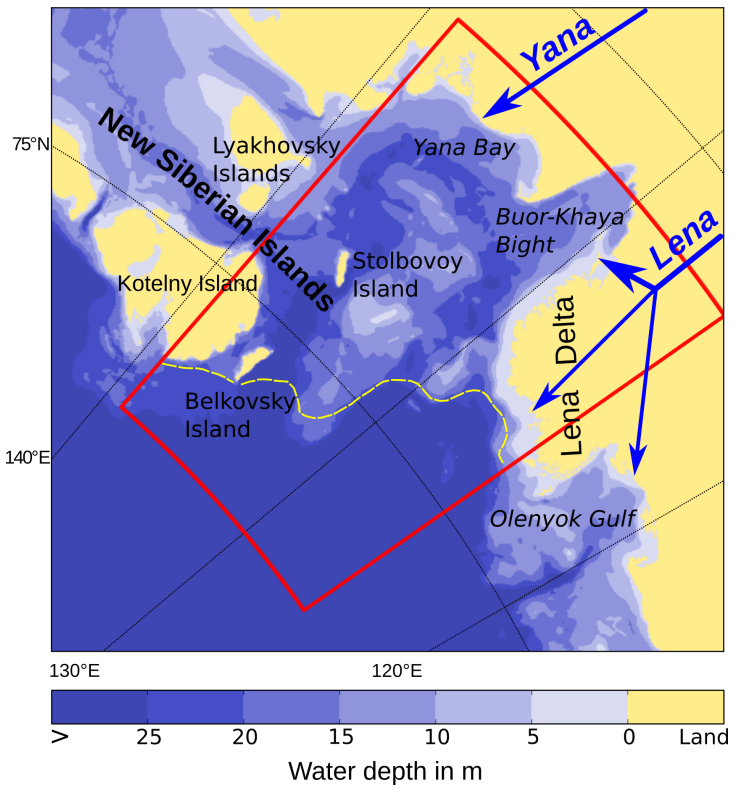
- To describe the **annual fast ice cycle** and reveal the **mechanisms driving the seasonal development** of fast ice.

Objective 2 - Interannual variability and changes

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

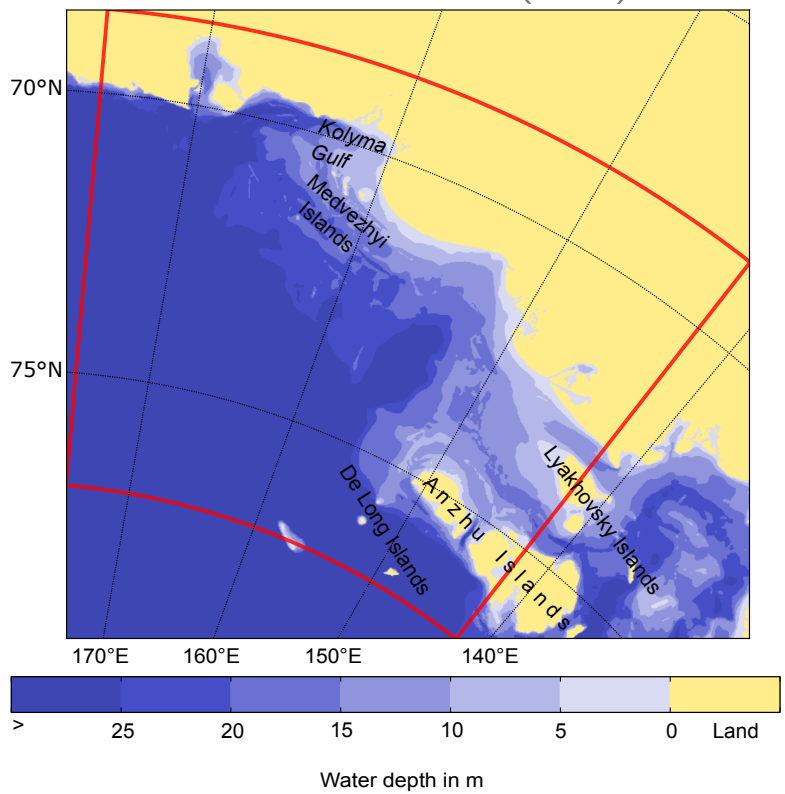
II. Regions of interest and fast ice information

Laptev Sea (LS)



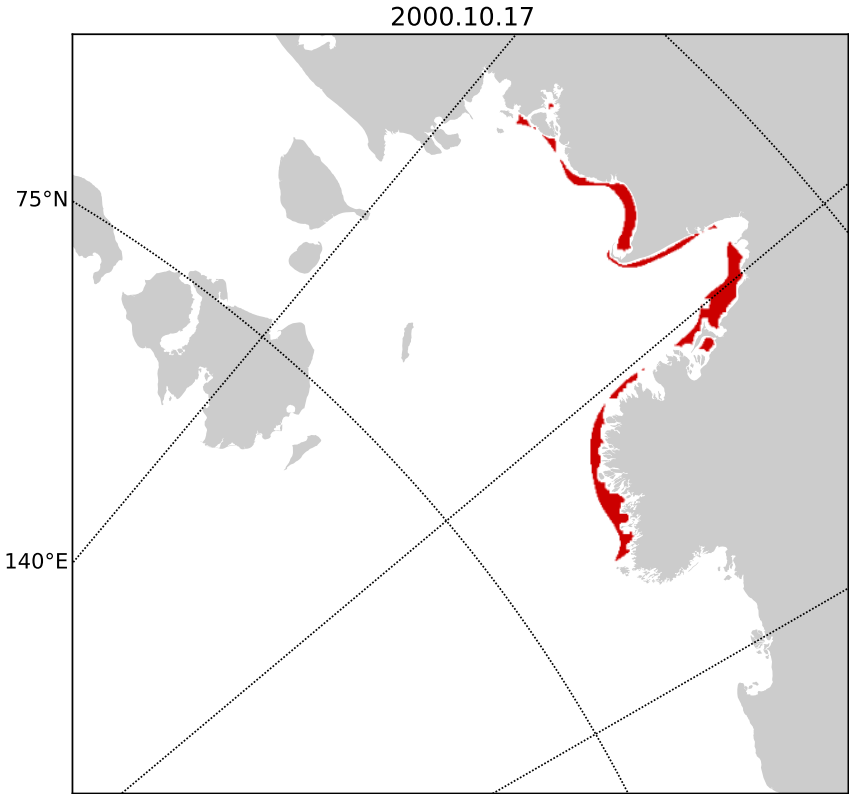
AARI charts, 1999-2013, weekly

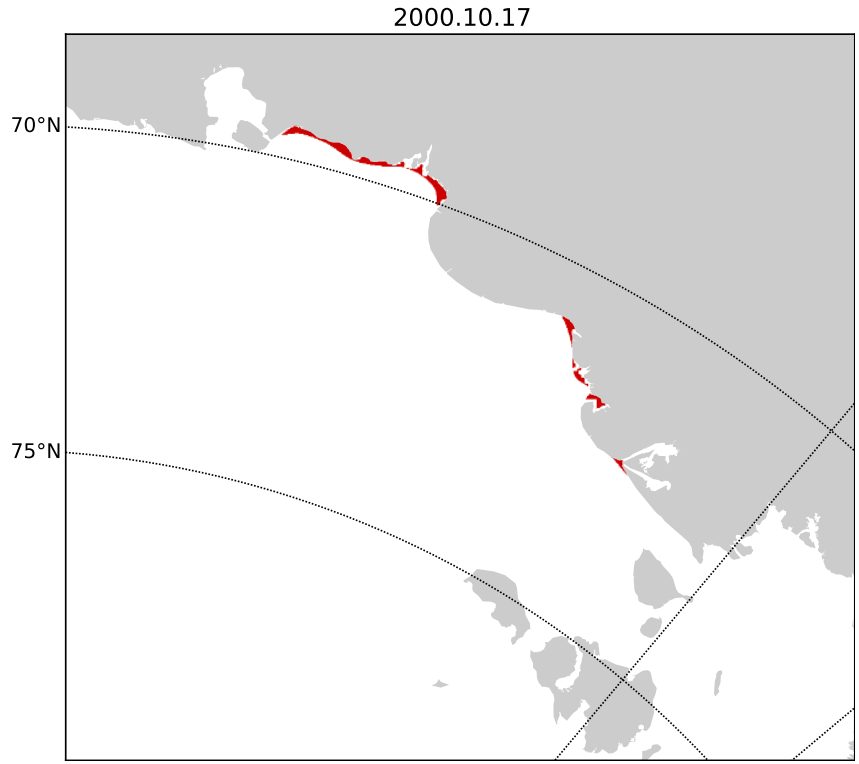
East Siberian Sea (ESS)



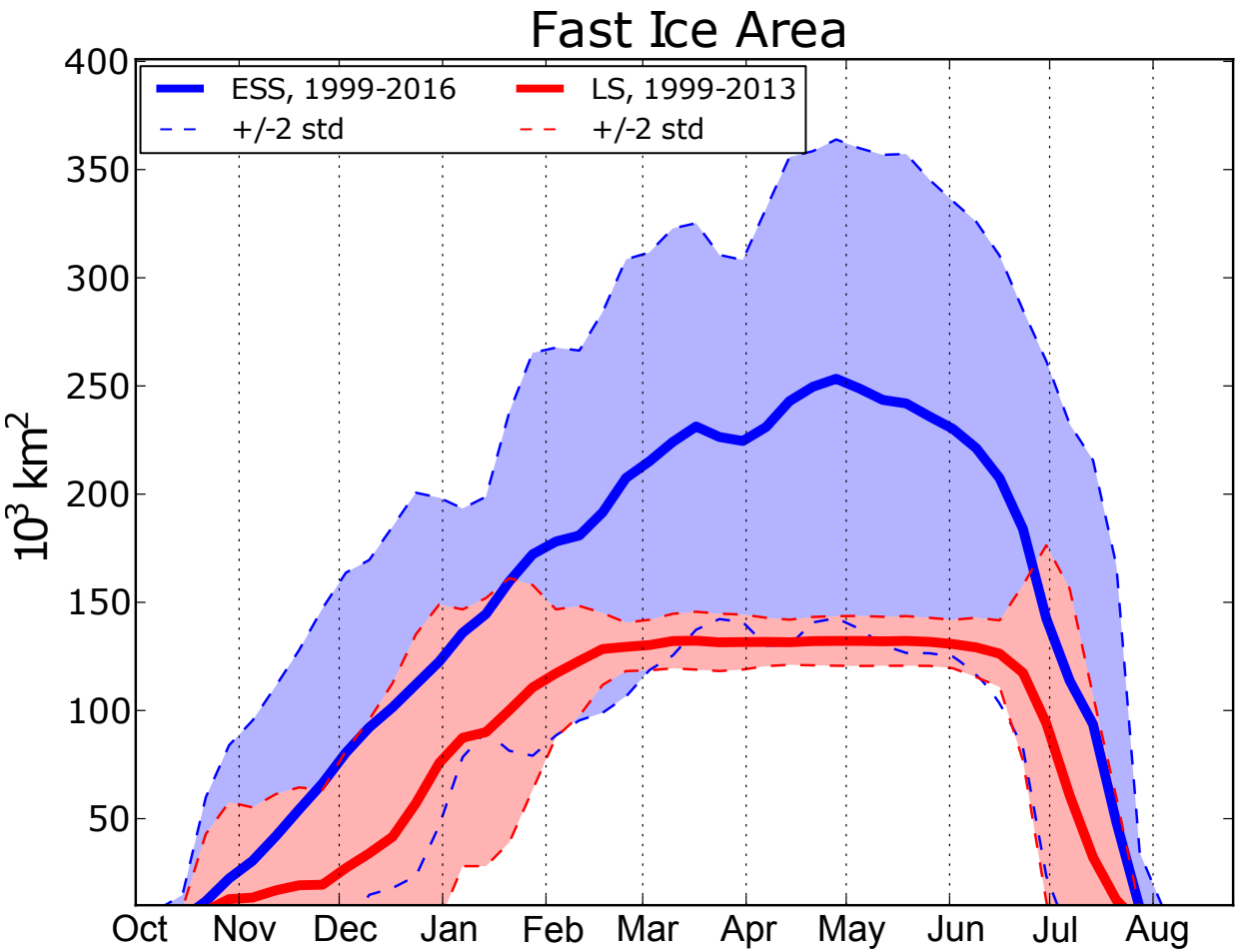
AARI charts, 1999-2015, weekly

II. Annual fast ice cycle, 2000-2001





II. Mean annual fast ice cycle



Interannual variability

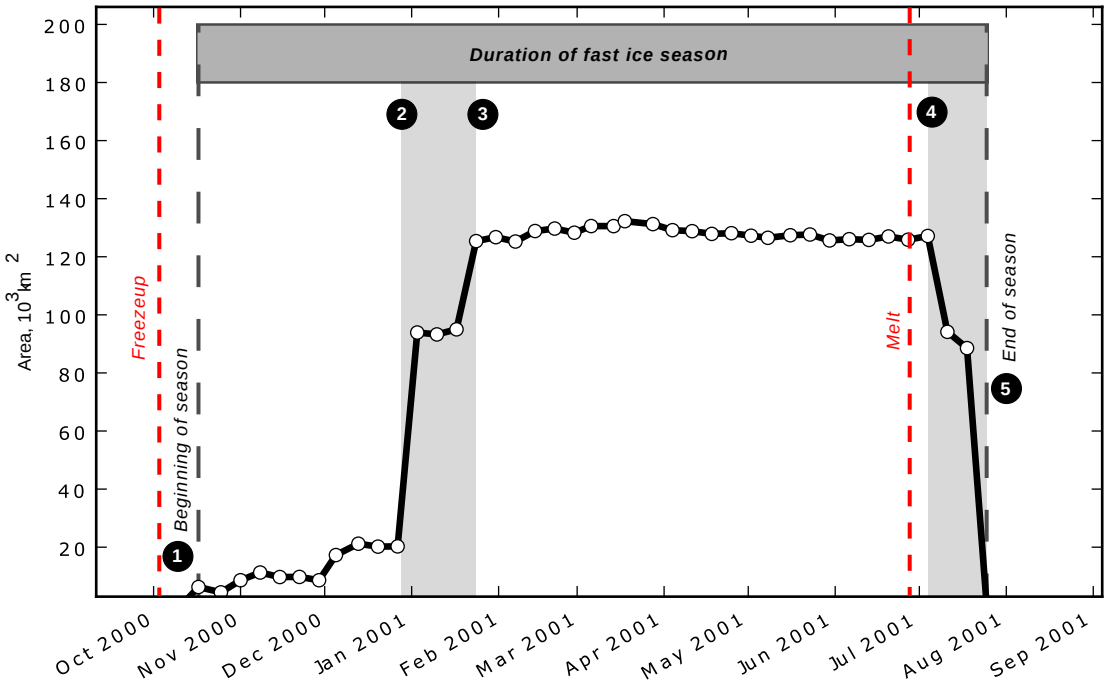
Laptev Sea:

- 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)

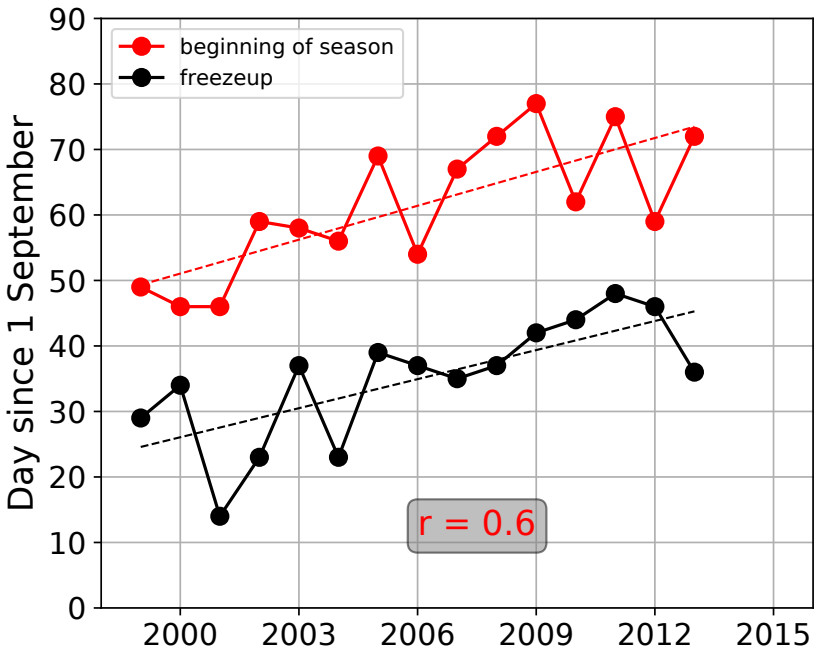
Laptev Sea,1999-2013

Time series of Key events 1-5

East Siberian Sea, 1999-2015

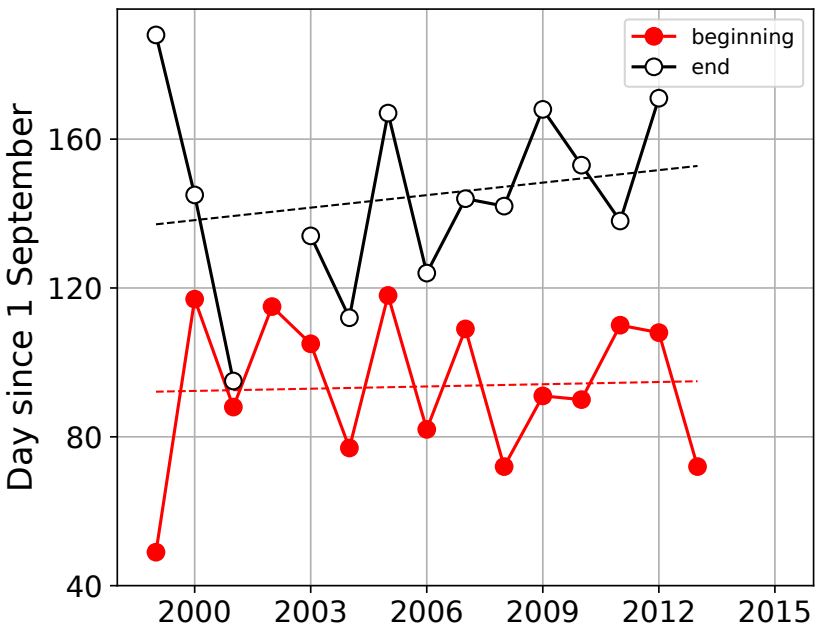
Time series of Key events 1 and 5

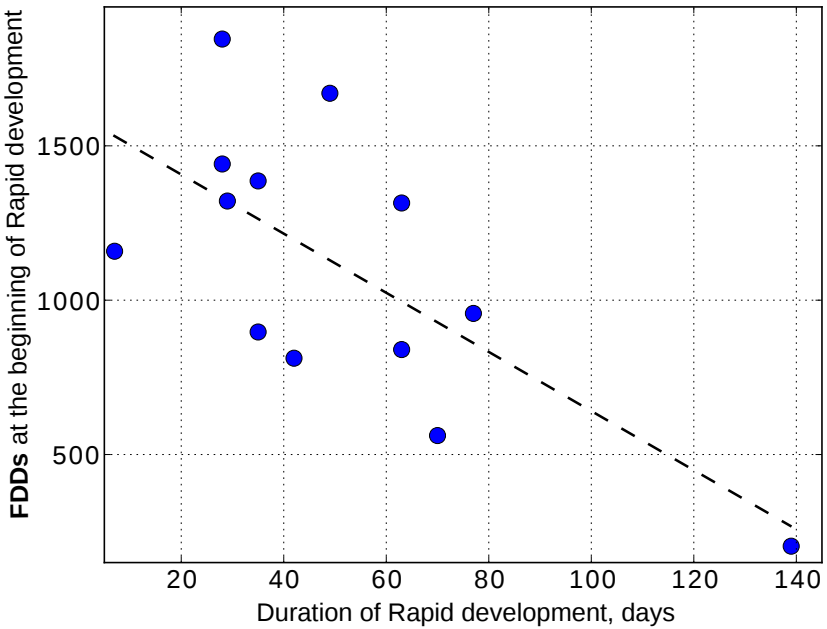
II. Beginning of season



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

II. Rapid development

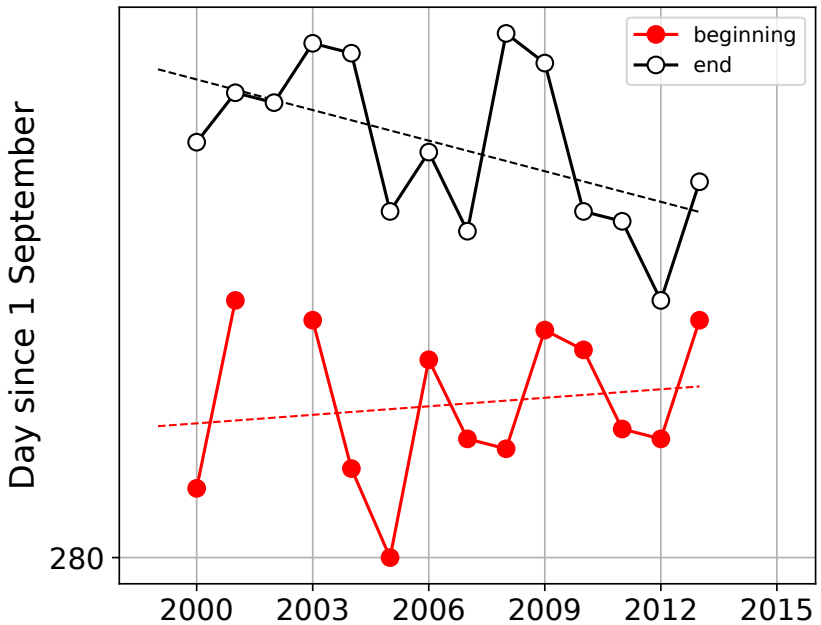


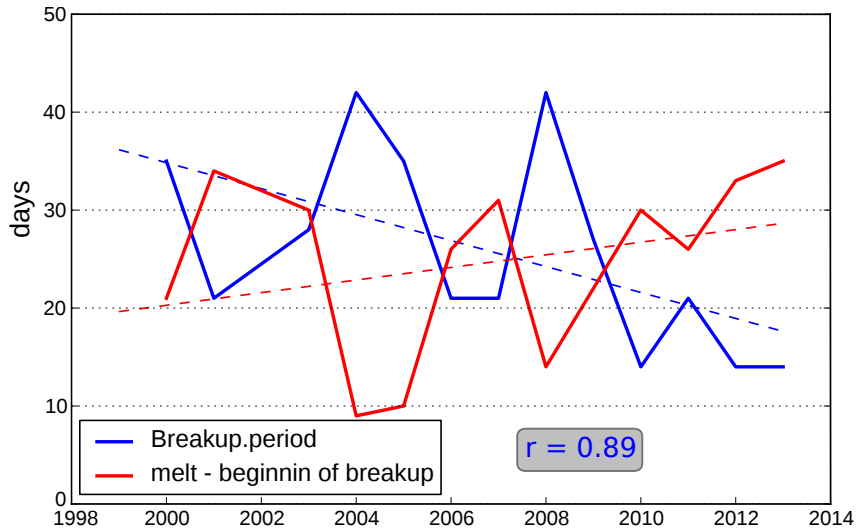


- high variability of dates
- tendency towards later end
  0.4 days/year (p=0.07)

- duration of period depends on accumulated FDD
- Modal ice thickness Hi(FDD) = 70-80 cm

II. Breakup

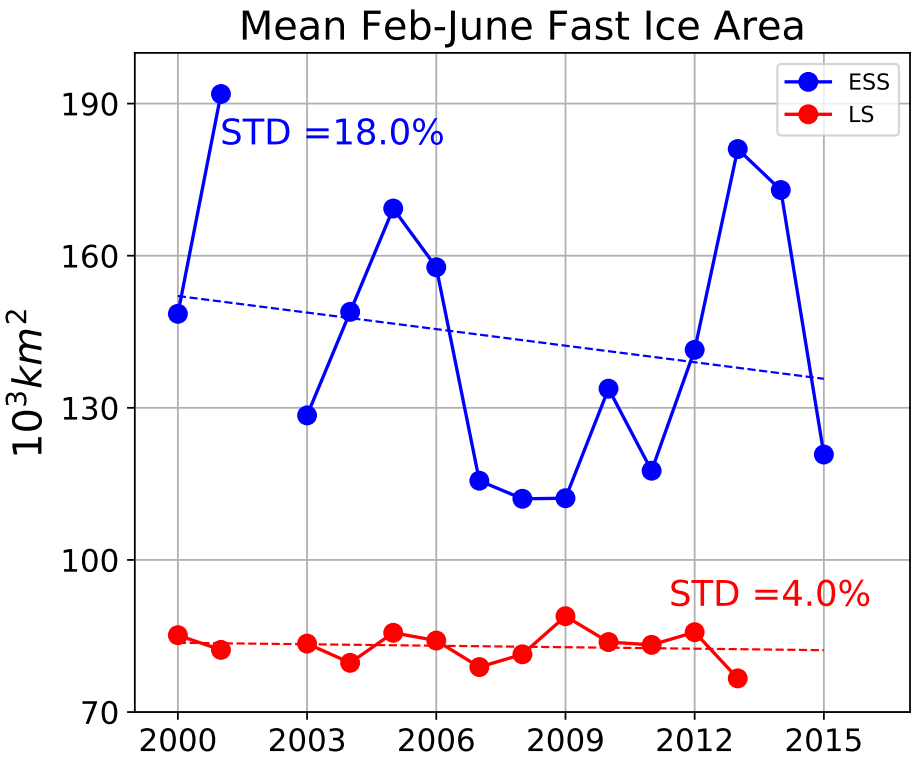




- tendency towards earlier end
  -1.0 days/year (p=0.06)
- no changes in beginning
  0.3 days/year (p=0.63)

- 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 changes in winter areal extent

II. Annual variability and interannual changes

Laptev Sea

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

East Siberian Sea

- high variability of winter extent
- no changes in winter extent
- shorter fast ice season (by 1.5 day/year)

II. Annual variability and interannual changes

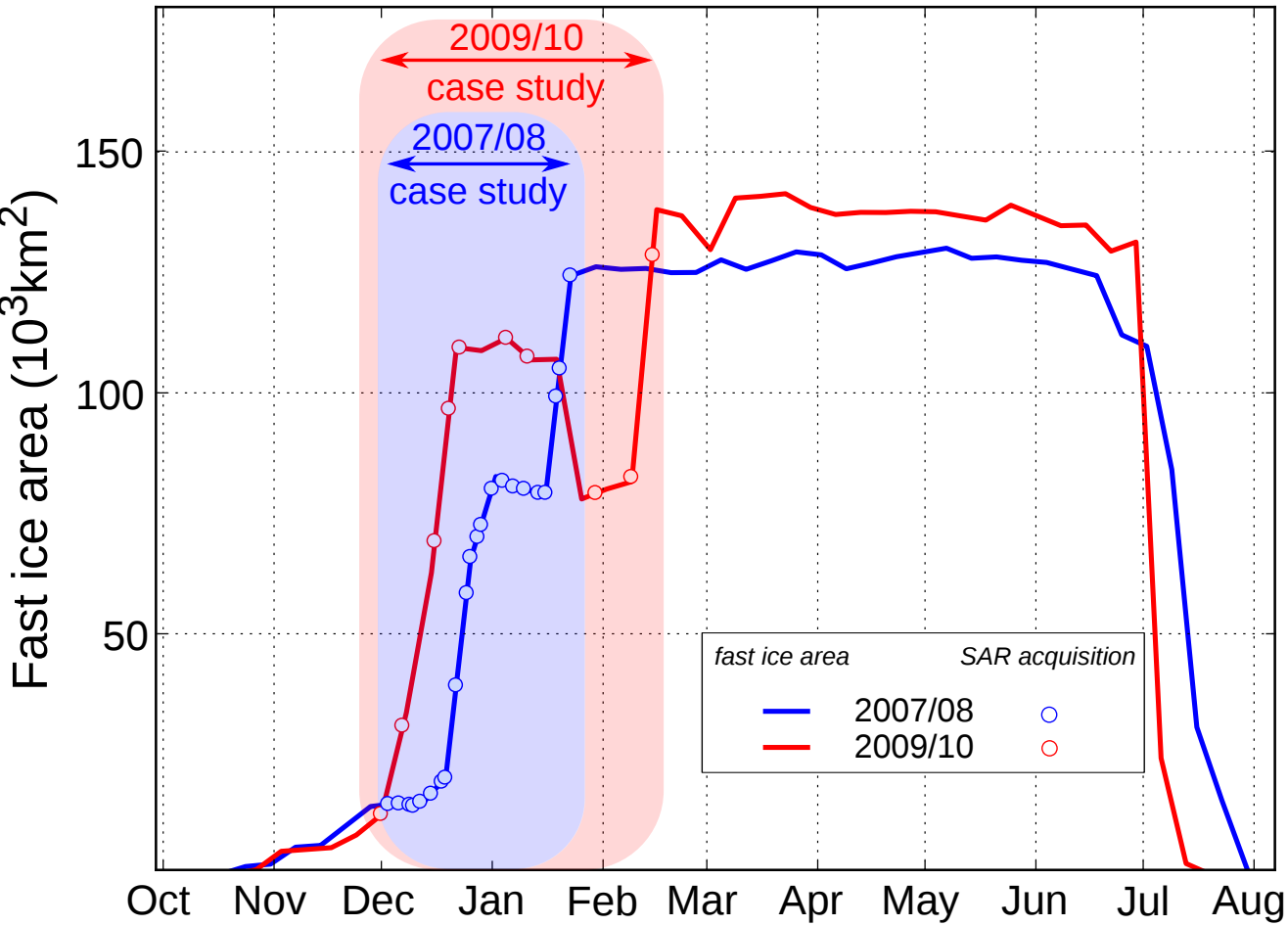
Laptev Sea

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

East Siberian Sea

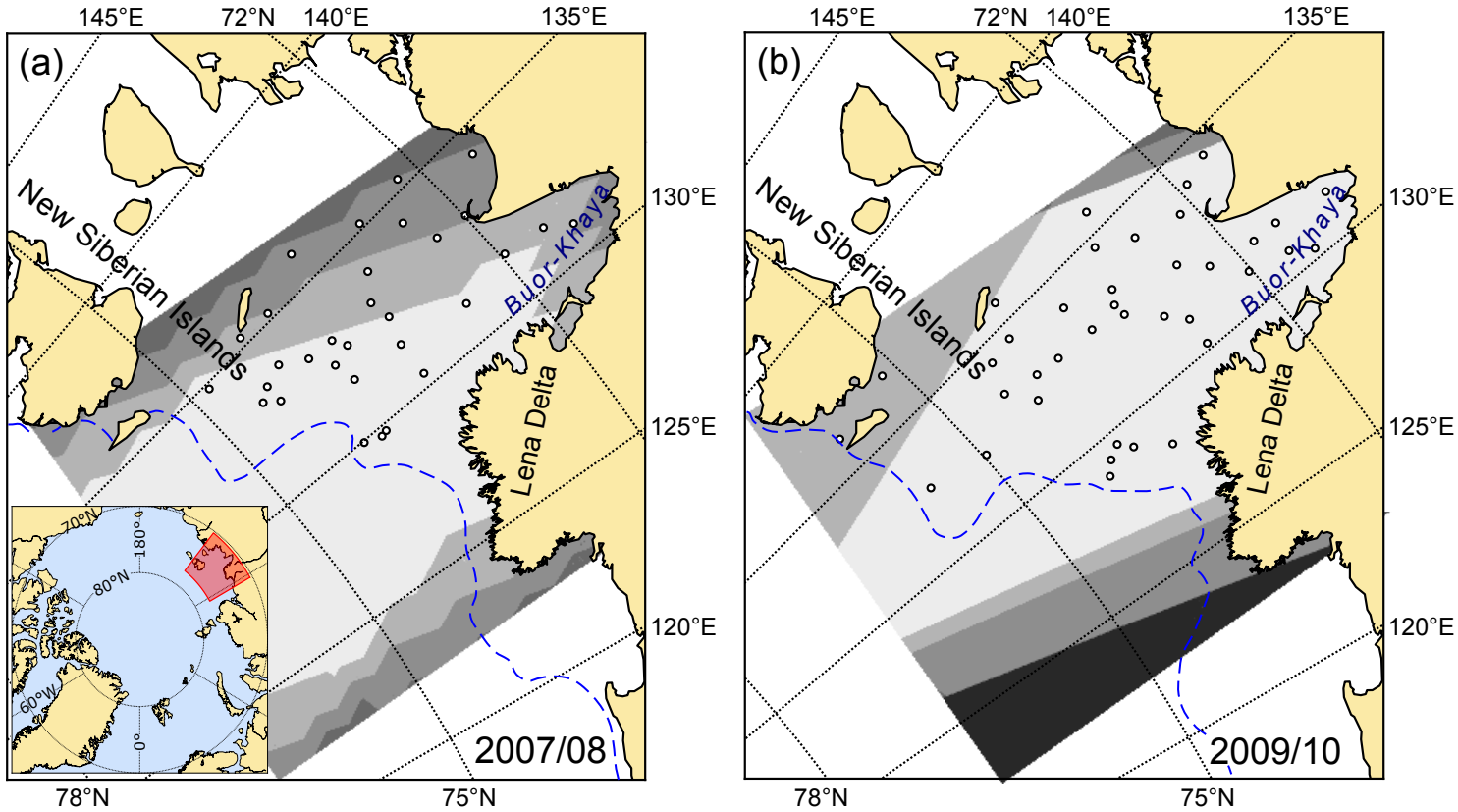
- **high variability of winter extent**
- no changes in winter extent
- shorter fast ice season (by 1.5 day/year)

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



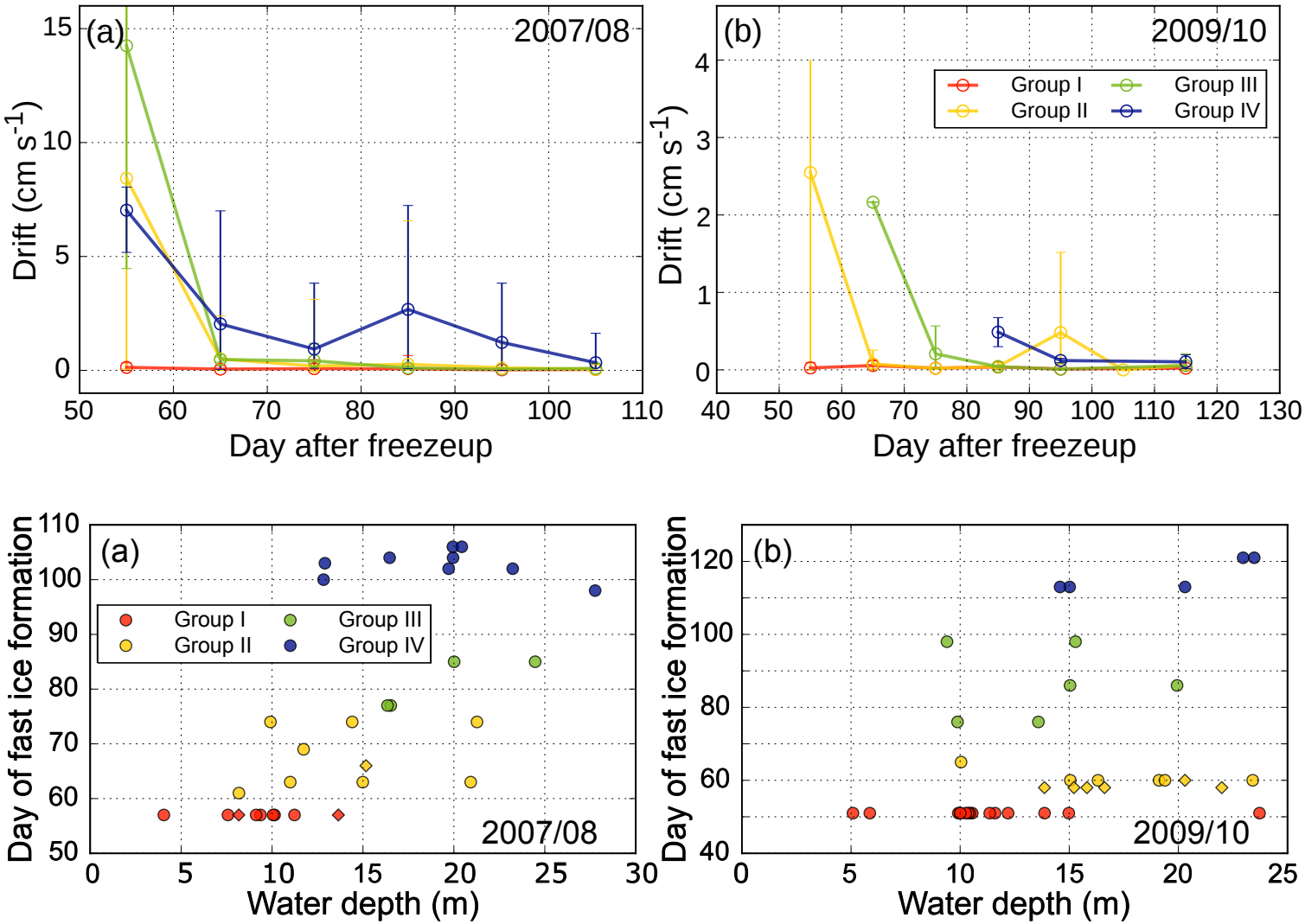
- SAR image every 2-14 days

III.Tracked sea ice features

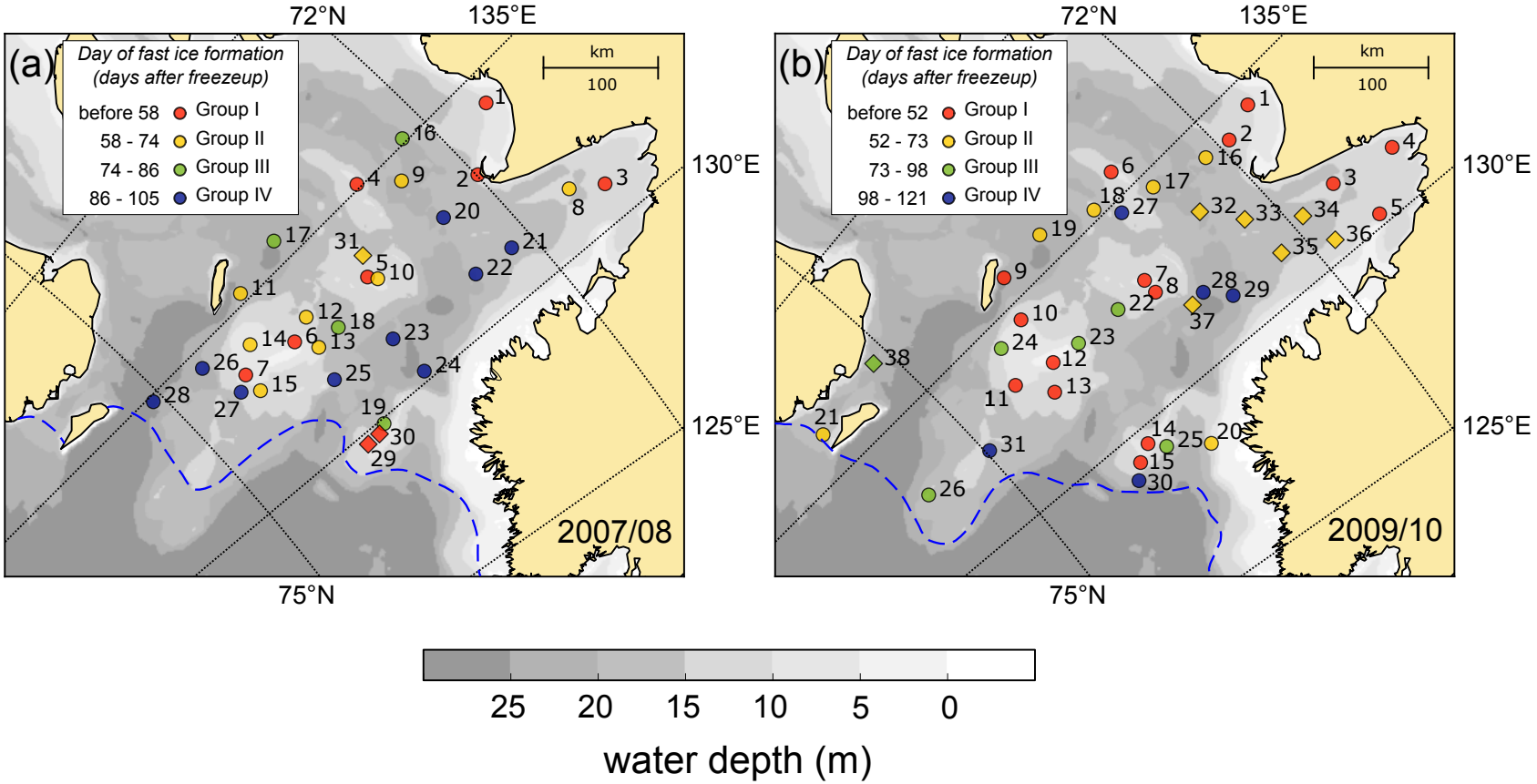


fast ice = 0 cm/s drift speed

III. Patterns of drift



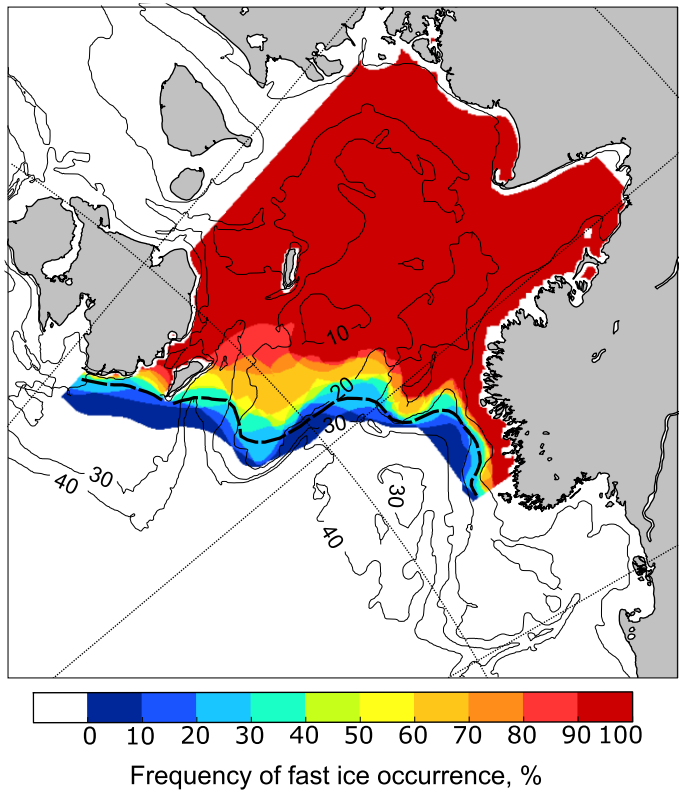
III. Final location of features



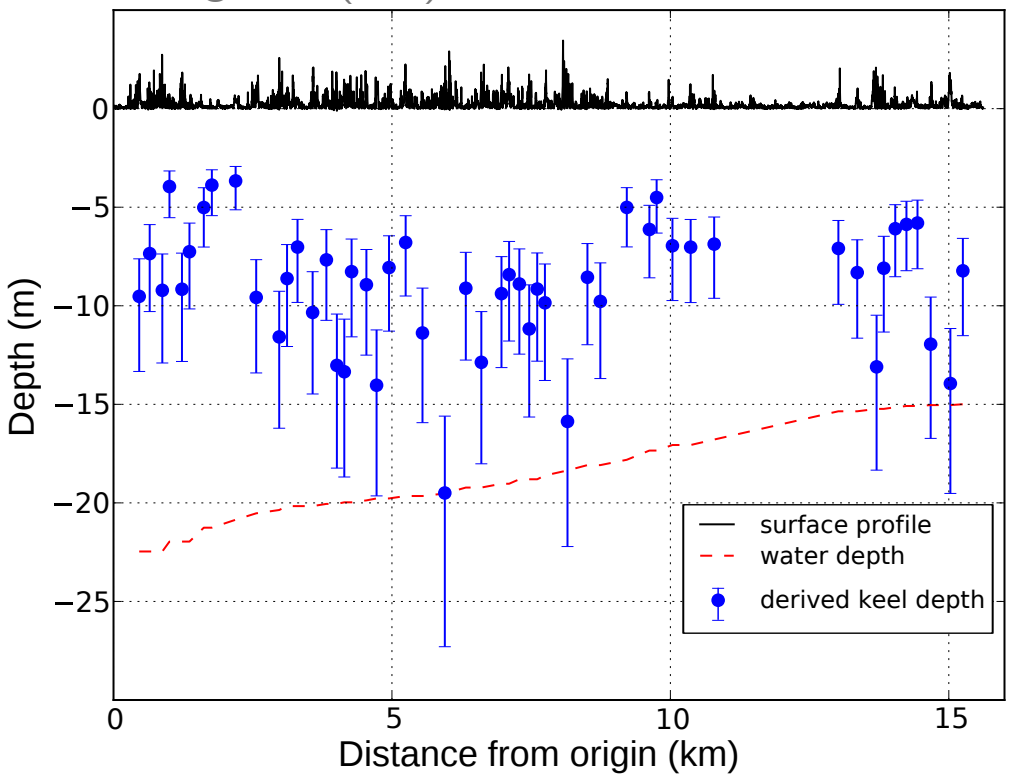
- relatively thin ice becomes grounded over the shoals (red circles)
- it serves as stabilizing points for surrounding sea ice
- low variations in winter extent predefined by the bathymetry

III. Deep sea ice ridges

End of Rapid Development

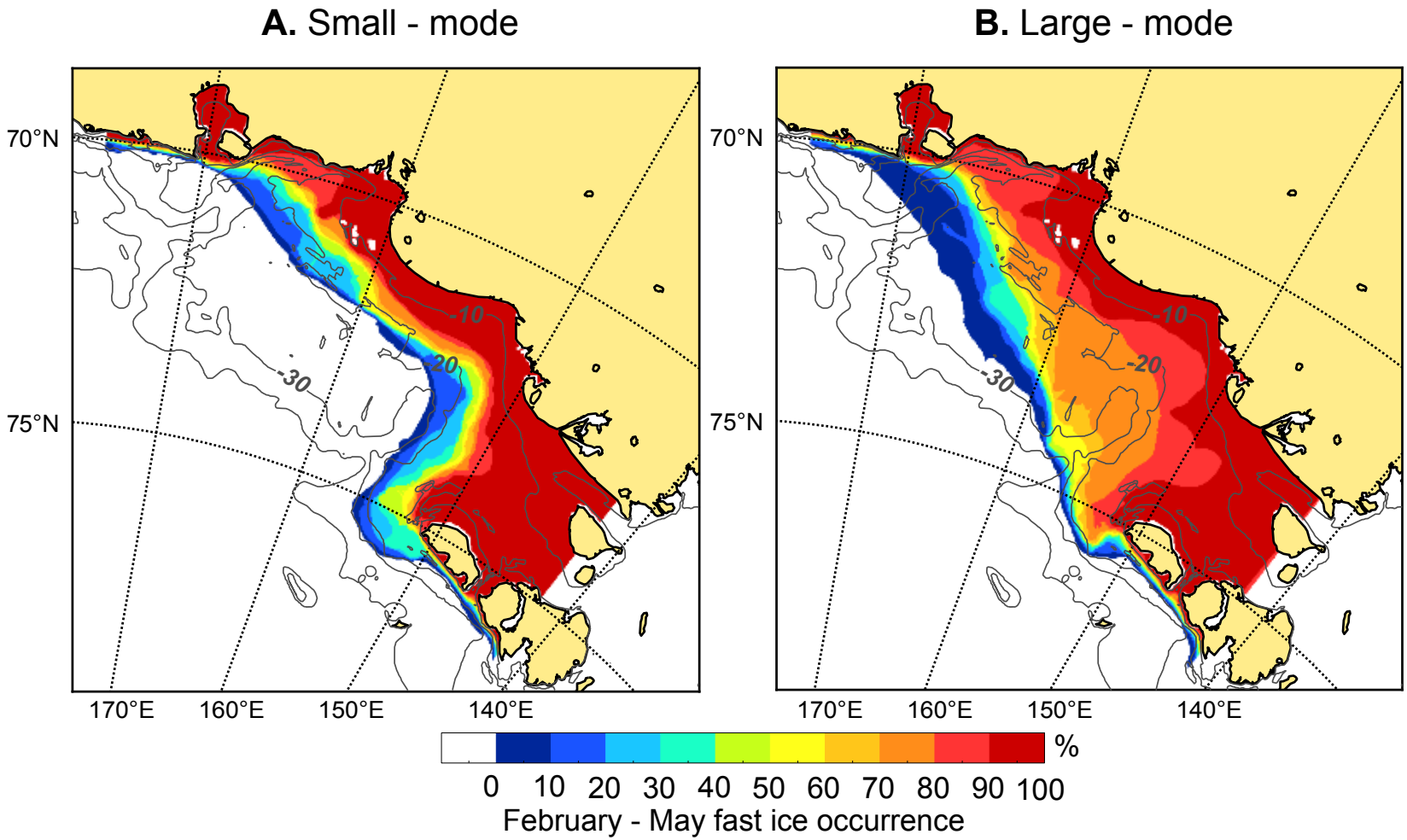


Electromagnetic (EM) ice thickness measurements



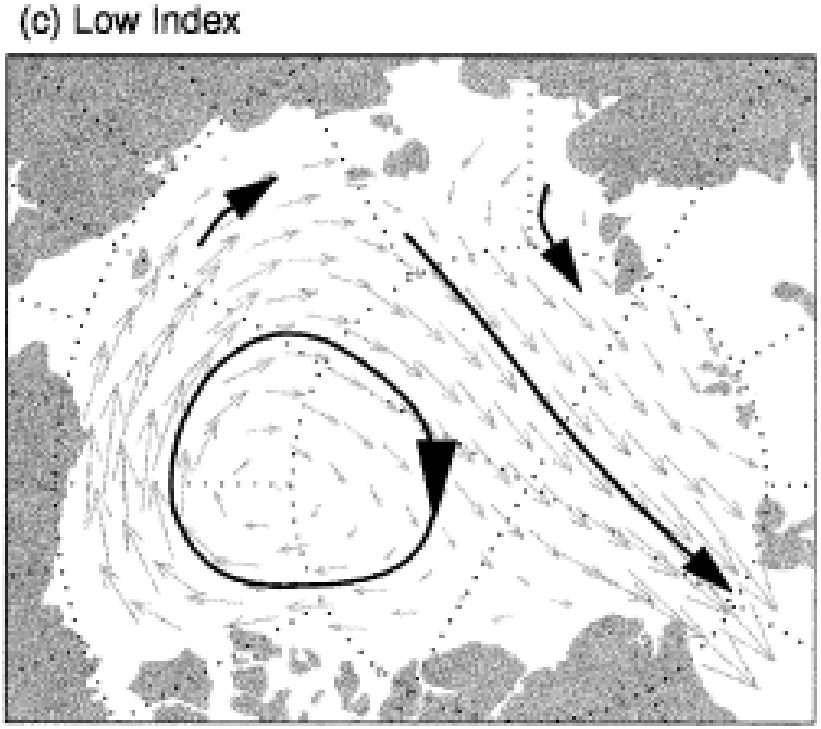
- variations in winter fast ice edge is likely controlled by grounding of deep ice ridges

III.East Siberian Sea Fast ice modes

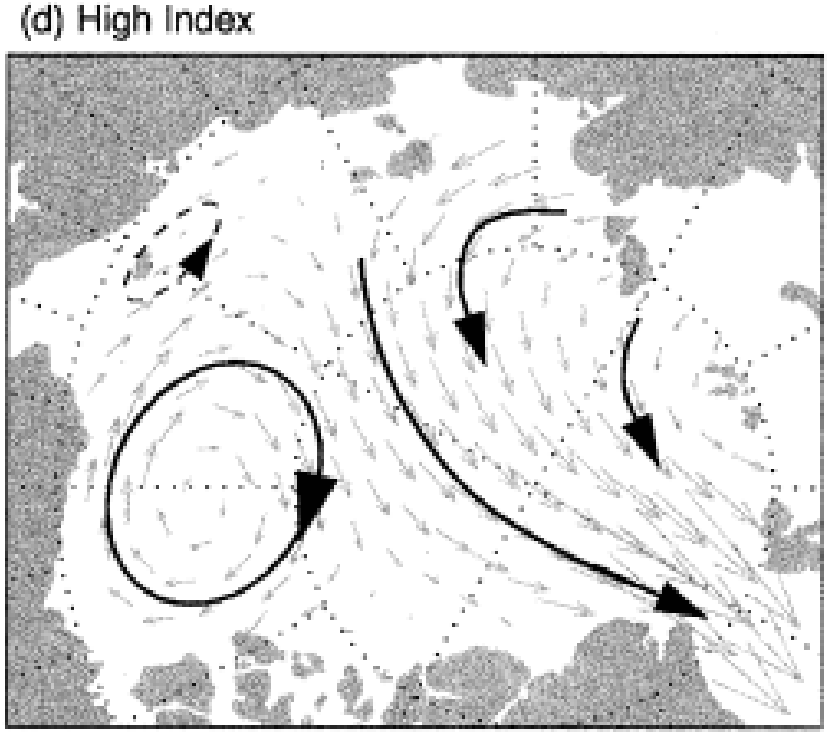


III. Arctic circulation

Negative Arctic Oscillation index (AO)

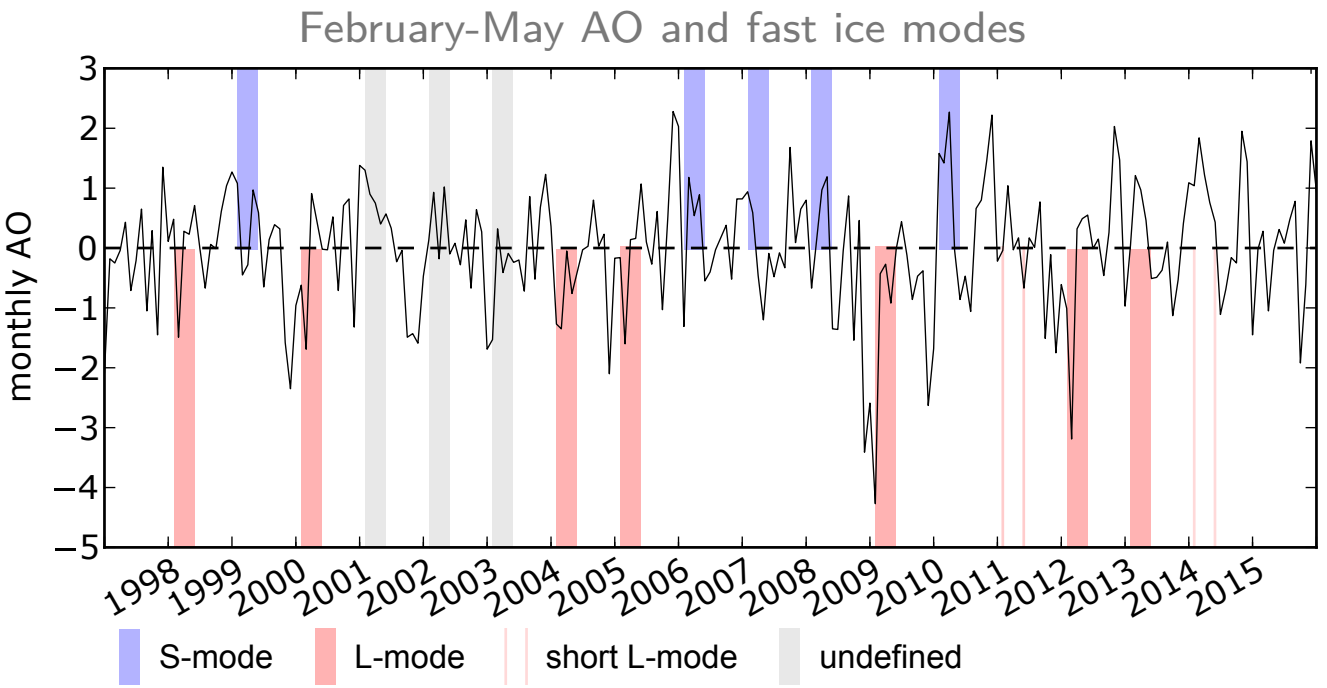


Positive Arctic Oscillation index (AO)

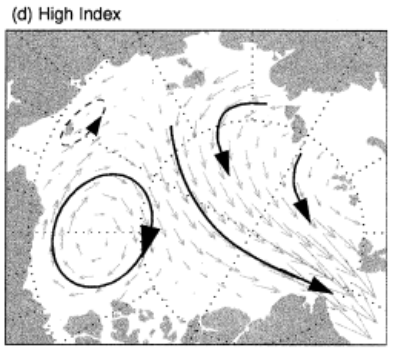


(Rigor et al. 2002)

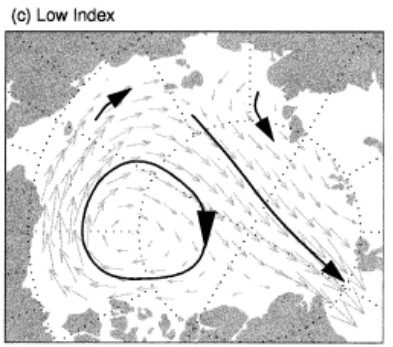
III.East Siberian Sea fast ice modes



Positive AO



Negative AO



Hypothesis

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

IV. Summary and outlook

Objective 1 - Annual variability

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

Laptev Sea

- re-occurring grounded features define **stable configuration**
- **stable configuration** reached when Hi >90 cm

Open questions

- role of grounding in the East Siberian Sea requires verification
- mechanisms of breakup are not well-understood

IV. Summary and outlook

Objective 2 - Interannual variability and changes

- Tendency towards shorter fast ice season (LS - 2,8 days/year, ESS - 1.5 days/year)
  - later fast ice formation increase probability of coastal polynya events
  - higher rates of coastal erosion
  - sediment entrainment
  - methane release
- No changes in winter fast ice extent
- Shorter time required for the Laptev Sea fast ice to breakup in summer