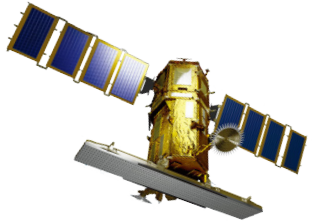
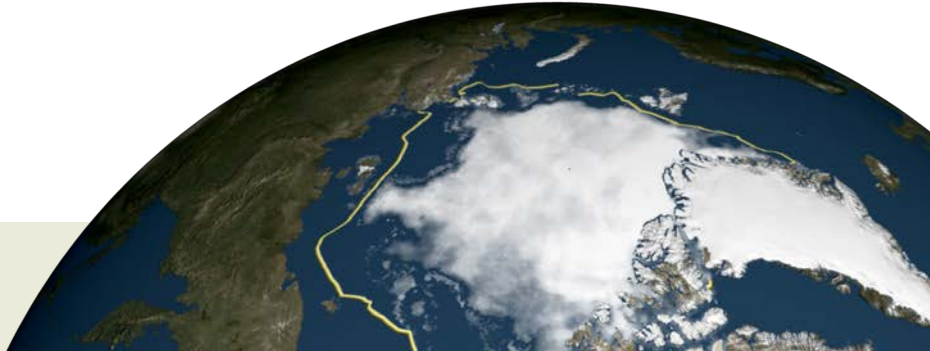
Sea Ice Remote Sensing
– Applications for Climate and Shipping –

Gunnar Spreen

University of Bremen

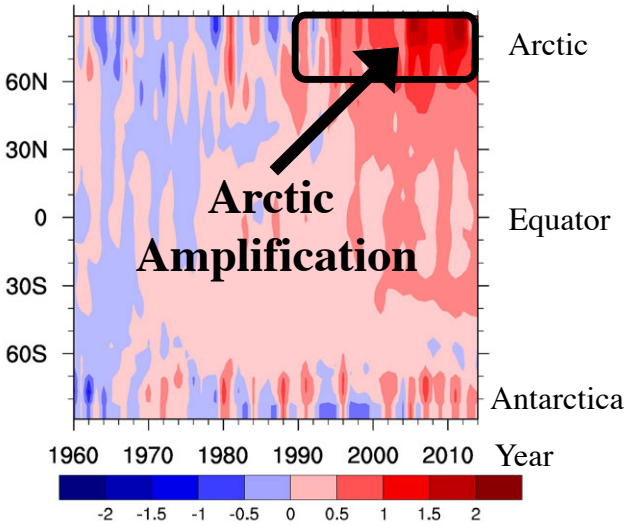
and members of the Remote Sensing Group for Polar Regions,
collaborators at AWI, NPI, JPL, UHH, and more





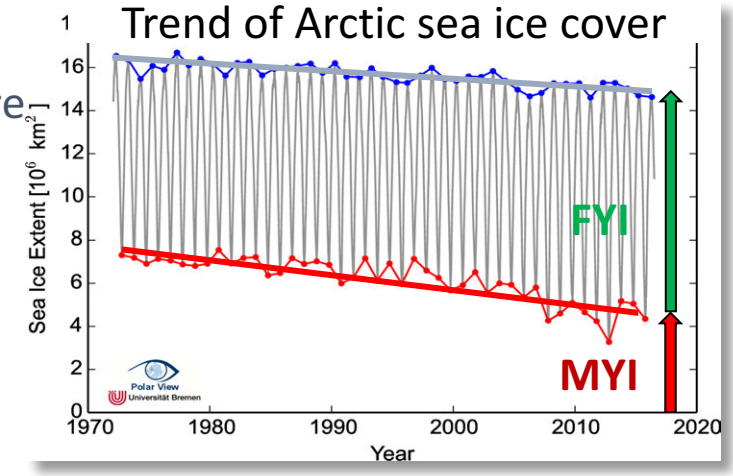
Universität Bremen

Effects of a Changing Arctic



Temperature Anomaly (Kelvin),
Reference: 1951-1980

- **Arctic Amplification**: increase in air temperature at twice the global rate
- **Sea ice albedo feedback** contributes to warming
- Changes of weather and precipitation patterns

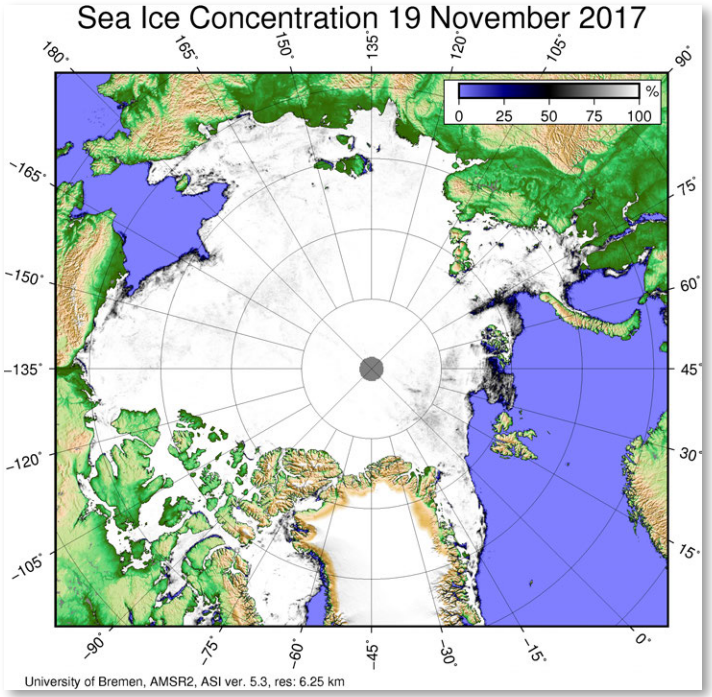


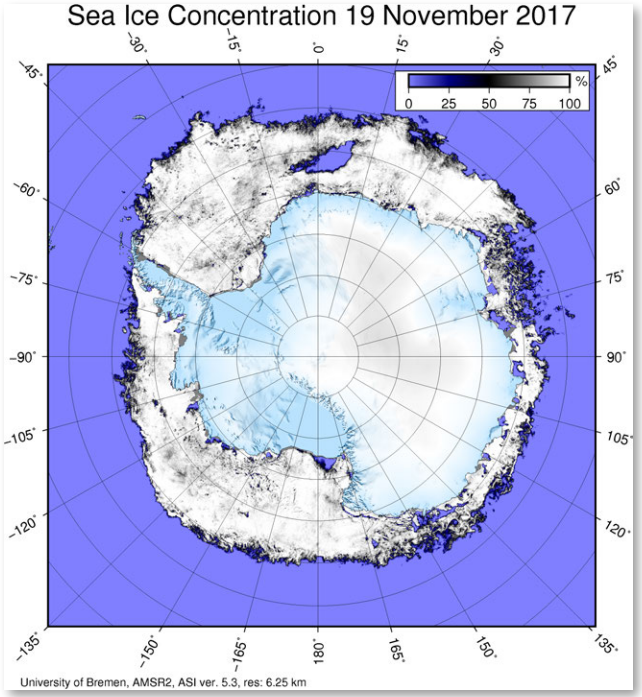
- **Changing marginal ice zone** effects Arctic marine eco-system and biogeochemical cycles
- **More wave action** on coasts → damages

What do we do?

- Remote sensing of sea ice and the polar atmosphere
  - variety of sensors from low resolution passive microwave to higher resolution optical and SAR sensors; altimetry
- Key research questions
  - Retrieve **new quantities** and establish reliable **error estimates**
  - **Merge** existing observations to new products
  - Closing the gap between sea ice monitoring and **climate system understanding**
- Strong collaboration with Alfred-Wegener-Institute and other partners
  - Field observations for validation and case studies
  - Bringing satellite observations and modeling studies together

Sea Ice Concentration

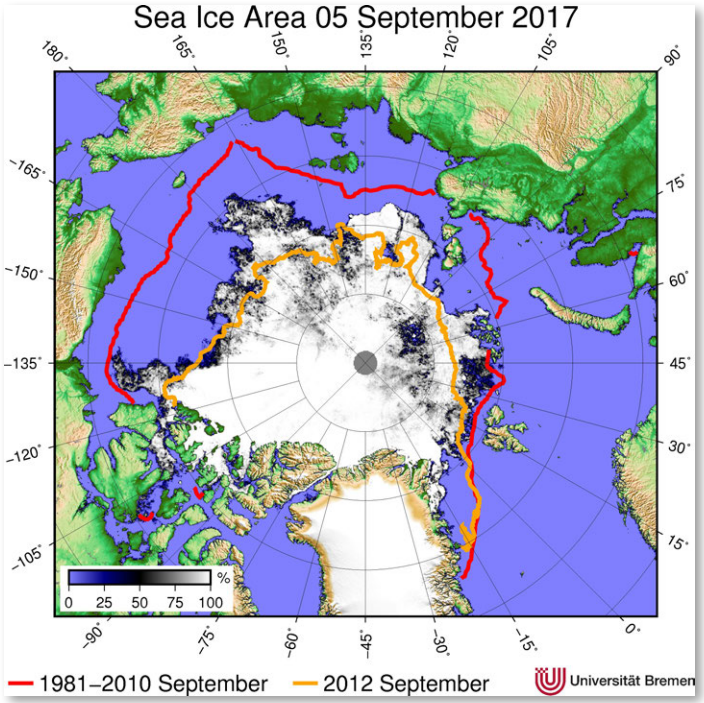


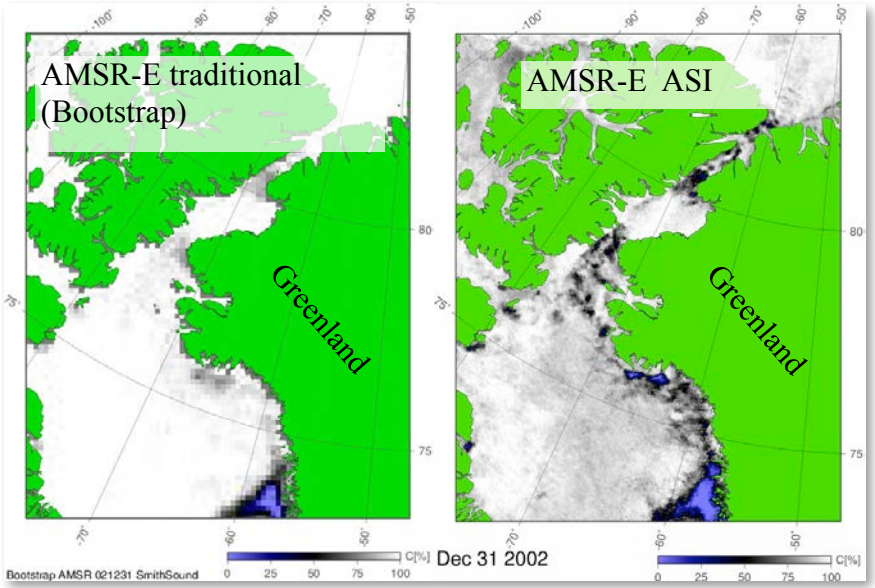


- Most widely used sea ice quantity
- University of Bremen: 89 GHz channels/higher spatial resolution (5 km)
- Based on AMSR-E/2 89 GHz
- www.seaice.uni-bremen.de
- www.meereisportal.de

[Spreen et al., 2008]

Sea Ice Concentration





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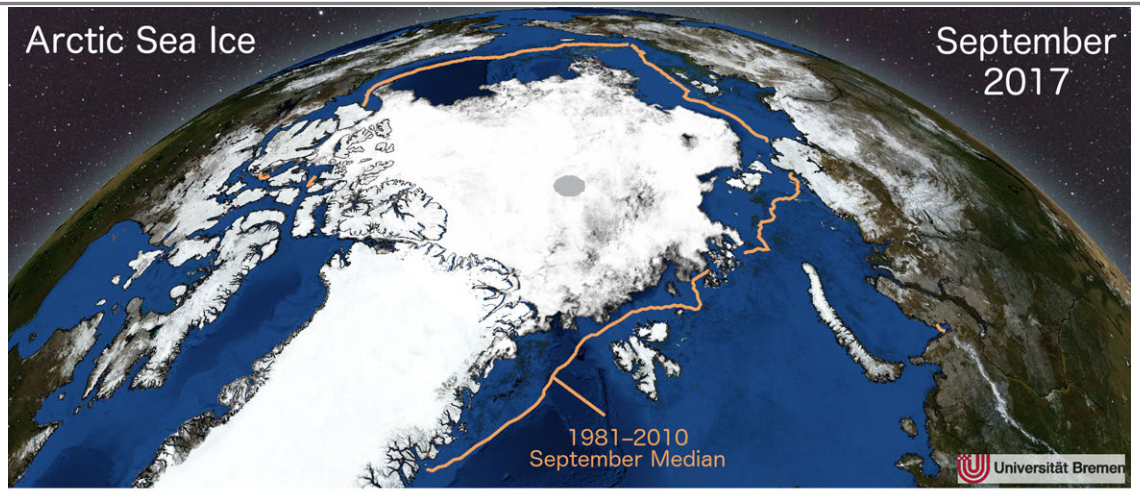
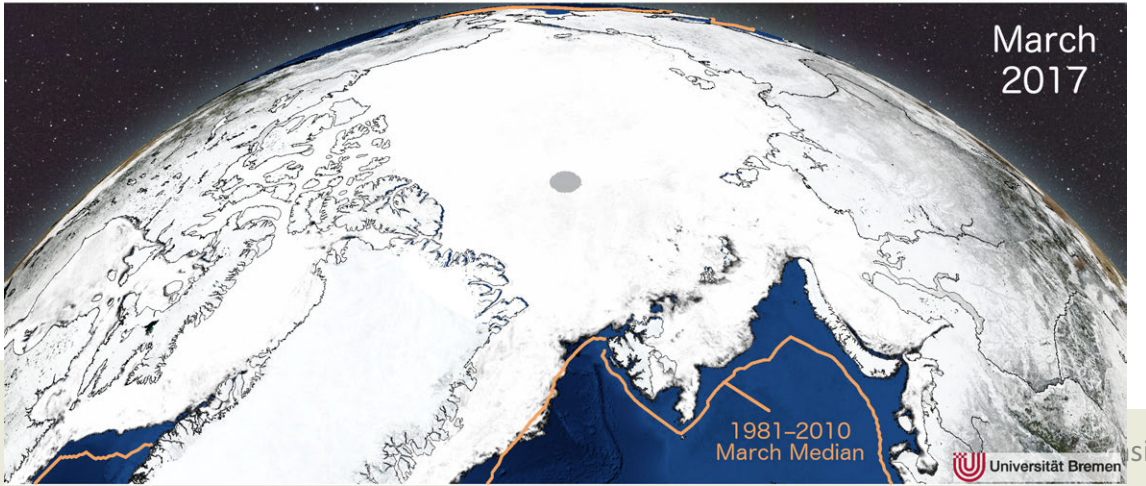
Sea Ice Concentration – Time Series





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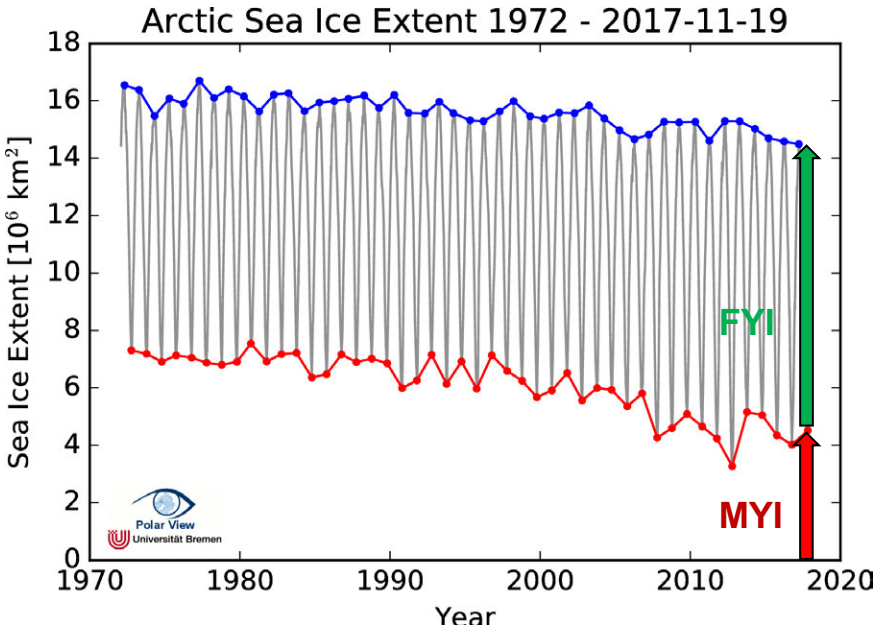
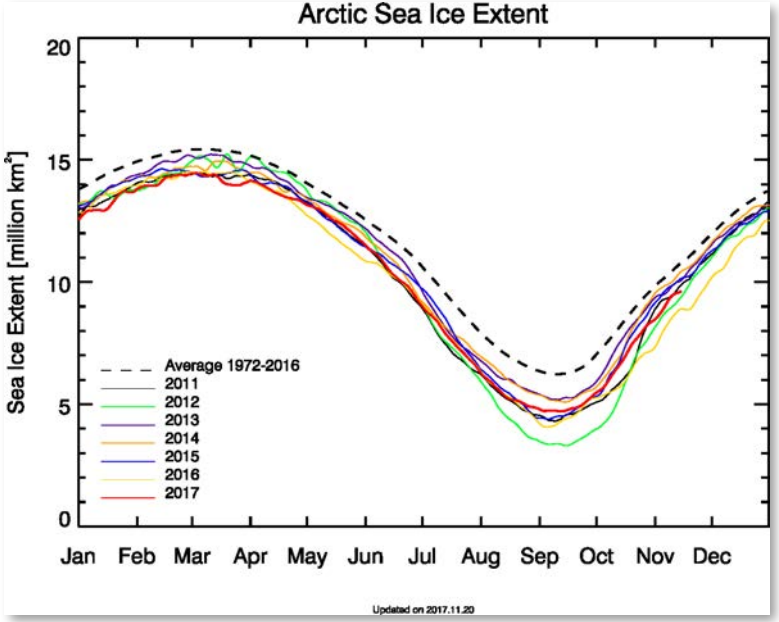
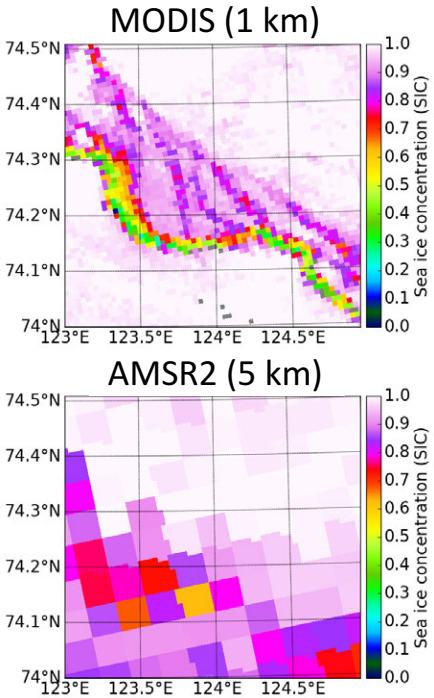




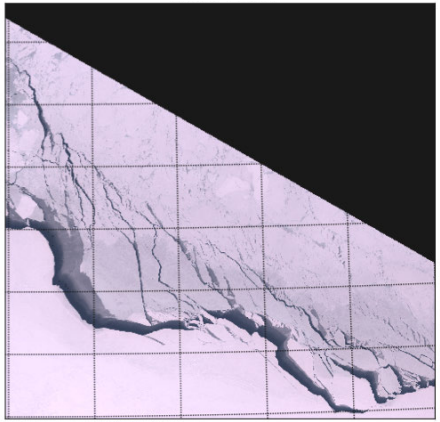
- Time series since 1972
- Annual trend: –4.5%/decade
- Summer trend: –13%/decade

- www.seaice.uni-bremen.de
- Data since 2002
- 6 and 3 km resolution
- daily 2 hemispherical, 27 regional maps

Current Improvements – Ice Concentration

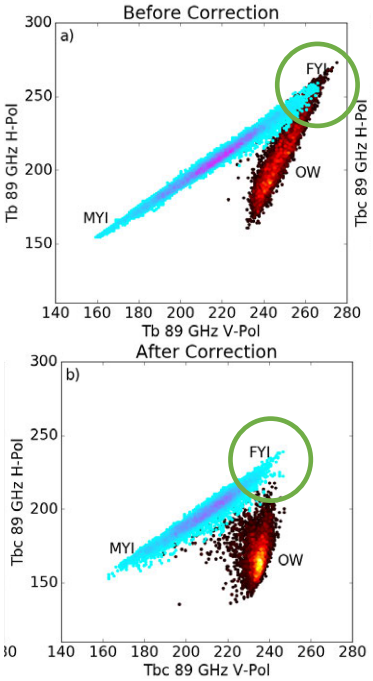


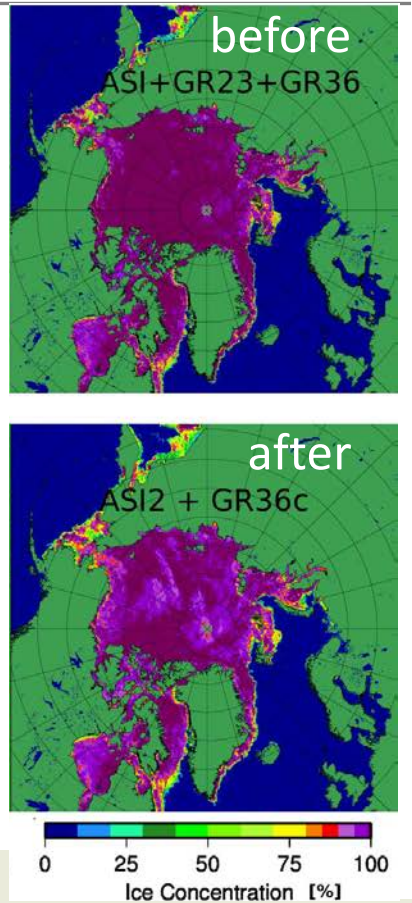
Landsat (30 m)



Laptev Sea

- Merging radiometer and optical data at 1 km resolution

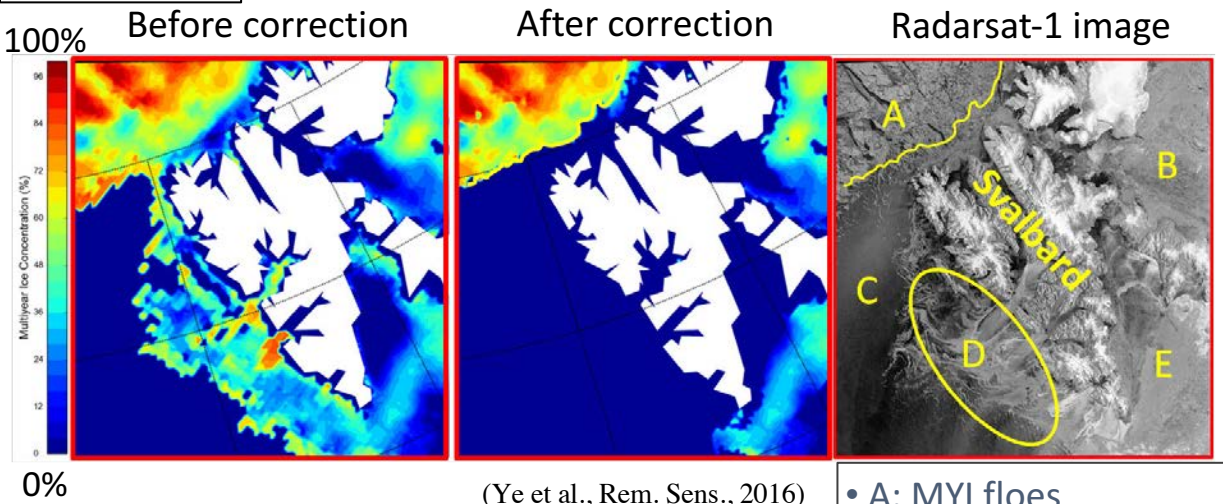




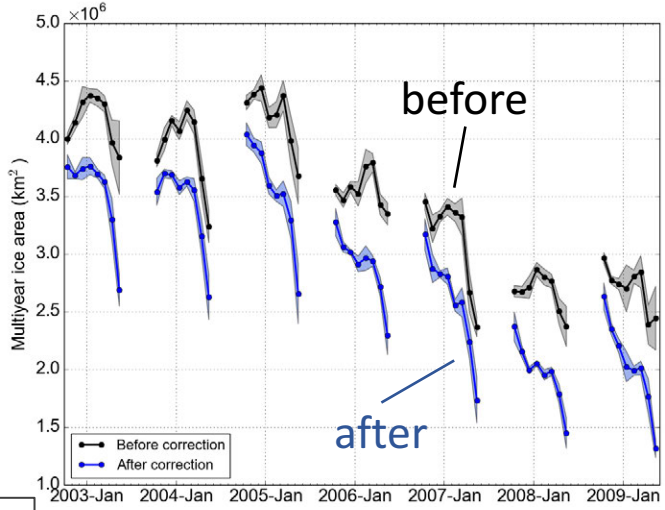
- Correcting atmospheric influence at 89 GHz using reanalysis data

Improved Multiyear Ice Concentration

April 2, 2003



(Ye et al., Rem. Sens., 2016)



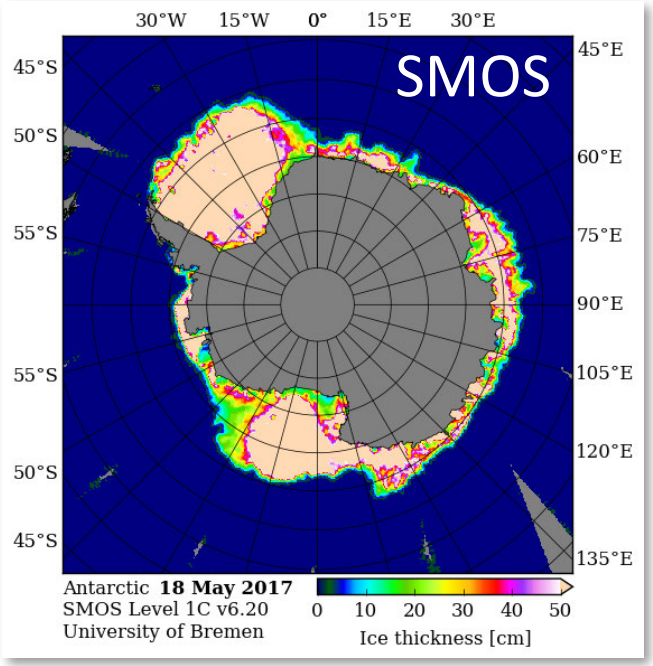
- Multiyear ice concentration suffer from misclassification due to
  - Rough first-year ice
  - Melt-refreeze cycle in the snow
- New filters to improve dataset

- A: MYI floes
- B, E: smooth texture
- C: open water
- D: streaks of high values

After correction

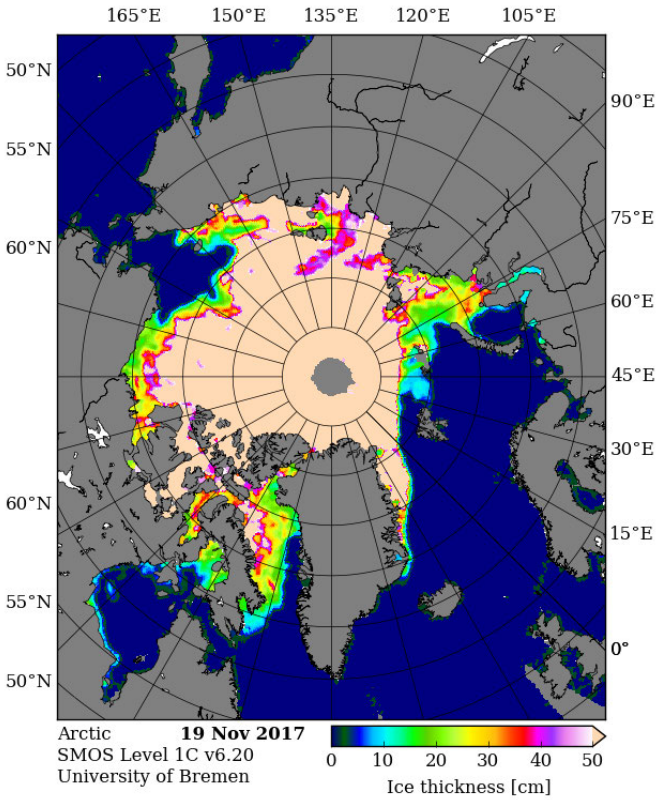
- a reduction of MYI area (5.2×10^5 km^2 on average)
- better monotonic decrease

Thickness of Thin Sea Ice: SMOS & SMAP



Huntemann et al., TC, 2014
Patilea et al., TCD, 2017

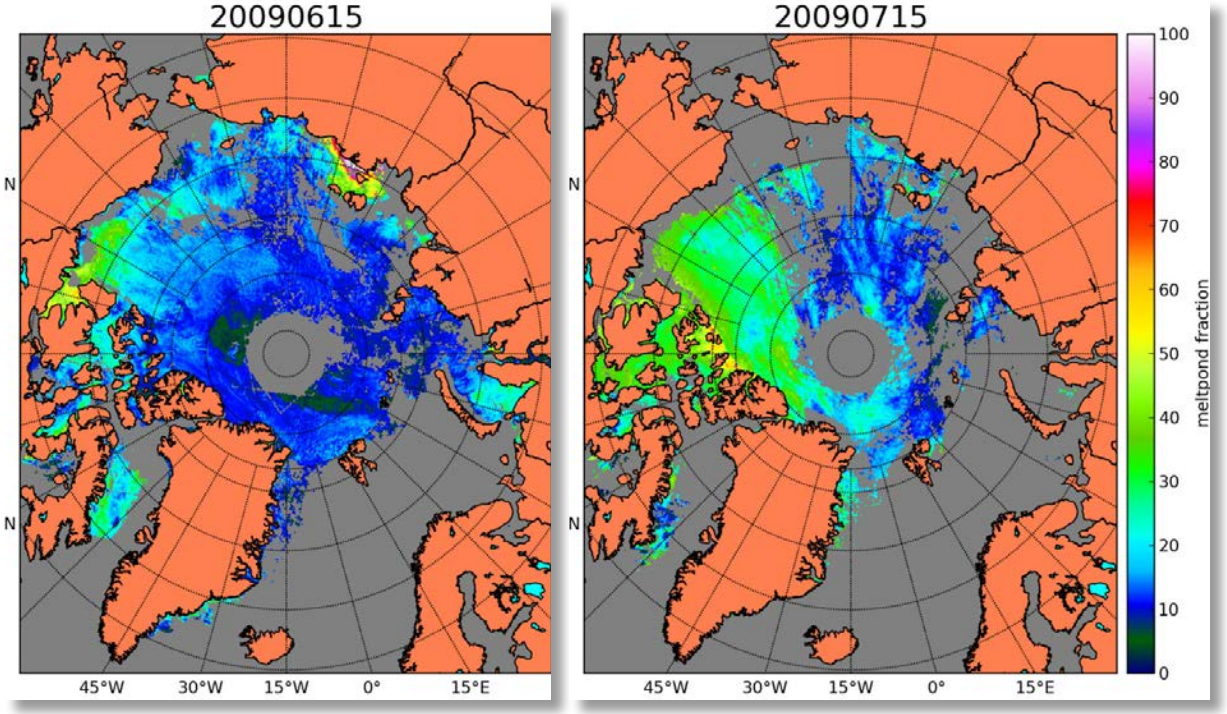
- L-band radiometers SMOS (ESA) and SMAP (NASA)
- <50 cm ice thickness
- SMOS since 2010; merged SMAP/SMOS soon
- U Bremen algorithm uses intensity I and polarization difference Q at 40–50°



- www.seaice.uni-bremen.de
- www.meereisportal.de

Melt Pond Fraction retrieval from MERIS

- **Data 2002–2011:** MERIS (412–900 nm) on ENVISAT, 1 km x 1 km resolution, 6 wavelengths, 9/15 ch. used.
- **Forward model:** ice as random mixture of grains with inclusions (air bubbles, brine, sediments, etc.), melt ponds, in VIS/NIR, scattering by Rayleigh-Gans approx.
- **Constraints on the model parameters** to remove the unphysical solutions are developed analyzing a set of ~200 field spectra of ponds and ice. **Model does not use *a priori* values for sea ice or pond optical properties!**

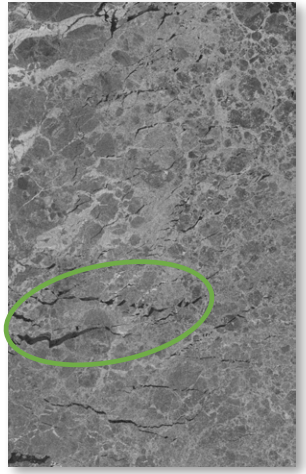


Istomina et al. 2015 and 2015a

Data at: www.seaice.uni-bremen.de

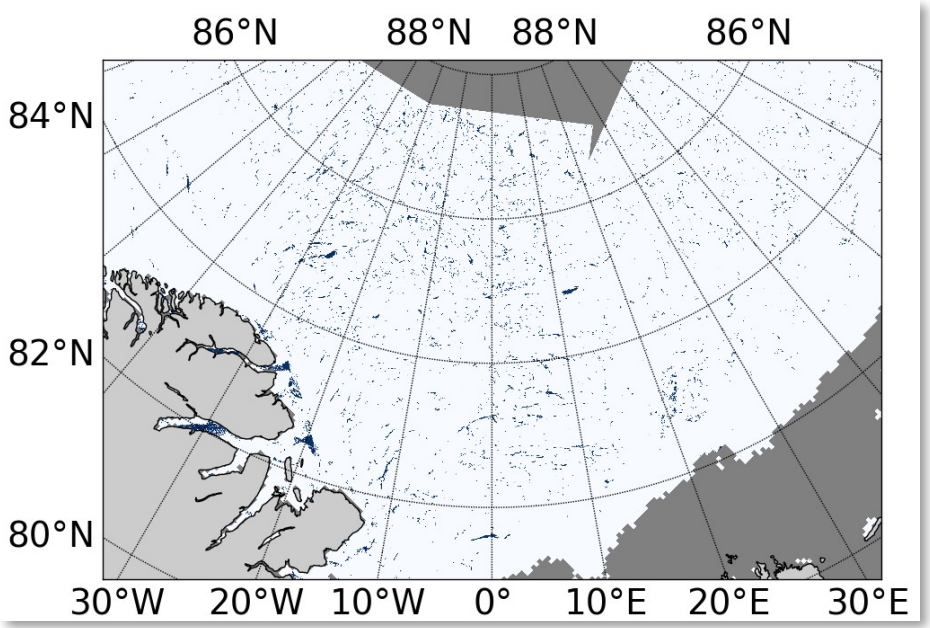
Lead detection using SAR data from Sentinel-1

SAR data (Sentinel-1)



Optical data (Sentinel-2)

- Leads are important for heat & gas fluxes and for shipping
- Sentinel-1 Synthetic Apertur Radar (SAR) data since 2015

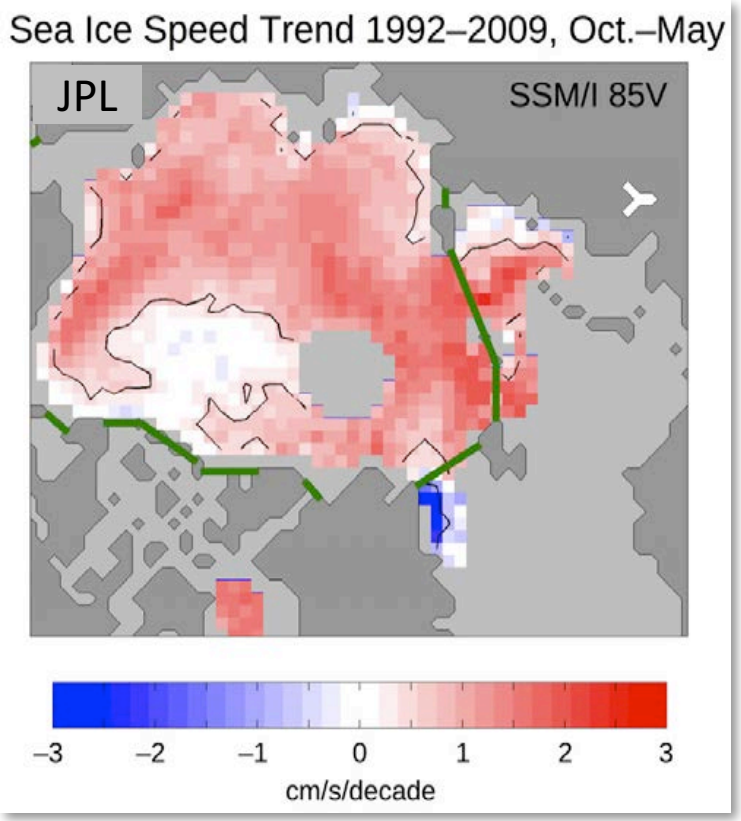


2016-01-05

- Two polarizations (HH, HV)
- Covers large parts of the Arctic daily at 100 m resolution
- Daily lead and lead frequency maps for the European Arctic

Murashkin et al., Ann. Glac., in review

Climate System Understanding

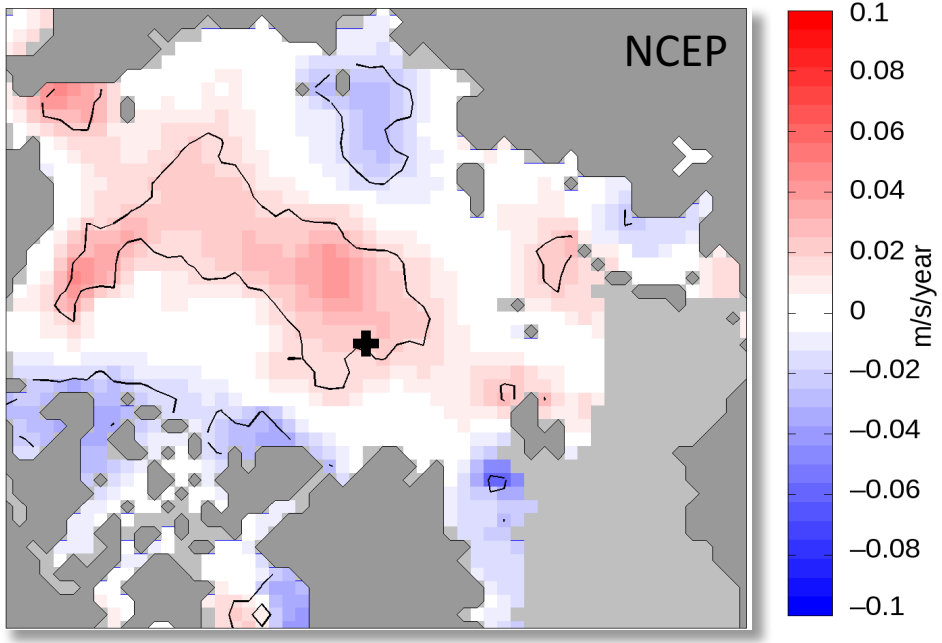


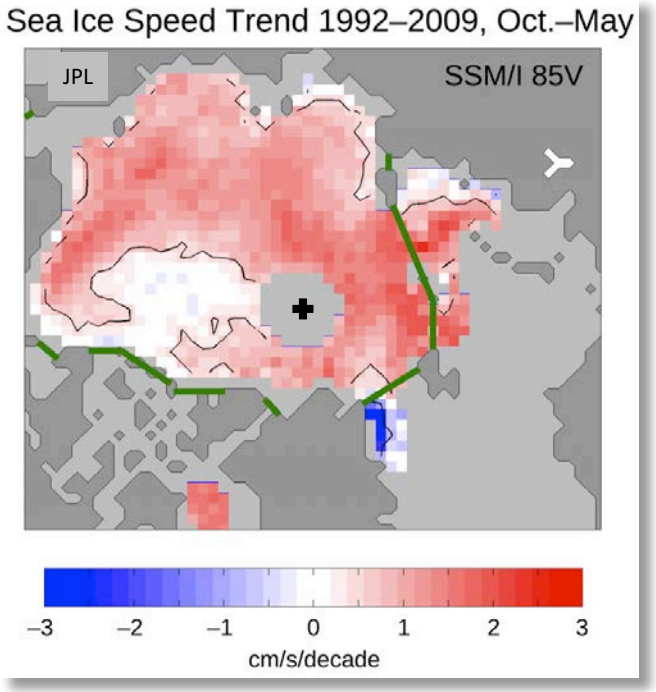
Sea Ice Speed Trend

- 1992–2009, winter (Oct–May)
- Positive trend in sea ice drift speed in most of the Arctic Basin
- Sea ice drift from SSM/I satellite radiometer

Spreen et al., GRL, 2011

1992–2009 Wind and Ice Speed Trend





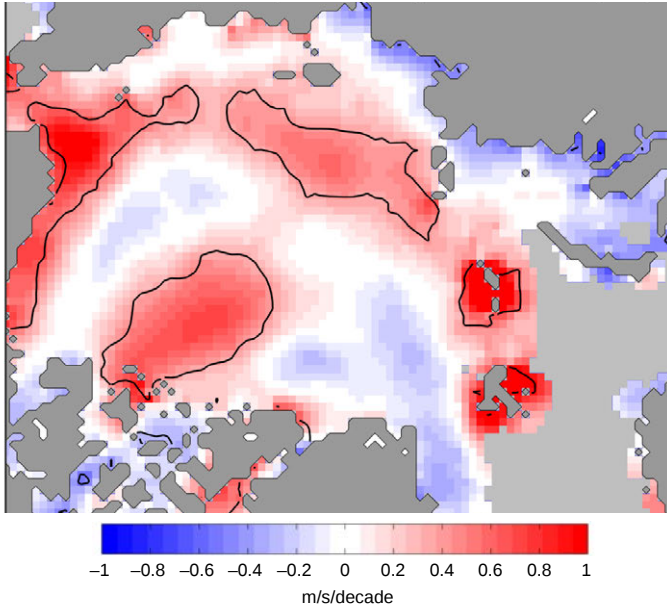
- winter: Oct-May
- 1992 - 2009

✚ North Pole

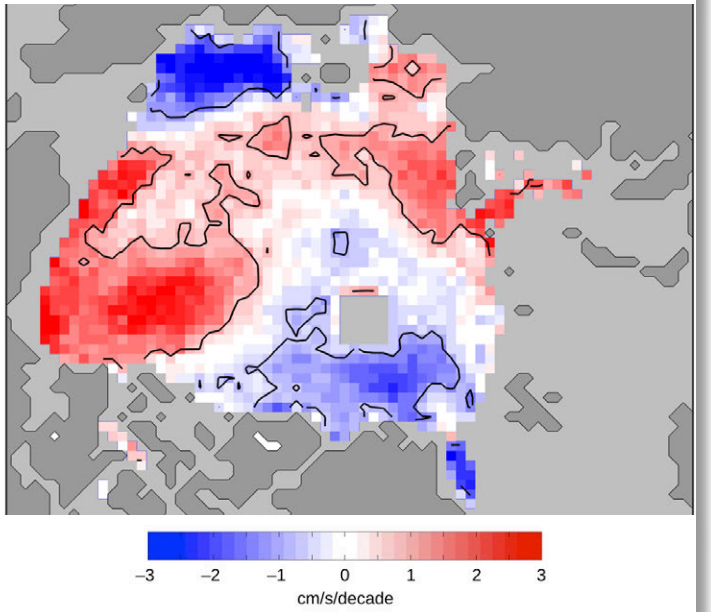
➢ all 4 reanalyses: only small trend in wind speed

2007–2016 Wind and Ice Speed Trend

NCEP wind speed trend 2007–2016, Sep.–May



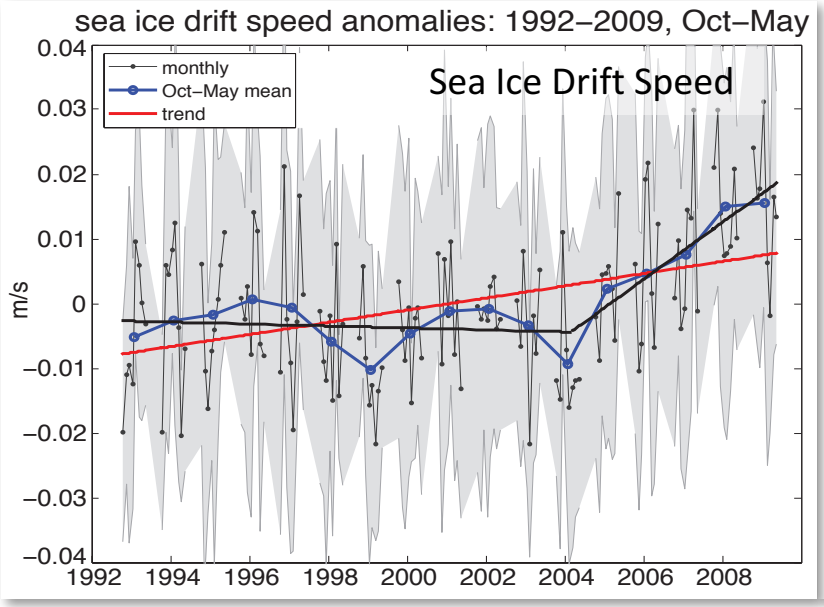
Sea ice speed trend 2007–2016, Sep.–May

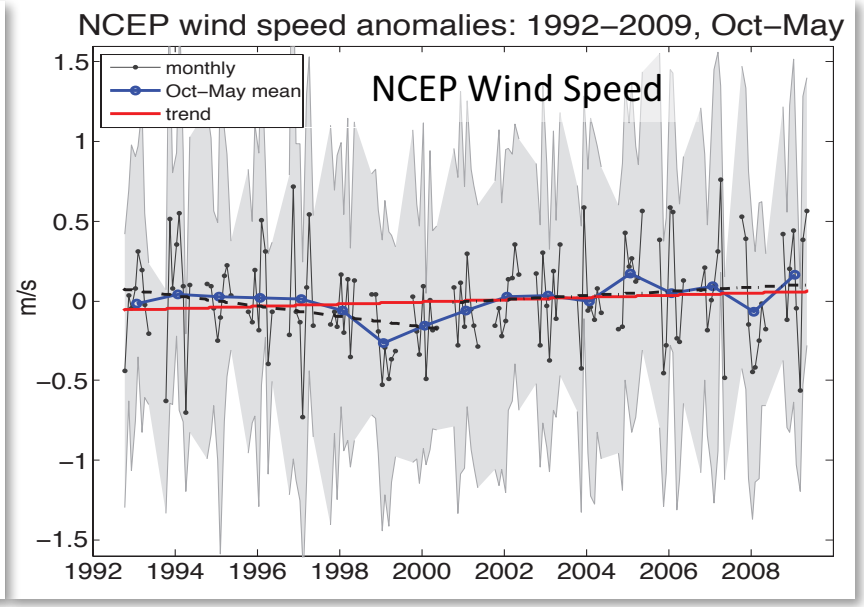


- Wind and ice drift increase in the Beaufort and north of Kara and Laptev Seas

- NCEP wind speed and IFREMER ice drift trend pattern show strong correspondence during the last 10 years.

1992–2009 Time Series Sea Ice Speed and Wind

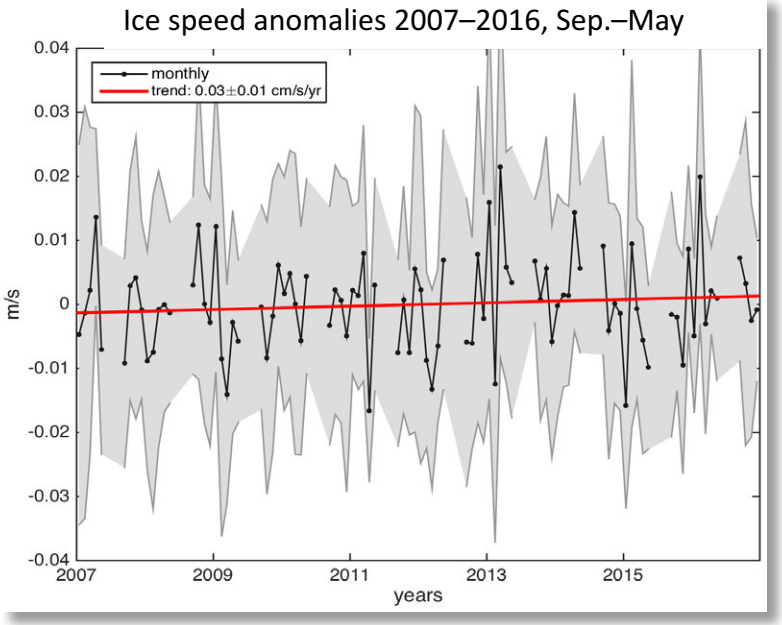


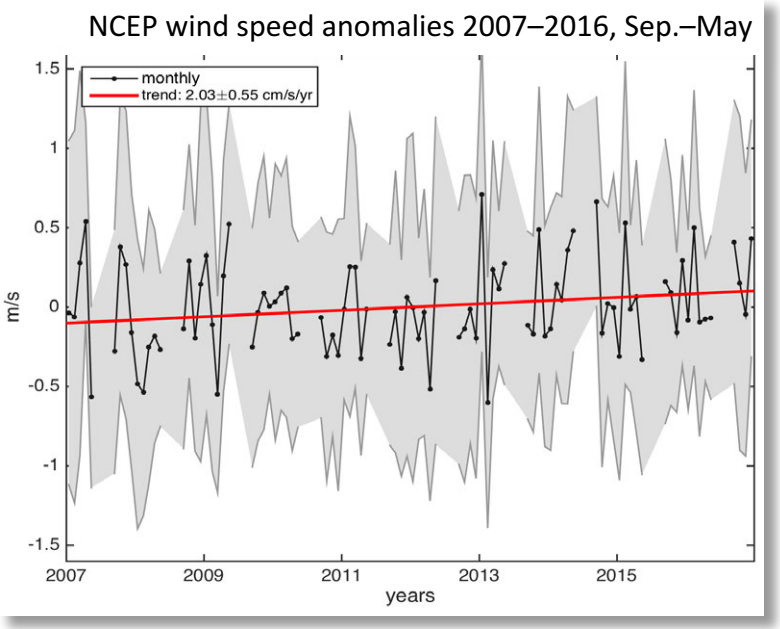


- Positive trend of 0.9 ± 0.1 cm/s/decade or 11% per decade in sea ice speed
- Only small positive trends (1 to 2%/decade) in wind speed in all 4 reanalyses
- Strongest ice drift trend after 2004 (+46%/decade)

Spreen et al., 2011

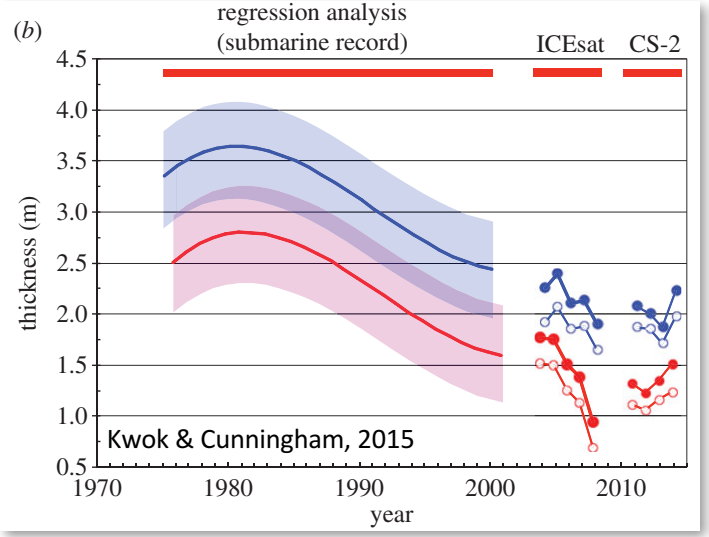
Time Series 2007–2016

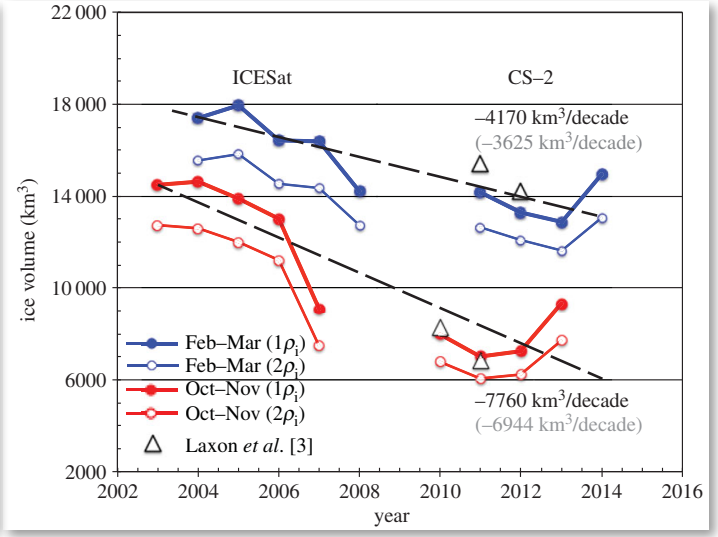




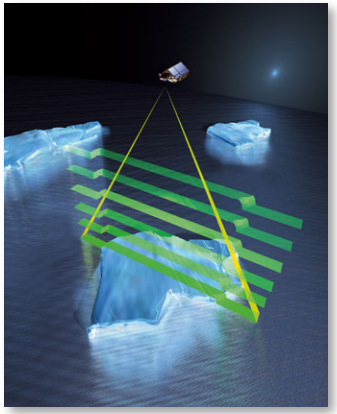
- Smaller trend of 3%/decade (p=0.98).
- No continuation of 2004–2009 trend of 46%/decade.
- Wind speed shows similar trend, 4%/decade (p>0.99) and variability (R=0.7) ➔ could explain ice speed trend.

Sea ice Thickness Change





CryoSat-2



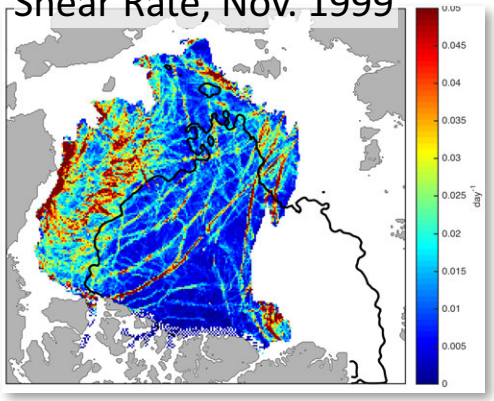
- Strong decrease in ice thickness from combined submarine and satellite altimeters (ICESat (laser), CryoSat-2 (radar)) record for 1976–2014.
- Recent years, however, show strong variability and no clear trend

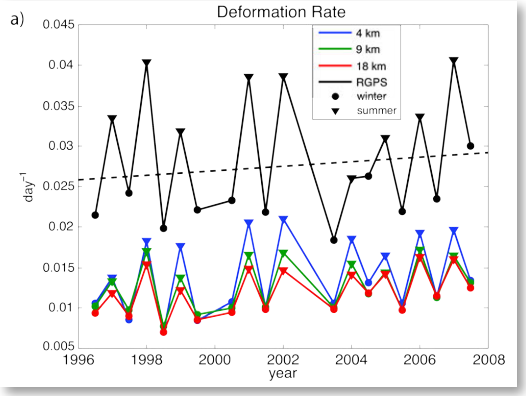
➢ Thinning induced ice speed trend might be reduced

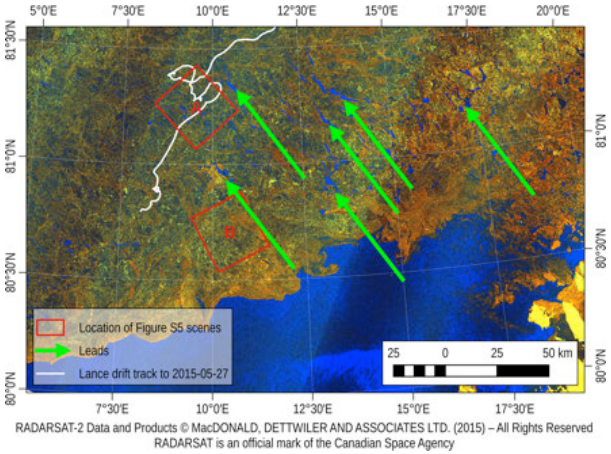
- Is there a shift in the Arctic climate system during the last 10–15 years?

Climate System Understanding

Shear Rate, Nov. 1999







- Changes in sea ice deformation from SAR data
- Create long time series from several sensors
- Comparison to coupled model and reanalysis data
- Understand why did ice moves faster and deforms more ➔ ocean & atmosphere coupling

- Assmy et al. (2017) Leads in Arctic pack ice enable early phytoplankton blooms below snow-covered sea ice. *Scientific Reports.*
- Phytoplankton bloom below sea ice in May
- Leads in the ice provide light for bloom
- Satellite data can be used for upscaling

– Key research questions –

- Retrieve **new quantities** and establish reliable **error estimates**
- **Merge** existing observations to new products
- Closing the gap between sea ice monitoring and **climate system understanding**

Thank you!