ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

Louisa Tiemann[1], Marcel Nicolaus[1], Mario Hoppmann[1], Marcus Huntemann[1,2], Christian Haas[1]

Sea-ice Properties derived from Ice Mass-balance Buoys using Machine Learning

Polar 2018
Open Science Conference
2018/06/21

Alfred-Wegener-Institut[1],
Universität Bremen[2]

Picture by Peter Gege

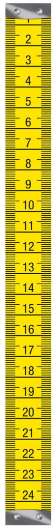
SPICES

Universität Bremen

POLMAR

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

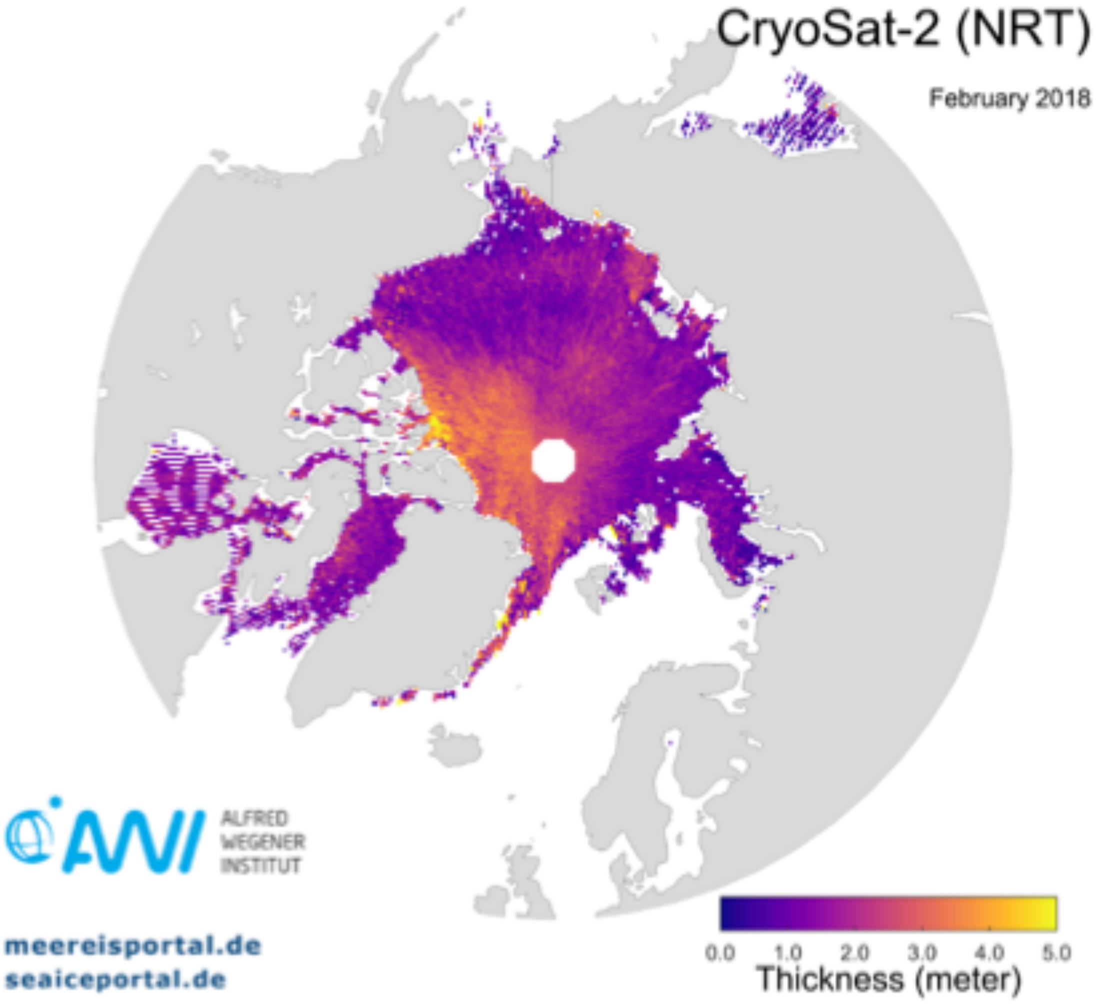
Sea ice observations



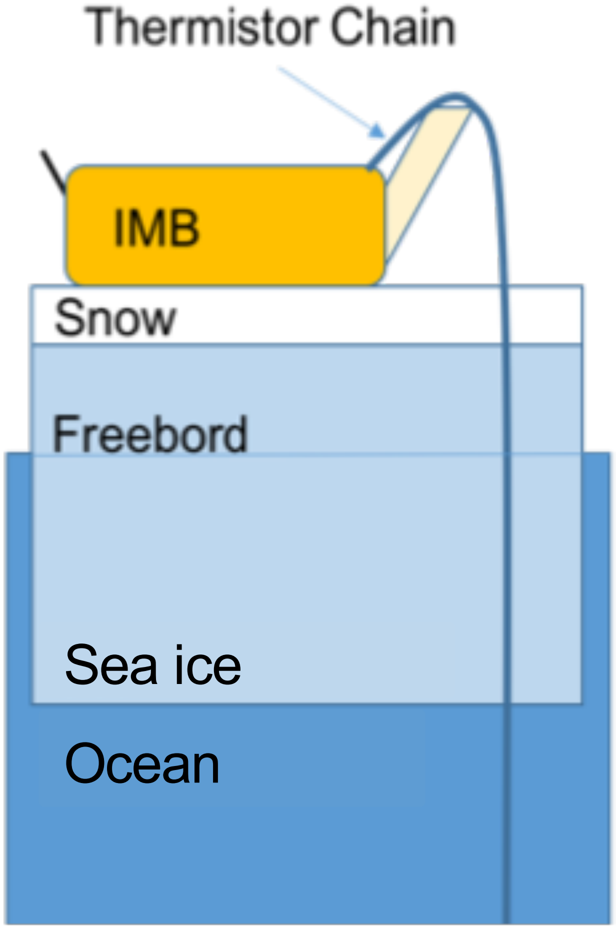
Point measurements to global scale

- Manual measurements
- Floe scale distribution
- Remote sensing

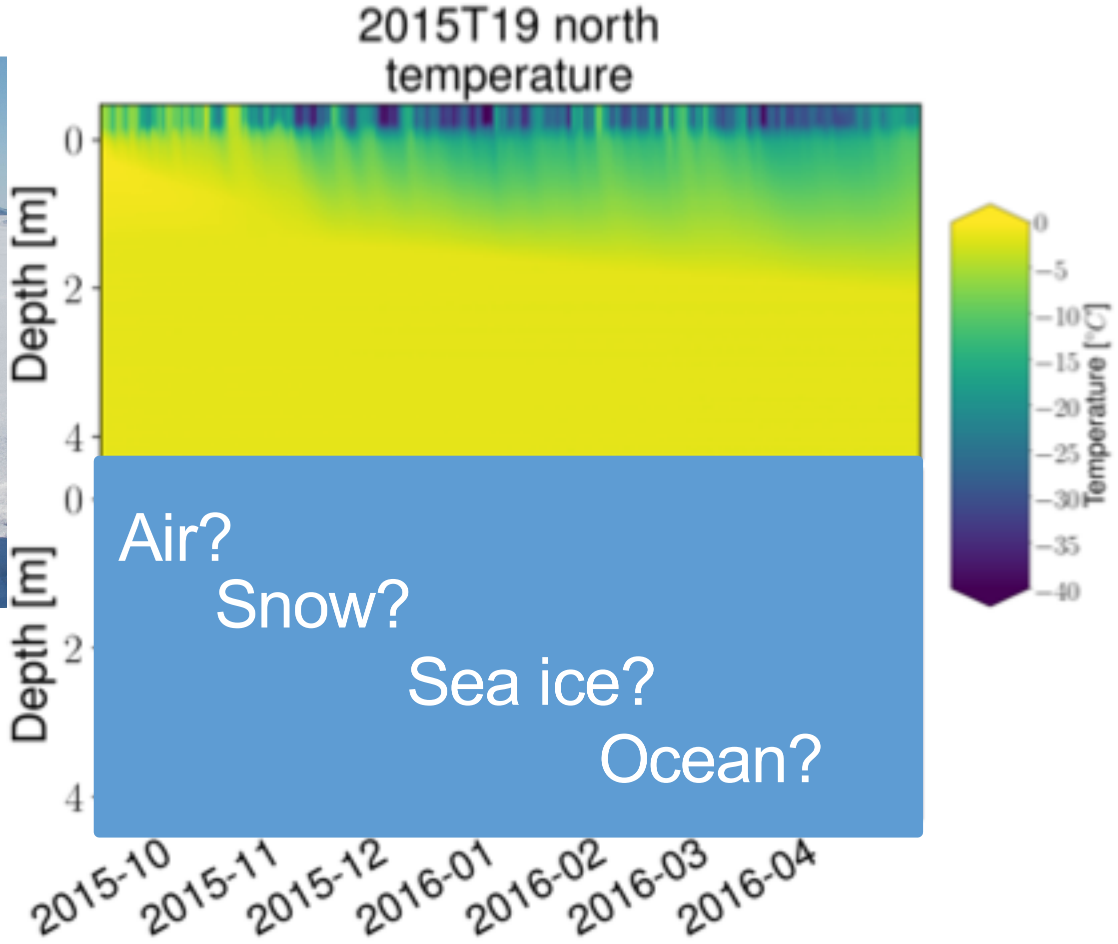
➡ Autonomous instruments



Sea ice mass balance buoys (IMB)



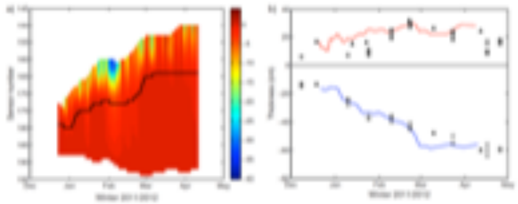
- Thermistor chain IMBs
- 0.02 m sensor spacing
- Unique heating cycle
- Small and easy to deploy
- Established since 2010 by Jackson et al. (2013)

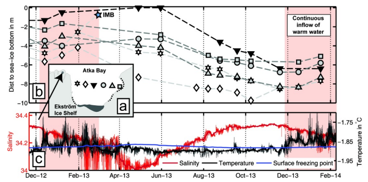


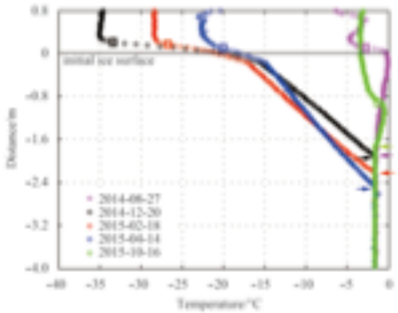
Physical Properties and Processes

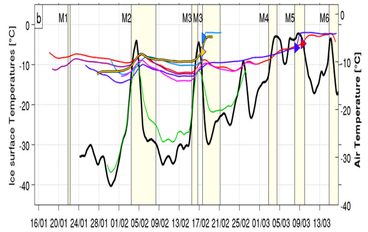
Exemplary process studies using thermistor chain IMBs

- Seasonal evolution of ice mass balance in a freshwater lake in Lapland, Finland, Cheng et al. 2014
- Platelet ice under landfast sea ice, Atka Bay Antarctica, Hoppmann et al. 2015
- sea ice mass balance and one-dimensional-thermodynamic model comparison, Chukchi and Beaufort Seas Arctic, Zhongxiang et al. (2016)
- Flooding on first year ice in the marginal ice zone, Arctic Provost et al. 2017





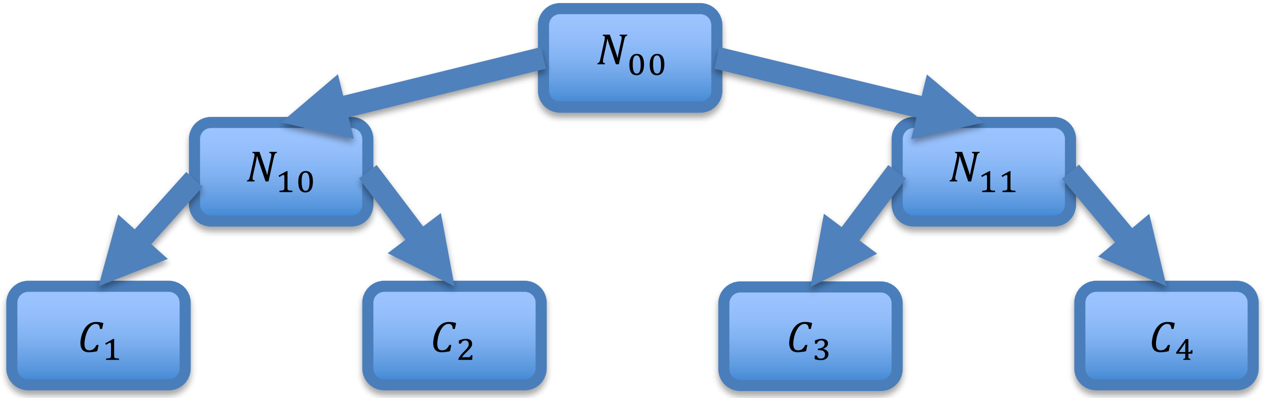




- Complete IMB dataset?
- Arctic and Antarctic?
    - Consistent processing?
- Seasonality and regional differences?

Random Forest Algorithm

- Ensemble of independent decision tree classifiers $\{T_b\}_1^B$ (Breiman, L. 2001)

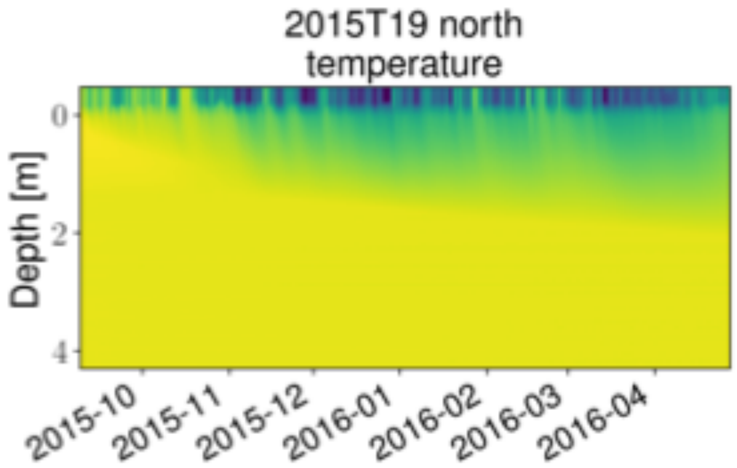


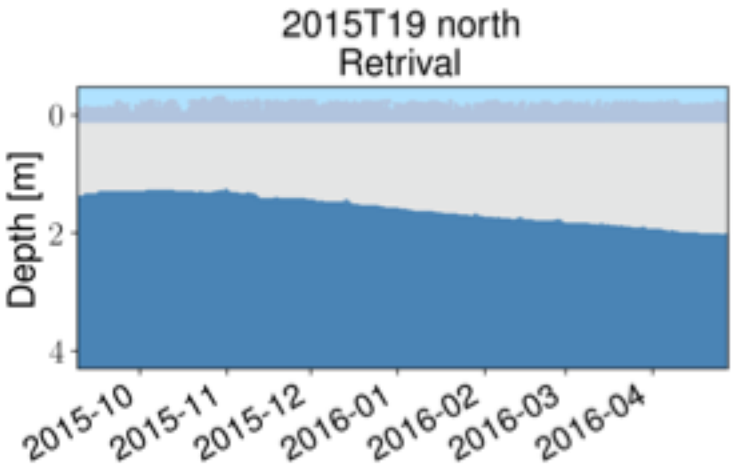
- Classification by averaging over probability of each tree vote (bagging)
- Supervised learning

- Features:
  - Temperature (T)
  - Temperature difference ($\Delta T_{30}, \Delta T_{120}$)
  - Vertical gradients ($dT/dh\,, d\Delta T_{120}/dh$)
  - Standard deviations
    ($T, \Delta T_{120}$, 48, 72, 96 hours)

Random Forest Algorithm

- Ensemble of independent decision tree classifiers $\{T_b\}_1^B$ (Breiman, L. 2001)



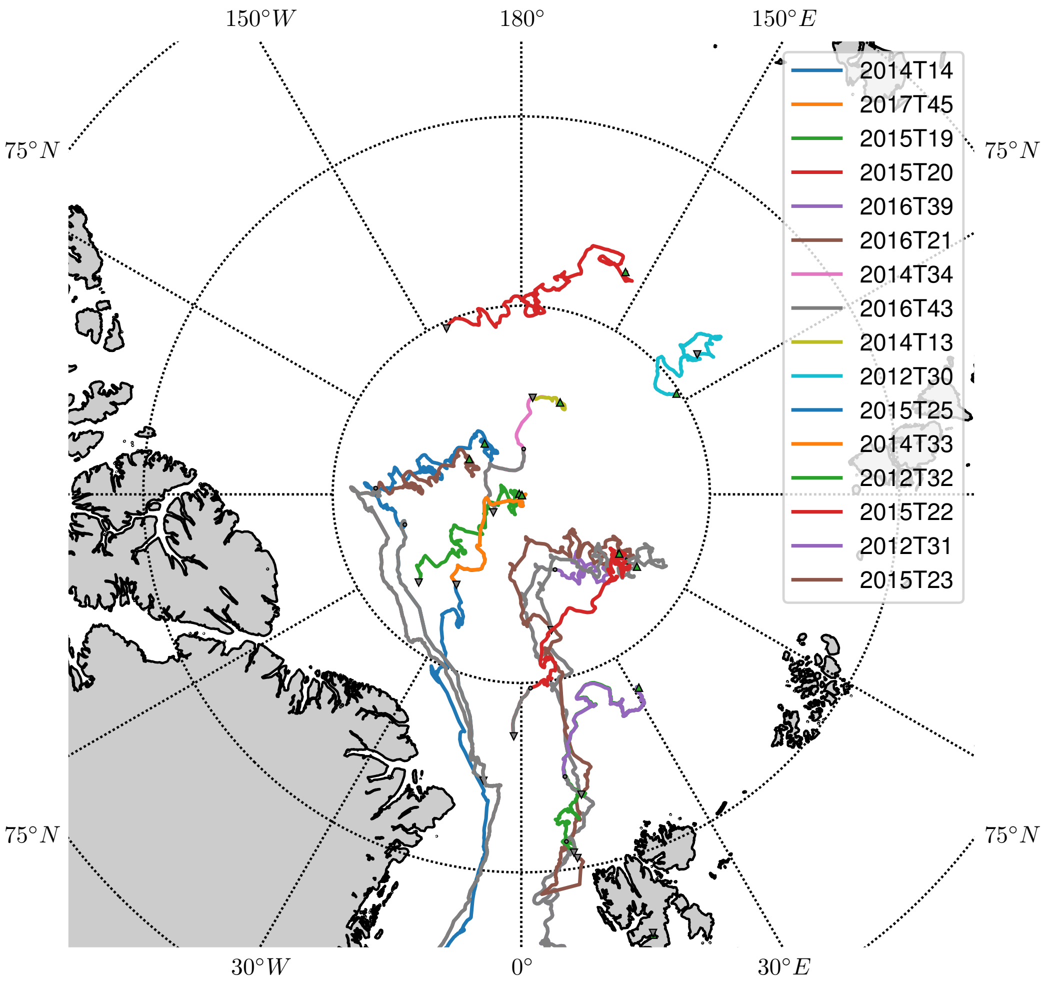


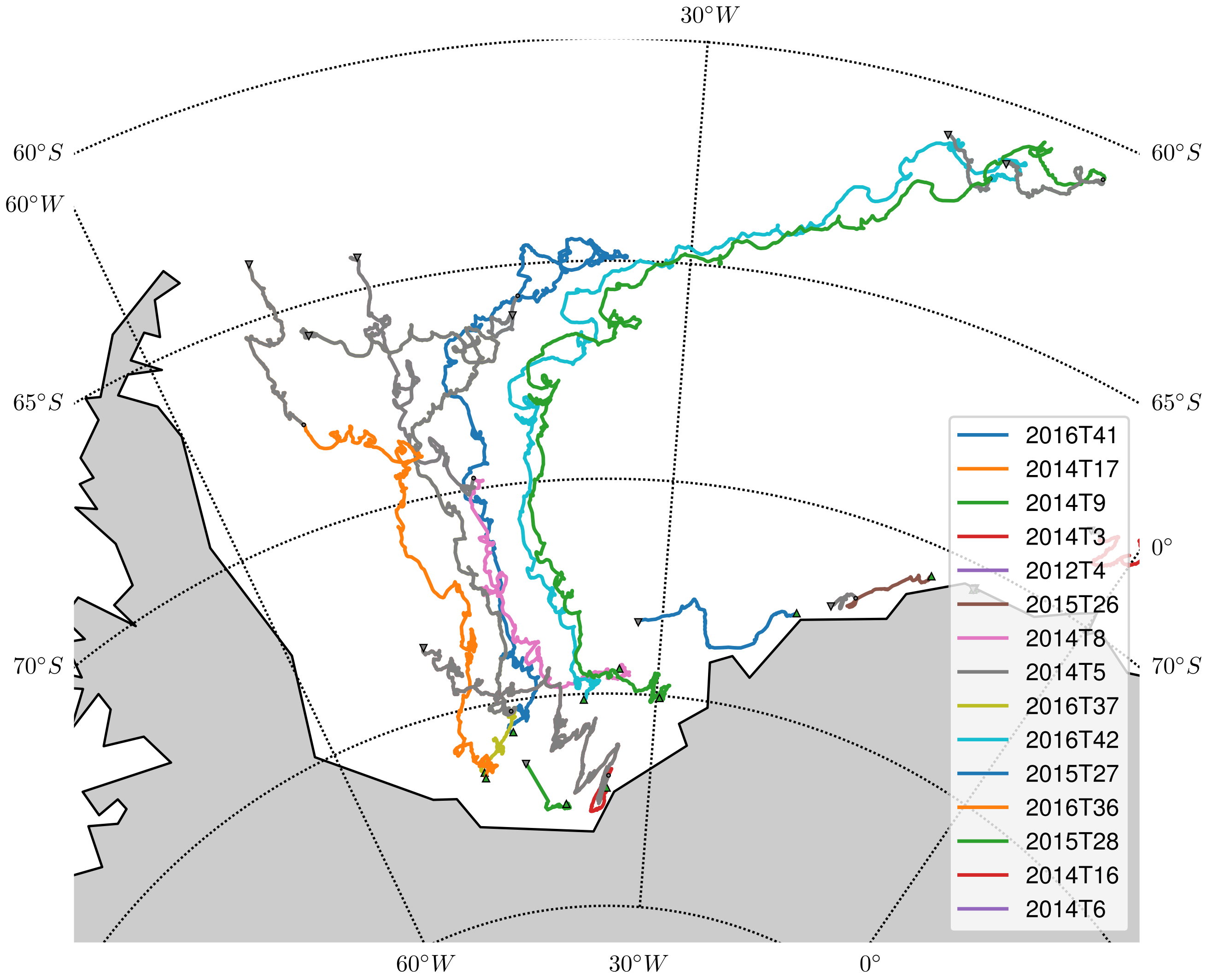
- Classification by averaging over probability of each tree vote (bagging)
- Supervised learning

- Features:
  - Temperature (T)
  - Temperature difference ($\Delta T_{30}, \Delta T_{120}$)
  - Vertical gradients ($dT/dh\,, d\Delta T_{120}/dh$)
  - Standard deviations

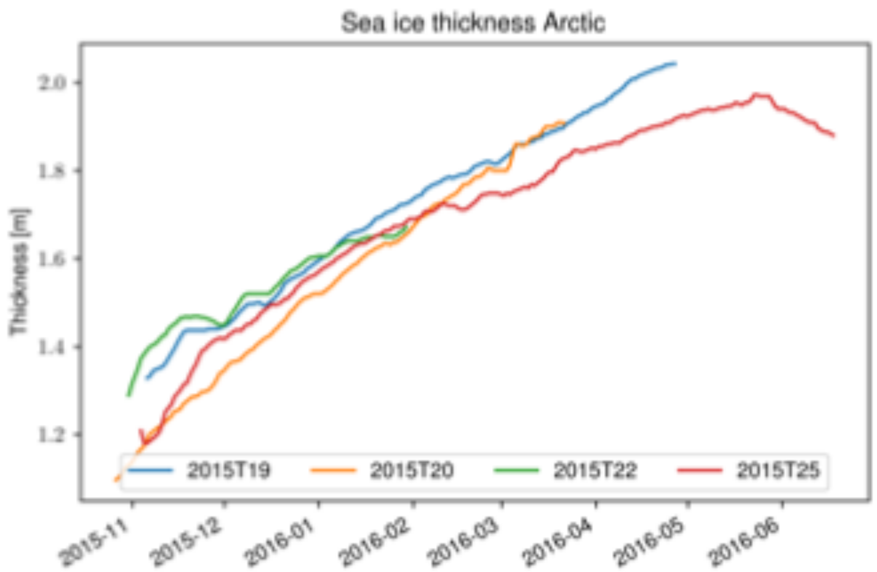
    ($T, \Delta T_{120}$, 48, 72, 96 hours)

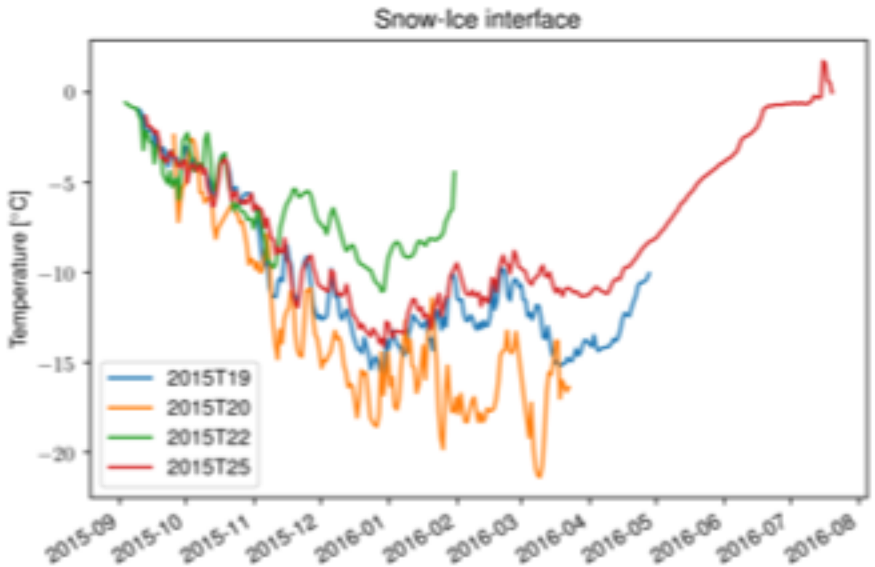
Sea ice mass balance buoy dataset

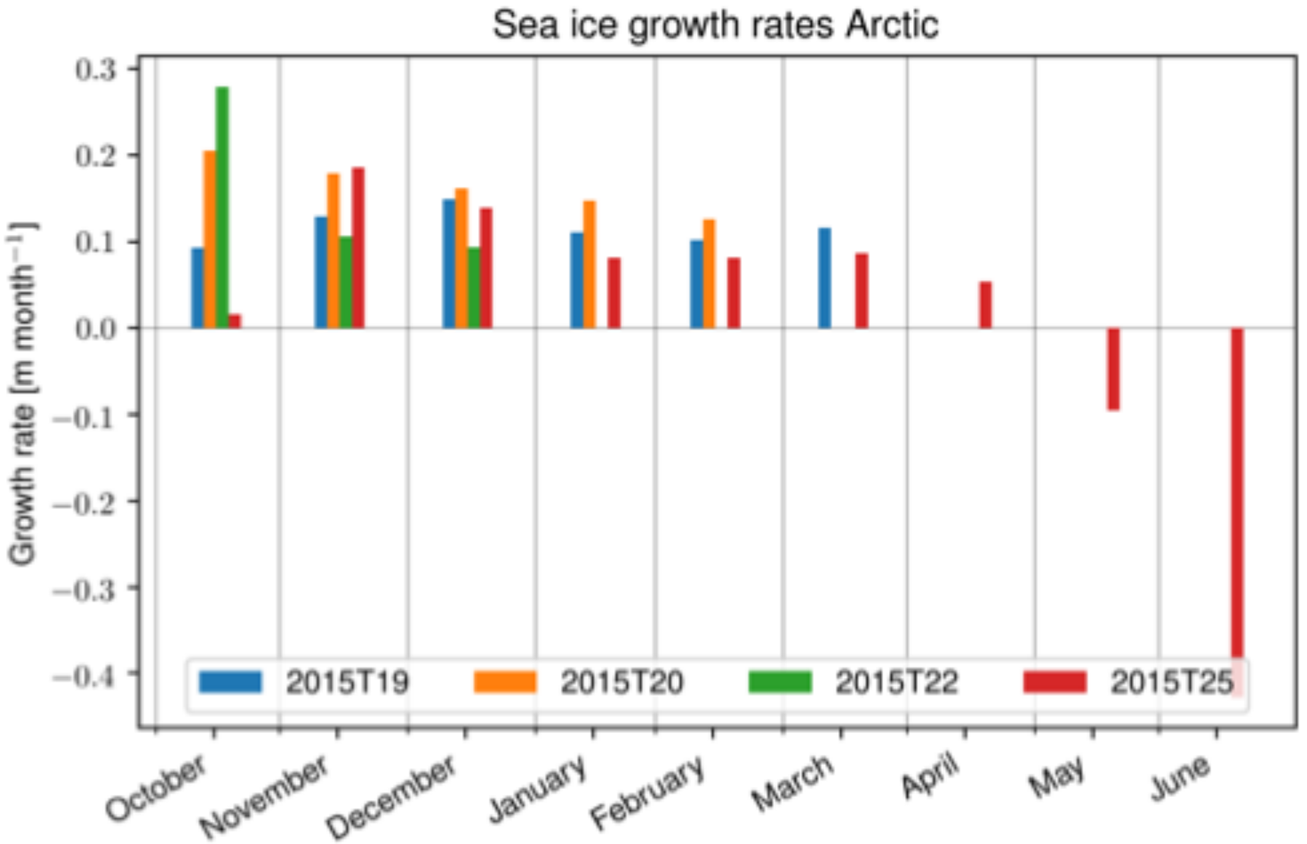




Arctic – central – 2015 – mass balance

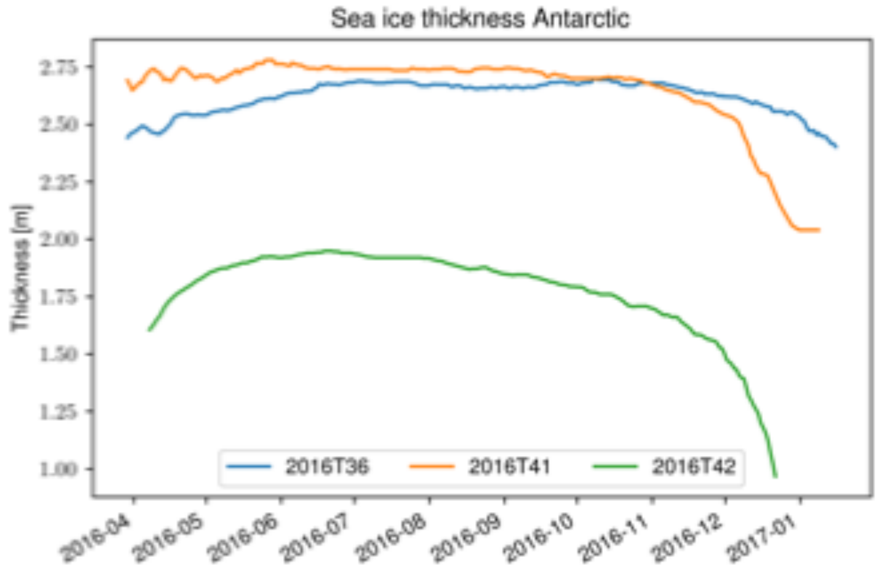


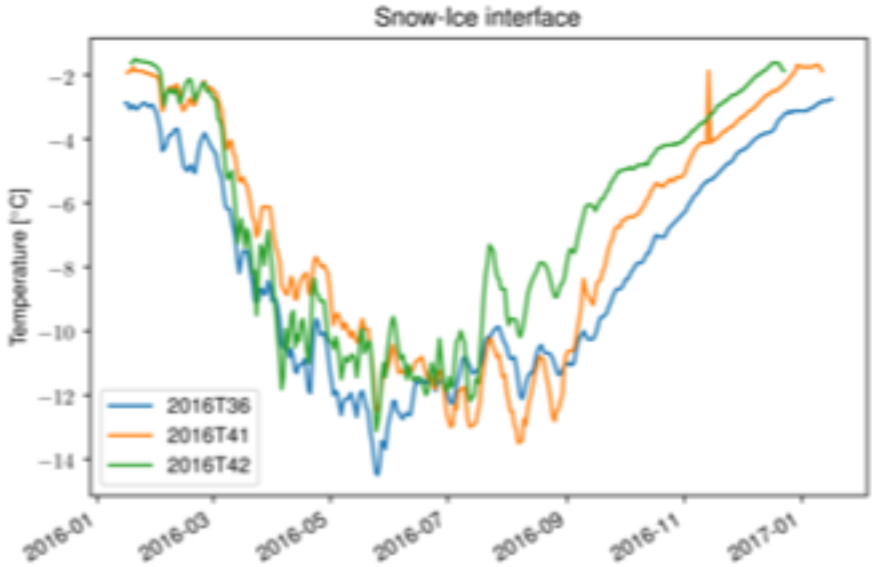


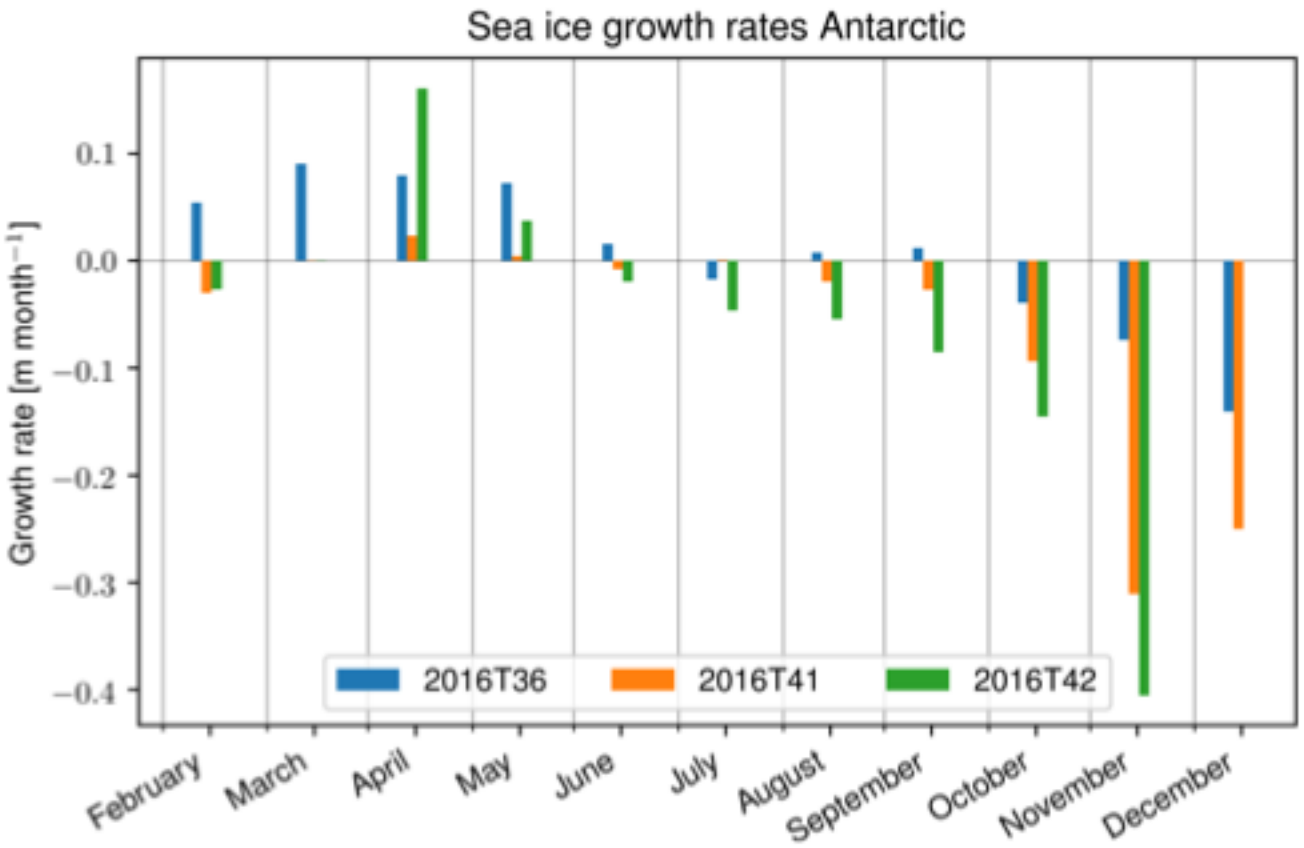


- Pronounced seasonal cycle in sea ice growth rates
- Range: 10 cm/month
- Highest growth rates: Autumn
- Variable snow thickness evident from interface temperatures

Antarctic – Weddell Sea – 2016 – mass balance

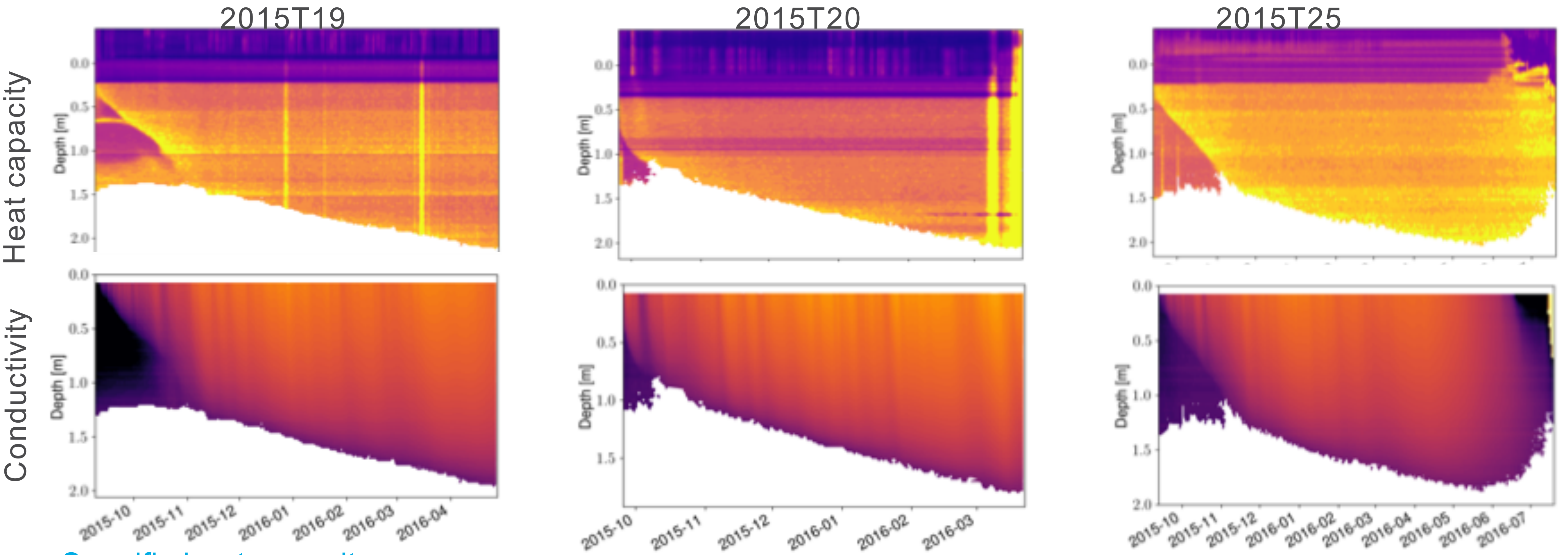


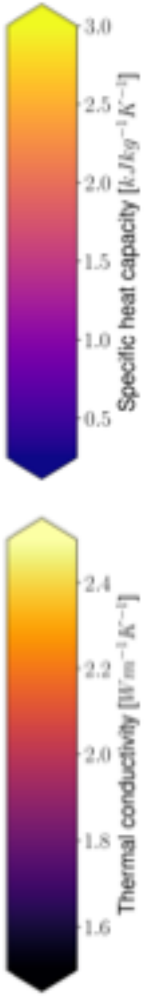




- deployed on multi-year ice
- Large melt rates
- thick snow cover

Sea ice parameters Arctic – regional differences





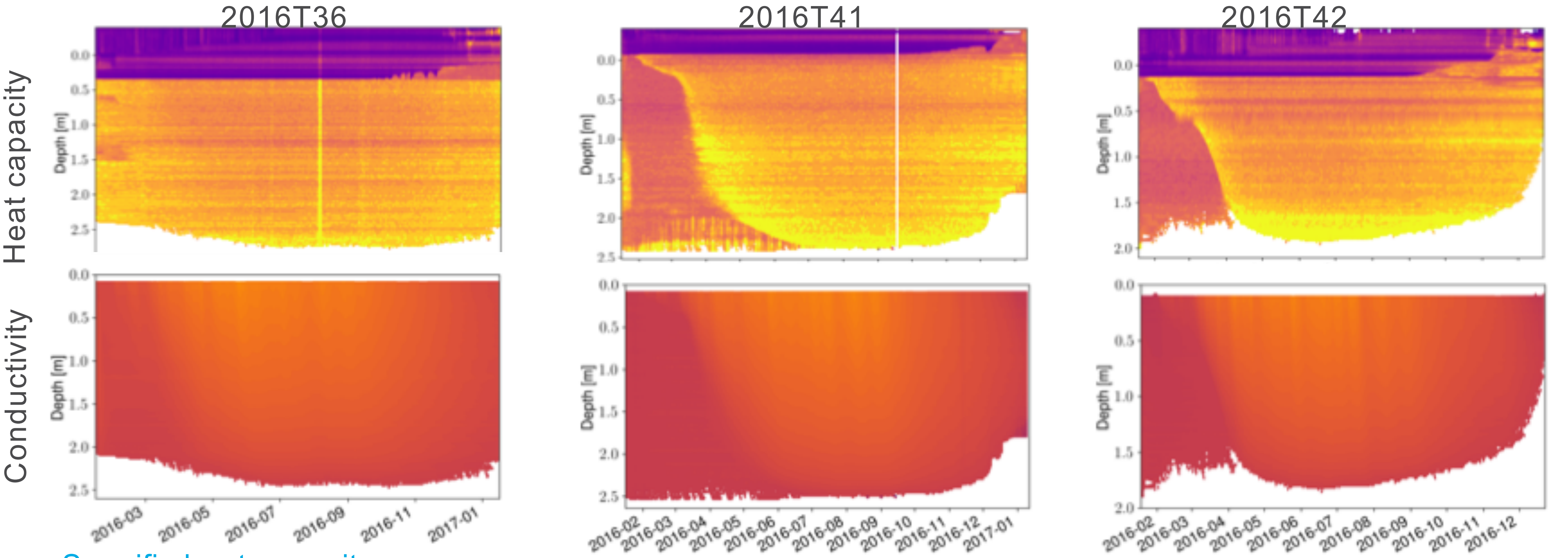
Specific heat capacity

- Bases on unique temperature differences profiles
- Range sea ice: 2.0 – 3.0 $kJkg^{-1}K^{-1}$
- Range snow: 0.8 – 1.7 $kJkg^{-1}K^{-1}$
- Vertical layering
- Specific heat capacity reveals processes at snow-ice interface

Thermal conductivity

- Based on temperature profiles
- Parametrization (Pringle et al. 2007) for sea ice
- Range: 1.8 – 2.25 $Wm^{-1}K^{-1}$ during winter
- Lowest at sea ice bottom

Sea ice parameters Antarctic regional differences



Specific heat capacity

- Bases on unique temperature differences profiles
- Range sea ice: 2.0 – 3.0 $kJkg^{-1}K^{-1}$
- Range snow: 0.8 – 1.7 $kJkg^{-1}K^{-1}$
- Vertical layering, maxima at the bottom
- Specific heat capacity reveals processes at snow-ice interface

Thermal conductivity

- Based on temperature profiles
- Parametrization (Pringle et al. 2007) for sea ice
- Range: 2.1 – 2.35 $Wm^{-1}K^{-1}$ during winter

Summary

- Random forest algorithm for sea ice mass balance
- Near-real time processing for Arctic and Antarctic IMBs
- Spatial and season Variability of key parameters:
  - Thickness, growth rates, thermal conductivity, heat capacity
- Snow-ice interface processes
  - Snow-ice formation in Antarctic in September/October
  - Snow-ice formation in Arctic in June
- Growth rates:
  - Pronounced seasonality

→ **Sea ice live!**

Poster Foyer!

Fri_277_OS-7_1320

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

SPICES

Universität Bremen

POLMAR

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

Bibliography

- Breiman, Leo. (2001) "Random Forests." *Machine Learning* 45(1): 5–32
- Cheng, Bin; Vihma, Timo; Rontu, Laura; Kontu, Anna; Kheyrollah Pour, Homa; Duguay, Claude; Pulliainen, Jouni (2014) Evolution of snow and ice temperature, thickness and energy balance in Lake Orajärvi, northern Finland. Tellus A: Dynamic Meteorology and Oceanography, 66:1
- Hoppmann, Mario; Nicolaus, Marcel; Hunkeler, Priska A; Heil, Petra; Behrens, Lisa K; König-Langlo, Gert; Gerdes, Rüdiger (2015) Seasonal evolution of an ice-shelf influenced fast-ice regime, derived from an autonomous thermistor chain. Journal of Geophysical Research-Oceans, 120(3), 1703-1724
- Provost, C., Sennéchael, N., Miguet, J., Itkin, P., Rösel, A., Koenig, Z., et al. (2017). Observations of flooding and snow-ice formation in a thinner Arctic sea-ice regime during the N-ICE2015 campaign: Influence of basal ice melt and storms. Journal of Geophysical Research: Oceans, 122, 7115–7134
- Zhongxiang,Tian; Cheng, Bin; Zhao, Jiechen; Vihma, Timo; Zhang, Wenliang; Li, Zhijun; Zhang, Zhanhai (2017) Observed and modelled snow and ice thickness in the Arctic Ocean with CHINARE buoy data. Acta Oceanol. Sin. Sin. 36: 66