N-ICE2015
NORWEGIAN YOUNG SEA ICE CRUISE

HE24B-2880

Critical role of snow on sea ice growth in the Atlantic sector of the Arctic Ocean

Ioanna Merkouriadi[1], Bin Cheng[2], Robert M. Graham[1], Anja Rösel[1] & Mats A. Granskog[1]

NORWEGIAN POLAR INSTITUTE

FINNISH METEOROLOGICAL INSTITUTE

Abstract

During the Norwegian young sea ICE (N-ICE2015) campaign in early 2015, a deep snow pack was observed, almost double the climatology for the region north of Svalbard. Significant amounts of snow-ice were found in second-year ice (SYI), while much less in first-year ice (FYI). Here we use the HIGHTSI 1-D snow/ice thermodynamic model, forced with reanalyses, to show that snow-ice contributes to thickness growth of SYI in absence of any bottom growth, due to the thick snow. Growth of FYI is tightly controlled by the timing of growth onset relative to precipitation events. A later growth-onset can be favorable for FYI growth due to less snow accumulation, which limits snow-ice formation. We surmise these findings are related to a phenomenon in the Atlantic sector of the Arctic, where frequent storm events bring heavy precipitation during autumn and winter, in a region with a thinning ice cover.

Background

N-ICE2015 expedition aimed to examine the shift of the Arctic Ocean to a new regime, where old and thick sea ice has been replaced by thinner and younger sea ice, and its effect to energy flux, ice dynamics and the sea-ice associated ecosystem.

From January to June 2015, RV Lance was tethered several times to the ice and moved passively with the ice drift. Four different drifts took place (Fig. 1), and over each floe, ice camps were set up for the collection of atmospheric, snow, sea ice, oceanographic and biological data. Here we focus on observations collected during in Floe 1 (in blue), covering the dates 15 January to 21 February 2015.

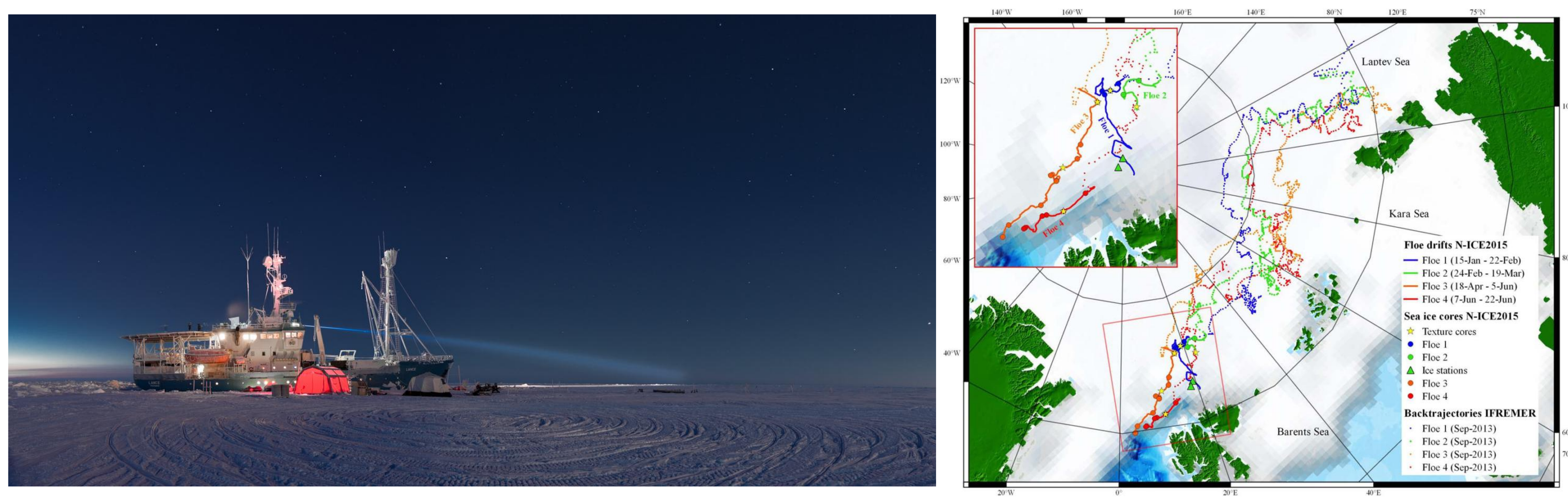

Figure 1. Left: RV Lance during the N-ICE2015 expedition (photo by Paul Dodd), Right: Location of N-ICE2015 floe drifts and calculated back trajectories (i.e. the origin) of the ice floes until September 2013 (*Itkin et al.*, 2017). Insert shows in detail where ice cores were collected during each floe drift or at ice stations [*Granskog et al.*, 2017].

Material and methods

HIGHTSI was forced with reanalysis data from ERA-I, MERRA-2 and CFSRv2 along the back trajectory of Floe 1: **1 August – 31 January** (Fig. 3).

Ocean heat flux was chosen to be either constant or to vary seasonally based on earlier measuremens in the region (Fig. 3d).

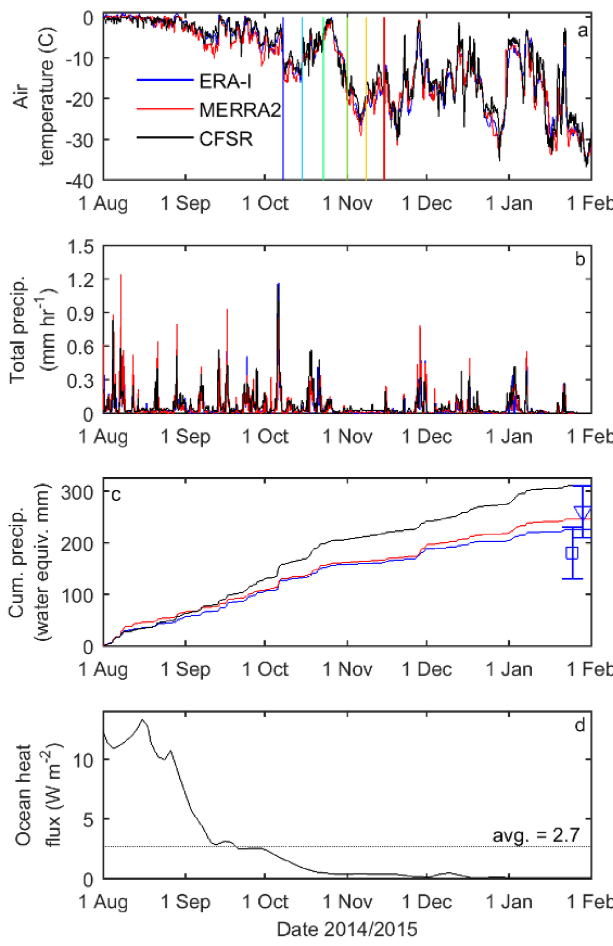

Figure 3. (a) Air temperature, (b) total precipitation, (c) cumulative precipitation and (d) ocean heat flux along the back trajectories of Floe 1 and 2 (1 Sep – 31 Mar)

- Snow and ice thickness measured repeatedly along 2-4 km transects (Fig. 2).
- Snowpits were dug twice a week for snow physical properties: i.e. temperature and density profiles (Fig. 2).
- Ice core oxygen isotope analysis for snow contribution in sea ice.

	FYI	SYI
Snow depth	33 ± 14 cm	52 ± 12 cm
Snow water equivalent	103 ± 37 mm	169 ± 39 cm
Sea ice thickness (modal)	0.95 m	1.40 m
Snow in sea ice	0-30 mm w.e.	~200 mm w.e.

Results

Second-year ice

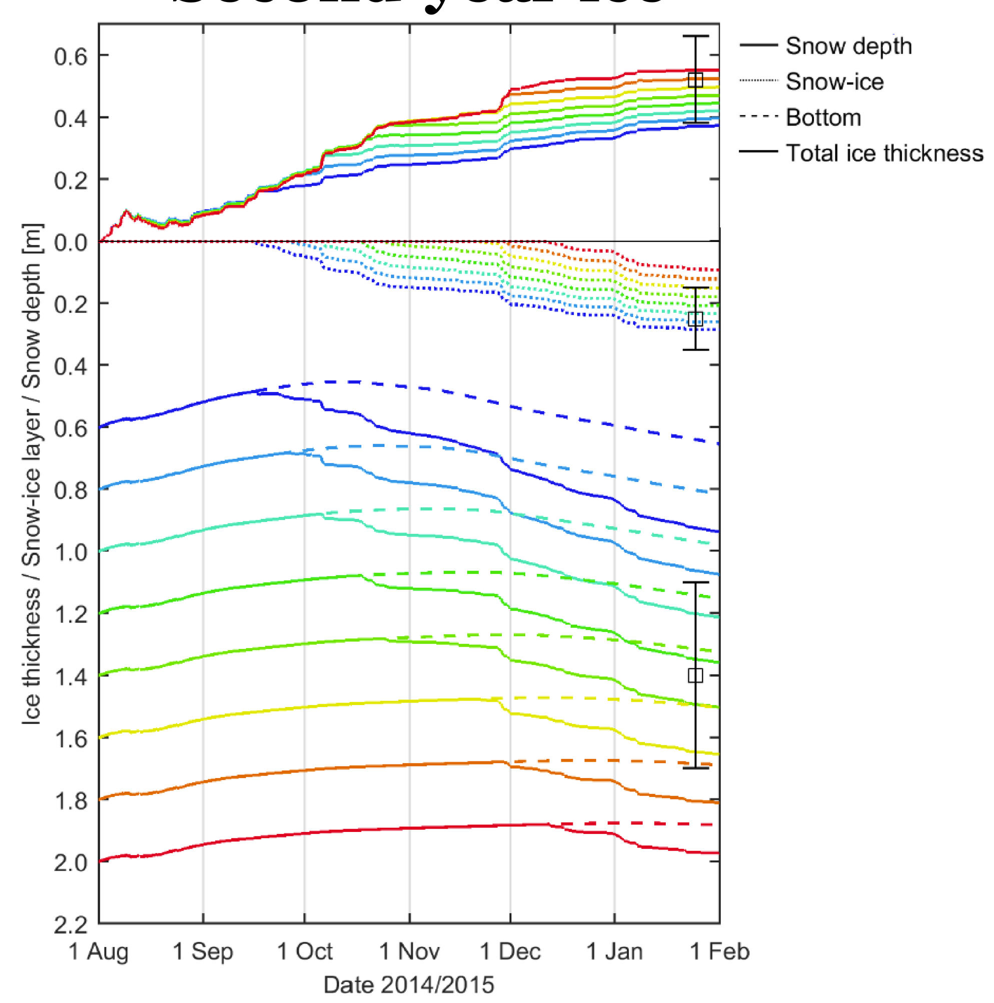

Figure 4. Summary of snow depth, snow-ice layer thickness, ice bottom growth and total ice thickness in SYI model experiments with MERRA-2 forcing, and a seasonal ocean heat flux (see Fig. 1). Different colors correspond to different initial SYI thickness on 1 August. Solid lines in the upper part of the plot represent snow accumulation on top of the SYI. Dotted lines just below indicate the evolution of snow-ice layers. Lower most solid lines indicate the evolution of total ice thickness, whereas dashed lines indicate the evolution of the ice bottom melt/growth, without accounting for snow-ice. Error bars represent the mean and standard deviation of snow depth (top), snow-ice layer thickness (middle) and ice thickness (bottom) for SYI observed on Floe 1 during N-ICE2015.

Study sensitivity to initial SYI thickness (0.6-2.0 m) (Fig. 4).
•Snow-ice forms in all cases.
•Bottom melt in early autumn due to mild air temperatures and large oceanic heat flux.
•Negative net thermodynamic bottom growth for ice thickness above 0.8 m.
•By January, snow-ice is main contributor in sea ice mass balance.
•Best agreement with N-ICE2015 observations for initial thickness 1.2-1.4 m.

First-year ice

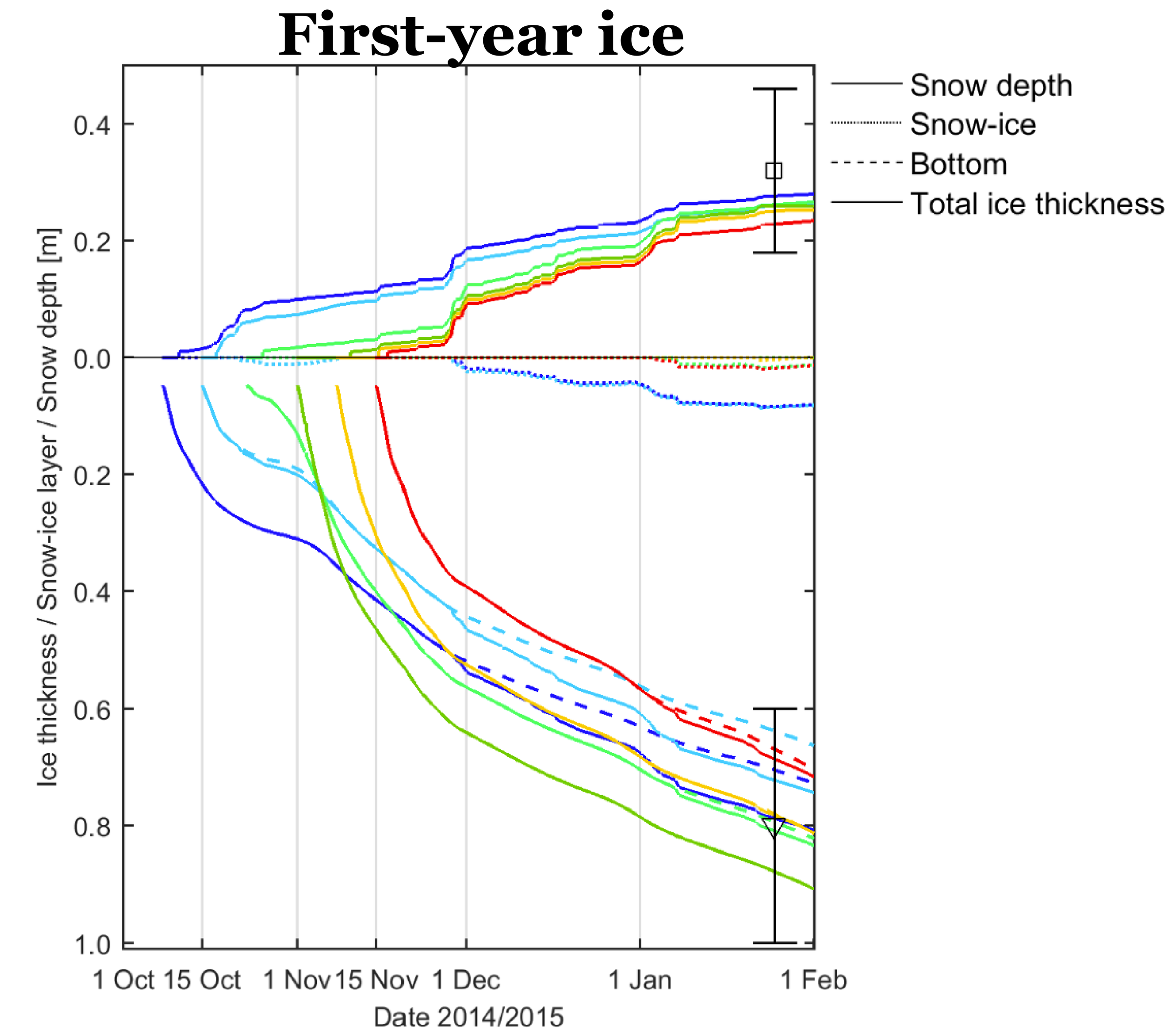

Figure 5. Summary of snow depth, snow-ice layer thickness, ice bottom growth and total ice thickness in FYI model experiments with MERRA-2 forcing, and a seasonal ocean heat flux (see Fig. 1). Different colors correspond to different growth-onset dates. Solid lines in the upper part of the plot represent snow accumulation on top of the FYI. Dotted lines just below indicate the evolution of snow-ice layers. Lower most solid lines indicate the evolution of total ice thickness, whereas dashed lines indicate the evolution of the ice bottom melt/growth, without accounting for snow-ice. Error bars represent the mean and standard deviation of snow depth (top) and ice thickness (bottom) for FYI observed on Floe 1 during N-ICE2015.

Study sensitivity to freeze-up dates for FYI (8 October – 15 November) (Fig. 5).
•More snow-ice forms when freeze-up date is in October.
•Snow-ice is limited in later freeze-up dates due to very low precipitation in beginning of November (Fig. 3) → sea ice grows thick enough before snow starts accumulating.
•Total FYI growth is not proportional to ice growth duration.
•Results in good agreement with N-ICE2015 observations when growth onset in November (no, or very little snow-ice in FYI cores)

Was season 2014-2015 representative for the region?

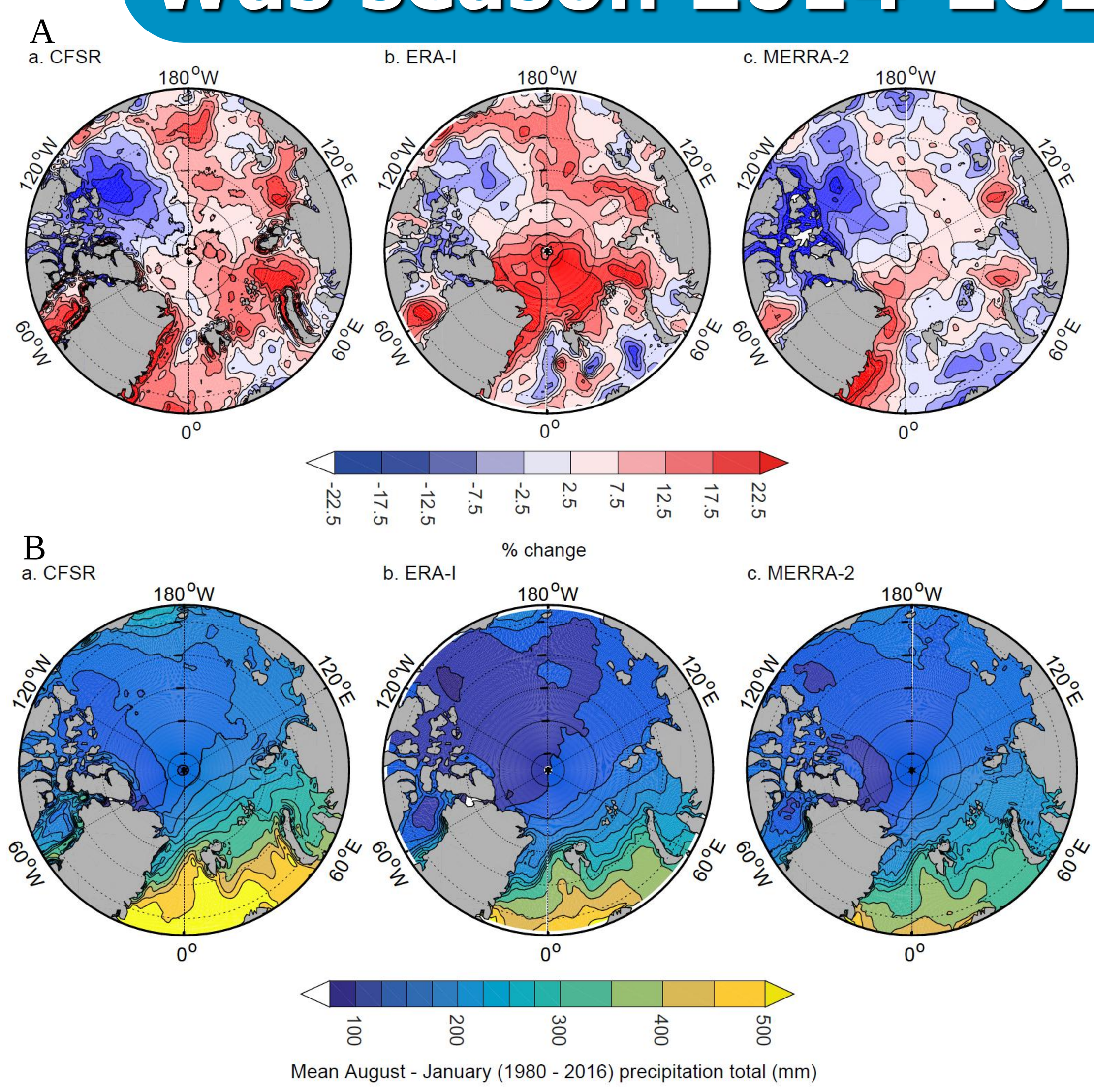

Figure 6: A: Percentage change in 1 August – 31 January precipitation from 2006-2016 vs. 1980–2005 in CFSv2, ERA-I and MERRA-2. B: Mean precipitation fields in mm/year from 1980-2016 in CFSv2, ERA-I and MERRA-2.

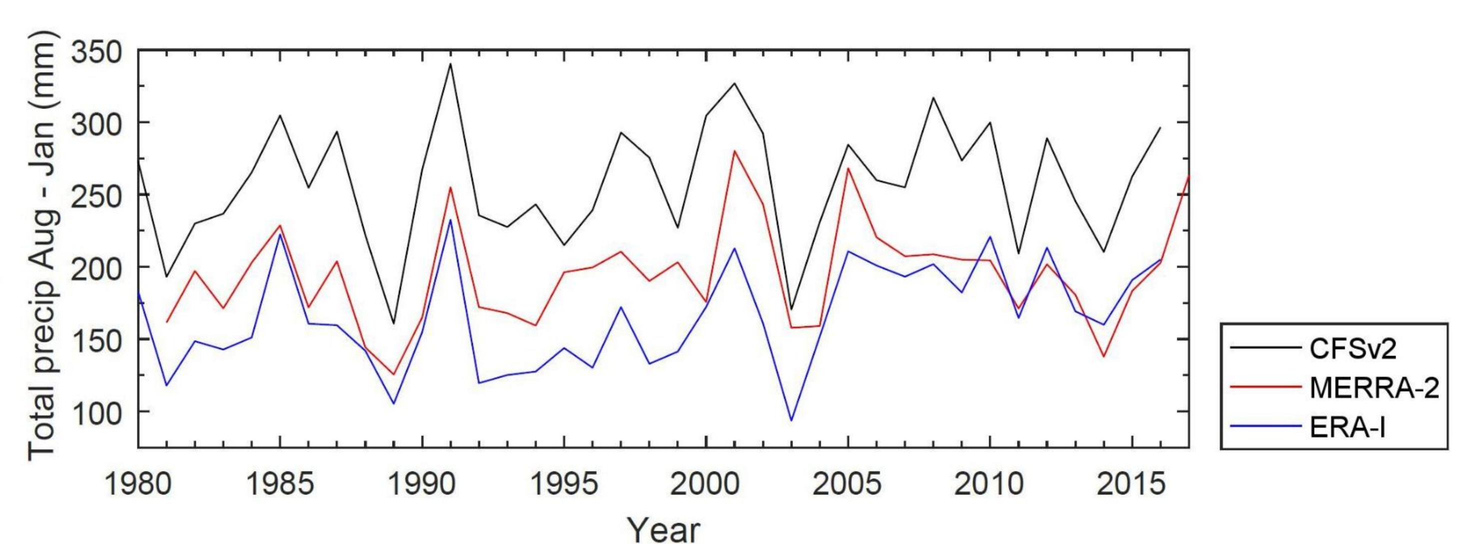

Figure 7. Total precipitation in ERA-I, MERRA-2 and CFSv2 for each autumn/winter (1 August – 31 January) north of Svalbard from 1979 to 2017

The pan-Arctic change in 1 August to 31 January precipitation from 2006 to 2016 versus 1980–2005 for the different reanalyses (Fig. 6), shows differences between the three products and also some similarities. Overall pattern of increased precipitation in the Kara and East Greenland Seas, and reduced precipitation in the Beaufort Sea.
2014–2015 was not an exceptional year in terms of precipitation (Fig. 7) based on the reanalyses, and with thinner ice snow-ice formation is likely to be a common phenomenon in the Atlantic sector of the Arctic.

Conclusions

- For SYI: Snow-ice formed even for thick (2 m) ice in autumn → Net thickness growth in the winter was a result of snow-ice formation alone.
- For FYI: Snow-ice formation controlled by the FYI growth onset relative to snowfall / Total thickness of FYI is not proportional to duration of growth.
- Significant differences in precipitation in the reanalyses
- Snow-ice has a potential to prevail north of Svalbard, in response to thinner ice and high precipitation.
- It is necessary to look separately into the response of FYI and SYI (or older).
- New snow climatology is needed in the eastern Arctic.

For information on N-ICE2015 publications and data visit:
www.npolar.no/nice2015

References

Graham et al. (2017) doi:10.1002/2016JD025475.
Granskog et al. (2017) doi:10.1002/2016JC012398.
Itkin et al. (2017) doi:10.1002/2016JC012403.
Merkouriadi et al. (2017) doi:10.1002/2017JD026753.
Rösel et al. (2018) doi:10.1002/2017JC012865