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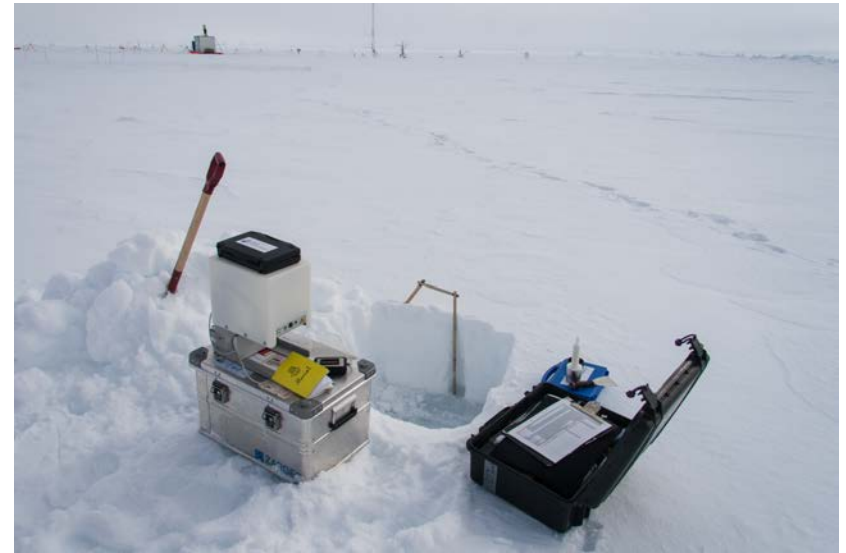
Snow depth on Arctic and Antarctic sea ice derived from Snow Buoys

21 Apr 2016

Snow Rules !

Direct impacts

- Thermodynamics
- Mass balance
- Remote sensing signatures
- Fresh water budgets



Indirect effects

- Sea ice thickness measurements
- Total thickness measurements (EM techniques)
- Interpretation of surface conditions
- Model and remote sensing validation and development

=> Need for better snow depth and properties data

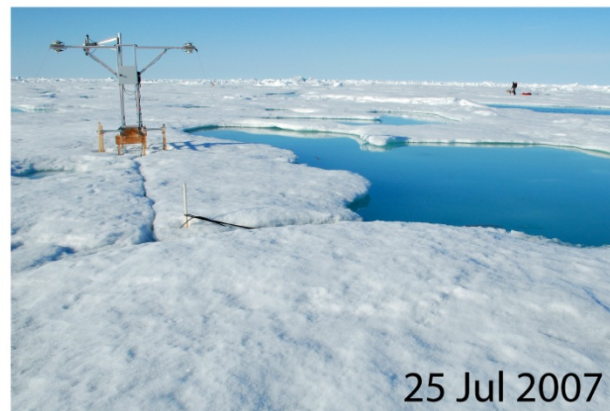
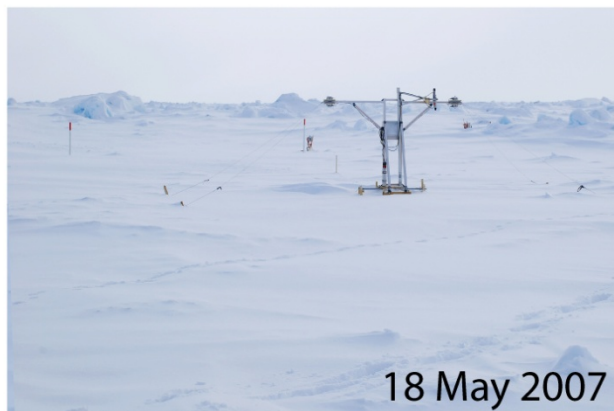
Challenges for Seasonality

Limited possibilities from field observations

- Combining various campaigns at different times
 - Arctic => Climatology Warren et al (1999)
 - No Antarctic climatology
- Great experience from few multi-seasonal studies
 - Arctic: SHEBA, Tara, N-ICE, NP-stations

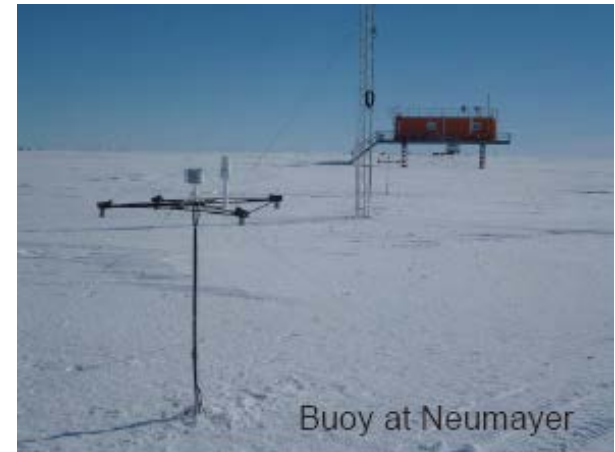
Snow depth product from passive MW data Markus & Cavalieri (1998)

Huge variability => Need for time series data



Snow Depth Buoy

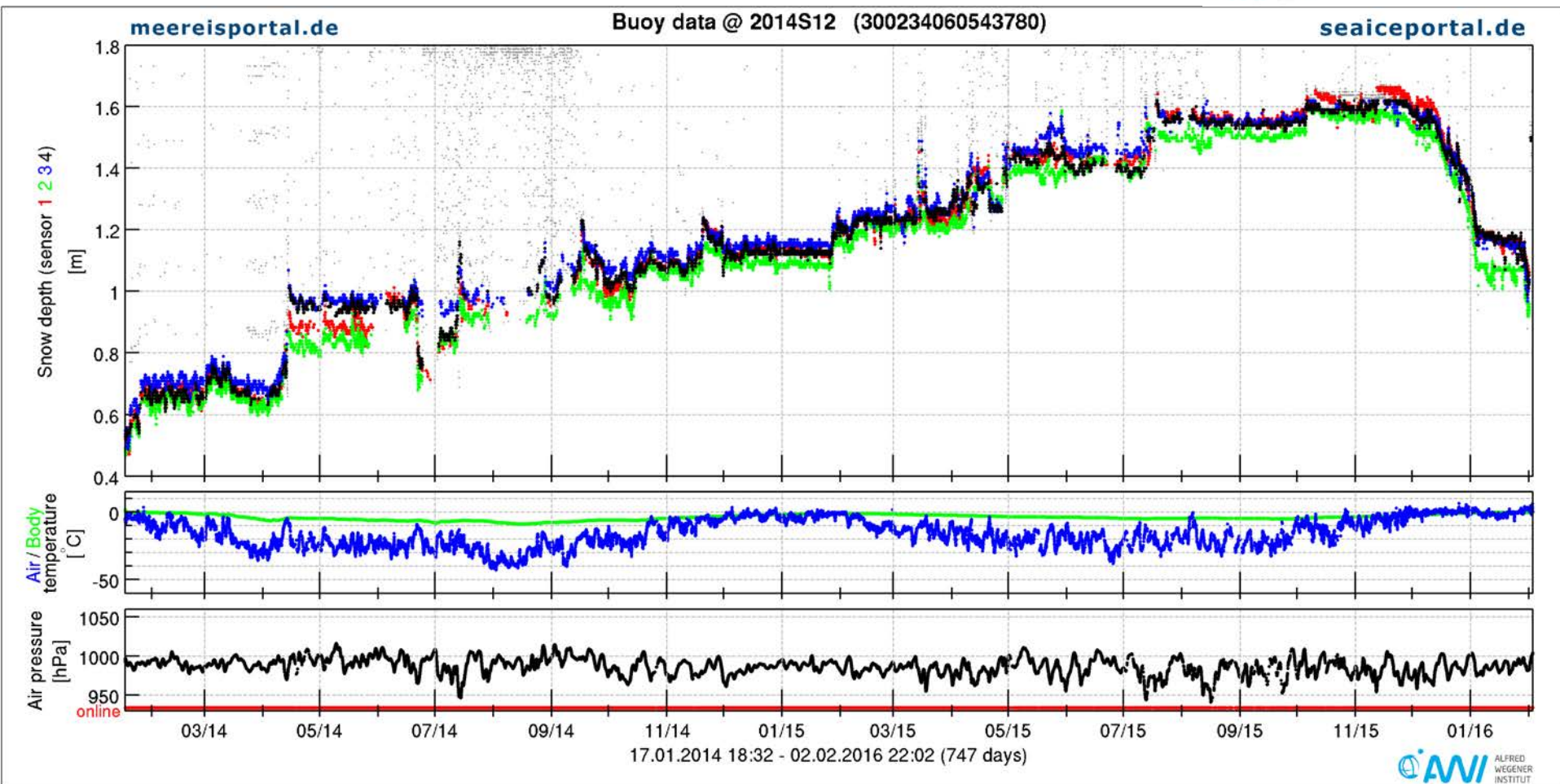
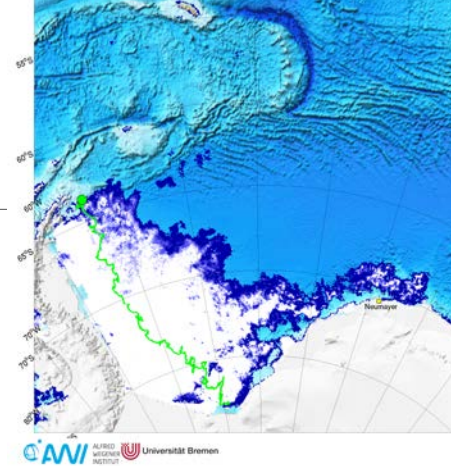
- Parameters
 - **4 x snow depth** (variability & reliability)
 - **Air temperature**, body (snow/ice) temperature
 - **Barometric Pressure**
 - GPS, as all units
- Data transmission: Iridium
- Data provision into GTS
- Power supply (batteries > 1year)
- Now: Version 3 (development since 2012)



Parameter	Sensor	Accuracy	Interval
Distance to Surface	Max Botix, Sonar MB7092	1 cm	7 / hour
Air Temperature	YSI, 44032	0.5 °C	7 / hour
Surface Temperature	YSI, 44032	0.5°C	20 / hour
Barometric Pressure	Vaisala, PTB 110	1 mbar	20 / hour
Data transfer	Iridium 9602 SBD		every 3 hours
GPS Position	Jupiter 32xLP module & antenna	10 m	every 3 hours
Power Supply	Lithium battery (15V)		7 / hour

Data Example 2014S12

- Weddell Sea drift
from Jan 2014 to Feb 2016 (>2 years)



Data Portal and Archive



<http://data.seaiceportal.de>

meereisportal.de

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Suchbegriff

SeaikeKnowledge SeaikeMonitoring SeaikeModelling SeaikeExpedition DataPortal

Sea ice in the polar regions of the Arctic and Antarctic covers approximately seven percent of our planet, which is bigger than the total area of Europe. These seven percent have a relatively large impact on global climate. Sea ice is particularly driving heat and freshwater exchange of the polar oceans and therefore plays a key role in the earth's climate system. Structure, volume and spatial extent of sea ice are highly differentiated and variable. As a result of these physical characteristics, sea ice has great effects on the energy budget of the earth's surface. Sea ice is highly complex, but at the same time it is certainly one of the most interesting and influential materials on our planet. Additionally, sea ice is an especially fascinating habitat that is essential for the ecosystem of the polar regions.

seaikeportal.de is an initiative of the Helmholtz Climate Initiative (REKLIM), the Alfred Wegener Institut, Helmholtz Centre for polar and marine research, in cooperation with the University of Bremen (Institute for environmental physics). Its aim is to gather all important and up-to-date information connected to the subject of sea ice. The portal is offering comprehensive background information, processed data and direct access to the data base.

Real time course plot R.V. Polarstern
Where is Polarstern?

Cooperation partner

iup Institut für Umweltphysik

AWI ALFRED WEGENER INSTITUT HELMHOLTZ ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG Alfred-Wegener-Institut

REKLIM

Active Buoys

Please find the live data and all metadata of deployment of all active buoys in the table below. But note that those data are raw data.

Name	Last Latitude	Last Longitude	Active	Photo	Live Plot	Last Profile	Live Map	Live Data
2014S14	83.82	-31.64	01.04.14	Download	Download		Download	Download
2015S22	79.78	4.26	01.03.15		Download		Download	Download
2015S23	81.44	9.08	20.04.15		Download		Download	Download
2014S25	71.37	-156.53	26.09.14	Download	Download		Download	Download
2015S27	81.19	20.49	23.04.15		Download		Download	Download
2015S28	81.66	10.60	18.04.15		Download		Download	Download
2015C1	80.32	16.80	27.01.15				Download	Download
2015C2	80.95	18.94	19.01.15				Download	Download
2015C3	81.41	9.47	20.04.15				Download	Download
2015C4	81.12	16.14	14.01.15				Download	Download
2015C5	80.66	17.95	01.02.15				Download	Download
2015C7	81.34	9.11	20.04.15				Download	Download
2014T14	69.05	-21.95	26.08.14	Download	Download	Download	Download	Download

Past Buoys

Please find the data and all metadata of all buoys that stopped transmission in the table below. In addition, links to final data are given.

Name	Last Latitude	Last Longitude	Active	Photo	Plot	Map	Data
2013S3	86.54	-2.45	09.04.13 - 13.06.13 (65 days)	Download	Download	Download	Download
2013S4	71.37	-156.53	09.04.13 - 28.06.13 (80 days)	Download	Download	Download	Download
2014S13	79.31	4.91	30.03.14 - 20.07.14 (112 days)	Download	Download	Download	Download
2014S15	87.17	-55.48	29.08.14 - 31.12.14 (124 days)	Download	Download	Download	Download

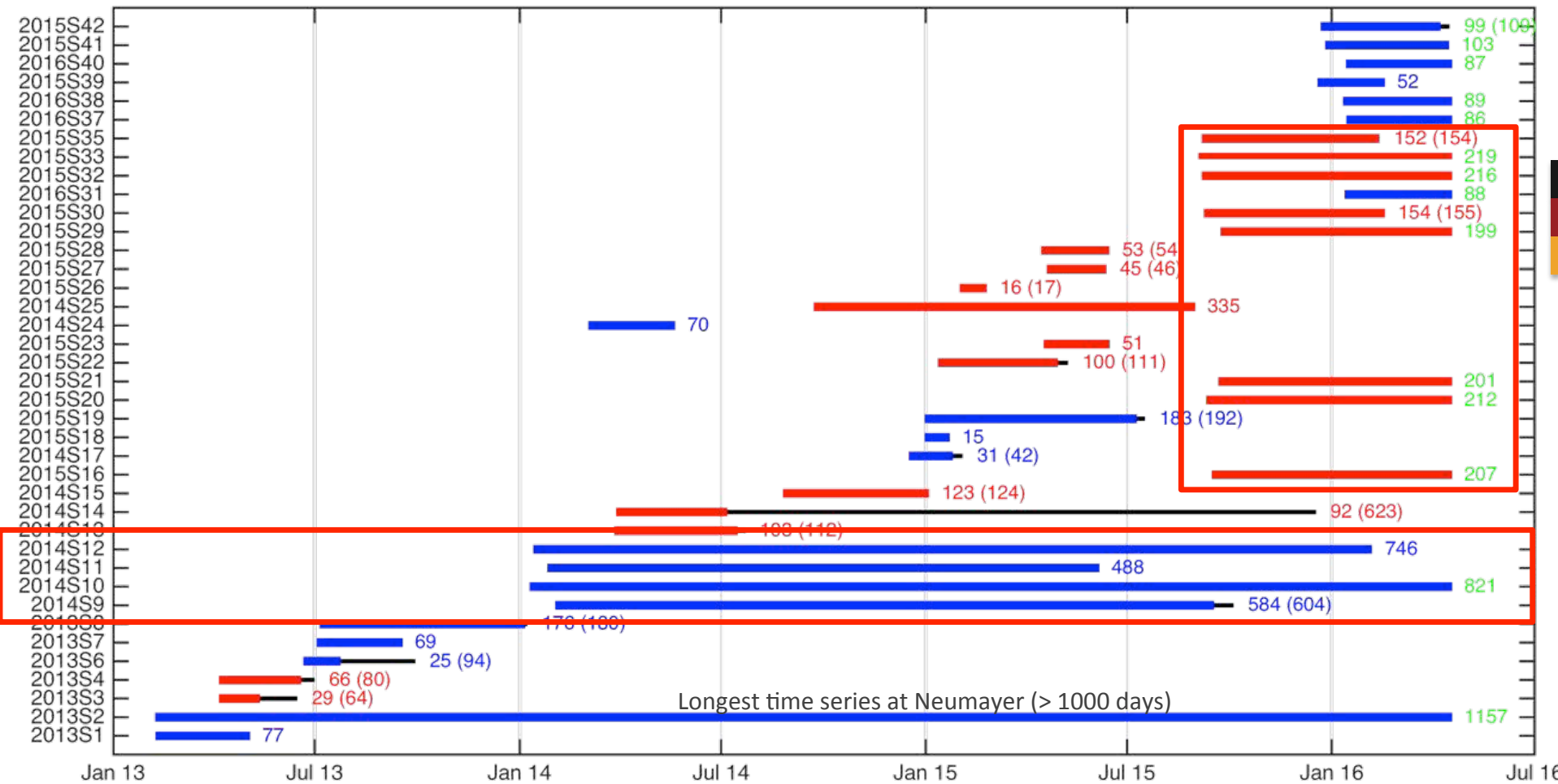
- Buoy tracks and data (daily)
- Meta data and deployment info
- Active and past buoys

PANGAEA®

Data Publisher for Earth & Environmental Science

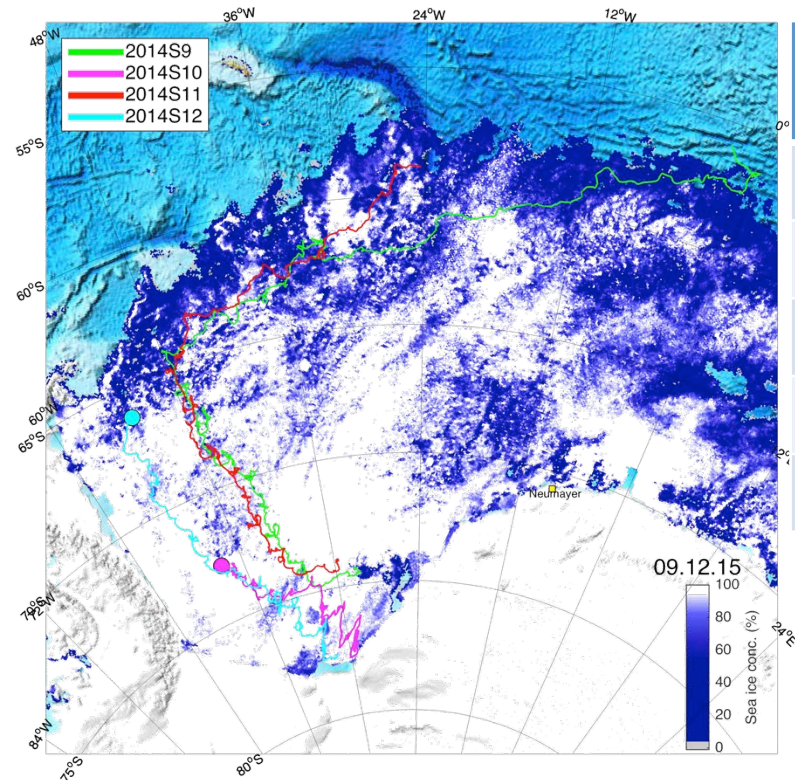


Lifetime Statistics



Green = 13 units currently reporting

Weddell Sea Snow Buoys in 2014/15

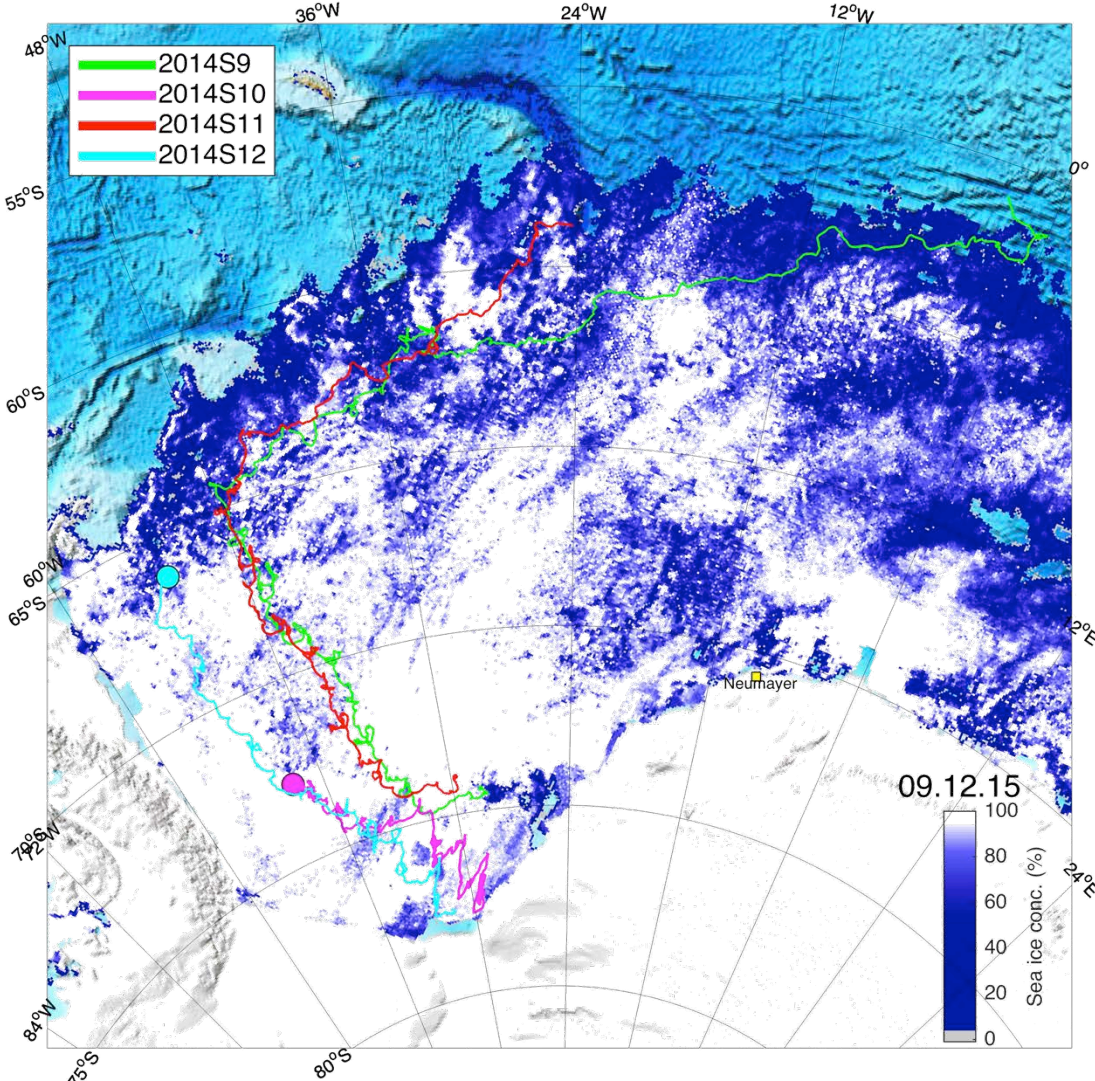


Buoy	Ice	zi (m)	fb (m)	zs (m)	Extras
2014S9	FYI	1.05	0.08	0.08	
2014S10	FYI	1.32	0.12	0.03	IMB
2014S11	FYI	1.61	0.29	0.29	IMB+ Array
2014S12	FYI	1.65	0.13	0.03	
2013S2					Ice shelf

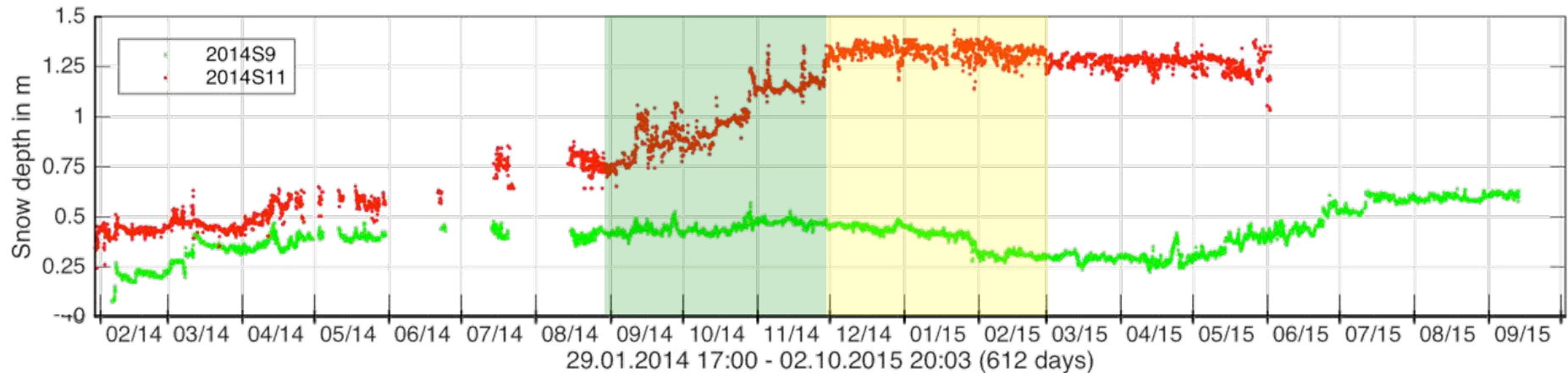
- S9 and S11 (Pair 1)
- S10 and S12 (Pair 2)
- All on level FYI with pos. freeboard
- All deployments Jan/Feb 2014



Animated Drift



Pair 1 = Close Pair (North)



- **Spring 2014**

- S11: Accumulation 60 cm in spring 2014
- S9: Constant in spring

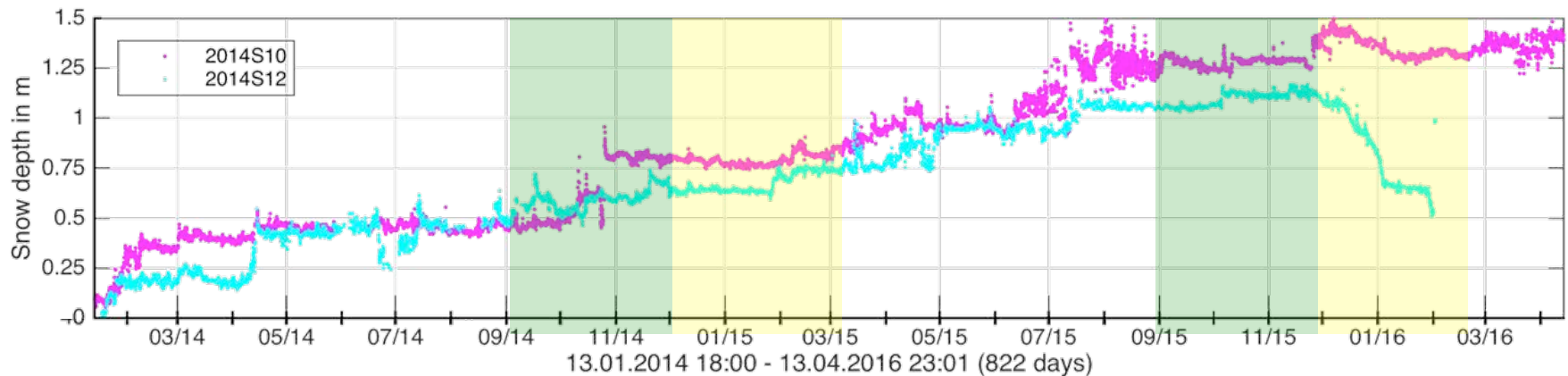
- **Summer 2014/15**

- S11: Some compaction (melt): ~10 cm
- S9: Significant compaction (melt) by 20 cm

- Annual budget (Feb 2014 to Feb 2015)

- S11: + 90 cm
- S9: + 20 cm

Pair 2 = Distant Pair (South)



Spring 2014

Consistent increase of 20 to 35 cm

Spring 2015

Little change

Summer 2014/15

No compaction / melt

S12: Summer increase of 15 cm

Summer 2015/16

Strong melt at ice edge

Temporary compaction / melt

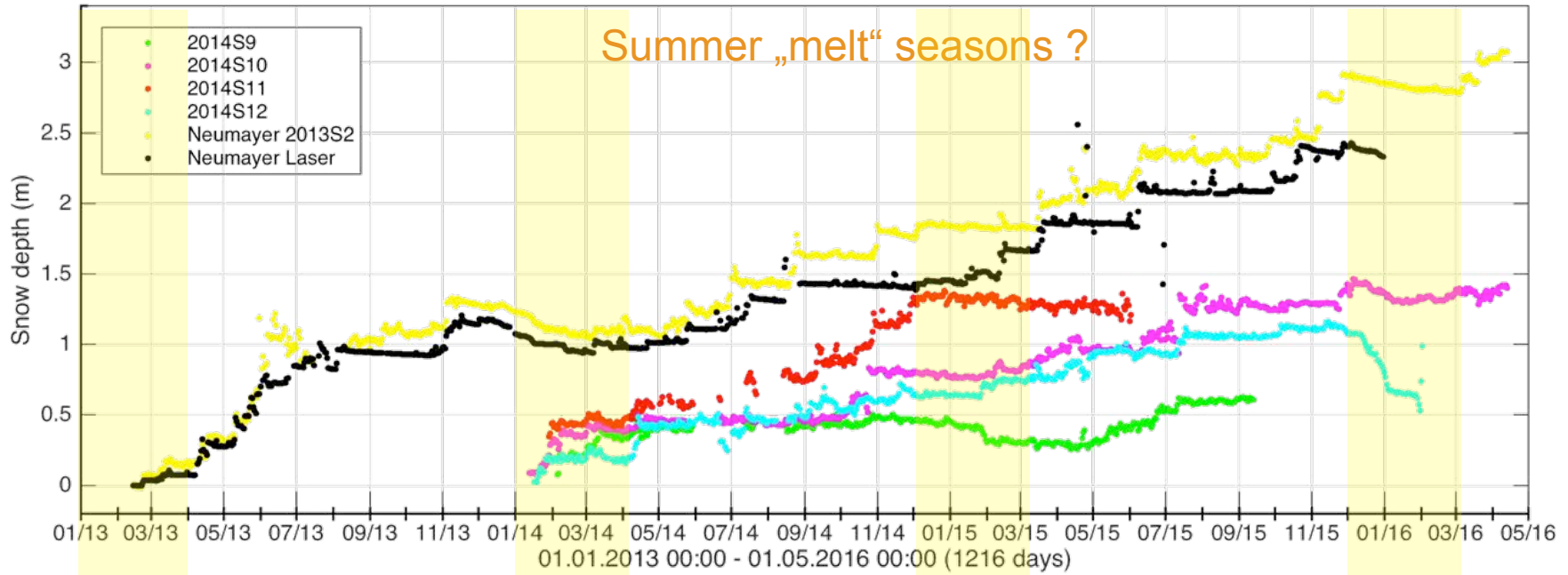
Annual budget 2014/15

Increase by 75 cm

Annual budget 2015/16

Increase by 50 cm

Seasonality (Drift + Neumayer)

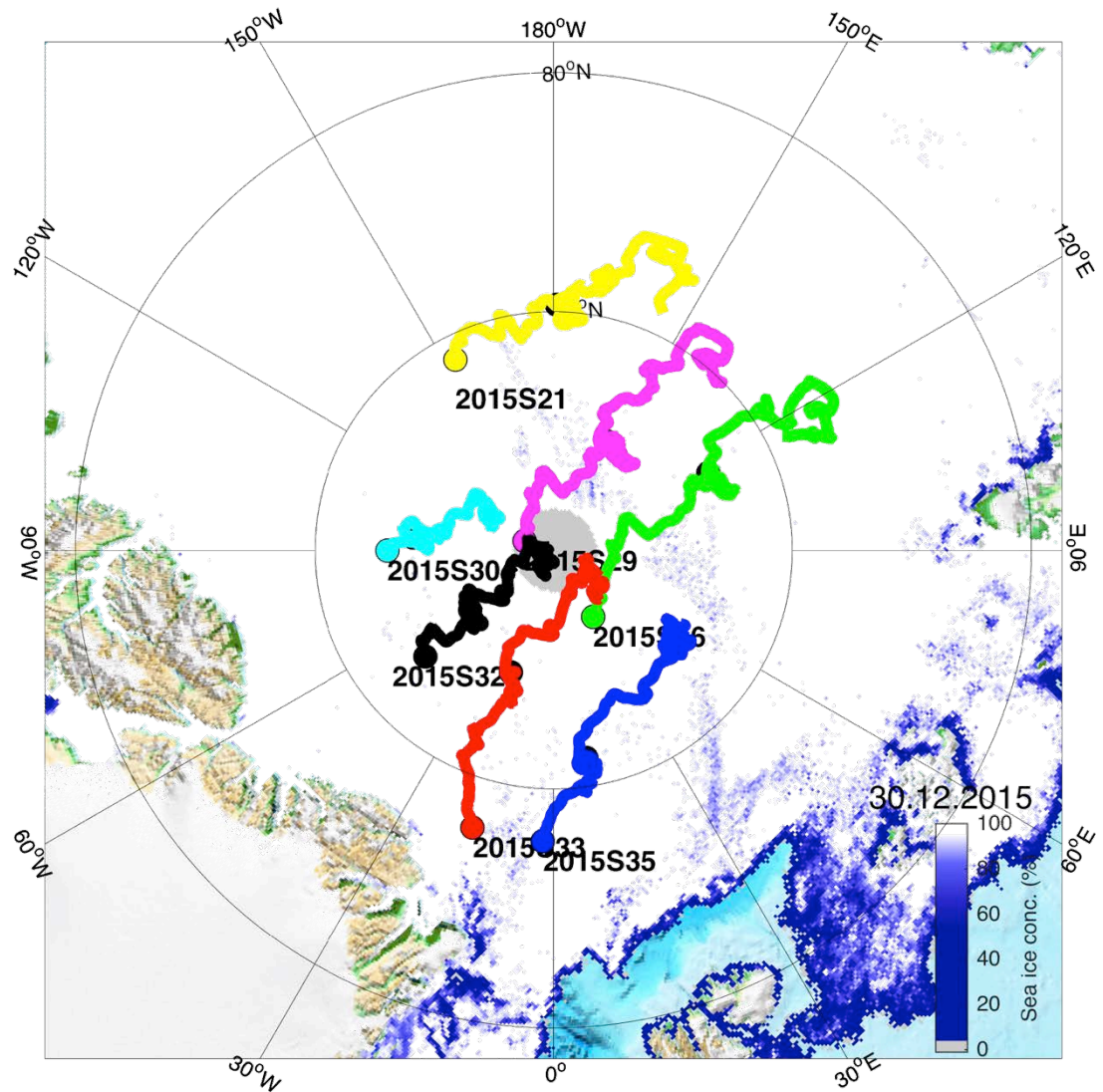


- Seasonal snow depth evolution:
 - Annual accumulation 20 to 90 cm
 - Event driven, partly long times of constant snow depth
 - No consistent summer decrease (melt), no melt in Southern Weddell Sea
 - Annual variability at Neumayer:
 - decrease in summer 2014 & 2016, but not in 2015

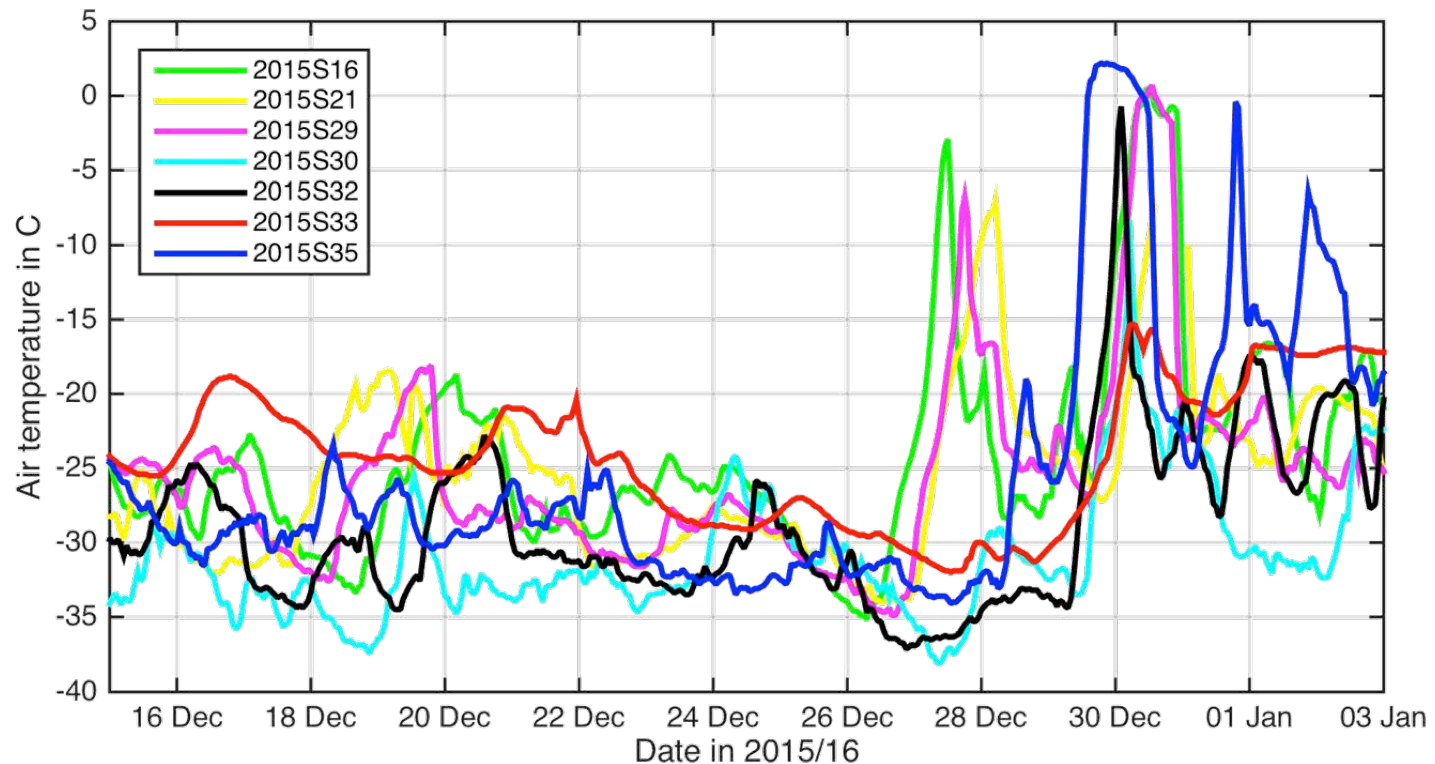
Arctic Snow Buoys in 2015/16

Deployments during Polarstern PS94

- 7 Snow Buoys since Sep/Oct 2015
- Air temperature coverage of entire winter
- Snow depth time series = indicator of surface melt



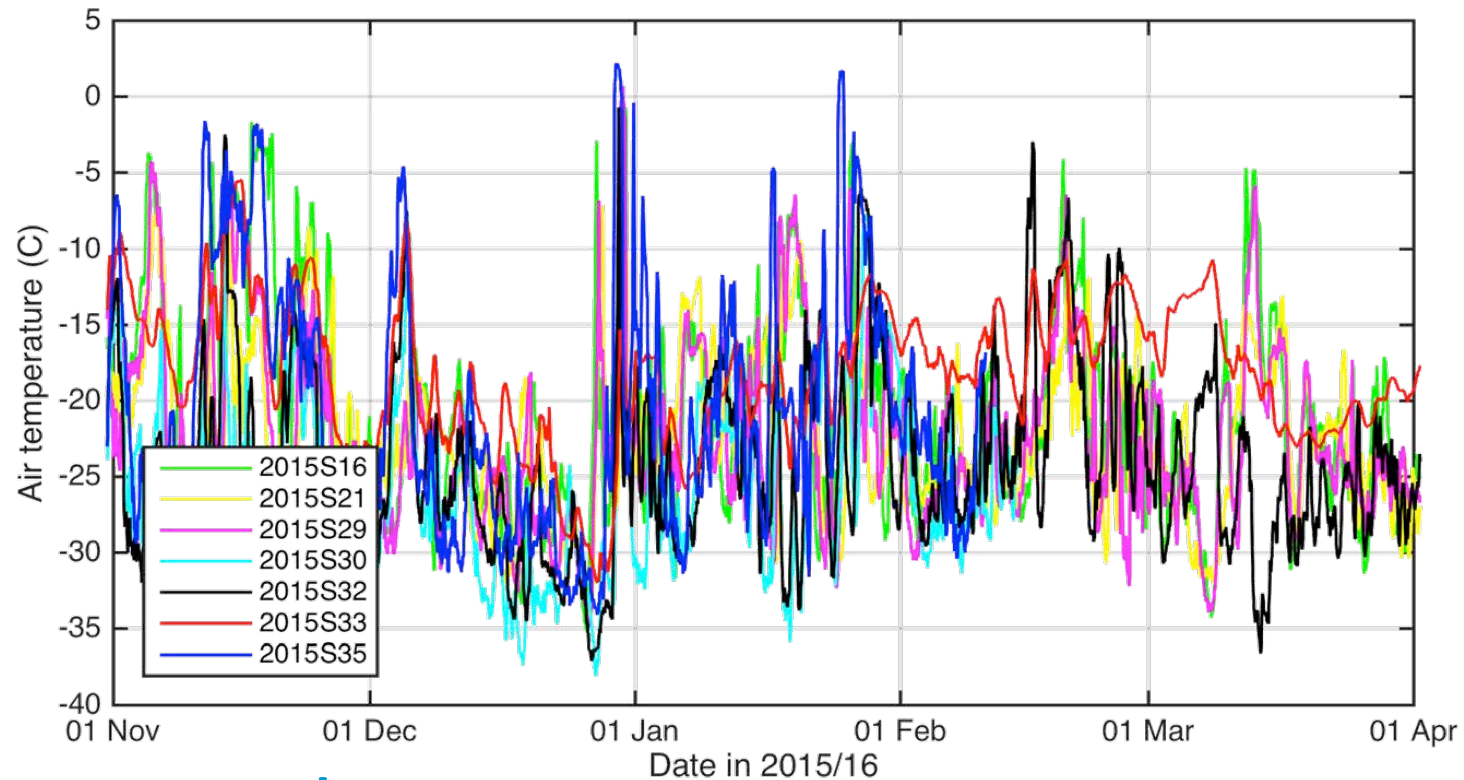
Warm Winter 2015/16



Snow Buoy Results

- Exceeding 0°C end of December 2015
 - => **NEWS** (through GTS reports & Arctic Buoy Program)
- Caused by warm air advection through Fram Strait

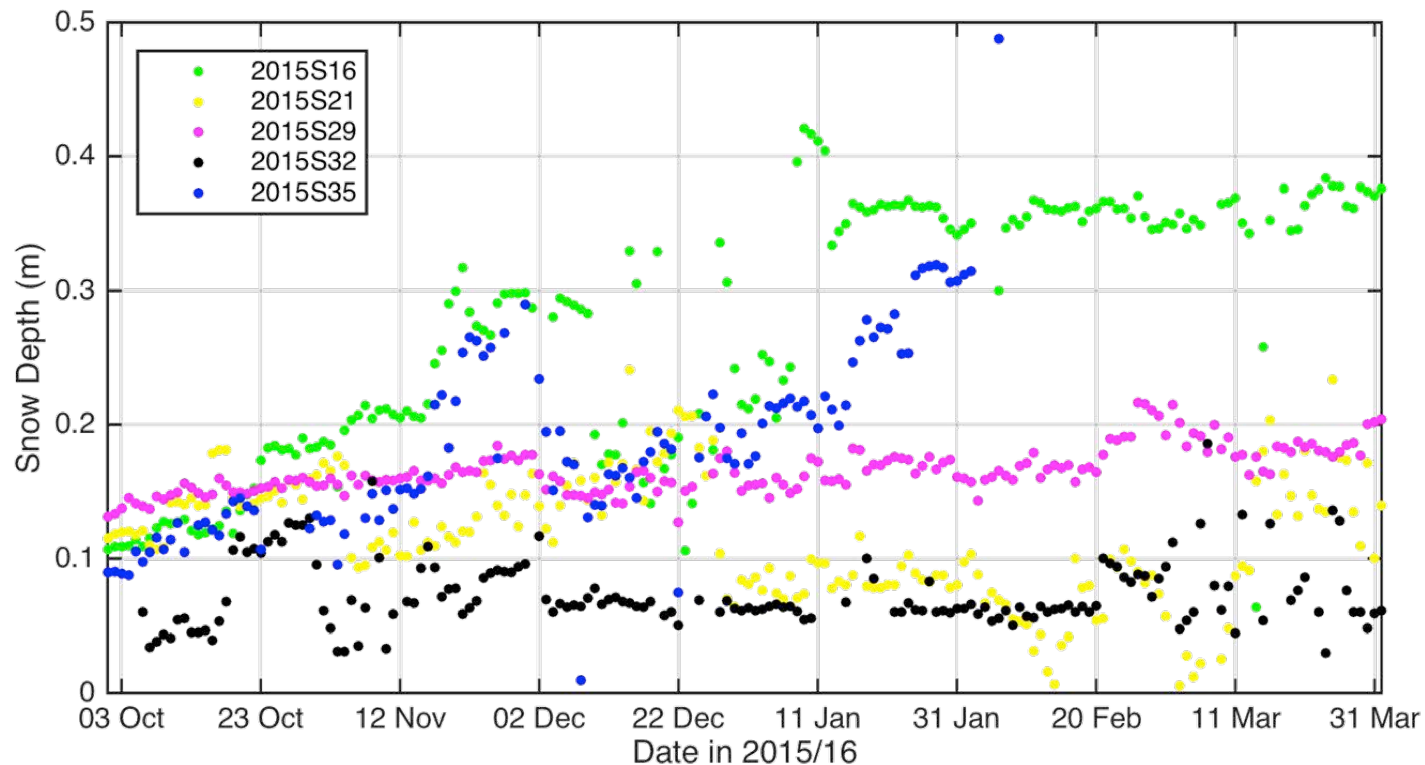
Warm Winter 2015/16



Snow Buoy Results

- Multiple warm spells during winter all the way to North Pole

Effects on Snow Depth



Snow Buoy Results

- No snow or sea ice melt detected
- Only buoy S21 shows decrease of 0.1m
- 4/7 buoys cover the entire time

Summary & Outlook



- **Snow buoys** advance seasonal understanding of snow cover on sea ice
- **Weddell Sea net accumulation** of 20 to 90cm
 - No summer melt in southern Weddell Sea
 - No complete snow melt in any data set
 - Strong melt along ice edge
- **Arctic air temperature:** warm winter 2015/16
 - Impacts on sea ice thickness / mass balance
 - Importance of distributed observational networks
- Variability on different **temporal and regional scales**
=> More time series needed to develop full seasonality
- Further needs
 - Joined analyses with satellite and model results
 - Community effort of deployments and analysis