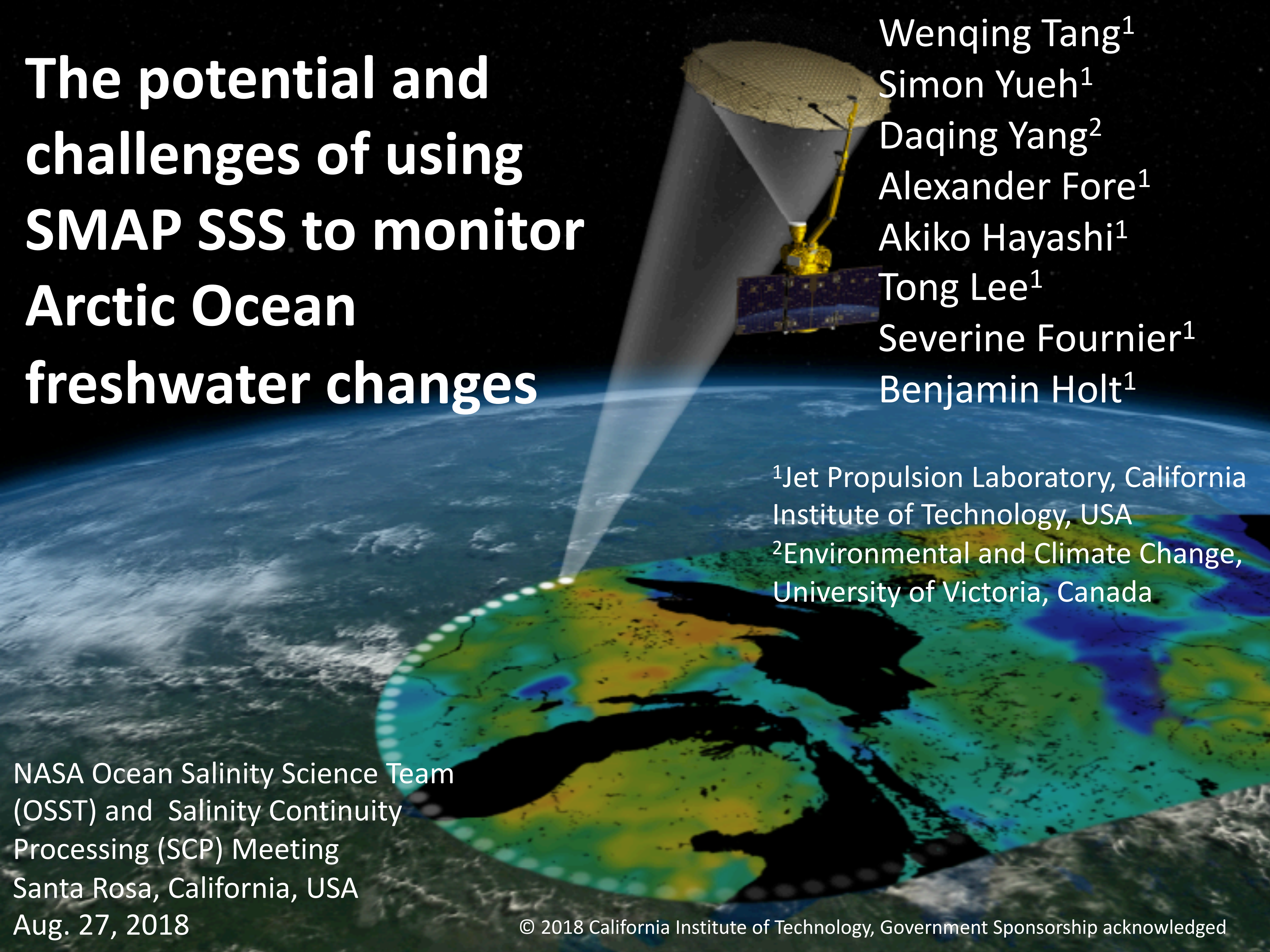

The potential and challenges of using SMAP SSS to monitor Arctic Ocean freshwater changes

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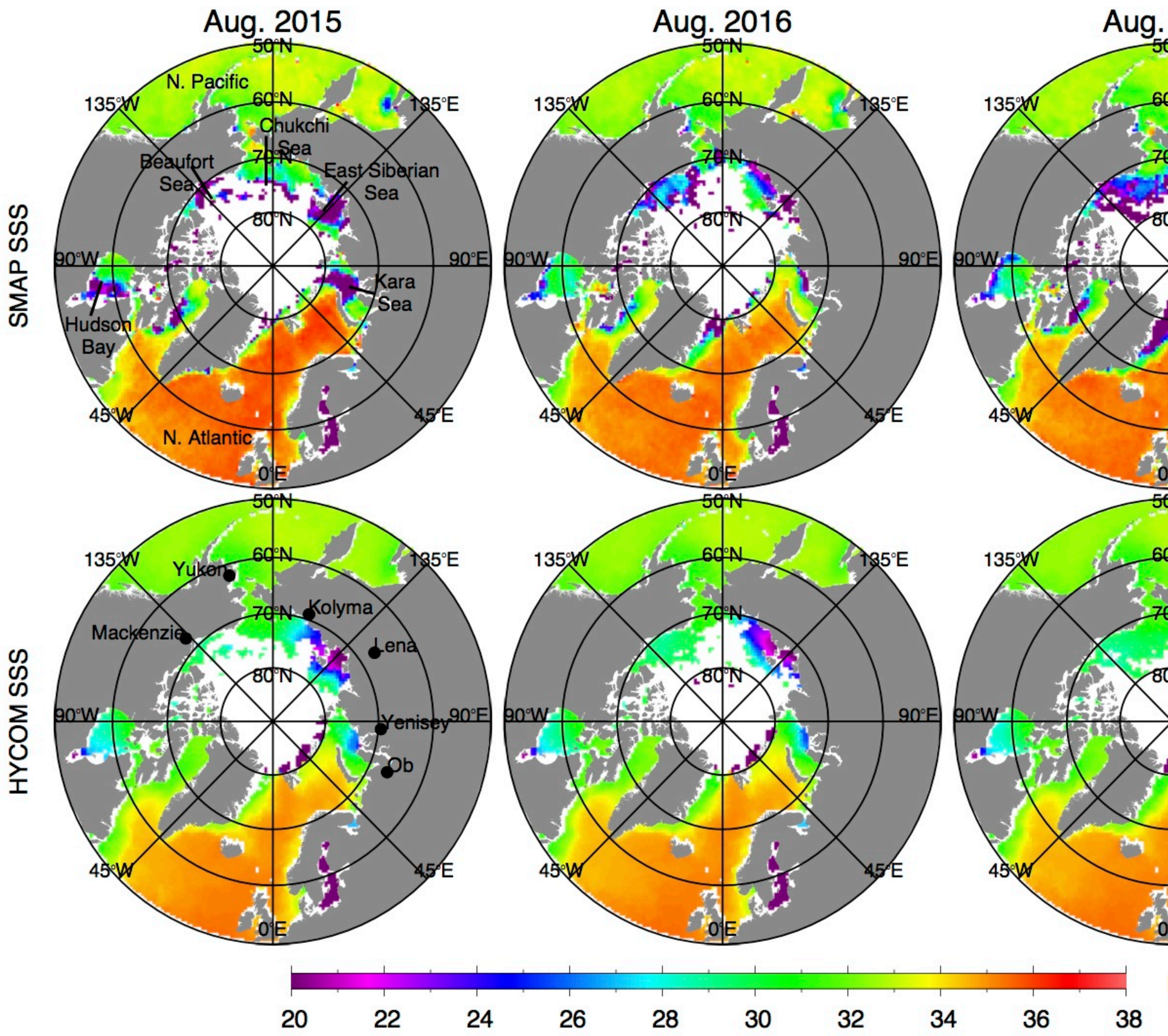
Introduction

- Arctic Ocean is experiencing rapid changes: loosing of sea ice, becoming fresher and warmer, increasing of atmospheric moisture, and intensifying of the regional freshwater cycle…
- Ocean salinity plays a critical role of linking the freshwater components within the atmospheric, terrestrial and cryospheric water cycles to ocean circulation.
- In particular, salinity responds to river discharge, sea ice melt and growth, surface freshwater forcing (P-E), and exchanges with subarctic oceans via oceanic transports.
- This study explores the potential of SMAP SSS in monitoring Arctic Ocean freshwater changes

Challenges

- L-band sensitivity to SSS reduces in cold water
- Sea ice contamination if undetected
- Larger uncertainty of roughness correction
- Relatively large uncertainty of ancillary data (e.g. SST)
- Lack of in situ salinity measurements for calibration and validation

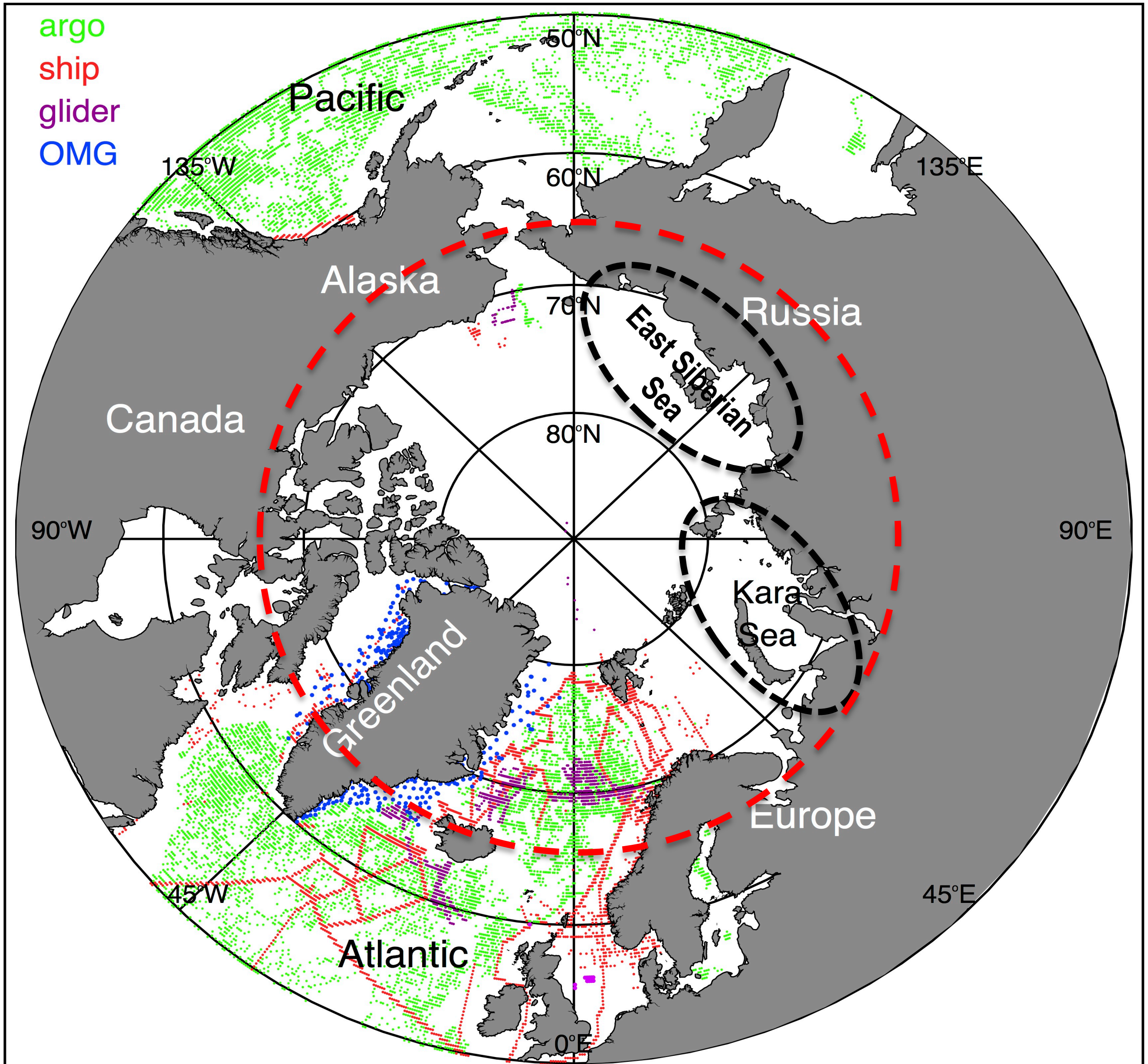
SMAP SSS in ice-free areas of Arctic Ocean reveal large inter-annual variation



Outline

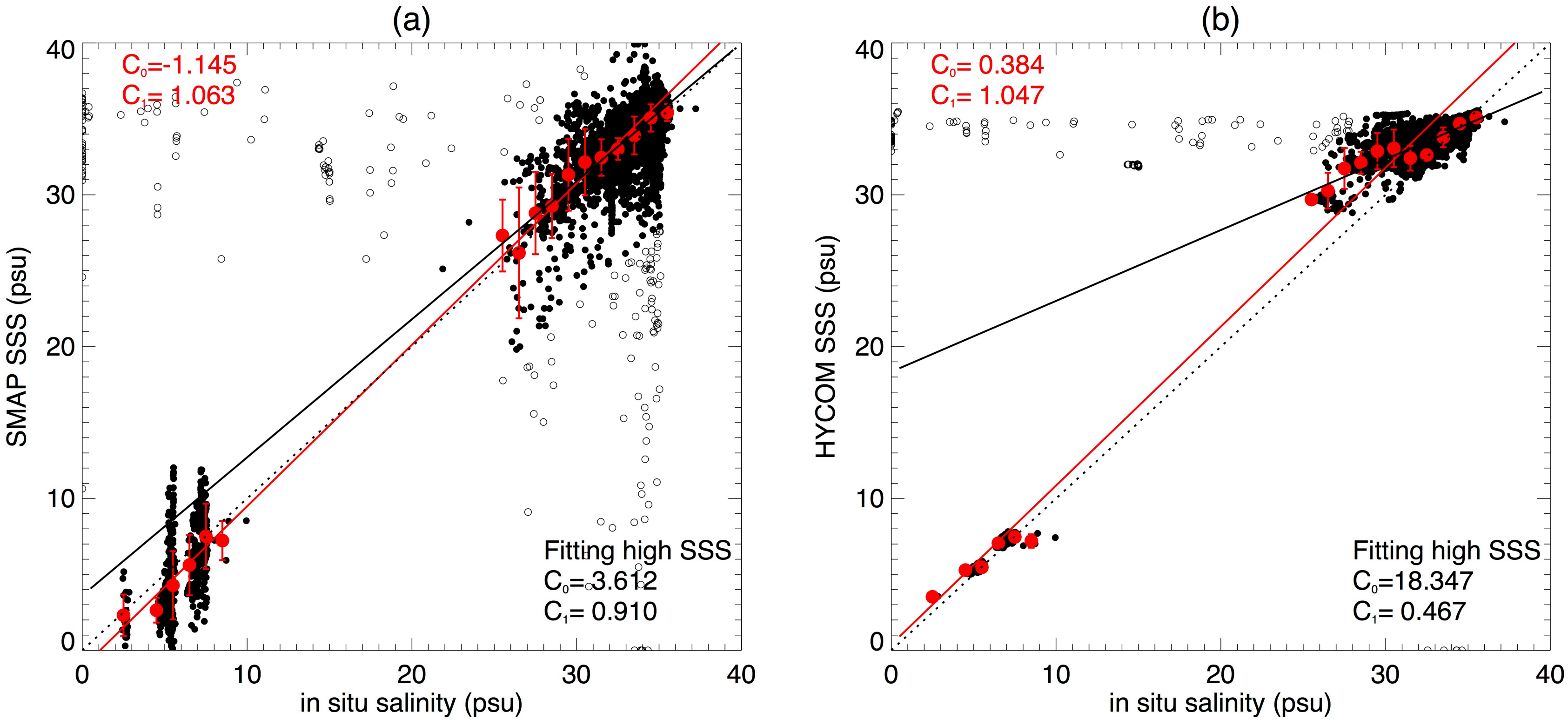
- Validation with in situ data from Argo floats, ships, gliders and field campaigns
- Relation with the seasonal cycle of sea ice
- Response to river discharge in the Kara Sea
- SSS variability in major Arctic Ocean gateways

Distribution of locations of in situ salinity from April 2015 to March 2018



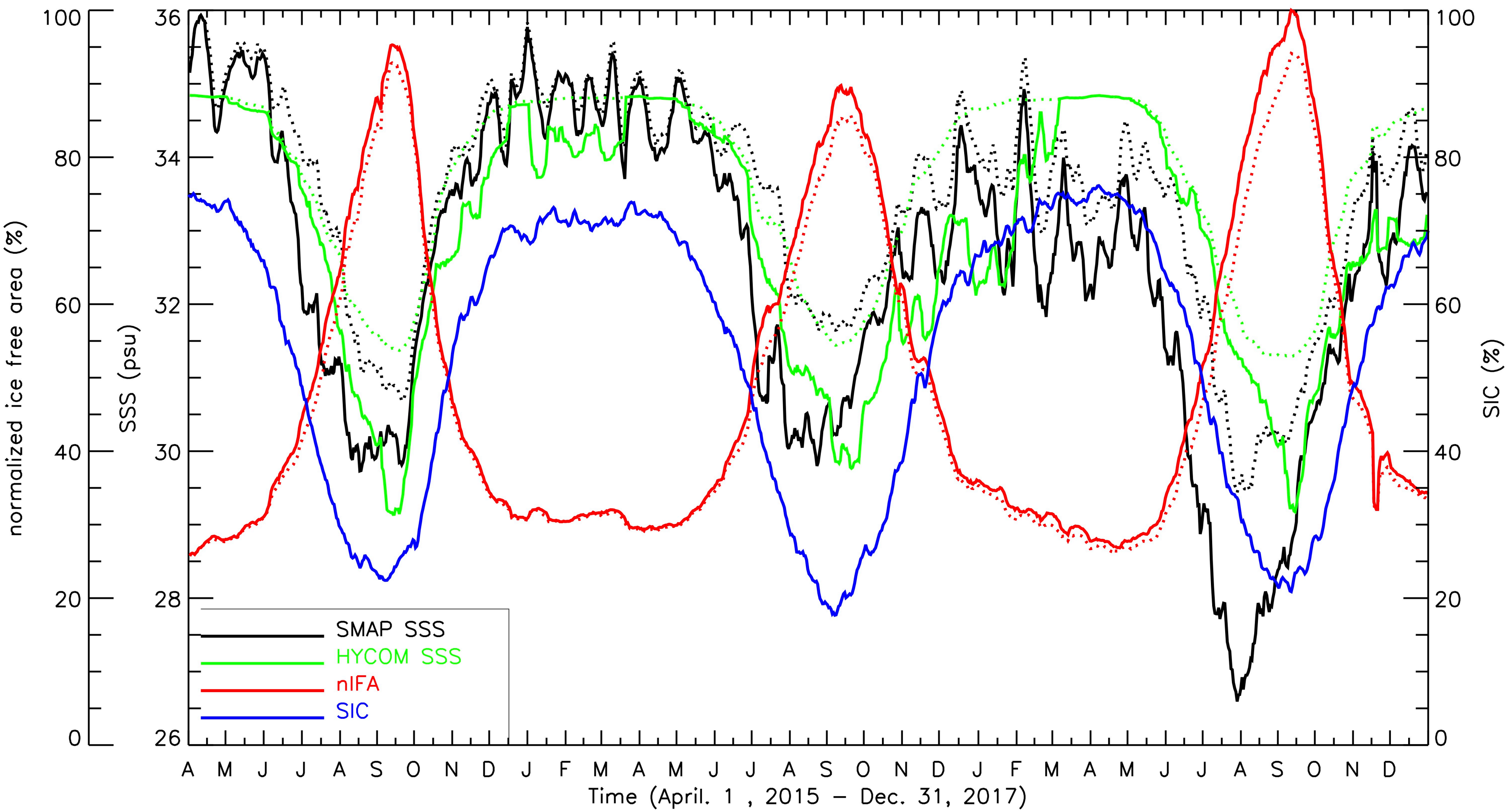
- North of 50°N, near 20,000 pairs of SMAP SSS and in situ salinity collected by floats, gliders, ships and in field campaigns collocated within 12.5km and daily window
- North of 65°N, the number of collocation drops more than 70%
- Very few or no in situ data in marginal seas within Arctic circle, such as in the Kara sea, East Siberian Sea

Validation of SMAP SSS with in situ data North of 50°N



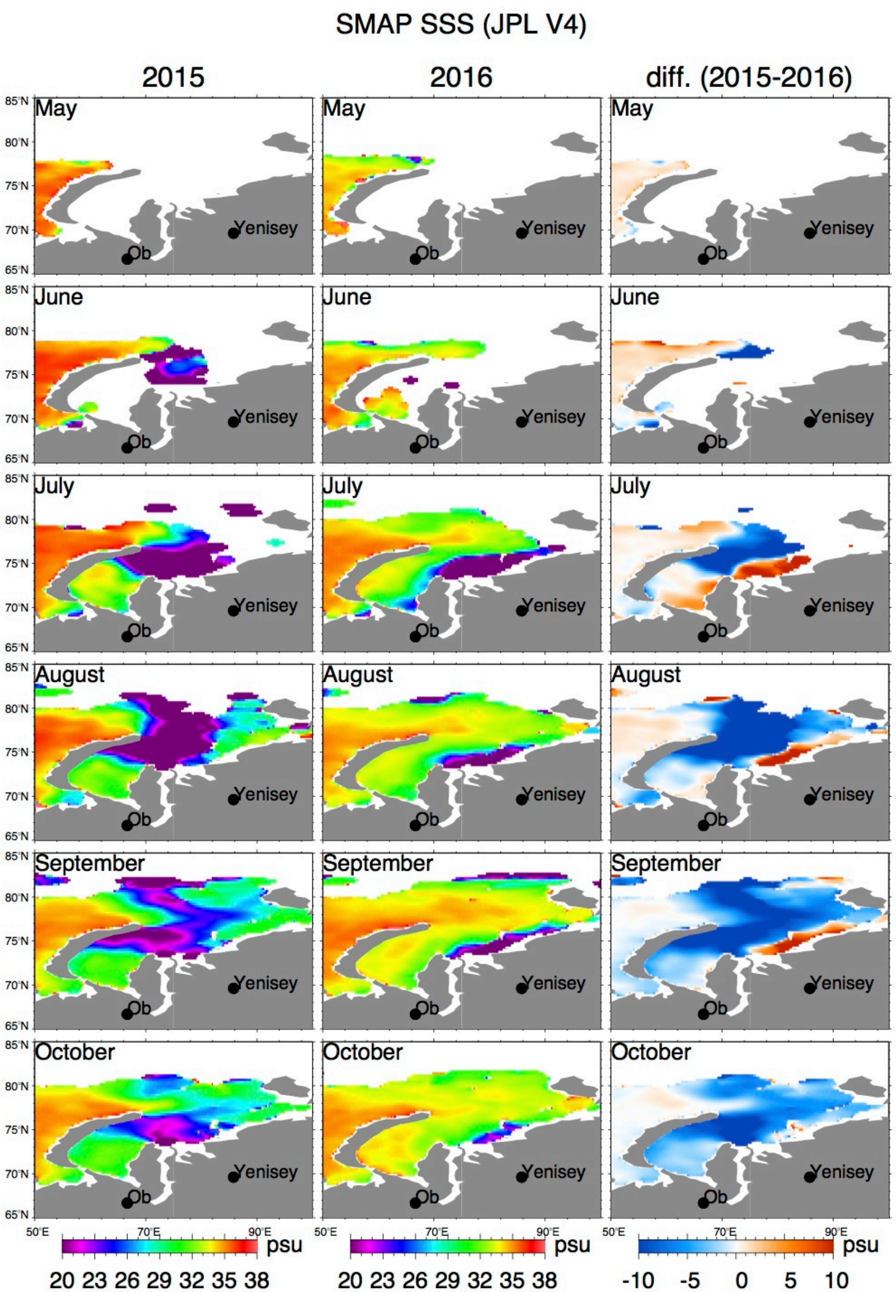
	North of 50°N					North of 65°N				
	N	Bias	Std.	RMSD	Corr.	N	Bias	Std.	RMSD	Corr.
SMAP	19738	0.442	2.391	2.431	0.805	5785	0.342	2.829	2.849	0.509
HYCOM	19738	0.270	2.110	2.128	0.934	5785	0.285	2.337	2.354	0.892
After excluding outliers										
SMAP	19543	0.385	0.987	1.060	0.817	5712	0.339	1.179	1.227	0.518
HYCOM	19617	0.149	0.661	0.678	0.942	5749	0.182	0.840	0.860	0.900

The seasonal cycle of Arctic Ocean SSS and Sea Ice



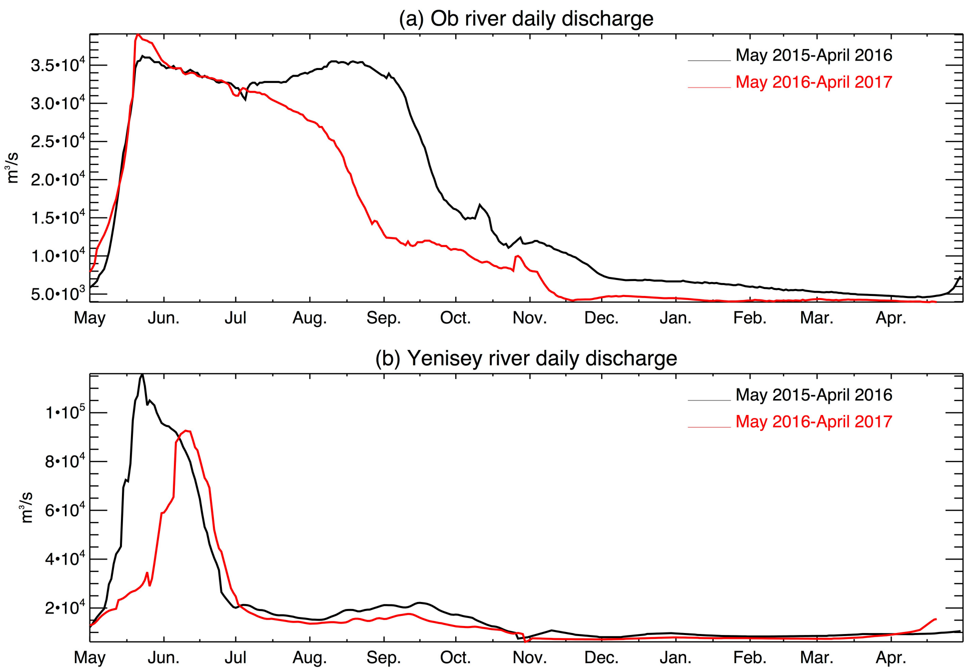
In seawater near the ice edge, sea ice formation and melt have significant contributions to the mixed layer salt budget, with growing importance toward the ice edge [Ren et al., 2011].

SMAP SSS reflect impact of river discharges in the Kara Sea



- Massive northern rivers transport huge quantities of water from the continents to the Arctic Ocean. The freshwater inputs associated with river runoff should be reflected in the SSS field.
- From June to October, SMAP observed dramatic contrast between 2015 and 2016.
- Because the whole region has become almost ice-free after July, the impact of new freshwater inputs from sea ice melt is likely to be minimal
- Therefore the dramatic freshening signature spreading through middle of the Kara Sea from July to September in 2015 and along the Siberia coast in 2016, must have originated from the other freshwater source – river discharge

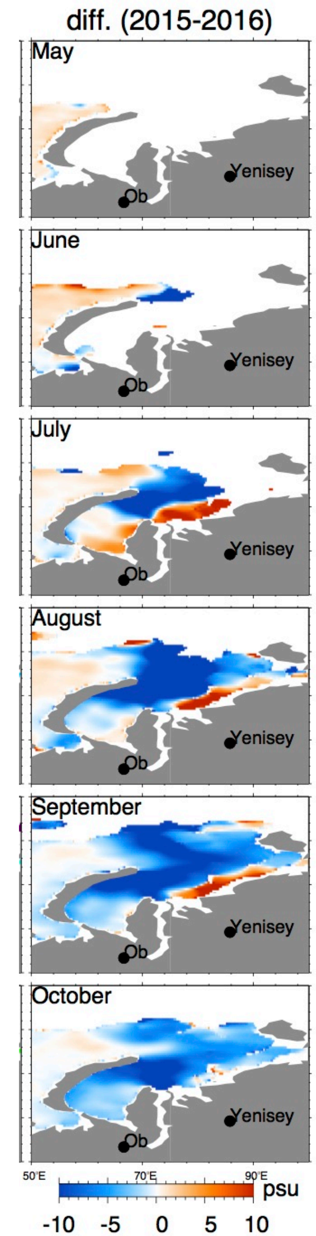
SMAP SSS reflect impact of river discharges in the Kara Sea



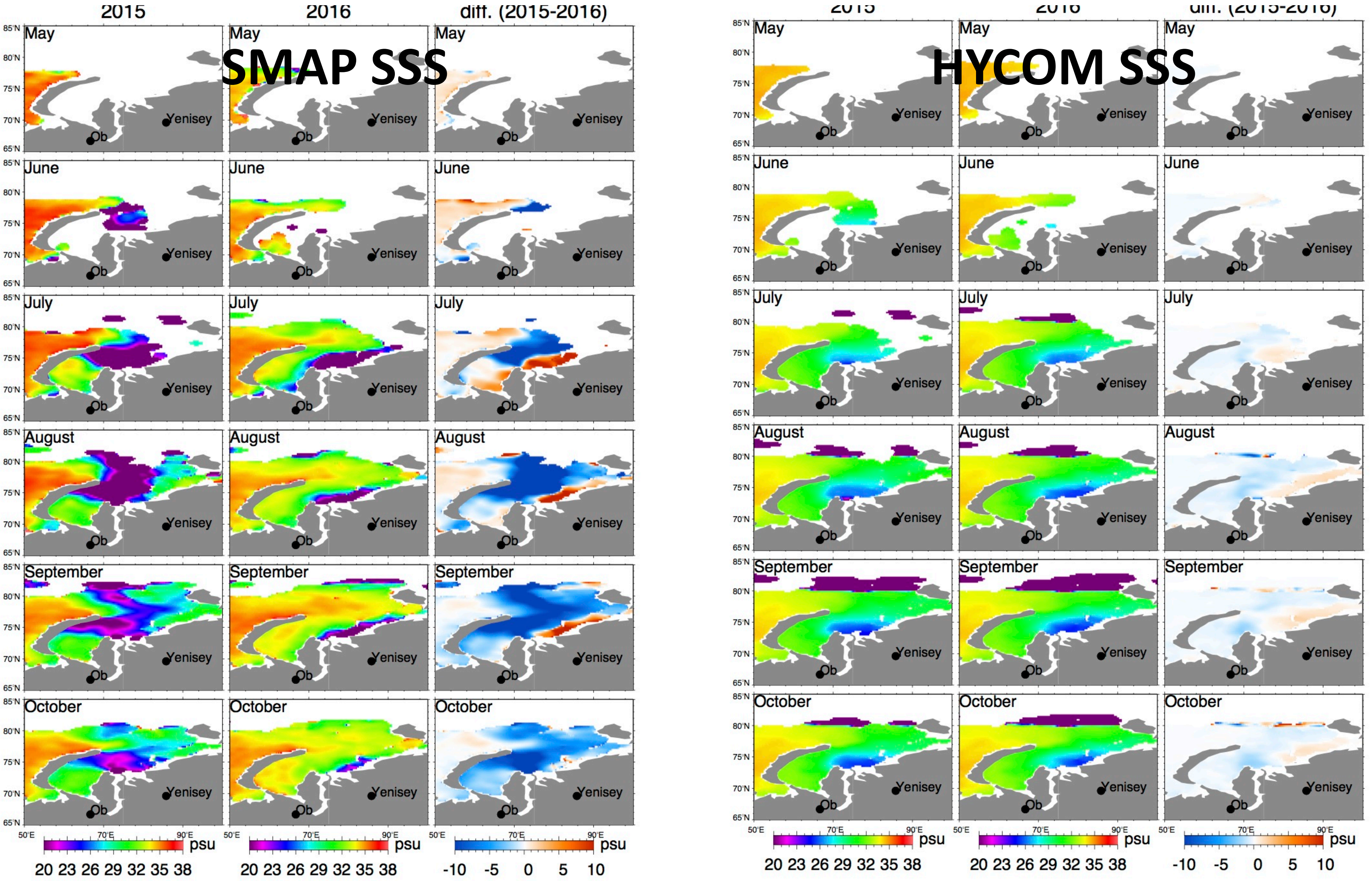
Unit: km^3	May-June		July-October	
	Ob’	Yenisey	Ob’	Yenisey
2015	148.89	335.17	285.03	184.17
2016	154.11	241.78	194.12	152.70
Δ (2015 minus 2016)	-5.22	93.39	90.90	31.47
Δ (Ob’ & Yenisey)	**88.17**		**122.37**	

Caveat: SSS anomaly may depend on how the discharge freshwater transported horizontally and vertically, in terms of depth and spread of the diluted water body. Nevertheless, the agreement in order of magnitude is encouraging.

- The daily discharge from the Ob’ River and Yenisey River show differences consistent with SMAP observation.
- Combining the discharges from the Ob’ and Yesiney during May to October together, the Kara Sea received more than 210 km^3 extra freshwater in 2015 relative to 2016.
- Assuming the extra ~210 km^3 freshwater spread over half of the Kara Sea (total surface area 926,000 km^2), it may produce 15 psu salinity changes within top 1 m surface water layer, or 7.5 psu within top 2 m.

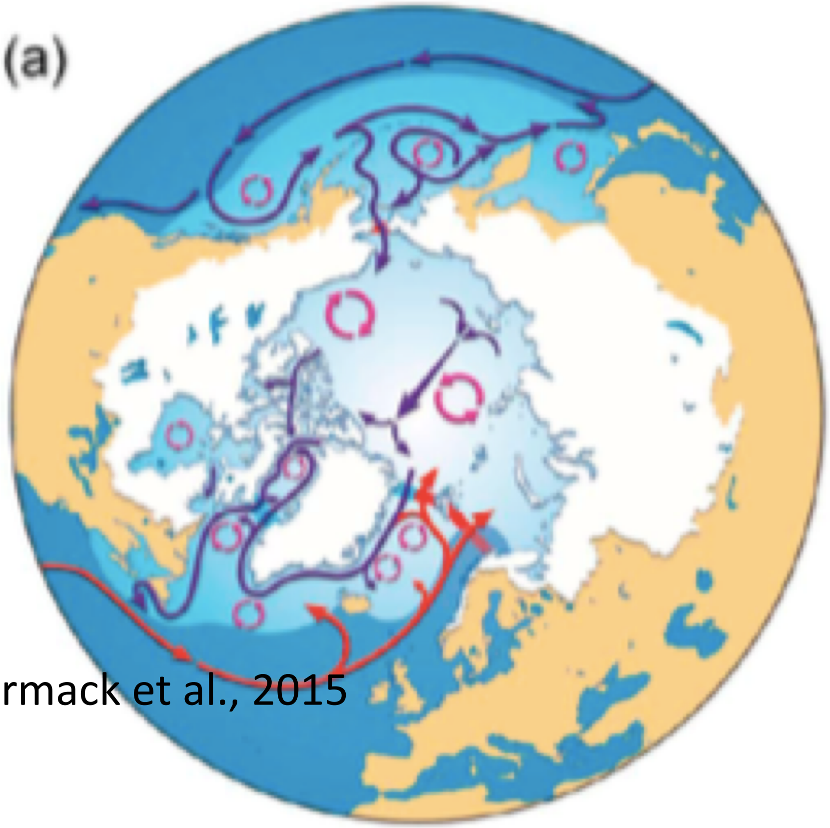


Sea surface salinity and river discharge

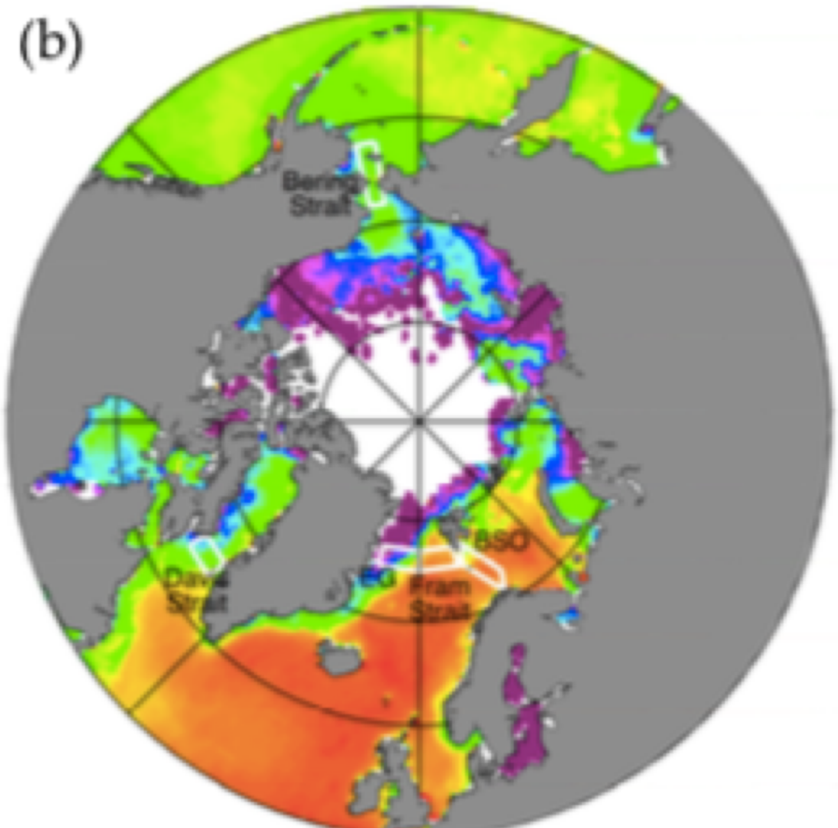


The anomaly in HYCOM SSS is an order of magnitude smaller, due to its climatological forcing which suppress the magnitude of interannual variation in regions with no or very few in situ data to constraint the model.

Sea Surface Salinity Variability at Arctic Ocean Gateways

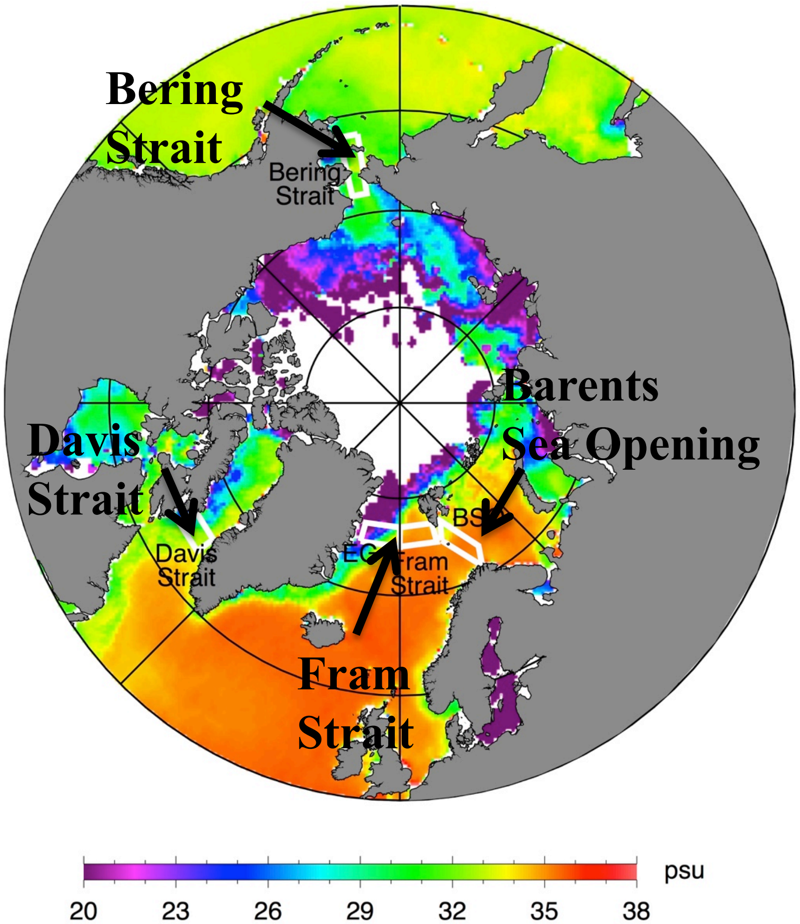


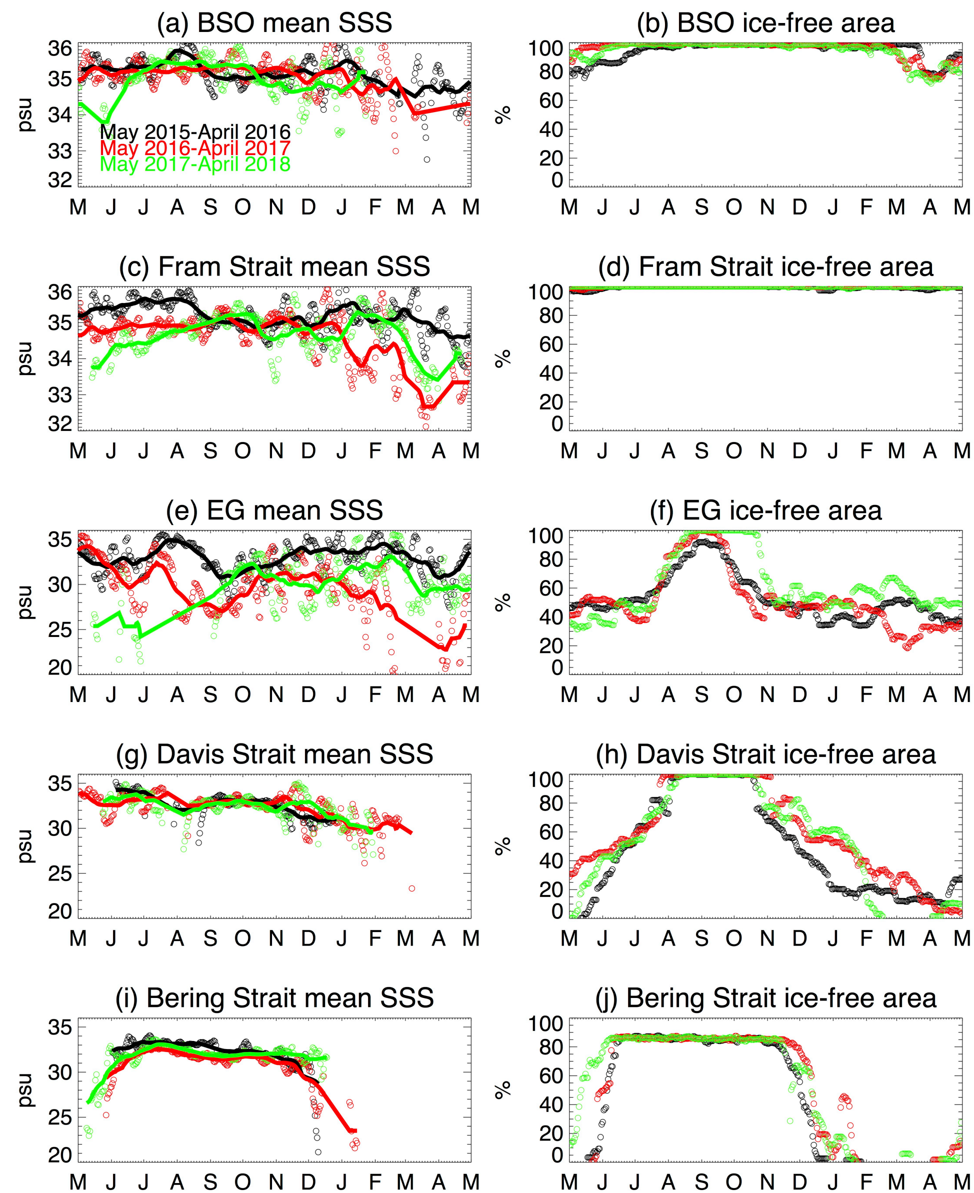
Carmack et al., 2015



The Arctic Ocean exchanges freshwater with the sub-oceans through four major gateways: **the Bering Strait** inflows fresh Pacific waters; **the Barents Sea Opening** and part of **the Fram Strait** inflow the salty Atlantic water; through **the Davis Strait and part of the Fram Strait between Greenland and Svalbard** which comprise the major outflow locations of water modified by the Arctic Ocean in addition to sea ice flux

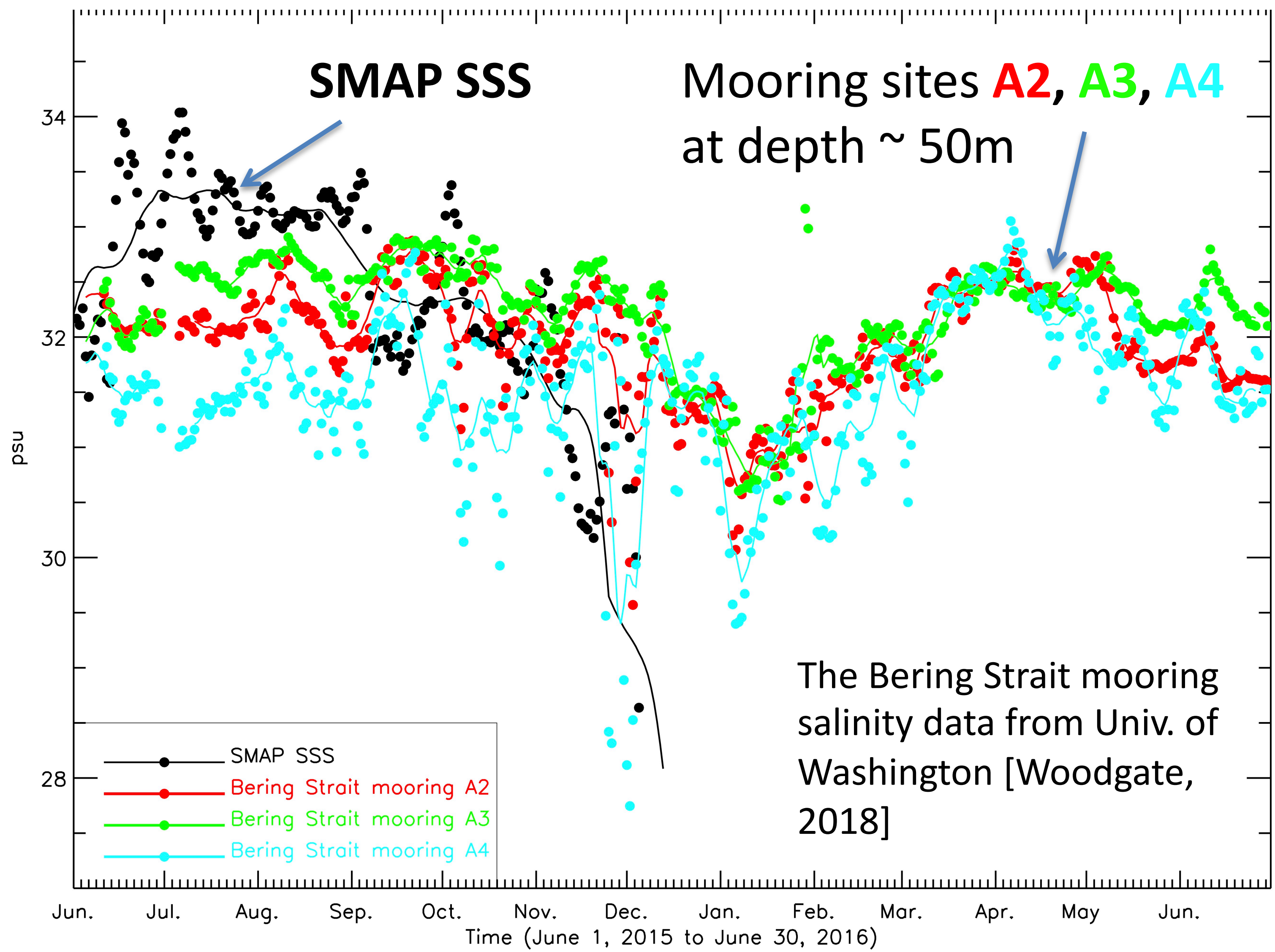
Sea Surface Salinity Variability at Arctic Ocean Gateways





At major Arctic gateways, SMAP SSS captures seasonal and interannual variations with magnitudes larger than the retrieval uncertainty.

The Bering Strait: SMAP SSS and mooring measurements



SMAP SSS depicted a change ~5 psu, well resolved by the 1 psu accuracy, and appeared to have a consistent trend with the A4 mooring on the amplitude and timing of the freshening peak in Dec. 2015.

Summary

- Near 20,000 collocated pairs of SMAP SSS and in situ data North of 50°N results RMS difference ~1 psu with correlation of 0.82.
- In regions lacking in situ data (North of 65°N), SMAP SSS shows seasonal and inter-annual variation consistent with sea ice concentration.
- In the Kara Sea (there is no in situ data), the large SSS contrast between 2015 and 2016 observed by SMAP is corroborated by the anomalous freshwater inputs from the Ob' and Yenisey rivers.
- Analysis of SSS variability at major Arctic Ocean gateways demonstrates that SMAP provides useful information in monitoring large freshwater signals in the Arctic Ocean.