Variability of Space-based Sea Surface Salinity and the Freshwater Contents in the Hudson Bay

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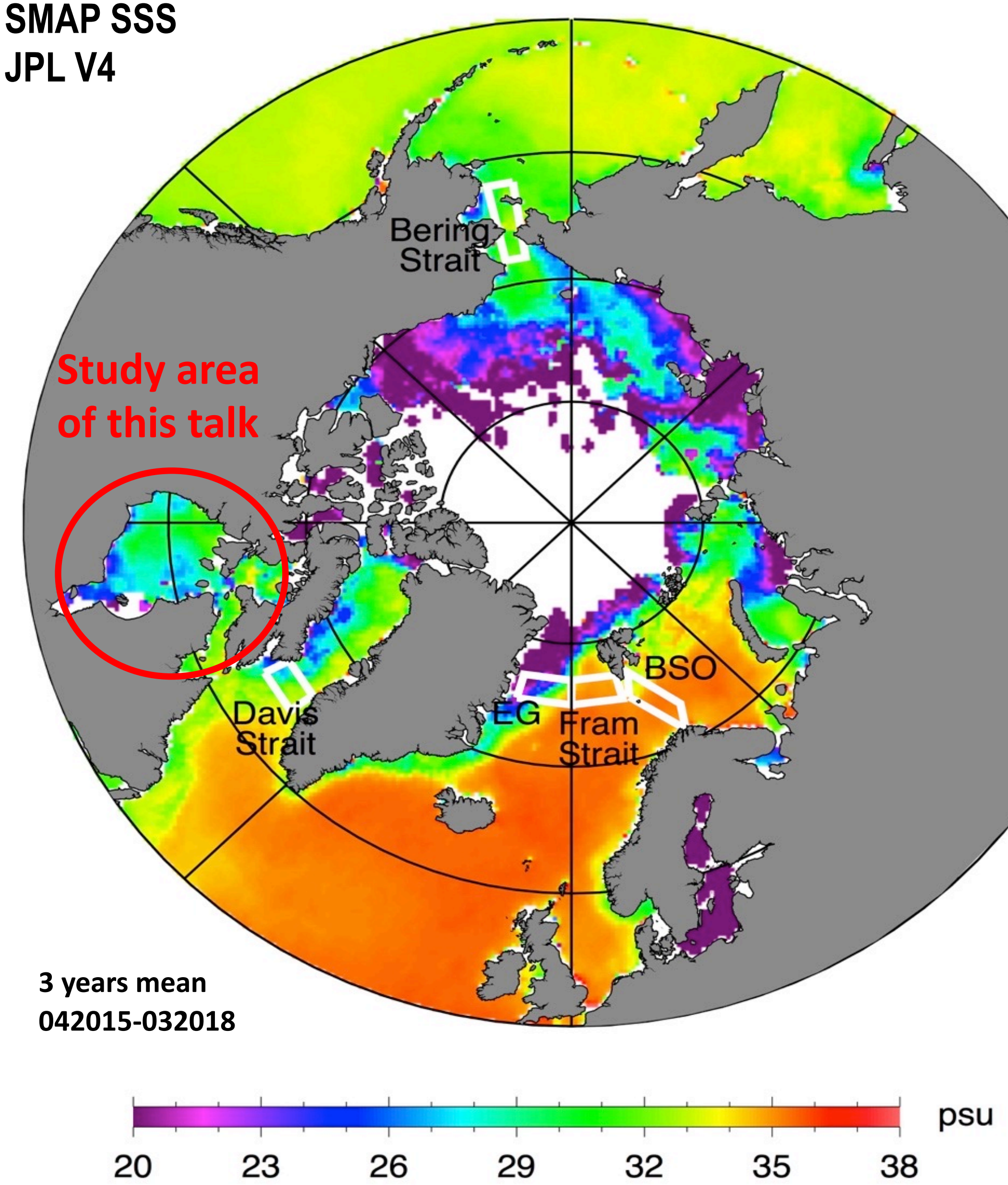
Motivation and objective - Previous work

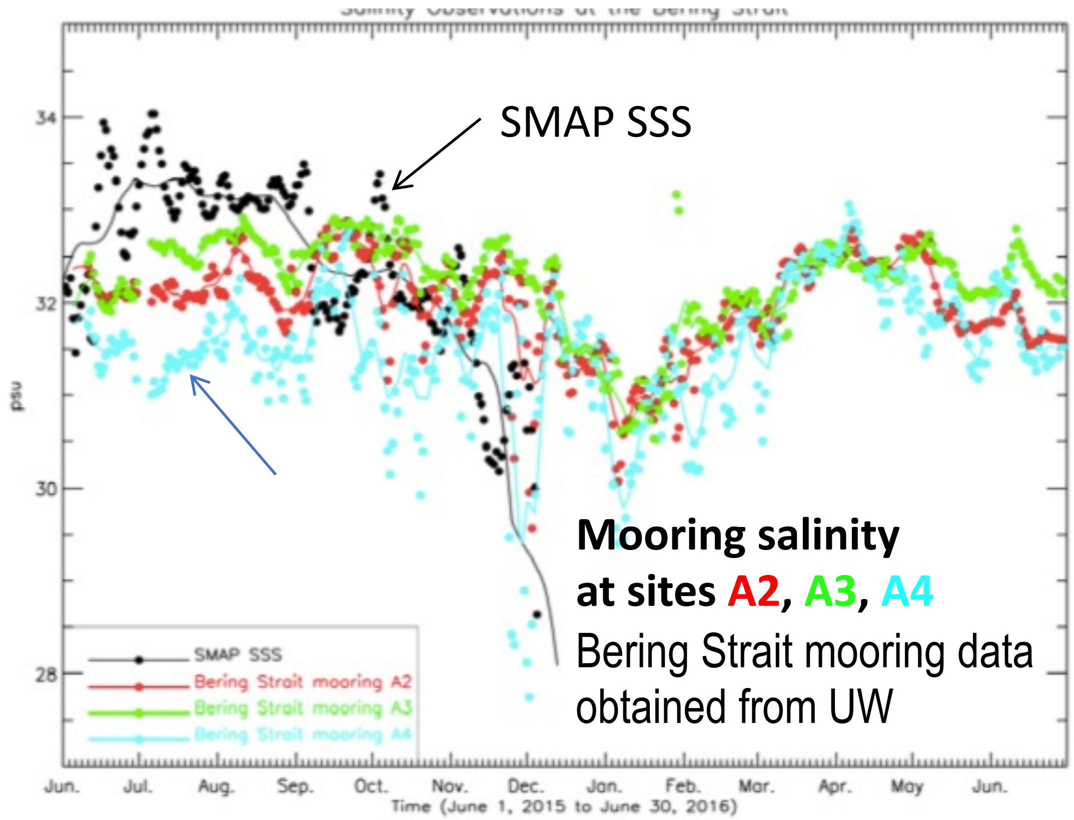
SMAP SSS
JPL V4



3 years mean
042015-032018

Salinity observations at Bering Strait

Tang et al. 2018

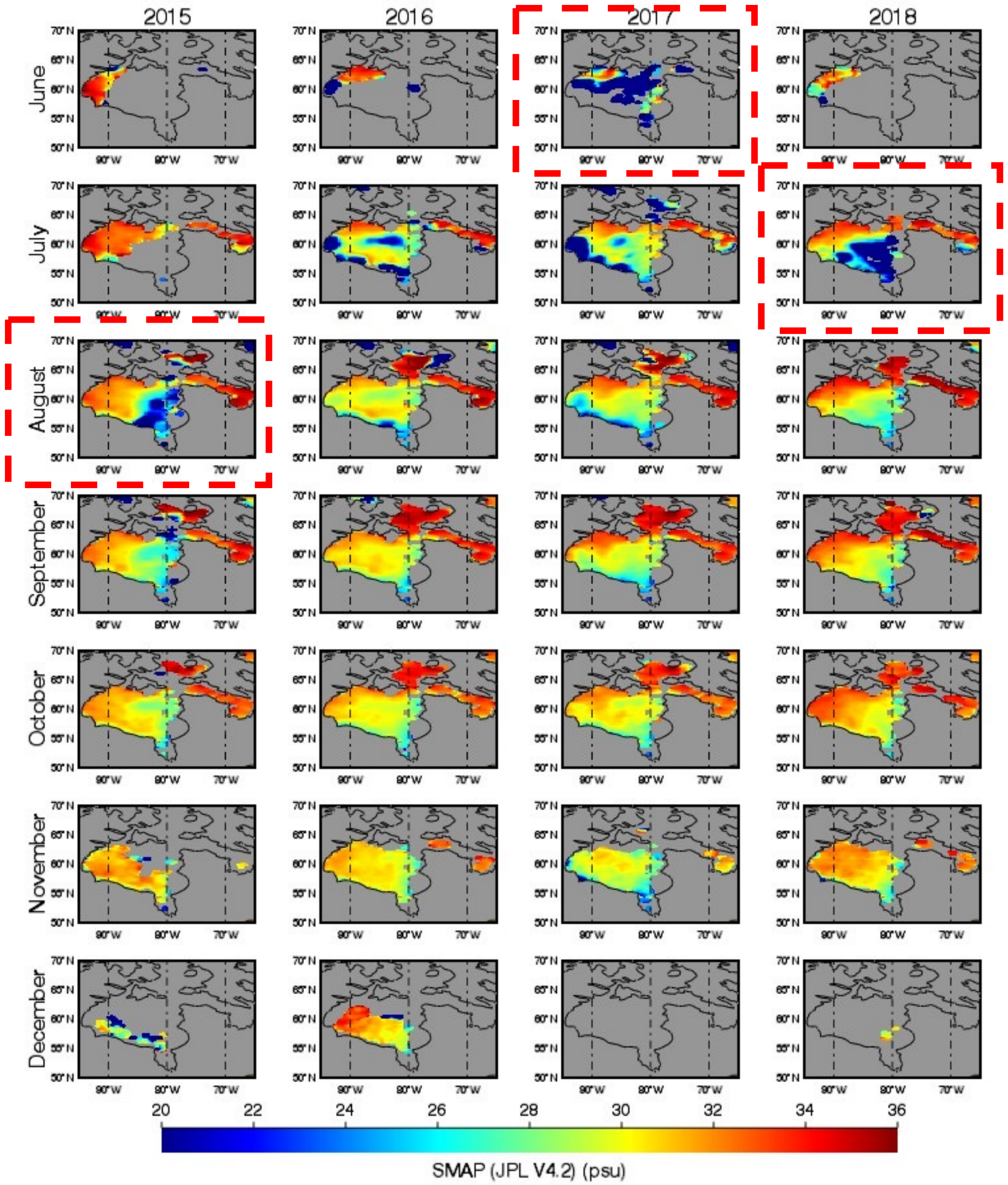


Satellite remote sensing is highly desired to play a significant role in monitoring the rapid changes in the Arctic Ocean. And sea surface salinity should play critical role, linking various freshwater components.

L-band microwave sensitivity to seawater salinity largely degrades in cold water and suffers from sea ice contamination. However, is there potentially useful information in current L-band data?

At major Arctic gateways, SMAP SSS captures seasonal and interannual variations with magnitudes larger than the retrieval uncertainty (~1 psu).

Sea Surface Salinity (SMAP JPL V4.2)



SSS shows high interannual variability early in sea melt season, e.g.

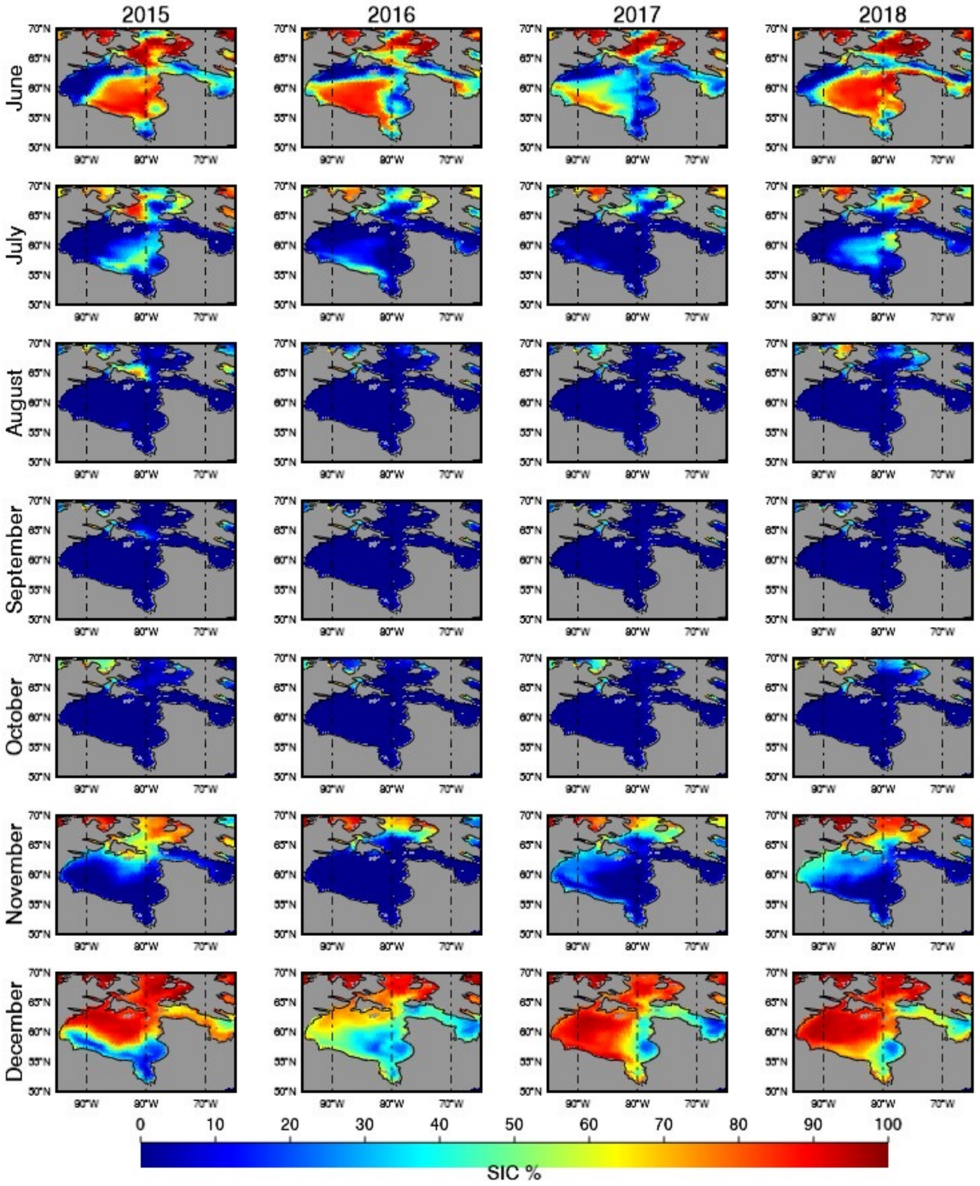
August 2015: Fresh patch extending from James Bay across eastern HB

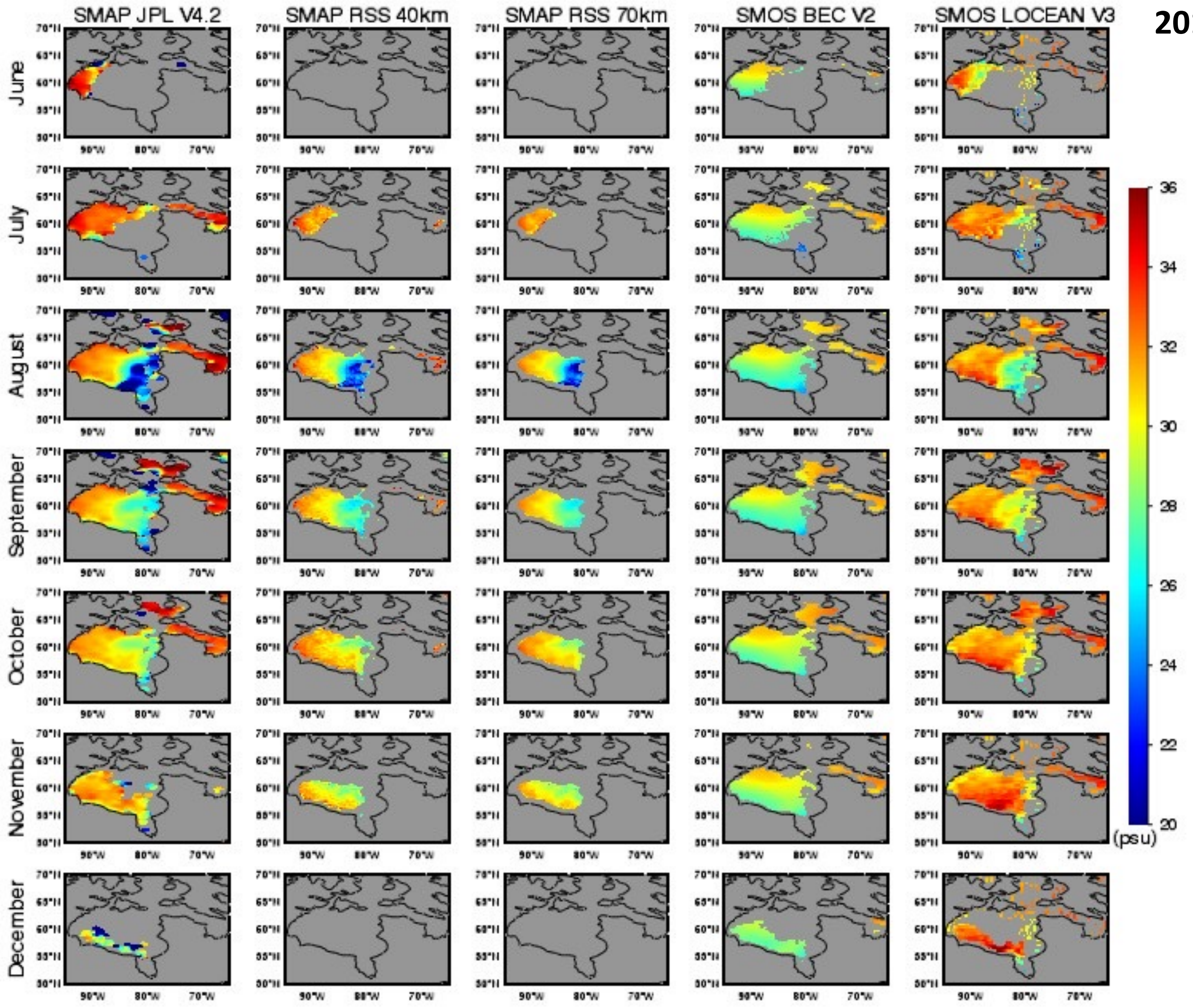
June 2017: Early melt extend from north HB to interior

July 2018: Fresh signature from eastern HB to interior

Are those real fresh signatures or due to undetected sea ice?

Sea Ice Concentration (NSIDC)





2015

Five SSS products retrieved from SMAP and SMOS measurements based on different retrieval algorithms

What can we learn from observed differences between products?

There is no in-situ salinity data available in the Hudson Bay in period overlap with satellite missions

Hudson Bay

Surface area: 819,000 km^2

Depth: average 120 m, maximum 250 m

Ice thickness: average 1.0m, maximum 1.6 m

Basic characteristics of HB

- Hudson Bay is the largest inland sea in northern hemisphere, connected to Arctic ocean via Foxe basin and the North Atlantic via Hudson Strait.
- Hudson Bay freezes in winter, completely covered by sea ice and snow with average depth of 1 meter. Around 1300 km^3 low salinity liquid water trapped in ice is released in spring/summer when ice/snow melts. [Prinsenberg, 1988]
- Hudson Bay receives vast amounts of river runoffs flowing in from terrestrial river systems with more than half of that through the James Bay in the south.

Significance

- Located south of the Arctic circle, climate change in the Hudson Bay is evident: air temperature have risen ~1°/decade; season of sea-ice cover is shortened; and; dramatic changes in the timing and volume of river runoff
- Bridging the Arctic and temperate domains of central Canada, Hudson Bay therefore represents an important sentinel of cryospheric change [Macdonald et al., 2011]

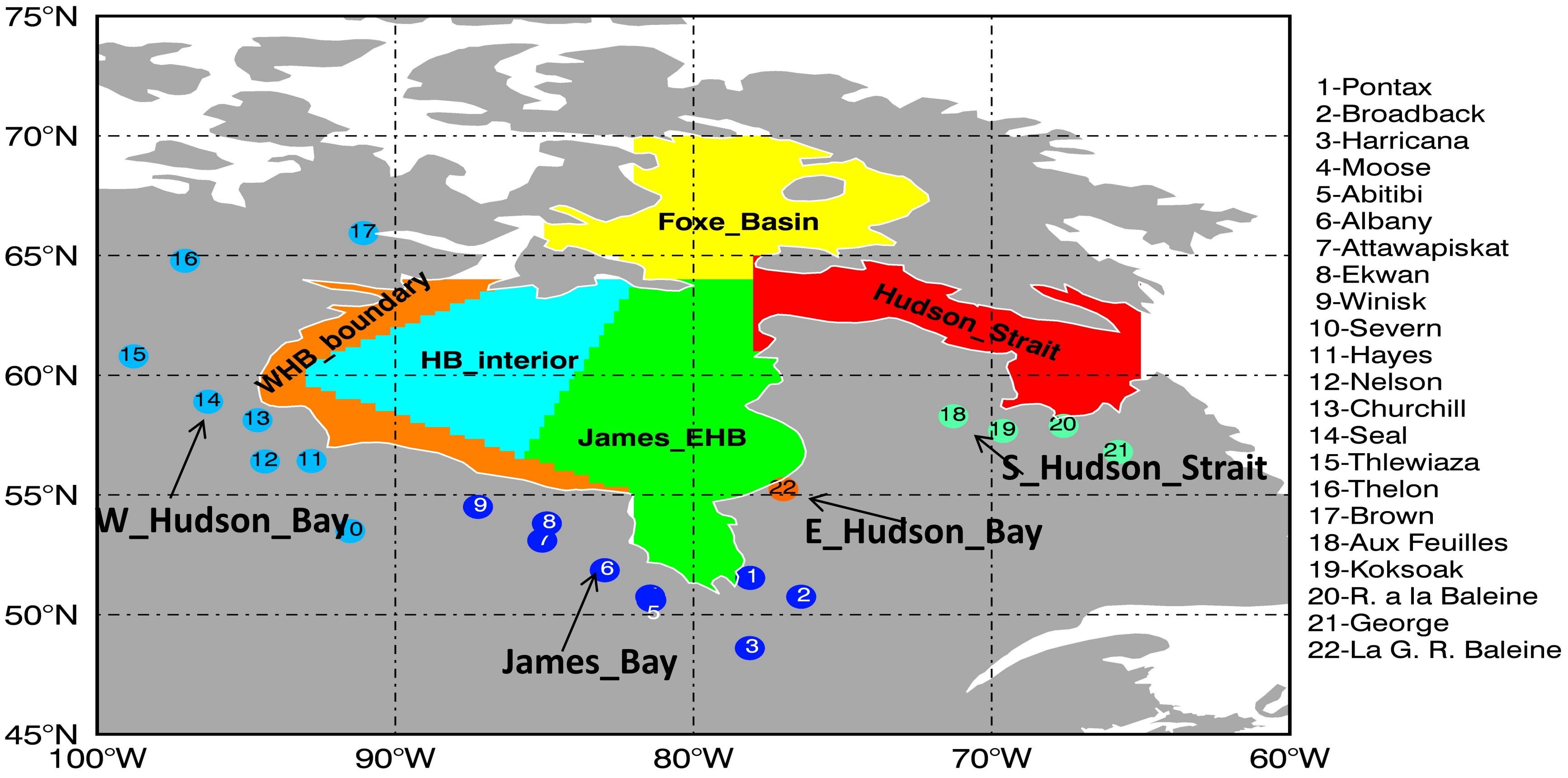
The role of sea surface salinity

- SSS links freshwater components from sea ice, runoff, surface forcing (precipitation minus evaporation) and exchange with Arctic Ocean and the Northern Atlantic

Objective: Use Hudson Bay as a test bed, to investigate the potential utility of current satellite SSS products in monitoring freshwater components in polar region, and identify areas for future improvements

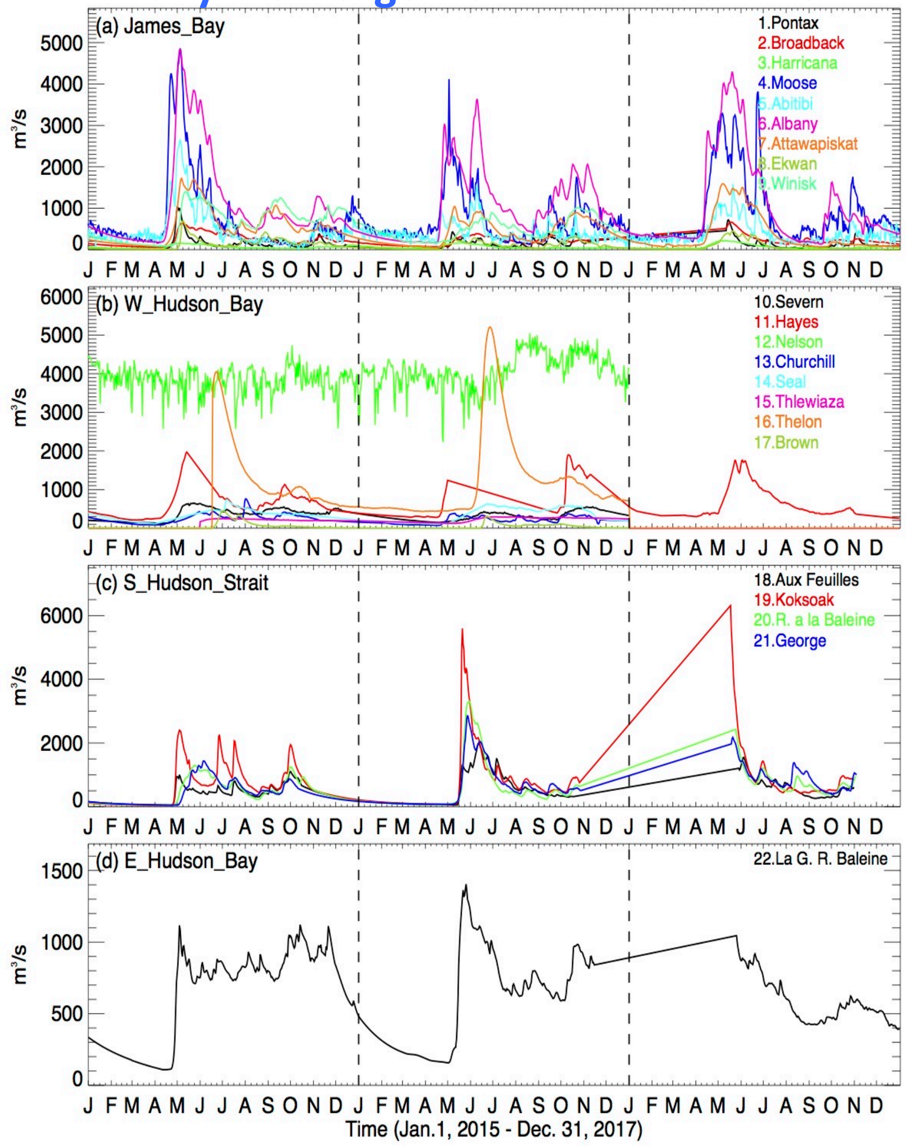
Approach: We examine SSS feature in the context of independently measured freshwater components in the Hudson Bay:

- Daily river discharge from all rivers surrounding the Hudson Bay
- Monthly Precipitation (P), evaporation (E), and the net surface forcing (P-E)
- Freshwater contribution from sea ice change derived from sea ice concentration

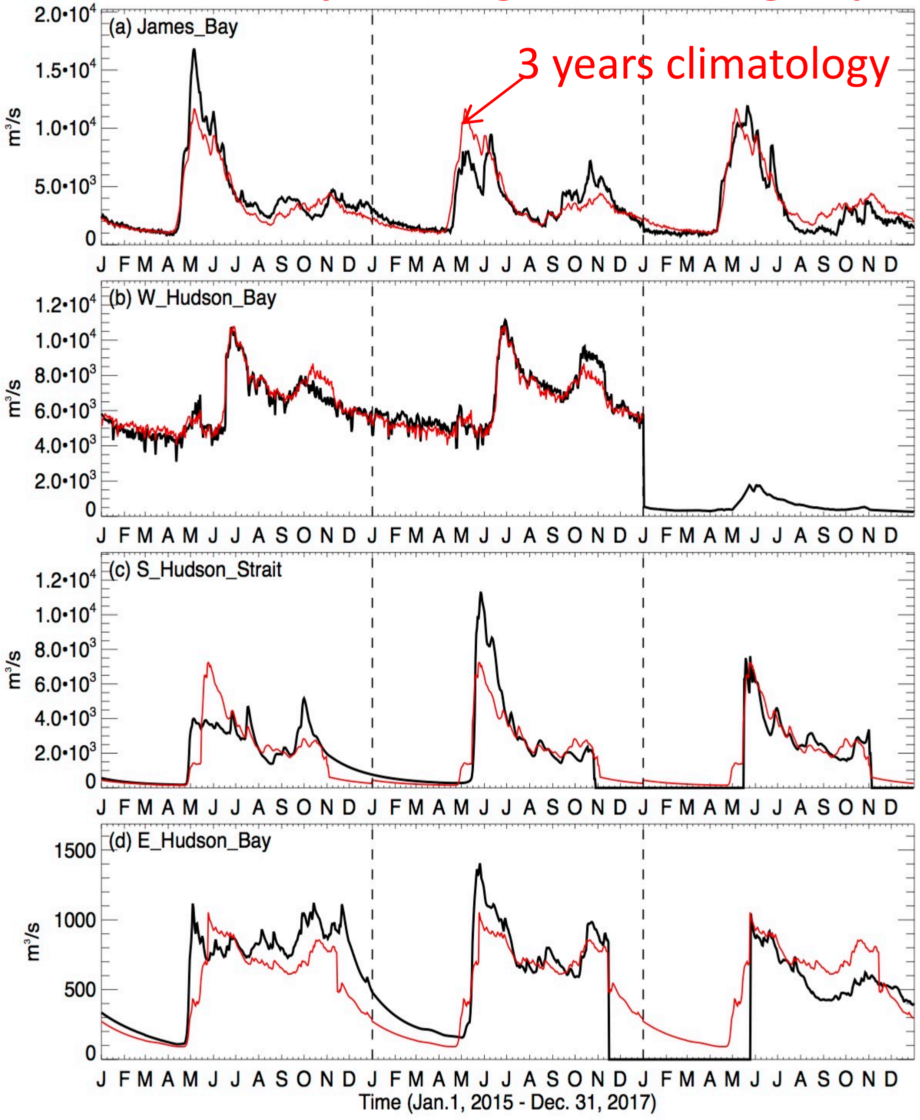


Freshwater input from river discharges

Daily Discharge from individual river



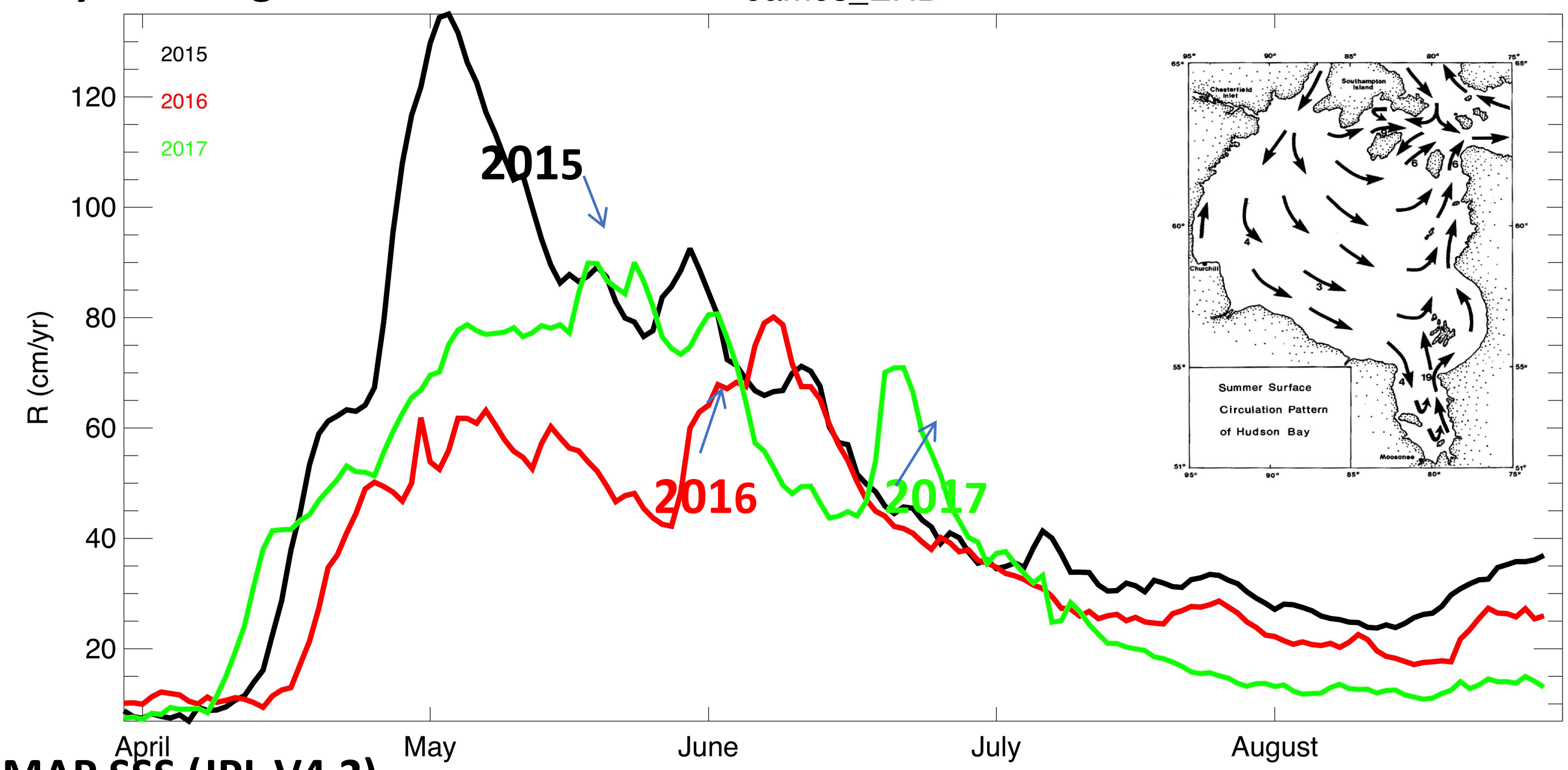
Combined daily discharge from river groups



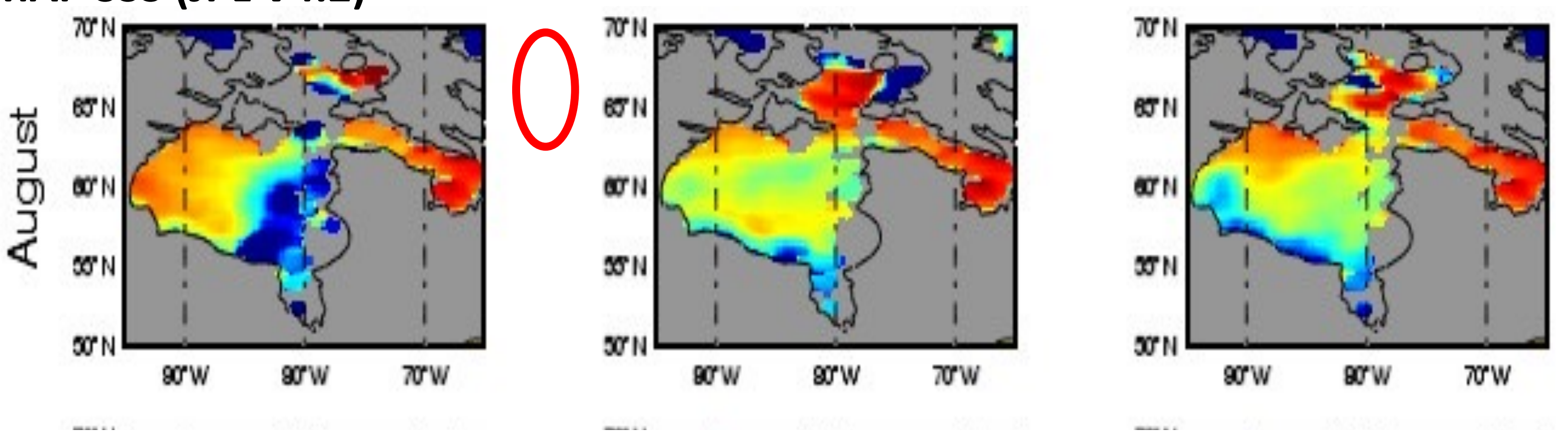
3rd year of discharge data of some river west of the Hudson Bay is not available

SSS response to river discharge anomaly

Daily Discharge



SMAP SSS (JPL V4.2)

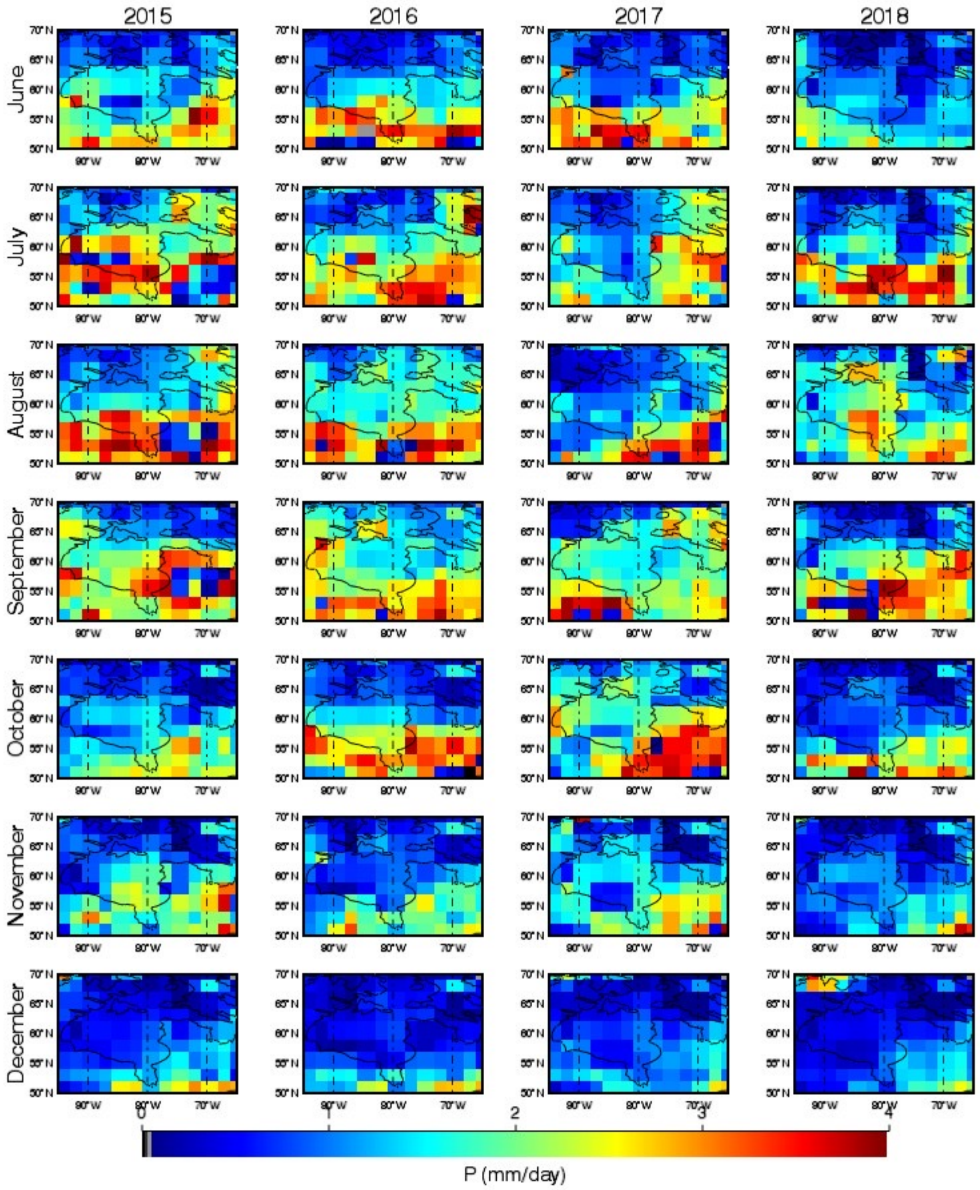


2015 **2016** **2017**

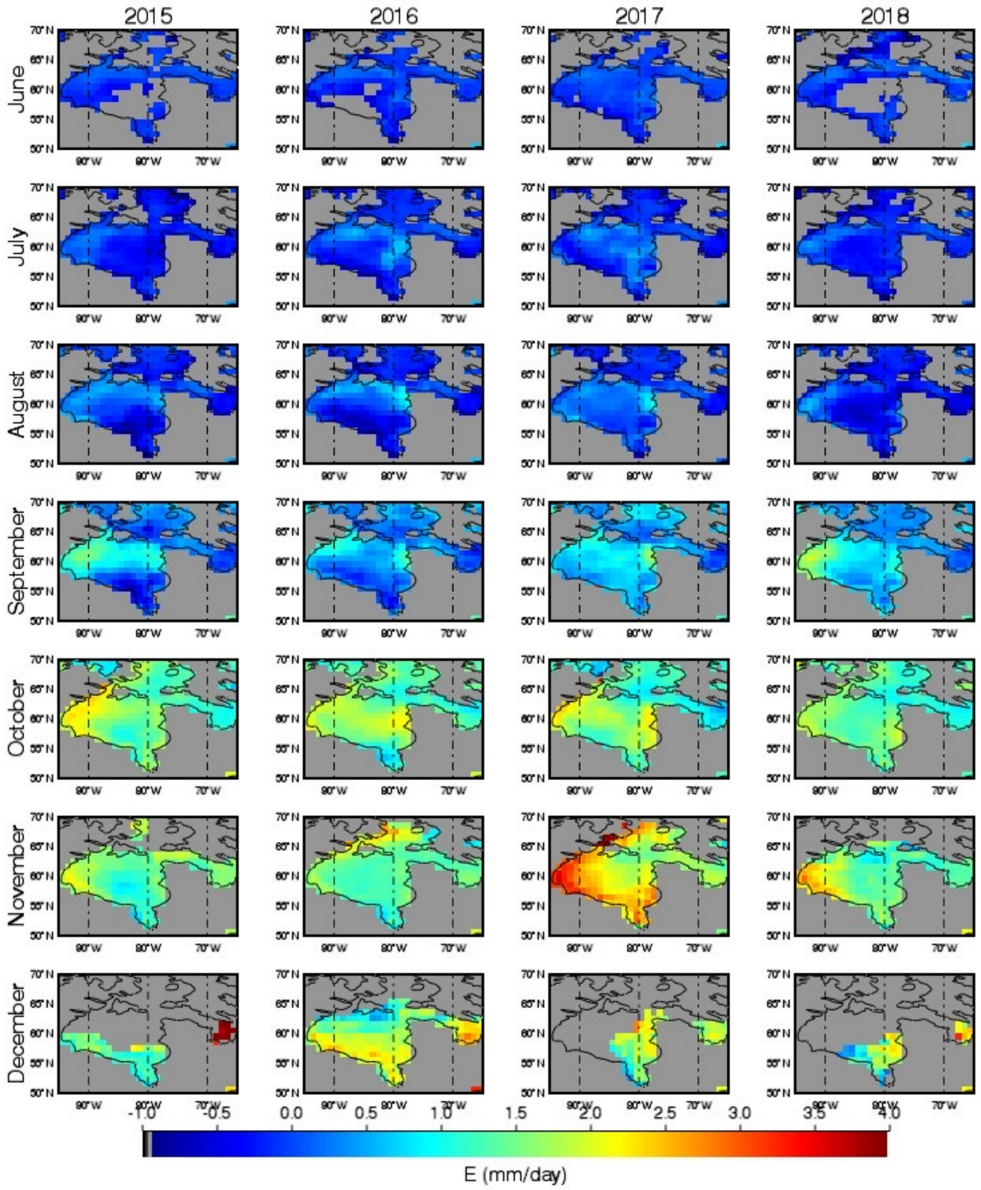
- ➢ The extreme fresh signature in SSS August 2015 along the path from James Bay northward to the Hudson Strait) is consistent with with the abnormal positive discharge from southern rivers
- ➢ Integrated from April to August, rivers around the James Bay brought in 80.4 km^3 freshwater in 2015, which is 13.6 km^3 or 20% more than the three years' average
- ➢ James Bay river discharge peaked in May 2015, three months ahead of the low SSS observed by SMAP. Because the Hudson Bay was covered by ice, satellite was not able to observe the progress of river plume.

Surface freshwater forcing (P-E) in the Hudson Bay

Precipitation (CMAP)

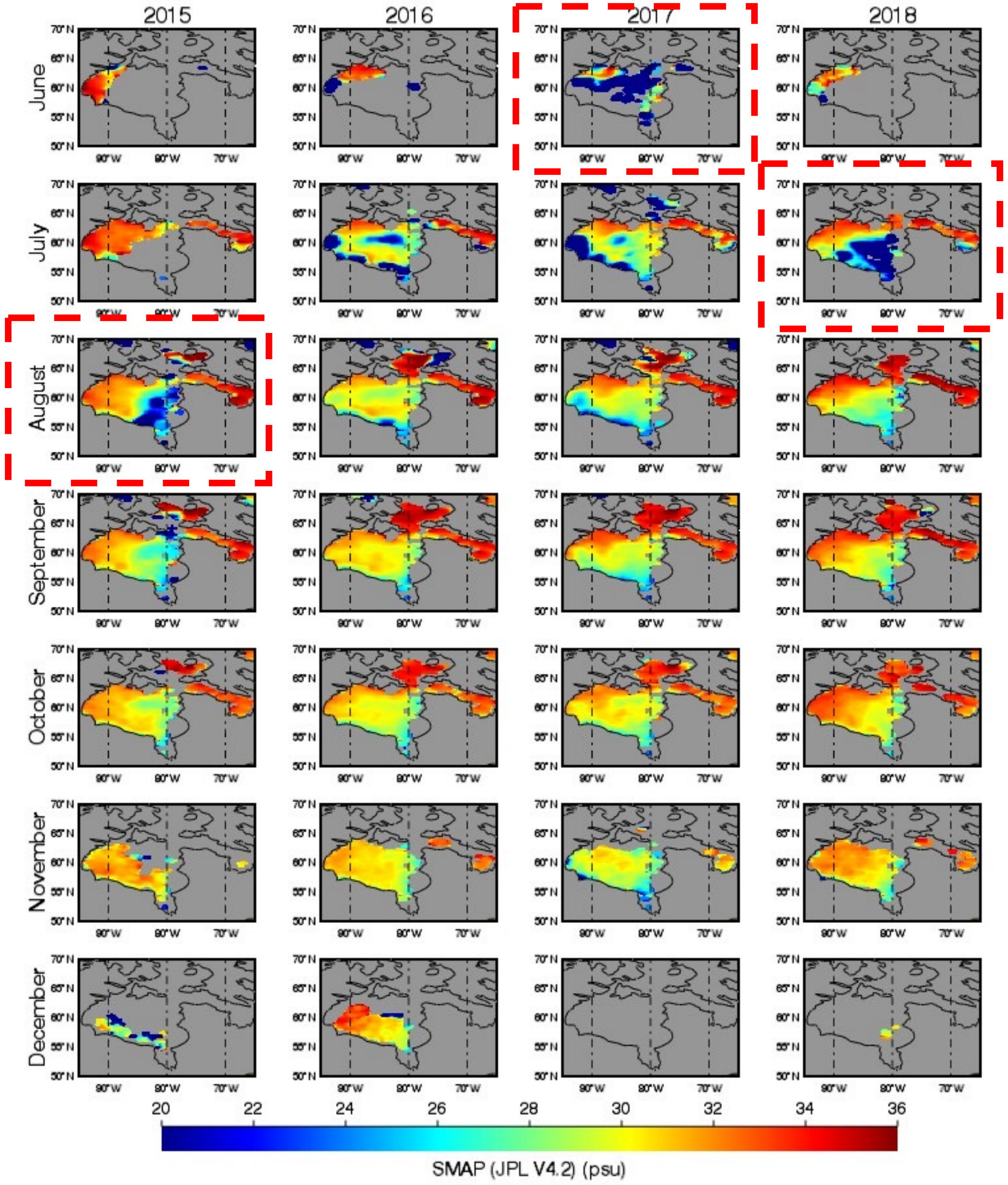


Evaporation (Oaflux)

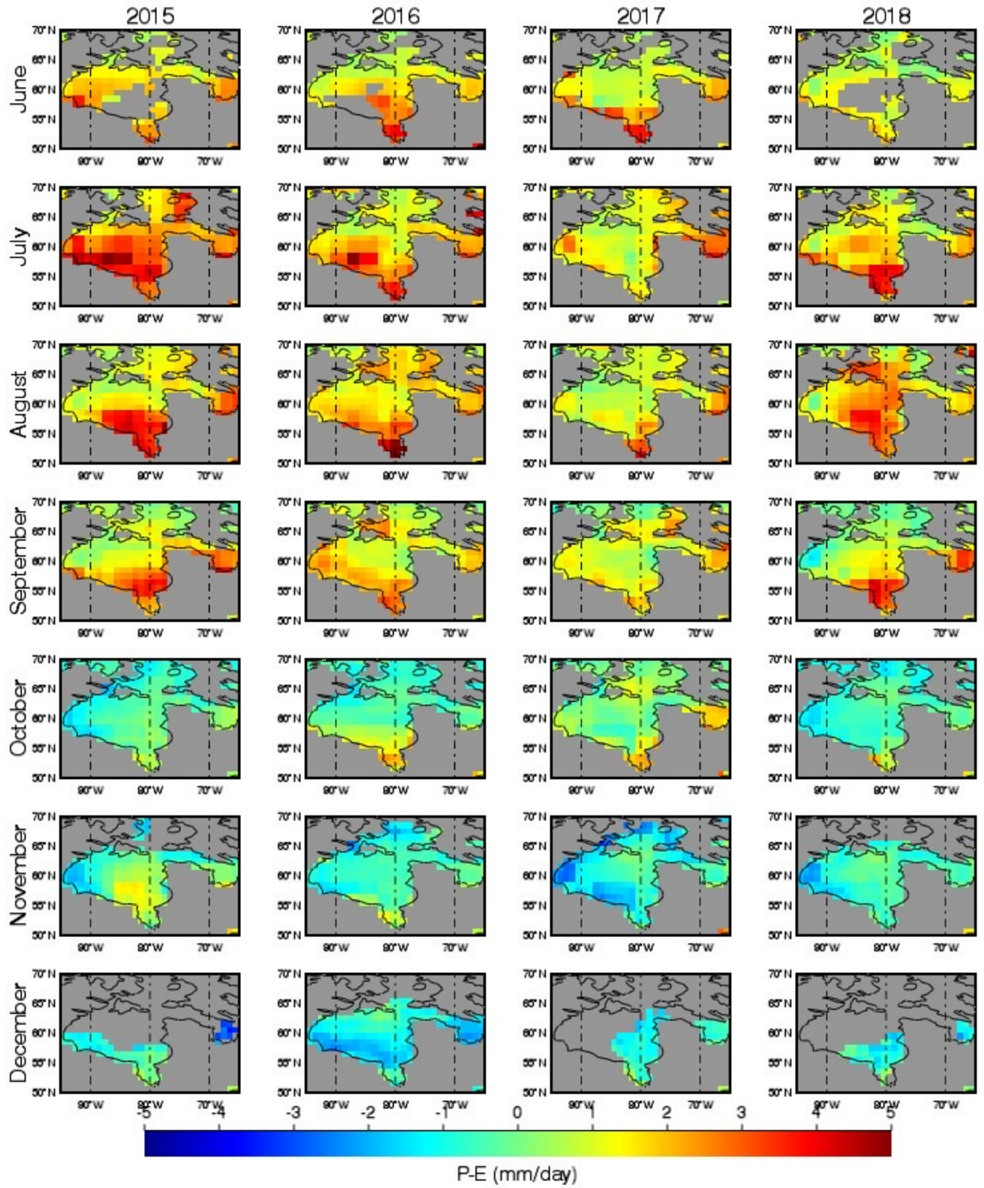


SSS response to surface forcing P-E

Sea Surface Salinity (SMAP JPL V4.2)



P – E (anomaly)



P-E anomaly in HB contributes positively to August 2015 fresh signature, but slightly negative to the June 2017 fresh signature

Freshwater input from sea ice change

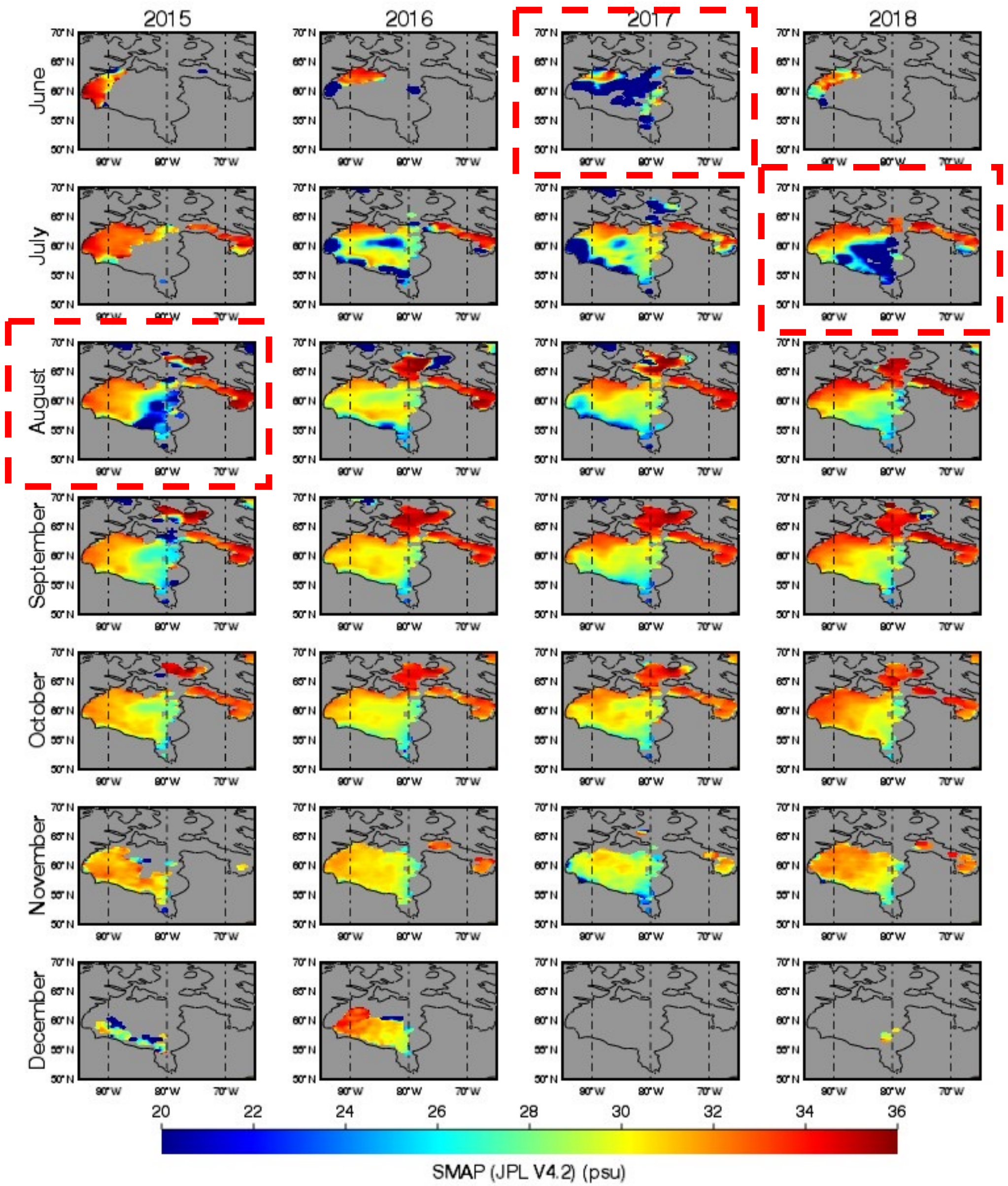
The freshwater input from local sea ice changes, I_{local}, is roughly estimated from sea ice concentration, assuming a uniform ice thickness of 1 m (~previous knowledge of average thickness cross the bay):

$$I_{local} = \frac{\left(C(t_2, x, y) h_{ice}(t_2, x, y) - C(t_1, x, y) h_{ice}(t_1, x, y)\right) \cdot Area \cdot \rho_{ice}}{Area \cdot \rho_{ice} \cdot (t_2 - t_1)}$$

C(t,x,y): monthly sea ice concentration
h_{ice}: sea ice thickness
ρ_{ice}: density of ice

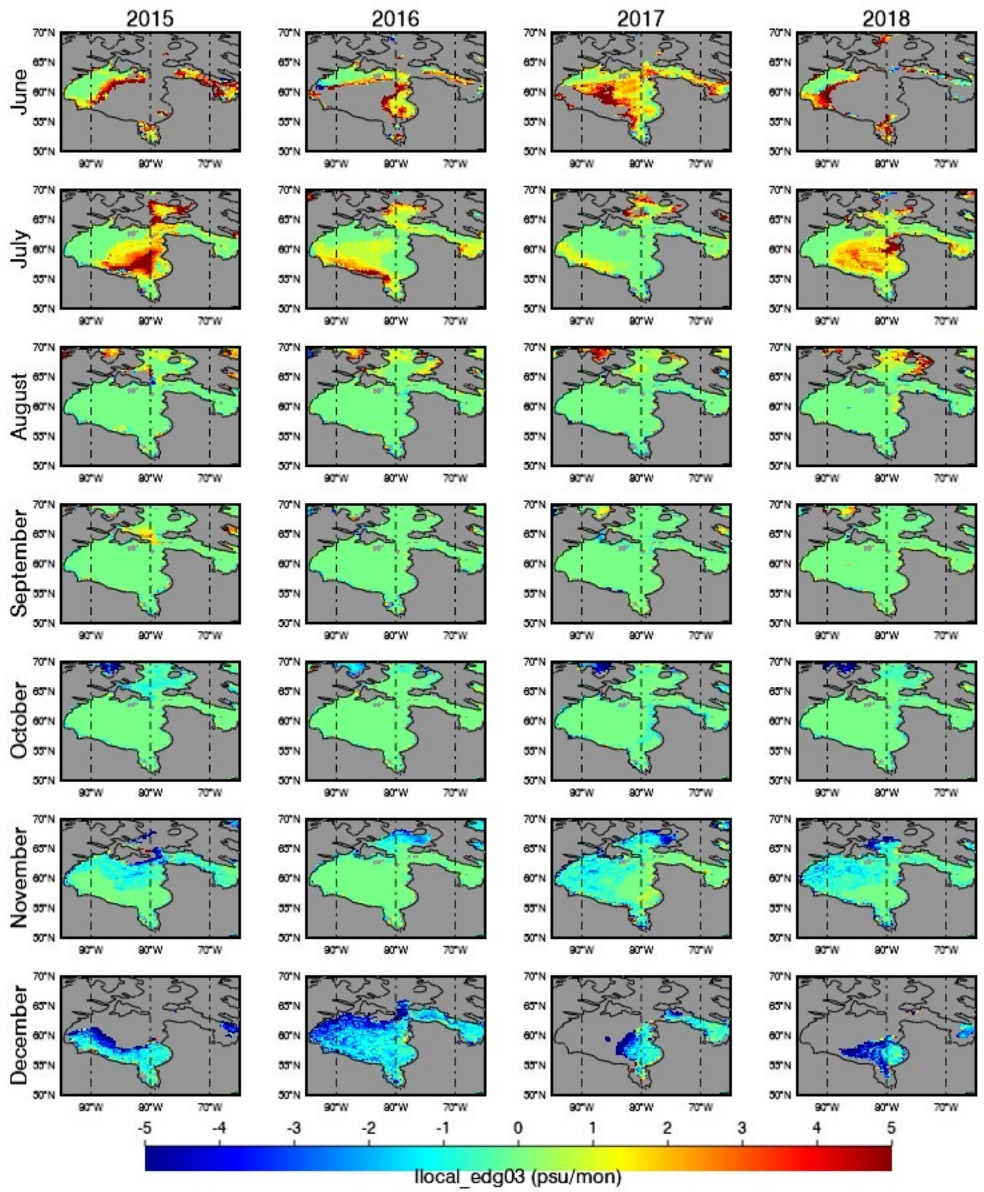
SSS response to sea ice melt

Sea Surface Salinity (SMAP JPL V4.2)



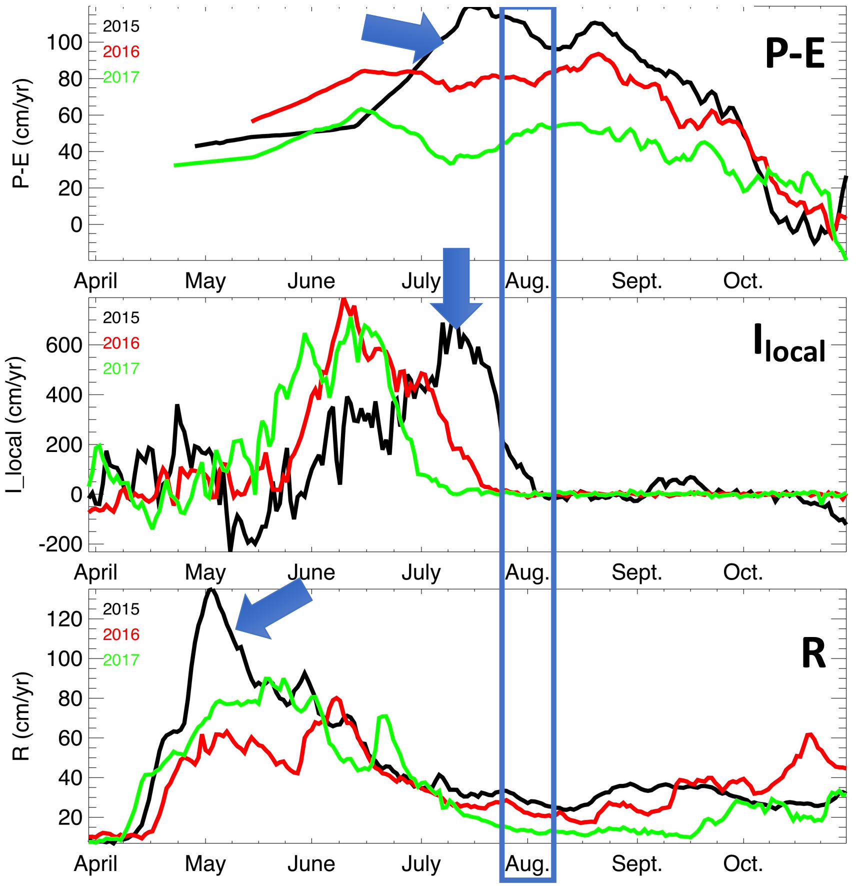
Early onset of sea ice melting in June 2017 created anomalous positive freshwater input in the interior of Hudson Bay, resulting low SSS. The late ice melt onset in 2015 (Aug.) is also consistent with low SSS

Freshwater inputs from sea ice changes

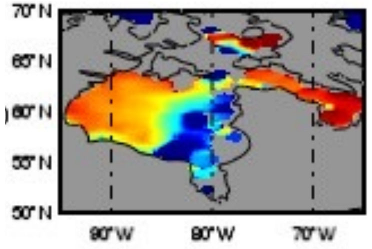


SSS reflect combined effect of regional freshwater seasonal cycles anomaly of various processes

James and eastern Hudson Bay



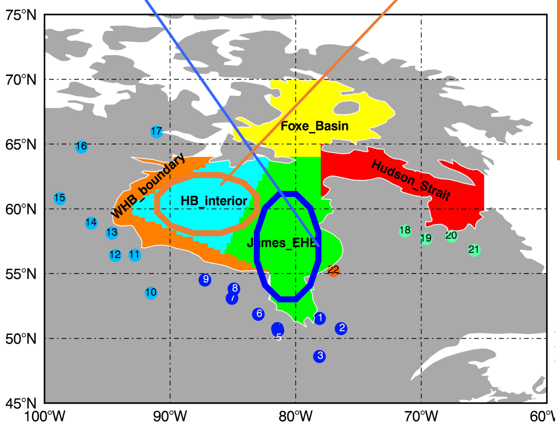
August 2015



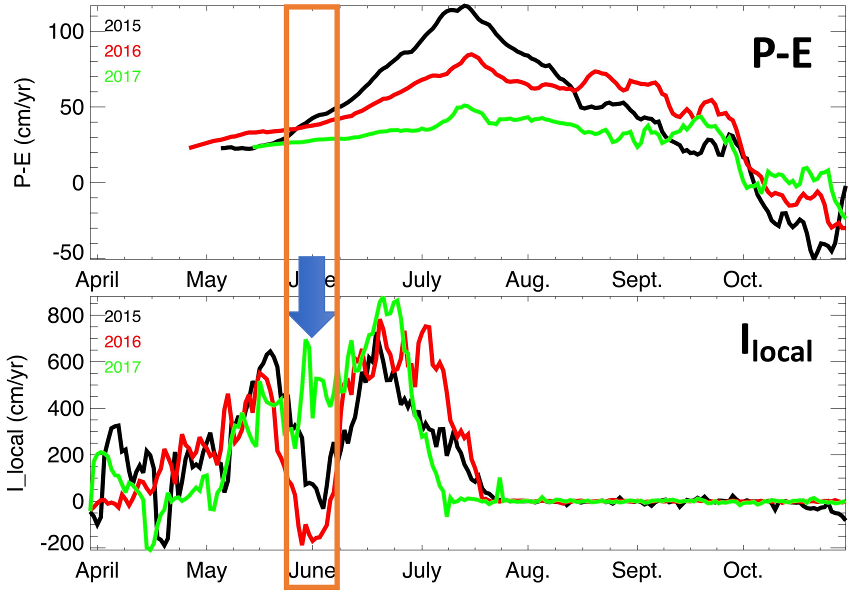
All components of freshwater supports anomalous fresh signature in August 2015 (differ in time)

Integrate over area of each sub-regions the freshwater inputs from:

- surface forcing (P-E),
- sea ice (I_{local})
- river discharge (R)

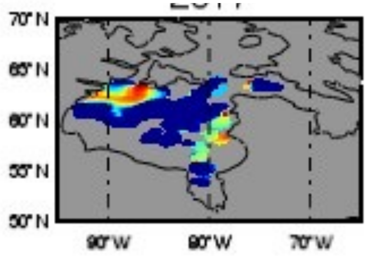


Hudson Bay Interior



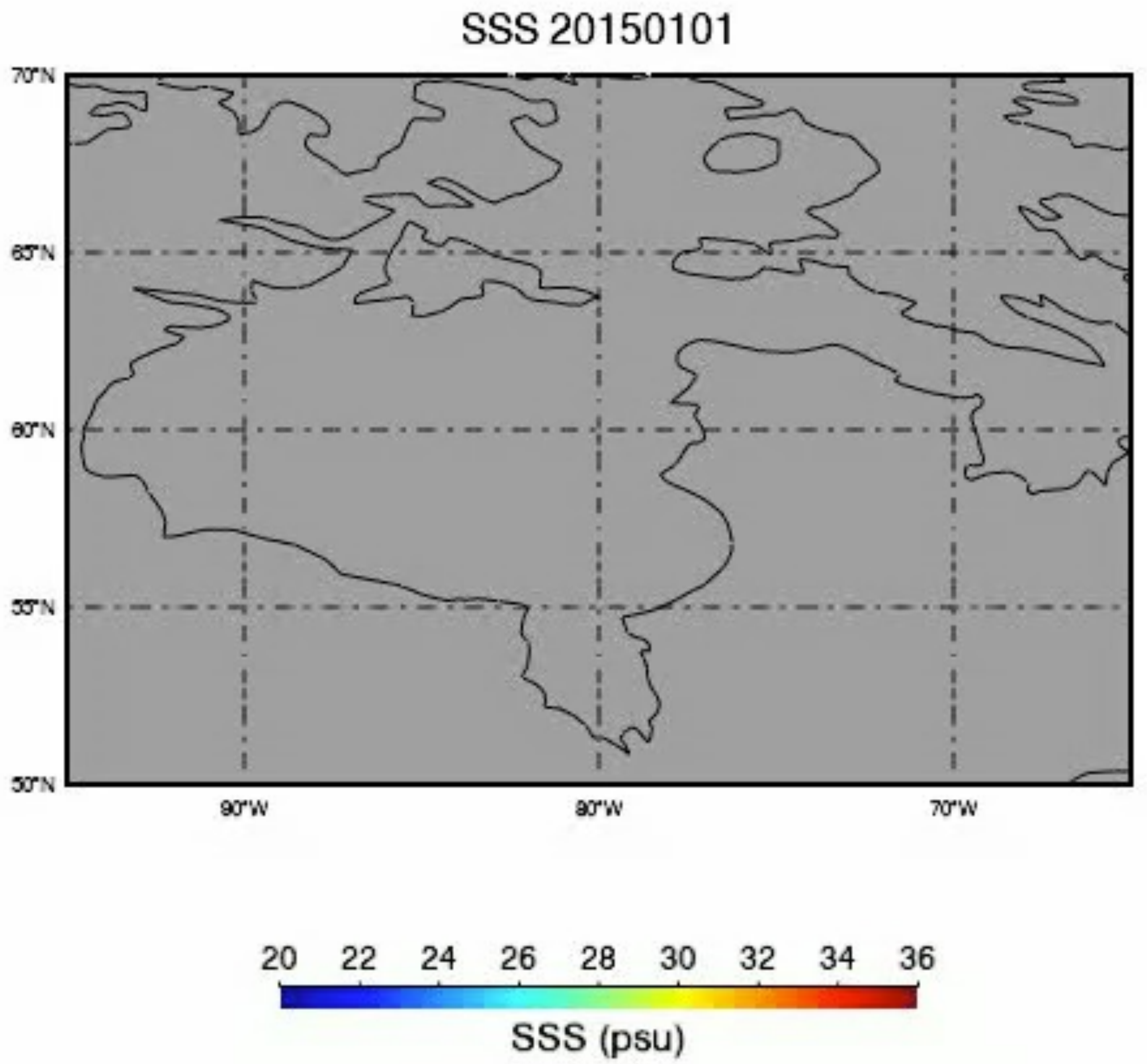
Early sea ice melt in June 2017 is responsible for the extremely low SSS

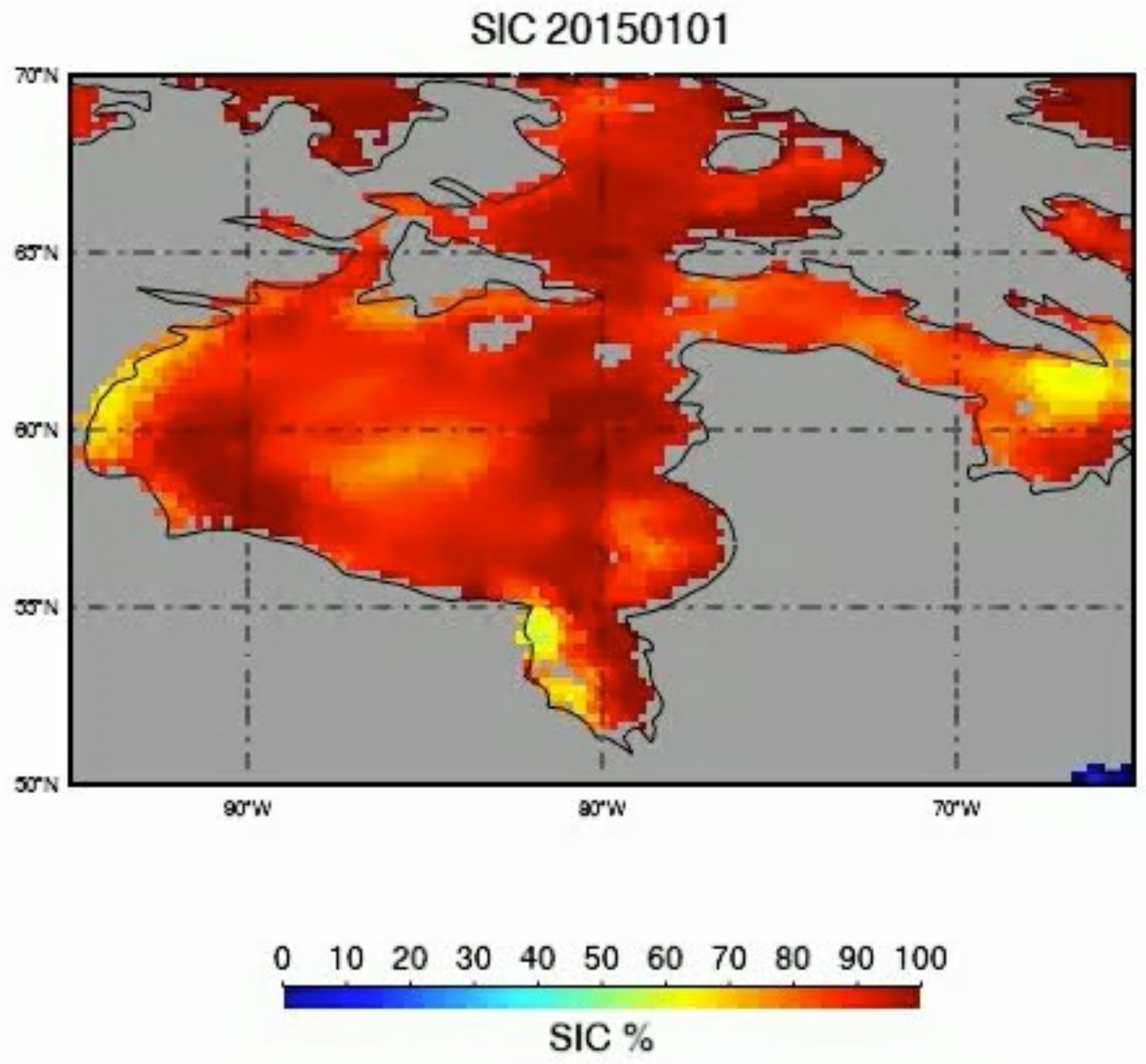
June 2017



Summary

- SSS retrieved from SMAP and SMOS in the detects freshwater seasonal cycle anomaly in the Hudson Bay, encouraging further exploration of the potential utility from current mission in monitoring changes in the Arctic Ocean
- Further improvement of retrieval algorithm for satellite SSS products in polar-region, e.g.
  - Relax the requirement of sea ice concentration for SSS retrieval
  - Implement sea ice correction to account for the emissivity difference between ice (unwanted) and open water (used for retrieval)
  - Consider the rapid changes Arctic Ocean is experiencing when constrain the SSS retrieval by climatology (various forms)


SSS 20150101
70°N
65°N
60°N
55°N
50°N
90°W
80°W
70°W
20 22 24 26 28 30 32 34 36
SSS (psu)


SIC 20150101
70°N
65°N
60°N
55°N
50°N
90°W
80°W
70°W
0 10 20 30 40 50 60 70 80 90 100
SIC %