

Satellite salinity to monitor the freshwater fluxes in the Arctic Ocean -> Arctic + Salinity Project

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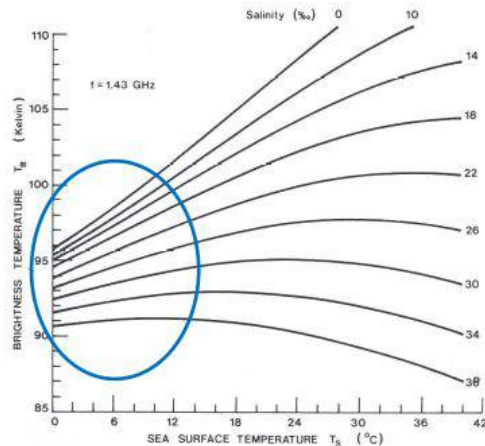
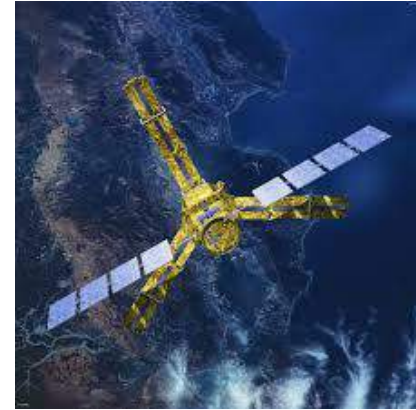
⁵ ESA

8th June 2022



MEASURING SSS AT HIGH LATITUDES IS VERY CHALLENGING:

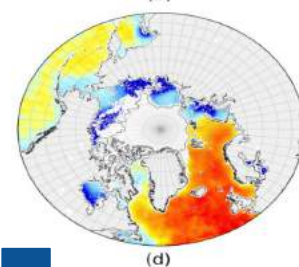
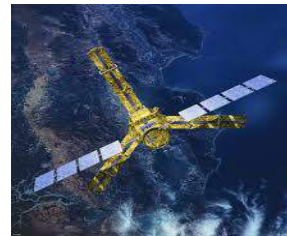
- Low sensitivity of TB to salinity at cold waters.
- Land-sea contamination (LSC) and ice-sea (ISC) contamination
- Lack of in-situ measurements, which put a problem on the validation



Sensitivity of the TB to SSS at cold waters is 0.3 K/psu (in general waters 0.5K/psu) ->making more complicated the retrieval of the SSS

Objective:

- New product of SMOS ARCTIC SSS
 - Daily 2012-2020
 - Spatial resolution: 25 Km, (grid EASE 2.0)
 - Temporal resolution: 9 days
 - Freely available in the BEC webpage (<https://bec.icm.csic.es/>)
- Assess the improvement of the Assimilation on TOPAZ forecasting system
- Case Studies:
 - Derive SSS from CDM
 - Study the salinity trends
 - Greenland melting



Assimilated on
TOPAZ

ESA ARCTIC+ SSS algorithm

New algorithm (Martínez et al. 2022):

- Compute all TBs at BOA, First Stokes $I = (TBH + TBV) / 2$
- Debiasing: Compute SMOS Climatology TB BOA Flat and subtract from previous (enhanced discretization of EAF)
- Inversion: Minimization of difference between TB meas - TB mod

$$F = \| I_{\text{flat}}^{\text{mod}} - I_{\text{flat}}^{\text{meas}} \|^2,$$

- A salinity per each TB BOA
- Temporal bias correction with HYCOM
- Spatial bias correction with WOA15
- Generation of SSS satellite overpasses

Improved BEC SMOS Arctic Sea Surface Salinity product v3.1

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¹ Barcelona Expert Center (BEC) and Institute of Marine Sciences (ICM),

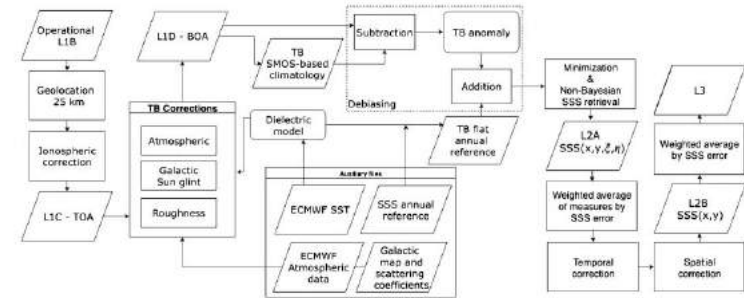
CSIC, P. Marítim de Barceloneta, 37–49, 08003 Barcelona, Spain

² ARGANS, Derriford, PL6 8BX Plymouth, UK

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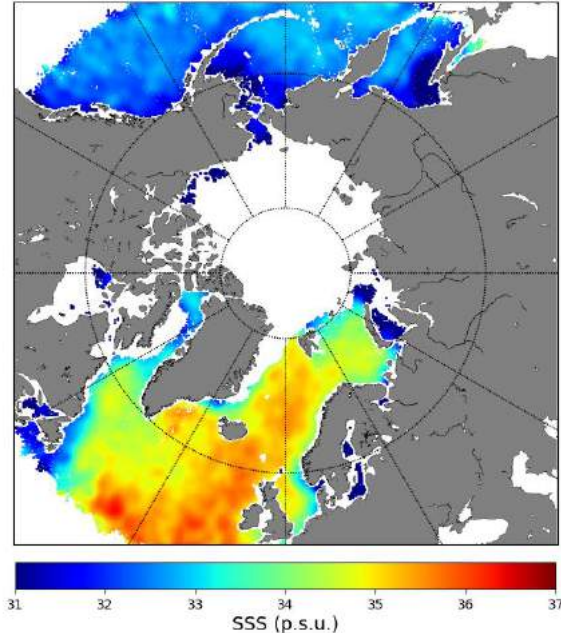
⁴ Telespazio-Vega UK Ltd., for ESA-ESRIN, Largo Galileo Galilei 1, 00044 Frascati, Italy

⁵ ESA-ESRIN, Largo Galileo Galilei 1, 00044 Frascati, Italy



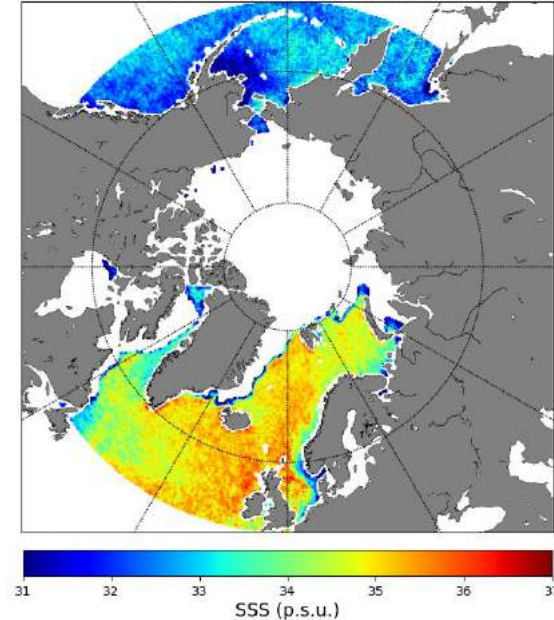
BEC Arctic v2.0

Arctic+ SSS data 20160615 to 20160624



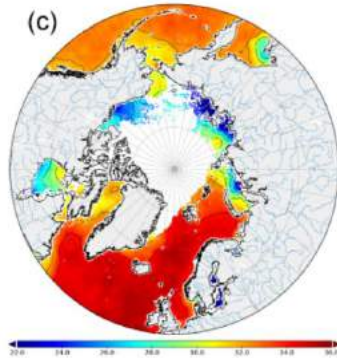
BEC Arctic v3.1

Arctic+ SSS data 20160607 to 20160615

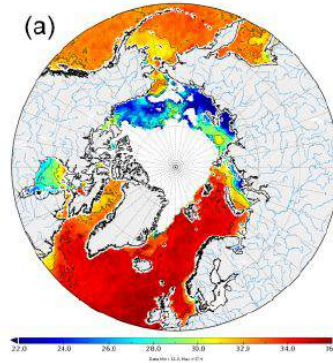


- BEC Arctic 2.0 is significantly smoother and does not resolve horizontal gradients.
- Arctic+v3.1 version is noisier but represents better the geophysical signal.

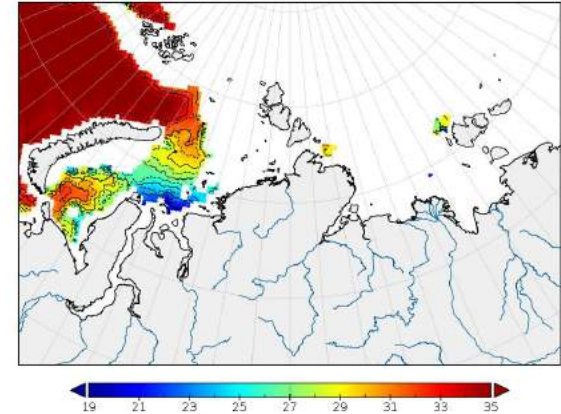
BEC v2.0 (old version)



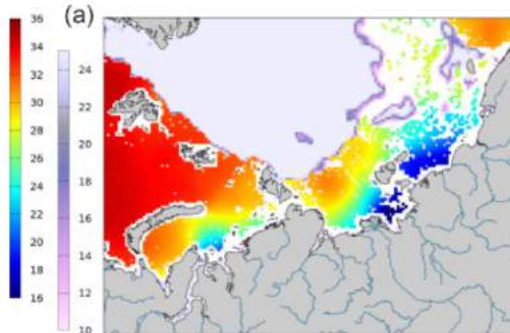
BEC v3.1



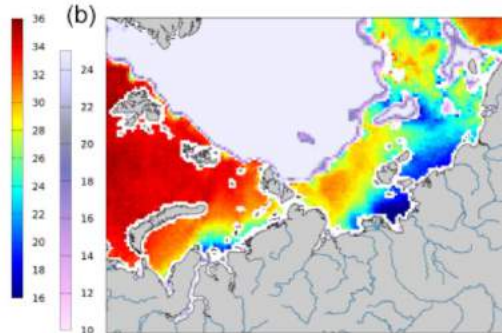
Sea Surface Salinity
Time: 2015-06-24 12:12:30



BEC v2.0

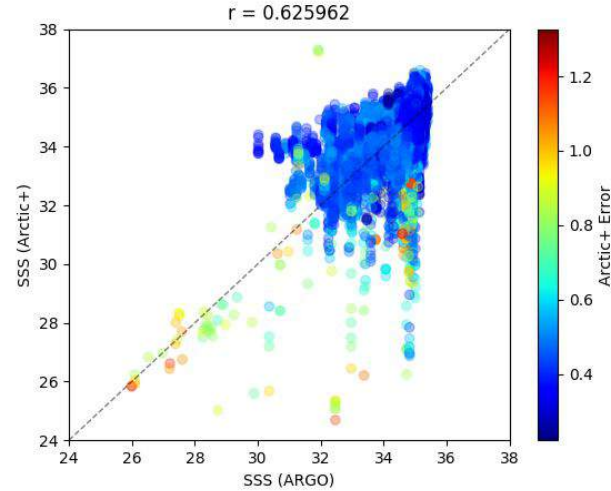
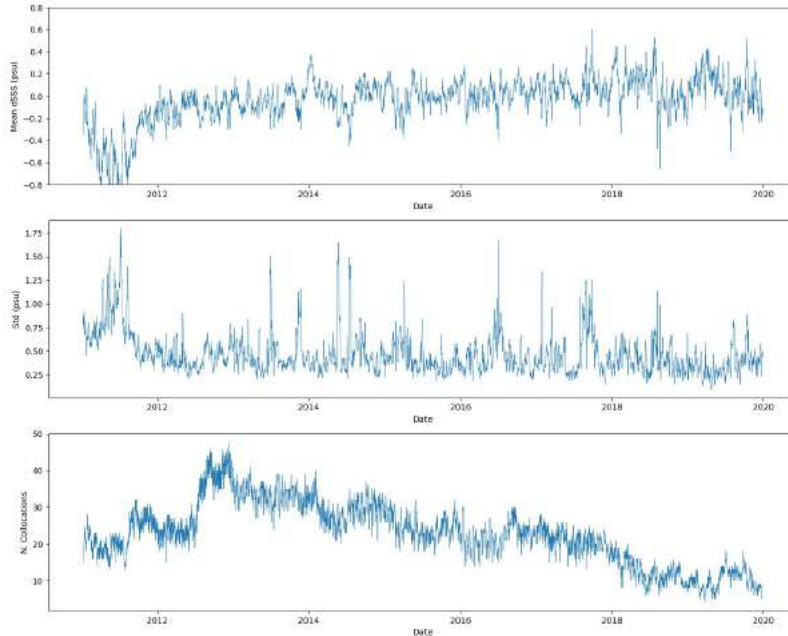


BEC v3.1



- Better coverage
- Improved effective spatial resolution -> better monitoring of the mesoscale structures as well as rivers discharge.

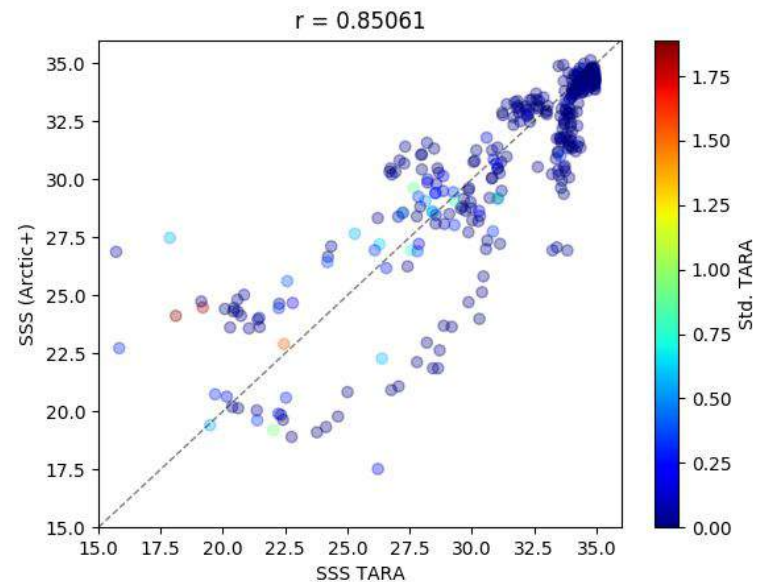
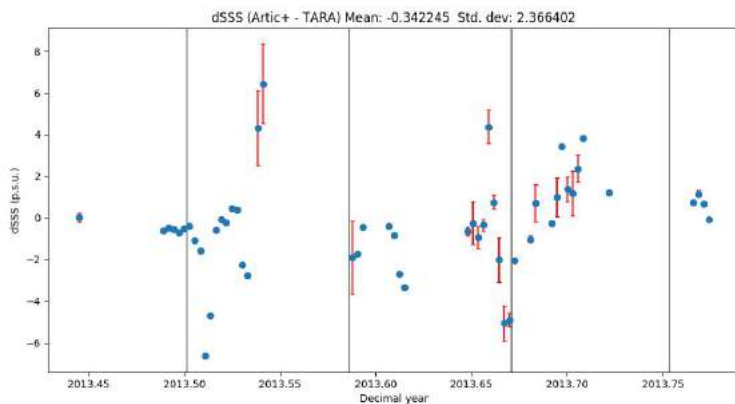
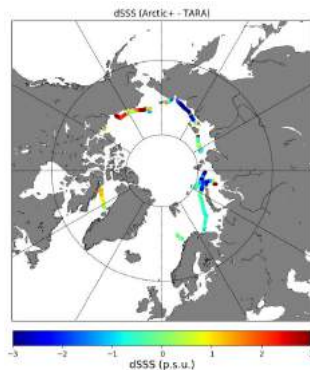
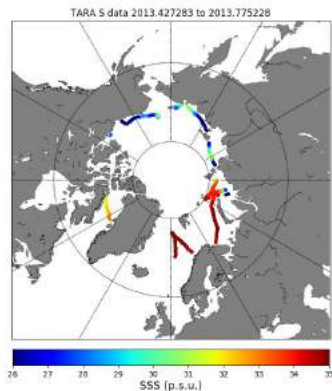
Validation: with ARGO floats



Mean: -0.034193
Std.: 0.468795
RMS: 0.501824
Median: -0.012358
Robust Std. 0.366743
Av. R: 0.614912
Total Points: 75073

- Arctic v3.1 is less biased than the previous product and produces more retrievals/spatial coverage.

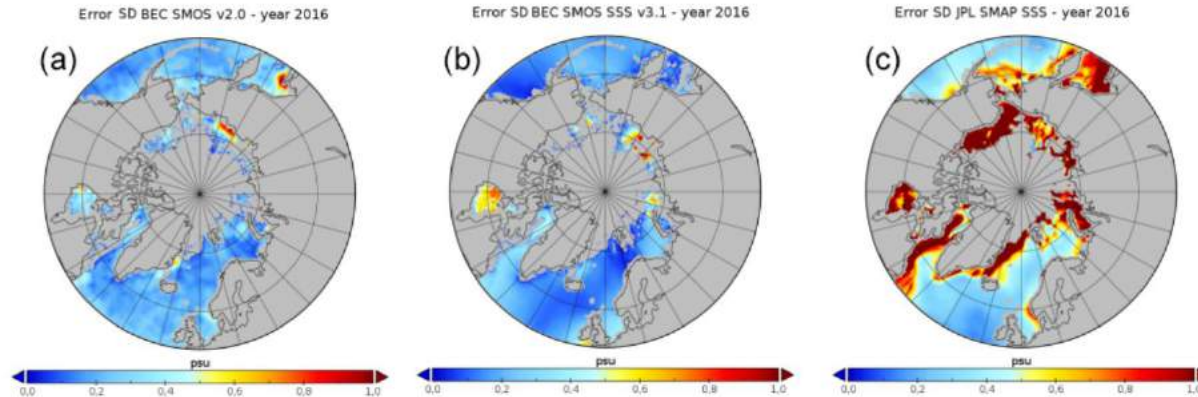
Validation: with TARA oceans data



Mean dSSS: -0.342245
Std. dSSS: 2.366402
R: 0.85061

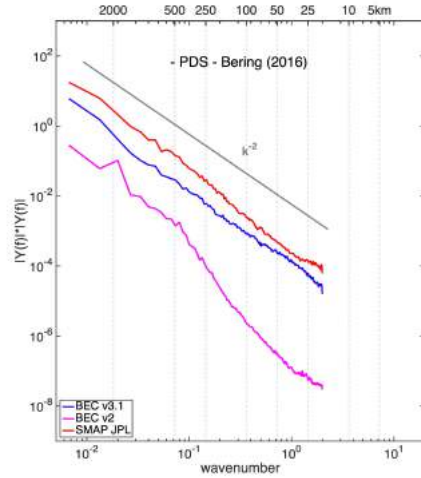
Correlated Triple collocation analysis

- Provided estimates of the measurement error STD of three systems measuring the same variable.
- Requires having a long enough series of collocated triplets of the measurements (González-Gambau et al., 2020, Hoareau et al. 2018)

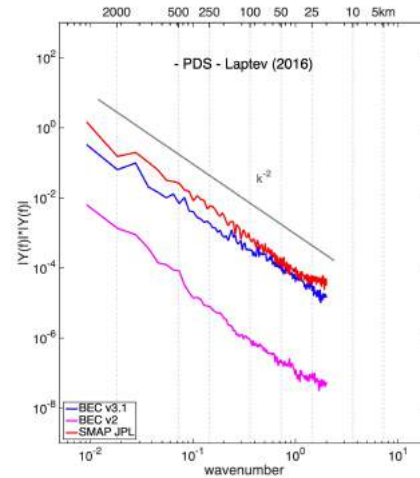


- Over the majority of the Arctic, BEC v3.1 has the smallest error
- v2 is better in Hudson Bay, east coast of Greenland, and Kara Sea
- JPL SMAP has the greatest error

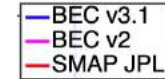
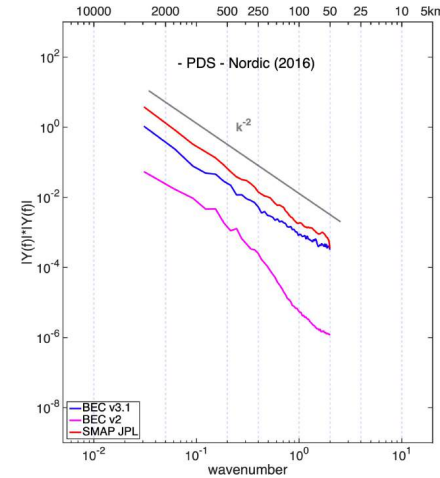
Bering Strait



Laptev Sea



Nordic Sea



Arctic+ v3.1 data have the most consistent spatial representation at smaller scales compared to SMAP and BEC v2.0, allowing a more accurate description of Arctic SSS processes.

TOPAZ: Coupled ocean and sea ice forecasting system, assimilates sea surface temperature (SST), altimetry data, temperature and salinity profiles, ice concentration, ice thickness, and ice drift with the Ensemble Kalman Filter (EnKF).

- We investigate the benefit of assimilating SMOS - SSS into TOPAZ
- Setup of assimilation runs in reanalysis mode

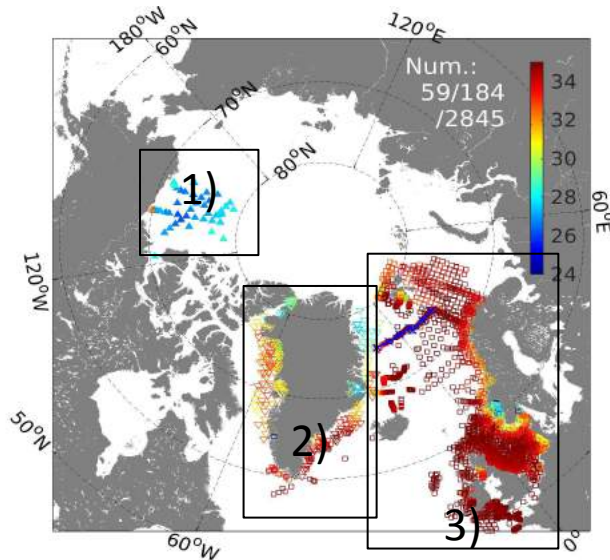
Exp.	Start date	End date	SSS	Other Obs.
0	-	-	<i>no</i>	Yes
V2	6 th Jul	28 th Dec	V2	Yes
V3	6 th Jul	28 th Dec	<u>V3.1</u>	Yes

BEC SMOS Arctic SSS:

v2 old version, 9-day maps
v3.1 new vers., 9-day maps

Validation against independent SSS from in situ profiles

- 1) Beaufort Gyre: BGEP, WHOI
- 2) Ocean Melt Greenland: OMG, NASA ICES
- 3) ICES (<https://ocean.ices.dk/HydChem/HydChem.aspx?plot=yes>)



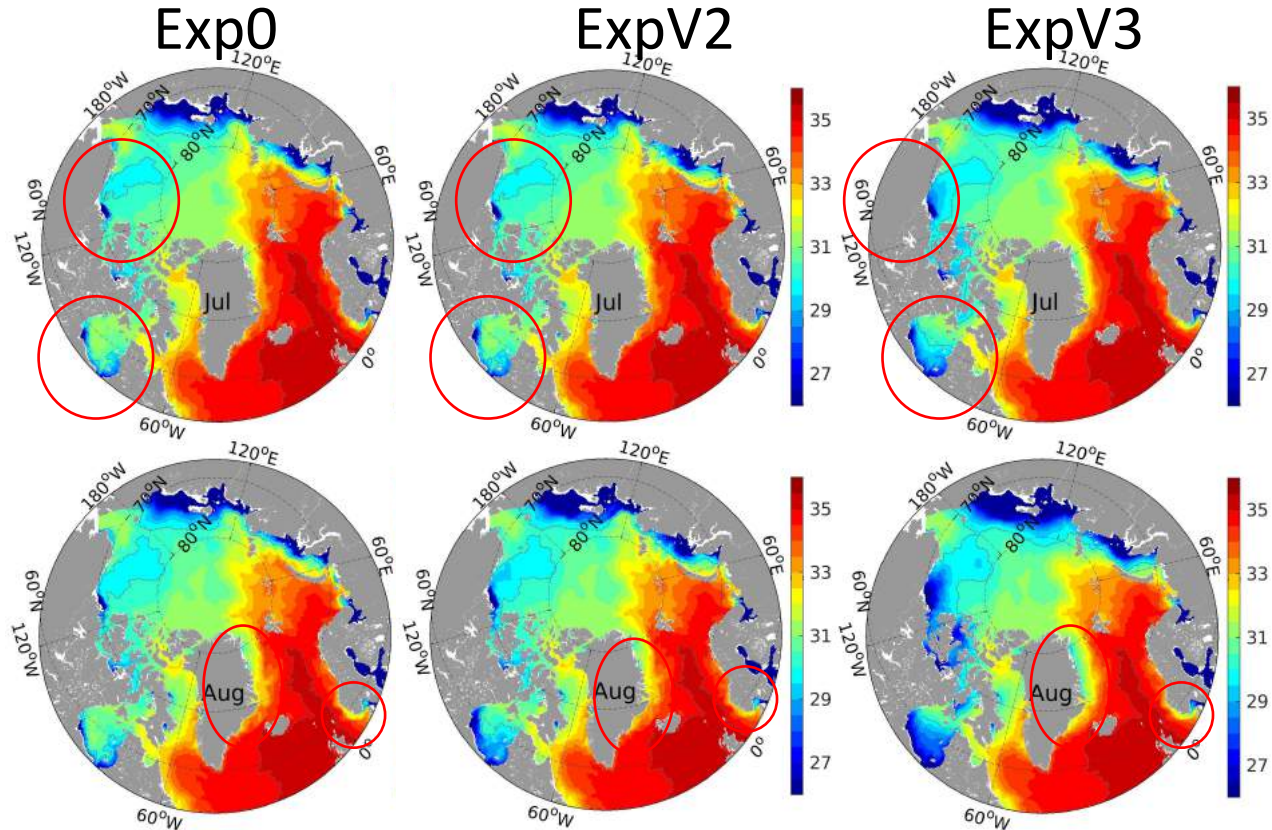
- SSS averaged near sea surface ($\leq 8\text{m}$);
- Compared with daily SSS from model runs
- Period: Jul. - Dec. 2016

Assimilation experiments with TOPAZ

Monthly SSS in the 3 TOPAZ runs: Jul - Aug

After one month of assimilation:

- Fresher water near the coast, especially in ExpV3;
- Norwegian Coastal Current is fresher
- East of Greenland fresh water extends further south
- Hudson Bay fresher in V3
- Beaufort Sea: freshens further in ExpV2 and ExpV3 -> Bad river description in model



Independent validation profiles show the SSS errors reduce using V3.1 more than V2.0:

- In **Beaufort Sea, reduction of the saline bias** by 15.9% (V2) and 28.6% (V3), the RMSD reduction are 10.8% (V2) and 16.2% (V3);
- Around **Greenland, reduction of SSS errors** by 17.3% (V3) for the saline bias and 8.2% (V3) for the RMSD. V2 did not lead to any improvement there.
- In the Nordic Seas and North Sea, reduction of saline bias by 0.05 psu (V3 only).
- **V3 corrects a known fresh bias in the Kara Sea** (local error in river data)

→ paper: Xie et al. in preparation



SMOS SSS assimilation in TOPAZ
4b enhance salinity output

The latest upgraded TOPAZ Arctic reanalysis (v.4b) in COPERNICUS , covering 1991-2020, assimilates the SMOS SSS v3.1 in the period 2013-2020

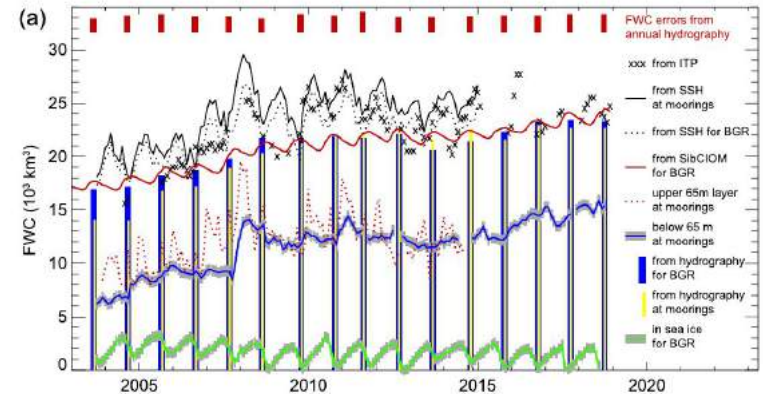
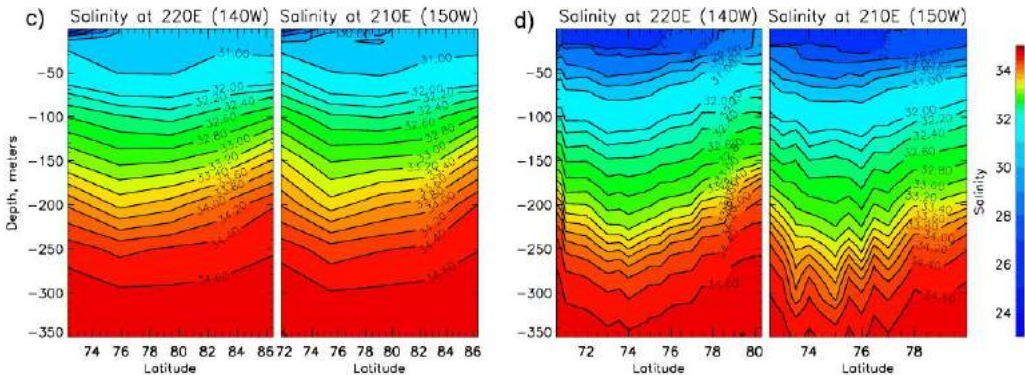
Salinity and FWC trends in Beaufort Gyre

The Beaufort Gyre centered the major reservoir of fresh water in the Arctic.

Proshutinsky et al. 2019: With data collected from cruises, moorings, Ice-Tethered Profiler observations, and satellite altimetry, they document an increase of liquid (water) freshwater content more than 6,400 km³ from 2003 to 2018, a **40% growth relative to the climatology of the 1970s.**

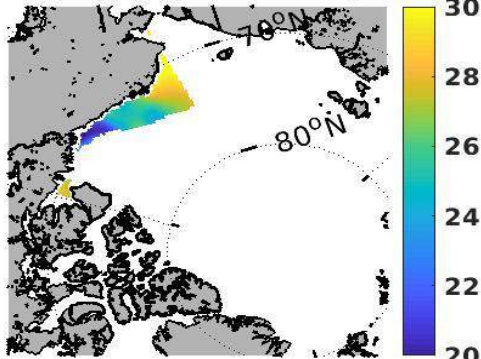
1970

2017

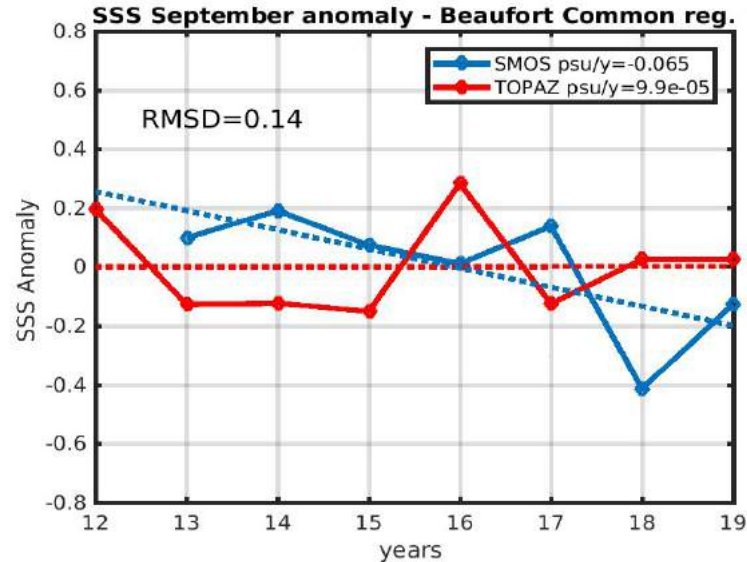


Salinity and FWC trends in Beaufort Gyre

WOA SSS common region



Sep



TOPAZ 3
(without
assimilation)

- ❑ SMOS: observe freshening, as reported by many papers trend SSS = -0.65 psu/decade
- ❑ TOPAZ 3: flatness can be due to several causes, i.e inhomogeneous coverage of salinity profiles, which cause jumps in the time series when assimilated, rivers discharge not well reproduced.

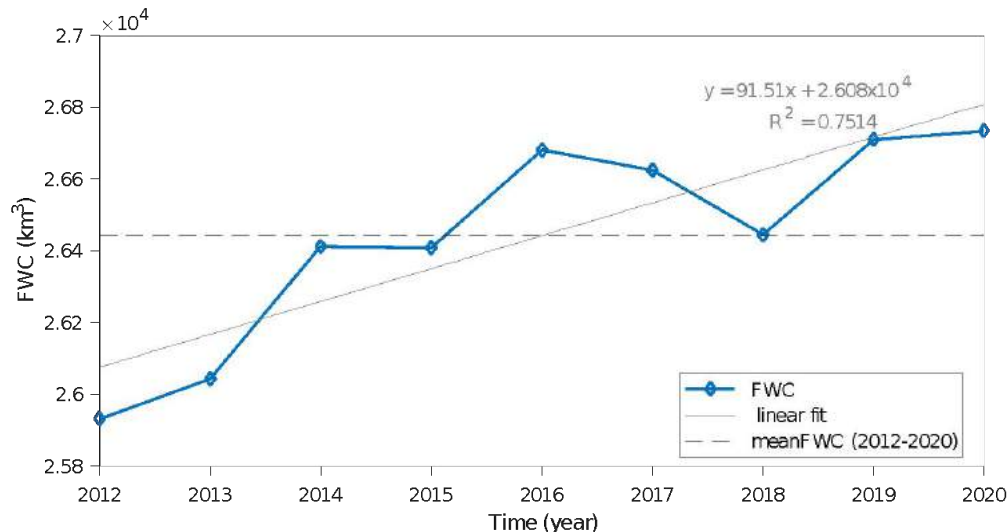
Freshwater content computed using TOPAZ4 v.4b

(with assimilation of SMOS data)

$$FWC = \int_{z=0\text{ m}}^{z=266\text{ m}} \frac{S_{ref} - S(z)}{S_{ref}} dz$$

$$S_{ref} = 34.8\text{ psu}$$

(Haine et al. 2015)



FWC increase is observed with TOPAZ v4b when assimilating SMOS

THANK YOU FOR YOUR ATTENTION