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

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BEC Barcelona Expert Center

Institut de Ciències del Mar

NERSC

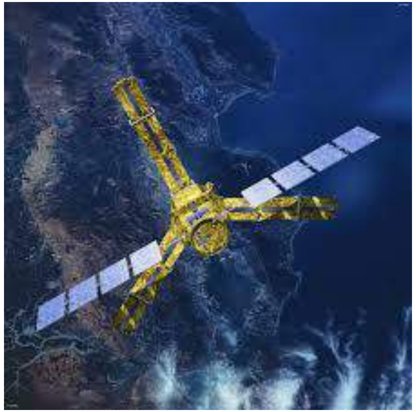
ARGANS

Arctic+ Salinity

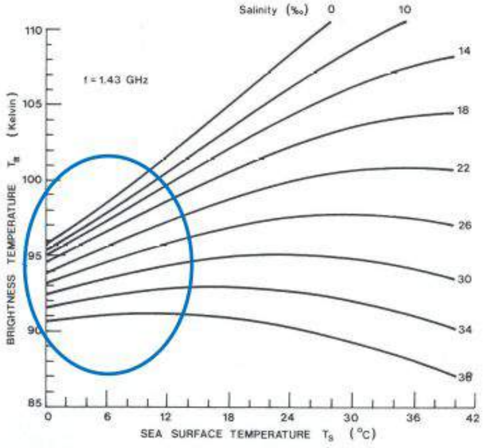
esa European Space Agency

Sea surface salinity at high latitudes

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

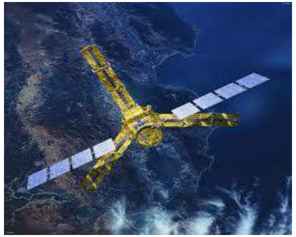


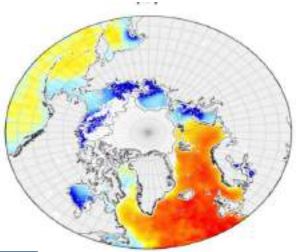
Sensitivity of the TB to SSS at cold waters is 0.3 K/psu (in general waters 0.5K/psu) ->making more complicated the retrieval of the SSS

ESA ARCTIC+ SSS project (2019-2021)

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





(d)

Assimilated on TOPAZ

ESA ARCTIC+ SSS algorithm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https://doi.org/10.5194/essd-14-307-2022

Earth System Science Data

Improved BEC SMOS Arctic Sea Surface Salinity product v3.1

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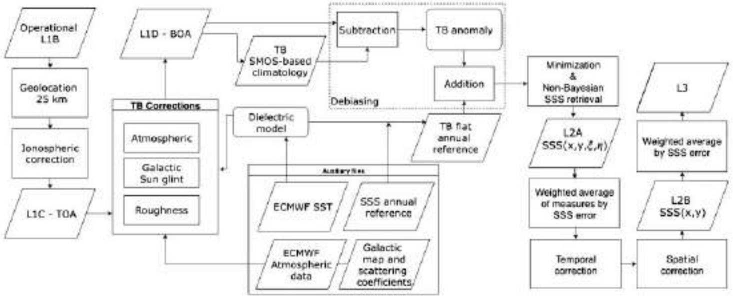
New algorithm (**Martínez et al. 2022**):

- 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

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

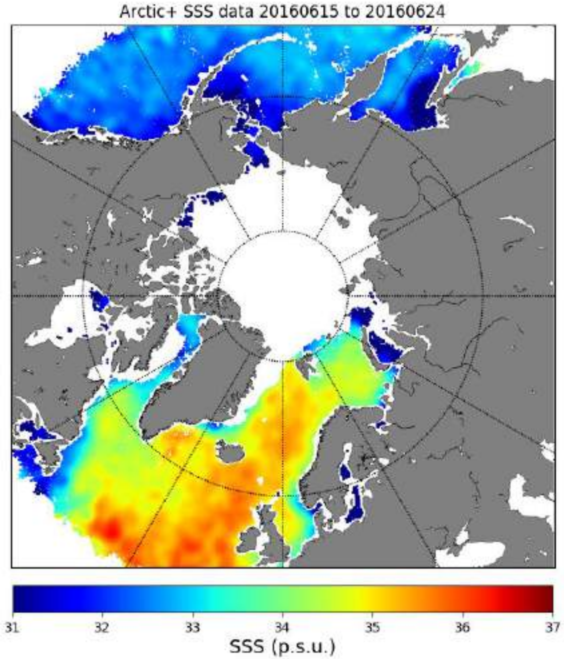
- A salinity per each TB BOA
- Temporal bias correction with HYCOM
- Spatial bias correction with WOA15
- Generation of SSS satellite overpasses



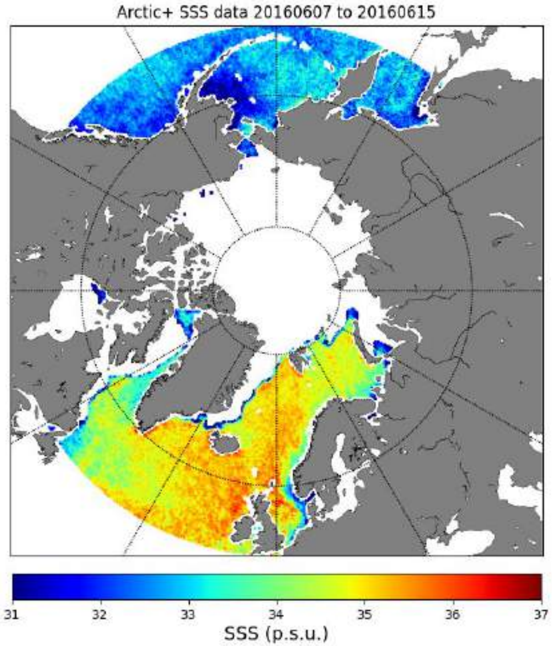
Based on Olmedo et al. 2017, 2021

Validation: Visual inspection

BEC Arctic v2.0



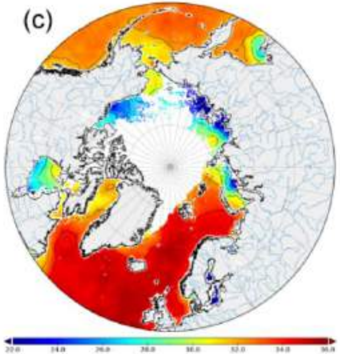
BEC Arctic v3.1



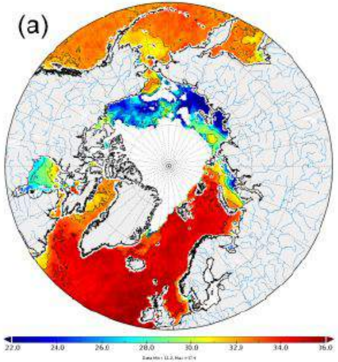
- BEC Arctic 2.0 is significantly smoother and does not resolve horizontal gradients.
- Arctic+v3.1 version is noisier but represents better the geophysical signal.

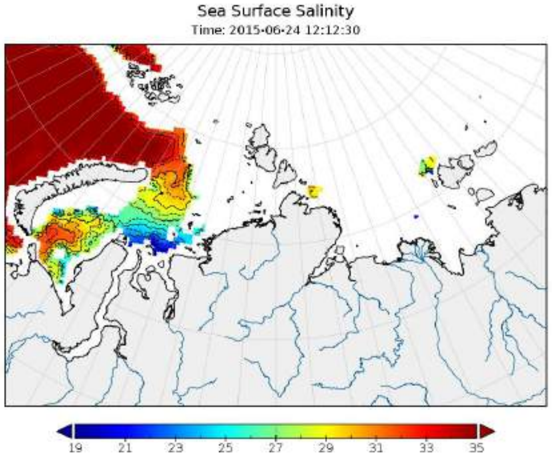
ESA ARCTIC+ SSS project (2019-2021)

BEC v2.0 (old version)

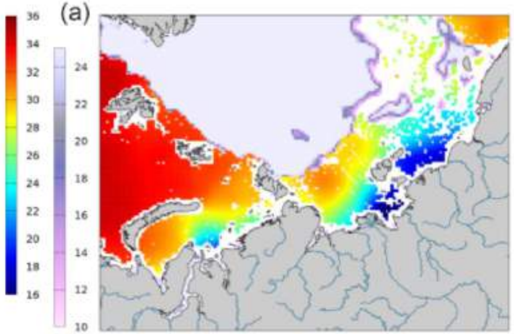


BEC v3.1

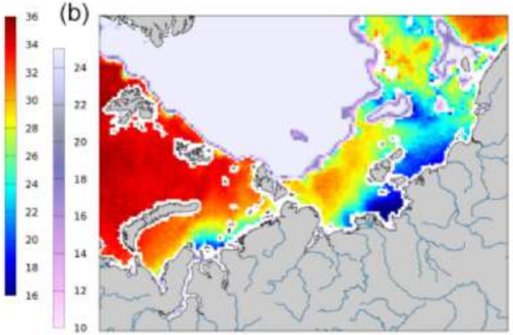




BEC v2.0

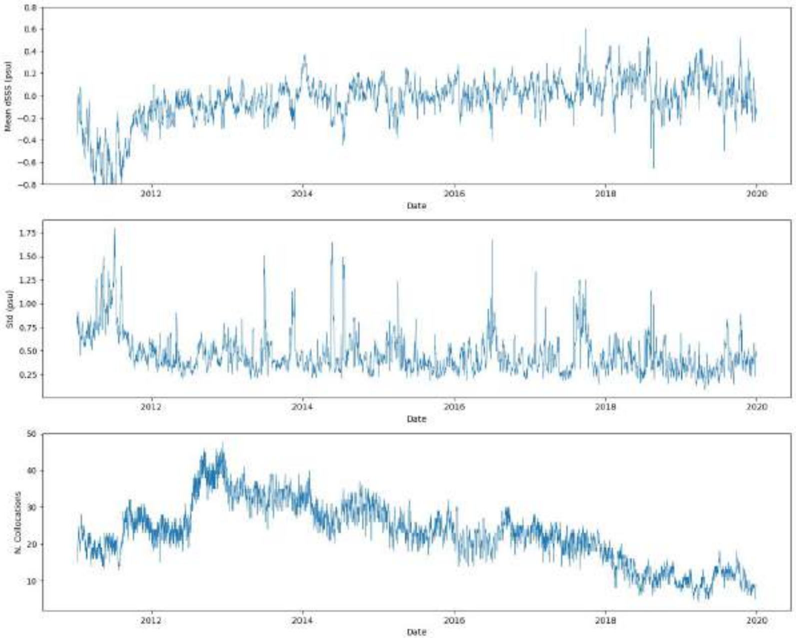


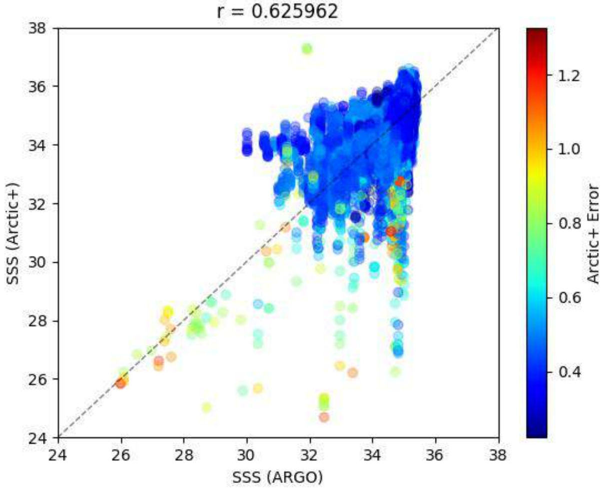
BEC v3.1



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

Validation: with ARGO floats

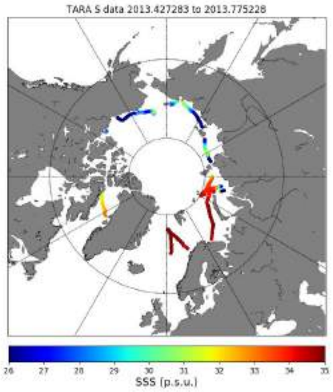


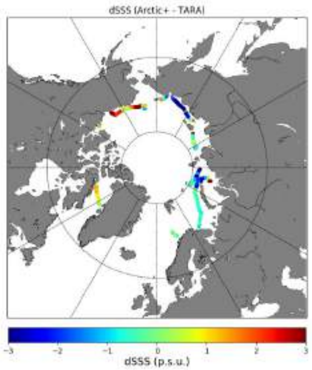


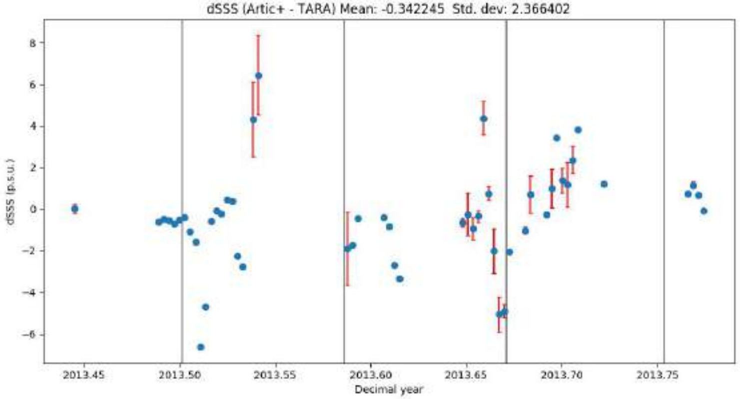
- Arctic v3.1 is less biased than the previous product and produces more retrievals/spatial coverage.

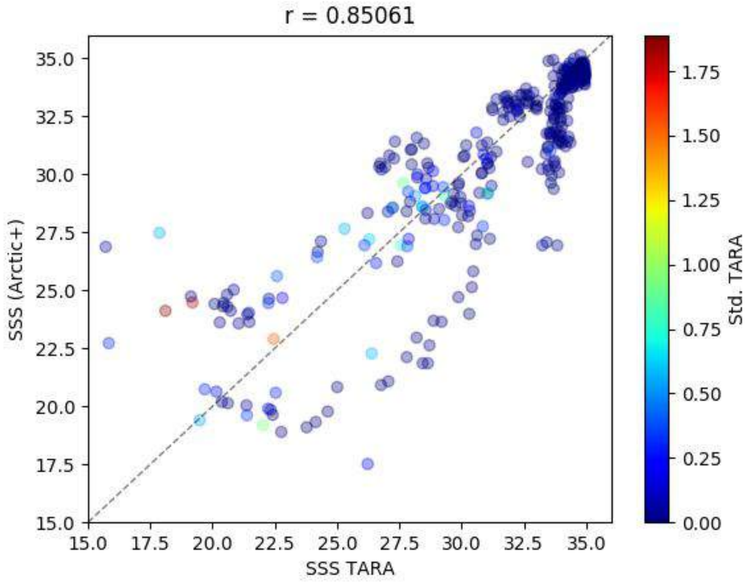
Mean: -0.034193
Std.: 0.468795
RMS: 0.501824
Median: -0.012358
Robust Std. 0.366743
Av. R: 0.614912
Total Points: 75073

Validation: with TARA oceans data





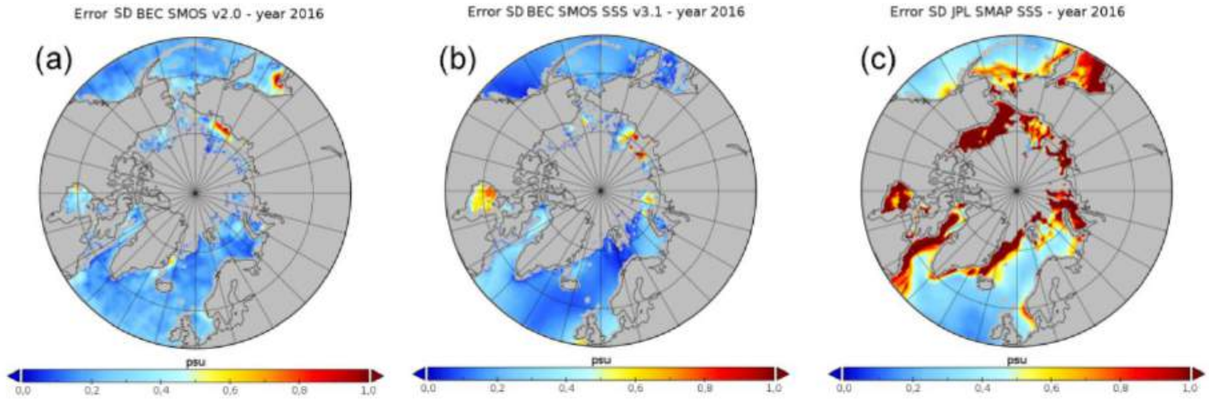




Mean dSSS: -0.342245
Std. dSSS: 2.366402
R: 0.85061

Correlated Triple collocation analysis

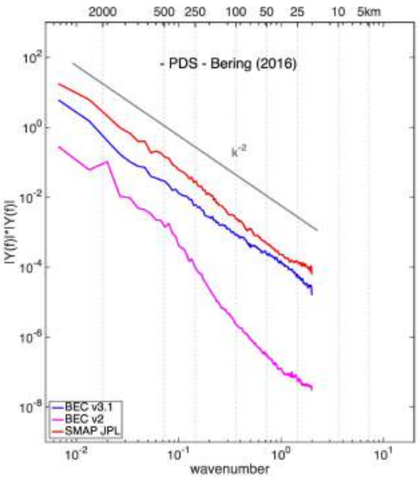
- Provided estimates of the measurement error STD of three systems measuring the same variable.
- Requires having a long enough series of collocated triplets of the measurements (González-Gambau et al., 2020, Hoareau et al. 2018)



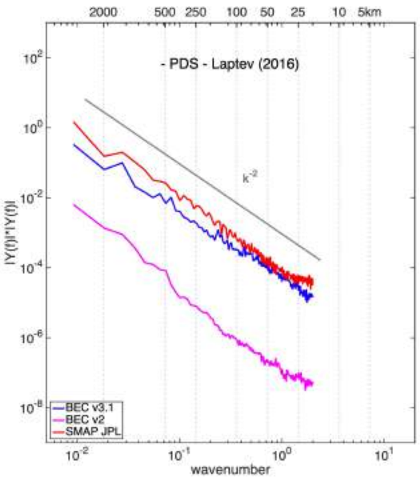
- Over the majority of the Arctic, BEC v3.1 has the smallest error
- v2 is better in Hudson Bay, east coast of Greenland, and Kara Sea
- JPL SMAP has the greatest error

Spectral analysis

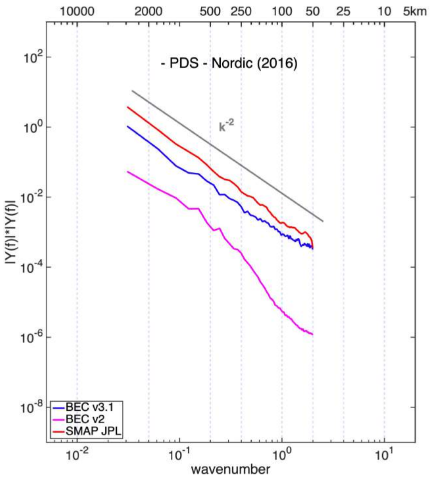
Bering Strait

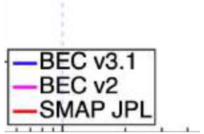


Laptev Sea



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.

Assimilation experiments with TOPAZ (EnKF)

BEC
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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	-	-	*no*	*Yes*
V2	6th Jul	28th Dec	*V2*	*Yes*
V3	6th Jul	28th Dec	*V**3.1***	*Yes*

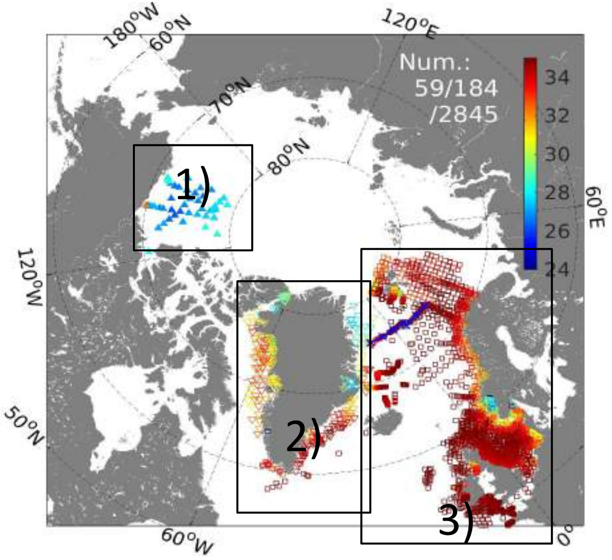
BEC SMOS Arctic SSS:

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

Assimilation experiments with TOPAZ (EnKF)

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 (<=8m);
- 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:

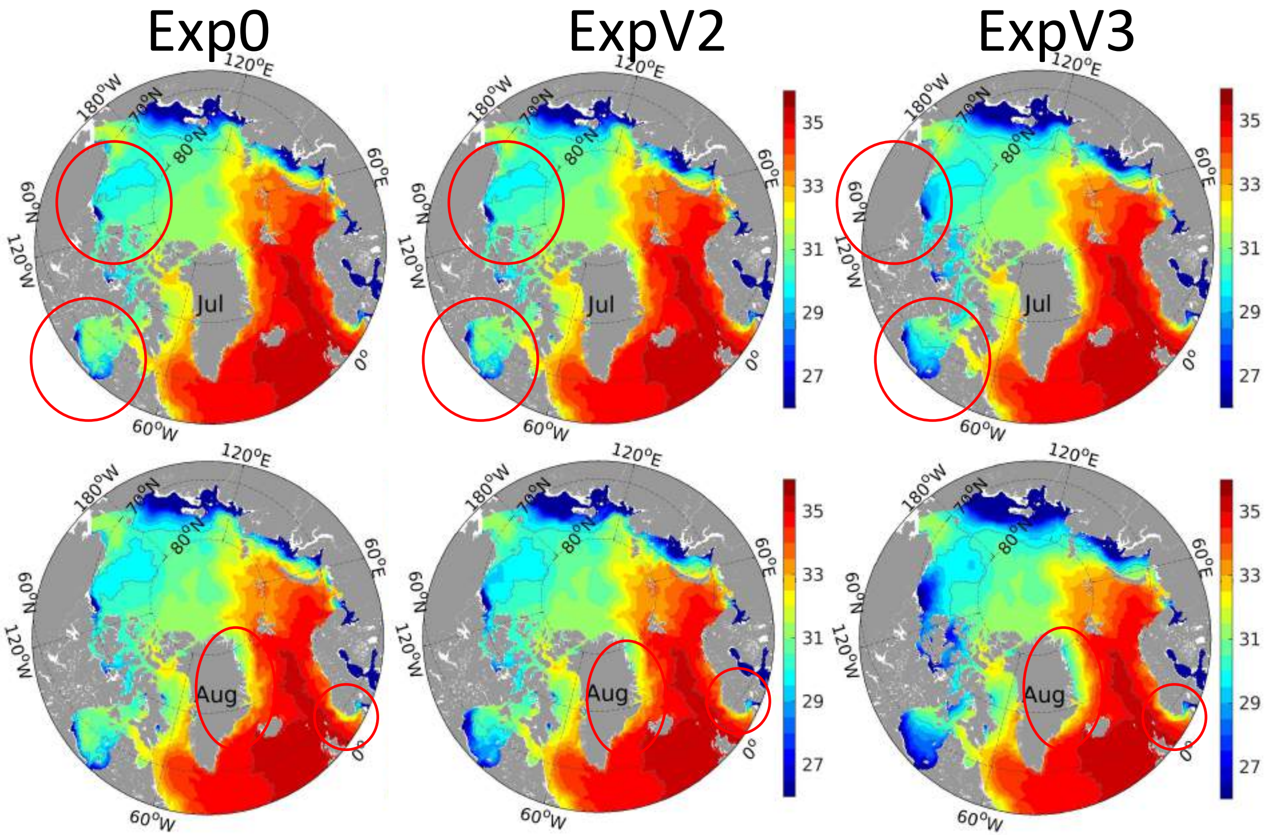
- Fresher water near the coast, especially in ExpV3;

- 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



ASSIMILATION RESULTS

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

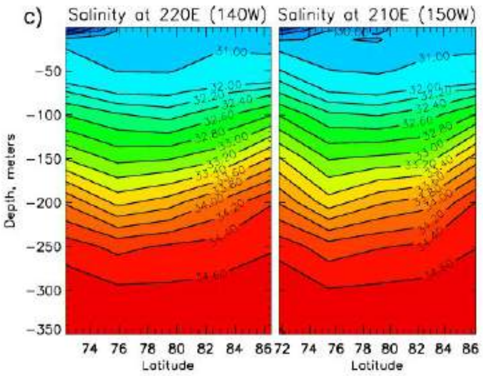
The latest upgraded TOPAZ Arctic reanalysis (v.4b) in COPERNICUS , covering 1991-2020, assimilates the SMOS SSS v3.1 in the period 2013-2020

Salinity and FWC trends in Beaufort Gyre

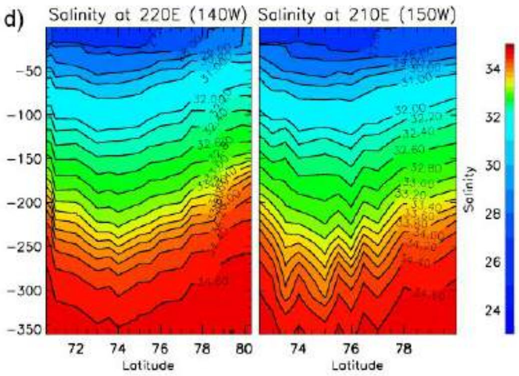
The Beaufort Gyre centered the major reservoir of fresh water in the Arctic.

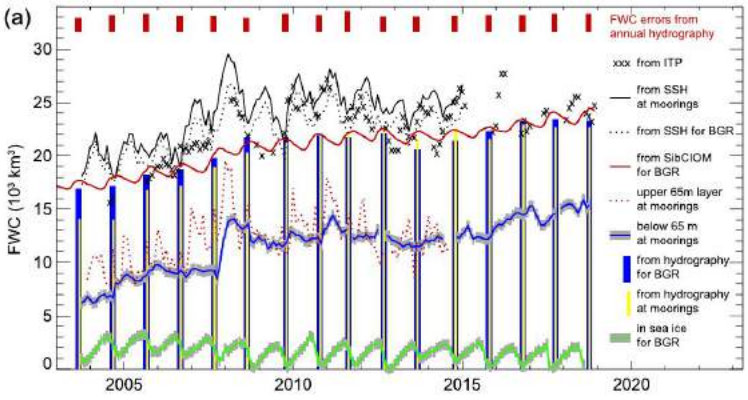
Proshutinsky et al. 2019: With data collected from cruises, moorings, Ice-Tethered Profiler observations, and satellite altimetry, they document an increase of liquid (water) freshwater content more than 6,400 km3 from 2003 to 2018, a **40% growth relative to the climatology of the 1970**s.

1970

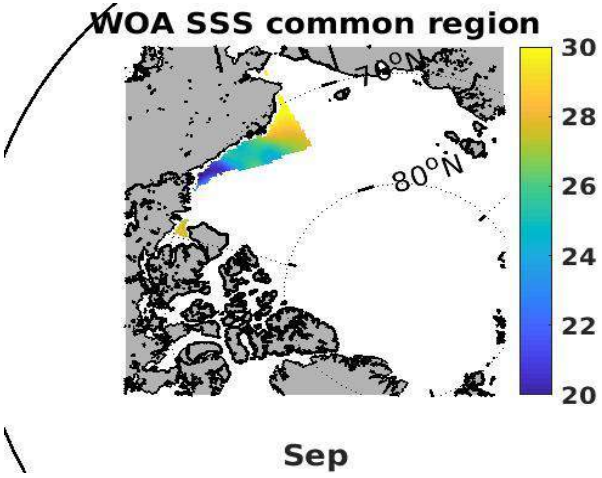


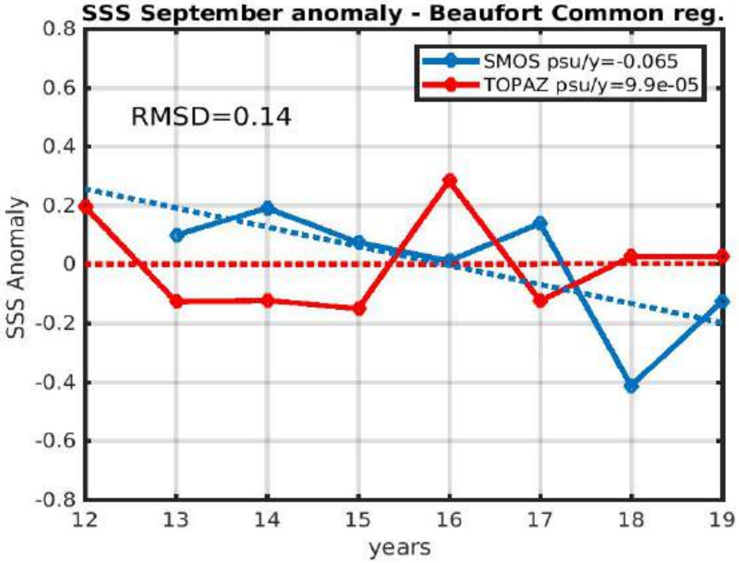
2017





Salinity and FWC trends in Beaufort Gyre





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.

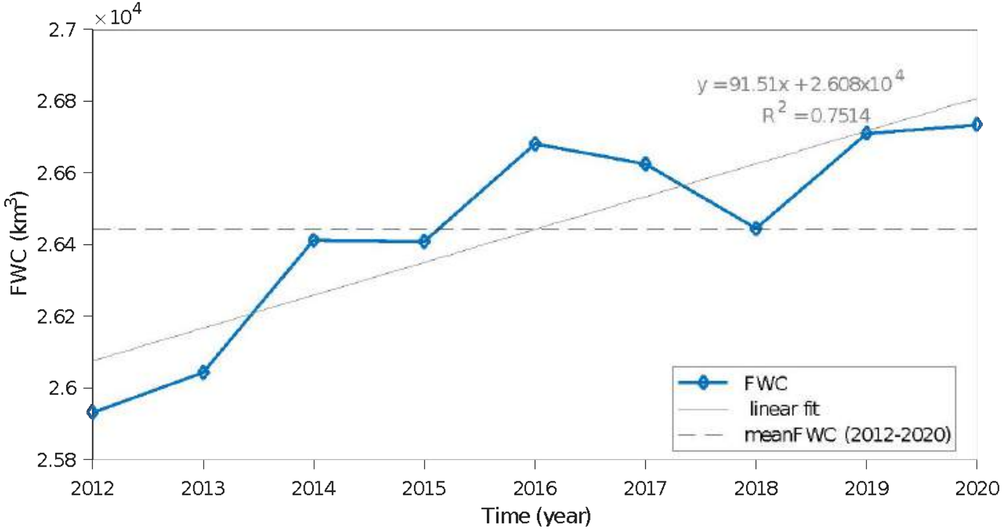
Salinity and FWC trends in Beaufort Gyre

Freshwater content computed using TOPAZ4 v.4b
(with assimilation of SMOS data)

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

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

(Haine et al. 2015)



FWC increase is observed with TOPAZ v4b when assimilating SMOS

THANK YOU FOR YOUR ATTENTION