Technical University of Denmark

Arctic Sea Level Change in the GRACE-era

OSTST, Chicago
October 2019

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DTU Space
National Space Institute

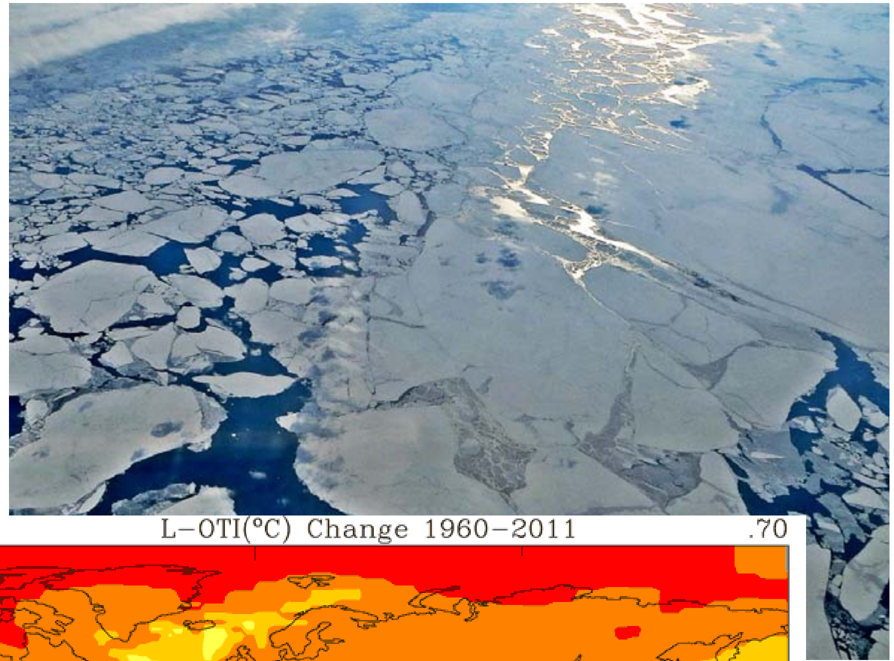
Why the Arctic Ocean?

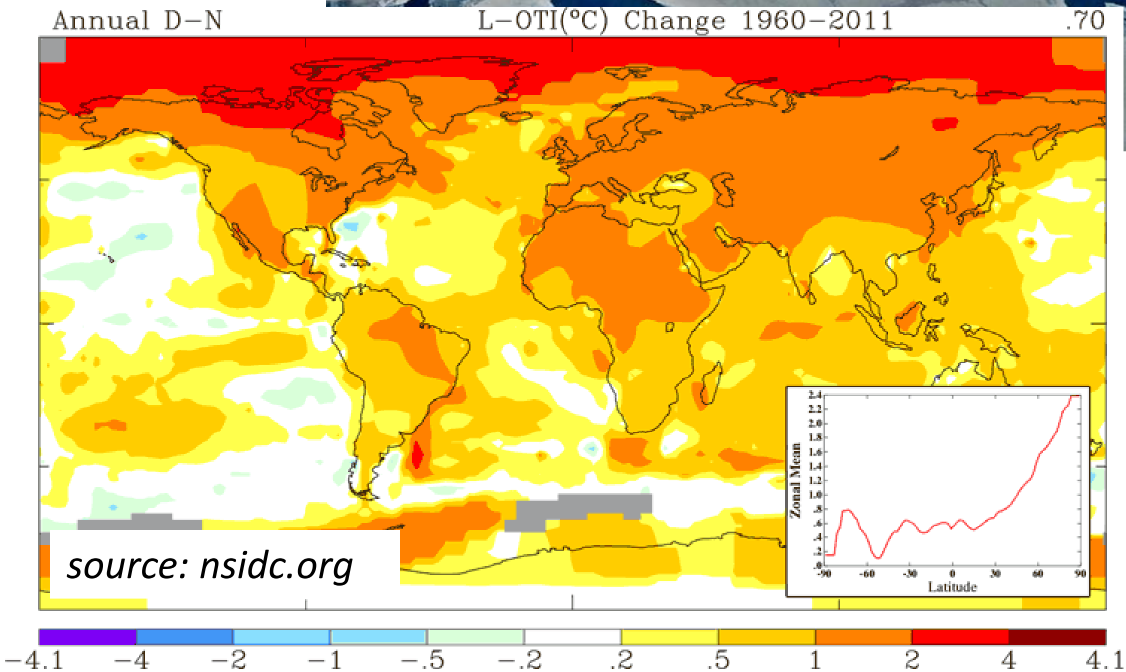
Arctic is the region in the world with most rapid climate change

Sea level is an important climate indicator and a proxy for many ongoing changes

- Freshwater influx
- Ocean heat uptake
- Land Ice change

Sea Level estimates are evident for Sea Ice Freeboard estimates.





source: nsidc.org

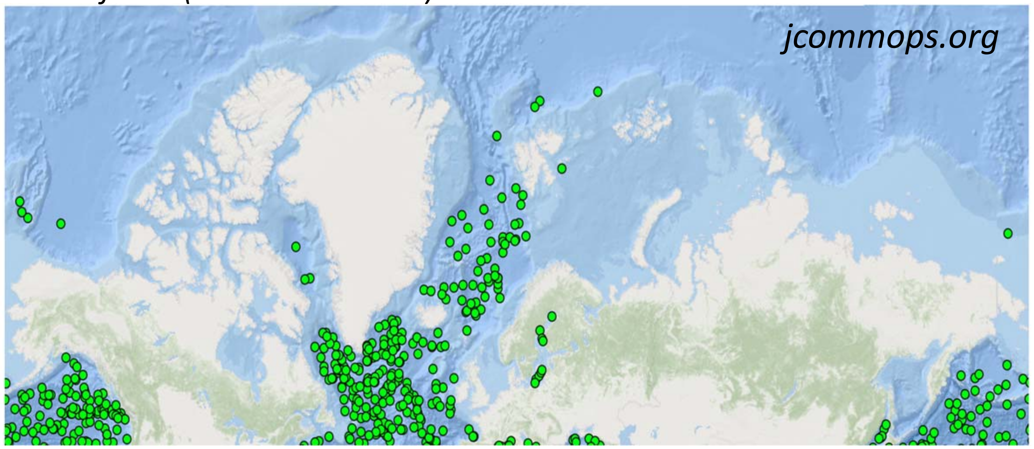
Sea level in the Arctic

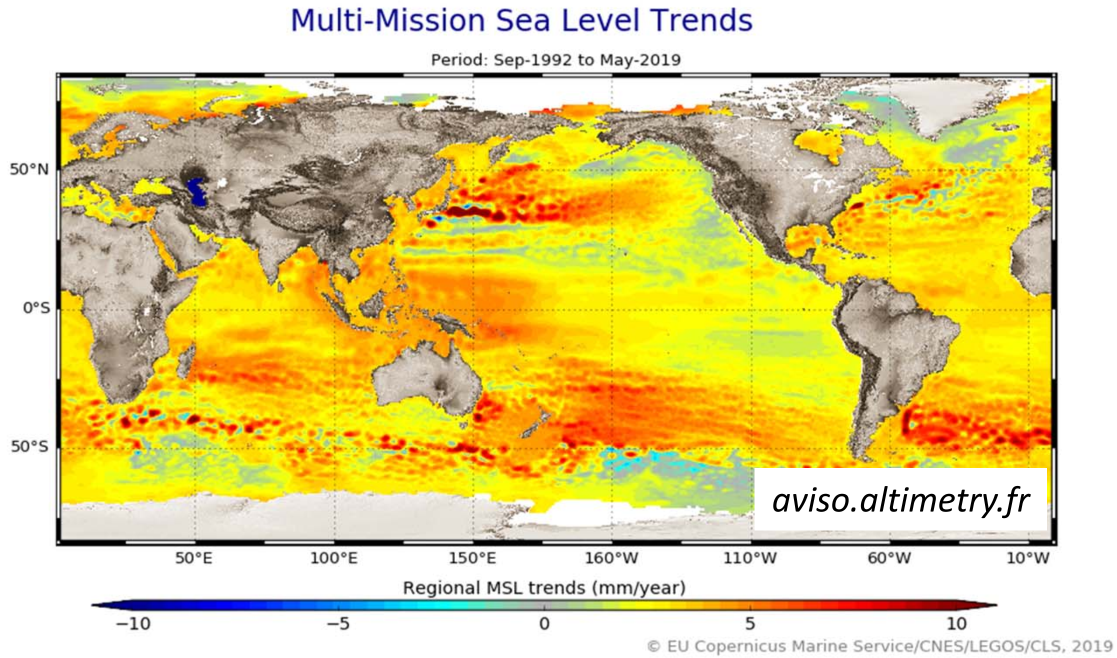
No or few continuous In-situ measurements
- Harsh conditions and high costs

Conventional altimetry has difficulties in the Arctic
- Few satellites covering north of 66 deg N
- Satellites challenged by floating sea ice

ERS-1/2, Envisat, CryoSat-2 provide a continuous 28 year Arctic sea level record (up to 81.5N).

ARGO floats (October 4th 2019)



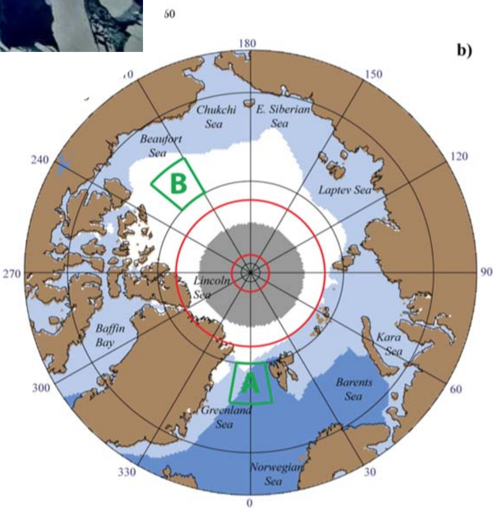


Sea level in the Arctic: SSH from Altimetry

- Most of the Arctic is permantly or seasonal covered with ice

White = >50% SIC in September
Light blue = >50% SIC in March

Red line = Max latitude for polar orbiting satellites



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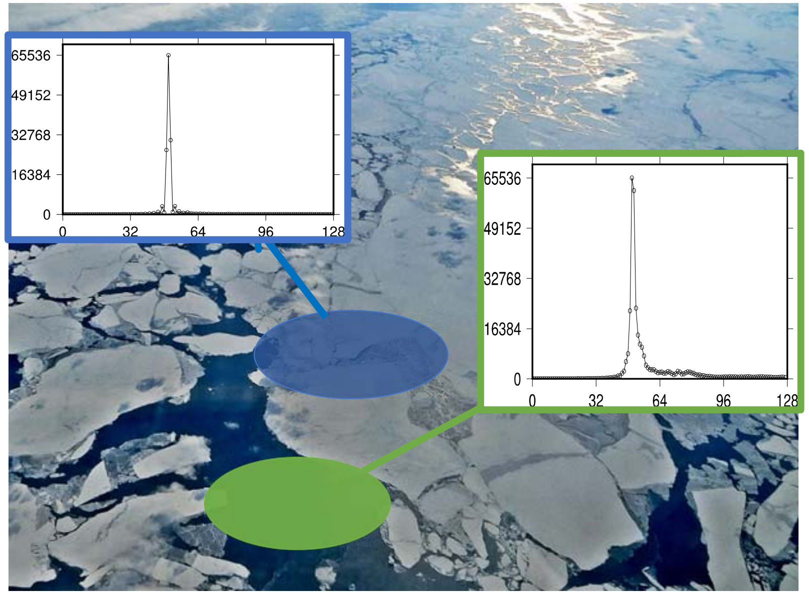
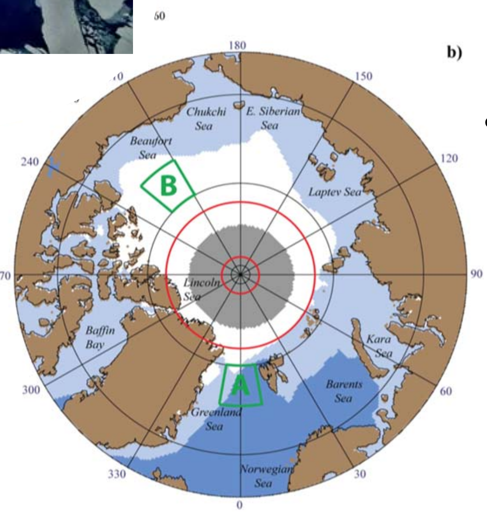


- Most of the Arctic is constantly or seasonal covered with ice
- Leads between ice floats can be used to measure SSH
- Return waveforms can look very similar.
  - ‘Mixed’ signal between sea ice ocean
  - Problem with melt ponds on top of sea ice that looks like ocean
- Scattering properties (**Pulse Peakiness** (LRM and SAR) and **Stacked Standard Deviation** (SAR only)) of waveform used to distinguish between surface types



- SAR Altimetry has finer spatial resolution, thus more data from leads.

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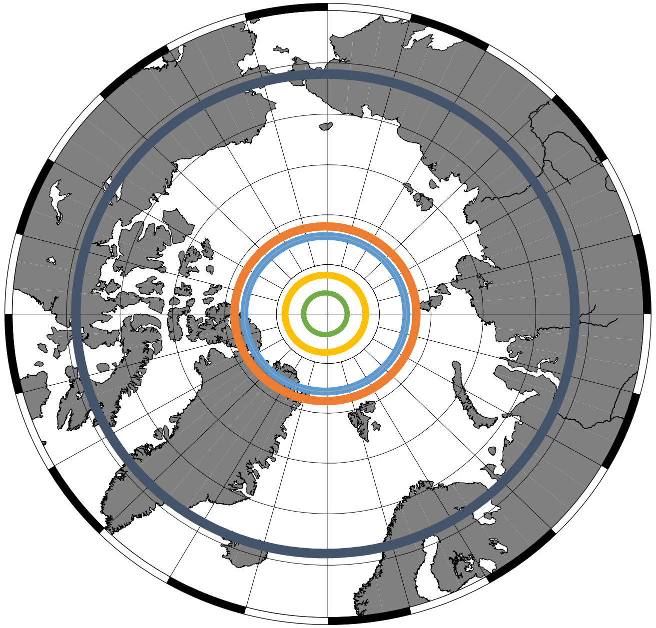
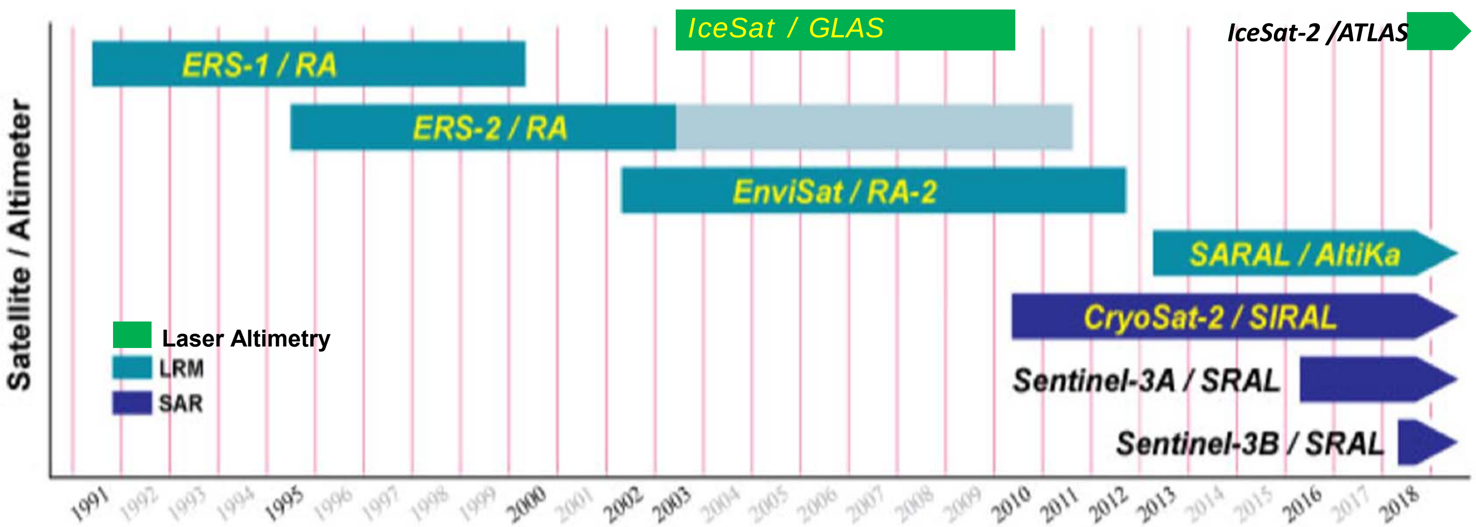
Sea level in the Arctic: SSH from Altimetry

- TOPEX/Poseidon, Jason-1,-2,-3
- Sentinel-3A/3B
- ERS-1, -2, Envisat, SARAL
- IceSat
- CryoSat-2, IceSat-2

Max latitude reached by the satellites





Sea level in the Arctic: SSH from Altimetry

Trend estimates (2003-2015): Envisat (2003-2011) / CryoSat-2 (2011-2015)

	DTU	CPOM	RADS
Modes used	SAR + LRM	SAR + LRM	Only LRM (1Hz)
Inverse Barometer	MOG2D	ECWMF	MOG2D
Wet Troposphere	Doris/GIM/Bent	ECWMF	ECMWF
Dry Troposphere	ECMWF	ECWMF	ECWMF
Sea State Bias	ALES+/RADS (only open water)	CLS	NOAA
Ionospheric correction	ECMWF	CNES	JPL GIM
Ocean Tide	FES2014	FES2004	GOT4.10
Solid/PoleTide	Cartwright/Wahr	Cartwright/Wahr	IERS

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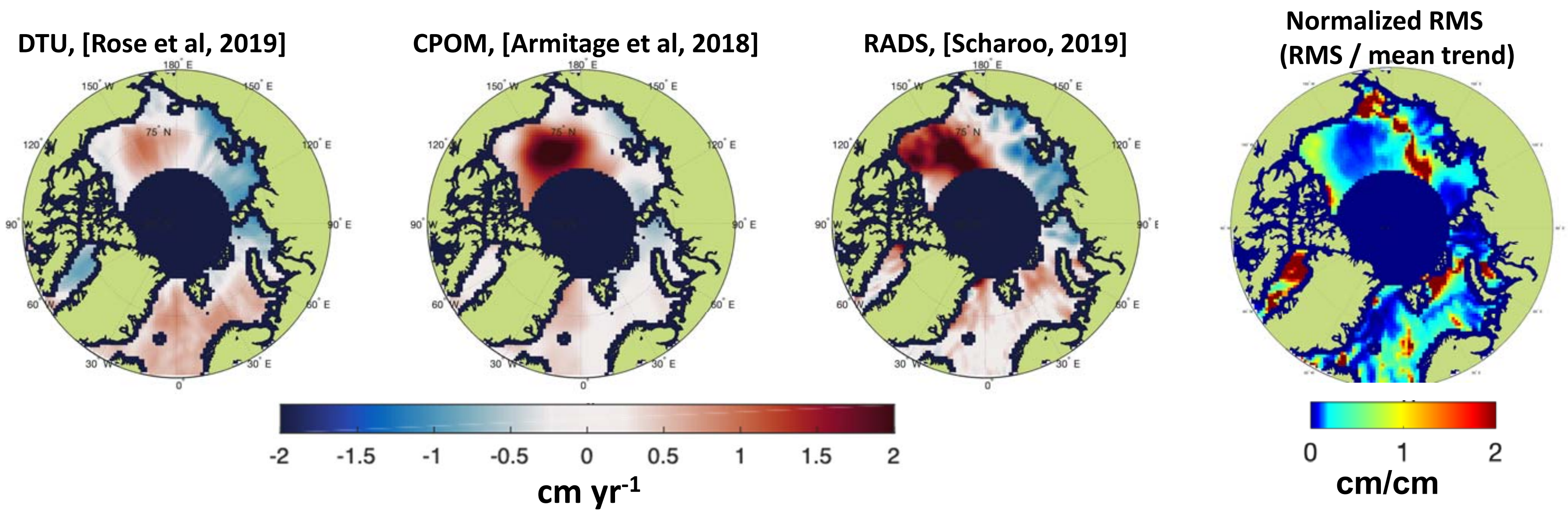


Sea level in the Arctic: Sea Level Budget

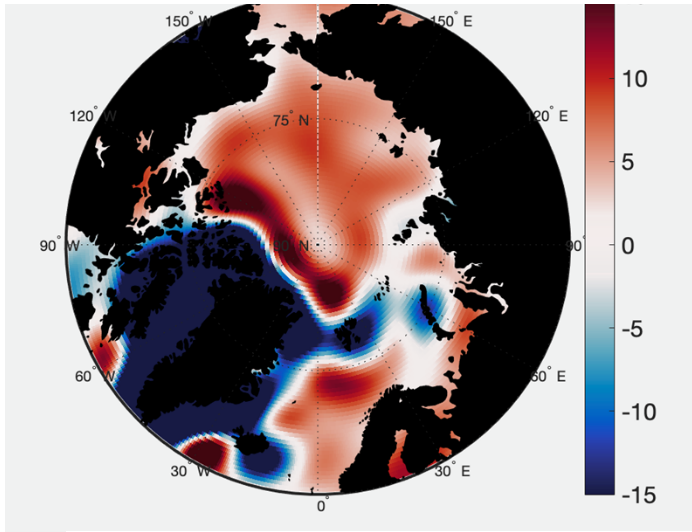
SSH = Ocean Mass + Steric Changes

(Altimetry = GRACE + ARGO)

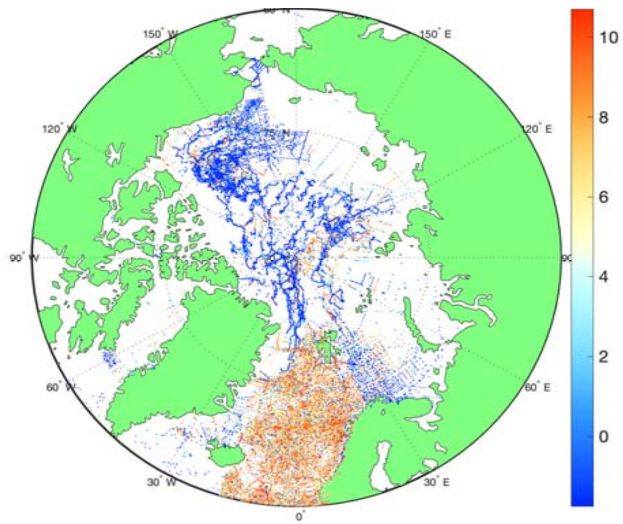
Arctic challenge:

- Signal leakage - mass loss from land is 10 to 1000 times larger (measured in equivalent water heights) than changes in the ocean
- In-Situ measurements in the Arctic are locally very sparse

SH-based EWH trend (03-15) [mm/yr]



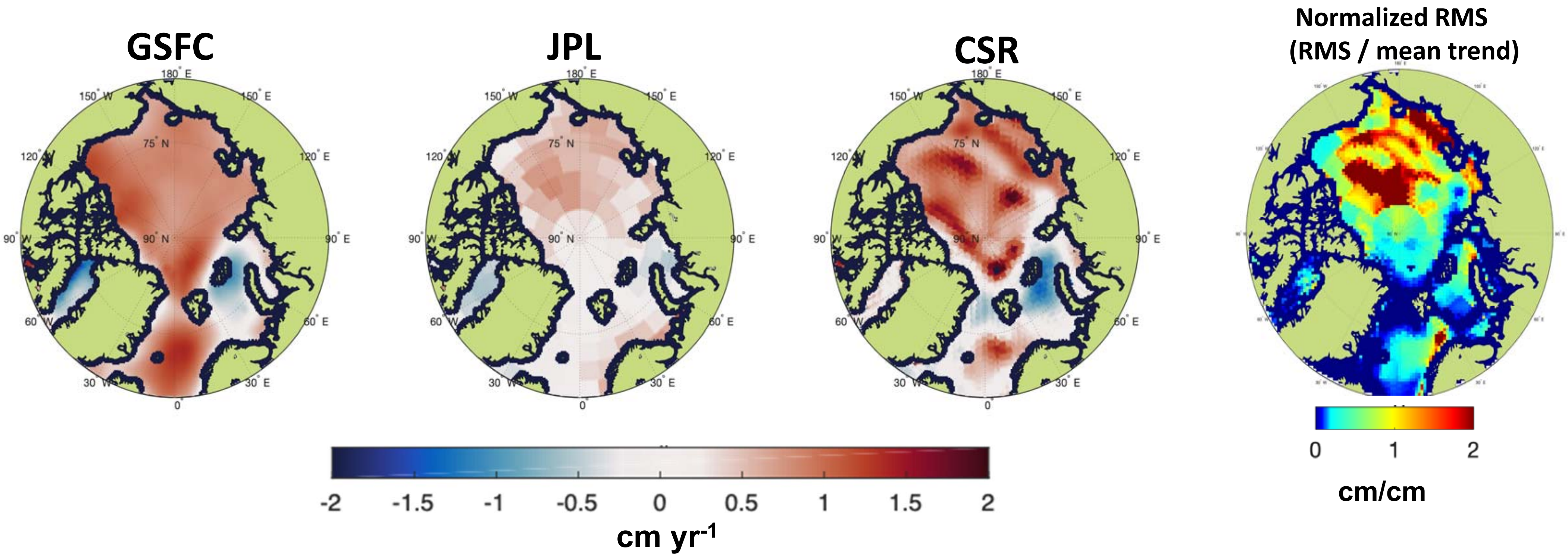
Surface temp from T/S profiles



Data from UDASH-database (Behrendt et al, 2017).

Sea level in the Arctic: Sea Level Budget – GRACE mascons

2003-2015



Sea level in the Arctic: Sea Level Budget – Steric

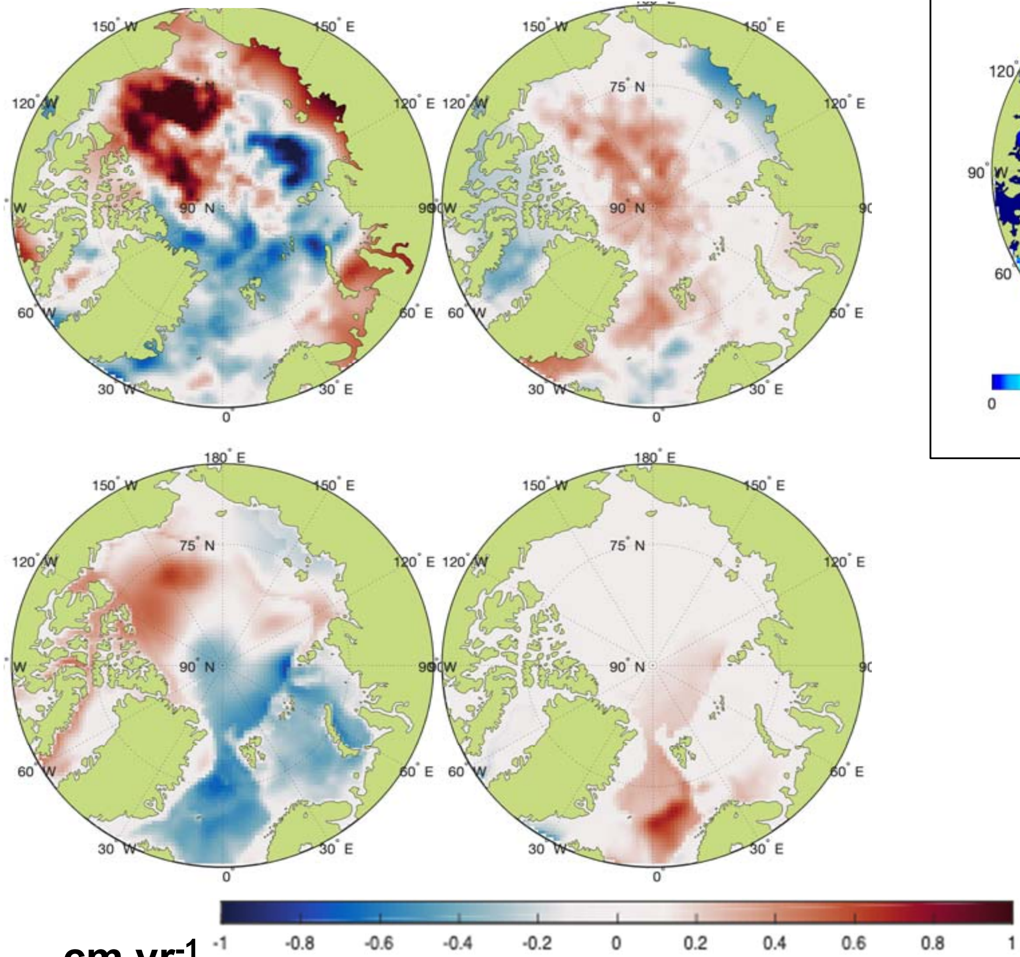
2003-2015

Halosteric

Thermosteric

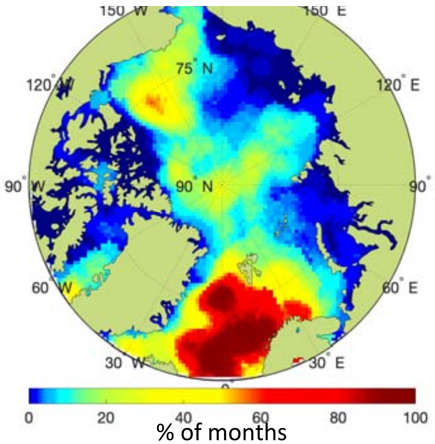
DTUSteric
(only in-situ based)

ECCOv4r3
(constrained by
GRACE and Altimetry)

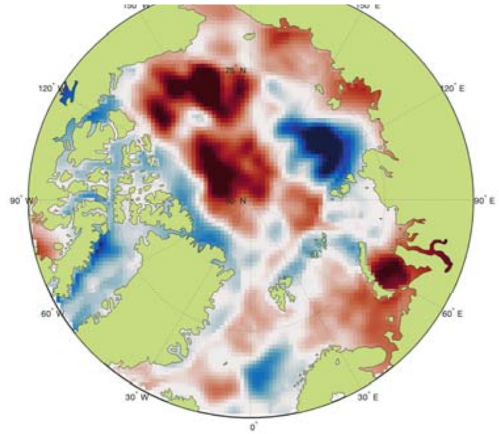


cm yr^{-1}

Data coverage
in DTUSteric



DTUSteric - ECCO



Sea level in the Arctic: Sea Level Budget

Combination (Mass + Steric) R-coeff.	Altimetry solutions		
	RADS	DTU	CPOM
JPL + DTU	0.61	0.35	**0.76**
JPL + ECCOv4	-0.16	0.40	-0.10
GSFC + DTU	0.50	0.40	0.67
GSFC + ECCOv4	-0.10	0.37	0.00
CSR + DTU	0.49	0.19	0.69
CSR + ECCOv4	-0.05	0.16	0.17
OBPmean + DTU	0.54	0.32	0.74
OBPmean + ECCOv4	-0.11	0.33	0.04

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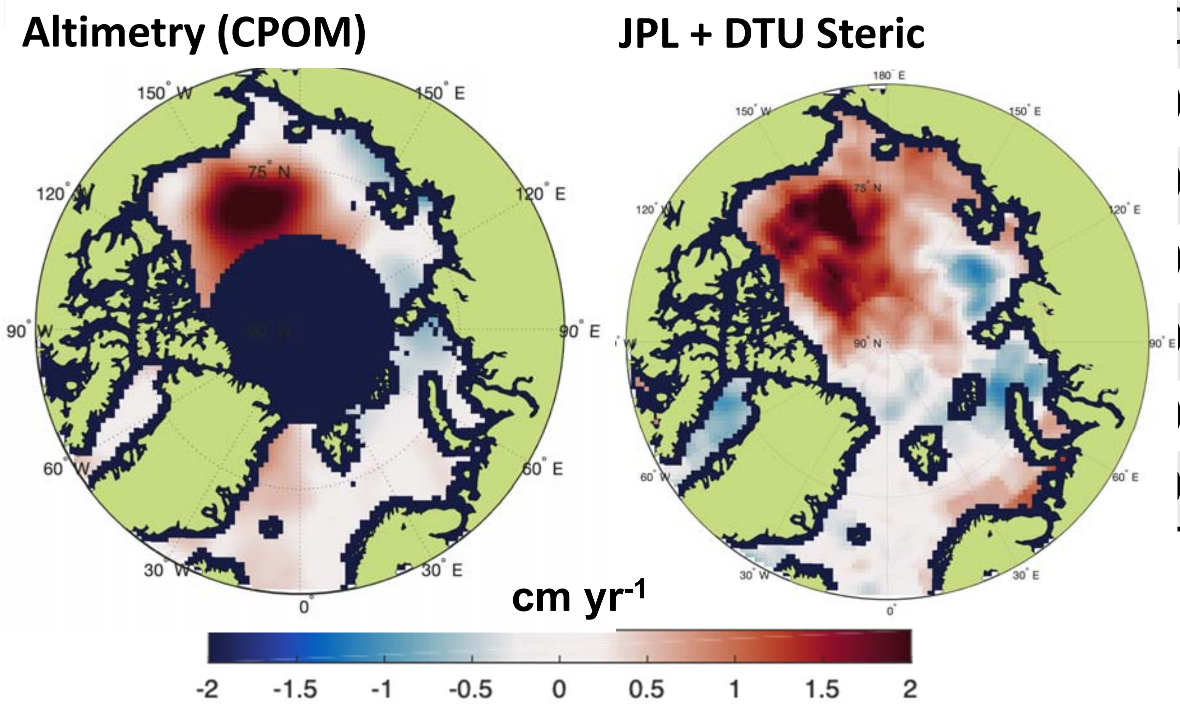
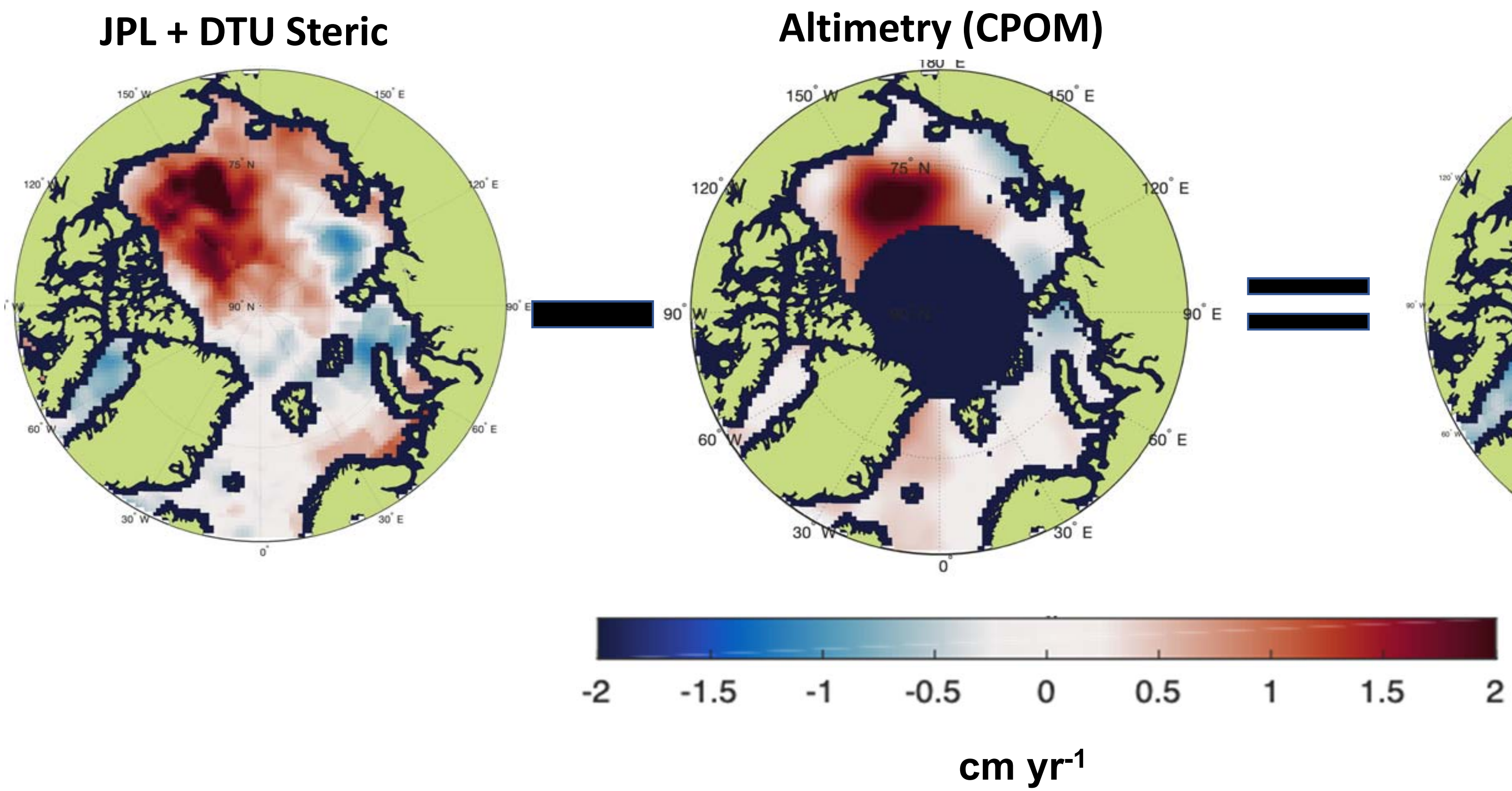
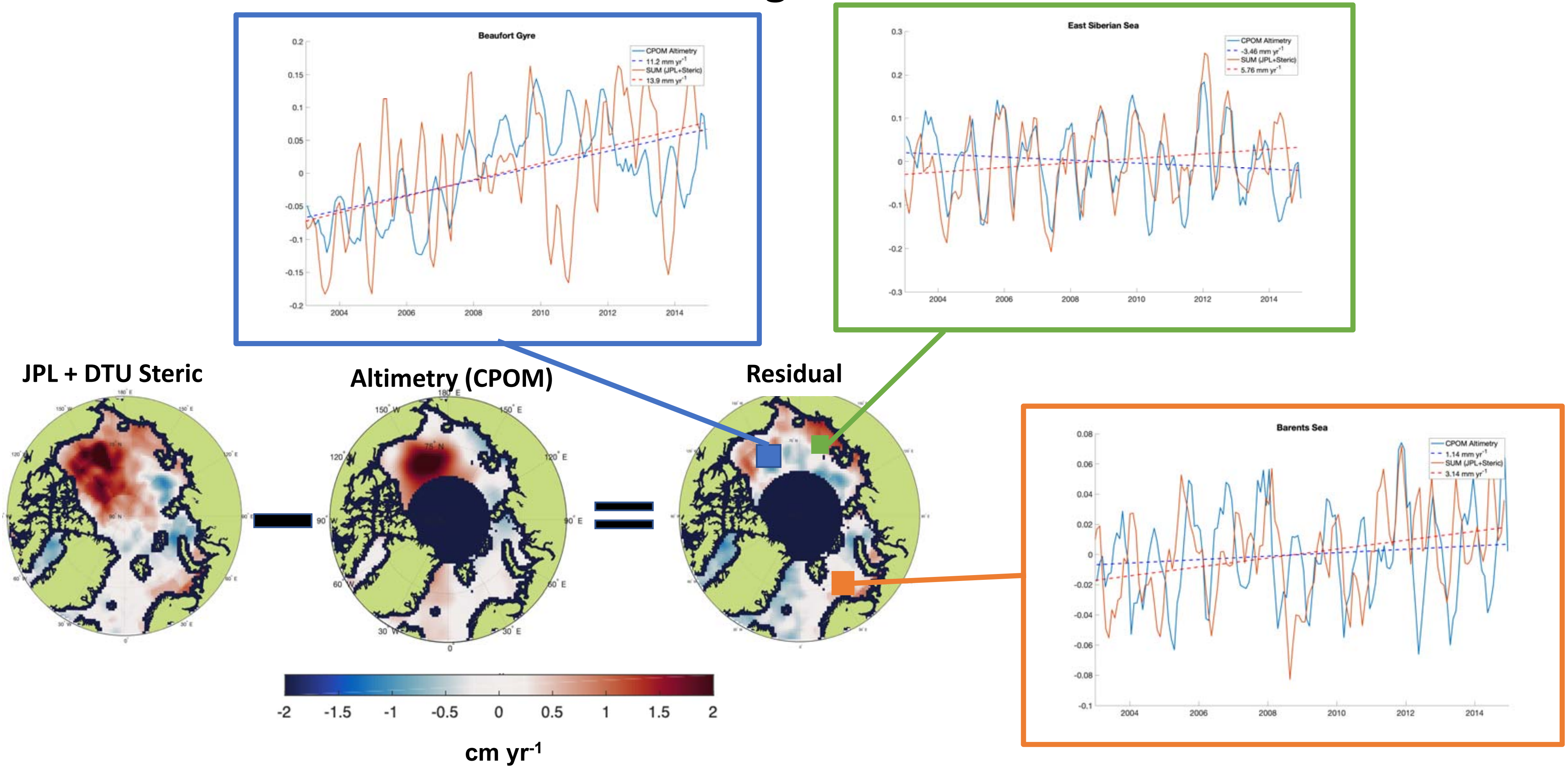


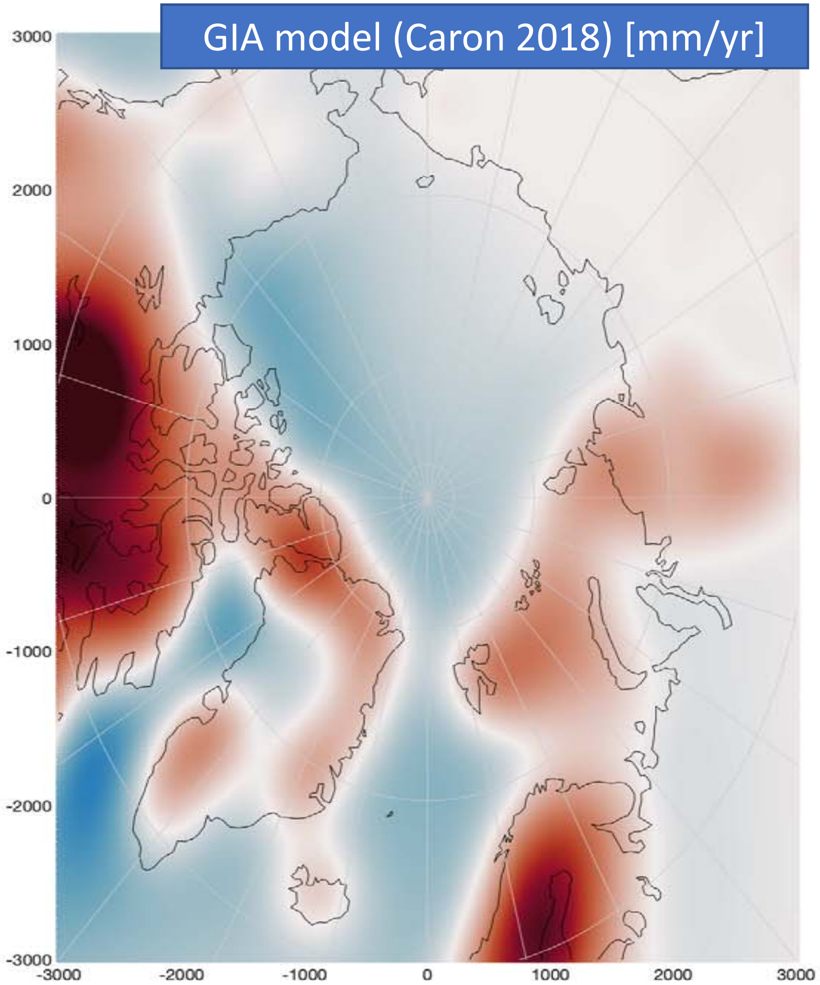
Sea level in the Arctic: Sea Level Budget

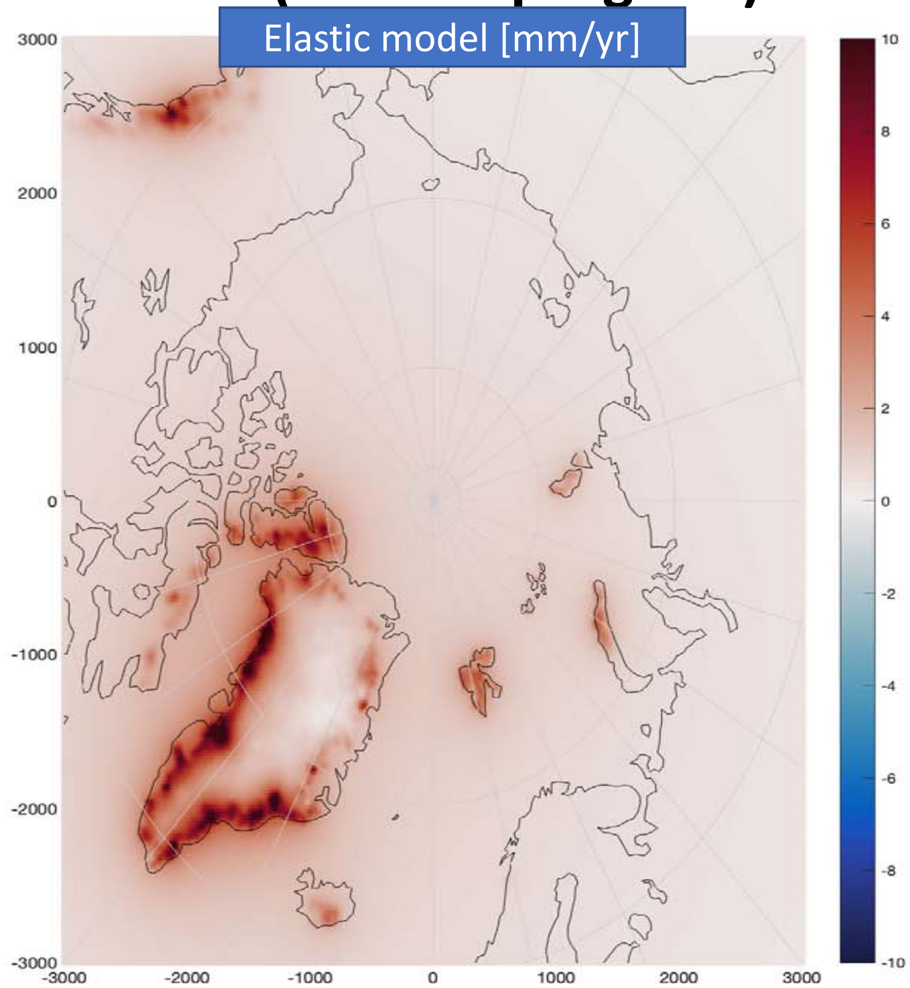


Sea level in the Arctic: Sea Level Budget - Trends



Sea level in the Arctic: Tide-Gauges – VLM model (work in progress)





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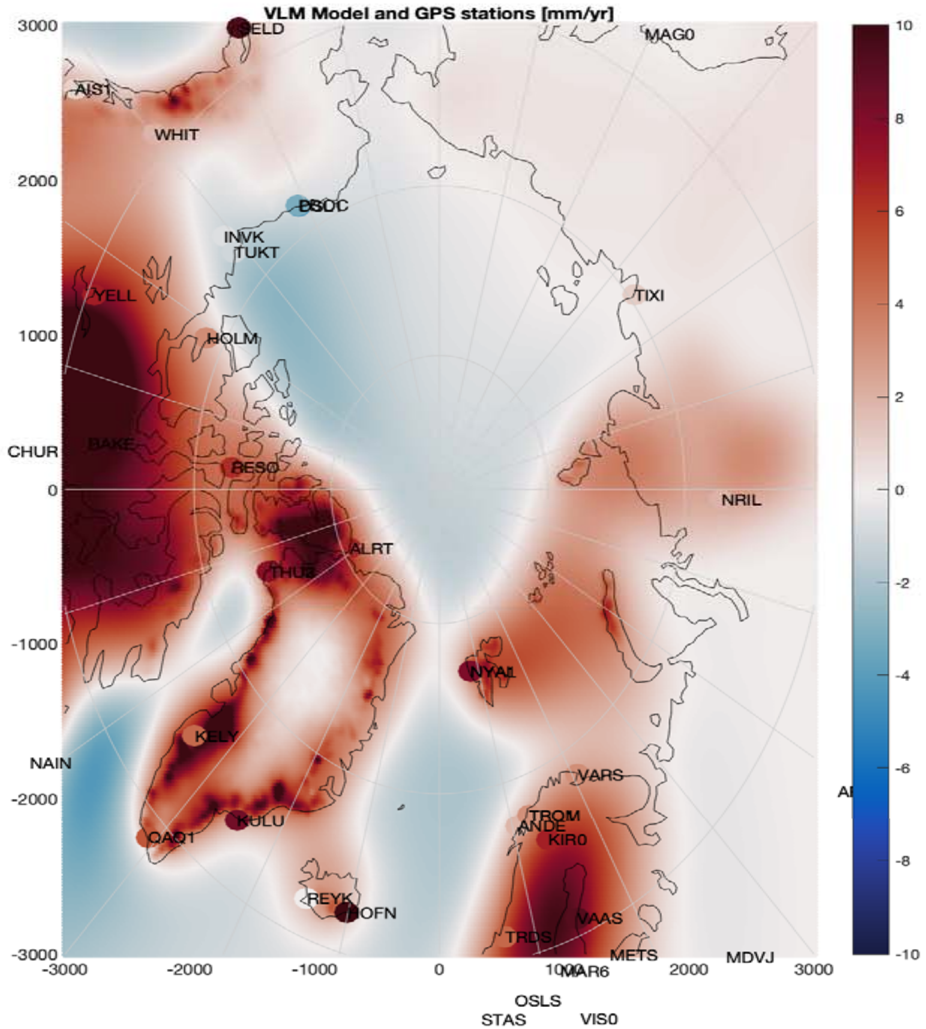
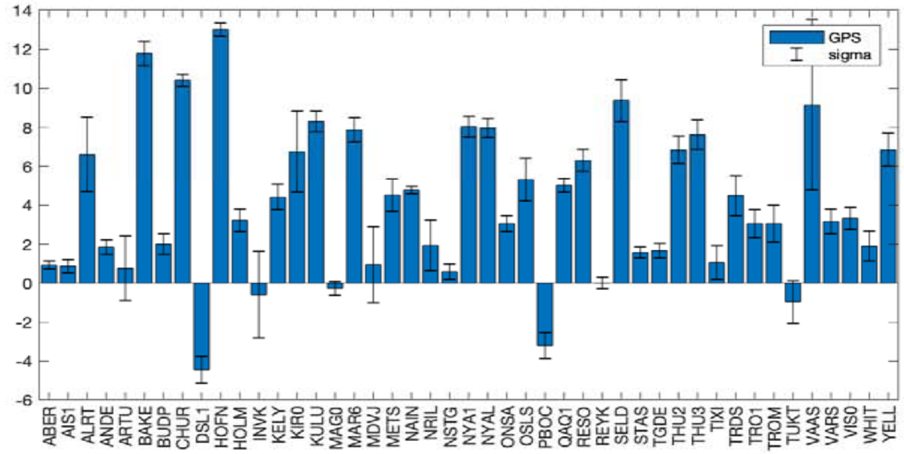
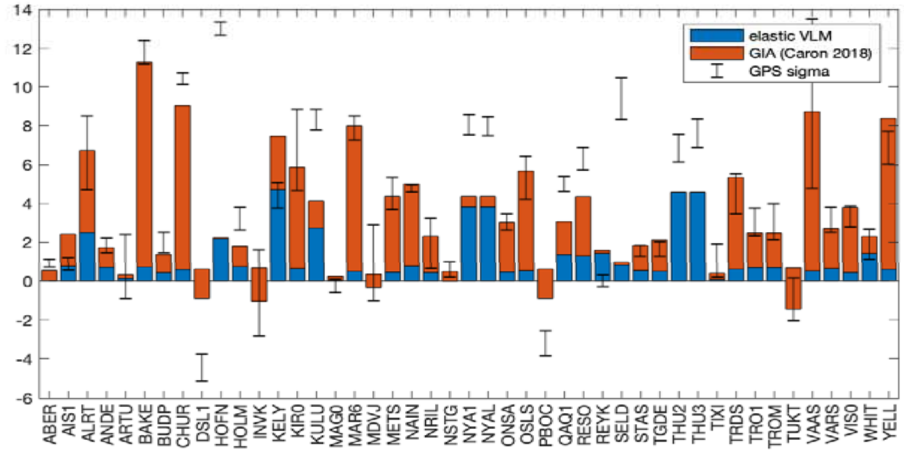
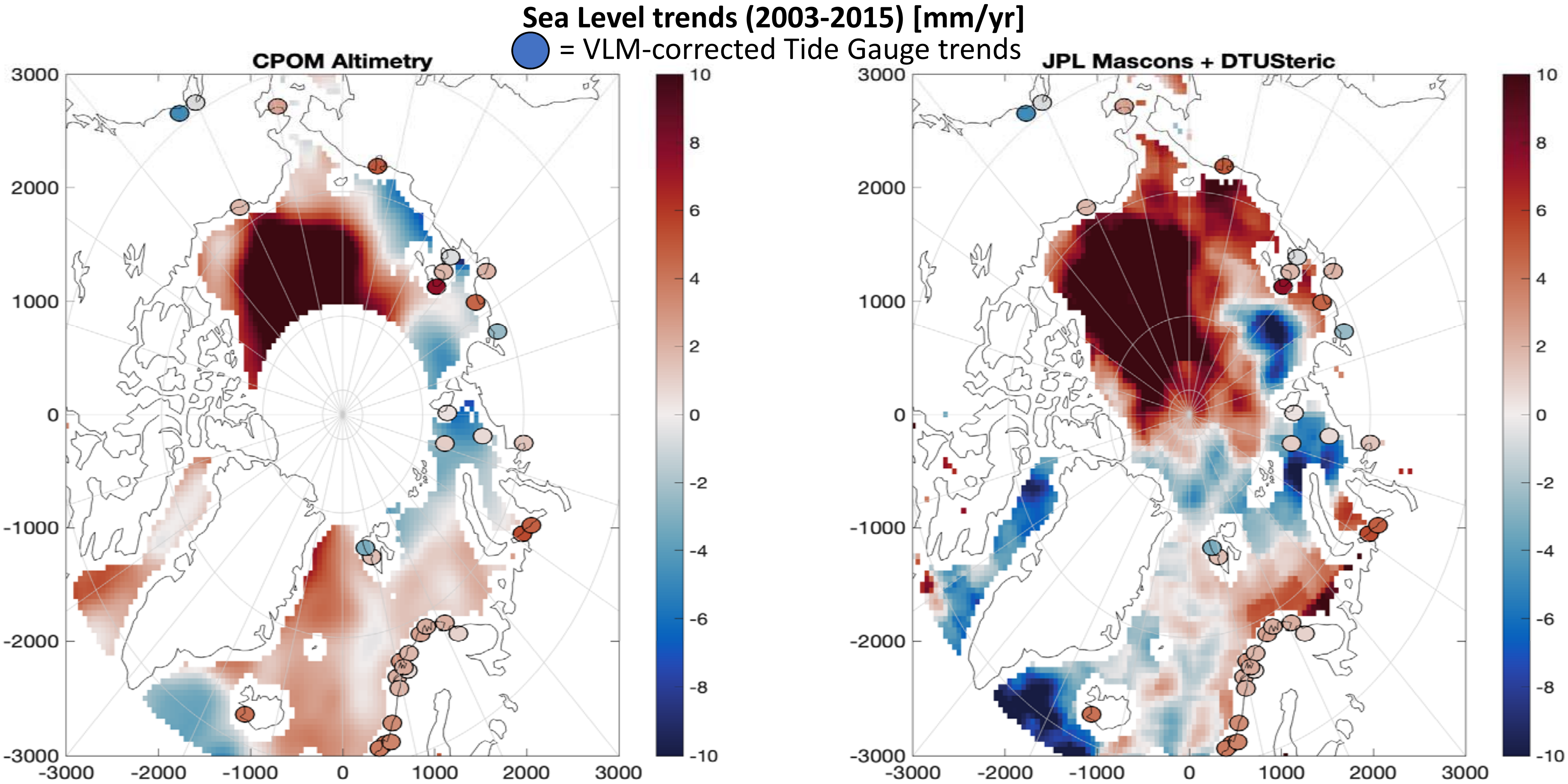






Sea level in the Arctic: Comparison with Tide-Gauges (work in progress)



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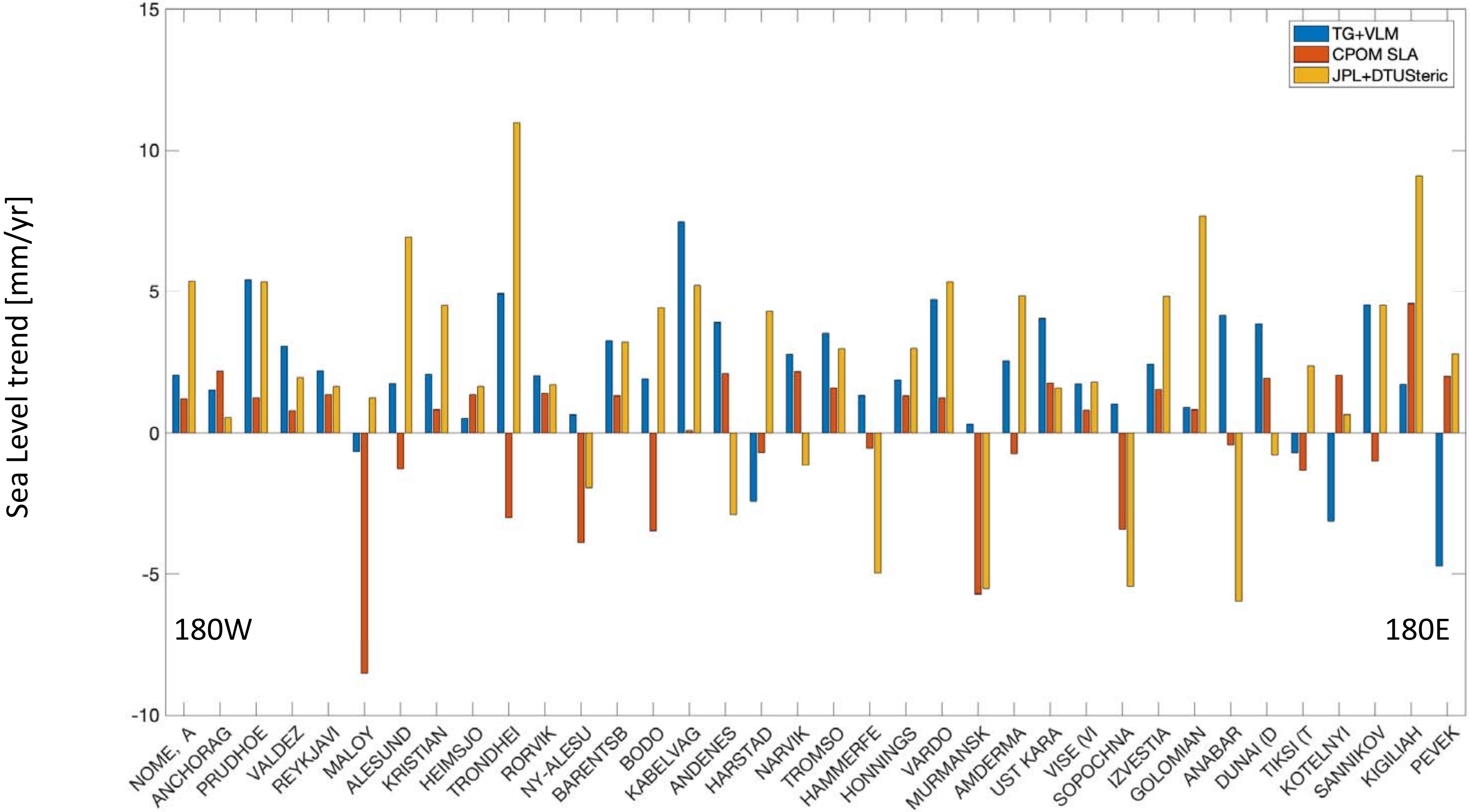


Conclusions

- A combination of JPL Mascons and the DTU Steric product has a fairly good agreement with the regional sea level trends from CPOM altimetry.

- The seasonal nature of the steric data and lack of consistent T/S data makes temporal correlation challenging

- The seasonal variability of the steric data is not represented in the altimetric data.

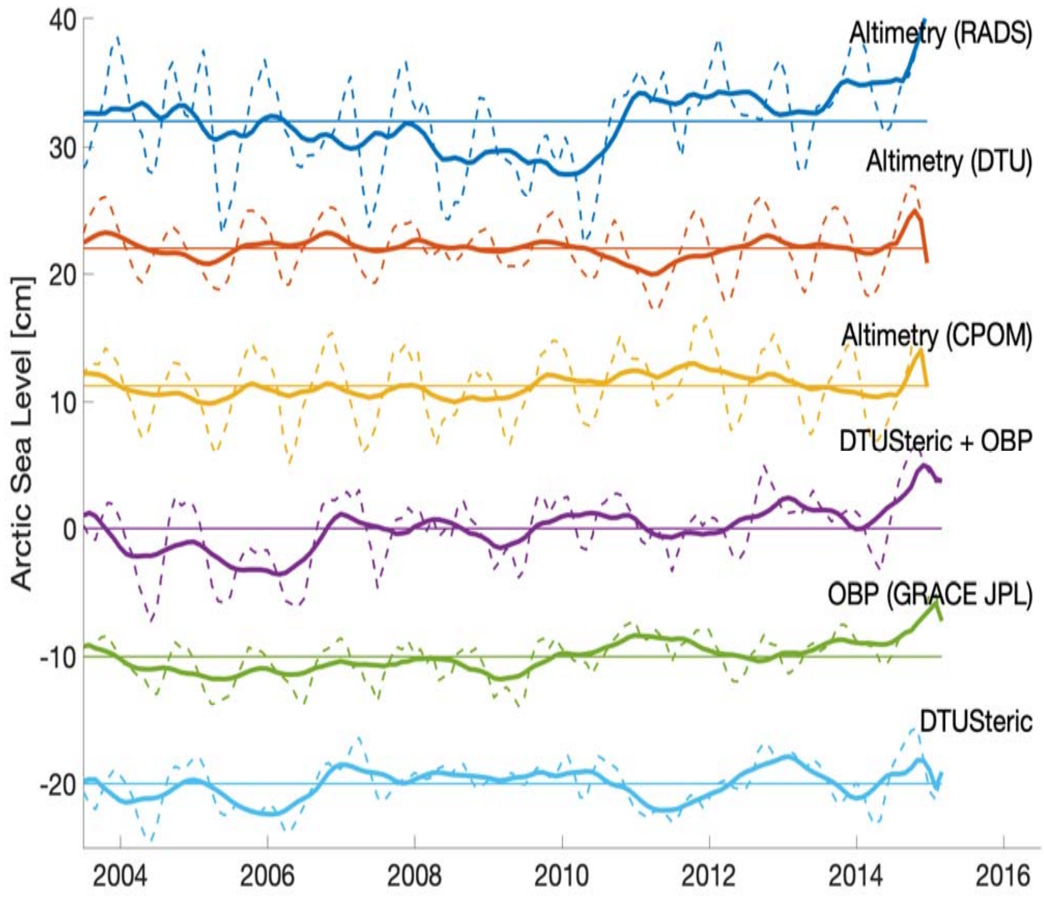
- Comparison with Tide-Gauges shows SLA-difference for both Altimetry and JPL+DTUSteric

Next steps

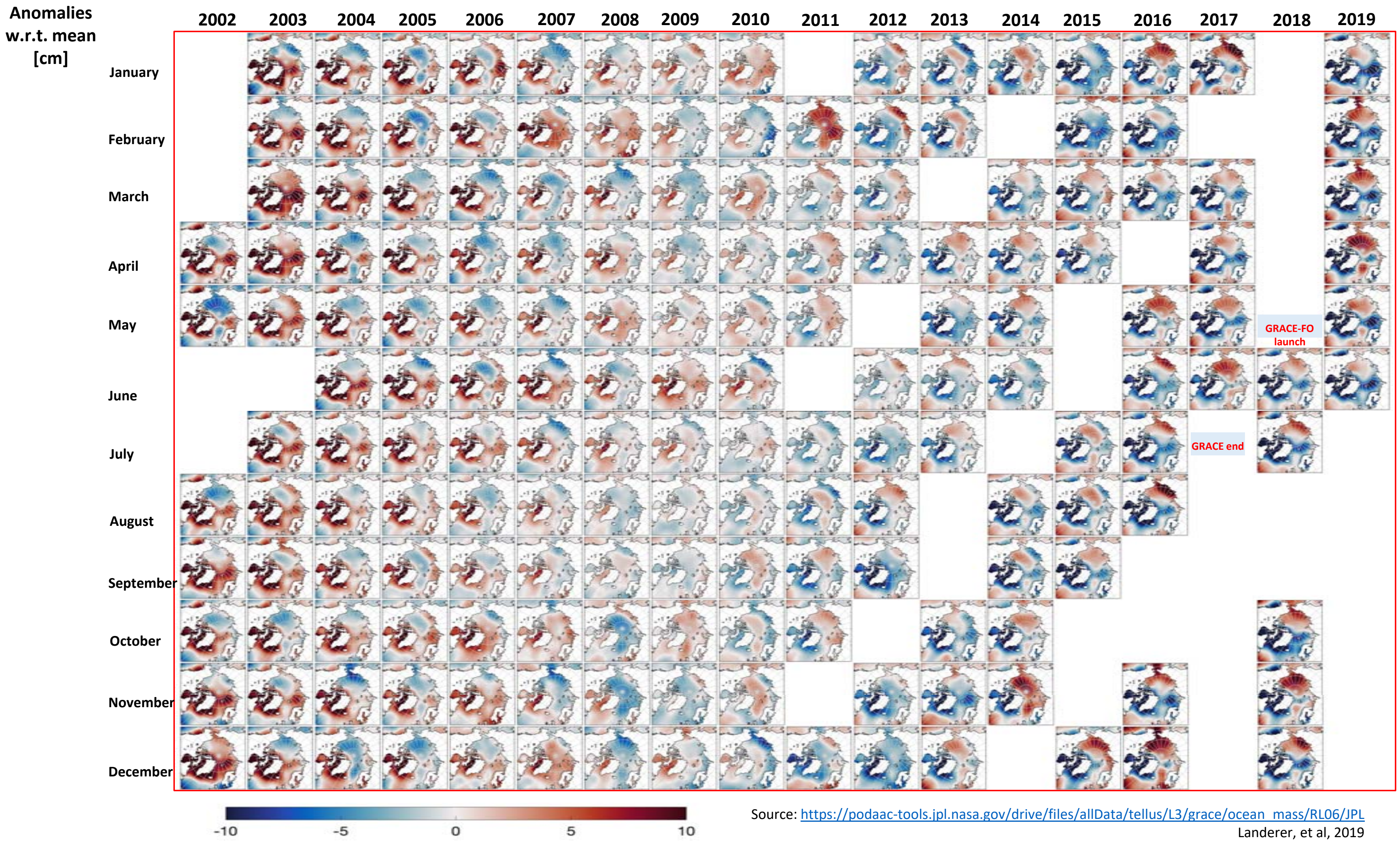
- More precise global VLM model and looking into the likely source of difference in SLA trends (GRACE, Steric, Altimetry, VLM model or Tide-Gauge)
- Comparing with ICESat-2 data (see also poster: **SC4-017 - ICESat-2 and CryoSat-2 in the Arctic Ocean for November 2018**)

Extra slides

Sea level in the Arctic: Sea Level Budget - Trends



Sea level in the Arctic: Sea Level Budget - GRACE

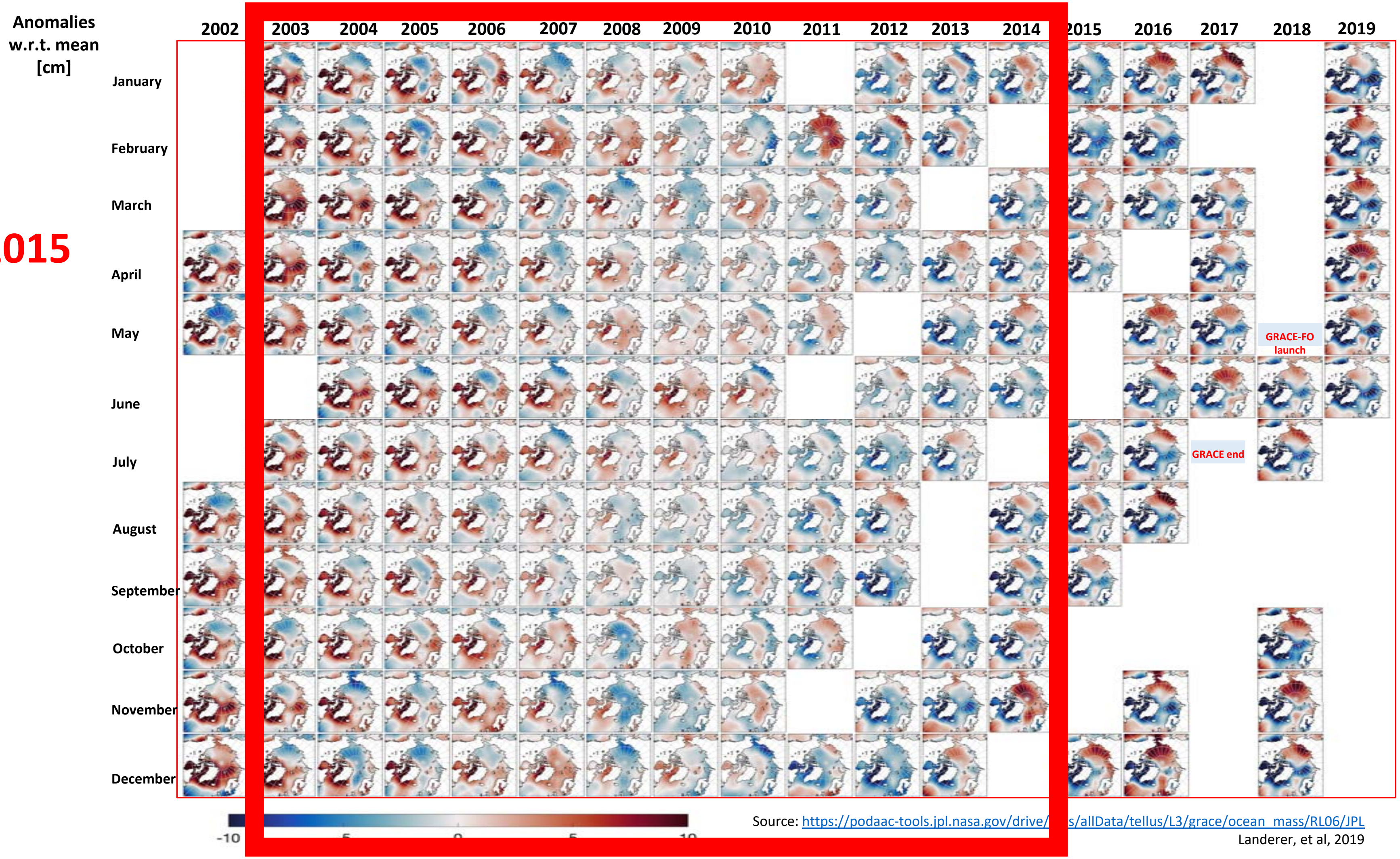


Source: https://podaac-tools.jpl.nasa.gov/drive/files/allData/tellus/L3/grace/ocean_mass/RL06/JPL

Landerer, et al, 2019

Sea level in the Arctic: Sea Level Budget - GRACE

For this study:
Data from 2003-2015



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