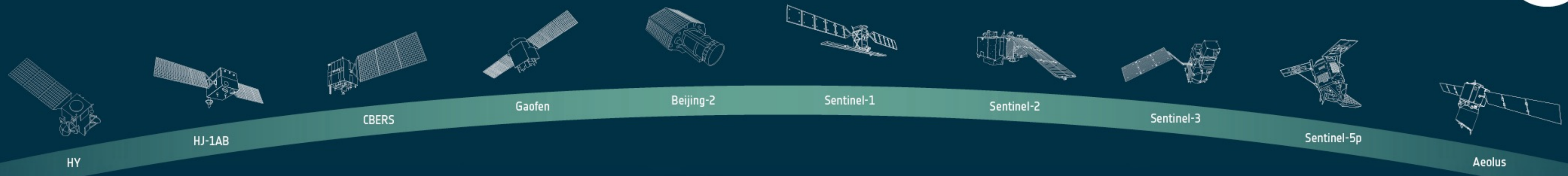


2022 DRAGON 5 SYMPOSIUM

MID-TERM RESULTS REPORTING

17-21 OCTOBER 2022

[PROJECT ID.59376]

[Pacific modulation of the Sea level variability of the Beaufort Gyre System in the Arctic Ocean]

17-October-2022

ID. 59376

PROJECT TITLE: Pacific modulation of the Sea level variability of the Beaufort Gyre System in the Arctic Ocean

PRINCIPAL INVESTIGATORS: [Johnny. A. Johannessen (Norway), Jianqi Sun (China)]

CO-AUTHORS: [Roshin. P. Raj, Antonio. Bonaduce, Yang. Liu, H. Regan. S. Chatterjee]

PRESENTED BY: [Roshin. P. Raj]

Objectives

- Assess the role of variability of atmospheric modes in the Pacific Ocean and the Arctic Ocean on the BH and on the sea level variability of the region
- Advance the current understanding of the different mechanisms influencing the sea-level variability in the BG
- Validate climate models using observations and assess the sea level change with respect to natural versus anthropogenic origin

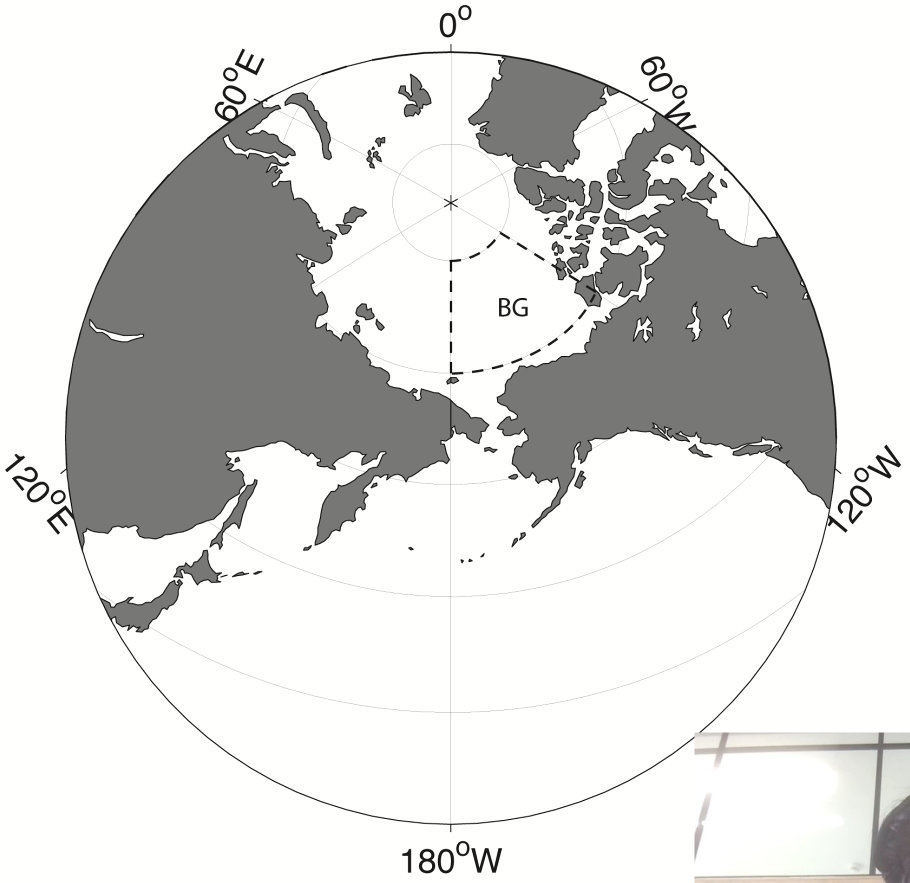


Figure. Study Area. Black dashed box represents the Beau

EO Data Delivery

Data access (list all missions and issues if any). NB. in the tables please insert cumulative figures (since July 2020) for no. of scenes of high bit rate data (e.g. S1 100 scenes). If data delivery is low bit rate by ftp, insert “ftp”

ESA Third Party Missions	No. Scenes
1. SSMI	
2. AMSR	
3.	
4.	
5.	
6.	
Total: 2	
Issues: 0	

ESA, Explorers & Sentinels data	No. Scenes
1. ERS	
2. Envisat	
3. Cryosat	
4. Sentinel-3	
5. SMOS	
6. GOCE	
Total: 6	
Issues: 0	

Chinese EO data	No. Scenes
1. HY	
2.	
3.	
4.	
5.	
6.	
Total: 1	
Issues:0	

Insitu and other datasets

In-situ data measurements and requirements

Beaufort Gyre Exploration Project

Ice Tethered Profilers

EN4 dataset and CMEMS CORA dataset

Field data collection campaigns and periods in P.R. China or other study areas

Climate models and Reanalysis

Results after 2 year of activity

Updates....

- **Recent advancements in the Arctic Sea Level Research from space**
- **Assessment of Arctic Sea Level in CMIP6 models**
- **Teleconnection impacts**

Recent advancements in the Arctic Sea Level Research from space

2020

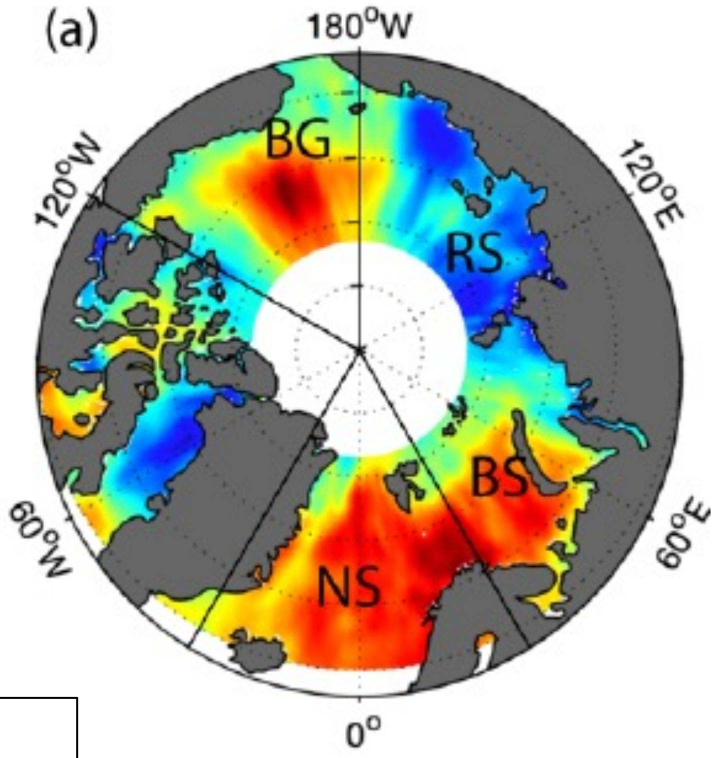
remote sensing

Arctic Sea Level Budget Assessment during the GRACE/Argo Time Period

Roshin P. Raj [1,*], Ole B. Andersen [2], Johnny A. Johannessen [3], Benjamin D. Gutknecht [4], Sourav Chatterjee [5], Stine K. Rose [2], Antonio Bonaduce [1], Martin Horwath [4], Heidi Ranndal [2], Kristin Richter [6], Hindumathi Palanisamy [7], Carsten A. Ludwigsen [2], Laurent Bertino [1], J. Even Ø. Nilsen [8], Per Knudsen [2], Anna Hogg [9], Anny Cazenave [7] and Jérôme Benveniste [10]

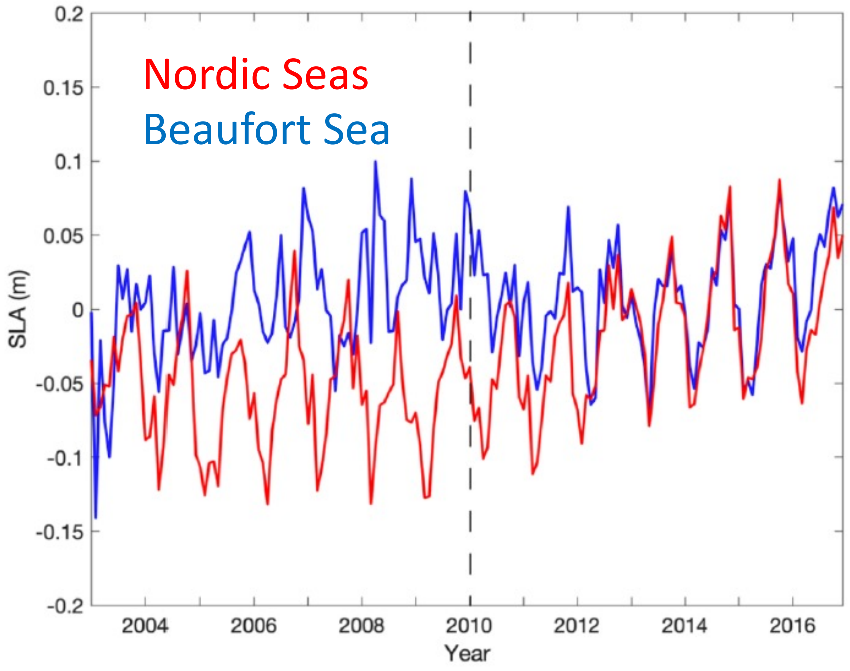
Recent advancements in the Arctic Sea Level Research from space

Arctic Sea Level Budget Assessment

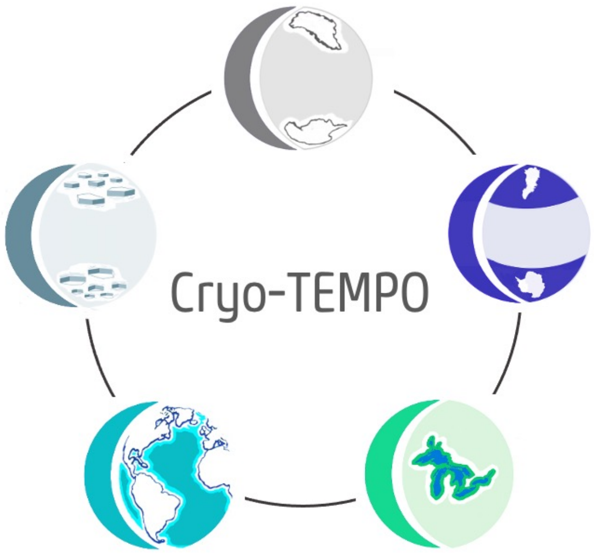


Polar GAP

Sea level trend (2003-2016)



Recent advancements in the Arctic Sea Level Research from space



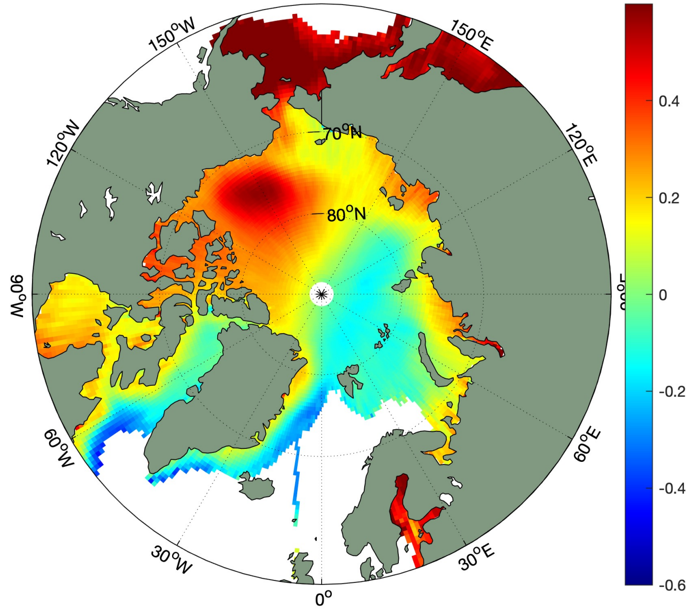
ESA's Cryo-TEMPO project brings together a team of radar altimetry scientific experts and software engineers, to generate agile and state-of-the-art thematic data products

SAR and **SARIn modes** processed with a Threshold First Maximum Retracker Algorithm (TFMRA).

Data from 2010- present

Reduction of the Polar GAP

ADT (2010-2020)



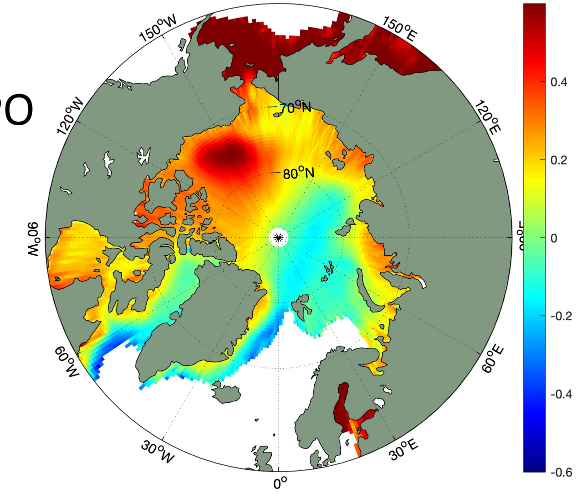
Raj et al., 2022a, in prep

Recent advancements in the Arctic Sea Level Research from space

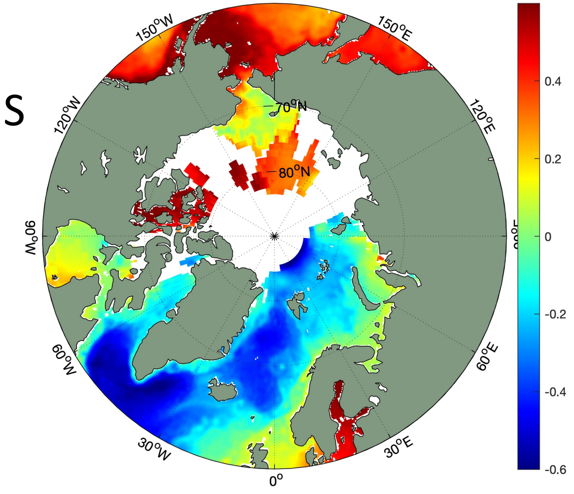
Intercomparison

winter climatology (2010-2020)

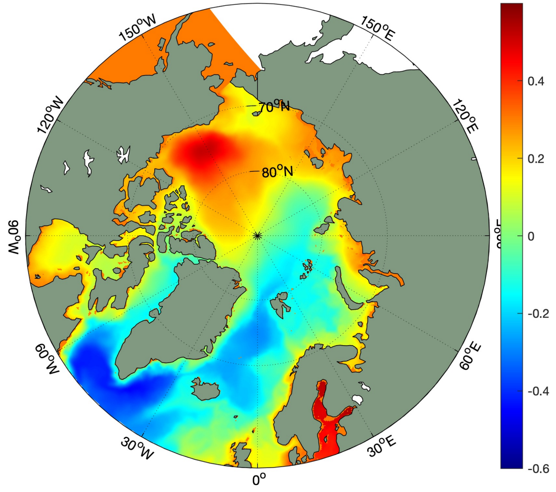
CryoTEMPO



CMEMS



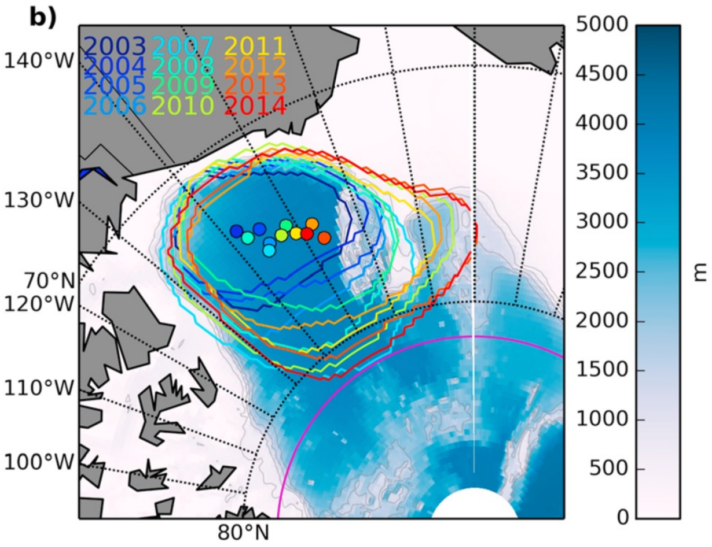
TOPAZ



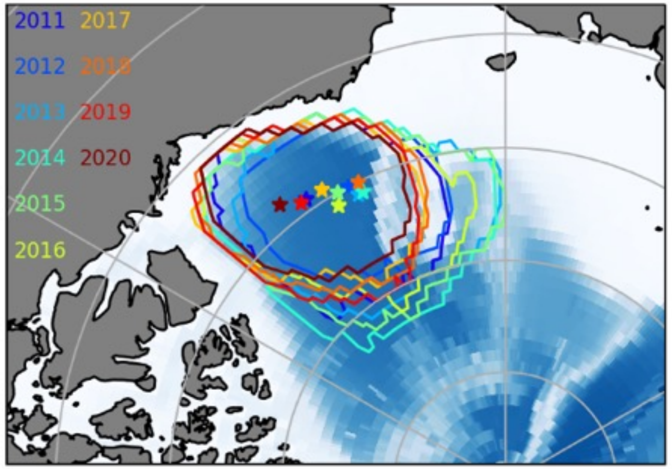
Raj et al., 2022a, in prep

Recent advancements in the Arctic Sea Level Research from space

Beaufort Gyre variability



CryoTEMPO



JGR Oceans

RESEARCH ARTICLE
10.1029/2018JC014379

Special Section:
Forum for Arctic Modeling and

The Beaufort Gyre Extent, Shape, and Location Between 2003 and 2014 From Satellite Observations

Heather C. Regan[1], Camille Lique[1], and Thomas W. K. Armitage[2]

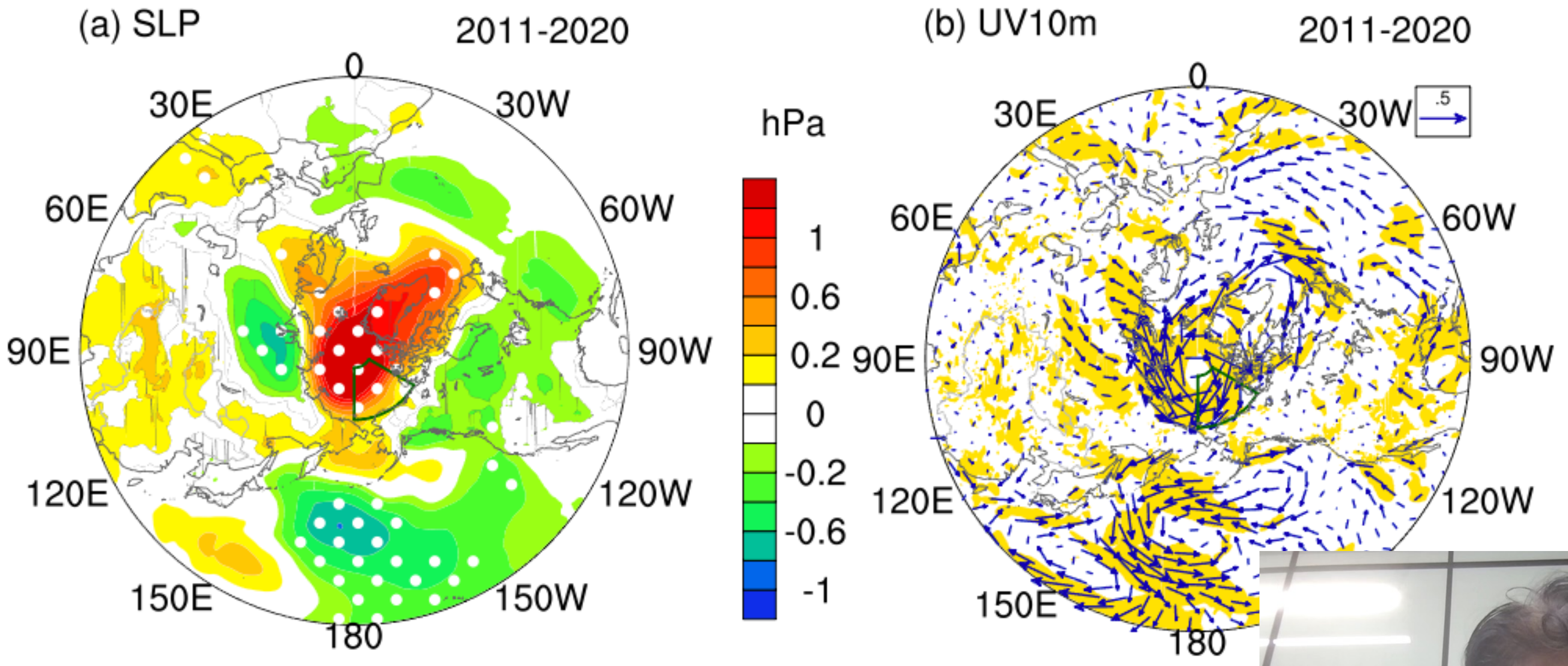
Expansion of the Gyre No longer exists after 2016

Pacific modulation of the sea level variability in the Beaufort Sea

When BSADT index positive,

Atmospheric mode seems like

negative phase of NPO



Liu et al., 2022, in prep

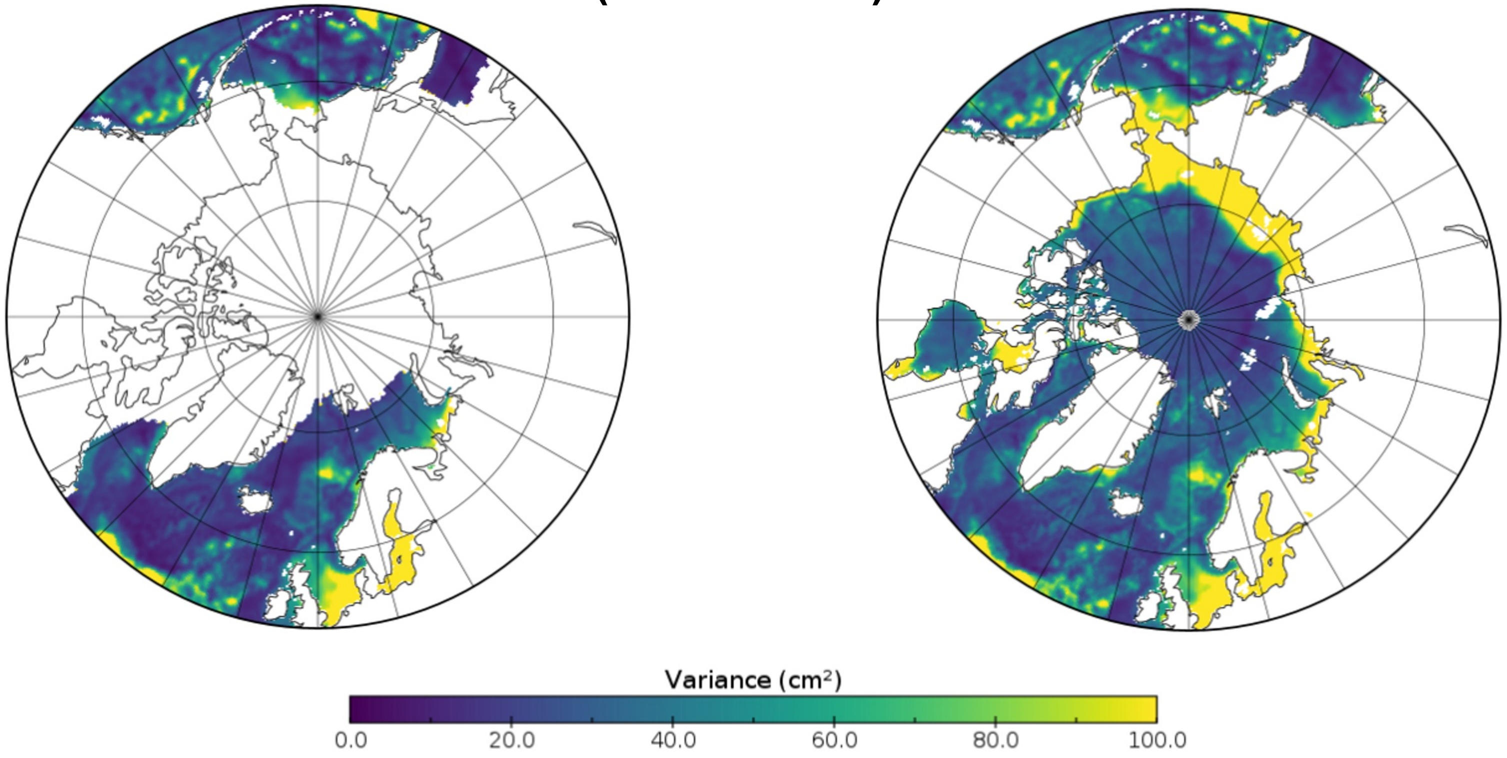
Potential of Enhanced Altimetry at the high-latitudes

AltiDoppler project: **Sentinel-3A, CryoSat-2, and SARAL/AltiKa altimetry** mission data are newly reprocessed and optimized for the Arctic Ocean

(2016 – 2020)

Standard (1 Hz) Altimetry Data

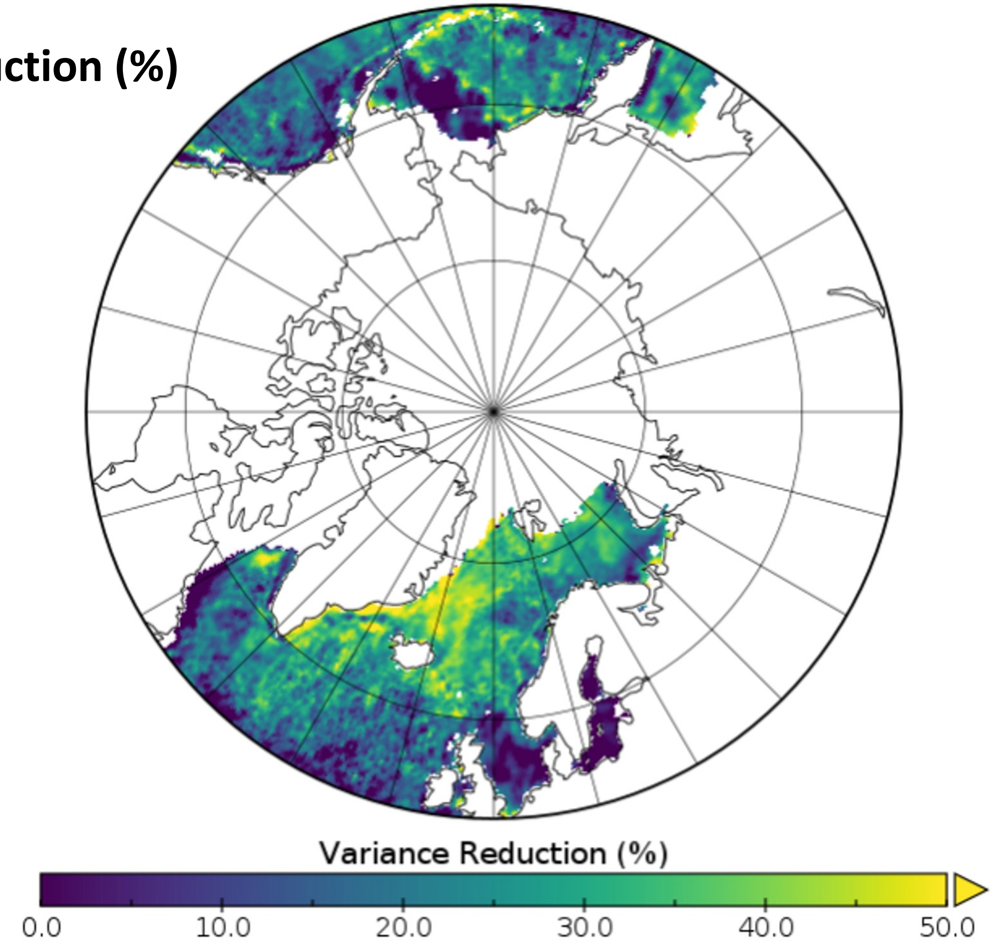
Experimental (5 Hz) Altimetry Data



Bonaduce et al., 2022, in prep

Potential of Enhanced Altimetry at the high-latitudes

SLA Variance Reduction (%)



Bonaduce et al., 2022, in prep

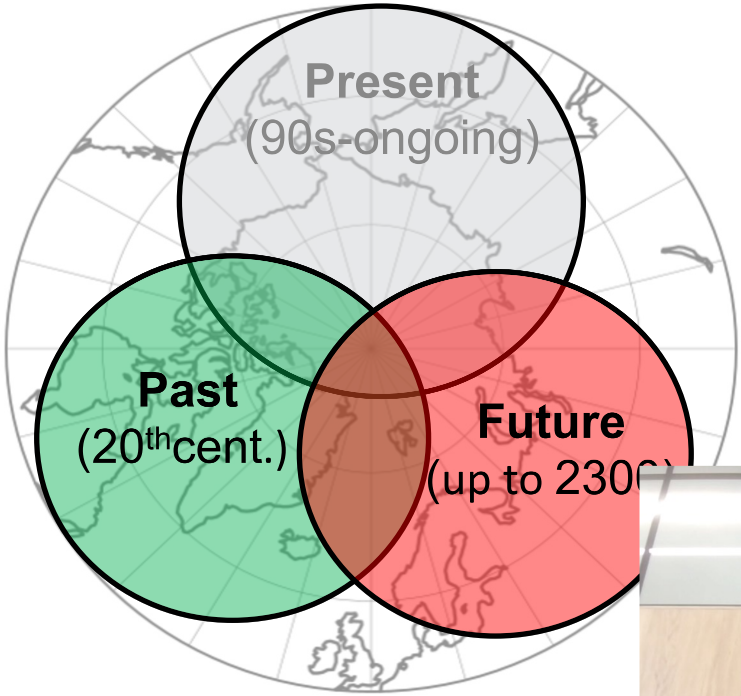
Sea Level Prediction and Reconstruction (SeaPR) Unit

Goal

SeaPR aims to establish a Sea Level Prediction and Reconstruction Unit at BCCR to provide and increase confidence in sea-level predictions and projections for more informed decision making.

2022-2025

- Understanding of the processes governing sea level during present times and assess predictability
- Reconstruct and attribute 20th century changes
- Project sea level with increased confidence

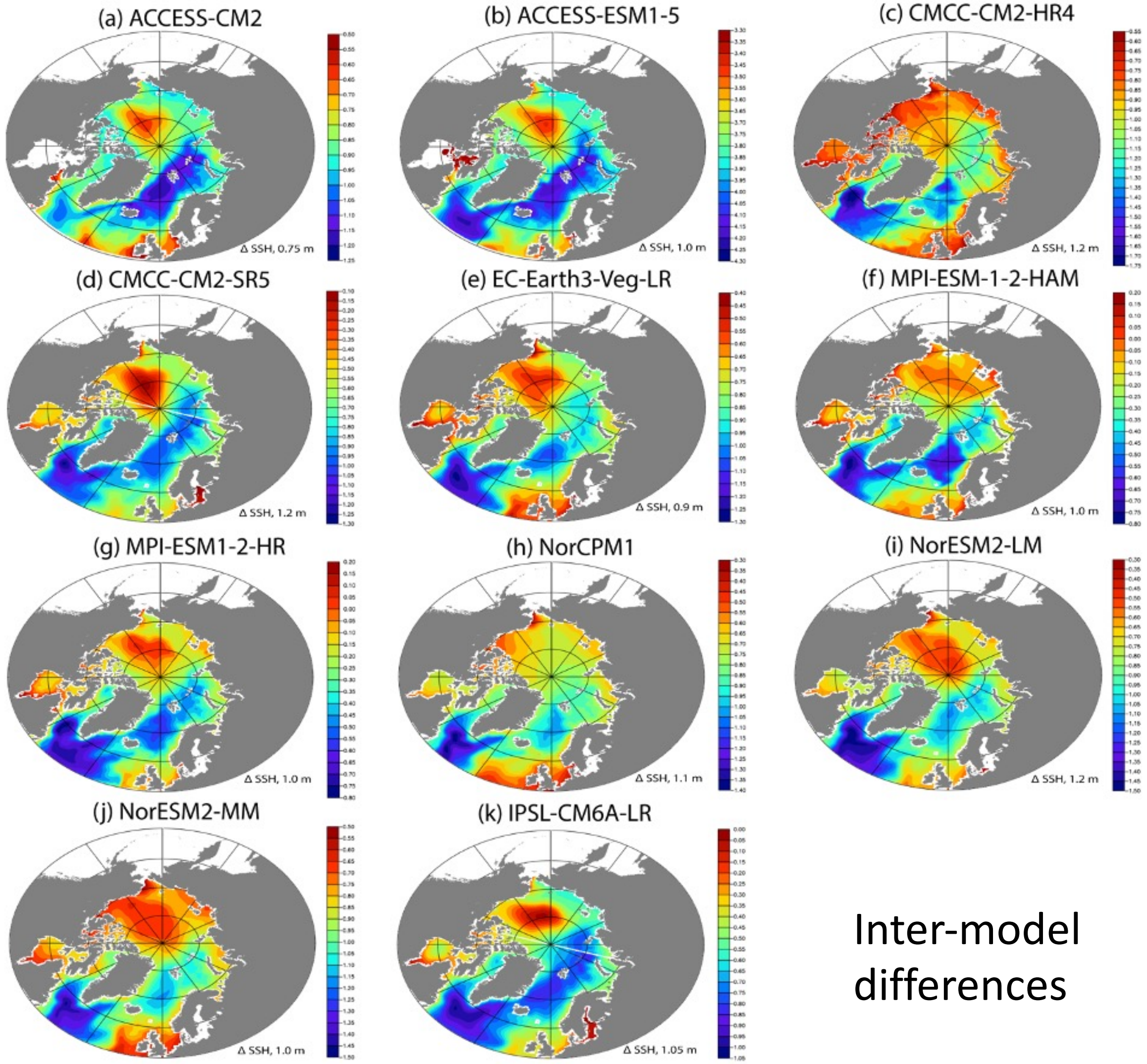


PI: A. Bonaduce, Co-PI: R. P. Raj, Co-PI: K.

Assessment of Arctic Sea Level in CMIP6 models

Assessment of Arctic Sea Level in CMIP6 models

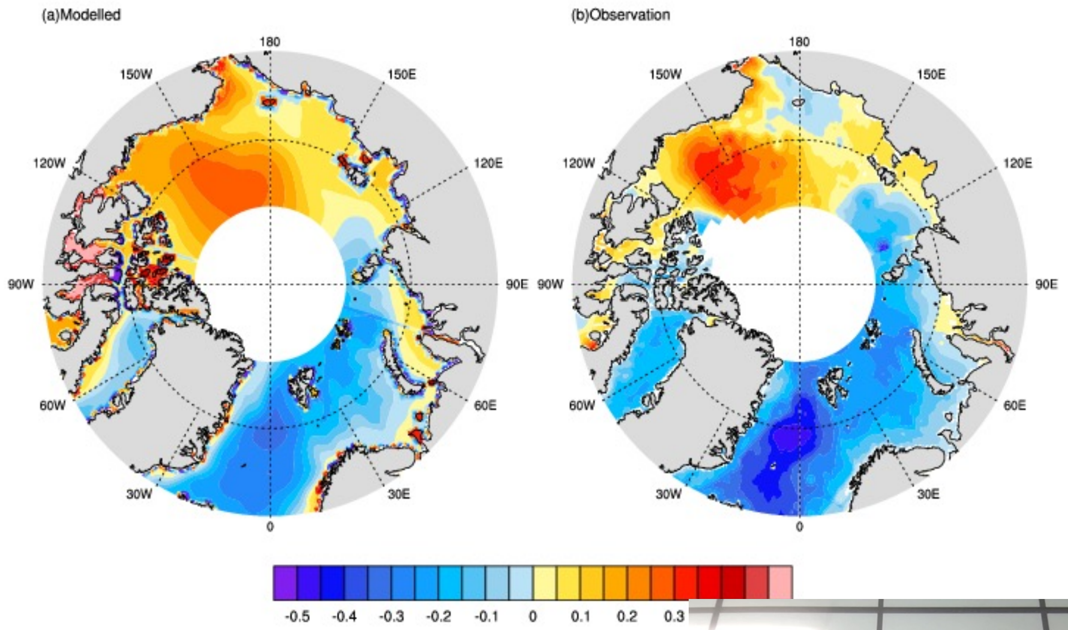
Mean SSH (1993-2014)



Inter-model differences

Ensemble Mean

Observations



Chatterjee et al., 2022

Assessment of Arctic Sea Level in CMIP6 models

1 ACCESS-CM2
2 ACCESS-ESM1-5
3 CAMS-CSM1-0
4 CIESM
5 CMCC-CM2
6 CMCC-CM2-SR5
7 CMCC-ESM2
8 CNRM-CM6-1
9 CNRM-ESM2-1
10 CanESM5-CanOE
11 CanESM5
12 E3SM-1-0
13 E3SM-1-1-ECA
14 E3SM-1-1
15 EC-Earth3-AerChem
16 EC-Earth3-CC
17 EC-Earth3-Veg-LR
18 FGOALS-f3-L
19 FGOALS-g3
20 FIO-ESM-2-0
21 GISS-E2-1-H
22 HadGEM3-GC31-LL
23 HadGEM3-GC31-MM
24 INM-CM4-8
25 INM-CM5-0
26 IPSL-CM6A-LR
27 KIOST-ESM
28 MIROC6
29 MPI-ESM1-2-HR
30 MPI-ESM1-2-LR
31 MRI-ESM2-0
32 NESM3
33 NorCPM1
34 NorESM2-MM
35 TaiESM1
36 UKESM1-0-LL

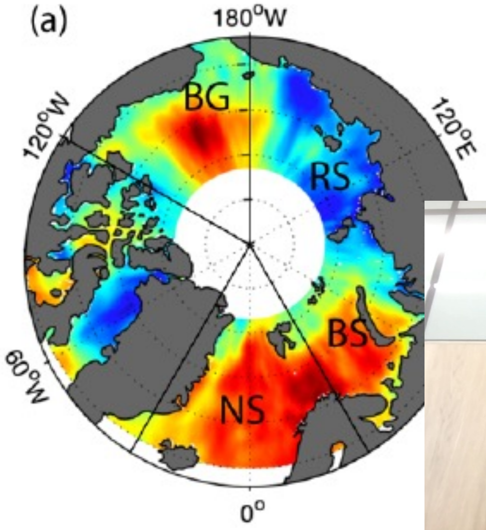
Raj et al., 2022b, in prep

Historical simulations
Monthly (1993-2014)

36 Climate models

ESA SLB CCI data

0.5 degree regrid



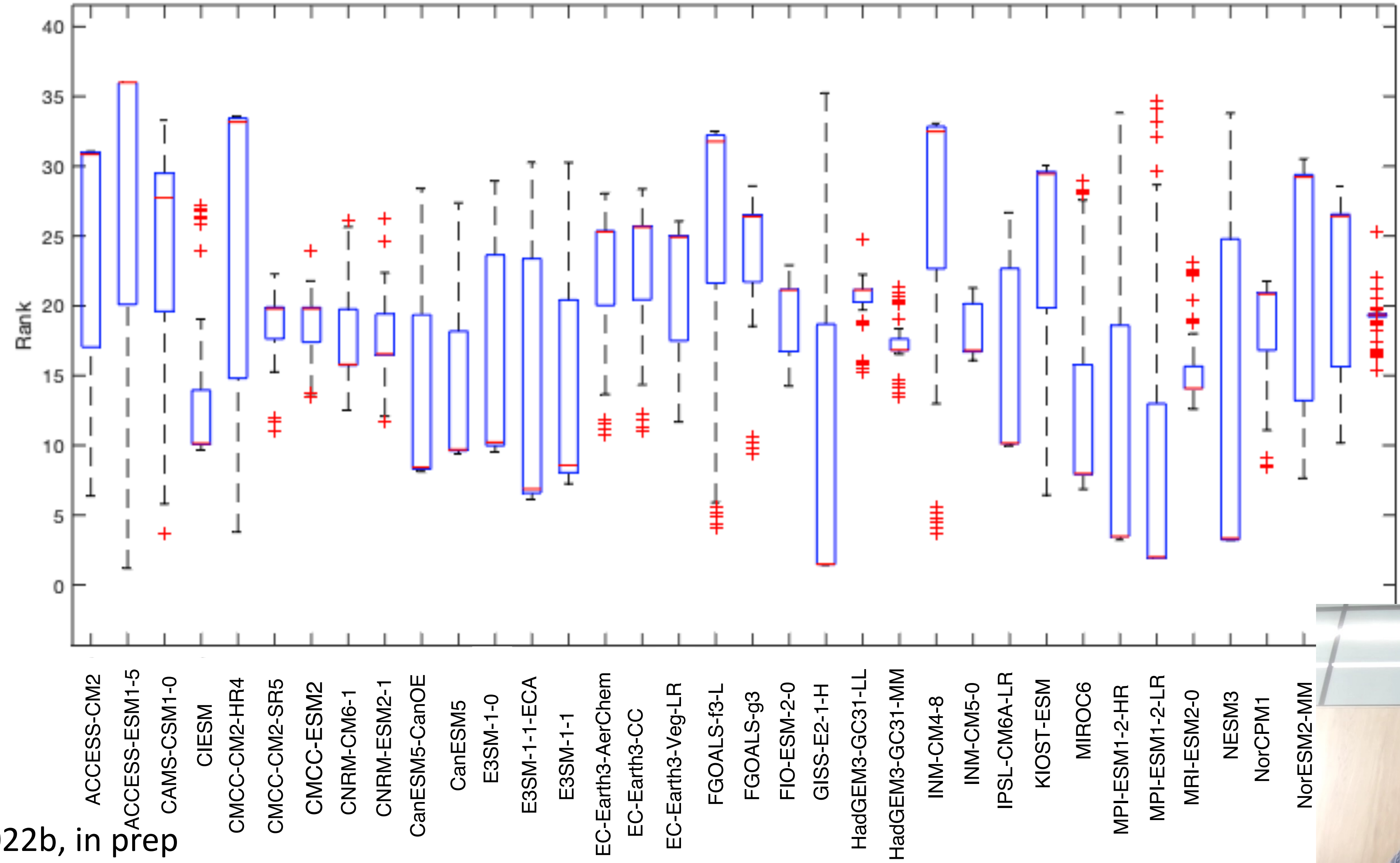
Assessment of Arctic Sea Level in CMIP6 models

1 Anomaly Correlation Coefficient (ACC)
2 Index of Agreement (d)
3 the Index of Agreement (d1)
4 the Modified Index of Agreement (d (Mod.))
5 the Index of Agreement Refined (dr)
6 Euclidean Distance (ED)
7 the Mean Absolute H2 Error (H2 (MAHE))
8 the Mean H2 Error (H2 (MHE))
9 the Root Mean Square H2 Error (H2 (RMSHE))
10 the Mean Absolute H3 Error (H3 (MAHE))
11 the Mean H3 Error (H3 (MHE))
12 the Root Mean Square H3 Error (H3 (RMSHE))
13 the Mean Absolute H4 Error (H4 (MAHE))
14 the Mean Absolute H5 Error (H5 (MAHE))
15 the Mean H5 Error (H5 (MHE))
16 the Root Mean Square H5 Error (H5 (RMSHE))
17 the Mean Absolute H7 Error (H7 (MAHE))
18 the Mean H7 Error (H7 (MHE))
19 the Root Mean Square H7 Error (H7 (RMSHE))
20 the Mean Absolute H10 Error (H10 (MAHE))
21 the Inertial Root Mean Square Error (IRMSE)
22 the Kling-Gupta Efficiency (2009) (KGE (2009))
23 the Kling-Gupta Efficiency (2012) (KGE (2012))
24 the Mean Arctangent Absolute Percentage Error (MAAPE)
25 the Mean Absolute Error (MAE)
26 the Mean Absolute Log Error (MALE)
27 the Mean Absolute Percentage Deviation (MAPD)
28 the Mean Absolute Scaled Error (MASE)
29 the Mielke-Berry R ((MB) R)
30 the Median Absolute Error (MdAE)
31 the Median Error (MdE)
32 the Median Squared Error (MdSE)
33 the Mean Error (ME)
34 the Mean Variance (MV)
35 the Mean Squared Error (MSE)
36 the Normalized Eclidean Distance (NED)
37 the Normalized Root Mean Square Error - IQR (NRMSE (IQR))
38 the Normalized Root Mean Square Error - Mean (NRMSE (Mean))
39 the Normalized Root Mean Square Error - Range (NRMSE (Range))
40 the Nash-Sutcliffe Efficiency (NSE)
41 the Modified Nash-Sutcliffe Efficiency (NSE (Mod.))
42 the Pearson Correlation Coefficient (R (Pearson))
43 the Coefficient of Determination (r2)
44 the Root Mean Square Error (RMSE)
45 the Spectral Angle (SA)
46 the Spectral Correlation (SC)
47 the Spectral Gradient Angle (SGA)
48 the Symmetric Mean Absolute Percentage Error (1
49 the Symmetric Mean Absolute Percentage Error (2
50 the Spearman Rank Correlation Coefficient (R (Sp
51 the Volumetric Efficiency (VE)
52 the Watterson s M (M)

52 Error Metrics

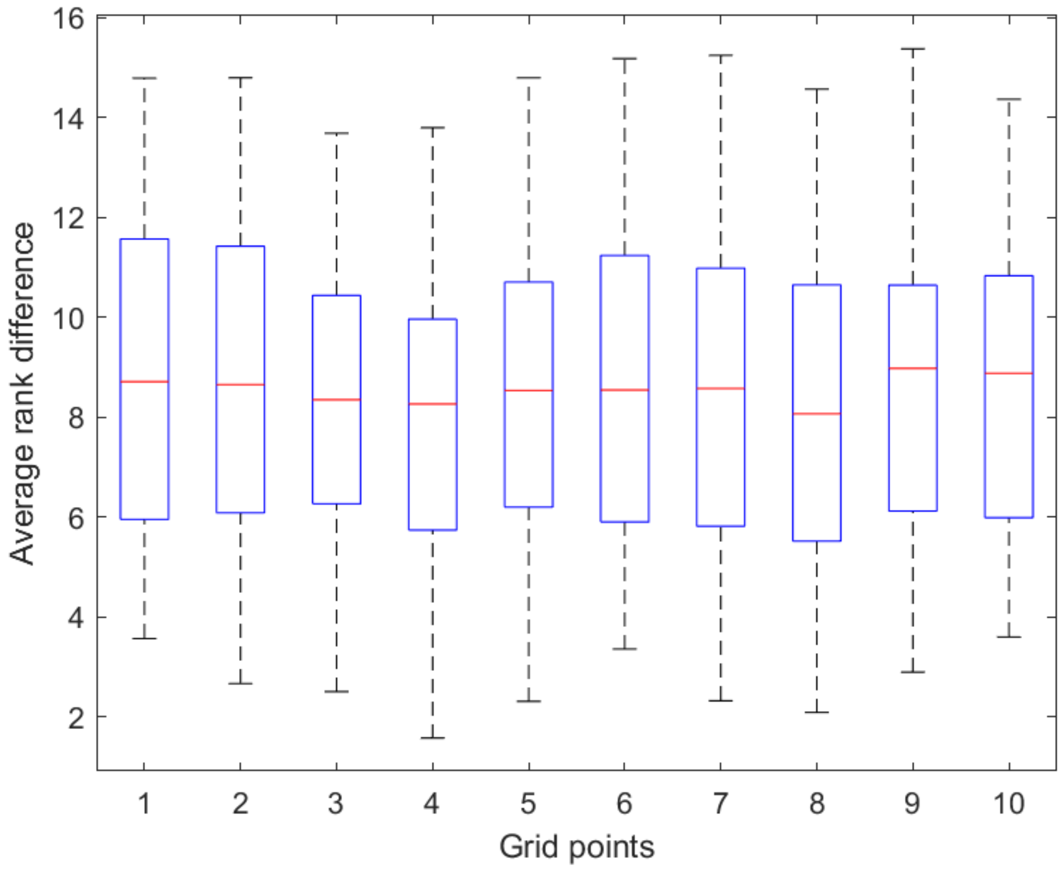
Raj et al.

Assessment of Arctic Sea Level in CMIP6 models



Raj et al., 2022b, in prep

Assessment of Arctic Sea Level in CMIP6 models



Box plot of average rank difference at random grid points

The average rank difference is determined as the mean of all pair-wise rank differences for any pair of metrics.

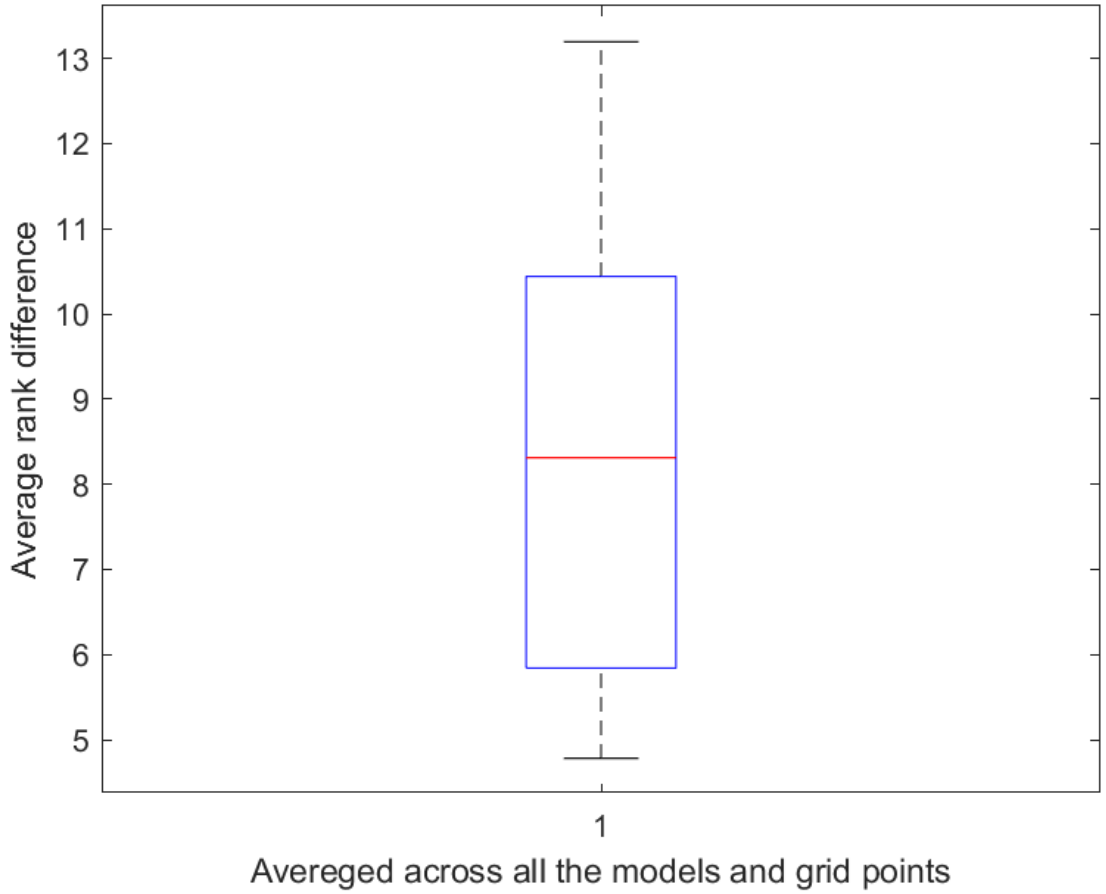
The following equation is used to estimate each individual rank difference (r_{ij})

$$r_{ij} = M_j - M_i$$

Where i = 1 to n-1 and j = 2 to n. n is the total number of error metrics.

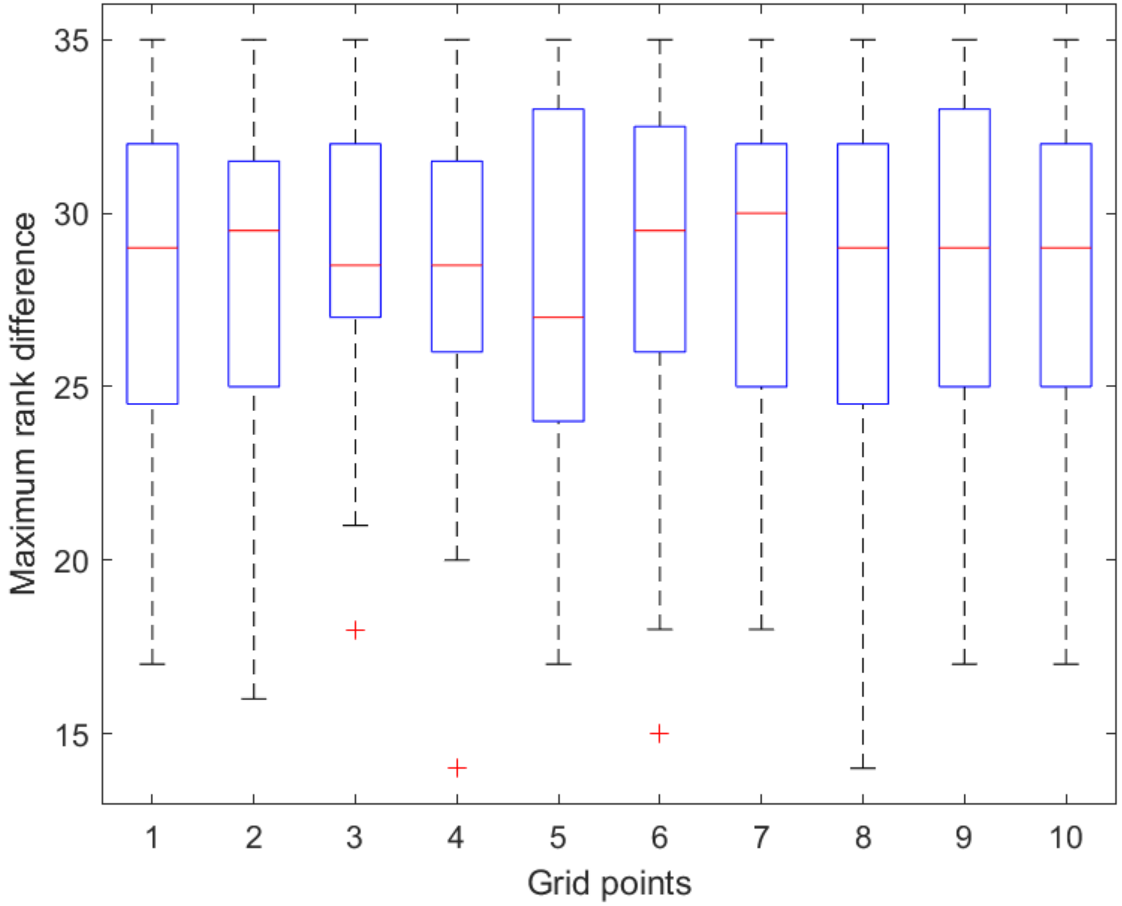
Raj et al., 2022b, in prep

Assessment of Arctic Sea Level in CMIP6 models



Box plot of the mean of average rank difference across all the grid points

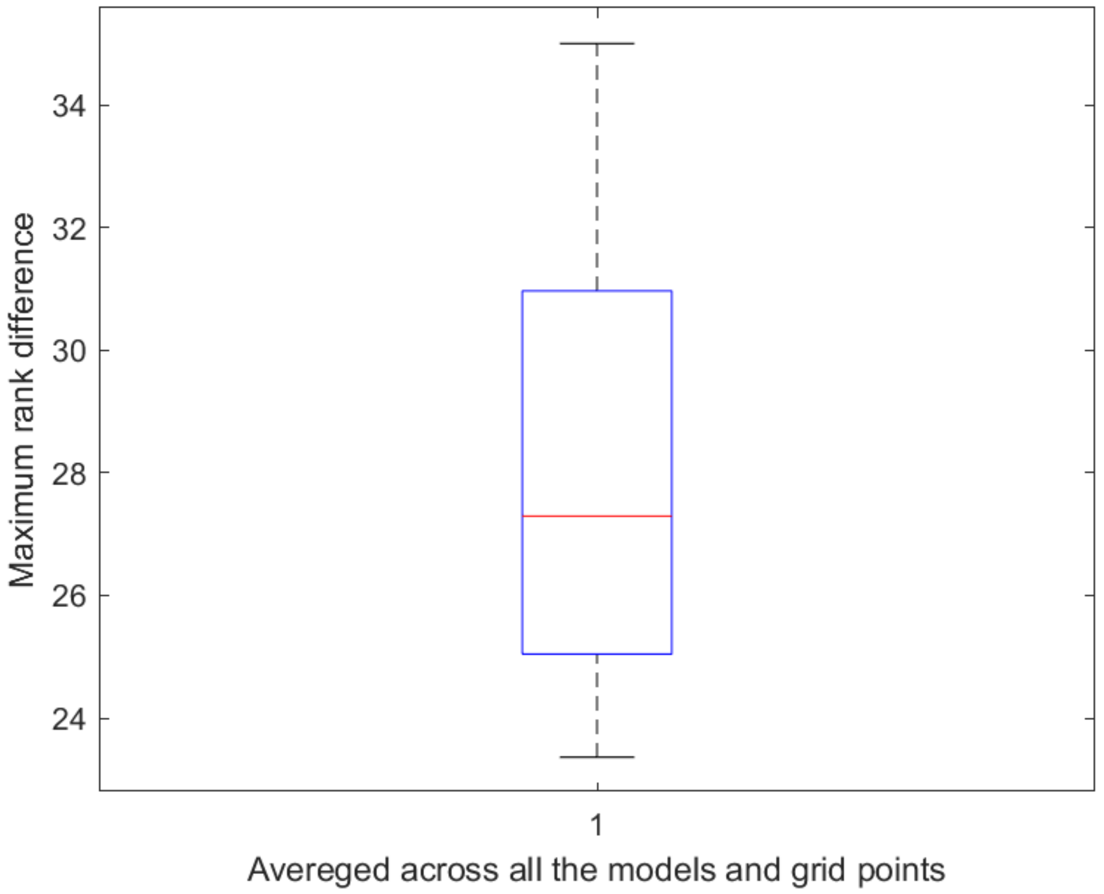
Assessment of Arctic Sea Level in CMIP6 models



Box plot of maximum rank difference at random grid points

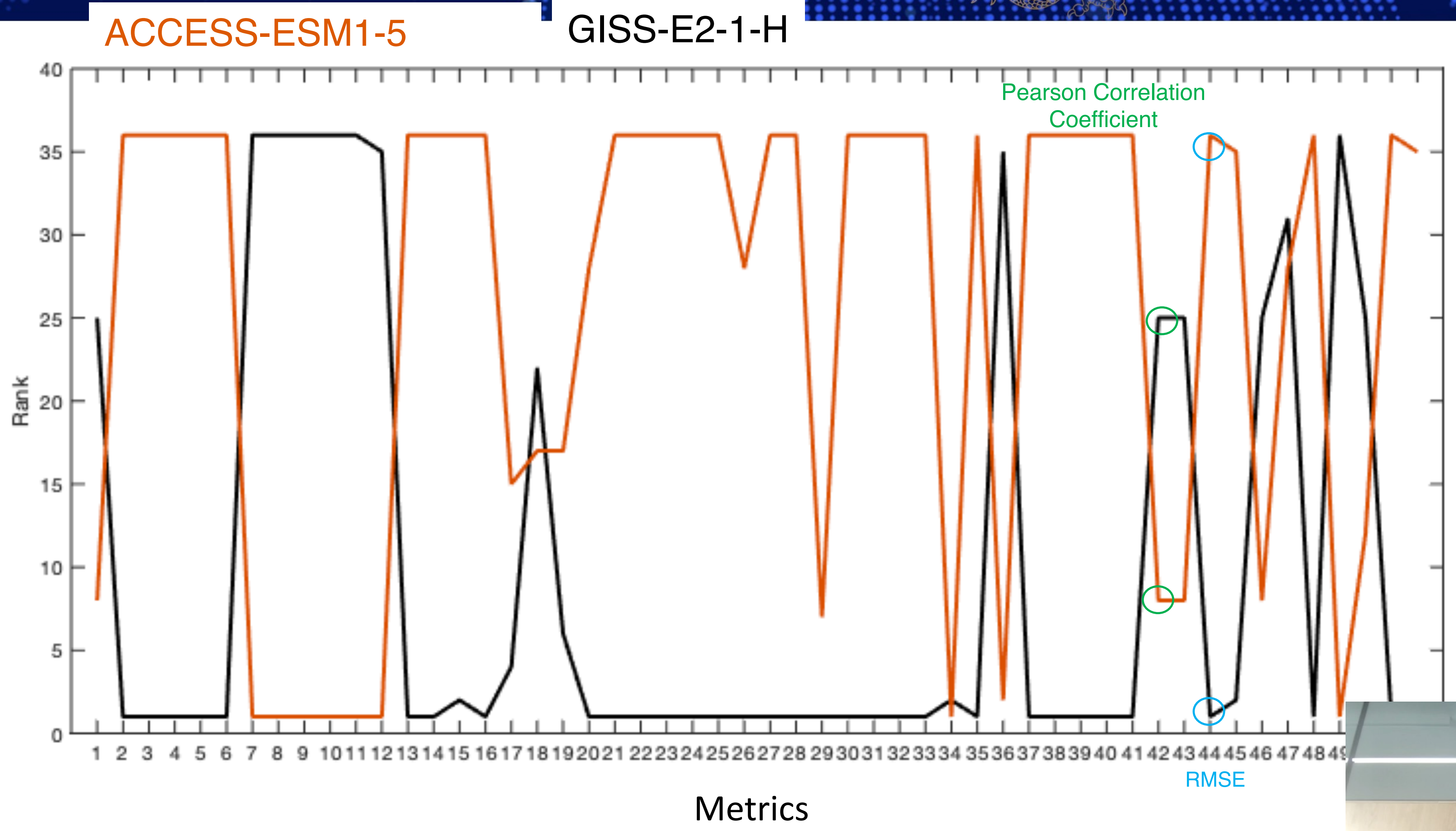
The maximum rank difference is determined as the maximum of all pair-wise rank differences for any pair of metrics.

Assessment of Arctic Sea Level in CMIP6 models



Box plot of the mean of maximum rank difference across all the grid points

Assessment of Arctic Sea Level in CMIP6 models

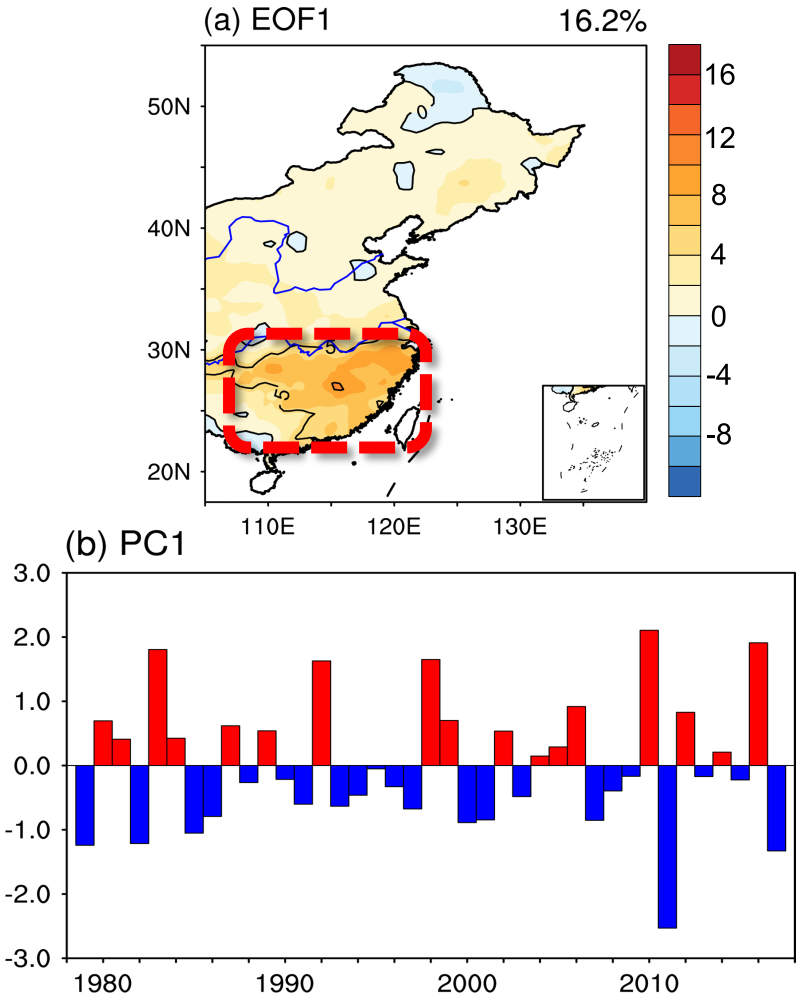


Teleconnection impacts

Zhang Mengqi, Sun Jianqi, 2021: Impact of October snow cover in central Siberia on the following spring extreme precipitation frequency in southern China. *Frontiers in Earth Science,* 9: 785601, doi: 10.3389/feart.2021.785601.

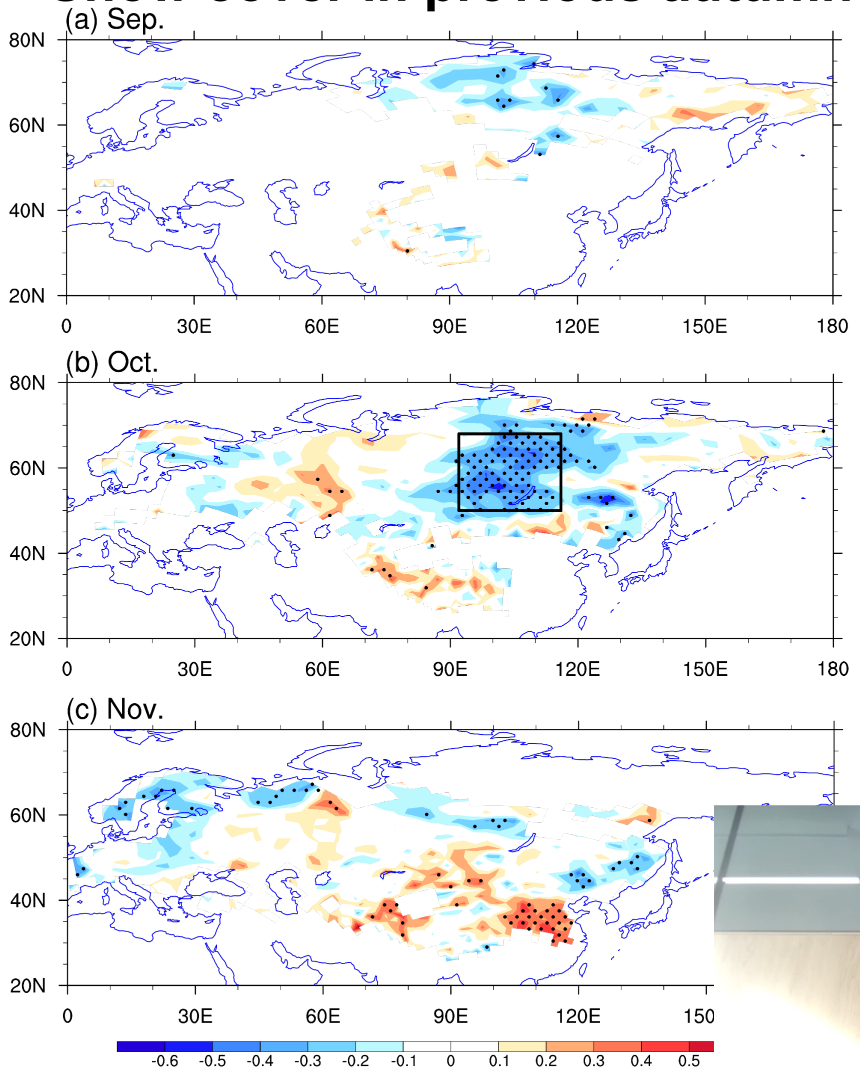
Impact of Snow on South China spring extreme precipitation

EOF1 of spring extreme precipitation frequency



Extreme precipitation: larger than 90th percentile of all rainy days in spring

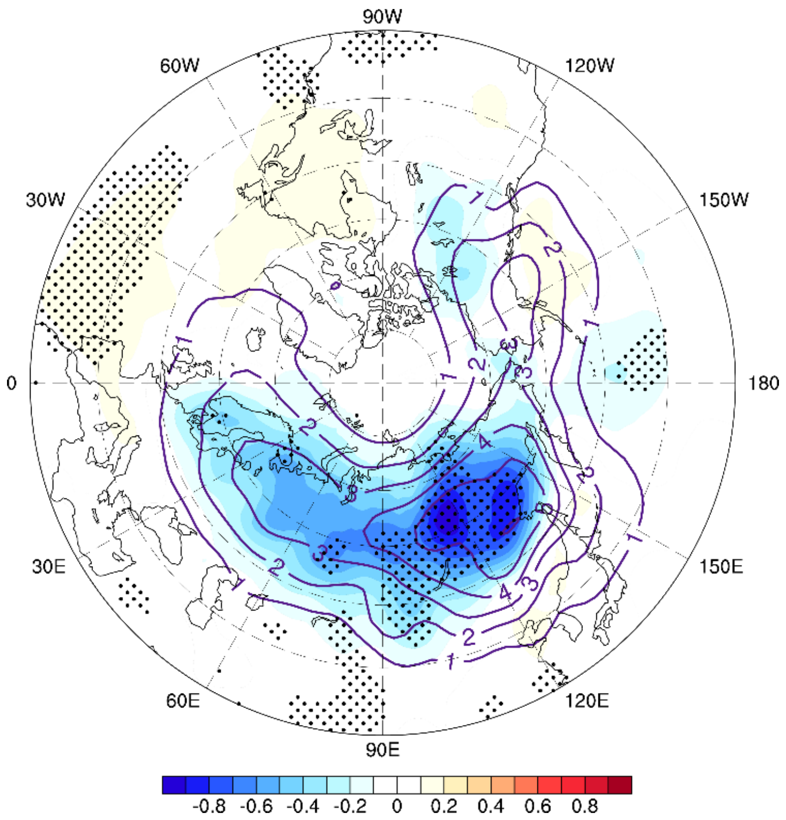
Snow cover in previous autumn



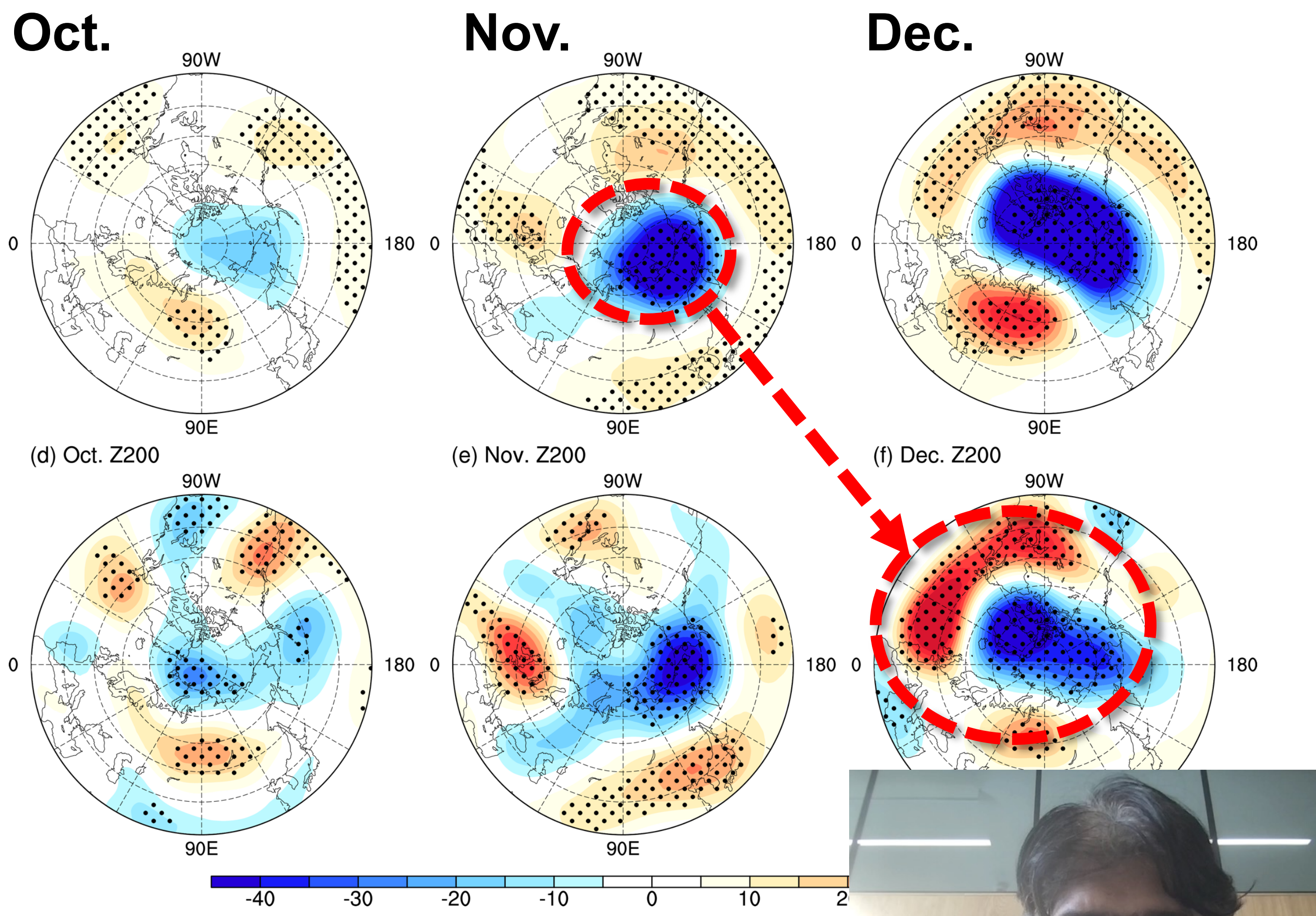
(Zhang and Sun 2

Circulation anomalies related to October Snow reduction

Oct. 50 hPa vertical wave activity flux



50 hPa + 200 hPa geopotential height

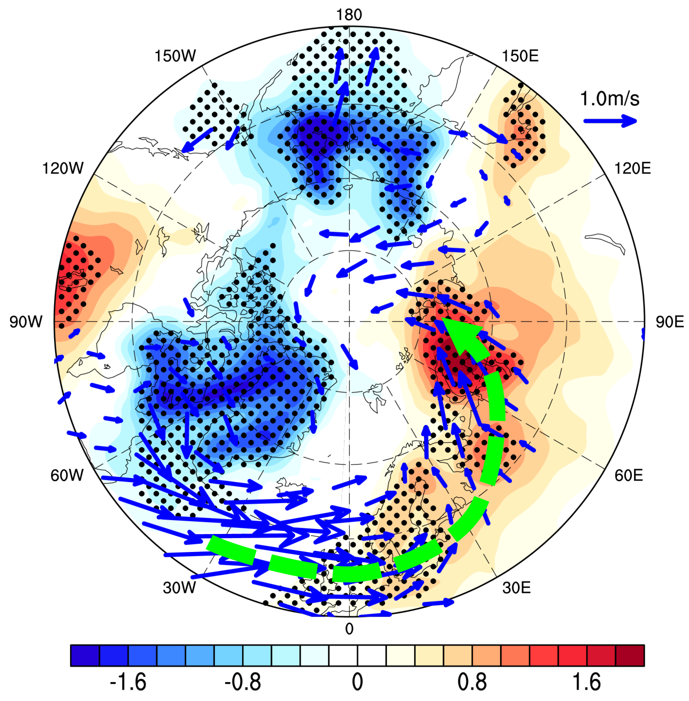


Oct. snow decrease → **Strengthened stratospheric polar vortex** → **Dec**

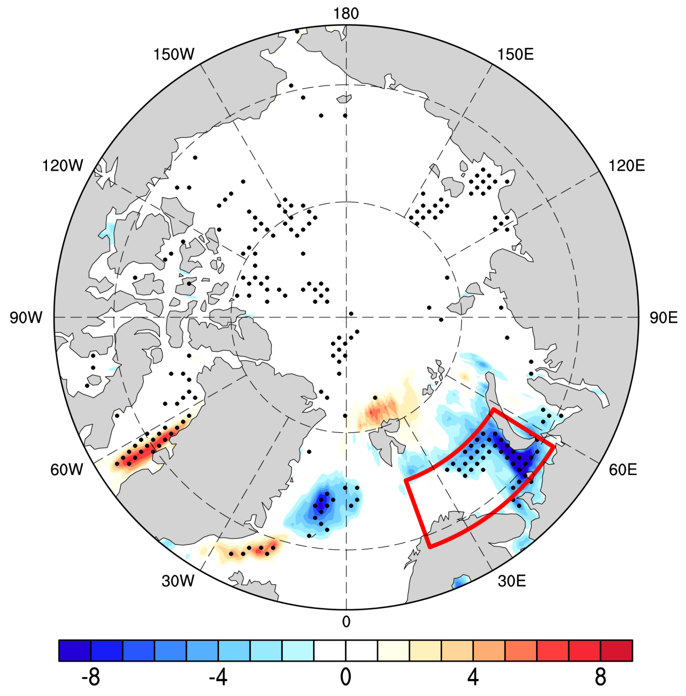
(Zhang and Sun 2

Winter circulation anomalies related to October Snow reduction

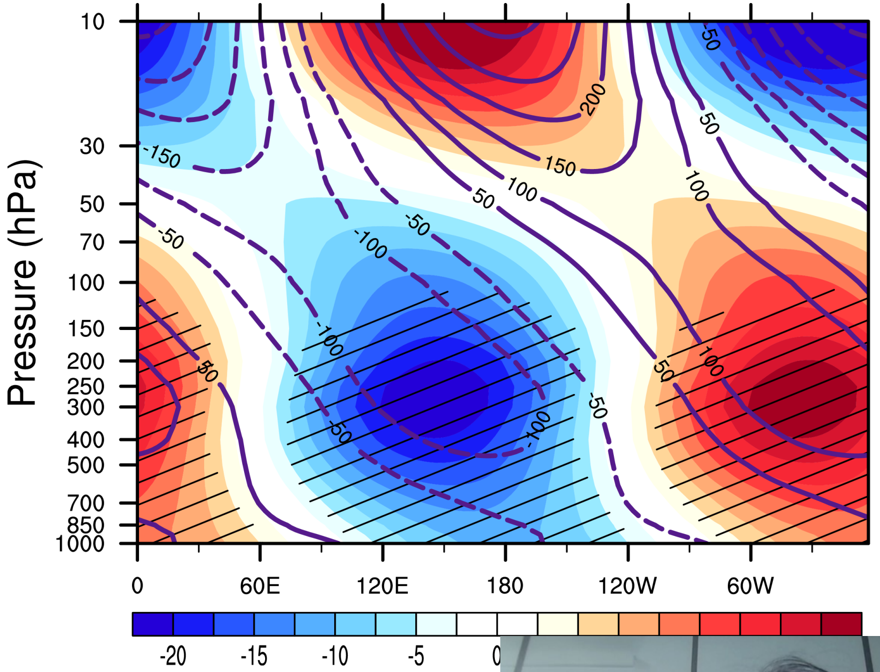
Dec. surface wind + air temperature



Jan. – Feb. Arctic Sea ice



Jan. – Feb. zonal wavenumber-1 component

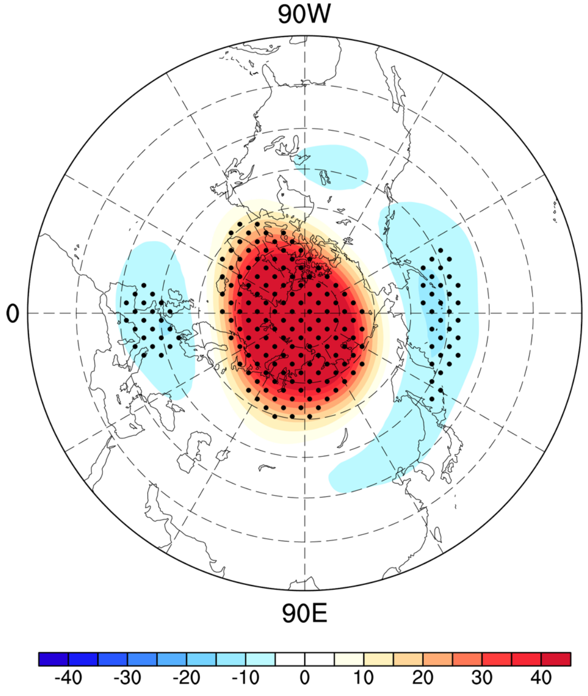


Dec. NAO → **Barents–Kara sea ice decrease** → **Zonal wavenumber-1 component** → **U**

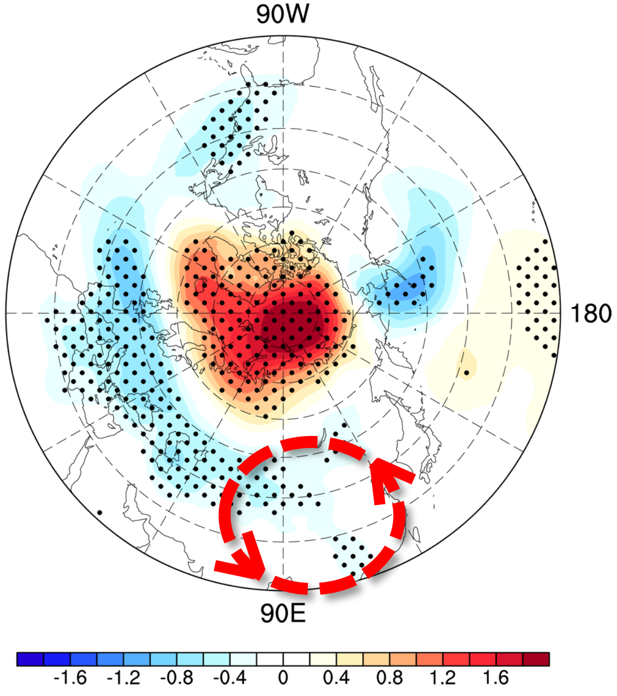
(Zhang and Sun 2

Spring circulation anomalies related to October Snow reduction

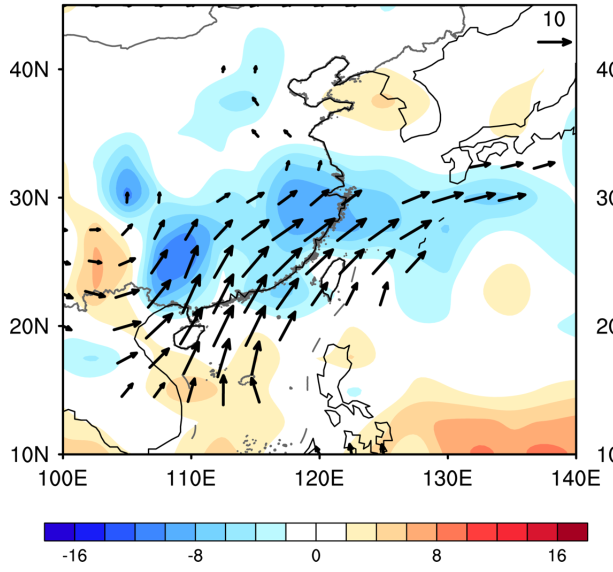
50 hPa geopotential height



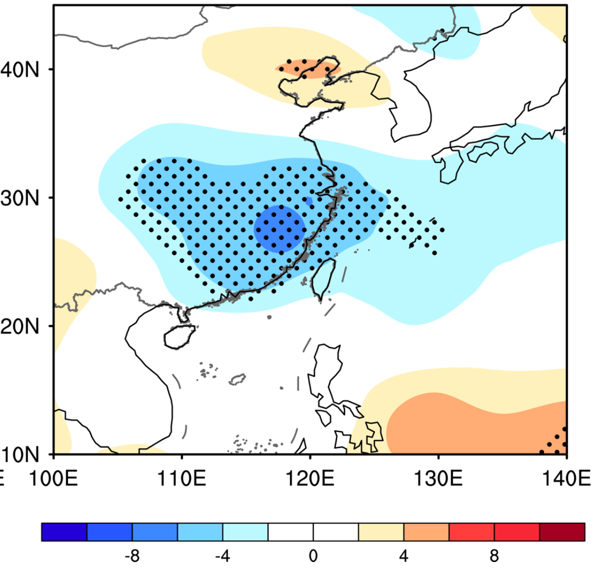
Sea level pressure



Moisture



500hPa omega



Weakened Stratospheric polar vortex → Negative AO → East Asian cyclone → S

(Zhang and Sun 2

Project's schedule, planning & contribution of the partners for the following year

	2020		2021				2022				2023				2024	
	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2
Kick-Off	x															
Young Scientist 1 (MSc)									x	x						
Young Scientist 2 (MSc)													x	x		
Annual reporting				x				x				x				x
Scientific paper 1				x												
Scientific paper 2						x										
Scientific paper 3										x						
Scientific paper 4														x		
Final report																x

Contribution of the partners for the following year

Working on a **Joint paper (Paper 3)** on the Pacific modulation of the Beaufort Sea sea level
Yang Liu (C), Jianqi Sun (C), Roshin. P. Raj (N)

Training of young scientists on the project, including plans for academic exchanges

Norway

- Training of two MSc students from UiB respectively during autumn 2022 and 2023.

China

- Ms. Yunrun Tian is a PhD candidate with a research focus on climate linkage between the Arctic and the lower-latitudes.
- Ms. Sichang Liu is a Master candidate with a research focus on climate variability over the Northern mid-to-high latitude.

Project ---- On track

Thank you !!!

Questions ?

email: *roshin.raj@nersc.no*