HiLAT-RASM: High-Latitude Application and Testing of Earth System Models - Phase II

October 14, 2020

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CU Boulder

HiLAT-RASM

- Collaboration between
  - HiLAT SFA: High-Latitude Application and Testing of Earth System Models
    - hilat.org
  - RASM project: Regional Arctic System Model
    - my.nps.edu/web/rasm
- Project partners
  - LANL: Los Alamos National Laboratory
  - PNNL: Pacific Northwest National Laboratory
  - NPS: Naval Postgraduate School
  - UW: University of Washington
  - CU Boulder: University of Colorado, Boulder
- Plus many collaborators

LANL lead:
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NPS lead:
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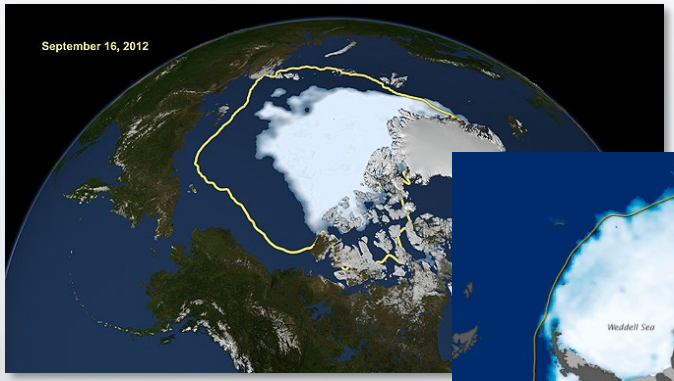
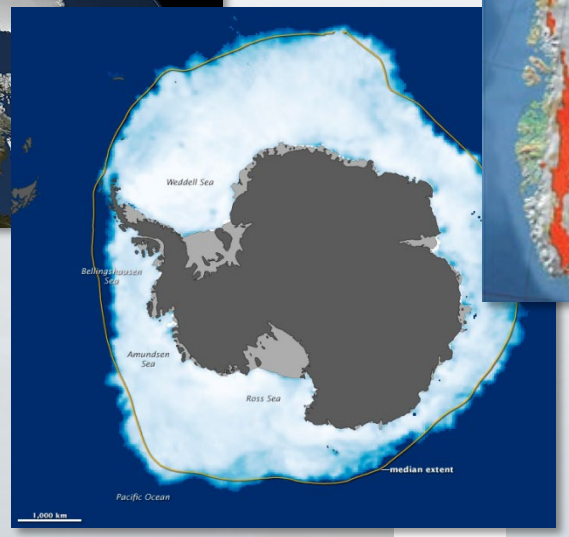
HiLAT-RASM

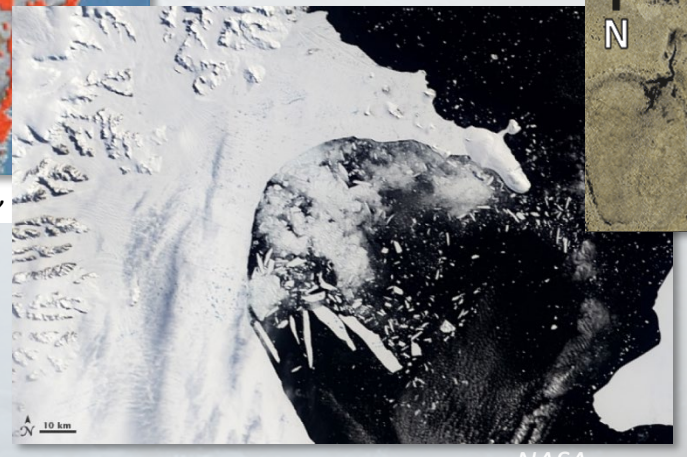
- The high-latitude Earth systems are changing fast, with global implications.
- Our ability to predict the evolution of the high-latitude Earth systems is *limited by incomplete knowledge* of the processes that govern the systems' variability, and response to continued anthropogenic forcing.



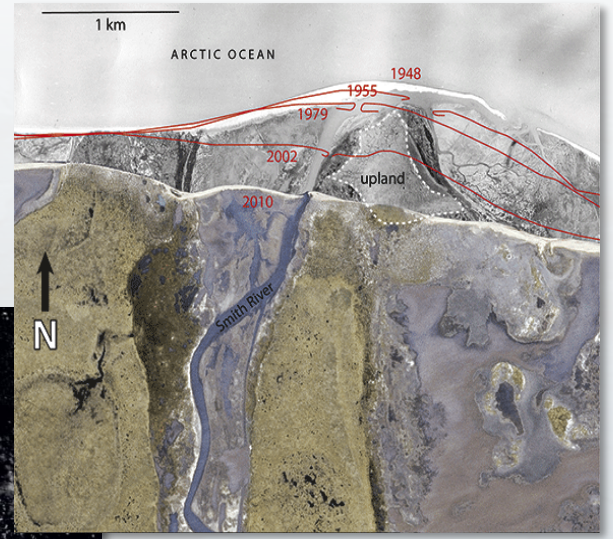


NASA

ACIA,



NASA

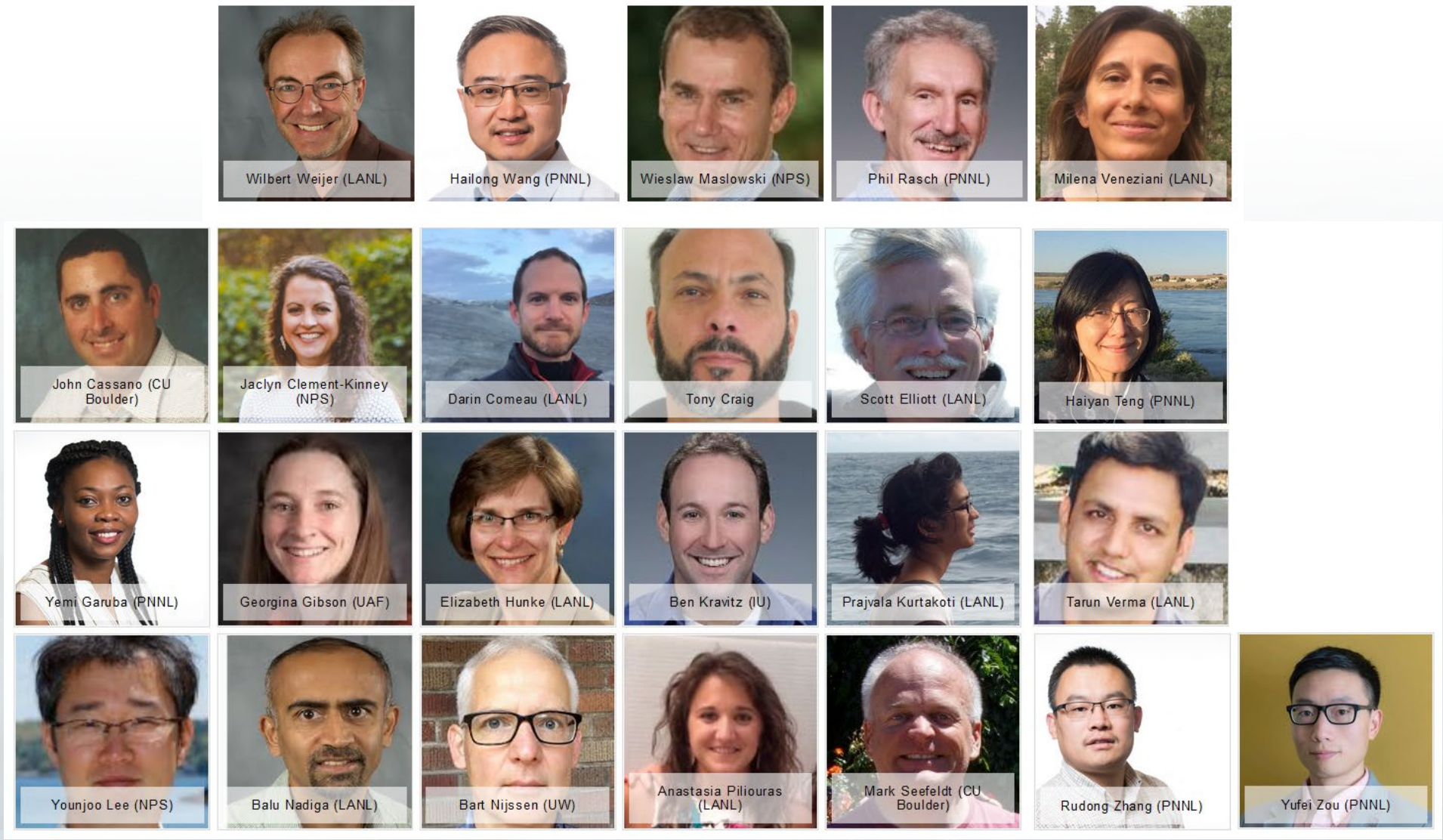


USGS

HiLAT-RASM: Goal

- *Reduce uncertainties* and *enhance predictive understanding* of high-latitude environmental change and its global consequences
- Use a hierarchy of global and regional models to understand:
  - the *transport and exchange processes* between high and low latitudes
  - the *regional feedbacks* that modulate the high-latitude response to these exchanges
- High-latitude Earth system components are tightly coupled
  - ***Studying high-latitude processes and feedbacks requires integrative approach***

The Team


Wilbert Weijer (LANL)
Hailong Wang (PNNL)
Wieslaw Maslowski (NPS)
Phil Rasch (PNNL)
Milena Veneziani (LANL)
John Cassano (CU Boulder)
Jaclyn Clement-Kinney (NPS)
Darin Comeau (LANL)
Tony Craig
Scott Elliott (LANL)
Haiyan Teng (PNNL)
Yemi Garuba (PNNL)
Georgina Gibson (UAF)
Elizabeth Hunke (LANL)
Ben Kravitz (IU)
Prajvala Kurtakoti (LANL)
Tarun Verma (LANL)
Younjoo Lee (NPS)
Balu Nadiga (LANL)
Bart Nijssen (UW)
Anastasia Piliouras (LANL)
Mark Seefeldt (CU Boulder)
Rudong Zhang (PNNL)
Yufei Zou (PNNL)

Our Themes and Topics

Theme 1 – Role of sea ice in mediating meridional heat transports in the ocean and atmosphere

Topic 1.1: Partitioning of meridional heat transport: The Arctic

Topic 1.2: Partitioning of meridional heat transport: The Southern Ocean

Theme 2 – Role of fine-scale and transboundary transport processes in Arctic change

Topic 2.1: Impact of fine-scale processes on Arctic Amplification

Topic 2.2: The impact of changes in riverine fluxes on Arctic warming

Theme 3 – Extra-polar impacts of Arctic change

Topic 3.1: Arctic impacts on mid-latitude weather and climate

Topic 3.2: Regimes, variability, and impacts of the Arctic Ocean and sea ice circulation

Theme 4 – Decadal predictability of high-latitude environmental change

Topic 4.1: Reduced modeling of high-latitude predictability

Topic 4.2: Dynamical downscaling of Arctic predictability

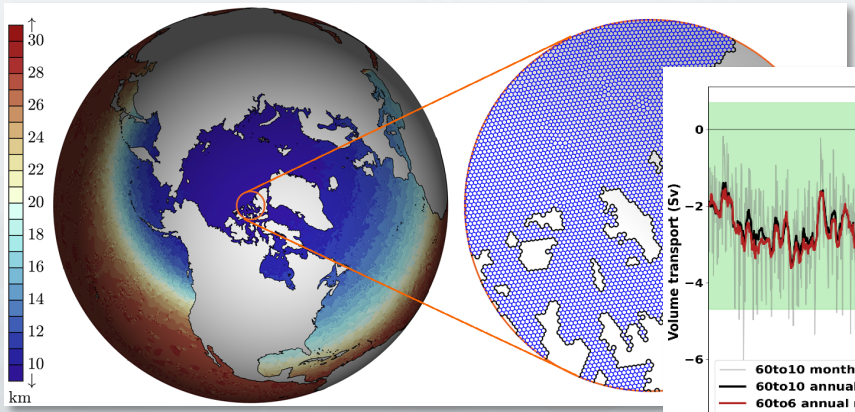
Accomplishments

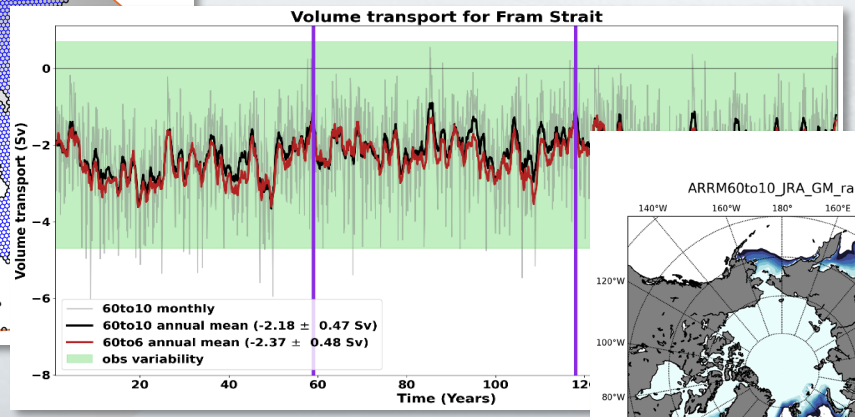
- HiLAT-RASM Publications
  - 2019: **17** first author (25 total)
  - 2020: **14** first author (31 total)
  - In review: **7** first author (12 total)
- Community integration
  - We organized RGMA high-latitude webinar series
- Leadership
  - Polar CORDEX
  - IARPC
  - US CLIVAR
  - AGU
  - CICE Consortium
  - MOSAiC
  - WMO Study Group on Cryosphere (SG-Cryo)

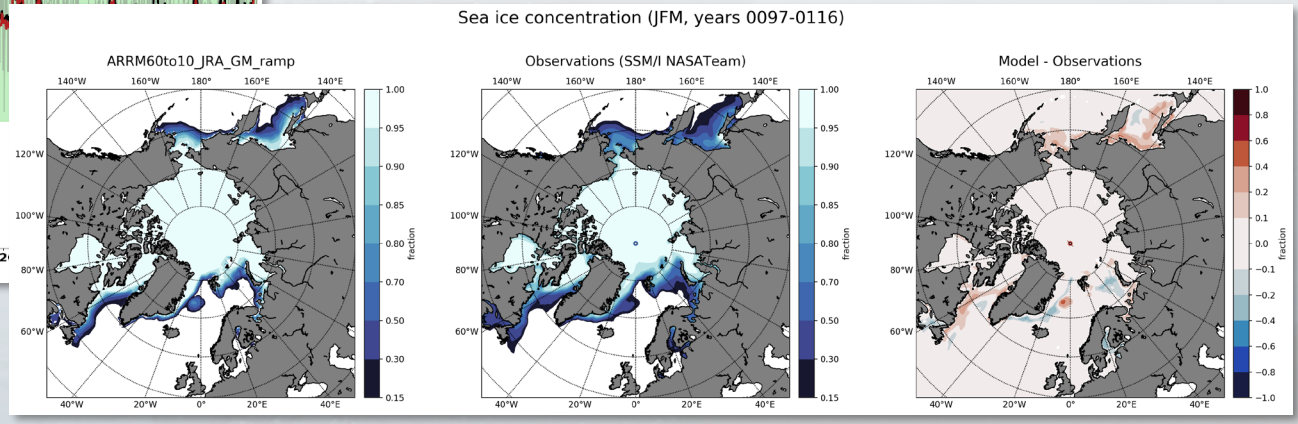
E3SM-Arctic

- Our team is working on Arctic-refined configurations of E3SM: *E3SM-Arctic*
  - Ocean-sea ice configuration (JRA55-forced)
  - Two grids: *60-to-10* and *60-to-6*
  - Key metrics are well represented
    - Veneziani et al. (in review)
  - Currently working on a fully-coupled configuration

Presentation:
Milena Veneziani
High-Latitudes breakout
Today 15:09-15:16







Veneziani et al. (in review)

RGMA CMIP6 Analysis Activity

- We co-organized the RGMA CMIP6 Analysis Activity

Presentation:
Wilbert Weijer
Plenary
Tomorrow 13:30-13:50

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Home » News » DOE Scientists Take on Colossal CMIP6 Data Analysis Challenge

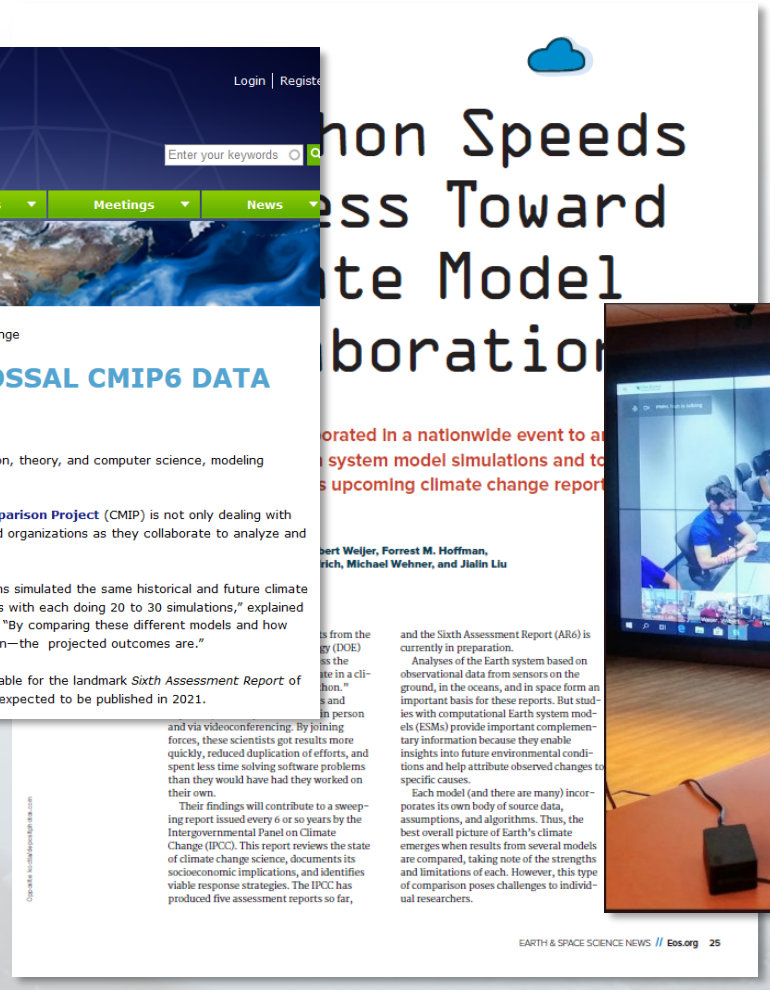
DOE SCIENTISTS TAKE ON COLOSSAL CMIP6 DATA ANALYSIS CHALLENGE

Global earth system modeling is a complex science. In addition to observation, theory, and computer science, modeling involves model output "data"—*a lot of data*.

A massive task for scientists contributing to the **Coupled Model Intercomparison Project** (CMIP) is not only dealing with the vast quantities of data, but integrating activities across the project and organizations as they collaborate to analyze and compare simulation output from modeling centers around the world.

In the case of the current phase, CMIP6, international research organizations simulated the same historical and future climate scenarios with their own earth system models. "We have 40 different models with each doing 20 to 30 simulations," explained Wilbert Weijer, an oceanographer at Los Alamos National Laboratory (LANL). "By comparing these different models and how they simulate the same scenarios, we can measure how robust—or uncertain—the projected outcomes are."

These outcomes—documented in the form of published papers—will be available for the landmark *Sixth Assessment Report* of the **Intergovernmental Panel on Climate Change** (IPCC). The report is expected to be published in 2021.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system model simulations and to
upcoming climate change report
bert Weijer, Forrest M. Hoffman,
rich, Michael Wehner, and Jialin Liu
and the Sixth Assessment Report (AR6) is currently in preparation.
Analyses of the Earth system based on observational data from sensors on the ground, in the oceans, and in space form an important basis for these reports. But studies with computational Earth system models (ESMs) provide important complementary information because they enable insights into future environmental conditions and help attribute observed changes to specific causes.
Each model (and there are many) incorporates its own body of source data, assumptions, and algorithms. Thus, the best overall picture of Earth's climate emerges when results from several models are compared, taking note of the strengths and limitations of each. However, this type of comparison poses challenges to individual researchers.
and via videoconferencing. By joining forces, these scientists got results more quickly, reduced duplication of efforts, and spent less time solving software problems than they would have had they worked on their own.
Their findings will contribute to a sweeping report issued every 6 or so years by the Intergovernmental Panel on Climate Change (IPCC). This report reviews the state of climate change science, documents its socioeconomic implications, and identifies viable response strategies. The IPCC has produced five assessment reports so far,
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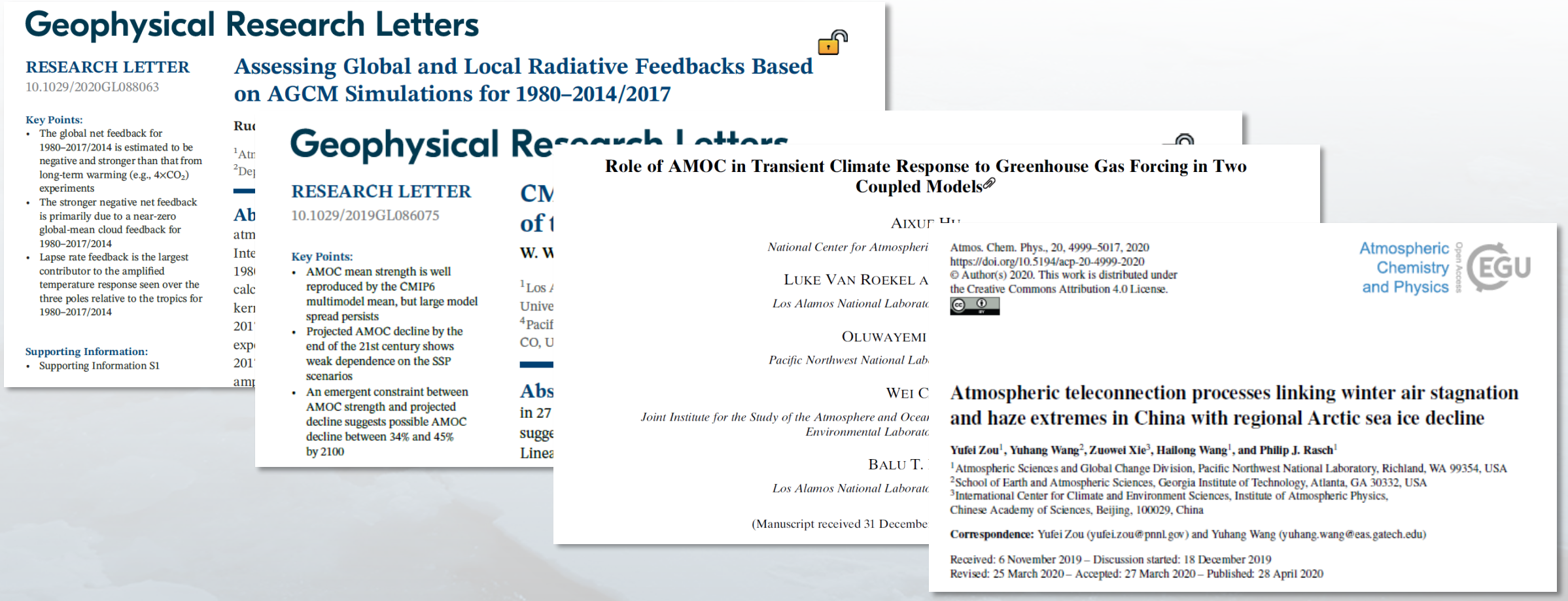
CMIP6 Analyses

- We published several CMIP6 analyses



Geophysical Research Letters

RESEARCH LETTER
10.1029/2020GL088063

Assessing Global and Local Radiative Feedbacks Based on AGCM Simulations for 1980–2014/2017

Key Points:
- The global net feedback for 1980–2017/2014 is estimated to be negative and stronger than that from long-term warming (e.g., 4×CO_2) experiments
- The stronger negative net feedback is primarily due to a near-zero global-mean cloud feedback for 1980–2017/2014
- Lapse rate feedback is the largest contributor to the amplified temperature response seen over the three poles relative to the tropics for 1980–2017/2014

Supporting Information:
- Supporting Information S1

Geophysical Research Letters

RESEARCH LETTER
10.1029/2019GL086075

Key Points:
- AMOC mean strength is well reproduced by the CMIP6 multimodel mean, but large model spread persists
- Projected AMOC decline by the end of the 21st century shows weak dependence on the SSP scenarios
- An emergent constraint between AMOC strength and projected decline suggests possible AMOC decline between 34% and 45% by 2100

Role of AMOC in Transient Climate Response to Greenhouse Gas Forcing in Two Coupled Models

Atmospheric Chemistry and Physics

Atmos. Chem. Phys., 20, 4999–5017, 2020
https://doi.org/10.5194/acp-20-4999-2020
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Atmospheric teleconnection processes linking winter air stagnation and haze extremes in China with regional Arctic sea ice decline

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Revised: 25 March 2020 – Accepted: 27 March 2020 – Published: 28 April 2020

Involvement in Other MIPs

- ISMIP6
  - Alice Barthel
- SIMIP6
  - Elizabeth Hunke
- FAFMIP
  - Yemi Garuba
- Polar CORDEX
  - John Cassano, Wieslaw Maslowski

Theme 1 – Role of sea ice in mediating meridional heat transports in the ocean and atmosphere

We are exploring:

- Polynyas and high-latitude air/sea exchange
  - *Kaufman et al. (2020)*
  - *Kurtakoti et al. (2018; in review)*
  - *Lee et al. (in prep)*
  - *Veneziani et al. (in prep)*
- Atlantic Meridional Overturning Circulation
  - *Weijer et al. (2019, 2020)*
  - *Hu et al. (2020)*
  - *Hirschi et al. (2020)*
  - *Cheng et al. (2018)*
- Feedbacks between ocean, atmosphere, and sea ice through Partial-Coupling experiments
  - *Garuba and Rasch (2020)*
  - *Garuba et al. (in review; in prep)*

Presentations:

Oluwayemi Garuba
High Latitudes breakout
Today 14:41-14:48

Wilbert Weijer
High-Latitudes breakout
Today 14:48-14:55

Younjoo Lee
High Latitudes breakout
Today 14:55-15:02

Aixue Hu
Multi-year breakout
Today 14:06-14:12

Ariel Morrison
Clouds breakout
Today 14:30-14:35

Wei Cheng
Plenary
Tomorrow 17:30-17:40

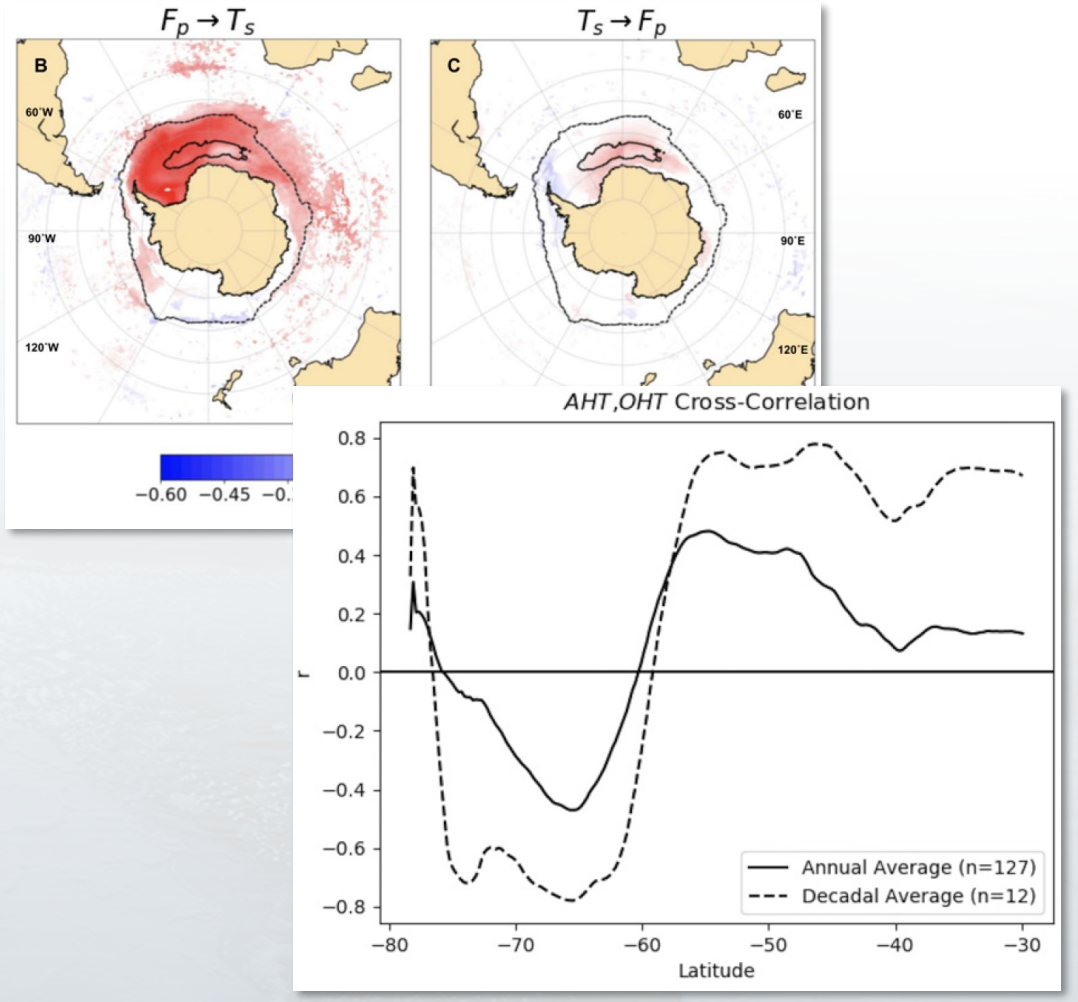
Theme 1 – Role of sea ice in mediating meridional heat transports in the ocean and atmosphere

The Science

- *Polynyas* have a strong impact on the local heat budget of the ocean and atmosphere
- We use Granger Causality to explore the impact of Weddell Sea polynyas on meridional heat transport in E3SMv0-HR

Key findings

- OHT and AHT are anti-correlated south of 60°S
  - But positively correlated north of ice edge
- OHT variability *responds to* polynya formation
  - So does not cause polynyas



Kaufman et al. (2020)

Theme 2.1 – Impact of fine-scale processes on Arctic Amplification

We are exploring:

- Arctic local radiative feedbacks and impact on Arctic warming
  - *Zhang et al. (2018; 2020)*
  - *Donohoe et al. (2020)*
- The representation and historical trends of Arctic moisture intrusions or atmospheric rivers in E3SM, ERA5 and CMIP6 models
  - *Wang et al. (in prep)*
- The representation of sea ice in CMIP6 models
  - *Watts et al. (in review)*
  - *SIMIP Community (2020)*
- The impact of model physics on initial conditions for improved seasonal predictions
  - *Roberts et al. (2019)*
  - *Maslowski et al. (in prep)*

Presentations: Rudong Zhang
High-Latitudes breakout
Today 13:45-13:52

Hailong Wang
Clouds breakout
Today 14:35-14:40

Wieslaw Maslowski
High Latitudes breakout
Today 14:20-14:27

Matthew Watts
High Latitudes breakout
Today 13:59-14:06

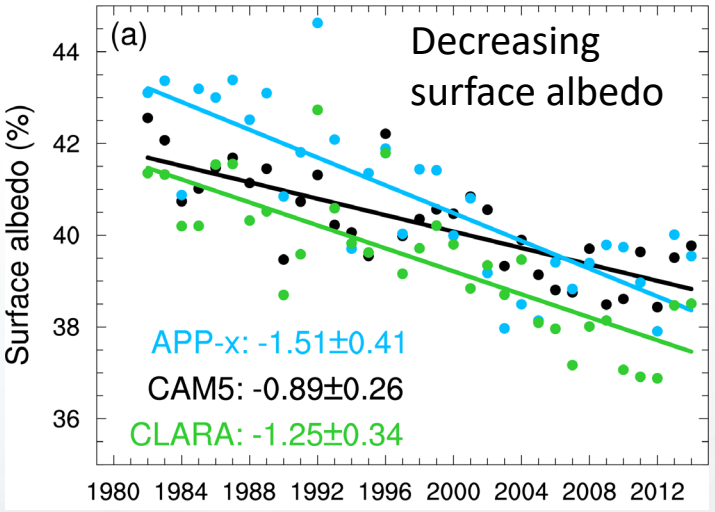
Theme 2.1 – Impact of fine-scale processes on Arctic Amplification

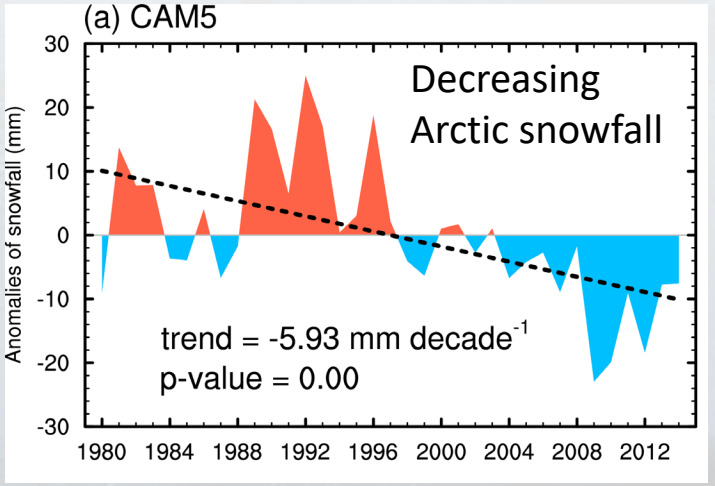
The Science

- What causes the -1% per decade declining trend of Arctic surface albedo since the 1980s?
- In Zhang et al. (2019, PNAS) we used CAM5 and reanalysis products to understand the driving forces behind it.

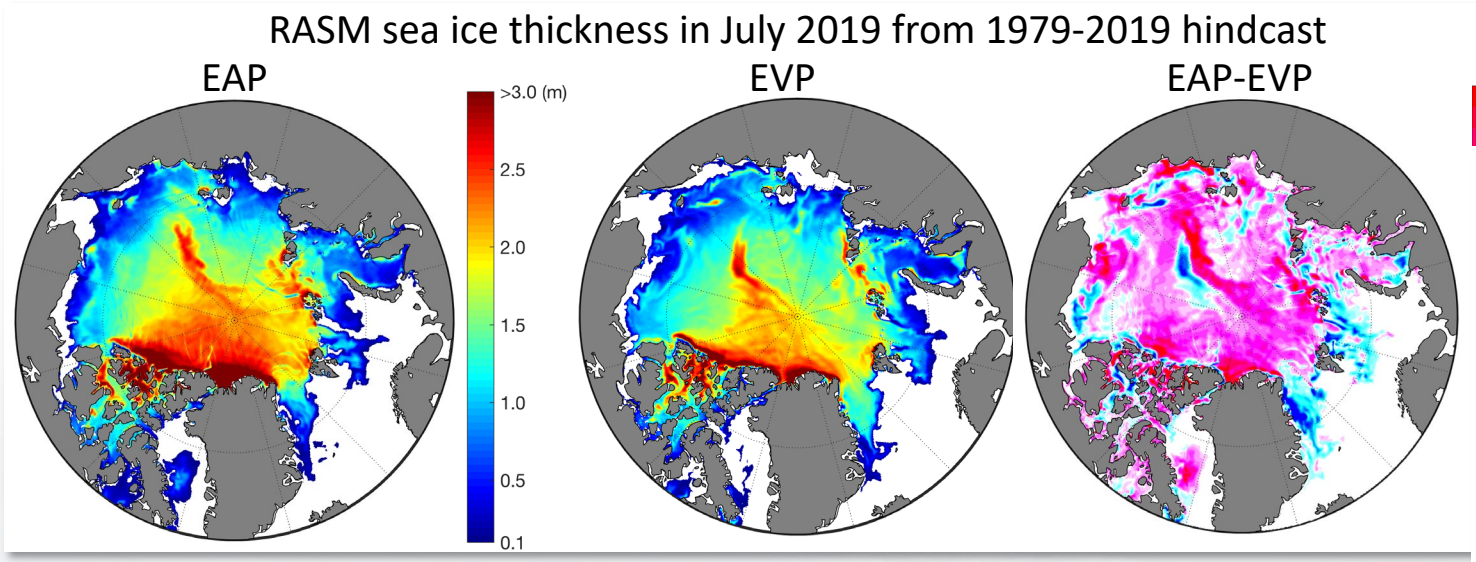
Key findings

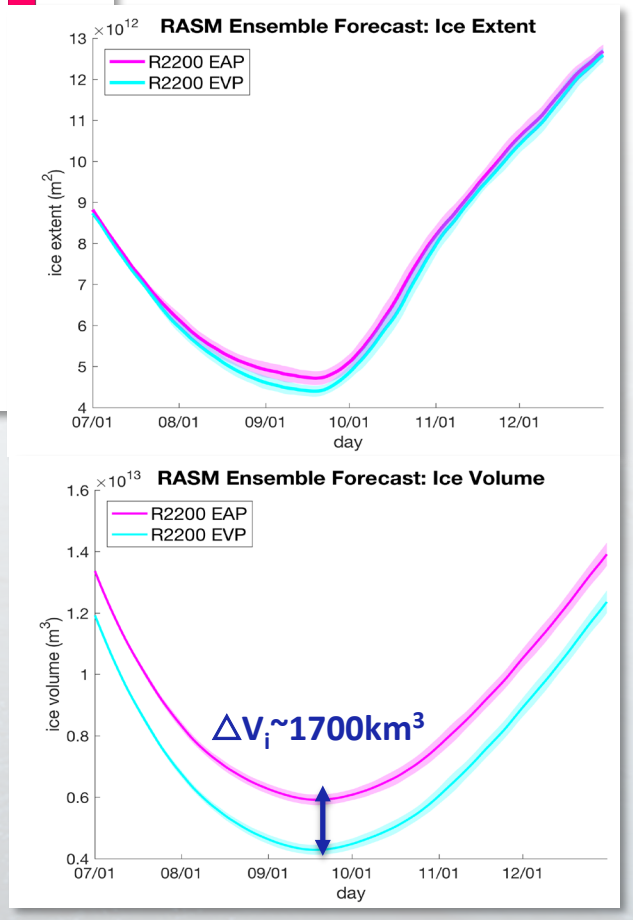
- The decrease of snow cover over the Arctic land and sea ice explains 70% of the surface albedo reduction since the 1980s.
  - Sea ice fraction reduction accounts for 30%.
- Decreasing trend in Arctic snowfall had a significant explains 31% of the decreasing trend in snow cover
  - although total precipitation has been increasing.





Theme 2.1 – Impact of fine-scale processes on Arctic Amplification





The Science

- Accurate initial conditions are critical for seasonal sea ice predictions.
- We study the importance of model physics (e.g. sea ice rheology) for improving initial conditions across all model components (without data assimilation); and their impacts on seasonal prediction

Key findings

- A single change in component model physics, e.g. parameterization of sea ice rheology, can significantly affect the simulated and predicted sea ice volume, without much change of sea ice area

Maslowski et al. (in prep)

Theme 2.2 – The impact of changes in riverine fluxes on Arctic warming

We are exploring:

- Morphodynamics of Arctic deltas
  - *Piliouras & Rowland (2020)*
  - *Schwenk et al. (2020)*
  - *Vulis et al. (2020)*
  - *Lauzon et al. (2019)*
- Organic BGC in rivers and the coastal Arctic
  - *Jayasinghe et al. (2020)*
  - *Elliott et al. (2019)*
  - *Meskhidze et al. (2019)*
- Arctic marine BGC in a changing climate
  - *Clement Kinney et al. (2020)*
  - *Frants (in review)*
  - *Gibson et al. (2020; in prep)*
  - *Jeffery et al. (2020)*

Presentations:
Georgina Gibson
Ecosystems breakout
Yesterday 14:48-14:54

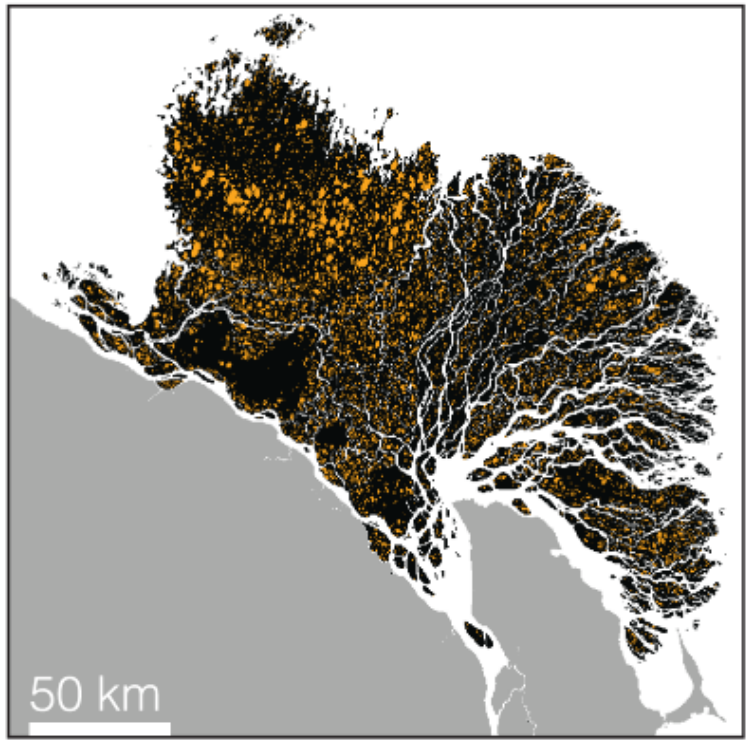
Jaclyn Clement Kinney
Ecosystems breakout
Yesterday 15:00-15:06

Amadini Jayasinghe
Coastal breakout
Yesterday 14:25-14:30

Scott Elliott
Coastal breakout
Yesterday 14:30-14:35

Anastasia Piliouras
High Latitudes breakout
Today 15:09-15:16

Theme 2.2 – The impact of changes in riverine fluxes on Arctic warming



Map of the Lena delta showing lakes (yellow) connected to the channel network (white) that have a higher likelihood of filtering out nutrients and suspended sediment.
Piliouras & Rowland (2020)

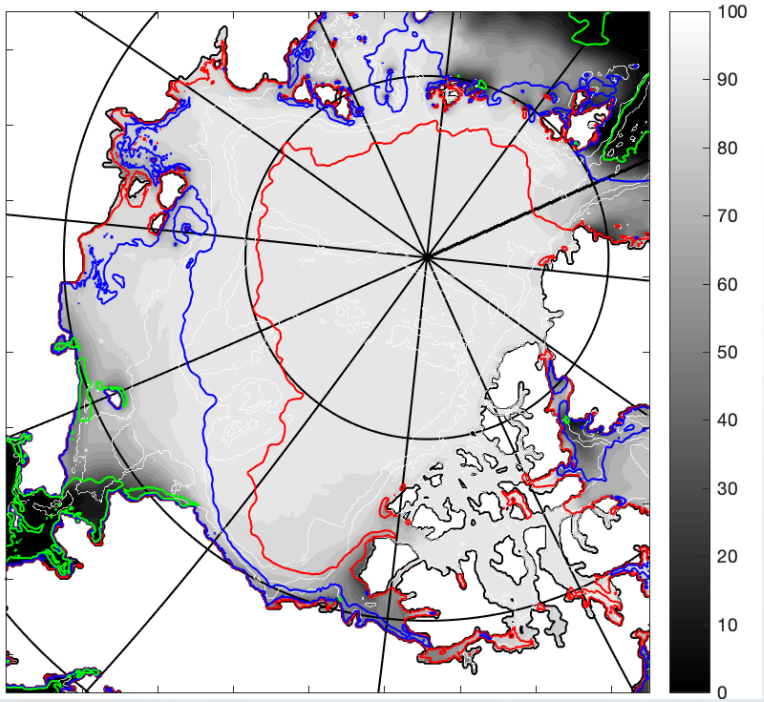
The Science

- How do deltas filter and buffer the riverine fluxes before they enter the Arctic Ocean?

Key findings

- First comprehensive comparison of Arctic delta morphologies
- Increased understanding of how delta channel networks convey riverine fluxes to the coast
  - and susceptibility of deltas to drowning by sea level rise

Theme 2.2 – The impact of changes in riverine fluxes on Arctic warming



Mean June concentration (%; shading) and sea ice mean primary production (contours: 200; 400; 800 mg C/m^2/d). *Clement Kinney et al. (2020)*

The Science

- It is well known that plankton blooms can occur underneath sea ice.
- But how much do under-ice plankton blooms contribute to primary production?
- We address this by performing simulations with the RASM model

Key findings

- under-ice blooms in waters covered by > 50% ice account for the majority of central Arctic primary production
- They exhibit increasing decadal trends in part due to increasing radiative flux

Theme 3 – Extra-Polar Impacts of Arctic Change

We are exploring:

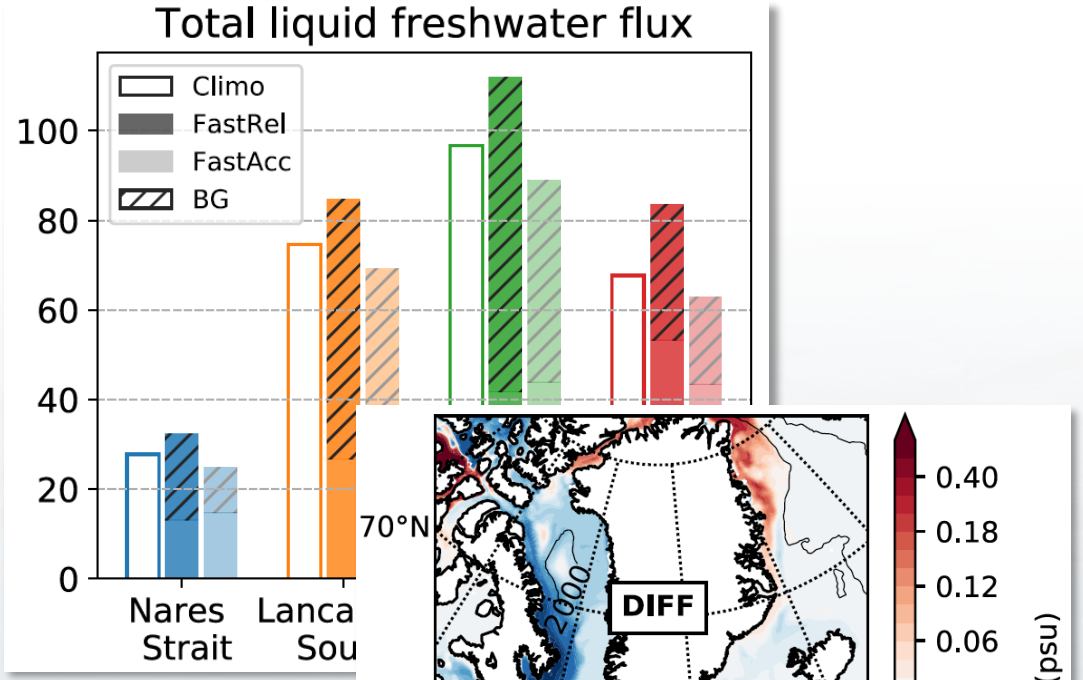
- Impact of Arctic changes on East Asian monsoon and haze; ENSO events; and US wildfires
  - *Lou et al. (2019a; 2019b)*
  - *Zou et al. (2020; in review)*
- The use of System Identification techniques to understand lower-latitude impacts of high-latitude change
  - *Sutherland et al. (in review)*
- Impacts of Beaufort Gyre freshwater on subpolar North Atlantic
  - *Zhang et al. (in review)*

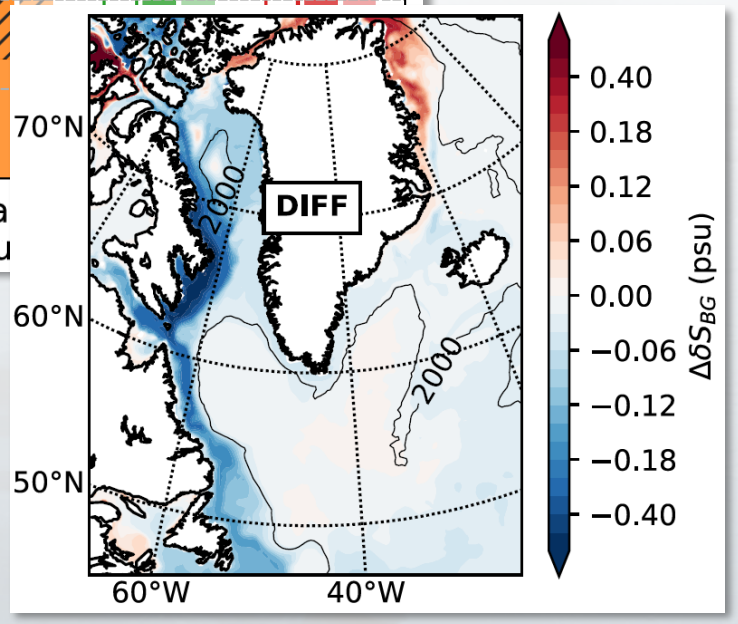
Presentations:
Ben Kravitz
Synoptic breakout
Yesterday 16:14-16:21

Yufei Zou
Clouds breakout
Today 14:55-15:00

Jiaxu Zhang
High Latitudes breakout
Today 15:02-15:09

Theme 3 – Extra-Polar Impacts of Arctic Change





Zhang et al. (in review)

The Science

- The Beaufort Gyre has accumulated an anomalous amount of freshwater.
- What are the impacts on the subpolar North Atlantic when this freshwater is released?
- We study the impact of BG freshwater release in E3SMv0-HiLAT using novel tracer approaches.

Key findings

- BG freshwater exits the Arctic mostly through the Canadian Arctic Archipelago, rather than Fram Strait
- Salinities in the Labrador Sea can locally be reduced by 0.4 psu in response to rapid freshwater release
  - with potential impacts on AMOC.

Theme 4 – Decadal predictability of high-latitude environmental change

We are exploring:

- Reduced-order and Machine Learning approaches to explore predictability
  - *Comeau et al. (2019)*
  - *Foster et al. (2020)*
- Downscaling of CESM-DP-LE to RASM
  - *Maslowski et al. (in prep)*
- New techniques for drift correction of initialized ensembles
  - *Nadiga et al. (2019)*

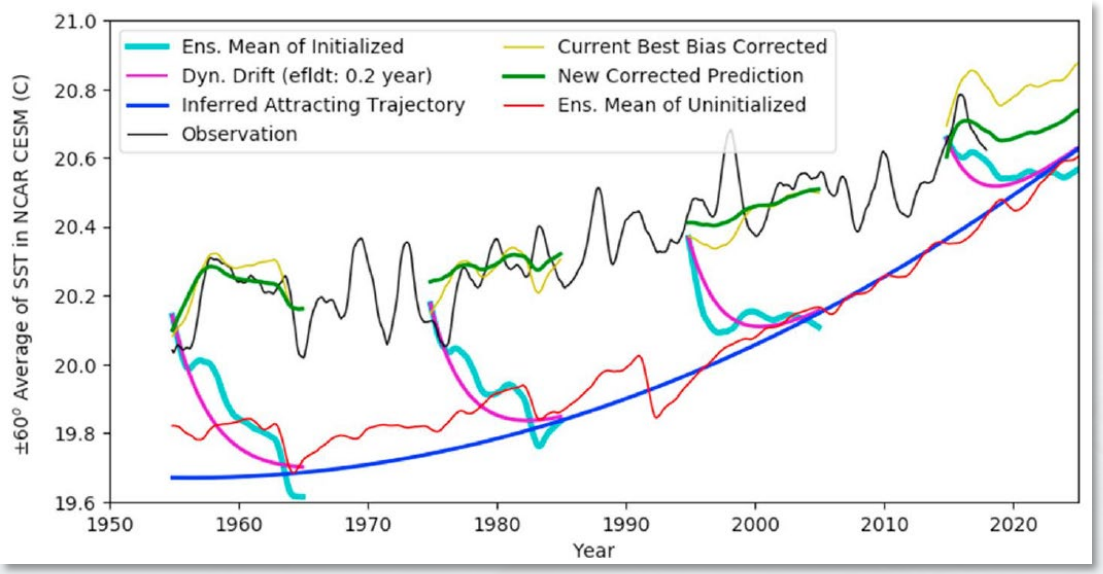
Presentations:
Wieslaw Maslowski
High Latitudes breakout
Today 14:27-14:34

Balu Nadiga
High Latitudes breakout
Today 15:16-15:23

Haiyan Teng
Multi-year breakout
Today 13:30-13:36

Tarun Verma
Multi-year breakout
Today 15:24-15:30

Theme 4 – Decadal predictability of high-latitude environmental change



Nadiga et al. (2019)

The Science

- Initialized predictions often have significant drift that limits their use.
- We develop a model to correct for this drift.

Key findings

- Drift of initialized trajectories can be modeled as *exponential attraction* towards the *uninitialized* system
- Correcting for this drift improves predictive skill.

Thanks!