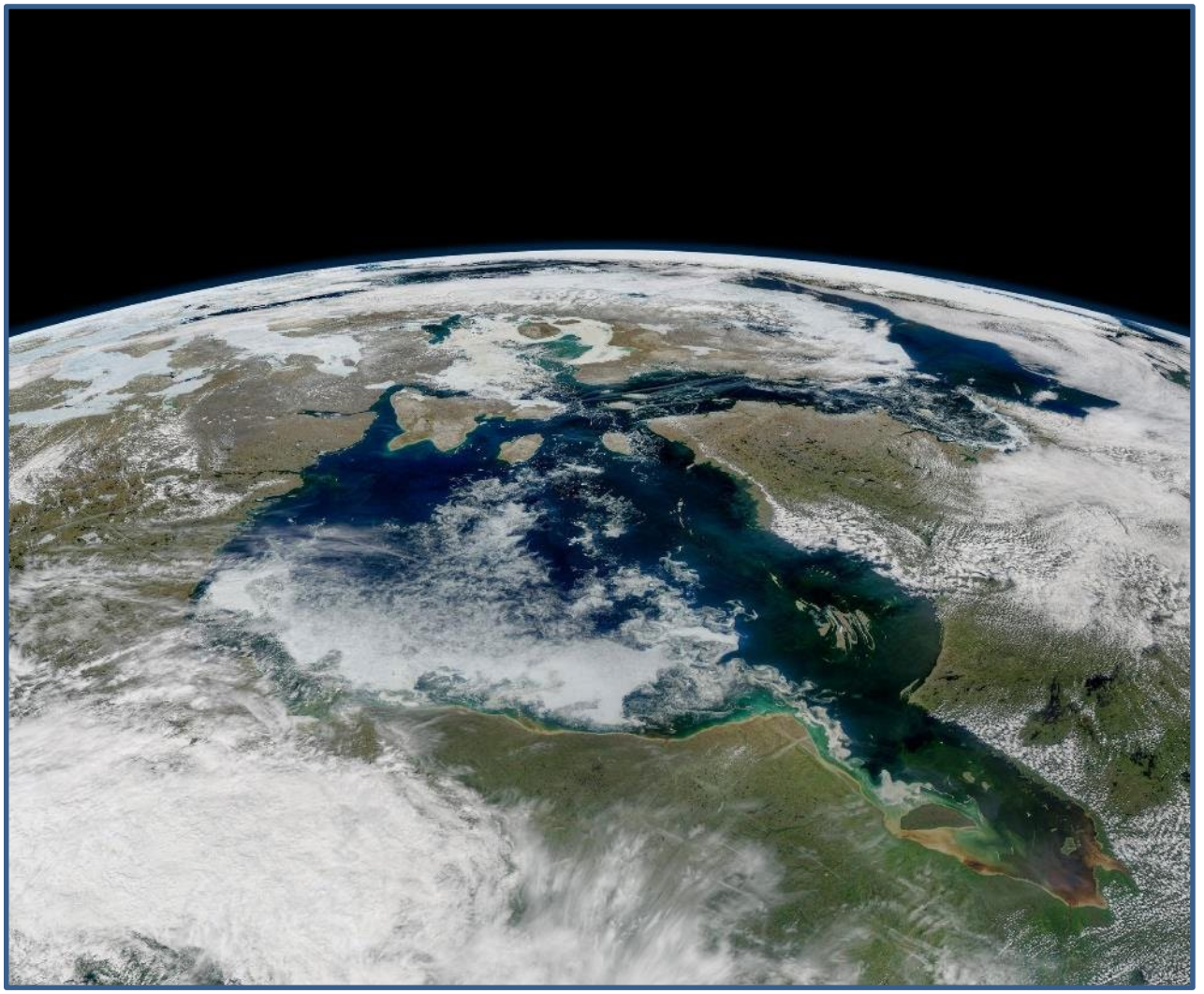
Team 6: NEMO Modelling for the Hudson Bay Complex



Credit: NASA Earth Observatory

compute canada | calcul canada

Manitoba Hydro

University of Alberta

eas Earth & Atmospheric Sciences

NSERC CRSNG People. Discovery. Innovation.

CEOS Centre for Earth Observation Science

University of Manitoba

BaySys objectives

“To examine the influence of freshwater on Hudson Bay marine and coastal systems”

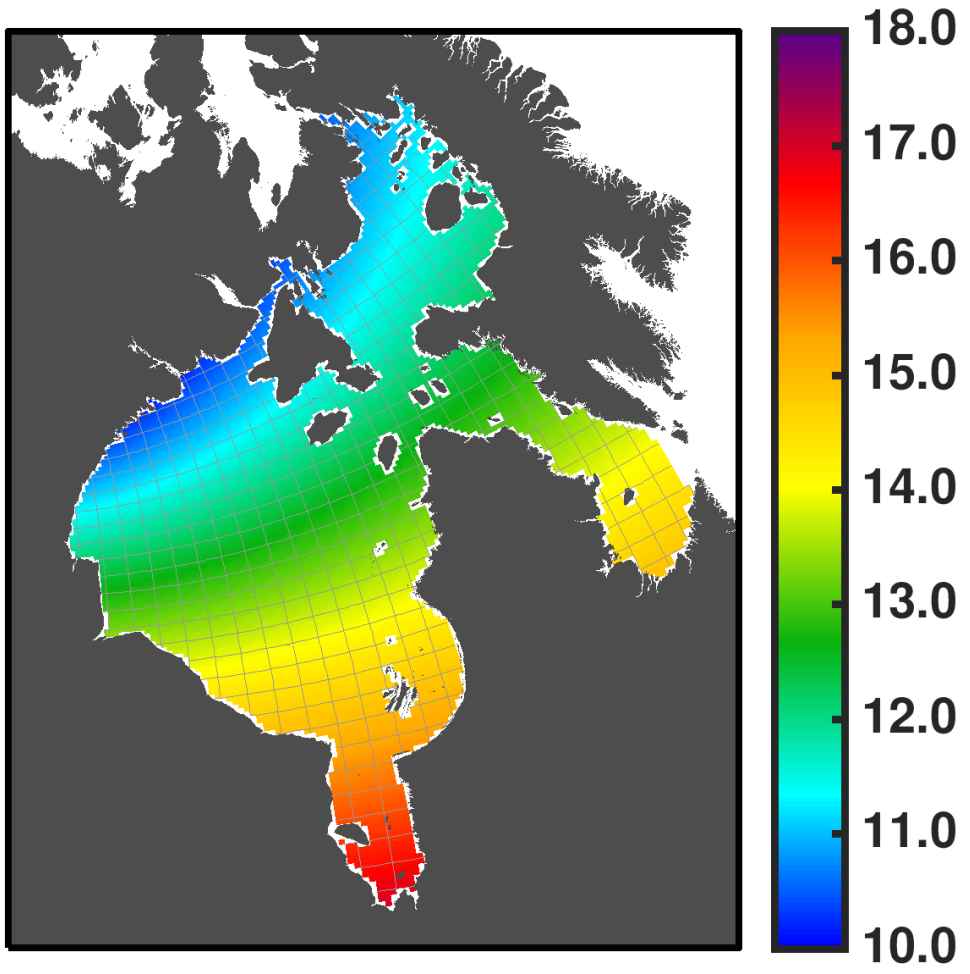
“To provide a scientific basis to separate climate change effects from those of regulation of freshwater on physical, biological and biogeochemical conditions in Hudson Bay”

Team 6 objectives

- To provide output in the Hudson Bay Complex, in the form of ice and oceanographic variables relevant for BaySys
  - Based on different scenarios for climate change (CMIP) and runoff (HYPE)
- To investigate the relative impacts of climate change and regulation on freshwater-marine coupling within the HBC from a modeling perspective
- To provide an integrated observational-modeling freshwater/marine framework for model-data comparison at two scales
  - Local (~ 20 - 100 km; estuary and coastal)
  - Regional (~100 - 1000 km; bay-wide) scales
- To improve our understanding of physical mechanisms responsible for observed phenomena
  - To improve representation of these processes for future simulations.
- To investigate and improve our understanding of freshwater dynamics, as well as momentum, mass and heat flux in HBC in response to climate change and regulation

ANHA NEMO Configuration in the HBC

Hudson Bay Complex



Model: NEMO 3.6 (ocean)
LIM2 + EVP (sea ice)

Resolution: ¼ degree
(~ 10 – 15 km within Hudson Bay)

Initialization: 3D T, S

Atmospheric forcing:

- Surface temperature, humidity, u_{atm},v_{atm}
- precipitation (including snow)
- radiation (SW & downwelling LW)

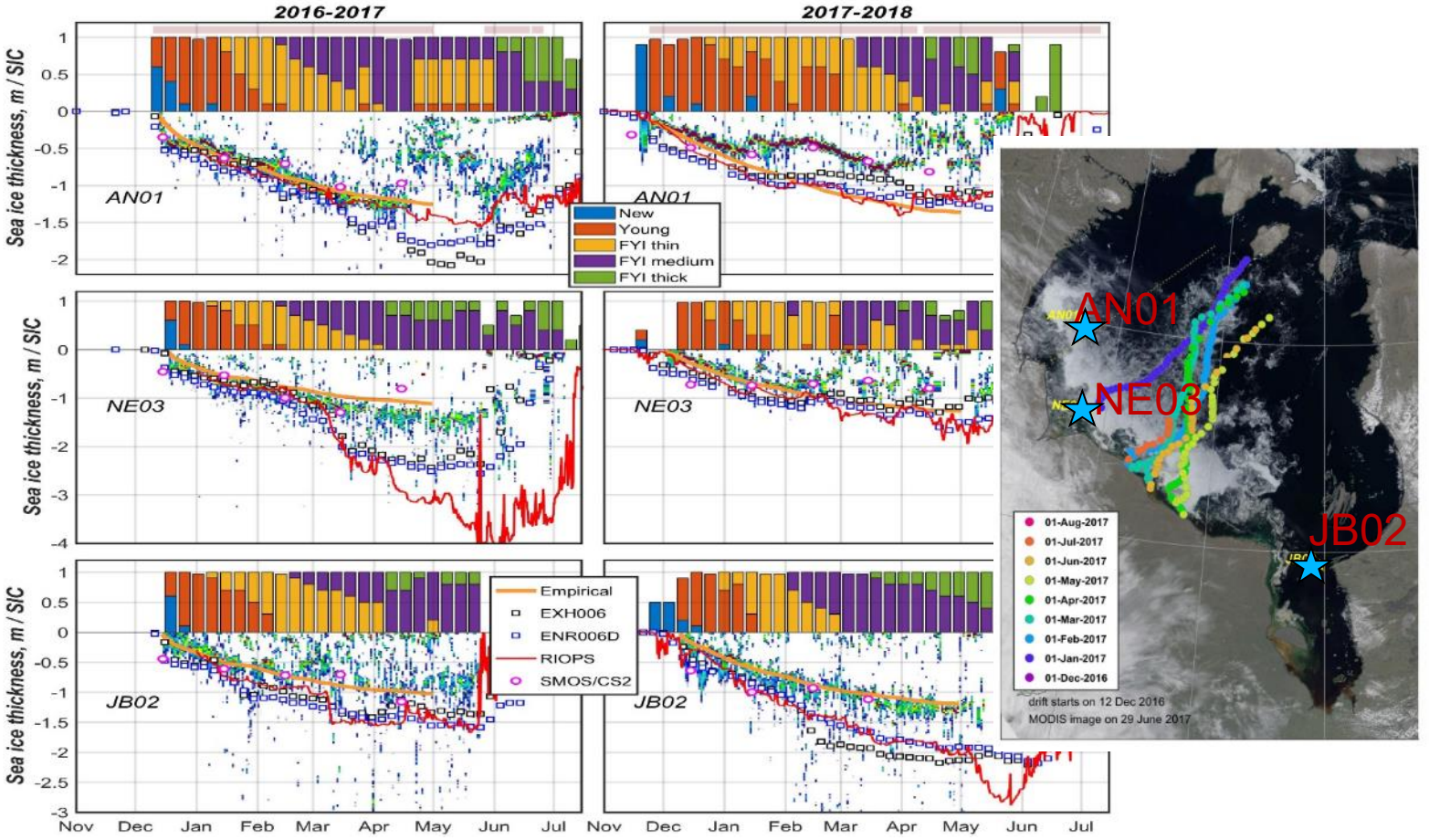
OBC: U_{ocean}, V_{ocean}, T & S

Runoff in HBC: HYPE (Team 2)

NO temperature & salinity restoring

Tides:

Sea Ice Thickness Comparison with BaySys Moorings

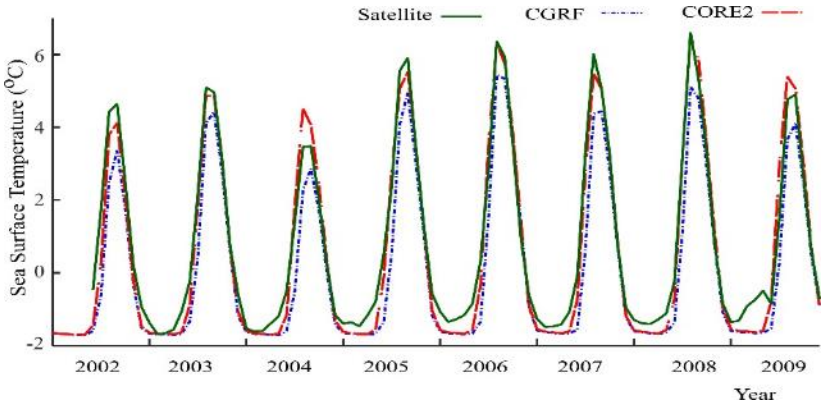


Figures courtesy Sergei Kirilov

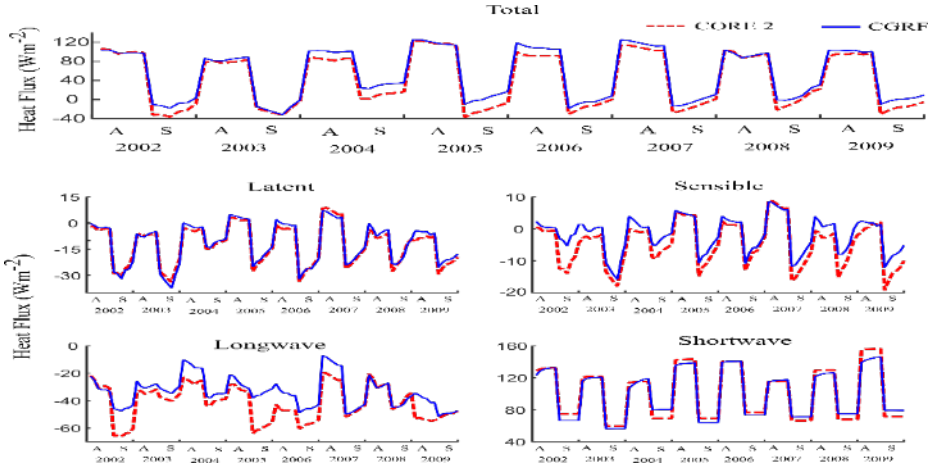
3 Published Papers so far

- I: Modelling Sea Surface Temperature (SST) in Hudson Bay Complex Using Bulk Heat Flux Parameterization: Sensitivity to Atmospheric Forcing and Model Resolution (Atmosphere-Ocean)
  - Shabnam JafariKhasragh, Jennifer V. Lukovich, Xianmin Hu, Paul G. Myers, Kevin Sydor and David G. Barber

Q . How well the model represents the SSTs over HBC?

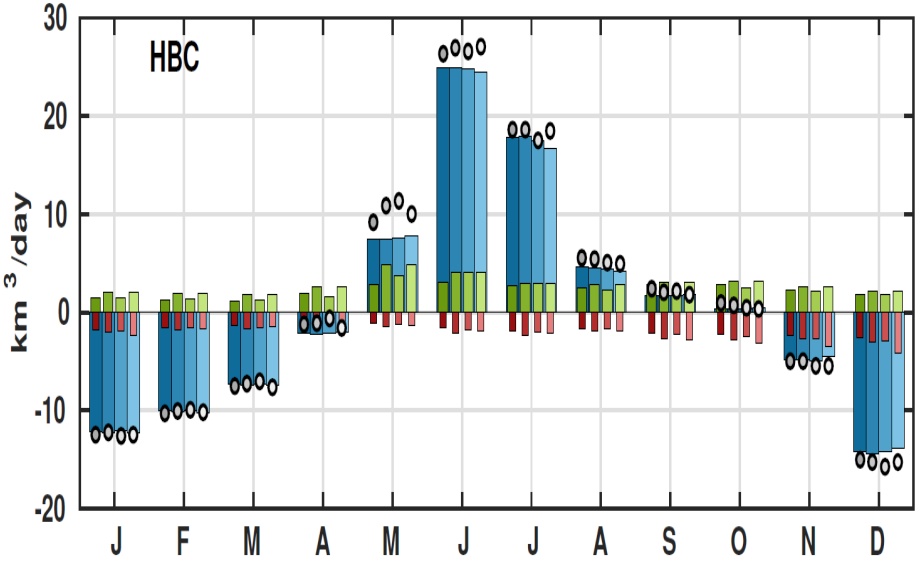


Q . What are the relative contributions to heat flux for each simulation?



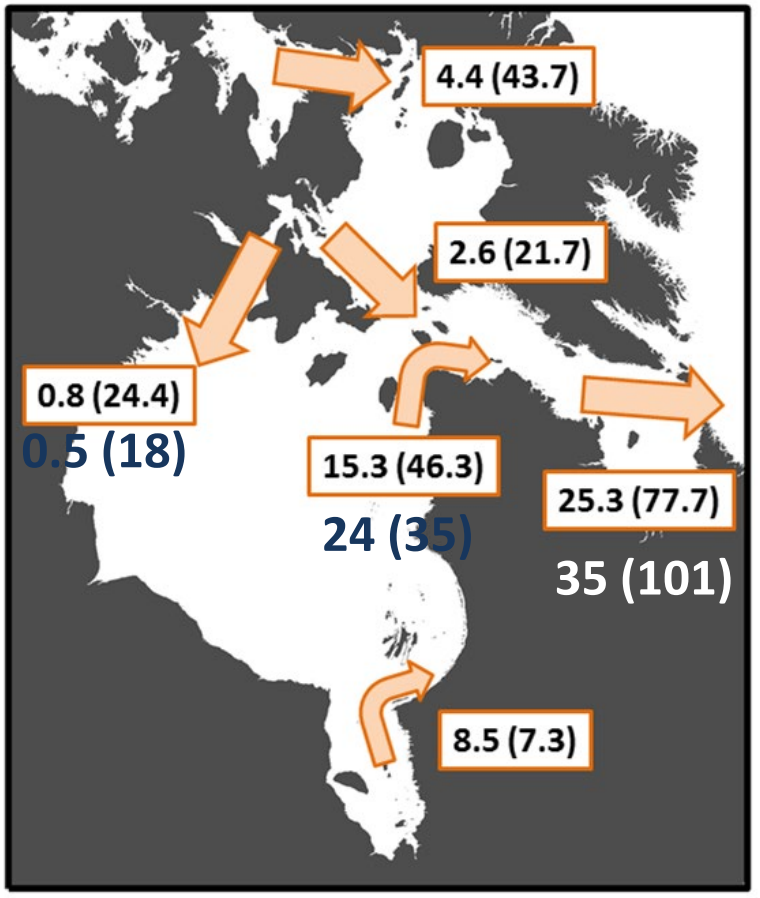
II: Sensitivity of freshwater dynamics to ocean model resolution and river discharge forcing in the Hudson Bay Complex, 2019, NA Ridenour, X Hu, SJ Khasragh, JC Landy, JV Lukovich, TA Stadnyk, ..., Journal of Marine Systems

Seasonal FW budget for the HBC (below)



Shading indicates different experiments

Green: river
Blue: surface fluxes
Red: advected FW
Circles: FW storage

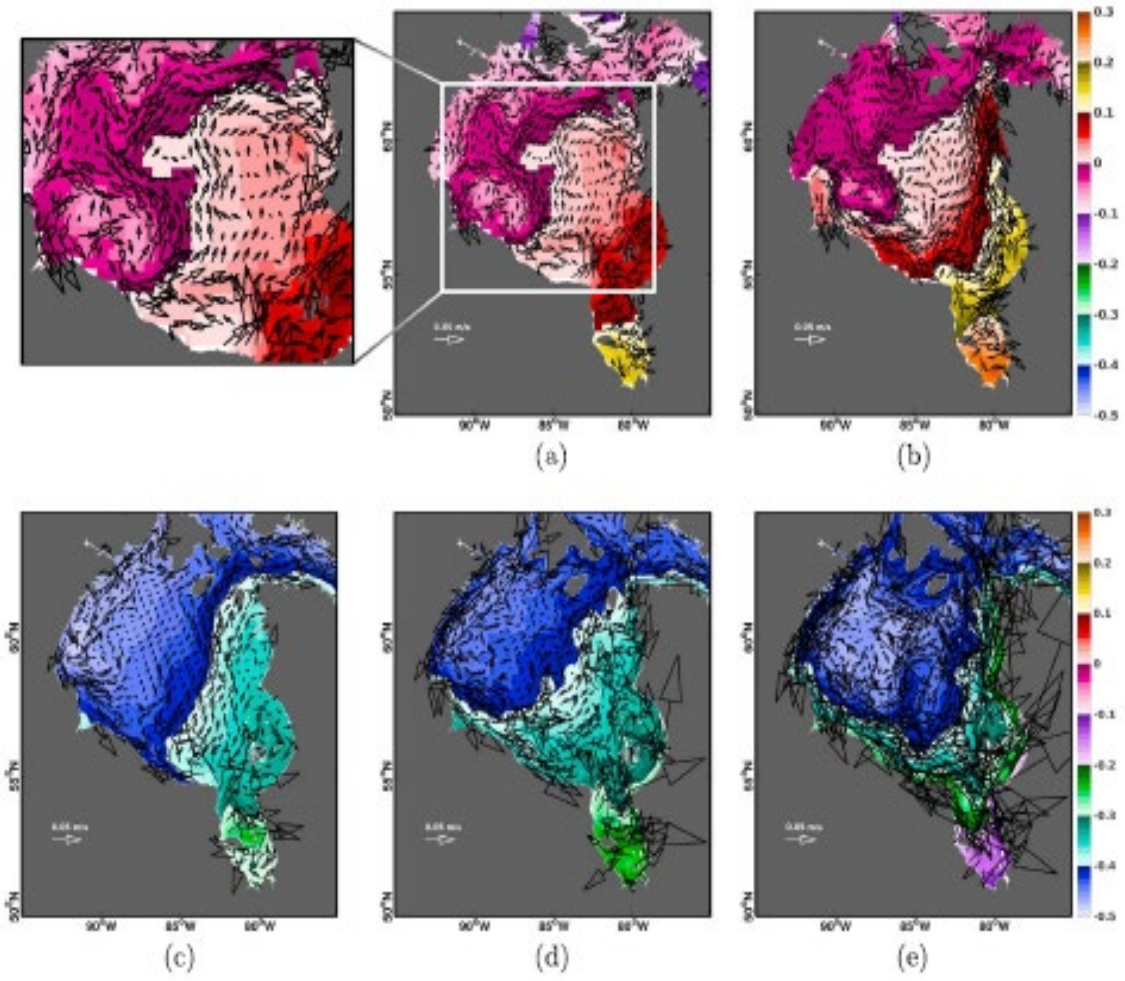


Freshwater (volume) components in mSv

III: Revisiting the Circulation of Hudson Bay: Evidence for a Seasonal Pattern, 2019, NA Ridenour, X Hu, K Sydor, PG Myers, DG Barber, Geophysical Research Letters, 46, https://doi.org/10.1029/2019GL082344

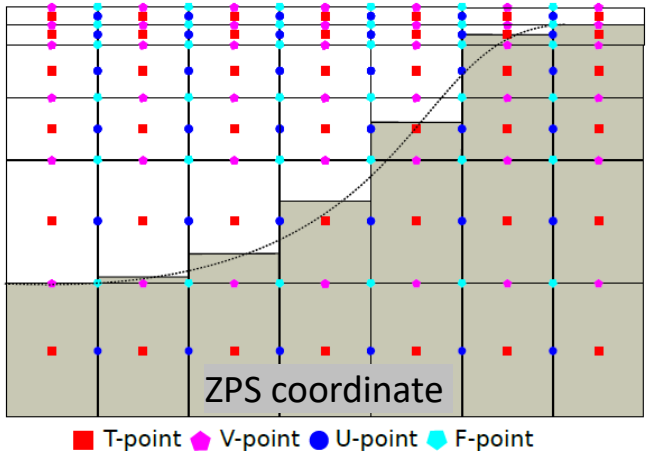
AVISO Absolute Dynamic Topography and geostrophic currents for summer (a, July-Sept) and fall (b, Oct-Dec)

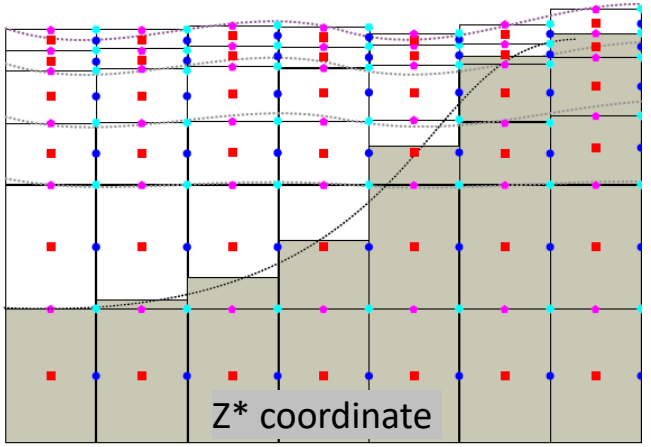
Our model (ANHA12) sea surface height and geostrophic velocities for spring (c, May-June), Summer (d), and fall (e).



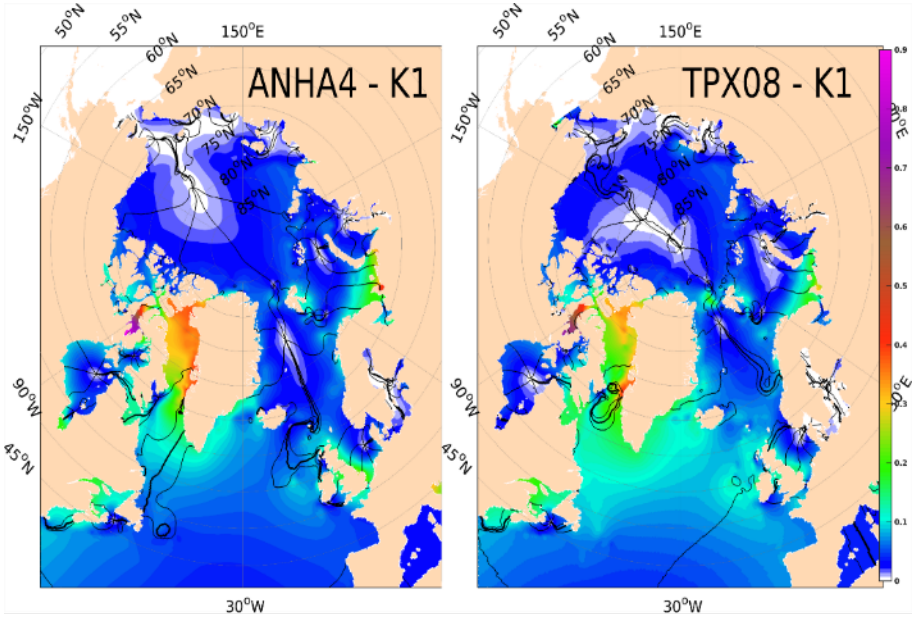
Numerical Improvement: Tides

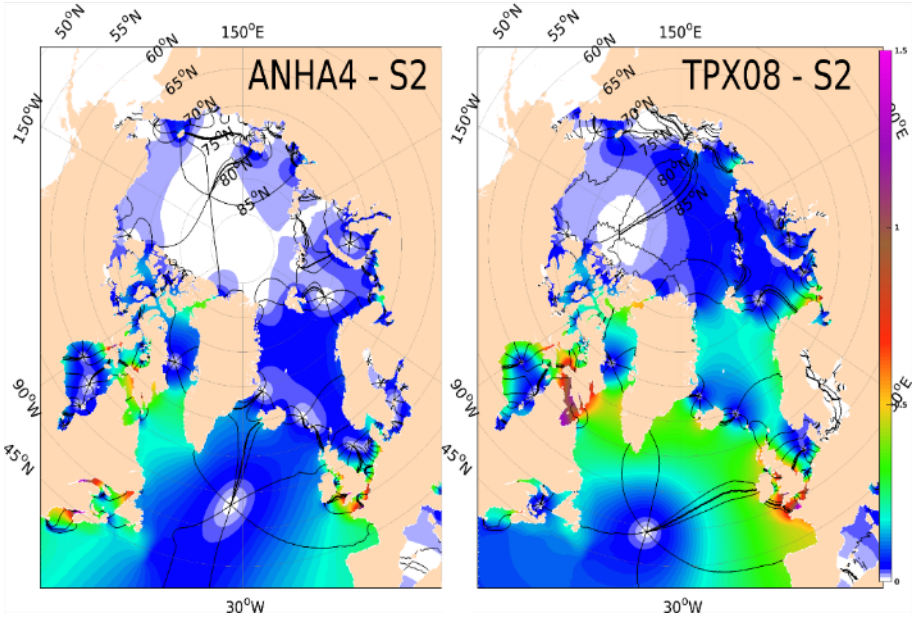
- Technical changes:
  - New coordinate system: z*
    - Variable dz
  - New time split scheme
    - Barotropic ts: 6 seconds
    - Baroclinic ts: 1080 seconds
- Physical changes expected:
  - Better mixing at the surface
  - Better mixing at the bottom
  - Addition of the tidal currents

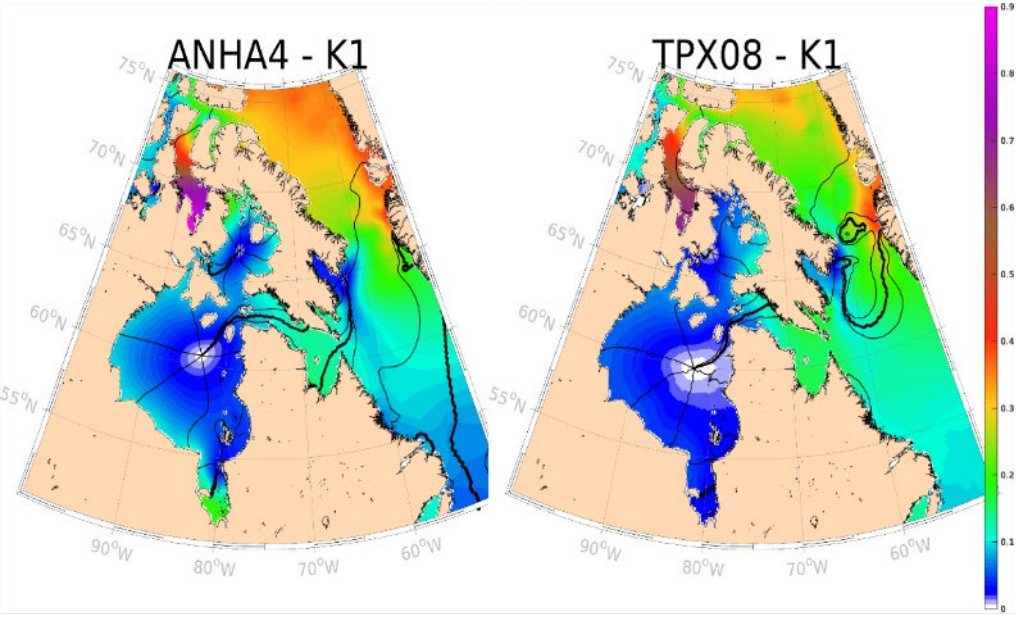


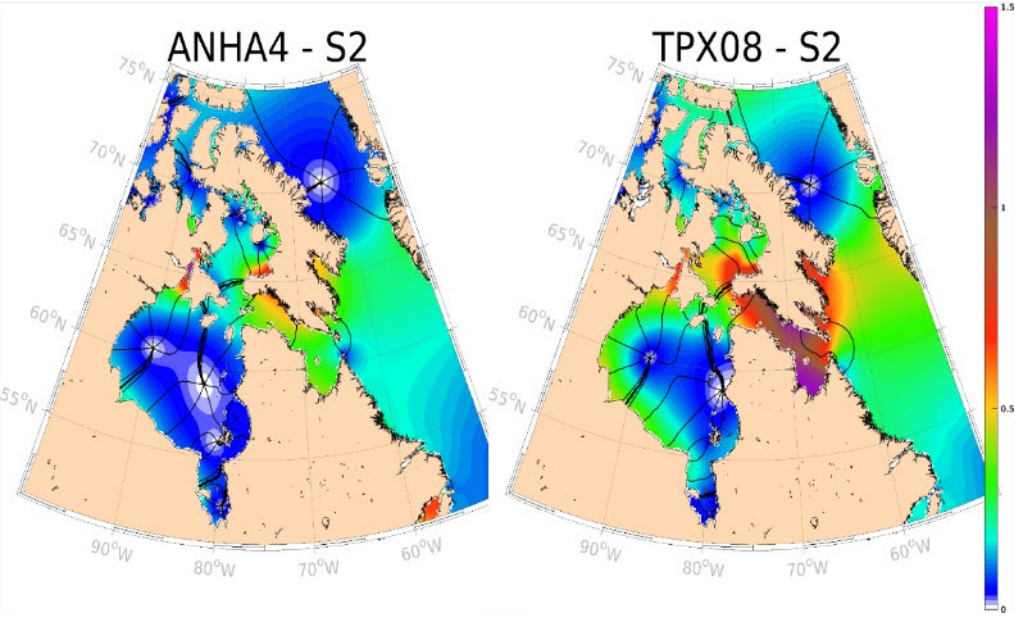


Tide Representation with ANHA4

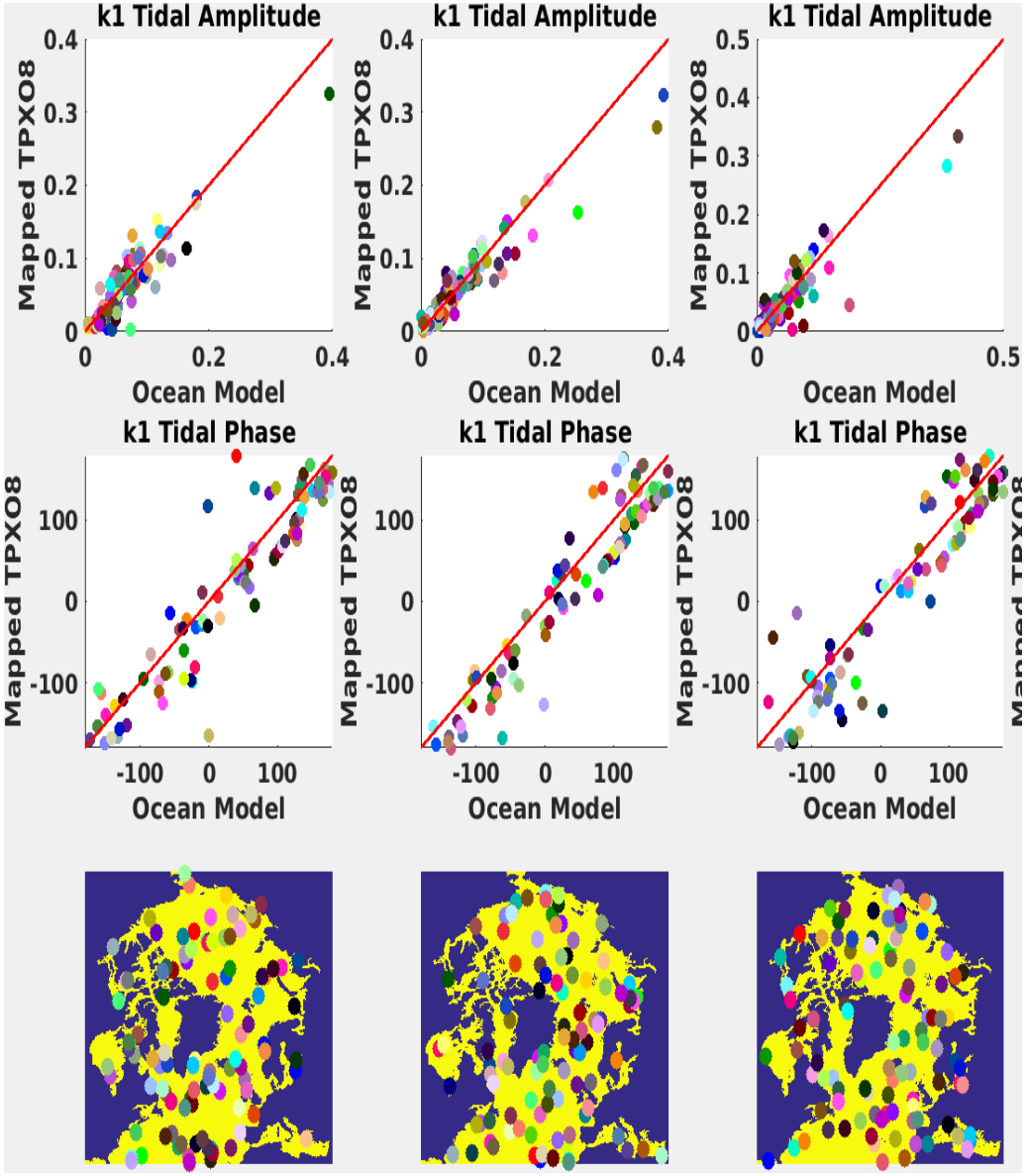


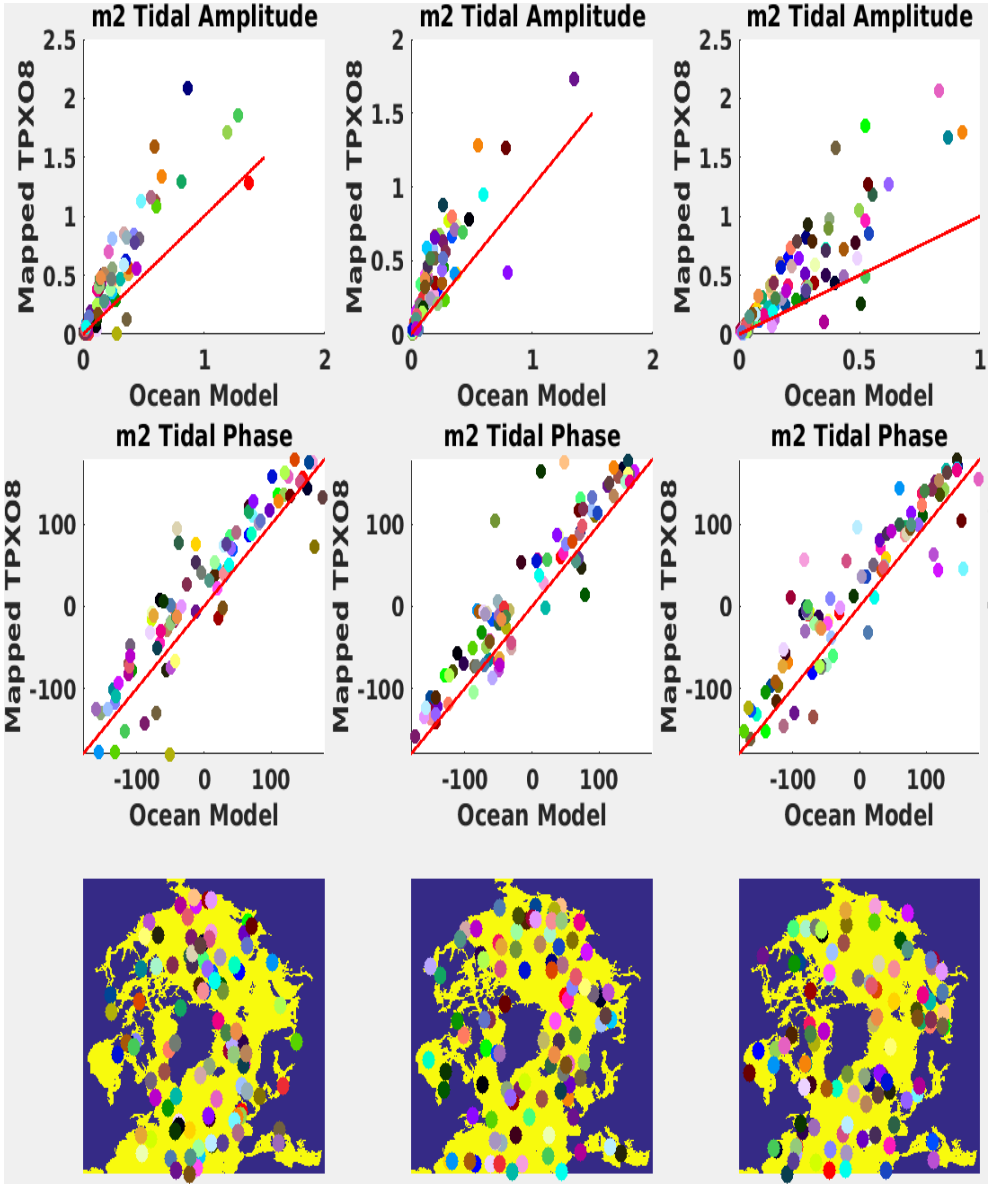




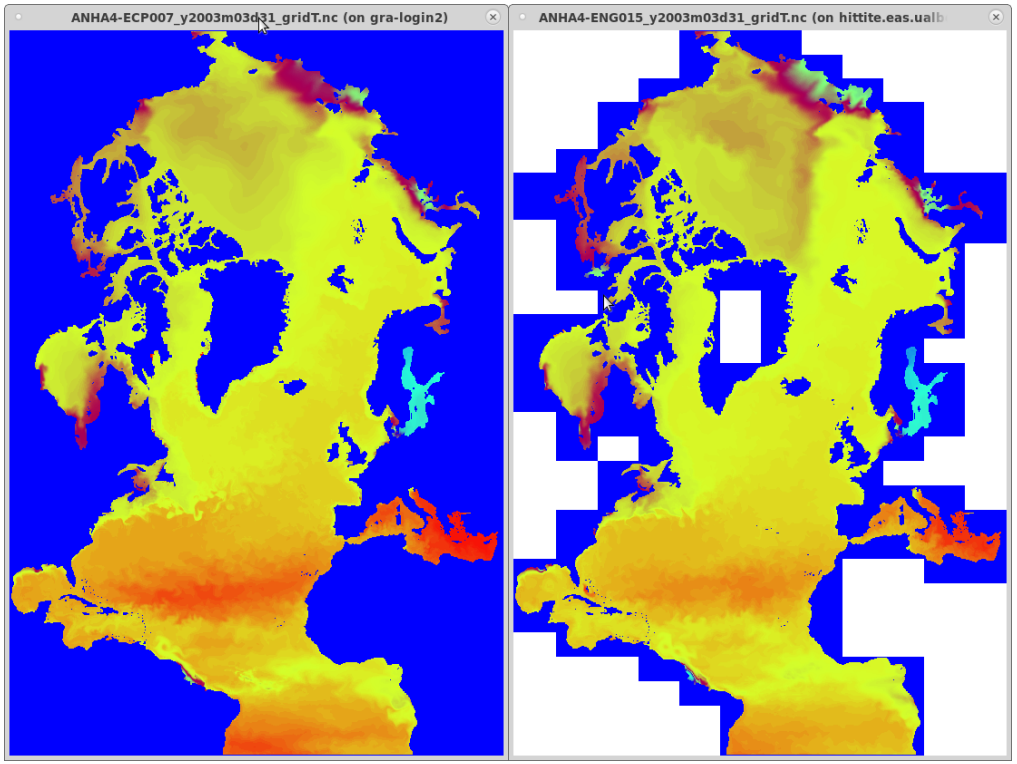


Tide Representation with ANHA4



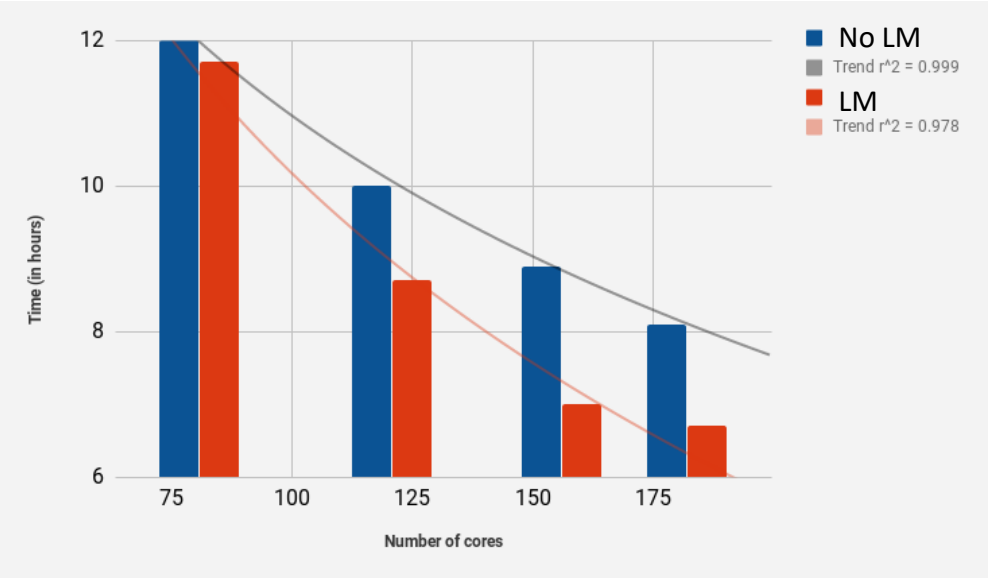


Numerical Improvement: Land masking



No land masking

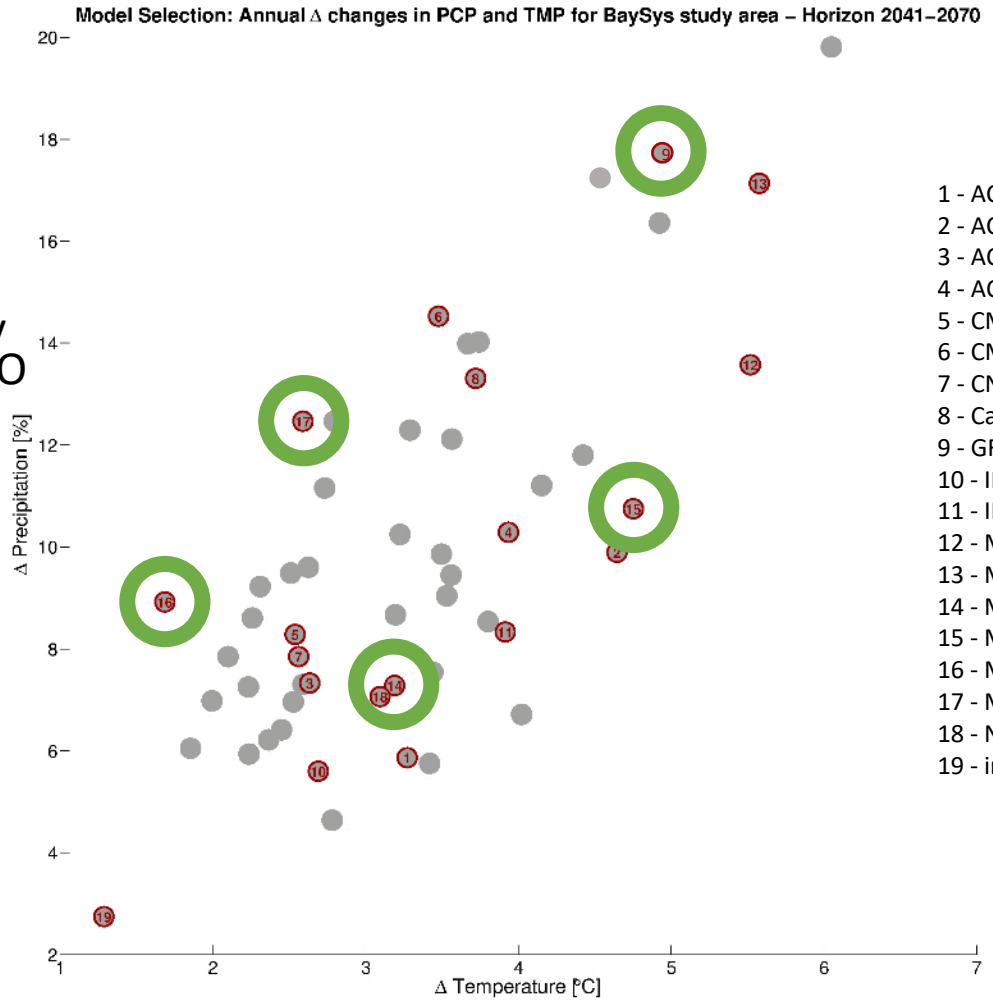
Land masking



- **Up to 30% more efficient for the same number of CPU requested**

BaySys climate simulation selection to address uncertainty

71 simulation ensemble
19 selected for Hudson Bay
5 selected for driving NEMO



1 - ACCESS1-0_rcp45_r1i1p1 - A10
2 - ACCESS1-0_rcp85_r1i1p1 - A10
3 - ACCESS1-3_rcp45_r1i1p1 - A13
4 - ACCESS1-3_rcp85_r1i1p1 - A13
5 - CMCC-CM_rcp45_r1i1p1 – CMM
6 - CMCC-CMS_rcp85_r1i1p1 – CMS
7 - CNRM-CM5_rcp45_r1i1p1 - CN5
8 - CanESM2_rcp45_r1i1p1 - CE2
9 - GFDL-CM3_rcp45_r1i1p1 - GF3 - NEMO
10 - IPSL-CM5A-LR_rcp45_r1i1p1 - IAL
11 - IPSL-CM5A-LR_rcp85_r1i1p1 - IAL
12 - MIROC-ESM_rcp85_r1i1p1 - MIE
13 - MIROC-ESM-CHEM_rcp85_r1i1p1 - MIC
14 - MIROC5_rcp45_r1i1p1 - MI5 - NEMO
15 - MIROC5_rcp85_r1i1p1 - MI5 - NEMO
16 - MRI-CGCM3_rcp45_r1i1p1 - MR3 - NEMO
17 - MRI-CGCM3_rcp85_r1i1p1 - MR3 - NEMO
18 - NorESM1-M_rcp45_r1i1p1 – NOE
19 - inmcm4_rcp45_r1i1p1 - INM

Marco Braun, Ouranos

Historical/Future Experiments

Historical Control

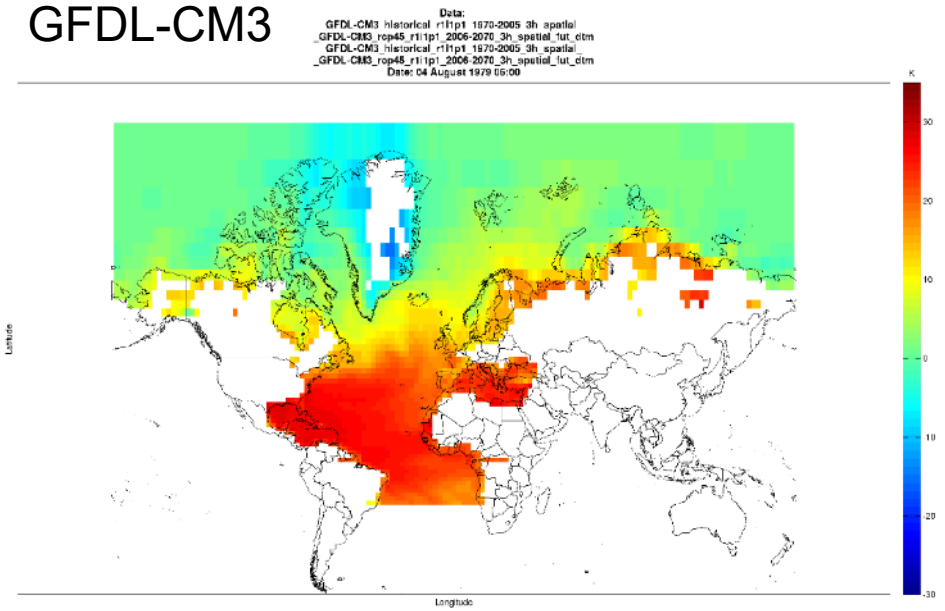
- ERA-Interim
- MIROC
- MRI-CGCM3
- GFDL-CM3

Future

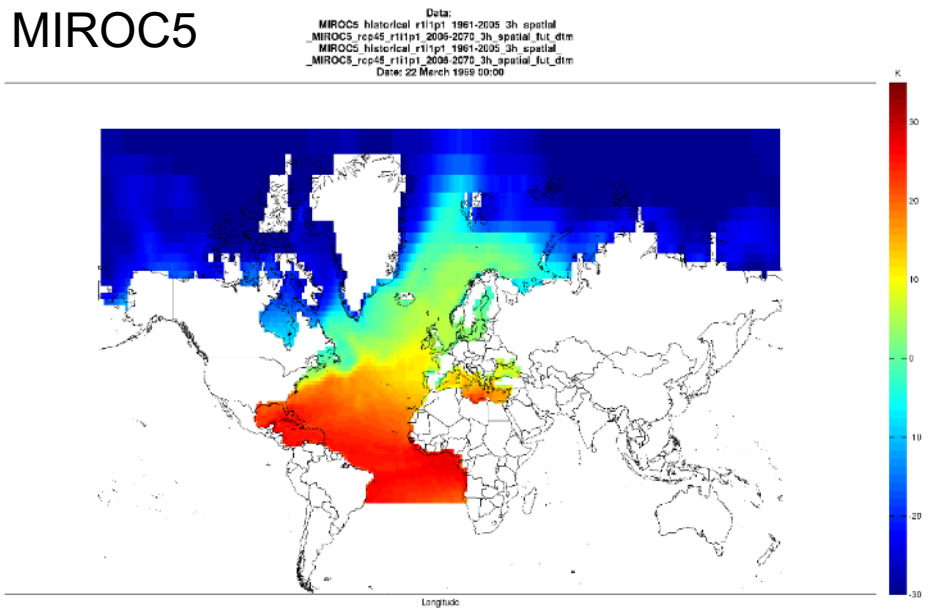
- MIROC Regulated RCP 4.5
- MIROC Naturalized RCP 4.5
- MIROC Regulated RCP 8.5
- MIROC Naturalized RCP 8.5
- MRI-CGCM3 Regulated RCP 4.5
- MRI-CGCM3 Naturalized RCP 4.5
- MRI-CGCM3 Regulated RCP 8.5
- MRI-CGCM3 Naturalized RCP 8.5
- GFDL-CM3 Regulated RCP 4.5
- GFDL-CM3 Naturalized RCP 4.5

Bias Corrected Forcing Fields Provided by Ouranos

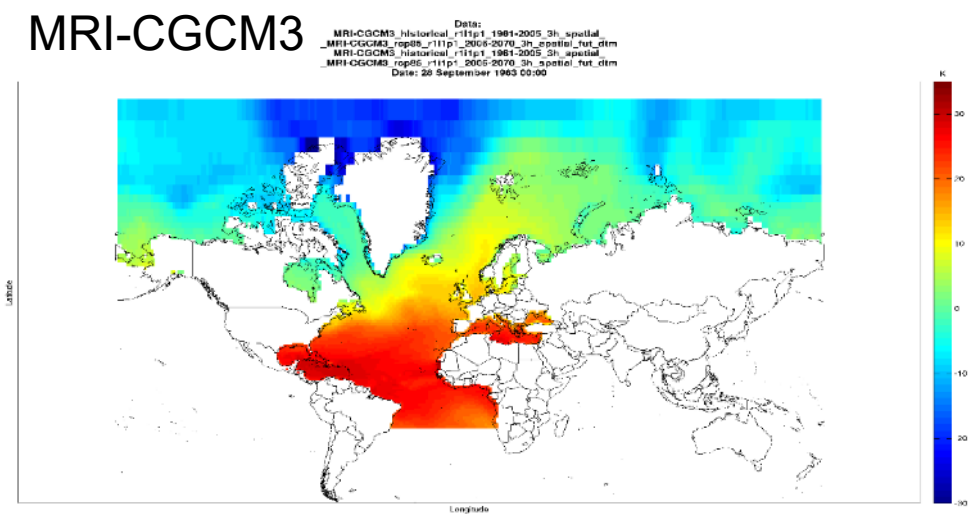
GFDL-CM3



MIROC5



MRI-CGCM3



- All forcing fields converted into format to use for forcing the NEMO model
- HYPE and Arctic-HYPE output for each scenario set up for NEMO model
- Model run and tested for each scenario with forcing

Naturalized Experiments

Historical Control

- ERA-Interim
- MIROC
- MRI-CGCM3
- GFDL-CM3

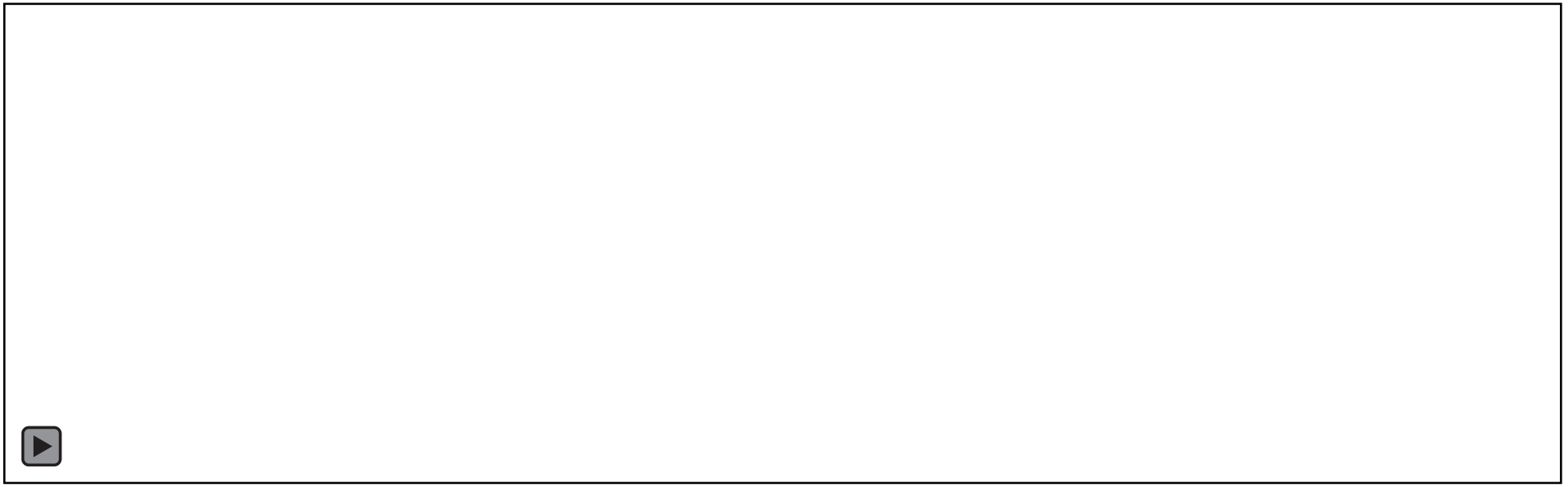
Future

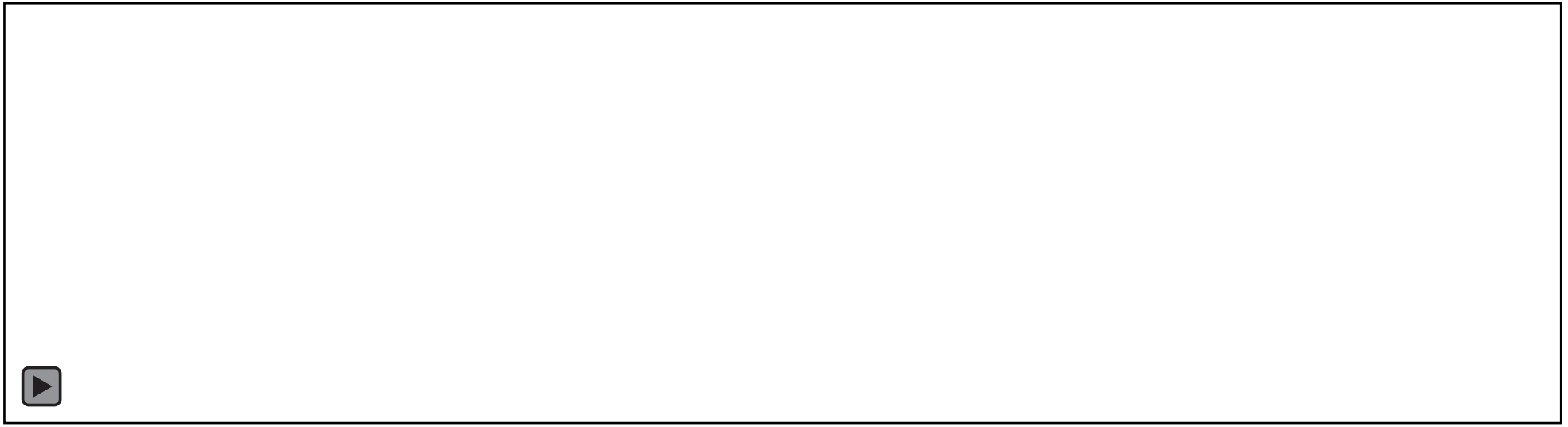
- MIROC Naturalized RCP 4.5
  - Completed (2070)
- MIROC Naturalized RCP 8.5
  - Presently 2057
- MRI-CGCM3 Naturalized RCP 4.5
  - Presently 2059
- MRI-CGCM3 Naturalized RCP 8.5
  - Presently 2057
- GFDL-CM3 Naturalized RCP 4.5
  - Completed (2070)

Completed

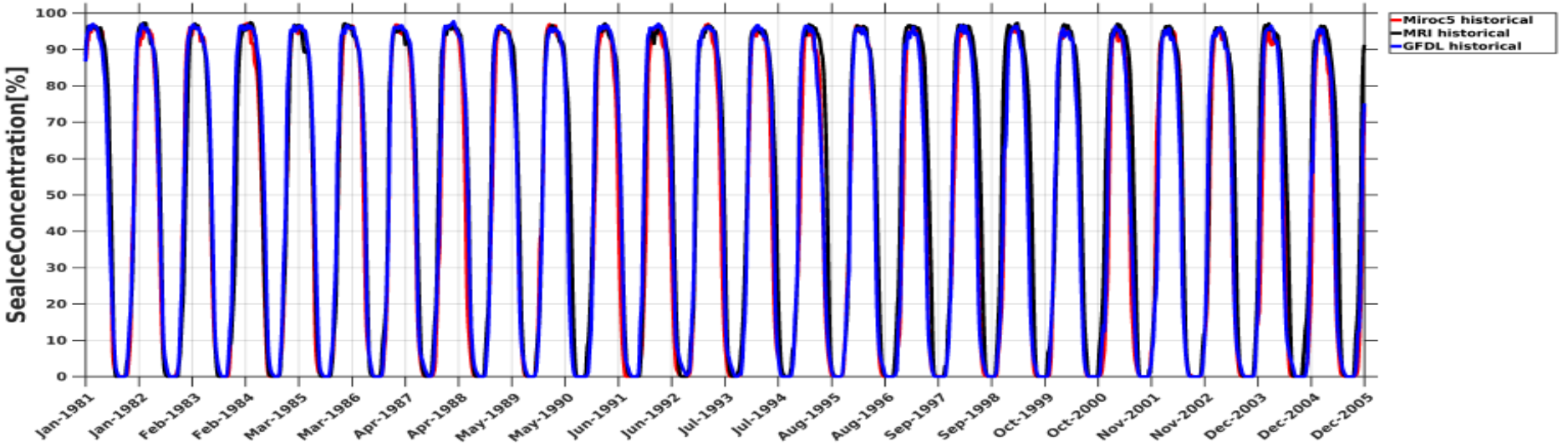
1980 2005 2006 2070

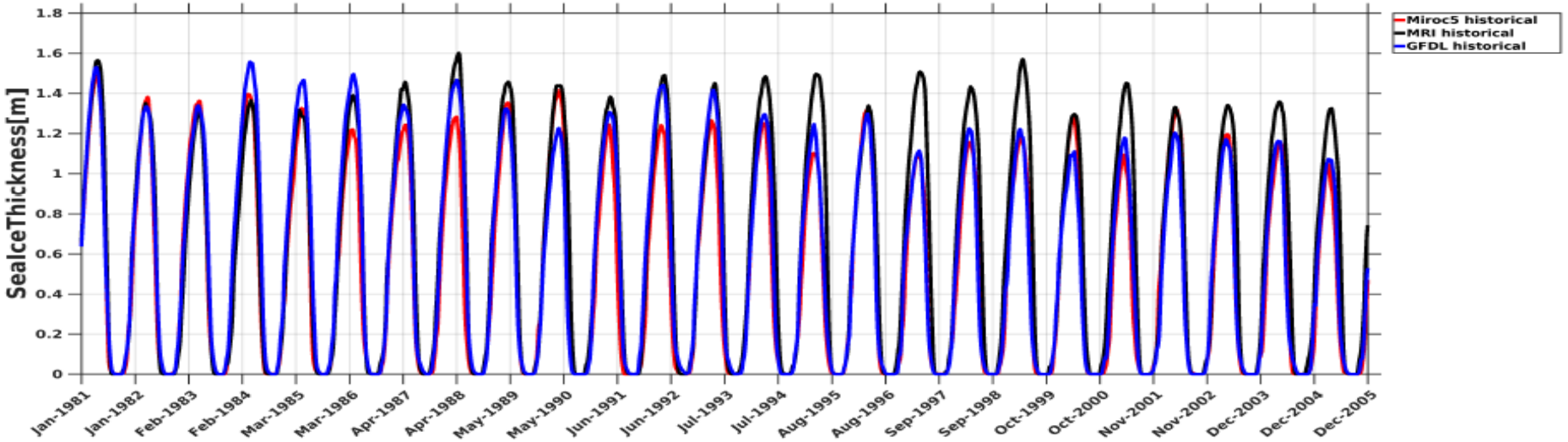
Historical (1980-2005) Sea-Ice





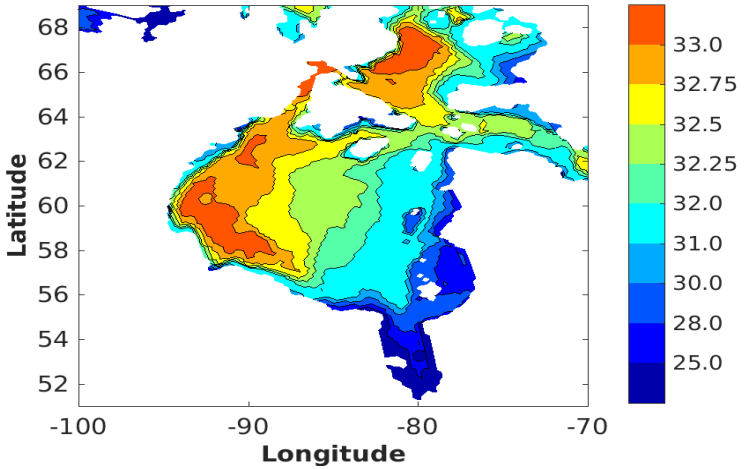
Historical (1980-2005) Sea-Ice



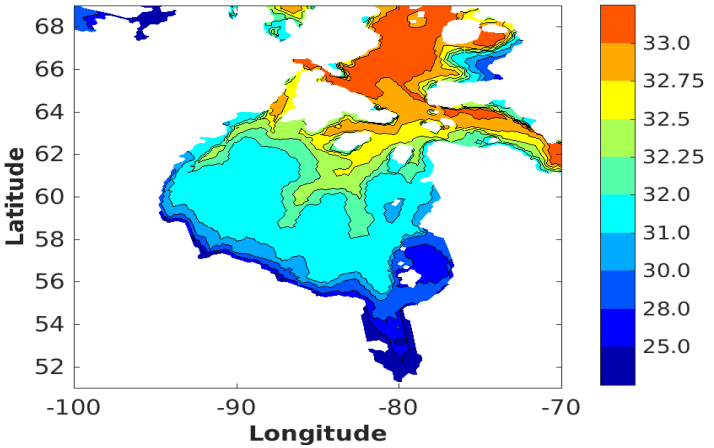


Preliminary Historical Run Output

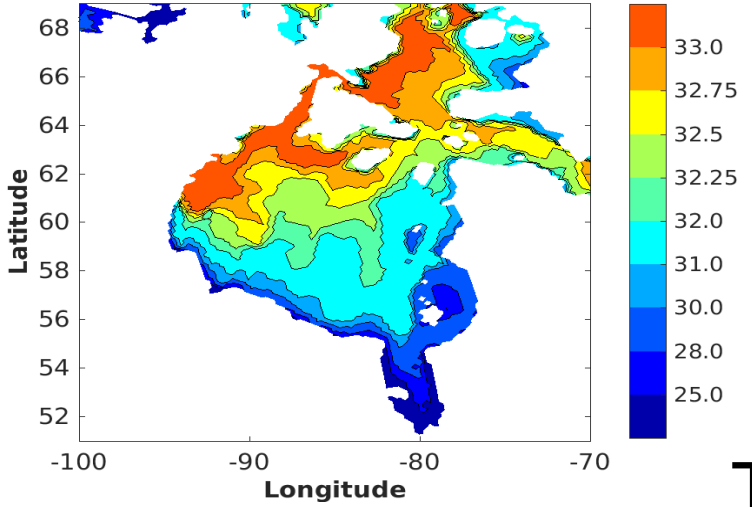
ERA
Winter
1990



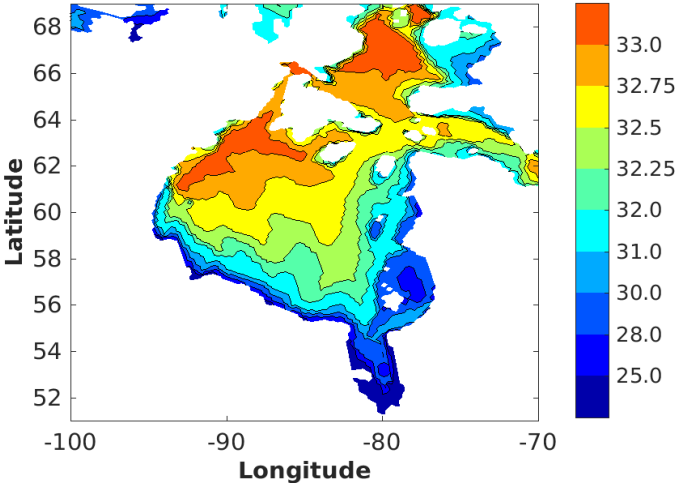
MIROC
Winter
1990



MRI
Winter
1990



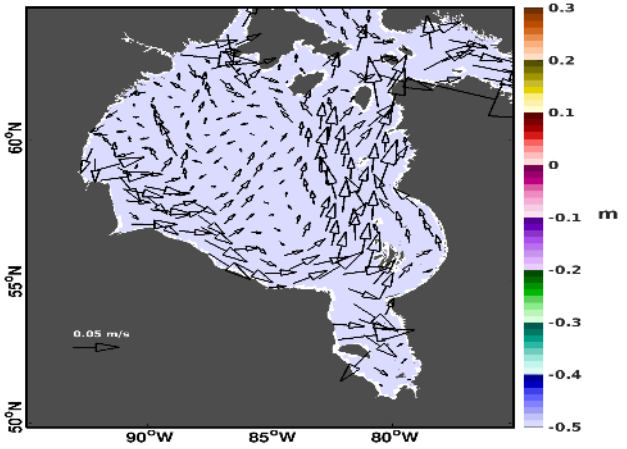
GFDL
Winter
1982



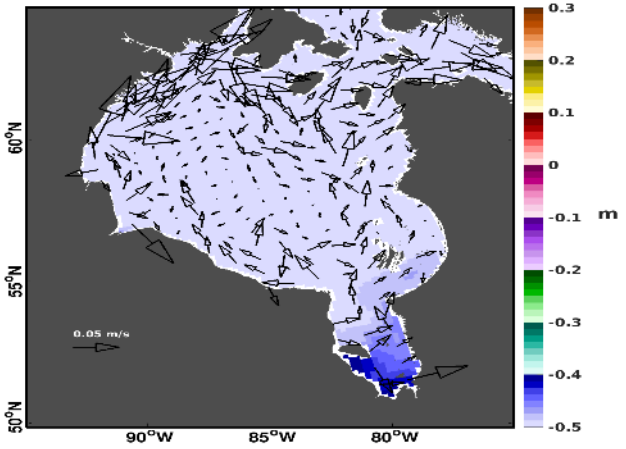
Top 100
Salinity

Preliminary Historical Run Output

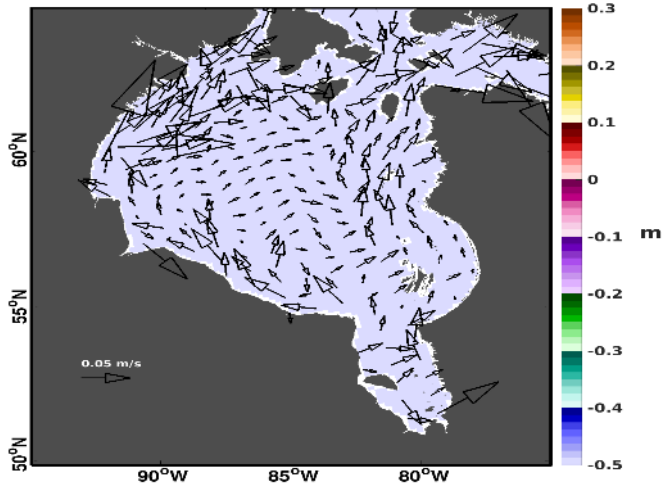
ERA
Winter
1990



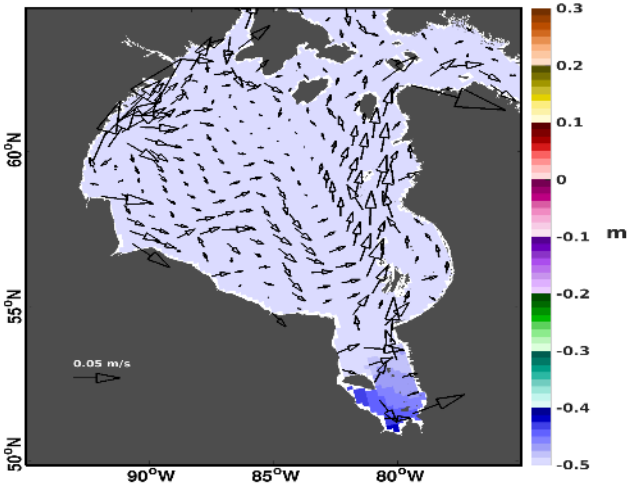
MIROC
Winter
1990



MRI
Winter
1990



GFDL
Winter
1982

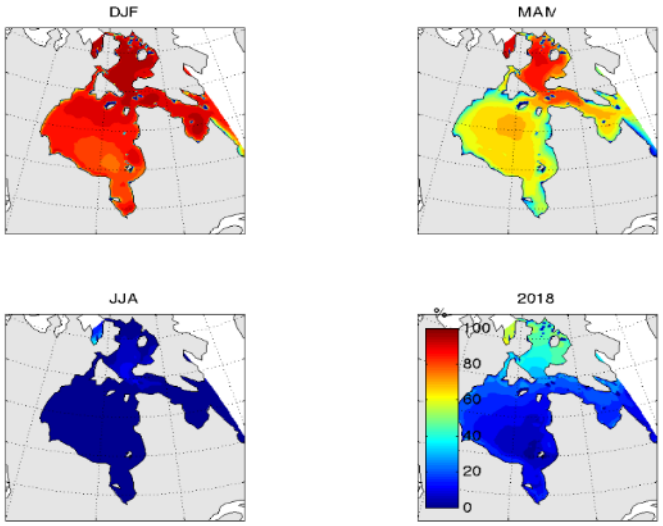


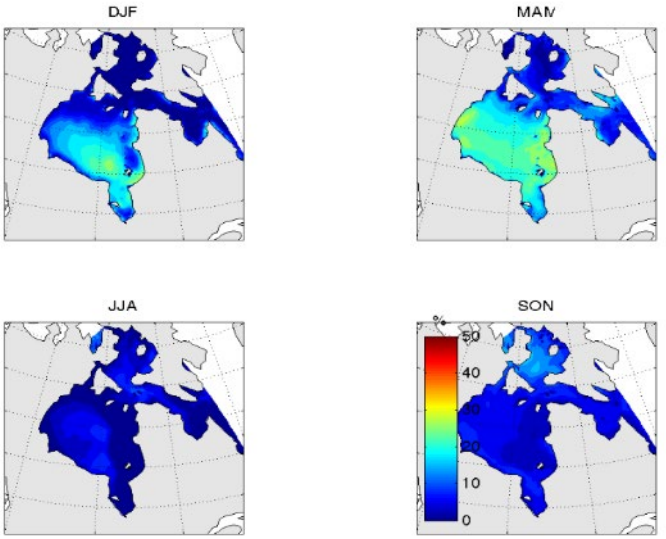
Winter
Circulation

Present Day (2018) Sea-Ice from Future Runs

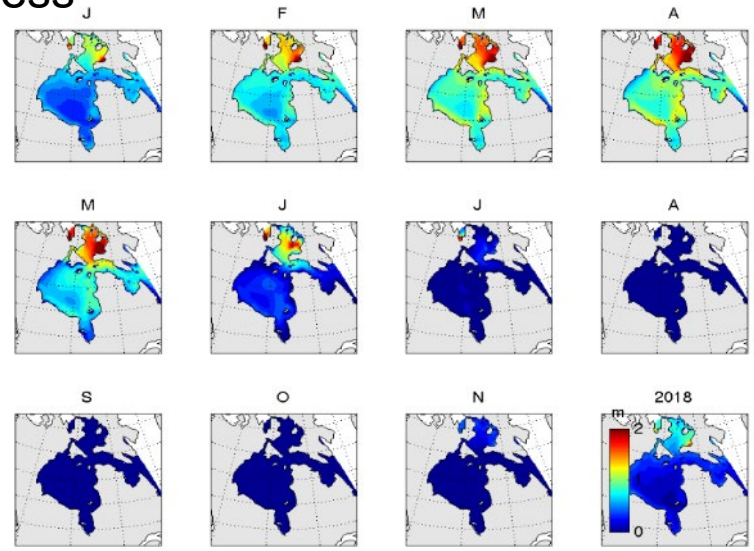
Jennifer Lukovich

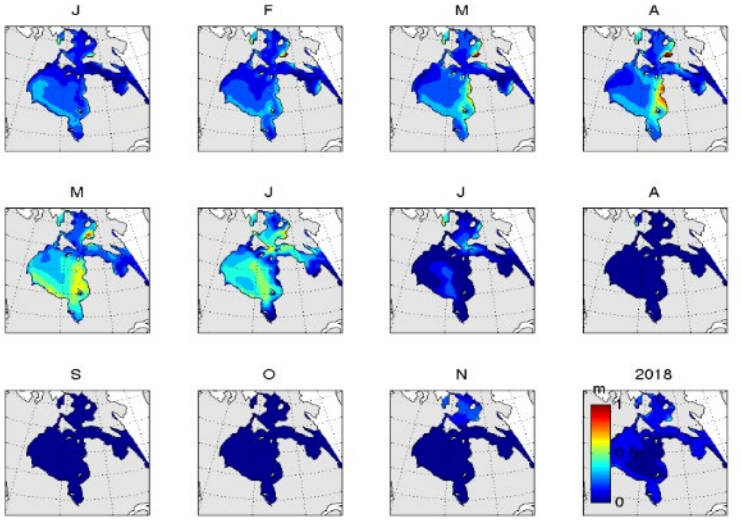
Concentration





Thickness



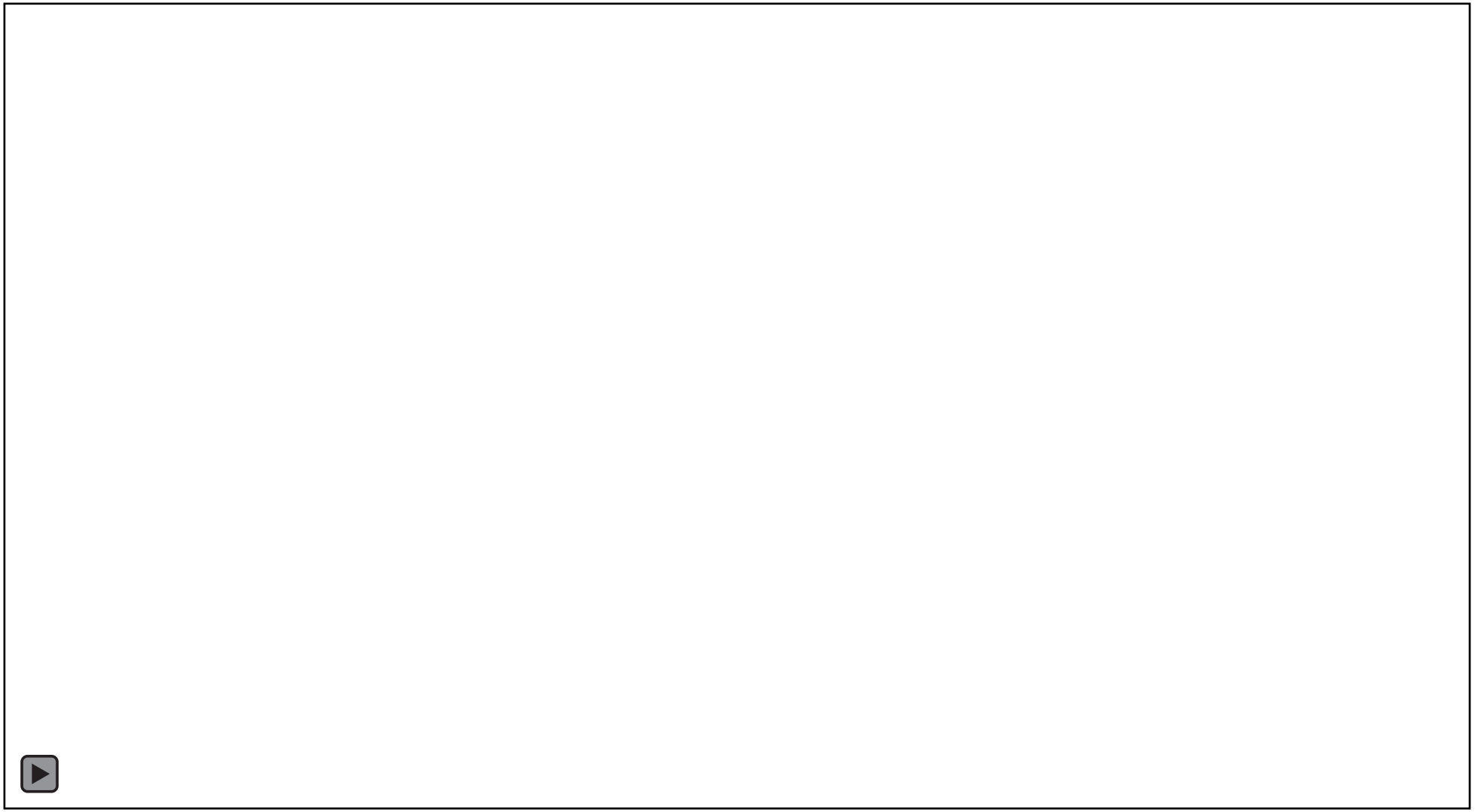


Means

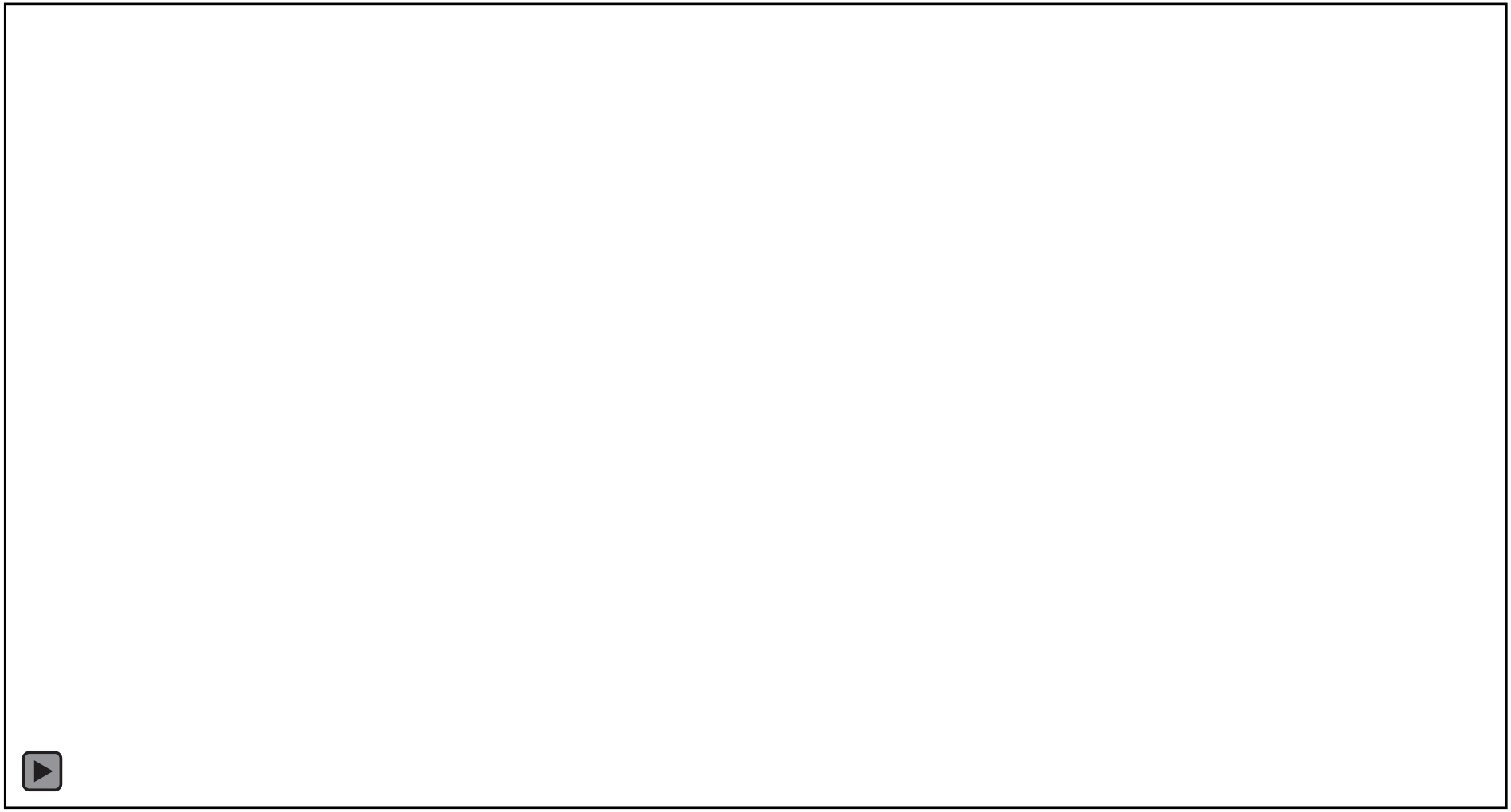
Standard Deviations

Into the Future (2005-2040) Ice Concentration

Into the Future (2005-2040) Ice Thickness

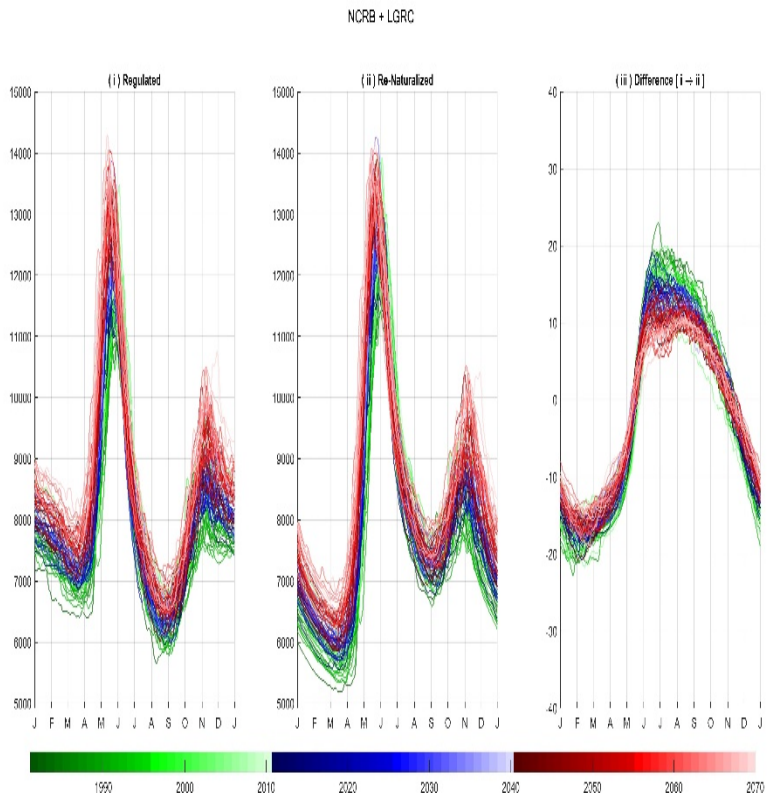


Into the Future (2005-2040) Top 50 m Temperature



Regulated Experiments

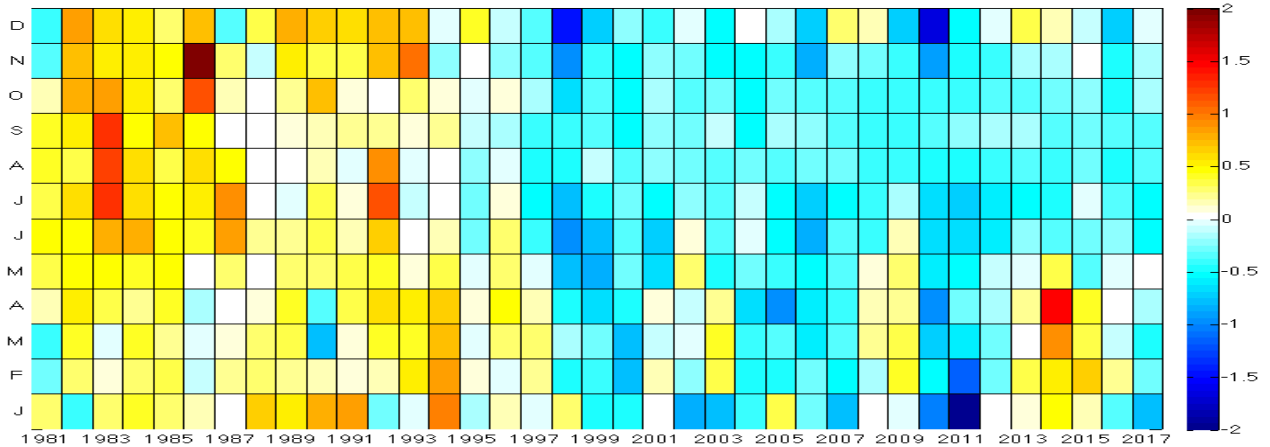
- Historical Regulated Experiments
  - To be completed early December 2019
- Future Regulated Experiments
  - To be completed early 2020



Andrew Tefs – BaySys Team 2

BaySys subgroup objectives
Lead by J. Lukovich

- *Baseline evaluation*
  - Evaluation of forcing (atmospheric and discharge) and sea ice conditions in HBC during 2016-2018 timeframe
  - Model/observational data comparisons
- *Relative climate change and regulation impacts analysis*
  - Standardized characterization of relative climate change and regulation impacts on freshwater/marine coupling using consistent suite of diagnostics for relevant ice and oceanographic variables



SIC Year-month standardized anomalies for HBC