Diagnosing Sea Ice in the Unified Forecast System (UFS)

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Atmospheric Composition

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Coupled Model Evaluation

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ESRL/PSL: Zachary Lawrence, Amy Solomon, Maria Gehne, Chris Cox
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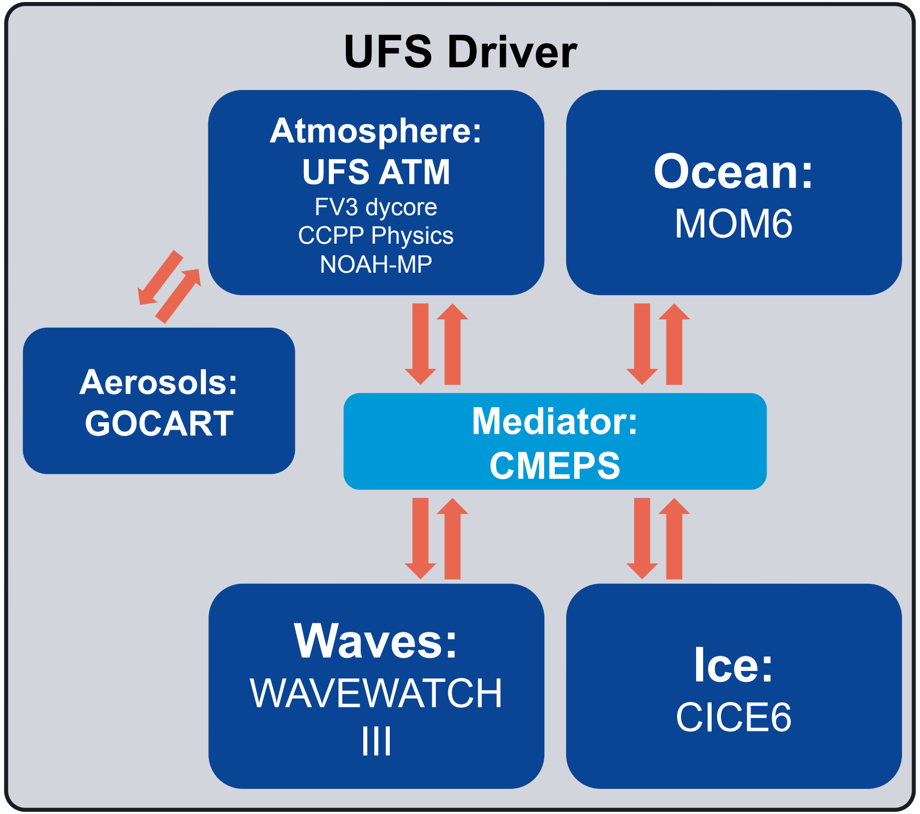
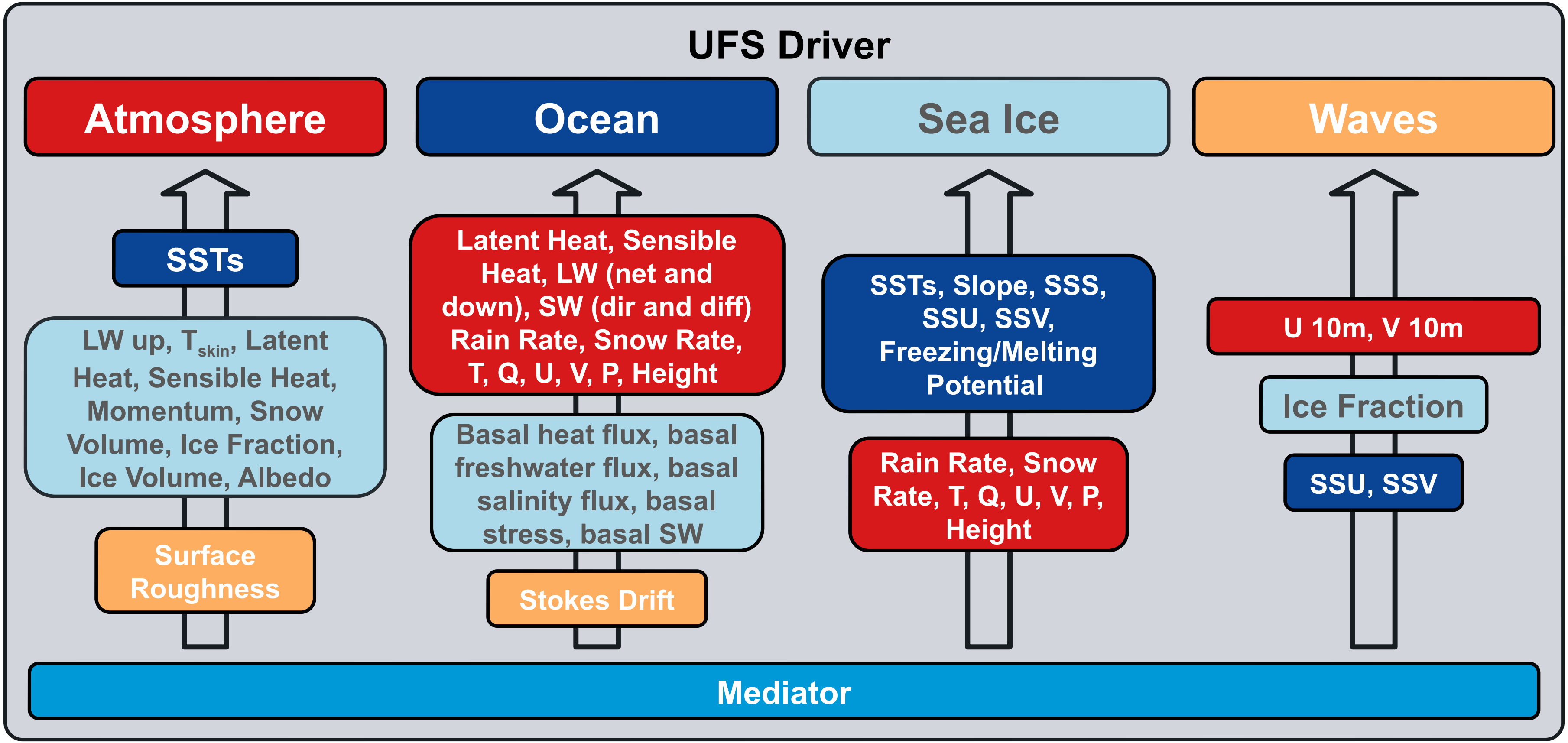
Sea Ice Modeling in UFS



CICE6

- Department of Energy Based Model
  - Los Alamos National Laboratory (LANL)
- CICE consortium
  - DOE, NSF, US Naval Research Lab, NASA, NOAA, DMI, Environment Canada, iPAN
- ¼ degree tripolar grid (same as ocean)
- 5 thickness categories
- Mushy thermodynamics
- B-grid
- JEDI-SOCA (Sea-Ice Ocean and Coupled Analysis) for initialization (sea ice concentration, sea ice thickness, snow thickness)

CICE Coupling



Sea Ice Results from Prototype 8

Forecast Setup:

- Every 1st and 15th day from April 2011 to March 2018
- 35 Day Forecasts
- Prototype Testing Runs

Observations:

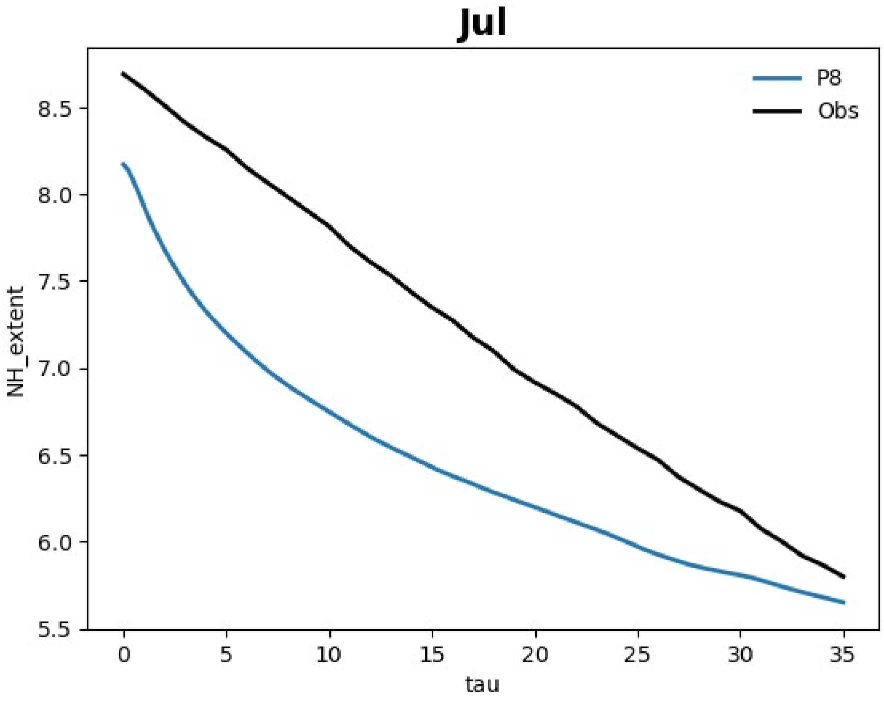
- Sea Ice Concentrations/ Extent
    - NASA A-Team Sea Ice Thickness

Initial Conditions:

- CICE: CPC analysis (CSIS) (Liu et al. 2019)
- MOM6: CPC 3DVAR
- FV3: GEFS Reanalysis

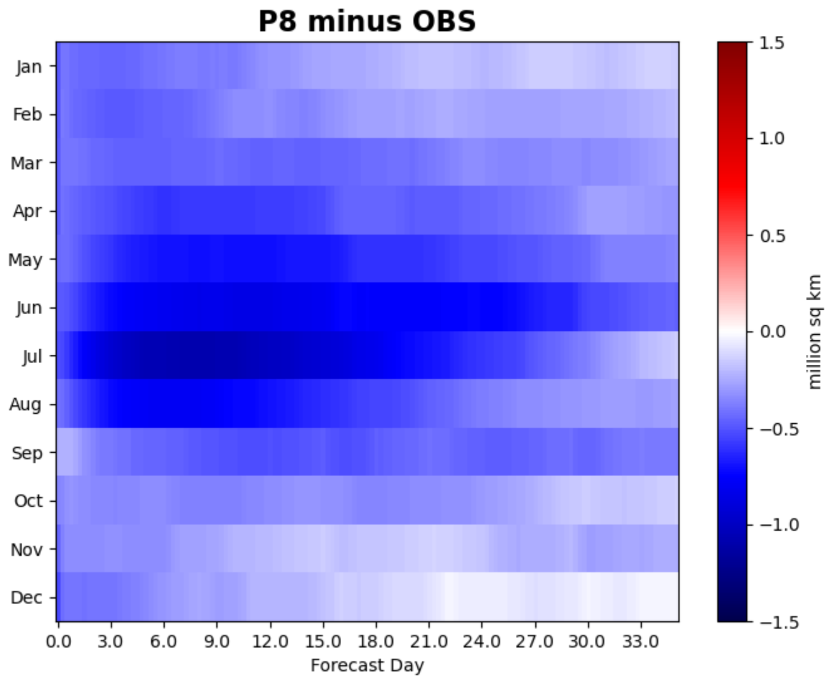
Northern Hemisphere Comparison

NH Sea Ice Extent

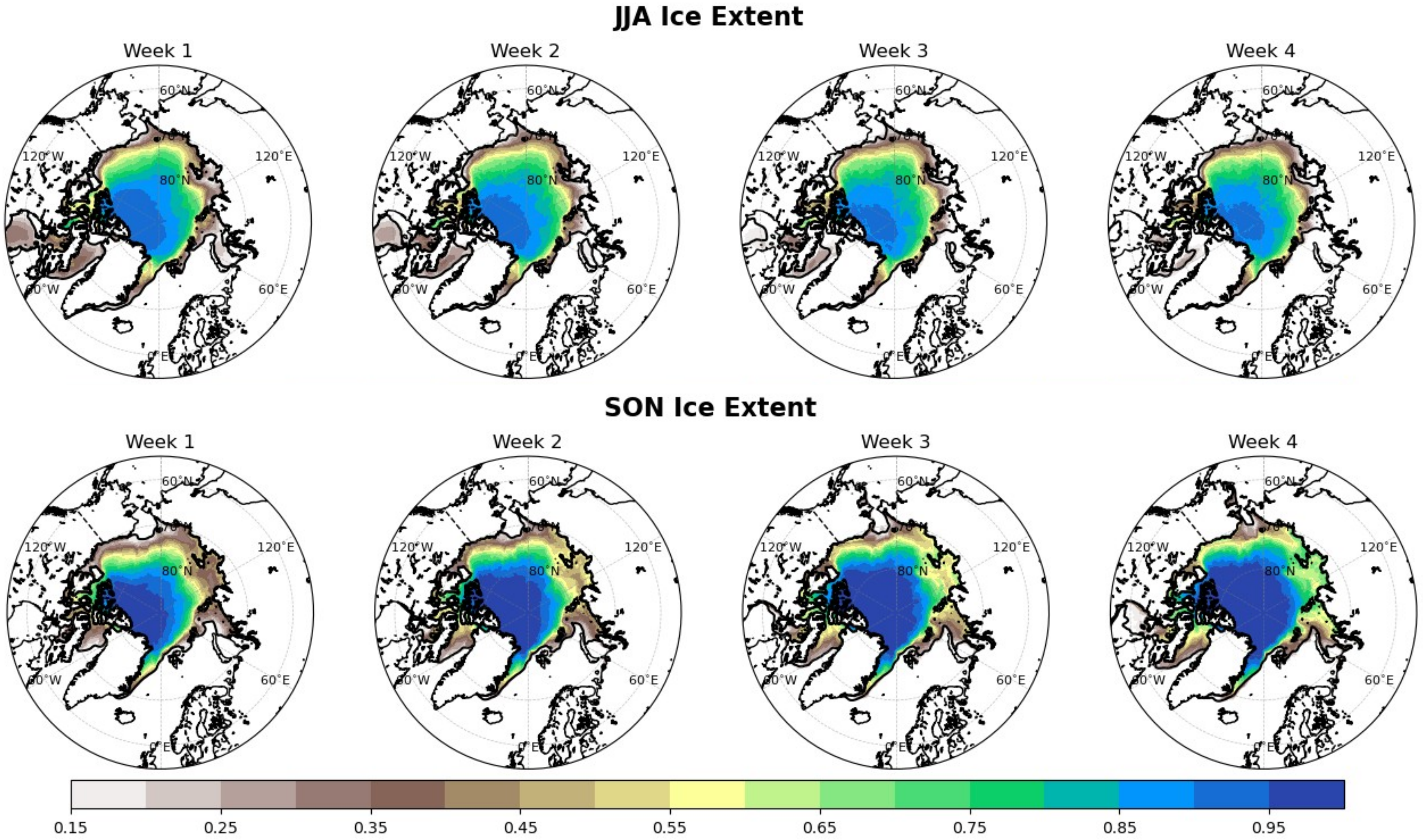


- Sea Ice Extent
  - Area with > 15% sea ice

NH Sea Ice Extent

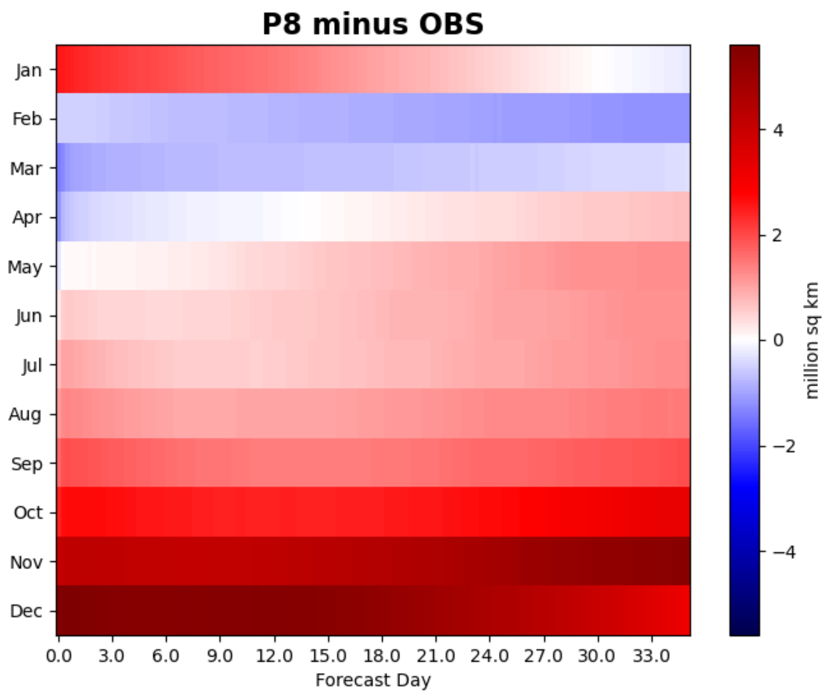


- **Negative bias in Sea Ice extent**
- **Negative bias in initial conditions**
- **Greater negative biases during summer melt months**
  - **More rapid melt**

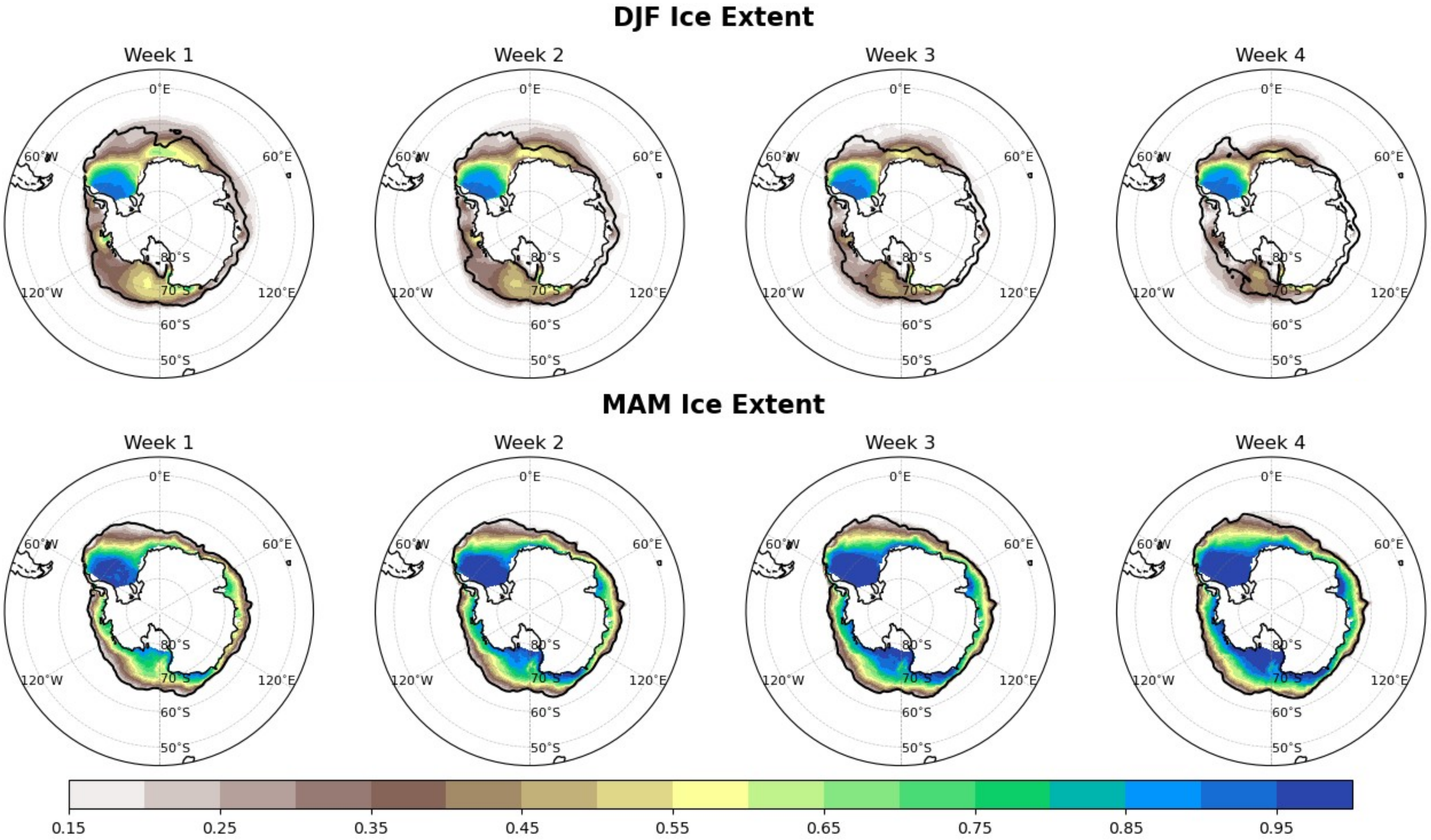

JJA Ice Extent
Week 1
Week 2
Week 3
Week 4
SON Ice Extent
Week 1
Week 2
Week 3
Week 4
60°N
80°N
120°W
120°E
60°W
60°E
0°E
0.15
0.25
0.35
0.45
0.55
0.65
0.75
0.85
0.95

Southern Hemisphere Comparison

SH Sea Ice Extent



- SH sea ice extent biases are larger than NH biases.
- P8 SH sea ice extent is mostly greater than observations except during seasons melt period.
- Larger differences in initial sea ice compared to observations when comparing to NH


DJF Ice Extent
Week 1
Week 2
Week 3
Week 4
MAM Ice Extent
Week 1
Week 2
Week 3
Week 4
0°E
60°E
120°E
60°W
120°W
80°S
70°S
60°S
50°S
0.15
0.25
0.35
0.45
0.55
0.65
0.75
0.85
0.95

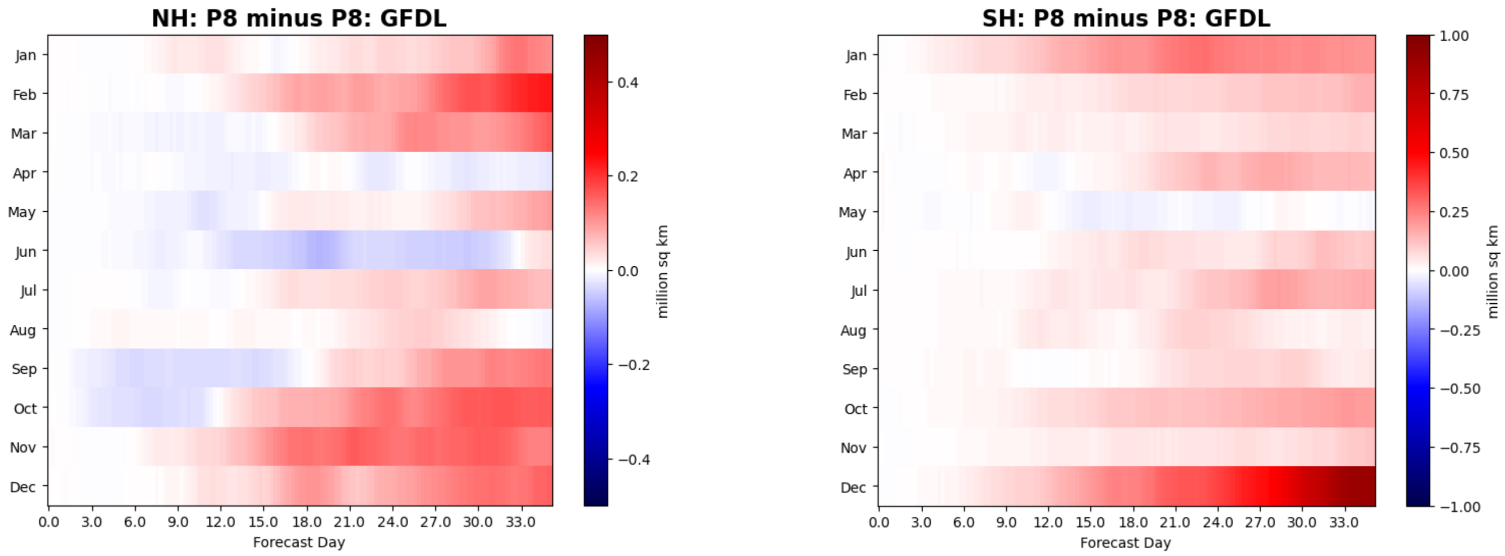
Sensitivity to Physics

- P8 is result of constant development of the UFS
- Each prototype had multiple changes that results in difficulties when isolating the cause of change
- Limited HPC resources to test individual changes
- However, GSL re-ran P8 with the old GFDL physics for analysis
- Hypothesis: Thompson microphysics can represent the clouds in the Arctic more accurately, in particular with respect to low-level mixed-phases clouds, which leads to a better representation of surface radiation, and then sea ice.

Thompson Microphysics	GFDL Microphysics
P8	previous prototypes of UFS (ops since 2019)
double microphysics (mixing ratio and droplet size)	single moment microphysics (mixing ratio)

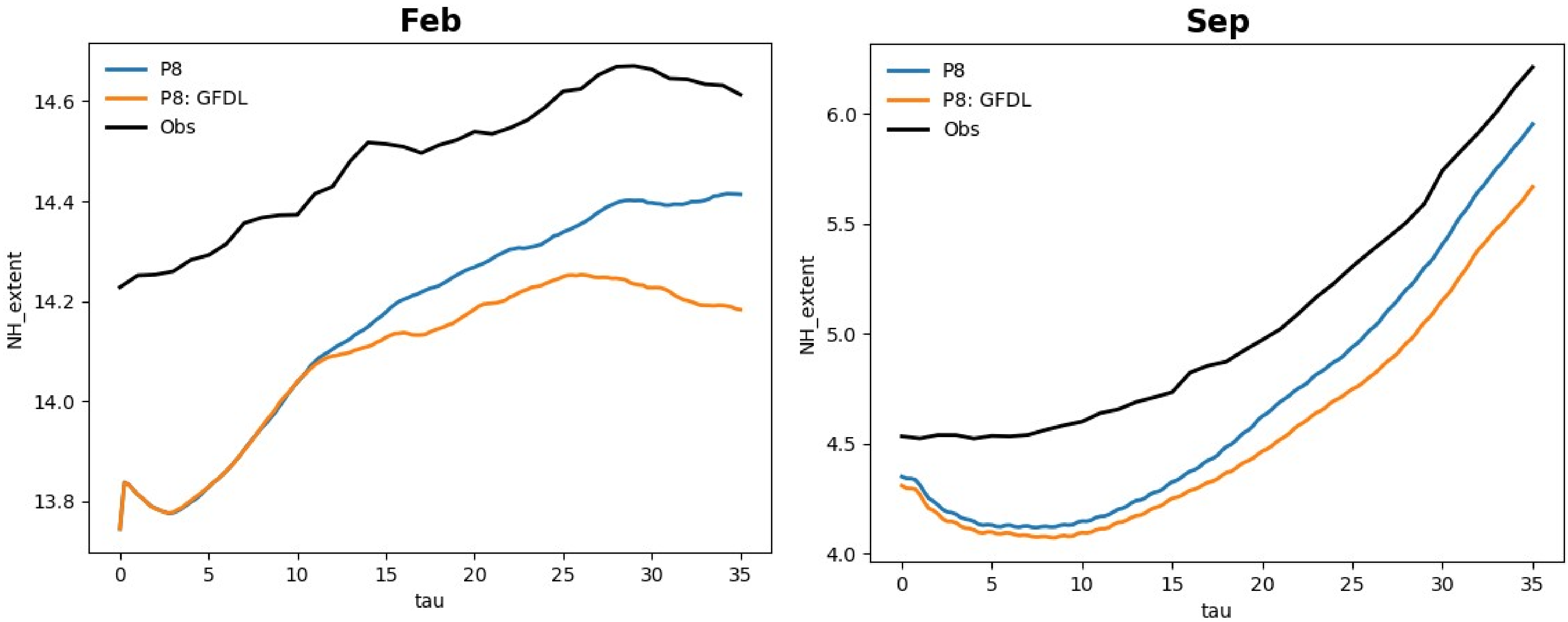
Runs completed by NOAA/ OAR/ GSL Ben Green and Shan Sun

Sea Ice Extent: Sensitivity to Physics



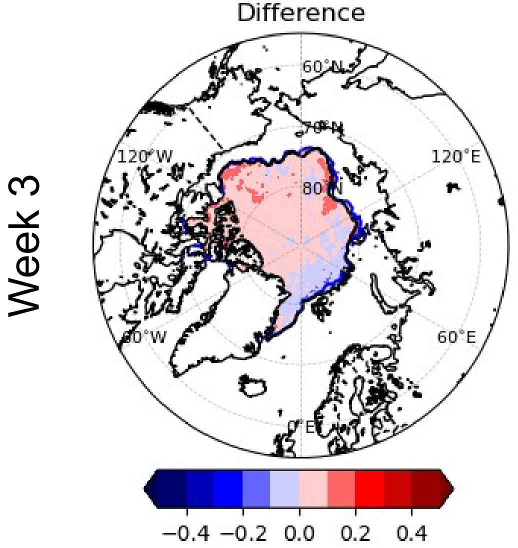
- Overall, there are not large differences between NH sea extent with the changes in microphysics
- However, Thompson microphysics systematically produces more sea ice in the NH winter months

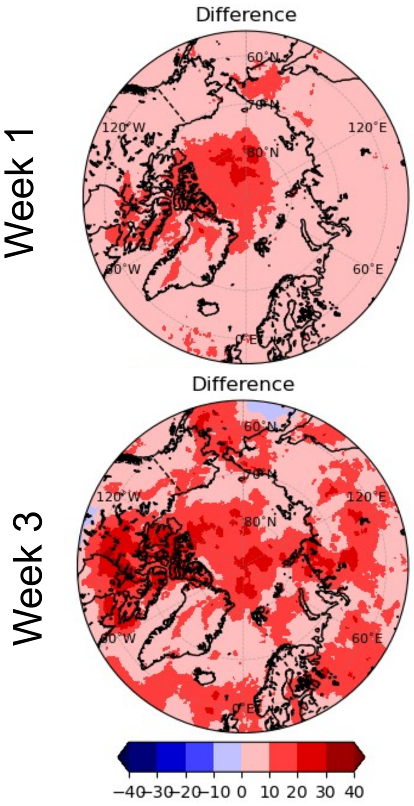
NH Sea Ice Extent



NH September: Sensitivity to Physics

Thompson (P8) minus GFDL

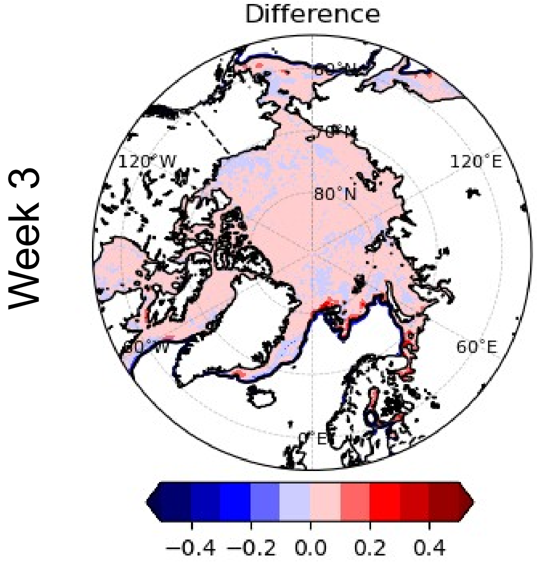


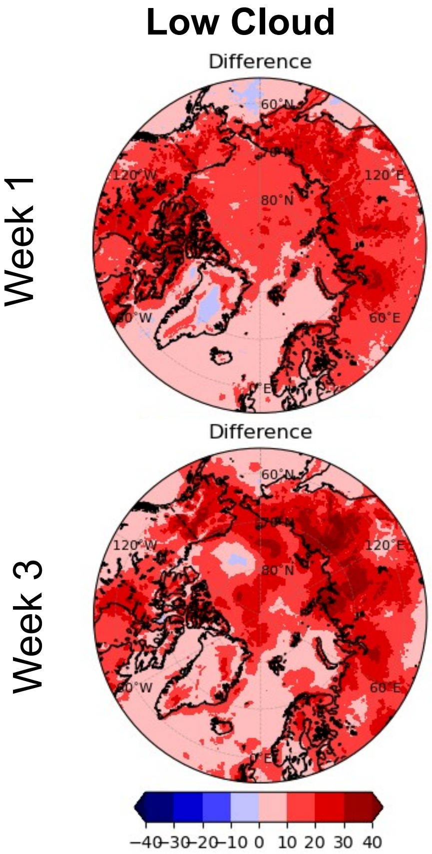


- Higher low cloud cover cloud occurs in Thompson microphysics compared to the GFDL microphysics.
- Differences in clouds start early in the forecast

NH February: Sensitivity to Physics

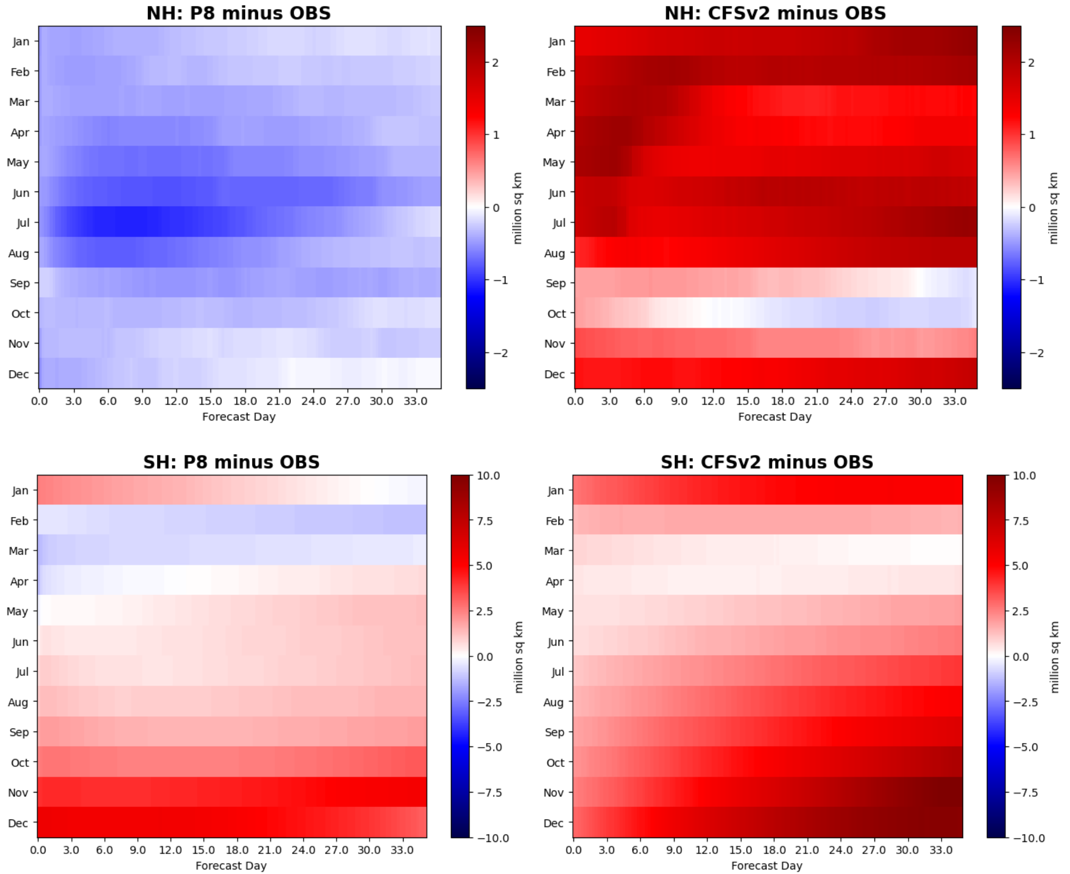
Thompson (P8) minus GFDL





- Higher low cloud cover cloud occurs in Thompson microphysics compared to the GFDL microphysics.

Comparison to CFSv2



- **Raw, uncorrected model results**
- **P8 sea ice extent biases are much smaller than CFSv2 biases in Northern and Southern Hemisphere**
- **Recalibration needed for biases corrections for S2S UFS runs**

Conclusions

- Initial look at large scale sea ice in the global UFS runs
- Sea ice extent in NH is reasonable
- Larger biases occur in the SH compared to the NH.
    - The initial sea ice in SH summer season should be examined is greater detail
- The switch to Thompson microphysics slightly alters the sea ice extent predictions
    - In particular, NH winter sea ice is greater with Thompson microphysics and results in closer agreement to observations
    - Corresponding with higher low-cloud fractions. However, more analysis of cloud properties is needed
- Shorter Term Updates:
    - Ensembles
    - Initialization in weakly coupled DA system
- Longer Term Updates/testing:
    - C-Grid
    - Meltponds, aerosols

Thank You!

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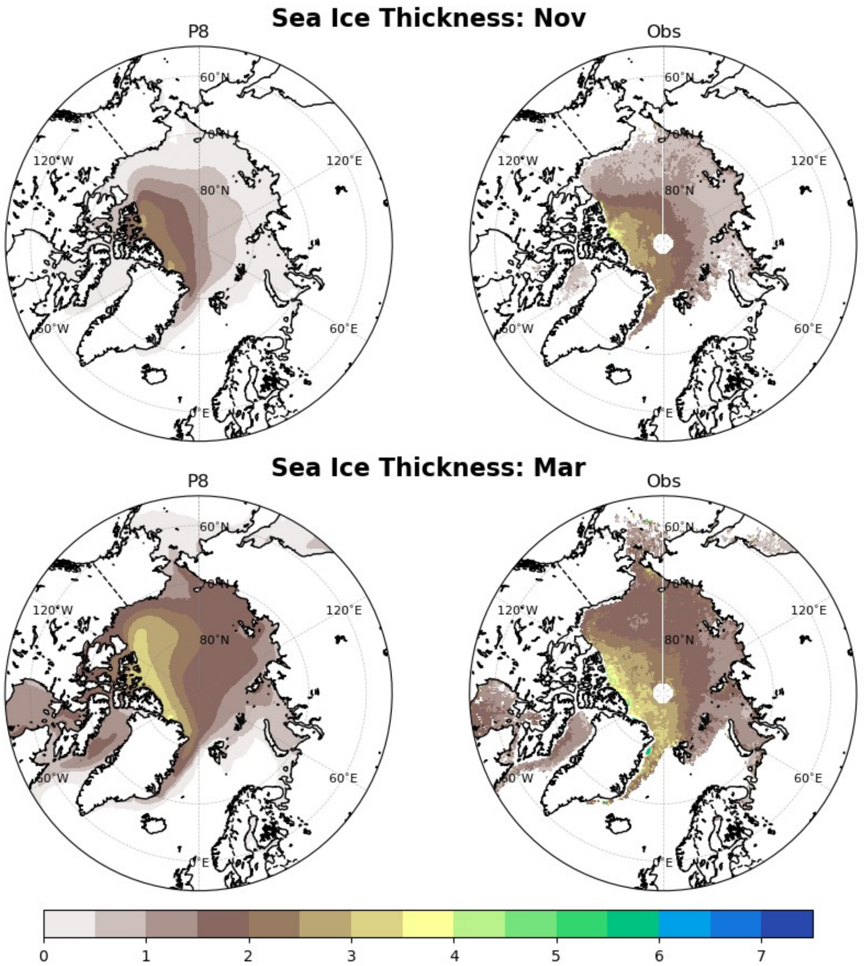

Sea Ice Thickness Comparison

- Week 1 average of Sea ice thickness
- Initialized from CPC analysis
  - Biases similar to initialization Collow et al. (2019)
- Overall decent agreement for no assimilation of thickness
- Higher sea ice thickness values north of Canada in the model compared to observations