Dynamical Downscaling Using WRF in a Fully Coupled Regional Climate Model

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Overview

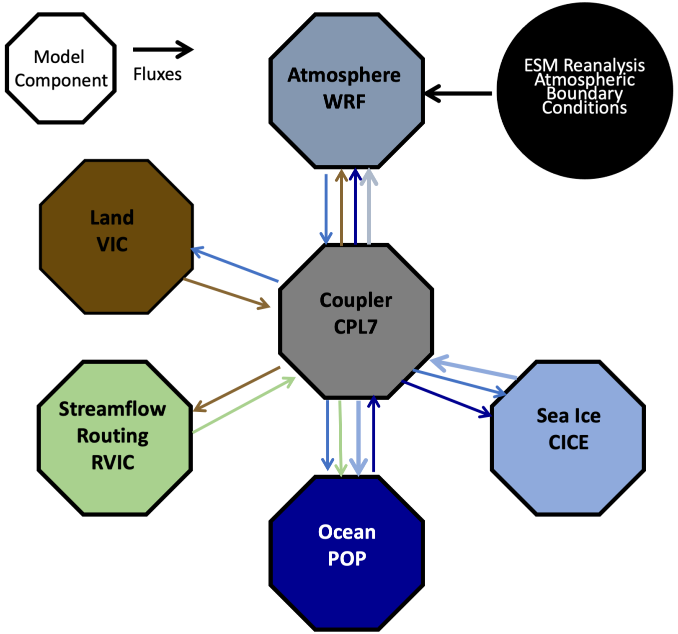
- Use the fully coupled Regional Arctic System Model (RASM) to dynamically downscale decadal simulations from the Community Earth System Model – Decadal Prediction Large Ensemble (CESM-DPLE)

- Scientific Questions:
  - How does the downscaled RASM simulation respond to biases in the CESM DPLE driving data?
  - Does the use of nudging in the upper atmosphere limit the ability of RASM to develop its own near surface climate?

- Key: The surface state and fluxes are provided by the coupled component models and not the source global dataset as would be the case in an atmosphere-only dynamical downscaling

Regional Arctic System Model (RASM)

- A limited-area, coupled atmosphere-land-ocean-sea ice model focused on climate simulations of the Arctic



Component	Code	Resolution	Contributor
Atmosphere	WRF	50 km	U. Colorado
Land	VIC	50 km	U. Washington
Ocean	POP2	1/12˚(~9 km)	NPS
Sea Ice	CICE	1/12˚(~9 km)	NPS
Coupler	CPL7	20 min.	NPS

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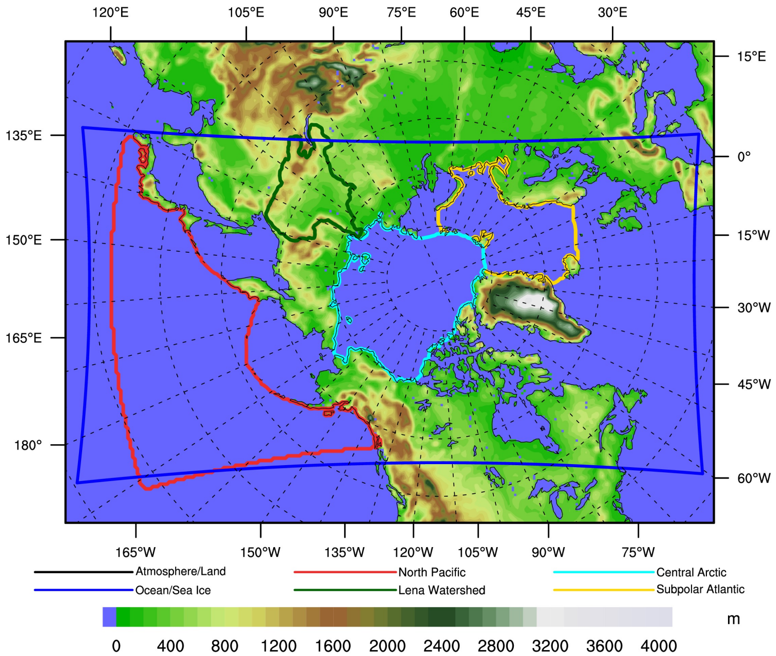
Regional Arctic System Model (RASM)

- RASM focuses on understanding mesoscale processes and the resulting feedbacks that are critical to improved representation of the state of the Arctic Climate System

- Regions are used to analyze atmospheric state and fluxes unique to that location and surface state



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CESM Decadal Prediction Large Ensemble (DPLE)

- CESM v1.1 – same model as CESM large ensemble (CESM-LE)
- 40 ensemble members with a Nov 1 start from 1954 to 2015 (62 ensembles)
- Each member is run for 122 months (10 years + 2 months)
- Only 10 members have the required 6 h output to force RASM simulation

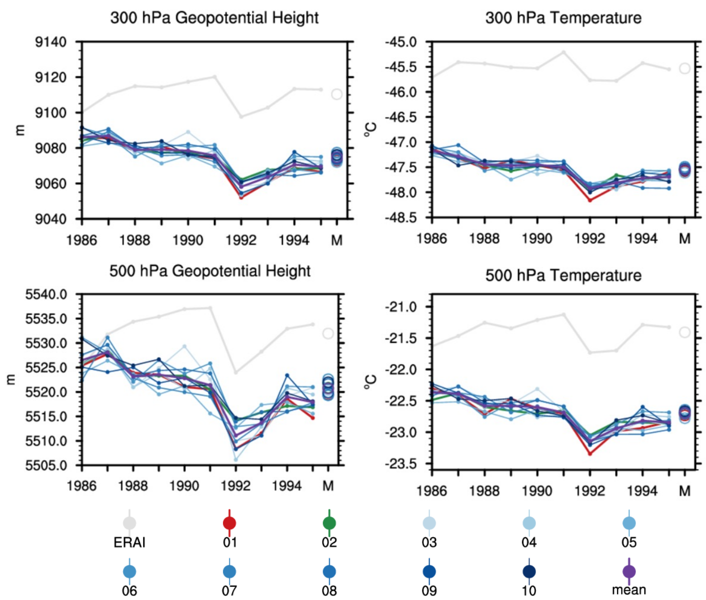
- Created WRF input files from the CESM-DPLE output

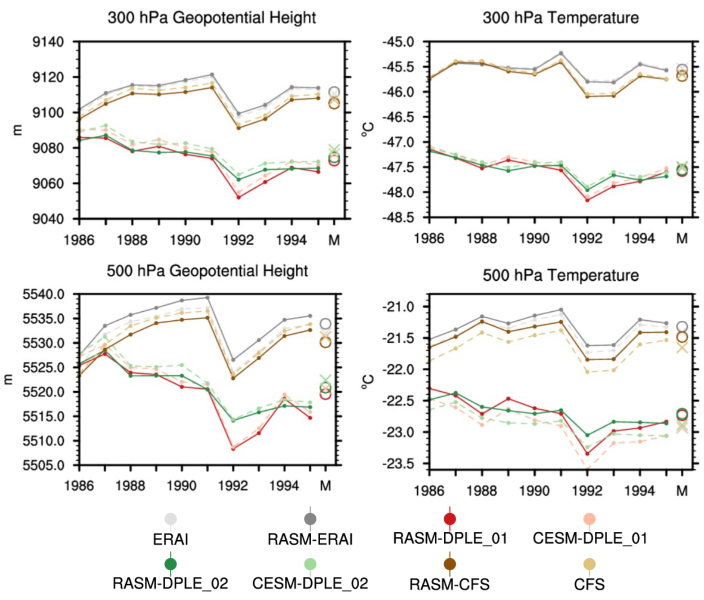
CESM-LE (Kay et al., 2015)
CESM-DPLE (Yeager et al., 2018)

RASM Experimental Setup

- Two RASM simulations forced by reanalyses (RASM-ERAI, RASM-CFS)
  - Initialized 1 September 1979 and run until 2018 (2020)
- 10 RASM-DPLE simulations forced by CESM-DPLE ensemble members
  - Initialized 1 Dec 1985 and run through Dec 31 1995
  - Atmosphere specified from driving CESM-DPLE data
  - Ocean, sea ice and land initialized from RASM-ERAI simulation
- 2 RASM_alt-DPLE simulations run with modified WRF physics
  - Same as above but replacing Grell3D cumulus with Kain-Fritsch cumulus
- All RASM simulations use grid nudging of T, U and V above ~500 hPa

Atmospheric State – Upper Levels: 1986 to 1995

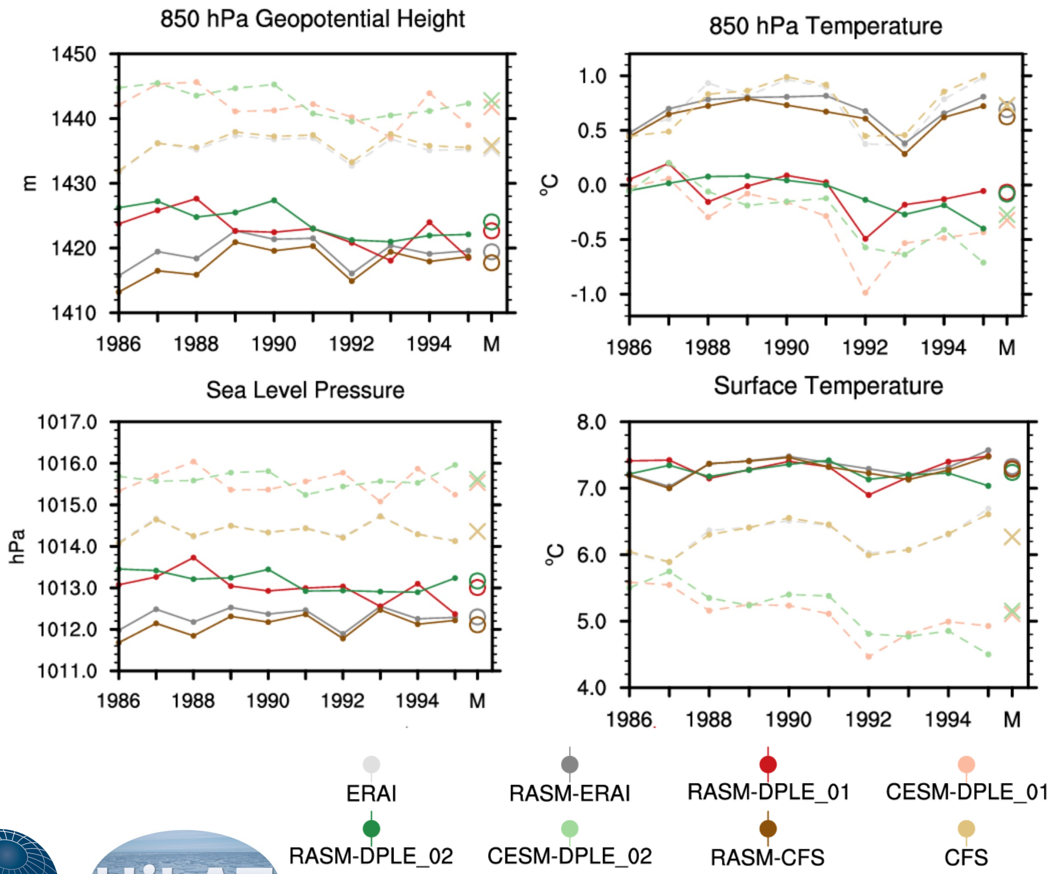




- Each RASM simulation follows that of its corresponding forcing data
- Biases are apparent between the DPLE and reanalyses

- RASM-DPLE ensemble members show a variation in weather across the years
- The first two ensemble members are selected for further study

Atmospheric State – Lower Levels: 1986 to 1995



- The RASM results are clustered together in the lower levels
- The DPLE bias in RASM simulations is no longer present
- The RASM simulations evolve into their own climatic state differing from forcing data
- The imprint of the weather from the forcing data is shown in the pattern of variability

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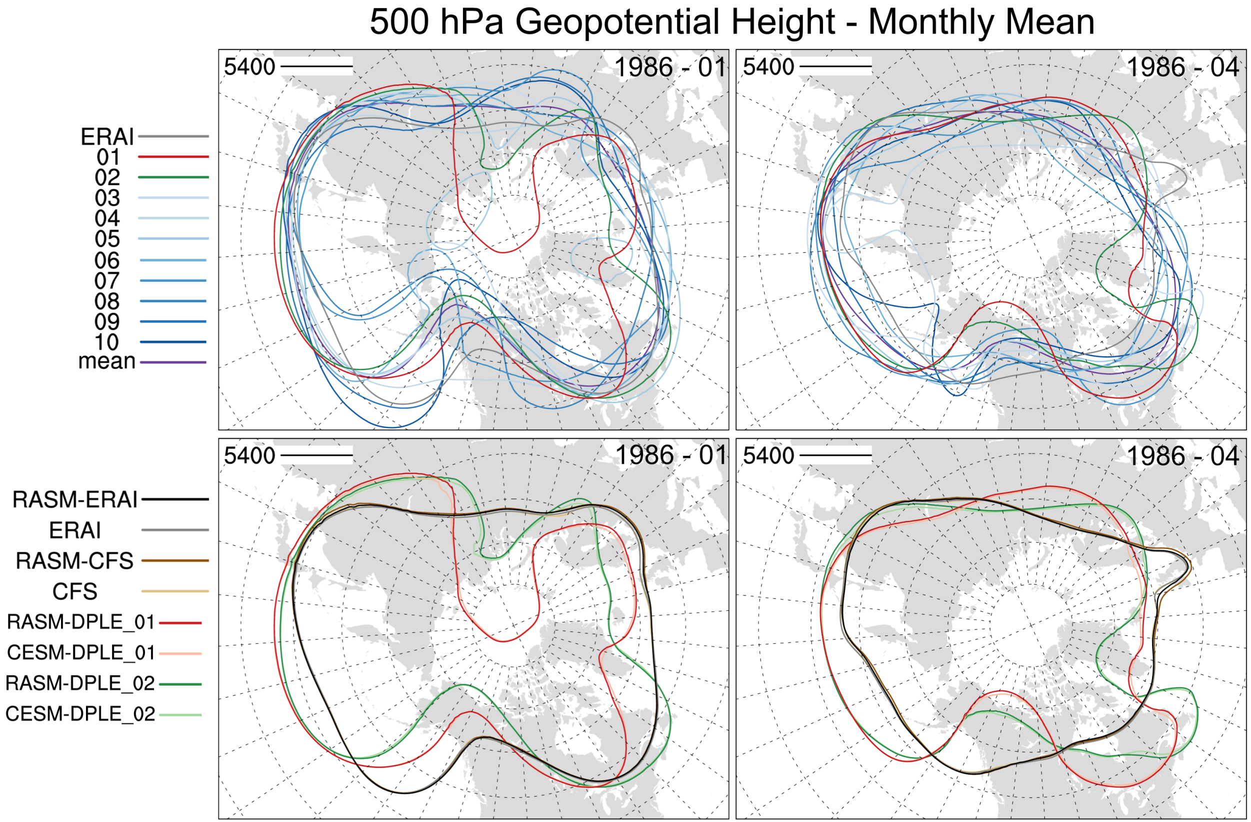
500 hPa Spaghetti Plot – Monthly Mean



- The Z500 contours indicate the variability in the weather across the RASM-DPLE ensemble members and differences from ERAI

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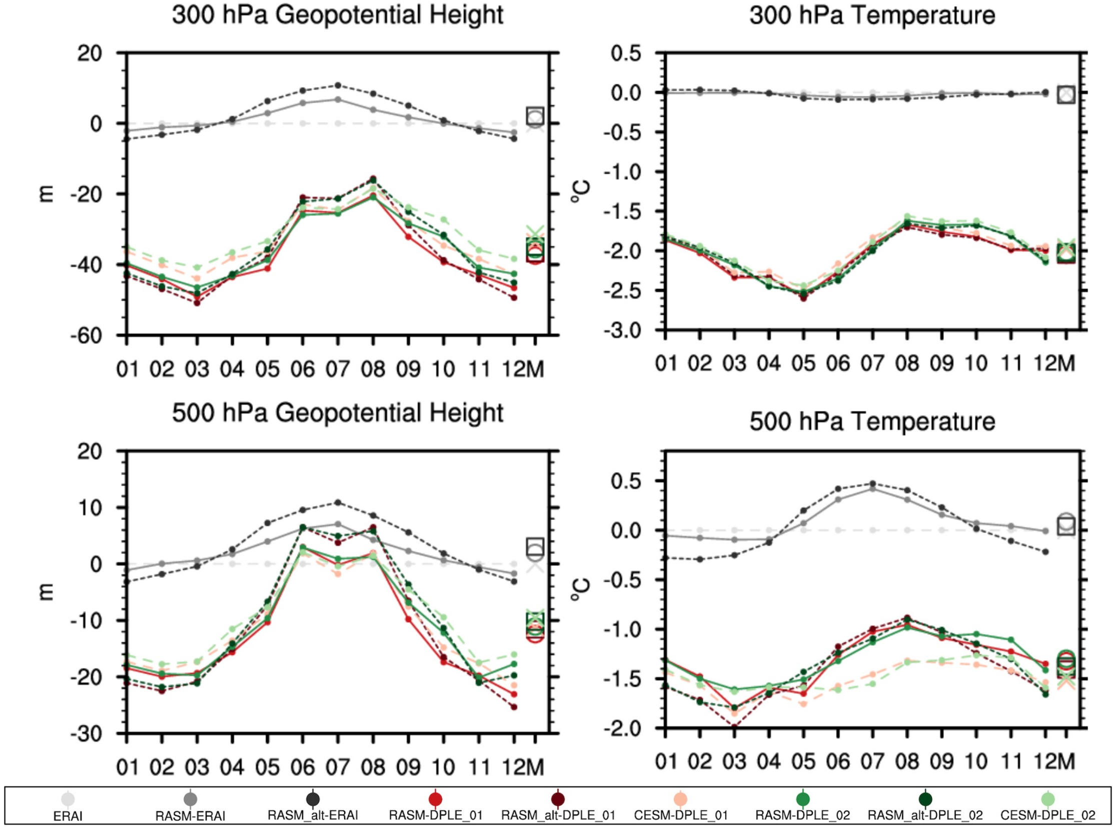
Upper Levels: Monthly Means 1986 to 1995 – RASM Domain



- The RASM simulations follow the pattern of the corresponding forcing data
- RASM_alt simulations are very similar to the original RASM simulations
- Changes in model physics have little impact on the RASM state in upper levels

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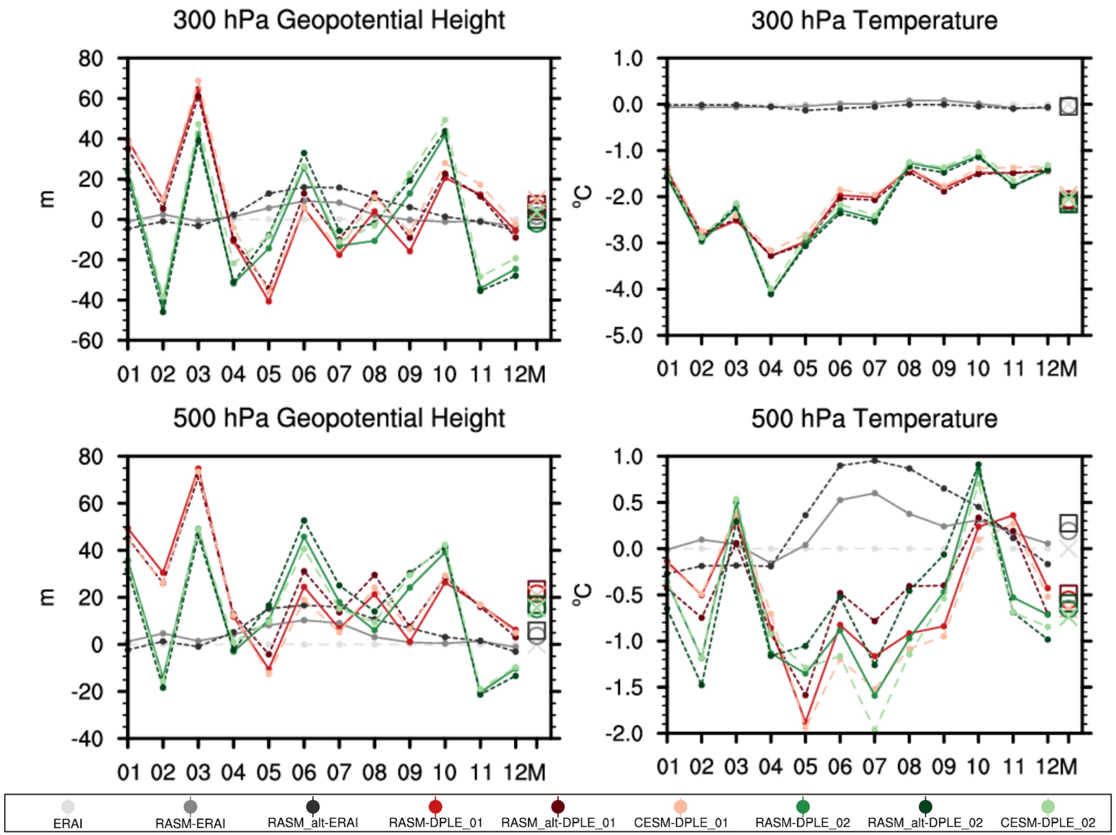
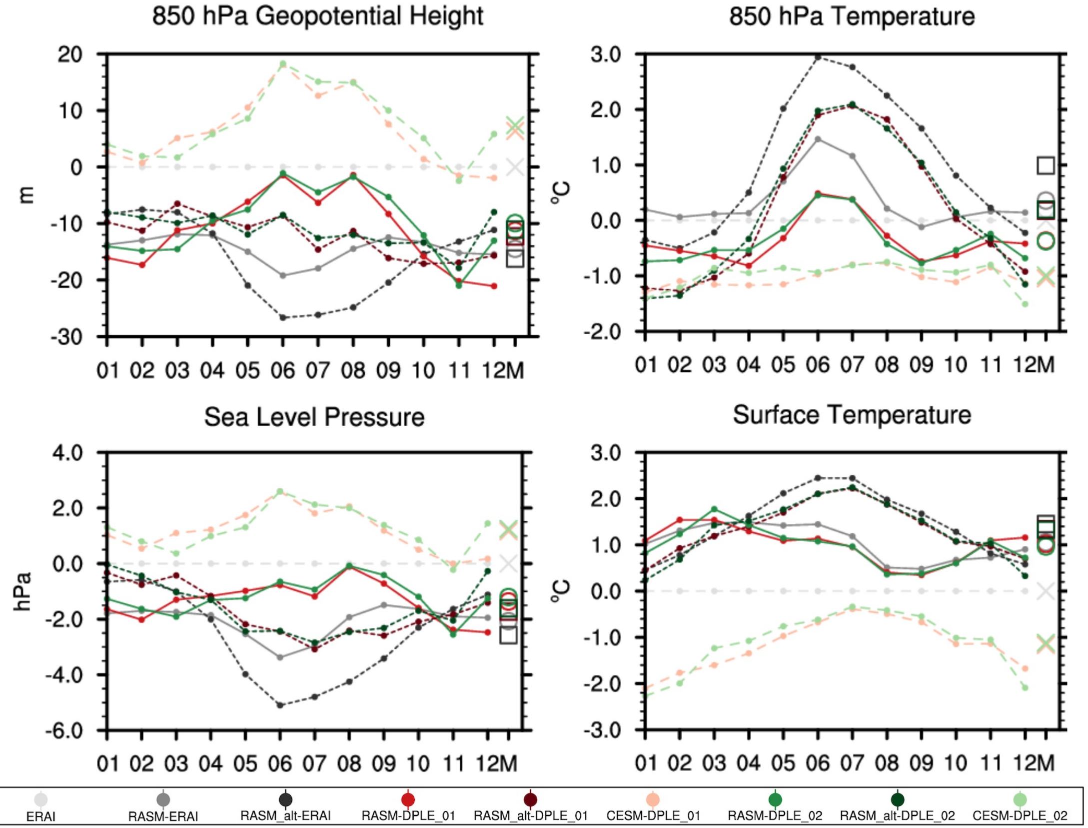
Upper Levels: Monthly Means 1986 to 1995 – Central Arctic



Lower Levels: Monthly Means 1986 to 1995 – RASM Domain



- The DPLE biases in the upper levels are removed in the RASM simulations in the lower levels as RASM goes to its own climatic state
- The atmospheric state in the lowest levels tends to cluster around the modeling system / configuration
- The imprint of the weather from the different forcing data is still noticeable

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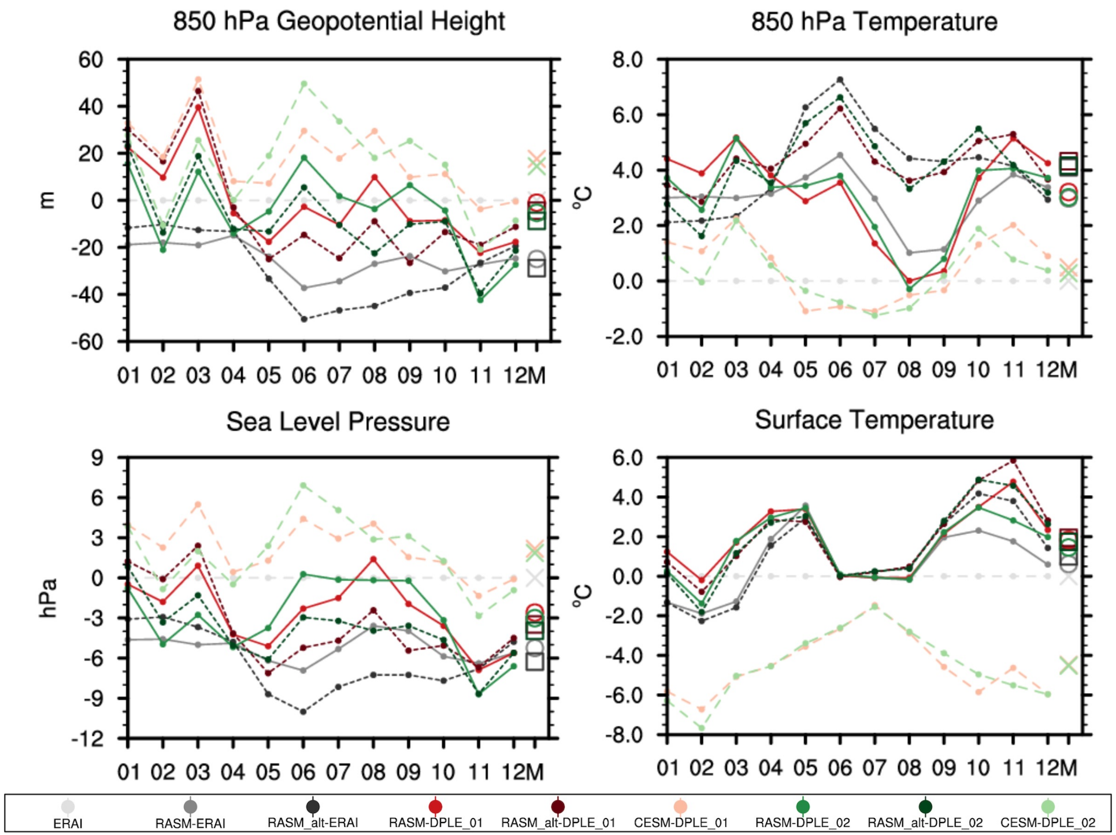
Lower Levels: Monthly Means 1986 to 1995 – Central Arctic



- The change in WRF physics has less of an impact on the Central Arctic (largest in the NP)

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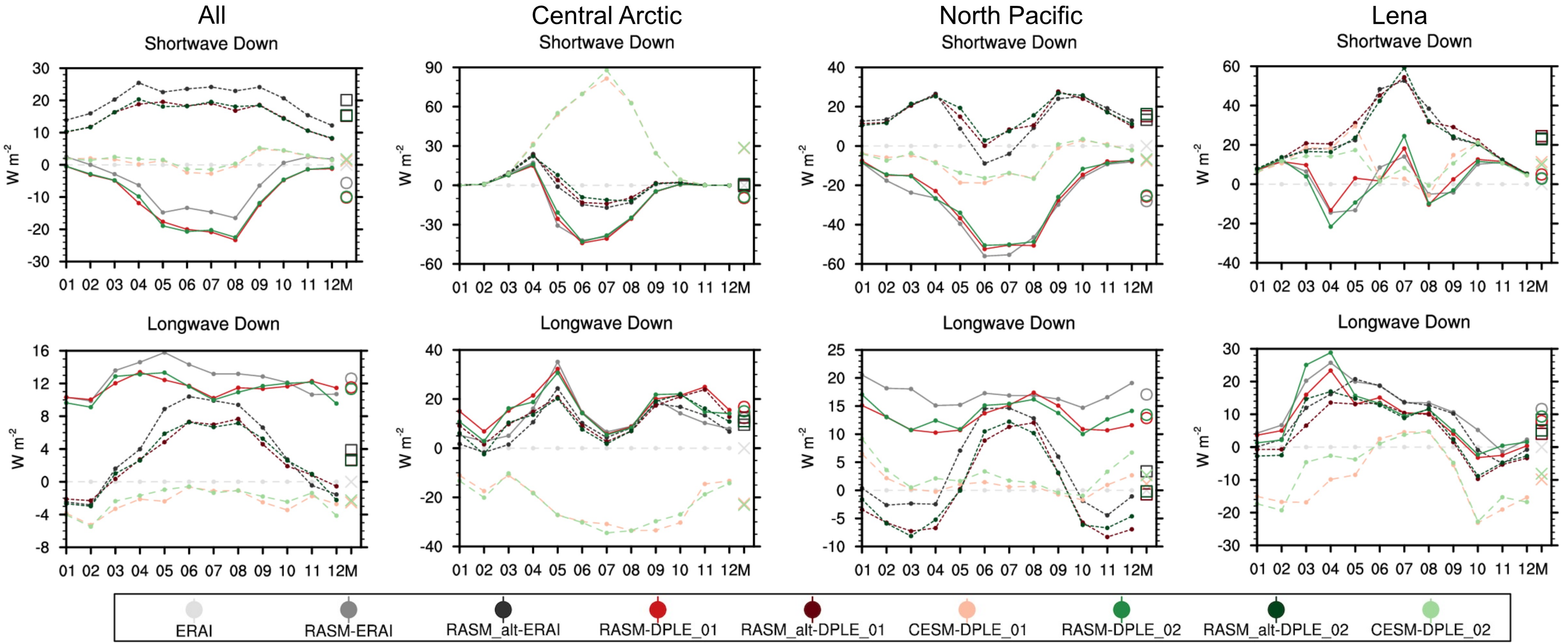
Surface Radiative Flux: Monthly Means 1986 to 1995



- Surface radiative fluxes are distinct for RASM, RASM_alt, and CESM simulations indicating that model physics dominates these variables

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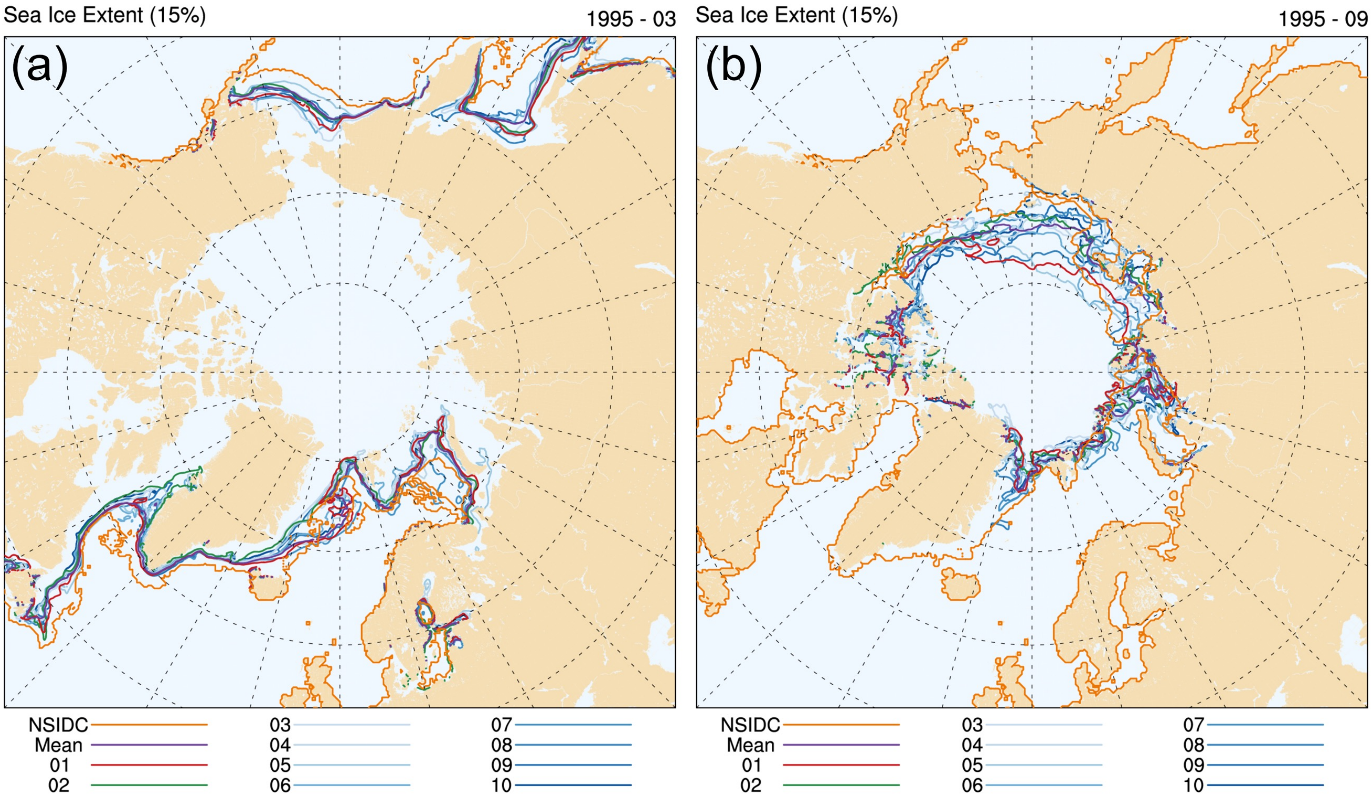
Impacts on a Coupled Modeling System: Sea Ice



- Despite similarities in the surface atmospheric climate state, the RASM-DPLE simulations still evolve to different coupled sea ice states due to the differences in the evolution of the weather

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Conclusions

- Fully coupled RASM simulations were successfully forced with CESM-DPLE output
- Nudging above 500 hPa constrains RASM's upper atmospheric state to be similar to the driving data and insensitive to changes in model physics
- In the lower atmosphere RASM's state becomes similar regardless of the driving data but varies with changes in model physics
- Throughout the depth of the atmosphere, and regardless of the model physics, RASM's state mirrors the variability in the driving data
- Fluxes, surface temperature and precipitation are strongly controlled by model physics with distinct states for RASM, RASM_alt and CESM simulations, but these variables do show some influence from differences in driving data

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