The role of atmospheric teleconnections and local forcings in predicting Greenland Ice Sheet surface mass loss

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Predicting GrIS surface mass balance

- The link between ocean and atmospheric forcings and ice sheet mass loss is critical to constraining ice sheet response to environmental change.

- Constraining the processes important in the predictability on subseasonal and seasonal timescales can help us better constrain near-term changes in ice sheet mass loss.

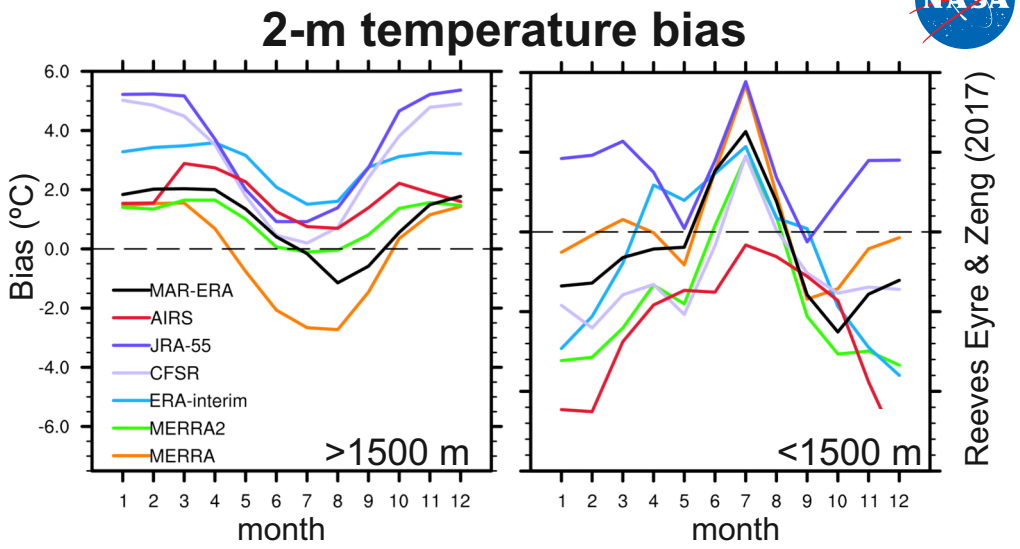
- **How well do we represent surface mass balance losses with in our seasonal prediction system?**

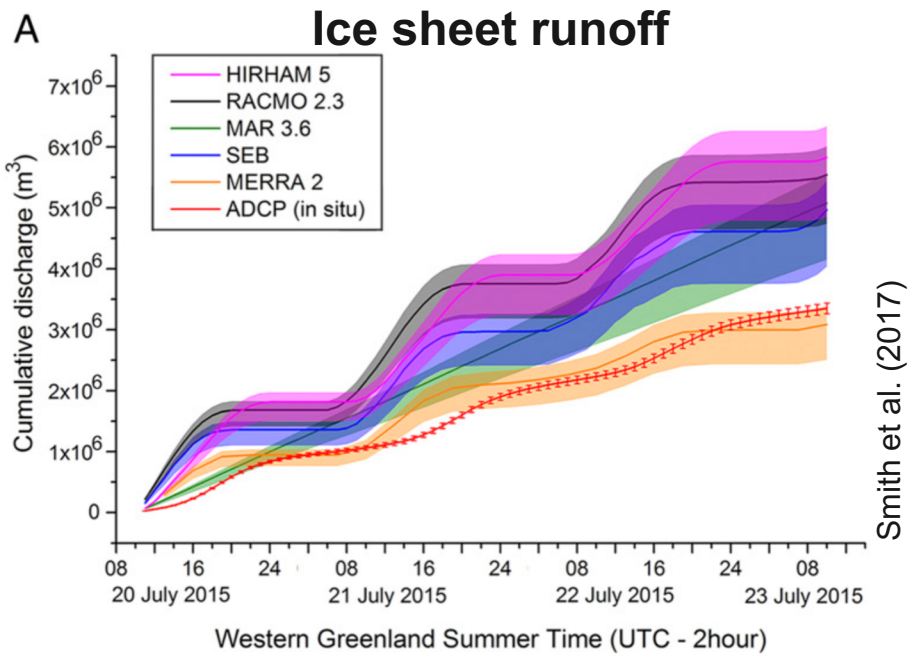
- **Can we diagnose processes within our seasonal prediction system that lead to better or worse representation of ice sheet mass balance?**

Photo: Jason Gulley

MERRA-2: cryospheric processes

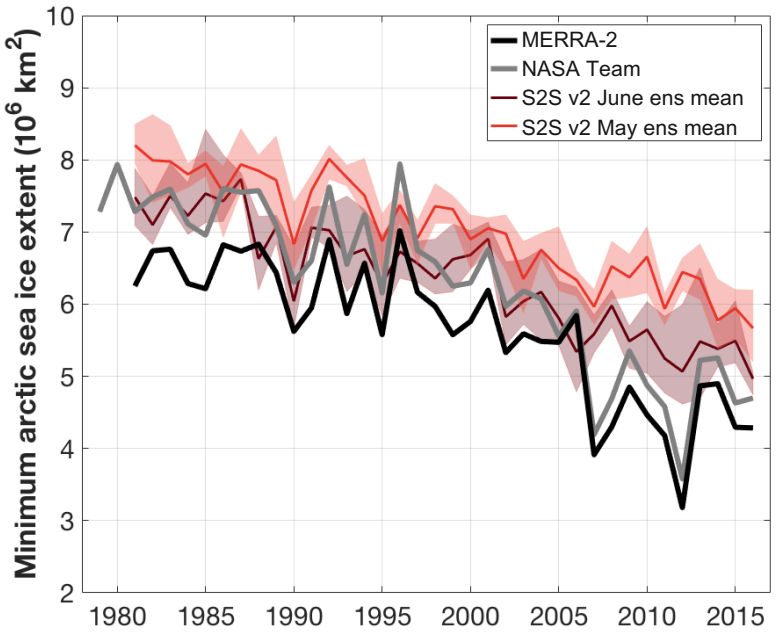
- MERRA-2 outputs are on a 0.625°×0.5° longitude-by-latitude grid and 72 vertical layers.
- Details, see Gelaro et al. (2017) and Bosilovich et al. (2016)
- MERRA-2 background model has been improved over glaciated land surfaces in comparison to MERRA to produce improved air temperatures and reduced biases in the net energy flux (Cullather *et al,* 2014).
  - Explicit representation of snow densification, meltwater runoff, percolation, refreezing, and surface albedo (Lynch-Stieglitz 1994; Stieglitz et al. 2001)



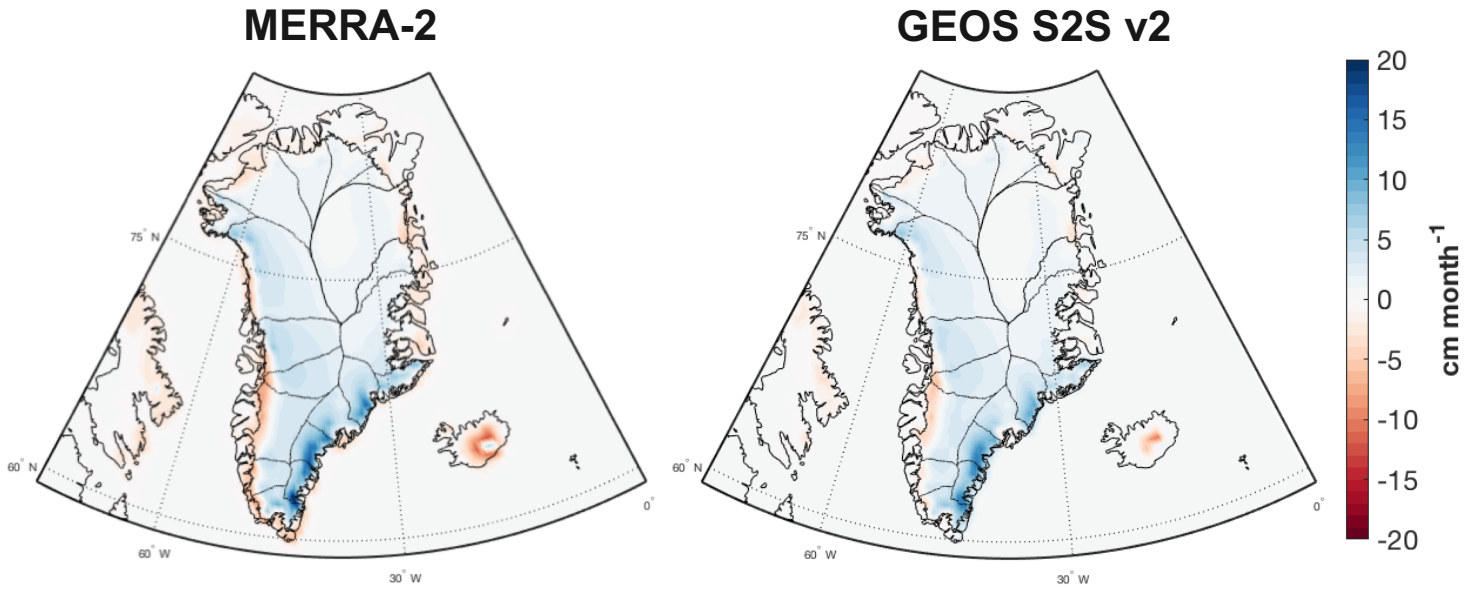


GEOS-S2S version 2

- The GEOS S2S system includes an AOGCM (GEOS, Catchment Land Surface Model, MOM5, CICE4, GOCART), ODAS, and a methodology for weakly coupled AO-CDAS (Molod et al., in prep).
  - Atmospheric and land initial conditions are “MERRA-2 like” (Gelaro et al., 2017).
  - Ocean and sea ice initial sea ice conditions are assimilated from GMAO FPIT reanalysis with the addition of PIOMASS for sea ice thickness (Molod et al., in prep).

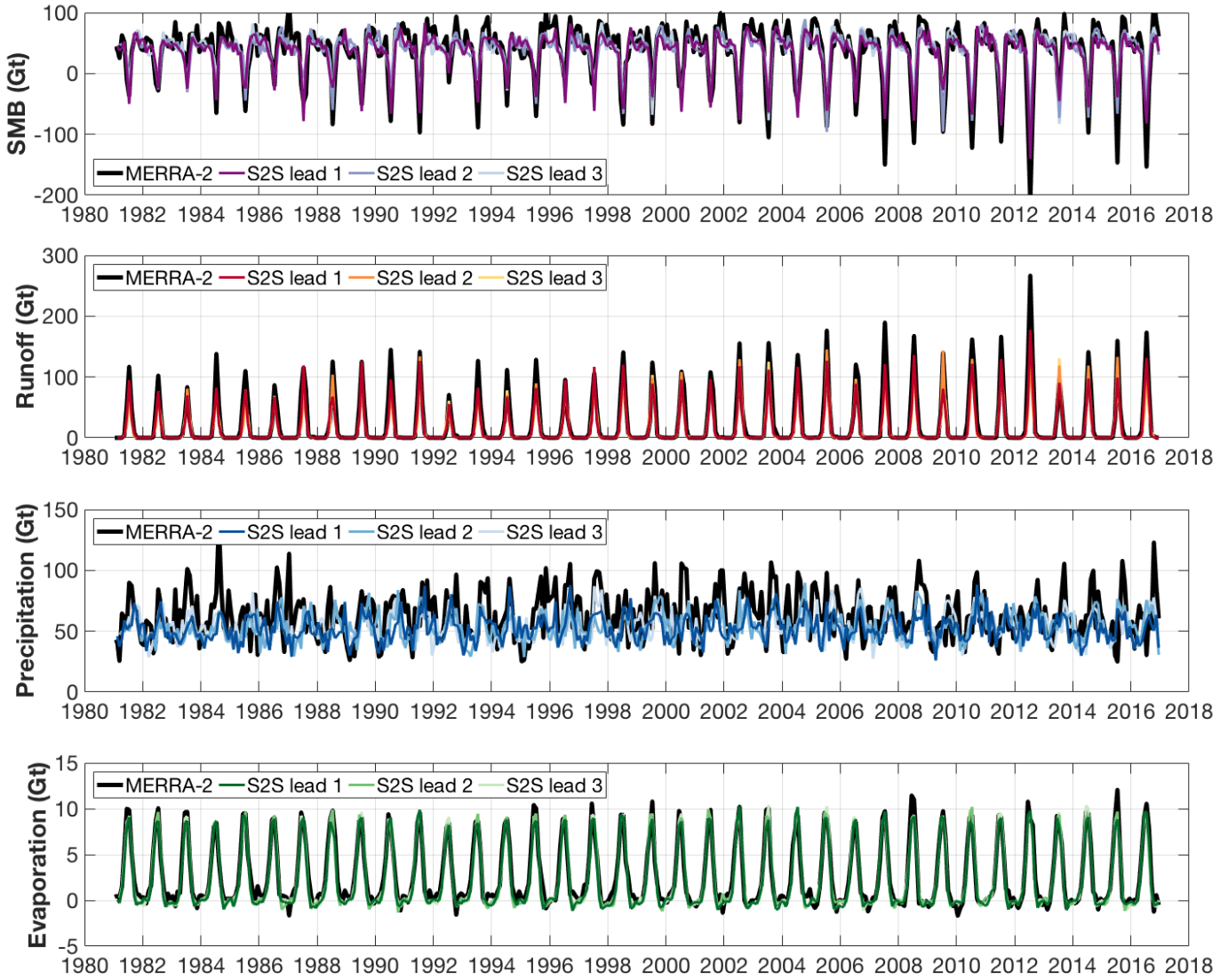


- Monthly retrospective seasonal forecasts between 1981 and 2016.
- Lagged start dates form an ensemble of 4 for any month (no perturbations on initial conditions).



Forecasting GrIS mass balance

- **The components of SMB tend to be underpredicted within the retrospective forecasts with caveats.**
  - Evaporation, though small, generally seems to be well quantified over the year.
  - Arctic precipitation is known to be elevated in MERRA-2 (Boisvert et al., 2018).
  - Summer runoff is underestimated with dampened variability causing the primary differences between MERRA-2 and GEOS S2S v2 during June, July and August.



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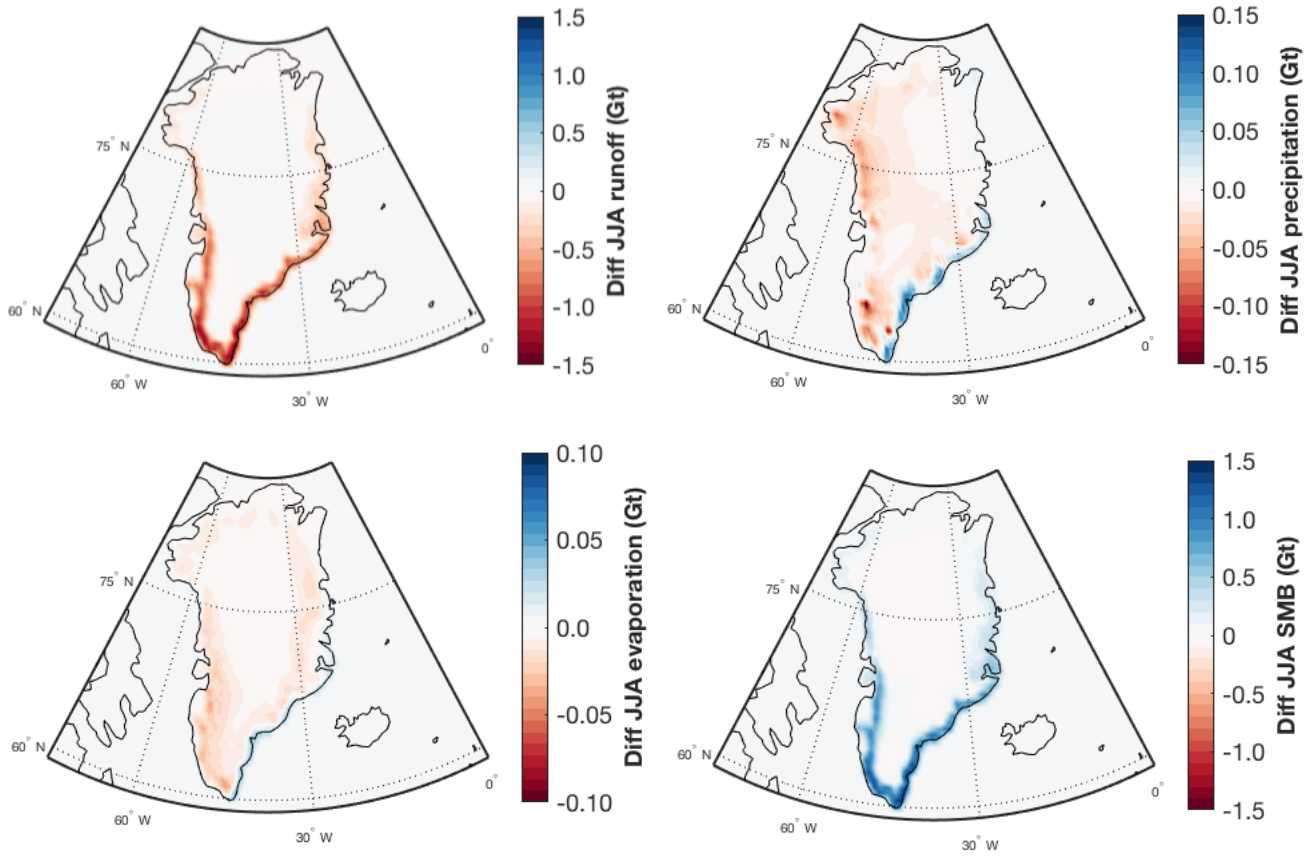
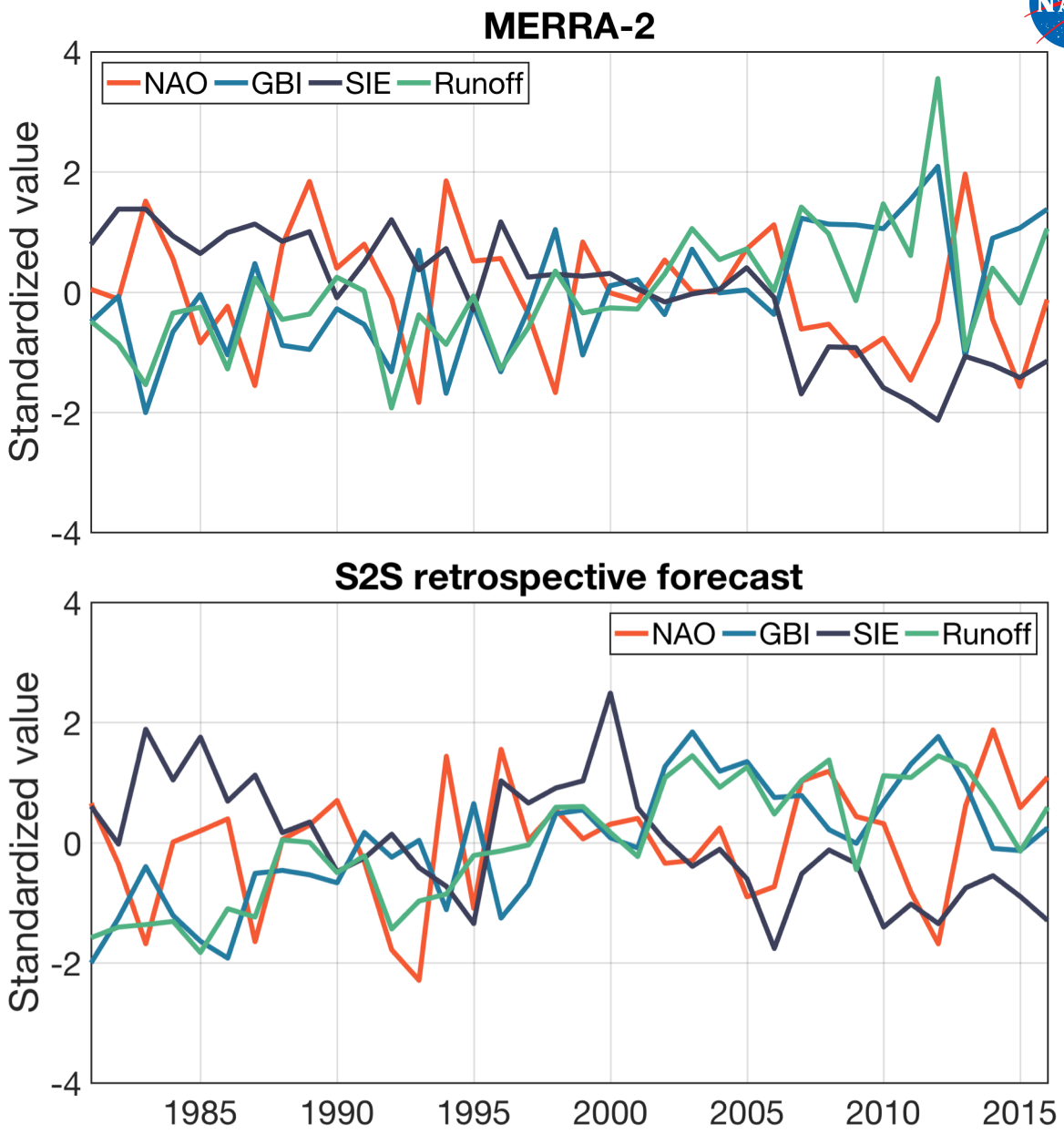
S2s v2 – MERRA-2



Atmospheric drivers of GrIS SMB

- Both MERRA-2 and S2S v2 display statistically significant correlations between detrended NAO & GBI (-0.8 and -0.65, respectively) and GBI and ice sheet runoff (0.69 & 0.65, respectively).
  - The NAO displays a spatially variable correlation with runoff and SMB in MERRA-2 that is lacking in S2S v2.

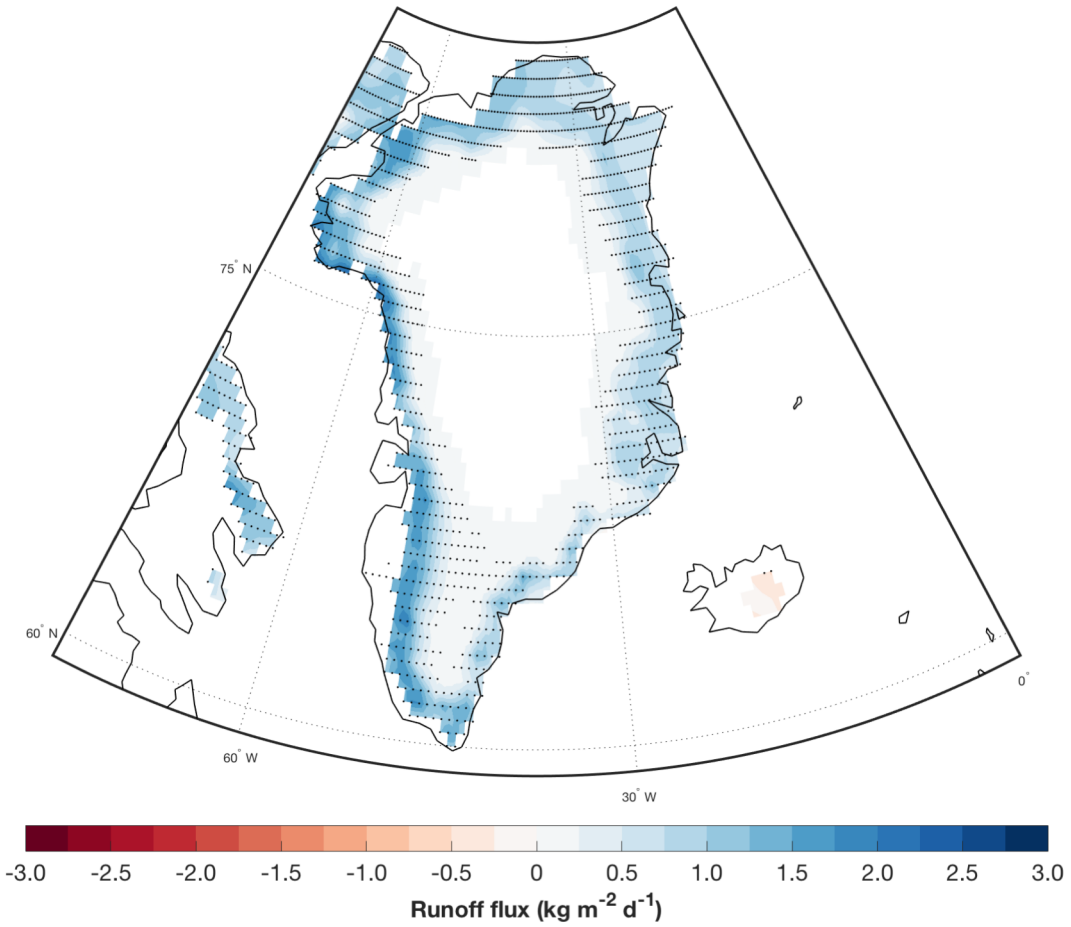
- MERRA-2 displays a relatively strong relationship between sea ice extent and runoff (S2S v2 does not).
  - Sea ice extent in Baffin bay does exhibit weak but significant correlation with runoff in both MERRA-2 and S2S v2 (-0.42 & -0.3, respectively).



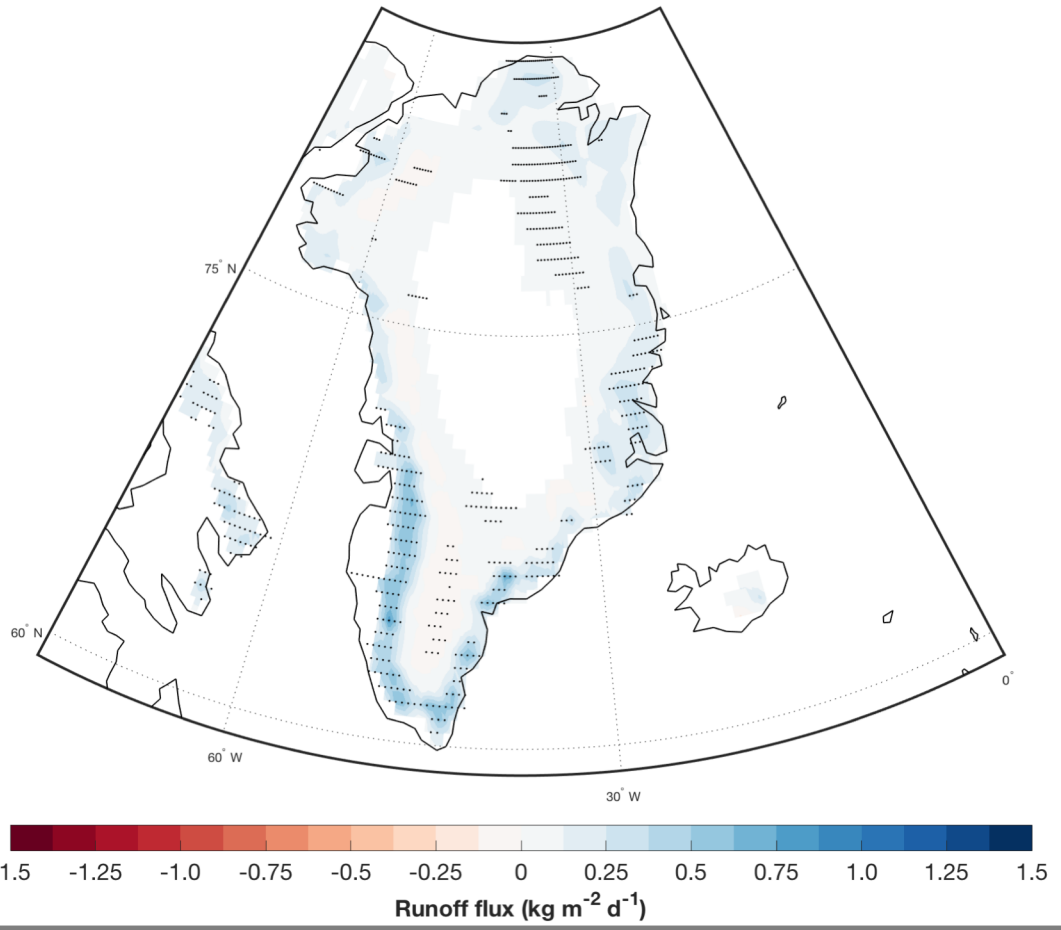
Importance of the GBI on ice sheet runoff

- Removing the long-term trends from both the GBI and runoff result in differing impact of the the GBI.

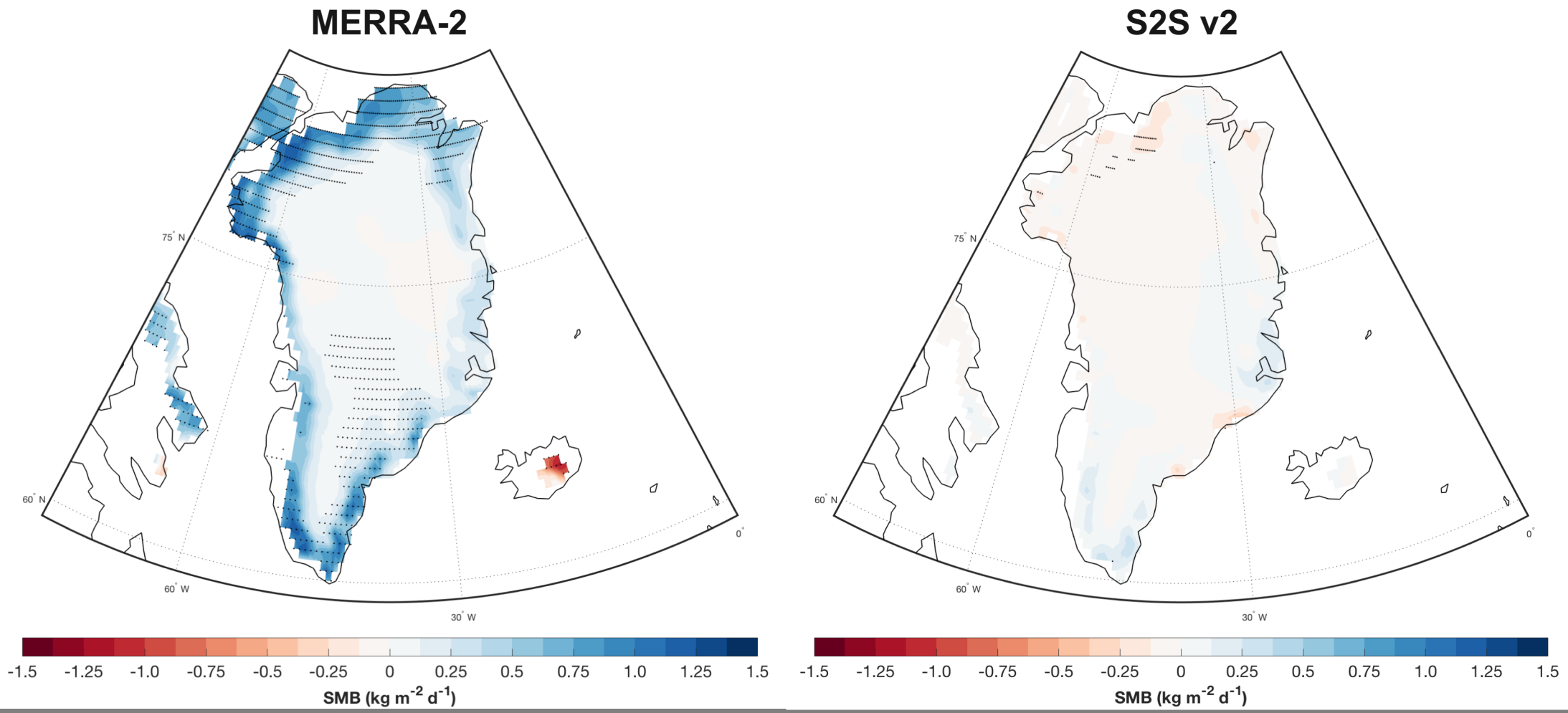
MERRA-2



S2S v2

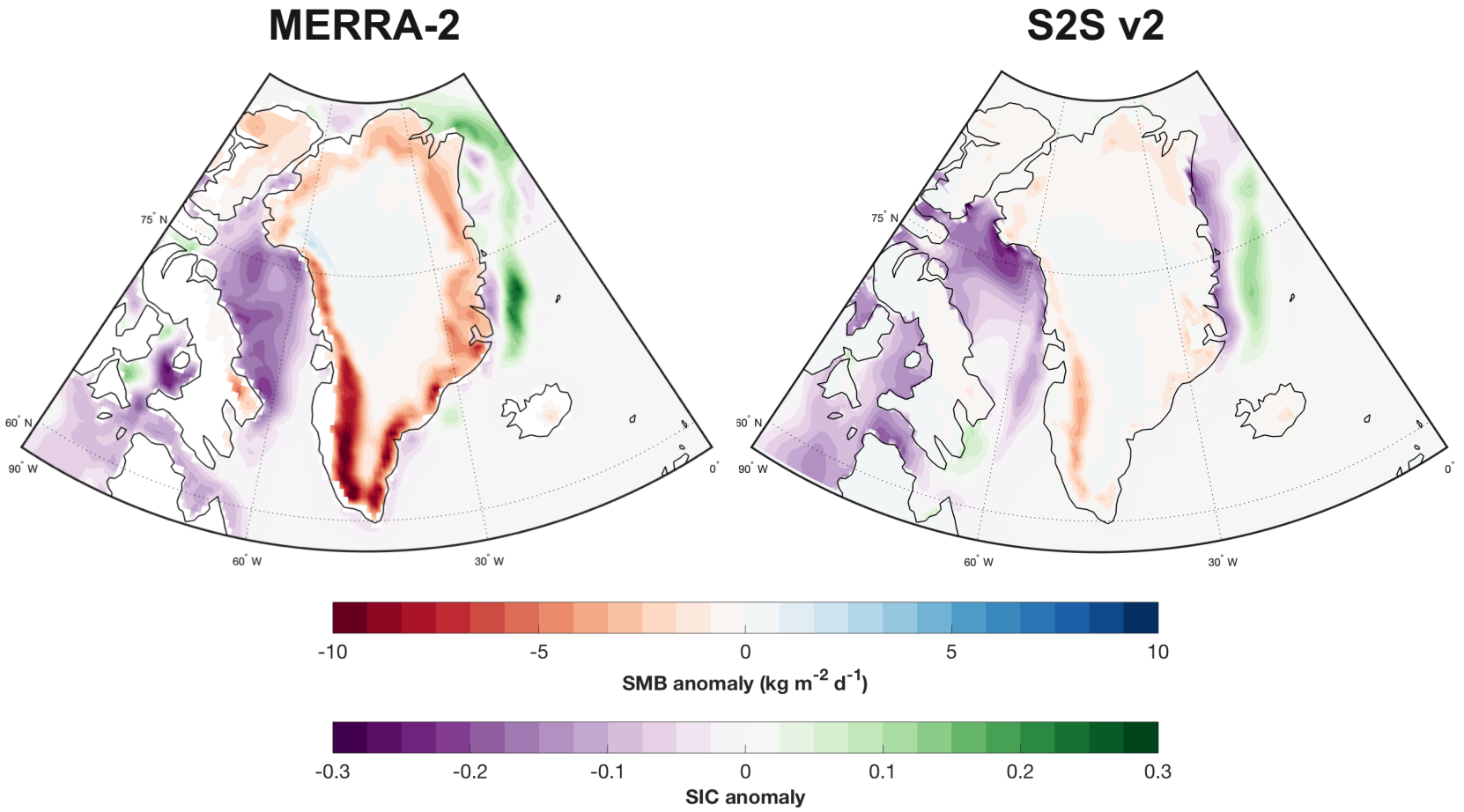


Importance of the NAO on ice sheet mass balance



Insight from 2012

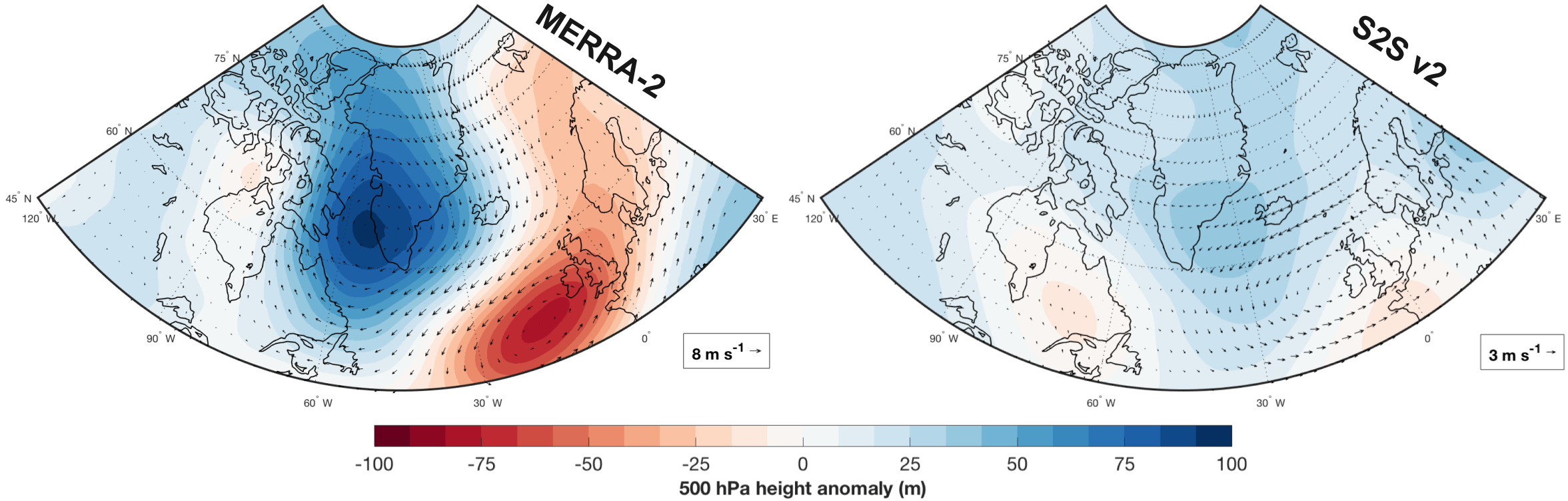
- During 2012, the JJA NAO was well forecasted S2S v2 in May.
- Despite this, the surface mass balance anomaly was muted when compared to reanalysis.
- Sea ice concentration was also relatively higher than MERRA-2 in several regions.



Insight from 2012

- There is the development of strong anticyclonic behavior over much of Greenland in MERRA-2. This is well observed in other reanalyses as a major contributor to 2012 anomalous melting.

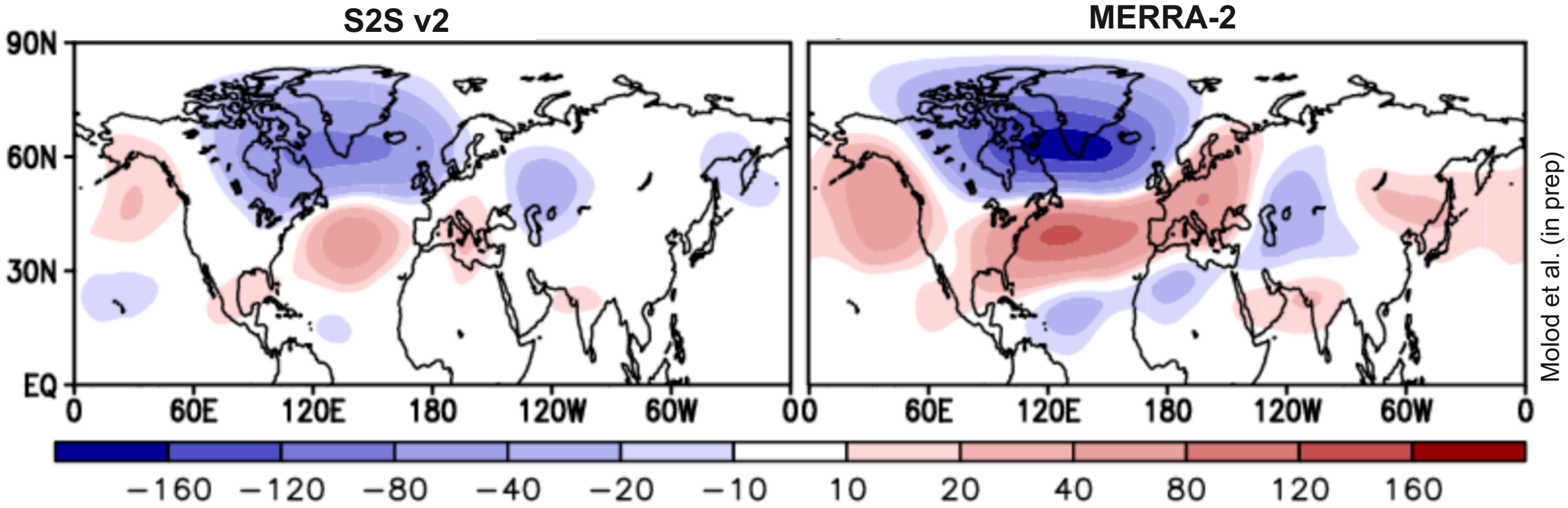
- The 500 hPa pressure and wind anomalies are relatively muted in S2S v2.



NAO forecasting in S2S v2

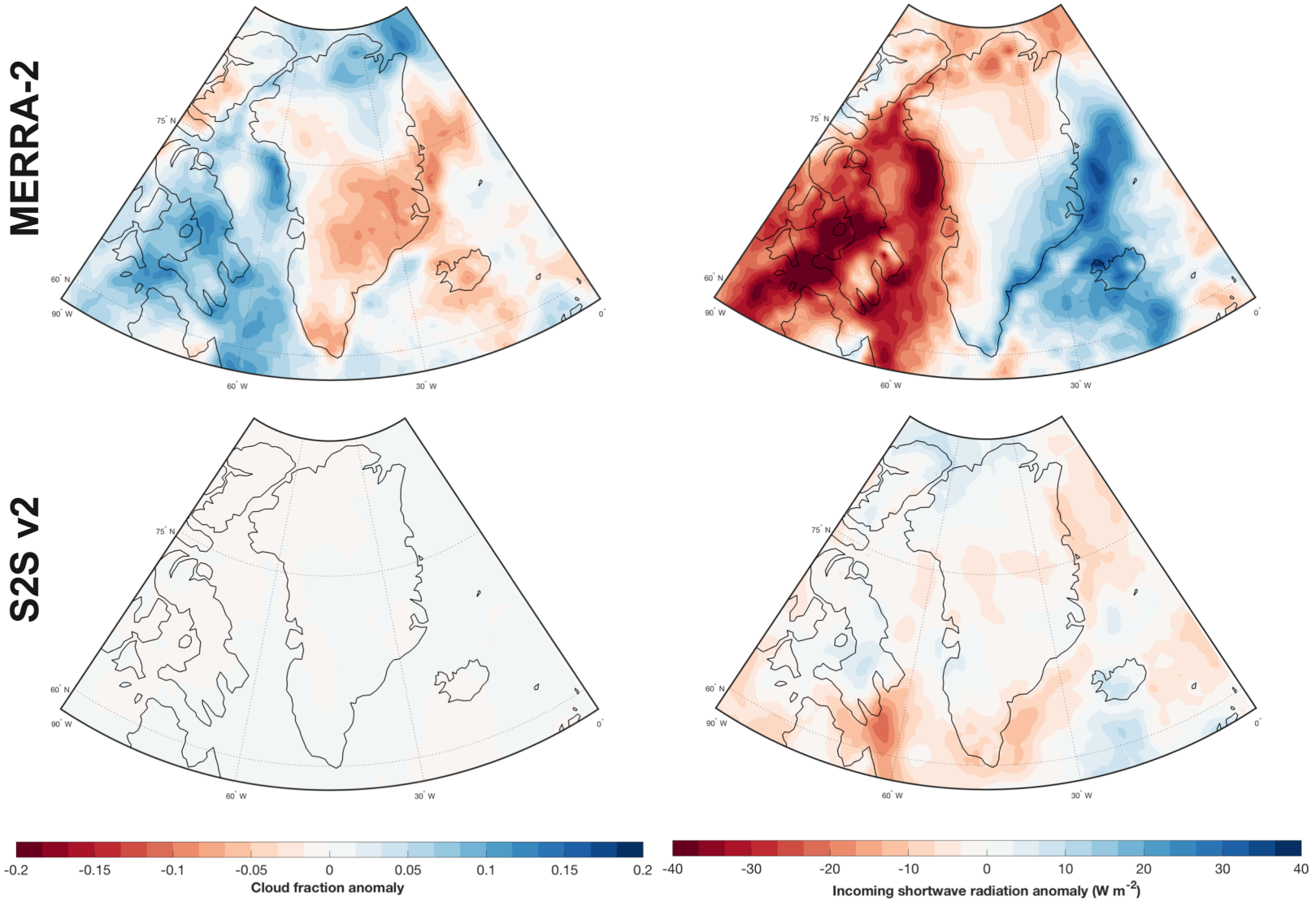
- Geographical locations of the positive/negative anomalies seen in MERRA-2 are quite realistically reproduced in the S2S v2.

- The variability and magnitude of the anomalies is underestimated, resulting in limited impact over Greenland.



Insight from 2012

- MERRA-2 suggests that mechanisms of increased SMB loss are coastally delineated.
- S2S v2 displays very limited (no) changes in incoming solar radiation and cloud cover.
- Net radiative fluxes suggest that nearly all decrease in SMB in S2S v2 is associated with an surface albedo feedback (e.g. Tedesco et al., 2013).



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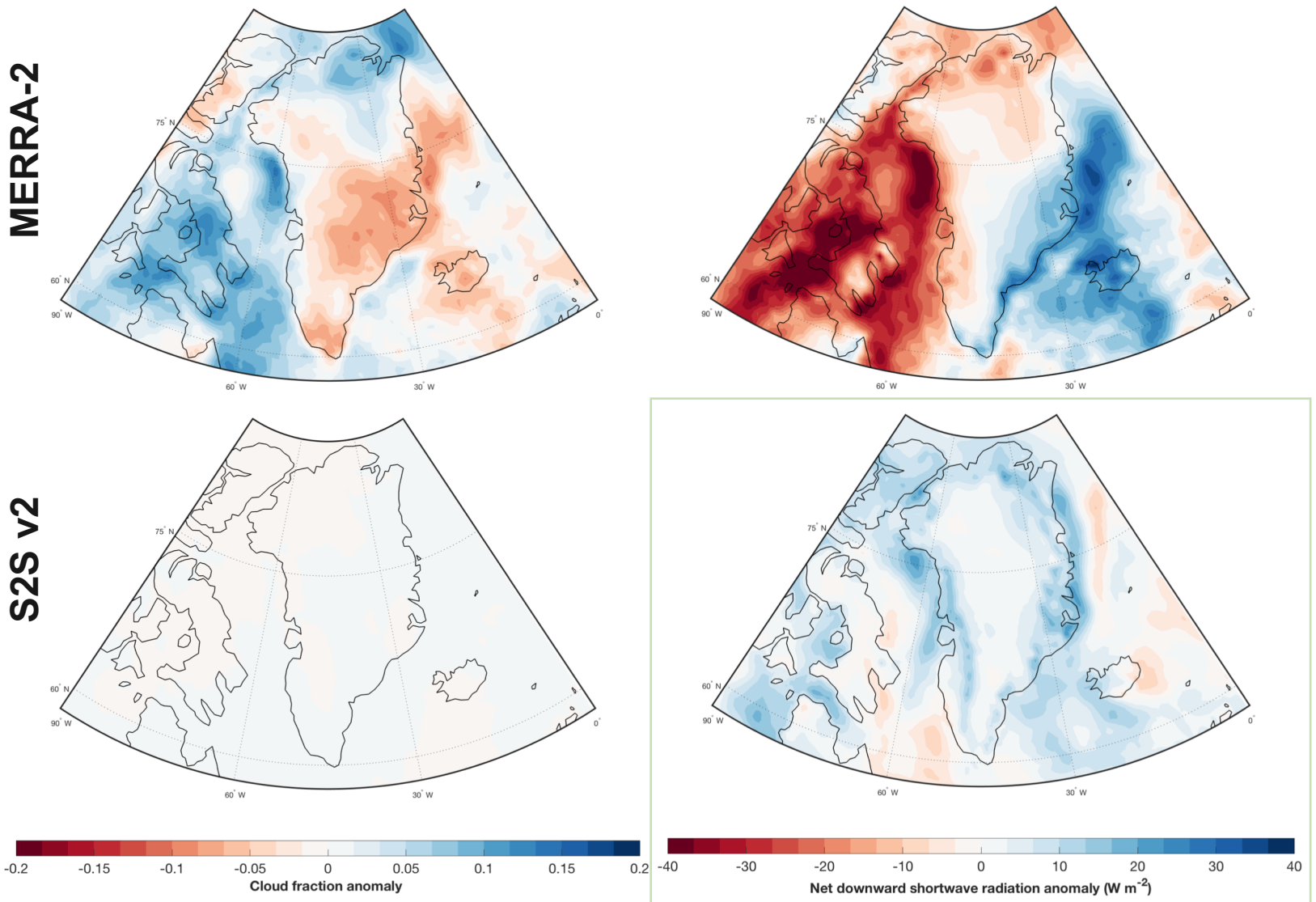

Final Thoughts

- GEOS S2S v2 is able to reproduce the general magnitude and trend of SMB evolution during the retrospective forecast period, but large perturbations, such as 2012, lack the magnitude.

- The NAO has a strong influence on summer surface mass balance, primarily through its influence on anticyclonic behavior driving an increase in surface runoff.

- Initial conditions could be particularly important when considering ice sheet surface albedo feedbacks.

- Future work involving independent studies to isolate the relative importance of radiative fluxes/ sea ice, additional teleconnections.