Investigating The Impact Of Sea Ice Concentration Extremes On Atmospheric Moisture Transport And Low-Level Winds Over Greenland And Surrounding Seas

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1. Background & Questions

Two of the most striking changes occurring in the Arctic over the past decade are the **decline in sea ice extent** and **increased mass loss** from the **Greenland ice sheet (GrIS)**. Previous research points to a correlation between sea ice extent and surface-melting on the Greenland ice sheet, especially in southwestern region during late summer (Rennermalm et al. 2009). However the physical link between the two is relatively unknown.

From an Arctic system perspective, the physical linkages between sea ice extent and the GrIS mass loss remain to be explored. Here we investigate a 35-year distribution of atmospheric moisture advection over the GRiS and oceans using **the MAR** (for Modèle Atmosphérique Régional) regional climate model (Fetteweis, 2007)

Research Questions

1. Does Sea Ice extent variability influence GrIS surface energy and mass balance through moisture advection?
2. What is the local and large-scale forcing of ocean heat and moisture advection on the GrIS?
3. What are the physical processes involved?

2. Data & Methods

Simulations of :

- Moisture Flux Convergence
- Winds
- Specific humidity
- Surface Mass Balance (SMB)

are provided by the MAR regional climate model (v3.5.2)

- 35 year simulation, 1979 to 2014
- Grid: 36 km x 36 km
- 25 vertical sigma layers
- Driven by 6-hr NCEP 1 reanalysis

- **Sea Ice Concentration (SIC):** NSDIC
- **Greenland Blocking Index (GBI)**: ERA-Interim (1979–2013) reanalysis, ECMWF (Dee et al. 2011) at 0.5°.

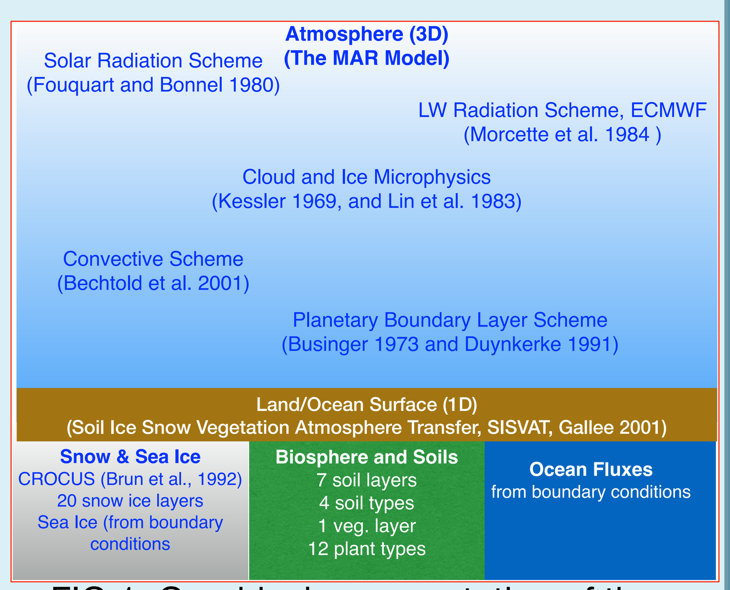


FIG 1. Graphical representation of the parts of the MAR regional model. (see Fetteweis 2007)

Moisture Flux Convergence (MFC)

MFC arises from the conservation of water vapor in pressure coordinates

$$\frac{dq}{dt} = E - P$$

where, *q* is specific humidity, *E* and *P* represent evaporation and precipitation. Using the continuity equation, it can be expanded to flux form, to show the conservation of the total mass of moisture:

$$\underbrace{\frac{\partial q}{\partial t}}_{\text{local change of q}} + \underbrace{\nabla \bullet \left(qV_h\right)}_{\text{Horizontal MFC}} + \underbrace{\frac{\partial}{\partial p}\left(q\omega\right)}_{\text{Vertical MFC}} = \underbrace{E - P}_{\text{Sources \& Sinks}}$$

The horizontal MFC expands to show advection of specific humidity and mass convergence.

$$MFC = \underbrace{-u\frac{\partial q}{\partial x} - v\frac{\partial q}{\partial x}}_{\text{Advection Term}} \underbrace{- q\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right)}_{\text{Convergence Term}}$$

3. Climatology of MFC, SIC, & SMB

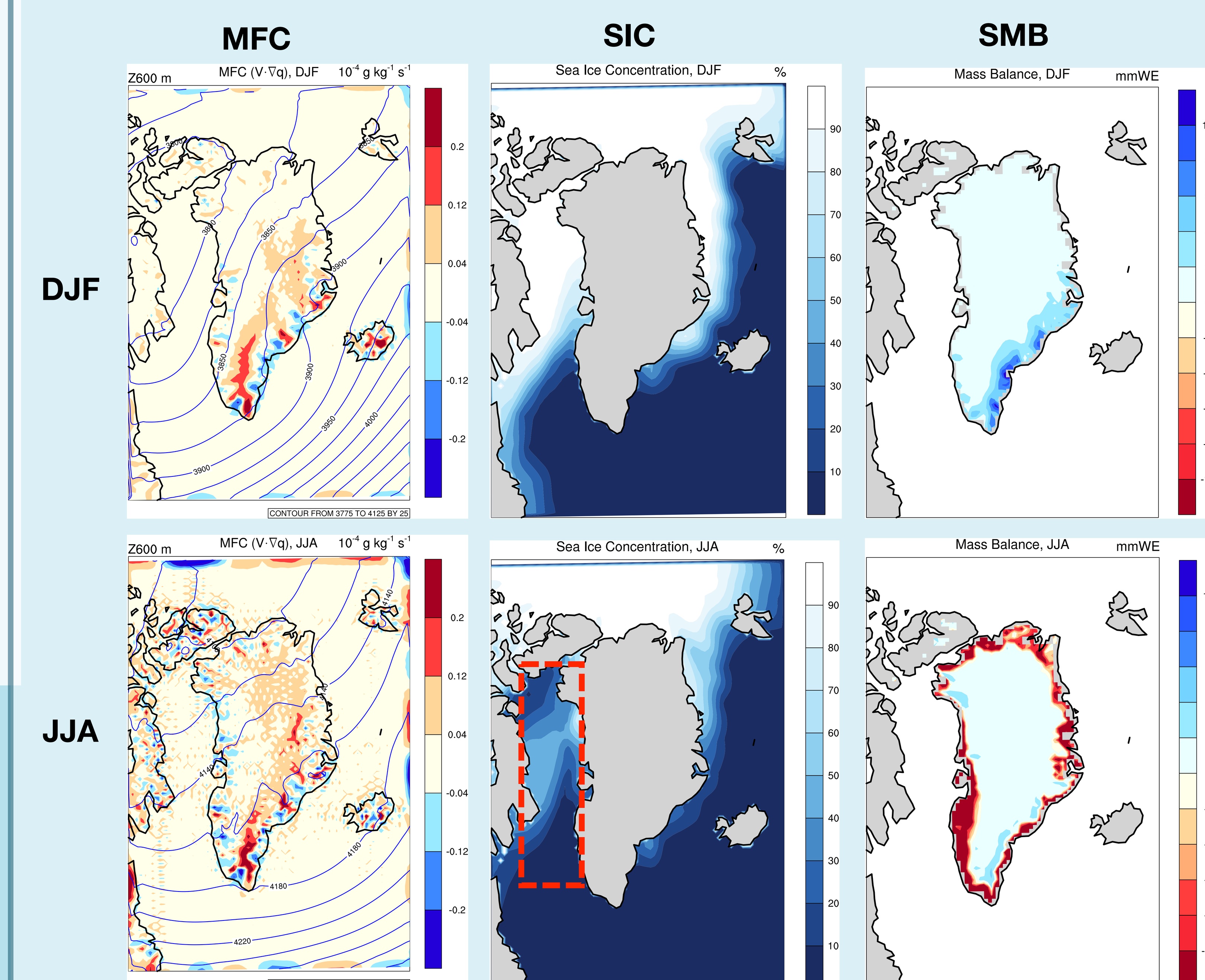


FIG. 2. Seasonal average maps of MFC, SIC, and SMB for December-January-February (DJF, top row) and June-July-August (JJA, bottom row) based on the entire 35-year climatological distribution. (The red dashed box in the SIC JJA plot shows the region for the MFC vs. SIC comparison in FIG 4.)

4. MFC during low SMB events (high mass loss)

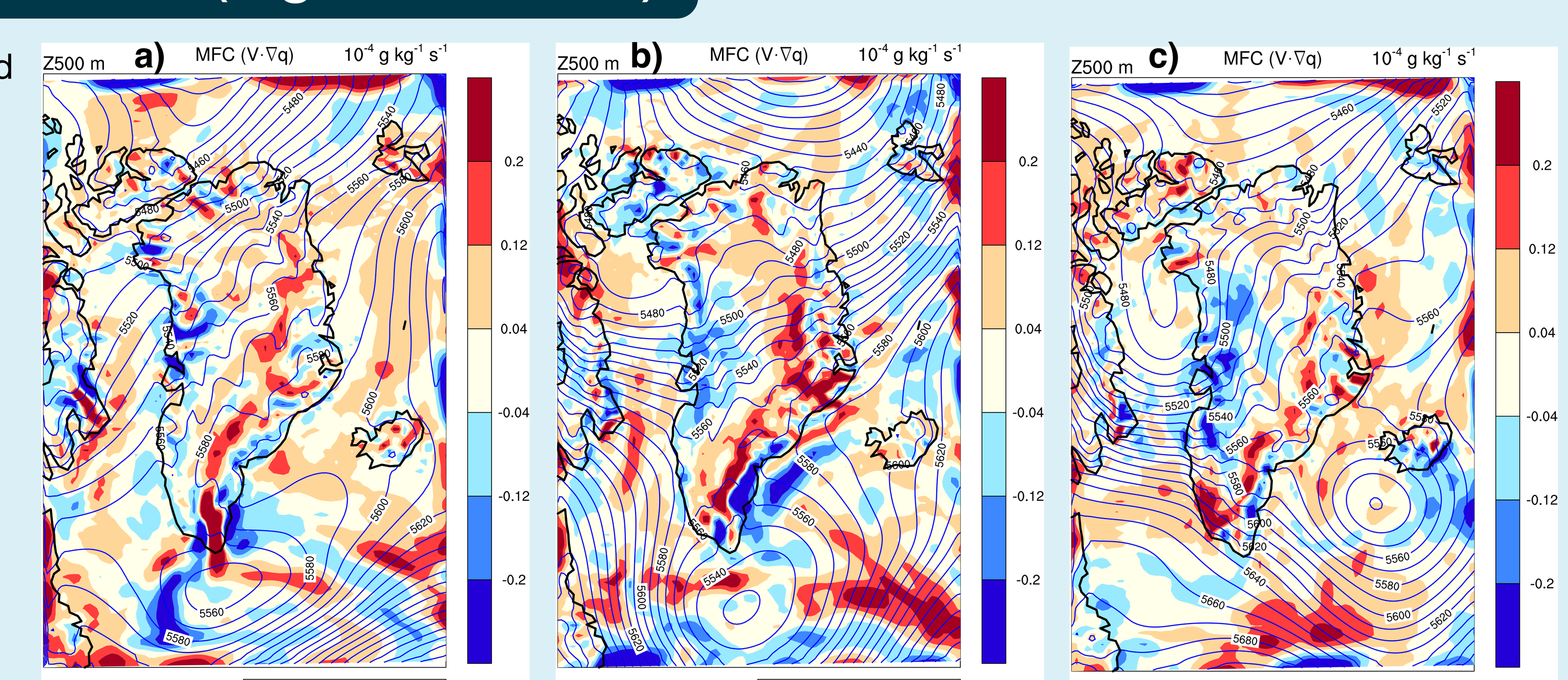
FIG. 3. Composite maps of 600 hpa MFC and 500 hPa geopotential heights over the Greenland/ Ocean region for:

a) Epoch 1, 1979 to 1990
b) Epoch 2, 1991 to 2002
c) Epoch 3, 1993 to 2012

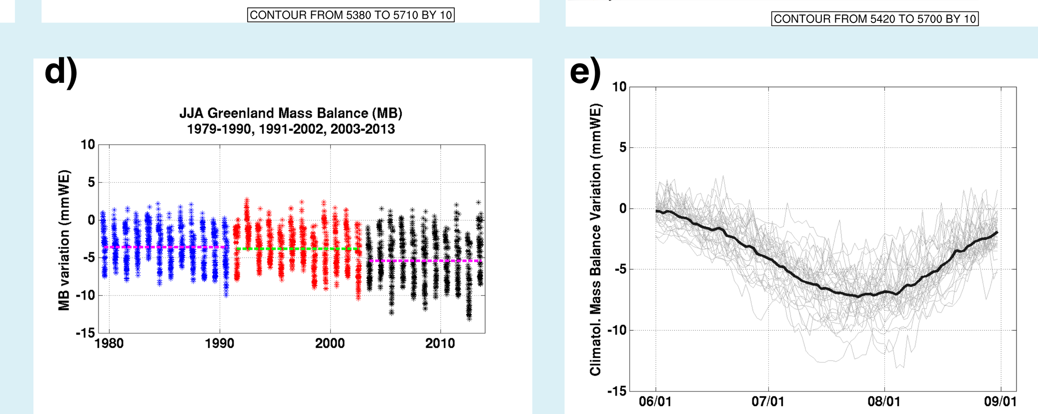
The epochs are created from all days where low SMB ranked within the 25% percentile range, divided into:

d) three distinct epochs of equal length
e) based on SMB minimums in the 35-year distribution

The maps show regions of moisture divergence **(blue)** and moisture convergence **(red.)**



Moisture divergence prominently occurs over the western portion of the GrIS, where the greatest mass loss occurs. It is also the region where the most melt occurs.



5. MFC during SIC minimums & strong GBI

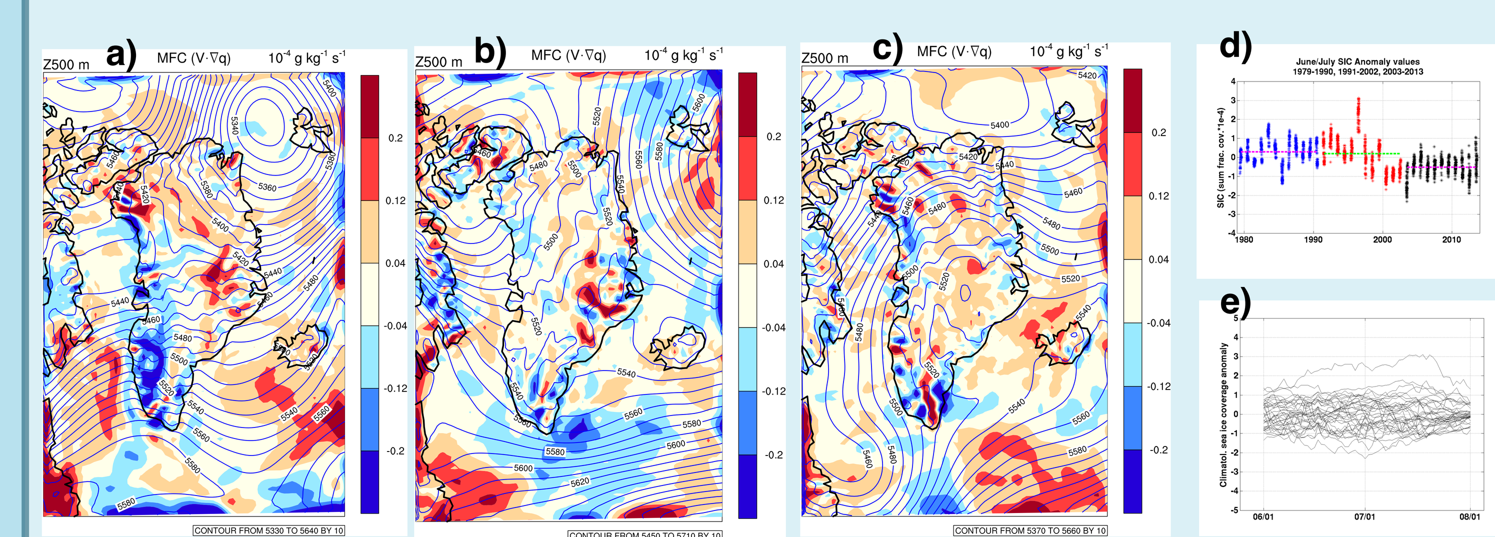
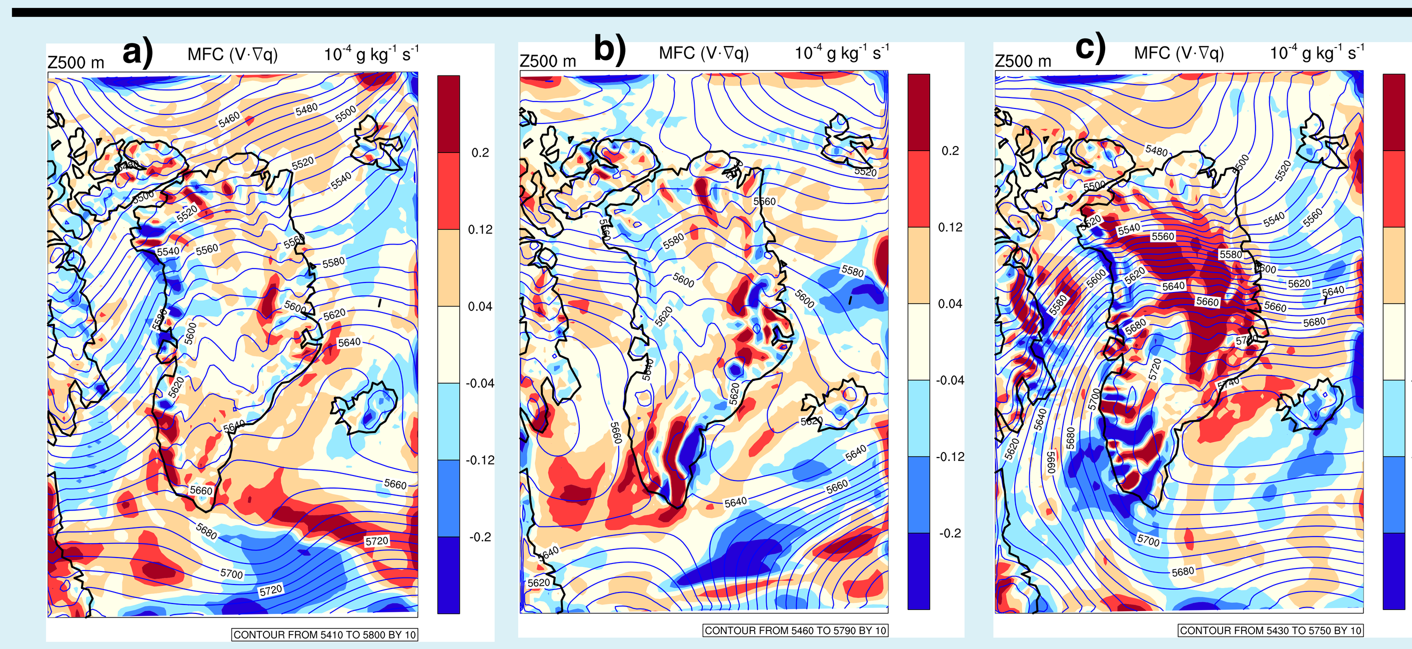


FIG. 4. Composite maps of 600 hPa MFC and 500 hPa heights for a) epoch 1 b) epoch 2, and c) epoch 3, for dates of minimum SIC anomalies) during June–July (top 10%.) The daily values of minimum SIC are shown in d) and e) shows the climatology of SIC minimums in June–July.

Moisture divergence occurs over western GrIS during epoch , but is less prominent in the later epochs when SICis reduced.



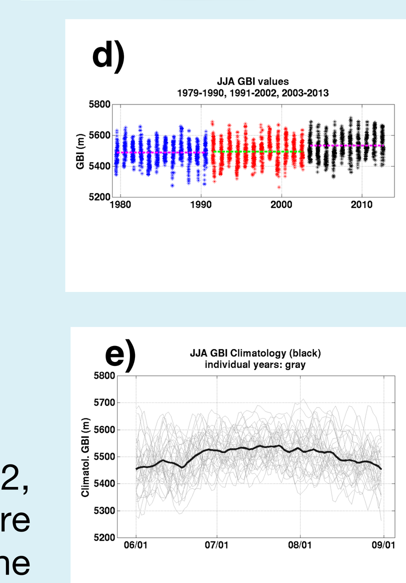


FIG. 5. Composite maps of 600 hPa MFC and 500 hPa heights for a) epoch 1, b) epoch 2, and c) epoch 3 for dates of strong GBI during the 35 year period. Greenland blocks are synoptic-scale ridges of high pressure extending poleward, from the North Atlantic to the Arctic, that *advect* warm subtropical air northward over the ice sheet. Here, we see not only moisture divergence over western GrIS, but also an increase of moisture convergence over the mid & north GrIS, indicating an increase in accumulation.

6. Summary and Future Work

This research is the beginning of a much larger effort to understand how atmospheric moisture moves through the Arctic system, over Greenland and the surrounding seas.

We use the MAR regional climate model to simulate atmospheric conditions of Greenland and the surrounding seas for a 35-year period from 1979 to 2014, and analyze the MFC during low SMB, declining SIC, and strong GBI events.

During periods of low SMB, moisture divergence occurs over the western GrIS. This indicates that during times of high melt, we also have moisture divergence aloft. This means during low SMB event we get drier conditions.

We also have moisture divergence over the west GrIS during strong GBI events. This also indicates that strong melting occurs on the west GrIS during strong GBI events. The results also show that more moisture converges over the northeast GrIS during the later year, 2002-2012.

During seasonal decline of sea ice, less SIC occurs. Coincidentally, there is less moisture divergence over the west GrIS, which indicates wetter conditions. Future work will investigate whether the sea ice decline increases atmospheric moisture and reduce

Questions? Contact: enoble@ccny.cuny.edu

Fettweis, X. Reconstruction of the 1979? 2006 Greenland ice sheet surface mass balance using the regional climate model MAR. The Cryosphere 1, 21–40 (2007).
Fettweis, X. et al. Brief communication 'Important role of the mid-tropospheric atmospheric circulation in the recent surface melt increase over the Greenland ice sheet'. The Cryosphere 7, 241–248 (2013).
Hanna, E. et al. The influence of North Atlantic atmospheric and oceanic forcing effects on 1900–2010 Greenland summer climate and ice melt/runoff. Int. J. Climatol. 33, 862–880 (2013).
McLeod, J. T. & Mote, T. Atmospheric Bottlenecks over the Arctic: A Climatological Investigation of ExtremE Greenland Blocking Episodes and Their Impact on Melting across the Greenland Ice Sheet. (2013)
Rennermalm, A. K., Smith, L. C., Stroeve, J. C. & Chu, V. W. Does sea ice influence Greenland ice sheet surface-melt? Environ. Res. Lett. 4, 024011 (2009).
Tedesco, M. A new record in 2007 for melting in Greenland. Eos Trans. AGU 88, 383–383 (2007).
Stroeve, J. et al. Arctic Sea Ice Extent Plummets in 2007. Eos Trans. AGU 89, 13–14 (2008).