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Assessing the impact of Arctic sea ice variability on Greenland Ice Sheet surface mass and energy exchange

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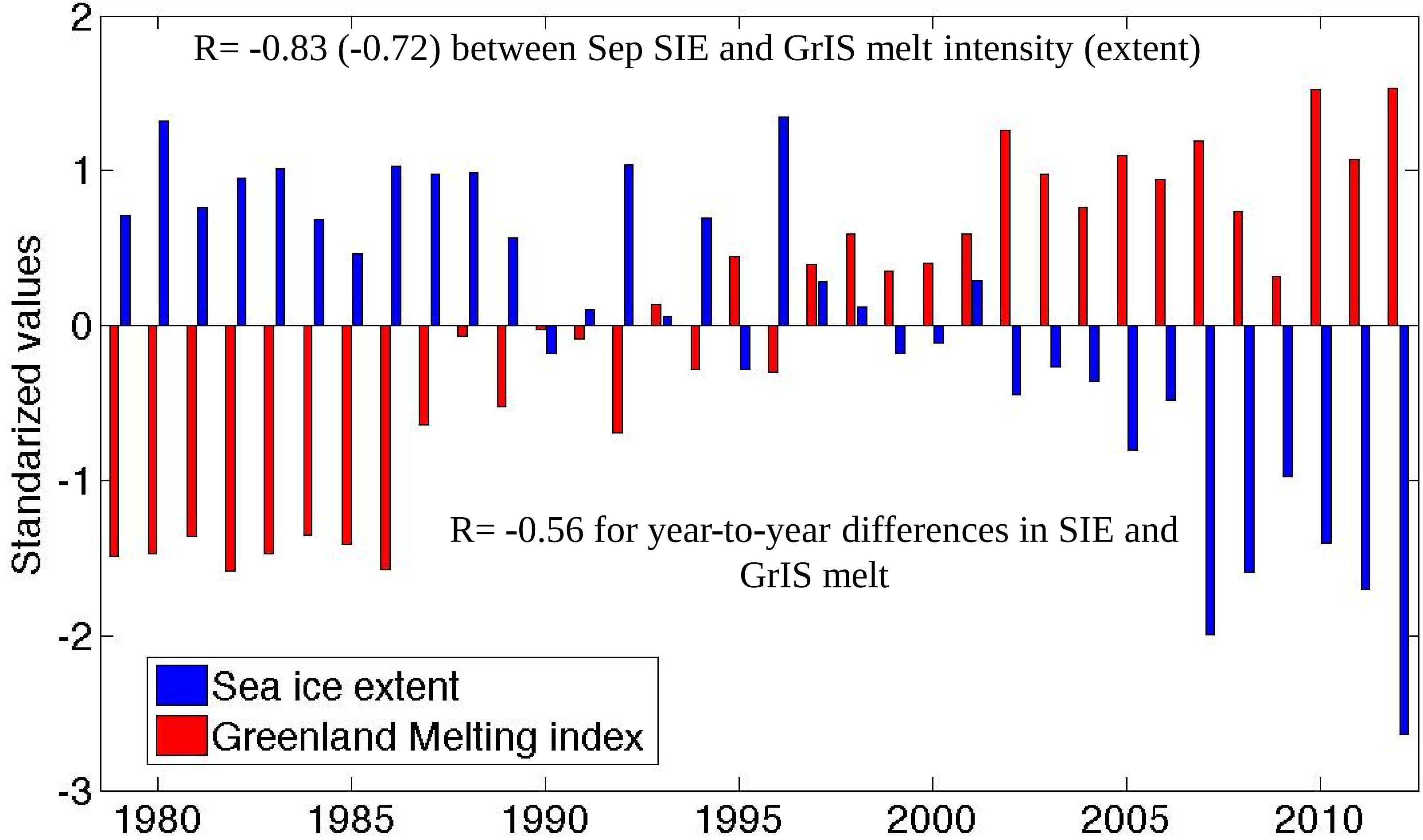
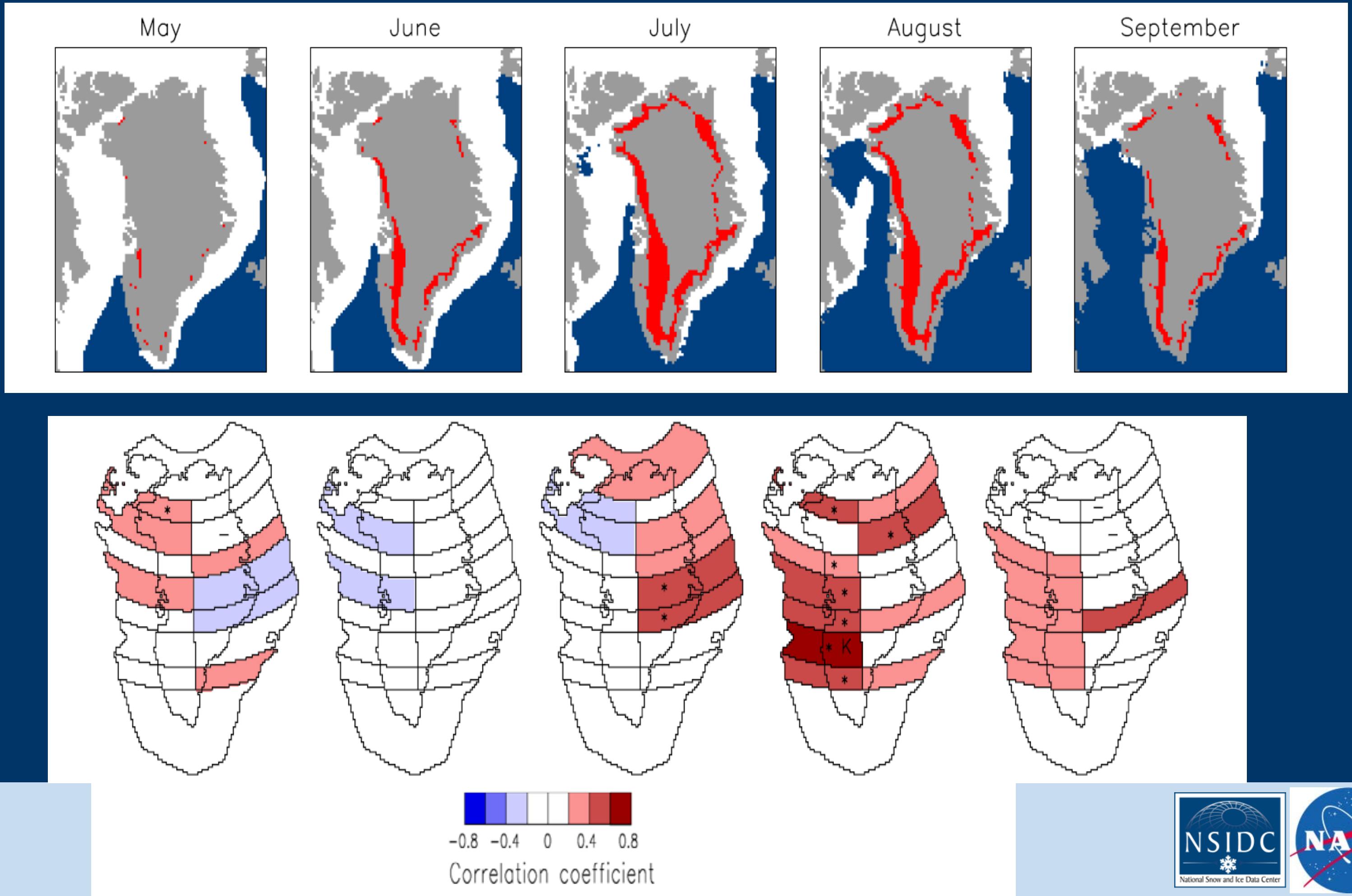
Enhanced Greenland Melt and Sea Ice Loss

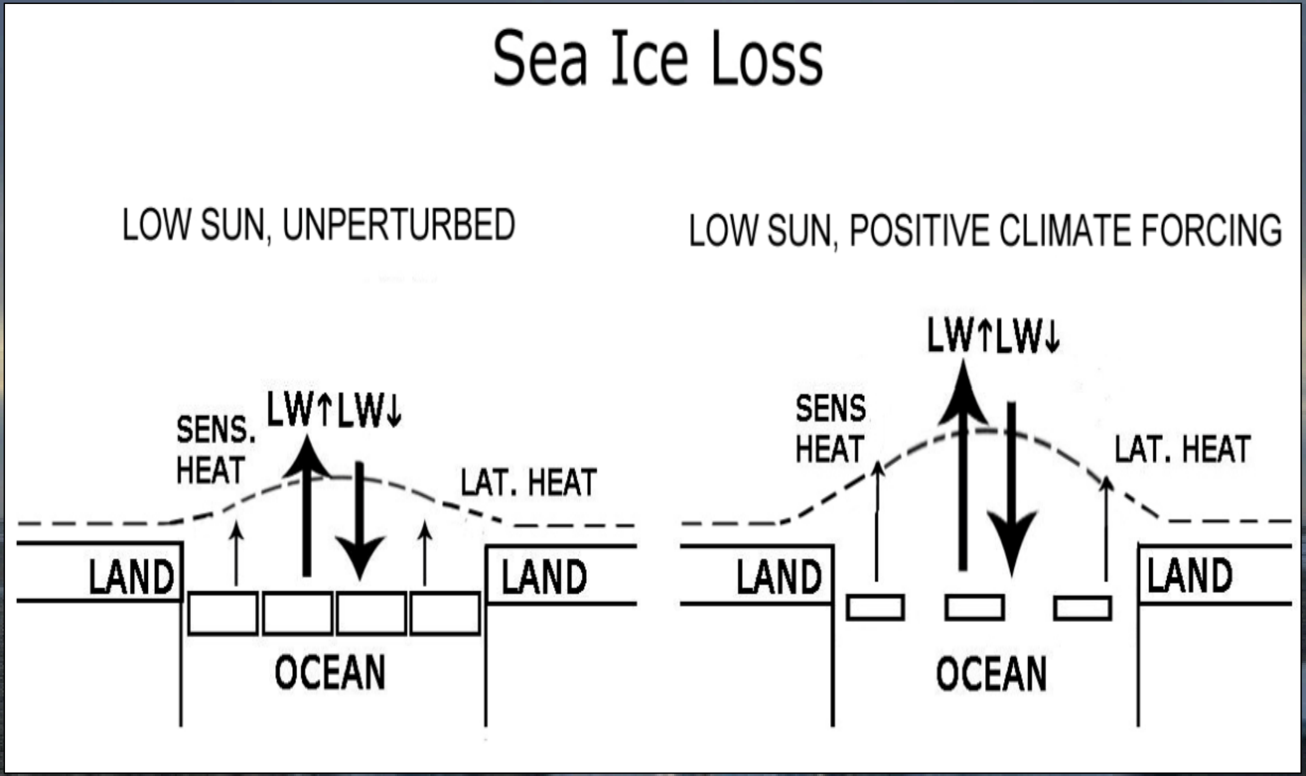


SIE vs GrIS melt extent

- *Rennermalm et al.* (2009) suggested a relationship between sea ice extent and GrIS melt extent in August in western Greenland and eastern Greenland in July



Rationale for a sea ice influences



Physical processes driving surface melt over Greenalnd can be separated into components of the net flux of heat between the atmosphere and the surface of the ice sheet Fsfc:

$$F_{sfc} = Q_H + Q_E + LW_{sfc} + SW_{sfc}$$

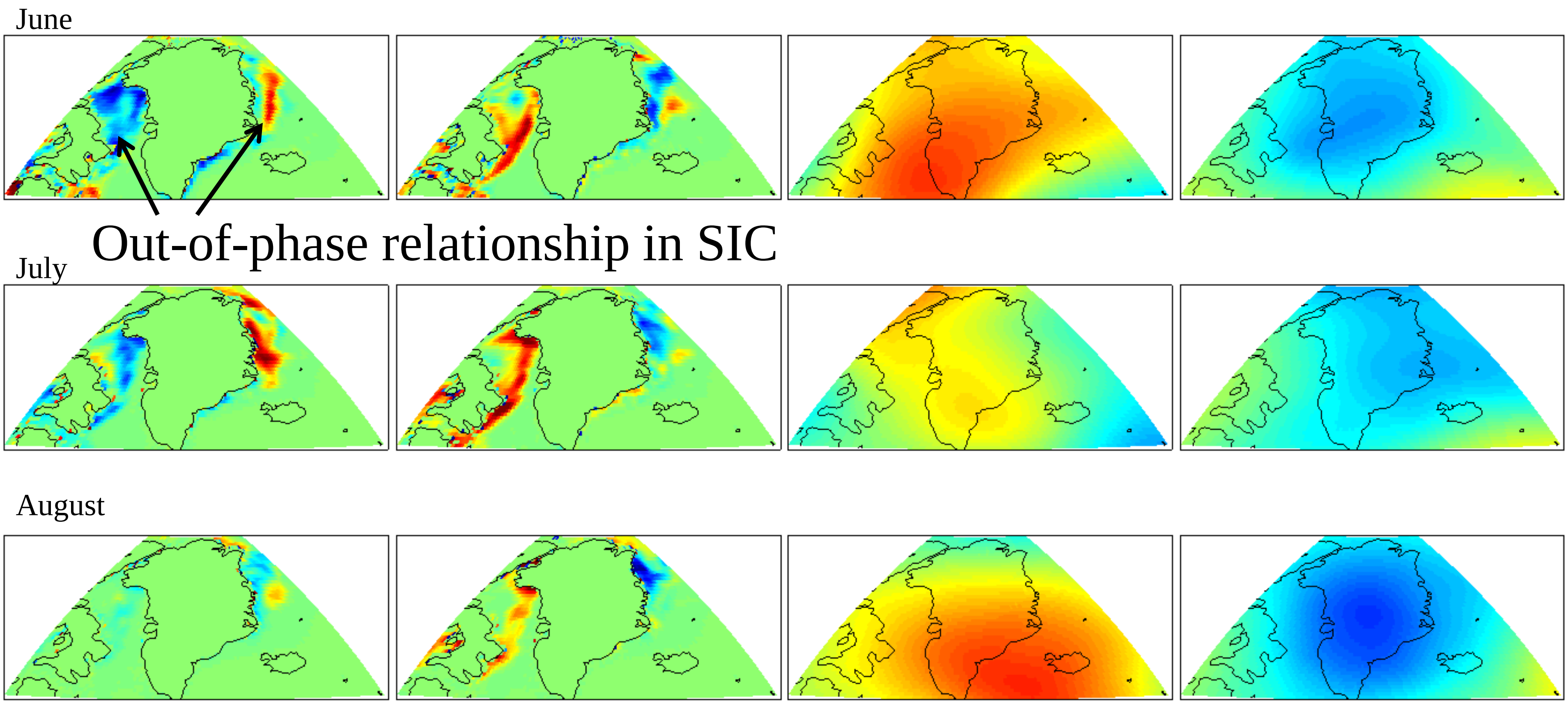
Outline of analysis

- We have looked at:
  - SVD analysis between sea ice concentrations and Greenland melt
  - SVD analysis between sea ice, Greenland melt and 500 hPa heights
  - Correlation between melt onset over sea ice and Greenland
  - Changes in cyclone activity, intensity and precipitation that *may* impact on Greenland accumulation
- We evaluated changes in atmospheric properties from AIRS data (2003-2013) and impacts on melt.
  - Next step is looking more into feedbacks (started with CMIP5)

SVD analysis for 5 highest/lowest GrIS melt years

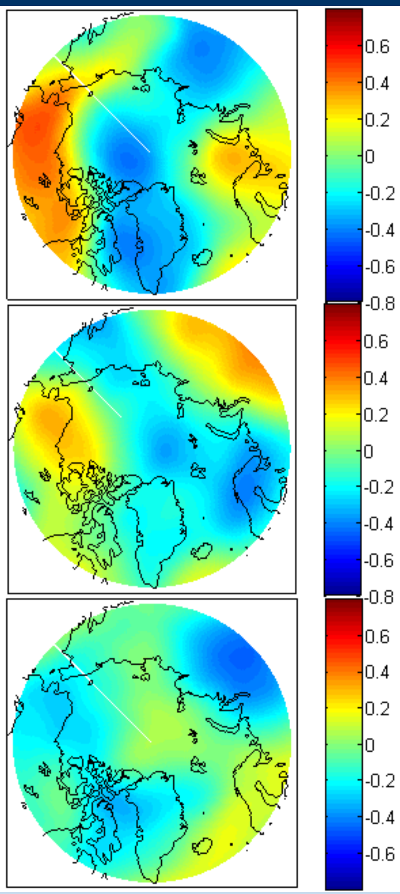
Detrended SIC Anomalies | Mean 500 hPa Height Anomalies

5 highest melt | 5 lowest melt | 5 highest melt | 5 lowest melt



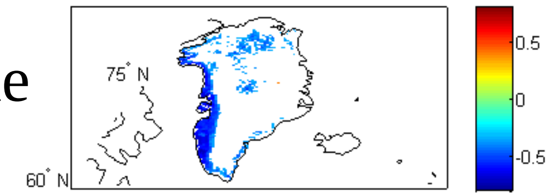
Heterogeneous Correlation Maps (Baffin Bay)

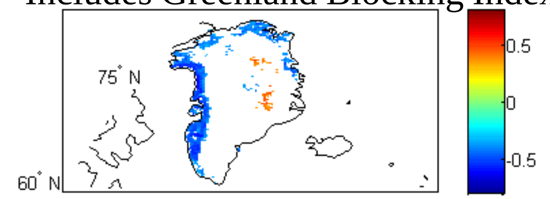
SIC correlation with 500hPa heights | **SIC correlation with melt-water production** | **SIC partial correlation with melt-water production**



Includes Greenland Blocking Index

June





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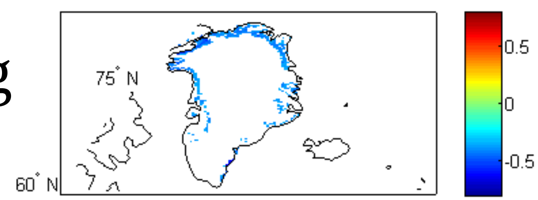
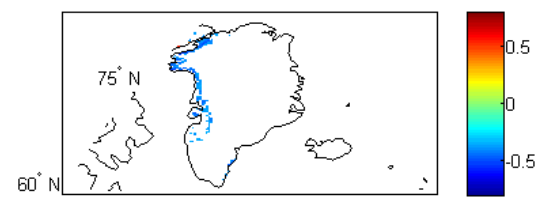
For Baffin Bay in June, the strong correlation with Baffin SIC is unrelated to 500hPa height anomalies

Aug

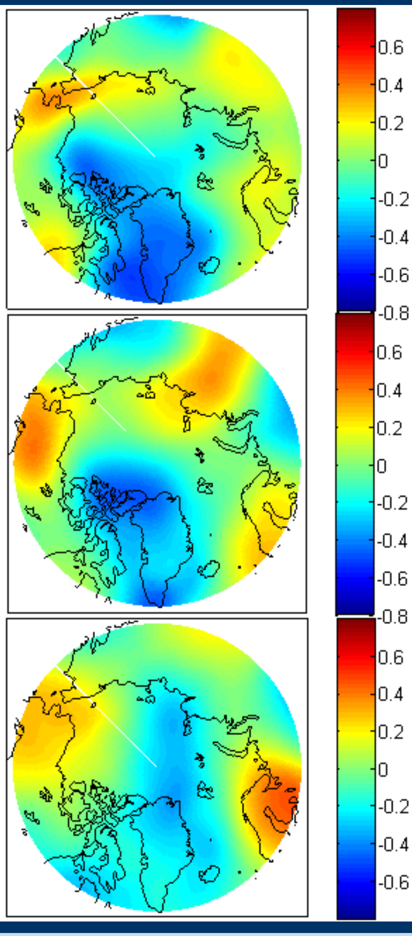




All data are first detrended

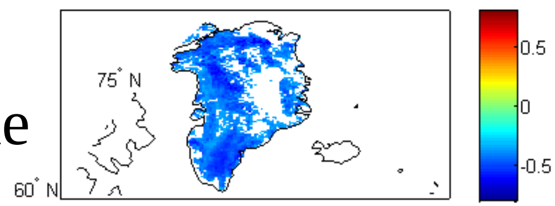
Heterogeneous Correlation Maps (Beaufort)

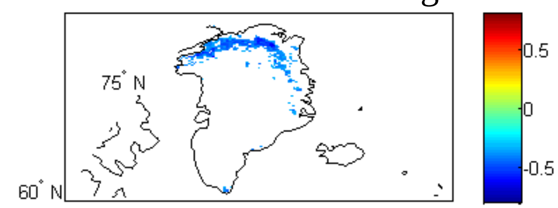
SIC correlation with 500hPa heights | **SIC correlation with melt-water production** | **SIC partial correlation with melt-water production**



Includes Greenland Blocking Index

June





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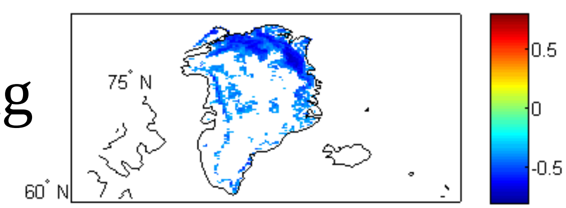
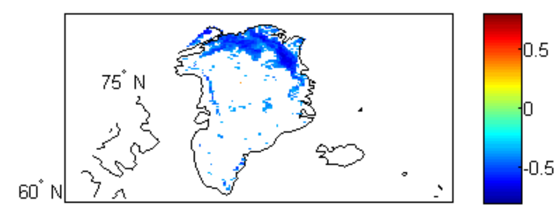
For Beaufort Sea in June and August, the strong correlation with Beaufort SIC is related to 500hPa height anomalies

Aug





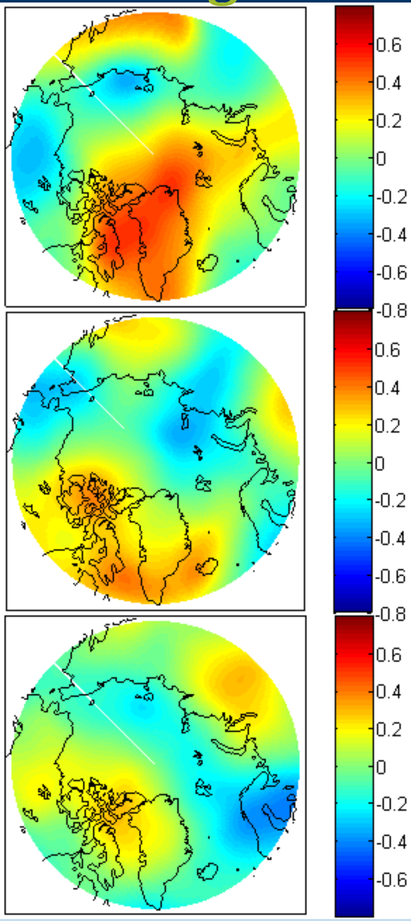
All data are first detrended

Heterogeneous Correlation Maps (E. Greenland Sea)

SIC correlation with 500hPa heights

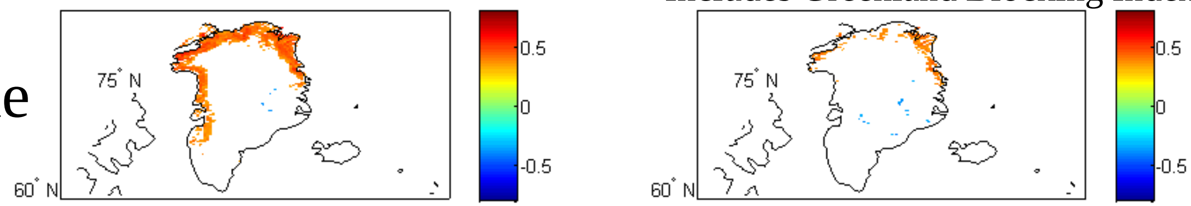
SIC correlation with melt-water production

SIC partial correlation with melt-water production



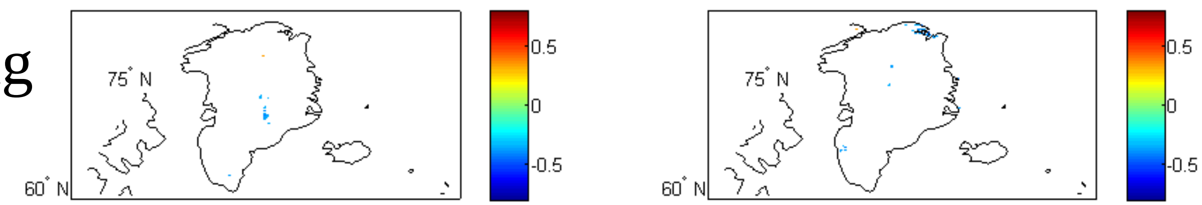
Includes Greenland Blocking Index

June



Strong inverse correlation in June with E. Greenland SIC is also largely a result of 500 hPa height anomalies

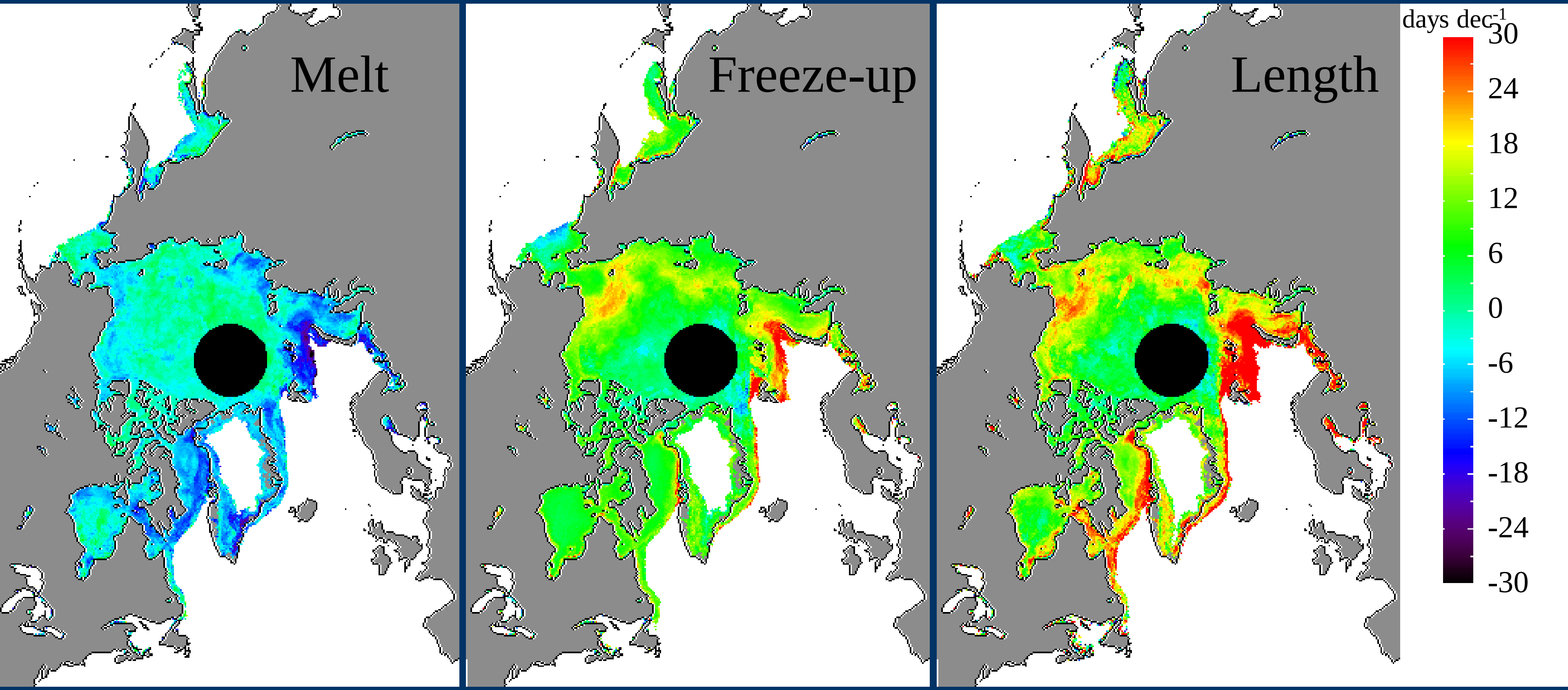
Aug



All data are first detrended

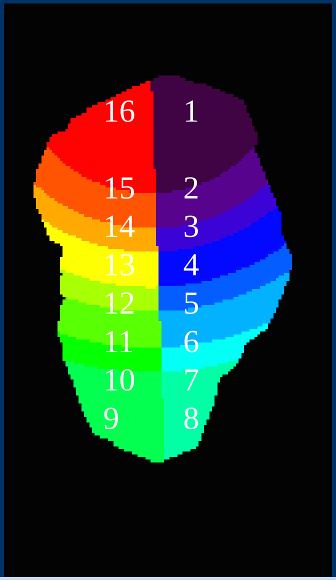
Melt Onset, Freeze-up and Duration

Tends on Melt Onset, Freeze-up and Length of Melt Season (1979-2014)



Relationship between sea ice EMO and Greenland MO

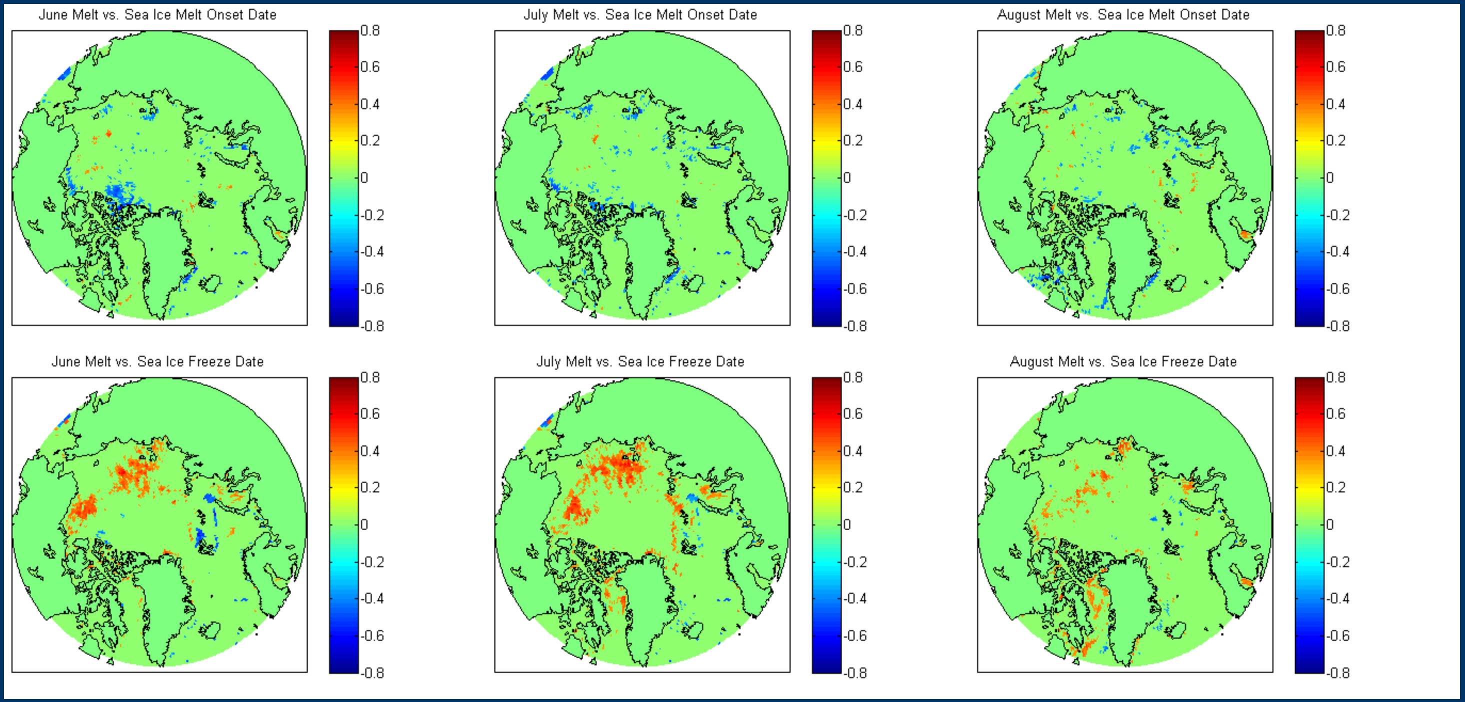
- In general, Greenland melt onset lags sea ice retreat/melt onset by 3 to 6 weeks



Region	Detrended Sea Ice EMO and MO vs GrIS MO (*r*)	Sea Ice EMO minus GrIS MO (days)	Sea Ice MO minus GrIS MO (days)
1	0.12 (0.07)	12	2
2	0.31 (0.15)	32	31
3	0.11 (0.05)	40	39
4	0.12 (0.00)	41	42
5	0.14 (0.22)	52	40
6	-0.21 (-0.16)	44	23
10	0.10 (-0.11)	36	41
11	0.01 (-0.14)	20	18
12	0.12 (0.00)	19	11
13	0.17 (0.14)	27	15
14	0.14 (0.08)	23	15
15	0.00 (0.11)	28	21
16	0.37 (0.39)	15	5

Larger-scale relationships with melt/freeze

Correlation between detrended melt averaged over Greenland with detrended sea ice melt onset (top) and freeze-up (bottom)



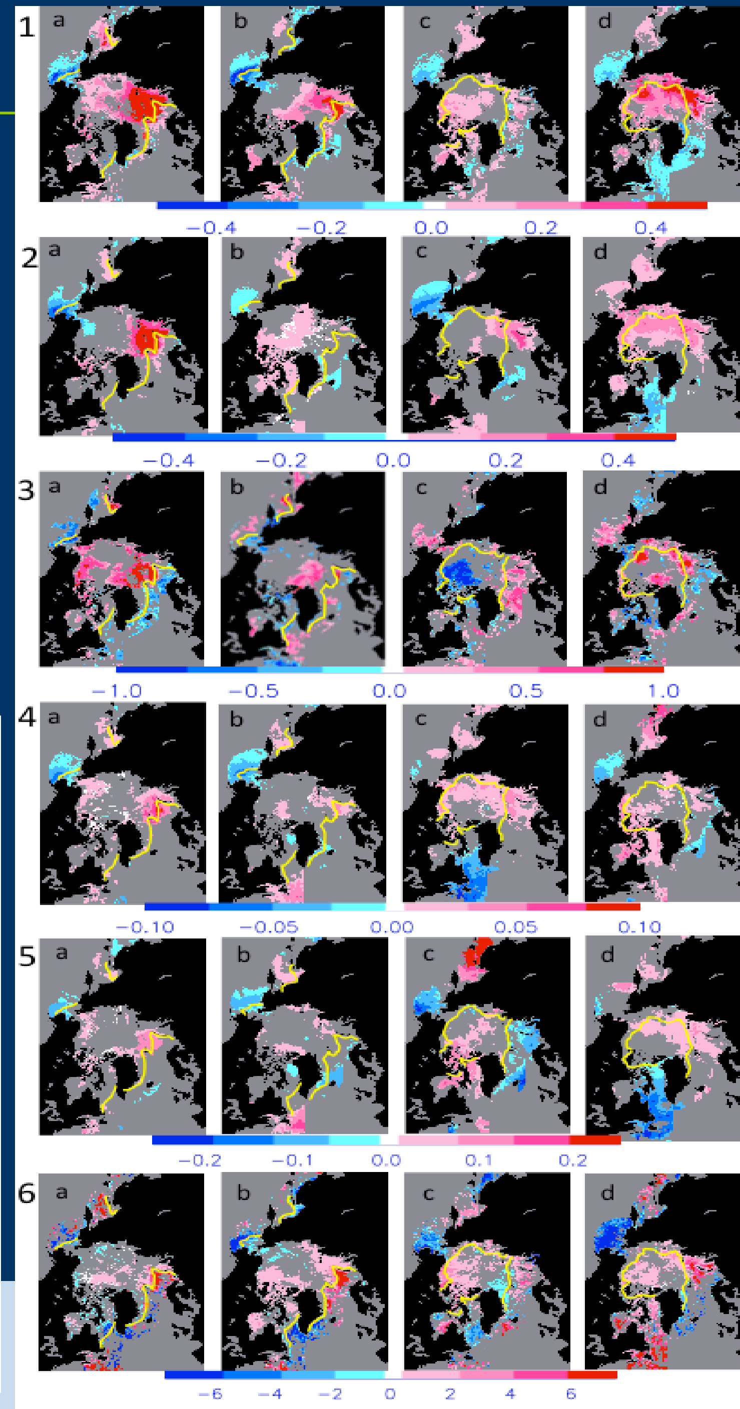
- Results show positive correlations from Beaufort over E. Siberian Sea and Baffin Bay with freeze-up.
- Atmospheric patterns that support positive GrIS melt anomalies generate negative SIC anomalies that persist long enough to impact autumn freeze-up.

AIRS data reveals warmer and wetter Arctic (2003-2013)

- Largest warming occurs from Nov-Apr
- Ice loss results in increased evaporation (moisture flux) from Aug-Oct, increasing water vapor and cloud cover.

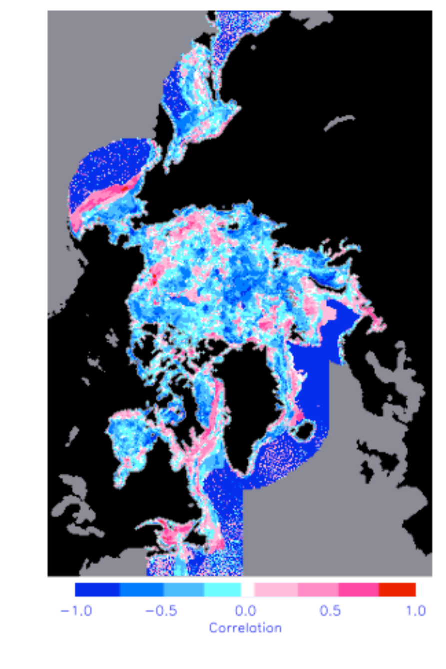
T_{sfc} T_{air} q_s col H_2O MF CF OLR

	1. Ts (K)	2. Ta (K)	3. qs $x10^{-3}$ (g kg^{-1})	4. Toth2o ($x10^{-3}$ kgm^{-2})	5. MF ($x10^{-5}$ g $m^{-2}s^{-1}$)	6. CF (%)	7. OLR (W m^{-2})
Jan	0.10	0.07	2.7	-17	-3.85	0.03	0.14
Feb	0.11	0.02	4.4	8.5	9.19	0.37	0.19
Mar	0.35	0.29	4.5	35	2.62	0.37	0.33
Apr	0.21	0.10	-1.1	32	3.09	0.39	0.23
May	0.00	0.01	7.0	37	-4.89	0.25	-0.07
Jun	0.01	0.05	2.0	82	6.01	0.40	-0.06
Jul	0.06	0.05	1.4	79	4.35	0.08	0.03
Aug	0.05	0.03	7.9	8.9	13.4	-0.003	-0.03
Sep	0.14	0.10	14.	32	12.0	0.07	0.29
Oct	0.19	0.08	19.	-2.5	18.0	0.14	0.10
Nov	0.39	0.28	27.	46	2.65	0.62	0.34
Dec	0.26	0.19	5.2	21	1.51	0.08	0.19

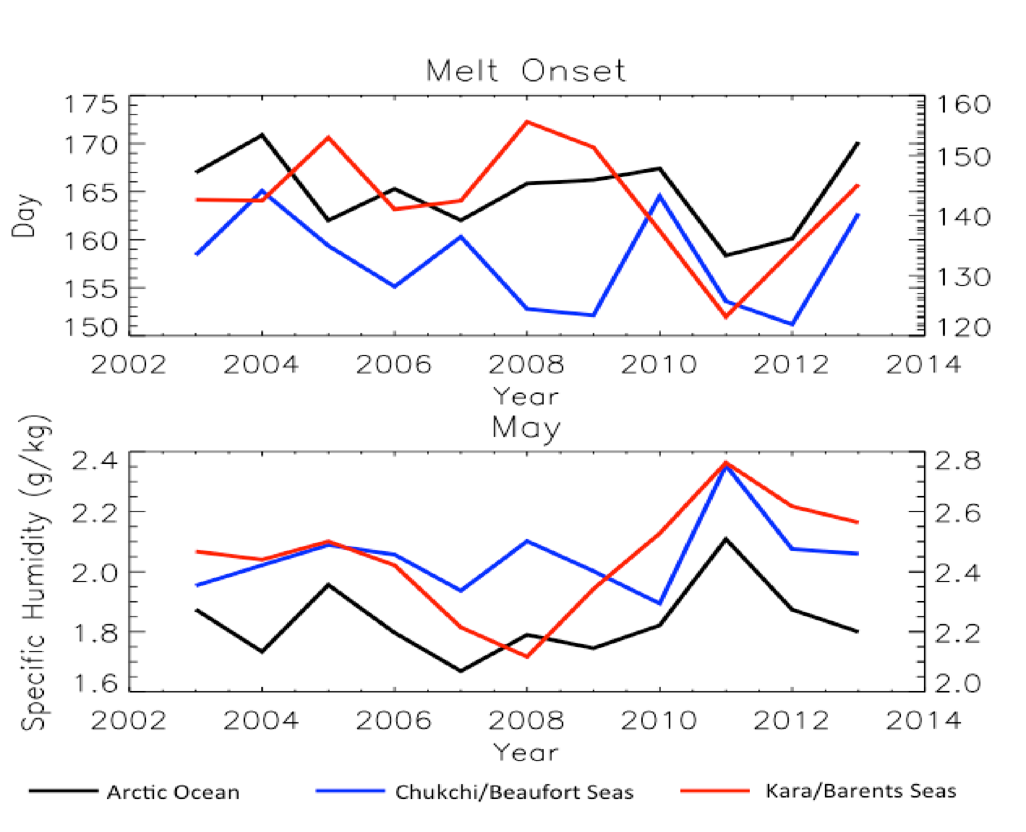


Atmospheric changes revealed by AIRS

- Increasing specific humidity and downward moisture flux in May causes earlier melt onset

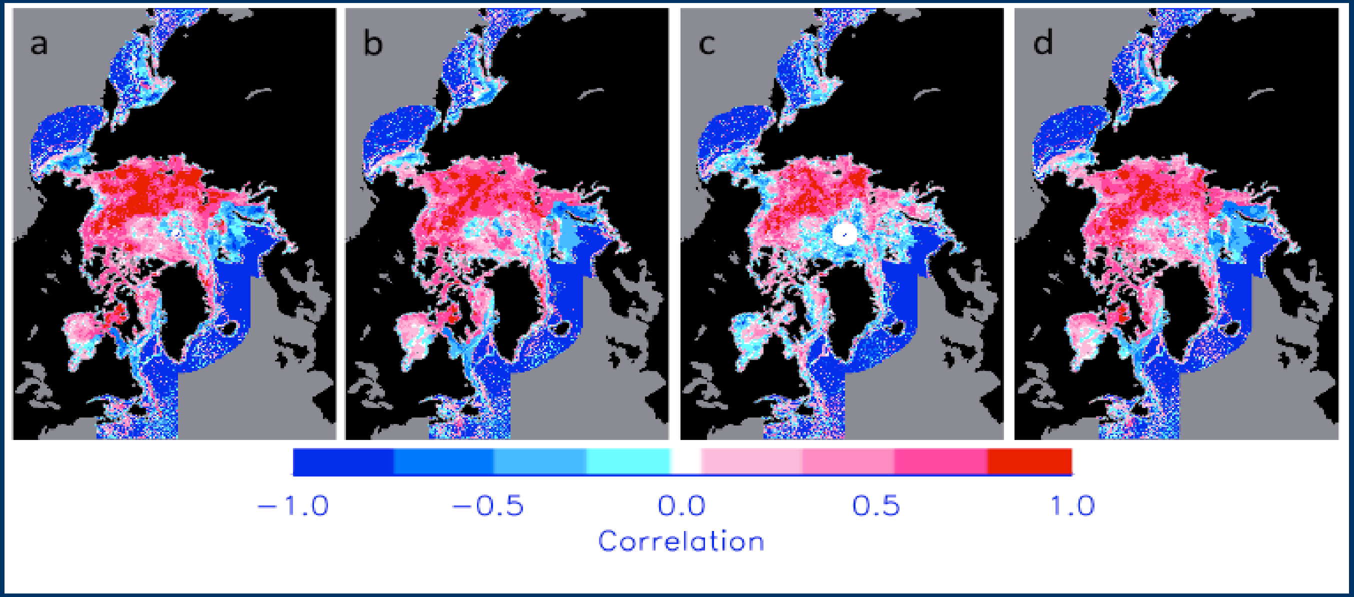


Correlation coefficients between specific humidity in May and melt onset date



Atmospheric changes revealed by AIRS

- Warming skin temperatures and radiative responses to increased water vapor and cloud cover delay autumn freeze-up.

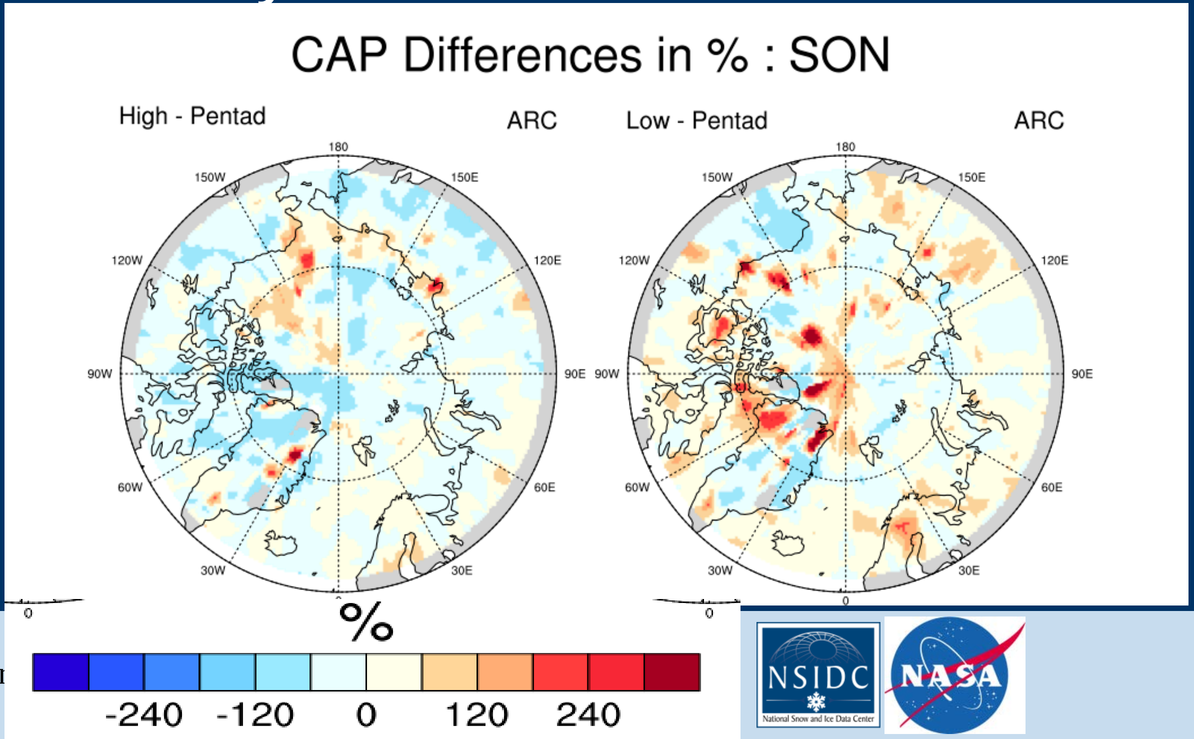


Correlation coefficients between September a) skin temperature, b) 1000 hPa air temperature, c) moisture flux and d) specific humidity with freeze-up dates

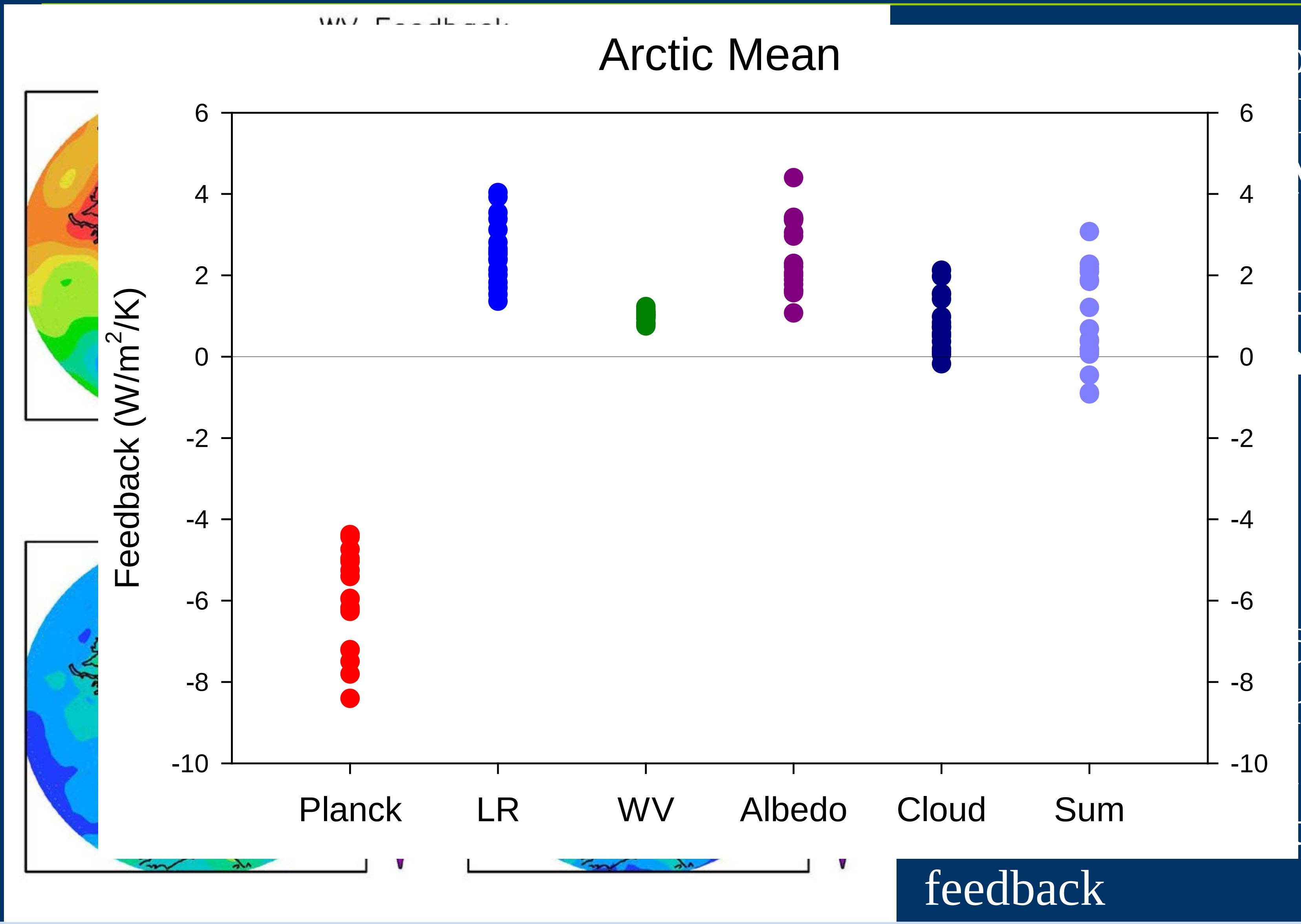
Changes in cyclone activity

- Stroeve et al. (2011) previously documented an increase in cyclone frequency, intensity and cyclone associated precipitation in GNB seas in autumn (1979-2008).
- Analysis through 2013 no longer finds a robust increase in cyclone activity.

Low ice years associated with more autumn precipitation over northern Greenland?



Feedbacks in CMIP5 models 4xCO2 runs



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Summary statements

- SVD analysis reveals linkages between sea ice and Greenland melt.
  - Local influences appears limited to Baffin Bay region.
  - Atmospheric patterns support enhanced Greenland melt together with less sea ice in Beaufort Sea combined with more ice in E. Greenland Sea.
  - Atmospheric patterns that support positive GrIS melt anomalies and negative SIC anomalies persist long-enough to impact freeze-up.
- Melt onset over sea ice is largely driven by advection of warm, humid air into the Arctic that occurs on average a month earlier than over the ice sheet.
- We find little changes in cyclone frequency and intensity, though regionally there appears to be an increase in cyclone associated precipitation in autumn that may impact on snowfall over Greenland.