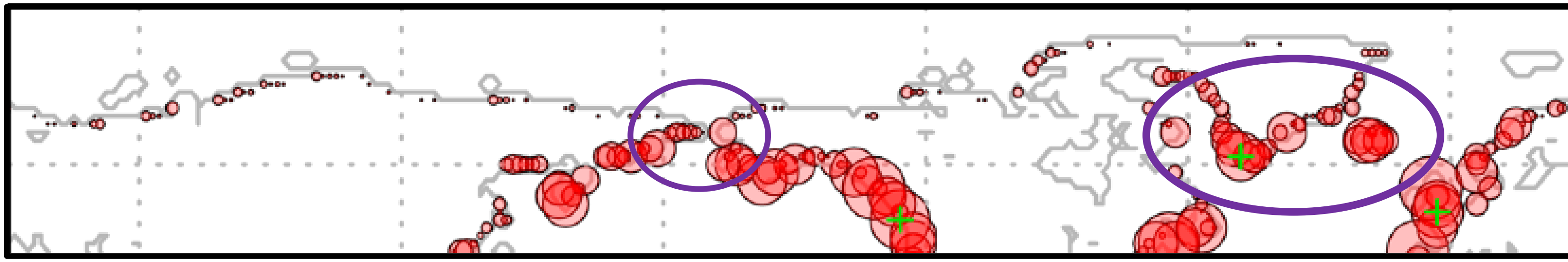
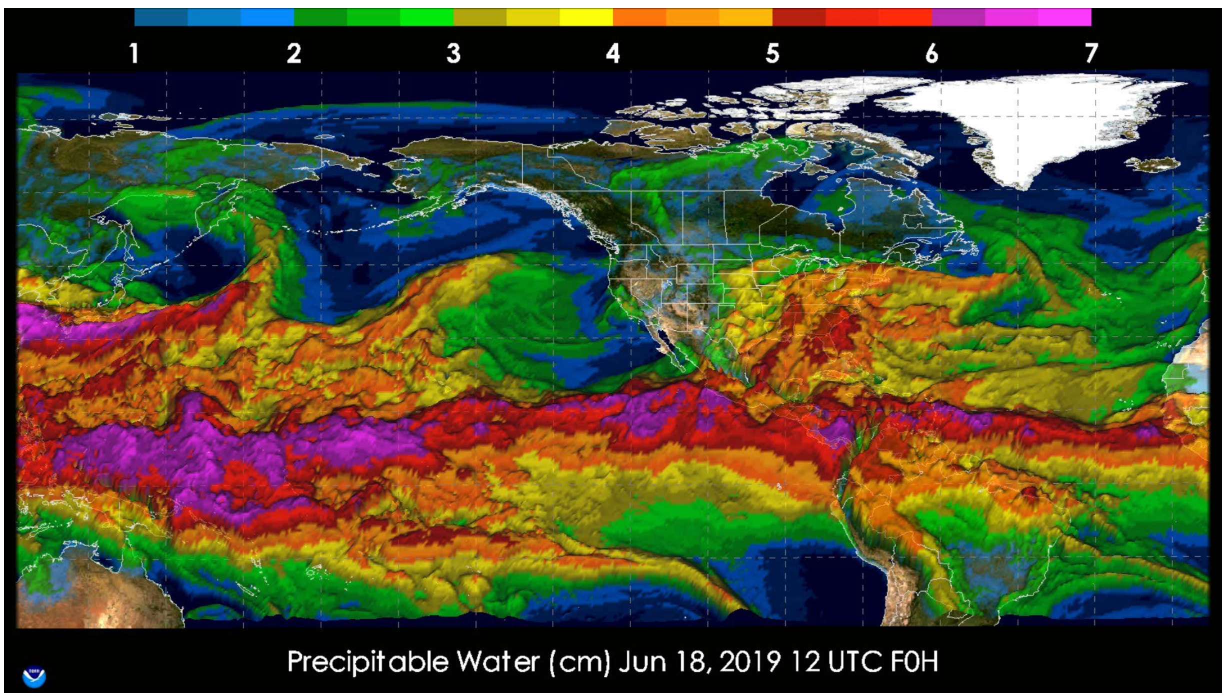
ARS in the Arctic



Land falling ARs north of 45°N. Guan and Waliser, 2015 JGR



Considerations regarding ARs and the Arctic:

- For some time warm air intrusions have been of interest because of the reduction in Arctic sea ice via the radiative effects of warm clouds.

- However, mass loss from the Greenland Ice Sheet (GIS) is important to sea level rise.

15 June 2016 WOODS AND CABALLERO

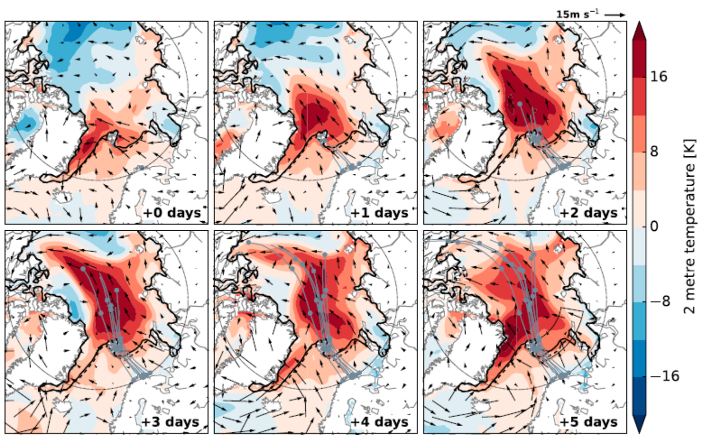
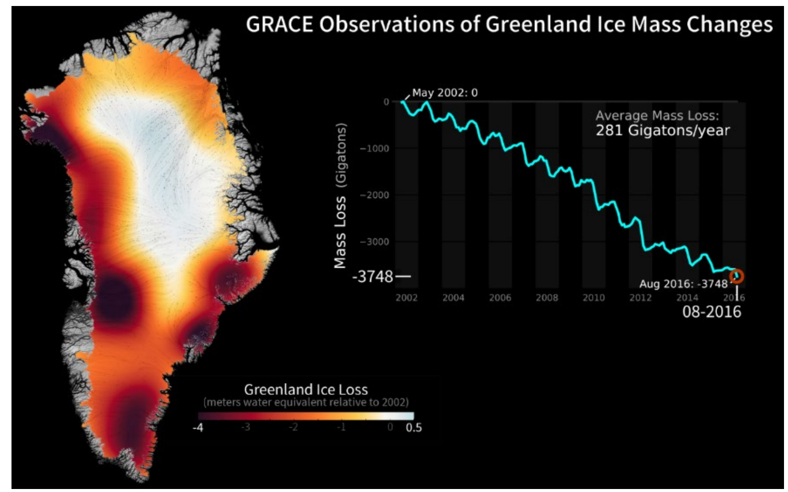
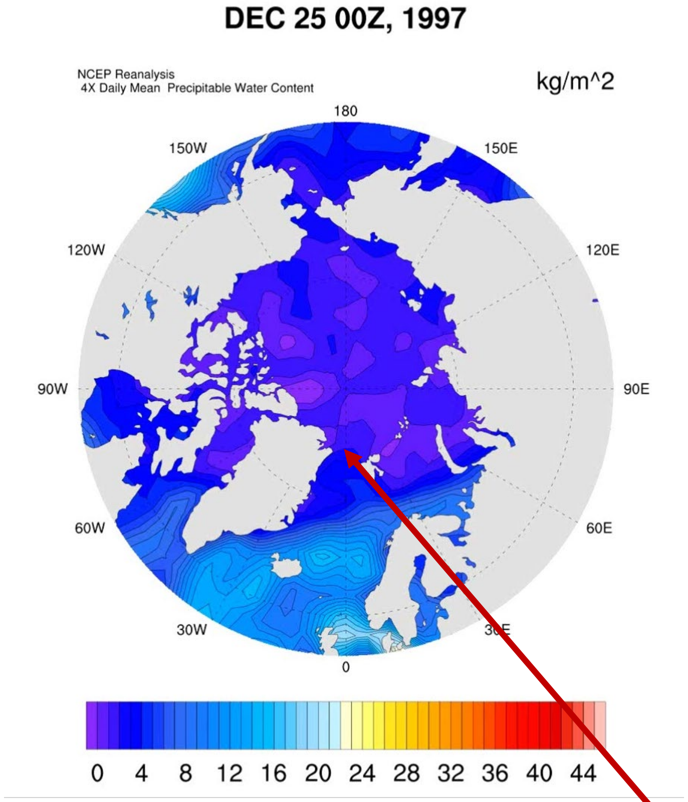


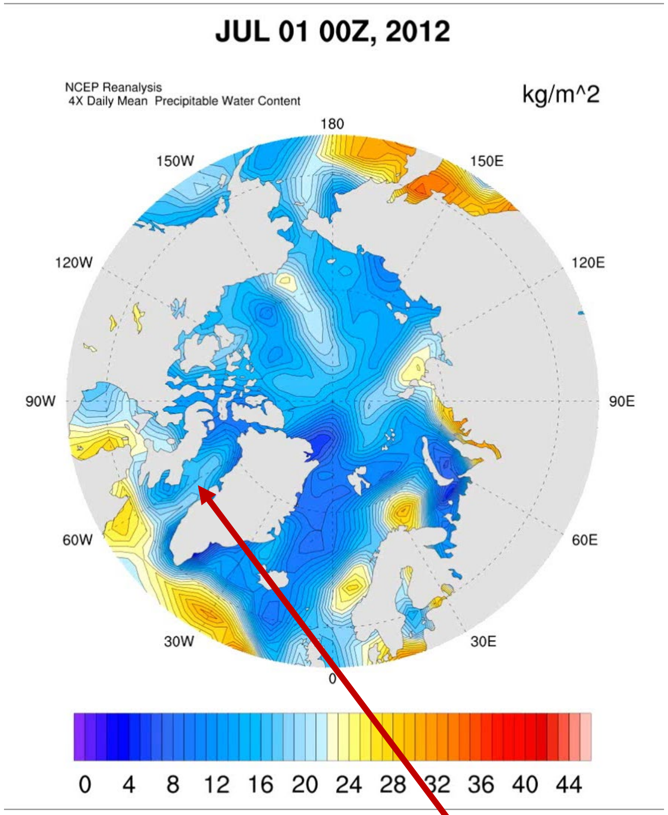
Fig. 2. Case study of an intrusion event beginning over northern Norway at 1800 UTC on 27 December 1999.



1. Recent literature has shown that ARs can be directly relevant to the melting of the GIS
2. An outstanding question is the relevance of ARs originating in the mid latitudes to the evolution of warm air intrusions over the sea ice in the interior of the Arctic.

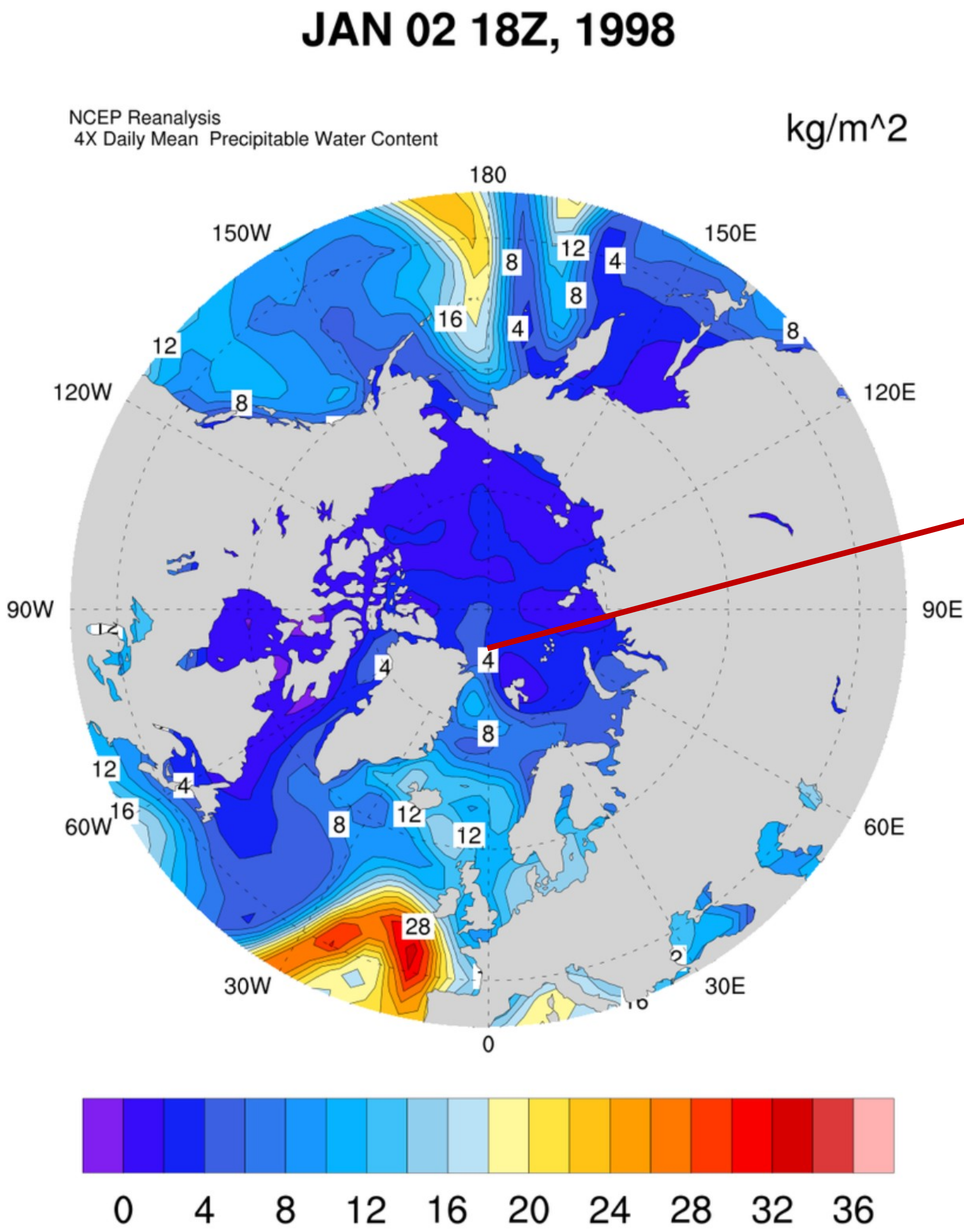
Warm- air Intrusions: Winter vs. Summer



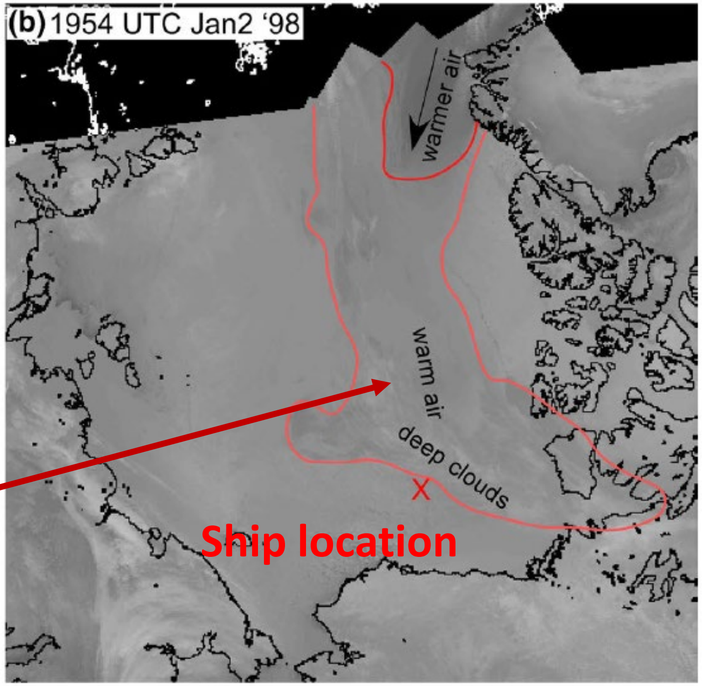


Jan 2, 1998 warm air intrusion to the SHEBA domain

July 27-28, 2012 Greenland Melt



SHEBA



Clim Dyn (2017) 49:1341–1364
DOI 10.1007/s00382-016-3383-1

CrossMark

Linking atmospheric synoptic transport, cloud phase, surface energy fluxes, and sea-ice growth: observations of midwinter SHEBA conditions

P. Ola G. Persson[1,2] · Matthew D. Shupe[1,2] · Don Perovich[3,4] · Amy Solomon[1,2]

Received: 31 December 2015 / Accepted: 2 October 2016 / Published online: 12 October 2016

ARs and Greenland – Legacy of an extreme event

- July 11, 2012 was the first extensive melting of the GIS since 1889 which was the first since ~1200AD.

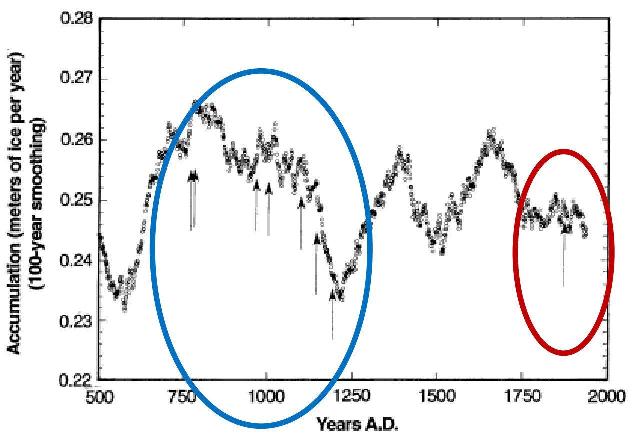
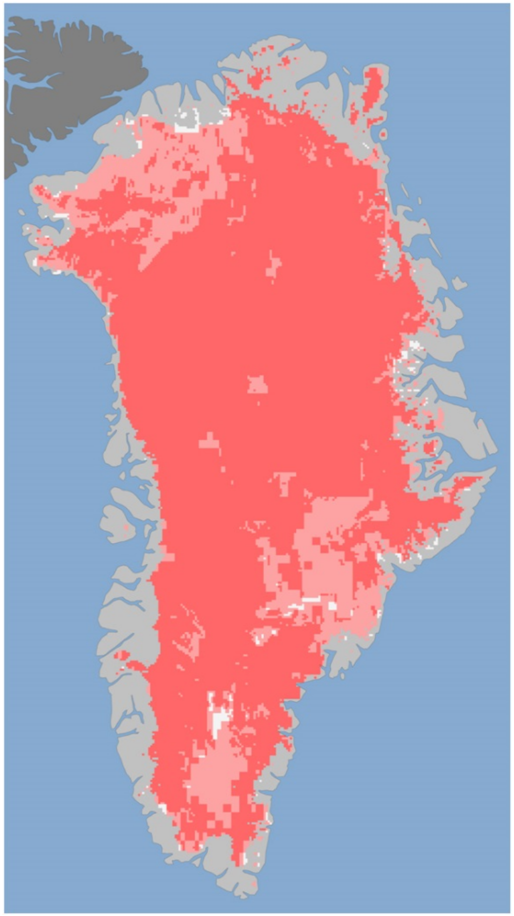


Fig. 2. The 100-year smoothed accumulation record from the GISP2 core for the period A.D. 500 to the present. The arrows show locations of visually identified melt layers in the ice core.

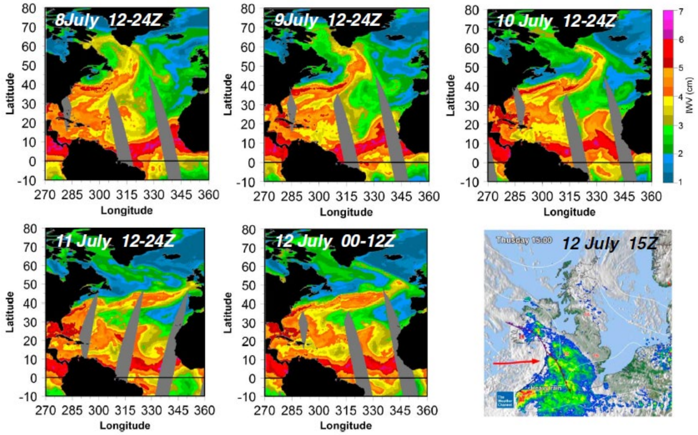
The Accumulation Record from the GISP2 Core as an Indicator of Climate Change Throughout the Holocene
Author(s): D. A. Meese, A. J. Gow, P. Grootes, P. A. Mayewski, M. Ram, M. Stuiver, K. C. Taylor, E. D. Waddington and G. A. Zielinski
Reviewed work(s):
Source: *Science*, New Series, Vol. 266, No. 5191 (Dec. 9, 1994), pp. 1680-1682

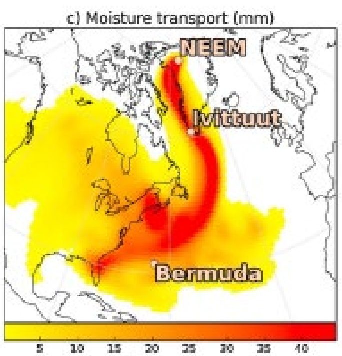


The extreme melt across the Greenland ice sheet in 2012

S. V. Nghiem, D. K. Hall, T. L. Mote, M. Tedesco, M. R. Albert, K. Keegan, C. A. Shuman, N. E. DiGirolamo, and G. Neumann
--GRL 2012

- This event in 2012 was attributed to an AR (Neff et al. 2014).





- Bonne et al. 2015 showed, via an analysis of water vapor isotopes, that origins of the AR lay in the south Atlantic.

- Mattingly et al. 2018 found that, since 2000, ARs have increased in frequency.

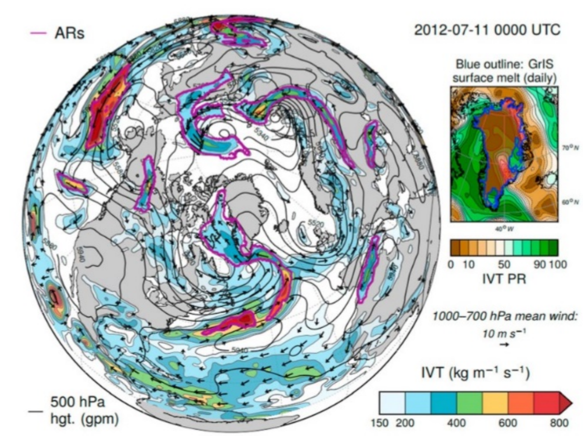
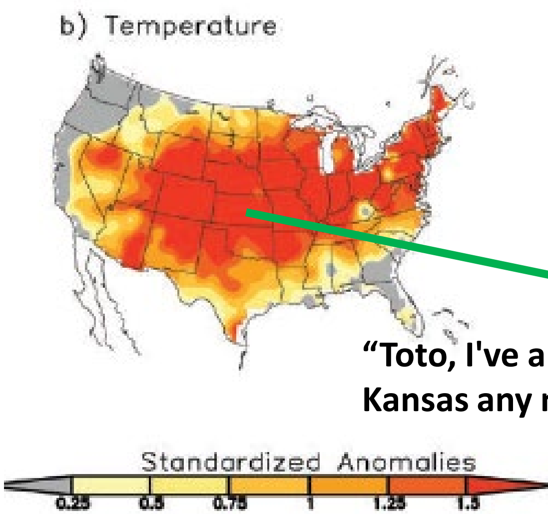


Figure 1. Example of ARs detected using MERRA-2 data at 11 July 2012 0000 UTC. Purple outlines identify features classified as ARs based on the criteria outlined in Table 1.

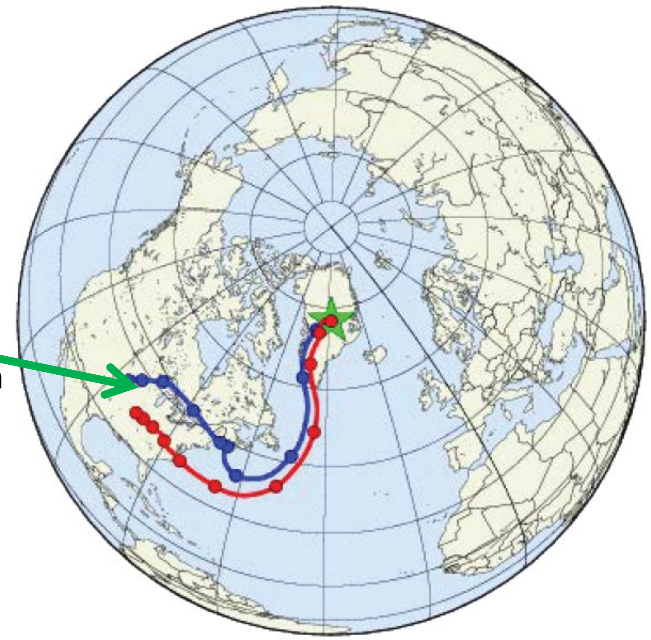
The pieces of the puzzle that came together in our analysis of the 2012 melt event:

1. Where did the air come from?



“Toto, I've a feeling we're not in Kansas any more.”

Back trajectories



US record heatwave leaves dozens dead

The BBC's Rajesh Mirchandani says people have been enduring triple-digit temperatures

At least 42 people have died in a heatwave that has brought soaring temperatures to a dozen US states from the Midwest to the East Coast.

Crops shrivelled and roads and railway lines buckled in the heat.

Related Stories

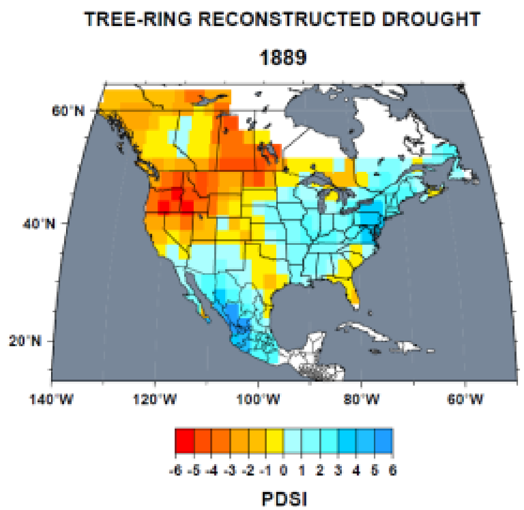
How to survive a heatwave

CAUSES AND PREDICTABILITY OF THE 2012 GREAT PLAINS DROUGHT

BY M. HOERLING, J. EISCHEID, A. KUMAR, R. LEUNG, A. MARIOTTI, K. MO, S. SCHUBERT, AND R. SEAGER

The pieces of the puzzle that came together in our analysis of the 2012 melt event:

2. How did the 2012 episode compare to the one in 1889: was there also a drought and a heat wave? Were there other factors?



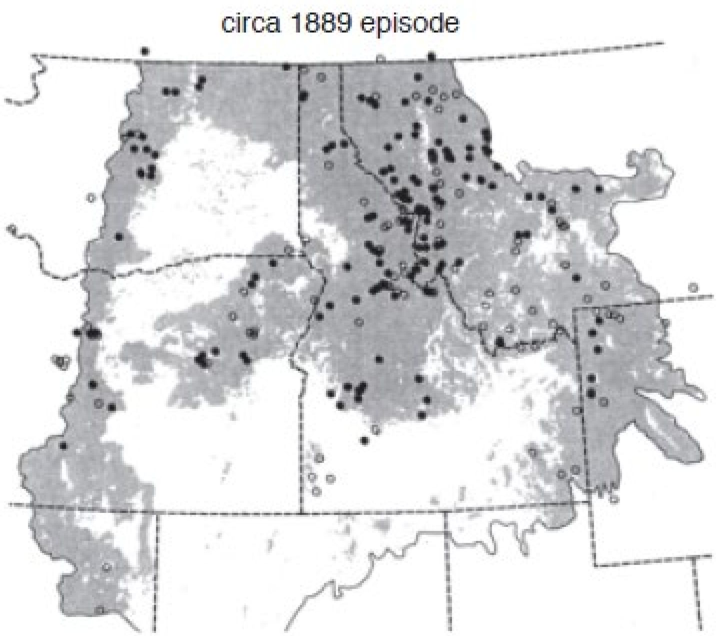
Accounts of the period:

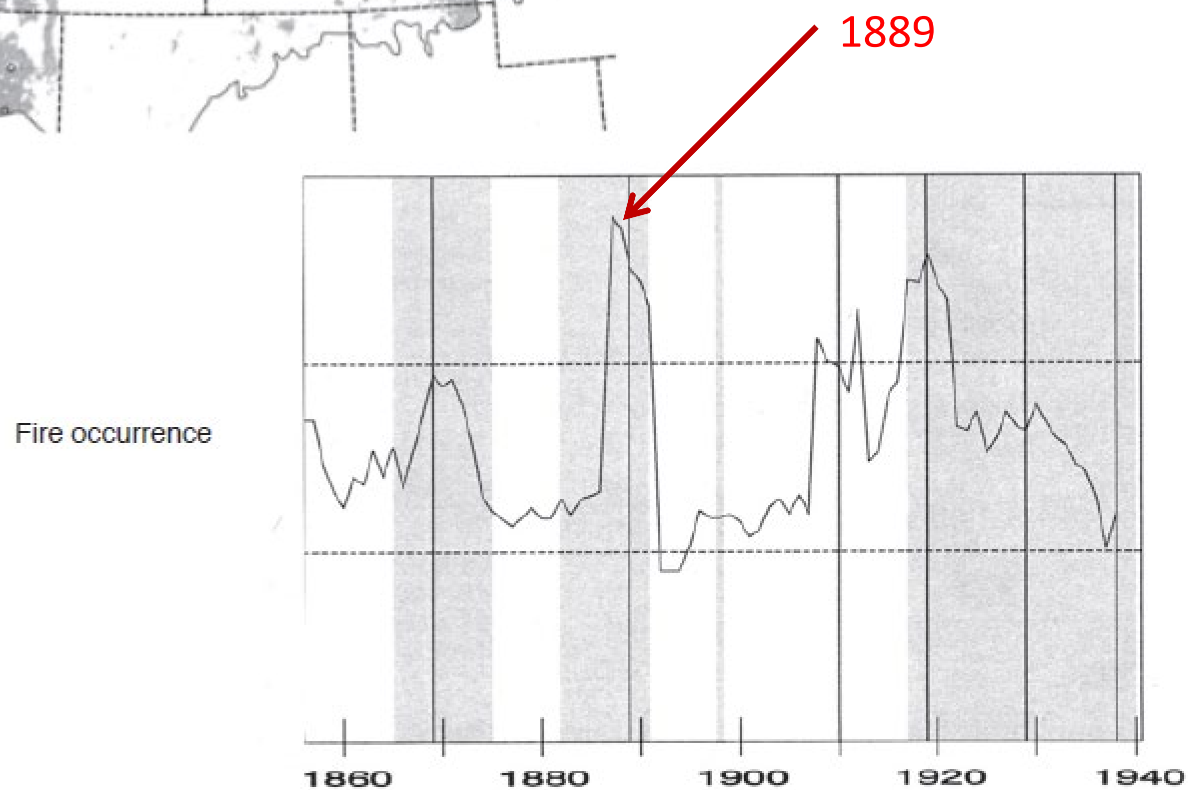
"The Great Dakota Boom that roared through the 1880s had begun to diminish by 1887, and a severe drought in the summer of 1889 brought it to a crashing halt."

--Kepfield, S.S., *" They Were in Far Too Great Want": Federal Drought Relief to the Great Plains, 1887-1895.* South Dakota History, 1998. **28**: p. 244-270.

Fire Episodes in the Inland Northwest (1540-1940) Based on Fire History Data

Stephen W. Barrett
Stephen F. Arno
James P. Menakis



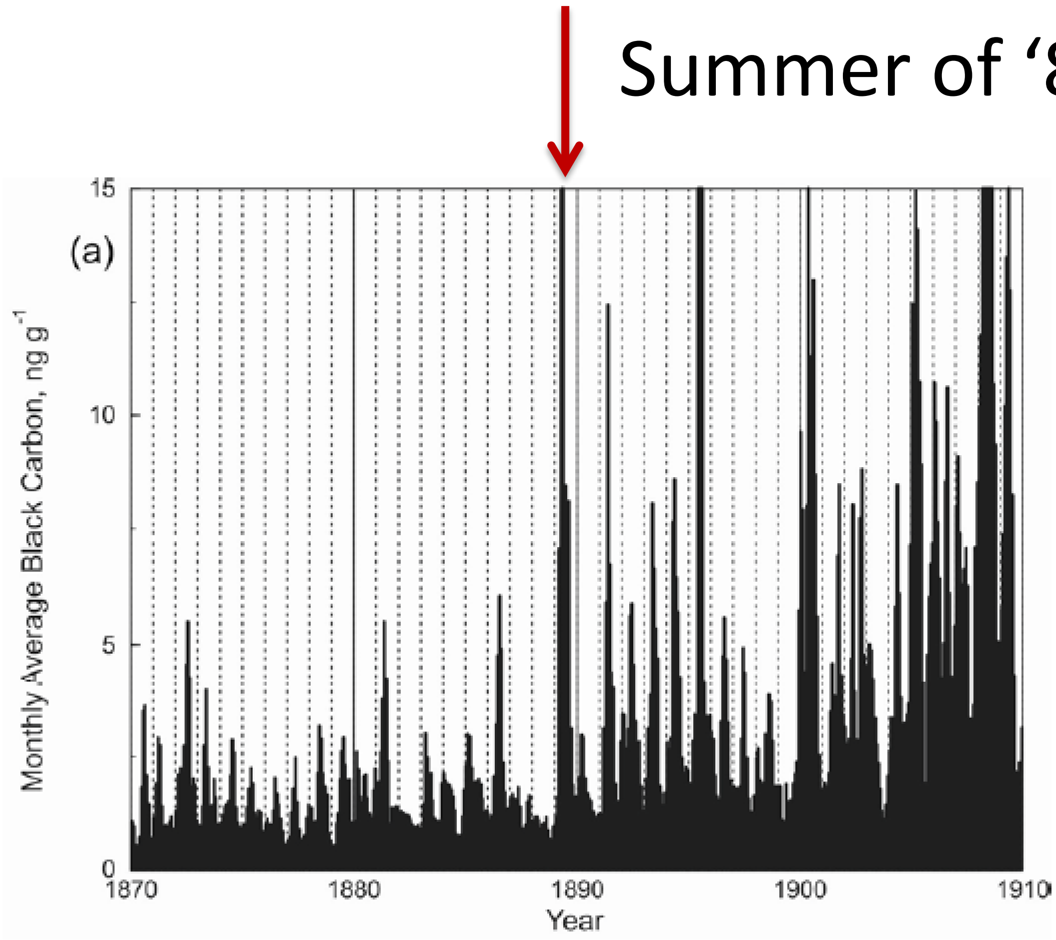


Major John Wesley Powell, director of the U.S. Geological Survey, portrayed the fires of 1889 in testimony to Congress:

> This past season, as an attaché to the Senatorial committee investigating the questions relating to the arid lands, I passed through South Dakota, North Dakota, Montana, Washington, Oregon, and Idaho by train. Among the valleys, with mountains on every side, during all that trip a mountain was never seen. This was because the fires in the mountains created such a smoke that the whole country was enveloped by it and hidden from view (Powell 1891, 208).

---Arno, S. F., and S. Allison-Bunnell (2002), *Flames in Our Forest, Disaster or Renewal*, Island Press, Washington DC.

Summer of ‘89



McConnell, J. R., R. Edwards, G. L. Kok, M. G. Flanner, C. S. Zender, E. S. Saltzman, J. R. Banta, D. R. Pasteris, M. M. Carter, and J. D. W. Kahl (2007), 20th-century industrial black carbon emissions altered arctic climate forcing, *Science*, *317*(5843), 1381-1384.

Key findings in 2012 and 1889:

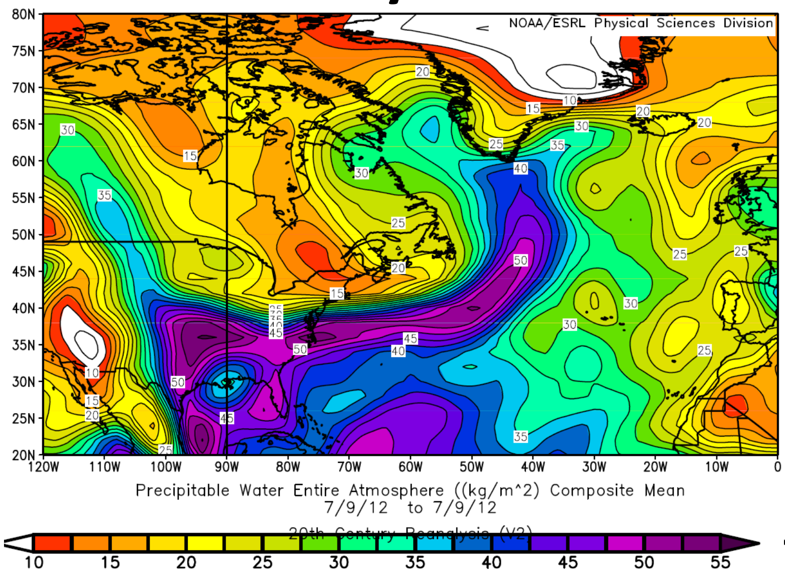
- Source of hot, dry air in the mid-continent
- Ocean was warmer than normal south of Greenland (positive phase of the AMO)
- Ridge-trough pattern favorable for southerly flow (ridge intersecting SE Greenland coast, trough to the west).
- Northward transport of warm moist air along the west coast of Greenland via an “atmospheric river,” a narrow filament of high moisture air.
- Transport path from heat sources over the continent, over the ocean, and then northward to Greenland (water vapor isotope studies confirm this - Bonne et al. 2015).

New consideration from 1889: The role of biomass burning for changes in surface albedo over ice.

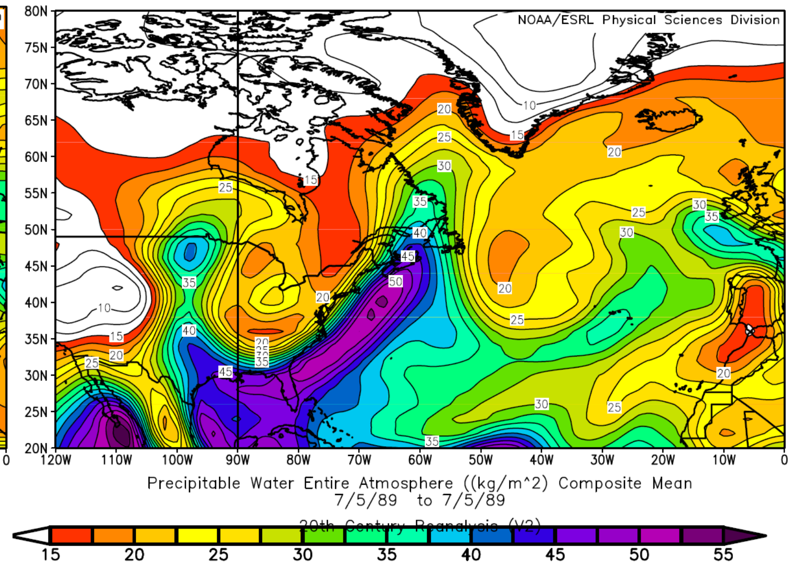
The pieces of the puzzle that came together in our analysis of the 2012 melt event:

3. How did the ARs in 1889 and 2012 compare in structure?

9 July 2012



5 July 1889



Key result: The 20CR captured the basic structure of atmospheric rivers (ARs) affecting Greenland during extreme melt episodes in 1889 and 2012. A major factor was transport of warm humid air along the west coast of Greenland

So two episodes in a hundred and twenty years – how long would we have to wait for another?

750-1200 AD → 1889 → 2012 → 2019

Capital Weather Gang

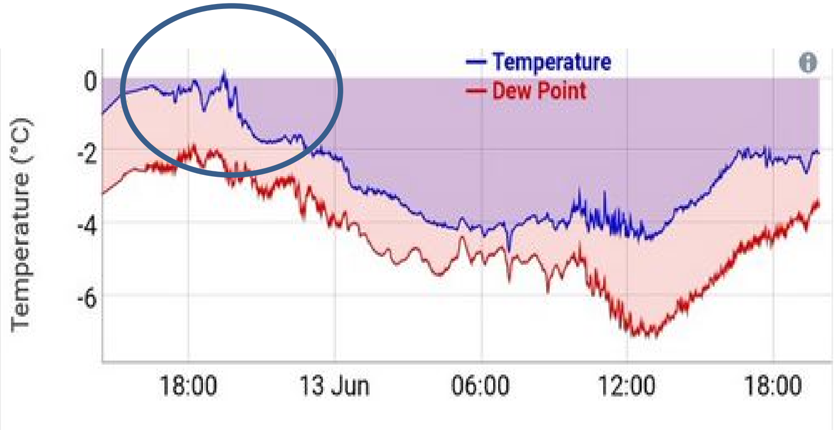
Temperatures leap 40 degrees above normal as the Arctic Ocean and Greenland ice sheet see record June melting

And it may be messing with our weather.

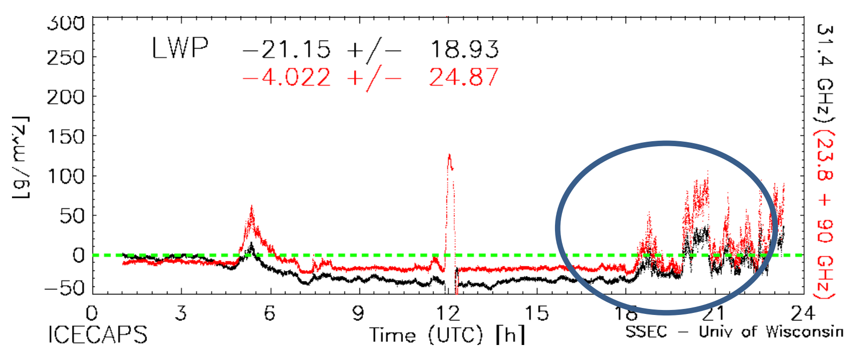
Washington Post, 16 June 2019

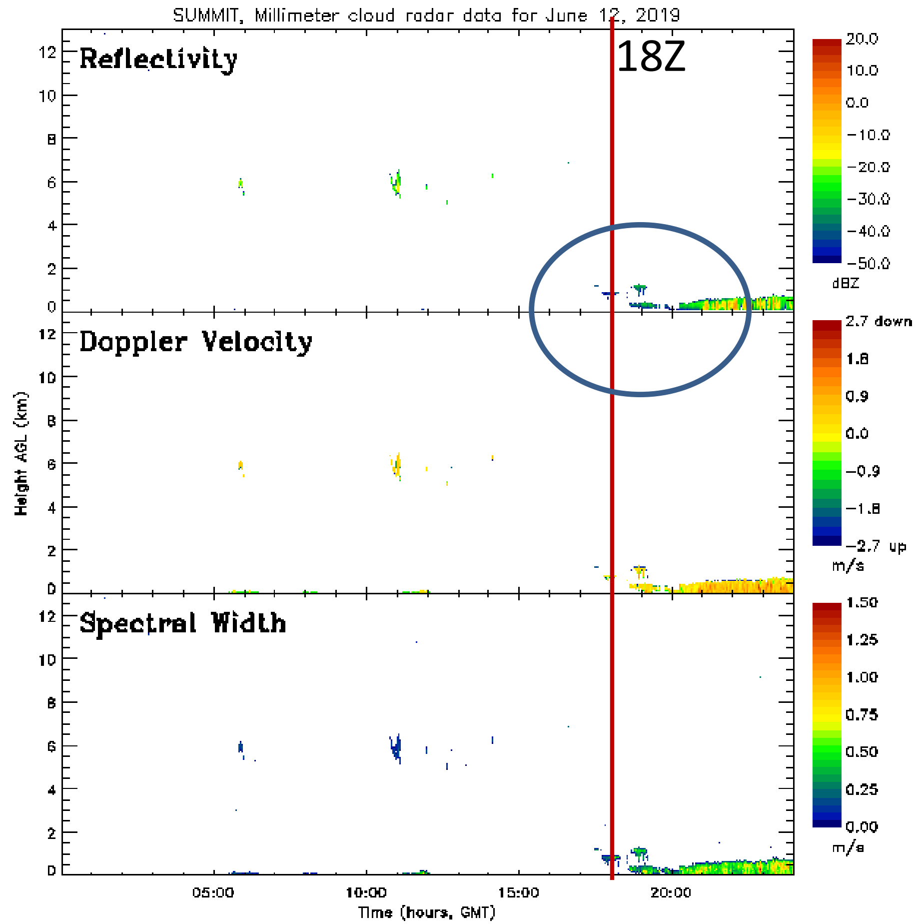
What do we know so far about this event on 12 June 2019?

1. Clouds and temperatures



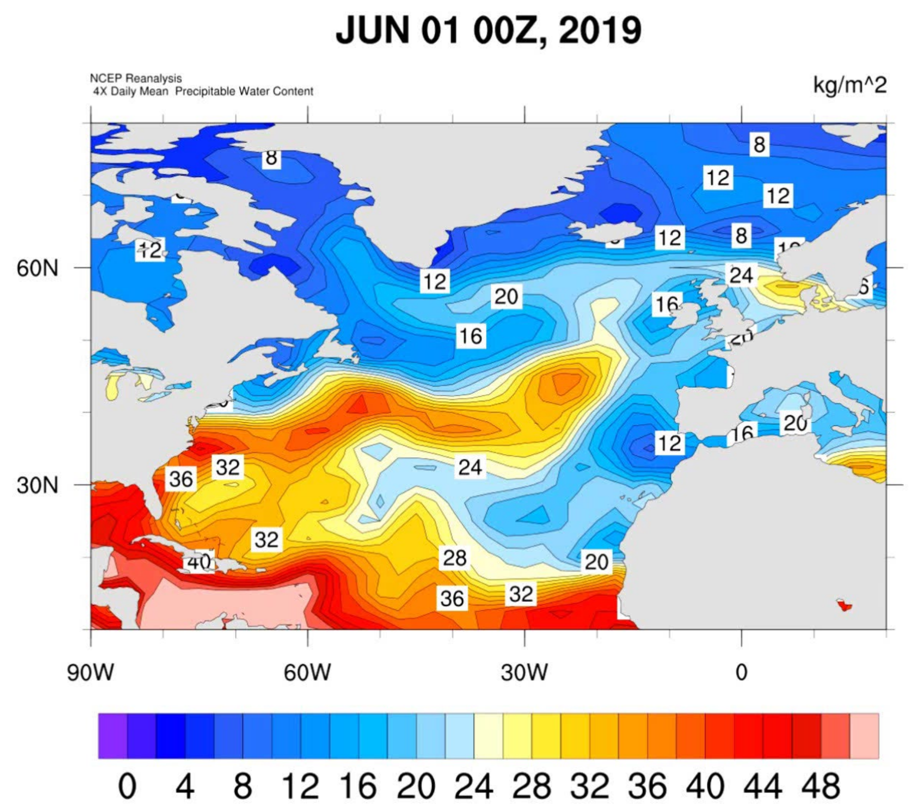
Temperature peaks with arrival of clouds – as in 2012

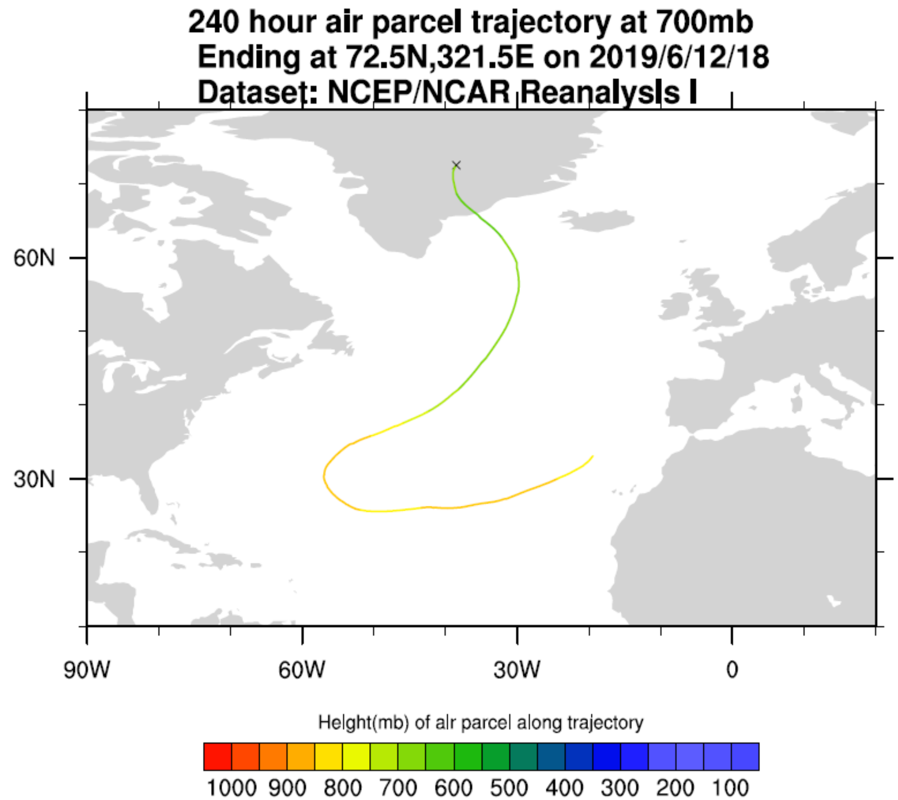




What do we know so far about this event on 12 June 2019?

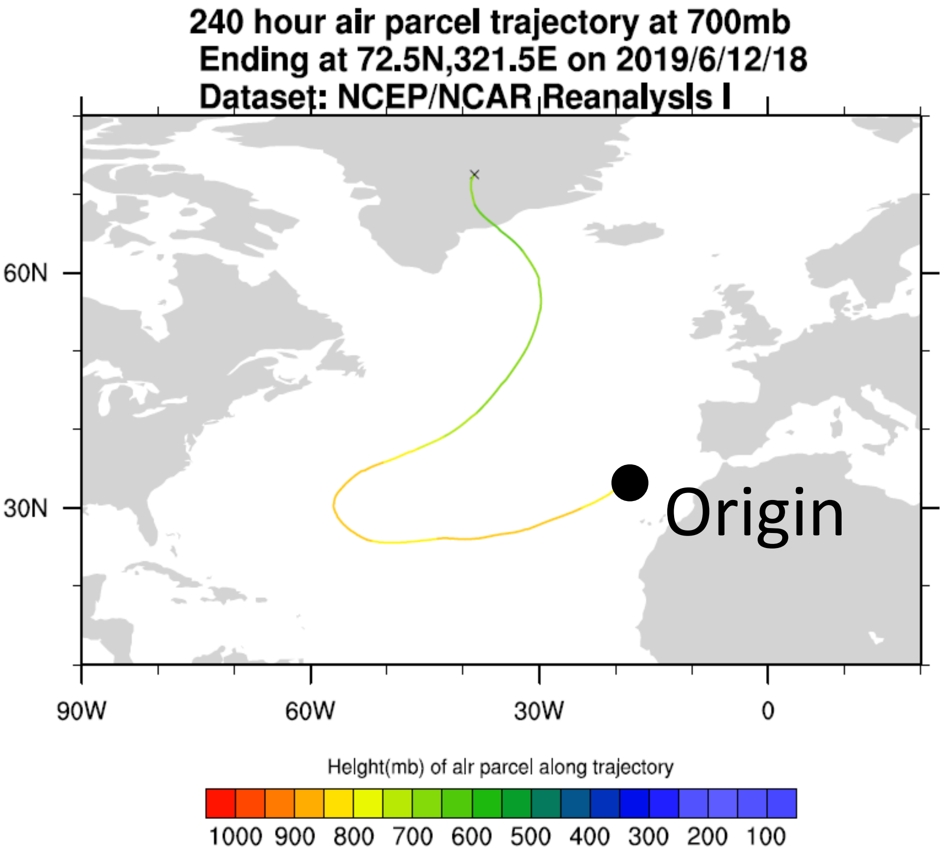
2. Where did the air come from 3-12 June?

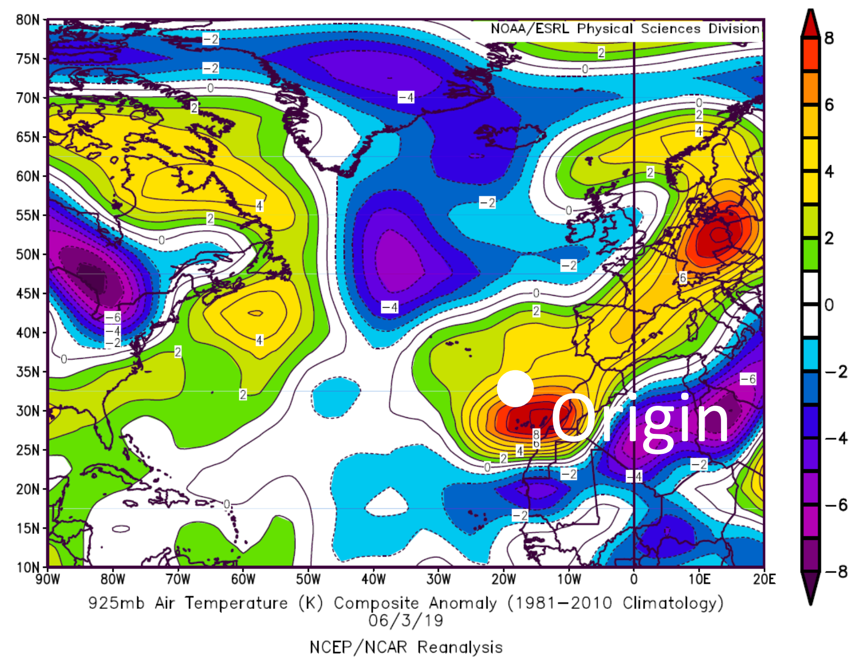




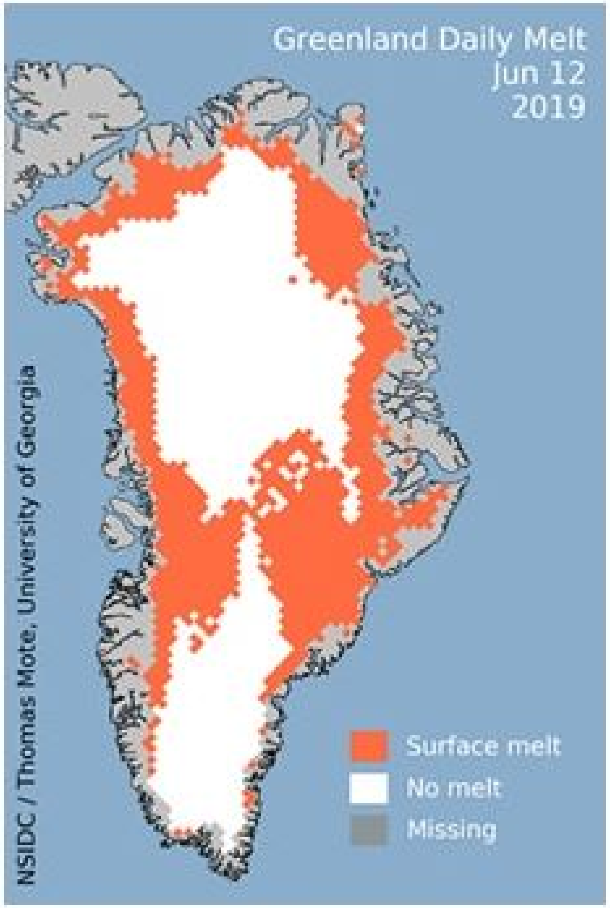
What do we know so far about this event on 12 June 2019?

3. Was it warm in the origin area?



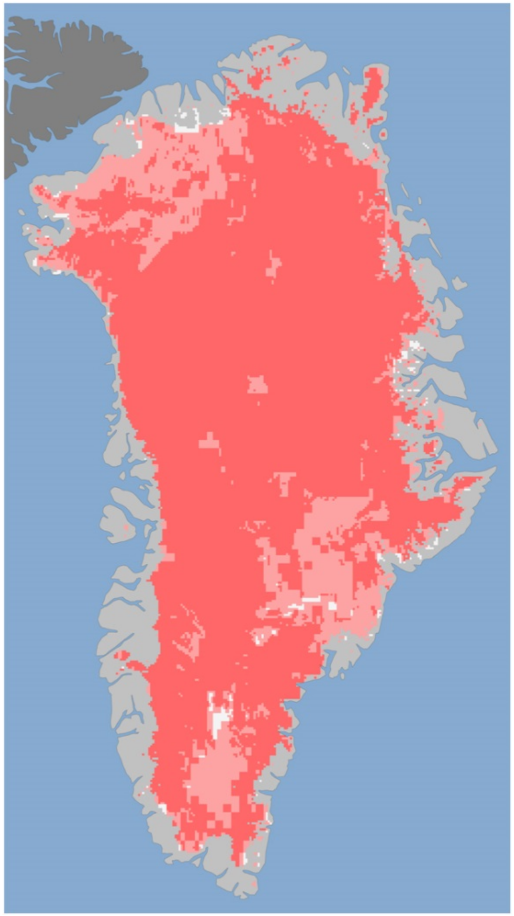


June 12, 2019

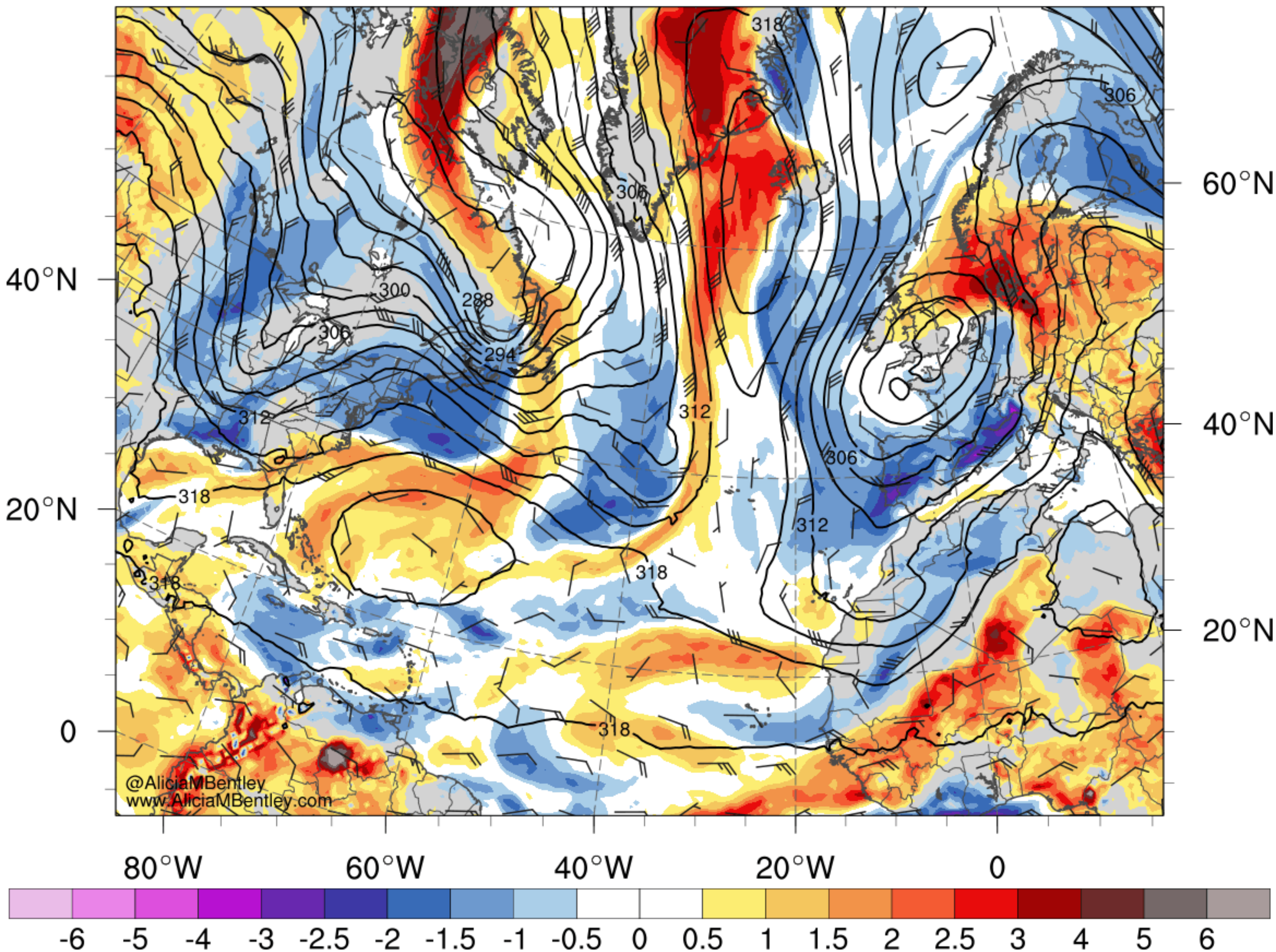


Extent of Greenland ice sheet melting on June 12. (National Snow and Ice Data Center)

July 11, 2012



700-hPa geo. height (black, dam), wind (barbs, kt), standardized precip. water anomaly (shaded, sigma)
Initialized: 1800 UTC 12 Jun 2019 | Forecast hour: 0 | Valid: 1800 UTC 12 Jun 2019

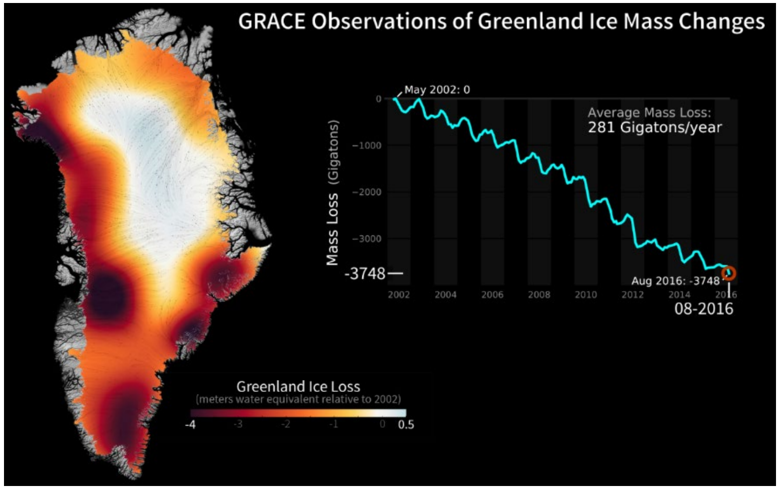


Discussion

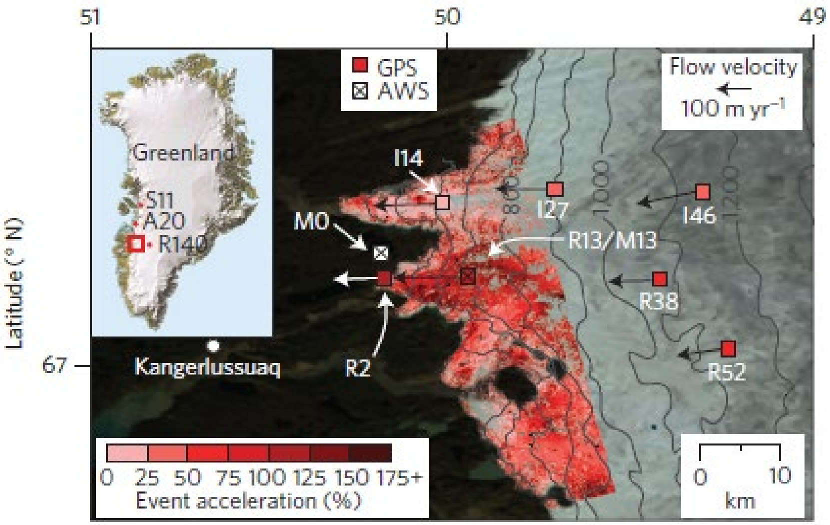
Greenland Topography, ARs, Some Dynamics and a few Hurricanes

Motivation:

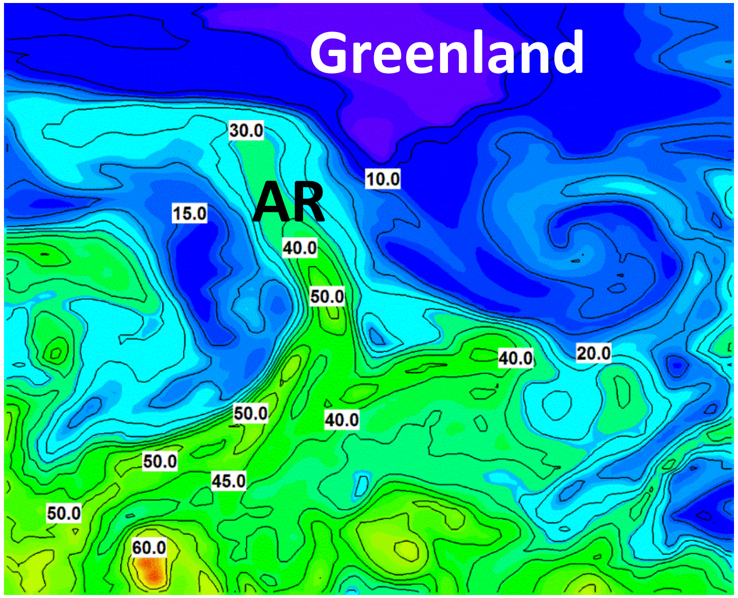
Mattingly et al. (2018: *JGR*) has reported that the frequency of **ARs melting Greenland had increased since 2000,** with the greatest effect on the west coast of Greenland.



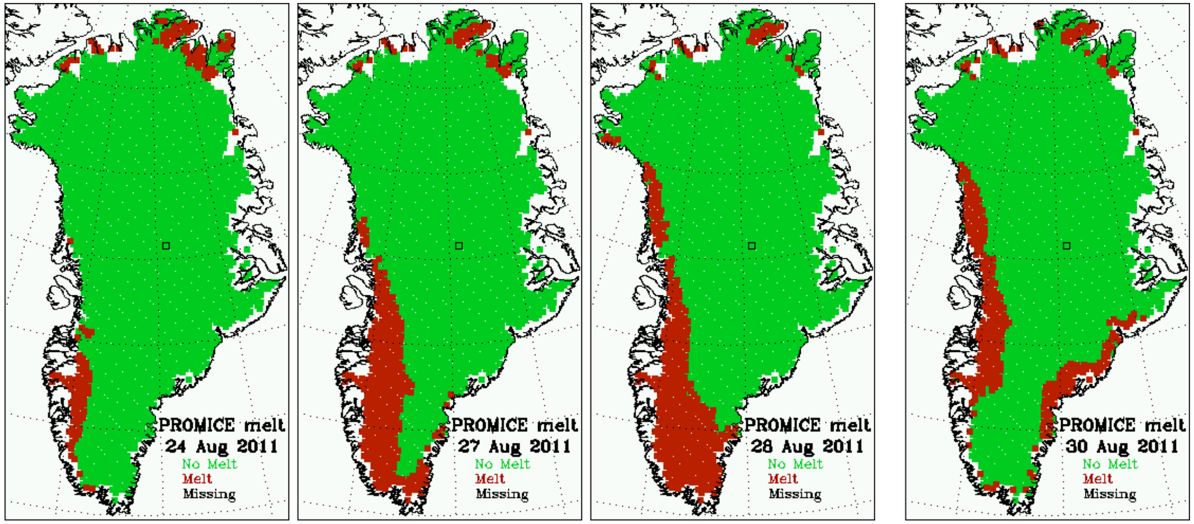
Doyle et al. (2015) reported on a late summer extreme rainfall event on the SW coast of Greenland 23 August to 3 September 2011. **It was reported that the mass loss in this one event represented 10% of the annual total.**



Neff (2018: *Nat. Clim. Change*) used the event on 24 August 2011 (Doyle at al.) as an example of the impact of an atmospheric river on the melting of Greenland.



Progression of the melt over Greenland…



Together, the Greenland and Antarctic Ice Sheets contain more than 99 percent of the freshwater ice on Earth. Credit: NSIDC

Sea level rise:
Greenland 20 m
Antarctica 200 m

AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER
10.1002/2017GL072845

Key Points:
- Understanding sea level acceleration requires consideration of multiple spatially varying physical processes
- Recent acceleration is well modeled using Greenland and Antarctic ice loss and ocean dynamics
- Acceleration from ice loss alone translates to regional rise of 0.2–0.75 m in one century, depending on location

Supporting Information:
- Supporting Information S1

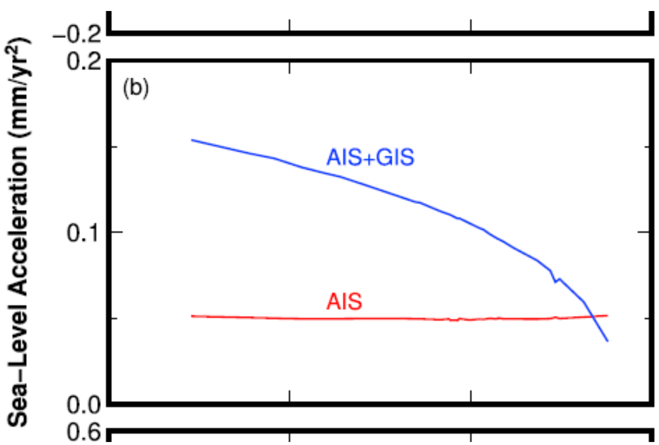
Correspondence to:
J. L. Davis,
jdavis@ldeo.columbia.edu

Causes of accelerating sea level on the East Coast of North America

James L. Davis[1] and Nadya T. Vinogradova[2]

[1]Lamont-Doherty Earth Observatory of Columbia University, New York, New York, USA, [2]Cambridge Climate Institute, Boston, Massachusetts, USA

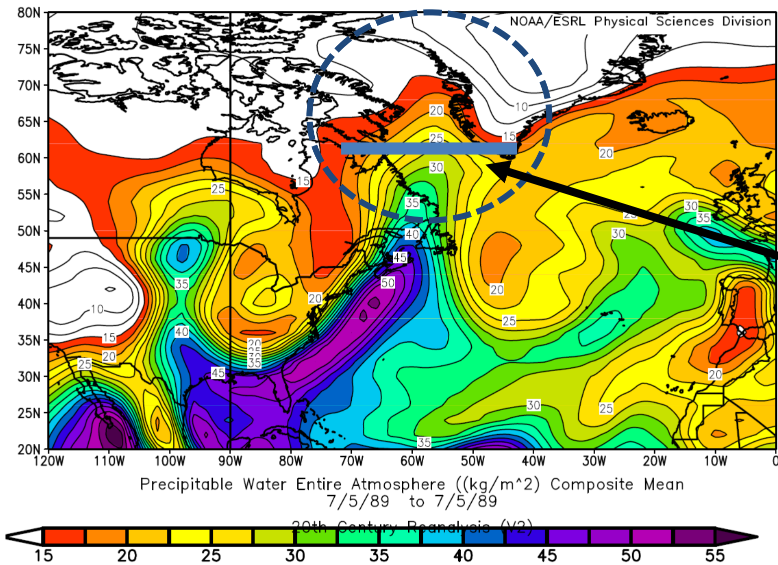
Abstract The tide-gauge record from the North American East Coast reveals significant accelerations in sea level starting in the late twentieth century. The estimated post-1990 accelerations range from near zero to ∼0.3 mm yr^{-2}. We find that the observed sea level acceleration is well modeled using several processes: mass change in Greenland and Antarctica as measured by the Gravity Recovery and Climate Experiment satellites; ocean dynamic and steric variability provided by the GECCO2 ocean synthesis; and the inverted barometer effect. However, to achieve this fit requires estimation of an admittance for the dynamical and steric contribution, possibly due to the coarse resolution of this analysis or to simplifications associated with parameterization of bottom friction in the shallow coastal areas. The acceleration from ice loss alone is equivalent to a regional sea level rise in one century of 0.2 m in the north and 0.75 m in the south of this region.

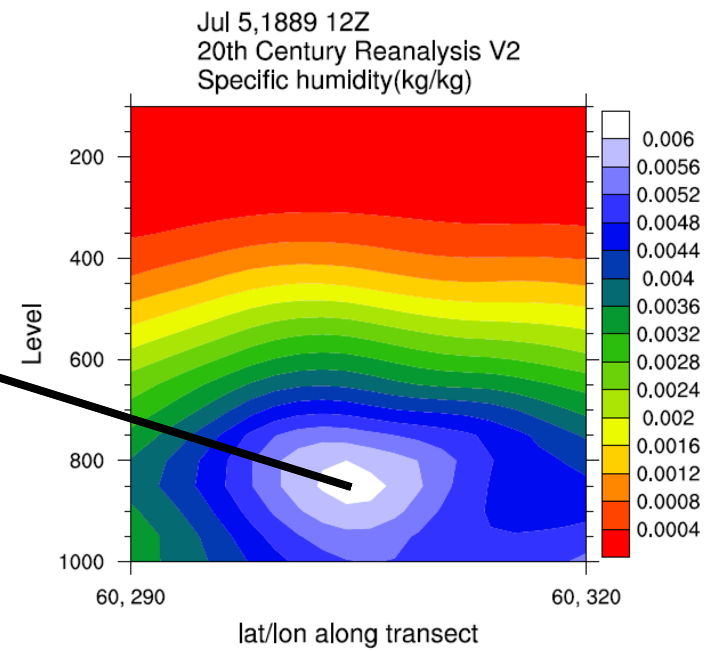


20oN 50oN

Sea level changes as a function of latitude on the US east coast – maximizes to the south.

Topographic effects of Greenland:
In 1889, the maximum in specific humidity was at 850 hPa and confined along the Greenland coast





Liu and Barnes (2015) showed that transport along the western Greenland occurred during cyclonic wave breaking (CWB)

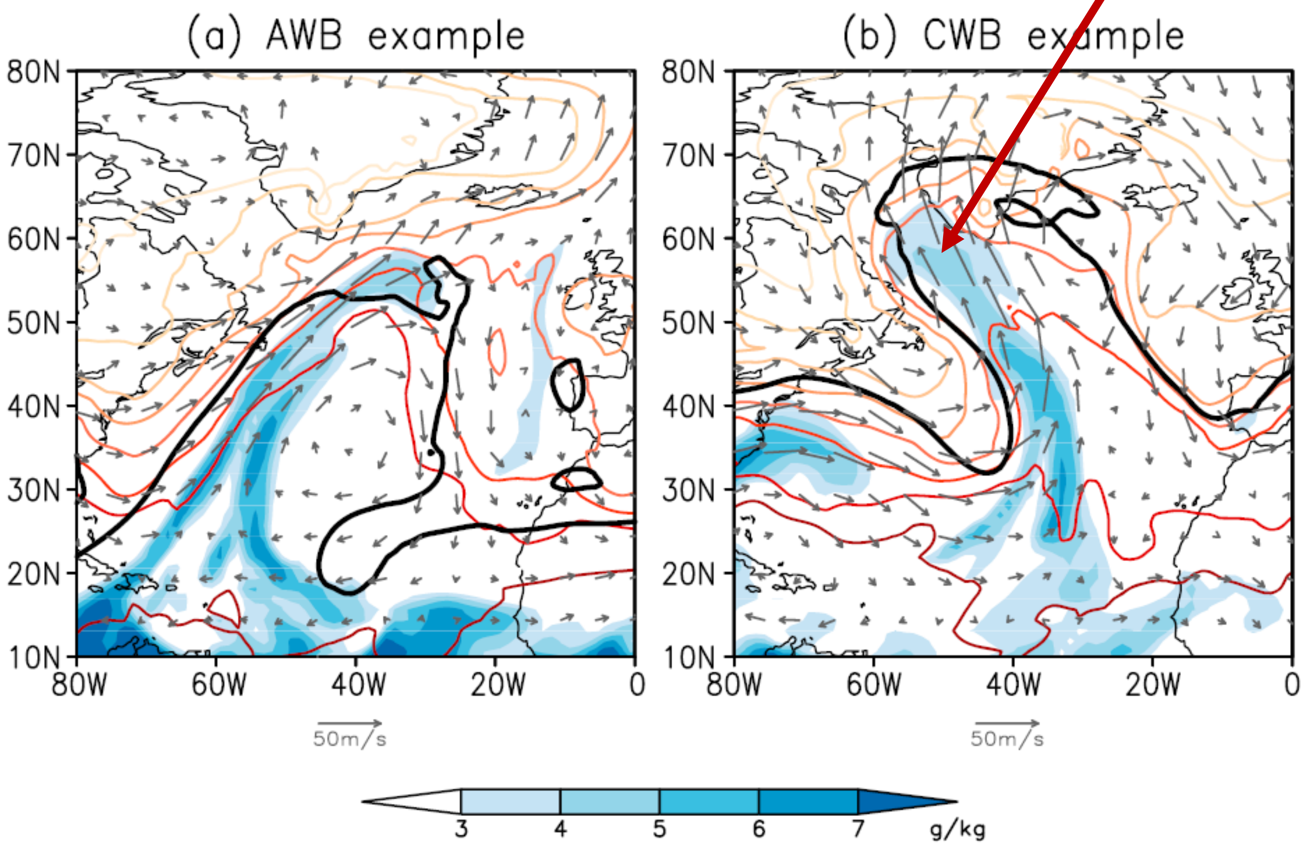
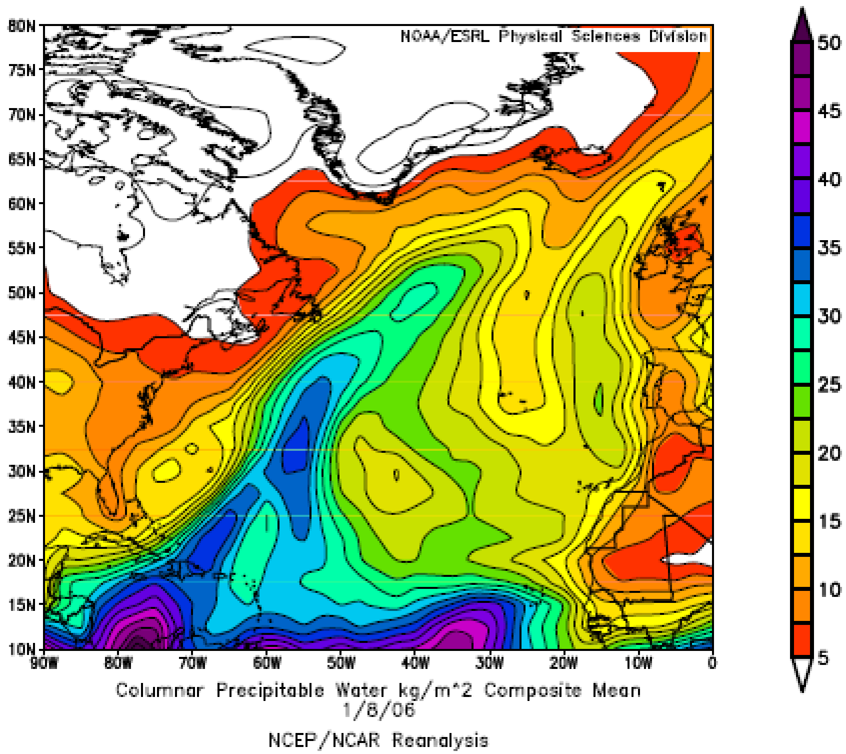
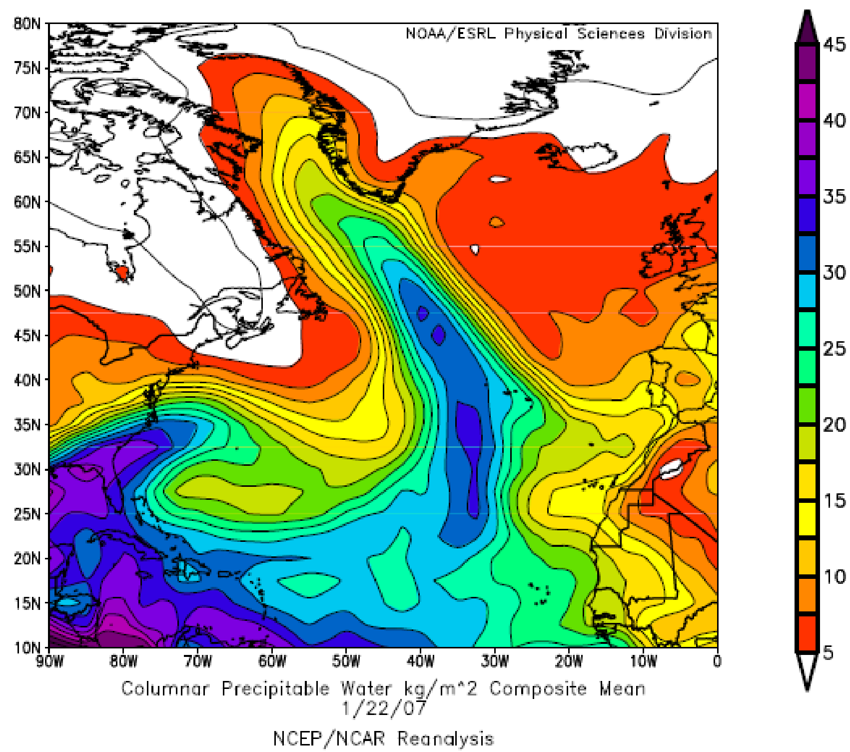


Figure 5. Mixing ratio of water vapor (shading), potential temperature (colored contours), and horizontal wind (arrows) on 700 hPa for (a) an anticyclonic wave breaking on 8 January 2006 and (b) a cyclonic wave breaking on 22 January 2007. The potential temperature contour interval is 5 K. The thick solid black line is the potential temperature contour on the 2 PVU surface that is used to identify Rossby wave breaking events.

AWB

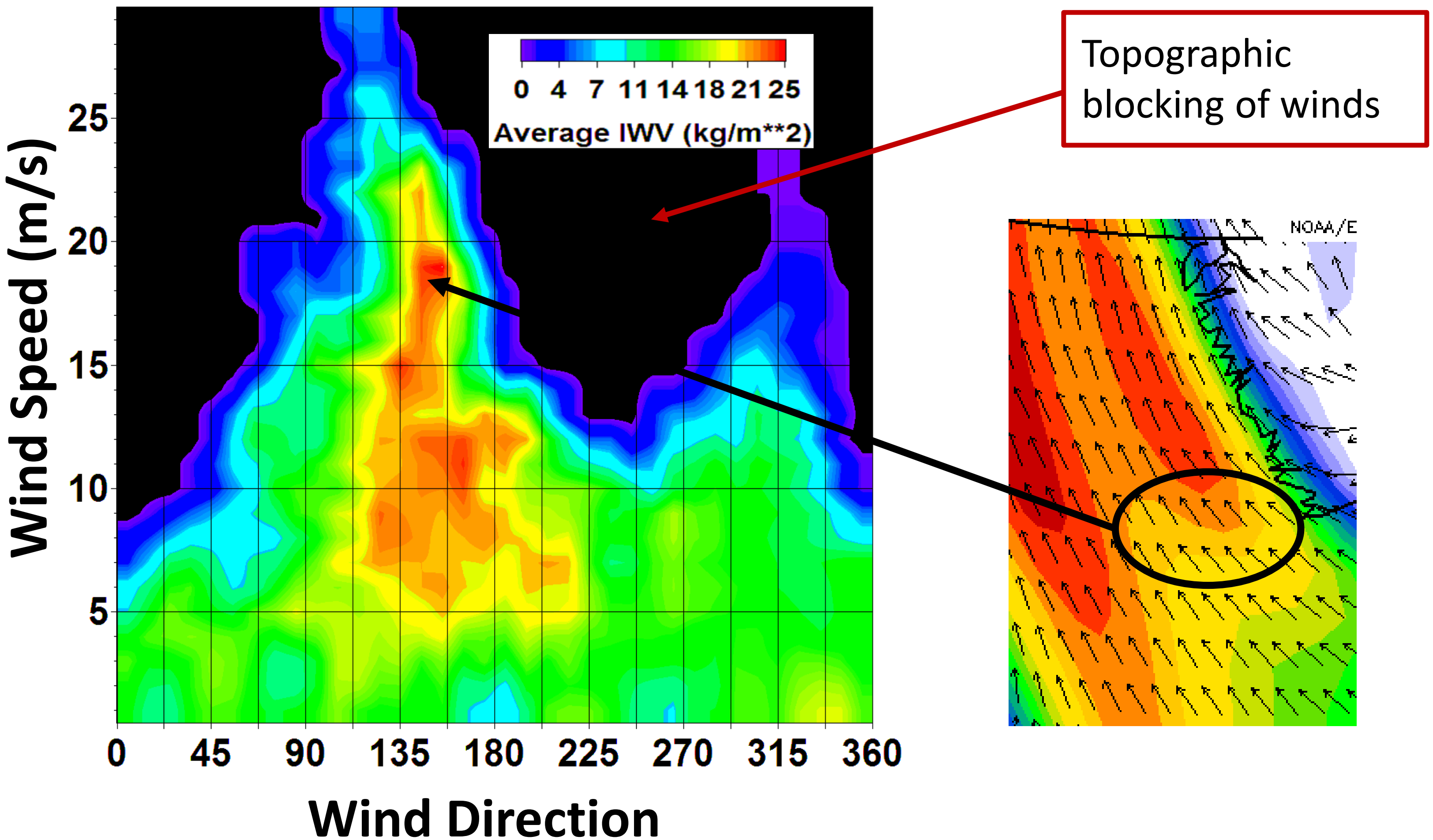

NOAA/ESRL Physical Sciences Division
Columnar Precipitable Water kg/m^2 Composite Mean
1/8/06
NCEP/NCAR Reanalysis

CWB

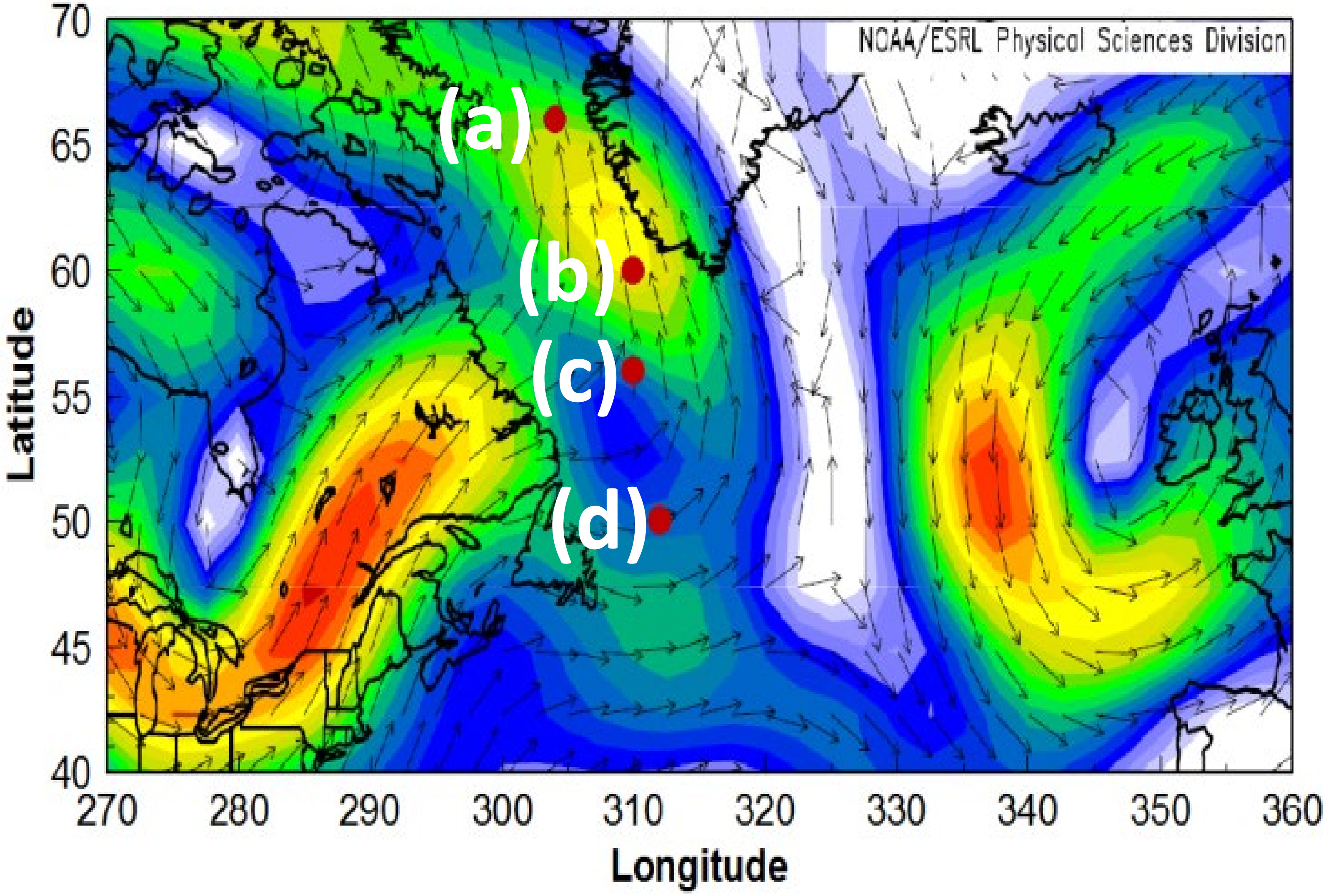

NOAA/ESRL Physical Sciences Division
Columnar Precipitable Water kg/m^2 Composite Mean
1/22/07
NCEP/NCAR Reanalysis

Topographic effects of Greenland: Distribution of winds: Developing a simple AR diagnostic tool….

Average IWV as a function of wind speed and direction at 60N, 50W and 850 hPa, JJA 2000-2012



This led us to ask what is the synoptic pattern at larger scales when there are stronger surges of warm moist air along the west coast of Greenland:



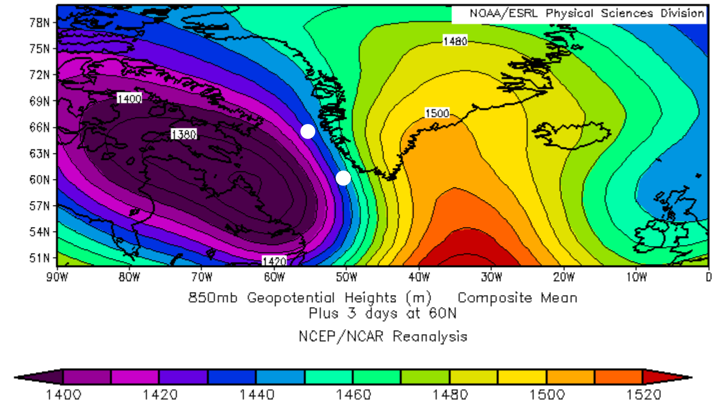
Question: What is the synoptic environment associated with northward transport of moisture and warm air along the west coast of Greenland?

Taking advantage of the topographic barrier effect of Greenland*, we identified 69 cases between 2000 and 2012* and created composite fields after setting criteria for northward transport at 850 hPa as follows:

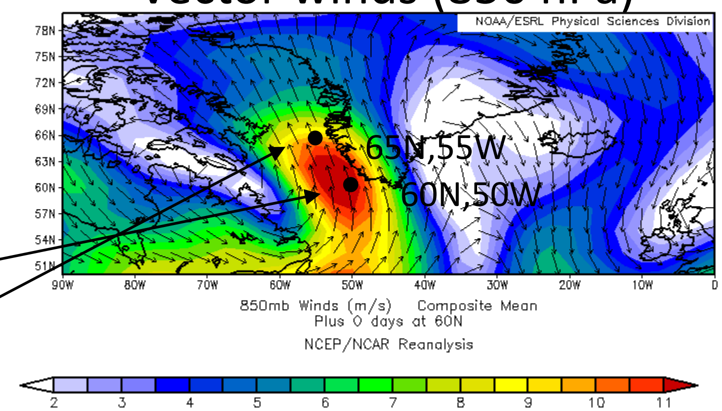
Criteria set at two locations:

- 60N,50W: IWV>25 kg/m^2, WS>10m/s, and
- 65N,55W: IWV> 20 kg/m^2, WS>10m/s

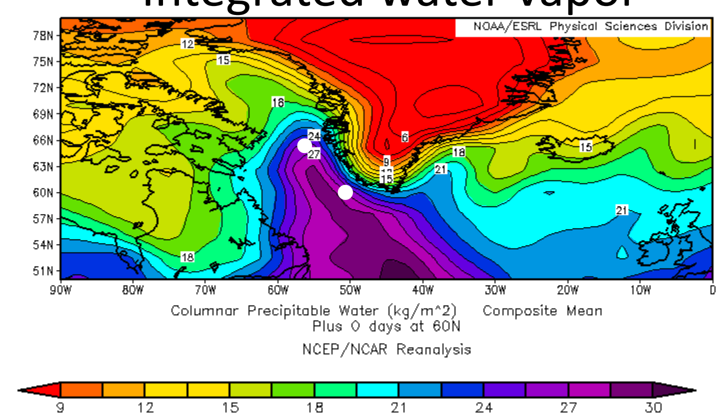
Geopotential Height (850 hPa)



Vector winds (850 hPa)

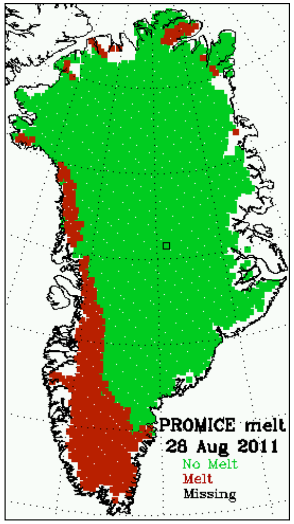


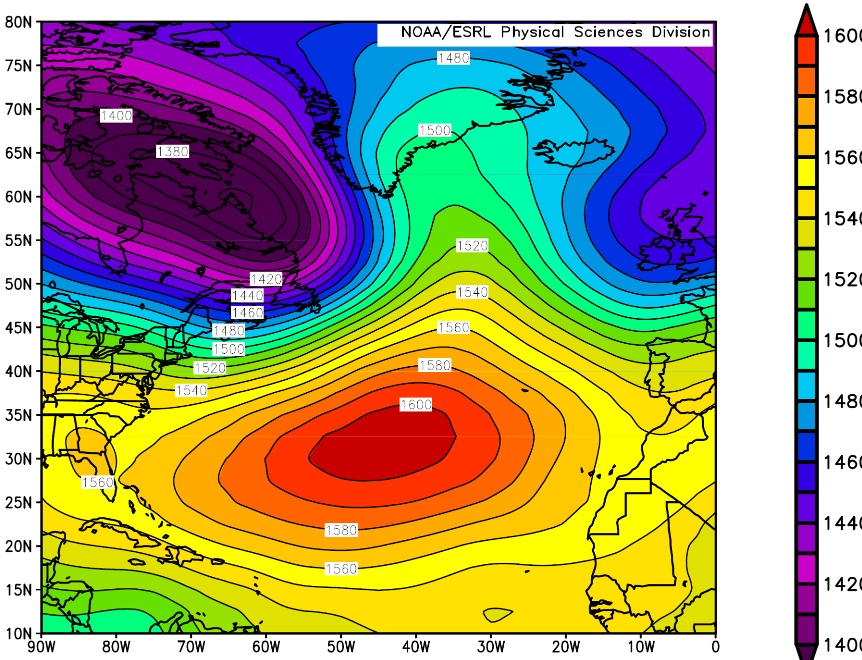
Integrated water vapor



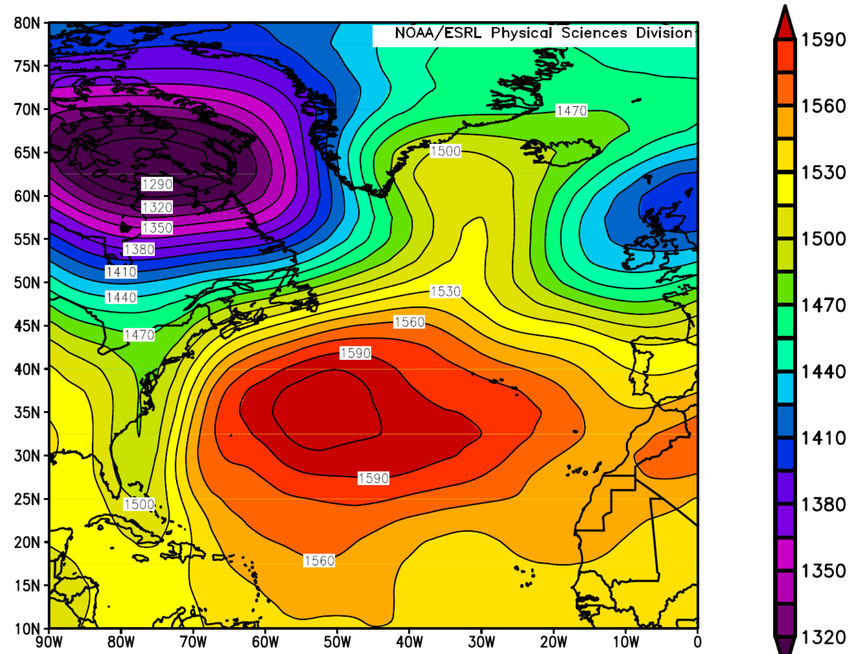
The larger scale synoptic pattern composited from our 69 cases from 2000 to 2012 of strong AR events

We then looked at the larger scale geopotential height field composited for August 24-28, 2011





850mb Geopotential Heights (m) Composite Mean
ARs at 65N,55W, IWV>20 kg/m**2, V>10 m/s (69 cases 2000–2012)
NCEP/NCAR Reanalysis

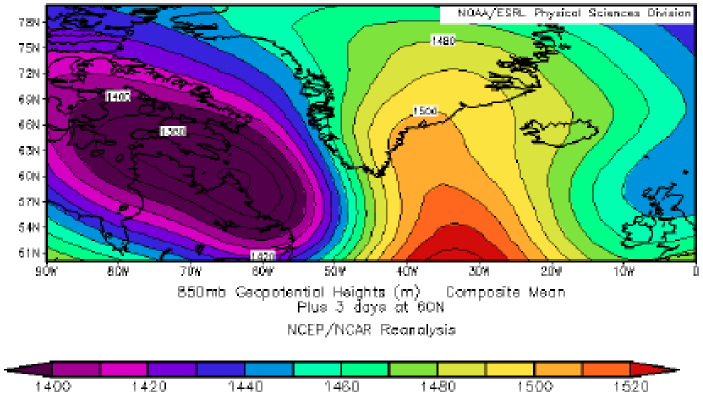


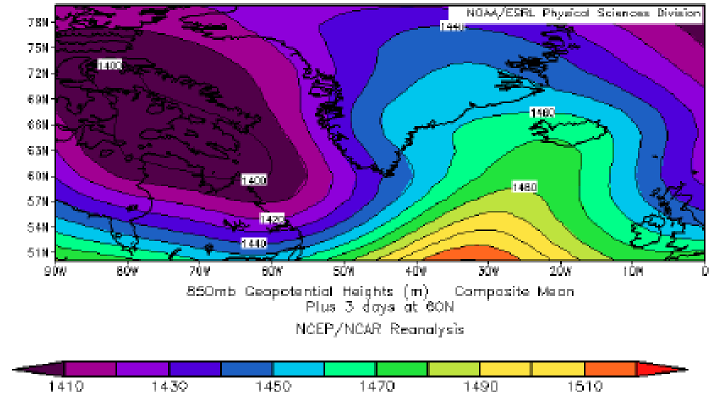
850mb Geopotential Height (m) Composite Mean
8/24/11 to 8/28/11
NCEP/NCAR Reanalysis

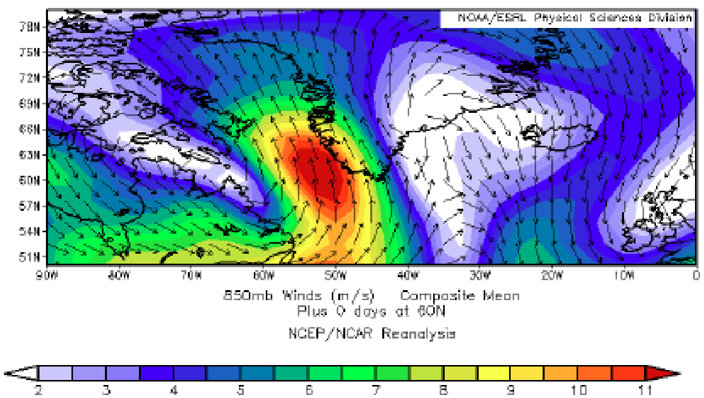
Evolution of the synoptic pattern – shifting to the east

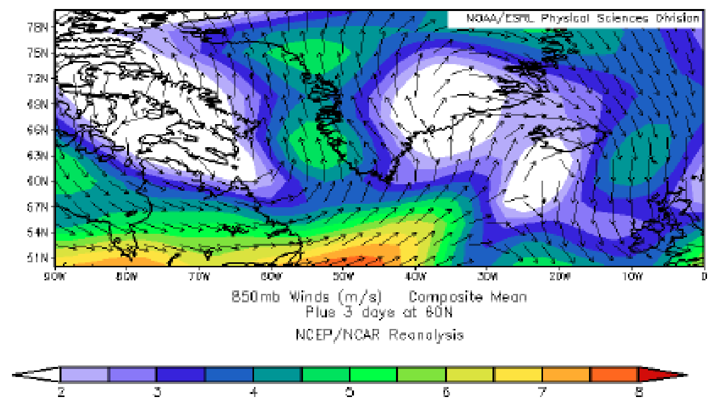
IWV>25 kg/m^2 at 60N50W, WS>10m/s, and IWV>20 at 65N55W, JJA 2000-2012 (69 cases)

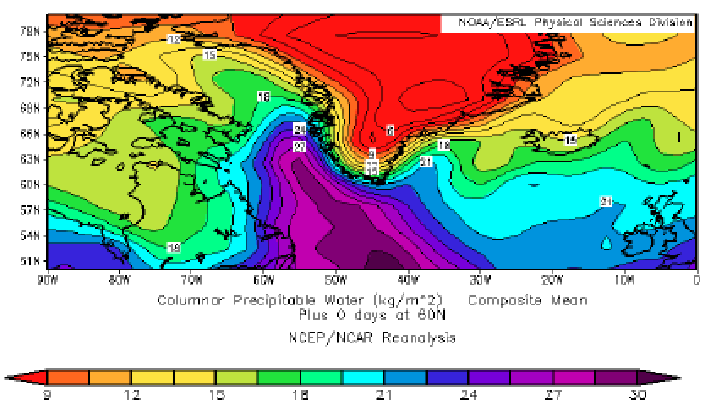
0 days | +3 days

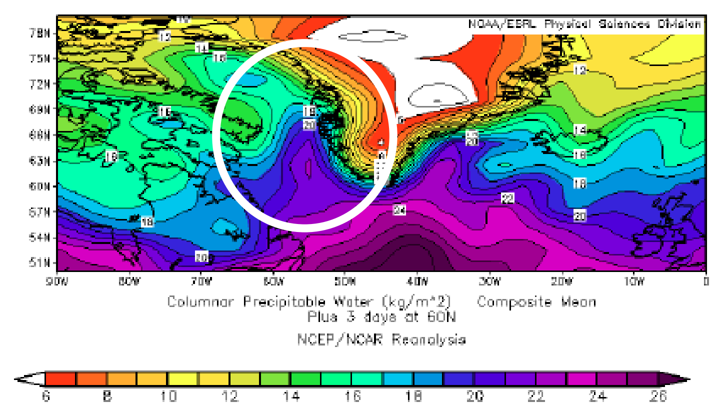












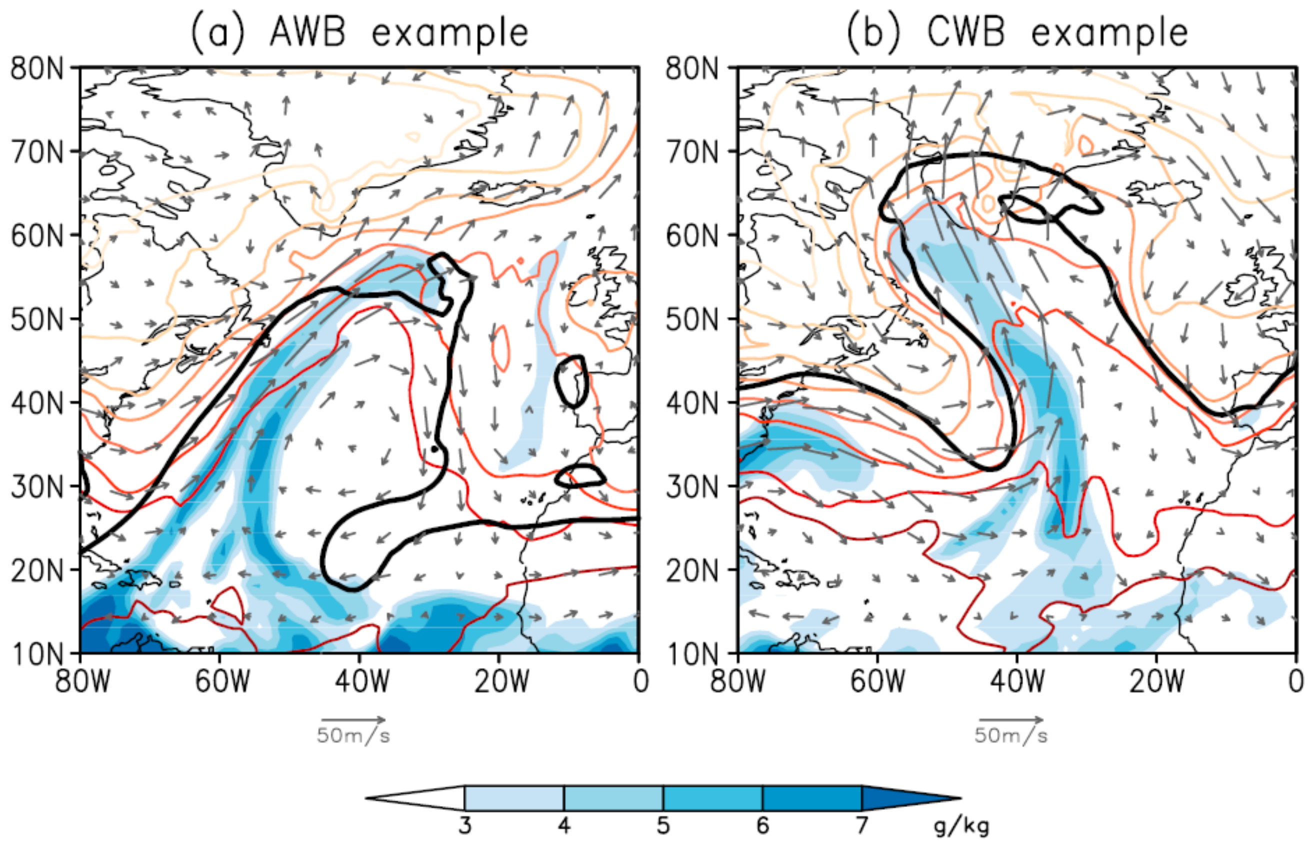
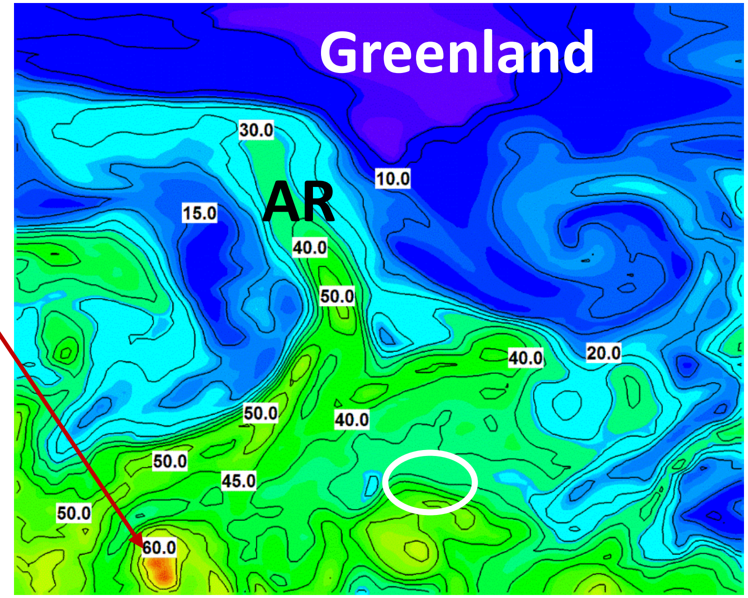
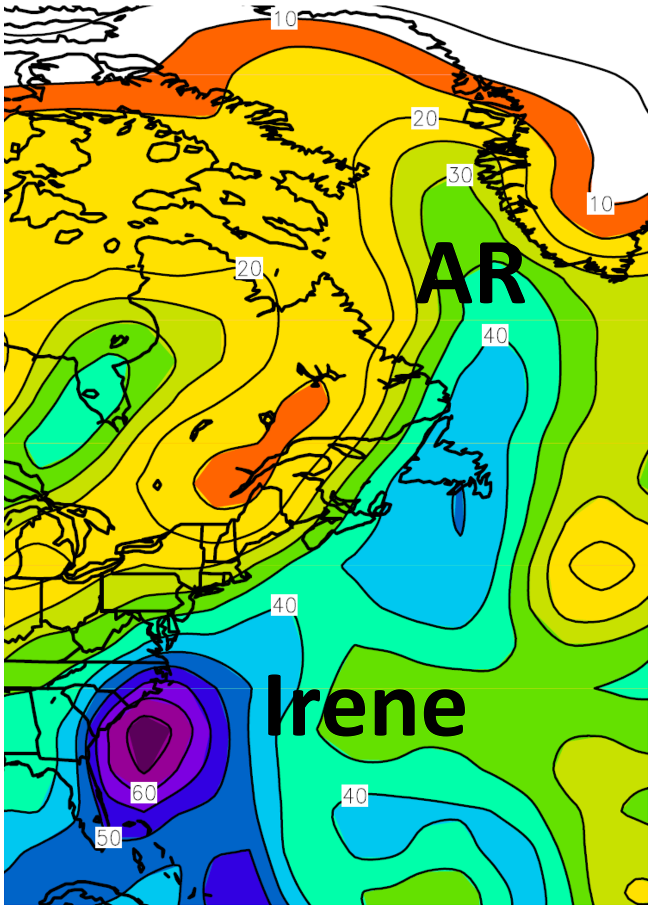


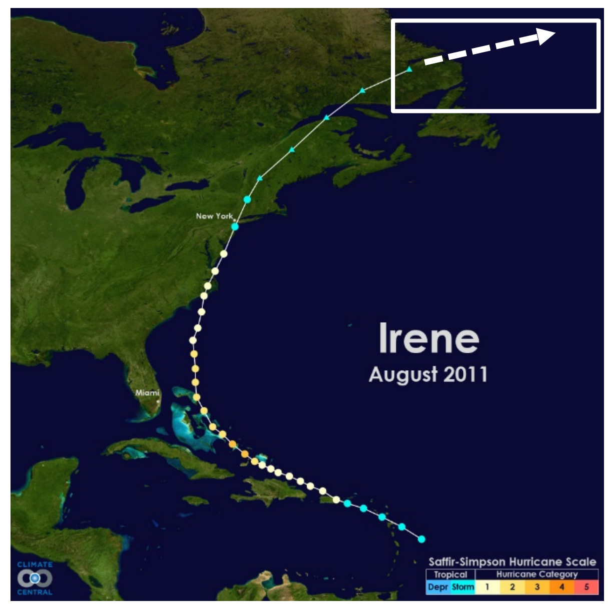
Figure 5. Mixing ratio of water vapor (shading), potential temperature (colored contours), and horizontal wind (arrows) on 700 hPa for (a) an anticyclonic wave breaking on 8 January 2006 and (b) a cyclonic wave breaking on 22 January 2007. The potential temperature contour interval is 5 K. The thick solid black line is the potential temperature contour on the 2 PVU surface that is used to identify Rossby wave breaking events.

24 August 2011 coastal rain event

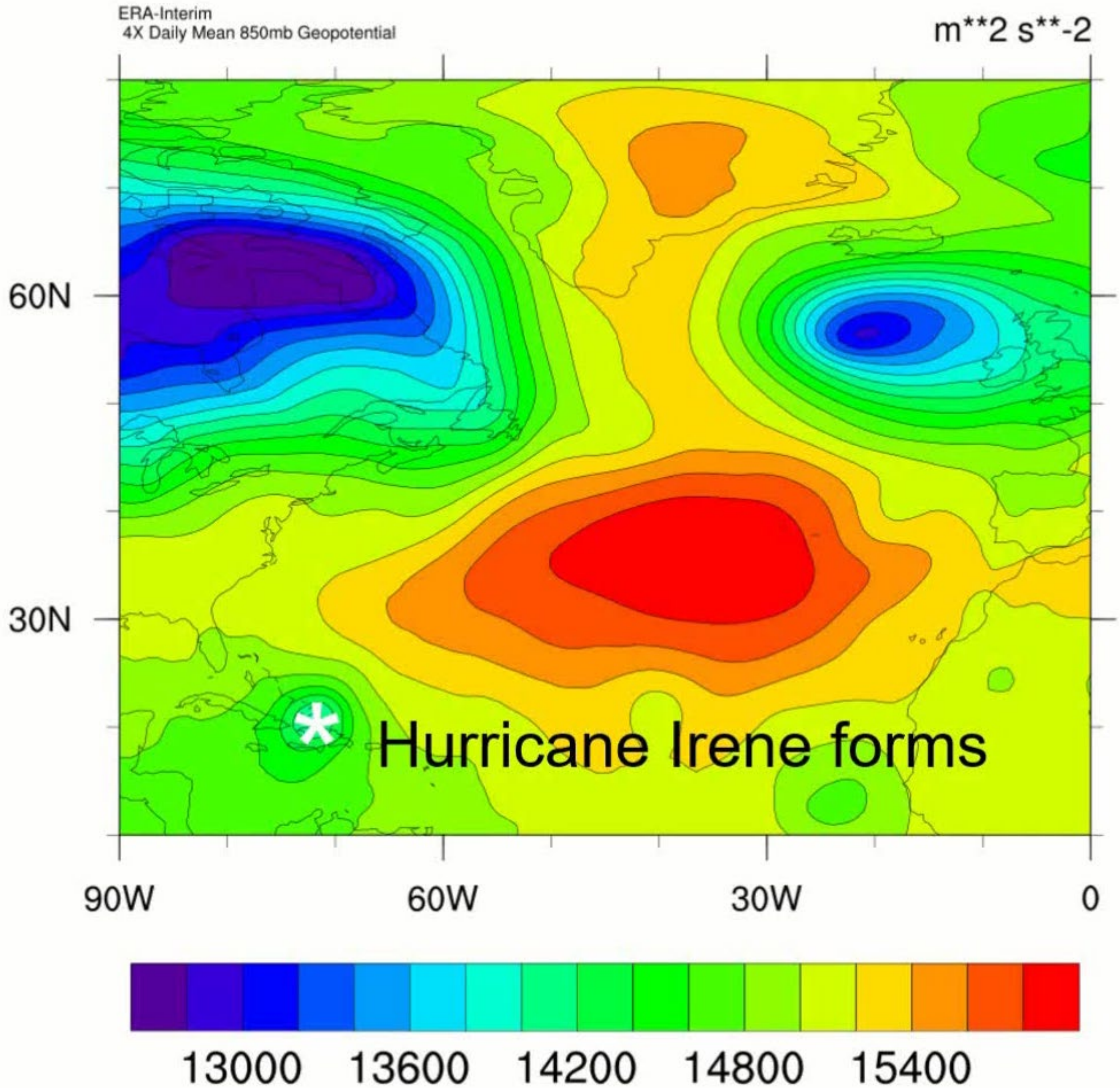
A little surprise



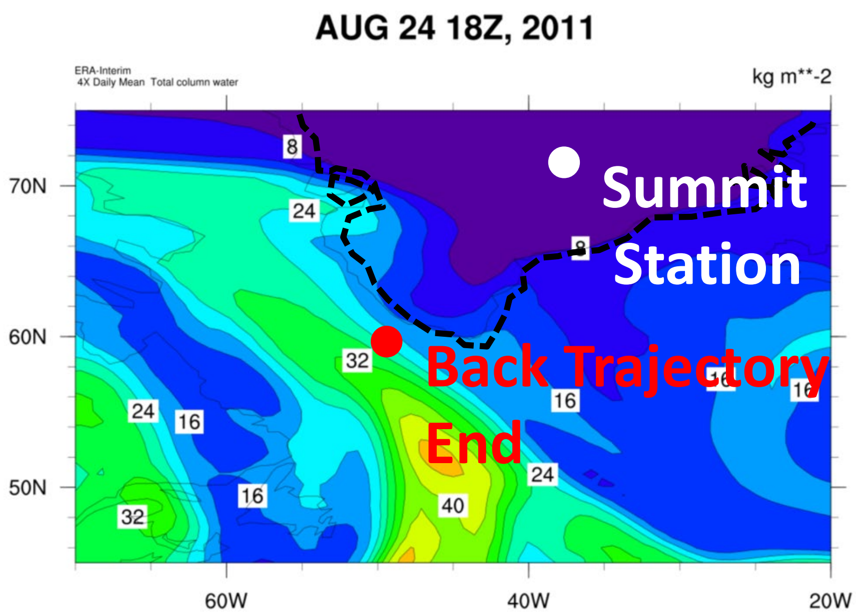


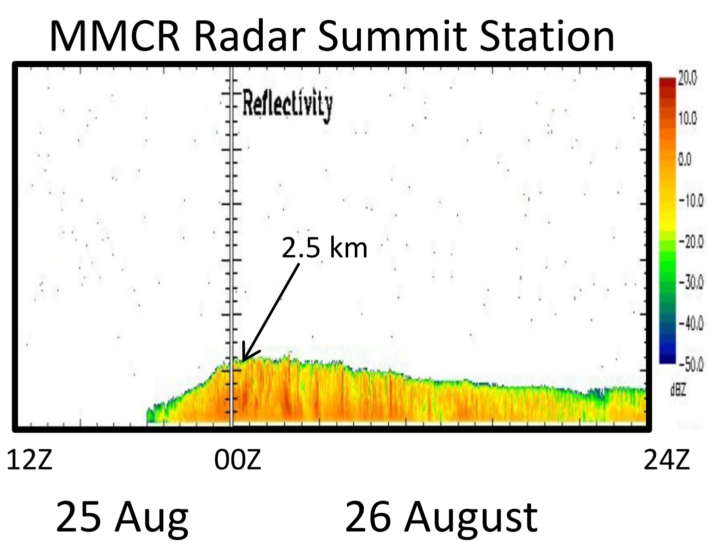


AUG 24 00Z, 2011

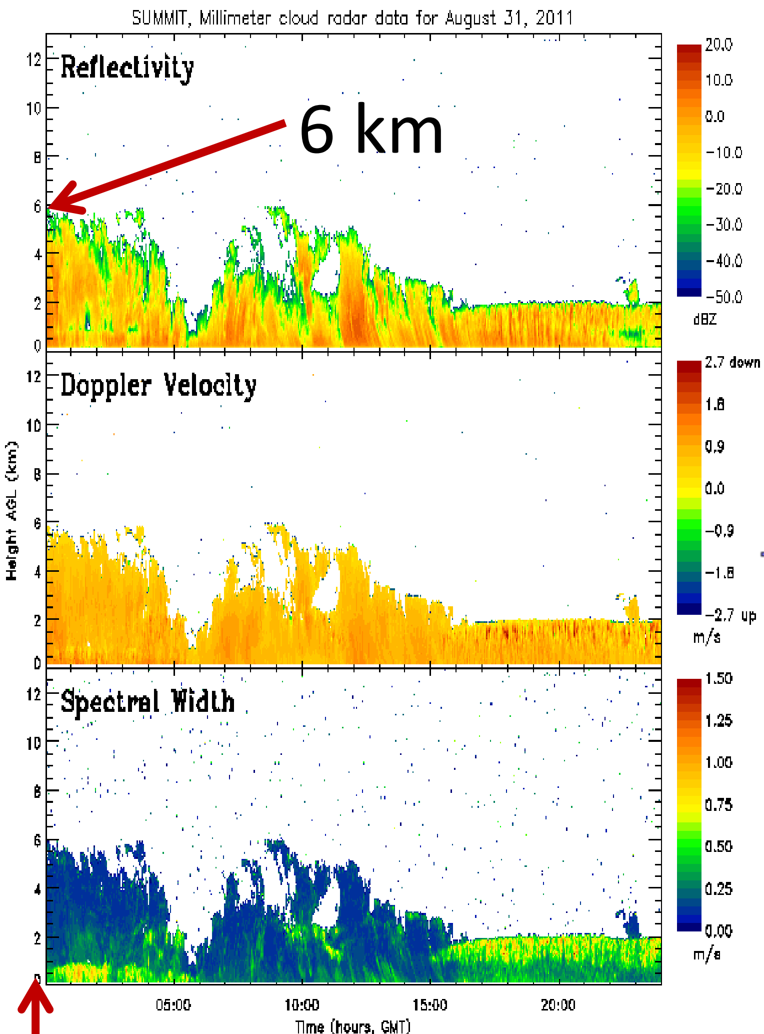


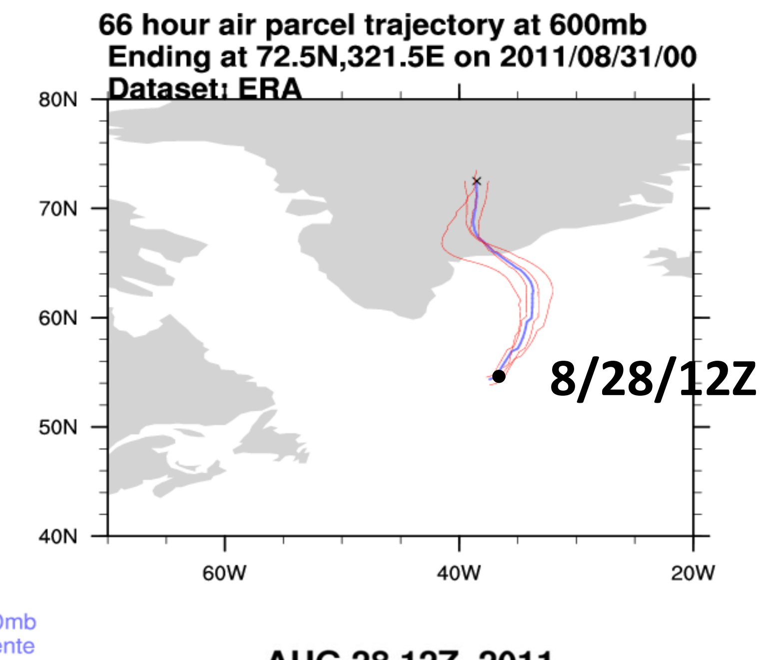
Moisture transport from the AR over the ice sheet to Summit Station

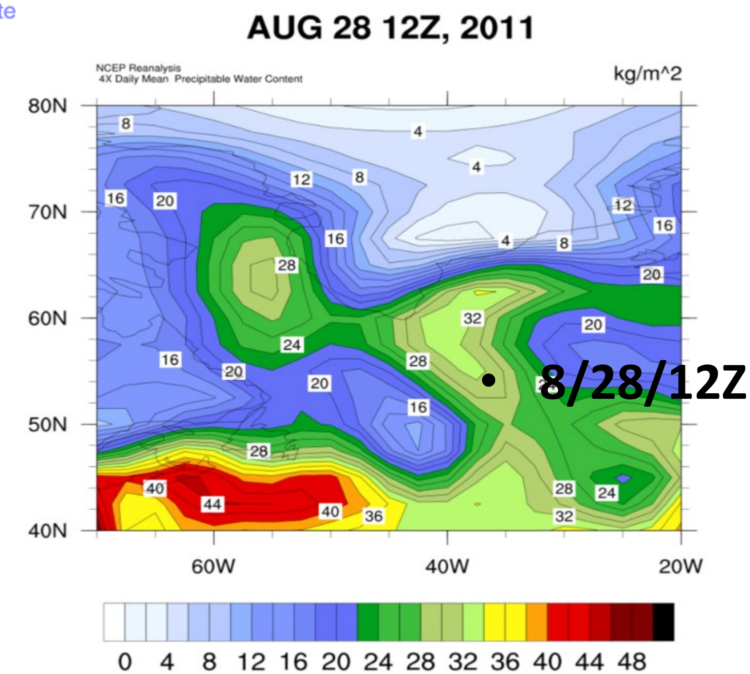




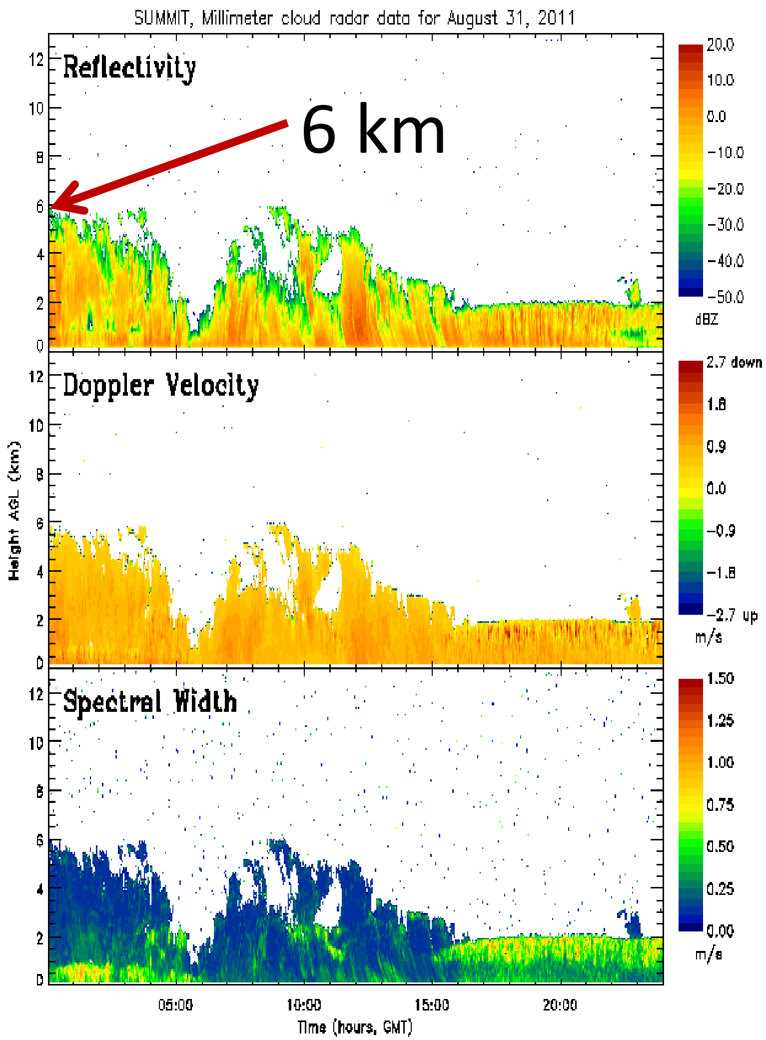
After the River….







End time for trajectory from south of Greenland

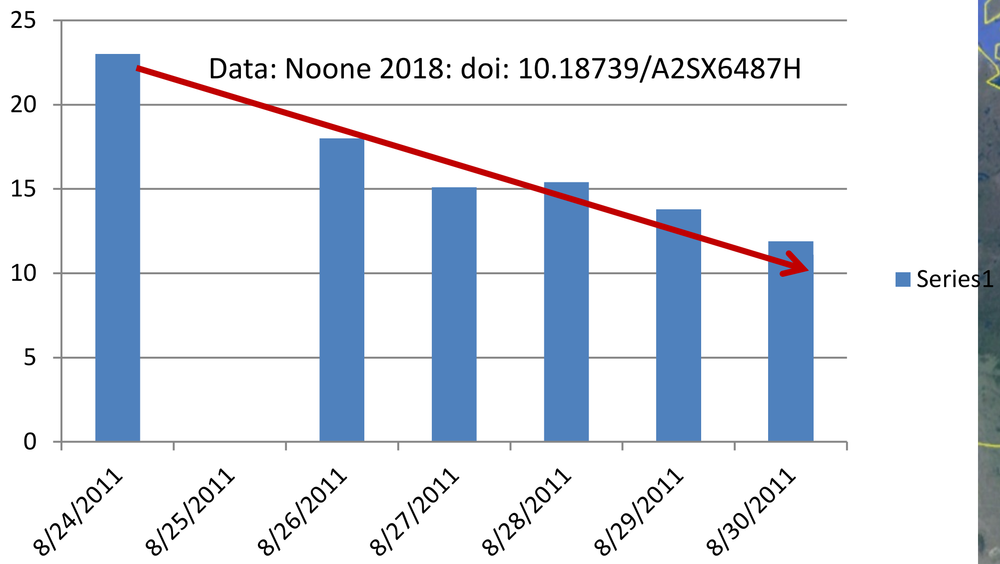


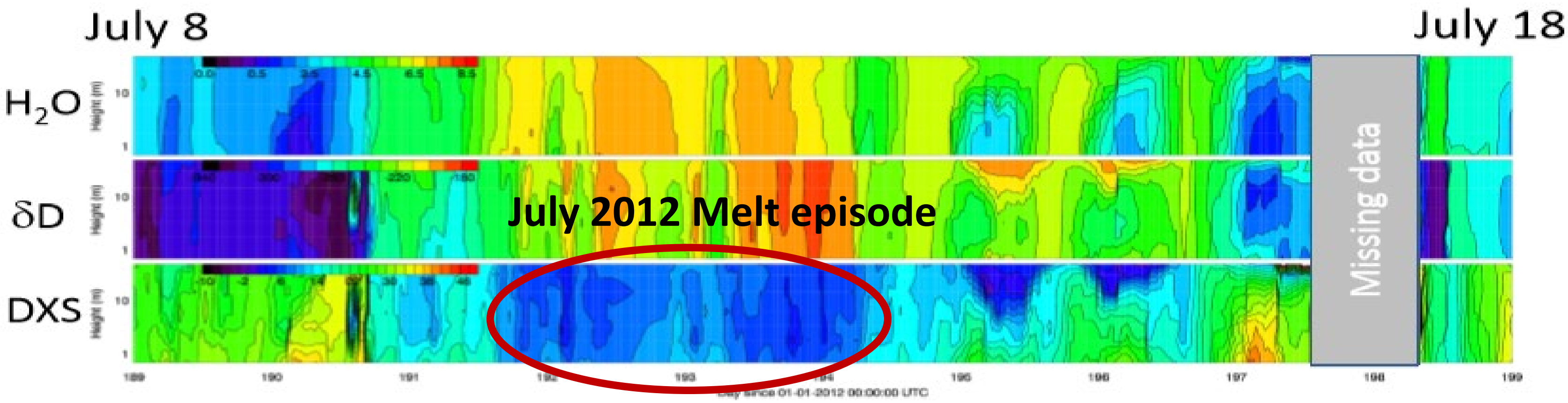
MMCR image (left) shows complex cloud structure involving both deeper ice clouds and lower stratiform mixed-phase clouds (as evident in the spectral width). Periodically, those stratiform clouds are interrupted by deeper ice clouds. The interruptions in the liquid cloud may be cased by seeder-feeder processes as a result of the falling ice from above (suggesting enhanced flow of moisture aloft that impacts the lower levels).

Back trajectories from Summit Station showed moisture origins on 28 August 12Z south of Greenland

IWV distribution showedthe results of fragmentation of IWV, presumably from local mesoscale circulations redistributing the water vapor in the initial AR.

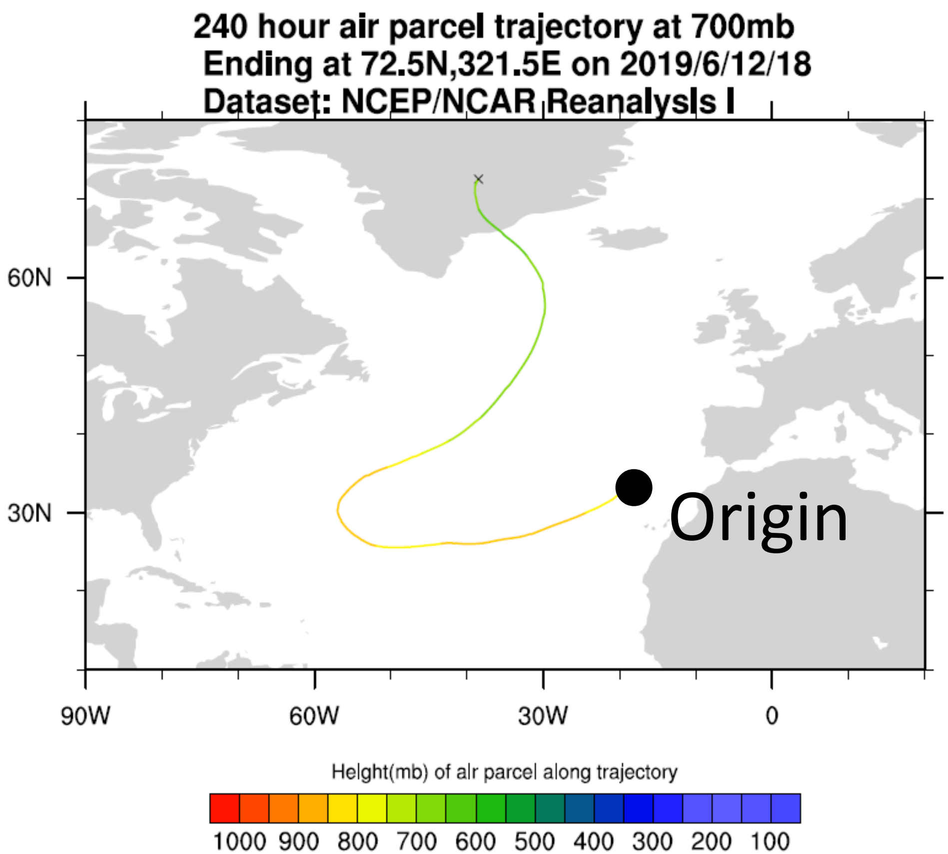
Daily snow samples at Summit show a decrease in Deuterium Excess from 23 permil to 12 permil from 24 to 30 August indicative of a southern source consistent with the 2012 melt episode (Bonne et al. 2015).

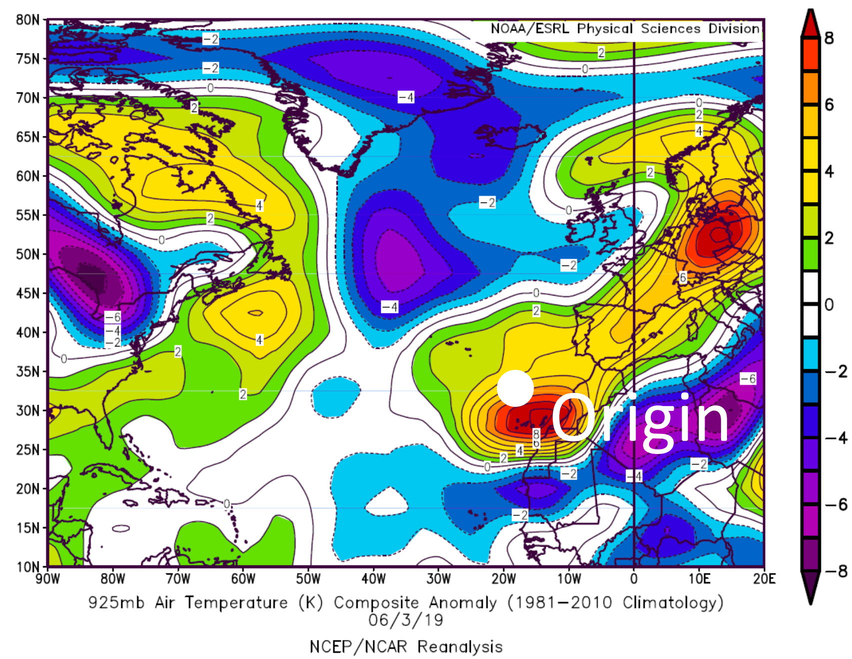




Noone et al. Unpublished IPICS poster showing decrease in D-excess and increase in water vapor with warmer air.

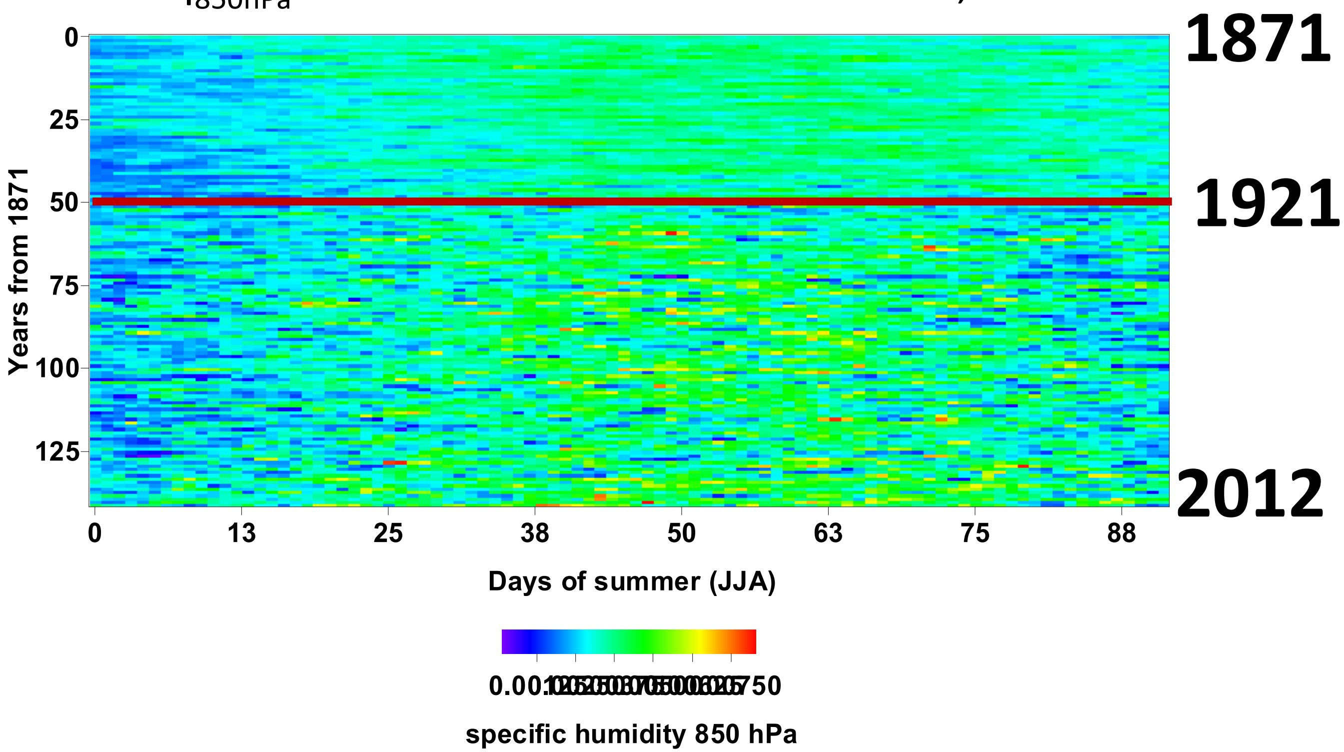
Question for future research: Water vapor isotopes were measured at the East GRIP ice coring site (75º 38’ N, 36º 0’ W) in 2019 – what will they say about air mass origins? (See HC Steen-Larsen!)





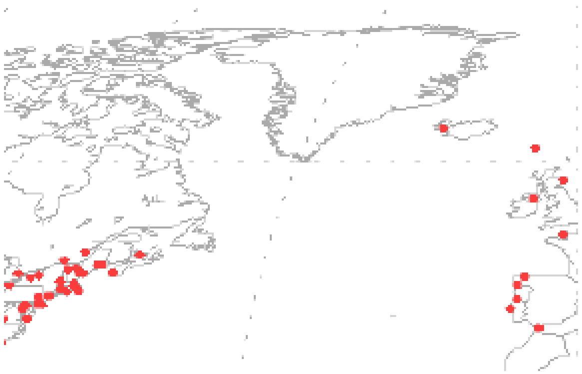
What can we learn from past events? What are the challenges in using the Twentieth Century Reanalysis?

q_{850hPa} for JJA from 1871 to 2012 at 60°N, 305°W

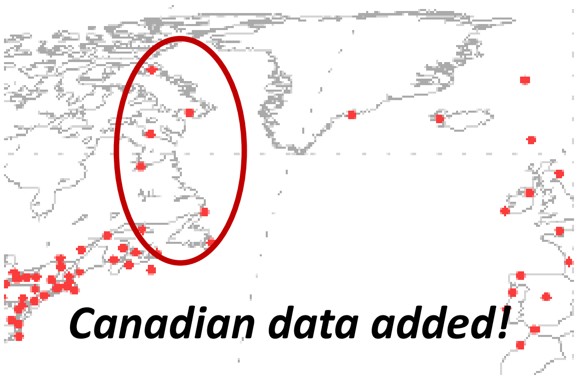


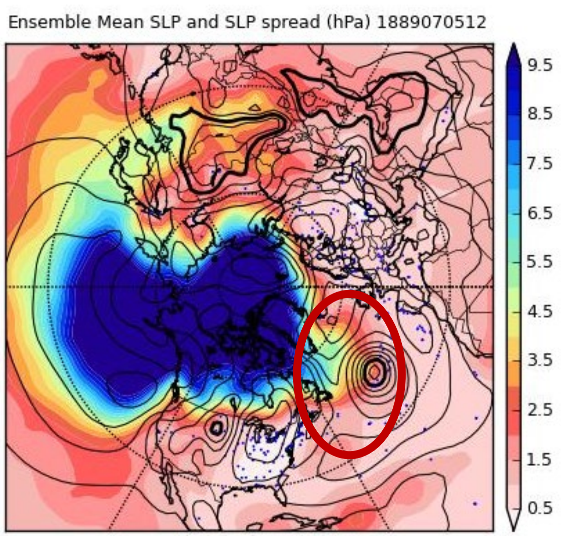
So – what changed in the 1920s???

1889

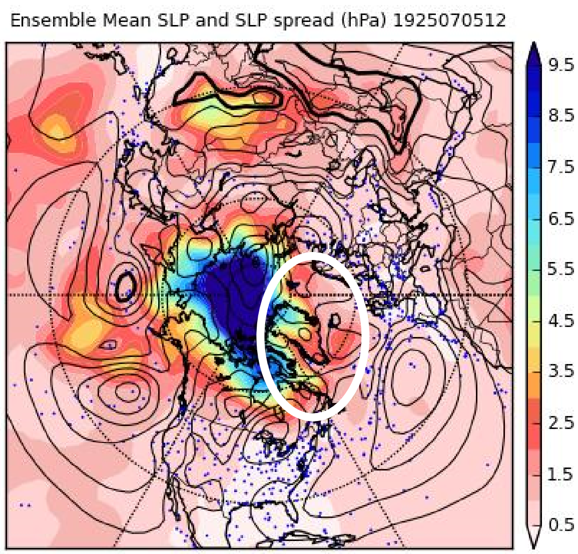


1925





5 July 1889

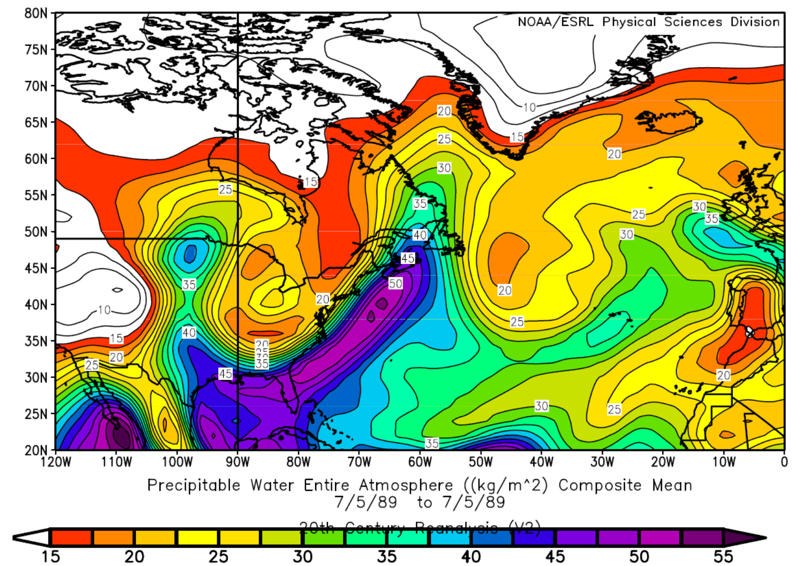


5 July 1925

1889

SLP, Sea surface temperature, ozone, CO2 etc … and ENKF…

5 July 1889



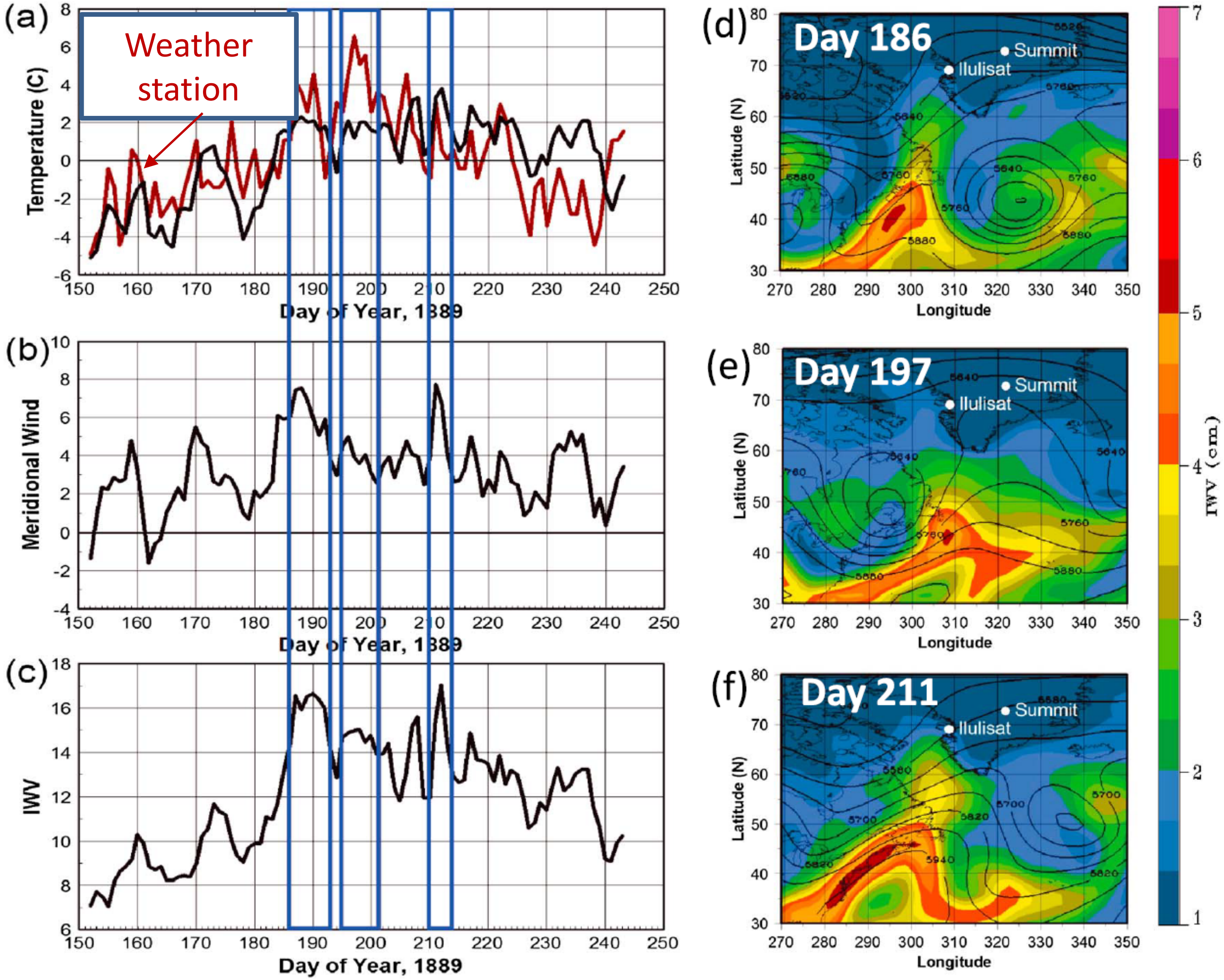
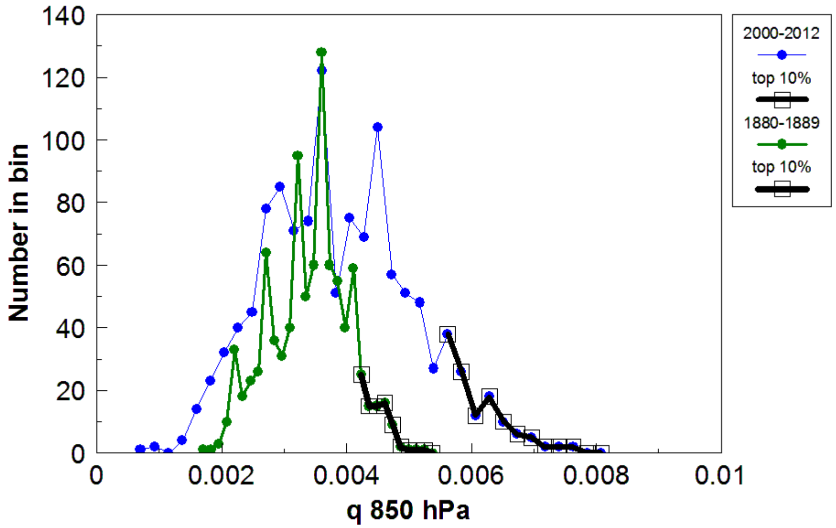
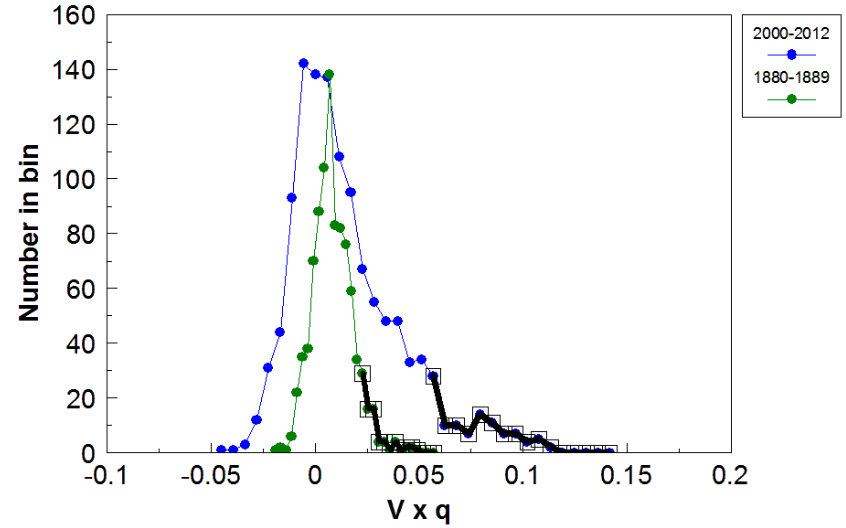


Figure 8. Left: (a) Time series of 2 m minimum temperature at Ilulisat for the summer of 1889 from the 20CR (black) and the local weather station (red), (b) 850 hPa meridional wind from the 20CR at the location of Ilulissat, and (c) integrated water vapor (IWV) above Ilulissat. Three event periods are indicated by the blue boxes where there was either a maximum in temperature and/or strong northward movement of IWV. Right: Snapshots of IWV from the 20CR on Days (d) 186, (e) 197, and (f) 211 during the event periods identified on the left. Dark red areas of IWV represent total column water vapor of over 5 cm seem in the scale on the far right. Contour interval (500 hPa) is 60 m.

1) Distribution of q and qv for 1880-1889 (green) and 2000-2012 (blue)
2) Identify top 10% in each distribution (black)
3) Set thresholds and identify potential events

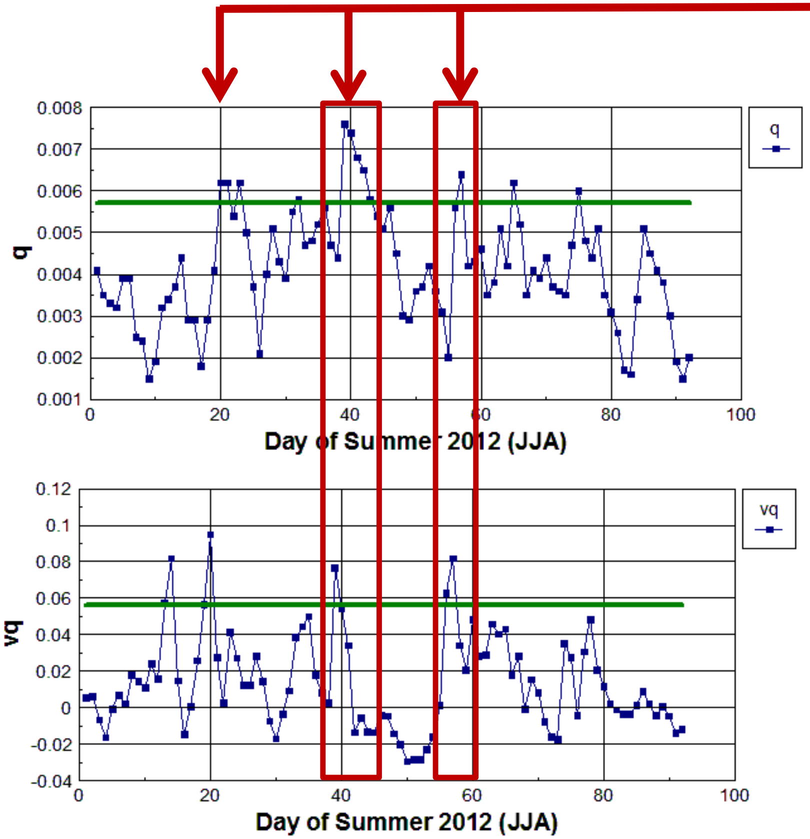




Thresholds:
1880-1889: vq>0.023, q>0.0042
2000-2012: vq>0.057, q>0.0056

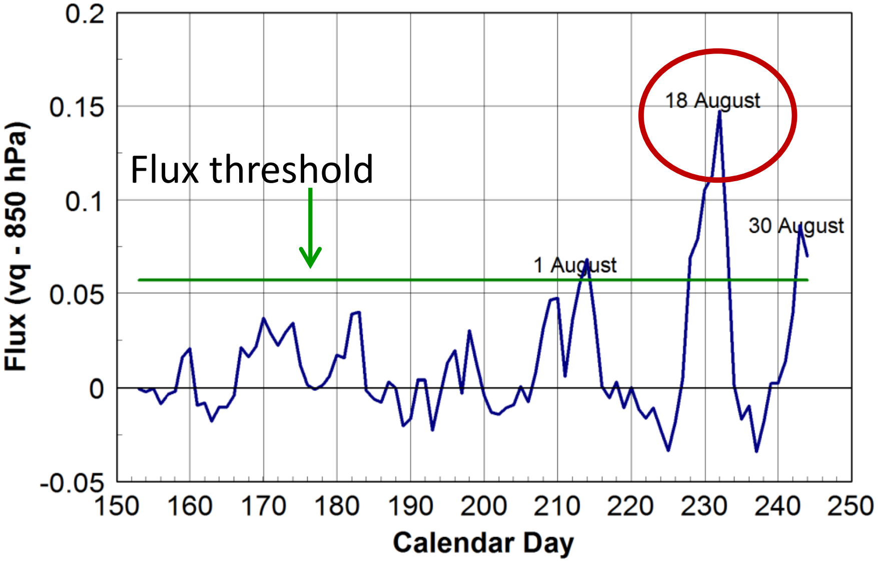
Application to melt year 2012:

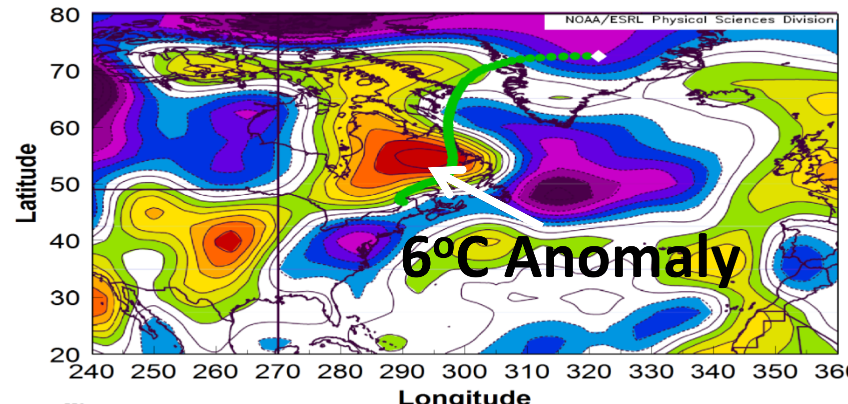
Three temperature maxima identified in Neff et al. 2014

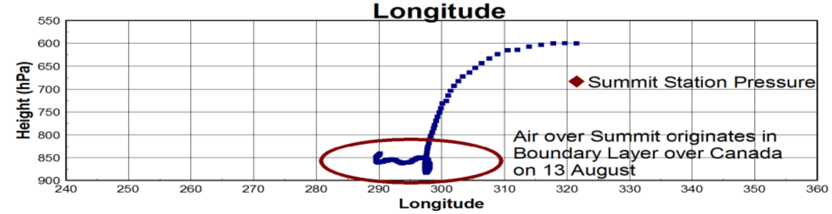


2012: Short-term transport on 9 July preceding the melt episode on 11 July but sustained high water vapor. Partial melt on 29 July associated with short-term transport of non-persistent water vapor.

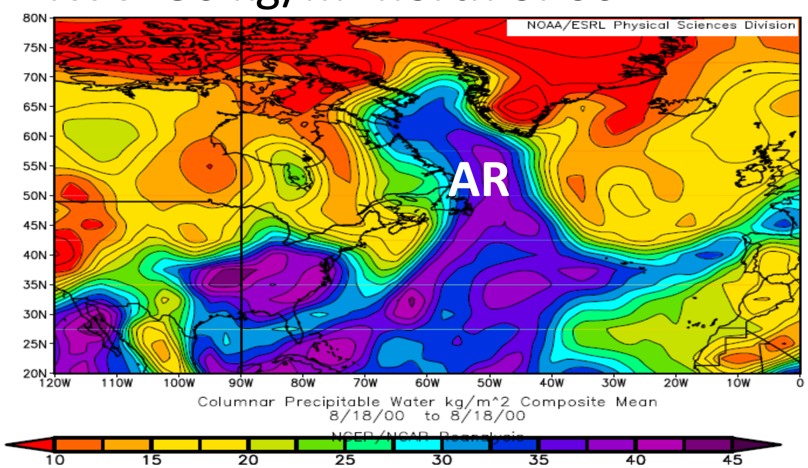
Example using thresholds – JJA 2000: 18 August



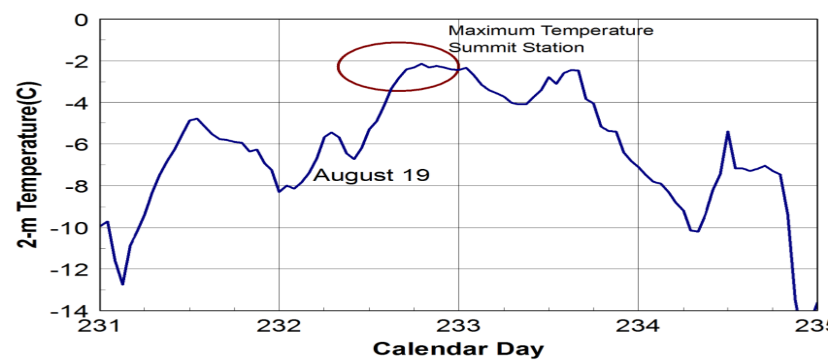




IWV>30 kg/m^2 north of 60^o

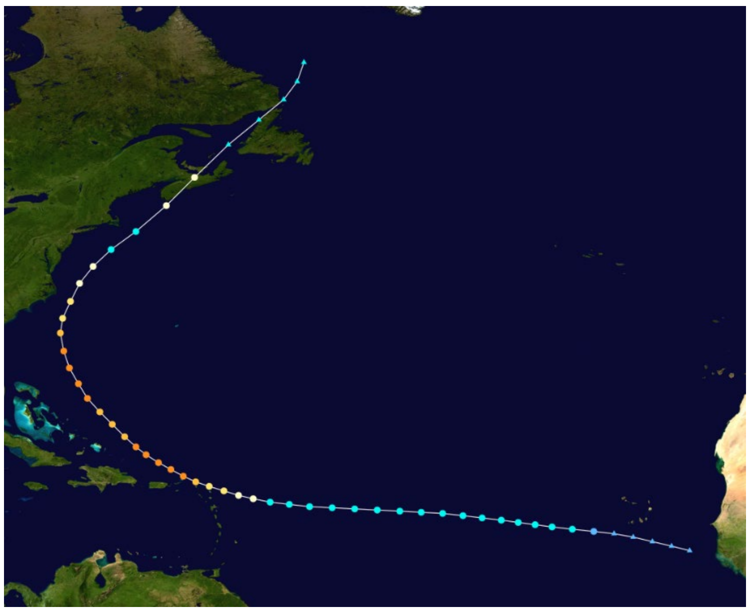


--Temperature maximum one day later at Summit:

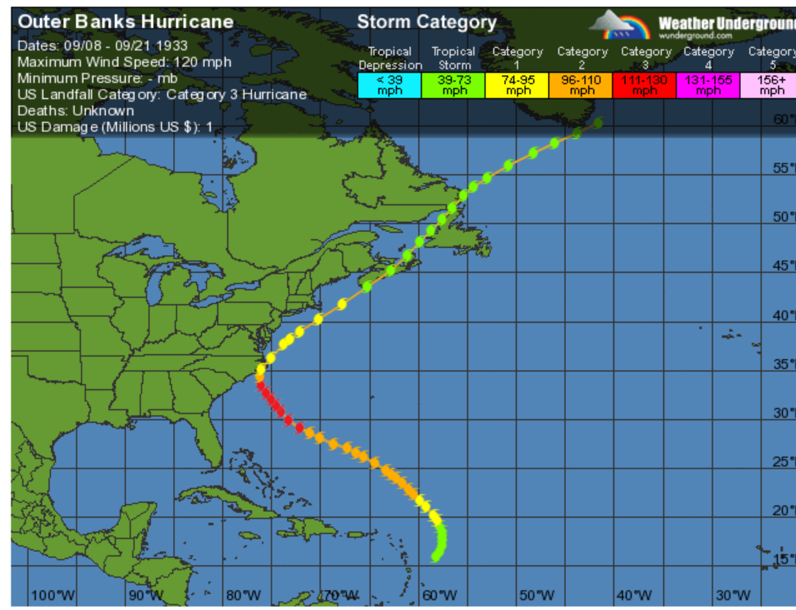


--Summit met data courtesy of Konrad Steffen

Can the 20CR be used for hurricanes?

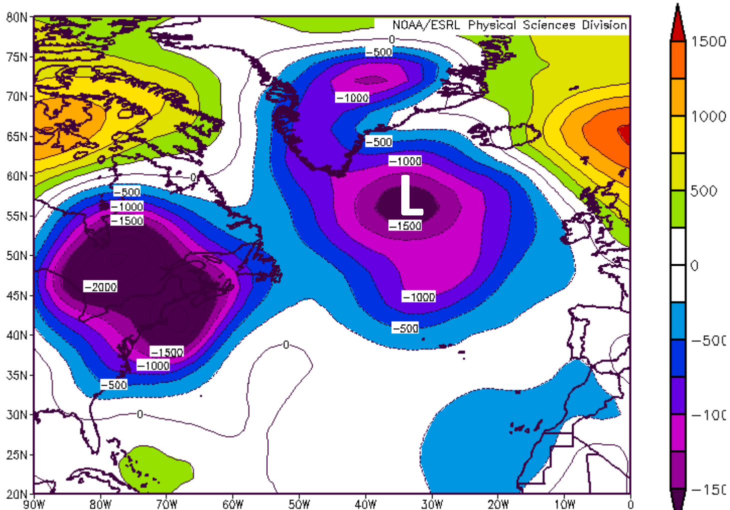


Hurricane Earl (August 25 – September 4, 2010)

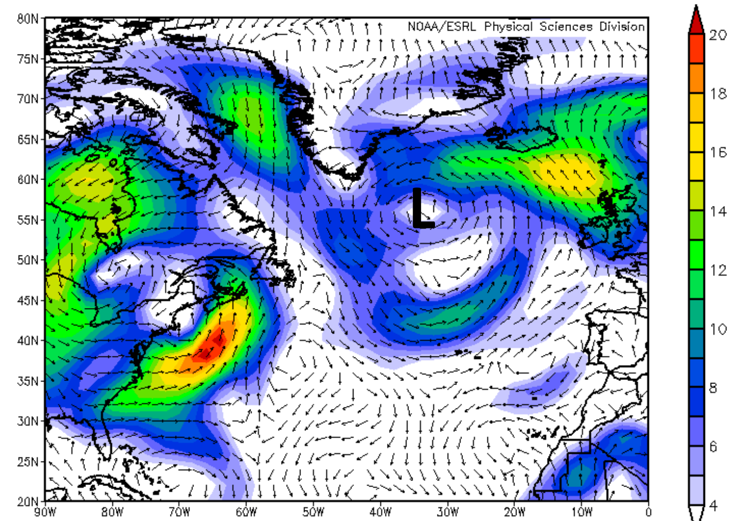


Outer Banks Hurricane (Hurricane 12) of 1933

Earl 2010

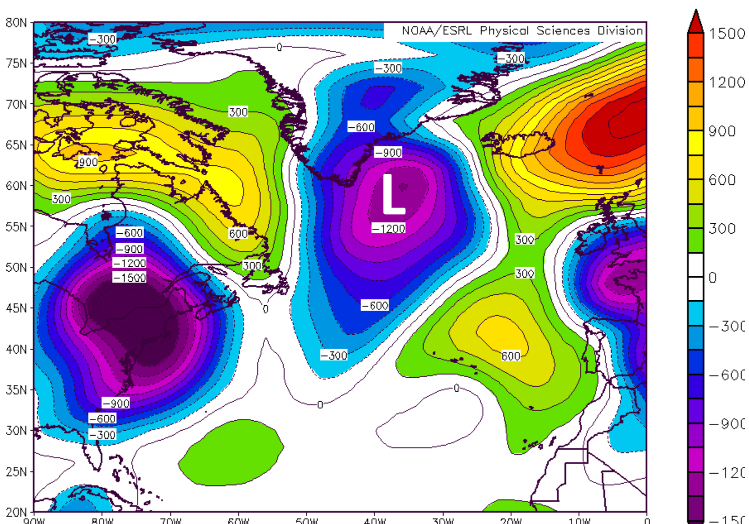


SLP (Pa) Composite Anomaly (Climatology)
9/4/2010
20th Century Reanalysis (V2c)

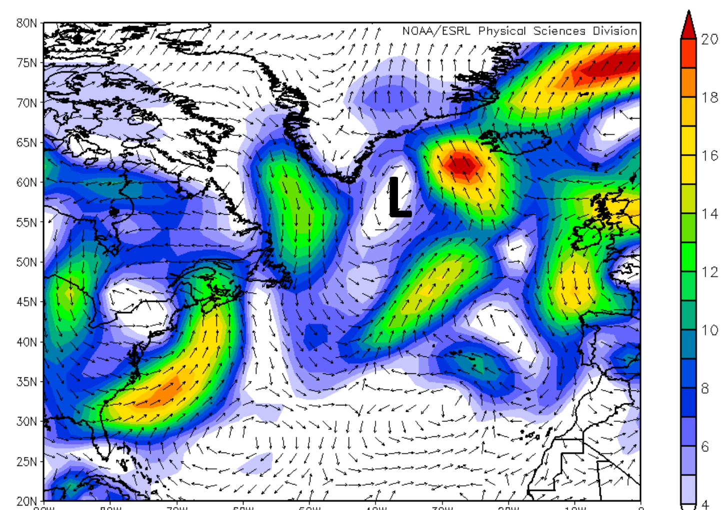


950mb Vector Wind (m/s) Composite Anomaly (Climatology)
9/4/2010
20th Century Reanalysis (V2c)

Outer Banks Hurricane 1933

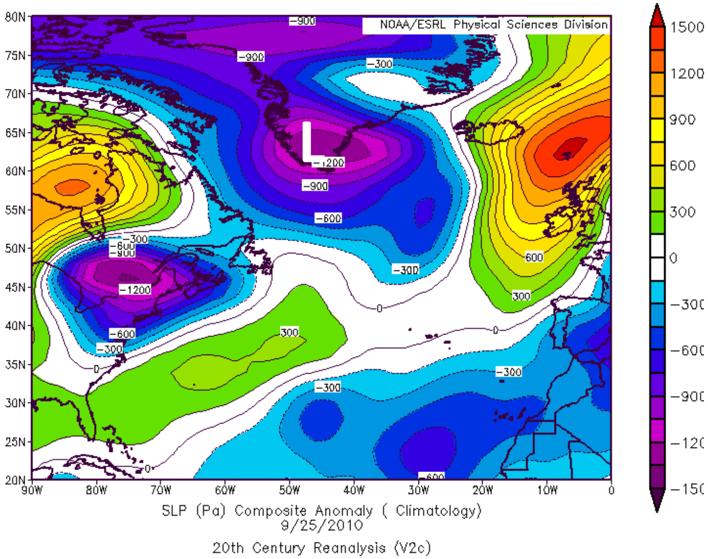


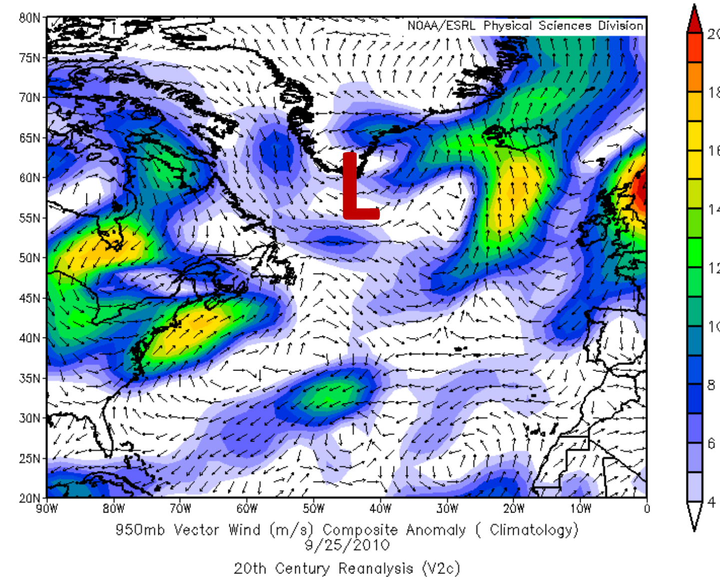
SLP (Pa) Composite Anomaly (Climatology)
9/21/1933
20th Century Reanalysis (V2c)



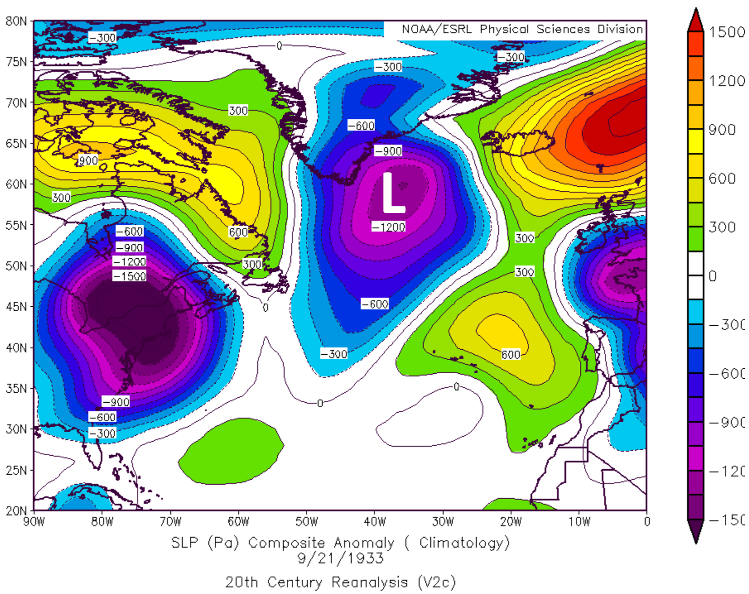
950mb Vector Wind (m/s) Composite Anomaly (Climatology)
9/21/1933
20th Century Reanalysis (V2c)

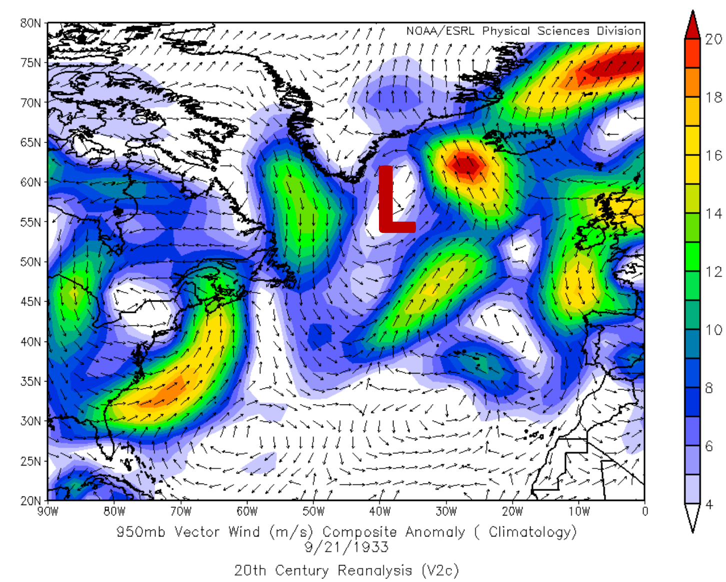
Igor 2010



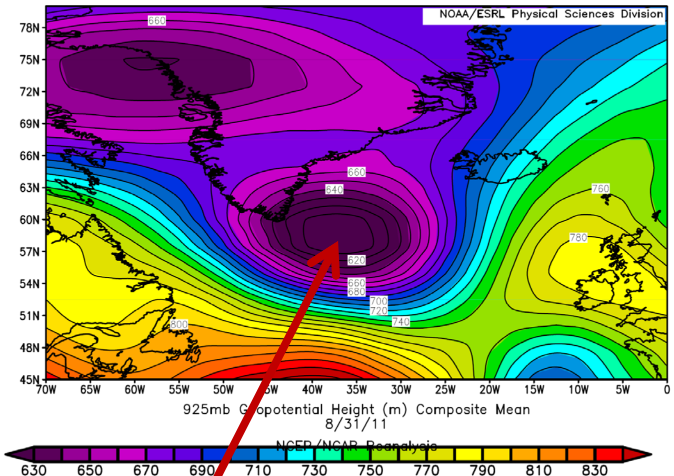


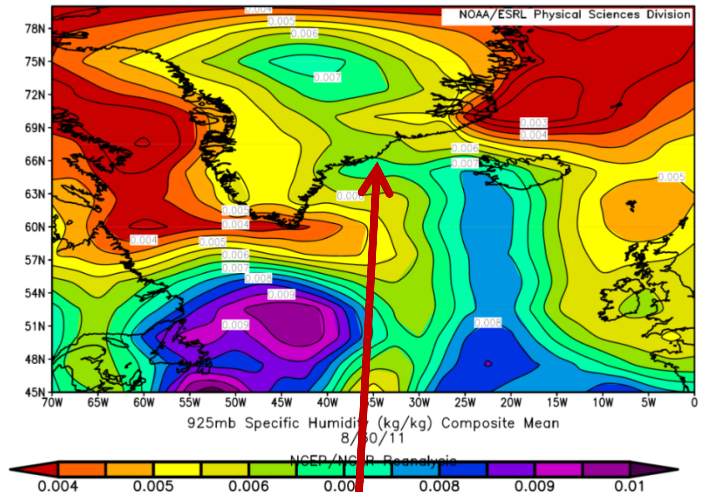
Outer Banks Hurricane 1933

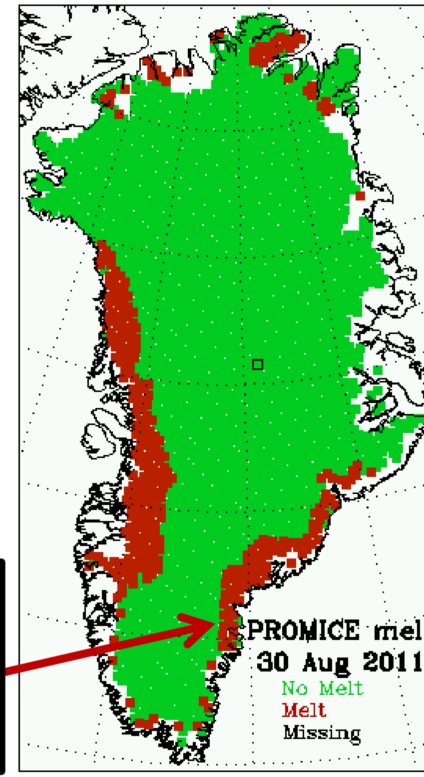




Role of Irene in promoting the melting of SE Greenland coast:







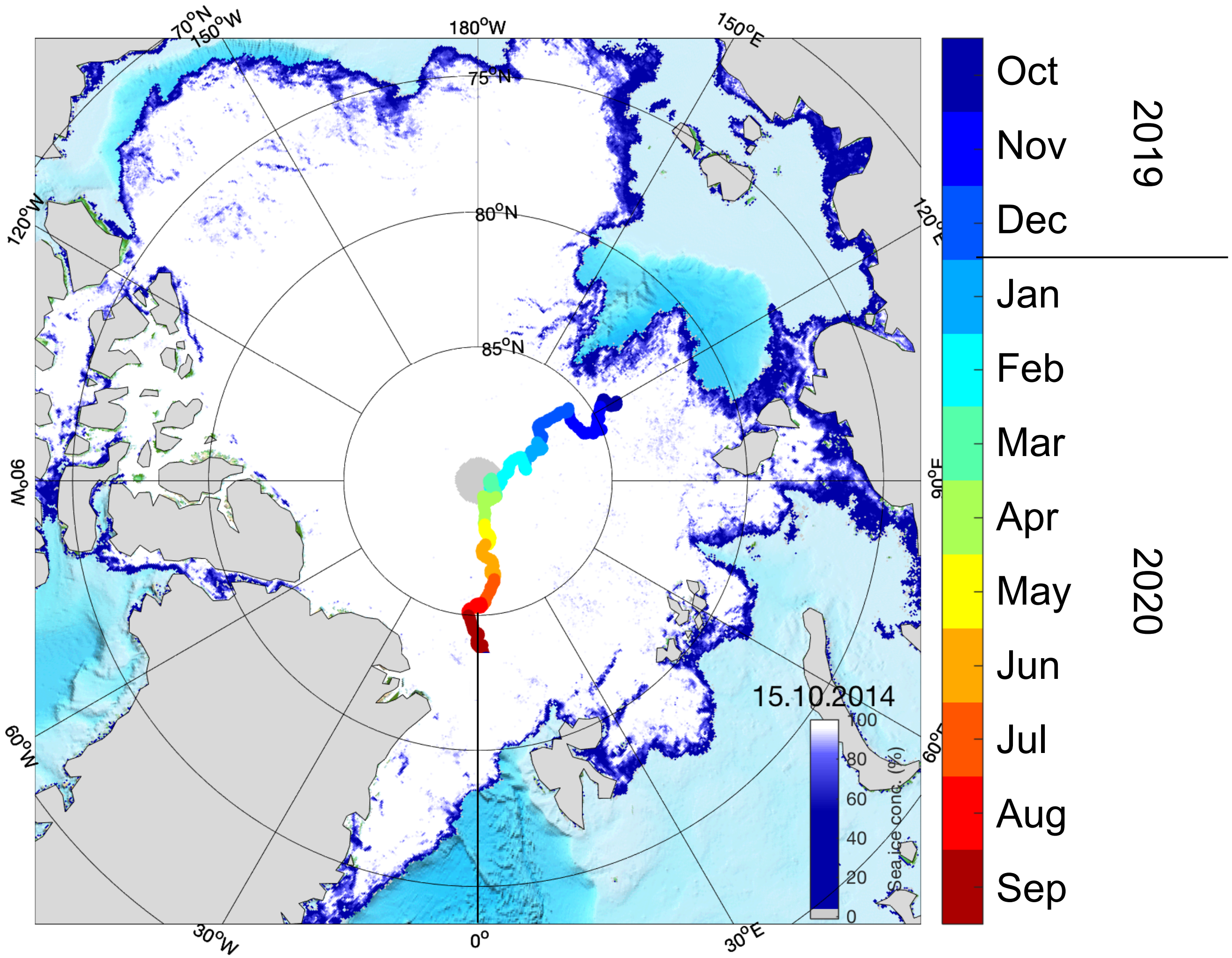
Remnant of Irene prior to merging with low pressure to the north (gph at 925 hPa)

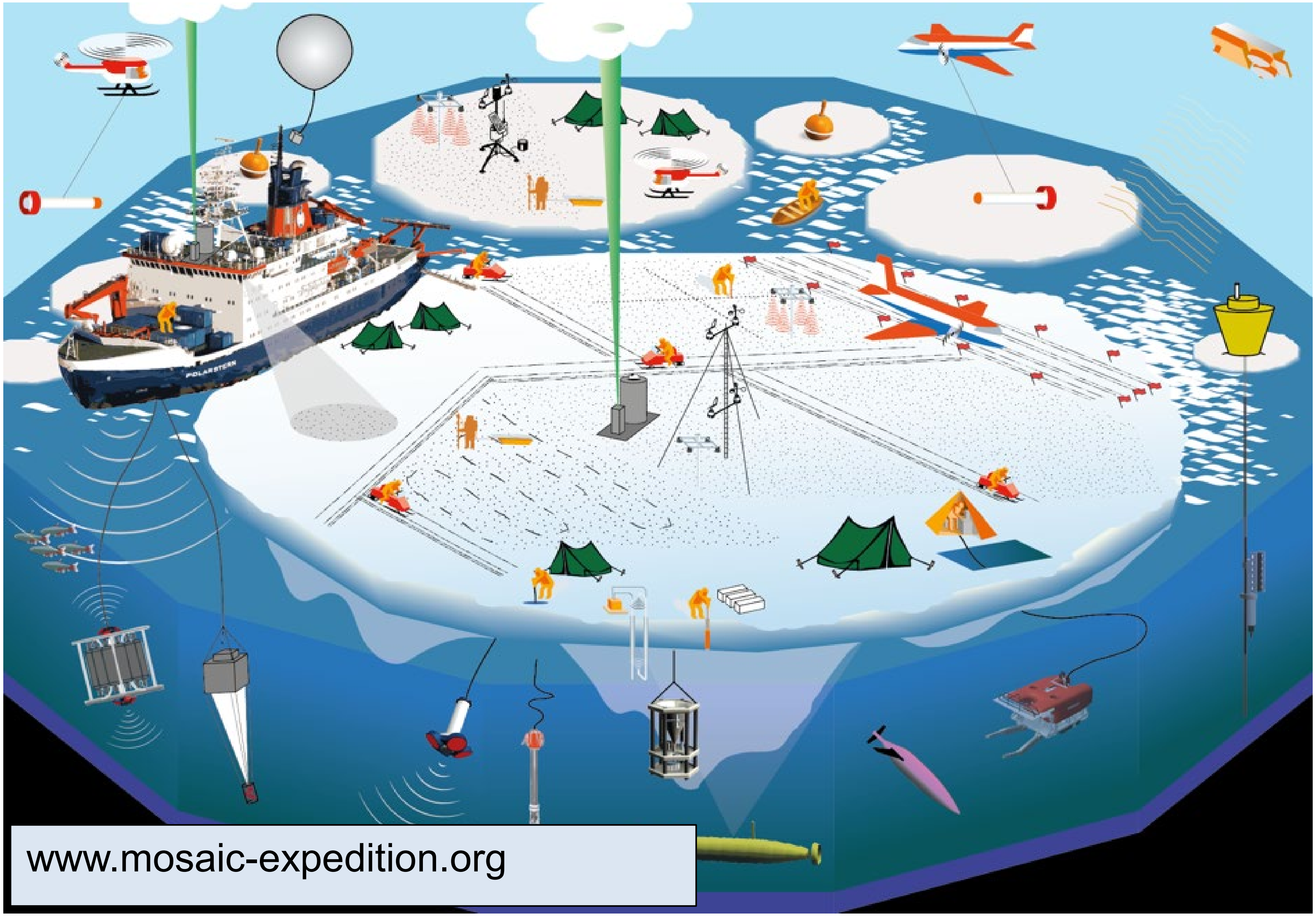
Moisture plume (q at 925 hPa) associated with the melting along the SE coast of Greenland

MOSiAC 2019-2020

Example Drift Trajectory

85N / 120E

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www.mosaic-expedition.org