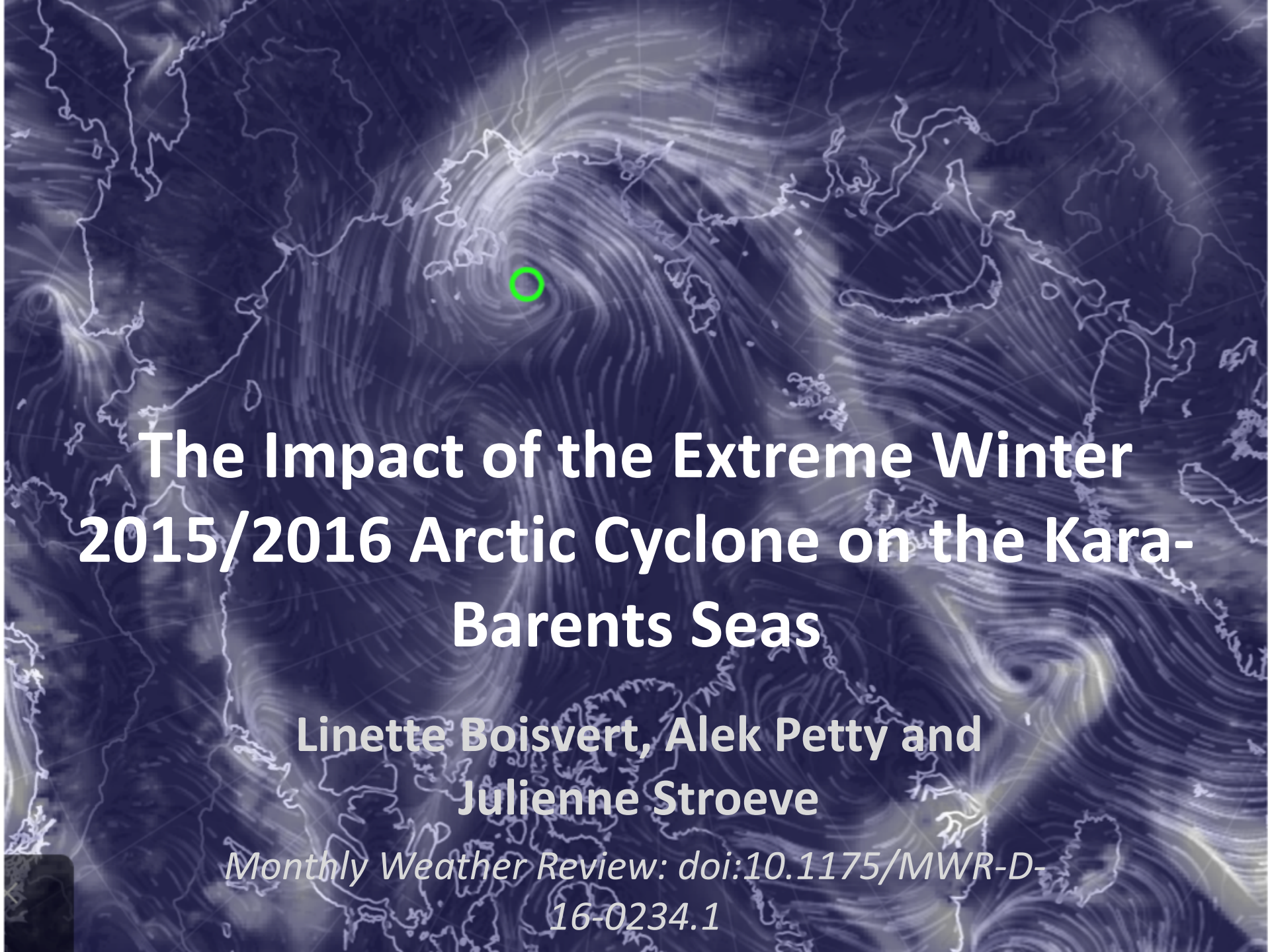


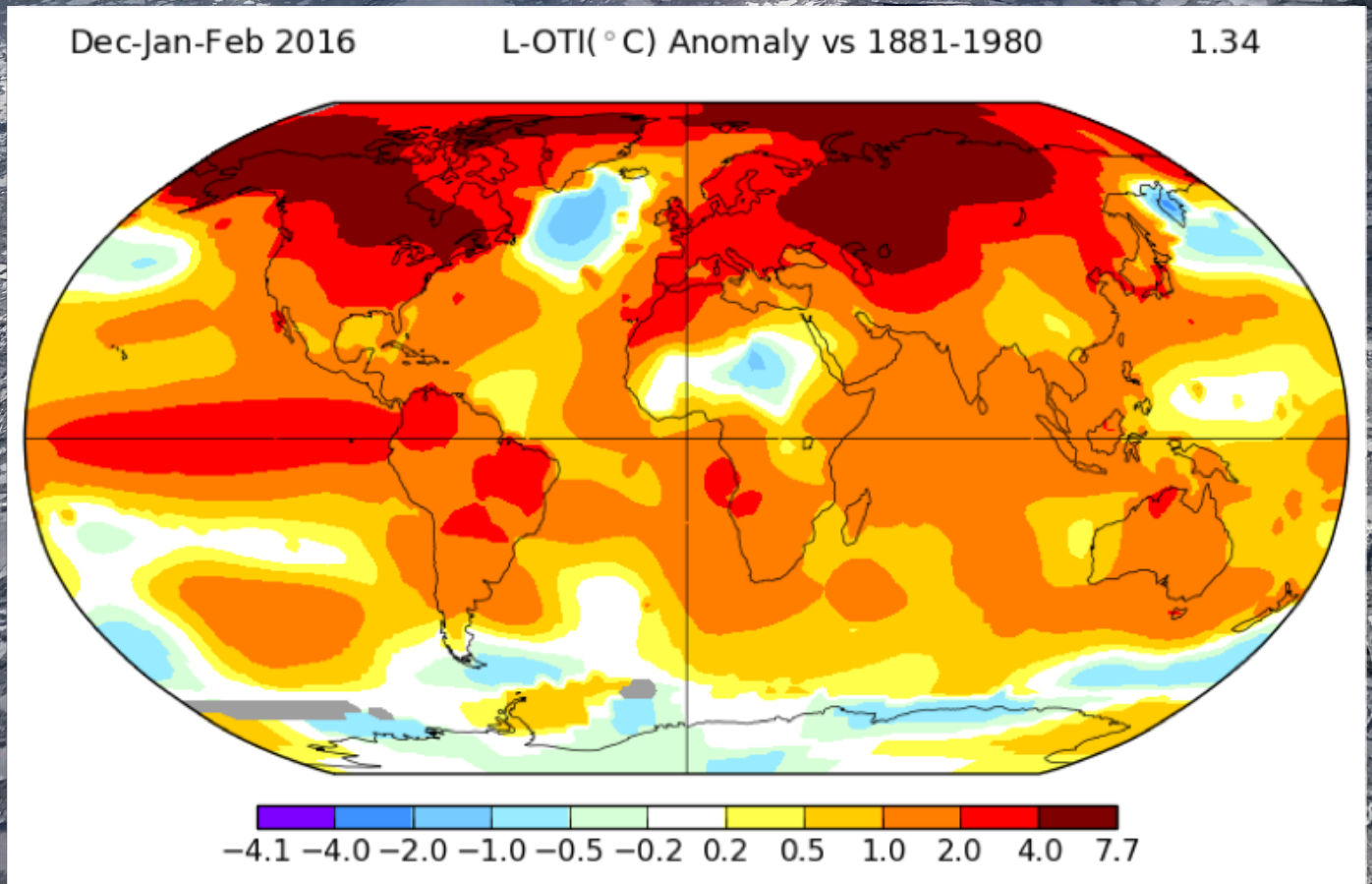
The Impact of the Extreme Winter 2015/2016 Arctic Cyclone on the Kara-Barents Seas

Linette Boisvert, Alek Petty and Julienne Stroeve

Monthly Weather Review: doi:10.1175/MWR-D-16-0234.1

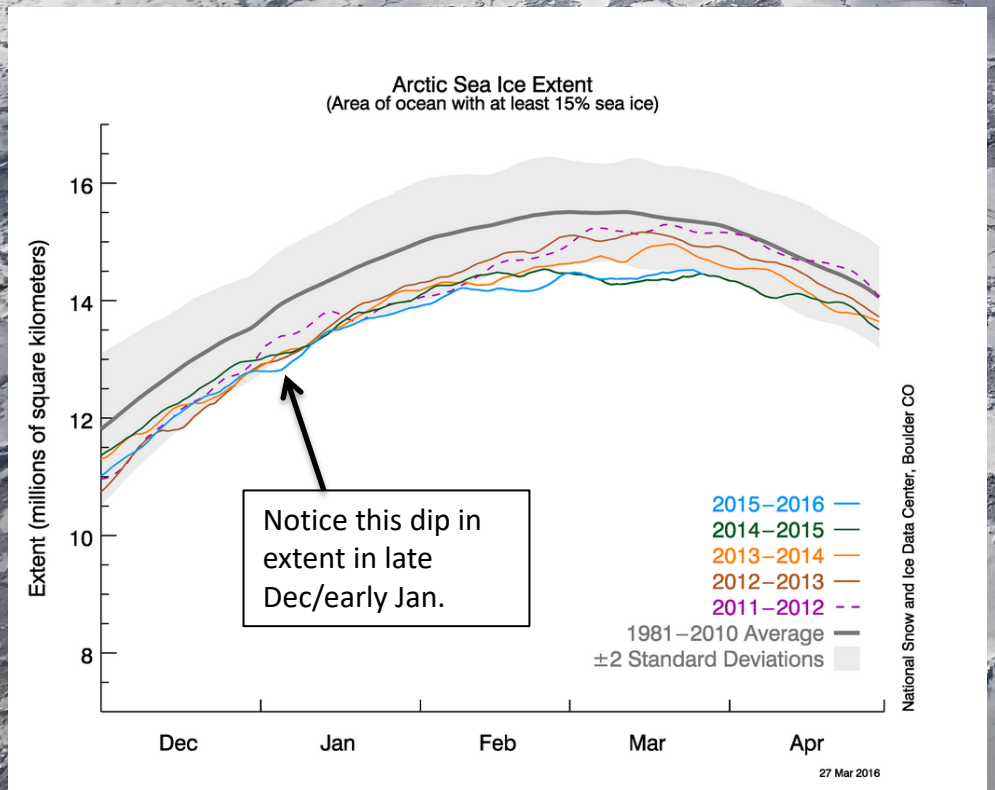
2015/2016 Winter

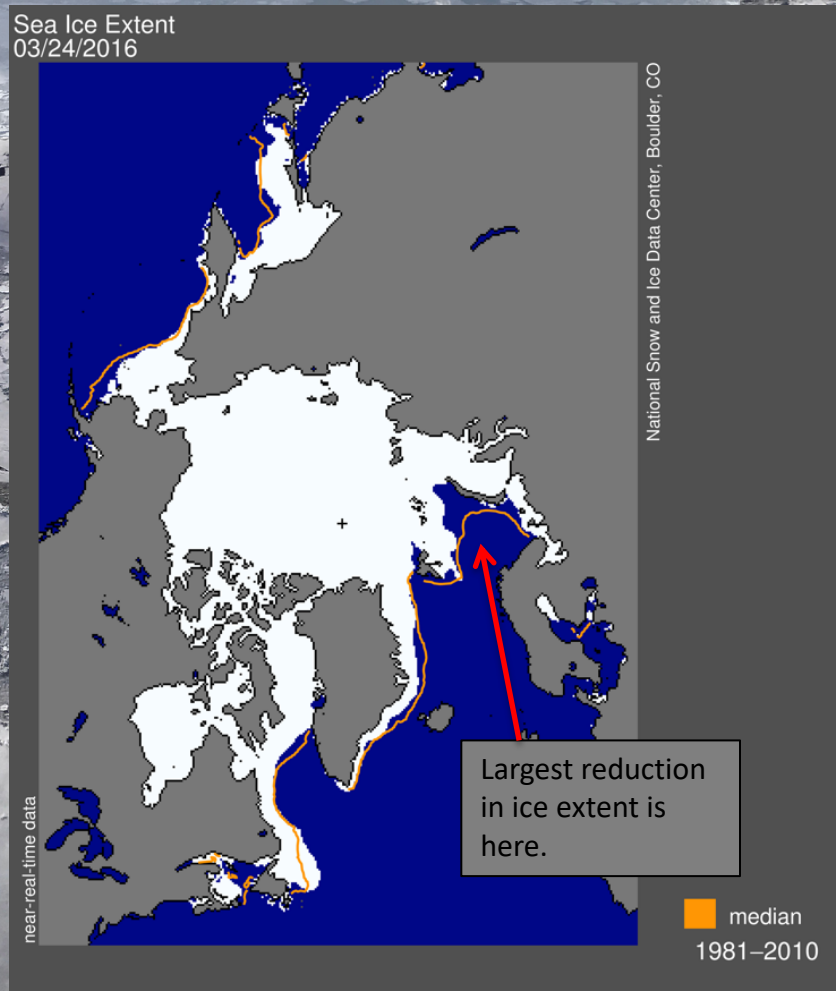
- The 2015/2016 December–February was the warmest winter since 1880 from NASA's GISSTEMP
  - Much of this warming occurred within the Arctic region



2015/2016 Winter

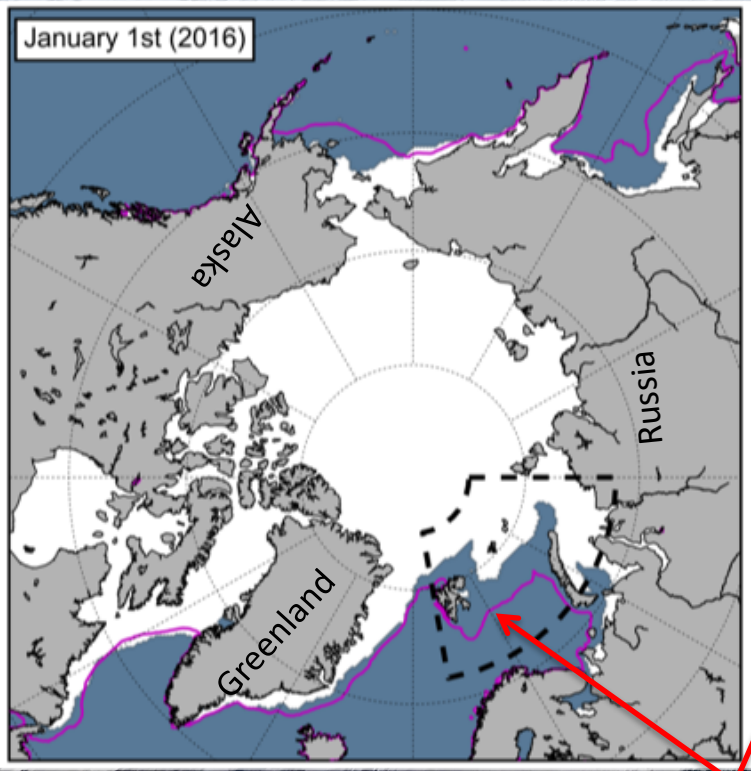
- In 2016, Arctic sea ice experienced the lowest January, February and maximum extent recorded since 1979

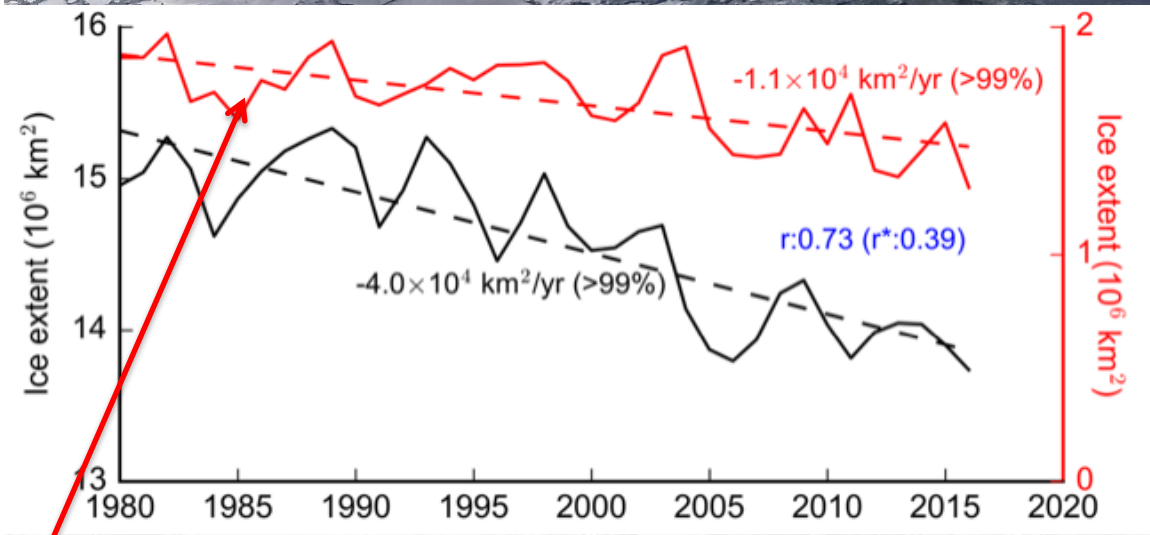




2015/2016 Winter

- Record low ice conditions were largely driven by anomalous low ice conditions in the Barents and Kara seas, a region that drives most of the pan-Arctic winter sea ice variability.





Barents & Kara seas

2015/2016 Winter

Capital Weather Gang

Freak storm pushes North Pole 50 degrees above normal to melting point

By Angela Fritz December 30, 2015

https://www.washingtonpost.com/news/capital-weather-gang/wp/2015/12/30/freak-storm-has-pushed-north-pole-to-freezing-point-50-degrees-above-normal/

https://robertscribbler.com/2015/12/27/warm-arctic-storm-to-hurl-hurricane-force-winds-at-uk-and-iceland-push-temps-to-72-degrees-f-above-normal-at-north-pole/

Freak North Atlantic Storm Featuring Extremely Low Pressures

Sunday afternoon, a powerful, hurricane force low pressure system was in the process of rounding the southern tip of Greenland. This burly 960 mb beast roared out of an

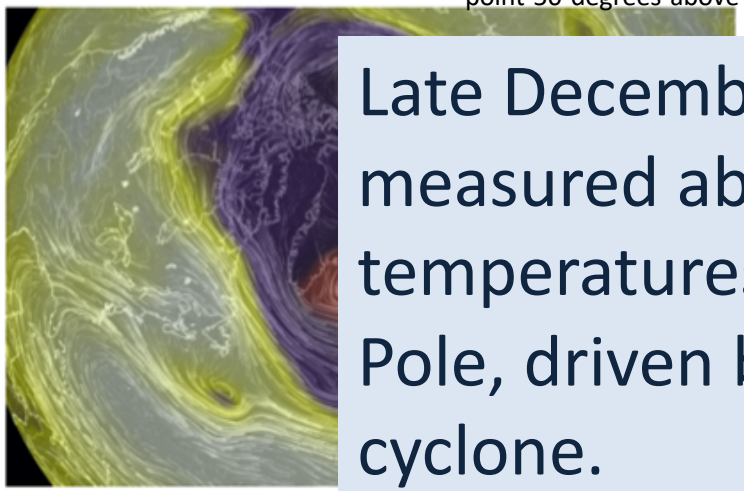
rounded Greenland and entered the

vide gale force wind field even as it

sts. To its east, the storm now links with

outh-to-north winds up from a region

land, over Svalbard, and into the Arctic



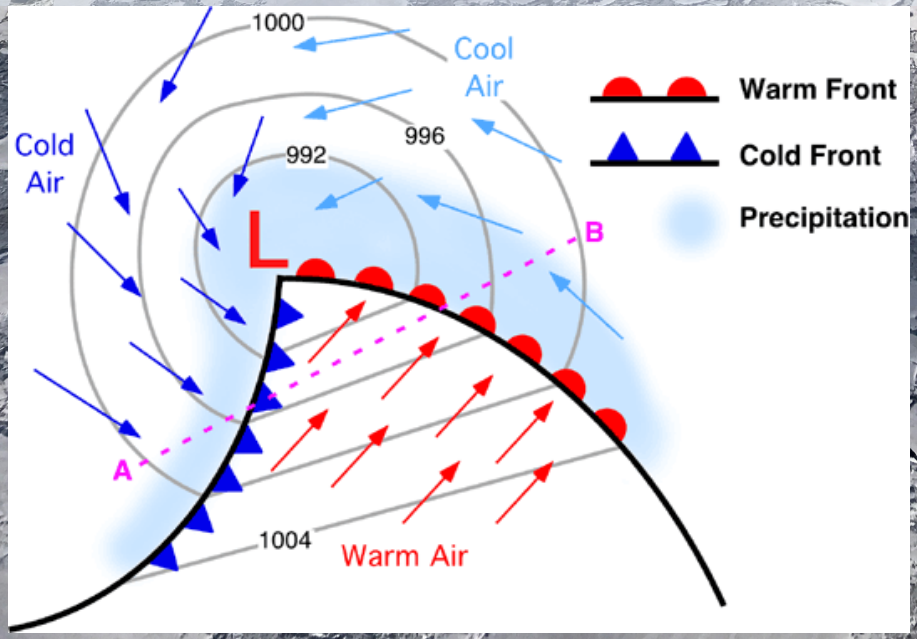
This storm in the far North Atlantic is the same storm that caused two tornado outbreaks and widespread flooding in the United States. Now, it's

Late December 2015, NCEP-GFS measured above freezing temperatures around the North Pole, driven by a strong Arctic cyclone.

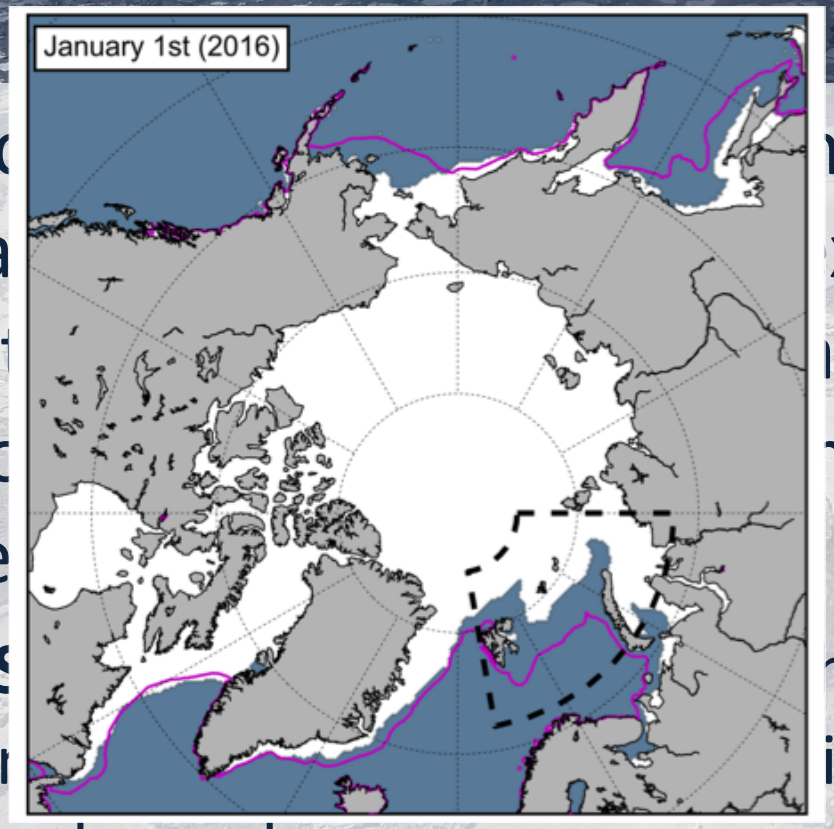
- Various blogs and news outlets bring this storm to our attention.

Why is this interesting?

- In winter, cyclones are thought to be the main transporter of heat and moisture into the Arctic [*Sorteberg and Walsh*, 2008]
  - Could contribute to sea ice melt in the absence of solar radiation.
  - Little is known about effects of winter cyclones on sea ice.
- The changing magnitude and frequency of winter cyclone events in the Arctic remains uncertain however.



Focus of this study

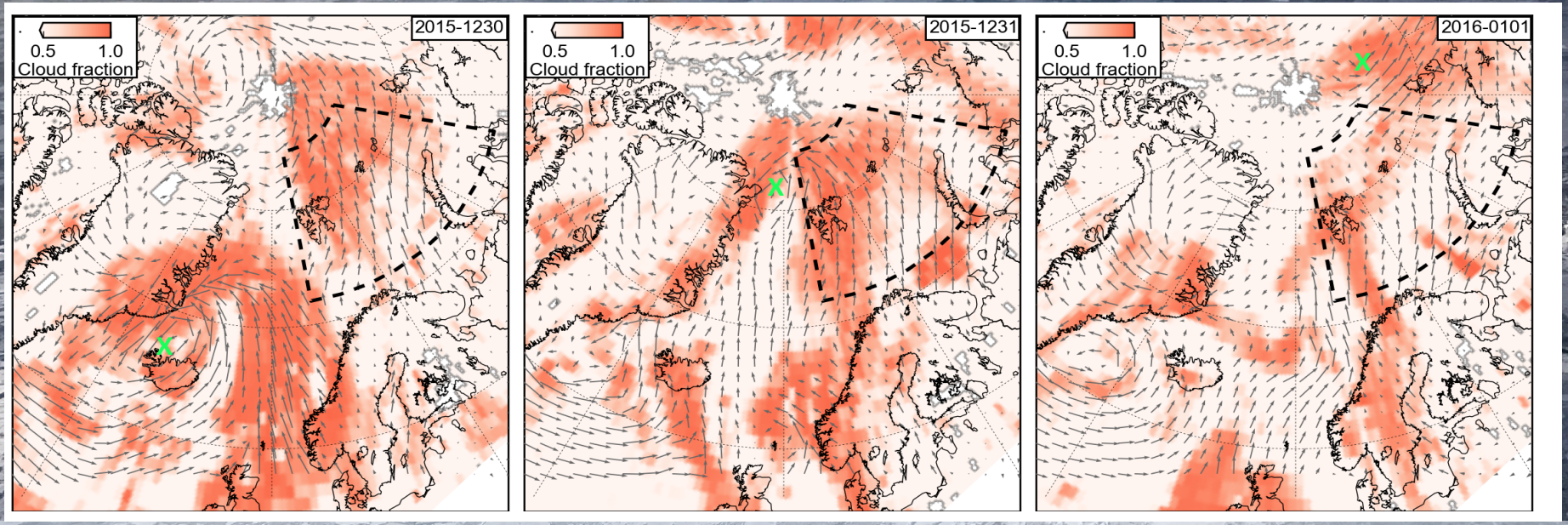


- The impac ner with the record wa xtent, and the uncertaint ct of winter cyclones c nt a more detailed e
  - Use **AIRS** here-surface forcing i ion before, during and after the cyclone

(28 December 2015 – 04 January 2016).

- AIRS is a cross-track high spectral resolution infrared sounder onboard NASA's Aqua satellite, launched on May 4, 2002.
- **AIRS Data used in this study**: Daily level 3, version 6 skin temperature, near surface air temperatures & specific humidity, and cloud fraction.
- 10m wind speeds are taken from MERRA-2.

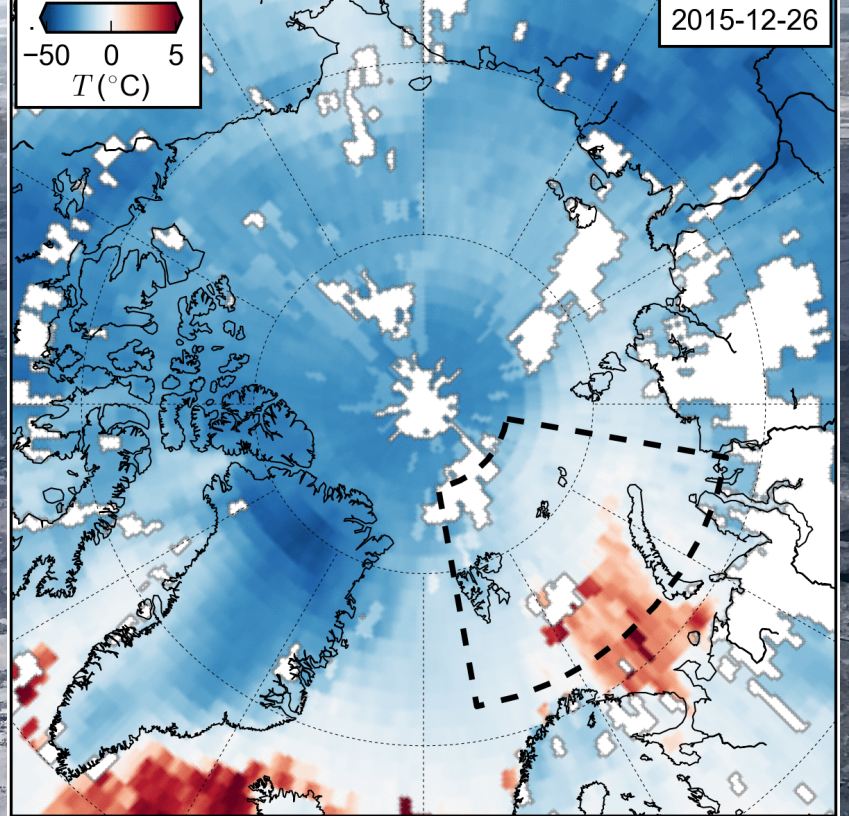
2015/2016 Winter Cyclone

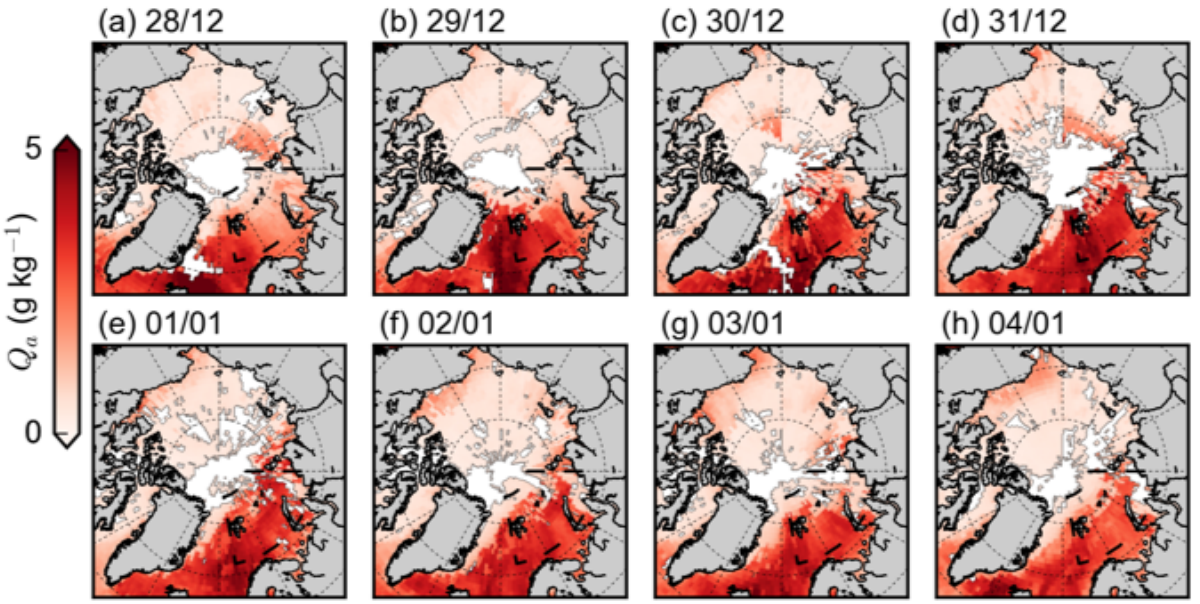


- Formed on 28 December 2015 (990hPa) in the middle of the North Atlantic (43°N) (not shown).
  - Traveled NE towards the UK as the pressure slowly dropped.
- On December 29 (960 hPa) it turned NW towards Iceland, rapidly intensifying (not shown).
- On 30 December (930 hPa) it moved northward along the coast of Greenland into the central Arctic near 90°N.
- On 31 December (970 hPa) it weakened slightly.
- On 01 January (975 hPa), the cyclone moved to the north of Severnaya Zemlya Island.

2015/2016 Winter Cyclone

- During this time a warm, moist, southerly air mass was transported over the BaKa region

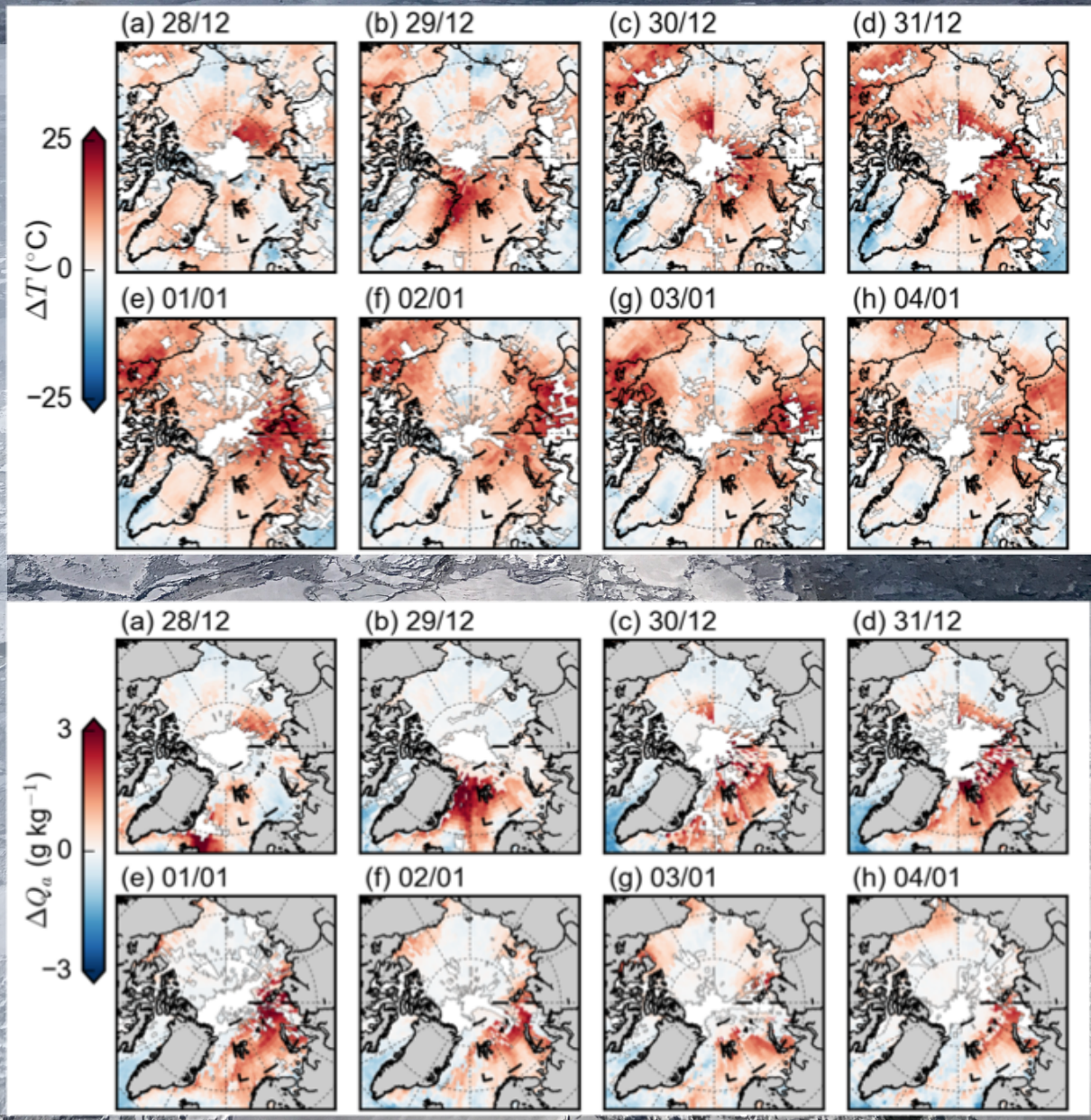




2015/2016 Winter Cyclone

- Temperatures & specific humidity in some places were:
  - ~20°C (>6σ) & ~3 g kg^{-1} (~9σ) above average (2003-2014)
- On average, during the peak of this cyclone (30 December 2015- 01 January 2016)
  - Mean temperatures & specific humidity:

    ~10°C (>3σ) warmer & ~1.4 g kg^{-1} (>4σ) higher than the 2003-2014 average
- This suggests this cyclone had a large impact on the surface energy budget in the region.



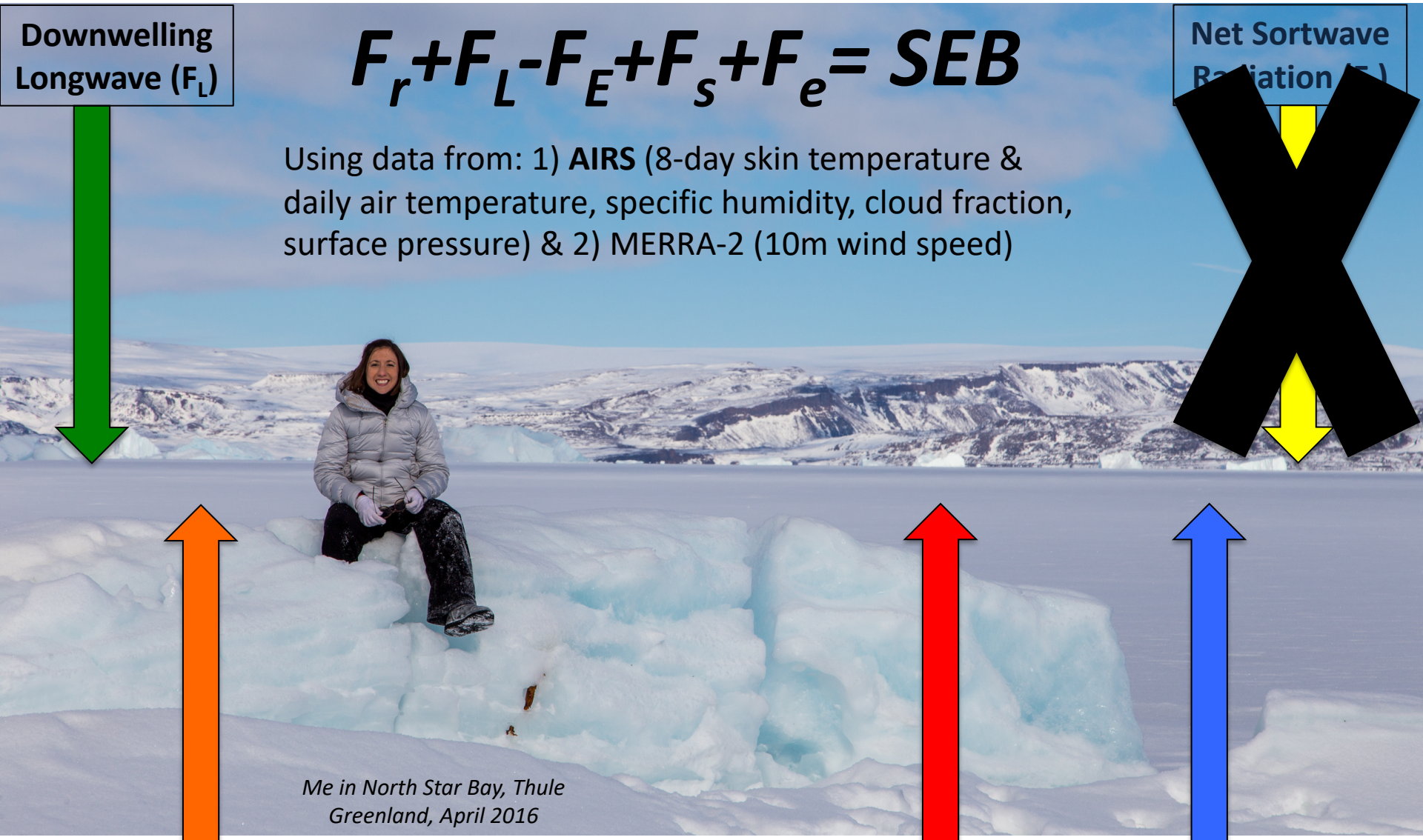
Surface Energy Budget

$$F_r + F_L - F_E + F_s + F_e = SEB$$

Downwelling Longwave (F_L)

Net Sortwave Radiation (F_r)

Using data from: 1) **AIRS** (8-day skin temperature & daily air temperature, specific humidity, cloud fraction, surface pressure) & 2) MERRA-2 (10m wind speed)



Me in North Star Bay, Thule Greenland, April 2016

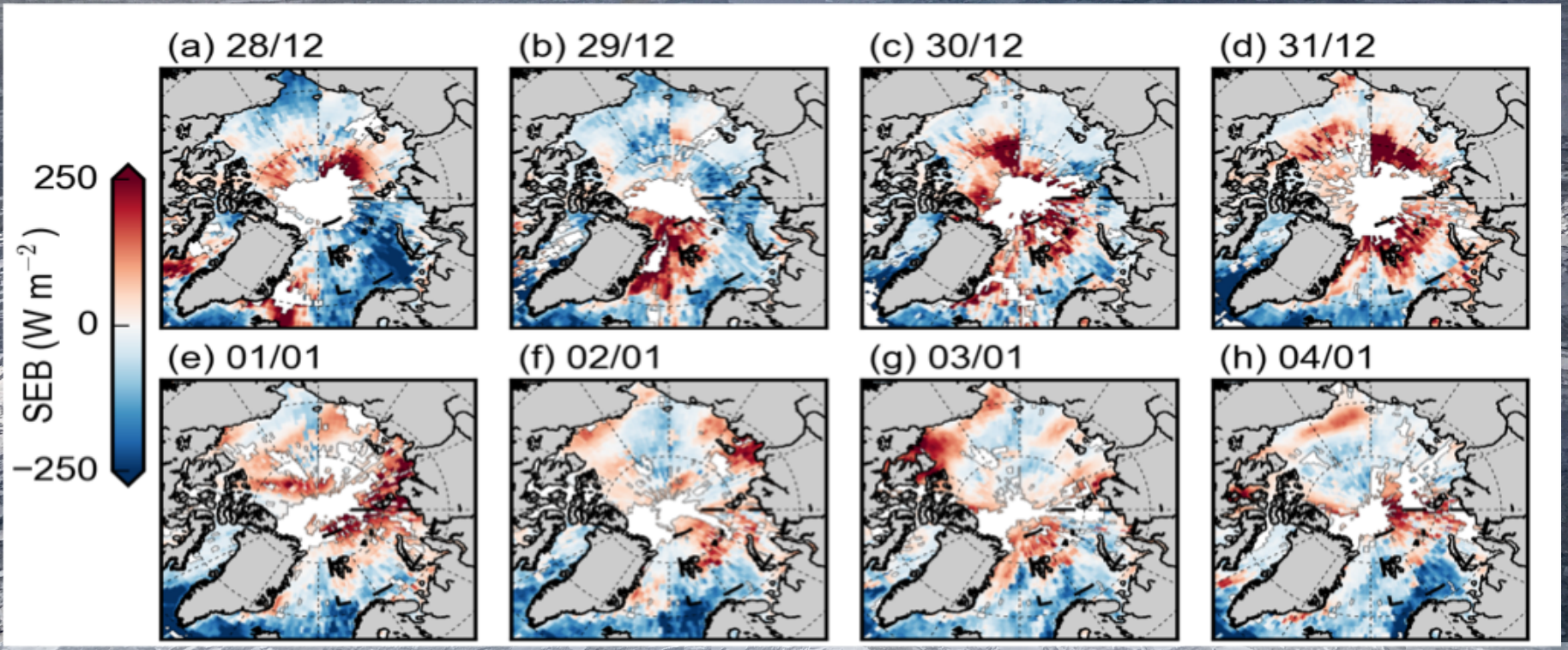
Emitted Longwave (F_E)

- SEB > 0 Surface gains energy
- SEB < 0 Surface loses energy

Sensible Heat Flux (F_s)

Latent Heat Flux (F_e)

Surface Energy Budget

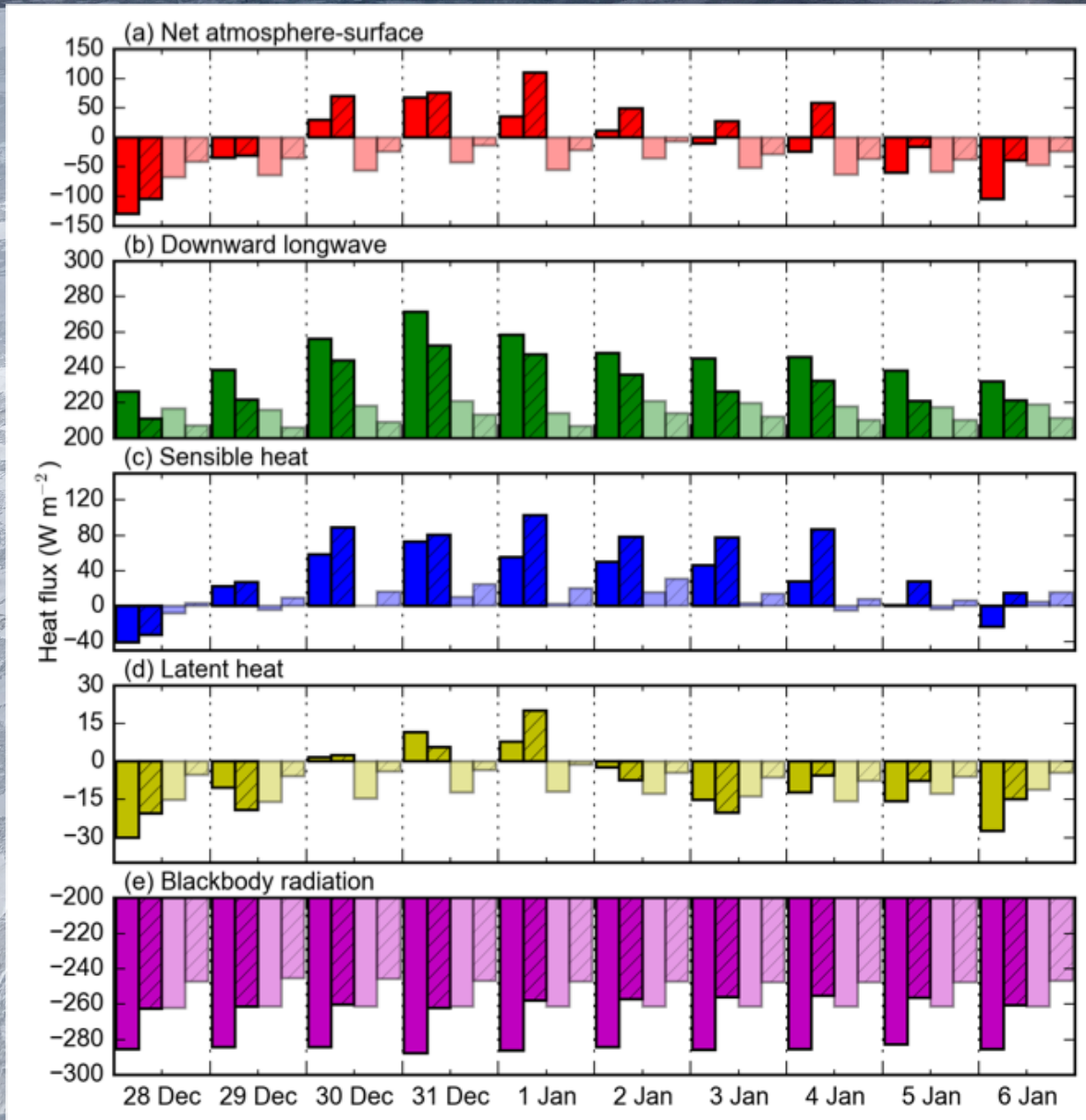


- Normally, the SEB is small
  - dominated by the upwelling longwave heat flux and LWD opposing each other & turbulent heat fluxes are negligible.
- Before the cyclone transported this air mass into the region (~28 Dec.), the SEB was negative (i.e. the ocean surface was losing energy to the atmosphere), favoring ice formation/growth. Afterwards, the SEB became positive (i.e. the surface was gaining energy from the atmosphere).

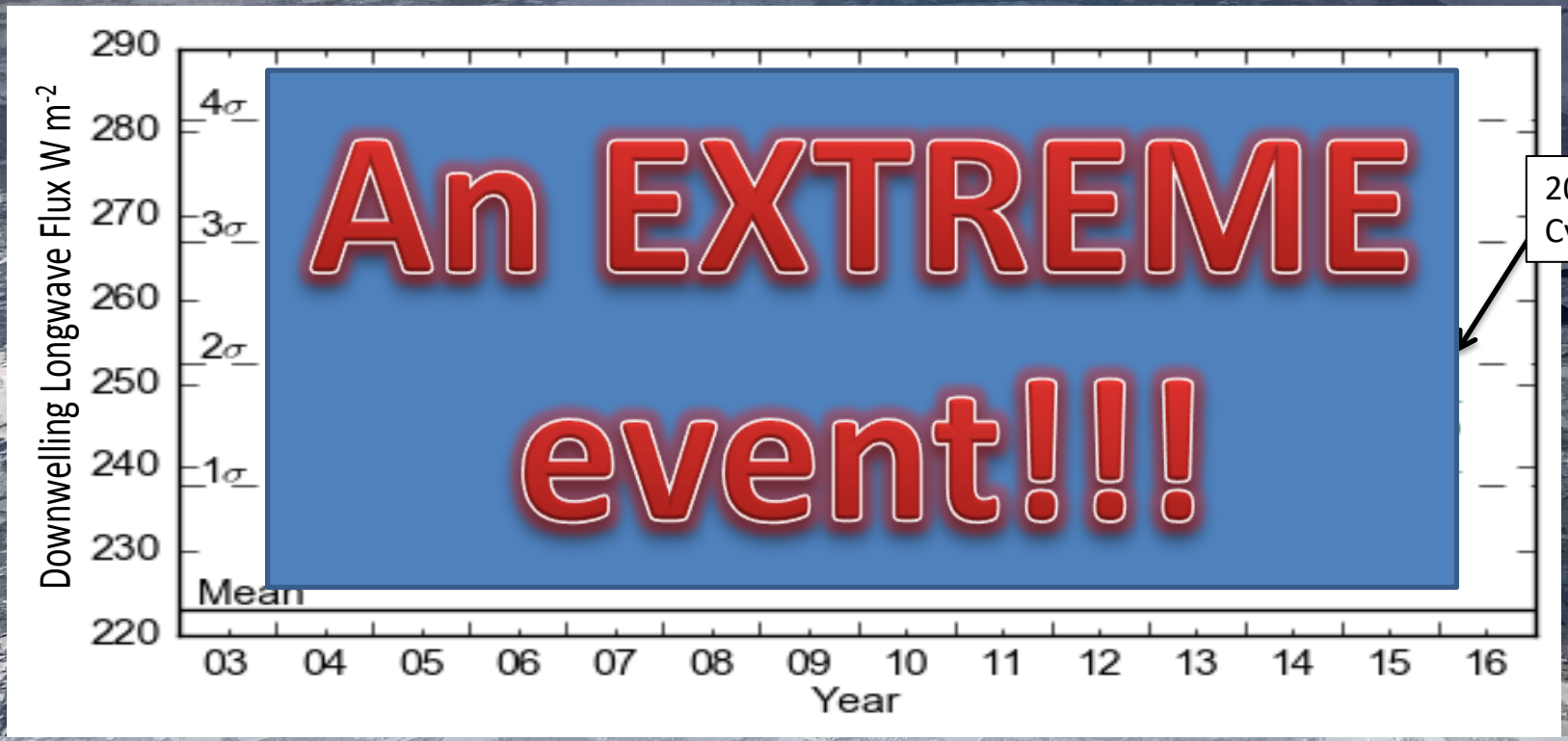
Surface Energy Budget

Barents-Kara seas region

- Darker colored bars for Dec 28, 2015-Jan 06 2016:
  - Solid bars: both ocean & sea
  - Hatched bars: areas covered with >50% sea ice concentration.
- Lighter shaded bars are average 2003-2014 values:
  - Solid bars: both sea ice & ocean
  - Hatched bars: sea ice >50% ice concentration.



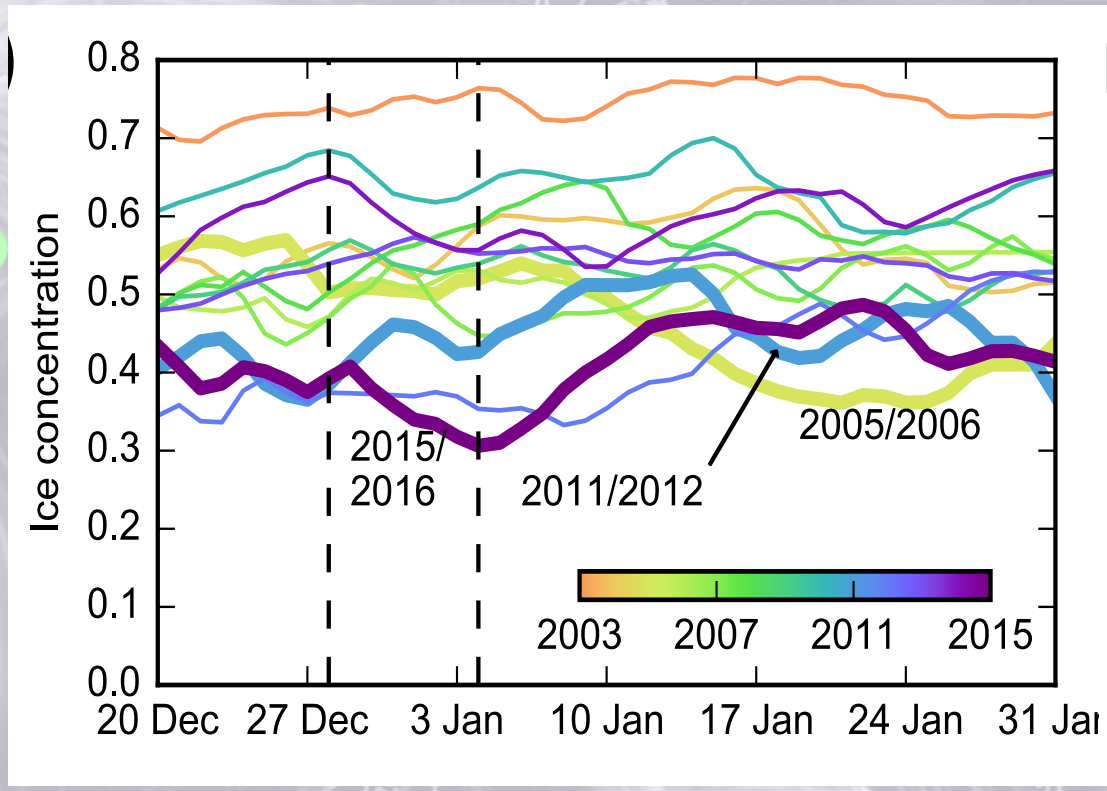
How does this cyclone compare to other events in the AIRS record?



- 15 elevated events were found in the BaKa region since 2003.
- The 2015/2016 event had a mean LWD of ~250 W m^{-2} (~2σ from the mean), which was ~8 W m^{-2} greater than the average of all other elevated events (~242 W m^{-2}).
  - The maximum LWD (31 December 2015) was the largest on record (>3σ) and was ~40 W m^{-2} greater than the mean of all other event maxima.

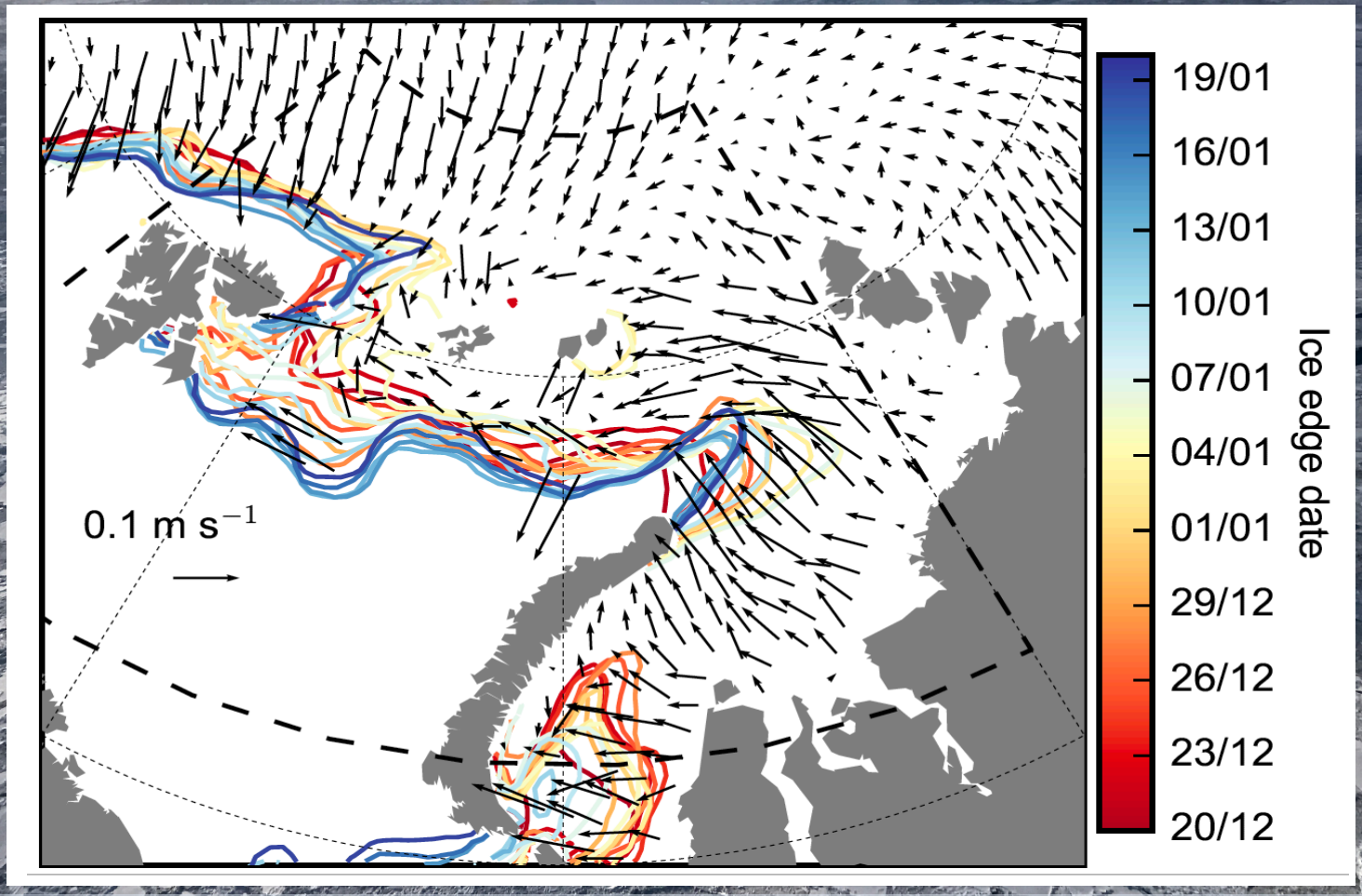
Exploring the Sea Ice Response

- **Between 30 December 2015 – 06 January 2016, the SIC decreased by ~10% (from 40% to 30%).**
- Takes ~2 weeks (from ~28 December to 14 January) for the sea ice extent to return to what we might have expected from linear trend persistence.



- Interestingly, the 2011/2012 SIC showed a similar decline, which coincides with the January 2012 LWD elevated event (previous slide).
- The most pronounced SIC decline occurred during January 2006, and was attributed to unusually strong and warm southerly winds [*Comiso*, 2006]

Dynamic Response



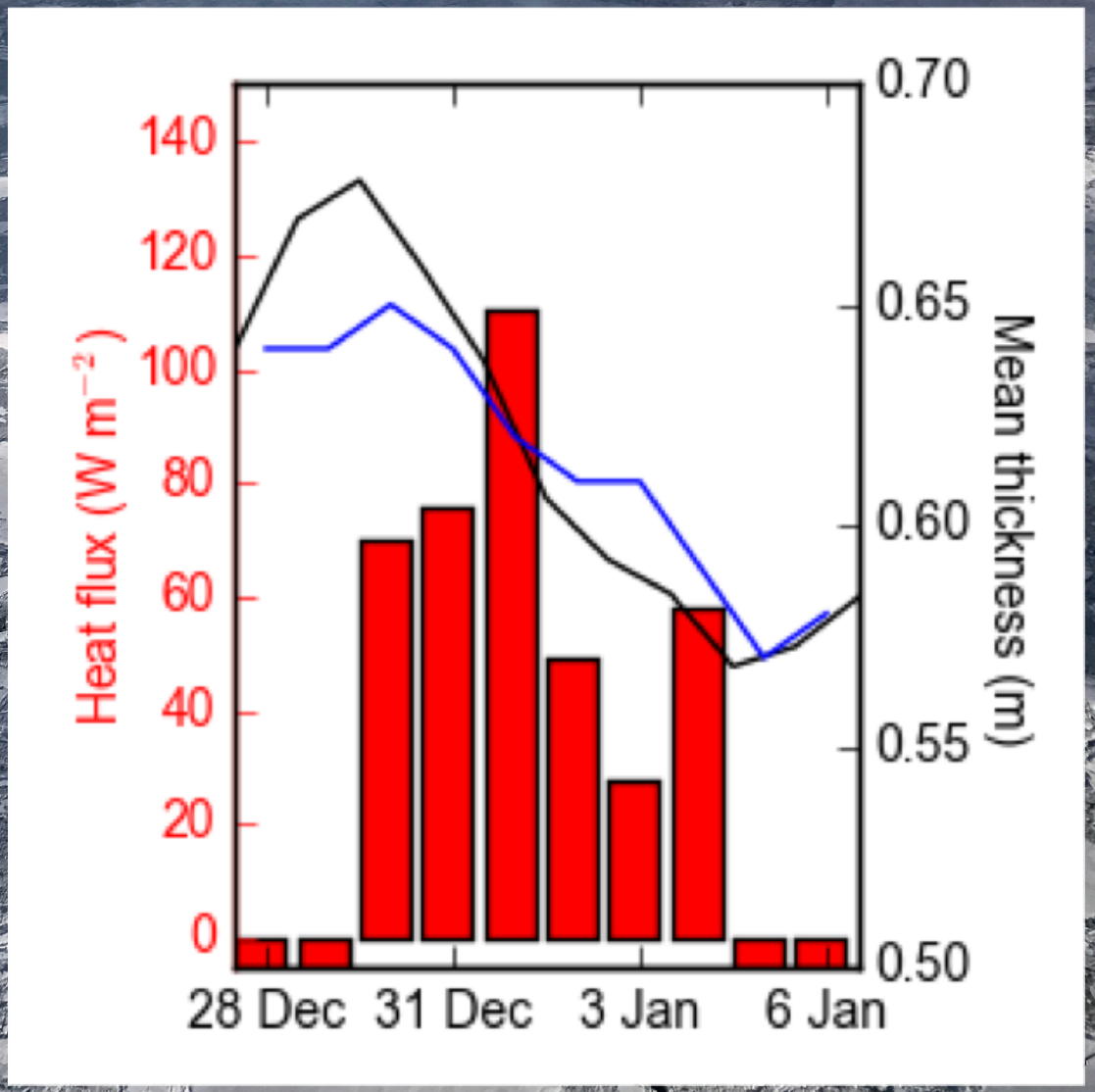
- The CERSAT/AMSR2 ice drift vectors suggest a clear cyclonic (anti-clockwise) ice circulation in the BaKa region during the cyclone.

Thermodynamic Response

- The estimated ice thickness changes can then be expressed:

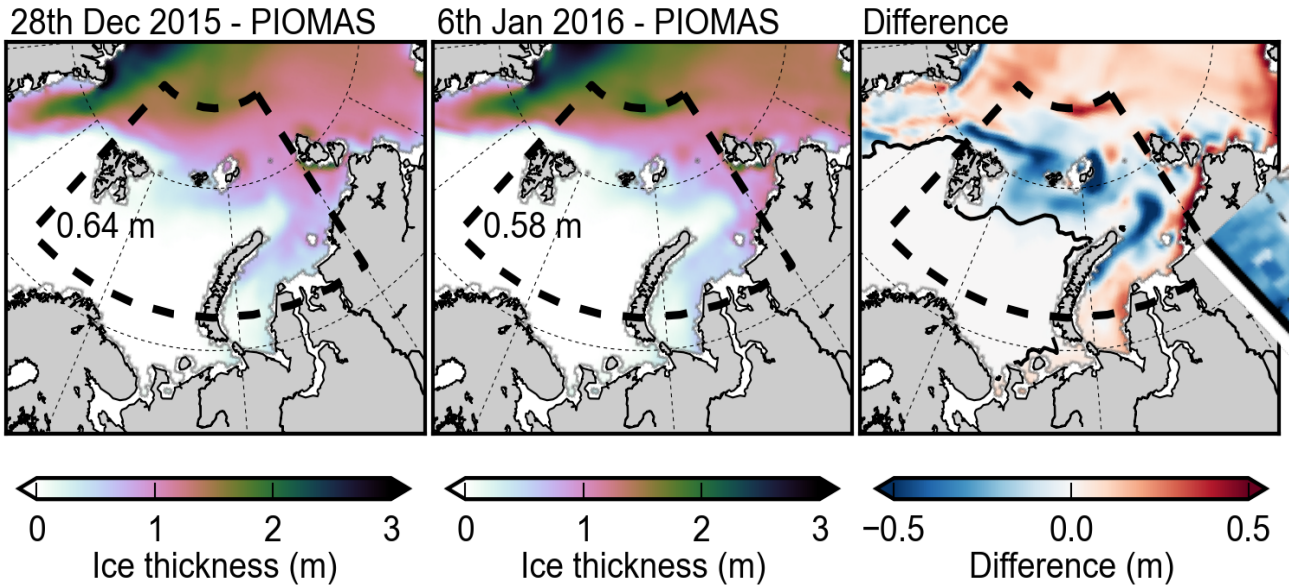
$$\delta h = -\delta Qi/(\rho Lf)$$

- where δQi is the mean SEB over sea ice covered BaKa region (**calculated with AIRS data**), ρ is the density of ice and L_f is the latent heat of fusion of sea ice.
- Initialized with the mean thickness of ice on 28 December 2015 (~64 cm) from PIOMAS, v2.1.
- Our results (black line) show that ~8 cm of ice melt for the 10 days of SEB forcing (28 December to 06 January).
- The PIOMAS model (blue line) estimates a mean decrease of ~8 cm over this same time period!



Thermodynamic Response

- Daily thickness changes/variability estimated closely match PIOMAS, & areas where the SEB are large and positive, are similar to those regions where PIOMAS indicates decreases in ice thickness.



Arctic Winter Cyclone

https://www.nasa.gov/feature/goddard/2016/extremely-warm-2015-16-winter-cyclone-weakened-arctic-sea-ice-pack

Conclusions

- Daily atmospheric data from AIRS were used to study an extreme warm and humid air mass that was transported over the BaKa region by an Arctic cyclone, between late December 2015 & early January 2016.
- The air mass transported by the cyclone was unlike any recorded during the winter AIRS record.
  - This cyclone weakened the sea ice pack in the Barents-Kara seas region aiding in the winter 2015/2016 sea ice minimum extent, which is largely driven by ice extent in the Barents-Kara seas.
  - Thus studying the effects on the SEB and its impact on the sea ice is crucial, especially considering the strong sea ice declines experienced in recent decades.

- Future projections of Arctic sea ice imply continued declines in thickness over the coming decades, meaning the impact of similar elevated events could be significantly greater.