

The contribution of föhn winds to northeast Greenland summer melt and their relationship with atmospheric rivers

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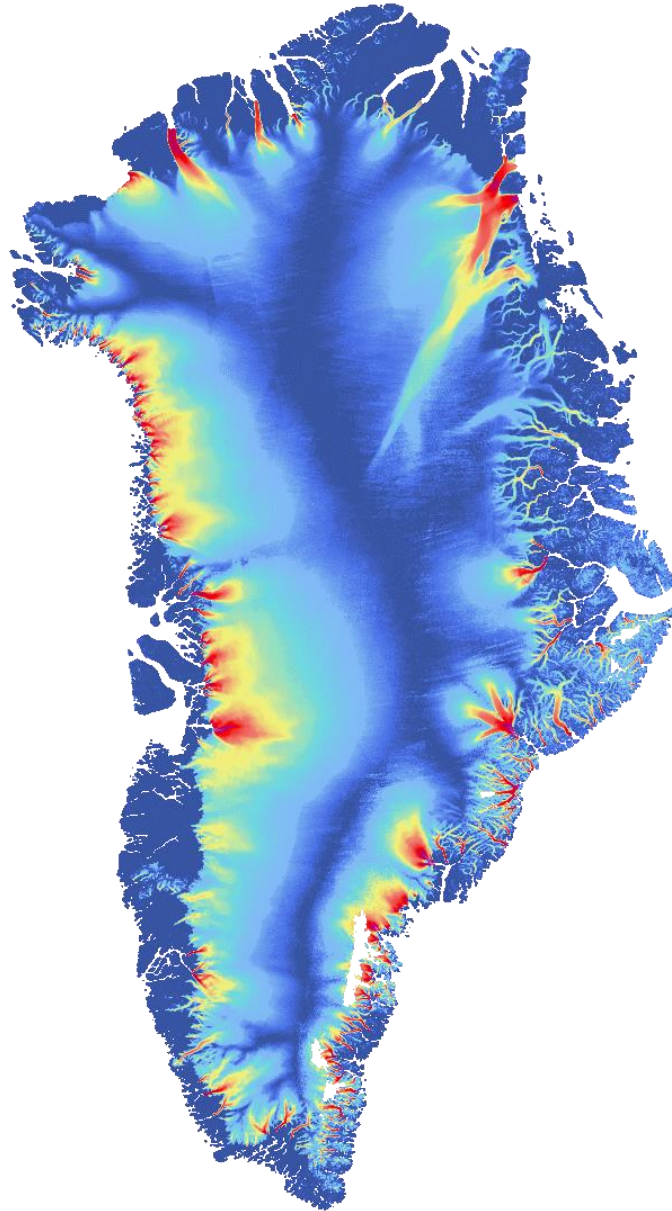
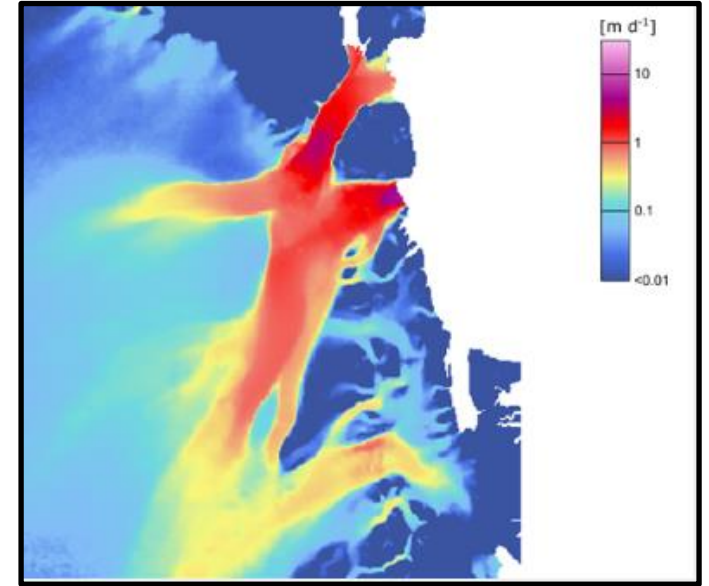
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The Northeast Greenland Ice Stream (NEGIS)

- Drains 12% of Greenland Ice Sheet (GrIS)
- **Increased ice velocity and mass loss** since mid 2000's
- Increased basal thinning due to warming ocean
- 3°C+ air temperature rise since 1979

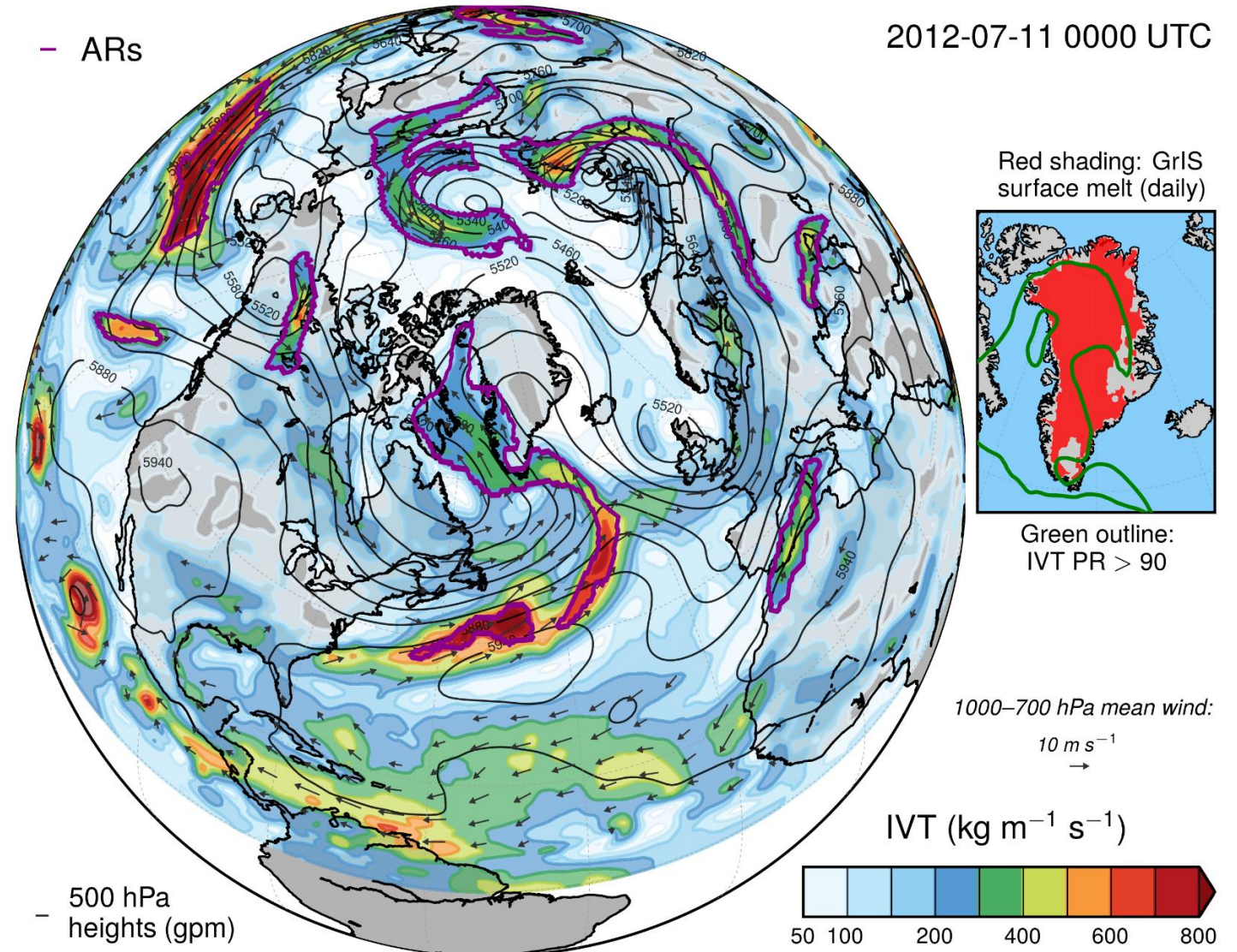


esa-icesheets-cci.org

Atmospheric rivers force Greenland Ice Sheet melt events

Atmospheric rivers (ARs)
are long, narrow corridors of
strong water vapor transport

July 2012: nearly the entire
Greenland Ice Sheet (GrIS)
experienced surface melt
during AR event

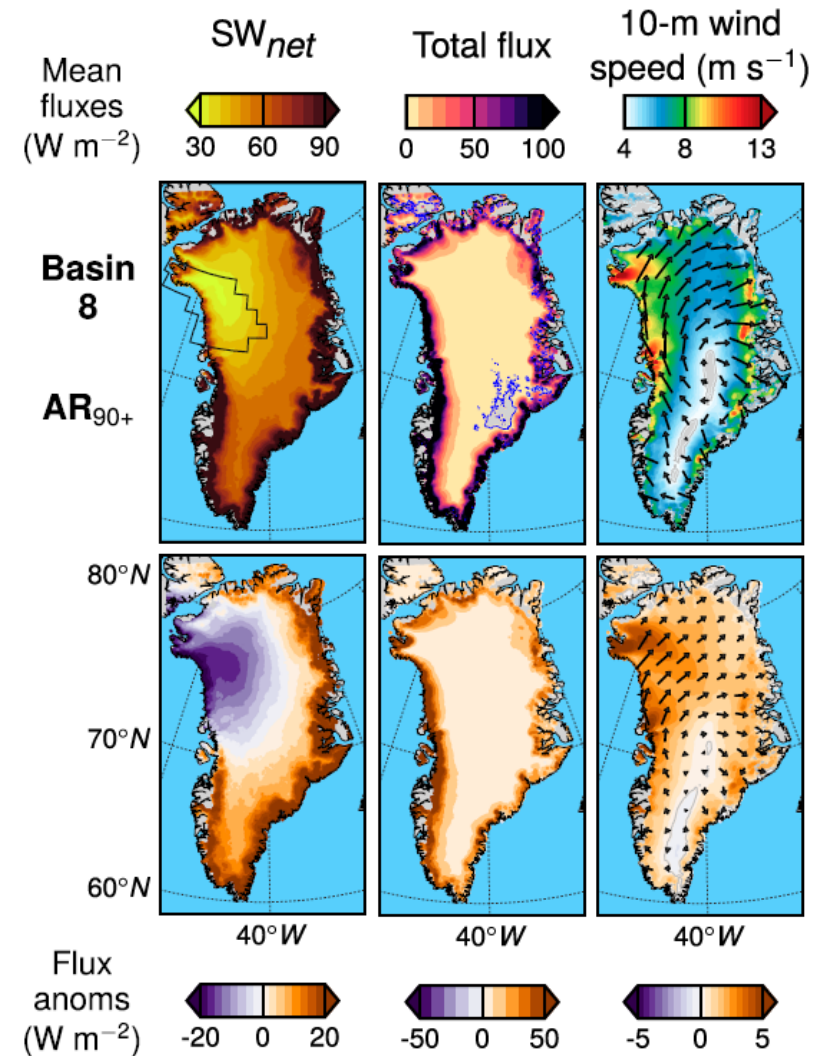


Surface energy balance response to NW Greenland ARs

When **atmospheric rivers (ARs)** make **landfall in the northwest of Greenland**, positive total surface energy flux anomalies are observed in the **northeast of Greenland**

- Energy anomalies peak 1–3 days after AR landfall

Mattingly et al. (2020) showed these energy anomalies are often driven by **föhn winds** as air traverses crest of ice sheet and flows downslope

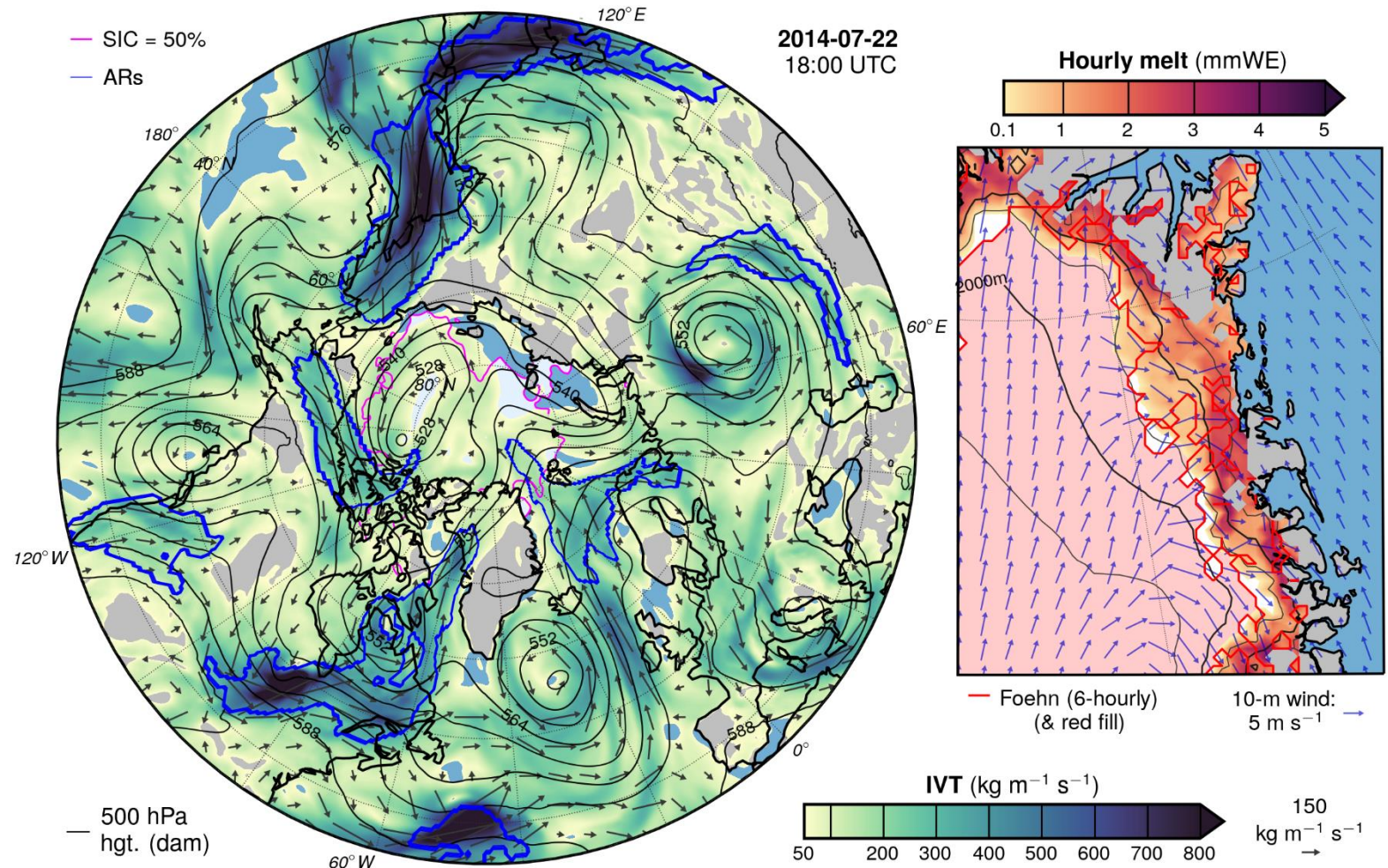


Research questions

What proportion of NE Greenland summer melt occurs in response to NW Greenland ARs?

What processes generate downsloping föhn winds in the NE? How much summer melt in the NE occur during föhn conditions?

Can trends in ARs and/or föhn help explain the increasing NE Greenland mass loss trend?



See this [link](#) or scan QR code at right for video animation of AR-föhn event during July 2014



Data and methods

MERRA-2 and ERA5 reanalysis to identify ARs

- *Mattingly et al. (2018)* and *Wille et al. (2021)* algorithms

Modèle Atmosphérique Régional (MAR)

- 15km horizontal resolution
- NE Greenland domain: ~74-83°N, ~43-10°W
- Results using RACMO model to come!

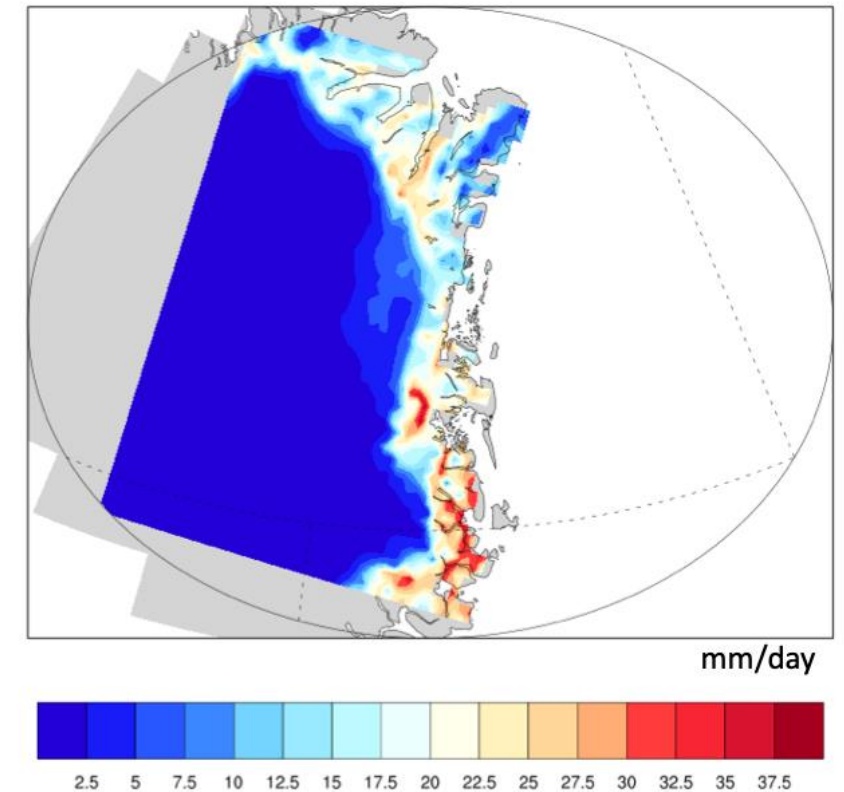
Föhn detection algorithm applied to MAR:

- Westerly winds and
- Wind speed $> 5 \text{ m s}^{-1}$ and
- RH $< 15^{\text{th}}$ percentile or
- RH decrease $> 10\%$ and T increase $> 2^{\circ}\text{C}$

Polar Weather Research and Forecasting (WRF) model used for case studies (*Turton et al., 2020*)

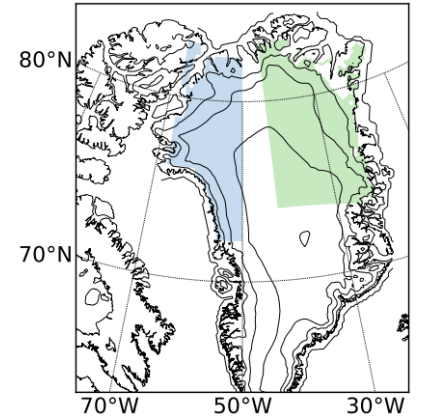
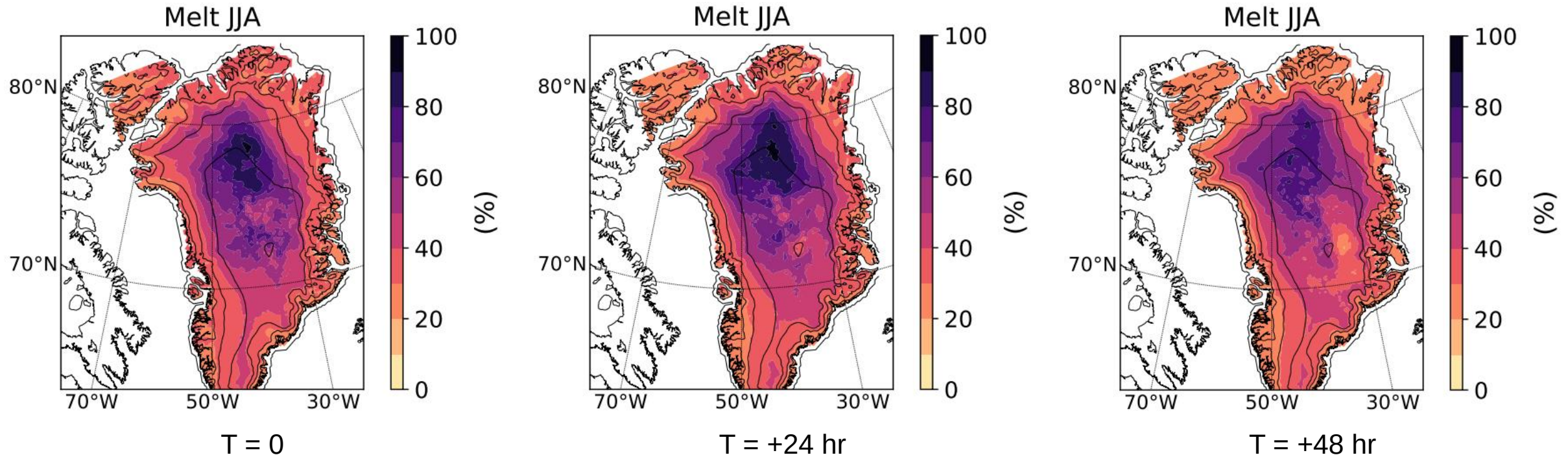
- 1.5km horizontal resolution

JJA Av Melt Production



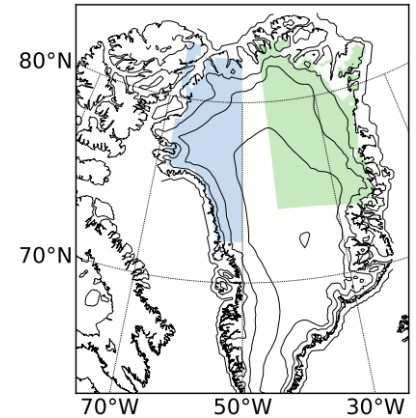
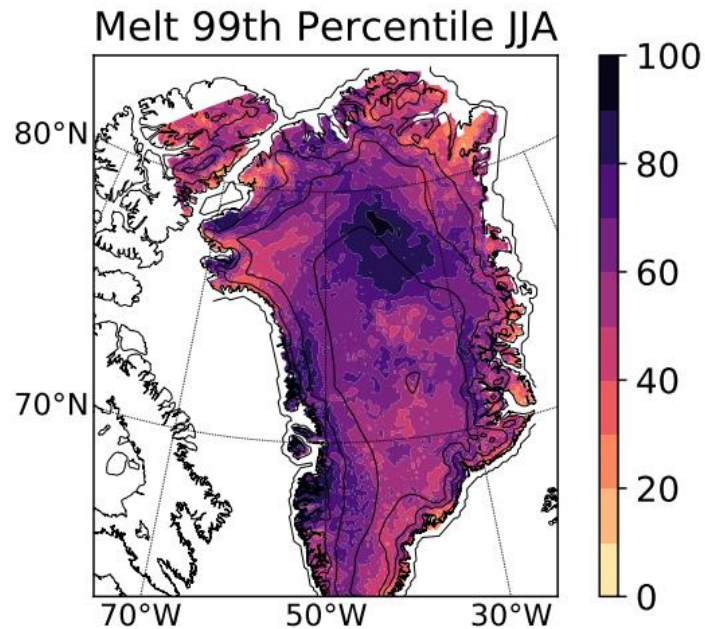
Result 1: NE melt follows NW Greenland ARs

Percentage of JJA melt occurring 0, +24, and +48 hours after AR present in NW Greenland (blue box)

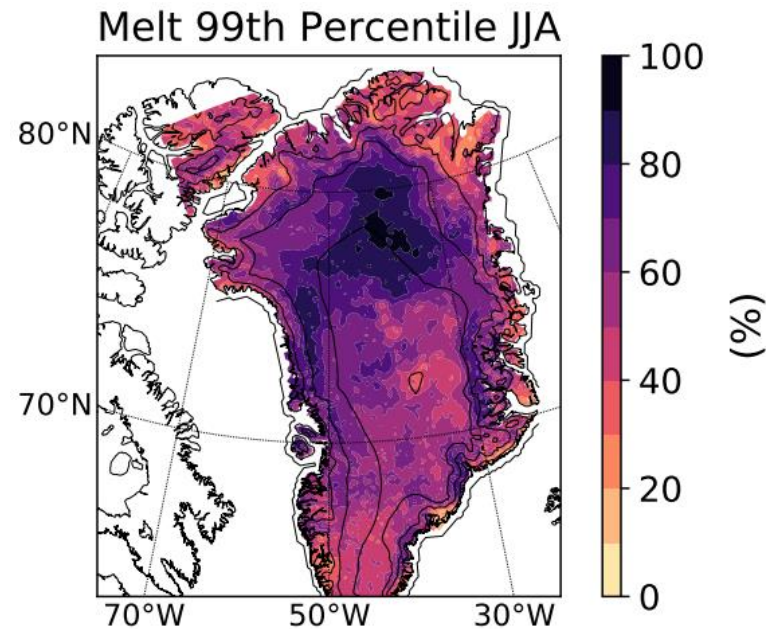


Result 1: NE melt follows NW Greenland ARs

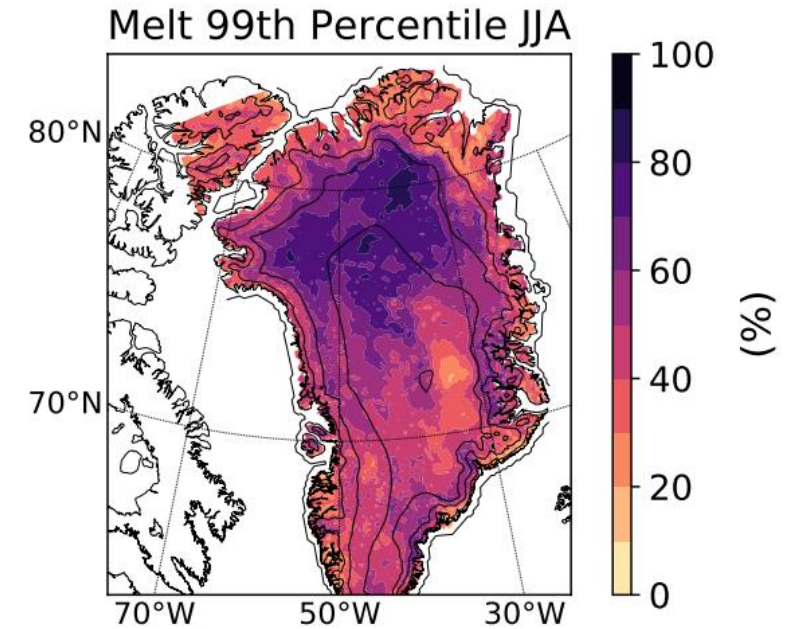
Percentage of *extreme* JJA melt ($> 99^{\text{th}}$ percentile) occurring 0, +24, and +48 hours after AR present in NW Greenland (blue box)



T = 0



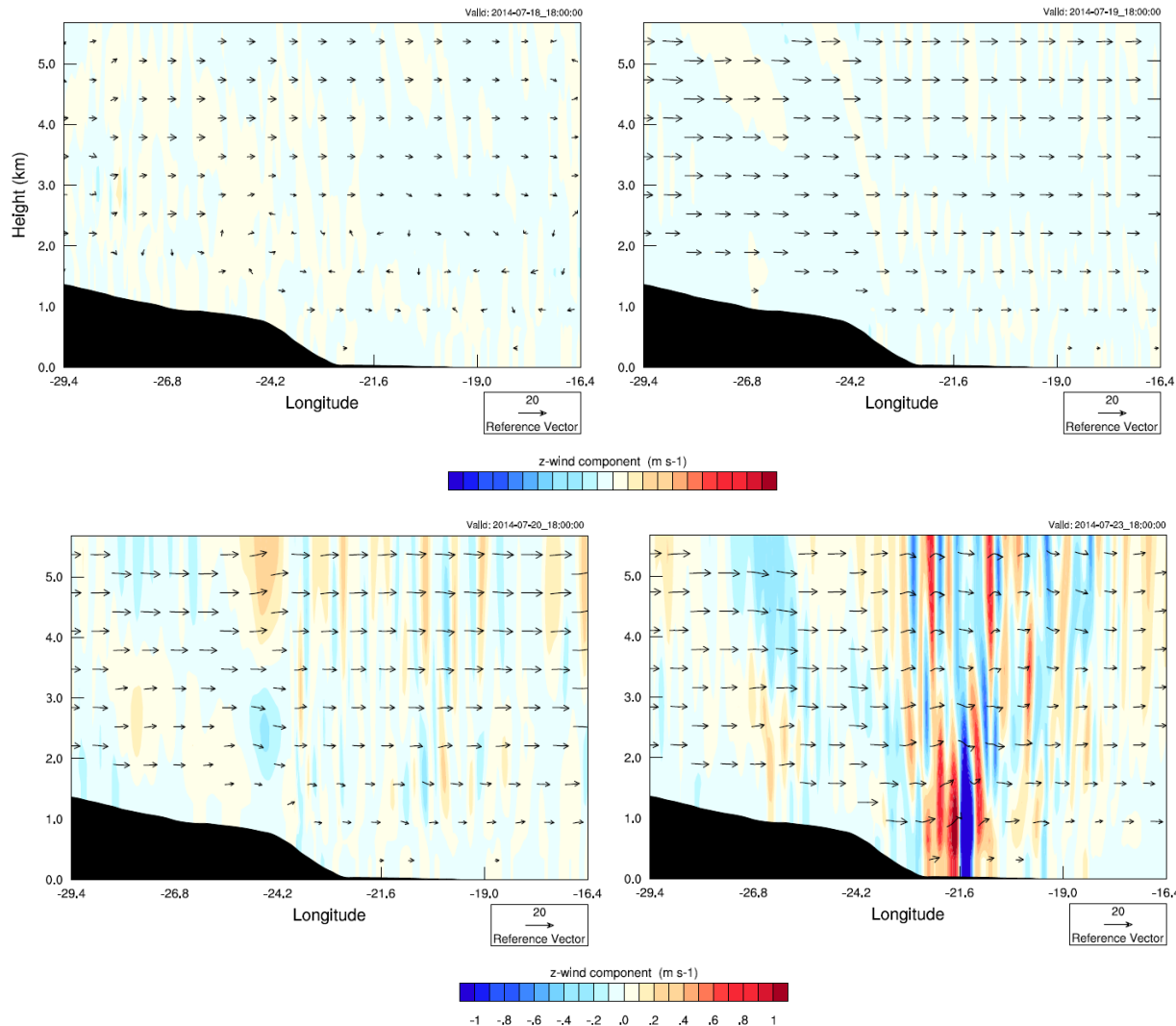
T = +24 hr



T = +48 hr

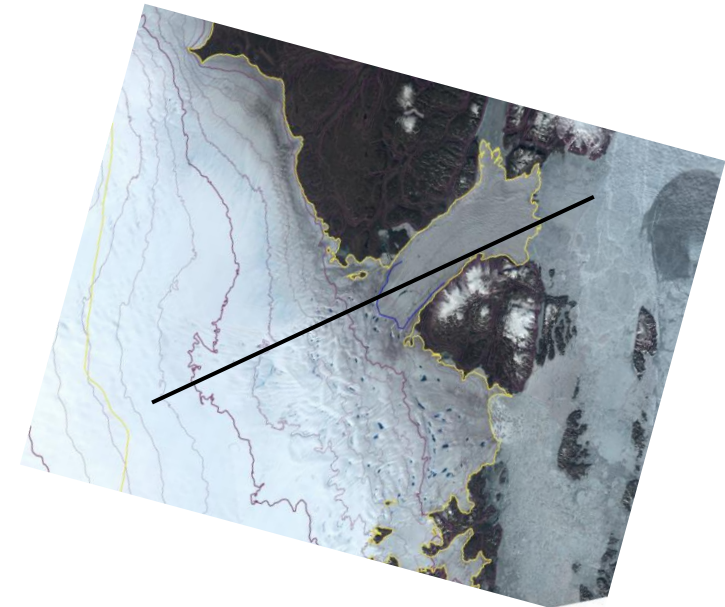
Result 2: Föhn drives melt in NE after NW ARs

Case study assessment: July 2014



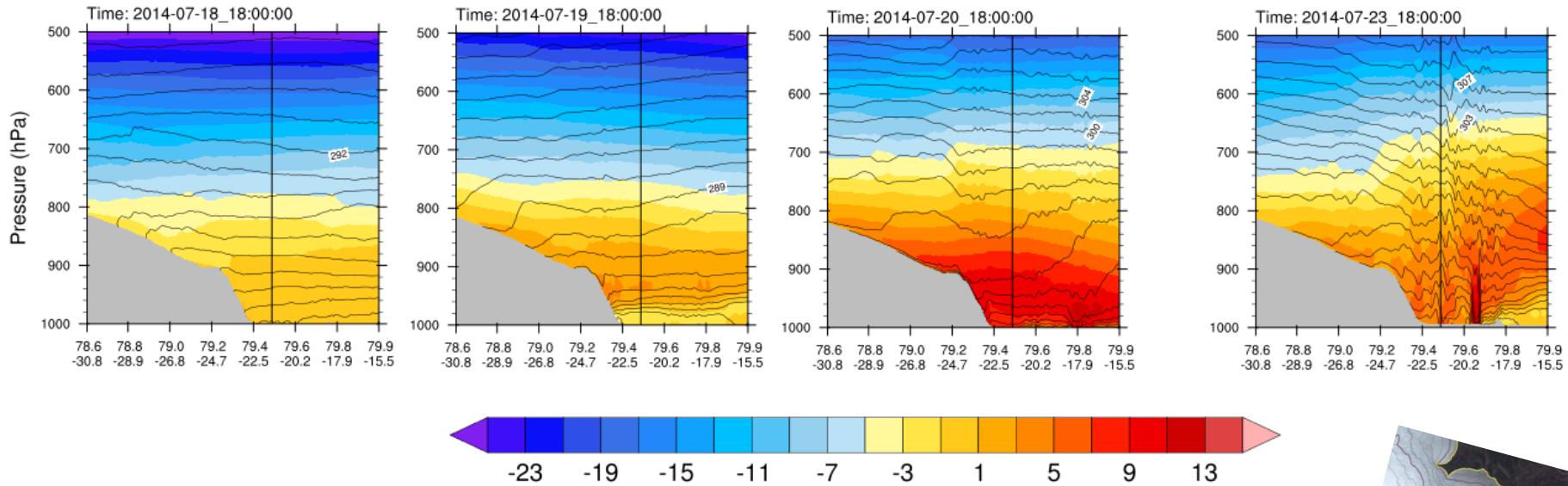
Polar WRF high-resolution simulations of northeast Greenland

Downslope flow, instability and mixing at lower levels



Result 2: Föhn drives melt in NE after NW ARs

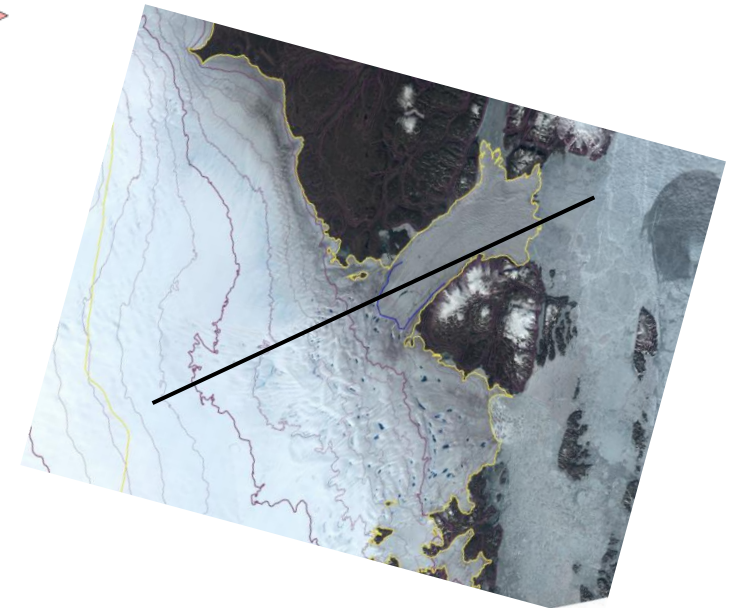
Case study assessment: July 2014



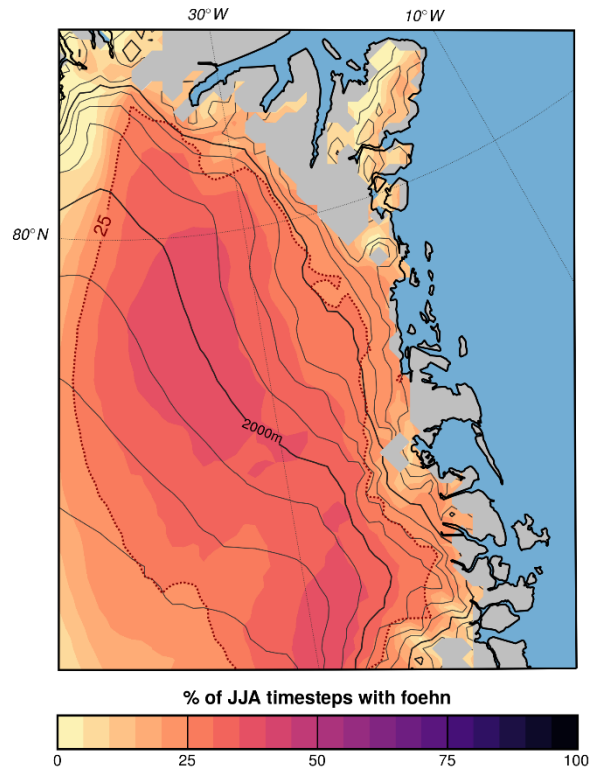
Isentropic drawdown, whereby potentially warmer air from aloft is drawn down towards the surface, is a föhn signature in many regions

Föhn detected from July 20 – 26 over much of the northeast section

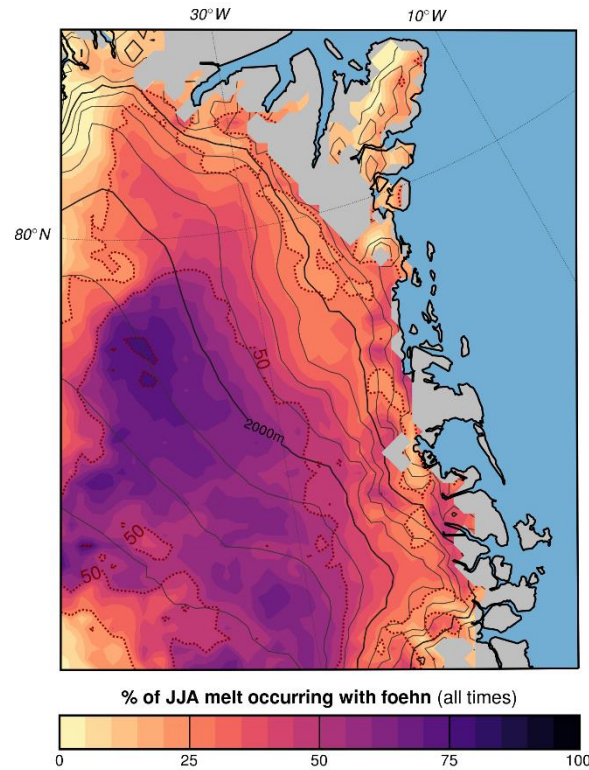
Observed föhn conditions also at two automatic weather stations on glacier



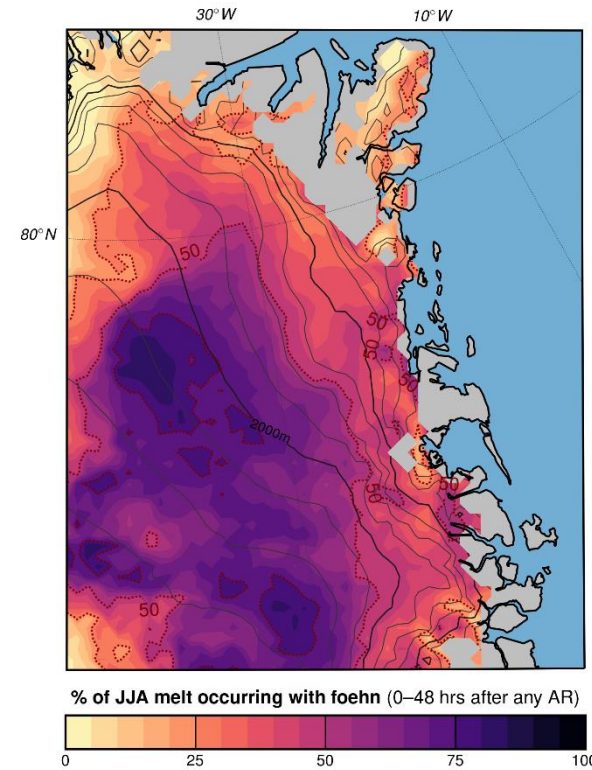
Result 2: Föhn drives melt in NE after NW ARs



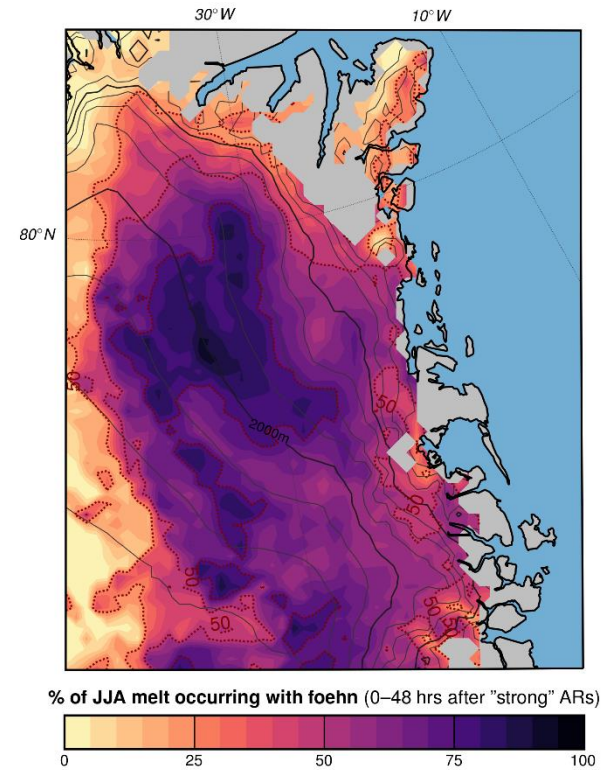
Föhn frequency during JJA



Percentage of JJA melt occurring with föhn



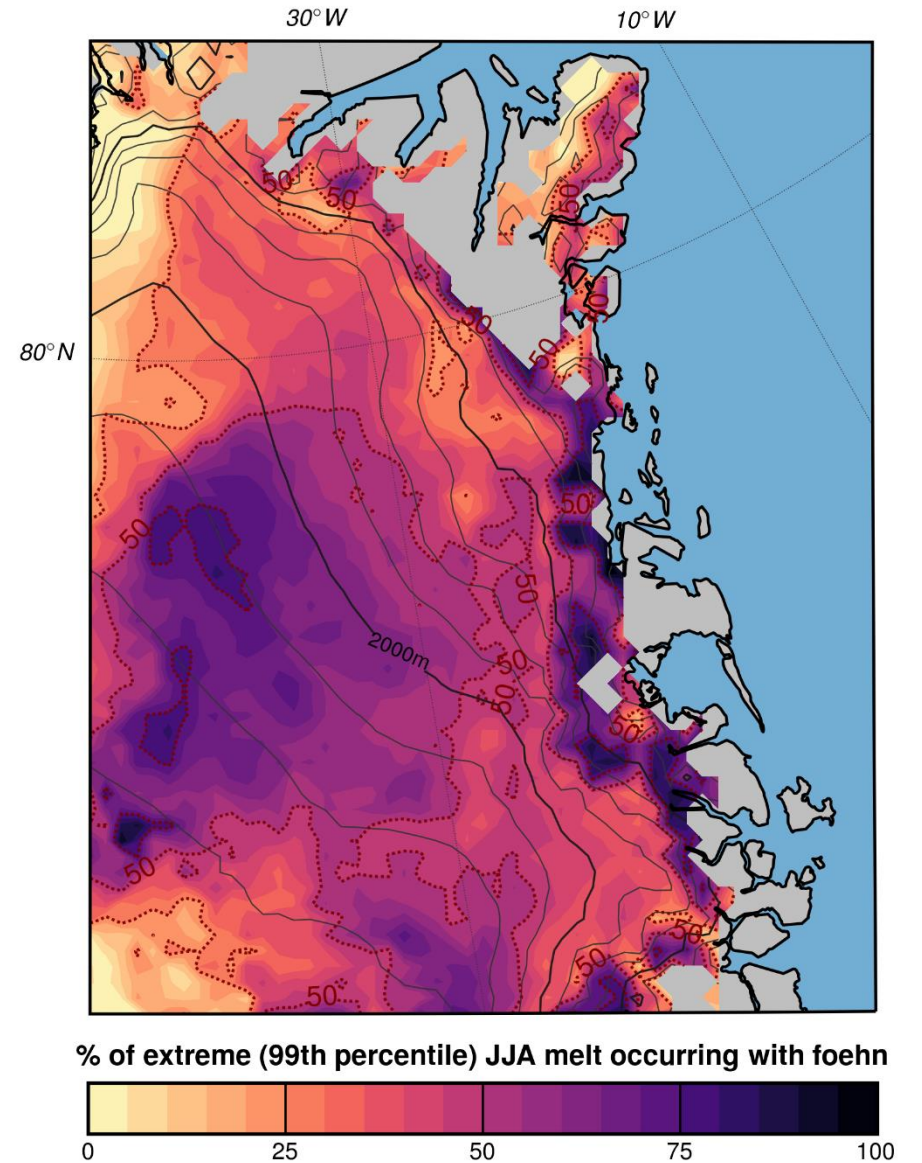
Percentage of JJA melt occurring with föhn (0–48 hrs after NW AR)



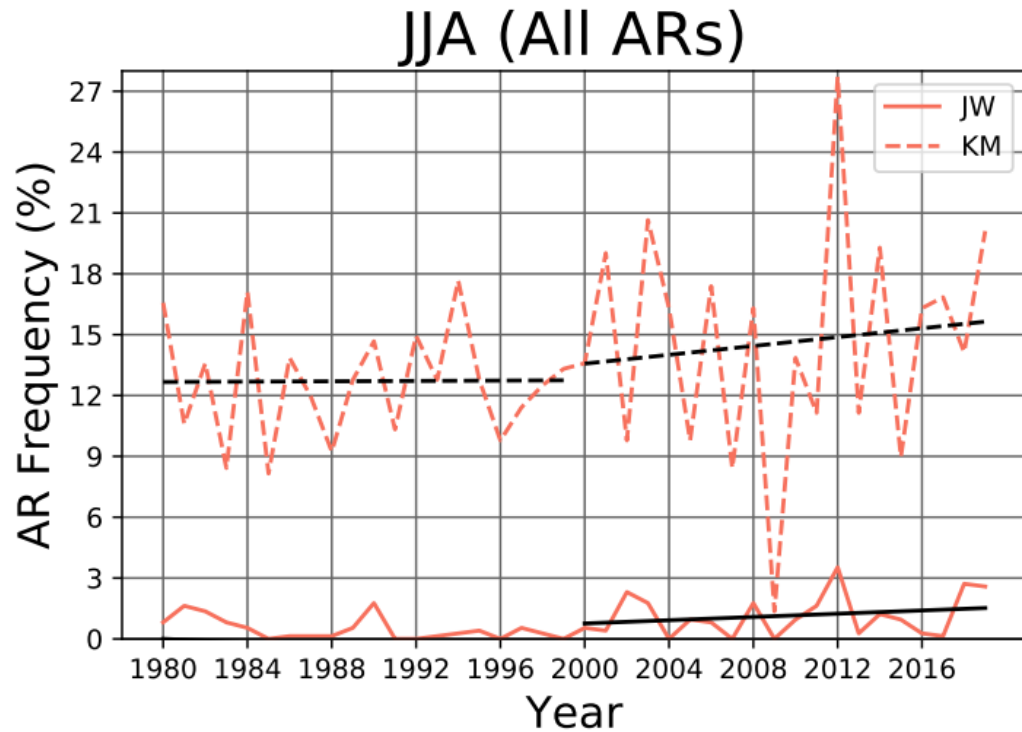
Percentage of JJA melt occurring with föhn (0–48 hrs after > 90th percentile NW AR)

Result 2: Föhn drives melt in NE after NW ARs

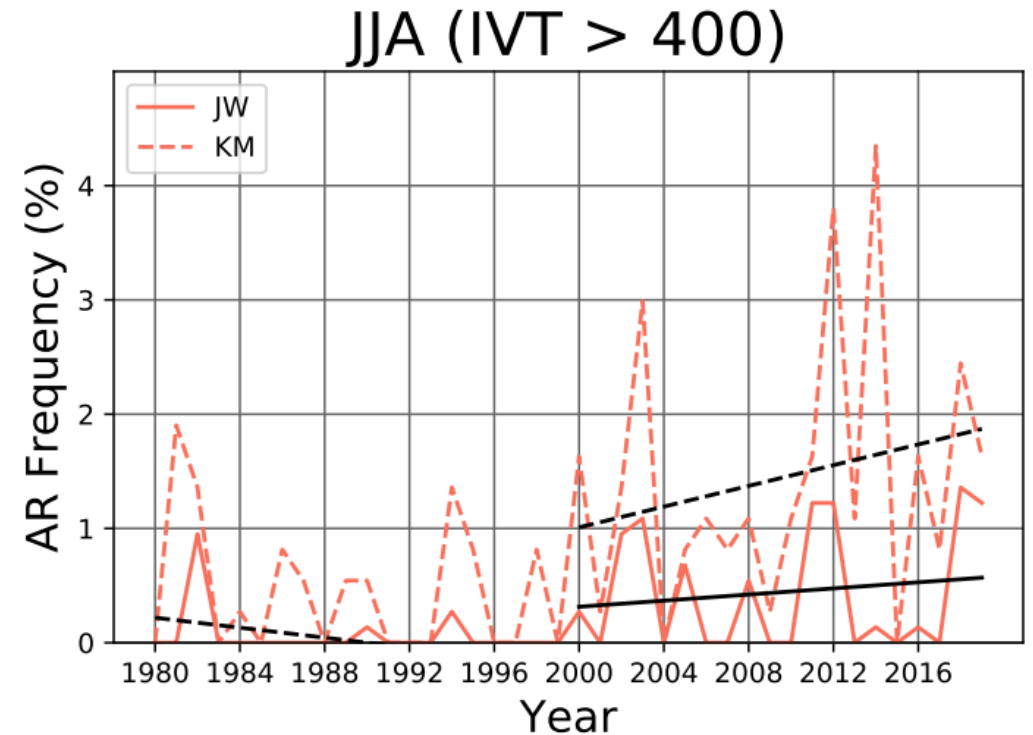
The majority of extreme (> 99th percentile) melt in lower elevations occurs during föhn conditions



Result 3: Increasing AR & föhn trends



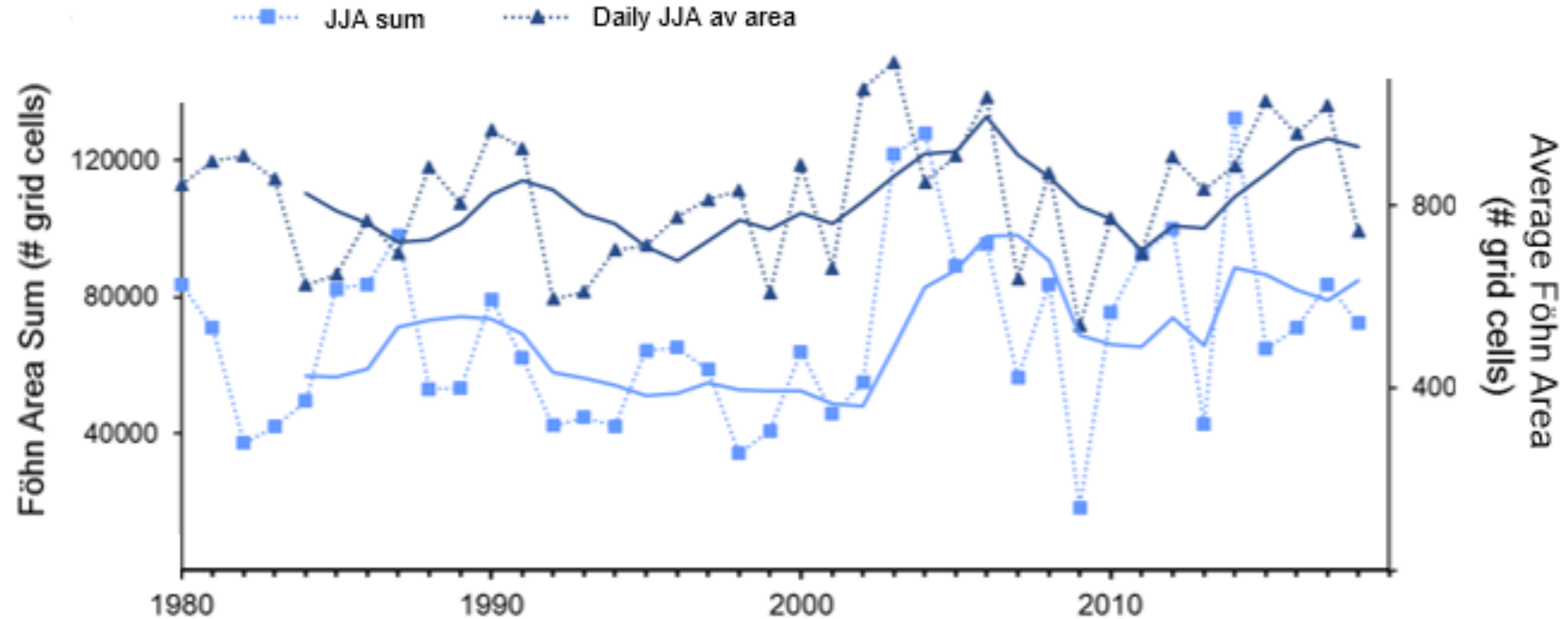
All ARs



“Intense” (IVT > 400 kg m⁻¹ s⁻¹) ARs

NW Greenland AR frequency trends from Wille (JW) and Mattingly (KM) algorithms

Result 3: Increasing AR & föhn trends



Increase in annual total NE Greenland föhn area also after 2000, coinciding with AR increase

Conclusions

- Atmospheric rivers (ARs) in northwest Greenland lead to summer melt events in the northeast, typically with a 1–3 day delay
- **Downsloping föhn winds** drive much of the melt, particularly during the most intense AR events
- Intense NW Greenland AR events and NE Greenland föhn have **increased in frequency** since ~2000

References

Mattingly, K. S., Mote, T. L., and Fettweis, X. (2018): Atmospheric River Impacts on Greenland Ice Sheet Surface Mass Balance, *J. Geophys. Res. Atmos.*, 123, 8538–8560, doi:10.1029/2018JD028714.

Mattingly, K. S., Mote, T. L., Fettweis, X., van As, D., Van Tricht, K., Lhermitte, S., Pettersen, C., and Fausto, R. S. (2020): Strong Summer Atmospheric Rivers Trigger Greenland Ice Sheet Melt through Spatially Varying Surface Energy Balance and Cloud Regimes, *J. Climate*, 33, 6809–6832, doi:10.1175/JCLI-D-19-0835.1.

Turton, J. V., Mölg, T., and Collier, E. (2020): High-resolution (1 km) Polar WRF output for 79°N Glacier and the northeast of Greenland from 2014 to 2018, *Earth Syst. Sci. Data*, 12, 1191–1202, doi:10.5194/essd-12-1191-2020.

Wille, J. D., Favier, V., Gorodetskaya, I. V., Agosta, C., Kittel, C., Beeman, J. C., et al. (2021): Antarctic Atmospheric River Climatology and Precipitation Impacts, *J. Geophys. Res. Atmos.*, 126, e2020JD033788, doi:10.1029/2020JD033788.