Meteorological Drivers of Arctic Rain-on-Snow (ROS) Events

An Examination of Two Diverse Case Studies Resulting in ROS Impacts

Jessica Voveris[1], Mark Serreze[1]
National Snow and Ice Data Center, Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder

https://nsidc.org/rain-on-snow

ROS events are classified as extreme events when they occur in the Arctic, generating a range of impacts that include flooding concerns to icing conditions for the transportation sector. These events also have the potential to cause large starvation events among native hooved animals, like caribou and reindeer. This research seeks to understand the weather patterns governing ROS conditions, from the primary causal mechanism of blocking patterns to the effects from atmospheric rivers (ARs).

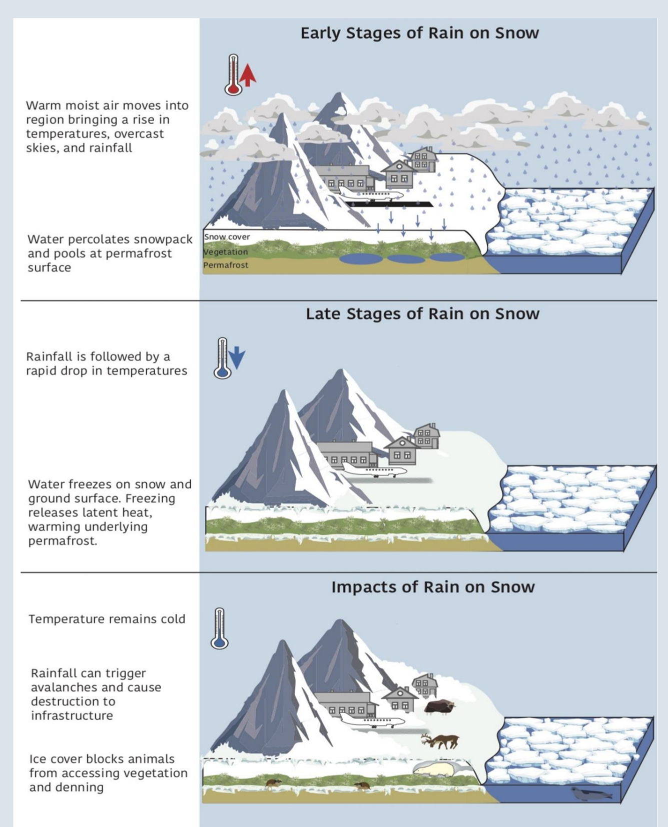
Overarching Weather Patterns

At the synoptic scale – which incorporates weather systems on spatial scales around 1000 km and temporal scales of about a week – blocking patterns are present in all cases. They also appear as the primary causal mechanism in each case. ARs (or narrow transient corridors of strong water vapor transport) influence each case. The 2016 Greenland case resulted in a direct influence from an AR, in that the AR made landfall and contributed to the ROS conditions. For the 2021 Iqaluit case, an AR was present in the North Atlantic, and a shortwave trough stripped moisture from the AR and carried it north to Baffin Island, leading to an indirect effect from an AR.

At smaller spatial scales, "warm noses" of increased air temperatures and warm air advection and corridors of enhanced moisture transport led by a low-level jet are also present in each case, albeit at different depths and strengths.

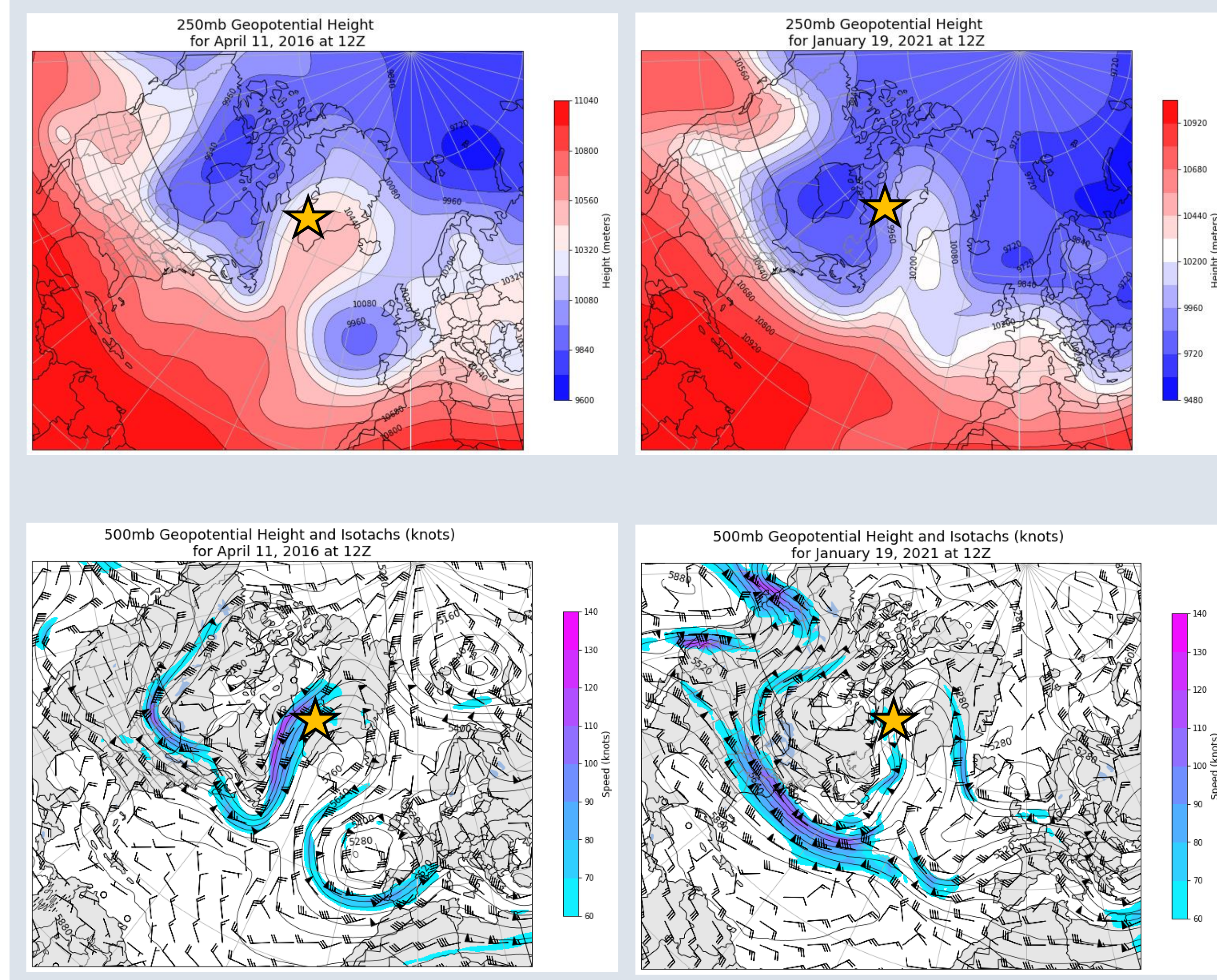
Atmospheric Upper Levels:

- Right-First Panel – Blocks can be seen in the 250-mb geopotential height contours, characterized by persistence, contour shape, and meridional (south-to-north or north-to-south) flow, as seen in the 500-mb winds with isotachs.
- Right-Second Panel – ARs were present in each case, as seen in the integrated water vapor transport (IVT) panel, and the moisture source originated from the tropics, which can be viewed in the panel with precipitable water (PWAT) and mean sea level pressure (MSLP) overlaid.



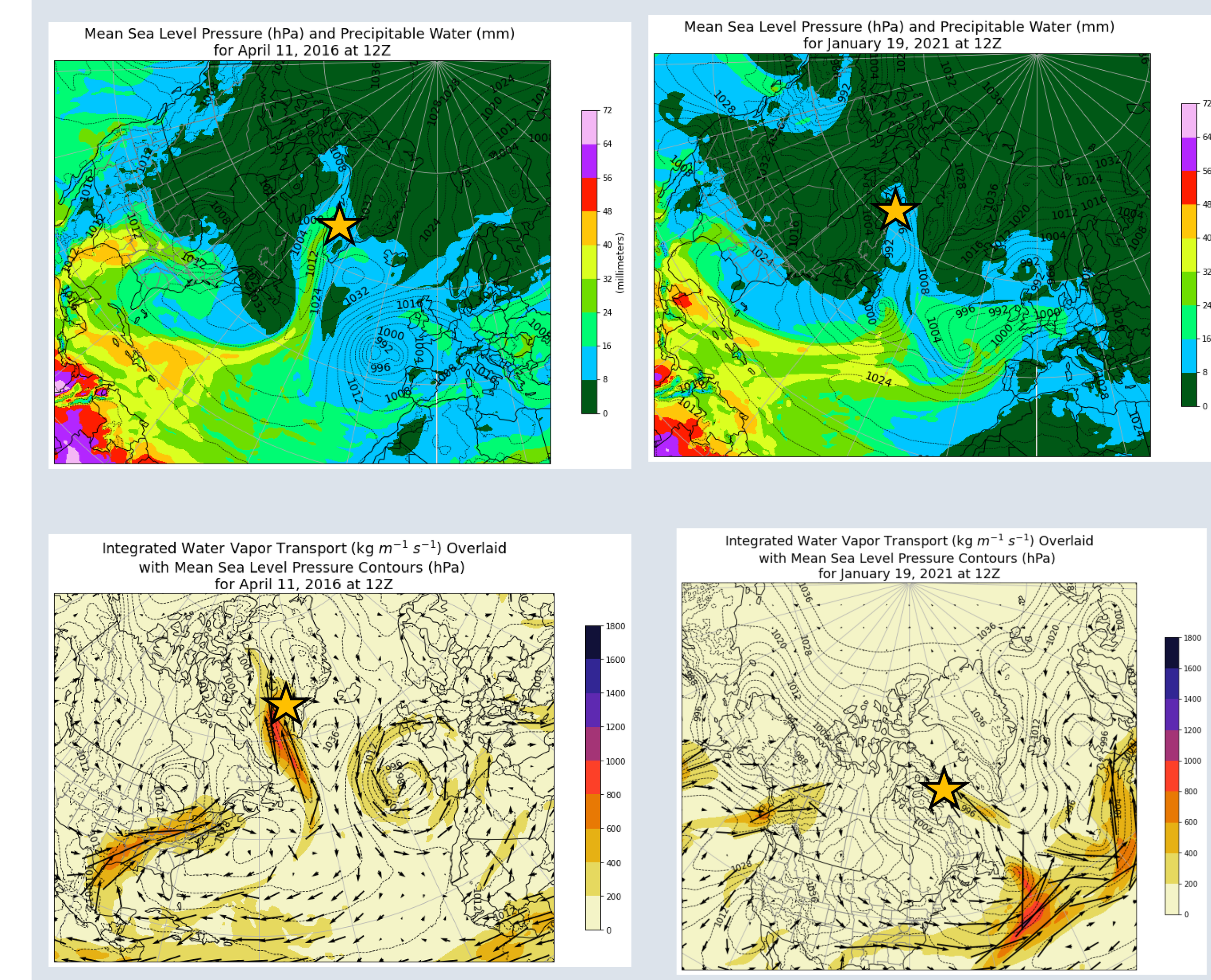
Left graphic courtesy of Serreze et al. 2021 showing the conditions that lead up to and characterize Arctic ROS occurrence

April 2016 Western Greenland Event | **January 2021 Iqaluit, Canada, Event**



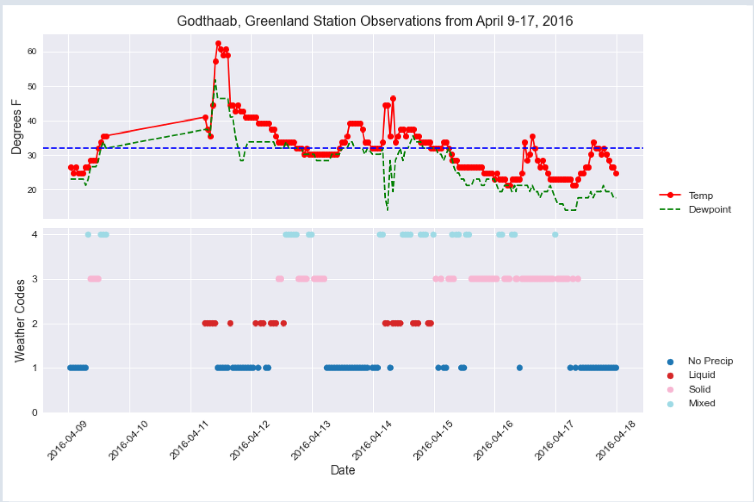
Orange star marks the location of the ROS event

April 2016 Western Greenland Event | **January 2021 Iqaluit, Canada, Event**

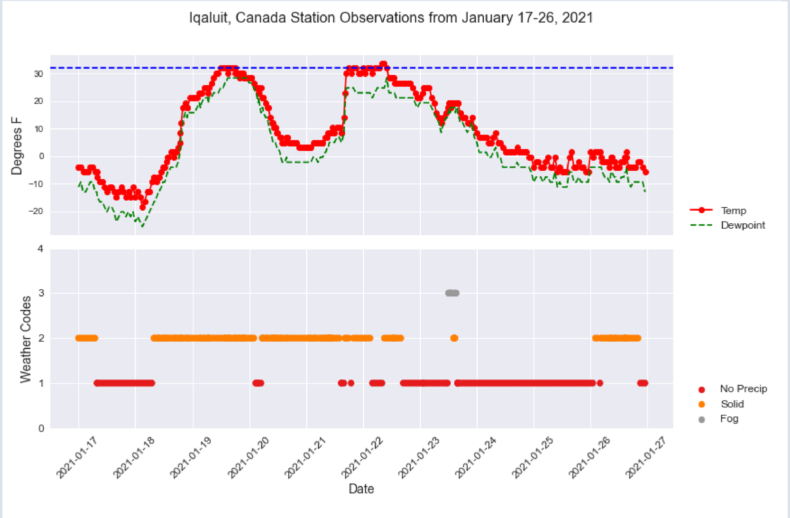


Orange star marks the location of the ROS event

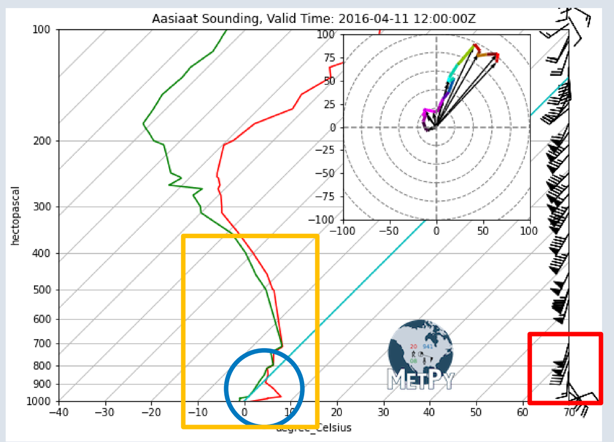
Insights from Observational Data



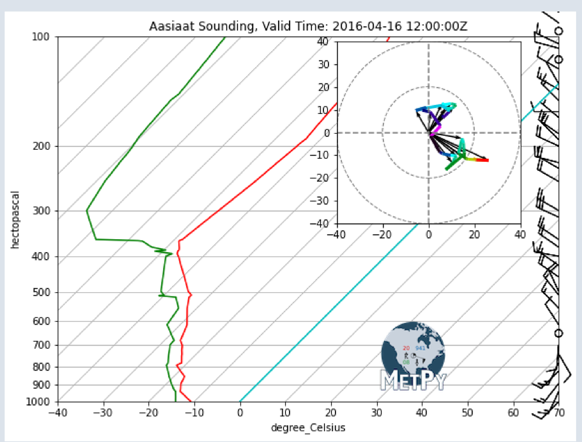
Station Data from Godthaab, Greenland, in April 2016



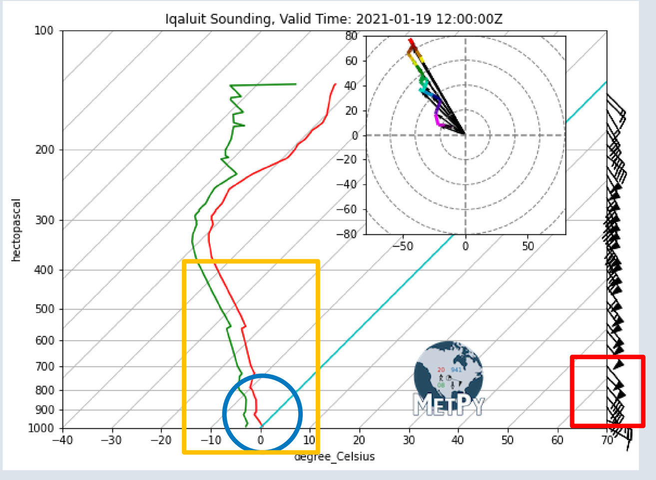
Station Data from Iqaluit, Canada, in January 2021



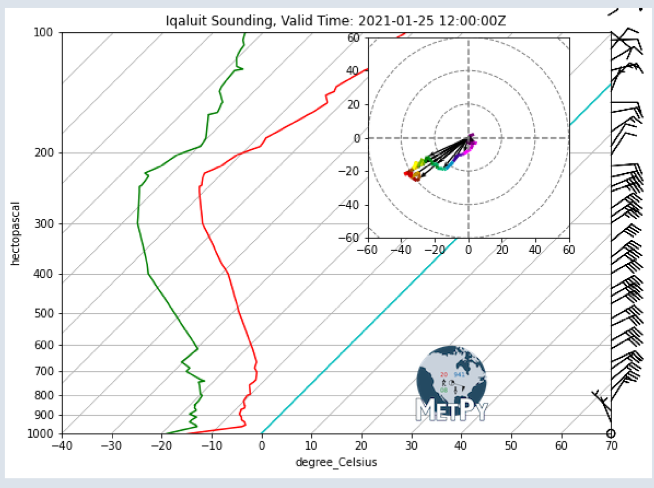
Sounding During the 2016 Greenland ROS Event



Sounding Taken Post Greenland ROS Event



Sounding During the 2021 Iqaluit ROS Event



Sounding Taken Post Iqaluit ROS Event

The soundings show air temperatures (red line), dewpoint temperatures (green line), and wind speed and directions as barbs on the right-hand side plotted with height. The plots also include a hodograph showing winds plotted in polar coordinates.

The major features to gleam from the soundings taken during the ROS event include the low-level warm nose or layer above freezing (blue circle), the strong low- to mid-level winds (red square), and the high moisture throughout the atmospheric column (yellow box).

The post-ROS event sounding shows how these features change with a changing air mass.

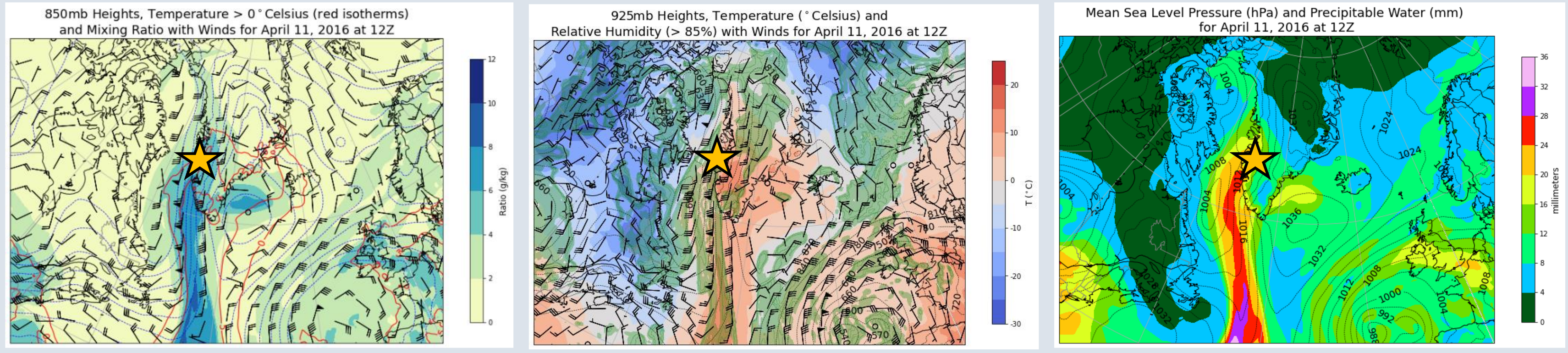
Divergent Weather Characteristics at the Middle to Low Levels:

850-mb Weather Analysis – The Greenland case shows a corridor of high mixing ratio values (high moisture) corresponding with a large area of above freezing temperatures across southern Greenland. However, Iqaluit has an area of lower mixing ratio values, with some moisture transport, but no area of temperatures above freezing at this level.

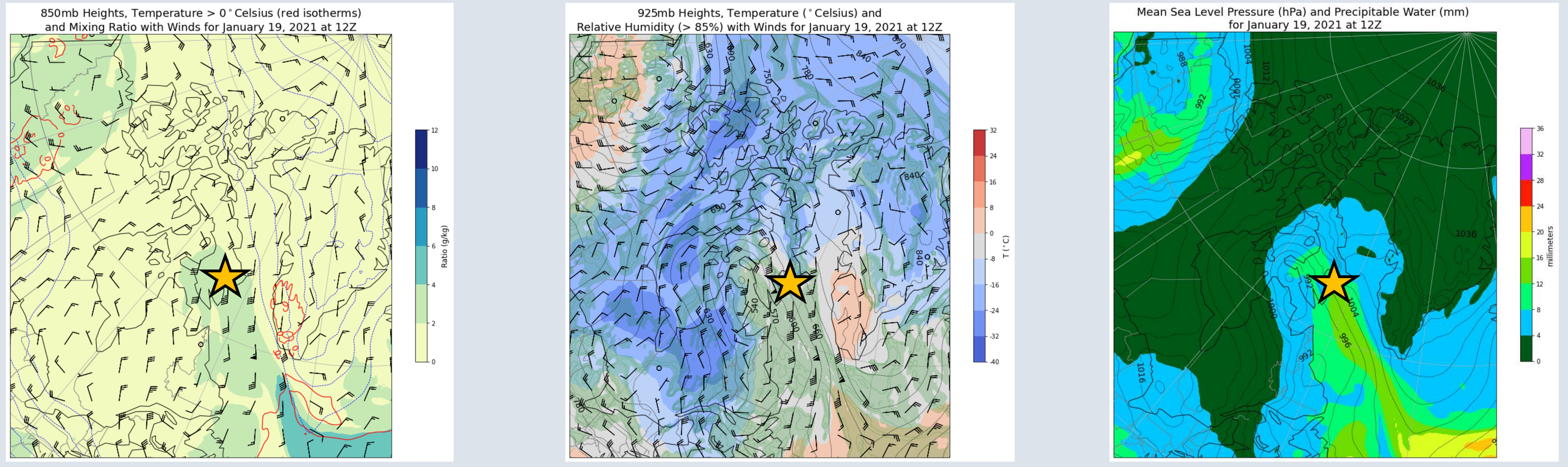
925-mb Weather Analysis – Well above freezing air temperatures are found at this level, and winds indicate both warm air advection and moisture transport in the Greenland case. Wind speeds are also strong (>50 knots) for this event. For Iqaluit, air temperatures are in the -8° to 0° C range, so they are not above freezing at this level. Despite this, wind speeds are elevated with this case as well, between 40 and 45 knots, with continuing warm air and moisture transport.

PWAT/MSLP Analysis – Both cases show above average PWAT being carried into the location of interest by low-pressure systems, with moisture originating south.

April 2016 Western Greenland Event



January 2021 Iqaluit, Canada, Event



Orange star marks the location of the ROS event

May 13. 2022

References:
Serreze, Mark C., Julia Gustafson, Andrew P. Barrett, Matthew L. Druckenmiller, Shari Fox, Jessica Voveris, Julienne Stroeve, et al. 2021. "Arctic Rain on Snow Events: Bridging Observations to Understand Environmental and Livelihood Impacts." *Environmental Research Letters* 16 (10): 105009. https://doi.org/10.1088/1748-9326/ac269b.