The Influence of Atmospheric Rivers on High-Latitude Wintertime Precipitation

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Collaborators: Kyle Mattingly[3], Mark Kulie[4] Joe Munchak[5], Mareile Wolff[6]

Nov 7, 2019

NASA PMM Science Team Meeting

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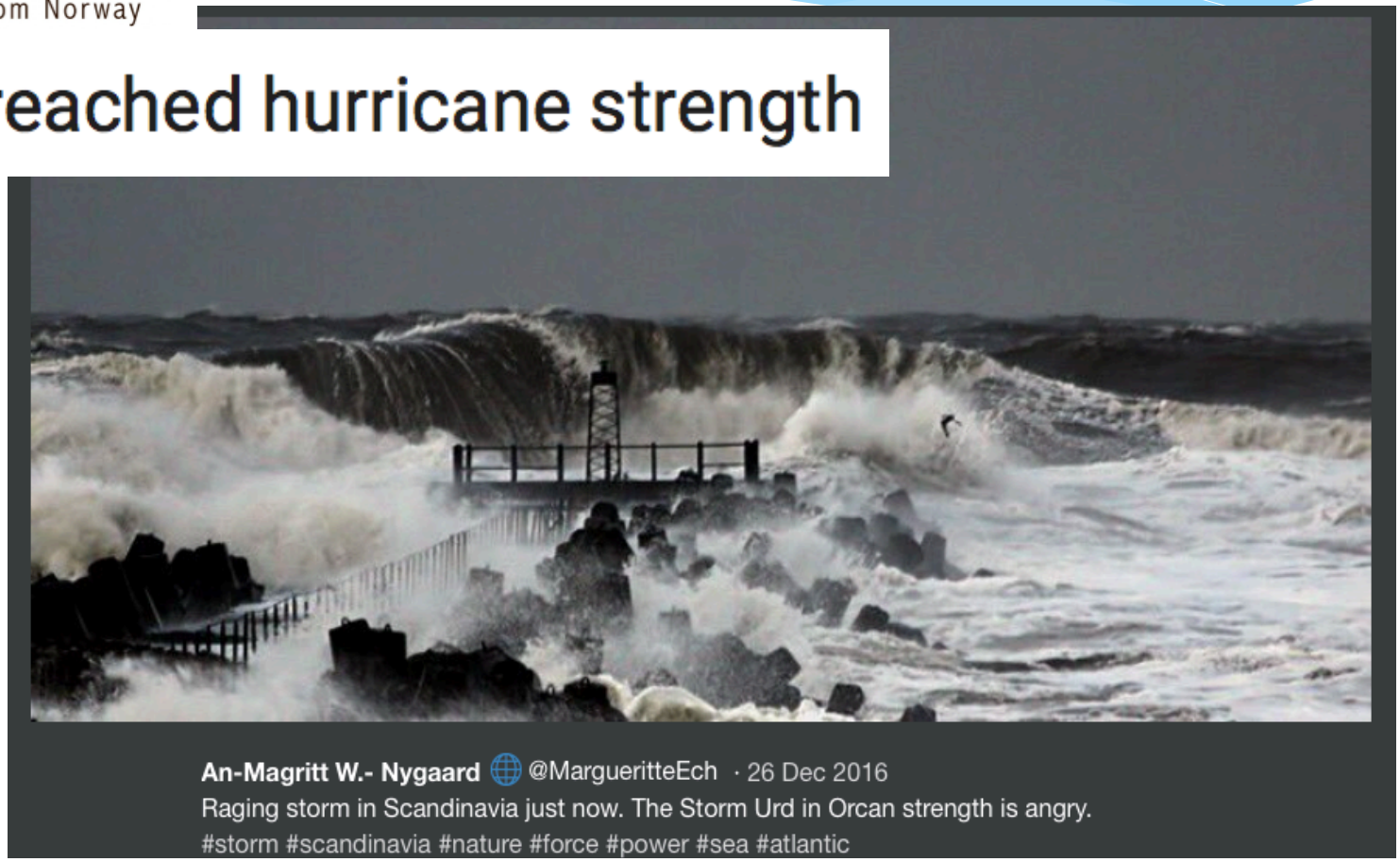
5 NASA Goddard Space Flight Center, Greenbelt, Maryland
6 Norwegian Meteorological Institute, Oslo, Norway

This work is funded under NASA Grant # 80NSSC19K0712

Extreme Storm Urd – December 2016

NORWAYTODAY
Small and big news from Norway

'Urd' has reached hurricane strength



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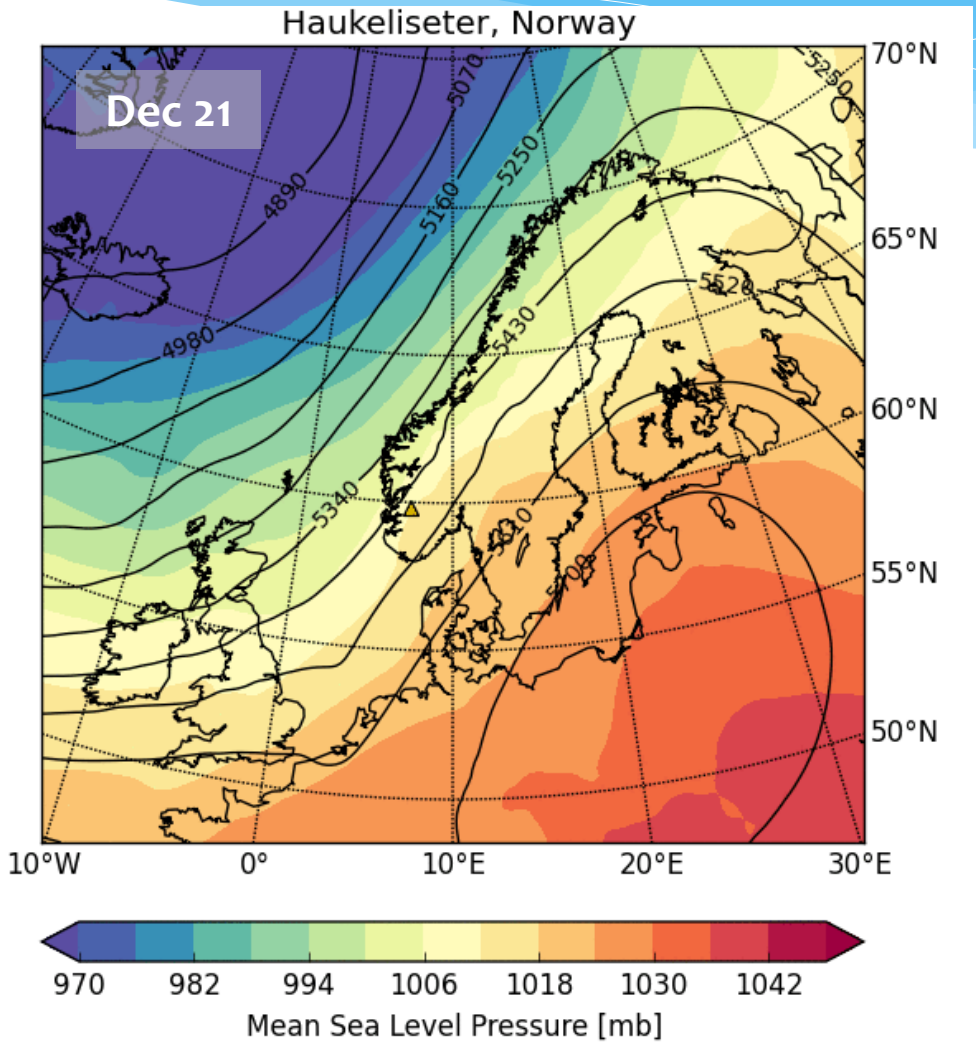

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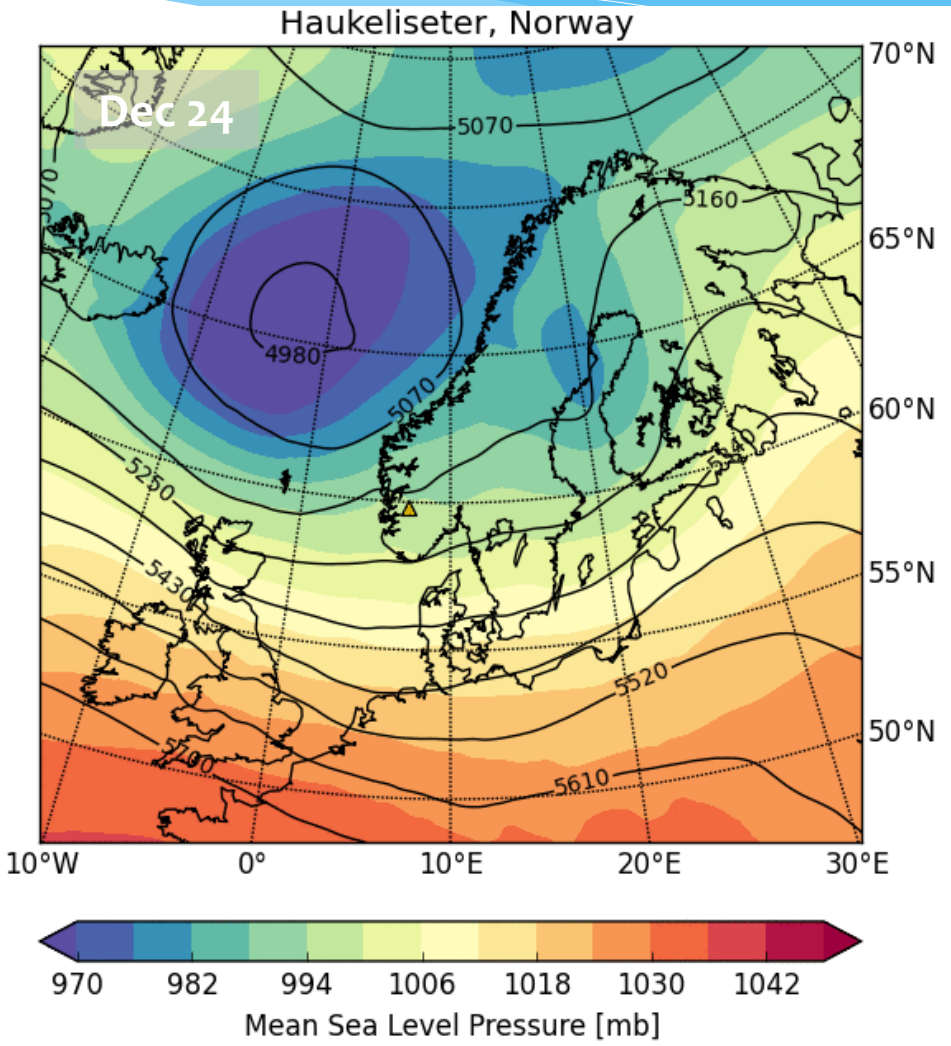

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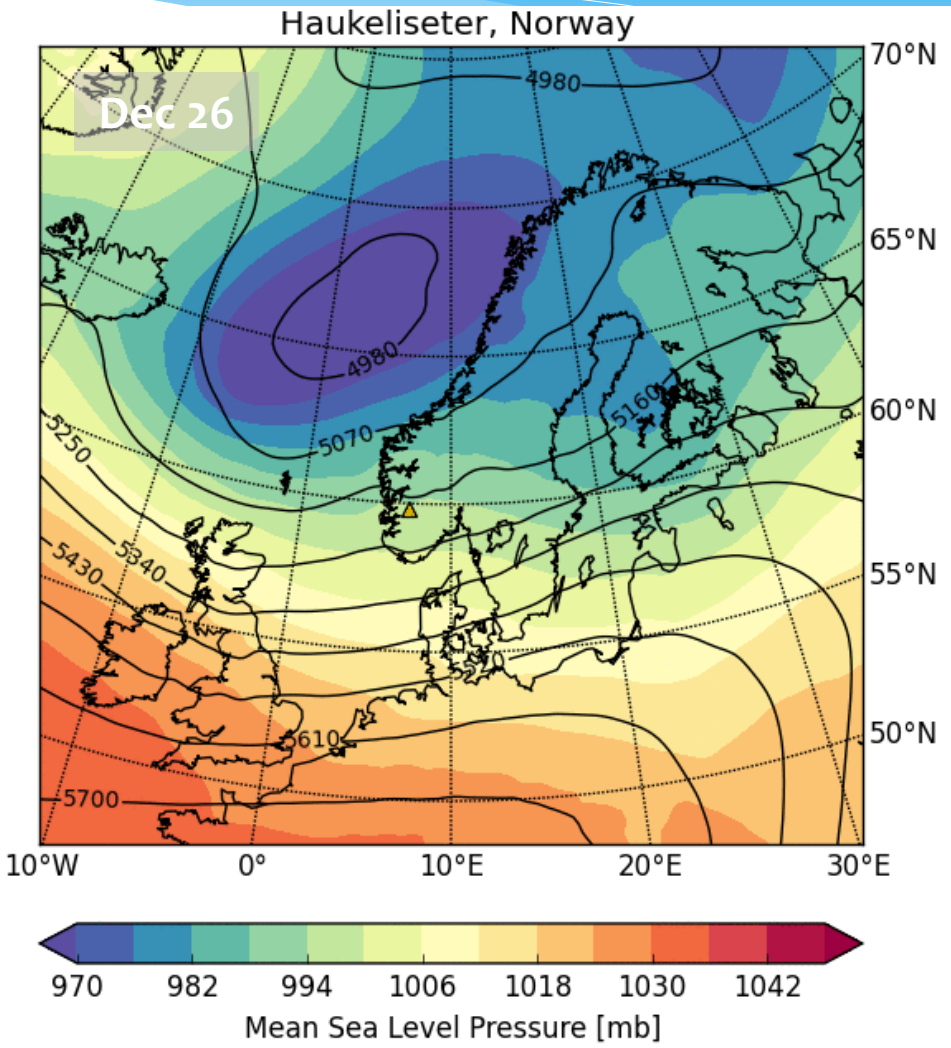

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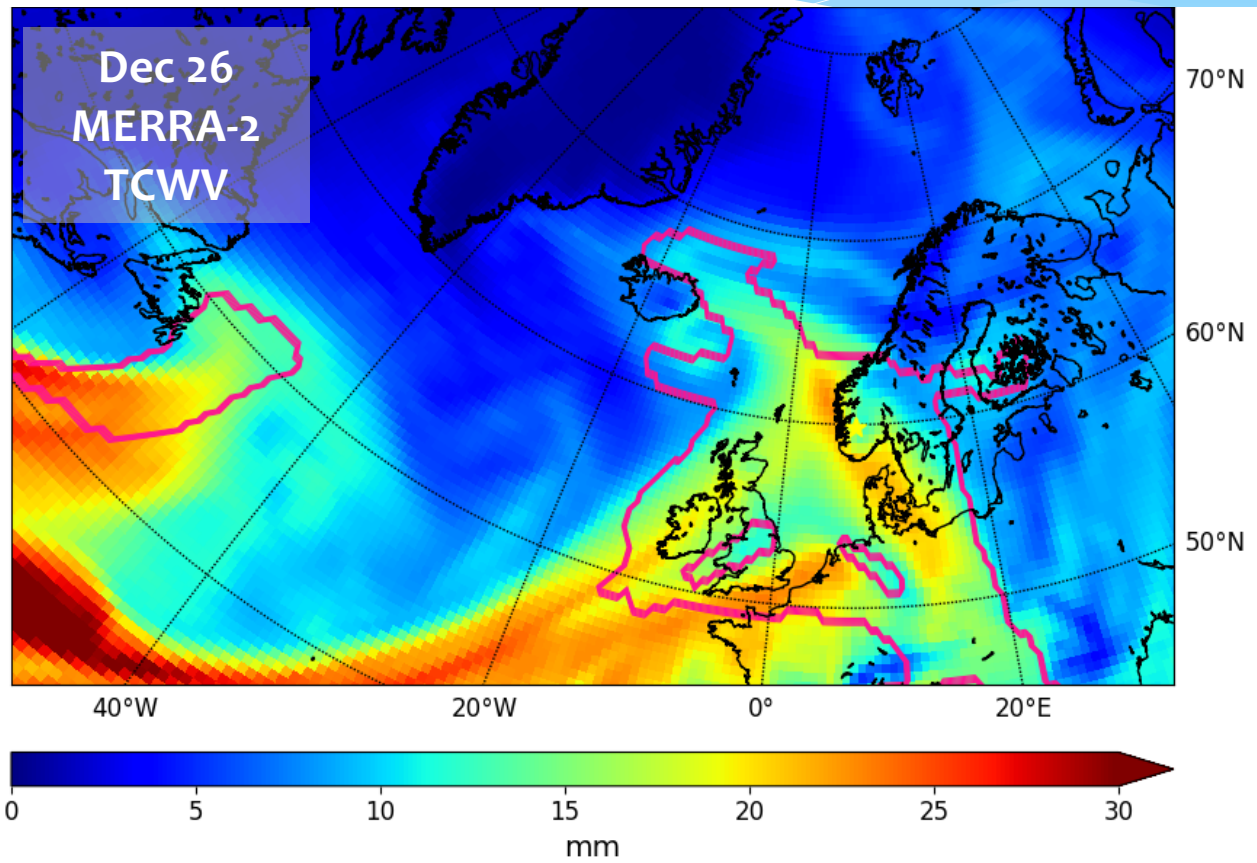


Motivating Questions

* Do extreme snow and mixed-phase events associated with **atmospheric rivers (AR)** contribute disproportionately to the water cycle in high-latitude regions?
* How well do GPM observations **characterize the structure and intensity of snow** from AR-enhanced events?

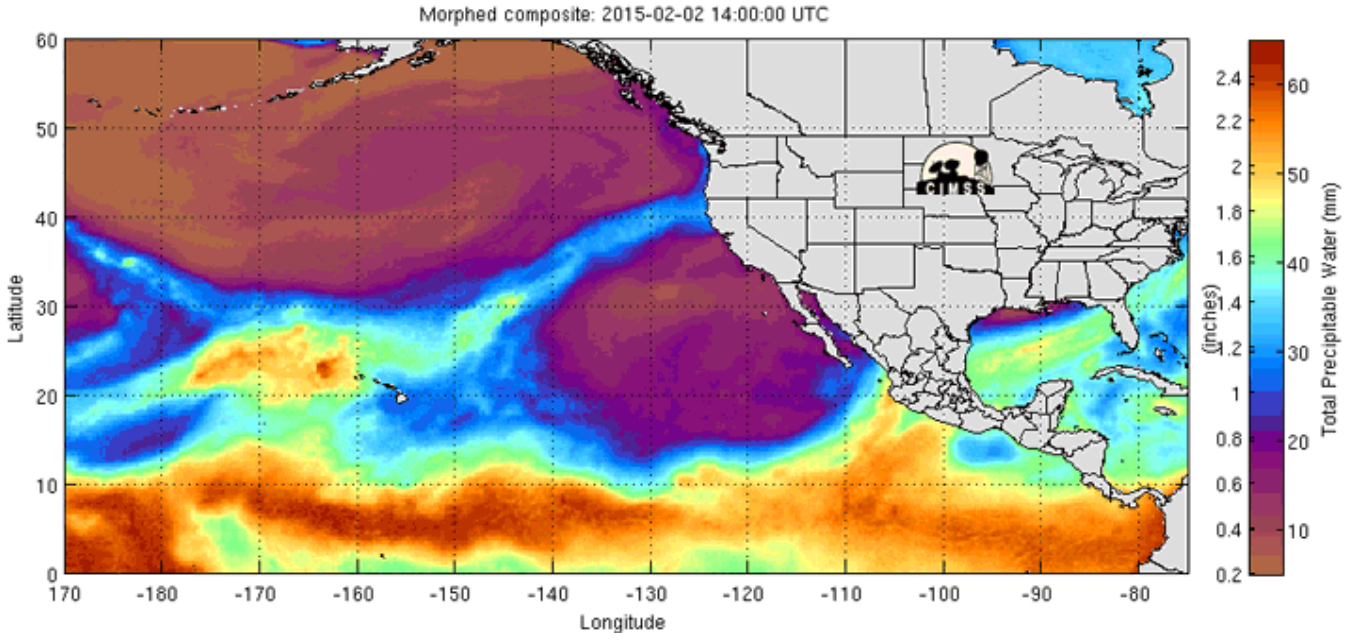
Atmospheric Rivers – What are they?

Long, narrow regions of the atmosphere that transport relatively high amounts of water vapor outside the tropics to mid- and high-latitudes

- e.g. Pineapple Express

Potentially disruptive

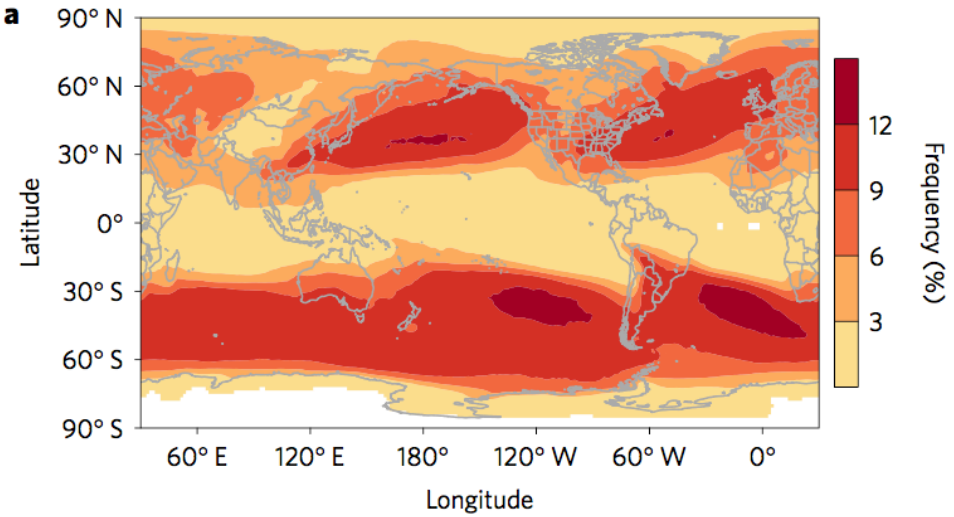
- Flooding
- Winds
- Damage



CIMSS, MIMC-TPWv2

Atmospheric Rivers – High-Latitudes

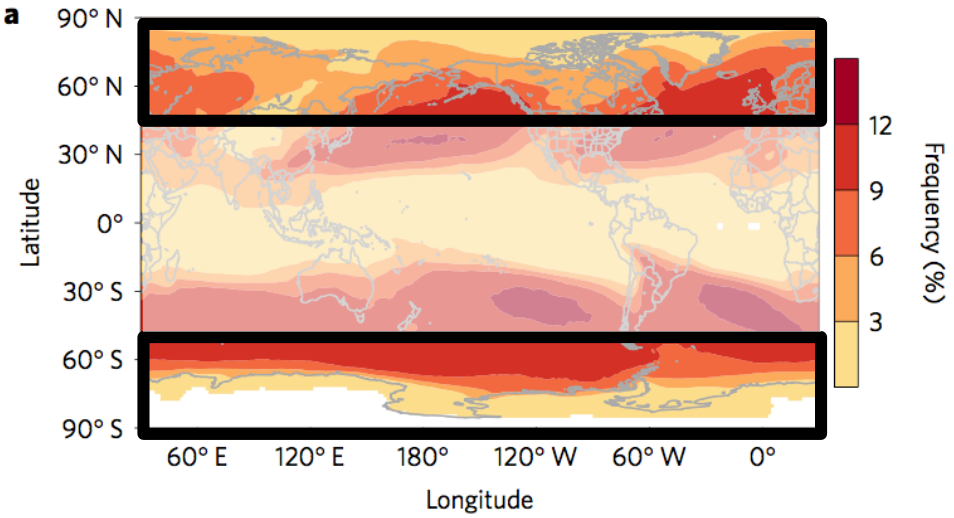
Frequency of Atmospheric River Events



Modified Figure 1 from Waliser and Guan (2017)

Atmospheric Rivers – High-Latitudes

Frequency of Atmospheric River Events



Modified Figure 1 from Waliser and Guan (2017)

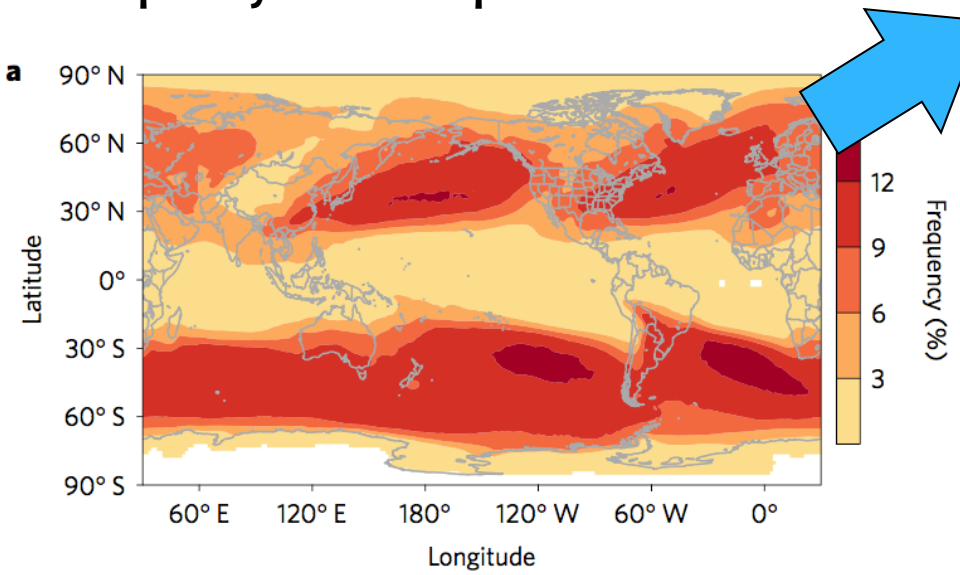
In the high-latitudes (≥ 50°N/S):

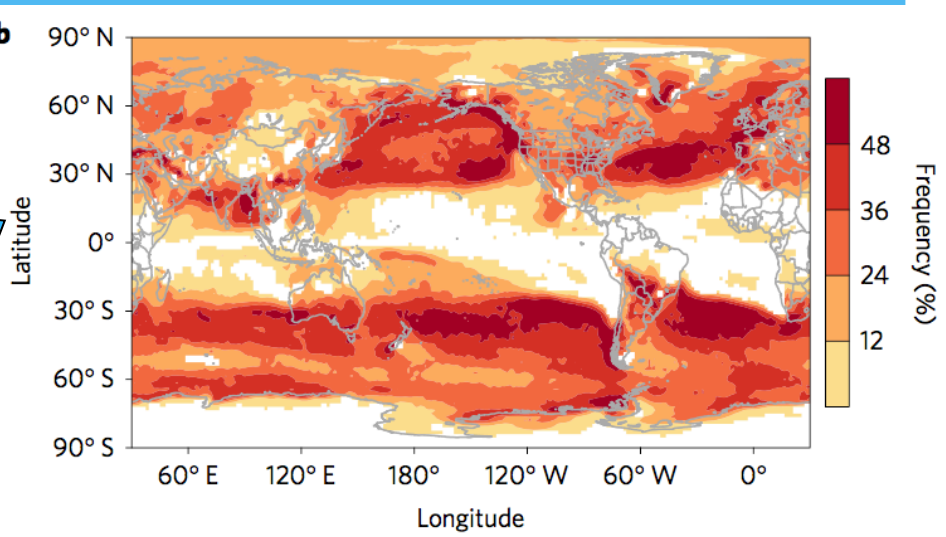
- Occurrence of ARs > 10%

Atmospheric Rivers – High-Latitudes

Extreme Winds

Frequency of Atmospheric River Events





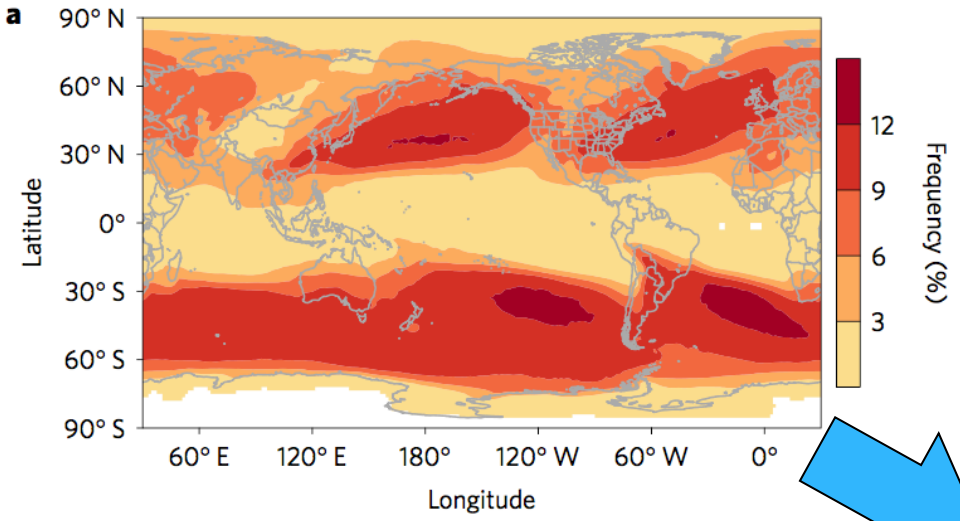
Modified Figure 1 from Waliser and Guan (2017)

In the high-latitudes (≥ 50°N/S):

- ~50% AR events have extreme winds at landfall

Atmospheric Rivers – High-Latitudes

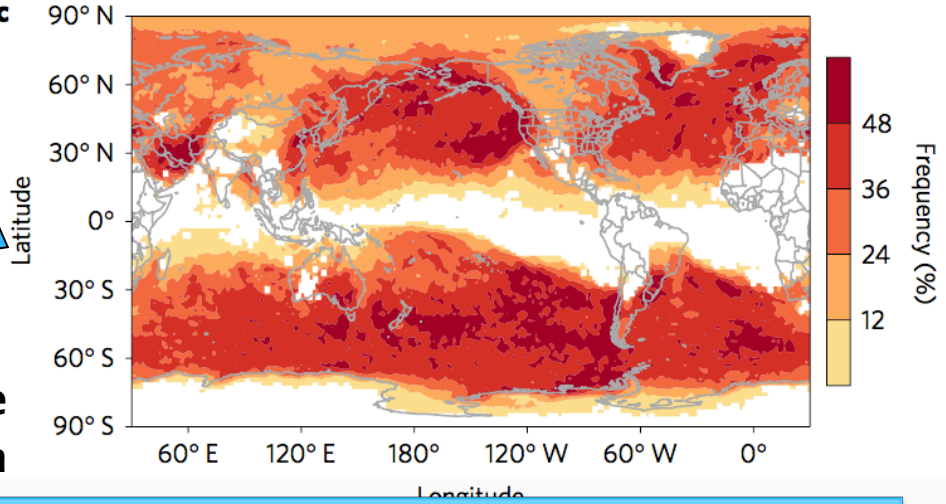
Frequency of Atmospheric River Events



Modified Figure 1 from Waliser and Guan (2017)

In the high-latitudes (≥ 50°N/S):

- >40% AR events are associated with extreme precipitation

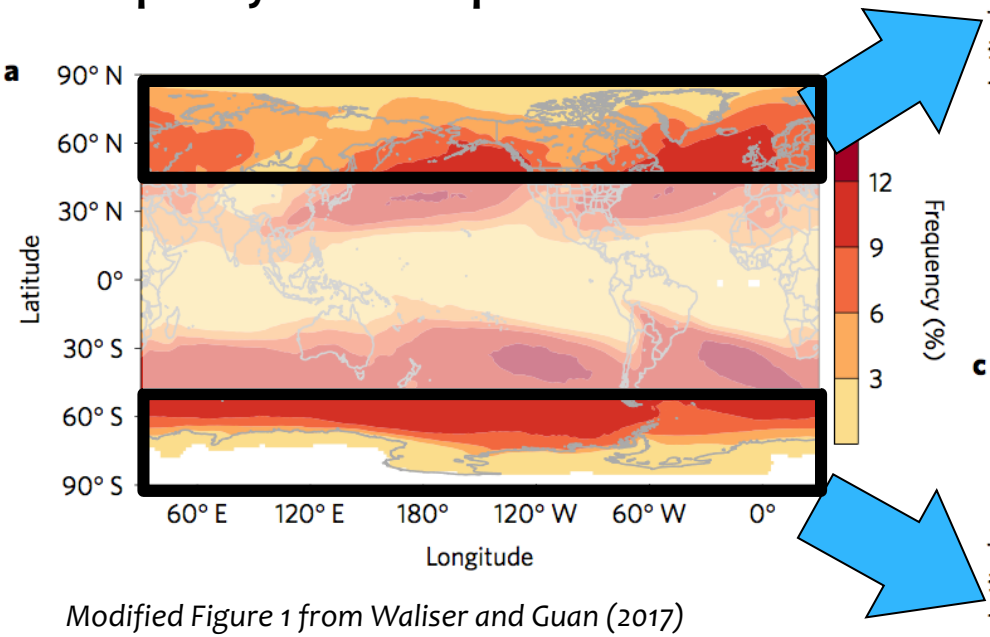


Extreme Precipitation

Atmospheric Rivers – High-Latitudes

Extreme Winds

Frequency of Atmospheric River Events



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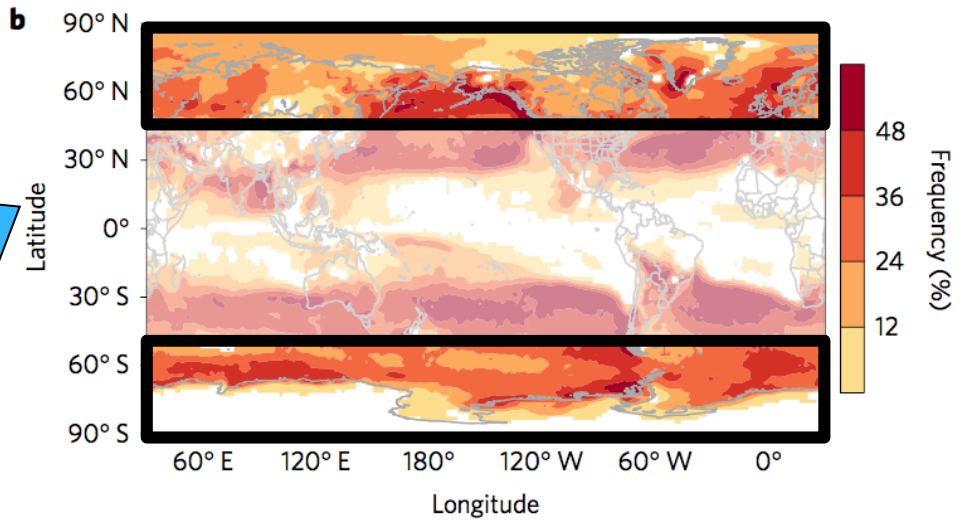
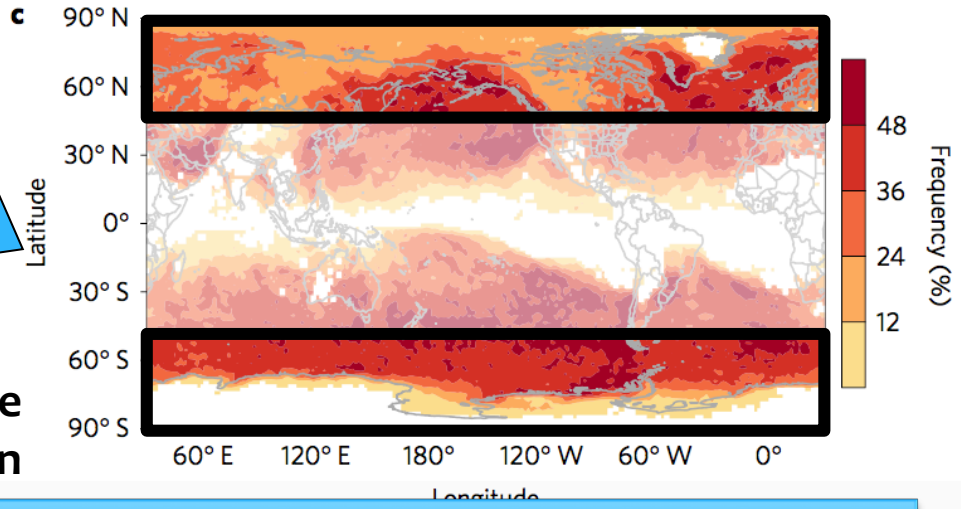




Extreme Precipitation

Integrated Water Vapor Transport

Integrated Water Vapor Transport = IVT

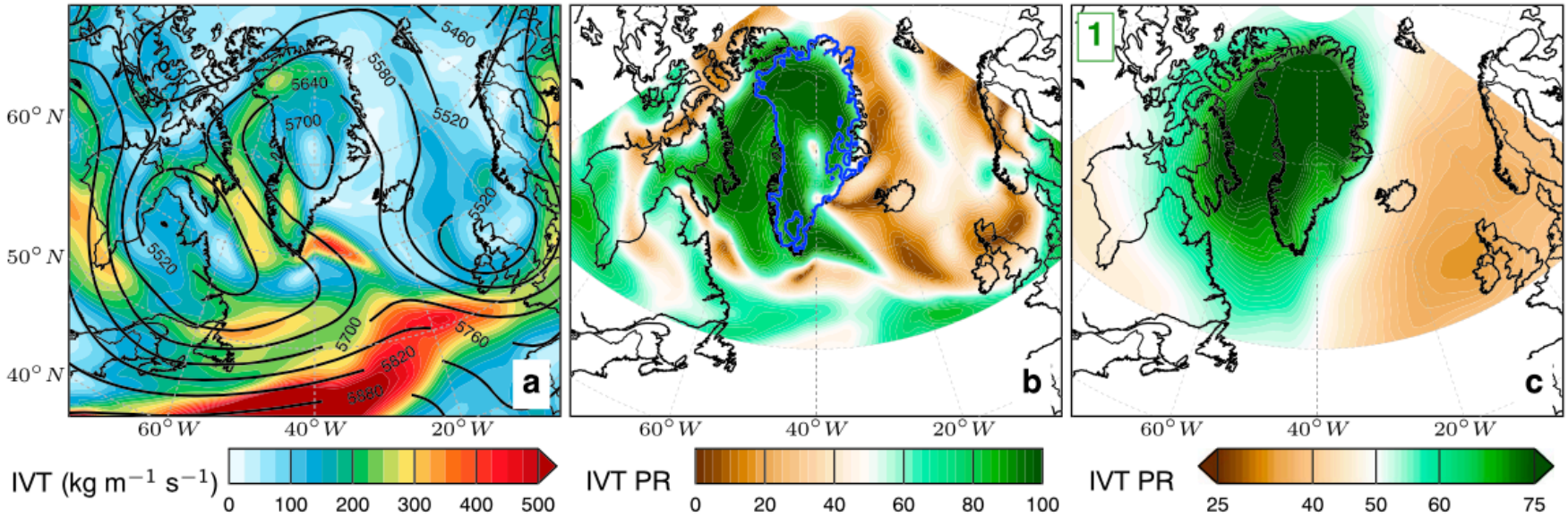
Collaborator: **Kyle Mattingly** (Rutgers University)

Mattingly et al., Geophysical Research Letters, 2016

doi: 10.1002/2016GL070424

$$IVT = \frac{1}{g}\int_{1{,}000\ hPa}^{200\ hPa} qV\ dp$$

MERRA-2:
specific humidity, winds



Atmospheric Rivers – Detection

$$IVT = \frac{1}{g}\int_{1{,}000\ hPa}^{200\ hPa} qV\ dp$$

Intensity:

Integrated Water Vapor Transport = IVT

Raw IVT threshold of >150 kg m^{-1} s^{-1}

IVT Percentile Rank of >85th %-ile

Table 1
Summary of AR Identification Criteria

	Raw IVT	IVT PR	Minimum size	Location	Length	Length-to-width ratio	Zonal transport component	Meridional transport component
Criterion applied to potential AR objects	>150 kg m^{-1} s^{-1}	>85th %-ile	>150 reanalysis grid points (0.5° × 0.5°)	Some part of object located poleward of 10°N	>1500 km	>1.5	*u* wind >2 m s^{-1} (from west) if object centroid is south of 35°N	*v* wind >0 m s^{-1} (from south) if object centroid is south of 70°N
Purpose/ other notes	Relatively low threshold accounts for lesser magnitude of moisture transport in higher latitudes		First pass which reduces number of objects processed by algorithm in subsequent tests		Great circle distance between the two most distant perimeter points of object	"Effective Earth surface width"—object length divided by object Earth surface area	Filters out zonal tropical moisture plumes with east-to-west moisture transport	Ensures that ARs transport moisture poleward, but allows for high-latitude ARs approaching Greenland from Arctic

Mattingly et al., JGR, 2018

Atmospheric Rivers – Detection

Size

Length and "narrowness"

Length threshold of >1500 km

Length to width ratio >1.5

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Atmospheric Rivers – Detection

Collaborator: **Kyle Mattingly** (Rutgers University)

Mattingly et al., Journal of Geophysical Research: Atmospheres, 2018

doi: 10.1029/2018JD028714

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Atmospheric Rivers – Detection

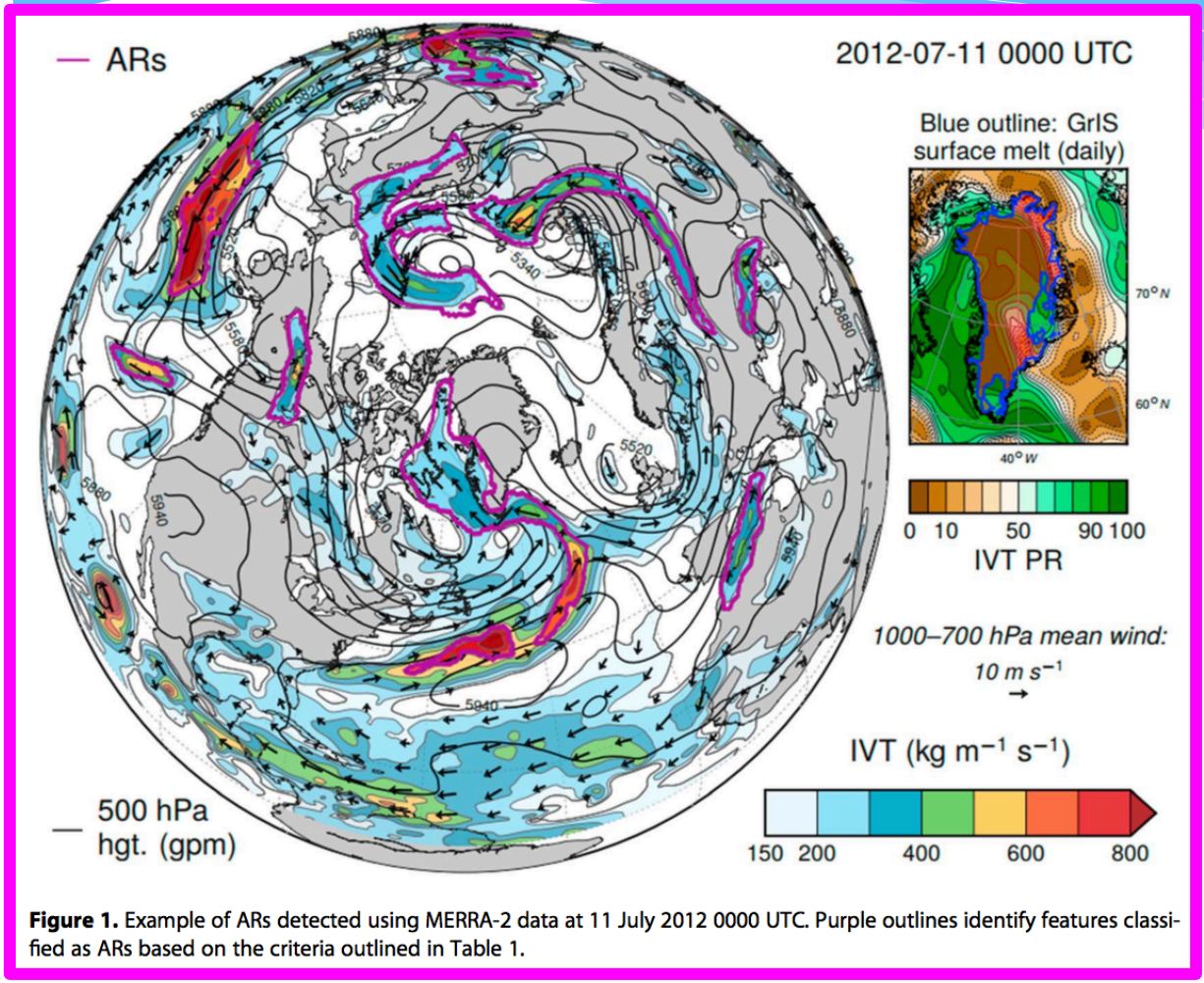


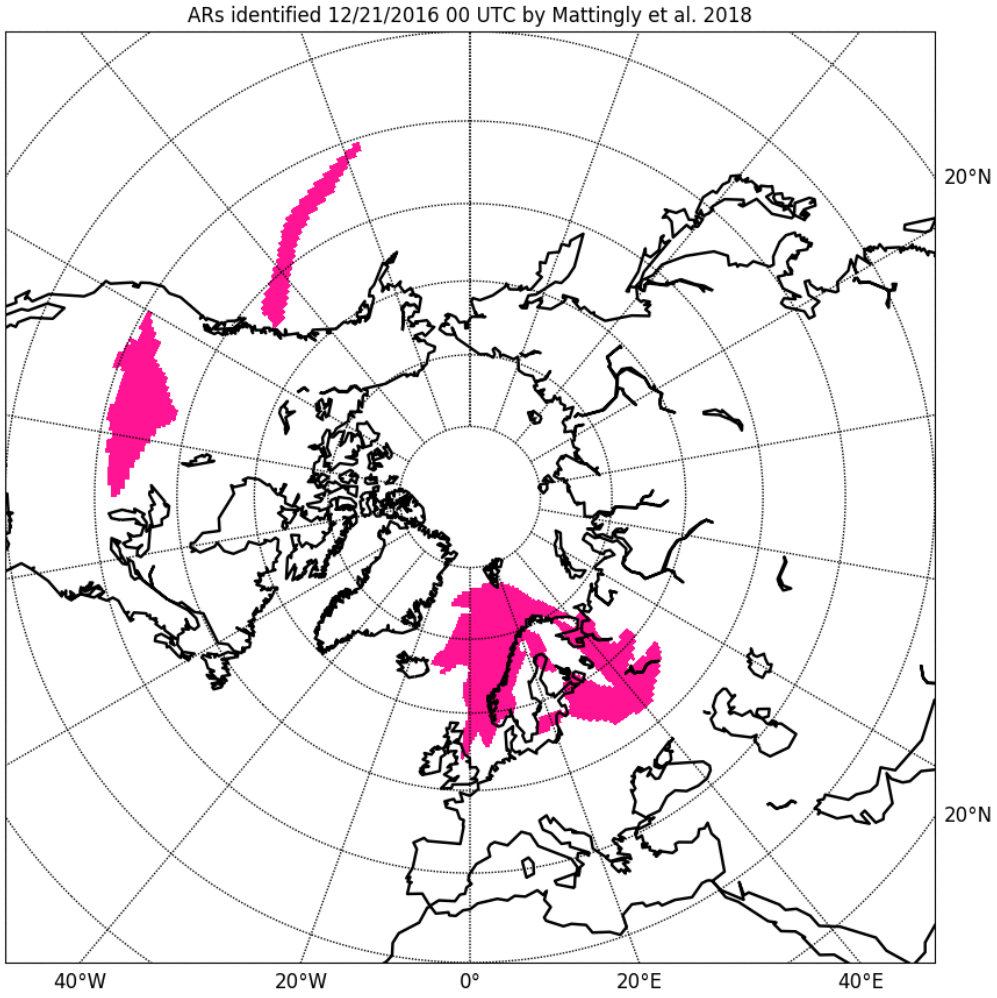
Figure 1. Example of ARs detected using MERRA-2 data at 11 July 2012 0000 UTC. Purple outlines identify features classified as ARs based on the criteria outlined in Table 1.

AR identification database for Northern Hemisphere high-latitudes:

- IVT from MERRA-2
- Re-gridded to 0.5° by 0.5°
- 6-hourly resolution
- 1979 – 2018

Mattingly et al., JGR, 2018

Atmospheric Rivers – Detection



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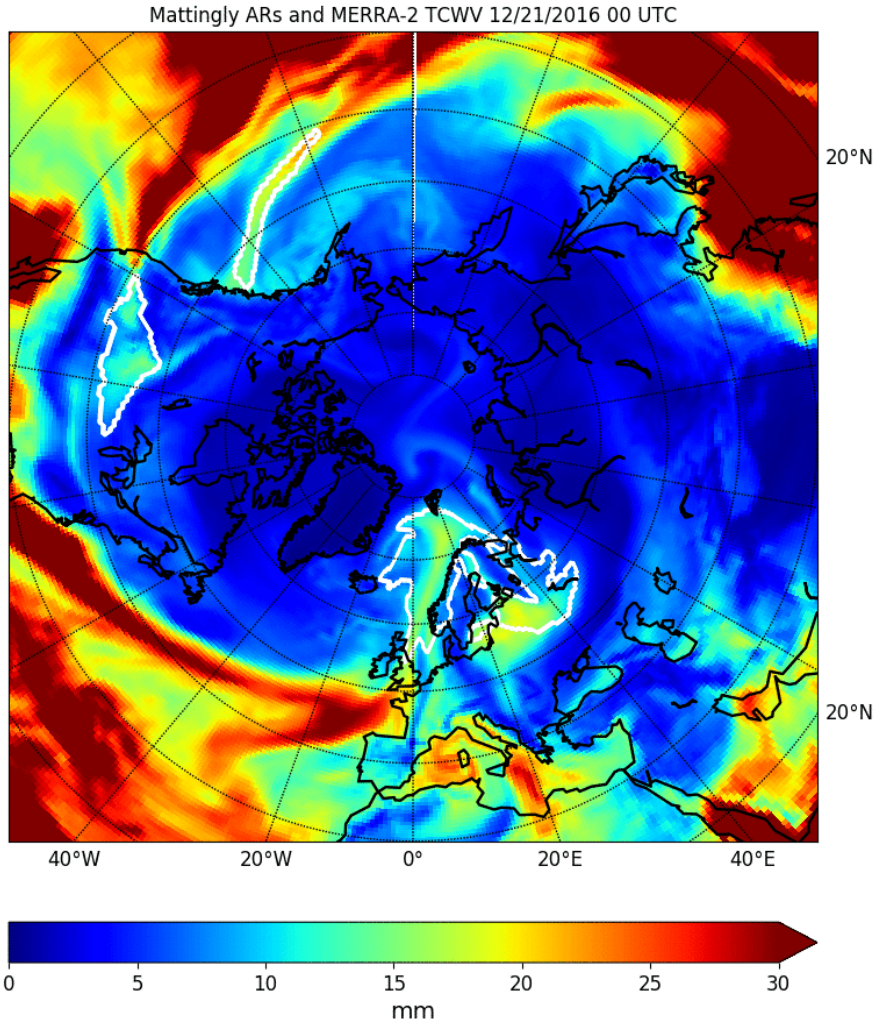
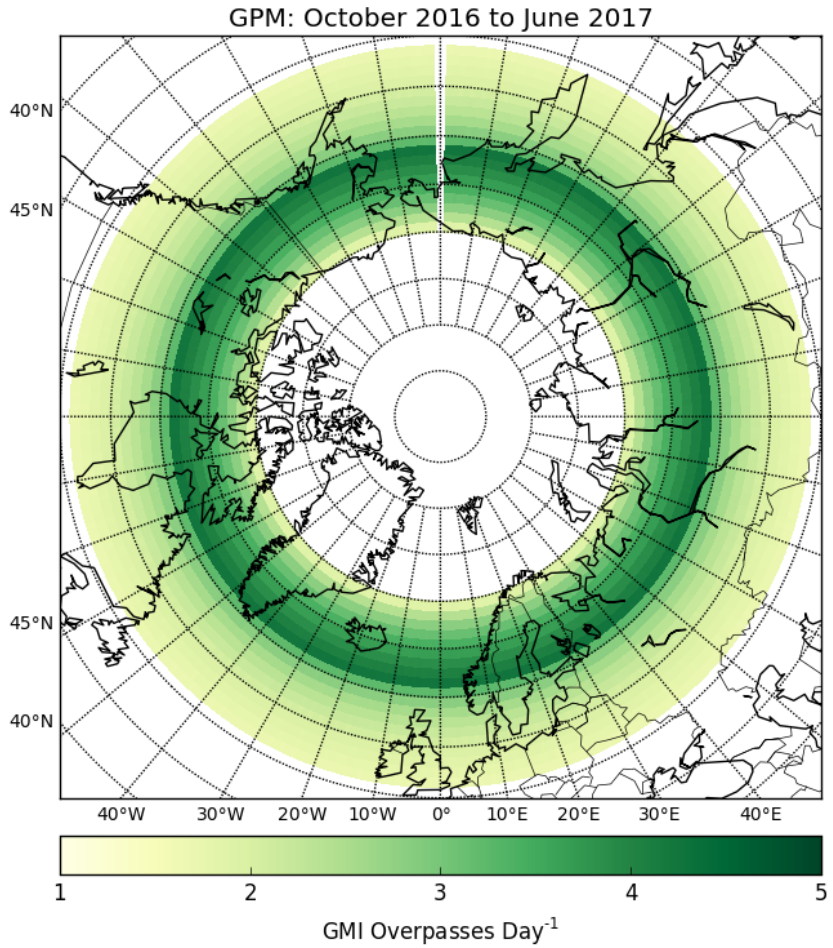
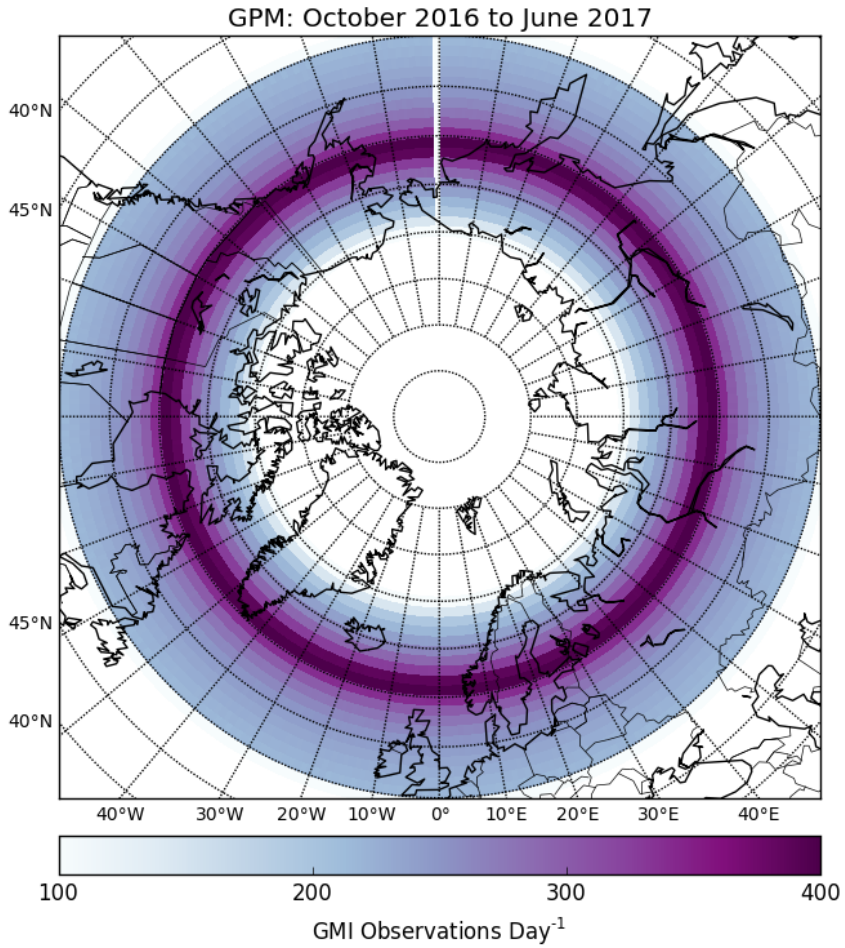


Project Objectives

* **Objective 1:** Leverage the **abundance of global GPM observations at high-latitude** to assess high-impact, **AR-influenced wintertime precipitation** events between March 2014 and present
  * Evaluate the accuracy of reanalysis-based high-latitude AR identification methods using GMI water vapor products
  * Characterize the frequency and spatial structure of AR-enhanced snow and mixed-phase precipitation using GMI brightness temperatures and snow rate products (GPROF) and examine the temporal evolution of these extreme events

GPM Orbit – High-latitude Advantage





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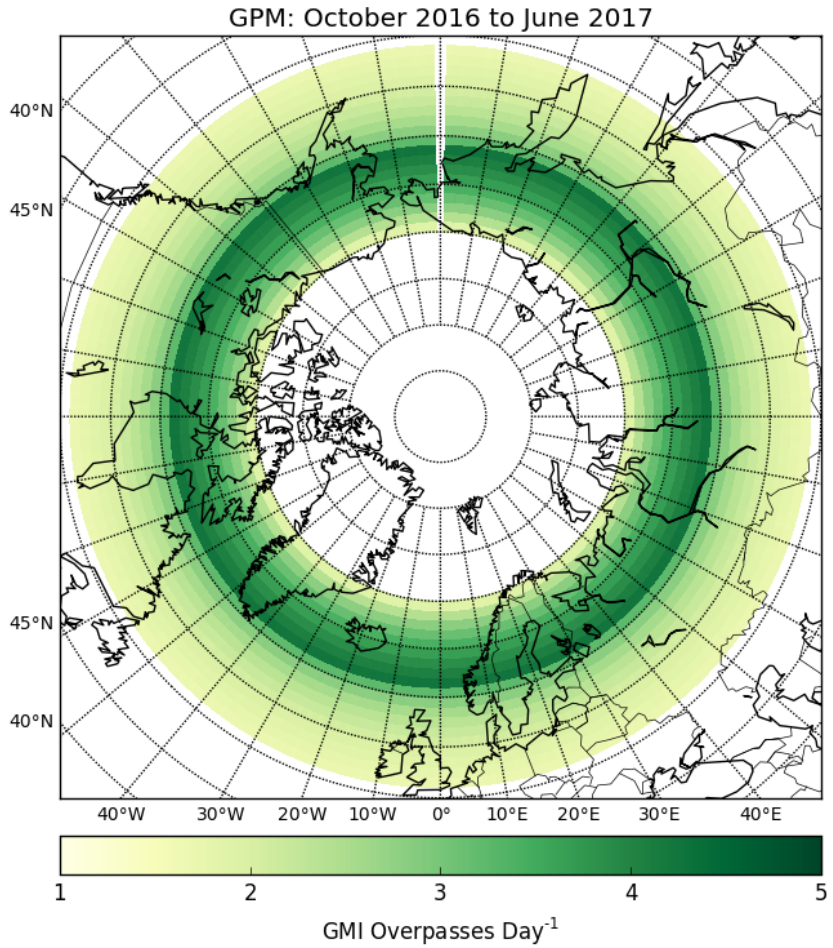


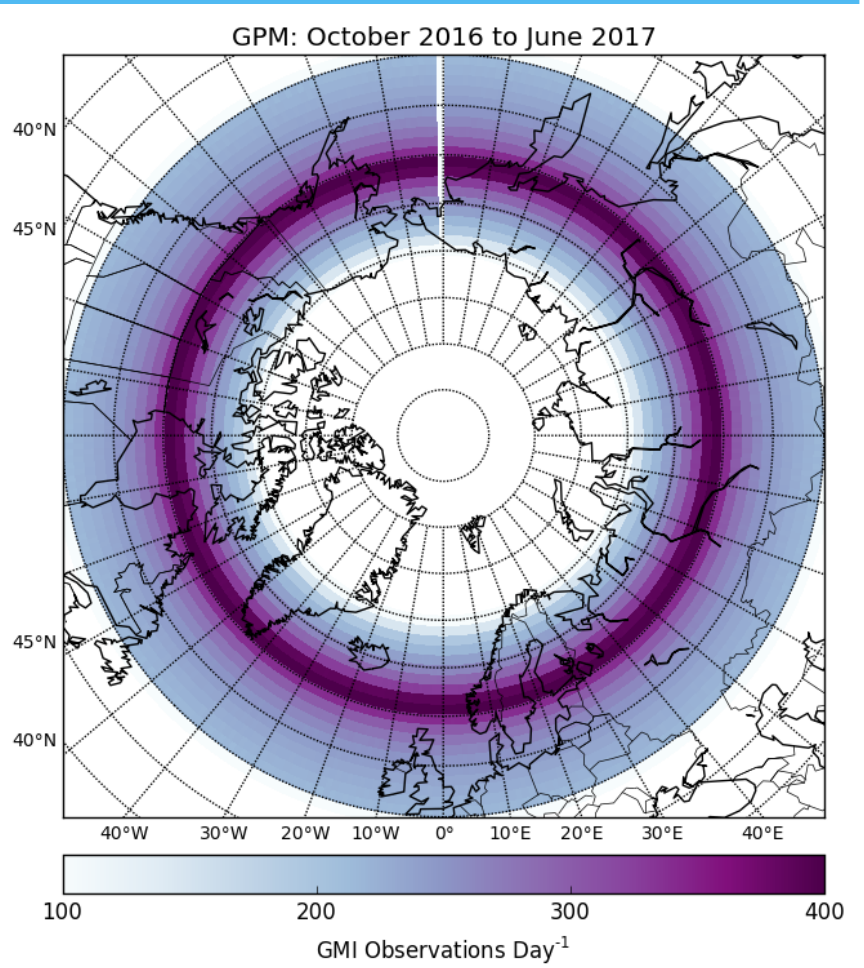
GPM at High-Latitude:

- GPM has several overpasses
  - 2 – 5 per day between 50°N and 69°N
  - Maximum at 61°N

GPM Orbit – High-latitude Advantage

GMI at High-Latitude:

- GMI swath width is 885 km which allows 100s of observations per day per $(1°)^2$
  - 200 – 400 observations per day between 50°N and 69°N



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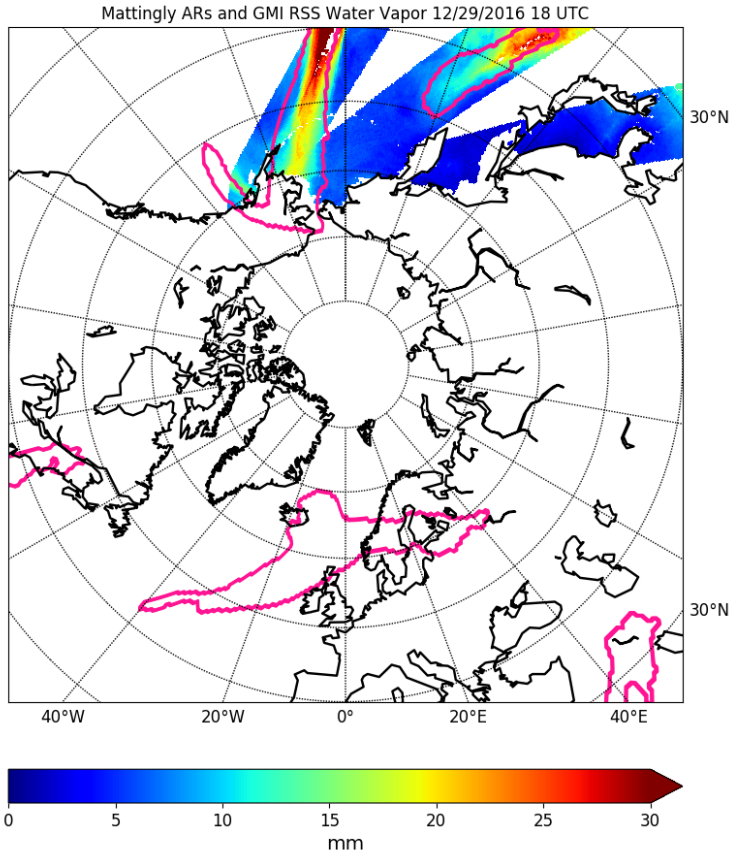
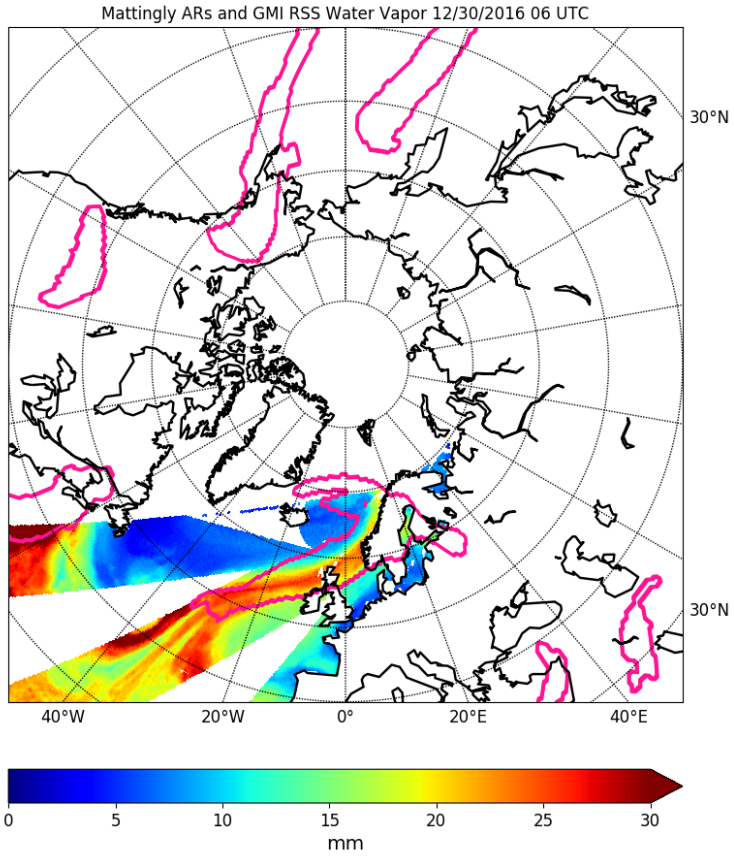
ARs and GMI Water Vapor





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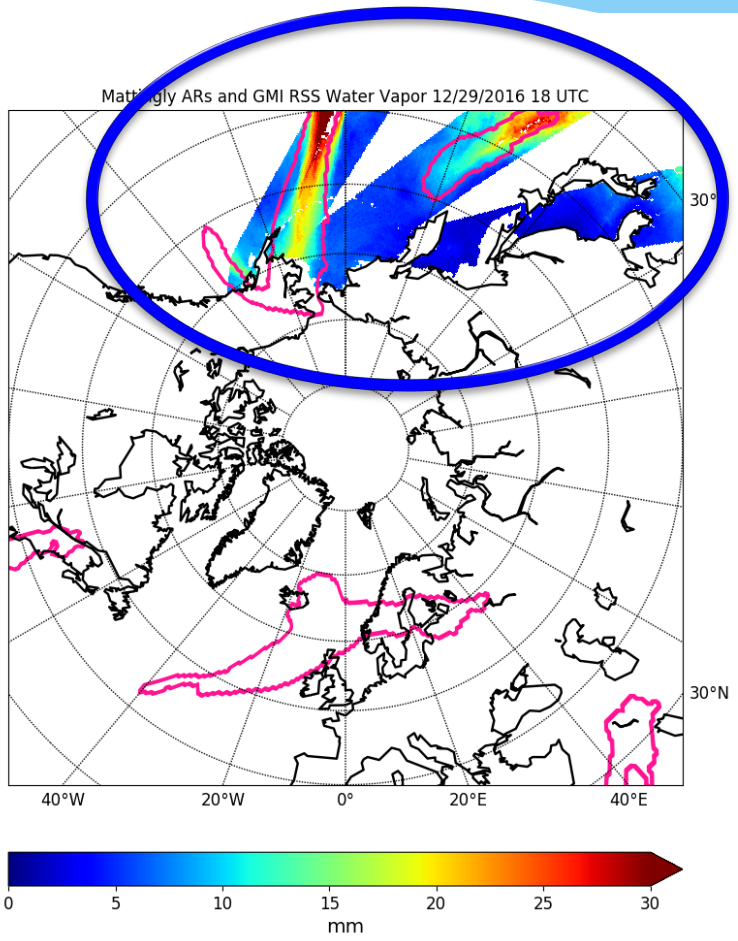

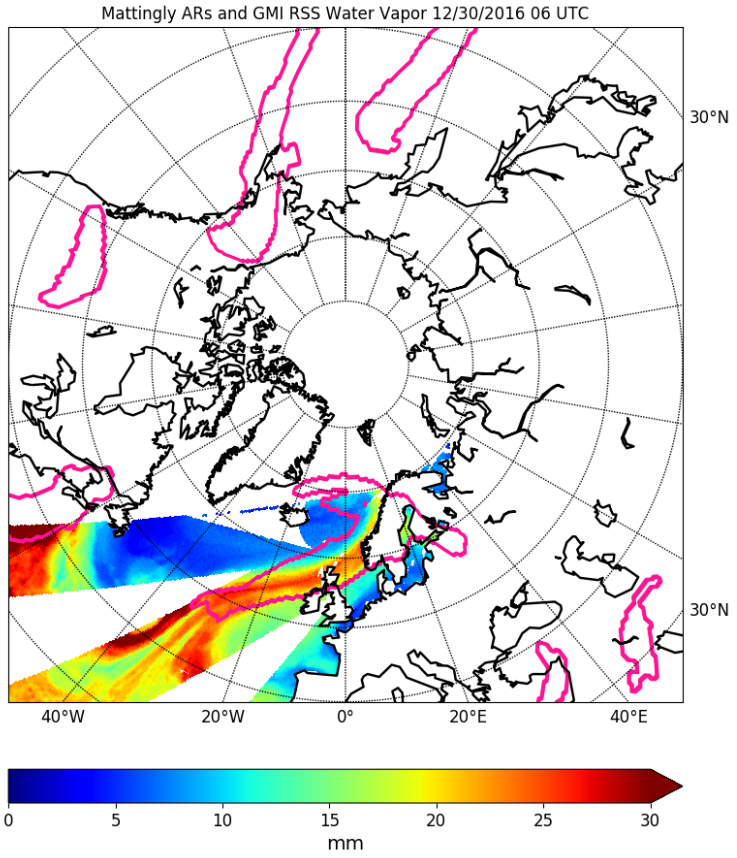

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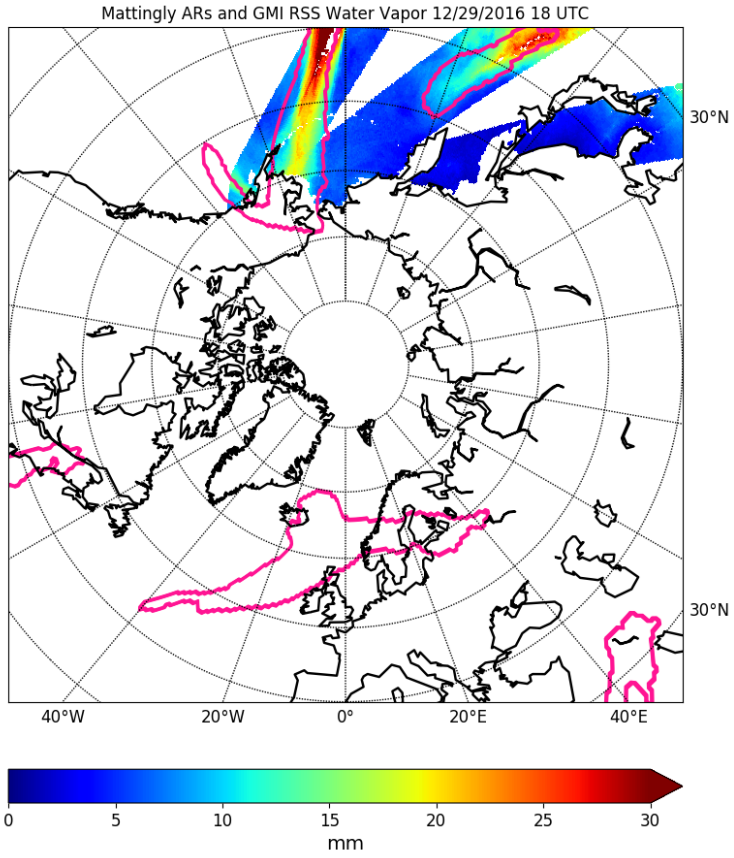

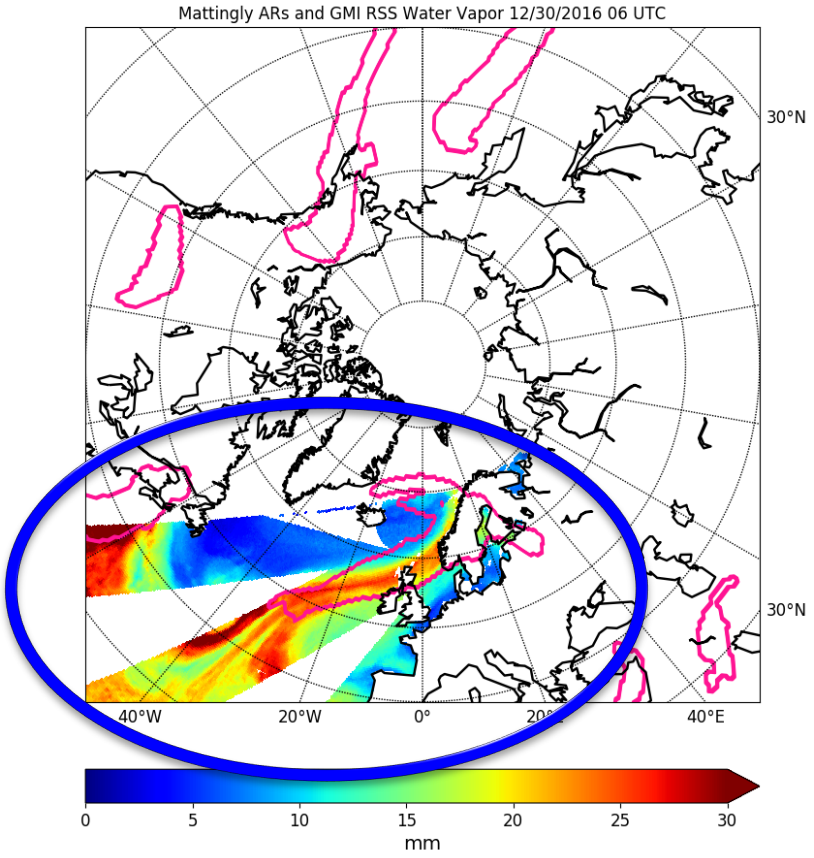

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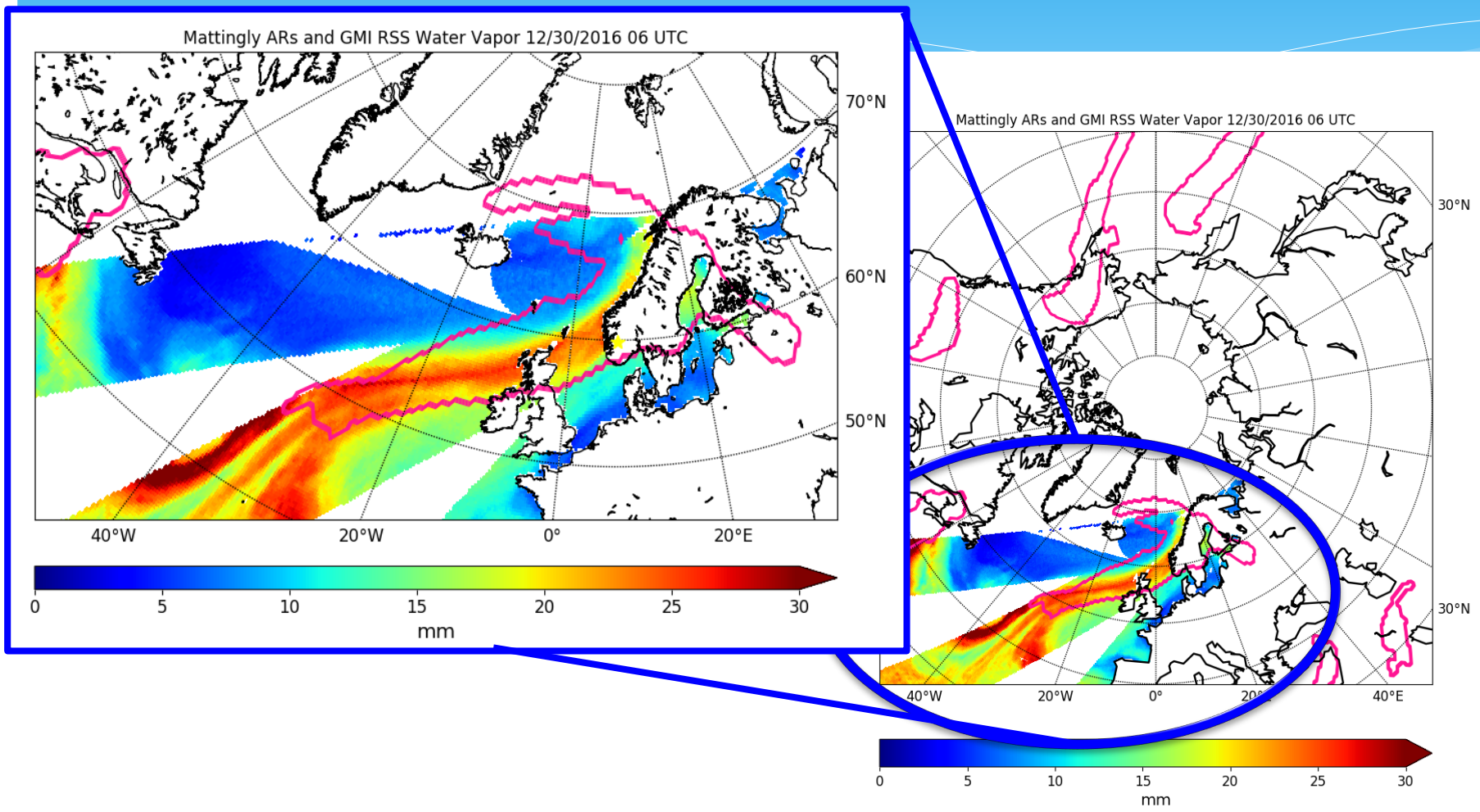

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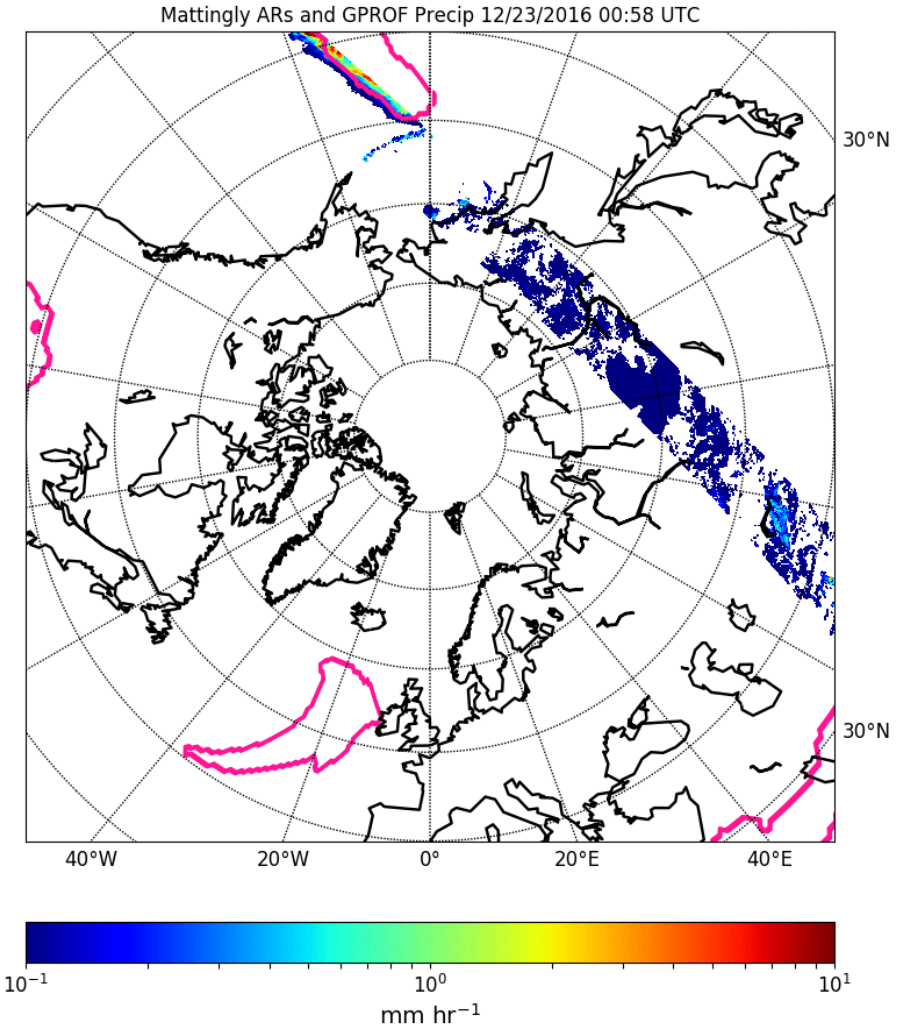
ARs and Precipitation (GPROF)



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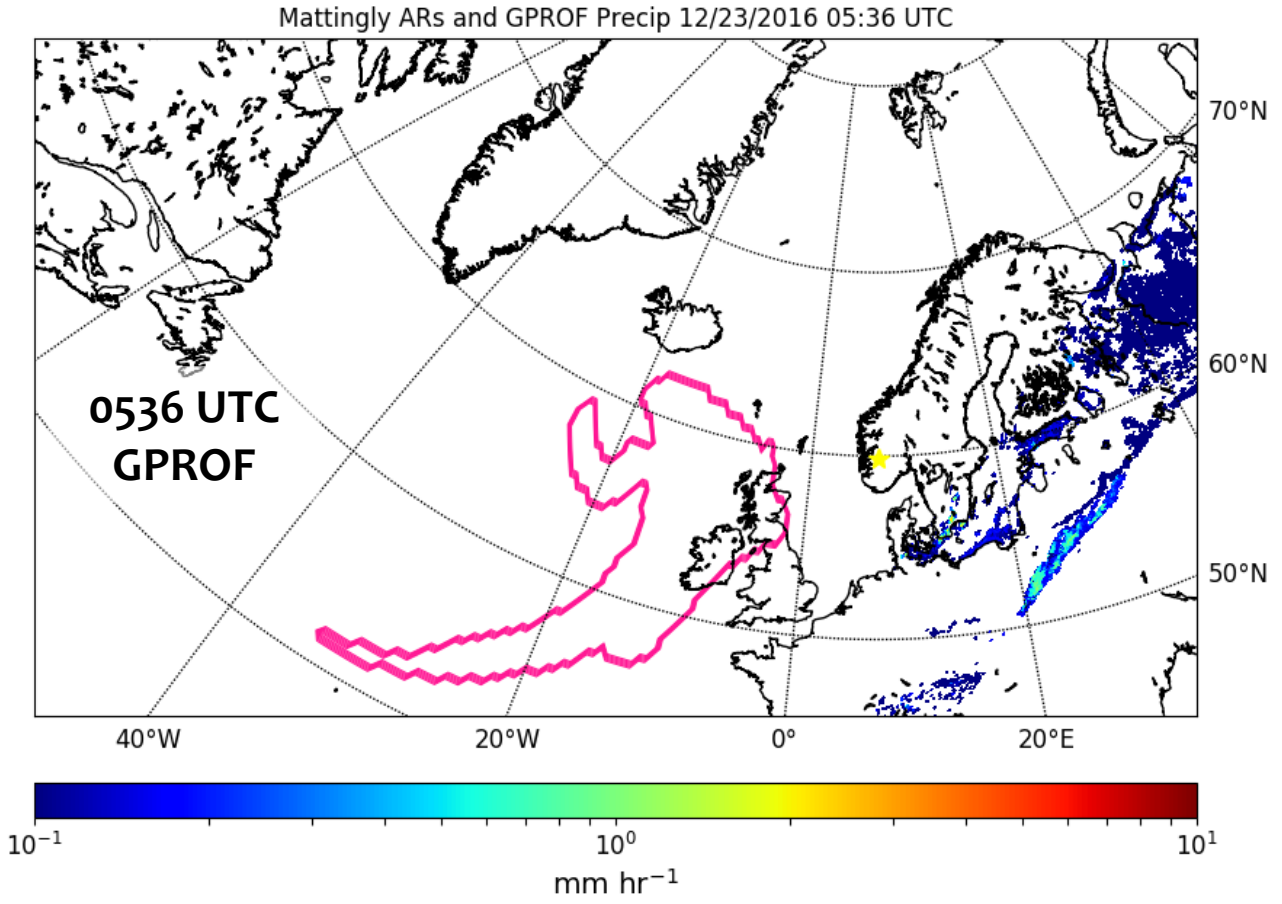

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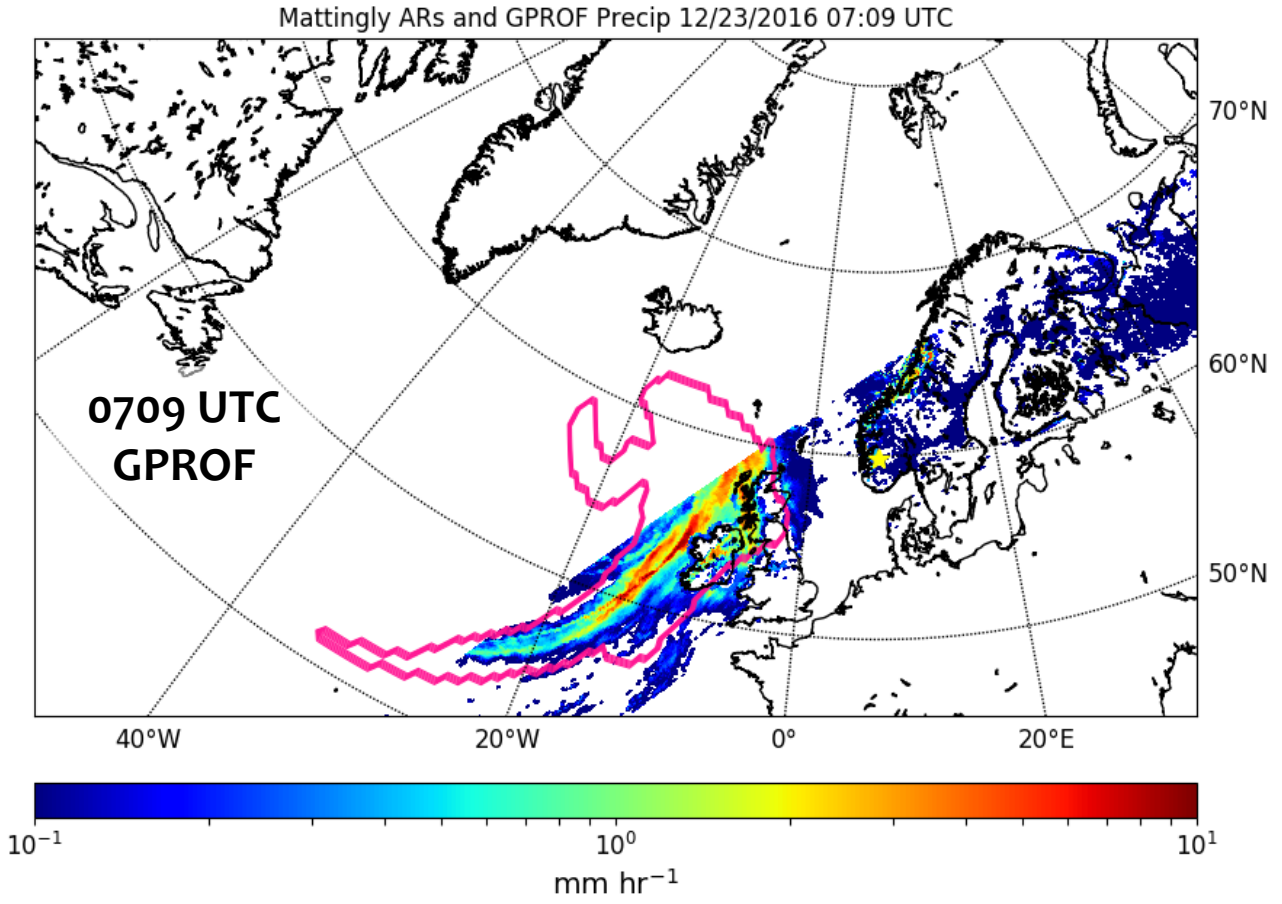

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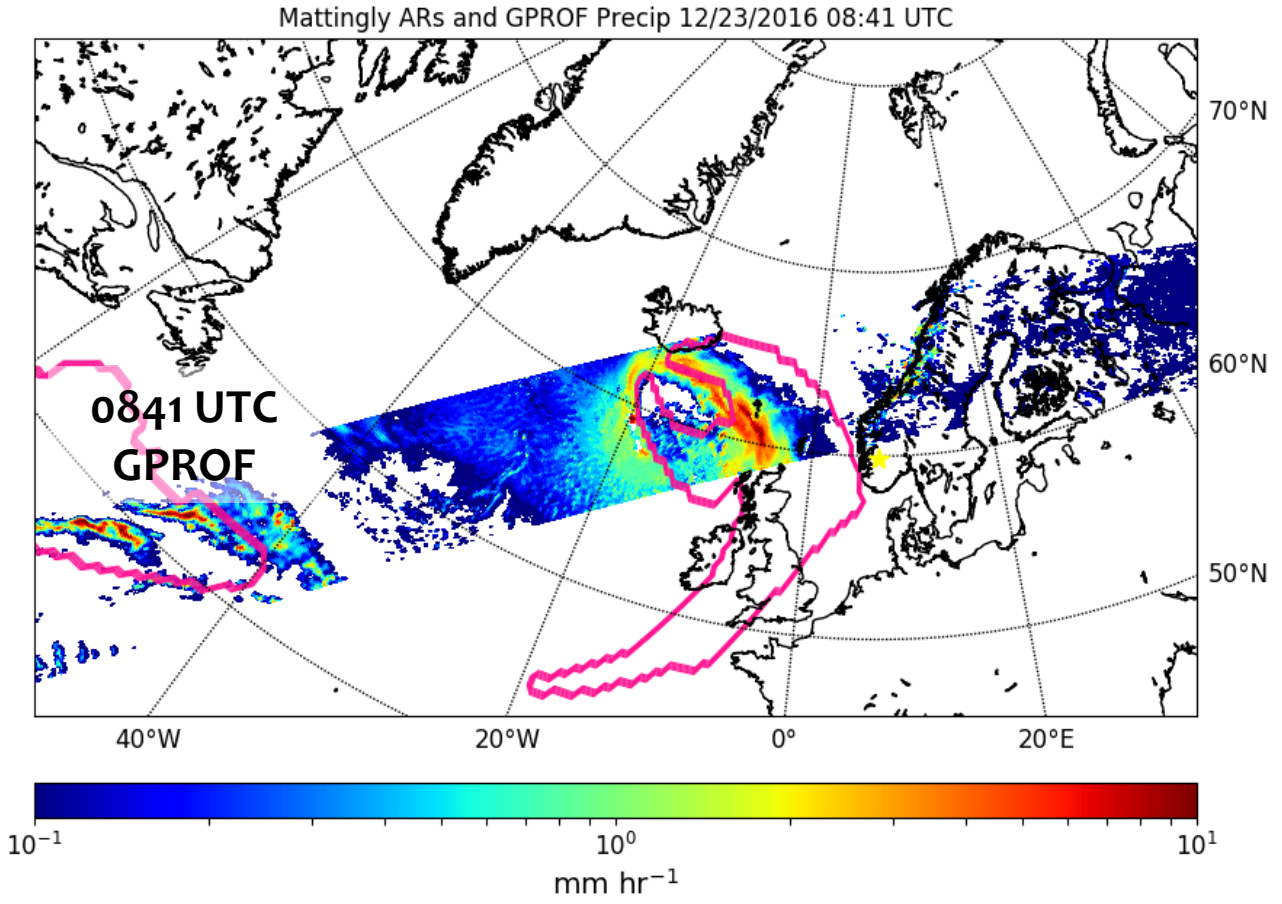

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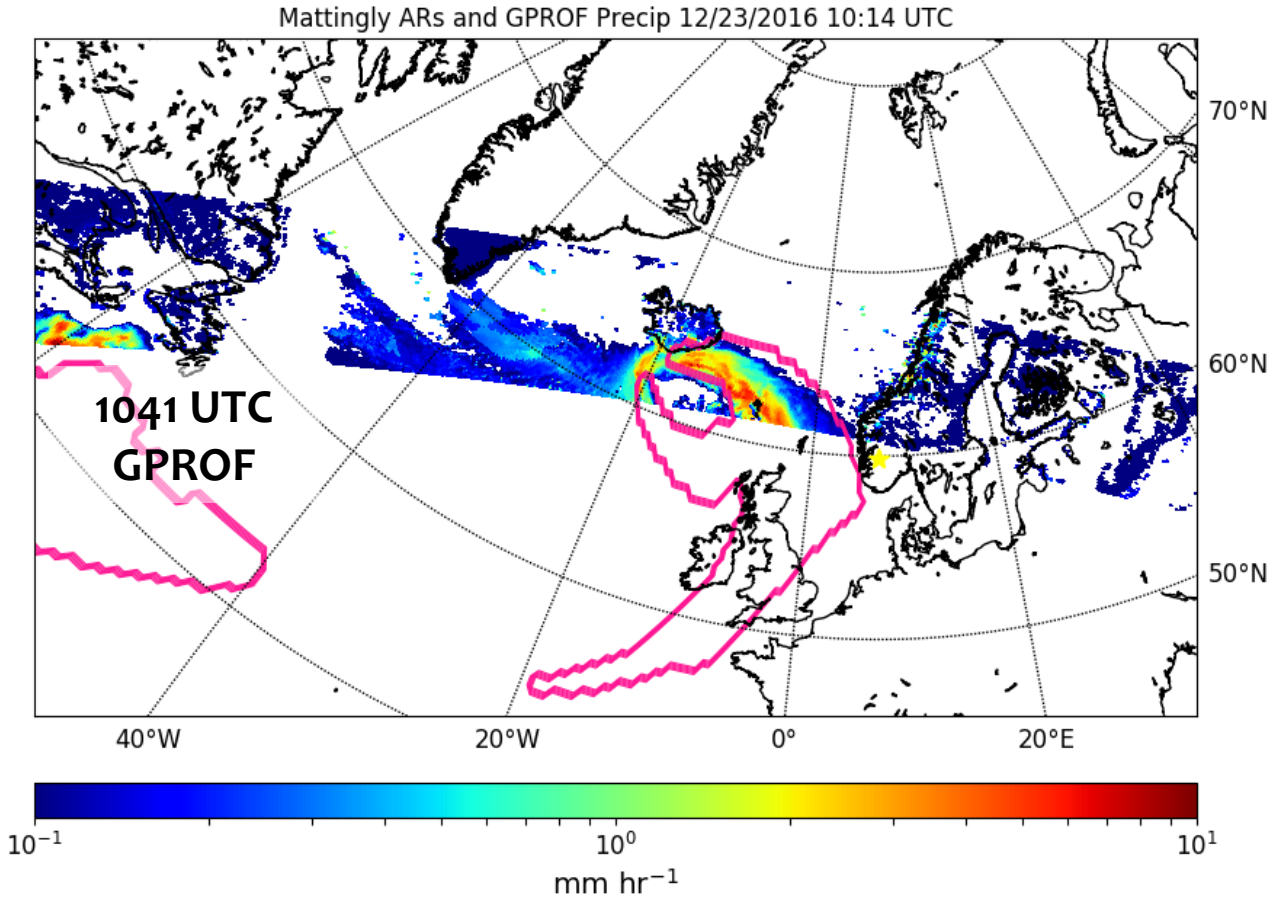

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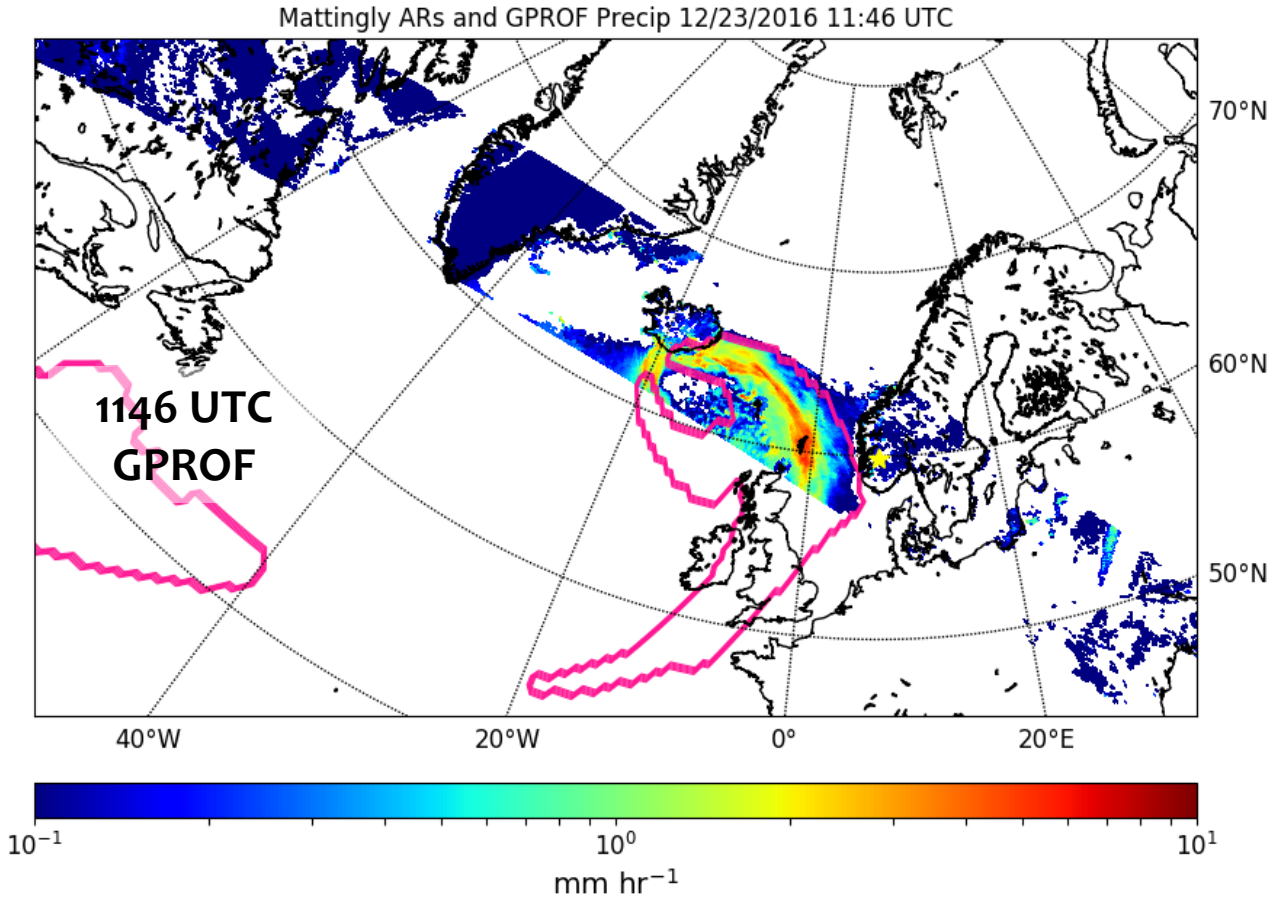

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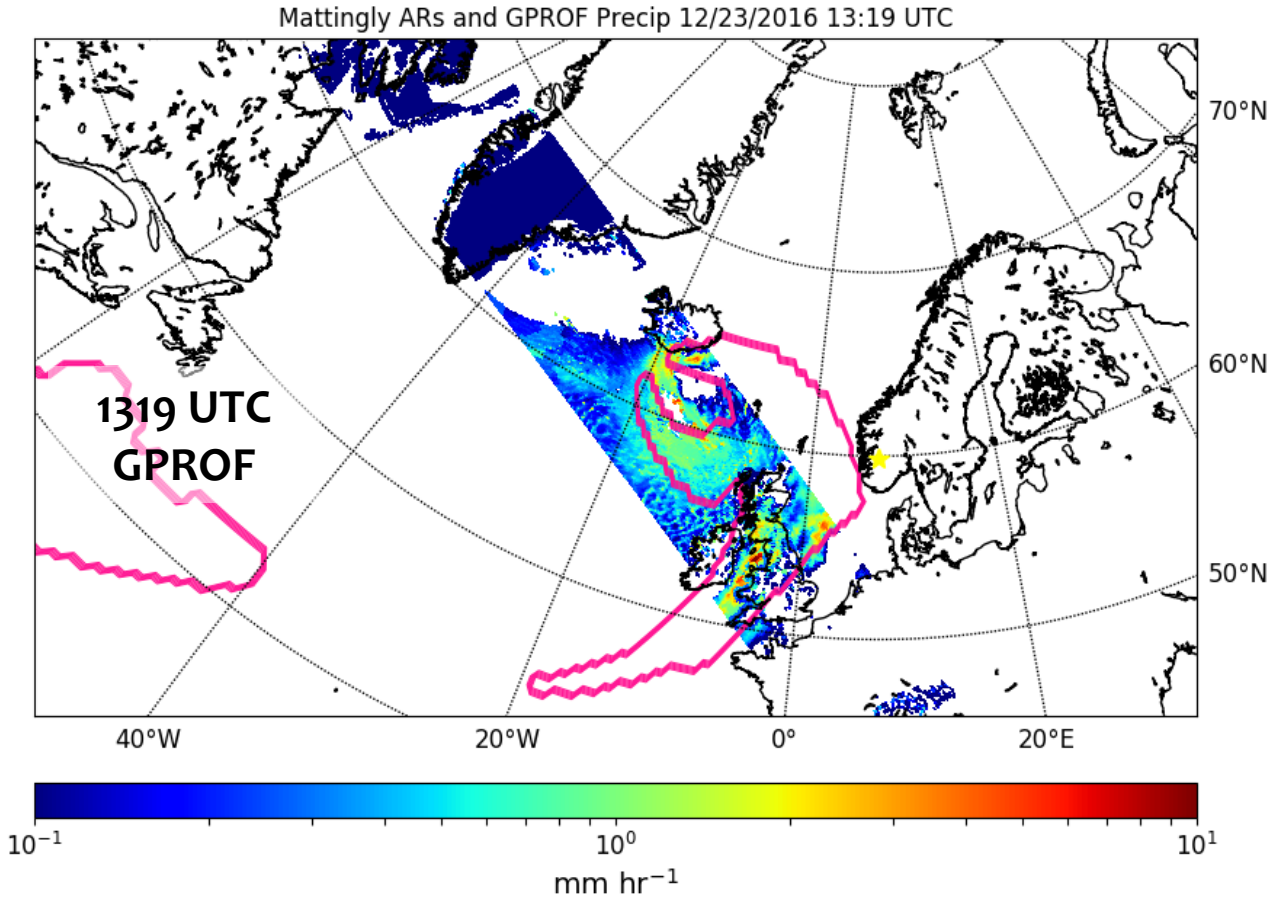
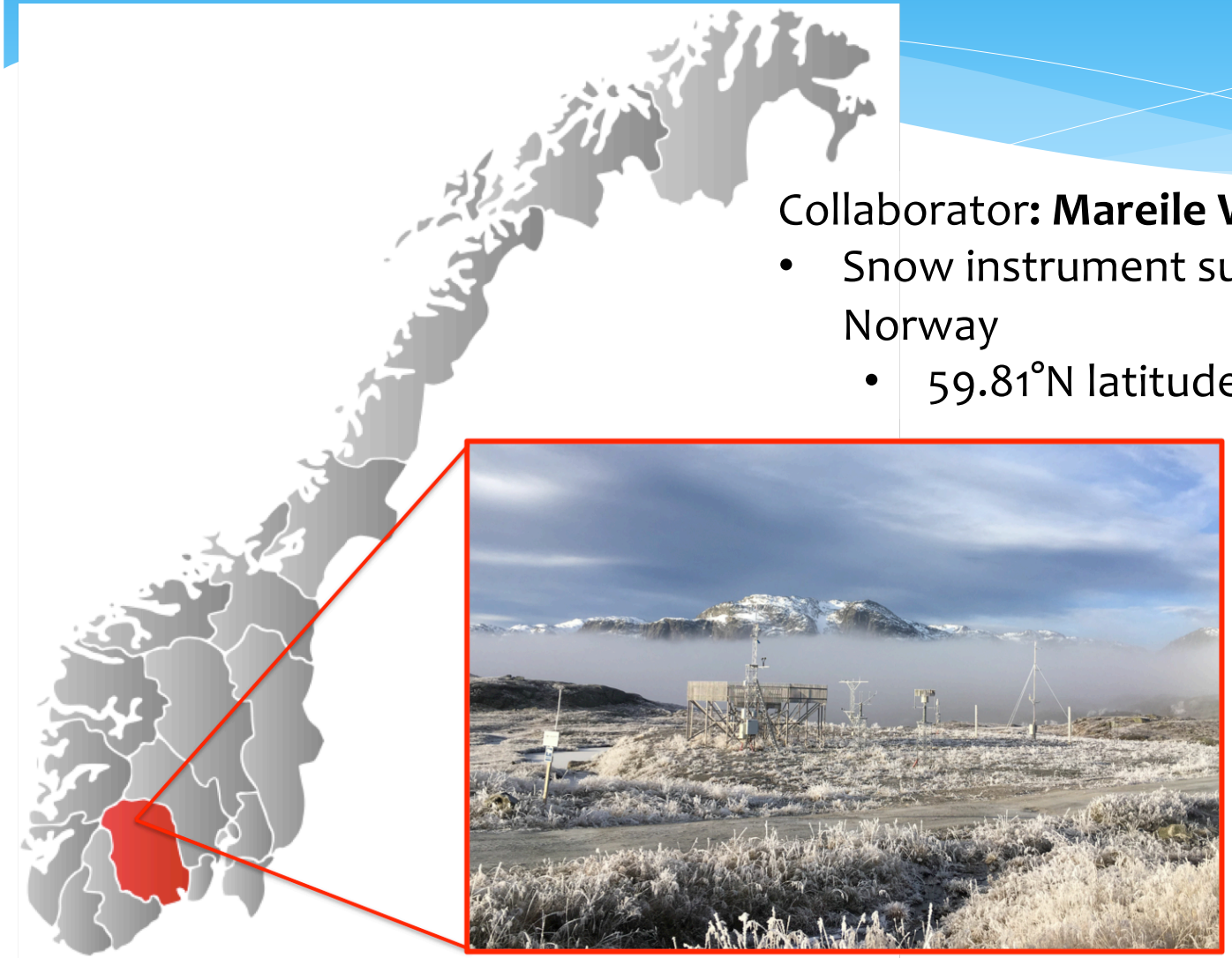


Project Objectives

* **Objective 2:** Utilize **ground-based in-situ and remote-sensing instrument observations** located at a high-latitude site to evaluate GMI snow estimates during AR events
  * Assess estimates of the fractional snow accumulation associated with ARs derived from GMI observations using ground-based observations
  * Evaluate the microphysical characteristics of the AR-enhanced precipitation using ground-based remote-sensed and in-situ measurements

Ground-Based Observations



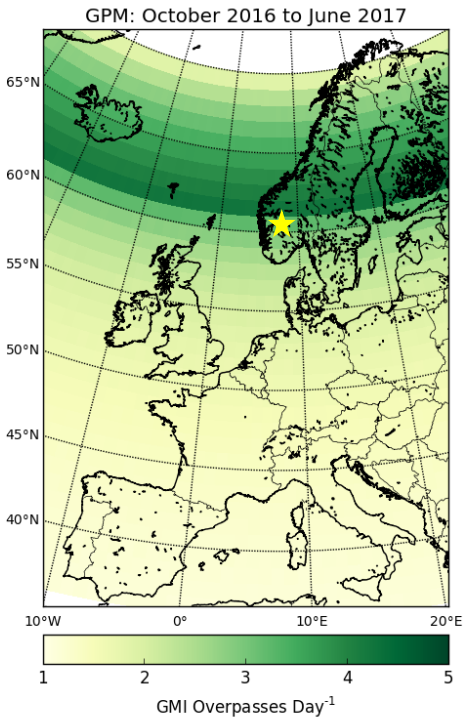
Collaborator**: Mareile Wolff** (MetNorway)

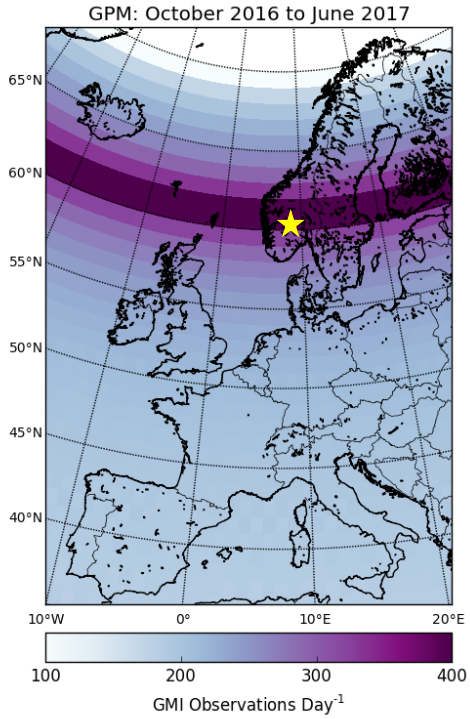
- Snow instrument suite in Haukeliseter, Norway
  - 59.81°N latitude, 991 m elevation

Ground-Based Observations

- Meteorological data (temperature, relative humidity, winds)
- Snow accumulation
  - Double Fence Automated Reference
- Broadband radiation

Data available from 2014 – present



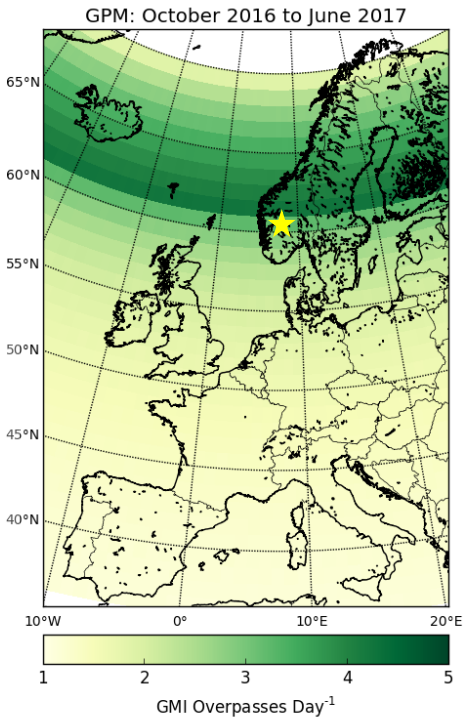


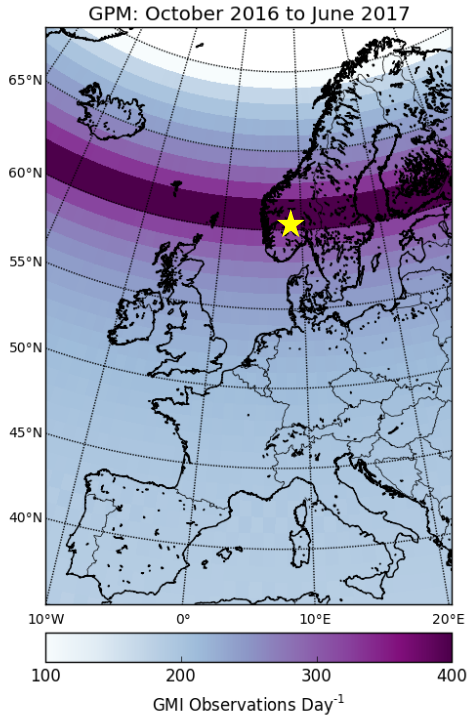
Ground-Based Observations

- MicroRain Radar
- Precipitation Imaging Package

First deployment winter 2016 – 2017

Second deployment winter 2020 – 2021

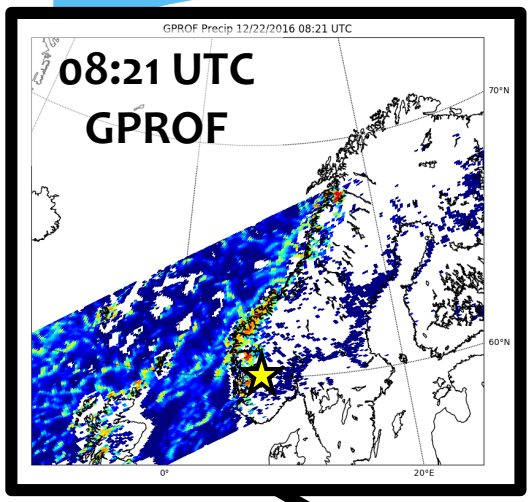


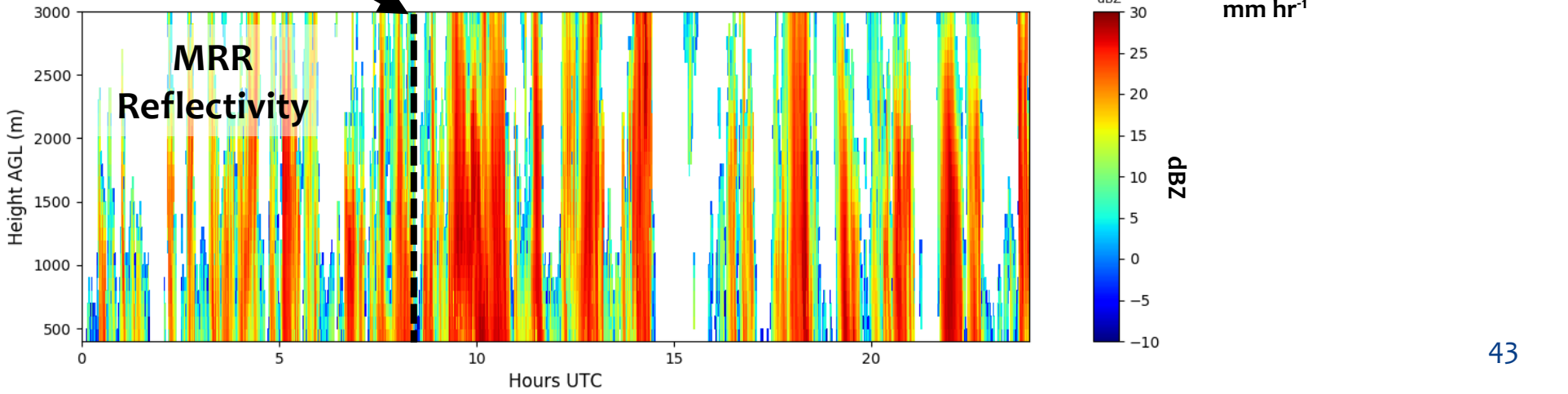


Project Objectives

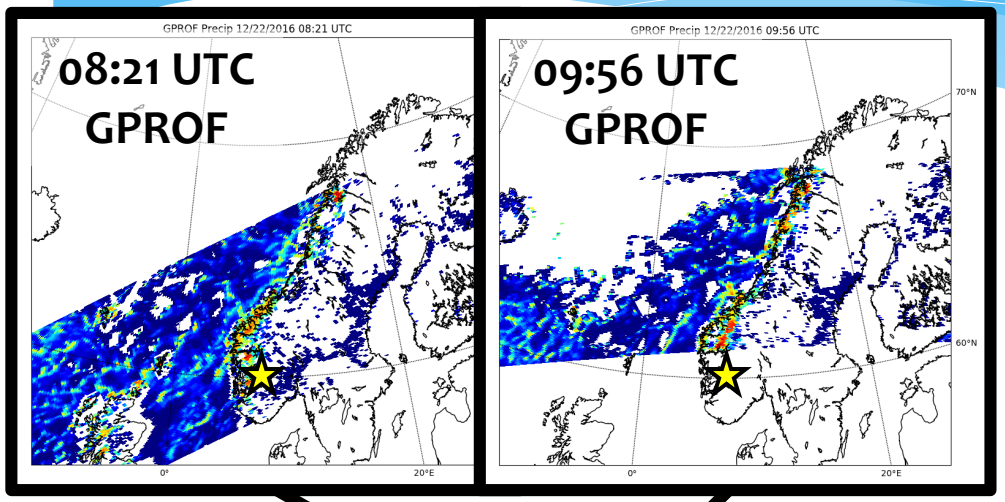
* **Objective 2:** Utilize ground-based in-situ and remote-sensing instrument observations located at a high-latitude site to evaluate GMI snow estimates during AR events
  * **Assess estimates of the fractional snow accumulation associated with ARs derived from GMI observations using ground-based observations**
  * Evaluate the microphysical characteristics of the AR-enhanced precipitation using ground-based remote-sensed and in-situ measurements

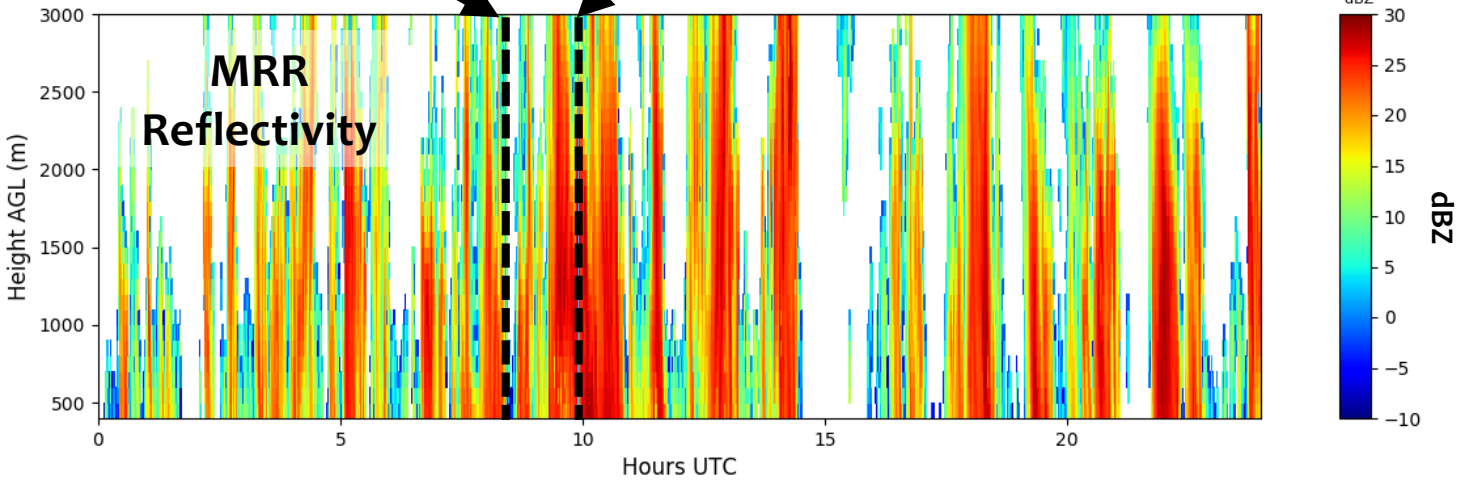
GV and GMI Collocation

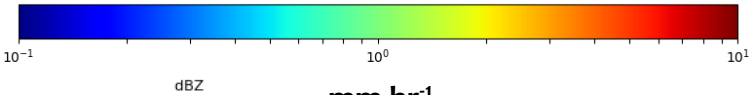




GV and GMI Collocation







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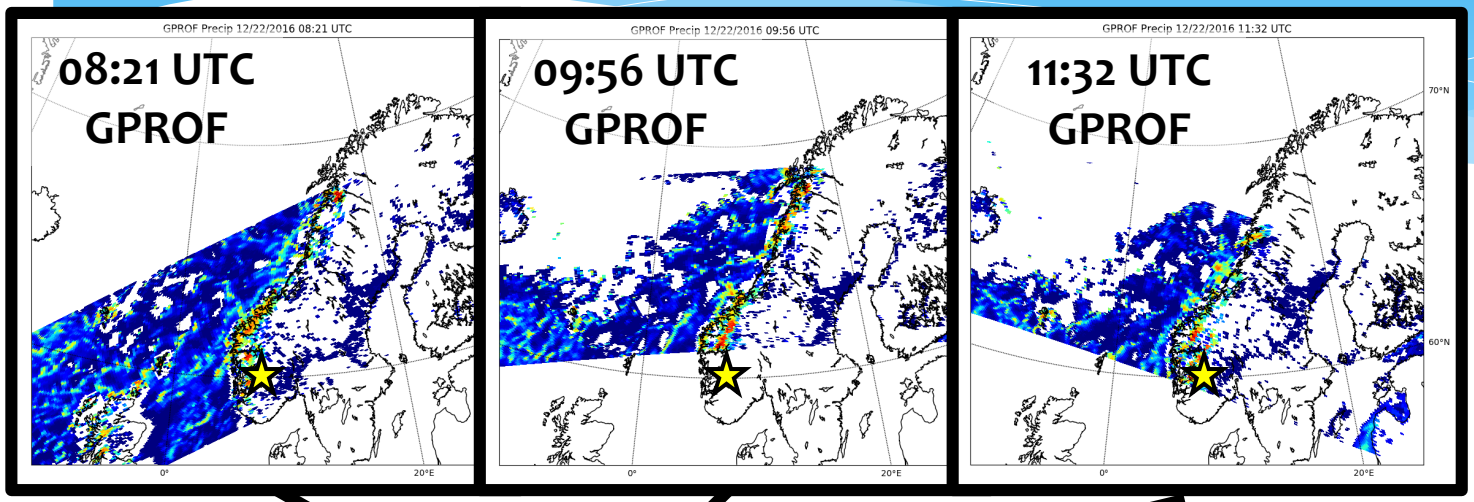
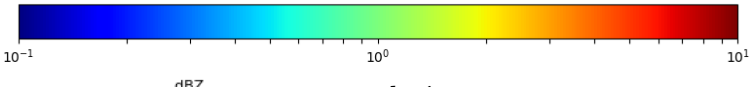
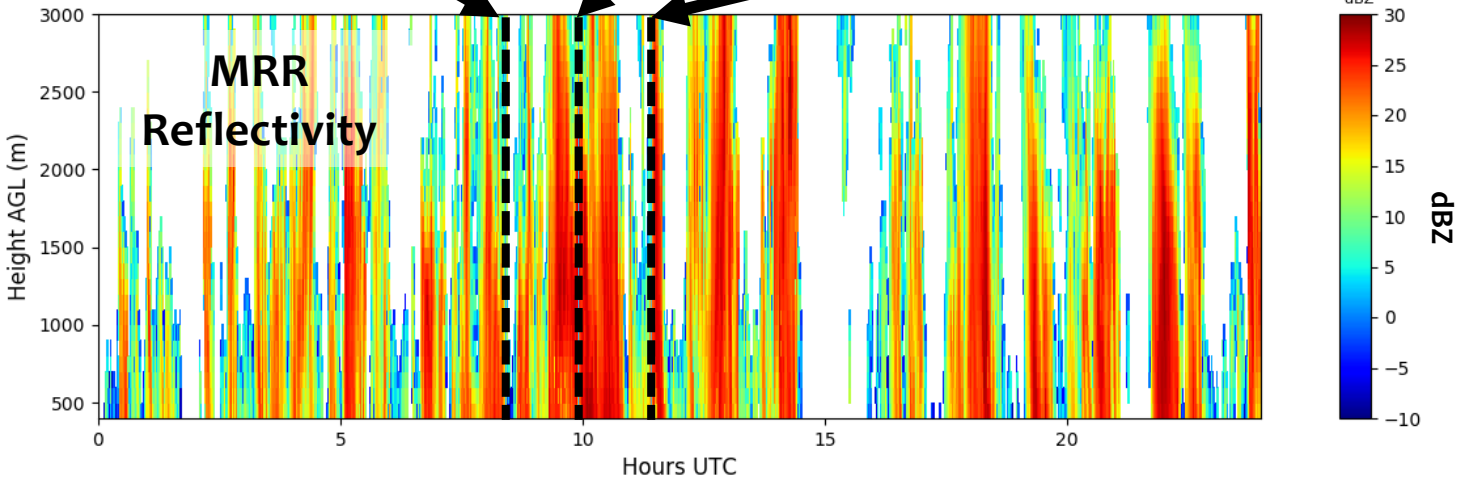
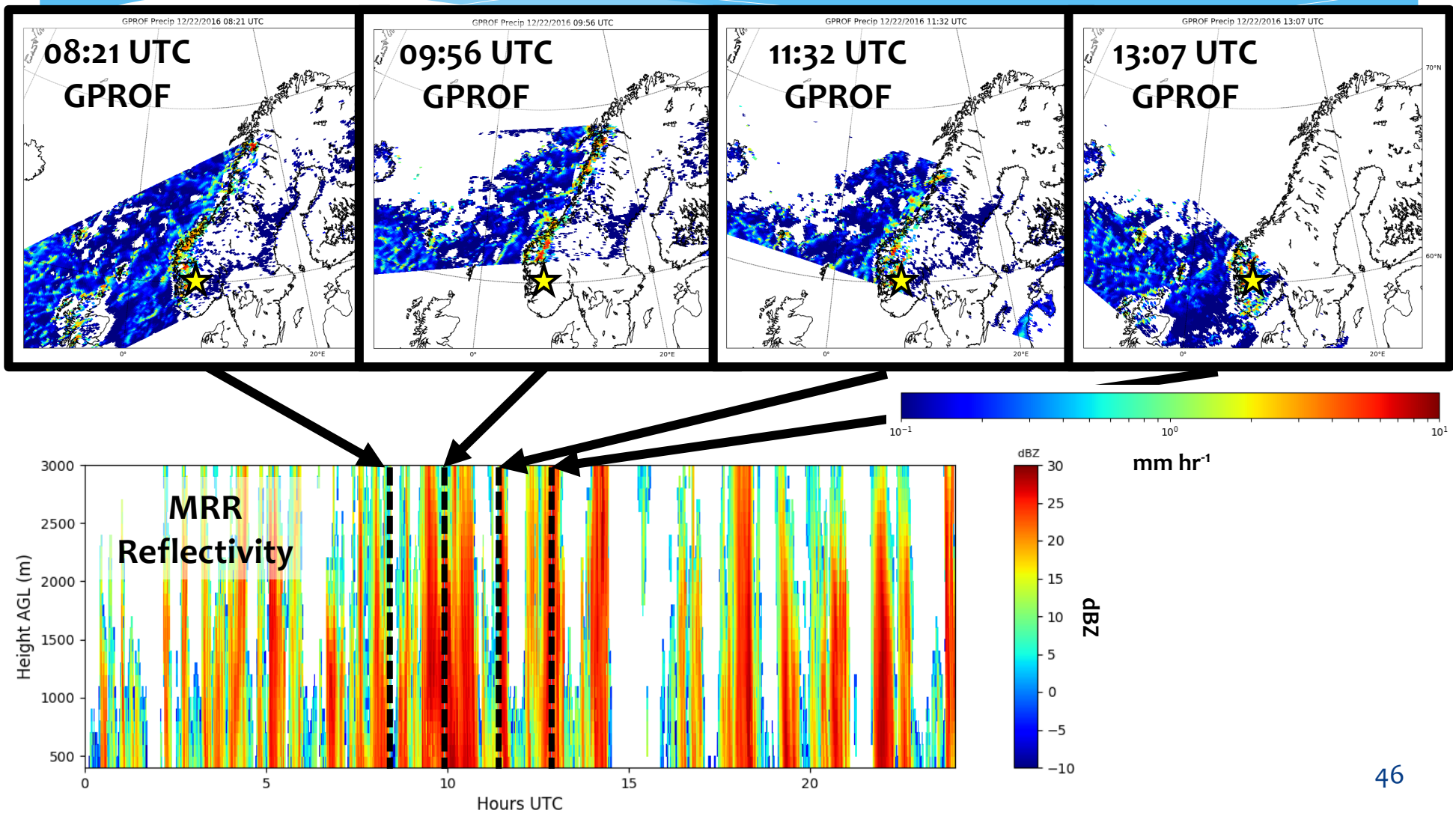






GV and GMI Collocation



Project Objectives

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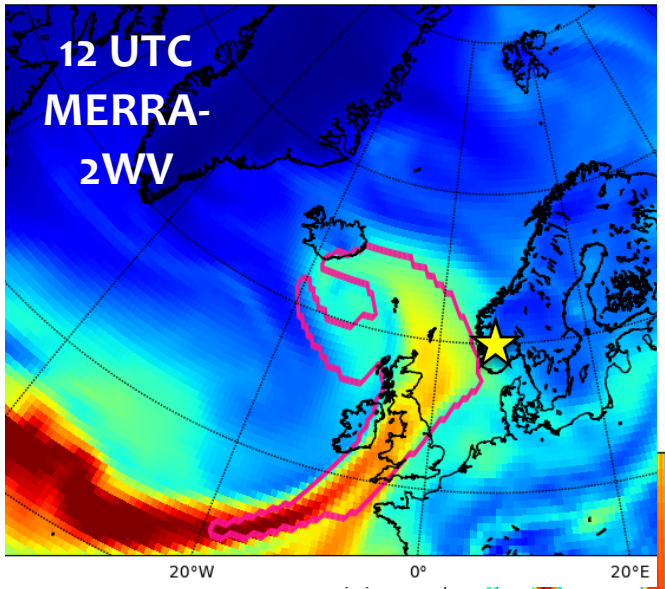
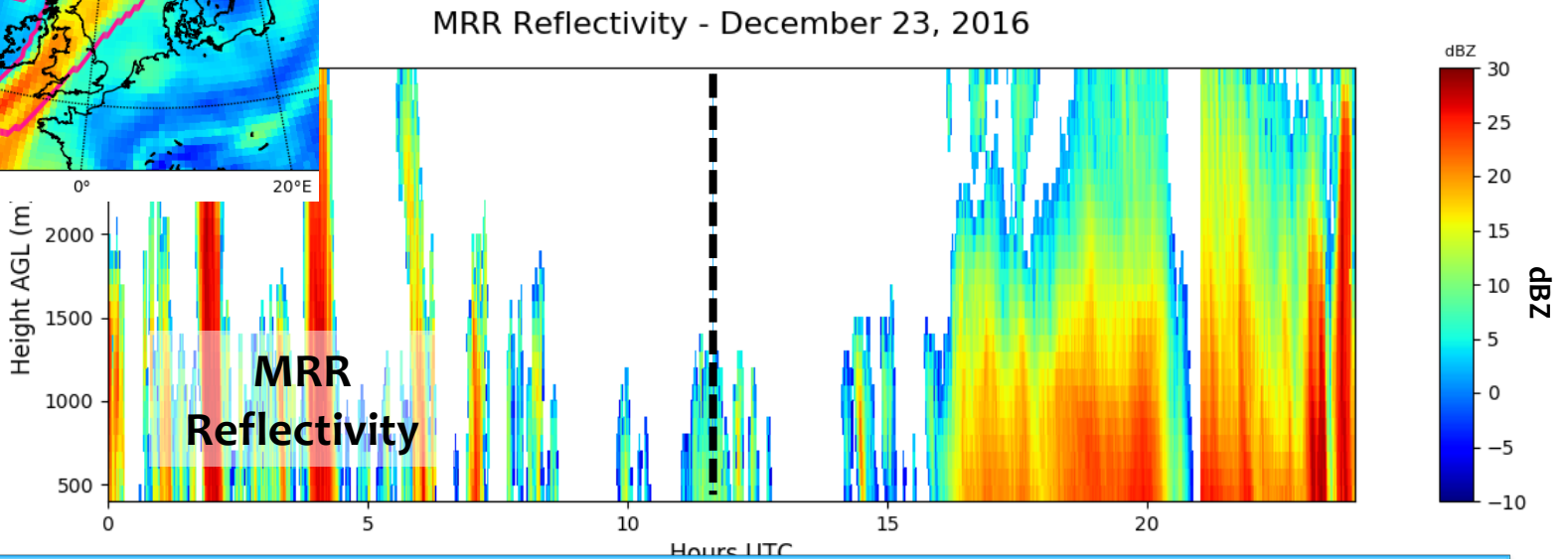
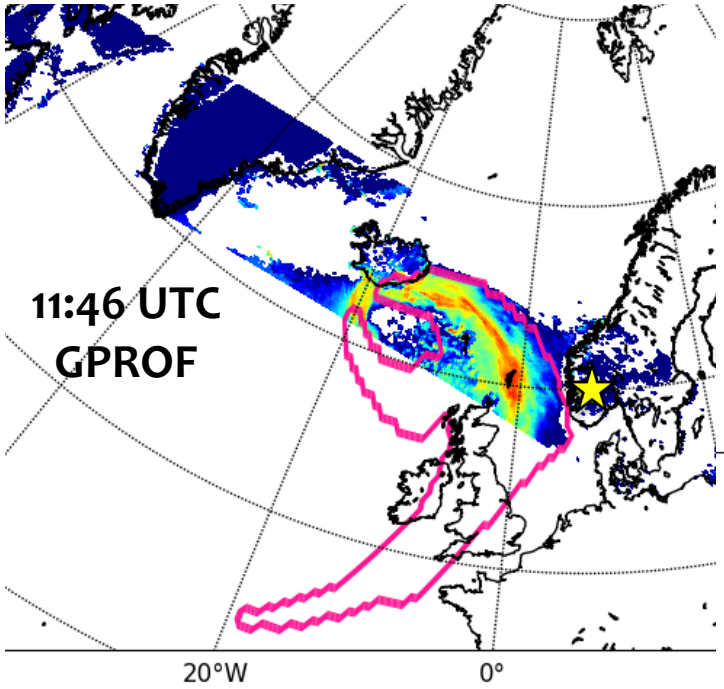
GV Observations and ARs



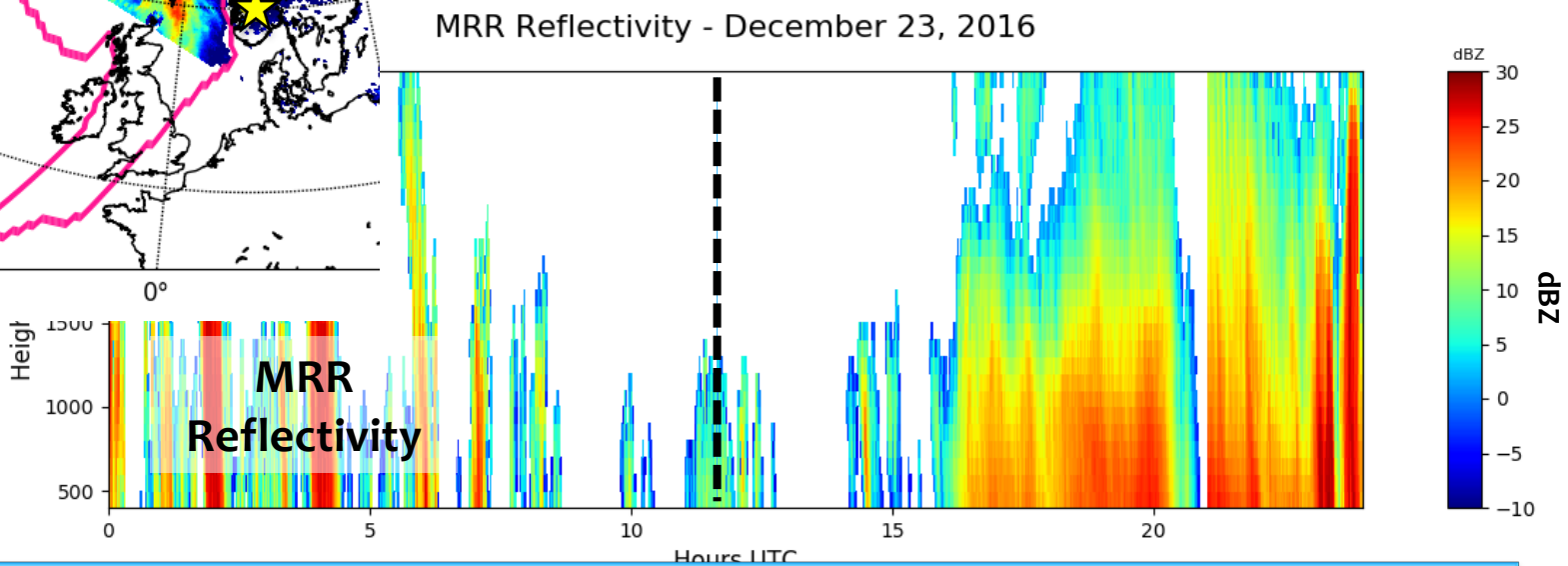
AR approaching the site,
still off shore at 1200UTC.



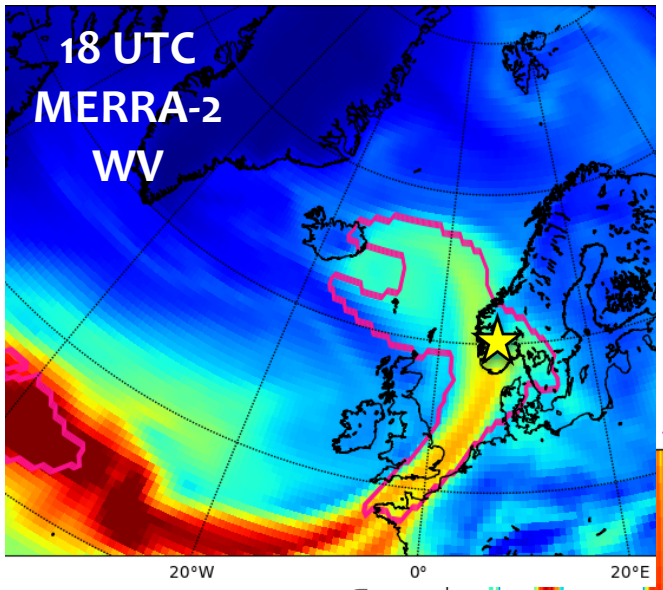
GV Observations and ARs



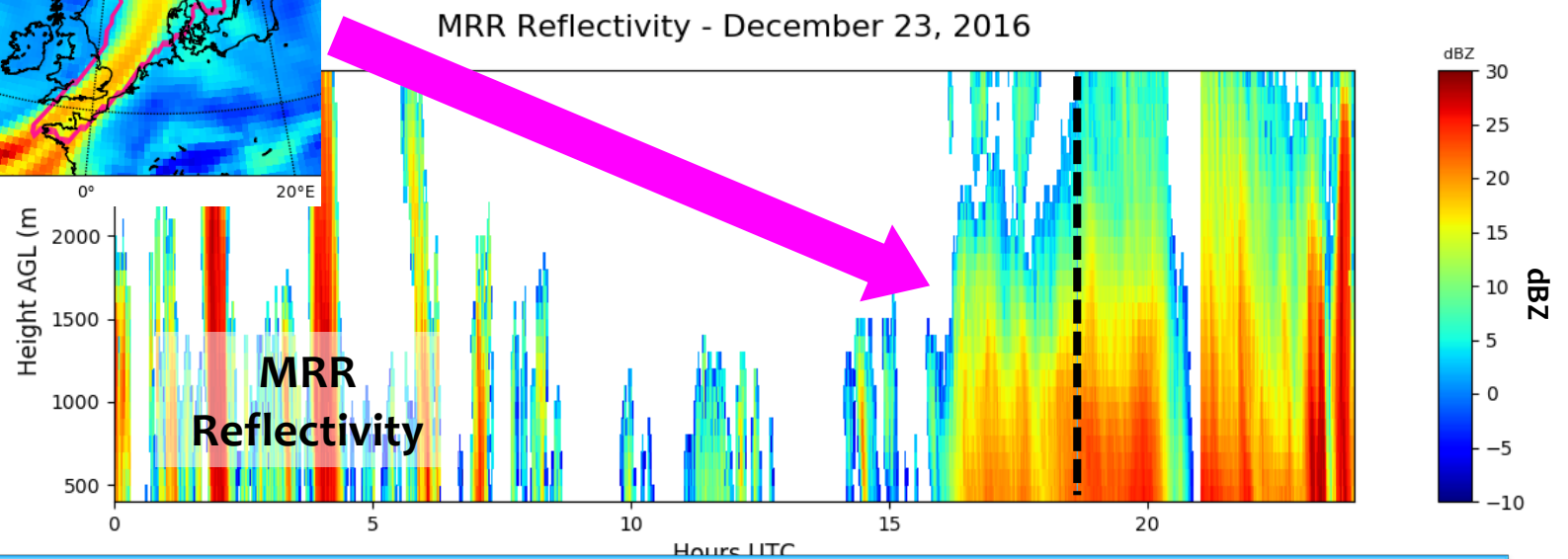
AR approaching the site,
still off shore at 1200UTC.



GV Observations and ARs



AR impacting the site (arrow) and onshore at 1800UTC.



Summary

* **Current Work:**
  * Developed collocated GPM observations with identified ARs
    * GMI water vapor product
    * GMI GPROF precipitation rate product
  * Evaluating ground-based observations for specific 2016-2017 events
* **Planned work:**
  * Extend the collocated observations to include GMI brightness temperature (with Joe Munchak and Mark Kulie)
  * Extend AR detection through 2019 (and beyond) and to southern hemisphere (with Kyle Mattingly)
  * Year 2 deployment of MRR and PIP to Norway in 2020-2021 (with Mareile Wolff)