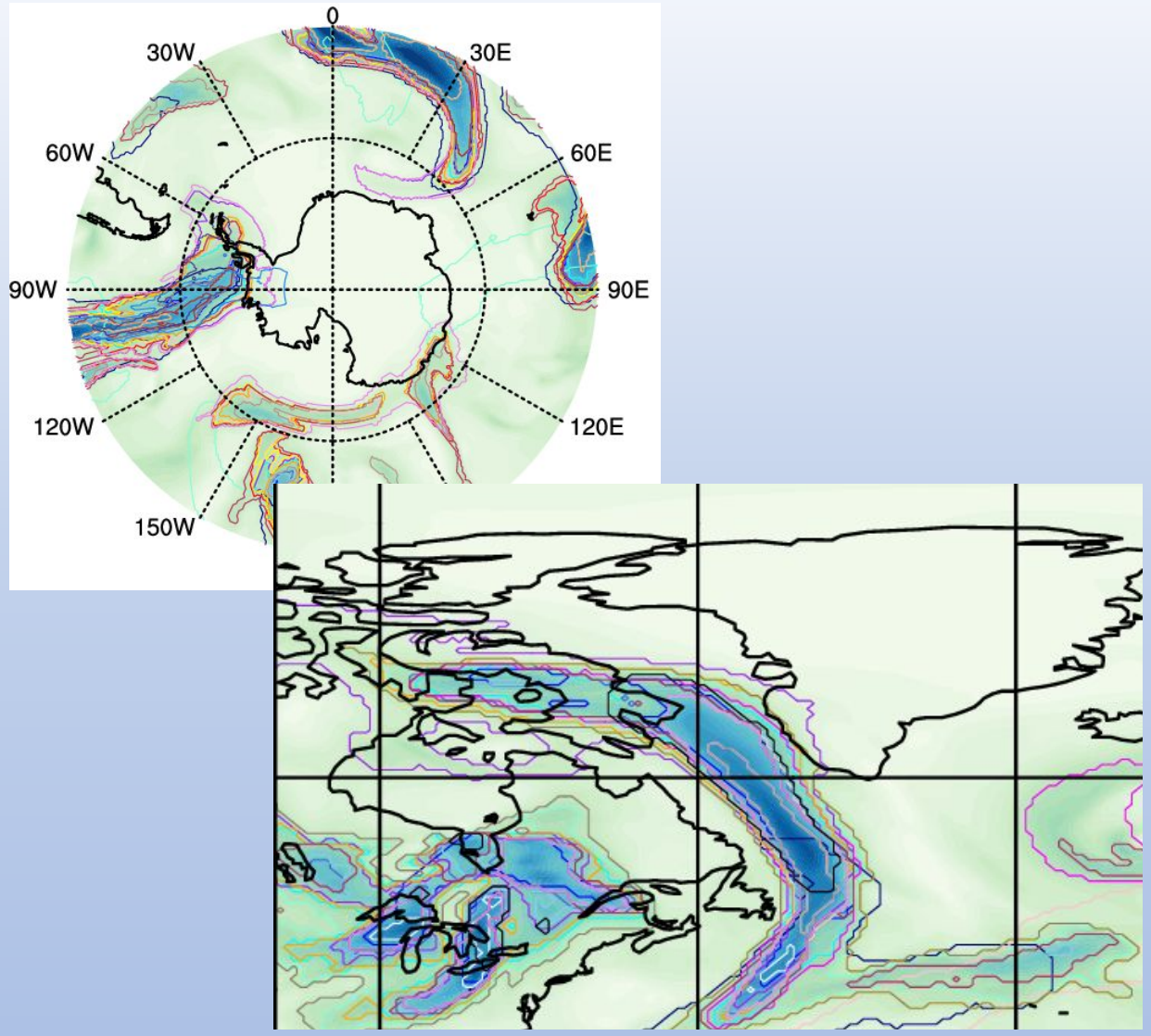


Identifying High Latitude Atmospheric Rivers with Machine Learning

Christine A. Shields (NCAR)
Teagan King (NCAR)
Katie Dagon (NCAR)
Sol Kim (UC Berkeley)
Annette Greiner (LBNL)

February 23, 2023
Polar Climate Working Group

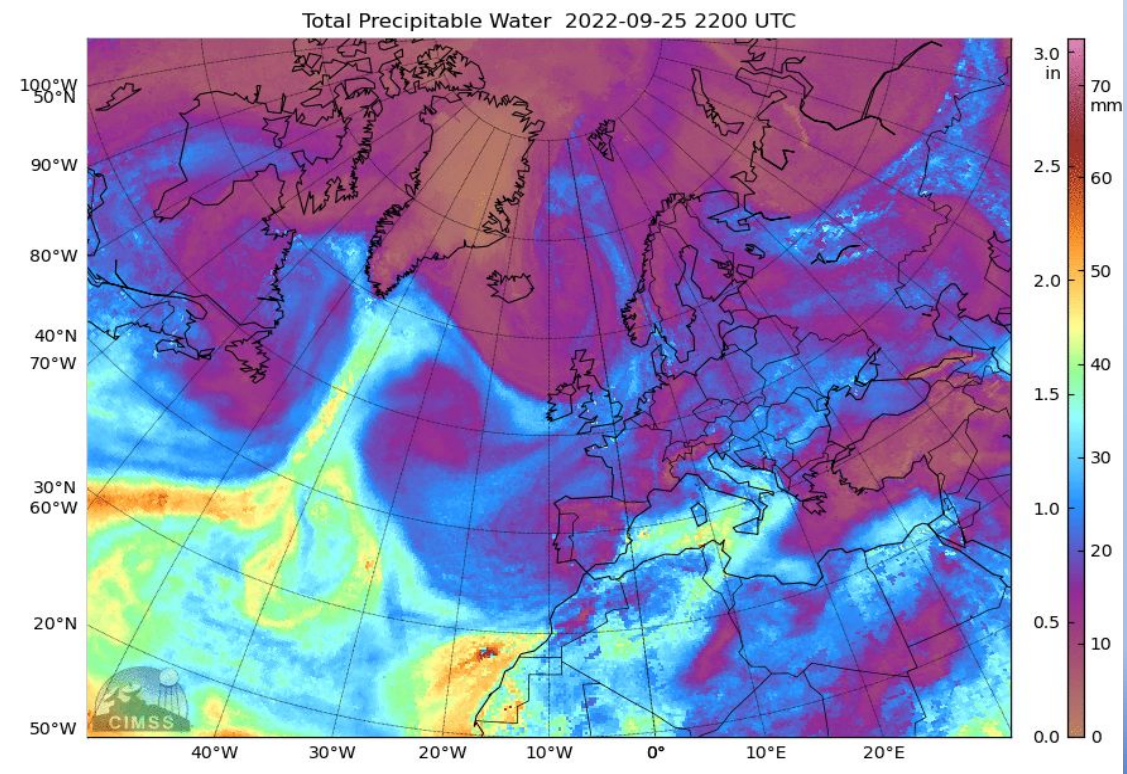
catalyst

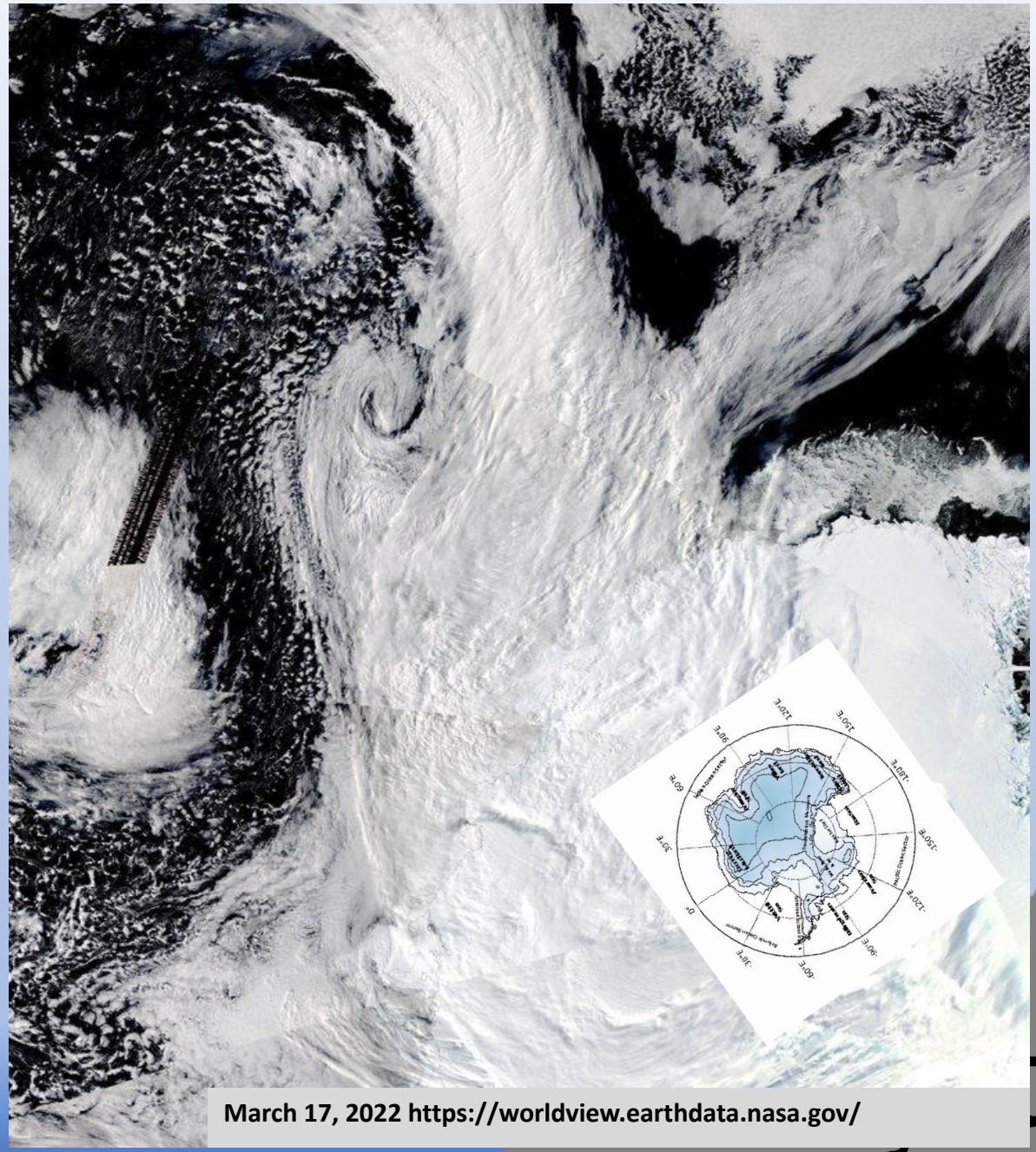
What are High Latitude Atmospheric Rivers?

Why do we need polar-specific detectors?

Machine Learning is an option!

Our project thus far….





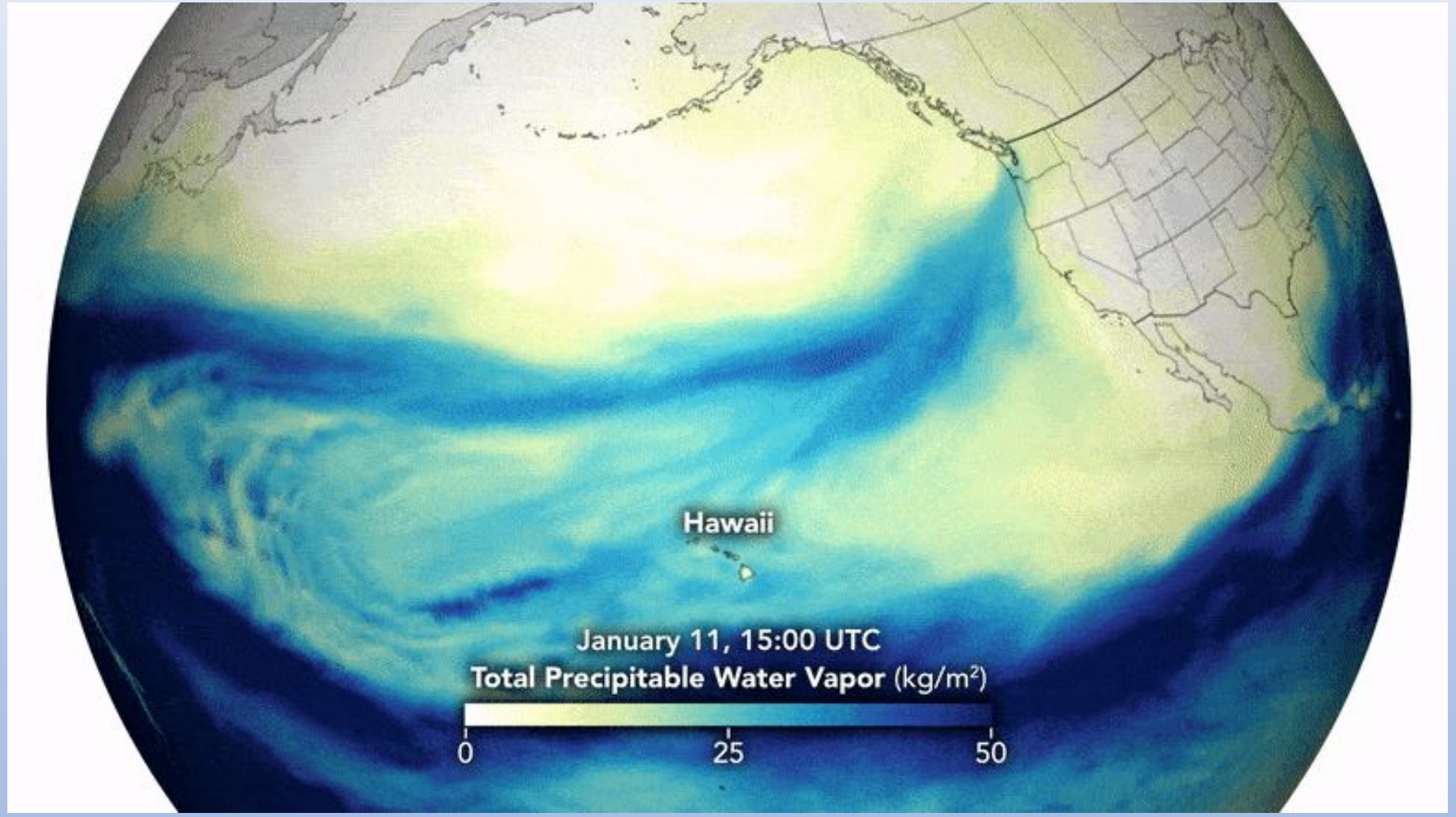
March 17, 2022 https://worldview.earthdata.nasa.gov/

What is an Atmospheric River (AR)?

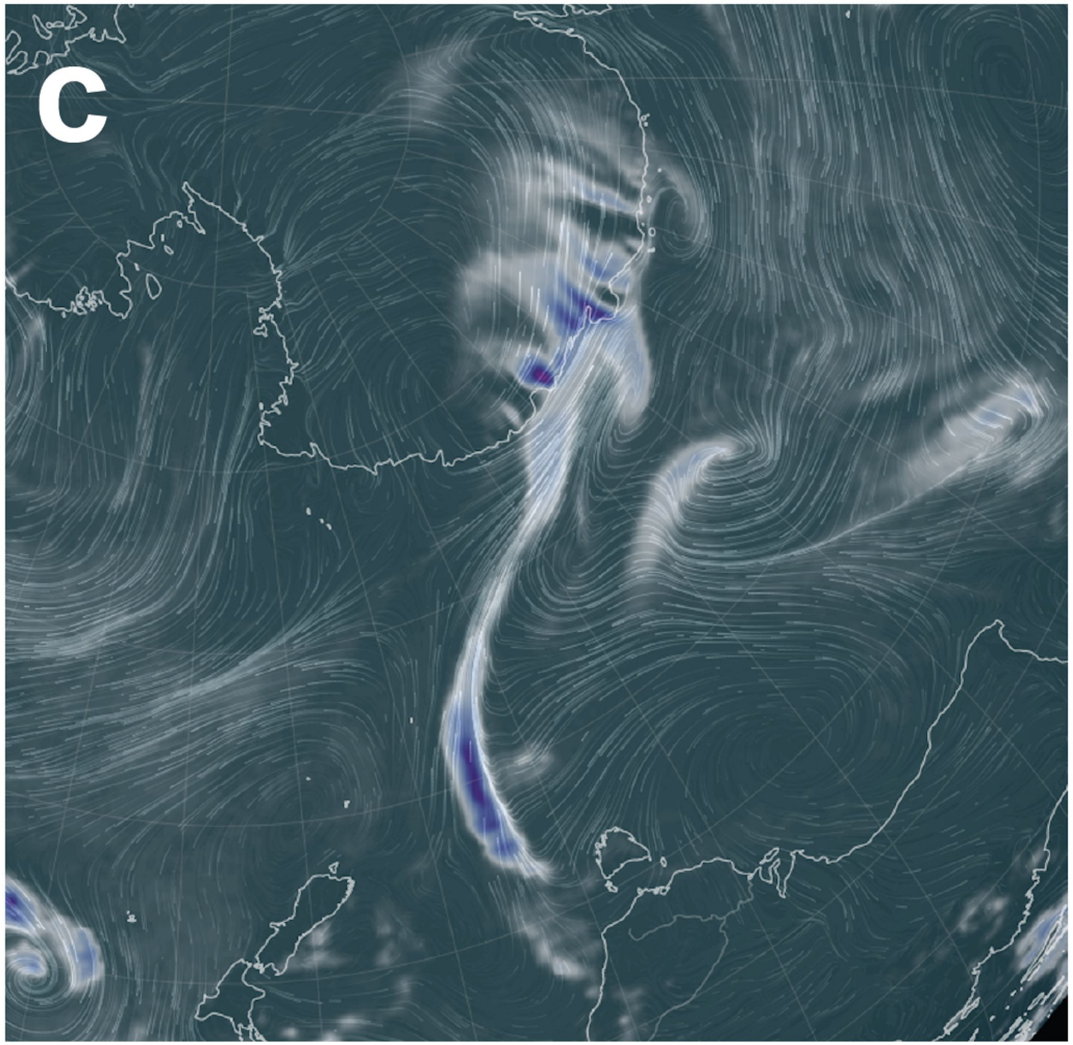
Synoptic scale, filamentary moisture transport vehicles!

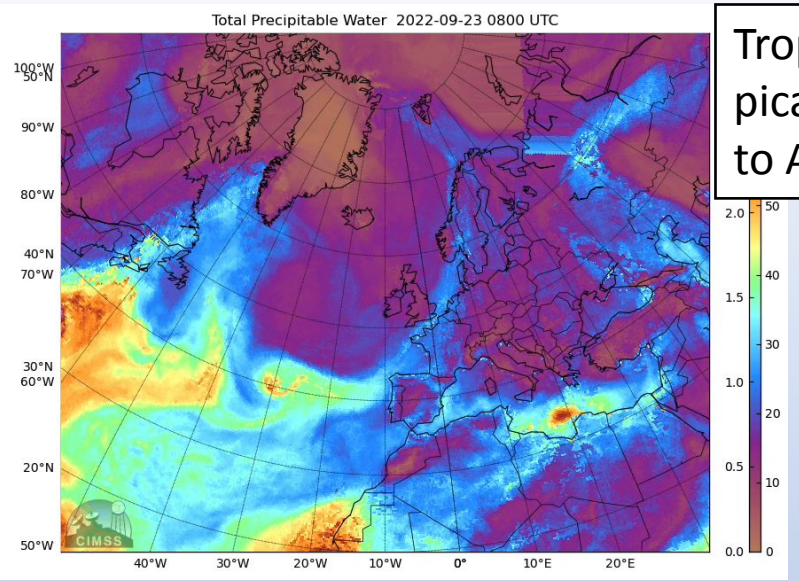
Mid latitude Impacts: Drought busters (beneficial) to extreme precipitation and floods (damaging)

Polar Impacts: Sea ice changes and +/- SMB land ice



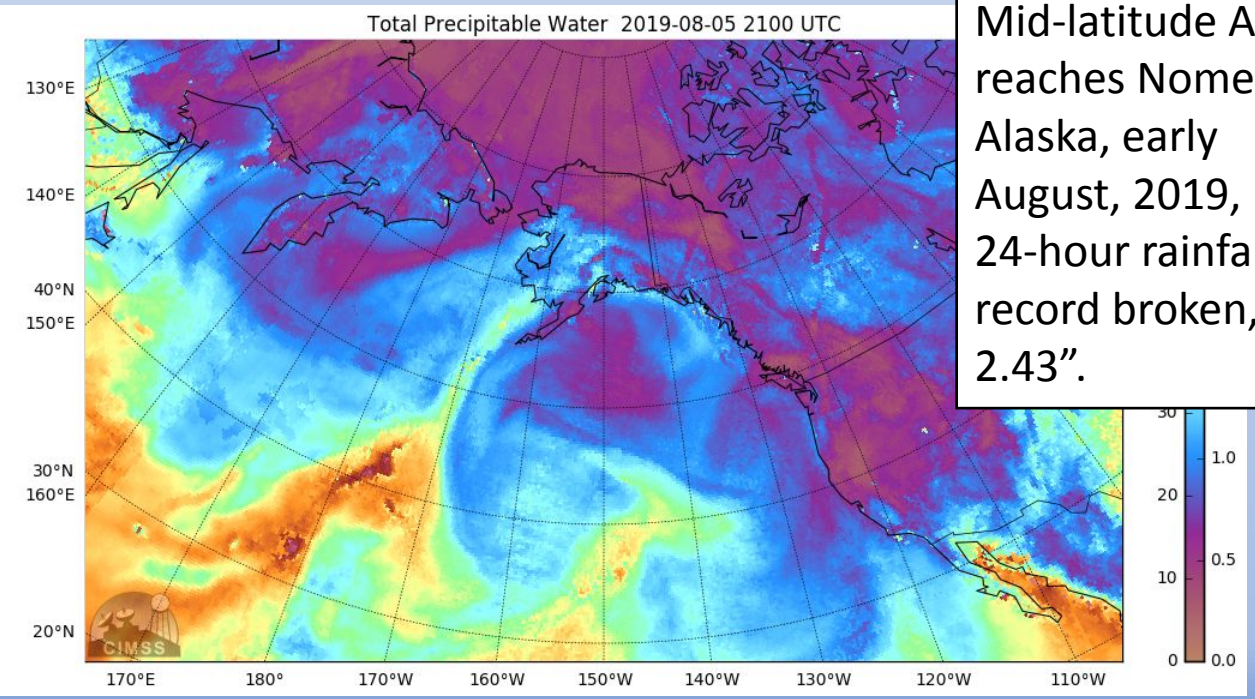
Antarctic Atmospheric River Event March 16, 2022





Tropical-Extratropical Transition to AR

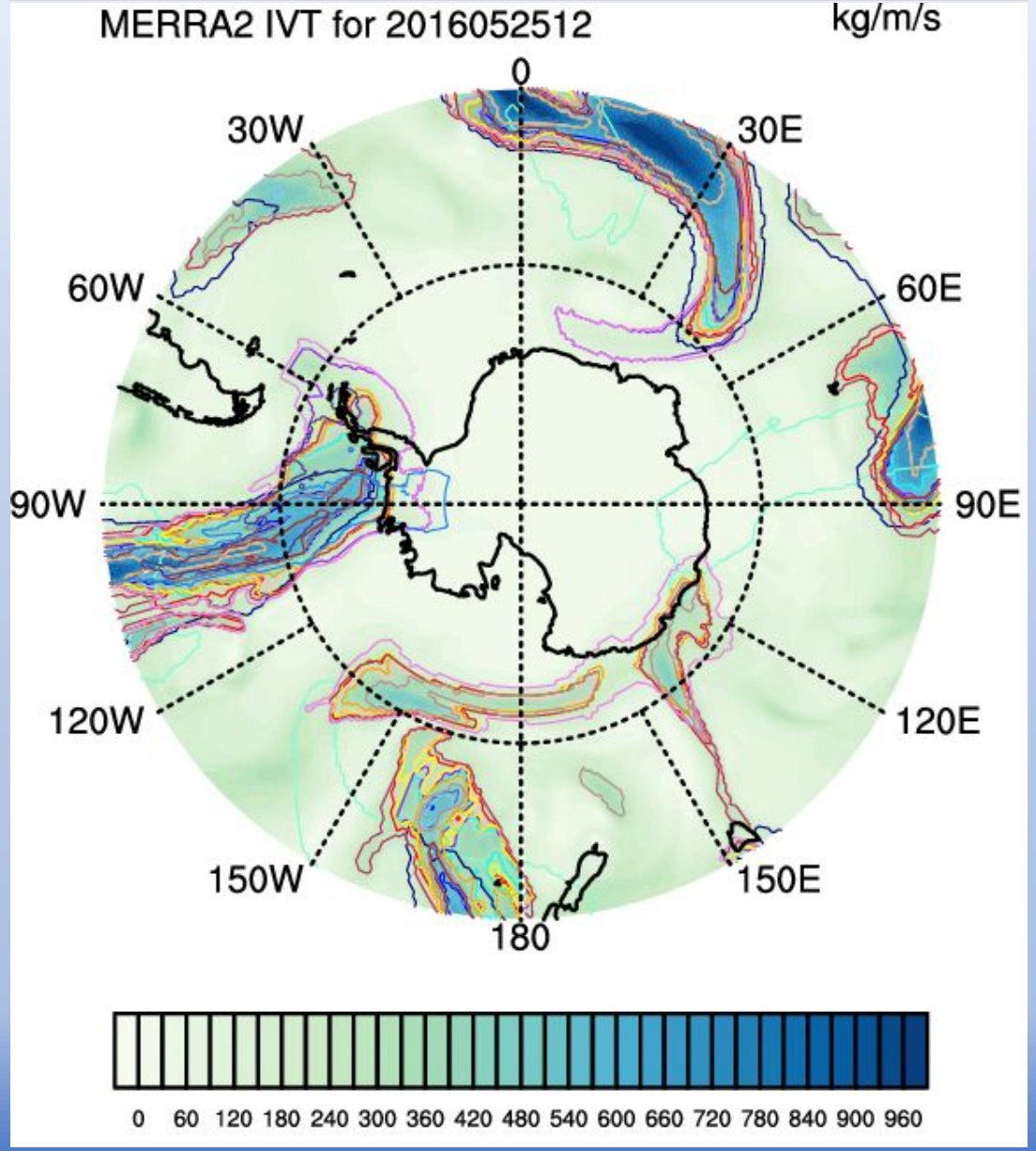
Credit: MIMIC-TPW v2 © 2022 Space Science & Engineering Center University of Wisconsin - Madison



Mid-latitude AR reaches Nome, Alaska, early August, 2019, 24-hour rainfall record broken, 2.43”.

Credit: University of Maine, National Oceanic and Atmospheric Administration (NOAA); NSIDC Science News

ARTMIP ARDTs (Atmospheric River Tracking Method Intercomparison Project)



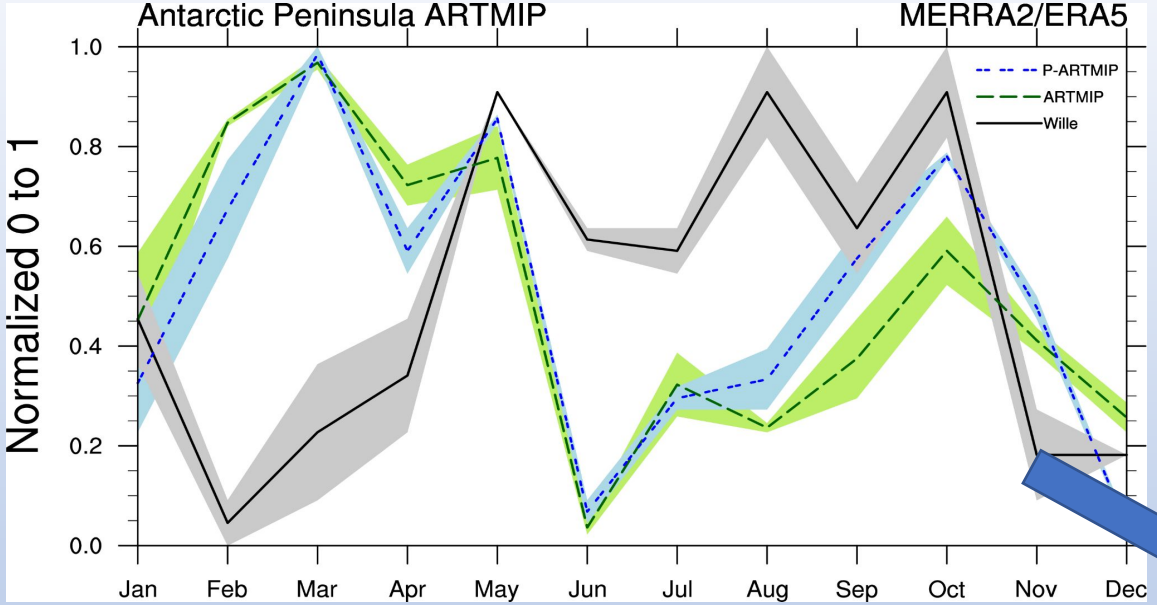
Uncertainty in AR Detection Tools

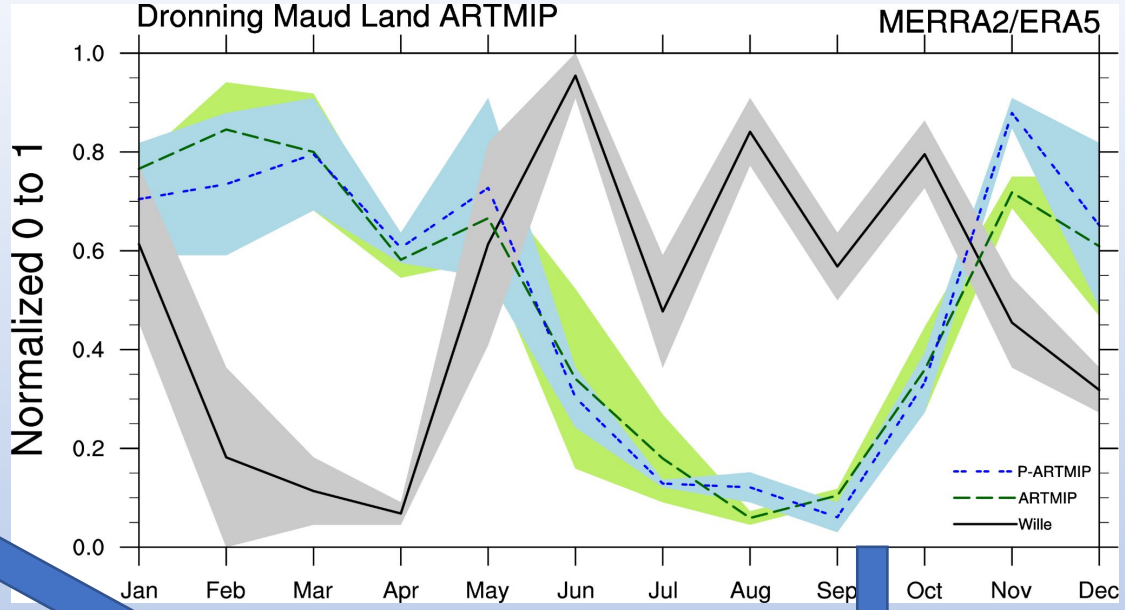
Global ARs designed for mid-latitudes and weight zonal and meridional components equally

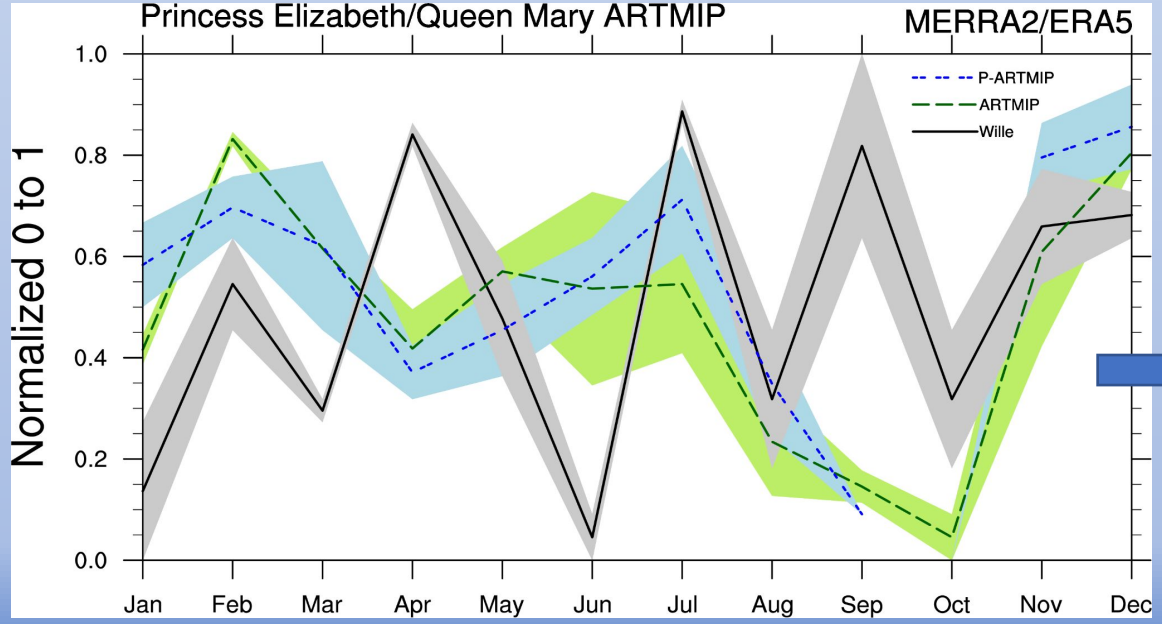
Antarctic-Specific factors in meridional geometry and cold, low humidity environments

West Antarctica Peninsula projects further out into Southern Ocean, so for ARDTs designed for mid-latitudes, these ARDTS are more likely to detect the AR.

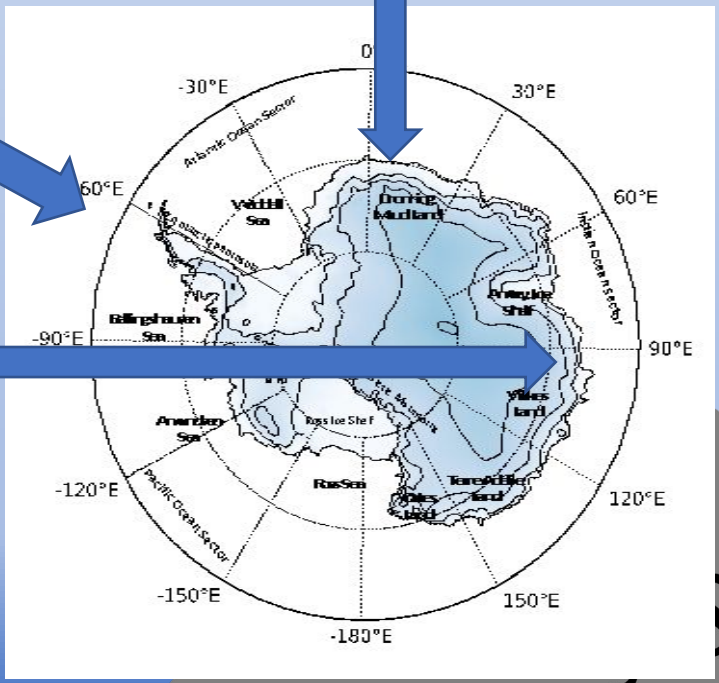
catalyst

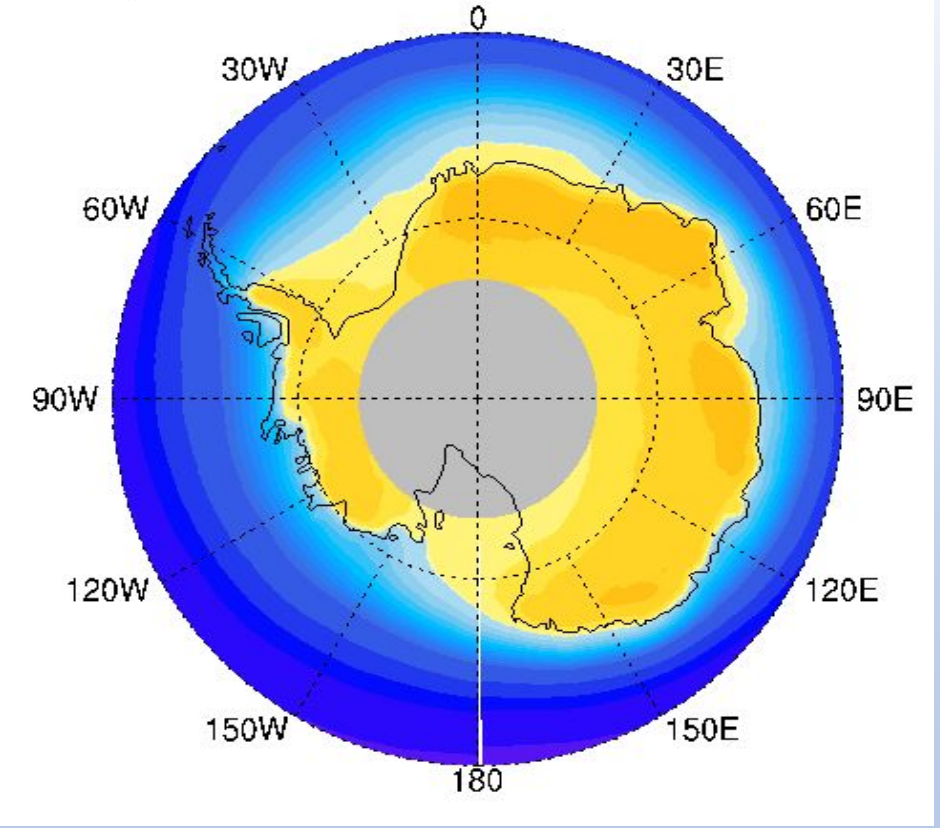


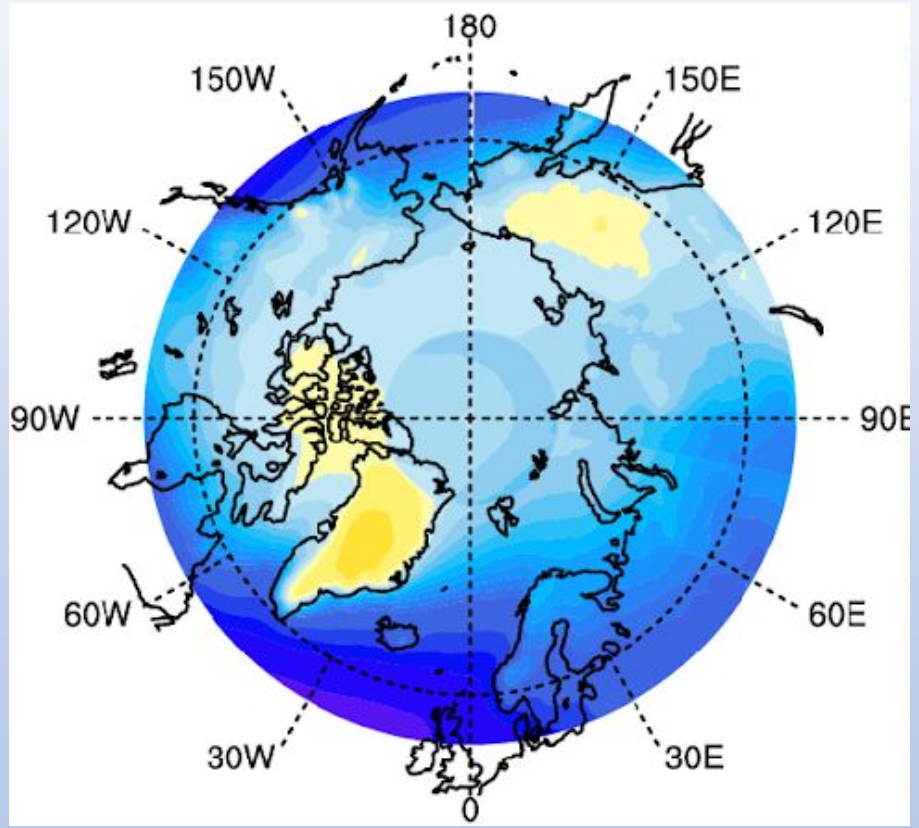




Polar Spec
Global-Some Polar logic
Global

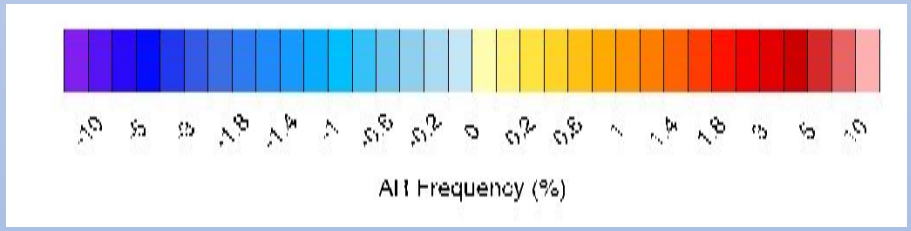




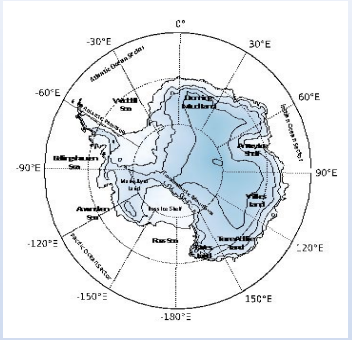


High latitude specific ARDTs vs global ARTMIP ARDTS

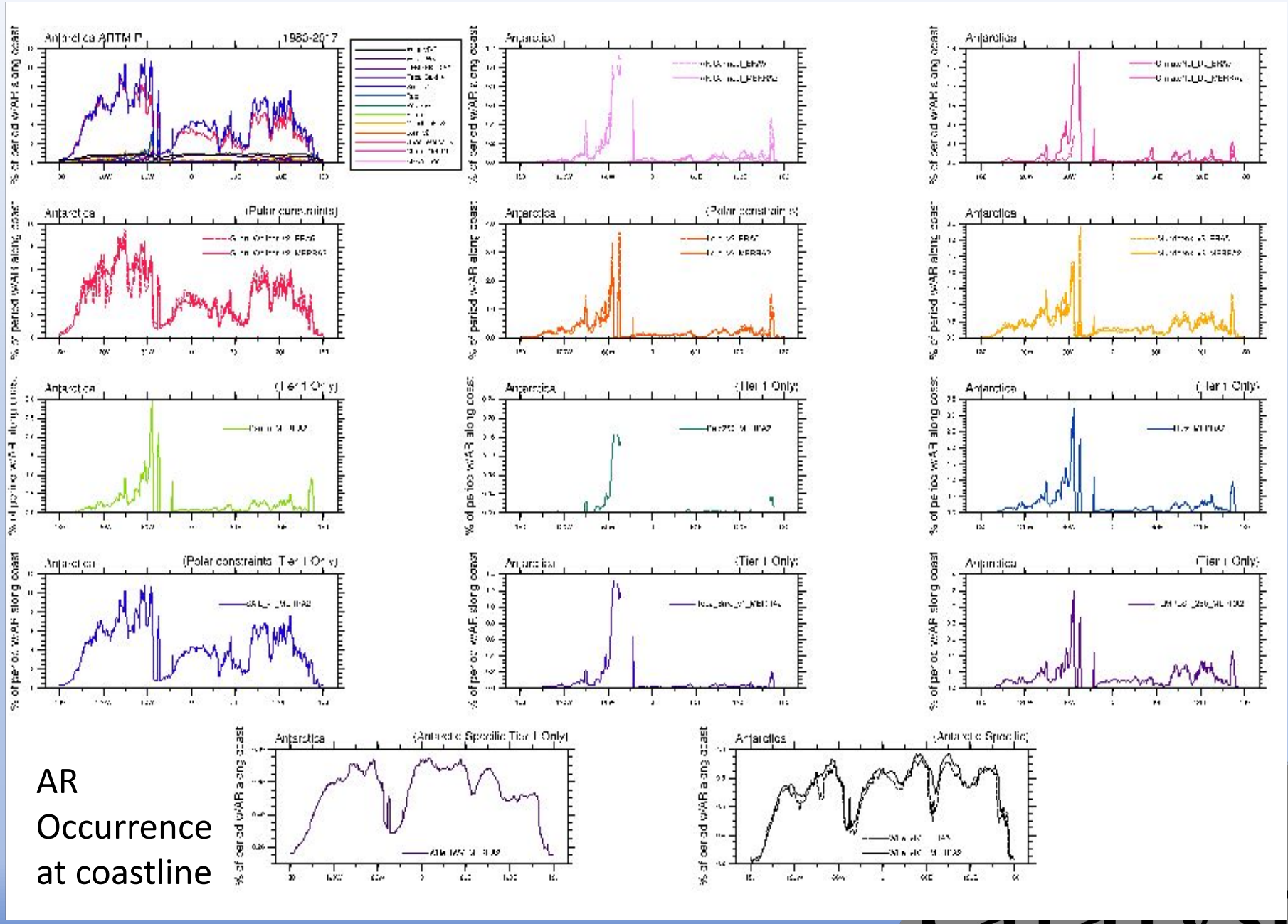
Difference in heatmap between high-lat ARDTs and global ARTMIP ARDTs show that globals still do not capture ARs on the ice sheets.



Shields et al., 2022, GRL



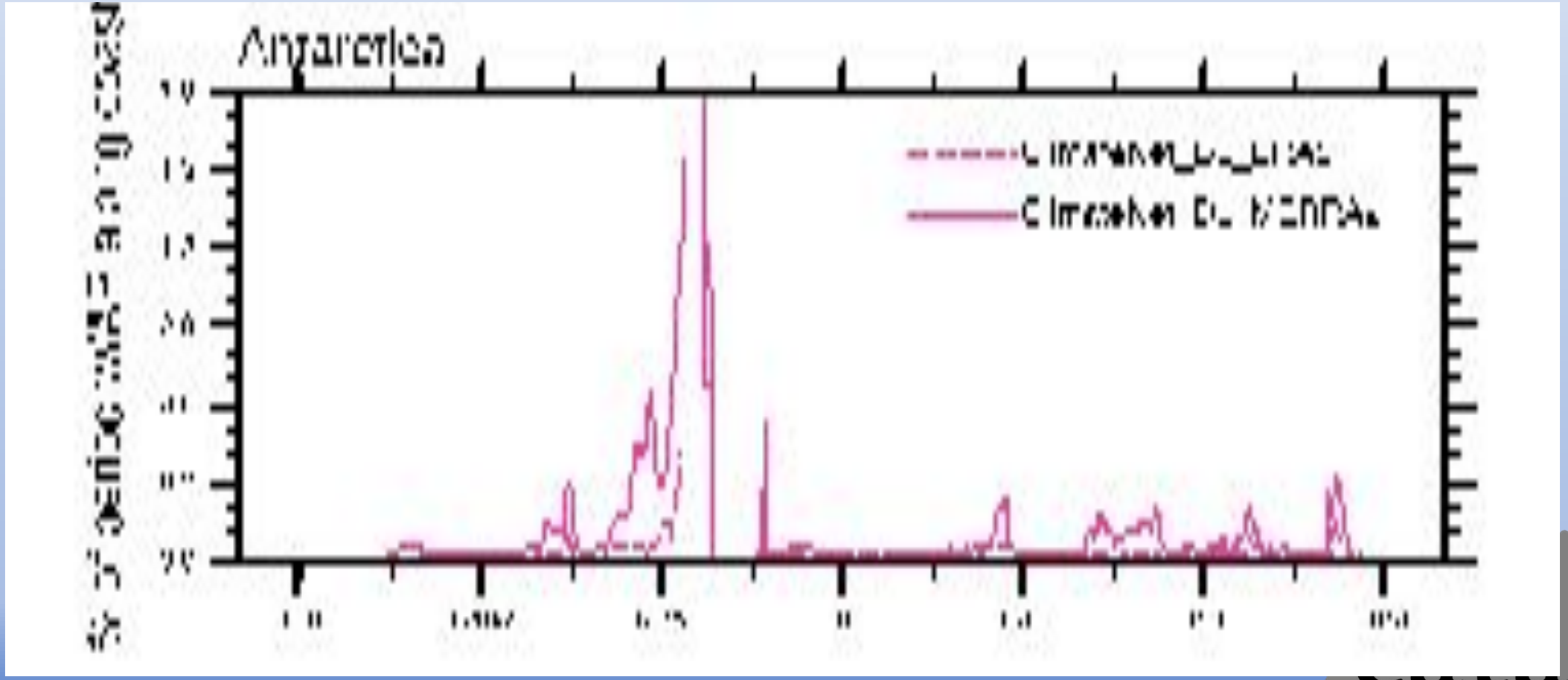
Longitudinal landfall by ARDTs show majority detect only at the Peninsula



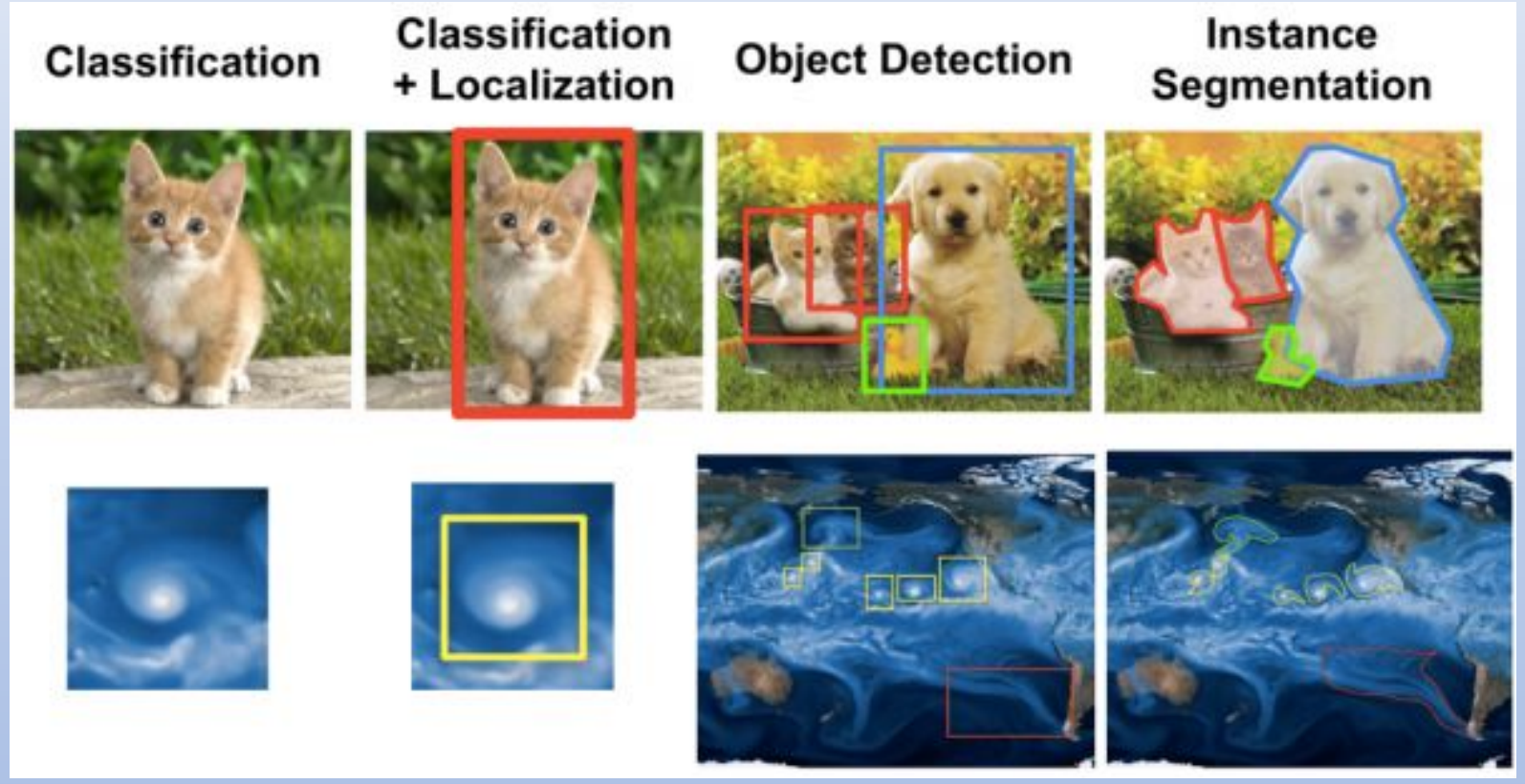
AR Occurrence at coastline

Machine Learning ARDTs

- Threshold free (avoid pitfalls for thresholding for climate change)!
- Only good as it's training data, currently emphasizing mid-latitudes and Antarctic Peninsula



How does Machine Learning and ClimateNet work?



For details on ClimateNet, see:
Prabat, Kashinath et al., GMD, (2021)

Geosci. Model Dev., 14, 107–124, 2021
https://doi.org/10.5194/gmd-14-107-2021

Article | Peer review | Metrics | Related articles

Model description paper 08 Jan 2021

ClimateNet: an expert-labeled open dataset and deep learning architecture for enabling high-precision analyses of extreme weather

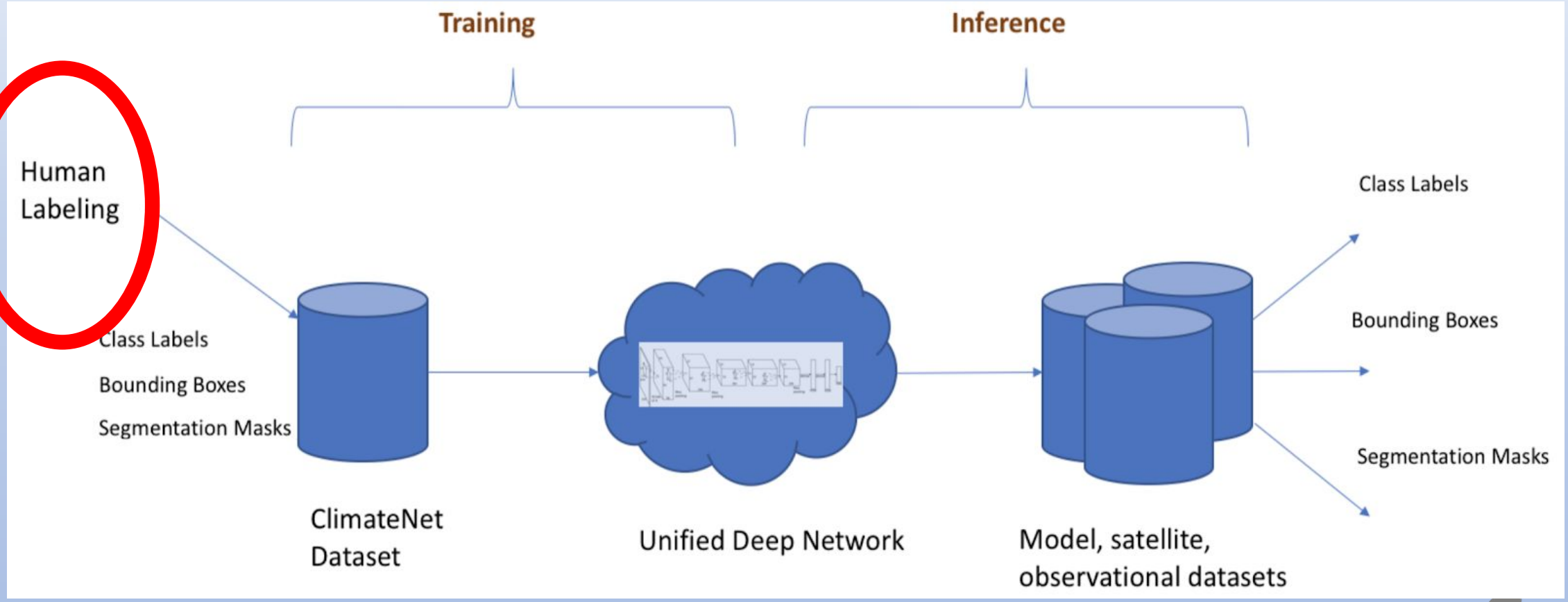
Prabhat[1,2,★], Karthik Kashinath[1,★], Mayur Mudigonda[10,★], Sol Kim[2], Lukas Kapp-Schwoerer[3], Andre Graubner[3], Ege Karaismailoglu[3], Leo von Kleist[3], Thorsten Kurth[4], Annette Greiner[1], Ankur Mahesh[2,1], Kevin Yang[2], Colby Lewis[2], Jiayi Chen[2], Andrew Lou[2], Sathyavat Chandran[5], Ben Toms[6], Will Chapman[7], Katherine Dagon[8], Christine A. Shields[8], Travis O'Brien[9,1], Michael Wehner[1], and William Collins[1,2]

[1]Lawrence Berkeley National Laboratory, Berkeley, CA, USA
[2]Department of Earth and Planetary Science, University of California, Berkeley, CA, USA
[3]ETH Zurich, Zürich, Switzerland
[4]NVIDIA, Santa Clara, CA, USA
[5]Department of Computer Science, Rice University, Houston, TX, USA
[6]Department of Atmospheric Science, Colorado State University, Fort Collins, CO, USA
[7]Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA, USA
[8]National Center for Atmospheric Research, Boulder, CO, USA
[9]Department of Atmospheric Science, Indiana University, Bloomington, IN, USA
[10]Terrafuse, Berkeley, CA, USA
★These authors contributed equally to this work.

Correspondence: Karthik Kashinath (kkashinath@lbl.gov)

Image from: https://www.nersc.gov/research-and-development/data-analytics/climatenet/

Training data matters



For details on ClimateNet, see:
Kashinath et al. (2021)

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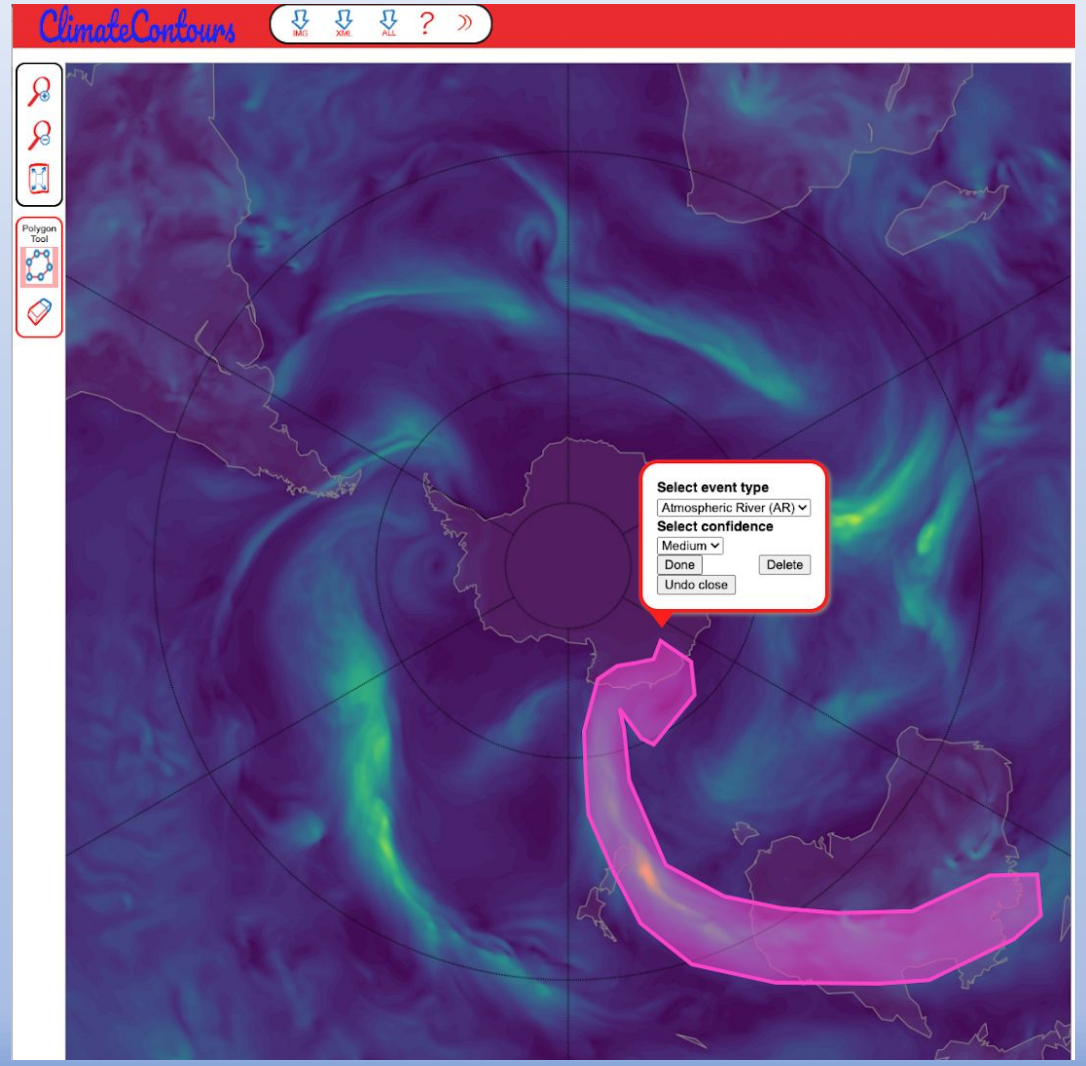
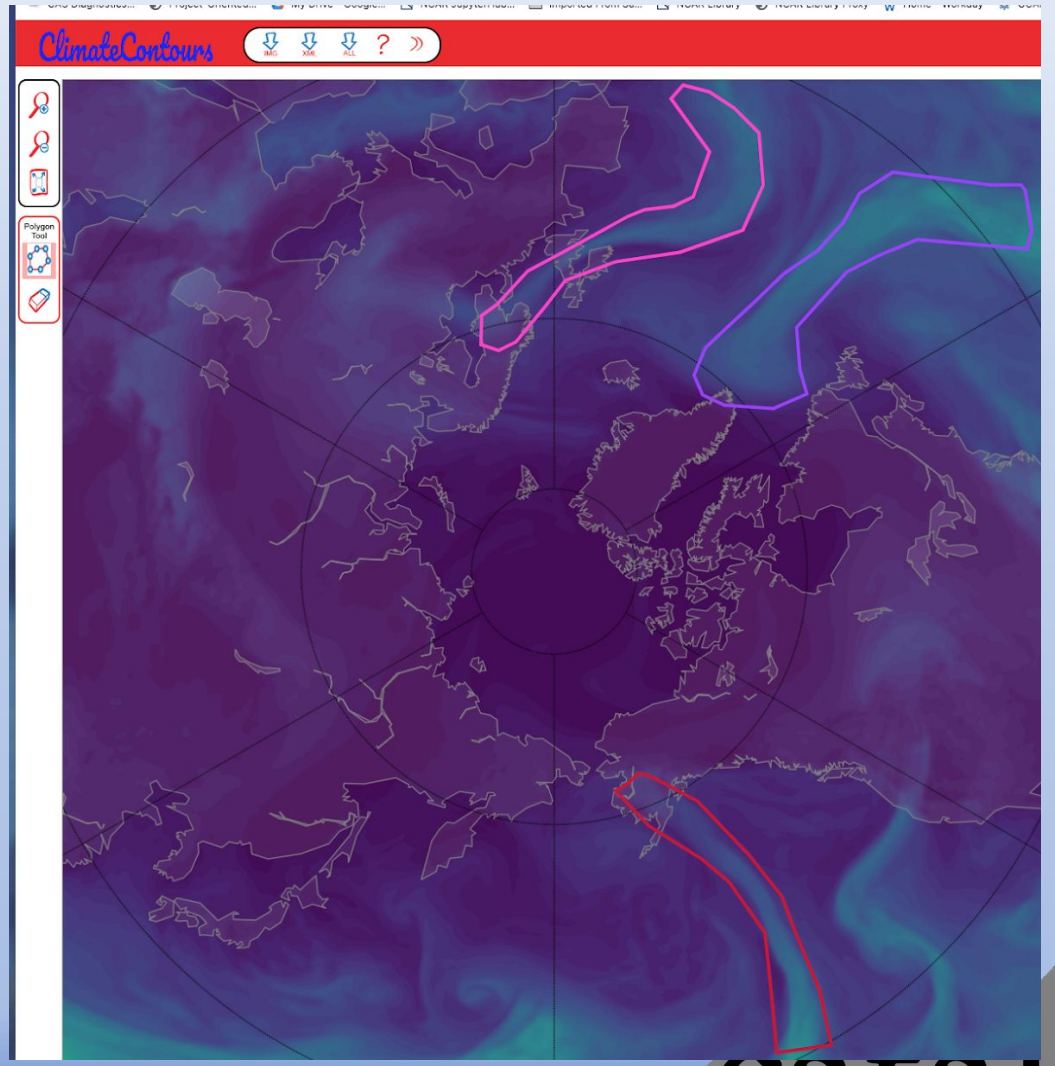
ClimateNet Labelling Tool Used To Create Training Data





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Different variables used for hand label evaluation

Channels:

Integrated Vapor Transport

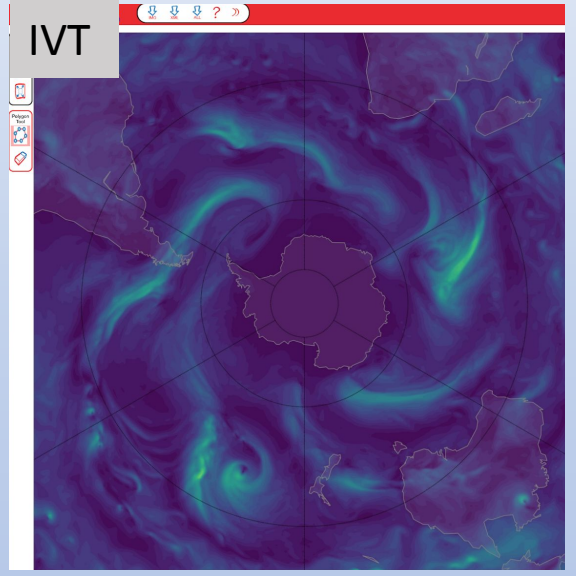
Integrated Water Vapor

IWV & Wind at 850mbar

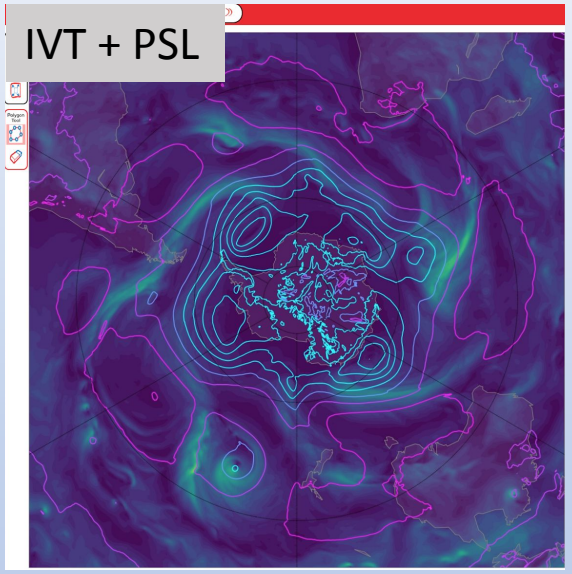
Pressure at Sea Level

IVT & PSL

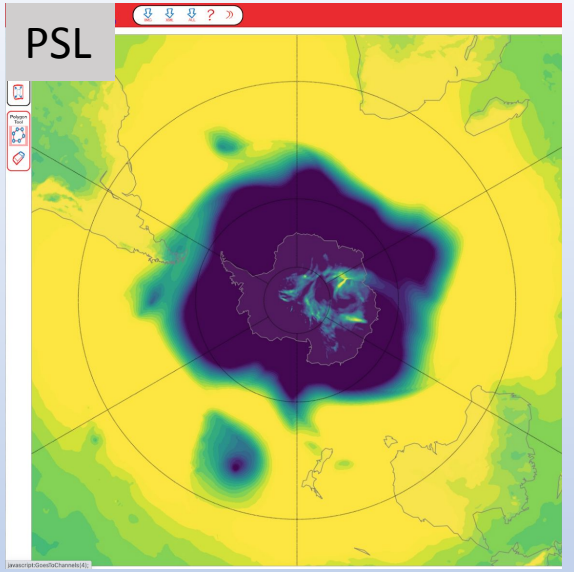
IVT



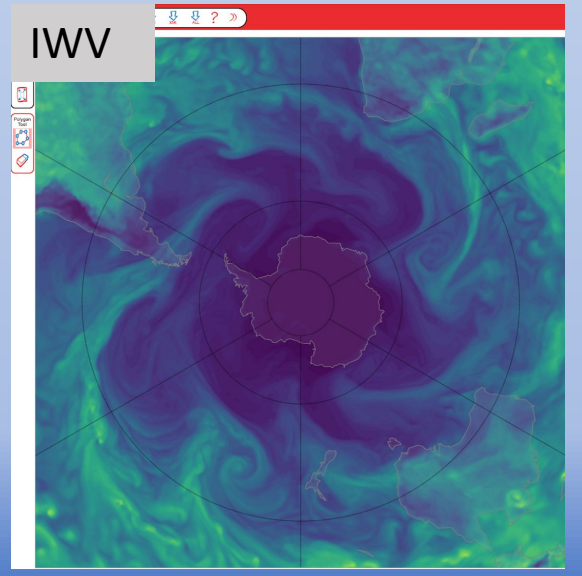
IVT + PSL



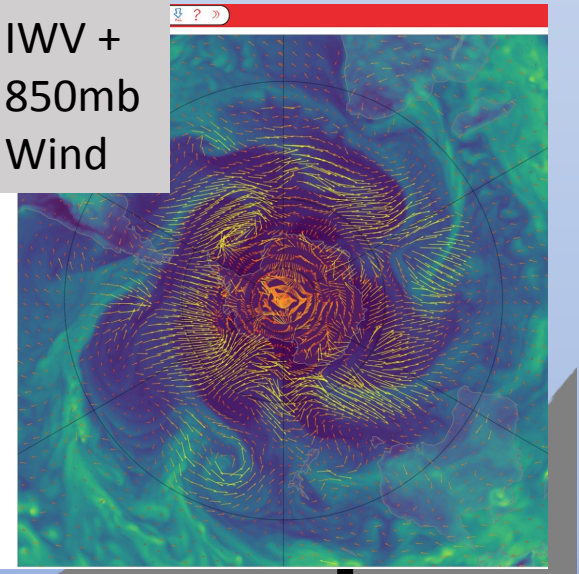
PSL



IWV



IWV + 850mb Wind



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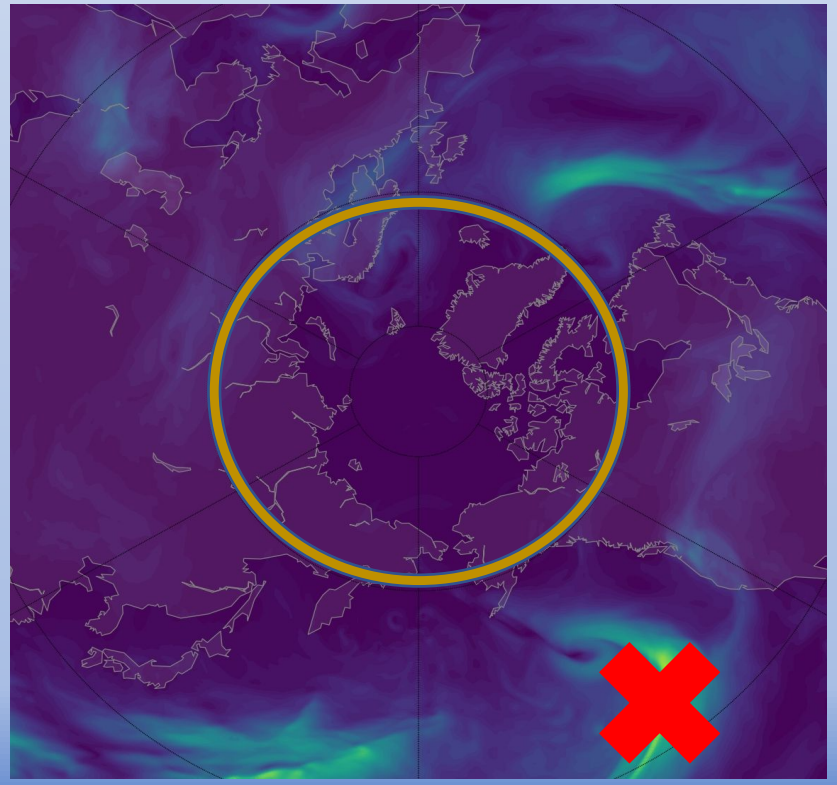
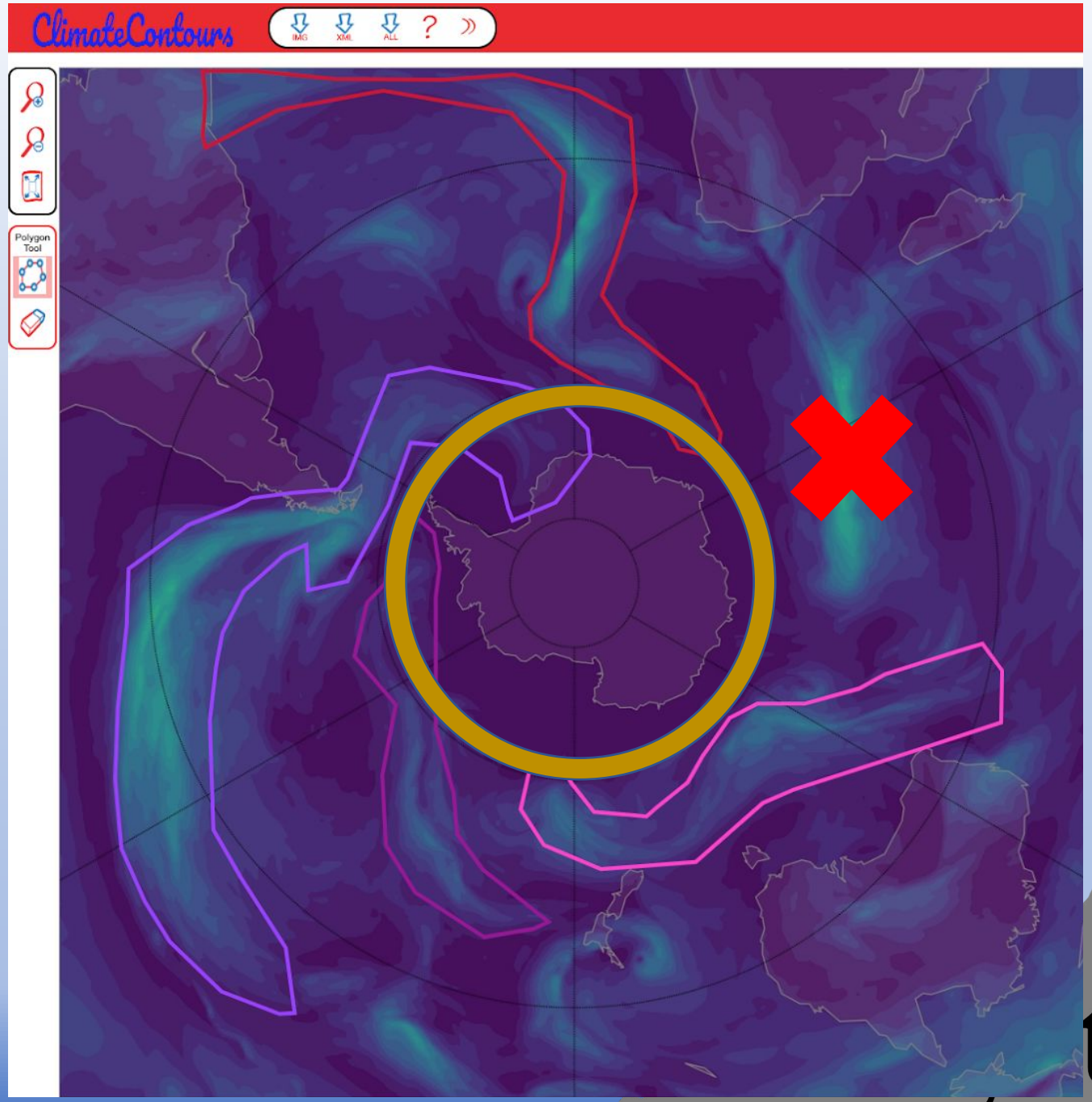
Focused on High Latitude AR shapes and not mid-latitude shapes, i.e. ARs reaching poleward of 60 N/S





Labelling Campaigns, Training Data, and Quality Control

Labelling Campaigns:

1) CU PolAR Day, Boulder, CO, August 2022
2) Polar AMS, Madison WI, August 2022
3) IARC, Santiago, Chile, October 2022
4) Random labelling via Contouring Tool website

Interested in helping? shields@ucar.edu

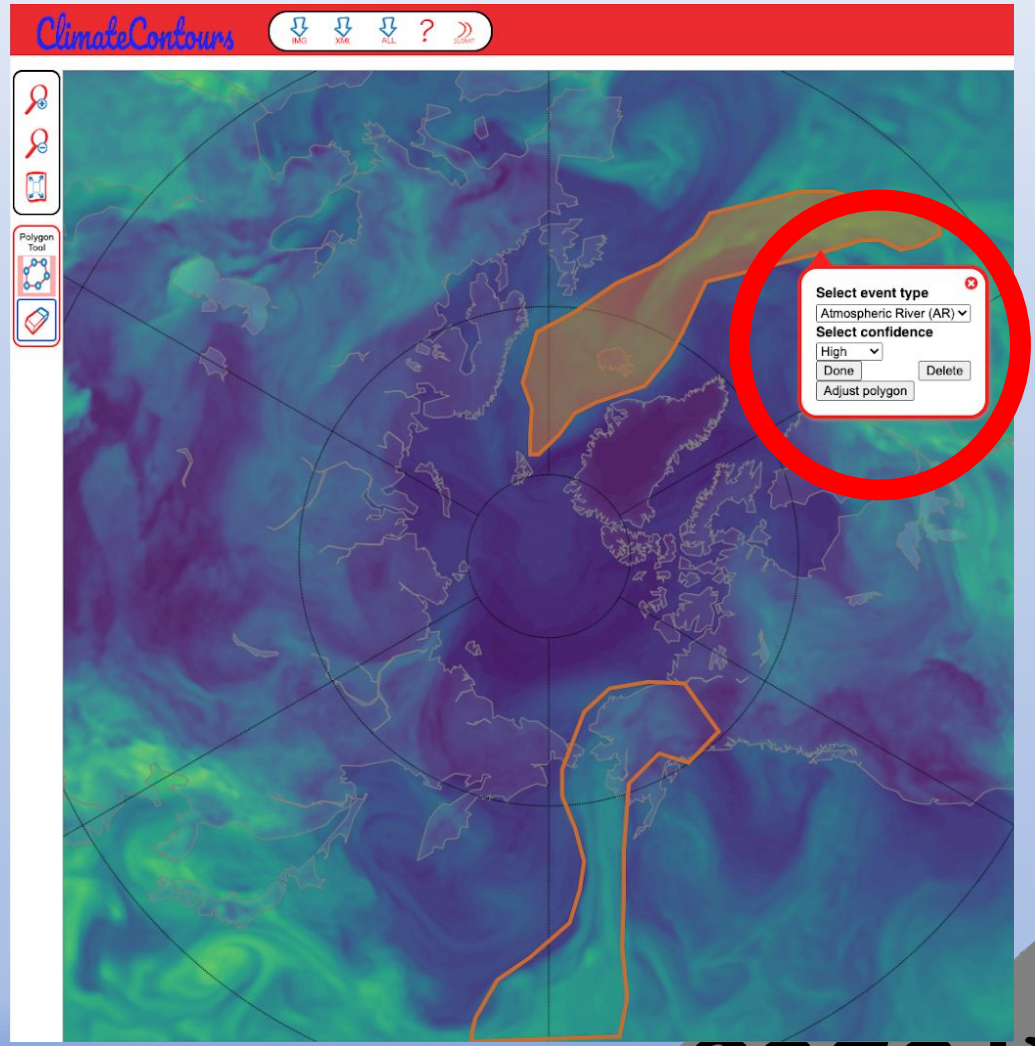
Antarctic Masks created: 301

Arctic Masks created: 92 (probably need more)

Quality Control:

QC tool to remove inconsistent images, or mistakes:

Annette, Sol, Teagan, Christine



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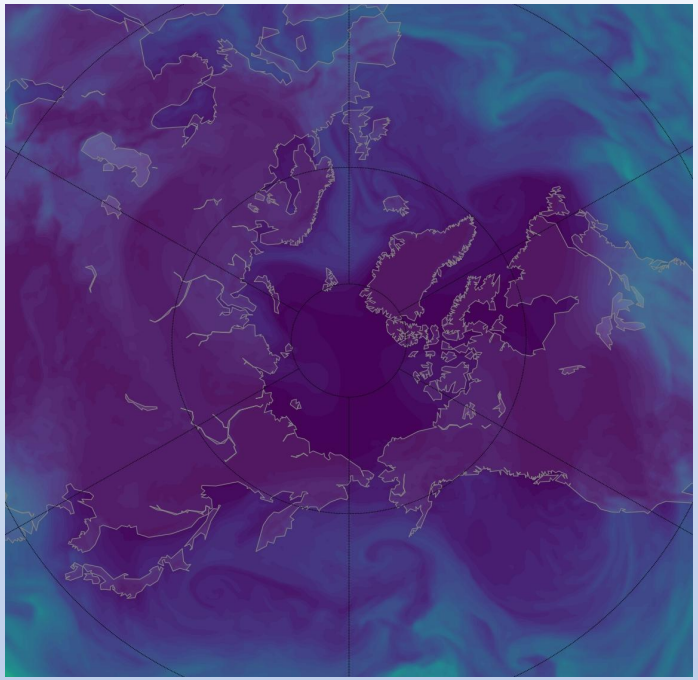
Applying CGNet for training…

- Remapping: Polar stereographic to lat/lon coordinates so that QC'd masks match data
- TMQ used for preliminary training
- CAM5 25km data for both masks
- Training vs Testing (80% & 20%) ensures landfall examples are in training
- *Weights and Biases* is a tool for optimizing training parameters



W&B

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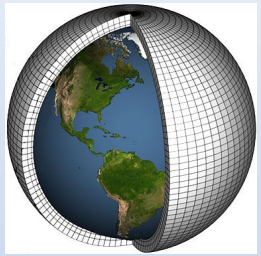
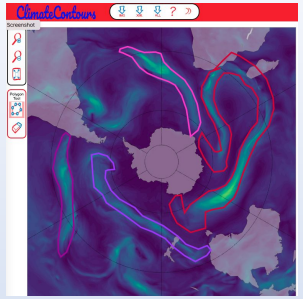
Polar Version





CAM5 NERSC processed data (from labeling campaigns)

Training data: subset of available date range

Test data: different subset of date range

Train CGnet

1 channel: TMQ

Other polar AR-specific variables

We are here with Polar ARs

CESM1.3 HighRes (ne120) Simulations

Historical 2000-2005

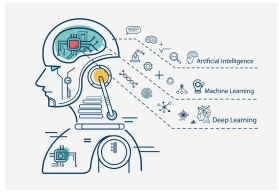
RCP2.6: 2006-2015

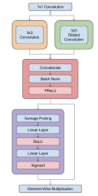
RCP8.5: 2086-2100

Postprocessing CESM history files

- Variable-specific processing
- Remap CESM variables from ne120 to 0.25 deg
- Separate i… …irement for CGnet)

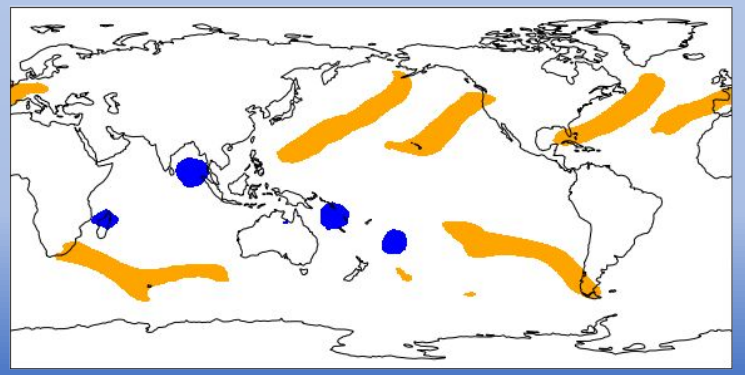
Run CESM processed data through previously trained CGnet models (Inference)

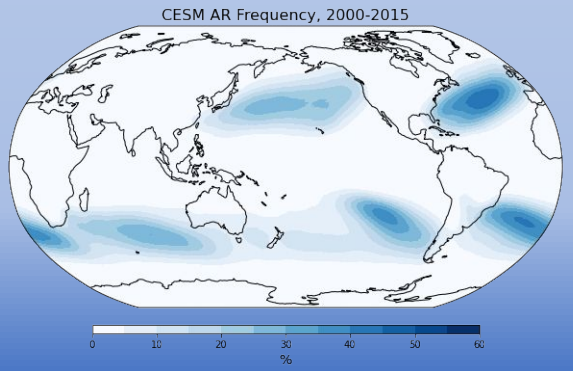


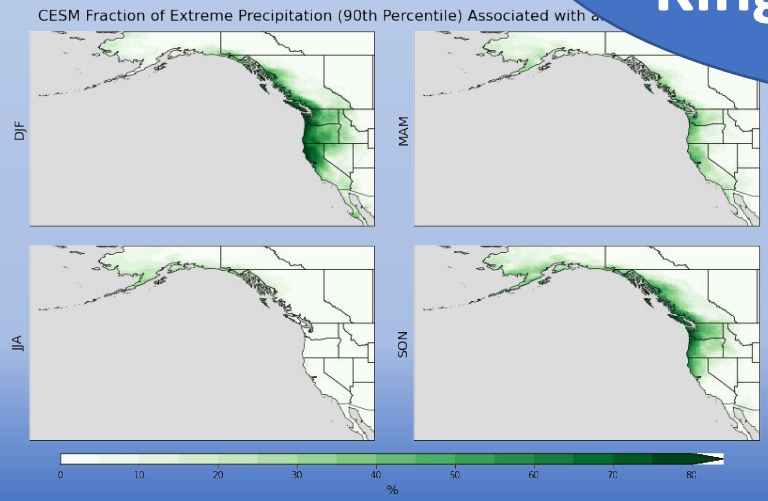


This has been done for global ARs already, (Dagon, King, Truesdale)

Generate Masks!

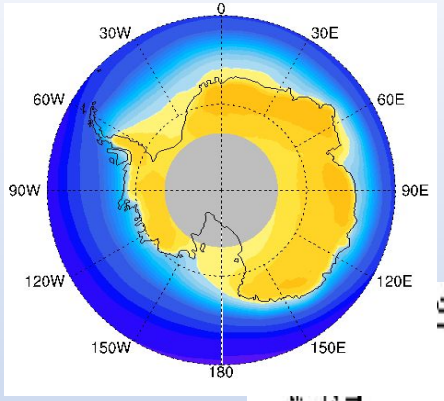


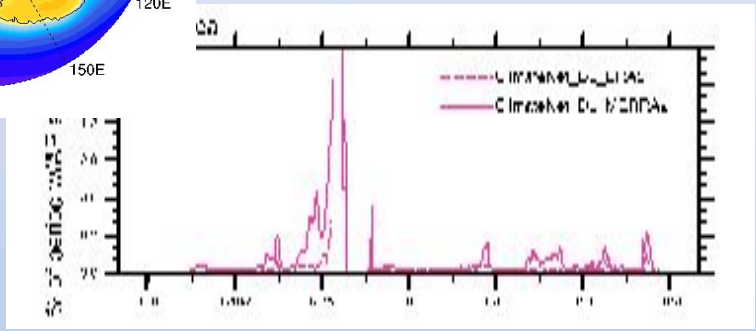


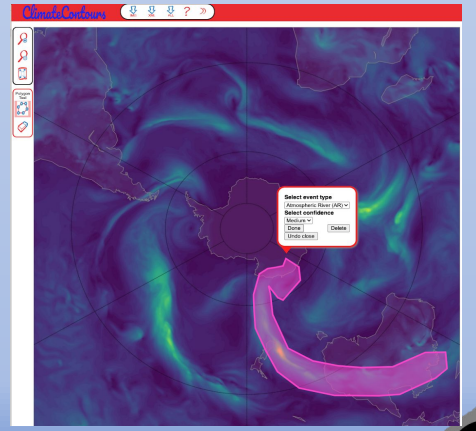


Summary

- Global ARDTs may not be appropriate for Antarctic ARs detection, especially for interior locales
- Machine Learning is one way to avoid using pitfalls associated with classic thresholding techniques
- Global ML ARDTs are trained with data designed to capture mid-latitude ARs and do not accurately capture polar ARs
- Application of the LBNL Climate Contouring Tools has created Antarctic/Arctic AR training datasets
- CGNet ML framework is being use to create a ML threshold free ARDT for high latitudes
- Interested in helping create me training data, see me!







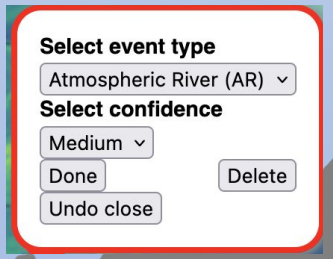


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Photo Credit: Jonathan Wille/MODIS-Terra Aqua/NASA WorldviewSatellite imagery from an atmospheric river over Antarctica on January 25, 2008, which triggered the disintegration of ice in the Larsen A and Larsen B shelves. (Antarctic Peninsula)

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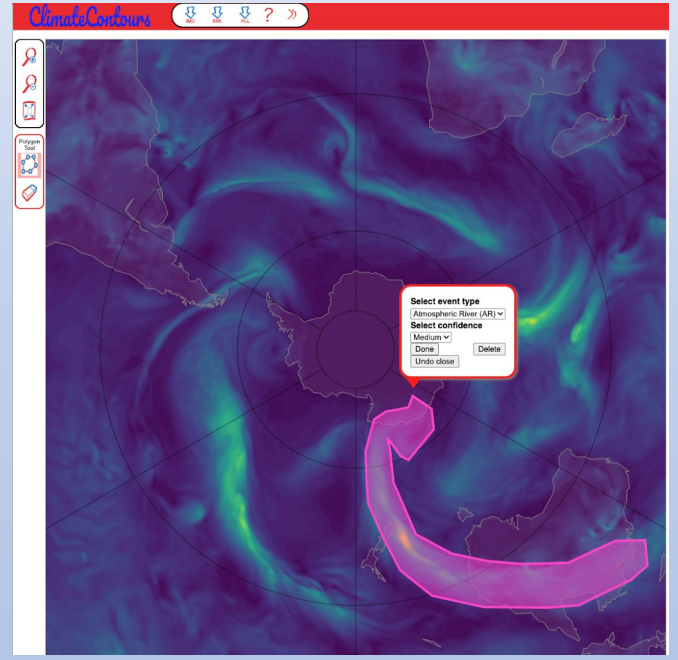
Extra Slides

Contouring Tool:

Antarctic: https://climatecontours-gold.nersc.gov

Arctic: https://climatecontours-arctic.nersc.gov



Summary of Rules and Guidelines:

https://tinyurl.com/36b8yrwk

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Preliminary results….

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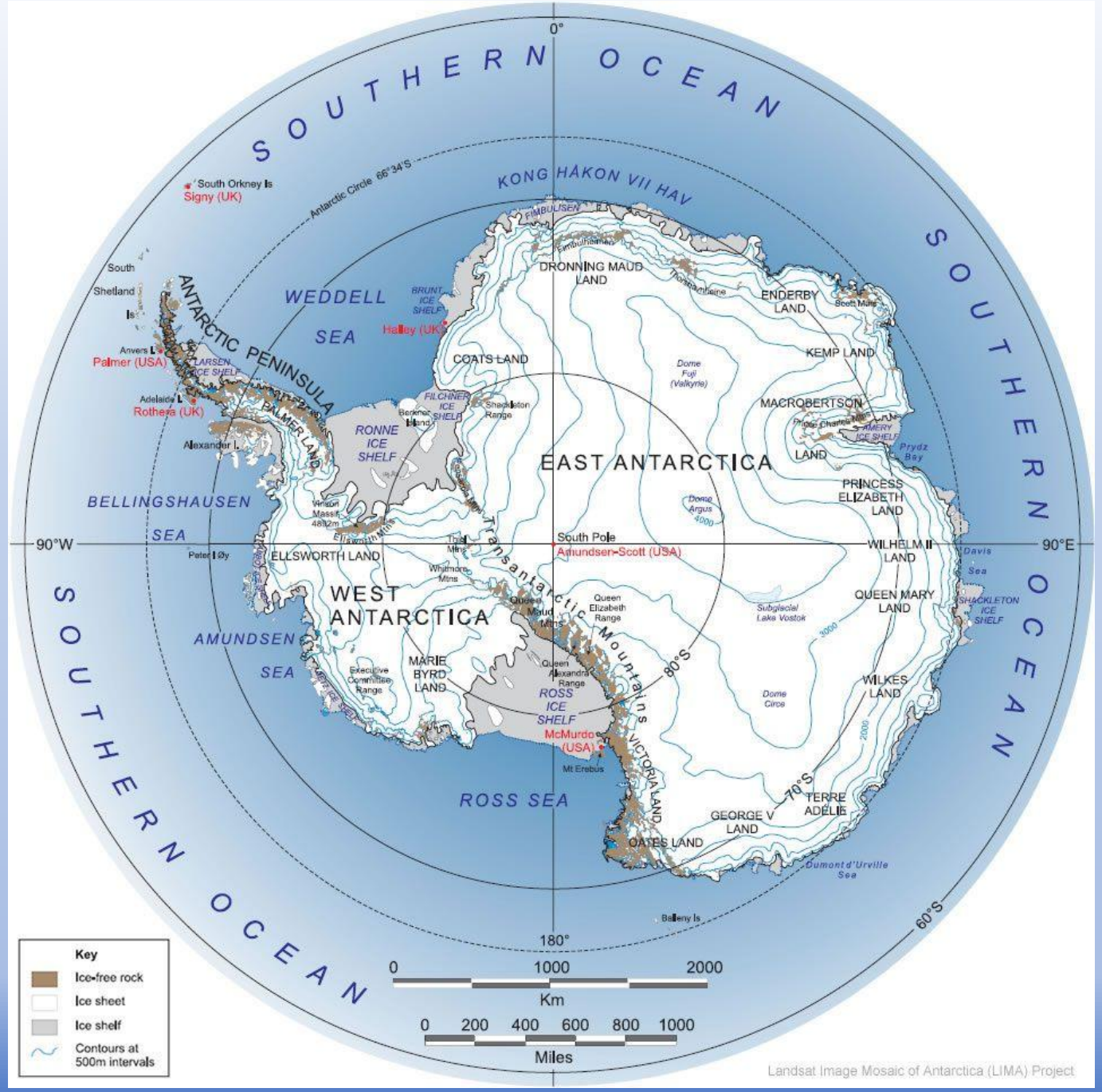
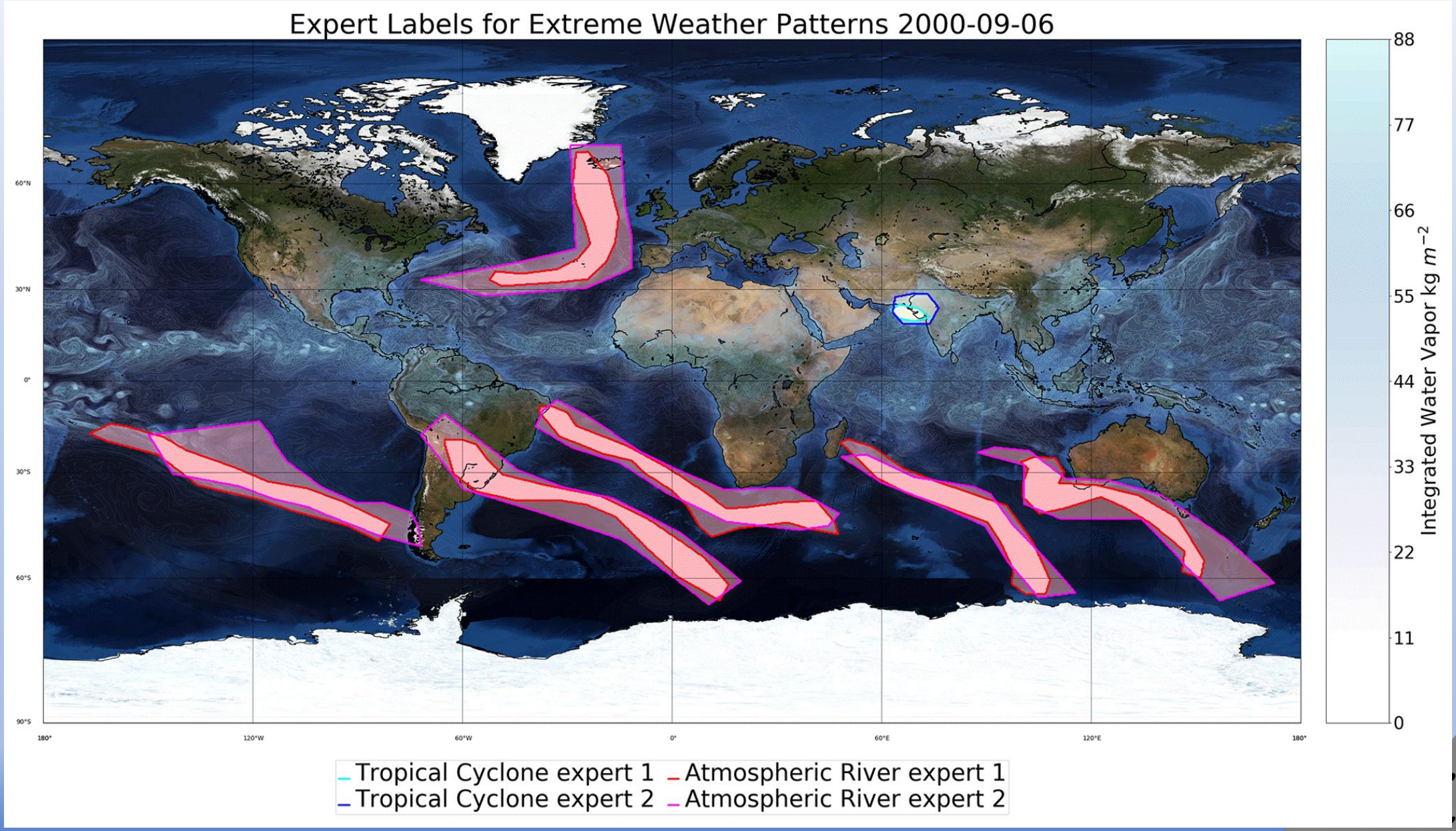
Antarctic Geography

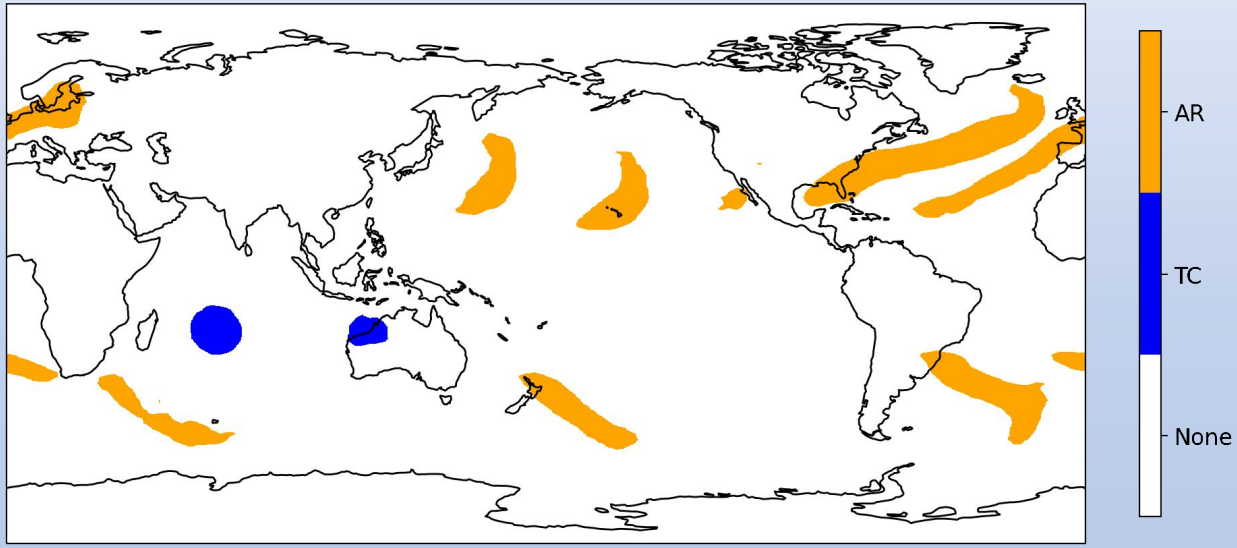


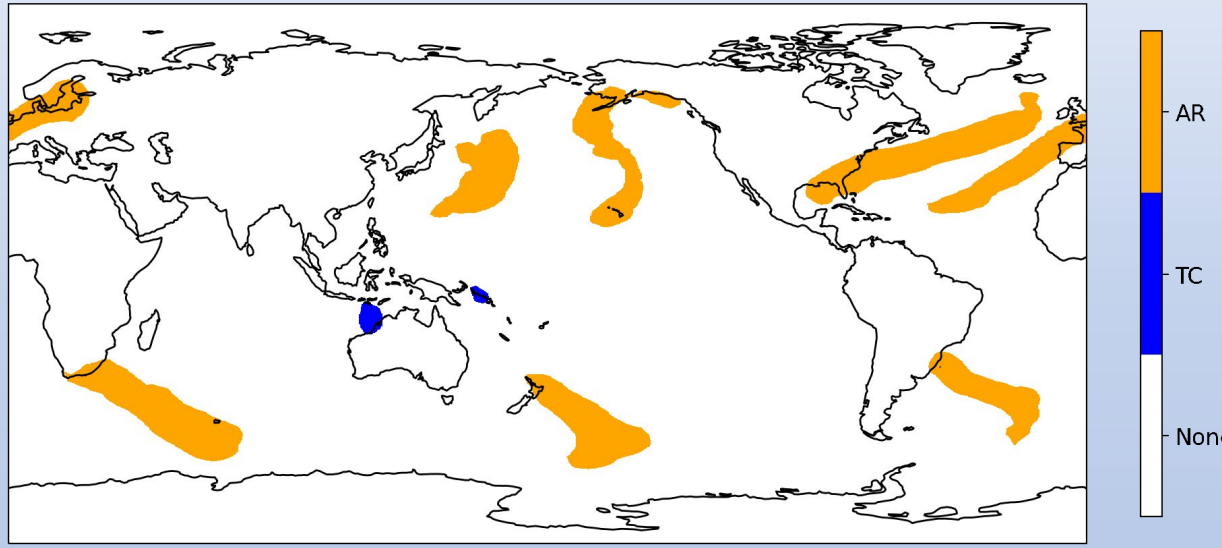
catalyst

Example Contouring Tool Data for CGNet



ClimateNet training data:
Do the results change when altering input fields?





Trained on 4 fields:
vertically integrated precipitable water, sea level pressure, and u/v winds at 850mb

Trained on 1 field:
vertically integrated precipitable water

Unable to detect TCs, but able to **detect ARs with similar spatial/temporal representation as model trained on all 4 input fields**

Slide courtesy of Katie Dagon and John Truesdale

catalyst