Analysis of the 19 June 2020 Twin Arctic Cyclones and Tropopause Polar Vortices

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Background

This presentation will be focused on a synoptic overview of the 19 June 2020 case and associated forecast skill

Tropopause Polar Vortex

- A **Tropopause Polar Vortex (TPV)** is a coherent vortex along the tropopause
- **Cyclonic TPVs** are identified by a local minimum in temperature and dynamic tropopause height, and local maximum in potential vorticity
- TPVs occur primarily in high latitudes poleward of the midlatitude jet

(Hakim and Canavan 2005)

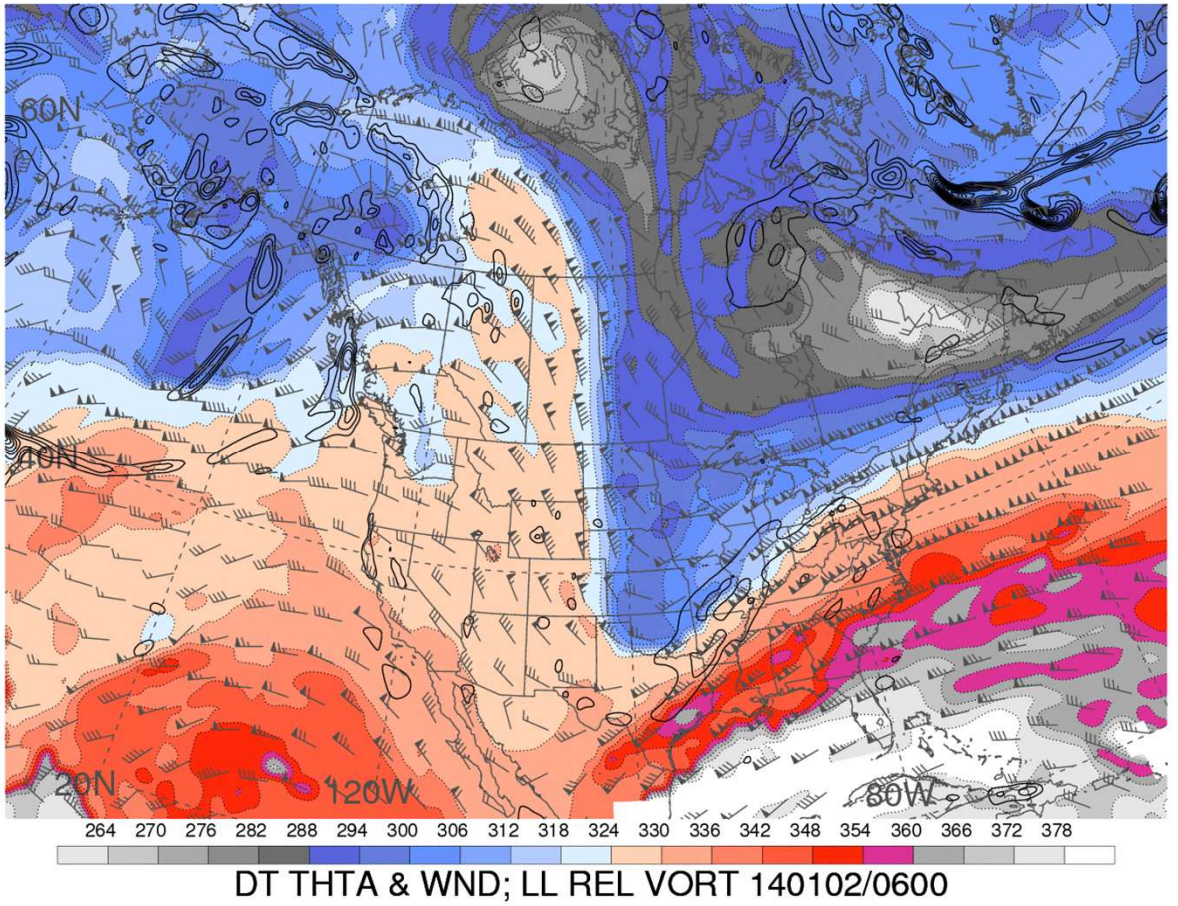

Image credit: ***Heather Archambault***

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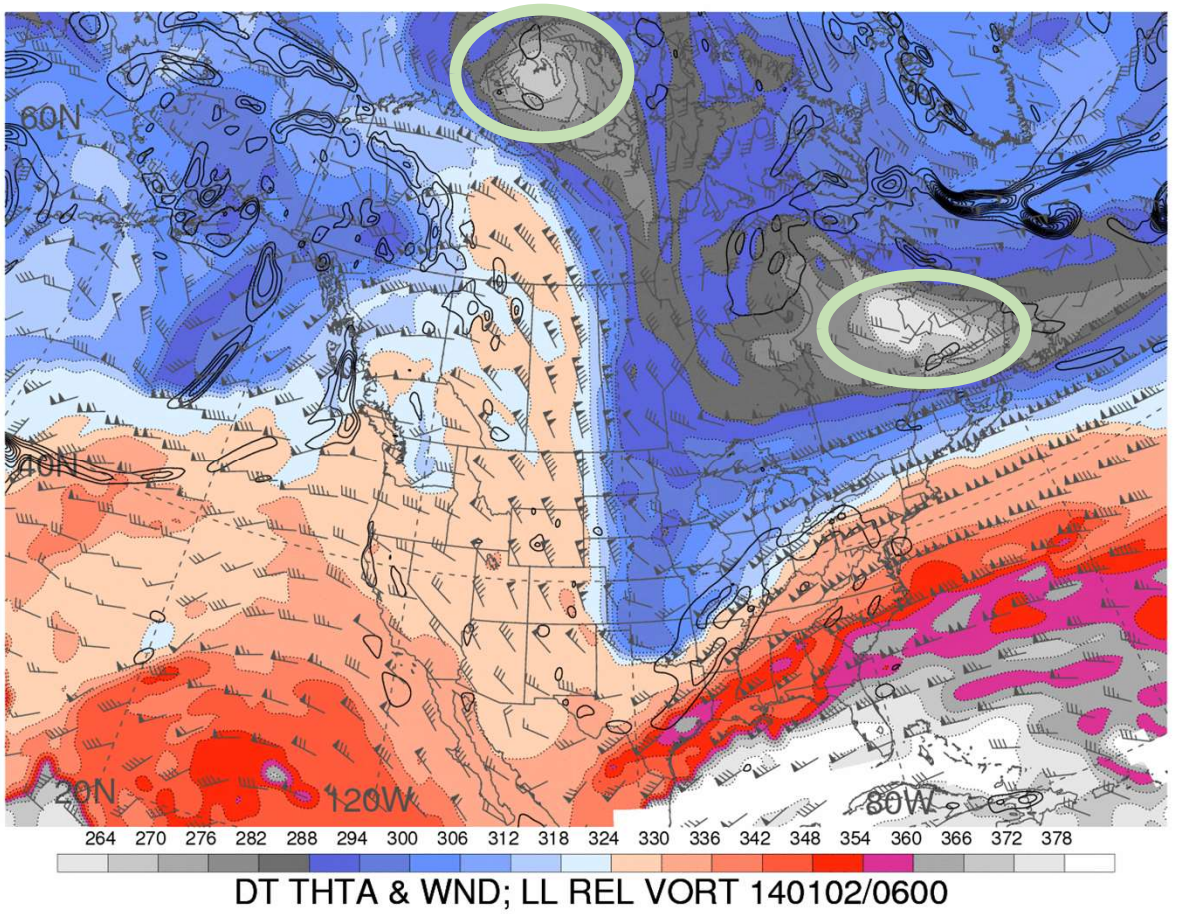


Image credit: ***Heather Archambault***

Tropopause Polar Vortex

- Vortices along the tropopause meet the definition of a TPV if they:
  - Spend at least 60% of their lifetime poleward of 65ºN latitude
  - Last for two or more days
    (Hakim and Canavan 2005)

- Common characteristics of TPVs include:
  - Typical radii of 100–1000 km (Szapiro and Cavallo 2018)
  - Lifetime ranging from days to months (Szapiro and Cavallo 2018)

TPV Pathways to Midlatitudes

TPVs can be transported into the midlatitudes, impacting weather in North America, Europe and Asia

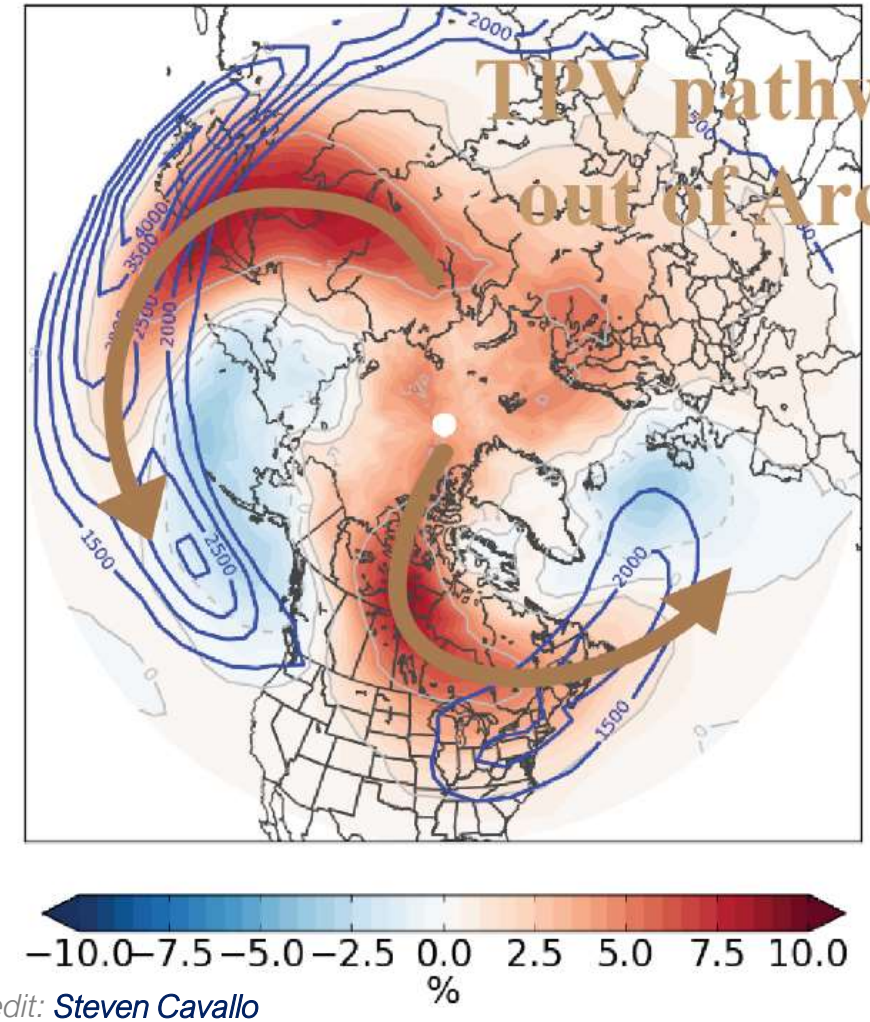


Image credit: ***Steven Cavallo***

Shading: Probability of TPV in winter minus full year

Contours: Jet streaks

Tropopause Polar Vortex

Why should I care about TPVs?

Tropopause Polar Vortex

Why should I care about TPVs?

SEVERE WEATHER

- TPVs entering the midlatitudes influence jet streak patterns associated with severe weather outbreaks (Preliminary work from Bray and Cavallo)

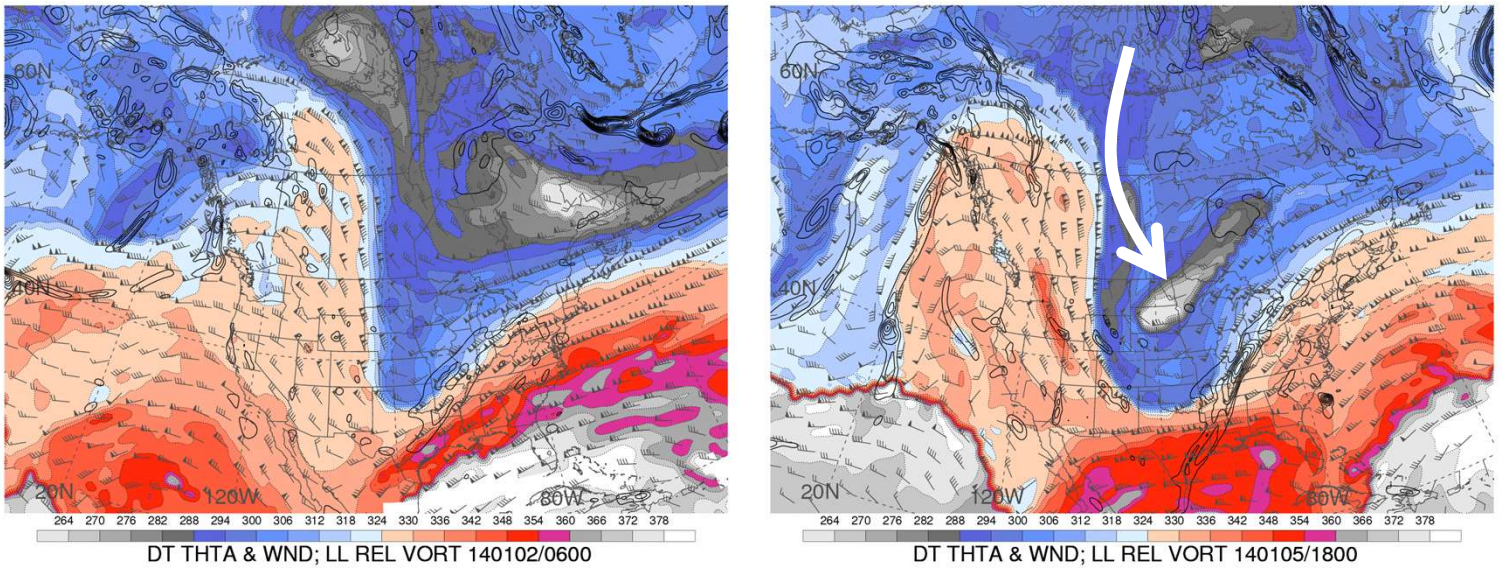
- Statistically significant patterns in forcing for ascent, instability and wind shear

Tropopause Polar Vortex

Why should I care about TPVs?

COLD AIR OUTBREAKS

- TPVs can be transported into the midlatitudes, and are associated with North American cold air outbreaks (Biernat 2017, Lillo et al. (in prep))



January 2014 U.S. Cold Air Outbreak

*Image credit: **Heather Archambault***

Tropopause Polar Vortex

Why should I care about TPVs?

ARCTIC CYCLONES

- TPVs often precede Arctic Cyclone (AC) formation and are vertically coupled with ACs at their peak intensity (Simmonds and Rudeva 2014)

- Arctic Cyclones are associated with sea ice loss (Zhang et al. 2013)

High Latitudes & Predictability

- Observations are often sparse in the Arctic compared to lower latitudes

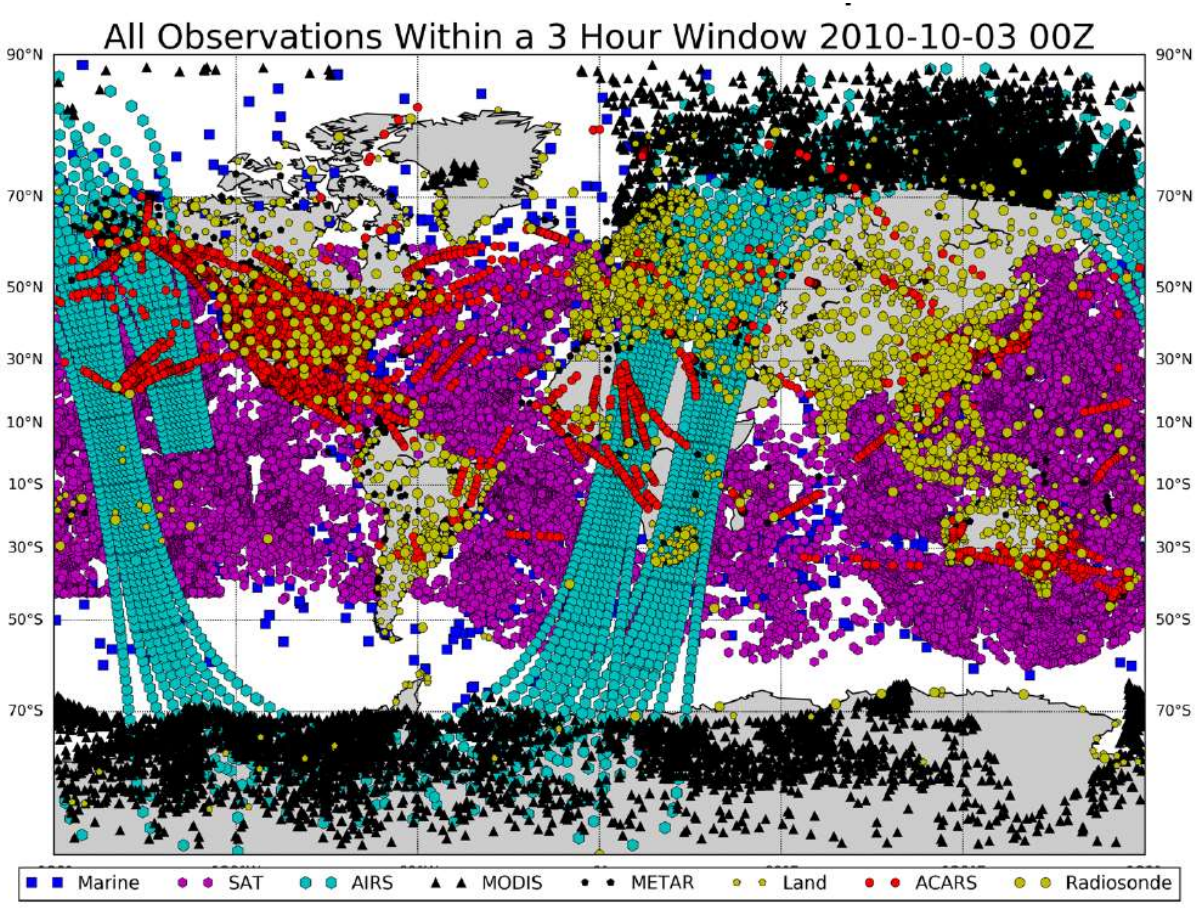


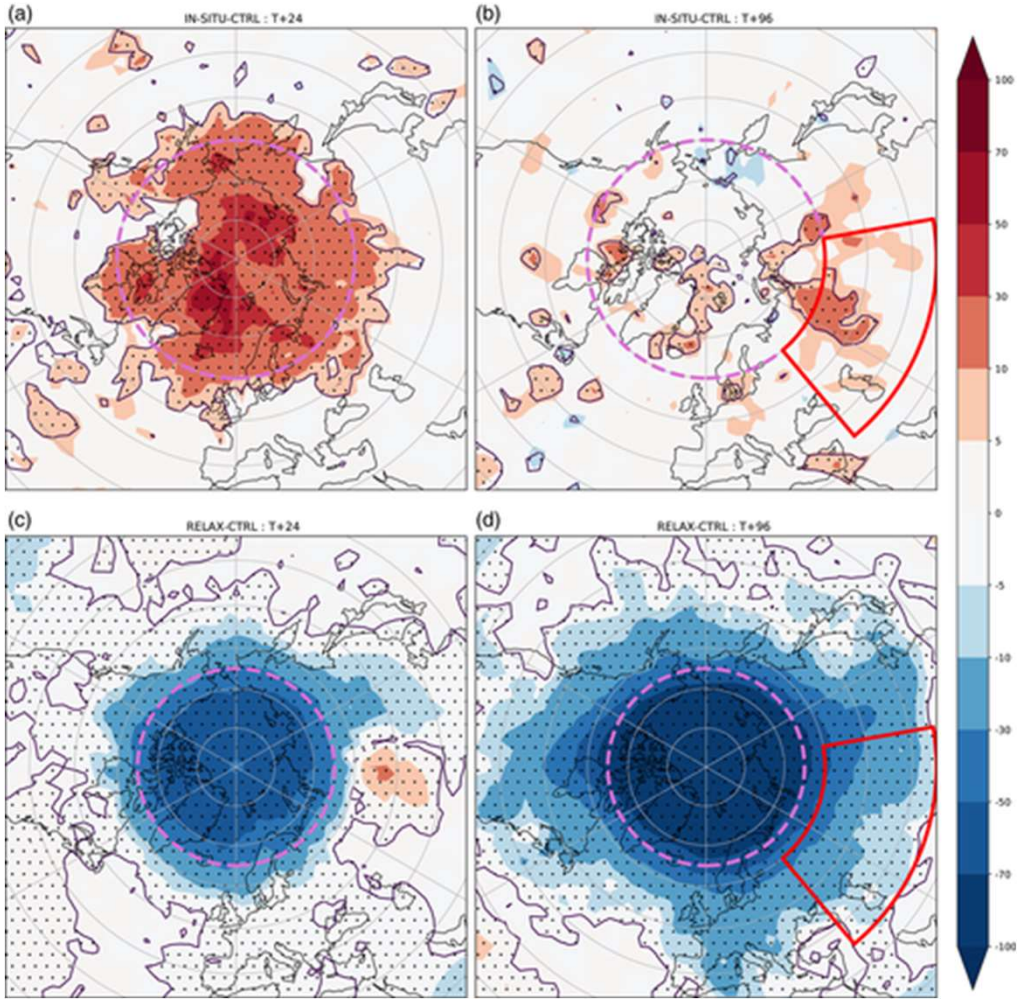
Image credit: ***Chris Riedel***

- Radiosonde measurements of moisture are unreliable at cold temperatures prevalent in the upper Arctic troposphere (Miloshevich et al. 2001)

- Rejection of individual upper-tropospheric moisture observations during data assimilation can lead to large sensitivity (Rinke et al. 2019)

High Latitudes & Predictability

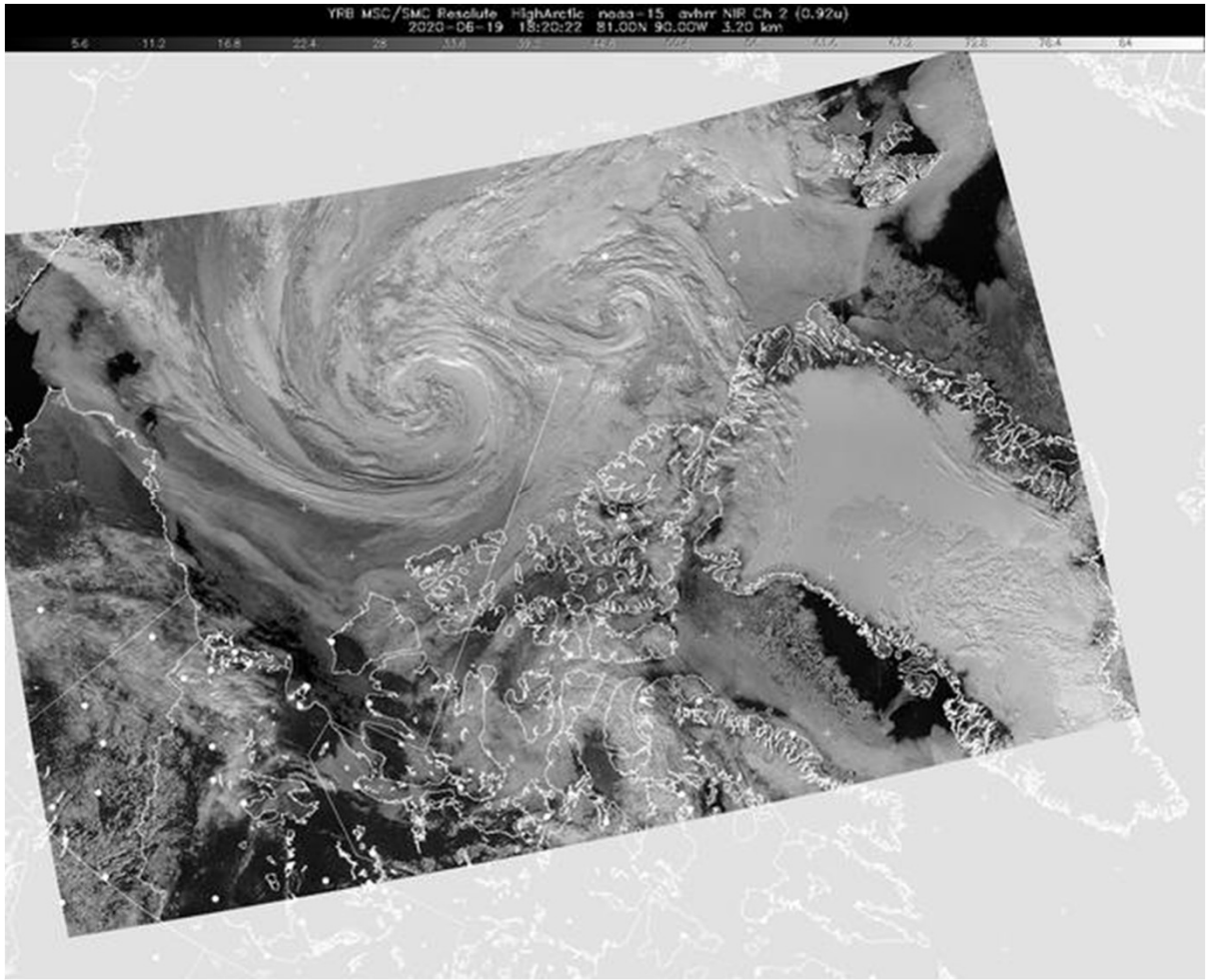
- Data denial experiments (i.e., OSE) show the importance of the Arctic on medium-range forecast skill in the midlatitudes



- Withholding in-situ satellite data degrades medium-range forecast skill, particularly over northern Asia (Day et al. 2019)
- Relaxing the forecast towards the operational ECMWF analysis results in improved forecast skill (Day et al. 2019)

19 June 2020 Synoptic Overview

- A pair of Arctic Cyclones (ACs) was observed north of Canada on 19 June 2020

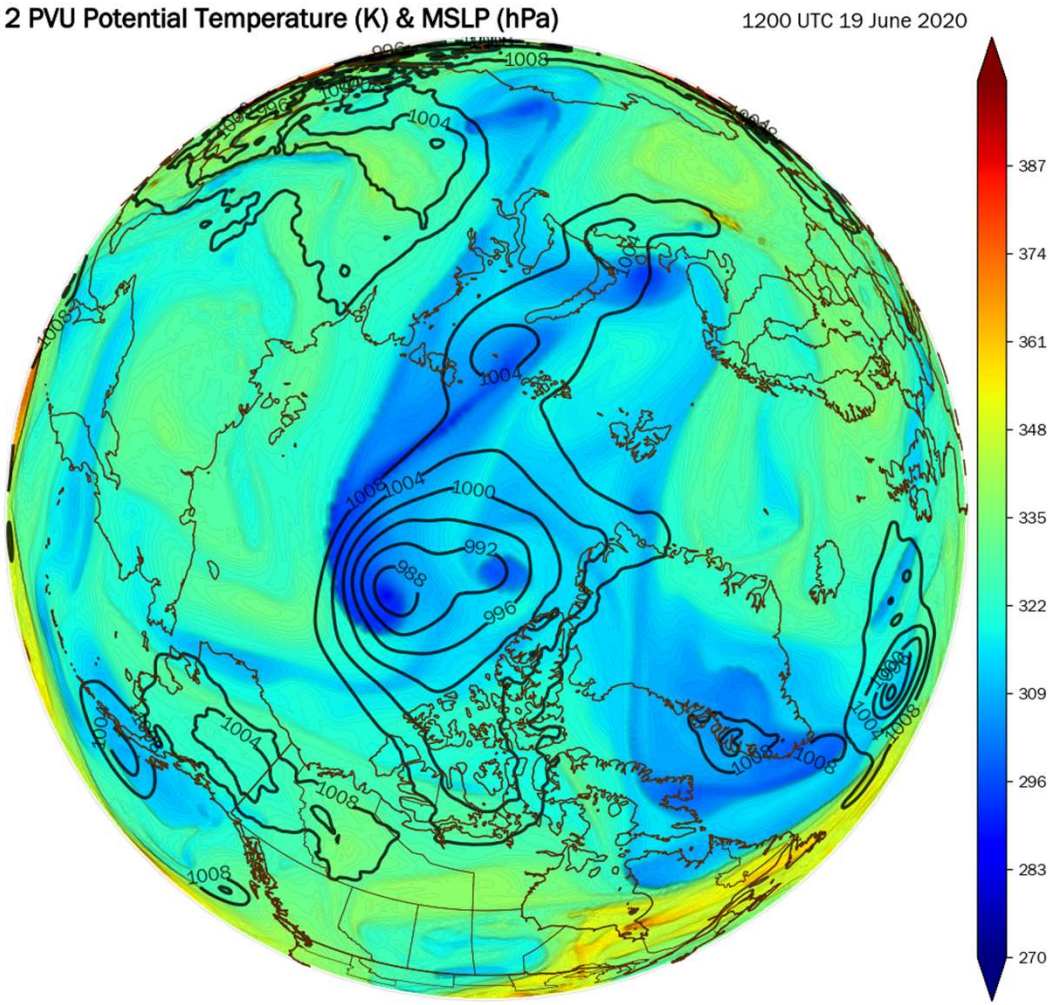


Operational NWP Analyses

- The AC closer to Greenland is weaker than the farther AC

ERA5 Reanalysis
Valid 1200 UTC 19 June 2020

0.25º grid spacing

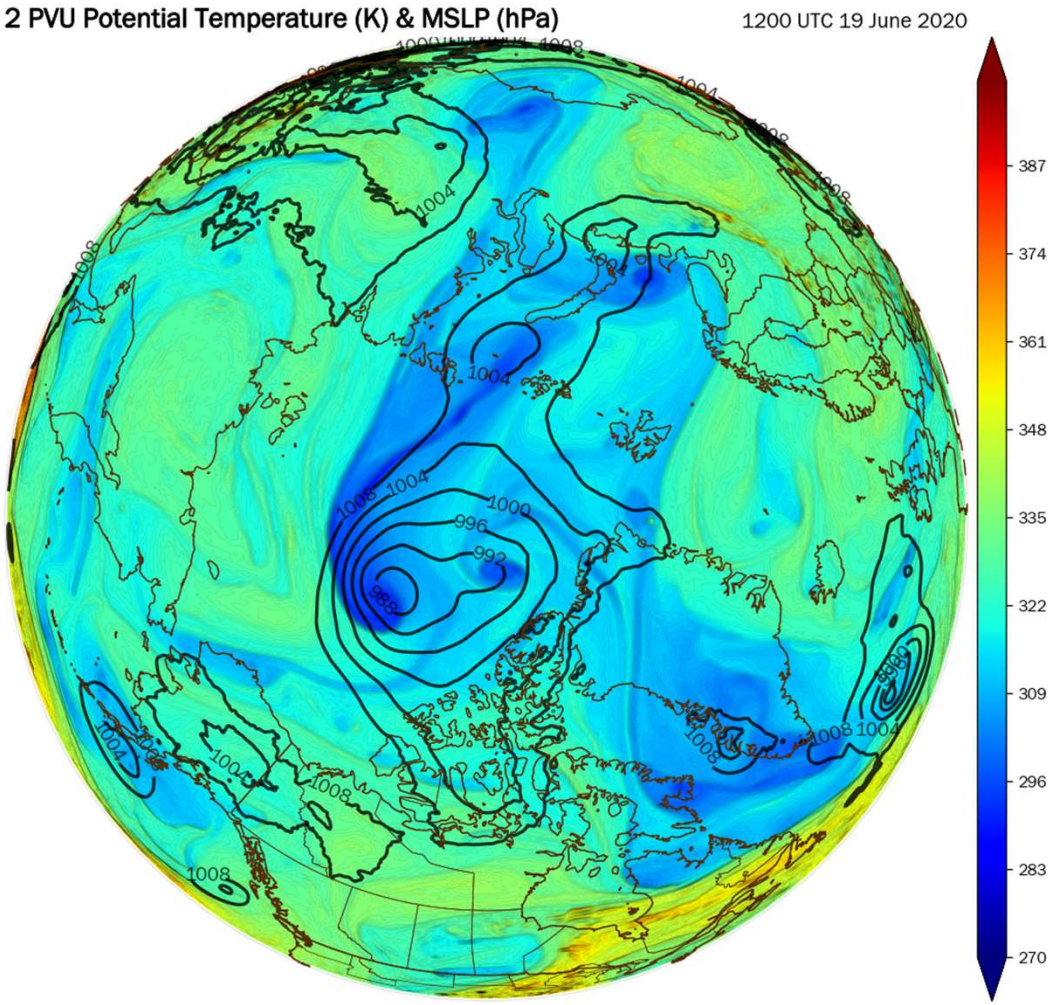


Operational NWP Analyses

- The AC closer to Greenland is weaker than the farther AC

Operational ECMWF Analysis
Valid 1200 UTC 19 June 2020

0.10º grid spacing

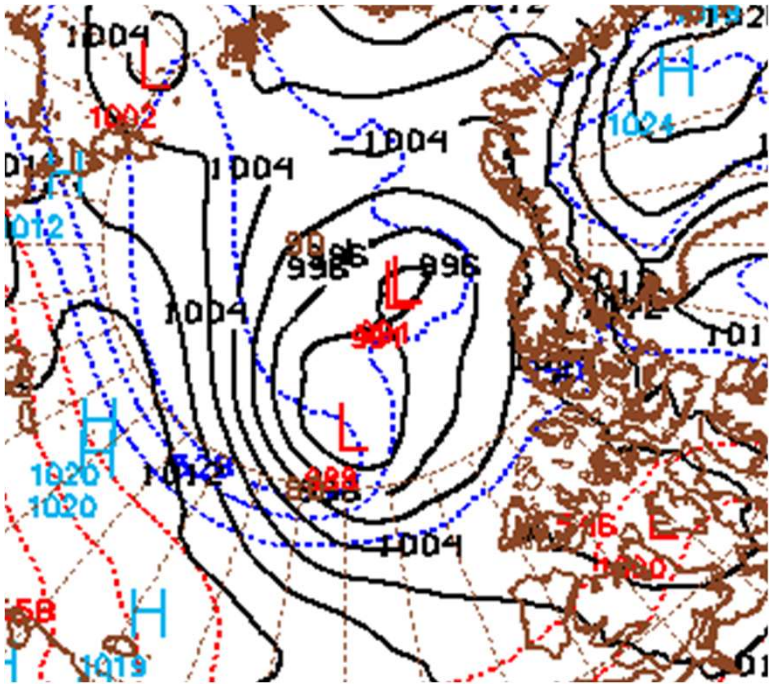


Operational NWP Analyses

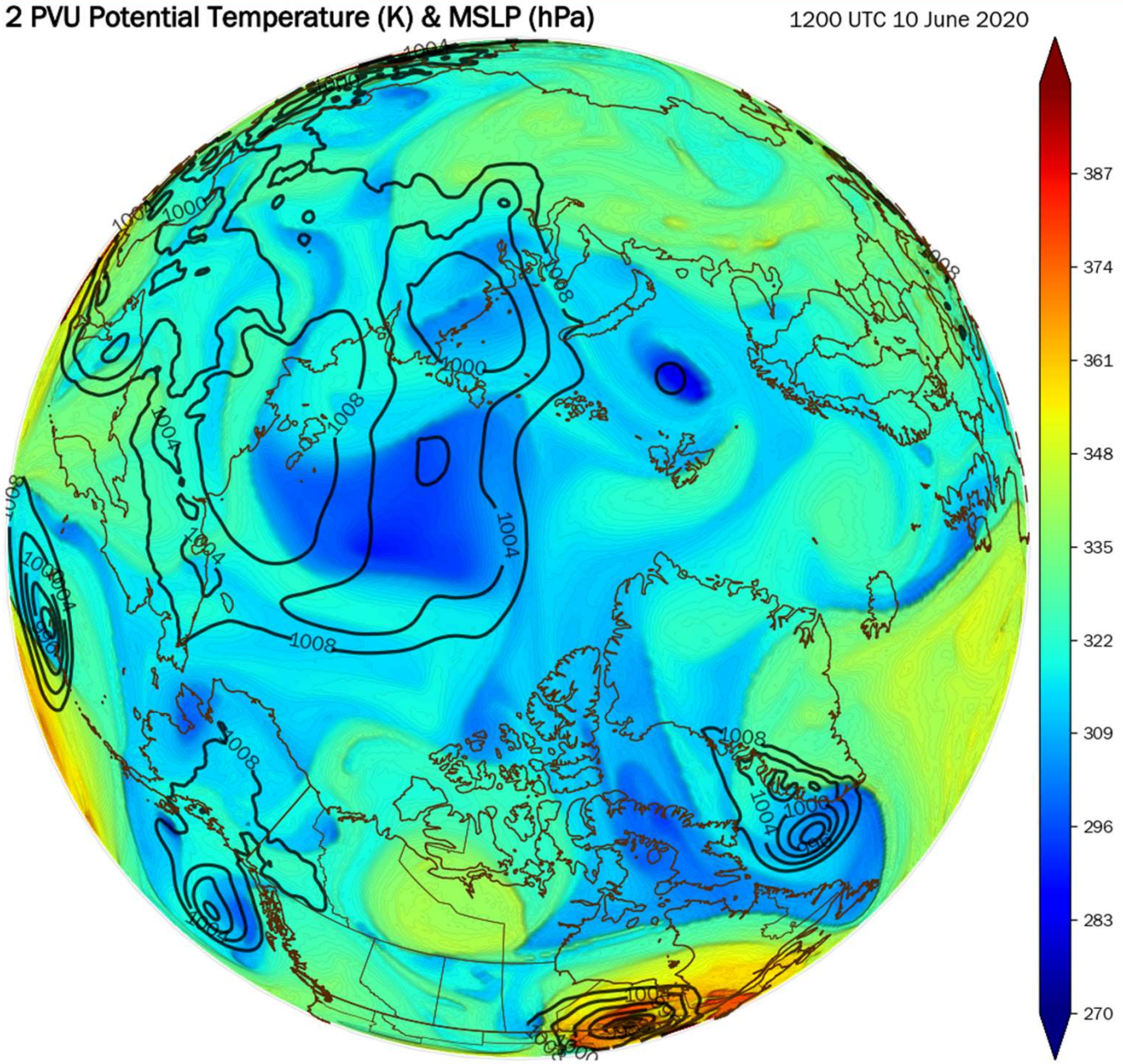
- The AC closer to Greenland is weaker than the farther AC

Operational GFS Analysis
Valid 1200 UTC 19 June 2020

0.25º grid spacing



19 June 2020 ERA-5 Overview



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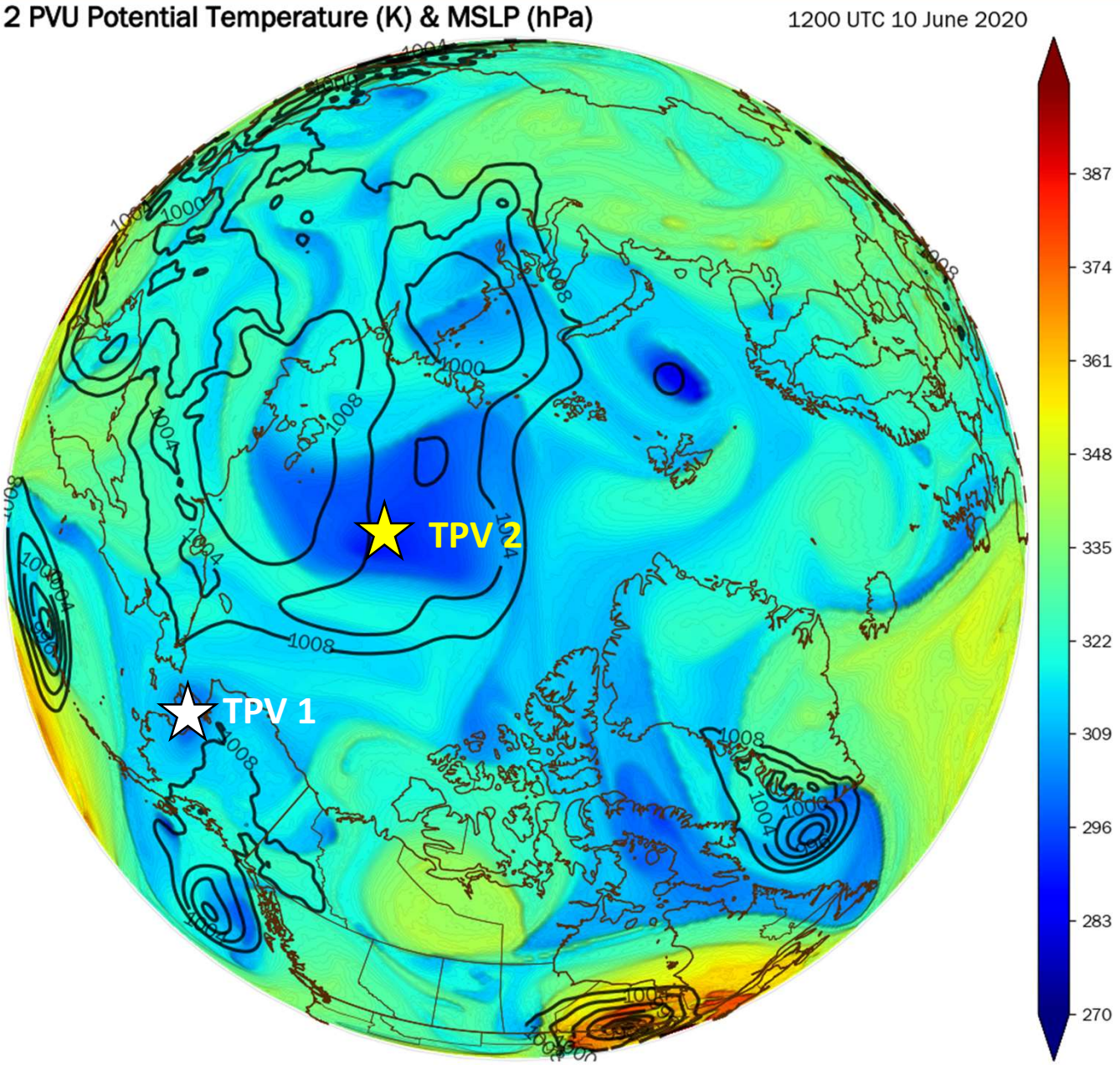

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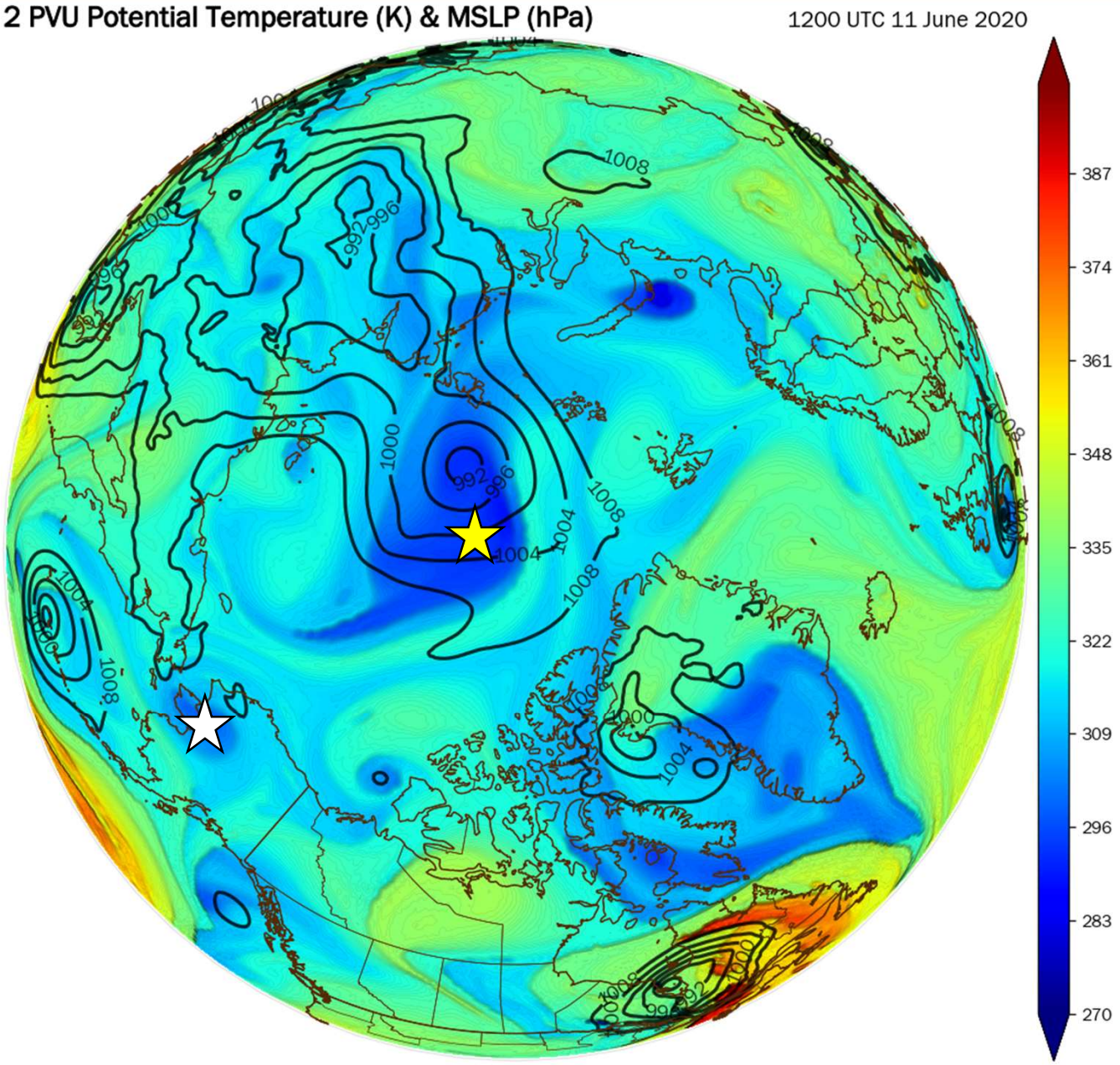

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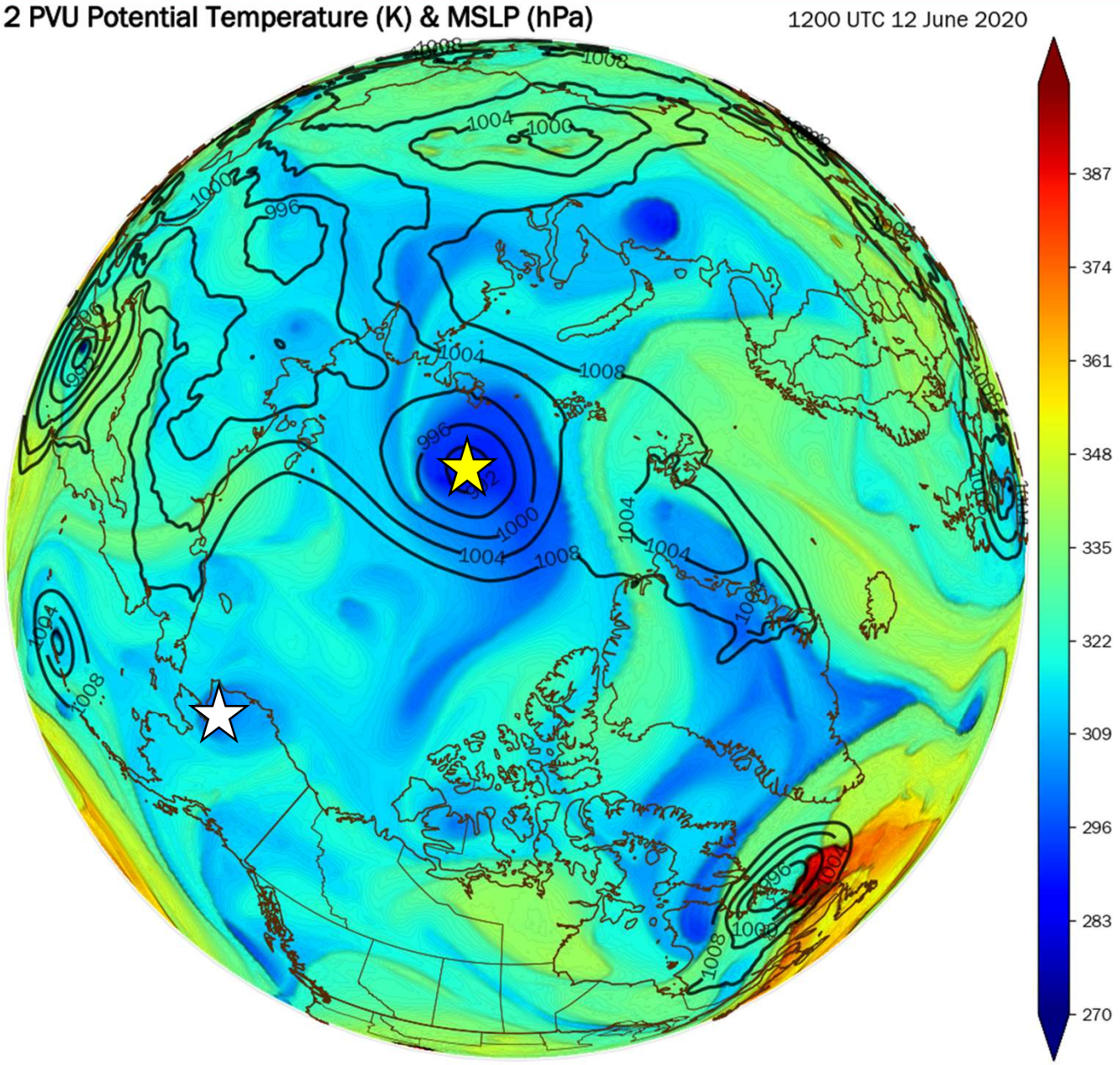

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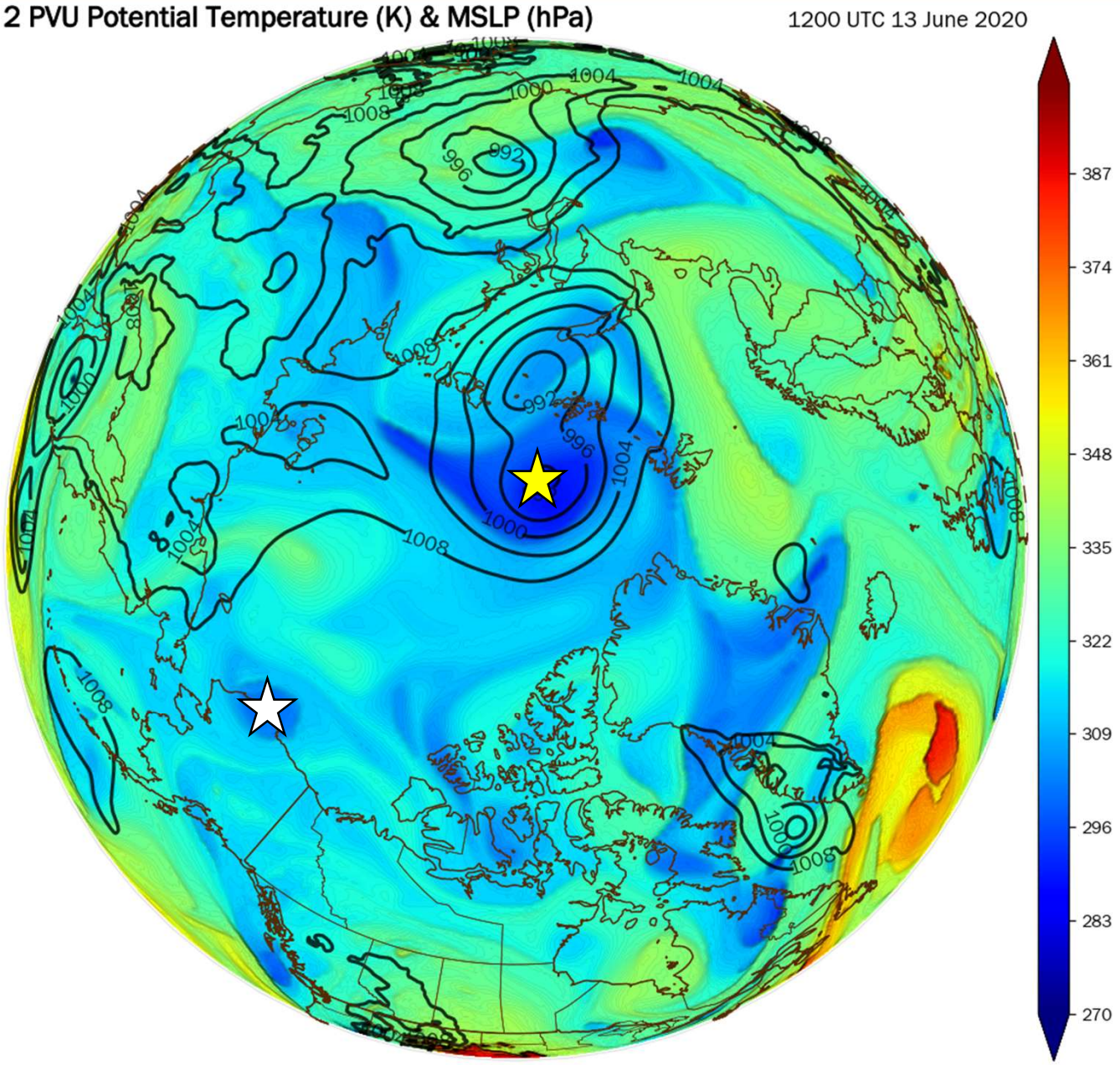

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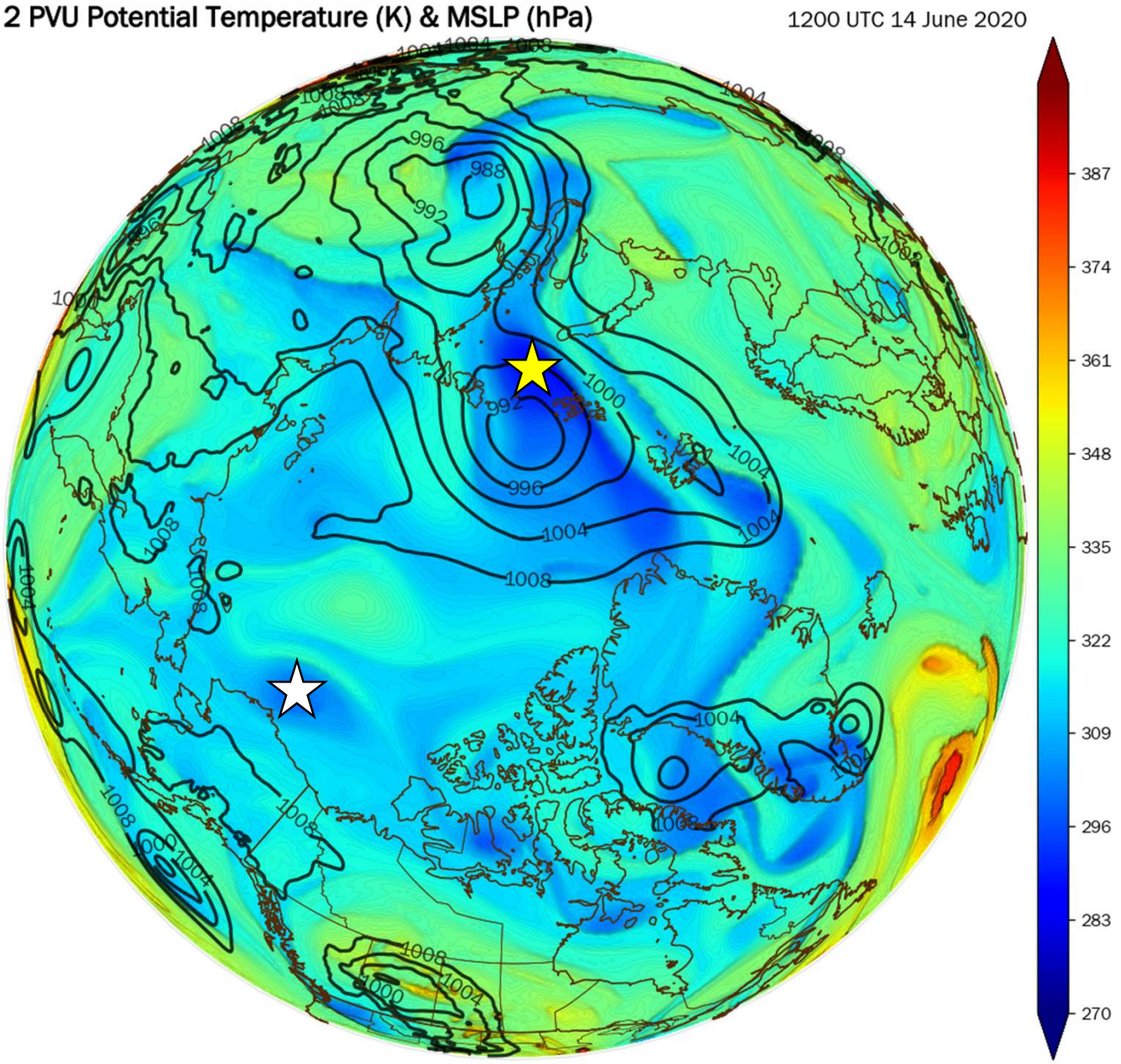

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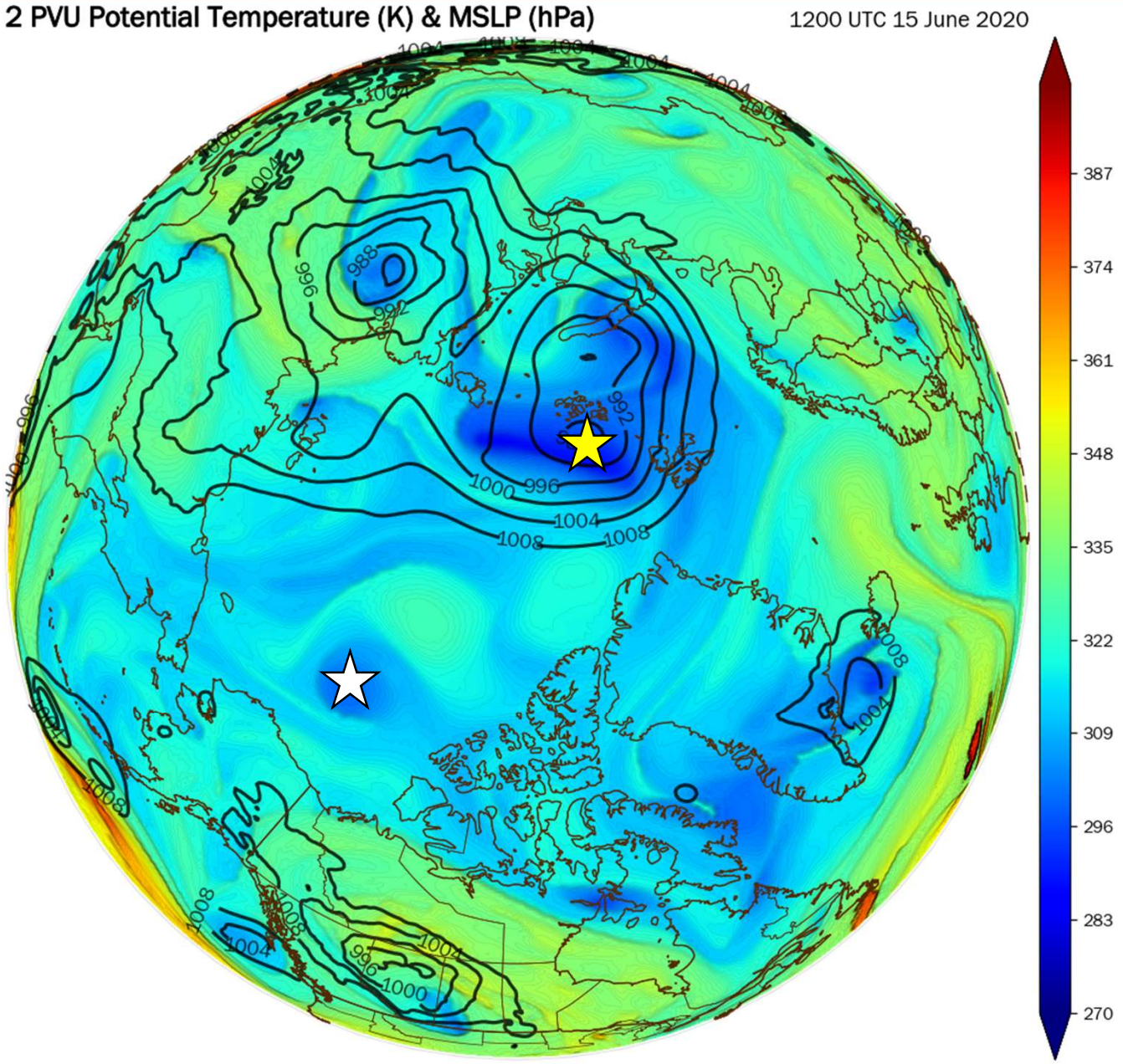

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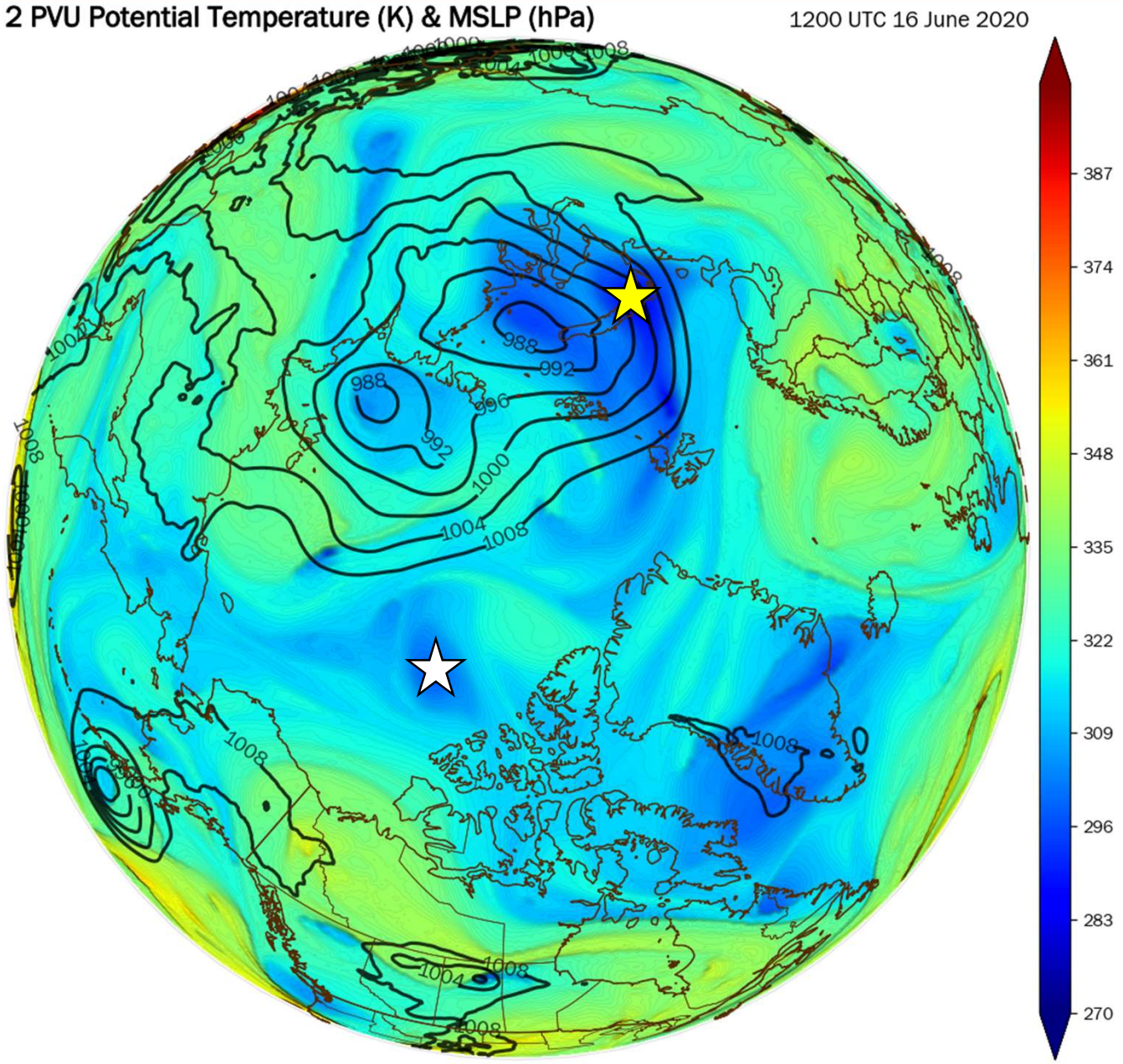

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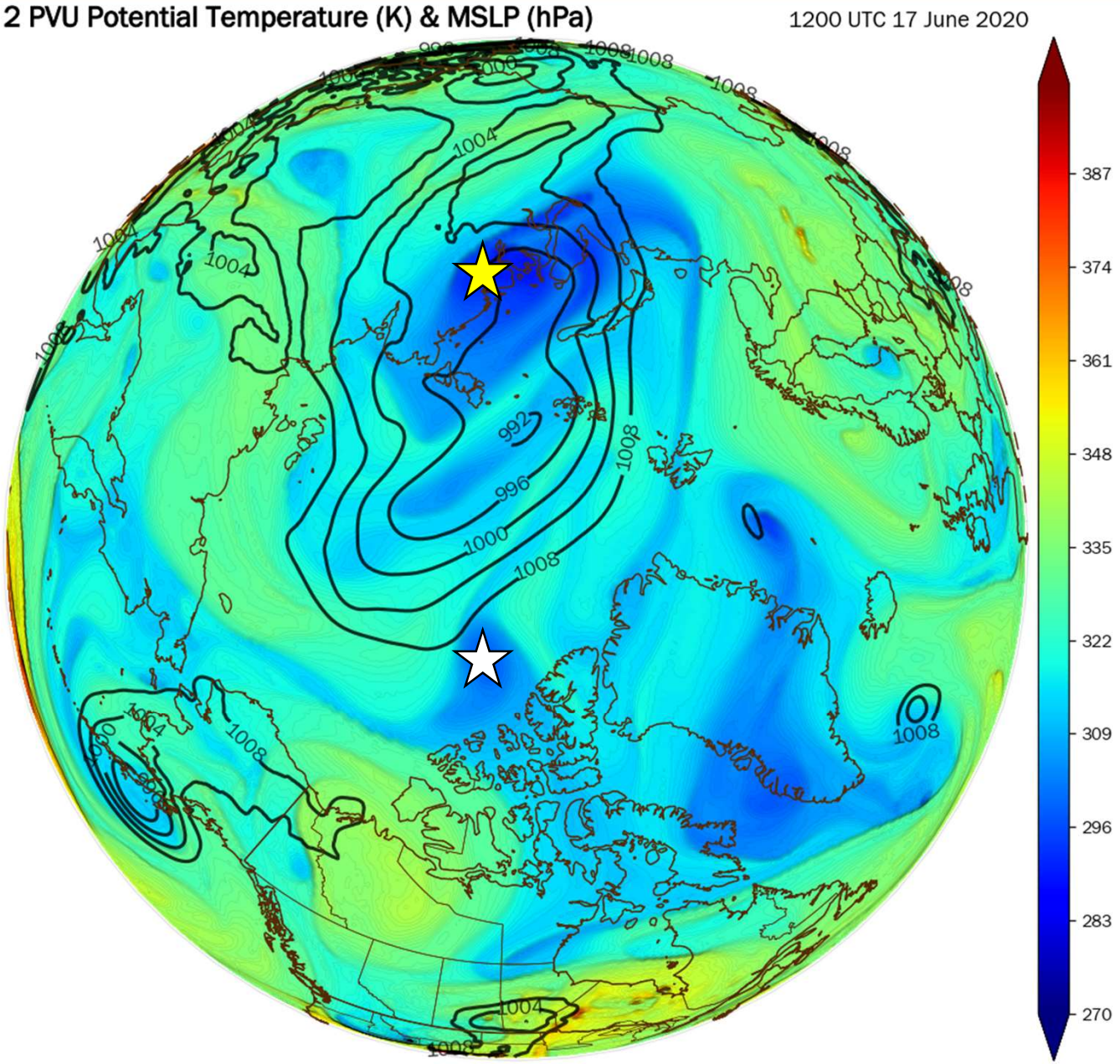

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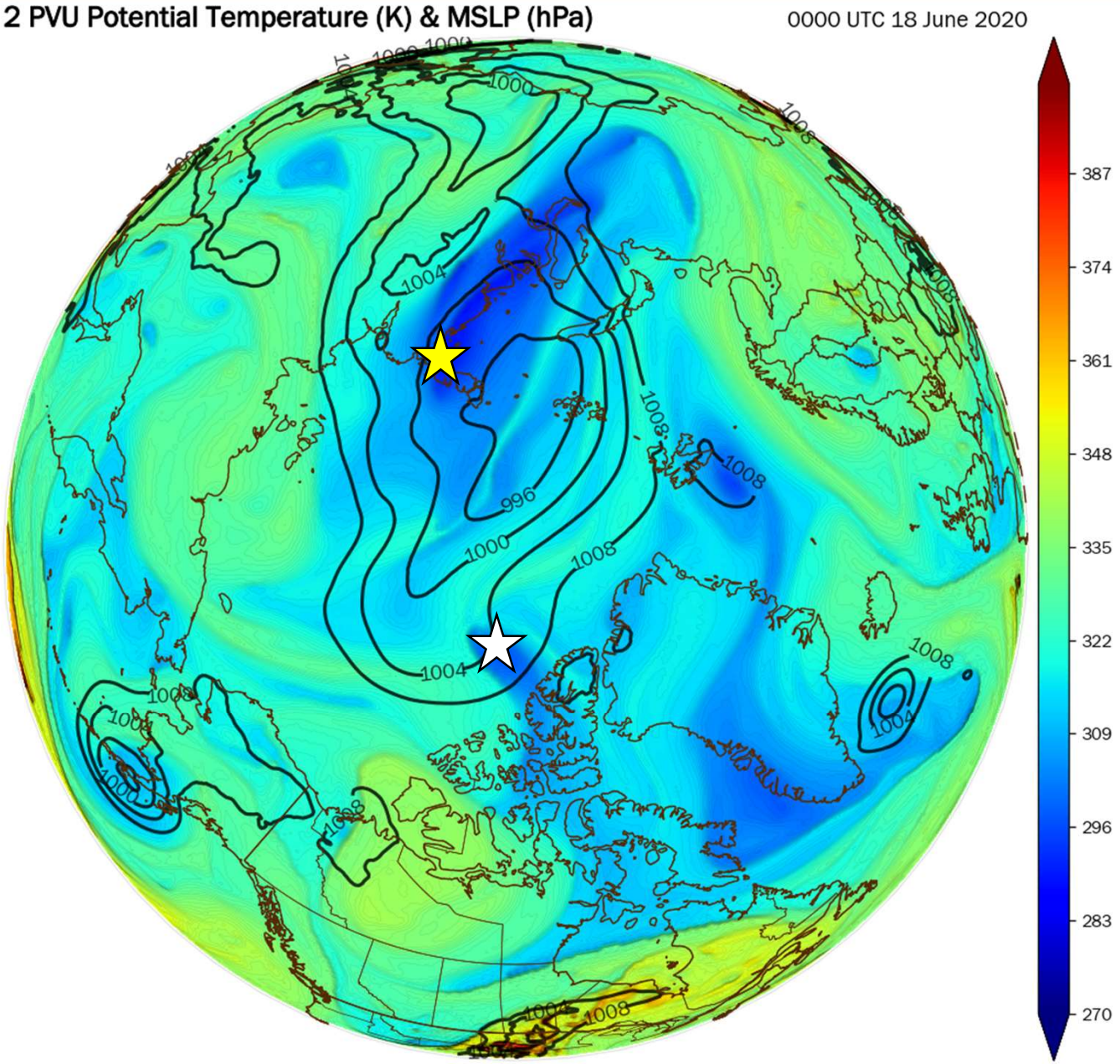

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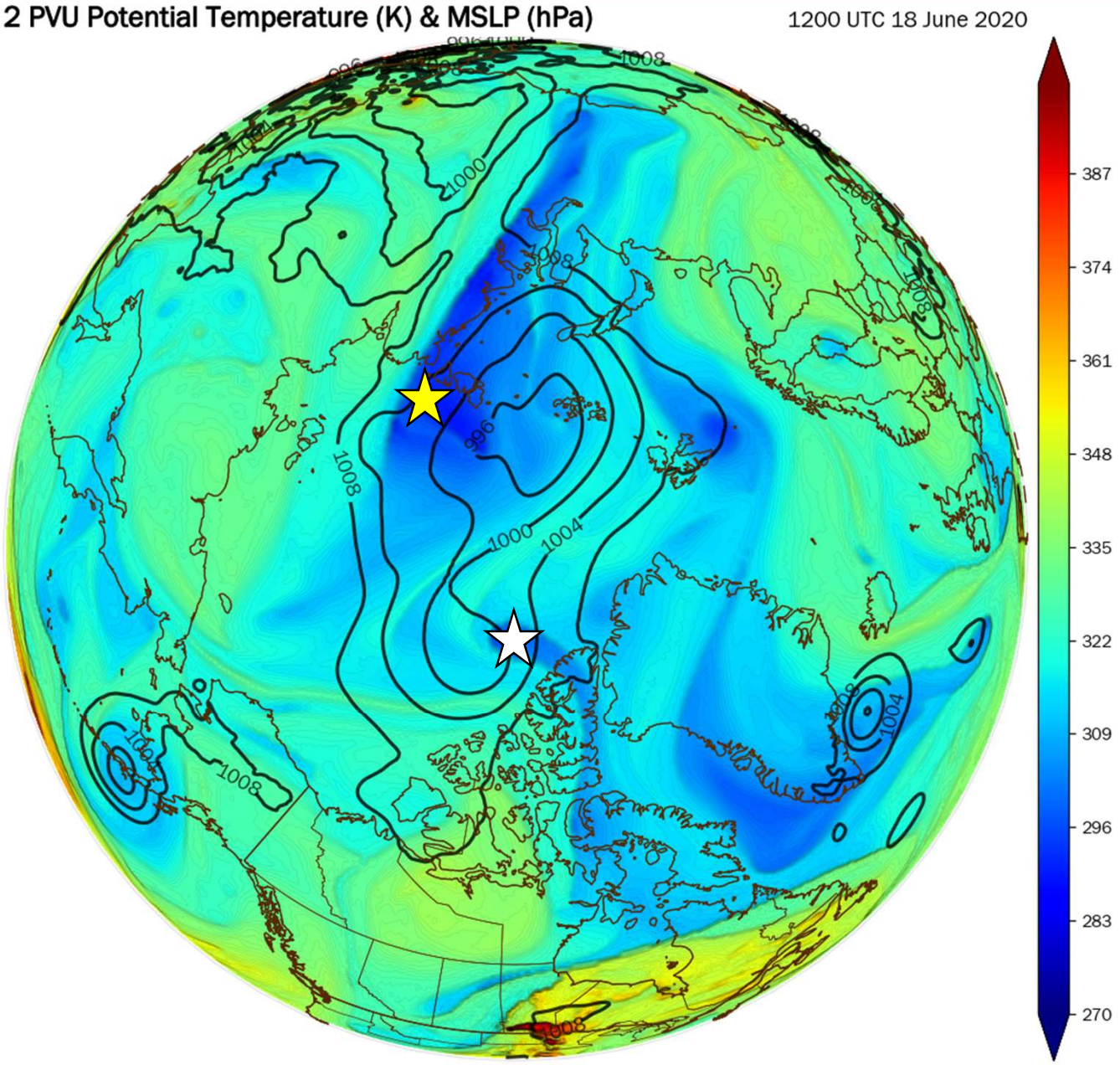

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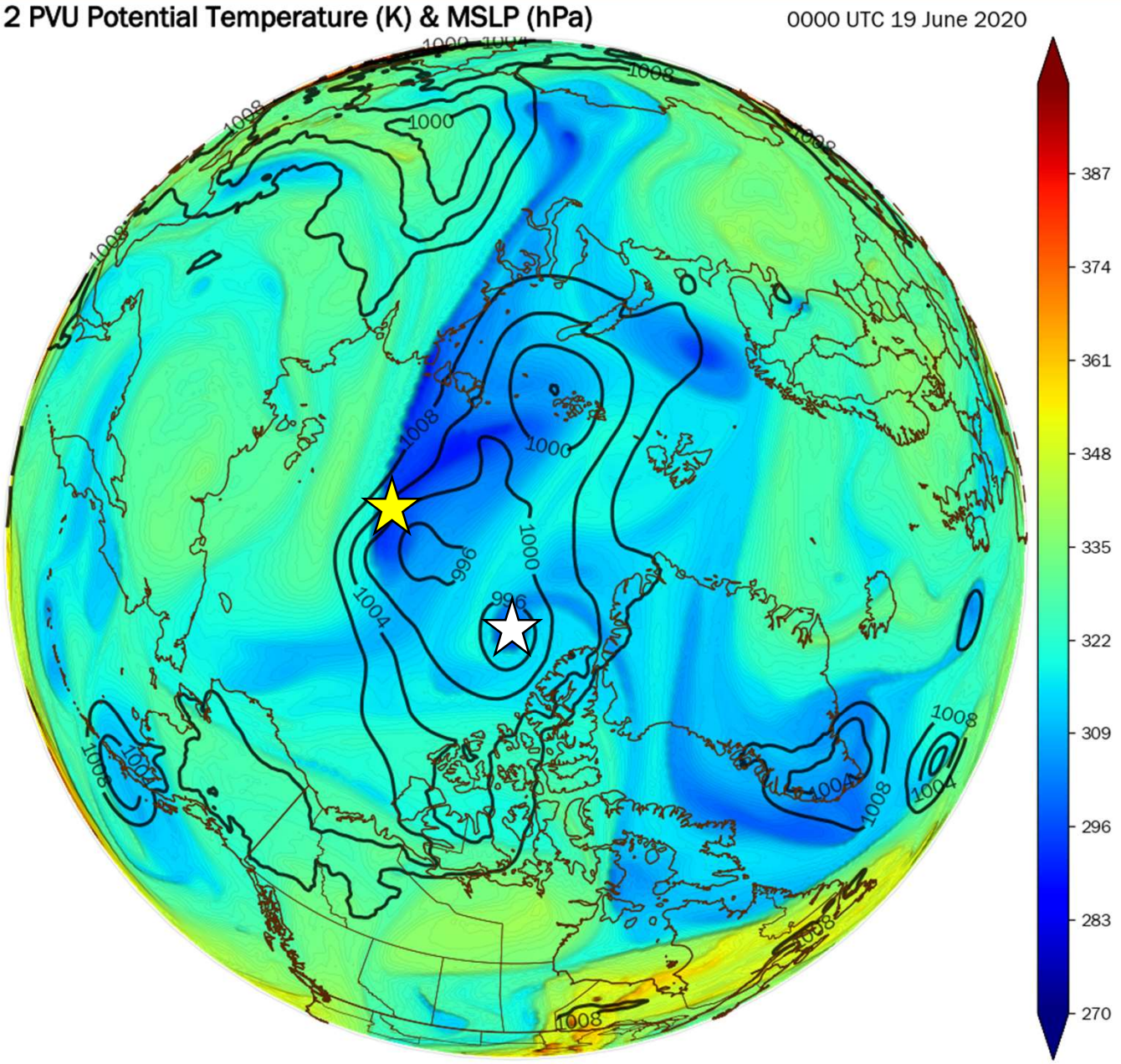

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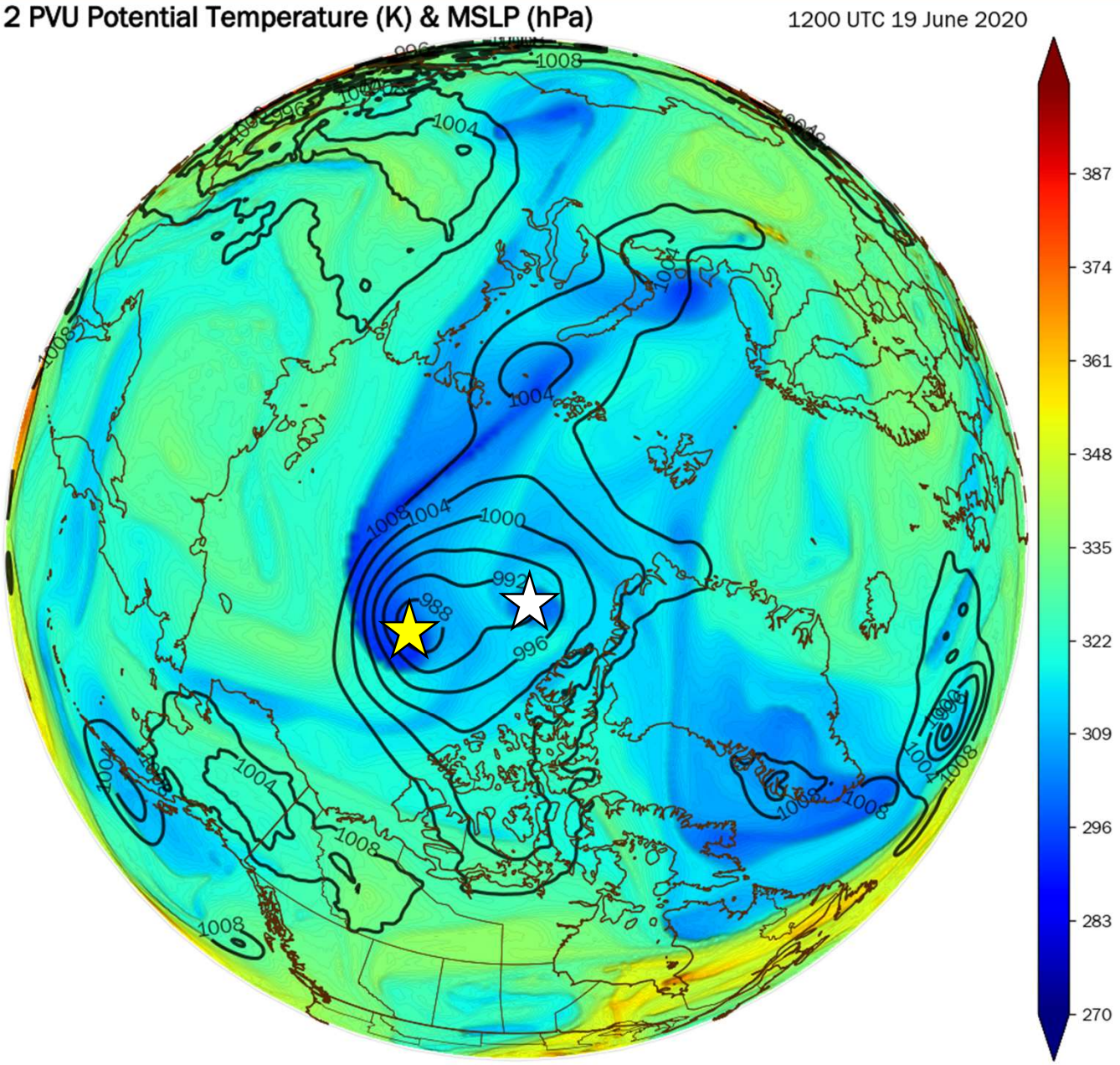

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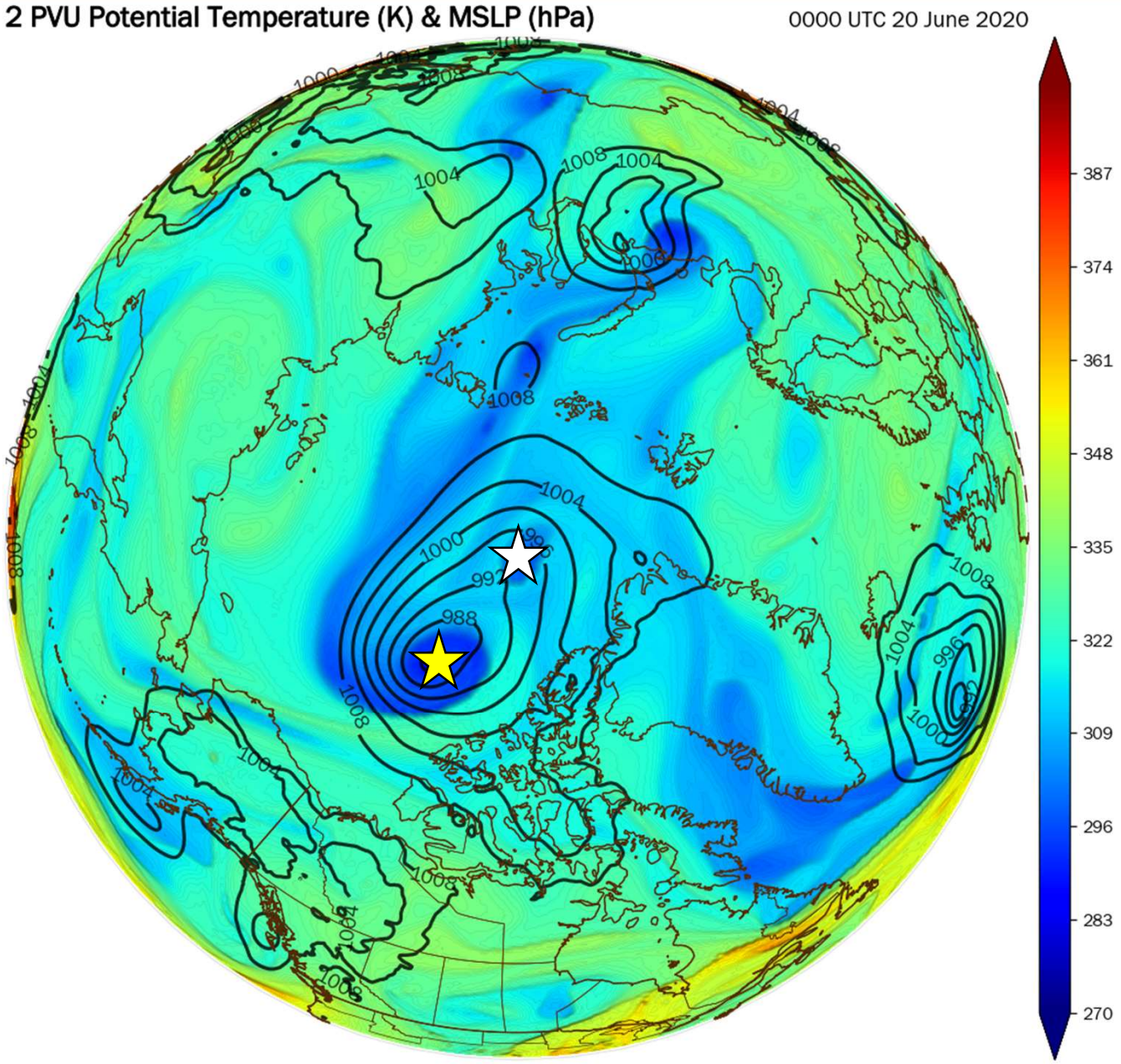

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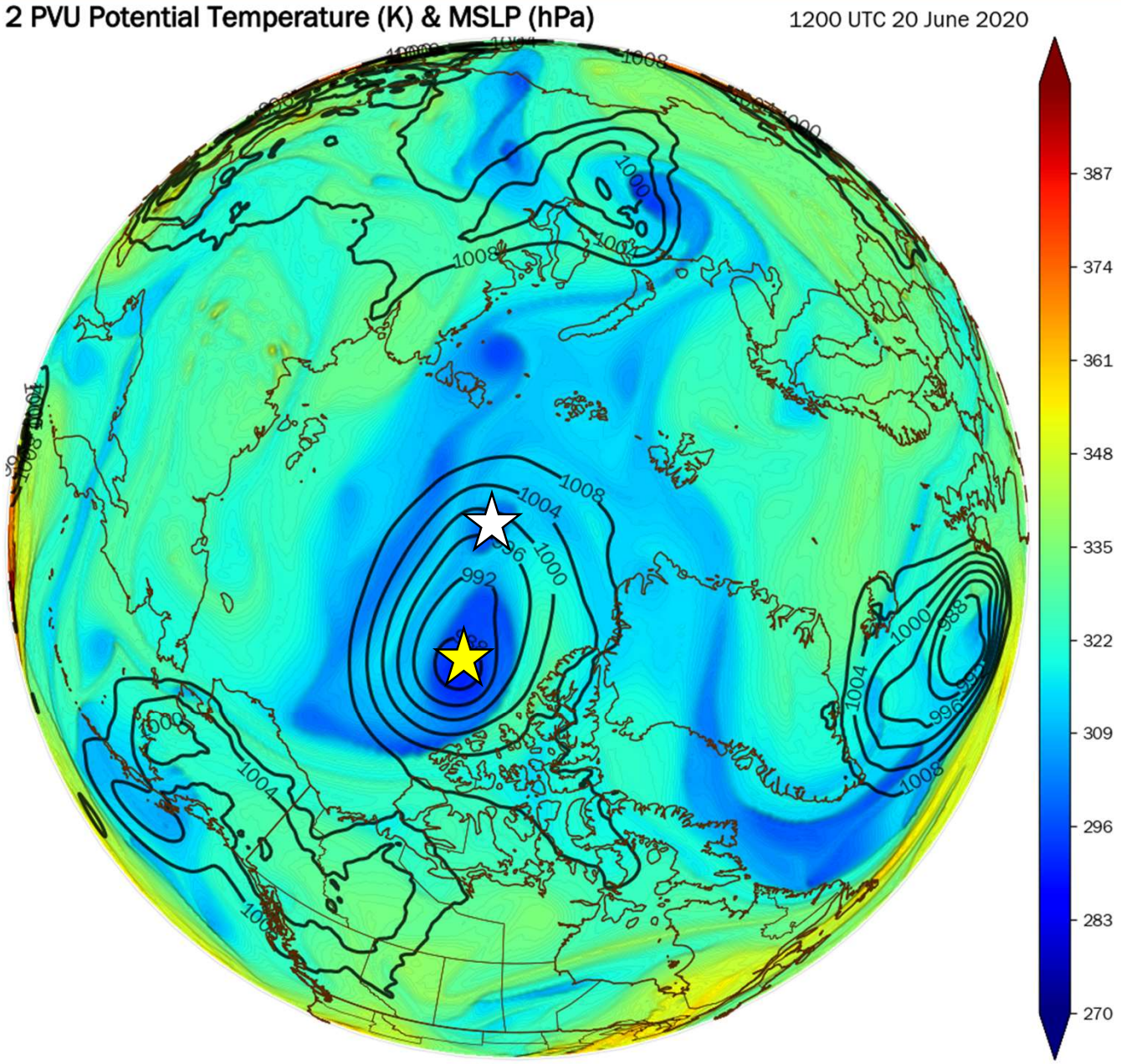

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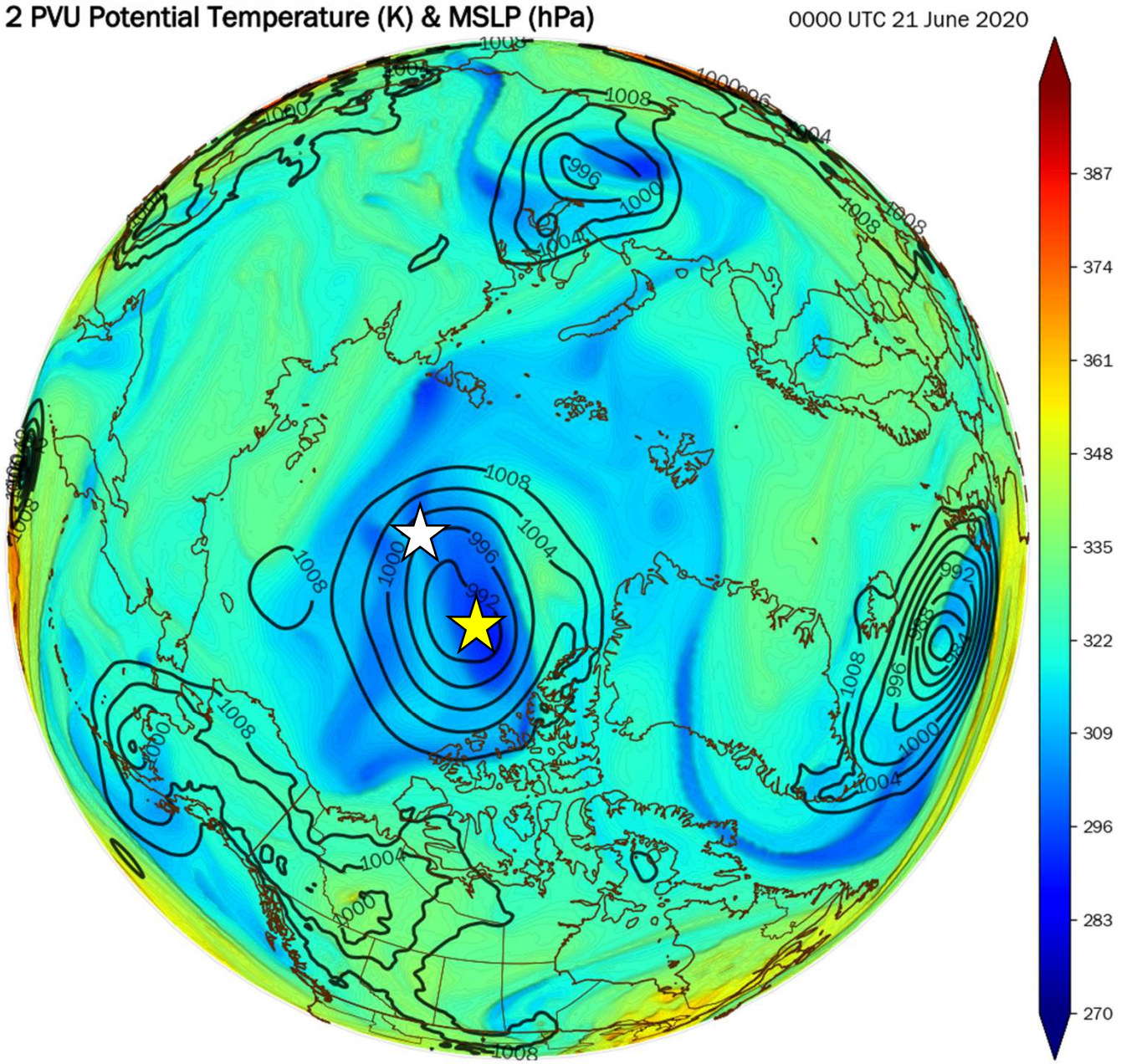

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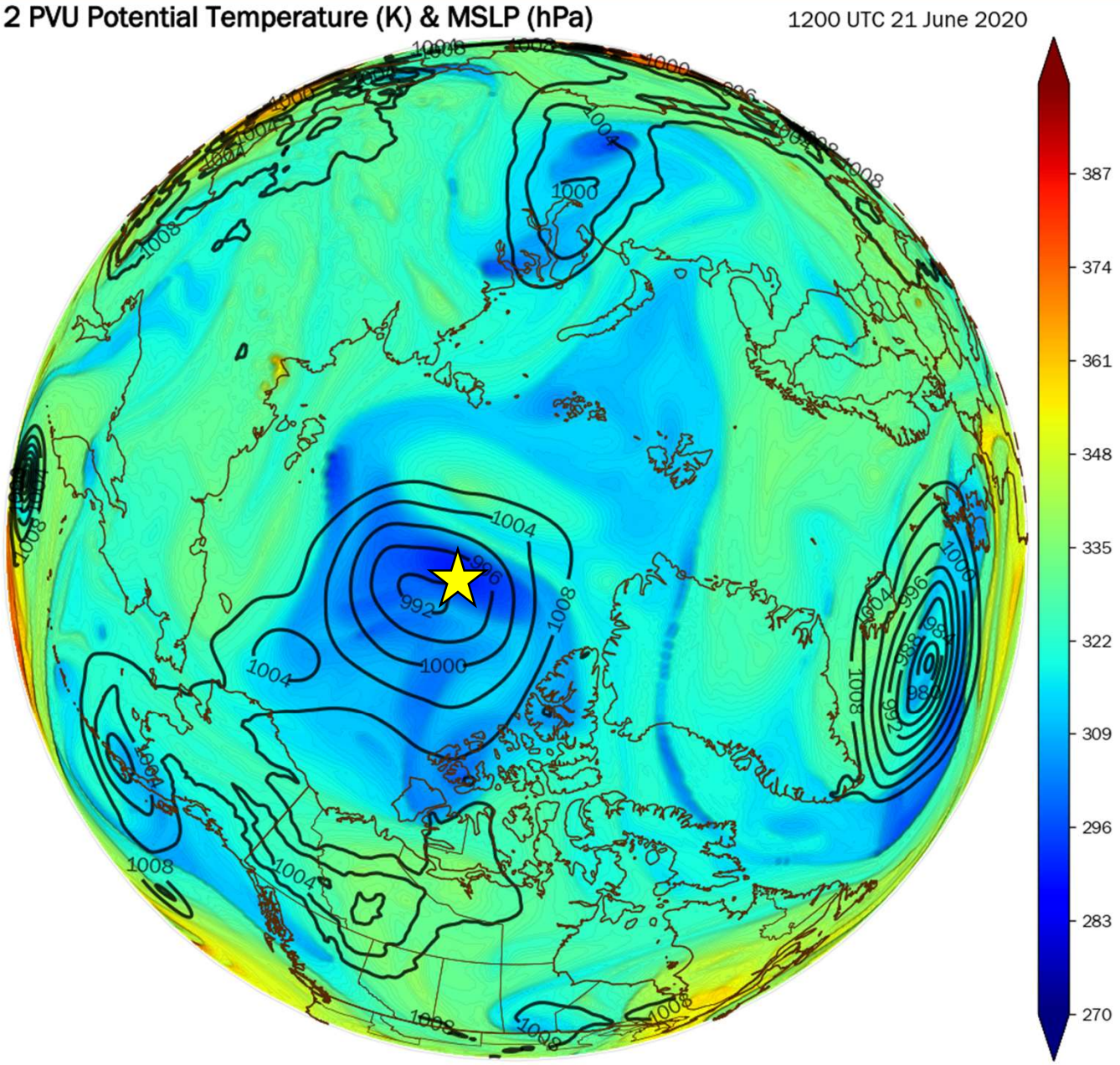

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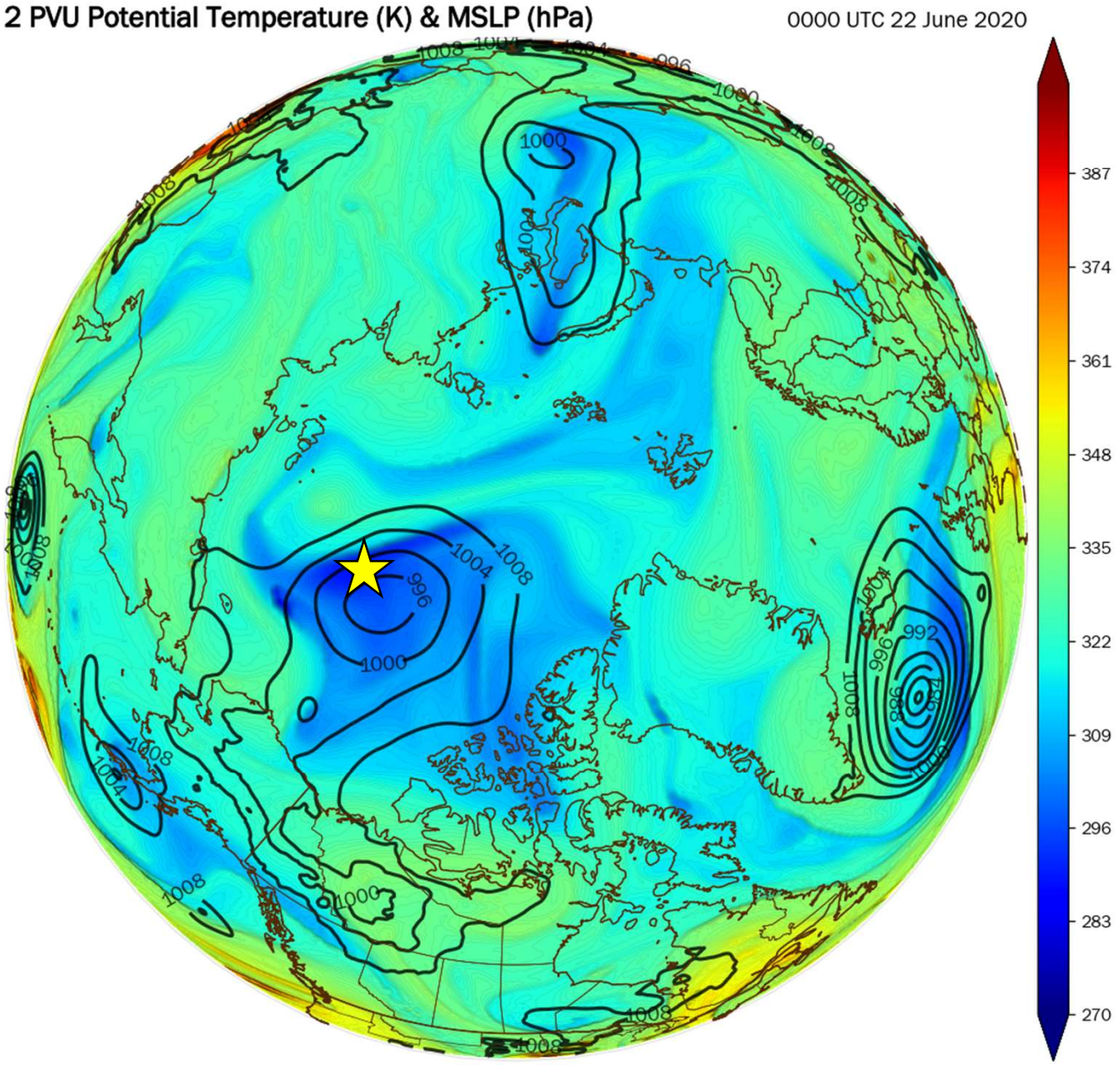

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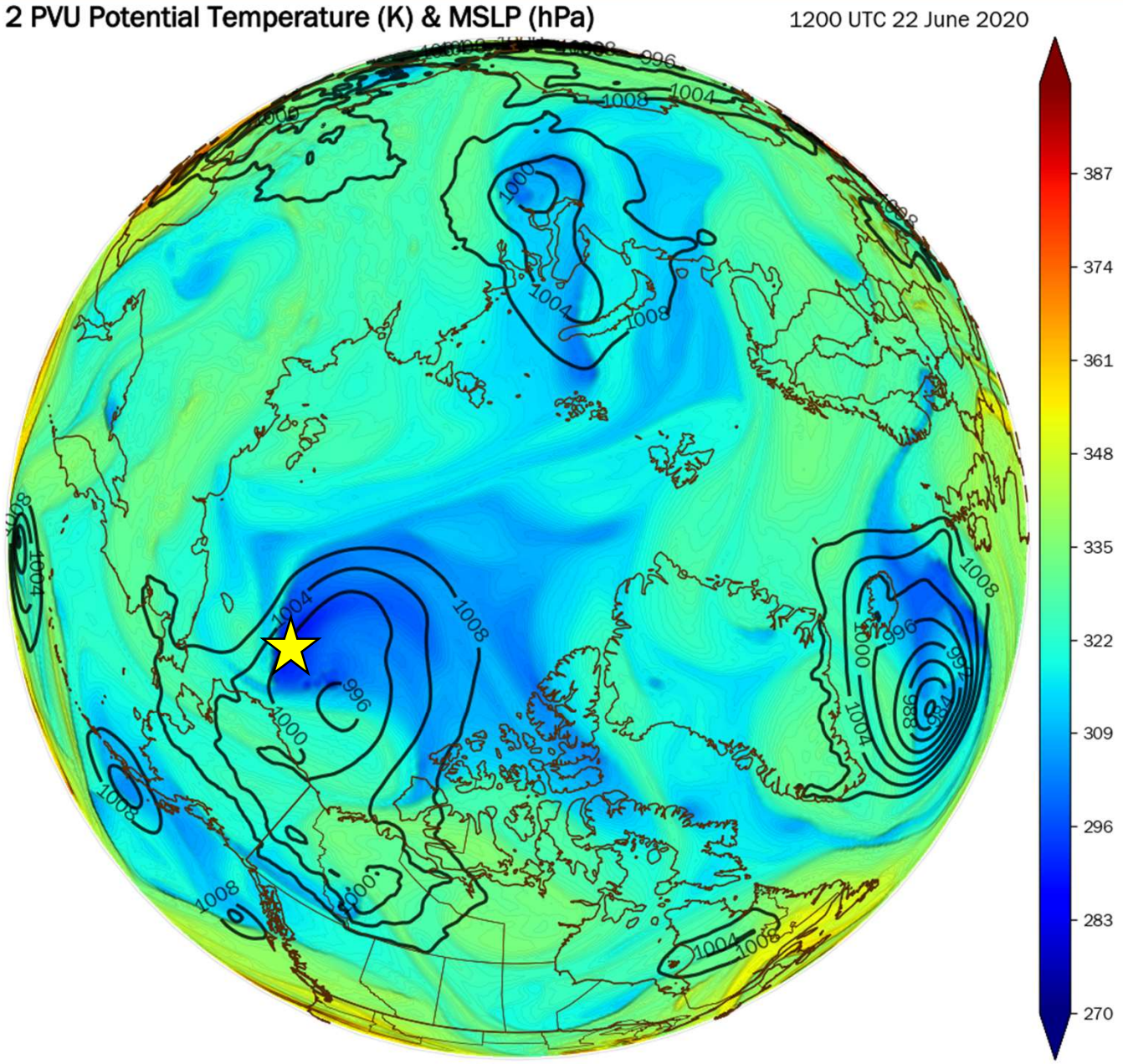

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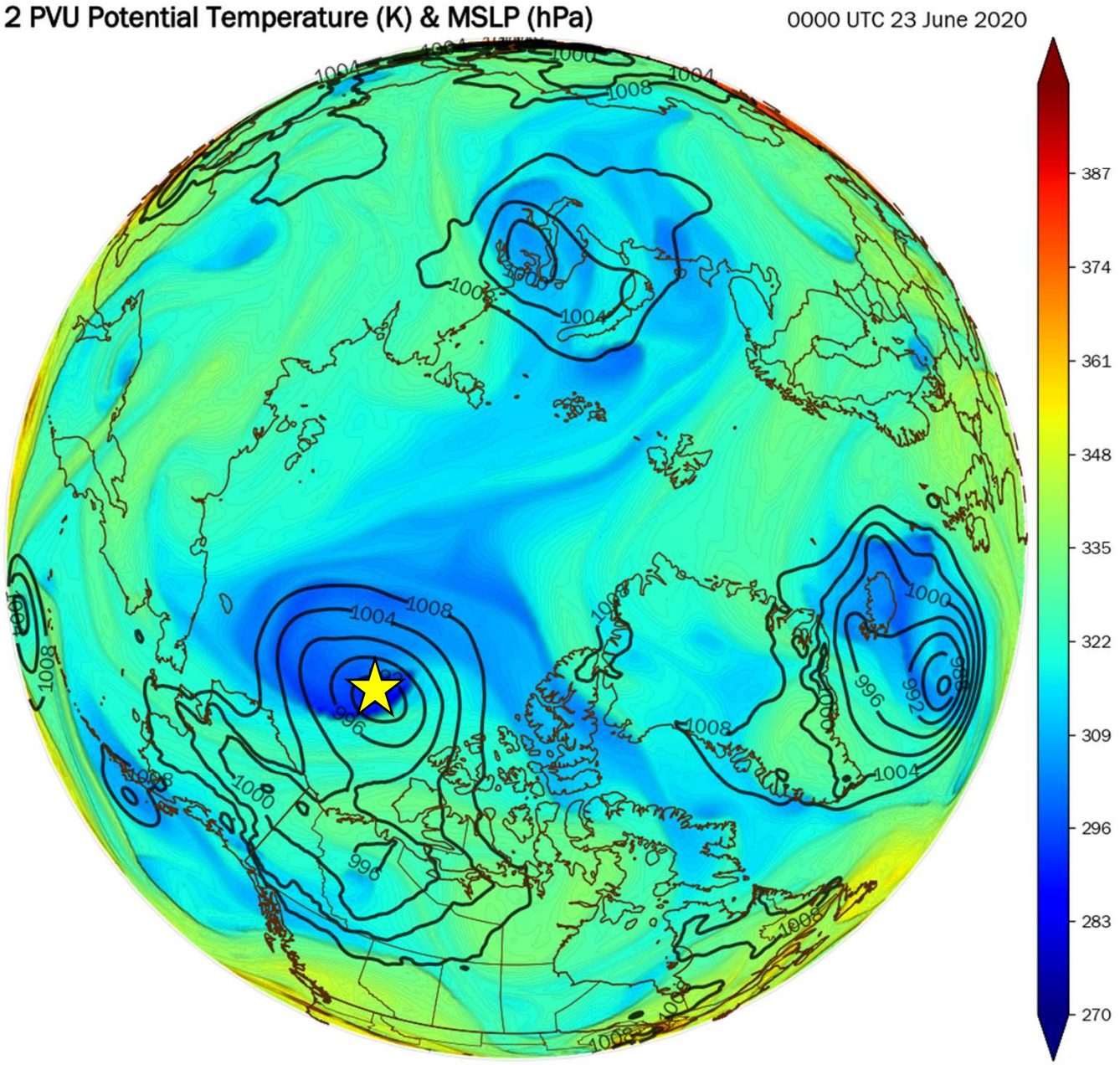

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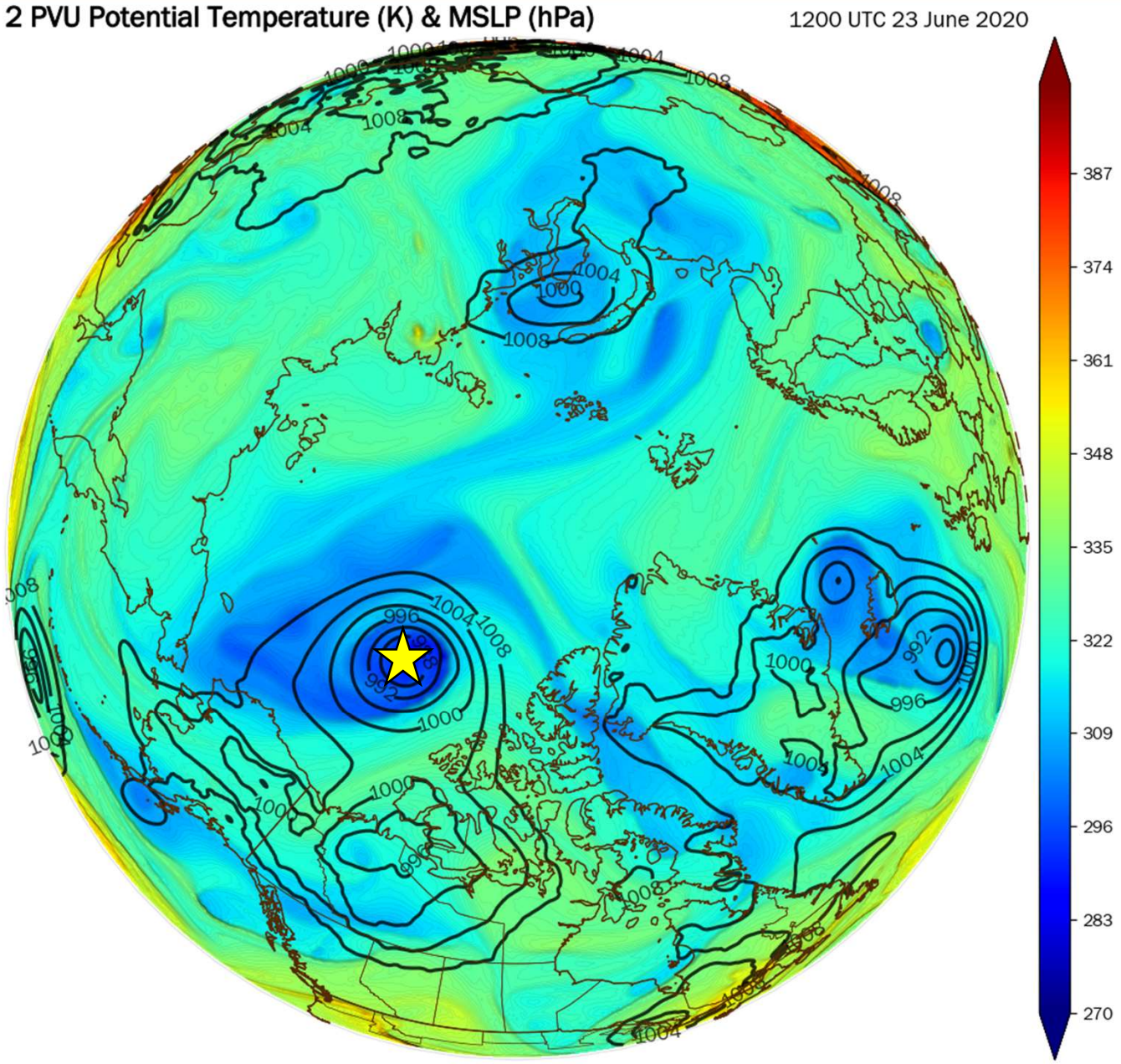

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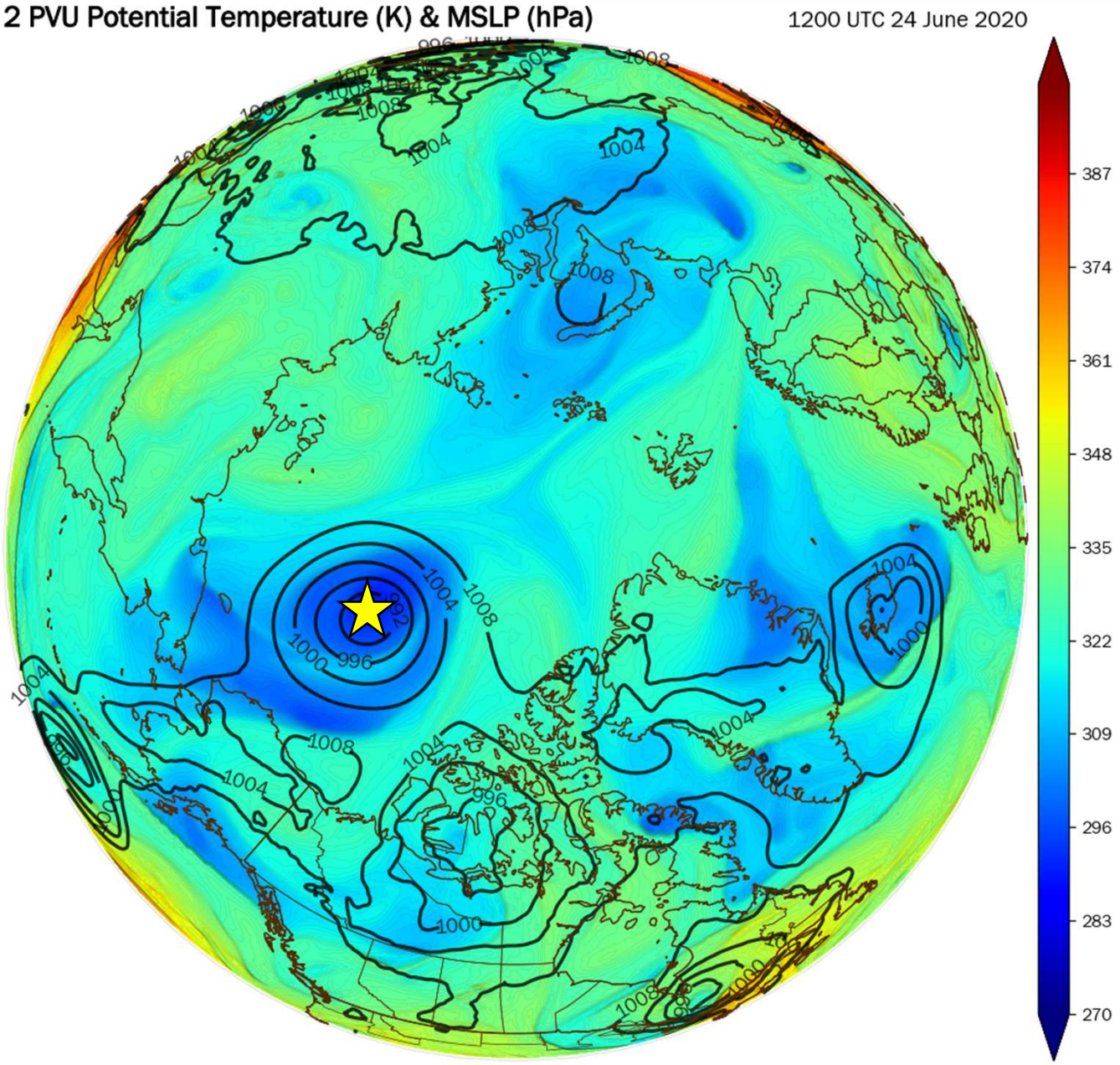

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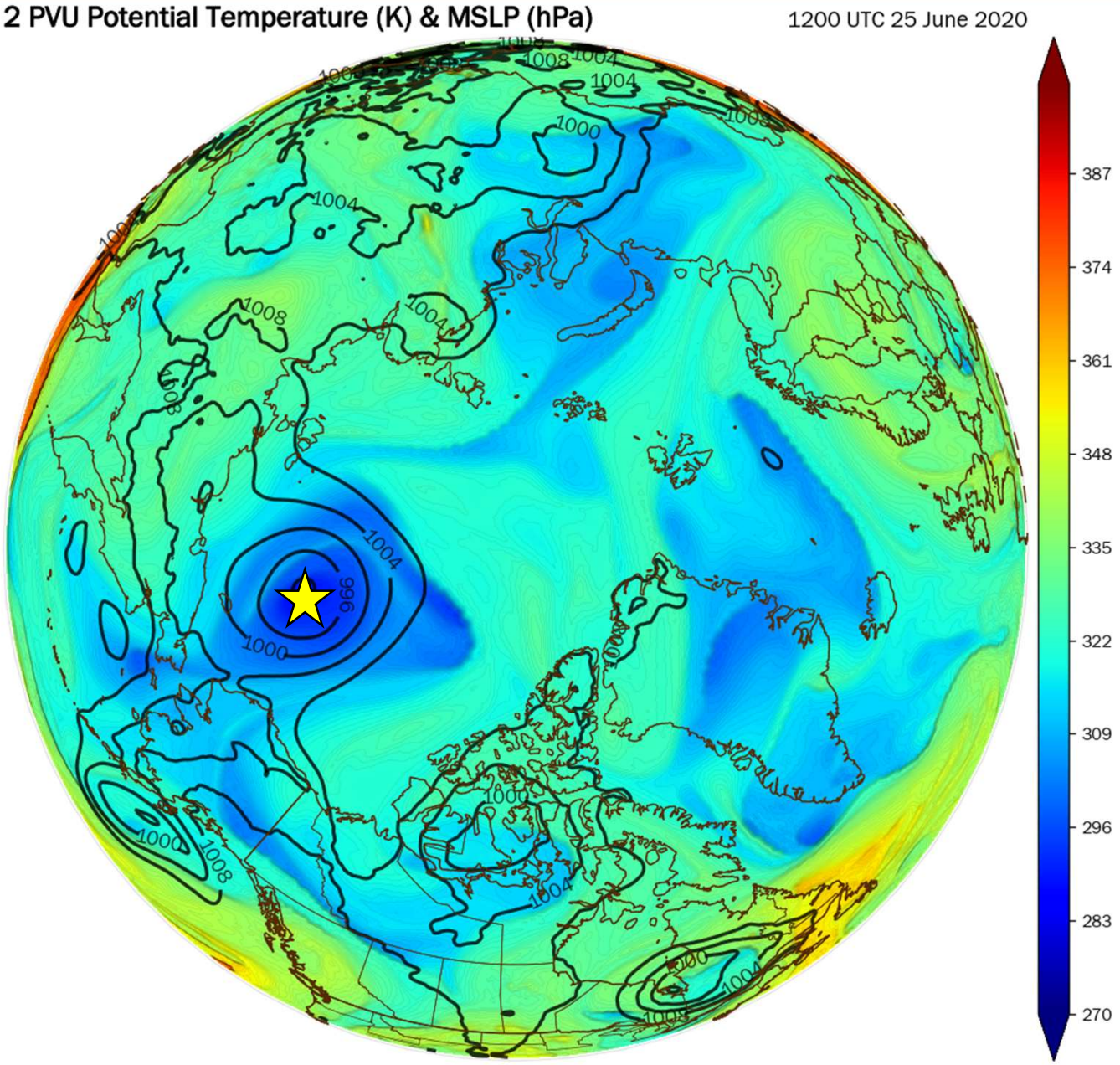
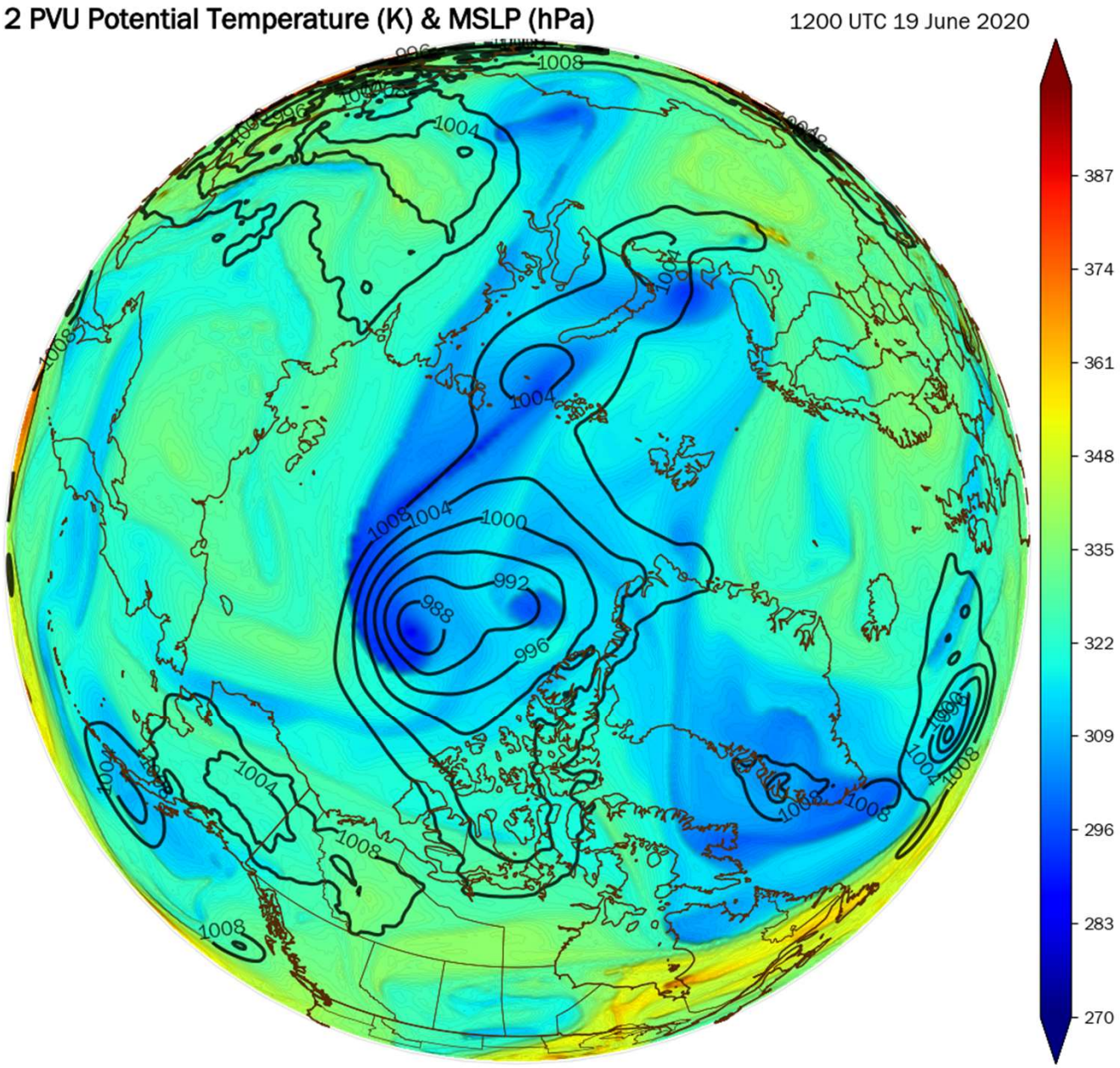


19 June 2020 Forecast Evolution



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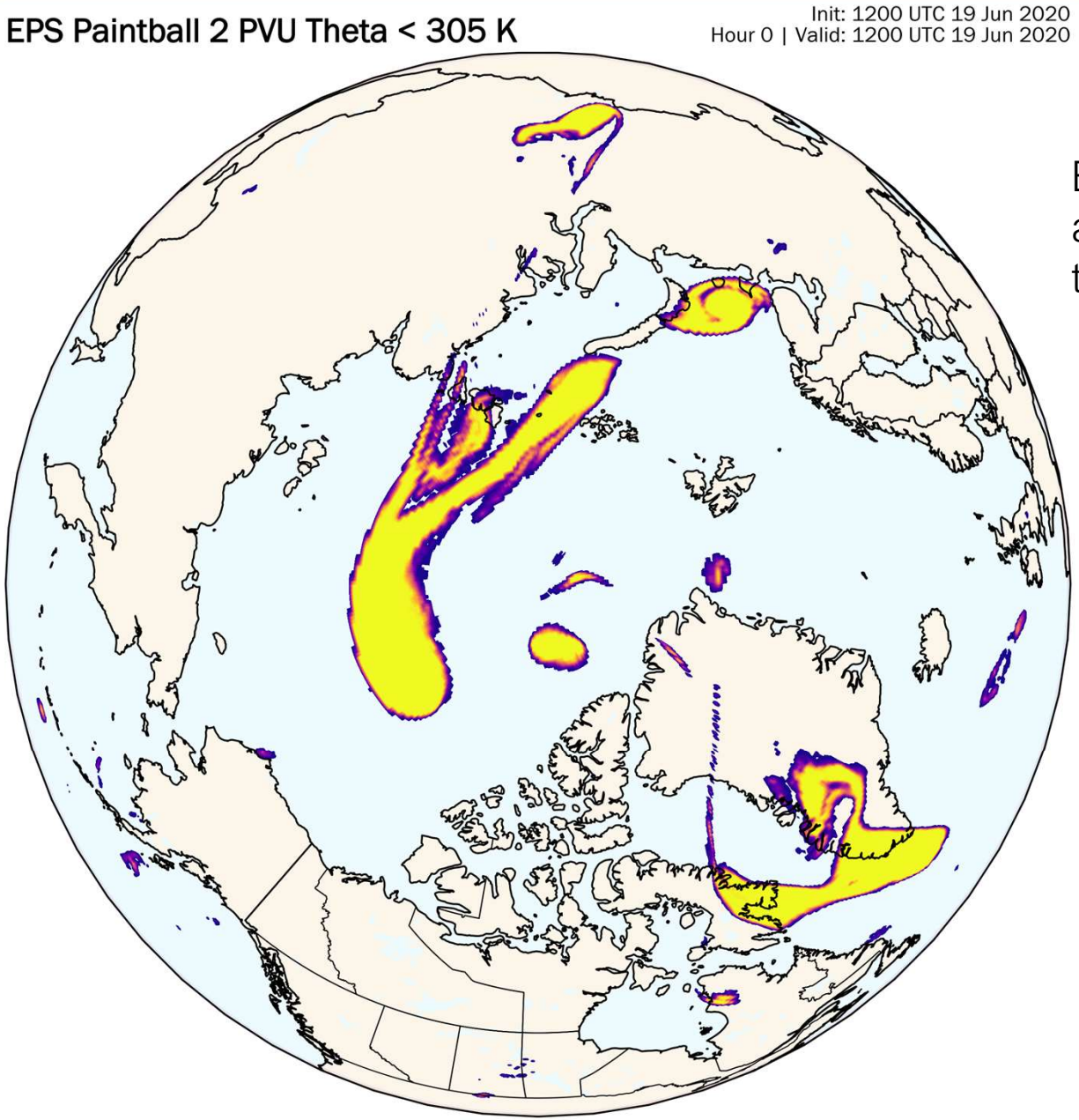
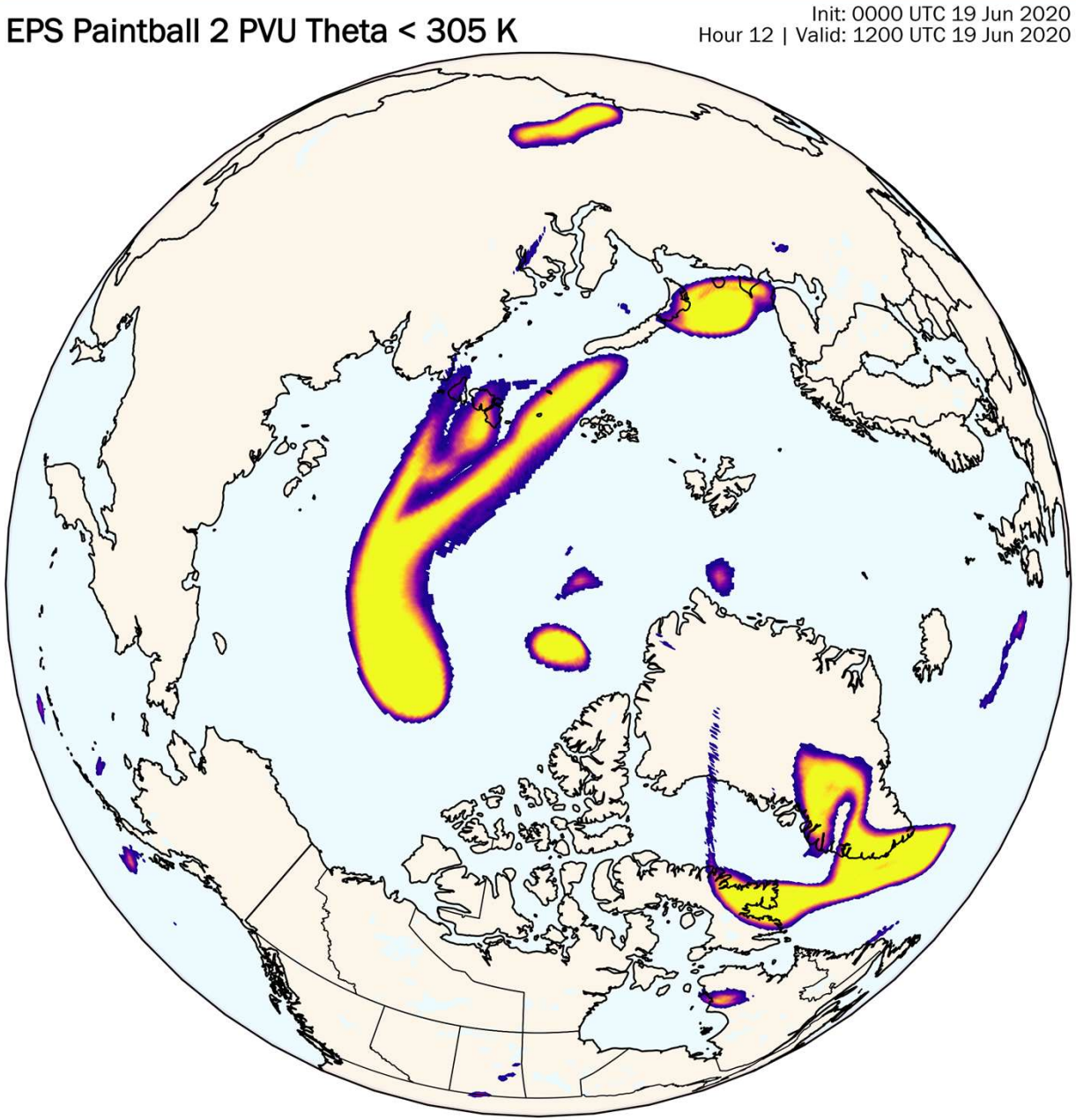


Forecast Hour 0

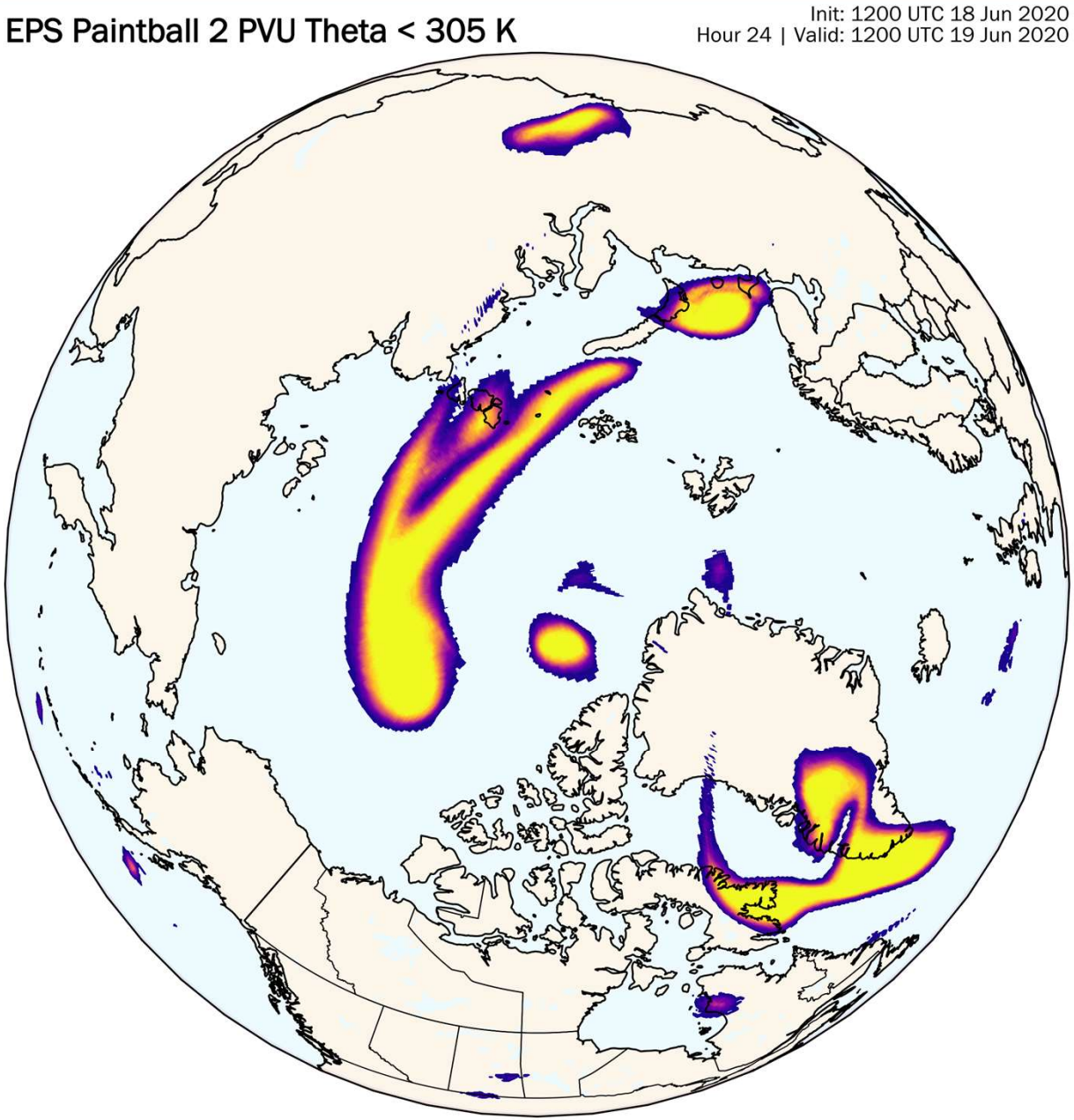
Both TPVs are apparent in the analysis, using 305 K as the threshold

19 June 2020 Forecast Evolution



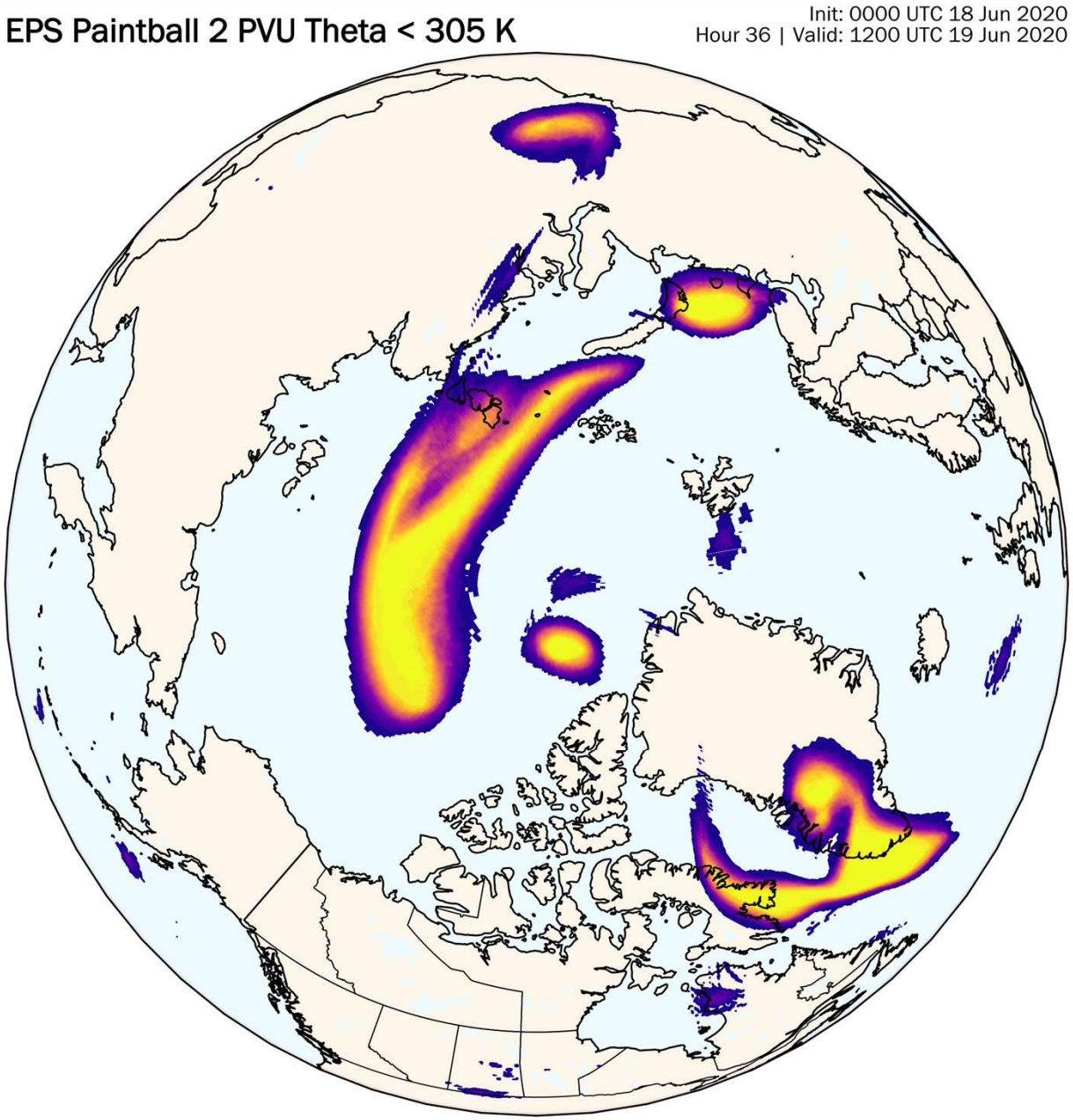
Forecast Hour 12

19 June 2020 Forecast Evolution



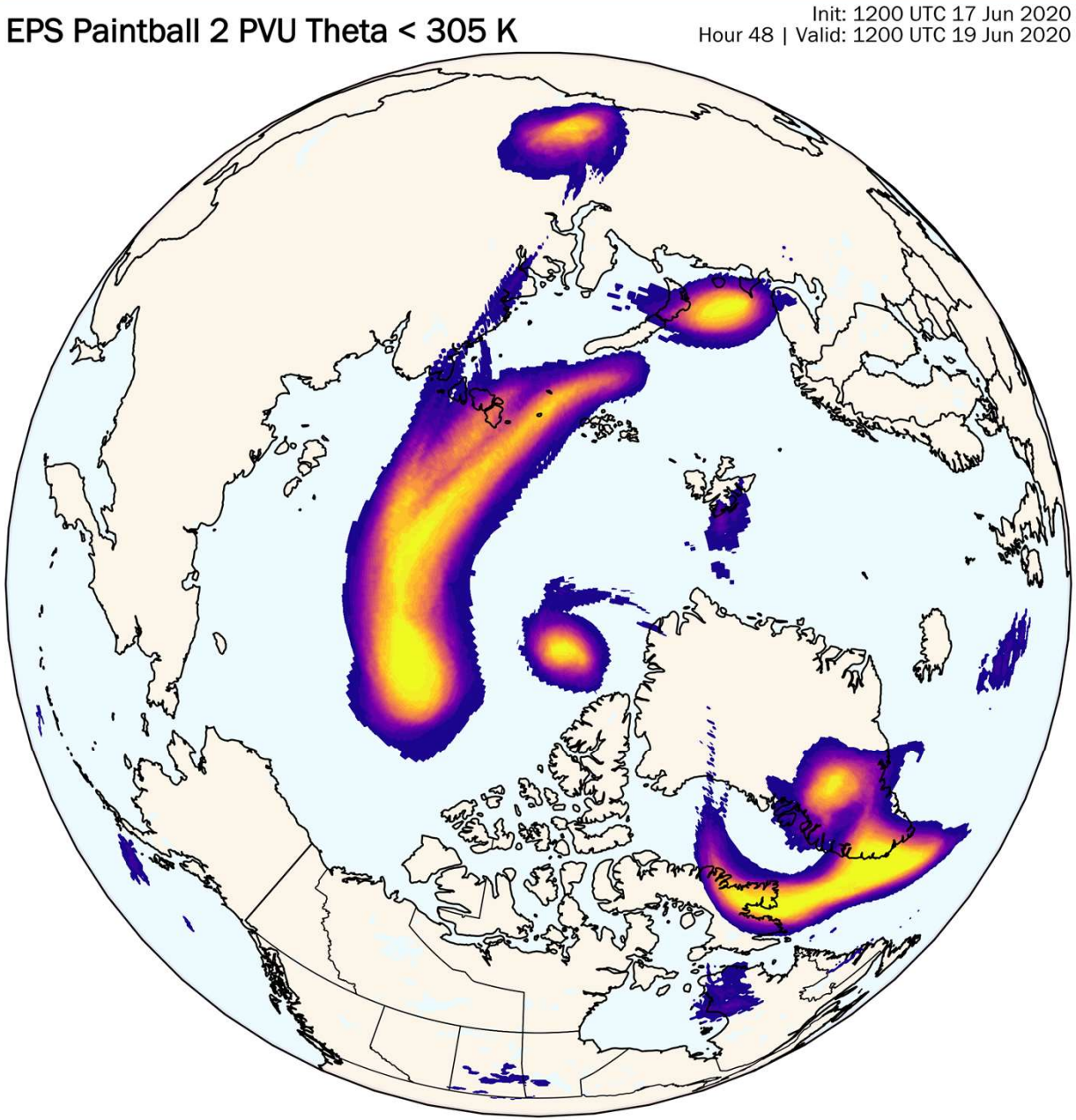
Forecast Hour 24

19 June 2020 Forecast Evolution



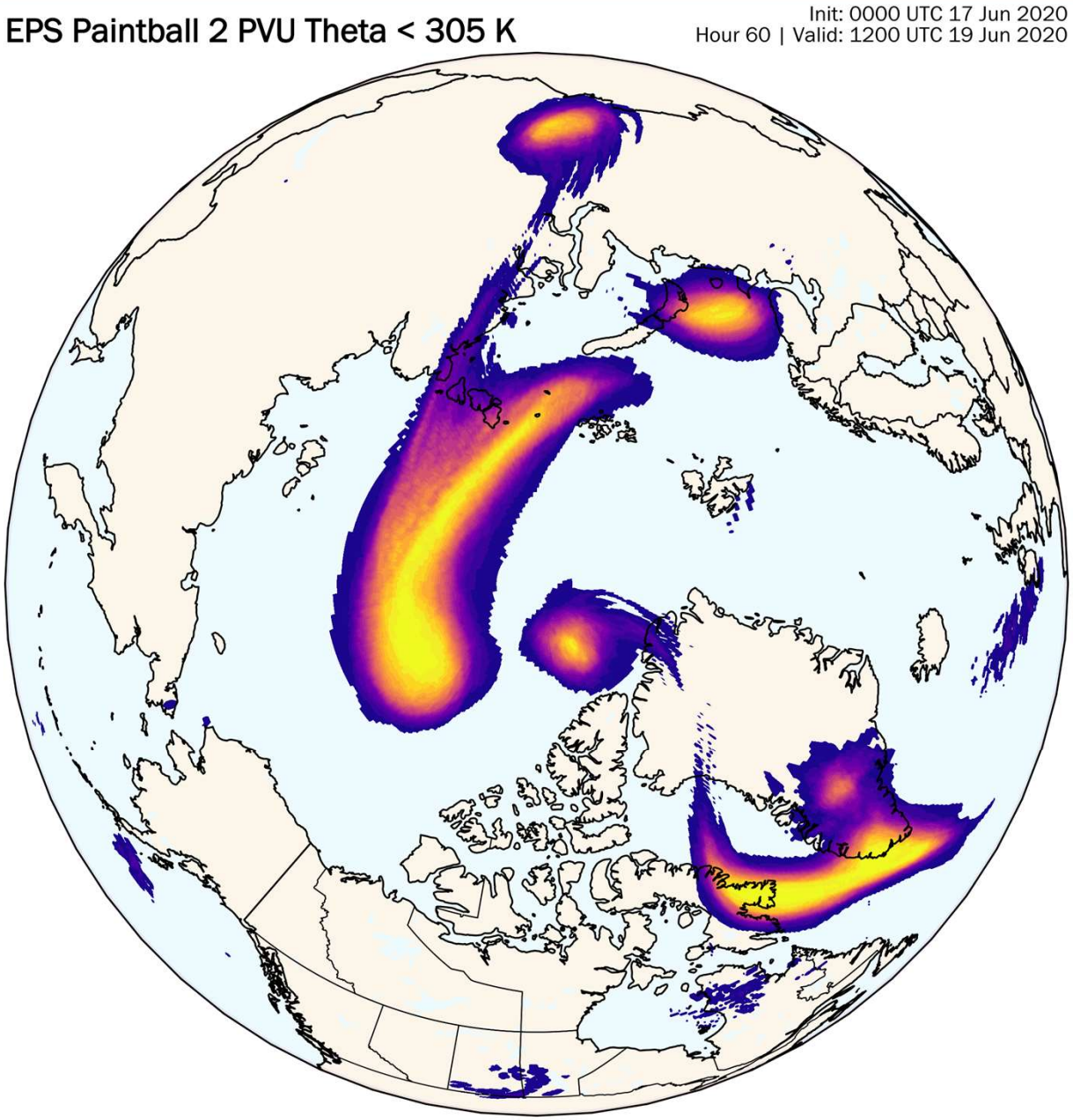
Forecast Hour 36

19 June 2020 Forecast Evolution



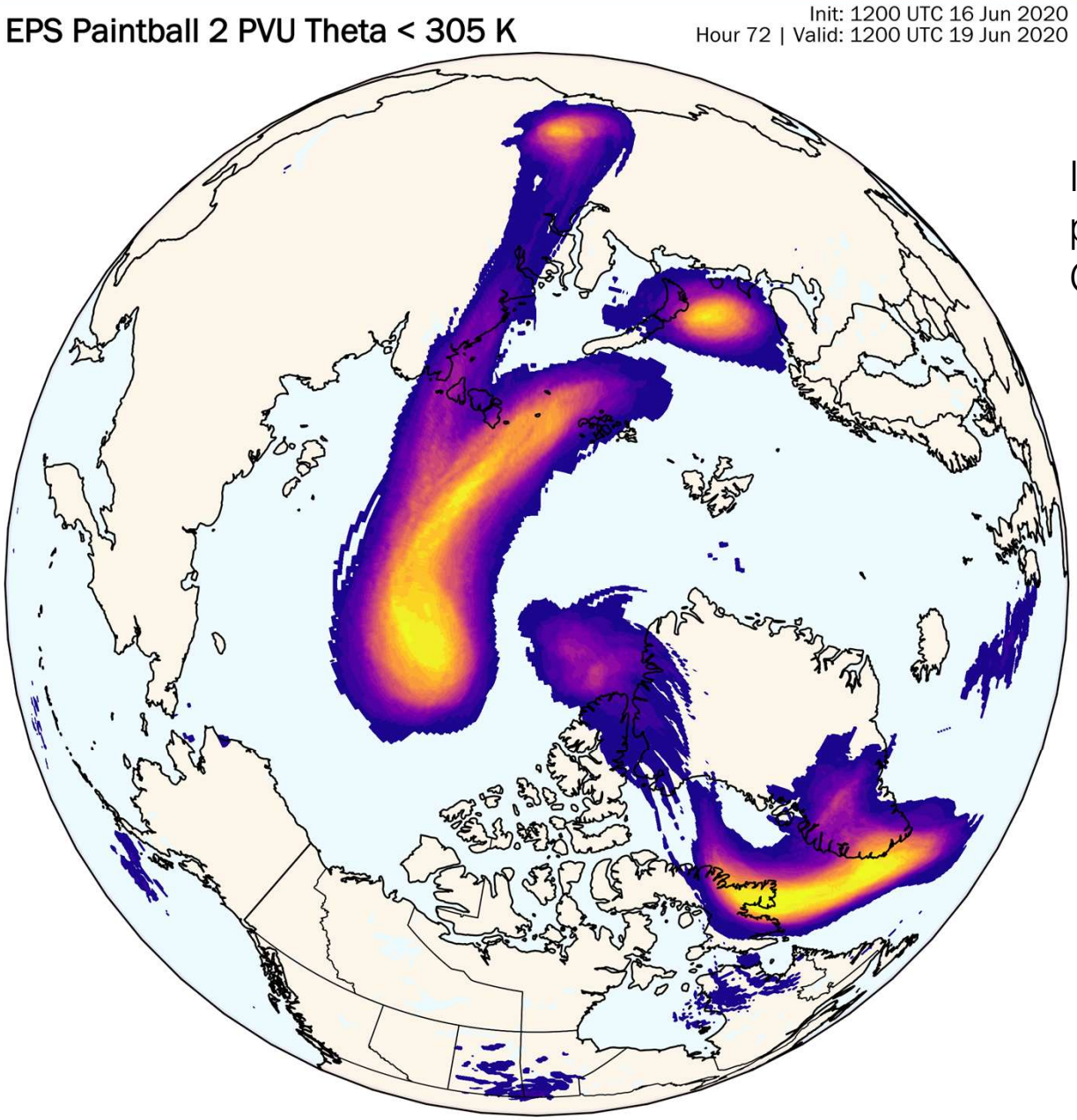
Forecast Hour 48

19 June 2020 Forecast Evolution



Forecast Hour 60

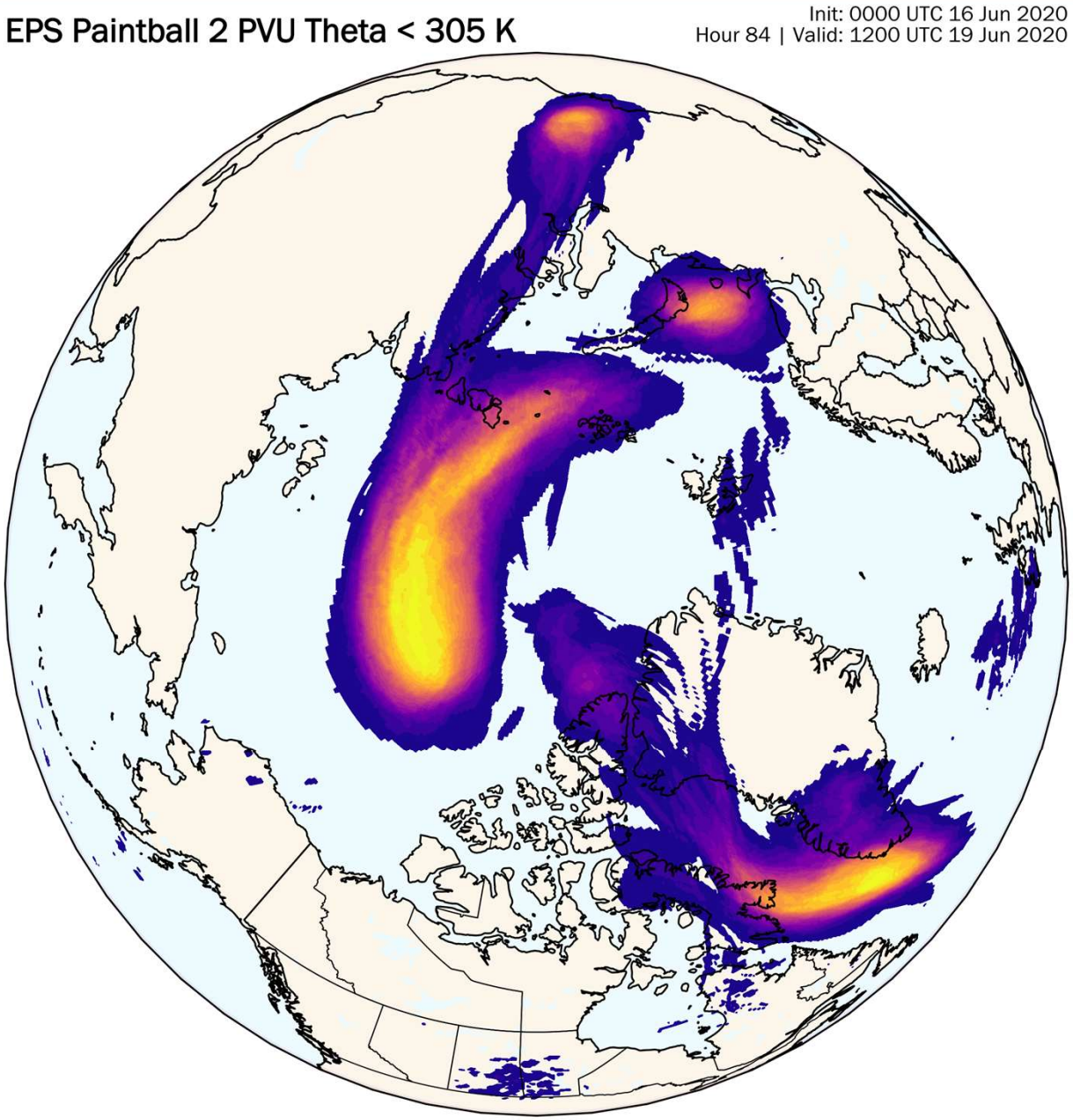
19 June 2020 Forecast Evolution



Forecast Hour 72

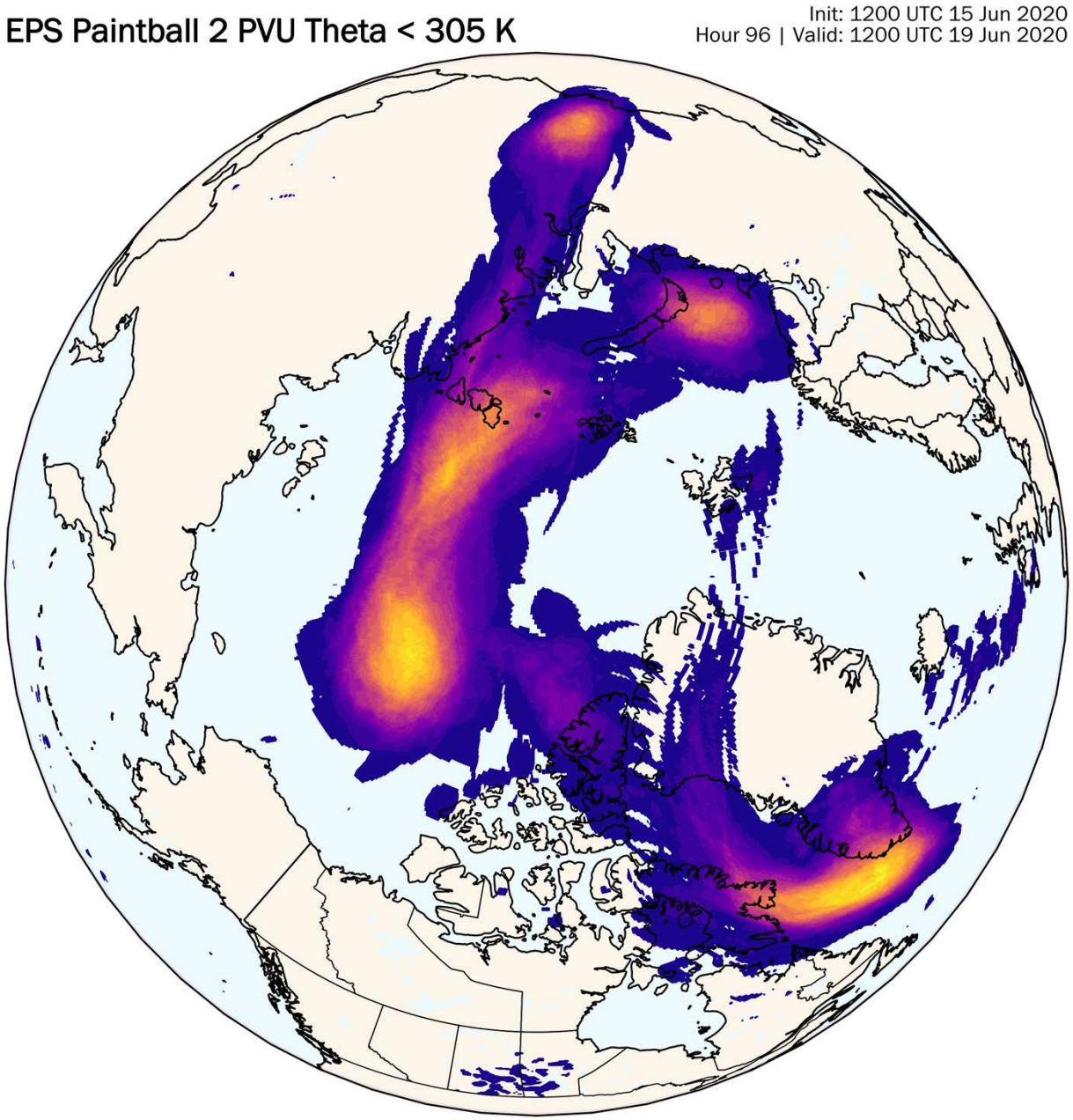
Increased spread in the position of the TPV near Greenland becomes apparent

19 June 2020 Forecast Evolution



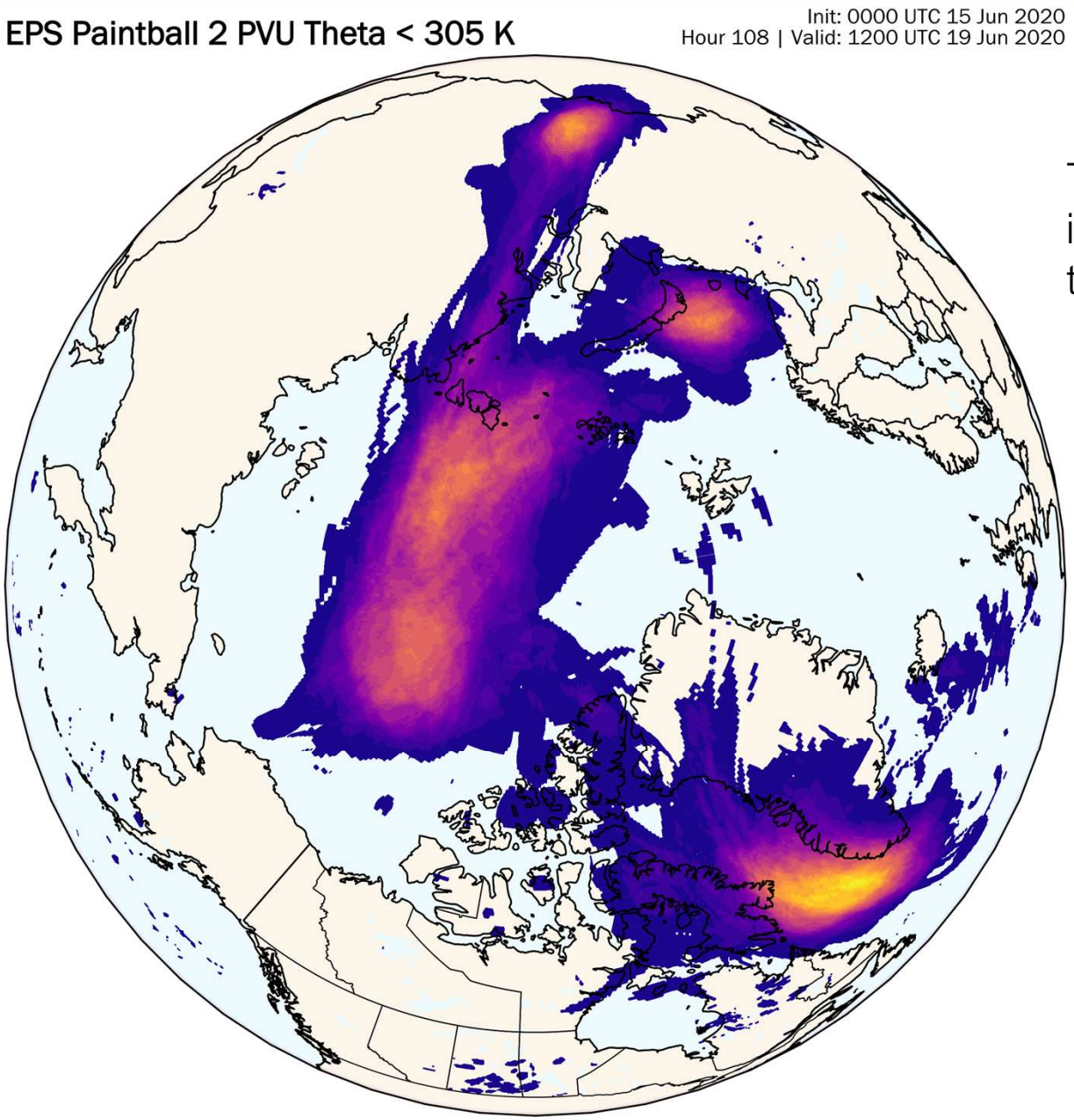
Forecast Hour 84

19 June 2020 Forecast Evolution



Forecast Hour 96

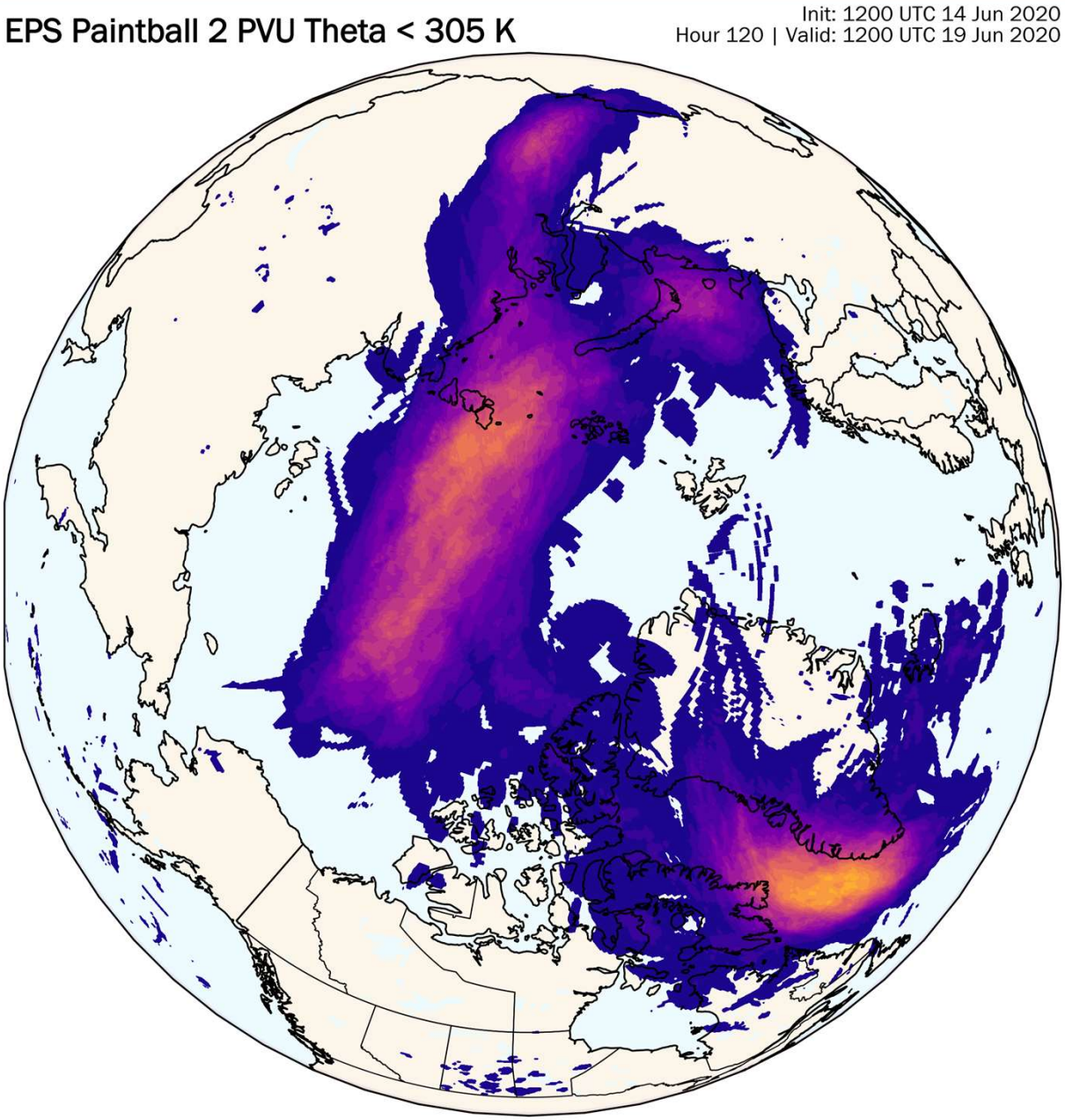
19 June 2020 Forecast Evolution



Forecast Hour 108

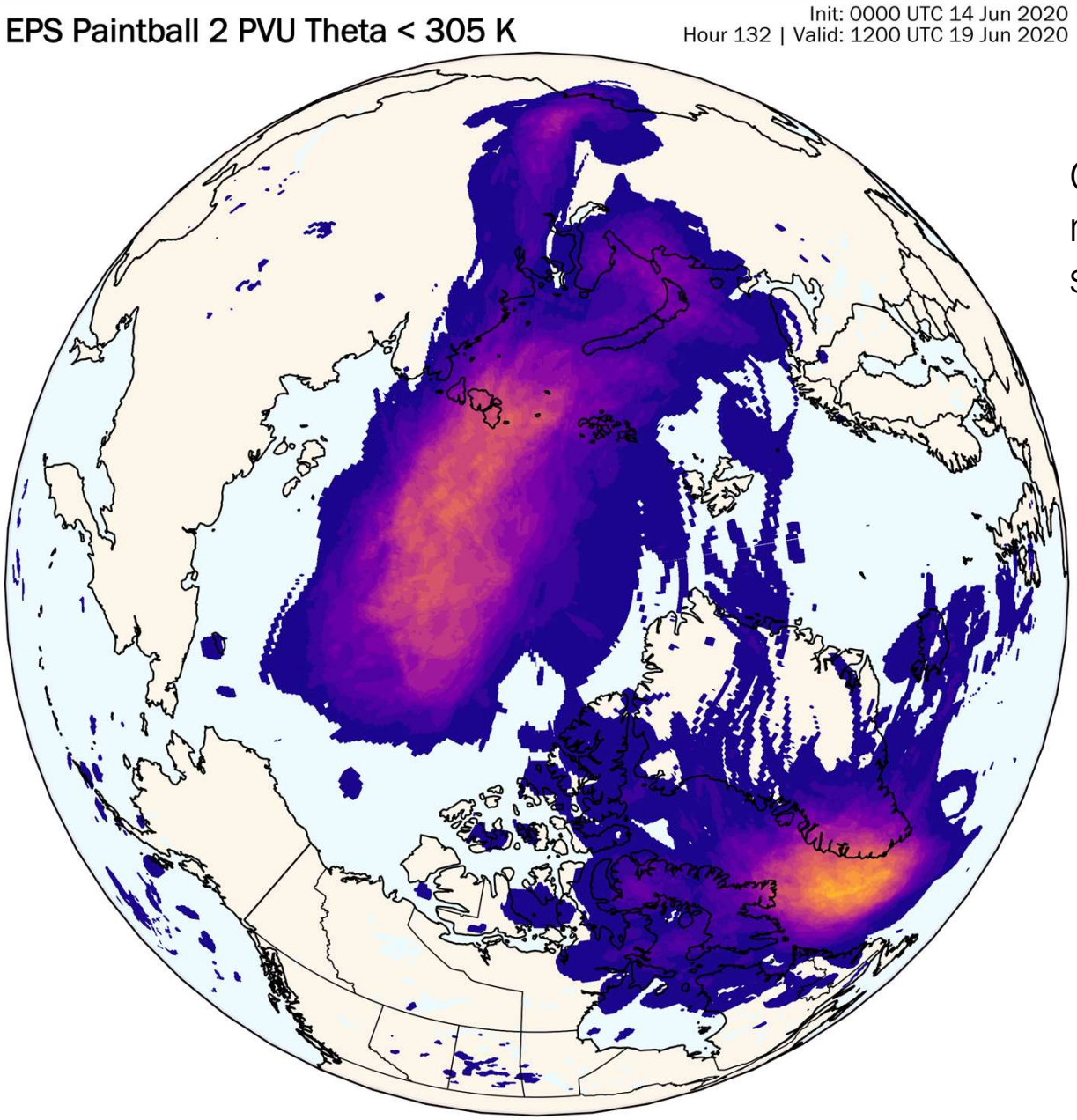
The TPV closer to Greenland is no longer as well defined in the ensemble spread

19 June 2020 Forecast Evolution



Forecast Hour 120

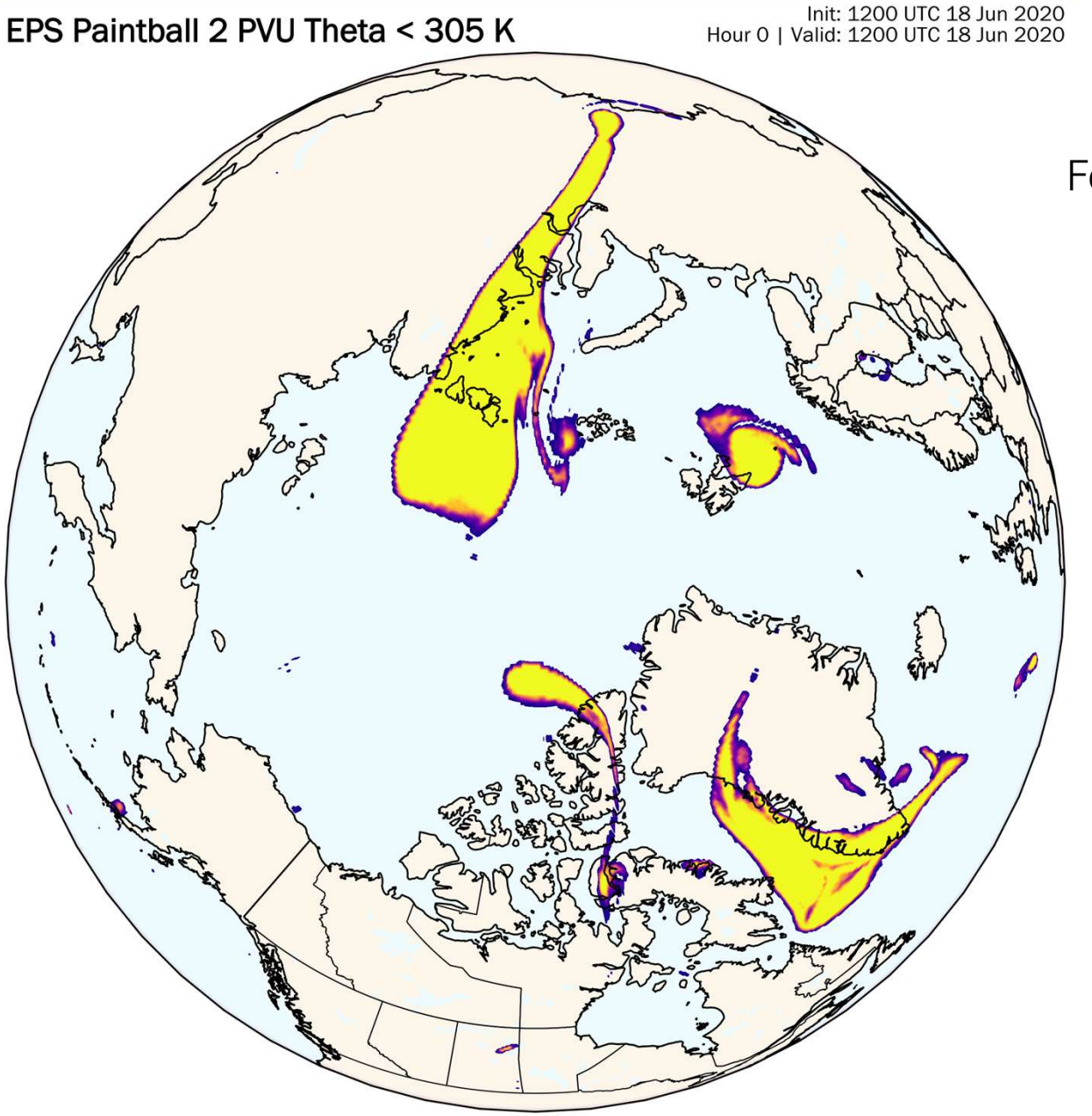
19 June 2020 Forecast Evolution



Forecast Hour 132

Original TPV near Greenland now has very large position spread

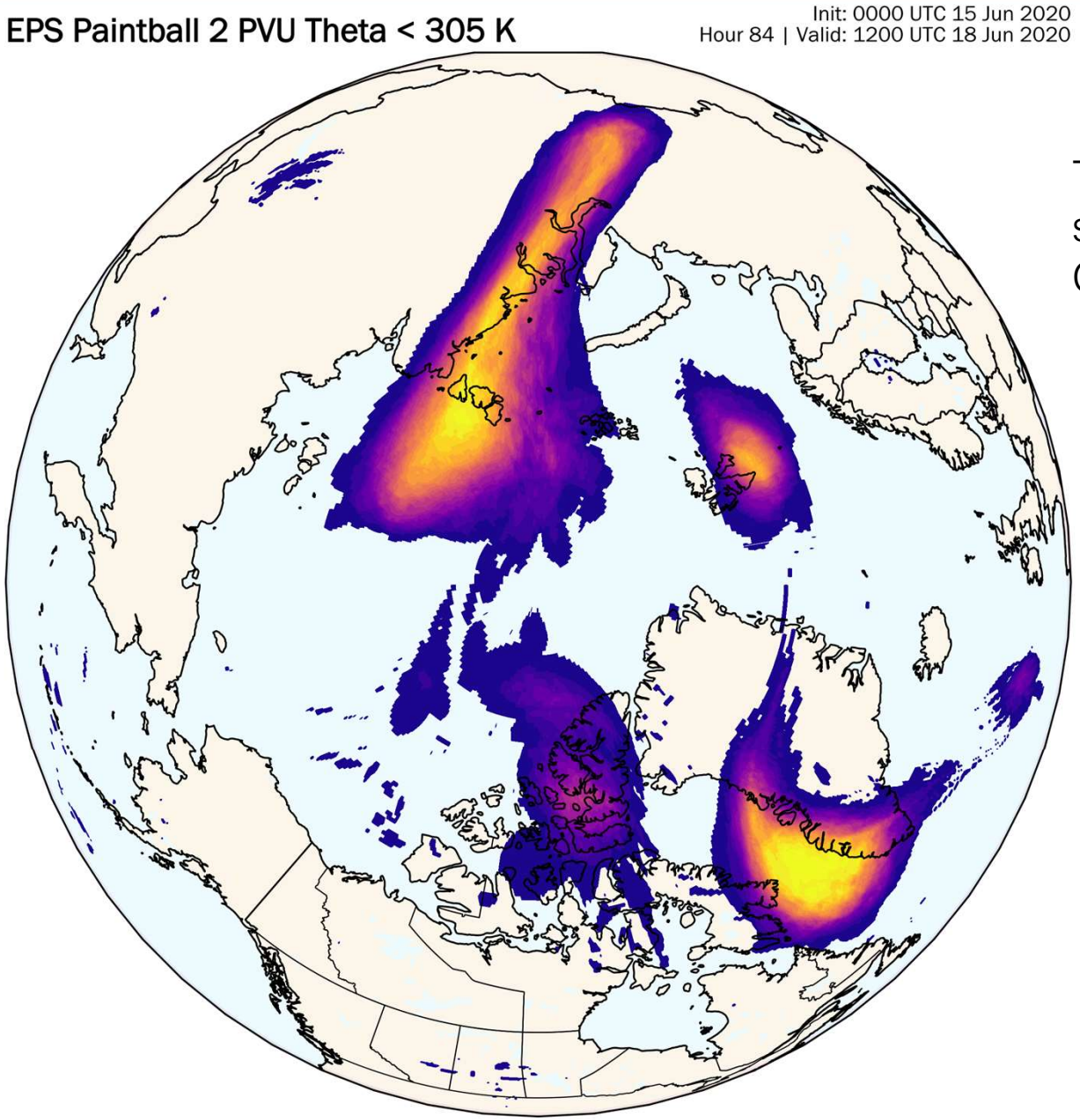
19 June 2020 Forecast Evolution



Forecast Hour 0

Focusing in on 18 June 2020

19 June 2020 Forecast Evolution

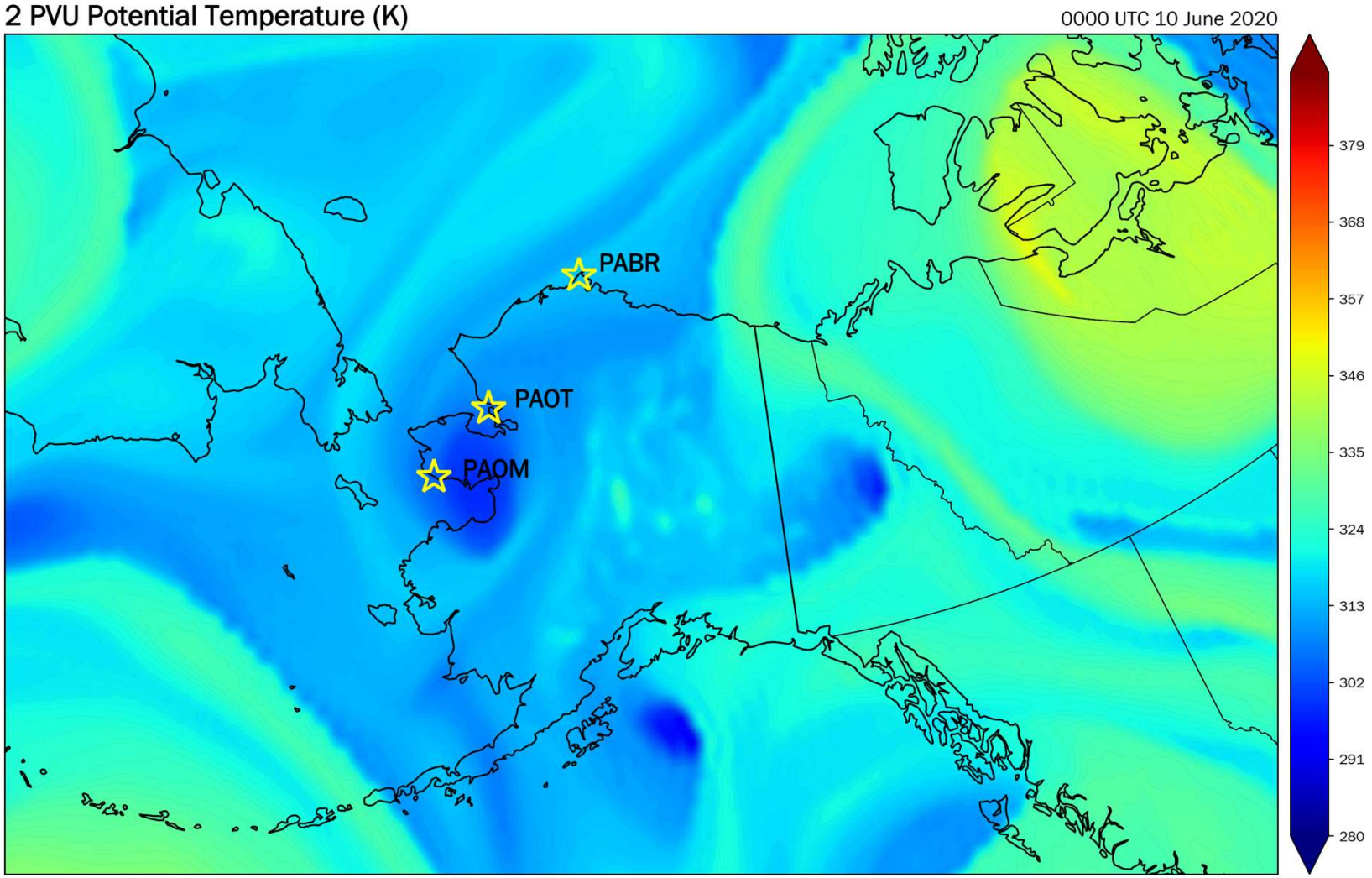


Forecast Hour 84

The TPV of concern is now substantially farther south over Canada

MPAS Experiment

- The eastern TPV moved directly over three radiosonde sites in the preceding days, making this case an **Observing System Experiment (OSE)** candidate



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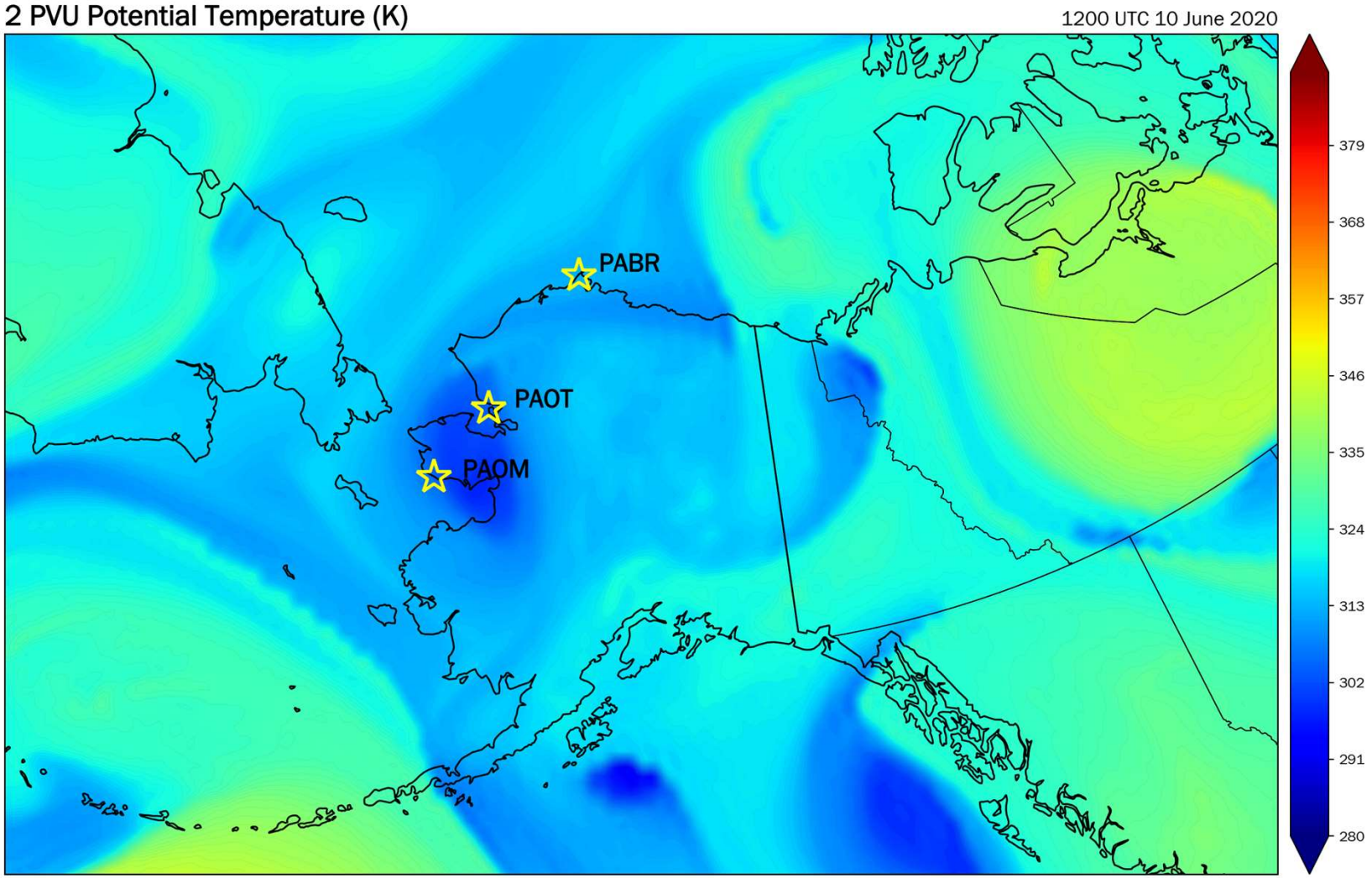

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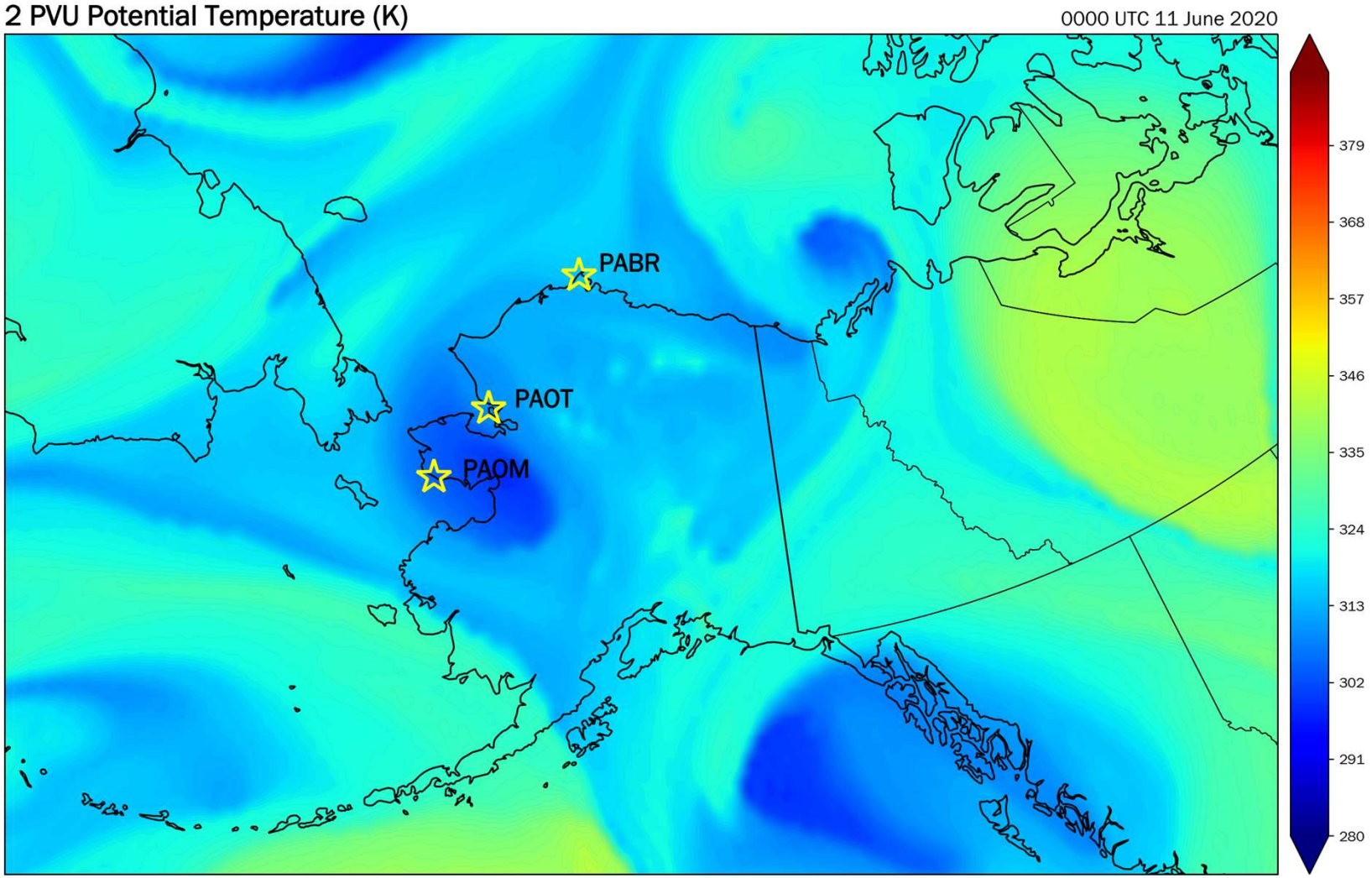

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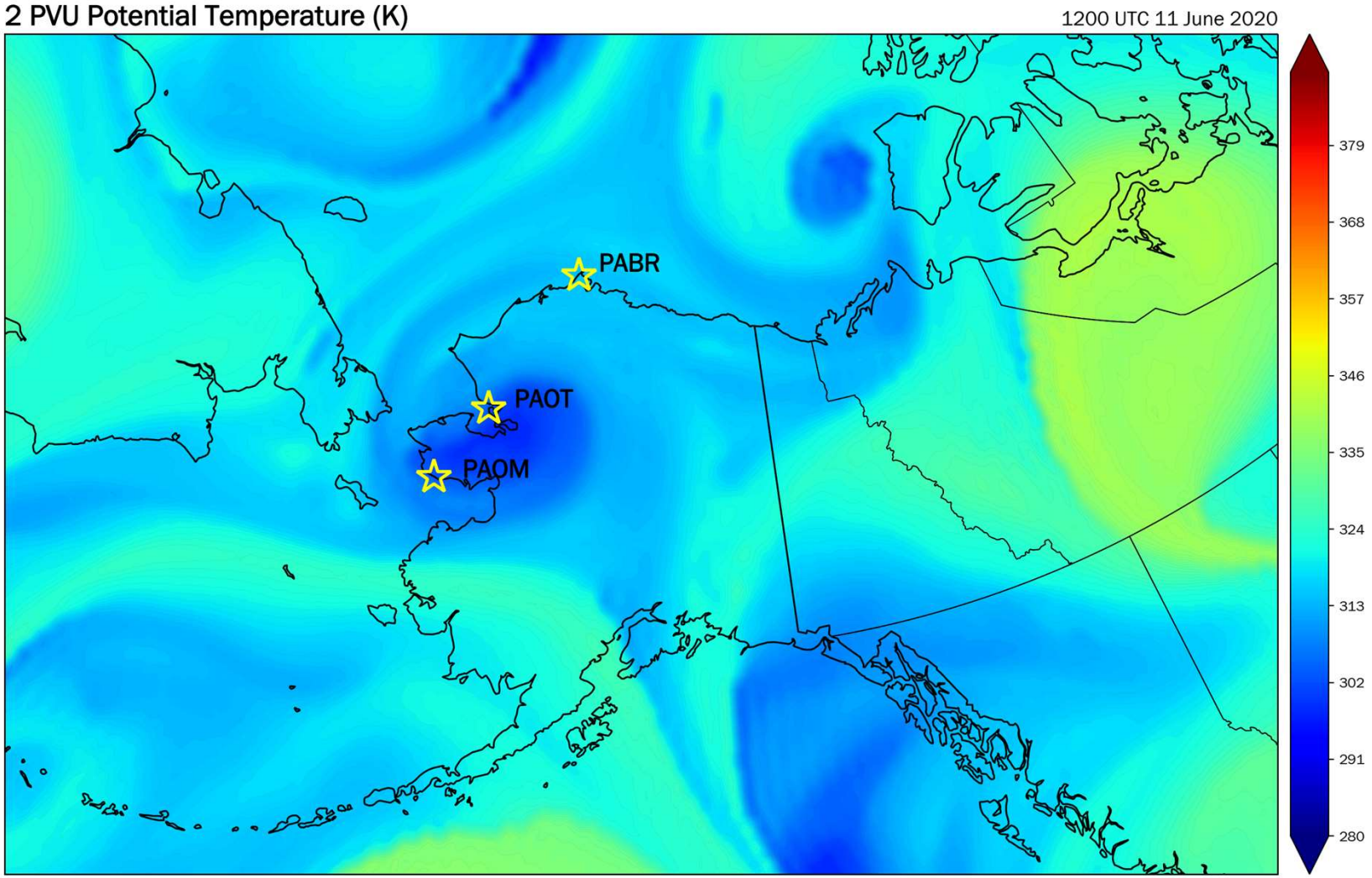

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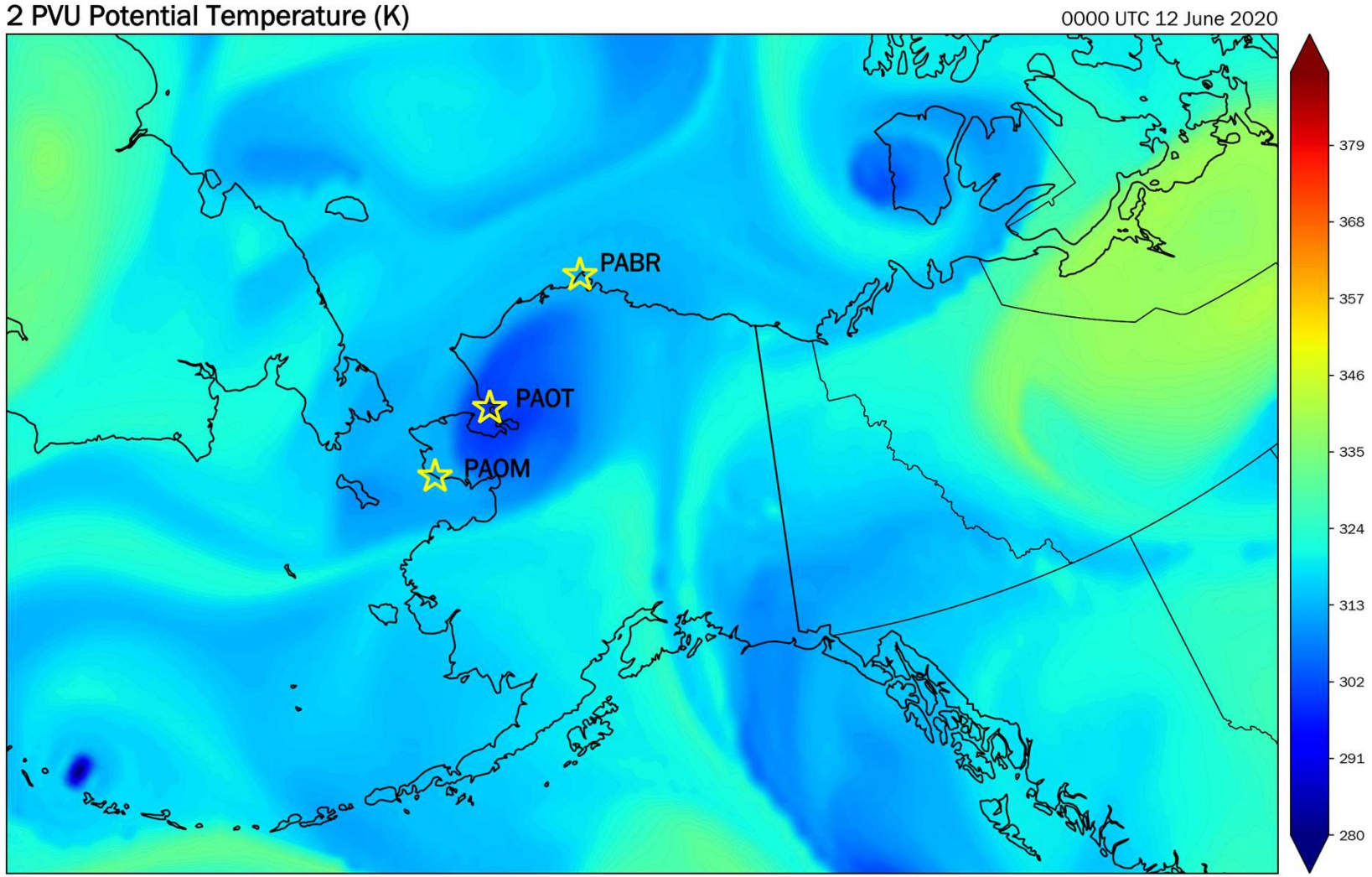

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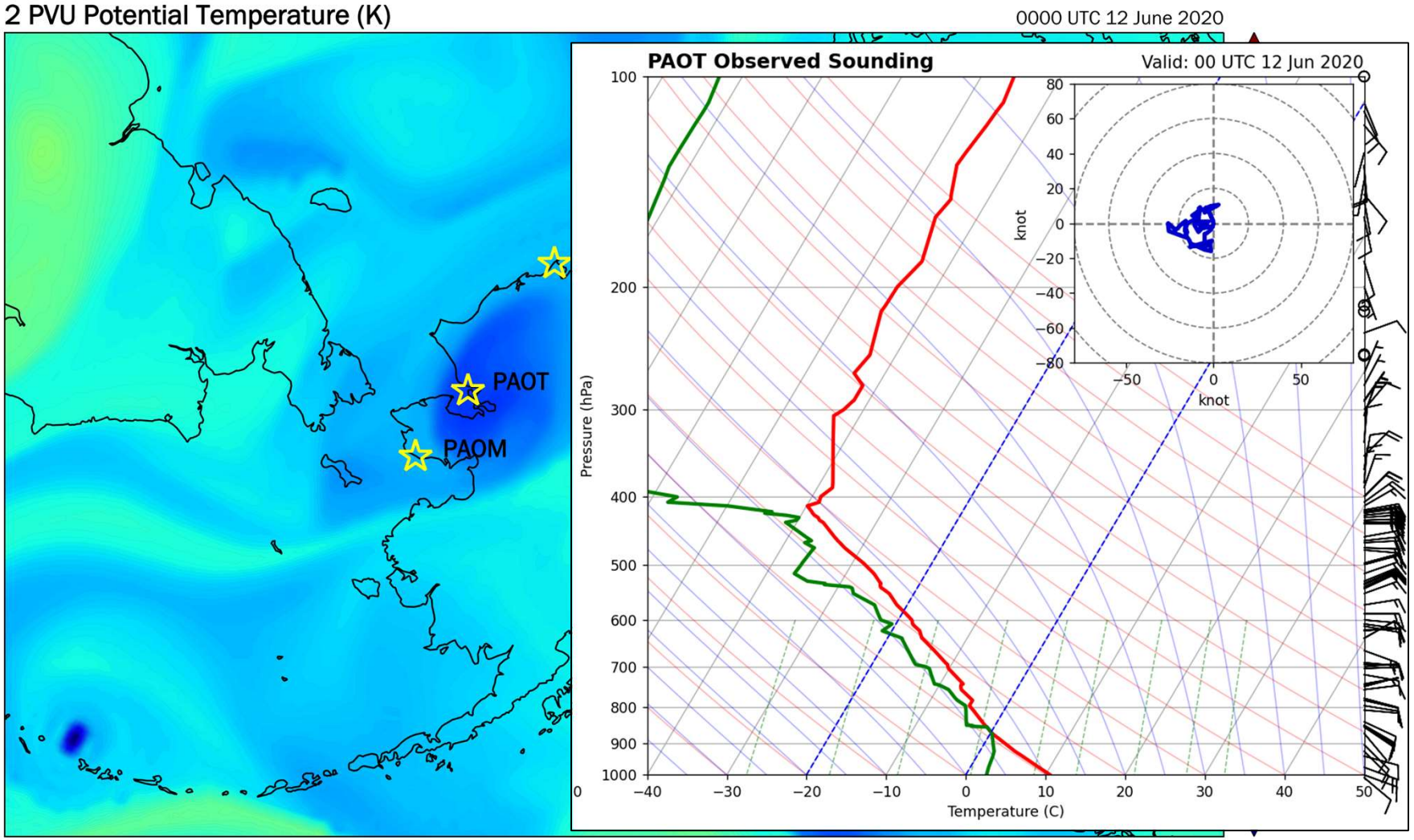

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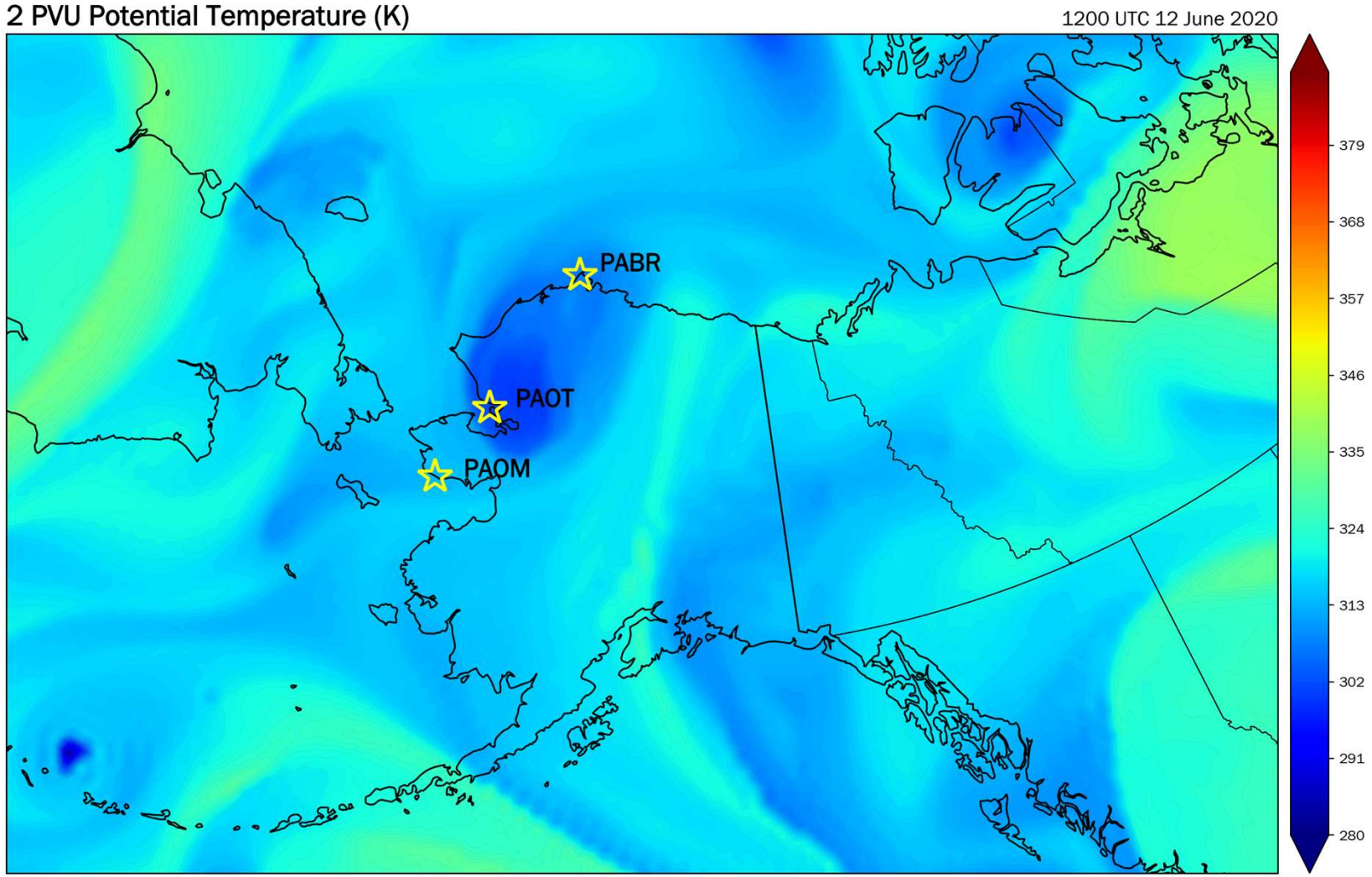

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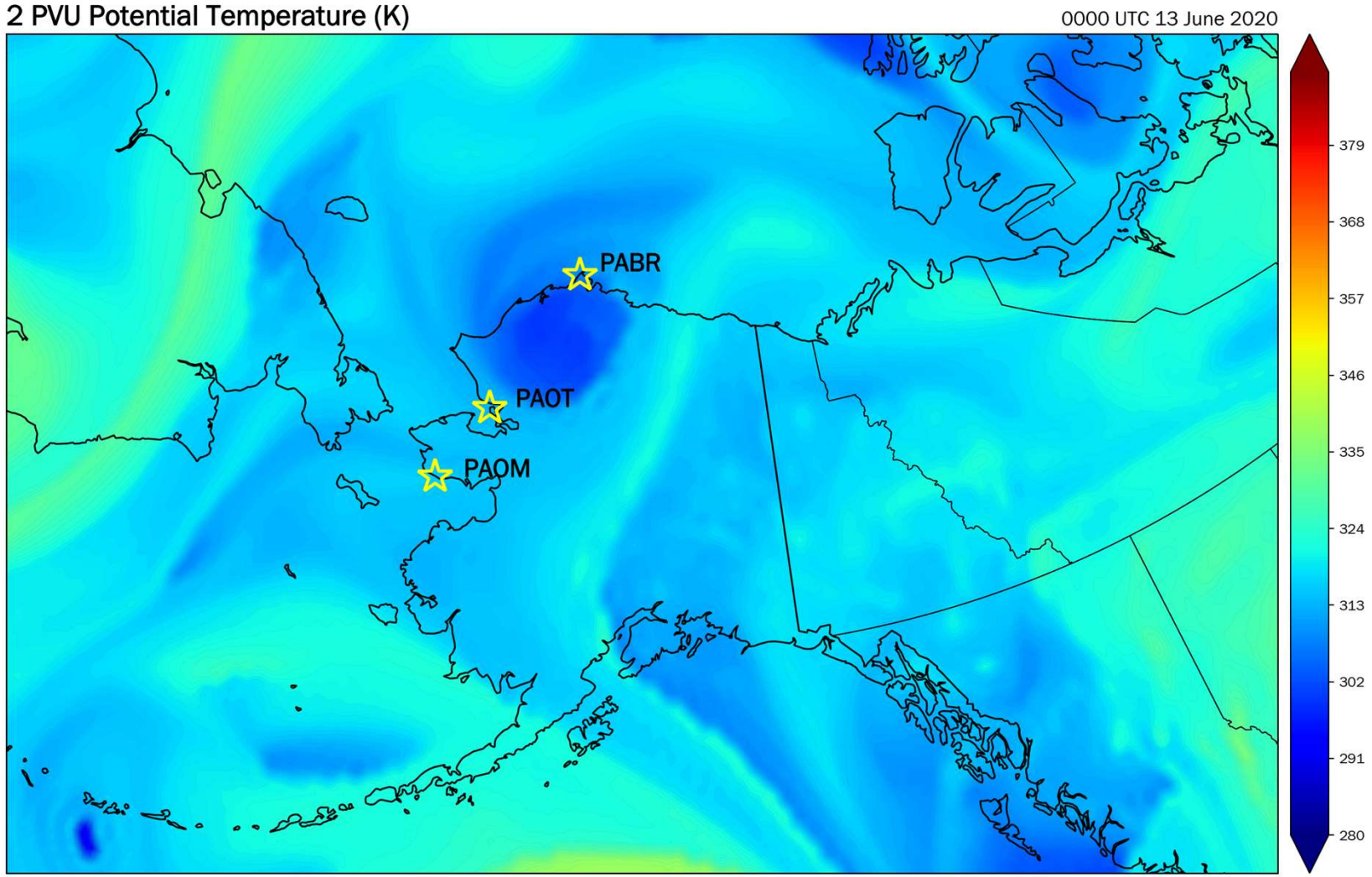

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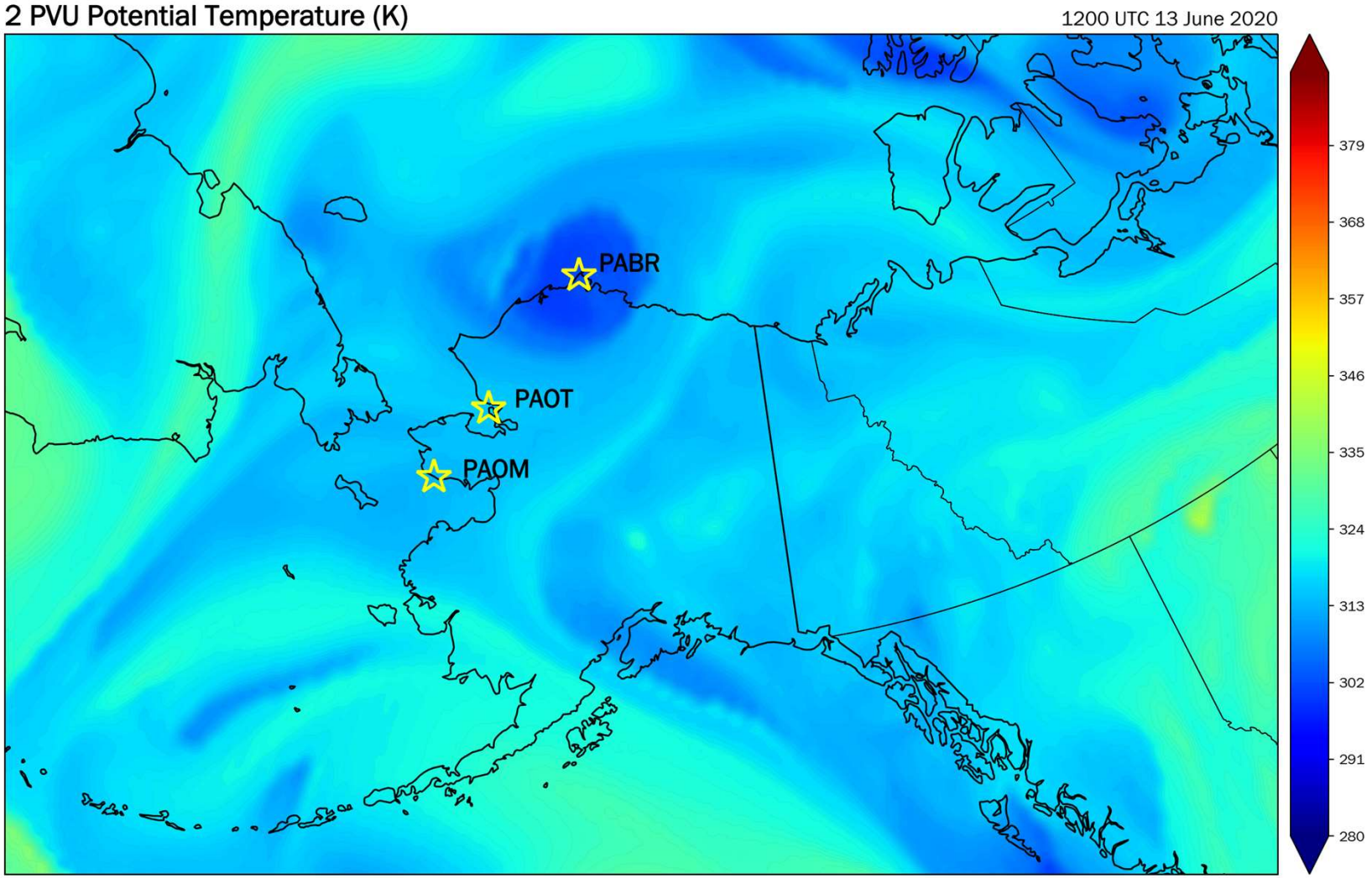

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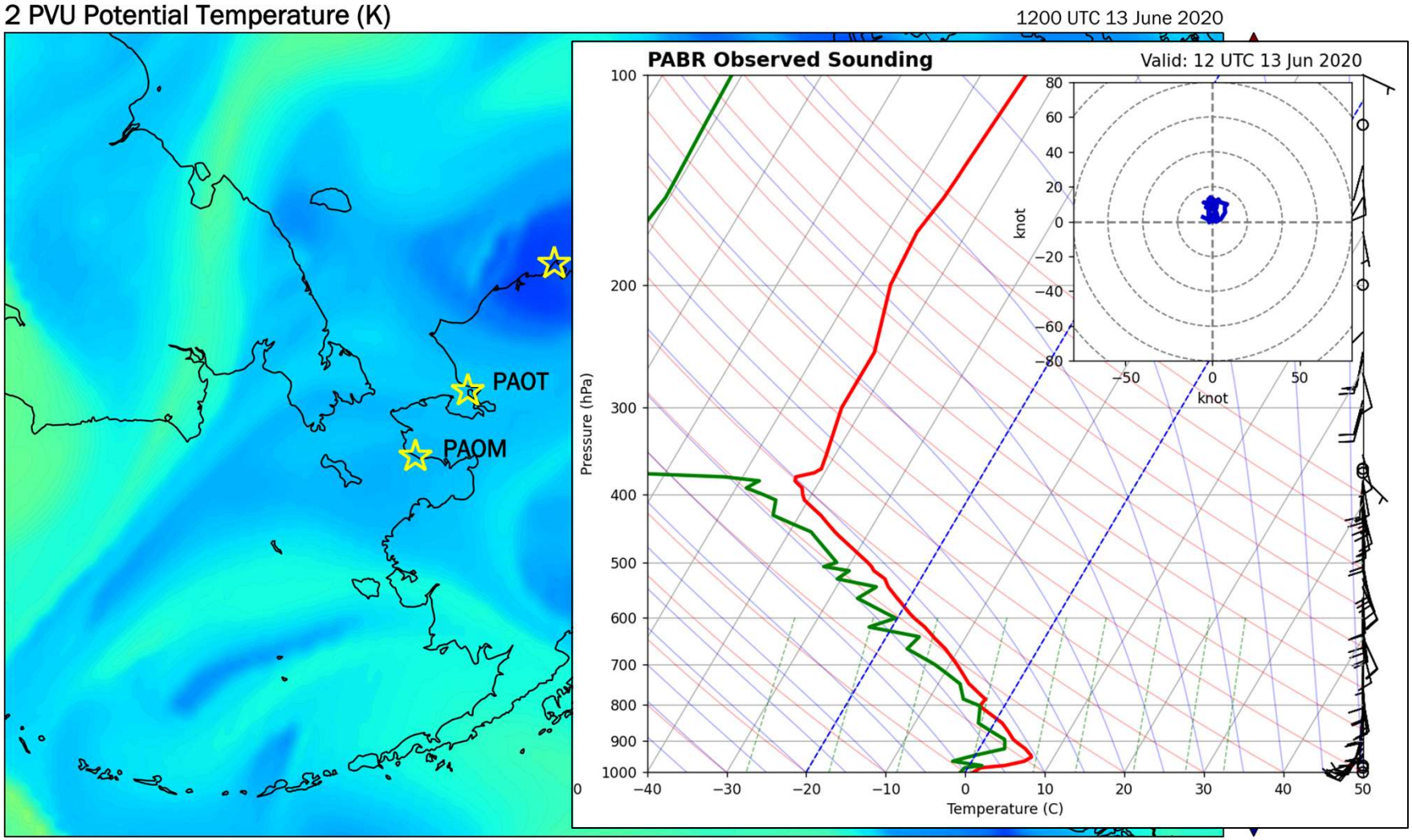

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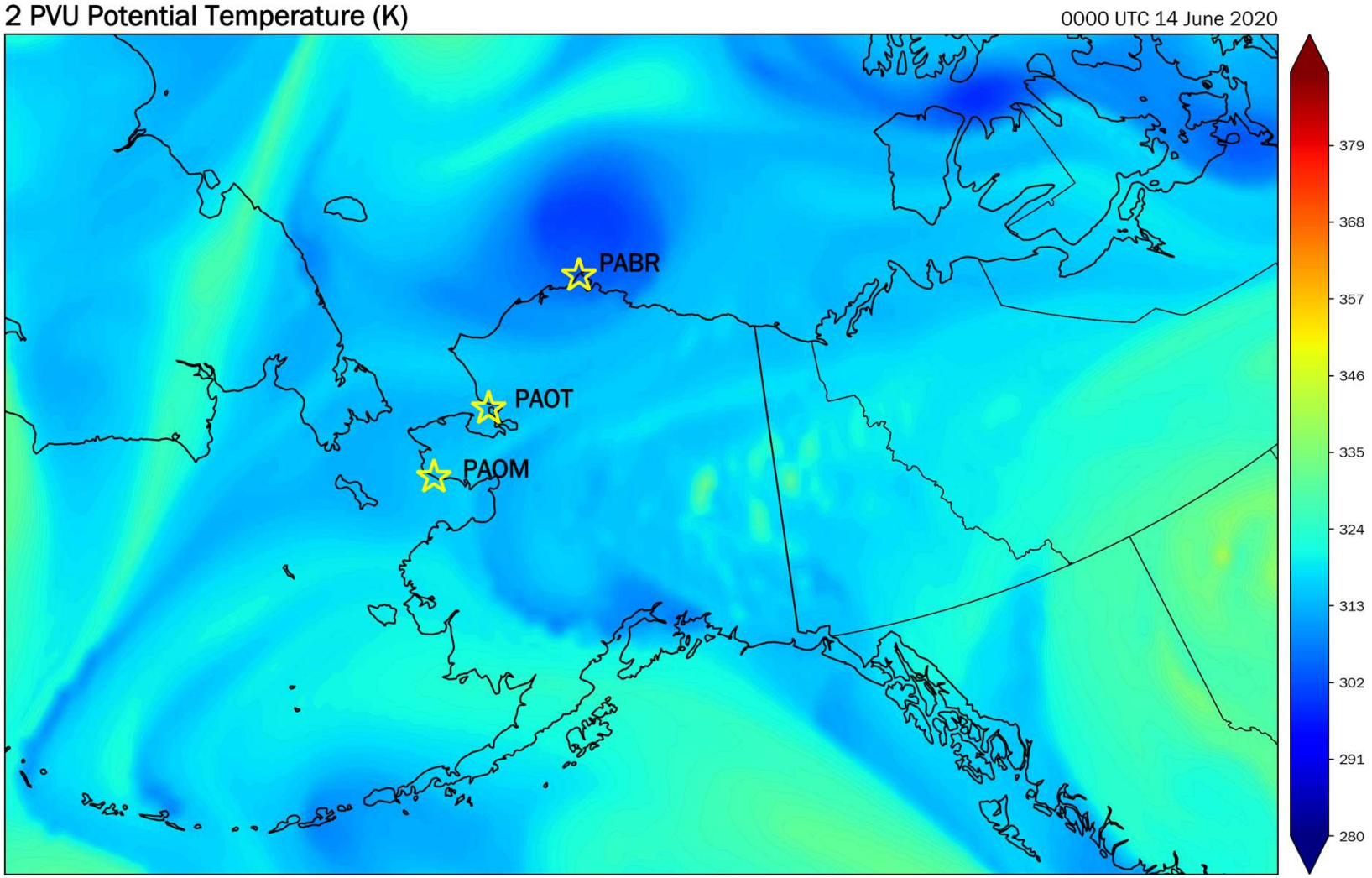
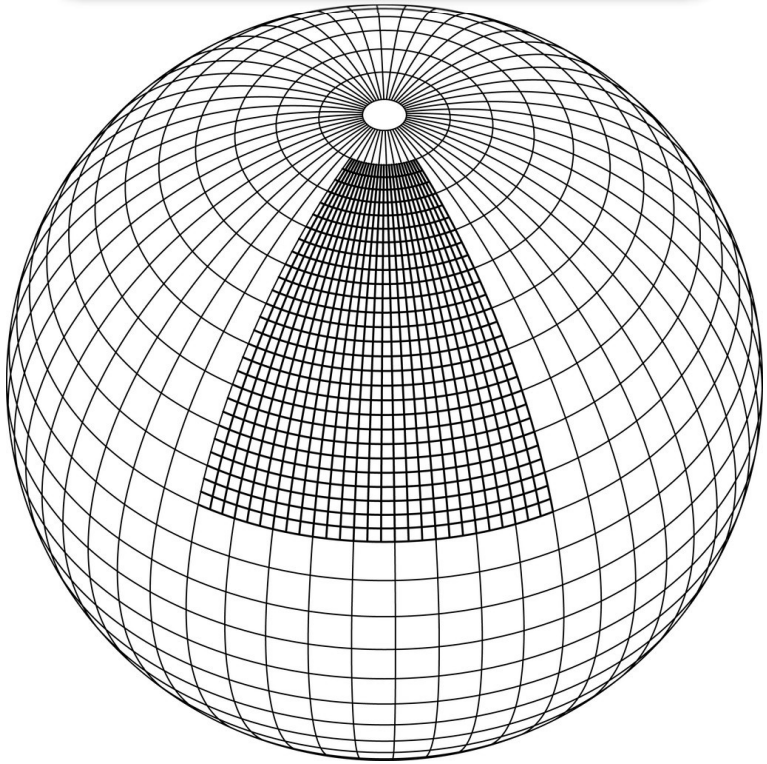


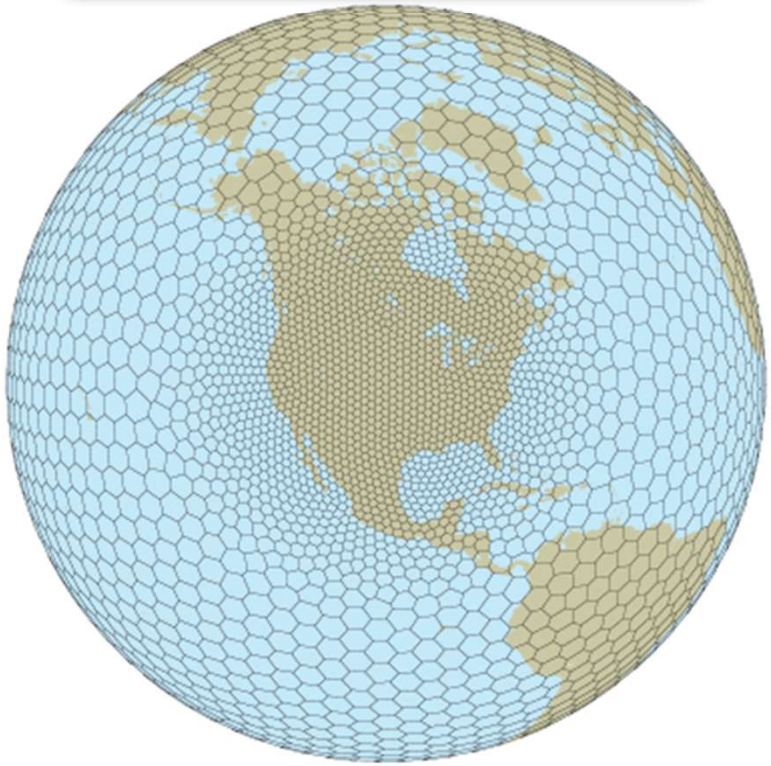
MPAS Experiment

- MPAS was chosen for this experiment
- Its unstructured grid and refined mesh avoid dealing with North Pole singularity

WRF



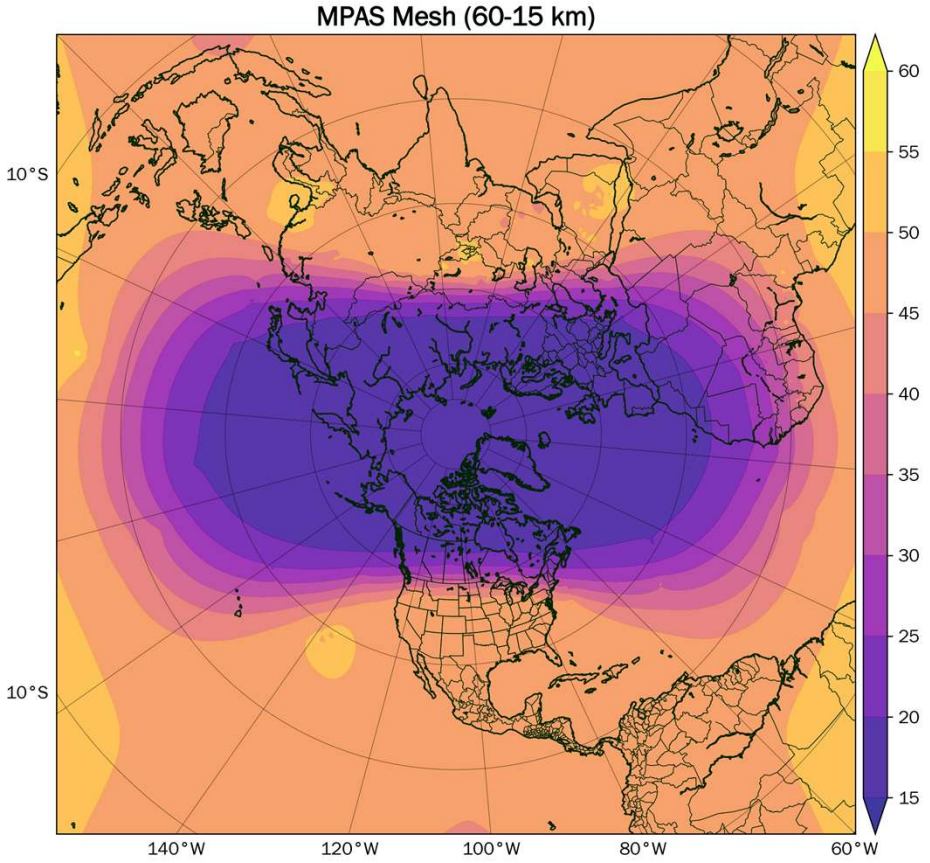
MPAS



MPAS Experiment

Model Configuration

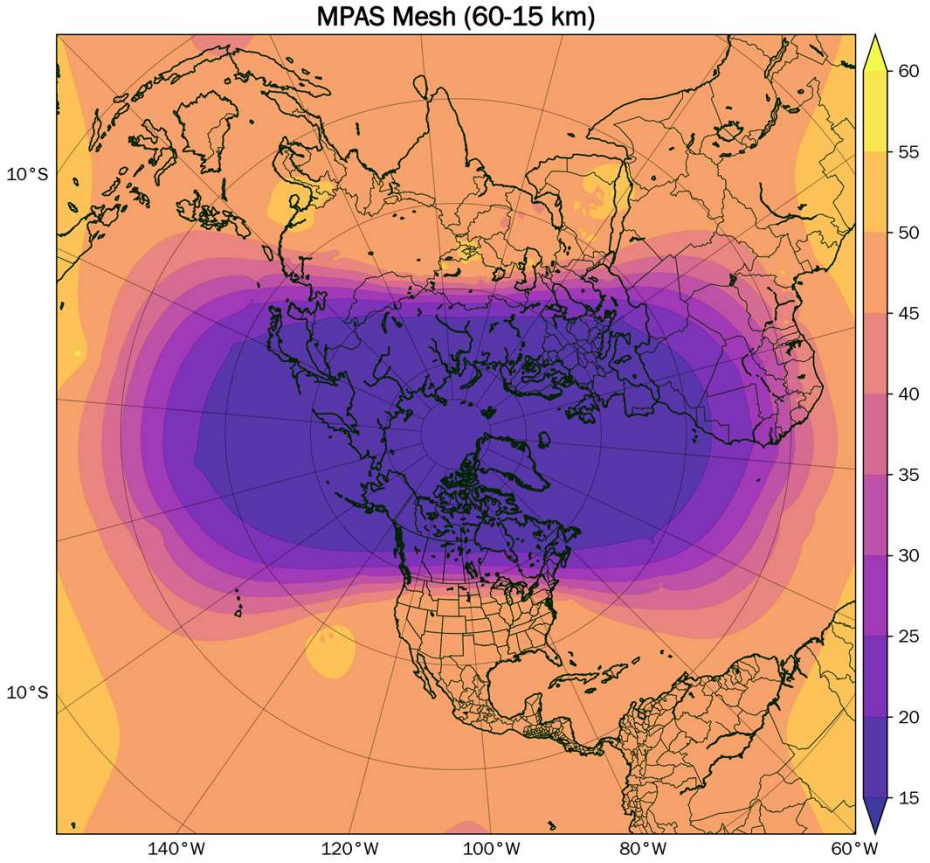
Horiz. Resolution	60-km → 15-km
ICs	GEFSv11
Convection Scheme	New Tiedtke
MP Scheme	Thompson
PBL Scheme	YSU
Land Surface Model	NOAH
Radiation	RRTMG



MPAS Experiment

Model Setup

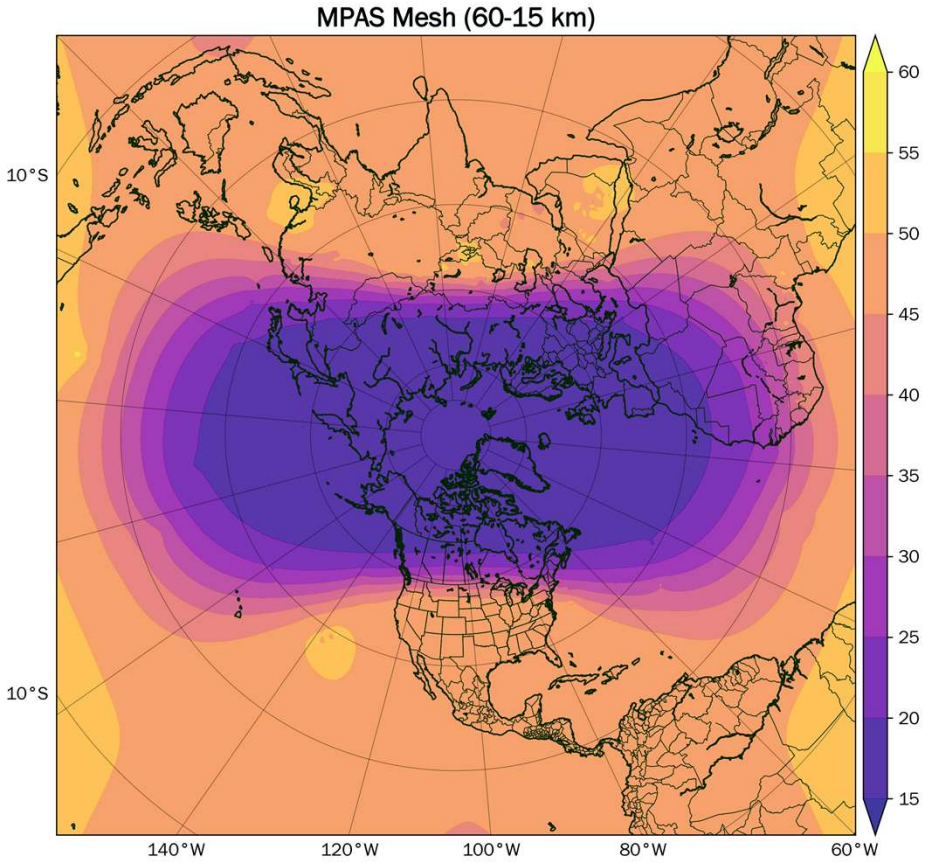
- Two sets of 30-member ensembles
- Ensembles initialized off of 48 and 54 hour lead time GEFS ensemble forecasts
- GEFS ensembles spun up for 12 hours with MPAS before beginning DART cycling



MPAS Experiment

DART SETUP

- Ensemble Adjustment Kalman Filter (EaKF)
- Using "**mpas_atm**" configuration



Conclusions & Future Work

- Two TPVs merged over the Arctic Ocean on 19-20 June 2020, associated with two large ACs
- The forecast skill of the eastern TPV degraded quickly with lead time associated with position error
- Work is currently underway to run an Observing System Experiment (OSE) to assess the role of the limited observations on the eastern TPV