U.S. plans for contributions to NAWDIC

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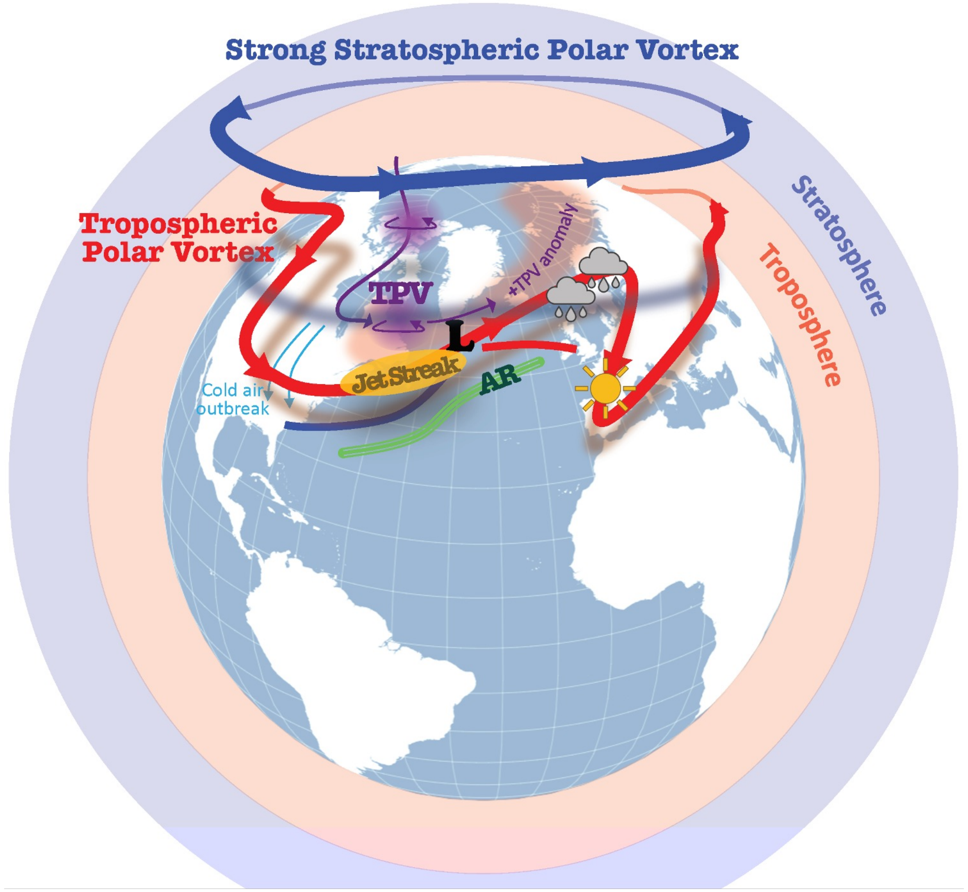

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High Impact Weather

High-impact weather (HIW) events (e.g., extreme temperatures, heavy precipitation, strong winds, persistent drought) have significant socioeconomic costs and pose direct threats to national security (e.g., destabilizing supply chains and damaging infrastructure).

Large waves in Plobannalec-Lesconil, France, as Storm Ciara/Sabine was hitting western and northern Europe. Credit: New York Times

- Despite considerable progress during recent decades, accurate predictions of the location, timing, and intensity of these typically mesoscale HIW events at ***medium-to-extended*** forecast lead times continue to pose a challenge for state-of-the-art numerical weather prediction (NWP) models.

- These challenges can be attributed to the multiscale interactions of physical processes involved in the formation of HIW events.

- At long lead times, predictability of HIW is dependent on accurate depictions of the intensity, position, and character of the jet streams.

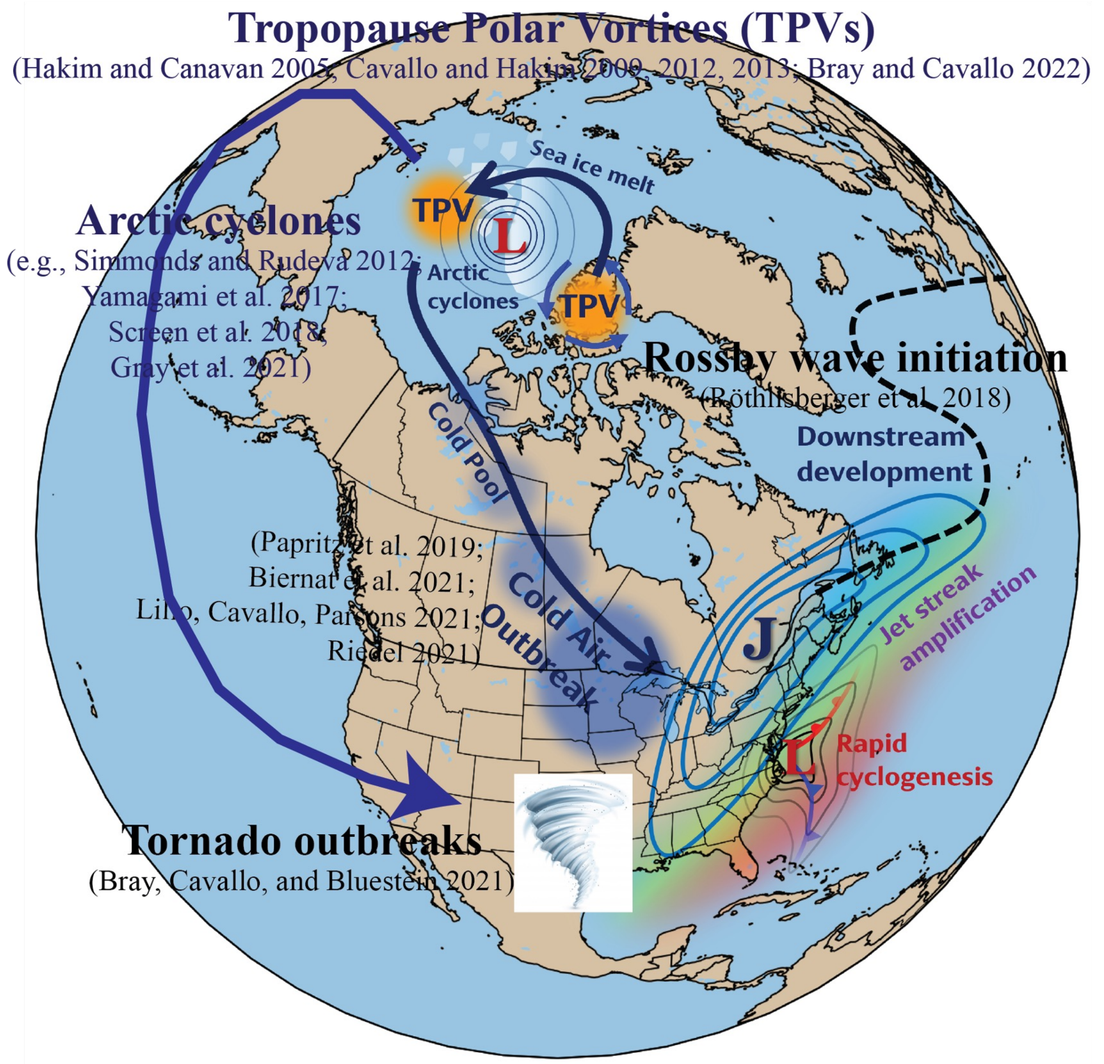
- An improved understanding of the structure and evolution of upper-tropospheric jet streams will fill knowledge gaps that translate to improved predictions of HIW at ***medium-range to extended forecast lead times***.

Precursors to High Impact Weather (HIW)

- We propose to contribute to NAWDIC by providing the first systematic mesoscale observational investigation of the antecedent atmospheric dynamics that influence the tropopause structure within the near-jet environment and lead to downstream HIW

- We plan to study the mesoscale tropopause structure and surrounding upper-troposphere and lower-stratospheric (UTLS) processes that serve as precursors for HIW.

- What antecedent dynamics will we target?
  - ➢ Tropopause Polar Vortices (TPVs)
  - ➢ Dynamics supporting jet superpositions
  - ➢ Mesoscale stratosphere-troposphere interactions
  - ➢ Diabatic processes (i.e., upscale growth of PV anomalies, cloud-radiative feedback, turbulent generation of PV near jets)



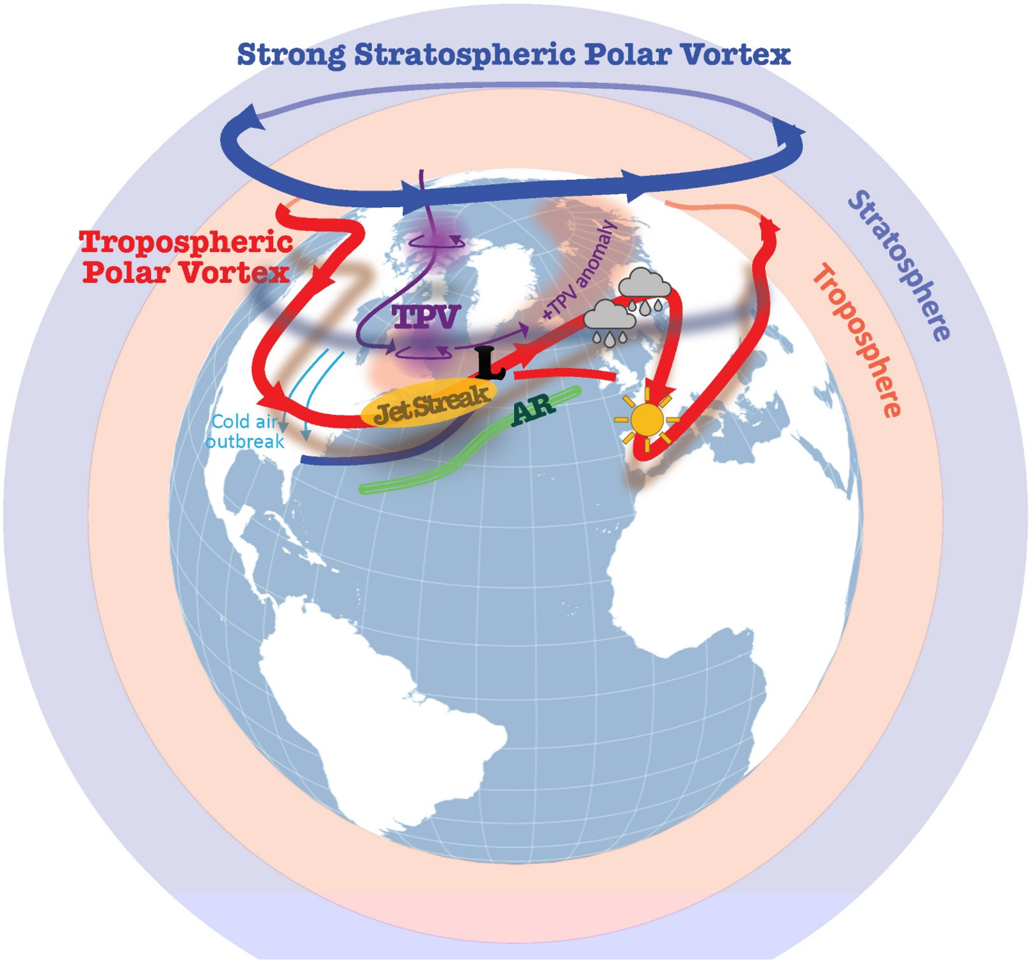
Science Objectives

We will advance the knowledge of:

1. UTLS influences on jet stream dynamics and mesoscale tropopause structure,

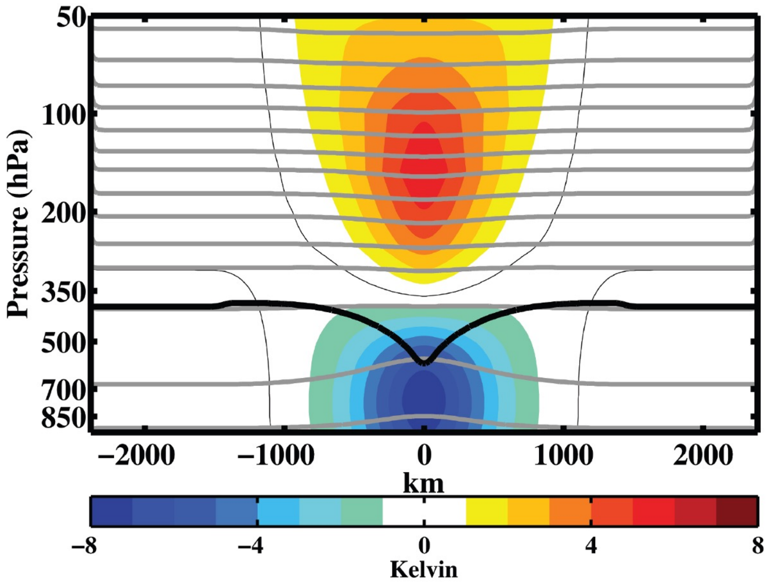
2. the dynamical and physical processes that control TPVs prior to their interaction with the jet stream, and

3. the role of stratospheric variability in modulating the structure of the jet stream.



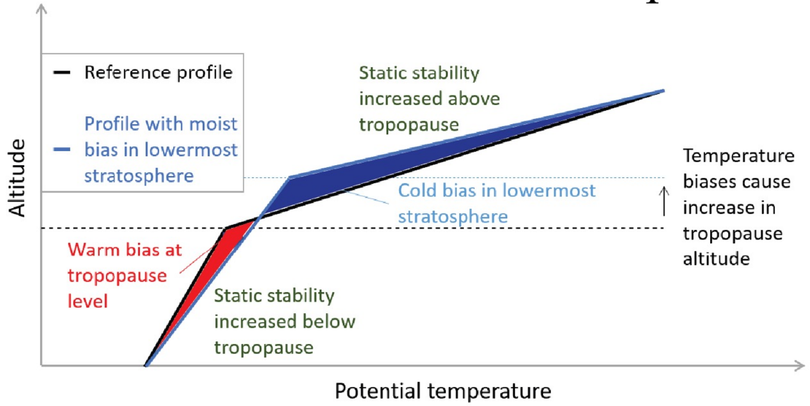
Motivation

Temperature anomalies in a TPV



From Cavallo and Hakim, 2013

Effects of a moist bias on temperature



Adapted from Bland et al., 2021

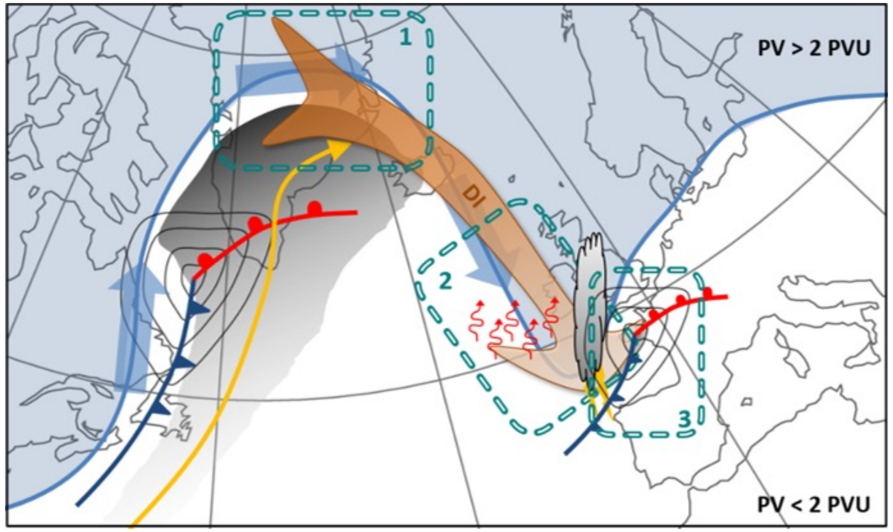
- TPVs are characterized by a cold anomaly in upper-troposphere and warm anomaly in lower stratosphere
- Moisture is systematically too high in operational models and reanalyses (e.g., Bland et al. 2021, Krüger et al. 2022)
- Result is that temperatures are too warm in upper-troposphere and too cold in lower stratosphere
- ***This implies that a cyclonic TPV will be too weak*** (i.e., the warm anomaly will be too cool, and the cold anomaly will be too warm).

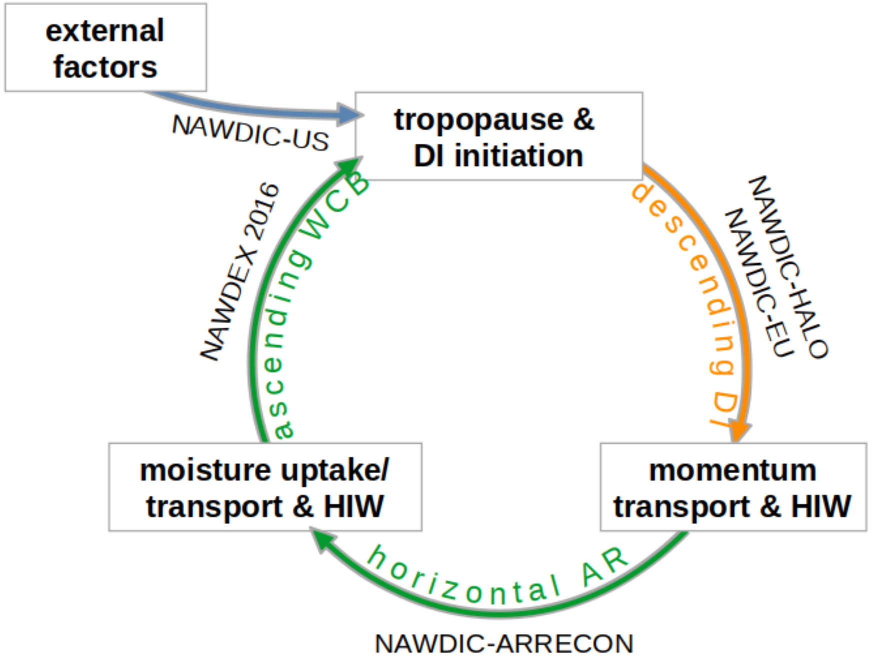
Connection to NAWDIC

- Multi-scale interactions of synoptic-scale weather systems affecting HIW in Europe are organized in the North-Atlantic stormtrack.

- External factors such as incoming Rossby wave activity or TPVs approaching the jet stream as well as moist processes affect this air mass interaction in the North Atlantic.

- We are interested in Atmospheric River (AR) outflow and the impacts on the jet/mesoscale tropopause structure, or manifestations of upstream tropopause gradients on downstream dry intrusions, etc.



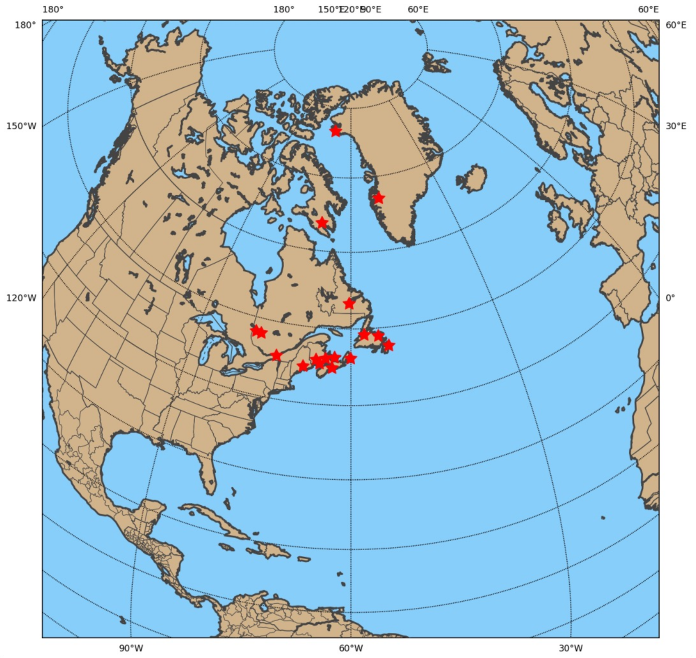


Possible Base of Operations

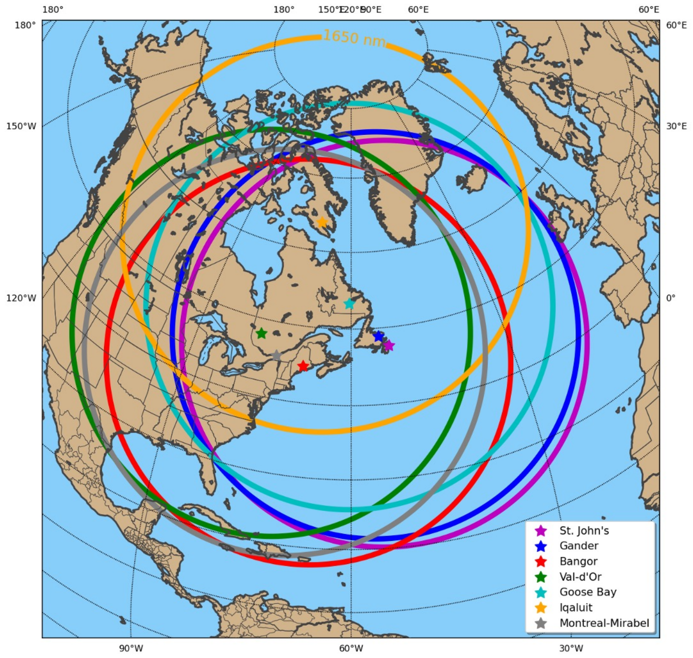
List of Airports Under Consideration

Airport Code	Name	Runway length (feet)	latitude	longitude
YMX	Montreal-Mirabel	12000	45.67	-74.03
KBGR	Bangor	11440	44.81	-68.82
YYR	Goose Bay	11051	53.31	-60.38
YQX	Gander	10200	48.96	-54.61
YQM	Moncton	10000	46.09	-64.78
YVO	Val-d'Or	10000	48.1	-77.8
BGTL	Thule	9997	76.53	-68.7
BGSF	Kangerlussuaq	9219	67.01	-50.71
YFB	Iqaluit	8605	63.75	-68.55
YYT	St. John's	8500	47.62	-52.74
YDF	Deer Lake	8005	49.21	-57.4
YFC	Fredericton	8005	45.87	-66.53
YHZ	Halifax	7700	44.89	-63.52
YUY	Rouyn-Noranda	7500	48.21	-78.83
YSJ	Saint John	7201	45.33	-65.89
YQY	Sydney	7070	46.17	-60.05
YYG	Charlottetown	7000	46.29	-63.13

Locations of Possible Bases



1650 nm Range Rings



Important Considerations for choosing the Base of Operations for NASA/NSF GV:

- Runways must be paved with lengths >= 7000 ft (2133 meters)
- GV aircraft range is 3300 nautical miles (6111 km)
- Instruments can operate down to -73°C
- Weather at bases: Shouldn't be too windy, stormy, frequent low visibility, or high-volume airport traffic

Possible Instrumentation

Example GV payload from HIPPO

HIAPER Airborne Instrumentation Solicitation (HAIS):
- HIAPER Airborne Radiation Package (HARP)
- Vertical Cavity Surface Emitting Laser Hygrometer (VCSEL)
- Microwave Temperature Profiler (MTP)
- Fast Ozone

EOL GV instrumentation:

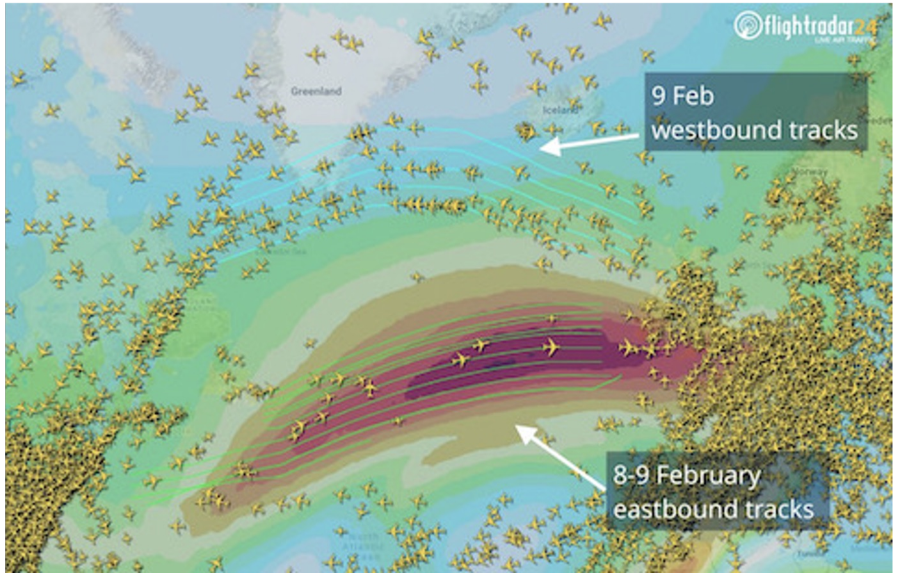
- AVAPS dropsondes
- HCR (Cloud radar), HSRL (Lidar)
- Fast ambient temperature, pyranometers and pyrgeometers, Infrared Radiation Pyrometer (KT-19)
- Radome Gust Probe 3D-wind system, Wind Gust pod
- Downward/side/forward pointing cameras
- Special instrument: Microwave Temperature and Humidity Profiler (MTHP) (Boon Lim, JPL)
- Plus, many other standard instruments

Case: February 2020

- Record breaking trans-Atlantic flight times.
  - British Airways: JFK to Heathrow in 4hr 56 min on 8 Feb (avg = 6hr 13 min)
  - 231 mi (372 km) per hour, the fastest on record at that time since 1957.
  - Los Angeles to London flight ground speed of 801 mi

Above: *Tracks of Storm Ciara/Sabine (03 – 16 Feb. 2020)*

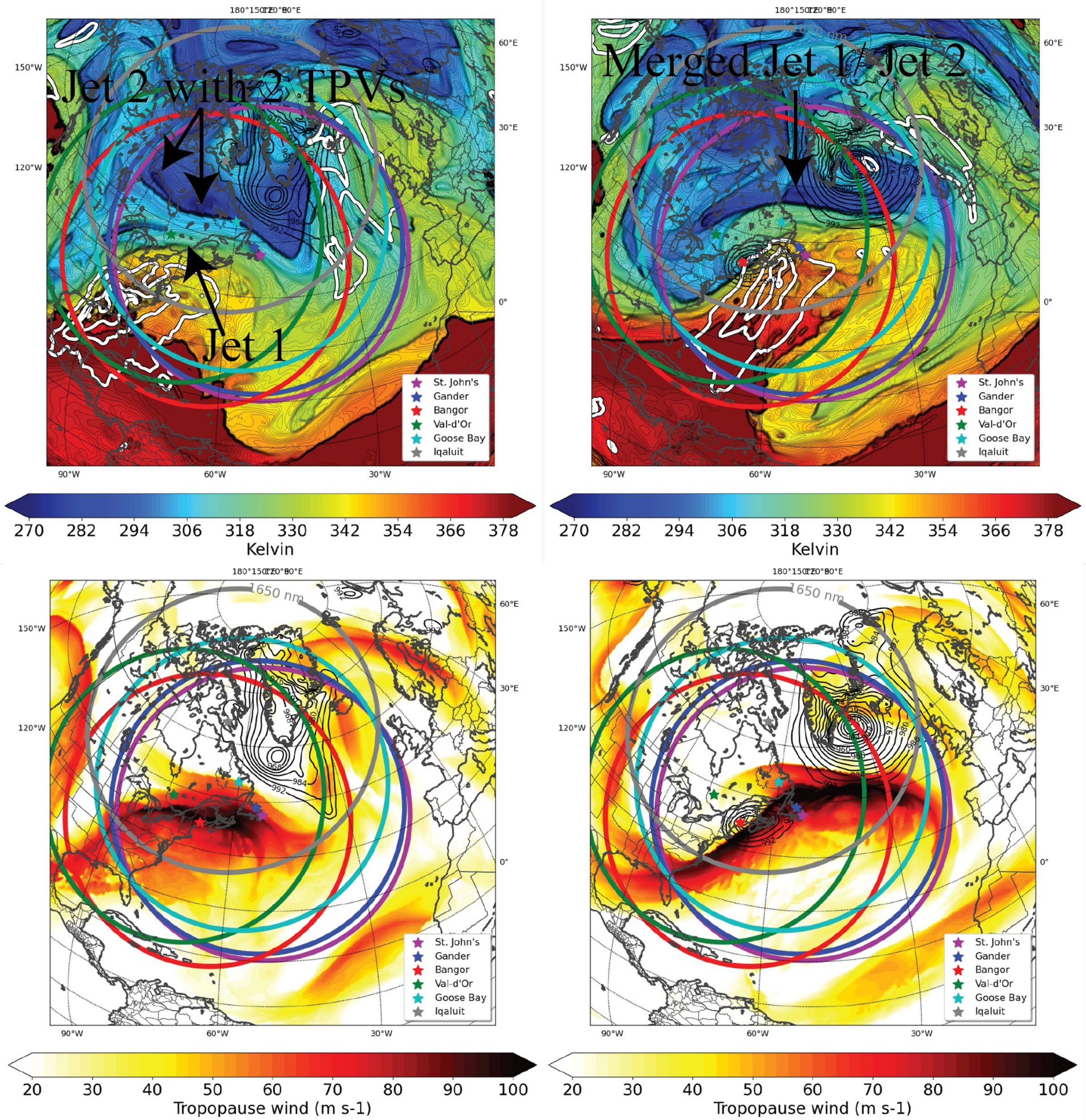
- A stratospheric wave reflection event & downward stratosphere-troposphere coupling (first 10 days of February).
- TPVs exiting the Arctic, interacting with the jet.
- Active WCBs, diabatic outflow, jet interactions.
- Two high-impact European windstorms, one with near-record low SLP (920 hPa).
- "Drop-out" in Northern Hemisphere forecast skill ~07 February.



Above: *Snapshot of flights with jet stream wind speeds.*

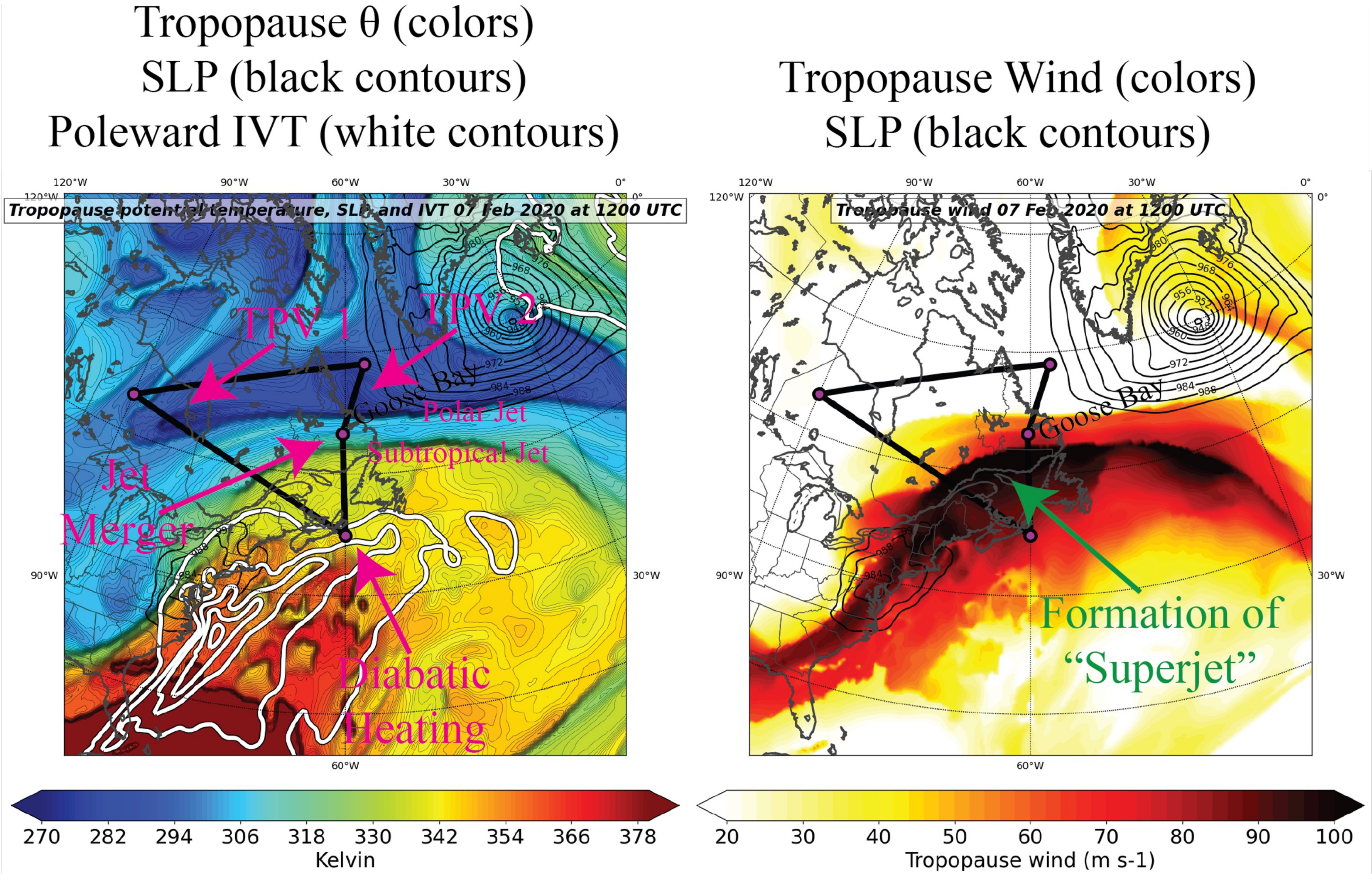
Case: February 2020

12 UTC 06 February **00 UTC 08 February**



- Polar/Subtropical Jet Superposition
  - ➢ Diabatic heating (Poleward IVT shown with thick white contours) in Eastern US and Canadian Maritimes contributes to Jet 1 merging with Jet 2
  - ➢ The Diabatic heating was associated with Storm Ciara, located at this time near the northeastern US coast.
- TPV merges with Polar Jet
  - ➢ Strongest jet stream winds occur when a TPV merges into the Polar Jet (which was after the Superposition event described above)
- Storm Ciara:
  - ➢ Estimated €1.9B ($2.08 Billion / US dollars) in damages from US to Europe.
  - ➢ Max wind 136 mph (219 km/hr) at Cape Corse, Corsica, France
  - ➢ 17 fatalities and over 1.185M power outages

Flight Tracks (12 UTC 07 Feb. 2020)

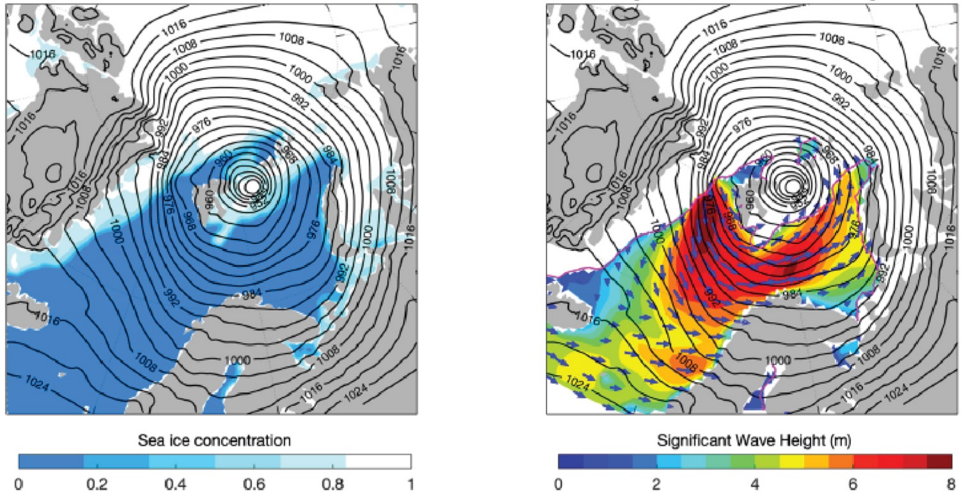


Base: Goose Bay Total flight path: 6064 km (3275 nm)

Case: January 2022

13 UTC 24 January 2022

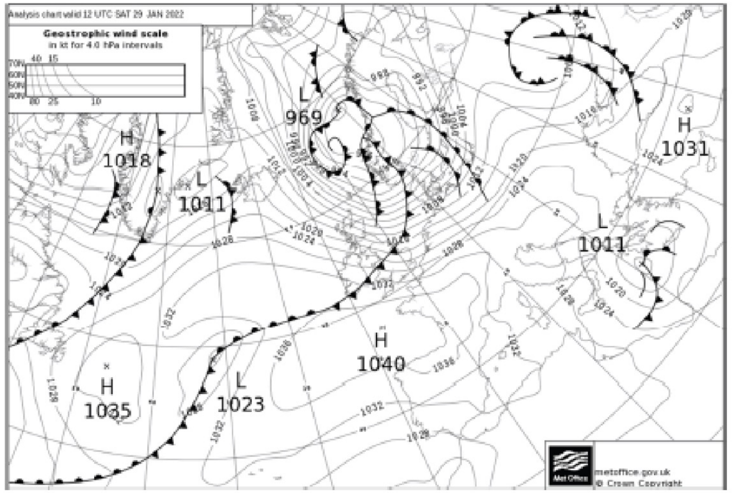
Sea ice concentration | Significant wave height



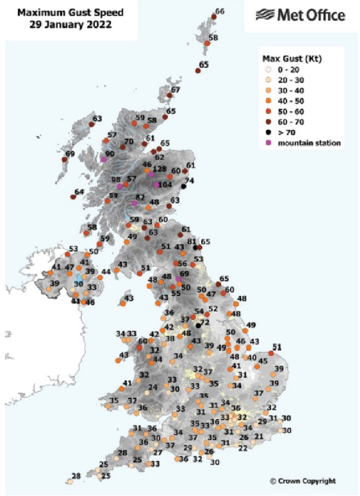
Adapted from Blanchard-Wrigglesworth et al. (2022)

Malik (29 January 2022)

Surface Analysis



Maximum Wind Gusts



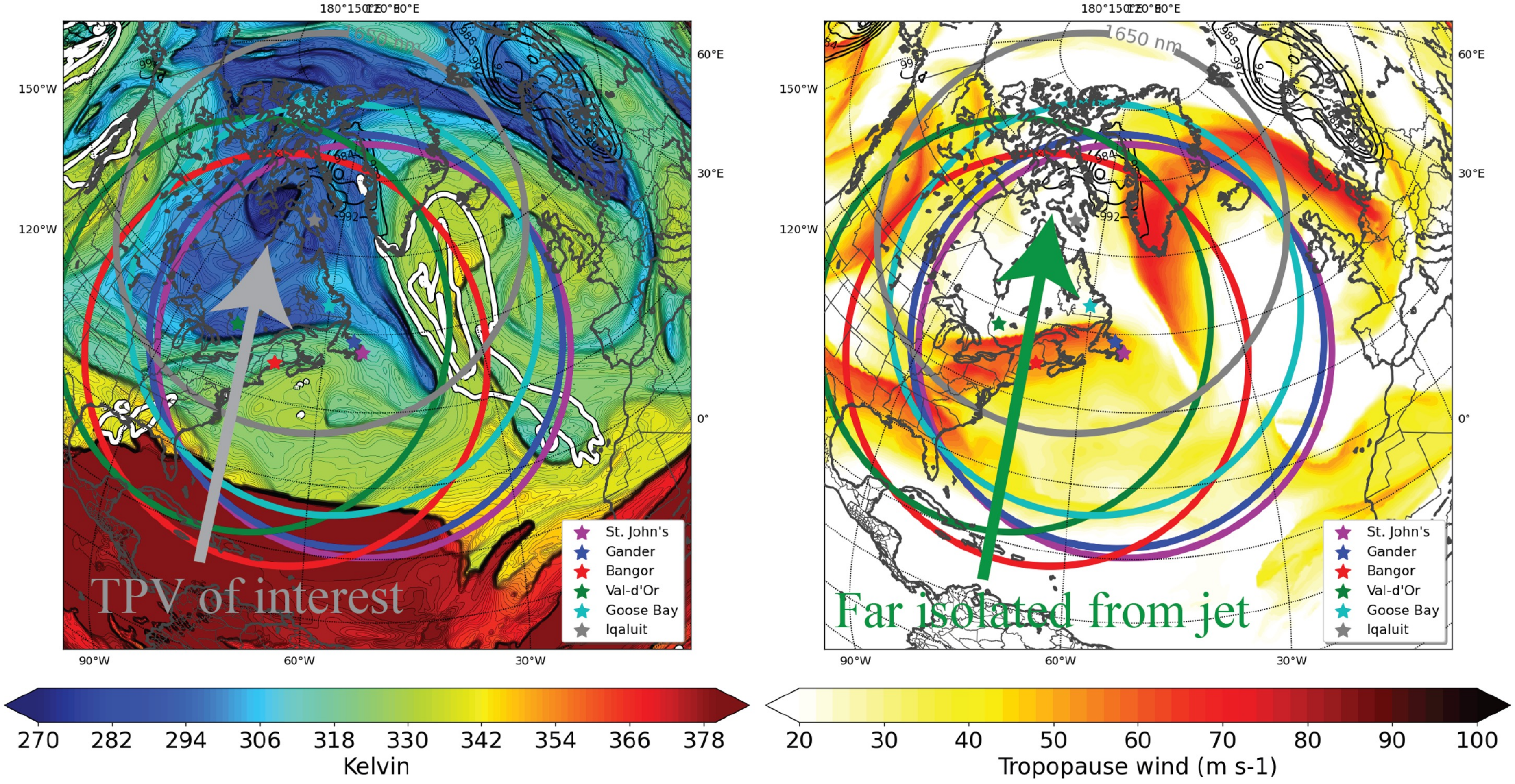
Images are from MetOffice UK Press Release

- Strongest Arctic Cyclone on record occurred January 2022 (932 hPa)
  - ➢ Record wind speeds and significant sea ice loss (despite this being January!)
  - ➢ Temperatures were not warm enough to melt the sea ice in a short amount of time
  - ➢ Satellite observations show waves traveling into the ice pack, which may have contributed to its fast breakup
- Storms Malik and Corrie
  - ➢ Malik brought widespread wind gusts of over 60 kt and was one of the ten most significant winter storms to affect the UK since the storm naming system was introduced for the 2015/2016 season.
  - ➢ Estimated 147 mph max wind speed, 965 hPa minimum pressure.
  - ➢ 7 deaths and ~(€363M/$397M) in damage to the UK

Case: January 2022

06 UTC 20 January 2022

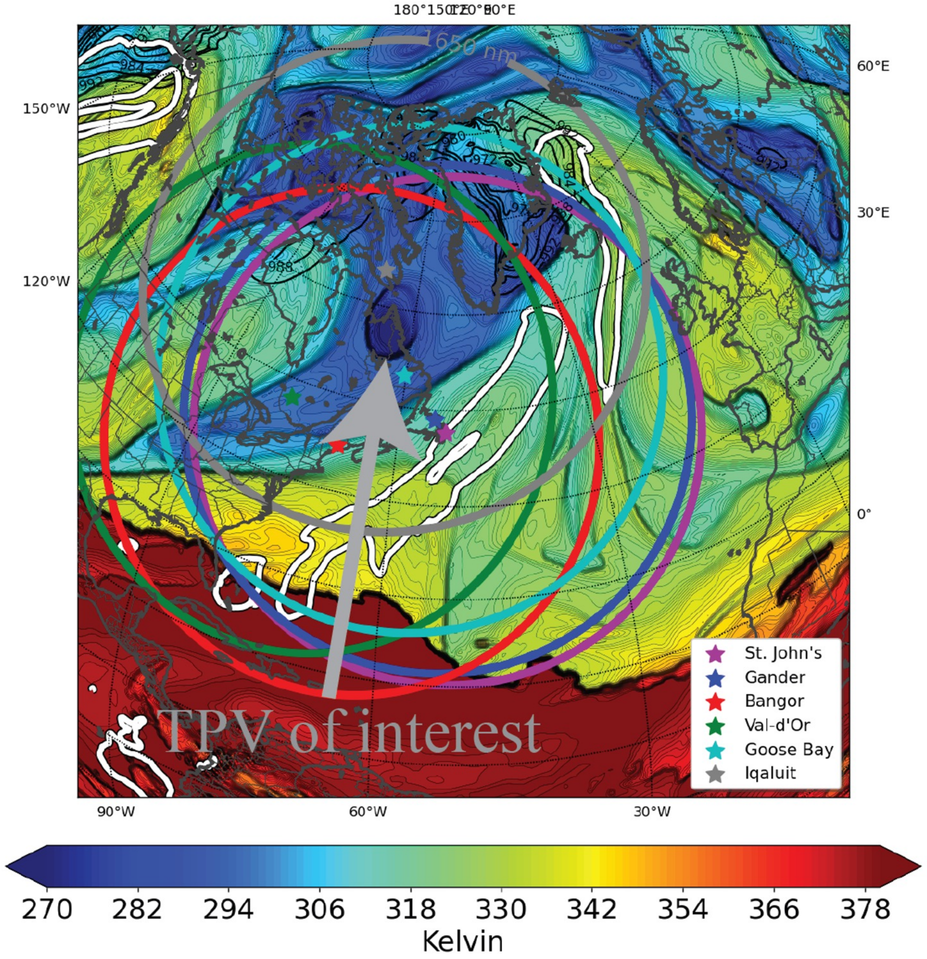
Tropopause θ, SLP   Tropopause Wind, SLP



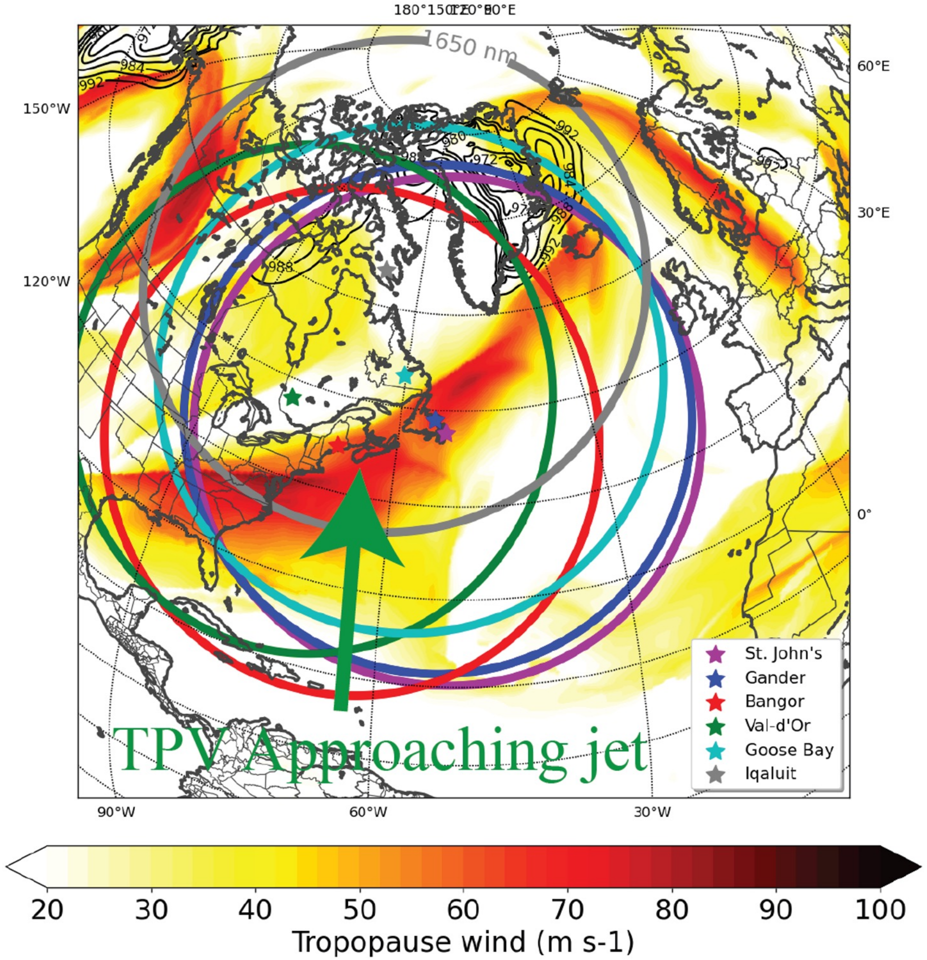
Case: January 2022

12 UTC 21 January 2022

Tropopause θ, SLP



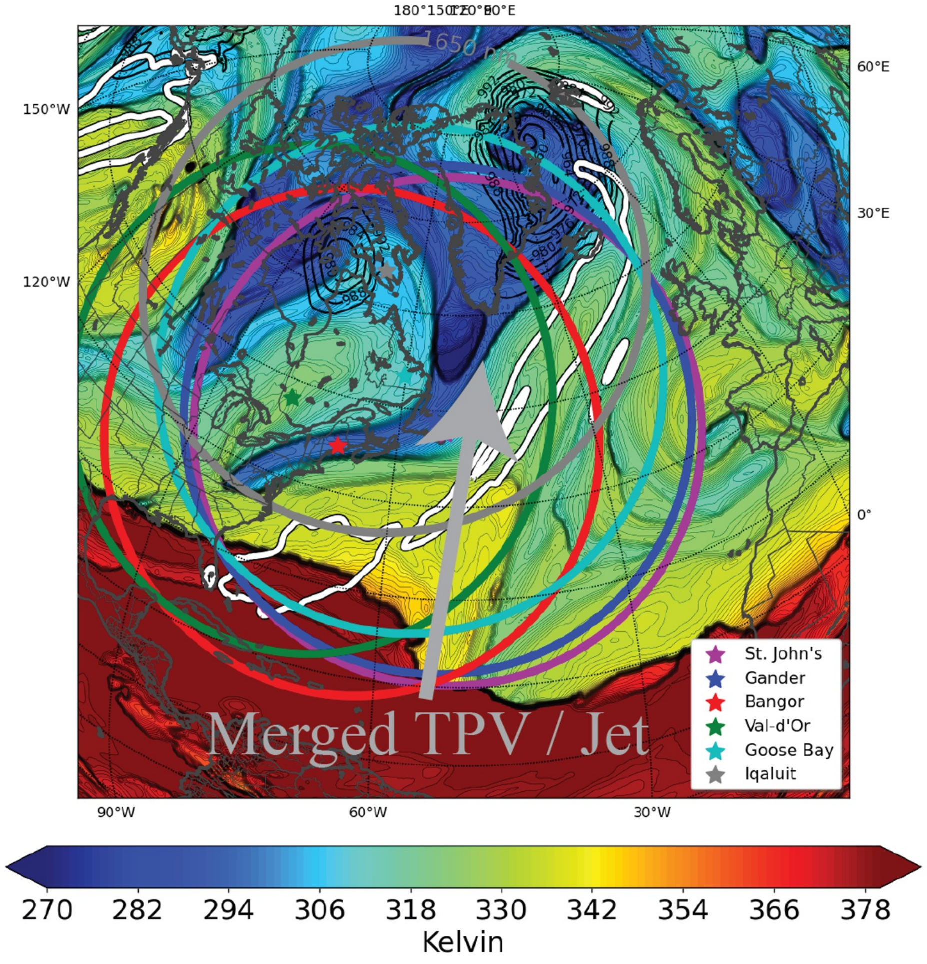
Tropopause Wind, SLP



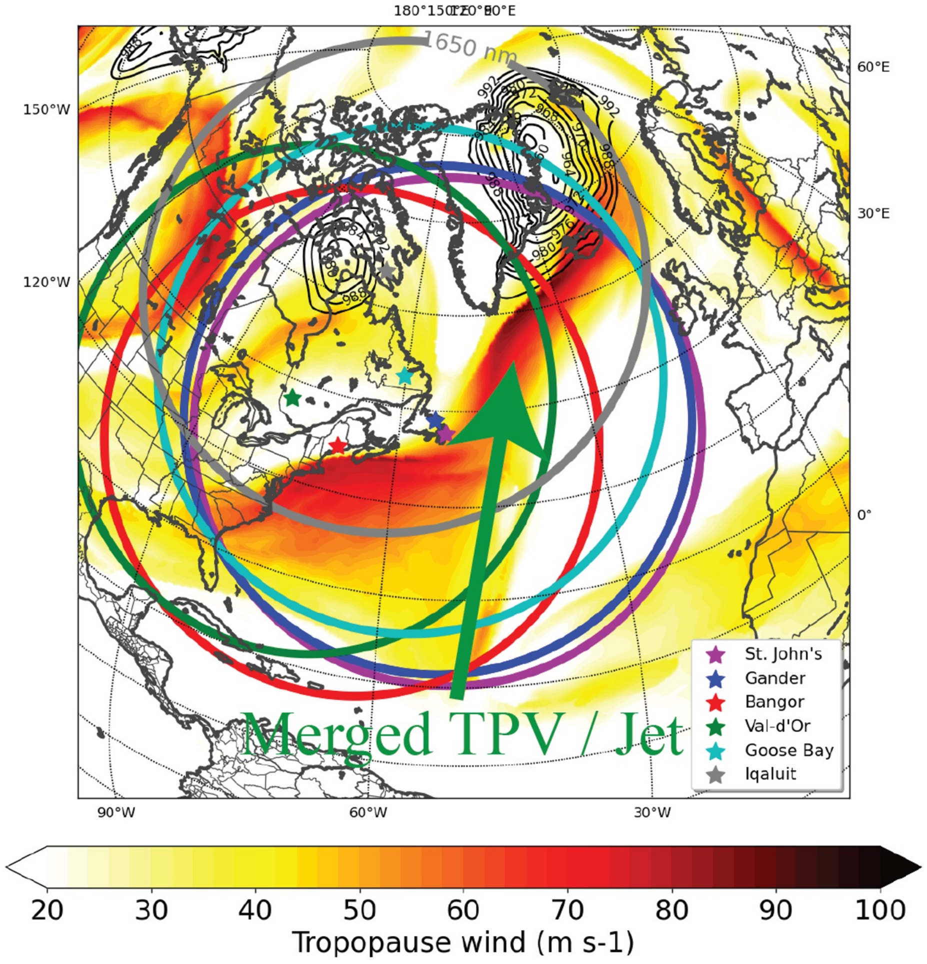
Case: January 2022

06 UTC 22 January 2022

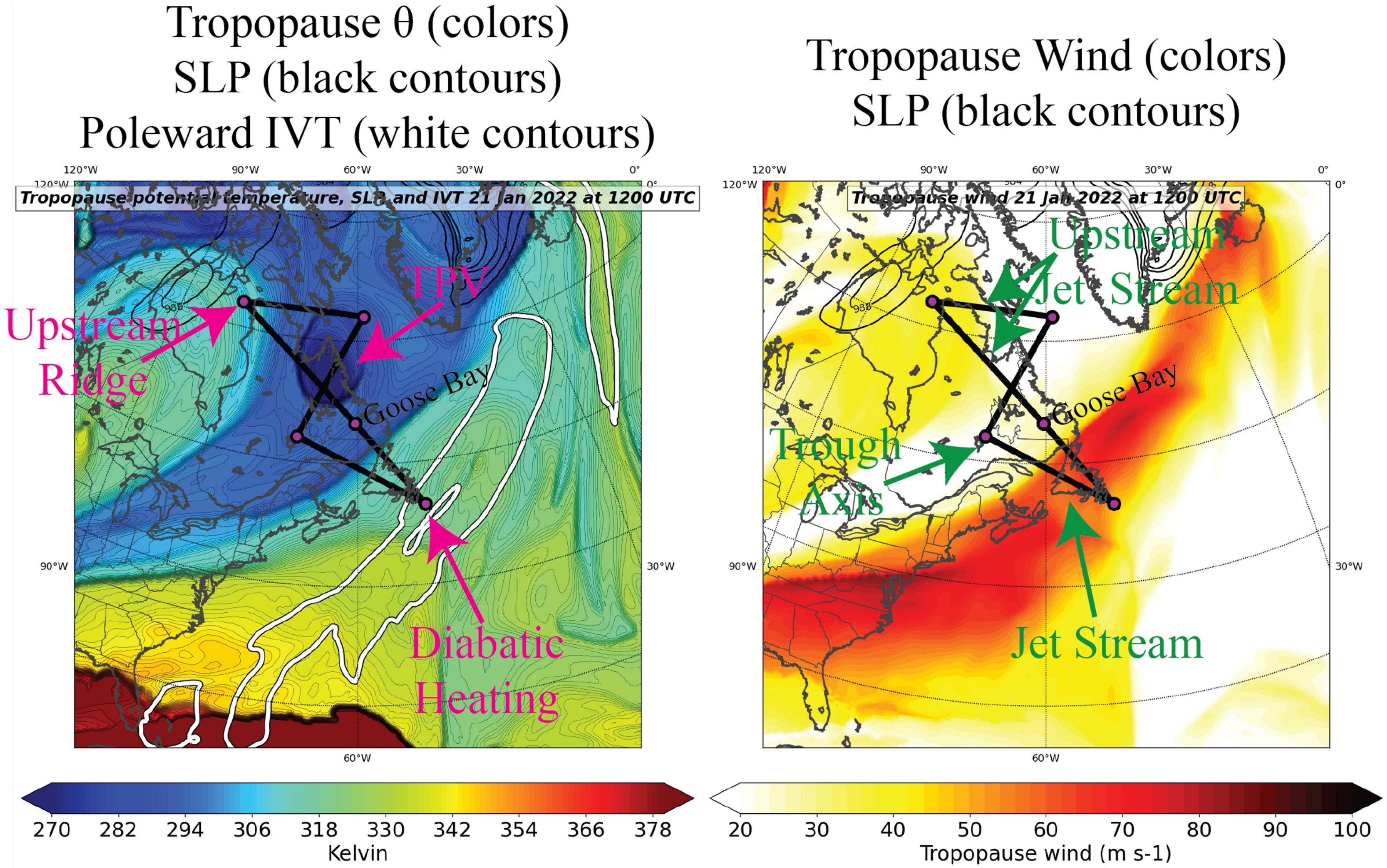
Tropopause θ, SLP



Tropopause Wind, SLP



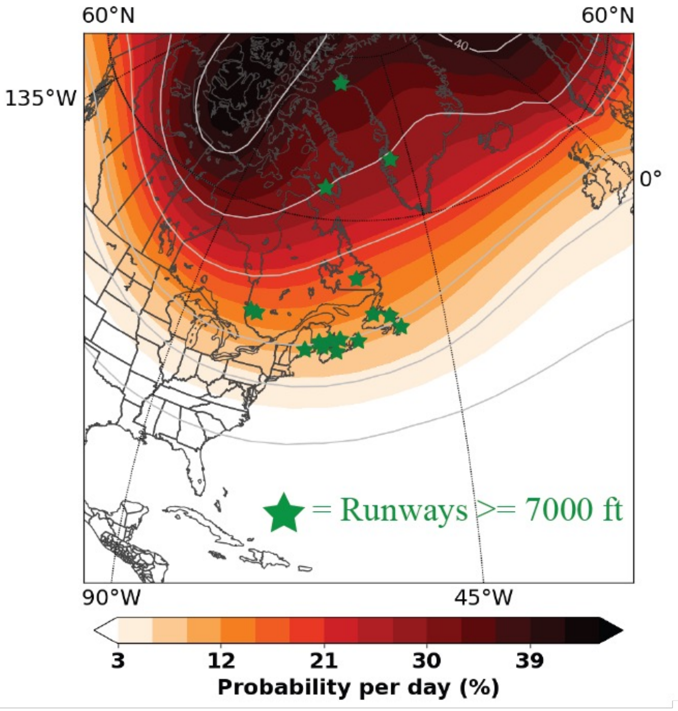
Flight Tracks (12 UTC 21 Jan. 2022)



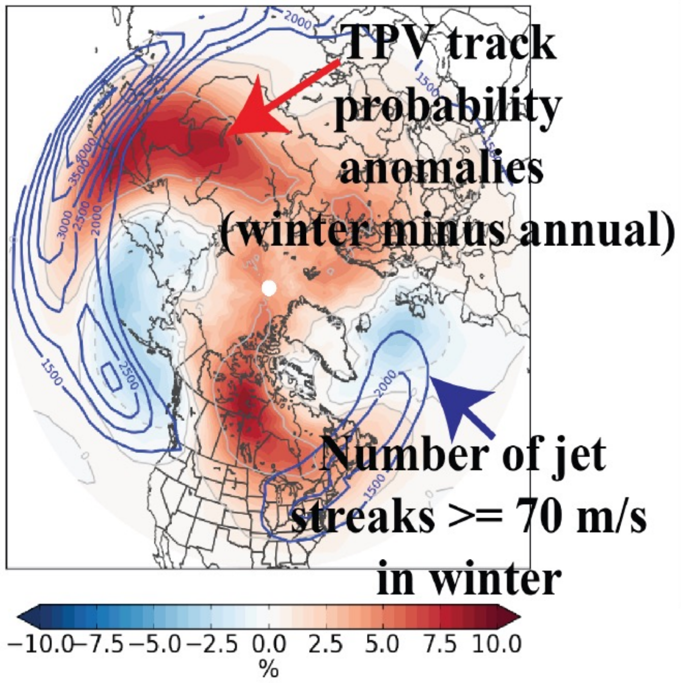
Base: Goose Bay Total flight path: 6106 km (3297 nm)

Climatologies

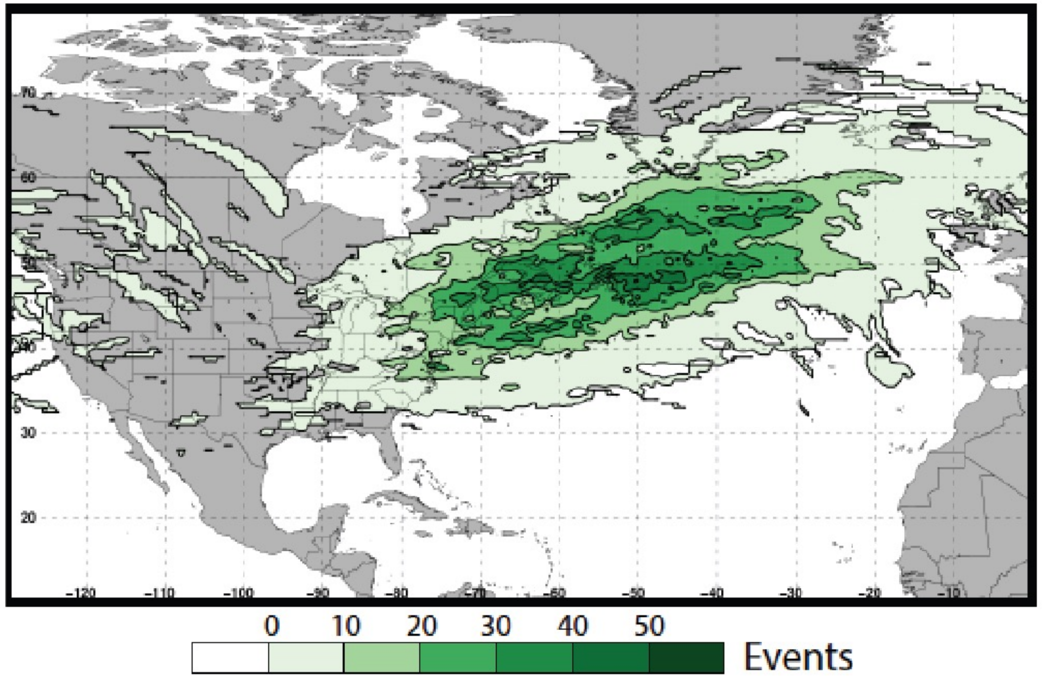
TPV probability/day
Winter (DJF)



TPV probability
difference/day
Winter - Summer



Frequency of 100 m/s jets (N=1672)



- TPVs tend to have a preferential pathway out of the Arctic through Eastern North America.
- The intersection of TPVs with the jet stream is where the most frequent occurrence of strong streaks occur.

Summary and Future Plans

- We are planning for a large-scale aircraft campaign (GV with NSF and/or 777 with NASA) to observe the mesoscale tropopause structure and surrounding upper-troposphere and lower-stratospheric (UTLS) processes that develop upstream of HIW

- Targets of interest will be
  - ➢ Tropopause polar vortices
  - ➢ Polar and subtropical jet streams, and their occasional superposition
  - ➢ Diabatic heating and initiation/growth of Rossby Waves
- We are considering several bases of operations in eastern North America, mainly in eastern Canada
- We will be next be discussing these plans with NSF and NASA program managers, as well as NCAR to determine the next steps.