High-Impact Weather Events Associated with Interacting Tropical Cyclones over the Western Pacific in August 2016

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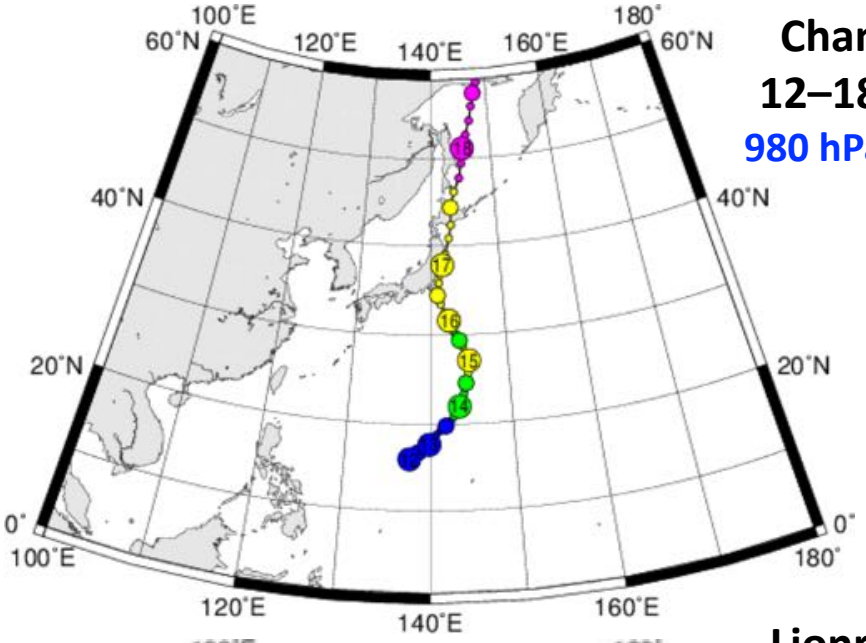
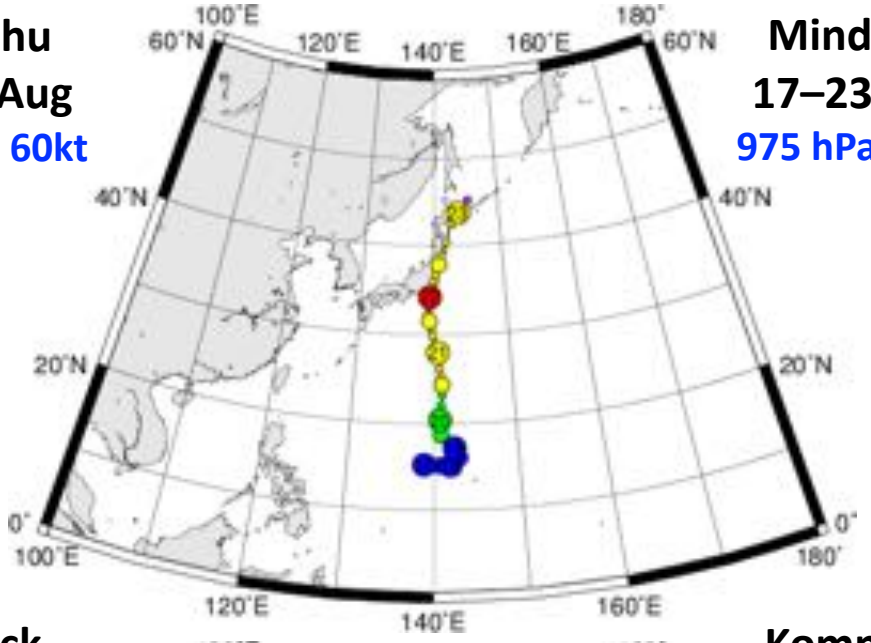
Motivation

A story of binary and trinary tropical cyclone interactions in the Western Pacific in August 2016 and their resulting impacts

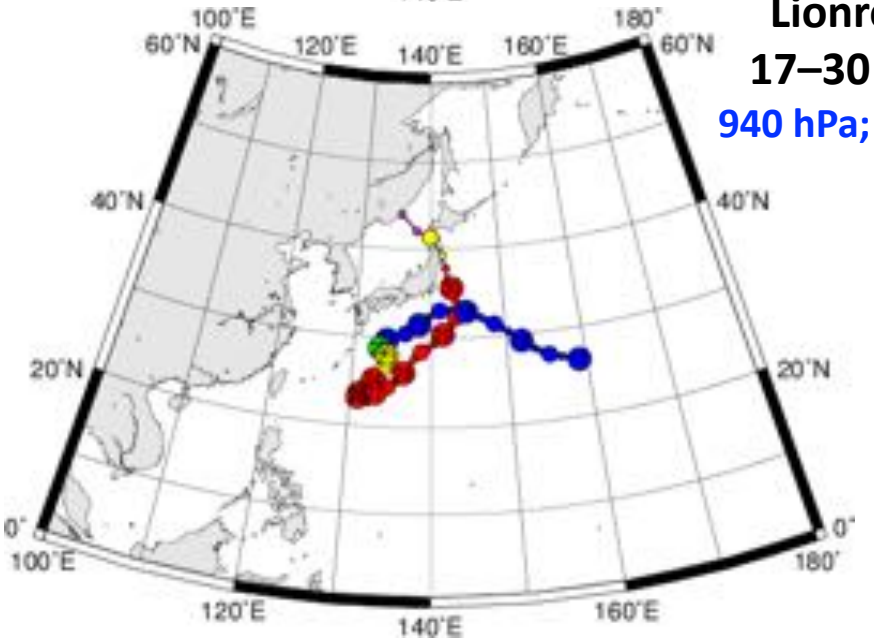
Western Pacific TC Tracks: 15–30 August 2016



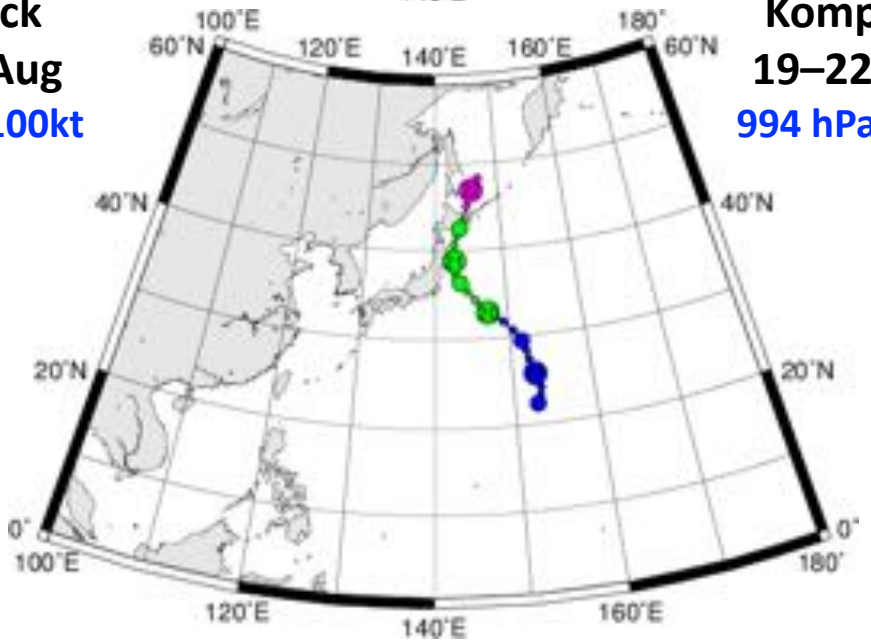
Chanthu
12–18 Aug
980 hPa; 60kt



Mindulle
17–23 Aug
975 hPa; 75kt



Lionrock
17–30 Aug
940 hPa; 100kt



Kompasu
19–22 Aug
994 hPa; 40kt

Impacts

Source: http://www.chicagotribune.com/news/nationworld/ct-japan-typhoon-lionrock-20160831-story.html

- **Catastrophic flooding in Japan, Russia, North and South Korea**
  - **Over 500 deaths (most in North Korea)**
  - **Over 1 billion dollars in damage (USD)**

Source: http://siberiantimes.com/other/others/news/n0721-typhoon-lionrock-hits-russian-pacific-rim-as-eastern-economic-forum-kicks-off/

TC Lionrock's Timeline:
The Motivational Story

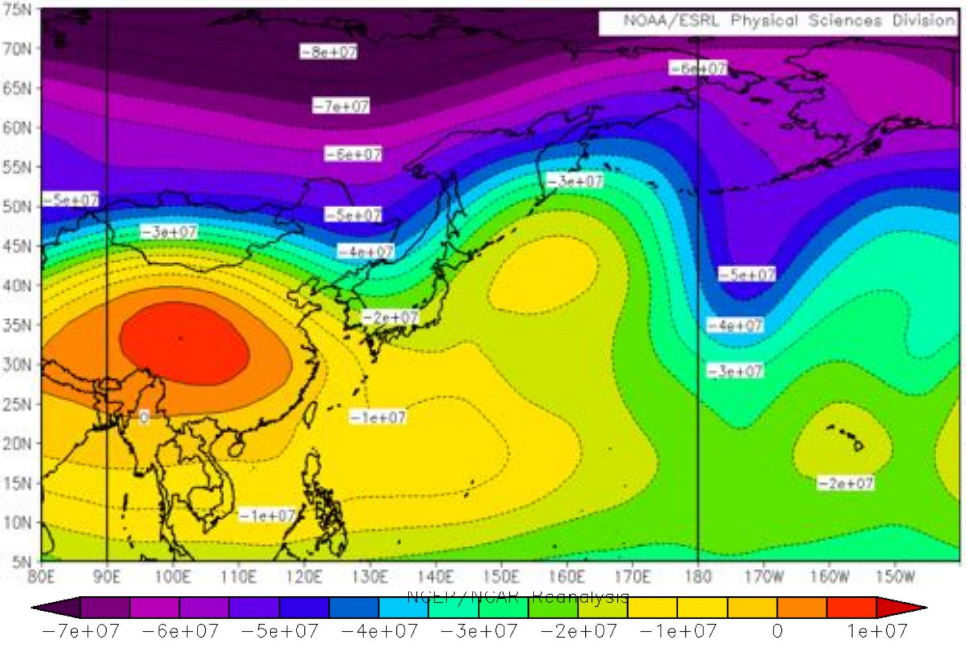
- **Pre-TC Lionrock:**
  - TCs Conson/Chanthu perturb Pacific PV waveguide; PV streamer forms
- **TC Lionrock:**
  - Develops from interaction of a PV streamer with a WPAC monsoon gyre
  - Forms via the tropical transition process in northern part of gyre
  - Moves W/SW and reaches peak intensity east of Taiwan
  - Turns to the NE after "capture" by a digging upper-level trough
  - Triggers a predecessor rainfall event with flooding rains over Japan
  - Undergoes ET, merges with an EC, and produces flooding in East Asia

Datasets

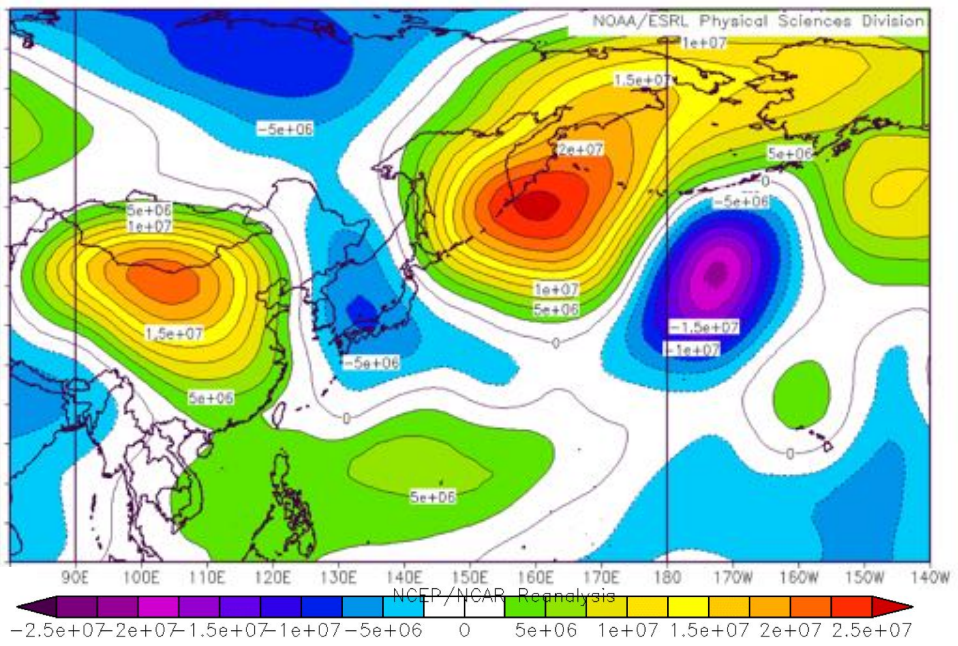
- **ERA-5** (available from 2008–2016; *Hersbach et al. 2017)*
- **GPM-IMERG v3** (Huffman et al. 2017)
- **GridSat-B1 v2** (Knapp et al. 2011)

Mean (Left) and Anomaly (Right) 250-hPa Streamfunction 15–31 Aug 2016

250-hPa streamfunction 15–31 Aug 2016



250-hPa streamfunction anomaly 15–31 Aug 2016



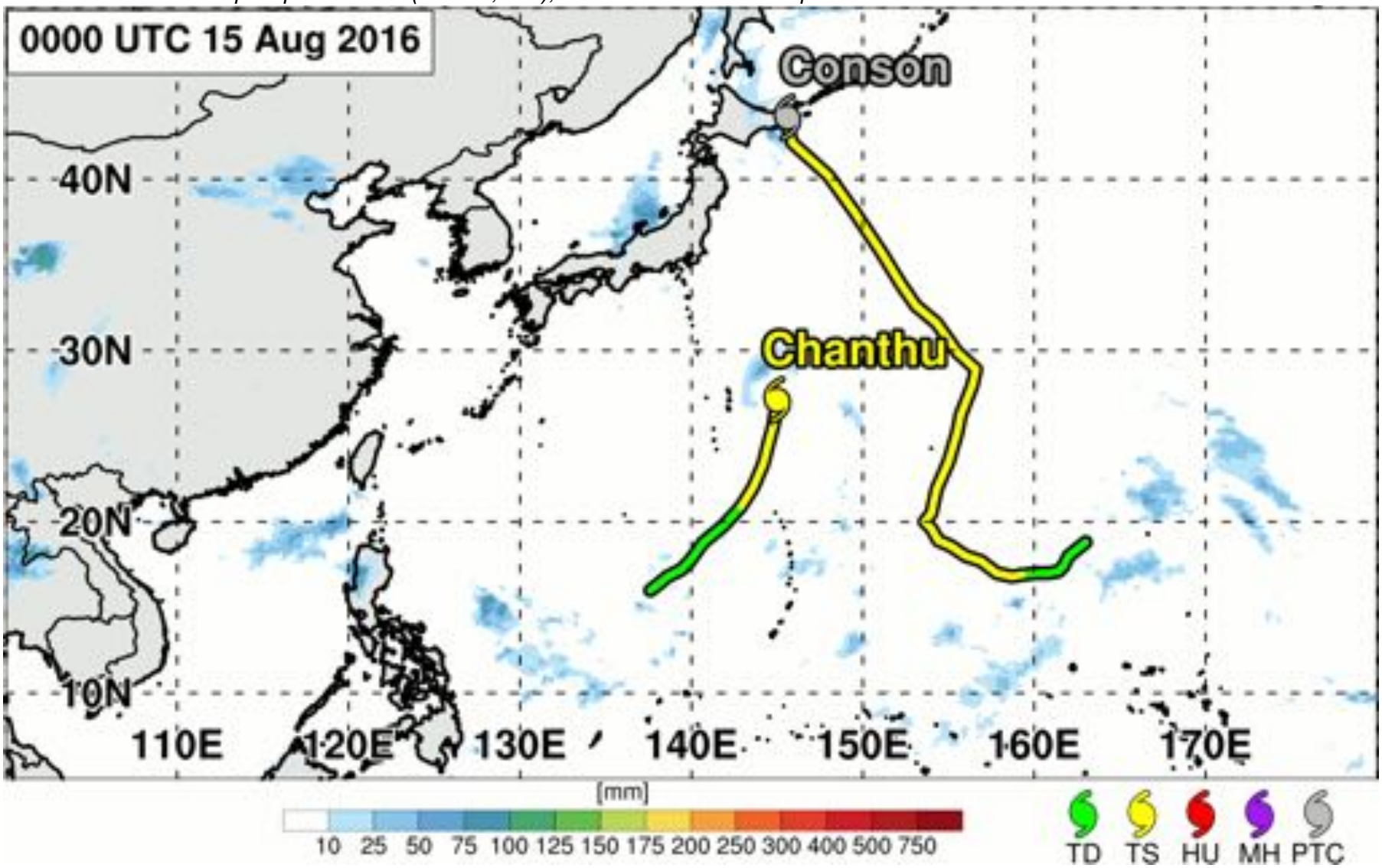
Source: NOAA/ESRL PSD Map Room

Loops

Lionrock and “TC Friends”

Loops: Lionrock and “TC Friends”

GPM IMERG summed precipitation total (shaded, mm), TC tracks annotated on plot



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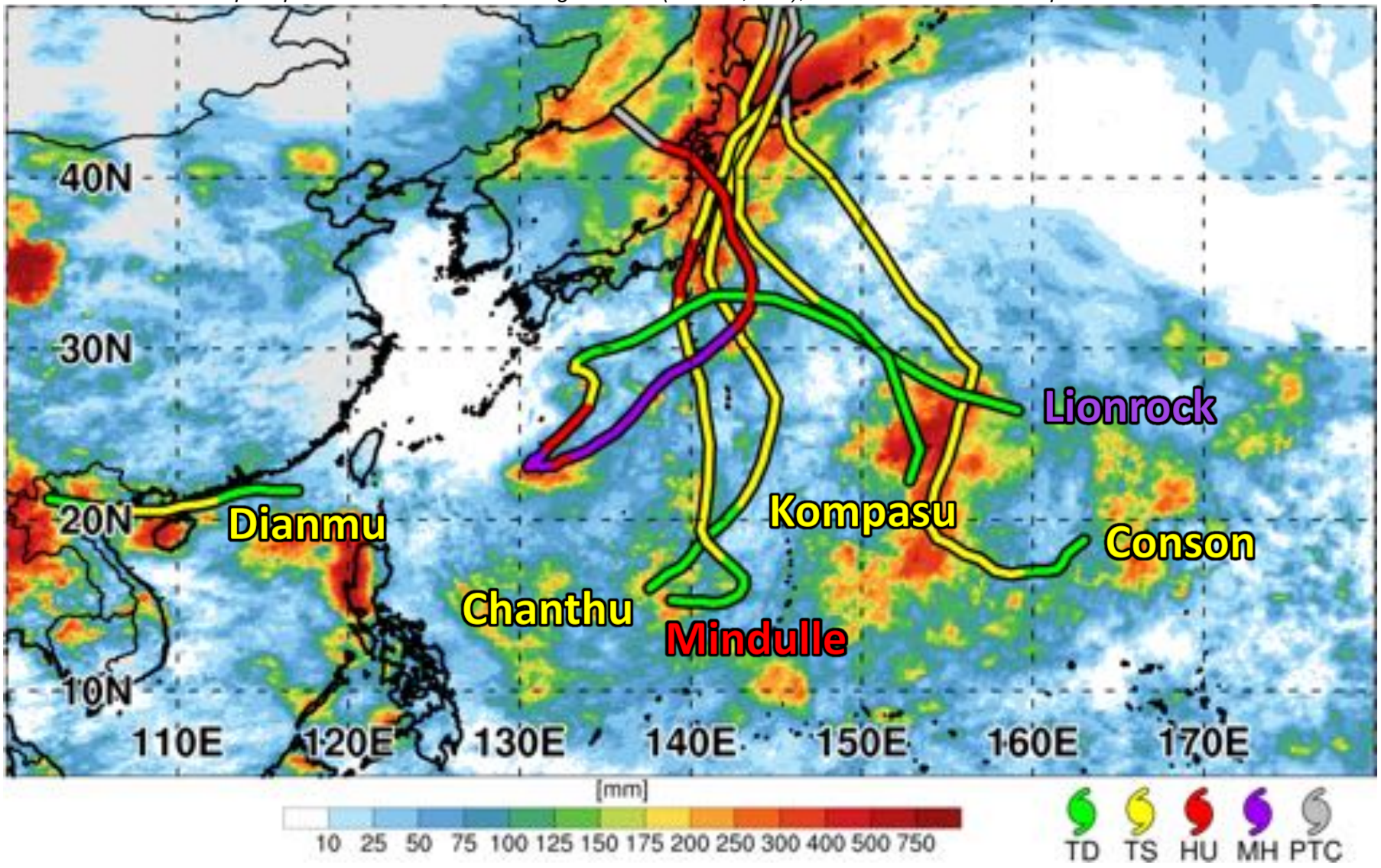

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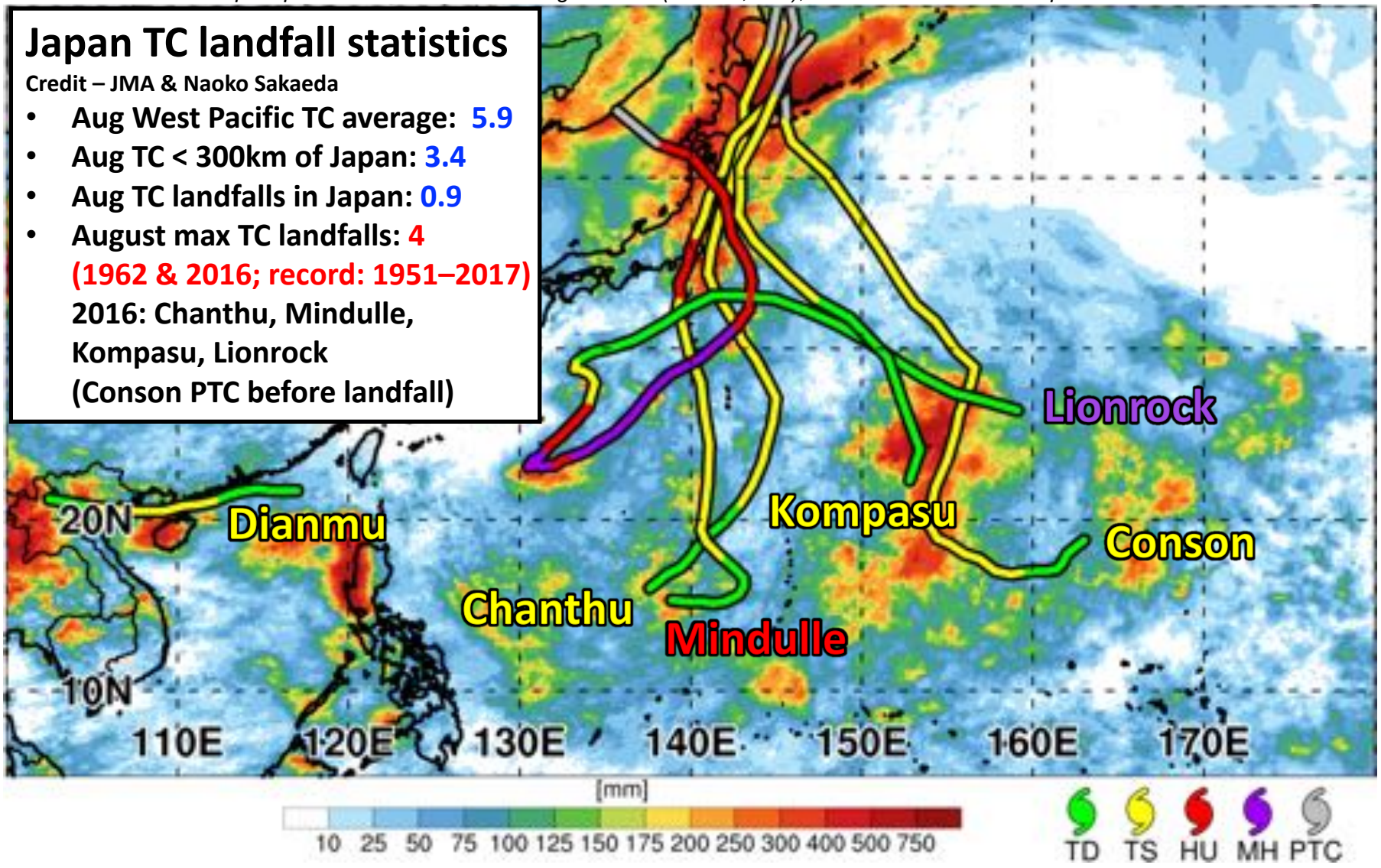
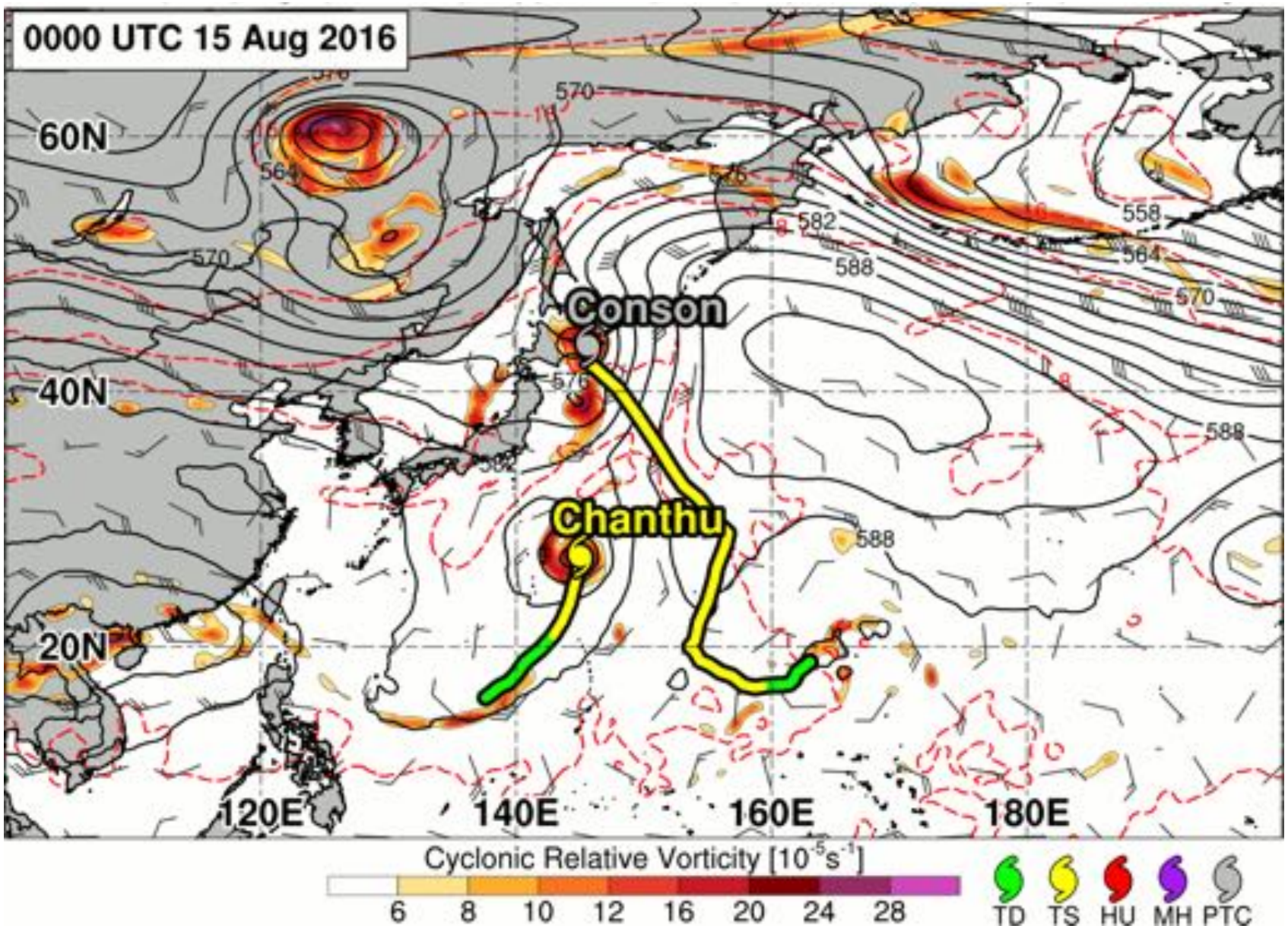


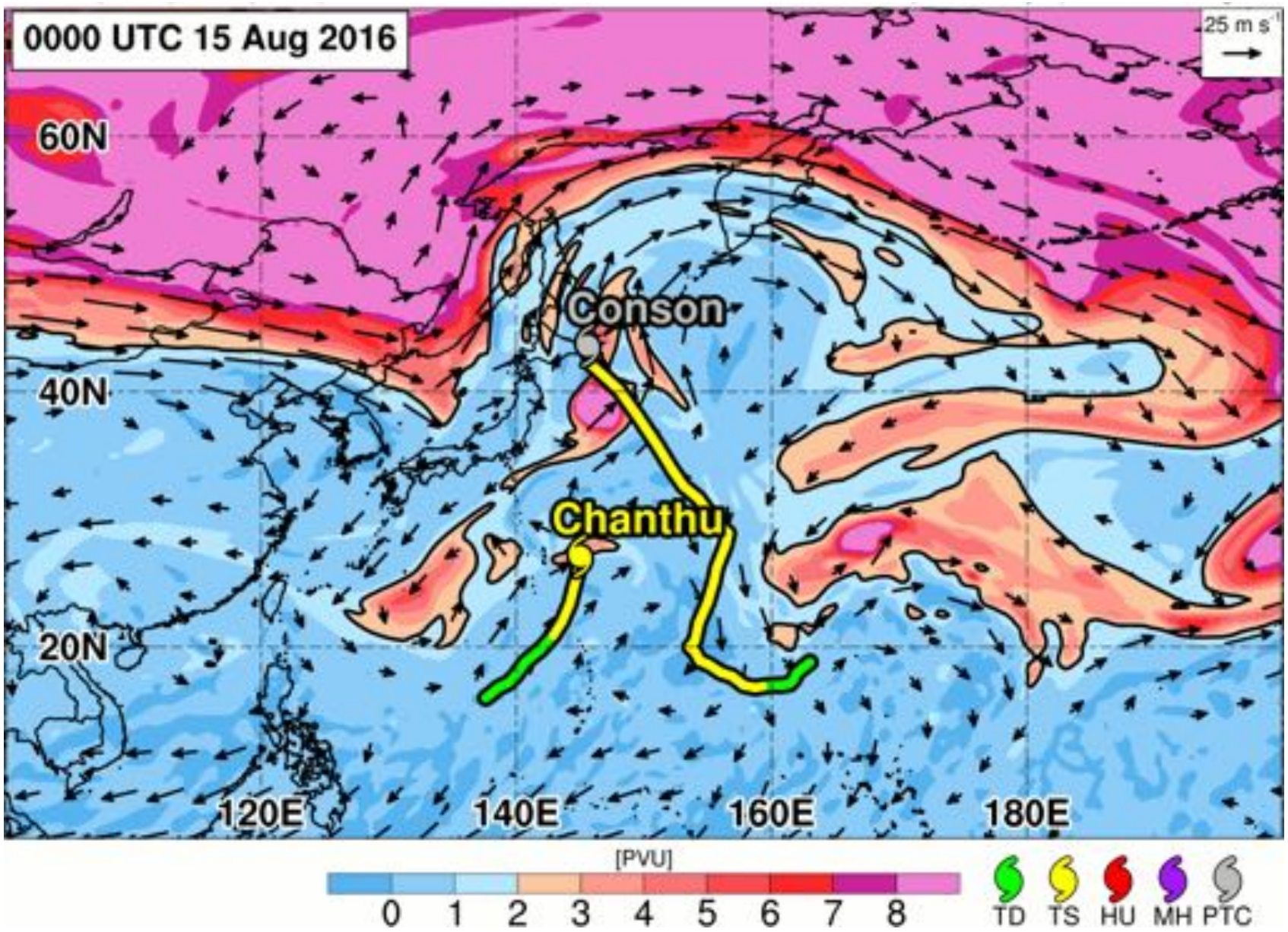
Loops: Lionrock and “TC Friends”

500-hPa cyclonic vorticity (shaded, > 6 × 10^{-5} s^{-1}), geopotential height (black contours, every 3 dam), temperature (red dashed lines, every 4°C), winds (barbs, kt), TC tracks annotated on plot



Loops: Lionrock and “TC Friends”

350-K potential vorticity (shaded, PVU), winds (vectors, m s^{-1}), TC tracks annotated on plot

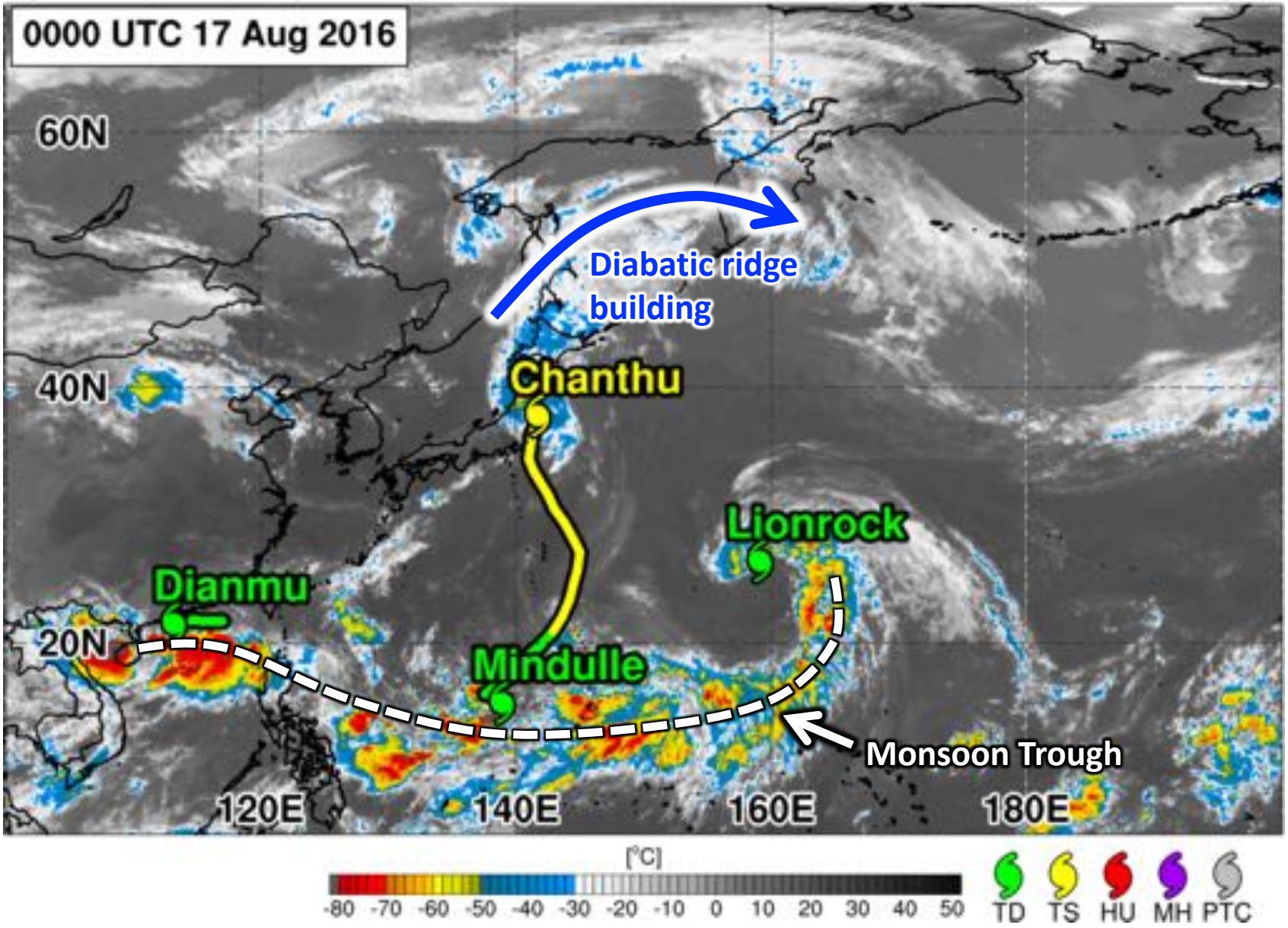


Stills

Summary of TC Lionrock Timeline

Tropical Transition of TC Lionrock

GridSat brightness temperature (shaded, ˚C), TC tracks annotated on plot



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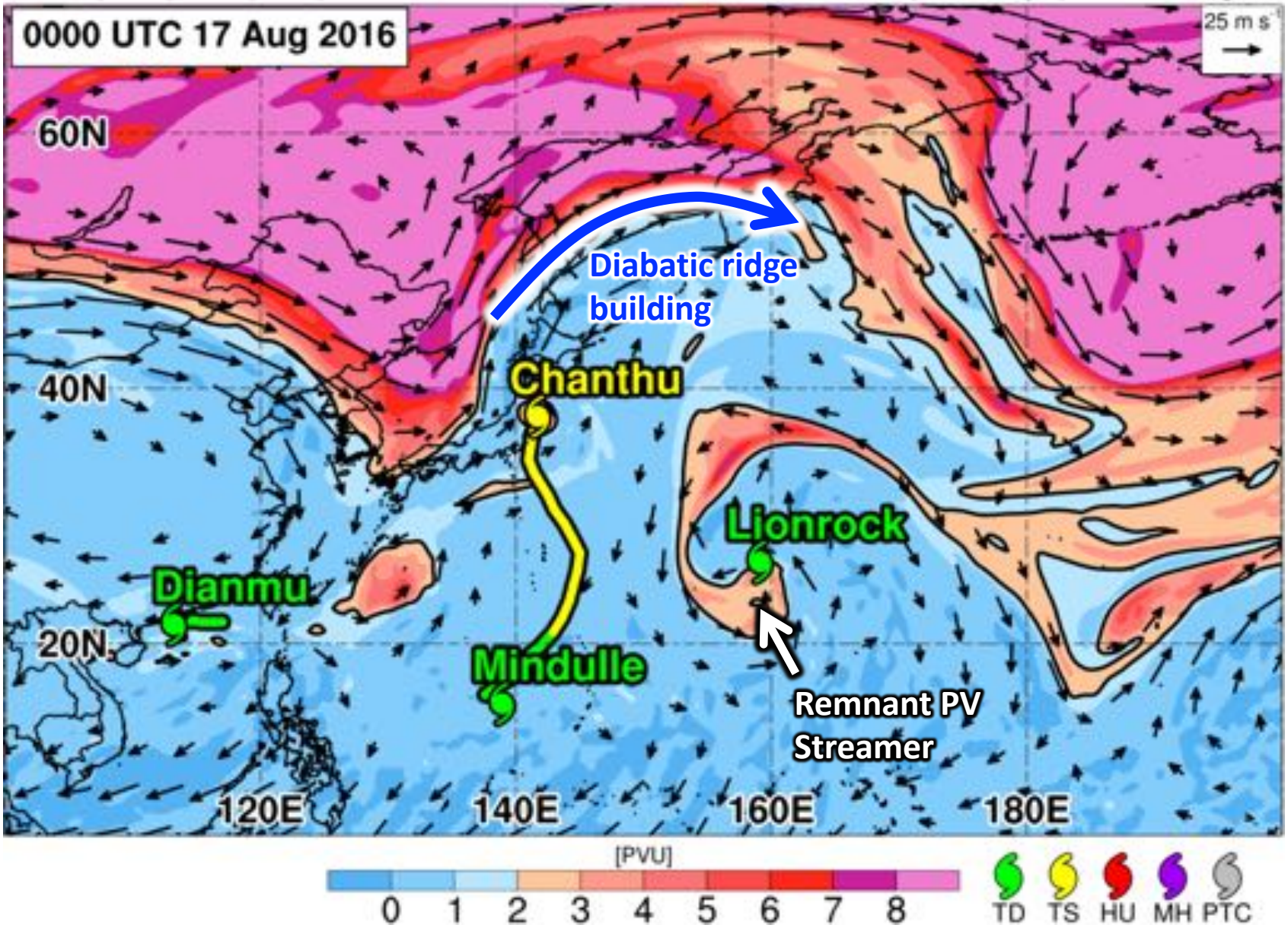
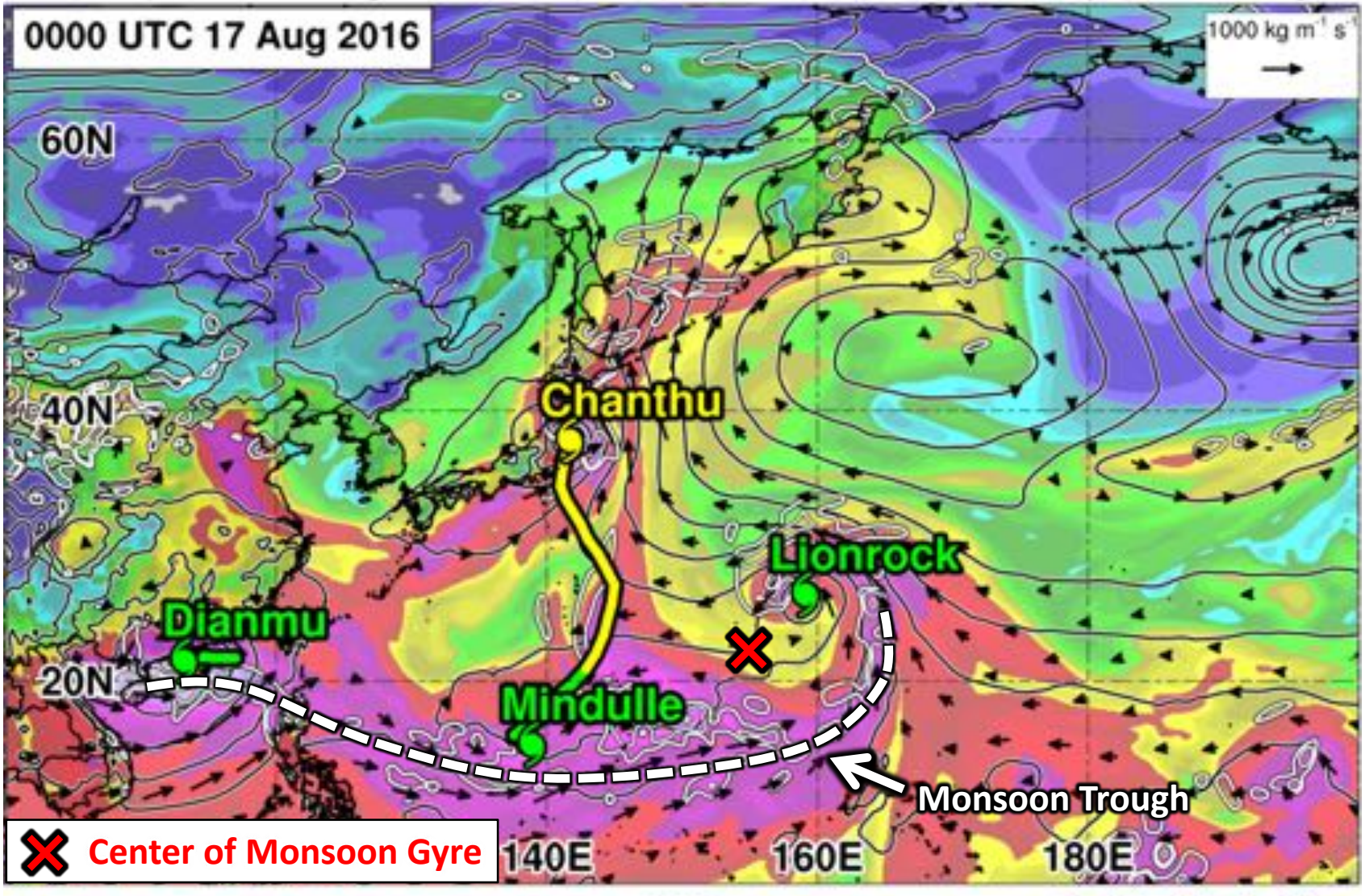


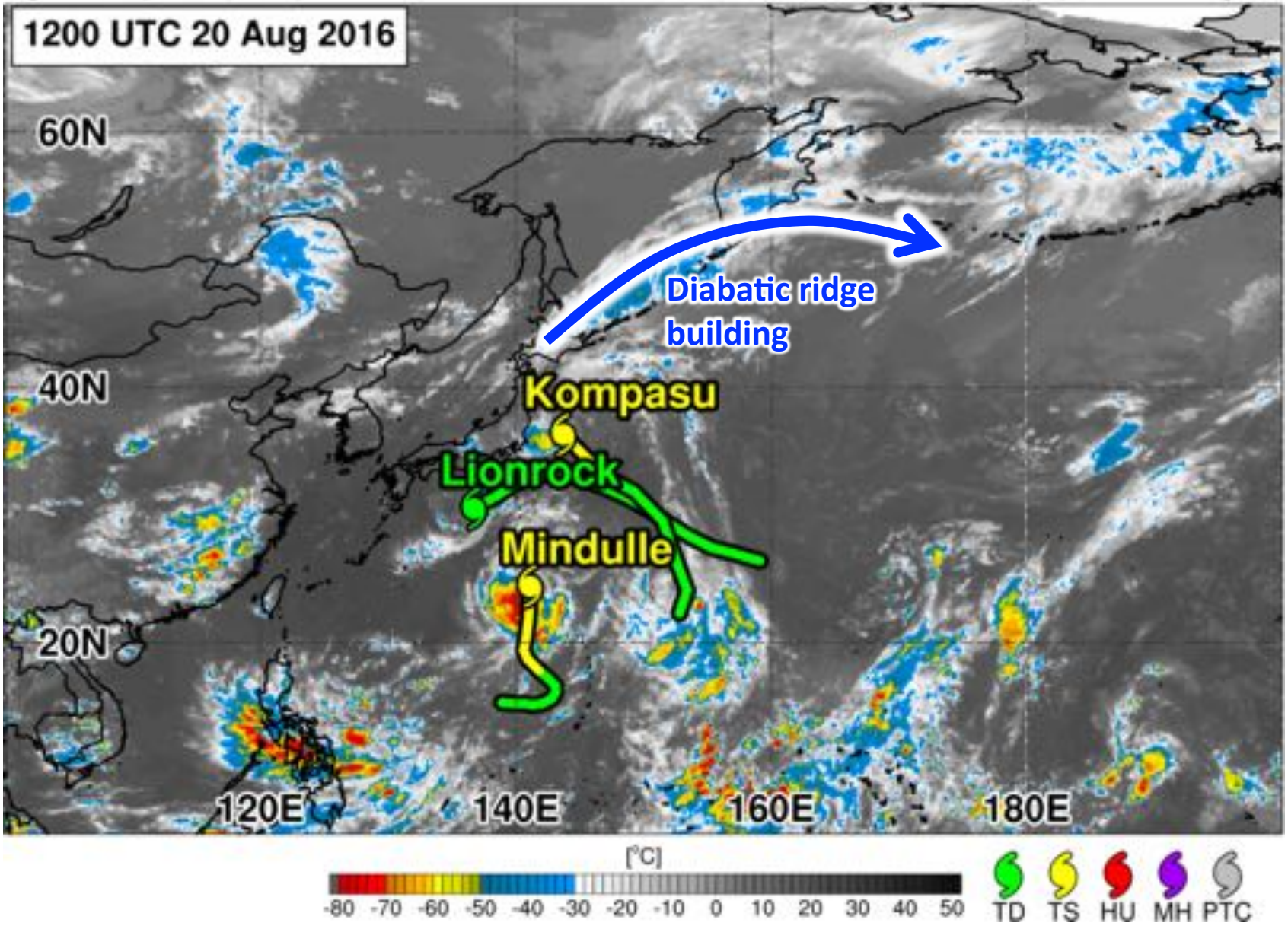
Tropical Transition of TC Lionrock

Precipitable water (shaded, > 1 × 10^{-5} s^{-1}), 1000–300-hPa integrated vapor transport (vectors, > 250 kg m^{-1} s^{-1}), integrated moisture flux convergence (white contours, > 50 kg m^{-2} s^{-1}), sea level pressure (black contours, every 4 hPa)



TC Lionrock's trinary interaction with TCs Mindulle and Kompasu

GridSat brightness temperature (shaded, °C), TC tracks annotated on plot



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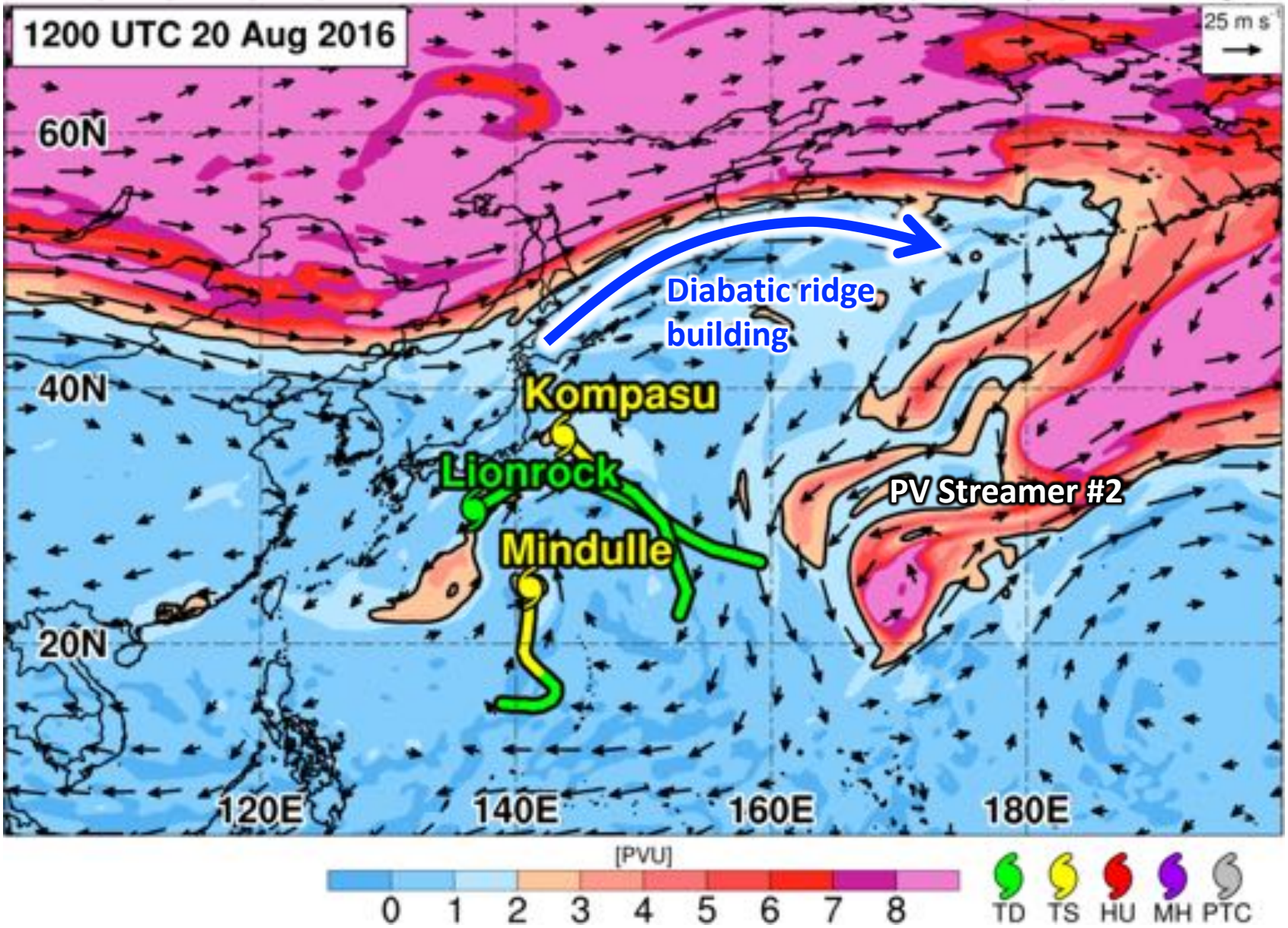

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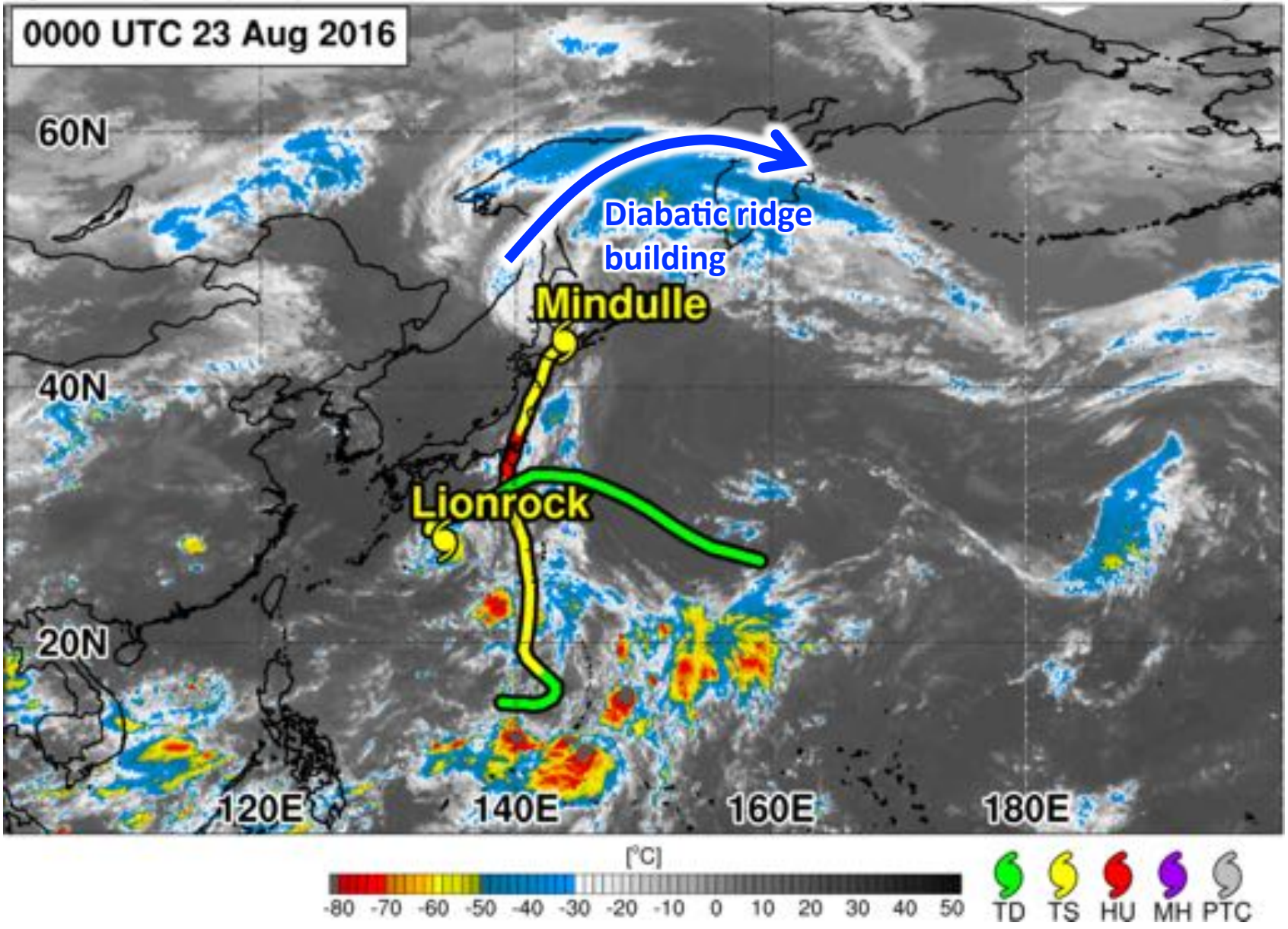

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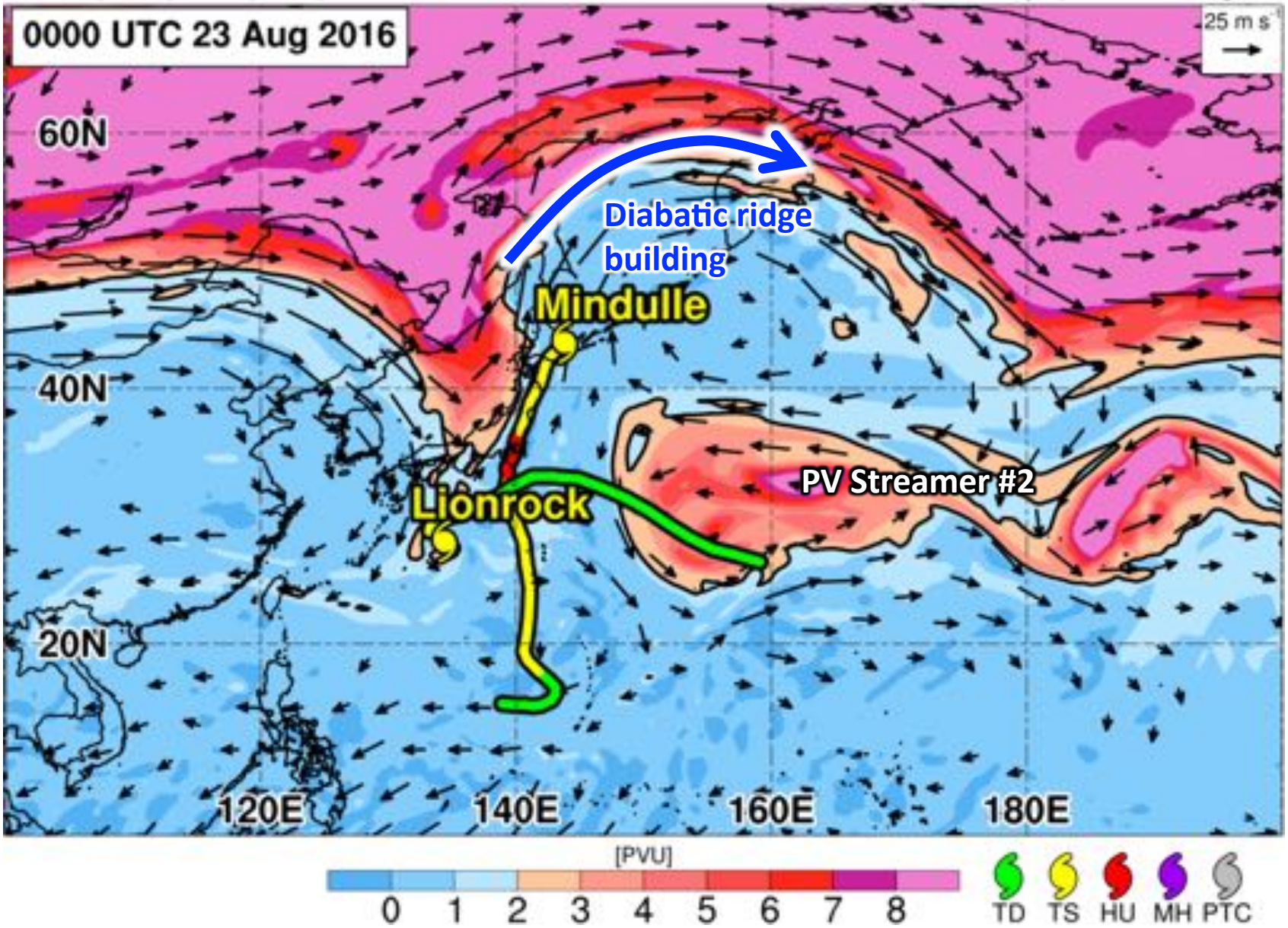

TC Lionrock Reaches Peak Intensity and Turns NE

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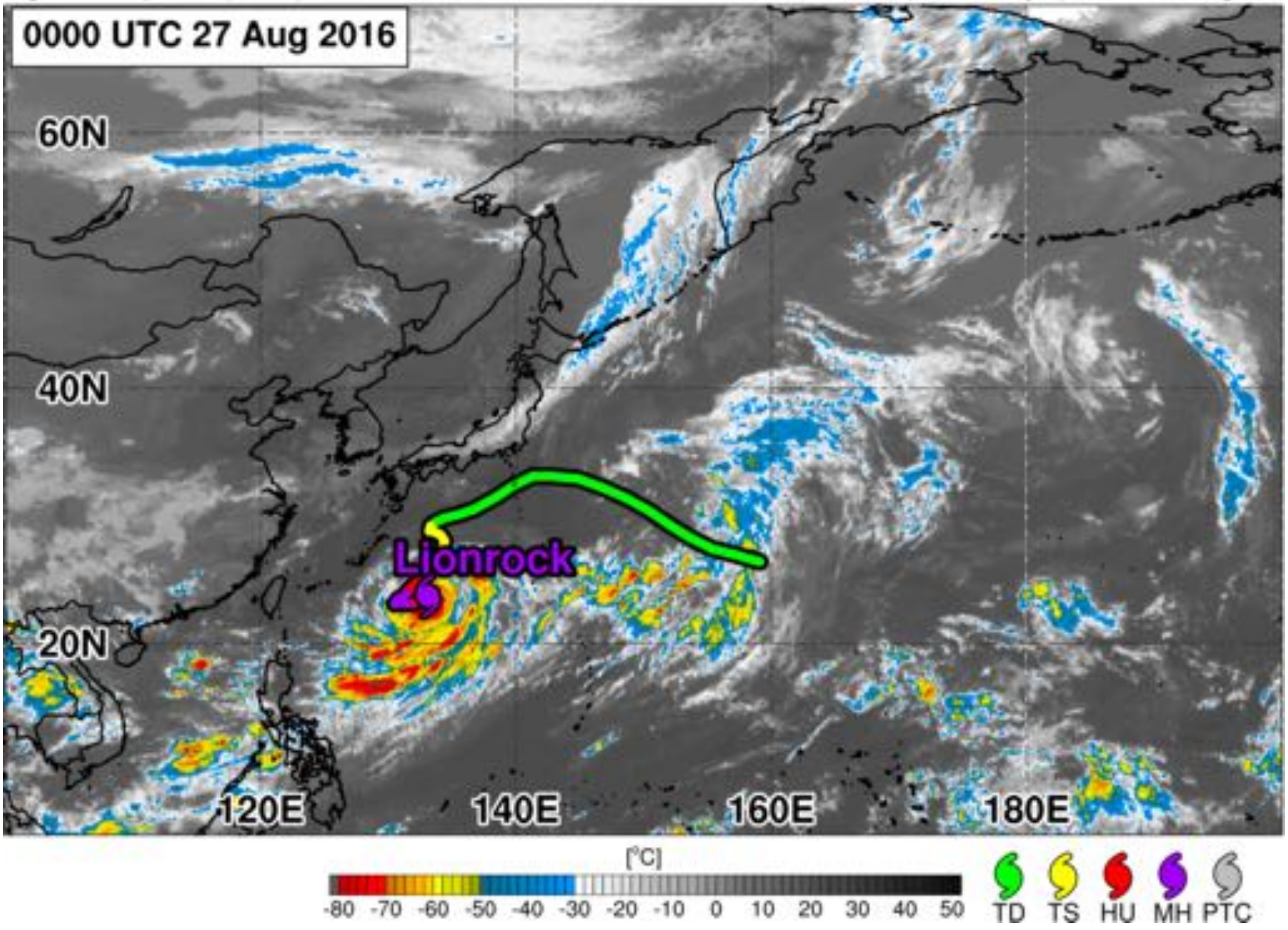
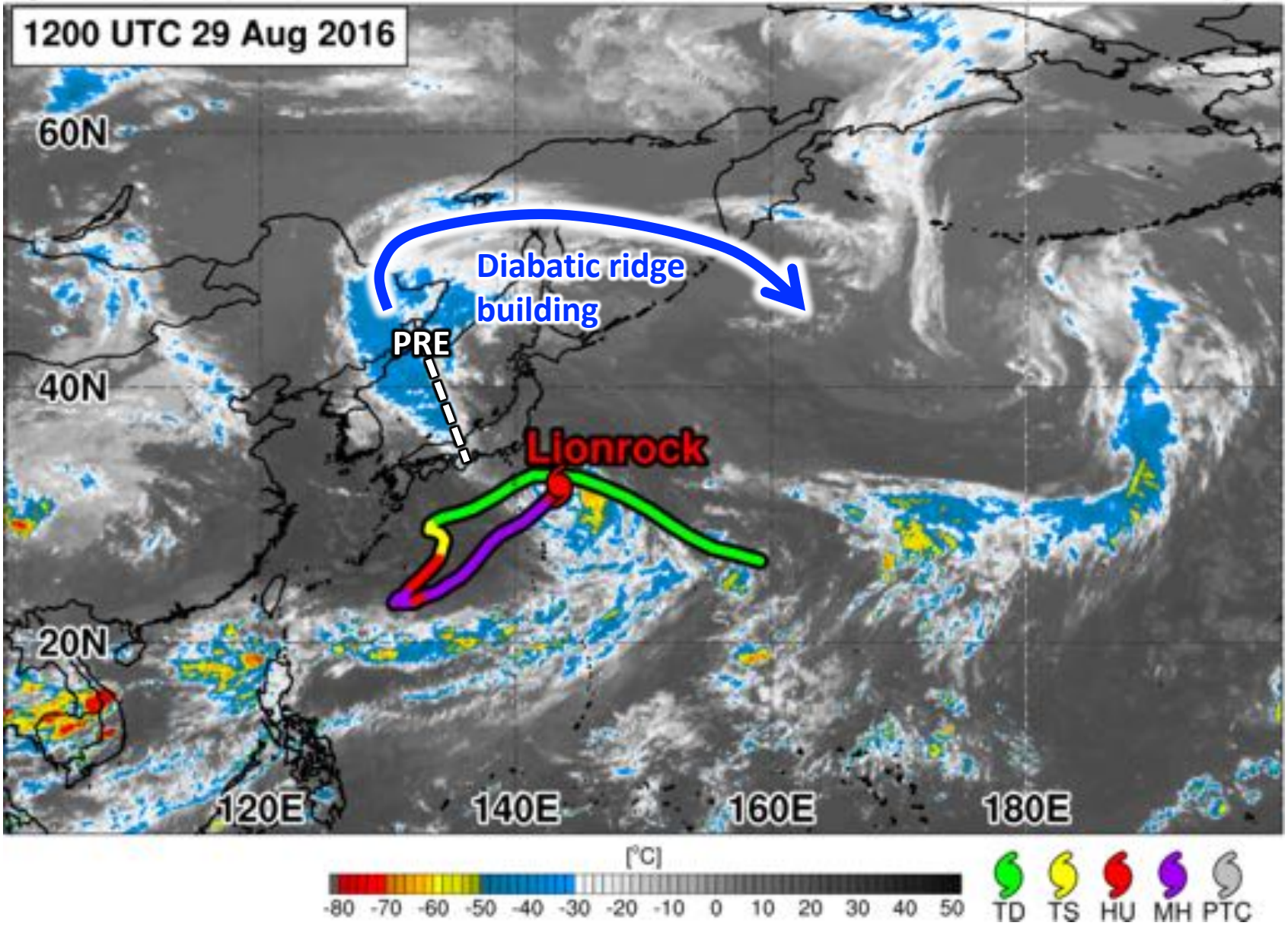


Beginning ET and PRE Development

GridSat brightness temperature (shaded, ˚C), TC tracks annotated on plot



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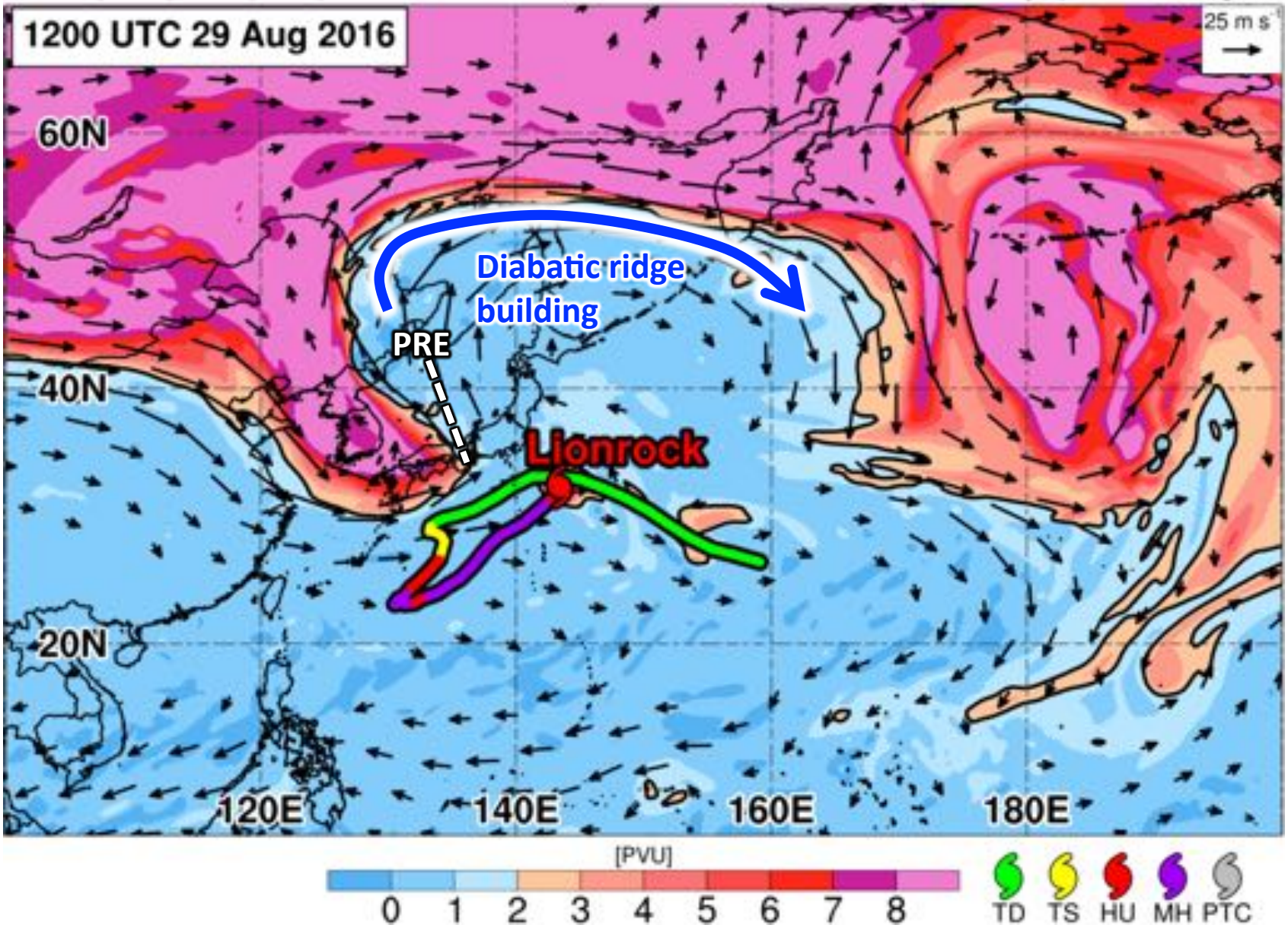

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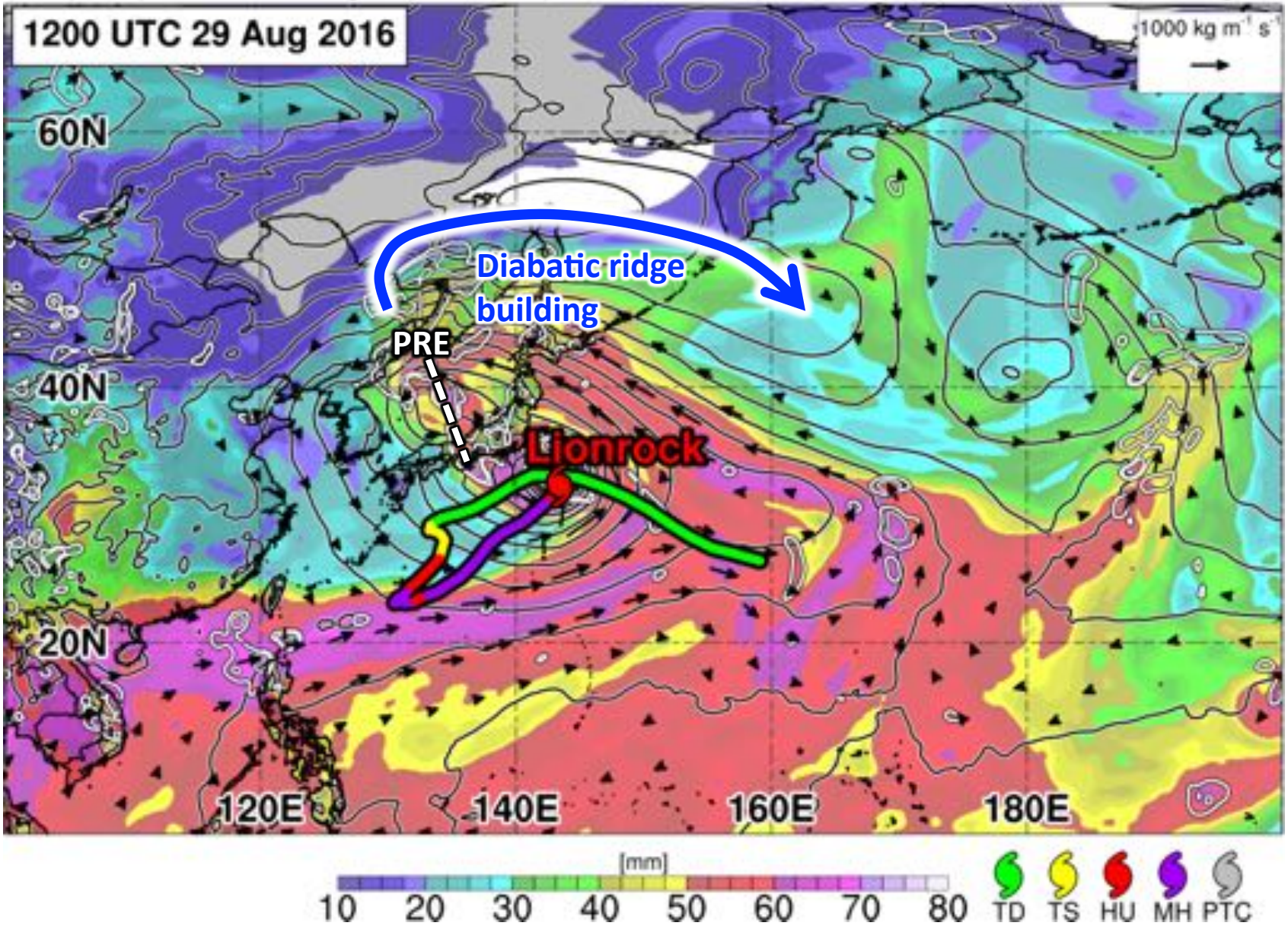
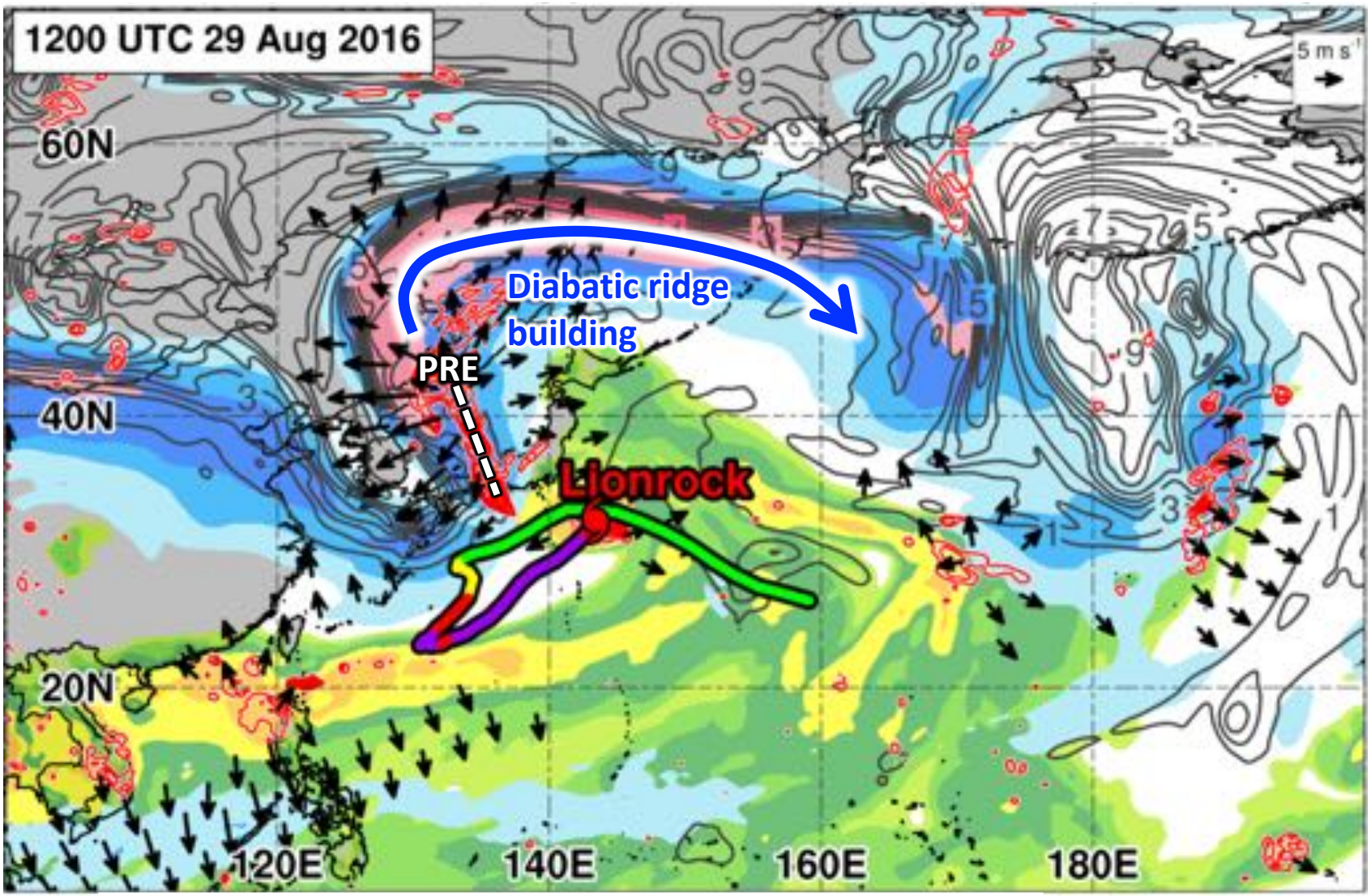


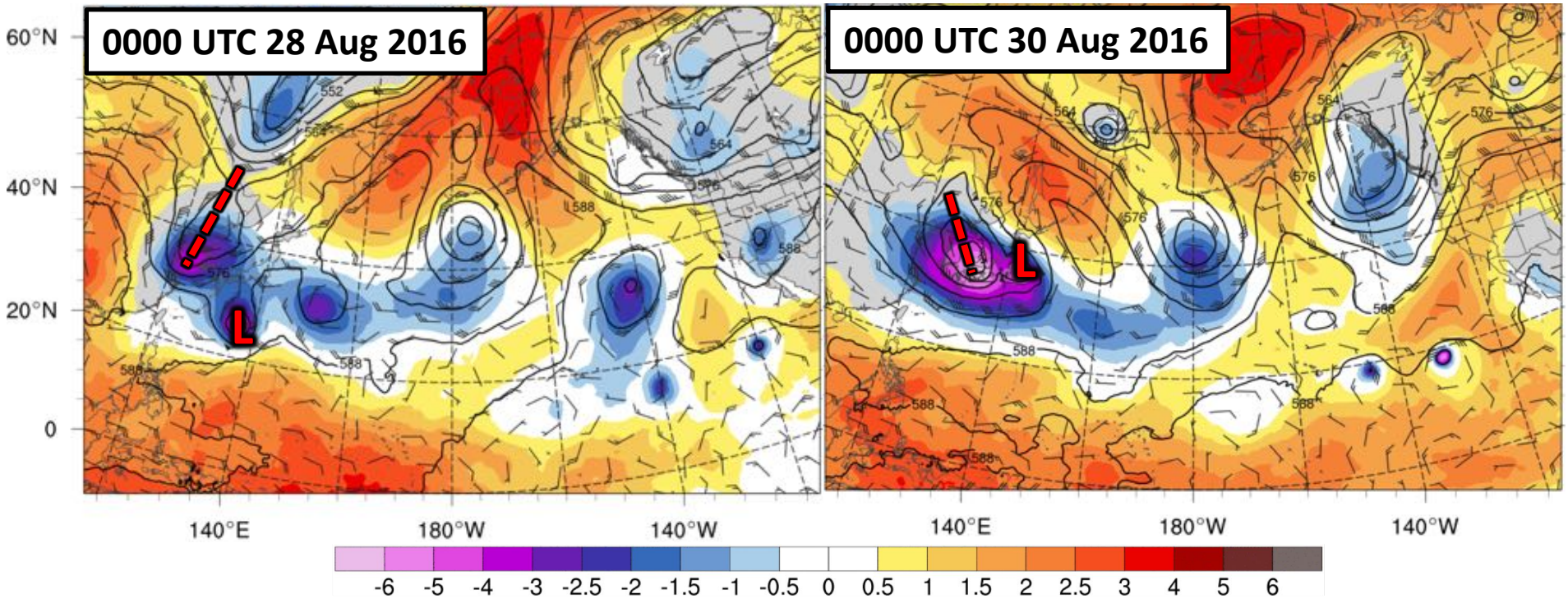
Beginning ET and PRE Development

200-hPa winds (shaded, > 20 m s^{-1}), 250–150-hPa layer mean PV (gray contours, PVU), 250–150-hPa layer mean irrotational wind (vectors, m s^{-1}), 600–400-hPa layer mean upward vertical motion (red contours, < -5 × 10^{-3} hPa s^{-1}), Precipitable Water (shaded, mm)



Beginning ET and PRE Development

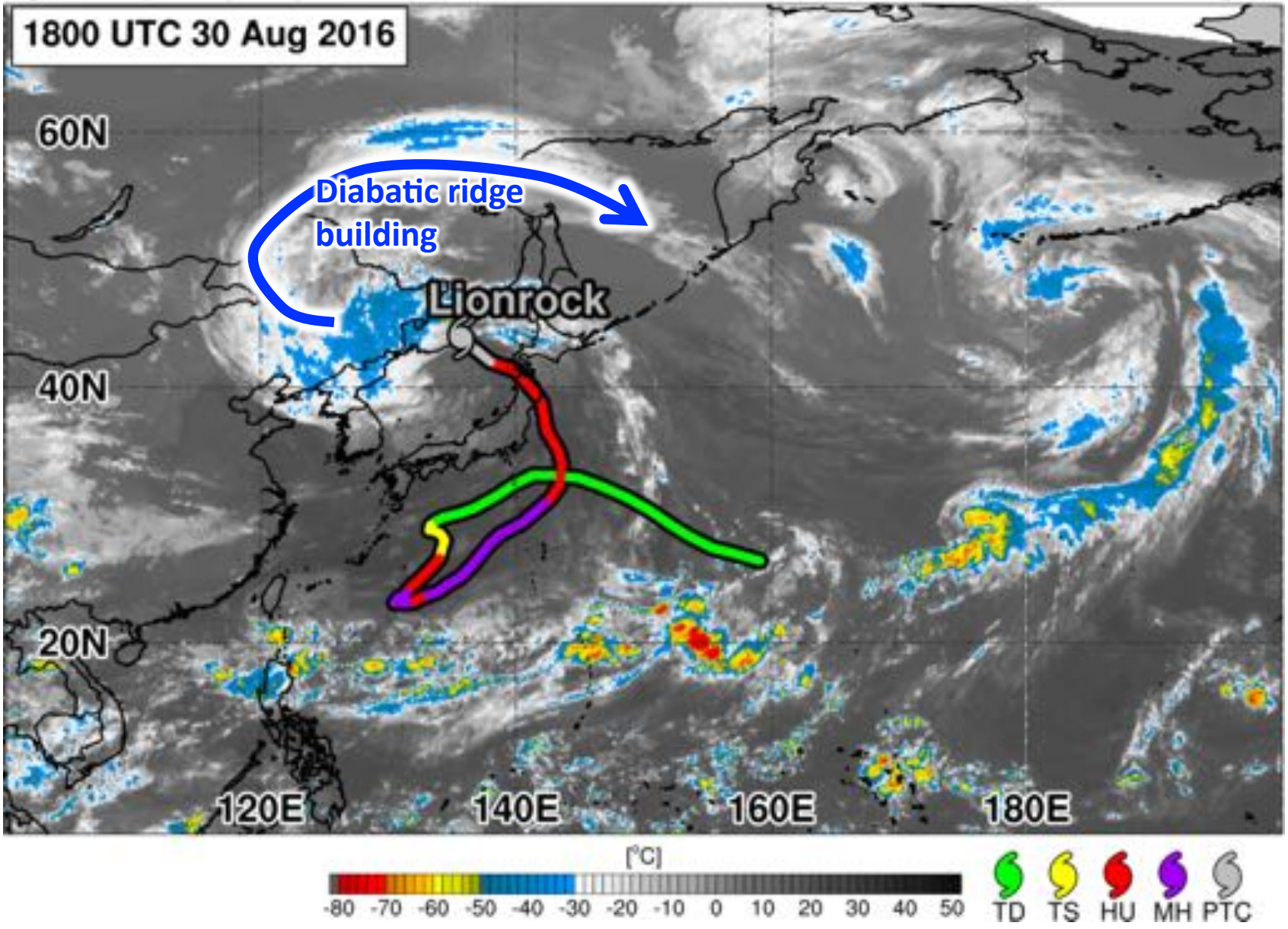
500-hPa standardized geopotential height anomalies (shaded, σ), 500-hPa geopotential heights (black contours, dam)



- **Extraordinarily rare mid-latitude trough for time of year**
  - **500-hPa standardized geopotential height anomaly < −6 sigma!**

“Capture” of TC Lionrock

GridSat brightness temperature (shaded, °C), TC tracks annotated on plot



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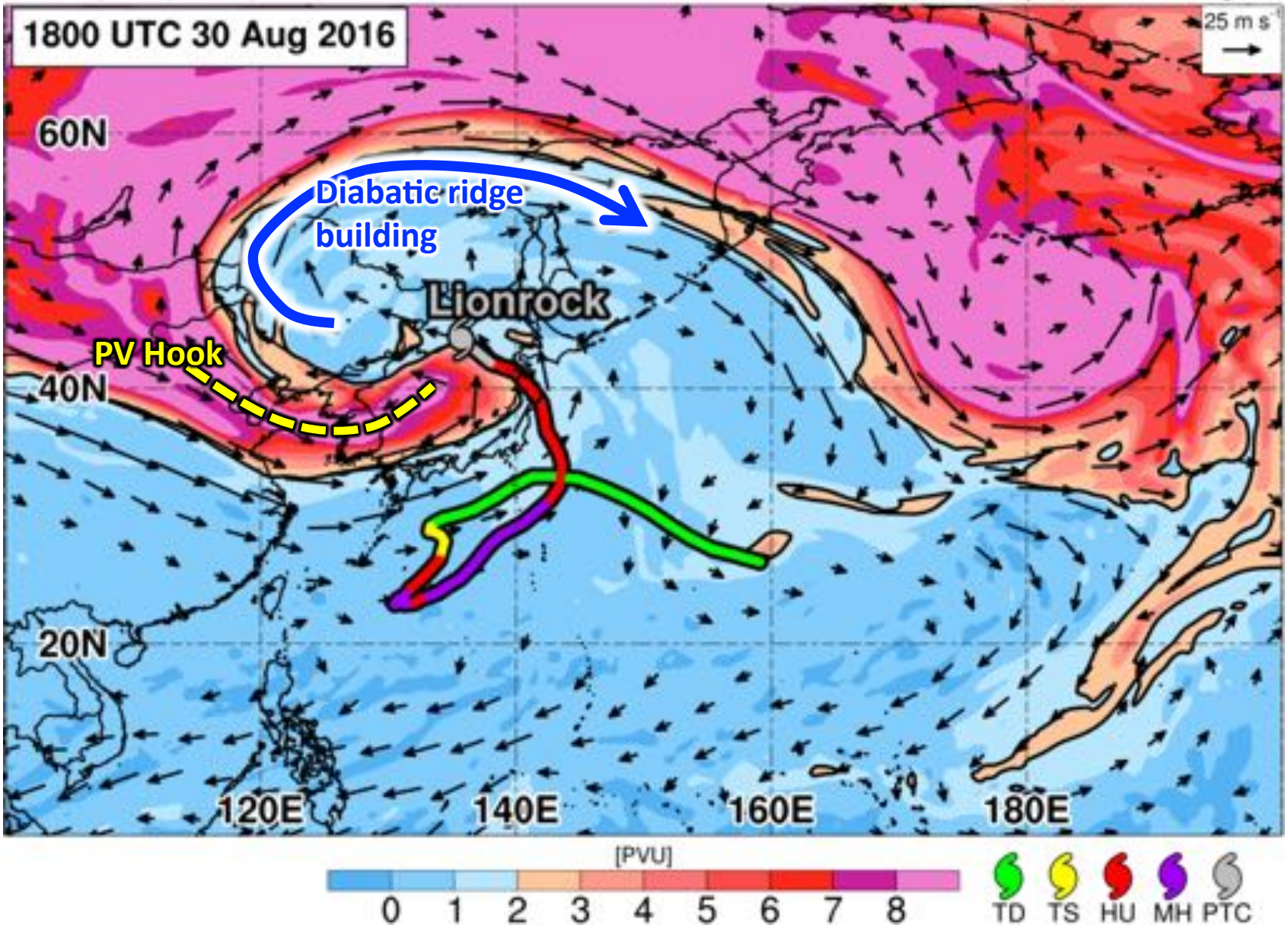

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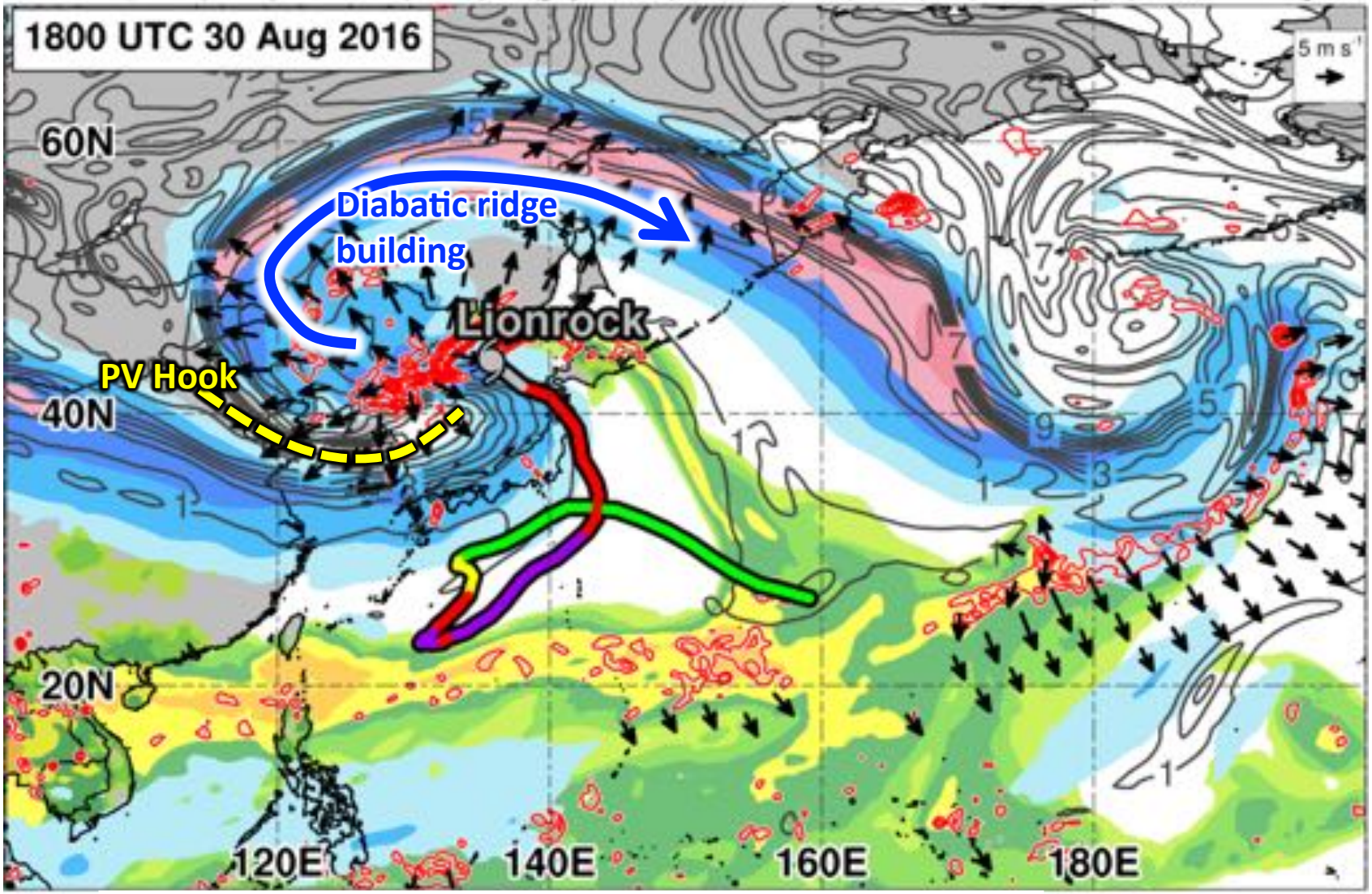

Conclusions

- **High-amplitude, late-summer flow pattern leads to Rossby wave breaking (RWB), tropical-midlatitude interactions, and meridional air mass exchanges**

- **RWB enables PV streamers to interact with a monsoon trough/gyre, contributes to several TC genesis events, and allows multiple TCs to make landfall in Japan***

- **TC Lionrock forms via tropical transition from a PV streamer disturbance, follows a complex track, and engages in binary and trinary interactions with other TCs**

- **TC Lionrock interacts with an unusually strong early season trough, undergoes ET, and triggers a strong predecessor rain event and widespread flooding**

* **Four landfalling TCs and one PTC is a modern August record for Japan (1951–2017)**

Science Opportunities

- **Quantify the trinary interaction of TC Lionrock with TCs Kompasu and Mindulle within a western Pacific monsoon gyre circulation**
- **Determine predictability limitations and uncertainties associated with the observed TC–TC, TC–gyre, and TC–trough interactions**
- **Investigate whether the ET of Mindulle contributed to Lionrock's subsequent ET, downstream PRE formation, and Lionrock's subsequent TC Sandy-like "left hook"**
- **Ascertain whether diabatically driven downstream ridge building resulting from the Lionrock ET contributed to trough reestablishment near the Dateline**
- **Establish whether the Dateline trough, an eastern Pacific ridge, and a western North American trough contributed to "endless summer" in the eastern CONUS**
- **Evaluate whether the observed multiple TC–TC and TC–trough interactions over the western Pacific impacted the downstream ensemble predictability horizon**