Severe Weather in Southern Europe and Severe Flooding in Pakistan in August 2022: Linked Blocking-Related Extreme Weather Events

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CLIVAR Blocking Workshop
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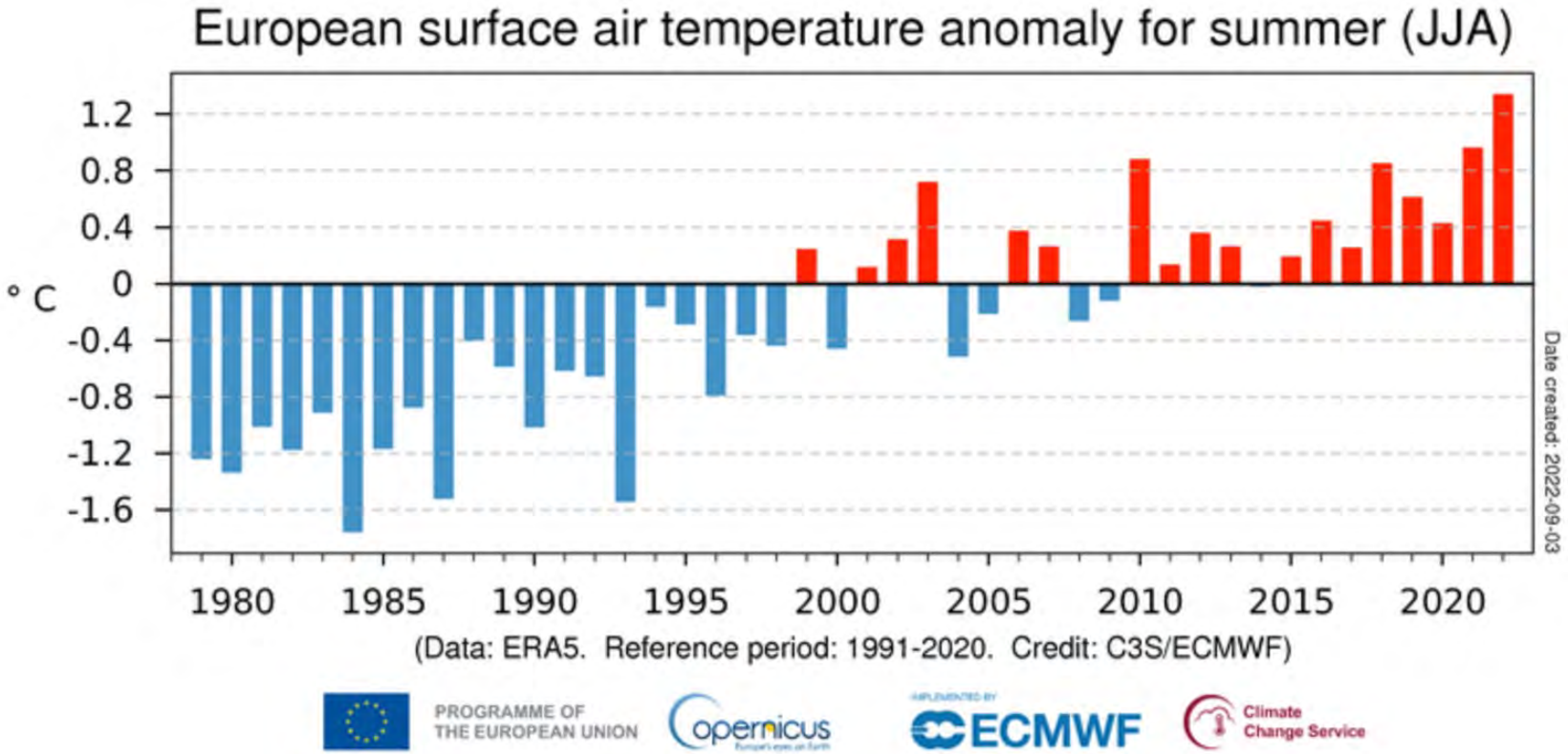
Motivation

- **Recording-breaking heat waves plagued much of western and central Europe during June and July 2022**
- **An impressive “US-style” severe weather outbreak (serial derecho) occurred over southern Europe on 18–19 August 2022**
- **Eurasian trough and Bay of Bengal depressions facilitated record-breaking flooding in Pakistan in August 2022**

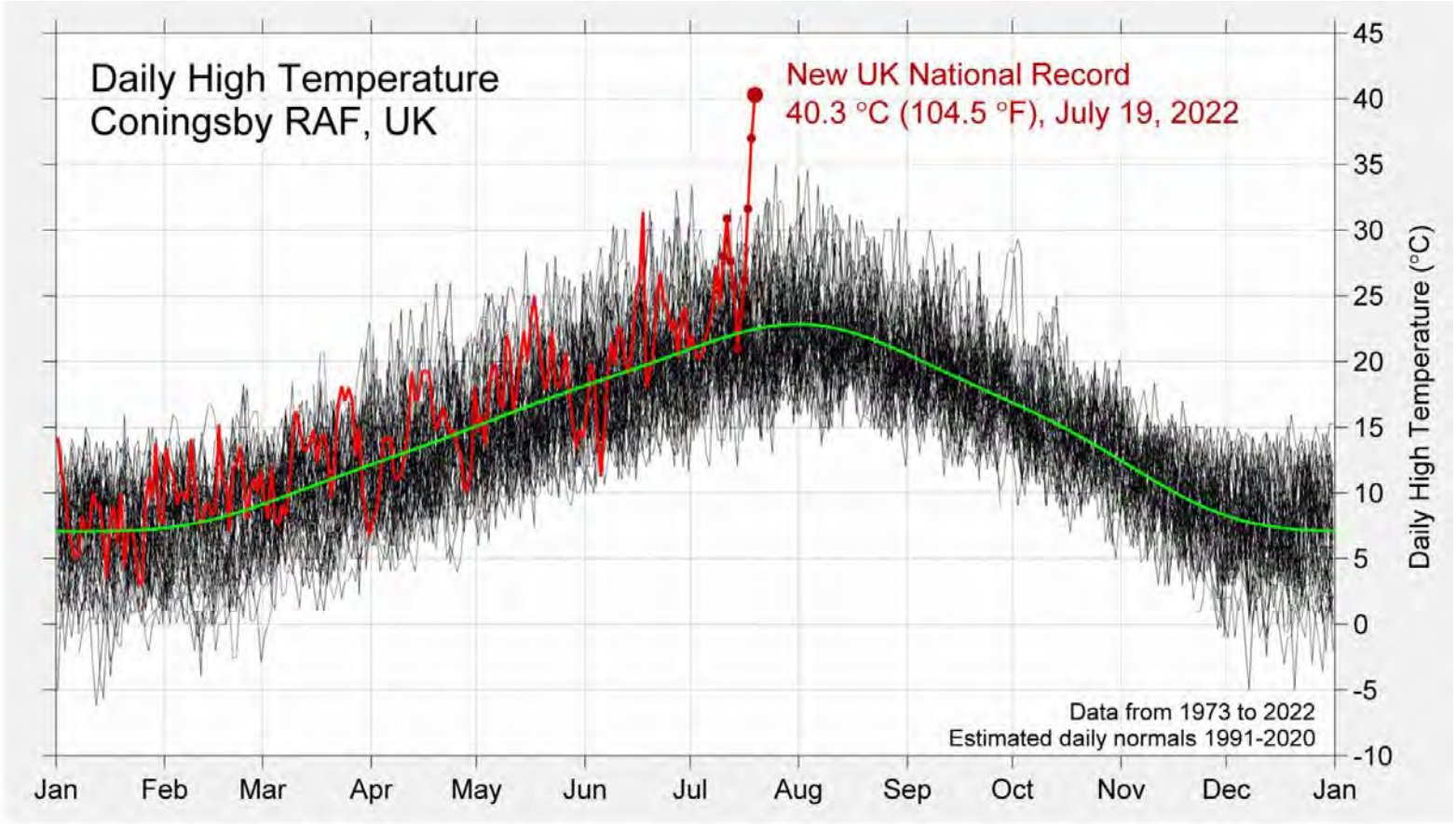
Purpose: Investigate to what extent the aforementioned extreme weather events can be understood from a subseasonal perspective

Extreme Heat in Western and Central Europe in June and July 2022

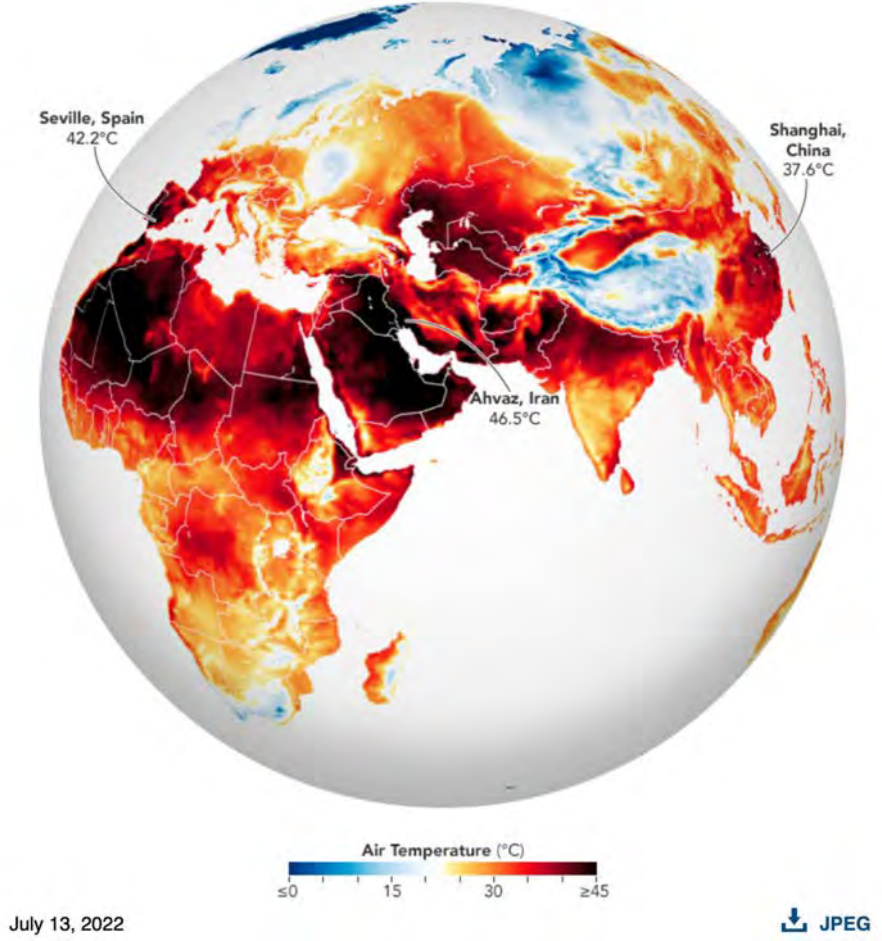
European Surface Air Temperature Anomaly (°C)
June-August: 1979–2022



Daily High Temperatures: Coningsby RAF, UK (2022)
New UK National Record: 40.3°C (19 July 2022)



July 2022: Heatwaves and Fires Scorch Europe, Africa, and Asia

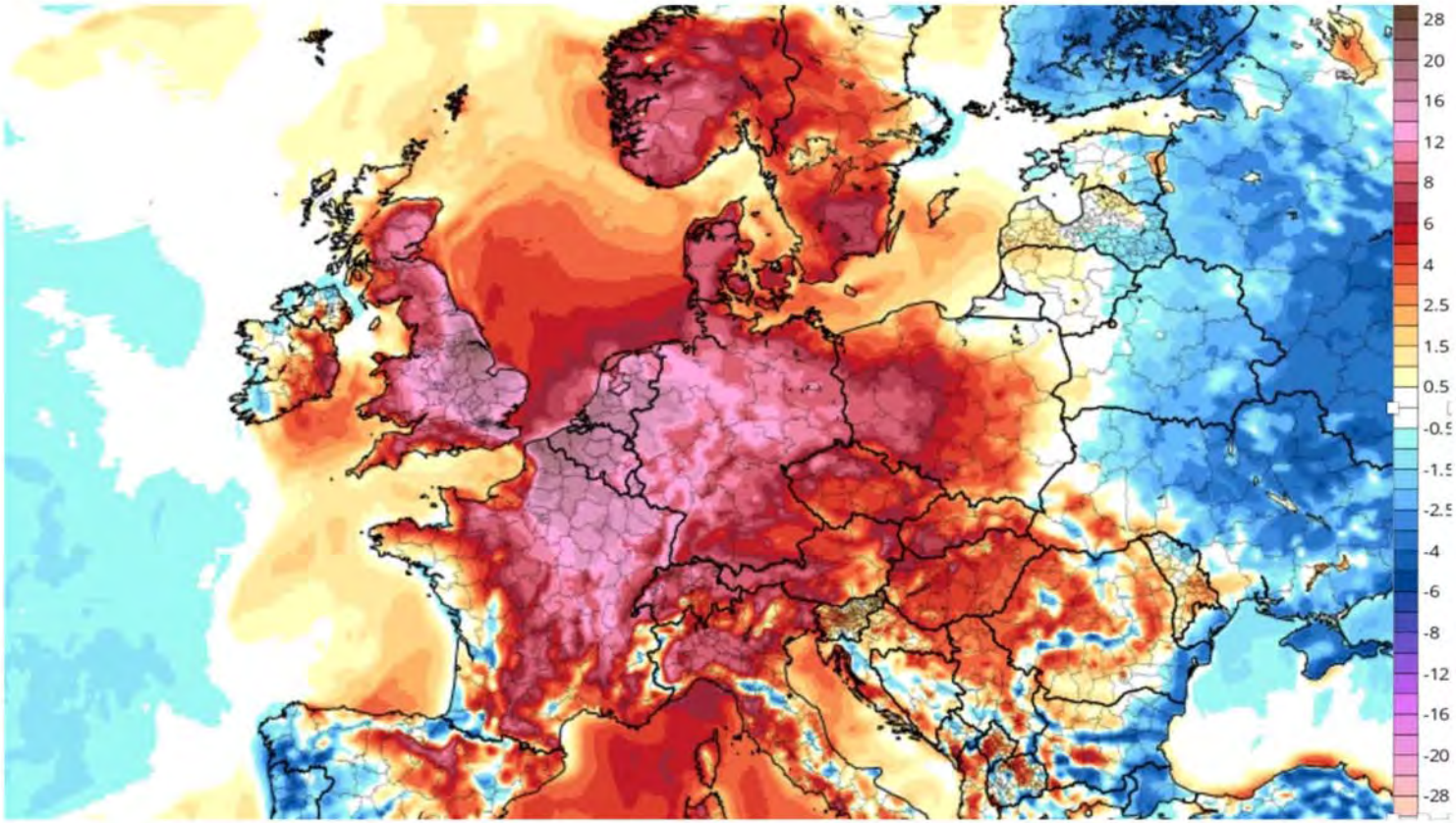


Leiria, Portugal: 45°C on 13 July
Shanghai, China: 41°C on 13 July
London, UK: 40.3°C on 19 July

Source: NASA Earth Observatory

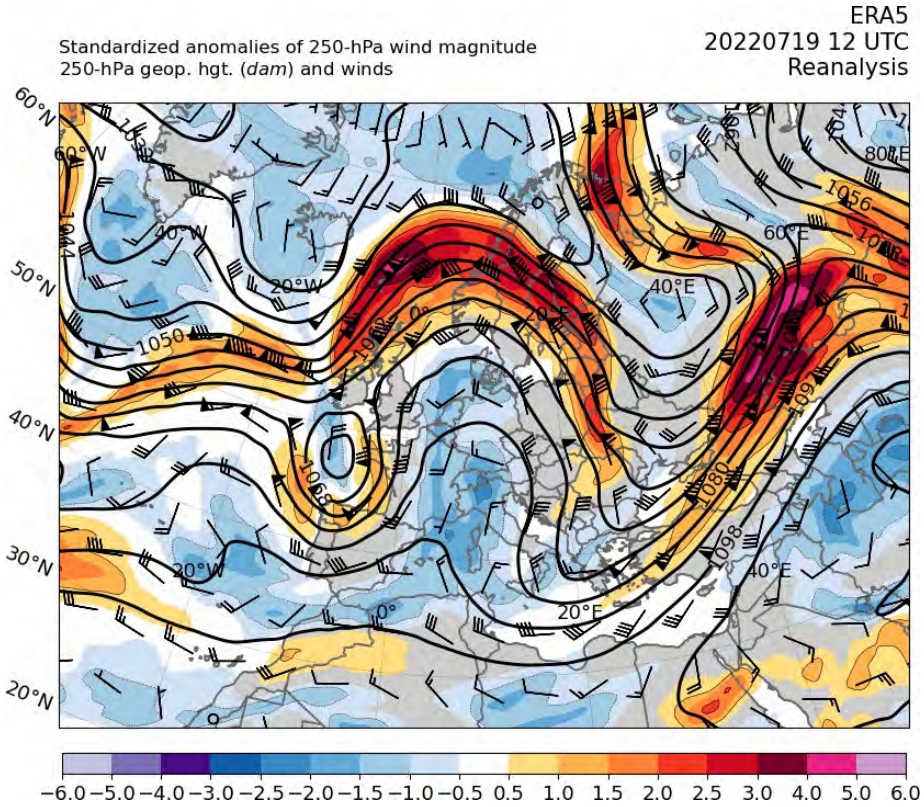
Western Europe's Hottest Summer Day: 19 July 2022

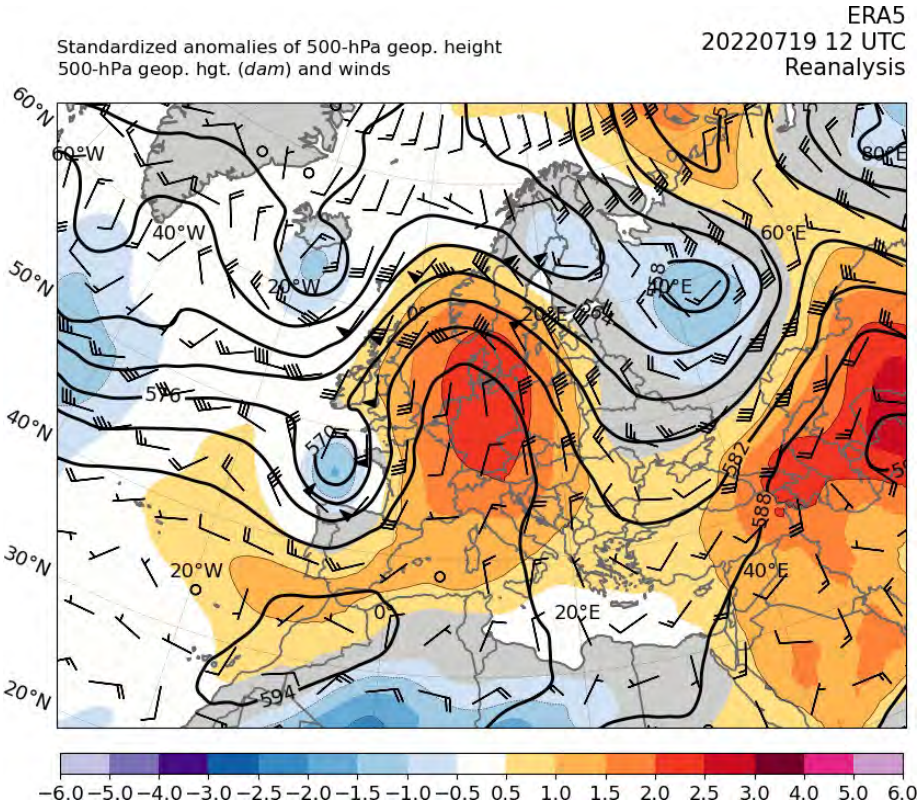
by **BOB HENSON**
JULY 19, 2022



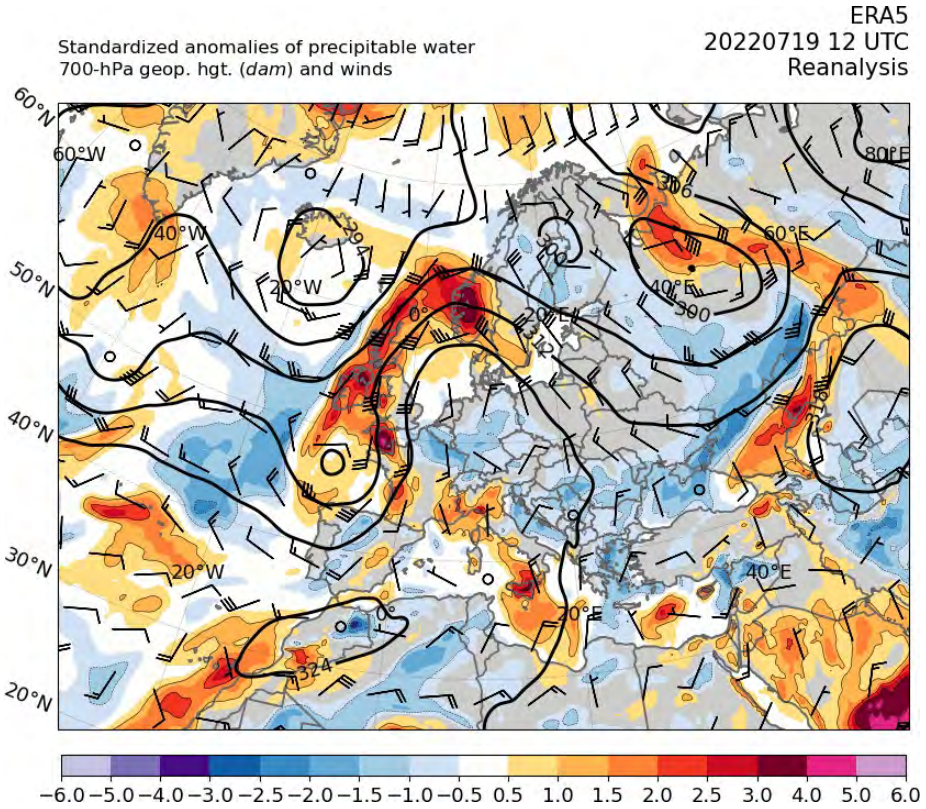
Model-analyzed temperatures at 12Z Tuesday, July 19, 2022 (noon GMT) were transcending average values for the time of day and season by 12 to 24 degrees Celsius—or 22 to 33 degrees

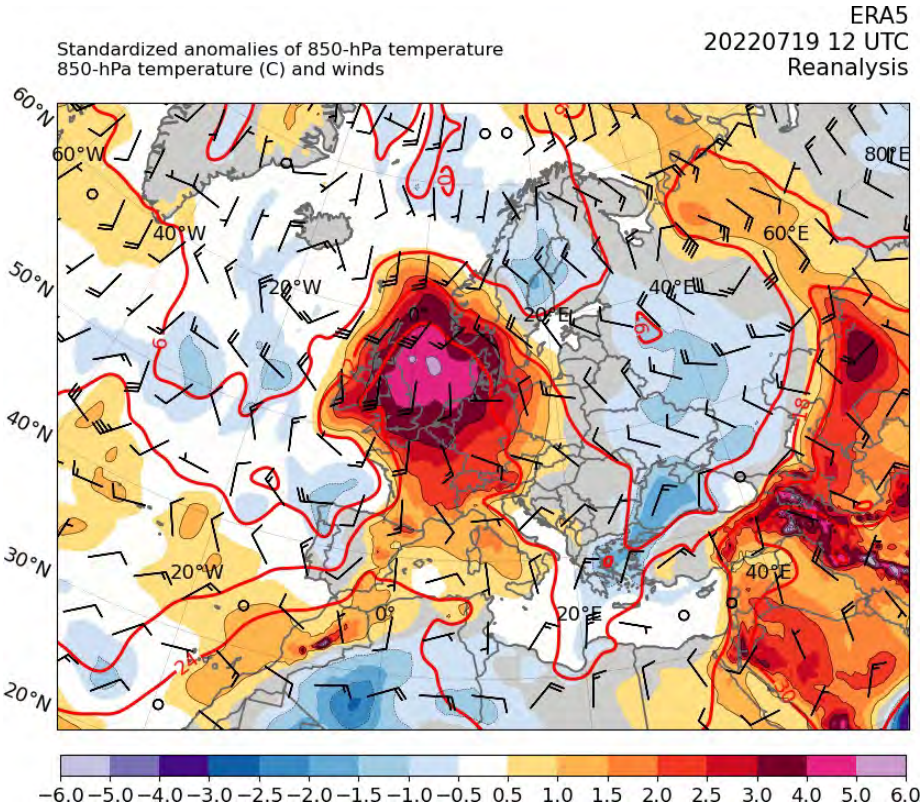
Standardized 250-hPa Wind Speed Anomalies and Winds (left); Standardized 500-hPa Height Anomalies and Winds (right) for 1200 UTC 19 July 2022





700-hPa Standardized Precipitable Water Anomalies, Heights, Winds (left); 850-hPa Standardized Temperature Anomalies (right) 1200 UTC 19 July 2022





Central Europe Severe Weather Outbreak on 18 August 2022

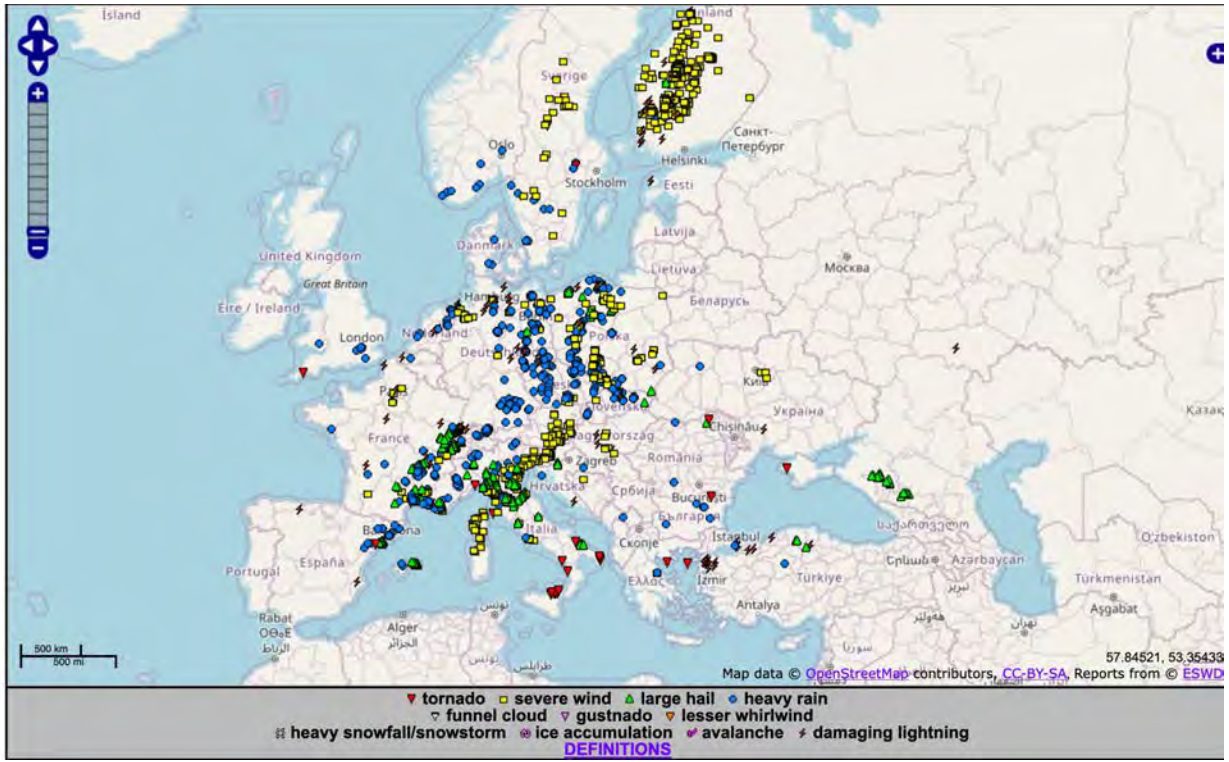
European Serial Derecho of 18-19 August 2022

- **Strong upper-level forcing for ascent east of a prominent upper-level trough**
- **Strong deep convection developed downshear of the above upper-level trough**
- **Strong surface wind gusts arose from convectively generated downdrafts**

A “Mothership” Cloud Approaches Corsica: 18 August 2022

“Mothership” Squall Line Cloud (Impressive by Great Plains Standards)

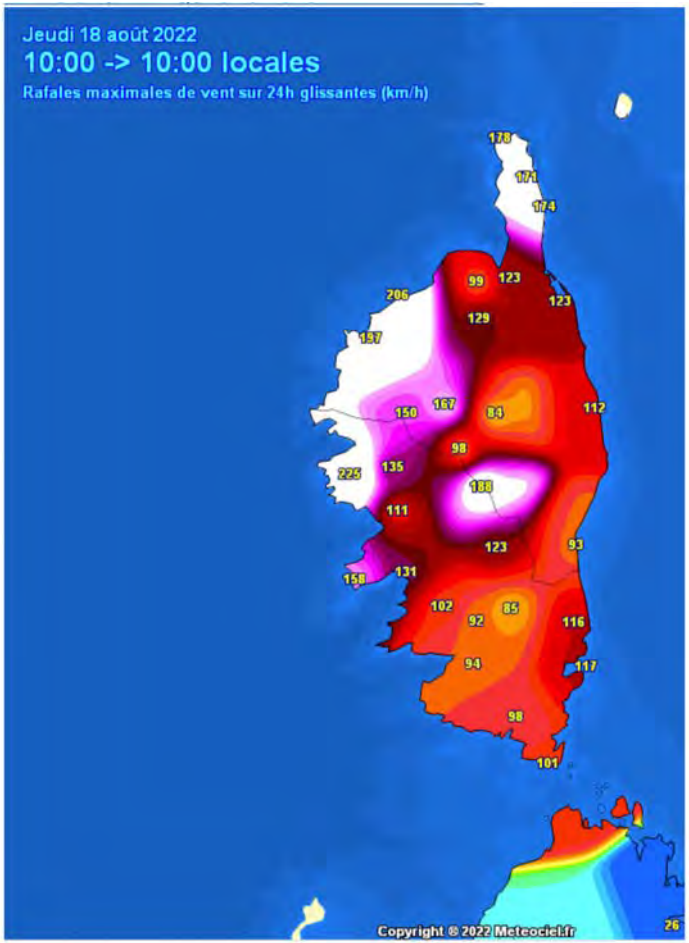
European Severe Weather Database: Severe Weather Reports (14–21 August 2022): https://www.eswd.eu/)



0–6-km bulk shear ~25 m s^{-1}
CAPE > 1500 J kg^{-1}

Serial derecho lasted for 13 h
Path length > than 800 km
Max wind speed: 225 km/h

Derecho Maximum Wind speeds (Corsica)

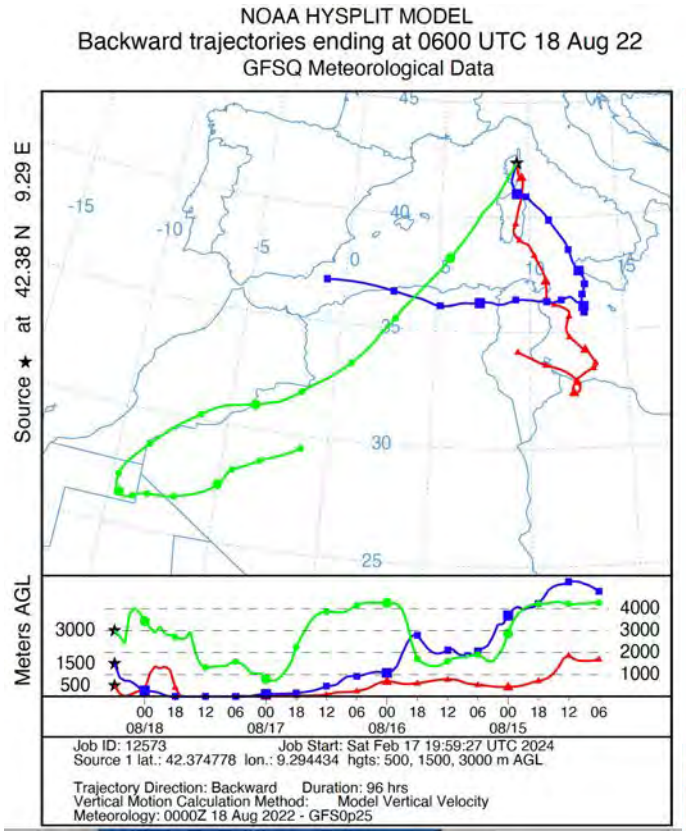


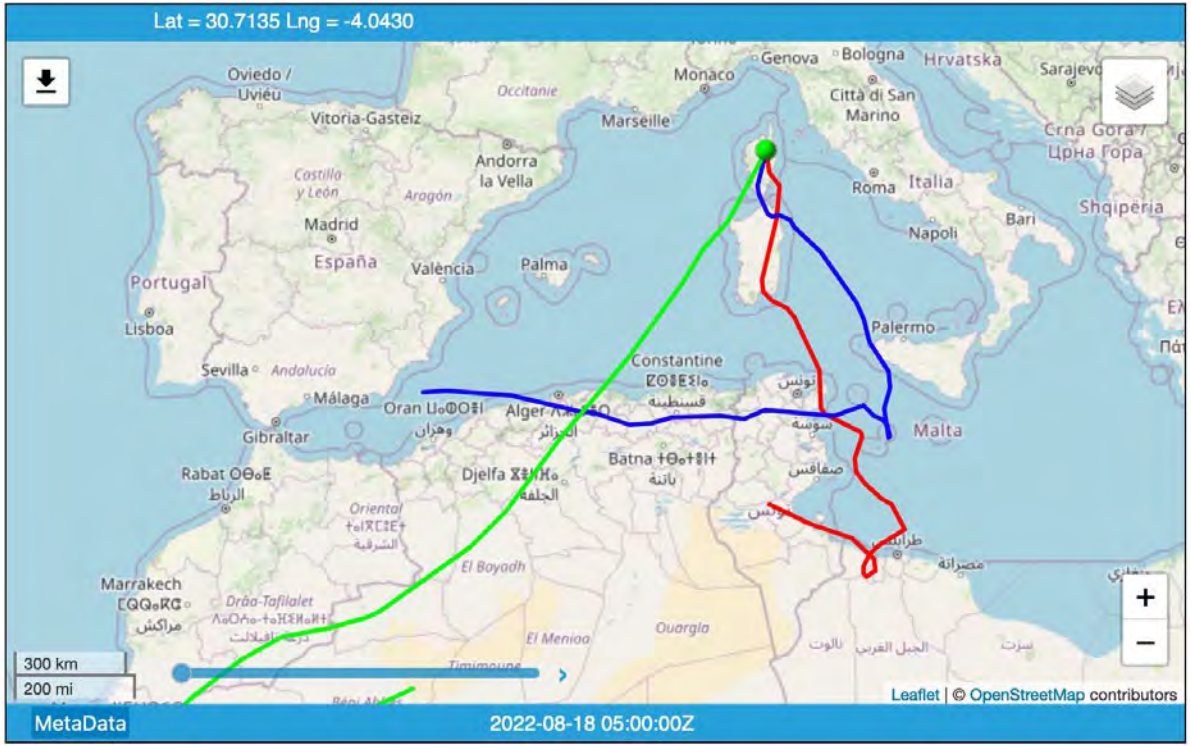
Corsica Maximum Wind Speeds (km h^{-1}) on 18 August 2022

Peak Wind Speed: 225 km h^{-1}

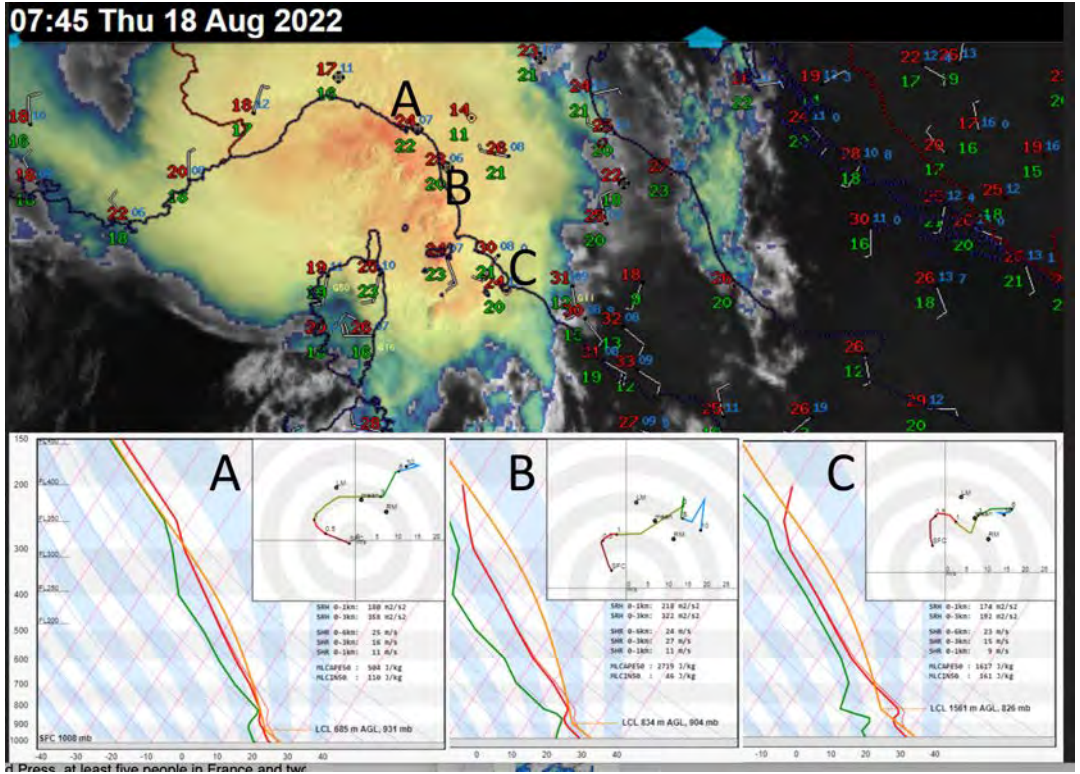
Mediterranean sea surface temperatures 3-5 C above normal helped to increase derecho intensity

Northeast Corsica: 96h Back Trajectories From 0600 UTC 18 August 2022





Satellite-Sounding Composite: 0745 UTC 18 Aug 2022



MLCAPE:
A: 504 J kg^{-1}
B: 2719 J kg^{-1}
C: 1617 J kg^{-1}

Shear: 0-6 km:
A: 25 m s^{-1}
B: 24 m s^{-1}
C: 23 m s^{-1}

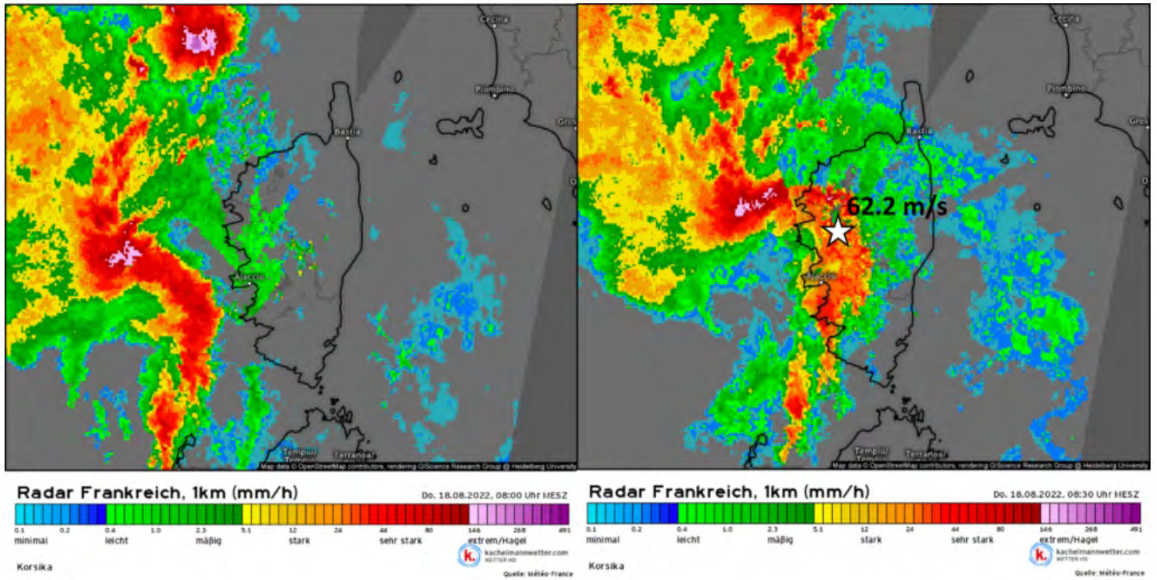
SRH: 0-3 km:
A: 358 m^2 s^{-2}
B: 322 m^2 s^{-2}
C: 192 m^2 s^{-2}

"While the presence of high CAPE and very strong shear helped the intense bow echo to develop, the crucial point was the upscale growth from the isolated storm to the squall line between Menorca and Corsica. We speculate that the development of the cold pool within the storm helped with the upscale growth. While the maritime boundary layer remained very moist, the presence of drier air and steep lapse rates above 900 hPa could have created strong downdrafts."

https://www.essl.org/cms/the-derecho-and-hailstorms-of-18-august-2022/

Bow Echo Evolution Over Corsica: 18 August 2022

0000 UTC

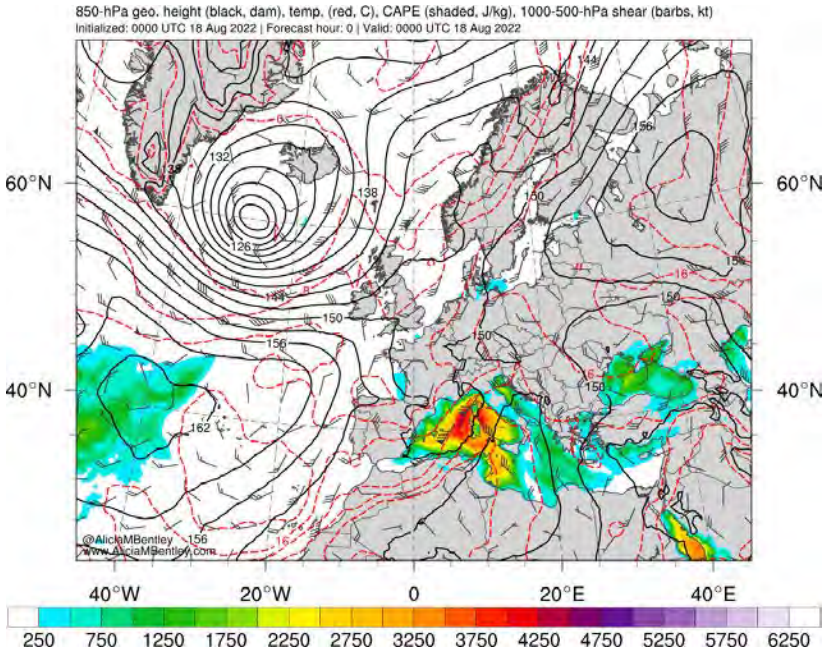


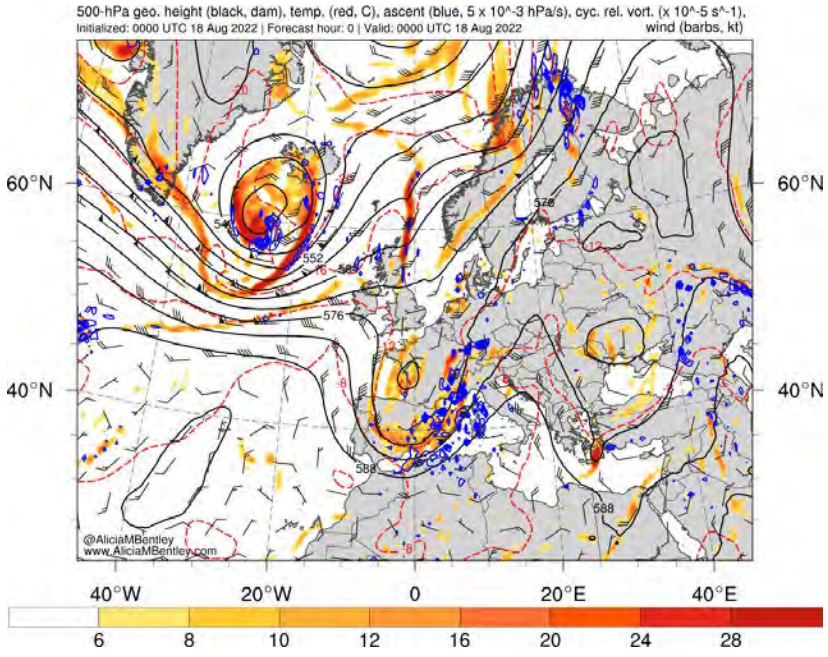
0600 UTC

Bow-echo evolution over Corsica as shown by radar between 06:00 and 06:30 UTC.
The location of the most severe wind gust is shown by the star.
Source: kachelmannwetter.com, meteologix.com

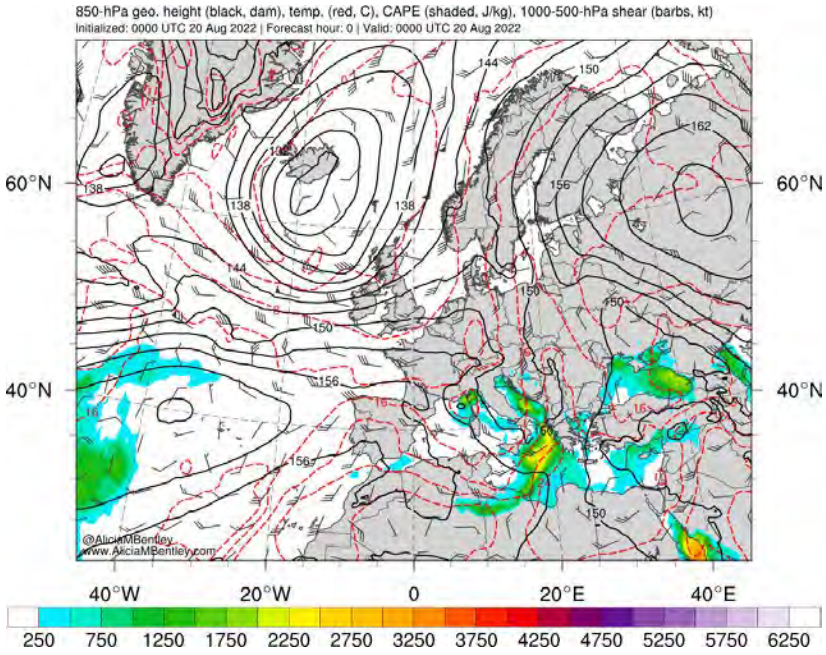
"The central part apex of the bow echo accelerated to an incredible speed of 40 – 50 m/s, compared to a mean wind of 17 m/s, which suggests the presence of a very strong rear inflow jet. The storm moved in the direction of the 0-3 km shear vector, i.e. in the direction of the strongest lift along the cold pool."

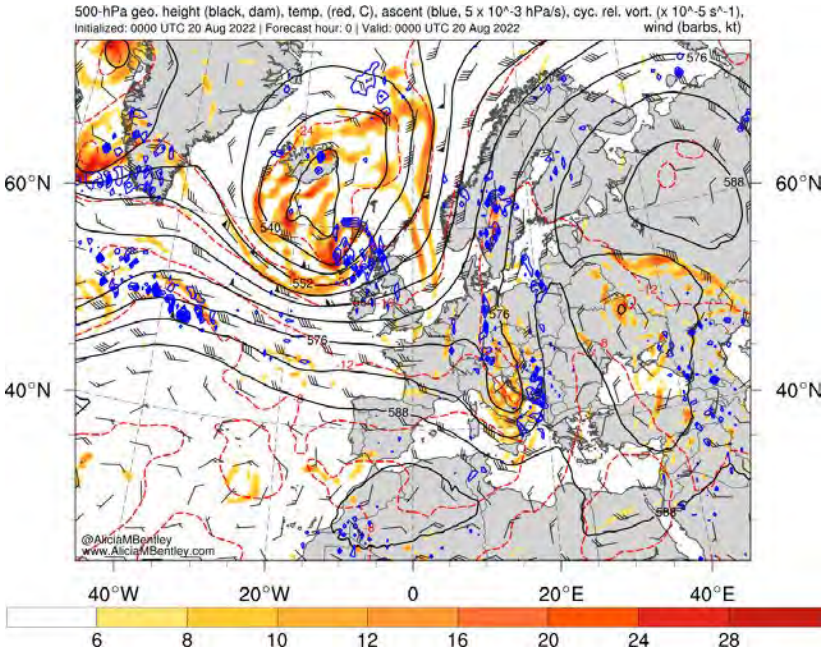
Left: 850-hPa Heights, Temps, CAPE (J/kg), 1000–500-hPa Shear (barbs, kt)
Right: 500-hPa Heights, Temps, Ascent (blue), and Cyclonic Rel. Vorticity (shaded)
Time: 0000 UTC 18 August 2022





Left: 850-hPa Heights, Temps, CAPE (J/kg), 1000–500-hPa Shear (barbs, kt)
Right: 500-hPa Heights, Temps, Ascent (blue), and Cyclonic Rel. Vorticity (shaded)
Time: 0000 UTC 20 August 2022





Inaccurate Rain Forecast Sparks Political Storm In Hungary

The dismissals, announced by Minister of Technology and Industry Laszlo Palkovics (pictured), followed harsh criticism of the meteorological service in Hungary's government-aligned media. (file photo)

Hungary's top two weather officials have been fired after a mistaken rain forecast prompted the postponement of a fireworks display that caused a political uproar.

What had been billed as "Europe's biggest fireworks display," scheduled for August 20 in the evening to celebrate St Stephen's Day -- the national holiday, was postponed by the government hours before the start after the National Meteorological Service issued an extreme weather warning.

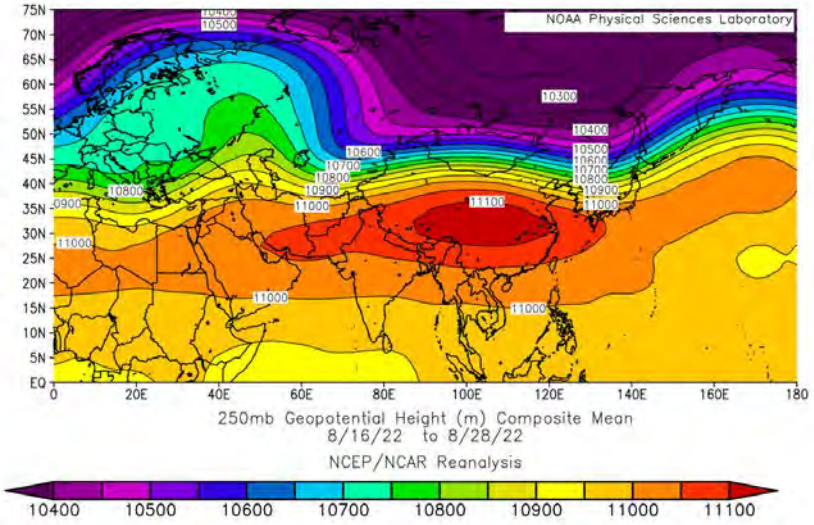
The weather, however, stayed calm -- leading to the dismissal of the head and deputy head of the weather service, Kornelia Radics and Gyula Horvath.

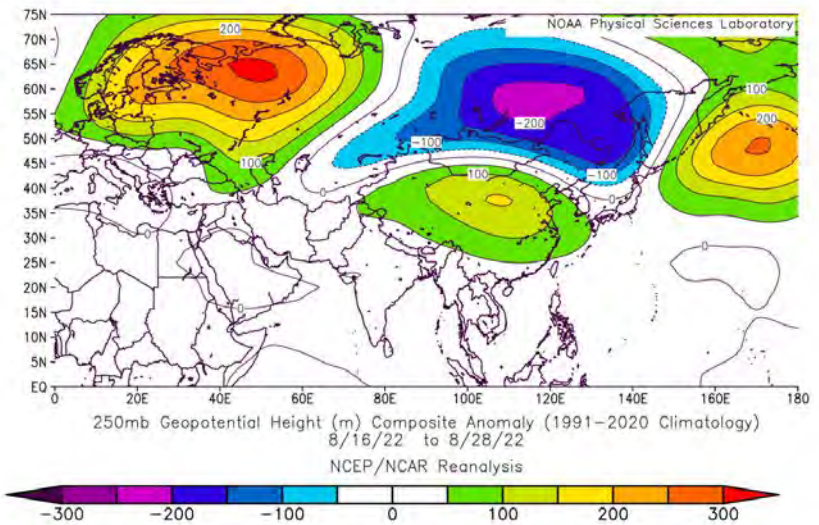
Forecaster Fallout

Top Two Hungarian Meteorologists fired after Blown Convective Storm Forecast for 21 August 2022*

***Perhaps they were fired for not being "sharp" enough to borrow a "TC-tested" Sharpie pen from you know who?**

Mean (Left) and Anomaly (Right) 250-hPa Geopotential Heights: 16–28 August 2022





Source: NOAA-ESRL-PSD (https://psl.noaa.gov/data/getpage/)

Key Takeaways

- **Severe weather outbreak was driven by an unusually intense progressive upper-level trough**
- **Saharan dry air and steep lapse rates supported convectively driven, evaporatively cooled downdrafts.**
- **Downstream flow amplification across Eurasia facilitated massive Pakistan flooding**

Pakistan Flooding: August 2022

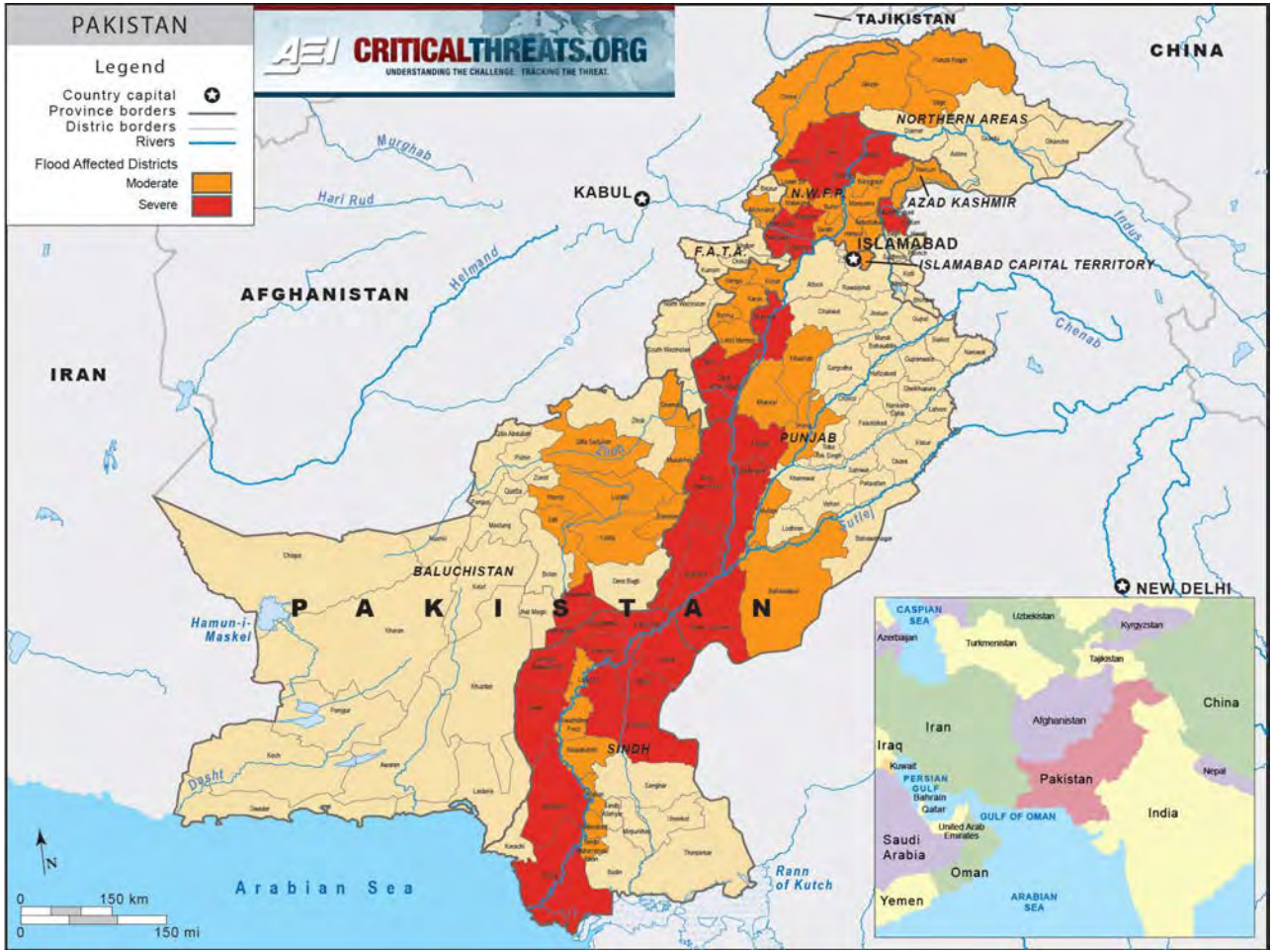
- 1739 deaths, 12,867 injured, more than 2.1 million homeless
- Damage costs: 10% of GDP; ~2 million home damaged or destroyed
- Worst floods since 2010; 10–12% of the country was flooded

Unprecedented Flooding In Pakistan

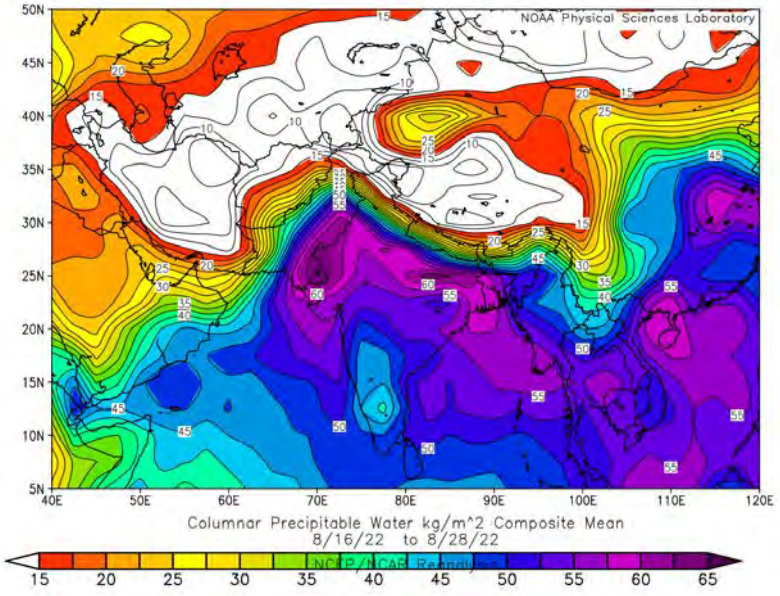
Homes are surrounded by floodwaters in Jaffarabad, Pakistan on 1 Sep 2022

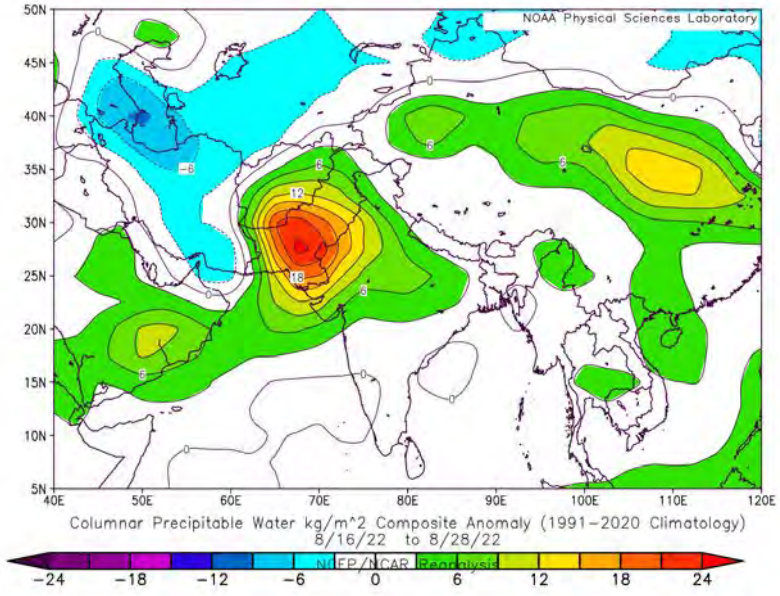
Source: https://www.washingtonpost.com/world/2022/08/31/pakistan-floods-photos-videos-maps/

August 2022 Pakistan Flood Map: Source: UN OCHA (Dawn News)



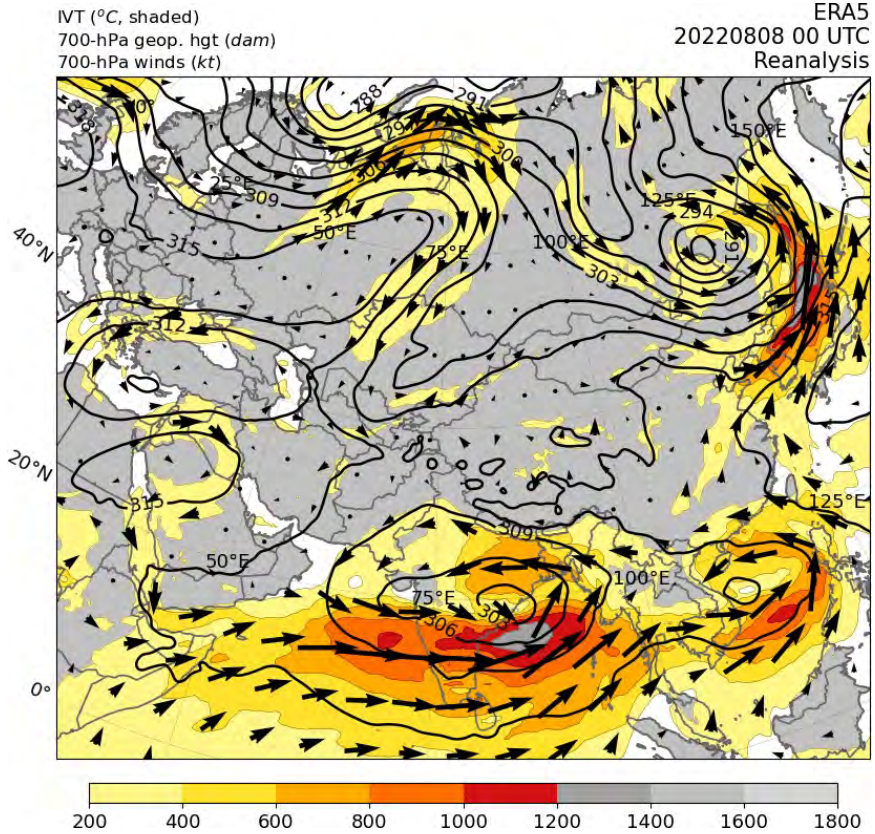
Mean (Left) and Anomaly (Right) Precipitable Water (mm): 16–28 August 2022

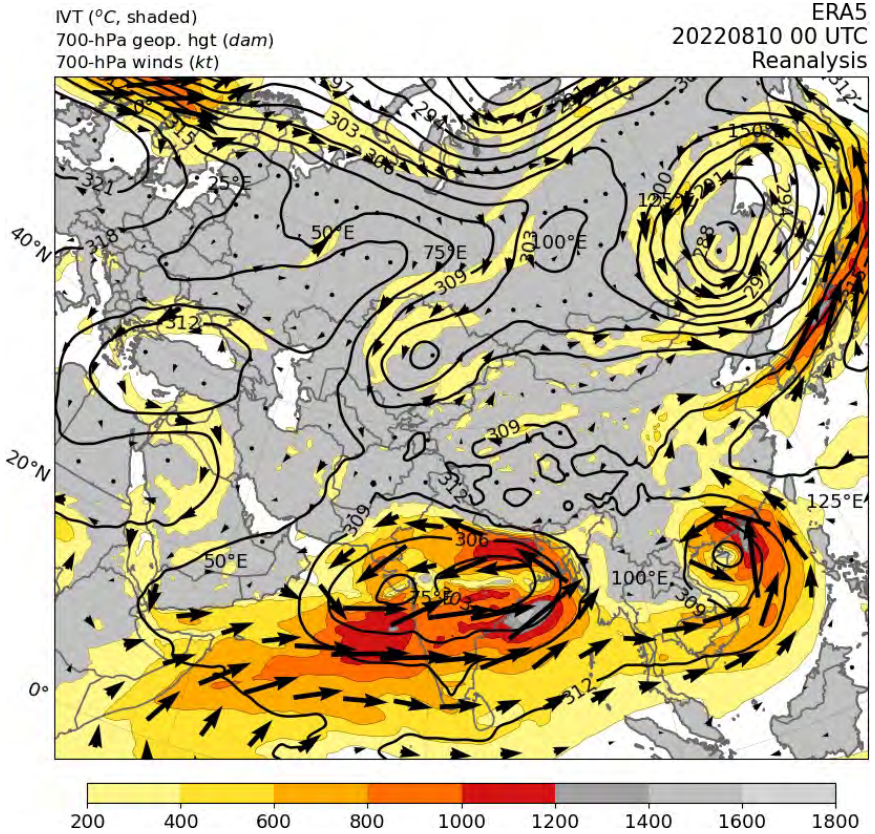




https://psl.noaa.gov/data/getpage/

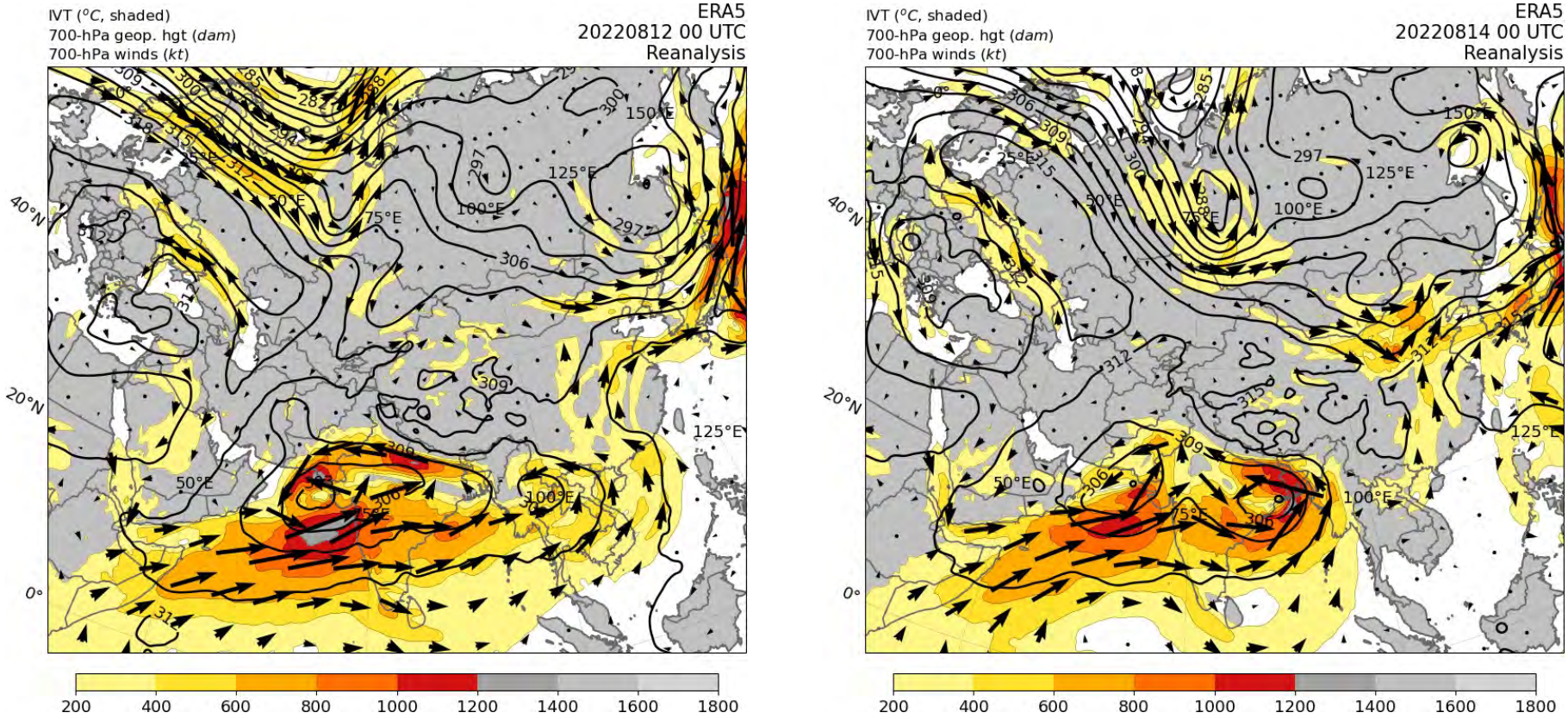
700-hPa Heights, Winds, and IVT for 0000 UTC 8 August 2024 (Left) and 0000 UTC 10 August (Right)





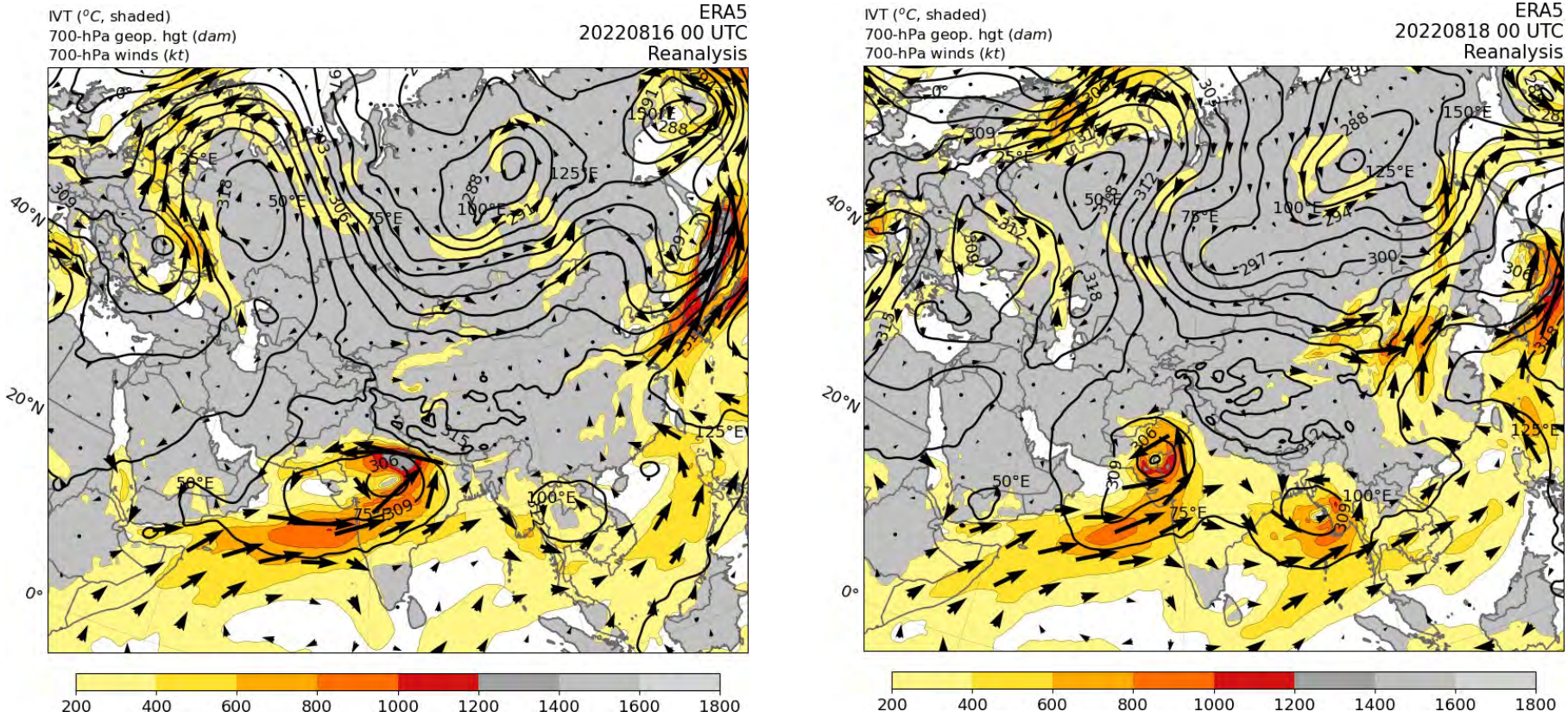
IVT Units: kg m^{-1} s^{-1}

700-hPa Heights, Winds, and IVT for 0000 UTC 12 August 2024 (Left) and 0000 UTC 14 August (Right)



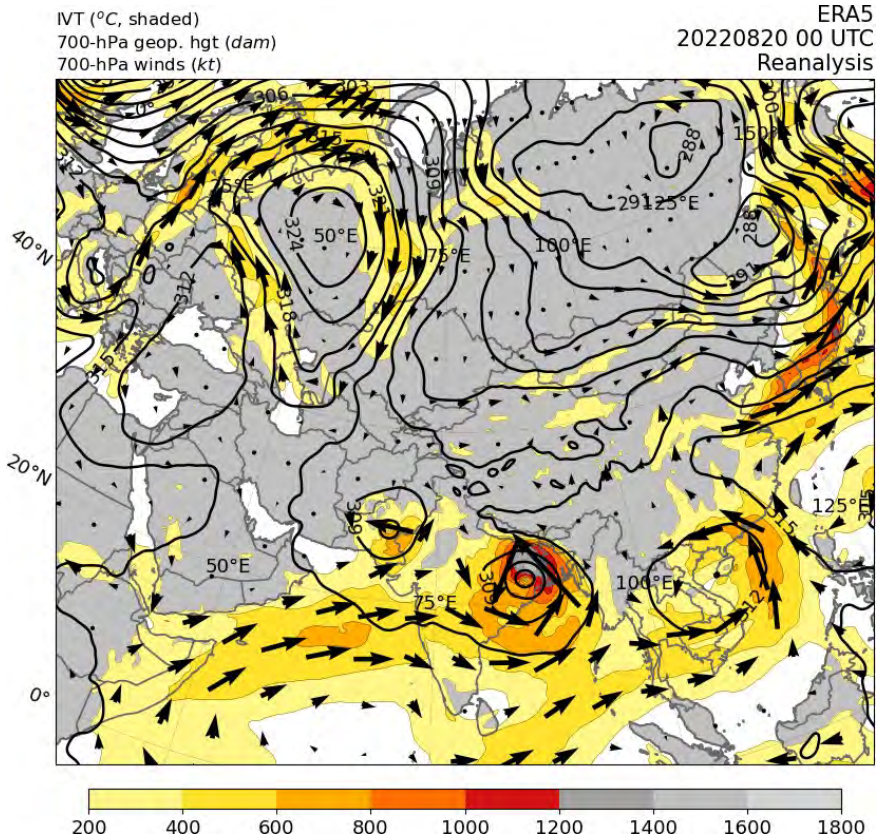
IVT Units: kg m^{-1} s^{-1}

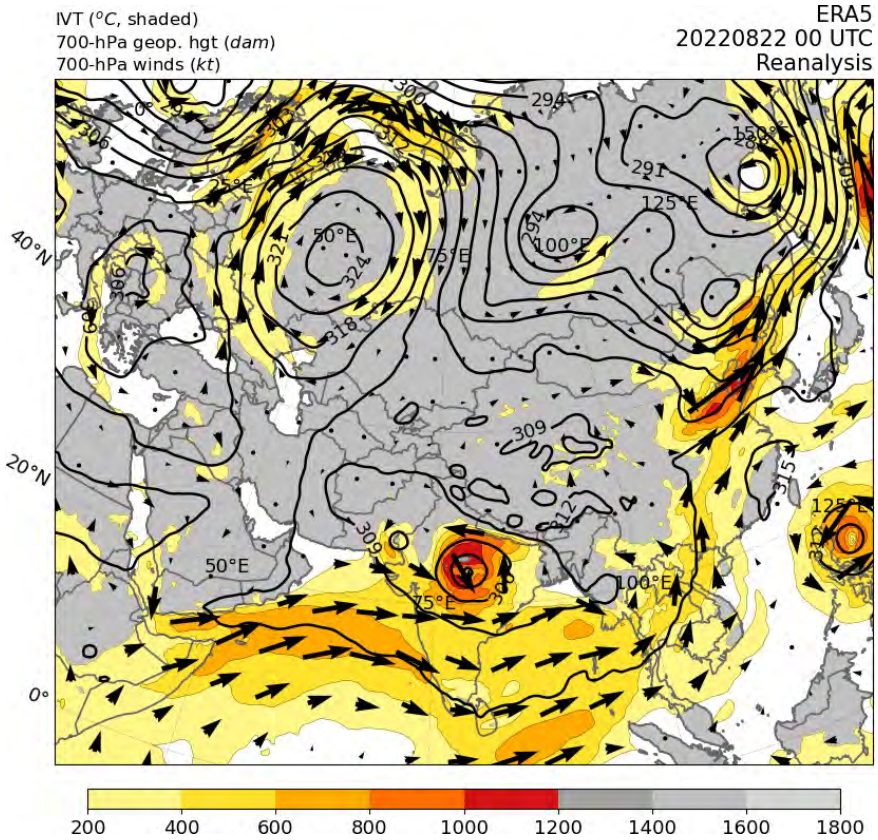
700-hPa Heights, Winds, and IVT for 0000 UTC 16 August 2024 (Left) and 0000 UTC 18 August (Right)



IVT Units: kg m^{-1} s^{-1}

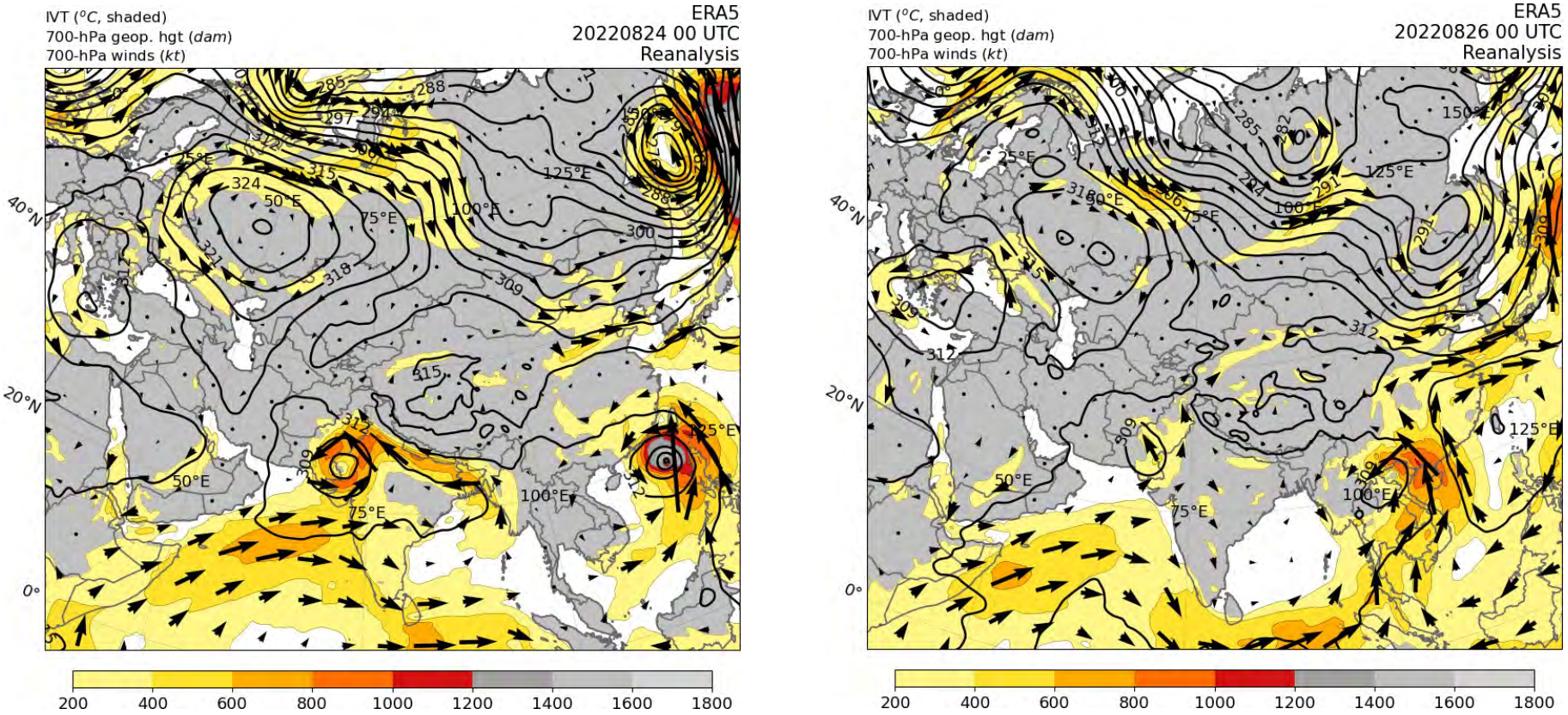
700-hPa Heights, Winds, and IVT for 0000 UTC 20 August 2024 (Left) and 0000 UTC 22 August (Right)





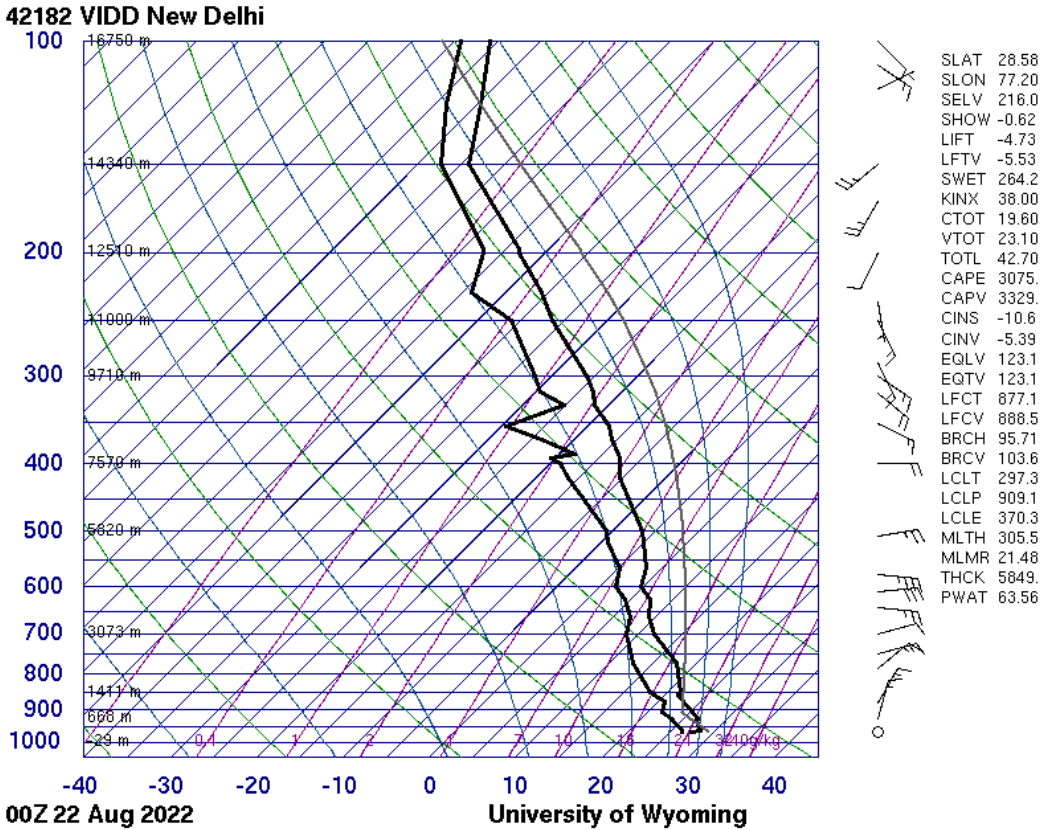
IVT Units: kg m^{-1} s^{-1}

700-hPa Heights, Winds, and IVT for 0000 UTC 24 August 2024 (Left) and 0000 UTC 26 August (Right)



IVT Units: kg m^{-1} s^{-1}

New Delhi, India (VIDD) Sounding: 0000 UTC 22 August 2022



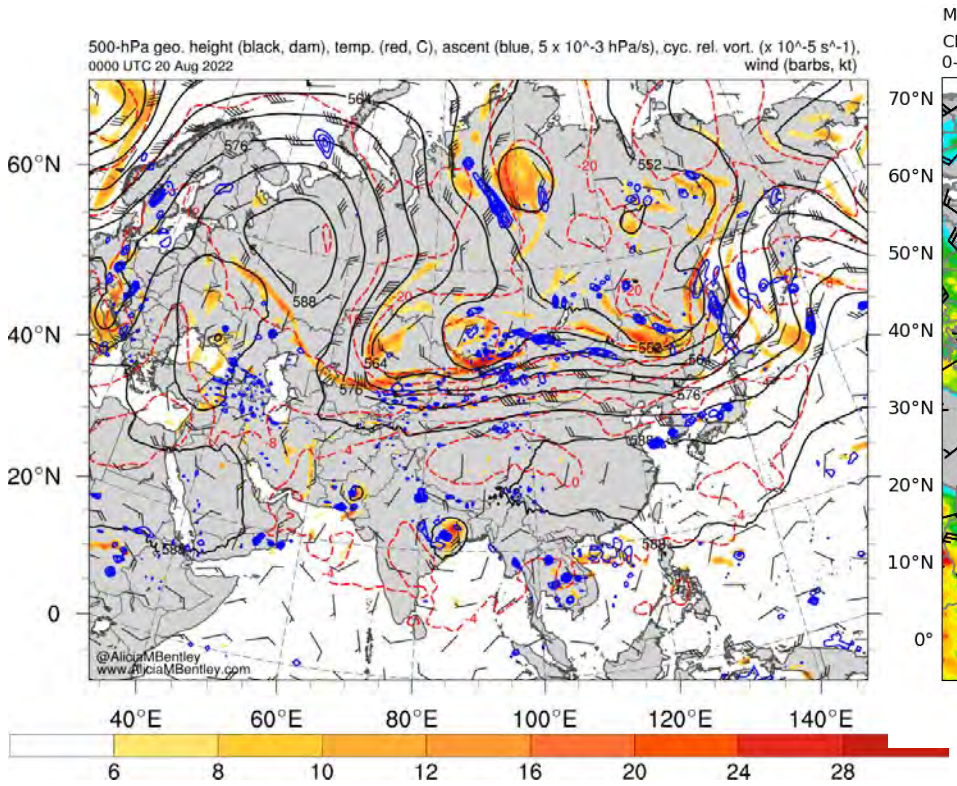
PW = 63.56 mm

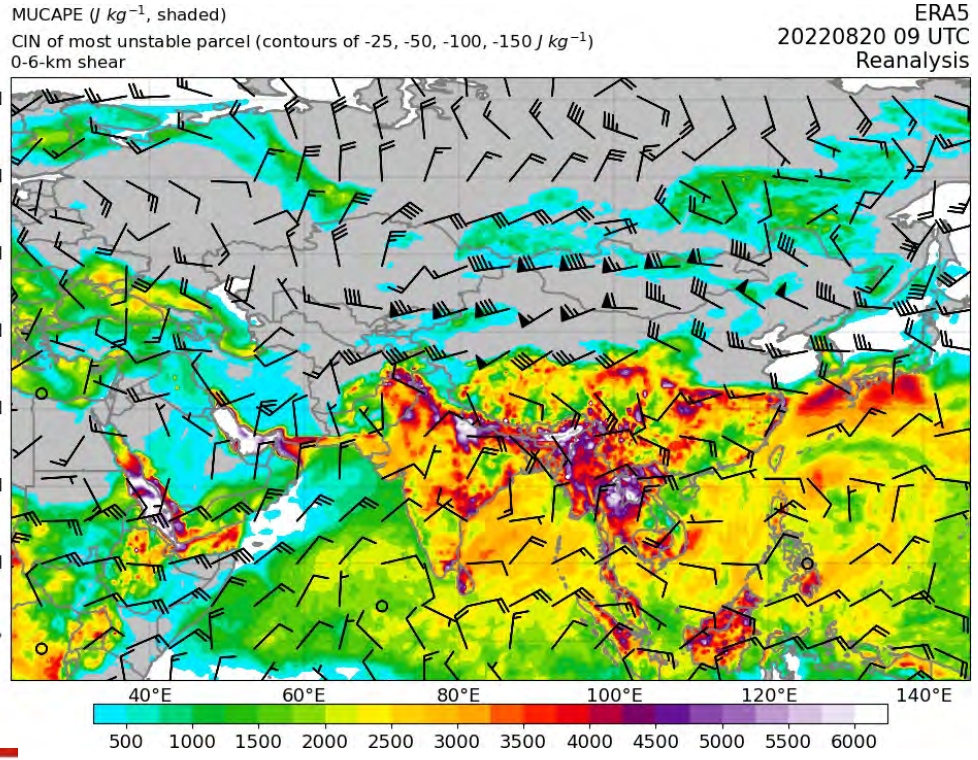
Deep warm-air advection poleward of BOB tropical depression #6

No raobs available from Pakistan

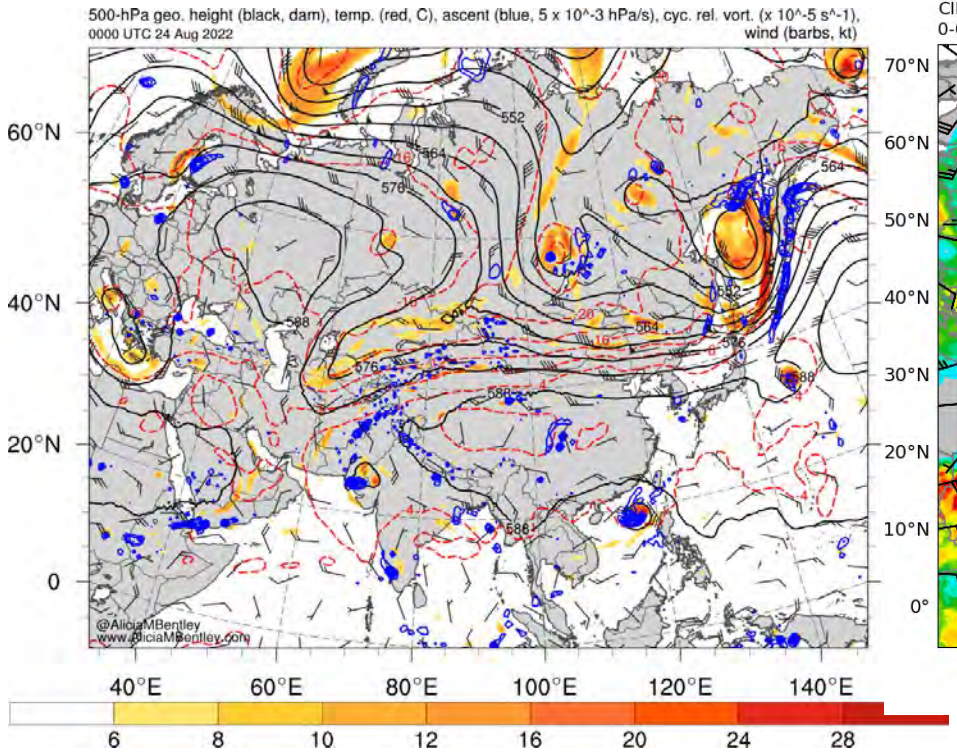
Source: http://weather.uwyo.edu/upperair/sounding.html

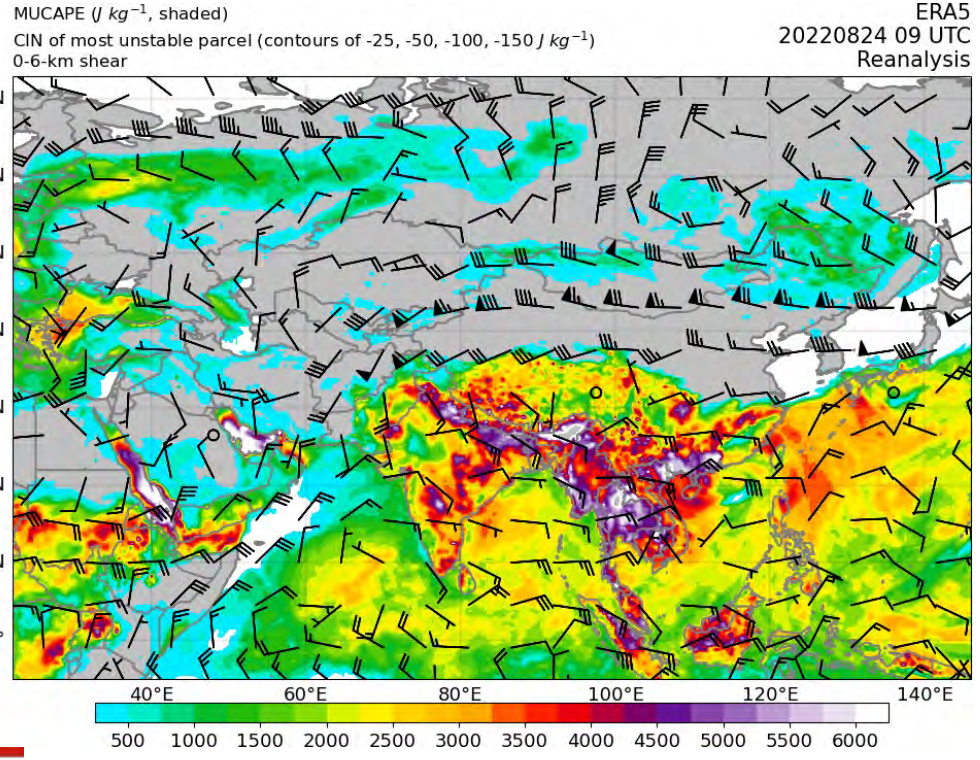
Left: 500-hPa Heights, Winds, Ascent (blue), and Cyclonic Relative Vorticity
Right: MUCAPE (J/kg, shaded), and 0–6-km Shear (m s^{-1})
Time: 0000 UTC 20 August 2022



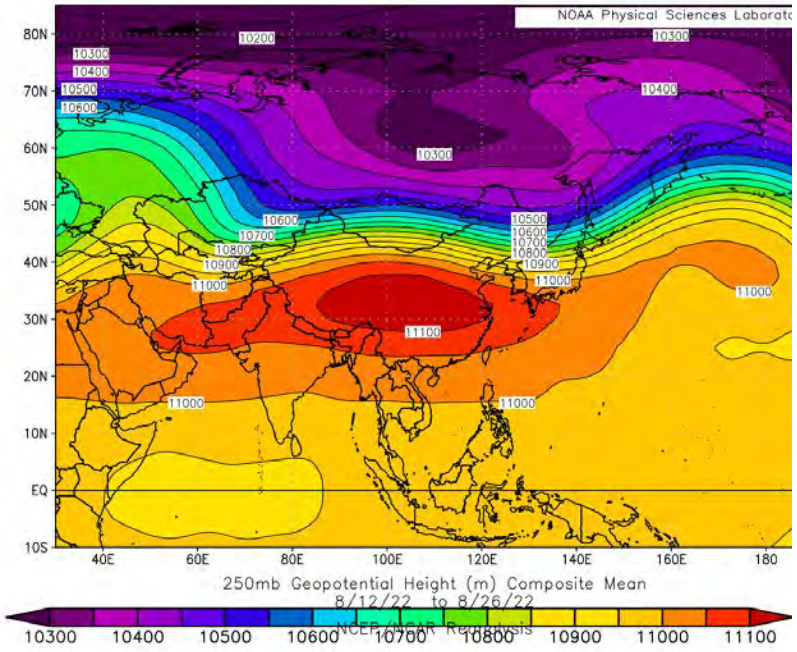


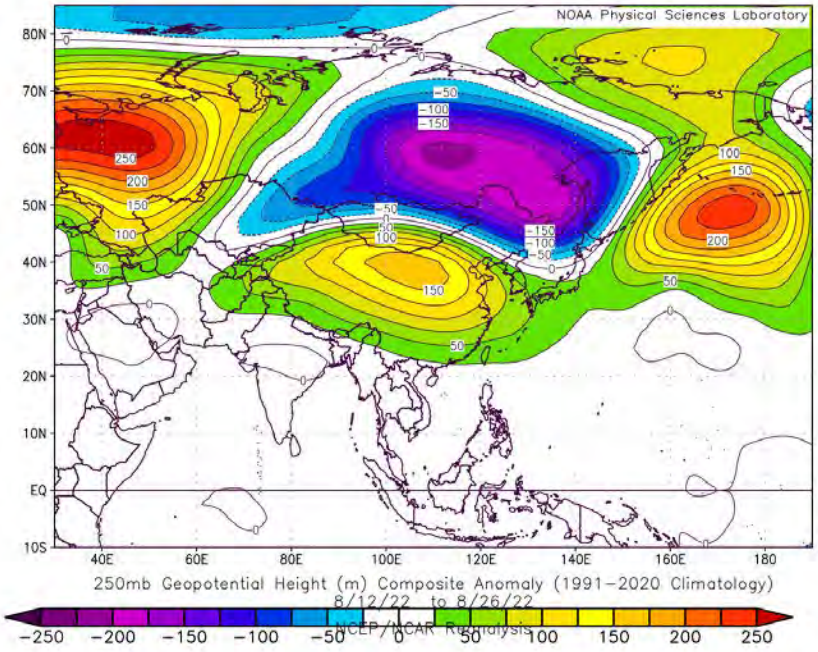
Left: 500-hPa Heights, Winds, Ascent (blue), and Cyclonic Relative Vorticity
Right: MUCAPE (J/kg, shaded), and 0–6 km Shear (m s^{-1})
Time: 0000 UTC 24 August 2022



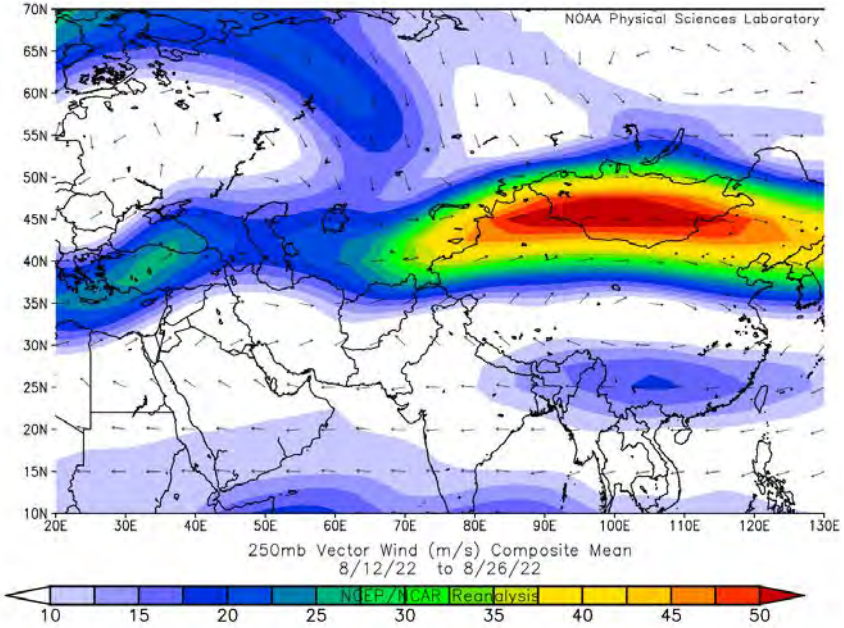


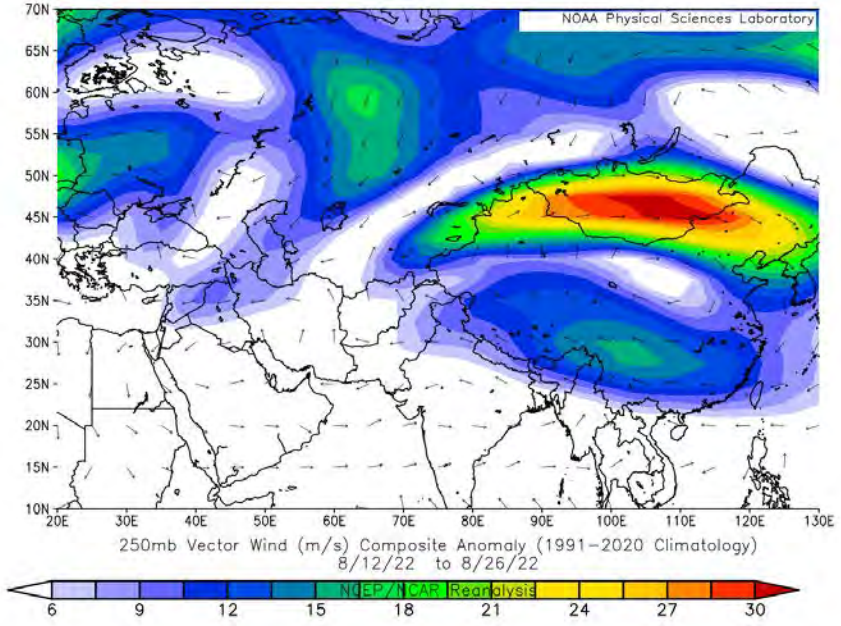
Mean (left) and Anomaly (right) 500-hPa Geopotential Heights for 12–26 August 2022



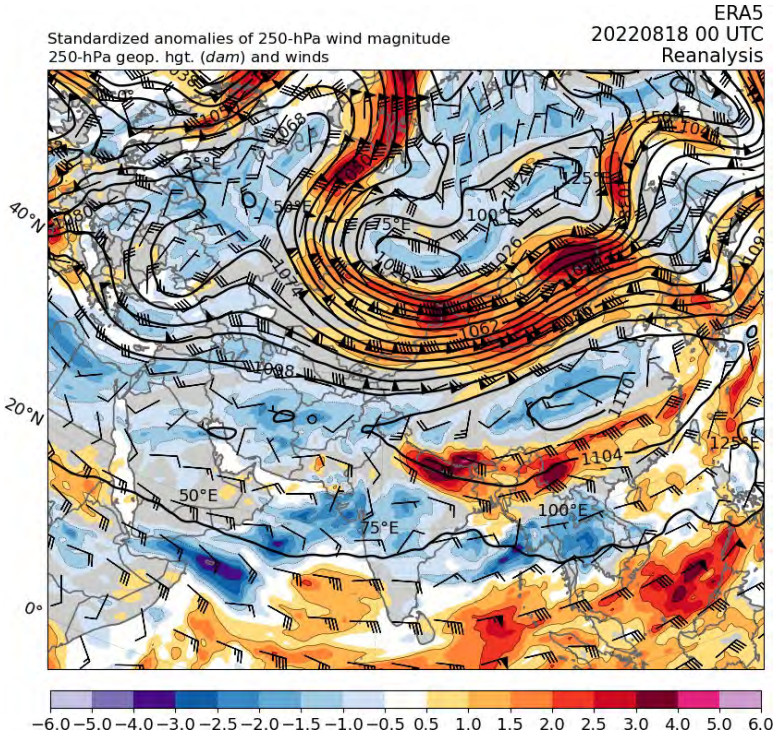


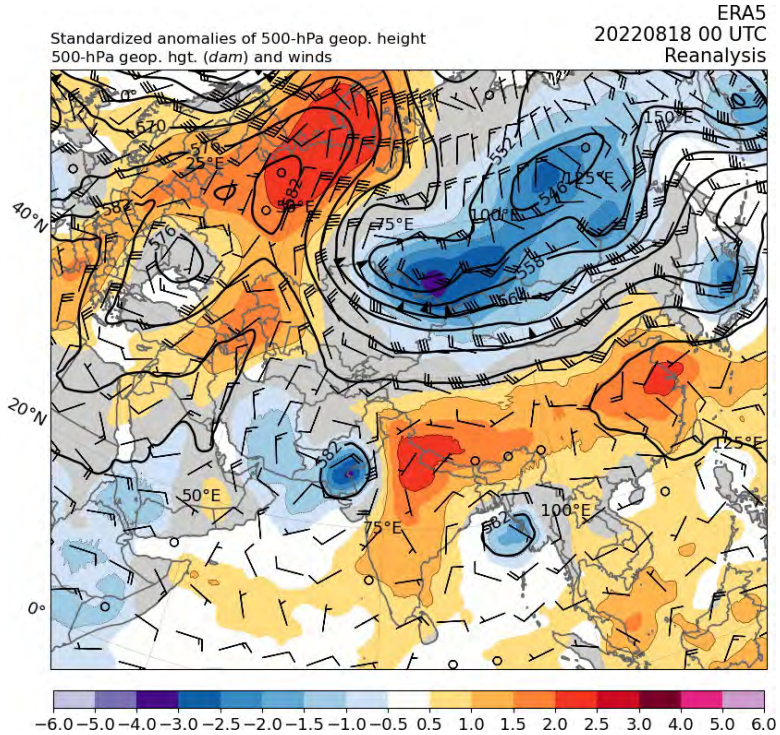
Mean (left) and Anomaly (right) 250-hPa Winds (m s^{-1}) for 12–26 August 2022



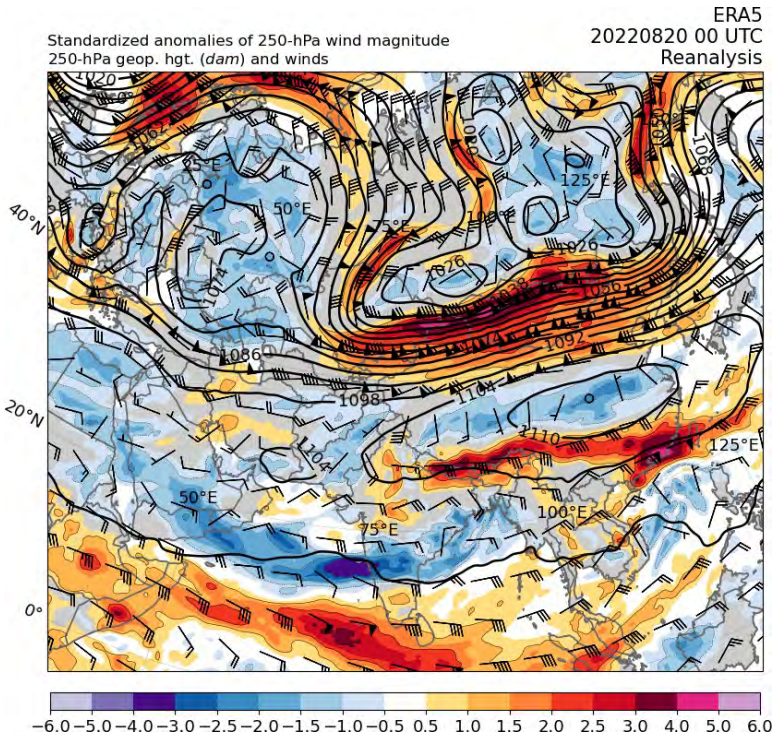


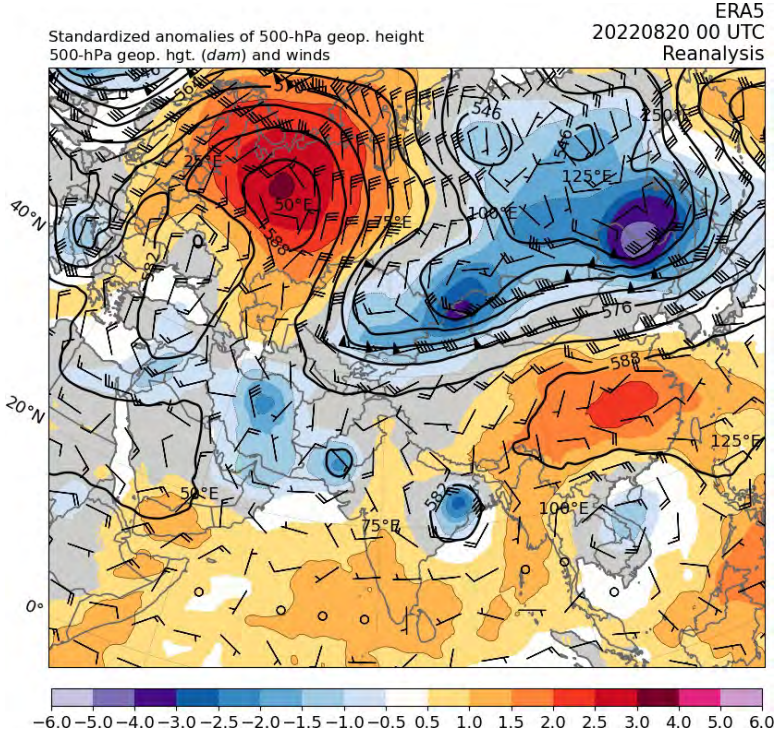
Left: 250-hPa Heights, Winds, and Standardized Anomaly Winds
Right: 500-hPa Heights and Standardized Anomaly Heights
0000 UTC 18 Aug 2022



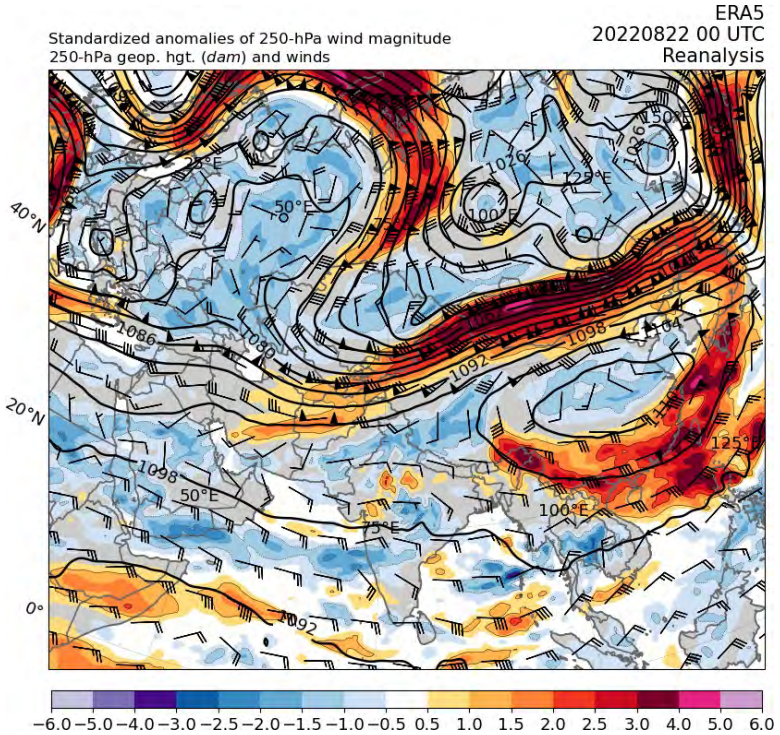


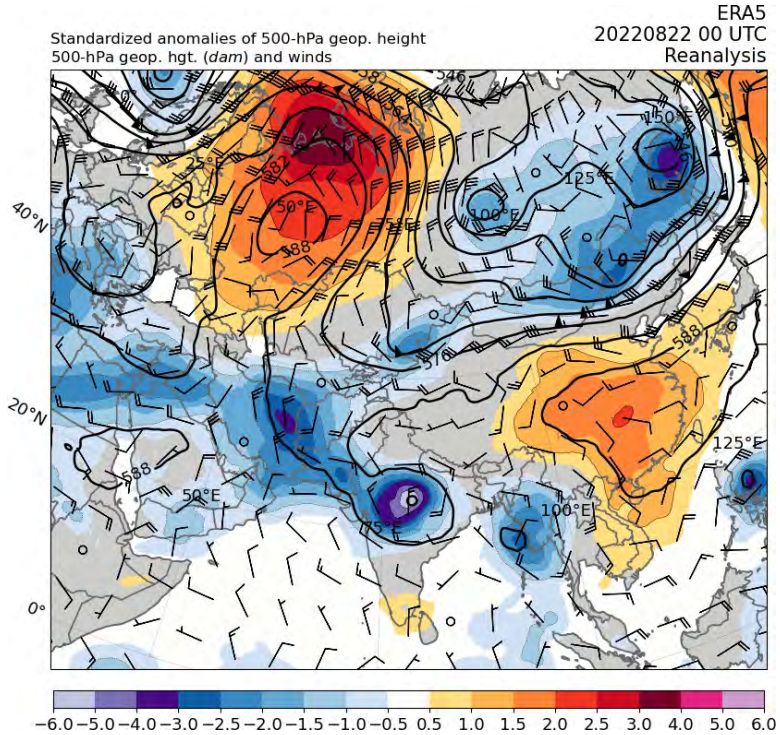
Left: 250-hPa Heights, Winds, and Standardized Anomaly Winds
Right: 500-hPa Heights and Standardized Anomaly Heights
0000 UTC 20 Aug 2022



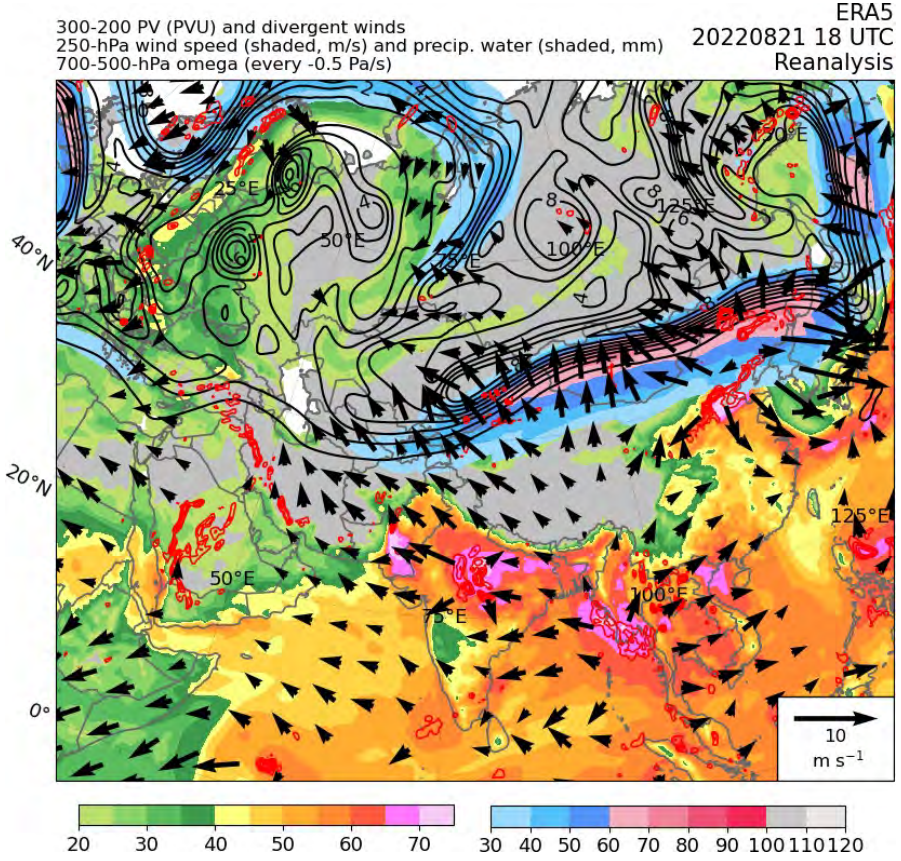


Left: 250-hPa Heights, Winds, and Standardized Anomaly Winds
Right: 500-hPa Heights and Standardized Anomaly Heights
0000 UTC 22 Aug 2022





300–200-hPa PV (contours) and Irrotational Winds (arrows), and 250-hPa Winds (m s^{-1})
Precipitable water (shaded, mm), and 700–500-hPa Vertical Motion (-0.5 Pa s^{-1})
1800 UTC 21 August 2022



Testable Hypotheses

- **The evolution of the large-scale flow pattern favored an anomalously strong jet stream to the north of the Tibetan Plateau**
- **Negative potential vorticity advection by the irrotational wind due to deep convection over Pakistan and India further strengthened this jet stream**
- **Rainfall was especially heavy and persistent in the equatorward entrance region of the aforementioned jet stream**

Summary

- Intense Mediterranean trough was a catalyst for severe weather and downstream flow amplification across Eurasia
- Strong downstream upper-level ridge over eastern Europe resulted in the formation of a deep upper-level trough over central Asia
- Central Asia trough facilitated moisture transport from the Bay of Bengal and the Arabian Sea toward India and Pakistan
- Heavy rainfall in Pakistan can be linked equatorward jet-entrance region dynamics (very rare for August)

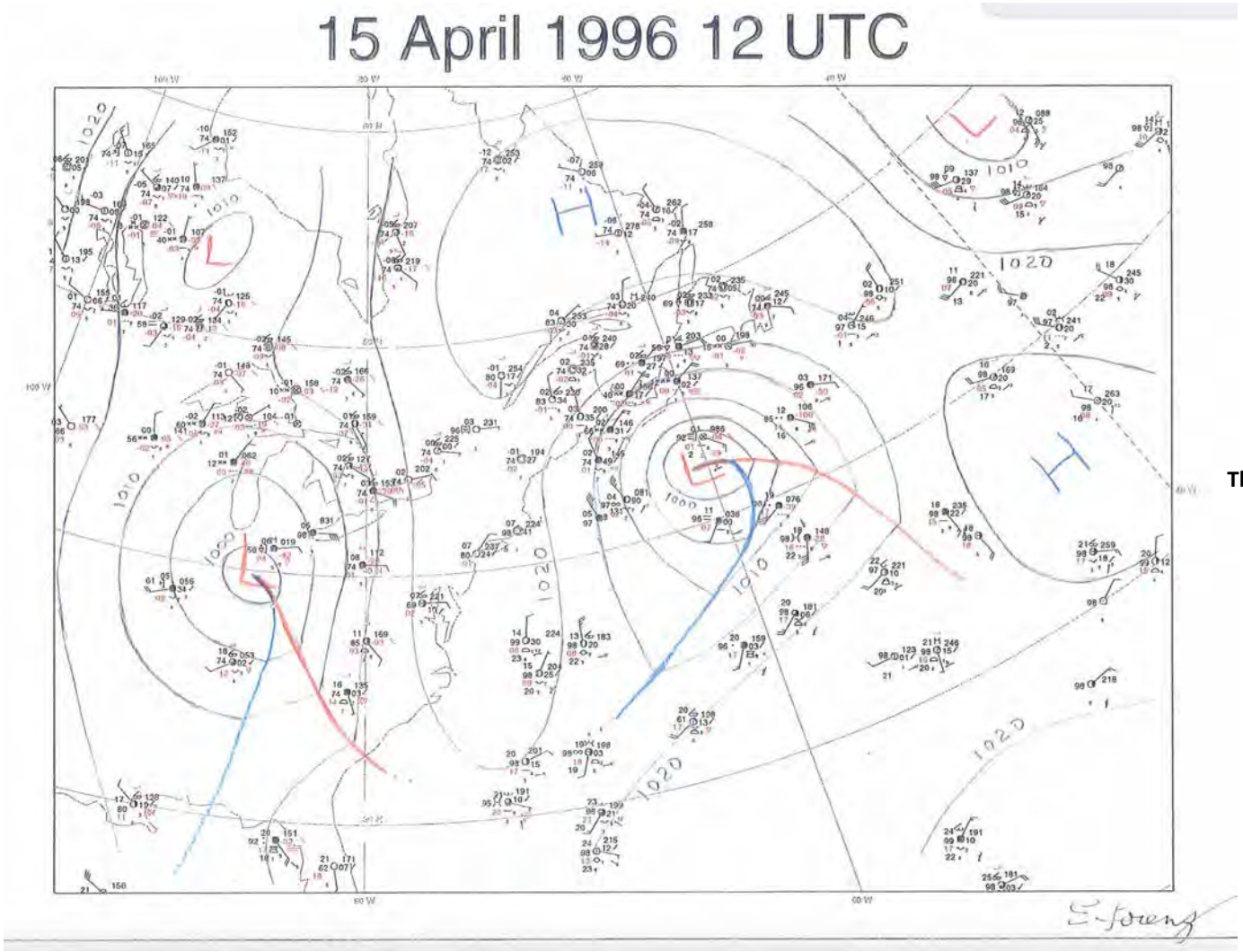
A Concluding Comment:

- **Excerpt from Randall and Emanuel (2024): The Weather-Climate Schism**

- **"The atmospheric science community includes both weather and climate scientists. These two**
- **groups interact much less than they should, particularly in the United States. The schism is**
- **widespread and has persisted for 50 years or more. It is found in academic departments,**
- **laboratories, professional societies, and even funding agencies. Mending the schism would**
- **promote better, faster science. We sketch the history of the schism and suggest ways to make**
- **our community whole."**

- **What would Edward Lorenz think about this continuing schism between weather and climate researchers? I postulate that he would agree with Randall and Emanuel (2024)***

*** Randall and Emanuel (2024): The Weather-Climate Schism** (https://doi.org/10.1175/BAMS-D-23-0124.1)

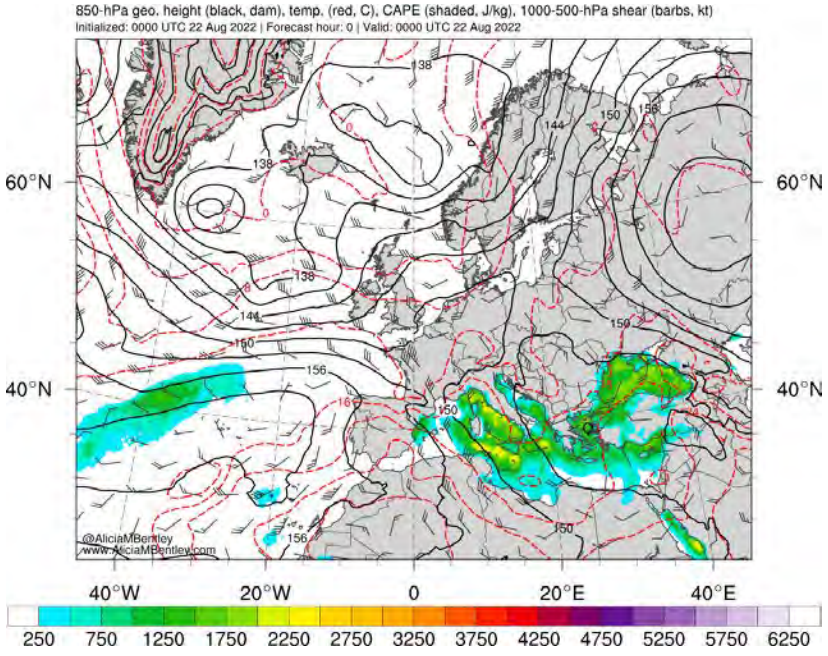


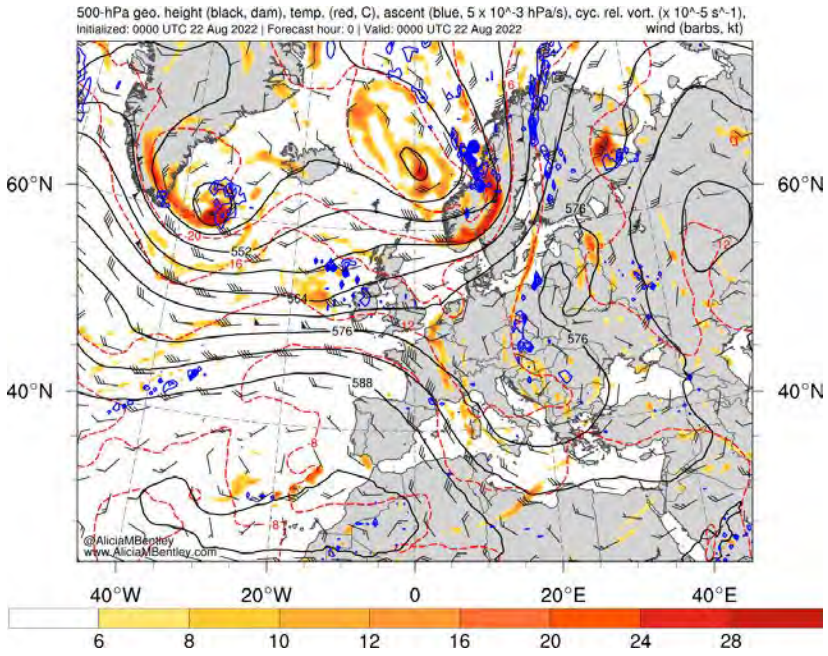
ECMWF
1200 UTC
15 April 1996

Thanks to Jim Doyle for his great foresight in saving this hand-analyzed weather map

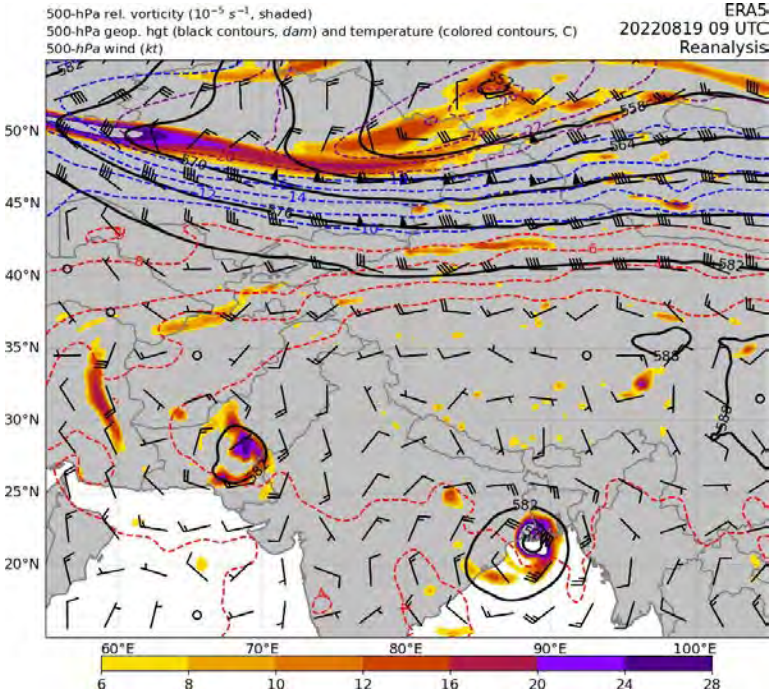
Extra Slides

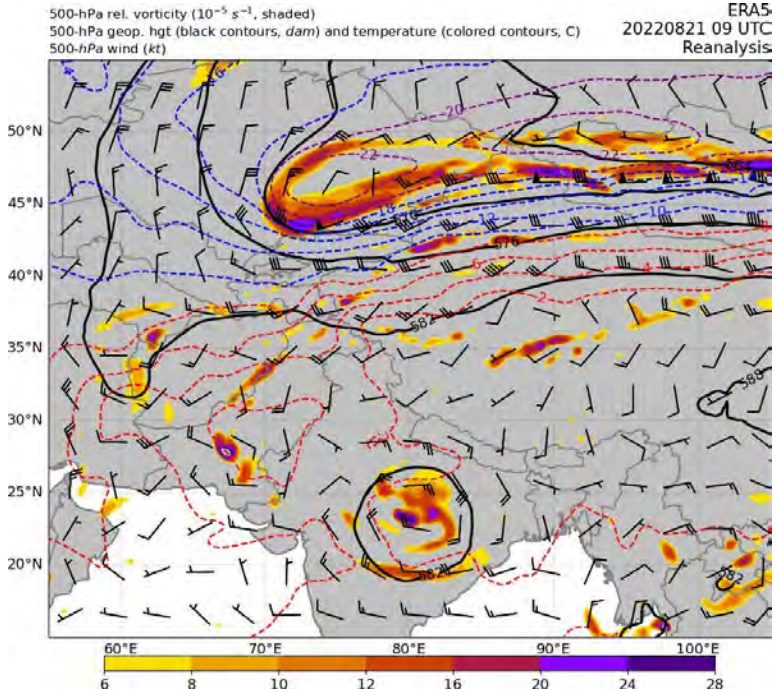
Left: 850-hPa Heights, Temps, CAPE (J/kg), 1000–500-hPa Shear (barbs, kt)
Right: 500-hPa Heights, Temps, Ascent (blue), and Cyclonic Rel. Vorticity (shaded)
Time: 0000 UTC 22 August 2022



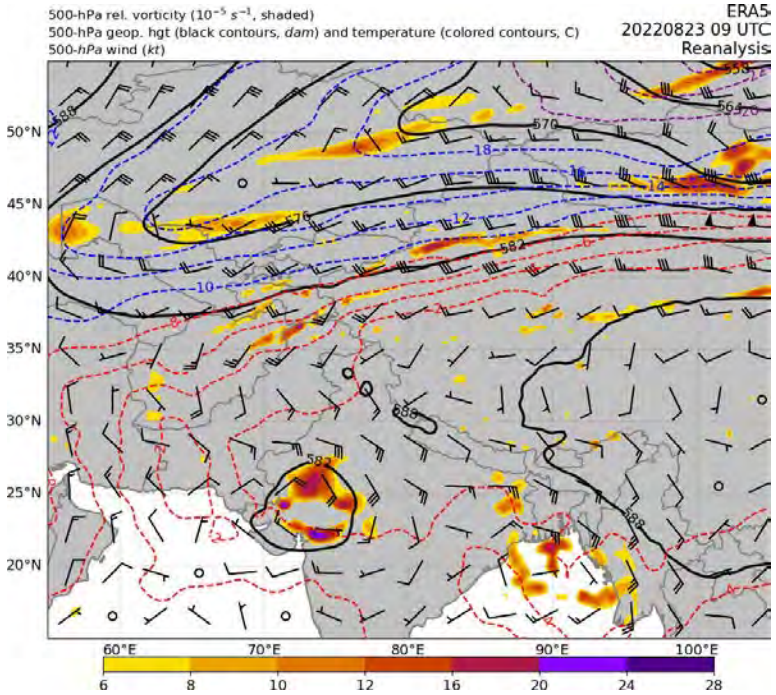


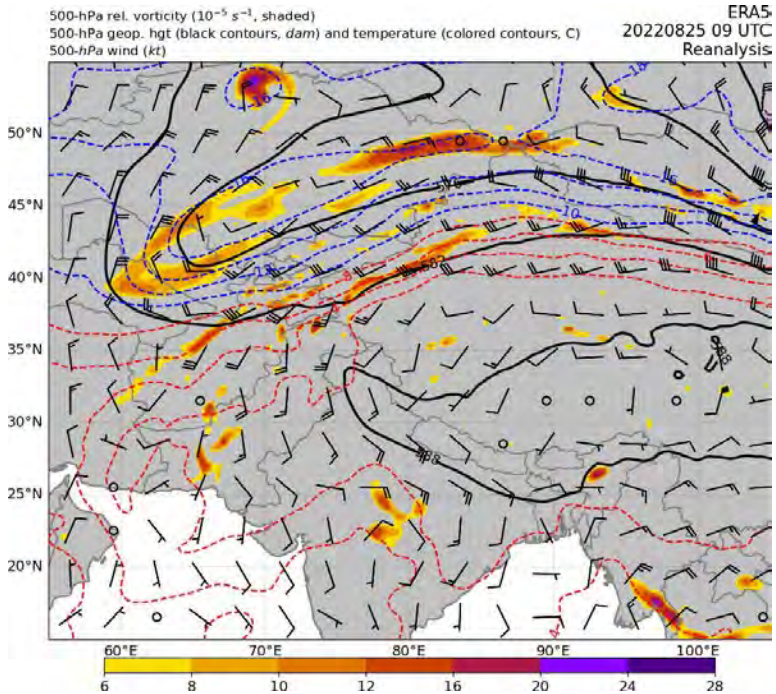
500-hPa Heights (dam) and Relative Vorticity (10^{-5} s^{-1}), 500-hPa Temperatures (C) and 500-hPa Winds (kts): 0900 UTC 19 August (Left) and 0900 UTC 21 August 2022 (Right)





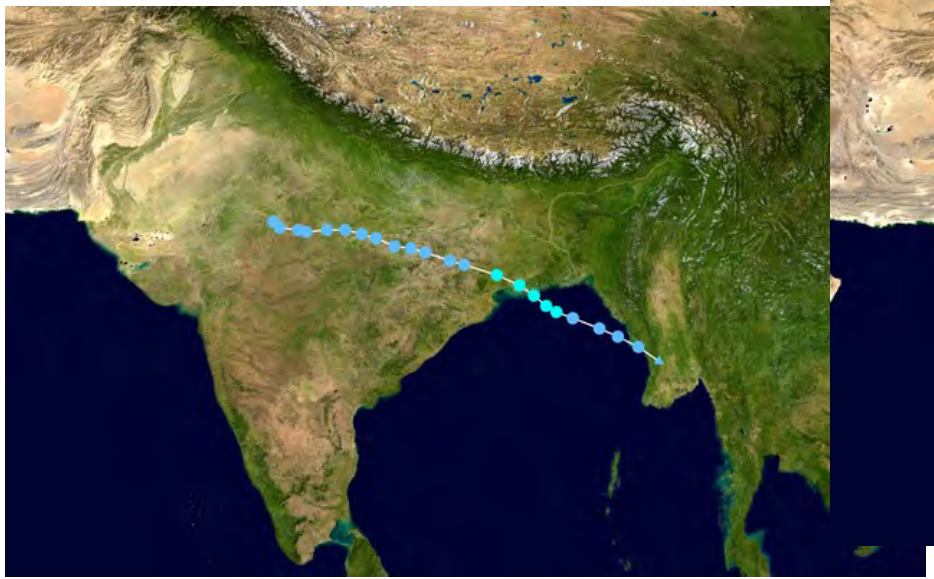
500-hPa Heights (dam) and Relative Vorticity (10^{-5} s^{-1}), 500-hPa Temperatures (C) and 500-hPa Winds (kts): 0900 UTC 23 August (Left) and 0900 UTC 25 August 2022 (Right)



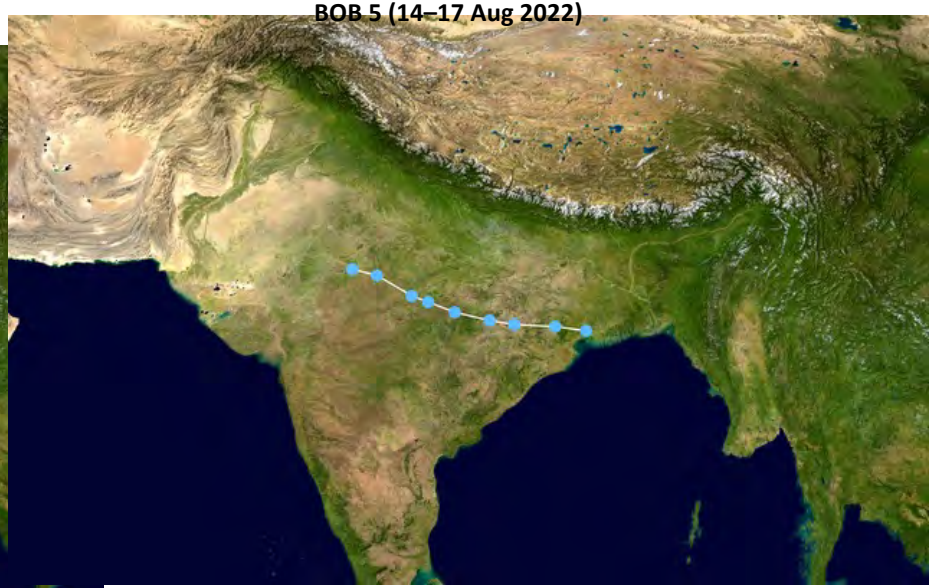


Bay of Bengal (BOB) Tropical Depression Tracks

BOB 6 (18–23 Aug 2022)



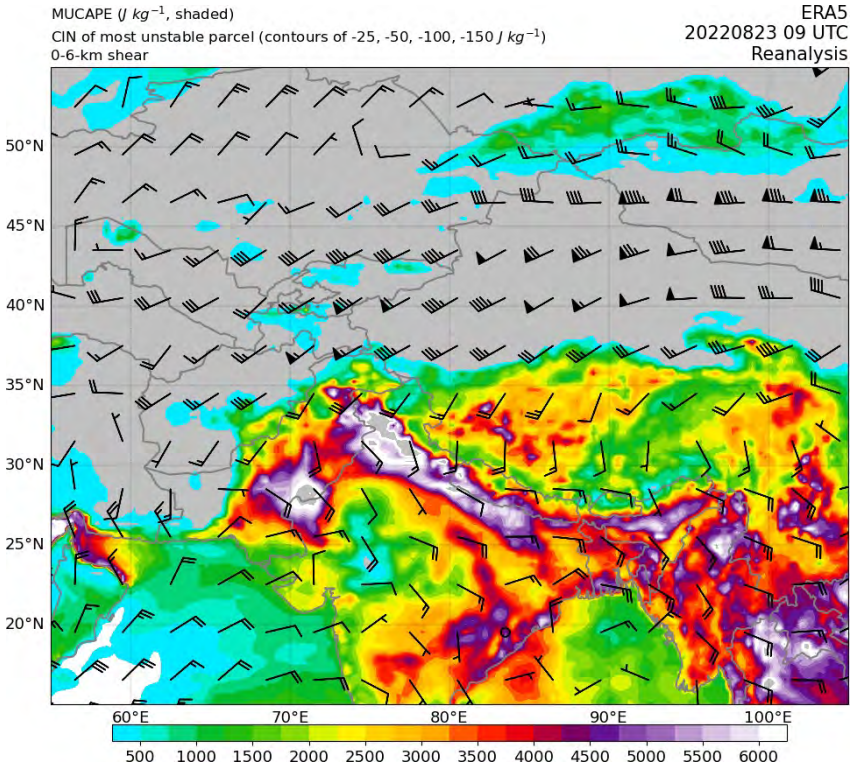
BOB 5 (14–17 Aug 2022)

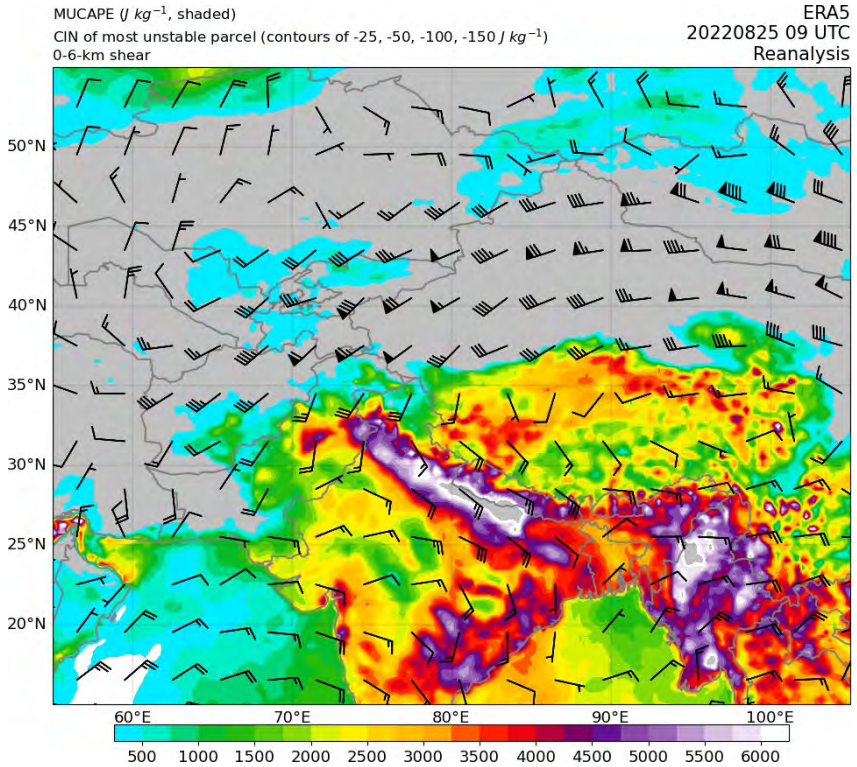


1. Emanuel et al. (2008): A Hypothesis for the Redevelopment of Warm-Core Cyclones over Northern Australia, *Monthly Weather Review.* **136** (10): 3863–3872. DOI: https://doi.org/10.1175/2008MWR2409.1
2. Andersen and Shepherd, 2017: Inland Tropical Cyclones and the "Brown Ocean" Concept. In: Collins, J., Walsh, K. (eds) Hurricanes and Climate Change. Springer, Cham. https://link.springer.com/chapter/10.1007/978-3-319-47594-3_5

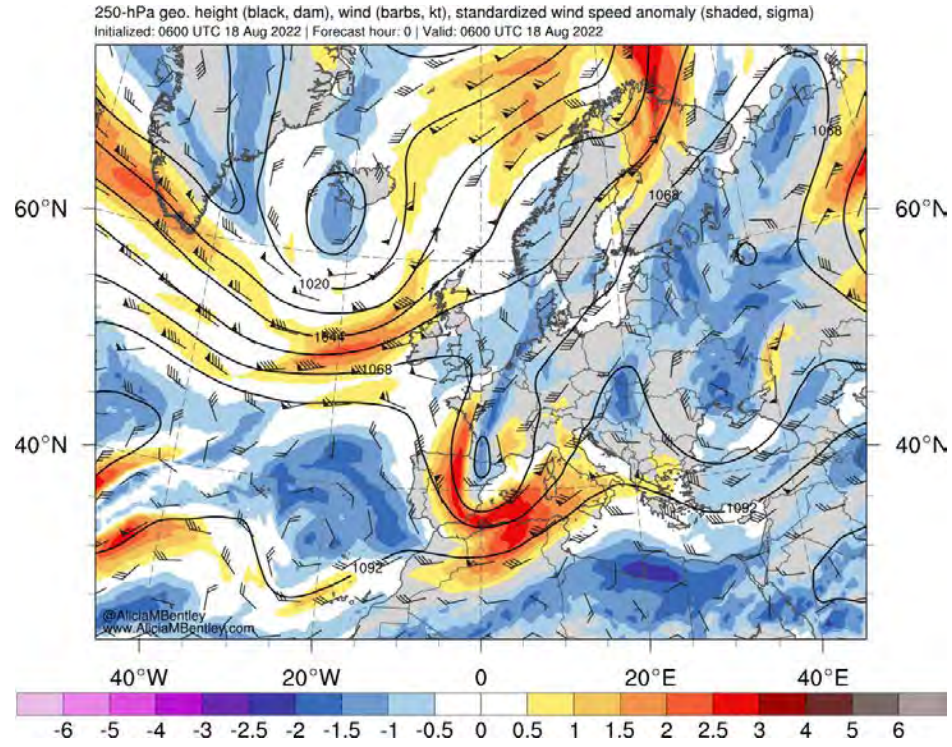
Source: https://en.wikipedia.org/wiki/2022_North_Indian_Ocean_cyclone_season

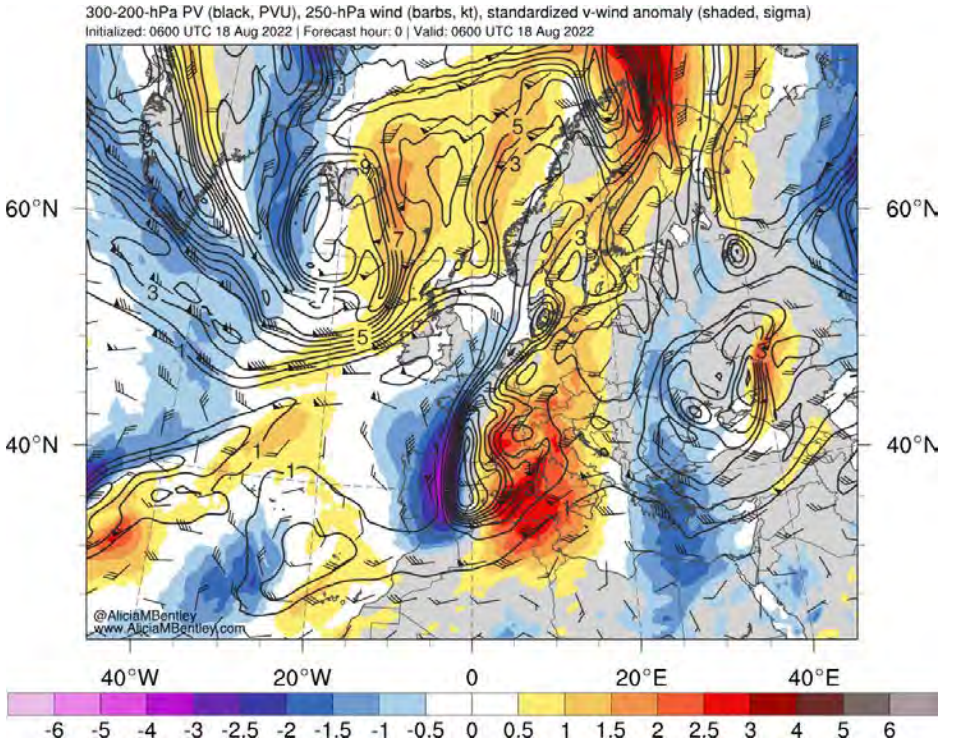
MUCAPE (J kg^{-1} Shaded) and 0-6 km Shear (Wind Barbs) for (Left) 0900 UTC 23 August 2022 and (Right) 0900 UTC 25 August 2022





Left: 250-hPa Heights, Winds, and Standardized Wind Speed Anomalies
Right: 300–200-hPa PV, 250-hPa Winds, and Standardized V-Wind Anomalies
0600 UTC 18 August 2022





Left: 850-hPa Heights, Winds, and Standardized Temperature Anomalies
Right: 925-hPa Heights, Winds, and Standardized Wind Speed Anomalies
0600 UTC 18 August 2022