Overview of Medicanes, Polar Lows, and Subtropical Cyclones

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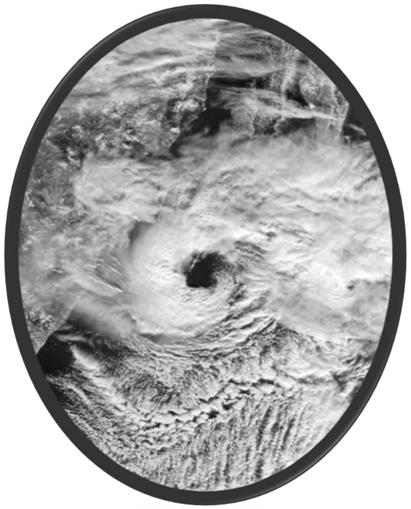
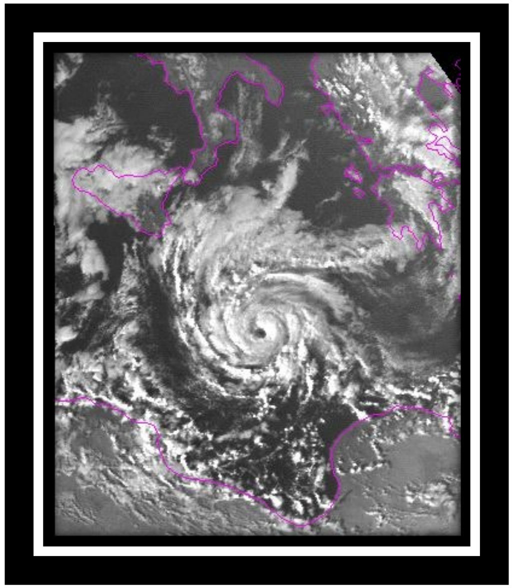
Lorenz Center, MIT

A Mediterranean Brigantine Drifting Onto a Rocky Coast in a Storm -- Willem van de Velde, the Younger, circa 1700

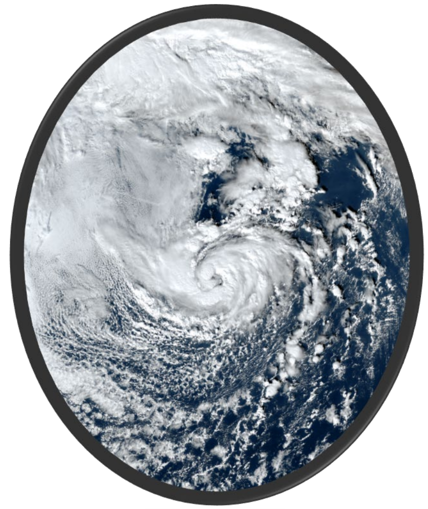
A Rogues' Gallery:



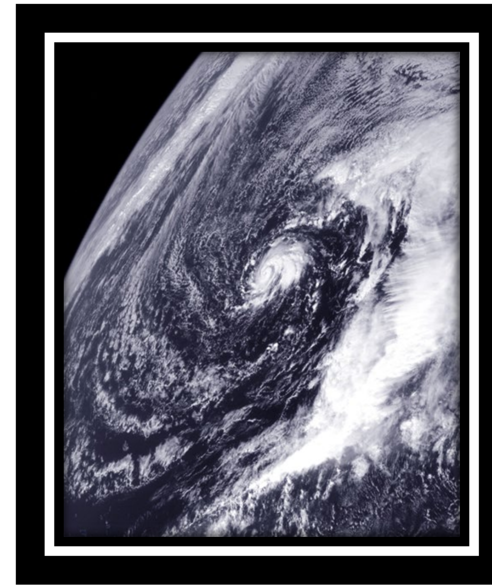
Polar Lows



Medicanes



Subtropical Cyclones



Kona Storms

Hypothesis: These are all operate on the same physics and, as a class, deserve a name

Challenge: Create a name for this class of cyclone

(Best done by group effort at a bar/restaurant)

Examples

- Polar Lows
- Medicanes
- Subtropical Cyclones
- Kona Storms

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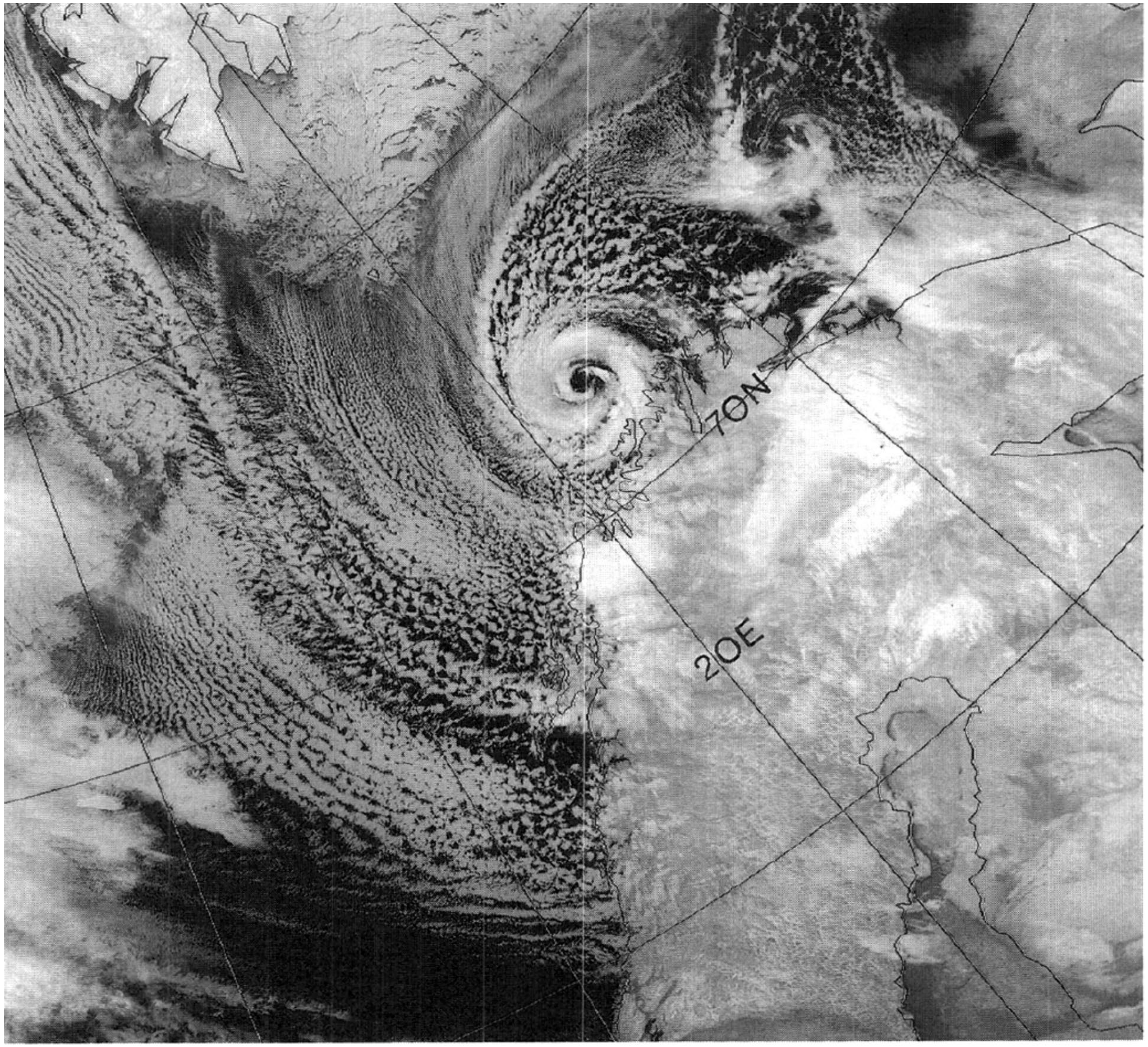
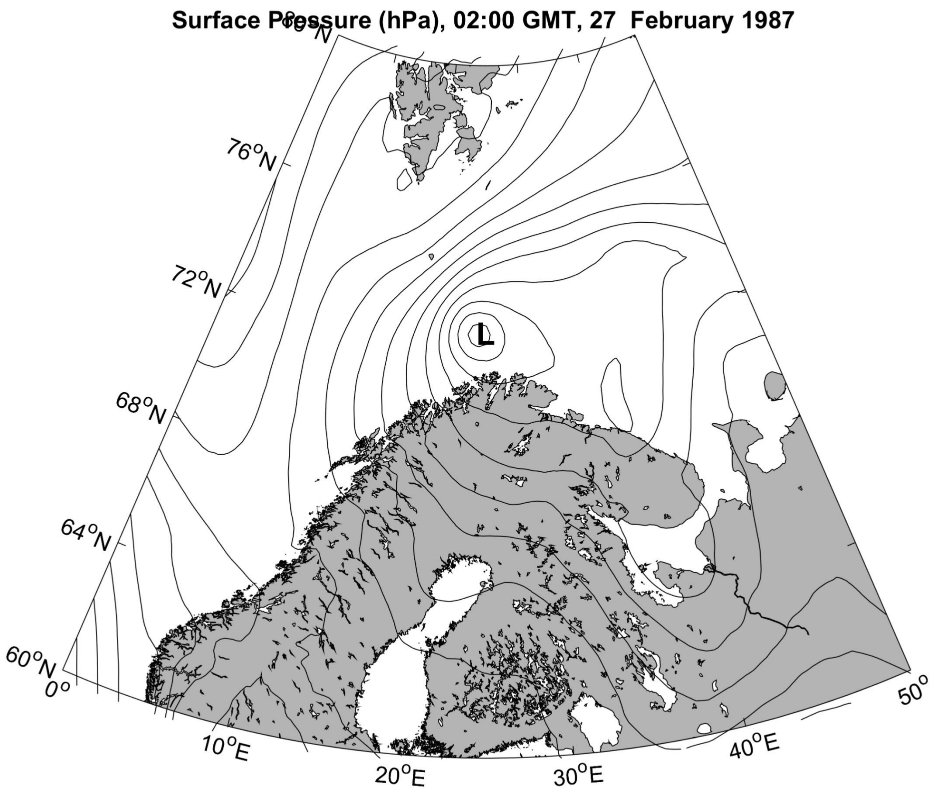
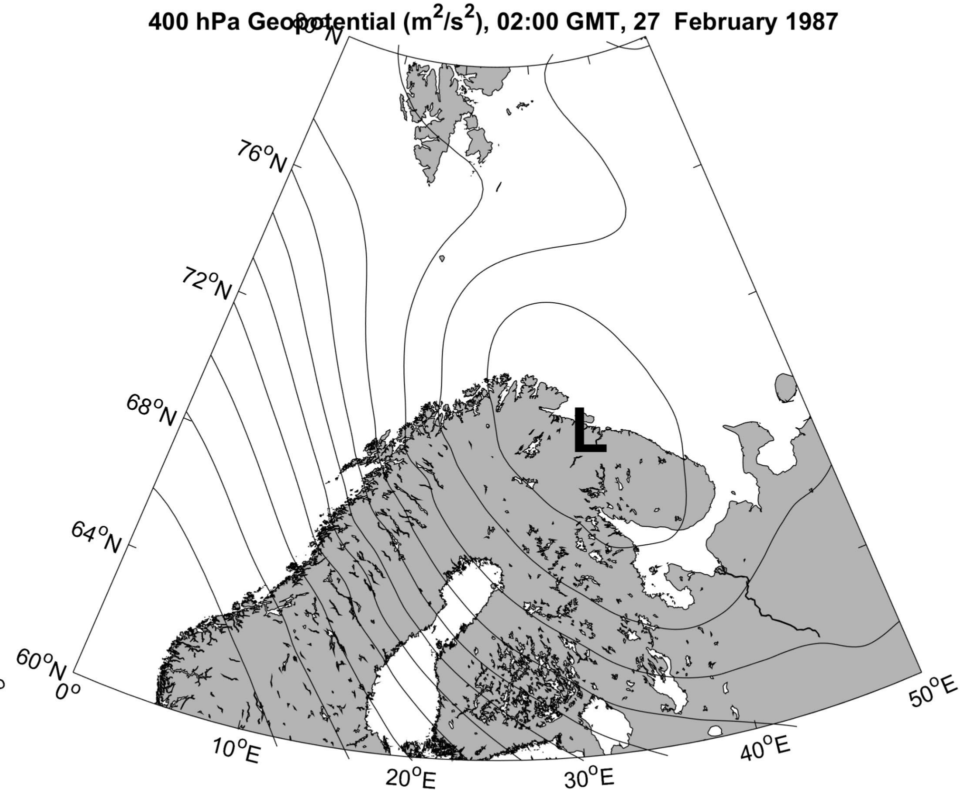
Polar Low over the Barents Sea at 02:24 GMT, 27 February 1987



Polar Low over the Barents Sea at 02:24 GMT, 27 February 1987

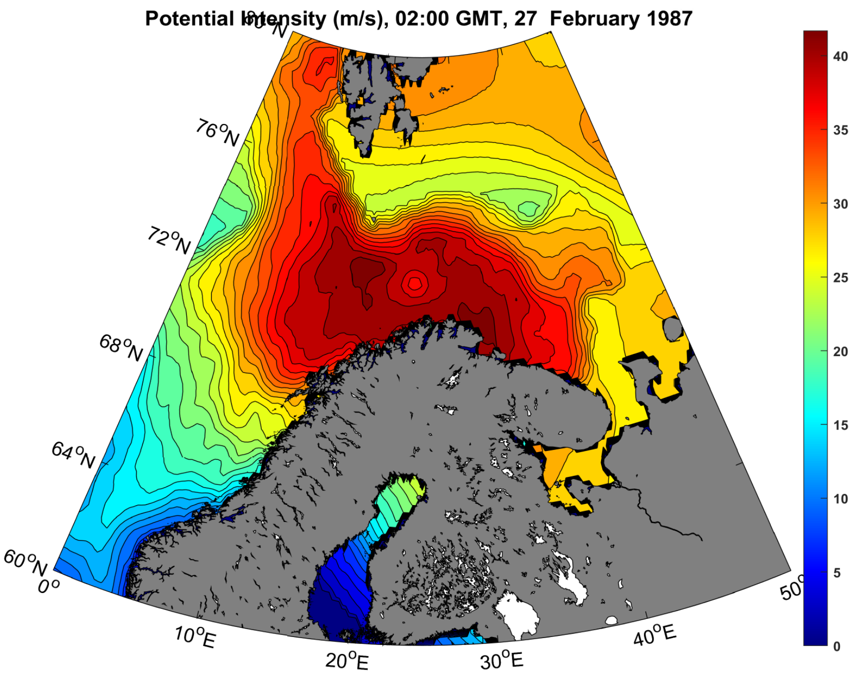


Surface Pressure

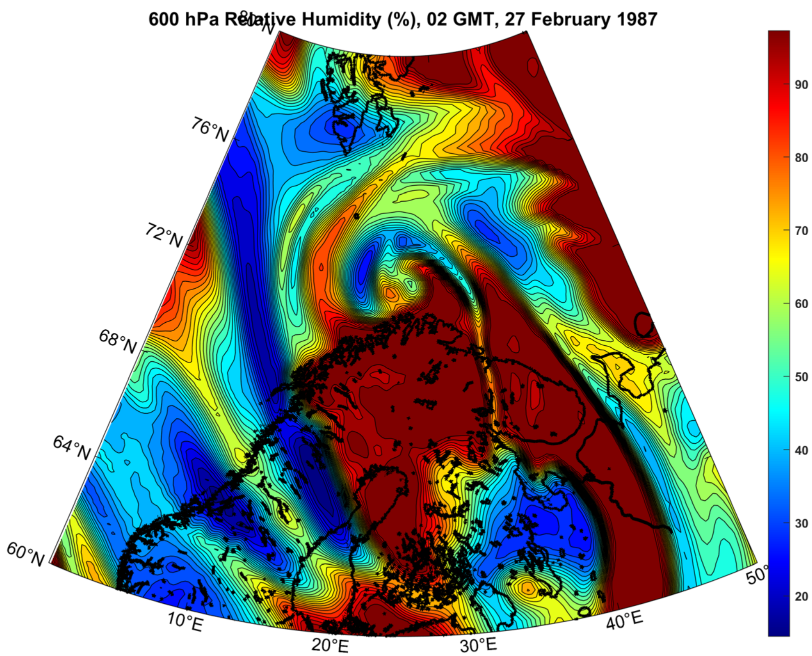


400 hPa Geopotential

Polar Low over the Barents Sea at 02:24 GMT, 27 February 1987

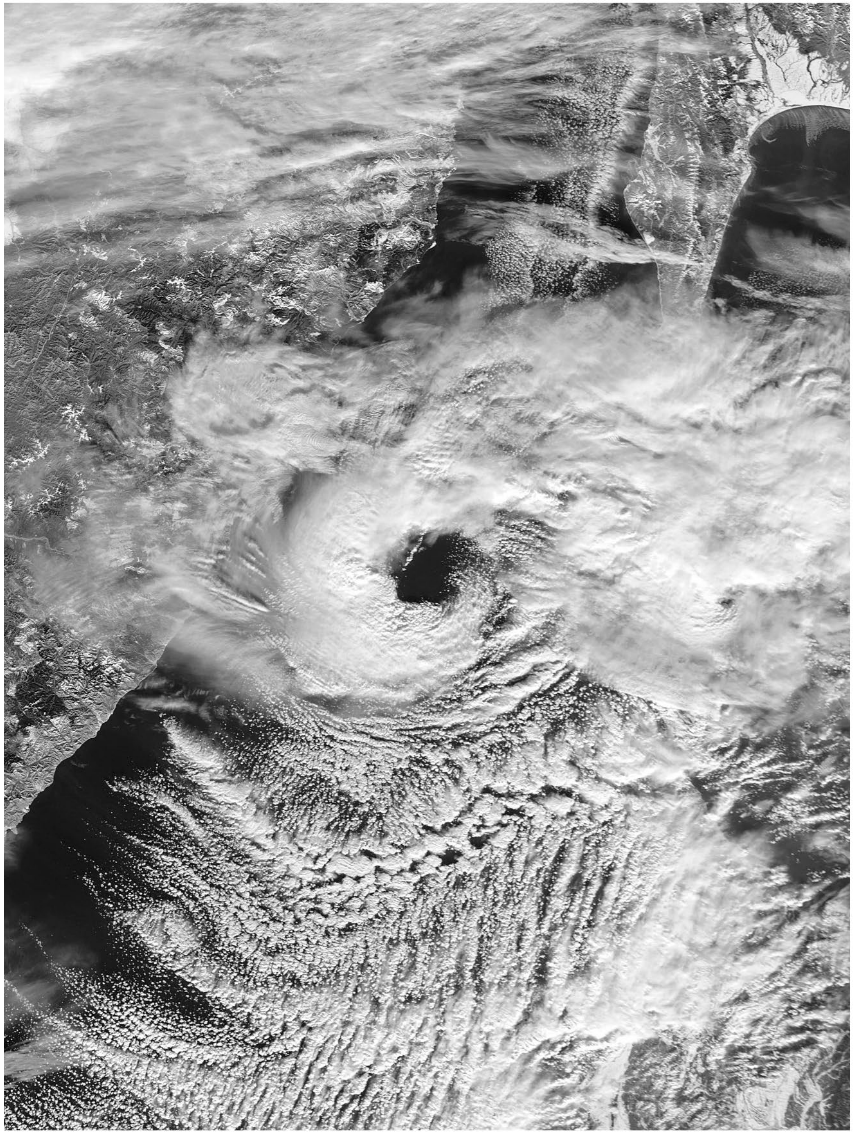


Potential Intensity (m/s)

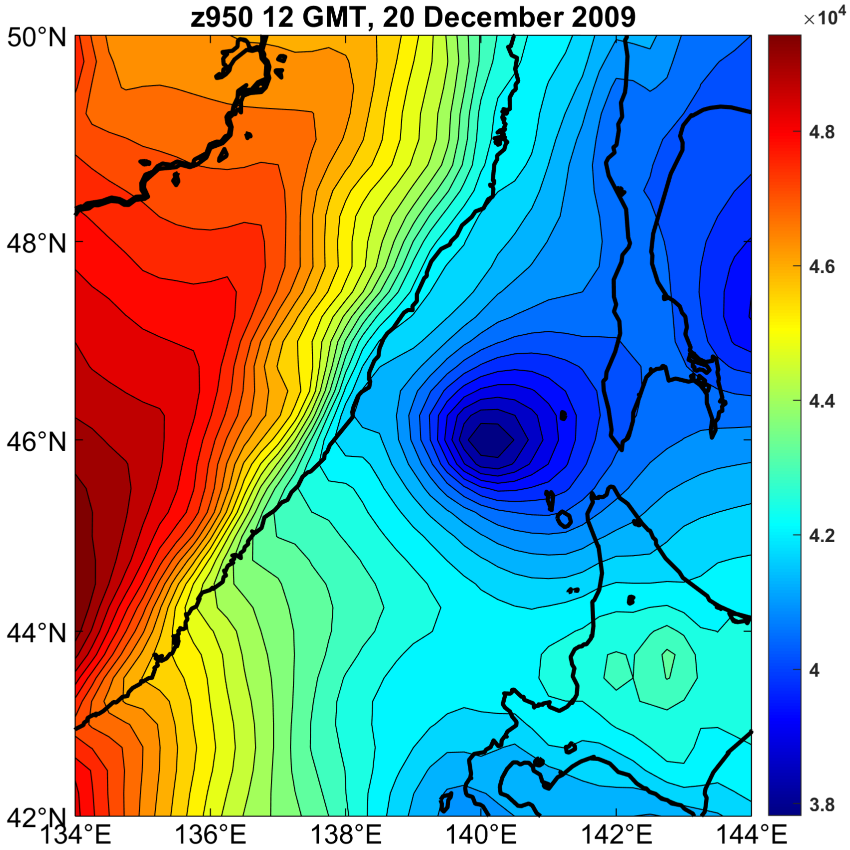


600 hPa Relative Humidity (%)

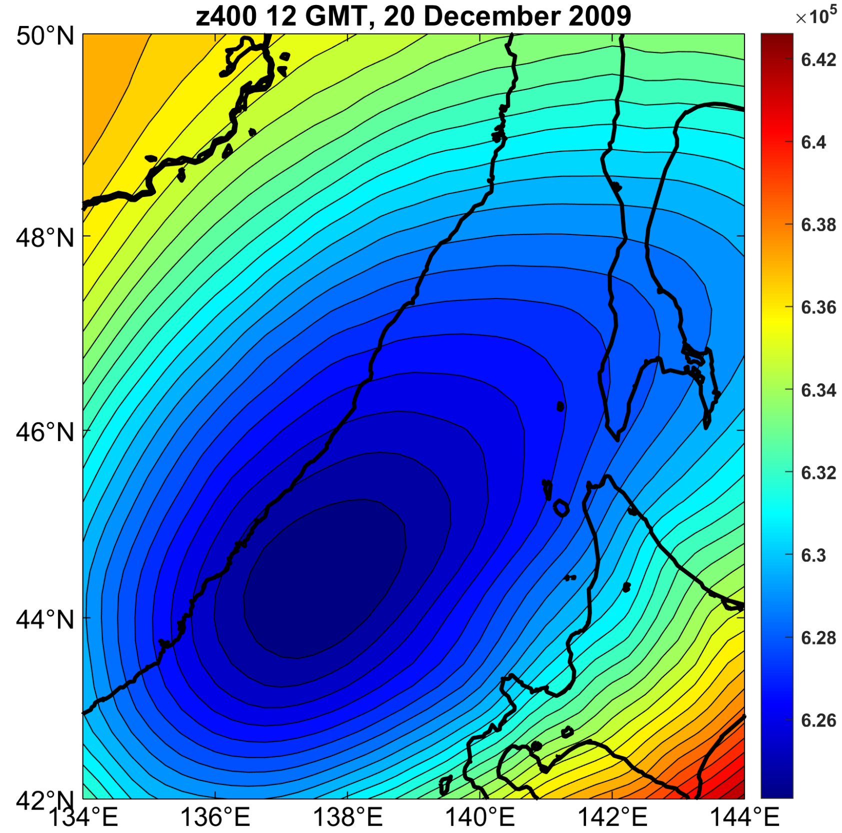
Polar Low over the Northern Sea of Japan at 02:00 GMT, 20 December 2009



Polar Low over the Northern Sea of Japan at 02:00 GMT, 20 December 2009

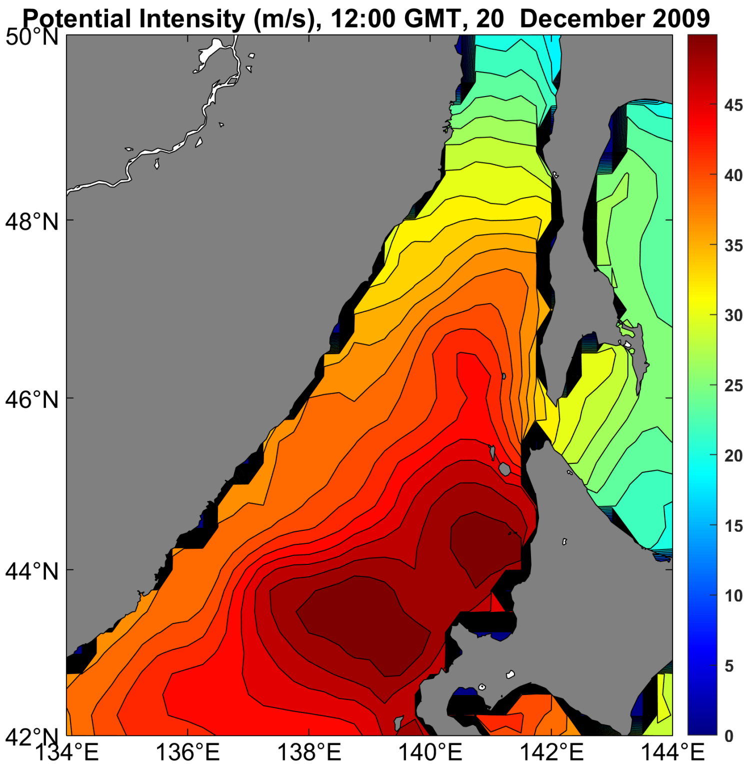


950 hPa Geopotential

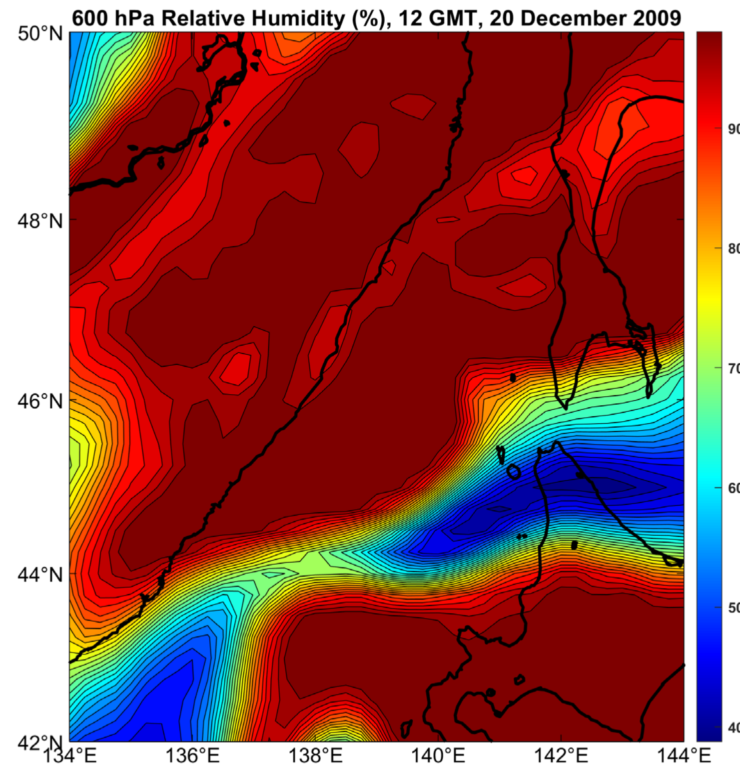


400 hPa Geopotential

Polar Low over the Northern Sea of Japan at 02:00 GMT, 20 December 2009

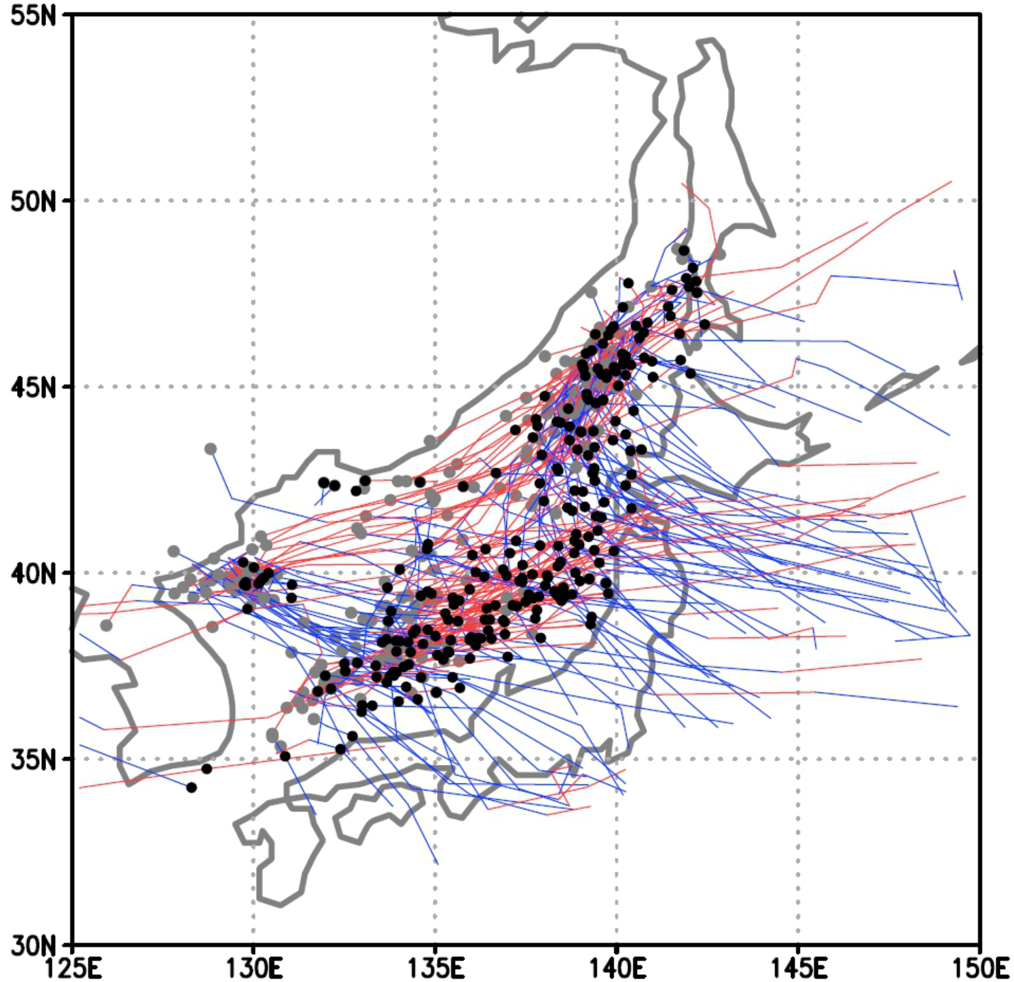


Potential Intensity (m/s)



600 hPa Relative Humidity (%)

Origin points and tracks of polar lows over the Sea of Japan identified in JRA-55 reanalyses over the period 1979-2015.



Yanase, W., and co-authors, 2016: Climatology of polar lows over the Sea of Japan using the JRA-55 reanalysis. *J. Climate*, **29,** 419-437.

Examples

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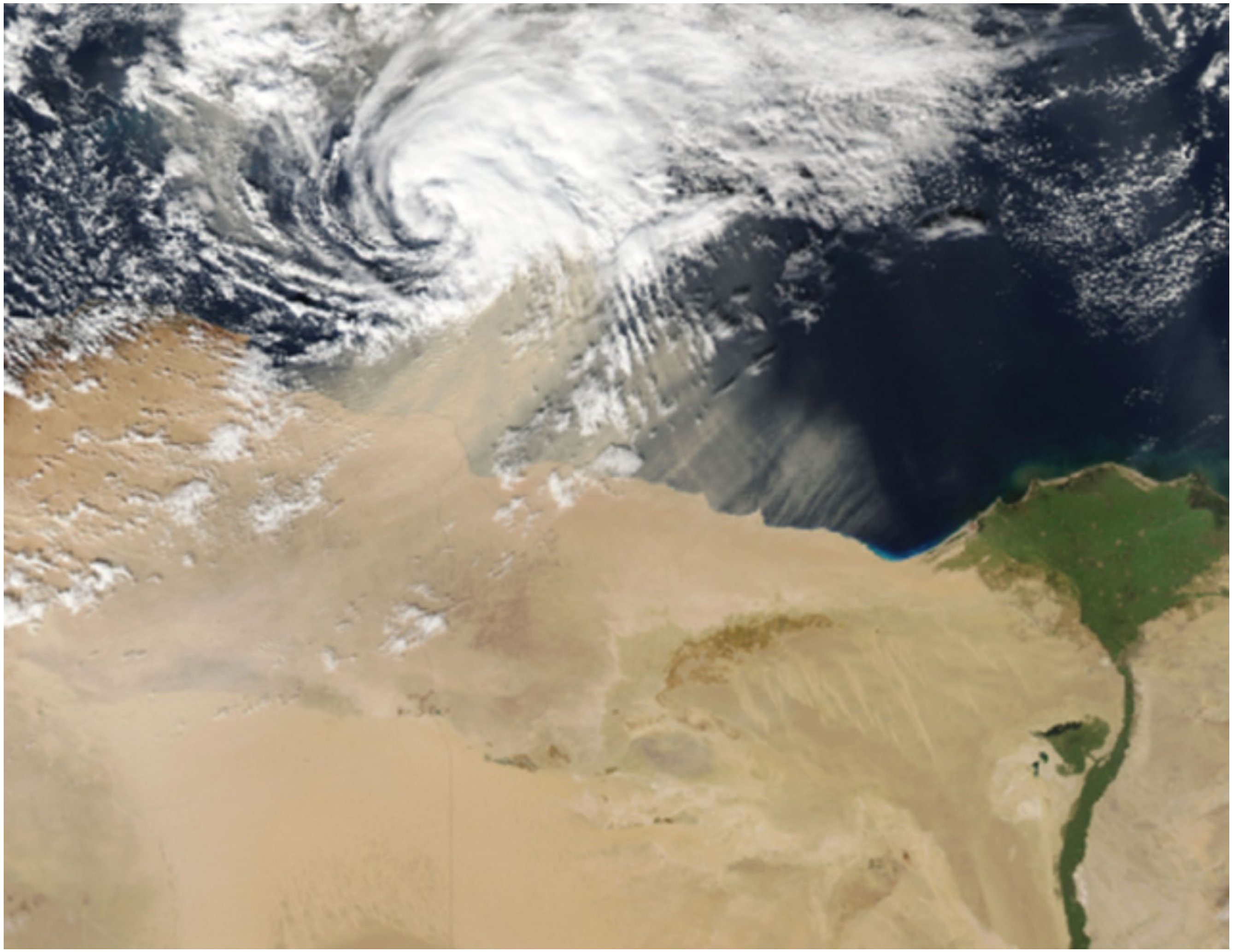
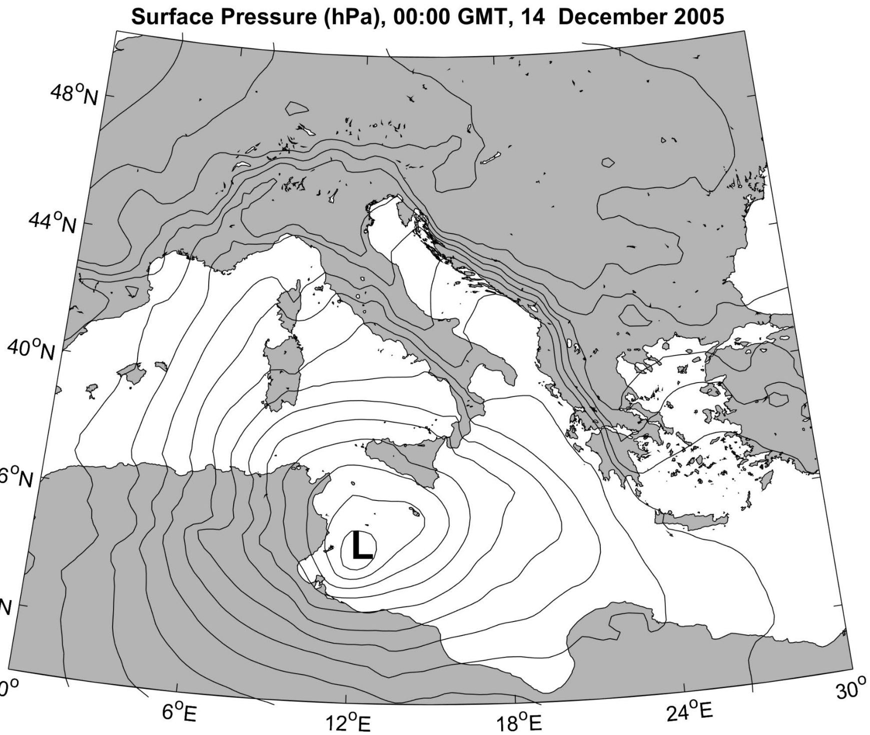
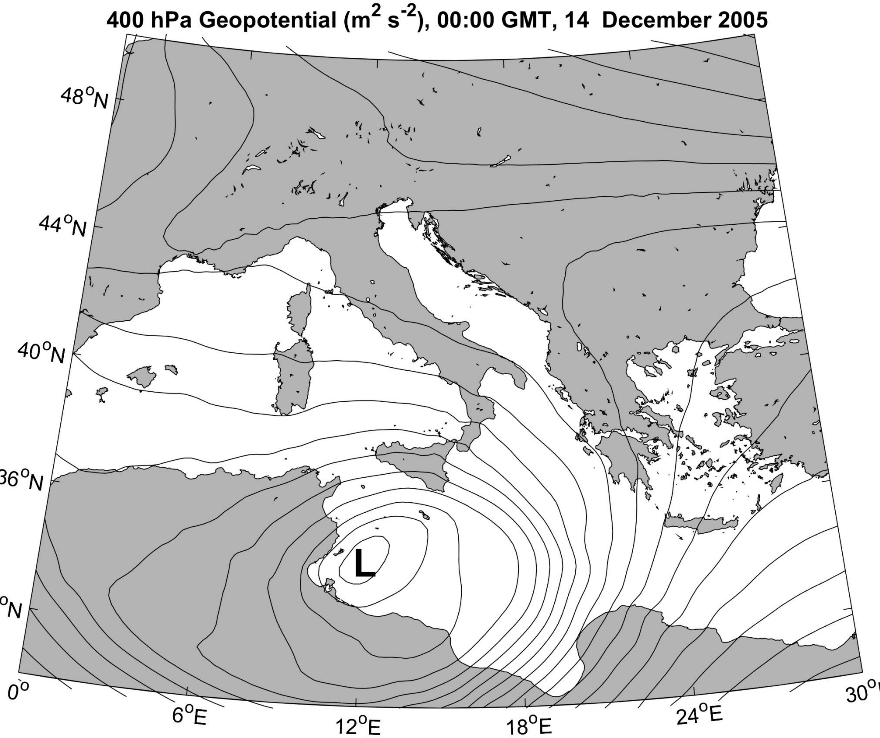
Medicane Between Libya and Crete, 00 GMT 15 December 2005



Medicane Between Libya and Crete, 00 GMT 14 December 2005

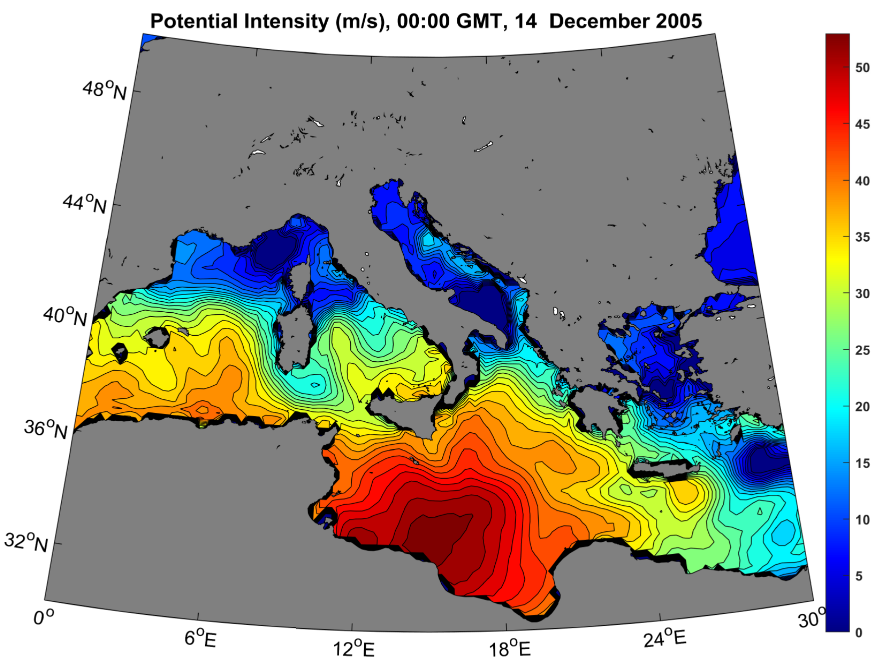


Surface Pressure

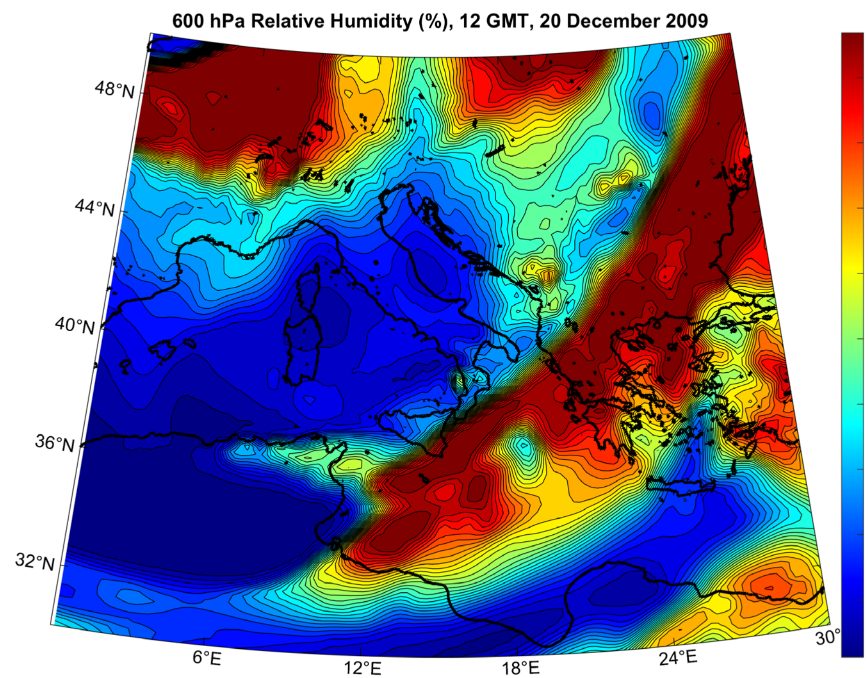


400 hPa Geopotential

Medicane Between Libya and Crete, 00 GMT 15 December 2005

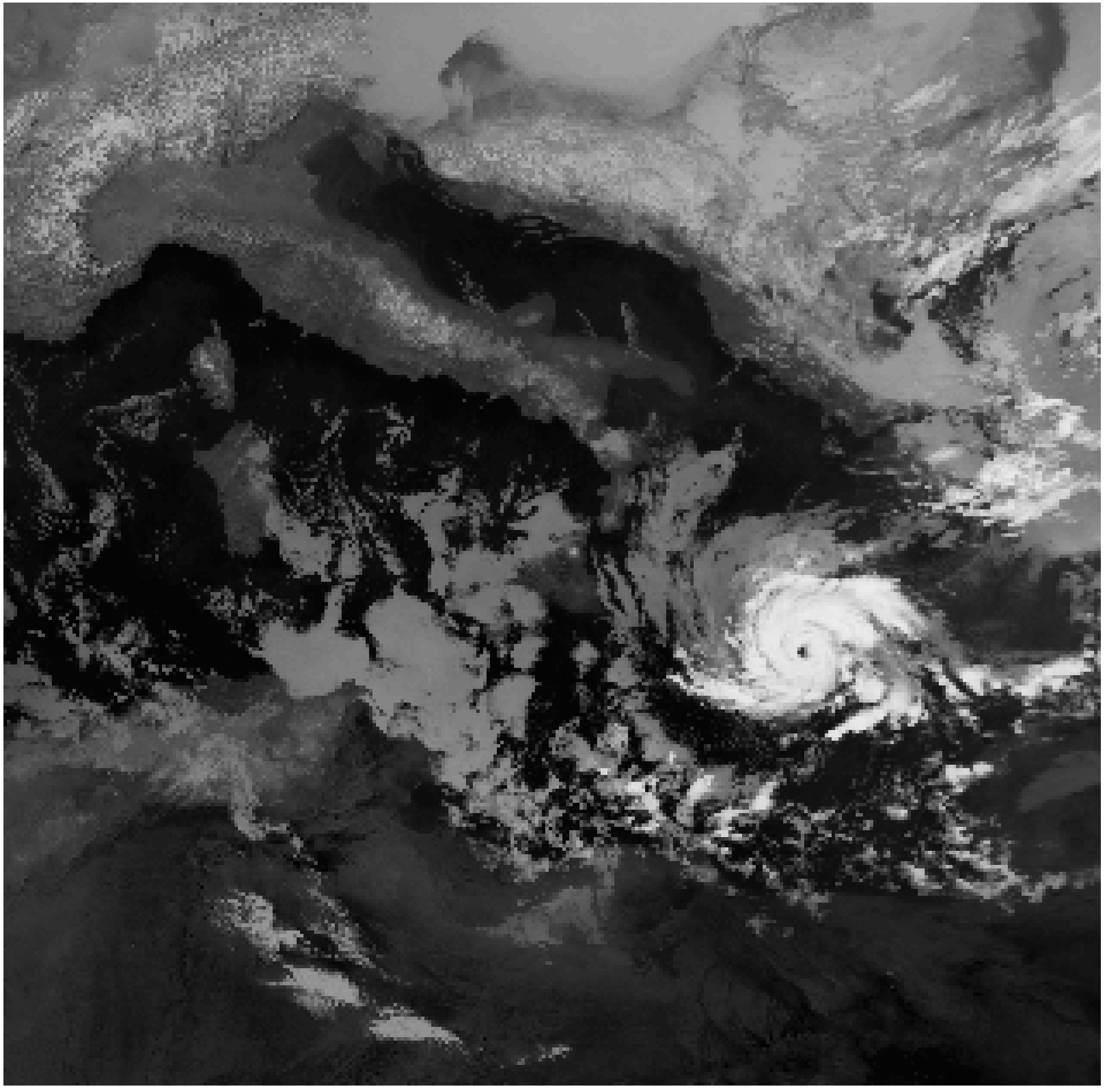


Potential Intensity (m/s)

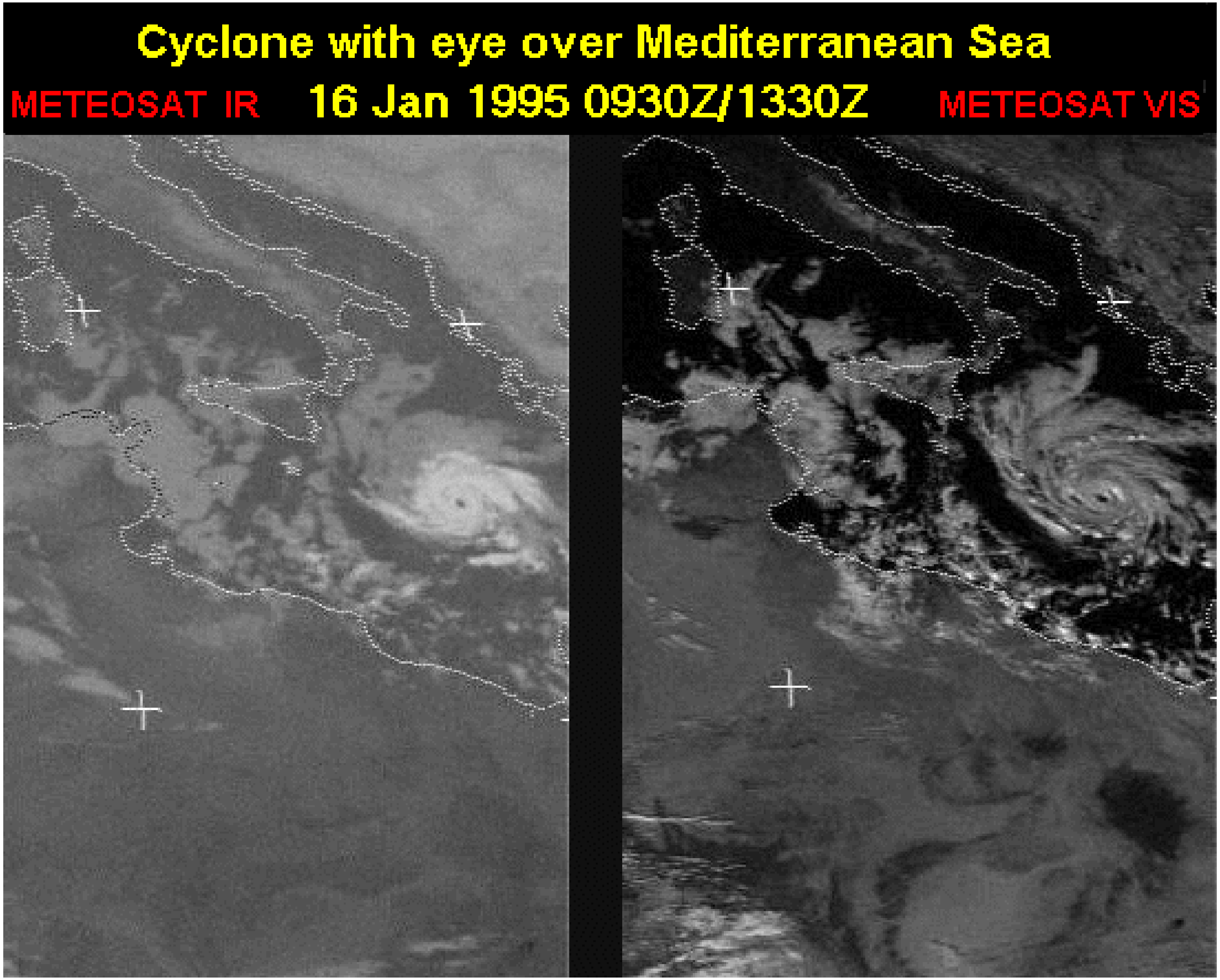


600 hPa Relative Humidity (%)

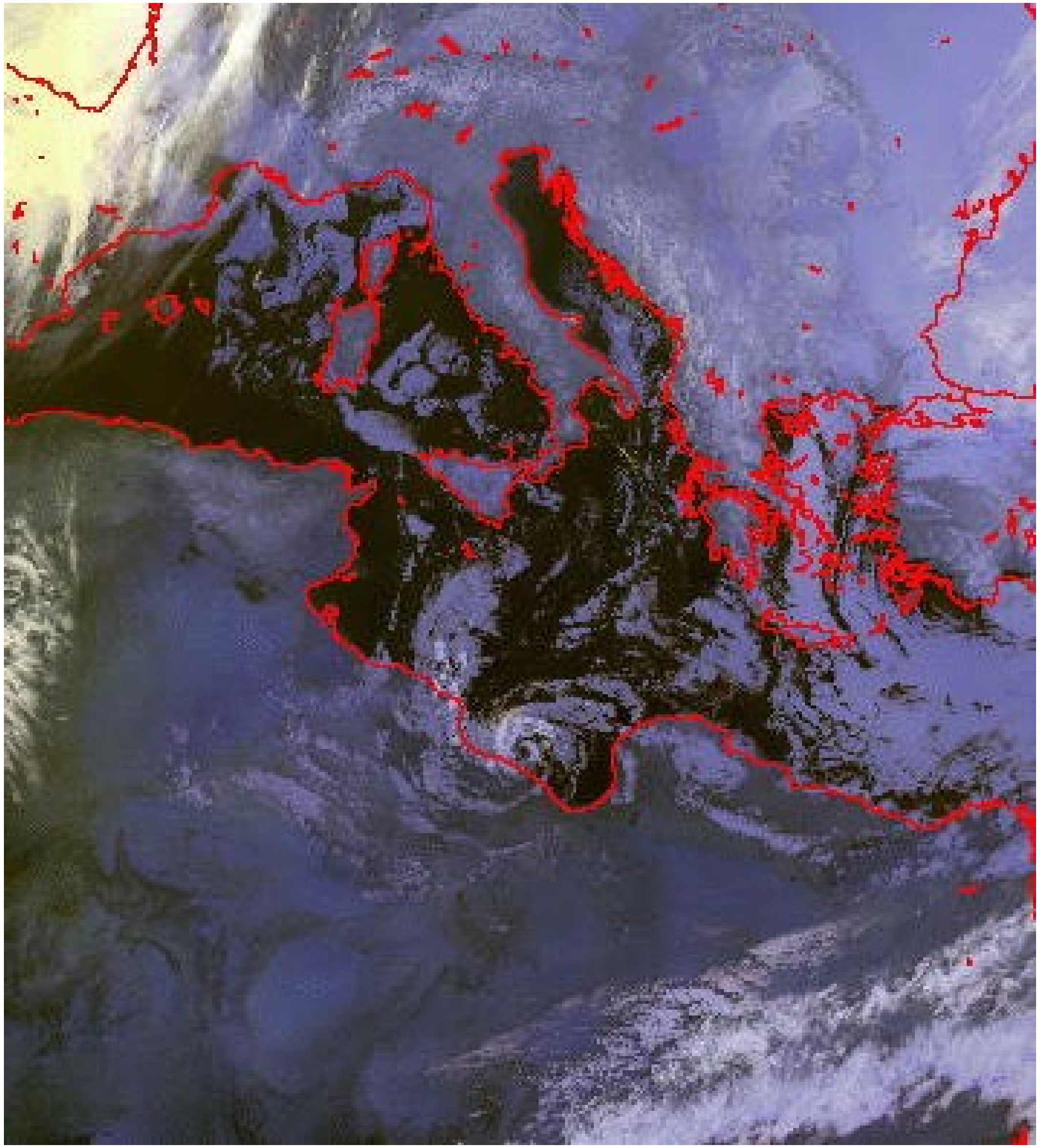
‘Medicane’ of 15 January 1995



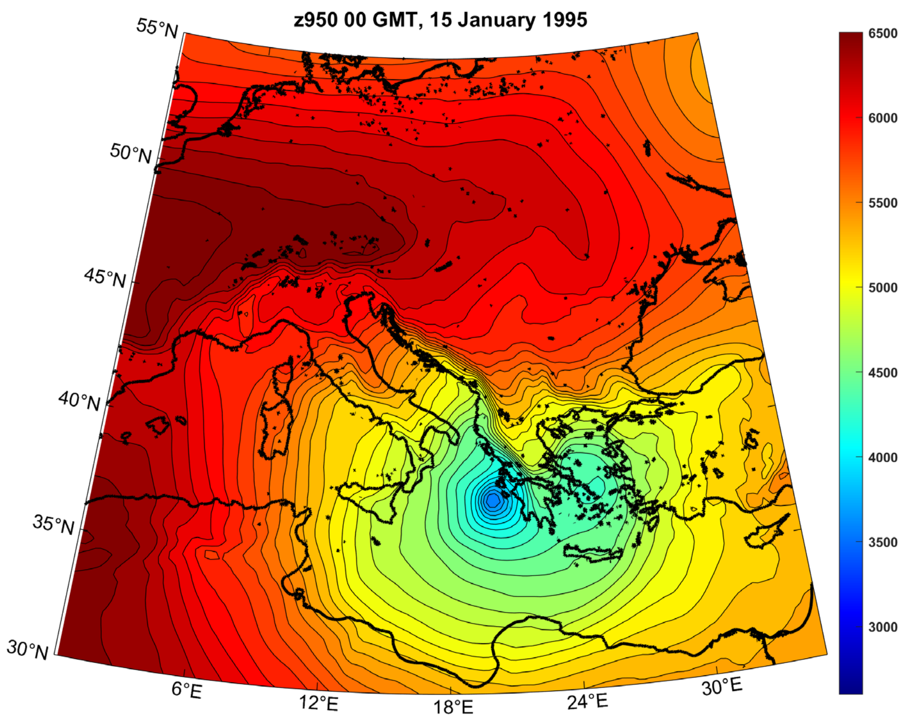
16 January 09 and 13 GMT



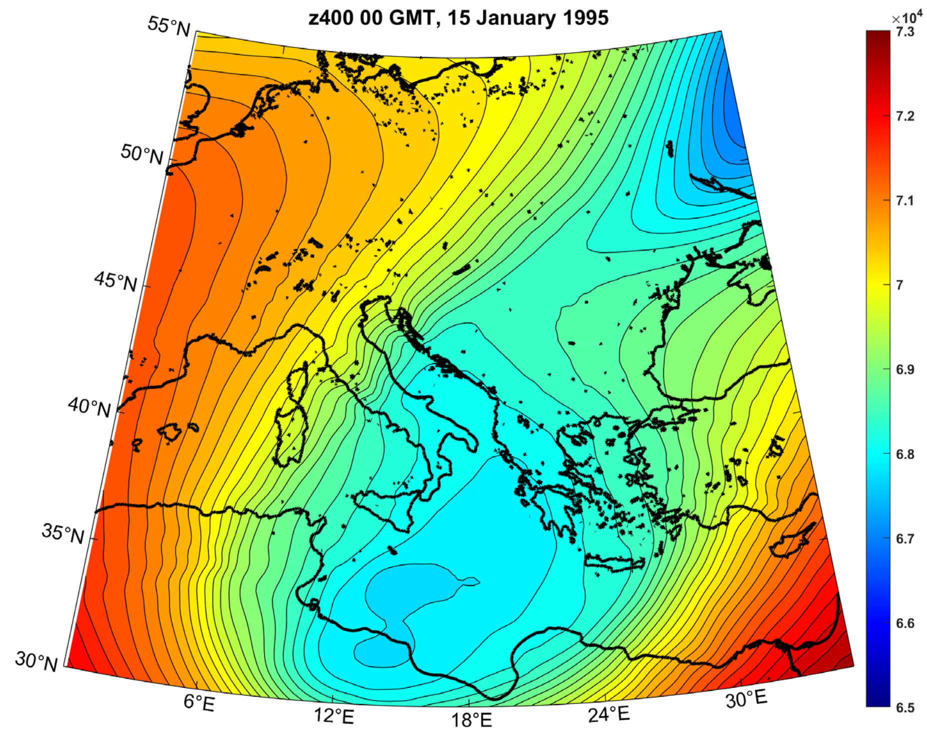
17 January 18 GMT



Medicane on 15 December 1995



Surface Pressure

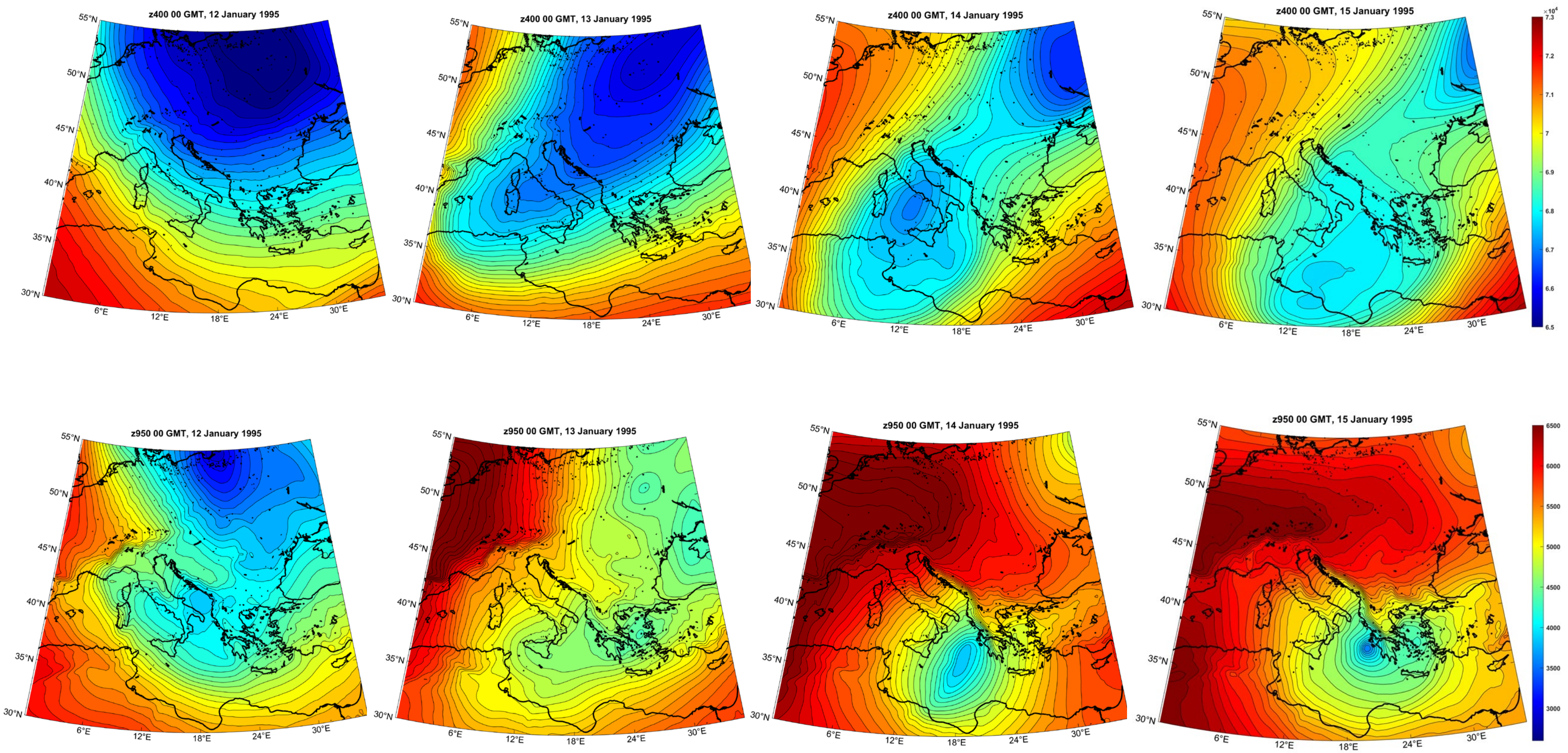


400 hPa Geopotential

Evolution

400 hPa

950 hPa

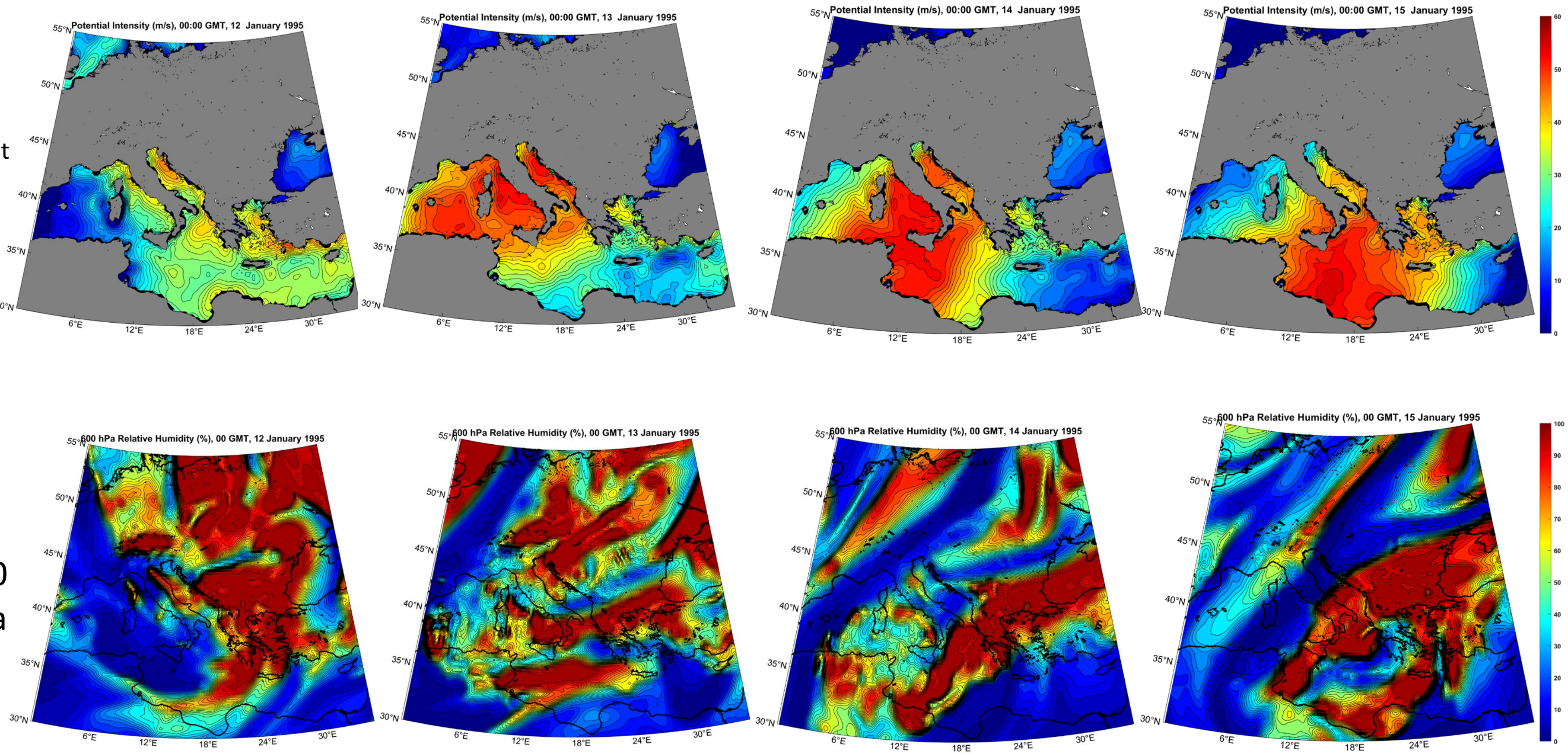


Dec. 12 Dec. 13 Dec. 14 Dec. 15

Evolution

V_{pot}

RH 600 hPa



Dec. 12 Dec. 13 Dec. 14 Dec. 15

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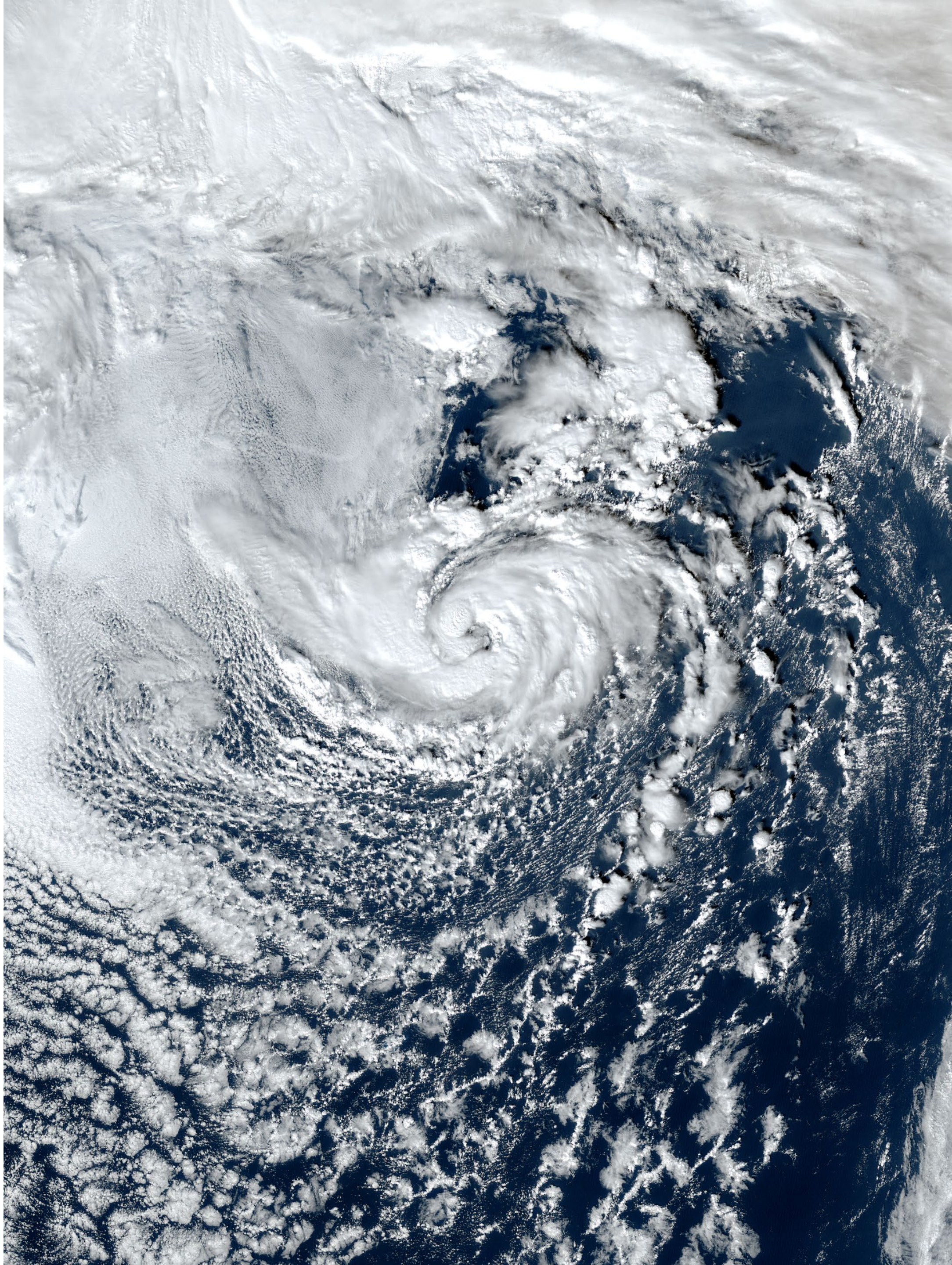
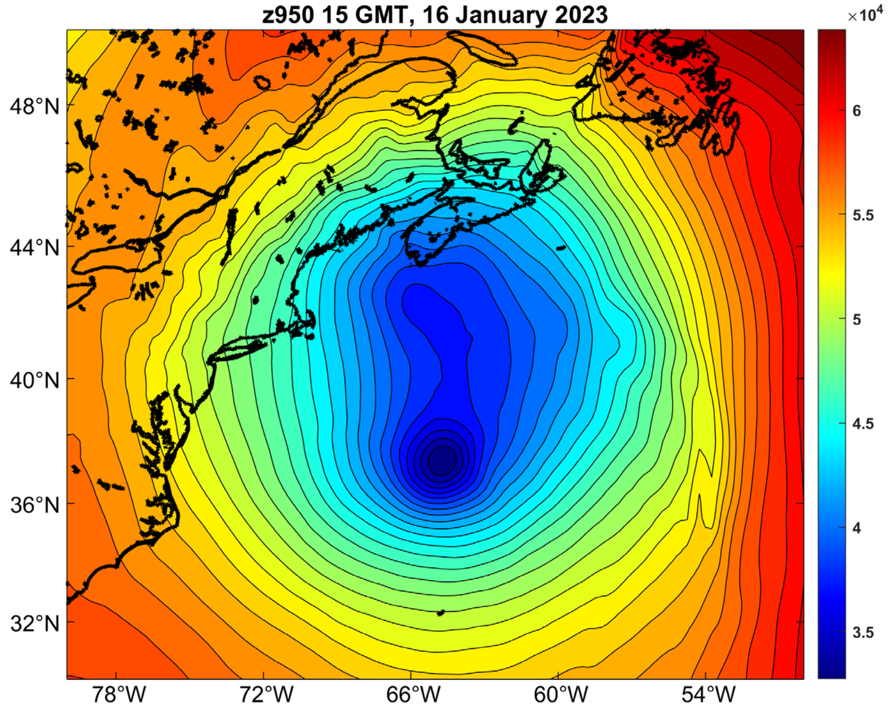
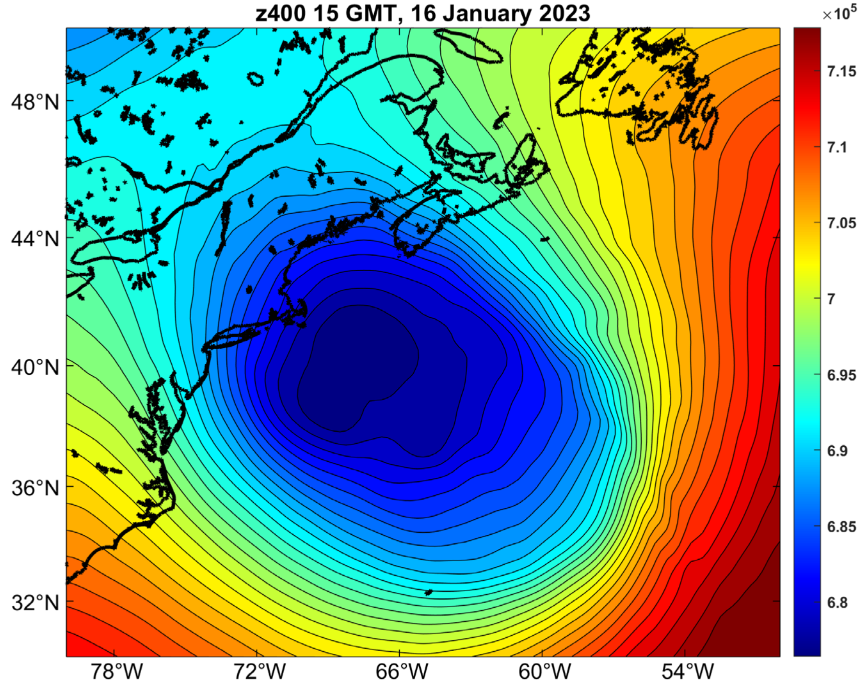
Unnamed subtropical cyclone southeast of Nantucket, Massachusetts, on 16 January 2023



Atlantic Subtropical Cyclone of 16 January, 2023

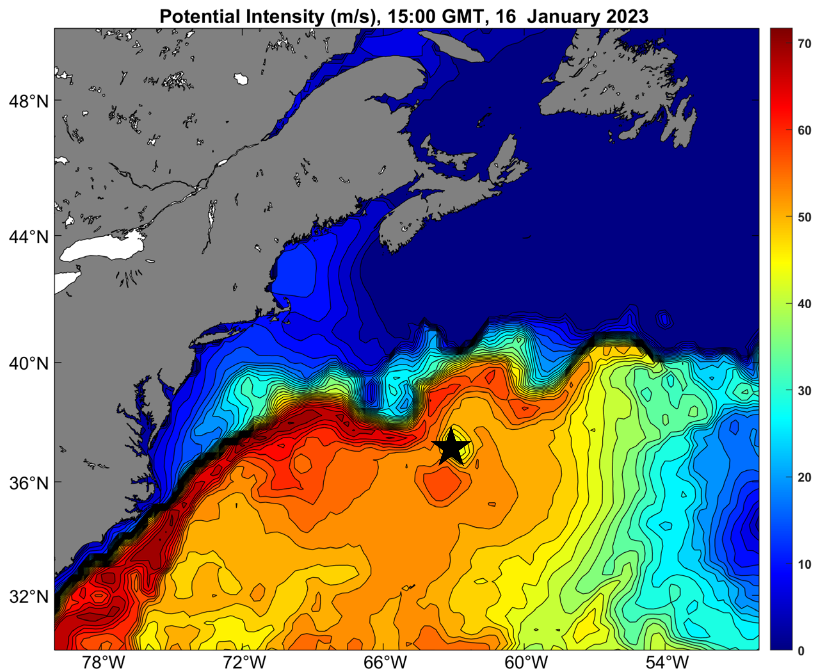


950 hPa Geopotential

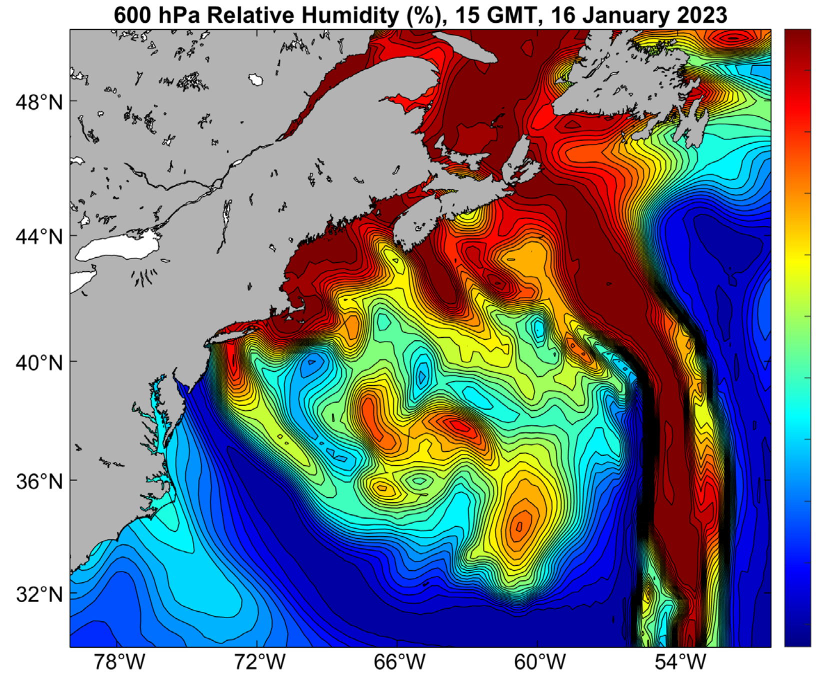


400 hPa Geopotential

Atlantic Subtropical Cyclone of 16 January, 2023



Potential Intensity (m/s)



600 hPa Relative Humidity (%)

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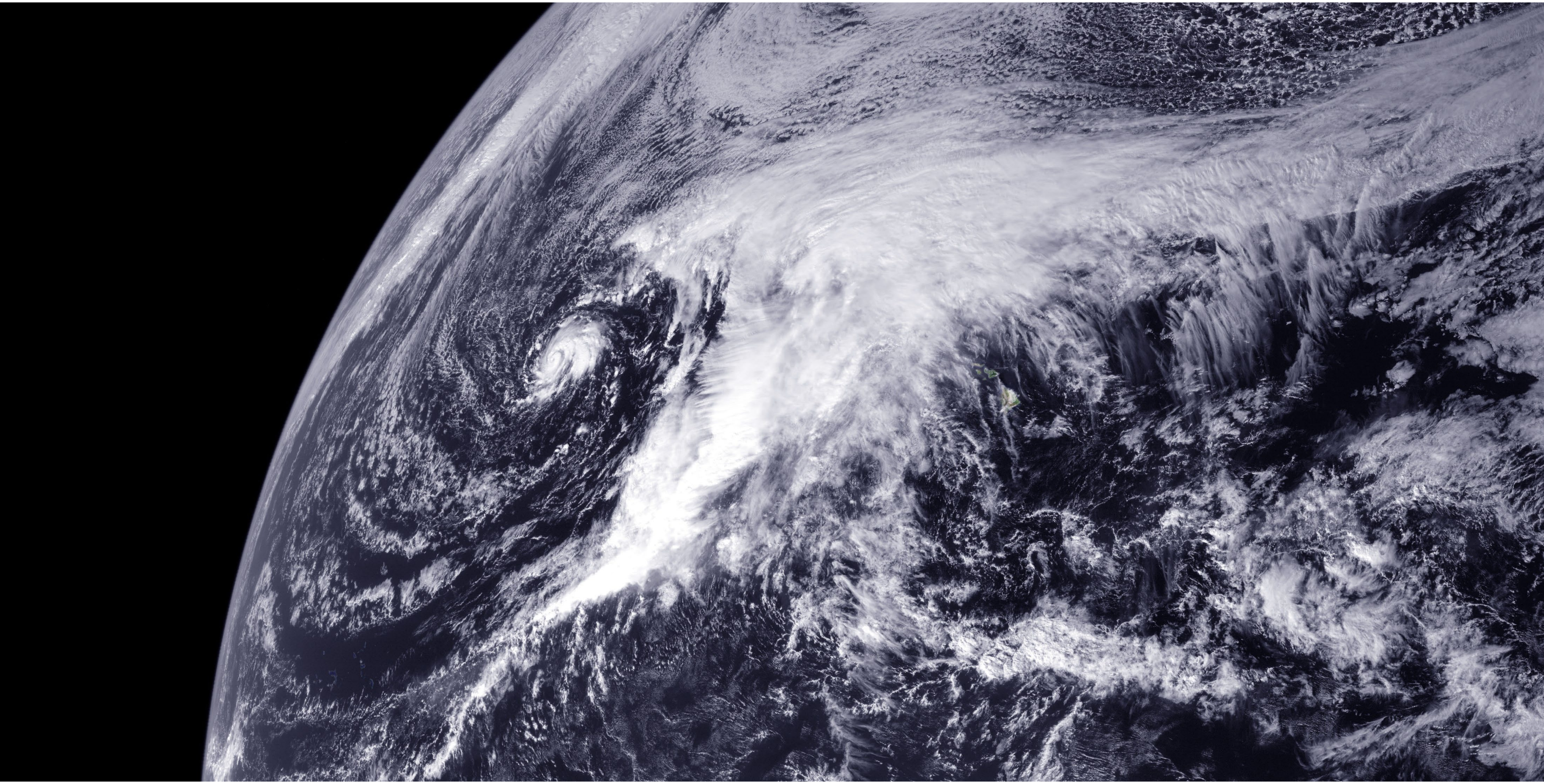
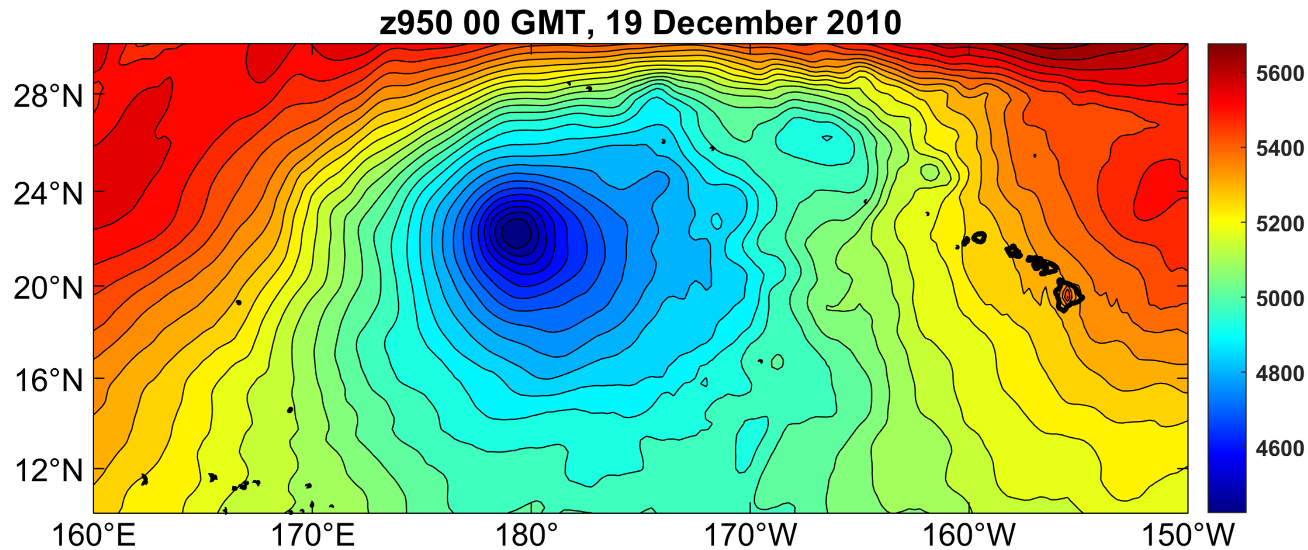
Kona Storm, 00 GMT 19 December 2010

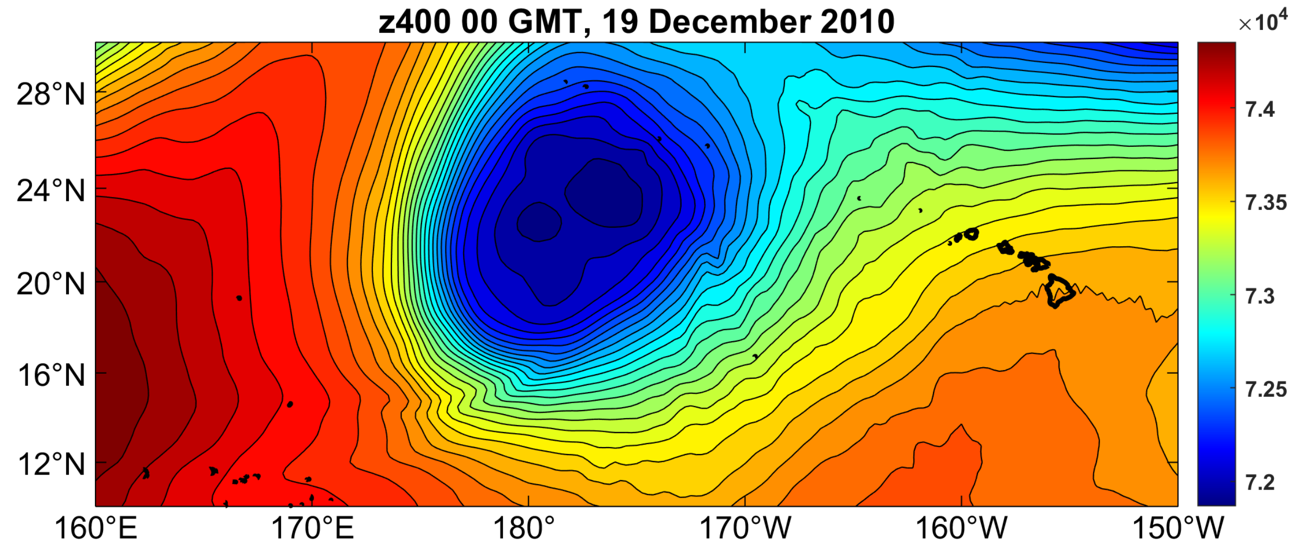


Kona Storm, 00 GMT 19 December 2010

950 hPa Geopotential

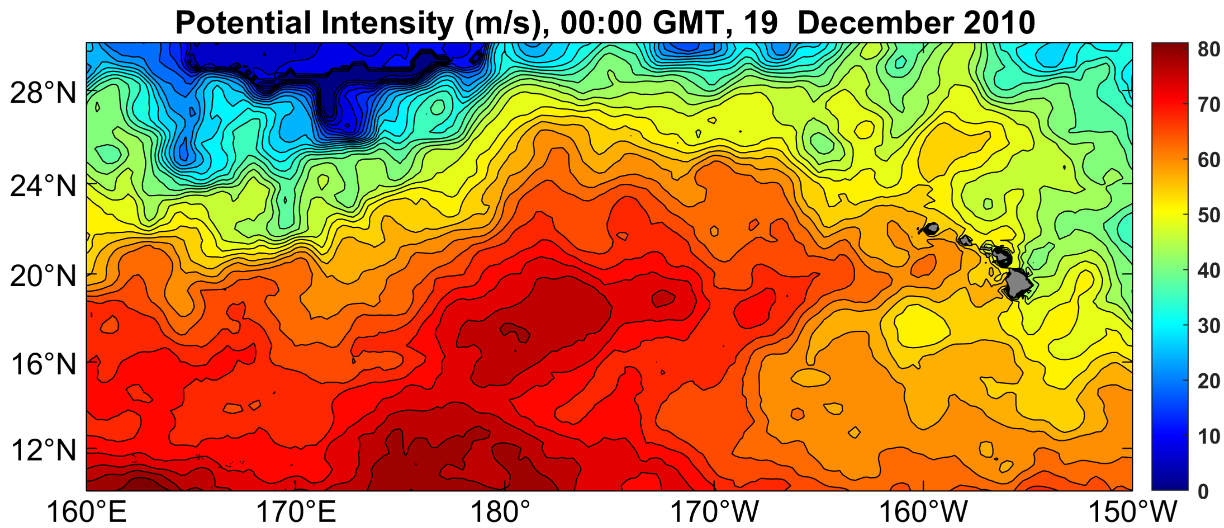


400 hPa Geopotential

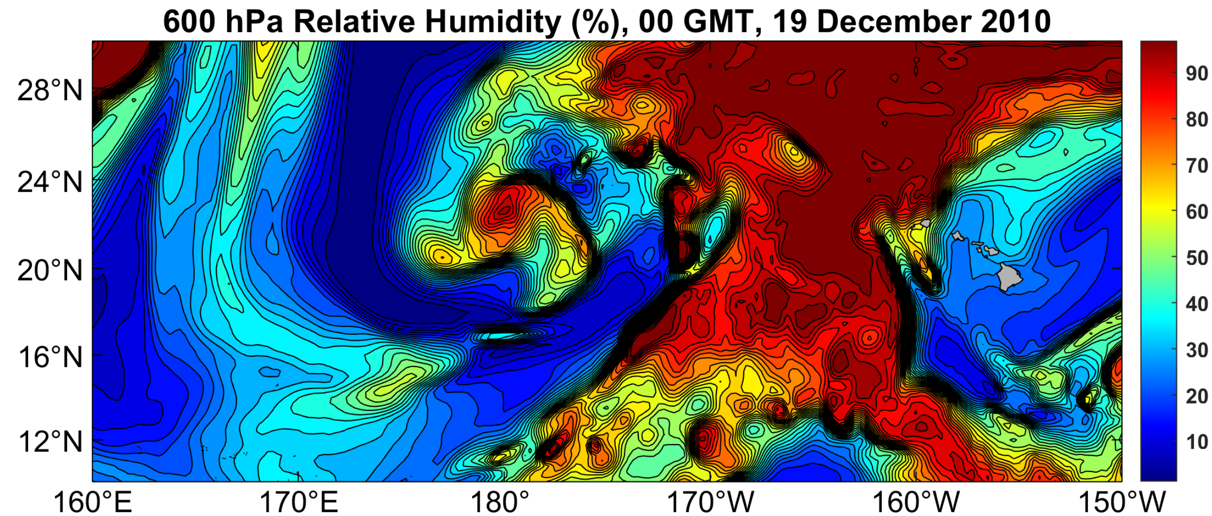


Kona Storm, 00 GMT 19 December 2010

Potential Intensity (m/s)



600 hPa Relative Humidity (%)



Upper Cutoff Lows Are Ideal Embryos for Hurricane-like Development

- Potential intensity of climatological mean state unconducive or marginal for development
- Approach of upper PV anomaly leads to lifting, cooling and moistening of air mass
- Potential intensity may be substantially enhanced under cold, upper lows

Enhancement of potential intensity by upper low:

$$V_{mod}^2 = V_p^2 - \frac{C_k}{C_D}\left(\phi'_{cl} - \phi'_s\right)$$

$\phi'_{cl} =$ geopotential perturbation of closed low near tropopause

$\phi'_s =$ geopotential perturbation of closed low near surface

January 1995 medicane case:

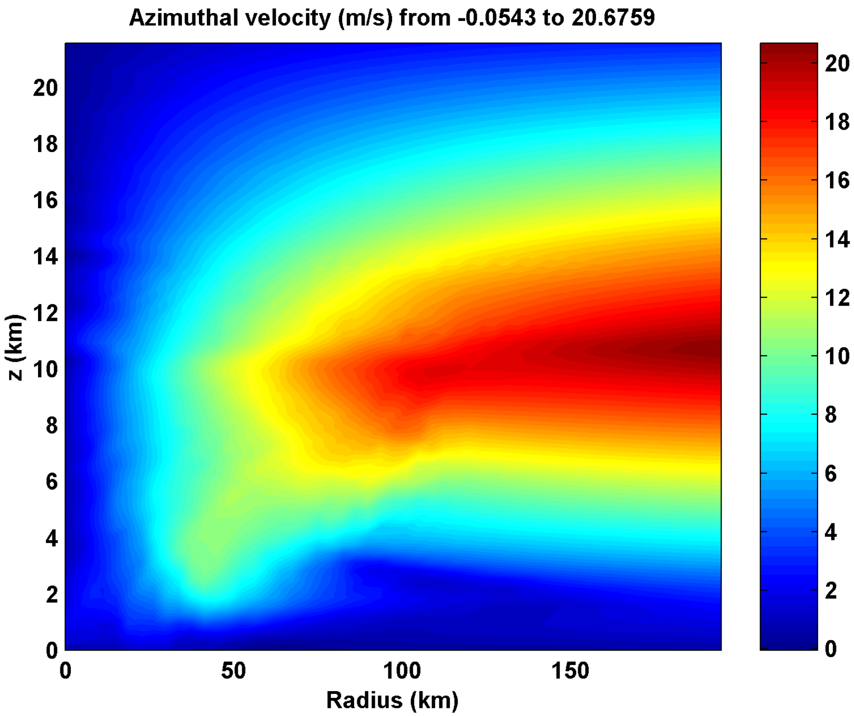
$$\phi'_{cl} - \phi'_{s} \simeq -1500\ m^2 s^{-2}$$

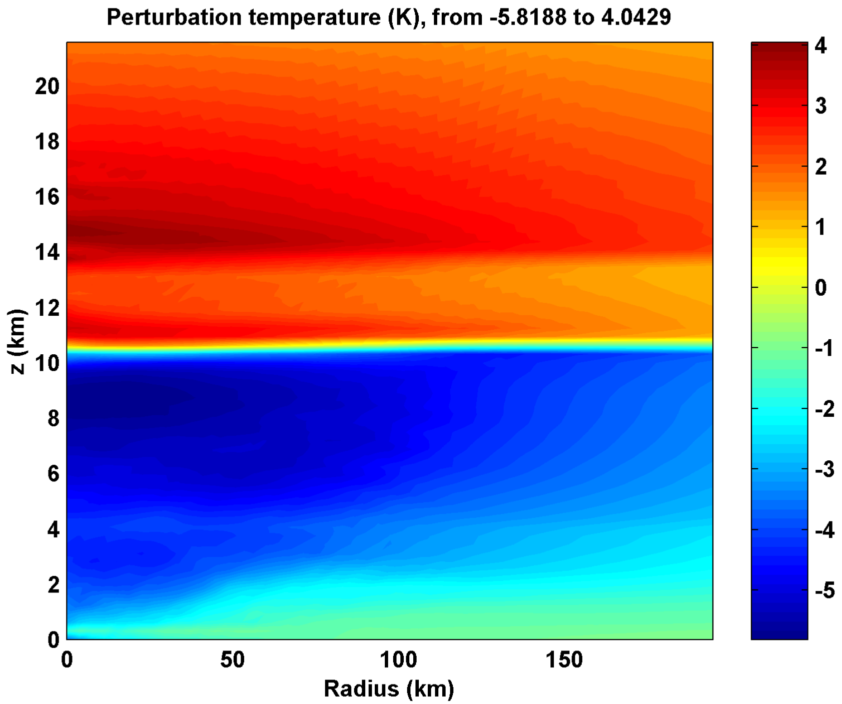
$$V_{mod} \simeq 40\ ms^{-1}$$

Numerical Simulations: Axisymmetric Genesis under Cold Cutoff Low in Initial State

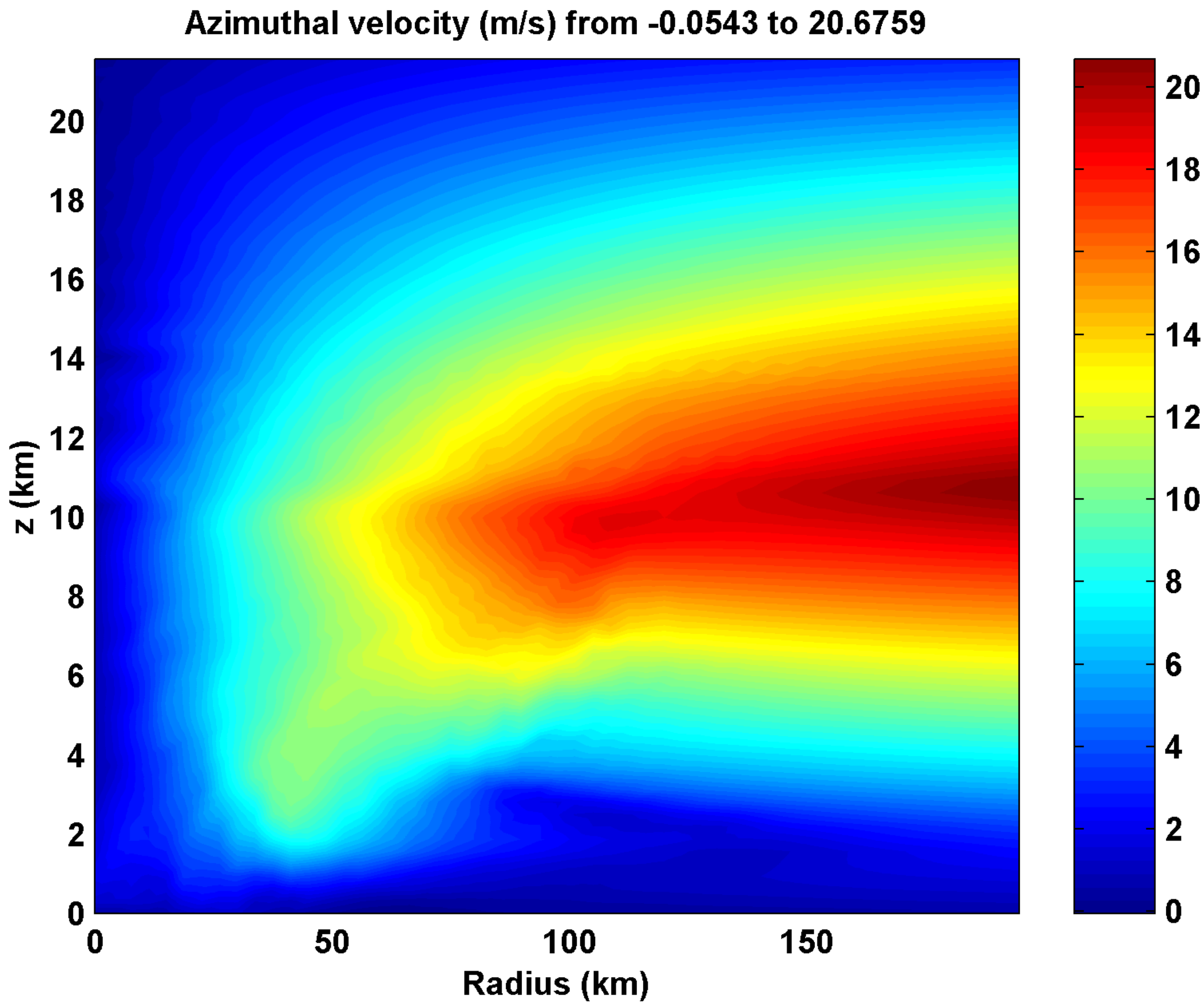
- Far environment does not support tropical cyclones
- Cold upper low with zero surface winds in initial condition. Maximum wind 20 ms^{-1} at 300 km radius and 10 km altitude
- Axisymmetric, nonhydrostatic, cloud-resolving model of Rotunno and Emanuel (*J. Atmos. Sci.,* 1987); see Emanuel and Rotunno, *Tellus*, 1989. 3.75 km horizontal resolution; 300 m in vertical

Day 1


Azimuthal velocity (m/s) from -0.0543 to 20.6759
z (km)
Radius (km)
0
50
100
150
0
2
4
6
8
10
12
14
16
18
20

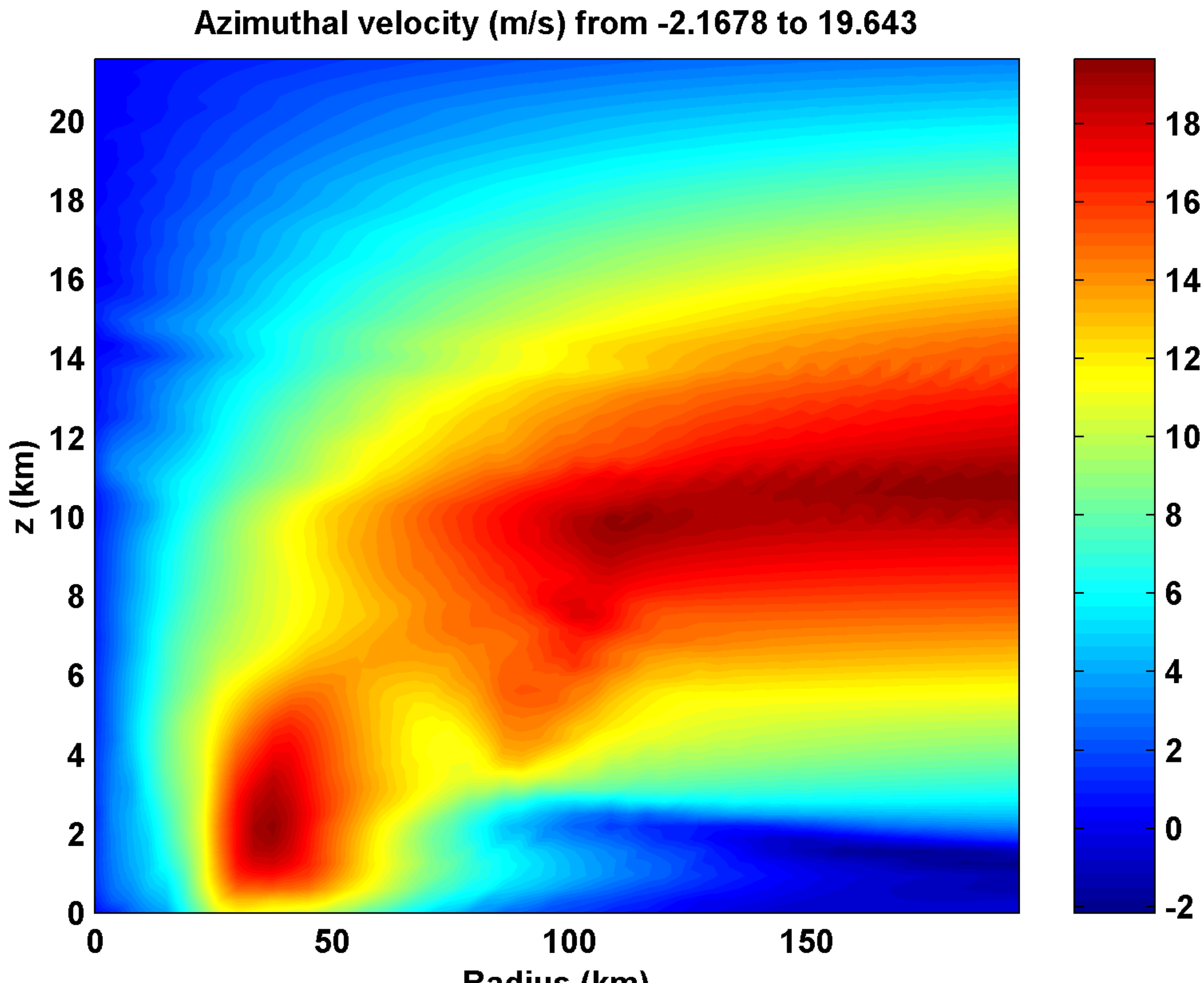

Perturbation temperature (K), from -5.8188 to 4.0429
z (km)
Radius (km)
0
50
100
150
4
3
2
1
0
-1
-2
-3
-4
-5

Day 1

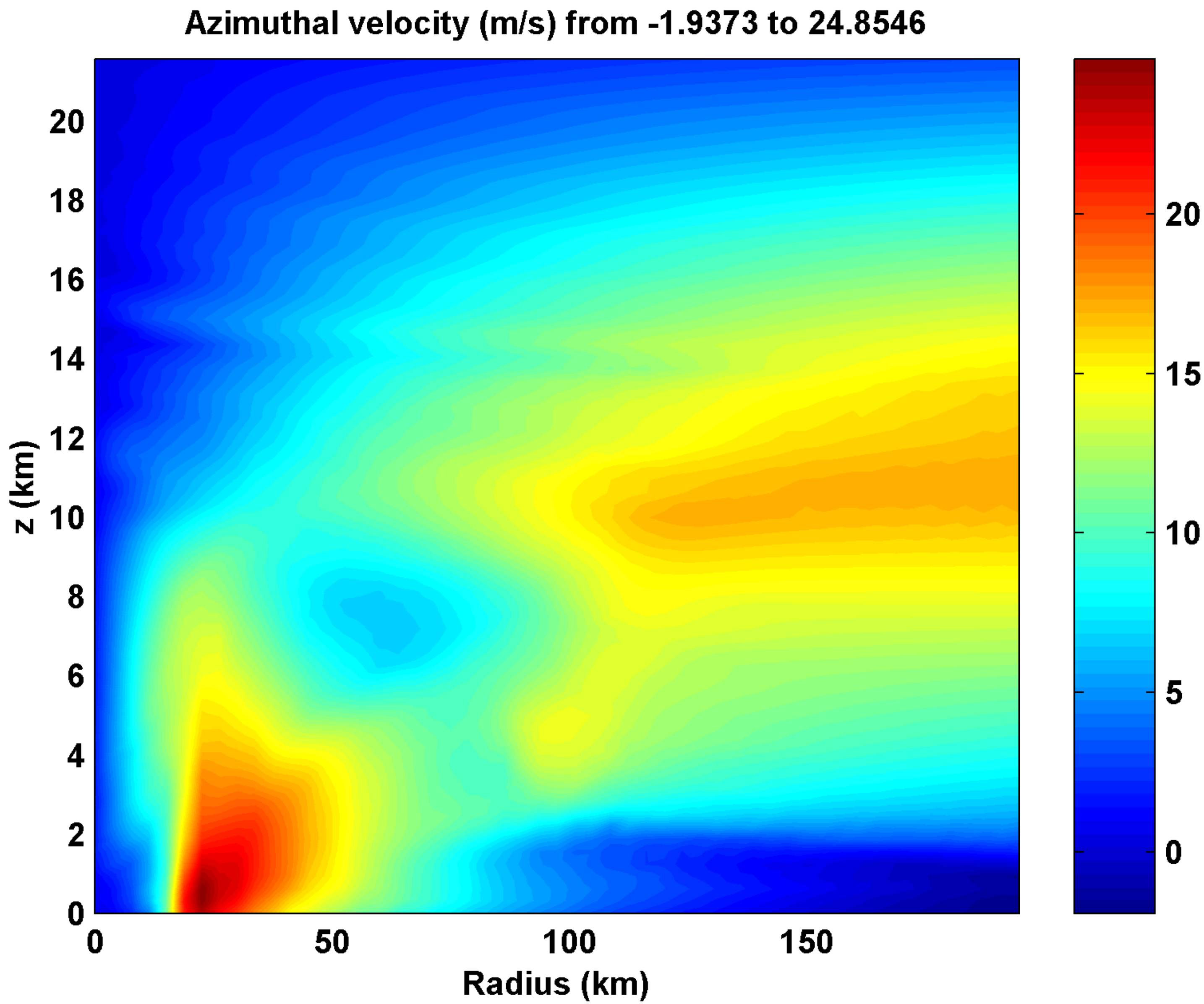


Azimuthal velocity (m/s) from -0.0543 to 20.6759
z (km)
Radius (km)
0
2
4
6
8
10
12
14
16
18
20
0
50
100
150
0
2
4
6
8
10
12
14
16
18
20

Day 2

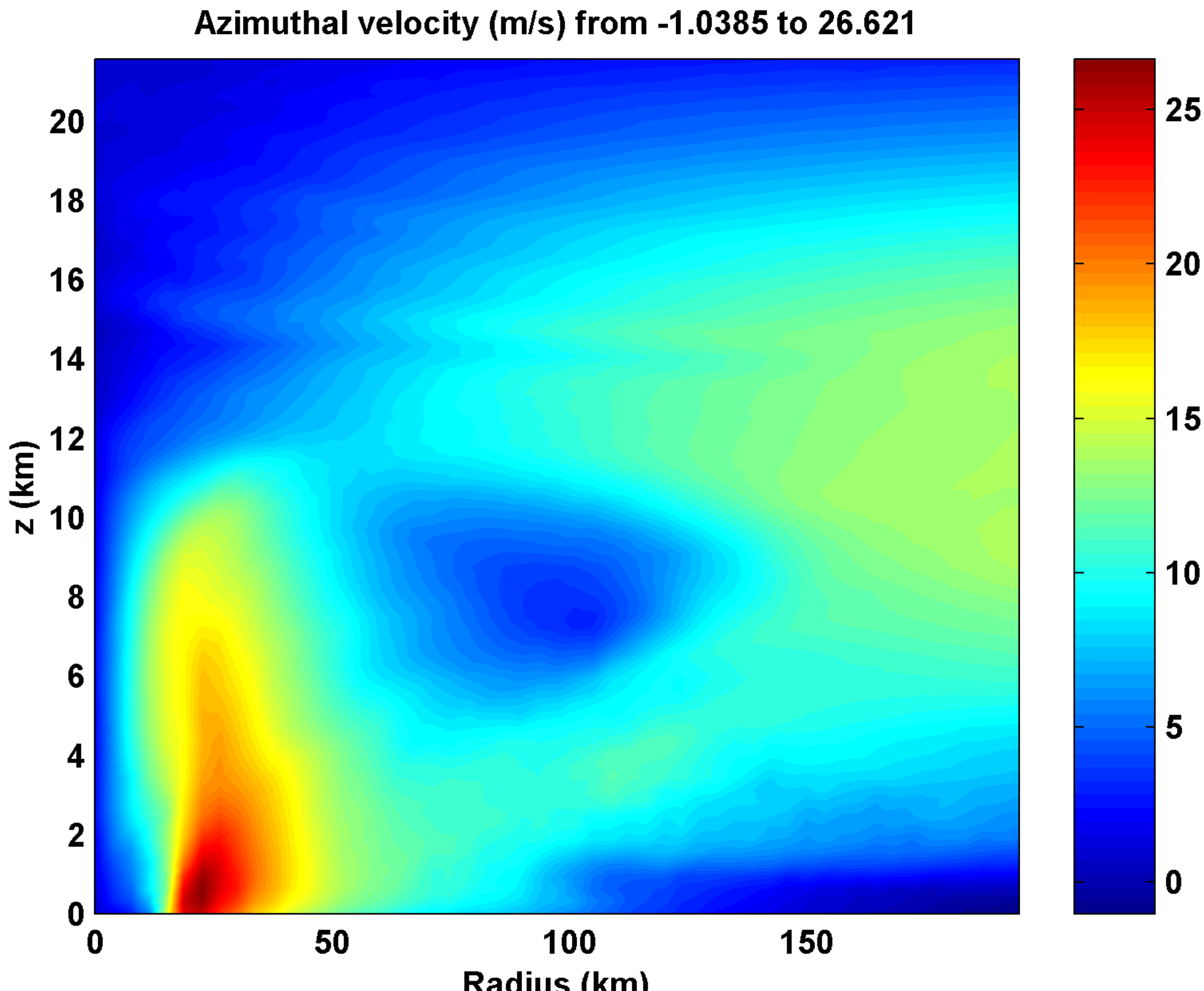

Azimuthal velocity (m/s) from -2.1678 to 19.643
z (km)
0
2
4
6
8
10
12
14
16
18
20
Radius (km)
0
50
100
150
-2
0
2
4
6
8
10
12
14
16
18

Day 3

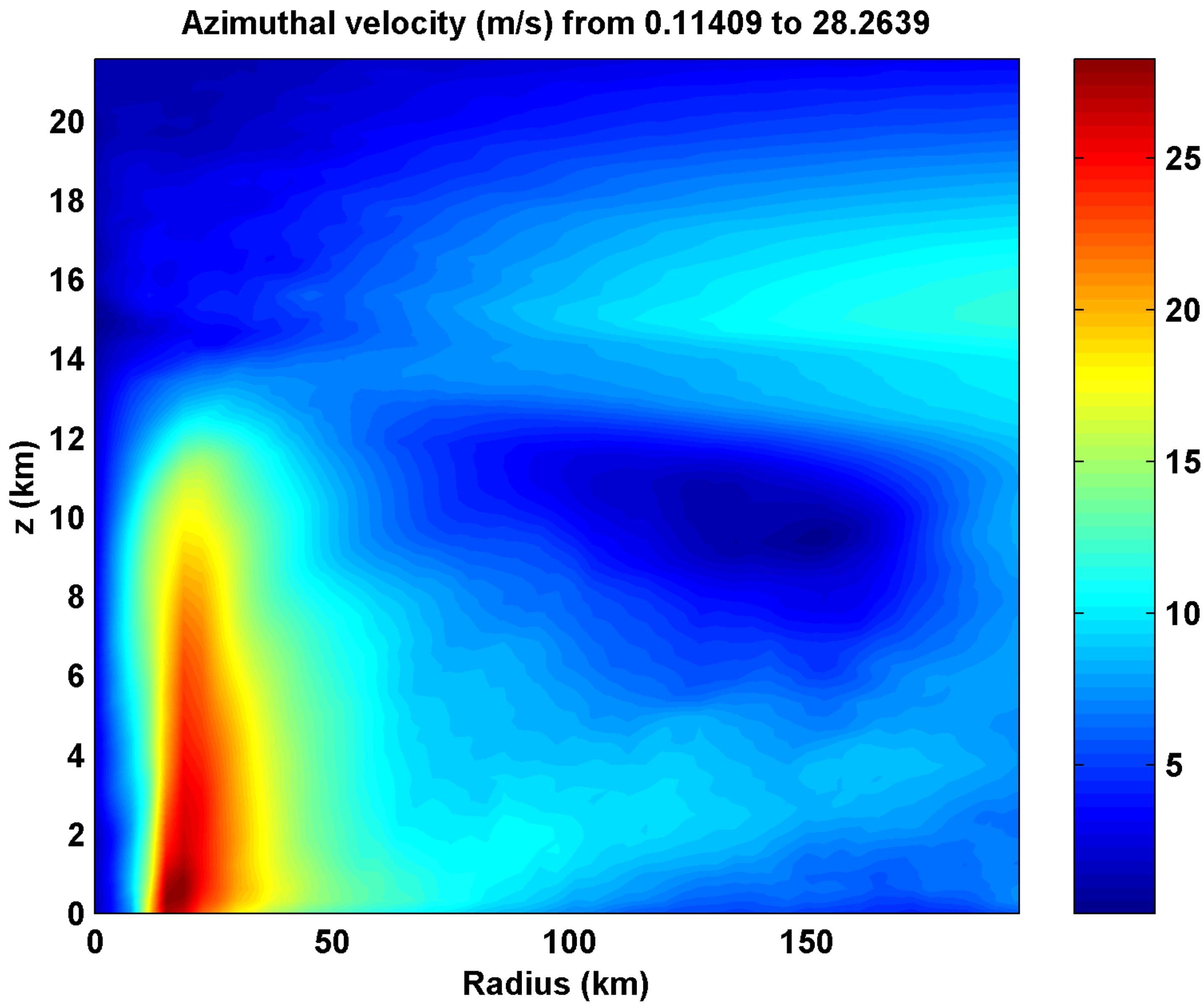


Azimuthal velocity (m/s) from -1.9373 to 24.8546
z (km)
0
2
4
6
8
10
12
14
16
18
20
0
50
100
150
Radius (km)
0
5
10
15
20

Day 4

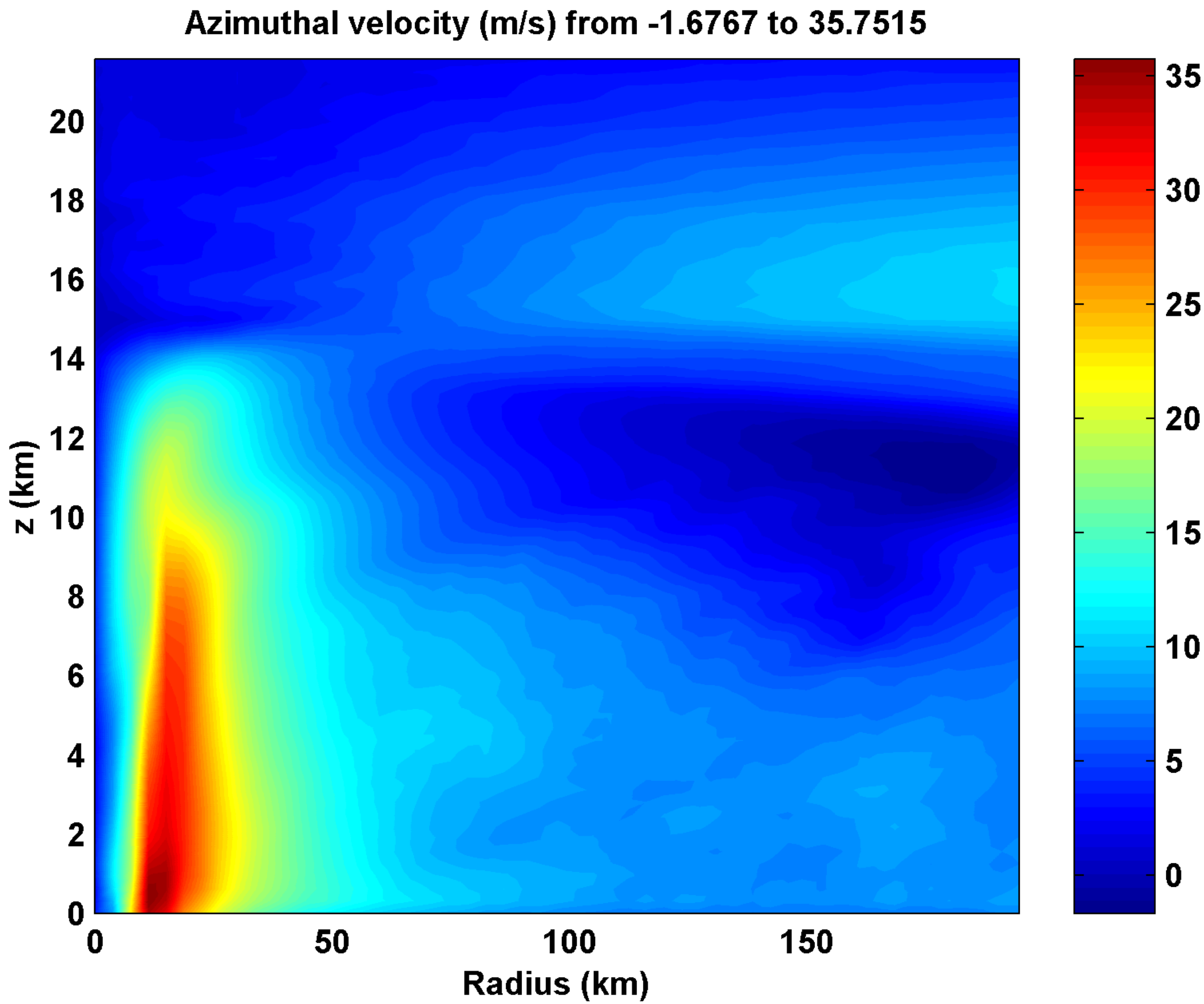

Azimuthal velocity (m/s) from -1.0385 to 26.621
z (km)
0
2
4
6
8
10
12
14
16
18
20
0
50
100
150
Radius (km)
0
5
10
15
20
25

Day 5



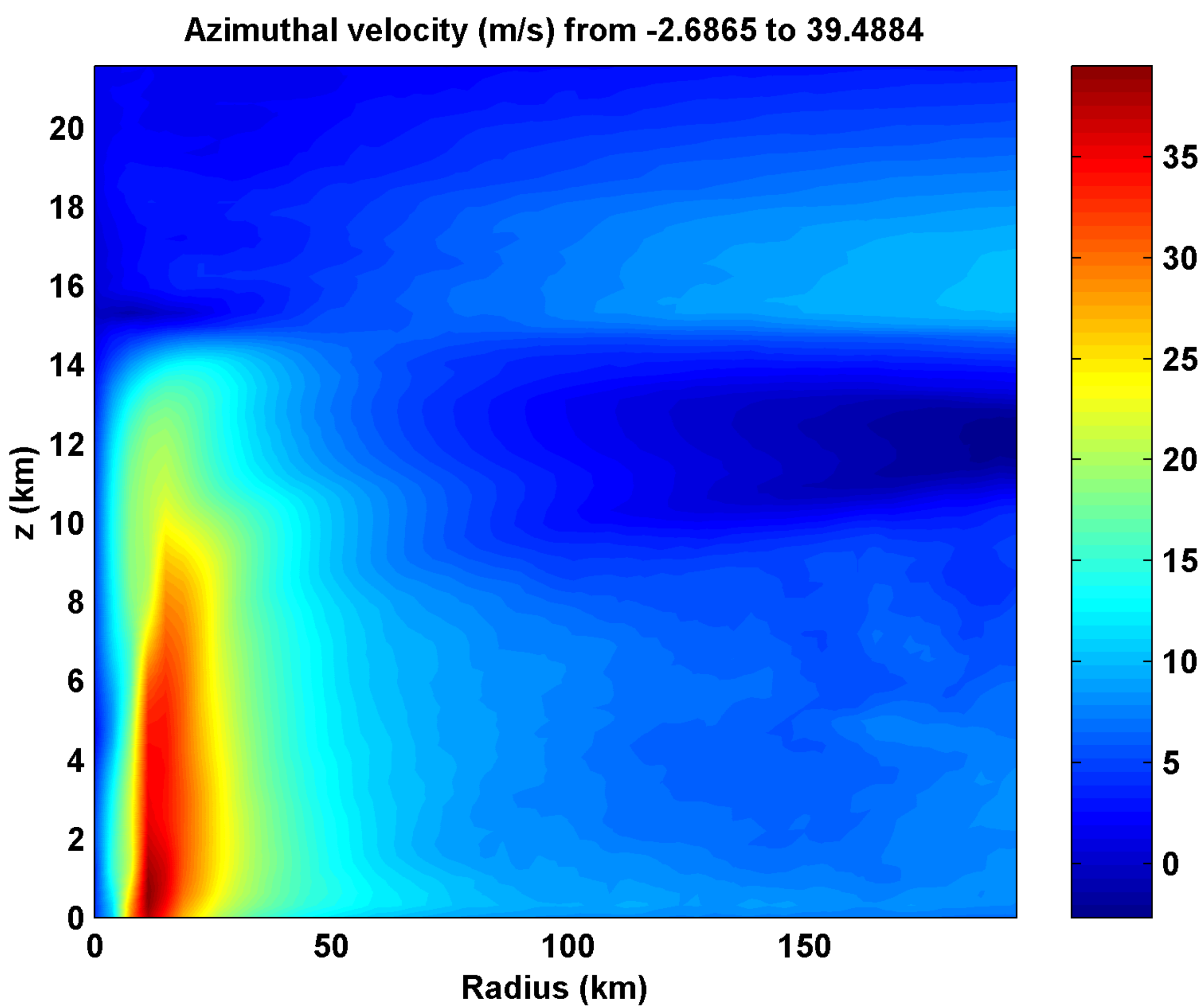
Azimuthal velocity (m/s) from 0.11409 to 28.2639
z (km)
0
2
4
6
8
10
12
14
16
18
20
0
50
100
150
Radius (km)
5
10
15
20
25

Day 6



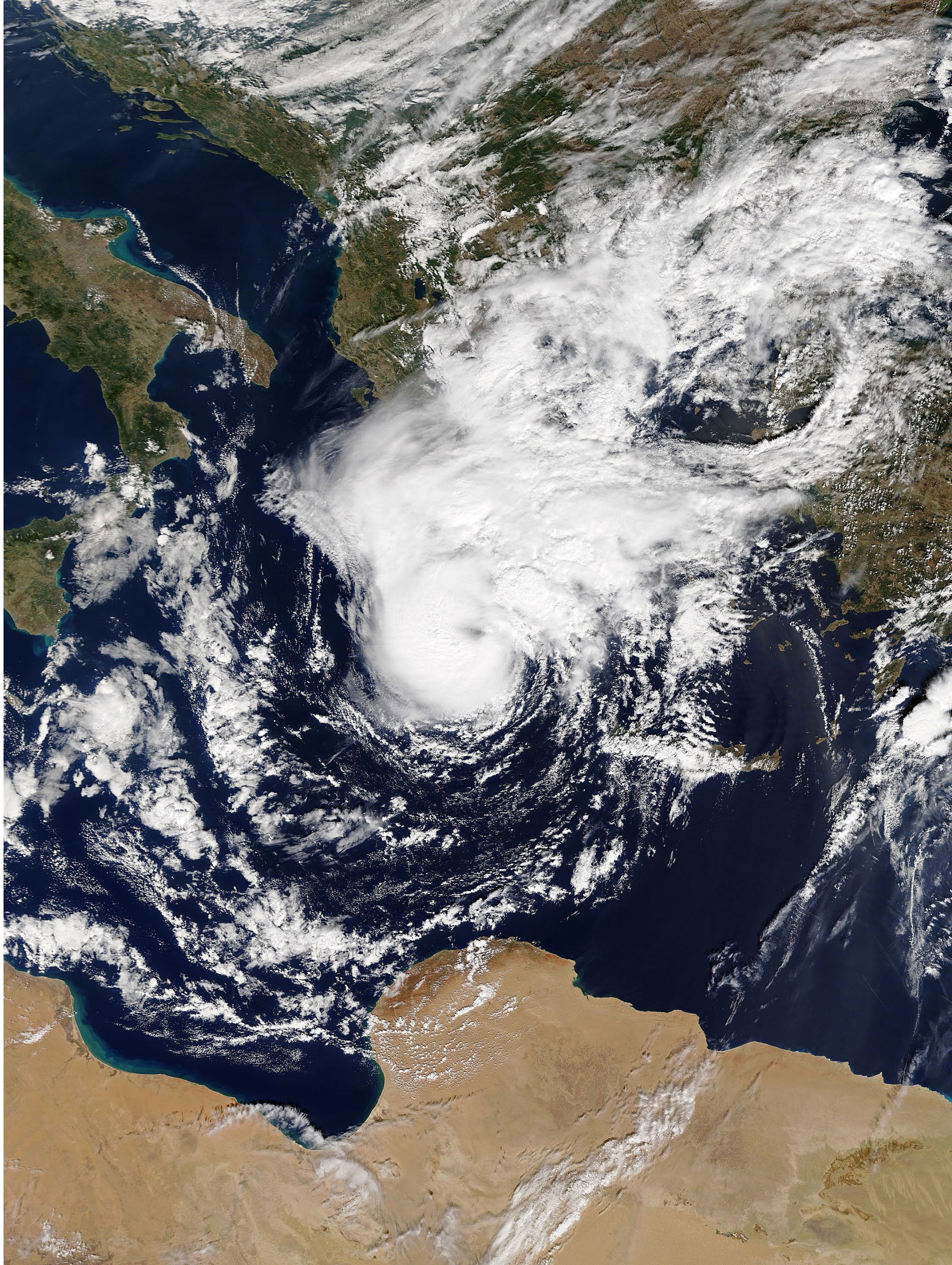
Azimuthal velocity (m/s) from -1.6767 to 35.7515
z (km)
20
18
16
14
12
10
8
6
4
2
0
0
50
100
150
Radius (km)
35
30
25
20
15
10
5
0

Day 7

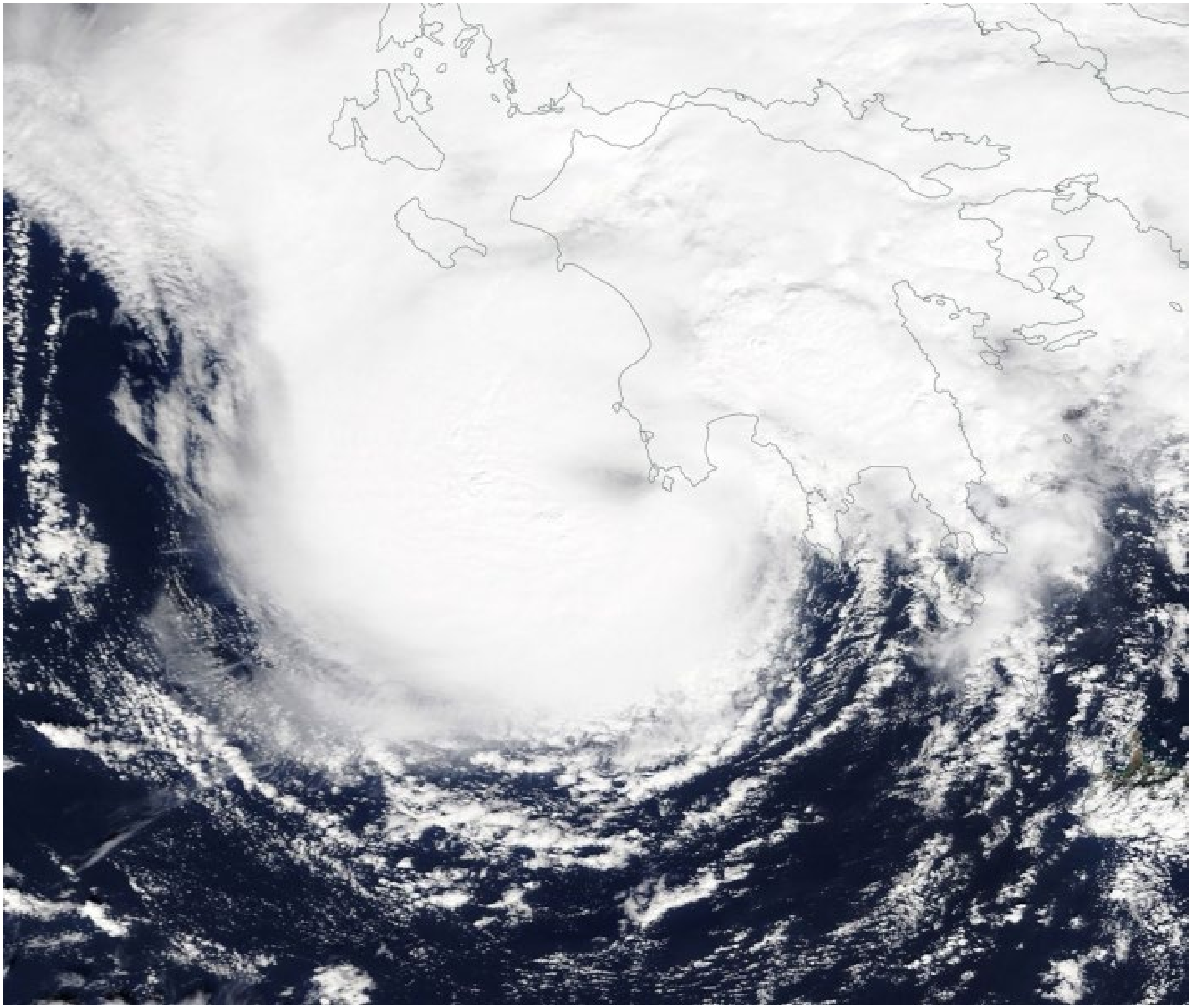

Azimuthal velocity (m/s) from -2.6865 to 39.4884
z (km)
0
2
4
6
8
10
12
14
16
18
20
Radius (km)
0
50
100
150
0
5
10
15
20
25
30
35

Variations on the Theme

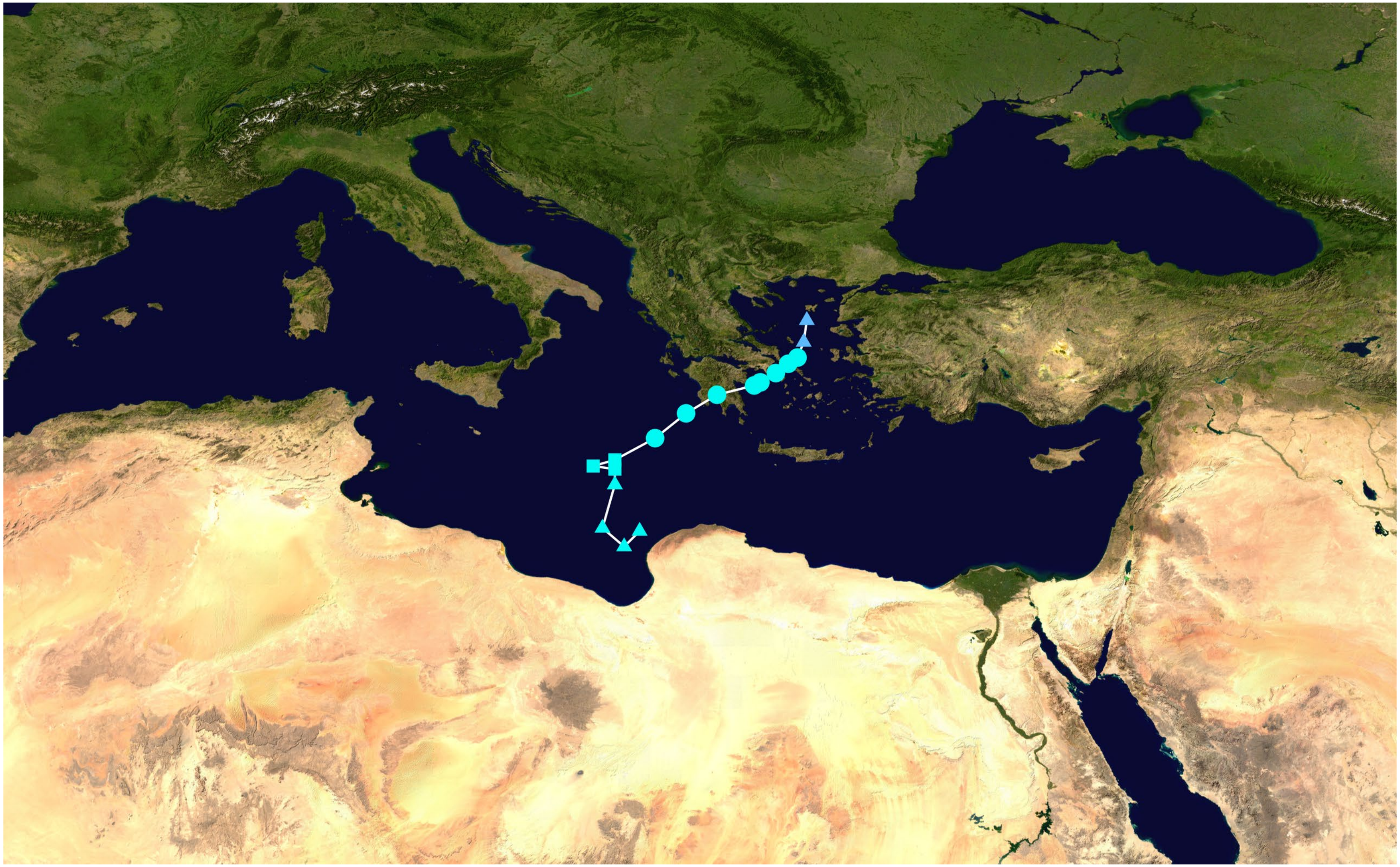
Cyclone Zorbas (“the Greek”?) near peak intensity, making landfall over the Peloponnese on at 11:14 GMT, 29 September 2018



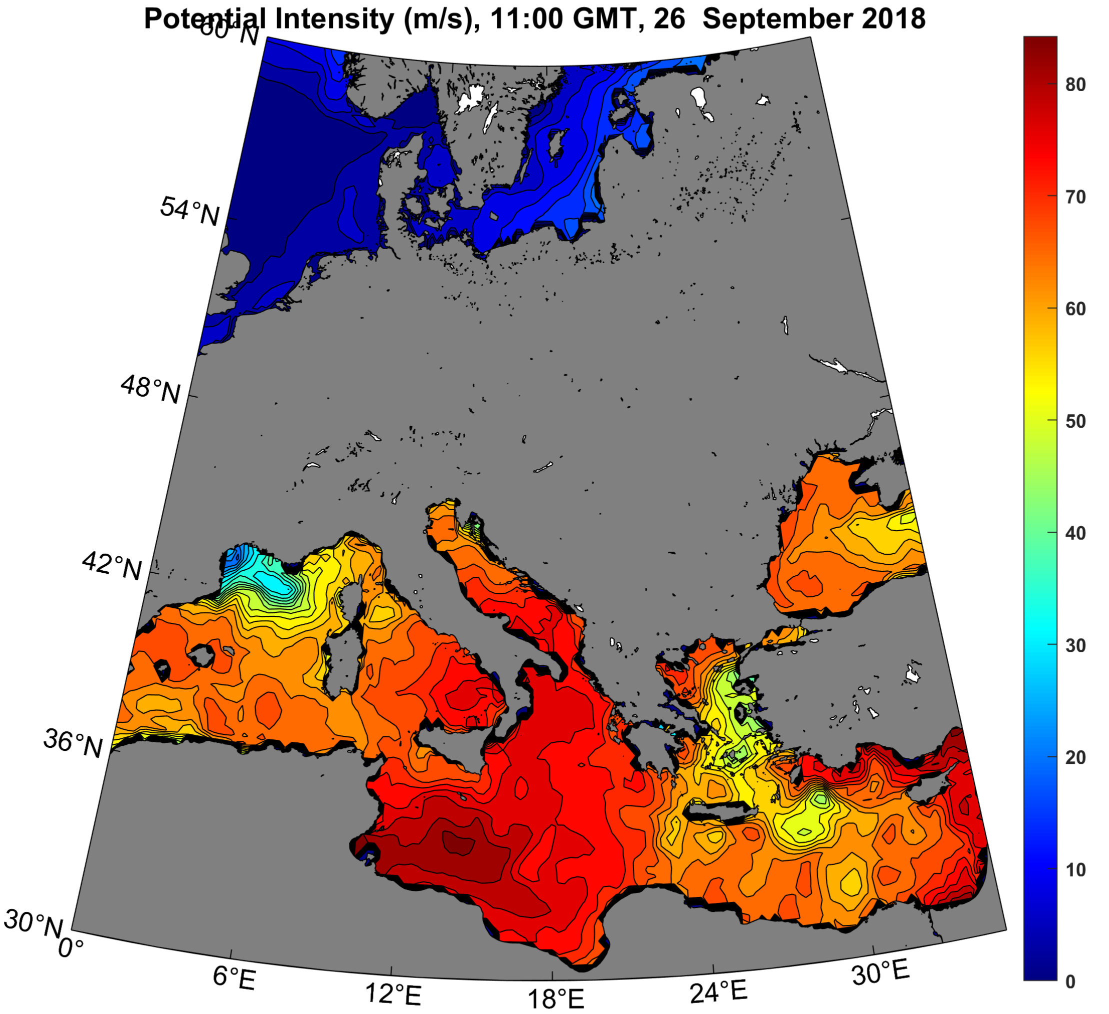
Close-up



Track of Zorbas, September 27-October 2, 2018

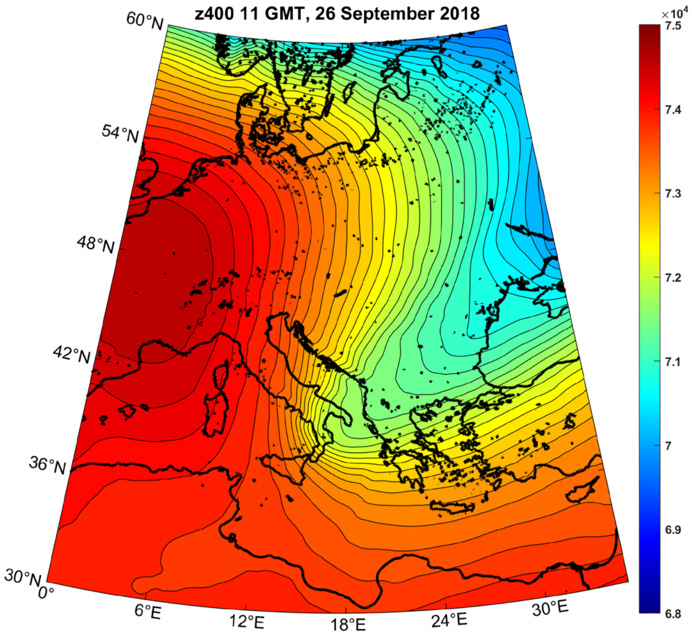


Antecedent Potential Intensity was Large

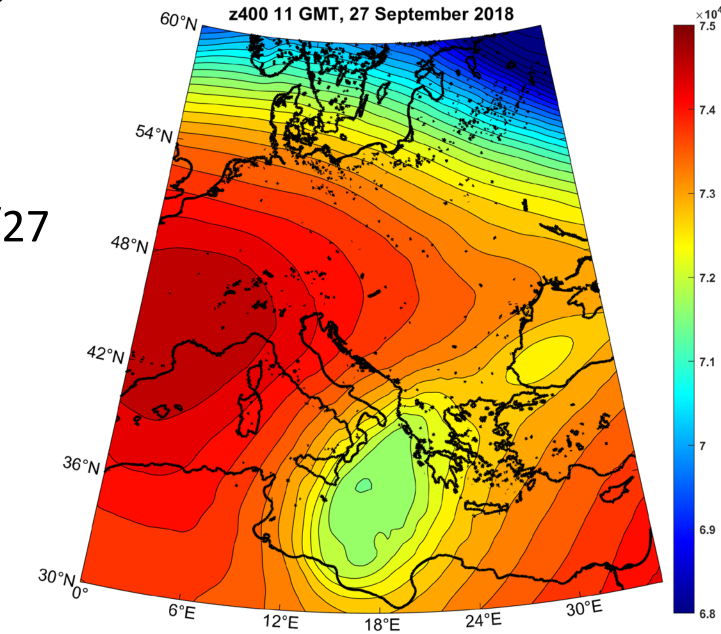


ϕ_{400}

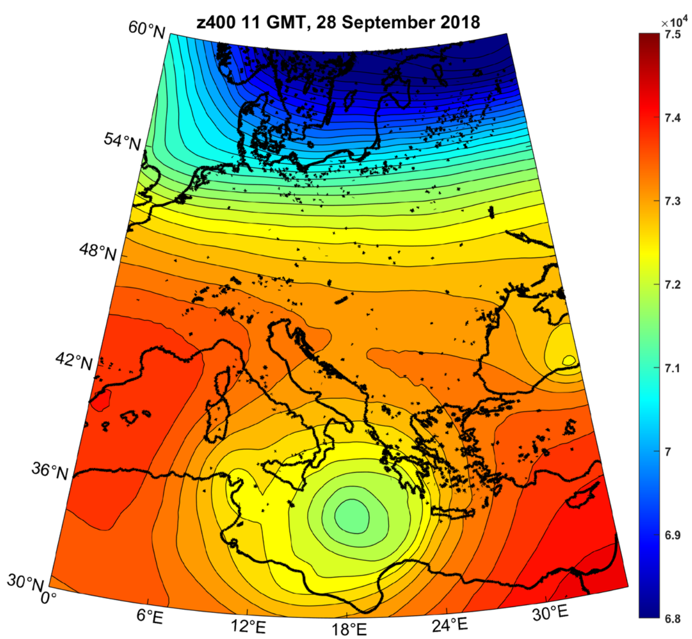
9/26



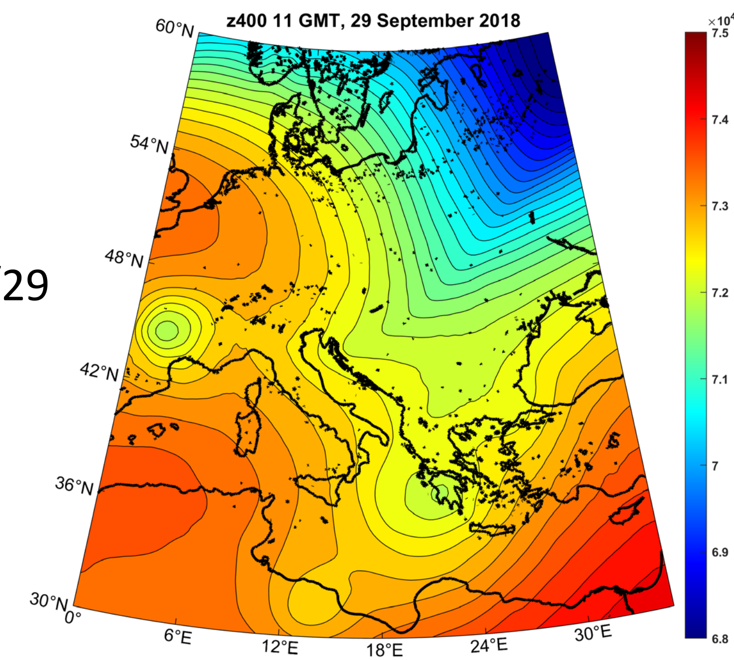
9/27



9/28



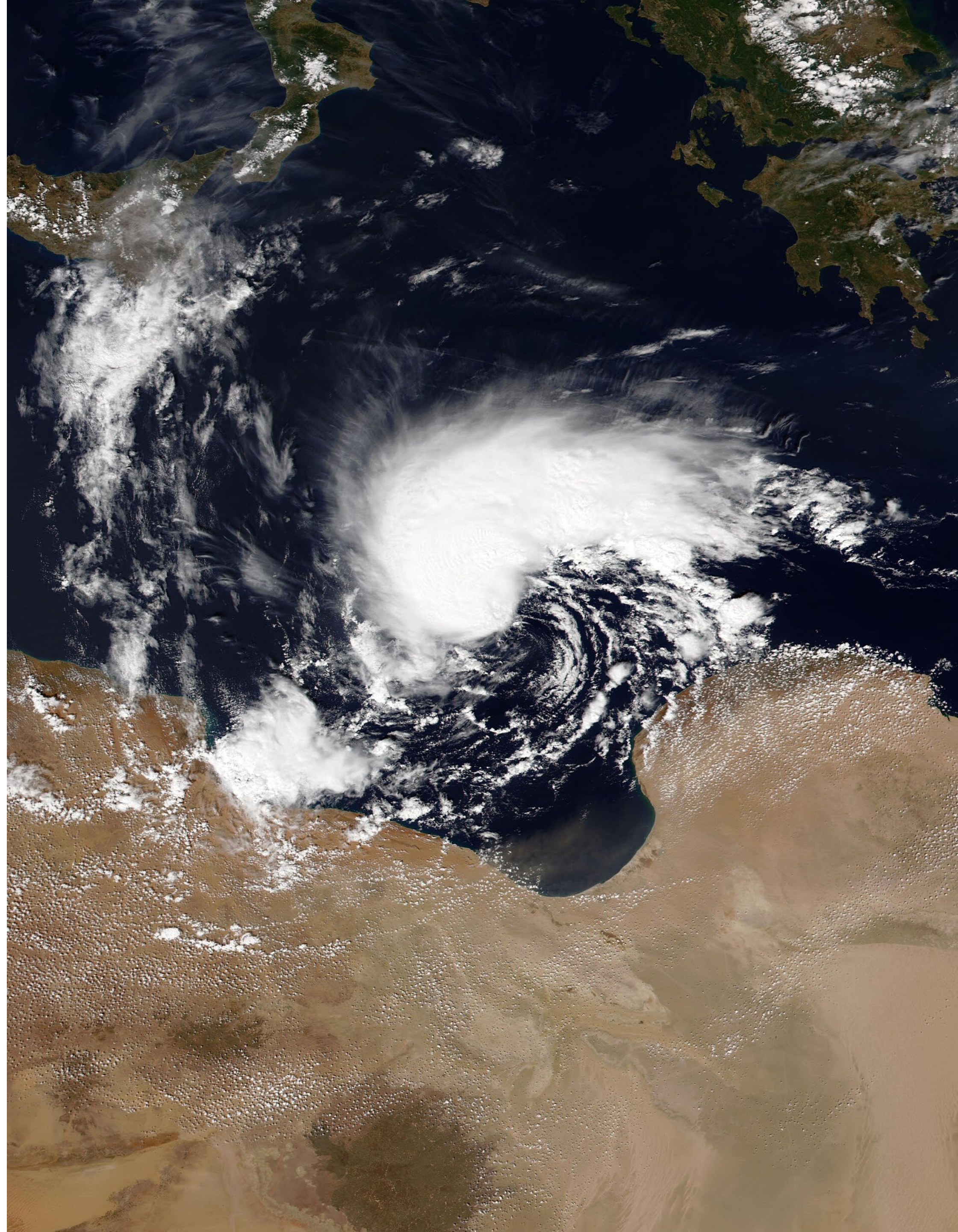
9/29



Cyclone Zorbas

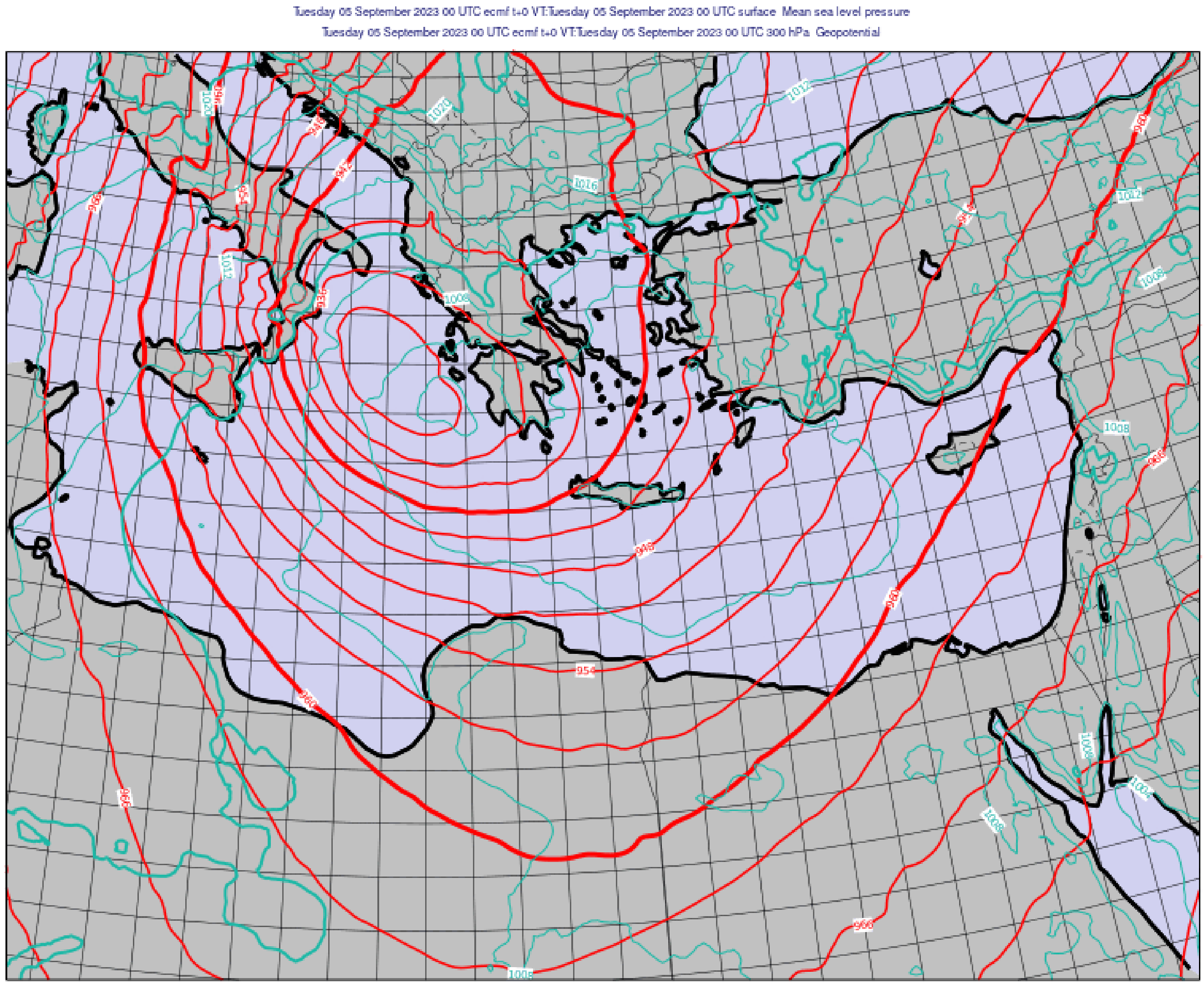
- Classical case of “tropical transition”
- Little if any local enhancement of potential intensity by cold low aloft
- Zorbas struck Greece as a classical Cat 1 hurricane

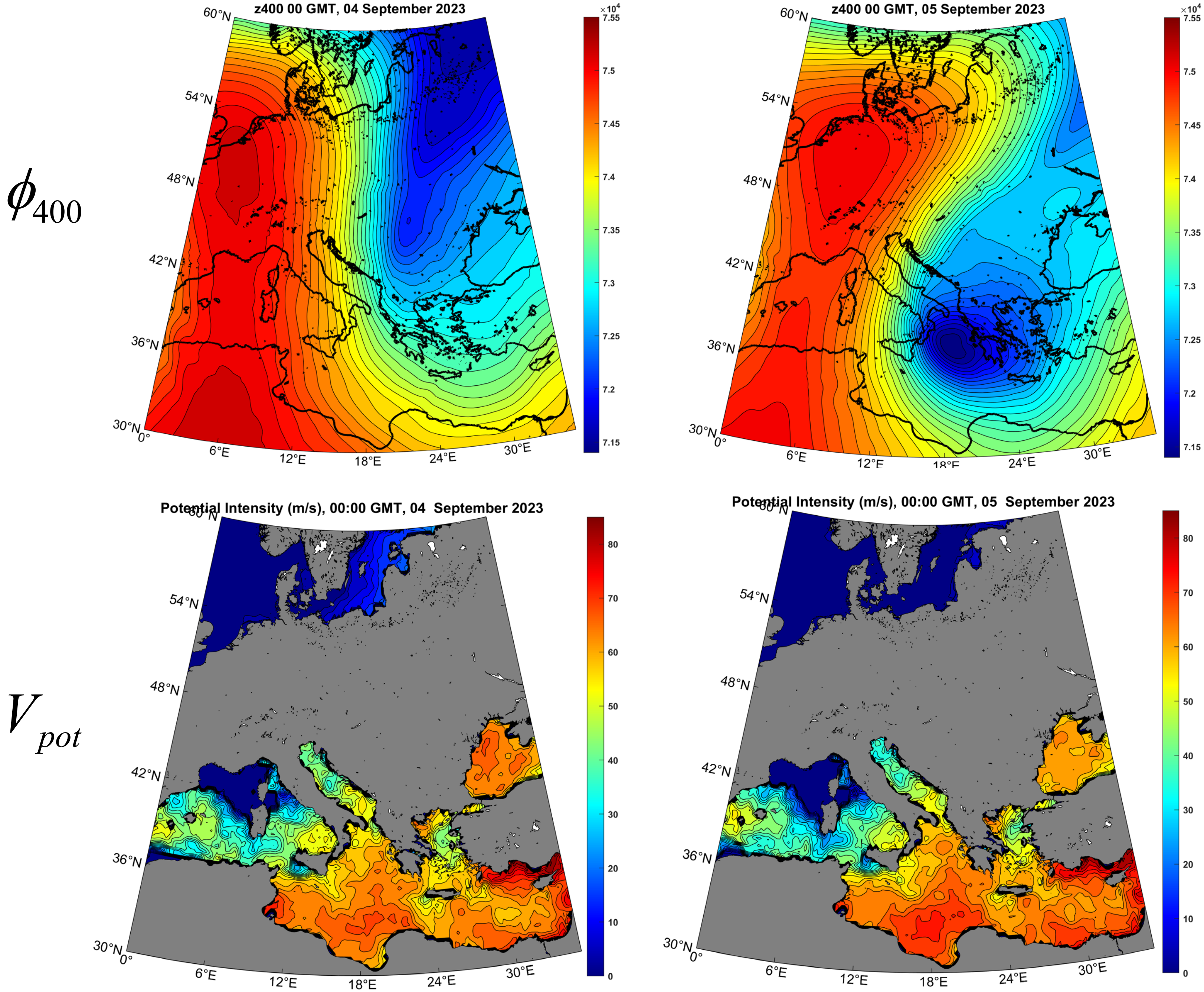
Storm Daniel, 4-12 September 2023



Storm Daniel, 4-12 September 2023

An animation of Z300 and mslp, from ECMWF operational analyses at 9km resolution, at 6h intervals, 9/5/00 – 9/12/18. Courtesy Tim Hewson.



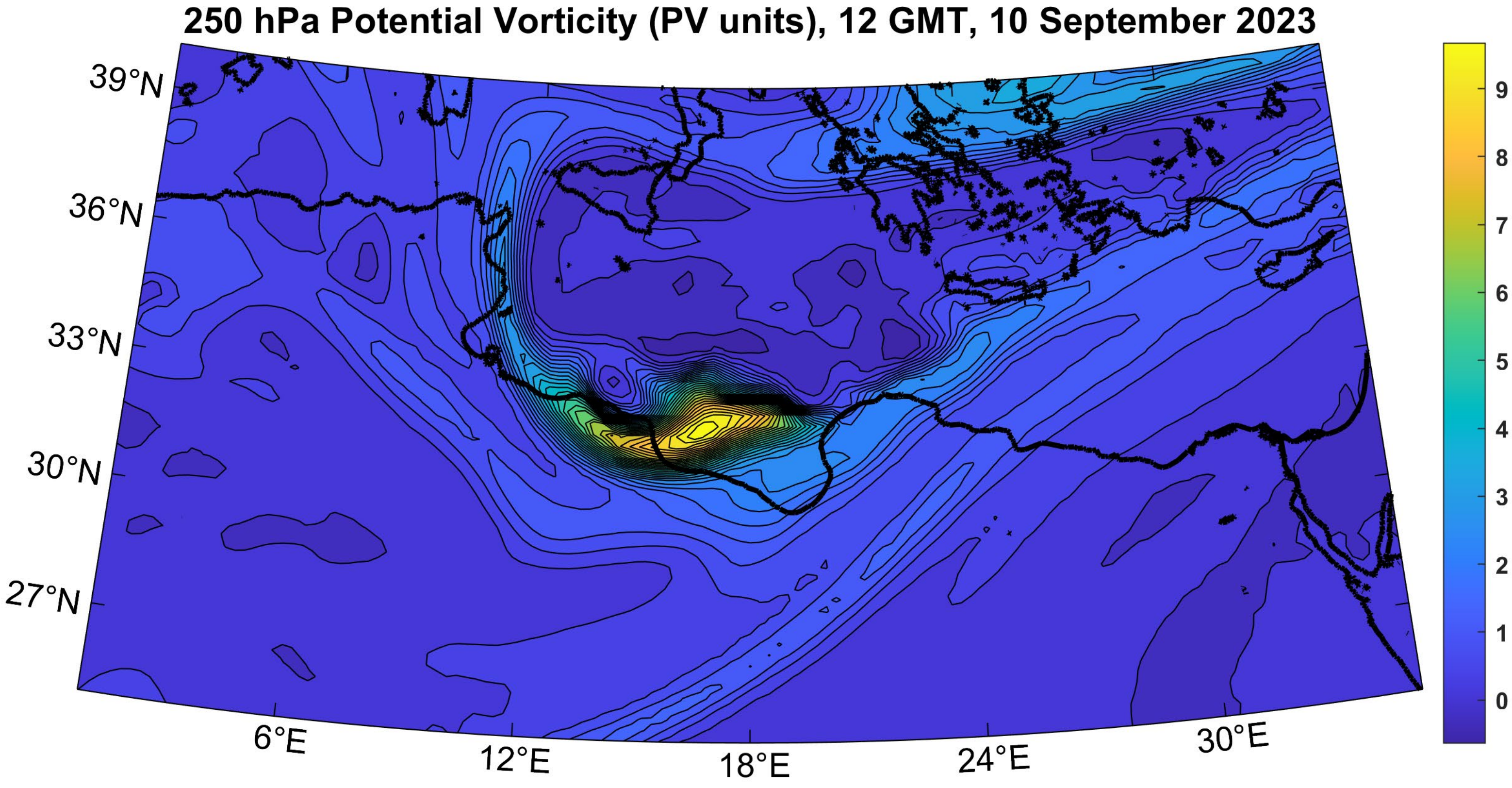


ϕ_{400}
V_{pot}
z400 00 GMT, 04 September 2023
z400 00 GMT, 05 September 2023
×10^4
7.55
7.5
7.45
7.4
7.35
7.3
7.25
7.2
7.15
Potential Intensity (m/s), 00:00 GMT, 04 September 2023
Potential Intensity (m/s), 00:00 GMT, 05 September 2023
80
70
60
50
40
30
20
10
0
60°N
54°N
48°N
42°N
36°N
30°N
0°
6°E
12°E
18°E
24°E
30°E

Storm Daniel

- Tropical transition case like Zorbas
- Small enhancement of potential intensity by cold low aloft
- But wait ….

Just before landfall, Daniel was “nudged” by its parent upper low in the form of a “PV satellite”



Summary

- Cyclones in this class form in climatological mean states that are, at best, marginal for surface flux-driven development (too dry, potential intensity too small)
- Approach of upper low cools and moistens air mass, increasing potential intensity
- Troposphere underneath cold upper low ideal embryo for incubating hurricane-like storms
- Long-term risk of medicanes: Stay tuned for talk by Romu Romero tomorrow