Puerto Rico Climate Office

Perspectives on Adaptation

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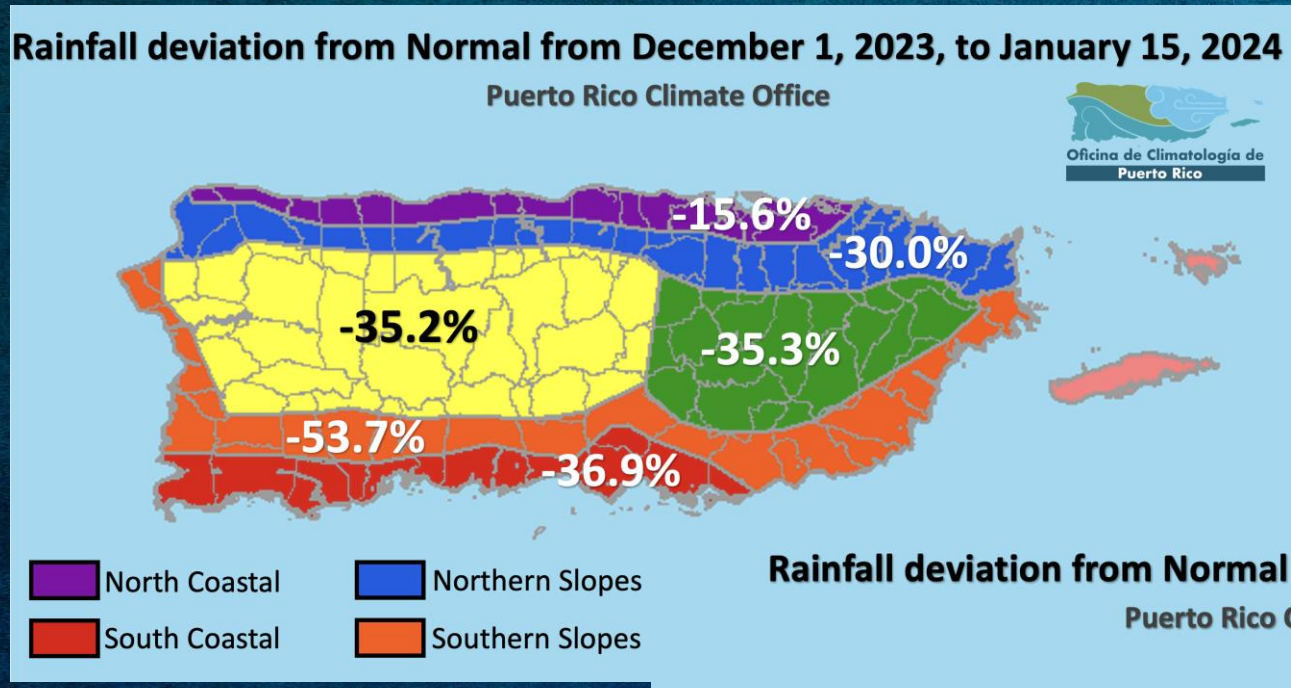
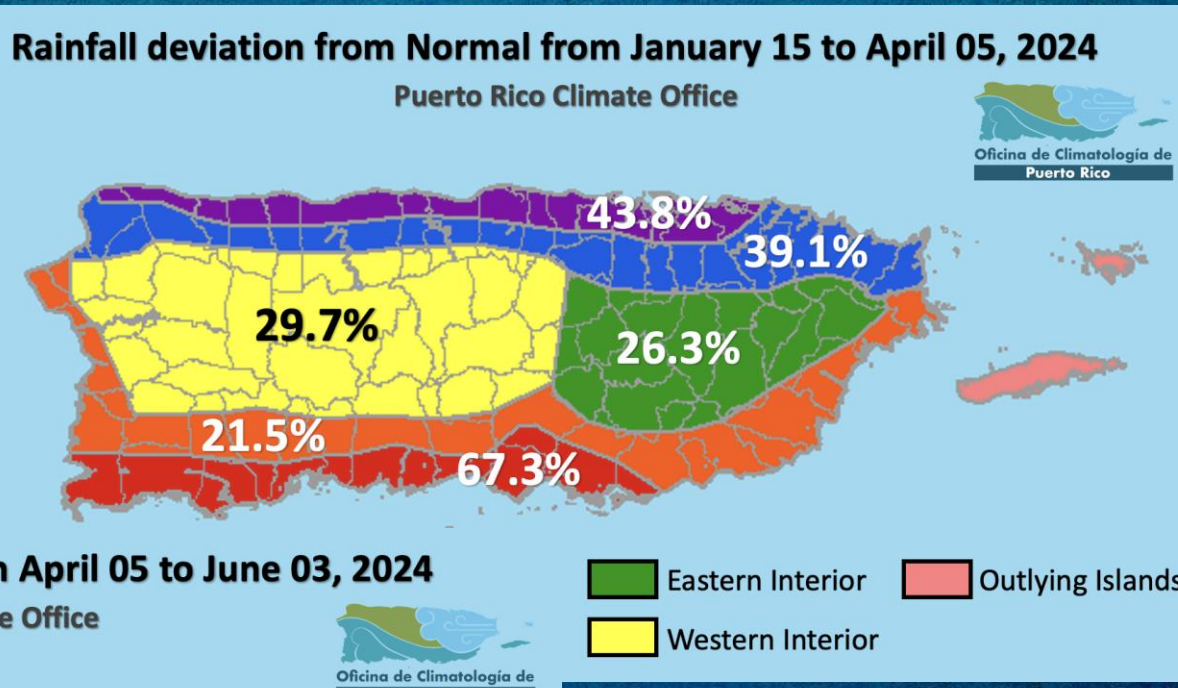
Climate Change
Adaptation Summit

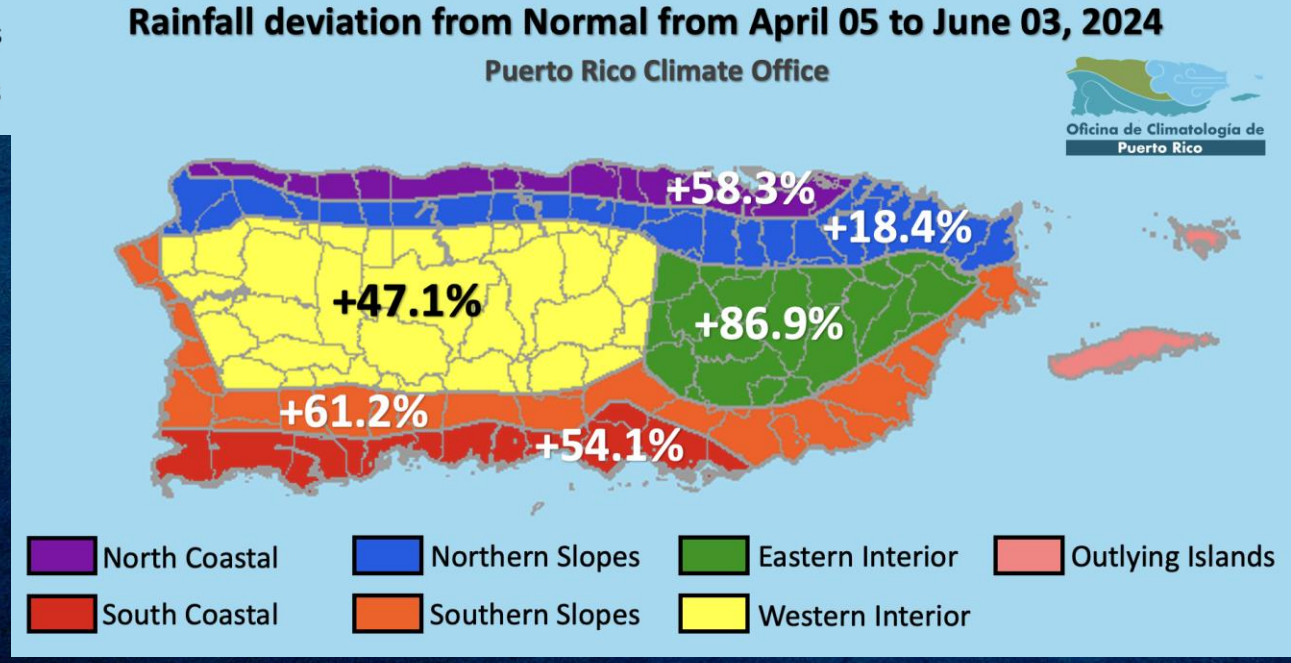
What should be our priorities?

- Puerto Rico – as the rest of the world – is experiencing very evident changes in climate
- These changes are undisputably attributed to increases in atmospheric CO_2
- Our Climate Office, along with many agencies and scientists within an outside Puerto Rico continue to document and study the climate transformation
- We are an Island of 9,000 km^2 , with 3.2 million people, producing 3 out of every 10,000 tons of CO_2 emitted in the world every year.
- Puerto Rico has not fully recovered from the effects of Hurricane María and is experiencing an accelerating population loss and aging
- We are still in the grips of a Fiscal Control Board appointed by the US congress to deal with an estimated 70 US Billion dollars in debt.
- Where should our resources go? Should we prioritize reducing our carbon emissions or protecting the lives and property of our people?
- This Summit has been called to address our urgent need for adaptation

Rainfall Monitoring

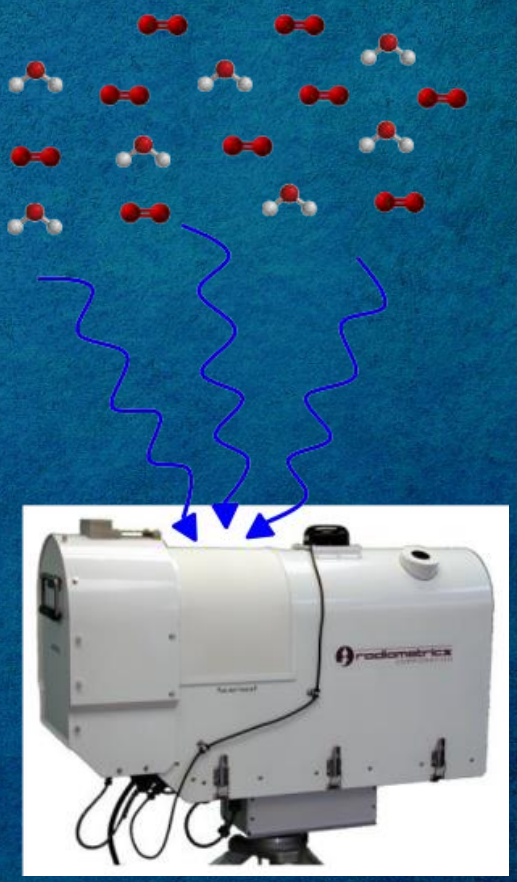




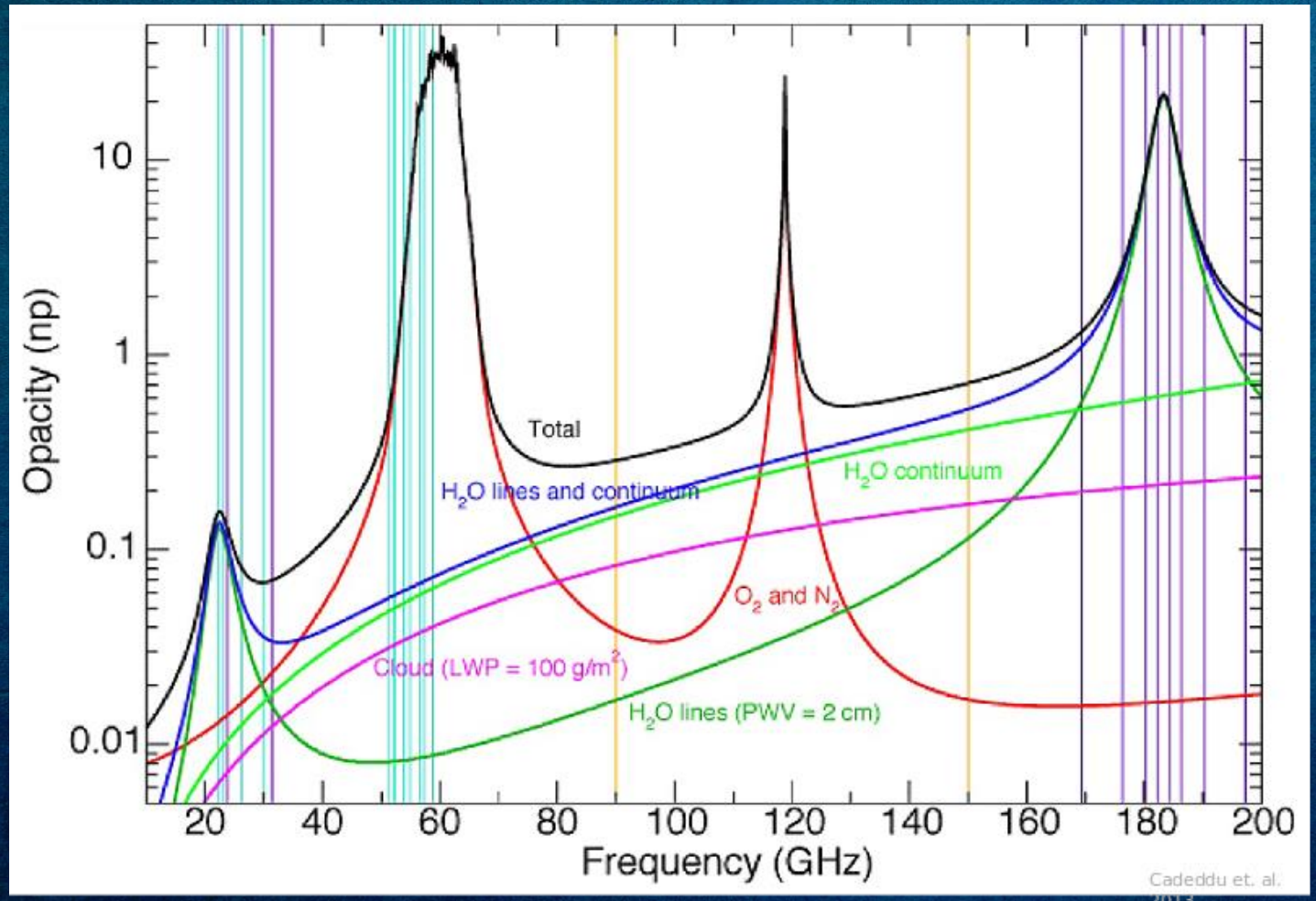


Microwave Radiometer Observations in Mayagüez

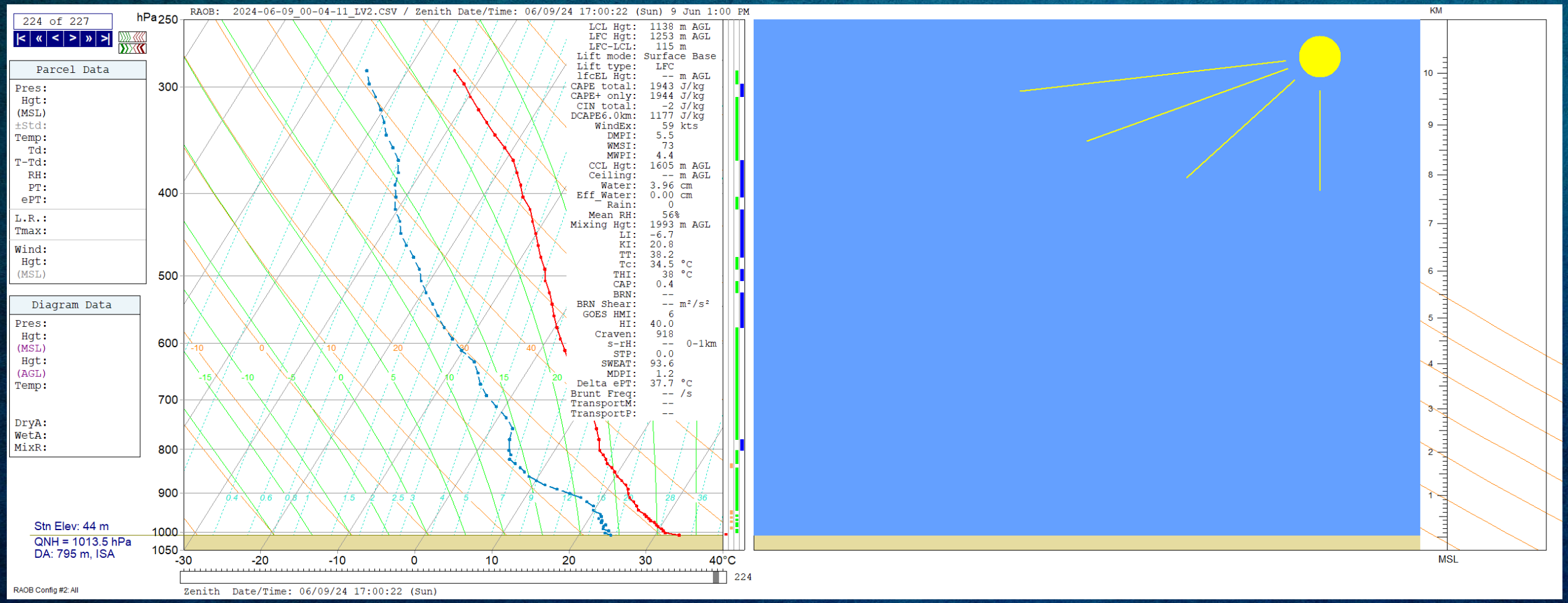
- Radiometrics – MP3000A
  - + 35 calibrated channels (K and V bands)
  - + 22 – 30 GHz – Water vapor profiles (21 channels)
  - + 50 – 59 GHz – Oxygen band (Temp. and liquid water) (14 channels)
  - + Real-time analysis – Neural Network trained to San Juan
  - + Zenith, 20 deg, 160 deg above horizon East-West scans
  - + Azimuth rotation : +/- 45 deg, scans in measurement cycle
  - + High temporal resolution: 5 min/cycle
  - + High spatial resolution (47 heights) 100m: 0 – 1km, 250m: 1 - 10km



Emission Spectrum of the Atmosphere

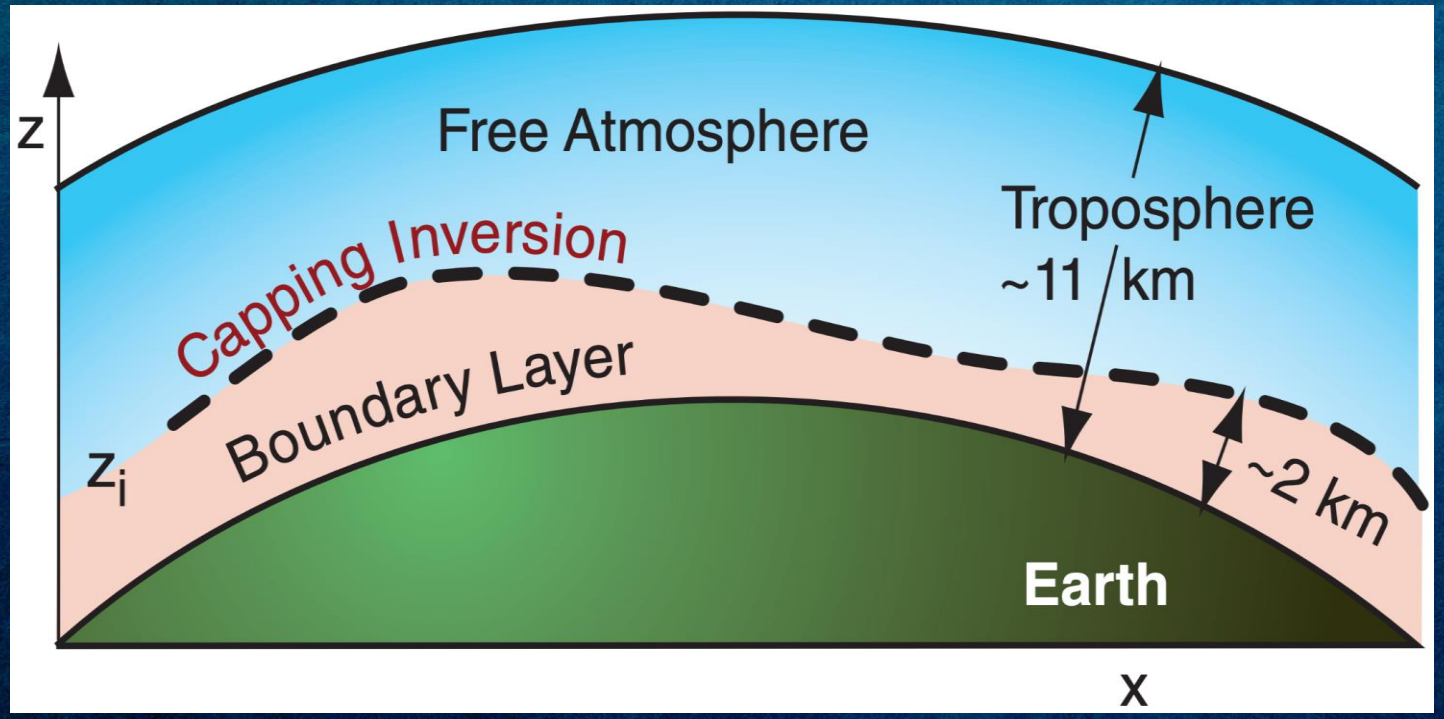


Atmospheric Profile

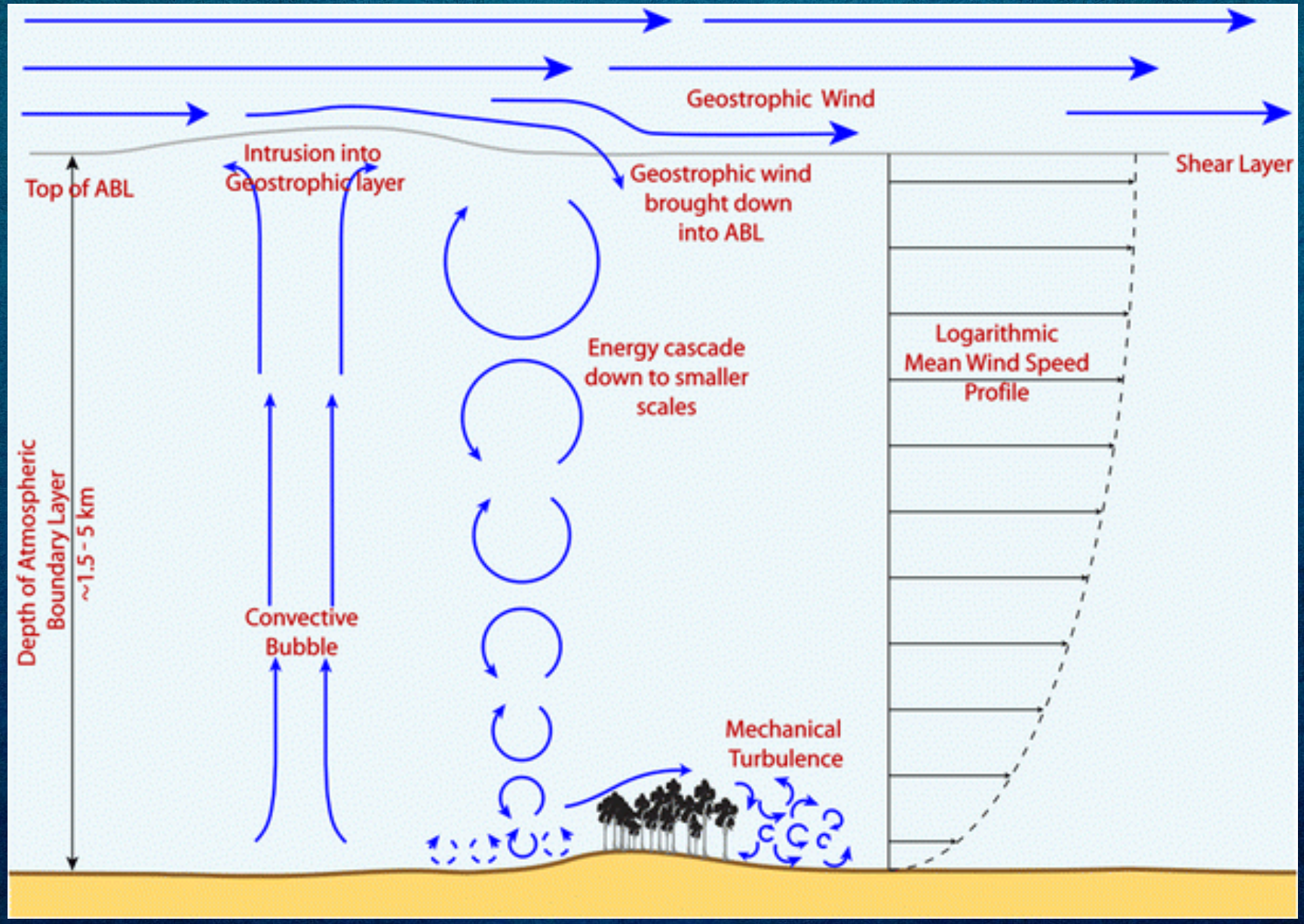


What is the PBL?

The planetary boundary layer (PBL) is the region of the atmosphere that is directly influenced by the Earth's surface. The PBL height is important for a variety of atmospheric processes, including cloud formation, precipitation, and air quality.



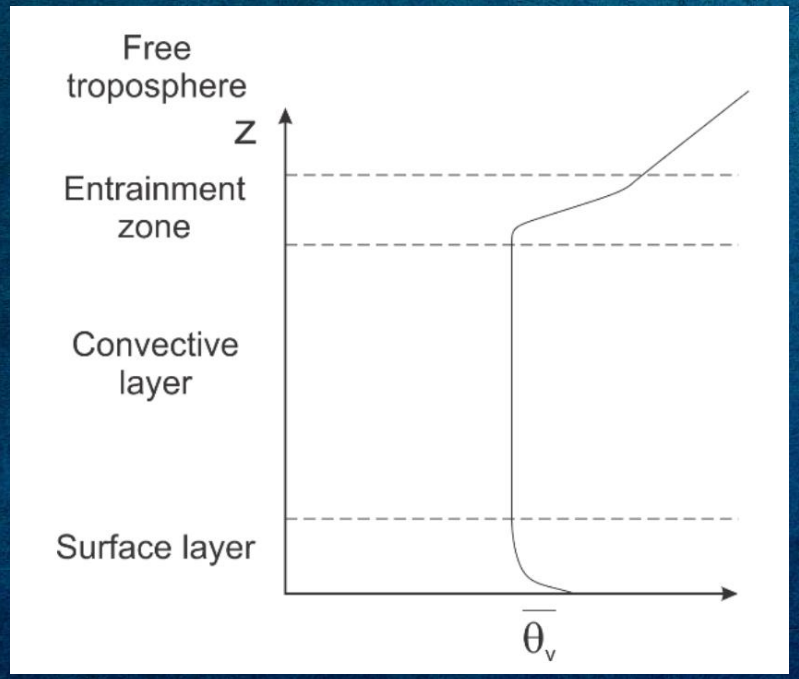
Boundary Layer Structure

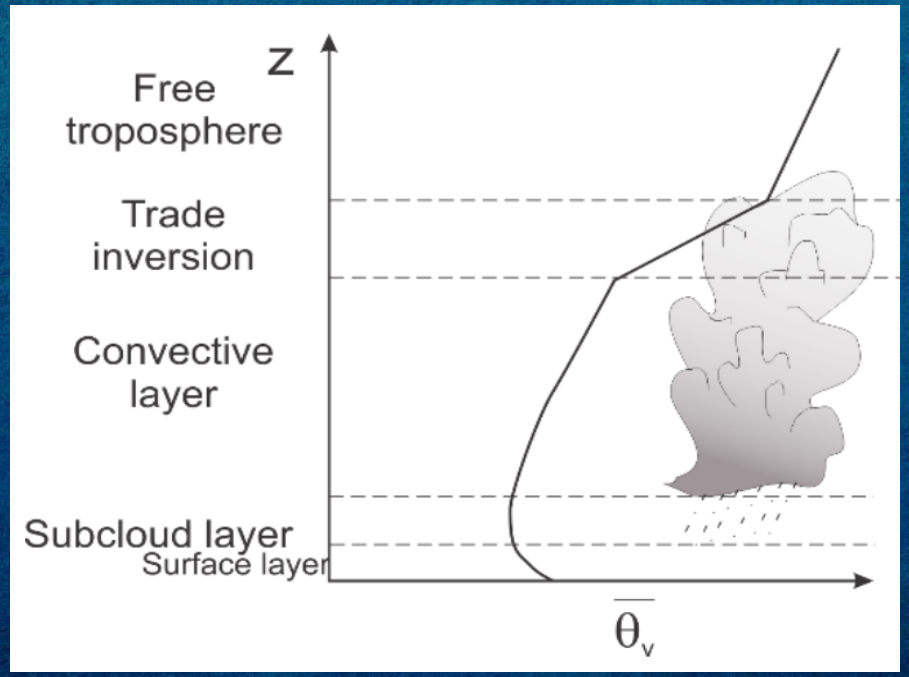


Virtual potential temperature

$$T_v \equiv T\left(\frac{1+r/\varepsilon}{1+r}\right), \qquad \varepsilon \equiv R_d / R_v \cong 0.622$$

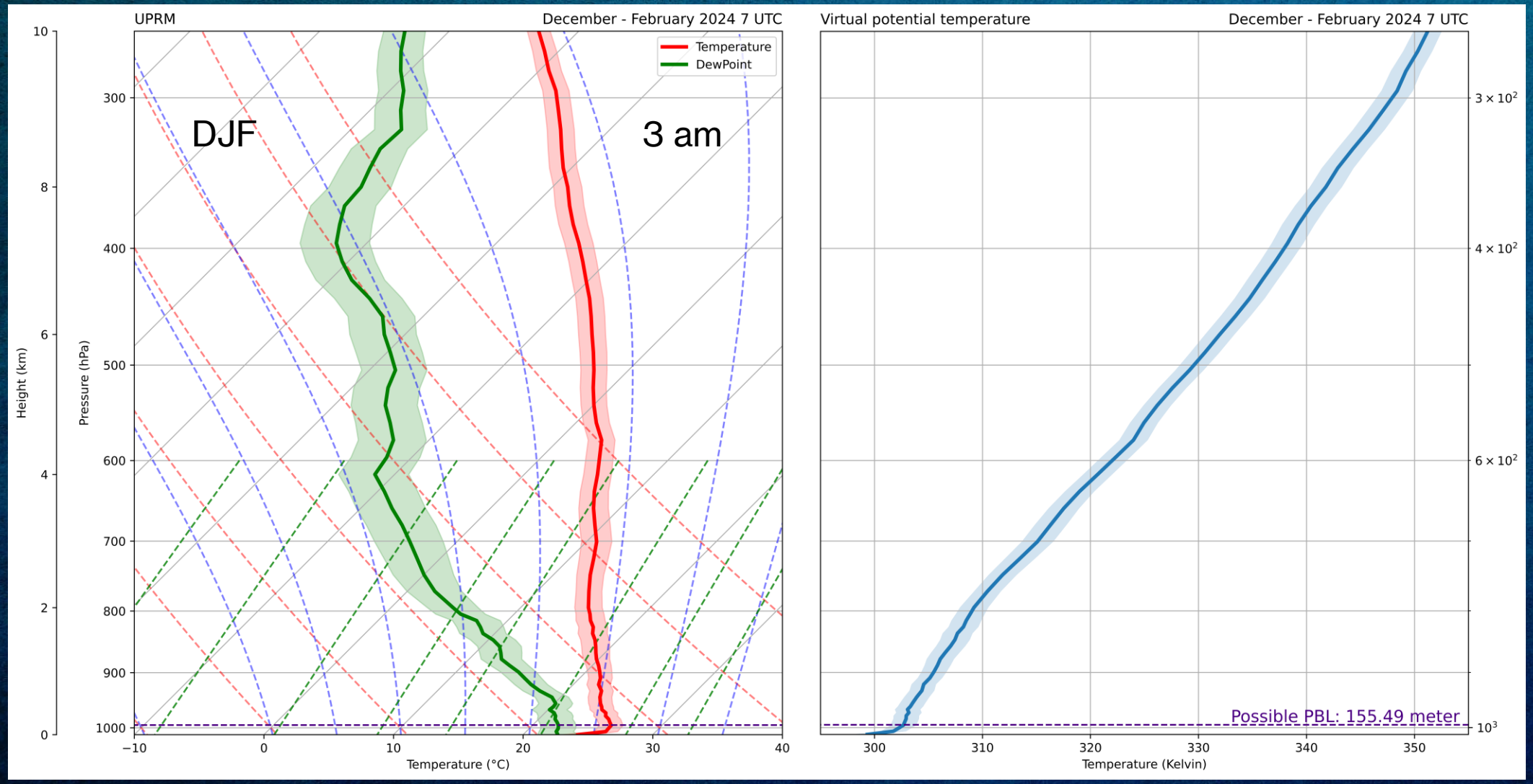
$$\theta_v = T_v \left(\frac{p_0}{p}\right)^{R_d/c_p}$$





Vertical thermodynamic structure of clear boundary layers and a trade cumulus boundary layer

Mayagüez Profile Climatology (J.A. Álvarez)



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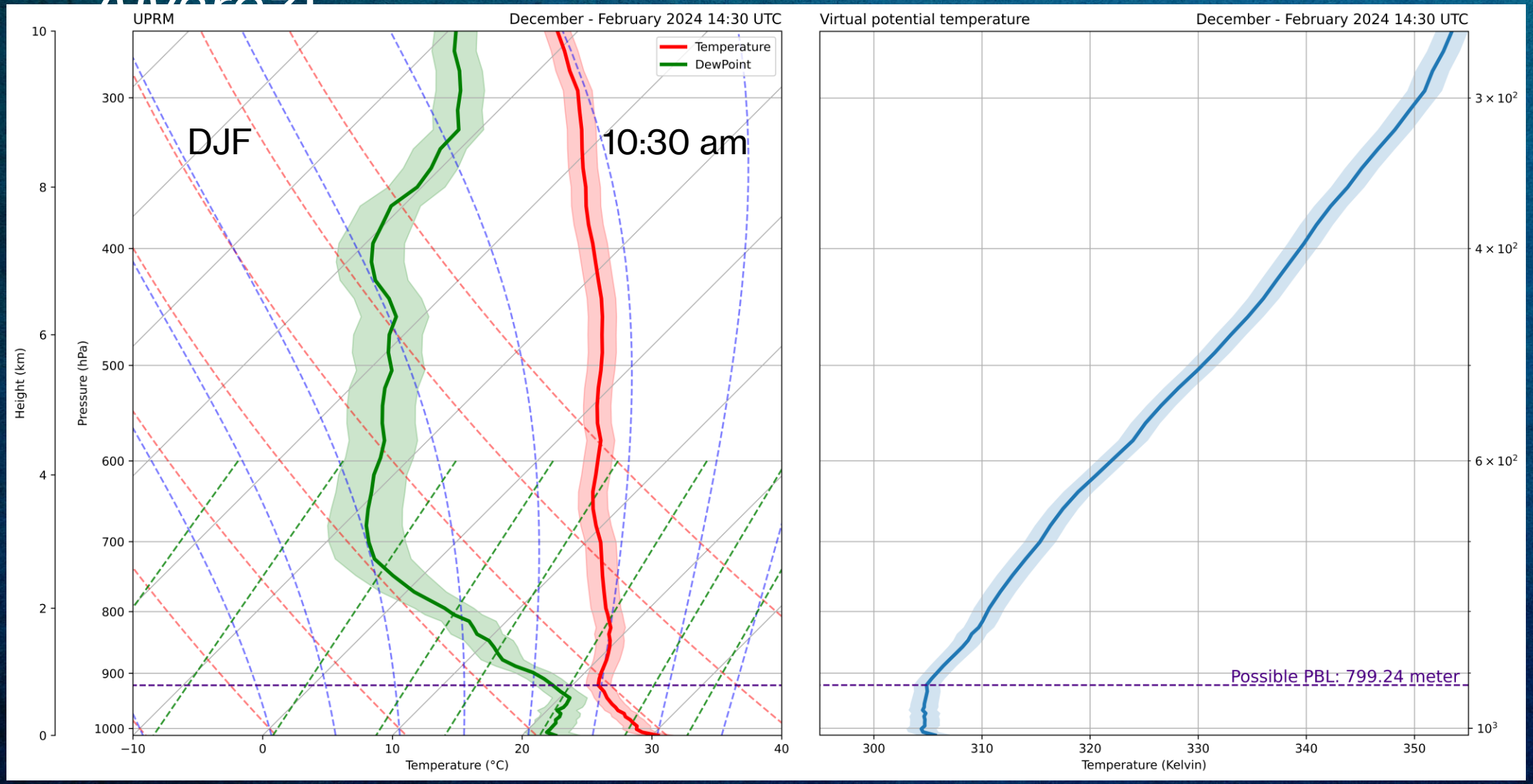

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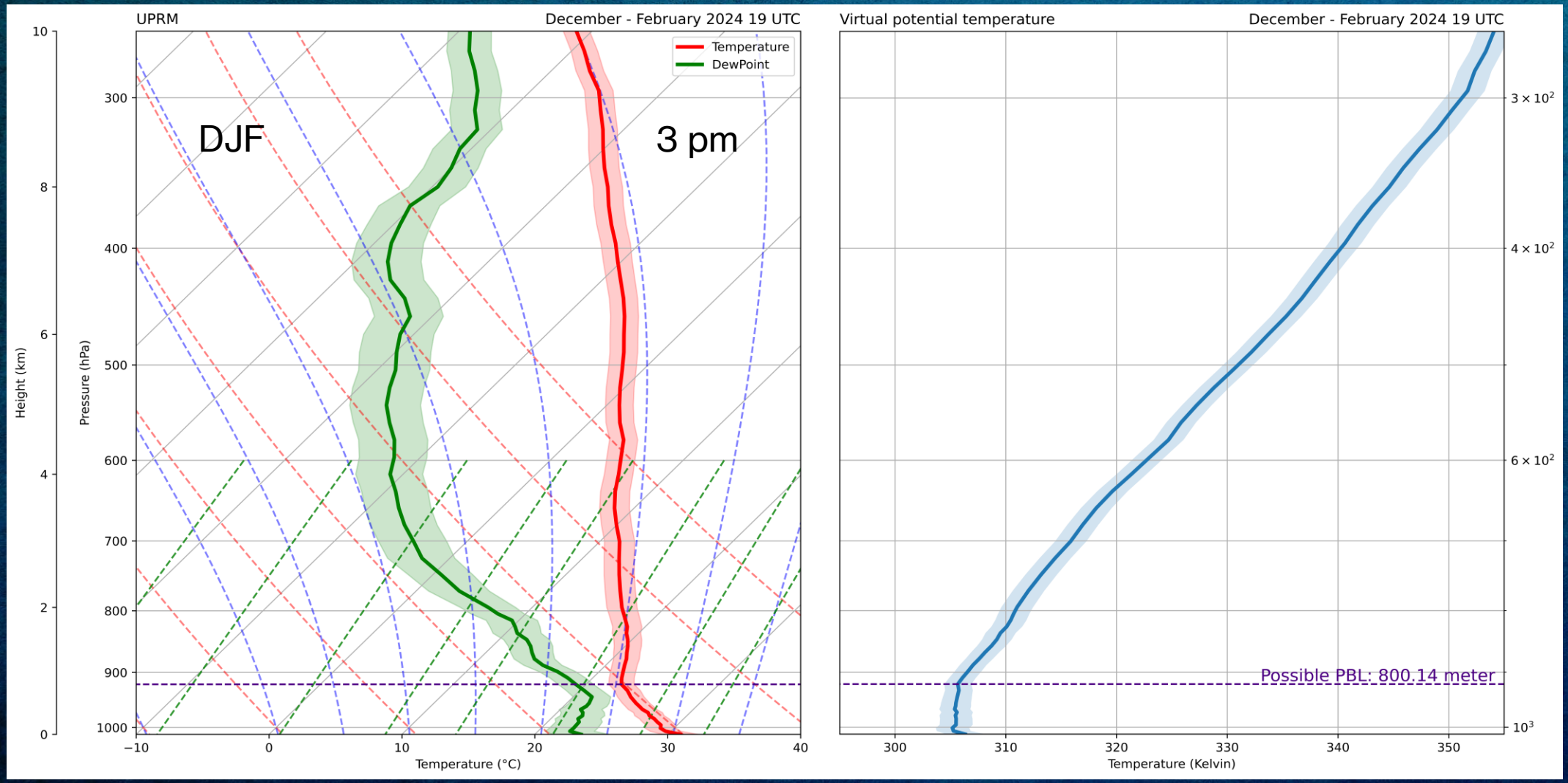

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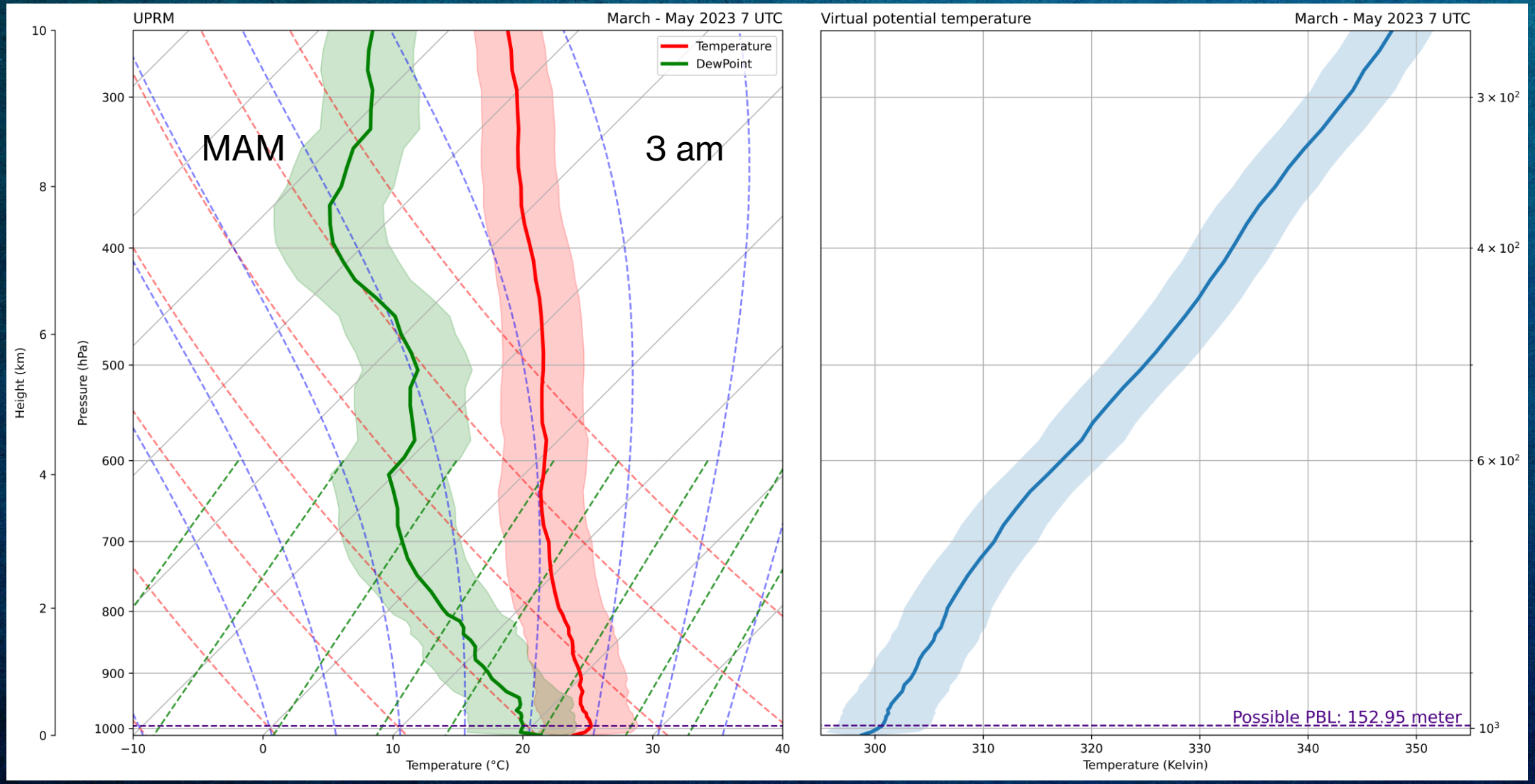

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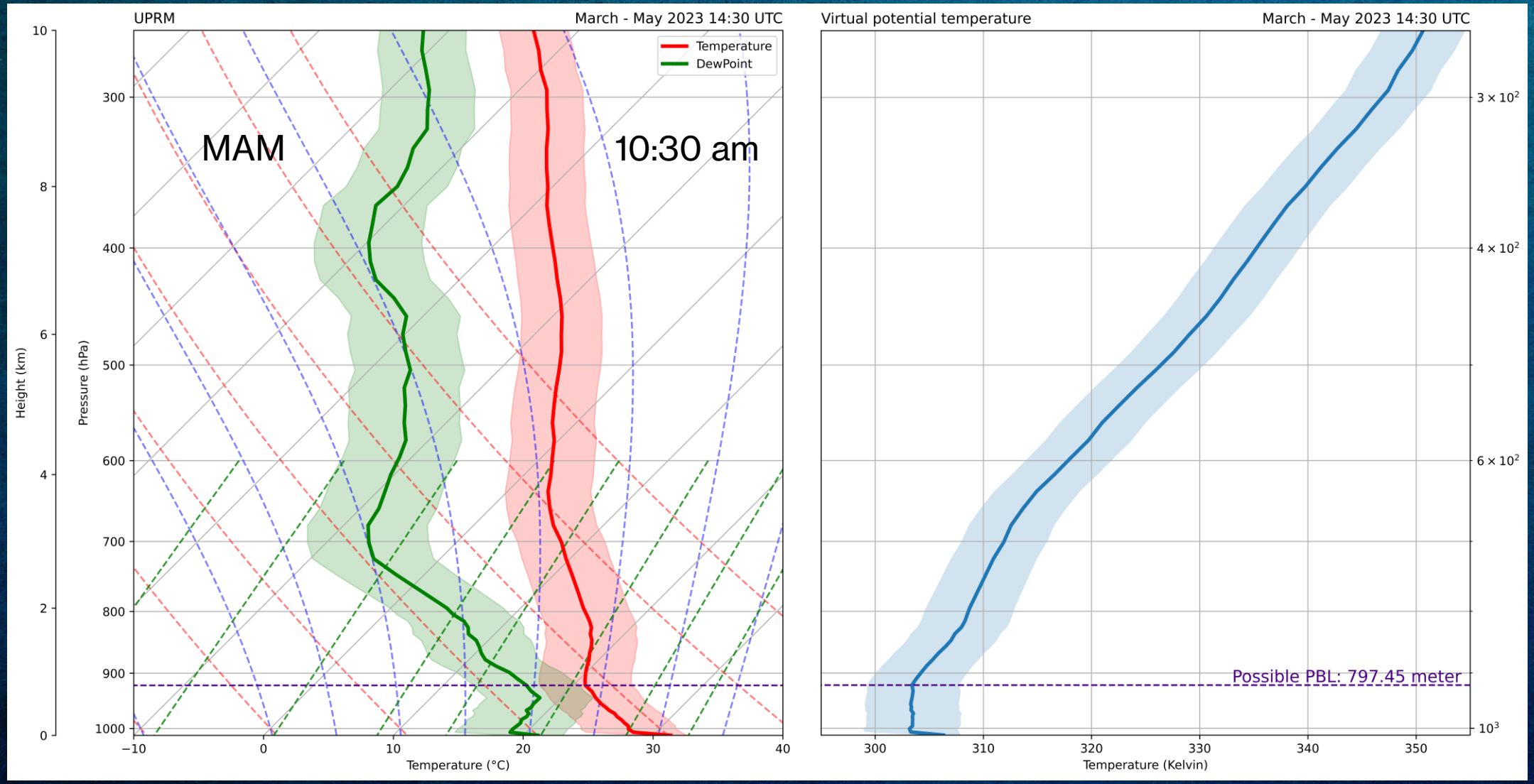

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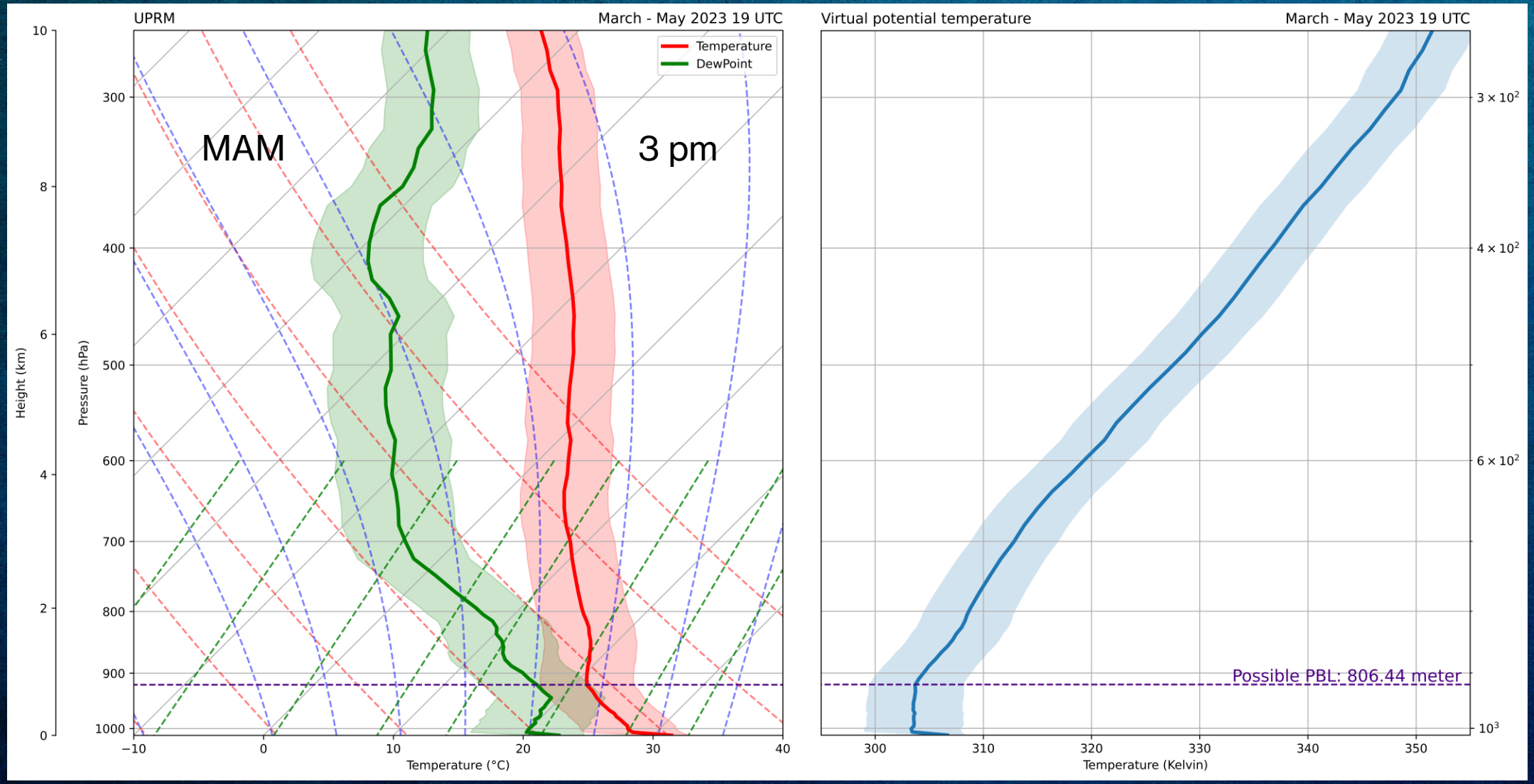

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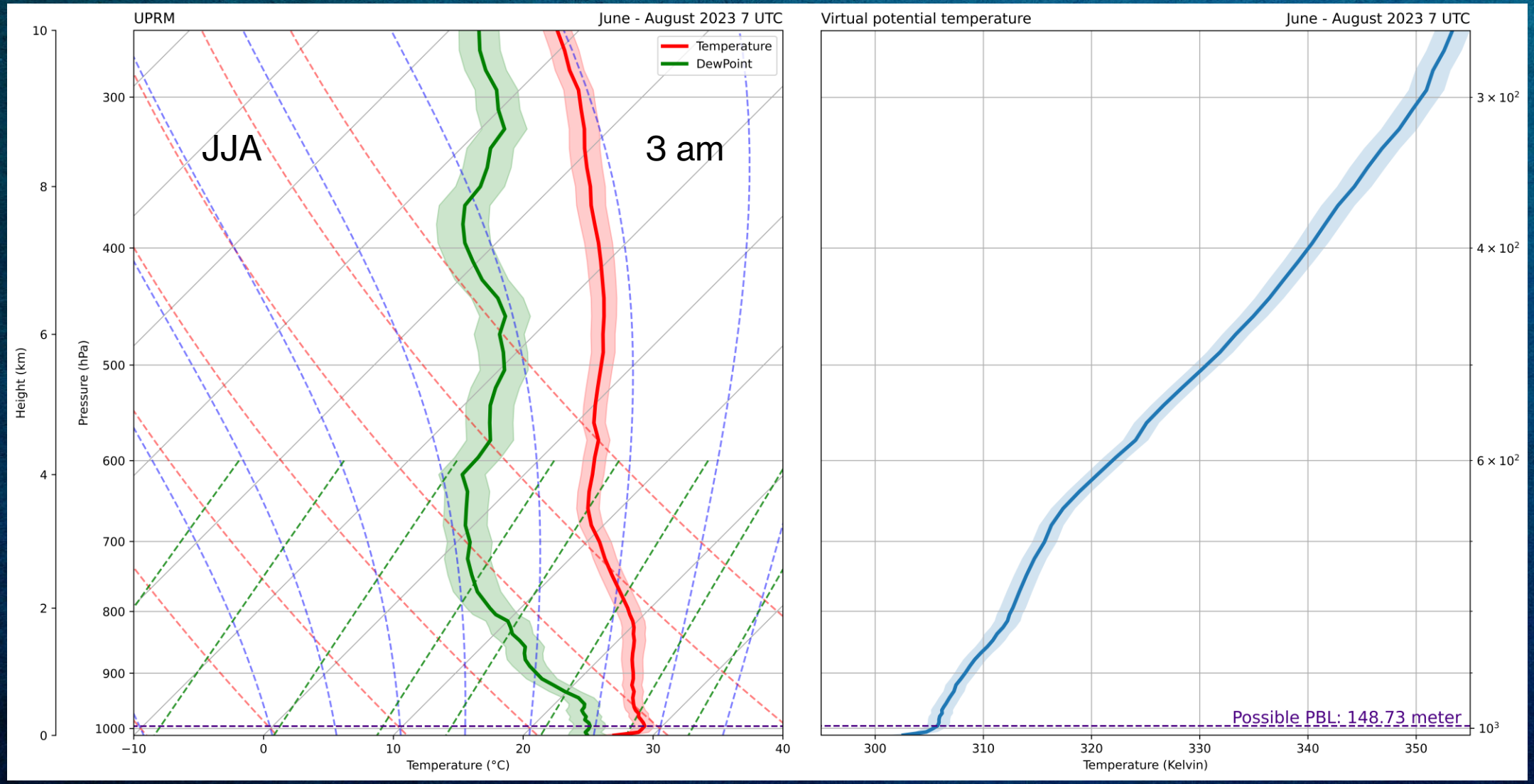

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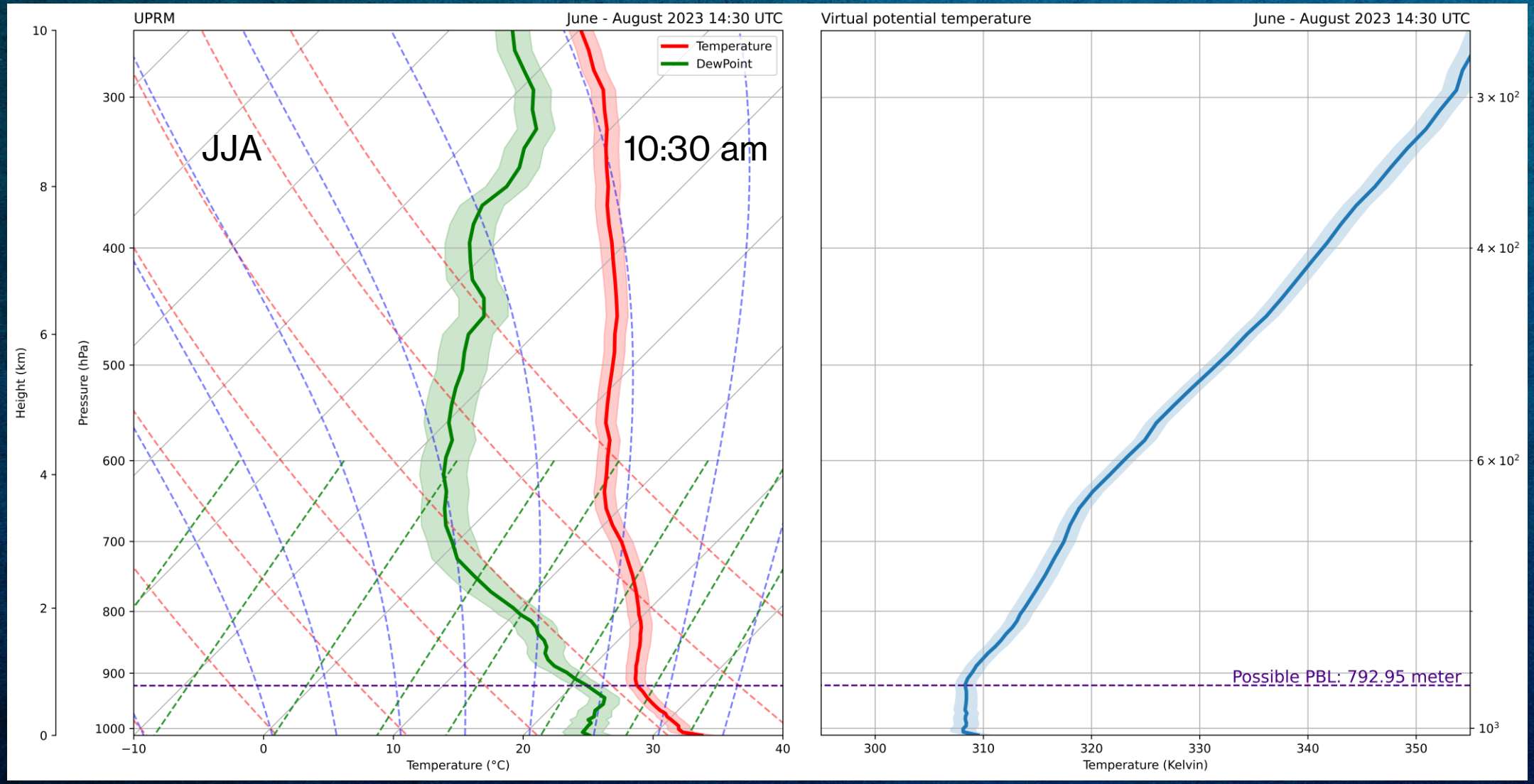

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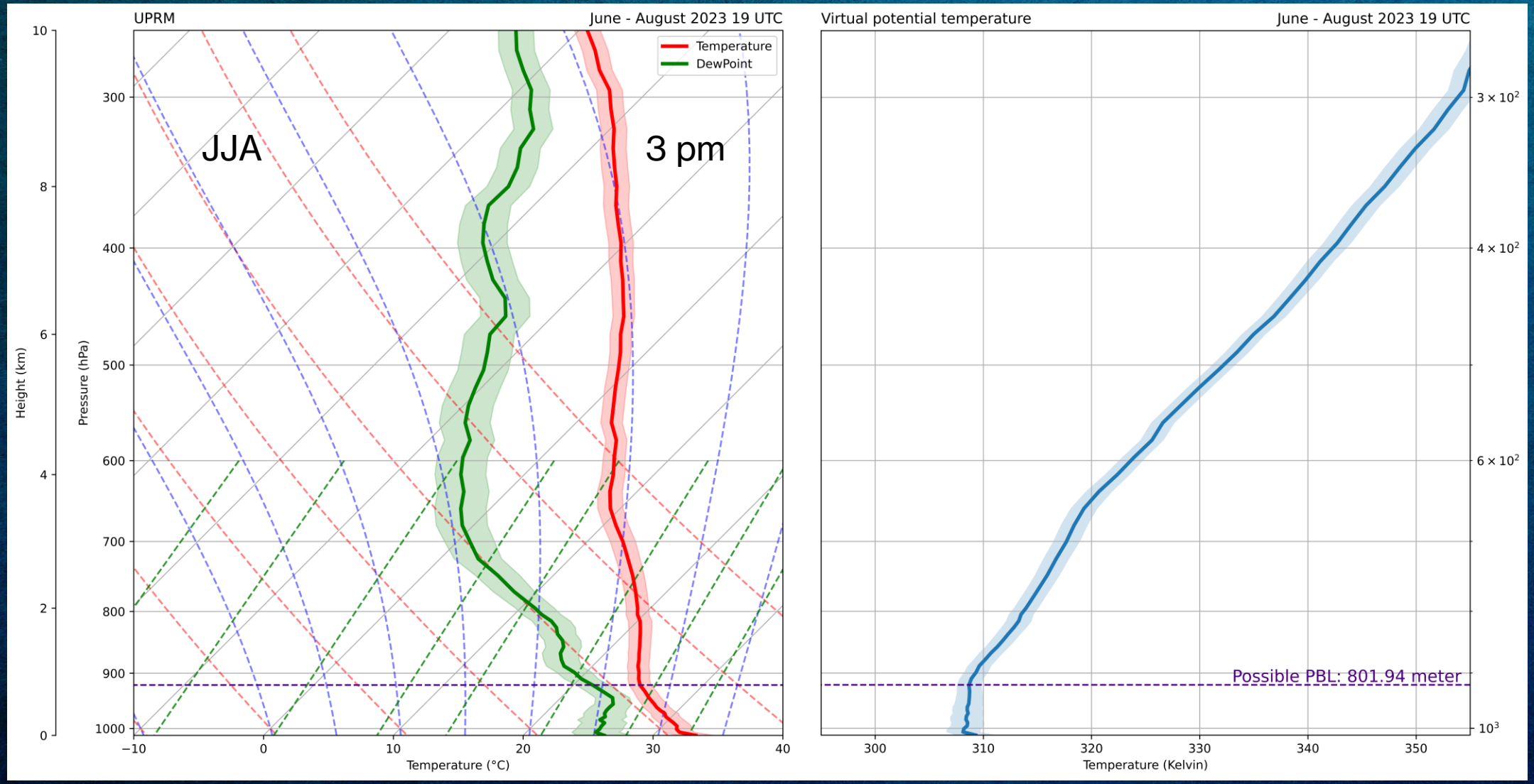

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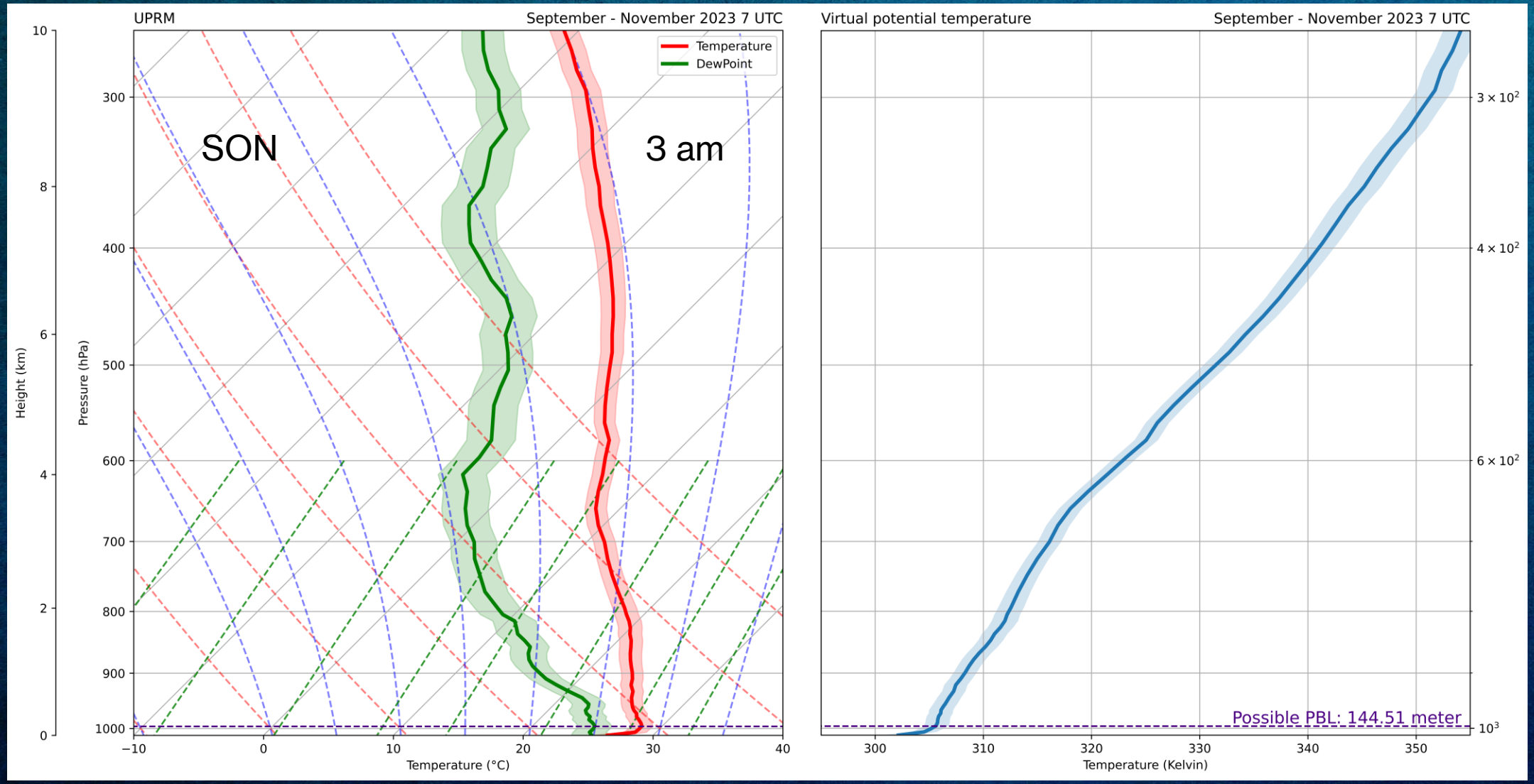

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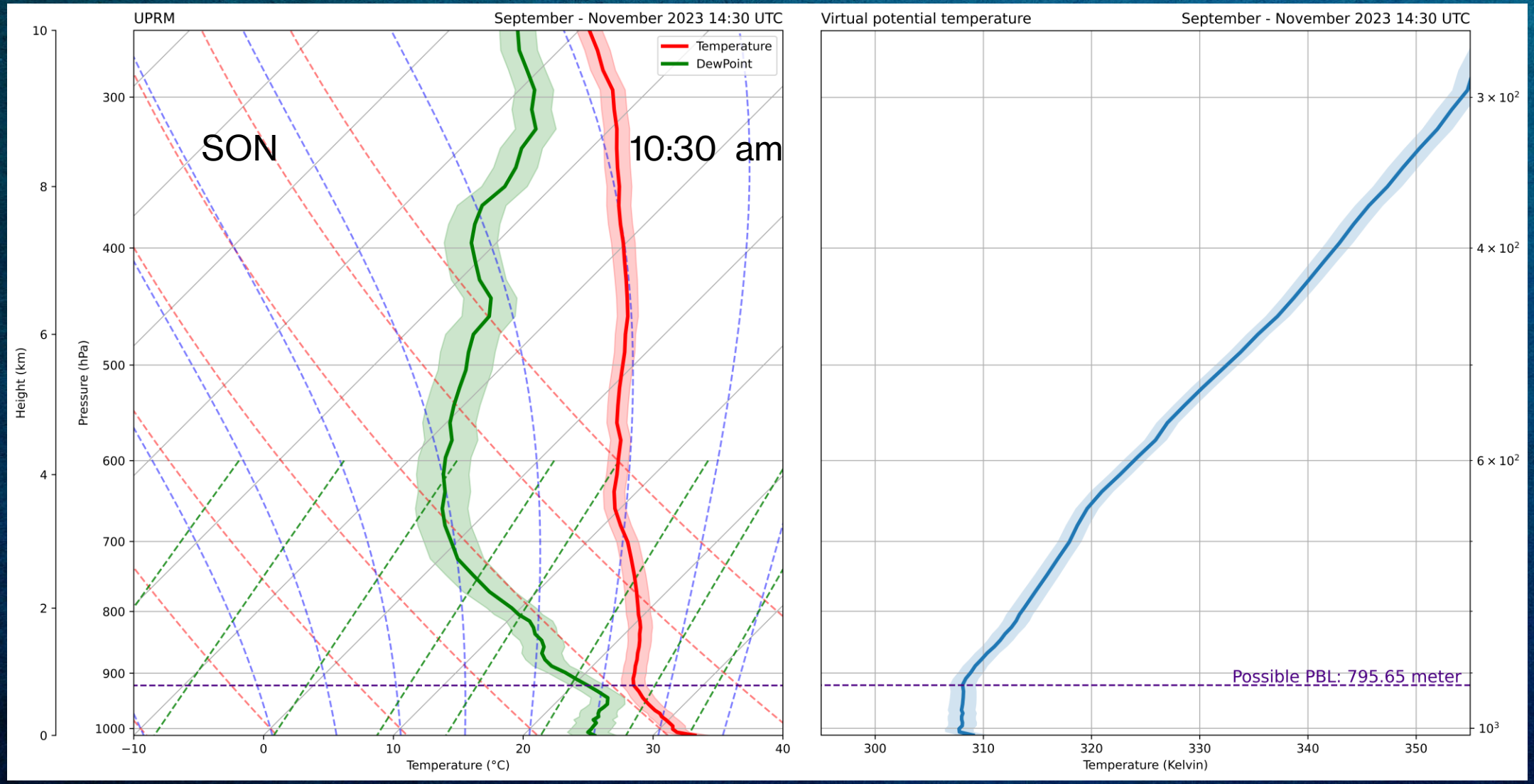

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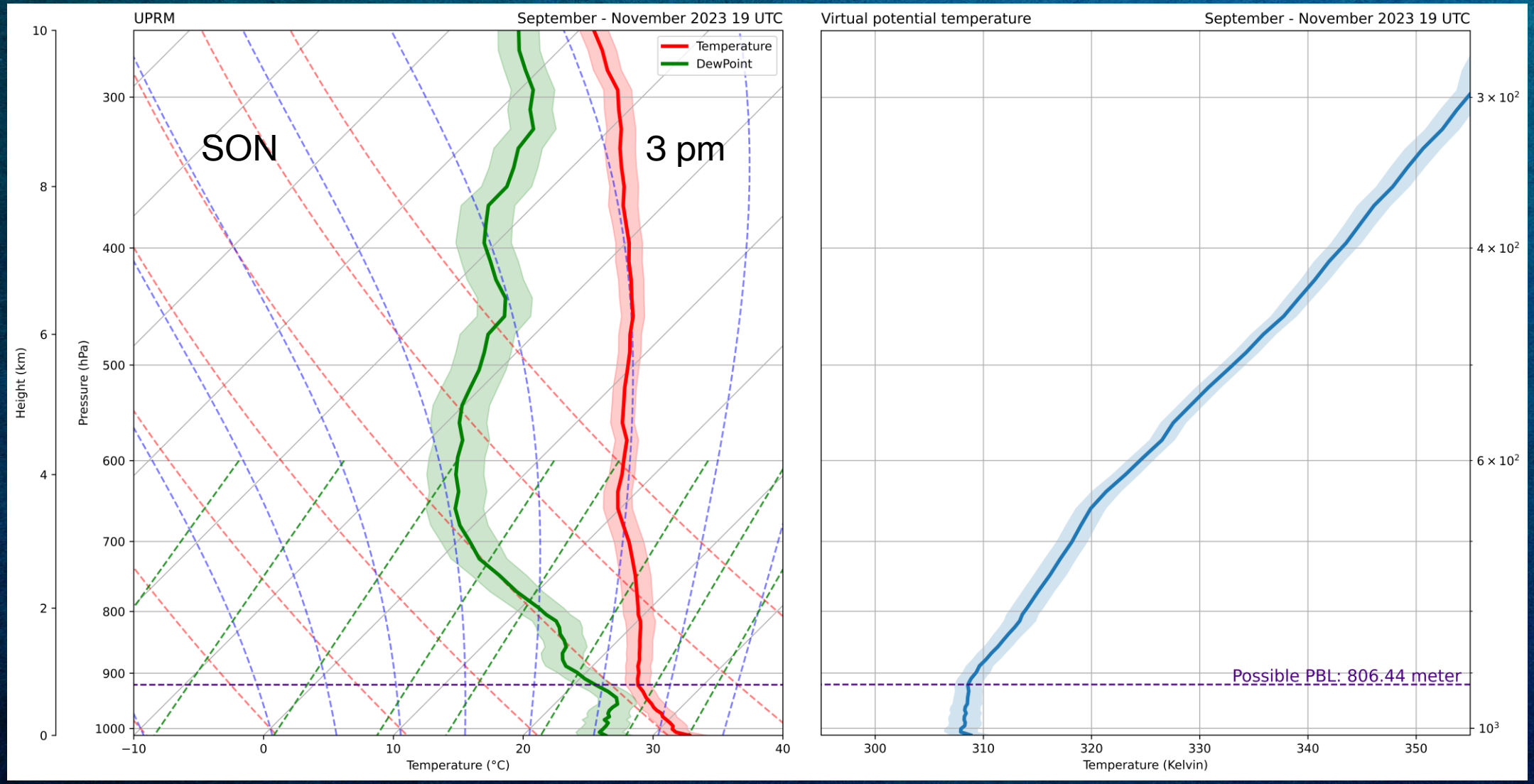
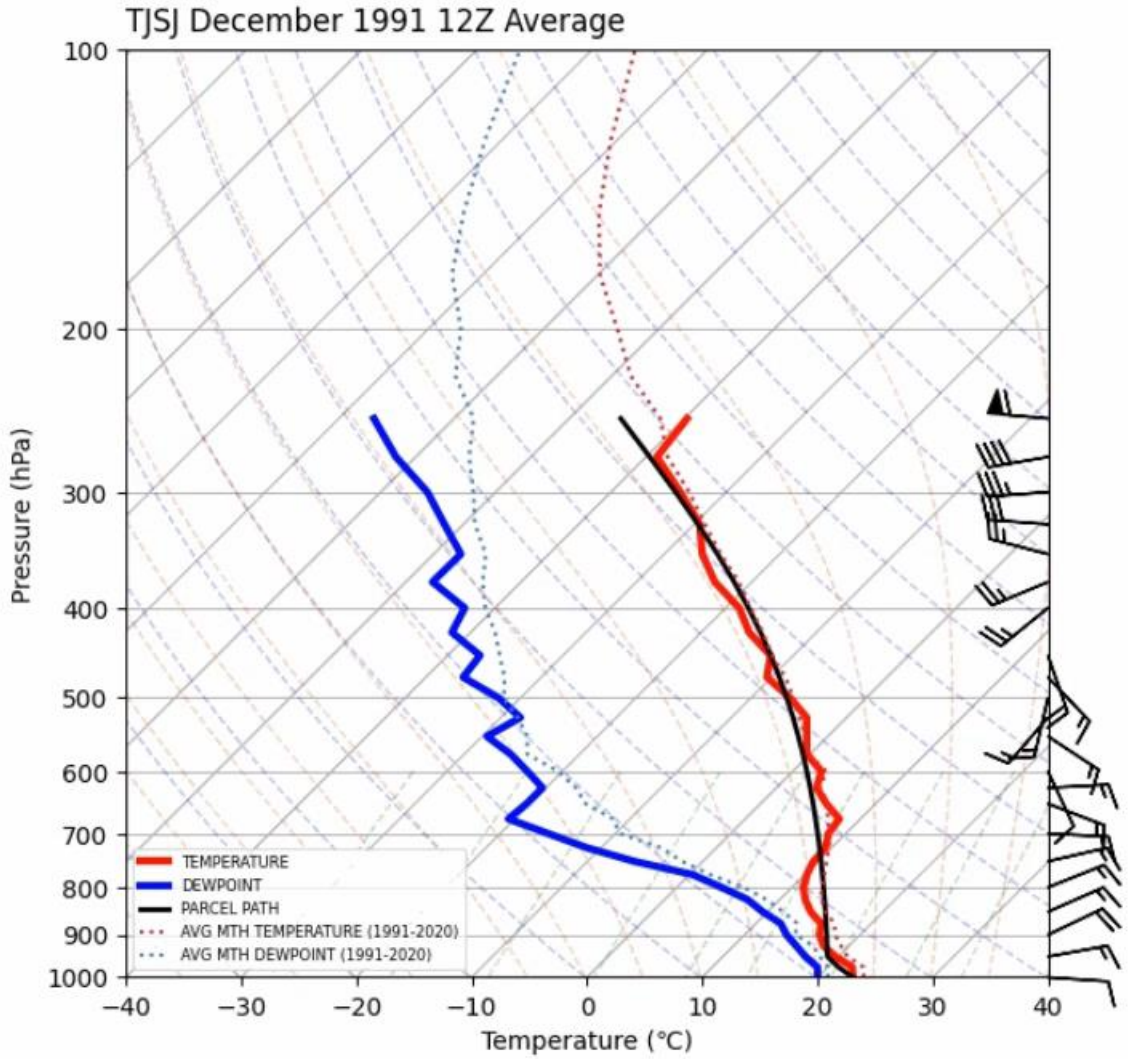
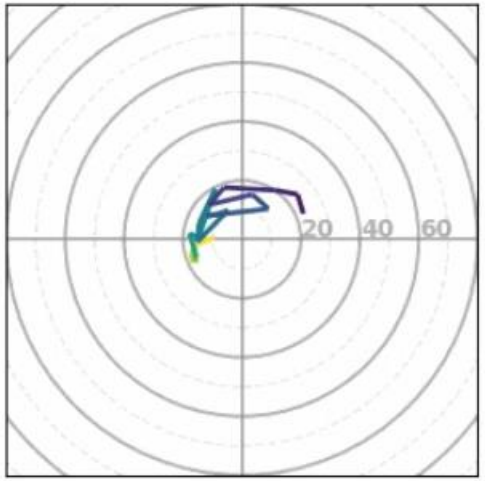


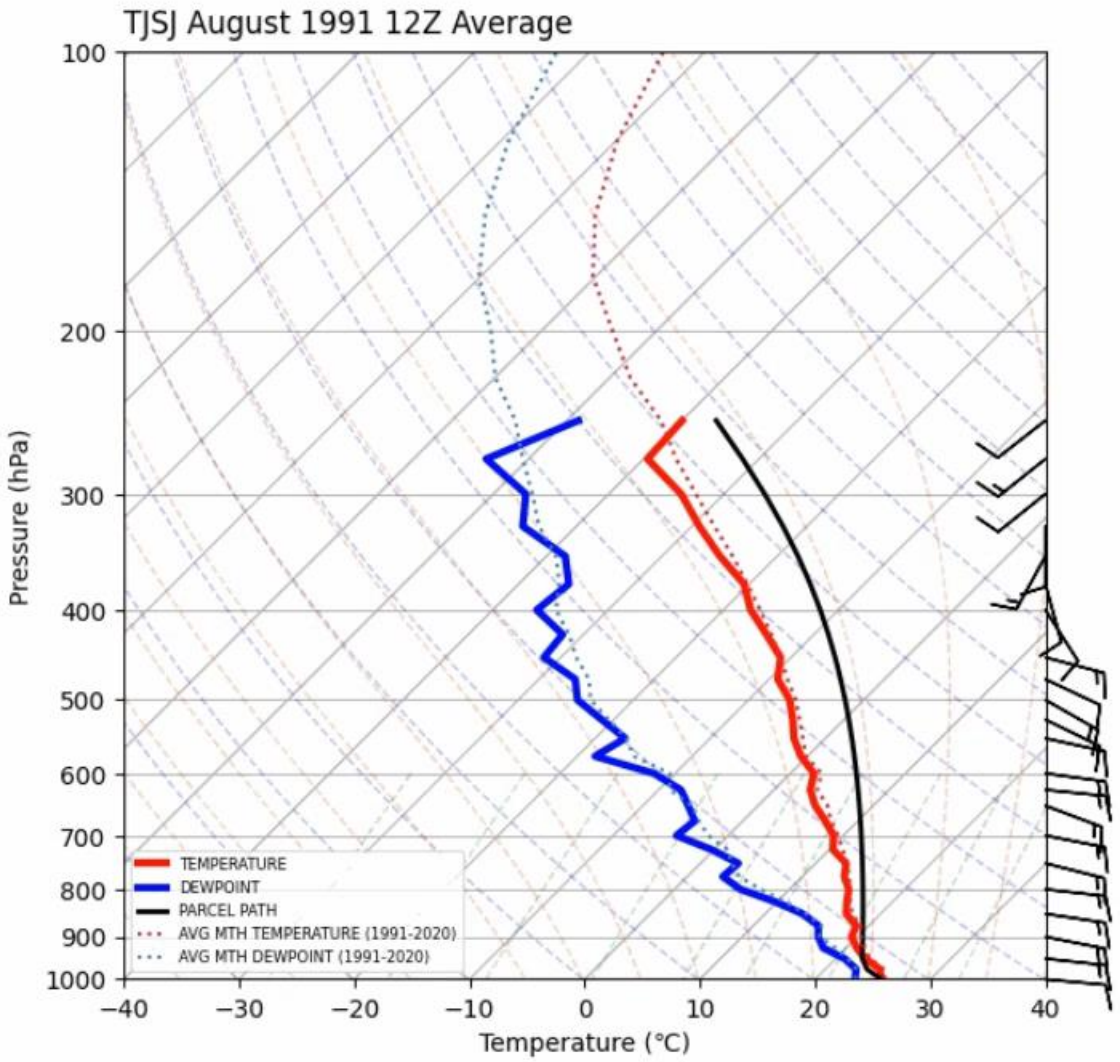
Atmospheric Profile Climatology of San Juan (R. Vázquez)





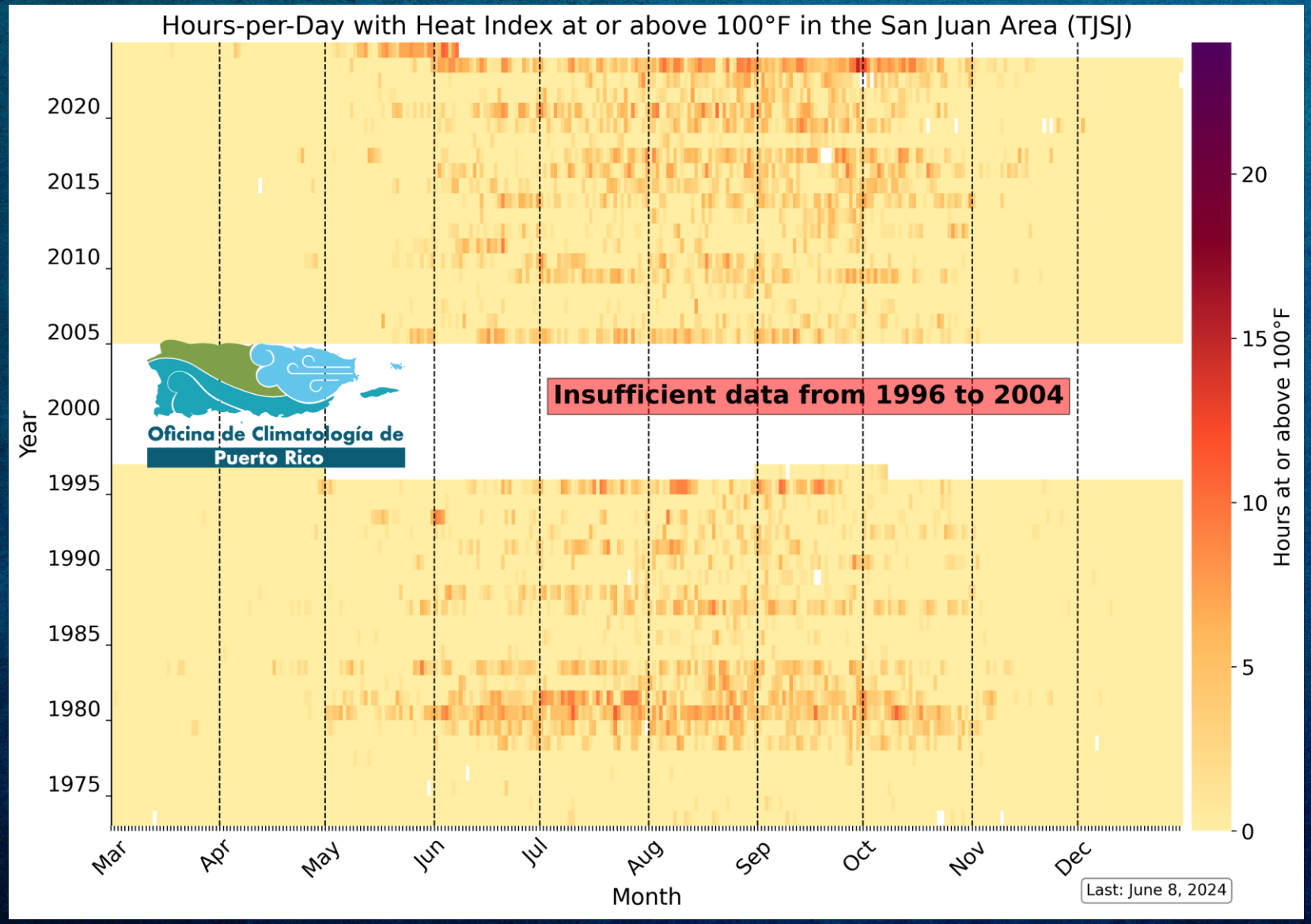
SHOW	6.07	EQTV	437.31
LIFT	1.12	LFCT	895.91
LFTV	0.5	LFCV	917.96
SWET	164.41	BRCH	67.9
KINX	5.37	BRCV	102.87
CTOT	16.09	LCLT	291.89
VTOT	20.35	LCLP	948.84
TOTL	36.45		
CAPE	210.86	MLTH	71.37
CAPV	285.61	MLMR	13.53
CINS	-8.13	THCK	5723.89
CINV	-5.29	PWAT	407.73
EQLV	472.94		

Climatology of San Juan



SHOW	1.01	EQTV	174.73
LIFT	-4.31	LFCT	910.94
LFTV	-5.12	LFCV	929.62
SWET	207.18	BRCH	2864.96
KINX	22.99	BRCV	3241.71
CTOT	19.85	LCLT	295.37
VTOT	23.77	LCLP	957.73
TOTL	43.62		
CAPE	1899.4	MLTH	299.06
CAPV	2148.79	MLMR	18.01
CINS	-9.6	THCK	5757.82
CINV	-4.63	PWAT	43.99
EQLV	175.11		

# of San Juan (Kevin Martínez)



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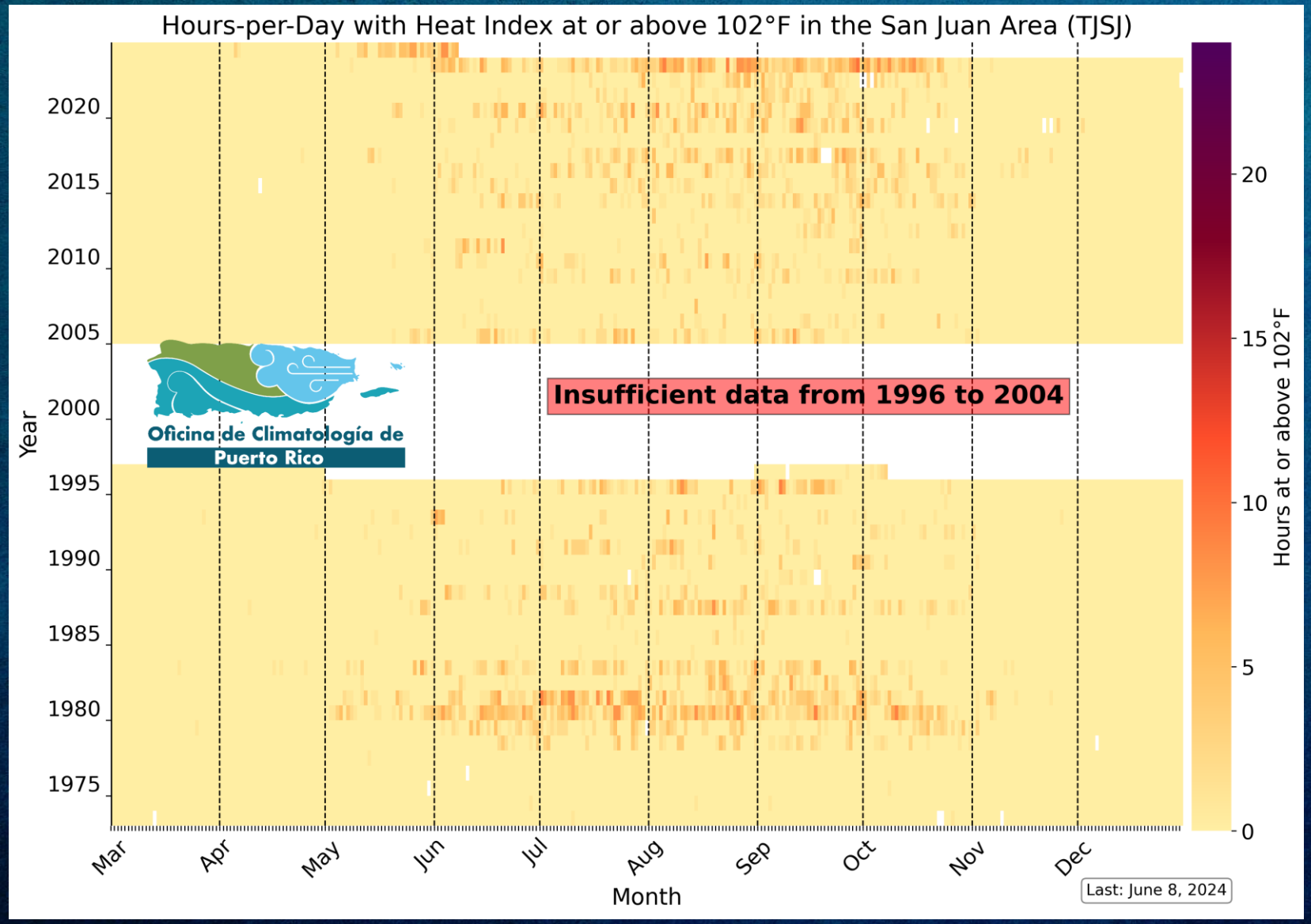

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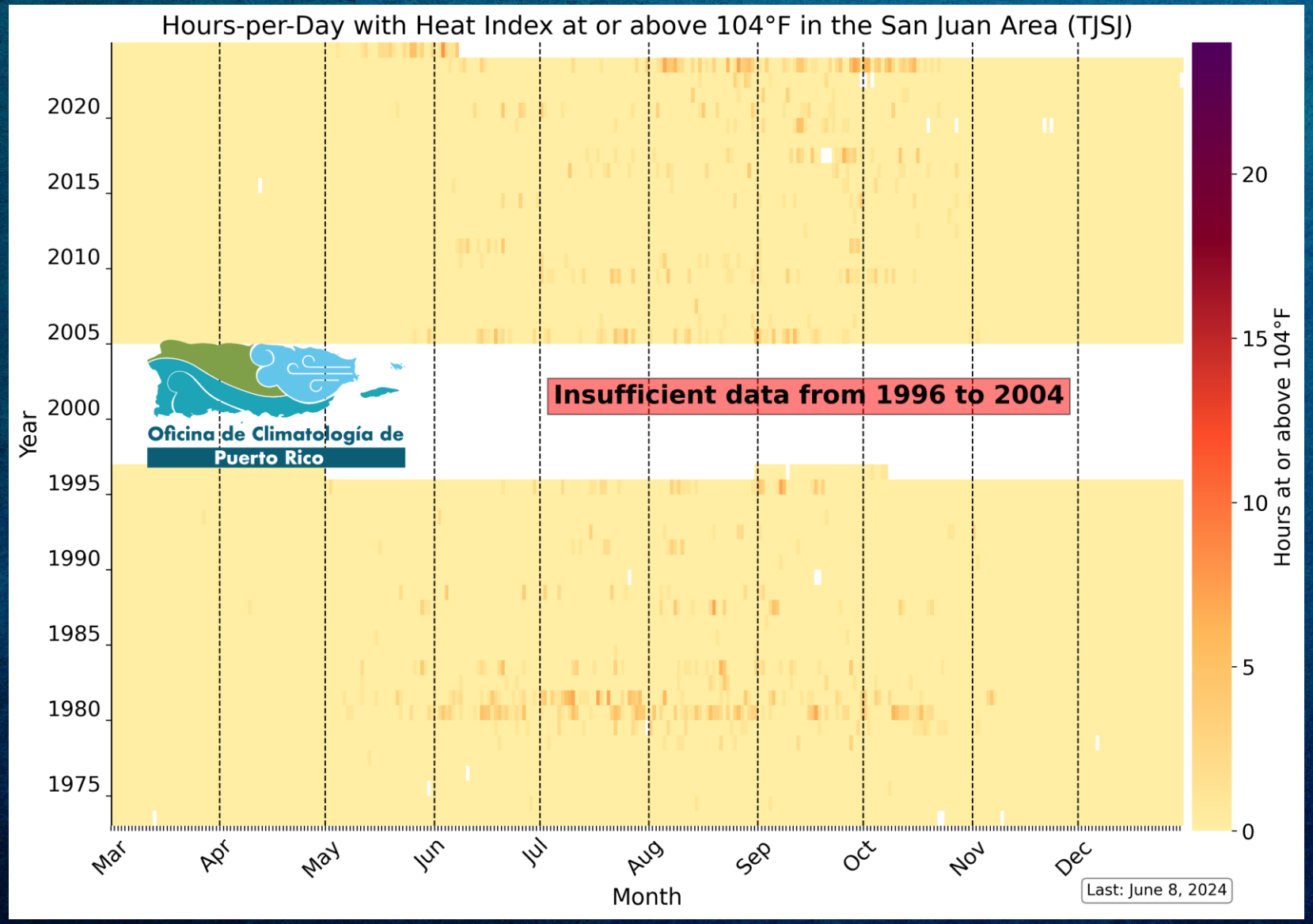
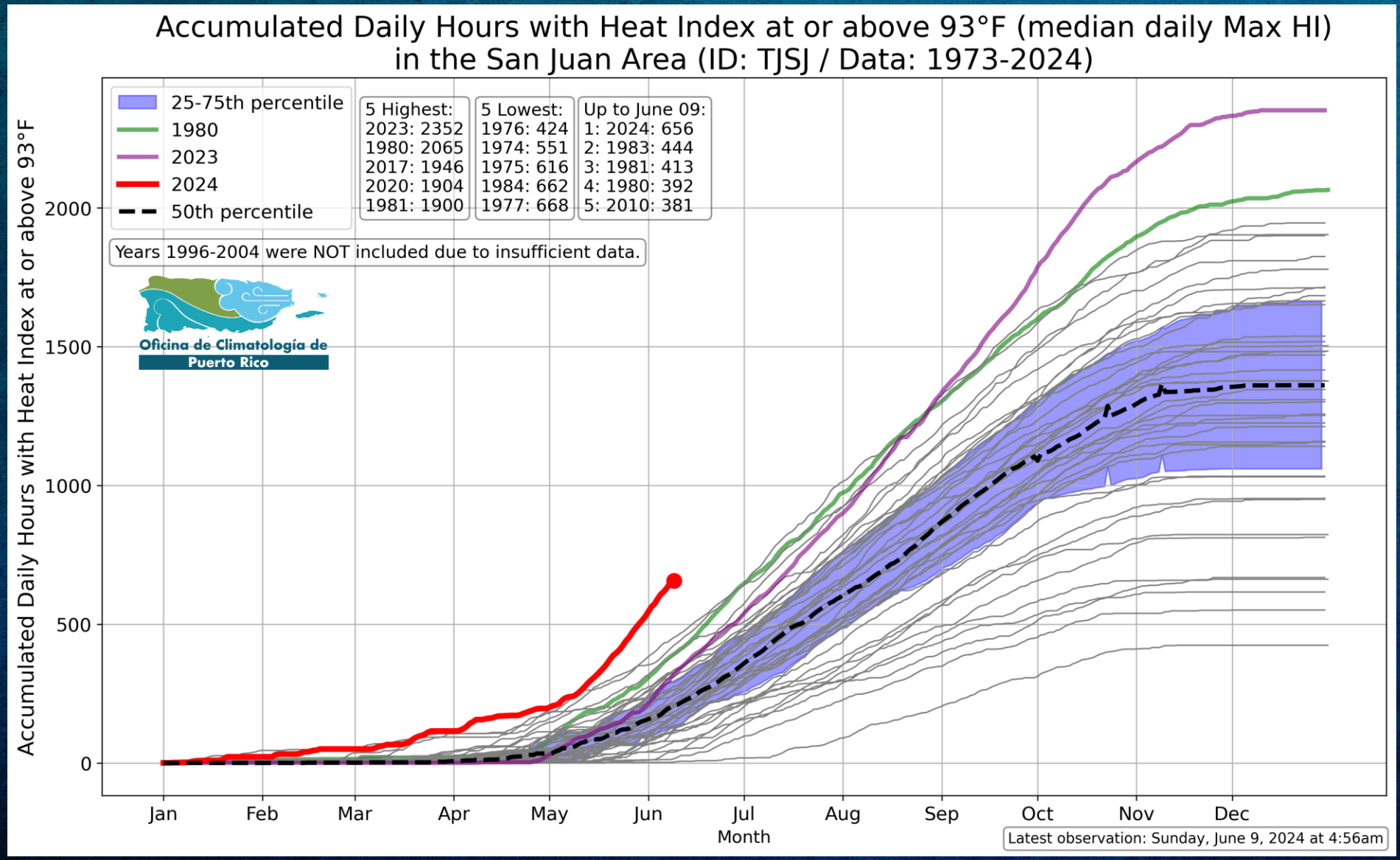


Heat Climatology of San Juan (Kevin Martínez)



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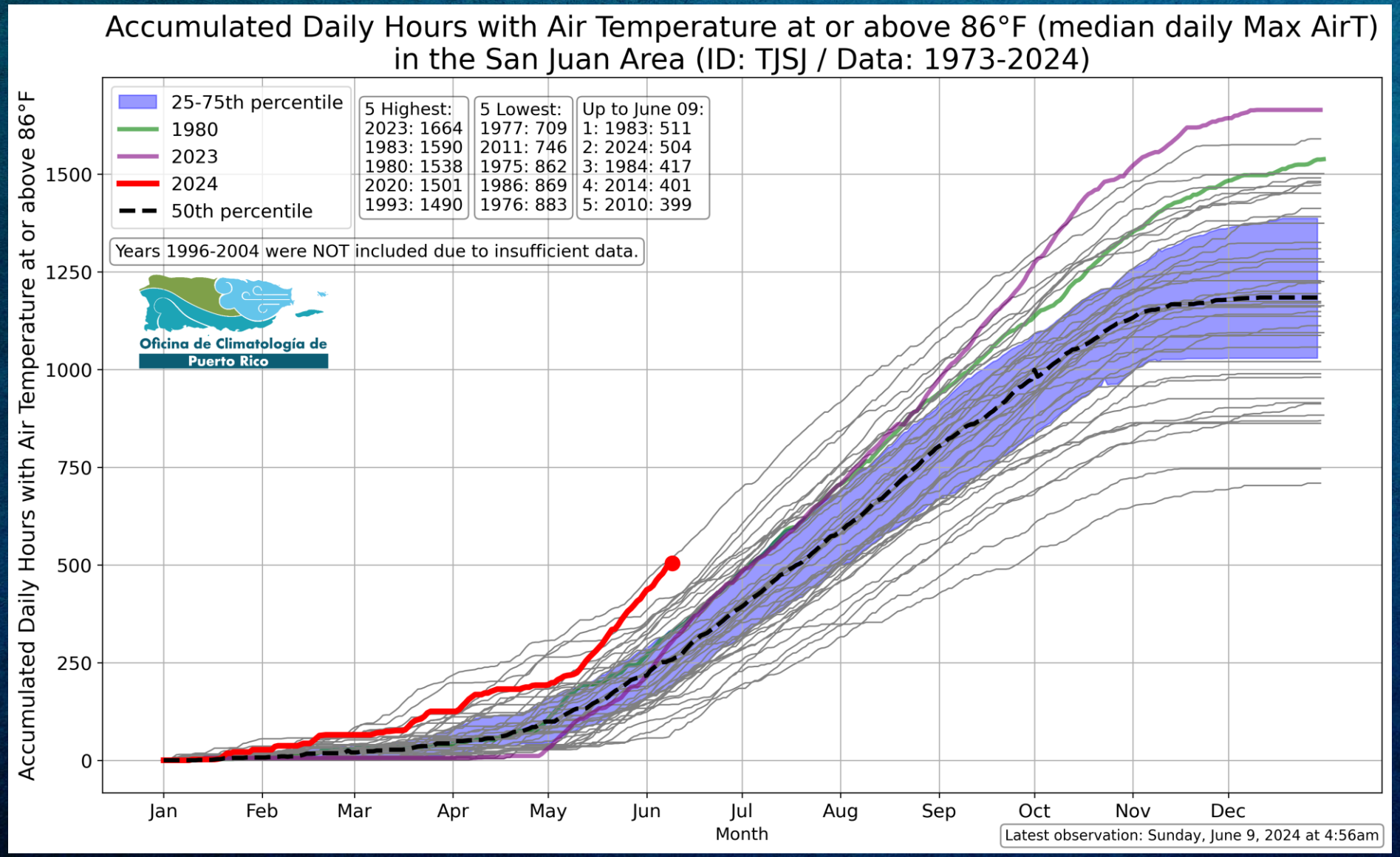

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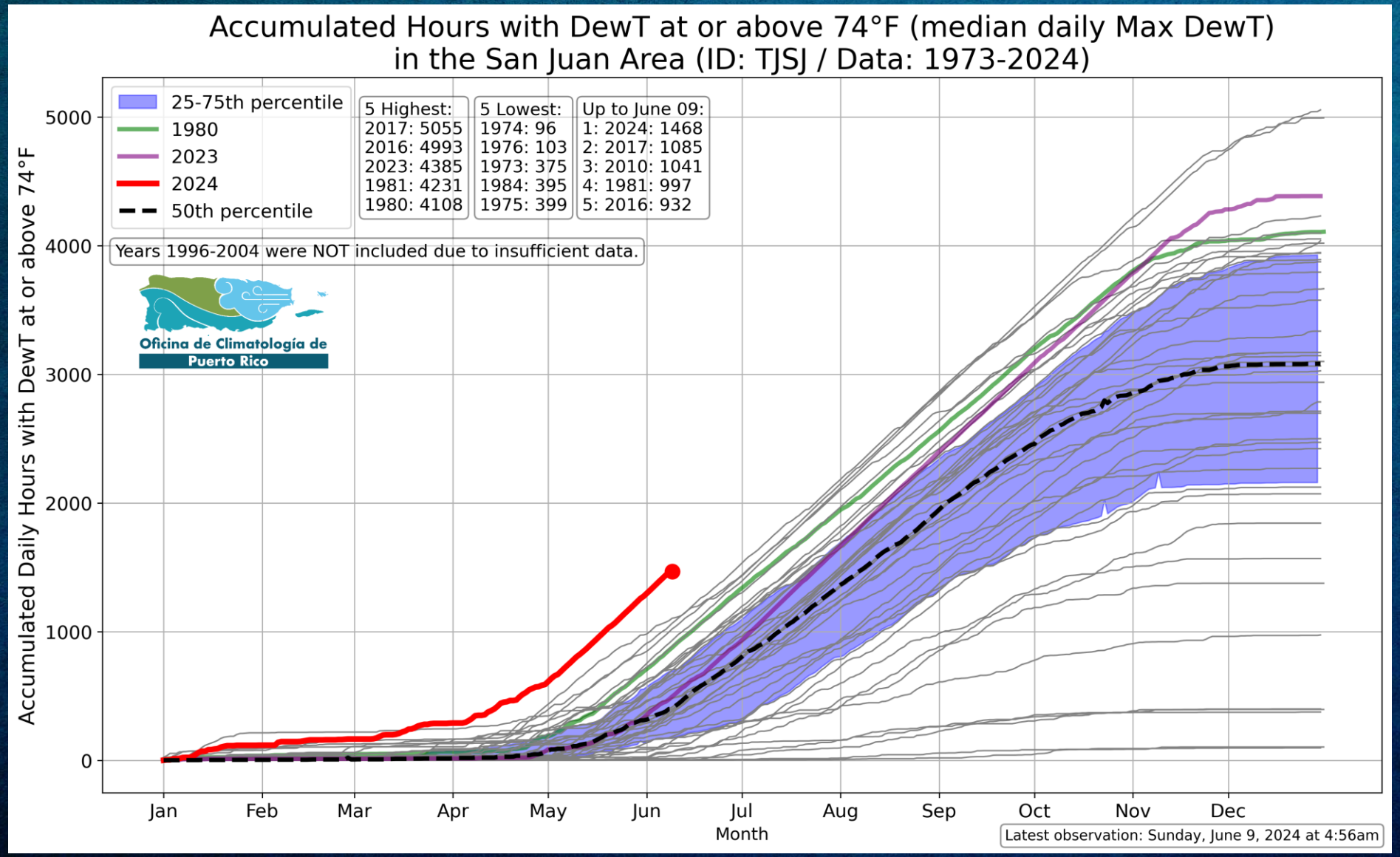


Heat Index (the problem with)

Vapor pressure. Ambient vapor pressure of the atmosphere. (1.6 kPa)

Dimensions of a human. Determines the skin's surface area. (**5' 7" tall, 147 pounds**)

Effective radiation area of skin. A ratio that depends upon skin surface area. (0.80)

Significant **diameter of a human**. Based on the body's volume and density. (15.3 cm)

Clothing cover. **Long trousers and short-sleeved shirt** is assumed. (84% coverage)

Core temperature. Internal body temperature. (98.6°F)

Core vapor pressure. Depends upon body's core temperature and salinity. (5.65 kPa)

Surface temperatures and vapor pressures of skin and clothing. Affects heat transfer from the skin's surface either by radiation or convection. These values are determined by an iterative process.

Activity. Determines **metabolic output**. (180 W m^{-2} of skin area for the model person **walking outdoors at a speed of 3.1 mph)**

Heat Index (the problem with)

Effective **wind speed.** Vector sum of the body's movement and an average wind speed. Angle between vectors influences convection from skin surface (below). (**5 kts**)

Clothing resistance to heat transfer. The magnitude of this value is based on the assumption that the **clothing is 20% fiber and 80% air**.

Clothing resistance to moisture transfer. Since clothing is mostly air, pure vapor diffusion is used here.

Radiation from the surface of the skin. Actually, a radiative heat-transfer coefficient determined from previous studies.

Convection from the surface of the skin. A convection coefficient also determined from previous studies. Influenced by kinematic viscosity of air and angle of wind.

Sweating rate. Assumes that **sweat is uniform and not dripping from the body**.

Heat Index (the problem with)

$$HI = -42.379 + 2.04901523 \cdot T + 10.14333127 \cdot R - 0.22475541 \cdot T \cdot R - 6.83783 \times 10^{-3} \cdot T^2 - 5.481717 \times 10^{-2} \cdot R^2 + 1.22874 \times 10^{-3} \cdot T^2 \cdot R + 8.5282 \times 10^{-4} \cdot T \cdot R^2 - 1.99 \times 10^{-6} \cdot T^2 \cdot R^2$$

where T = ambient dry bulb temperature (°F)

R = relative humidity (integer percentage).

Temp(F)	RH%	T_{equiv} = HI (F)	RH_{equiv} %
90	60.5	100	25.8
93	56.7	105	21.1
93	63.4	110	17.6
95	62.2	115	15.2

WBGT
Wet-bulb-globe-temperature

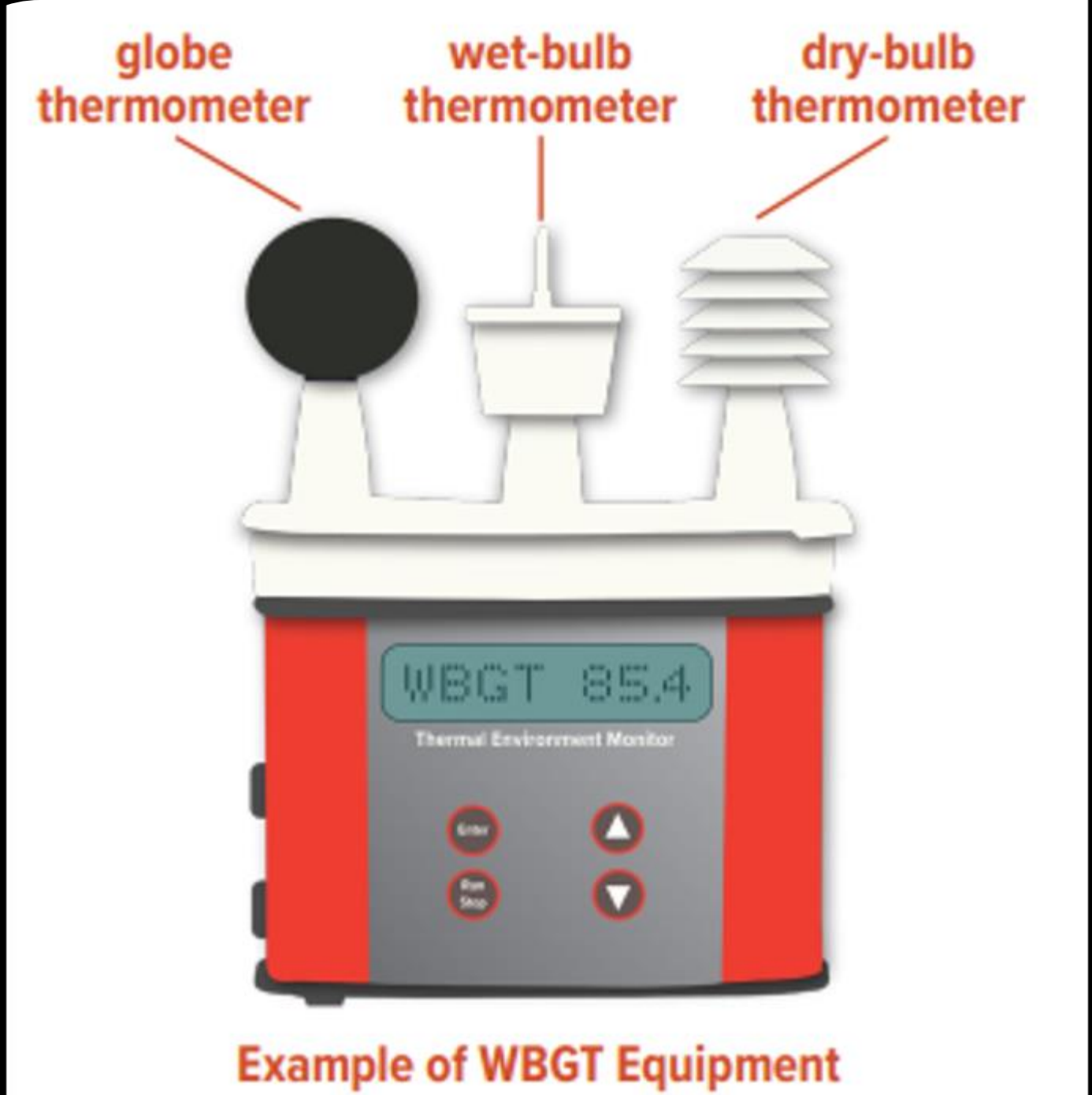
$WBGT = 0.7 \cdot T_{wb} + 0.2 \cdot T_g + 0.1 \cdot T_d$

where

T_{wb} = wet bulb temperature (°F) ,

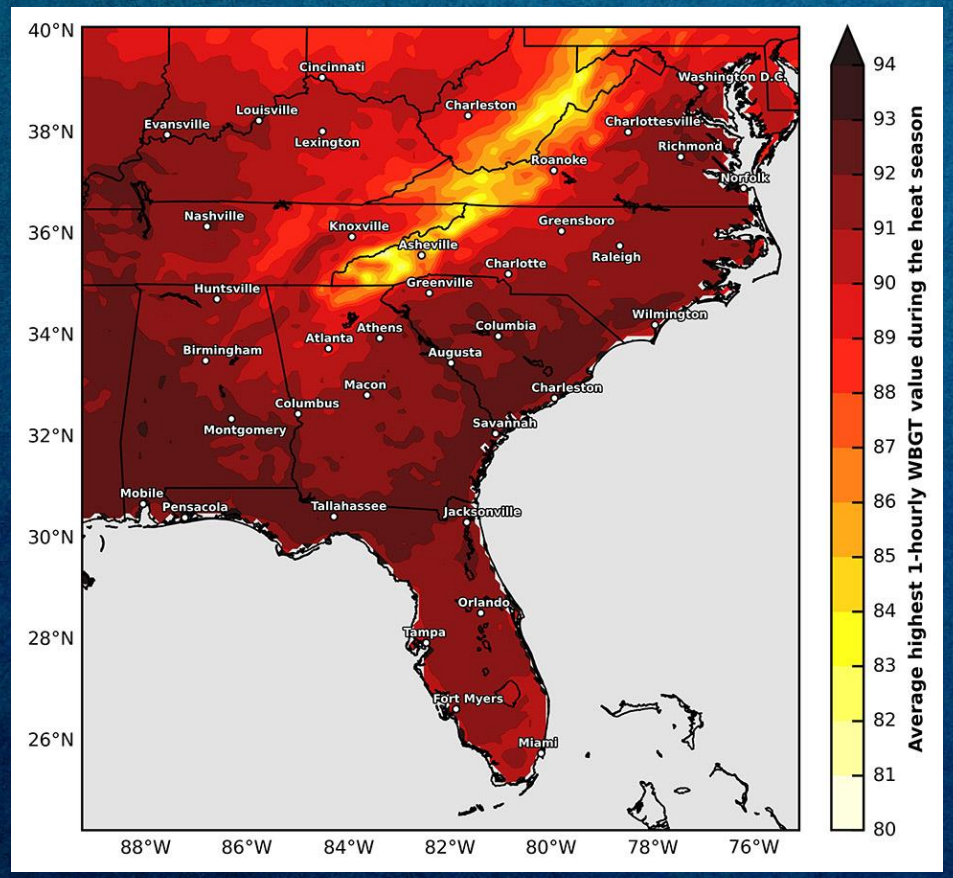
T_g = globe temperature (°F),

T_d = dry bulb temperature (°F)



Example of WBGT Equipment

WGBT Climatology and Forecast Tool SERCC



Some Extreme Heat Adaptation Measures

- Improve monitoring of high "heat" conditions
  - More frequent observations across the island
  - Higher quality observations
  - Move towards a consensus measure of "heat"

- Integrate passive cooling measures into building codes
  - Higher insulation, better utilization of wind currents, increase shading elements

- Urban reforestation (trees are not just for shade!)
  - A large mango tree can evaporate 400 liters of water in a day
  - Providing the equivalent cooling power of a 70,000 Btu/h air conditioning unit
  - Create a guide to urban tree planting along with their cooling power potential


Gracias