The Physics of Summertime Antarctic Extreme Heat Events

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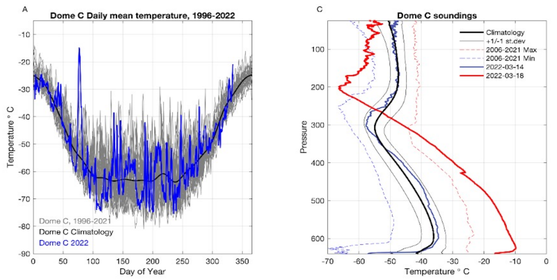
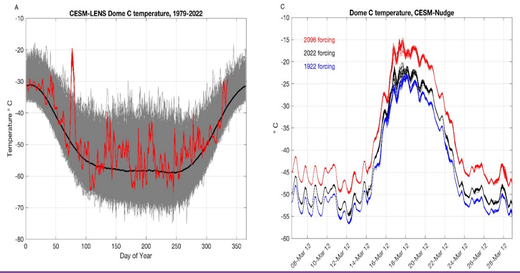
Across much of the globe, extreme heat events have become more frequent and intense, amplifying the risk of their associated socio-economic damages. Antarctic heat waves remain poorly understood, despite their impact on surface ice melt, sea level rise, and coastal ecosystems. Motivated by the world record heatwave of March 18, 2022 at Dome C in Western Antarctica, we examine the evolution, drivers, and characteristics of historical summertime (DJF) Antarctic extreme heat events.

The Largest Ever Recorded Heatwave: Dome C, Antarctica March 18, 2022

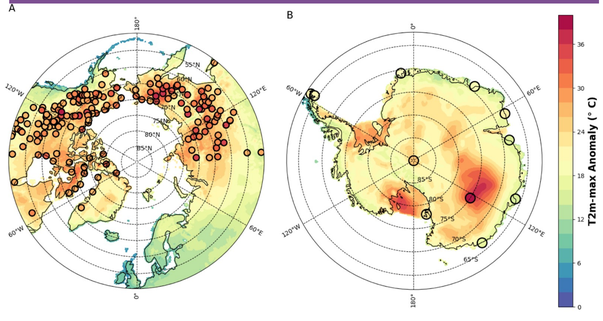
- It reached a 2-meter temperature anomaly of ~39°C (70°F)
- The heatwave was driven by a large Ω-ridge which advected warm, moist air onto the Antarctic continent



- When nudged to observations, CESM1.2 can reproduce the record heatwave
- Recent anthropogenic warming has had a small, but growing impact on heatwave intensity and duration



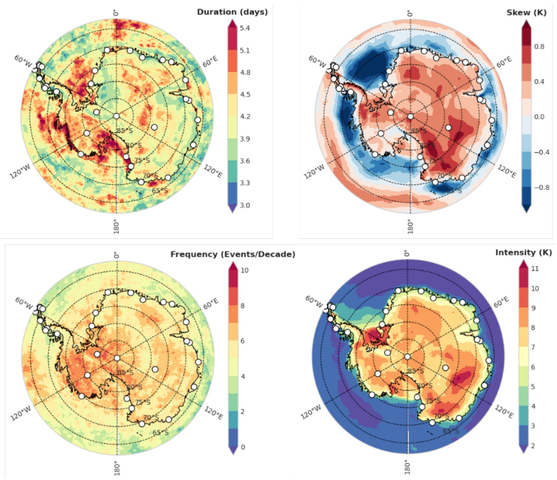
Dome C set a new World Record Temperature Anomaly



Magnitude of largest recorded heatwaves globally, as quantified with station data (shaded dots), and ERA-5 (background shading) in the Northern **(A)** and Southern **(B)** hemispheres.

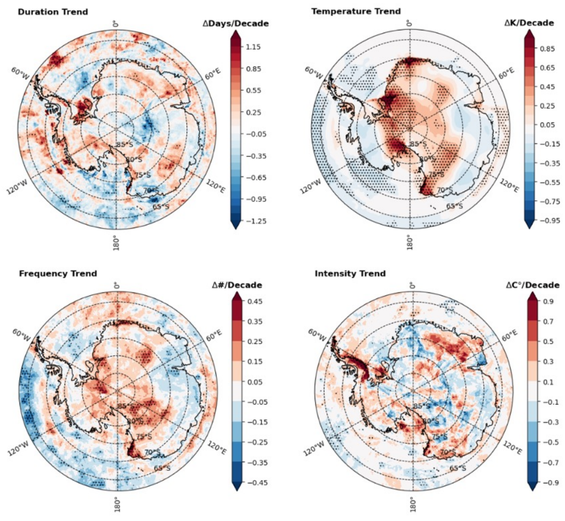
Frequency, Duration, and Intensity

- **Heatwaves are defined as events where the daily maximum 2-meter temperature from ERA5 between 1979-01-01 and 2022-12-31 exceeds the historical 95th percentile for three or more consecutive days**
- Spatial variations in heatwave properties are explained by differences in orography, ocean influence, sea ice, and patterns of atmospheric circulation



Historical Trends in Frequency, Duration, and Intensity

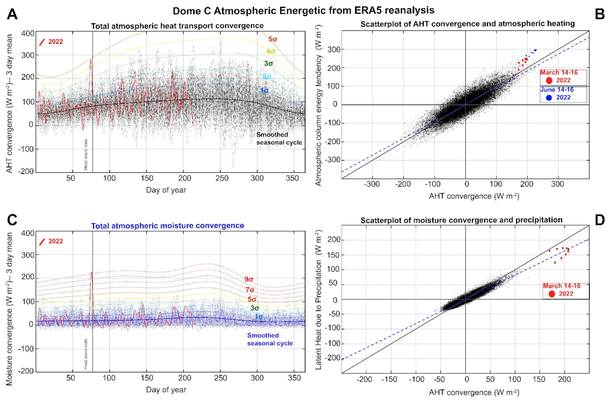
- Frequency trends are well explained by temperature trends
- Intensity trends along the Antarctic peninsula are not thermodynamically driven
- Further study is necessary to determine what portion of regional trends are attributable to anthropogenic climate change



Drivers and Evolution: Energy Budget Analysis

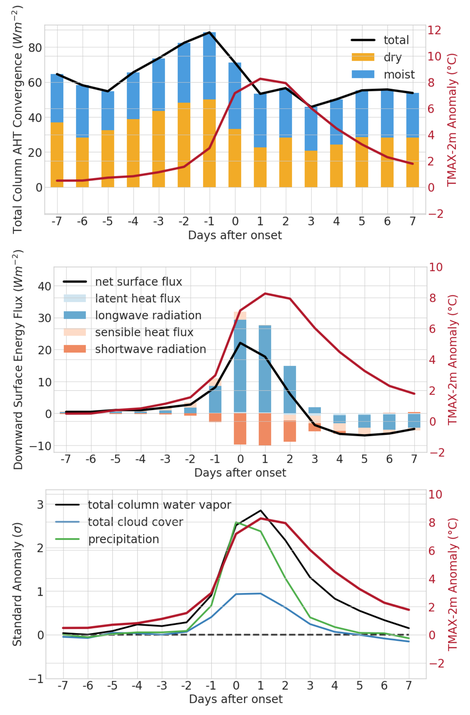
Atmospheric Heat Transport (AHT):

- Major atmospheric warming events are preceded by AHT convergence
- AHT can be partitioned into moist and dry components.
- Moisture convergence (e.g. atmospheric river) played a central role in the Dome C heatwave



Surface Energy Budget:

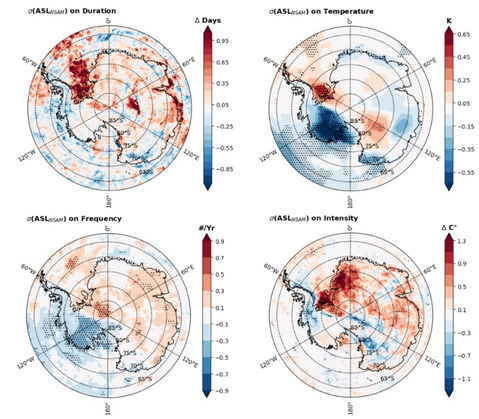
- High elevation extreme heat events are driven by downwelling longwave radiation anomalies, enhanced moisture and clouds
- On average, dry and moist AHT play equal roles in atmospheric warming



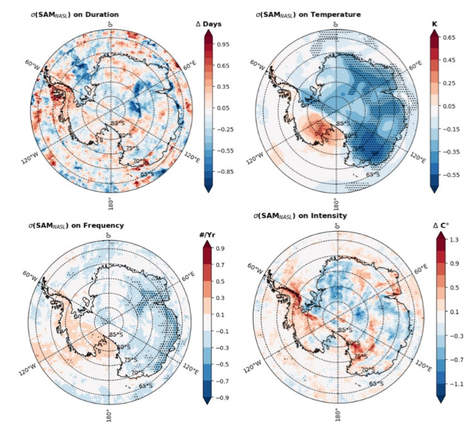
The Impact of regional modes of variability on heatwaves

Red and blue contours indicate positive and negative heatwave anomalies, respectively, associated with a one standard deviation SAM or ASL event.

The Impact of the Amundsen Sea Low (ASL):



The Impact of the Southern Annular Mode (SAM):



Next Steps

- Decompose coastal Antarctic heatwaves into their various drivers (southerly katabatic events vs. northerly moist events)
- Examine vertical structure of extreme heat events to diagnose surface and total column anomalies.
- What are the impacts of extreme heat events on surface melt rates?

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