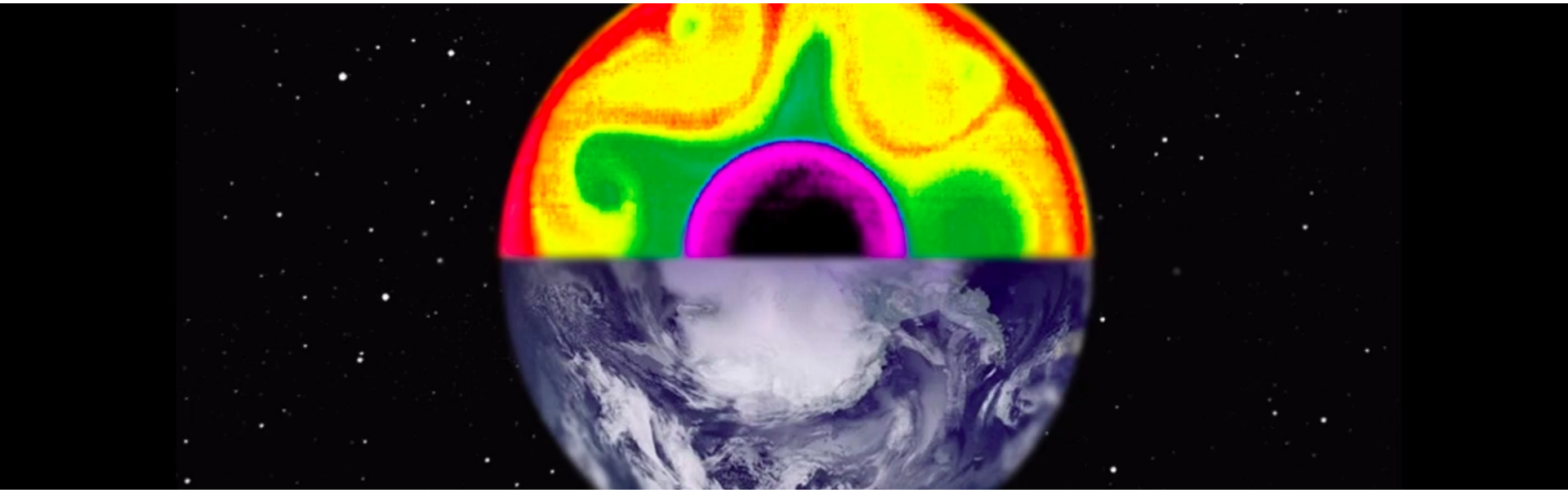
The effects of meridional temperature contrast on local temperature fluctuations in the mid-latitude atmosphere: a laboratory experiment



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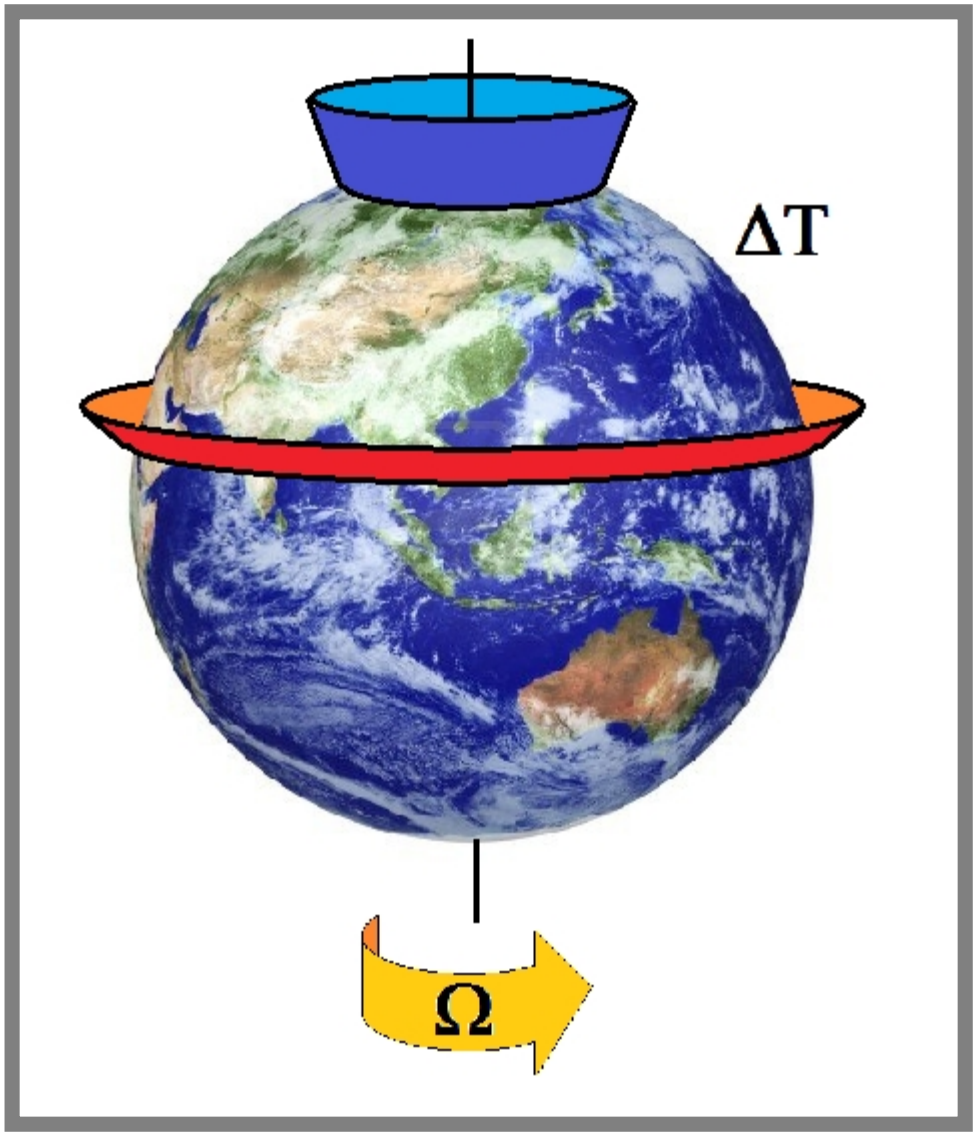
A minimal model of mid-latitude weather

- Rotation + meridional ΔT = weather

- **Idea:** Let's construct minimalistic laboratory analogs to better understand the basic Rossby wave dynamics of the mid-latitudes



A minimal model of mid-latitude weather

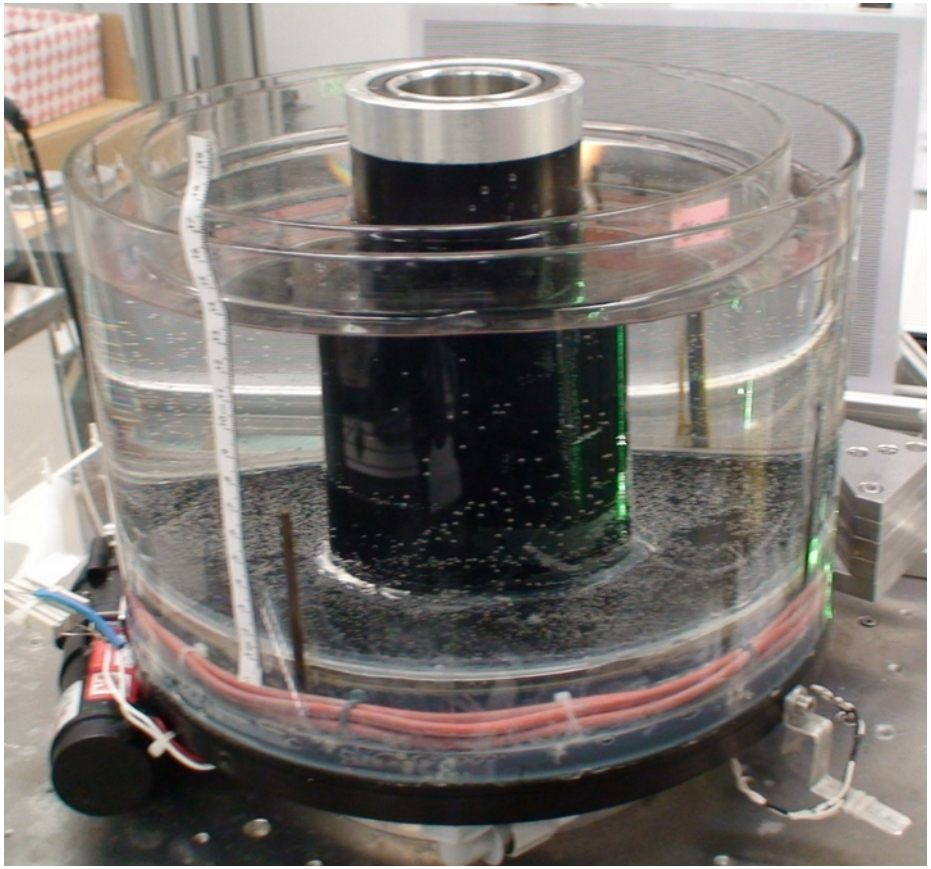
- **A differentially heated cylindrical tank, mounted on a turntable. "Rotating annulus"**

Dimensions (BTU LAS):

inner radius = 45 mm

outer radius = 120 mm

depth = 50 mm



A minimal model of mid-latitude weather

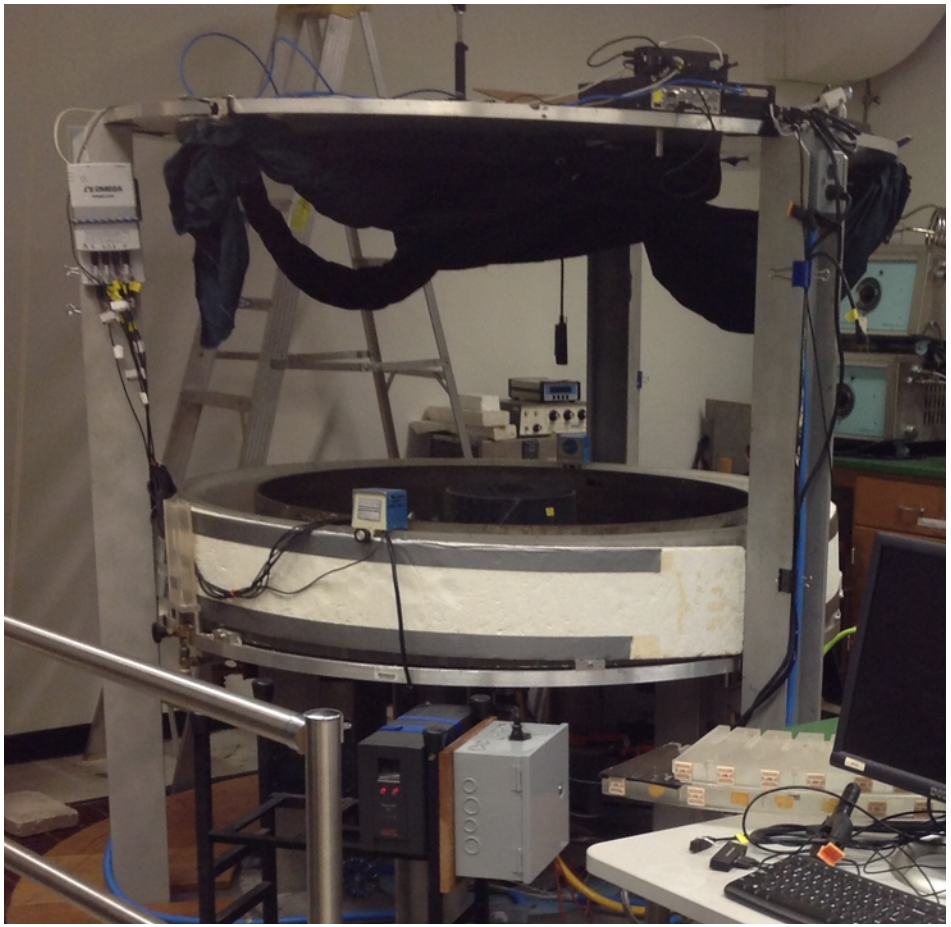
- **A differentially heated cylindrical tank, mounted on a turntable. "Rotating annulus"**

Dimensions (FSU GFDI):

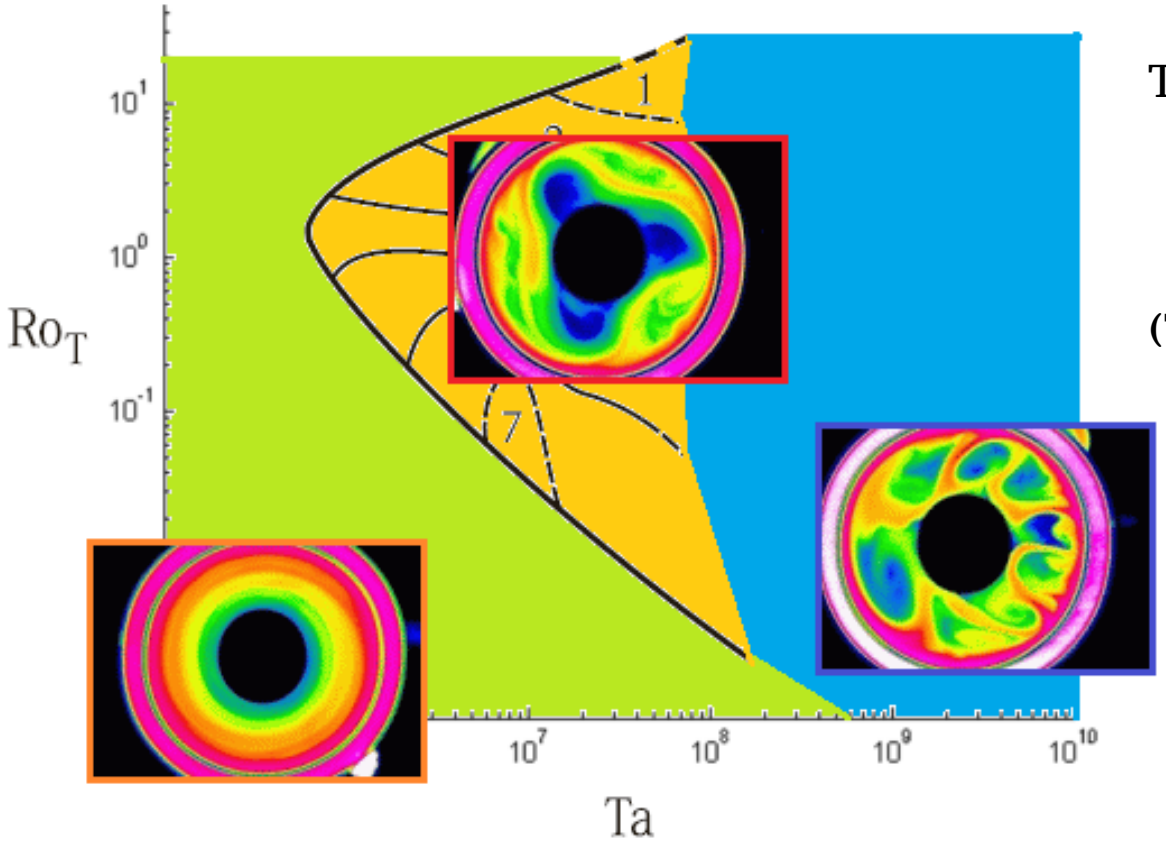
inner radius = 160 mm

outer radius = 610 mm

depth = 80 mm



The regime diagram, key parameters



Taylor number:

$$Ta = \frac{4 \cdot \Omega^2 \cdot (b-a)^5}{\nu^2 \cdot d}$$

(Thermal) Rossby number

$$Ro = \frac{g \cdot d \cdot \alpha \Delta T}{\Omega^2 \cdot (b-a)^2}$$

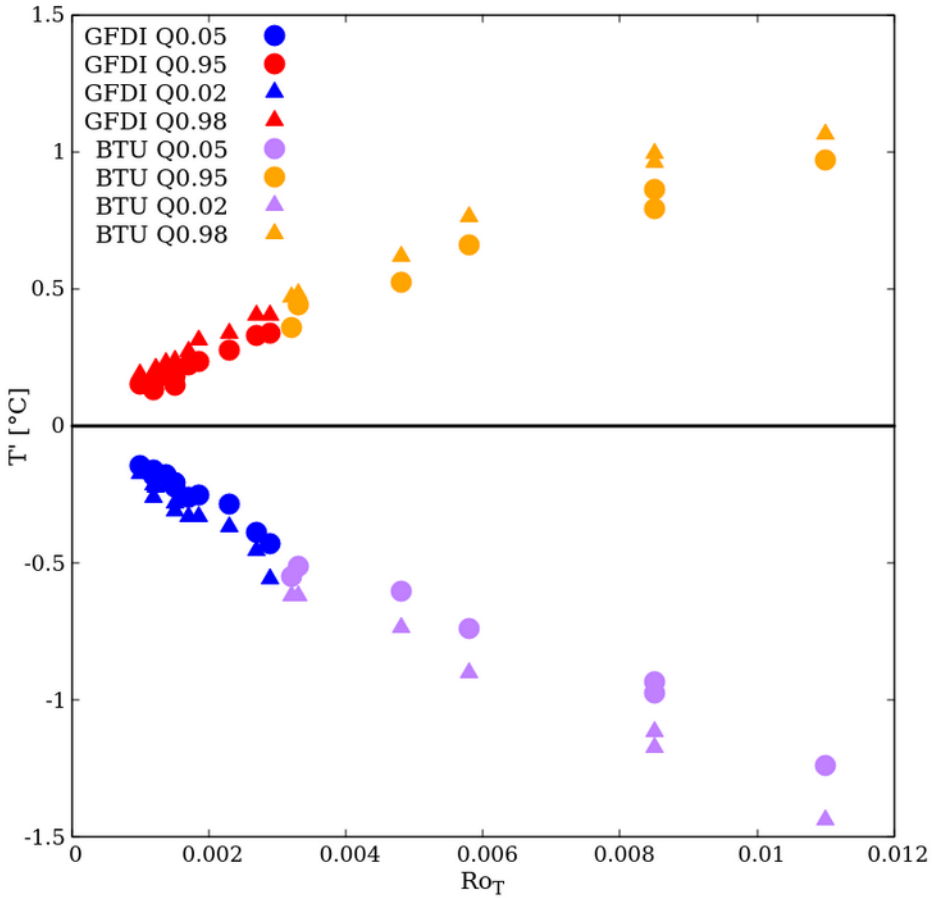
“Meridional” temperature contrast vs. temperature fluctuations

- Large annulus → very small Rossby numbers (quasigeostrophic turbulence)
- Temperature time series from fixed locations

- **Question:** How do the statistical properties of extreme events in this model weather (and climate) depend on the meridional temperature contrast?

“Meridional” temperature contrast vs. temperature fluctuations

- The distribution of fluctuations widens with the increasing temperature contrast → **increasing Rossby number (~ ΔT).**



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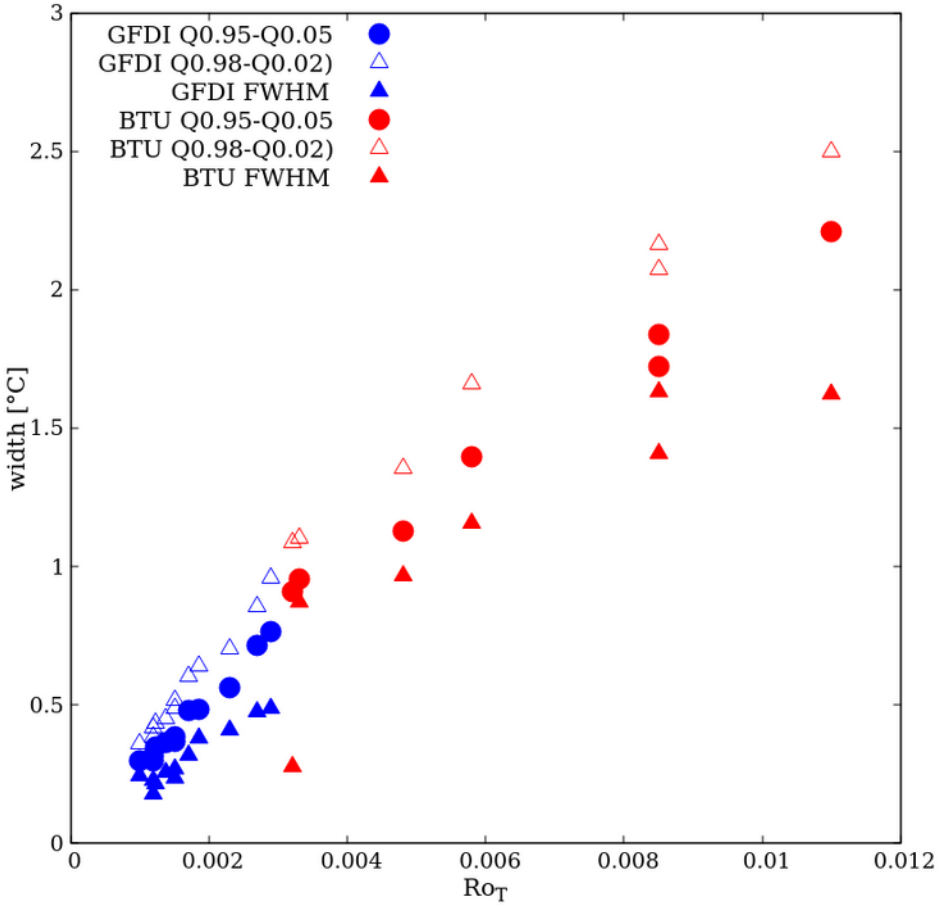


“Meridional” temperature contrast vs. temperature fluctuations

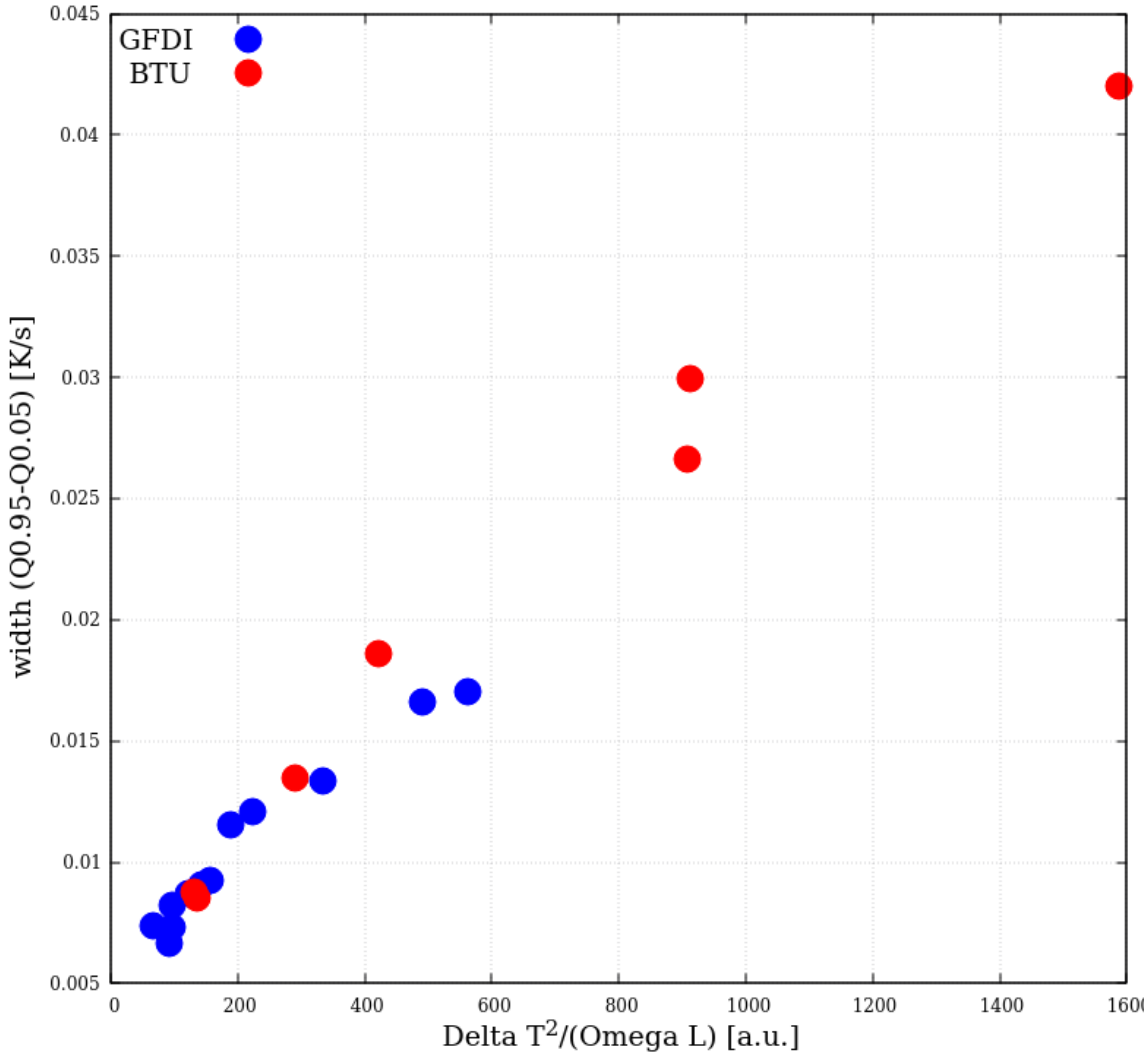
Taking the histograms of the (smoothed)

time derivatives

of the temperature fluctuation time series, and their “width” based on the Q0.05 and Q0.95 quantiles

→ **data collapse via *advective scaling***

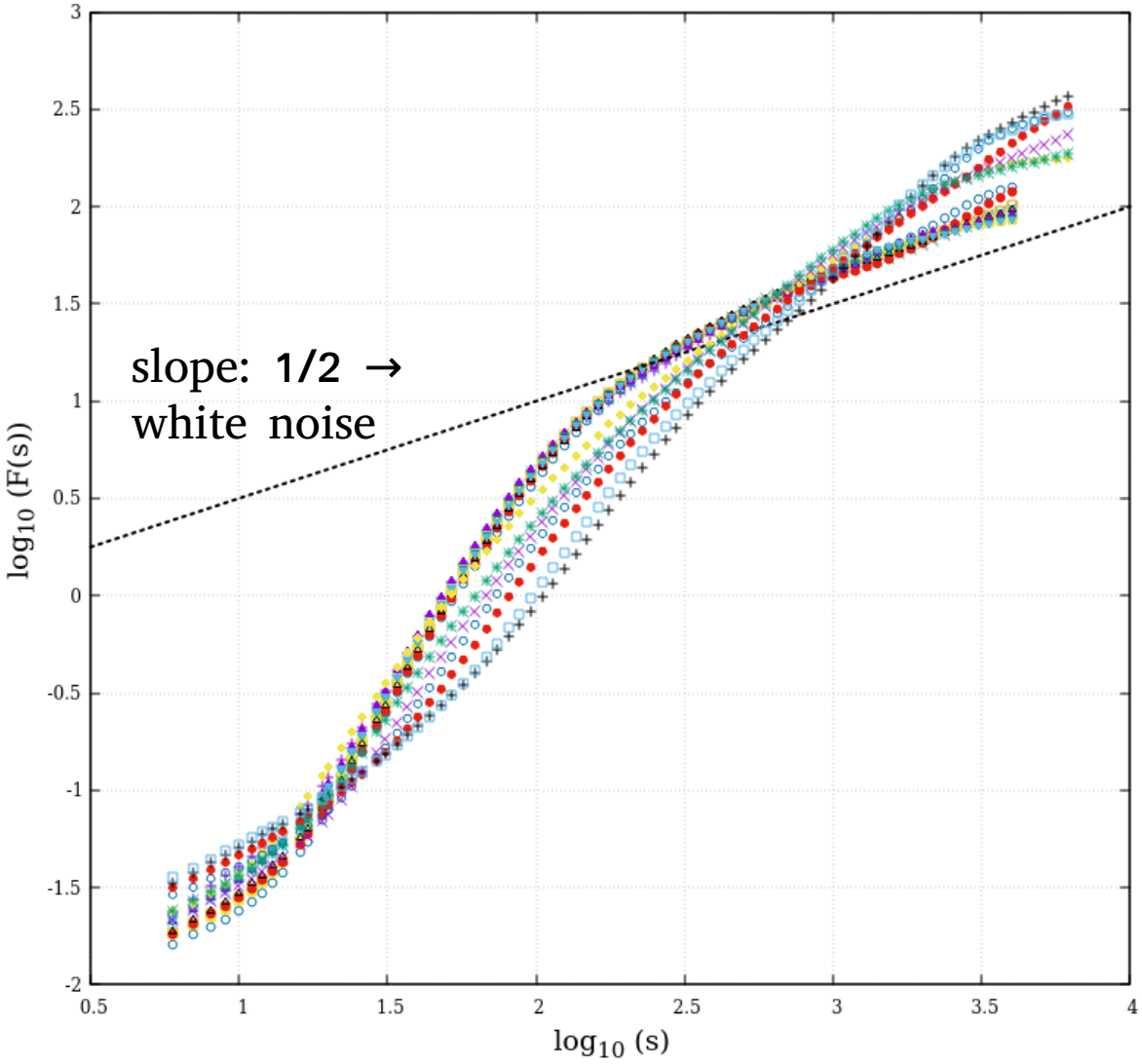
($dT/dt \sim U \cdot \nabla T \sim \Delta T^2/(\Omega L)$**)**



“Meridional” temperature contrast vs. persistence – DFA2 spectra

Detrended Fluctuation Analysis (DFA2). The time window τ at which the slope of the log-log DFA2 spectra (the local exponent α) is the largest represents the time scale on which the process can be considered the most “persistent”.

→ **This appears to scale with the convective (Rayleigh) time scale ~ 1/(ΔT L).**



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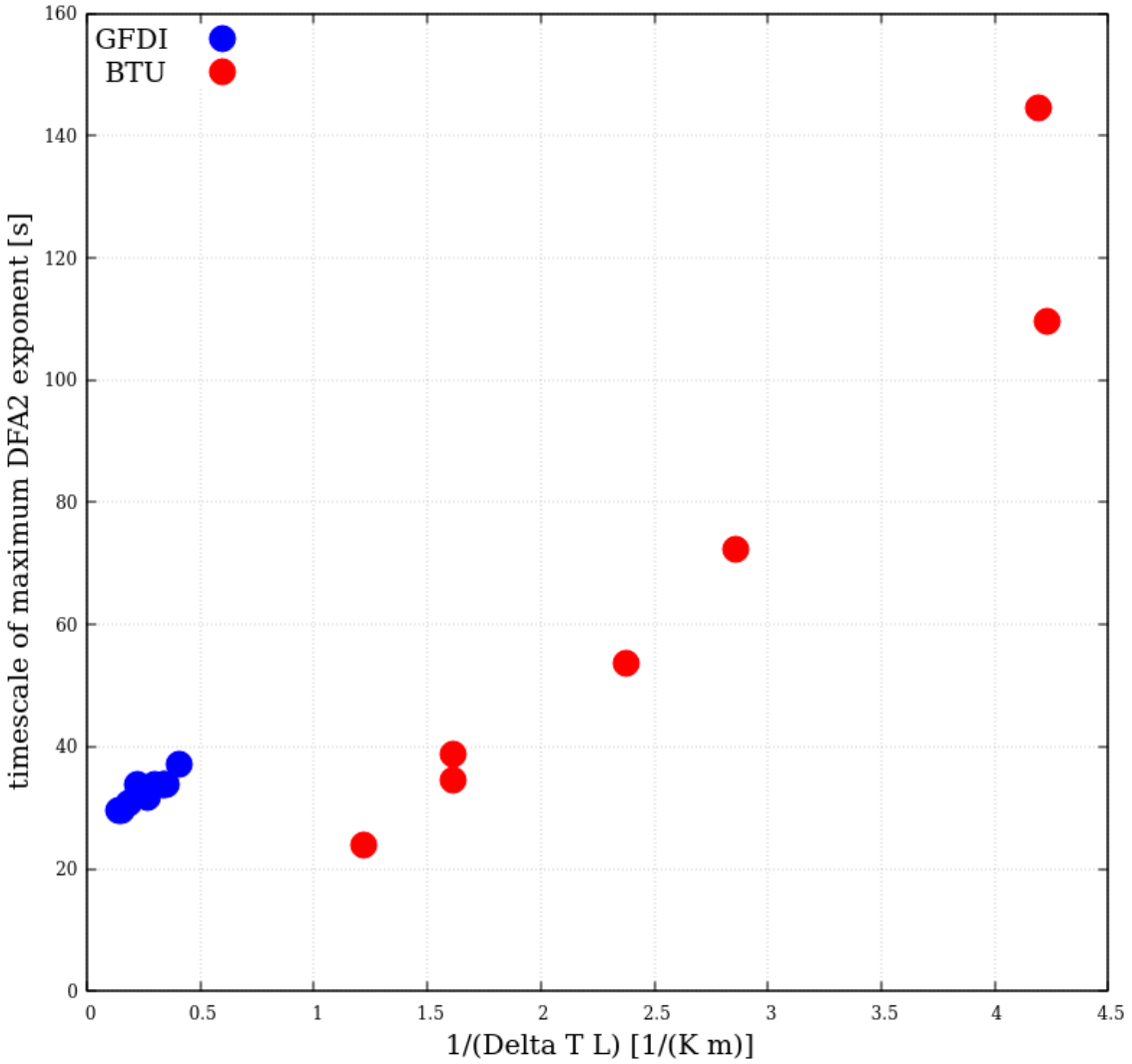

“Meridional” temperature contrast vs. temperature fluctuations

Question: How do the statistical properties of extreme events in weather and climate depend on the meridional temperature contrast?

Partial answers:

If only Rossby wave dynamics was involved (minimum mid-latitude atmosphere), a marked polar amplification would yield

- a narrower distribution of temperature fluctuations, whose width **scales with ~ ΔT**
- generally smaller “jumps” in temperature, **scaling with ~ ΔT^2**
- the correlation timescale (“persistence”) of the weather would significantly increase, **scaling with ~ $1/\Delta T$**

Thank you for your attention!