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

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In a water-filled rotating annulus setup, a widely studied laboratory toy model of the mid-latitude atmospheric circulation, we investigated the statistical properties of pointwise temperature "station data" from a series of long experiment runs. Our aim was to explore how the thermal boundary conditions affect temperature fluctuations in a quasi-geostrophic flow system dominated by irregular Rossby waves. While the rotation rates and the geometrical dimensions of the experimental configuration were kept identical in all runs (yielding Taylor number $Ta \approx 3.3\times10^{11}$), the values of the prescribed "meridional" temperature contrast ΔT – measured between the two coaxial lateral sidewalls of the annular tank – were different, thus Rossby numbers ranged from Ro = 0.009 to 0.026. We found that for larger values of ΔT the temperature distribution became wider, and the thermal fluctuations appeared more symmetric under time-reversal. Discrete AR(1) autoregressive processes were fitted to the time series of temperature fluctuations, and the resulting correlation timescales and average forecast errors of the AR(1) models also increased with ΔT. The persistence of the "weather" in the tank was also evaluated in terms of Hurst exponent spectra. Our results imply that in a realistic polar amplification scenario, where the meridional temperature contrast decreases over time, mid-latitude extreme temperatures (due to Rossby wave dynamics) are not expected to occur more frequently. However, the temporal autocorrelation and predictability of daily temperature signals may decrease, and sudden cooling events may become more likely to occur than sharp increases in temperature.