Analytical model for the higher order moments of midlatitude atmospheric temperature distributions

Objective

Since atmospheric temperature distribution at a given location is not normally distributed, mean and variance of temperature alone cannot predict the likelihood of extreme temperature events, such as heat waves and cold spells. For such predictions, understanding of the higher-order moments is necessary.

Approach

We propose a simple model where the temperature at a given point is determined by the temperature of the air blown from elsewhere by winds whose original locations follow a normal distribution (i.e., wind is likely to originate nearby and is less likely to originate farther away, following a normal distribution). The model calculates higher-order moments solely from the average temperature profile in space and the average distance traveled by the winds. The theory agrees with output of an idealized climate model (see Figure 2).

Impact

Frequency of extreme temperature events have been challenging to measure and project. However, our simple kinematic model shows that two average quantities (temperature profile in space and distance traveled by the winds) can give a good estimate of higher-order moments which are linked to extreme temperature events. Since both average quantities are readily observed and predicted, this work can improve the prediction of heat waves and cold spells.

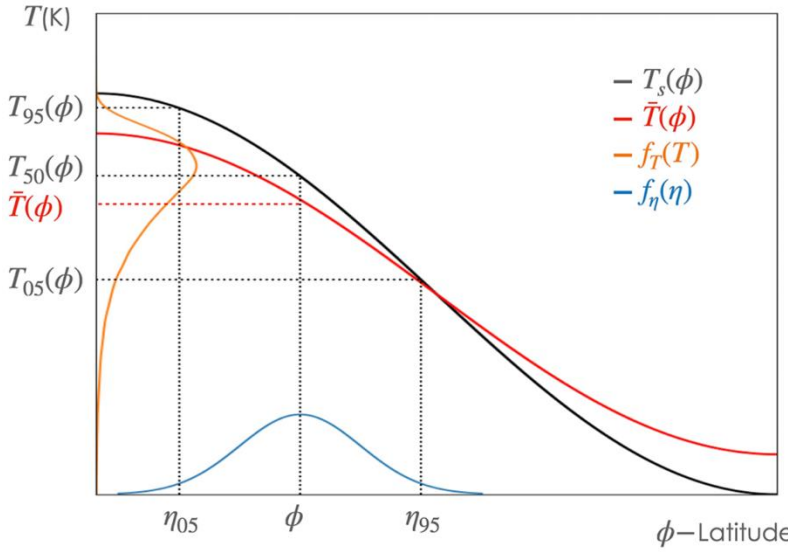

Figure 1: How higher-order moments of temperature arise within our theory. When wind (rather, location of the origin of wind) has a normal distribution (blue) and average temperature is nonlinear in location ϕ (black line), corresponding temperature (orange) becomes non-Gaussian.

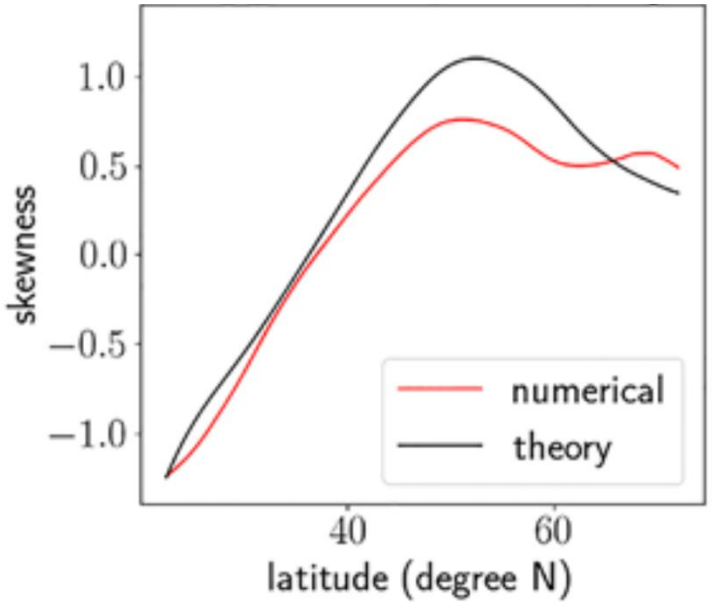

Figure 2: Skewness of temperature distribution in ISCA climate model. Red line shows values calculated directly from ISCA climate model, and black line shows values calculated via equation from our proposed theory.

Kircher, K., Proistosescu, C., & Sriver, R. L. (2025). Analytical model for the higher order moments of midlatitude atmospheric temperature distributions. Geophysical Research Letters, 52, e2024GL111626. https://doi.org/10.1029/2024GL111626