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The warming hole as an internal climate variability phenomenon

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A potentially outstanding manifestation of the effects of internal variability is the so-called warming hole that extends over the south-eastern United States. In this region no warming trend was detected during most of the 20th century and even a slight cooling was observed in the second half of the century. Although many mechanisms were proposed in the attempt to explain the presence of this peculiar feature (e.g. changes in land use and aerosol emissions), we demonstrate that the warming hole may have at least partly resulted from internal variability temporarily obscuring the warming signal in the region.

The role of internal variability is tested using a 21-member ensemble generated by the fully coupled NCAR's Community Earth System Model (CESM) for the period 1950-2100 with slightly perturbed initial conditions. The possibility of simulating the warming hole in the reference period 1960-2004 is investigated by introducing a simple identification criterion based on near-surface temperature changes. Not unexpectedly, the warming hole does not appear in the simulated ensemble average temperature changes but is identified in 6 out of the 21 runs. In a perfect-model approach and assuming correct external forcing, this is suggestive of the fact that the warming hole may occur under particular circumstances due to internal variability.

In a second step we explore what modes of variability account for the lack of warming in certain realisations of the model. To this end, a principal component analysis was performed on the set of the 21 simulated mean winter 500hPa geopotential height trend patterns over North America (10-90°N, 170°E-30°W) in the period 1960-2004. The first two EOFs collectively explain approximately 63% of the total variance and are recognised as representative of the time evolution of two different configurations of the Pacific/North American Pattern (PNA). Resorting to a regression method, the temperature trend contribution of this mode is then removed from individual runs, which results in the disappearance of the warming hole in filtered fields.

Our experiment thus suggests that internal variability masking the warming signal may account for a large portion of the observed warming hole. In particular, the observed negative temperature trends in the south-eastern United States may have been produced by a long-term positive trend of the Pacific/North American Pattern, shifting towards a positive phase. Such a trend is indeed detectable in observations and is also evident in those model runs featuring a warming hole when looking at the time series of the principal component of the second EOF, associated with the warming hole structure.