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Determining inter-polar coherence in the face of age-model uncertainty

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Estimation of the relative timing between climatic events is crucial for assessing the spatial extent of climate variations, determining whether processes are dynamically linked, and testing for causal relationships. The relationship between temperature variations recorded in ice-cores from Greenland and Antarctica is considered. Records of both atmospheric methane and $\delta^{18}O_{\text{atm}}$ are available from Greenland and Antarctic ice-cores. These gases are well mixed in the atmosphere and, thus, variations are assumed to be nearly synchronous between the hemispheres. An algorithm is presented to place Greenland and Antarctic ice-cores on a consistent chronology by concurrently aligning the methane and $\delta^{18}O_{\text{atm}}$ records. This alignment procedure improves over previous methods by permitting multiple records to be concurrently aligned, providing uncertainty estimates, and not requiring the data to be interpolated to a regular grid.

Although the accuracy of the relative timing of Greenland and Antarctic records is improved, the remaining age-model uncertainty has important consequences for inter-polar coherence and phase estimates. A simple relationship is analytically derived for the effects of age-model uncertainty on coherence and phase estimates and is checked using Monte Carlo procedures. Owing to age-model uncertainty, the coherence and phase between Greenland and Antarctic temperature variations can only be assessed at periods longer than two kiloyears. At periods longer than this cut-off a coherent temperature relationship exists: Antarctica leads Greenland by two to three kiloyears at frequencies below $1/10$ kiloyears, but at higher frequencies, approaching the millennial scale, the records exhibit increasingly anti-phased behavior. The millennial scale phase relationship is consistent with the combined effects of an Antarctic phase-lead and the existence of asymmetric proxy variability between the poles.