

Stratosphere-troposphere coupling: Stability of the annular mode time scale and role of the stratosphere

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The proper simulation of the annular mode (AM) time scale may be regarded as an important benchmark for climate model performance. Previous research demonstrated that climate models systematically overestimate the AM time scale, which may imply that the model's climate circulation is overly sensitive to external forcing, as suggested by the fluctuation-dissipation theorem. Previous research made it also clear that the AM time scale converges very slowly, thus necessitating relatively long time series. Here we address the problem of stability of the AM time scale and investigate the robustness of a time scale derived from the 50 yr long historical reanalysis record. We use a 4000 yr long control simulation with the GFDL climate model CM2.1 and investigate the AM time scale from individual 50 yr long segments. We find substantial centennial scale variability in the simulated time scale: some segments exhibit hardly any resemblance to the observations, but there are also cases that agree well with the observations. This sampling variability attaches large uncertainties to time scales diagnosed from decadal records. Even under the fixed climate forcing conditions of our control run, at least 100 yrs of data are required in order to keep the uncertainty in the northern AM time scale to 10%; for the southern AM the required length increases to 200 yrs. If nature's AM time scale is similarly variable there is no guarantee that the 50 yr historical reanalysis record is a fully representative target for model evaluation. We further investigate whether a relationship can be found between the structure of the AM time scale in the stratosphere and that in the troposphere. For the northern AM, we find a robust relationship between magnitude and seasonal timing of the time scale in troposphere and stratosphere, confirming and extending earlier results of a dynamical coupling between the stratosphere and the troposphere and of influences of stratospheric variability on variability in the troposphere. Over the southern hemisphere, however, such an influence is less clearly developed.