Geophysical Research Abstracts
Vol. 13, EGU2011-6402, 2011
EGU General Assembly 2011

Global Climate Reconstructions of the Past 400 years Using Ensemble Kalman Filtering

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Past climate states are usually reconstructed based on the empirical relationship between climate proxy records and climate variables during the past century. This approach, however, is applicable only to a small set of climate variables for which robust linear relationships with climate proxies can be found. Furthermore, climate proxies are spatially incomplete and noisy, thus limiting the level of detail of such reconstructions and the fundamental assumption of stationary relations may be questioned. Climate model simulations driven with reconstructed forcing time series, on the other hand, provide spatially explicit information about all variables modelled. They are based on physics rather than on (stationary) statistical relations, but at best they provide a range of possible realisations of climate states that are consistent with the forcings. From a sufficiently large set of simulations differing in initial conditions, we can derive statistical properties of the climate system at any one time. By combining this information with proxy records, we are then able to compute comprehensive reconstructions that are consistent with both the proxy data and model physics.

The method will be applied to reconstruct global climate on a seasonal to monthly scale for the period from 1600 to the present using a set of 30 simulations with the ECHAM5.4 model driven with reconstructed climate forcings such as SSTs, land surface properties or solar irradiance. Apart from the varying boundary conditions and forcings, the simulations are unconstrained. We assimilate climate proxy data in the aggregated model output using the Ensemble Kalman Filter (EnKF) on monthly or seasonal model time scales. In contrast to empirical-statistical reconstructions, the EnKF approach allows us to exploit the state-dependent relationship between different climatic variables estimated from the ensemble of model simulations to constrain variables that are only loosely related to climate proxies. Each of the 30 ensemble members is corrected using this approach, yielding a new ensemble with a much reduced spread and higher skill.

In this presentation the method will be demonstrated in a pseudo approach using only the 30 simulations in the 17th century. One of the 30 members is considered as truth, pseudo proxies for temperature (mimicking the distribution of available tree ring proxies) are extracted from that simulation and perturbed with sufficient red noise to reduce their correlations to 0.3-0.7. The set of 29 remaining simulations, together with the degraded pseudo-proxies, is then used to reproduce the 30th simulation. Results demonstrate that skill is possible with this approach, yielding good temperature reconstructions mainly at northern midlatitudes and in areas where information from climate proxies is available. In remote areas, on the other hand, reconstructions do not have more skill than the original ensemble mean (i.e. the skill that comes from the forcings). Interestingly, skill is found in other variables than temperature, such as the strength of the stratospheric polar vortex. However, corrections are necessary to account for the overestimation of covariance due to the small sample. The approach will now be applied to early instrumental and proxy data back to 1600.