Session: C33 Poster: W236A

Conceptual understanding of climate change with a globally resolved energy balance model

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The future climate change projections are essentially based on coupled general circulation model (CGCM) simulations, which give a distinct global warming pattern with arctic winter amplification, an equilibrium land-sea warming contrast and an inter-hemispheric warming gradient. While these simulations are the most important tool of the Intergovernmental Panel on Climate Change (IPCC) predictions, the conceptual understanding of these predicted structures of climate change and the causes of their uncertainties is very difficult to reach if only based on these highly complex CGCM simulations. In the study presented here we will introduce a very simple, globally resolved energy balance (GREB) model, which is capable of simulating the main characteristics of global warming. The model shall give a bridge between the strongly simplified energy balance models and the fully coupled 4-dimensional complex CGCMs. It provides a fast tool for the conceptual understanding and development of hypotheses for climate change studies, which shall build a basis or starting point for more detailed studies of observations and CGCM simulations. It is based on the surface energy balance by very simple representations of solar and thermal radiation, the atmospheric hydrological cycle, sensible turbulent heat flux, transport by the mean atmospheric circulation and heat exchange with the deeper ocean. Despite some limitations in the representations of the basic processes, the models climate sensitivity and the spatial structure of the warming pattern are within the uncertainties of the IPCC models simulations. It is capable of simulating aspects of the arctic winter amplification, the equilibrium land-sea warming contrast and the inter-hemispheric warming gradient with good agreement to the IPCC models in amplitude and structure. The results give some insight into the understanding of the land-sea contrast and the polar amplification. The GREB model suggests that the regional inhomogeneous distribution of atmospheric water vapor and the non-linear sensitivity of the downward thermal radiation to changes in the atmospheric water vapor concentration partly cause the land-sea contrast and may also contribute to the polar amplification. The combination of these characteristics causes, in general, dry and cold regions to warm more than other regions.