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Annual cycle of the global-mean energy budget in a mechanistic middle atmosphere GCM

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A new mechanistic climate model from the surface to the lower thermosphere is presented. The model is based on a standard spectral dynamical core and includes an idealized radiation scheme with continuous computation of energy fluxes. The surface energy budget is fully taken into account by means of a slap ocean with prescribed lateral oceanic heat-flux convergence. The moisture budget is based on a new transport scheme and simple parameterizations of condensation and convection. Subgrid-scale parameterizations include gravity waves and turbulent diffusion. Each parameterized process is formulated in an energy conserving fashion such that the resulting numerical error of the net radiation at the top of the atmosphere (RTOA) is about 0.2 W/m/m.

The model shows a pronounced annual cycle of the RTOA of several W/m/m, with the minimum occurring in late NH winter. On a seasonal timescale this variation is synchronous with an equally strong imbalance at the surface. The annual cycle of the RTOA results from the hemispheric differences in the distribution of land and ocean surfaces, which are characterized by different heat capacities and albedos. While the absorbed solar radiation (ASR) is dominated by a semi-annual component associated with maximum absorption at the surface during the equinoxes, the global-mean surface temperature is governed by an annual component with a minimum during late NH winter. The reason is a smaller surface heat capacity in the NH, giving rise to global-mean cooling particularly during early NH winter. The annual cycle in the surface temperature then implies a corresponding behavior in the outgoing long-wave radiation (OLR), which gives the main contribution to the annual component of the RTOA. These mechanistic model results are supported by existing observational analyses. Analysing the global-mean energy budget as a function of height, the residual circulation is found to account for a downward dynamical energy flux from the stratosphere into the troposphere of about 1 W/m/m, which is consistently balanced in the model by a net upward radiation flux between about 300 and 10 hPa.

The implications of this study are that 1) an imbalance in the RTOA may contain significant contributions from natural oceanic variability and 2) the dynamical energy flux from the middle into the lower atmosphere requires to include a realistic stratosphere in climate models.