Zonal-mean circulation response to reduced air-sea momentum roughness

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The impact of uncertainties in surface layer physics on the atmospheric general circulation is comparatively unexplored. Here the sensitivity of the zonal-mean circulation to reduced air-sea momentum roughness (Z_{0m}) at low flow speed is investigated with the Community Atmosphere Model (CAM3). In an aquaplanet framework with prescribed sea surface temperatures, the response to reduced Z_{0m} resembles the La Niña minus El Niño response to El Niño Southern Oscillation variability (see Figure 1) with: i) a poleward shift of the mid-latitude westerlies extending all the way to the surface; ii) a weak poleward shift of the subtropical descent region; and iii) a weakening of the Hadley circulation, which is generally also accompanied by a poleward shift of the inter-tropical convergence zone (ITCZ) and the tropical surface easterlies. Mechanism-denial experiments show this response to be initiated by the reduction of tropical latent and sensible heat fluxes, effected by reducing Z_{0m}. The circulation response is elucidated by considering the effect of the tropical energy fluxes on the Hadley circulation strength, the upper tropospheric critical layer latitudes, and the lower-tropospheric baroclinic eddy forcing. The ITCZ shift is understood via moist static energy budget analysis in the tropics. The circulation response to reduced Z_{0m} carries over to more complex setups with seasonal cycle, full complexity of atmosphere-ice-land-ocean interaction, and a slab ocean lower boundary condition. Hence, relatively small changes in the surface parameterization parameters can lead to a significant circulation response.

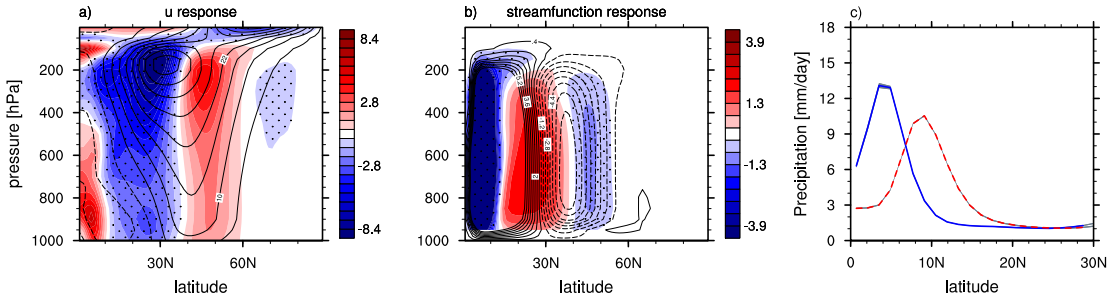

Figure 1: Zonal-mean zonal wind [m/s] (a) and Eulerian mass streamfunction x10^{11}[kg/s] (b)r esponse to reduced Z_{0m} (i.e., reduced Z_{0m} minus the original Z_{0m} climatology) in aquaplanet simulations, in coloured shading (negative values are stippled). Contours show the original climatology (6 m/s and 1.6 kg/s spacing for zonal wind and streamfunction, respectively). The negative contours are dashed. Total precipitation [mm/day] for the original (solid line) and the reduced (dashed line) Z_{0m} simulations is shown in (c). The gray area around the total precipitation lines shows the 95\% confidence interval. Note that the gray area is barely visible because the response is strong and highly significant.