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Influence of changing surface temperature gradients on mid-latitudinal circulation and western hemispheric summer temperature extremes

Kai Kornhuber (1,2), Peter Hoffmann (1), Dim Coumou (1,3)

(1) Potsdam Institute for Climate Impact Research – Earth System Analysis, Telegrafenberg A 31, 14473 Potsdam, Germany (kai.kornhuber@pik-potsdam.de), (2) Universität Potsdam, Am Neuen Palais 10, 14469, Potsdam, Germany, (3) Institute for Environmental Studies (IVM), VU University Amsterdam

Many recent summers in the Northern hemisphere (NH) mid-latitudes have seen severe heatwaves (2003, 2004, 2009, 2010, 2012, 2015, (Black et al. 2004; Diffenbaugh & Scherer 2013; Russo et al. 2014; Hoy et al. 2016)). During many of those extremes the mid-latitudinal tropospheric circulation was characterized by an amplified, quasi-stationary and hemispheric wave pattern with a dominant influence of wavenumber seven (Coumou et al. 2014; Petoukhov et al. 2016; Kornhuber et al. 2016).

Analyzing NH summer reanalysis data we show that the position where these heat extremes occur is not arbitrary. If the amplitude of wave seven is large, the wave gets “locked” in a specific preferred phase position. As a consequence of this phase-locking behavior some regions are more likely to experience extreme weather during high-amplitude events. Meridional wind speeds associated with the preferred phase are particularly strong over longitudes of the western hemisphere (180°W – 40°E) leading to positive temperature anomalies over the US and Western Europe. Using a widely-used blocking-index we demonstrate that longitudes over these regions experience an increased probability of blocking during high amplitude wave seven events.

We show that during the above mentioned extreme summers, amplified waves were locked in their preferred phase-position creating the right dynamical background condition for severe heatwaves to occur.

Further, regression analyses reveal that a pronounced Ocean – Land temperature contrast (Tdiff) and weak poleward surface temperature gradient (dT/dy) are associated with an amplified wave seven in its preferred phase-position. Our study suggests that the observed positive trend in Tdiff and negative trend in dT/dy favors the occurrence of high-amplitude, quasi-stationary wave seven in its preferred phase position and therefore persistent heatwaves in the US and western Europe.