Annual Seminar 2015

Physical processes in present and future large-scale models

1–4 September 2015

Summary

Land water and energy budgets and their impacts on extremes - Sonia Seneviratne

Land water and energy budgets affect near-surface climate in several ways, including impacts on temperature, boundary layer development and precipitation, among others (e.g. Seneviratne et al. 2010, Mueller and Seneviratne 2012, Guillod et al. 2015). In addition, they also modulate drought development on land. Observational data reveal that as a result, the response of the continental water cycle to anthropogenic forcing presents a very distinct signature compared to that of global climate (e.g. no “wet-gets-wetter, dry-gets-drier” response in precipitation-evapotranspiration in historical data, Greve et al. 2014), which emphasizes the need to consider the specificities of land climate when assessing drivers of climate variability on continents. Figure 1 highlights that while land conditions are often seen as a result of climate variability (downward arrow), they themselves affect climate variability in a substantial way. In addition, the role of humans in this coupled system affects both climate directly through greenhouse gas (and aerosol) emissions as well as indirectly through modifications of land properties (land use changes). These complex interactions need to be properly represented in state-of-the-art climate and weather models in order to capture climate variability and provide reliable simulations and predictions.

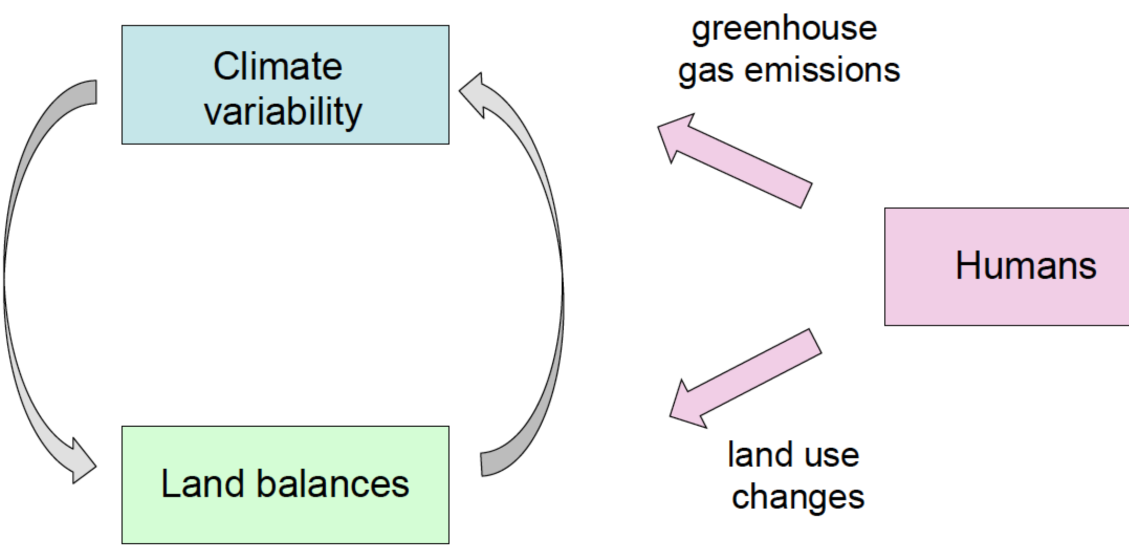

Fig. 1. Interactions between land processes and climate variability, and role of humans as forcing to these two elements.

This presentation focused on land-atmosphere interactions affecting climate extremes. The following main examples were provided:

Surface moisture deficits (generally linked to accumulated precipitation deficits and/or excess evapotranspiration) are found to be a strong control for the subsequent occurrence of heatwaves and hot extremes in several regions in the globe, in both present and future climate (e.g. Mueller and Seneviratne 2012, Seneviratne et al. 2013, Whan et al. 2015). This is linked to a lack of evaporative cooling during dry periods, which leads to an additional warming of temperature, and particularly extremes. This mechanism could explain in part the continued warming of hot extremes on land during the so-called "hiatus" period (Seneviratne et al. 2014).

The control of soil moisture on land evapotranspiration is a major mechanism affecting drought development on continents. It explains why the response of the land water cycle to additional greenhouse forcing in the 20th century does not follow the so-called "dry-gets-drier, wet-gets-wetter" paradigm (Greve et al. 2014), and also constrains drought changes in the 21st century (Greve and Seneviratne 2015).

Modifications of land albedo through land use or land cover changes (for instance as a consequence of no-till farming) are found to lead to an asymmetric cooling of summer temperatures, with the largest cooling found for the hottest extremes (Davin et al. 2014). This highlights possible avenues for the development of land climate engineering scenarios aiming at the reduction of subregional to regional temperatures (Wilhelm et al. 2015).

These various examples illustrate the essential role that land-climate interactions play for the occurrence of extremes on continents. These findings have important implications for climate projections, but also for weather and seasonal forecasting. In particular, they show the need for the better consideration of land surface initialization and the representation land surface processes, parameters and forcings in the development of short- to long-range weather predictions.

References

Davin, E.L., S.I. Seneviratne, P. Ciais, A. Olioso, and T. Wang, 2014: Preferential cooling of hot extremes from cropland albedo management. *Proc. Natl. Acad. Sci.*, 111(27), 9757-9761, doi:10.1073/pnas.1317323111.

Greve, P., B. Orlowsky, B. Mueller, J. Sheffield, M. Reichstein, and S.I. Seneviratne, 2014: Global assessment of trends in wetting and drying over land. *Nature Geoscience*, 7, 716-721, doi: 10.1038/NGEO2247.

Greve, P., and S.I. Seneviratne, 2015: Assessment of future changes in water availability and aridity. *Geophys. Res. Lett.*, 42(13), 5493-5499, doi:10.1002/2015GL064127.

Guillod, B.P., B. Orlowsky, D.G. Miralles, A.J. Teuling, and S.I. Seneviratne, 2015: Reconciling spatial and temporal soil moisture effects on afternoon rainfall. *Nature Communications*, 6, 6443.

Mueller, B., and S.I. Seneviratne, 2012: Hot days induced by precipitation deficits at the global scale. *Proc. Natl Acad. Sci.*, 109 (31), 12398-12403, doi: 10.1073/pnas.1204330109.

Seneviratne, S.I., T. Corti, E.L. Davin, M. Hirschi, E.B. Jaeger, I. Lehner, B. Orlowsky, and A.J. Teuling, 2010: Investigating soil moisture-climate interactions in a changing climate: A review. *Earth-Science Reviews*, 99, 3-4, 125-161, doi:10.1016/j.earscirev.2010.02.004

Seneviratne, S.I., M. Wilhelm, T. Stanelle, B.J.J.M. van den Hurk, S. Hagemann, A. Berg, F. Cheruy, M.E. Higgins, A. Meier, V. Brovkin, M. Claussen, A. Ducharne, J.-L. Dufresne, K.L. Findell, J. Ghattas, D.M. Lawrence, S. Malyshev, M. Rummukainen, and B. Smith, 2013: Impact of soil moisture-climate feedbacks on CMIP5 projections: First results from the GLACE-CMIP5 experiment. *Geophys. Res. Lett.*, 40 (19), 5212-5217.

Seneviratne, S.I, M. Donat, B. Mueller, and L.V. Alexander, 2014: No pause in the increase of hot temperature extremes. *Nature Climate Change*, 4, 161-163.

Whan, K., J. Zscheischler, R. Orth, M. Shongwe, M. Rahimi, E.O. Asare, and S.I. Seneviratne, 2015: Impact of soil moisture on extreme maximum temperatures in Europe. *Weather and Climate Extremes*, 9, 57-67, doi:10.1016/j.wace.2015.05.001.

Wilhelm, M., E.L. Davin, and S.I. Seneviratne, 2015: Climate engineering of vegetated land for hot extremes mitigation: an Earth System Model sensitivity study. *J. Geophysical Res.*, 120, 2612-2623, doi:10.1002/2014JD022293.