A Moist Static Energy Perspective on Atmospheric Rivers

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Most of the latent heat transport across the mid-latitudes occurs through filamentary structures called atmospheric rivers (ARs, e.g. Zhu and Newell, 1997). Although a lot of progress has been made in the past twenty years, several gaps remain in our understanding of ARs, including their role in atmospheric dynamics (e.g. Ralph et al, 2015) and the associated sensible heat transport. Here, we study atmospheric rivers from an energetic perspective, and ask:

- Can we find simple energetic variables to describe the intensity of ARs? Even if ARs are defined in terms of latent heat, can we also describe these structures in terms of sensible heat and geopotential?
- Which physical processes contribute to the formation of ARs on the large scale? For instance, how important are the roles of air-sea fluxes and radiative feedbacks?

To answer these questions, we perform large-scale moist static energy and moist static energy spatial variance budgets (e.g. Wing and Emanuel, 2014) on reanalysis data of well-known AR case studies (e.g. Ralph et al, 2010). We find that the spatial variance of moist static energy can describe the intensity of AR structures in the mid-latitudes. Its main components are the spatial variance of sensible heat (the associated cold front) and the spatial correlation between latent and sensible heat (the fact that moist and warm zones coincide). Furthermore, we find that the air-sea fluxes and radiative feedbacks are small on the large-scale: The main contributor to the formation of an AR is the export of latent heat from the Tropics to mid-latitudinal regions that are already hot and moist. Finally, we derive an approximate energetic budget for the lifecycle of an AR from our case studies.

This framework is a first step towards a thermodynamical understanding of ARs. Applications include better parametrizations of the inland sensible heat transport, which can have important consequences on the erosion and production of the snowpack.