Colloquium

The Influence of Moisture on Seasonally Varying Circulations in Planetary Atmospheres

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It is well known that atmospheric water vapor, which depends nonlinearly on temperature through the Clausius-Clapeyron relation, has a profound impact on Earth's climate. First, it is a potent greenhouse gas, exerting a strong positive radiative feedback. Second, it undergoes phase transitions, with the associated latent heat release having direct and indirect influences on tropical and extratropical circulations. An aspect that has, however, remained relatively unexplored is that atmospheric water vapor, by contributing to the energy content of an atmospheric column, can alter its effective heat capacity and can thus potentially mediate the circulation response to any seasonally varying forcing. In this talk, I will show how this effect can lead to interesting seasonal behaviors, which we explore in simulations with an idealized GCM in aquaplanet configuration. Simulations of Earth-like monsoons in this model show a progressive delay in the timing of monsoon onset with global warming, consistent with Earth System Model outputs in the CMIP archives. Analyses of the moist static energy budget reveal how, at the beginning of the warm season, atmospheric latent energy storage becomes increasingly important as the climate warms. This storage is able to compensate any change in net energy input, negating the need for change in the circulation, and thus leading to the observed monsoon onset delay. In a broader planetary context, changes in atmospheric latent energy storage also play an important role in the extratropical circulation of Earth-like planets with high obliquity simulated with the same idealized GCM. I will show how on high-obliquity planets with a small surface thermal inertia, net energy deficit during the winter months is primarily balanced by the latent energy component of the atmosphere, which buffers any significant atmospheric cooling. As temperatures finally start to decrease, condensational latent heat release of atmospheric moisture further slows down the cooling and keeps the winter pole warmer than the midlatitudes until after the winter solstice. This prevents vigorous baroclinic eddy activity as well as the development of a Ferrel cell and storm track.

Monday, February 10, 2025 11:30am - 12:30pm

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