14D.3 EXPLORING THE IMPACT OF THE DIURNAL CYCLE ON THE CONVECTIVE INTENSITY CONTRAST BETWEEN LAND AND OCEAN

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Introduction: Deep tropical convection over land is known to have greater convective intensity deep convection over the ocean (Zipser 2003). This can be seen in maps of lightning flash rate per unit rain rate, figure 1, which accounts for the total amount of convection occurring at a location, while preserving information about the local intensity. The lightning flash rate of an individual storm is tied to its updraft velocity (Boccipio 2002), which is a natural metric for convective intensity, though one that is difficult to measure in the real world. The majority of this work focuses on how the lower surface heat capacity over land, and its correspondingly larger diurnal cycle in surface temperature affects convective intensity through convective available potential energy (CAPE) differences from the ocean, and is found to not a mechanism that produces large differences as those shown in figure 1a. A second hypothesis related to saturation deficits in the free troposphere acting to increase CAPE is briefly presented as an alternative mechanism.

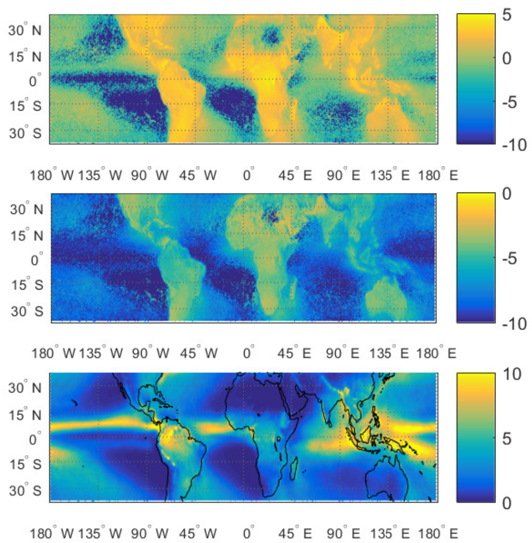

Figure 1: *Comparison of log of lightning flash rate (top), log of lightning flash rate per unit precip (middle), and TRMM 3B42 precipitation*

Land surfaces are associated with lower effective heat capacities than ocean surfaces, and are associated with larger diurnal cycles in surface temperature. The diurnal cycle mechanism also relies on the fact the free tropospheric temperature gradients are weak (Charney 1963), and that gravity waves from oceanic tropical convection affect the free troposphere over tropical continents (Sobel et al. 2001). Because of its high heat capacity, SST over the ocean is relatively constant, limiting the range of free tropospheric temperatures that tropical convection can set the atmosphere to. Anomalously high surface temperatures that occur over land may then interact with a free tropospheric temperature profile set by convection with a cooler surface temperature. Given some sounding where you only warm the temperature of the lowest levels, you will increase the overall CAPE by shifting the location of the level of free convection relative to the rest of the profile. We test this hypothesis in a cloud resolving model (CRM) by inputting an island with a diurnally oscillating fixed surface temperature adjacent to an ocean with a constant fixed surface temperature. We explore how high percentiles of mid-free tropospheric updraft velocity differ when differences in precipitation over the two regions are accounted for.

Another way for CAPE to potentially be greater over land than over ocean is for there to be a greater saturation deficit (difference between a plume's specific humidity and its saturation specific humidity) over land (Singh and O'Gorman 2013, 2014). The premise for this mechanism is once again based on the idea that tropical convection sets its environment's temperature profile. For a given horizontal entrainment rate, a drier environment will result in lower saturation moist static energies (h^*) for the entraining plume. This convective plume also sets the environment's background temperature via gravity wave propagation (Sobel et al. 2001), and so results in colder free tropospheres the greater the environmental saturation deficit is (Singh and O'Gorman 2013). For a level of free convection (LFC) with a fixed temperature and height, the colder the free troposphere is, the greater the undilute CAPE (CAPE calculated pseudoadiabatically from a non-entraining plume) will be. It seems plausible that land based convection will be situated in an environment with a drier free troposphere than oceanic convection, which gives potential for larger saturation deficits to explain differences in convective intensity.

Using radiative convective equilibrium (RCE) as a testing ground for all of the diurnal cycle simulations and most of the saturation deficit simulations. For two of the saturation deficit simulations, we used field campaign data from TOGA COARE (Webster and Lukas 1992) and ARM SGP 1998 (Stokes and

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Schwartz 1994). Because we are interested mostly in the intensity of the convection rather than the amount of convection, it is important to account for differences in precipitation quantity between simulations. We do this by using the statistical techniques of Poisson and binomial sampling (Särndal et al. 2003).

The first section below focuses on the results of the diurnal cycle hypothesis and how differences in the probability distribution function (PDF) of precipitation affect convective intensity. The second section below explores the impact of saturation deficit.

Diurnal Cycle Simulations: The CRM used in this study is the System for Atmospheric Modeling (SAM) (Khairoutdinov and Randall 2003). We ran 3D simulations in a "Bowling Alley" domain that was 1024km in the x direction and 32km in the y direction, with 1km resolution, periodic boundary conditions, and interactive radiative cooling. The left half of the x domain contained our island with surface temperature oscillating between 295K and 305K; the right half of the domain had a fixed SST of 300K.

The island portion of the domain had greater mean precipitation than the ocean portion, and prior to accounting those differences, the island had greater 500hPa updraft velocities at the 99.99th percentile of a CDF, which is our metric for convective intensity. However, when we account for the total amount of precipitation using Poisson sampling, which adjusts the mean value to be the same in both locations, we find that high intensity updraft velocities are no longer stronger over the island, but instead are the same as those over the ocean as shown in figure 2. Performing Poisson sampling as well as binomial sampling (which controls for the total PDF rather than just a mean value), we combined tropical rainfall measuring mission (TRMM) 3B42 data, as well as TRMM lightning data to make every gridpoint on the planet have the same mean precipitation, and the same precipitation PDF. Controlling for the mean broadly increased lightning flash rates over land, while controlling for the entire PDF decreased lightning flash rates over tropical continents (figure 3), although not enough to account for the land-ocean contrast.

During our analysis, we found that CAPE was not higher over our island compared to our ocean. Additional analysis has implied to us that convective fluxes as well as boundary layer entrainment act very quickly to remove anomalous moisture fluxes from our boundary layer. We propose that this result falls in line with those of boundary layer quasi-equilibrium (Raymond 1995).

Saturation Deficit Simulations: Using the same CRM as before, we ran equilibrium simulations where we adjusted the free tropospheric specific humidity to be some fraction (1, 0.9, and 0.75) of a TOGA COARE mean sounding. We then compared the high intensity updraft velocities controlling for precipitation as above, and found that the driest simulations had the highest convective intensities.

We also ran directly forced simulations from field campaign data, comparing an oceanic field campaign (TOGA COARE) to a continental campaign (ARM SGP). We found that the continental campaign had much stronger convective intensities than the oceanic campaign. Those strongest periods of convection were associated with precipitation in an environment that was dry relative to the total ARM SGP campaign. We concluded that at least in the case of our simulations dry periods of convection are associated with the strongest convective intensities, and that these results line up with the proposed saturation deficit mechanism.

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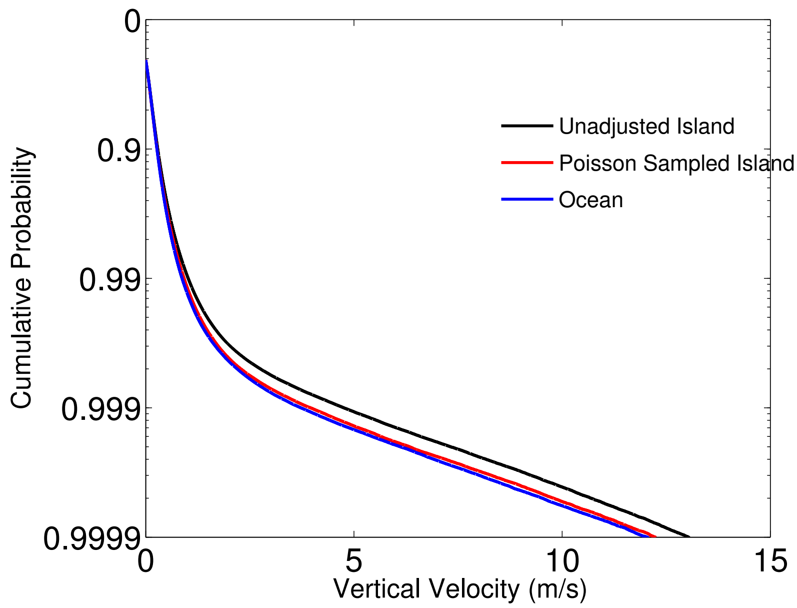

Figure 2: *Cumulative distribution function of unadjusted 500hPa updraft velocity over the island (black), Poisson sampled island updraft velocity (red), and ocean updraft velocity (blue). Note that going down the y-axis increases in intensity.*

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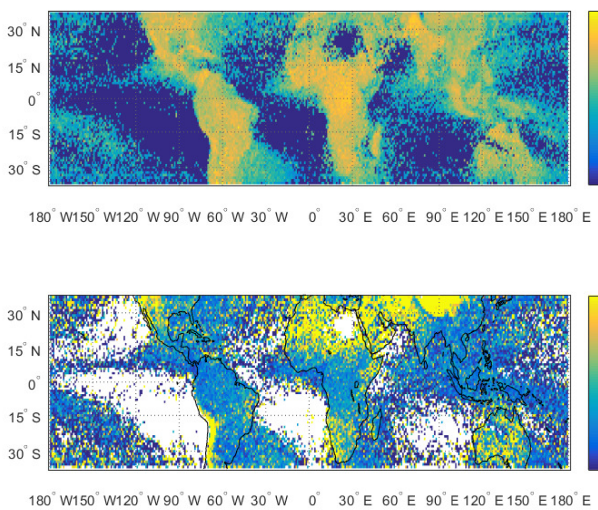

Figure 3: *a) Binomially sampled lightning flash rate such that each location has the same precipitation PDF. b) Ratio of the binomially sampled lightning flash rate to the unsampled lightning flash rate. Values below 1 indicate a decrease in lightning.*