2A.3 EXPLORING THE TROPICAL LAND-OCEAN CONVECTIVE INTENSITY DIFFERENCE THROUGH SURFACE BOWEN RATIO VARIATIONS AND HIGH PERCENTILES OF THE CAPE DISTRIBUTION

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Introduction: There are large differences in the intensity of deep convection between land and ocean in the tropics (Zipser 2003). This is clearly seen in order of magnitude differences in lightning flash rate between land and ocean, with land have much greater flash rates (Cecil et al.2014). Lightning flash rate is generally thought to be a good proxy for updraft velocity (Boccipio 2002). The few in situ observations of deep convective tropical updrafts seem to confirm this idea (Lucas et al. 1994). It is our goal to focus on two specific hypotheses that may explain these differences. The first is that convective available potential energy (CAPE) is simply greater over land than over ocean at high percentiles. We test this using 9 years of 4 times daily ERA-interim data to calculate CAPE between 45N and 45S. The second hypothesis is that differences in the surface Bowen ratio result (SBR) in deeper boundary layers over land, resulting in wider updrafts at cloud base, resulting in less entrainment, and thus more intense convection over land. We explore this hypothesis using cloud resolving model simulations.

CAPE differences over land and ocean would be a parsimonious explanation as to why there are large observed lightning differences. However, previous studies have suggested that there are not very large differences in CAPE over land and ocean (Williams and Renno 1993, Riemann-Campe et al. 2009). A previous study from reanalysis data only captured the mean CAPE of the tropics (Riemann-Campe et al. 2009) and suggested that while mean CAPE was slightly higher over land, the differences didn't seem to be enough to explain the regional differences in lightning activity. It also seems more reasonable to us that a thunderstorm is likely using a higher CAPE than the climatological mean to produce deep convection, and so we wished to test whether high percentiles of CAPE over land and ocean are different.

Horizontal entrainment of environmental air into a convective plume weakens the buoyancy of the plume (Williams and Stanfill 2002). Varying the surface Bowen ratio affects the depth of the boundary layer. Deeper boundary layers wider clouds at cloud base that could limit environmental entrainment's impingement into the updraft core (Zipser 2003, Lucas et al. 1994, Williams and Stanfill 2002, Lucas et al. 1996, Williams et al. 2005). Conceptually, this can be represented by a formulation for entrainment where the entrainment is inversely proportional to boundary layer depth.

Using radiative convective equilibrium (RCE) and initial condition simulations in a cloud resolving model, we test the impact of differing SBR on high-percentile updraft strength. We used a parcel model to test whether entrainment that is inversely proportional to boundary layer depth is representative for our simulations. CAPE is explored using ERA-interim reanalysis data from 2000-2008 and separated by percentile as well.

Below, we separate into the two main ideas that were tested. First we explore the CAPE distribution and its relationship to lightning flash rate. Following that, we explore the surface Bowen ratio.

CAPE: Our analysis of ERA-interim data was calculated using 9 years of 4 times daily reanalysis data from 2000-2008. We calculated the pseudoadiabatic CAPE at each grid point between 45N and 45S.

As shown in figure 1, at the 75th percentile, CAPE was actually higher over a large portion of the ocean than it was over land, a contrast to the observed difference in convective intensity. At higher percentiles like the 99th, CAPE was sometimes higher over land, but well within an order of magnitude.

It was also found that regions with higher 99th percentile CAPEs do not correlate with regions of higher lightning flash rate, using the Tropical Rainfall Measuring Mission Lightning Imaging Sensor lightning flash rate climatology.

Surface Bowen Ratio Variations: The cloud resolving model used in this study is the System for Atmospheric Modeling (SAM) (Khairoutdinov and Randall 2003). We ran 200m resolution 2D and 3D simulation pairs of high and low SBR with varying microphysical scheme into RCE. The initial condition simulations were run for a single model day and with specified SBR of 0, 0.25, 0.5, and 1.

The surface Bowen ratio was altered in these simulations by changing the evaporative conductance α parameter which we inserted into the bulk formula for latent heat flux in the model:

$$LHF = \alpha C_e |v| (q_s - q) \quad (1)$$

where LHF is the latent heat flux, C_e is the bulk transfer coefficient, $|v|$ is the magnitude of the wind speed at some height above the surface, q_s is the

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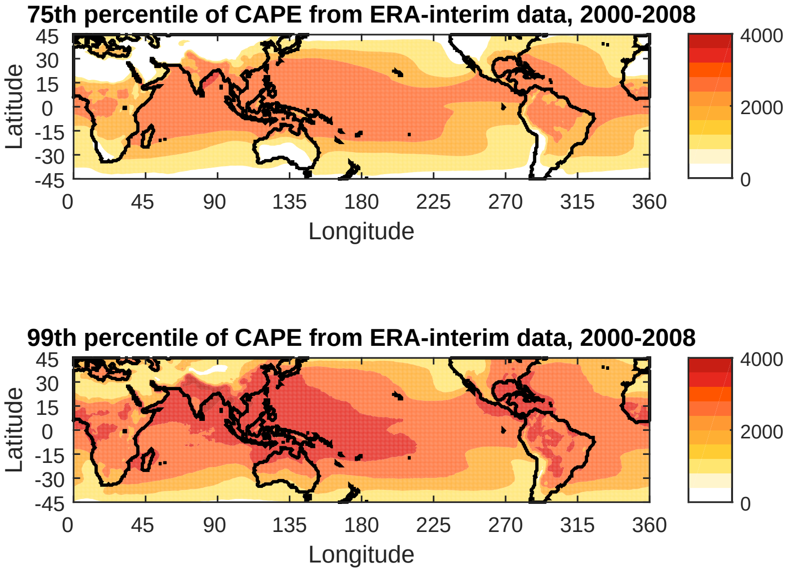

Figure 1: *75th and 99th percentiles of CAPE from ERA-interim reanalysis from years 2000-2008. Units of CAPE are in J/kg*

saturation specific humidity near the surface, and q is the near surface specific humidity.

Increasing the SBR results in cooler free tropospheres due to a) the boundary layer following the dry adiabat to higher heights in the high SBR case, and b) increased differences between SST and first model level temperature are needed in order for surface fluxes to balance radiative cooling. As free tropospheric temperature is known to be a strong control on convective intensity (Singh and O'Gorman 2014), we increased the SST of the high SBR simulations in order to maintain the same free tropospheric temperature.

Higher surface Bowen ratios were found to not produce any notable differences in high percentile updraft velocity. The cumulative distribution functions of simulations pairs show that higher SBR is not associated with increased updraft velocity, as seen in figure 2 (showing a 3D simulation pair). We also looked at the maximum updraft velocity over a range of sampling intervals. There were no significant differences between simulation pairs at the 95% significance level.

Initial condition simulations showed an even stronger negative response to increases in SBR, with mean maximum updraft velocity over the first day decreasing with increasing SBR.

We modified a parcel model from (Singh and O'Gorman 2013) to use our CRM's environmental variables. We tested whether entrainment inversely proportional to boundary layer depth best represented the results we found. It was found instead that entrainment completely independent of boundary layer depth was more representative, as seen in figure 3 when compared to figure 2.

Conclusions: The goal of the study was elucidate the physical mechanisms that influence updraft intensity using both cloud resolving models and reanalysis data.

Results from the reanalysis data showed that CAPE differences between land and ocean are not a likely cause of the observed differences in convective intensity.

Our CRM simulations showed that higher SBRs don't result in greater high percentile updraft velocities, and initial condition simulations had weaker updraft velocity with higher SBR.

Using a parcel model, we were able to show that entrainment being inversely proportional to boundary layer depth is not a good representation of what occurs in our simulations. Entrainment independent of boundary layer depth is more appropriate.

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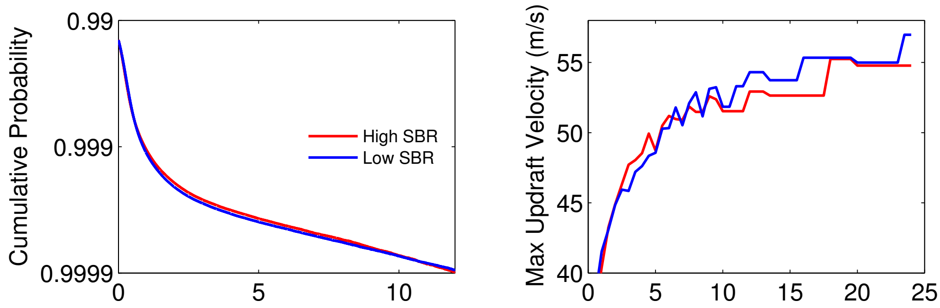

Figure 2: *Cumulative distribution function of 500hPa vertical velocity (left) and maximum updraft velocity as a function of sampling interval (right). Red lines represent the high SBR simulation while blue lines represent the low SBR simulation.*

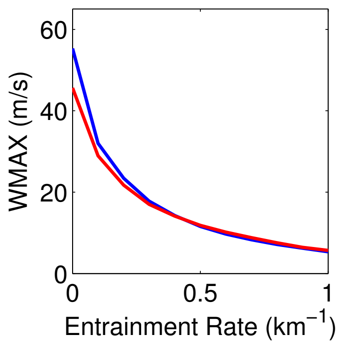

Figure 3: *Maximum vertical velocity versus entrainment rate for a convective plume. Red lines represent the high SBR simulation while blue lines represent the low SBR simulation. Entrainment is independent of boundary layer depth.*

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