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CHARACTERIZING CONVECTIVE INHIBITION DURING THE SUB-TROPICAL MID-SUMMER DROUGHTS

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1. INTRODUCTION

The role of moisture availability in regulating convective development is poorly understood. The dominant role for moisture is through convective triggering whereby rising air parcels in the boundary layer are moist enough to achieve saturation, begin releasing latent energy, and overcome the conditional instability barrier.

The secondary role of tropospheric moisture is less apparent. Regulation of deep convection by mid-troposphere drying is thought to be important both as an in-situ restriction on deep convection and as a source of moisture from detraining congestus-type convection. This moisture restriction and feedback regulation of convection could be crucial in setting the time-scale of convective response of a wide range of phenomena from the diurnal-cycle over land to the convectively coupled Madden-Julian Oscillation - the modelling of which suffers due to convective processes that are too deep too quickly.

2. THE SUB-TROPICAL MID-SUMMER DROUGHT

The mid-summer drought (MSD) is an annually occurring feature throughout Central America, Southern Mexico, the Gulf of Mexico and the Caribbean. It manifests as a local (in time) minimum in precipitation between the maxima of mid-June and mid-September (Magana et al., 1999). Fig 1 (a) shows the ratio of September precipitation to July rainfall. It reveals the widespread coherence of the MSD over the Caribbean and much of southern Florida. July rainfall averages as low as 50-60% of the September value in these areas.

Less well documented is a similar feature centered to the East of the Philippine sea - a region with a much sparser observational network. Fig 1 (b) shows a minimum in July rainfall when compared to the later maximum in rainfall during August - a month or so earlier than the equivalent Caribbean rainfall peak.

The MSD is not associated with the meridional migration of the ITCZ and so a number of alternative mechanisms have been proposed (e.g., Chen et al. 2001; Mapes et al., 2005). The mechanisms focus on the dynamcal forcing leading to increased surface pressure during the MSD period.

For the purposes of a convective inhibition study this phenomenon represents an ideal example. The near-surface forcing in terms of boundary layer equivalent potential temperature increases monotonically throughout the spring and summer, the convective response does not. Clearly there is a large-scale tropospheric suppression influence on convection through the MSD period

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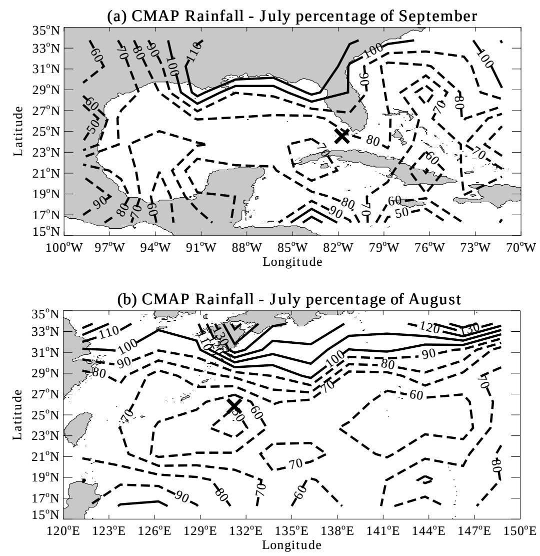

Figure 1. Average MSD rainfall as a percentage of the late summer rainfall maximum for (a) Gulf of Mexico/Caribbean Sea; and (b) Philippine Sea region. CMAP rainfall data (1979-2001).

3. A COMPOSITE SOUNDING ANALYSIS

An extensive radiosonde data-set has been analyzed for numerous stations within the MSD regions of the Caribbean and Philippine sea. Constructing climatologies directly from the raw sonde data retains the full observed vertical resolution. This is ideal for analyzing the convective potential which may be strongly attenuated by shallow dry layers. Course resolution reanalyses products would tend to smear out such layers.

3.1 MSD Annual Cycle

The mean annual cycle of surface pressure (from the (mostly) twice-daily radiosonde data) and rainfall (from CPC/CMAP data) is shown for two stations; Key West, Florida Fig. 2(a) and Minamidaitojima, Japan Fig 2(b).

The MSD in both regions is characterized by an increase in surface pressure as the ocean surface high re-intensifies from the east. The Philippine feature is much shorter and less distinct in surface pressure, but appears able to suppress the rainfall just as significantly.

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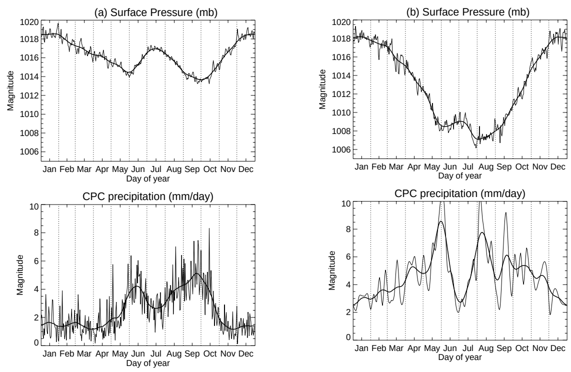

Figure 2. Mean annual cycle of surface pressure and precipitation for radiosonde stations (a) Key West (1954-1999); and (b) Minamidaitojima (1968-1999). Locations marked by X in Figs. 1(a), (b). Daily averages - thin line. 31-day smoothed average - thick line.

3.2 Upper-air Field Tendencies

Focusing on the more complete Key West record the annually-averaged evolution of upper air fields are shown in Fig. 3. Warming and moistening tendencies through May and into early June mark the seasonal increase in rainfall. Coincident with a strengthening southerly jet lower-troposphere drying occurs which is sufficient to eventually reduce convection going into July, even though the boundary layer continues to warm and moisten. A deep tropospheric drying and cooling is indicative of the suppressed convection through July. The combined effects of the retreating high and

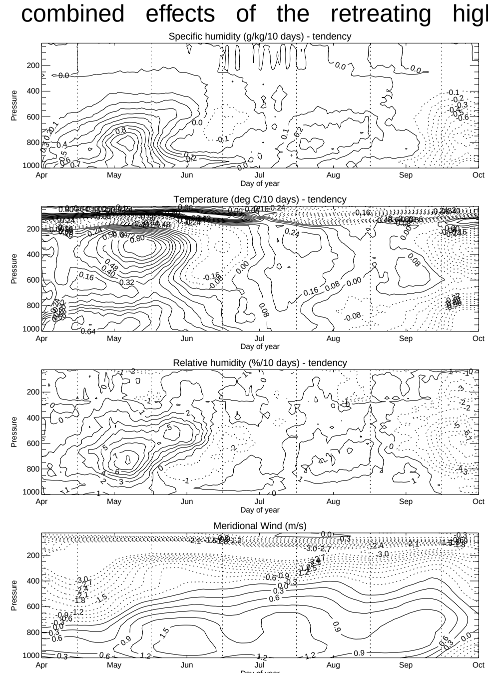

Figure 3. Key West radiosonde derived annual-average tendencies of upper--air fields (a) specific humidity; (b) temperature; (c) relative humidity and (d) evolution of meridional wind.

decreased stability eventually lead to strong convection being re-established through the end of August and into the September maximum.

3.3 Convective Inhibition

Figure 4(a) is an analysis of CAPE of a total-water and entropy conserving non-entraining parcel ascending from the boundary layer to the tropopause. Using this metric one could deduce that the potential for strong convection (high CAPE) is as high during the MSD in July as in September. This potential is obviously not realized in reality and is due to the cooler upper-troposphere - resulting from the convective deficit during July.

Analyzing an entraining parcel that is subject to the constraint of non-negative kinetic energy upon ascent (Fig 4 (b)), better separates the convective potential for the MSD and the September rainfall maximum. This is because a significant number of parcels are unable to traverse the lower-tropospheric drying levels in June and therefore terminate well before reaching significant elevations. The early summer rainfall maximum is difficult to characterize in terms of local convective potential mainly due to the more frontal nature of rainfall at this time of year.

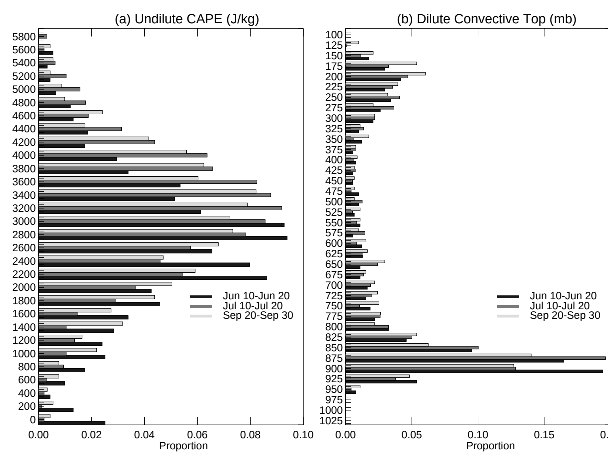

Figure 4. PDFs of individual sounding convective potential during the early summer rainfall maximum, the MSD and the late summer maximum.(a) CAPE assuming an undilute parcel ascent; (b) Cloud-top pressure assuming a strongly entraining parcel.

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