10D.2 RELATING RADAR-DERIVED CLOUD POPULATIONS AND THE VERTICLE STRUCTURE OF HEATING IN EQUATORIAL WAVES

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1. INTRODUCTION

The Tropical Ocean-Global Atmosphere Coupled Ocean-Atmosphere Response Experiment (TOGA COARE) offered an ideal time to study equatorial disturbances such as the Madden-Julian Oscillation (MJO; Madden and Julian 1971) and two day waves (Takayabu 1994). The vertical structure of heating of these disturbances can be broken down into two vertical modes (Kiladis et al 2005; Haertel and Kiladis 2004). This study will show the relationship between these vertical modes and cloud populations derived from radar data.

2. DATA/METHODS

All of the data used for this study were collected during the TOGA COARE experiment which lasted from 1 November 1992 through 28 February 1993. Three types of data were used, sounding data, satellite data, and radar data. The heating structures were developed from the sounding data (for more information see Haertel et al (2004) and Kiladis et al (2005)). Gridded satellite peak brightness temperature T_b over the TOGA COARE intensive flux array (IFA), was temporally filtered for fluctuations of 1.5 to 3 days to get an index of the 2 day wave (Haertel and Kiladis 2004). The filtered index for the MJO is the same as in Kiladis et al. 2005.

The radar data used was gathered from the MIT radar on the three voyages of the *Vickers* during TOGA COARE. The radar was located within the IFA of the experiment and was active for most of the period with some time inactive between the voyages.

Convective cloud heights were then estimated by assuming the echo tops to be equal to the cloud tops for convective clouds (Johnson et al. 1999), (only convective cloud populations were used for this study). To split the clouds into the type of convective cloud, the following echo height boundaries were used as in Johnson et al. 1999; cumulus 0-4 km, congestus 5-9km, and cumulonimbus 11-16 km.

To determine when during the passage of the waves or oscillations the different cloud types were passing over the IFA the cloud values were projected onto the filtered T_b at a series of lags (Wheeler et al. 2000). T_b was given the value of -20° C for the 2 day wave and -30° C for the MJO. These values were chosen because they are the average lowest temperature during the passage of a strong 2 day wave or MJO. This gives us the predicted values of the number of clouds at various times during the passage of one of the 2 day waves or MJOs.

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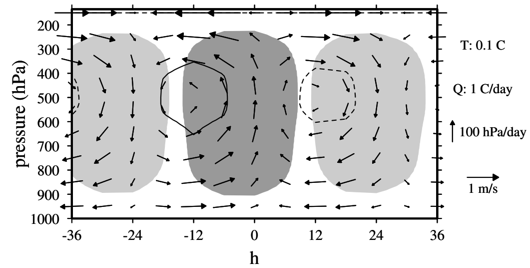
3. DISCUSSION/RESULTS

For both the 2 day wave and the MJO, the heating structures were broken down into 2 modes, one with a heating maximum at 500 hPa and one with a maximum at 750 hPa (figures 1a and 1b for the 2 day wave and figures 2a and 2b for the MJO). Comparing the heating to the cloud populations shows much of what would be expected, the shallow convection occurs in conjunction with the 750 hPa heating and the deep convection occurs in conjunction with the 500 hPa heating.

a)



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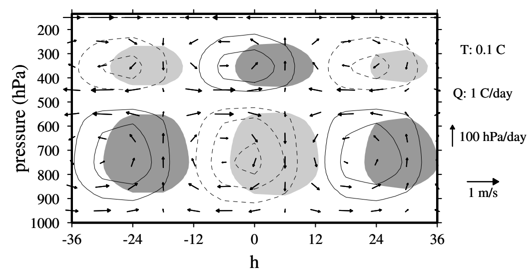

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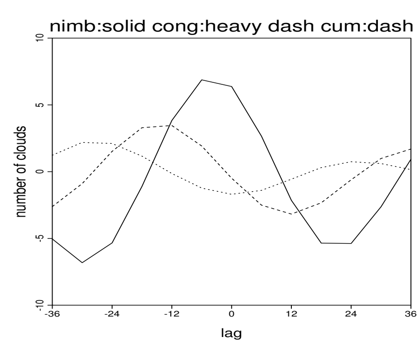


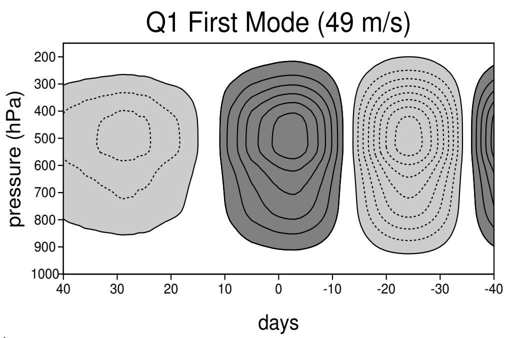
Figure 1. a) Two day wave mode with a heating maximum at 500 hPa (Haertel and Kiladis 2004). b) Two day wave mode with a heating maximum at 750 hPa (Haertel and Kiladis 2004). C) 2 day wave cloud populations

3.1 Two Day Wave

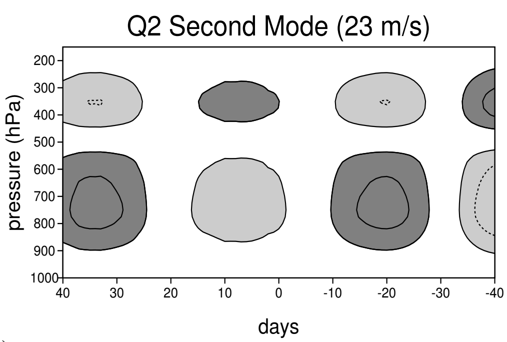
As the 2-day wave passes over the IFA shallow (cumulus) convection occurred first, followed by congestus and cumulonimbus convection respectively. Shallow convection peaked around -26 hours, congestus just before -12 hours and lastly cumulonimbus just before the highest T_b (as shown in figure 2c). This progression is what one would intuitively think just given the nature of the waves.

These findings also coincide with the expected heating modes. The peak 750 hPa heating occurs approximately -22 hours, just after the cumulus peak and just prior to the cumulonimbus peak. At the same time the cooling peaks at approximately the same time that the cumulus and congestus minimums occur. The cumulonimbus peak occurs at nearly the same time as the 500 hPa heating, just before the 0 hour, with the max cooling and minimum clouds occurring at the same time as well.

a)



b)



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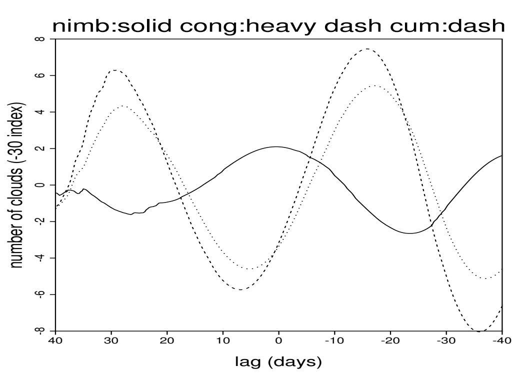

Figure 2. a) MJO heating mode with a maximum at 500 hPa. b) MJO heating mode with a maximum at 750 hPa. c) MJO cloud populations

3.2 MJO

The MJO cloud populations look similar to the 2 day wave's with the cumulus clouds (figure 2c) peaking first at -17 days, followed shortly by the congestus clouds at -15 days, and then the cumulonimbus peaking just after the peak T_b by a couple of days. The cloud populations and heating also occur together for the MJO. The shallow (750 hPa) heating peaks about 2 days before the shallow convection and the deep (500 hPa) heating peaks about 4 days before the deep convection.

4. SUMMARY/FUTURE WORK

This study shows how closely we can associate cloud populations and the heating structures. Because we already have a base of how the heating structures look, compared with cloud populations it would seem that if we counted clouds we would be able to then figure what the heating structures would look like as well.

The peaking of the different levels of cloud populations occur in conjunction with their respective heating depth modes. The next step may be to relate stratiform precipitation to low level cooling and upper-level heating. Hopefully these findings will allow us to predict the values of the heating from the cloud populations.

5. REFERENCES

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