3C.3 The Madden-Julian Oscillation and Tropical cyclogenesis in the Gulf of Mexico

Anantha R. Aiyyer and John Molinari
State University of New York, Albany, New York, USA

1. Introduction

The large-scale environment over the Gulf of Mexico and the eastern Pacific during the hurricane season of 1998 is the subject of this study. We are motivated by the formation of five tropical cyclones within this region between Aug. 31-Sep. 17. The environmental conditions during this period appear to be consistent with the description of the Madden Julian Oscillation (MJO) presented by Maloney and Hartmann (2000). Results from analysis of filtered datasets as well as idealized numerical modeling are presented to support the claim that favorable conditions created by the MJO may have fostered cyclogenesis through the amplification of transient disturbances (e.g., easterly waves) that are ubiquitous in this region

2. Method

The primary datasets used in this study include the uninitialized gridded analyses from the European Center for Medium Range Weather Forecasts (ECMWF) and Outgoing Longwave Radiation (OLR) dataset from the Cooperative Institute for Research in Environmental Sciences (CIRES). Datasets are filtered using the Lanczos filter (1956). A 20-day cutoff period is used to describe the slowly varying background field associated with the MJO.

Idealized numerical experiments are performed to examine the role of the MJO environment in the evolution of waves arriving from upstream. We use a non-divergent barotropic model which consists of the barotropic vorticity equation linearized about a time-invariant basic state on a sphere. The model equations are cast into finite difference form on latitude-longitude grid and integrated in time using the third order Adams Bashforth scheme. To simulate waves arriving from upstream, the model is forced by a Rossby wave source (e.g., Kuo et. al, 2000). The wave forcing considered here is monochromatic, with a period of 4 days.

3. Results

Figure 1 depicts the genesis date and location of the five storms that formed between Aug. 31-Sep. 17. We note that not only these storms occurred during a short span of 18 days, they are also concentrated over a relatively small geographical area.

The low-pass filtered OLR and 850 hPa vector winds for 22 August are shown in fig. 2. The zonally elongated region of convection indicates the location of the Inter Tropical Convergence Zone (ITCZ). The axis of the ITCZ is located around 10^{o} N, with maximum convection within the eastern Pacific. The prevailing winds are mostly easterly within the Caribbean, the Gulf of Mexico and the eastern Pacific. As seen in fig. 3, the situation is dramatically different two weeks later. The convection has spread into eastward and northward into the Gulf of Mexico. Over the eastern Pacific, westerlies have displaced the easterlies that existed previously. Prominent cyclonic circulations can be seen over the Gulf of Mexico and offshore, over the eastern Pacific. This environment during this time (fig. 3) bears a striking similarity with the active MJO described by Maloney and Hartmann (2000). The MJO-related enhanced convection is accompanied by cyclonic vorticity and convergence over a large area - two crucial factors that foster tropical cyclogenesis (not shown).

Throughout this period, several disturbances that could be tracked across the Atlantic entered the Gulf of Mexico and eastern Pacific (not shown). In order to contrast the impact of the environmental condition on these transient disturbances before and during the MJO, two periods are considered: an inactive MJO period (July 21--Aug. 11), and an active MJO period (Aug. 27--Sep. 17). Barotropic exchanges between the environment (20 day low-pass filtered fields) and the eddies (2-20 day band-pass filtered fields) as well as measures of eddy activity are diagnosed using the ECMWF operational analyses. Fig. 4 shows the mean eddy kinetic energy (EKE) for the two periods. During the inactive period, eddy activity appears to be mainly concentrated within the ITCZ in the eastern Pacific while any significant activity is lacking within the Gulf of Mexico. On the other hand, during the active period, the EKE is significantly higher within the Gulf of Mexico and off-shore in the eastern Pacific. These areas are also associated with enhanced barotropic conversions (not shown) from the environment to the eddies during the active MJO, and are consistent with the genesis locations of the storms within this period.

We use the mean fields from the aforementioned active and inactive MJO periods to specify the time invariant basic states (not shown) in the barotropic model forced with the Rossby wave source. The mean EKE for the active and inactive MJO environments after 20 days of simulation are shown in fig. 5. While the details differ from their observed counterparts shown in fig. 4, the basic outcome is the same in that significant eddy growth within Gulf of Mexico and eastern Pacific, where the five storms originated, occurs only for the active MJO basic state. These results suggest that the environment associated with the active MJO played an important role in the formation of the five storms and

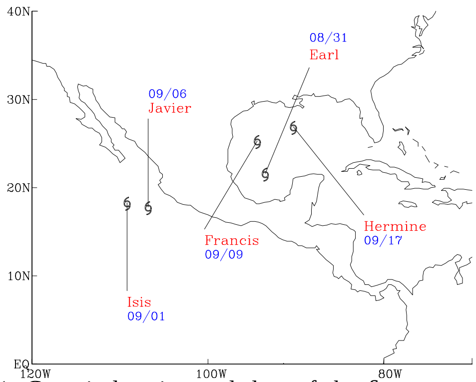

Figure 1. Genesis location and date of the five storms that formed during Aug. 31-Sep.17, 1998.

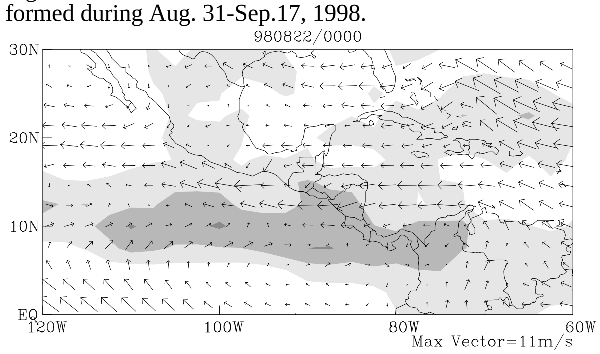

Figure 2. Low-pass filtered OLR (< 240 Wm^{-2} shaded, interval of 30 Wm^{-2}) and 850 hPa vector winds for Aug. 22, 1998.

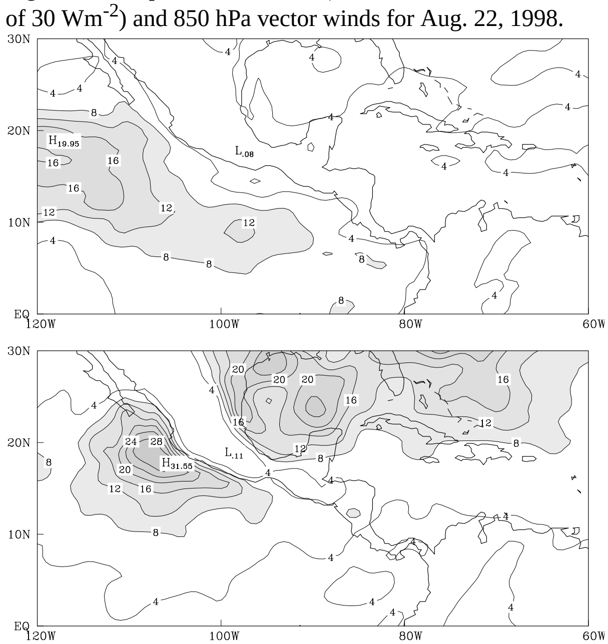

Figure 4. Mean eddy kinetic energy (m^{2}s^{-2}) for the inactive MJO period (top) and active MJO period (bottom) using ECMWF operational analysis.

that analysis based on simple barotropic dynamics can provide some insight into this process.

Acknowledgments

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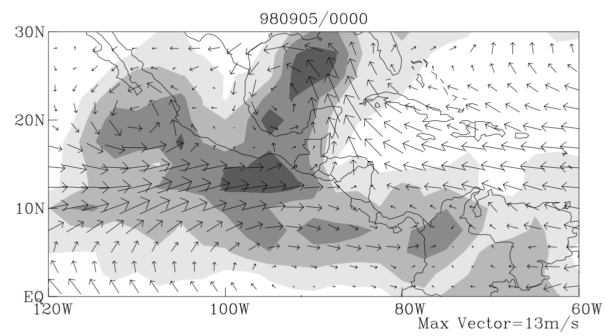

Figure 3. Low-pass filtered OLR (< 240 Wm^{-2} shaded, interval of 30 Wm^{-2}) and 850 hPa vector winds for Sep. 5, 1998.

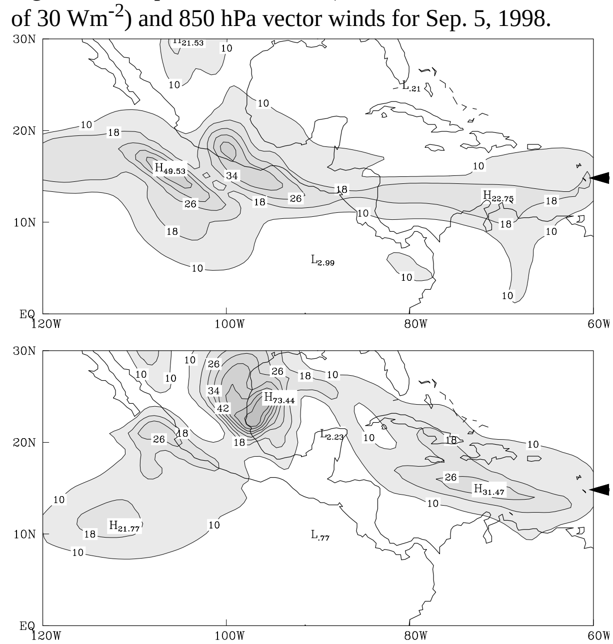

Figure 5. Mean eddy kinetic energy (m^{2}s^{-2}) for the inactive MJO period (top) and active MJO period (bottom) from the linear barotropic model simulations. The location of the Rossby wave forcing is marked by the black arrow.