7A.6 IMPORTANCE OF TROPICAL EASTERLY WAVES TO THE DEVELOPMENT OF SURGES OVER THE GULF OF CALIFORNIA

David J. Stensrud*
NOAA/National Severe Storms Laboratory, Norman, Oklahoma

1. INTRODUCTION*

The North American Monsoon (NAM) is an important feature in the summertime over the southwestern United States (Douglas et al. 1993). During the monsoon months of July through September, Arizona receives over 40% of its annual rainfall, whereas regions of western Mexico receive between 60 and 80% of their annual rainfall during this same time period. Forecasting the development and evolution of deep convection during the NAM can be challenging, particularly in Arizona as the region is influenced by both midlatitude and tropical disturbances on a routine basis. Deep convection over the southwestern United States often produces frequent damaging surface winds, lightning, and flash flooding.

The one ingredient for deep convection in the southwestern United States that is often the deciding factor for whether or not convection can develop is low-level moisture. Owing to the orography of the region, with mountain ranges of various heights located to the east, north, and west, a significant source of low-level moisture is the Gulf of California. Any mechanism that can transport moisture from the Gulf of California into the southwestern United States plays a potentially important role in creating a favorable environment for deep convection. The gulf surge is one mechanism by which moisture is transported northward into the United States.

Hales (1972) and Brenner (1974) examine several gulf surge events and find that they often produce a drop in surface temperature, a rise in surface dewpoint temperature, a shift to stronger southerly winds, and a rise in sea level pressure. The low-level cooling and moistening produced by surges reach a maximum just above the surface and decrease with height. Observations and model simulations suggest that gulf surges are coastally trapped disturbances that propagate northward along the western slopes of the Sierra Madre Occidental (Stensrud et al. 1997). Strong gulf surges appear to be related to tropical disturbances passing across the southern Gulf of California, and also are related to a subsequent increase in thunderstorm activity in Arizona.

Stensrud et al. (1997) and Fuller and Stensrud (2000) show that a tropical easterly wave (TEW) is one tropical disturbance that appears to produce gulf surges, and therefore is important to the weather in Mexico and the southwestern United States. A TEW produces convergence and rising motion in association with the passage of the wave trough, thereby providing the lift often needed for convective initiation. Low-level outflows from the development of deep convection are produced over the southern Gulf of California region and these outflows initiate gulf surges in mesoscale model simulations. Once initiated, the surge moves northward, often reaching into Arizona and helping to transport low-level moisture into this desert environment.

Fuller and Stensrud (2000) compare the time of passage of TEW troughs diagnosed using 14 years worth of ECMWF reanalysis data with gulf surge onset times as identified from surface data from Yuma, Arizona, located in the far southwestern part of the state. Results indicate that TEWs often cross western Mexico 1 to 3 days prior to a surge being observed at Yuma. This high correlation between TEW passage and

* Corresponding author address: David J. Stensrud, NOAA/NSSL, 1313 Halley Circle, Norman, OK 73069. Email: David.Stensrud@nssl.noaa.gov

surge onset provides strong circumstantial evidence that TEWs are capable of producing surges and thus should be tracked by operational forecasters interested in the northward flow of low-level moisture into the southwestern United States. The present study is another attempt to refine our understanding of the linkages between TEWs and gulf surges.

2. METHODOLOGY

Relatively large domain simulations are produced using The Pennsylvania State University – National Center for Atmospheric Research Mesoscale Model version 5 (MM5; Dudhia 1993). The single model domain has 350x180x23 points with 25 km horizontal grid spacing (Fig. 1). Two 30 day runs are produced, one with 12-h boundary conditions provided by the NCEP global analyses (CTRL), and the second with the 12-h boundary conditions modified to remove waves with periods representative of TEWs (noTEW).

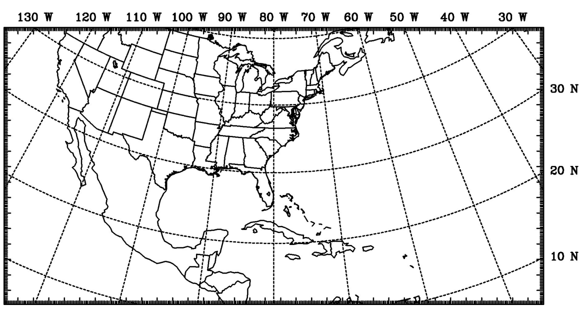


Figure. 1. MM5 model domain used for the two 30 day simulations of July 1990.

An analysis of the v-component wind field from along 70 W during July 1990 at 700 hPa shows a distinct peak in wave energy at 4.3 days at 20 N latitude, well within the typical 2 to 7 day periods associated with TEWs (Fig. 2). Thus, it appears that the NCEP global analyses contain TEWs. To compute the boundary conditions for MM5 for the noTEW run, the model grid points along the edges of the domain are analyzed similarly at all vertical levels and waves with periods between 2 and 7 days are set to have zero amplitude for latitudes below 30 N and the wave amplitudes are linearly increased to their analyzed values between 30 and 35 N. This modified boundary condition file is used for the noTEW run. Thus, TEWs may exist in the model initial condition but are largely removed from the evolving boundary conditions as the model integration proceeds.

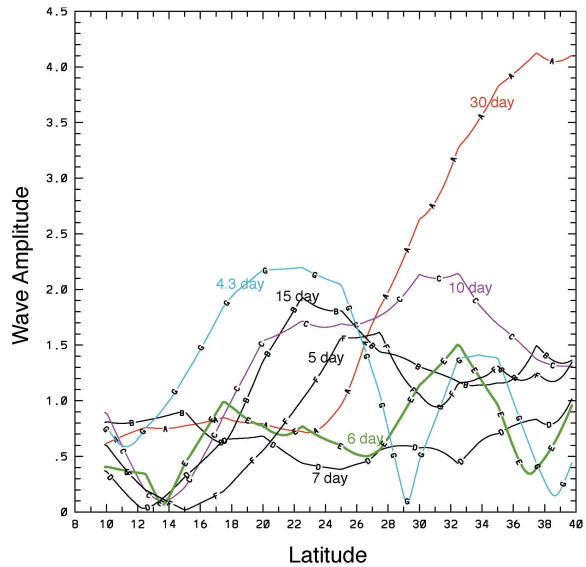
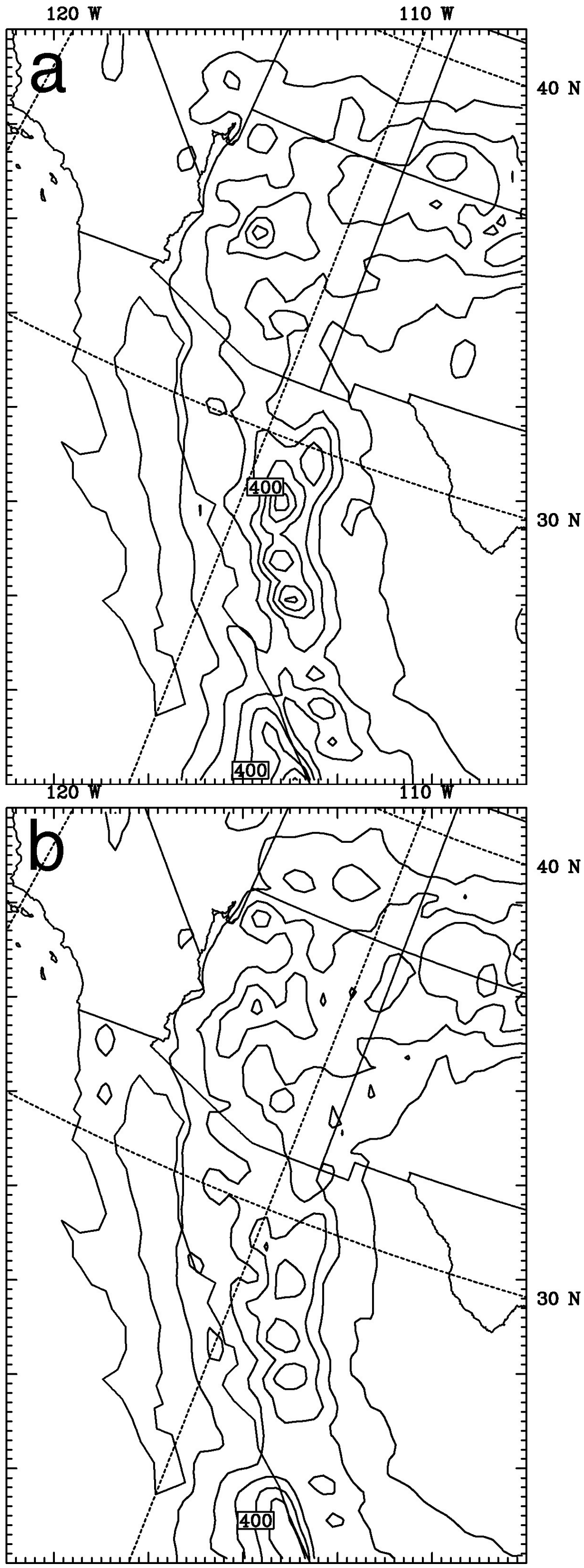


Figure 2. Wave amplitude as a function of latitude for the v-component wind at 700 hPa during July 1990 for various wave periods. Data taken along 70 W longitude.

3. MODEL RESULTS

Results indicate that the TEWs influence convection in western Mexico and the southwestern United States. A comparison of the total rainfall simulated during July 1990 indicates that the CTRL run produces larger rainfall totals along the higher terrain of the Sierra Madre Occidental in Mexico and the Mogollon Rim in Arizona than the noTEW run (Fig. 3). It appears that some of the model convection has been shifted towards the Gulf of California in the noTEW simulations, although the mean rainfall totals in the monsoon region are roughly equivalent in the two runs. A comparison of the evolution of the model runs at grid points in the northern and middle Gulf of California suggests that the noTEW run does not depart significantly from the CTRL in many respects (not shown). However, it appears that at the very least the longevity of surges is reduced in the noTEW runs. A more careful analysis of the model data is needed to better understand these results and their interpretations with respect to TEWs and gulf surges.



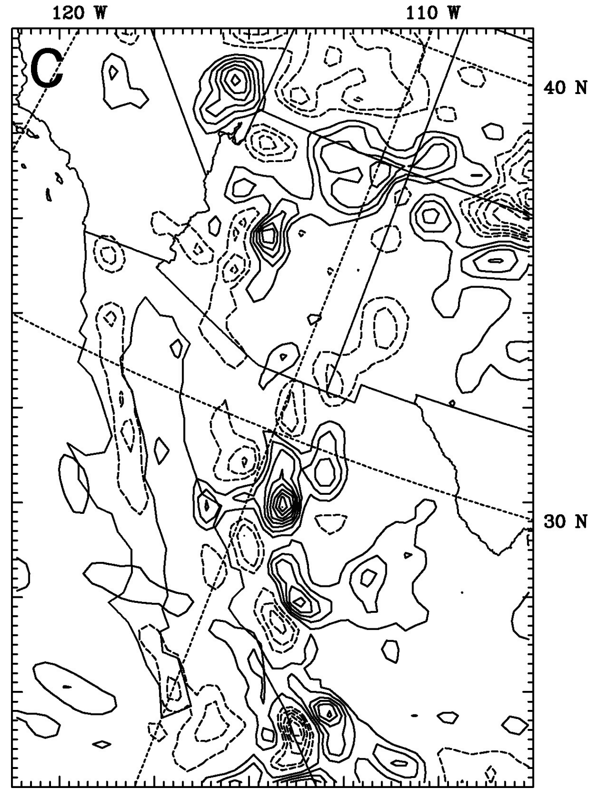


Figure 3. July 1990 total rainfall (mm) from the (a) CTRL and (b) noTEW simulations and (c) their difference field, (CTRL-noTEW). Isolines shown every 100 mm in (a) and (b) and every 25 mm in (c). Note the enhanced precipitation in western Mexico in the CTRL simulation.

4. SUMMARY

Results from two one-month MM5 simulations over the region influenced strongly by the NAM indicate that TEWs influence the amount and distribution of rainfall over Mexico and the southwestern United States. It also appears that TEW influence gulf surge events, although further study is needed to quantify this relationship better. These results tentatively support the conclusions of Stensrud et al. (1997) and Fuller and Stensrud (2000) in which TEWs are hypothesized to produce gulf surges that transport low-level moisture northward along the Gulf of California and into the United States.

Forecasters interested in moisture transport from the Gulf of California northward via gulf surges should use global model forecasts, satellite data, and upper-air observations to track these features and estimate the time of their passage across western Mexico. Tracking mid-level troughs using horizontal plots of winds and temperature in the mid-levels leads to the identification of a myriad of features that may not have the vertical depth or longevity to significantly influence the NAM. In essence, many of the features identified on horizontal maps are not TEWs, since TEWs are associated with a distinct scale and propagation speed (Reed et al. 1977). These characteristics are not easily diagnosed from horizontal plots. Thus, the tracking of TEWs is best accomplished using Hovmoller diagrams of the 700 hPa meridional wind component (see Fuller and Stensrud 2000), since many other features cross the tropical regions and may otherwise be difficult to distinguish from TEWs. This tracking should begin in the mid-Atlantic and extend past the western shore of Mexico. This type of analysis should greatly facilitate the identification of TEWs and their role in producing gulf surges during operational forecast operations.

5. REFERENCES

Brenner, I.S., 1974: A surge of martime tropical air - Gulf of California to the southwestern United States. *Mon. Wea. Rev.*, **102**, 375-389.

Douglas, M.W., R.A. Maddox, K. Howard, and S. Reyes, 1993: The Mexican monsoon. *J. Climate*, **6**, 1665-1677.

Dudhia, J., 1993: A nonhdrostatic version of the Penn State / NCAR mesoscale model: Validation tests and simulation of an Atlantic cyclone and cold front. Mon. Wea. Rev., 121, 1493-1513.

Fuller, R.D., and D.J. Stensrud, 2000: The relationship between easterly waves and surges over the Gulf of California during the North American monsoon. *Mon. Wea. Rev.*, **128**, 2983-2989.

Hales, J.E., Jr., 1972: Surges of maritime tropical air northward over the Gulf of California. *Mon. Wea. Rev.*, **100**, 298-306.

Reed, R.J., D.C. Norquist, and E.E. Recker, 1977: The structure and properties of African wave disturbances as observed during phase III of GATE. *Mon. Wea. Rev.*, **105**, 317-333.

Stensrud, D.J., R.L. Gall, and M.K. Nordquist, 1997: Surges over the Gulf of California during the Mexican Monsoon, *Mon. Wea. Rev.*, **125**, 417-437.