

SIMULATION OF THE GENESIS OF HURRICANE JAVIER (2004) IN THE EASTERN PACIFIC

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1. Introduction

NASA is preparing for the Tropical Cloud Systems and Processes (TCSP) field experiment in July 2005, a joint effort with NOAA to study tropical cloud systems and tropical cyclone genesis in the Eastern Pacific. A major thrust of the TCSP program is the improvement of the understanding and prediction of tropical cyclone genesis, intensity, motion, rainfall potential, and landfall impacts using remote sensing and in-situ data, as well as numerical modeling, particularly as they relate to the three phases of water. The Eastern Pacific has the highest frequency of genesis events per unit area of any region worldwide (Elsberry et al 1987). African easterly waves, mesoscale convective systems (MCSs), and orographic effects are thought to play roles in the genesis of tropical cyclones there (Frank and Clark 1980, Velasco and Fritsch 1987, Zehnder 1991, Zehnder and Gall 1991). The general consensus is that tropical depressions form in association with one or more mid-level, mesoscale cyclonic vortices that are generated within the stratiform region of the MCS precursors. To create the warm core tropical depression vortex, however, the midlevel cyclonic circulation must somehow extend down to the surface and the tangential winds must attain sufficient strength ($\sim 10 \text{ m s}^{-1}$) to enable the wind-induced surface heat exchange (WISHE, Emanuel 1987) to increase the potential energy of the boundary layer air.

Several hypotheses have been presented in the literature describing how a mid-level mesoscale cyclonic vortex associated with an MCS can contribute to the formation of a weak surface circulation and a tropical depression vortex. These include the lowering of a midlevel vortex through evaporation in the stratiform region of an MCS (Bister and Emanuel 1997), the merger of multiple mesoscale vortices associated with MCSs (Ritchie and Holland 1997, Simpson *et al.* 1997), and the merger of a population of convective vortical hot towers (Montgomery *et al.* 2004). Of course, these mechanisms for

development are not mutually exclusive, but may act concurrently. To investigate the roles of each mechanism in the genesis of tropical cyclones in the Eastern Pacific, we use the WRF model to simulate the genesis of Hurricane Javier (2004).

2. Methodology

The WRF model is used with three grids (36, 12, and 4 km) in order to at least coarsely resolve the convection. The simulation is started at 12 UTC 7 September 1998, ~ 3 days prior to the formation of the tropical depression, and run for 3.5 days. Physics options include the Mellor-Yamada-Janjic Eta boundary layer scheme, the Monin-Obukhov (Janjic Eta) surface layer scheme, the Kain-Fritsch cumulus scheme (on the 36- and 12-km grids only) and the WSM 6-class cloud microphysics. Radiative processes are calculated every 10 minutes on the 36- and 12-km grids and every 5 min on the 4-km grid using the RRTM longwave and Goddard shortwave schemes. Initial and boundary conditions are obtained from NCEP final GFS analyses.

3. Results

This paper focuses on the evolution of the low-level winds and precipitation and identifies several key features that appeared to be important to the formation of the tropical depression that later became Hurricane Javier. (Additional fields will be presented at the workshop.) These features include the ITCZ and its convection, two major MCSs that formed north of the ITCZ, and gap flow across the Isthmus of Tehuantepec.

Figure 1 shows the simulated radar reflectivity at 0.5 km and the surface wind vectors every 6 h for the period from 00 UTC 9 September to 00 UTC 11 September. At the first time (Fig. 1a), a broad region of convection associated with the ITCZ is seen in the southern portion of the 4-km domain. An upper-level wave disturbance (not shown) was beginning to move over the mountains of Honduras and Nicaragua (upper-right corner of domain) and some weak downslope flow was converging with onshore flow

along the western coasts of those countries, leading to the development of convection there. The convection moved offshore (Fig. 1b) and by 12 UTC 9 September (Fig. 1c), a major MCS with a broad area of northeasterly offshore flow behind (northeast of) it was present. Northerly flow through the mountain gap at the Isthmus of Tehuantepec extended almost 500 km offshore and was located to the west of the MCS. By 18 UTC (Fig. 1d), the MCS began to weaken and by 00 UTC 10 September (Fig. 1e), a much smaller MCS was moving to the west ahead of a broad region of strong southeasterly flow in the coastal zone. The remnants of the MCS redeveloped into an intense squall line oriented perpendicular to the coast and moving ahead of the strong southeasterly winds (Fig. 1f). It moved into the region of the northerly gap flow by 12 UTC 10 September (Fig. 1g). The combination of northwesterly flow in the northwestern-most part of the domain, northerly gap flow, an increasing area of southeasterly flow in the coastal zone behind and to the south of the squall line, and southwesterly flow south of the ITCZ all came together to produce a broad area of cyclonic flow at the surface. At later times (Figs. 1h and 1i), both the surface cyclonic circulation and the surrounding convection became better organized to form the tropical depression.

Many of these features were observable in GOES and Quikscat satellite imagery. GOES data (not shown) confirm the early development of convection in the coastal zone, although with a more complete dissipation of the MCS by 00 UTC 10 September (Fig. 1e). GOES data show the subsequent development of the squall line oriented perpendicular to the coast around 06 UTC and its movement west-northwestward. The GOES data also show a major MCS to the south of the squall line, possibly along the ITCZ, which was not well reproduced by the model. The squall line and the MCS later merged, in a manner similar to that shown in Figs. 1g-1i, to form the tropical depression. Quikscat data on 9-10 September (not shown) reveal the presence of a persistent gap flow, the offshore flow contributing to the early MCS, the surge of southeasterly flow

behind the squall line, and the eventual organization of the depression circulation.

4. Summary

The WRF model was able to fairly accurately reproduce many features of the genesis process observed by satellite. Instead of genesis resulting from the mesoscale vortex of a single MCS, or from the merger of many very small scale vortical hot towers (which were not adequately resolved), in this case genesis appears to occur as a result of the merger of flows associated with several MCSs as well as orographically induced flows such as that through the Isthmus of Tehuantepec. The analysis is currently very preliminary and further work is needed to determine the roles of synoptic, mesoscale, convective scale, and orographic processes.

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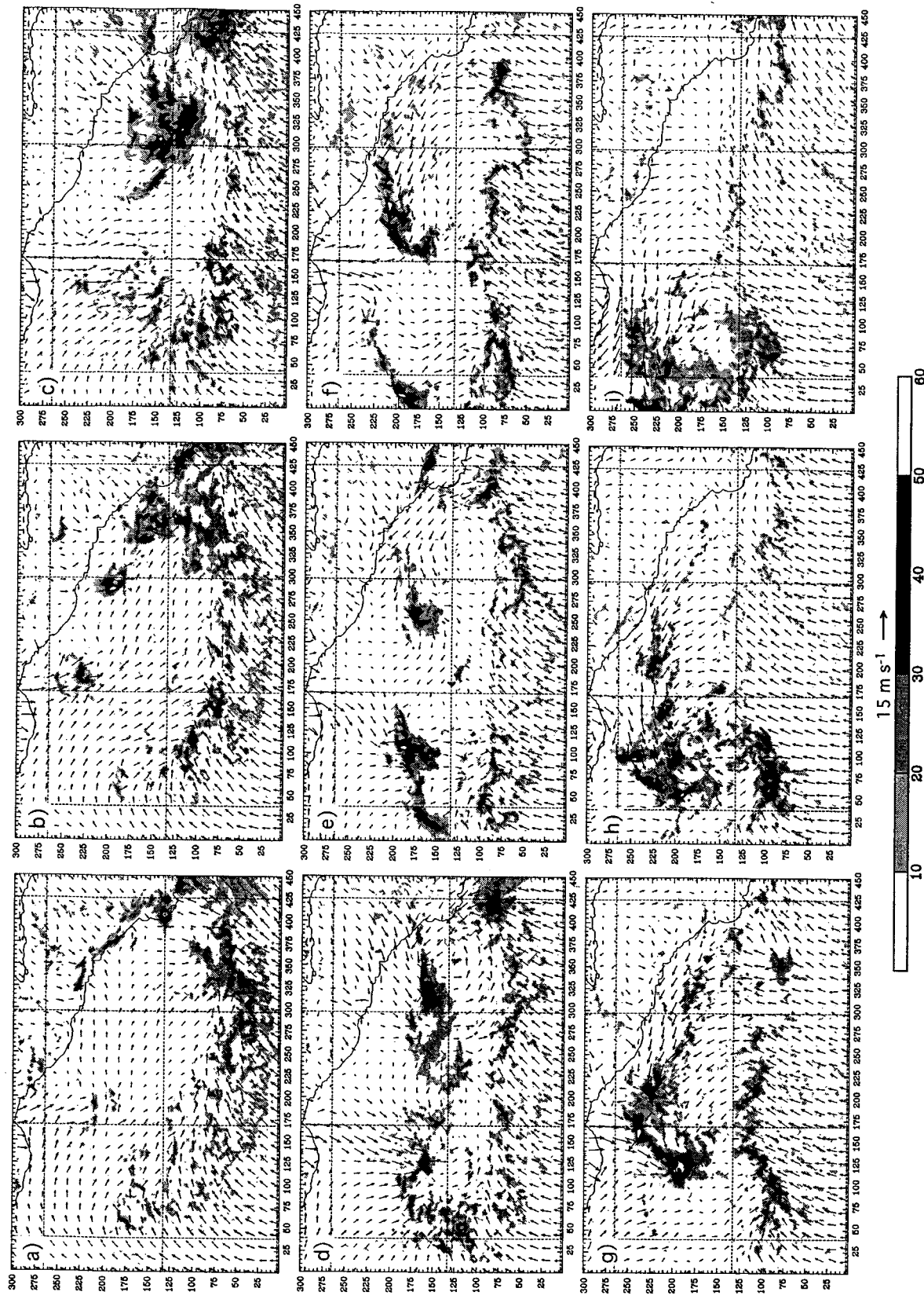


Figure 1. Simulated radar reflectivity (shading) at 0.5 km and surface wind vectors at 6-h intervals from 00 UTC 9 September (a) to 00 UTC 11 September (i).