1D.4 SUPPORTING EMERGENCY MANAGERS DURING TROPICAL CYCLONE APPROACH IN BAJA CALIFORNIA, MEXICO

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1. INTRODUCTION

The Baja California Peninsula extends from 22.8°N to 32.5°N (Fig. 1) and has a predominantly dry climate. However, during the summer, humid air masses moving northward from the tropics to provide favorable conditions for the development of localized, convective systems. This activity may result in episodes of strong winds and heavy rainfall as well as significant property damage to the population and surrounding environment. Tropical cyclones from the eastern Pacific and north Atlantic basins have tracks approaching Mexico and may cause widespread destruction. Therefore, these phenomena are important to be carefully monitored.

Figure 1 also shows the landfall distribution along the Mexican coasts from the period 1970-2010. During the last 11 years, including the season of 2013, 22 tropical cyclones moved over land in western Mexico and roughly half of them crossed Baja California. Since the peninsula comprises a length covering a third of the total coast in Mexico, it is also an area of potential danger that requires special attention each season.

To protect life and property, during storm approach, emergency managers perform tasks oriented to prepare the population. In 2000, the Mexican government created an early warning system (Sistema de Alerta Temprana para Ciclones Tropicales or SIAT-CT) as a tool to monitor storms from the surrounding basins.

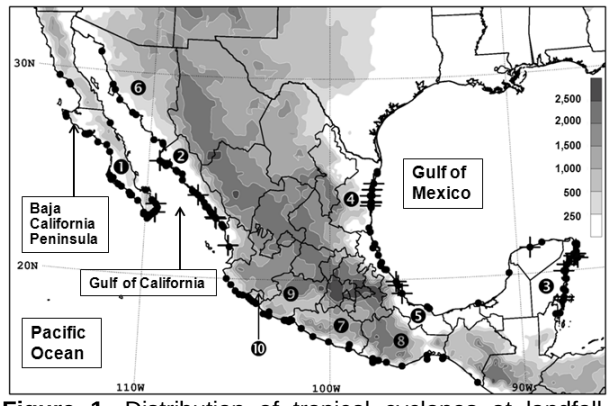

Figure 1. Distribution of tropical cyclones at landfall (dots) in Mexico. Plus signs are major hurricanes and circled numbers are the top ten states, in decreasing order, affected during the period 1970-2010. Terrain elevations above 250 m are given by shaded contours.

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According to SIAT-CT (2014), when a developing tropical cyclone represents danger to the population, a coordination plan is activated. This includes both state and municipal levels around the potentially affected regions. Government representatives, military personnel, and academic institutions are among the participants. The United States National Hurricane Center (NHC), in collaboration with Servicio Meteorológico Nacional (SMN) in Mexico, is responsible for examining weather conditions, for providing intensity and track forecasts as well as for delimiting zones of coastal impact. Updates are released every six hours and, upon landfall, there are three-hour advisories to the public.

By request of the La Paz municipality, since 2006, CICESE has been presenting a meteorological perspective associated with the structure, intensity, and motion of approaching storms (Fig. 2). With respect to the southern peninsula, this municipality covers 31% of total population and 27% in spatial extent. The associated graphical analyses make use of high-resolution satellite imagery to explain spatial and temporal patterns of cloudiness and predicted track. The official forecasts, from the NHC, are used to define a set of anticipated scenarios prior to and during landfall, including estimates of maximum wind speeds and accumulated rainfall. This material, as a whole, provides an integral examination of storm behavior during the approach as well as potential passage across Baja California. The information is available to emergency managers, among other applications, to determine evacuation areas and shelter availability.

Figure 2. La Paz municipal council meeting, on September 6 2013, during the approach of Tropical Storm Lorena. The meeting is headed by Mayor Esthela Ponce. CICESE provides a meteorological perspective via graphical products made on a real-time basis.

2. DATASETS

Digital imagery from Geostationary Operational Environmental Satellites (GOES), provided by Unidata, is applied to document the spatial and temporal

distribution of cloud cover. This includes the analysis of high-resolution information with visible (1 km), infrared (4 km) and water vapor (8 km) imagery from GOES-15. Figure 3 shows an example of the products that are prepared for emergency managers. These products are sent via electronic-mail messages along with brief text, using a simple language to the general public, which describe current and expected weather conditions during the next 24-72 hours. These messages are sent within 30 minutes after the 1500 UTC and 2100 UTC updates given by the NHC.

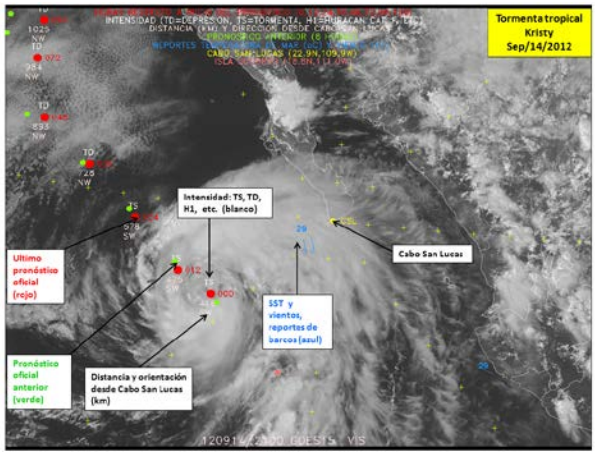

Figure 3. Geostationary satellite image from the visible channel during the approach of tropical Storm Kristy, in the eastern Pacific season of 2012.

Another component of our support is an interpretation of the official, track and intensity forecasts. This includes an explanation of the benefits, limitations and cautions to be exercised with the content stated in the official forecasts. This implies a revision of all the available information (forecast and public advisories, discussions and wind speed probabilities) as well as other predictions derived from selected regional and global-scale models in the Automated Tropical Cyclone Forecasting (ATCF) system.

3. ON-LINE PRODUCTS

Another way to keep emergency managers, as well as other groups in Baja California, informed is the availability of GOES imagery via the web site http://met-bcs.cicese.mx. This has been available since 2009 and allows the display of individual images as well as animations with updates each 15-30 minutes. The geographical coverage is focused in northwestern Mexico, including the southern peninsula as well as surrounding portions of the Gulf of California and the eastern Pacific.

Using Google Analytics, a tool that generates detailed statistics on web-site traffic, we are able to estimate the number of visits. Figure 4 shows a time series of visits to the above site during the 2013 season and allows identifying several patterns. One interesting feature is the increase during the approach of tropical cyclones. As each storm moves close to the peninsula, there is a well-defined maximum. In particular, note the increase associated with Tropical Storm Juliette (August 28-29). The genesis of this storm, just south from the peninsula, was not well-anticipated (Steward 2013) and the center of circulation passed within 200 km from the coast to make landfall 250 km northwest of Cabo San Lucas.

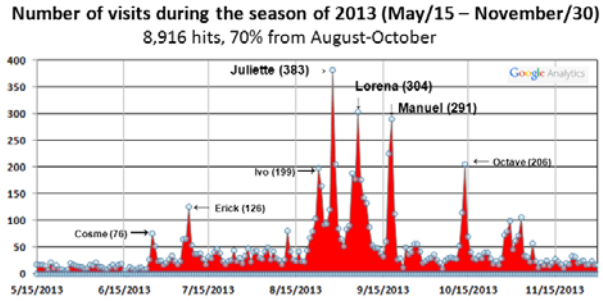

Figure 4. Time series of daily visits during the tropical cyclone season of 2013.

4. AFFECTED POPULATION

In order to provide a simple tool to estimate affected population during storm approach and/or landfall, we are developing an algorithm that may be used by emergency managers. Figure 5 shows, as an example, the tracks issued 12, 24, 48 and 72 hours prior to the actual landfall of Hurricane John in 2006. This event is associated with strong winds, heavy rainfall and deaths (Farfán et al. 2012). Our estimates of affected population range from none, for the forecast issued 72 hours prior to landfall, to more than 300,000 which is associated with the actual track.

These tracks are used to count the number of inhabitants within defined bands around the storm center. We assume a variable diameter consistent with the NHC observations and they decrease upon weakening over land. The inclusion of data from population surveys, allows us to determine storm impact from different forecasts issued prior to landfall and compare them with the results using the best track.

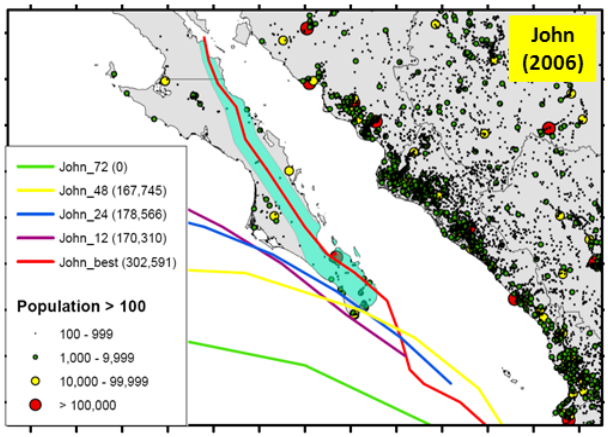

Figure 5. Estimates of affected population from official forecasts and the best track, in red, associated with Hurricane John (late August-early September, 2006).

5. THE HWRF MODEL

Some of the landfall events are investigated with the application of the HWRF model. A recent version (Tallapragada et al. 2013) was installed at CICESE's computing facility and, by performing research-mode simulations, the model has been applied to study several eastern Pacific landfalls from the period 2006-2010. The high-resolution fields, in space and time, allow more detailed information on the interaction of the incident circulation with the peninsular topography. For example, Fig. 6 shows a case study in which Hurricane Norbert (2008) made landfall, after recurvature, at 54 hours after model initialization. The simulation suggested weakening over the peninsula and re-intensification upon arrival to the Gulf of California (not shown). This event is associated with extensive property damage, flooding, and power outages (Franklin 2008).

The model has also been applied to simulate tropical cyclones from the season of 2013 and we plan to use it, in a real-time mode, during the upcoming 2014 season. This will be experimental work that, in addition to emergency managers in western Mexico, will be available for additional guidance to SMN forecasters. At CICESE, these results will be used to determine model performance with respect to wind and rainfall distributions as they are compared with the observations from regional networks in Baja California. Due to limited observations in the eastern Pacific, this fact generates issues to be examined in more detail. An important aspect to be tested is the sensitivity with respect to the initial position, intensity and structure. Another issue is the westward bias documented by Farfán et al. (2012) in which tracks from the official forecasts tend to move away from the continent and an example is shown in Fig. 5. Recall that the 72-hour forecast resulted in no impact to the peninsular population which was, actually, affected by extraordinary accumulations of rainfall (up to 235 mm) and landfall as a category-two hurricane.

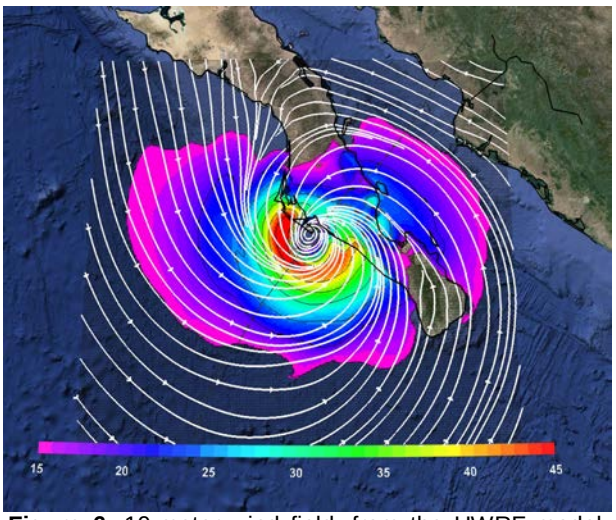

Figure 6. 10-meter wind field, from the HWRF model, during the landfall of Hurricane Norbert (October, 2008). White lines are streamlines and shaded contours isotachs (m s^{-1}) from the nested grid's 3-km resolution.

6. OUTREACH TRAINING

We provide training to emergency managers in the peninsula as well as to personnel from the hotel industry in the municipality of Los Cabos. Such groups learn the basic knowledge on storm formation, intensification and dissipation as well as practical information on official forecasts and warnings issued during recent events affecting coastal the areas of northwestern Mexico. This component is oriented to provide short courses for undergraduate and graduate students from higher-education institutions in Latin America. See Farfán and Raga (2012) for a list of topics and participant countries.

7. SUMMARY

Tropical cyclone monitoring is an important responsibility in western Mexico and becomes a priority during landfall. Upon approach to the coast, an early warning system (SIAT-CT) is activated which involves federal, state and municipal levels. Since 2006, CICESE has been assisting emergency managers and authorities in Baja California to: 1) have access to real-time, high-resolution GOES imagery for analysis of storm location and motion; 2) better understand official forecasts from the NHC and communications issued by the SMN; and 3) provide additional information, beyond the essential datasets, to perform warning and decision-making responsibilities over the southern peninsula.

Acknowledgments. This work was supported by partial funding from the Inter-American Institute for Global Change Research (IAI), the Mexican Council on Science and Technology (CONACYT) and the Hydro Meteorological Disasters and Climate Research Network (REDESCLIM). CICESE's Computing Department provided support with the HWRF model applications in dedicated, high-performance equipment. Figure 5 was provided by Stephen V. Smith.

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