Third Annual Report
1 July 2008 - 30 June 2009

1. Project Information

Project Title: "Tropical cyclones: current characteristics and potential changes under a warmer climate"
Project Number: CRN II -048
Principal Investigator: Graciela Binimelis de Raga
Key Words: tropical cyclones, East Pacific basin, climatology, intensification

2. Project Funding

No complementary funds were received for this project

3. Research Activities and Findings

The original work plan for the period 1 July 2008 -30 June 2009 was divided into four following categories. We report below the advances in categories *I* and *II.* The progress in category *III* is reported under **Section 7** of this report and the publications generated in this period are reported under **Section 5**.

Progress on *Data analysis*:

I.1 Climatological study from satellite data over oceans (O. Sanchez CICATA-Mexico, GB Raga and J. Zavala-Hidalgo, CCA-Mexico)

This activity has now been **concluded**. Several presentations were made at different conferences and a paper has been submitted for publication and is currently under review. The study reviewed the oceanic conditions encountered by major hurricanes (category 3 or higher) in the East Pacific (East of 120W), between 1993 and 2007. The **key findings** of the study can be summarized as:

- Several cases were identified in which the sea surface height anomalies were correlated with cyclone trajectory and intensification, as was observed in other cyclonic basins
- However, the climatological results do not find a systematic increase in cyclone category with sea surface height anomaly.
- The role of the ocean eddies in the East Pacific appears to be smaller than hypothesized

I.2 Climatological study using NCEP-R2 and NARR data (R. Romero-Centeno, CCA-México)

This task has progressed a bit slower than was planned. The research first followed on the steps of Romero-Centeno's doctoral thesis and focused on the relationship between wind and geopotential height patterns (and anomalies) and precipitation in the EPAC. Her work encompassed more than just the relationship to tropical cyclones, investigating the conditions that lead to high precipitation. Her results indicate that very large scale patterns of geopotential anomalies

(hemispherical in scale) are associated with more or less precipitation in the EPAC region. The geopotential fields are related to the low level winds in the EPAC. The anomalies seem to be "locked" in time and can be related to the "mid-summer drought" experienced in Southern Mexico and Central America. This "drought" is really a reduction in the summer precipitation amount that is observed during July and August. The geopotential anomalies in June and July are completely reversed in sign and then in September, the same distribution as June is observed. The results indicate the range of variability of the "drought" phenomenon, from interannual down to synoptic. A paper was submitted for publication on this topic.

Her research has also covered a case study analysis performed using the North American Regional Re-analysis (NARR), to study factors leading to the intensification of selected tropical cyclones. Relative vorticity at low levels and vertical shear of the horizontal wind are two of the parameters that influence the intensification of tropical cyclones. The calculation of the relative vorticity and the vertical shear of the horizontal wind was performed in boxes of 4x4 degrees centered on the location of the tropical cyclones, and followed the cyclones every 6 hours. The results, as can be seen in Figures 1 and 2, are described as a function of cyclone intensity (given by the letters TD= tropical depression, TS= tropical storm, H= hurricane), for Hurricane John (2006). Note for example, the low values of wind shear that accompany the transition from TS to H in Figure 2.

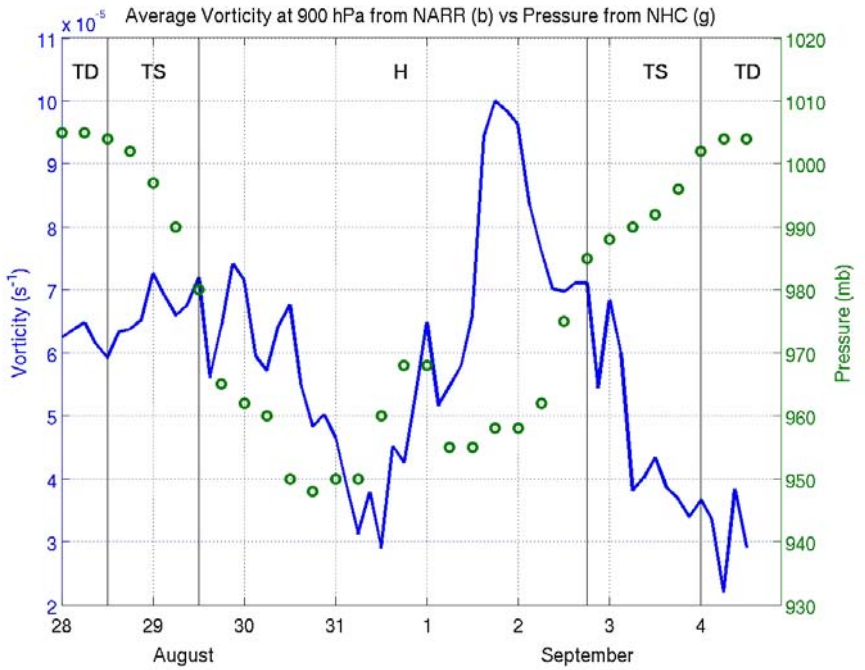

Figure 1: Time evolution of the low level relative vorticity for John (2006)

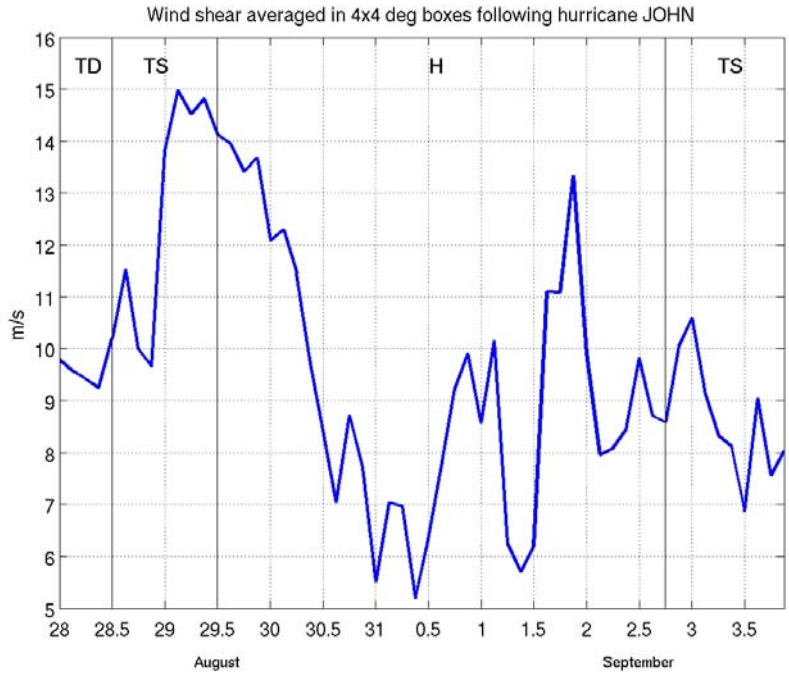

Figure 2: Time evolution of the vertical shear of the horizontal wind for John (2006)

The work is still **ongoing** and will be concluded in the next 3 months.

I.3 Data analysis from TCSP/IFEX (J Marin and GB Raga, CCA-Mexico; J. Cisneros and D. Raymond, NMT-USA)

This task has now been **concluded,** resulting in two scientific publications. The study centered on the analysis of results from observations and the model Global Forecast System (GFS) run operationally at the National Center for Environmental Prediction (NCEP) in the US. Several developing cyclones were studied to determine the factors that led to their evolution. The approach followed calculated the tendency of the circulation around the cyclones and the balance of entropy. The **key findings** of the study can be summarized as:

- The circulation increases in the developing cyclones due to the mass convergence at low levels
- As it intensifies, the height of this low level convergence is reduced, confined to a shallower region.
- The surface heat fluxes are very important in the intensification of the cyclones
- The ventilation (related to the advection of air with low entropy) can cause the cyclone to decelerate and dissipate

I.4 Data analysis using the NARR and SODA databases (F. Oropeza and GB Raga, CCA-Mexico)

This task was not initially proposed but the need for such an analysis evolved from the required input for the modeling that was carried out. The databases used are the North American Regional Re-analysis (NARR) and the Simple Ocean Data Assimilation (SODA). This task is still **ongoing** and we report here on the progress.

The following parameters were computed for a number of tropical cyclones in the East Pacific:

- Ocean heat content
- Relative vorticity in the lower troposphere (850 hPa)
- Coriolis parameter
- Vertical shear of the horizontal wind (between 850 and 200 hPa)
- Relative humidity at mid-troposphere (500 hPa)
- Atmospheric stability

As an example, Figure 3 shows the distribution of the ocean heat content during the period when Hurricane Pauline (1997) developed. Note the variability observed in the EPAC.

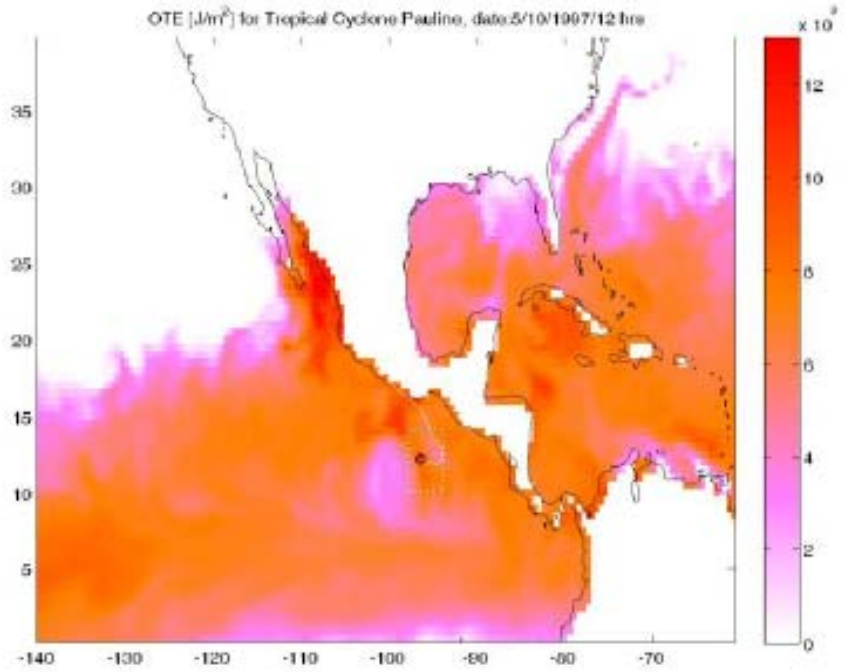

Figure 3. Distribution of the ocean heat content calculated using the SODA database for September 1997. The box is centered in the best track location for Hurricane Pauline, that made landfall in Oaxaca.

All these parameters were calculated in a domain of 4x4 degrees centered in the cyclone and then normalized to ease comparison. As an example we present the time evolution of these parameters for Hurricane Pauline (1997), which caused large damage and loss of life upon land-falling in Mexico.

Figure 4 indicates that the conditions that appear to dominate the period prior to cyclone intensification are the ocean heat content and the relative humidity in the atmosphere. Several cyclones were analyzed in this manner and a poster was presented on the topic in a recent symposium on hurricanes. The work is still **ongoing** and part of the PhD research of F. Oropeza.

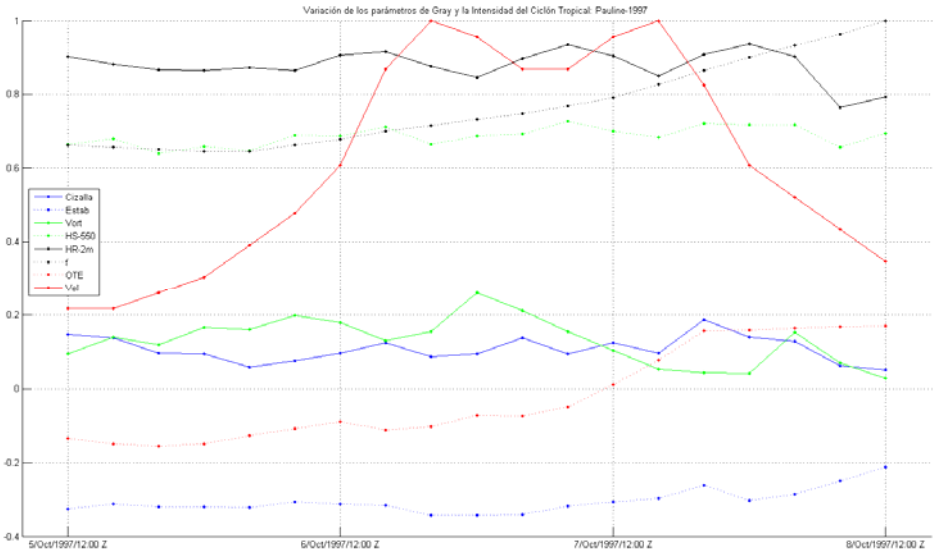

Figure 4. Normalized time evolution of key parameters that can lead to cyclone intensification for Hurricane Pauline (1997). Also shown (in red) is the time evolution of the maximum tangential velocity, indicating the period of intensification.

I.5 Data analysis of selected cases that recently made landfall in Mexico (L. Farfán CICESE-Mexico; R. Romero-Centeno and GB Raga CCA-Mexico)

An observational study was carried out to determine some of the characteristics of tropical cyclones that developed in the Mexican Pacific during 2006 and 2007 and made landfall in northwestern Mexico: John, Lane, and Paul in 2006 and Henriette in 2007 (Figure 5).

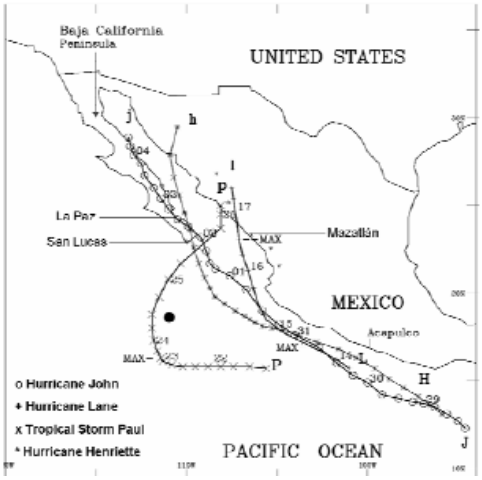

Figure 5. Tracks of Tropical Cyclones: John, Lane and Paul in 2006 and Henriette in 2007. Initial positions are represented by uppercase letters and final positions by lowercase letters. Position location is marked every 6 hours; numbers are fixes at 0000 UTC; and position at maximum intensity (MAX) is indicated. The large black dot represents Isla Socorro.

These tropical cyclones brought strong winds, deep convection, and heavy rainfall to

communities in the Baja California Peninsula and mainland Mexico. Analyses of the Global forecasting System (GFS) model identified significant features in the large-scale flow during the approach of each system. Significant precipitation from a single system can be observed at some of the stations analyzed, and as an example, we present here the results for Hurricane John. Figure 6 shows the accumulated precipitation derived from TRMM for its whole trajectory. Figure 7 shows the comparison between in situ and TRMM data after landfall in the Baja California peninsula, indicating a substantial underestimate by TRMM.

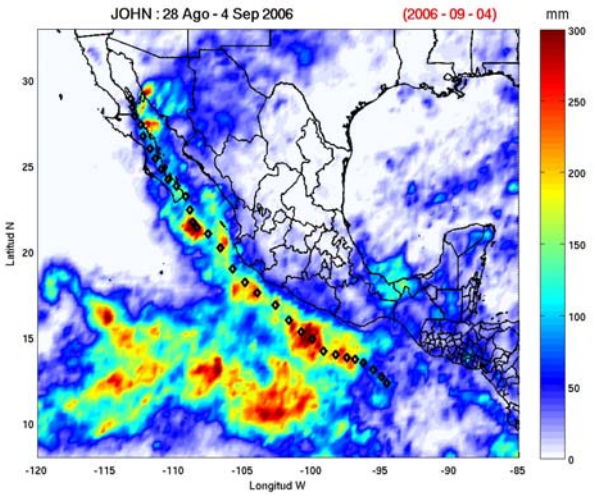

Figure 6. Accumulated precipitation derived from the estimates of the TRMM sensors for Hurricane John during its whole trajectory.

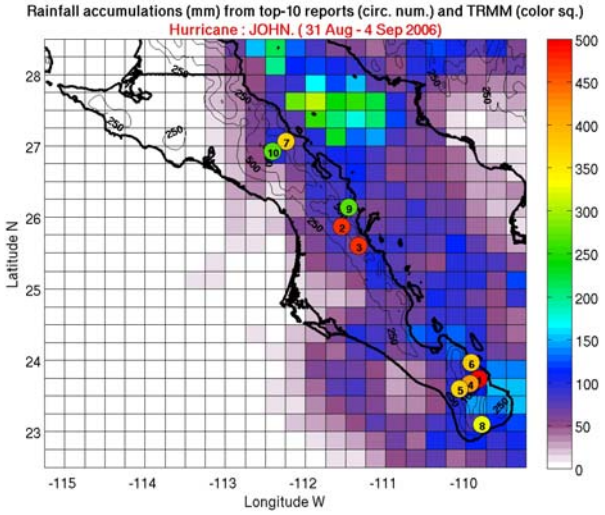

Figure 7. Comparison of the accumulated precipitation derived from the TRMM sensors and in-situ, for Hurricane John after landfall.

This task has now been **completed** and a manuscript is ready for publication. The **key findings** from the study are the following:

- Hurricane John (2006) provided a well-defined period of heavy precipitation

along the eastern coast of Baja California with contributions in the range of 42–75% of the accumulations received during the entire warm season.

- Hurricane Lane was the strongest system at the time of landfall (Category 3) over the mainland. However, the other cyclones also provided much of the precipitation accumulated during the season.
- Of the four cases, Tropical storm Paul was the only re-curving system and its track occurred under the influence of an anticyclonic circulation in the Gulf of Mexico, along with a wave trough that reached the southwestern United States.
- Advection of dry air over northwestern Mexico was associated with the absence of convective activity over the Baja California Peninsula; heavy rainfall was concentrated over the States of Nayarit and Sinaloa during the landfall of Hurricane Lane.
- Middle level advection of dry air, from troughs approaching the western United States, is an important element in predicting the tracks and rainfall of tropical cyclones making landfall.

Progress on *Modeling:*

II.1 Operational modeling with WRF during the cyclone season (L. Farfan CICESE-Mexico; D. Pozo and GB Raga, CCA-Mexico) and comparison with observations (R. Romero-Centeno and J. Zavala-Hidalgo (CCA-Mexico)

This research activity has now been **concluded.** Several presentations were made at different conferences. A formal publication was under way, but since the post-doc (D. Pozo) has left the project and taken a new position, it may not be finalized. Therefore, we report here some of the results. The 3 cyclones that made landfall during the 2006 season were simulated with the Weather Research and Forecasting (WRF) model. Simulations included 2 nested grids (30 and 10 km resolution) and were performed for 4 days. The Final (FNL) analyses from the Global Data Assimilation System provided the initial and lateral boundary conditions for simulations every six hours. The Mellor-Yamada parameterization was selected for the boundary layer processes and Monin-Obukhov describes those in the surface layer. The Kain-Fritsch cumulus parameterization was used in the external domain and the microphysics scheme of Lin et al. (1983) was used in the inner one. Simulations using the Thompson et al. (2004) microphysics scheme in the inner domain and the simplified Arakawa-Schubert cumulus parameterization in the outer one were performed to test sensitivity.

Name	Cumulus option	Microphysics option
JohnKL	Kain-Fritsch	Lin
JohnKT	Kain-Fritsch	Thompson
JohnAT	Arakawa-Schubert	Thompson

Table1. Description of simulations performed in this study for hurricane John. Similar names are used for Paul and Lane.

The **key findings** of the modeling study are:

- None of the simulations accurately reproduce cyclone intensification.
- Track errors in simulation JohnKL are the smallest among simulations since the simulated translation velocity in John is the closest to the one from the NHC. Note however, that the simulated trajectory for JohnKL fails to make landfall in the southern tip of Baja California, predicting a more westerly course than observed.
- Simulation JohnKL is the one that best reproduces the observed cloud field from GOES, while simulation JohnAT gives the worst results. Simulations using the Thompson microphysics overestimate the high clouds. While simulations with Lin microphysics underestimate high clouds, they reproduce much better the low clouds, still underestimating them. Simulations with the K-F cumulus parameterization shows a better agreement with the observed precipitation distribution and specifically, JohnKT, shows the best agreement with TRMM and surface station observations.
- The National Hurricane Center failed to predict landfall of John (2006) until only 12 hours before actual landfall. We hypothesize that the lack of sounding observations in the NW region of Mexico may have deteriorated the forecast of the global models.

II.2 Ocean modeling for the EPAC region (F. Oropeza and GB Raga, CCA-Mexico)

F. Oropeza visited the Institute of Marine and Coastal Sciences at Rutgers University for 4 weeks in August 2008. His visit was very successful and he was able to implement the regional ocean model for the East Pacific. He has carried out exploratory simulations, whose results clearly indicate the presence of warm anticyclonic ocean eddies as observed. However, the exact timing of these eddies does not correspond exactly to the location of the observed ones on specific cases, related to particular tropical cyclones. It was therefore decided that a somewhat different approach would be explored. This task is still **ongoing** and there are no key findings yet.

II.3 Analysis of results from "Hurricane" model (Emanuel, 2003) (F. Oropeza and GB Raga, CCA-Mexico)

The model represents an asymmetric vortex that can intensify while interacting with a simplified ocean (with constant ocean heat content and stratification). The model was implemented for the East Pacific and sensitivity runs were performed using synthetic cases. The case of Linda (1997) that reached Category 5, was selected for the simulations. Linda developed during the early phase of El Niño in the East Pacific and it's trajectory did not threaten the coastline, reaching maximum intensity (900 hPa) about 600km South of the Baja California Peninsula. The sea surface temperature conditions are observed in Figure 8.

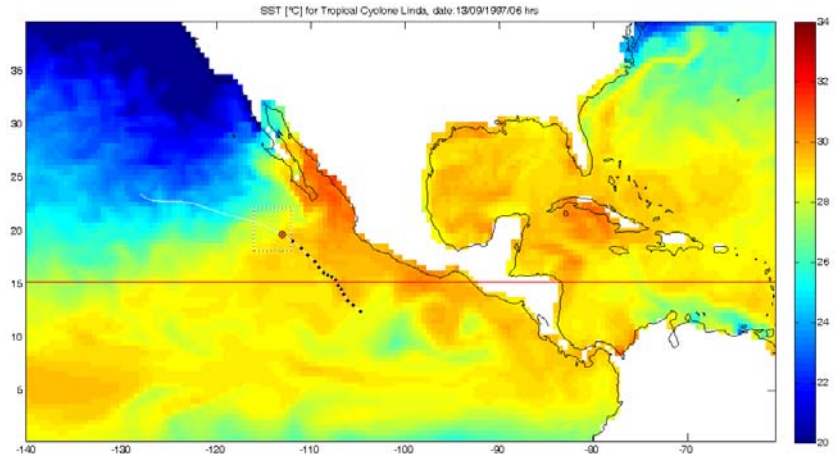

Figure 8. Sea surface temperature conditions observed during the week that Hurricane Linda developed. The black dots indicate the trajectory and the red dot corresponds to the period when the maximum intensity was reached.

The time evolution of the cyclone development is shown in Figure 9 (lower panel), with maximum tangential winds of over 80 m/s. The trajectory is overlaid on the distribution of sea surface height anomalies (top panel). The red areas correspond to positive ocean heat content anomalies, which can potentially influence cyclone intensification.

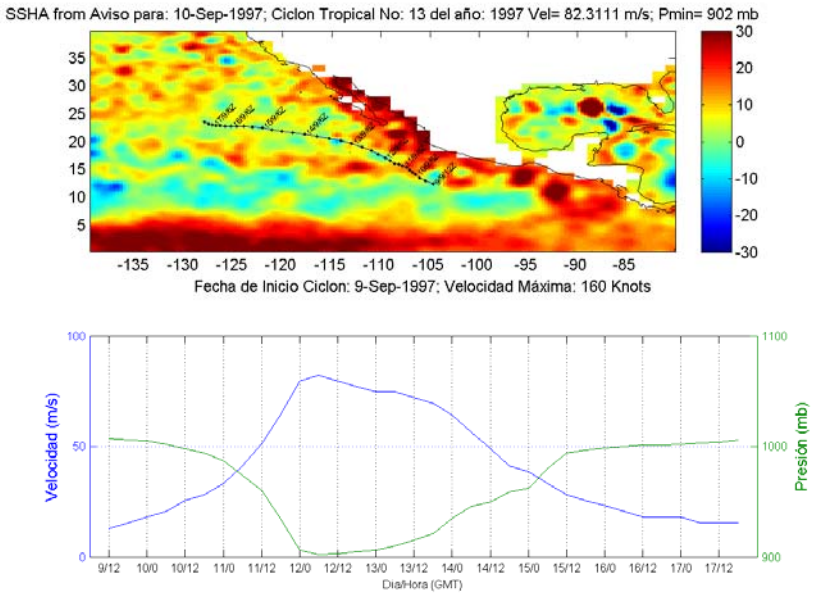

Figure 9. Lower panel: Time evolution of the central pressure (in green) and the maximum tangential velocity (in blue). Top panel: Trajectory of Hurricane Linda overlaid on the sea surface height anomaly observed during the period.

The results of the maximum tangential velocity of the observed and simulated

hurricanes are shown in Figure 10. For reference, the colored horizontal lines indicate the limits between the different categories (H-1 through H-5, on the right side of the graph). Note that the model is able to simulate a hurricane that reaches Category 5 but only barely and clearly underestimates the maximum wind speed attained in reality, by 15%. A run considering only sea surface temperature as lower condition for the model (no inclusion of ocean heat content) results in a slightly less strong simulated hurricane. The decrease in maximum velocity is about 3%, suggesting that in this particular case, the ocean did not play a major role in cyclone intensification. The ocean stratification in the model is only a function of the temperature and not of the salinity profile, which could play a role in further strengthening the stable layer at the thermocline and leading to a larger role of the ocean heat content anomaly in cyclone development. F. Oropeza is working on incorporating salinity profile in the model.

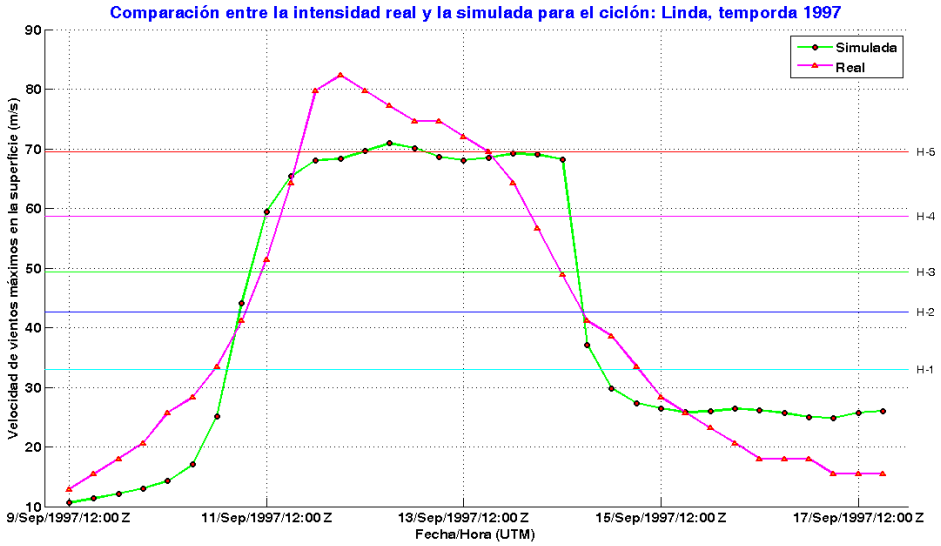

Figure 10. Simulated (in green) and observed (in purple) time evolution of the maximum tangential velocity in Hurricane Linda.

The model is being used to simulate numerous cases in the East Pacific and it is undergoing modifications to include the dependence of the stratification on the salinity profile. This task is still **ongoing** and part of the doctoral research of F. Oropeza..

II.4 Analysis of results from coupled ocean-atmosphere global climate models runs (R. Romero-Centeno and GB Raga, CCA-Mexico).

This task has not been started yet and will be scheduled for the following months.

II.5 Coastal wave modeling

This task is at a very preliminary stage, since the original work was going to be carried out by the co-PI from Costa Rica. Due to the departure of Dr. Lizano from the team, the Cuban component assumed the responsibility to perform simulations with the costal wave model. The objective is to try to predict the wave activity close to shore, using the winds predicted from the atmospheric simulations carried out using WRF for those same cyclones. The co-PIs from Cuba have scheduled a visit to CCA-UNAM in September 2009, to finalize this activity.

4. Contributions of Co-PIs

Costa Rica:

O. Lizano (CIGEFI) left the project in 2008.

Cuba:

I. Mitrani and D. Martínez (INSMET) are responsible for numerical simulations of ocean waves associated with cyclones and their coastal impact.

Mexico:

J. Zavala-Hidalgo and GB Raga (CCA-Mexico), together with O. Sanchez (CICATA-Mexico) concluded the analysis of the sea surface height anomaly (from satellite data Topex/Poseidon) in the region of the East Pacific, East of 120W, where the cyclones that affect Mexico are formed. A manuscript was submitted for publication and is currently under review.

The PhD student J. Marin (CCA-Mexico) supervised by GB Raga successfully graduated and no longer is part of the team, since he is now working in another country.

GB Raga and her PhD student F. Oropeza (CCA-Mexico) have undergone an in-depth analysis of each individual cyclone case since 1970 to identify rapidly intensifying cyclones, postulating the hypothesis that those cyclones may have intensified by interacting with areas in the ocean with higher heat content. F. Oropeza visited the Institute of Marine and Coastal Sciences at Rutgers University for 4 weeks in August 2008. His visit was very successful and he was able to implement the regional ocean model for the East Pacific. He has carried out exploratory simulations, whose results clearly indicate the presence of warm anticyclonic ocean eddies as observed. However, the exact timing of these eddies does not correspond exactly to the location of the observed ones on specific cases, related to particular tropical cyclones. It was therefore decided that a somewhat different approach would be explored. He proceeded to determine the atmospheric factors leading to intensification of individual case studies using the North-American Regional Reanalysis Project (NARR). The results were presented at an international conference as a poster and an oral presentation is scheduled at another conference in Montreal in July 2009.

L. Farfán (CICESE-Mexico) took the lead in a manuscript based on the data analysis of the land-falling cyclone cases in 2006 and 2007, in comparison with the modeling results using WRF. This task is done in collaboration with G.B. Raga, D. Pozo, R. Romero-Centeno and J. Zavala-Hidalgo (UNAM). The results were presented at several international conferences and a manuscript is available.

R. Romero (CCA-UNAM) has carried out the estimates of several parameters from the North American Regional Re-analysis database for the selected cases that are the focus of the manuscript with Farfán as first author. She has recently started the study of the climatological conditions that are associated with land-falling cyclones in the East Pacific.

United States of America:

D. Raymond (NMT-USA) together with his PhD student J. Cisneros have continued the analysis of the airborne Doppler radar and dropsonde data from the TCSP/IFEX project, as well as participated in the T-PARC project in the Western Pacific, following the same methodology to investigate cyclogenesis and intensification.

5. Publications

Refereed publications

1. Marin, J., D. Raymond and G.B: Raga, **2009**: Intensification of tropical cyclones in the GFS model. *Atmos Chem. Phys.,* **9**, 1407-1417. (Impact Factor=4.362).
2. Marin J.C., G.B. Raga, and D. Raymond, **2009**: Assessment of global numerical models in the East Pacific as evidenced from EPIC2001 project. *Dynam. Atmos. Ocean.,***45**, 2-18. (IF=1.970)
3. Sánchez Montante' Orzo, G. B. Raga and Jorge Zavala-Hidalgo, **2009:** Is the ocean responsible for the small number of intense tropical cyclones in the Eastern Tropical Pacific? Submitted to *Dynamics of Atmospheres and Ocean*.
4. Romero-Centeno, Rosario, G. B. Raga, and Jorge Zavala-Hidalgo, **2009:** Atmospheric patterns associated with high-frequency wind events over the Central Northeastern Tropical Pacific during summer. Submitted to *J. Climate.*
5. Farfán,L M, Rosario Romero-Centeno, G. B. Raga, Diana Pozo and Jorge Zavala-Hidalgo, **2009**: On the landfall of Eastern Pacific Tropical Cyclones John, Lane and Paul (2006) over Northwestern Mexico. Submitted to *Monthly Weather Review.*

Conference presentations (No extended abstracts)

1. Romero Centeno, Rosario, G. B. Raga y Zavala-Hidalgo, Jorge: Patrones característicos asociados con los cambios en la circulación atmosférica en el Pacifico Tropical Nororiental durante el verano. Unión Geofísica Mexicana, 26-31 Octubre, Puerto Vallarta, **2008.**
2. Olivera, Marcelo V., G.B. Raga, Roberto Orbe C.: Enfermedades transmitidas por vectores. International EcoHealth Forum, Mérida, Yucatán, 1-5 diciembre, **2008**.
3. Farfán, Luis M. and G.B. Raga: Training on Eastern Pacific tropical cyclones for Latin American students. Joint Assembly of the American Geophysical Union, 24-27 May, Toronto, **2009.**
4. Farfán, Luis M: A weather analysis system for the Baja California peninsula: tropical cyclone season of 2008. Joint Assembly of the American Geophysical Union, 24-27 May, Toronto, **2009.**
5. Oropeza, F. and G. B. Raga: Climatology and selected case studies of the role of ocean eddies in the intensification of tropical cyclones in the Eastern Pacific. 2nd

International Summit on Hurricanes and Climate Change, 31May – 5 June, Corfu, Greece, **2009**.

6. Sanchez-Montante, O., A. Olivares-Hernandez, G.B. Raga and J. Zavala-Hidalgo: Ocean surface conditions associated to tropical cyclones' intensification over American tropical seas. 2nd International Summit on Hurricanes and Climate Change, 31May – 5 June, Corfu, Greece, **2009**.
7. Oropeza, F. and G. B. Raga: Intensification of Tropical Cyclones in the Eastern Pacific and its Relationship with Ocean Eddies. Joint Assembly of IAMAS-IAPSO-IACS, 19-29 July, Montreal, **2009.**

6. Data

No new data has yet been generated in this project. A CD was generated during the spring course that contained all the course material, including all the lectures that were offered. (Note: this CD can be mailed to IAI if needed)

7. Capacity building

The ***highlights*** in this aspect during this past year are:

- 2nd Spring Course on Tropical Cyclones (1 week during early March 2009, in Acapulco, Guerrero). This course was offered at a graduate student level and focused on the physics of different aspects of cyclone formation and evolution. More details are given below.
- 1-day Symposium on the Human Dimensions of Tropical Cyclones, incorporating the views of personnel working in civil defense agencies at different government levels (local, state, federal), same location. More details are given below.
- Third PI-workshop during to spring course, same location. More details are given below.
- One PhD student (J. Marin, CCA-UNAM) has graduated from the project. Two other PhD students (F. Oropeza at CCA-UNAM and J. Cisneros at NMT-USA) continue in the project and will graduate within the next year.
- Addition to our research group at CCA-UNAM of Dr. Marcelo Olivera (PhD in Economics, from Bolivia) and Roberto Orbe (undergraduate student).

More details on some of the highlights are given here:

2nd spring course on Tropical Cyclones in Acapulco, Mexico

Preparations for spring school started in December 2008, with the invitation to speakers and an open call for participants. Selection of the participants was made by the end of January, candidates were notified and arrangements were made to purchase their airline tickets when applicable. Logistical aspects (computers, internet access) and preparation of material (handout notes for students and CD) were carried out during January-February.

From 9 through 12 March, 2008, a 32-hour course was held in Acapulco and it was focused on training graduate students from Mexico, the United States, Cuba, Costa Rica, Argentina, Colombia and Chile. A total of 26 students attended, most of them currently attending graduate programs in Atmospheric Sciences or Oceanography. Twenty one students were awarded either total or partial funding to attend, from the funds available from our IAI grant. Participants also included personnel from the Mexican Ministry of Transport (Merchant Navy), Mexican Institute for Water Technology (IMTA, Spanish acronym), Air Force and a Mexican Center for Social Anthropology (CIESAS, Spanish acronym). A total of 10 instructors provided lectures on:

- Climatology and formation of tropical cyclones (L Farfan, CICESE)
- Dynamic and thermodynamic models (D. Raymond-NMY, R. Prieto-IMTA, V. Lopez-CCA, F. Oropeza-CCA)
- Air-sea interaction and ocean response (J. Zavala-Hidalgo-CCA)
- Ocean waves and coastal impacts (A. Salinas-IMTA)
- Variability and climate-related predictions (G. Raga-CCA)
- Remote sensing of atmospheric variables (R. Romero-Centeno-CCA)
- Remote sensing of oceanic variables (O. Sanchez-Montante-CICATA)

Professor Kam-biu Liu (Lead PI of CRNII-050), from Louisiana State University, offered a lecture on geologic techniques to study past activity, back to the last 5,000 years, providing the paleo-climate context of modern day observations of tropical cyclones. The last afternoon of the course was devoted to a forum in which students divided into small groups presented to the rest of the attendants, their views on the links between tropical cyclones and climate change, based on a review of the recent literature on the topic. Students were required to review selected papers prior to attending the course, which were available through the web page for the course.

Participants at the short course offered in Acapulco, Mexico

Symposium on the Human Dimensions of Tropical Cyclones in Acapulco, Mexico

A one-day symposium was held on 13 March, as a follow-up to the short course. The objective of this symposium, which was open to the press, was to discuss the socio-economic impacts associated with tropical cyclone landfall. Eight lecturers discussed the following topics: the impact on coastal regions and inland flooding, the link between cyclonic precipitation and water resources vital for societies (particularly in the NW region of Mexico), the flow of information between climatic research centers and government agencies, as well as the impact in health (dengue) and agriculture (corn and bean crops, staples of Mexican diet). Civil defense personnel from the city of Acapulco and the State of Baja California Sur, as well as a representative of the State Water Commission form Sonora provided practical insight on the experience of cyclone landfall, discussing preparedness and response measures. The press was invited to this symposium and representatives from 4 different media attended. Interviews were aired in the local evening news and the following day in 3 local newspapers. Copies of the printed interviews can be found on the web page for the project (http://cabernet.atmosfcu.unam.mx/IAI/aca_press.html)

PI-workshop in Acapulco, Mexico

The PI-meeting also took place in Acapulco, during the evenings of the 2nd spring course of tropical cyclones. A large fraction of the time was devoted to the discussion of the research plan for the following months, with particular emphasis on assigning responsibilities for the tasks that had not progressed as desired. Dr. Kam-biu Liu (CRNII-050) was invited to attend the discussions.

Full details of all the events in which Co-PIs have participated are given in the Excel file provided: CapacityBuilding_forms_CRNII_048.xls.

8. Regional collaboration/Networking

A closer collaboration with Kam-Biu Liu, from Louisiana State University, who is the lead PI of CRNII-050 project has developed through the years. Conversations were started in May 2007 during a symposium on Tropical Cyclones held in Crete and Dr. Liu has since participated in both Spring Courses on Tropical Cyclones (La Paz 2008 and Acapulco 2009). During both trips, L. Farfan drove him to visit several sites that may be considered as potentially suitable for the drilling of sand/sediment cores that is part of his CRN II project. Dr. Liu is scheduled to collect samples in the Mexican Pacific region near Acapulco this coming December. His results would allow to put the modern record of tropical landfalls into historical perspective. Dr. L. Farfan presented a seminar at Louisiana State University during a visit to Baton Rouge in March 2009.

The project has benefited significantly by the addition to our research group at CCA-UNAM of Dr. Marcelo Olivera and Roberto Orbe (undergraduate student). M. Olivera applied for a post-doctoral position at CCA-UNAM that was approved in January 2008. He is a native of Bolivia, but obtained his PhD from the College of Economy at

UNAM and his doctoral research involved the economic aspects of hydrocarbon extraction in national parks in Bolivia. He started working with us in March 2008 and is currently supervising the undergraduate student R. Orbe, funded by sources other than this CRN project. Their research focuses on the impact of the intense precipitation associated with land-falling tropical cyclones on certain crops (maize and beans) and tourism (case study: Acapulco). His postdoctoral position was renewed for a second year, starting on March 2009.

9. Media coverage and Prizes

An interview with the local TV- station in Acapulco was given by Dr. G. B. Raga during the symposium in Acapulco and excerpts were aired by the station in their evening news program on 13 March. Written reports appeared on 3 local newspapers on 14 March.

10. Policy Relevance

The majority of the results obtained are too biased towards basic science to be considered relevant to policymakers. Some aspects of the study on the impact of heavy precipitation due to landfall on the spread of dengue in Acapulco may be of interest to local authorities, to time the regularly scheduled spraying with meteorological conditions.

11. Main conclusions

We summarize here the key findings listed under each sub-section.

Climatological study from satellite data over oceans

- Several cases were identified in which the sea surface height anomalies were correlated with cyclone trajectory and intensification, as was observed in other cyclonic basins
- However, the climatological results do not find a systematic increase in cyclone category with sea surface height anomaly.
- The role of the ocean eddies in the East Pacific appears to be smaller than hypothesized

Data analysis from TCSP/IFEX & GFS

- The circulation increases in the developing cyclones due to the mass convergence at low levels
- As it intensifies, the height of this low level convergence is reduced, confined to a shallower region.
- The surface heat fluxes are very important in the intensification of the cyclones
- The ventilation (related to the advection of air with low entropy) can cause the cyclone to decelerate and dissipate.

Data analysis of selected cases that recently made landfall in Mexico

- Hurricane John (2006) provided a well-defined period of heavy precipitation along the eastern coast of Baja California with contributions in the range of 42–75% of the accumulations received during the entire warm season.
- Hurricane Lane was the strongest system at the time of landfall (Category 3) over the mainland. However, the other cyclones also provided much of the precipitation accumulated during the season.
- Tropical storm Paul was the only re-curving system and its track was influenced by an anticyclonic system in the Gulf of Mexico, along with a wave trough reaching the SW of US.
- Advection of dry air over NW Mexico was associated with the absence of convective activity over the Baja California Peninsula; heavy rainfall was concentrated over the States of Nayarit and Sinaloa during the landfall of Hurricane Lane.
- Middle level advection of dry air, from troughs approaching the western United States, is an important element in predicting the tracks and rainfall of tropical cyclones making landfall.

Modeling with WRF and comparison with observations

- None of the simulations accurately reproduce cyclone intensification.
- Track errors in simulation JohnKL are the smallest among simulations since the simulated translation velocity in John is the closest to the one from the NHC. Note however, that the simulated trajectory for JohnKL fails to make landfall in the southern tip of Baja California, predicting a more westerly course than observed.
- Simulation JohnKL is the one that best reproduces the observed cloud field from GOES, while simulation JohnAT gives the worst results. Simulations using the Thompson microphysics overestimate the high clouds. While simulations with Lin microphysics underestimate high clouds, they reproduce much better the low clouds, still underestimating them. Simulations with the K-F cumulus parameterization shows a better agreement with the observed precipitation distribution and specifically, JohnKT, shows the best agreement with TRMM and surface station observations.
- The National Hurricane Center failed to predict landfall of John (2006) until only 12 hours before actual landfall. We hypothesize that the lack of sounding observations in the NW region of Mexico may have deteriorated the forecast of the global models.

12 Work plan for next year with associated costs

The original project was scheduled for 3 years. However, due to the bureaucratic delays, the project formally started in January 2007, so an extension was requested and approved by IAI Directorate. The work plan proposed for the next months (1 July 2009 - 1 April 2010) would allow all the original objectives to be fulfilled. The remainder of the work can be divided into 4 categories, as follows:

i) Data analysis:

- Continue climatological study using NCEP-R2 and NARR data (R. Romero-Centeno, CCA-UNAM)

- Analysis of results from coupled ocean-atmosphere global climate models runs (R. Romero-Centeno and GB Raga, CCA-UNAM, L. Farfan, CICESE).
- Analysis of lightning data for cyclones close and far from land (F. Oropeza and G. Raga, CCA-UNAM)

ii) Modeling:

- Improvements on the ocean stratification parameterization in model "Hurricane" (F. Oropeza, CCA-UNAM)
- Coastal wave modeling (I. Mitrani and D. Martinez, INSMET-Cuba)

iii) Capacity building:

- Preparations for spring school: invitation to speakers, open call for participants (November 2009), logistical aspects (computers, internet access),
- Preparation of a text book in Spanish for the next Spring Course on Tropical Cyclones. L. Farfán will visit G. Raga at CCA-UNAM during November to start working on the text and the plan is to have it ready by March.
- 3rd Spring Course on Tropical Cyclones (1 week during early March 2010, in La Paz, Baja California Sur). (Partial funding is already available)
- 1-day Symposium on the Human Dimensions of Tropical Cyclones, same location. With participation of personnel working in civil defense agencies at different government levels (local, state, federal) and members of associated SGP-HD project led by R. Varady and C Scott.
- Last PI-workshop during Spring Course, same location, to coordinate final report

iv) Publications:

- Manuscript for publication on the role of ocean eddies on cyclone intensification in the EPAC (Oropeza and Raga)
- Manuscript for publication on the synoptic scale variability of meteorological parameters (e.g. geopotential and precipitation) during the cyclone season in the Pacific (Romero-Centeno and Raga)
- Manuscript for publication on lightning in TC close and far away from the coastline (collaboration with Alex Khain from University of Jerusalem, Raga & Oropeza)
- Text book in Spanish on Tropical Cyclones, with emphasis on the EPAC (Raga and Farfán)
- Final report to IAI