Second Annual Report
1 July 2007 - 30 June 2008

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

As an introductory remark, it should be noted that the process of getting the agreements between UNAM and the other institutions signed has been slow. Currently we have fully signed agreements with CICESE (Mexico) and New Mexico Institute for Mining and Technology (NMT, USA), and funds should be transferred to NMT shortly. Funds for CICESE's participation in this project have finally come through from internal CICESE funds. The agreement with CIGEFI (Costa Rica) is at the stage where the transfer of funds is also being settled. However, because of the long delays the Co-PI from Costa Rica has recently asked (27 June 2008) to be removed from the project. We have asked him to reconsider and are awaiting his final decision. The agreement with INSMET (Cuba) has been signed and is currently in transit by post back to Cuba. Unfortunately, the courier company that UNAM operates with does not deliver to Cuba, so regular post had to be used, with the obvious delays. Funding to be transferred to our Cuban colleagues has not been sent to UNAM yet. Finally, there has been no movement in the agreement with IMTA, since the moment when the request of change on Co-PI was introduced. Even though there have been several obstacles in the bureaucratic process, there are several activities that were carried out by all participants and interesting results were obtained in the project, that were reported in international venues.

To proceed with the report of the last 12 months, we first recall the original work plan for the period 1 July 2007 -30 June 2008. Such work plan was divided into four following categories, reproduced here form the first annual report for reference. 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**.

I. Data analysis:

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

I.2 Begin climatological study using NCEP-R2 and ECMWF data (R. Romero-Centeno, CCA-Mexico; R. Prieto, IMTA-Mexico)
I.3 Continue with data analysis from TCSP/IFEX (J Marin and GB Raga, CCA-Mexico; J. Cisneros and D. Raymond, NMT-USA)

II. Modeling:
II.1 Operational modeling with WRF during the cyclone season (L. Farfan CICESE-Mexico; D. Pozo and GB Raga, CCA-Mexico, D. Martínez, INSMET)
II.2 Ocean modeling for the EPAC region (F. Oropeza and GB Raga, CCA-Mexico)
II.3 Analysis of results from coupled ocean-atmosphere global climate models runs (R. Romero-Centeno and GB Raga, CCA-Mexico).
II.4 Coastal wave modelling (O. Lizano, CIGEFI)

III. Capacity building:
III.1 Preparations for spring school: invitation to speakers, open call for participants (October2007), logistical aspects (computers, internet access), preparation of material (handout notes for students)
III.2 Spring school (2 weeks, most likely during early March 2008, in Baja California Sur, likely location: Los Cabos)
III.3 First workshop for participants (following spring school)

IV. Publications:
IV.1 Presentations at the 28th Conference on Hurricanes and Tropical Meteorology, 29 April – 2 May, 2008 in Orlando, with extended abstracts.
IV.2 Manuscript for publication on climatology of SSH anomaly in the EPAC and selected case studies of tropical cyclones, by O. Sanchez, J. Zavala-Hidalgo, GB Raga.
IV.3 Manuscript for publication on the comparison of airborne Doppler radar, dropsonde and GFS modeling results for selected tropical cyclones during IFEX, by D. Raymond, J. Cisneros and J. Marin.
IV.4 Annual report to IAI

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)

After the characterization was made of the climatological base state (1993-2006) in the EPAC, the altimetry data has now been used to estimate the anomalies associated with selected intense tropical cyclones that had trajectories close to the Mexican coastline. The hypothesis behind this analysis is to determine the role of warm ocean anomalies (not just warm sea surface temperature) in the intensification of tropical cyclones close to the coast. Warm ocean anomalies are associated with high altimetry anomalies. This interaction has been shown in other basins (in the Western Pacific by Lin et al, 2005; in the Gulf of Mexico for Katrina) to provide a crucial influx of energy into the cyclones that leads them to significant and rapid intensification. The analysis so far does not seem to indicate the same intensification response in the EPAC region. It is

unclear to us at this time why this mechanism does not seem to be relevant for cyclone intensification. Nevertheless, there are a few cases in which there is a correlation between the presence of high altimetry anomalies and intensification. Kenna (22-26 October 2002) was a category 5 hurricane that hit the coast near the resort area of Puerto Vallarta. Figures 1 and 2 show the track of Kenna (indicated by the circles), initially parallel to the Mexican coast and not varying much in intensity the first few days. In Figure 1, the observed sea surface temperature (SST) along the track was above 29C, yet the cyclone did not show any significant intensification, remaining category 1 for about 2 days. Note that the following day, the cyclone moved to slightly cooler sea surface temperature, yet the system reached category 4 in just one day. Figure 2 presents the sea surface height (SSH) anomalies during that week, indicating that the cyclone initially moved over a widespread region of low SSH anomaly (associated with less heat in the ocean mixed layer). Once the cyclone moved towards the northern edge of the low anomaly in SSH, even though the temperature was lower, there was more available heat in the ocean mixed layer for the hurricane to extract and fuel itself. The further march towards even higher SSH anomalies allowed the hurricane to reach category 5 before making landfall.

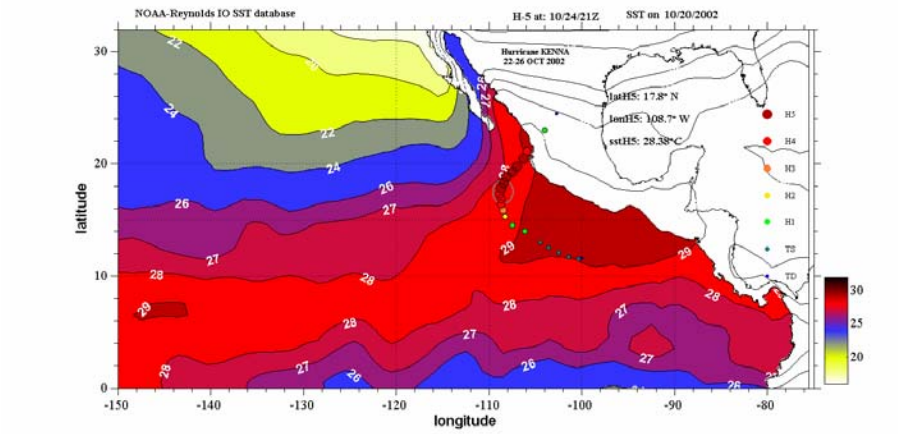

Figure 1. Sea surface temperature (in contours) in the EPAC corresponding to 22-26 October 2002. The circles indicate the official best track for Hurricane Kenna.

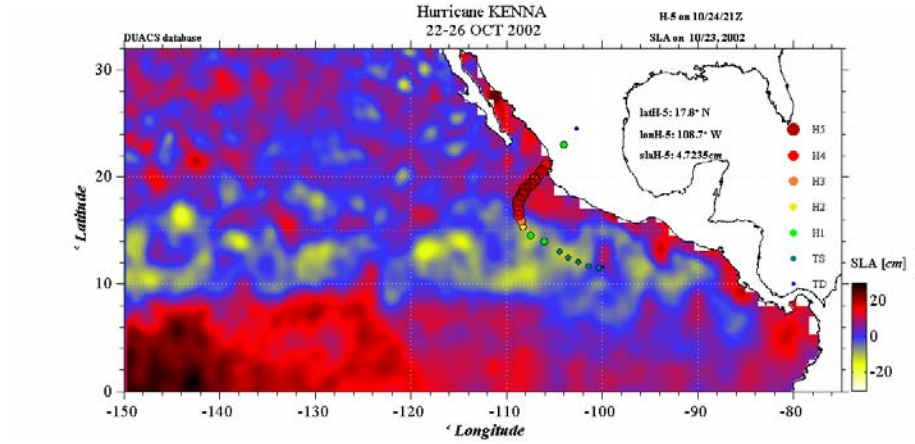

Figure 2. Sea surface height anomalies (in contours) in the EPAC corresponding to 22-26 October 2002. The circles indicate the official best track for Hurricane Kenna.

These results were presented at the Annual Meeting of the Mexican Geophysical Union (UGM, November 2007). A manuscript is currently under preparation and will be submitted for publication before the end of this second year of the project. A doctoral student at UNAM, F. Oropeza has started working on regional ocean modeling in the EPAC basin, which will investigate the physical mechanisms behind the empirical correlations observed. In summary, we assess that this task has been carried out successfully.

I.2 Climatological study using NCEP-R2 and ECMWF data (R. Romero-Centeno, CCA-Mexico; R. Prieto, IMTA-Mexico)

This task has not progressed as planned. Dr. Prieto has left our team and the analysis by Dr. Romero-Centeno has been slow in coming. Her research follows on the steps of her doctoral thesis and has focused on the relationship between wind and geopotential height patterns (and anomalies) and precipitation in the EPAC. Her work encompasses more than just the relationship when tropical cyclones are present, investigating the conditions that lead to high precipitation. Her results indicate that very large scale patterns of anomalies (clearly hemispherical in scale) in geopotential are associated with more or less precipitation in the EPAC region. The anomaly seems to be barotropic and is present throughout the troposphere up to 100 hPa. It is locked in time, 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. This intra-seasonal variability is currently the topic of intense research and several presentations during the 28th Conference on Hurricanes and Tropical Meteorology addressed it. Dr. Romero-Centeno gave an oral presentation at this conference and is currently working on the final stages of a manuscript for submission to the Journal of Climate. The results indicate the range of variability of the "drought" phenomenon, from interannual down to synoptic.

Even though the progress has been slow, we will still pursue the stated task, identifying in the climatological record, the patterns of anomalies associated with land-falling tropical cyclones.

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

This task has progressed very successfully, with results being consolidated into a couple of publications. One has already been submitted and the other one will be sent before September 2008. The results were presented as posters and orally at the recent 28th Conference on Hurricanes and Tropical Meteorology. The interim report sent in February 2008 presented details of the results and they are also included in the extended abstract published (attached to this report)

Progress on *Modelling:*

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)

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. One of the goals was to analyze the tropical cyclones that made landfall in northwestern Mexico: John, Lane, and Paul in 2006 and Henriette in 2007. The tracks of these systems are shown in Figure 3.

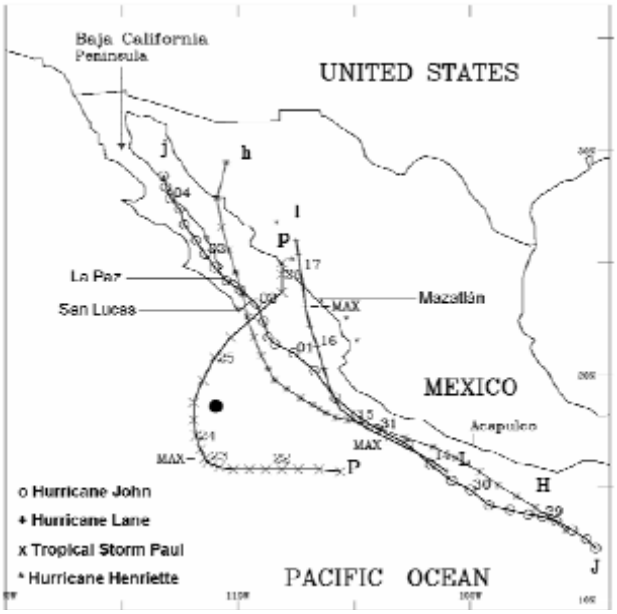

Figure 3. Tracks of Tropical Cyclones: John, Lane and Paul in 2006 and Henriette in 2007. Initial positions are represented by uppercase letters and final positions by lowercase letters. Position location is marked every 6 hours; numbers are fixes at 0000 UTC; and position at maximum intensity (MAX) 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. Table 1 presents the precipitation observed at some stations in Baja California and the Mexican mainland, during the passage of 3 of the cyclones studied, compared with the accumulated for the 4-month period (July through October). Note how significant the precipitation from a single system can be at some of the stations.

Station	John	Lane	Paul	Jul-Oct
Loreto	265	0	57	355
La Paz	79	0	2	169
San Lucas	129	0	36	308
Cholx	75	0	50	573
Puicos	14	16	224	738.2
Mazatlán	89	257	32	1001
Acaponeta	98	154	18	989
Tepic	27	28	36	898

Table 1. Rainfall accumulations (mm) at eight sites from three 2006 tropical cyclones: John (31 August–4 September), Lane (15–17 September), and Paul (24–26 October) and the warm season accumulation (1 July – 31 October).

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.

A similar methodology to the one used in this study is currently being applied to the tropical cyclone seasons from 1970 through 2007. An examination of large-scale fields associated with landfall strikes over the Baja California Peninsula and over the mainland is now in progress. This expansion of case studies will increase our knowledge of the impact of storms over northwestern Mexico and will provide practical information for operational forecasters.

The 3 cyclones that made landfall during the 2006 season were simulated with the Weather Research and Forecasting (WRF) model. Simulations of hurricanes John and Paul were initiated in August 31, 2006 at 00 UTC and October 22, 2006 at 00 UTC,

respectively. Both 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 (GDAS) 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. New simulations using the Thompson et al. (2004) microphysics scheme in the inner domain and the simplified Arakawa-Schubert (SAS) cumulus parameterization in the outer one were performed to test sensibility. Table 2 shows a description of the simulations.

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

Table2. Description of simulations performed in this study for hurricane John. Similar names are used for Paul.

None of the simulations reproduce accurately the storm intensification. Hurricane Paul does not show any intensification at all, despite it presents a good agreement with the large-scale fields from the FNL analysis. This can affect the simulated trajectory and convective organization.

Track errors in JohnKL are the smallest among simulations since the simulated translation velocity in John is the closest to the one from the NHC. JohnKL (JohnAT) best (worst) reproduces the observed cloud field from GOES. Simulations using the Thompson (Lin) microphysics overestimate (underestimate) the high clouds. Lin reproduces much better the low clouds although it underestimates it. 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.

Note that the simulated trajectory for JohnKL fails to make landfall in the southern tip of Baja California, predicting a more westerly course than observed (Fig. 4). On 1 September, John turned toward the north-northwest as the mid-level ridge to the north of the hurricane weakened. This large scale feature was not captured by the simulation and neither by the National Hurricane Center (NHC) official track, which presented large errors beyond 96 h in Table 3. Less than a day before landfall, the NHC official report and JohnKL show the TC to move near Cabo San Lucas, rather than to the northeast,

where landfall occurred. Most of model's forecast tracks did not predict the landfall of John, possibly due to a lack of radio-sonde data in northwestern Mexico that usually are ingested during the model initialization procedure. Paul's track was more complicated than that of John; nevertheless, PaulKL simulation was able to capture its behavior adequately (Fig. 4). Afterwards, the simulation failed owing to a slower than expected northward turn of the hurricane. Errors in the trajectory of PaulKL are smaller than those in JohnKL when they are compared with the NHC official forecast errors (Table 3).

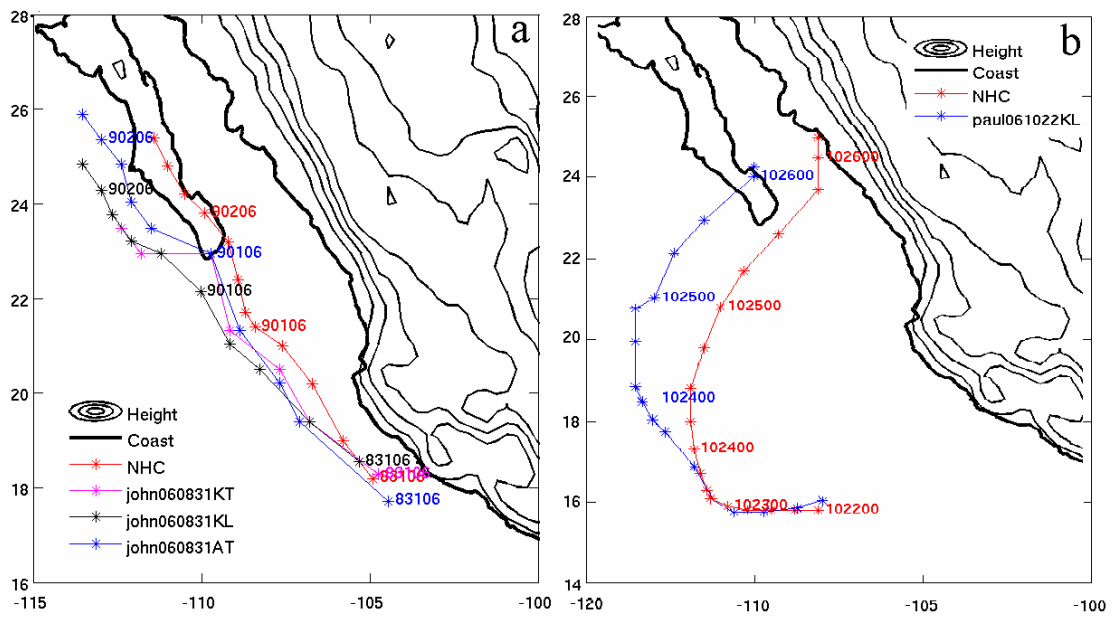

Figure 4. Best track (red) from the National Hurricane Center and simulated (WRF) positions. a) Hurricane John, 28 August-4 September 2006. b) Hurricane Paul, 21-26 October 2006.

The large-scale air flow at middle levels is the main factor determining the storm motion. However, the vortex depth, its radial structure and azimuthal asymmetry can also modify the track (Wang and Holland 1996; Fovell and Su 2007; Wang 2002). This implies that a poor representation of the vortex (or the storm intensification) could cause errors in the storm trajectory.

Simulations do not reproduce the storm intensification observed in the NHC official report. JohnKL shows a minimum central pressure of 970 hPa, while a minimum of 950 hPa was reported by the NHC. In addition, its temporal evolution show large differences (Fig. 5a). In the case of PaulKL, no intensification was simulated (not shown).

Forecast Technique (hurricane)	Forecast Period (h)					
	12	24	36	48	72	96
WRF (PaulKL)	43.3	23.5	117.9	110	138	120.4
OFCL (Paul)	38	71	96	144	201	231
WRF (JohnKL)	63.8	92.7	170.3	204.4	180.9	
WRF (JohnKT)	63.9	94.5	199.7	207.3	-	-
WRF (JohnAT)	80.4	77.5	199.2	214.2	209.0	-
OFCL (John)	24	37	51	71	145	242
NHC Official (2001-2005 mean)	35	60	83	103	145	192

Table3. Forecast errors (n mi) for Hurricanes Paul and John.

Large-scale characteristics that have a key role in the tropical cyclone (TC) intensification, such as the sea surface temperature (SST) and the vertical wind shear (VWS), are slightly different in JohnKL due to its deviation from the NHC track (Figs. 5b,c). Such differences negatively affect the TC intensification. The simulated geopotential field at 850, 700 and 200 hPa (not shown) is also similar to that in analyses (+-20 m error) in both simulations. This suggests that problems in reproducing the intensification of TCs could be associated to the inability to represent the smaller-scale processes that occur in the eye-core and have an important role in the storm's development. It is interesting to point out that the FNL analyses do not show the reported intensification (green lines in Fig. 5a). Another important factor could be the poor representation of the surface fluxes in the region as a result of the inadequacy of the chosen parameterization.

In conclusion, none of the simulations reproduce accurately the storm intensification. Hurricane Paul does not show any intensification at all, despite presenting good agreement with the large-scale fields from the FNL analysis. This can affect the simulated trajectory and convective organization.

Track errors in JohnKL are the smallest among simulations since the simulated translation velocity in John is the closest to the one from the NHC. JohnKL (JohnAT) best (worst) reproduces the observed cloud field from GOES. Simulations using the Thompson (Lin) microphysics overestimate (underestimate) the high clouds. Lin reproduces much better the low clouds although it underestimates it. 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. See the attached extended abstract by Pozo et al, for figures presenting the comparison.

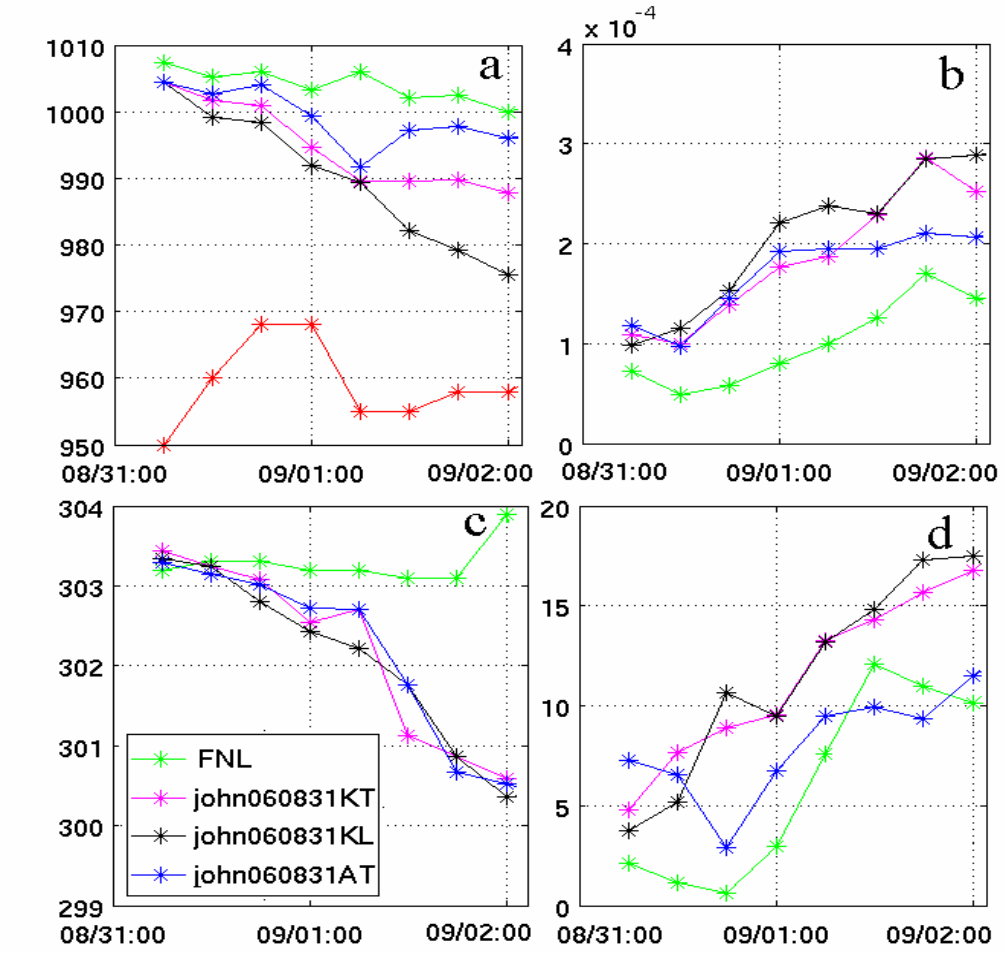

Figure 5. Hurricane John. Temporal evolution of a) Minimum central pressure b) Mean vorticity over the storm. c) Sea surface temperature. d) Mean vertical shear (850-200mb) over the storm.

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

An in-depth analysis of each individual cyclone case since1970 (corresponding to the satellite record) has been performed to identify "rapidly intensifying" cyclones. Of particular interest are those cyclones that intensify in relatively short periods (24-48 hours) to the higher cyclone categories (3 through 5). The working hypothesis is that those cyclones may have intensified by interacting with areas in the ocean with positive sea surface height anomalies, corresponding to higher heat content in the oceanic mixed layer. So far there is only an empirical correlation and the doctoral thesis will search for the physical mechanisms responsible, through regional ocean modeling using the model ROMS, developed at the Institute of Marine and Coastal Sciences at Rutgers University. F. Oropeza has already started the process of implementing the regional model to the EPAC region. The needed boundary conditions for the regional model will be obtained from the simulations of the global ocean model developed at the

Naval Research Laboratory, where his undergraduate supervisor is currently working and has provided him with the output. The analysis of those simulations in the EPAC suggests that the global model is capturing the development of anti-cyclonic eddies associated with higher heat content in the mixed layer, both in winter (as has been known for some time) as during the summer. It is during the summer that those eddies have the potential to interact with developing tropical cyclones. It remains to be seen how the regional ocean model simulates the sea surface height anomalies that can be compared against the Topex/Poseidon database and the ARGO buoys.

II.3 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 year.

II.4 Coastal wave modelling (O. Lizano, CIGEFI)
This task is at a very preliminary stage, since the formal agreement with CIGEFI has not been finalized and no transfer of funds has yet occurred. Dr. Lizano performed some initial simulations with the costal wave model, applied to the 3 land-falling tropical cyclones from the 2006 season. 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.

In summary, the progress report on Data and Analysis and Modeling presented here leads us to the conclusion that while the proposed goals have been largely obtained in Data Analysis, those in Modeling are lagging somewhere behind expectations. A larger effort will be made to accomplish the Modelling goals early in the next period.

4. Contributions of Co-PIs

Costa Rica:
O. Lizano (CIGEFI) implemented the coastal wave model using current an future hurricane climate scenarios for the Eastern Tropical Pacific coast. In particular, the detailed bathymetry is needed for some of the bays and ports on the West coast, to assess the potential risk to coastal cities. He has preformed preliminary simulations with lower resolution of the land-falling cyclone cases of the 2006 season. This work was carried out even though only recently the agreement was finalized.

Cuba:
I. Mitrani (INSMET), together with Anneris Calnick, will be responsible for numerical simulations of ocean waves associated with cyclones, farther from the shore. They will interact more closely with O. Lizano, since they share expertise in the topic.

Mexico:
J. Zavala-Hidalgo and GB Raga (CCA-Mexico), together with O. Sanchez (CICATA-Mexico) have almost 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 is being finalized and will be submitted for publication in September 2008.

GB Raga and her PhD student J. Marin (CCA-Mexico) in collaboration with Dr. Raymond (NMT-USA) have finalized the analysis of the FNL data for the East Pacific and have already submitted a manuscript for publication. The results from the modeling work using the global forecasting system (GFS), were analyzed to determine the dynamic and thermodynamic forcings leading to cyclone intensification. The results were presented at the 28th Conference on Hurricanes and Tropical Meteorology and the manuscript is being finalized to be submitted in September 2008. The student is expected to obtain his PhD before the end of 2008.

GB Raga and her PhD student F. Oropeza (CCA-Mexico) have undergone an in-depth analysis of each individual cyclone case since1970 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. So far there is only an empirical correlation and the doctoral thesis will search for the physical mechanisms responsible, through regional ocean modeling (using ROMS). F. Oropeza will travel to USA for 4 weeks in August to participate in a training course at the Institute of Marine and Coastal Sciences at Rutgers University.

L. Farfán (CICESE-Mexico) has taken the lead in the task to generate a manuscript out of 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). Two posters were presented at a scientific conference and the manuscript will combine the results into one more comprehensive publication. It is foreseen that this manuscript will be submitted for publication by November 2008.

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. Their results were presented in a poster at the 28th Conference on Hurricanes and Tropical Meteorology and a manuscript is currently in preparation in collaboration with J. Marin. Dr. Raymond gave an oral presentation at the abovementioned conference, presenting the theoretical aspects behind the analysis that J. Cisneros and J. Marin have carried out.

5. Publications

Several extended abstracts have been published of the research presented at different scientific conferences:

1. Farfán Luis M., Rosario Romero-Centeno, G. B. Raga and Jorge Zavala-Hidalgo, **2008**: Land-falling Tropical Cyclones in the Eastern Pacific. Part I: Case studies

from 2006 and 2007. *28th Conference on Hurricanes and Tropical Meteorology*, 28 April- 2 May, Orlando.

2. Pozo, D., G.B. Raga, Luis Farfan, Rosario Romero-Centeno and Jorge Zavala-Hidalgo, **2008**: Land-falling East Pacific hurricanes. Part II: WRF simulations of John and Paul (2006). *28th Conference on Hurricanes and Tropical Meteorology*, 28 April- 2 May, Orlando.
3. Raymond, David J., Jorge Cisneros, Sharon Sessions, Julio Marin, G. B. Raga and Zeljka Fuchs, **2008**: Environmental Influences on the Spin-up of Tropical Cyclones. *28th Conference on Hurricanes and Tropical Meteorology*, 28 April- 2 May, Orlando.
4. Marín, Julio C., David J. Raymond and G. B. Raga, **2008**: Evaluating the intensification of Tropical Cyclones with the GFS model. *28th Conference on Hurricanes and Tropical Meteorology*, 28 April- 2 May, Orlando.

Conference presentations (No extended abstracts)

1. Sánchez-Montante, O., G.B. Raga y J. Zavala-Hidalgo: Condiciones oceánicas superficiales asociadas a la ocurrencia de huracanes en el Pacífico Oriental. Unión Geofísica Mexicana, Puerto Vallarta, **2007**.
2. Romero-Centeno, Rosario, Jorge Zavala-Hidalgo, and G. B. Raga: Characteristic patterns associated with atmospheric circulation changes over the Northeastern Tropical Pacific in summer. 28th Conference on Hurricanes and Tropical Meteorology, May **2008**.
3. Farfán Luis M., G. B. Raga, Diana Pozo, Rosario Romero-Centeno, and Jorge Zavala-Hidalgo: A training course on tropical cyclones over the Eastern Pacific Ocean. Earth and Space Science Informatics Session, Spring Meeting of the American Geophysical Union, May **2008**.

No formal publications are yet available from our research. However, one manuscript has already been submitted for publication and 4 others are in advanced stages of preparation (based on results that were presented at international conferences) and will be submitted shortly:

1. Marin, J., D. Raymond and G.B. Raga, **2008**: Assessment of global numerical models in the East Pacific as evidenced from EPIC2001 project. Submitted to *Dynamics of Atmospheres and Ocean* (April 2008).
2. Sánchez Montante, Orzo, G. B. Raga and Jorge Zavala-Hidalgo, **2008:** Is the ocean responsible for the small number of intense tropical cyclones in the Eastern Tropical Pacific? To be submitted to *Geophysical Research Letters*.
3. Marin, J., D. Raymond and G.B. Raga, **2008:** Intensification of tropical cyclones in the GFS model. To be submitted to *Quarterly Journal of the Royal Meteorological Society.*
4. Manuscript for publication on the synoptic scale variability of meteorological parameters (e.g. geopotential and precipitation) during the cyclone season in the Pacific by R. Romero-Centeno, J. Zavala-Hidalgo and G. B. Raga. To be submitted to *Journal of Climate*.
5. Manuscript for publication on the observational and modeling results of the landfalling cyclones from 2006 and 2007 by L. Farfan, G.B. Raga, R. Romero-Centeno, J. Zavala-Hidalgo and D. Pozo. To be submitted to *Monthly Weather Review.*

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

Three PhD students are currently are currently doing research on topics very much related to the objectives of this project:

- Jorge Cisneros from Costa Rica, a registered student at New Mexico Institute of Mining and Technology under the supervision Dr. Raymond
- Julio Marín from Cuba, a registered student at UNAM supervised by Dr. Binimelis de Raga (90% progress)
- Fernando Oropeza from Mexico, a registered student at UNAM supervised by Dr. Binimelis de Raga (30% progress)

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 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). The research carried out so far has resulted in the manuscript entitled: “La dimensión económica de los desastres naturales” that was submitted to the journal “Búsqueda” in Bolivia and an oral presentation was given at a national symposium held in early June 2008 in Torreón, Mexico. A pre-proposal was recently submitted to the Mexican Scientific Agency (Conacyt) to evaluate the economic costs of heavy rains on health, in particular the increased probabilities of dengue and malaria in the state of Guerrero on the Mexican Pacific coast that is affected by rains associated with tropical cyclones. The addition of Dr. Olivera and Mr. Orbe to our team strengthens the admittedly weak human dimension component of our project. It will also allow more interaction with the PIs in the associated HD project led by Drs. Varady and Scott in Arizona, who are investigating the potential beneficial effect of rains associated with tropical cyclones in the Mexican states of Sinaloa, Sonora and Baja California Sur.

Course at the Universidad de Buenos Aires

A 75 hour-long course on tropical meteorology with emphasis on tropical cyclones was offered at the Atmospheric and Ocean Sciences Department at the Universidad of Buenos Aires (UBA).

Selected views of the participants and instructors during the course at the University of Buenos Aires (July-August 2007).

The course took place during July and August 2007 and it was divided into 30 hours of theory and 45 hours of "hands-on" work on different databases of tropical cyclones. In particular, satellite data (temperatures, winds and precipitation) will be analyzed for 3 hurricanes that developed in the EPAC during the 2006 season (category-4 John, category-2 Lane and category-3 Paul). Results from modeling of those cases using WRF were also provided to the students for analysis. Dr. L. Farfan participated as an instructor in this course for 1 week, presenting observational case studies from the EPAC region. Dr. J. Zavala taught 3 lectures on ocean dynamics and oceanic response to tropical cyclones. Dr. R. Romero, a post-doc in this project helped with the practical aspects of the course, introducing students to Matlab and providing them with scripts to download and analyze information from sensors on the GOES, QuikScat and TRMM satellites. This course served as a dual purpose activity:

- It increased the knowledge of tropical phenomena in the undergraduate student base in Latin America which could in the future become interested in continuing research in the topic (as graduate students) and can be considered an activity of outreach within this CRNII project.
- it constituted a sort of "rehearsal" for the spring courses planned for the second and third years of the project in Mexico, where all Co-PIs served as instructors, and where students from several countries participated.

1st spring course on Tropical Cyclones in La Paz, Mexico

From 10 through 14 March, 2008, a 32-hour course was held in La Paz and it was focused on training graduate students from Mexico, the United States, Cuba, Costa Rica, Brazil and Chile. A total of 28 students attended, most of them currently attending graduate programs in Atmospheric Sciences or Oceanography. Twenty one graduate 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 Weather Service and the Federal Electricity Commission, as well as representatives from a government insurance agency.

A total of 11 instructors provided lectures on:

- Climatology and formation of tropical cyclones
- Dynamic and thermodynamic models
- Air-sea interaction and ocean response
- Ocean waves and coastal impacts
- Variability and climate-related predictions.

Professor Kam-biu Liu, 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 morning 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. Discussions of the science also led to the topic of the flow of information from scientists to society at large and the key role that scientists should play in that flow.

A similar course is planned for Spring 2009 in the context of the CRN project, in what it is hoped to become an annual event. The discussions during the forum on the link between scientists and society, has led us to plan a follow-up course, focusing on more practical aspects of this transfer of information on tropical cyclones to a more general audience. The Spring 2009 course will include a 2-day special session on training to emergency managers of public and private agencies located in communities along the West coast of Mexico. This will also strengthen the ties with the associated HD project, since the lead-PIs have expressed interest in participating as instructors.

View of all participants at the short course offered in La Paz, Mexico

Instructors of short course offered in La Paz, Mexico, from left to right: K-B Liu, J. Zavala, R. Romero, I. Mitrani, D. Pozo, L. Farfan, G.B. Raga, R. Prieto, O Sanchez, O Lizano and D. Raymond

PI-workshop in La Paz, Mexico

The PI-meeting also took place in La Paz, for two days prior to the beginning of the 1st spring course of tropical cyclones. During the meeting, the PIs and students presented their advances during the year. A large fraction of the second day was devoted to the discussion of the participation of the members that had not yet started their research due to the problems in getting the agreements signed and the funds transferred. There was also discussion about the human dimension component and how to augment our contribution.

Full details of all the events in which Co-PIs have participated are given in the Excel file provided: CapacityBuilding_forms_CRNII_048.xls. Complementary information on the students that participated in the courses in Buenos Aires and in La Paz is also included, as separate sheets within the same workbook.

8. Regional collaboration/Networking

A closer collaboration is being currently planned with Kam-Biu Liu, from Louisiana State University, who is the lead PI in another CRN project. Conversations were started in May 2007 during a symposium on Tropical Cyclones held in Crete and Dr. Liu accepted our invitation to give an invited lecture at our spring course on Tropical Cyclones in La Paz. During this trip, 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. Another aspect that was discussed as of interest to both projects is a very preliminary research on land-falling cyclones on the Mexican West, looking at historical from Spanish records (both in libraries in Mexico and Spain) during the colonial era, from early 1500s up to Mexican independence. We are planning to submit a small proposal to further this joint project. The costs would primarily be related to the field work and laboratory analyses of core samples taken by Dr. Liu's team in the identified suitable sites on the Pacific coast of Mexico. An undergraduate may be hired at UNAM to analyze the historical records from the colonial times that are currently being gathered.

9. Media coverage and Prizes

An interview with the local TV- station in La Paz was given by Dr. Binimelis de Raga during the sort course in La Paz, and another interview was given by Dr. Luis Farfán. Excerpts from both interviews were aired by the station in their news program.

10. Policy Relevance

The results obtained thus far are too preliminary to be considered relevant to policymakers.

11. Main conclusions

From the preliminary analysis carried out so far, we can draw the following conclusions.

i) The analysis of the SSH anomalies in the EPAC has revealed a very interesting annual cycle, suggesting that the oceanic conditions may not be optimum in the EPAC during tropical cyclone season, therefore, the presence of warm eddies may play a large role in the rapid intensification of cyclones.

ii) The observational study of land-falling tropical cyclones yield the following results:
   a. 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.
   b. 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.
   c. 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.
   d. 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.
   e. 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.

iii) From the modeling study with WRF we can conclude:
   a. None of the simulations reproduce accurately the storm intensification. Hurricane Paul does not show any intensification at all, despite presenting good agreement with the large-scale fields from the FNL analysis.
   b. Track errors in the simulation of hurricane John are the smallest when the KL parameterizations (JohnKL) are selected, the simulated translation velocity in John is the closest to the one from the National Hurricane

Ccenter. JohnKL reproduces best the observed cloud field from GOES, while JohnAT does the worst job. 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.

iv) The analysis of the results from the GFS model indicate that as the tropical cyclones start to intensify, the convergence of absolute vorticity dominates in the vorticity balance, resulting in the increase of the absolute circulation, leading to the spin-up of the cyclone.

v) Once the cyclone reaches a mature stage, the friction term dominates in the vorticity balance, resulting in a decrease in the absolute circulation and the final decay of the system.

vi) The thermodynamic analysis indicates that the ventilation term, which represents the inflow of low entropy air into the cyclone is important in the demise of the cyclone.

12 Work plan for next year with associated costs

The work plan proposed for Year 3 (1 July 2008 -30 June 2009) can be divided into 4 categories, as follows:

i) Data analysis:
-Conclude climatological study from satellite data over oceans (O. Sanchez CICATA-Mexico, F. Oropeza, GB Raga and J. Zavala-Hidalgo, CCA-Mexico)
- Continue climatological study using NCEP-R2 and ECMWF data (R. Romero-Centeno, CCA-Mexico)

ii) Modeling:
-Ocean modeling for the EPAC region using ROMS (F. Oropeza and GB Raga, CCA-Mexico). F. Oropeza will attend a 4-week course at Rugers University to
-Analysis of results from coupled ocean-atmosphere global climate models runs (R. Romero-Centeno and GB Raga, CCA-Mexico).
-Coastal wave modelling (I. Mitrani and A. Calnick, INSMET-Cuba); O. Lizano, (CIGEFI-Costa Rica, pending decision to remain as part of project)

iii) Capacity building:

- Preparations for spring school: invitation to speakers, open call for participants (October2008), logistical aspects (computers, internet access), preparation of material (handout notes for students)
- 2nd Spring Course on Tropical Cyclones(1 week during early March 2008, in La Paz, Baja California Sur). This course is offered at a graduate student level and focuses on the physics of different aspects of cyclone formation and evolution.
- 2-day meeting geared towards personnel working in civil defense agencies at different government levels (local, state, federal).

- Second PI-workshop prior to spring course, same location

iv) Publications:

- Manuscript for publication on climatology of SSH anomaly in the EPAC and selected case studies of tropical cyclones, by O. Sanchez, G.B. Raga and J. Zavala-Hidalgo, by September 2008.
- Manuscript for publication on the intensification of tropical cyclones from GFS modeling results by J. Marin, D. Raymond and G.B. Raga, by November 2008.
- Manuscript on the observational and modeling results of the land-falling cyclones form 2006 and 2007 by L. Farfan, G.B. Raga, D. Pozo, R. Romero-Centeno and J. Zavala-Hidalgo, by November 2008
- Manuscript for publication on the synoptic scale variability of meteorological parameters (e.g. geopotential and precipitation) during the cyclone season in the Pacific by R. Romero-Centeno, J. Zavala-Hidalgo and G. B. Raga, by September 2008.
- Annual report to IAI

Detailed cost estimates for planned activities (Note: The financial report presents totals per categories and per institution in the table provided):

Expenditures for 2nd Spring School and PI-Workshop	Cost (usd)
Travel for 2 invited speakers (Drs. Kam-Biu Liu, R. Varady or C. Scott from Arizona) @ 1000 usd x 2	2000
Per diem costs for 2 invited speakers: 7 days@210usd per day x 2	2940
Travel for 10 participants from Mexico @ 600 usd x 10	6000
Travel for 8 participants from South and Central America@ 1000 usd x 8	8000
Living costs for 18 participants: 8 days@ 100usd x 18	14400
Travel for Co-PIs from Mexico @ 600 usd x 7	4200
Travel for Co-PIs from other countries @ 1000 usd x 6	6000
Per diem costs for Co-PIs: 12 days@210 usd per day x 13	32760
Printing of handouts and CDs	2000
Secretarial help (before and during school: 4 weeks)	2000
Rental of space for PI workshop and spring course, microphones, PC projector, internet access, etc	2000
Follow-up 2-day workshop for civil defense authorities and lecture for general public.	1000
Total (from UNAM's budget)	**83300**

Other activities, to be charged to separate budgets

Other expenditures @ UNAM	Cost (usd)
1 Post-doc and 1 research assistant @ 1500 usd per month x 2 x 12	36000
Publication costs 2 @ 1500 usd	3000
Travel to international conference @ 1000 usd x 2 people	2000
Per diem @ 210 usd per day x 6 x 2	2500
Registration fees @ 500 usd x 2	1000
Total	**44500**

Other expenditures @ IMTA	Cost (usd)
Total	**0**

Other expenditures @ CICESE	Cost (usd)
Student scholarship	5700
Travel/workshops	3000
Total	**10700**

Other expenditures @ INSMET	Cost (usd)
Research expenses (Cluster)	8000
Travel	2000
Total	**10000**

Other expenditures @ NMT	Cost (usd)
Research Associate (summer months)	13000
Travel	4500
Total	**17500**

Other expenditures @ CIGEFI*	Cost (usd)
Student scholarship	6000
Research expenses	1500
Total	**7500**

*pending decision to remain as part of the project