Introduction:

The purpose of this meeting was to expand developing cooperation between the US and Mexican LTR programs to the study of the effects of hurricanes on tropical forests. The first meeting, held in Merida MX in January 2009 using supplemental support to the LUQ-LTER program, gathered together a core group of researchers committed to establishing a network of sites and scientists to expand, improve, and synthesize research on hurricanes and their effects (see report at http://lno.lternet.edu/merida). Moreover, meeting participants agreed to develop two manuscripts, established working groups to prepare a proposal to the Research Coordination Network program, initiated a bibliography of research on Caribbean hurricanes, and began development of a web page that describes these achievements and the sites that will be involved in the new network. The goals of this second meeting were to: 1) complete the manuscripts under development, 2) expand the working group to include additional ecologists and social scientists from the Greater Caribbean Basin, and develop a collaborative network of participants, and 3) maintain the momentum that the first meeting provided until we obtain longer-term funding. Products include outlines of two manuscripts and a governance plan for the developing network. Evelyn Gaiser and Bob Waide led the meeting and prepared these notes.

1. MANUSCRIPTS

A. Elasticity (Lead: Miguel Martinez). This manuscript describes a conceptual framework for integrating hurricane science across the Caribbean region through a formal research network. A model has been refined that normalizes hurricane impact by its influence on cover or biomass of dominant structural components of the ecosystem, which could be applied similarly to dry and wet forests, mangroves, or near-shore marine ecosystems. This impact index could be considered a driver of change in population number, species diversity or ecosystem function. The forms of these responses can then be examined across levels of organization, ecosystem types and histories represented by data available in the network in order to address factors controlling ecosystem vulnerability or resistance to disturbance. Participants committed to contributing to a manuscript providing examples that support this conceptual approach. A February target deadline for submission of materials to this manuscript. The outline is attached.

B. Conceptual Framework (Lead: Mike Willig). This manuscript addresses the question of how we would redirect future work on hurricanes and their effects based on the state of our present knowledge. During the past 10 years, frequent hurricanes/tropical storms have affected all countries in the Caribbean with significant economic consequences. Site- and network-based ecological research needs to align with both basic scientific and public need for understanding, and where possible,
mitigating the impact of hurricanes on natural and built infrastructure. However, most studies on hurricanes are opportunistic and focus on a few variables related as response of a single hurricane. They are typically uncoordinated with each other in terms of the identity of the variables and the scales at which they are measured. In addition, studies tend to focus on hurricane events as defined in terms of wind-power/barometric pressure on the Saffir-Simpson scale. However, the effects of precipitation associated with hurricanes may be more significant than the effects from wind, and therefore new characterizations of hurricane events need to be developed that incorporate wind speed, storm surge, and precipitation to appropriately measure the intensity, frequency, and extent of disturbances. Because of the importance of precipitation events leading to catastrophic flooding, the effects that hurricanes have on ecosystems go far beyond the impacts associated with direct hits. Consequently, the domain of study should encompass broader temporal and geographical scales. To understand the consequences of these disturbances, we must incorporate socio-economic feedbacks. We suggest that to appropriately manage ecosystems, the full array of hurricanes effects at different time and geographical scales should be considered. This is impossible to achieve based on isolated and uncoordinated studies scattered across sites. Therefore, we need an integrated network of sites and scientists studying the long-term multi-scale effects of hurricanes. Participants committed to contributing to a manuscript providing examples that support this conceptual approach. A February target deadline for submission of materials to this manuscript. The outline is attached.

C. Cross-Site Comparisons (Lead: Victor Rivera-Monroy). Several team efforts are underway to design hurricane research efforts in a common framework across North and Central America. Victor outlined two multi-authored research papers that (1) integrate existing findings across sites, and (2) suggest pathways forward to implementing hurricane science in a common framework across the US/Mex-LTER networks.

D. Literature Review (Lead: Robert Waide). Movement forward toward a formal literature review was discussed. Each participant offered a particular area of expertise that could be brought to a review manuscript. It was unclear how this manuscript would differ from existing reviews on hurricane impacts, although it was noted that the multi-disciplinary nature of a multiple-authored publication on the topic would probably be novel. The current bibliography will be posted to the website for updating, and this review will either become a manuscript or the introduction to a network proposal.

2. GOVERNANCE

On the second day of the meeting, break-out groups were designated to discuss ways to formalize the research network by developing ‘governance’ in the following areas: Planning and Visioning, Publicity and Outreach, Opportunities and Future Meetings.

A. Planning and Visioning (Lead: Mike Willig)
**Vision Statement:** To reduce uncertainty in an era of climate change from a biophysical and socioecological perspective, thereby advancing health, prosperity, and sustainability in the region.

**Mission Statement:** To advance understanding of the ways in which geographic, environmental, and socioeconomic factors affect resistance and resilience of socioecological systems to hurricane disturbance in the Greater Caribbean Region by creating a network of sites and multidisciplinary collaborators dedicated to integrated research and education.

**Ad Hoc Governance**
Leadership/Board/Steering Committee
(Alan, Evelyn, Maria, Victor, Marina, Manuel Maass)

**Functional Groups**
A. Funding Committee
B. Communication Committee (WWW, newsletter)
C. Liaising & Connecting (Multidisciplinary) Committee
D. Education Committee
   1) Undergraduate
   2) Graduate
   3) Post-doctoral Fellows
E. “Young Scientists” Committee
F. Cross-site Exchange of Scientists Committee
G. Policy, Management, & Conservation Committee
H. Information Management, Use Policy, and Cyberinfrastructure Committee

**B. Publicity and Outreach (Lead: Jennifer Holm).**

- Publicity:
  - Creation of website (further development of existing websites) to publicize network.
  - Manuscripts (getting all us to come on board to write papers that fall in the two conceptual models).
  - Handout pamphlet
    - Define a “mission statement” (from the planning committee group) or goals of a network in a small piece of literature/handout
    - Hand out at meetings and conferences (AGU/ESA).
    - Pamphlet – UConn/Mike can create for free.
  - Recruitment (done by steering committee)
  - Blogger Radio? – Alan Covich
  - Network Directory = Mike and Skip – will help make a directory of network members; including picture, contact info, statement of research background and interest. UConn. Money? Blogger can do this.

- Outreach
  - Short courses??
  - Create clear resources and opportunities that we can lend to researchers who do similar work – so let other researchers know that they can use our conceptual models as a framework to analyze their data.
  - Post-review paper; deliver our network’s results on understanding about hurricane’s affects to “stakeholders” who are subject to hurricane’s influences.
• Governments, state agencies, NGOs, farmers, park managers?
• Help local communities respond to natural disasters – which can be mediated by MEX LTER, LUQ LTER?
• Make workshops to teach stakeholders.
• Generate a map of what we do and where we are – Marie/Columbia (Lamont). Used by policy makers, maps of vulnerability.
  o Creation of image database and site maps.
  • Gather images from the group.
  • Archive of photos
  • What are the visuals that we still NEED. Get a map of interest. Visual for reef to ridge.
  • Maps = vulnerability maps, site maps.
• Network Name & Logo = we need to focus on geographically location.
  o CHURN, HARM
  o North Atlantic
  o Non geographical, hurricane is just Atlantic, non hurricane name?
  o Where is climate change going to effect storms?
  o Principle focus on Atlantic Storms
  o Restrict to the Americas
  o Put ALL these things up on a survey.
  o IT LTER (International tropical storm long term ecological research)

C. Opportunities (Lead: Maria Uriarte)

The group plans to pursue several potential sources of funding for the network.

Research Coordination Network Proposal to NSF

Intellectual goals. The group will proceed to build a hurricane network in phases. In the first phase the focus will be in coordinating research from “ridge to reef” by engaging expertise from scientists working in terrestrial (e.g., forests), coastal (e.g., wetlands), and marine systems. A second goal in this phase will be to explicitly incorporate a socioeconomic component, with a strong emphasis on the importance of land use in mediating dynamic interactions between social and ecological systems. In the second phase the group will aim to attract engineers and hydrologists. This focus may facilitate funding by appealing to a number of directorates within NSF (e.g., DEB, SBE, GEO).

Geographical area. Initially the group will focus on the Caribbean basin. Eventually, we plan to engage groups working in TC in other regions.

Recruitment and outreach. The group will reach out to potential participants in different career stages via professional societies (e.g., ESA, IALE, AGU, Geography), NEON working groups, listservs, and a number of other media. New participants will be incorporated by conducting group activities such as group data analyses, manuscript preparation, symposia at professional meetings, and public presentations.

Responsibilities: J. K. Zimmerman, L. Schneider, M. Uriarte, E. Gaiser, R. Waide will coordinate proposal development with input from the group.
**Foundations.** There was some discussion about foundations that may be willing to support our network. Some participants believed that we could make the network attractive to foundations by pitching the proposal in a REDD framework or by emphasizing the socio-ecological components of the research framework.

**Responsibility:** L. Schneider will contact the Moore Foundation to assess whether there is interest.

**International organizations.** The socio-ecological aspects of the research network may be of interest to the World Bank or UNDP.

**Responsibilities:** M. Willig will explore the WB option

**D. Future Meetings (Lead: Miguel Martinez-Ramos)**

Find a major theme for each meeting. For example: **Integrating human and ecological dimensions to understand socio-ecological hurricane impacts**

1. Establish the state of the art,
2. Present experiences (aims, approaches, methods, systems)
3. Discuss challenges, gaps, opportunities, uncertainties.
4. Explore new perspectives and research directions

**Products**

1. Synthesis paper, and or special issue in a Journal based on contributing papers or book with chapters
2. Collaborative research, training, and outreach programs on socio-ecological issues with an interdisciplinary perspective

**Mechanics**

Symposium, working groups, and plenary sessions

**Venue possibilities**

ESA meeting. August 2010

SCME meeting. November 2010

Morelia (UNAM Campus). Fall 2010 or summer 2011

**Places with different hurricane histories**

Different ecosystem types

Different landscapes contexts

Different socio-economical contexts

Ecologists and social scientists
What we want to research?

Ecological x Social interactive effects on socio-ecosystems?

Comparative, multi-site, approach

Context: local to regional

Response variables

Ecological

Social

Ecosystem attributes and functions related to ecosystem services
CONCEPTUAL FRAMEWORK MANUSCRIPT

LEAD: MIKE WILLIG

Title: “A new agenda to advance the study of hurricane disturbance in the Americas”

Goal: To orient a new research agenda and culture of collaboration concerning hurricane research

INTRODUCTION (Mike and Bob)

1. Disturbance as a paradigm … importance of understanding infrequent high intensity storms from biophysical and socioeconomic perspectives. Make the climate change connection.

2. Greater Caribbean is an area supporting hurricane-mediated systems and is a hot spot of biodiversity that includes multiple nations with different socioeconomic systems and standards of living.

3. Current understanding of ecosystem dynamics through the long-term, in systems that span the gradient from fully built (e.g., cities) to lightly managed, requires consideration of a fully amplified domain of investigation that comprises an integrated coast (reef) to terrestrial system (i.e., “Landscape / seascape / Peoplescape” --- reef to ridge).

   A. Multiple scales (cross scale) investigation

   B. Bidirectional impacts

   C. Ecosystem Services

4. The intensity of hurricanes should include consideration of factors beyond wind speed and energy (e.g., Saffir-Simpson Index), such as precipitation and surge. (Incorporation of remote technologies such as Modis/Disturbance Index; network of buoys). This will effectively produce a multidimensional classification of disturbance regimes and the domain of investigation.

5. A synoptic network of sites and multidisciplinary collaborators is needed to advance understanding of the ways in which geographic, environmental, and socioeconomic factors affect resistance and resilience of socioecological systems to hurricane disturbance in the Greater Caribbean.

RESULTS (and DISCUSSION)

1. Illustrative examples from site-based case studies (apply the concepts [above] to particular instances)

   A. Katrina--Mississippi Watershed & NOLA (Victor & Loretta)
B. Mitch – Honduras (Don)

C. Hugo -- Puerto Rico (Jess & Skip)

2. Illustrative example(s) of a longitudinal study that traces the spatial trajectory of a hurricane over time to illustrate its changing intensity and severity -- Georges (Skip & Marianna)

SYNTHETIC DISCUSSION

(Overarching points to consider after "Results" and to "prime” content of results)

• Reference early in the Discussion Section, the summary and review work on hurricanes in the Caribbean (e.g., Biotropica Special Features) and include reference to our "on-line bibliography".

• Comparison of case studies (unique and general elements) from biophysical and socioeconomic perspectives.

• Identification of lacunae in understanding.

• Utility of the socioeconomic gradient (or environmental or geographic) to understand resistance and resilience.

• What do we learn about disturbance based on a multisite comparison?

• Attributes of a Synoptic network of sites and collaborator

A. Produce a common geospatial and socioeconomic framework

B. Similar phenomena (ideal list)

C. Similar spatiotemporal foci at multiple scales (ideal list)

D. Comparative basis for resistance and resilience (Miguel’s manuscript) in the long-term

• Comparison of Human versus “Biophysical” responses

• Ecosystems services link biophysical systems to human systems = socioecological systems

• Multiple scales of effects and responses

• Evaluate if socioeconomic context of the “domain” determines the extent to which biophysical systems and human systems are “coupled”, resistant, and resilient

• Role of residuals and legacies

• “Natural experiments” to quantify the re-assembly of structure and function of socioeconomically systems
• How have hurricanes altered the delivery of ecosystem services?

• Major state changes in components of the socioecological system as a result of hurricane-induced disturbance

• Considerations of hazard research in each case study (Maria Uriarte and Luciana Porter)

**TIMELINE**

1ST DRAFT OF SECTIONS (NOT SYNTHETIC DISCUSSION) TO MRW BY 1 JAN

MRW TO CONCATENATE AND EDIT "FIRST DRAFT", AND REDISTRIBUTE BY 3 JAN

TELECONFERENCE OF LEADERS BY JAN 8 TO FORMULATE DISCUSSION

EDITS BACK TO MRW ON "FIRST DRAFT" BY 13 JAN

MRW TO COMBINE "FIRST DRAFT" WITH EMERGING DISCUSSION, AND REDISTRIBUTE BY 15 JAN (= SECOND DRAFT)

COMMENTS ON SECOND DRAFT BACK TO MRW BY 21 JAN

MRW TO EDIT AND SYNTHESIZE COMMENTS AND RETURN THRID DRAFT TO ENTIRE GROUP BY 28 JAN.

FINAL COMMENTS FROM ALL TO MRW BY FEB 7

MRW TO SYNTHESIZE AND SUBMIT TO JOURNAL FOR CONSIDERATION BY 15 FEB
I. Introduction

• Hurricanes are one of the major disturbance agents affecting both terrestrial and aquatic ecosystems.

• Hurricanes are growing in importance (socio-ecological effects) because prognostics indicating that hurricanes will increase in frequency and intensity under present global warming scenarios. BE CAREFUL WITH THIS

• There is a growing research work on ecological impacts of hurricanes, especially in the Caribbean area (Pacific and GOM), encompassing a wide array of organisms, ecosystems (both aquatic and terrestrial) and approaches (demographic, community and ecosystem ones).

• However, the research effort has been conducted without having a comprehensive theoretical/conceptual framework conducting to detect general patterns on hurricane effects across different ecological levels (from organisms to populations, to communities to ecosystems), different ecosystems (e.g., aquatic and terrestrial), and different organisms (invertebrates, vertebrates, different plant growth forms).

• Here, we develop one of such a conceptual framework. We illustrate the utility of the framework developing an SUCH AS elasticity analysis (i.e., the relative change in the recovery rate of the system –population, community, ecosystem- due to a relative change in hurricane disturbance magnitude) and applied it to exemplary study cases.* The framework can be used to approach basic (ecological theory, designing experimental and empirical studies) and applied issues (conservation, ecosystem functions, and human-ecosystem interactions –socioecosystems). [make sure socioecological issues are at the forefront – that impacts are across ecological and built gradients]

*Some examples of elasticity analysis – from economics to hydrology (importance of standardizing currency or relativizing across social and ecological disciplines). Perhaps this is one of many tools (does not apply to interactive systems). Cite context for elasticity analysis. Highlight emergent properties.

Mention that Network exists

Landscape context

Temporal context?

Relating potential ecosystem services impact at different levels of biological hierarchy
**Hypotheses/Questions:**

II. **The conceptual model**

**Figure 1** illustrates possibilities in the ecological effects produced by hurricanes on the target system: reduction of the response variable of the system (demographic, community, ecosystem) and increase of the response variable. The model considers a previous state value of the system (P), measured by a respond variable (demographic, community, ecosystem), which is changed to a new value due to hurricane disturbance ($A_o$). After a time interval ($t_0$-$t_1$), the system may change to a new recovery or degraded value ($A_t$).

Here we will illustrate with real examples the application of the conceptual model for population, community (may need multivariate index value) and ecosystem cases (including ecosystem services examples)

Recovery trajectories can be non linear. For example, a concave function may result if recovery is very low after disturbance and accelerate as time pass (put here a real example); if recovery is very fast after disturbance and the rate of recovery decline as time passes the function could by convex-like (**Figure 2**). Examples?

What landscape features influence the shape of recovery/resilience? Interactions with other disturbances.

III. **Elasticity analysis**

Based on these simple parameters, we constructed a elasticity index that assess the relative change in recovery rate due to a relative change in hurricane disturbance magnitude. First we define hurricane disturbance magnitude (M) as $P - A_o$, i.e., the absolute change in the RV value caused by a hurricane disturbance. Second, we define the absolute rate of recovery (R) as $(A_t - A_o)/(t_0-t_1)$, i.e., the absolute change in the RV value within a time interval after hurricane occurrence. Then, we define a relative magnitude disturbance index (RM) as $M/P$ and a relative recovery rate index (RR) as $R/M$.

$RV =$ Response variable of the system (demographic, community, ecosystem variable)

$P =$ value of the response variable of the system before hurricane occurrence.

$A_o =$ value of the response variable just after the hurricane disturbance.

$A_t =$ value of the response variable a time interval after hurricane disturbance.

1. Hurricane disturbance magnitude, $M = P - A_o$
2. Recovery of the system, $R = (A_t - A_o)/(t_0-t_1)$
3. Relative magnitude of the hurricane disturbance, $RM = M/P$
4. Relative recovery rate of the system, \( \text{RR} = \frac{R}{M} \)

Difficult to apply to communities and perhaps other attributes of change – one of many potential tools. Different forest types or localities within an ecosystem may respond very differently. Response may depend on history, particularly prior events.

Geomorphology matters – may need to define gradient of settings and potential vulnerabilities.

Shifting baseline in the face of climate change!

Measurement to indicate lack of return to pre-existing conditions. Trajectories rather than recovery.

Use analytical tool to illustrate complexity

Audience – target journal?

Use one example to use approach across sites – perhaps litterfall is a good example because the data exist across sites and it is a good metric of effect.

Figure 3 shows idealistic relationships between RR vs RM. The slope of these relationships indicates the elasticity of the RV.

IV. Applications. Basic and applied issues.

It could be nice to have study cases comparing effects at population, community, ecosystem levels. Also, we can use cases at the same ecological level for organisms differing in life-histories, growth-forms, and or contrasting ecosystems using same ecological level.

Need to account for lags in both X and Y.

V. Scaling the model from a local to a landscape perspective.
$P = (P_0 - A_0) \text{ } R = (A_1 - A_0)$

Hurricane disturbance
Tim Hurricane disturbance

\[ A_0 \]

\[ A_1 \]

\[ P \]

\[ T_0 \]

\[ T_1 \]

\[ R \]
MODELOS PREDICTIVOS DE DISTRIBUCIÓN ESPACIAL DE ESPECIES Y COMUNIDADES

Fig. 6. Examples of response curves for different statistical approaches used to model distribution of plants and vegetation: (a) Generalized linear model with second order polynomial terms; (b) generalized additive model with smoothed spline functions; (c) classification tree; (d) environmental envelope of the BIOCLIM type; (e) canonical correspondence analysis; (f) Bayesian modeling according to Aparicio (1992). $p_p$ = posterior probability of presence of the modeled species, $p_{pp}$ = a priori probability of presence, $p_a$ = a priori probability of absence, $p_{pa}$ = product of conditional probability of presence of the various predictor classes, $p_{ap}$ = product of conditional probability of absence of the various predictor classes.
Fig. 7. Predicted maps representing (a) the probability of occurrence of a species (Spruce Mountains, Nevada; see Guisan et al., 1999), (b) the distribution of most probable abundance values of a species at each pixel (Bolgen area, Swiss Alps; from Guisan, 1997), (c) the potential distribution of a species based on a non-probabilistic metric (CART) (Shoshone National Forest, Wyoming; Zimmermann, N.E. and Roberts, D.W., unpublished data) and (d) the most probable entity (vegetation map; Pays d’En-Haut; Swiss Alps; from Zimmermann, 1996; the legend numbers represent vegetation types).
Hurricanes in context of other disturbances in terms of impact on both natural and social systems – Alan

Effect of species richness in response to hurricanes of different kinds - Bob

How landscape influences the impacts of hurricanes – Laura

Scaling issues, modeling issues - Maria

Deep history of hurricanes - Emily

Resistance and resilience at the community level – Mike

Role of residuals (materials remaining from hurricanes) – Mike

Linking long time series to predict long term patterns – Rodrigo

Long term or paleoecological cyclical patterns - Evelyn

Risk assessment in human decision making (modeling) - Hugh

Climatology of hurricanes – Bruce

Cross-disciplinary experiences in perceiving and measuring impacts of hurricanes - Jess

Interactions of hurricanes and climate change (particularly sea level rise) – Loretta

Importance of experimental work in discerning effects of hurricanes -Loretta

Hydrology of hurricanes – rainfall, floods - Tom

Different attributes of hurricanes – multidimensional stressors – Mike

Ecosystem services – Mike

Use of simulation modeling to predict hurricane effects - Jennifer

Interactions of hurricanes with other disturbances (particularly human disturbance) – Luciana

Connecting services to policy – Luciana

Response vs. recovery (trajectory vs. recovery) – Mike

Use of IPCC models in projecting hurricane impacts - Victor

Geographical distribution of hurricanes over 100 years - Jorge