Creating a More Disaster Resilient America (CAMRA): The Findings from a Workshop on a New Cross-Directorate Program on Disaster Resilience, Vulnerability, and Risk Reduction[1]

28 October 2011

[1] This report and the workshop reported on herein were supported by a grant from the National Science Foundation (SES-1137255), Walter Gillis Peacock, Gregory Tripoli, and Sharon L. Wood PIs. Any opinions, findings, and conclusions or recommendations expressed in this report are those of the authors and do not necessarily reflect the views of the National Science Foundation.

PIs and Steering Committee:

Walter Gillis Peacock, Texas A & M University

Sharon L. Wood, University of Texas

Gregory Tripoli, University of Wisconsin

Phillip R. Berke, University of North Carolina

Susan L. Cutter, University of South Carolina

Bruce F. Houghton, University of Hawaii

Ahsan Kareem, University of Notre Dame

Anne S. Kiremidjian, Stanford University

Workshop Participants

Thomas Birkland, North Carolina State University

Thomas Bogdan, Space Weather Prediction Center

Harold Brooks, NOAA

Michel Bruneau, SUNY-Buffalo

Robert Chen, Columbia University

Shuyi Chen, University of Miami

Rachel Davidson, University of Delaware

Ronald Eguchi, ImageCat

John Eichelberger, USGS

Nicholas Flores, University of Colorado

Fausto Guzzetti, CNR/IPR, Italy

Terri Hogue, University of California Los Angles

Carolyn Kousky, Resources for the Future

Tracy Kiuewski-Correa, University of Notre Dame

Forrest Masters, University of Florida

Kishor Mehta, Texas Tech University

Michael Lindell, Texas A&M University

Richard Luettich, University of North Carolina

Mel Shapiro, UCAR

Jane Southworth, University of Florida

Dorothy Reed, University of Washington

Kathleen Tierney, University of Colorado

William Wallace, Rensselaer

Creating a More Disaster Resilient America (CAMRA): Findings from a Workshop on a New Cross-Directorate Program on Disaster Resilience, Vulnerability, and Risk Reduction

With almost every new major natural disaster event, the United States sets yet another new record for disaster losses. This pattern of ever-rising losses mimics a much more dramatic trend seen worldwide. In contrast to global trends, however, the United States has taken solace in declining loss of life associated with natural disasters. Unfortunately, Hurricane Katrina and the associated staggering loss of life has reminded us how tenuous the trend of declining loss of life might be considered.

The reasons for escalating trends in losses in the United States and globally are complex and numerous. A primary factor shaping these trends is the ever-increasing concentration of human populations and infrastructure in highly vulnerable areas. Not only have more people been settling in hazardous areas, their expansion is often coupled with the destruction of important environmental resources like wetland that provide ecosystem services they that may mitigate losses. We are still far too dependent upon and quick to choose short-term technological fixes such as levees, seawalls, and beach re-nourishment programs that themselves can have environmentally-detrimental consequences for our increasingly vulnerable communities.

When a disaster occurs, we are often faced with losses far exceeding the capacity of local communities or regions; hence, massive infusions of public and private resources from outside the area are needed to meet response and recovery needs. Further recovery is often uneven and likely to exacerbate preexisting vulnerabilities. In short, the picture emerging within our own nation and across the globe is one of communities becoming ever more *vulnerable* to natural hazards, at greater *risk* to disasters, and less disaster *resilient*.

Patterns of greater vulnerability and risk, coupled with lower levels of disaster resilience are occurring against a backdrop of numerous significant scientific advances in engineering as well as advances in the broader physical and social sciences that address natural as well as technological disasters. Too often these scientific advances occur within disciplinary silos despite increasing scientific awareness that disasters must be understood as a product of the complex interaction among biophysical systems, human social systems, and their built environments. While disciplinary advances are important and needed for scientific future advancements, there remains a need for addressing complex and inherently multi-disciplinary issues associated with natural disasters to reduce disaster vulnerability and risk while enhancing resiliency. This need is precisely what is being considered by three directorates – Engineering, Geosciences and Social, Behavioral and Economic Sciences [SBE] – within the National Science Foundation. The proposal considers a new multi-disciplinary program focusing on Disaster Resilience, Vulnerability, and Risk Reduction. Specifically, these directorates propose an innovative program that will advance our knowledge of the processes of and interdependences between natural and social systems and the built environment as they relate to specific natural and technological hazards. The goal of this proposed program is to ***C***reate ***a M***ore ***R***esilient ***A***merica; hence, the name ***CaMRA***.

I. Toward a Disaster Resilience, Vulnerability and Risk Reduction Program.

The call for a new interdisciplinary program focusing on disaster resilience, vulnerability, and risk reduction is consistent with a host of recent events and publications calling for a more comprehensive approach to disaster and hazards related research. Some of these include:

1. The *Second Assessment*[2], which undertook an assessment of hazard and disaster research and research needs for addressing vulnerability and resiliency (Mileti 1999);
2. The *Grand Challenges for Disaster Reduction* produced by the Subcommittee on Disaster Reduction, which sought to assess priority science needs for stimulating community resilience and reducing vulnerability;
3. 'The National Research Council's assessment of research funded by the NSF as part of the National Earthquake Hazards Reduction Program (NEHRP) entitled, *Facing Hazards and Disasters* (NRC 2006), which not only assessed the nature of the research funded, but outlined future research needs;
4. The National Science Board's efforts to identify hurricane science research needs and culminated in the a proposed *National Hurricane Research Initiative* (NSB 2007);
5. The *Rising to the Challenge* report that, among many issues, focused on the critical failures to integrate social science research into the existing national environmental observatories (Vjajjhala, Krupnick, McCormick, Grove, McDowell, Redman, Shabman, Small 2007);
6. NOAA's efforts to develop a social science research agenda supporting the physical science associated with hurricane forecast and warning (Gladwin, Lazo, Morrow, Peacock and Willoughby 2007 and 2009);
7. USGS's efforts to identify our nation's needs for natural hazard risk reduction and management (Shapiro, Bernknopf, and Wachter 2007)[3];
8. The findings of a USGS and NSF supported workshop calling for the creation of a *National Resiliency and Vulnerability Observatory Network (RAVON)* to address resiliency and vulnerability science needs (Peacock, Kunreuther, Hook, Cutter, Chang, and Berke 2008);
9. The *National Earthquake Resilience* (NRC 2011a) report that called for the creation of an observatory network on community resilience and vulnerability;
10. The *Grand Challenges in Earthquake Engineering Research* (NRC 2011b) report which called for the development of a community resilience framework linking interdisciplinary approaches and a community resilience observatory;
11. A recent report on a SBE workshop focusing on observatories in the social science (Moran, Entwisle and Brown, 2011).

These reports call for new approaches to address disasters, viewing them not as acute, short-term episodic events, but rather as events which evolve and emerge from long-term chronic issues. Such issues demand a comprehensive approach focusing on *natural hazard vulnerability, risk reduction and disaster resiliency*. While some reports addressed disciplinary science needs, most, if not all, recognized a need for interdisciplinary research. Indeed, a number suggested that it is only through the promotion of innovative, integrative, and transformative interdisciplinary science that we as a nation can hope to change the roles human/social systems are playing in increasing vulnerability and reducing resiliency to hazards and disasters. The seemingly intractable and complex nature of these issues demands a comprehensive multidisciplinary approach.

Three of the most recent reports further stressed the need to transform the nature of how vulnerability and resiliency science is undertaken. They explicitly promote the establishment of an observatory network allowing long-term data collection activities that are vital for monitoring and modeling the dynamics and processes shaping the evolution of resilience and measures to reduce vulnerability to hazards and disasters

[2] *Disasters by Design* (Mileti 1999), summarizes the findings from the *Second Assessment* of hazard research in the United States. Accompanying volumes in support of its arguments include: *Paying the Price* (Kunreuther and Roth Sr. 1998), *Cooperating with Nature* (Burby 1998), *Facing the Unexpected* (Tierney, Lindell, and Perry 2001), and *American Hazardscapes* (Cutter 2003).

[3] For two additionally useful USGS publications see references for: USGS 2007 and McMahon, Benjamin, Clarke, Findley, Fisher, Graft, Gundersen, Jones, Loveland, Roth, Usery, and Wood. 2005.

(Peacock et al 2008; NRC 2011a & 2011b). Just as ongoing national observatories focused on environmental sciences have been created to monitor change over time and explicit need for long-term observatories addressing disaster resilience and vulnerability is recognized. The call for observatories of this nature is consistent with the findings of the recent Social, Behavioral and Economic (SBE) workshop recognizing observatories as a viable and promising approach for a promoting scientific development related to a number issues. These issues included both *sustainable cities* and the study of *resiliency and vulnerability of socioecological systems* (Moran, Entwisle and Brown 2011). Furthermore, the SBE observatories workshop report suggests exploring both place-based and thematic observatories, a finding that echoes conclusions from the RAVON workshop report (Peacock et al., 2008) and is consistent with conclusions discussed below.

2.0. The Workshop and its Charge.

It is against this backdrop that a *Workshop for a Cross Disciplinary Program for Disaster Resilience, Vulnerability, and Risk Reduction* was funded by the Engineering, Geosciences, and Social, Behavioral, and Economic Sciences directorates. The workshop was held at the National Science Foundation over a two day period in June, 2011, and gathered together over 30 leading scientists and researchers whose work focuses on natural disasters and hazards from the broader social, physical and engineering disciplines as representatives of the types of research generally funded by each directorate. The charge to workshop was to develop a framework for this new interdisciplinary program by exploring interdisciplinary opportunities that should be targeted, disciplinary research questions that might enhance interdisciplinary research and address key constraints for interdisciplinary research. Exploration of these topics was facilitated by a set of “white-paper” presentations by representatives from each disciplinary area addressing each of these questions for the topics of resilience, vulnerability, and risk reduction.[4] In the final analysis the workshop called for the creation of an observatory network of “collaboratories,” provided recommendations for how such a network might evolve, and made recommendations for data collection and sharing by the network. The following provides a summary of the major findings and recommendations of the workshop, beginning with a brief discussion of some of the constraints.

3.0 Constraints to Interdisciplinary Research on Resiliency, Vulnerability and Risk Reduction

Workshop participants identified a number of constraints to the development of a comprehensive inter- and multi-disciplinary research on disaster resilience, vulnerability, and risk reduction. In this section, we identify limitations that will need to be addressed for research and knowledge related to hazards and disasters to advance.

Current funding tends to be disciplinarily-focused. The simple fact that the National Science Foundation has disciplinarily-focused directorates that generally attend to science- based needs within these areas assures that much of the funded research tends to be more or less disciplinary in nature. This, of course, is critical and to be expected, because much of science is and should be disciplinarily-focused; but, this disciplinary focus can limit the funding possibilities for undertaking important multi-disciplinary research. The focus on disciplinarily-based research can have the unintended consequence of limiting the development of a common vocabulary across disciplines which limits conceptual and theoretical development of interdisciplinary perspectives and ultimately limits integrative transformative model development. These limitations were evident during the white paper presentations on resilience, vulnerability, and risk reduction offered by sets of representatives from each disciplinary area. While there certainly were commonalities in vocabulary, there were also considerable variations. At times inconsistencies in meaning and approaches were evident across disciplines, making manifest the need to undertake integrative multidisciplinary approaches.

[4] All white paper presentations can be found at: http://archone.tamu.edu/drvrr

Current funding mechanisms almost exclusively support one-shot case studies of limited duration. Cross-section case studies preclude long-term data collection activities which are necessary not only for the monitoring of change in resiliency and vulnerability, but more importantly for the development of models of complex system dynamics and change over time. An allied issue emerging all too often from these short-term one shot case studies of disaster events is the failure of these independent studies to replicate measurement protocols of common concepts. Such a failure severely limits comparability across data collection efforts and hazard phenomena inhibiting the progressive pursuit of scientific knowledge.

Poor coordination of the many independent data collection programs in the public and private sectors. Many data resources are collected by public and private sector entities that could provide needed data for understanding land use change and associated evolution of vulnerability, for example. These data are simply lost to the scientific community because most researchers have neither the time nor the resources necessary to compile, systemize, process, and develop these data for scientific efforts. A classic example is the often-recognized need to develop land parcel and associated building inventory databases (NAS 2007). These can be fundamental for understanding and modeling land-use change, environmental impacts of the built environment, and natural hazard vulnerability of the built environment. Similarly, the general lack of a mechanism to compile, inventory, and access data collected via normal funding of short-term research projects also constrains data sharing among researchers and use by practitioners.

A failure to capture the full complexity of coupled systems. Finally, a number of workshop participants noted that most studies offer only limited and partial views of place. More specifically, there is a general failure by the research community to capture the full complexity of coupled socio-ecological systems when addressing disaster resilience and vulnerabilities. As noted above, the scientific consensus is that disasters can only be understood as a phenomena emerging from the complex interactions among the network of physical and social systems and the built environment. To develop a complete understanding of resilience and vulnerability demands a more comprehensive place-based perspective on coupled socio-ecological systems. This finding again pushes for long-term, comprehensive place-based data collection activities demanding an integrated, multidisciplinary approach.

4.0. Toward a Framework for CaMRA: A Cross-Directorate Program on Disaster Resilience, Vulnerability, and Risk Reduction.[5]

The following sections outline the principle parameters that workshop participants held as being important for the establishment of a cross-directorate program on disaster resilience, vulnerability, and risk reduction. Many if not most of these parameters stem from the constraints identified by workshop participants.

4.1The program should focus on natural and technological hazards.

In the aftermath of 9-11 and the establishment of the Department of Homeland Security, the federal government has invested extensively in its university-based centers of excellence to conduct research focusing on deliberate or willful acts of terrorism. This program should not redundantly address these issues. Rather, the focus of this program should be the intersections between the realms of geosciences, engineering and SBE sciences. Natural hazards and disasters constitute a major threat to U.S. population and our nation’s communities and economy; hence, there is a demand for concerted research efforts to address and reduce vulnerabilities and enhance resiliency. Consequently, communication between the DHS centers of excellence and CaMRA should lead to concerted actions.

---

[5] It should be noted that many of the workshop conclusions parallel those of the RAVON workshop hence these discussions draw heavily from and paraphrase Peacock et al., 2008, pages 4-6.

4.2 The program must focus on interdisciplinary research.

Hazard vulnerability, disaster resiliency, and risk reduction demands research involving the interactions and interdependencies among human social systems, their built environments and physical systems, hence the need for interdisciplinary research is self-evident. Indeed, the National Science Foundation has through a variety of initiatives, such as its Coupled-Natural and Human (CNH) systems and Human and Social Dynamics (HSD) programs, sought to directly fund interdisciplinary research. A recent assessment of the need to integrate social sciences into existing NSF environmental observatories calls for focusing on not simply funding social science research, but stimulating interdisciplinary environmental research (Vjajjhala et al 2007). Here, workshop participants are directly calling the integration of physical, social, and engineering sciences.

It is also important to acknowledge the findings of the National Research Council (2006) assessment related to interdisciplinary research funded by NSF through the NEHRP program. This assessment devoted considerable space to interdisciplinary hazard and disaster research, noting that in their later years, the earthquake engineering research centers (EERCs) did indeed facilitate, foster, and support interdisciplinary research (NRC 2006: 200-12). This success suggests that "NSF should institute mechanisms to sustain the momentum that has been achieved in interdisciplinary hazards and disaster research" (NRC 2006:212). It also notes that one of the difficulties in establishing interdisciplinary research for the EERCs was that they initially were more focused on engineering research, and only with extensive prodding began to incorporate social sciences into their agendas. Similarly, as noted above, the environmental observatories have been slow to integrate social sciences in their on-going research initiatives, despite the NRC's *Grand Challenges in Environmental Science* report which identified eight themes which all demand the incorporation of the social sciences (NRC 2001). The workshop, therefore, recommends that from its inception, CaMRA must promote truly integrative interdisciplinary research as a fundamental dimension of its research agenda.

4.3 The program should stimulate comparative hazard research.

The NRC's (2006:6) recommends that "[c]omparative research should be conducted to refine and measure core components…" related to vulnerability, resilience, and risk. The report made this recommendation because the much of research funding under NEHRP through NSF primarily focused on earthquakes. Thus, the call was for promoting comparative multi-hazard research on such core concepts as mitigation, preparedness, response and recovery. Very real and substantive differences, particularly from a physical science perspective, exist when attempting to model and understand natural hazards. However, when seeking to understand the dynamics of resilience, vulnerability, and risk for coupled socio-ecological systems, there will also be important dimensions that can undoubtedly benefit from comparative research across hazards. Indeed, it should be noted that hazards and not disasters per se, should be the focus of this new program.

In the context of a cross-directorate program on vulnerability and disaster resilience and risk reduction, the notion of comparative research must also be expanded across a variety of dimensions including socio-political and regional. For example, the regulatory environments can vary considerably across states when it comes to building codes and insurance. It is important to examine the differing roles insurance, insurance markets, and building codes/standards can play in stimulating mitigation and risk reduction. Furthermore, jurisdictions such as counties and cities vary considerably across states in terms of their legal abilities to promulgate land use and building code regulations and policies. In Florida, for example, counties and cities have considerable ability to engage in comprehensive planning, including instituting a great variety of land use regulations, while in Texas, these abilities are limited to municipalities. Hence, for many social science and engineering studies, comparative research will be critical for scientific advancement.

4.4 The program must facilitate long-term data collection activities.

The need for long-term data collection activities stems directly from the dynamic and changing nature of vulnerability, resilience, and risk. , Vulnerability is conceptualized as being a function of hazard exposure, often assessed in terms of the likelihood a hazard event of given magnitude and scope will strike a particular area, and most critically, the physical properties or characteristics of a the built environment that shape its susceptibility to damage due to hazard (NRC 2006:72-3). Risk takes vulnerability a step further in quantifying the probability of various levels of damage, although an important element of risk is perception, which can vary widely between the scientific community and the public. During the last two decades however, our notions of vulnerability have expanded beyond physical properties to include a social dimension as well. Social vulnerability is defined as the capacity of social systems to anticipate, cope, resist, and recover from disaster impacts (Blakie et al. 1994; Heinz Center 2000). This social dimension is a function of social structures and processes that determine access to scarce resources (e.g., income, wealth, social capital, and power), cultural factors, and driving forces such as urbanization and demographic change. The important point is that vulnerability and risk, especially risk perception, are not static, particularly when considering the distributional aspects across time and space/place. Rather, vulnerability and risk will change and evolve through time, given changes to the natural, built and social environment. Capturing and modeling these changes requires longitudinal data.

Disaster resilience is still emerging as a central concept in hazard and disaster research community, although its origins are generally attributed to work in ecology. Holling (1973) defined resilience as the ability of a system to absorb, change, and still persist.[6] A highly influential group in the ecological community, the *Resiliency Alliance*[7], has expanded upon this original definition to suggest that resilience is the ability of a system to resist or absorb an impact, organize itself to overcome or recover, and adapt or learn from the experience (Carpenter et al. 2001; Folke et al. 2002; Resilience Alliance 2007). This definition is based not on a simple notion of an eco-system, but rather focuses on complex socio-ecological systems. Ravon workshop's participants proposed the following working definition for resilience: the ability of social systems along with the bio-physical systems upon which they depend,[8] to resist or absorb the impacts of natural hazards, to rapidly recover from those impacts and to reduce future vulnerabilities through adaptive strategies[9] (Peacock et al., 2008:5). This definition explicitly expands our vision to include social systems, their built environments (see for example Bruneau et al., 2003 or Tiernery and Bruneau 2007) as well as the ecological systems or upon which they depend or operate within (Berke and Campanella 2006).

Creating a more disaster-resilient America requires a more complete understanding and modeling of resilience, vulnerability and risk in complex place-based socio-ecological systems. The resounding recommendation of the workshop participants was that this program must ensure long-term data

[6] See Walker, Gunderson, Kinzig, Folke, Carpenter, and Schultz 2006; Walker, Holling, Carpenter and Kinzig 2004, and Walker, Anderies, Kinzig, and Ryan 2006 for more recent applications to coupled socio-ecological systems.
[7] http://www.resalliance.org/1.php
[8] Another concept employed to characterize social systems and the systems composing their bio-physical (built and natural systems) environment is an ecological field (Bates (1997) and Bates and Pelanda 1994).
[9] Examples of other definitions can be found in: Mileti 1999; Berke and Campanella 2006; Buckle, Marsh, and Smale 2001; Bruneau, Chang, Eguchi, Lee, O'Rourke, Reinhorn, Schinozuka, Tierney, Wallace, and von Winterfeldt 2003; Godshalk 2003; Walter 2004; UN/ISDR 2005. It should be noted that some definitions, particularly those addressing hazards, focus more narrowly on social systems. Yet these systems are embedded and interactive with natural systems and are dependent on their physical environment. Hence, natural systems should not be ignored by hazard/disaster researchers.

collection activities. Participants proposed the establishment of a network of research sites or multidisciplinary observatories, termed *collaboratories*, to engage in long-term, systematic data collection in multiple locations to monitor vulnerability and resiliency. The development of longitudinal, systematically-collected databases will allow for the analysis and modeling of resiliency, vulnerability, and risk through time from a variety of disciplinary perspectives. Strategically locating collaboratories in regions subject to disasters can have the effect of pre-positioning the network to undertake a variety of post-event studies on a longitudinal basis critical for a fuller understanding of recovery processes. To facilitate longitudinal and comparative work however, such a network will demand the development of common measurement protocols, instruments, and data collection as well as the sharing of strategies to promote comparative research across locations. The structure of the network will be discussed further below.

5.0. Toward a research agenda:

As discussed above, a critical dimension of CaMRA's research agenda must be to clarify multi-disciplinary concepts. Resilience, vulnerability, and risk display a good deal of commonality both within and between disciplinary fields, but commonality is insufficient to sustain a comprehensive interdisciplinary research program. Therefore, conceptual and theoretical development of these concepts within a multi- and interdisciplinary research environment must be a primary goal of the research enterprise itself. These developments will be important building blocks of this program's success.

The ultimate agenda of this program will be to develop and model the complex interactions between and among coupled socio-ecological systems (bio-physical, social, and built environmental systems) in response to natural hazards. The goal is also to reduce vulnerability and risk and to enhance resilience to natural disasters using what is learned and optimizing outcomes through models. This all hinges on a research agenda focusing on the formation of a network of interdisciplinary collaboratories of researchers from the broader Geosciences (GEO), Social, Behavioral and Economic (SBE) Sciences, and Engineering (ENG) disciplines to develop and model facets of the complex interactions between and among coupled socio-ecological systems to reduce vulnerability and enhance the resilience and sustainability of coastal communities to natural disasters.

Figure 1 provides a conceptual model that outlines the broad contours for CaMRA's research agenda. Within each disciplinary sphere (Geoscience, SBE, and Engineering) there will be model development; yet ultimately these models will be combined to develop comprehensive interdependent models related to sustainability and broader socio-economic impacts of hazards/disasters. For example, there might be socio-economic models for land-use change which could be coupled with engineering models on infrastructure and the built environment, which in turn will be coupled with physical models assessing the ecosystem impacts related to gains and losses in ecosystem services due to development and hazard vulnerabilities. These modifications in ecosystem services, like losses in flood mitigation services provided by wetlands, can in turn have consequences for potential physical hazard impacts on the built environment which will again feed back to potential socioeconomic disruptions from flooding.

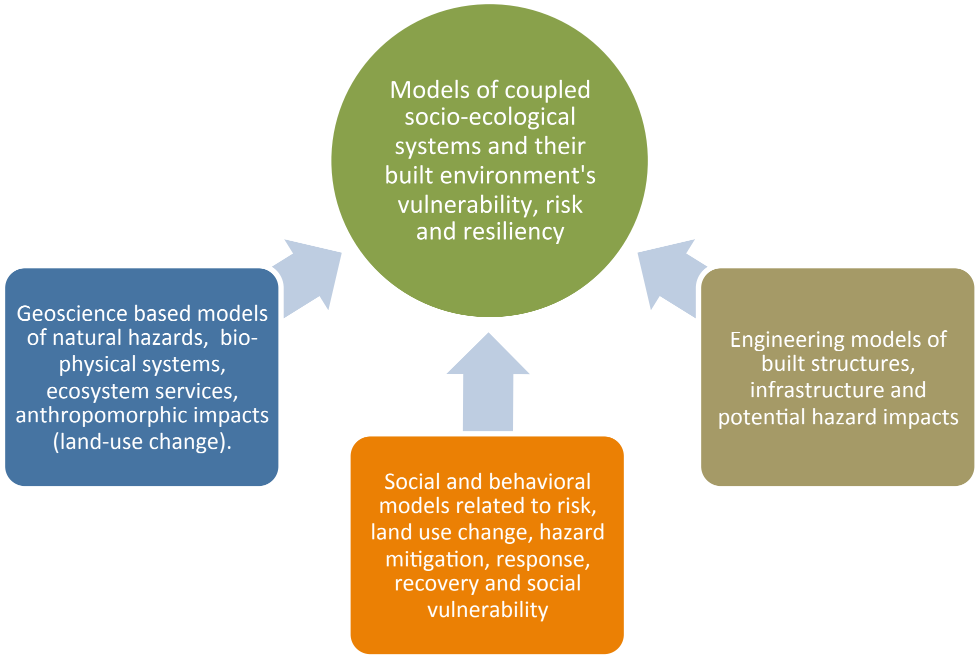

Figure 1. A Conceptual Representation of CaMRA's Research Agenda

The focus on place-based collaboratories and decision support tools can enhance interdisciplinary science and generate broader impacts for communities in the US. Place-based collaboratories will target efforts of both science and engineering teams to develop conceptual and computational techniques to model the complex interactions among co-located physical, social, and built environmental systems. In other words, to better understand and model broader social and economic consequences (e.g., population loss, demographic shifts, business interruption and failure, fiscal impacts) of natural disasters such as hurricanes and their associated hazards (wind, surge, and inland flooding) in complex urban communities, modeling must be done at a relatively fine spatial resolution. Such models will necessitate linking wind and hydrological models, engineering models for buildings, infrastructure, and associated lifelines, and socio-economic models for households, businesses and vulnerable populations. Furthermore, the development of decision support tools, based on coupled models, will enable local communities and stakeholders to better understand and visualize current vulnerabilities and risks and, most importantly, the consequences (positive or negative) of developmental decisions.

While the focus will be on the creation of interdisciplinary models and approaches, there will undoubtedly be disciplinary-specific agendas nested within the broader agenda. During the workshop, many specific research questions that could be addressed within the boarder CaMRA agenda were offered. To capture the flavor of these research topics,[10] the following are offered as representative:

- Multi-scale, time-dependent models for forecasting and predicting hazardous events, and linking this technology to improve risk communication.
- Both structural and non-structural mitigation measures, including such topics as disaster-resilient designs and materials, "smart" buildings and lifeline systems and their interdependencies, cost-effective retrofitting technologies for existing buildings and infrastructure, land-use policies and controls.

[10] These research topics were drawn from both those suggested within the workshop and those offered a part of a pre-meeting document drawn up by the program officers promoting this effort.

- Interdisciplinary models linking and coupling risk assessment between systems. For instance, tropical cyclone predictions, ocean wave models, and surge models coupled with damage assessment and population evacuation and dislocation models. Such interdisciplinary approaches would aim to capture the effects of cascading hazards moving from one system to another and assess vulnerability and risk accordingly.
- Linking infrastructure and structural damage models with business interruption models, coupled with population displacement and dislocation estimation models.
- Social, organizational, political, and economic dimensions of disaster mitigation, preparedness, response, and recovery.
- Individual, household, community, and regional adoption of mitigation measures as well as recovery lessons.

6.0 Toward a CaMRA network structure.

As noted in both the RAVON and SBE Observatory workshop documents, there are many examples upon which to model the CaMRA network (see Peacock et al., 2008 & Moran, Entwisle and Brown 2011). Network examples range from the National Center for Ecological Analysis and Synthesis (NCEAS, http://www.nceas.ucsb.edu/), through the Long-Term Ecological Research Network (LTER, http://www.lternet.edu/sites/lno/ or http://lno.lternet.edu/), to the National Environmental Observatory Network (NEON, www.neoninc.org).[11] NCEAS is a decentralized structure in which the center loosely coordinates research while providing a data repository and metadata development functions. LTER is a network of "centers" or nodes that are more or less strategically located around the nation to capture diverse ecosystems. Nodes seem to have substantial autonomy and vary considerably in their interdisciplinary nature and the types of data they collect. It is important to note that researchers in LTER nodes need not always be located at those node locations. Rather, nodal researchers often come from outside the node to conduct their research, although there is generally a base of researchers located at and staffing the regional center for the node. NEON is by far the most structured of these networks in that it implements standardized data collection including common field instruments for long-term data collection, networked sensors, and the like placed at nodes that are located strategically across the country. NEON does, however, allow for flexibility in local data collection unique to a node and they have implemented the ability to rapidly deploy instrumentation in sudden events such as forest fires.

6.1 A Collaborative Network.

The overwhelming consensus of the workshop was in favor of the development of a network of multidisciplinary observatories. To capture the multidisciplinary focus of these observatories, the term *collaboratories* was suggested. These collaboratories will serve as platforms for integrated data collection across various disciplines to enable model development, implementation, and validation and may include forecast verification through multiple spatial and temporal scales. While the there was strong consensus for the need for place-based collaboratories, there was also the recognition that collaboratories focused around particularly significant issues might be necessary. Thus two forms of collaboratories were proposed: place-based and thematic.[12]

---

[11] Other examples including: the Water and Environmental Research Systems (WATERS) Network and earlier observatory initiatives such as the Collaborative Large-Scale Engineering Analysis Network for Environmental Research (CLEANER) and Consortium of Universities for the Advancement of Hydrologic Science (CUAHSI).

[12] It should be noted that the call for both place based and thematic collaboratories directly echoes the conclusions of the RAVON and SBE Observatory workshop reports (Peacock et al., 2008 & Moran, Entwisle and Brown 2011).. Furthermore the call for place based observatories is consistent with NRC reports related to Earthquake research (NRC 2011a & 2011b).

Regional or place-based collaboratories would be platforms designed to carry out coordinated interdisciplinary data collection activities. Each would have a degree of autonomy to engage in unique research and data collection activities that are appropriate for their location, but they would also be required to engage in network-wide dedicated data collection. Specifically, each place-based node should undertake a core set of research and data collection activities, coordinated across the network. An important goal of place-based nodes for the network would be the long-term collection of common data, requiring the development of common network protocols and instrumentation. It should be noted that these data collection activities would include both existing and historical secondary data such as parcel and building inventory data, but also primary data collection as well. Thematic collaboratories, on the other hand, would target their research activities on specific resiliency science themes or issues. These would not be place-based, but rather consist of networks of researchers that are targeting their efforts to tackle particular topics and issues that will directly benefit the science undertaken by the network.

The criteria for selection of place-based network nodes were a point of considerable discussion. Ideally, there should be a manner with which to rationally select locations that would maximize natural hazard coverage; however, such selection criteria might not always ensure that the best science was being funded. Hence, given the nature of this enterprise, the first criterion must be the intellectual merit of the research proposed. However, once that decision is made, other workshop participants offered a set of criteria[13] to help NSF program officers and reviewers in the selection process. These include: 1) an existing, multi-disciplinary resident group of researchers with a credible track record and a high probability of transformative research; 2) a high likelihood of continuing research excellence; 3) clear and demonstrable links between the researchers and a community of practice; 4) some degree of regional distribution assessed both in terms of bio-physical environmental characteristics including hazard types and socio-political environments ensuring diversity in legal, political, socio-economic, cultural, and demographic characteristics; and 5) places with a strong interest or potential for involvement of local community to enhance education, outreach and training.

As is evident from the above, workshop participants envision a network structure somewhere between that of the LTER and NEON. While there was a clear understanding that each collaboratory node should be able to engage in unique interdisciplinary science, there was also the need to ensure common long-term data collection activities and data sharing among the network and larger science communities. This implies the need for coordinating activities among network nodes and perhaps even the development of a governance structure. Indeed, the development of a technical directorate to provide coordination of technical committees that make recommendations on protocols for data collection and sharing activities and other matters may well be necessary. Such a directorate might rotate among network nodes. While the workshop did not directly address these governance matters, it did suggest that these decisions would be addressed as part of the roll-out process.

6.2. The Roll-out of the Network

The workshop also suggested that the network of collaboratories should evolve via a multi-phased process. The first phase would consist of an RFP process awarding a set of 3-5 incubatory grants. These grants would not be planning grants, but rather proof-of-concept grants focusing on funding an initial round of place-based collaboratories. These grants should be awarded for 2 to 3 years of around $750K and should include multiple investigators, an interdisciplinary team, and at least two universities, one of which must be Ph.D.-granting. As part of the grant requirements, there will be required meetings among research teams across projects at NSF, to develop network by-laws and governance recommendations, as well as common data collection and sharing agreements and protocols. Workshop participants felt that research teams actually involved in ongoing research and data collection activities related to this initial

[13] It should be noted that these closely resemble those suggested by the RAVON report.

stage in the development of the network might be in the best position to develop and decide on the networks governance structure and by-laws, because they will have to live within these by-laws and governance structure.

Phase 2 will entail the actual funding of the first round of CaMRA collaboratories and the development of the network. The initial RFP will be for 3 to 5 collaboratories funded in the multi-million dollar range for an initial period of 5 years. Grantees must include inter-network agreements for common data collection and sharing. There will be an expectation for a possible renewal after 5 years. This RFP competition will be open to all, not just incubation grant recipients, and again proposals must include multiple investigators, at least two institutions, including a Ph.D.-granting institution. This phase may include another round of incubator grants as well. Importantly this phase should also include a network center grant, to develop the network technical directorate to manage common network activities and governance. Subsequent phases would expand the network.

7. Conclusion

Kunreuther and Michel-Kerjan (2009) suggested that our nation and the world are entering into a *new era of catastrophes* in which we are all facing large scale risks at an ever-accelerating pace. Interestingly, those observations were made prior to the recent events of Hurricane Ike, our nation's fourth largest disaster, even though it was a relatively minor hurricane, and the still unimaginable consequences in both loss of life and damage resulting from the recent Japanese earthquake and resulting tsunami. To meet this new era of catastrophes, we need to transform the nature of how we conduct the science on resiliency, vulnerability and risk such that it is consistent with the scientific consensus that disasters can only be understood as a product of the complex interaction among biophysical systems, human social systems, and their built environments.

CaMRA offers a transformative structure in which to carry out long term interdisciplinary science directly addressing the important issues of disaster resilience, vulnerability and risk reduction. It vision is:

> *...a future in which multi-disciplinary research enhances the capacities of our nation's communities to withstand and rapidly recover from natural disasters.*

And, its mission is:

> *… to provide the research community, policy makers, and society with the scientific knowledge and understanding necessary to reduce natural hazard vulnerability and enhance community resiliency.*

References:

Bates, F.L. 1997. *Sociopolitical Ecology: Human Systems and Ecological Fields.* New York: Plenum Press.

Bates, F.L. and C. Plenda. 1994. An Ecological approach to Disasters, in R. R. Dynes and K. J. Tierney (eds) Disasters, *Collective Behavior and Social Organizations*. Pp. 149-159, Newark, Delaware: University of Delaware Press.

Berke, P.R. and T. J. Campanella. 2006. Planning For Postdisaster Resiliency. *ANNALS* 604 (March):192-207.

Blaikie, P., Cannon, T., Davis, I. and Wisner, B. 1994. *At Risk: Natural Hazards, People's Vulnerability and Disasters.* London: Routledge.

Buckle, P., Marsh, G., and Smale, S. 2001. *Assessing resilience and vulnerability: Principles, strategies and actions guidelines*. Mt Macedon, Australia: Emergency Management Australia.

Burby, R. 1998. *Cooperating with Nature.* Washington D.C.: Joseph Henry Press.

Bruneau, M., S.E. Chang, R.T. Eguchi, G. C. Lee, T. D. O'Rourke, A. M. Reinhorn, M.Shinozuka, K. Tierney, W. A. Wallace, and D. von Winterfeldt. 2003. A Framework to Quantitatively Assess and Enhance the Seismic Resilience of Communities. *Earthquake Spectra*, 19(4): 733-752.

Cutter, S. L. 1996. Vulnerability to Environmental Hazards. *Progress in Human Geography.* 20(4):529-539.

Cutter, S.L. (ed.) 2003. *American Hazardscapes*. Washington D.C.: Joseph Henry Press.

Gladwin, H., J.K. Lazo, Betty Hearn Morrow, Walter Gillis Peacock and Hugh E. Willoughby. 2007. Social Science Research Needs for the Hurricane Forecast and Warning System. *Natural Hazards Review* 8(3):87-95.

Gladwin, H., J.K. Lazo, Betty Hearn Morrow, Walter Gillis Peacock, and Hugh E. Willoughby. 2009. Social Science Research Needs for the Hurricane Forecast and Warning System. *Bulletin of the American Meteorological Society,* January:25-29

Holling, C. S. 1973. Resilience and stability of ecological systems. *Annual Review of Ecological Systems* 4:1–23.

Kunreuther, H. C. and Roth. R. Sr. 1998. *Paying the Price.* Washington, D.C. Joseph Henry Press.

Kunreuther, H. C. and E. O. Michel-Kerjan. 2009. At War with Weather: Managing Large-Scale Risk in the New Era of Catastrophes. Cambrige, MA: MIT press.

Manyena, S. B. 2006. The concept of resilience revisited. *Disasters* 30(4): 433-450.

McMahon, G., S.P. Benjamin, K. Clarke, J.E. Findley, R.N. Fisher, W.L. Graft, L.C. Gundersen, J.W. Jones, T.R. Loveland, K.S. Roth, E.L. Usery, and N.J. Wood. 2005. Geography for a Changing World – A Science Strategy for the Geographic Research of the U.S. Geological Survey, 2005-2015. SD: USGS Circular 1281. http://geography.usgs.gov/documents/USGSGeographySciencePlan.pdf

Mileti, D. S. 1999. *Disasters by Design: A Reassessment of Natural Hazards in the United States.* Joseph Henry Press: Washington D.C.

Moran, E.F., B. Entwisle and C. Brown. 2011. Report of a Workshop on the Future of Observatories in the Social Sciences.

National Research Council. 2001. *Grand Challenges in Environmental Sciences.* Washington, DC: The National Academies Press.

National Research Council. 2006. *Facing Hazards and Disasters: Understanding Human Dimensions*, Washington D.C.: The National Academies Press.

National Research Council. 2007. National Land Parcel Data: A Vision for the Future. Washington D.C.: The National Academies Press.

National Research Council. 2011a. *National Earthquake Resilience: Research, Implementation, and Outreach. Washington, D.C.:* The National Academies Press.

National Research Council. 2011b. *Grand Challenges in Earthquake Engineering Research: A Community Workshop Report.* Washington, D.C.: The National Academies Press.

National Science Board. 2007. Hurricane Warning: The Critical Need for a National Hurricane Research Initiative. (NSB-06-115) Arlington, VA: National Science Foundation.

Peacock, W.G., Howard Kunreuther, William H. Hooke, Susan L. Cutter, Stephanie E. Chang, and Phillip R. Berke. 2008. Toward a Resiliency and Vulnerability Observatory Network: RAVON. Final Report NSF Grant SES-08311115. Hazard Reduction and Recovery Center, Texas A&M University. http://archone.tamu.edu/hrrc/Publications/researchreports/RAVON.pdf

Resilience Alliance. 2007. *Assessing and managing resilience in social-ecological systems: A practitioner's workbook*. Retrieved June 1, 2007, from www.resalliance.org.

Shapiro, C.D., R.L. Bernknopf, and S.M. Wachter. 2007. *A Roundtable on a National Framework for Natural Hazards Risk Reduction and Management: Developing a Research Agenda.* U.S. Geological Survey Open –File Report 2007-1106, Reston Virginia.

Tierney, K., & Bruneau, M. (2007). Conceptualizing and measuring resilience: A key to disaster loss reduction. *TR News,* 14-17.

Tierney, K. J., Lindell, M. K., and Perry, R.W. 2001. *Facing the Unexpected: Disaster Preparedness and Response in the United States.* Washington, D.C.: Joseph Henry Press.

Timmerman, P. 1981. *Vulnerability, Resilience and the Collapse of Society: A review of models and possible climatic applications*. Toronto, Canada University of Toronto.

UN/ISDR. 2005. Hyogo framework for 2005-2015: Building the resilience of the nations and communities to disasters [Electronic Version]. Retrieved January 4, 2007, from www.unisdr.org/wcdr/intergover/official-docs/Hyogo-framework-action-english.pdf

U.S. Geological Survey. 2007. *Facing Tomorrow's Challenges—U.S. Geological Survey science in the decade 2007-2017.* USGS Cir. 1309. pubs.usgs.gov/circ/2007/1309/pdf/C1309.pdf

Vjajjhala, S., A. Krupnick, E. McCormick, M. Grove, P. McDowell, C. Redman, L. Shabman, M. Small. 2007. *Rising to the Challenge: Integrating Social Science into NSF Environmental Observatories*. Washington DC: Resources for the Future. (http://www.rff.org/Documents/NSFFinalReport.pdf).

Walker, B. H., J. M. Anderies, A. P. Kinzig, and P. Ryan. 2006. Exploring resilience in social-ecological systems through comparative studies and theory development: introduction to the special issue. *Ecology and Society* 11(1): 12. [online] URL: http://www.ecologyandsociety.org/vol11/iss1/art12/.

Walker, B. H., L. H. Gunderson, A. P. Kinzig, C. Folke, S. R. Carpenter, and L. Schultz. 2006. A handful of heuristics and some propositions for understanding resilience in social-ecological systems. *Ecology and Society* 11(1): 13. [online] URL:http://www.ecologyandsociety.org/vol11/iss1/art13/

Walker, B., C. S. Holling, S. R. Carpenter, and A. Kinzig. 2004. Resilience, adaptability and transformability in social–ecological systems. Ecology and Society 9(2): 5. [online] URL: http://www.ecologyandsociety.org/vol9/iss2/art5

Walter, J. (Ed.). 2004. *World disaster report 2004: Focus on community resilience*. Geneva, Switzerland: International Federation of Red Cross and Red Crescent Societies (IFRC).