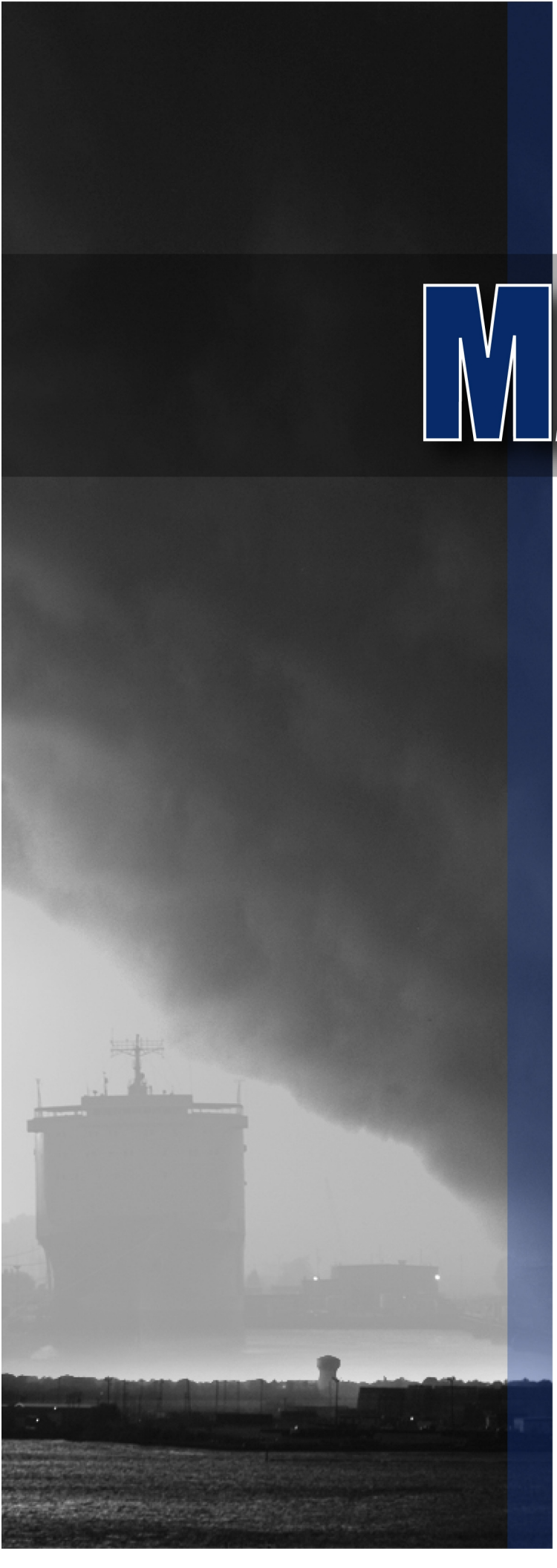

MARI

Mitigation & Adaptation Research Institute

Learning to Live with Changing Climate and Rising Sea Levels

OLD DOMINION UNIVERSITY
IDEA FUSION

MARI
MITIGATION & ADAPTATION RESEARCH INSTITUTE
OLD DOMINION UNIVERSITY

DRAFT

"Learning to Live with Changing Climates and Rising Sea Levels"

Hampton Roads:
A Natural Climate Change and Sea Level Rise Laboratory for the World

MITIGATION AND ADAPTATION RESEARCH INSTITUTE

MARI

Our Vision:

"*Supporting the transition to a prepared, resilient, and adaptive society coping with changing climates and rising sea levels*"

Old Dominion University
Norfolk, VA, USA

"*The Old Dominion University Climate Change and Sea Level Rise Initiative will bring the university and the region's foremost experts together to find solutions to the challenges facing our region and other regions globally."*

- President John Broderick, August 24, 2010

Preamble

The Climate Change and Sea Level Rise Initiative (CCSLRI) at ODU has been active since the fall of 2010. The initial goal was to assess faculty interest and determine the potential for research and education funding. We have found that faculty are interested: they see climate change and sea level rise research as a potential part of their research agenda and welcome networking with a broad range of other ODU faculty through the CCSLRI. At the same time, there is a need for a collaborative catalyst to inform and bring together a wider variety of actors who could offer more synergies needed to address this urgent task. As a consequence of the public attention on climate change and sea level rise as a societal challenge, funding for research related to the complex issues of human response to the impacts of climate change and sea level rise is more abundant at international, federal, state, and non-governmental levels. The linkage of the CCSLRI to societal stakeholders, particularly through the Hampton Roads Sea Level Rise/Flooding Adaptation Forum, revealed the need for a research institute focusing on impact mitigation and adaptation and serving the knowledge needs of these stakeholders. Although no rigorous analysis, such as a SWOT analysis has been performed to assess ODU's position in the climate change and sea level rise "research market," it appears to be appropriate to take the next step by taking on the twin roles of conducting this research and serving as the community's catalyst and a societal resource.

The next step proposed here is the the establishment of a transdisciplinary institute at ODU focusing on the practice-relevant knowledge need to find solutions to the challenge of climate change and sea level rise in the broader context of sustainable development. What is proposed is the establishment of a Mitigation and Adaptation Research Institute (MARI) at ODU.

"*Man may perish by his own explosive and insidious inventions. For an adjustment to them he leaves himself precious little time, and progressively less as his technological wizardry runs wild and rushes on. If he is to survive at all, it cannot be through slow adjustment. It will have to be through design more subtly considered and circumspect, through more cautious planning in advance.*" --- RICHARD NEUTRA, architect, 1954.

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A3 Mitigation and Adaptation: A Review of History and Contemporary Usage
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Note: Sections and text parts in blue color are still to be written or very preliminary sketches.

ABSTRACT

This document proposes the establishment of a transdisciplinary Mitigation and Adaptation Reserach Institute (MARI) at ODU. This institute will produce the practice-relevant knowledge coastal communities in Hampton Roads and beyond need to cope with the unprecedented challenges posed by changing climate and rising sea levels as well as the threats of extreme weather events. Hampton Roads is experiencing one of the highest sea-level rise rates in the U.S. This implies that problems will occur earlier than in most other regions, and, therefore, solutions will have to be identified and implemented here earlier than elsewhere in the country. This proposal lays out why it is crucial to establish MARI, which would utilize the unique situation of Hampton Roads as a natural laboratory for climate change and sea level rise. Given the existence of an already partially engaged stakeholder community consisting of military, private sector, academic, local and regional government actors, MARI would be well-situated geographically to “jump start” practice-relevant research and actionable solutions. This document articulates both the strategies and tactics regarding how such an institute could be implemented at ODU, taking into account the limitations and challenges resulting from the disciplinary structure of colleges and institutions.

The vision of MARI is that of thriving coastal communities. In pursuit of this vision, MARI's mission is to engage in mitigation and adaptation research to provide the practice-relevant knowledge needed by coastal communities to handle the challenges, and utilize the opportunities, of climate change and sea level rise. MARI is based on the recognition that comprehensive knowledge is the basis for solutions, and that this knowledge can only be derived through interdisciplinary and cross-sectoral collaboration. The proposed governance structure takes into account that transdisciplinary entities need to be linked to the highest decision level at ODU and at the same time have a strong foundation in the existing colleges. This governance structure also seeks to set in place a dynamic collaborative decision-making process that will leverage appropriately the need for “top-down”, “bottom-up” and horizontal decision-making, collaboration and information flow. The research areas addressed by MARI include all aspects of mitigation of climate change and its impacts as well as adaptation to the changes that cannot be prevented with a view on sustainable development. The educational efforts of MARI will focus on transdisciplinary, problem-motivated courses, certificates, and degrees. Student engagement and leadership development are vital for the linkage between ODU and its societal environment. A comprehensive outreach program will ensure that stakeholders are involved in the co-creation of the knowledge they need and that that they have the capabilities to make use of this knowledge. To a large extent, the institute has to be driven by the knowledge needs of societal stakeholders not only in the region, but nationally and internationally. The stakeholder-guided nature and the complex challenges to be addressed by the practice-relevant research carried out or facilitated by MARI requires an agile internal organization that can rapidly respond to emerging knowledge needs. MARI will have an internal structure that is designed for problem and solution-oriented research. Importantly, the institute aims to be a source of new business opportunities and, in cooperation with the business world, help to generate jobs in the area of mitigation and adaptation.

The Institute

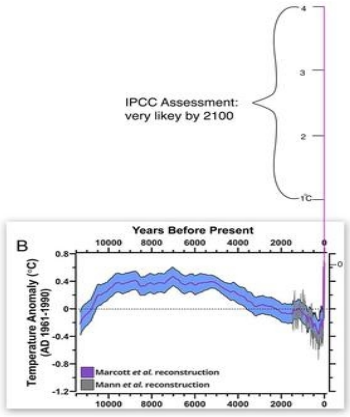
Old Dominion University is in the process of establishing the **Mitigation and Adaptation Research Institute** (MARI). This institute will engage in research that produces the practice-relevant knowledge needed to cope with the impacts of climate change and sea level rise on the coastal zone and the urban coast in particular. In doing so, MARI will respond to the knowledge needs of a wide range of community stakeholders, including government, military, private sector, and citizens. The high rate of local sea level rise, the exposure to extreme weather events, and the complex socio-economic structure makes Hampton Roads a natural laboratory for climate change and sea level rise. MARI will utilize this laboratory and work with stakeholders within and outside the region to generate the knowledge that can enable them not only to reduce the negative impacts but also to utilize the opportunities in the changes to come. To ensure that the stakeholders get the knowledge they can apply, MARI will work closely with them to ensure a co-creation of practice-relevant knowledge and to support them in the use of this knowledge.

Vision and Mission

*MARI's **vision** is that of thriving coastal communities. In pursuit of this vision, MARI's **mission** is to engage in mitigation and adaptation research to provide the practice-relevant knowledge needed by coastal communities to handle the challenges, and utilize the opportunities, of climate change and sea level rise.*

Leaving the Holocene: The Challenge of Climate Change

Climate change and sea-level rise pose unprecedented threats to communities across the world, especially the heavily-populated urban coasts. The changes experienced during the last century are unprecedented during the Holocene, that is, the relatively stable 10,000 years in which civilization could develop. There is increasing evidence that the changes anticipated for the 21st Century will push the climate outside the range known to civilization and into a phase of much greater variability. This will challenge decision-making in all societal sectors, and it will require a new level of preparedness to mitigate the impacts and adapt to the changes.



Likely changes in 21st Century global temperature compared to changes during the last 11,000 years. *The anticipated changes in global temperatures (as well as many other climate-relevant variables) during the 21st Century will by far exceed changes documented in paleo data both in magnitude and the pace of changes. This will put the planet in a state unknown to civilization and the ecosystems of today. Modified by Plag (2014) from Marcott et al. (2013). See Figure 2 in the report for a larger version.*

There is Urgency

Climate change is impacting the daily life of people already now. The time for mitigating climate change and its impacts and adapting to the changes is running out. There is an urgent need to develop adaptation science and to produce the practice-relevant knowledge that address all these issues.

Sea Level Rise: A Threat to an Increasingly Urban and Coastal Civilization

Human population has moved from rural areas in urban, and most of the rapidly growing urban areas are in the coastal zone. During the 1933 flood in Hampton Roads only 35,000 people were living in Virginia Beach and Norfolk; today 1 Million people are exposed in the same area to the risk of extreme weather events. Both on a global scale and in the U.S., an increasing fraction of the population and the most productive infrastructure are in the coastal zone. They are at increasing risk from accelerating sea level rise (SLR), and a rapid SLR already in the near future cannot be excluded. The likely SLR will increase the risk of disasters caused by storms and storm surges, and the frequency and severity of storms is expected to increase and further acerbate this risk. Because of the dependence of humanity on the coastal zone, these disasters threaten food and water security, supply chains, public health, and crucial parts of Earth's life-support system. The coastal zone thus is a frontline for humanity's sustainability. The high economic productivity and importance of the coastal zone rules out a simple retreat to safer areas, and new solutions for living in the coastal zone with a variable sea level need to be found. To achieve this, we need to improve our understanding of the vulnerabilities, increase our foresights, have more insight into the societal decision making processes, develop the institutional framework for mitigation and adaptation, provide a wide range of options, and identify the barriers and obstacles that hamper mitigation and adaptation.

“Nuisance Flooding” is increasingly common In Hampton Roads. Many low-lying areas are exposed to increasingly more frequent flooding as a result of the recent rise in Local Sea Level (LSL), which is low compared to what might happen over the next decades. In some areas, roads and buildings are by now exposed to flooding for up to 200 hours per year and this might rapidly increase to 500 or more hours per year in the near future.

Preparing for a Range of Possible Futures

Understanding the probabilities of LSL rise, coastal communities need to prepare for rising sea levels and develop concepts for living where it is safe and working where it is needed.

MARI and its stakeholders

MARI's vision and mission imply a strong linkage between the institute and a wide range of societal stakeholders in climate change mitigation and adaptation. MARI will proactively and continuously seek input from stakeholders to gain a thorough understanding of their knowledge needs. The institute will work with them to design and co-create the knowledge and seek with them the most appropriate solutions, be they, for example, engineering or technological approaches intended to mitigate against the impact of severe storms and flooding or adaptive approaches intended to live and prosper within new environmental constraints.

MARI serves a wide range of stakeholders. Climate change mitigation and adaptation is cross-sectoral and stakeholders relevant to MARI reside in all societal sectors. MARI will develop infrastructure, organizational frameworks, and procedures that ensure a strong and continuous linkage between them and the institute (see Figure 4 in the report.)

A Stakeholder-Driven Institute

Continuous input from stakeholders in climate change mitigation and adaptation will enable MARI to create the practice-relevant knowledge society needs to find sustainable solutions to the challenge of climate change and sea level rise, which cannot be found without a solid foundation in solution-focused research.

MARI's Research Focus

MARI will focus on problem-motivated basic and applied research on all aspects of mitigation of climate change and its impacts as well as adaptation to the changes that cannot be prevented with a view on sustainable development. Implementation of mitigation and adaptation measures require societal decision making, and MARI will research the opportunities and obstacles in decision and policy making and the institutional framework for mitigation and adaptation. The institute will aim to develop a wide range of options for mitigation and adaptation. Doing so in an effective manner requires an understanding of the ranges and probabilities of the hazards and the identification of vulnerabilities, and MARI will research the effect of climate change on sea-level and weather-related hazards and the vulnerability of coastal communities to these hazards and provide risk assessments. The research will cover the robustness of the built environment in the urban coast, the robustness and resilience of crucial services such as food, water, communication, transportation, power, and public health, and the resilience of the social fabric in its socio-economic and socio-ecological settings. MARI will compare urban coasts in different cultural, social, economic and environmental settings to gain an understanding of the key factors that can support or limit the adaptive capabilities of coastal communities.

MARI will facilitate and engage in collaborative, transdisciplinary research that is motivated by real-world problems and focused on the finding of solutions. In its research project, MARI will ensure a balance between the traditional academic disciplines and ensure that basic research on transdisciplinary methodology is inherently integrated in the research. MARI will work with societal stakeholders to develop options to mitigate and adapt to climate change and sea level rise, and in doing so, MARI will also research methodology for sustained co-design, co-creation, and co-usage of practice-relevant knowledge.

Defining Mitigation and Adaptation

(1) Mitigation of Climate Change and SLR: actions that limit and reduce changes in the Earth's system that are known to force climate change or increase SLR.

(2) Mitigation of climate change and SLR impacts: actions that aim to protect against certain levels of impacts of climate change and/or SLR.

(3) Adaptation to climate change and SLR: actions that increase our preparedness for a wide range of probable climate change and SLR and allow us to adapt to the changes if and when they happen.

MARI's Contribution to Education

MARI will engage in the development of transdisciplinary approaches to education related to scientific and societal challenges of climate change, sea level rise, and sustainability in general. The institute's role will be mainly in the development of transdisciplinary, problem-motivated courses, certificates, and degrees, and MARI will provide the teaching and education by taking maximum advantage of existing resources and faculty, always in a interdisciplinary fashion. The institute will begin by offering courses, which will be followed by certificates and, eventually, degrees. Certificates and degrees will be hosted in appropriate colleges and MARI members will engage in the required teaching.

The complexity of the coastal zone as well as the nexus linking energy, food, water, and public health require a work forces and societal leadership that has an understanding of the coastal environment, including the urban coast, and its life-support systems as well as the impacts climate change, sea level rise, and environmental chances can have on this sensitive socio-ecological and socio-economic environment. MARI will develop a footprint on the workforce and leadership in Hampton Roads and beyond that will support the development of adaptive capabilities.

A Need for Transdisciplinary Education
To support, maintain and guide sustainable coastal communities, a work force and societal leadership is needed that can communicate across traditional disciplines and societal sectors, and to achieve this, a strong transdisciplinary element in education is needed.

MARI and Student Engagement

MARI will engage students in many different ways in its activities. Linking students to the societal environment is a cornerstone in engaging students. Bringing students in contact with the issues both in academic programs and activities that link them to societal problems is necessary to help students understand the challenge they will face over the decades to come. MARI will work with existing student engagement programs at ODU to achieve this. Of particular importance is collaborative leadership development. While MARI will develop certificates open to leaders in society, there is also a need to engage students in the effort of developing the leadership capabilities that are needed in mitigation and adaptation. Coupling the need and advantages of civic engagement in the deliberation of mitigation and adaptation strategies for the development and public acceptance of resilience-related policies, MARI will encourage Service Learning projects and courses that emphasize leadership development, critical thinking, and personal reflection while encouraging community, civic engagement, and personal responsibility. Student engagement and leadership development are vital for the linkage between ODU and its societal environment.

An Uncertain Future Needs Engaged Citizens
Students are important for the future of our society and engaging them in addressing climate change is crucial for future generations of engaged citizens and a sustainable development.

MARI and its Outreach

The outreach activities of MARI are embedded in the general outreach concept of ODU. They have the goal to link MARI to its stakeholders and by that to ensure that knowledge created responds to stakeholder needs and is available to those who can put it to work. The institute will conduct outreach, in both face-to-face and online settings, in particular by standing up and maintaining a comprehensive web presence. A focus is on multi-faceted dissemination of knowledge enabling mitigation and adaptation to climate change and SLR. Knowledge

Management will be at the heart of this strategy. Maintaining and cultivating collaborative relationships with stakeholders in, and beyond, Hampton Roads is key to the success of MARI and to the understanding of the needs and requirements of those stakeholders with respect to mitigation and adaptation. The comprehensive outreach program will ensure that stakeholders are involved in the co-creation of the knowledge they need and that they have the capabilities to make use of this knowledge.

Bringing Knowledge to Where it is Needed

Creating knowledge is just the first step; in order to affect real change, managing that knowledge effectively and efficiently is crucial, with proactive outreach as the front and end stage of MARI's Knowledge Management process.

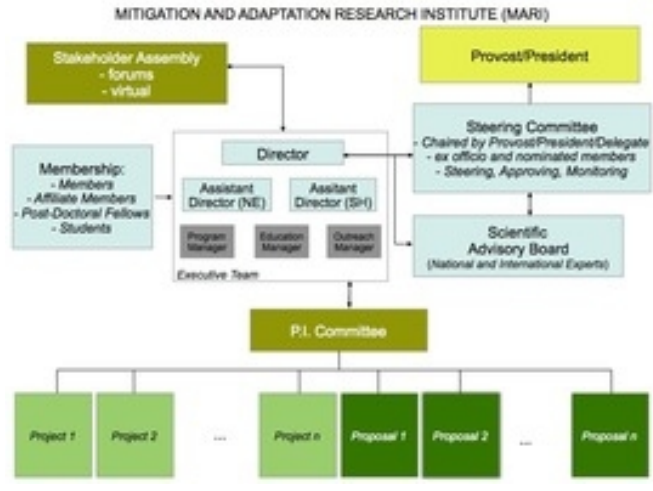
MARI within ODU

MARI is based on the recognition that comprehensive knowledge is the basis for solutions, and that this knowledge can only be derived through interdisciplinary and cross-sectoral collaboration. The institute is being established in a way that ensures a transdisciplinary approach, with a governance structure that facilitates the inclusion of all academic disciplines. The governance structure as well as the monitoring and evaluation procedures are designed to foster direct input from stakeholders.

The proposed governance structure takes into account that transdisciplinary entities need to be linked to the highest decision level at ODU and at the same time have a strong foundation in the existing colleges. This governance structure also seeks to set in place a dynamic collaborative decision-making process that will leverage appropriately the need for “top-down”, “bottom-up” and horizontal decision-making, collaboration and information flow.

Facilitating Transdisciplinary Research and Education

The discipline-based organization in higher education requires new elements outside this traditional environment that can built transdisciplinary education and research programs linking colleges and departments across boundaries.

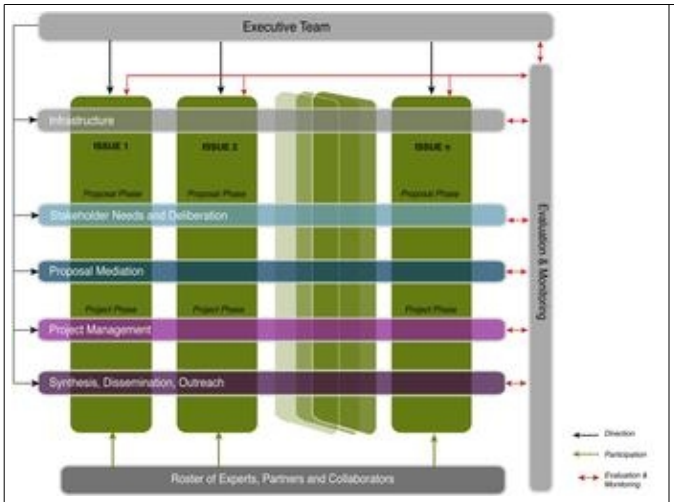


A transdisciplinary institute in a disciplinary environment. MARI is governed by a Steering Committee with representation of relevant ODU bodies, which endorses the research and business plans of MARI, monitors it work and finances, and appropriates resources for MARI. Important advice comes from a Scientific Advisory Board, which consists of national and international experts and ensures the connection of MARI with relevant research programs. The Executive Team takes care of the day-to-day business and the programatic development of the institute (see Figure 4 in the report for a larger version).

The Anatomy of MARI

Being driven by the knowledge needs of a wide range of stakeholders and conducting problem-motivated and solution-focused research requires a novel approach to the internal structure of the institute. The expertise needed at any given time depends on the problems addressed, and MARI will have to draw on ODU's expertise, as well as outside expertise, depending on the nature of a problem. The internal structure of MARI is designed to leverage to the greatest feasible extent existing ODU technological and human capabilities. MARI also has an agile internal organization that can rapidly respond to emerging knowledge needs.

MARI will have a constructionist approach, which requires a framework bringing together different experts, a wide range of tools, comprehensive databases, and project findings and results for a solution-focused outcome that is practice-relevant. The internal structure of MARI is designed to provide all those functions required to transition from the traditional de-constructionist nature of science providing information to a constructionist approach providing solutions.



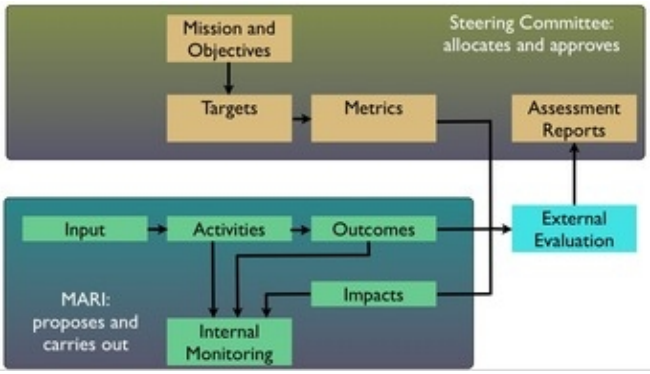
A design facilitating a constructionist, solution-oriented approach to societal problems. MARI will provide several "horizontal" functions, which will facilitate and support trans-disciplinary projects addressing issues related to the impacts of climate change and SLR on (mainly) urban coasts. The project participants will come from a roster of experts in the faculties at ODU, other regional universities and research institutes, and international collaborators. Evaluation and monitoring of projects as well as MARI as a whole will provide essential feedback on the success, stakeholder acceptance, and impacts of MARI.

Supporting the Construction of Solutions

To facilitate solutions, MARI will provide the function that support problem-motivated projects based on common infrastructure, databases and knowledge bases, and enable to construction of comprehensive and innovative solutions from multi-project outcomes.

Measuring the Impacts of MARI

MARI is a novel approach to an emerging science field that focuses on practice-relevant knowledge and at the same time has to engage in basic research and develop the foundation for the science of adaptation. Adaptation research can only be of societal relevance if the research is strongly linked to the stakeholders making use of the knowledge created, and MARI will have to develop a conceptual and practical framework for the co-design and co-creation of knowledge. Marching into unknown terrain in several dimensions, MARI will face a number of challenges related to the academic and research organization at ODU, the science foundation, and the working with stakeholders. Most of these challenges will surface as surprises. For the success of MARI, it will be important to closely monitor the progress and to evaluate the approaches taken. Evaluation needs to cover all dimensions, including the research carried out and the usefulness of knowledge created, the academic contribution, the economic basis, the linkages to societal stakeholders, and the societal benefits of MARI, including the impact on local businesses and jobs created.



Monitoring and evaluation of MARI. The Steering Committee determines mission and objectives of MARI and approves outcome-related targets and metrics proposed by MARI. MARI uses resources allocated by the Steering Committee and solicited from external sources to carry out the activities and generate outcomes. MARI also monitors activities, outcomes and impacts. The result of the monitoring is made available to the Steering Committee on a regular basis. On request from the Steering Committee, the external evaluation compares outcomes and impacts to the metrics and targets approved by the Steering Committee and prepares an assessment report.

The Societal Benefits of MARI

The societal, environmental and economic costs of climate change and sea level rise are expected to grow rapidly. MARI will contribute to enable a wide range of stakeholders to reduce the costs through mitigation where possible and timely adaptation where needed.
Importantly, the institute aims to be a source of new business opportunities and, in cooperation with the business world, help to generate jobs in the area of mitigation and adaptation.

1 INTRODUCTION

1.1 Complexity of the Climate Change and Sea Level Rise Challenge

Climate change is likely to have many challenging economic, social, and environmental consequences that will require mitigation of impacts and adaptation to changing conditions. The urban coasts are among the most exposed areas that, in addition, have to accommodate a migration of population from the interior of the continents into the coastal zone. For example, in the U.S., the coast is substantially more crowded than the country as a whole. In 2010, 39% of the U.S. population lived in coastal shoreline counties that represent less than 10% of U.S. land area excluding Alaska (NOAA, 2013a). Population in the coastal floodplain is increasing, and in 2010, 5% of the U.S. population lived in the coastal floodplains (Figure 1). The migration of population into the coastal zone challenges governance with the need to protect coastal ecosystems from a growing population, and at the same time protect a growing population from changing coastal hazards.

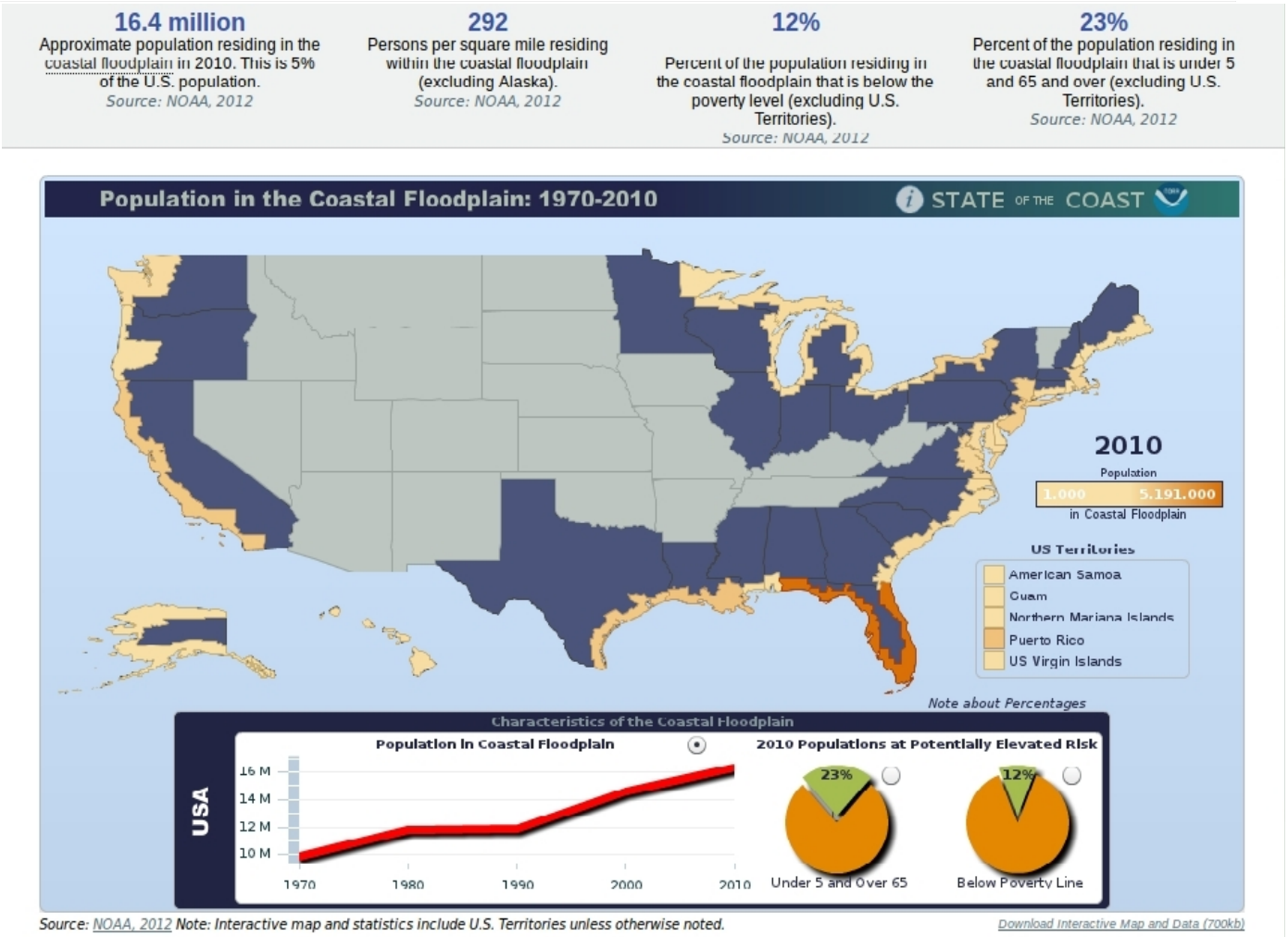


Figure 1: Population in current coastal flood planes. Dark blue: states with coastal zones. Shades of brown indicate the amount of population in the coastal floodplane of each state. Note that the original map is interactive showing the temporal development of coastal population for each state. From NOAA (2013b).

Sea level rise (SLR) is one of the most challenging consequences of on-going and likely future climate change (see, e.g., Horton et al., 2014), but it is not the only one. Increasingly variable weather is causing more frequent and more extreme heat waves, droughts, and precipitation, and on the northern hemisphere, these extremes can be linked to a vanishing cryosphere (Tang et al., 2013). Extending flooding causes problems for the maintenance of infrastructure and public services, and more of the built environment is exposed to flooding and increased humidity. Public health impacts are escalating as a result of increased surface-level ozone and more intense and longer pollen periods, mold in increasingly humid climates and impacted buildings, epidemics caused by new or re-mobilized infectious diseases, food poisoning caused by droughts, and pollution of food, drinking water and air caused by floodwaters (e.g., Craig, 2010; Plag and Jules-Plag, 2013). The growth of a carcinogenic mold in corn exacerbated by droughts reached record highs in 2012 (e.g., Bloudoff-Indelicato, 2013). Food, water and energy security are more difficult to maintain under a changing climate (Hoff, 2011), and food prices are expected to increase (Hanlon et al., 2013), which will impact the poorer part of the population more and increase pressures on social welfare systems. Business are also challenged by the changing environmental conditions, as well as disruptions of impacted supply chains. Globally, the inequity of climate change is expected to impact the poorer regions more (e.g., Myers and Kulish, 2013), which increasingly will lead to migration and social destabilization.

In the face of these multi-faceted impacts of climate change, the urban coasts are challenged with the decision to invest today in mitigation of increasing sea-level related hazards and adaptation to variable sea levels or face an escalating disaster risk with severe impacts in the future. Climate change appears to be increasing the probability of a large, rapid SLR due to accelerated melting of land-based ice masses (Jiang et al., 2012; National Research Council, 2013; Little et al., 2013). In most low-lying coastal areas, the current SLR is already a challenge for coastal settlements and infrastructure (Ayyub and Kearney, 2012), and in many locations, land subsidence increases the rate of local sea level (LSL) rise (e.g., Boon et al., 2010; Eggleston and Pope, 2013). Climate change also impacts the frequency and magnitude of extreme events (e.g., Huber and Gulledge, 2011), thus adding an additional uncertainty particularly to the planning of coastal urban areas.

To enable informed societal deliberations about mitigation and adaptation, there is an urgent need to inform the public in a timely manner about the challenges of climate change and SLR and the potential mitigation and adaptation solutions that could reduce the impacts on the urban coasts and beyond. Managing the risks associated with climate change and SLR requires knowledge-intensive adaptive management and policy-making that is informed by relevant scientific knowledge (Lemos et al., 2012). In terms of the hazards, realistic risk estimates for LSL rise and extreme events including the detection of any acceleration of LSL rise and changes in the probability of the extreme events induced by climate change are needed.

Hampton Roads is ideal as a natural climate change and sea-level rise laboratory. Already, Hampton Roads is challenged by growing frequency and magnitude of coastal flooding (Atkinson et al., 2013). Land subsidence, changes in the coastal dynamic sea surface topography, and a general rise in sea level add up to a relative high rate of LSL rise and keep pushing up the number of flood events (e.g., Salenger et al., 2012; Ezer et al., 2013, Kopp, 2013). This has many practical impacts on businesses, coastal infrastructure, operation of military bases, real estate value, public health and overall community resilience. The region urgently needs practice-relevant mitigation and adaptation knowledge to address the current situation and to prepare for more severe changes in mean LSL and the frequency and magnitude of inundations and extreme events. With a high LSL rise rate and a complex socio-economic structure, the region also presents an excellent study area and case for the development

of workable mitigation and adaptation strategies for urban coasts that are facing the risk of significant LSL rise. One of the main reasons why people may not be willing to take action to mitigate climate change or adapt to it is a lack of first-hand experience of the impacts and consequences of climate change (Spence et al., 2011). In Hampton Roads, people do experience first-hand the many impacts of SLR on their daily lives. By linking climate change to these impacts, the region can provide empirical evidence for the acceptability of adaptation measures in a unique way.

Considerable research efforts have focused on understanding the sea-level related hazards and the changes in these hazards as the climate changes. We have a well-developed understanding of what processes cause LSL changes and how these processes will be impacted by climate change (e.g., Bindoff et al., 2007). The physics behind both the slow changes in the means as well as changes in the probability of extreme events is well understood. However, predictive capabilities are limited, posing the problem of planning long-term developments for a future with large uncertainties. There is an urgent need to improve our predictive capabilities particularly at interannual to decadal time scales (e.g., Plag et al., 2009; Moss et al., 2013) and to develop "early warning systems" for abrupt changes and impacts (National Research Council, 2013; Showstack, 2013). At the same time, for longer time scales, a paradigm shift from the widely used deterministic approach to a probabilistic one is needed (e.g., Dessai et al., 2009), necessitating a natural sciences focus on probability density functions (PDFs) for climate change and SLR.

A prerequisite for mitigation and adaptation is a comprehensive understanding of vulnerabilities. Importantly, this knowledge needs to be accessible to societal decision and policy makers. In many cases, scientific knowledge is available in publication channels not used by end users who are planning and implementing mitigation and adaptation measures at the local level (see, e.g., the conclusions of a survey of coastal managers reported by Moser and Tribbia, 2007). Accessible knowledge of vulnerabilities to the slow changes in climate and sea level as well as modified frequency and magnitude of extreme events provides a basis for informed planning of mitigation of impacts and a focus on developing adaptive capabilities. Knowing the climate thresholds of ecosystems, the built environment, and human communities is necessary for an assessment of adaptation options.

What is much less understood are the social and economic factors that determine our adaptive capabilities, impact our decision making, and, particularly for extreme events, often are decisive for the development of disasters. Moss et al. (2013) identify the need to develop a practice-relevant adaptation science and reemphasize that adaptation requires science that analyzes decisions, identifies vulnerabilities, improves foresight, and develops options. The social construct of vulnerability and risk, which depends on social, cultural, political and economic conditions that are based on societal historical experience, limits the options that are considered for mitigation and adaptation. Research on the factors determining the social construct of climate change and SLR risk is in an early state. In disaster risk reduction research, much focus has been on developing a robust built environment that can function under climate change and increasing extreme events (e.g., Corotis, 2012). However, recent experience with extreme events exceeding the threshold limitations in the built environment emphasized the importance of the social fabric and social capital for the resilience of communities (Putnam, 1995; Klinenberg, 2002). Disaster risk reduction therefore needs to aim at resilience and the development of policies and strategies requires an understanding of the role of social capital for resilience (Yardley et al., 2011). The development of adaptive capabilities deserves attention as part of the effort to increase resilience to climate change (Engle, 2011). Climate change will present us with surprises (National Research Council, 2013). It will be important to develop practices to utilize these surprises in an "antifragile" approach to increase preparedness for future surprises (Taleb, 2012). In

particular, the current science–policy relationship needs to be augmented by social structures that can learn from previous unexpected events. In this response to climate change, science does not have the primary goal to reduce uncertainties and prediction errors, but rather to develop processes that can utilize uncertainties and surprises to increase robustness, strengthen resilience, and reduce fragility of the social systems during times when the infrastructure fails.

Mitigation and adaptation related to climate change and SLR require a solution-focused approach. The goal is to be prepared for whatever climate change will take place. The knowledge created in mitigation and adaptation research needs to be practice-relevant. This requires openness in terms of disciplines and equality between them. There can be only limited practice-relevant solutions without collaboration among the natural sciences, engineering, social sciences, and humanities.

Climate change and SLR are not only challenges for society, they are also opportunities. Increasingly, resources will have to be directed toward mitigation of both climate change and its impacts. Adaptation to changing environmental conditions will require an effort unparalleled in human history. There is a rapidly developing consensus that climate will continue to change and SLR will accelerate. In response to this seminal challenge, new approaches and practices to the provision of public services such as transportation, communication, energy, food and water, sewage and health need to be developed leading to a changing business and job market model. Considering the fact that climate change mitigation and adaptation impact all areas of economy and society, it is obvious that there will be many new business opportunities in a rapidly developing market during the coming decades. At the same time, business is challenged by the increased risks associated with climate change and need to adapt to the changing risk environment (Crawford and Seidel, 2013). The trade-off between mitigation of climate change versus adaptation to, and mitigation of, impacts has important consequences for developed and developing countries alike (Michaelowa, 2001), which need to be taken into consideration in the planning of strategies. In this process, MARI can be a partner of the private sector spawning new businesses and facilitating job creation.

1.2 Terminology: Mitigation and Adaptation

The terms mitigation and adaptation are used in many scientific disciplines and societal communities in combination with other terms, resulting in a wide range of interpretations. In Appendix A3, we review the history of the terms and consider some examples of contemporary usage, include the definitions provided by the climate science community surveyed by the IPCC. While there is often a disciplinary consensus on the use of the terms, an interdisciplinary consensus has not emerged. Importantly, a societal consensus on the use of these terms is not in sight. We therefore provide here a definition of how MARI defines these terms. These definitions may be modified over time if necessary in the facilitation of transdisciplinary collaboration.

It is important to note that at all levels we always have the choice to mitigate (prevent) or adapt (manage), with rather different social and economic consequences. Our language should be flexible enough to reflect these choices. For MARI, we therefore consider three terms as relevant, which combine the definition of climate change mitigation common in the climate change research community with a narrower definition of climate change adaptation and the mitigation of climate change impacts in the sense of crisis management and disaster risk reduction:

(1) Mitigation of Climate Change and SLR: actions that limit and reduce changes in the Earth's system that are known to force climate change or increase SLR.

(2) Mitigation of climate change and SLR impacts: actions that aim to protect against certain levels of impacts of climate change and/or SLR. In general, MARI views impact mitigation as protection

measures that generally “play against nature” (Stein and Stein, 2014).

(3) Adaptation to climate change and SLR: actions that increase our preparedness for somewhat uncertain climate change and SLR and allow us to adapt to the changes if and when they happen. MARI views adaptation as measures that generally “play with nature.”

Importantly, (2) and (3) are local and regional problems, while (1) needs to be addressed at a more global level. However, actions taken in the context of (2) and (3) can positively or negatively contribute to (1). In particular, a shift from (global) mitigation of climate change and SLR to a more regional and local mitigation of, and adaptation to, impacts has a major impact on the distribution of costs and benefits between developed and developing countries. A shift to adaptation will increase the challenges for the developing world (Michaelowa, 2001).

The natural laboratory of Hampton Roads seems to be ideal for research related to (2) and (3). However, there are many aspects of (1) that are directly a result of actions under (2) and (3), and actions under (1) have implications for (2) and (3). The scope of MARI therefore will have to be wide enough to include all aspects of mitigation and adaptation; not just climate change mitigation and adaptation, but also, for example, disaster mitigation and social and economic adaptation. Moreover, it will be important that MARI utilizes synergies with others who are examining ways of lessening the rate of climate change (though new technologies, adjustments in economic market incentives, emerging scientific understandings, policy changes, etc.). Particularly with respect to the social and economic aspects of (1), which are mostly very much linked to (2) and (3), the expertise available at ODU could make a valuable contribution. To reflect the broad scope of MARI, the institute's name does not explicitly refer to climate change and SLR.

In the climate change community, climate change adaptation comprises all activities of adapting to the inevitable consequences of global warming, e.g., retreat, defend, or through different processes including the way we build, the policies and decisions we make, cultural, social, and economic changes, etc. However, these processes can have distinctly different goals, immediate impacts, and long-term perspectives, and it is helpful to distinguish between those processes that aim to protect against climate change impacts and those that lead to being adapted to these changes. We denote the former as climate-change impact mitigation and the latter in a more narrow sense as climate change adaptation.

In general, mitigation of impacts through protection faces the challenge that conditions exceeding the thresholds of the protection can lead to extreme disasters. The economically reasonable and feasible planning of mitigation requires a reliable deterministic knowledge of future changes and the probability density functions of hazards. If there are large uncertainties in the extreme end of the hazard spectrum, then the planning of protections is an exceedingly difficult task implying the choice between high costs for the protection now or high costs for the ensuing disasters if the protection fails. Facing high uncertainties about the future conditions, the development of adaptive capabilities provides a greater flexibility to adjust if the actual climate change or SLR should require such an adjustment.

In general, mitigation points to a process of reducing a threat and preventing something from happening. Adaptation is more used for processes that enable an organism or system to handling certain conditions and the changes in these conditions. Successful adaptation does reduce impacts and disaster risk, and so does mitigation. Adaptation seems to be more focused on changes in human behavior or use, while mitigation of impacts is more often used to refer to changes in the built environment. Impact mitigation seems to have the goal to reduce a threat and to prevent impacts, and it often involves protection, engineering, technology, etc. If these measures fail (e.g., a storm surge comes over a dike or

breaks through), the disaster is normally exaggerated because preparedness for this case is low. Adaptation has the goal to accept the changing conditions by changing our behavior or use of the built environment or our exposure to new hazards (retreat).

1.3 Structure of the Proposal

In Section 2, we describe the extent of the challenge our society faces due to climate change and sea level rise now and in the near future, and we review the current thinking related to mitigation of climate change and its impacts as well as adaptation to the changes in climate and a variable sea level. Mitigation and adaptation research are in an early state, and we give an overview of the current theoretical approaches and practice-relevant results in Section 3, where we also identify the core scientific questions and issues. Section 4 constitutes the core of the proposal and lays out the vision, mission and organization of MARI. In Section 5, we provide more details on research, education and outreach plans of MARI. Finally, Sections 6 and 7 discuss the financial aspects of MARI and develop an implementation plan, respectively.

2 THE SOCIETAL CHALLENGE OF CLIMATE-CHANGE AND SEA-LEVEL RISE ADAPTATION AND MITIGATION

2.1 Understanding the Scale of Change and the Hazards

Climate change recorded during the last hundred years is exceeding the variability of climate on century time scales observed during the 11,000 years (Marcott et al., 2013). There is broad consensus in the scientific community that these changes are the result of humanity's recent impact on the Earth's system, in particular the chemistry of the atmosphere (IPCC, 2013). There is also consensus that these impacts have committed us to even larger climate change to take place during the current century. There are concerns that climate change could push the Earth's system into a state outside of what is considered a “safe operating space for humanity” and there is indication that this is already happening today (Rockström et al., 2009).

The changes in the last century in surface cover, biodiversity, and chemistry of atmosphere, soils, and oceans happened at a pace rarely, if ever, encountered in past millions of years, except during extreme volcanic eruptions (such as the eruption of Toba 75,000 years ago; e.g. Jones, 2007) or impacts of large asteroids. The projected changes for the 21st century exceed by far anything documented in paleo data for the last 11,000 years (Figure 2) and also for the last 1,000,000 years (e.g., Karl et al., 2009). As a consequence, humanity is challenged with an uncertain future on an unknown planet.

Although we are gaining a better understanding of the climate change we can expect, there is little consensus on how this change will happen and how it will impact the carrying capacity of the planet and reduce food and water security for a still growing population, affect economy and social and political stability in a globally interconnected world, or result in unanticipated changes in the physics and chemistry of the planet exacerbating the effects climate change. As a consequence, the most pernicious impacts of climate change may still be hidden from us and may emerge as challenging surprises. There is also the possibility of unpredicted abrupt impacts of climate change that can emerge any time in the future (National Research Council, 2013). The main impacts of climate change are expected to surface in more frequent and more extreme weather events, including intensifying precipitation events (IPCC, 2013).

The recent and projected climate change to a large extent will be irreversible. Thus, our civilization is

facing the challenge to live under climate conditions and geographical distribution of climate zones substantially different from today's pattern. Mitigation on impacts and adaptation to the new environmental conditions will require social, economic, legal and political changes.

Climate change and SLR adaptation and mitigation do not take place in a vacuum, instead being affected by established societal norms, public perceptions, existing and future policy goals, governance structures, political institutions, and economic and financial constraints. In particular, the social construct of vulnerability and risk, which differs between cultures and has changed over time, has a determining influence on how the risks associated with climate change are perceived and the focus of deliberation on mitigation and adaptation. While in some cultural settings, the risks are perceived as existential and deliberations focus on how to adapt, in other cultures and economic settings, the facts about climate change are doubted by many and no substantial risks are widely accepted.

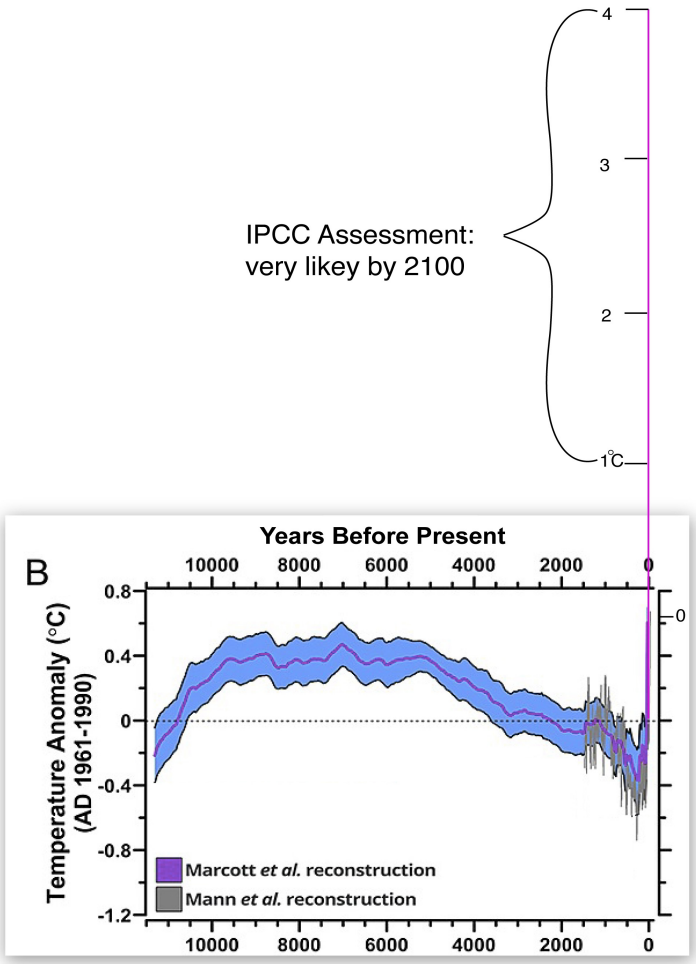


Figure 2: Likely changes in 21st global temperature compared to changes during the last 11,000 years. The anticipated changes in global temperatures (as well as many other climate-relevant variables) during the 21st century will by far exceed changes documented in paleo data both in magnitude and the pace of changes. This will put the planet in a state unknown to civilization and the ecosystems of today. Modified by Plag (2014) from Marcott et al. (2013).

Throughout history societal challenges caused by major changes in the natural environment have often neither included mitigation nor in-place adaption, but have been limited to retreat and migration as the mere option for adaptation. While retreat might have been the only option available for past societies

after major changes in the environment, like for example the eruption of Mount Vesuvius AD 79, the substantial losses of land after the large medieval floods in the North Sea region, or the climate changes at the end of the medieval optimum that caused the retreat of the Norse settlers from Greenland, simple retreat is no longer an option today for a global civilization on a densely populated planet. Instead of retreat and migration more sophisticated concepts for mitigation and adaption need to be developed.

While it is somewhat obvious that simple retreat is no longer an option, an analysis of these historical developments will help to understand the dimensions of societal and political changes caused by climate change and SLR. When for example the large medieval floods caused substantial losses of land in the North Sea region, the consequences were not limited to the immediate effects, but a complete change of the political landscape of the region as well, most notably the end of sovereignty of some regions and even the loss of a language.

Simple retreat is also no longer an option because of the unparalleled scale of the processes that cause climate change and the global nature of the impacts of climate change and SLR. The fact that climate change and sea level rise are inherently global in spatial scale and inter-generational in temporal scale requires a trans-boundary solution where both the developed and developing countries are taking responsibility and action in an unprecedented post-national approach. Unfortunately, the social construct of climate change risk and vulnerability exhibits a wide range across different cultures, economic and environmental conditions, and social settings. While in many parts of the developing world, where climate change is already fundamentally impacting the livelihood of people, vulnerabilities and associated risks are obvious and part of the public awareness, some parts of the developed world are still in a state where immediate impacts are tolerable and public awareness is pre-occupied with other concerns. Particularly in the U.S., parts of the society, including elected officials, ignore the vulnerabilities and risk to which the U.S. society is exposed, despite the fact that scientific evidence is abundantly available (for example, through reports prepared by federal and state agencies, such as CCSP, 2008; Karl et al., 2009; Titus et al., 2009). The public deliberations in the U.S. therefore often divert from the problem and the need to develop mitigation and adaptation strategies to a controversial discussion about the reality of climate change.

2.2 The Societal Challenge of Climate Change in the USA

In the U.S., the highly variable social, cultural, and political environment, combined with a focus on elaborated uncertainty about climate change and SLR and the potential impacts, challenges mitigation and adaptation efforts (Biesbroek et al., 2009; Brody et al., 2010). Unlike other climate-related issues, such as renewable energy, emission disclosure and carbon cap-and-trade, where states have actively enacted policies (Rabe 2010), the policy landscape relating to climate change and SLR mitigation and adaptation is almost barren, marked by policy inaction. For example, between 2008 and 2011, the U.S. National Conference of State Legislatures (NCSL) Energy and Environment Legislation Tracking Database noted only eight legislative items in four states related to sea level rise. Of these, five failed, two were still pending, and only one was enacted. This suggests that despite SLR being an issue that could significantly impact coastal states and the country as a whole, few states even considered mitigation and adaptation enabling legislation.

The currently still slow nature of SLR, coupled with the prevailing perception that in the U.S. any potential immediate threat is limited only to coastal regions, makes it a largely invisible, easily ignored problem that often takes a backseat to more pressing issues. Furthermore, the association between SLR and climate change has also resulted in SLR itself becoming a politicized and contentious issue, further constraining mitigation and adaptation solutions. The lack of SLR awareness among the general public and policy makers in the U.S., coupled with strong economic pressures to allow development in coastal

areas, makes addressing SLR even more challenging and difficult, as evidenced by the experiences in South Carolina and North Carolina (Moser, 2005). As Brody et al. (2010) found in their study of SLR policy at the sub-national level, "it is clear that climate change mitigation and adaptation are generally low-priority issues for local and state decision-maker organizations in the USA when compared with other issues such as jobs or transportation" (p. 600). Yet, unlike climate change in general, the local impacts of SLR are more tangible and identifiable (e.g., flooding and beach erosion), making the issue more relevant to those in vulnerable coastal areas.

Vulnerability to climate change and SLR, both at the individual and community level, are both barriers to and enablers of mitigation and adaptation actions. At the individual level, social and cognitive factors such as emotions, knowledge, self-efficacy, and risk perceptions may influence the motives and willingness to be involved in mitigation and adaptation efforts. Uncertainty and risk perceptions are particularly important. As Sundblad et al. (2009) concluded from the work of Sjöberg (2007), "beliefs about consequences are more important determinants for policy attitudes than are probability estimates of unwanted events or perceived risks of activities leading to such events. Hence, the mere existence of risk consequences is more important than whether the probability is high or low" (p. 294). At the community level, the social vulnerability of certain segments of the population and overall community resiliency may play a role in constraining or encouraging mitigation and adaptation to climate change and SLR.

Since SLR is both a local and global problem, mitigation and adaptation are constrained by a multi-level governance structure (Biesbroek et al., 2009). A specific constraint is who should take the lead in mitigation and adaptation action, and at what governance level. At the state level, in Virginia for example, one of the factors challenging a state-level mitigation and adaptation response is the perception by proponents that conservative opposition currently makes passing legislation intended to address climate change and sea level rise politically unfeasible (Harper, 2013). Primarily because the SLR problem and its impacts tend to be perceived as localized, there is disagreement among state legislators that SLR is a problem that should be addressed by the state at the state level. Beyond the issue of multi-level governance, mitigation and adaptation are also constrained because they often require multi-sectoral partnerships. A cohesive and coherent multi-sectoral response requires effective collaborations across governmental, nonprofit, educational, business, and community/grassroots sectors.

Finally, even when adaptation and mitigation are explicitly being considered, the consideration is complicated by the classic rivalry between economic interests of companies and individuals, the socialized costs related to current and future climate change and SLR, and other environmental interests. These policy trade-offs are further exacerbated by politics. In the U.S., the science of climate change is closely tied to the politics of climate change; politics have penetrated the debate to the point where ideology often trumps science (Jacques et al., 2008). Mitigation and adaptation responses to climate change and SLR have taken on a partisan quality, with liberals supporting policies to mitigate or adapt to climate change and conservatives frequently opposing such policies, sometimes even denying or expressing skepticism of the existence of climate change. To be sure, climate change has been politicized in other countries as well (see, for example, Weingart et al., 2000), but the U.S. appears to have a more intense political debate regarding the existence and seriousness of climate change compared to other Western countries.

While the societal challenges confronting effective mitigation of, and adaptation to, climate change and SLR are problematic and complex, there is reason to believe a concerted interdisciplinary and inter-organizational effort located at ODU intended to address these issues would be both welcome by the

wide variety of relevant actors and become a potentially powerful catalyst toward affecting practice and policy. On the surface, this would seem to be the case given the importance of these twin issues and the growing awareness among many stakeholders in the Hampton Roads community and elsewhere of this importance. The recently concluded European Union-funded interdisciplinary collaborative conference co-sponsored by ODU's Department of Ocean, Earth and Atmospheric Sciences (OEAS) and Graduate Program in International Studies (GPIS) provided clear indications that this is indeed the case. The ACCESS-EU conference, titled 'Transatlantic Solutions to SLR Adaptation: Moving Beyond the Threat', brought European and American experts together October 30-31, 2013 to discuss the technical, economic, social, and political issues connected with adaptation to rising sea levels. More than 100 experts from academia, city and state government, US Navy and Army Corps of Engineers, businesses and non-governmental organizations participated in the conference. There were many disciplines represented from both the natural and social sciences, including, among others, Oceanography, International Studies, Political Science, Engineering, Geography, Marine Science, Economics, Communications, Public Health, History and Public Administration.

The conference was successful in its goal of bringing together a like-minded community to begin addressing the way forward globally, regionally and specifically here in Hampton Roads. The approach of the conference was participant-centered in an attempt to identify opportunities for interdisciplinary collaborative research and action aimed at affecting policy and practice. Evaluations conducted by ODU indicate that participants were very positive about the conference itself and the possibilities for future collaborative action and research, with many open-ended responses focused on the need for ODU specifically to play host to interdisciplinary efforts going forward. As a result of the conference, it is clear that there are actors and organizations willing and eager to participate and, importantly, significant sources of funding available for the unique institute proposed here.

2.3 Addressing the Challenge in the U.S.: Legal, Governmental, and Political Framework

Over the last 80 years, the US Federal government has developed two approaches to the mitigation of, and adaptation to coastal hazard (flooding, waves, and erosion). In a reactive approach, federal agencies react to stakeholder needs. In a proactive approach, focus is more on the strengthening of the adaptive capabilities.

In 1930, the Rivers and Harbors Act (P.L.71-520) created the Beach Erosion Board (BEB) with the U.S. Army Corps of Engineers (USACE), the agency designated by Congress to protect the nation's shores from flooding, wave damage and erosion. From the beginning, USACE has been reactive by listening to the needs of local groups (stakeholders such as citizens, businesses, cities, etc.) who express their problems to their congress representatives. Under this approach, projects that begin with local interests are proposed in the Water Resources Development Act (WRDA), and those benefiting must take a share of the initial construction costs and life-cycle maintenance costs. This approach to coastal hazard mitigation must be considered as *reactive* since the lead (in theory) to solve local problems must come from the local stakeholders: USACE listens to the needs and serves as agent for the people to try to solve the local problem.

USACE's approach primarily has aimed at mitigation of impacts by 'structural' changes, i.e. through changing and strengthening the physical system by using armoring (hard) structures, beach stabilization structures (breakwaters) and beach nourishment (soft) alternatives. In the U.S. context, changes to the physical system are generally easier to accept by the local communities, but generally harder to perform in an environmentally acceptable manner.

But USACE also considers non-structural alternatives through adaptation, such as elevation, changes in

zoning, and retreat. For example, low-lying areas of Baytown, Texas (24 km east of Houston) on the Galveston Bay suffer frequent flooding from minor storms and subsidence due to oil and gas withdrawal. Both structural (earth levees, concrete floodwalls) and nonstructural (permanent relocation and evacuation) alternatives were studied in the early 1970's and the feasibility report to Congress recommended the retreat alternative. Congress authorized this project under the WRDA, 1978. The benefit/cost ratio was 1.3 for the retreat alternative and only 0.1-0.3 for the structural alternatives. Annual project benefits were estimated to be $3.530 million (1979 dollars) and included reductions for insurable flood damages; reductions for utility service costs; reductions of temporary, emergency evacuation, public health and public relief costs; and value of land under new uses. The environmental assessment report was approved by the EPA. Unfortunately, the project was not carried out because the necessary local 20% cost share could not be provided. In July, 1979 a bond election was held to provide the local funding and it failed by a 60/40 percent margin. People who did not live in the flood plain felt that those who did would be paid far too much for relocation. In 1980, Congress was ready to authorize funding, but the local residents decided to stay and the USACE placed the project in its inactive category. Because the benefit/cost ratio was 1.3, the annual benefits to the Federal government exceeded the 20% local cost share amount, and the Federal government could have paid for the entire project and still realized net economic benefits to the Federal government.

The proactive approach started to develop in the frame of the National Flood Insurance Act in 1956 and the National Flood Insurance Program (NFIP) beginning in 1968 (P.L. 90-448), which both had the emphasis on nonstructural responses to coastal hazards. Today, FEMA manages the NFIP and has always considered a wide variety of nonstructural alternatives for flood hazard mitigation. The requirement that the elevation of the first floor living space be above the 100-yr recurrence interval flood event is the most common.

In 1972, Congress passed the Coastal Zone Management Act (CZMA) (P.L. 92-583) and began a federal effort to assist the states by improved land-use planning and appropriate construction location and design. The National Oceanic and Atmospheric Administration (NOAA) administers the CZMA through a partnership with the coastal states that elect to participate.

Thus, FEMA's and NOAA's approach has been to change and strengthen institutional, political and legal systems by adaptation. In this, FEMA and NOAA have been proactive by telling the local groups (individuals, businesses, cities, etc.) what needs to be done to mitigate their coastal hazards. This is a federal government "top-down" approach that local groups must accept if they want to purchase flood insurance, receive federal funds for planning purposes, etc. This approach of two federal government agencies can be considered proactive since the initiative to solving the nation's coastal hazard problems comes directly from the federal government. The FEMA and NOAA identify the needs and enforce the rules to address the problem. Changes to societal system often are harder to accept by impacted communities but easier to perform in an environmentally acceptable manner.

Many other events, laws and federal agencies have been involved in coastal hazard mitigation over the past 80 years. The Heinz Center Report (The Heinz Center, 2000) presented five categories or management approaches:

1) Structural Shoreline Protection
2) Insurance and Disaster Assistance
3) Planning Incentives
4) Withdrawal of Subsidies and Incentives
5) Public Ownership and Land Management

The report presents a summary of approaches to coastal erosion management by all parties that is also valuable for all types of coastal hazards.

All three primary Federal government agencies (USACE, FEMA, NOAA) responsible for coastal hazard mitigation and adaptation have addressed climate change and the potential for accelerated sea level rise in the coming years (e.g., Brekke et al., 2011). Since 1983, the "Principles and Requirements for Federal Investments in Water Resources" have provided direction to Federal agencies when evaluating and selecting major water projects, including projects related to navigation, storm resilience, wetland restoration, and flood prevention (with the latest version, CEQ, 2013, released in 2013). These principles were in the past limited to USACE, Bureau of Reclamation, Tennessee Valley Authority and Natural Resources Conservation Service. In order to increase consistency and comparability in Federal water resources investment decision making these Principles have been expanded to include other relevant projects, programs and activities undertaken by the Environmental Protection Agency (EPA), the Department of Commerce, the Interior, Agriculture, and Homeland Security consistent with statutory authorities.

2.4 Cost-Benefit Analysis

The Cost-Benefit-Analysis (CBA) presented here is a first-order one-dimensional approach, which only considers the risk associated with fatalities caused by extreme events. The approach does not take into account the complexity of problems cause by slow changes in mean climate and LSL, which would require a more sophisticated framework (e.g., Wegner and Pascual, 2011). Here we apply a standard approach used, for example, by government agencies. This approach uses the risk of death faced within a population to determine the annual cost a person or the community should be willing to spend in order to reduce this risk. We focus on the risk associated with hurricanes. Assuming a Poisson distribution for the occurrence of extremes, the chance that a 1 in 100 years event occurs at least once in any given century is about 63%. If we assume that a 1 in 100 years hurricane would kill 1% of the population in the Virginia Beach/Norfolk area, then an individual living in this area faces a risk of about 1 in 16,000 to be killed by such a storm surge. To proceed with the CBA, we must decide how much it is worth spending to reduce this mortality risks. The traditional approach has been to put a monetary value on each life which we can expect to save by some policy change. The value of one life saved is called the value of a statistical life (VSL). VSLs are typically calculated either from labor market data (e.g., by looking at how much of a wage premium workers demand for performing more dangerous jobs), from product market data (e.g., by looking at how much extra consumers will pay for a safer car, or a house in a less polluted area), or by survey. Basically, the idea is to see how much of their own money people are willing to spend to reduce their own mortality risks - the idea is that government policies should not force taxpayers to "purchase" more or less safety through government policies than they are willing to purchase when they choose freely (see Viscusi and Aldy, 2003, for a survey on VSL calculations). After conducting a review of the literature, the US Department of Transportation (DOT) has recently determined that the appropriate VSL to use when dealing with potential road fatalities in the US is $9.1 million (Trottenberg and Rivkin, 2013). This means that the DOT assumes that a US citizen is (or should be) willing to pay about $910 to eliminate a 1 in 10,000 risk of a fatality.

Using this consideration, an individual living in the Norfolk/Virginia Beach area should be willing to pay about $550 per year to eliminate the 1 in 16,000 risk of being killed by a storm surge. If we further assume that the risk cannot be eliminated but realistically be reduce to half, then the individual should be willing to pay about $275 per year to achieve this. Assuming a total population of 1,000,000 people in the area, then the population in Norfolk and Virginia Beach should be ready to invest $275 Million

per year in reducing the risk associated with the 1 in 100 years event.

Considering that in this particular area, limited transportation is a key obstacle for successful evacuation, then the best way of investing these fund would be in improvement of evacuation transportation routes. It is obvious that these improvements would not only reduce the disaster risk rapidly but also result in many other immediate benefits for the regions. This simple CBA provides a very strong argument for the immediate investment into improved transportation for the Hampton Roads area. The regions is suffering from significant traffic problems impacting the daily lives of many. Thus, any effort made to improve horizontal evacuation options would immediately increase the quality of life of many.

3 REVIEW OF MITIGATION AND ADAPTATION RESEARCH

3.1 Mitigation and Adaptation Research: A Review

Research on mitigation of climate change and its impact and adaptation to climate change and SLR is to a large extent in a very early state. Since the 1950ies, when climate change was increasingly recognized in science as a potential problem for humanity (see, e.g., the history compiled by Weart, 2008, 2013), much of the research has concentrated on the changes in climate and the associated hazards due to weather extremes, SLR, and impacts on human lives and property, food and water security, economy, and ecosystems. Research on options for mitigation and adaptation has focused more on technical solutions, while research on decision and policy-making and social, cultural, political, and economic obstacles for mitigation and adaptation is in its advent. In particular, the central role of the social construct of vulnerability and risk as a determinant for the societal response to any given threat has only recently been recognized, and research on the variables that determine the social construct still needs to be carried out before the social construct can be conceptualized for societal deliberations of mitigation and adaptation strategies.

Understanding climate vulnerability is also just emerging. For a number of natural hazards such as earthquakes, landslides, tornadoes, cyclones, floods and droughts, a thorough understanding of the vulnerabilities has been developed and many technological and engineering approaches are at hand to reduce in particular the vulnerability of the built environment. Vulnerability to significant changes in climate or a rapidly rising sea level is not well understood, primarily because we have not experienced such changes during the time of human civilizations. The development of mitigation and adaptation strategies suffers from the limited understanding of the vulnerabilities. In particular, the water-food-energy nexus complicates the development of climate-change mitigation strategies (Hoff, 2011; Hanlon et al., 2013). The link between climate change impacts and public health further complicates the development of adaptation strategies (Craig, 2010).

Historical research has often described societal, cultural, and political changes as well as adaption efforts after extreme natural events, including major earthquakes, volcano eruptions, climate variation, and coastal and inland floods. Examples are the large medieval floods in the North Sea region. But up to now this research has mostly been limited to a descriptive or antiquarian approach. Recent studies, for example, by Soens (2013) demonstrate that such historical research is, however, not limited to a descriptive approach, but can identify the societal patterns of the past that have caused specific strategies for mitigation and adaption and the long term socio-economic outcomes of these approaches. While it is often perceived that retreat was more or less the only option available for historical societies to deal with changing climates or SLR, a number of historical studies also demonstrated that these societies reacted by changes in the built environment (for example, the ‘golden ring’ around Frisia ca. 1300) as well as changes in socio-economic patterns (Soens, 2013). Research on risk-based historical

decision processes and the perception of risk in various historical societies is still at the beginning, but projects carried out at research centers like the Rachel Carson Center for Environment and Society have shown that the perception of (environmental) risks is directly related to the societal context and, more importantly, changes substantially over time.

Mitigation of climate change impacts and adaptation to climate change require participation of all societal sectors and progress is hampered by science knowledge gaps in all areas (Moss et al., 2013). Decision-makers often lack the information needed to develop adaptive capabilities or they do not have the means to apply the information. In other cases, knowledge may exists, but not in a form that decision-makers can act on or not accessible to them. Acceptable options for adaptation may require engineering innovations and also depend on social science knowledge that could guide the deployment of new technologies as well as the necessary adjustment to public policies, investments and management. Adaptation science that comprehensively addresses all aspects of this complex socioeconomic and socio-environmental process is emerging. Moss et al. (2013) characterize this emerging science as "*both basic – in that it contributes to understanding fundamental physical, environmental, and socioeconomic research questions – and applied, because it is problem focused.*" Particularly the applied part of adaptation science requires a co-design and co-production of knowledge, where scientists and practitioners jointly define the questions and maintain frequent interactions to ensure that the knowledge created is relevant to the solutions sought by the practitioners (Dilling and Lemos, 2011). Efficient working practices for co-design and co-production of knowledge have not been developed, and existing practices are often challenging to implement and sustain because the stakeholders involved have a wide range of different roles, interests and incentives, and there are large differences in methodology and vocabularies. Thus, adaptation science needs to address the co-design and co-creation of knowledge as an integral part of the science. Likewise, adaptation science has to link knowledge to decision-making and close the current "usability gap" that limits the practice-relevance of much of the scientific knowledge. This requires a clarification of the factors that impact decision-making (such as cost, feasibility, social acceptance, tradition, etc.; Moss et al., 2013), and an integration of information into the existing contexts (Lemos et al., 2012).

3.2 Innovation, Technology, and Engineering in Mitigation of Climate Change and Sea Level Rise Impacts

Currently, research is less focused on social capital, social construct of vulnerability, risk, resilience, ... Mitigation and adaptation strategies are generally being developed independently of each other, and unfortunately the public health perspective has not been well represented too. Perhaps it will be critical to address this issue.

Mitigation of impacts through prevention …

Adaptation through changes in land use, building codes, …

Innovation during the last several hundred years are introducing fundamental changes in peoples lives at an increasing speed. However, these innovations have not contributed to humanity solving the sustainability crisis and getting closer to sustainable development, which could be termed an innovation paradox (Glavovic, 2013a). At the same time, we are in dire need of more innovations that can actually help to develop solutions for the unsustainability of our current situation and trajectory (Glavovic, 2013b). However, it will be crucial to guide the innovation process to ensure that a continuation of the innovation paradox is not exacerbating unsustainability and keeping us on a

trajectory far away from sustainable development. As this is true for sustainability in general, it also applies to mitigation and adaptation related to climate change and sea level rise.

There is considerable focus on innovations that would lead to mitigation of climate change. Based on the reasoning that Greenhouse Gases (GHGs) resulting from our use of fossil fuels, i.e., carbon dioxide (CO2) emissions, are the main cause of climate change, a focus has been on technologies to reduce CO2 emissions by using alternative energy sources ranging from the use of solar radiation, wind, geothermal heat, tidal currents and waves for the production of electrical power, the use of solar radiation and geothermal sources for heating, and biological production of fuels, electrical power, and heating to the substitution of fossil fuels by nuclear energy. Other efforts focus on ways to extract CO2 from the atmosphere, impact the albedo of the planet, or reduce the incoming radiation. The large-scale geo-engineering approaches discussed in this context carry a high risk and are controversial. Reduction of CO2 emissions through more efficient energy usages is linked to changes in building codes as well as more efficient means of transportation.

It is important to note that equating climate change mitigation to a reduction of fossil fuels and CO2 emissions, as is often done in the public, neglects the fact that 35-45% of the climate forcing results from non-CO_2 GHGs (Ripple et al., 2013). However, research on how to reduce other GHCs such as methane is much less and significant innovations are not in sight. Much of the emissions of non-CO2 GHGs are resulting from food production (meat and rice) ...

Climate change adaptation is mostly seen as the process of enabling the built environment, social communities, and ecosystems to function and exist under the changing climate conditions that could not be mitigated. There is considerable research on how to adapt buildings to changing climate conditions (...), including heat and drought resilient infrastructure and buildings (…). The National Institute of Building Science (NIBS) ...

There is also considerable research into adaptation of ecosystems to changing climate conditions (…).

Where less research efforts are underway is the adaptation of social systems (see next section).

3.3 The Human Component: Social Sciences and Humanities' Contribution to Mitigation and Adaptation Research.

With respect to extreme events and disasters, there is extensive literature on emergency management in the field of public administration; however, much of the literature is focused on organizational response and interactions during and post major disasters. Emergency response of major disasters is complicated by its extremely high cost, the span of recovery over a long period of time, and the responsibilities across many different actors such as federal, state, regional, and local agencies. Therefore, the focus on the management of recovery efforts is not surprising. However, there is the recognition that beyond reactionary recovery efforts, government attention needs to turn to proactive mitigation and adaptation efforts (Brody et al., 2010) and an increase in preparedness (see e.g., the Executive Order, The White House, 2013).

Based on lessons learned from past recovery efforts, Gerber (2007) emphasizes that government policies and their implementation can reduce the impact of natural disasters through regulatory policies. Some policies are locally focused such as building codes and land use controls. Other policy recommendations are focused on the federal level such as removing subsidies for flood insurance and requiring protective measures from homeowners to receive federal aid (Landy, 2008). Interestingly, these studies do not distinguish *mitigation* from *adaptation*.

The distinction is clear in more interdisciplinary studies. Kirshen et al. (2005) define mitigation efforts as policies aimed at reducing likelihood of adverse effect of climate change. They define adaptation as reducing the severity of the impact from the inevitable adverse changes. These two efforts are complementary. Similarly, Brody et al. (2010) explain that these complementary efforts tend to involve federal, regional, or super regional actors to produce large scale policies such as transportation and energy policies. Adaptation is more focused at the local levels by focusing on zoning and land development and planning.

Unfortunately, there seems to be a disconnect between increasing awareness of scholars and practitioners and the adoption of mitigation and adaptation plans. Some scholars have found that practitioners are deeply concerned but there are few adaptation plans (Mozumder et al., 2011). There may be mitigation plans with no mention of adaptation in them (Kirshen, eta al., 2005). The perceived importance of mitigation and adaptation varies significantly across types of emergency management professions, and the level of concern may also vary by coastal proximity (Brody, et al., 2010). This observed disconnect is leading to a focus on addressing barriers to mitigation and adaptation planning and implementation, such as lack of information, leadership, and institutional framework (Mozumder, et al., 2011).

Research on economic impacts of climate change is slowly gaining more emphasis. For example, in the past decade, tourism scholars have placed considerable emphasis on the growing importance of the need to research climate change and how it will affect host communities and tourists (Amelung et al., 2007; Becken, 2005; Reddy and Wilkes, 2013). One of the primary concerns for the tourism industry is the impact on tourist flows and seasonality for many destinations (Amelung et al., 2007; Bigano et al., 2008; Perry 2006). Changing temperatures will mean destinations have longer shoulder seasons and could change the time of year more tourists visit (Amelung et al., 2007; Perry, 2006). There are multiple studies that address climate change mitigation and adaptation.

Mitigation is addressed in the tourism literature in the context of mitigating climate change. Most researchers are concerned with the impact of the carbon emissions of the tourism industry on the environment and how this contributes to climate change. The need to reduce energy usage and carbon emissions in order to mitigate climate change is paramount to ensuring the sustainability of the tourism industry. Another concern is how the need to reduce emissions could negatively impact tourism's economic impact (Becken and Patterson, 2006; Peeters and Dubois, 2010; Peeters and Eijgelaar, 2014; Reddy and Wilkes, 2013).

Adaptation to climate change is a popular topic, especially in the context of case studies (Reddy and Wilkes, 2013). A number of adaptation studies focus on winter and ski tourism, since they face many challenges with less cold weather and snow as the planet heats up (Balbi et a;., 2013; Hoffman et al., 2009; Scott et al., 2006). Some of the case studies from coastal areas come from island nations such as Samoa and Fiji, both of whom are dealing with rising sea levels, among other issues as a result of climate change (Becken, 2005; Wong et al., 2012). Researches mention mitigation in these studies, but primarily in relation to mitigating climate change, not mitigating the impacts of climate change. The primary method of data collection in most of the case studies is interviewing stakeholders. In New Zealand, a study with small business entrepreneurs found that daily business operations were more important than concerns about climate change. The only way in which it might become an immediate concern was when they had to deal with the aftermath of a natural disaster (Hall, 2006). In Fiji, a researcher found that accommodation providers were adapting to the impacts of climate change through the construction of seawalls and planting mangroves to stop erosion, trying to control pollution levels to protect coral reefs and conserving water (Becken, 2005). A common theme in the studies is

the importance of informing stakeholders of climate change and how they receive this information. Entrepreneurs in New Zealand trusted extension workers and government sources over popular media sources (Hall, 2006). Researchers in Fiji found stakeholders needed more information and adaptation measures that were feasible and practical to them, given their limited financial resources (Becken, 2005; Moreno and Becken, 2009). The lack of financial resources was found to be a barrier to adaptation (Becken, 2005). Another study investigated the possibilities of private and public partnerships in order to help the Samoan government cover the costs of adapting to climate change impacts (Wong et al., 2012).

Multiple studies point to the need for more research in climate change mitigation and adaption. Some researchers suggest possible conceptual frameworks and research questions which may advance the tourism and climate change research agenda (Dubois and Ceron, 2006; Patterson et al., 2006). Patterson et al. (2006) suggest a multi-scalar, multi-temporal model to adaptation and mitigation research in tourism, over the standard two-dimensional approach that has been taken in the past. Dubois and Ceron (2006) indicate the importance of localized case studies in raising the awareness of stakeholders about climate change impacts. They provide a variety of suggestions for ways to approach both adaption and mitigation research in tourism (Dubois and Ceron, 2006).

There seems to be a lack of research on urban coastal tourism destinations and the adaptation to and mitigation of climate change impacts, especially in the United States. Coastal tourism climate change studies are primarily international and focused on island nations. Hampton Roads could provide an excellent localized study area of the tourism industry and climate change since much of the area is reliant on the industry as an economic generator (Virginia Beach Convention and Visitors Bureau, 2013).

The Organization for Economic Cooperation and Development (OECD) and the UN Environmental Program (UNEP) tried to assess how prepared countries' tourism sectors were to adapt to climate change. A main conclusion was that "In most countries, no strategic reviews exist of vulnerabilities and potential adaption strategies for tourism" (Scott et al., 2012, p. 287). With several exceptions, there were no adaptation policies on the books for any of the countries surveyed by OECD and UNEP for the tourism sector. International organizations display a variety of responses to the challenge of climate change for tourism (Scott et al., 2012). The UN World Tourism Organization (WTO) has tried to raise climate change awareness since 2003 when it organized an international conference on the topic. The World Travel and Tourism Council is primarily focused on climate change mitigation with regard to emissions from the tourism industry. The OECD has been working to reduce emissions but also encourage adaptation strategies. UNEP has also worked to raise awareness of climate change and developed capacity building materials in order to facilitate adaption to current and future impacts of climate change. They have even hosted several seminars to bring together academics, government and industry players in tourism (Scott et al., 2012).

A similarly diverse awareness of, and response to climate change can be found in other business sectors. Research is needed to better understand the factors that impact the awareness and willingness to respond and adapt in the private societal sector.

Review research on decision-making …

Discuss rational agent model versus non-rational decision-making …

Recent experience shows that the kind of large-scale political and social changes necessitated by the realities of climate change can in fact be identified and implemented successfully, even quickly. Examples of this type of change are both indicative of the potential for MARI to be successful in aiding effective change and potential templates for reform and subjects for further research.

The best, most instructive example is that of ozone depletion. The depletion of the ozone layer and climate change were once twin issues, both threatening extreme long-term global hazards. Both challenges, additionally, were 'collective-action' problems involving public goods, with the incentive structure seemingly built to encourage 'free riders'. From a political-economic perspective, large corporations producing CFCs had incentives and the political-economic power to maintain that production while the individuals most likely to be harmed – current and especially future citizens, were relatively powerless and underrepresented. The difficulty of negotiating an effective treaty that would be both acceptable to developed and developing countries alike looked overwhelmingly problematic. However, the successful negotiation and subsequent international ratification of the Montreal Protocol of 1987 led to the elimination of and substitution for CFCs in a relatively short time frame. There is a body of research, running across the Social Sciences and Humanities, that discusses these changes. In the end, nations acted in concert with other nations, rather than as 'free riders' (Beron, et al, 2003). Political and economic leaders, as part of an 'epistemic community' of experts, chose to support rather than oppose the necessary measures (Haas, 2004). This support turned out to be economically efficient and rational as well, with Dupont and other corporations choosing to proactively research and market CFC substitutes (Falkner, 1992). While this example deals with the mitigation of the hazard, rather than effects, it still provides a hopeful example of possibility for collective, proactive action against a complex, slow-moving and difficult to communicate global hazard involving public good. The substantive similarity between these issue areas, including the complexity involved in finding and implementing effective solutions, suggest hope for rapid effective change and provide something of a template for climate change mitigation specifically as well as effects mitigation and adaptation. Additionally, it indicates the potential for the private sector to benefit from adaptation and mitigation efforts.

4 MARI: THE MITIGATION AND ADAPTATION RESEARCH INSTITUTE

4.1 Vision and Mission

MARI's vision is that of thriving coastal communities. In pursuit of this vision, MARI's mission is to collaboratively engage in transdisciplinary mitigation and adaptation research to provide the practice-relevant knowledge needed by coastal communities to handle the challenges, and utilize the opportunities, of climate change and sea level rise. MARI will facilitate and engage in research, education and outreach to promote and enhance the understanding of climate change and SLR and their multi-faceted impacts on the built environment and the social fabric of coastal cities. MARI will work with societal stakeholders to develop options to mitigate and adapt to these impacts and support these stakeholders in the application of the knowledge resulting from the research.

MARI will aim to provide the practice-relevant mitigation and adaptation knowledge needed by regional stakeholders in the planning and implementation of solution-oriented measures that can increase preparedness and reduce the impacts of climate change and SLR in the urban coasts. MARI will research the historic, social, economic and environmental processes and factors that determine our capabilities to comprehend the vulnerabilities to, and risks associated with, climate change and SLR, and to develop strategies to reduce these through mitigation and adaptation. Central to mitigation and adaptation is the social construct of risk and vulnerability, which ultimately determines our capability to mitigate and adapt, and MARI will research the processes that determine this social construct. The

likely future climate change and SLR presents a challenge to our civilization unparalleled in human history (Section 1). Nevertheless, the historic knowledge of how civilizations have coped with major challenges is invaluable for the development of mitigation and adaptation strategies. Historic knowledge combined with recent understanding of our decision-making processes based on progress in neuroscience, social sciences and behavioral economy, provides a basis for a holistic approach to strategy development.

A particular focus of MARI will be on climate change and SLR as an opportunity to facilitate new businesses and jobs that can act in a growing mitigation and adaptation market from local to global levels. As a research institute, MARI can respond to the knowledge needs of business and also engaged in the development of the workforce required by the businesses to utilize the economic opportunities in climate change and SLR.

Functioning as a think tank for a transdisciplinary group of experts and societal stakeholders, MARI will develop strategies for mitigation of disaster risks and adaptation to a variable LSL and increased magnitude and frequency of inundation. The institute will work with experts, stakeholder groups and the general public to identify the vulnerability of the built environment as well as the social fabric in Hampton Roads and beyond to climate change and SLR as a basis for decisions on mitigation and adaptation. MARI will advise policy and decision makers, including governmental planning departments at local, state, national and global levels, on mitigation and adaptation measures.

To enable societal deliberations about mitigation and adaptation, MARI will make a general effort to inform the public in a timely manner about the challenges of climate change and SLR and the potential mitigation and adaptation solutions that could reduce the impacts on the region. In terms of the hazards, the institute will provide realistic risk estimates for LSL rise and extreme events including the detection of any acceleration of these phenomena induced by climate change. As part of an “early warning system,” it will aim to forecast changes in mean LSL on decadal time scales and alert decision makers about the increased probability of a rapid LSL rise over the next decade.

4.2 Values

The values guiding the new institute derive from the fact that comprehensive knowledge is the basis for solutions, and that this knowledge can only be derived through interdisciplinary and cross-sectoral collaboration. Thus, MARI will value transdisciplinary research motivated by well-identified knowledge needs of societal stakeholders with which the institute has a close relationship. Recognizing that applying the knowledge to develop solutions beneficial to society will require a work force capable of handling complex problems with many conflicting interests, MARI will value education that seeks to increase the capabilities of experts to work in an interdisciplinary environment on complex issues.

4.3 Governance, Leadership, and Membership

The proposed governance structure is guided by the following principles:

- The institute is lean making use of existing ODU assets as much as possible.
- The institute facilitates the networking across college boundaries and the funding of cross-college projects.
- The institute facilitates interdisciplinary and transdisciplinary education and engages in the development of interdisciplinary programs.
- The institute links ODU to its societal environment and facilitates the participation of stakeholders in the design and creation of knowledge.

The membership of the institute will be kept flexible to respond to emerging knowledge needs. MARI will provide core functions currently not available elsewhere in ODU.

A governance structure for MARI within ODU is sketched in Figure 3. The transdisciplinary nature of the topical focus of MARI requires the institute to be outside the traditional discipline-oriented college structure of ODU. We propose an institute under the direction of a Steering Committee reflecting this nature of the institute.

MARI also requires a leadership representing the wide range of academics involved in MARI projects. We therefore propose the leadership to consist of a director aided by two assistant directors representing natural sciences and engineering, and social sciences and humanities. The director represents the institute and is responsible for the development of a research and business plan. The director reports to the Steering Committee. The assistant directors provide input to the research and business plan and they ensure that natural sciences, engineering, social sciences, and humanities are equally connected to, and represented in MARI.

We propose a Steering Committee with representation of relevant ODU bodies. The Steering Committee comprises representation of the "owners" of MARI. Ex-offico membership of the Steering Committee includes the Steering Committee chair, the MARI Director, and representatives of the departments linked to MARI through Members (see below). Nominated membership would be used to ensure representation of relevant expertise and educational components. The Steering Committee endorses the research and business plans of MARI, monitors it work and finances, and appropriates resources for MARI.

The Director and Steering Committee are supported by a Scientific Advisory Board, which consists of national and international experts in science and research related to climate change, sea level rise, mitigation, adaptation, and, more generally, sustainability. This Board has the goal to connect MARI with relevant programs in mitigation and adaptation research as well as to provide guidance for the development of research plans.

Day-to-day leadership is provided by the Executive Team consisting of the Director and the two Assistant Directors. As the institute develops, a Program Manager might be added with the responsibility to ensure coordination between the various projects and programs of MARI. Depending on the development of educational and outreach programs, it may also become necessary to add an Outreach Manager and Education Manager to the Executive Team.

Members of the MARI include:

- *Members* are ODU faculty affiliated with MARI – members may have joint affiliation with other ODU colleges/departments;
- *Affiliate Members* are faculty with joint affiliations in institutions outside of ODU, including both national and international institutions;
- *Post-Doctoral Fellows* are post-doctorial researchers at MARI;
- *Graduate students* are those students engaged in graduate studies supervised by members of MARI.

Particular attention is required to ensure that tenure-track and tenured ODU faculty can engage in MARI projects. This will be crucial to achieve both a strong inter- and transdisciplinary institute and a good integration into the existing college structure. It is proposed that tenure-track and tenured MARI members would have their tenure with an academic department in the colleges and have their teaching obligations there, while part or all of their research efforts would be allocated for MARI projects.

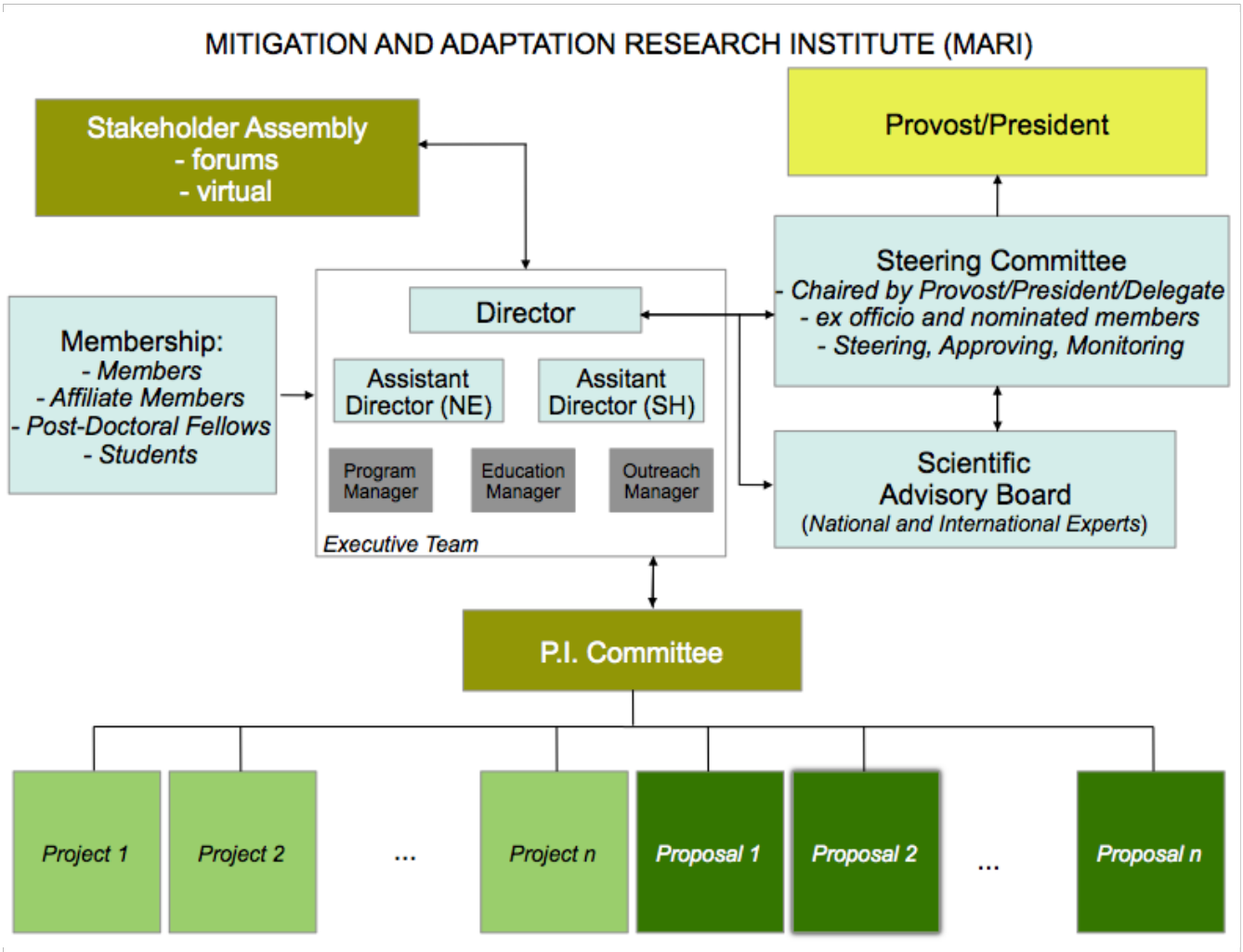


Figure 3: Proposed governance structure of the MARI. See text for a detailed description.

Most of the participation of ODU faculty in MARI projects would have to be covered by external funding. However, some of the faculty, particularly the more junior faculty, would need some form of buy-out of their research time to be able to fully engage in MARI proposals and projects not (yet) funded externally. To facilitate this, MARI will aim to establish a "fellowship" program (see Section 6 for details) in which MARI initially would give fellowships to ODU tenure-track or tenured faculty to spend time on MARI research (including proposal preparation studies and proposal writing). In a longer-term perspective, the fellowship program would also allow to bring in outstanding external experts for extended visits.

The number of Members of MARI will be flexible. The stakeholder-driven and problem-focused nature of MARI requires a project-based internal organization (see next Section), and several MARI staff members will provide so-called “horizontal functions” that are needed to identify, propose, manage, and synthesis complex projects cross-cutting through several disciplines. A committee of the Principal Investigators (P.I.s) ensures that synergies between projects are utilized and crosscutting issues are addressed efficiently.

We envisage an institute well embedded and networked with all relevant existing bodies in the

university. Frequent contact to stakeholders inside and outside ODU is crucial for the mission of MARI. A recurrent Stakeholder Assembly, initially university-wide and at a later stage open to the public, will ensure the linkage. This will be augmented by a web-based permanent assembly.

4.4 Organizational Structure

The following considerations concerning the internal structure apply to MARI at the end of the first five years. Considering the goal of MARI to facilitate solution-oriented cooperative research across disciplines and faculties both at ODU and other regional institutions, the core of MARI will be a group that can bring together ODU's and the region's foremost experts to address climate-change and SLR-related problems in urban coasts and, together with stakeholders, design and create the knowledge required to find solutions to these challenges. To a large extent, the issues will have to be identified together with stakeholders, and the solutions will have to be developed in collaborative projects using a transdisciplinary approach. The structure of MARI will have to be tailored to work with stakeholders in the identification of issues, to bring together the experts required to develop and carry out the solution-oriented projects, to communicate the solutions to the stakeholders, to participate in deliberations that will lead to policies and decisions concerning the paths to take to prepare the region for climate change and SLR, and to assist in implementation of these paths.

For MARI, we envision an organizational structure as depicted in Figure 4. MARI is intended to be stakeholder-driven and to address complex societally relevant research issue. Therefore, the organizational structure needs to have the flexibility to pull in potentially large, trans-disciplinary groups of experts. There are several functions needed to facilitate both the identification of the issues to be addressed, the development of project plans, the solicitation of proposal and project teams, the management and monitoring of the projects, and the dissemination of the project outcomes. We denote these functions as horizontal functions that serve several projects in a cross-cutting way and also ensure that the synergy and cross-cutting benefits of the projects are utilized.

In Figure 4, MARI provides common infrastructure used by the different projects including geographical information systems (GIS), GeoDesign tools, tools for the interaction with stakeholders, crowd-sourcing tools, information systems, and educational platforms and tutorials to ensure common messaging. Building a common infrastructure for adaptation research that allows the combination of environmental, social and economic data, provides access to best practices, and supports scenarios for research has been identified as a priority by Moss et al. (2013). The infrastructure will include a Global Coastal Zone Information System (GCZIS), which most likely will be linked to a regional node of the International Coastal Atlas Network (ICAN, see http://ican.science.oregonstate.edu/).

The GCZIS will have a strong focus on adaptation. It will have considerable crowd-sourcing elements for the collection of coastal zone information related to climate change impacts, mitigation options, and adaptation. Another element of the infrastructure will be a Virtual Stakeholder Table (VST), which will facilitate informed deliberations of stakeholders on climate change and SLR issues. Science and technology experts both from ODU and outside collaborators will participate as stakeholders in these deliberations, and thus participate in the co-design and co-creation of practice-relevant knowledge needed to develop the mitigation and adaptation solutions. VST will be a core element for the identification of stakeholder needs. MARI will include at least one senior expert with the main task to facilitate the deliberations needed to identify practice-relevant knowledge needs and to ensure that this knowledge is utilized in the decision processes concerning mitigation and adaptation.

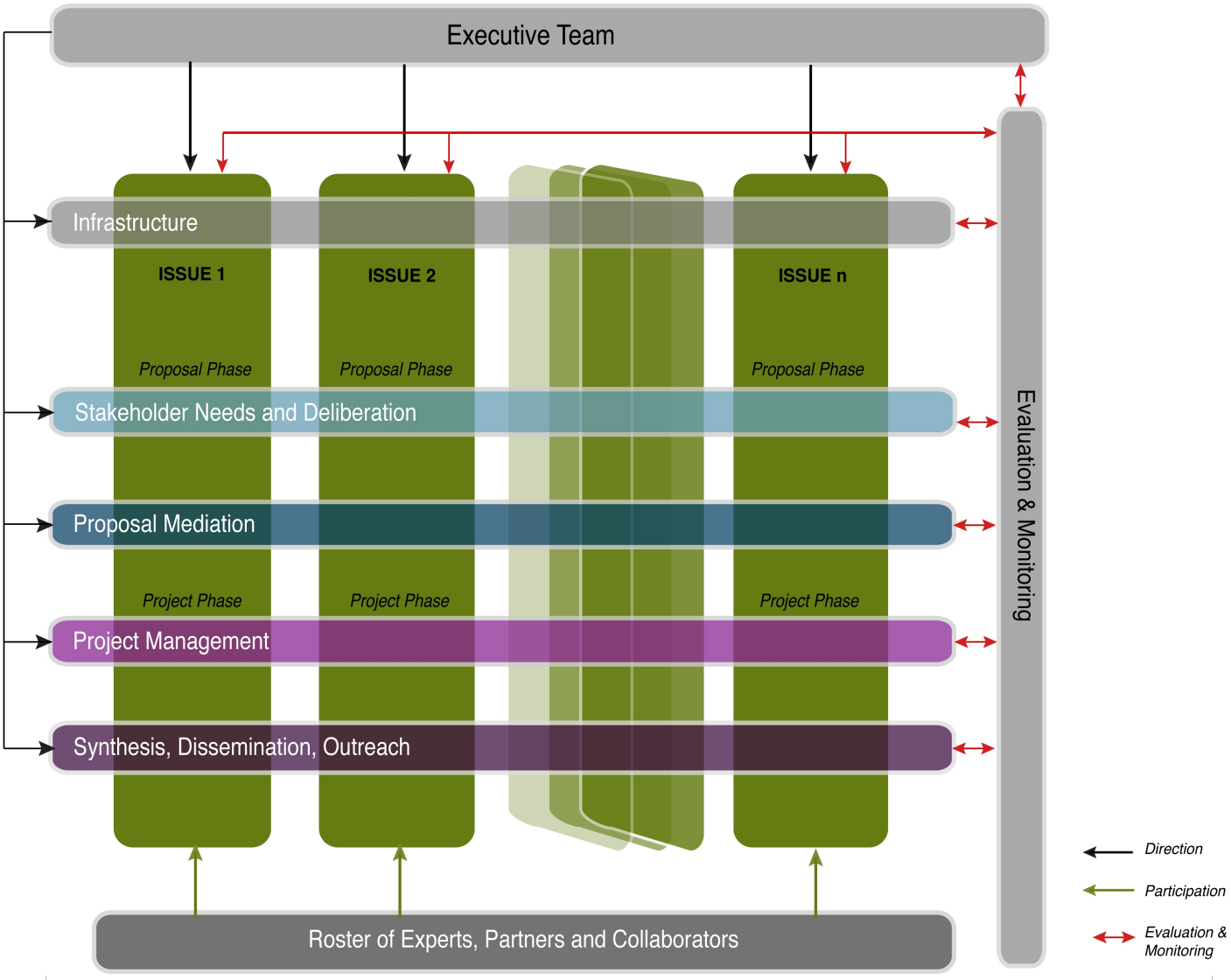


Figure 4: Proposed structure of MARI. MARI will provide several "horizontal" functions, which will facilitate and support trans-disciplinary projects addressing issues related to the impacts of climate change and SLR on (mainly) urban coasts. The project participants will come from a roster of experts in the faculties at ODU, other regional universities and research institutes, and international collaborators. Evaluation and monitoring of projects as well as MARI as a whole will provide essential feedback on the success, stakeholder acceptance, and impacts of MARI.

The infrastructure will also include elements for the management, monitoring and evaluation of projects. While standard project managements and accounting is expected to be provided by the central ODU administration, MARI will support P.I.s and Co-P.I.s with a reporting system, documentation, and outreach of the projects, following up on action items, and the evaluation of projects.

Based on the outcomes of the stakeholder deliberations and the identification of their practice-relevant knowledge needs, proposals for problem-motivated and solution-focused research projects can be developed. MARI will include one to two senior experts who can mediate the development of collaborative, trans-disciplinary proposals.

The horizontal function of Project Management will be provided by at least one senior expert who can support P.I.s in the monitoring and evaluation of projects as well as in addressing complex issues arising from the trans-disciplinary nature of the projects. Since co-creation of knowledge is an important requirement to ensure a strong focus on solutions, the expert will also assist P.I.s in the interaction with a broad range of stakeholders.

One to two experts will focus on synthesis of project outcomes both across individual project parts and across different projects, dissemination of the outcomes both in peer-reviewed scientific literature and media for the general public, and outreach to specific stakeholder groups who can utilize the knowledge for actual implementation. A key aspect of this function will be to ensure involvement of the science and technology experts in the implementation of the solutions as needed.

Why would faculty want to participate in proposals and projects led by/facilitated through MARI? This needs to be explained here or elsewhere ...

Proposal submission will be in the normal way through ODURF. MARI may provide organization help in addition to the proposal support staff at the Research Office. The allocation of IDC is of course something that will have to be determined. Regardless the submission process will be same as the process we are accustomed to.

4.5 MARI Infrastructure

Integration of projects across disciplines and problems can be facilitated by the provision of common cyberinfrastructure providing extensive functionality to the projects and inherently integrating databases, data collection, analysis and modeling tools, and presentation and dissemination channels. Therefore, MARI will provide extensive cyberinfrastructure in support of all projects carried out by MARI members. In particular, the following cyberinfrastructure will be made available:

MARI provides common infrastructure used by the different projects including geographical information systems (GIS), GeoDesign tools, tools for the interaction with stakeholders, crowd-sourcing tools, information systems, and educational platforms and tutorials to ensure common messaging. To the extent possible, these systems and tools will be based on existing infrastructure at ODU and integrated in other ODU developments. A key element of the IT infrastructure of MARI is the GCZIS, which will integrate environmental, social, and economic data; include coastal atlases, have considerable crowd-sourcing elements for the collection of coastal zone information related to climate change impacts, mitigation options, and adaptation; and offer a VST, which will facilitate informed deliberations of stakeholders on climate change and SLR issues. In a recent interview published in Wired (December 2013, page 106), Melinda Gates was asked “What innovation do you think is changing the most lives in the developing world?” She responded “Human-centered design. Meeting people where they are and really taking their needs and feedback into account. When you let people participate in the design process, you find that they often have ingenious ideas about what would really help them. And it's not a onetime thing: it's and iterative process.” This statement applies not only to the developing world. Also in the developed world, people's participation in the design process of innovation and knowledge is the best way of meeting the needs of the people. The VST will provide the methodological framework and the technological tools to ensure broad participation and enable the iterative process mentioned by Melinda Gates.

The outreach program of MARI will include a comprehensive web-based component (Section 5.3). The web strategy will include 3 tiers consisting of (1) a representative web page providing more static information as part of ODU web site; (2) a web work space providing access to dynamic web pages with often rapidly changing contents; (3) crowd-sourcing tools and information services linking citizen as information providers with models, databases, and GIS capacities to provide up-to-date information (see Section 5.3 for details). This web component will require considerable web server capacity.

MARI also has a number of IT requirements that serve several needs, including (1) data storage and dissemination capacity for integrated database inclusive of spatial data, demographics, models, and practice-relevant knowledge content; technologies and deployment strategies for sharing content; (2) modeling and analysis capacities for social vulnerability indices; best practices for refined risk assessment; hazard vulnerability threshold analysis; time series analysis; agent-based modeling; physical modeling; process and systems modeling; and (3) communication capacity for social media strategy, webinars (recorded & interactive), web tutorials and interactive virtual and face-to-frace workshops

The IT needs of MARI will be dictated by theses core function and the projects generated. The explicit IT initiatives and staffing contingent planned for the inception of MARI define foundational IT infrastructure requirements and give insight into the resources which will be necessary in the future. IT needs define both requirements for personnel, hardware and software.

In terms of staffing, technology-driven initiatives planned by MARI will require significant expertise in web-delivery, programming, database, GIS, networking, and information security. It will be necessary for MARI to rely heavily on existing resources and competencies (GIS, database, networking, security, project management) available within ODU Information Technology Services (ITS) and to acquire additional expertise in project-specific areas of specialization (model webs, crowd sourcing, etc.).

The significant challenge of adequate IT-related staffing for MARI is three-fold:

1. Expertise: MARI's Infrastructure Expert will be required to respond to expansive array of tasks which includes, but is not limited to: systems design, mapping, data analysis, report writing, complex remote sensing/imagery analysis, software development, database administration, and project management.

2. Volume of Work: The amount of IT-centric work necessary for MARI to function smoothly requires a multitude of experts. By necessity, IT-centric work should be tasked to ITS team members according more to their strongest skill sets, under the guidance of the MARI Infrastructure Expert.

3. Funding: What is the source of funding required for the basic IT infrastructure needs of MARI? Identification of resources which are available without additional funding is a necessary first step.

At inception, MARI will need a dedicated position of an Infrastructure Expert. This position will be defined in terms of a technically proficient IT manager. In addition, a virtual position for adaptive IT support will be created. A range of options are available for filling the second position, most importantly including substantial involvement from existing ODU GIS and ITS staff. ODU ITS has a small staff with well-developed expert GIS capability. The GIS group includes 1 FT GIS Lead Engineer/Project Manager (McLeod), 1 FT GIS database expert, 1 PT GIS Technician, and 4 PT student workers. 1 new full-time position has recently been requested. The MARI IT manager will use the second position to acquire IT resources with the variable expertise needed by MARI projects.

ODU GIS resources are presently insufficient to fully accommodate the foreseen needs of MARI. Therefore, the MARI IT manger will have considerable GIS and GeoDesign expertise. As more

projects require specific GIS and GeoDesign, a junior level Infrastructure Expert position will have to be added within MARI to provide direct and targeted technical support for MARI initiatives while working closely with the existing ITS GIS group. Programing expertise in web-based crowd-sourcing, model webs, and mobile communication and sensor technology are also required to support the infrastructure requirements of MARI.

The pace of change of geospatial technologies is extraordinary and rivaled only by other emerging high-tech industries such as, nanotechnology and bio-technology. It is critical that GIS, practitioners regularly engage in all manner of industry related training. Yearly allocations for training of IT-related positions should be incorporated into the Institute's budget.

4.6 Integration into ODU

MARI must integrate with the existing education, research and service activities at ODU. There are a number of ODU Centers that are of relevance to the mission of MARI, and coordination with, and between these centers will be a key function of MARI. MARI as proposed will be considerably different from any existing research effort at ODU, the reason for this being the broad transdisciplinary scope. This will both be a challenge and a novel opportunity: MARI cannot be successful if it is set up in a more traditional approach of university institutes. It needs to be an utility to bring the whole of the university faculty to another level of working together to solve society's problems.

An example is ODU's Insurance and Financial Service Center, which aims to serve as an intermediary to bring the right students and corporations together, both providing the industry with the next generation of talent and students with a satisfying, meaningful, and well-paying livelihood. MARI research is of direct relevance to this mission. Another example is the Emergent Risk Initiative (ERI), which envisions the creation of the next generation body of knowledge in risk management for current and future systems and organizations characterized by uncertainty, emergence, complexity, and interdependence. Likewise, the Global Health Center has a research focus that is connected to climate change and sea level rise. The recently established maritime history focus at the Department of History (manifested by the implementation of a Graduate Certificate Program in Maritime History; GCMH) provides a base for historical research on Climate Change and SLR in the marine realm.

Education – MARI may foster the creation of new courses and degree programs and other professional certificates. Many of these will be part of existing departmental offerings but it may become necessary to create courses directly by MARI once the educational needs are more clearly known and MARI's place in the academic structure is clarified.

Research – MARI will facilitate new research activities especially those that are inter- or trans-disciplinary. MARI will use its funding resources to provide support in areas of research that may require initial internal support.

MARI will be organized to link effectively with existing organizations already successfully operating within ODU. The intention is to help those organizations not replace them. It is recognized that the leaders these existing organizations have considerable credibility that must not be lost.

There are several existing organizations (e.g. International Studies, Bio-optical Research Group, International Studies Program, Emergent Risk Initiative, etc.) that may be functionally attached to MARI. This will be done via either formal arrangements or regular communications.

The proposed organizational structure of MARI is intended to assure effective communication between all parts of the University to assure success for all involved.

Service – MARI may develop service functions to serve government or businesses. These would either be done as part of normal University service activities or could be on a contractual basis.

4.7 MARI Stakeholders

In an extensive case study titled *Weathering the Storm: Building Business Resilience to Climate Change*, Crawford and Seidel (2013) examine the risk and opportunities for corporations in dealing with climate risk. They find that corporations are not taking actions due to the lack of *user-friendly, localized* projections that would allow then to justify taking near term actions related to climate risks. Instead they have a wait and see attitude, which typically results in reacting after the loss. The report states:

"*Many companies often also lack in-house knowledge or expertise about extreme weather and climate change; lack accessible, user-friendly localized projections of future changes in climate; need models and tools that link projected changes in climate to impacts germane to company operations; and have a lingering perception that climate change is too uncertain and long-term an issue to require near-term action.*"

This highlights a gap in practice-relevant knowledge. MARI will be well suited to work with corporations to co-produce the relevant data, knowledge and tools.

Linkages with External Organizations: Stakeholders

MARI will link to relevant external organizations at local, regional, national and international levels.

Local: Over the past three years excellent relationships have been formed with all the cities in the Hampton Roads area, the Hampton Roads Planning District Commission and Planning Commissions on Northern Neck and Eastern Shore. This has been done mainly through the forums supported by ODU and Virginia Sea Grant. Participants have included assistant city managers, storm water managers, coastal engineers, public policy, emergency managers, etc. The funding has been with HRPDC as a partner.

Commonwealth: MARI will interact with other state universities mainly through Virginia Sea Grant and the Faculty of Practice. Specific interactions will be required with the Virginia Institute of Marine Science and its Center for Coastal Resources Management, the Virginia Coastal Policy Clinic at the College of William and Mary, and the Center for Climate Change Communications at GMU.

The Commonwealth has several organizations that MARI will interact with. The Commonwealth established the Recurrent Flooding Sub-Panel within the Department of Veterans Affairs and Homeland Security. Coastal zone management is in the Department of Environmental Quality.

Regional: Governmental organizations include the Mid-Atlantic Regional Council on the Ocean (MARCO) and the Mid-Atlantic Regional Association Coastal Ocean Observing System. [need to add transportation, housing, health,….]

National: MARI will seek funding from the usual Federal agencies: NOAA (NWS, NOS, OAR, NMFS), DOD(ONR, NavFac), DOI, DOT, HUD, NIH.

International:

Description of the relevant regional, national and international organizations and programs and the emerging or potential roles MARI can take … Relevant programs and groups include the Group on Earth Observations (GEO, see http://www.earthobservations.org*) and the GEO Coastal Zone Community of Practice (see* http://www.czcp.org*) and Sea-Level Rise Community of Practice; the*

Future Earth Initiative (see http://www.icsu.org/future-earth*); and the Research Data Alliance (see https://rd-alliance.org/node).*

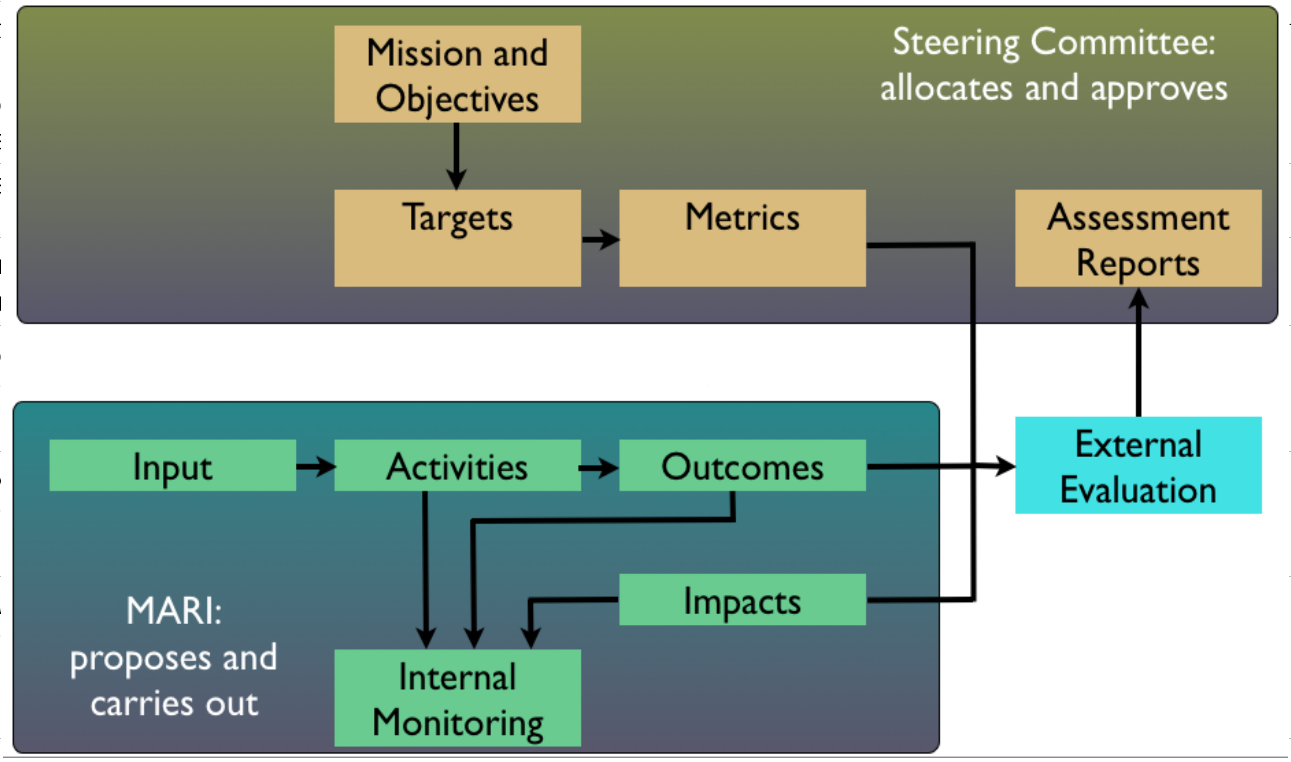
Non-profits: MARI will interact with relevant non-governmental not-for-profit organizations, including but not limited to Wetlands Watch, Chesapeake Bay Foundation, Chesapeake Climate Action Network, Nature Conservancy, Sierra Club, World Resources Institute, Climate Central, Pew Foundation, Sloan Foundation, Rockefeller Foundation ...

4.8 Evaluation and Monitoring

MARI is a novel approach to an emerging science field that focuses on practice-relevant knowledge and at the same time has to engage in basic research and develop the foundation for the science of adaptation. Adaptation research can only be of societal relevance if the research is strongly linked to the stakeholders making use of the knowledge created, and MARI will have to develop a conceptual and practical framework for the co-design and co-creation of knowledge. Marching into unknown terrain in several dimensions, MARI will face a number of challenges related to the academic and research organization at ODU, the science foundation, and the working with stakeholders. Most of these challenges will surface as surprises.

For the success of MARI, it will be important to closely monitor the progress and to evaluate the approaches taken. Evaluation needs to cover all dimensions, including the research carried out and the usefulness of knowledge created, the academic contribution, the economic basis, the linkages to societal stakeholders, and the societal benefits of MARI, including the impact on local businesses and jobs created.

Figure 5: Monitoring and evaluation of MARI. The Steering Committee determines mission and objectives of MARI and approves outcome-related targets and metrics proposed by MARI. MARI uses resources allocated by the Steering Committee and solicited from external sources to carry out



	Assembly	Board		
Impacts	MARI ExeTeam with input from P.I. Committee and Stakeholder Assembly	Steering Committee with input from Scientific Advisory Board	Three years	Report to Steering Committee
Targets	MARI ExeTeam	External evaluation	On request	Report to Steering Committee

The key actors and elements of the monitoring and evaluation plan for MARI are summarized in Table 1. Figure 5 shows the organization of the monitoring and evaluation. The metri moniEvaluation should be carried out on an annual basis by an external expert group that has sufficient linkage to all stakeholders, internally and externally, to assess the impacts of MARI in the different dimensions. A well-defined quantitative metrics will be developed based on agreed upon tangible targets to be achieved within a given time period, typically five years. The responsibility for the monitoring of progress is with the MARI Executive Team (ExeTean). The ExeTeam will record short-term, mid-term, and long-term outcomes, and compare these to the outcomes detailed in the MARI work plan. This work plan defines the activities and outcomes that are needed to reach the targets. The ExeTeam also will collect information related to impacts, and a main component of the metrics will be a quantitative measure for the societal benefits associated with these impacts. For the monitoring, input from the P.I. Committee and the Stakeholder Assembly will be solicited as detailed in Table 1.

The ExeTeam will evaluate progress based on short-term outcomes and report on this progress in a bi-monthly newsletter. Semiannual and annual reports on mid-term and long-term outcomes, respectively will be used by the Steering Committee to evaluate MARI's progress and contribution. The scientific and societal impacts of MARI will be evaluated by the Steering Committee on a regular basis (two or three years). The Steering Committee will solicit input from the Scientific Advisory Board for the evaluation. The Committee will also request external evaluation on a two to three year interval.

Action items of Monitoring and Evaluation Plan (*Adapted from Fukuda-Parr, Lopes, and Malik, Earthscan Publications Ltd, 2002*)

- Create baseline database to document the problem or situation;
- Decide indicators for outcomes;
- Plan data collection on outputs and how they contribute toward achievement of outcomes;
- Plan systemic reporting with more qualitative and quantitative information on the progress toward outcomes;
- Captures information from stakeholders related to achieving desired outcomes.

4.9 Societal Benefits of MARI

5 MARI ACTIVITIES

5.1 Research

MARI will develop a research agenda that is guided by the practice-relevant knowledge that is needed to facilitate preparedness of coastal communities. The three main fields of research are (1) mitigation of

climate change; (2) mitigation of impacts of climate change and SLR impacts, and (3) adaptation to changing environmental, social and economic conditions arising from climate change and SLR that could not be mitigated. For these fields, understanding decision processes and knowledge requirements is a common theme. Decision processes are guided not only by costs and feasibility considerations but also by cultural traditions, historical experience and values determining social acceptance. Our values have changed over time and what was acceptable a century ago may no longer be considered appropriate. Likewise, adaptation to climate change may require a different interpretation of values in order to reduce issues related to social justice and potential inequities related to impacts of climate change.

Historical research will be able to support all three main fields of research by identifying how past societies have dealt with mitigation and adaptation and thus providing a template for the relation of socio-economic and political structures on the one hand and contemporary decision processes in the context of mitigation and adaptation on the other hand. With Hampton Roads being a natural laboratory for mitigation of impacts of, and adaptation to changing climate and SLR, it seems to be particularly interesting to focus historical research on the medieval North Sea region, as this area faced similar challenges even if different in dimension.

Right now we have nobody on the team with a background in language studies, but we might think about adding this field to the list of disciplines that might be able to contribute to MARI.

Coastal communities will have to assess their current shore line protection and determine the appropriate mitigation of impact or adaption strategies. These strategies will likely be a mix of soft and hard engineering solutions. Soft engineering solutions include wetland creation, dune building, beach nourishment and green infrastructure. Hard engineering solutions include stormwater management, levees, seawalls, and floodgates or tidal barriers. (Mitchell, et al., 2013) The implementation of these strategies may build on one another, initially a soft engineering strategy might provide an acceptable solution, but as local sea level (LSL) rise continues, these soft strategies might have to be transitioned to hard strategies. Development of a flexible timeline for implementation of these various strategies based on predicted LSL rise would enable coastal communities to accelerate or delay implementation plans based on actual LSL rise. Hampton Roads provides excellent research opportunities for the adaption of existing strategies and development of new strategies for coastal protection of the region. Excellent transdisciplinary research opportunities exist evaluating the societal, economic, and ecological impact of these coastal protection strategies.

In addition to coastal protection strategies, impact mitigation and adaptation strategies for the built environment present additional opportunities for research. Infrastructure systems, roads and utilities, will need accurate prediction models for LSL rise, storm frequency and intensity data and temperature rise. Hampton Roads potable water systems rely on reservoirs that require protection from storm surge (salt water) infiltration and storm water systems are already inundated during severe storms. Green infrastructure solutions, to capture, use and infiltrate stormwater are viable alternatives, but predicted temperature increases need to be considered in landscape design components. (Larsen, et al., 2011) Development of adaptation strategies for transportation systems, roads and ports, will be a high priority for the Hampton Roads region both of which will face challenges from LSL rise.

Currently building design is mandated by building code and based on regional historic climate. Buildings are designed for a 40 year life, but many structures have service lives of 70 years and will be impacted by changing climate within their design and service lives. Plausible scenarios of local climate change, including the possible changes in extremes must be developed, communicated and converted into design standards for regions. Reliable estimates of plausible temperature increases, LSL rise, and

magnitude of extreme weather events are needed so that local building codes and building designs can be adapted to account for these potential changes. Additional research in the areas of energy, ventilation and cooling, urban drainage, water resource use, air quality, and urban heat island effect are needed for new and existing building stock and on both the building and city levels. (*NEED to add Source*)

Identification of Vulnerabilities; requires:

– *integrated data base, methodology and scenarios …*

– *understanding climate thresholds in coastal communities …*

– *identify those factors that determine social vulnerabilities, including poverty, lack of social capital, cultural and value-based traditions, lack of knowledge and preparedness, ...*

Improved understanding of future climate change, sea level rise, and related stressors, requires:

– *understanding future changes in extreme events and the socio-economic processes these events can trigger;*

– *understanding the probabilities of changes in climate and sea level and their likely impacts on weather and environmental conditions;*

– *timely, actionable information applicable to decision making developed through co-design and co-creations;*

– *climate and sea level services on interannual to decadal time scales that support timely adaptation planning.*

Increase the range of mitigation and adaptation options and support learning from the recent past and presence to increase preparedness; requires:

– *identifying the barriers that limit current mitigation and adaptation; including the social construct of vulnerability and risk; legal, political, and economic conditions; value systems; cultural history; …*

– *developing approaches to overcome the barriers;*

– *designing and implementing a human observatory that would provide the socio-ecological observations need to learn from experience;*

– *developing metrics to monitor, assess, and evaluate mitigation and adaptation measures.*

The success of mitigation and adaptation will be largely a function of societal factors (political, socio-cultural, economic especially). As such, increasing the range of mitigation and adaptation options and their likelihood of being implemented successfully will require:

- *Identifying the political, cultural and economic barriers that limit current mitigation and adaptation in Hampton Roads specifically, the US more generally, as well as globally. These might include, among others, current US political polarization and gridlock; state and local funding limits; the social construct of risk mitigation; lack of political efficacy and low information of citizens; the role of corruption in hindering mitigation and adaptation measures, etc.*
- *Identifying and developing interdisciplinary approaches to overcome the barriers. This should include identifying local, regional and global mitigation best practices to be duplicated and worst*

practices to be avoided; identifying the most effective ways to communicate information to community members, citizens/voters, politicians, and business people; and identifying other issue areas in which best practices might be replicated. As a recent example, the complete turnaround in less than ten years in public opinion and, to a lesser, lagged, ongoing extent, policy and practice regarding gay rights and marriage.

- *Using the above approaches, designing and implementing a human observatory that would provide the socio-ecological observations needed to learn from experience.*
- *Developing metrics to monitor, assess, and evaluate mitigation and adaptation measures.*
- *Collaborative and transparent promulgation and promotion of the information.*

5.2 Teaching and Education

MARI faculty will engage in teaching in several ways. In general, they provide support to appropriate courses through guest lectures and they support a number of courses through projects that provide practical experience to students and the community. MARI also will develop degree programs in close cooperation with the relevant colleges. The ultimate goal of the degree programs is a workforce that can address mitigation and adaptation in a comprehensive way, understanding the environmental, social and economic context of the coastal zone.

As outlined in the introduction, there is an urgent societal need for more human capacity in integrated and holistic management of environmental, economic and social activities in the coastal zone. Considering the complexity of the coastal zone, constructive interaction of the various stakeholders and their participation in deliberative governance of the coastal zone requires a common knowledge base paired with specialization as a basis for the expertise needed to address the wide range of challenges faced by coastal communities. Building the necessary human capacity is a long-term process requiring a focused effort of the higher educational systems.

Ultimately, we envision multi-faceted Master's degrees relevant to coastal zone management and mitigation and adaptation planning as a core element in the educational program. In addition to the education of new students, it also is important to improve the capacity of the existing workforce, particularly at leadership level. Climate change, as well as societal and economic changes, require flexibility and adaptive capabilities, and a program element for leaders in all societal sectors will focus on the development of adaptive leadership capacity.

Developing new transdisciplinary degrees and leadership certificates are demanding both with respect to organizational aspects and contents. The interdisciplinary and transdisciplinary courses that need to be developed are challenging to the faculty, who is traditionally confined in a discipline-oriented course system. Any new courses will therefore need a community effort and those lecturing will need the constructive criticism from others than their own discipline.

MARI therefore takes a step-wise approach to the development of new educational elements, which will provide experience and feedback from participants, both teachers and students, along the way and give guidance to the form and contents of the final elements.

In this approach, the first element will be a lecture series. The second element will be certificates for undergraduates, graduate students, and for post-graduate persons who are, or are intending to be, in leadership positions in the different societal sectors. The third element is the development of a Master's degree.

Undergraduate level: Cluster – a group of specific courses that examine an identified theme from a

multidisciplinary perspective.

Graduate Level: Two main programs are consider:

– Integrated Coastal Zone Management (covering all aspects of coastal zone governance);

– Transdisciplinary methods and analytics (including GIS, data management, scientific computing, syndrome analysis, time series analysis on different time scales, and complex system theory).

MARI will also work with ODU's Living and Learning Community program. With the support of the Division of Student Engagement and Enrollment Services, Housing & Residence Life provides a learner-centered environment conducive to the academic success of ODU students through an intentional Living-Learning Community program. Living-Learning Communities promote active and collaborative learning by offering students the opportunity to live and engage with other students who have similar academic and co-curricular interests. This environment will be utilized for new degree programs developed under the leadership of MARI.

Certificates in leadership ...

5.3 Student Engagement

Students are important for the future of our society and engaging them in addressing climate change is crucial for a sustainable development. MARI will therefore aim to engage students in many different ways in its activities. Linking students to the societal environment is a cornerstone in engaging students. Bringing students in contact with the issues both in academic programs and activities that link them to societal problems is necessary to help students understand the challenge they will face over the decades to come. MARI will work with existing student engagement programs at ODU to achieve this.

The existing student engagement programs at ODU include …

Of particular importance is a need for collaborative leadership development. While MARI will develop certificates open to leaders in society, there is also a need to engage students in the effort to develop the leadership capabilities that are needed in mitigation and adaptation. Coupling the need and advantages of involving civic engagement in the deliberation of mitigation and adaptation strategies that ultimately lead to the development and public acceptance of resilience–related policies, MARI will encourage the use of existing and the development of new co-curricular Service Learning projects and courses that emphasize leadership development, critical thinking, and personal reflection while encouraging community, civic engagement, and personal responsibility. Service Learning opportunities will be designed to imbue students with fundamental leadership knowledge and skills required to actively and effectively participate in community topics related to mitigating and adapting to local effects of climate change and sea level rise, while understanding the regional and global context.

To achieve this, MARI will engage in two activities:

(1) ***Identification of Current Service Learning and Co-Curricular Activities and Courses.*** The purpose of identifying existing ODU Service Learning co-curricular initiatives and courses would be to identify those student leadership-building entities that could readily lend themselves to building and enhancing relationships between ODU and the public on issues related to climate change and sea level rise.

(2) Development of Two-Course Sequence: A new for-credit two-course sequence will be designed around student acquisition of leadership knowledge and skills that culminate in the development of

action-oriented proposals that addresses local issues related to the impacts of climate change and sea level rise. In both cases, the emphasis is on student leadership and communication development for the explicit purpose of engaging the public in deliberations that serve to both inform and promote public awareness and actions required to mitigate and adapt to local impacts of climate change and sea level rise. Much like the design of the collaborative leadership development service learning-civic engagement initiative sponsored by the Barger Leadership Institute, University of Michigan (J. Owen-Smith, personal communication, January 22, 2014), a new two-course sequence on Collaborative Leadership Development in Service Learning is proposed (see Box 1).

Course 1: Collaborative Leadership Development in Service Learning – Civic Engagement: Project Development. Much of what has been written about leadership in America focuses on people with formal sources of authority and power. There is, however, also a long tradition of research and writing that suggests a more everyday form of pragmatic leadership that attests to American civil society (de Toqueville, 2002) as demonstrated historically through active civic organizations, associations, and movements. According to some recent scholars of leadership, it is this very decline of active citizenry that stands as a key reason behind the many social and political challenges facing America today (Putnam, 2001). In this first of a newly proposed two-course sequence, students will be exposed to leadership literature and case studies in which they actively debate the impact of situations on leadership style and effectiveness. This course will cause students to think about how leadership often occurs in contexts that are neither highly visible nor characterized by the exercise of formal power or authority. Students instead will come to realize that understanding, evaluating, and exercising leadership requires attention to collaboration, social influence, and persuasion. Students will come to discover that it is by these primary mechanisms that leaders in civic, religious, voluntary organizations, and mission-driven non-profit organizations, and even powerful leaders in positions of authority when facing significant challenges in for-profit enterprises, learn to rely on these collaborative tactics. This course will be built around readings and exercise grounded in organizational approaches in sociology and psychology, as well as from economics and political science. Most of this course, however, will be built around the development of circumscribed local action-oriented "pitch and plan" proposals related to mitigating and adapting to potential local impacts of climate change and sea level rise. Where large national initiatives can seem overwhelming and ambiguous to students, locally-focused projects appear more concrete to students and result in implementable solutions that move the dial forward (Weich, 1984). With the guidance of interested faculty, students will learn to work in teams, identify a local problem in the community, then "pitch and plan" a proposal in which they have to:

1) identify a mitigation or adaptation-related issue and define the situation and the different constituents involved;
2) determine how to take advantage of what's afforded by the situation; and
3) identify who they must work with.

By framing proposals in this manner, students learn that they cannot just steam-roll ahead, but rather have to work in the context of the local situation – identifying both challenges and opportunities, e.g., cultural, political, sociological, economical, religious, etc. The class will end in a ten minute presentation by each team to a panel of experts. Based on their presentation and the feasibility of the proposed project, selected teams will be invited to launch their projects in a follow-up course, *Collaborative Leadership Development - Civic Engagement*.

Course 2: Collaborative Leadership Development in Service Learning - Civic Engagement: Practicum-Project Launch. Building on Course 1: *Collaborative Leadership Development and Service Learning*, this second new course will focus on the launch of selected and ODU sanctioned Civic Engagement projects. With guidance from interested ODU faculty, students from the student team who proposal was selected for implementation, as well as students from projects which were not selected, will continue their study and development of collaborative leadership. In this course, systematic, critical reflection will be coupled with experiential learning through various Civic Engagement projects related to mitigating and adapting to local impacts of climate change and sea level rise. Tools and support will be provided to launch and implement projects designed to identify and remediate a problem facing our community. These real-world projects will serve as grist for student collaborative leadership development through group discussions, classroom exercises, and team level coaching interactions with interested faculty. These activities will be designed to promote cycles of critical thinking, action, and self-reflection that will allow students to link project work to both academic theories of leadership and the remediation of locally-related issues of mitigating and adapting to the impacts of climate change and sea level rise. Students will be assigned readings, participate in group discussions, and be involved in creating and attending group board meetings, working sessions, and meetings with their respective faculty coaches.

Box 1: Service Learning course focusing on collaborative leadership development.

5.4 Outreach

The outreach activities of MARI are embedded in the general outreach concept of ODU. They have the goal to link MARI to its stakeholders and by that to ensure that knowledge created responds to stakeholder needs and is available to those who can put it to work. A focus is on multi-faceted dissemination of knowledge enabling mitigation and adaptation to climate change and SLR.

Knowledge Management (KM) will be at the heart of this strategy. Creating knowledge is just the first step; in order to affect real change, managing that knowledge effectively and efficiently will be crucial, with proactive outreach as the front and end stage of MARI's KM processes (with the earlier stages related to the creation and electronic storage and publication of knowledge.)

Identifying and reaching out to key community stakeholders is the first step. The ongoing efforts of CCSLR, culminating in the recently concluded Sea Level Rise conference at ODU, have already yielded promising results. Stakeholders from local Hampton Roads military, government, business and non-profit organizations are identified and actively involved. Maintaining and cultivating those collaborative relationships is key to success. One important aspect of that upfront collaboration will be learning the needs and requirements of those various stakeholders vis-à-vis climate change and sea level rise. On the back end, knowledge accumulated from research must make it into the right hands, including local, regional and national political and economic decision makers. MARI members will facilitate the sharing of this knowledge via these stakeholder relationships via online and face-to-face collaboration.

A key gap exists specifically in the outreach and coordination capacity of full-time professional faculty members who have the knowledge, expertise, standing and access to leverage ODU, VASG, and Commonwealth-wide expertise, promote synthesis and integration of existing knowledge, and target outreach to the local, state and regional communities of greatest needs. ODU and VASG have shared goals and aim to leverage capacities in coastal and marine science to achieve mutual benefits and fulfill this gap. ODU and VASG have agreed to further build ODU's climate change adaptation outreach and coordination capacity in the CCSLRI to better serve Hampton Roads, the Commonwealth and the region. Specifically, the objective is to promote synthesis, integration, knowledge sharing, and coordination among research and education activities that will help the region reduce disaster risk, increase resilience, and adapt to climate change in general and increased flooding risk in particular, due to sea level rise. As a means to achieve this, ODU and VASG are jointly funding a Faculty of Practice in climate resilience and adaptation. The Faculty of Practice (FoP) is part of MARI, and will leverage institutional strengths and interdisciplinary approaches, particularly in collaboration with existing partner and with scientific, technical, and policy and planning capacity at VASG's other partner academic institutions, including but not limited to opportunities for joint product development and delivery, proposal generation, and other initiatives. The FoP is taking a leading role in collaborations that aim at the synthesis, integration, and facilitation of the transfer of scientific research-based information on coastal hazards applications to coastal communities, businesses, governments, and individuals. The FoP also promotes the on-going dialogue among the climate change and hazards community in the region that is advancing knowledge sharing, developing adaptation strategies and plans, setting adaptation priorities, forming partnerships, adopting best management practices, monitoring implementation of adaptation activities, and other adaptation activities at the local, regional, and state levels.

- Engage other researchers and Sea Grant specialists throughout Virginia, the region and nation in the development of on-going extension programs on resilience and adaptation to coastal hazards, incorporating those specialists' subject-area expertise as necessary or appropriate.

- Initiate and nurture partnerships with federal, state and local agencies to develop a coordinated approach to serving these specific clientele groups and the general public.
- Initiate, lead and partner on funding proposals with colleagues from ODU, the Hampton Roads region, and the VASG network.
- Transfer research-based knowledge about climate change resilience and adaptation as it relates to Virginia's urban communities, rural coastline, undeveloped shorelines, and other vulnerable communities in Hampton Roads and Virginia's Tidewater region.
- Provide relevant and useful information to regional leaders, commercial interests, property owners, and other critical stakeholders in the region.
- Serve as a liaison between the public and university researchers.
- Lead the development and delivery of educational programs to reduce risks of coastal flooding and other climate change hazards to people and property, in collaboration with existing hazards and climate change capacity in the region, state, and VASG network.

Plan Hampton Roads (PlanHR): To this end, MARI will provide leadership by identifying high-need knowledge areas and work with city planners in Hampton Roads, conservational professionals, U.S. Navy, and coastal residents toward the development of action plans designed to mitigate and support adaptation strategies that also will serve as a model for other coastal communities. The goal will be to develop short- and long-term management frameworks that anticipate future actions for all stakeholders involved. *PlanHR*, for example, might include: agreeing to a reduction in global warming emissions by a particular date in the future; sharing research outcomes and advice with Hampton Road's policy makers to ensure that cities' policies are grounded in the latest research; creating 3-D and digitally derived maps that indicate which areas in Hampton Roads are most vulnerable to flooding; developing a system of green roofs that will serve to decrease the "urban heat island" effect while reducing runoff during rains that exceed the capacity of storm water drains; increasing sewage capacity to prevent raw spillage into waterways that cause oxygen depletion in our estuaries and kills wildlife, creates fertile grounds for pathogens, and increases methane gas.

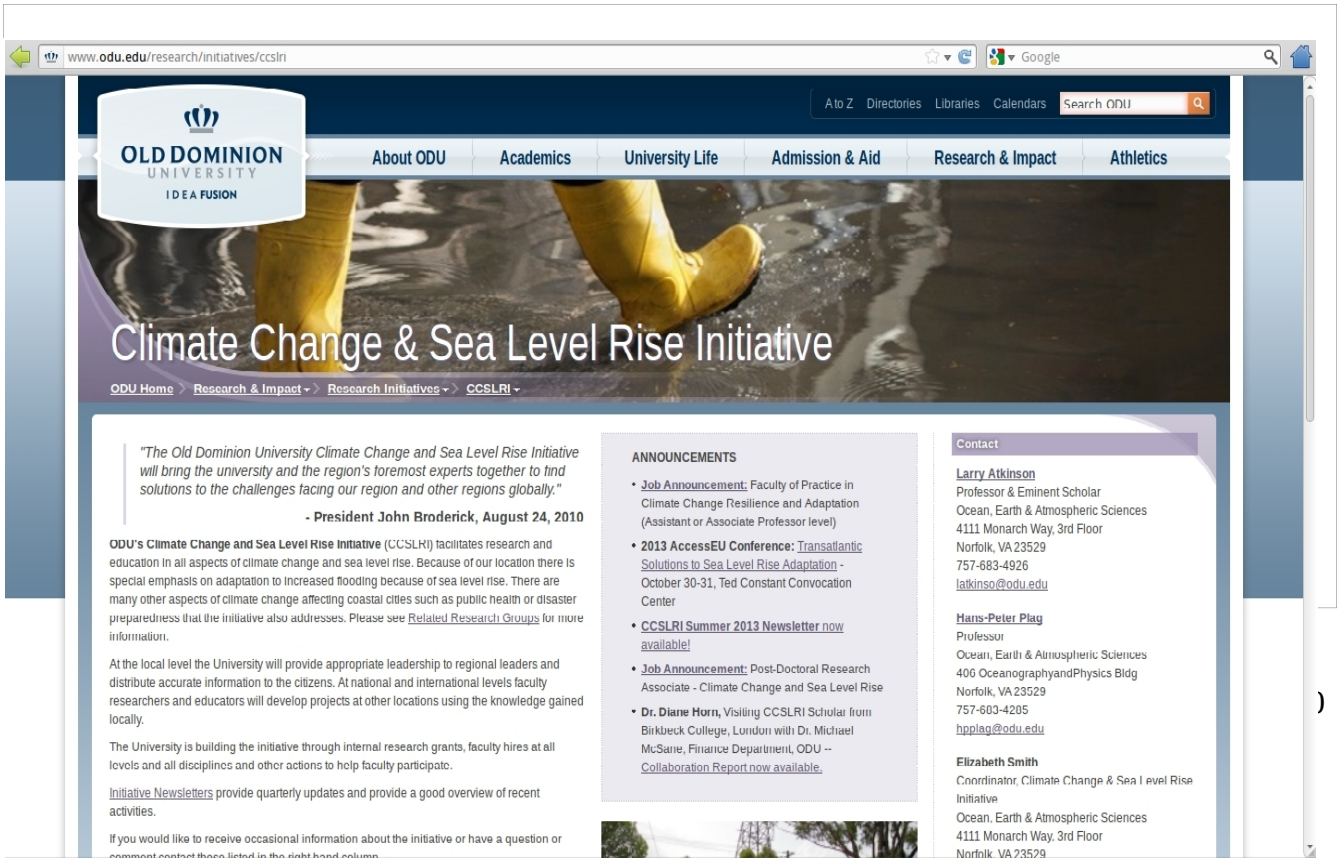


Figure 5: The Web page at http://www.odu.edu/research/initiatives/ccslri will transition to become the "static" MARI web page.

Town Hall Meetings: Additionally, specific out-reach programs will be designed to increase community involvement in policy deliberation and implementation for the purpose of reducing potential resistance to change in current environmental, water, and land-use policies.

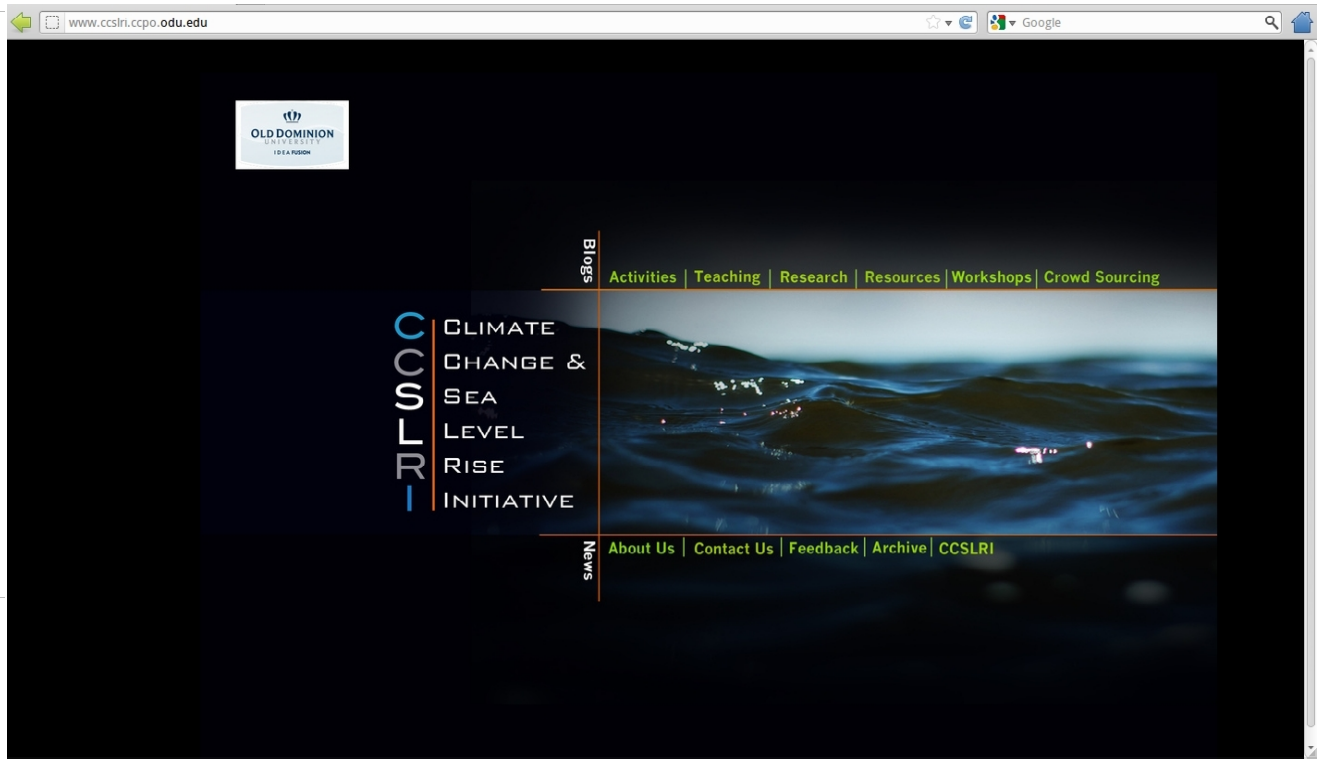
Media: A core element is a diverse presence in communication media, including the Web and social media. Web presence takes into account that the web has developed into both, a distribution media for information and a means to link to stakeholders. Crowd-sourcing elements are important for the latter.

MARI has a three-tier web strategy:

(1) As part of the ODU web presence, MARI maintains a web site with reviewed "static" information (Figure 5); the information presented here is of basic nature and not likely to change rapidly or in need of rapid updates, including best practices.

(2) As a dynamic workspace MARI maintains a web site (Figure 6) that provides comprehensive information on on-going and often rapidly developing information, including news items, meeting and workshop information, resources, blogs, and access to tools and resources. This work space also provides links to other appropriate national and international websites.

(3) For the linkage to stakeholders, including the general public, MARI is developing crowd-sourcing tools connected to information services.



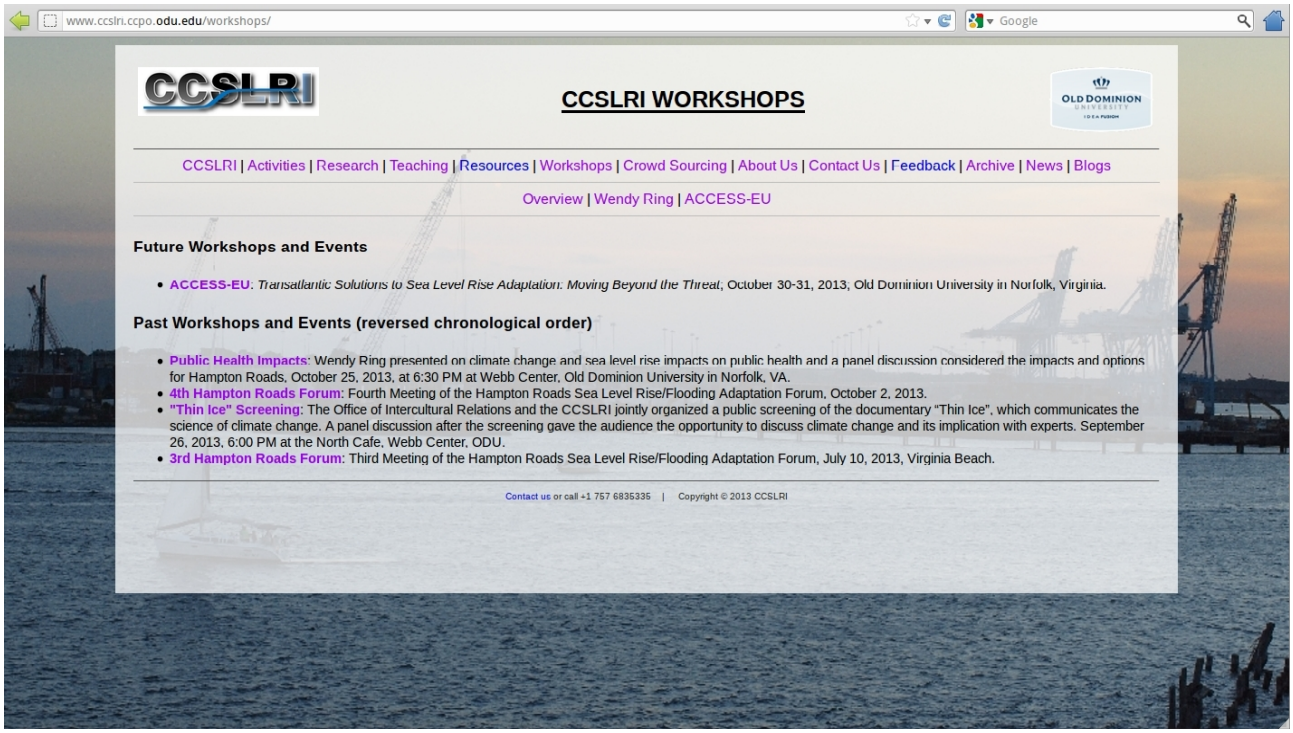


Figure 6: The web site at http://www.ccslri.ccpo.odu.edu will transition to become the web workspace of MARI. The upper screen shot shows the current entry page, and the lower screen shot gives an example of the dynamically changing page providing access to near-real time information on workshops and other meetings.

The web work space will have the function of a community-focused portal with the goal to link to stakeholders at all levels from individual families to elected officials. It will provide channels for community members to engage in various ways as well as comprehensive information sources. MARI will work with stakeholder to ensure that this portal is tailored to the wide range of information needs different stakeholders might have. The combination of peer-reviewed scientific information, science-based knowledge translated into actionable information, crowd-sourced data, and a pull component allowing stakeholder to generate knowledge on-demand will provide practice-relevant knowledge in a novel way. In particular, the pull component where stakeholders can ask their specific questions will add a new quality to the clearing-house function of the MARI web portal.

The VST integrated into the portal will allow for deliberations between stakeholders. It is envisaged that the VST will have different topical areas where decision makers can have specific well-informed deliberations, e.g. related to policy area such as Land Use, Flooding and transportation planning, Economic development in vulnerable areas, Tourism in vulnerable areas, and Emergency management in vulnerable areas.

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APPENDIX

A1 Definitions and Glossary

Adaptation to climate change: refers to a response to climate change that aims at reducing the vulnerability of biological systems (including human systems) to climate change effects. Adaptive capacity is closely linked to social and economic conditions and is unevenly distributed across different regions and populations, with developing countries generally having less capacity to adapt.

Coastal Shoreline County (from http://stateofthecoast.noaa.gov/glossary.html#a)**:** The Federal Emergency Management Agency (FEMA) has derived 452 Coastal Shoreline Counties. FEMA's 100-year flood plain, or Special Flood Hazard Area (SFHA), delineates where the National Flood Insurance Program's floodplain management regulations must be enforced and the area where the mandatory purchase of flood insurance applies. The Coastal Shoreline Counties are counties that have a coastline bordering the open ocean, or contain FEMA identified coastal high hazard areas in the SFHA. American Samoa, Guam, the Commonwealth of the Northern Mariana Islands, the U.S. Virgin Islands, and Puerto Rico are included in this suite. For more detailed information about Coastal Shoreline Counties visit: http://coastalsocioeconomics.noaa.gov/coast_defined.html.

Mitigation: Climate change mitigation: refers to actions aimed at limiting the magnitude and/or rate of climate change. Climate change mitigation involves reduction in anthropogenic emission of GHGs (including those emitted during energy production and usage, food production, and provision of resources), the enhanced removal of these gases from the atmosphere, the reduction of processes that can impact climate change (for example, in land use and modification of the water cycle), and the facilitation of processes that could slow-down climate change. Mitigation of climate change impacts refers to the lessening of impacts of climate change, such as impacts of sea level rise, for example, through changes in the built environment.

Practice-relevant knowledge: defined here as knowledge that is of relevance to solving practical problems or to the management of societal problems.

Probability density function: is a function that describes the relative likelihood for a random variable to take on a given value. The probability of the random variable falling within a particular range of values is given by the integral of this variable’s density over that range. The probability density function is nonnegative everywhere, and its integral over the entire space is equal to one.

Resilience: the ability to recover quickly from disturbances, illness or misfortune.

Resiliency: Resiliency is a different form of resilience. Both nouns refer to the same ability to recover quickly. But in today's English, *resilience* is far more common than *resiliency*, especially outside the U.S. and Canada. In North American publications, *resilience* appears about four times as often as *resiliency*. Outside North America, *resiliency* appears only rarely. In this document, we only use resilience.

Service Learning: Service Learning is a method of teaching students that combines classroom-learned knowledge with meaningful community service. This form of learning emphasizes critical thinking and personal reflection while encouraging a heightened sense of community, civic engagement, and personal responsibility. Under the Community Service Act of 1990, the US government and the authority of the Corporation for National and Community Service, whose mission is to encourage the development of Service Learning opportunities nation-wide that result in valuable learning experiences while helping communities, developed the Learn and Serve America (LSA) grant program that also sponsor's the President's Higher Education Community Service Honor Roll. LSA defines Service Learning as: "a method under which students or participants learn and develop through active participation in thoughtfully organized service that is conducted in and meets the needs of a community; is coordinated with an elementary school, secondary school, institution of higher education, or community service program, and with the community; and helps foster civic responsibility; and that is integrated into and enhances the academic curriculum of the students, or the educational components of the community service program in which the participants are enrolled; and provides structured time for the students or participants to reflect on the service experience" (42 US Code 12511).

Social capital: The commonalities of most definitions of social capital are that they focus on social relations that have productive benefits. The variety of definitions identified in the literature stem from the highly context specific nature of social capital and the complexity of its conceptualization and operationalization. Social capital does not have a clear, undisputed meaning, for substantive and ideological reasons. In the context of MARI, social capital refers to the institutions, relationships, and norms that shape the quality and quantity of a society's social interactions. Increasing evidence shows that social cohesion is critical for societies to prosper economically and for development to be sustainable. Social capital is not just the sum of the institutions, which underpin a society – it is the glue that holds them together. (see, e.g. The World Bank, 1999). This definition follows Robert Putnam's definition, for whom social capital "refers to the collective value of all social networks and the inclinations that arise from these networks to do things for each other" (Putnam, 1995).

SWOT analysis: is a tool for an analysis of the overall strategic position of a "business" in its environment. Its purpose is to identify the strategies that will create a firm specific "business model" that will best align available resources and capabilities to the requirements of the environment in which the organization operates. It provides a foundation for evaluating internal potential and limitations and the likely opportunities and threats from the external environment. SWOT is an acronym for Strengths, Weaknesses, Opportunities and Threats. By definition, Strengths (S) and Weaknesses (W) are considered to be internal factors over which an organization has some measure of control, while Opportunities (O) and Threats (T) are considered to be external factors over which the organization has essentially no control.

Threshold: refers to the level, point, or value at which an effect begins to be produced, and above

which something is true or will take place and below which it is not or will not.

A2. Acronyms

BEB:	Beach Erosion Board (BEB)
CCSLRI:	Climate Change and Sea Level Rise Initiative
CCSP:	U.S. Climate Change Science Program
CEQ:	Center of Environmental Quality
CoP:	Community of Practice
CZMA:	Coastal Zone Management Act
DOT:	Department of Transportation
EPA:	Environmental Protection Agency
FEMA:	Federal Emergency Management Agency
FoP:	Faculty of Practice
GCZIS:	Global Coastal Zone Information System
GEO:	Group on Earth Observations
GEOSS:	Global Earth Observation System of Systems
GIS:	Geographical Information System
GPIS:	Graduate Program in International Studies
IPCC:	Intergovernmental Panel on Climate Change
LSL:	Local Sea Level
MARI:	Mitigation and Adaptation Research Institute
NCSL:	U.S. National Conference of State Legislatures
NFIP:	National Flood Insurance Program
NGO:	Non-governmental Organization
NOAA:	National Oceanic and Atmospheric Administration
NSF:	National Science Foundation
ODU:	Old Dominion University
OEAS:	Department of Ocean, Earth and Atmospheric Sciences
OECD:	Organization for Economic Cooperation and Development
PDF:	Probability Density Function
SLR:	Sea Level Rise
UNEP:	UN Environmental Program
USACE :	U.S. Army Corps of Engineers
VSL:	Value of Statistical Life
VST:	Virtual Stakeholder Table
WRDA:	Water Resources Development Act

A3 Mitigation and Adaptation: A Review of History and Contemporary Usage

As pointed out in Section 1.2, different scientific disciplines and societal communities use the terms mitigation and adaptation in combination with other terms, resulting in a wide range of interpretations for the terms. An interdisciplinary consensus has not emerged, and a societal consensus on the use of these terms is not in sight, particularly if we consider an international context.

It is of interest to consider the question how and why these terms are used in specific ways in the various disciplines and on the various societal decision and policy-making levels. More importantly, it is relevant to understand to what degree the different usage of terminology might be an obstacle when it comes to developing strategies for adaption and mitigation. A common ontology is extremely important for transdisciplinary cooperation required to address as complex an issue as our response to the unparalleled challenge posed to our global civilization by climate change and SLR.

Here we provide first an overview of contemporary usage, and then briefly summarize the history of the terms. We then aim to provide a taxonomy of different mitigation and adaptation approaches. This will also provide a basis for our definition of terms as provided in Section 1.2. Our goal is to have sufficient granularity to denote responses that are distinctively different in immediate impacts and long-term viability with different terms.

Adaptation:
1. the act of adapting.
2. the state of being adapted; adjustment.
3. something produced by adapting: an adaptation of a play for television.
4. Biology:
a. any alteration in the structure or function of an organism or any of its parts that results from natural selection and by which the organism becomes better fitted to survive and multiply in its environment.
b. a form or structure modified to fit a changed environment.
c. the ability of a species to survive in a particular ecological niche, especially because of alterations of form or behavior brought about through natural selection.
5. Physiology: the decrease in response of sensory receptor organs, as those of vision, touch, temperature, olfaction, audition, and pain, to changed, constantly applied, environmental conditions.

Mitigation:
1. the act of mitigating, or lessening the force or intensity of something unpleasant, as wrath, pain, grief, or extreme circumstances: Social support is the most important factor in the mitigation of stress among adolescents.
2. the act of making a condition or consequence less severe: the mitigation of a punishment.
3. the process of becoming milder, gentler, or less severe.
4. a mitigating circumstance, event, or consequence.

Box 2: Definitions of adaptation and mitigation (from http://dictionary.reference.com/browse/adaptation).

Taking the definitions provided in standard dictionaries as a starting point (see Box 2), we can characterize adaptation as a more “internal” process that alters an organism or its behavior while mitigation is a more “external” process that protects the organism by reducing a threat or severe condition. In contemporary usage, this characterization is reflected: while mitigation points to a process of reducing a threat and preventing something from happening, adaptation is more used for processes that enable an organism or system to handling certain conditions and the changes in these conditions.

Successful adaptation does reduce impacts and disaster risk, and so does mitigation.

Adaptation seems to be more focused on changes in human behavior or use, while mitigation of impacts is more often used to refer to changes in the built environment. Impact mitigation seems to have the goal to reduce a threat and to prevent impacts, and it often involves protection, engineering, technology, etc. If these measures fail (e.g., a storm surge comes over a dike or breaks through), the disaster is normally exaggerated because preparedness for this case is low. Adaptation has the goal to accept the changing conditions by changing our behavior or use of the built environment or our exposure to new hazards (retreat).

In the scientific community represented by the Intergovernmental Panel on Climate Change (IPCC), mitigation and adaptation are used in combination with “climate change.” In this community, “climate change mitigation” is defined as the process of mitigating (i.e., reducing) climate change mainly by reducing the climate forcing that results from increasing atmospheric concentration of Greenhouse Gases (GHG) or other anthropogenic forcing factors, such as albedo changes. It is interesting to note that in some groups, climate change mitigation is equated to a reduction of fossil fuels and carbon dioxide emissions, neglecting the fact that 35-45% of the climate forcing results from non-CO_2 GHGs (Ripple et al., 2013). In a more general sense, climate change mitigation is any action taken to permanently eliminate or reduce the long-term risk and hazards of climate change. The climate change research community defines “climate change adaptation” as the process of enabling the built environment, social communities, and ecosystems to function and exist under the changing climate conditions that could not be mitigated. Adaptation to climate change refers to adjustments in natural and human systems in response to actual or anticipate climate stimuli or their effects, which moderate harm or exploit beneficial opportunities.

There is a wide range of options to impact GHG emission and absorption of atmospheric GHGs, and many of these options also provide opportunities to build adaptive capabilities. For example, adapting the built environment to increased temperatures can also help to reduce the GHG emissions resulting from the use of a building. Changes in systemic socio-economic and political and policy factors in response to climate change can also contribute to the mitigation of climate change.

In communities focusing on crisis management and disaster risk reduction, mitigation is used for the process of preventing a hazardous situation turning into a crisis or disaster, while adaptation refers to the process of handling the crisis. An example of this usage is the definition of "Mitigation" given by the Federal Emergency Management Agency (FEMA, see http://www.fema.gov/what-mitigation):

"*Mitigation is the effort to reduce loss of life and property by lessening the impact of disasters. Mitigation is taking action now—before the next disaster—to reduce human and financial consequences later (analyzing risk, reducing risk, insuring against risk). Effective mitigation requires that we all understand local risks, address the hard choices, and invest in long-term community well-being. Without mitigation actions, we jeopardize our safety, financial security, and self-reliance.*"

This definition is consistent with the use of the term in insurance industry, where mitigation denotes activities, efforts, and investments that reduce the likelihood (probability) or consequences (severity) of a threat. The term adaptation is not used widely. If we take the insurance approach, risk is the product of hazard probability, vulnerability, and exposed assets. For most natural hazards, we have little means to impact hazard probability, but we can reduce vulnerability and/or exposure. While reducing vulnerability (of infrastructure) often equates to reducing impacts of the hazard, reducing exposure often requires a change in life and land use (adaptation). Thus, even if insurances do not use the term adaptation, it is implicitly addressed as a way of reducing disaster risk.

The social definition of vulnerability is different from the technical definition used by insurances and in engineering approaches to disaster risk reduction (see, e.g., Ayyub et al., 2012 for a description of an engineering approach to risk and vulnerability). In the social context, adaptation is even more important in reducing social vulnerability.

EPA and the U.S. Army Corps of Engineers use mitigation in the sense of “mitigation of impacts” in the context of the Clean Water Act (see, e.g., http://water.epa.gov/lawsregs/guidance/wetlands/wetlandsmitigation_index.cfm). Here, “Compensatory Mitigation” is used in the permitting process of projects to ensure environmental impacts to aquatic resources are avoided or minimized as much as possible. Consistent with the administration’s goal of “no net loss of wetlands” a Corps permit may require a property owner to restore, establish, enhance or preserve other aquatic resources in order to replace those impacted by the proposed project. This compensatory mitigation process seeks to replace the loss of existing aquatic resource functions and area. More generally, “Environmental Mitigation” refers to a similar process applied to all natural resources.

The recent White House Executive Order - Preparing the United States for the Impacts of Climate Change (see http://www.whitehouse.gov/the-press-office/2013/11/01/executive-order-preparing-united-states-impacts-climate-change) does not apply the term mitigation and includes the term “mitigation of impacts” into “adaptation.” It defines:

(a) "preparedness" means actions taken to plan, organize, equip, train, and exercise to build, apply, and sustain the capabilities necessary to prevent, protect against, ameliorate the effects of, respond to, and recover from climate change related damages to life, health, property, livelihoods, ecosystems, and national security;

(b) "adaptation" means adjustment in natural or human systems in anticipation of or response to a changing environment in a way that effectively uses beneficial opportunities or reduces negative effects; and

(c) "resilience" means the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions.

In the climate change community, climate change adaptation comprises all activities of adapting to the inevitable consequences of global warming, e.g., retreat, defend, or through different processes including the way we build, the policies and decisions we make, cultural, social, and economic changes, etc. However, these processes can have distinctly different goals, immediate impacts, and long-term perspectives, and it is helpful to distinguish between those processes that aim to protect against climate change impacts and those that lead to being adapted to these changes. We denote the former as climate-change impact mitigation and the latter in a more narrow sense as climate change adaptation. In general, mitigation of impacts through protection faces the challenge that conditions exceeding the thresholds of the protection can lead to extreme disasters. The economically reasonable and feasible planning of mitigation requires a reliable deterministic knowledge of future changes and the probability density functions of hazards. If there are large uncertainties in the extreme end of the hazard spectrum, then the planning of protections is an exceedingly difficult task implying the choice between high costs for the protection now or high costs for the ensuing disasters if the protection fails. Facing high uncertainties about the future conditions, the development of adaptive capabilities provides a greater flexibility to adjust if the actual climate change or SLR should require such an adjustment.

It is important to note that at all levels we always have the choice to mitigate (prevent) or adapt (manage), with rather different social and economic consequences. Our language should be flexible

enough to reflect these choices. For MARI, we therefore consider three terms as relevant, which combine the definition of climate change mitigation common in the climate change research community with a narrower definition of climate change adaptation and the mitigation of climate change impacts in the sense of crisis management and disaster risk reduction:

(1) Mitigation of Climate Change and SLR: actions that limit and reduce changes in the Earth's system that are know to force climate change or increase SLR.

(2) Mitigation of climate change and SLR impacts: actions that aim to protect against certain levels of impacts of climate change and/or SLR.

(3) Adaptation to climate change and SLR: actions that increase our preparedness for somewhat uncertain climate change and SLR and allow us to adapt to the changes if and when they happen.

Importantly, (2) and (3) are local and regional problems, while (1) needs to be addressed at a more global level. However, actions taken in the context of (2) and (3) can positively or negatively contribute to (1). In particular, a shift from (global) mitigation of climate change and SLR to a more regional and local mitigation of, and adaptation to, impacts has a major impact on the distribution of costs and benefits between developed and developing countries. A shift to adaptation will increase the challenges for the developing world (Michaelowa, 2001).

There is increasing consensus that no matter how successful climate change mitigation will be, climate will continue to change and sea levels will continue to rise. We may have options to limited the extent of the changes, but the “re-engineering” of the planet's surface, chemistry, and climate dynamics during the recent centuries have committed us to significant and unavoidable changes. Since we will see more changes, it is important to learn to live with these, either by mitigating the impacts, or by adapting to the impacts, or both.

The natural laboratory of Hampton Roads seems to be ideal for research related to (2) and (3). However, there are many aspects of (1) that are directly a result of actions under (2) and (3), and actions under (1) have implications for (2) and (3). The scope of MARI therefore will have to be wide enough to include all aspects of mitigation and adaptation; not just climate change mitigation and adaptation, but also, for example, disaster mitigation and social and economic adaptation. Moreover, it will be important that MARI utilizes synergies with others who are examining ways of lessening the rate of climate change (though new technologies, adjustments in economic market incentives, emerging scientific understandings, policy changes, etc.). Particularly with respect to the social and economic aspects of (1), which are mostly very much linked to (2) and (3), the expertise available at ODU could make a valuable contributions. To reflect the broad scope of MARI, the institute's name does not explicitly refer to climate change and SLR.

A3. MARI Logo

The MARI Logo takes a starting point in the fact that civilization has been blessed by more than 6,000 years of small and slow changes in climate and sea level. However, this time seems to have come to an end and humanity is facing a time of rapid climate change and rising sea levels, a time with large uncertainties about the challenges to come. The question of how to mitigate climate change and its impacts and how to adapt to the changes and impacts that cannot be mitigated requires a concerted effort of all scientific disciplines in an effort to provide the practice-relevant knowledge that our societies need to meet an existential unparalleled challenge. MARI is focused on the knowledge gap opened up by climate change and sea level rise, and it will work with all societal stakeholders towards the co-design and co-creation of this practice-relevant knowledge. The culture of “Idea Fusion” at ODU is an essential and fertile basis for this novel and challenging process.

A5: Hardware Details