MARISA

a NOAA Mid-Atlantic RISA team

Award Title: Mid-Atlantic Consortium for Climate Assessment and Decision Support (MACCADS)[1]

Program Summary and Research Highlights:
September 1, 2016 – June 30, 2017

MARISA's Mission:

Helping Mid-Atlantic communities become more resilient to a changing climate through improved data, place-based decision support, and public engagement.

RAND CORPORATION

PennState

JOHNS HOPKINS UNIVERSITY

Cornell University

[1] In September 2016, MACCADS was officially renamed as the Mid-Atlantic Regional Integrated Sciences and Assessments (MARISA) program.

The MARISA Team

Lead Principal Investigators (PI)

Debra Knopman, PhD, Senior Principal Researcher, RAND Corporation

Klaus Keller, PhD, Professor of Geosciences, The Pennsylvania State University

Co-Investigators (CI)

Benjamin Hobbs, PhD, Director, Environment, Energy, Sustainability & Health Institute and Schad Professor of Environmental Management, The Johns Hopkins University

Melissa Finucane, PhD, Senior Behavioral and Social Scientist, RAND Corporation

Jordan Fischbach, PhD, Policy Researcher, RAND Corporation

Robert Nicholas, PhD, Research Associate, Earth and Environmental Systems Institute, The Pennsylvania State University

Senior Researchers

Arthur DeGaetano, PhD, Professor, Earth and Atmospheric Sciences, Cornell University

Robert Lempert, PhD, Principal Physical Scientist, RAND Corporation

Program Manager

Neil Berg, PhD, Associate Physical Scientist, RAND Corporation

Post-doctoral Scholars, Graduate Students, and Research Assistants

Jared Oyler, PhD, Post-doctoral Scholar, The Pennsylvania State University

Huai Jiang, PhD, Post-doctoral Scholar, The Johns Hopkins University

Fengwei Hung, Graduate Student, The Johns Hopkins University

Sara Schwetschenau, Graduate Student, Carnegie Mellon University; Summer Associate, RAND Corporation

Devin Tierney, Research Assistant, RAND Corporation

Kelsey Ruckert, Programmer, The Pennsylvania State University

The MARISA Advisory Committee

MARISA has established an Advisory Committee to provide program-level feedback on research directions and priorities and to help guide the team with an external perspective on potential barriers and opportunities.

At MARISA's start in September 2016, we invited the following six members to the Advisory Committee:

- **Ellen Mecray**, NOAA Regional Climate Services Director – Eastern Division
- **Zoe Johnson**, NOAA Chesapeake Bay Program Climate Change Coordinator
- **Mary Ratnaswamy**, Co-Director, US Department of Interior Northeast Climate Services Center
- **Genevieve LaRouche**, Head, Chesapeake Bay Field Office, US Fish and Wildlife Service Region 5
- **Leon Clarke**, Senior Scientist and Group Leader, Integrated Modeling and Energy, Joint Global Change Research Institution and Pacific Northwest National Laboratory
- **Susanne Moser**, Director, Susanne Moser Research and Consulting

As engagements progressed in the winter of 2017, the MARISA team recognized the need to include more local-level decisionmakers on the Advisory Committee and therefore extended an invitation to **Kristin Baja**, formerly the Climate and Resilience Planner for the City of Baltimore and now the Climate Resilience Officer for the Urban Sustainability Directors Network. We also recognized the need to include representatives from the private firms, particularly in agriculture, given the importance of this sector to the region. In the spring of 2017, the MARISA team reached out to **Michael Okoroafor**, Vice President of Global Sustainability and Packing Innovation, McCormick & Company, who readily agreed to join our Advisory Committee.

The MARISA team and Advisory Committee have met on January 23, 2017 and April 27, 2017, and will next be meeting in July/August 2017. Our plan is to hold meetings on a quarterly basis to the extent possible.

New Areas of Focus and Partnership

MARISA has five areas of focus during its first year of performance:

1. Assessing climate risks, uncertainties and vulnerabilities

As one of MARISA's first tasks, team members interviewed more than 25 officials, experts, and other stakeholders from public and private organizations operating in the region to gain insight into climate-related issues that pose the most significant challenges to their near- and longer-term operations and plans. Responses from these interviews are helping to guide MARISA's research objectives and analytical priorities on key decisions in the region affected by a changing climate; and over time, increase public awareness of climate-impacted decisions and inform development of robust adaptation strategies by public and private players to benefit the region. These strategies will be undertaken in the context of a broader set of economic and demographic changes underway in the region. Ben Hobbs, Debra Knopman, Klaus Keller, Rob Nicholas, and Neil Berg jointly conducted interviews with representatives from organizations listed in Table 1.

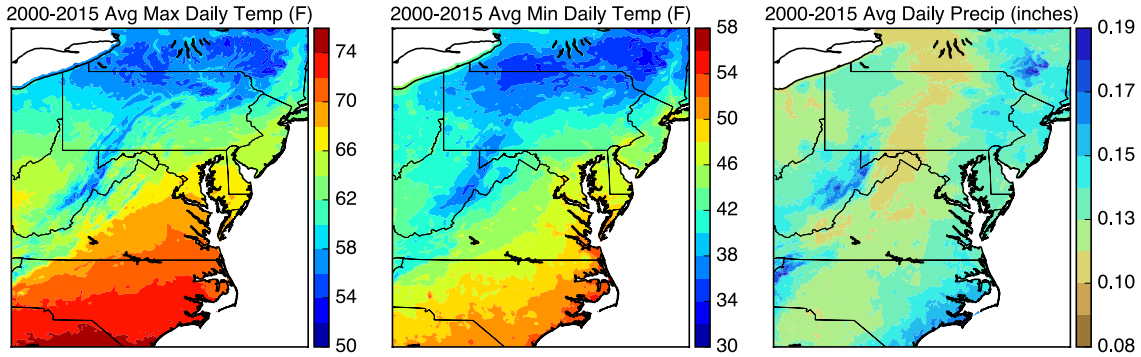
Table 1. Organizations interviewed by MARISA during January – June 2017

Federal Government • National Oceanic and Atmospheric Administration (NOAA) • U.S. Geological Survey (USGS) • U.S. Department of Agriculture (USDA) • U.S. Army Corps of Engineers (USACE)	**State Government** • Maryland Department of Natural Resources • Maryland Department of Transportation • Virginia Department of Environmental Quality	**Local Government** • District of Columbia Department of Environment and Energy • District of Columbia Water and Sewer Authority (DC Water) • Baltimore City, MD • Harford County, MD
Academia • West Virginia University • University of Delaware • Virginia Institute of Marine Science/College of William and Mary • Virginia Sea Grant/Old Dominion University • Consortium for Climate Risk the Urban Northeast • Northeast Climate Science Center • Georgetown Climate Center • George Mason University	**Regional Governmental Organizations** • Metropolitan Washington Council of Governments • Washington Metropolitan Area Transit Authority (Metro) • Susquehanna River Basin Commission	**Non-governmental Organizations** • Eastern Shore Land Conservancy • Mid-Atlantic Regional Council on the Ocean **Private Sector** • PJM Interconnection • Baltimore Gas and Electric • McCormick and Company

Ben Hobbs, Fengwei Hung, and Huai Jiang are leading the decision-screening process to distill feedback from the interviews into a catalogue of unique decisions, investments, or other long-term commitments in the region that are currently impacted and/or may be impacted by a changing climate. They have also developed criteria for ranking decision points to help guide the most important issues for further study (discussed further on pages 14-15). The results of their decision-screening analysis will be submitted to an academic journal in summer 2017, along with a RAND Perspectives publication in the same time frame.

Based on stakeholder feedback acquired through the first-year MARISA interviews and building upon previous research efforts, Klaus Keller and Rob Nicholas are overseeing the development climate data sets that focus on decision-relevant "scales and tails", that is, products that help answer questions on spatial and temporal *scales* suitable for policymaking and also improve upon (the often uncertain) extreme processes at the *tails* of distributions. Recently, Rob Nicholas and Jared Oyler have developed a climate data set that was supported by MARISA called Chesapeake Weather, or "ChesWx", a 4-km gridded product of daily maximum and minimum temperature and precipitation from 1948-2015 that spans the entire Chesapeake Bay Watershed (Figure 1). ChesWx uses new interpolation methodologies to improve spatial estimates of extreme precipitation frequency and intensity. This product helps to fill the data gap of Mid-Atlantic extreme precipitation that stakeholders identified as a priority in multiple interviews. In the near future, ChesWx will serve as a training data set for empirically downscaled climate projections over the Mid-Atlantic. Additional details can be found in the "Research Findings" section on page 15.

Figure 1. ChesWx historical climate over the Chesapeake Bay Watershed (experimental version released in April 2017): (left) 2000-2015 average daily maximum temperature (degrees F); (center) 2000-2015 average daily minimum temperature (degrees F); (right) 2000-2015 average daily precipitation (inches). Full data set can be accessed at www.marisa.psu.edu/data/.



Preliminary engagements also suggest that stakeholders in the Chesapeake Bay Watershed may benefit from new sea level projections that help resolve key sources of deep uncertainty, for instance, rapid Antarctic ice sheet mass loss and changes in storm surges. Additional details on MARISA-developed sea level projections can be found in the "Key Research Findings" section on page 13.

2. Supporting adaptation planning, decision making, and adaptive management

MARISA supports integrated, flexible processes for supporting decision-making and building adaptive capacity to climate variability and change in diverse settings in the Mid-Atlantic region, with an initial focus on the Chesapeake Bay Watershed. MARISA's mission is help Mid-Atlantic communities become more resilient to a changing climate through improved data, place-based decision support, and public engagement.
A range of sectors and issues are within MARISA's scope, for example, public and private investments in infrastructure, urban and residential development generally, rural and agriculture activities, ecosystem restoration, and other services vital to the economic and social well-being of the Chesapeake Bay Watershed.

The specific adaptation projects that MARISA will rigorously examine are still being finalized based on the aforementioned decision-screening process by Ben Hobbs and the JHU team. However, initial findings indicate that there are three major decision spaces that MARISA will concentrate on: land flooding, water management, and transportation and urban environments. We list below specific decisions or investments under consideration today that could benefit from the inclusion of climate information or assistance with framing decisions under uncertainty in regard to climate change.

1. Land flooding/management
    a. Where should states purchase land or easements?
    b. Where should coastal communities invest in living shorelines to counter erosion and provide storm surge buffers?
    c. Where should planners and engineers construct protection works and what level of protection should they be built to?
    d. What level of protection against extreme temperature should be provided to electric substations?
2. Water management
    a. What green and grey infrastructure measures should be invested in for stormwater management?
    b. How should Total Maximum Daily Loads (TMDLs) and Best Management Practices (BMPs) be modified according to projected changes in extreme rainfall?
    c. Which dams should be relicensed, rehabilitated, removed, or re-regulated?
3. Transportation and urban environments
    a. Where should states and counties invest in heat resistant pavements?
    b. Where should states and counties invest in decreasing vulnerabilities of roads and mass transit networks to flooding?
    c. When can communities expect to experience persistently problematic floods that disrupt their mobility and how should governments address this issue?
    d. Where and how should cities invest in mitigating urban heat island impacts?

Through ranking processes and discussions with the Advisory Committee, MARISA intends to select 1-3 specific case studies for further analysis beginning in Year 2. Research is expected to include the development of an integrated systems model for multi-objective analyses, the development of plausible climate futures and feasible adaptation strategies, and decision-support tools that display model results in interactive and user-friendly visuals for non-experts to utilize in their adaptation planning processes.

3. Supporting regional climate assessment and services

Rob Lempert is serving as Chapter Lead for the Adaptation Response chapter in the upcoming 4th National Climate Assessment (NCA4). Neil Berg also participated in a planning session for the NCA4 Northeast Chapter on February 9, 2017.

Melissa Finucane is leading efforts to partner with neighboring RISA teams Great Lakes Integrated Sciences and Assessment (GLISA) and the Consortium for Climate Risk in the Urban Northeast (CCRUN) for a multiple-RISA program evaluation. Proposed activities include developing a webinar series to discuss best practices and share lessons learned amongst climate resilience practitioners and officials across the Great Lakes, Mid-Atlantic, and Northeast. Additional evaluation details can be found in the Program Evaluation and Impact section on page 11.

Debra Knopman and Neil Berg have initiated contact with CCRUN and the U.S. Department of Interior Northeast Climate Science Center (NE CSC) to co-develop regional-scale research proposals centered on climate change impacts to public health, transportation networks, and water/electrical utilities that span the Mid-Atlantic and Northeast regions.

Rob Nicholas, Jared Oyler, Art DeGaetano, and Neil Berg are working together to integrate ChesWx (see Figure 1) into the Northeast Regional Climate Center's Applied Climate Information System (ACIS). ACIS is an online climate data visualization tool that can produce interactive graphics and disseminate data in user-friendly electronic formats to a broad range of stakeholders and end-users.

4. Training a new generation of leaders in climate change adaptation and risk management

MARISA is committed to training students in climate risk adaptation and management. During our first year of performance, MARISA has supported two graduate students and two post-doctoral researchers. Through the pursuit of supplemental funding opportunities, MARISA hopes to increase the number of graduate students and post-docs that participate on upcoming MARISA projects.

At Johns Hopkins, graduate student Fengweng Hung and post-doc Huai Jiang are contributing to the decision-screening task under the mentorship of Ben Hobbs. They have participated in several stakeholder engagements, performed a comprehensive literature review on climate-impacted decisions in the Mid-Atlantic, and have created an

Excel-based tool that catalogues and ranks specific case studies revealed in the stakeholder engagements.

At Penn State, post-doc Jared Oyler led the development of ChesWx (see Figure 1) under the mentorship of Rob Nicholas. Jared performed all research and development tasks for the ChesWx product including: (1) investigation of strengths and weaknesses of current precipitation station observations and gridded products for the MARISA domain, particularly in how they represent all components of precipitation: amount, frequency, intensity, and extremes; (2) investigation, design, implementation, testing, and operationalization of the ChesWx data management system and statistical framework within a high performance computing environment; and (3) preparation of corresponding documentation and manuscripts (1 manuscript in revision, 1 manuscript in preparation).

MARISA hired a Summer Associate, Sara Schwetschenau, a graduate student at Carnegie Mellon University who will work full-time on the MARISA project from June-August 2017. Sara will lead the creation of a catalogue of available physical models and their attributes in the Chesapeake Bay Watershed and greater Mid-Atlantic region. The catalogue will create a central repository of water supply, water quality, coastal/riverine flooding, rainfall-runoff, land use/land cover, estuary, salt-water intrusion, and other physical models previously or currently in use in the Mid-Atlantic. Geographical scope, spatial and temporal resolution, coding language, treatment of climate information, user guides, and other key attributes will be attached to each model entry in the catalogue.

Two products will result from this summer research project: (1) a report summarizing redundancies and gaps across models and opportunities to address potential gaps, and (2) a web-based interactive catalogue where users can enter desired traits for a model (e.g., spanning a specific location, simulates conditions on a particular time step, etc.) to reveal the matching model(s). Ultimately, this work will lay the groundwork for more advanced and integrated systems modeling in Year 2 of the MARISA project.

Klaus Keller, Rob Nicholas, and Rob Lempert help lead the Summer School on Sustainable Climate Risk Management (SCRiM) that takes place each year at PSU. The event specializes in training post-docs, advanced graduate students, and early-career professional in decisionmaking and policy communities that research climate risk issues. This year, the event will be held from July 30 to August 4, 2017 and will include sessions on uncertainty quantification, earth system modeling, integrated assessment, and stakeholder engagement. Attendees will gain first-hand experience using simple models and relevant datasets to understand robust decisionmaking and other analytical methods for climate risk analyses.

Alongside student training, MARISA seeks to increase the knowledge and technical skills of community officials and other non-experts that incorporate climate information into their line of work, but may not have formal education in climate science or handling climate data. As the MARISA research portfolio matures in Year 2, we expect to hold at least one workshop aiming to provide practitioners and stakeholders technical and scientific training behind the modeling and decision analytics of our research.

Finally, MARISA is committed to an open-source environment of data, computer code, and other training materials. Rob Nicholas and others at PSU have created a MARISA Data Portal (http://www.marisa.psu.edu/) and a GitHub code exchange (https://github.com/midatlanticrisa) for free, public access to MARISA scientific and technical materials.

5. Advancing program performance and evaluation

Melissa Finucane is leading the effort to measure and understand the mechanisms of MARISA impacts and to also evaluate the impacts of cooperation and coordination of adjacent RISA teams in the Northeast, Midwest, and Southeast. Devin Tierney is providing research support on this task, along with guidance from external collaborators Susanne Moser (also a MARISA Advisory Committee member) and Linda Shi. Additional program evaluation details can be found in the "Program Impact" section of this report on page 11.

States Using New or Tailored Climate Services

Interactive Mid-Atlantic Observational Map

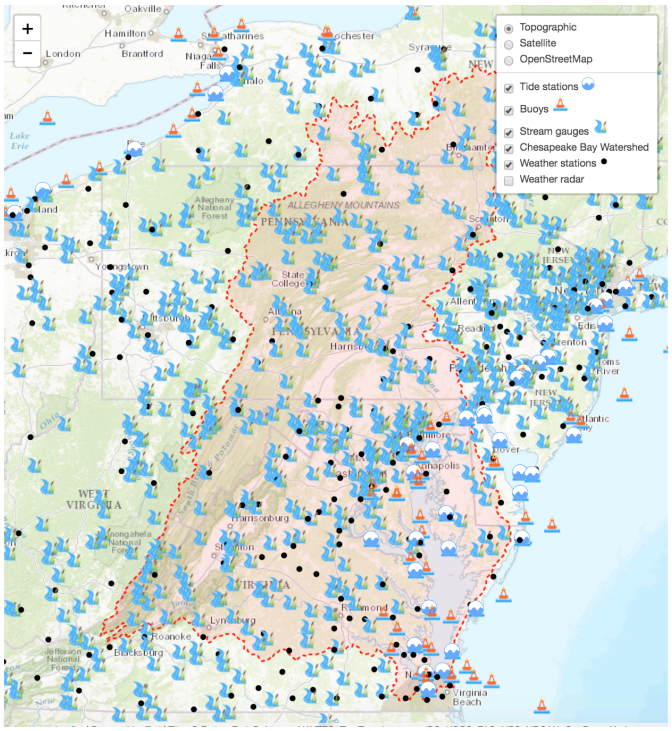
MARISA has developed an interactive map enabling access to a broad range of weather, streamflow, tidal, and buoy data that encompasses all or portions of each state (Virginia, West Virginia, Maryland, D.C., Pennsylvania, Delaware, and New York) in the MARISA region. An example screenshot from the interactive map is shown in Figure 2, highlighting weather stations, buoys, stream gauges, and tidal stations in the greater Mid-Atlantic that user can quickly access.

Specifically, the interactive map displays USGS stream gauges, National Data Buoy Center Buoys, NOAA tides and currents tide stations, weather stations from the National weather service, the extent of the Chesapeake Bay watershed from the USDA Natural Resources Conservation Service of New York, and the weather radar from the Iowa Environmental Mesonet generated NEXRAD composite. Only the stations within the MARISA region are displayed. The stream gauges display their discharge over the past seven days (updated twice a day; 6am and 6pm EST). Buoys display all current meteorological observations measured at the station, however, some do not record current observations. Lastly, the weather stations display the current meteorological observations measured at the station (updated hourly).

This interactive map is intended to benefit stakeholders and end-users in the Mid-Atlantic region by providing a central repository of observed data for quick visuals and downloads. Users can identify a desired location to reveal available tide stations, buoys, stream gauges, and weather stations are available in that area. A person can then quickly obtain current or most-recent observations, compare them to the radar, and if interested, follow the link to the station page to download data or gather more information. The

team is also developing means to track website traffic and data downloads to monitor usage and utility of the interactive map and ChesWx.

Figure 2. Interactive observational map showing real-time information collected at weather stations, stream gauges, buoys, and tide stations in the greater Mid-Atlantic. The full map can be accessed at www.marisa.psu.edu/map/.



Historical Chesapeake Bay Watershed Extreme Precipitation and Temperature Dataset

Engagements with several stakeholders and officials in the Mid-Atlantic region (see Table 1) revealed a gap in information and understanding of historical precipitation and temperature extreme impacts to public health, transportation, and land management. In response to this feedback, MARISA developed ChesWx (see Figure 1) to provide a regional data set providing local-scale information on daily extremes of precipitation and temperature. This product could be used by state and local officials to guide decision-making on, for instance, how extreme precipitation currently influences the performance of Best Management Practices for water quality concerns or how extreme warmth alters the frequency and duration of no-work times due to an increase in hazardous work conditions (an issue particularly relevant to maintenance schedules in the water and transportation sectors). Additional details on the ChesWx product and a summary of its research impacts are described on page 15 under the "Research Findings" section.

Program Evaluation and Impact

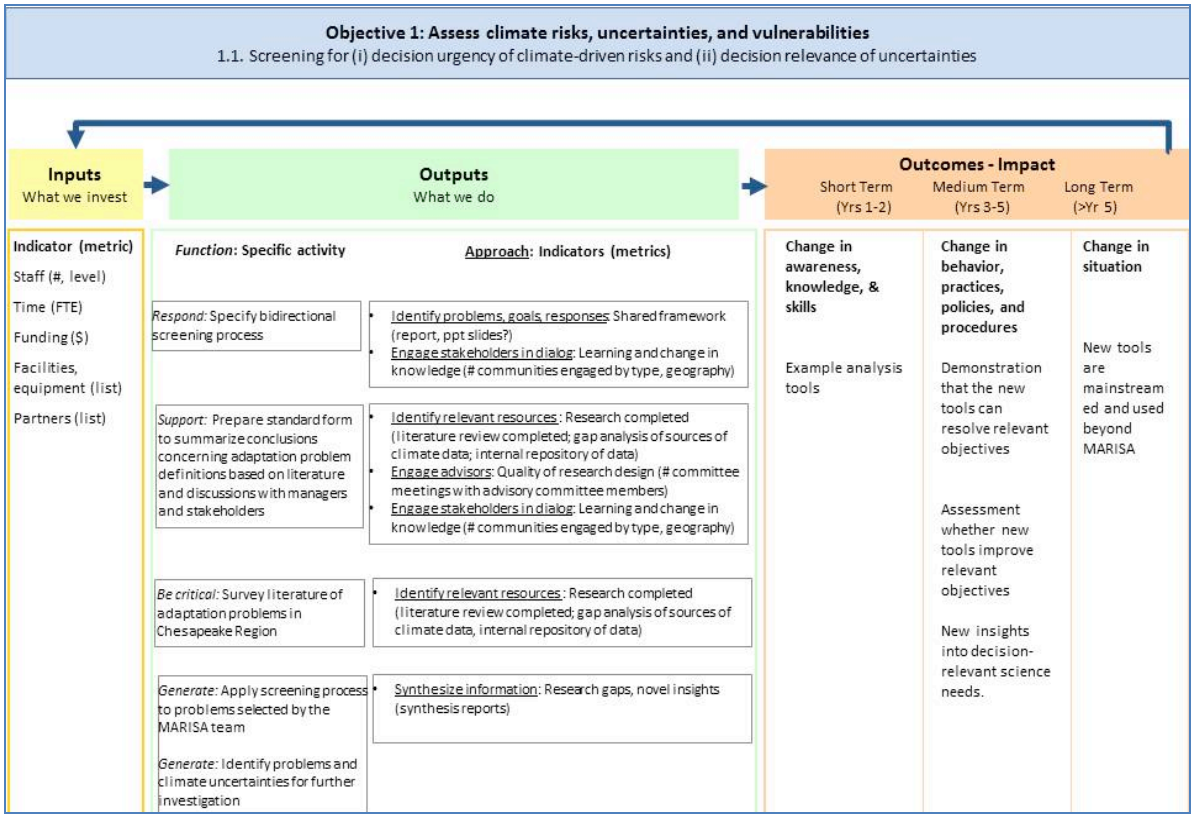
Measuring overall program-level impact

Evaluation is an explicit objective of the MARISA program. Our evaluation activities (1) support adaptive improvement of MARISA performance and (2) assess the value of the program as a regional leader supporting real-world decision makers with climate information and services that are unique yet coordinated with other regional programs.

Measures of the overall program-level impact of MARISA are derived from an Action-Logic Model (ALM), shown for each MARISA objective for Year 1 in Figure 3. The ALM depicts categories of indicators and metrics for inputs, outputs, and outcomes, associated with each of the four functions of the MARISA program: support, respond, generate, and be critical. In addition, we will capture indicators and metrics for two additional categories, namely assumptions and external factors.

In Years 1-2, program outcomes (impacts) related to changes in awareness, knowledge, and skills. Example metrics for these outcomes include: identifying example analysis tools, developing new data sets and new interactive tools, availability of new datasets and tools on the MARISA website, and publication of a report or article synthesizing the features of the datasets and tools identified.

Figure 3. MARISA Action-Logic-Model for Year 1: (top panel) Objective 1.1 - Screening for decision urgency of climate-driven risks and decision relevance of uncertainties; (middle panel) Objective 1.2 - Producing climate projections with a focus on decision-relevant scales and tails; (bottom panel) Objective 2.1 – Developing planning tools to identify and evaluate adaptive integrated water management strategies.



Objective 1: Assess climate risks, uncertainties, and vulnerabilities
1.2. Producing climate projections with a focus on decision-relevant scales and tails

Inputs — What we invest
- Indicator (metric)
- Staff (#, level)
- Time (FTE)
- Funding ($)
- Facilities, equipment (list)
- Partners (list)

Outputs — What we do

Function: Specific activity	Approach: Indicators (metrics)
Generate: Provide decision relevant climate information	• Generate data/models/new analysis: Key findings (new tools / data products); Novel insights
Respond: Collaborate on the design, testing, and use of data products with stakeholders, decision makers, and analysts	• Engage advisors: Quality of research design (# committee meetings with advisory committee member, feedback on research design) • Engage stakeholders in dialogue: Quality of planning process(# of meetings, feedback on data products); Quality of communication materials (# of meetings, feedback on data products) • **Tools and data are being used in MARISA** • **Tools and data are being used beyond MARISA**
Support: Collaborate on the training of new leaders	• Train & educate stakeholders: Raising stakeholder awareness of climate science (# of workshops, attendance at workshops, participant feedback); Translating science to policy (publications cited in policy and decision-relevant publications)
Generate: Design and implement a web-page to provide information	• Provide public clearinghouse: Compile existing research (website created, website traffic) • Public communication: Interest among stakeholders (website traffic, # of publication downloads, media coverage)

Outcomes - Impact

Short Term (Yrs 1-2)	Medium Term (Yrs 3-5)	Long Term (>Yr 5)
Change in awareness, knowledge, & skills	**Change in behavior, practices, policies, and procedures**	**Change in situation**
Changed awareness of the need for and potential avenues to designing studies	Use of decision-focused design to provide climate information New insights into decision-relevant science and methods needs (i.e., feedback from decision-analysis back to science)	New tools and data are mainstreamed and used within and beyond MARISA

Objective 2: Support adaptation planning, decision making, and adaptive management
2.1. Developing planning tools to identify and evaluate adaptive integrated water management strategies

Inputs — What we invest
- Indicator (metric)
- Staff (#, level)
- Time (FTE)
- Funding ($)
- Facilities, equipment (list)
- Partners (list)

Outputs — What we do

Function: Specific activity	Approach: Indicators (metrics)
Be Critical: Intelligence scan of Mid-Atlantic/Chesapeake Bay tools models, data sets, ongoing projects	• Identify relevant resources: Research completed (literature review, gap analysis of sources of climate data, systems model cataloging, internal data repository) • Provide public clearinghouse: Compile existing research (website created, website traffic) • Synthesize information: Research gaps (synthesis reports)
Support: RDM scoping/XLRM Workshop	• Identify problems, goals, responses: Shared framework (report, ppt slides?) • Engage advisors: Quality of research design (# committee meetings with advisory committee member, feedback on research design)

Outcomes - Impact

Short Term (Yrs 1-2)	Medium Term (Yrs 3-5)	Long Term (>Yr 5)
Change in awareness, knowledge, & skills	**Change in behavior, practices, policies, and procedures**	**Change in situation**
• New data set developed • New interactive tools developed • Data and interactive tools available through MARISA website • Synthesis report (or journal article) published	• Tools and data are being used in MARISA • Tools and data are being used beyond MARISA • New integrated models developed building on developed catalog	

Summary of evaluation results

In Year 1, we reviewed our proposed ALM with the MARISA research team and Advisory Committee and revised the model to ensure the theory of impact depicted was

appropriate for the Mid-Atlantic context. We have identified indicators and metrics for objectives 1.1, 1.2, and 2.1, and are currently summarizing those metrics in a spreadsheet for final approval by the MARISA team. We have also initiated discussions with nearby RISA programs to identify an approach to evaluating the combined impact of the programs.

Thus far in Year 1, MARISA impacts are predominantly characterized by (1) identification and engagement (through in-depth interviews) of multiple stakeholders from government and non-government agencies in the Mid-Atlantic region and (2) systematic identification (and ranking) of regional adaptation problems. These impacts have:

- increased awareness in the region by introducing MARISA to a broad array of local decision makers;
- increased skills in the region by developing a decision screening tool for systematically ranking regional adaptation problems; and
- increased knowledge in the region by capturing and sharing findings from stakeholder interviews and decision screening to describe the nature of decision makers and the decision problems they are working on.

<u>Building expertise and ability of local/regional decision-makers to prepare and adapt to climate variable and change</u>

While the MARISA team has not finalized specific projects that seek to build adaptive capacity to climate variability and change on local and regional scales, our initial engagements during the first year of performance sought to generally increase public awareness of the multiple ways in which a changing climate is already affecting or will soon affect costs and operations of public services, ecosystem services, and recreational assets in the region. The results of this exercise are summarized in a forthcoming publication (Berg et al. 2017).

The model catalogue being created by Sara Schwetschenau (details provided on page 8) is expected to benefit Mid-Atlantic decision-makers by providing them targeted knowledge on the physical models available to address their specific issues at hand. Due to feedback suggesting ineffectiveness of high-level generalized climate resilience frameworks and toolkits on local spatial scales, MARISA's model catalogue is an important first step to creating customized and rigorous examinations of vulnerabilities to a given climate impact and ultimately co-developing feasible adaptation solutions between stakeholders and the scientific community.

ChesWx and the interactive observational map developed by the Penn State MARISA team members are similarly anticipated to benefit local and regional stakeholders after those data products are integrated into ACIS. After integration, decision-makers will have access to high-quality historical climate information in user-friendly data formats with accompanying explanatory text to ensure appropriate applications in their decision processes.

Finally, by disseminating invitations to stakeholders connected to MARISA, the SCRiM Summer School (details provided on page 8) has emphasized the inclusion of decision-makers in this year's event.

Research Findings

1. Decisions Most Impacted by Climate Variability and Change in the Mid-Atlantic

MARISA's overarching goal behind conducting over 25 stakeholder interviews (see Table 1) was to better understand first-hand perspectives on how climate variability and change is impacting or may impact decisions, investments, plans, operations, and other issues including social equity facing a wide range of organizations and communities around the CBW. Feedback from the engagements have been summarized in an Excel tool where users (i.e. MARISA team and Advisory Committee members) can enter rankings across an array of criteria – scenario inclusion, climate relevance, urgency, importance, feasibility, evaluation difficulty, partner and end user availability, and co-benefits availability – to quantitatively sort through roughly 30 discrete climate impact case studies for further exploration in Year 2. A sample of this Excel tool is shown in Figure 4.

Figure 4. Sample of the Excel decision-screening tool where assign general weights to the nine criteria and then enter specific rankings for each of the nine criteria for a given problem in the left column. The final weighted ranking is shown in red numbers in the rightmost column.

Decision Description	Specific Problem	Near-term Commitments	Criterion Grade & Weights									
			Assign weights to the 8 Criteria									
			15	15	15	15	10	10	10	5	5	
			1. Scenarios inclusion	2. Climate relevance	3. Urgency	4. Importance	5. Feasibility	6. Evaluation difficulty	7. Partner and end user availability	8. Co-Benefits availability	9. Flexibility	Weighted total grades
Where to construct coastal protection works, and to what level of protection?	Residential land area protection	Use traditional flood protection measures. Develop natural features. Restrict development.	4	5	4	5	4	4	3	3	4	415
Where should states buy coastal land or easements?	Land acquisition or easements for providing an undeveloped buffer between coastal waters and vulnerable land uses	Land acquistion/ Land easements (with a certain time scale); required distance buffers between coast and vulnerable land use	4	5	3	3	5	5	4	3	4	400
		Harden transit facilities and raise										

Results of this analysis not only provides a transparent account of how MARISA is prioritizing its future research objectives and priorities, but it also increases public awareness of the multiple ways in which a changing climate is already affecting or will soon affect costs and operations of public services, ecosystem services, and recreational assets in the region.

2. Chesapeake Weather (ChesWx)

From the beginning, extreme precipitation and inland flooding have been major foci for the MARISA team; the importance of these issues for the region first became apparent during the team's pre-proposal listening workshop and has been borne out in our subsequent conversations with regional stakeholders and decisionmakers over the past nine months. In light of this, one of the team's early decisions was to invest resources in the development of a new regional climate dataset with the specific aim of improving the representation of precipitation extremes in the observational record. Substantial progress has been made in this effort, resulting in the release of an experimental version of the ChesWx dataset (http://marisa.psu.edu/data/), a 4-km gridded, daily analysis of observed minimum temperature, maximum temperature, and precipitation for the period 1948-2015 (see Figure 1).

Development and validation of the dataset by Jared Oyler and Rob Nicholas are ongoing, with an official release expected in Summer 2017, but two major findings have already emerged from this work:

> (a) Adjustments commonly used to account for differences in weather station observation practices can have substantial impacts on the statistical characteristics of observed precipitation including overestimates of wet-day frequency and suppression of intensity for extreme precipitation events. These results are documented by Jared Oyler and Rob Nicholas in the manuscript "Time of Observation Adjustments to Daily Station Precipitation May Introduce Undesired Statistical Issues," which is currently in review with *International Journal of Climatology*.
>
> (b) Existing high-resolution gridded observational precipitation datasets vary widely in their spatiotemporal statistical properties, particularly with regard to extremes, despite the fact that these datasets largely rely on the same sets of station observations in their construction. The statistical properties of the precipitation datasets are sometimes also very different from their original input station observations. This means that conclusions drawn from modeling exercises that attempt to assess the impacts of extreme precipitation could differ substantially depending on the precipitation data chosen for the analysis. These results will be presented by Jared Oyler and Rob Nicholas in a manuscript, currently in preparation, that also documents the new ChesWx dataset they have developed.

3. Sea level projections for Norfolk, VA

MARISA has produced preliminary local sea level projections for the area of Norfolk, VA that resolve key sources of deep uncertainties. This is achieved by using a set of scenarios that spans a wide range of potential future climate forcings and using a broad, mechanistically-motivated sampling approach to account for geophysical uncertainties. For example, we employ a probabilistic accounting of the potential sea-level rise due to rapid Antarctic ice sheet mass loss, which has previously not been incorporated into

probabilistic projections of sea levels. We provide probabilistic projections of local sea levels as multiple probability density functions, one for each potential future climate scenario. This was motivated by (i) questions from decision makers about how to interpret the scenarios produced, for example, by federal agencies (e.g., Sweet et al, 2017) and (ii) the interest in decision analyses that require probabilistic projections of future flood risk. The preliminary analyses suggest that the NOAA extreme sea-level rise scenario (Sweet et al. 2017) is in the upper tails of our probabilistic scenarios for a high future climate forcing scenario. While this is consistent with the *a prior*i intuition, our method now enables the identification of key drivers of the uncertainty and a relatively straightforward integration into robust decision-analytical frameworks.

4. Catalogue of Physical Models in the Chesapeake Bay Watershed

Since the 1980s, computational models have been created to assist scientists and decisions makers in their analyses of the Chesapeake Bay Watershed. These models range from detailed hydrodynamic models assisting researchers to better understand ocean-estuary interactions to screening models intended for decision makers evaluating a range of land change scenarios intended to manage pollution in the Bay. While the Bay is rich with models, our early engagements and observations of information gaps revealed that confusion exists about the various types and appropriate uses of models in the region. To help organize disparate sources of information on models into a centralized database, MARISA is creating an interactive catalogue of over 120 models in the region. The catalogue will sort models by numerous attributes, such as spatial extent and resolution, temporal resolution, coding language, calibration and validation results, ability to ingest future climate scenarios, ownership/maintenance details, and whether the model is open source or proprietary.

The results of this model catalogue will be summarized in a forthcoming review paper discussing redundancies and gaps in the models, along with potential opportunities to couple various models together to form a more comprehensive, integrated system that enables multi-objective analyses (e.g. stormwater control and watershed-level water quality). The catalogue will also be made interactive via an online web interface where users can select their desired attributes for a given problem or issue at hand to reveal appropriate models that could be used to address that issue. Our expectation is that local governments would not typically perform the modeling work themselves, but rather would use this interface as a first step to identify the available tools for future work by scientists and other technical experts.

Top Accomplishment From the Past Year

MARISA's top accomplishment this year was execution of a large, structured engagement process to identify the Mid-Atlantic's most pressing needs and climate-sensitive decisions (see Figure 2 and accompanying text). From over 25 engagements, the team was able to distill feedback from a range of government, academic, non-profit, and private sector stakeholders into the following key areas where decisions or investments are currently or are expected to become impacted by a changing climate: land management, water management, and transportation (particularly in urban

environments). The results of these engagements will help establish MARISA's research priorities, raise awareness of MARISA's existence and potential value-added to support decision-making in the region, and lay the groundwork for partnerships and collaboration in subsequent years.

Outreach and Communications Activities

Listed below are the primary outreach or communication activities undertaken by MARISA in Year 1 of our program.

1. Over 25 stakeholder outreach and engagement meetings (see Table 1) to assess decisions already impacted or expected to be impacted by climate variability and change, reveal gaps in data or information, and understand opportunities for MARISA to immediately help improve climate resilience in the Chesapeake Bay Watershed.

2. Design and implementation by the RAND team of the new MARISA website (www.MidAtlanticRISA.org) serving a central place for program information, periodic updates, and links to relevant data sets and other material. Design and implementation by the Penn State team of the new MARISA Climate Data Portal (http://marisa.psu.edu), which is already being used to host regional climate datasets (including the experimental ChesWx product) and an interactive map providing access to a variety of weather, streamflow, tidal gauge, and buoy data for the region.

3. Creation of social media presence on Twitter (@MidAtlanticRISA) and Facebook (https://www.facebook.com/marisaproject/) to directly engage with MARISA stakeholders and benefactors.

4. MARISA has partnered with SCRiM to promote and co-support the 5th Annual Summer School on Sustainable Climate Risk Management (http://scrimhub.org/opportunities/summer-school/), enabling deeper engagement with the regional stakeholder/decisionmaker community.

5. Presentations at the National Weather Service/Climate Prediction Center, National Adaptation Forum, American Water Resources Association, the City of Norfolk, and the Northern Virginia Regional Commission, along with participation in working group meetings for the Chesapeake Bay Program, Metropolitan Washington Council of Governments, and the NOAA Eastern Region Climate Services.

Key Publications

1. Berg, N., D. Knopman, B. Hobbs, K. Keller, and R. Nicholas. Resilience to a Changing Climate in the Chesapeake Bay Watershed: Progress, Challenges, Information Gaps, and Opportunities. 2017. RAND. In review.

Abstract: As part of the Mid-Atlantic Regional Integrated Sciences and Assessments (MARISA) program, the authors gathered first-hand feedback on activities related to resilience and adaptation to climate variability and change in the Chesapeake Bay watershed. Over 20 discussions were conducted between January and April 2017 with federal, state, and local government officials; coastal and environmental managers; transportation planners; water and electric utility officials; land conservationists; hydrologists; atmospheric scientists; and other local stakeholders. Presented here is a synthesis of responses to a series of questions used to guide these discussions, supplemented where appropriate with references to published information gathered by the MARISA team. These questions pertained to decisions and investments under consideration today that would most benefit from the inclusion of climate information; adaptation initiatives that have been accomplished and proposed future adaption options; key knowledge and data gaps in climate resilience and adaptation initiatives; opportunities to advance climate resilience efforts; and finally, challenges or threats to advancing those efforts. Answers to these questions will help to increase awareness of how a changing climate is currently impacting or will soon impact a variety of services, investments, and decisions in the region; and help to transparently set MARISA's analytical priorities and efforts to assist the region on these issues.

2. Oyler, J.W., R.E. Nicholas. Time of observation adjustments to daily station precipitation may introduce undesired statistical issues. 2017. International Journal of Climatology. In review.

Abstract: Interstation observations of daily precipitation are often temporally misaligned due to differences in station time of observation. Several time of observation adjustment methods have historically been applied to improve interstation temporal alignment, but the efficacy of such adjustments has not been fully tested. Here, we examine the ability of several time of observation adjustments to improve observation compatibility under three different adjustment scenarios: adjusting morning observations to midnight, adjusting afternoon observations to midnight, and adjusting afternoon observations to morning. We find that all adjustment methods provide necessary improvements to the temporal alignment of daily precipitation observations, especially with respect to morning versus midnight time of observation totals. However, for a majority of the adjustments, improved temporal alignment comes at the cost of significantly altering observed precipitation intensity, frequency, and extremes. We also find adjustments have the potential to overcorrect and increase both general and extreme event spatiotemporal coherence.

Narrative Examples

During the first year of performance, MARISA prioritized engagement with a range of stakeholders and officials to clearly understand how we could best support near- and long-term decisions, investments, and other climate-sensitive issues plaguing the region in the second year of our program. As a result, MARISA has not directly influenced plans, policies, or strategies as a result of our initial service to the region. However, our focused engagement process has laid the foundation for MARISA in the second year of

performance to support decision-making across multiple levels of government and within the private sector regarding climate impacts to plans, policies, and operations in land management, water management, transportation, and urban resilience. Since MARISA focuses on impact-driven and use-inspired research, we will strive to quantify the economic, social, ecological, health and other benefits from our upcoming decision support efforts in the region.

Implementing Data Management Plan

ChesWx is a 4-km gridded analysis of daily minimum temperature, maximum temperature, and precipitation for the Chesapeake Bay watershed and the greater Mid-Atlantic region. An experimental release of the dataset is available on the MARISA Climate Data Portal at http://marisa.psu.edu/data/.

Cited References

Berg, N., D. Knopman, B. Hobbs, K. Keller, and R. Nicholas. "Resilience to a Changing Climate in the Chesapeake Bay Watershed: Progress, Challenges, Information Gaps, and Opportunities". 2017. RAND. *In review.*

Sweet, W. V., R. E. Kopp, C. P. Weaver, J. Obeysekera, R. M. Horton, E. Robert Thieler, and C. Zervas (2017), "Global and Regional Sea Level Rise Scenarios for the United States", NOAA Technical Report NOS CO-OPS 083. https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf