SERDP REPORT

SERDP Climate Change Program Review and NOAA Partnership Meeting Summary Report

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Report Summary

On July 7th-9th, 2015, the Department of Defense's (DoD) Strategic Environmental Research and Development Program (SERDP) and the National Oceanic and Atmospheric Administration (NOAA) held a joint meeting in Boulder, CO. This meeting brought together more than 50 researchers to review the status and contributions from completed and late stage research, explore new insights from ongoing research, and identify potential new challenges and opportunities to guide future SERDP research investments. In addition, the meeting provided a venue for SERDP and NOAA to explore common research needs and collaborative opportunities.

The organizers developed a series of sessions that included a combination of presentation and discussion on the following topics: regional perspectives, including sessions on the Pacific Islands, Southeast, Southwest, and Alaska; climate information at moderate time scales (two to 20 years); and decision framing.

The presentations and discussions throughout the meeting reinforced the fact that SERDP has invested in a wide variety of research to date. The body of SERDP-funded research includes questions driven by an interest to better understand the functioning of the physical and biological world under non-stationary conditions, as well as applied and use-inspired research that relates to specific applications and decisions. From the meeting presentations and discussions, the author identified nine general themes. These themes could be informative to supporting the SERDP research strategy, and they are presented in no particular order:

- Impacts to permanent built and natural infrastructure and planning new infrastructure in dynamic systems
- Characterization of ecological, social, and physical thresholds to inform decisions
- Projections of climate and sea level conditions over moderate (two to 20 year) time scales
- Rigorous development and testing of adaptation frameworks and assessment frameworks
- "Useful" research products that capture early transition opportunities and support an understanding of how to accelerate and expand such opportunities
- Synergies achievable through SERDP-NOAA partnership
- Characterization and use of full system uncertainty to improve the robustness of decision making
- Improved understanding of the value of information for decision making and resource requirements
- Methods, tools, and metrics for communication and engagement with stakeholders that support decision making and mainstreaming of climate information

Past SERDP investments have improved the understanding of climate impacts in vulnerable regions, adaptation measures to minimize the impacts, and frameworks to help guide assessments, among other outcomes. Looking ahead, a clear articulation of criteria to help prioritize new research directions can assist SERDP in effectively pursuing its future investment strategy.

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We are thankful to all of the experts who participated in the meeting and agreed to have their presentations shared. Material in presentation summaries directly reflects material presented to try and maintain consistency in message, and any errors introduced in interpretation are those of the author. Note that the views in this report are the author's alone, and do not necessarily reflect the views of the experts that presented nor of SERDP or NOAA.

Acronyms

AMOC	Atlantic Meridional Overturning Circulation
CARSWG	Coastal Assessment Regional Scenario Working Group
DCERP	Defense Coastal/Estuarine Research Project
DIC	Dissolved Inorganic Carbon:
DOC	Dissolved Organic Carbon
DoD	Department of Defense
ESPC	Earth System Prediction Capability
ESRL	Earth System Research Laboratory
ESTCP	Environmental Security and Technology Certification Program
EWL	Extreme Water Level
GFDL	Geophysical Fluid Dynamics Laboratory
GUI	Graphical User Interface
ICAR	Intermediate Complexity Atmospheric Research Model
NCA	National Climate Assessment
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
RC	Resource Conservation and Climate Change
SERDP	Strategic Environmental Research and Development Program
SLR	Sea Level Rise
STC	SERDP Technical Committee
SWE	Snow Water Equivalent
USACE	United States Army Corps of Engineers
USGCRP	United States Global Change Research Program

1. Introduction and Background

The Strategic Environmental Research and Development Program (SERDP) is the Department of Defense's (DoD) environmental science and technology program. SERDP planning and execution is done in partnership with the Department of Energy and the Environmental Protection Agency, and includes participation by many other federal and non-federal organizations as funded entities. SERDP directs research in four program areas: environmental restoration; munitions response; resource conservation and climate change; and, weapons systems and platforms. SERDP's resource conservation and climate change program area supports science needed to sustainably manage DoD's installation infrastructure. SERDP investments in "use-inspired" research are improving the understanding of potential impacts of climate change to DoD assets and missions to assist DoD in responding to these impacts through effective adaptation and mitigation strategies.

SERDP climate change investments are focused on:

Vulnerability and Impact Assessment: development of region-specific tools and models to better understand the potential impacts to built and natural infrastructure of permanent installations, ranges, and surrounding communities.

Adaptation Science: studying how to enhance the resistance, resilience, or recovery capacity to enable built and natural infrastructure on DoD permanent installations to continue to provide benefits in the face of climate change, and improving the understanding of how to manage species and ecosystems that will be affected by climate change.

Land Use and Carbon Management: improving the understanding of carbon cycle dynamics across the various vegetation types and landforms that DoD manages to ensure upland and coastal ecosystems and their carbon management is compatible with maintaining military mission support, desired ecosystem services, and biological diversity.[1]

In addition, SERDP recently began funding climate-related research that will investigate adaption to changes in the hydrologic cycle under non-stationary climate conditions, including: (1) the non-uniform spatial and temporal distribution of potential climate-induced changes in the intensity and variability of heavy precipitation and run-off events, and (2) the implications for adaptation from these changes for geographic regions and applications of interest to the DoD.

1.1 Meeting overview and charge

On July 7th-9th, 2015, SERDP and the National Oceanic and Atmospheric Administration (NOAA), a lead agency for climate change-related research and user transition and a key Federal partner for the DoD, held a joint meeting in Boulder, CO. SERDP and NOAA managers designed the meeting, "to recap the status of and contributions from completed and late stage research, explore new knowledge and insights emanating from ongoing research, and build on the SERDP experience to identify potential new

[1] For more information on SERDP climate change investments see: https://www.serdp-estcp.org/Program-Areas/Resource-Conservation-and-Climate-Change/Climate-Change

challenges and research opportunities to guide future investments." In addition, the meeting was meant to "enable SERDP and NOAA to explore common research needs and collaborative opportunities" (see Appendix for full meeting charge).

Specific meeting objectives provided to participants were to:

1. Recap SERDP-funded vulnerability/impact assessment research at the regional scale and key findings from ongoing decision framework research.
2. Identify not only future research needs in the preceding areas, but also future climate modeling and information needs from the "user" perspective: i.e., from the perspectives of (a) those needing the information to make planning and management decisions and (b) those scientists investigating the use of such information to drive biological, physical, and engineering process models to determine responses to weather and climate change.
3. Explore potential collaborative relationships between NOAA and SERDP to address use-inspired, climate change-related research questions of mutual interest and of benefit to their respective missions.
4. Provide input to a post-meeting strategy document to guide SERDP research investments for the next three to five years and to identify any demonstration/validation needs that could be addressed through the Environmental Security and Technology Certification Program (ESTCP).

The meeting included more than 50 participants from SERDP staff, NOAA staff, SERDP Technical Committee (STC) members, SERDP project Principal Investigators (PI) and co-PIs, representatives of the US Global Change Research Program, Air Force Weather Service, Office of Naval Research, and a few select invitees.

See the Appendix for the full agenda and meeting objectives.

1.2 Document purpose and intended audience

The purpose of this document is to provide a summary of the meeting with an emphasis on identifying conclusions, research needs, and cross-cutting themes. This summary can serve as input to the SERDP process for developing a future investment strategy. The primary audience is SERDP/ESTCP and NOAA managers, as well as the meeting participants.

This document is structured according to the meeting session topics with a summary of each session and an emphasis on the findings, significant conclusions, and research needs identified from the on-going or recently completed research. Each section includes brief summaries for each presentation, drawing directly on presentation materials and notes taken during the meeting to summarize the discussions. Section 5 provides perspective on themes and research needs that emerged across the sessions.

2. Summary of Opening Plenary

Presenters in the opening plenary session provided the context for and focus of SERDP climate-change related research, perspectives on NOAA capabilities and future directions that could be relevant to SERDP, and a summary of advances from SERDP-funded climate change modeling research. These

presenters articulated the objectives for the meeting and began to frame some of the key topics to be addressed.

Alexander MacDonald, the Director of NOAA Earth System Research Laboratory (ESRL), presented information on the Earth System Analyzer (MacDonald 2015), which builds on NOAA capabilities to meet the objectives of improving weather prediction and the knowledge of Earth system climate forcing and feedback to constrain climate prediction. The Earth System Analyzer is also designed to help prepare NOAA to handle global emergencies and determine knowledge needs related to geo-engineering. The Earth System Analyzer is a framework to continuously analyze the entire Earth system at high resolution (i.e., 3km), including variables of the physical, chemical, and biological components.

Anne Andrews, Acting Director of SERDP and ESTCP, provided perspective on the changing needs that SERDP and ESTCP aim to meet and how a new investment strategy can help them meet those needs over the next three to five years. She emphasized the fact that investments in SERDP need to be relevant to DoD and focus on actionable science that is relevant to policymakers and installation managers. Dr. Andrews also reinforced the interest in identifying opportunities for collaboration and synergy between SERDP and NOAA.

John Hall, SERDP Program Manager for Resource Conservation and Climate Change, reviewed the history of SERDP and ESTCP (Hall, 2015a), including the emphasis of SERDP research in "Pasteur's Quadrant," of use-inspired basic research, and to some extent in "Edison's Quadrant," of applied research (this is the primary domain of ESTCP). SERDP climate-change related research fits into a broader DoD context that is informed by the 2010 and 2014 Quadrennial Defense Reviews (DoD 2010, 2014a), and the 2014 Climate Change Adaptation Roadmap (DoD 2014b). Within this context, SERDP plays a role in developing the science and tools required by DoD for adaptation, provides technical input on pace, spatial scale, and assumptions that underpin adaptation decisions, and supports actionable science. Dr. Hall also offered a brief review of the SERDP investment strategy in the past and initial ideas for the future SERDP investment strategy.

Robin Webb, the Director of the Physical Sciences Division at ESRL, presented on the broad set of capabilities within NOAA for meeting four strategic goals related to healthy oceans, a weather-ready nation, climate adaptation and mitigation, and resilient coastal communities and economies (Webb 2015). Dr. Webb provided an overview of the vision and mission within key NOAA line offices, as well as the many research laboratories. This material was useful context for understanding the breadth of NOAA capabilities and resources, which might be leveraged in collaboration with SERDP.

Rao Kotamarthi and Katherine Hayhoe presented an overview of the SERDP-supported climate modeling products, including the development of a "user manual" for climate model information (Kotamarthi, et al. 2015). In general, SERDP research on climate information aims to inform many different research gaps, such as understanding the value added of higher resolution dynamical downscaling, the merit of statistical versus dynamical downscaling in different contexts, whether statistical downscaling from dynamical downscaling products adds additional information or improves bias, approaches for quantifying extremes in the distribution of temperature and precipitation, and better characterization of

biases in model estimates of surface temperature and precipitation. The results of SERDP-funded climate modeling efforts will be disseminated via an online portal, which will be open to all users and was expected to be available by August 2015.

Along with the portal, SERDP-funded researchers are developing a manual as an easily accessible report on climate products and their use. The manual will provide a broad outline of user needs and guidance for matching climate model output to initiate an analysis. SERDP intends to provide an opportunity for meeting participants to provide feedback on the document. There exists a tremendous set of different user needs that will be presented in three main groups: Type 1 includes groups studying problems where climate is a minor part of overall uncertainty or when historical trends and future projections are inconclusive or unresolved. Type 2 includes agencies that might not need detailed quantitative information or situations where historical and future trends are evident but magnitudes are highly uncertain. Type 3 includes groups who need robust quantitative projections to make robust decisions, and may use historical and future trends to inform detailed modeling of impacts and preparedness. The manual will include information on scenarios, global modeling, the value of downscaling, regional climate modeling, and statistical downscaling. The manual will also have an overview of uncertainty issues to help users understand the relationship to impacts, vulnerability, and resilience modeling and assessment.

3. Summaries and Research Needs from Regionally Focused SERDP-Funded Research

To date, SERDP has funded a range of research with a regional focus, including regions that are likely to experience climate impacts, or already are experiencing climate impacts: the Pacific Islands, Alaska, and the U.S. Southeast and Southwest. The meeting included regional sessions that provided perspective on the types of climate-related issues elucidated for the region through SERDP-funded (and other) research. A session goal was to highlight successes and challenges associated with available climate information to inform process and vulnerability/impact assessment models, such as potential mismatches in scale and how these affect uncertainty characterization and the use of climate data in process and vulnerability/impact assessment models. Presenters were asked to comment on research needs in these or other areas they determined to be priorities. This section provides a summary across all presentations, including key themes and research needs, as well as summaries for each presentation that highlight key conclusions and specific research needs.

3.1 Overall session summary and research needs

The session on regionally focused SERDP-funded research covered a diverse set of projects, which varied in the climate-related hazard of interest, spatial scale, time scale, and approach, among other features. Project's Principal Investigators identified research needs (see summaries below) that differ within each region and across regions. Two general research needs (or research objectives that would benefit other parts of the region), expressed by the PIs are related to gaining a better understanding of the impacts of climate change on permanent built infrastructure in dynamic systems and potential ecosystem and hydrological changes due to climate impacts.

The impact of climate change on fixed infrastructure was discussed in several systems. For example, infrastructure impacts resulting from changes in permafrost in Alaska (Ajo-Franklin, 2015; Bjella, 2015; Douglas, 2015), and infrastructure impacts from sea level rise (SLR), typhoon activity, and changes to water resources in the Pacific Islands (Donnelly, et al., 2015; Storlazzi, 2015; Gingerich, 2015). Fixed infrastructure in these locations is being already being damaged by dynamic environments, which are projected to experience continued change. Research needs common to this issue include advanced infrastructure monitoring, adaptive design, prediction and identification of high-risk areas, and determining thresholds points for infrastructure failure. In addition, spatial variability of impacts—which was highlighted in the permafrost environment and which can apply to other settings—poses challenges to both linear structures (e.g., roads, pipelines) and vertical structures. Research gaps remain to improve the characterization of the spatial variability of impacts and methods to adapt to it.

Across the regions, researchers identified a need for improvements in the science related to understanding climate influences on major changes to historical conditions, including changes in dominant vegetation, fire, and precipitation or the hydrological cycle (Schuur, 2015; Brooks, 2015; Hoerling, 2015). As an example, DoD installations need better information on how climate may change where and when fire severity will increase. Many climate-driven ecosystem impacts are still not well understood, including how ecosystems are likely to change following fires that may be more frequent or intense than the prevailing fire regime, and how ecosystems will respond to long-term changes in water availability.

3.2 Presentation summaries for the Pacific Islands region

Five presentations demonstrated the breadth of research on climate impacts in the Pacific Islands. Several presentations focused on research related to exploring threats of a changing climate in general (Donnelly et al., 2015), impacts of sea-level rise (SLR) on atolls and reef-lined coasts (Storlazzi, 2015), and changing water resources in Guam (Gingerich, 2015). These projects are helping to advance the basic understanding of how climate-related processes relate to impacts and the implications for management decision making. Two other projects focused on methodological advances related to the prediction or estimate of future changes, including typhoon risk (Emanuel, 2015) and estimates of extreme water levels (Sweet, 2015). Research needs and challenges identified in the presentations include issues of propagation of uncertainty in modeling climate-driven processes and potential impacts, improvements needed in climate modeling to capture ENSO dynamics and key impact events in the paleo record, and challenges in extrapolating results across heterogeneous settings.

Presentation Title	**Estimating Typhoon Risk to Pacific Islands in Current and Future Climate**
Presentation Authors:	Emanuel, K.

Project or Presentation Objectives:	Risk assessment by direct numerical simulation of typhoons is problematic because global models do not simulate the storms that cause the most destruction. To overcome this challenge, this project employed a risk assessment approach that seeds each ocean basin with weak, randomly located cyclones that are assumed to move with the large scale atmospheric flow. The next step was to run a high resolution typhoon model for each cyclone, noting how many achieve at least tropical storm strength, and then used the small fraction of surviving events to determine storm statistics (Emanuel et al. 2008).
Key Findings Presented:	Typhoons clearly vary with climate, with a risk that hurricane threats will increase over this century. Historical records of typhoons are too short and imperfect to estimate hurricane risk. Better estimates can be made from paleotempestology and downscaling typhoon activity from climatological or global model output.
Further Research Needs Presented:	Future research needs or key gaps were not presented.

Presentation Title	**Advancing Best Practices for the Formulation of Localized Sea Level Rise/Coastal Inundation "Extremes" Scenarios for Military Installations in the Pacific Islands (RC-2335)**
Presentation Authors:	Sweet, W.
Project or Presentation Objectives:	The purpose of this project was to develop guidance that can be used to formulate probabilistic estimates of extreme events under a changing climate for specific locations in the Pacific Islands. Extreme water levels result from a combination of global, regional, and local processes and the relative importance of these processes varies from location to location. This project is investigating the relative importance of these processes for extreme water levels in particular locations. In addition, the project is analyzing how various approaches to extreme value analysis may be constrained by temporal and spatial data limitations, and how they might be combined with statistical or other techniques to overcome these limitations.
Key Findings Presented:	Case study results from Guam and Honolulu provided examples of probabilistic forecast products for extreme water levels to the end of the century. The researchers found that for most locations tides, long-term trend and climate co-variability in "location parameter" dominate the time-varying (inter-annual) changes in extreme distribution. A workshop resulted in technical guidance on best practices for the formulation of localized sea level rise/coastal inundation "extreme" scenarios in the Pacific Islands. This project has also developed innovative proof-of-concept products that can be used to support decision making (see: http://www.noaaclimatepacis.org/slr/phase2.php).
Further Research Needs Presented:	Further research is needed to explore climatic co-variability in "scale parameter" (high-frequency storminess) from "location parameter" (low-frequency changes). In addition, research is needed to delineate still water level from wave-forced responses in tide-gauge extreme model, and on downscaled analyses for total water levels. Further research is also needed on downscale analyses for total water levels.

Presentation Title	Impacts of Changing Climate on Pacific Island-Based Defense Installations
Presentation Authors:	Donnelly, J., Karnauskas, K., Ashton, A., Emanuel, K., and Lin, N.
Project or Presentation Objectives:	This project aims to determine the scope and magnitude of climate related threats to DoD bases on Pacific Islands over the next century in the form of water availability, sea level rise, changes in tropical cyclone activity, and changes in coastal landforms.
Key Findings Presented:	As a result of increased evaporation, most islands are projected to experience increased water stress by the end of the century, including seasonal changes in freshwater availability. Tropical cyclone activity may increase considerably across the North Pacific, and projected El Niño like warming in the Pacific by 2100 may indicate more tropical cyclone risk for Kwajalein and Guam. Reef islands may be more naturally resilient to increased rates of sea level rise than previously thought, but they are dynamic landforms and fixed infrastructure is likely to lack resilience. Loss of reef islands is possible if they migrate to the lagoon edge where sediment is lost to the system. A threshold-like response may occur where islands intersect with their lagoons, as erosion can occur very rapidly.
Further Research Needs Presented:	The challenges and areas for additional research identified in this study are low confidence in CMIP5 predictions of ENSO patterns and magnitudes. Global climate model results need to be improved to capture some significant climate variability evident in proxy records (e.g., changes in Intertropical Convergence Zone, sea surface temperature, and hurricanes). Additionally, uncertainties related to climate mediated changes to sediment supply are large. The researchers identified a general gap in understanding related to geomorphic changes to Pacific Island atolls in the future.

Presentation Title	The Impact of Sea Level Rise and Climate Change on Atolls and Low-Lying, Reef-Lined Coasts (RC-2334)
Presentation Authors:	Storlazzi, C.
Project or Presentation Objectives:	The specific objectives of this project were to provide basic understanding of storm ocean surface wave-induced flood and overwash of atoll islands that house DoD installations, assess the resulting impact of SLR and storm-wave flooding on infrastructure under a variety of SLR and climatic scenarios to determine tipping points, and use Roi-Namur on Kwajalein Atoll as a test case based on historic information, SLR predictions, and global climate model output.
Key Findings Presented:	Research results demonstrated the processes by which sea level rise can lead to effectively larger waves reaching Pacific Islands that will result in higher wave run-up, and thus have greater impacts. In particular, increases in overwash events may lead to a tipping point in the ability of groundwater sources to recover from the associated sea-water infiltration, presenting significant long-term management challenges.
Further Research Needs Presented:	Different geology and geomorphology makes extrapolation to other locations difficult. Therefore, further research is needed on smaller atolls where lagoonal-set up is important and on high-elevation islands with greater hydraulic head. In terms of biogeomorphic island evolution, it is unknown if islands will grow vertically as occurred during the mid-Holocene highstand given constant sediment production. Further research is needed on how global climate change (thermal stress, ocean acidification, changing wave climate) will affect sediment production.

Presentation Title	Water Resources on Guam: Potential Impacts and Adaptive Response to Climate Change for Department of Defense Installations
Presentation Authors:	Gingerich, S.
Project or Presentation Objectives:	This project characterized water resources in northern and southern Guam to better understand potential changes to water resources in the future, including how streamflow, sediment loads, and turbidity will be modified and the resultant effects on surface-water availability; modifications to groundwater recharge and salinity; and climate-change impacts to DoD infrastructure supplying surface water and groundwater. Research also related to understanding adaptive strategies that can help manage water systems effectively. The ongoing work has an explicit focus on quantification of the ways different stakeholders (including water managers) interpret and understand technical information.
Key Findings Presented:	The number of tropical storms and typhoons is likely to decrease, although typhoons are likely to become stronger. In addition, impacts from El Niño are likely to continue and inter-annual variability is unlikely to change. Seasonal cycle in groundwater alkalinity may indicate less conduit recharge during dry season.

Further Research Needs Presented:	The presentation identified research challenges and gaps including the fact that climate change uncertainty is generally not expressed in relevant terms across models and therefore not well propagated through the various hydrologic models. In general, for this location current and future variability of typhoons and other extremes are not explainable. Also, long-term climate projections do not incorporation short-term climate cycles (e.g., PDO, ENSO), and managers primarily make decisions on shorter time horizons.

3.3 Presentation summaries for the Southeast and Southwest regions

Presentations on research in the Southeast and Southwest included an overview of available science and the presentation of that science in the Southwest (Castro 2015) and mid-Atlantic (McCrary et al. 2015), and detailed looks at how ecosystems (Wootten and Boyles, 2015; Lytle et al., 2015), fire (Brooks 2015), and water regimes (Hoerling, 2015) may change. Presentations included several research needs related to the value of downscaled climate information and limitations in current approaches.

Presentation Title	**Future Climate Outlooks for the Mid-Atlantic and Southeast**
Presentation Authors:	McCrary, R., Bukovsky, M., Mearns, L., Moss, R., and Brown, C.
Project or Presentation Objectives:	This presentation discussed the development and application of future climate outlooks. A climate outlook aims to provide an overview of climate information relevant to planning and adaptive management of military installations. The climate outlooks are an integrated expert judgment of likely future changes, based on a combination of current climate trends from observations with a variety of sources of information about possible future climates.
Key Findings Presented:	Climate outlooks developed include information on expert judgment confidence levels, a basic description of the climate, analysis of temperature and temperature extremes, analysis of precipitation and precipitation extremes, sea level rise and flooding, and impacts relevant variables.
Further Research Needs Presented:	Research needs include research on the differential credibility of climate model results and evaluation of downscaling methods and resolution required for credible local climate projections. In addition, the presenters pointed to a gap in our understanding of future changes in surface winds. The presentation noted a need for coordinated archiving of impacts related variables and unique model output of these variables.

Presentation Title	Testing process models with climate model output in the Southeast
Presentation Authors:	Boyles, R., and Wootten, A.
Project or Presentation Objectives:	This Defense Coastal/Estuarine Research Project (DCERP) focused on the Marine Corps Base Camp Lejuene and Fort Bragg. The project integrated climate change data and science into the research process through extensive engagement with researchers and managers. In addition, the research identified and documented relevant climate variables to inform ecosystem modeling efforts, and developed uniform historical climate data and future climate scenarios that are suitable to test and evaluate ecosystem process models.
Key Findings Presented:	Direct engagement with ultimate stakeholders (base land managers, base administration) is a key part of the process for delivering actionable information. Engagement with technical staff has helped to better understand climate information needs, but perspectives from key decision makers have been limited so far.
Further Research Needs Presented:	Further research is needed to determine if higher spatial resolution does not produce more meaningful results. A choice of resolution in downscaling may not mean a coarser resolution will provide less value for assessments and decision making.

Presentation Title	Climate Change in the Southwest: What We Know and Don't Know
Presentation Authors:	Castro, C.
Project or Presentation Objectives:	The presentation provided a review of key points from recent Southwest climate change assessment report, and provided two case examples on the use of dynamically downscaled information in regional climate projection: streamflow projection in the Colorado River basin and extreme events using convective resolving modeling.
Key Findings Presented:	In the Southwest, Pacific sea surface temperatures are the main factor contributing to natural climate variability and this information is used to help water resource planning on seasonal timescales. However, this information does not fully explain events in the paleoclimate record. The case studies showed that dynamic downscaling does add considerable value for certain management relevant questions. Dynamical downscaling yields less realizations, but probably greater physical confidence in the projection of extremes.
Further Research Needs Presented:	The presenter noted that future research could use the described methodological paradigms with global seasonal model forecast data from the North American multi-model ensemble, which are now available at a temporal resolution suitable for dynamical downscaling for a 30+ year retrospective reforecast.

Presentation Title	Climate Change and Fire in the Southwest
Presentation Authors:	Brooks, M.
Project or Presentation Objectives:	This presentation provided an overview of the historic, current, and future fire regimes in the Southwest. Changes in fuels, ignition sources, or physical variables can each alter fire regimes. The focal ecosystems for this presentation were southwestern forests and desert shrublands.
Key Findings Presented:	In Southwestern forest fire regimes, frequency of large fires is correlated with increasing mean temperatures, which cause earlier snow melt, longer summer fire seasons, and drier fuels. Further warming in the future will likely lead to longer fire seasons and more large wildfires, ultimately leading to a type-conversion of forests into shrublands. In desert shrubland fire regimes, increased extent of the moderate winter and moderate summer and high winter and high summer precipitation zones may lead to increased fire occurrence.
Further Research Needs Presented:	Research needs identified by the presenter include research to support better forecasting of the future regional location and magnitude of the North American Monsoon, and of the potential dynamics of atmospheric streams emanating from the Pacific. In addition, the presenter identified a need for improved understanding of climate/fire thresholds that results in type-conversion of vegetation types. Further development of applied responses that land managers can employ to mitigate the undesirable effects of shifting climate and fire regimes is also needed.

Presentation Title	Climate change and aquatic-riparian ecosystems in the southwestern U.S.
Presentation Authors:	Lytle, D., Olden, J., and Merritt, D.
Project or Presentation Objectives:	Climate-driven changes in the timing, frequency, and magnitude of flood and drought events in the western U.S. will affect aquatic organisms as well as stream-dependent birds, reptiles, and mammals. In addition, the non-stationary dynamics produced by shifting climate regimes are not handled well by current population models. This project attempted to improve the ability to model changes in streamflow regime and the ability to forecast population-level changes to management-sensitive aquatic and riparian organisms, by incorporating stochastic, non-linear streamflow dynamics into existing demographic models.
Key Findings Presented:	Researchers applied robust mapping between streamflow regime and biological response demonstrated in the study system to the investigation of the effects of individual disturbances (major flood or drought events), altered disturbance regimes (changes in event frequency and magnitude), and management actions (dam operations, water allocation). The results revealed potential tipping points in ecosystem structure and potential changes in response of functional guilds, which can be used to inform management decisions.
Further Research Needs Presented:	Future research needs or key gaps were not presented.

Presentation Title	A Situational Awareness of Decadal Variations in Regional Precipitation
Presentation Authors:	Hoerling, M.
Project or Presentation Objectives:	This presentation provided an overview of historical records of decadal variation in precipitation in the semi-arid west. The research used a variety of remotely sensed data in combination with in-situ observational records and global climate model results to isolate the influence of climate change on this variation.
Key Findings Presented:	Science-informed situational awareness is key to knowing to what you are adapting. The particular history of SST variations has very likely been more important than the particular history of external radiative forcing for recent decadal drying. Appreciable precipitation trends arise without forcing, via "climate noise" alone.
Further Research Needs Presented:	No specific research needs were presented or discussed.

3.4 Presentation summaries for Alaska

Presentations on research in Alaska addressed several issues related to changes in permafrost, as well as modeling of arctic amplification (Winton, 2015) and future snow loads (Jones and Daly, 2015). Several presentations examined the interaction of permafrost and infrastructure, specifically addressing infrastructure monitoring (Ajo-Franklin, 2015), adaptive design based on permafrost conditions (Bjella, 2015), and permafrost-infrastructure-ecologic-hydrologic relationships (Douglas, 2015). Presentations focused on issues not directly related to infrastructure, including potential impacts to ecosystem and biogeochemical processes from the effects of climate and fire on permafrost, soil carbon, and ecosystem carbon (Schuur, 2015), and the effects of permafrost thaw on hydrology (Walvoord, 2015). Presenters identified a wide range of research needs to improve the understanding of permafrost dynamics and impacts to infrastructure, as well as modeling future change in the Arctic.

Presentation Title	Permafrost Dynamics and Effects on Surface and Subsurface Hydrology: an Overview
Presentation Authors:	Walvoord, M.
Project or Presentation Objectives:	This presentation provided an overview of expected and observed effects of permafrost thawing in Alaska. It included background on how permafrost inhibits recharge and groundwater/surface water interaction and influences flowpaths and water residence times, thus impacting carbon cycling, aquatic exports, and surface/near surface water distribution. Evidence from a variety of studies that have employed different techniques was presented.

Key Findings Presented:	The observed and expected effects of permafrost thaw are: increased recharge, groundwater circulation, and river baseflow; a shift towards deeper flowpaths and longer water residence times; a positive shift in dissolved inorganic carbon: dissolved organic carbon (DIC:DOC) export; increased groundwater/surface water interaction; enhanced hydrologic connectivity of inland water and increased uniformity in surface water distribution trends; and reduced variability in lake chemistry and increase exchange of solutes & nutrients between aquatic systems.
Further Research Needs Presented:	The presenter described a variety of research gaps related to permafrost including a better process level understanding of interactions between thermal, hydraulic, and mechanical processes. Data about baseline permafrost information and the hydrogeologic framework are limited and long term monitoring to detect change in sensitive areas is lacking. Models are computationally intensive, require approximations, and bridging results from high-resolution physics-based models and low-resolution distributed/empirical models remains a challenge.

Presentation Title	**Fire, Permafrost, and Vegetation Change in a Warmer World**
Presentation Authors:	Schuur, T.
Project or Presentation Objectives:	This project assessed the effects of climate and fire on permafrost and how fire severity controls vegetation succession. This project also examined climate and fire effects on soil carbon and ecosystem carbon. Climate-driven changes may lead to important ecological tipping points and pose management challenges.
Key Findings Presented:	Boreal fire extent is increasing. Vegetation transition is occurring from evergreen to deciduous landscape. Receding permafrost will change the surface water available to plants and animals. Carbon storage will likely decrease in soil but may increase aboveground. The regional state of carbon storage is sensitive to stand age distribution and estimates of deep soil carbon pools.
Further Research Needs Presented:	Further research may determine where and when boreal fire extent is increasing and what happens to other ecosystems (tundra, shrublands) following fire. Research is also needed to determine how changing surface water availability from receding permafrost will interact with changing water inputs.

Presentation Title	**Permafrost Dynamics and Built Infrastructure**
Presentation Authors:	Bjella, K.
Project or Presentation Objectives:	This presentation provided an overview of challenges that thawing permafrost poses to built infrastructure, including the low or zero bearing capacity of thawed permafrost, differential settlement, and potential thermal 'run-away.' Characterization of ground ice condition is generally assessed with widely spaced and costly point sampling, which involves subjective connecting of the dots. Improved methods for characterizing the ground ice condition were discussed.

Key Findings Presented:	Expedient electromagnetic surveys can be used to determine local ground ice conditions over large areas with high resolution suitable for design. In addition, new building design techniques are needed to adapt to rapidly changing ground ice conditions.
Further Research Needs Presented:	Gaps remain in the understanding of thaw-settlement processes, as well as a need to develop and test low cost active characterization and monitoring systems, novel foundation designs, and ground temperature forecasts.

Presentation Title	**Subsurface Monitoring for the Impacts of Permafrost Change on Infrastructure**
Presentation Authors:	Ajo-Franklin, J., Wagner, A., Bjella, K., Daley, T., and Freifeld, B.
Project or Presentation Objectives:	This presentation provided an overview of climate-drivers of permafrost degradation in Alaska and potential impacts. The presenters used case studies on two infrastructure monitoring concepts ("smart infrastructure" and a distributed fiber-optic sensing package) to address the issue of permafrost degradation. Smart infrastructure has capabilities of awareness and responsiveness and has embedded sensor networks to monitor temperature, strain, soil moisture, and geophysical signatures. The fiber-optic sensing provides information on degradation and potential impacts from sensing temperature, strain, and ambient vibrations.
Key Findings Presented:	Distributed fiber-optic sensing has advantages over a smart infrastructure approach in scalability, robustness, and economy. The best approach for testing sensing networks is to take permafrost to failure in a controlled simulation of climate change. Data storage/real time processing is an issue.
Further Research Needs Presented:	As approaches to infrastructure monitoring advance, improvements in data storage and analysis will be a challenge due to the very large quantities of data generated. Research is need in the design for optimal smart structures, including feedback mechanisms via active thermosyphons and ventiducts. In addition, research is needed on operational metrics, such as avoided damage costs, for "resilient" permafrost facilities.

Presentation Title	**Effect of Arctic Amplification on design snow loads in Alaska (RC-2435)**
Presentation Authors:	Jones, K., and Daly, S.
Project or Presentation Objectives:	The goal of this project was to analyze snow water equivalent data from Alaska to determine characteristics of the annual maximum snow water equivalent (SWE), which can be used to create years of synthetic SWE with similar characteristics. This synthetic SWE was used as an input to extreme value analysis to calculate snow loads for long mean recurrence intervals. These snow load estimates are a key component of building design in snowy areas.
Key Findings Presented:	Observational SWE records can be aligned with global climate model outputs to calibrate projections of future snow loads.
Further Research Needs Presented:	Further work within the project is needed to add recent SNOTEL data for 2014 and 2015, check synthetic data characteristics, analyze data at National Weather Service (NWS) stations with SWE measurements, and analyze 10-km gridded data. General research gaps were not discussed.

Presentation Title	Arctic Climate Modeling: State of the Science and Research Challenges
Presentation Authors:	Winton, M.
Project or Presentation Objectives:	This presentation provided an overview of mechanisms driving arctic warming and approaches for reducing uncertainty in projections of warming for the arctic region. Sources of uncertainty in arctic amplification include sea ice feedback, cloud feedback, and the Atlantic Meridional Overturning Circulation (AMOC) decline.
Key Findings Presented:	Uncertainty in climate projections can be reduced by improving formulation and climatological simulation. It is important to look for emergent constraints like AMOC and snow-albedo to help narrow uncertainty. Trend observations may be useful for model calibration but possible contributions from low frequency natural variability must be taken into account.
Further Research Needs Presented:	Research is needed to better understand how to account for low frequency natural variability in modeled projections of future warming.

Presentation Title	User Perspective – what do we need to know? Permafrost-climate-disturbance-infrastructure in Alaska
Presentation Authors:	Douglas, T.
Project or Presentation Objectives:	This presentation provided an overview of issues related to permafrost and infrastructure on military installations in Alaska, and provided research results and needs in a specific management context: a proposed Joint-Pacific Alaska Range Complex with new roads, rail, and vertical infrastructure planned for remote locations. One challenge for the researchers to address was a lack of understanding of permafrost stability and hydrogeology. Additionally, climate change impacts on fire, threatened and endangered species, carbon itemization, contaminants, and land use may be major and will be multifaceted. Finally, compounding disturbances, such as thawing permafrost and a change in the fire regime, are unknown and unpredictable.
Key Findings Presented:	Several methods are available to combine remotely sensed data with field observation to improve the projections of lowland permafrost to fire. A holistic combination of remotely sensed measurements, field measurements, and model products can help identify areas where landscape change is likely. The soil thermal response to disturbance is strongest in the initial 10 years and then dissipates but can continue for decades, and is currently difficult to model.
Further Research Needs Presented:	The presenters identified a need for better elevational data in Alaska to support predictive modeling. A gap exists in our understanding of whether projected climate, landscape properties, and likelihood of change can be combined in a meaningful way that characterizes uncertainties to help identify where/how to build infrastructure.

4. Summaries and Research Needs Regarding Climate Information at Moderate Time Scales: 2 to 20 Years

Decision makers within DoD and elsewhere often identify the need for climate information over moderate times scales (defined here as two to 20 years) to inform actions. This session was designed to

explore potential approaches to meeting this need, along with identifying use-inspired research needs to anticipate challenges (as opposed to research that is reactive to user needs). Although some recent SERDP-funded research may help to address these needs, an explicit focus on research for providing climate information over moderate time scales would be a new direction for SERDP. This section provides a summary across all presentations, including key themes and research needs, as well as summaries for each presentation that highlight key conclusions and specific research needs.

4.1 Overall session summary and research needs

This session investigated challenges and approaches for projecting sea level, temperature, and precipitation over moderate time scales. With regard to sea level, specific research advances were presented and represent promising directions to improve information available to support decision making. The DoD Coastal Assessment Regional Scenario Working Group progress report (Hall, 2015b), showed a potential practical approach to providing local SLR information to military installations. Projections and timing of recurrent tidal, or "nuisance," flooding (Sweet, 2015) are possible, although many research questions remain.

Several presentations explored approaches for improving temperature and precipitation projections over moderate time scales (Arnold et al., 2015; Dole et al., 2015; Easterling et al., 2015; Kunkel, 2015), but drew only preliminary conclusions. Many challenges have been identified for advancing these projections. For predictions of one to two decades, the dominant sources of uncertainty are model uncertainty (different models simulate different changes to radiative forcing) and internal variability (natural fluctuation without radiative forcing). Generally, at smaller spatial scales and shorter time scales, the importance of internal variability increases (Hawkins and Sutton, 2009), and quantifying the uncertainty that arises from each source remains an important challenge (Kirtman et al. 2013).

4.2 Presentation summaries on temperature and precipitation projections for two to 20 years (including extremes)

The session included presentations from a range of perspectives on temperature and precipitation projections. Several presentations discussed potential methodological advances for projecting temperature (Hoerling, et al. 2015; Easterling et al., 2015, Dole et al., 2015) precipitation (Kunkel, 2015) or multiple future variables (Arnold et al., 2015). In addition, presenters discussed climate-related information for management needs and approaches for addressing them in the Navy (Harper, 2015). Many challenges for projecting temperature and precipitation over moderate timescales were discussed, and an overarching conclusion from the session was the need for research in this area on many fronts.

Presentation Title	**Naval Needs for Decadal Environmental Forecasting and Related Research**
Presentation Authors:	Harper, S.

Project or Presentation Objectives:	This presentation focused on the challenges of multi-year to decadal predictability including the complex interplay of initial conditions, external forcing, non-linear dynamics, and model error. The primary U.S. Navy climate change concerns are coastal infrastructure, global security, and changing operational environment. This project uses the 2013 Arctic Ice Coverage and Human Activity Assessment as an example of prediction challenges and strategy.
Key Findings Presented:	It is not clear when "initial value" predictability gives way to predictability arising from a forced response. Low-dimensional modes in the climate system may hold promise for a limited level of potential predictability in the two- to 20-year timeframe (but our models may need to improve significantly to realize it). The inter-annual to decadal time scale is a region of the weather-to-climate spectrum that deserves its own research focus.
Further Research Needs Presented:	The Navy supports the national, multi-agency collaboration for Earth System Prediction Capability (ESPC). The Navy is involved in development of adaptive climatological products to attempt to provide better guidance for strategic planning on season-to-annual time scales. All of these methodologies could be extended to decadal time scales, if appropriate indices were identified with sufficient potential predictability.

Presentation Title	**Weak (and Variable) Signals in a Landscape of High Variation: Where's the Information Content?**
Presentation Authors:	Arnold, J., Clark, M., Gutmann, E., Wood, A., Newman, A., Mendoza, P., Mizukami, N., and Rasmussen, R.
Project or Presentation Objectives:	All USACE civil works missions are vulnerable in some way to specific climate threats. This presentation provided an overview of efforts to determine exposure and actions to prepare for future climate-related threats. Water resource management requires complex decision making, and choices about model parameters, parameterizations, input forcings, and downscaling approaches must be made when conducting impact assessments to help determine the climate change sensitives of those decisions. Typical water resource application studies do no confront the uncertainties associated with those choices Results on how methodological choices affect the portrayals of near- and far-term climate change impacts on water resources, and the associated uncertainties that are informative to a risk management approach.
Key Findings Presented:	The NCAR, Bureau of Reclamation, and USACE Downscaling Intercomparison Experiment has provided a characterization of differences in statistical downscaling methods relevant to water resource management. The tested downscaling methods showed very different results from one another across the hydrologically significant metrics. The Intermediate Complexity Atmospheric Research Model (ICAR) is being developed as an alternative to available numerical and statistical weather or climate models.
Further Research Needs Presented:	NCAR, USACE, and partners at the Universities of Washington, Hawai'i, and Alaska-Fairbanks are also developing new strategies for observations and downscaled modeling, and for hydrologic model improvement outside the continental United States.

Presentation Title	Is the Climate Predictable on Decadal Time Scales?
Presentation Authors:	Easterling, D., Wehner, M., and Karl, T.
Project or Presentation Objectives:	This presentation focused on predicting temperature on decadal time scales. The researchers calculated the global temperature time series in a suite of model simulations and observed record and then calculated all possible 10 year trends in each time series to determine the probability of a negative or positive ten year trend. The presenters explored the utility of this approach for climate prediction for the next decade.
Key Findings Presented:	There may be some weak conditionality that the decade following a large negative trend will be positive. However, for most trend values, there is about a two-thirds chance of the next decade being warmer. Many issues with the data can lead to unclear results. If a decade cools or shows no trend there is a good chance the next decade will warm. New NOAA global temperatures show no hiatus in warming trends.
Further Research Needs Presented:	Additional research is generally needed to understand predictability of climate and uncertainty associated with climate predictions on decadal time scales.

Presentation Title	Challenge/Potential of Actionable Predictions of Extreme Precipitation
Presentation Authors:	Kunkel, K.
Project or Presentation Objectives:	This presentation discussed the application of trends to 20 year climate outlooks. The trends include water vapor trends, meteorological system trends, extratropical cyclones, and tropical cyclones.
Key Findings Presented:	Extrapolation of historical trends does not necessarily guarantee any skill. However, incorporation of most recent precipitation data into extreme precipitation values used in engineering design would be a step in the right direction, because data currently used do not have include recent trends. It seems likely that recent levels will be maintained over the next two to 20 years than return to early-mid 20th Century levels because of high confidence in anthropogenically-forced increases.
Further Research Needs Presented:	Research gaps remain to establish spatial and temporal nature of noise, through analysis of CMIP5 decadal simulations, as well as investigating predictability of climate modes of variability (e.g., ENSO, AMO, PDO).

Presentation Title	Factors Influencing Potential Predictability of Extremes from Years to Decades: Extreme Temperatures
Presentation Authors:	Dole, R., Hoerling, M., Eischied, J., Perlwitz, J., and Wolter, K.
Project or Presentation Objectives:	The general project objective was to identify how different physical processes contribute to the regional and seasonal trends in temperature extremes. The approach looked at winter and summer trends in mean temperatures, daily variability, and daily temperature extremes, using a single model with identical forcings in a 20-member ensemble.
Key Findings Presented:	Factors contributing to regional trends in extremes are local thermodynamic change from external forcing, non-local thermodynamic change, internal variability of the coupled climate system, surface forcings and feedbacks, and unforced internal atmospheric variability. Trends in temperature extremes differ by season, region, and type. The externally-forced part of regional trends in means and extremes is relatively limited; the full range of possible trends much less so.
Further Research Needs Presented:	The presenter noted that to inform adaptation and decision making, we may want to further investigate whether to focus on the most likely trends rather on ranges of possible outcomes within the specified time frame.

4.3 Presentation summaries on sea level rise projections for two to 20 years

Two presentations in this session focused on SLR. The first (Sweet, 2015) provided an overview of recent research on recurrent nuisance flooding along U.S. coastlines, identifying potential timing of tipping points for impacts to coastal infrastructure, including over moderate timescales. The second (Hall, 2015b) provided an overview and update on the DoD Coastal Assessment Regional Scenario Working Group. An outline of the working group approach to providing guidance on local SLR over moderate timescales was presented, along with future steps to complete SLR and extreme water level scenarios for use by military sites worldwide.

Presentation Title	DoD Coastal Assessment Regional Scenario Working Group: Progress to Date
Presentation Authors:	Hall, J.
Project or Presentation Objectives:	This presentation reported on the current status of work under the DoD Coastal Assessment Regional Scenario Working Group (CARSWG). The charge to the CARSWG is to provide SLR and extreme water level scenarios (EWL) for use in coastal vulnerability and impact assessments of military sites worldwide. The CARSWG is a multi-agency working group that involves federal and state agencies involved in relevant coastal science and its application. The presenter also provided perspectives on potential methods for addressing sea level changes in the two to twenty year time scale.
Key Findings Presented:	The CARSWG is developing a technical report that describes the basis for and methodologies for local/regionalized SLR and EWL scenarios for individual DoD coastal military sites worldwide. The report will use case studies to illustrate use of the scenarios within a risk-based decision framing context for determining flood risk and to provide regional exemplars of how different factors affecting local SLR and EWLs change with location.
Further Research Needs Presented:	The CARSWG work is continuing with several next steps provided in the presentation, including completing the initial development of the DoD site use database and graphical user interface (GUI). The presenter identified research needs related to improving projections of SLR over moderate time scales, including evaluating simplifying assumptions that may be appropriate, especially those related to regional ocean dynamics, land-ice melt fingerprints, and vertical land movement, over these time scales.

Presentation Title	Sea Level Rise and Recurrent Tidal Flooding
Presentation Authors:	Sweet, W.
Project or Presentation Objectives:	This presentation focused on recurrent “nuisance” flooding along the coast of the U.S. The presentation provided an overview of the impacts of nuisance tidal flooding, including timing of potential future “tipping points” that can spur management actions or new investments, even before permanent inundation from SLR.
Key Findings Presented:	Many locations along the U.S. coastlines will be impacted by nuisance flooding by the end of the century. The 30 day/year “tipping point” will be crossed by 2050 around the U.S. regardless of sea level change projection. These results provide a sense of timing and magnitude of impact that are critical for effective risk management.
Further Research Needs Presented:	Future research is required to establish a set of “indicators” that can be tracked and that local communities can translate to local impacts. In addition, new research is needed to develop projections of future flooding hazard that are aligned in time with SLR projections to help give consistent guidance to communities. The presenter noted that a “Coastal Flood Information System” is needed to provide “state of coastal flooding” and seasonal outlooks.

5. Summaries and Research Needs from Ongoing Decision Framework Research

SERDP has been investing in research on decision frameworks, the preliminary results of which formed the foundation of this session. The objective of this session was to promote additional discussion on how to go from deterministic (predict-then-act) to more robust decision making under uncertainty frameworks. This transition is motivated by a need to better consider plausible future conditions, contingent probabilistic information when appropriate, and risk tolerance. The session participants also identified the research needs necessary to continue to move forward the paradigm shift in our thinking. A related set of talksin this session explored the appropriate uses of downscaling and identified research or translation needs to address the user perspective on this issue.

5.1 Overall session summary and research needs

A variety of decision frameworks exist to support integration of climate change considerations into DoD decision making. These frameworks may not fall into discrete categories, but have been characterized as deterministic, decision analytic with probabilistic considerations, and those that seek robust solutions (Weaver et al. 2013). From the presentations in the session, it clear that this remains an active area of research. Case examples in several presentations (Brown, 2015; Moss, 2015) demonstrated progress in both developing frameworks and testing them in real-world contexts. A preliminary synthesis of some of these advances was presented with perspectives on application in additional DoD climate-sensitive decision processes (Bruzgul, 2015). A common research need highlighted in the presentations is additional evaluation of decision frameworks.

Other presenters in this session focused on climate model information and its application to decision making and provided a rich overview of SERDP-funded research and the state of the field. The presentations and discussion identified a variety of research needs, including key gaps in the understanding of feedbacks (clouds and aerosols to warming), severe weather, surface winds, and the location and magnitude of the North American monsoon. In addition, Mearns (2015) pointed out the need for more systematic evaluation and comparison of the various downscaling methods that would go beyond the proposed user manual.

5.2 Presentation summaries for decision framework research

Presentations on decision framework research drew heavily on the ongoing SERDP-funded projects, but also included perspectives drawn from other research experience of the presenters (Weaver, 2015). Several presenters offered potential frameworks that could be broadly applied (Brown, 2015; Moss, 2015). The transition or integration of adaptation design and implementation into these decision frameworks and assessment processes remains a research need (Bruzgul, 2015). Although significant advances have been made to improve downscaled climate information (Mearns, 2015; Kotamarthi et al., 2015), additional rigorous evaluation is needed (Dixon, 2015), and many research gaps remain.

Presentation Title	Decision Framing under Climate Change
Presentation Authors:	Weaver, C.
Project or Presentation Objectives:	This presentation provided background relevant to a continued dialogue on moving from deterministic decision making approaches to those that are rooted in decision making under uncertainty and robust decision frameworks. The presenter provided a general framing for the overall session around the science needs for decision making under uncertainty and robust decision making; risk based framing for assessment; the contributions of the Global Change Research Program, National Climate Assessment, and sustained assessment activities; and, opportunities for SERDP to contribute.
Key Findings Presented:	There has been an evolution in the climate change science community from identifying and working on the most pressing science needs to moving the results of that science into action. This has placed decision making front and center for future research strategies. Climate change, because of its long timeframes, diffuse impacts, and deep uncertainties, poses significant challenges to decision making. In addition, decision making has well-understood biases, including individual cognitive bias and group dynamical bias, posing added challenges to effective decision making.
Further Research Needs Presented:	The presenter noted a need to improve the methods and tools for overcoming challenges to climate-related decision making.

Presentation Title	Climate Information for Risk Management: Scenarios and Other Approaches (RC-2206)
Presentation Authors:	Moss, R.
Project or Presentation Objectives:	This presentation provided an overview of approaches and challenges for assessing climate vulnerability, with specific examples of research under SERDP project RC-2206. The objective of the project was to develop, pilot, and evaluate frameworks and methods to assess vulnerability to climate change at a range of military installations. The site assessments occurred within a systematic approach to priority setting, including vulnerability ranking, site-wide screening vulnerability assessments, climate adaptation design process, and adaptation options.

Key Findings Presented:	The climate vulnerability and adaptation research community needs to provide additional clarity about the user of a "tool," given the many different types and needs. In addition, starting an investigation by thinking about what tool we want to use will not be helpful. An alternative approach begins with understanding the information needed for decision making, and then figuring out what is needed from the climate information. A systematic approach to priority setting related to climate vulnerability and adaptation planning should be tiered, from analysis across installations, to within installations, to climate adaptation design, and ultimately action. Exposure needs to be translated into impacts, consequence, and risk management, and translating exposure to impacts requires a diverse set of models. The results of the vulnerability analysis need to fit into ongoing decision making. It helps to be clear about who the users are, what they need, and whether the tools offered are helpful. Available climate knowledge can be better used if research on vulnerability and decision making is accelerated, a wider set of approaches for exploiting available climate information is used, guidance is created on appropriate sources for different variables and types of climate information, and scenarios continue to evolve by diversifying types and using them in risk management frameworks. To support the assessment process, climate hazard exposure needs to be translated into impacts, consequence, and risk management terms, and the results of the assessment need to fit into decision making terms.
Further Research Needs Presented:	The presenter identified additional research needed to understand the links between climate science and vulnerability assessment, including more examples of how to effectively include climate information into the process. A gap in understanding what training and resources are needed to support assessments in many locations exists. In addition, the presenter pointed out a strong need to evaluate available tools and assessment frameworks to help guide improvements and application.

Presentation Title	**Do We Need (Ex Post) Probabilities for Adaptation? (RC-2204, RC-2516)**
Presentation Authors:	Brown, C.
Project or Presentation Objectives:	This presentation provided an overview of the decision scaling approach, using stakeholder defined risks, performing a climate stress test, and evaluating climate informed scenarios. The presenter used case examples for work at Fort Benning and the U.S. Air Force Academy. This approach identified robust solutions, addressing the limitations of deterministic or probabilistic decision making frameworks for climate change decisions.
Key Findings Presented:	Adaptation decision making is fundamentally different from mitigation problems, which rely on emission scenarios. Global climate models are not independent, which matters to the application to risk management decisions. Decision scaling and climate stress tests can be applied in a variety of risk management decision contexts.

Further Research Needs Presented:	The presenter identified a gap in understanding adaptation measures that are implementable in a real-world context, with consideration of appropriate regulatory guidelines, safety margins, and ways to design for 'safe' failure. In addition, more research is needed on how adaptation planning can occur over time, including the value of near term climate information, options-based approaches, and "rule of thumb" approaches. The presenter also highlighted a need for probabilistic approaches for estimating climate risk through improving the ability to estimate probabilities of 'problematic' climate change.

Presentation Title	**Downscaling: State of the Science and Research Needs**
Presentation Authors:	Mearns, L.
Project or Presentation Objectives:	This presentation provided an overview of the state of climate model downscaling science and future research needs. Key objectives of downscaling are to bridge the mismatch of spatial scale between that of global climate models and the resolution needed for impacts and adaptation assessments, and to resolve high-resolution processes that are responsible for regional climate.
Key Findings Presented:	Different objectives may require different downscaling techniques. The understanding of certain phenomena can benefit from very high resolution model outputs, including orographic precipitation, convective storms, diurnal cycle of convection, and urban and land-surface feedbacks. The authors found different definitions of the added value of higher resolution is and how to best demonstrate it—usually value is demonstrated through better validation at higher resolution, although this may not be sufficient.
Further Research Needs Presented:	A recent history of research needs shows that studies generally agree that there exists a lack of a well-developed framework for downscaling, and a need for more systematic evaluation and comparison of the various downscaling methods. Some current SERDP-funded work is addressing these needs.

Presentation Title	**Evaluating Statistical Downscaling Performance under Changing Climate Conditions: A Consumer Reports-like Perfect Model Framework**
Presentation Authors:	Dixon, K.
Project or Presentation Objectives:	The project employed a "perfect model" experimental design to quantitatively evaluate the "stationarity" assumption in statistical downscaling. The goal was to isolate and examine the implication of assuming that empirical downscaling relationships derived for the present climate can be applied to a future climate regime.

Key Findings Presented:	The approach results vary by variable of interest, time period of interest, the size of the GCM-projected response, and other factors. The presenter offered example findings, such as in a daily maximum temperature test, the skill of statistical downscaling methods diminished in the late 21st century projections relative to the 1979-2008 period. In addition, finding showed that statistical downscaling skill substantially diminished in regions of high contrast, such as coastal regions and areas of strong topographic change. Performance characteristics of extremes and derived variables can be examined using the perfect model design and a wide range of metrics. Synthetic data and different ways to degrade the perfect model predictors can provide alternative challenges.
Further Research Needs Presented:	Future work to extend the perfect model-based exploration of statistical downscaling stationarity could include using different emissions scenarios and times, developing application informed metrics, including more climate variables and indices, or including more statistical downscaling methods. Additional work could also make use of synthetic time series, different high resolution climate models, and altered GCM-based data to further evaluate statistical downscaling results.

Presentation Title	**Climate Change Decision Frameworks: Using Environmental Information and Assessments to Support Climate-Sensitive Decision Making in the Department of Defense**
Presentation Authors:	Bruzgul, J.
Project or Presentation Objectives:	This ongoing project is designed to summarize the early lessons and generalized findings from the different ongoing SERDP climate change decision framework studies. This includes providing practical answers to key questions relevant to climate change decision frameworks, processes, and implementation, and offering findings that SERDP can use to inform recommendations to DoD on climate change decision frameworks and mainstreaming the use of climate information. The primary audience for this project is the military Services and the Office of the Secretary of Defense.
Key Findings Presented:	The project will present findings across four areas: (1) identifying climate-sensitive decisions in DoD, which will help DoD decision makers consider the timeframe, level of governance, and type of activity (relative to those identified in the 2014 DoD Climate Adaptation Roadmap) of their decision to better choose a framework and align the climate information with the decision. (2) Frameworks to inform Climate-Sensitive Decisions, including discussion of moving beyond deterministic decision frameworks. (3) Incorporating climate information into decision-making, including considerations of the type of information and which point in the assessment process that it is most appropriate and beneficial. (4) Climate decision framework connections to adaptation responses, including insights on the relationship between assessment and adaptation action.

Further Research Needs Presented:	The presentation noted that a variety of research questions remain with regard to vulnerability assessment and their linkages to design and implementation of adaptation actions; some will be addressed by ongoing research. Research needs include a better understanding of what outputs from assessment are most salient to decision making at different levels of governance within DoD, and how those outputs can be most effectively delivered to decision makers. There exists a gap in research and case examples for how to design the outputs of a particular assessment to lead to clear next steps, which are actionable for decision making, and how to know when the assessment process should be done in direct integration with adaptation planning, as opposed to separate in time or process.

6. General Themes and Research Needs that can Inform Future SERDP Research Priorities

The presentations and discussion throughout the meeting reinforced the fact that SERDP has invested in a wide variety of climate change-related research to date. This body of research has advanced the understanding of climate-related processes, impacts, and adaptations in diverse settings around the world. The research includes questions driven by an interest to better understand the functioning of the natural world, as well as applied and use-inspired research that relates to specific applications and decisions. From this research, the author identified nine general themes and related research needs during the workshop. The themes and research needs presented in this section are all based on in the material presented as part of meeting; other sources of input (e.g., feedback from policymakers, installation managers, and Service representatives) may generate additional research needs for SERDP to consider in the future. Although these areas are described as distinct, overlap may occur between themes or SERDP may choose to aggregate the needs into different categories. The brief descriptions below reflect the ideas captured from participants during the meeting, but represent the opinion of the author's only. Additional background could be developed on each area to support an investment decision. The information is provided in no particular order.

Impacts to permanent built and natural infrastructure and planning new infrastructure in dynamic systems

Existing infrastructure is challenged to perform in highly dynamic systems, such as spatially variable permafrost and coastal environments exposed to overwash processes. Whereas some design standards for infrastructure may have supported performance under historical conditions, rapidly changing conditions driven by climate and non-climate stressors may have significant impacts on existing infrastructure. Information is lacking to support planning for new infrastructure in these dynamic environments or to adapt existing infrastructure to new conditions; these challenges may be distinct from one another. The uncertainty in available information may lead to over-engineering of new infrastructure, such as new buildings in historically snowy environments, at higher costs. In addition, a potential gap is present in the frameworks available to decision makers for considering and managing compounding impacts, such as thawing permafrost and a changing fire regime. Finally, scalable,

economic and robust monitoring tools and techniques are lacking to help inform how risks to infrastructure are changing, the precursors to failure, stages of failure (including catastrophic failure), and to improve the understanding of driving forces of changing risks and effectiveness of actions to respond.

Characterization of ecological, social, and physical thresholds to inform decisions

Information about potential thresholds is directly relevant to many decision making processes and can be used to determine when action is needed. A gap in understanding as to what ecological, social, and physical thresholds are most important occurs across the entire spectrum of DoD's decision space. Another gap relates to understanding exactly how climate model information informs what we know about the timing of thresholds. For example, in Alaska thresholds related to thawing of permafrost, melting of sea ice, and ecological regime changes all have implications for management decisions, which may be improved through better characterization of threshold magnitude and the timing at which the threshold will be exceeded.

Projections of climate and sea level conditions over moderate (two to 20 year) time scales

Decision makers have stressed the moderate timescale as one of the most relevant to planning and operations decisions, as many existing planning, operational, and investments processes operate on these time scales. The meeting challenged presenters to describe opportunities for identifying viable research pathways on projecting climate conditions and SLR rise over moderate time scales, which proved to be a difficult task. Although some ideas were offered in the presentations, significant advances are needed to build the scientific foundation for projections over this time horizon. Research is needed to advance methods that will improve the understanding of natural processes that drive climate over these timescales, as well as how to integrate recent observations into scenarios and projections of change in the next two to 20 years.

Rigorous development and testing of adaptation frameworks, as well as assessment frameworks

SERDP has supported research to develop and test decision and assessment frameworks. In addition, an ongoing study to synthesize early results from some of these investments should help articulate key findings from this research that are relevant to DoD. Research gaps remain, however, related to characterizing and evaluating the existing approaches to assessment as the frameworks themselves are evolving. In addition, research questions remain regarding how best to communicate climate information as part of the assessment process and to identify when assessment and adaptation planning should be conducted jointly. In addition, some work has been supported (by SERDP and others) to develop and evaluate frameworks for adaptation planning and action. Research is needed that assesses tradeoffs, costs, benefits, and timing or pathways for adaptive measures. As frameworks for assessing adaptation measures are developed, rigorous testing and metrics for evaluation will be needed to help improve frameworks over time and align approaches with decision contexts.

"Useful" research products that capture early transition opportunities and support an understanding of how to accelerate and expand such opportunities

Research that is use-inspired and helps develop "useful" products (often defined as application-ready and that may be co-produced) is needed to support DoD climate change adaptation decision making. This research should aim to generate knowledge that anticipates user needs, rather than be driven by a reaction to user needs. A gap in understanding is how to identify near-term opportunities to transition climate change research into useful products and the metrics that would promote the expansion and acceleration of these opportunities. ESTCP may consider a greater emphasis in this area.

In recent SERDP requests for proposals, research teams have been asked to consider how research can be transferred to users at the completion of the project. In addition, final research reports require researchers to address the implications of final results for implementation. However, a more systematic understanding of how to actually execute the transition to implementation, including meaningful assessment of resource requirements and user-readiness (both how ready products are for users and how ready users are for products) and metrics to measure success, could be encouraged.

Synergies achievable through SERDP-NOAA partnership

Some collaboration between SERDP and NOAA is already happening through ongoing research projects. Initial ideas for additional collaboration or partnership between SERDP and NOAA surfaced during the meeting, but more work is needed to identify specific opportunities and to articulate benefits to both entities. The NOAA labs provide a relevant set of capabilities to support SERDP research objectives, including observational capabilities that could inform carbon management research, climate modeling at the Geophysical Fluid Dynamics Laboratory (GFDL), and research at the National Severe Storm Laboratory to improve lead-times of severe weather forecasts and warnings, which could benefit installation operations. Collaboration on sea ice loss is happening, primarily through the Navy, and may have opportunities for expansion.

In addition, NOAA may be in a position to support technology transfer of SERDP research products. Future discussions between NOAA and SERDP/ESTCP can help clarify roles and opportunities in collaboration. A specific area of potential collaboration mentioned during the meeting was for a partnership focused on facilitating a transition from research to operations for updates to existing key operational resources, similar to work on NOAA Atlas 14 and the FEMA Digital Flood Insurance Rate Maps. Research may be needed to develop methods for updating operational products, whereas tools and approaches could be developed to help ensure new methods and updates are incorporated into engineering plans and decision making. In addition, improved knowledge is needed for provisioning information to decision makers. A collaborative effort might support research and testing of the provisioning of information for climate impact and vulnerability assessment or adaptation planning. In addition to partnerships with NOAA, SERDP will need to continue to stay in coordination with national initiatives, such as the U.S. Global Change Research Program's (USGCRP) National Climate Assessment (NCA) scenario development process, through investments in time and communications.

Characterization and use of full system uncertainty to improve the robustness of decision making

Although research to characterize uncertainty associated with specific components of systems has advanced, limited examples are available that characterize full system uncertainty. Where uncertainty and the propagation of uncertainty through linked models has been well traced and included in research results, communication regarding the significance of the uncertainty for decision making is often lacking. This includes uncertainty associated with the effectiveness or cost of adaptation options that can inform a decision-making process. For downscaled climate information, SERDP-funded research demonstrates that the choice of downscaling method leads to different results and associated uncertainties. In addition, the connections of DoD systems to the systems external to DoD (e.g., municipal utilities, surrounding ecosystems, local communities, etc.) and the associated uncertainty in modeling these connections are not well understood. Improvements in characterizing uncertainty from all sources relevant to decision making can help assess the applicability of decision-making frameworks designed to perform well given deep uncertainties, such as robust decision-making frameworks.

Improved understanding of the value of information for decision making and resource requirements

Whereas research has focused on generating greater amounts of information at higher resolution and detail, less attention has been given to understanding the explicit value of including additional information in decision making. Research to assess the value of information as it relates to climate information and decision making is not well developed and is needed to help guide decision makers in choices of investments for assessment and other decision processes. At the same time, the resource requirements needed to reduce uncertainty in information or to engage decision frameworks that seek robust solutions are not well characterized. SERDP research on the benefits of new information to a decision making process could be aligned with new efforts to improve the application of probabilistic or robust decision-making paradigms by demonstrating resource requirements in application testing.

Methods, tools, and metrics for communication and engagement with stakeholders that support decision making and mainstreaming of climate information

Despite being regularly acknowledged as a challenge, a gap still remains in understanding what communication modalities are most effective for which types of problems and for the variety of potential users. Research on the capacity of different audiences to use climate information may improve the overall understanding of how to communicate the right information to the right audience to improve a climate-sensitive decision. In addition, approaches to improving user capacity can be further tested and characterized, including systematic testing of training approaches in which mainstreaming of climate information into regular processes is the objective.

In the DoD context, research or testing is needed to better understand methods and appropriate use of stakeholder engagement in the research process itself. SERDP may need to consider the skills and disciplinary training appropriate for research and evaluation of research projects designed for co-production of knowledge, as well as metrics that can improve replicability of positive outcomes. In addition, more knowledge is needed on the role of boundary organizations (i.e., organizations working at the interface of scientific information and potential users) in informing DoD decisions, particularly in

cases in which nuanced use of complex approaches is needed. An example here is in helping to identify appropriate frameworks for analysis, complex modeling, and interpretation of results.

7. Conclusion

Past SERDP investments have been guided by many different influences, resulting in investments that have improved the understanding of climate impacts in vulnerable regions, adaptation measures to deal with the impacts, and frameworks to help guide assessment, among other outcomes. These results also help to identify promising areas for continued research and emerging research needs. As SERDP develops a strategic investment plan, a variety of criteria may help prioritize research directions. A clear articulation of these criteria can assist SERDP in effectively pursuing research outcomes with intentional purpose.

SERDP will continue to address research questions that are relevant to DoD stakeholders. Going forward, SERDP might explicitly consider criteria related to whether funded research will support an articulation to stakeholders of the domains where science has the most confidence and whether the research can provide input in the near-term into decision making. Similarly, if the research will not result in decision-ready information, will it be able to provide decision makers with insights into the timeframe for additional information that might be incorporated into decision making? Such results have the ability to empower decision makers to take actions and plan for the availability of new information. In addition, SERDP may choose to consider criteria related to the ability of research to reduce the near-term and long-term costs of adaptation, so that SERDP-funded research on improving vulnerability assessment and adaptation planning is complemented by research on the effectiveness and cost efficiency or benefits of adaptation measures. New metrics might be required to assess the merits of research that help inform near-term DoD decisions, lead to increased savings, and reduce impacts.

As SERDP sets criteria to guide investment priorities, another important consideration will be the definition of "problems"—recognizing that many things that the scientific community defines as a problem may be quite different from the problems faced by DoD managers. SERDP will need to clearly articulate the perspectives of these two audiences and decide how to prioritize investments to most affectively address them. In addition, SERDP will need to balance the pull to address prominent, near-term challenges with the value of improving the understanding of long-term, high-impact or transformative issues.

Finally, SERDP funding is part of a broader set of investments that contribute to improving the understanding of the potential impacts of climate change and developing effective adaptation and mitigation strategies that will enable DoD to respond appropriately. Criteria that capture the ability to leverage ESTCP investments, as well as investments by NOAA and other federal agencies, may directly inform SERDP priorities. Continued dialogue in forums such as the meeting summarized here, USGCRP forums and activities such as the NCA, and others can help SERDP to inform these choices.

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Appendix: Meeting Charge and Agenda

SERDP Climate Change Program Review and NOAA Partnership Meeting

July 7-9, 2015

National Oceanic and Atmospheric Administration
David Skaggs Research Center
Room GC402
325 Broadway
Boulder, CO 80305

Meeting Charge: The Strategic Environmental Research and Development Program (SERDP) has been funding climate change-related research since 2009. The National Oceanic and Atmospheric Administration (NOAA) is a lead science agency for climate change-related research and user transition and is a key Federal partner for the Department of Defense. This meeting will recap the status of and contributions from completed and late stage research, explore new knowledge and insights emanating from ongoing research, and build on the SERDP experience to identify potential new challenges and research opportunities to guide future investments. In addition, the meeting will enable SERDP and NOAA to explore common research needs and collaborative opportunities.

Specific meeting objectives are to:

1. Recap SERDP-funded vulnerability/impact assessment research at the regional scale and key findings from ongoing decision framework research.
2. Identify not only future research needs in the preceding areas, but also identify future climate modeling and information needs from the "user" perspective: i.e., from the perspectives of (a) those needing the information to make planning and management decisions and (b) those scientists investigating the use of such information to drive biological, physical, and engineering process models to determine responses to weather and climate change.
3. Explore potential collaborative relationships between NOAA and SERDP to address use-inspired, climate change-related research questions of mutual interest and benefit to their respective missions.
4. Provide input to a post-meeting strategy document to guide SERDP research investments for the next three to five years and to identify any demonstration/validation needs that could be addressed through the Environmental Security and Technology Certification Program (ESTCP).

Invited attendees: Up to 75 total. SERDP staff, NOAA staff, SERDP Technical Committee (STC) members, SERDP project Principal Investigators (PI) and co-PIs, US Global Change

Research Program, Air Force Weather Service, Office of Naval Research, and a few other select invitees.

Tentative Agenda and Speakers

July 7–9, 2015

SERDP Climate Change Program Review and NOAA Partnership Meeting

July 7, 2015

Morning:

0830 Welcome and Introductions (A [Sandy] MacDonald, NOAA, ESRL Director/A Andrews, DoD, SERDP, Acting Director; R Webb, NOAA/J Hall, SERDP)

0900 SERDP past accomplishments/new challenges (J Hall)

a. Overview of meeting objectives
b. Overview of SERDP-funded climate change-related research
c. Objectives for the regional sessions
d. Meeting user needs with actionable science
e. Translating science into action
f. Emerging research sessions
g. Concluding thoughts

Break (0945 to 1005)

1005 NOAA research interests (R Webb)

a. Mission
b. Science and research
c. Opportunities to collaborate

1050 SERDP-supported climate modeling products
(R Kotamarthi, ARNL and K Hayhoe, TTU; both RC-2242)

a. Data sets produced
b. Implications for possible use by others
c. User Guide—purpose and status

1120 Meeting outcomes report/investment strategy (J Hall)

Lunch/Networking (1130 to 1300)

Afternoon:

Regional Perspectives—Each regional session will provide a perspective on the types of climate- related issues that SERDP-funded (and other) research may have elucidated for the region and successes and challenges associated with the available climate information to inform

process and vulnerability/impact assessment models. The objective is to create a better understanding of the needs of the Vulnerability/Impact/Adaptation (VIA) communities (decision makers and scientists researching and translating in this arena) to assist informing climate data modelers and producers of potential research needs, in particular issues associated with potential mismatches in scale and how these affect uncertainty characterization and the use of climate data in process and vulnerability/impact assessment models. Moreover, for each region it is also an opportunity to identify unmet research needs in vulnerability/impact assessment and adaptation science.

Pacific Islands (ongoing, mid-stage projects)

1300 Introduction (M Alexander, NOAA)

1310 Estimating typhoon risk to Pacific islands in current and future climate (K Emanuel, MIT, RC-2336)

1325 Advancing best practices for the formulation of localized sea-level rise/coastal inundation "extremes" scenarios for military installations in the Pacific islands (W Sweet, NOAA, RC-2335)

1340 Impacts of changing climate on Pacific island-based defense installations (J Donnelly, WHOI, RC-2336)

1355 The impact of sea-level rise and climate change on atolls and low-lying, reef-lined coasts (C Storlazzi, USGS, RC-2334)

1410 Water resources on Guam: Potential impacts and adaptive response to climate change for Department for Defense installations (S Gingerich, USGS, RC-2340)

1425 Discussion (session speakers; J Barsugli, NOAA, discussion leader)

a. Process/VIA model requirements for climate information; needed model sensitivity analyses and validations
b. Climate information for the region(s): general outlooks/availability of data and downscaled products that meet process and VIA model needs
c. Major challenges/research needs: short-term and long-term

Break (1455 to 1515)

Southeast/Southwest (mostly completed, but some late-stage funded work)

1515 Introduction (R Webb, NOAA)

1525 Future climate outlooks for the mid-Atlantic and Southeast (R McCrary, NCAR, RC-2204/220

1540 Testing process models with climate model output in the Southeast (R Boyles, NCSU, RC-2245)

1555 Climate change in the Southwest: What we know and don't know (C Castro, UA, RC-2205)

1610 Climate change and fire in the Southwest (M Brooks, USGS, RC-1723)

1625 Climate change and aquatic-riparian ecosystems in the southwestern U.S. (D Lytle, OSU, RC-1724/2203)

1640 A situational awareness of decadal variations in regional precipitation (M Hoerling, NOAA)

1655 Discussion (session speaker; R Webb, discussion leader)

a. Process/VIA model requirements for climate information; needed model sensitivity analyses and validations
b. Climate information for the region(s): general outlooks/availability of data and downscaled products that meet process and VIA model needs
c. Major challenges/research needs: short-term and long-term

1725 Day 1 recap/July 8 agenda (J Hall/R Webb)

July 8, 2015

Morning:

Alaska (combination of late-stage and early stage projects)

0830 Introduction (K Knuuti, USACE-CRREL)

0840 Permafrost dynamics and effects on surface and sub-surface hydrology: An Overview (M Walvoord, USGS, RC-2111)

0855 Fire, permafrost, and vegetation change in a warmer world (T Schurr, NAU, RC-2109)

0910 Permafrost dynamics and built infrastructure (K Bjella, USACE-CRREL, RC-2436)

0925 Subsurface monitoring for the impacts of permafrost change on infrastructure (J Ajo-Franklin, LBNL, RC-2437)

0940 Effect of Arctic amplification on design snow loads in Alaska (K Jones, USACE-CRREL, RC-2435)

Break (0955 to 1015)

1015 Arctic climate modeling: State of the science and research challenges (M Winton, GFDL, NOAA)

1030 User perspective—what do we need to know? (T Douglas, CRREL, RC-2110)

1045 Discussion (session speakers; K Knuuti, USACE-CRREL, discussion leader)

a. Process/VIA model requirements for climate information; needed model sensitivity analyses and validations
b. Climate information for the region(s): general outlooks/availability of data and downscaled products that meet process and VIA model needs
c. Major challenges/research needs: short-term and long-term

1115 Regional wrap up (J Hall/R Webb)

Lunch/Networking (1130 to 1300)

Afternoon:

Climate Information at Moderate Time Scales: 2 to 20 years—Decision makers clamor for climate-related information over moderate time frames (versus weather predictions and long-range forecasts in the near-term). Over moderate time scales model-projected emission scenarios show minimal divergence. As a result, are other approaches available—perhaps more probabilistic in nature—that can be used to address this time frame? This session will explore this space with an eye towards identifying research needs addressing challenges that are use inspired.

1300 Introduction/nature of the challenge (J Hall)

1310 Naval needs for decadal environmental forecasting and related research (S Harper, ONR)

1330 Weak (and variable) change signals in a landscape of high variation: Where's the information content? (J Arnold, USACE-CW)

1350 Is the climate predictable on decadal time scales? (D Easterling, NOAA, RC-2517)

1410 Challenge/potential of actionable predictions of extreme precipitation (K Kunkel, NC State Univ, RC-2517)

1430 Factors influencing potential predictability of extremes from years to decades: extreme temperatures(R Dole, NOAA)

Break (1450 to 1510)

1510 DoD Coastal Assessment Regional Scenario Working Group: Progress to date (J Hall)

1530 Sea level rise and recurrent tidal flooding (W Sweet, NOAA)

1550 Discussion (session speakers; T Karl, NOAA, RC-2517, discussion leader)

a. Who is working this space?
b. What are the challenges unique to working this time horizon?
c. What are possible areas of research that could prove useful to end-users in the short term?

1650 Day 2 recap/July 9 agenda (J Hall/R Webb)

July 9, 2015

Morning:

Decision Framing—SERDP has in the past held a SERDP/ESTCP symposium technical session related to this topic as well as recently funded five ongoing climate change decision framework projects. These projects are now the subject of a SERDP synthesis report directed at policy and decision-makers. This objective of this session is to continue the dialogue of how to go from deterministic (predict-then-act) to more robust decision-making under uncertainty frameworks— that consider plausible future conditions, contingent probabilistic information when appropriate, and risk tolerance—and to identify the research needs necessary to continue to move forward the paradigm shift in our thinking. Moreover, this session also will explore the appropriate uses of downscaling and identify research/translation needs to address the user perspective of this issue.

0830 Framing the issue and role of the US Global Change Research Program efforts, including the National Climate Assessment and sustained assessment activities: A perspective (C Weaver, USGCRP)

a. Moving from deterministic decision-making to decision-making under uncertainty: necessity of, challenges, and opportunities for
b. "Risk-based" decision making and other framings: what are they and how are they different?
c. What can the USGCRP and NCA contribute?
d. What can SERDP contribute?

0850 Climate information for risk management: scenarios and other approaches (R Moss, Battelle & PNNL, RC-2206)

0910 Do we need (expost) probabilities for adaptation? (C Brown, RC-2204)

0930 Downscaling: State of the science and research needs (L Mearns, RC-2204/2206)

0950 Evaluating statistical downscaling performance under changing climate conditions: A consumer reports-like, perfect model framework (K. Dixon, GFDL, NOAA)

Break (1010 to 1030)

1030 Climate change decision frameworks: Using environmental information and assessments to support climate-sensitive decision making in the Department of Defense (J Bruzgul, ICF)

1050 Discussion (session speakers; R Moss, discussion leader)

a. What have we learned: e.g., (1) how to provide a scientific basis for a new paradigm that incorporates uncertain futures into decision-making and (2) best practices for use of GCM/downscaling data products by process modelers and decision-makers (when to do and for what region, what variables are of interest, and what spatial and temporal scale delineations are needed?).
b. What are the challenges for addressing decision-making under climate change uncertainty that remain?
c. What are possible additional areas of research that could prove useful in meeting these challenges?

1140 Meeting wrap-up (J Bruzgul)—Capture highlights and next steps discussed during the meeting/meeting report overview.

1150 Closing remarks (J Hall/R Webb)

Lunch/Networking/Travel (1200 +)

Afternoon (post meeting; optional for up to about 40 participants):

NOAA building tour (described at http://www.esrl.noaa.gov/outreach/tours.html)

Three presentations:

Facility for Climate Assessments (D Murray)
http://www.esrl.noaa.gov/psd/events/2015/review/pdf/posters/psd-review-demos-murray.pdf

The Climate Change Web Portal (M Alexander)
http://www.esrl.noaa.gov/psd/events/2015/review/pdf/posters/psd-review-demos-scott.pdf

Impact of Climate Variability and Change on Marine Ecosystems (M Alexander)
http://www.esrl.noaa.gov/psd/events/2015/review/pdf/posters/psd-review-posters2-alexander.pdf