Toward an Integrated Approach to Water

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About the AMS Policy Program

The AMS Policy Program has two primary goals. The first is ensuring that policy choices take full advantage of information and services relating to weather, water, and climate. The second is helping policy makers understand the ways that the broader society's welfare depends on information and services relating to weather, water, and climate. Meeting these two goals will help ensure that the scientific community receives the support and resources it needs to be able to make critical information and services available and, most importantly, will help the nation, and the world, avoid risks and realize opportunities related to the Earth system.

The Policy Program uses three primary approaches to help meet these two goals.

- We develop capacity within the AMS community for effective and constructive engagement with the broader society.
- We inform policy makers directly of established scientific understanding and the latest policy-relevant research.
- We help expand the knowledge base needed for incorporating scientific understanding into the policy process through research and analysis.

Through these activities, we create new ways to reduce society's vulnerability to weather and climate events by sharing our resources and information with policy makers and the public.

Executive Summary

Water is simultaneously a resource and a threat. It is centrally important to every aspect of the nation's socioeconomic wellbeing. It drives or contributes to: disaster preparedness and response, transportation, energy, national security, agriculture, and public health, among others. Water becomes a hazard when there is too much, too little, or if the quality is poor.

Existing and future vulnerabilities associated with coastal inundation, floods, droughts, the impact of routine and extreme weather events, and the threat of climate change all depend, primarily or in part, on water. The ever-changing, increasingly human-influenced water regime is characterized by localized, uncontrolled, intermittent, and sometimes huge flows of water (fresh and salt) across coastal zones, urban and rural areas, transportation infrastructure, agricultural resources, and through waterways.

This study is the culmination of a 3-year AMS Policy Program project to advance the integrated consideration of water—the full accounting of water for prediction, risk assessment, and risk management of weather and climate risks. The project was supported, primarily, through a grant from the National Oceanic and Atmospheric Administration (NOAA).

The integrated consideration of water consists of two related components: 1) the need for risk assessment and management efforts to understand and account for all sources of water and all factors that influence water's behavior, and 2) recognition that the hydrological cycle, and water (salt and fresh), is simultaneously a resource and a threat with wide-ranging implications.

For any particular weather or climate event, sources of water may include precipitation, tides, waves, sea level rise, storm surge, lakes, reservoirs, and rivers. The amount and characteristics of water involved in any event also depend, in part, on factors such as geomorphology, hydrological connectivity, land use patterns and grey or green infrastructure (e.g., marshes, wetlands, levees, seawalls, and other physical barriers). Accounting for all sources and factors is particularly critical for comprehensive risk assessment and management.

This study recapitulates and synthesizes three prior analyses: 1) *Understanding the Water Landscape of the United States: A Review of Science & Policy Recommendations*; 2) *Water & the Coasts: Opportunity, Vulnerability, & Risk Management*, a study based on two workshops that explored regional challenges in the gulf coast, west coast, atlantic coast, and the great lakes; and 3) *Opportunities for Forecast-Informed Water Resources Management*, based on a workshop that brought together forecasters and resource managers from around the country.

There is a vast and ongoing national dialogue on water from which much can be learned. *Understanding the Water Landscape of the United States: A Review of Science and Policy Recommendations* synthesized 30 different assessments that focused on national and regional scales. We identified overarching recommendations to increase actionable information related to water and to improve the use of that information for societal benefit. Notably, there are many goals for water resources management that sometimes conflict. When considered in isolation, sub-optimal outcomes often result.

The opportunities and challenges posed by water are especially acute at the coasts, which are both major resources and often highly vulnerable to extreme events. Coastal communities are also particularly sensitive to changes in land use, population distributions, and climate.

Water & the Coasts: Opportunity, Vulnerability, & Risk Management identified seven ways to enhance coastal risk management: 1) to provide actionable information; 2) to prepare and empower information users; 3) to create decision support products and services that harness scientific advances for societal benefit; 4) to build strong partnerships among stakeholders, practitioners, and information providers; 5) to develop the next generation workforce; 6) to align roles and responsibilities; and 7) to recognize linkages and potential leverage.

Water resources management is a primary need for every community across the country. Existing weather and hydrological forecasts provide a great deal of actionable information that could improve water resource management decisions. Furthermore, water resource management is well positioned to take advantage of improvements in forecasts over a wide range of time and spatial scales. *Opportunities for Forecast-Informed Water Resources Management* identified opportunities to improve the type and quality of available information and the uptake & use of the available information in water resource management.

The range and scope of issues related to water is enormous. Our three analyses barely scratch the surface of topics requiring attention in water. Nevertheless, the analysis synthesized here combines: nearly three dozen assessments; examination of coastal issues throughout the country; and exploration of resource management challenges across the United States. As a result, this synthesis is able to provide a very broad overview of the opportunities and needs in Earth observations, science, and services with respect to water.

We emphasize six main opportunities for the advancement of water-related issues:

- Improve the information available through observations, science, model capability, and computational resources

- Use the available information more effectively for societal benefit, most notably through improved collaboration, communication among Federal, state, and local authorities; stakeholders; scientists; and service providers
- Provide an effective policy framework for enhancing both the availability of information and society's ability to use it
- Create, strengthen, and evolve partnerships among public, private, academic, and NGO communities, recognizing that opportunities, needs, and capabilities evolve over time
- Strengthen the workforce in water
- Engage and empower the public to demand, understand, use, and contribute to water information and services

These six areas of emphasis often overlap. Each encompasses entire families of challenges, opportunities, and needs. Nevertheless, progress within each family has great potential to help society manage water-related risks and opportunities.

Additional challenges relating to water include the need to address issues at the appropriate level of government (federal, state, local, international) and to overcome boundaries among the governing water management authorities and responsible parties. These challenges arise, in part, because the scope of the water management challenge is widely distributed over individual, institutional, and governmental domains. At the same time, the focus of management attention is too often fragmented, incomplete, and focused on short-term objectives.

Finally, the larger context in which these water-related issues occur is extremely important to consider. Scientific, technological, and societal change is rapid with respect to observing technologies and platforms; computer analytic capabilities; and societal needs, both nationally and internationally. Preparation, planning, and responses for water share much with a wide range of challenges and opportunities across the weather and climate arena. Most notably challenges in transitioning research to operations (R2O) and in environmental prediction for the ocean, atmosphere, land surface, weather, climate, and space weather. Well-considered and sustained processes of determining the value of information and services will be vital to both scientific advancement and efforts to improve society's ability to benefit from scientific information.

Earth observations and science provide critical environmental intelligence that enables society to understand challenges and opportunities associated with the earth system. Services build on this information to expand society's capacity to manage risks and realize opportunities that environmental intelligence reveals. Societal decisions have the greatest chance to benefit people when grounded in the best available knowledge and understanding.

1. Background

Deliberate management efforts and inadvertent human disturbances alter the hydrological cycle and the distribution, characteristics, and behavior of water resources. Dams, levies, sea walls, water treatment facilities, and the use of grey and green infrastructure seek to control and improve water resources and minimize water related hazards. Inadvertent disturbances, such as those associated with buildings, roads, other land use patterns, and climate change, alter when, where, and how much water there is and how it behaves.

This ever-changing, increasingly human-influenced water regime continues to operate within a largely natural hydrologic cycle that is characterized by localized, uncontrolled, intermittent, and sometimes huge flows of water (fresh and salt) across coastal zones, urban and rural areas, transportation infrastructure, agricultural resources, and through waterways.

Water is centrally important to every aspect of the nation's socioeconomic wellbeing.

For any particular weather or climate event, relevant sources of water may include precipitation, tides, waves, sea level rise, storm surge, and rivers. The amount and characteristics of water involved in any event also depend, in part, on factors such as geomorphology, hydrological connectivity, land use patterns and grey or green infrastructure (e.g., marshes, wetlands, levies, seawalls, and other physical barriers). Accounting for all of the relevant sources and factors is particularly critical for comprehensive risk assessment and management. Furthermore, managing water related risks and opportunities over time (from minutes to decades) requires integrating short-term weather events, seasonal climate variability, and decadal climate changes.

The integrated consideration of water can help address a wide range of challenges and opportunities facing society including efforts to address existing vulnerabilities, to project future changes, and to manage emerging societal risks more effectively. As a result, there is great need for the integrated consideration of water. This will depend on developing a wholistic view of water: from mountains to coasts; over time; throughout the landscape; and across societal challenges (e.g., extreme weather events, floods, droughts, tsunamis, and climate change). To be successful, this integrated view of water must be advanced throughout the weather and climate community.

Notably, a more integrated consideration of water will depend on careful consideration of policy options, particularly those relating to observations, science, services, and regulation. Observations, science, and services provide the environmental intelligence and response capability on which effective risk

assessment and management can be based. Regulation (e.g., floodplain management through the National Flood Insurance Program and the Federal Flood Risk Management Standard) can also help protect against the loss of life and property.

Additional policy challenges relating to water include the need to address issues at the appropriate level of government (federal, state, local, international) and to overcome boundaries among the governing water management authorities and responsible parties. These challenges arise, in part, because the scope of the water management challenge is widely distributed over individual, institutional, and governmental domains. At the same time, the focus of management attention is too often fragmented, incomplete, and focused on single or short-term objectives.

Water becomes a hazard when there is too much, too little, or if the quality is poor.

The centerpiece of this project was a major national study—a series of three workshops plus additional research, and analysis—to identify, define, and develop the integrated water concept. The analytic elements contributing to this synthesis include: 1) a study of federal reports on water (Seid-Green 2016); 2) a study on coastal resilience that was based on two workshops that explored regional challenges in the gulf coast, west coast, Atlantic coast, and the great lakes (AMS Policy Program 2017); and 3) a study of forecast uses and needs in water resource management that was based on a workshop including forecasters and resource managers throughout the country (Miller and Blum 2018).

In addition to the study, this project enabled AMS Policy Program activities that: 1) help create and bring together a community of practice within the weather and climate community that is knowledgable about the integrated consideration of water, 2) inform the broader society directly about established scientific understanding and recent high-impact research related to water, and 3) develop a new generation of weather and climate leaders who understand the centrality of water to the risks and opportunities they focus on.

Major advances in weather and climate resiliency are possible through efforts that help align human needs with respect to water (i.e., that water in the right amount and of the right quality is available when and where it is needed) with what the hydrologic cycle delivers. Such advances would help minimize threats posed by water hazards and enhance resilience with respect to those threats. Furthermore, improved environmental intelligence for water would also benefit a wide range of economic sectors and practices including, most notably, water treatment efforts, transportation, disaster preparedness and response, agricultural operations, and energy production and distribution, among others.

Taken together, the studies and related activities that made up this project can help facilitate collaboration across federal agencies, private enterprise, and academia, and promote the effective development and use of Earth observations, science, and services (OSS) throughout society. This will help advance three intertwined strategic priorities: building resilient coastal communities, adapting to climate change, and creating a society that is prepared for and able to respond to weather events.

2. Studies, Workshops, & Analysis

This study recapitulates and synthesizes three prior analyses: 1) *Understanding the Water Landscape of the United States: A Review of Science and Policy Recommendations* (Seid-Green 2016); 2) *Water & the Coasts: Opportunity, Vulnerability, & Risk Management* (AMS Policy Program 2017), a study based on two workshops that explored regional challenges in the gulf coast, west coast, Atlantic coast, and the great lakes; and 3) *Opportunities for Forecast-Informed Water Resources Management* (Miller and Blum 2018), based on a workshop that brought together forecasters and resource managers from around the country. Each is described briefly below.

There is a vast & ongoing national dialogue on water from which much can be learned.

2.1 Understanding the Water Landscape of the United States: A Review of
Science and Policy Recommendations

There is a vast and ongoing national dialogue on water from which much can be learned (Seid-Green, 2016, from which this section is adapted). This study synthesized 30 different assessments that focused on national and regional scales. These assessments were authored by federal agencies, inter-agency task forces, and non-governmental organizations and coalitions. We developed a database of over 800 specific recommendations and identified twelve common recommendations:

1. Improve data collection
2. Improve data management
3. Increase scientific understanding for water resources decision making in a changing climate
4. Advance modeling capacity
5. Expand and tailor products for water resources managers
6. Support integrated approaches to water management
7. Address water rights
8. Expand and protect water supplies
9. Invest in water infrastructure
10. Establish federal coordination and planning processes
11. Invest in training and workforce development
12. Expand education and outreach

We also identified six topics that would benefit from additional attention in the national dialogue on water:

1. Increasing public knowledge and understanding
2. Planning for "big data"
3. Increasing public-private engagement
4. Preparing for hydrologic extremes
5. Understanding and managing surface and groundwater interactions
6. Understanding international dimensions

There are many goals for water resources management, including water supply, public safety, economic growth, and environmental health. Often these are considered separately. Managing for a single goal can lead to sub-optimal outcomes in the other areas. Sometimes balancing goals requires subjective value judgments. Integrated water resources management (IWRM) is seen as a way of managing these conflicts, and emphasizes that using good processes for decision-making is important for balancing competing, valid, objectives.

The opportunities & challenges posed by water are especially acute at the coasts.

Finally, resource constraints and compelling opportunity costs necessarily create challenges in meeting needs for observations, science, and services. Greater accessibility of data; improved coordination of existing programs and initiatives across agencies and all levels of government; effective partnerships among public, private, academic, and NGO communities have great potential to help maximize the value of limiting resources.

2.2 Water & the Coasts: Opportunity, Vulnerability, & Risk Management

The opportunities and challenges posed by water are especially acute at the coasts, which are both major resources and often highly vulnerable to extreme events (AMS Policy Program, 2017, from which this section is adapted). Coastal communities are also particularly sensitive to changes in land use, population distributions, and climate.

This study on coastal resilience identified seven ways to enhance coastal risk management: 1) provide actionable information; 2) prepare and empower information users; 3) create decision support products and services that harness scientific advances for societal benefit; 4) build strong partnerships among stakeholders, practitioners, and information providers; 5) develop the next generation workforce; 6) align roles and responsibilities; and 7) recognize linkages and potential leverage.

Provide Actionable Information through observations, science, and forecasts

Observational infrastructure; science (research, data assimilation, and models); and computational capabilities determine the accuracy of weather and water forecasts and provide the foundational information needed for risk management. Forecasts of water quantity and quality are most useful when they account for all sources of water (e.g., precipitation, tides, waves, sea level, and storm surge) and factors that affect water's behavior (e.g., land use and infrastructure).

Efforts to fill in observational gaps near the coasts and to improve the interoperability of different modeling approaches (e.g., river forecast, wave, ice, estuarine hydrodynamic, and storm surge models) have great potential to improve informational resources. Greater understanding of the linkages among the physical climate system, biological resources, and socioeconomic wellbeing would facilitate decision making and is possible through improved integration of physical, natural, and social sciences.

Prepare and Empower Information Users

When equipped to use information effectively, stakeholders, emergency managers, policy makers, the media, and the public make better decisions. We can recognize coastal vulnerabilities, effectively weigh options for risk management, and know how to respond when confronting hazards. However, influxes of people and turnover among coastal populations require that efforts to prepare and empower information users must be ongoing. Similarly, long periods of time between high impact events leads to complacency and requires strategies for ensuring that people know how to respond when hazards arise.

There are are many goals for water resources management that sometimes conflict. When considered in isolation, sub-optimal outcomes often result.

Formal education (pre-K through college and graduate training) and informal outreach to groups and individuals can help communities take up and use information effectively. These efforts will be most useful when grounded in insights from social sciences, particularly research on how to engage effectively (e.g., with stakeholders, emergency managers and other practitioners, information users, policy makers, the media, and the public) and to enhance risk communication.

Create Services & Decision Support Products that Harness Scientific Advances for Societal Benefit

Products and services that are accessible and tailored to specific user needs are easier to integrate into risk management decisions. Big data and data analytics offer new opportunities to create decision support products and enhanced risk management services. Data accessibility and ease-of-use among information providers and users improves the uptake and use of information.

Build Strong Partnerships Among Information Providers, Users, & Stakeholders

There is a need for strong, sustained networks of connected partners working together across federal agencies and among local, regional, and federal organizations and stakeholders. Institutionalizing key relationships can overcome the risk of turnover within agencies and among experts and service providers. Efforts to manage risks resources have the best chance of success when stakeholders understand differing perspectives and work to identify shared values that can be advanced together.

Accounting for all sources of water & all factors affecting its behavior is critical for comprehensive risk management.

Develop the Next Generation Workforce

Improving risk management over time will depend on providing scientists and practitioners with the knowledge, skills, and abilities (KSAs) needed most. Expertise in probabilistic modeling; stakeholder engagement; risk communication; integrated risk assessment; data analytics; and the integration of the physical, natural, and social sciences, among other KSAs, are likely to be particularly useful in the future.

Align Roles & Responsibilities

Conflicts arise among users who are separated across local, state, and federal jurisdictions. Suboptimal allocations of resources can occur when decision-making responsibilities are narrowly focused, and efforts to deal with a problem at one scale can create new problems at other locations or scales. This creates a need for aligning responsibilities and jurisdictions, and setting the appropriate spatial scales for management. Regional and national coordination is needed for issues that exceed local jurisdictions.

Federal roles with respect to water resource management may include: providing information (observations and science) and services; setting of standards; identifying best practices; providing a repository of case studies and/or lessons learned; helping to ensure and enhance public goods; regulation; identifying and

A wholistic picture of water: from mountains to coasts; over time; throughout the landscape; & across societal challenges (extreme weather, floods, droughts, tsunamis, and climate change).

correcting market failures, the establishment or altering of social mores (i.e., 'name and shame' or 'encourage and laud') and the provision of resources to local and regional efforts.

Federal efforts that apply to diverse local communities have greater chance of widespread adoption and success. Effective collaboration among the critical federal agencies (NOAA, USGS, NASA, EPA, and FEMA, among others) also enhances coastal risk management.

Determining public, private, and academic roles; adapting those roles as needs and capabilities shift over time; and facilitating collaboration among the public, private, and academic sectors will be critical for enhancing risk assessment and management efforts.

Recognize Linkages and Potential Leverage

Efforts to address coastal vulnerabilities can, at times, contribute to other priorities. Coastal risk management projects that achieve multiple goals may be more appealing to local communities and policy makers. For example, green infrastructure to mitigate coastal flooding may also provide fisheries habitat and recreational assets. The United States can both learn from other countries and share our resources and information with other countries (e.g., identify common needs, case studies, and lessons learned).

2.3 Opportunities for Forecast-Informed Water Resources Management

Water resources management is a primary need for every community across the country. Existing weather and hydrological forecasts provide a great deal of actionable information that could improve water resource management decisions (Miller and Blum, 2018, from which this section is adapted). Furthermore, water resource management is well positioned to take advantage of improvements in forecasts over a wide range of time and spatial scales. This study examined the potential to improve the type and quality of available information and the uptake and use of the available information in water resource management.

Forecast improvements to benefit water resource management can occur through observations, science, model capability, computational processing power, and data analytics. Specific opportunities include those that:

a. Improve the spatial resolution of forecasts. Information on the amount and timing of water entering into particular river basins and watersheds would be valuable
b. Improve predictions over timescales between two weeks and two years (sub-seasonal to inter-annual) to inform longer-range water resource planning
c. Provide information about the range of possible outcomes and their likelihood (i.e., probabilistic forecasts and ensemble simulations)
d. Improve the incorporation of water management decisions in model simulations (e.g., dam operations, water transfers, land-use changes, and water use)

Forecasts are most valuable when they are easily accessible, readily understood, and relevant to management decisions. The uptake and use of available forecasts by water resource managers could also be enhanced.
Specific opportunities include those that:

a. Refine forecast communication by taking advantage of insights from communication experts and related social scientists
b. Expand collaboration between forecaster and water resource management communities to ensure that forecasters understand information needs of managers and that managers are aware of the full range of forecast products and advances
c. Assess and communicate forecast accuracy (e.g., through model validation, test-beds, and case studies) so that managers can make informed decisions about the most effective use of available information
d. Eliminate barriers to using forecast information in WRM as appropriate with forecast advancement

Water resource management is well positioned to take advantage of improvements in forecasts over a wide range of time & spatial scales.

In general, policy choices can: 1) regulate (i.e., establish laws and requirements), 2) provide resources (e.g., funding for observations, science, or services), 3) create information repositories and increase awareness, 4) identify best practices, and 5) institutionalize working relationships. Each of these has potential relevance to forecasting and water resource management.

In addition, water resource management has several specific opportunities and needs. Notably, there are many goals for water resources management that sometimes conflict. When considered in isolation, sub-optimal outcomes often result. Jurisdictions (e.g., state, federal, and local) can work well for some issues but be misaligned for others. Federally, numerous agencies and congressional committees have jurisdiction and oversight over some aspects of water.

Comprehensive consideration of all water challenges and opportunities can be limited. For example, management of reservoirs for energy production can lead to suboptimal decision-making with respect to other water issues (flood control, drought mitigation, and conservation).

Policies that enhance observations, science, and model development and operation can improve forecast quality. Investments in quickly evolving communications technologies can promote forecast dissemination. Training forecasters and water resource managers as well as supporting pilot studies and testbeds may enable an efficient translation of experimental improvements into operations.

Notably, the potential benefits of improved forecasts and their use will not be equally distributed across water management objectives, regions, and stakeholder groups. As a result, there is almost certainly no "best" investment approach. For example, improving forecast skill on sub-seasonal to inter-annual timescales would be particularly beneficial for drought management. In contrast, management decisions for flood risk depend more on shorter-term forecasts. The incorporation of human decision-making (e.g., with respect to water storage and release) in forecasts will be most beneficial at highly regulated waterways where this is a significant factor in river flow.

Whether, and how best, to allocate resources among potential areas for improvement is beyond the scope of this study.

3. Synthesis of Findings & Future Directions

Taken together, the analyses above suggest six common areas of emphasis: 1) to improve the information available through observations, science, model capability, and computational resources, 2) to use the available information more effectively for societal benefit (improved collaboration and communication among stakeholders, scientists, and service providers), 3) to provide an effective policy framework for enhancing information and society's ability to use it, 4) to create, strengthen, and evolve partnerships among public, private, academic, and NGO communities, particularly as opportunities, needs, and capabilities evolve over time, 5) to continuously expand the potential of the current and future workforce, and 6) to empower the public to participate throughout the entire value chain to the maximum extent possible. Of course, these six areas of emphasis are not mutually exclusive but highly overlapping and inter-related. Efforts that recognize linkages among them have greater potential to confer significant advances.

Observations & science provide environmental intelligence that enables society to meet challenges & opportunities associated with the Earth system.

A key challenge to overcome is the different contributions, responsibilities and authorities among agencies (e.g., NOAA, USGS, NASA, NSF and USACE) based on type, location, and source of water (e.g., storm surge, precipitation, sea level rise, or river discharge). This creates a coordination, communication, and integration challenge for agencies. This is illustrated, to a degree, by differences in the modeling approaches used by surge and wave models and hydrologic models of river flow. These models have separate developmental histories and remain not fully integrated.

Taken together, the analytic work synthesized in this study can help inform and guide the environmental intelligence and response capabilities needed to more effectively manage risk and realize opportunities associated with weather, water, and climate. As a result, the conclusions can help advance three strategic priorities: building resilient coastal communities, adapting to climate change, and creating a society that is prepared for and able to respond to weather events.

Of course, the scale and scope of issues related to water is enormous and these general principles require far greater detail for implementation to be remotely possible. To be most effective, all efforts like these must recognize both the larger set of issues that we have been unable to tackle in this study (e.g., ground water) and the larger context in which these water-related issues occur.

For example, scientific, technological, and societal change is rapid with respect to observing technologies and platforms; computer analytic capabilities; and societal needs, both nationally and internationally. The target is moving and will continue to do so. Focused attention is needed on all these trends and must be sustained over time.

Preparation, planning, and responses for water share much with a wide range of challenges and opportunities across the weather and climate arena. Most notably challenges in transitioning research to operations (R2O) and in environmental prediction for the ocean, atmosphere, land surface, weather, climate, and space weather. Well-considered and sustained processes of determining the value of information and services will be vital to both scientific advancement and efforts to improve society's ability to benefit from information.

The range & scope of issues related to water is enormous.

This project also contributes to the AMS Policy Program's larger study series, which identifies and focuses on the root issues that promote or constrain society, science, and policy. To date, the AMS has conducted roughly 20 National studies on a wide range of topics (www.ametsoc.org/studies).

The larger study series helps expand the knowledge base needed for incorporating scientific understanding into the policy process. Studies are designed to: 1) identify and understand issues relating weather, water, and climate that influence social and economic well-being, 2) identify policy options that could improve information and services relating to weather, water, and climate, 3) analyze policy options objectively (i.e., the advantages and disadvantages of particular options), and 4) reveal the impact that policy choices have on environmental intelligence and society's capacity to benefit from that intelligence, and 5) identify remaining needs that, if met, could improve decision-making related to weather, water, and climate.

Water is simultaneously a resource and a threat. It is centrally important to every aspect of socioeconomic wellbeing and water becomes a hazard when there is too much, too little, or if the quality is poor. The ever-changing, increasingly human-influenced water regime is characterized by localized, uncontrolled, intermittent, and sometimes huge flows of water (fresh and salt) across coastal zones, urban and rural areas, transportation infrastructure, agricultural resources, and through waterways. Earth observations and science provide critical environmental intelligence that help us determine when there is too much water, too little, or of the wrong quality. Services help us manage risks and realize opportunities that environmental intelligence makes possible. Decision-making with respect to water, as with all societal choices, has the greatest chance to benefit people when grounded in the best available knowledge & understanding.

4. References

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