

NASA'S WATER RESOURCES ELEMENT WITHIN THE APPLIED SCIENCES PROGRAM

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ABSTRACT

The NASA Earth Systems Division has the primary responsibility for the Applied Science Program and the objective to accelerate the use of NASA science results in applications to help solve problems important to society and the economy. The primary goal of the NASA Applied Science Program is to improve future and current operational systems by infusing them with scientific knowledge of the Earth system gained through space-based observation, assimilation of new observations, and development and deployment of enabling technologies, systems, and capabilities. This paper discusses major problems facing water resources managers, including having timely and accurate data to drive their decision support tools. It then describes how NASA's science and space based satellites may be used to overcome this problem. Opportunities for the water resources community to participate in NASA's Water Resources Applications Program are described.

Index Terms— Water Resources, Hydrology, Remote Sensing

1. INTRODUCTION

Viewed from above our home planet stands out as a “blue marble” set against the vast blackness of outer space, with an abundance of water on its surface. Yet, only a small portion of this water is fresh and available for consumption by plants, animals and humans. With increasing population pressure and water usage coupled with climate variability and change, water issues are being reported by numerous groups as the most critical environmental problems facing us in the 21st century. Competitive uses and the prevalence of river basins and aquifers that extend across boundaries engender political tensions between communities, stakeholders and countries. Mitigating these conflicts and meeting water demands requires using existing resources more efficiently.

Unfortunately, most of the world's water has little potential for human use because it is salt water,

approximately 97.5 percent. This leaves us with just 2.5 percent of the world's water being potentially useful for humans, but most of this is locked up in ice sheets at the poles. The fresh water accessible to humans amounts to a paltry 0.26 percent of the total available water. Yet, on the average this is a fairly significant amount. The problem is that the average, both in time and space exists in very few places on the globe. In addition human impacts on the hydrologic cycle can be dramatic and increases in the global population have put major constraints on available fresh water supplies.

2. SUSTAINABLE WATER RESOURCES

The first step in developing a water resources sustainability strategy and management plan is to know the quantity and quality of water available. Water resources assessment is a necessary step if one is to develop societal benefits such as domestic and industrial water supplies, maintenance of human health, hydropower, irrigation, flood protection, droughts, navigation, recreation and preservation of the environment. This is not a trivial task even in data rich regions of the world, but in data sparse regions it becomes almost impossible. One has to start with adequate reliable hydrologic data on the quantity and the quality of the available water resources. One must then account for modifications in the hydrology brought about by human uses, agriculture, manufacturing and pollution control. For many regions of the world, and particularly in the developing world, these data do not exist or are unreliable. Embarking on a data collection campaign with traditional methods and instrumentation is extremely expensive and requires a large supporting infrastructure.

There are a number of U.S. water agencies (i.e., NOAA, US Army Corps of Engineers, Bureau of Reclamation, USDA National Resources Conservation Service, etc.) as well as private engineering and consulting firms that have a mandate for predicting the flow rate (or depth) of streamflow resulting from rainfall. These predictions are used for real time river management (flood forecasting, water supply, navigation, minimal flow rates for ecological requirements) as well as for design of engineering structures

(dams, bridges and culverts, channel protection and levees, etc) and non-structural methods such as flood plain zoning. In addition to the U.S. water agencies, there are numerous international groups, universities, non-government organizations and private companies that are working to develop and improve water resource decision support tools (DSTs).

What this boils down to is that there are a plethora of models and decision support systems available to predict water availability. All (or almost all) are capable of providing accurate predictions of streamflow if used for conditions for which they were developed *and there is adequate and accurate input data to drive the models.*

3. SATELLITE AND MODELING SOLUTIONS

Monitoring the surface and ground water supply is a vital societal need. Surface water includes both flowing water in streams and rivers, natural lakes, polar ice caps and man-made reservoirs. Ground water includes the large amounts of water stored beneath the Earth's surface in aquifers – vitally important to the viability of agriculture in arid climates. It is important to determine where supplies of fresh water are located, to quantify how much water is available, and to figure out if and how rapidly the water supply is increasing or decreasing. Increased demand threatens to deplete these precious water resources and accurate information on water availability is needed to meet the water resource needs of ever growing populations.

The major space agencies of the world and their partnering meteorological services maintain a vast array of Earth observing satellites capable of providing basic measurement hydrological data, weather, climate, land use, water use and diversions, and natural and human-induced hazards. Data collected and information created from Earth observations have the potential for providing critical inputs to sustainable water resources development and management. These Earth observations also provide information for informed decision making and for monitoring conditions and progress at multiple spatial and temporal scales. NASA's fleet of satellites that are able to provide important measurements of the hydrologic cycle that can be used for water resources assessment and management in regions of the world where traditional data are insufficient or nonexistent (Figure 1).

4. NASA APPLICATIONS

The NASA vision and mission statements include a clear focus on the Earth and life on Earth.

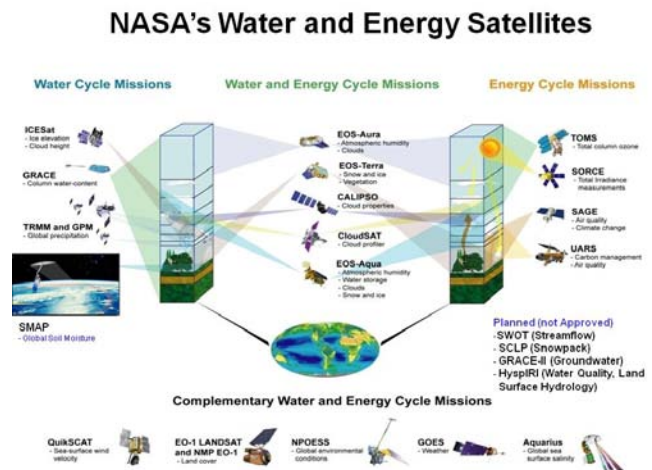


Figure 1. Illustration of current and planned NASA's water satellites.

NASA seeks to improve life on Earth by enabling people to use measurements of our home planet in valuable ways. NASA's Earth Science Division has primary responsibility for two Agency-wide, Earth oriented themes in the NASA strategic plan: Earth system science and Earth science applications. In serving these themes, the division works with its domestic and international partners to provide accurate, objective scientific data and analysis to advance our understanding of Earth system processes and to help policy makers and citizens achieve economic growth and effective, responsible stewardship of Earth's resources.

NASA has long been considered to be a science organization but only within the last few years has its Applied Science Program begun to have an impact of the solving of the nations technical, societal and economic problems. The Earth Systems Division within NASA has the primary responsibility for the Earth Science Applied Science Program and the objective to accelerate the use of NASA science results in applications to help solve problems important to society and the economy.

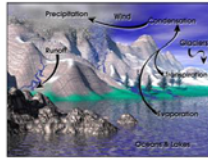
NASA's Applied Science Program has identified seven priority national applications (program elements) of which water resources is one. NASA collaborates with partner organizations to enable and enhance the application of NASA's Earth system science results to serve national priority policy and management Decision Systems Tools (DSTs). The Water Resources Program Element addresses issues of concern and decision-making related to water quality and availability. Some cross-cutting activities also relate to the Weather, Agricultural, Natural Disasters, Public Health and Ecological Forecasting program Elements. The Water Resources Program Element extends NASA research

Goals of NASA's Hydrology Research to Applications

Fundamental Research

Water and Energy Cycle Science

- Global Hydrological Cycle
- Fresh Water Resources and Availability
- Climate Change
- Measure Water Cycle (Soil Moisture, Evapotranspiration, Snowpack, Aquifers, Runoff, & Precipitation)



Applied Research

Science Utilization

- Reservoir Regulation
- River Flow Management & Floods
- Agriculture Planning
- Hydro Power Planning
- Drought Assessment
- Weather Forecasting
- Water Quality



Figure 2. Illustration of NASA's Applied Science Program converting research and technology for water resources.

results to decision support tools that address issues related to water availability and quality: The desired outcome is for partner organizations to use project results, such as prototypes and benchmark reports, to enable expanded use of Earth science data and products to enhance their decision-support capabilities.

The goal of the Water Resources Program is to enable partners' beneficial use of NASA Earth science observations, models, and technology to enhance decision support capabilities serving their water management and policy responsibilities (Figure 2). Major tenets of the Water Resources Program goal include:

- Develop and nurture partnerships with appropriate water management organizations
- Identify and assess partners' water management responsibilities, plans, and decision support tools and evaluate capacity of NASA Earth system science results to support the partners
- Validate and verify application of NASA Earth system science results with the partners' DSSs
- Communicate results and partners' achievements to appropriate water communities and stakeholders

5. NASA APPLICATIONS

The following list provides a brief description of the scope and depth of applied sciences projects being funded by NASA's Applied Sciences Program in the field of water resources. Figure 3 demonstrates the use of NASA products in a DST for a key societal benefit such as drought monitoring through the US Drought Monitor.

Details on any one of these can be found in the Program web site: <http://wmp.gsfc.nasa.gov>

- "Developing Seasonal Predictive Capability for Drought Mitigation Decision Support System"
- "Improving Water Supply Forecasts in the Western U.S. Using NASA Earth Science Results"
- "Enhancing Water Management Decision Support Systems with High Spatio-Temporal Resolution Mapping of Actual Evapotranspiration"
- "Improving Water Resources Management in the Western US through use of Remote Sensing Data and Seasonal Climate Forecasts"
- "National Drought Monitoring System for Drought Early Warning Using Hydrologic and Ecologic Observations from NASA Satellite Data"
- "Development of a Robust Drought Index for Agricultural Applications"
- "Introducing Remotely Sensed Irrigation Information into the USDA FAS Decision Support System"
- "Integrating Enhanced GRACE Water Storage into the U.S. and North American Drought Monitors"
- "Benchmarking NASA Snow Research Results in NWS Hydrological Decision Support"
- "Developing Seasonal Predictive Capability for Drought Mitigation Decisions Support System"
- "Developing Seasonal Predictive Capability for Drought Mitigation Decisions Support System"
- "Improving Water Quality Management: Use of Earth Observations in SPARROW"
- "Satellite Earth Image Products Applied to Development of Regulatory Water Quality Standards"
- "Improving BASINS/HSPF Predictions of Nitrogen Export to Improve TMDL Accuracy Using NASA Imagery"
- "A Land Data Assimilation System for Early Warning"
- "Project Nile Distributed Hydrological Information for Water Management in the Nile Basin"

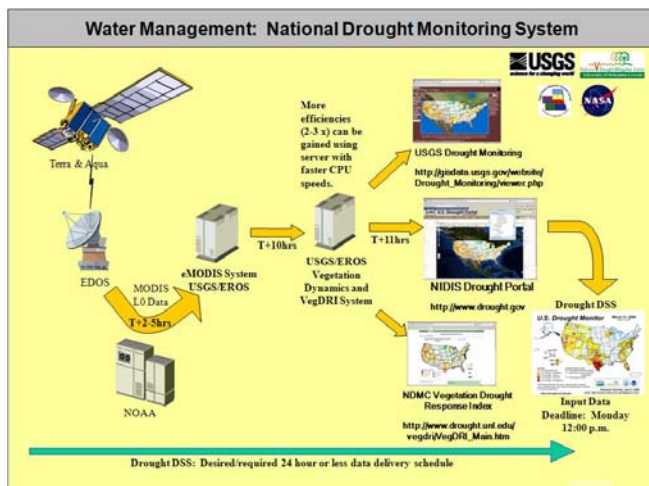


Figure 3. Illustration of an 'end to end project' for water resource applications.

6. FUTURE THRUSTS

In the future, the Water Resources Program's priorities focus on evolving products for DSTs as well as expanding the variety of measurements and model products to be tested

for use in these and other water management decision support tools. Also, potential products of planned satellites (e.g. Global Precipitation Mission (GPM), Surface Water and Ocean Topography (GPM), Cold Land Processes, and Soil Moisture Active Passive SMAP)) need to be evaluated for their potential to augment current and future DSTs. Potential future observational spacecraft products should be evaluated for both direct use within DSTs, and for indirect use through modeling to improve model output that is used by DSTs. A key challenge will be to infuse NASA satellite products into decision support systems using advanced data sharing and distribution technologies with an emphasis on the Internet for data assimilation to provide an integrative approach for adapting to the myriad of water availability and quality issues facing our nation.

7. SUMMARY

The Water Resources Program leverages appropriate activities, expertise, and assets selected through solicitations and research announcements to serve the program element's objectives. The NASA Water Resources Program has emphasized water issues working with US federal agencies including NOAA, USAID, USDA, Bureau of Reclamation, and EPA and state agencies such as the California DWR. For proposals selected through solicitations funded by the Applied Sciences Program, the Water Resources Program may provide supplemental funding. In addition, the program element may provide funds to projects selected or identified through other Science Mission Directorate solicitations. The

program and project managers facilitate appropriate partnerships between solicitation recipients and NASA partners. The activities are carried out through competitive grants that are peer reviewed to insure that they are technically feasible and address high priority Program goals. Governmental, private and academic organizations are encouraged to participate and compete for NASA support to enhance their problem solving mandates.

The following are useful web sites for those that want more details about the Applied Sciences Water Management Program or are interested in submitting proposals for support.

- Information on NASA research opportunities can be found at: <http://nspires.nasaprs.com/external/>
- This site has general information about Earth sciences and applications: <http://www.earth.nasa.gov>
- This site describes NASA's Applied Sciences Program: <http://science.hq.nasa.gov/earth-sun/applications/index.html>
- This site describes the Water Resources projects: <http://wmp.gsfc.nasa.gov>