Air and Water Monitoring for Homeland Security

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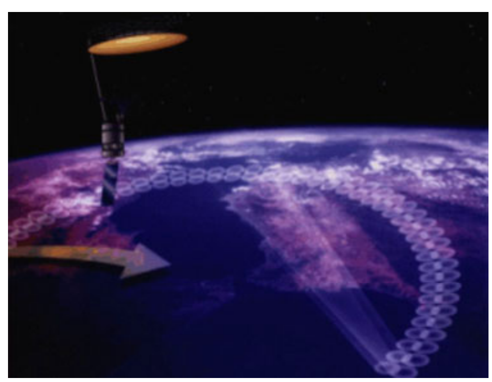
Last year's terrorist attacks on the World Trade Center and on the Pentagon have heightened our awareness of actual and potential threats to our nation's safety and security. Assuring homeland security has become a national priority (Bush, 2001), meaning that we must take decisive actions both to prevent and to mitigate future homeland security threats. On 8 October 2001, President George W. Bush established the Office of Homeland Security with the mission to "…develop and coordinate the implementation of a comprehensive national strategy to secure the United States from terrorist threats or attacks" (Executive Order 13228). Homeland security is a challenge of monumental scale and complexity, requiring a comprehensive, long-term strategy that involves partnership with State and local governments, the private sector, and citizens. The president's strategy will build an emergency management system that is better able to manage not just terrorism but all hazards affecting our nation and its people.

A critical element of homeland security lies in the vitality of our environment, which is primarily defined by the availability and quality of our air and water resources. Homeland security efforts must therefore include advanced understanding, assessment, and prediction of natural and human-induced variations in our environment, enabling retooled policies and planning, allocation of resources, and partnership strategies. Whether the cause is a terrorist, an accident, or a natural disaster, the efforts needed to avoid and to alleviate air- and water-related threats are similar. We must be able to identify and assess the magnitude of current threats, to evaluate various preventative and corrective actions, and to predict future threats.


Proposed Hydrospheric State Mission to observe soil moisture and soil freezing.

Over the past few decades, we have made substantial progress in our ability to monitor, assess, and predict air quality and water resources. However, only the scientific community has effectively realized these developments with marginal returns to management and operations. Now, more than ever, we must take action to make the necessary links for improved homeland security through knowledge-added disaster preparation, assessment, and

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mitigation. We must also view homeland air and water security at the global and multi-national levels, encompassing not only terrorism and vandalism but also natural disasters and potential adversities from human-induced change.

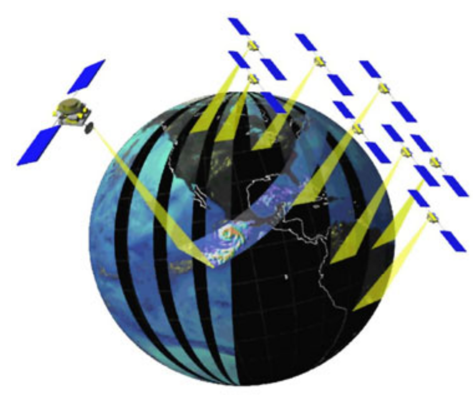
Air and Water Homeland Security Issues

The health of our society is built on the quality and availability of air and water. Contamination and disruptions in these basic environmental quantities by natural or anthropogenic forces have profound implications. While water is abundant in our global environment, it is neither evenly distributed over the globe nor always in a form suitable for human use. Population growth, contamination, and climate variation may result in calamities of water quality and quantity, exposing society and the environment to flood damage, drought, and contamination. As one of the leading industrialized nations of the world, our society is not only vulnerable to but also largely responsible for the contamination of the atmosphere. This contamination originates at factories, power plants, vehicles, and fires. Atmospheric contamination threatens our health and the health of the environment (trees, lakes, crops, animals, climate), and it damages buildings and other infrastructure. The progressive interplay of societal needs, ecologic concerns, public health, and scientific uncertainty continuously challenge the balance between the security of our nation's industrial productivity and our personal well-being. Thus, to ensure that cogent policies are made in light of these growing complexities, the advancement of scientific understanding of our environment must remain steadfast.

Terrorism poses a large threat to our water and air resources. Potential terrorist acts include contamination of water supplies; release of airborne toxins and bioaerosols; radioactive contamination; structural failure (reservoirs and holding facilities); and disruption of water supply infrastructure, including aqueducts and other transport systems, the filtration and cleaning systems, the pipelines, the cooling systems, and other delivery mechanisms. The downstream or downwind consequences of such acts of violence has much wider concern, including disruption of fire fighting and waste water treatment, floods and droughts, agricultural contamination, loss of fisheries, or environmental contamination of large regions. With proactive air and water monitoring and forecasting efforts, it may be possible to minimize the vulnerability of these vital resources and to prepare for the downstream consequences, lessening disruptions to the area's population.

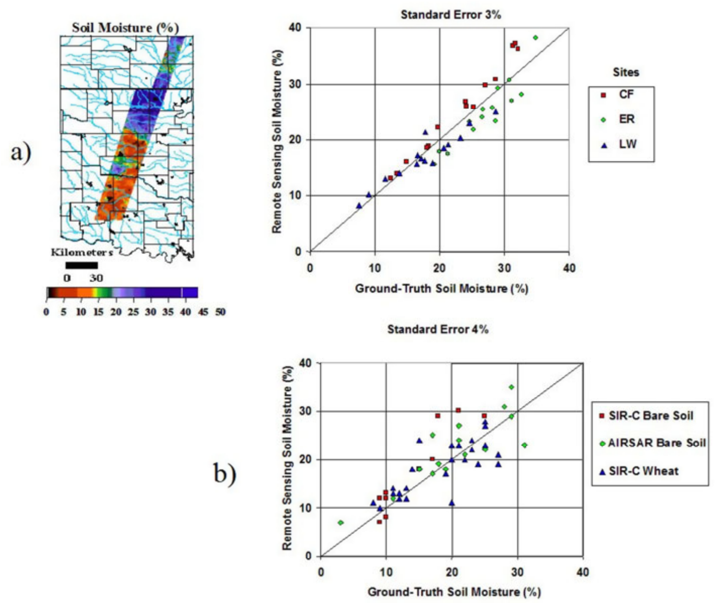
Air and Water Observations, Science, and Application

Breakthrough advances in spaceborne techniques to observe global and regional precipitation, surface soil-moisture, snow, surface soil freezing and thawing, surface inundation, river flow, and total terrestrial water-storage changes, combined with better estimates of evaporation, now provide the basis for a concerted air



The Global Precipitation Measurement mission is developing a constellation of satellites to improve ongoing efforts to predict climate, to improve the accuracy of weather and precipitation forecasts, and to provide more frequent and complete sampling of the Earth's precipitation.

and water monitoring effort in support of homeland security. The Global Precipitation Measurement mission is at the heart of this effort. A system that combines observations from a constellation of 6 to 8 passive microwave imaging radiometer-spacecraft is being developed to provide frequent sampling of instantaneous precipitation rates. As the primary input of water to the land surface, precipitation defines the terrestrial water cycle.



Estimation of soil moisture using the Electronically Steered Thin Array Radiometer (ESTAR) during the 1997 Southern Great Plains experiment (Jackson et al., 1999). Soil moisture remote sensing is based on a heritage of experiments using ground-based, airborne, and Space Shuttle instruments. (a) Soil moisture map and retrieval performance using airborne ESTAR measurements. (b) Soil moisture retrieval performance using Airborne Synthetic Aperture Radar (AIRSAR) and Spaceborne Imaging Radar-C (SIR-C) radar measurements acquired from the Shuttle.

After sea surface temperature, soil moisture is the most important surface boundary condition for weather and climate prediction. Knowledge of soil moisture is also vital to understanding the Earth system cycling of water, energy, and carbon through its control of transport of these quantities over land. The 1997 Southern Great Plains experiment (Jackson et al., 1999) demonstrated our ability to estimate soil moisture using an airborne radiometer (ESTAR). Satellite sensors such as the Advanced Microwave Scanning Radiometer aboard NASA's Aqua satellite, NASA's Gravity Recovery and Climate Experiment satellites, and the proposed Hydrospheric State Mission will provide much-needed data to understand and predict soil moisture conditions better, especially when integrated by assimilating land surface modeling systems such as NASA GSFC's Global Land Data Assimilation System (GLDAS). The combination of adequate soil moisture and precipitation observations, coupled with improved understanding of climatic phenomena such as ocean circulation anomalies, will greatly enhance weather and climate forecast skill, thus enabling us to better cope with future homeland security issues.

Most air toxics originate from anthropogenic sources, such as fossil fuel burning or chemical manufacture, but some air toxics originate from natural sources, such as volcanic eruptions, forest fires, and plant bioaerosols. Society is exposed to the pollutants by breathing contaminated air, by eating contaminated food, by drinking water contaminated by air toxins, or by making skin contact with contaminates. Air monitoring efforts that have long focused on in-situ sampling and analysis of industrial pollutants have recently been upgraded in some pilot projects to include monitoring of airborne bioaerosols, such as Anthrax. Finally, the use of advanced, state-of-the-art hyperspectral and ultraspectral sensors and Light Detection and Ranging (LIDAR) systems have been demonstrated and are promising for operationally monitoring chemical and biological airborne hazards on a global basis.

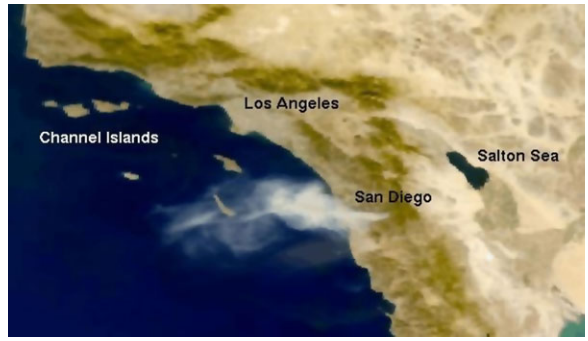


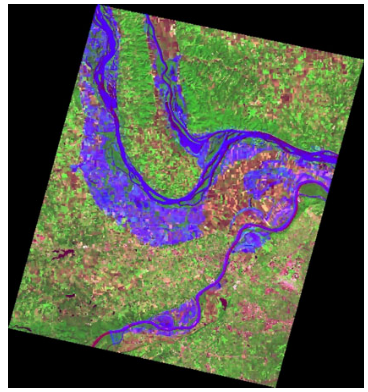
Image of fires near San Diego, California, acquired 3 January 2001 by ORBIMAGE's Sea-viewing Wide Field-of-view Sensor (SeaWiFS).

The increasing availability of air and water observations enables us to refine and constrain environmental prediction models that forecast weather and climate and their associated water availability and atmospheric transport. Weather prediction centers are continuously improving hurricane and tornado forecasts; emerging Web-based resources include short- and long-term forecast information, graphical watches, location-specific warnings, and various types of observations, such as radar, satellite, and lightning data. These observation and prediction resources are vital for homeland security interests; for example, they can predict the pathway of airborne contaminants, such as biological agents or radioactive dust from a "dirty" nuclear explosion. This prediction would allow the downstream communities to prepare for exposure or to move out of the way. Forecasts of precipitation and runoff can help us understand how, when, and where a contaminant might be transported. Hydrological predictions will facilitate intelligent decision-making to protect and aid the populace in the event of water supply contamination. Monitoring and predicting air and water quality on a global basis is useful to the armed forces during times of foreign engagement and allows us to foresee international civil unrest, which is exacerbated by droughts and other climatic phenomena. Our increasing capability to demonstrate effective, real-time predictions of weather and hydrologic phenomena provides tools for evaluating the impact of competing homeland security response options, gives emergency workers time to plan for future environmental conditions, and gives the public enough warning to allow preparation and evacuation options.

Planning, Communication, and Implementation

A traditional disconnect between the environmental management and the scientific research communities has prevented the definition of a mutually beneficial research agenda and the free flow of information to address new threats. As a result, a significant time lag occurs before scientific advancements are implemented to the benefit of society. Environmental management policy is often based on outdated knowledge and technology. Further, scientific research is often performed without understanding stakeholder needs. This paradigm lock has come about because the two main groups have become isolated: scientists by the lack of proven utility of their findings and stakeholders by legal and professional precedence and by disaggregated institutions. For example, global change research is largely focused on mean climate impacts (such as global temperature) of century-scale greenhouse gas changes, while environmental managers need a reliable prediction of extreme event variations (such as floods and droughts) in the seasonal to decadal timeframe.

We must take decisive action to eliminate this paradigm lock. It is essential that we continuously modernize and integrate our air and water observation, assessment, and prediction tools to provide reliable and timely information for homeland security. But this information is meaningless unless accompanied by timely and adequate mitigation action. Communication must be established to transmit information to users quickly, to evaluate various response options in a prediction system, to enable planning, and to take decisive mitigation action. The NOAA weather radio and the network of media resources can deliver hazard emergency messages to the public effectively. We must encourage and demonstrate similar bridge-building dialogue between scientists and policy makers to establish real pathways to define a society-relevant research agenda and to transfer state-of-the-art data and tools to the users who need them.



Flood images in the area around St. Louis, Missouri, in July and August 1993 produced by the Institute for Technology Development/Space Remote Sensing Center (ITD/SRSC). The broad blue areas, derived from ERS-1 radar data, show the extent of the flooding and are overlaid on an older SPOT image to delineate the rivers under normal circumstances.

We will likely be surprised by future attacks and by environmental variability, but we do not have to be unprepared. One way to reduce the adverse impact of surprise is to maintain an acceptable level of preparedness at all times. We must improve terrorism and hazard response plans so that when improved warnings become available, decision makers will know how to take action. Improving both air and water monitoring, prediction, and preparation will allow warning and response to work synergistically, providing enhanced homeland security.

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