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Introduction to Remote Sensing: Science for Society

Ronald J. Birk

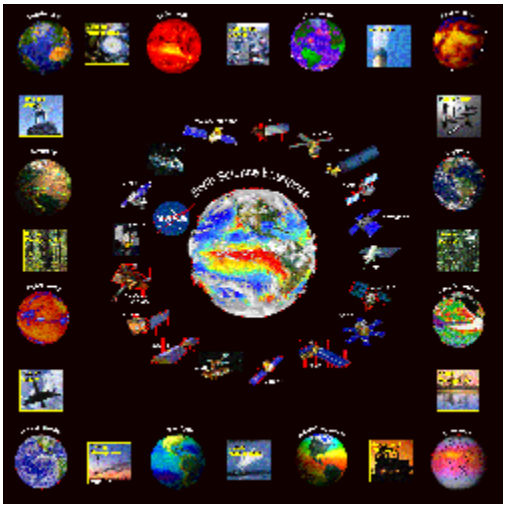
Tsengdar Lee

Science for Society: Extending Earth Science Research Results into Decision Support Tools

Ronald J. Birk, Director of the Applications Division and Tsengdar Lee,
Information Systems Specialist
Scientific Data Office of Earth Science, NASA Headquarters
Washington, DC

NASA's mission is driven by the pursuit of science, exploration and discovery:

To understand and protect our home planet;
To explore the Universe and search for life;
To inspire the next generation of explorers ...as only NASA can.



In the NASA Strategic Plan, the Earth Science Enterprise (ESE) plays a leading role in the goal to "understand Earth's system and apply Earth System Science to improve the prediction of climate, weather, and natural hazards.' An objective of conducting research in Earth system science is to ensure that the resulting knowledge is used to enhance decision support for society. Federal agencies and international organizations use decision support systems to deliver Earth science knowledge and information that result in economic and environmental security for applications of national priority.

For example, NASA Earth system science research results can benefit the Federal Aviation Administration (FAA) as it contributes to aviation management through the National Airspace System (NAS); the Federal Emergency Management Agency (FEMA) as it contributes to disaster risk management through the Hazards US (HAZUS) system; and the Environmental Protection Agency as it

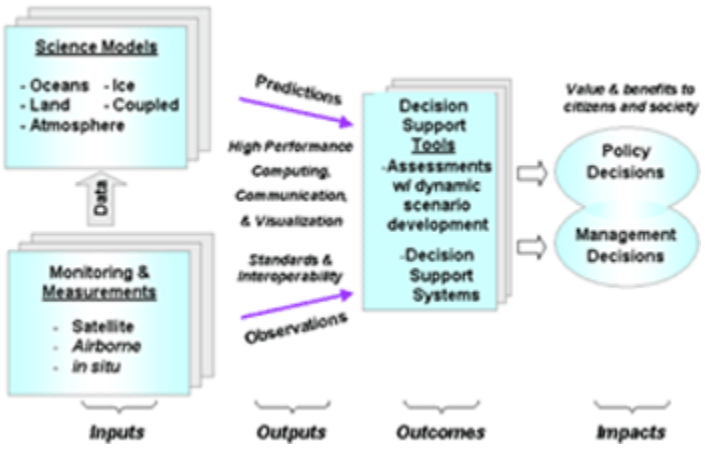
contributes to air quality management through the Community Multi-scale Air Quality (CMAQ) system.

Earth Science Applications Program Overview

The Earth Science Applications program of the NASA Earth Science Enterprise (ESE) benchmarks practical uses of NASA-sponsored observations from remote sensing systems and predictions from Earth system science research and modeling. NASA implements projects through partnerships with public, private, and academic organizations. These partnerships focus on innovative approaches for using Earth science information to provide decision support that can be adapted in applications worldwide.

The program focuses on applications of national priority to expand and accelerate the use of knowledge, science, and technologies resulting from the ESE mission of improving predictions in weather, climate, and natural hazards. The approach is to enable the assimilation of Earth Science model and remote sensing mission outputs to serve as inputs to decision support systems (see Figure 1). The outcomes are manifest in enhanced decision support and the impacts are projected to result in significant socio-economic benefits for each of the national applications.

Figure 1: Systems Architecture



NASA ESE has identified twelve (12) national applications (with partner federal agencies) that can be served by NASA aerospace research and development of science and technologies:

1. Enhanced weather predication for Energy Forecasting (DOE, EPA)
2. Weather/climate prediction for Agriculture Efficiency (USDA, DOE)
3. Carbon sequestration assessment for Carbon Management (USDA, DOE, EPA)
4. Digital atmosphere and terrain for Aviation Safety for transportation (DOT/FAA)
5. Early warning systems for air and water quality for Homeland Security (DHS, NIMA, USGS)

6. Environmental indicators for Community Growth Management (EPA, USGS, NSGIC)
7. Integrated hurricane and flooding prediction for Disaster Management (FEMA, NOAA)
8. Early warning systems for vector-borne infectious diseases for Public Health (NIH, CDC)
9. Environmental indicators for Coastal Management (NOAA)
10. Environmental models for Invasive Species (USGS, USDA)
11. Water cycle science for Water Management and Conservation (EPA, USDA)
12. Regional to national to international atmospheric measurements and predictions for Air Quality Management (EPA, NOAA)

NASA's Vision

NASA's vision starts with "to improve life here'. The Earth Science Applications program contributes to the NASA mission through the ESE mission to improve predictions in weather, climate and natural hazards by enabling and facilitating the assimilation of Earth observations and predictions outputs into decision support tools. The purpose is to enhance the performance of the decision support resources to serve citizens.

The initiative directly addresses NASA's mission statements.

1. To understand and protect our home planet: Space-based measurements acquired by NASA Earth observing systems contribute greatly to our understanding and ability to forecast weather, climate patterns and natural hazards. The NASA research results are applicable to improving aviation safety, homeland security, natural resource management, community management, and energy efficiency. NASA research is to used improve economic security, homeland security and national security. Through focused collaborations with other federal agencies, the Earth Science Applications program works with partners to benchmark the use of Earth science research results in decision support systems. These partnerships enable NASA results to provide essential contributions to increase the quality of life in our world.

2. To explore the Universe and search for life: Techniques used to harness Earth system science data and information for decision support systems can potentially demonstrate applications of observations and information technologies for the study of other planets in our solar system. Comparative studies between our planet and others in our solar system are useful for developing new ways of understanding the evolution of our planet's systems as well as assisting in the development of the next generation of observational systems for deriving new and useful information for exploration.

3. To inspire the next generation of explorers: Understanding how the Earth works and environmental awareness are topics that challenge and excite the youth of today. NASA's ability to bring real scientific breakthroughs to youth through a

variety of different venues opens doors for future scientists and engineers by creating excitement about studying the earth. People are inspired by innovative means of solving important issues that affect our world and the realization that research and development of aerospace science and technologies can provide meaningful solutions to critical needs on Earth has proven to be very inspirational to people of all ages. The Earth Science Applications program works closely with the Earth Science Education program to see that the results and successes of these various projects are communicated to the public.

Science and Technology Returns

In the process of benchmarking beneficial uses and applications for Earth science measurements and technology, the Earth Science Applications program is producing significant scientific and technological returns on the federal investment. Activities are underway in each of the twelve applications of national priority. For instance, in the area of community preparedness for disaster management, NASA is integrating science and technology to produce improved warnings and predictions of hurricanes, tornadoes, and other severe weather events, thus enabling more cost effective damage mitigation, emergency preparation, and subsequent emergency management with the Federal Emergency Management Agency (FEMA). With regard to agricultural competitiveness, applications activities is working with the US Department of Agriculture to benchmark predictions of El Nino and La Nina events on our Nation's farmlands. Technologies are being improved to monitor and assess the health and condition of crops and forests around the globe. In aviation safety, measurements and predictions from our weather and environmental satellites are being integrated with other traditional aviation weather information. These are just a few examples of how the NASA works through partnerships to utilize science and technology to serve society.

Benefits to society

The 12 applications of national priority were identified using a specific set of criteria including the consideration of potential socio-economic return, application feasibility, appropriateness for NASA, and partnership opportunities (The Earth Science Applications Plan) The benefits of the program to national needs and societal benefits are significant by design. Examples of NASA contributions include recovery support to events such as the World Trade Center, Hurricane Andrew, Montana wildfires, Hawaiian tsunamis, the Mount Etna volcano erupting, lost aircraft in Montana and California, floods on the Mississippi River. These capabilities have provided critical damage assessments and determination of secondary impacts.

NASA and NOAA researchers have shown that remotely sensed wind speed and direction from QuikSCAT can help detect tropical depressions and hurricanes up to 46 hours earlier than current methods. Hurricane cloud monitoring and wind

profile and prediction products from scatterometer (QuikSCAT), Special Sensor Microwave/Imager (SSM/I), Topex/Poseidon, Shuttle Radar Topography Mission (SRTM), Landsat, Atmospheric Laboratory for Applications and Science (ATLAS), and the Sea-viewing Wide Field-of-View Sensor (SeaWiFs) contribute to predicting candidate locations for hurricane landfall and surge, and provide assessments of damage and secondary impacts.

The potential socioeconomic benefits of many of these applications are significant. By minimizing unnecessary emergency evacuation measures, improved hurricane predictions provide as much as $40 million in cost savings for the Nation for each event. The value to our agriculture industry of a "perfect' El Nino forecast is said to be $320 million per year. Similarly, improved weather forecasting can save as much $8 million for individual energy companies by enabling utilities to better plan for anticipated energy requirements.

As only NASA can...

NASA, with its systems engineering experience, is uniquely positioned to benchmark practical uses of NASA observations from remote sensing systems and predictions from scientific research. NASA contributes the initial research and development of aerospace science and technology, and then supports the applications through partnerships with public, private, and academic organizations. These partnerships focus on innovative approaches for using Earth science information to provide decision support information that can be adapted in applications nationwide. NASA recognizes the organizations with the appropriate information infrastructure to apply NASA results from Earth science to meet observational needs to help manage forest fires, coastal environments, agriculture, impacts of infectious diseases, aviation safety, and hurricane forecasting.

Global Drivers

The Earth Science Applications program is recognized as being very timely given the explicit recognition in the Administration and Congress of the value of using Earth Science knowledge to enable and facilitate decision support systems in the public and private sector. On June 11, President Bush announced the establishment of the U.S. Climate Change Research Initiative (CCRI) to study areas of scientific uncertainty and to identify priority areas where investments can make a difference. The CCRI promotes a vision focused on the effective use of scientific knowledge in policy and management decisions, and continual evaluation of management strategies and choices. This strategy emerged from a common agreement on priority actions to be taken and is aligned with the National Academy of Sciences recommendations presented in the June 2001 Academy report, entitled "Climate Change Science: An Analysis of Some Key Questions.' Most relevant here, one of the aims of these proposed actions is to

develop research and data products that will facilitate the use of scientific knowledge to support policy and management decisions.

NASA conducts the research and development of the aerospace science and technologies that result in Earth observation systems and models of Earth system processes. A hallmark of NASA's Earth science modeling program is the integration of the measurements of key geophysical parameters of Earth processes in science models. An objective is to develop models of the best available understanding of the Earth system. The observations contribute understanding that is captured in algorithms and used to improve predictions of Earth process such as weather and climate. The observation and models that result from NASA research are connected to applications of national priority through assimilation into the policy and management decision-making processes of federal agencies and international organizations.

Benchmarking Earth Model Predictions

For 40 years, NASA has been developing the capability to use the perspective of space to provide global observations of the key parameters of our Earth system. NASA uses a systems approach to enable the measurements to be explored rigorously and scientifically. The NASA science community uses the measurements to advance global and regional models and improve predictive capability. Advanced computer technologies are used to visualize the resulting global observations and predictions to generate excitement about, and understanding of, our home planet.

NASA has successfully developed and deployed the flagship Earth Observation System (EOS). As of April 2003, the US space agency has 18 Earth observation satellites on orbit carrying 80 sensors. These remote sensing satellites are observing the Earth's atmosphere, land surfaces, ice covers, ecosystems, gravity fields, and surface deformations. About 3 terabytes of data are collected daily and transmitted to Earth receiving stations. These measurements are filtered, assimilated, and digested into the Earth Observations System Data Information System (EOSDIS) through intelligent data assimilation and modeling processes. The resulting calibrated and validated measurements of key parameters of Earth processes are assimilated into Earth science models that are responsible for producing predictions - and related knowledge useful in decision support systems. Since the Earth science research community cannot perform large-scale experiments on our environment, the Earth system model is the most optimal tool for Earth system scientists to use to perform simulations and produce "what if" scenarios of the evolution of our environment.

Earth science models represent a consolidation of scientific understanding of the range of physical processes associated with the Earth system. It is estimated that physical process field studies and routine observations must be conducted for at least 10 years before a given physical process can be represented in an integrated

Earth science model. In a special issue of the EOM journal (http://www.eomonline.com), NASA presents articles on eight of the Earth science models. These include a global and regional weather prediction model, a near-term coupled atmosphere-ocean model, a seasonal-to-interannual prediction model, a long-term climate change model, a coastal biological-physical oceanography model, a land surface hydrology model, and a bio-geochemistry model. These models represent years of Earth science modeling advancement and the consolidation of scientific findings from many of the Earth science disciplines. These state-of-the-science research and operational models are used in many decision support systems today.

NASA's High-End Atmospheric Model for Climate and Weather Predictions describes an advanced high-end atmospheric model designed to produce weather and climate predictions is introduced. Although it is still viewed as an experimental model, this has been the highest resolution global weather and climate model running routinely.

Seasonal Climate Prediction and Predicting Seasonal to Interannual Climate Variations describe a class of climate models designed to predict seasonal to interannual climate variations. Since the seasonal variation of the climate system depends heavily on the ocean - which carries the memory of the past and forces the future evolution of the climate system - coupled models are used for this type of prediction. These seasonal to interannual climate models have been used to guide water management, energy consumption prediction, and fishery production predictions.

Using Earth Science Tools to Improve Seasonal Climate Prediction for Agriculture addresses spatial resolution in global climate change research. The current climate change models do not have sufficient spatial resolution for regional assessments. Due to the lack of computational resources, techniques have been developed to downscale the global model outputs to a regional spatial scale. The downscaled information can then be used in agriculture decision-making.

In Using Regional Atmospheric Models for Commercial Applications, a regional weather forecast model is introduced. The model is used commercially and operationally at many installations, including the Kennedy Space Flight center.

Modeling the Coastal Ocean Processes Within the U.S. Continental Margins, Incorporating the Land Data Assimilation System into Water Resource Management and Decision Support Systems, and Biospheric Monitoring and Ecological Forecasting represent specific purpose models on coastal ocean modeling and regional water monitoring to agriculture production prediction. These NASA-supported models are producing predictions for specialized purposes.

It is easy to see from the broad range of applications that use Earth science model products that it will be helpful to have an integrated framework for Earth system modeling. The benefits of a common framework are the driver for the next phase of the consolidation of Earth system science research results. As stated in the ESE Research Strategy: "The ultimate challenge of Earth System Science is to consolidate the scientific findings in the different disciplines into an integrated representation of the coupled atmosphere, ocean, ice, land and biosphere system." The integrated Earth system model - currently consisting of coupled atmosphere, ocean, and land components - is used to contribute to science-based assessments of potential future changes. In the next 10 years, additional components will be added into the integrated Earth system model. These components will include ice, biosphere, solid earth, and chemistry transport models. NASA has already started projects to build a national Earth System Modeling Framework (ESMF). Through this modeling framework, various Earth science models will be able to communicate and exchange information inputs from Earth observation systems and outputs to decision support systems. The ESMF provides a unified external interface to serve a range of applications for Earth science model predictions. We are on a path towards creating a comprehensive description of the whole Earth model and an end-to-end system ranging from satellite data acquisition, data analysis, and modeling, all the way to the decision support systems.

Next Steps

As the Earth science community continues to increase our understanding of Earth system processes, there will be continued opportunities to assimilate observations and predictions into decision support tools and thereby increase the capacity to protect the home planet.

Your contributions in Earth science research and technology development are greatly valued and appreciated as the "stock-in-trade" to serve our society through applications of national priority. Our world needs the best available information and information infrastructure to enable decisions on policy and management of natural resources. To quote Dr. Jack Kaye, Director of our Earth Science Research Division,

"Science allows it,
Technology enables it,
Society requires it,
And the time is now!"