The mind may, as it appears to me, divide science into three parts. The first comprises the most theoretical principles, and those more abstract notions whose application is either unknown or very remote. The second is composed of those general truths which still belong to pure theory, but lead nevertheless by a straight and short road to practical results. Methods of application and means of execution make up the third.

Each of these different portions of science may be separately cultivated, although reason and experience show that none of them can prosper long, if it be absolutely cut off from the other two.

Alexis DeTocqueville
***Democracy in America*, 1835**

International CCMC-LWS Working Meeting:

Assessing Space Weather Understanding and Applications

April 3-7, 2017

Lawrence Friedl

NASA Earth Science
Applied Sciences Program

Making Space for Earth: Earth Science Applications

I. NASA Earth Science and Applications

II. Applied Sciences: Programmatic Methods

III. Metrics & Measures

IV. Final Four
- Earth Science Senior Review
- Missions: Early Adopters
- Socioeconomic Impacts
- Language

Summary Points

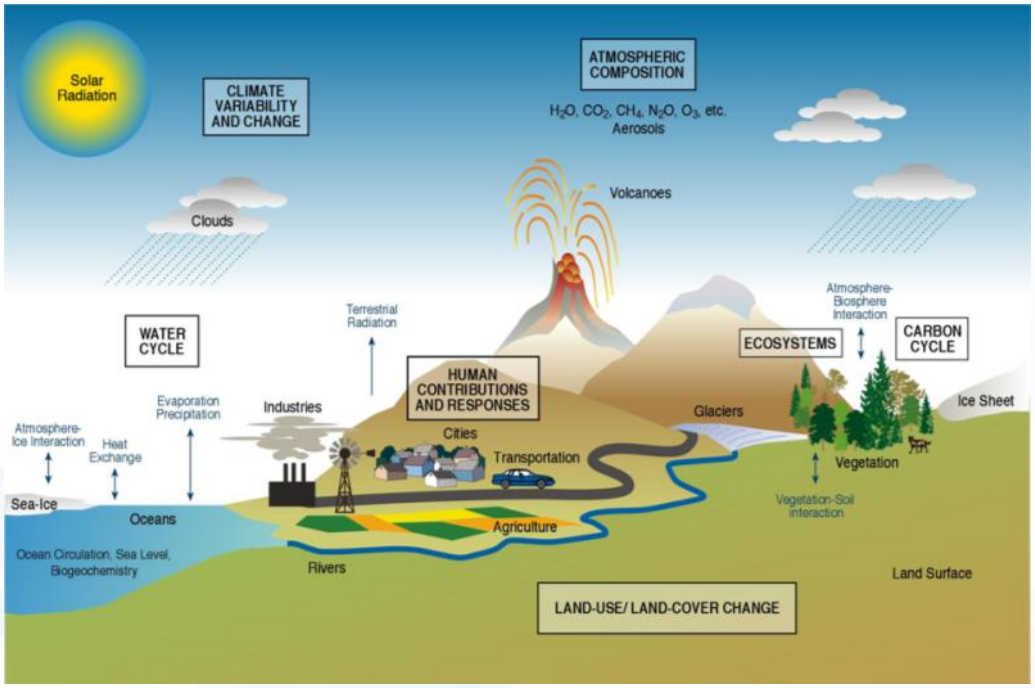
» Research, Applied Research, and Applications: *Emphasis depends on the activity*

» Clarifying success: *Demonstration of potential or Adoption & sustained use*

» Partner Outreach & Publications are not in conflict

» Role(s) for metrics: Reporting, Analysis, Motivation, Communication

NASA Earth Science



Supports basic and applied research on the Earth system and its processes to advance knowledge and benefit society.

In parallel with research, NASA pursues innovative and practical uses of Earth science data and results to inform decisions and actions.

Technology

Flight Missions

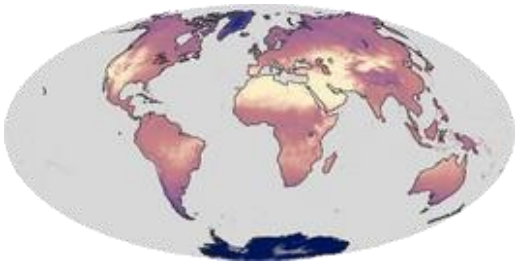
Research

Data Systems

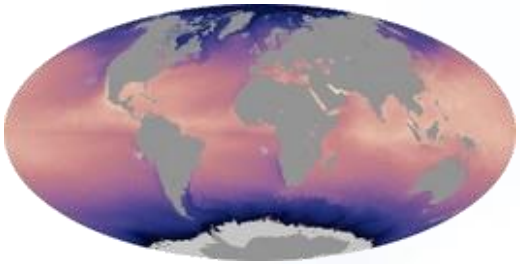
Education

Applications

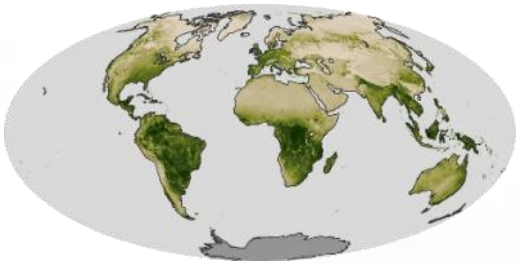
Some Types of Earth Observations . . .



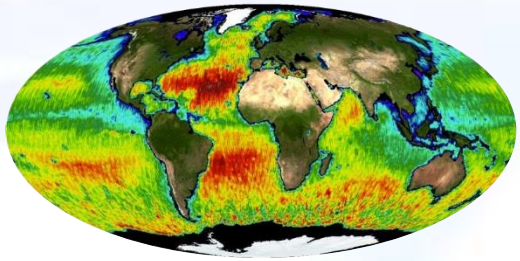
Land Temperature



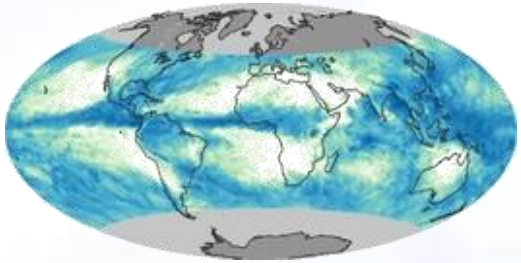
Sea Surface Temperature



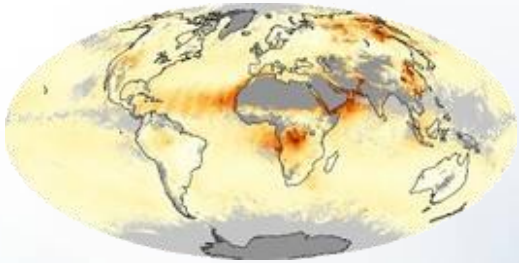
Vegetation



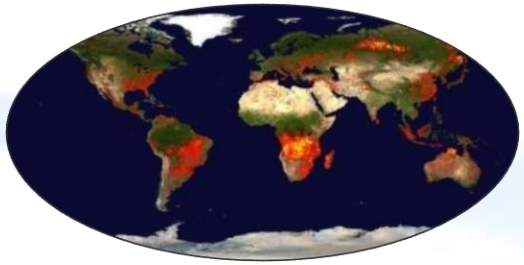
Sea Surface Salinity



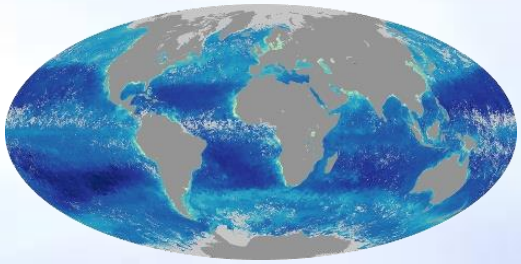
Total Rainfall



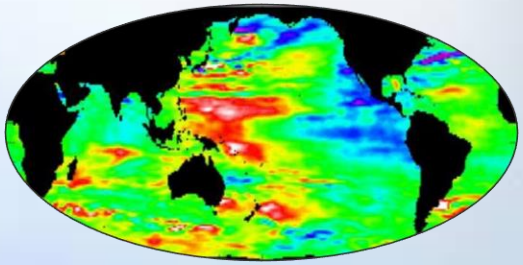
Aerosols



Fires & Thermal Anomalies



Chlorophyll



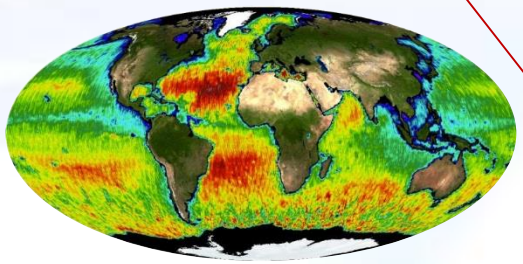
Sea Surface Height

Some Types of Earth Observations . . .

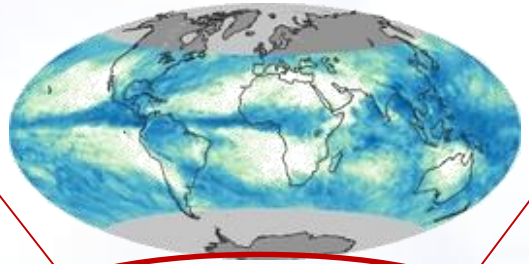
Land Temperature

Environmental factors for malaria transmission

Vegetation



Sea Surface Salinity



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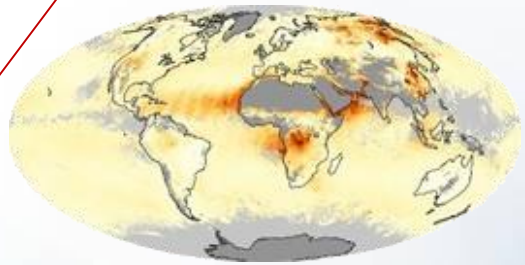
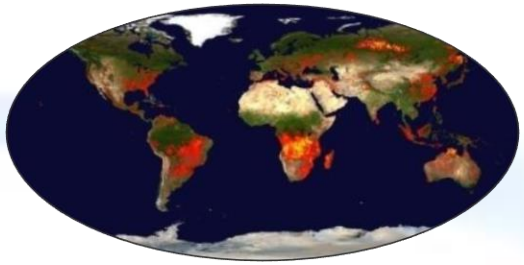


Aerosols



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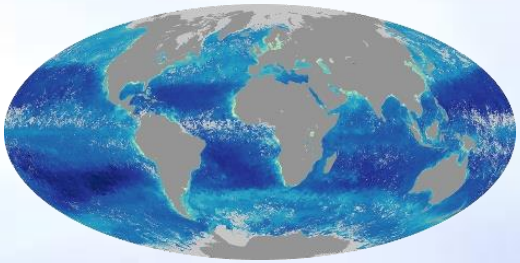
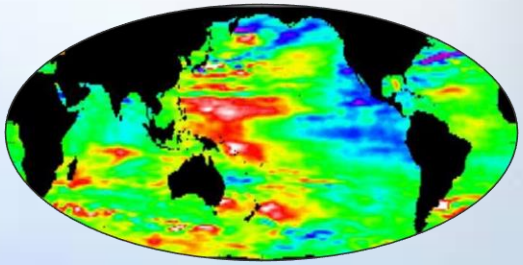


Chlorophyll

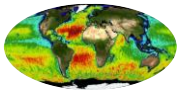


Sea Surface Height

NASA Earth Science Division

Flight (incl. Data Systems)

Develops, launches, and operates NASA's fleet of Earth-observing satellites, instruments, and aircraft. Manages data systems to make the data freely and openly available.

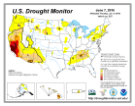


Research & Analysis

Supports research that advances knowledge of the Earth as a system and capabilities to conduct research. Six focus areas plus field campaigns, modeling, and scientific computing.

Technology

Tests and demonstrates scientific technologies for future satellite and airborne missions:
Instruments, Information Systems, Components, InSpace Validation.



Applied Sciences

Supports innovative and practical uses of Earth observations and scientific knowledge by private and public sectors to inform their decisions and actions.

Applied Sciences Program

NASA
Earth Science

Applied Sciences serves a fundamental role to advance global knowledge about effective ways to extend and apply Earth science and inform decisions and actions

Applied Sciences Program: Lines of Business

NASA
Earth Science

Societal & Economic Applications

Generate, test, develop, enable adoption, and extol applications ideas for sustained uses of Earth observations in decisions and actions.

Capacity Building

Build skills, workforce, and capabilities in US and developing countries to apply Earth obs. to benefit society and build economies.

Applications in Mission Planning

Identify applications early and throughout mission lifecycle, integrate end-user needs in design and development, enable user feedback, and broaden advocacy.

Innovative and practical uses of Earth observations

Applications Areas

NASA
Earth Science

Emphasis in 5 Applications Areas

Health &
Air Quality

Water
Resources

Ecological
Forecasting

Disasters

Wildland Fires
(through 2017)

Support opportunities in additional areas

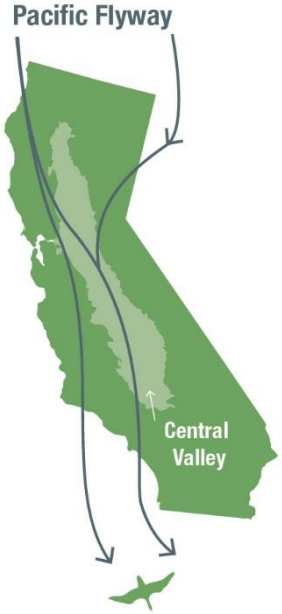
Agriculture / Food Security

Energy

Transportation

Climate & weather play into all areas

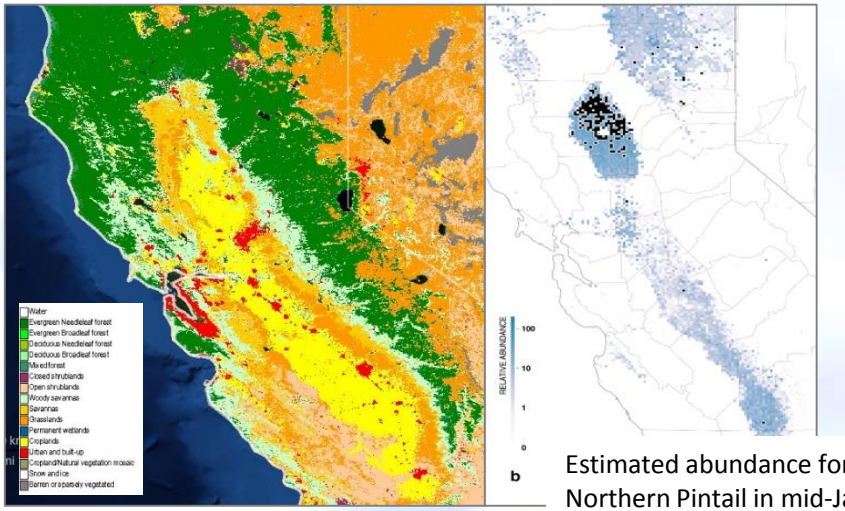
BirdReturns: Earth Obs Informs Reverse Auction to Increase Habitat for Migrating Waterbirds



300+

bird species use the Pacific Flyway

BIRD OBSERVATIONS LOGGED WITH eBird



Estimated abundance for Northern Pintail in mid-Jan.

MODIS and ASTER data combined with citizen science reports from eBird drive bird habitat models and help TNC identify the best bird habitats

TNC uses a Reverse Auction:

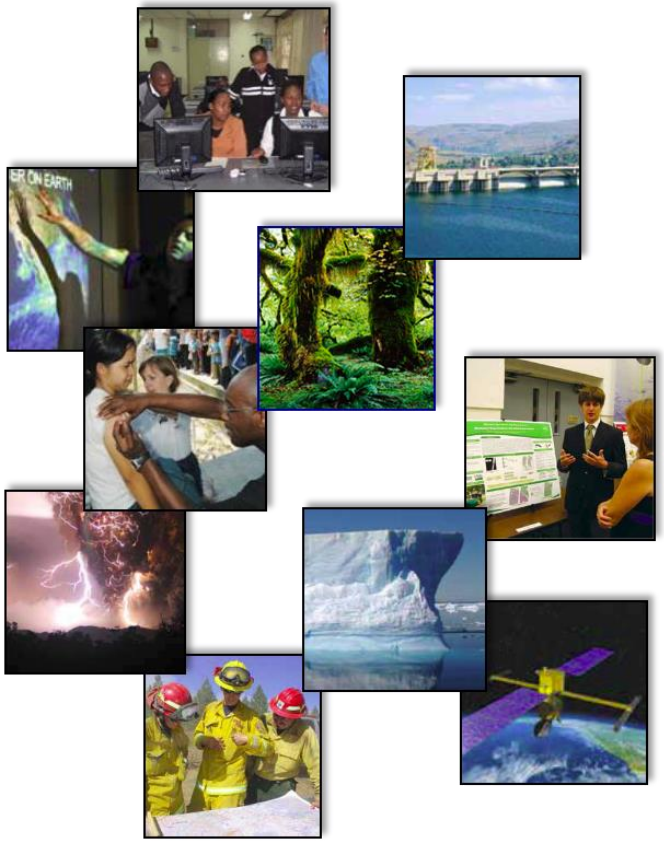
» Farmers submit bids to flood their fields during spring and fall migration

» TNC reviews bids on price, migration projections, and other factors

» TNC selects the best fields to flood for habitat at the best price; pays farmers.

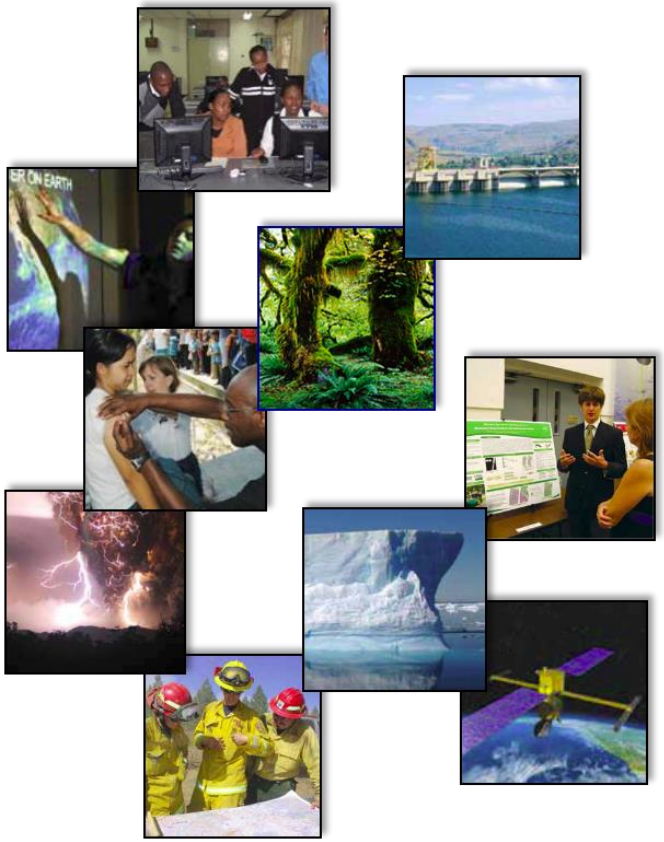
» And, farmland is only idle during migration

30,000 acres — *Cumulative total of temporary wetlands gained by end of 2015*



Programmatic Methods

- Applications Projects
- Feasibility Studies
- Feasibility-to-Applications Projects
- Applied Sciences Teams
  (with Tiger Team projects)
- Sponsor people on ESD Science Teams
- Workforce Development
  (via 10-week applications projects)
- Professional-level Trainings
- Early Adopters on Satellite Missions



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Feasibility-to-Applications

NASA
Earth Science

Purpose: Generate numerous applications ideas and focus investments on those with high-reward potential. Prioritize partners' "skin-in-the-game" to increase their involvement in project and support adoption.

Two-stage Approach:
Start with studies of possible ideas – 12-15months to work applications concept with partner. Then, select a subset to pursue as in-depth applications projects.

Year	Stage	Activity	NASA Share	Partner Share
Year 1	Feasibility	Prove out application potential	100%	Optional
Year 2	Decision Support	Develop application	~80%	~20%
Year 3	Decision Support	Continue development	~60-70%	~30-40%
Year 4	Decision Support	Complete application and transition	~30-40%	~60-70%

Have these active in: Water Resources, Disasters, Wildfires, Ecological Forec.

Performance Metric

ARL: Applications Readiness Level

Nine-stage metric to track the maturity of applications projects – from initial idea, through development, to the transition to sustained use.

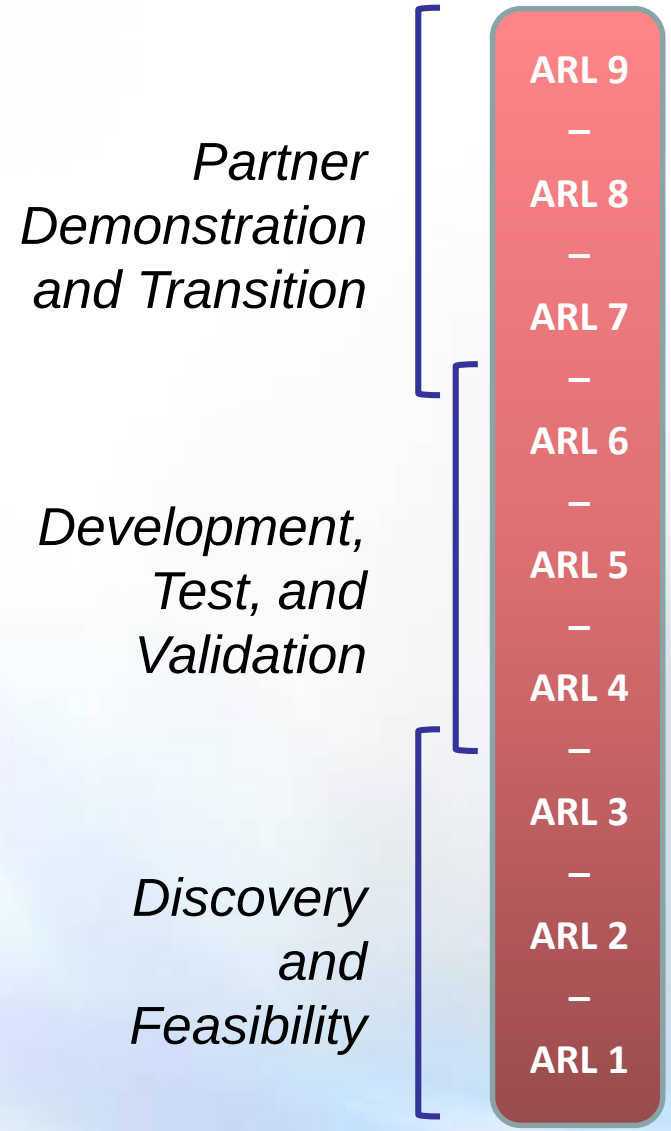
ARL as a tool:

» Communication Tool to convey expected advancement to PIs & project teams.

» Analysis Tool to assess progress of a project or state of entire project portfolio.

» Reporting Tool for performance goals.

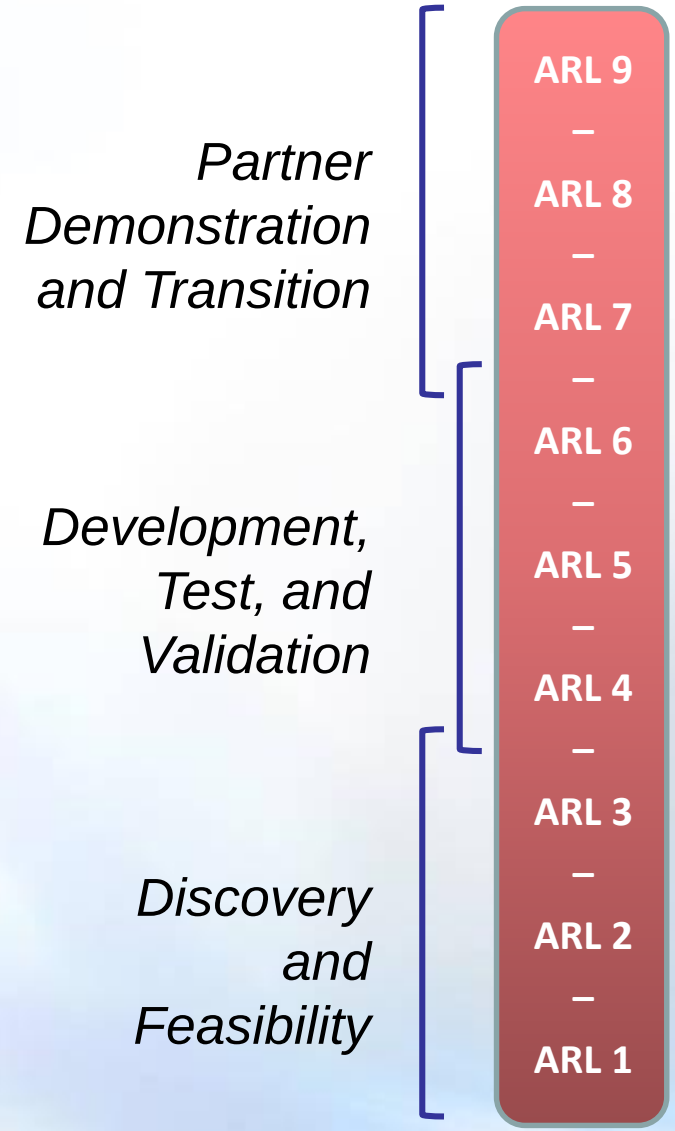
» Diagnostic Tool to identify where projects tend to break down in development.



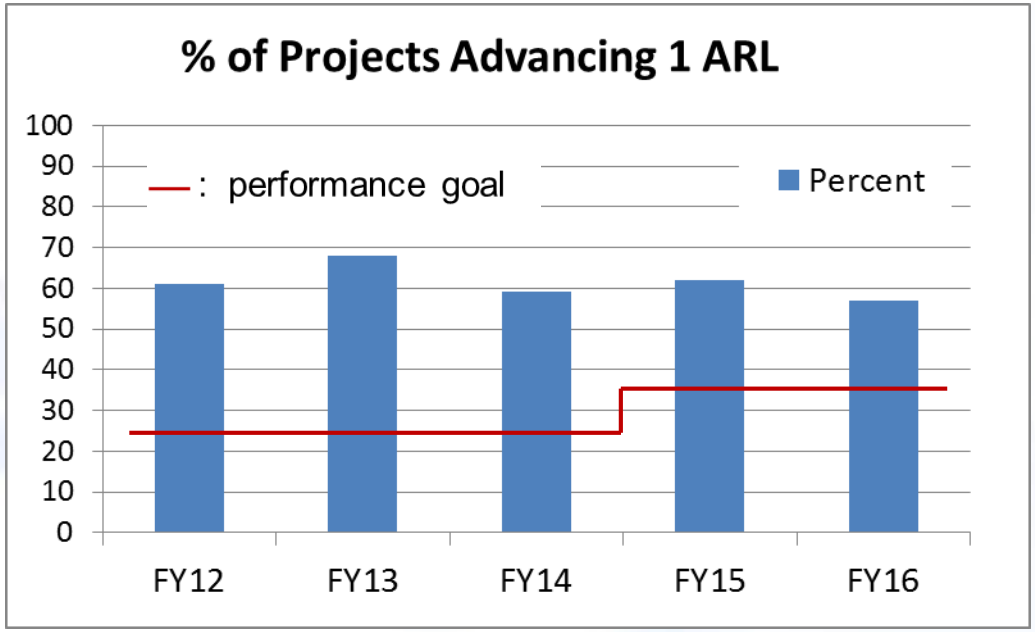
Performance Metric

ARL: Applications Readiness Level

9. **Approved, Operational Deployment and Use in Decision Making**
8. **Application Completed and Qualified**
7. **Application Prototype in Partners' Decision Making**
6. **Demonstrate in Relevant Environment**
5. **Validation in Relevant Environment**
4. **Initial Integration and Verification**
3. **Proof of Application Concept**
2. **Application Concept**
1. **Basic Research**



Performance



FY17 Goal: Advance 35% of Earth science applications projects one ARL level

FY16: 57% ≥ 1⁺ ARL (44 of 77 projects)

Partner Demonstration and Transition

Development, Test, and Validation

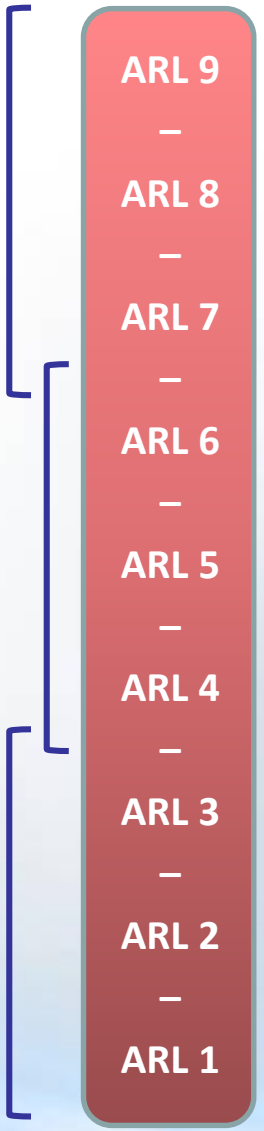
Discovery and Feasibility

ARL 9
–
ARL 8
–
ARL 7
–
ARL 6
–
ARL 5
–
ARL 4
–
ARL 3
–
ARL 2
–
ARL 1

ARL: Reflections

ARL as a tool:

- Applications projects often contain multiple elements or data sets
- At times, an undue focus on racing up the metric
- Rationales are as important as the level
- Articulate ARL expectations in projects solicitations
- Usability rather than Readiness



Applied Sciences Teams

NASA
Earth Science

An approach to extend research findings, new knowledge, data products, and techniques to managers and decision makers.

Key aspects:
- » Flexibility and agility
- » Increase throughput
- » Engage managers on timely topics
- » Identify new research questions

Capacity Building:
Increase skill in the research community on how to have positive interactions among researchers and managers/users.

Explicitly charged with interacting routinely with managers in the field to listen, collaborate, and address key topics of emerging and urgent need.

Researchers & applied scientists.
Team Members have two roles:
- » Core: Applications and/or applied research
- » Tiger Teams: Short-term, quick-response efforts in ad hoc sub-groups

Teams can also identify data products and provide feedback to ESD research & missions.

Air Quality Applied Sciences Team

NASA Earth Science

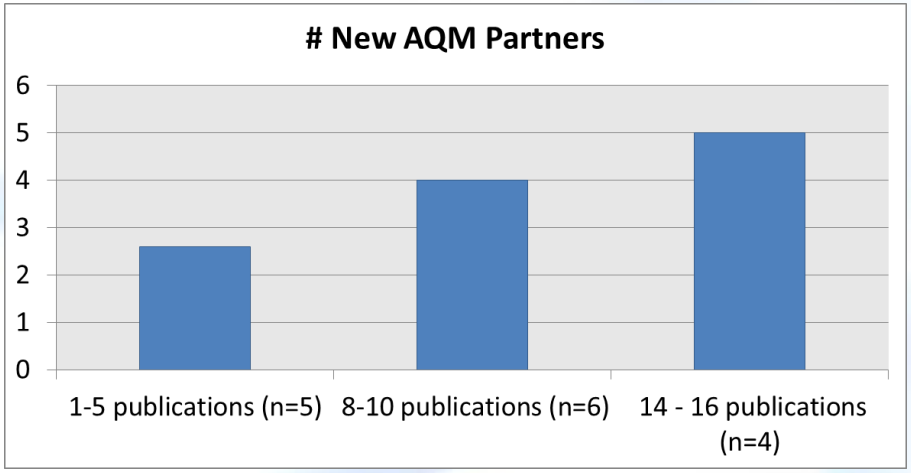
19 Members:
15 from universities and research institutes;
4 from NASA, NOAA, EPA

Produced ~90 applications through 2016:
4-5x the amount from a 19-project portfolio through traditional means.

…feedback from AQAST members and AQ managers allowed my research objectives to focus better and evolve over the last five years.
- NASA Researcher

@NASA_AQAST has 2500+ followers

Trade-off Between Partner Outreach and Publications? No.



AQAST primer on use of satellite data for AQ applications

Single-most downloaded Energy & Earth Science article since Jan. 2014

Atmospheric Environment 94 (2014) 647–662
Contents lists a http://dx.doi.org/10.1016/j.atmosenv.2014.05.061
Atmospheric Environment
journal homepage: www.elsevier.com/locate/atmosenv

Review

Satellite data of atmospheric pollution for U.S. air quality applications: Examples of applications, summary of data end-user resources, answers to FAQs, and common mistakes to avoid

Bryan N. Duncan [a, *], Ana I. Prados [a, b], Lok N. Lamsal [a, c], Yang Liu [d], David G. Streets [e], Pawan Gupta [a, c], Ernest Hilsenrath [b, f], Ralph A. Kahn [a], J. Eric Nielsen [g], Andreas J. Beyersdorf [h], Sharon P. Burton [h], Arlene M. Fiore [i], Jack Fishman [j], Daven K. Henze [k], Chris A. Hostetler [h], Nickolay A. Krotkov [a], Pius Lee [l], Meiyun Lin [m], Steven Pawson [a], Gabriele Pfister [n], Kenneth E. Pickering [a], R. Bradley Pierce [o], Yasuko Yoshida [a, g], Luke D. Ziemba [h]

Applied Sciences Teams

NASA
Earth Science

Notional Measures of Success (& Failure)

Capacity and Capabilities

- » Co-design projects with managers for applications development and deployment
- » Abilities to identify a failure or under-performing one

Results/Throughput

- » Collective output compared to that of a traditional solicitation

Diversification

- » Broaden range and type of orgs. exposed to uses of Earth obs
- » Broaden feedback on data products from non-research communities

Follow-on & Sustainability

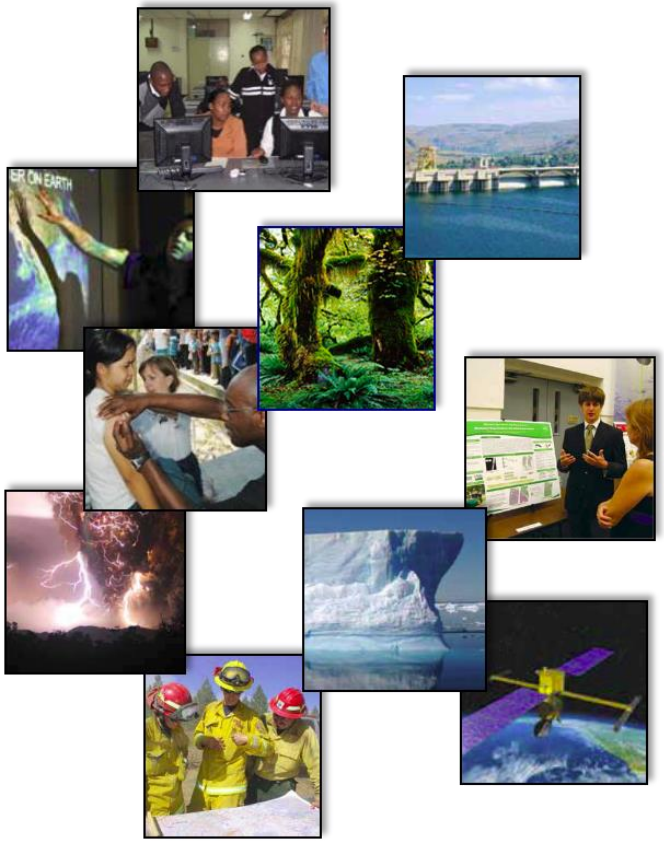
- » Uses of the Earth observations by the managers and organizations continues on after the Tiger Team projects
- » After projects end, managers and users still contact (and ideally fund) the members of teams to pursue work

Satisfaction and Reputation

- » View of research team as valuable, quality resource of information and help
- » Managers/users impressed of skillful pursuit by researchers to engage

Taking to Scale

- » Scale successful applications with one organization/state to multiple



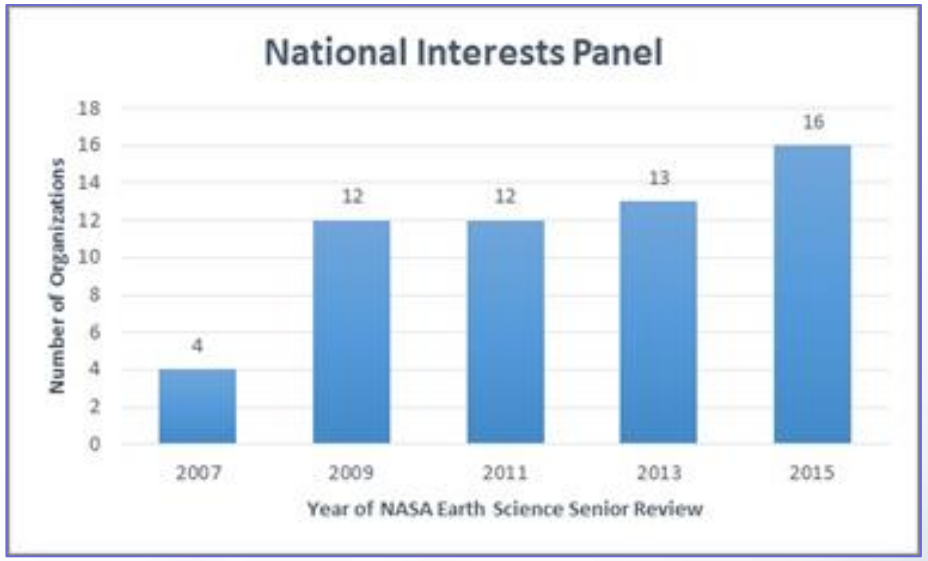
Final Four

- Earth Science Senior Review
- Missions: Early Adopters
- Socioeconomic Benefits
- Language

Earth Science Senior Review: National Interests Panel

NASA Earth Science

As input to the overall Senior Review panel, the National Interests Panel assesses the utility of data products from each mission for “applied and operational uses” that serve national interests, including: operational uses, public services, business and economic uses, military operations, government management, policy making uses, etc.



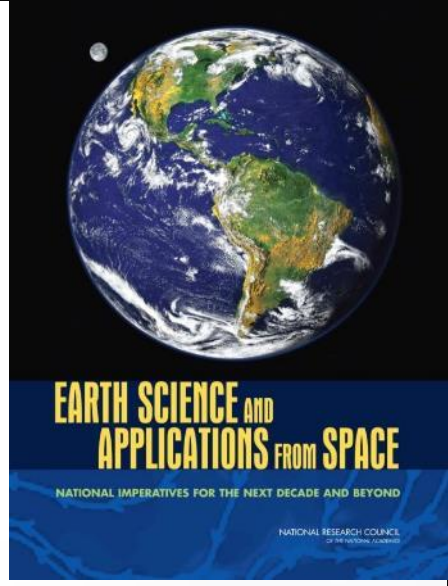
Evaluation factors:
Intrinsic value, Frequency of use, and Latency.

Overall rating: Utility
Very High, High, Some, Minor/NA

Panelists also rank order the satellites.

The 2015 NIP involved 16 organizations:
CDC, EPA, USGS, USDA, FAA, NOAA/NWS, NOAA/NOS, DHS/FEMA, US Army Corps of Engineers, Naval Research Lab, Conservation International, International Association of Wildland Fire, National States Geographic Information Council, Urban Regional Information Systems Association, Alliance for Earth Observations, US Geospatial Intelligence Foundation

Earth Science & Applications from Space



The national strategy outlined here has as its overarching objective a program of scientific discovery and development of applications that will enhance economic competitiveness, protect life and property, and assist in the stewardship of the planet for this and future generations.

2007 Earth Science Decadal Survey

Missions and Applications

Significant efforts for applications-oriented users to engage throughout the satellite mission lifecycle, especially planning, formulation, and development phases. Examples include:

- Community Workshops
- Early Adopters Programs
- Mission Applications Plans
- Applications Traceability Matrices
- Webinars and Tutorials
- Program Applications leads (akin to PE & PS)

NASA defines science to include research, applied research, and applications.

The relative emphasis on each is unique to an individual investigation.

Missions & Applications

NASA
Earth Science

Early Adopters

Purpose is to conduct pre-launch applications research to accelerate use of data after launch.

Organizations with clearly-defined needs for mission data products evaluate and demonstrate the utility of the data for their application and decision making.

Early Adopters:

- » Use data products prior to launch (simulated data and cal/val data from field campaigns)
- » Provide feedback on products and formats to increase applications value of mission
- » Streamline and accelerate use of data soon after launch and check-out
- » Supply own resources to do these activities

EA Video: https://youtu.be/e6WGTRmsPVg

SMAP: 50+ orgs are EAs from public and private-sectors, domestic & foreign

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EA Video: https://youtu.be/e6WGTRmsPVg

SMAP: 50+ orgs are EAs from public and private-sectors, domestic & foreign

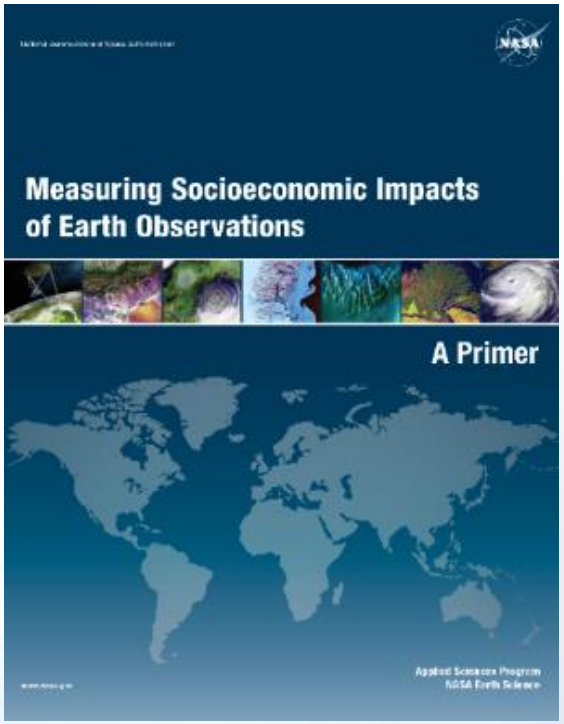
"The Early Adopters program has gotten whole other organizations and industries enthusiastic about the mission. Their early engagement with the mission insures their benefits will be available much sooner than would otherwise be the case."

– Kent Kellogg,
SMAP Project Manager

Socioeconomic Impacts

The Program conducts impact analyses of selected projects to assess the value and benefits (in social and economic terms) from uses of Earth obs. to inform decisions and associated actions.

- Strategically important for scientific community to have skills & abilities (or know how to access them) to document and communicate impacts
- Part of effort is bridging the social sciences and economic fields with the Earth science and physical science fields.



Primer: Inform the Earth science community and project teams about the language, key principles, techniques, and applications of socioeconomic impact analyses.

Socioeconomic Impacts

Impact Assessments on Applications Projects

Conducted ~10 impact assessments

Currently:
Support a collaboration between Economist & Earth Scientists on the societal value of a climate observing system

Nine impact assessments are in work for existing projects:

» 3 Water Resources Projects
» 2 Health & Air Quality Projects
» 4 Wildfires Projects

ROSES-15 A.45: Socioeconomic Benefits

Proposals to develop, implement, and manage a program of activities for the articulation of socioeconomic benefits of Earth science applications. Award is for a consortium of organizations. Two parts:

» Impact Assessments: Methods & Examples

» Capacity Building: Familiarity in Earth Science community on terms & concepts

Selection:
Valuation of Applications Benefits Linked with Earth Science Consortium (VALUABLES)

PI Organization: Resources for the Future

PI: Yusuke Kuwayama
(Replacement for Molly Macauley)

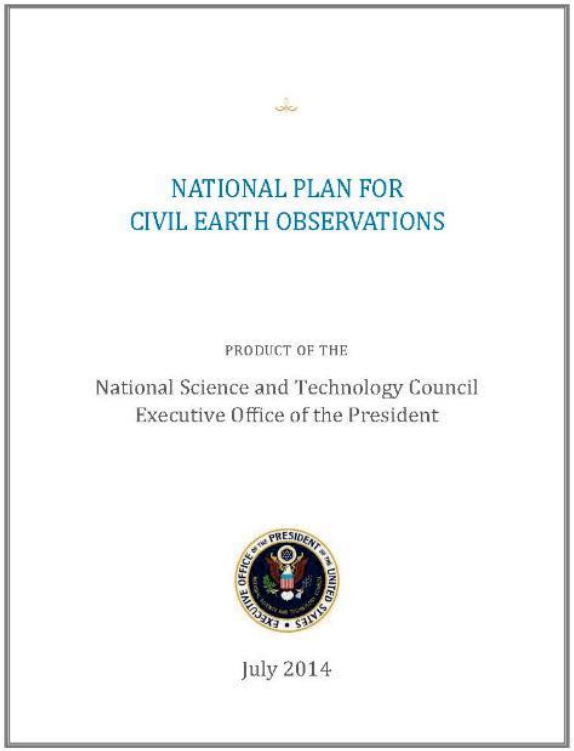
National Civil Earth Observations Plan

Defines a framework for constructing a balanced portfolio of Earth observations and observing systems

Classifies Earth-observation activities according to two broad categories:

- **Sustained Observations**: Measurements generally taken for seven years or more
- **Experimental Observations**: Measurements taken for a limited observing period generally for research or development purposes

Employs a measurement-driven approach by setting aside the immediate questions of hardware, sensors, and systems in order to prioritize measurement needs.


NATIONAL PLAN FOR
CIVIL EARTH OBSERVATIONS

PRODUCT OF THE

National Science and Technology Council
Executive Office of the President

July 2014

~~Research~~

Operations

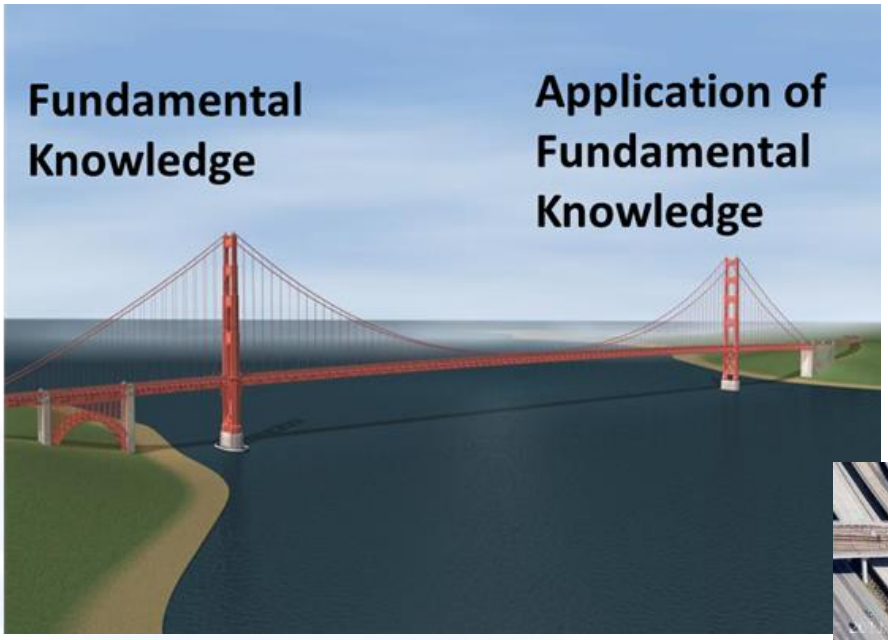
National Civil Earth Observations Plan

Sustained Observations:
Two Purpose-Driven Categories

For public services:
systematic measurements necessary to support products routinely generated for, and widely disseminated to, the general public

For Earth system research:
measurements supporting continuous data streams or generated data products that are needed for basic and applied research to advance human knowledge, to improve public services, and to support public and general education

NASA
Earth Science



The Neglected Heart of Science Policy: Reconciling supply of and demand for science. D.Sarewitz and R.Pielke Jr, 2007.

Crossing the Valley of Death. Faisal Hossain et al., BAMS, August 2014. DOI:10.1175/BAMS-D-13-00176.1

Accelerating Innovation in Climate Services. Mark Brooks, BAMS, June 2013. http://dx.doi.org/10.1175/BAMS-D-12-00087.1

International CCMC-LWS Working Meeting:

Assessing Space Weather Understanding and Applications

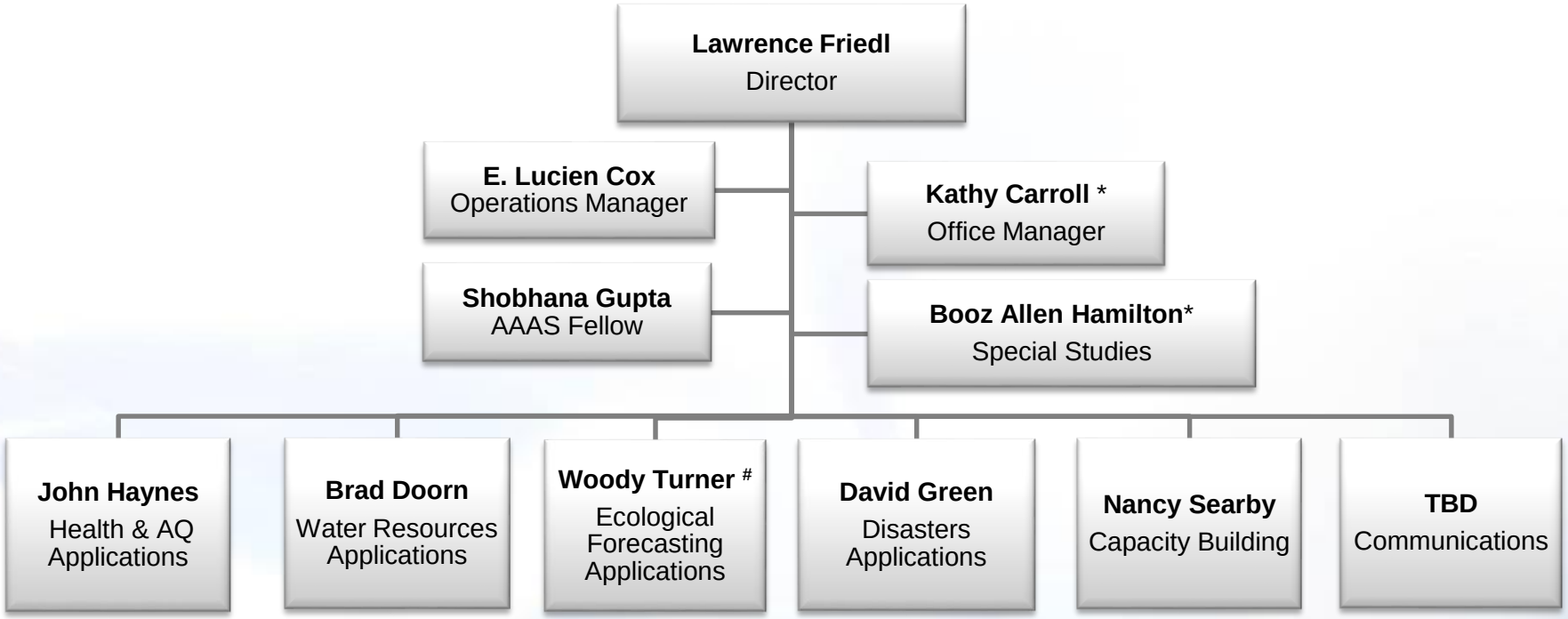
April 3-7, 2017

Back-up Materials

Organization Charts, Program Functions, Communications

SMD/ESD Applied Sciences Program

Organization Chart (Decem 2016)



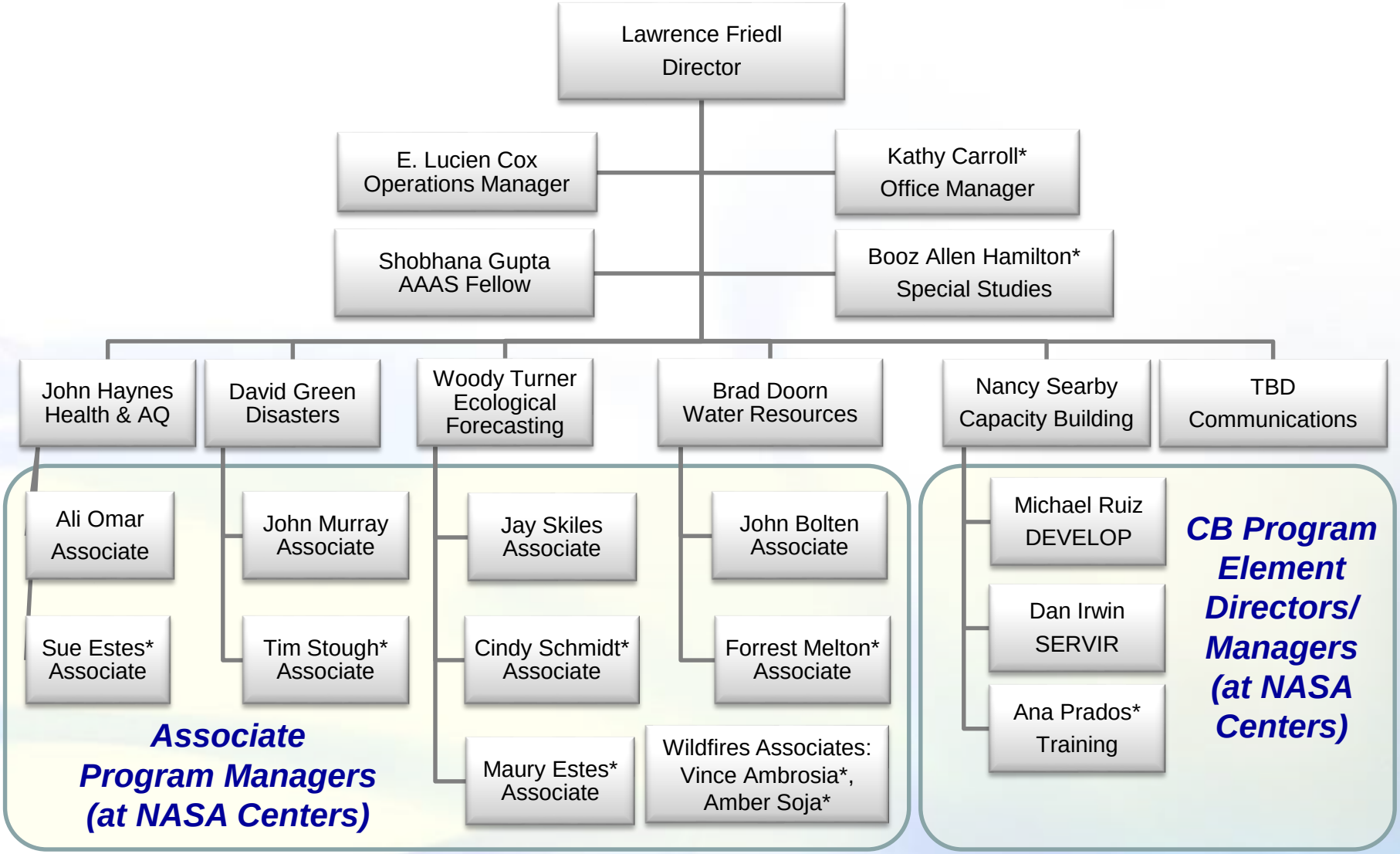
Wildfires Applications is a cross-cutting area. Friedl serves as the program manager to encourage cross-program approaches.

** Contractor*

 # Turner is shared with ESD-Research

SMD/ESD Applied Sciences Program

Extended Organization Chart (December 2016)



** Contractor. Additional people serve as Deputy Program Applications leads for satellite missions*

ESD/Applied Sciences Program

Applied Sciences serves a fundamental role to advance global knowledge about effective ways to extend and apply Earth science and inform decisions and actions.

Key functions within NASA and broad Earth science community:

- Advance applied research and innovative applications;
- Demonstrate near-term benefits of Earth science;
- Identify important areas for informing decisions with Earth science and identify major opportunities for use-inspired research;
- Enable broad-ER user feedback on Earth science datasets and models;
- Create new information products and extend uses of existing ones;
- Substantiate and validate benefits of Earth observations;
- Expand workforce familiar with Earth observations;
- Accelerate ideas and preparation for applications from future Earth science missions;
- Raise expectations for uses of Earth observations in policy, management, and business actions.

Program & Applications Issues

- Partner/User Reach
  breadth v. depth
- Program Role and Control
  direct involvement v. indirect
- Earth Science Missions and Products
  ones less used v. popular, familiar ones;
  ones with continuity v. ones to help continuity
- Project Portfolio: Scope, Size, Duration
  many small projects v. few larger/longer ones
- Application Enablement
  data product development for decisions
  v. product integration into decisions
- Innovation Focus
  innovation in research v. innovation to enable uptake by organizations
- Innovation Type
  impacts on many, everyday decisions
  v. grand challenges and game changers

Informing Decisions
Do organizations have a good sense of their own decisions and the kinds of analysis to support the decisions? What types of actions do they take based on the decisions? What metrics do they use to judge if decisions have improved?

Earth Science Research
Pace and amount is significant. Data can be voluminous and more than what is needed.

Match Making
Finding and linking interested and committed people and organizations.

Language & Lexicon
Being familiar and conversant in the terms and concepts of specific users.

Capacity Building

NASA
Earth Science

Improve the capabilities of individuals and institutions related to accessing and applying Earth observations. This context includes human, scientific, technological, organizational, institutional, and resource-based capacities.

DEVELOP is a national training and development program for individuals to gain experience applying Earth observations through 10-week interdisciplinary projects, including with state and local governments.

2016:
358 Participants,
77 Projects

ARSET, Applied Remote Sensing Training, builds skills in accessing and using Earth observations data across applications topics through computer-based training for government and private sector individuals.

2016:
3130 trainees,
9 webinars,
6 in-persons

SERVIR is a NASA NASA/USAID-sponsored initiative that enables uses satellite observations to help developing nations monitor, forecast, and respond to environmental changes.

USAID
FROM THE AMERICAN PEOPLE

2016:
Opened new hub in West Africa

Earth Venture: EVM-2 AO
First with an applications requirement

NASA
Earth Science

Text from EVM-2 AO:

For this EVM-2 solicitation, NASA places a strong emphasis on research and innovation for Earth system science issues, while expecting appropriate attention to applications-oriented aspects to further the overall value of the mission. (Section 2.3)

Part of Requirement:

For this EVM-2, NASA places the highest priority on research and innovation for Earth system science issues. However, proposals must also articulate, to the extent possible, a plan to address applications-oriented users for their measurements, investigation, and data products.

Applications in Criteria

Factor A-1 on investigations goals & objectives
Factor A-2 on programmatic value
Factor B-1 on instruments and mission design
Factor B-3 on data analysis, availability, plan

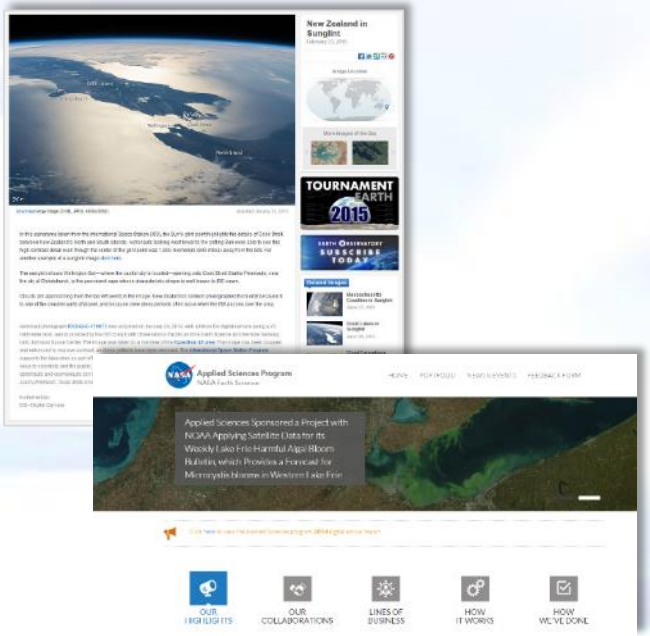
Highlights

- Intention is to provide data and info products to key applications user groups
- Proposed investigation does not need to "conduct an applications project"
- Expectation is a plan to support and enable applications projects by others
- Encourage proposal team to engage, talk with, and listen to people from relevant applications communities
- If no applications are possible, burden of proof is on proposer to justify

Communications

A significant emphasis on communications and outreach activities, especially to convey results to broad audiences.

Website, Earth Observatory



Videos

Articulation of Results

Results

Factors to consider in articulation and communication of results, as offered by ESD Director.

Earth Science Overall:

» What was the problem?

» What did we do?

» What did we learn? What came from our action?

» What was the result?

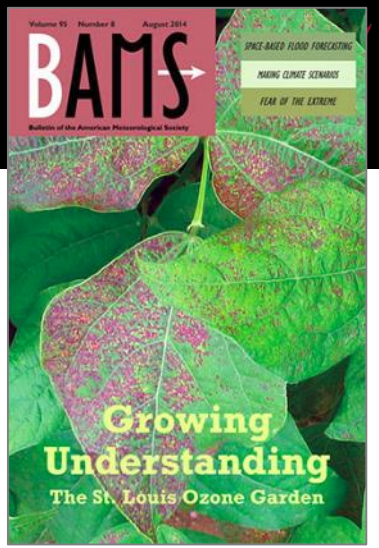
» What is the benefit and significance?

Applications:

» User group that clearly benefits and that clearly state its benefits (and use of Earth observations)

» Clear connection to NASA Earth science

» Context & anecdote that is clear



Crossing the Valley of Death:

Lessons Learned from Implementing an Operational Satellite-Based Flood Forecasting System

Step 1: Do the research on theoretical feasibility on a popular and interdisciplinary research publication forum.

Step 2: Disseminate widely the theoretical feasibility to potential stakeholder agencies through a two-way public education process and generate interest.

Step 3: Respond to skepticism in an engaging way; do not lose stakeholder interest by talking more than listening.

Step 4: Get commitment from stakeholder agencies to prototype and test the satellite forecasting system; start with the simplest of ideas when you teach them how to fish.

Step 5: Begin hands-on training of stakeholder staff for implementing the prototype system; patiently hand hold the staff and teach them from the ground up the basics of the system.

Step 6: Allocate supporting resources to address unexpected hurdles during launch of the prototype system.

Step 7: When launching the prototype, ensure complete ownership and independent operation; offer complimentary support as technical backstop.

From Faisal Hossain et al., BAMS, August 2014. DOI:10.1175/BAMS-D-13-00176.1

The underlying problem – that of linking knowledge and power in an open society – does not present itself in a convenient form of a procedural flow to be corrected, a structural defect to be repaired, or a disease to be prescribed for and cured.

– James Allen Smith