Ecological Modeling at NASA
&
A Brief Introduction to NASA's Ecological Forecasting Program

Woody Turner

Ecological Modeling for NASA Applied Sciences Workshop

Asilomar Conference Center
Monterey, CA
March 30, 2005

Outline

- Applied Sciences Program at NASA
- Program Context for Modeling at NASA
- Ecological Modeling at NASA
- Where we might go from here: one approach
- Ecological Forecasting
- This Workshop

Applications of National Priority

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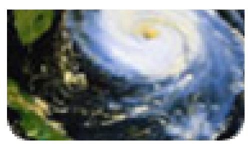
This is not a research program!

Coastal Management

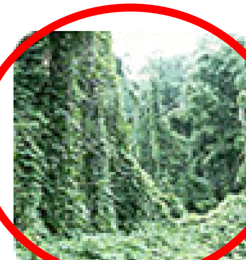


Disaster Management

Ecological Forecasting

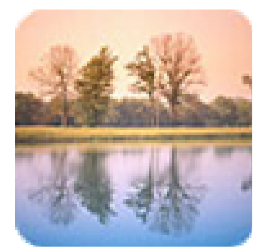
Energy Management

Homeland Security



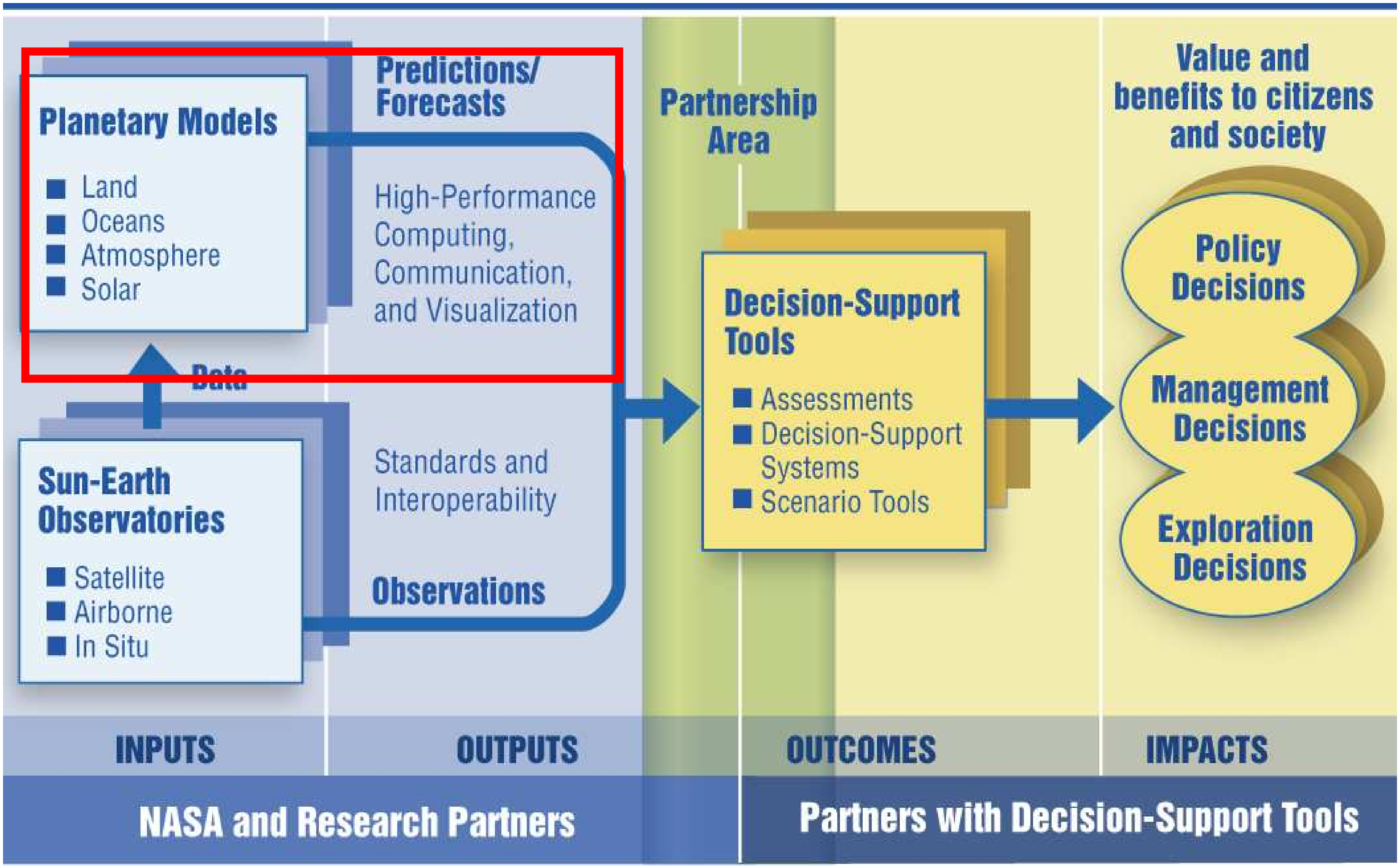
Invasive Species

Public Health

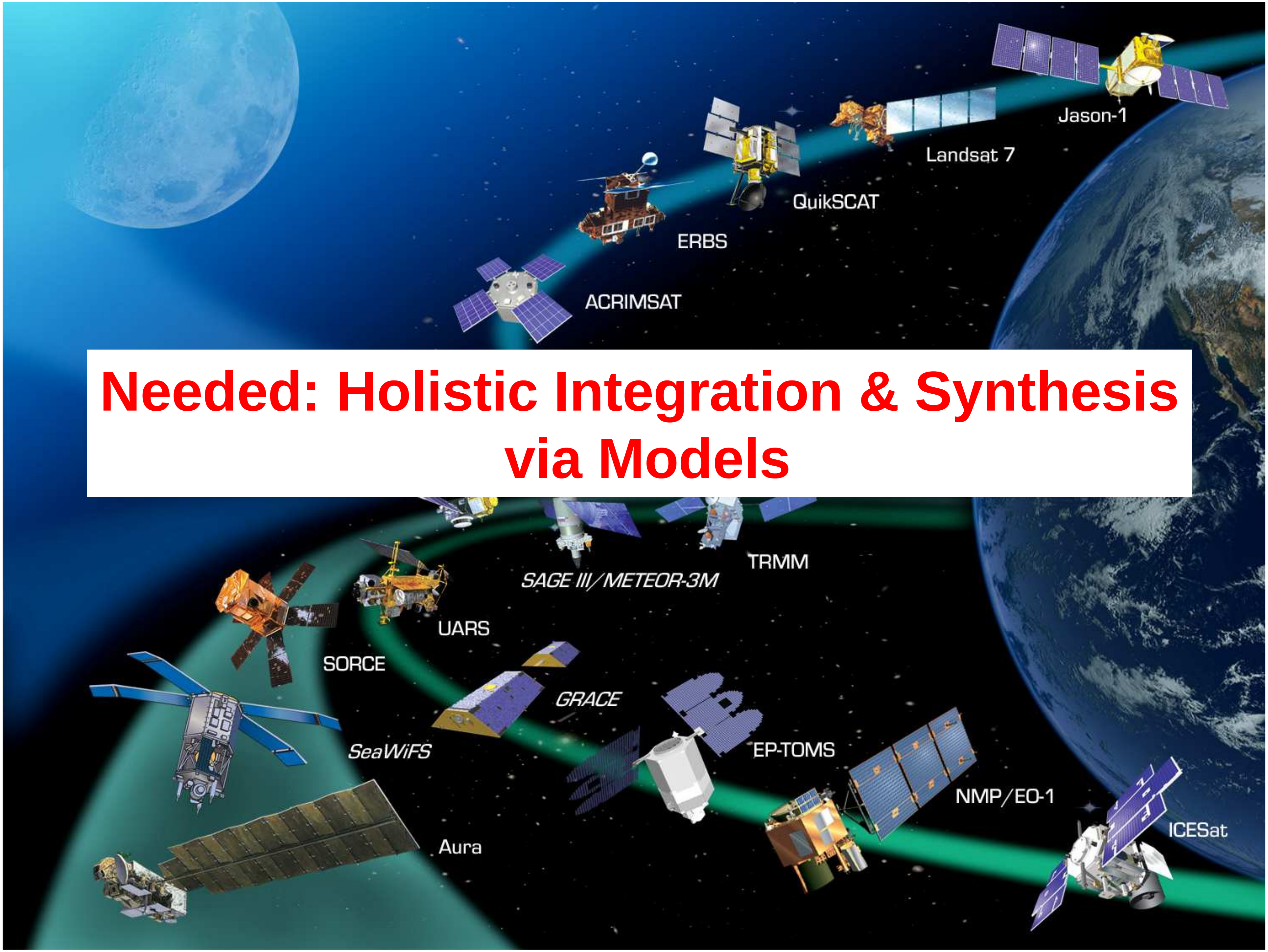


Water Management

Applied Sciences Paradigm



Needed: Holistic Integration & Synthesis via Models



30-Year Goal: Whole Planet System Simulators

• System of Systems

• Standards and interoperability

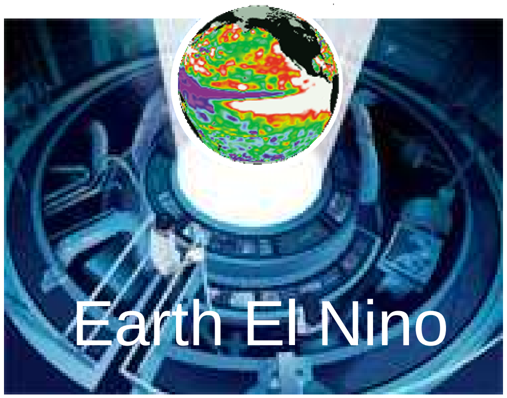
• Spiral, evolutionary development

• Go as you can pay

• Global access to research results

• Incremental functionality for holistic simulator

• Innovative space systems for Earth-Sun science to serve society



• Network innovative space systems & associated modeling systems (e.g., sensorweb & modelweb) to advance Earth-Sun system science

• Systems to assimilate observations into models

• Systems that utilize observation & model results to identify unexpected phenomena & adapt observing & modeling strategies in near real-time

GEOSS in the News

nature

24 February 2005 Volume 433 Issue no 7028

Making sense of the world

The Earth and our effects on it require monitoring and analysis worthy of their complexity and importance. Now is the time to bring global observation into the twenty-first century.

Last week, ministers from some 60 nations gathered in Brussels to create an integrated Earth observation system, the Global Earth Observation System of Systems (GEOSS). December's tsunami in the Indian Ocean has catapulted GEOSS from relativ

Today's climate observation system is cobbled together from data from research satellites, weather satellites, atmospheric sounders and whatever ground-based observation stations scientists can get their

RESOLUTION OF THE THIRD EARTH OBSERVATION SUMMIT

(As adopted 16 February 2005)

We, the participants in the Third Earth Observation Summit held in Brussels, Belgium, on February 16, 2005:

Recalling the Declaration of the first Earth Observation Summit, held in Washington, D.C., on July 31, 2003, and the Framework Document adopted at the Second Earth Observation Summit, held in Tokyo, on April 25, 2004;

Building on the commitment made at those Summits to move toward a comprehensive, coordinated, and sustained Earth observation system of systems, taking into account the particular needs of developing countries;

Remaining cognizant of the fact that observing and understanding the Earth system more completely and comprehensively will expand worldwide capacity and means to achieve sustainable development as envisioned in our commitments in the Johannesburg Plan of Implementation adopted at the 2002 World Summit on Sustainable Development, and will yield advances in many specific societal benefit areas, including disaster reduction, health, energy, weather, climate, water, ecosystems, biodiversity, agriculture and combating desertification;

Acknowledging the achievements of the established national, regional, and international observing systems, including those sponsored and cosponsored by a number of UN Specialised Agencies and Programmes;

ENVIRONMENTAL SCIENCE

Forging a Global Network to Watch the Planet

CAMBRIDGE, U.K.—The dream of creating a global earth-monitoring network came a step closer to reality last week. Proponents met in Brussels to launch a 10-year program to turn gauges, sensors, buoys, weather stations, and satellites that monitor Earth's surface, atmosphere, and oceans into a unified whole. The Global Earth Observation System of Systems (GEOSS), as it's called, is expected to evolve slowly from national systems into a comprehensive, coordinated, and sustained set of observations for the benefit of everyone, including developing countries. By adding links and standards, "earth science will step up to the next level: a total earth-observing system," says Conrad Lautenbacher Jr., head of the U.S. National Oceanic and Atmospheric Administration.

There is little coordination today among the roughly 50 satellites observing Earth—or the more numerous sensors in ground- and ocean-based networks. As a result, there are gaps in coverage as well as a massive duplication of effort. The drive to add coherence began in July 2003 when government ministers from some 30 nations along with heads of various agencies—collectively dubbed the Group on Earth Observations (GEO)—met for an Earth observation summit in Washington, D.C. At a second summit in Tokyo in April 2004, GEO came up with the idea of having a 10-year transition from the current hodgepodge of observations to a global coordinated system. And on 16 February in Brussels, the third summit signed off on GEOSS's 10-year implementation plan. The agreement puts GEO itself—with 60 countries and 33 organizations now on board—on concrete footing, with a permanent secretariat hosted by the U.N.'s World Meteorological Organization in Geneva.

Center of attention. Brussels, shown in this 2003 image from a European environmental satellite, hosted a summit to launch a decadal plan for GEOSS.

The goals of GEOSS are lofty: Its proponents say it will improve weather forecasts, reduce the devastation of natural disasters, monitor climate change, support sustainable agriculture, help understand the effect of environment on human health, and protect and manage water and energy resources.

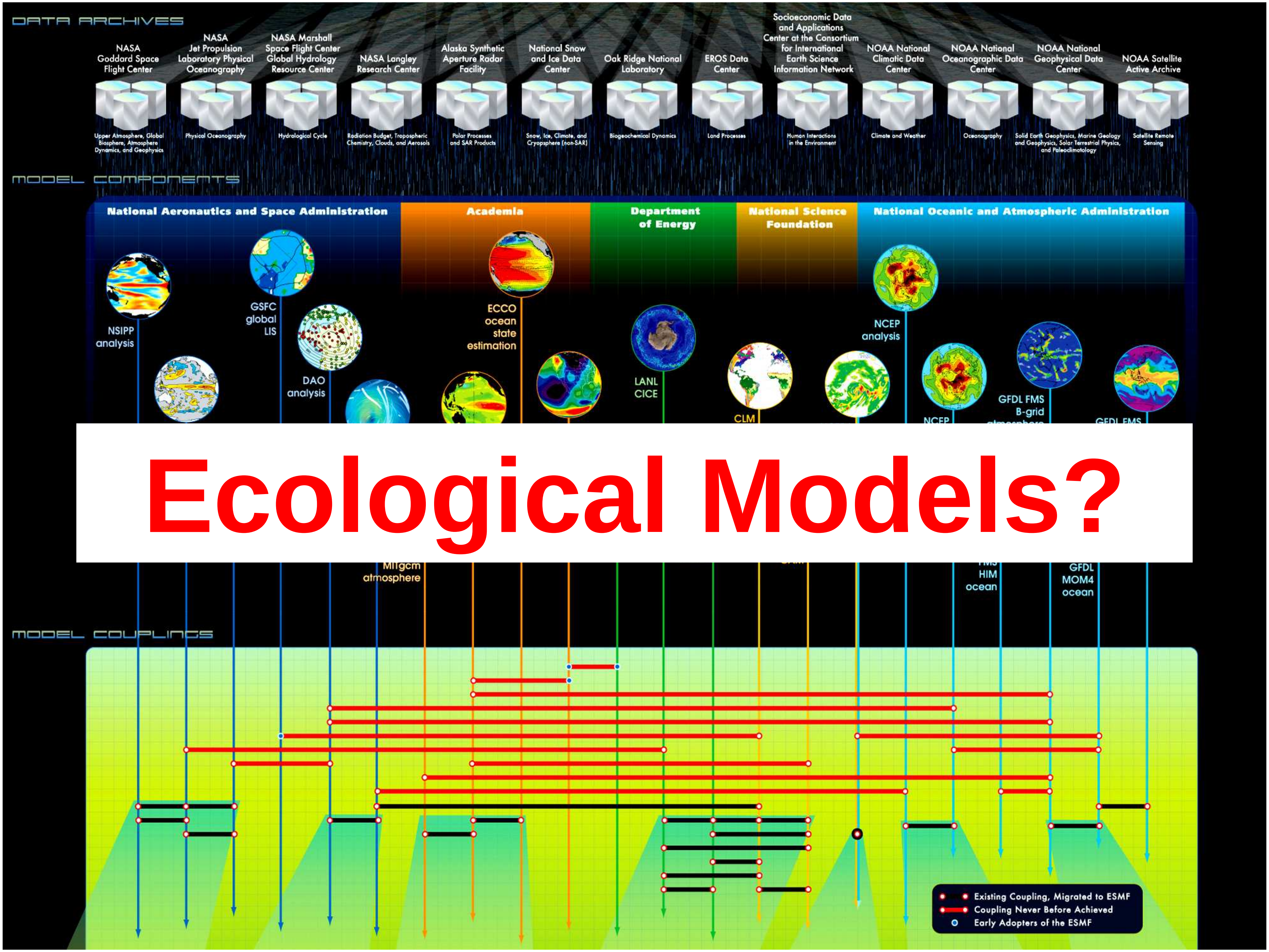
The first job, according to Errol Levy, scientific officer at the European Commission in Brussels, "is to look at what is measured now, what is needed," and find the gaps. GEOSS will initially build on existing satellites and sensors, such as NASA's Earth Observing System satellites and the European Space Agency's Envisat. The most difficult part, Lautenbacher says, will be achieving an agreement on data sharing. There will have to be some horse trading on who observes what and who launches which satellite. "Some of this is difficult. It will require serious negotiation," Lautenbacher says.

One of GEOSS's key aims is to involve developing countries. Lautenbacher says they "have the most to gain," in terms of helping them tackle problems such as desertification or the spread of malaria. But they can also contribute by launching weather balloons into the upper atmosphere or installing tide gauges to measure sea-level rise.

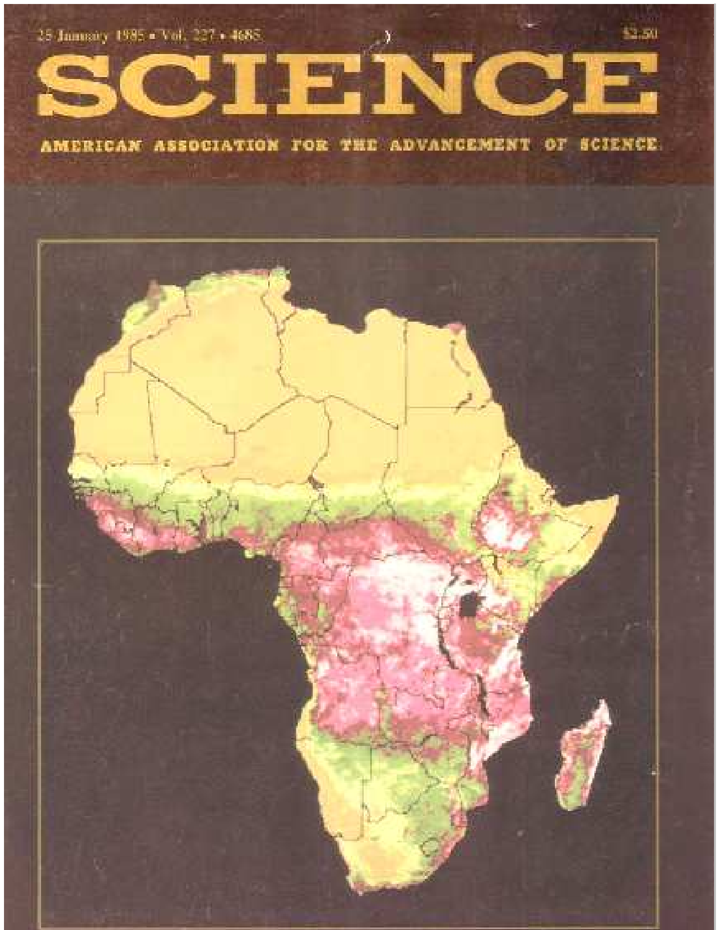
—DANIEL CLERY

CREDIT: 2004 ESA

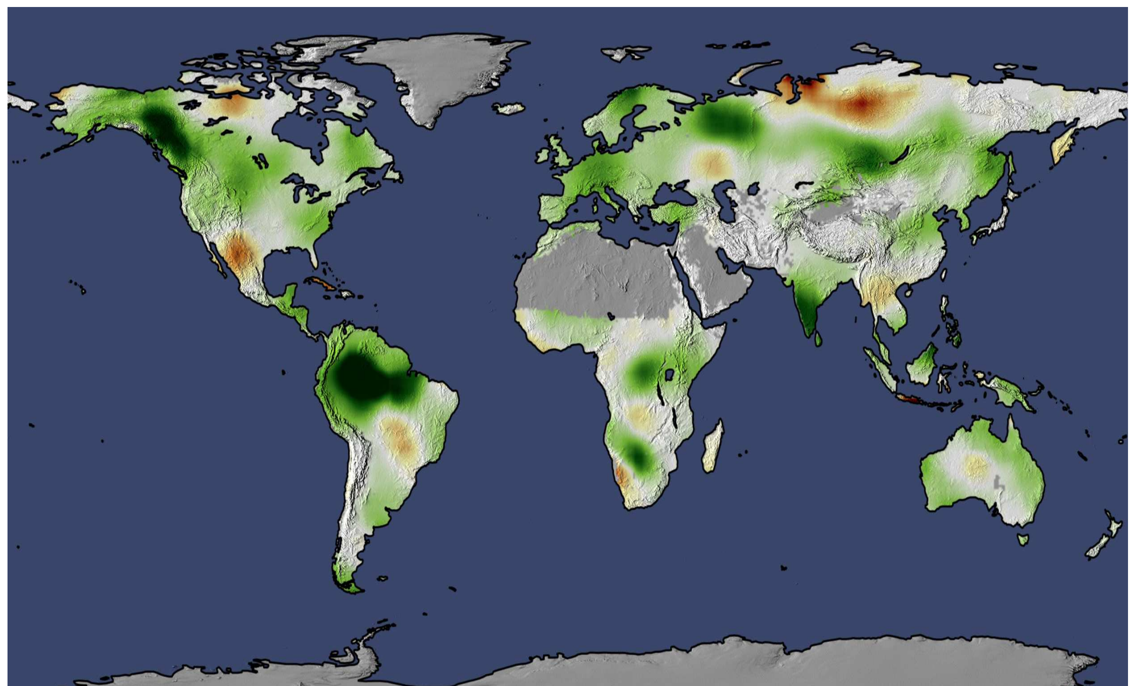
Ecological Models?



Taking the Next Step in NASA Ecology



Tucker et al. 1985. *Science* 227: 369-375.



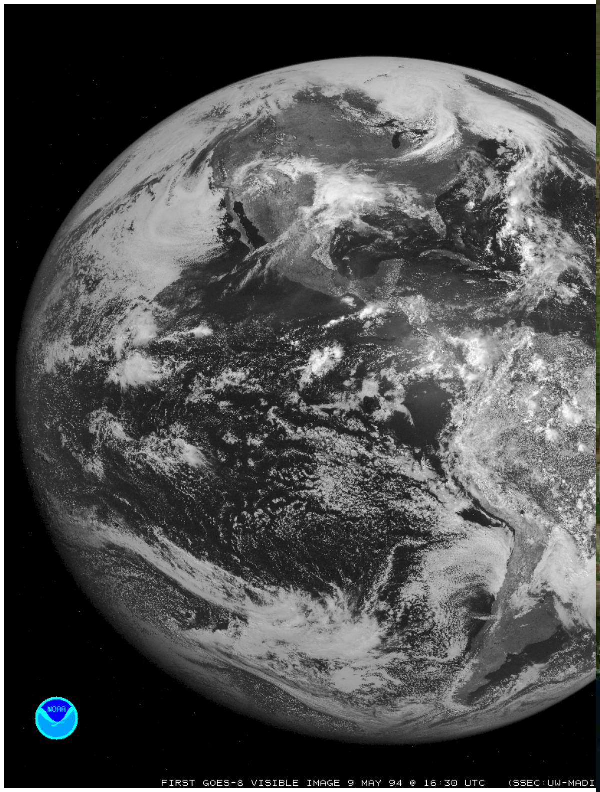
Nemani et al. 2003. *Science* 300:1560–1563.

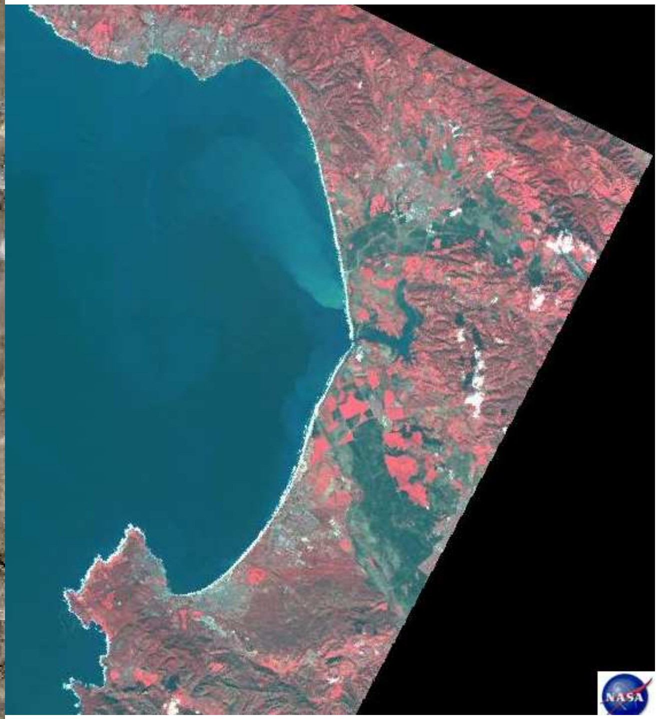
Ecological Modeling & NASA: One Way Forward for Near-Term

- **Landscape Scale to Global--Our Bread & Butter**
- **Challenge for all 3 Programs: Relate Landscape Scale to Organism**
- **How?** Clue: Every animal and plant in this ecosystem has an appointed place defined both by its level in the pyramid and by its niche. **Paul Colinvaux, 1980 Why Big Fierce Animals Are Rare**
  - **#1 Outside In/Inside Out to Define the Niche (The Landscape)**
  - **#2 Follow the Energy via Trophic Webs (The Organism)**

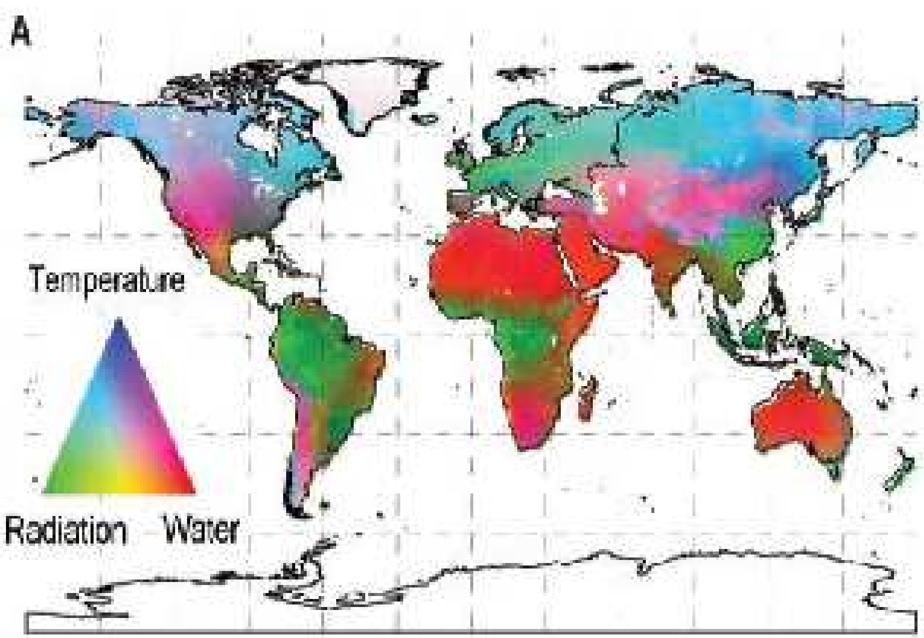
BOTTOM LINE: Models are the key for both!

Global to Landscape Scales: Our Bread & Butter





Outside In: Niche Definition + Statistics



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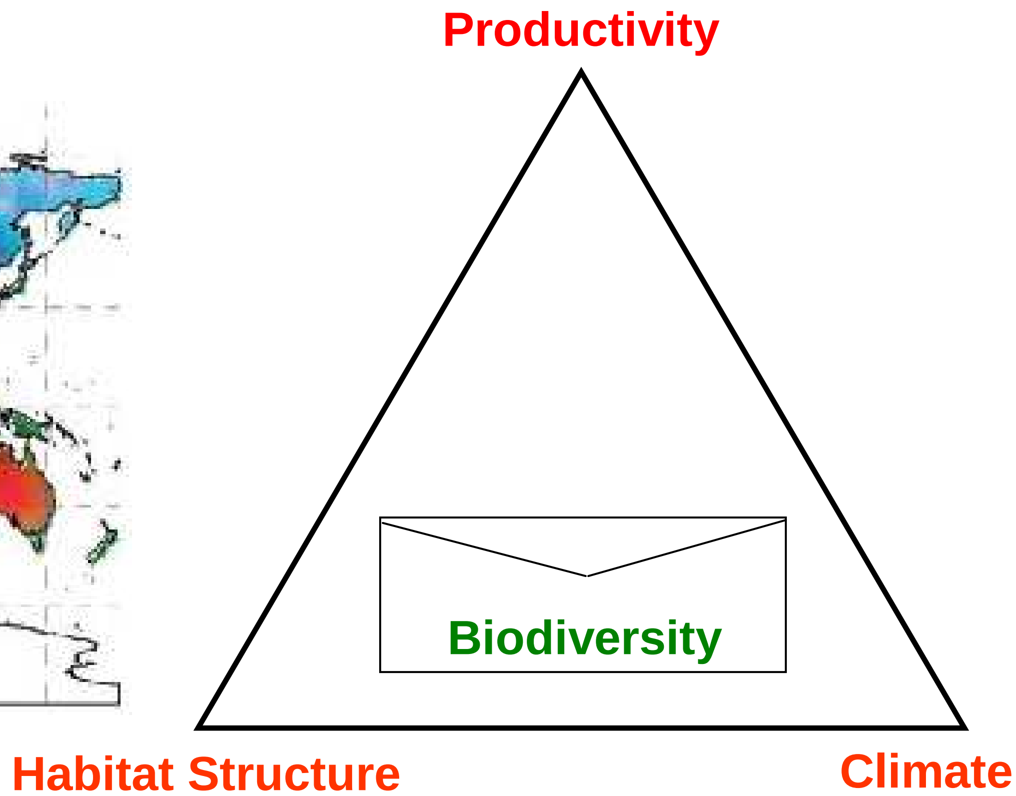
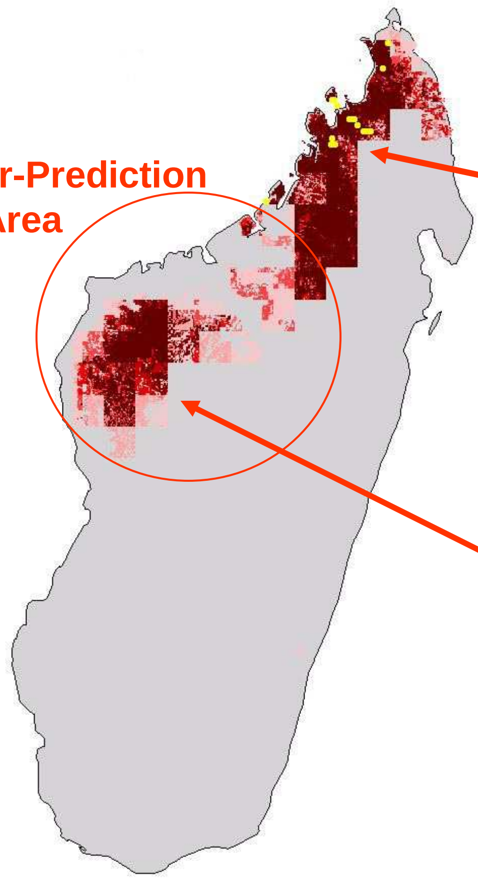
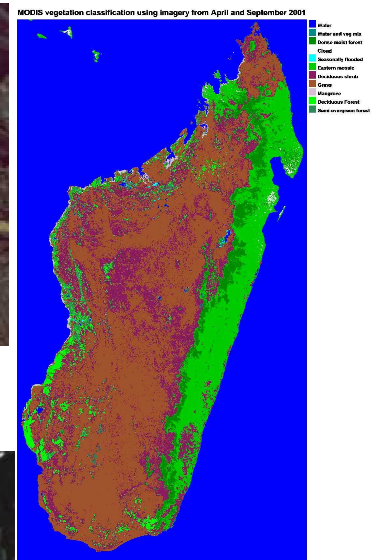


Ecological Forecasting of Unknown Sister Species Bringing Together Satellite, Field, & Museum Data

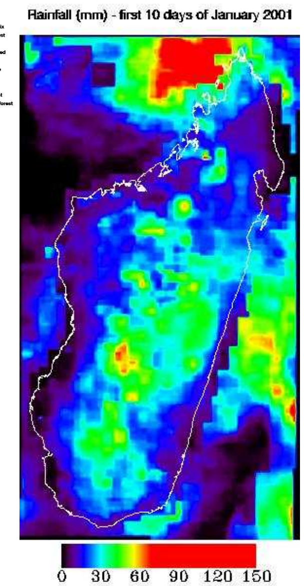


Brookesia stumpffi

Brookesia sp. nov.



MODIS Land Cover at 1km



NOAA Precipitation at 5 minutes resolution

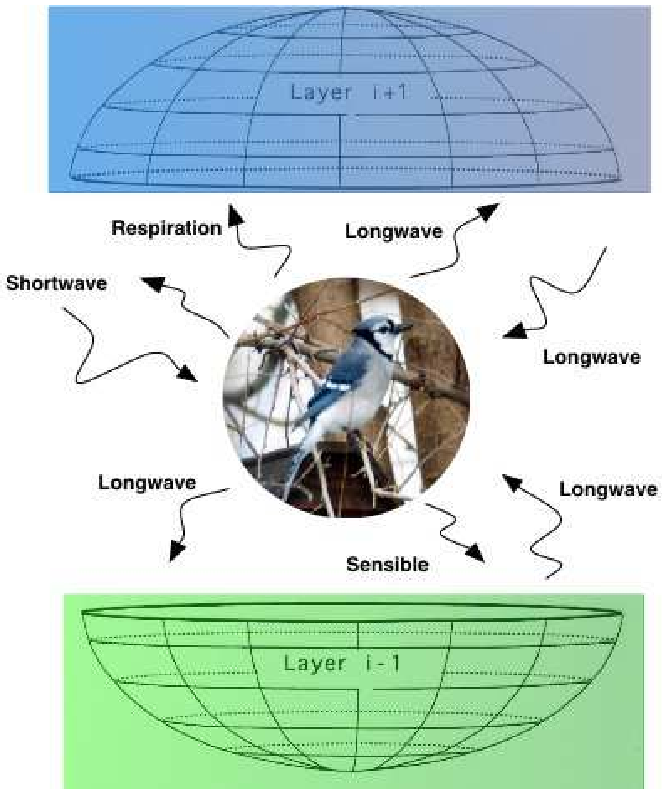
Examples of Environmental Data Us

Modeled Distribution for *Brookesia stumpffi*

- Using Satellite imagery, other environmental layers, & collections data from the field & museums to run the GARP model→successfully predicted the distributions of 11 chameleon species in Madagascar
- Accuracies of 75 to 85%
- Areas of over-prediction from the model & subsequent field surveys → discovery of 7 new species

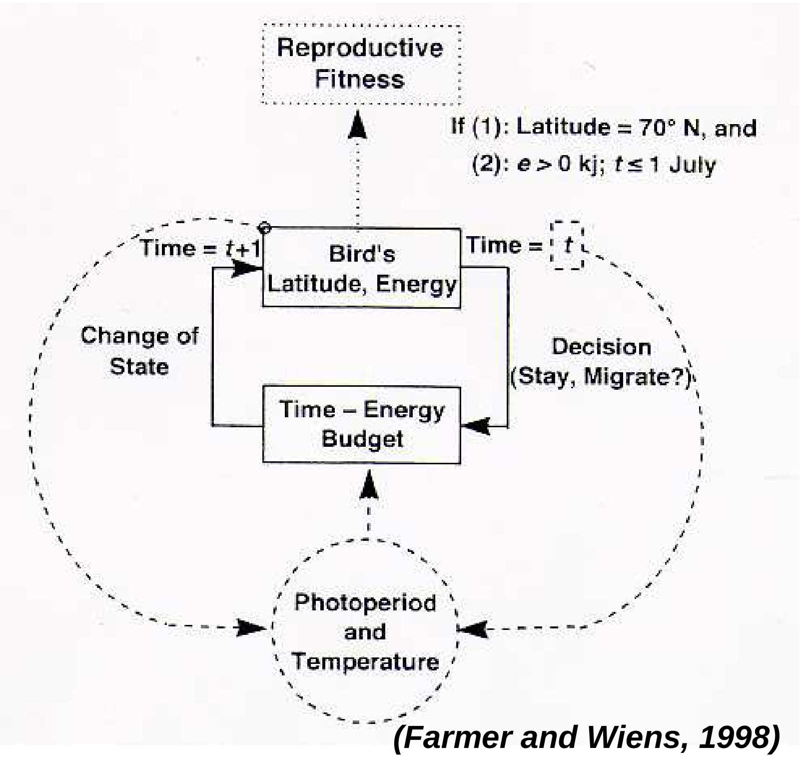
Source: AMNH/Chris Raxworthy

Inside Out: Physiology/Energetics to Niche



$Rn - H - lE + M = 0$

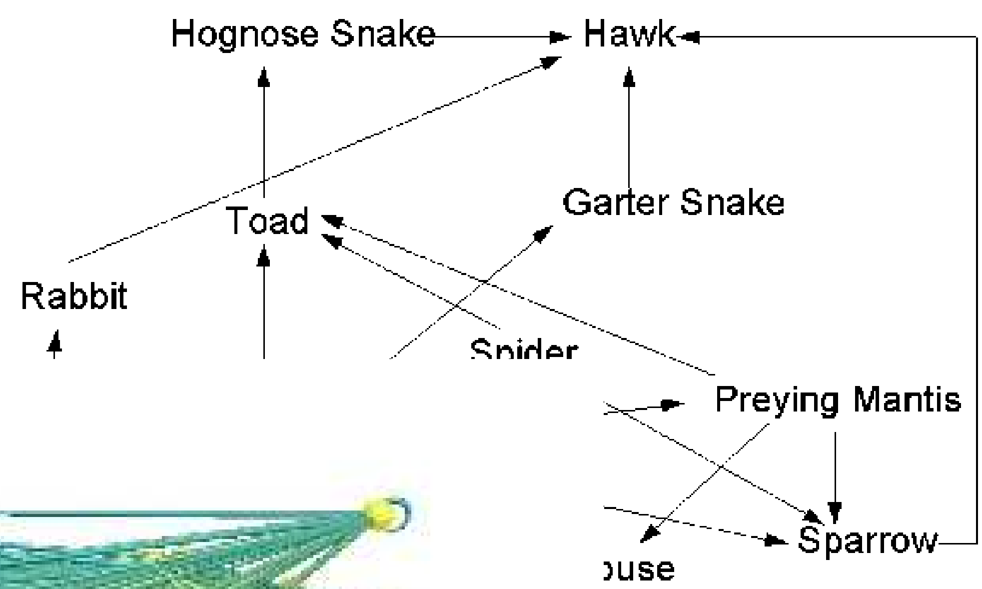
Energy Budget = f (Feeding, Resting, Migratory Flight)



(Farmer and Wiens, 1998)

(figures courtesy of GSFC/Jim Smith)

Trophic Models To Understand Relationships Among Organisms



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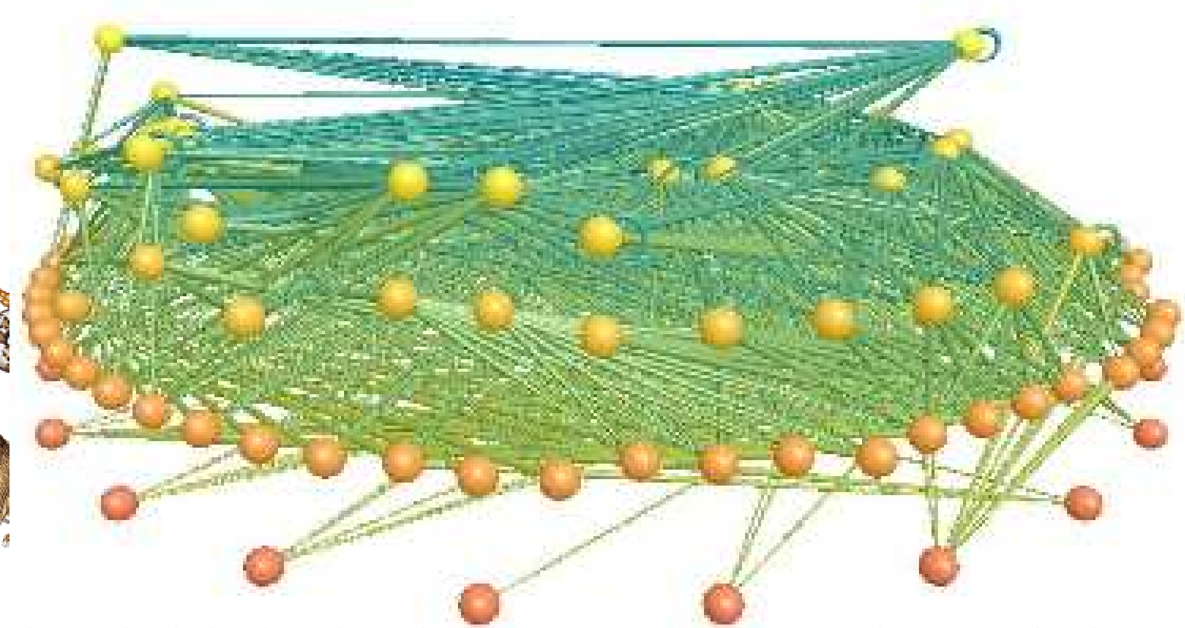
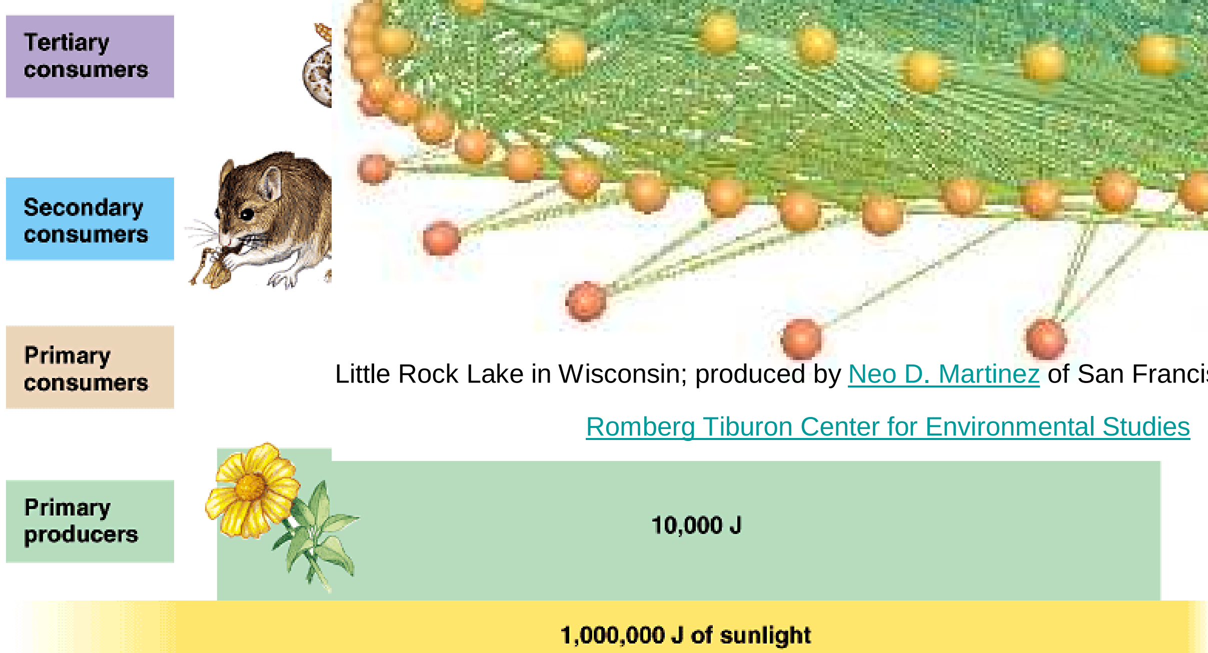
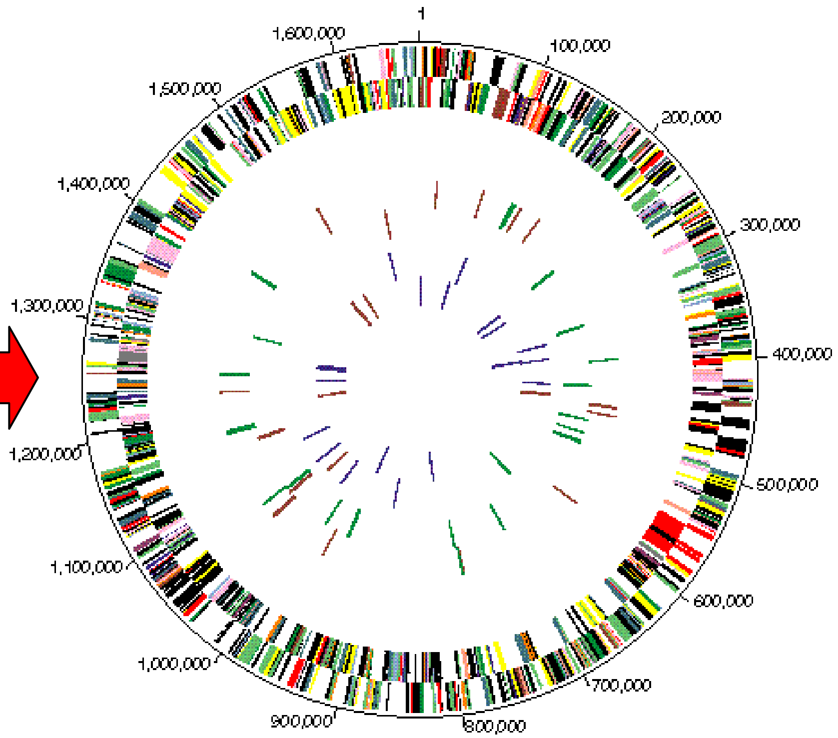




Little Rock Lake in Wisconsin; produced by [Neo D. Martinez] of San Francisco State University,

[Romberg Tiburon Center for Environmental Studies]

Where To?



Helicobacterium pylorii Genome from:
http://biocrs.biomed.brown.edu/Books/Chapters/Ch%2038/Pylori-Genome.gif

A Grand Synthesis for the 21st Century

Ecological Forecasting: Integrated System Solutions

EARTH SYSTEM MODELS

- Ecological Niche (GARP)
- Scalable spatio-temporal models a la NREL
- Regional Ocean Models & Empirical Atmospheric Models coupled with ecosystem trophic models
- Ecosystem (ED, CASA)
- Population & Habitat Viability Assessment (VORTEX, RAMAS GIS)
- Biogeography (MAPSS, BIOME3, DOLY)
- Biogeochemistry (BIOME-BGC, CENTURY, TEM)

(example models)

Predictions

- Species Distributions
- Ecosystem Fluxes
- Ecosystem Productivity
- Population Ecology
- Land Cover Change

Data

EARTH OBSERVATORIES

- Land cover: MODIS, AVHRR, Landsat, ASTER, ALI, Hyperion, IKONOS/QuickBird
- Topography/Vegetation Structure: SRTM, ASTER, IKONOS, LVIS, SLICER, Radars
- Primary Productivity/Phenology: AVHRR, SeaWiFS, MODIS, Landsat, ASTER, ALI, Hyperion, IKONOS, QuickBird, AVIRIS
- Atmosphere/Climate: AIRS/AMSU/HSB, TRMM (PR, LIS, TMI), AVHRR, MODIS, MISR, CERES, QuikScat
- Ocean: AVHRR, SeaWiFS, MODIS, TOPEX/Poseidon, JASON, AQUARIUS
- Soils: AMSR-E, AIRSAR

**Future Mission*

- Land Cover/Land Use & Disturbances (e.g., fire)
- Species Composition
- Biomass/Productivity
- Phenology
- Vegetation Structure
- Elevation
- Surface Temperature
- SST, SSH, Circulation, & Salinity
- Atmospheric Temp.
- Soil Moisture
- Precipitation
- Winds

Observations

DECISION SUPPORT TOOLS

SERVIR (Spanish acronym for Regional Visualization & Monitoring System)

- Monitor changes in land cover, weather, & fires to assist the sustainable management of the Mesoamerican Biological Corridor

Protected Area Management (with VISTA & TOPS)

- Coordinate multi-NGO effort to pool resources for monitoring protected areas per CBD 2010 goal
- Link to President's illegal logging initiative & CBFP

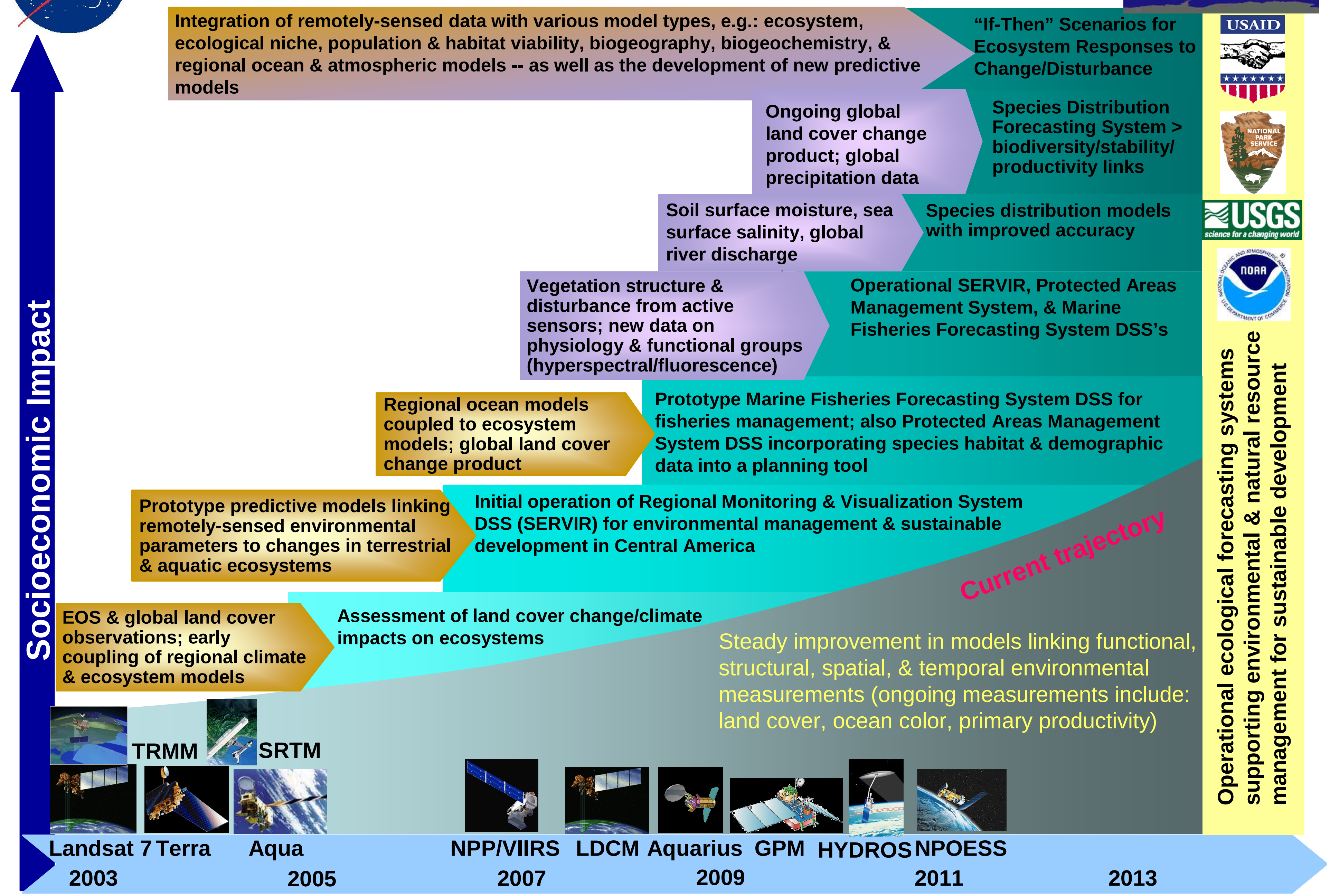
Impact of ENSO & PDO Events on Fisheries

- Combine physical ocean models & ecosystem trophic-level models to predict impacts of climatological changes on regional fisheries

VALUE & BENEFITS

- Management of a global hotspot of biodiversity, i.e. Mesoamerica, at a regional scale through the coordination of the activities of 7 countries - a model for other regions.
- Predict the impacts of changing land use patterns & climate on the ecosystem services that support all human enterprises.
- Develop ecological forecasts with reliable assessments of error.

Ecological Forecasting Roadmap



Two Schools of Engineering: Satellite System & Ecosystem

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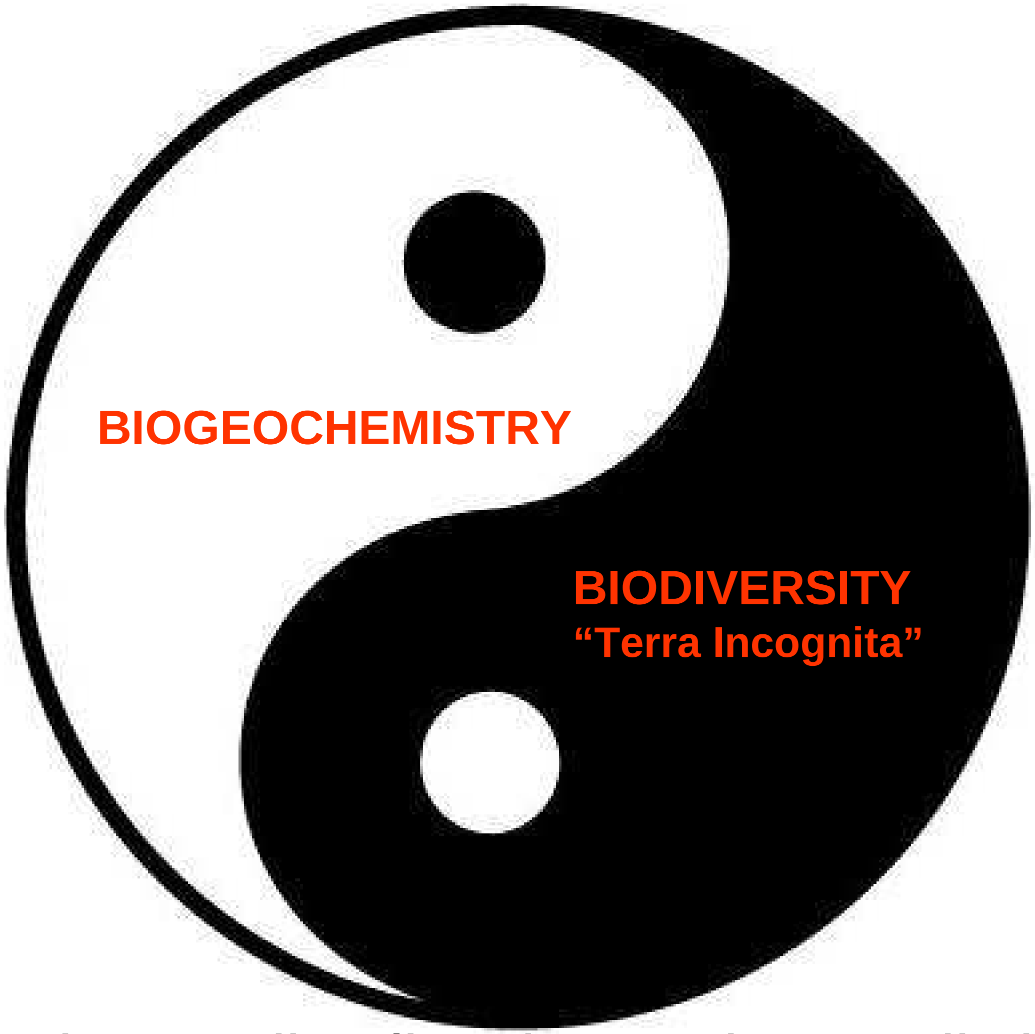
There is really nothing else so odd about life as its variety.

Paul Colinvaux, 1980 Why Big Fierce Animals Are Rare

Grand Challenge: Understanding this Variety



In understanding lies the road to prediction

(e.g.: if we want to understand the biogeochemical cycling of carbon &/or other elemental cycling, we need to know other half of ecosystem equation)

Goals for Workshop

- Focus: Ecological Models for Management (via research)
  - Subtext: Predictive Modeling of invasive species, public health issues, & biodiversity from biological & physical environmental data
- Bring Together NASA Ecological Modeling Community
  - Awareness → New Teams & Approaches
- Find Model Approaches Common to 3 Programs
  - Ingest NASA RS/Earth Observation Data
  - Useful for Decision Support
  - Bridging Spatial (& Temporal) Scales
  - Goal: Scenarios of responses to changing climate, land cover, management actions, policies, etc.
- Future Needs/Issues/Threats (data, models, research & DSS themes, systems of systems)
- If you had a million $$…?
- Next Steps: building on what we heard here

Presenters Please

- What system are you modeling?
- What are your model assumptions?
- What are (at least some of) your model uncertainties?
- What data you are using to run & validate the model?
- Why did you chose these data sets? Are other data relevant?
- How effective (i.e., how much can it tell us about the system under investigation & with what certainty?) is your model?
- Are we there yet with regard to this model or are there improvements to be made? If so, what are they?

While these may be implicit, please don’t simply assume we’ll know them! (Remember there are NASA HQ program managers in the room; so keep it simple.)

Workshop Products

- Report
- Other Publications
- Working Groups for Applied Programs
  - e.g.: Biodiversity & Ecological Forecasting Team
- New Directions
- Ideas?