Programmatic Lessons Learned from NEON

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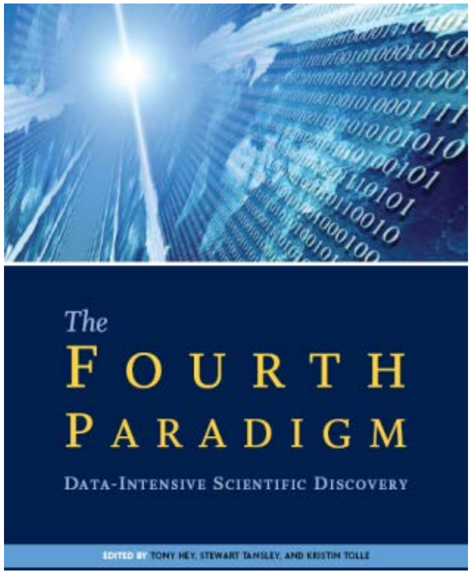
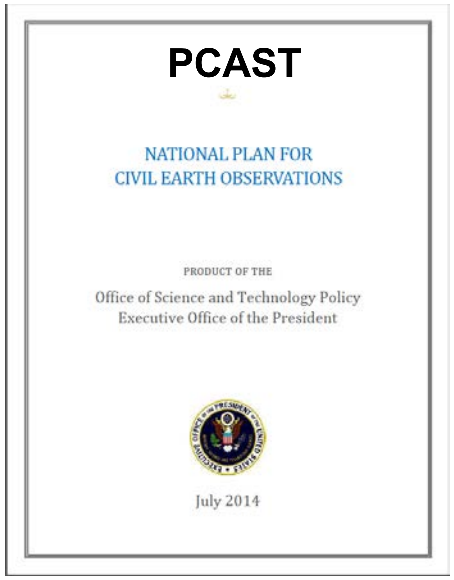
Battelle
The Business of Innovation

Era of Big Data – Societal Imperative



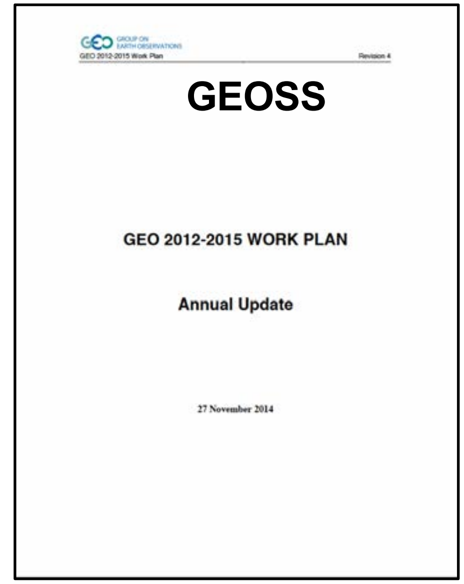
PCAST


NATIONAL PLAN FOR
CIVIL EARTH OBSERVATIONS

PRODUCT OF THE
Office of Science and Technology Policy
Executive Office of the President

July 2014

GEOSS


GEO 2012-2015 Work Plan

Revision 4

GEO 2012-2015 WORK PLAN

Annual Update

27 November 2014

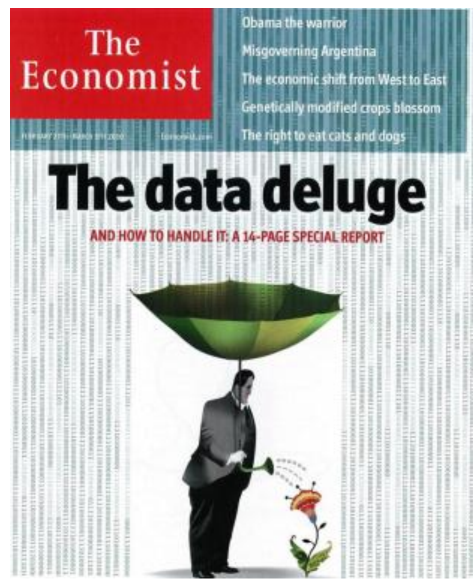
∨ 9/2008 ∧ 10/2009

∨ 2010 ∧ 7/2014

∨ 2/2011 ∧3/2010

∨ 8/2008 ∧ 2012-5

ESFRI



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Rationale For NEON

- **"Fragmented federal investment in monitoring ecological change weakens national priorities."**

- **"The economic and environmental dimensions of societal well-being are both indispensable, as well as tightly intertwined."**

- **"*We must address the threats to both the environmental and the economic aspects to our "ecosystem services.*"**

Holdren, J., T. Dickenson, G. Paulson, and others, 2014. *National Plan for Earth Observations*. National Science and Technology Council, Executive Office of the President. pp. 71

Presidents Council of Advisors on Science and Technology (PCSAT) 2011. Sustaining Environmental Capital: Protecting Society and the Economy. Report to the President. www.whitehouse.gov/ostp/pcast.

Ecosystem Science – Historical Context

Nature is always in dis-equilibrium, and constantly changing, that set up ‘intellectual’ ***tension between bottom up and top down forces*** (**A. Lord Tennyson** *1850*)

Panoply of species interactions, however chaotic are balanced one another, so that it appeared that nature was in ***equilibrium***. Interacting species viewed as a whole system (***S. A. Forbes*** *1887*)

Community succession, substituting space for time (chronosequence), acknowledged edaphic controls and competition of resources (***H. Cowles, E. Warming***, *1899*)

Concept of Climax stage of linear succession that is composed of both the organism- and the physical-environmental complex. (***F. Clements*** *1905*)

Ecosystem concept is **the idea that living organisms are continually engaged in a set of relationships with every other element constituting the environment in which they exist.** the community as an super organism. *(**A.G. Tansley** 1935)*

Accumulation and ***distribution of energy*** within an ecosystems that eventually achieve a condition of homeostasis (***E.P. + H.T. Odum*** 1953)

nods to H. Gleason, R. Whitaker, C. Elton,
G. E. Hutchinson, V. Vernadsky, many many others

Ecosystem Science – Historical Context

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ECOSYSTEM COMPONENTS / ECOSYSTEM STATES / STRUCTURE AND FUNCTION

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ECOSYSTEM STATES / STRUCTURE AND FUNCTION

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TIME /SPACE SCALES, STRUCTURE AND FUNCTION

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ECOSYSTEM COMPONENTS / ECOSYSTEM STATES / RESILIENCY

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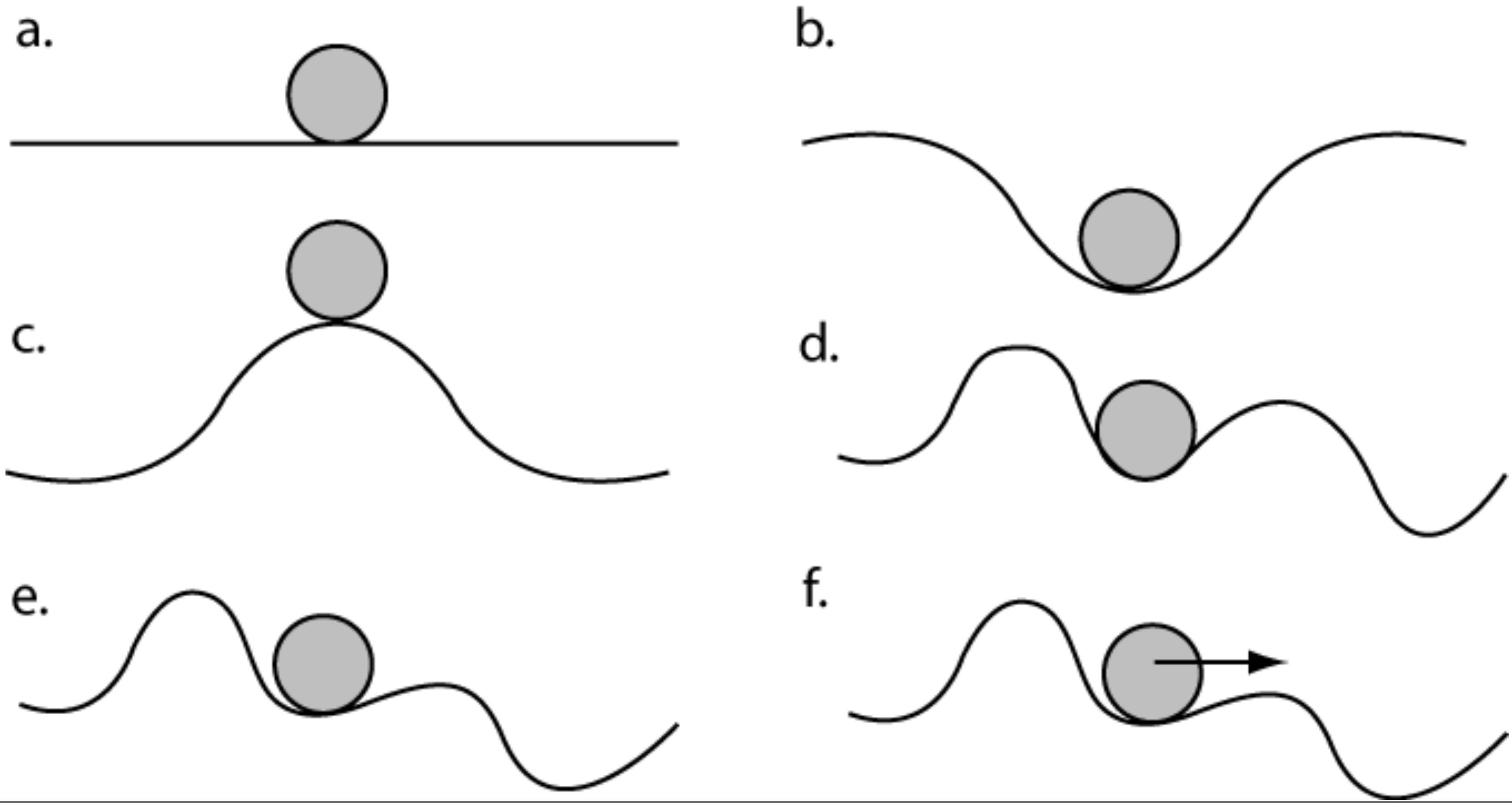
FLOWS OF MASS AND ENERGY / ECOSYSTEM STATES / MODELING FRAMEWORK

nods to H. Gleason, R. Whitaker, C. Elton,
G. E. Hutchinson, V. Vernadsky, many many others

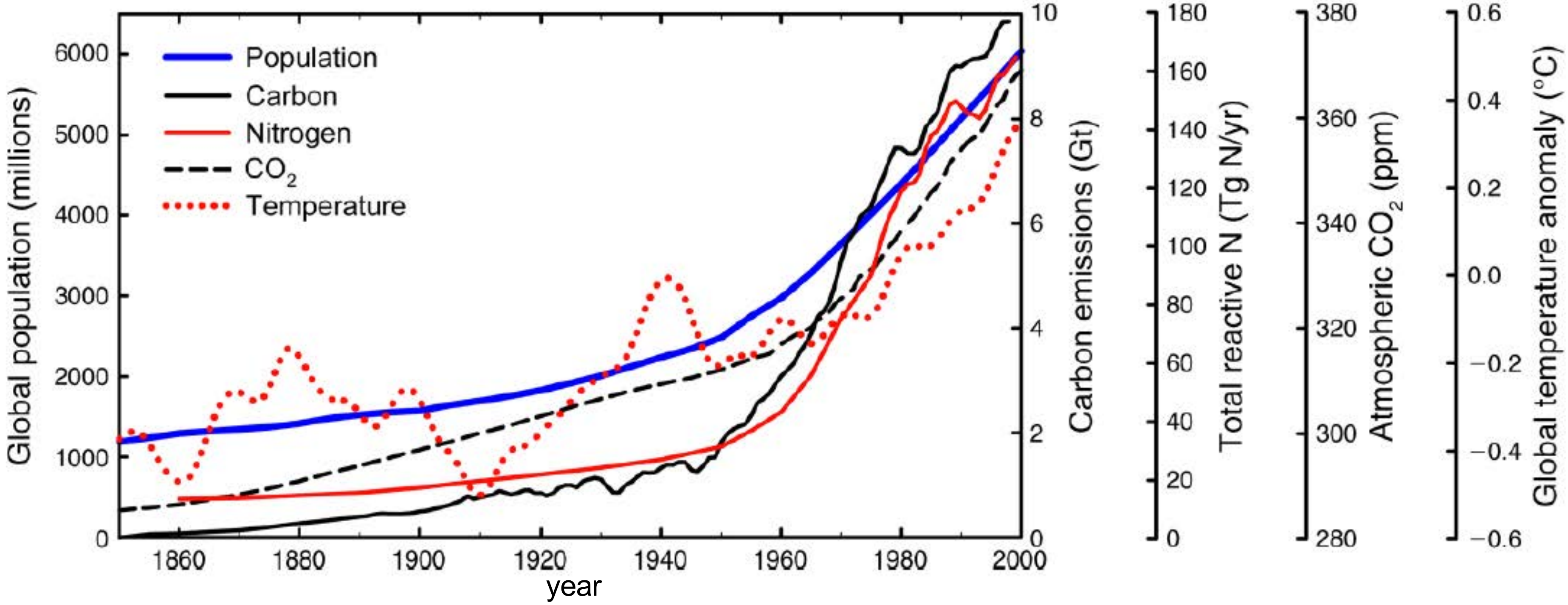
Ecosystem States

Conceptual Depiction of Ecosystem Stability against frequency /magnitude of perturbation

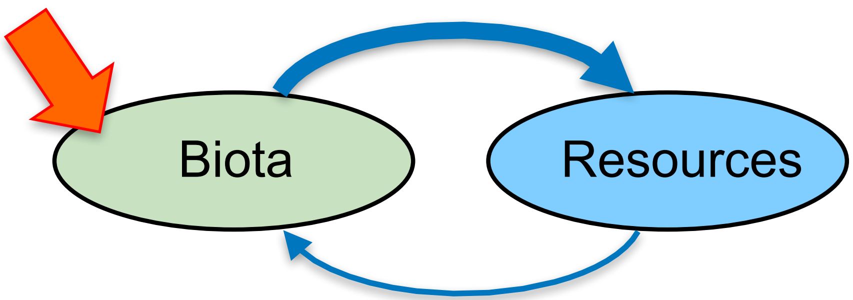


Chapin III, F.S., C. Folke, G.P. Kofinas, 2009. A framework for understanding change. In Principles of Ecosystem Stewardship. Springer, NY

Grand Challenge areas

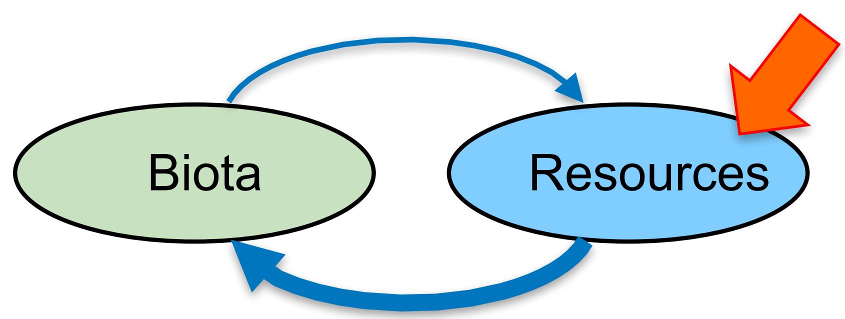


Discrete Disturbance



Natural Disturbance

Chronic Resource Alteration



Global Change

Smith, M.D., A.K. Knapp, and S.L. Collins. 2009. A framework for assessing ecosystem dynamics in response to chronic resource alterations induced by global change. Ecology 30:3279-3289

LESSONS LEARNED #1 + #2

1. ***Large scientific and societal imperatives*** to advance our understanding of ecosystem states and their future trajectories
2. ***The nature of anthropogenic change*** on ecosystem processes ***is different from classical stochastic disturbance ecology***—expect surprises!

NEON's Overarching Mission

NEON is charged to ***enable understanding* and *forecasting* of the *impacts*** of **Global Change** (e.g. *climate change, land use change* and *invasive species)* on *continental-scale* ***ecology*** by providing infrastructure to support research, education and to ***test basic ecological theory*** over *decadal timescales*.

CAUSES OF CHANGE

Climate Change: Understanding and predicting climate variability, including directional climate change and its impacts on natural and human systems

Land Use: Understanding and predicting changes in land use and land cover that are critical to biogeochemical cycling, ecosystem functioning and services, and human welfare.

Invasive Species: Understanding and forecasting the distribution of biological invasions and their impacts on ecological processes and ecosystem services.

Interactions ↔ *and Feedbacks*

RESPONSES TO CHANGE

Biogeochemistry: Understanding and predicting the impacts of human activities on the Earth's major biogeochemical cycles.

Biodiversity: Understanding the regulation of biological diversity and its functional consequences for ecosystems.

Ecohydrology: Understanding and predicting changes in freshwater resources and the environment.

Infectious Diseases: Understanding and predicting the ecological and evolutionary aspects of infectious diseases and of the interactions among pathogens, hosts/receptors, and ecosystems.

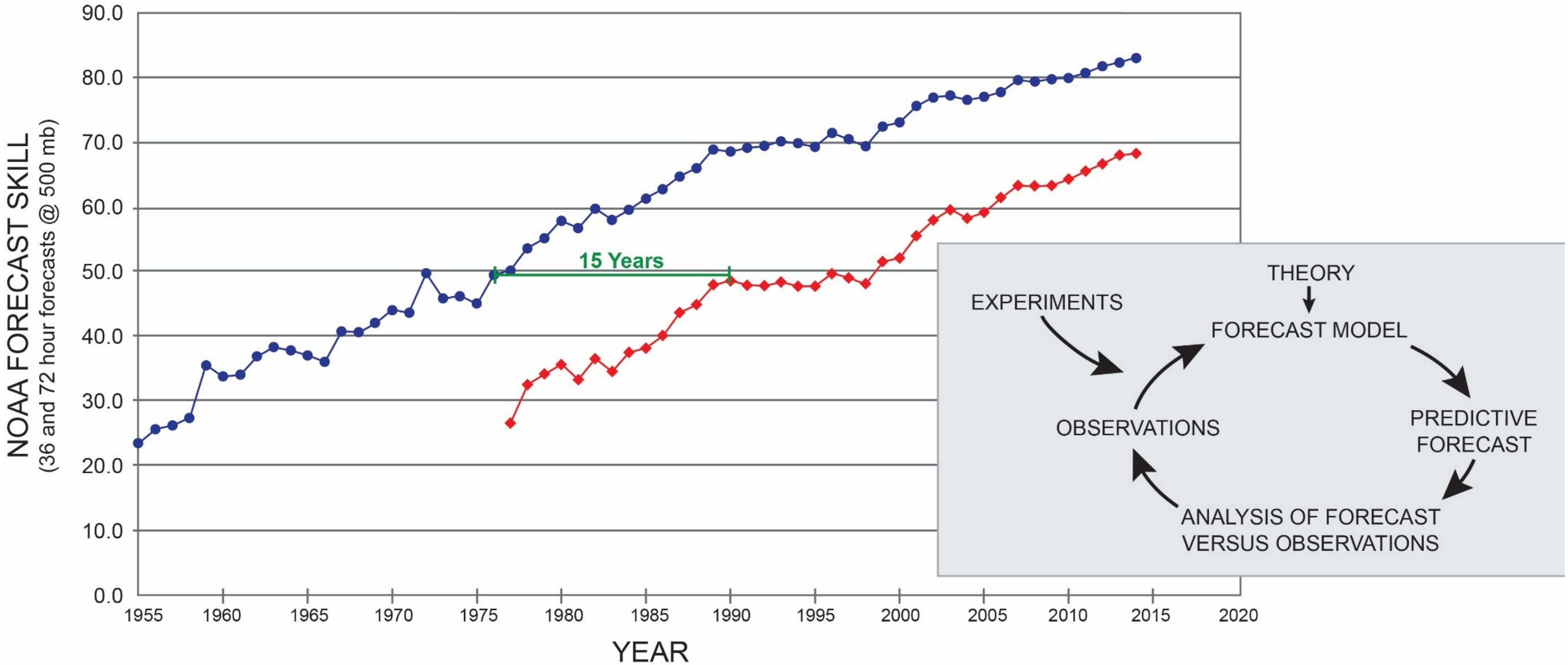
Key Elements of Ecological Forecasting

The overarching goal of NEON is
to enable understanding and forecasting of climate change, impacts of land use change, and invasive species on continental-scale ecology ***by providing infrastructure*** to support research in these areas.

Information infrastructure: Consistent, continental, long-term, multi-scaled data-sets and data products that provide a context for research and education.

Physical Infrastructure: A research platform for investigator-initiated sensors, observations, and experiments.

Ecological Forecasting



Improvements in NOAA weather forecasts come from repeated comparison between data and forecasts

Loescher, H. W., E. Kelly, and R. Lea, **2017.** National Ecological Observatory Network: Beginnings, Programmatic and Scientific Challenges, and Ecological Forecasting. In: *Terrestrial Ecosystem Research Infrastructures: Challenges, New developments and Perspectives.* Eds. A. Chabbi, **H.W. Loescher.** CRC Press Taylor & Francis Group. (in production)

How are Experiments and Observations related?

The need for observations of the starting point (**now**)

The need for quantitative information about specific processes -- **particularly non-linear and stochastic processes** (temperature sensitivity, susceptibility to drought, tipping points…)

- Estimates of system state
- Information on process parameters
- **Experiments/process studies to elucidate unknown processes and non-linear responses**
- Observations collected systematically over time and space to challenge iterative forecasts

A paradigm for Ecosystem / Ecological research?

LESSONS LEARNED #3 + #4 + #5 + #6 + #7

3. Plan, ***define your narrative clearly --***what you are doing scientifically?, and programmatically?

4. Adoption of ***the cause and effect paradigm***

5. μ/σ *verses* μ/σ

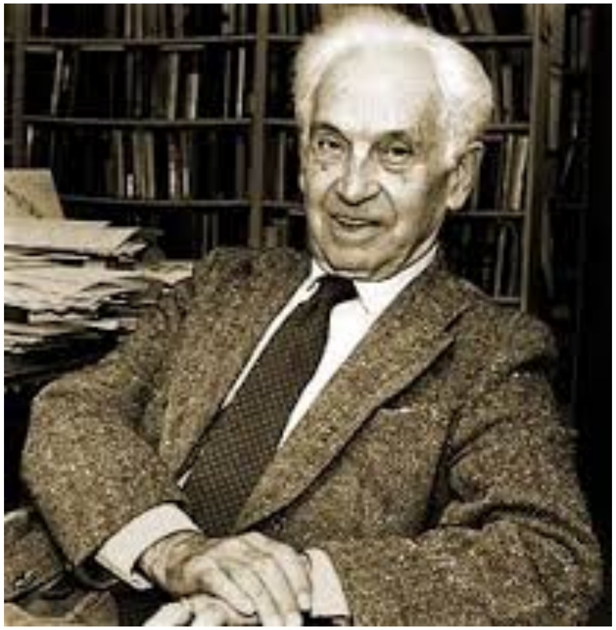
Phenomena of interest — Observation or experiment

6. Develop ***the ability to scale in time and space***

7. Adoption of ***an integrated framework to forecast ecology***

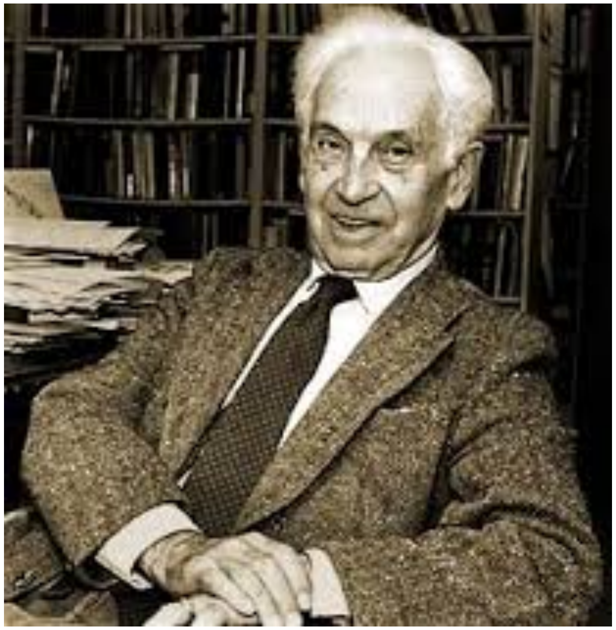
^ Philosophical

Ernst Mayr – 1904 to 2005



- biology ***were not simply reducible to mathematical formulae*** or to ***the laws of chemistry and physics***
- Criticized ***the reductionist behavior of ecologists***
- ***Establishing ecology as a legitimate science***

Ernst Mayr - *challenge to advance ecology*



External

- ***Apolitical science vs politicized science***
- ***Lacks the public/private discourse*** to communicate science
- ***Physical scientists dominate National Academies***
- Current challenge for ecology ***to meet societal imperatives is unclear***

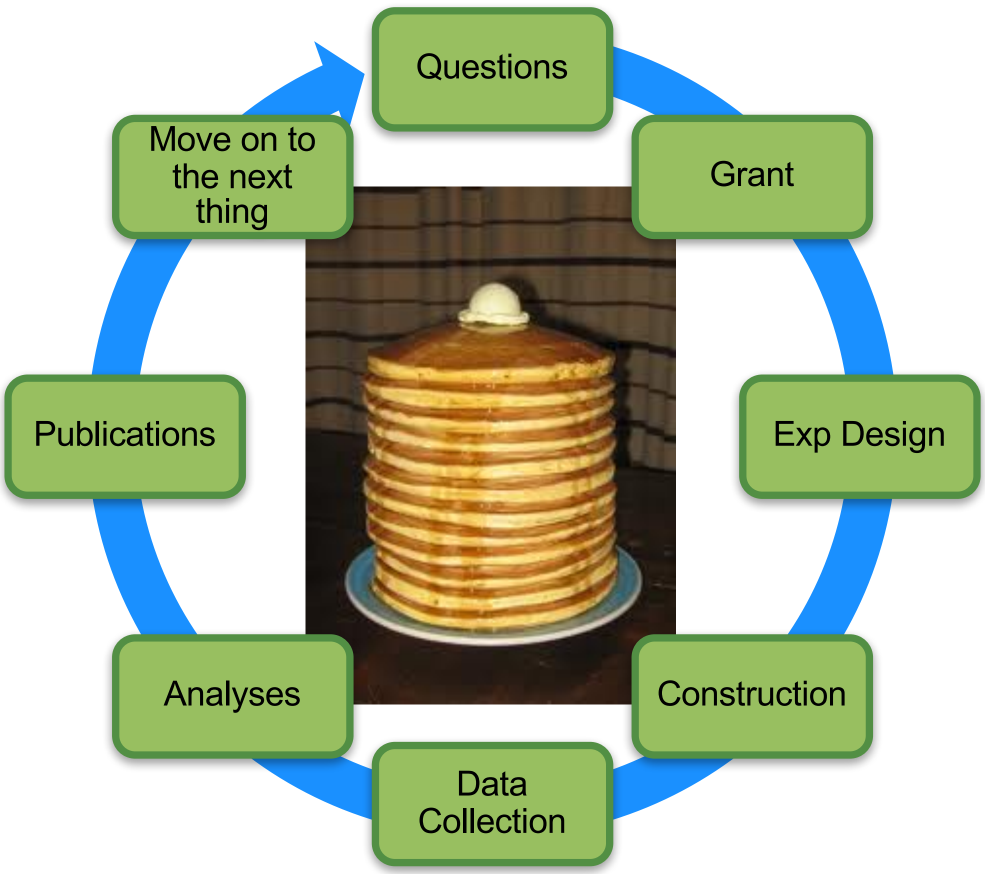
Internal

- ***Lack of universal laws***, and those that ***challenge theory***
- ***Confused understanding*** of nature, scope, goals of project (widespread)
- ***richly-complex time-variable problem***,
- ***Lacks the leadership in vision, management and science***
- Suffers from ***ego-saturation***
- Science: failure to launch – decade, ***near death experiences***

LESSONS LEARNED #8

8. Large cultural barriers, both internal and external, in the ecological community that limit the advancement of Ecology (**Culture Eats Everything** !!)

Balancing Scientific Creativity with developing Baseline Infrastructure / Programme



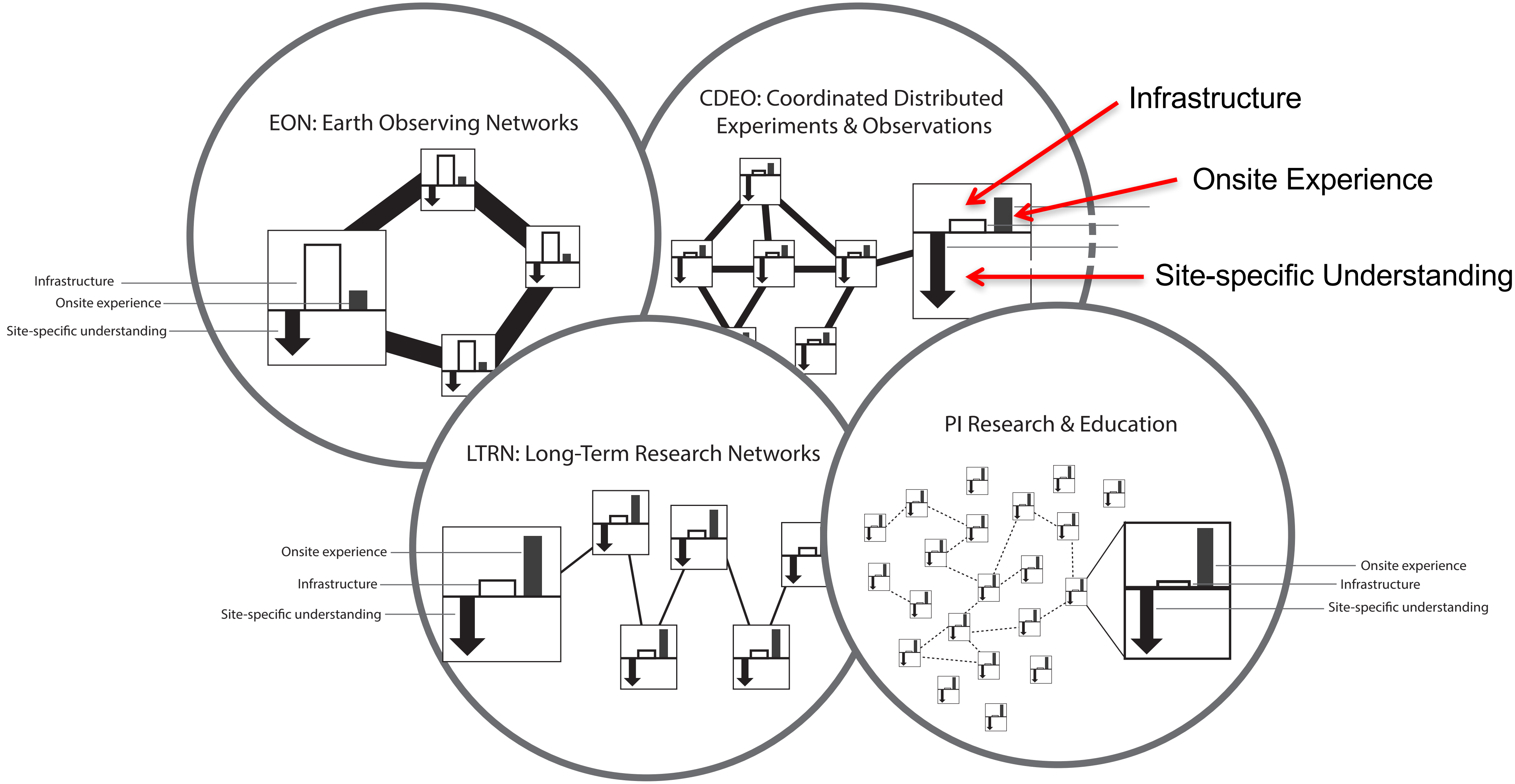
LESSONS LEARNED #9 + # 10

8. Large cultural barriers, both internal and external, in the ecological community that limit the advancement of Ecology (**Culture Eats Everything** !!)

9. Manage the ***balance*** between ***scientific creativity*** and establishing ***baseline infrastructure / programme***

10. Users are ***stakeholder*** and need to ***lead and co-develop*** from cradle-to-grave

Integration of Networks



Interoperability Framework

1. Aligning Science Questions and Hypotheses, Requirements, Mission Statements
   - Mapping Questions to 'what must be done'
   - Defines Joint Science Scope / Knowledge Gaps
   - define interfaces among respective Infrastructures

2. Traceability of Measurements
   - Use of Recognized Standards
   - Traceability to Recognized Standards, or First Principles
   - Known and managed signal:noise
   - Managing QA/QC
   - Uncertainty budgets

3. Algorithms/Procedures
   - What is the algorithm or procedural process to create a data product?
   - Provides "consistent and compatible" data
   - Managed through intercomparisons
   - What are their relative uncertainties?

4. Informatics
   - Standards – Data / Metadata formats
   - Persistent Identifiers / Open-source
   - Discovery tools / Portals
   - Ontologies, semantics and controlled vocabularies

LESSONS LEARNED #11 + # 12

8. Large cultural barriers, both internal and external, in the ecological community that limit the advancement of Ecology (**Culture Eats Everything** !!)

9. Manage the ***balance*** between ***scientific creativity*** and establishing ***baseline infrastructure / programme***

10. Users are ***stakeholder*** and need to ***lead and co-develop*** from cradle-to-grave

11. Define and establish ***INTEROPERABILITY***

12. ***Be surprised*** and filled with wonder about the natural (and anthropocene) world!! Embrace change!!

Issues, Challenges and Path Forward

Large Expectations for Societal Benefit

Integrating Environmental Data is Truly a Frontier Science + Grand Challenge

Collective - Community Process - Many Stakeholders

The Environmental Community Building Critical Mass but Broad Adoption and Evolution of Cultures remains a Challenge

Large need to Train and Educate New Cohorts of Users

Take Leadership

Thank You

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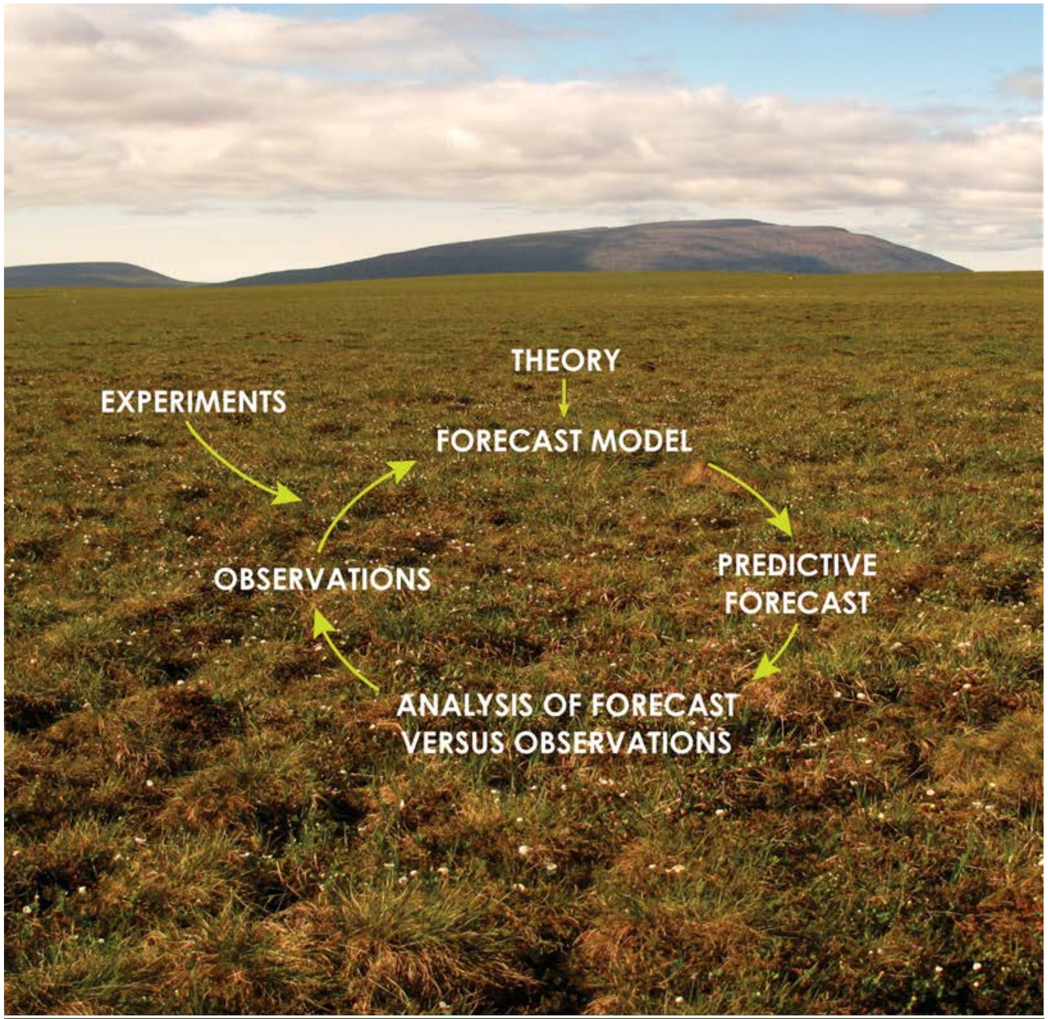


TERRESTRIAL ECOSYSTEM RESEARCH INFRASTRUCTURES
CHALLENGES, NEW DEVELOPMENTS AND PRESPECTIVES

Editors Abad Chabbi and Henry W. Loescher

CRC Press
Taylor & Francis Group

Publication date Jan 20, 2017

CORE OF TODAY'S ECOSYSTEM SCIENCE

… supports investigations of ecosystem structure and function across a diversity of spatial and temporal (including paleo) scales to advance understanding of:

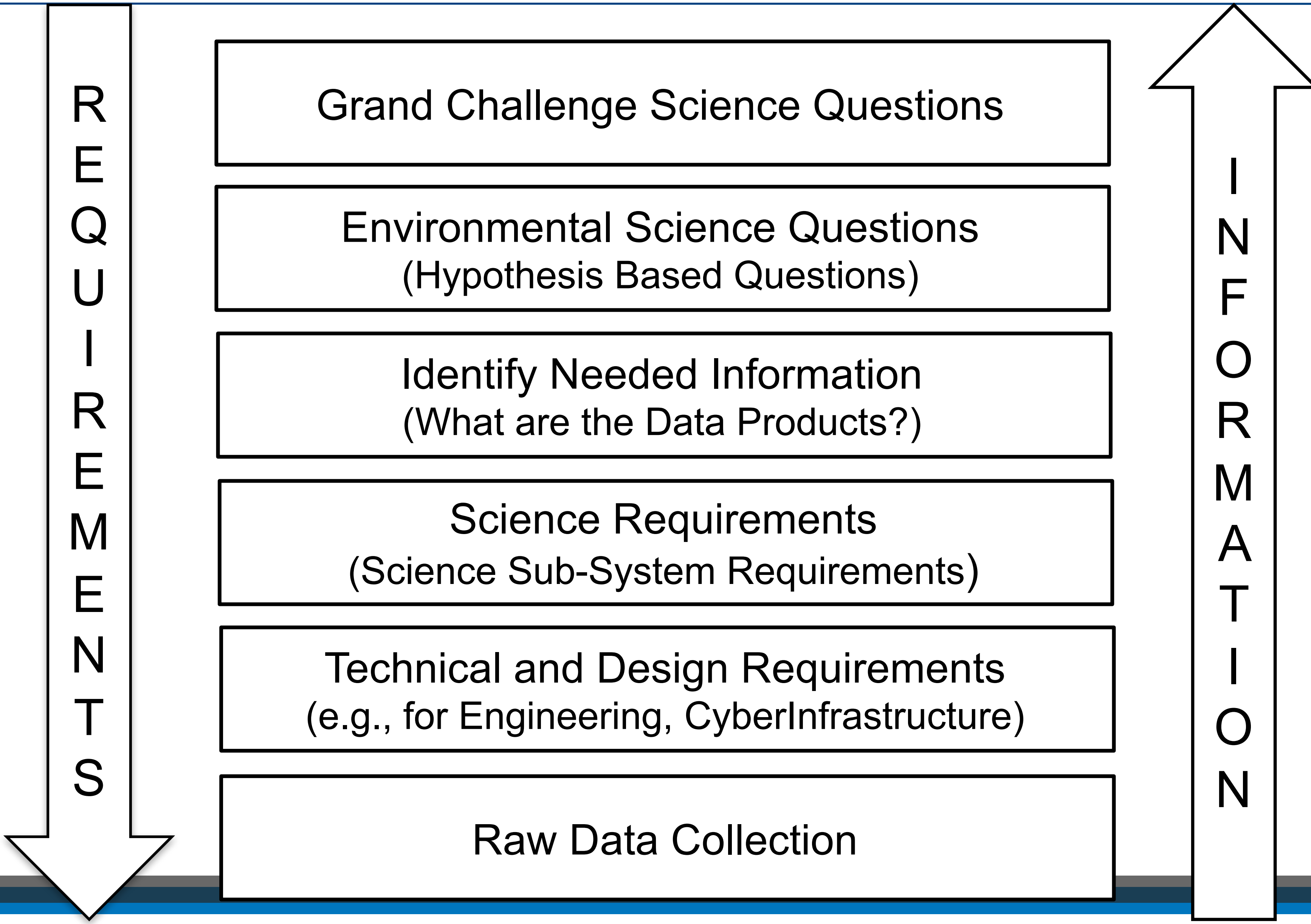
1) **material and energy fluxes and transformations** within and among ecosystems;

2) roles and relationships of ecosystem components in whole-system **structure and function**;

3) ecosystem dynamics, **stability, resilience, and trajectories** of ecosystem change through time; and

4) linkages among ecosystems in space, time, and across **spatial and temporal scales**.

NEON's Scientific / System Engineering Approach



GARTNER HYPE CYCLE