The National Ecological Observatory Network: Science strategy, data collection and products

Michael Keller* & NEON Project Team

*USDA Forest Service, Former Chief of Science, NEON Inc.

NEON GOALS

The overarching goal of NEON is to enable understanding and forecasting of the impacts of climate change, 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 serve as a context for research and education.

- **Physical Infrastructure:** A research platform for investigator-initiated sensors, observations, and experiments providing physical infrastructure, cyberinfrastructure, human resources, and expertise, and program management and coordination.

NEON's Scientific Approach

Forcing

Interactions
Feedbacks

Responses

Climate Change
Land-Use Change
Invasive Spp.

Spp. Composition
Phenology
Physiology
Stoichiometry
+
+
+

Biodiversity
Biogeochemistry
Ecohydrology
Infectious Disease

GRAND CHALLENGES

Forcing
Climate, Land Use
Invasives

Interactions, Feedbacks
Productivity, Functional Diversity,
Soil Moisture, Habitat Structure, etc.

Responses
Biodiversity, Biogeochemical,
Disease, Ecohydrology

Lead to focused questions that NEON can address on continental scales...

What implications do breeding bird phenological shifts have for West Nile Virus disease risk?

How does the changing pattern of land use affect terrestrial productivity at the continental scale?

What is the aquatic biological response to sustained increases in nutrients?

How are the rates of geographic spread and population growth of invasive species affected by land use and climate change?

That require specific data products to answer the questions...

Bird diversity; West Nile Virus prevalence in mosquitos

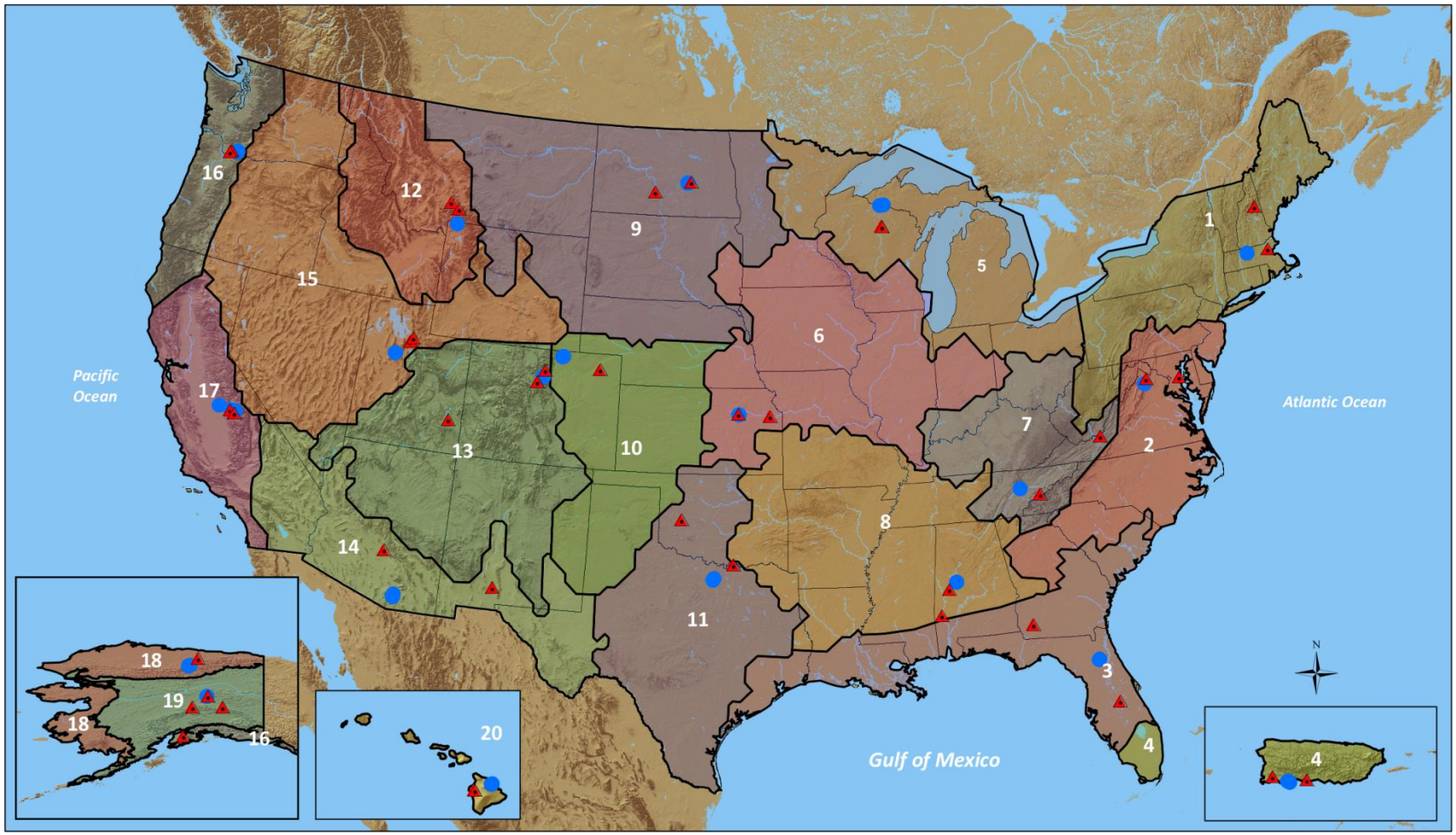
Benthic macro-invertebrate diversity and abundance; Stream metabolism

Land cover classification; Ecosystem exchange of carbon

Invasive species risk maps; Historical Climate Data

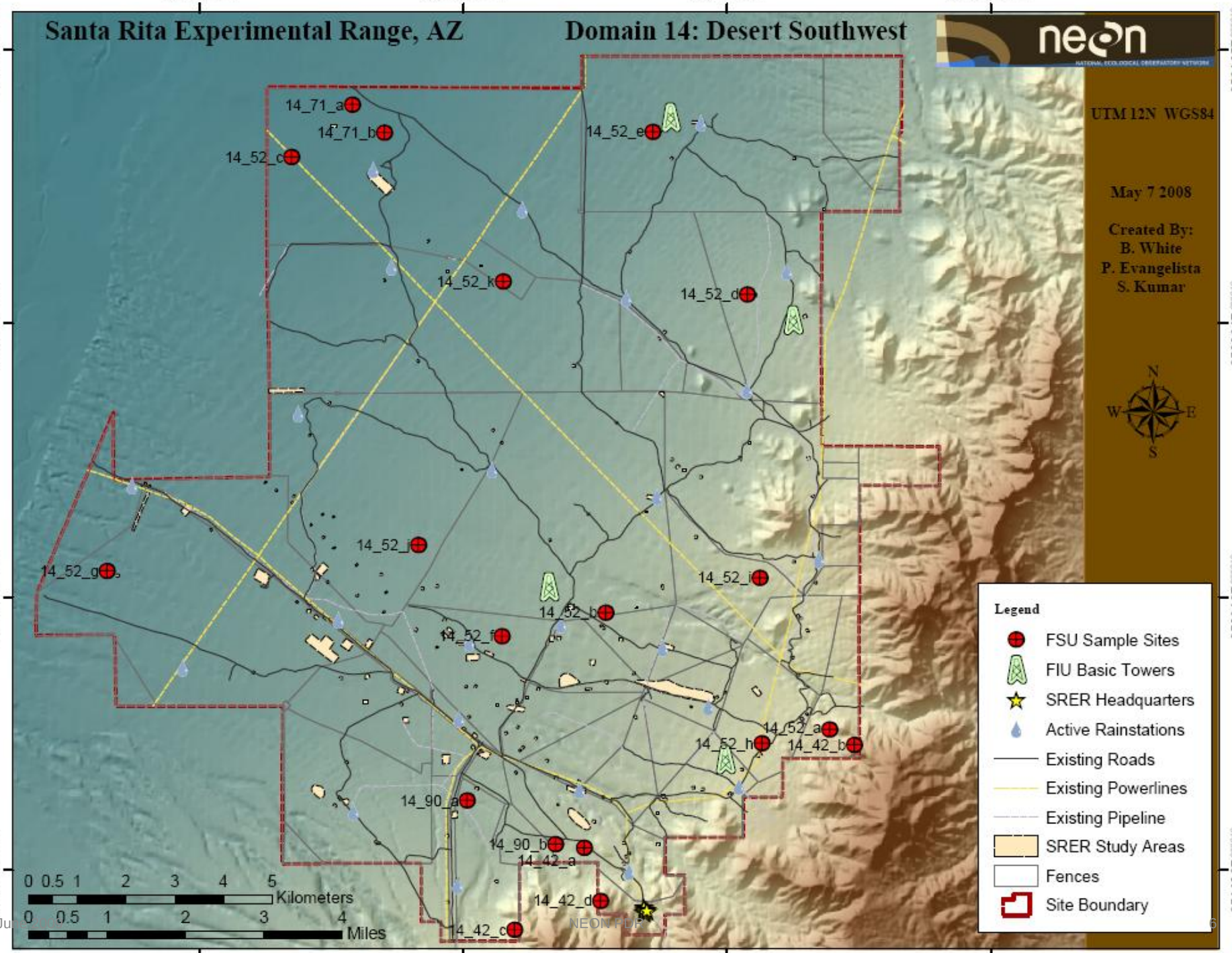
And NEON's infrastructure supports science packages that provide the measurements required to produce the data products

A National Observatory: 20 Eco-climatic Domains



NEON Domains

1 Northeast
2 Mid Atlantic
3 Southeast
4 Atlantic Neotropical
5 Great Lakes
6 Prairie Peninsula
7 Appalachians/Cumberland Plateau
8 Ozarks Complex
9 Northern Plains
10 Central Plains
11 Southern Plains
12 Northern Rockies
13 Southern Rockies/Colorado Plateau
14 Desert Southwest
15 Great Basin
16 Pacific Northwest
17 Pacific Southwest
18 Tundra
19 Taiga
20 Pacific Tropical


Santa Rita Experimental Range, AZ
Domain 14: Desert Southwest
neon
NATIONAL ECOLOGICAL OBSERVATORY NETWORK
UTM 12N WGS84
May 7 2008
Created By:
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P. Evangelista
S. Kumar
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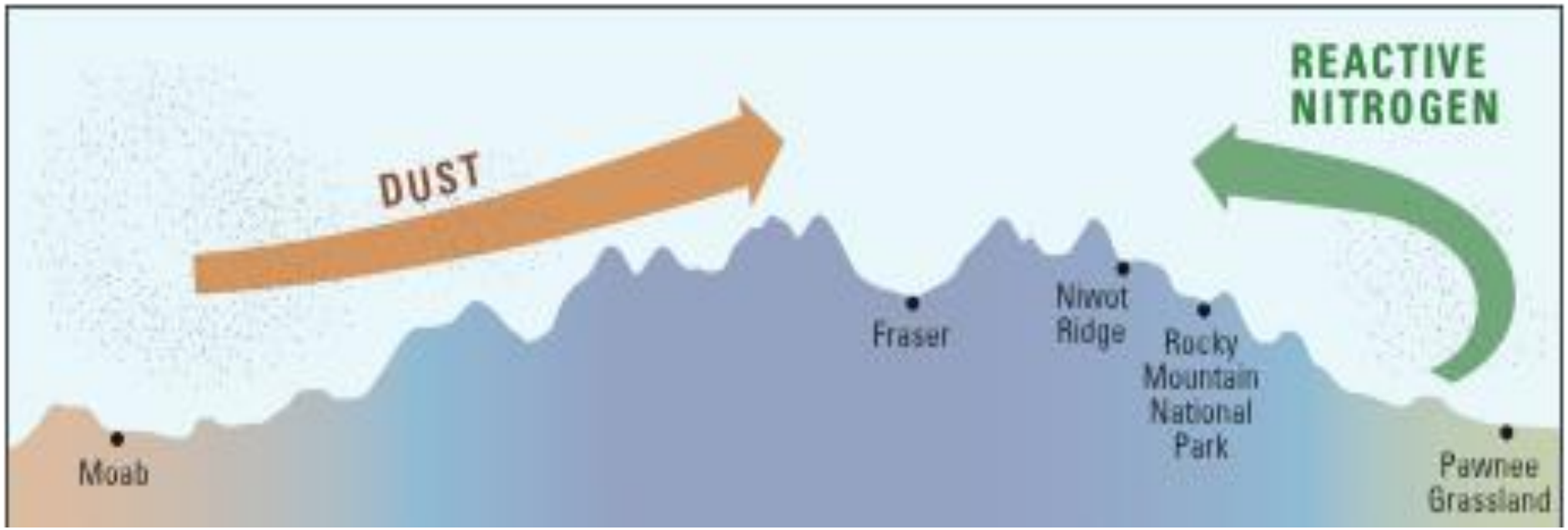
0 0.5 1 2 3 4 5 Kilometers
0 0.5 1 2 3 4 Miles
Legend
FSU Sample Sites
FIU Basic Towers
SRER Headquarters
Active Rainstations
Existing Roads
Existing Powerlines
Existing Pipeline
SRER Study Areas
Fences
Site Boundary

An example relocatable deployment



NEON Deployment

- Headquarters (incl. CI, labs, etc.) - Boulder
- 20 Domains
  - 20 Core sites (wildland)
  - 40 Relocatable sites (land-use sites)
- 10 Mobile laboratories (AK, HI, CONUS+PR)
- 3 Airborne Observation Platforms
- Land Use Analysis Package
- STREON Experiment

NEON Science Facilities (subsystems)

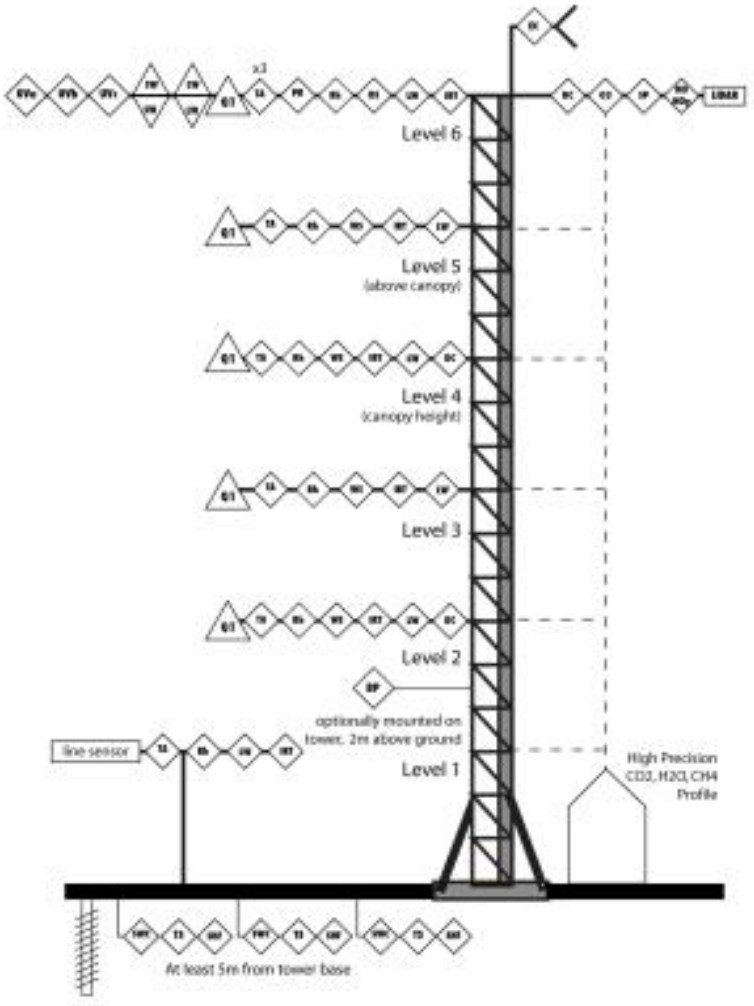
FSU	Fundamental Sentinel Unit	Human Observers/Samplers
FIU	Fundamental Instrument Unit	Automated Instrumentation
AOP	Airborne Observation Package	Aircraft Remote Sensing
LUAP	Land Use Analysis Package	Satellite Remote Sensing +

Fundamental Sentinel Unit

- Biodiversity
- Population Dynamics
- Productivity
- Phenology
- Infectious Disease
- Biogeochemistry
- Microbial Diversity and Function
- Ecohydrology

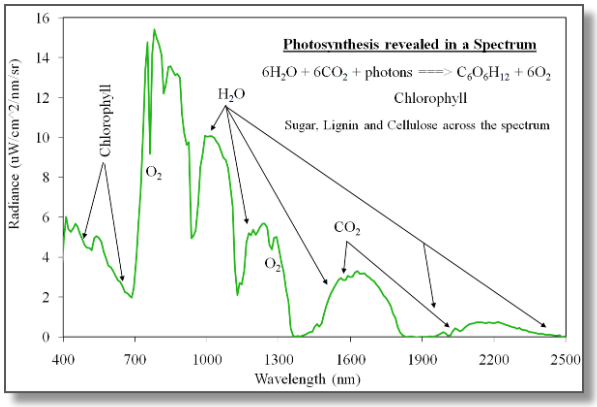
Fundamental Instrument Unit

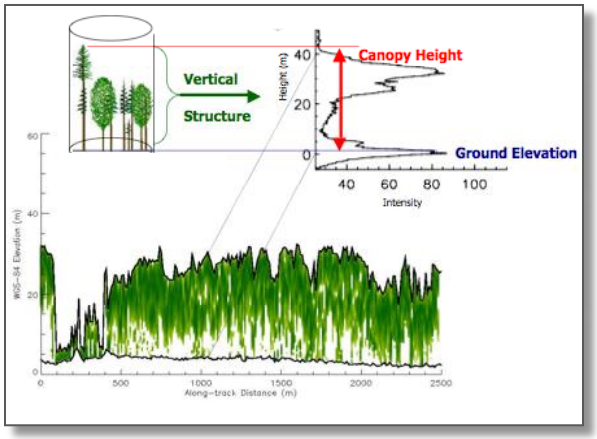
- Physical and chemical climate forcing
- Ecosystem responses
- Stand/plot level sampling
- Automated instrumentation
- Micrometeorological scalars and fluxes
- Soil array
- Aquatic array
- Over 2000 measurements per core site at frequencies of ~0.1 to 20 Hz

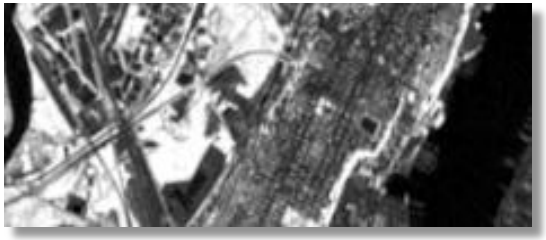


Airborne Remote Sensing (AOP)

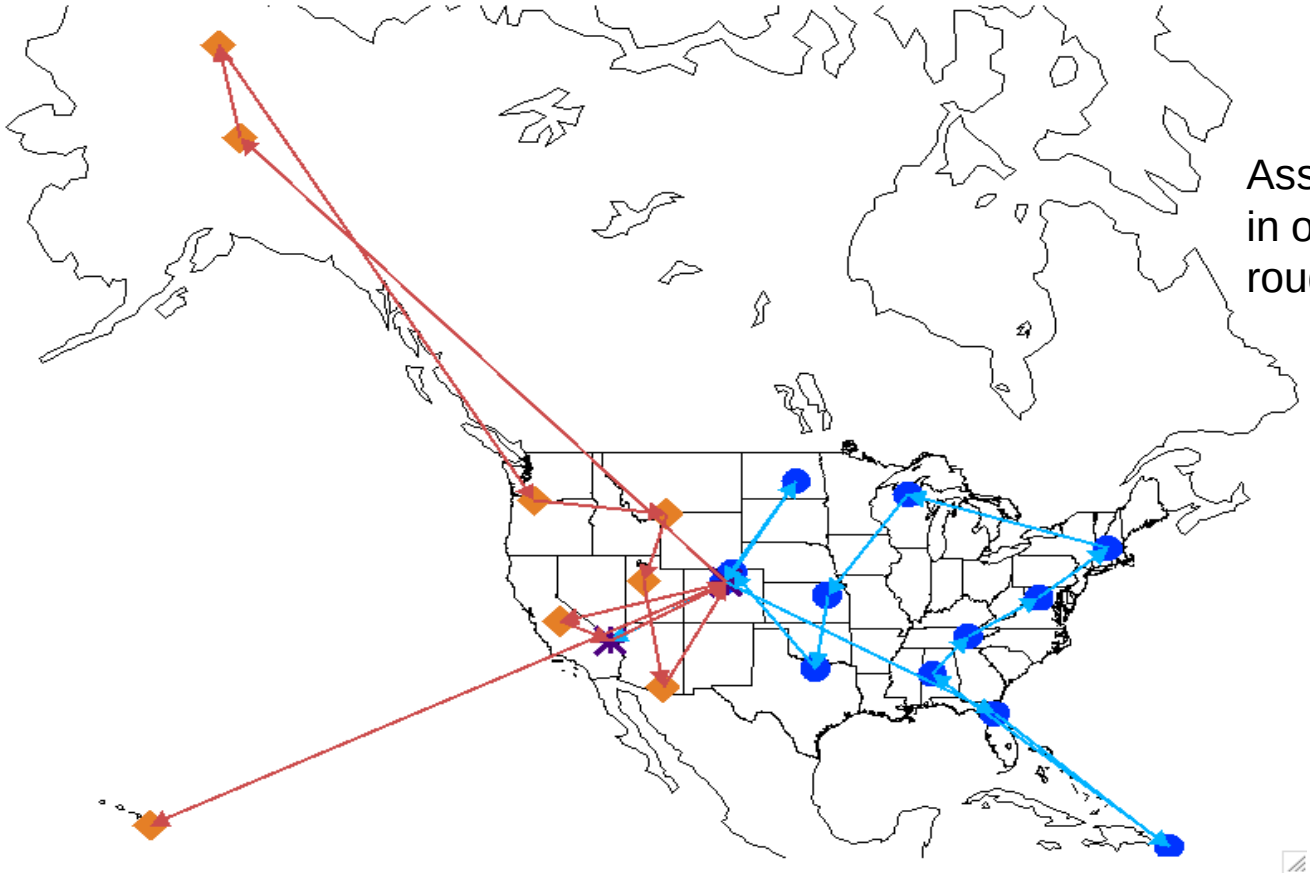
- Spectroscopy
  - Vegetation biochemical & biophysical properties
  - Cover type & fraction
- LiDAR altimetry
  - Vegetation Structure
  - Sub-canopy topography
  - biomass
- High resolution imagery
  - Land use & land cover







Notional Flight Plan for Standard Observations of NEON Core and Relocatable Sites

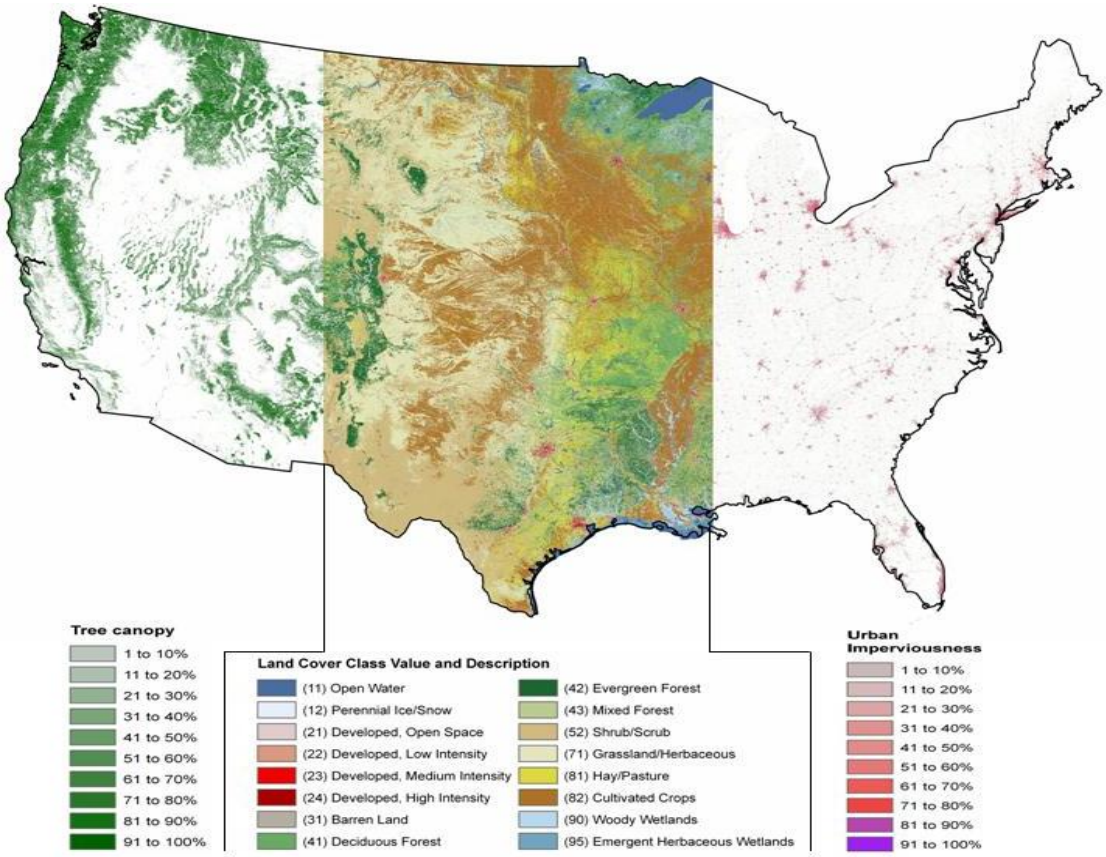


Assumes 2 payloads in operation from roughly April to Sept

*Notional flight plan for payload 1 (blue dots) and payload 2 (orange diamonds). The location of the vicarious ground site is indicated by the *. This flight plan has been optimized to survey each domain at its period of peak greenness and when cloud cover is expected to be minimal.*

Land Use Analysis Package

- Continental coverage
- Land cover
- Land use
- Vegetation biophysical properties
- Geographic data including census data
- User interface to facilitate geographic analysis by the non-specialist



STREON Experiment

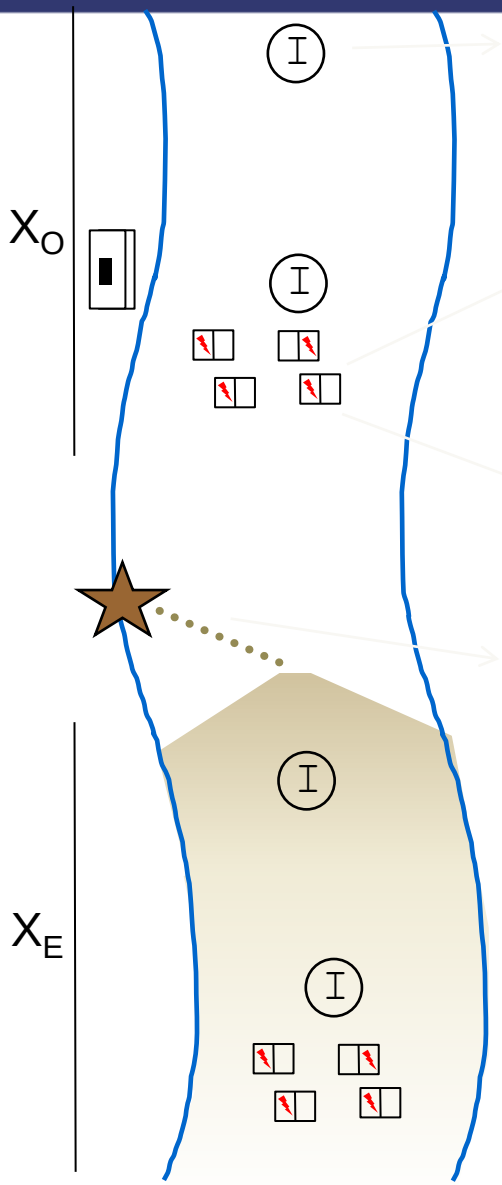
NEON control reach

X_O

water flow

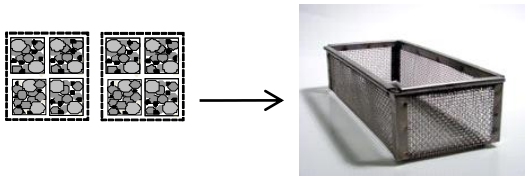
STREON treatment reach

X_E



Instrument station, water sampling site

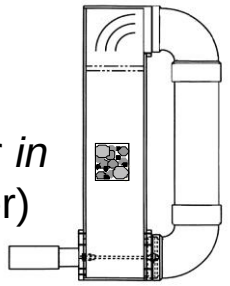
Experimental units (baskets)



Consumer exclosure
(electrified barriers)

Nutrient addition station

Basket incubation
(e.g. streamside flume or *in situ* recirculation chamber)



Spatial Scaling Strategy

LUAP

AOP

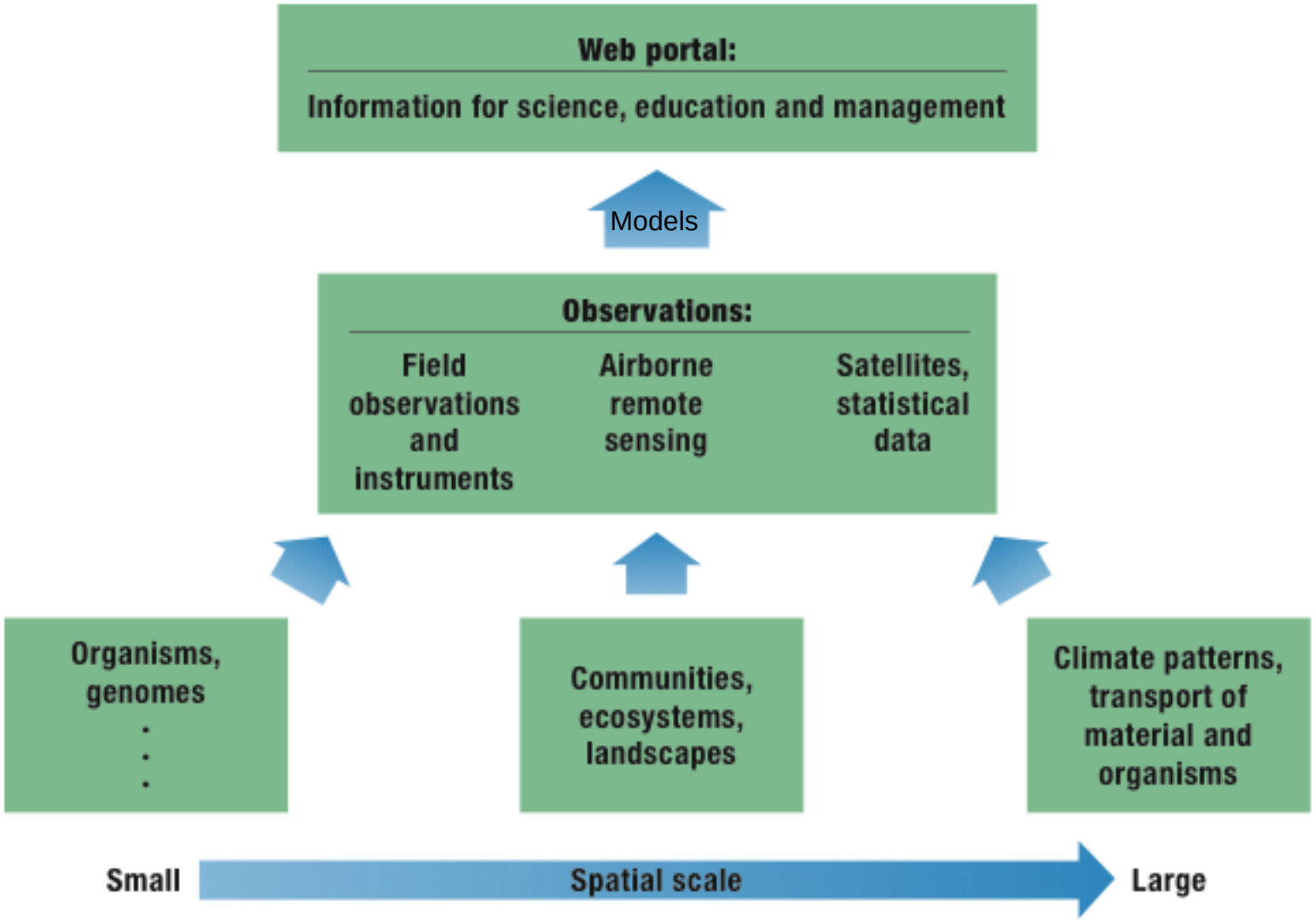
FIU

Mobile Labs

FSU+ AQS

Ecological Forecast models

Cascade of multi-scaled information from observations through analyses to users



Low and High Level Data Products

Level 1-3 Products

Winds, CO_2 concentration, H_2O vapor concentration

Minirhizotron Images

Small mammal species ID, small mammal age, small mammal gender

Flux assimilation model

Image analysis calibration

Mark-recapture model

Level 4 Products

Carbon and water fluxes and parameters: GPP, R_A, R_H, WUE, A_{max}

Root phenology

Population parameters: abundance, survival, recruitment, fecundity

539 L1 products + 35 L2-L3 products

118 L4 products

Key NEON Data

- Bioclimate Suite
  - Temperature, precipitation, humidity, radiation

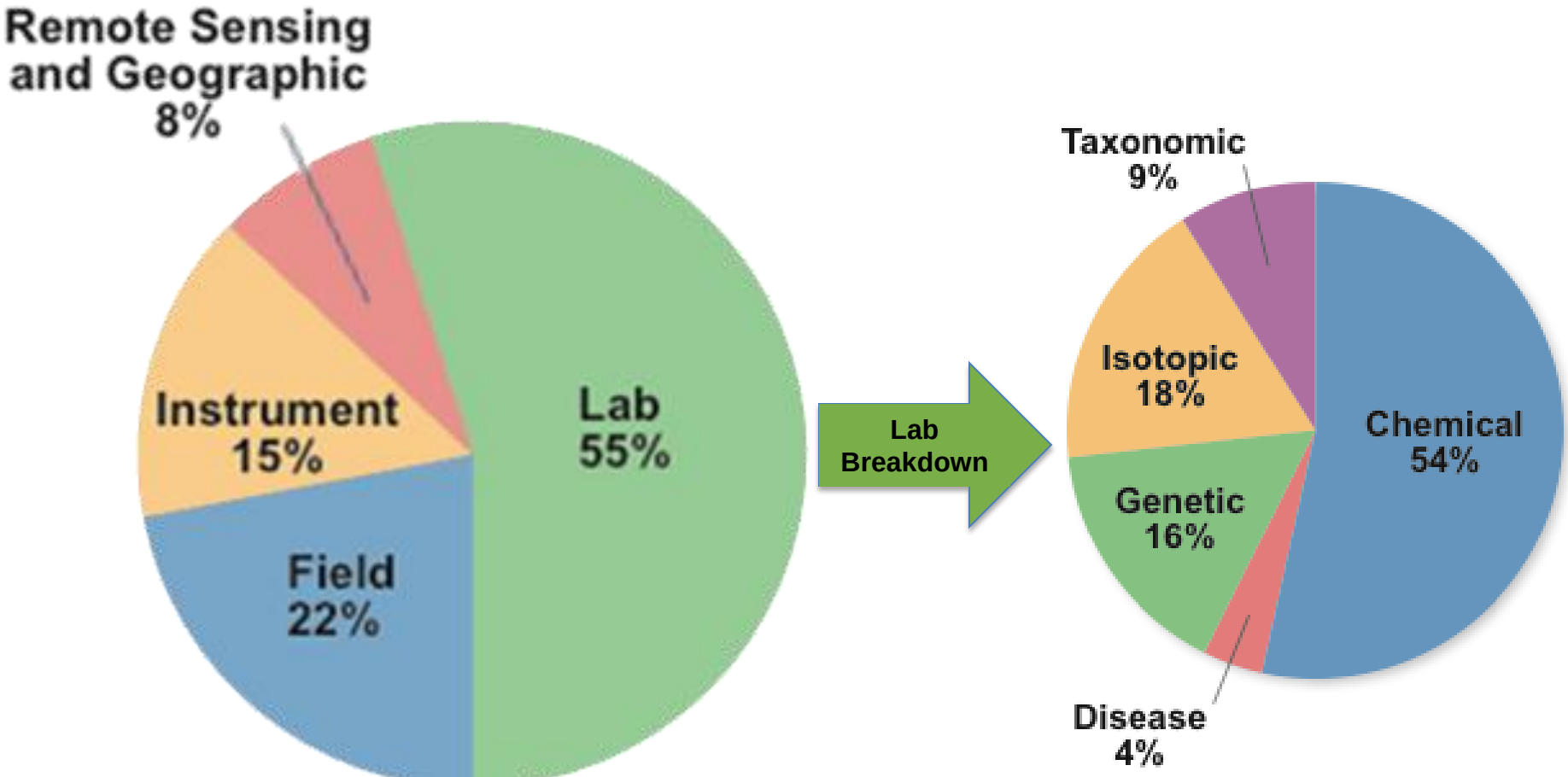
- Biodiversity Suite (includes invasive spp.)
  - Abundance and diversity (mosquitoes, aquatic invertebrates, beetles, fish, birds, plants, …)
  - Phenology (mosquitoes, beetles, plants)
  - Microbial function and diversity (functional genes, metagenomes)
  - Bioarchive (all taxa, substrates)

- Biogeochemistry Suite
  - Carbon stocks, fluxes, isotopes
  - Nutrient stocks, fluxes, isotopes
  - Chemical climate (N-deposition, Ozone)

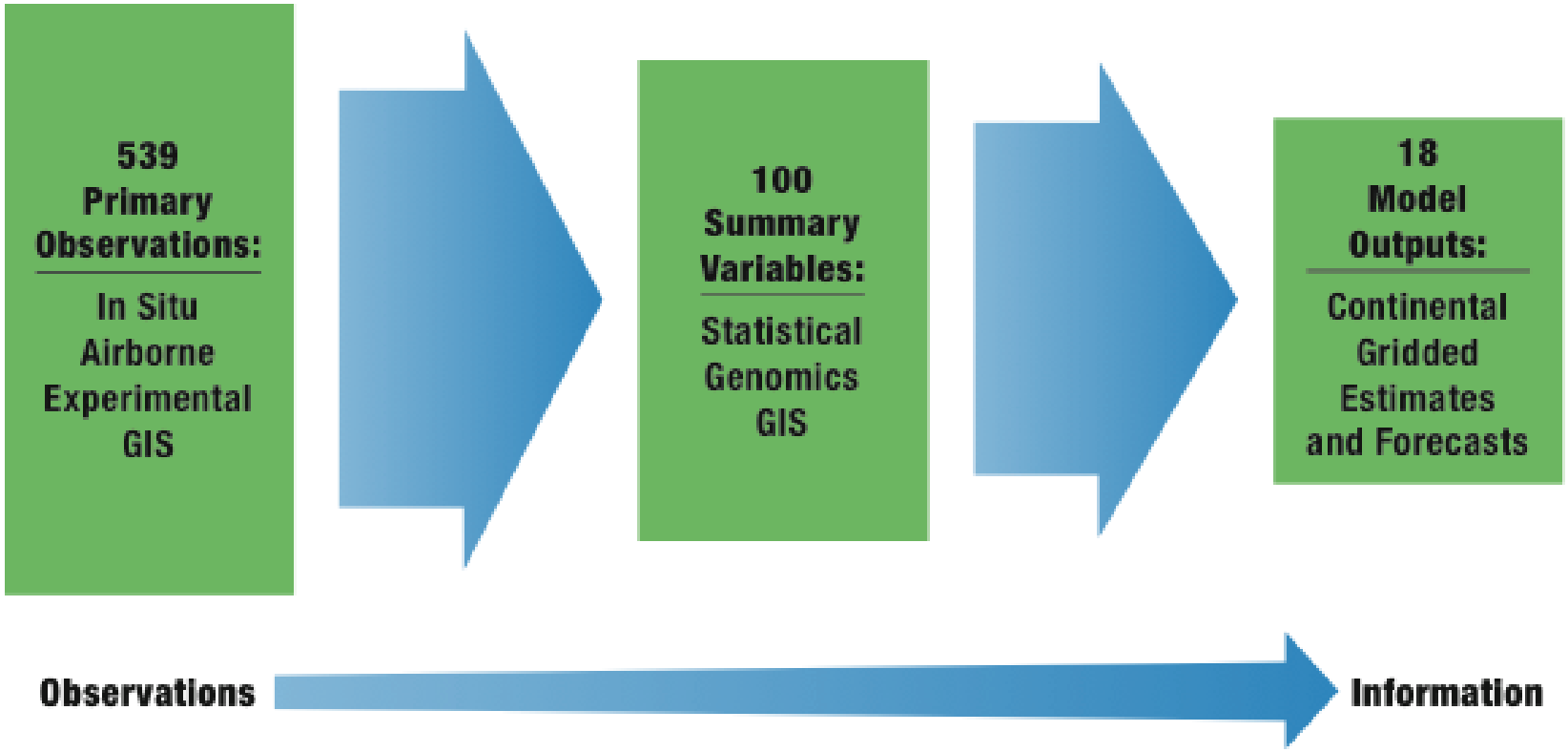
Key NEON Data

- Ecohydrology Suite
  - Water balance components (storage and flows)
- Infectious Disease Suite
  - Disease prevalence (Dengue, Hanta virus, Lyme disease, West Nile Virus)
- Land Use and Land Cover Suite
  - Remote sensing data (vegetation performance and structure)
  - Geographic data (topography, historical climate, etc.)
  - Statistical data (human geography)

NEON Level 1 Data Products



Information Processing

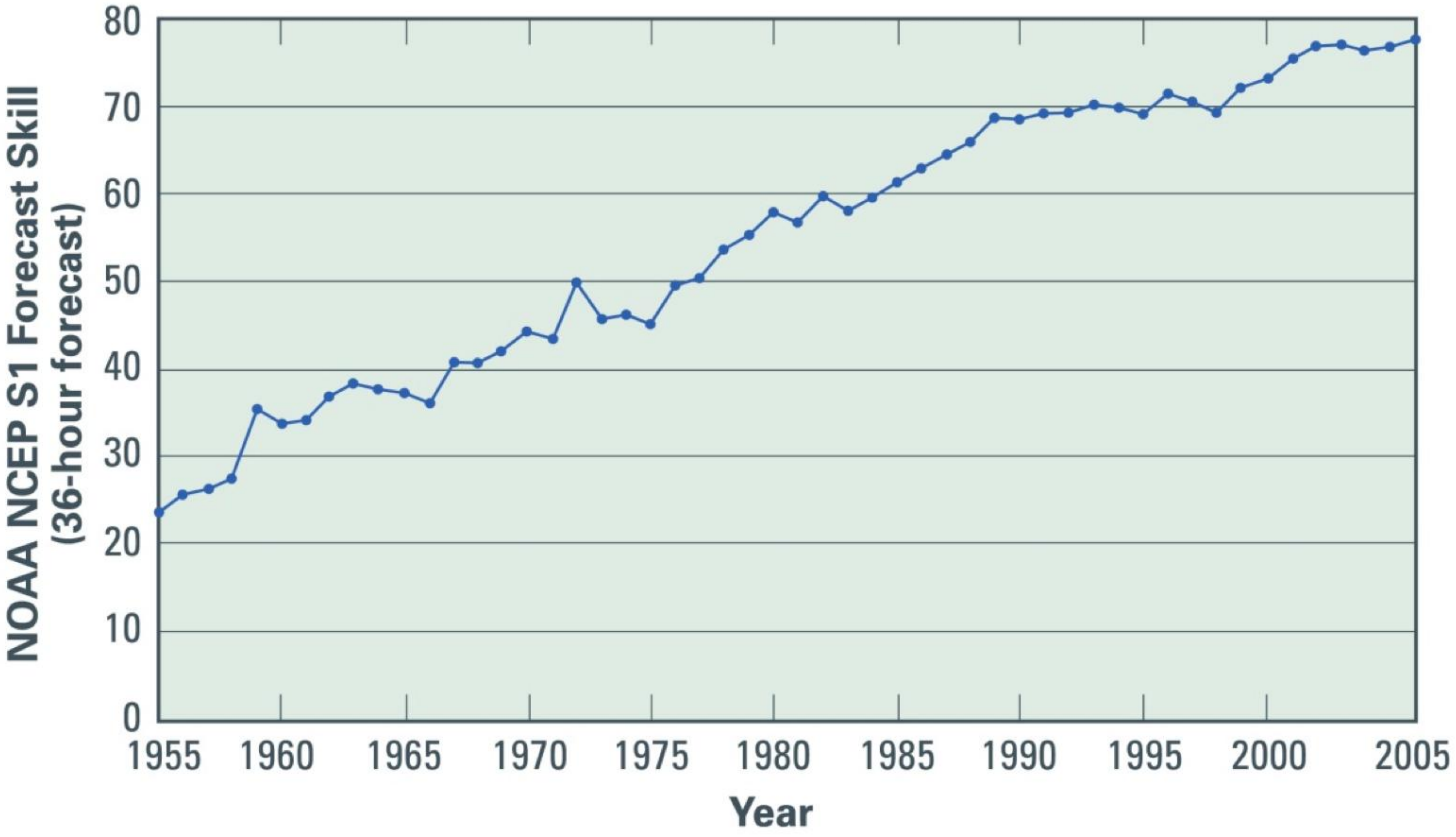


The overarching goal of NEON is to enable understanding and *forecasting* of climate change, land use change, and invasive species on continental-scale ecology by providing infrastructure to support research in these areas.

Ecological Forecasting

- What is the most likely future state of an ecological system?
- What-if: what is the most likely future state of a system given a decision today?

Data and Forecasting



Improvements in forecasts come from repeated comparison between data and forecasts

Science Case 1- Infectious Disease

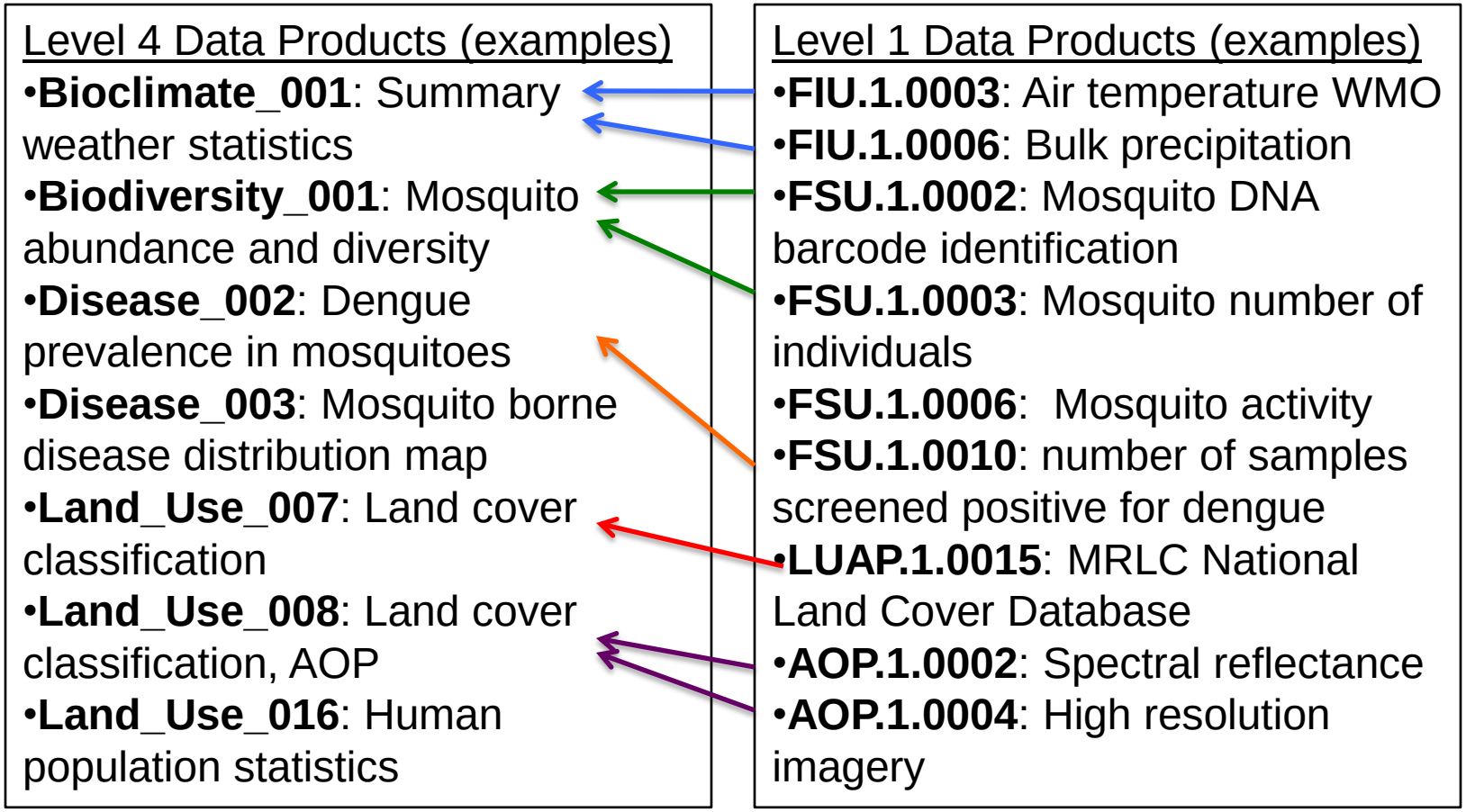
Question: How will climate change affect the spread of mosquito-borne diseases? The specific case of dengue fever.
Approach: Climate envelop model for Aedes aegypti (vector for dengue fever)

Level 4 Data Products (examples)
- **Bioclimate_001**: Summary weather statistics
- **Biodiversity_001**: Mosquito abundance and diversity
- **Disease_002**: Dengue prevalence in mosquitoes
- **Disease_003**: Mosquito borne disease distribution map
- **Land_Use_007**: Land cover classification
- **Land_Use_008**: Land cover classification, AOP
- **Land_Use_016**: Human population statistics

Level 1 Data Products (examples)
- **FIU.1.0003**: Air temperature WMO
- **FIU.1.0006**: Bulk precipitation
- **FSU.1.0002**: Mosquito DNA barcode identification
- **FSU.1.0003**: Mosquito number of individuals
- **FSU.1.0006**: Mosquito activity
- **FSU.1.0010**: number of samples screened positive for dengue
- **LUAP.1.0015**: MRLC National Land Cover Database
- **AOP.1.0002**: Spectral reflectance
- **AOP.1.0004**: High resolution imagery

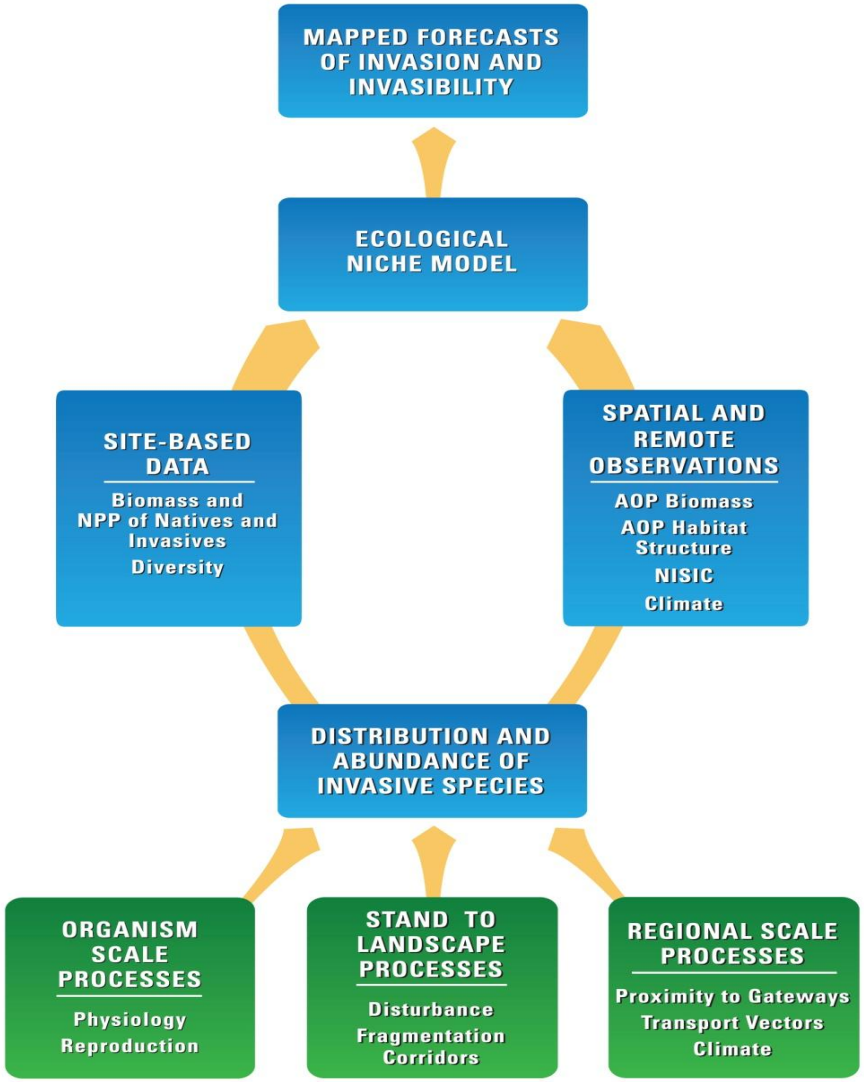
Science Case 1- Infectious Disease

Question: How will climate change affect the spread of mosquito-borne diseases? The specific case of dengue fever.
Approach: Climate envelop model for Aedes aegypti (vector for dengue fever)



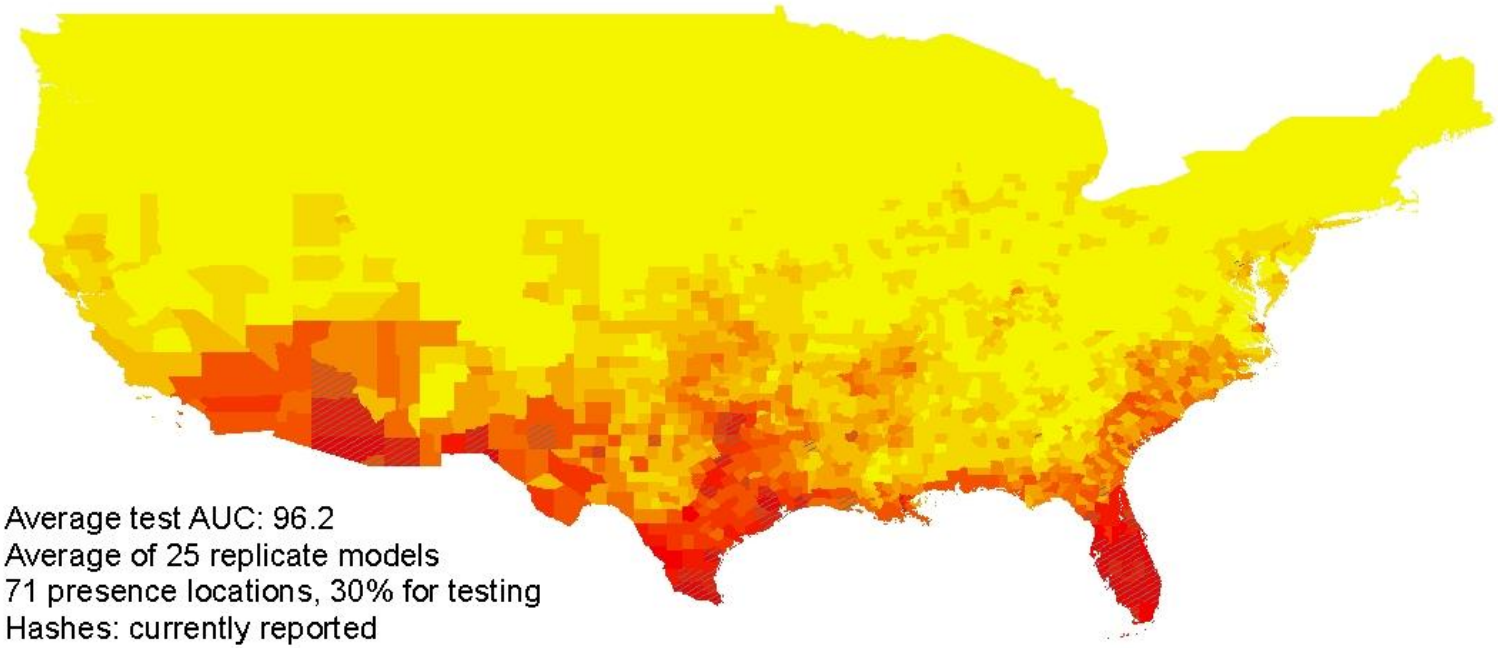
Integration of NEON data to produce analyses and forecasts

Potential NEON Invasive Species Analysis and Forecast



Science Case 1 – Infectious Disease

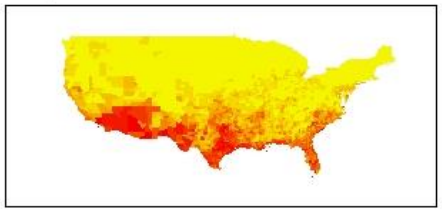
County habitat suitability for Aedes aegypti



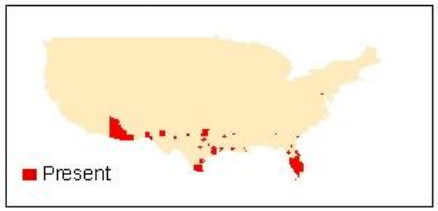
Average test AUC: 96.2
Average of 25 replicate models
71 presence locations, 30% for testing
Hashes: currently reported

Created with: Maxent v 3.2.19

Replicate model deviation



Current reported distribution



Greatest variable contribution (avg):
Annual mean temperature (54.2%)
Urban area (14%)
Mean temperature of wettest quarter (10.9%)
Mean temperature of coldest quarter (10.7%)

T. Stohlgren, unpublished

Science Case 2- Biogeochemistry

Question: How will climate change affect US ecosystem carbon uptake?
Approach: Carbon data-assimilation model

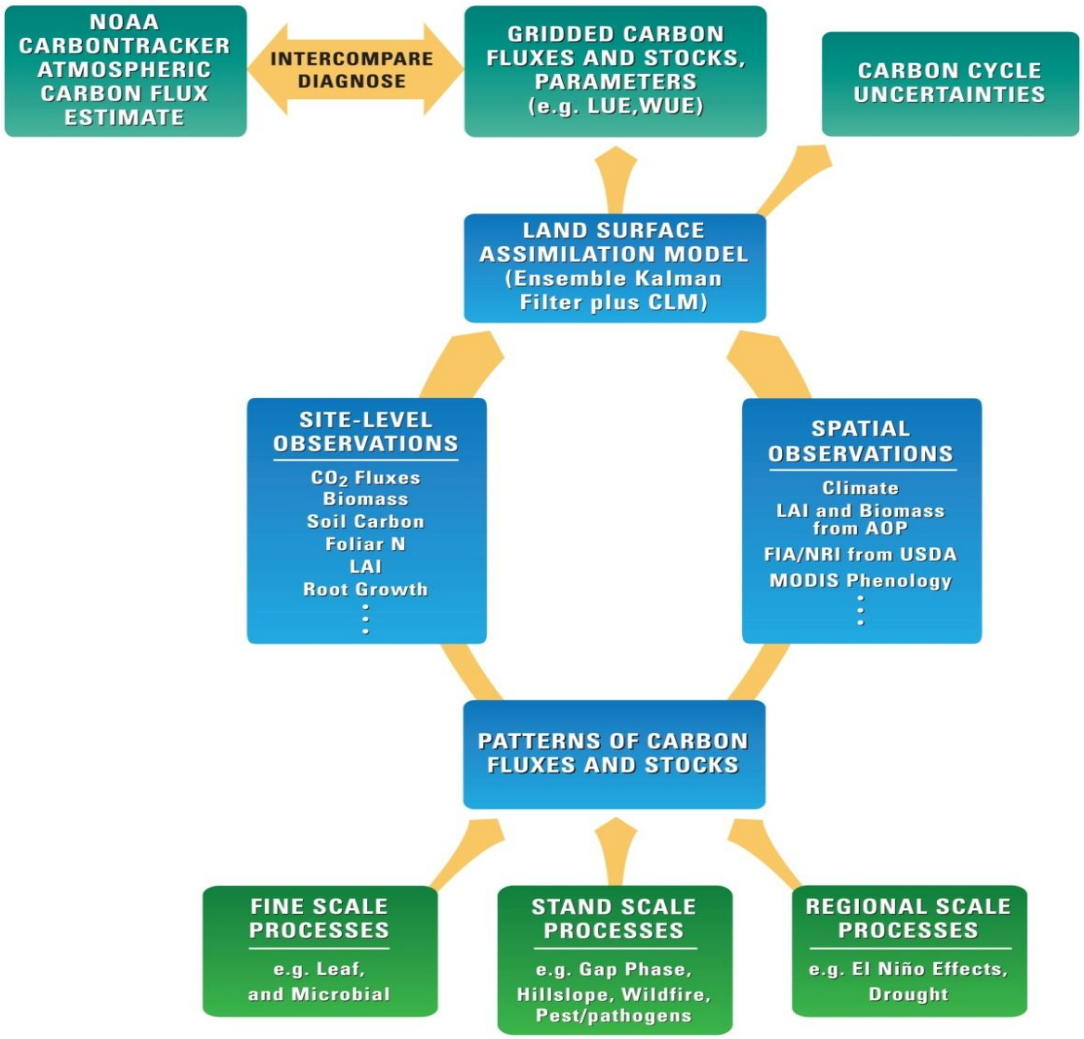
Level 4 Data Products (examples)

- **Bioclimate_001**: Summary weather statistics
- **Biogeochemistry_017**: Ecosystem exchange, tower
- **Biogeochemistry_019**: Ecosystem exchange of carbon, NEON Realm
- **Biogeochemistry_020**: Net Primary Productivity
- **Land_Use_007**: Land cover classification
- **Land_Use_008**: Land cover classification, AOP
- **Land_Use_024**: Historical Climate Data

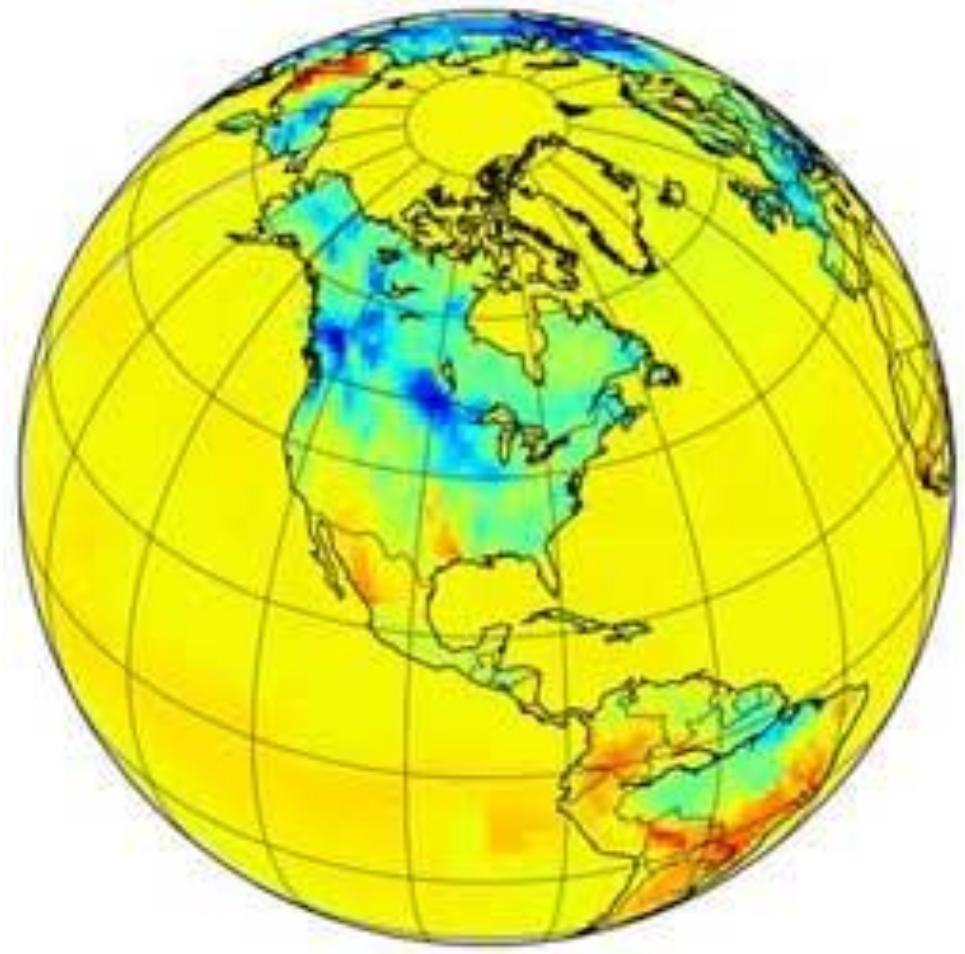
Level 1 Data Products (examples)

- **FIU.1.0003**: Air temperature WMO
- **FIU.1.0006**: Bulk precipitation
- **FIU.1.0010**: CO_2 concentration
- **FIU.1.0011**: CO_2 profile
- **FSU.1.0112**: DBH live trees
- **FSU.1.0116**: Litter traps, leaves
- **FSU.1.0125**: Coarse root live biomass
- **FSU.1.0142**: Coarse downed woody debris
- **LUAP.1.0015**: MRLC National Land Cover Database
- **AOP.1.0002**: Spectral reflectance
- **AOP.1.0004**: High resolution imagery

Integration of NEON data to produce analyses and forecasts



Science Case 2- Biogeochemistry



Results from NOAA Carbon Tracker (displayed) present estimates of carbon uptake by ecosystems based only on atmospheric data. NEON will complement this with a data-assimilation model based on terrestrial measurements.

Opportunities for Scientists and Educators

- Deployments:
  - Mobile Deployment Platform (10 mobile labs)
  - Airborne Observing Platform (1 of 3 platforms)
- Data Products
  - 539 Level 1 and 118 Level 4 data products.
  - New data products developed based on community inputs
- Bioarchive
  - ~130,000 samples per year (species and substrates)
- Experiments
  - Externally funded experiments using NEON sites and infrastructure

NEON Status

- The National Ecological Observatory Network (NEON), completed its Final Design Review in November 2009 -- a major milestone in the design and execution of the project.
- Pres. Obama made a request in the 2011 budget
- National Science Board (NSB), governing body of the National Science Foundation (NSF), has authorized the NSF Director, at his discretion, to make an award for construction of NEON.
- If all goes well … construction starts in FY 2011

The Human Dimension

- The ecological scientific and educational community forms a network (or many networks) of interacting autonomous peer groups collaborating on issues of mutual interest.

- NEON is a continental observatory and a facility for the scientific, educational and environmental management community to use…

- While the NEON staff **must** envision how NEON might be used to advance the field, NEON staff will not be the ones doing this…

- NEON's success or failure of NEON will be determined by how it is used by investigators and educators (**by you)** in hundreds of future research and education projects, in the field, in the lab, in classrooms, offices, in public, etc.…

NEON Advisory Structure

- STEAC – Science, Technology, and Education Advisory Committee (strategic advice)
- DSECC – Domain Science & Education Coordination Committee (input on domain level)
- TWG – Technical Working Group (input on specialized area to Product Team Lead or Project Scientist)

NATIONAL ECOLOGICAL OBSERVATORY NETWORK

The National Ecological Observatory Network is a project sponsored by the National Science Foundation and managed under cooperative agreement by NEON Inc.

www.neoninc.org

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