NEXT GENERATION ECOSYSTEM EXPERIMENTS - TROPICS

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U.S. DEPARTMENT OF ENERGY | Office of Science

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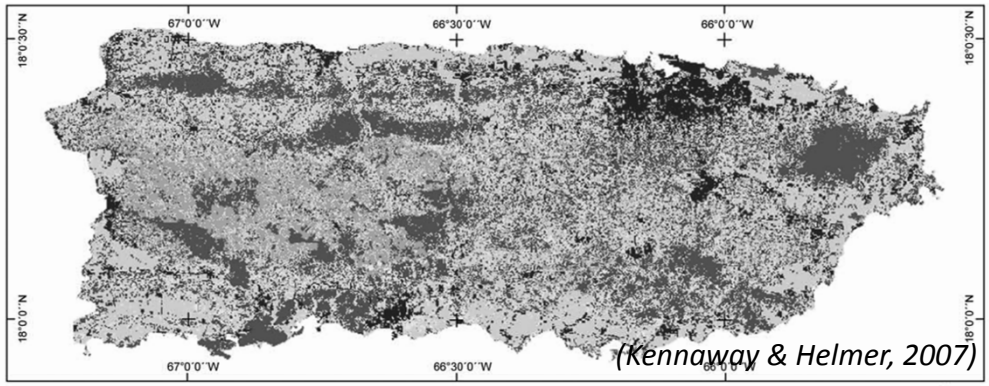
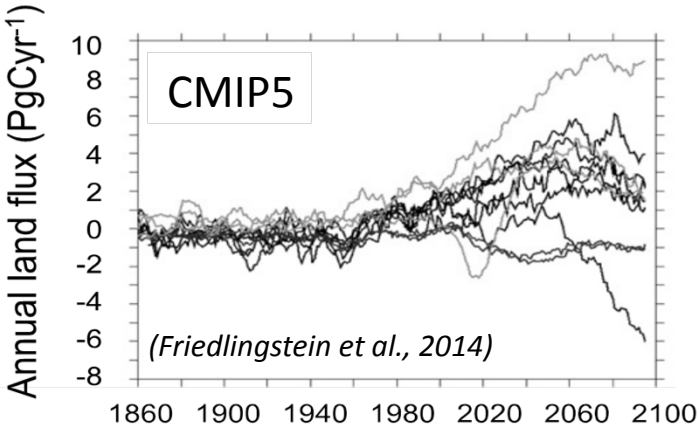
Why NGEE-Tropics?

- Tropical forests cycle more carbon and water than any other biome, and play critical roles in determining the Earth's energy balance
- Large uncertainties in tropical forest response to a changing atmosphere and a warming climate
- With 21st century warming, novel "no analog" climates emerge, potential for drought
- Large source/sink carbon fluxes from complex anthropogenic landscapes

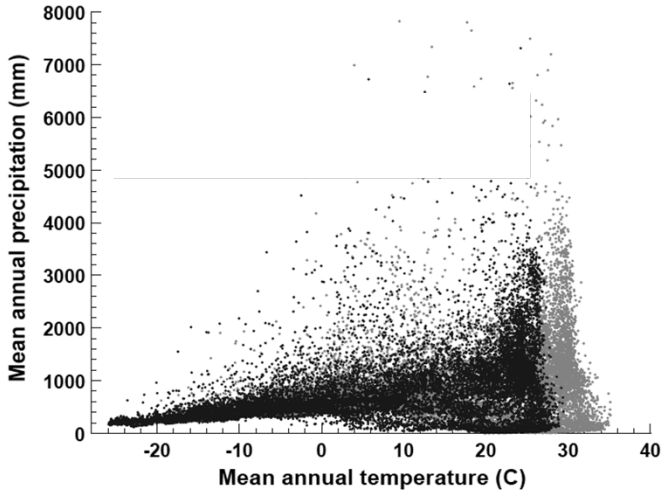
Secondary forest a key carbon sink in the tropics



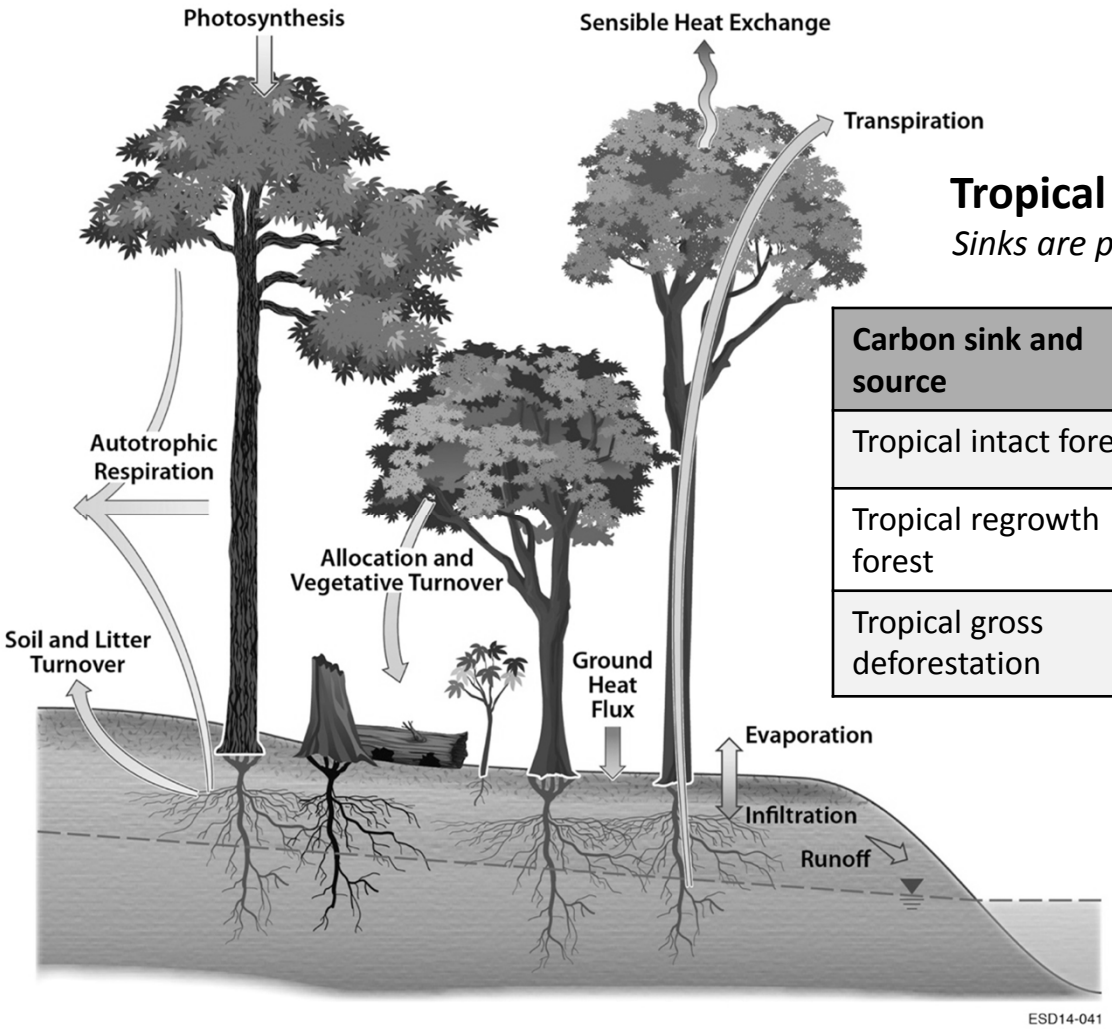
(Kennaway & Helmer, 2007)



Climate change – into novel regimes



Tropical Forests and the Global Carbon Cycle



Tropical forest carbon budgets (Pg C yr^{-1})

Sinks are positive values; sources are negative values

Carbon sink and source	1990-1999	2000-2007	1990-2007
Tropical intact forest	1.33 ± 0.35	1.02 ± 0.47	1.19 ± 0.41
Tropical regrowth forest	1.57 ± 0.50	1.72 ± 0.54	1.64 ± 0.52
Tropical gross deforestation	−3.03 ± 0.49	−2.82 ± 0.45	−2.94 ± 0.47*

(Pan et al., 2011)

*-0.9 ± 0.5 Pg C yr^{-1} globally for 2005-2014

2014 fossil fuel emissions 9.8 ± 0.5 Pg C yr^{-1}
36% (3.5 Pg C yr^{-1}) remained in the atmosphere

(Global Carbon Project 2015)

NGEE-Tropics Goal and Questions

Overarching Goal

- Develop a predictive understanding of tropical forest carbon balance and climate system feedbacks to changing environmental drivers over the 21st Century.

Grand Deliverable

- A representative, **process-rich tropical forest ecosystem model**, extending from bedrock to the top of the vegetative canopy-atmosphere interface, in which the evolution and feedbacks of tropical ecosystems in a changing climate can be modeled at the scale/resolution of a next generation Earth System Model grid cell (~10 x 10 km^2 resolution)

Overarching Questions

- How do tropical forest ecosystems respond to changing temperature, precipitation, and atmospheric CO_2 concentration?
- How do disturbance and land-use change in tropical forests affect carbon, water and energy fluxes?
- How will the response of tropical forests to climate change be modulated by spatial and temporal heterogeneity in belowground processes?

NGEE-Tropics Objectives

Q1. How do tropical forest ecosystems respond to changing temperature, precipitation, and atmospheric CO2 concentration?

Q2. How do disturbance and land-use change in tropical forests affect carbon, water and energy fluxes?

Q3. How will the response of tropical forests to climate change be mediated by spatial and temporal heterogeneity in belowground processes?

RO1 Forest response to droughts

RO2 C uptake and allocation responses to temperature and CO2

RO3 Vegetation dynamics under natural disturbance regimes

RO4 Anthropogenic disturbance and recovery

RO5 Spatial and temporal variability of water

RO6 Nutrient availability and controls on ecosystem processes

Traits Trait trade-offs across sites (FO1)

Manaus Hydrology-carbon cycle interactions (FO1)

Pantropical Baseline measurements (FO2)

Puerto Rico Nutrient-land use interactions (FO1)

Pantropical Identify Phase 2 field sites (FO3)

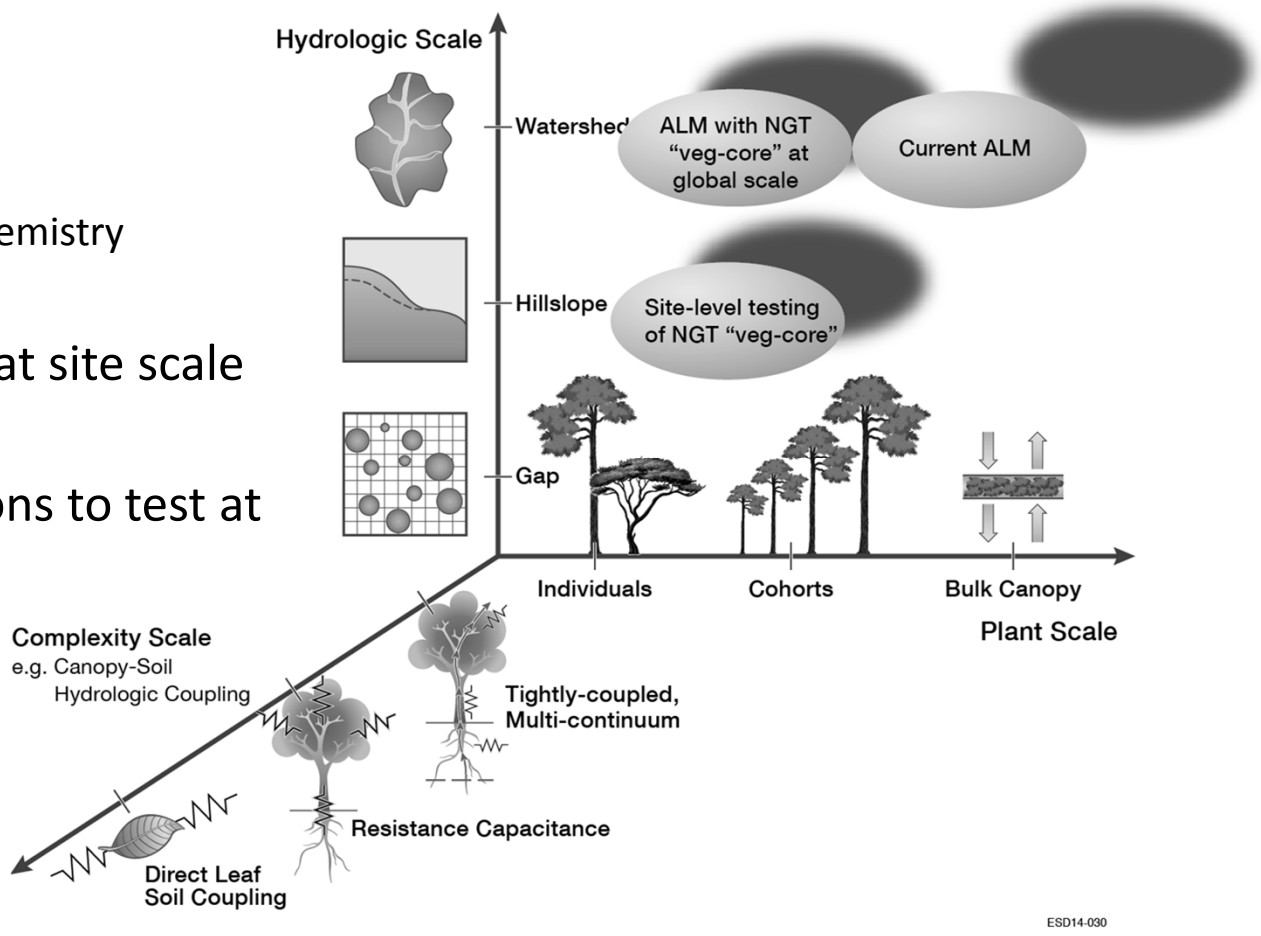
MO1: Tropical model testbeds for UA, UQ
MO2: Methods for plant trait distribution shifts
MO3: Spatial scaling approaches
MO4: Complexity scaling framework

DO1: Infrastructure for data synthesis supporting analysis products, model parameterization and benchmarking
DO2: Portal providing unified access to community data
DO3: A repository for NGEE Tropics data

ESD14-071

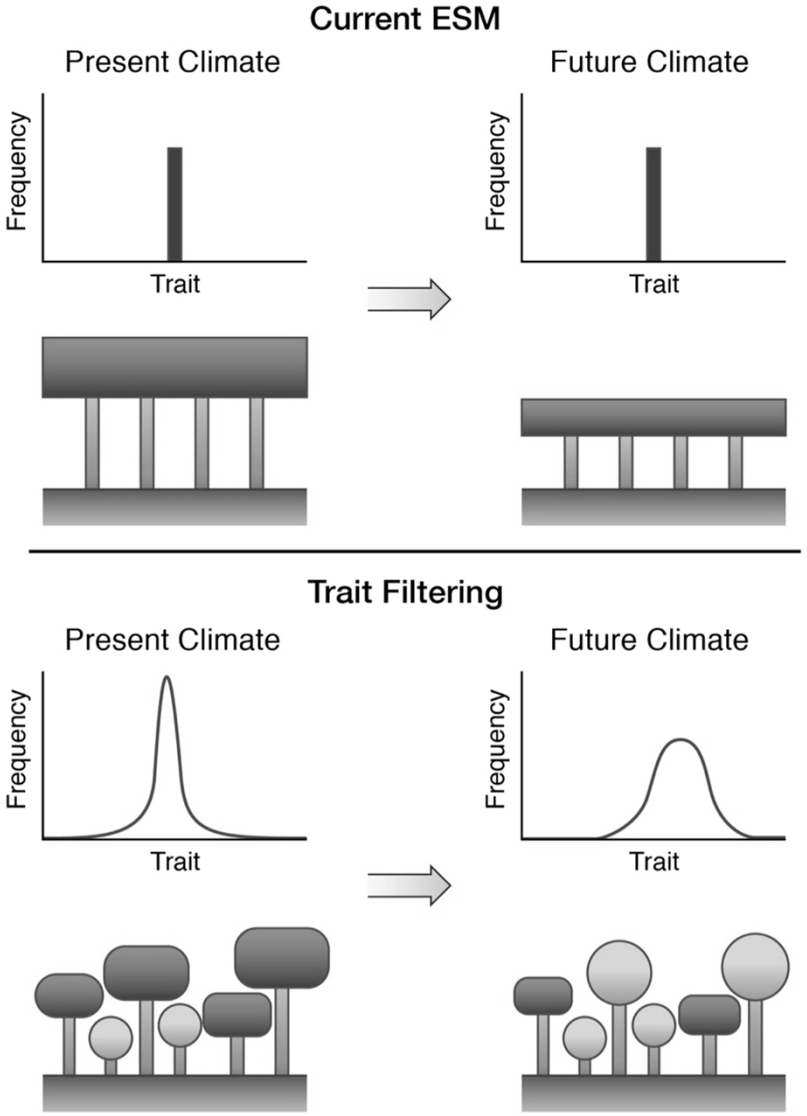
NGEE-Tropics Modeling Strategy

- Develop a new vegetation model, built around a demographic core
- Develop improved process representations
  - Plant hydraulics
  - Hydrology
  - Plant and soil biogeochemistry
  - Effects of land use
- Testing and validation at site scale across tropics
- ILAMB-type observations to test at larger scales



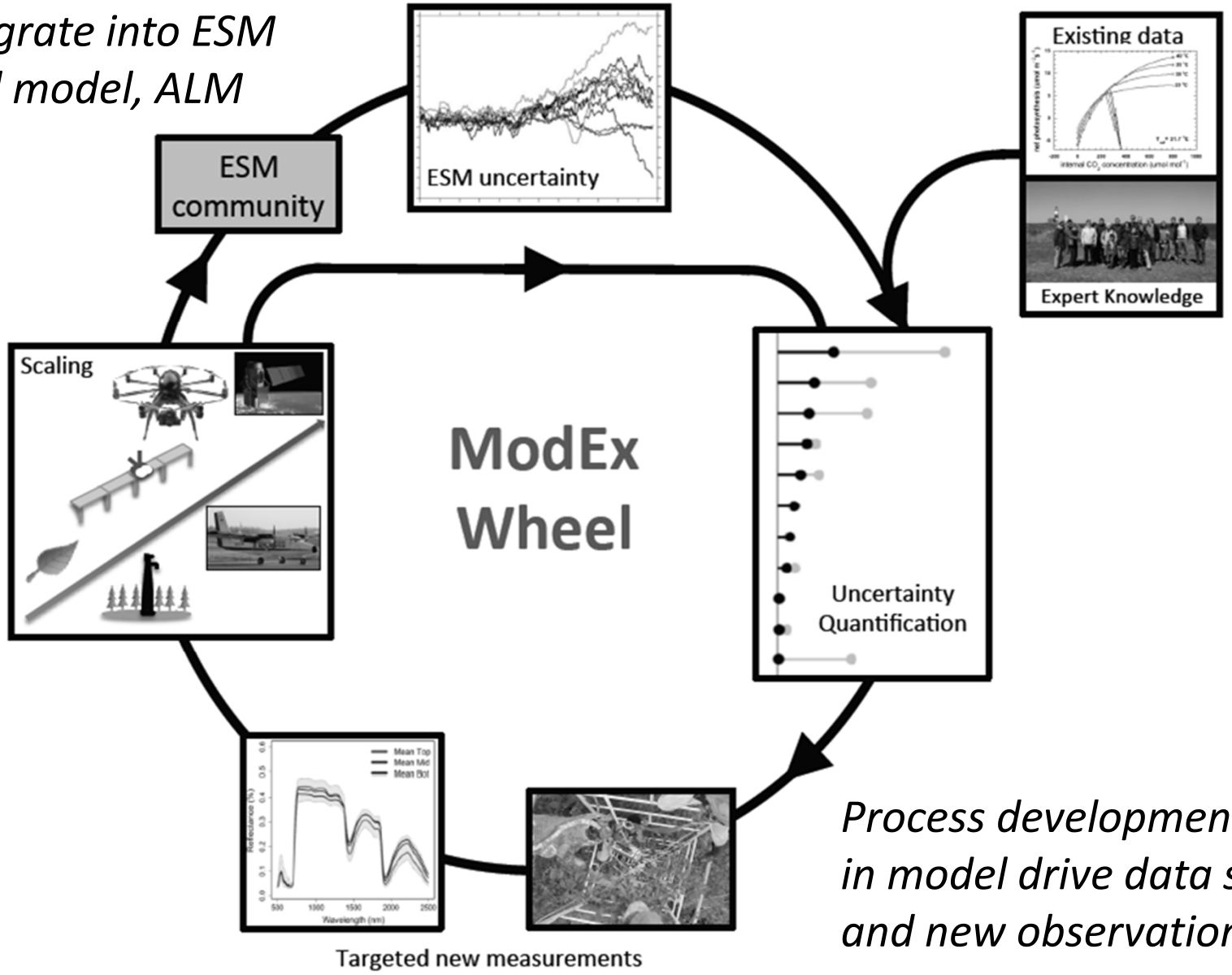
Novel Trait-Enabled Modeling Approach

- In current ESMs plant traits are static and lack diversity, limiting forest response
- Start with greater diversity that is important to ecosystem processes
- Plant interactions in response to climate change determines which types — therefore trait values — are most successful
- Trait filtering occurs through differential mortality; mortality linked directly to C fluxes



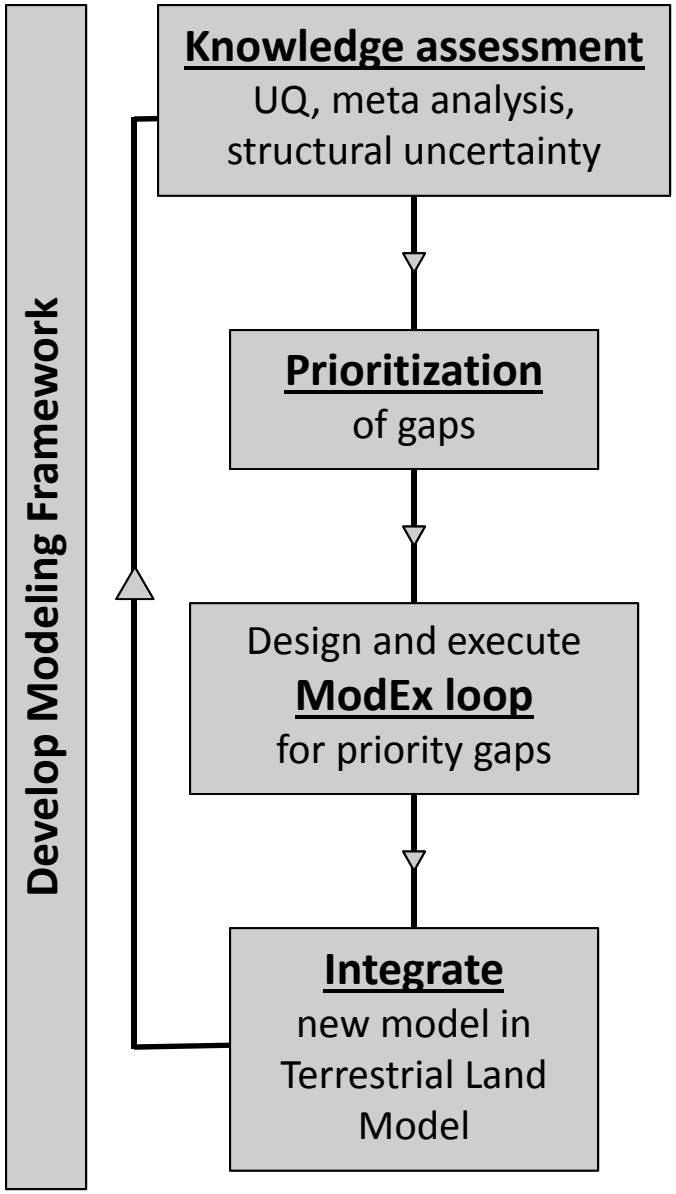
Integrated Model-Experiment (ModEx) Studies

Integrate into ESM land model, ALM



Process development needs in model drive data synthesis and new observations

The NGEE-Tropics Phases

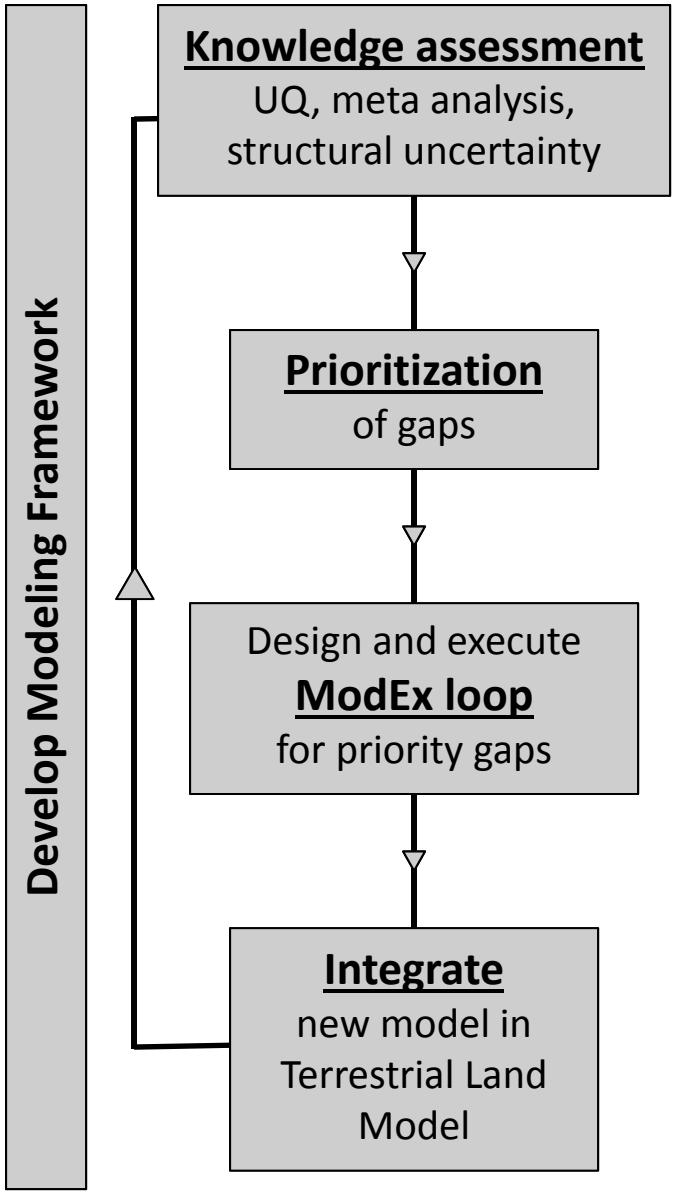


Phase 1 Milestones

Prioritize and demonstrate

- DOE, national, international partners engaged
- Existing models assessed to identify and prioritize uncertainties
- Data synthesized to benchmark and parameterize priority model processes (pantropical)
- Priority observations and experiments initiated (Pilot Study sites)
- Modeling framework and modules prototyped
- Initial development of pantropical studies for key process gaps (e.g. mortality)

The NGEE-Tropics Phases



Phase 2 Milestones

Implement and iterate

- Observations and experiments implemented to address priority uncertainties (pantropical)
- Model modules and parameters developed, tested, and applied using new and synthesized data
- Module coupling prototyped and model framework refined
- Initial coupled model framework applied to high priority science questions
- Benchmarking, UQ and data synthesis applied to define Phase 3 priorities

Phase 3 Milestones

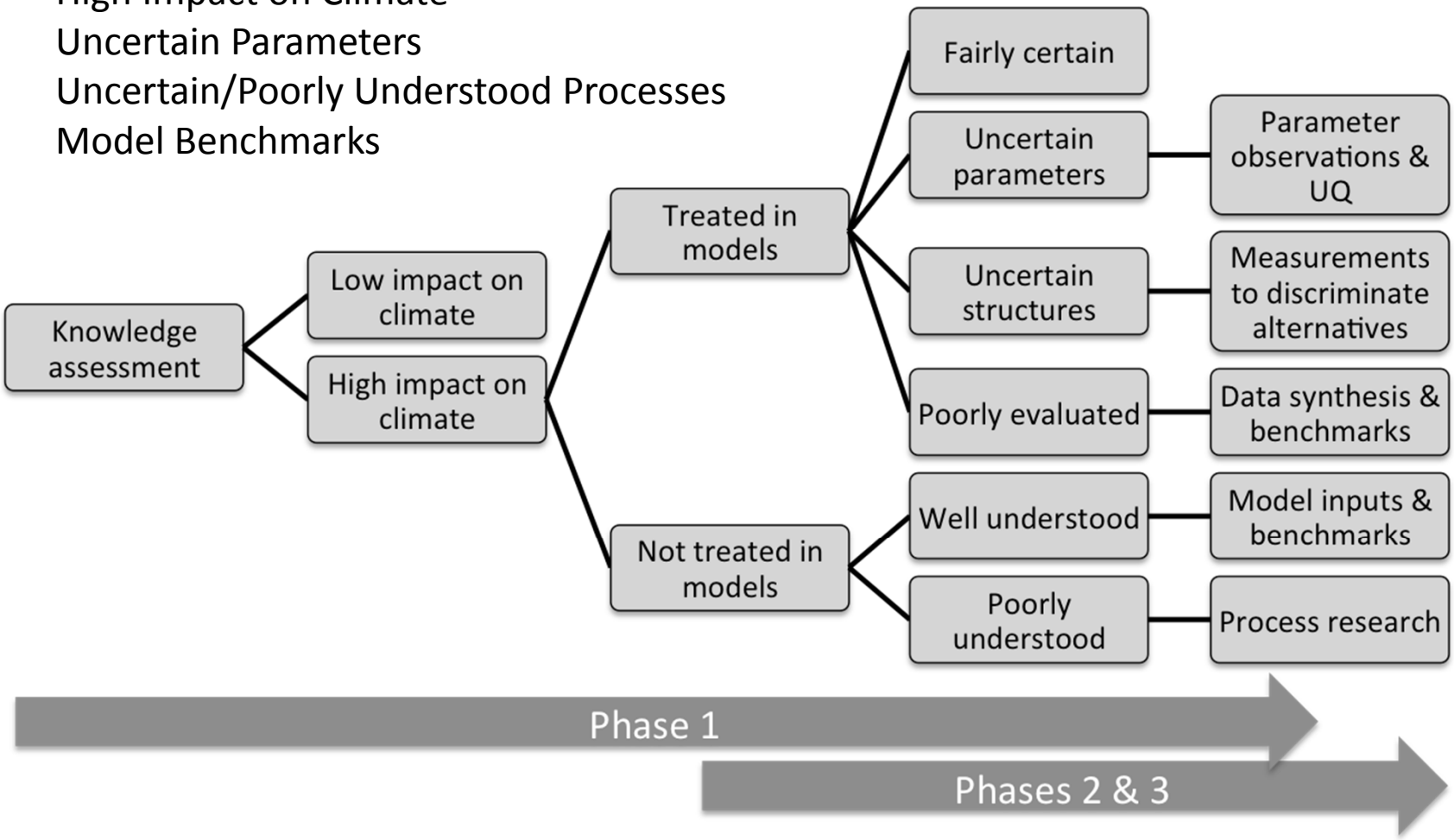
Integrate and apply

- Field campaigns continued toward final results and model integration
- Fully coupled model framework applied to high priority science questions
- Tropical model intercomparison project led by NGEE-Tropics team
- A robust model for ESM projection of the future of tropical forests delivered

Prioritize Knowledge Gaps for Study

Measurement Priorities

- High Impact on Climate
- Uncertain Parameters
- Uncertain/Poorly Understood Processes
- Model Benchmarks



Phase 1 Integrative ModEx Pilot Studies

Objectives: Demonstrate NGEE Tropics approach for known critical uncertainties; prototype novel field methods

- **Manaus, Brazil Pilot: Hydrology-carbon cycle interactions**

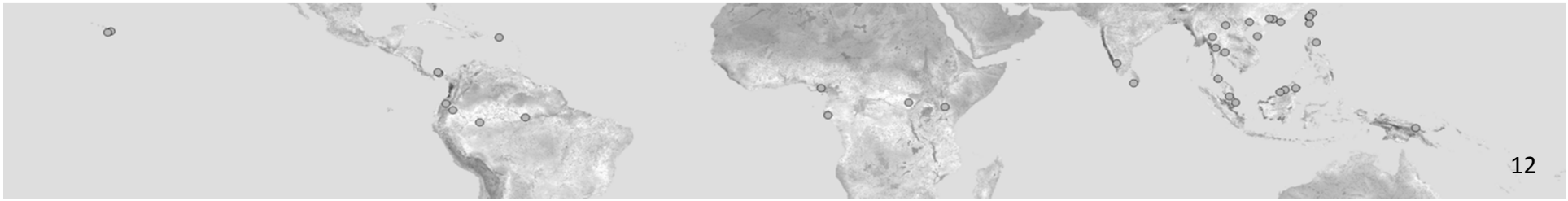
  How do forest carbon and water fluxes respond to water deficits on daily, seasonal and interannual timescales across local topographic moisture gradients?

- **Trait Tradeoffs Pilot: Panama and beyond**

  Can we simulate shifts in plant trait distributions across a rainfall gradient?

- **Puerto Rico Pilot: Nutrient-land use interactions**

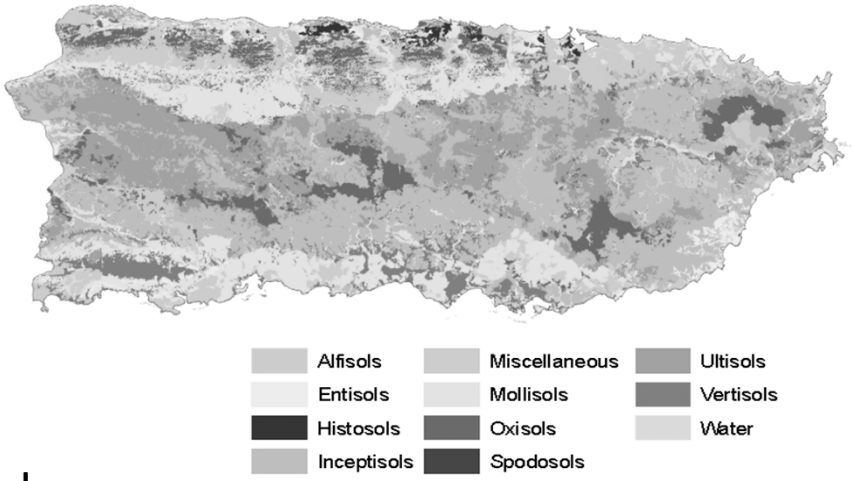
  How does soil nutrient (esp. phosphorus) availability influence plant nutrient acquisition traits, forest productivity and forest development following disturbance?

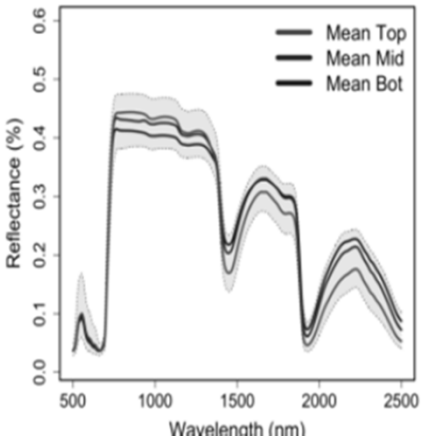


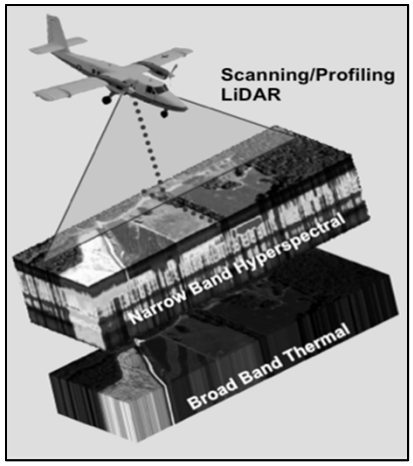
Puerto Rico Pilot: Nutrient- Land Use Interactions

- Transects across soil type and forest development
- Systems biology approach to understanding P availability and plant acquisition via roots
- N availability and N fixation
- Leaf level nutrient analysis and spectral signatures
- Airborne remote sensing to resolve individual canopy trees, leaf spectra to enable scaling from ground-based data

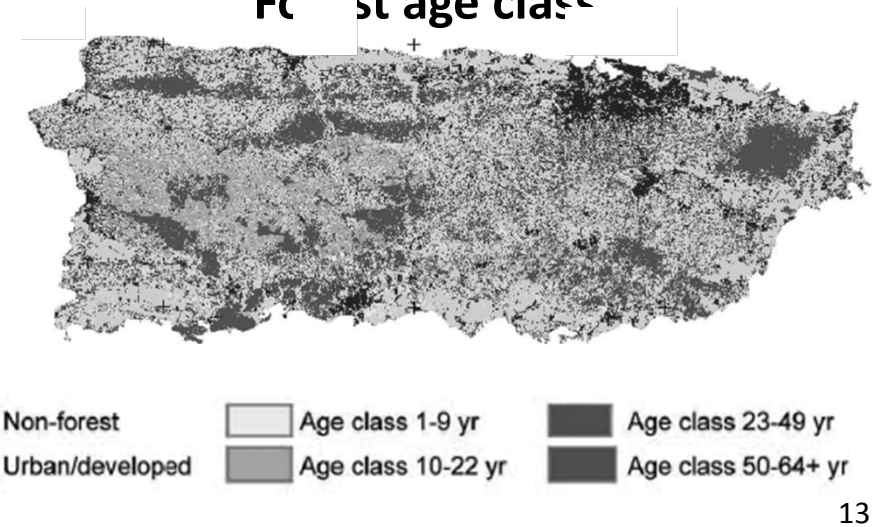
Soil orders







Forest age class



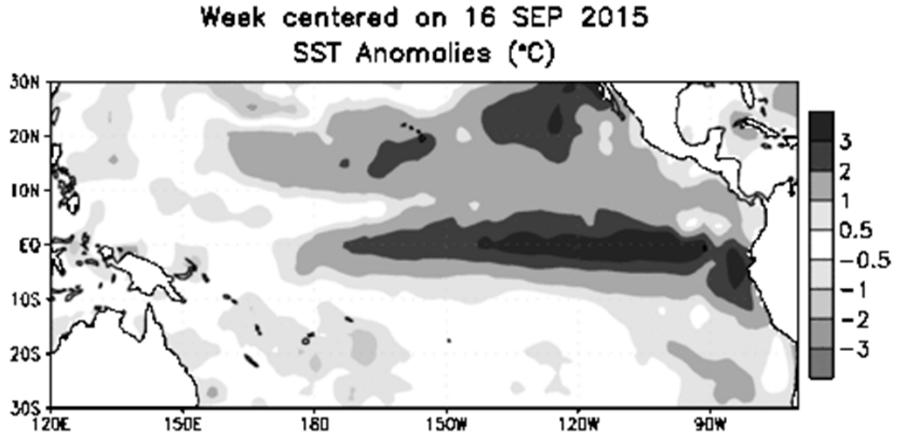
El Niño Southern Oscillation (ENSO) Effort

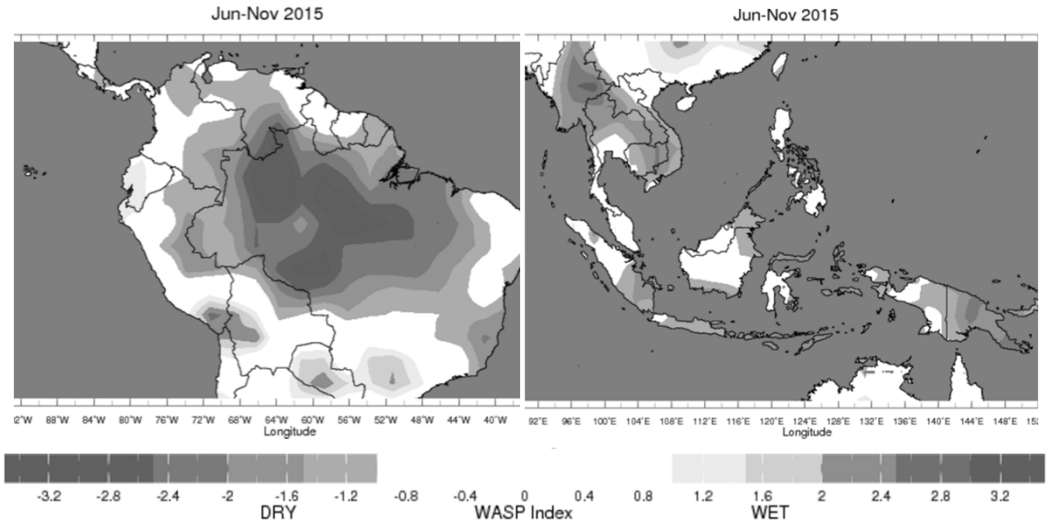
Motivation

- Current El Niño strong; ENSO-drought underway in Panama and Brazil
- Drought is relevant to many Phase 1 NGEE-Tropics objectives

Goals

1) Quantify drought impacts on tropical forest structure and function
2) Provide data for models
3) Further strengthen our pantropical collaborations



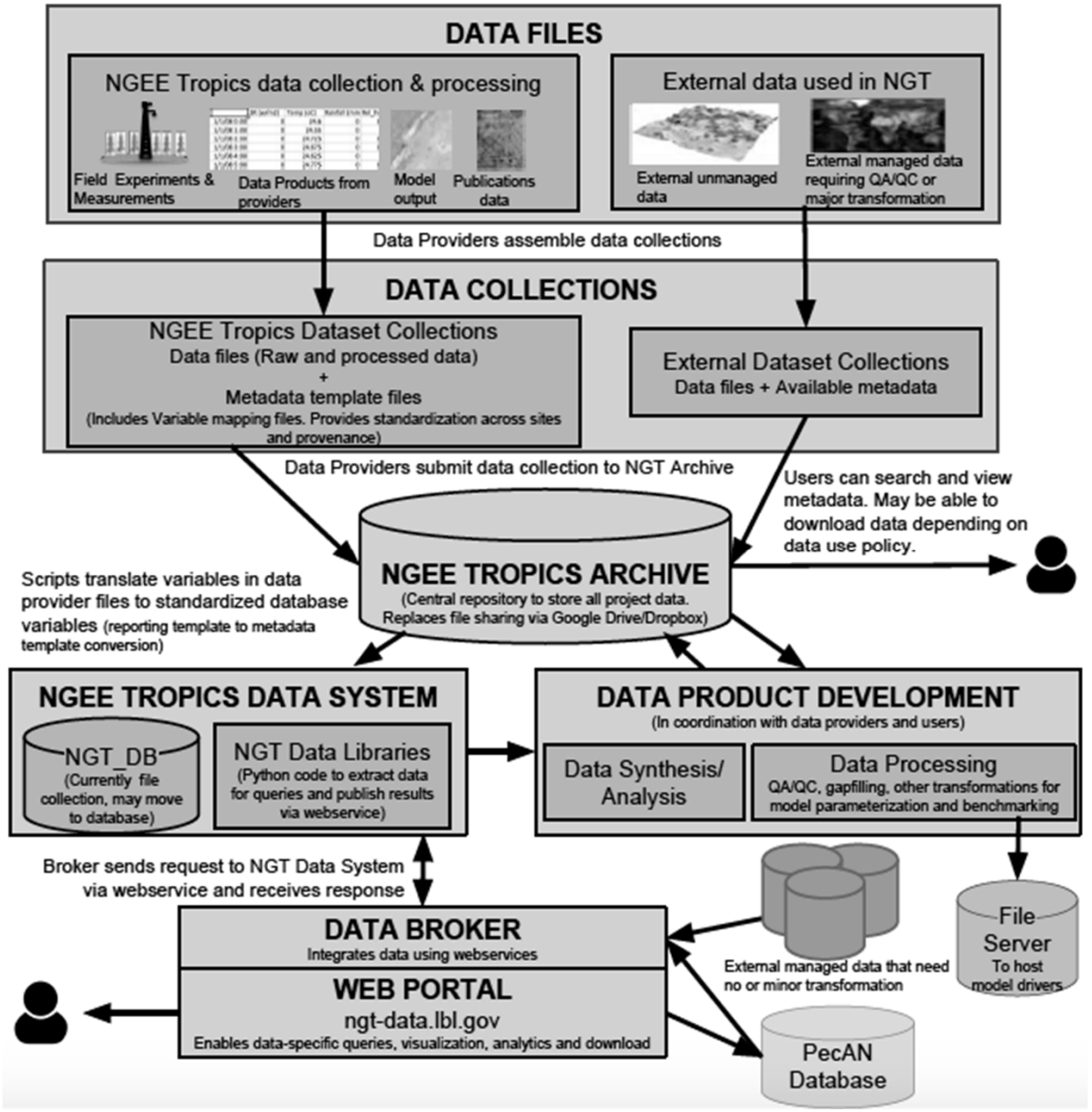


ModEx Approach to ENSO Measurements

- Measurements in Manaus, Tapajos, and three sites in Panama to understand and test model predictions of plant hydraulic and photosynthetic responses to drought
  - Sapflow, leaf gas exchange, water potential, leaf spectra, CO_2 response curves, leaf temperature, whole-tree water relations, soil moisture
- ENSO forest dynamics measurements in Africa, Asia, Pacific and the Americas
- Model predictions: LANL demographic hydraulic module, ED2-Hydro

Data Management and Synthesis

- NGEE-Tropics Data Archive (to be released end of March) to hold all NGEE Tropics datasets
- Designing templates for metadata reporting and files for ENSO and future datasets
- Creating QA/QC'd gap-filled, site-level drivers for the NGEE-Tropics model
- Will develop web portal to enable queries of NGEE Tropics and partner datasets



Partnerships Key to Our Success

- Key DOE activities
  - NGEE Arctic partnership on data management, project management, plant traits
  - ACME partnership on vegetation and soil biogeochemistry model development
- International collaborations
  - Collaborations with Instituto Nacional de Pesquisas da Amazônia (INPA) and Large-Scale Biosphere Atmosphere Experiment in Amazonia (LBA) in Brazil on field measurements, data synthesis, modeling
  - Collaboration with ForestGEO Global Network of forest demographic measurements and GEM Network of forest carbon measurements
  - Collaborations with International Institute for Tropical Forestry, Luquillo LTER, and Luquillo CZO in Puerto Rico on measurements of nutrient biogeochemistry and secondary forest development

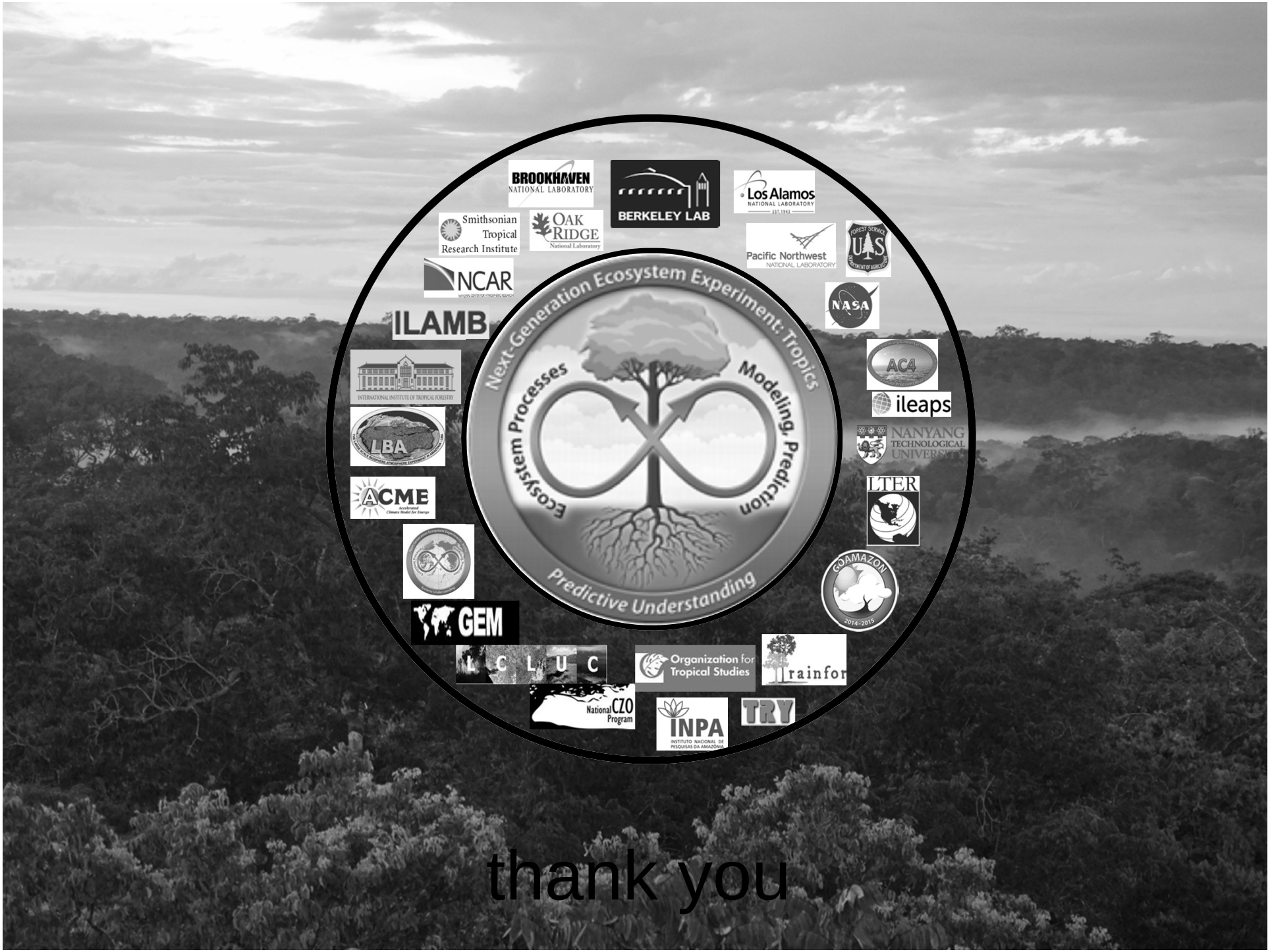
Transformational Outcomes

NGEE Tropics will deliver

- A demographic, trait-enabled vegetation modeling framework that captures how forest complexity influences carbon cycle responses under a changing atmosphere and warming climate

- New model structures rigorously informed and benchmarked with existing data, and new data products generated using our ModEx approach

- Significantly reduced uncertainties in tropical forest ESM carbon cycle feedbacks, and a greatly improved understanding of the role of tropical forests in Earth system functioning over the 21st Century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