Towards a diagnostic terrestrial C-H_2O model-data fusion analysis and prediction framework

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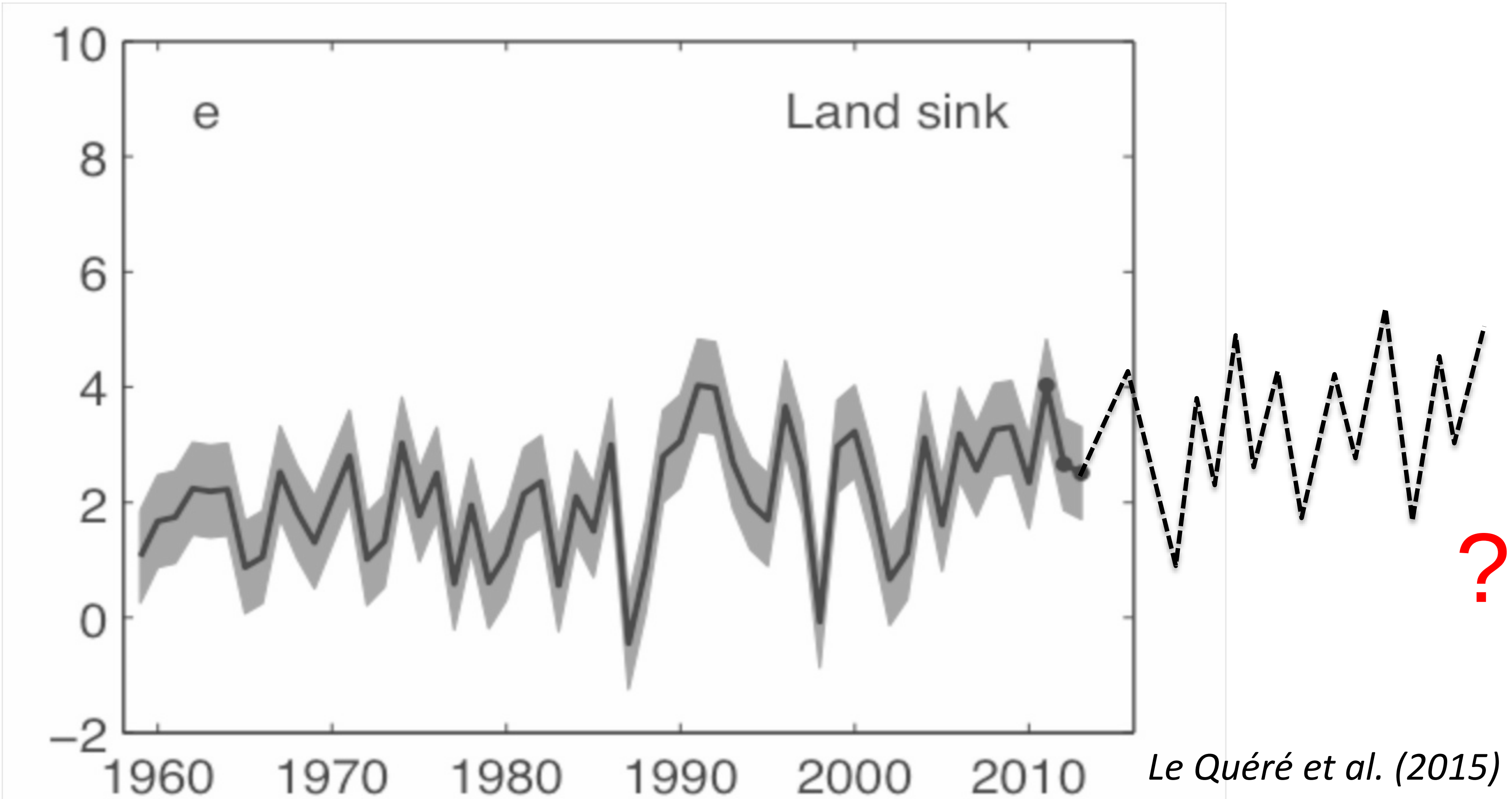


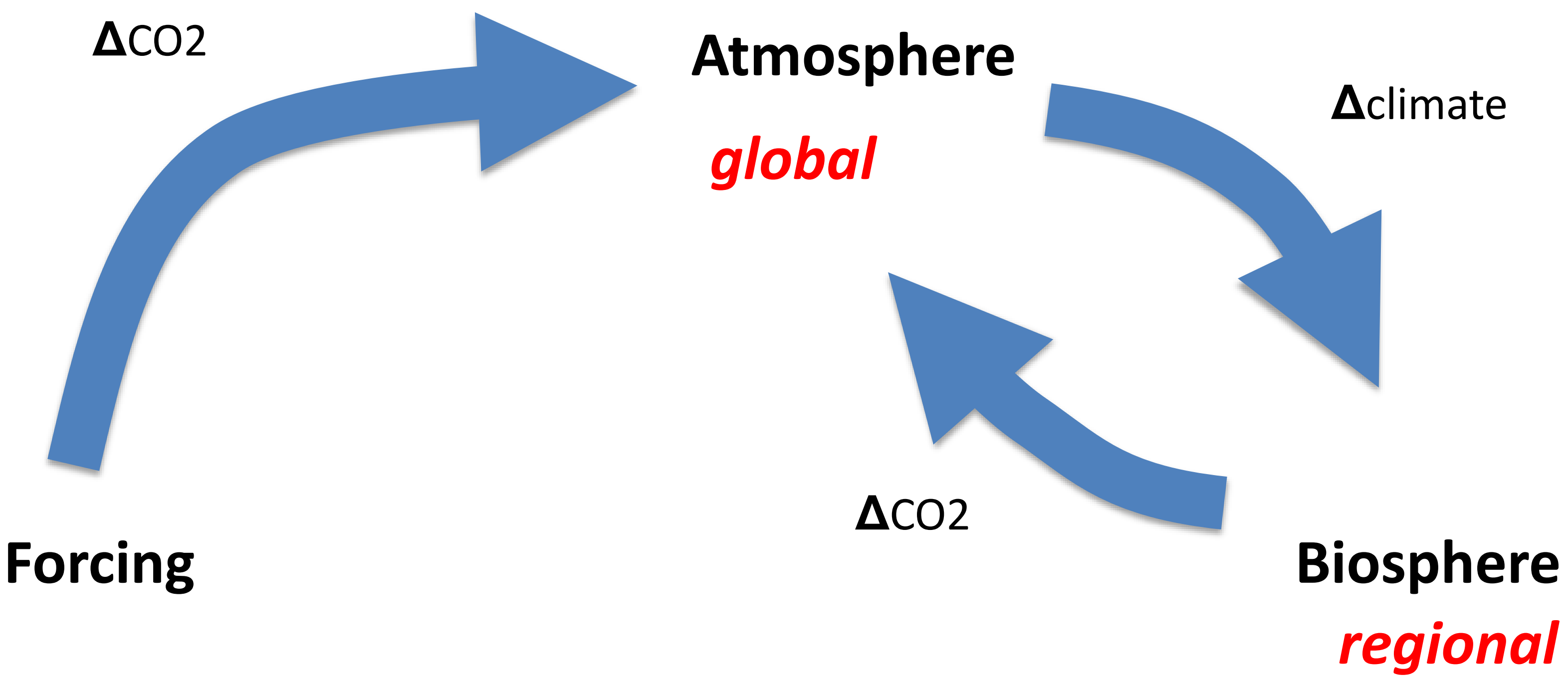
Improving predictions depends on quantitatively understanding of present-day terrestrial C cycle dynamics:

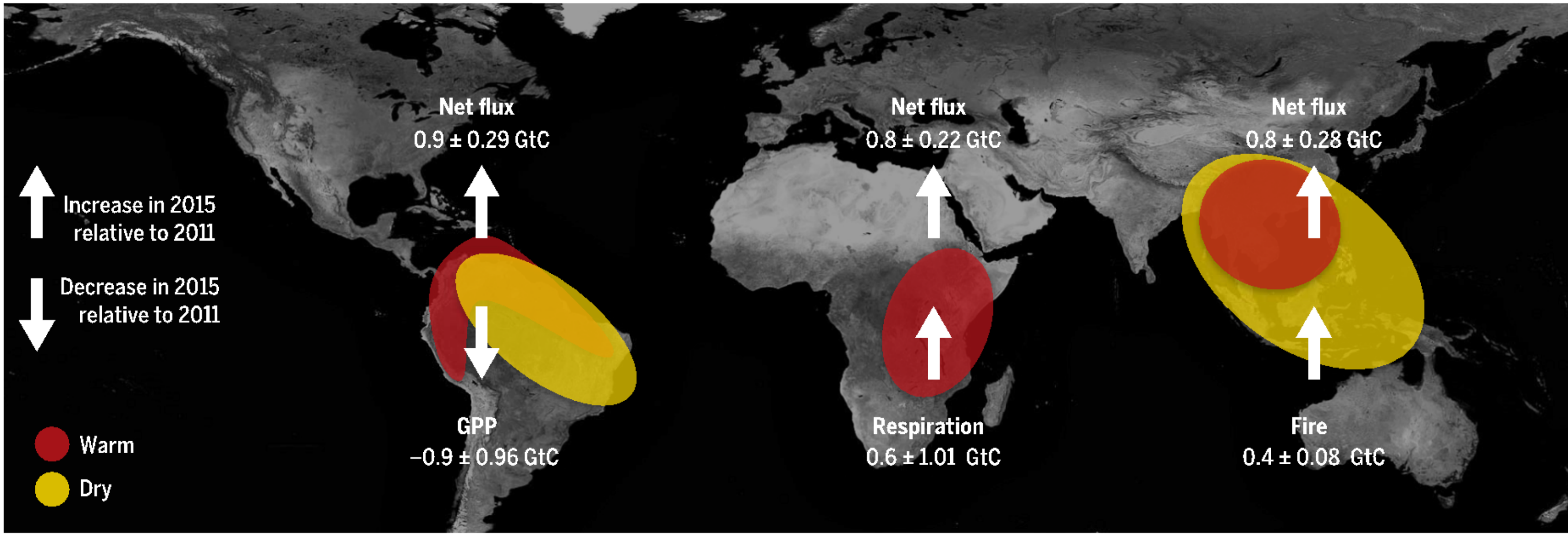
- Climate sensitivity of terrestrial C fluxes

- Ecosystem memory (lags, initial conditions, residence times)

- C cycle feedbacks and interactions with water, energy and nutrient cycles

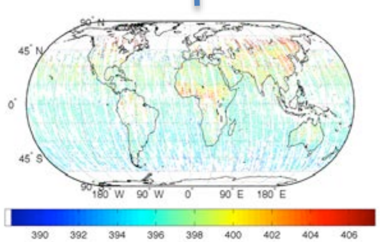
Terrestrial carbon-climate feedbacks

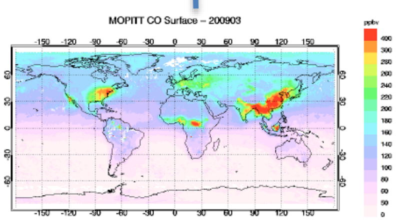


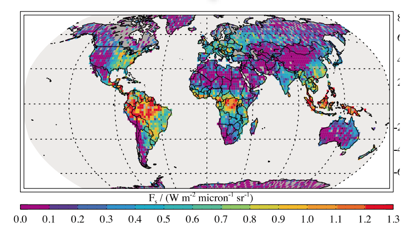


Diverse climate driver anomalies and carbon cycle responses to the 2015–2016 El Niño over the three tropical continents. Schematic of climate anomaly patterns over the three tropical continents and the anomalies of the net carbon flux and its dominant constituent flux (i.e., GPP, respiration, and fire) relative to the 2011 La Niña during the 2015–2016 El Niño. GtC, gigatons C.

Liu et al., 2017





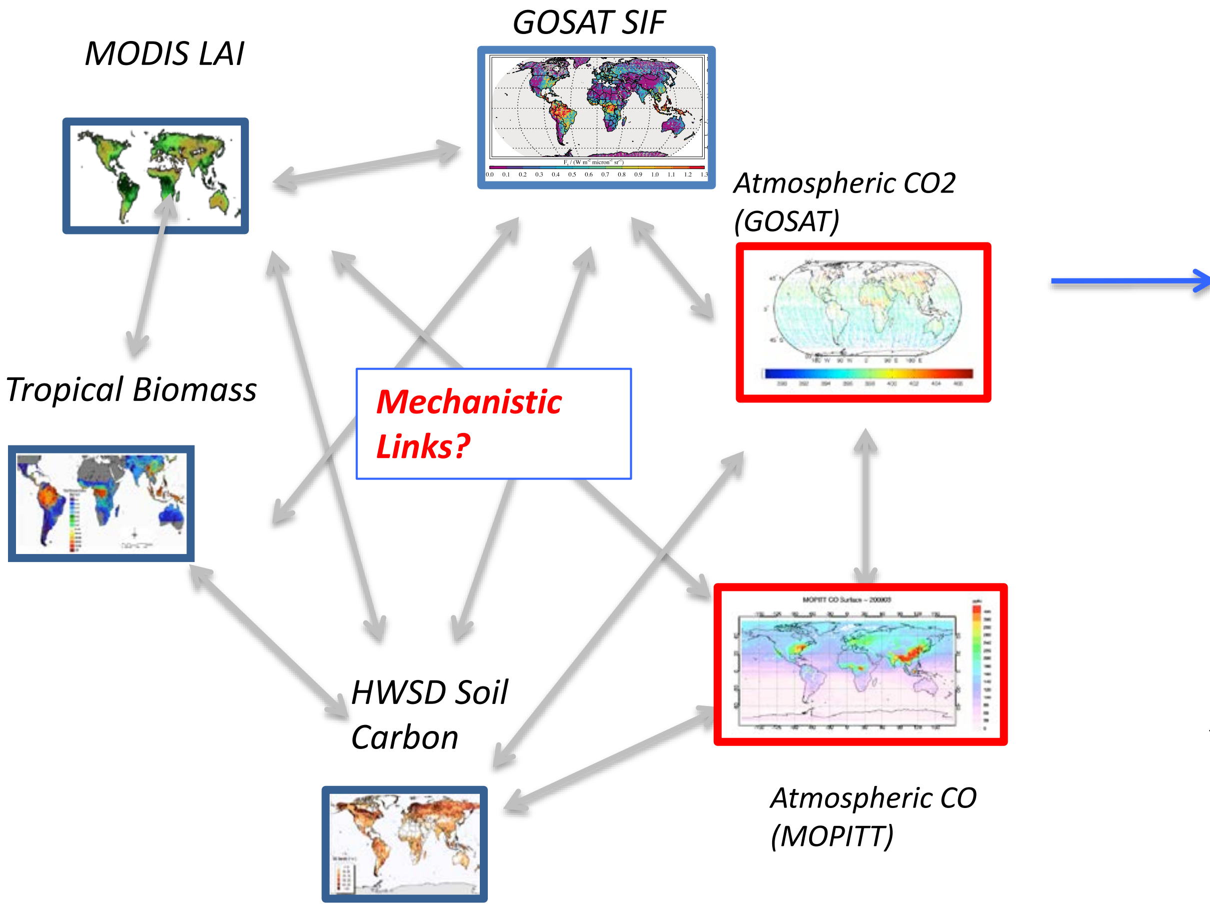


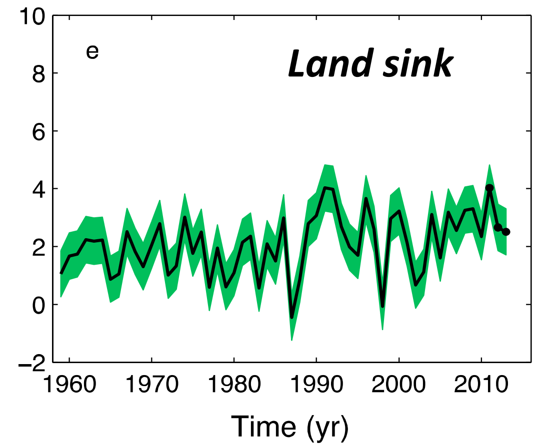
OCO-2 &
GOSAT CO2

MOPITT CO

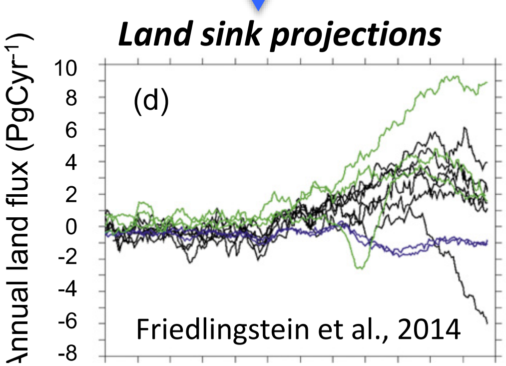
GOSAT SIF

Terrestrial C cycle: towards reducing process uncertainty.

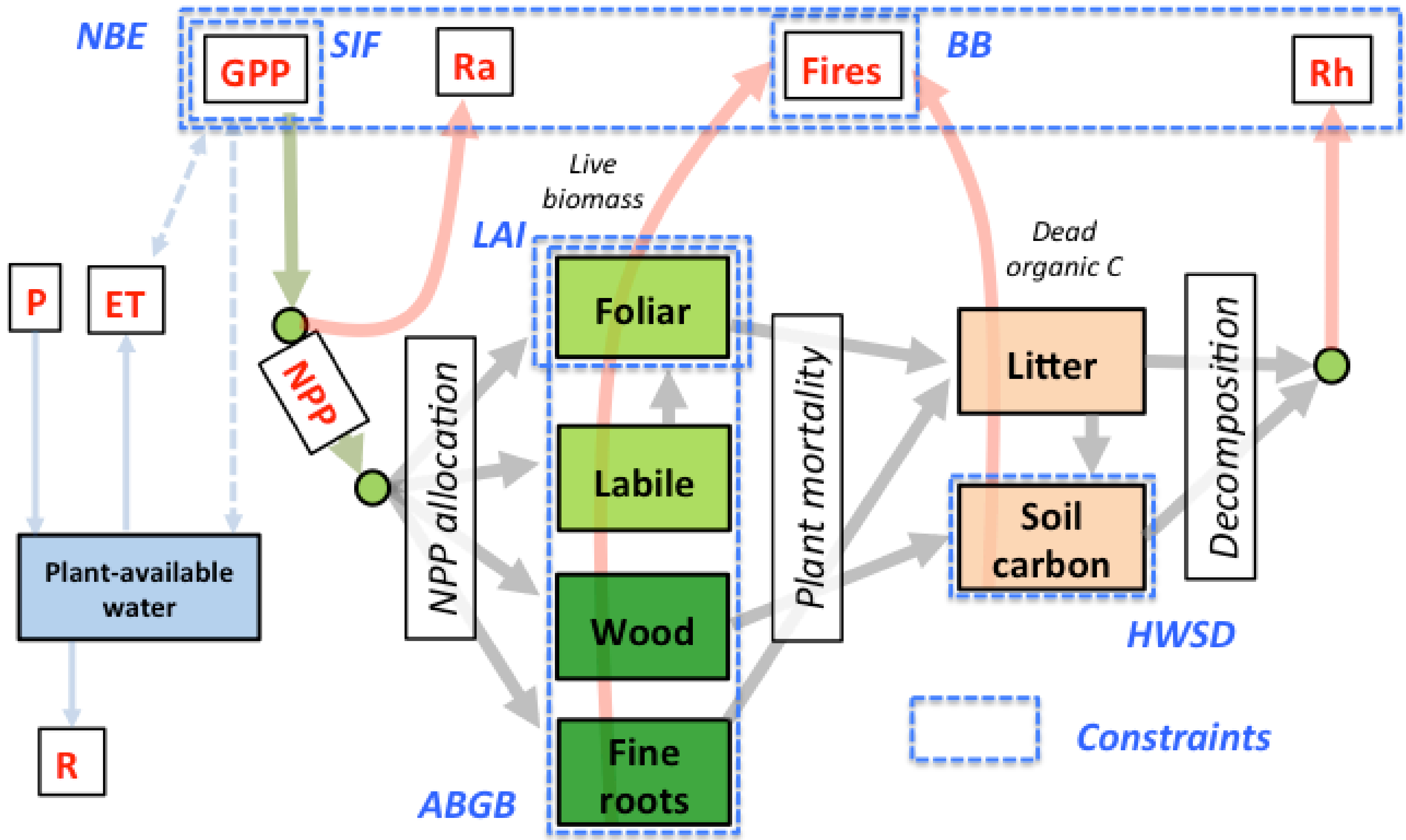




Le Quéré et al., 2016



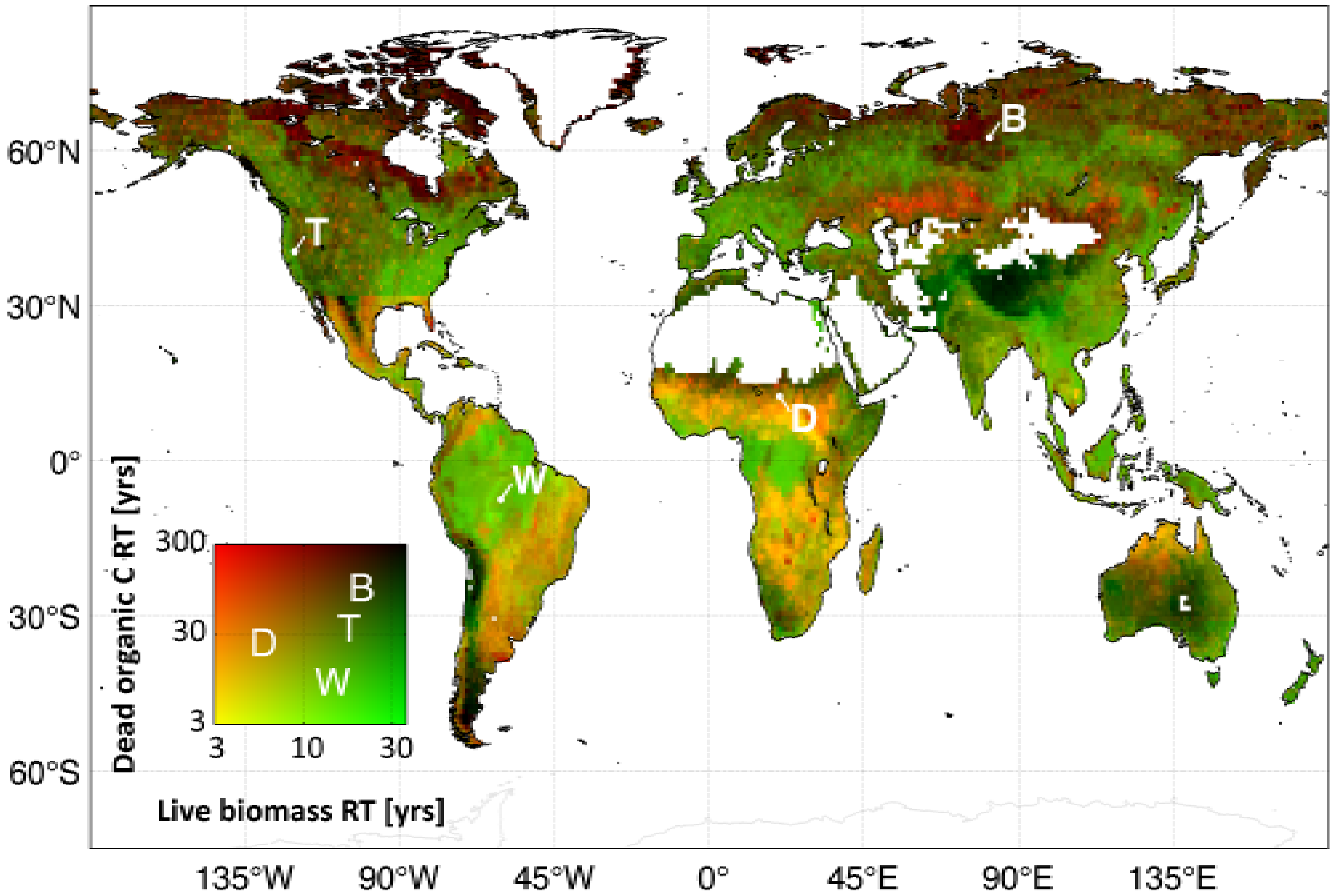
Carbon data-model framework (CARDAMOM)



Spatially-explicit optimization of terrestrial C cycle parameters

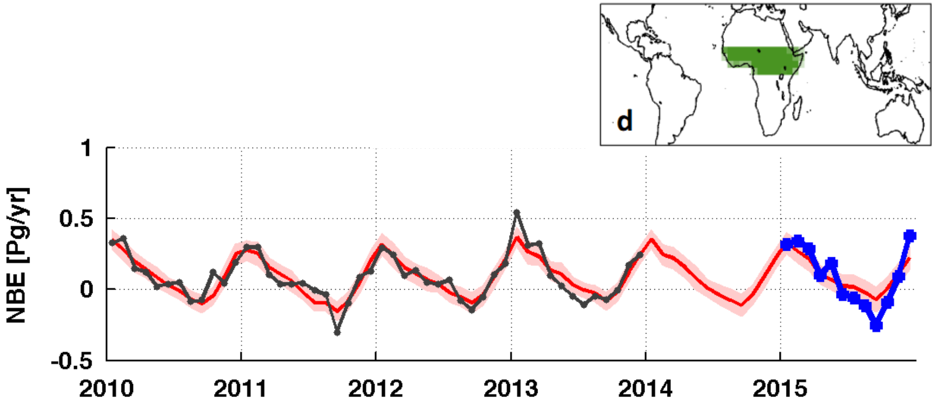
Williams et al. (2005), Bloom & Williams (2015), Bloom et al. (2016)

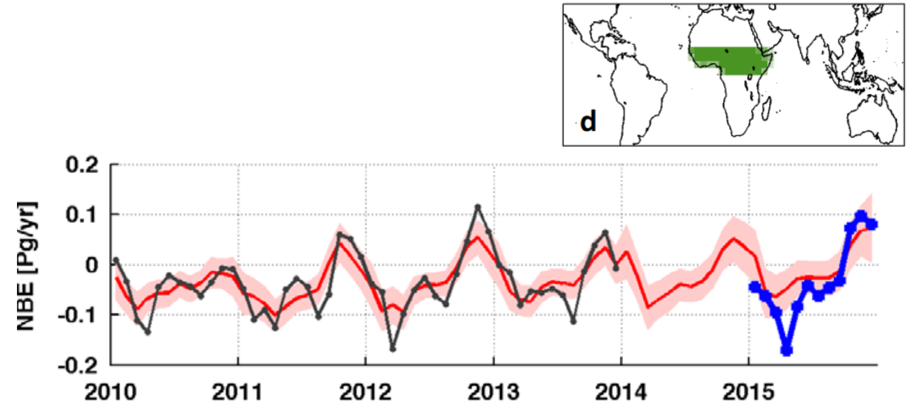
CARDAMOM: Terrestrial carbon cycle state and process variables



Bloom et al. 2016, PNAS

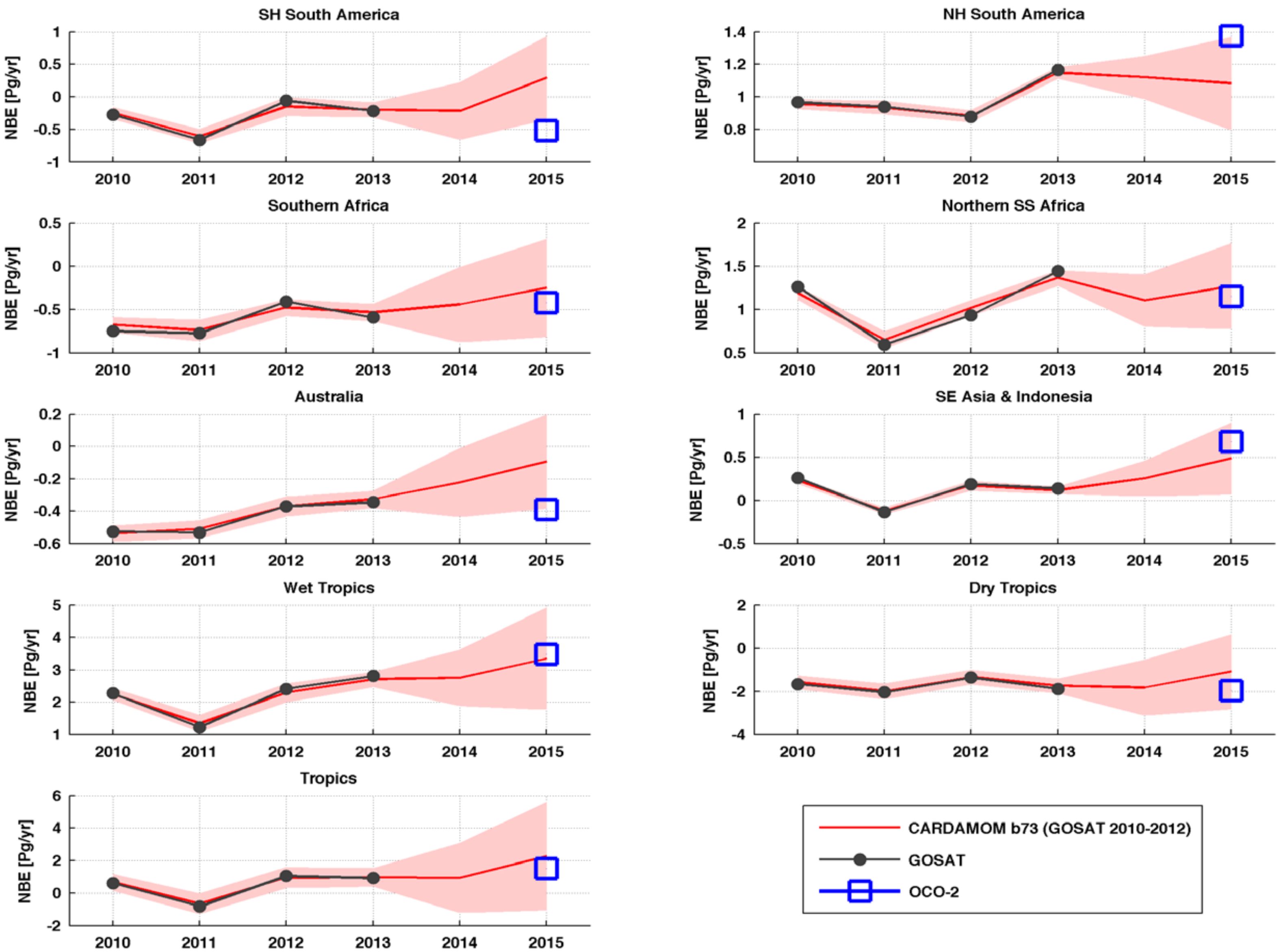
GOSAT and OCO-2 NBE – assimilation & prediction



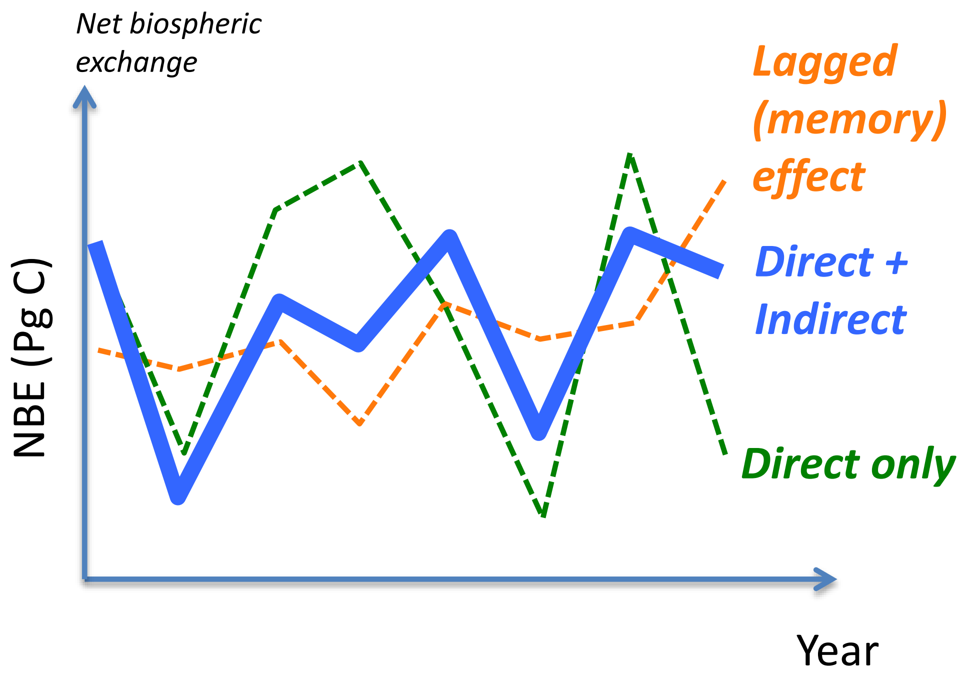


Red = CARDAMOM mean
Pink = CARDAMOM 1σ

Black = GOSAT-derived NBE (assimilated into CARDAMOM)
Blue = OCO-2 derived NBE (withheld for validation)


SH South America
NH South America
Southern Africa
Northern SS Africa
Australia
SE Asia & Indonesia
Wet Tropics
Dry Tropics
Tropics
NBE [Pg/yr]
2010
2011
2012
2013
2014
2015
CARDAMOM b73 (GOSAT 2010-2012)
GOSAT
OCO-2

Do memory effects contribute to NBE IAV?

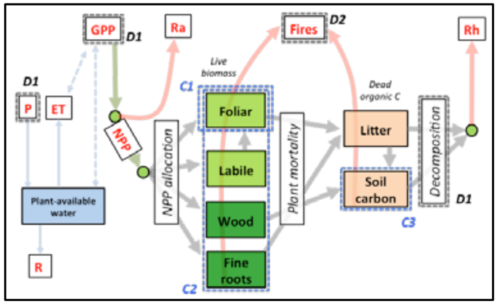


$$\Delta NBE_{total} = \Delta NBE_{direct} + \Delta NBE_{lagged}$$

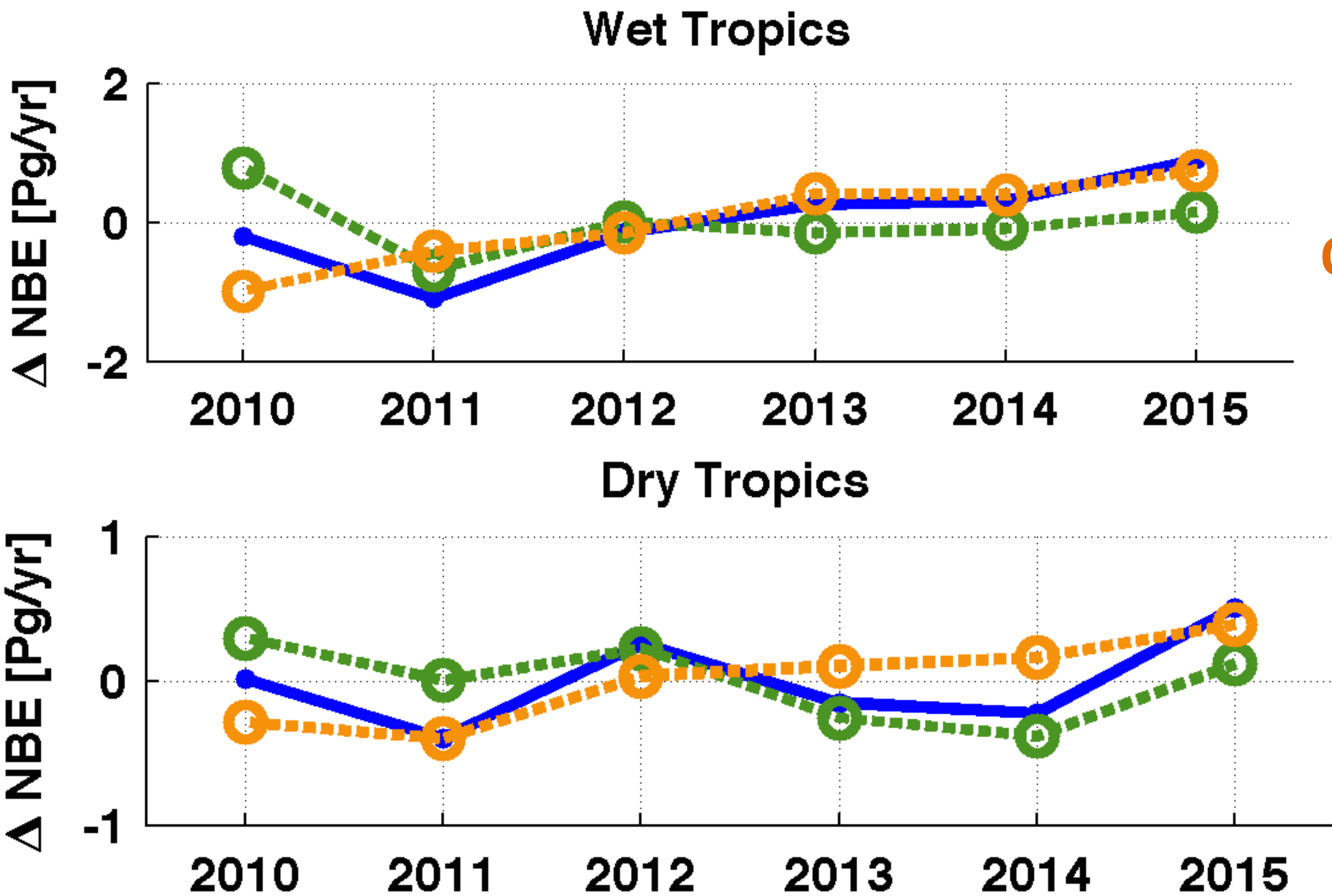
***Lagged effect:* attributable to ecosystem memory effects**

***Direct effect:* attributable to instantaneous met. forcings**

Direct & lagged NBE Attribution approach: meteorological forcing sensitivity of optimized CARDAMOM NBE



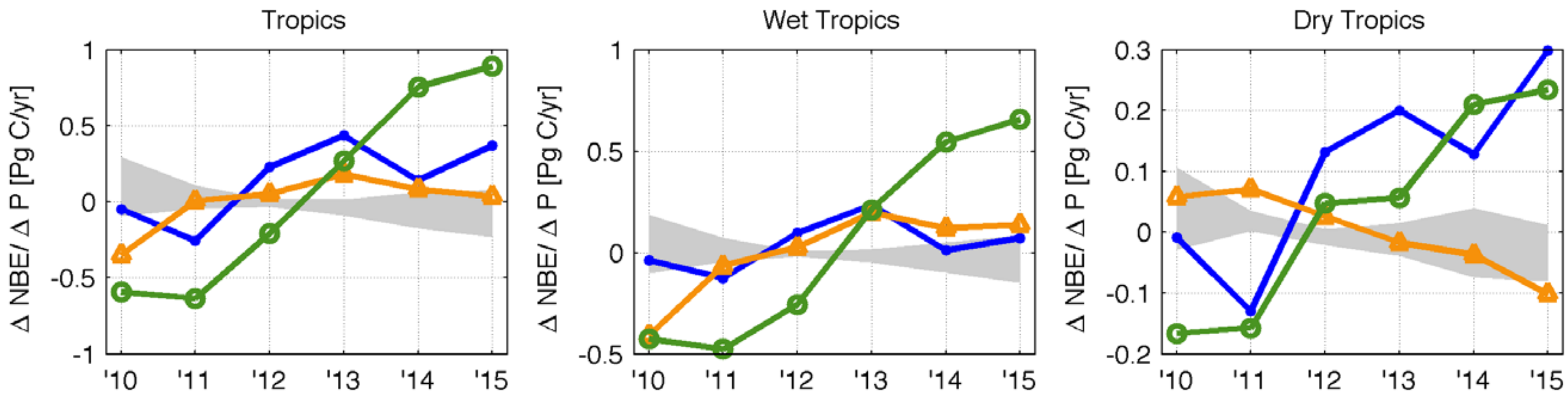
Ecosystem memory in tropical ecosystems

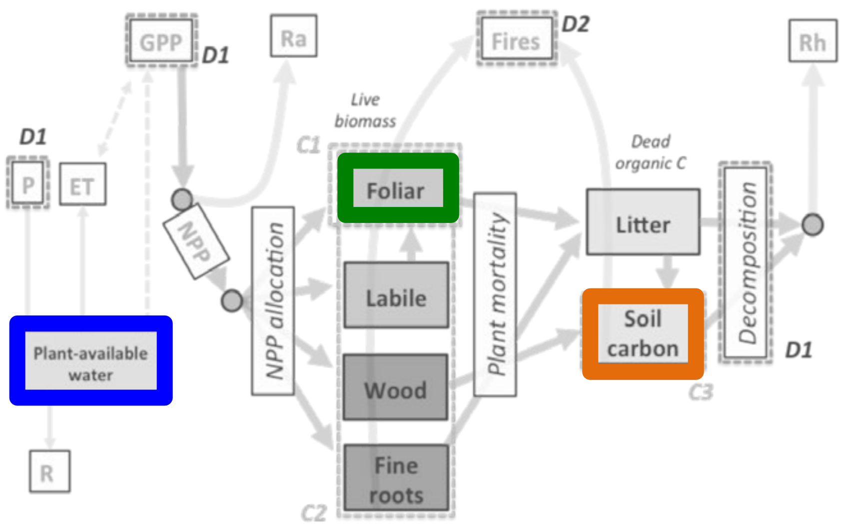


Blue = total
Green = direct
Orange = lagged

Bloom et al. (2018, in prep.)

Why?



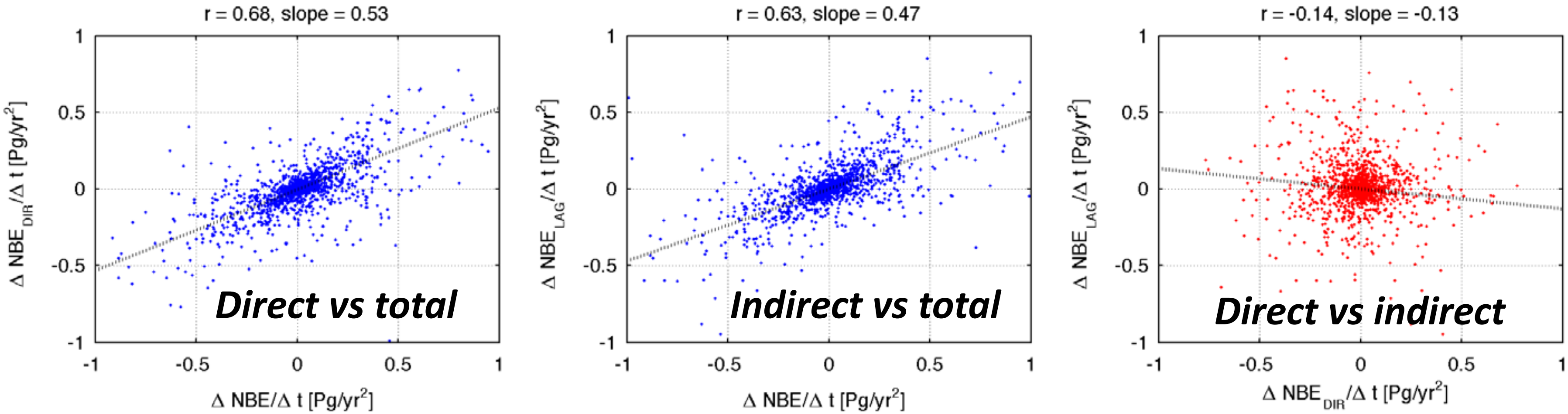


Blue = Plant-available H_2O
Green = Foliar C
Orange = Soil C

IAV and trajectories of plant-available H2O, canopy C and soil C stocks influence NBE responses to climate variability.

Bloom et al. (2018, in prep.)

Memory effects on tropical NBE IAV

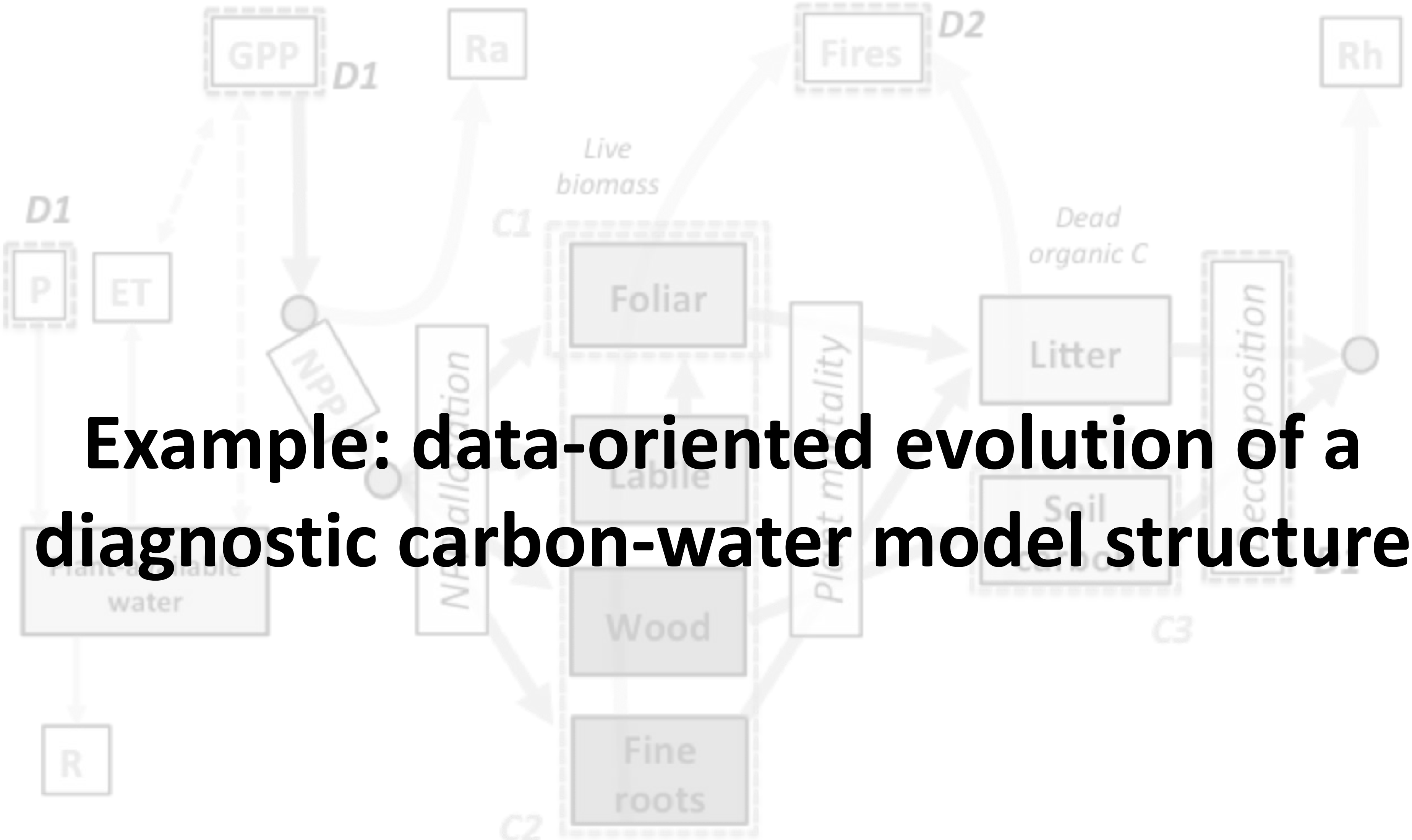


- Memory effects account for ~ 50% of tropical NBE IAV

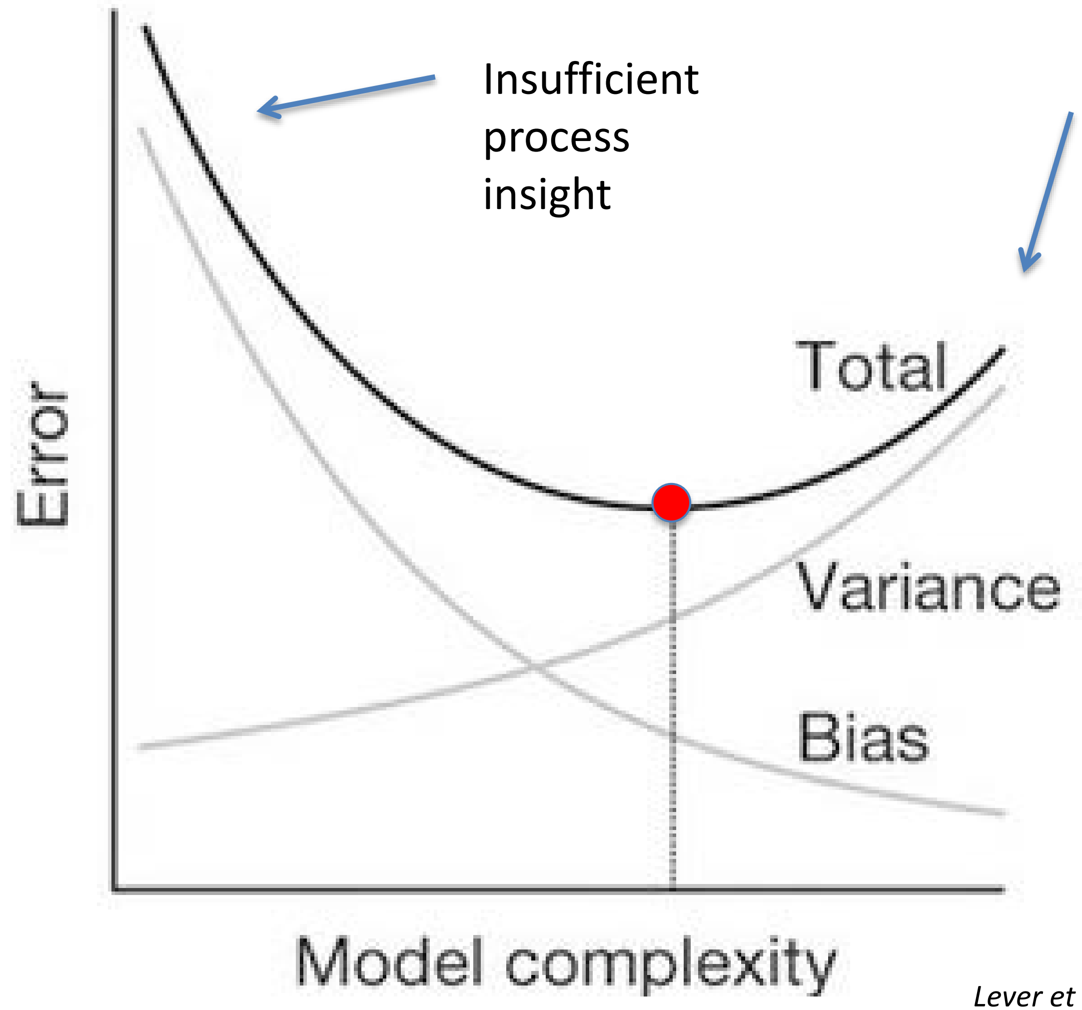
- Quantitative knowledge of NBE legacy effects is necessary to predict the evolution of the terrestrial C balance.

- Process-oriented diagnostic model central to advancing mechanistic understanding of terrestrial C cycling.

Example: data-oriented evolution of a diagnostic carbon-water model structure



Prediction error vs model complexity



Lever et al., 2016

What level of complexity do we need given:

(a) The current Earth-Observing system

(b) The quantities we're trying to predict?

CARDAMOM modular structure

1. Model
Diagnostic C & H2O models (DALEC), etc.

2. Drivers & Observations
Meteorology, LS datasets, plant traits, etc.

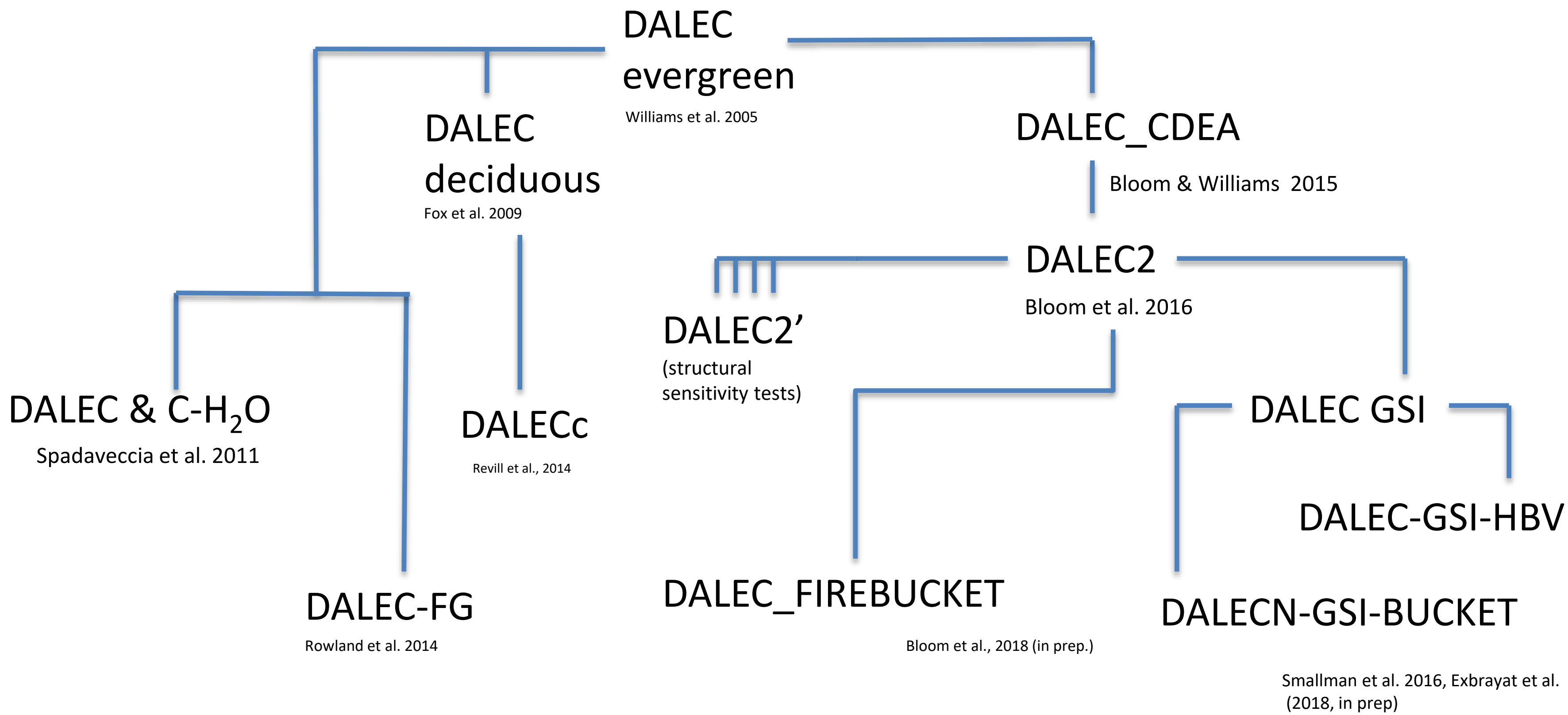
4. Data assimilation
MCMC, EnKF, etc.

3. Cost function
Observation operator, prior parameter constraints, ecological & dynamic constraints.

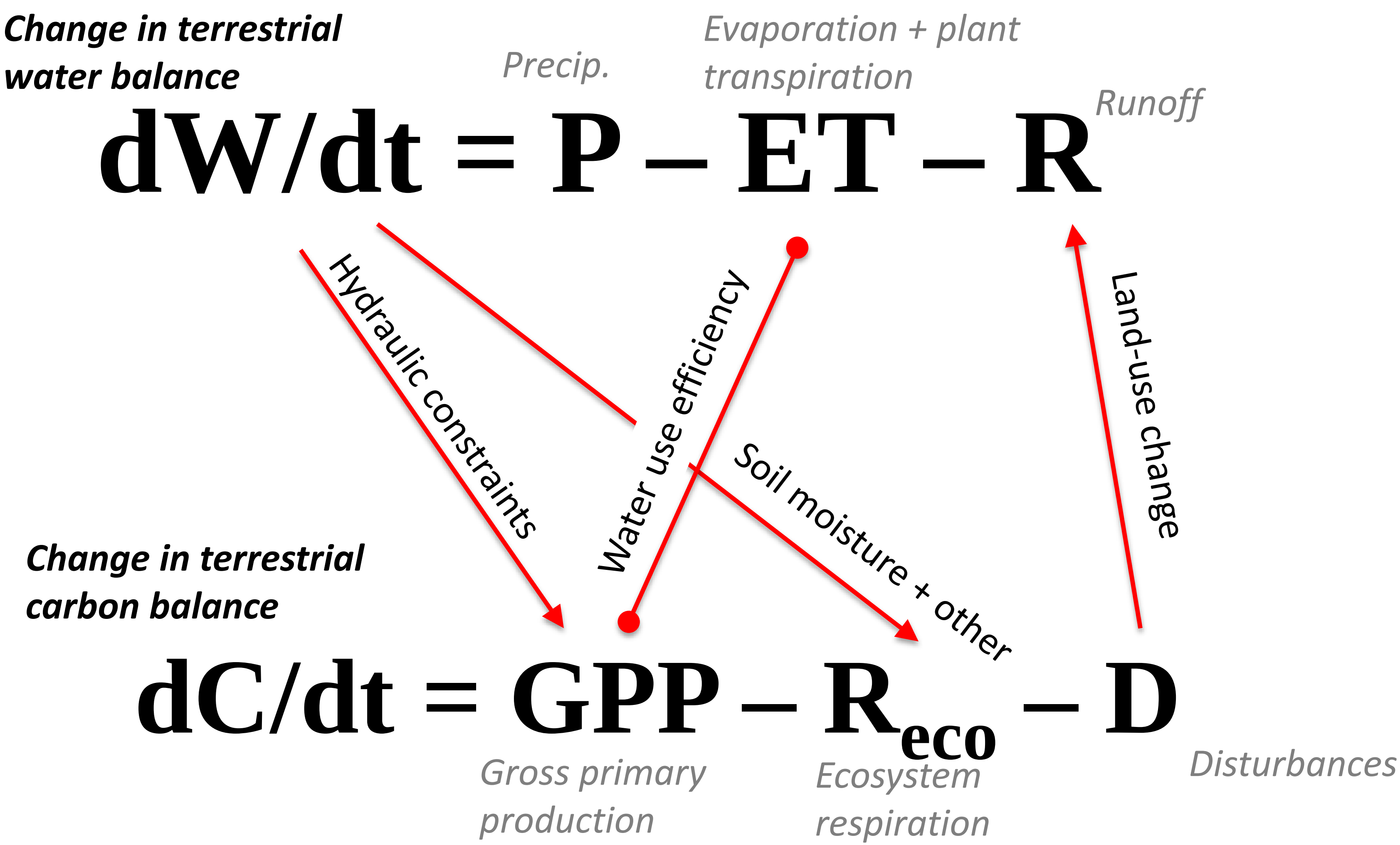
→ ***Science, prediction.***

DALEC genealogy: data & hypothesis driven evolution

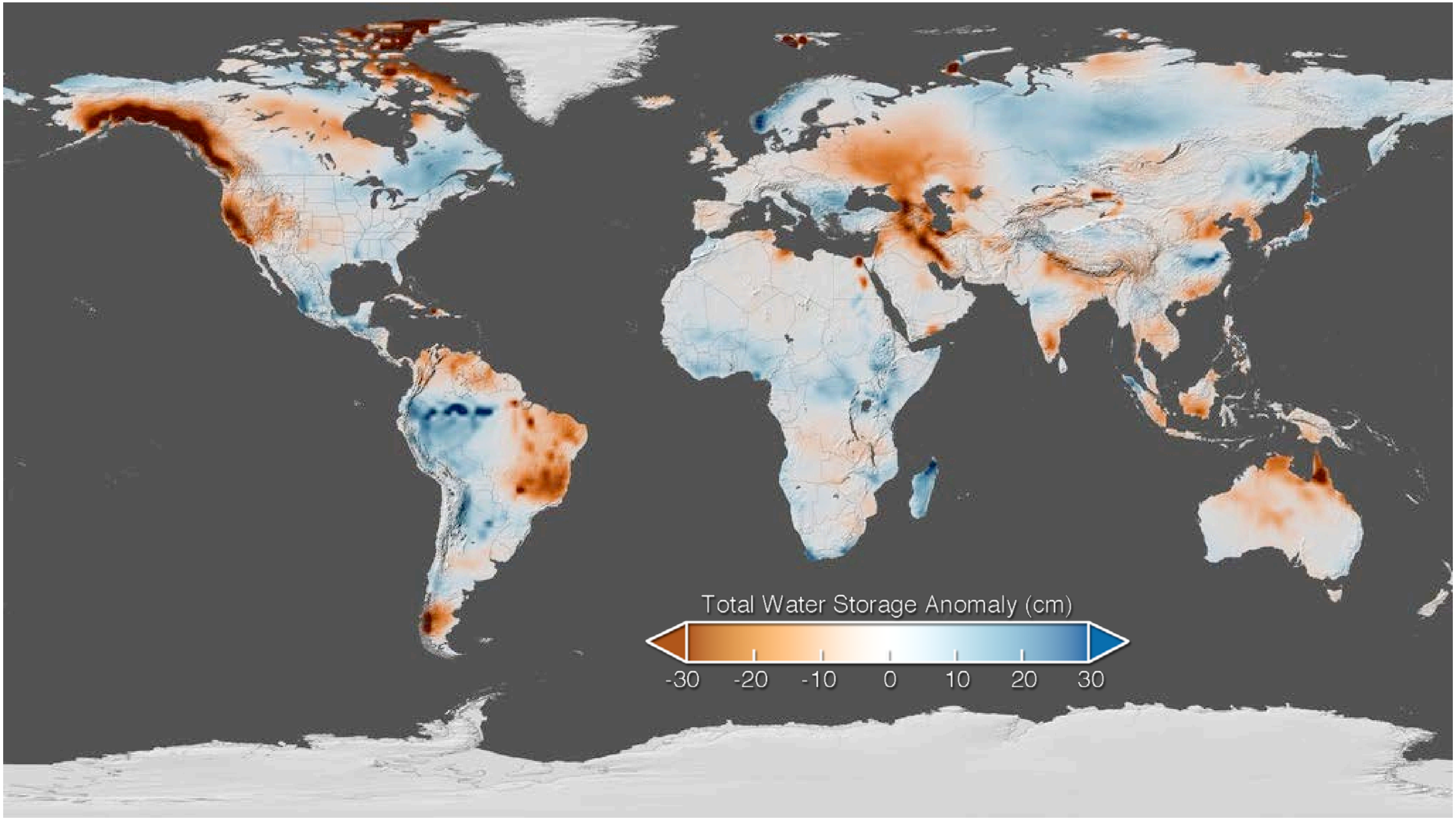
Data & hypothesis driven model development



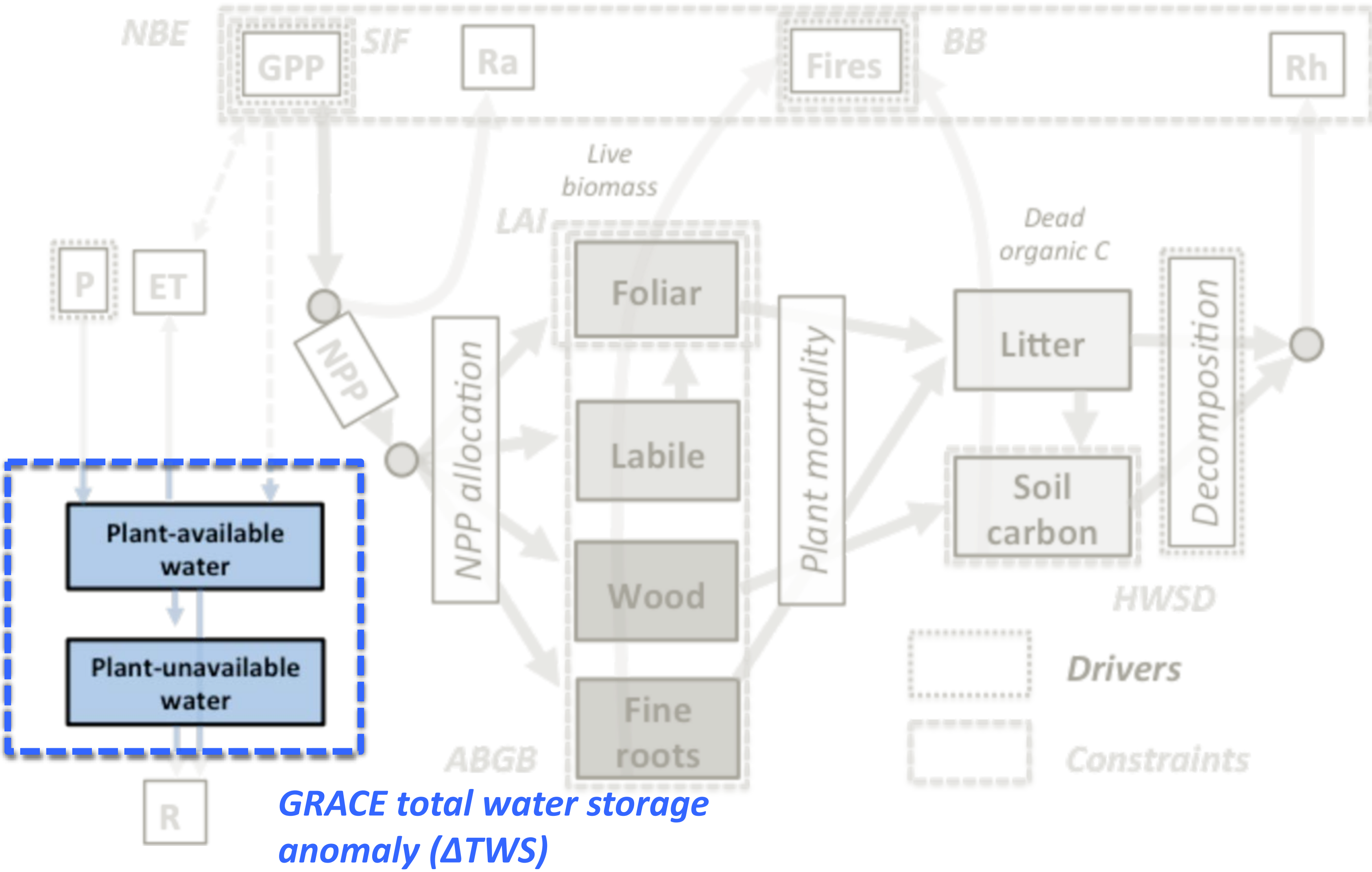
Carbon-water feedbacks



Gravity recovery and climate experiment (GRACE)

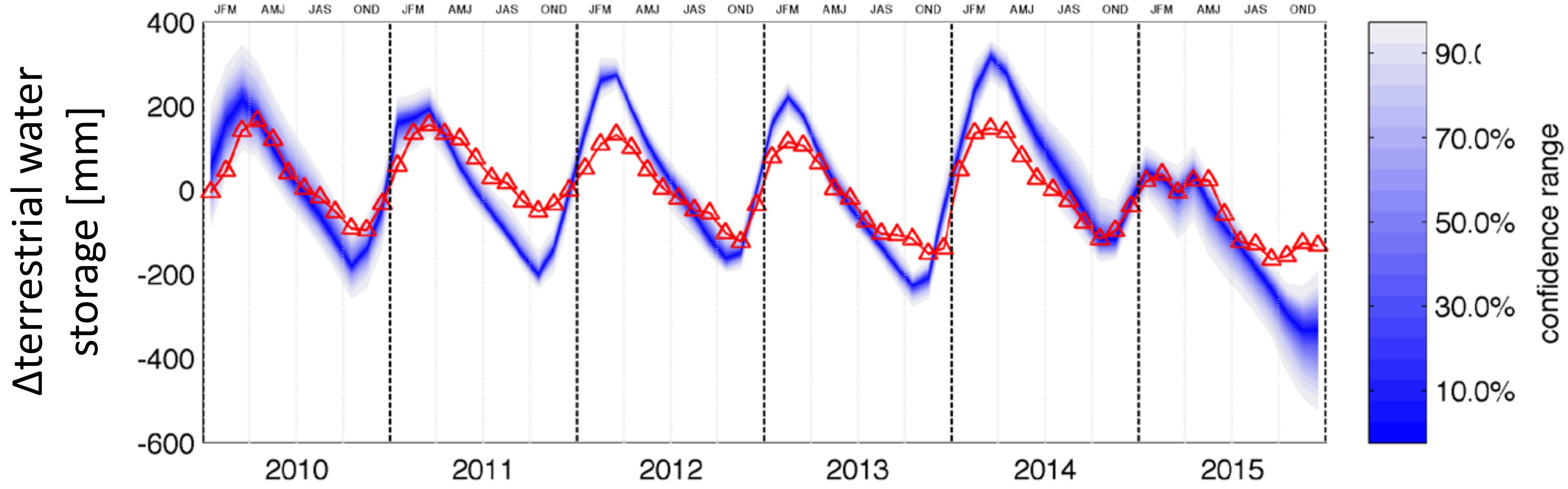


Example: data-driven model structure evolution

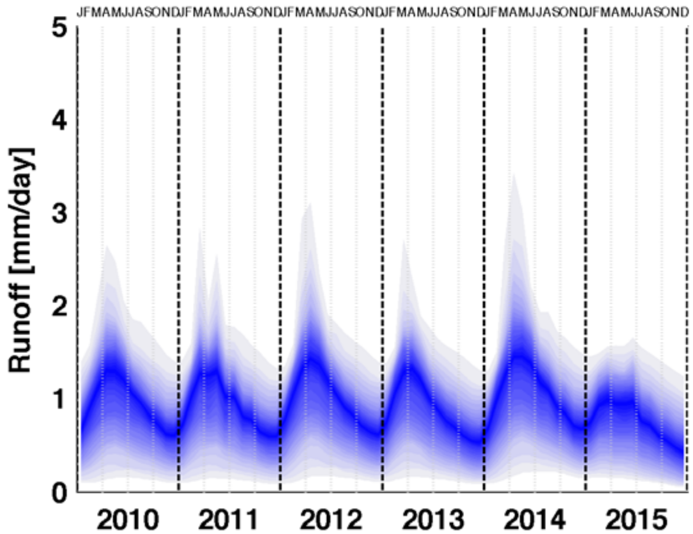


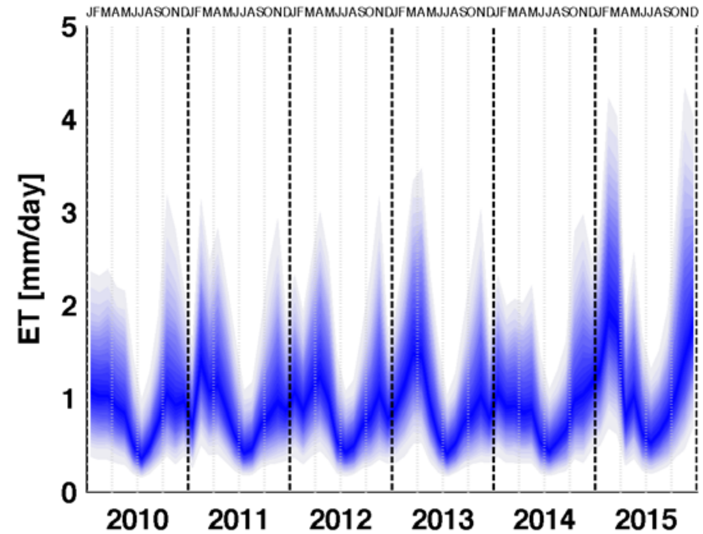
Blue = CARDAMOM

Red = GRACE (withheld)



CARDAMOM: C constrains only

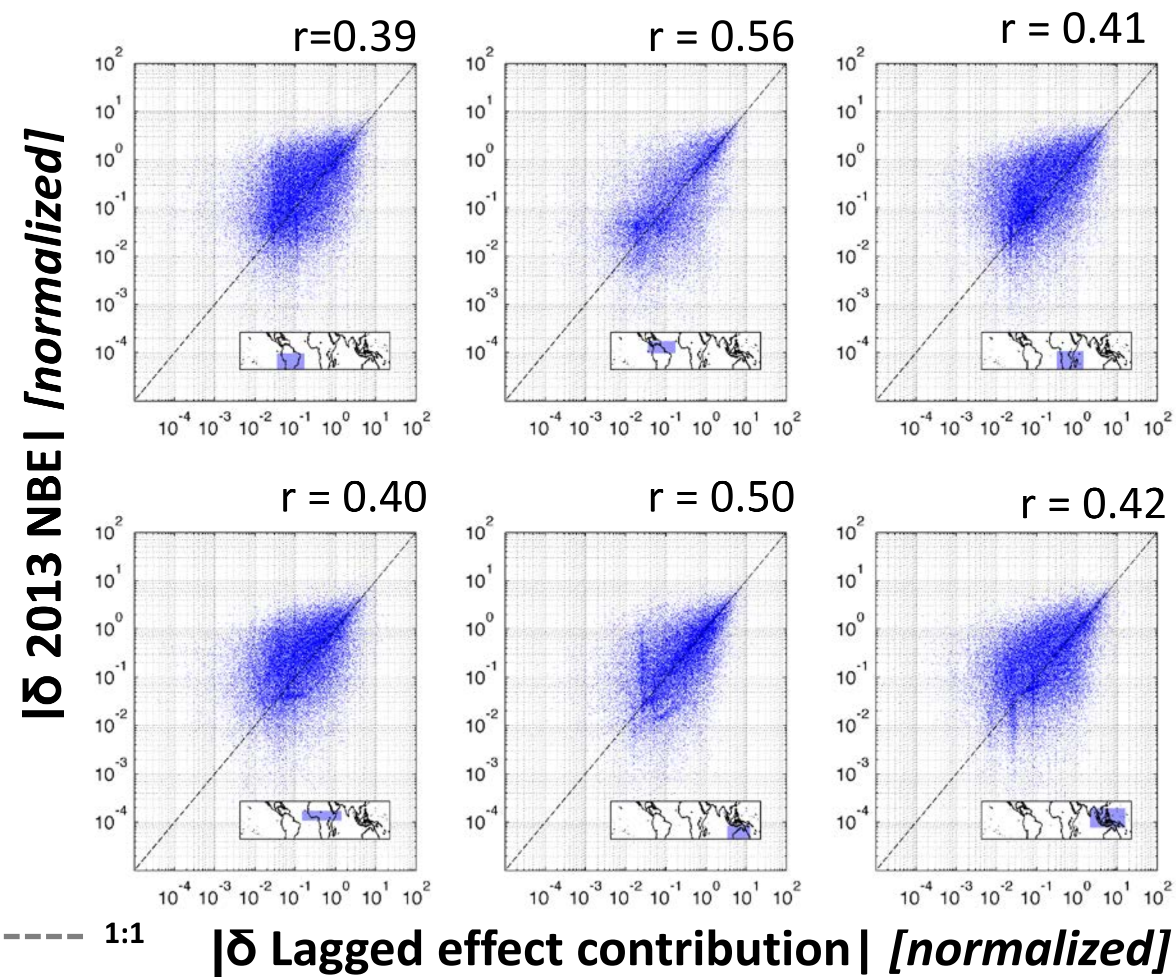




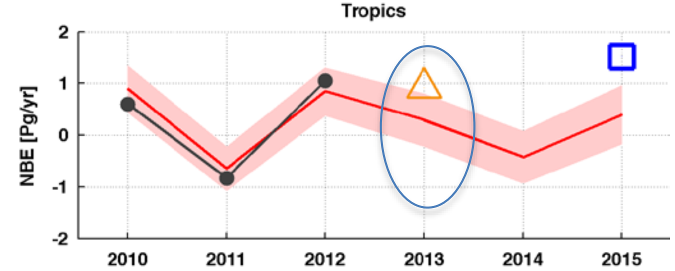
Conclusions & questions

- Joint understanding of climate sensitivity and ecosystem memory effects on present-day NBE IAV necessary for prediction.
- Observational constraints on both carbon and water cycle dynamics are central to building a land-surface predictive ability.
- How do we bring and test process-based model knowledge in a diagnostic C-H2O-energy model-data framework?
- What is the optimum balance between process fidelity and data consistency for decadal-to-centennial predictions?

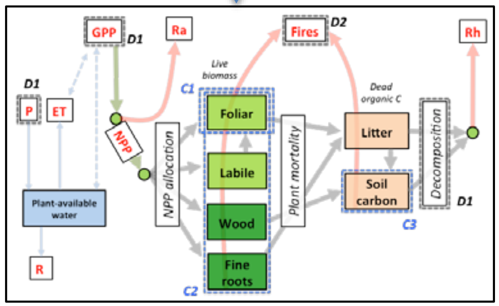
Do ecosystem memory effects matter for NBE IAV prediction?



Example: 2013 NBE mismatch



Random perturbations (δx) on optimized CARDAMOM parameters (x)



Optimized CARDAMOM parameters and state variables.

CARDAMOM (x + δx)