What are the future Big Science Questions for JULES ?

Peter Cox

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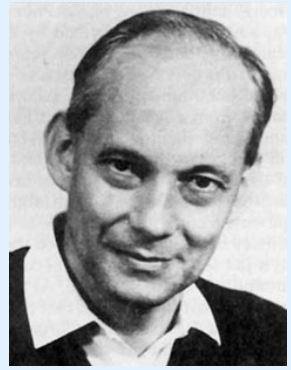
Met Office Chair in Climate System Dynamics
Mathematics Research Institute

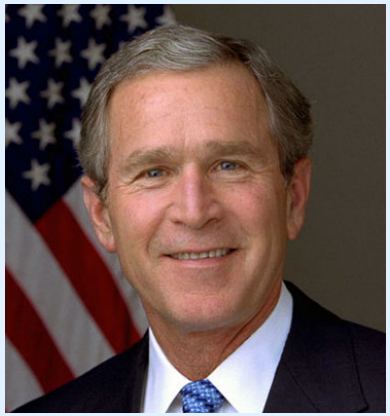
“A theory has only the alternative of being right or wrong.

A model has a third possibility:

it may be right, but irrelevant”.



Manfred Eigen



"I have said consistently that global warming is a serious problem.“

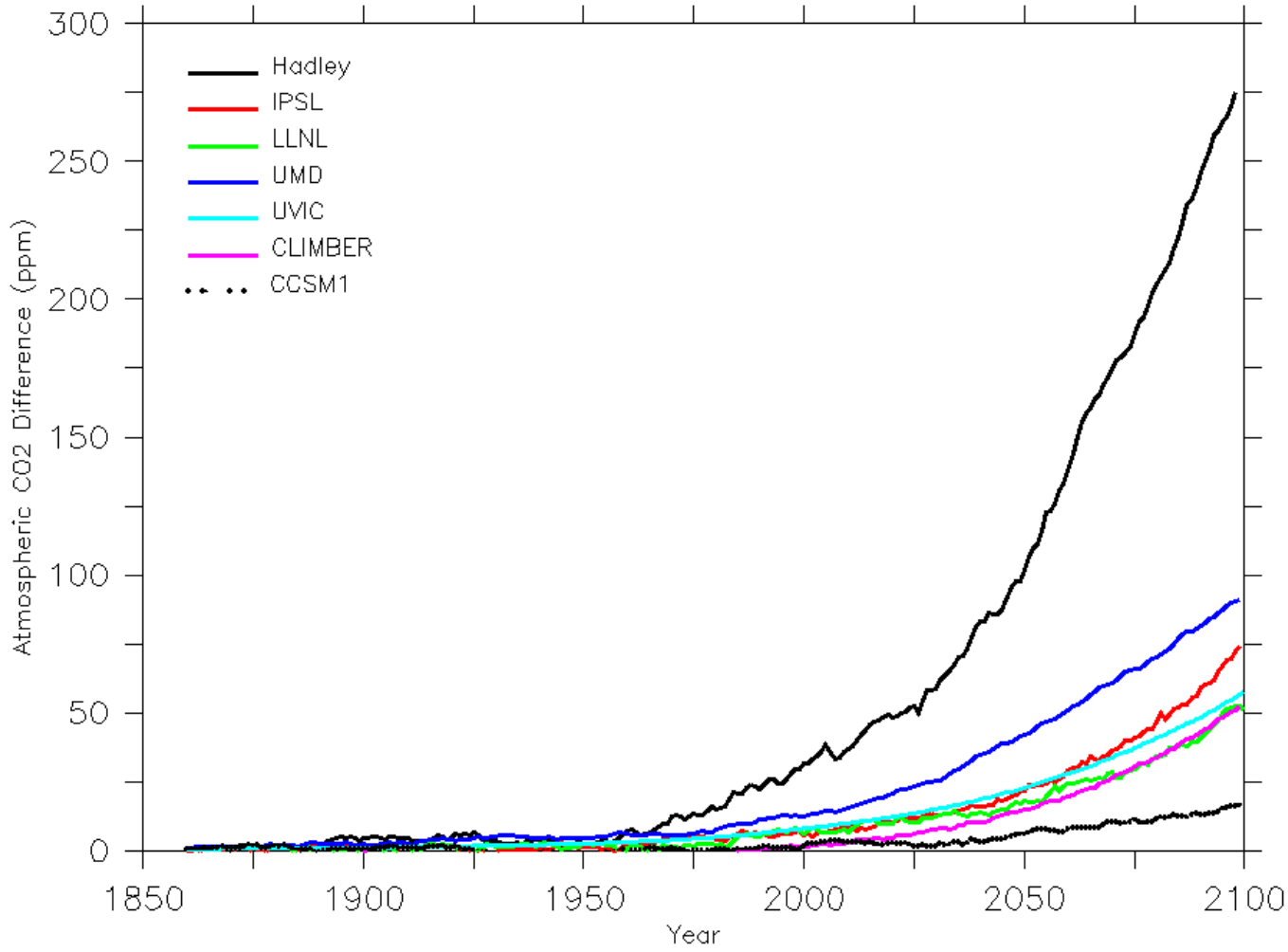
June 2006

“And we now have sufficient evidence that human-made climate change is the most far-reaching - and almost certainly the most threatening - of all the environmental challenges facing us.”

March 2005

How large is the climate - carbon cycle feedback?

Predictions of extra CO_2 due to climate effects on the carbon cycle

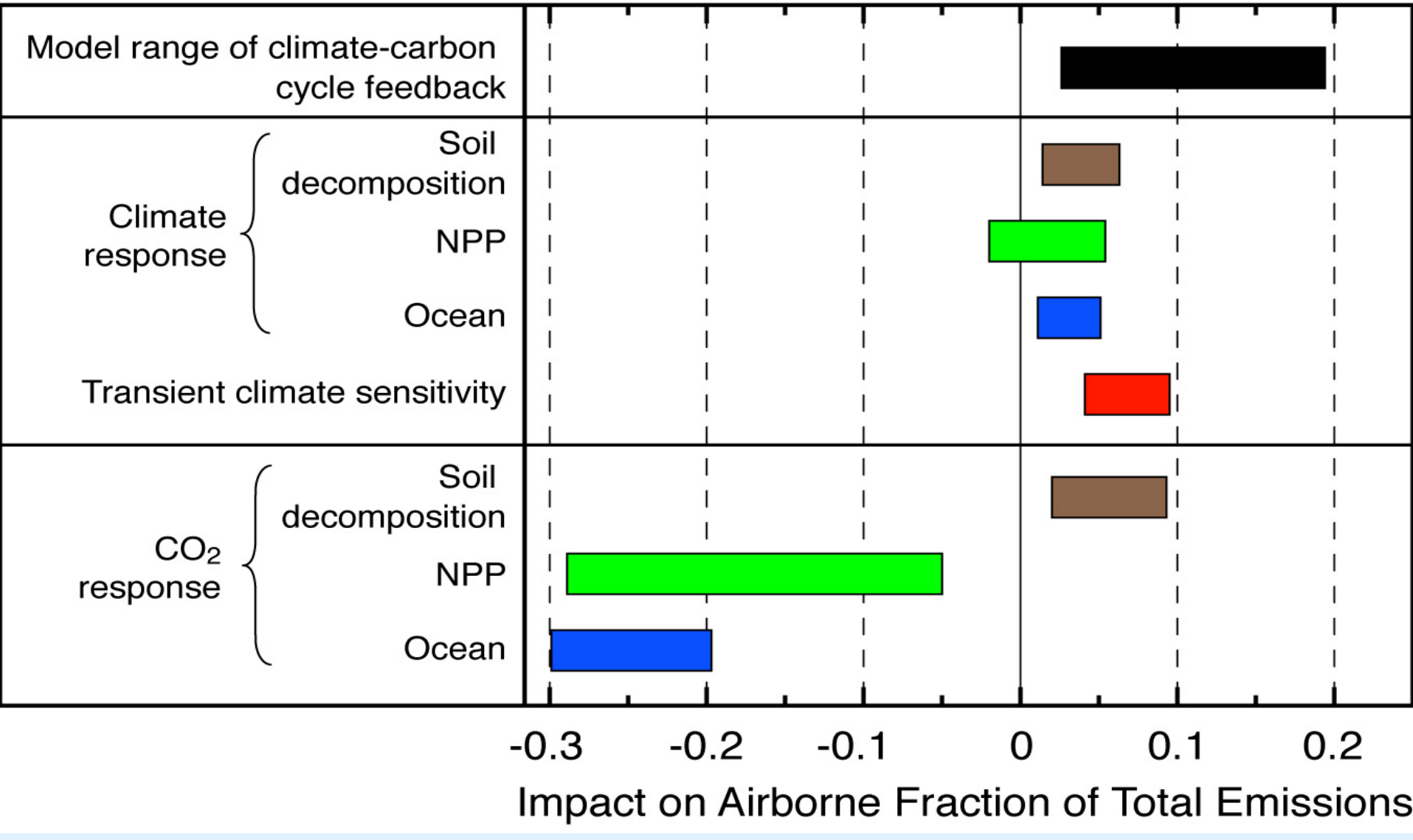


All models simulate a positive feedback, but with very different magnitudes..

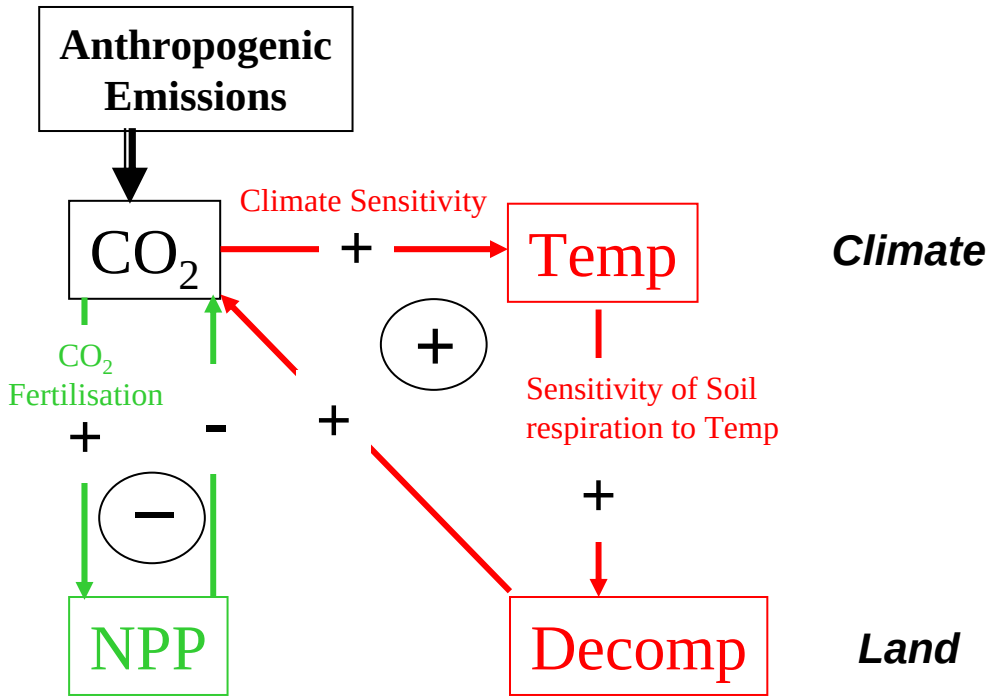
…getting on my high-horse for a minute…

Beware neglecting the "outliers" !

Uncertainties in Carbon Cycle Feedbacks



Climate-Land Carbon Cycle Feedbacks



Modelled GCM feedbacks are competition between CO_2-fertilisation of growth (negative feedback), and accelerated decomposition in warmer climate (positive feedback).

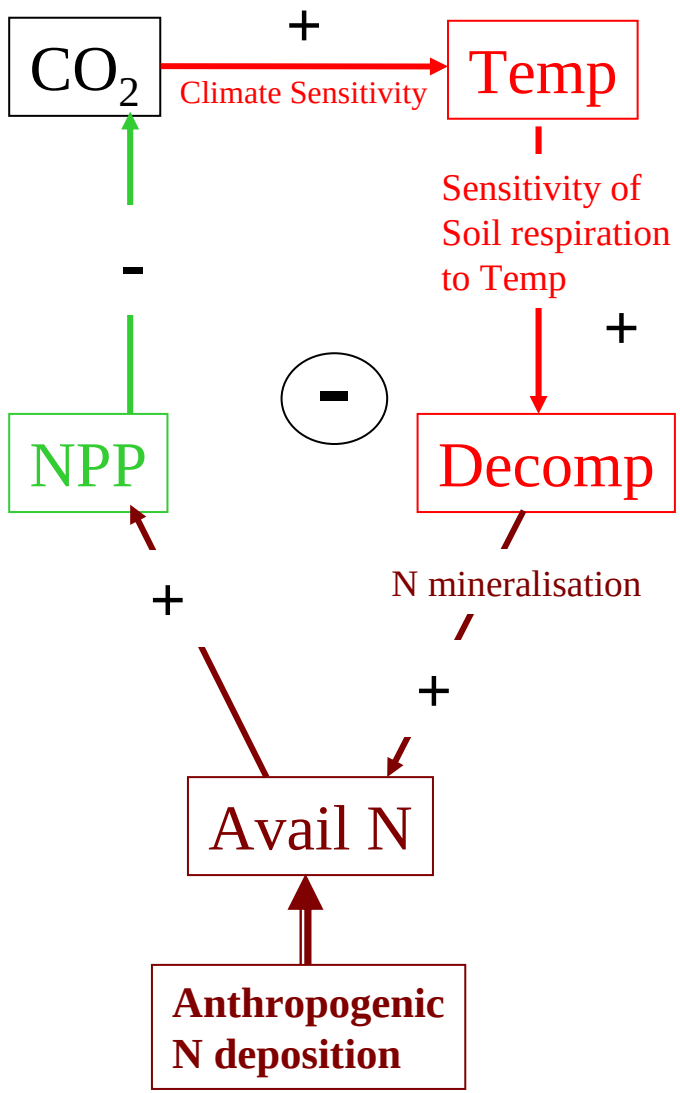
Key unknowns: Climate sensitivity to CO_2

Soil respiration sensitivity to temperature.

CO_2-fertilisation of growth

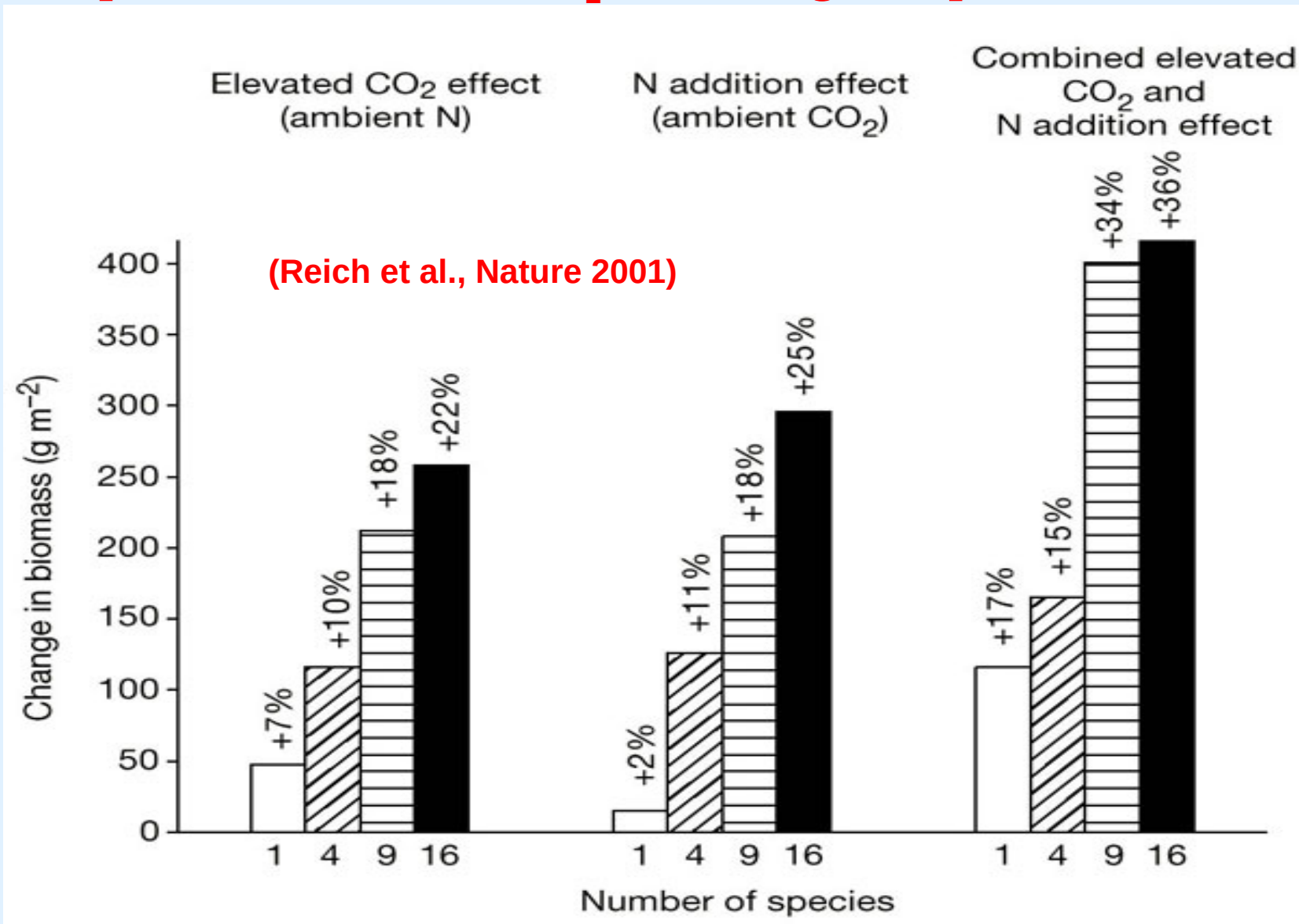
How will nitrogen cycling influence the land carbon sink ?

Increased N availability in a warmer world – the key missing negative feedback?



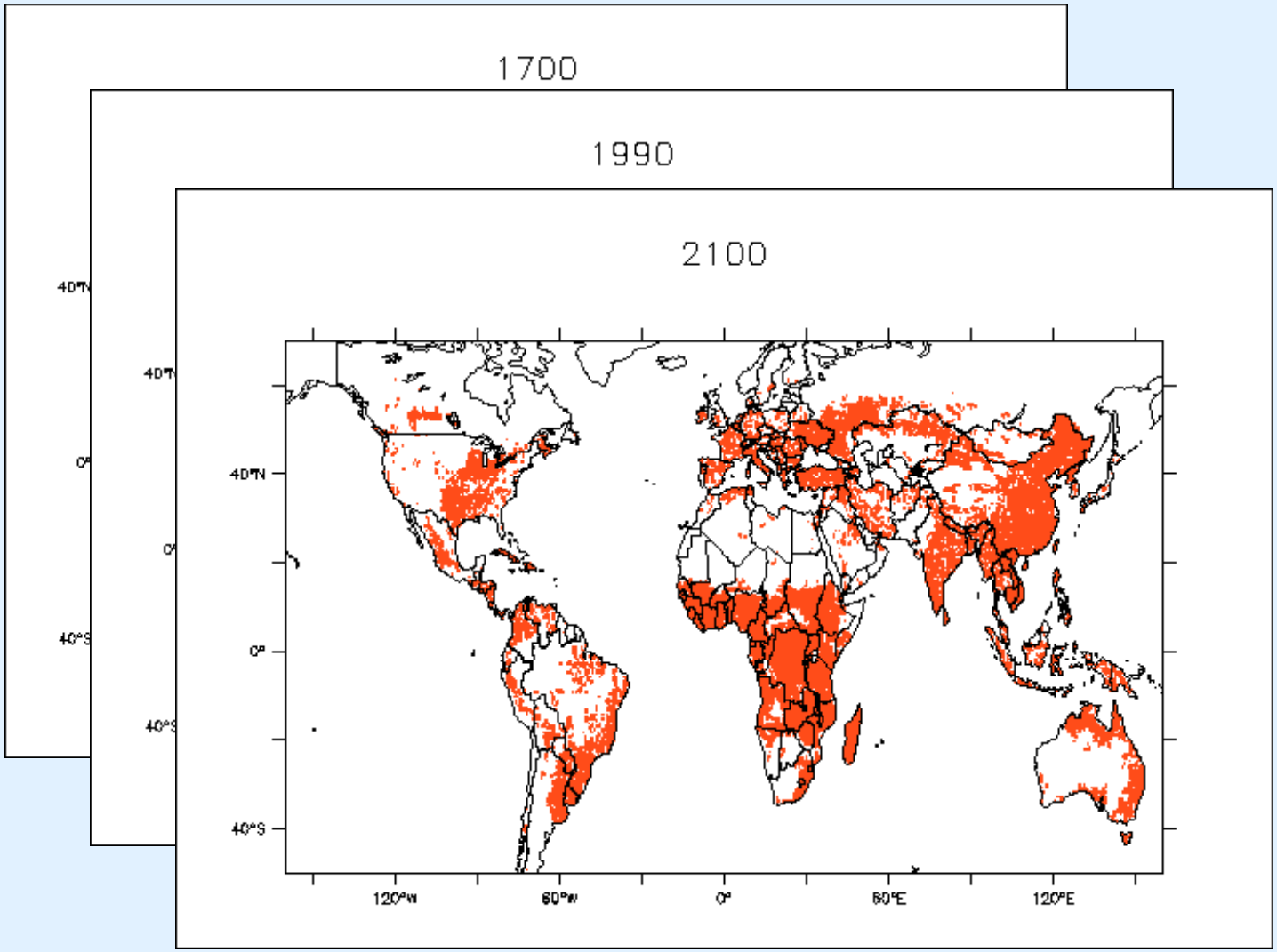
How does biodiversity affect the resilience of ecosystems to climate change ?

Evidence that Plant diversity enhances ecosystem responses to elevated CO_2 and nitrogen deposition

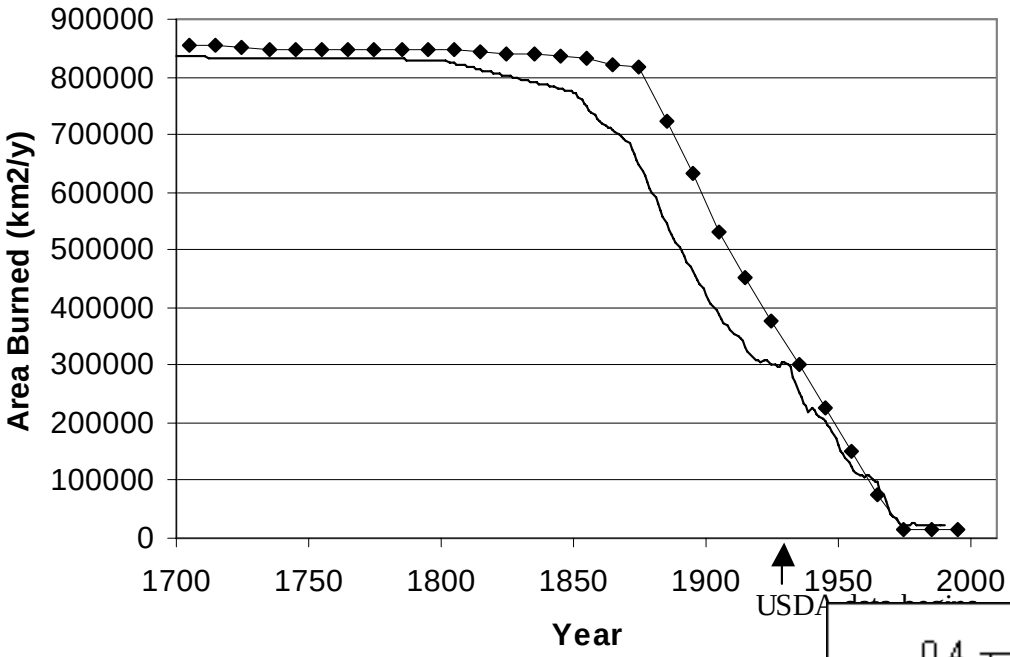


How important is land-management for carbon and water cycling ?

We are taking more of the land for agriculture and this is set to continue….

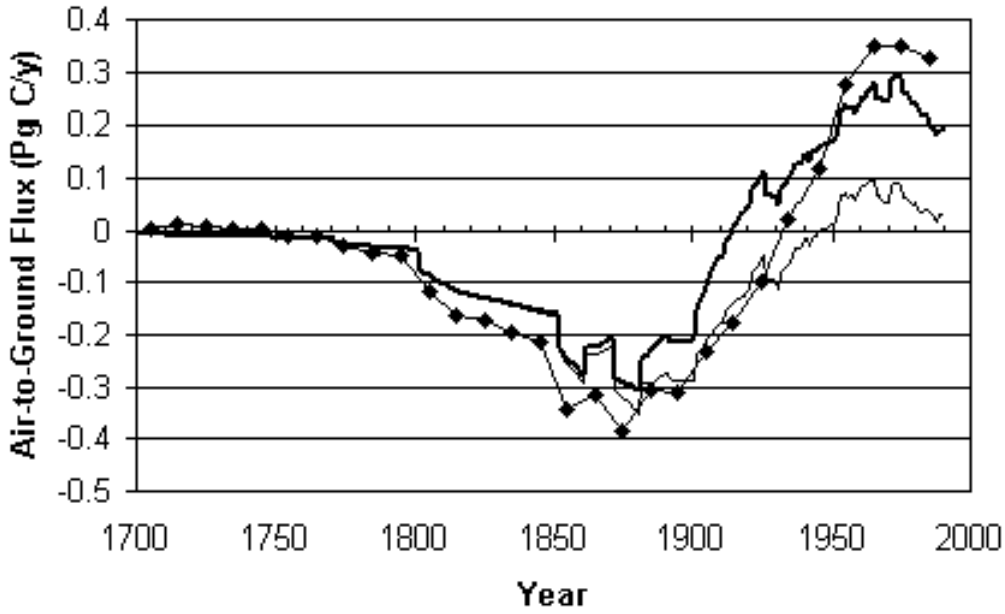


U.S. Fire History



..may account for….

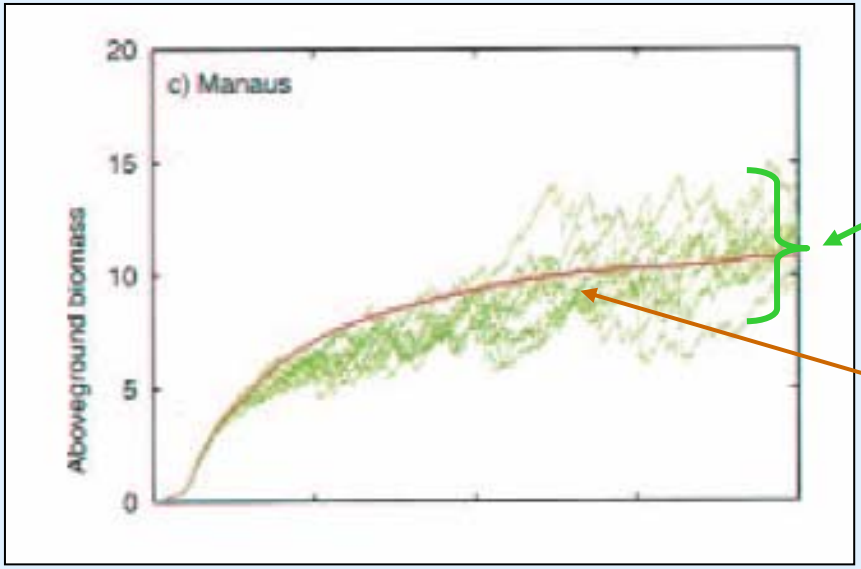
U.S. Land Carbon Sink



Importance of including land-management effects…

Hurtt et al. 2002

ED approach to Vegetation Dynamics Including age-class distributions



Explicit simulation of rainforest regrowth on multiple patches

Moment Equations for Statistics of Vegetation State

$$\underbrace{\frac{\partial}{\partial t} n(\mathbf{z}, \mathbf{x}, t)}_{\text{change in plant density}} = \underbrace{-\frac{\partial}{\partial \mathbf{z}_s}[g_s(\mathbf{z}, \mathbf{x}, \bar{\mathbf{r}}, t) n(\mathbf{z}, \mathbf{x}, t)]}_{\text{growth in stem}}$$

$$\underbrace{-\frac{\partial}{\partial \mathbf{z}_a}[g_a(\mathbf{z}, \mathbf{x}, \bar{\mathbf{r}}, t) n(\mathbf{z}, \mathbf{x}, t)]}_{\text{growth in active tissues}}$$

$$\underbrace{-[\mu(\mathbf{z}, \mathbf{x}, \bar{\mathbf{r}}, t) + \lambda(t)] n(\mathbf{z}, \mathbf{x}, t)}_{\text{mortality and disturbance}}$$

..enables modelling of land-management effects

Morecroft et al., 2001

How will fire frequency change under global warming ?

Forest Fires

- 1 to 2% of the land surface is estimated to burn annually (GBA 2000).
- There have been dramatic regional changes in fire frequency due to land management.
- How will climate change affect fire frequency ?

Where does knowing the state of the land surface improve the forecasting of rainfall ?

Land-atmosphere feedback strength from Models and EO data

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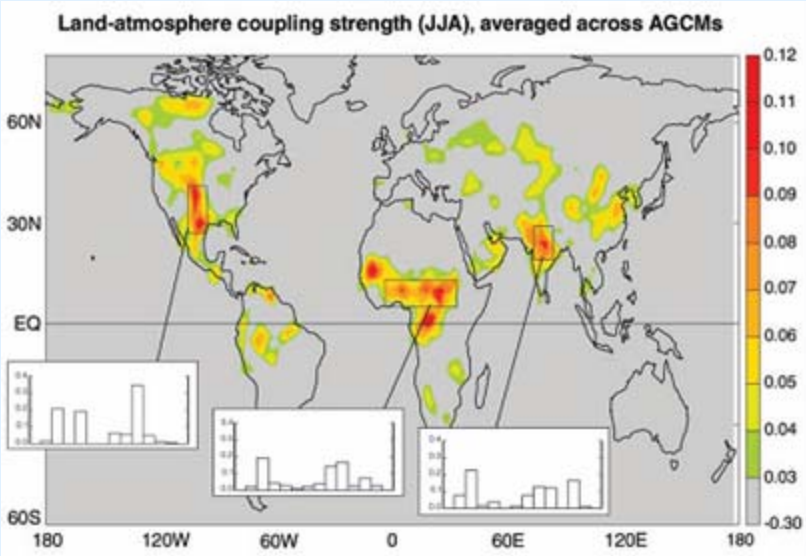
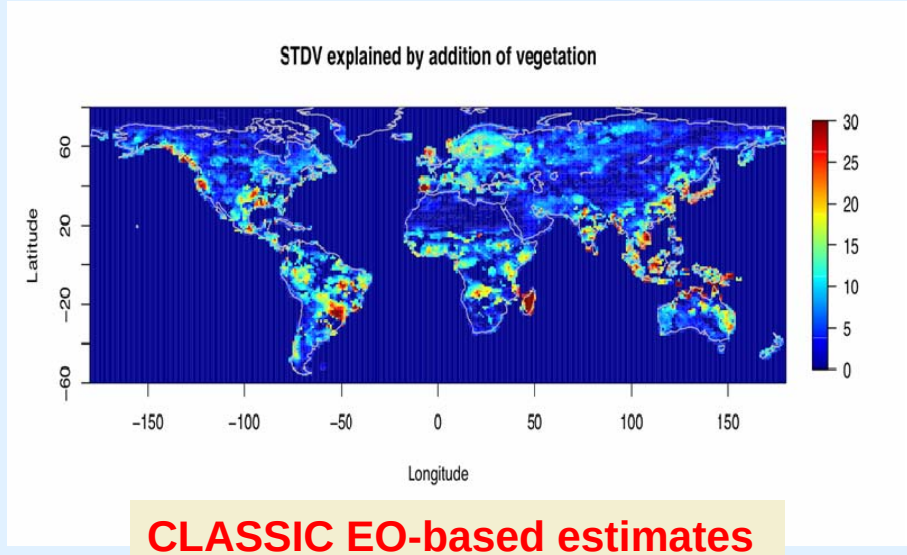
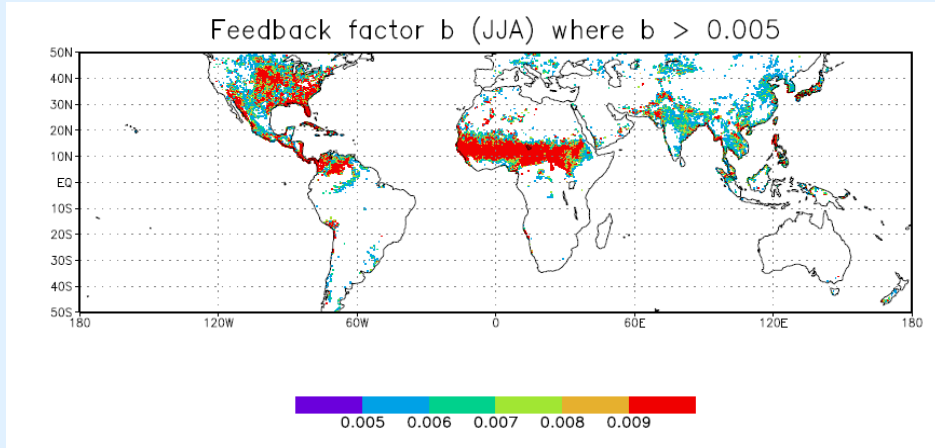
Koster et al., 2004



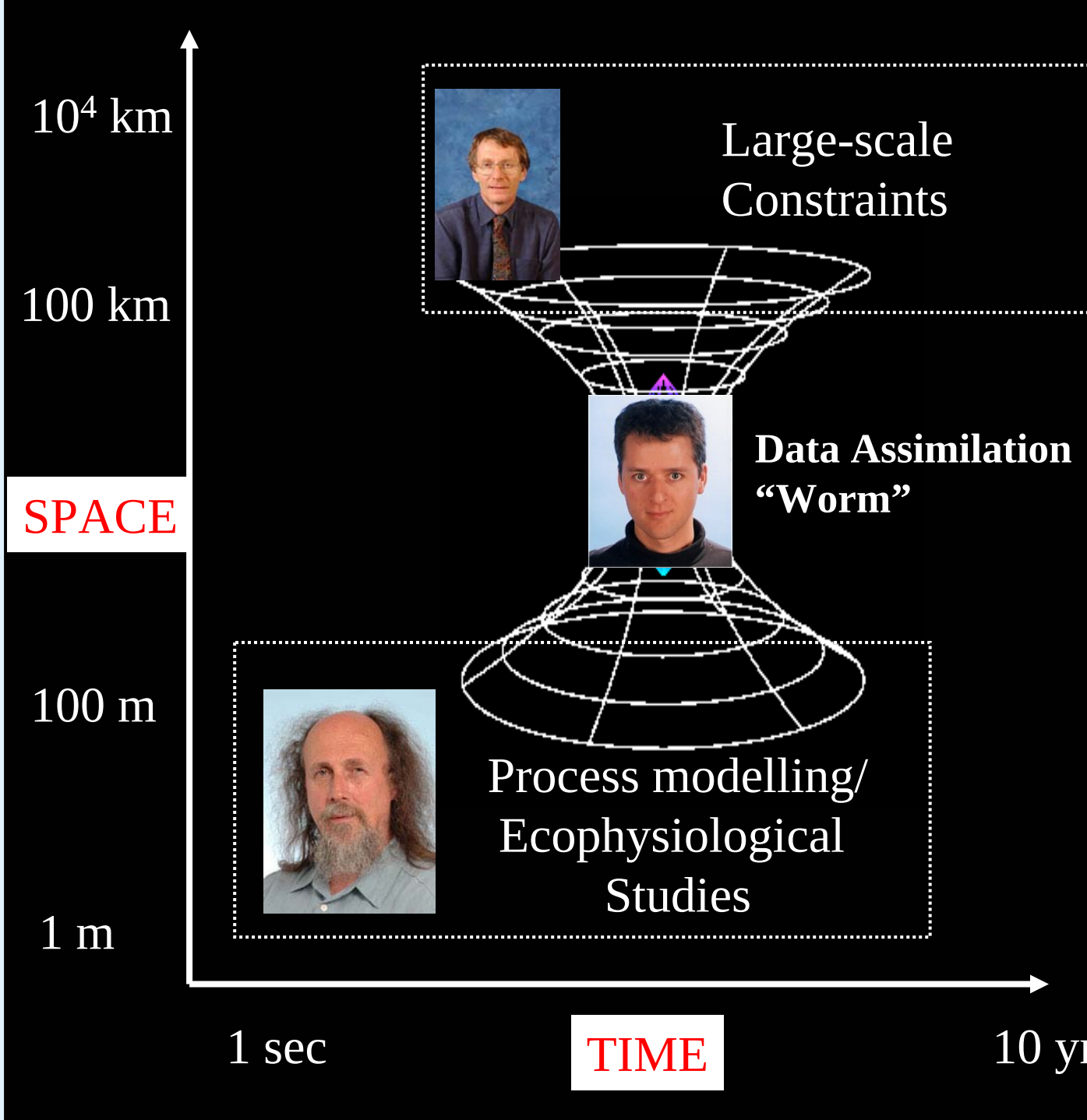


CLASSIC EO-based estimates

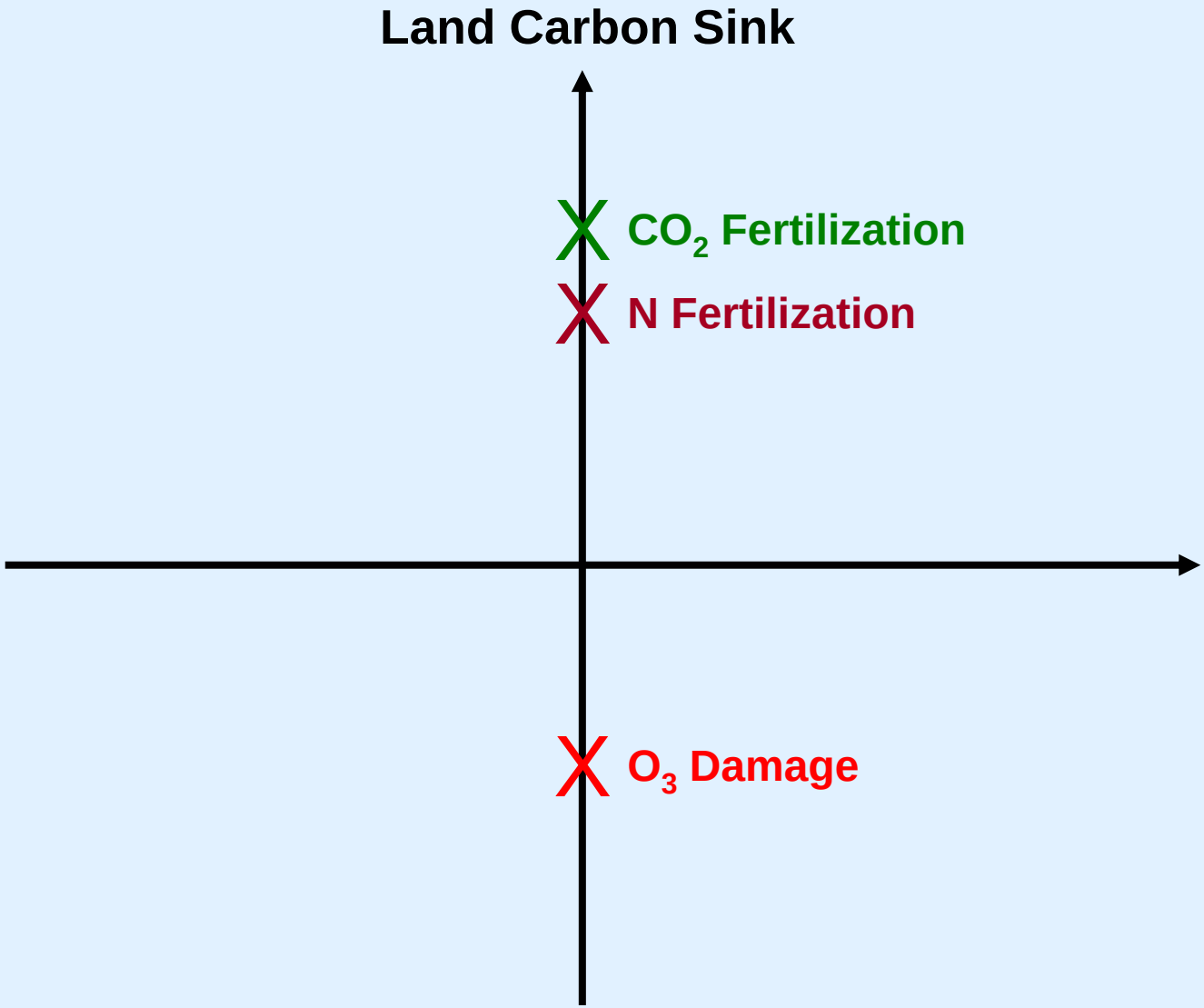


How should we use observational data to constrain predictions ?

Spanning Time & Space Scales through Model-Data Fusion



The Value of Multiple Constraints



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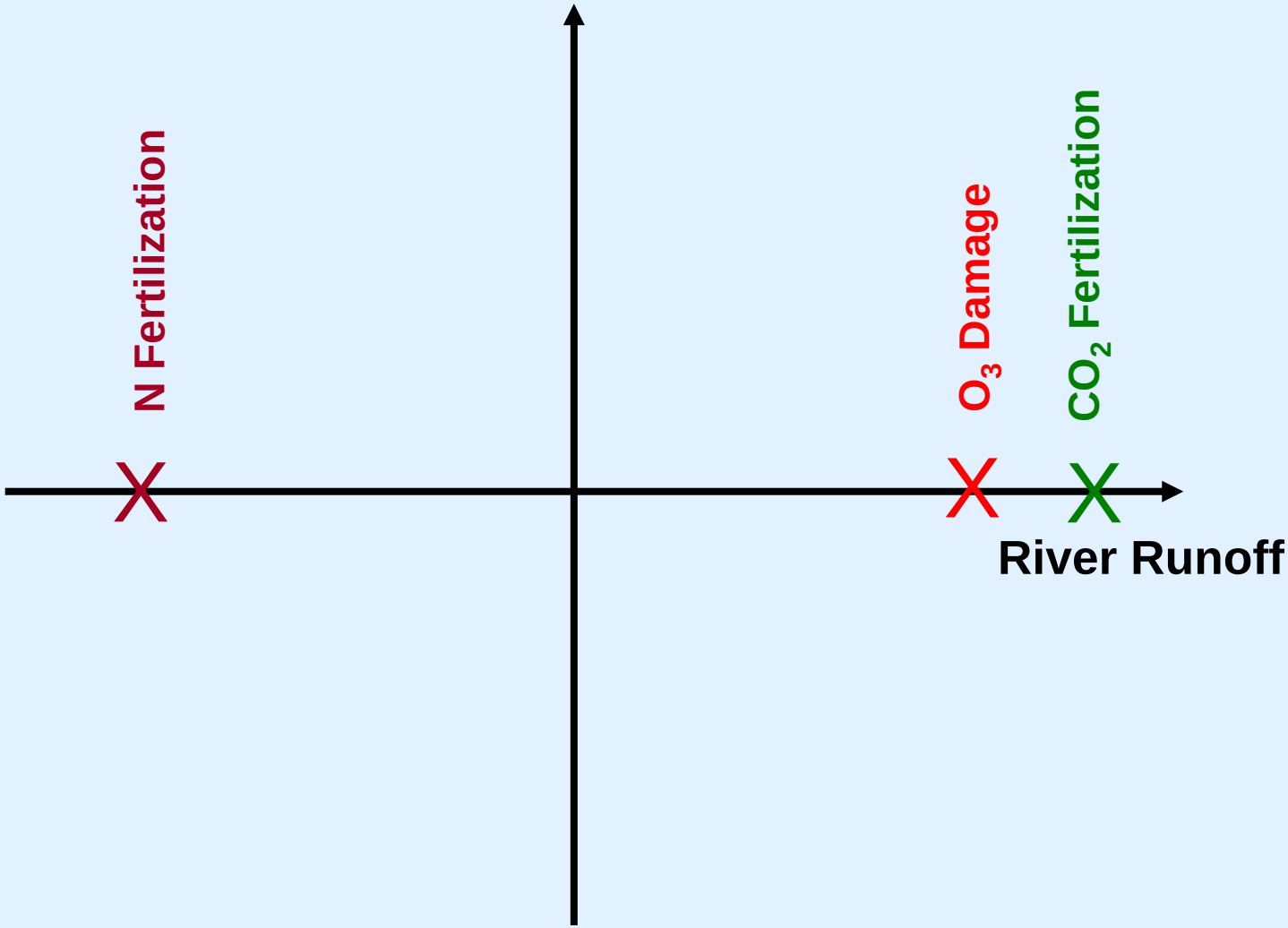

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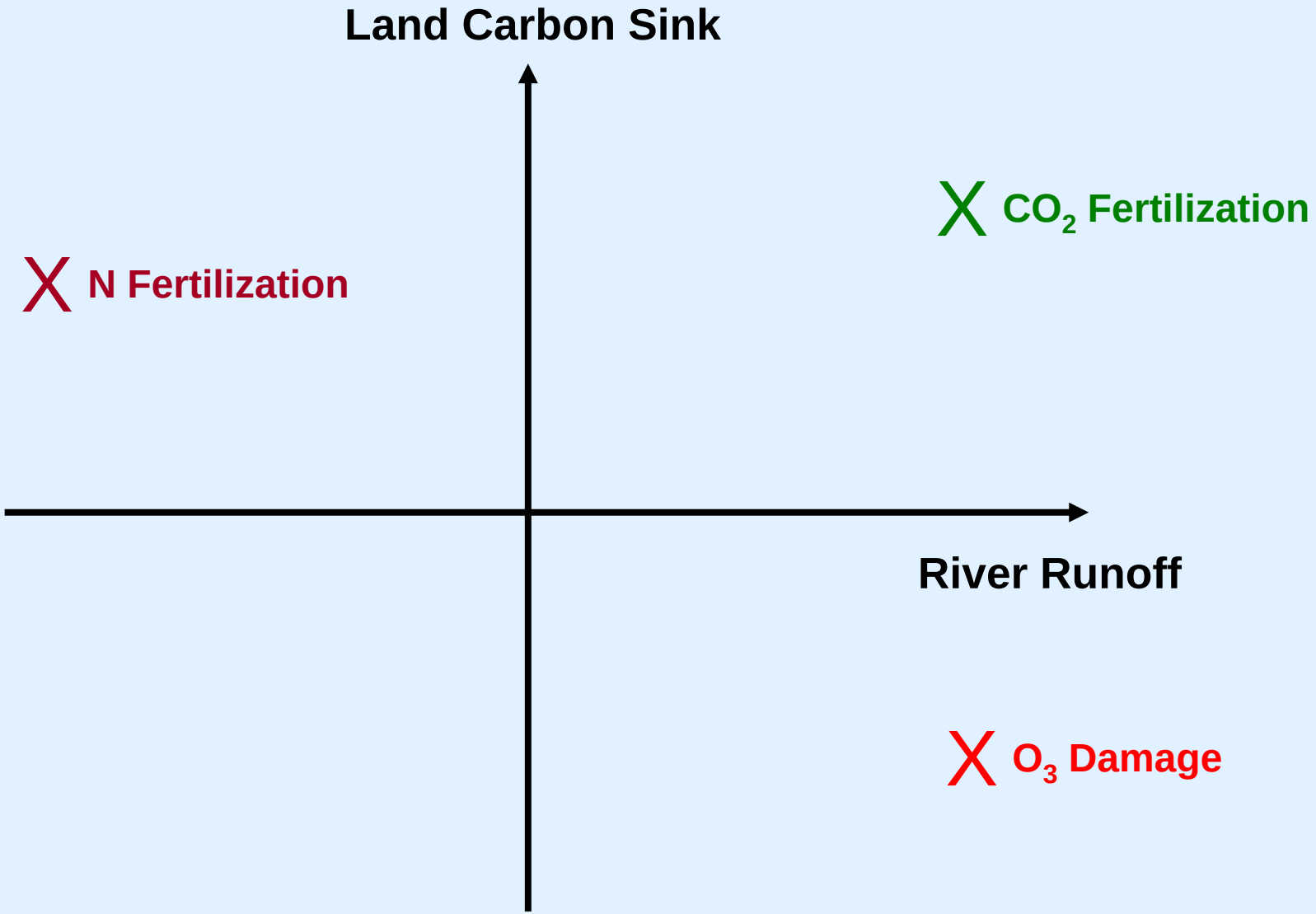

Some Big Questions to Ask JULES

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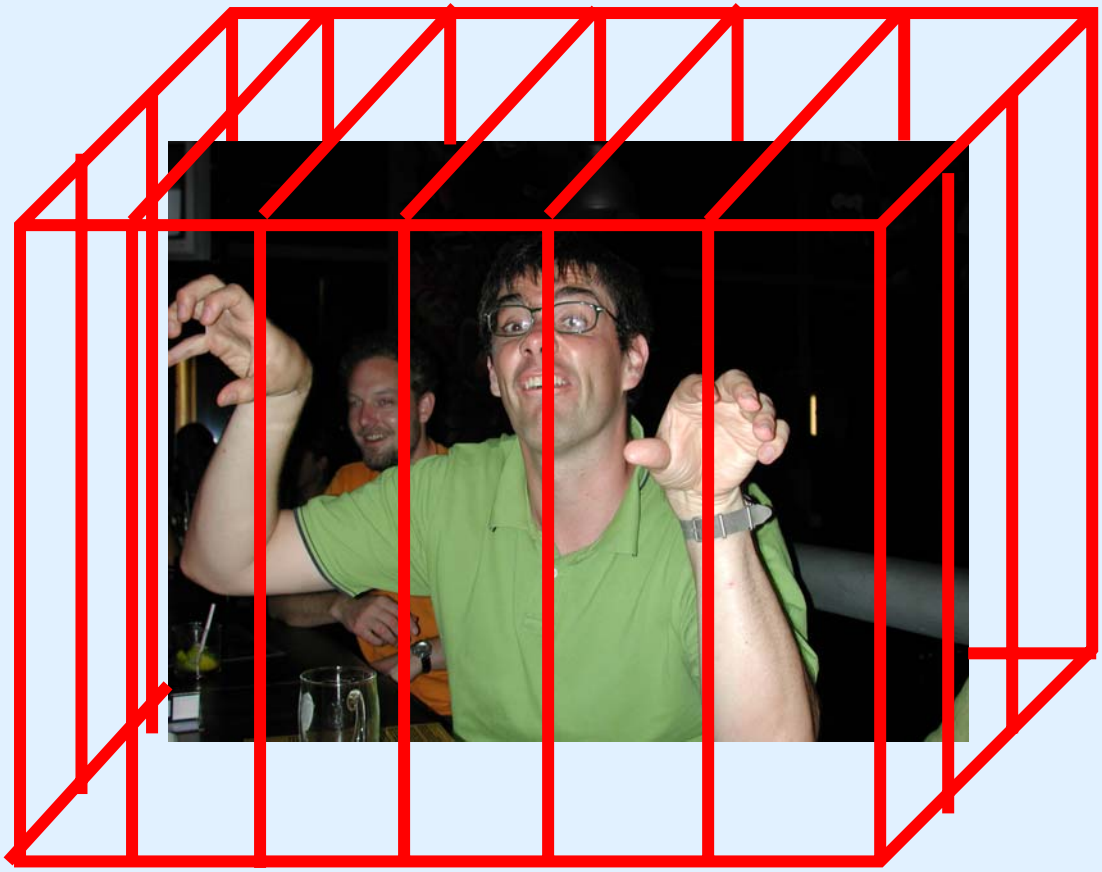
- How large is the climate – land carbon cycle feedback?
- How will nitrogen cycling influence the land carbon sink ?
- How does biodiversity affect the resilience of ecosystems to climate change ?
- How important is land-management for carbon and water cycling ?
- Where does knowing the state of the land-surface improve the forecasting of rainfall ?
- How should we use observational data to constrain predictions ?

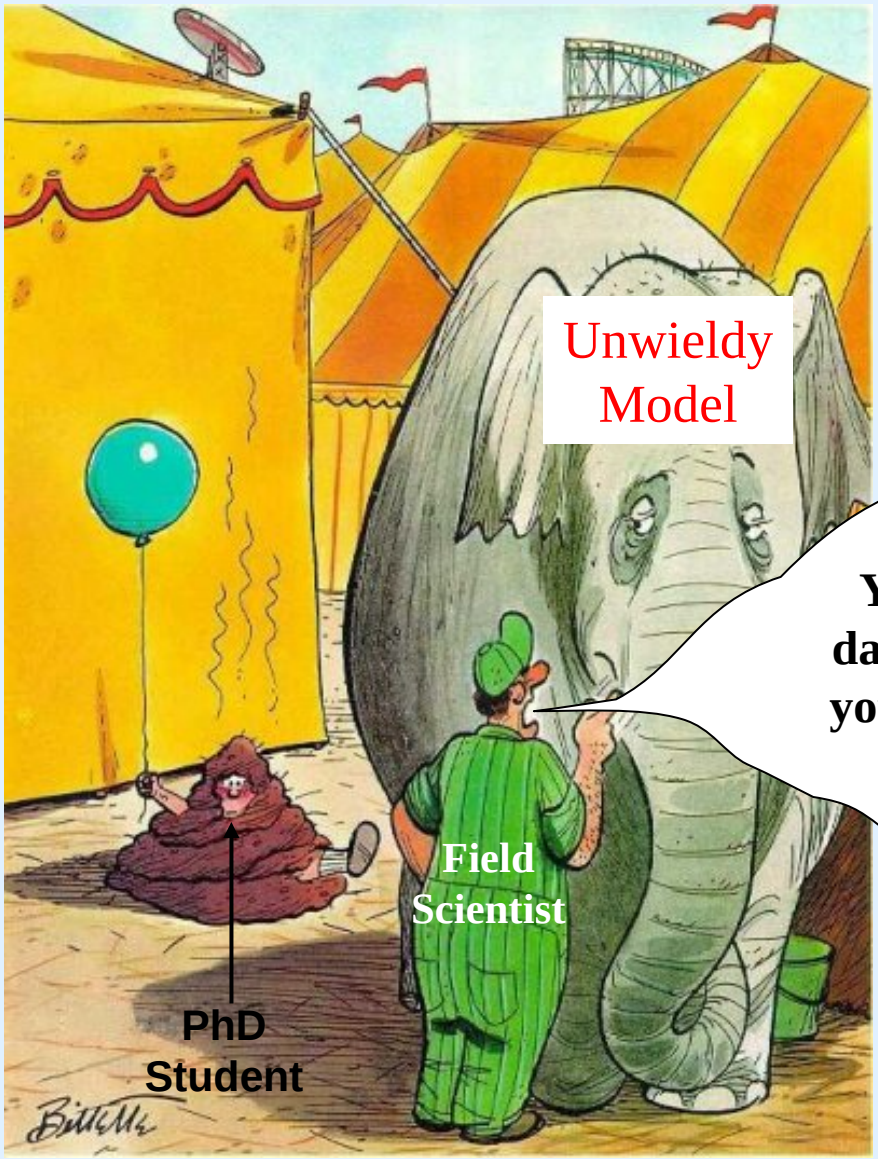
Outdated Views of Models and Data

- The Modeller's View



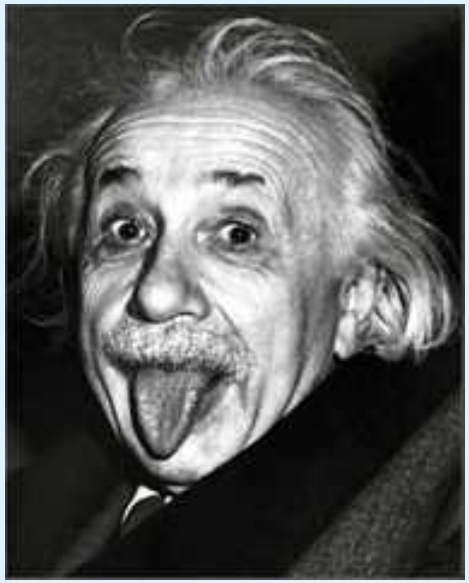
..modeller constrained by a "data cage"

Outdated Views of Data and Models – The Field Scientist's View



…models "process" valuable data and turn it into something with much less information content….

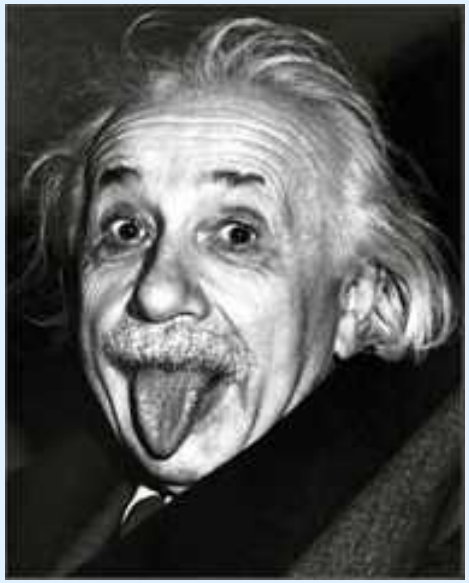
Quotes about Modelling



Albert Einstein

“Make everything as simple as possible, but not simpler”

Quotes about Modelling



Albert Einstein

“If the facts don't fit the theory, change the facts”

Quotes about Modelling

Richard Feynman

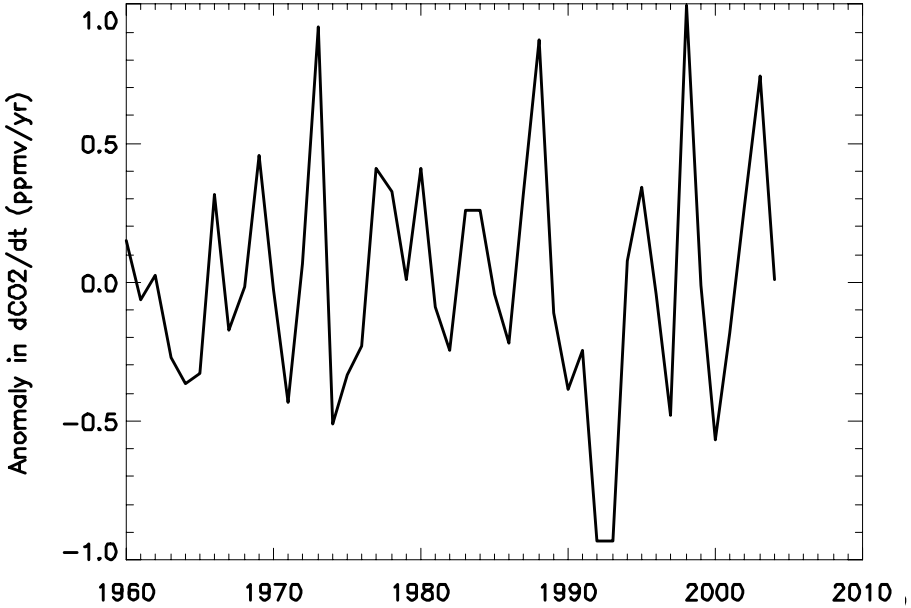
“It doesn't matter how beautiful your theory is, it doesn't matter how smart you are.

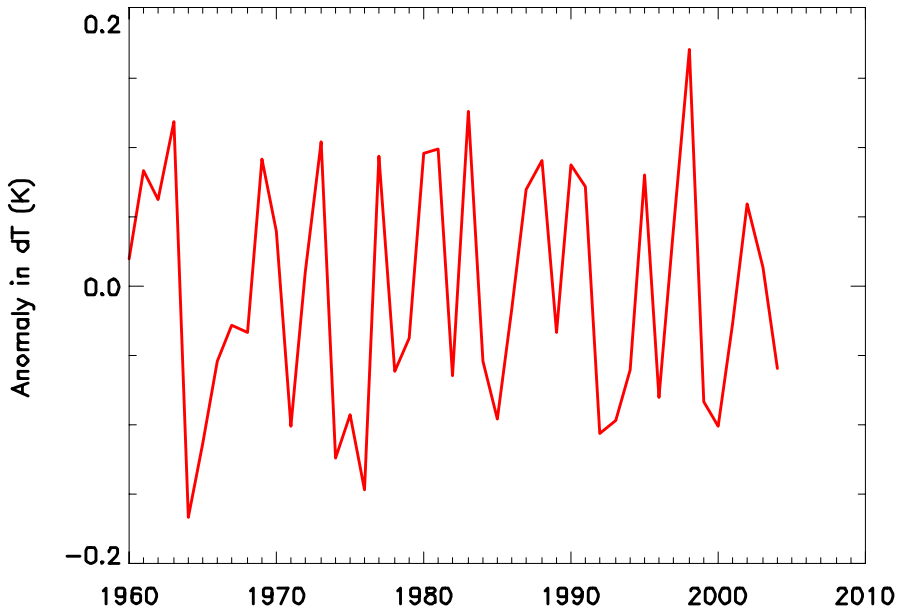
If it doesn't agree with experiment, it's wrong.”

Observational Constraints from

Interannual Variability

Relationship between Interannual Variability in CO_2 and Global Mean Temperature





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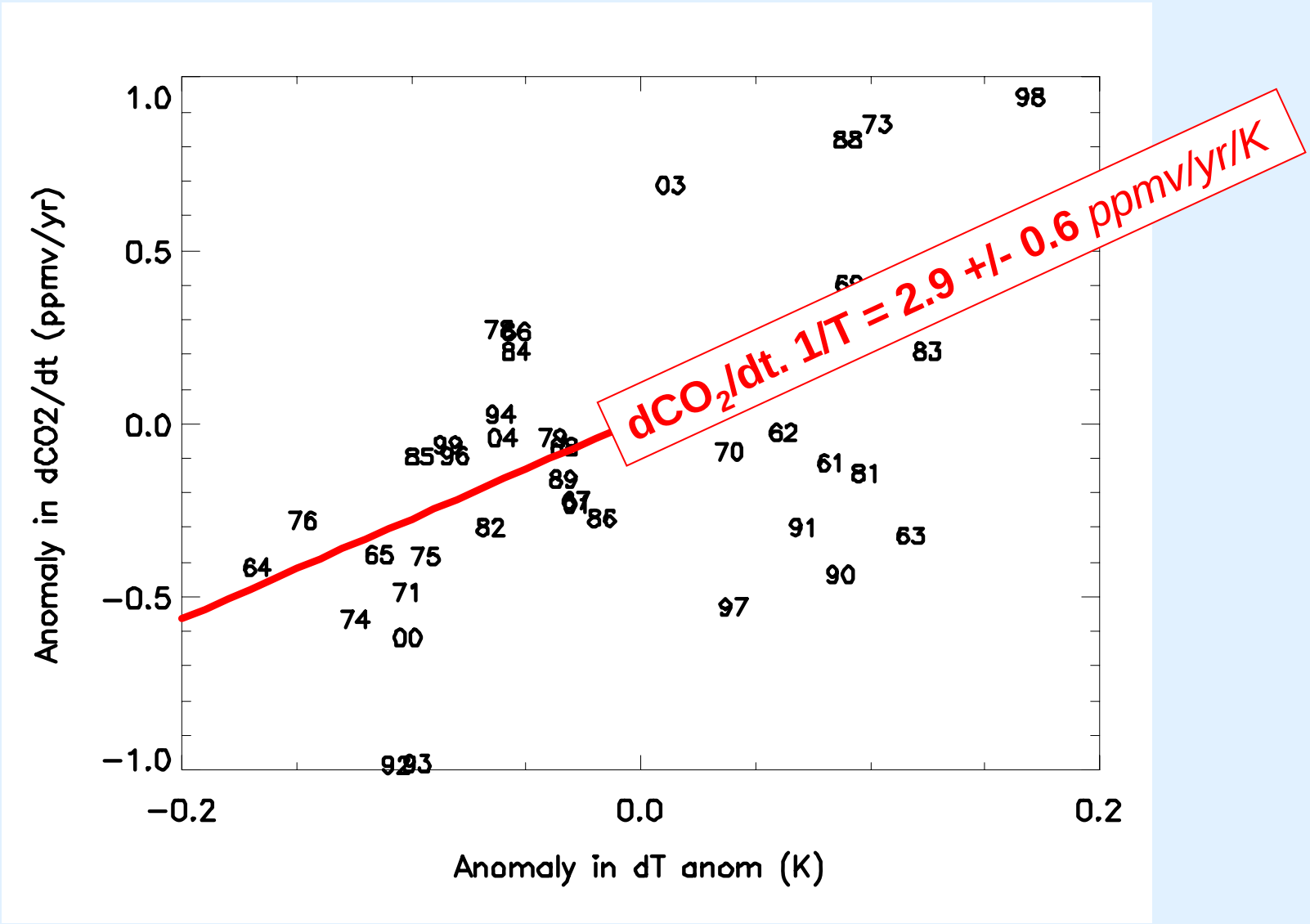

Inferring Carbon Cycle Sensitivity to Climate from Interannual Variability