

What are the future Big Science Questions for JULES ?

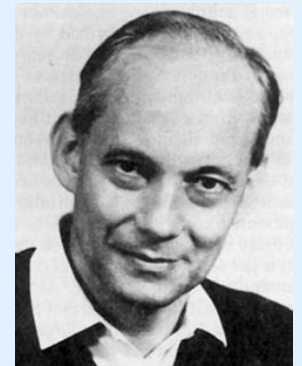
Peter Cox

University of Exeter
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

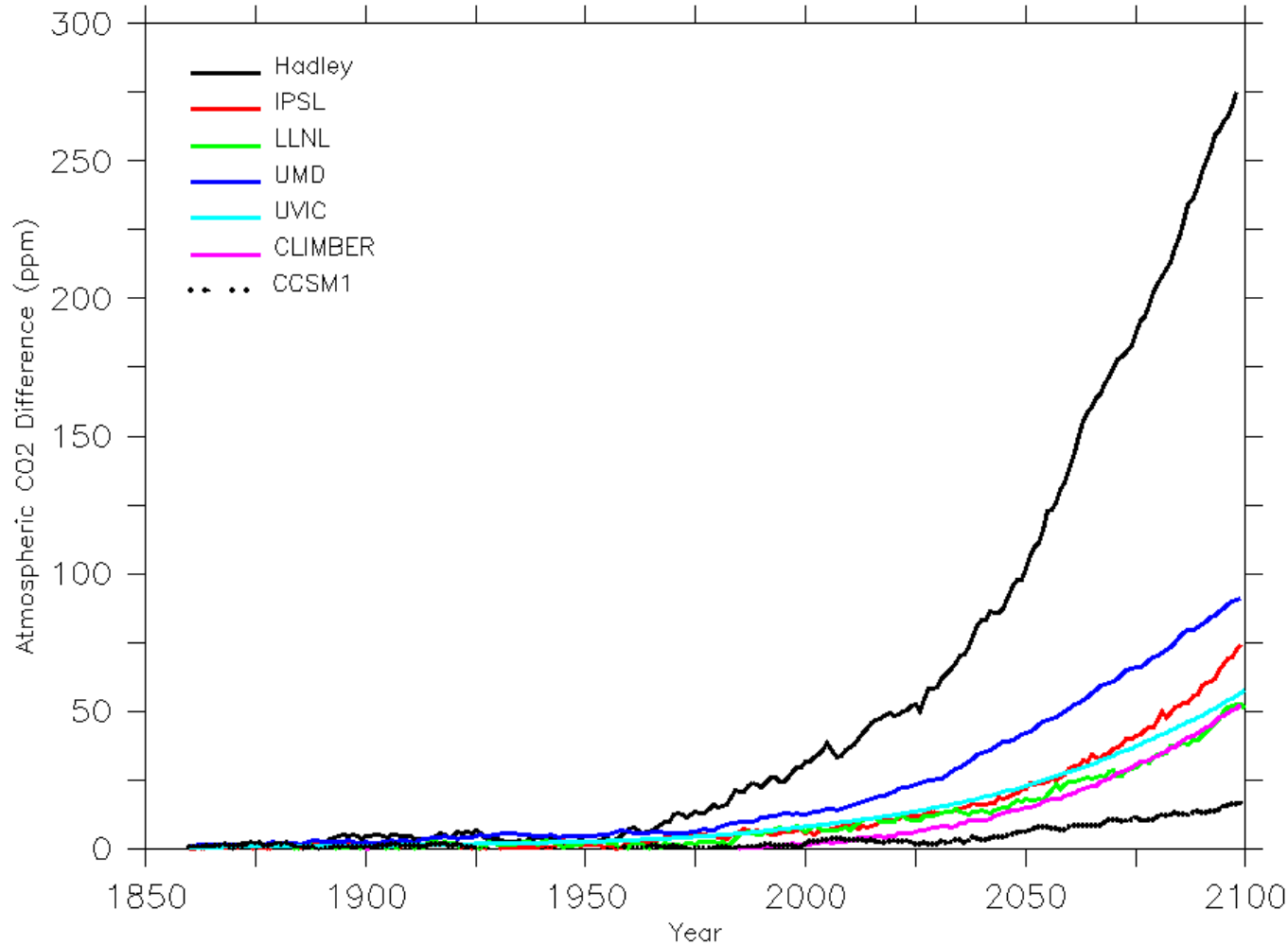


"And we now have sufficient evidence that human-made climate change is the most far-reaching - and almost certainly the most threatening - of all the environmental challenges facing us."

March 2005

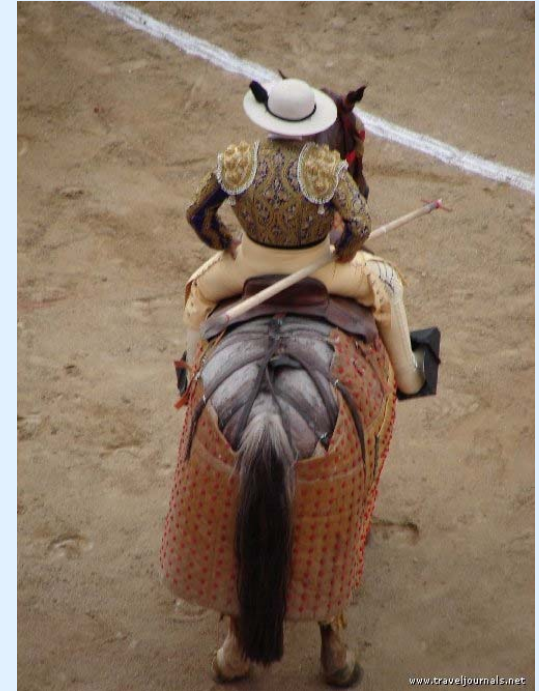
**How large is the
climate - carbon cycle
feedback?**

Predictions of extra CO₂ due to climate effects on the carbon cycle



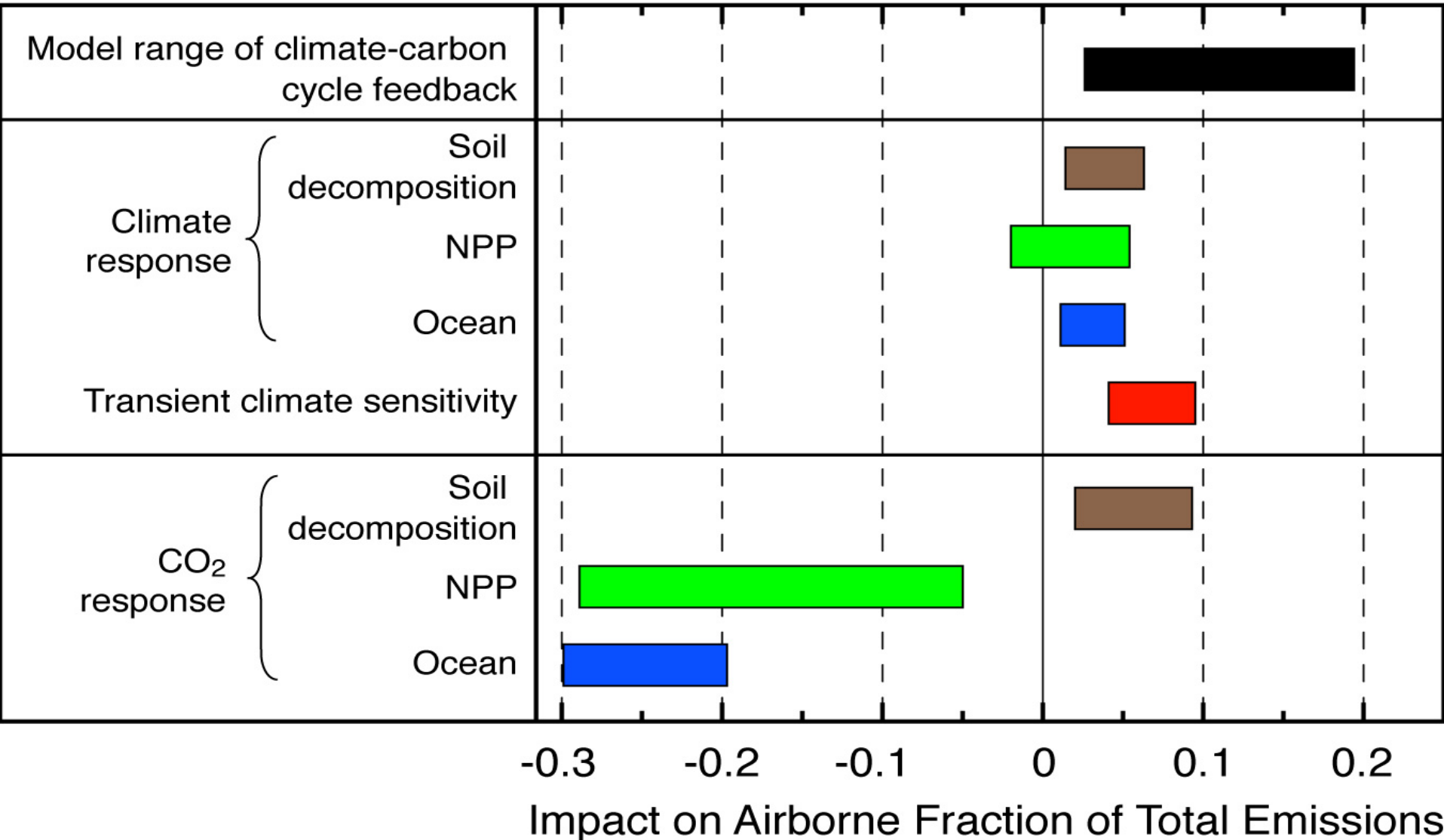
All models simulate a positive feedback, but with very different magnitudes..

...getting on my high-horse
for a minute...

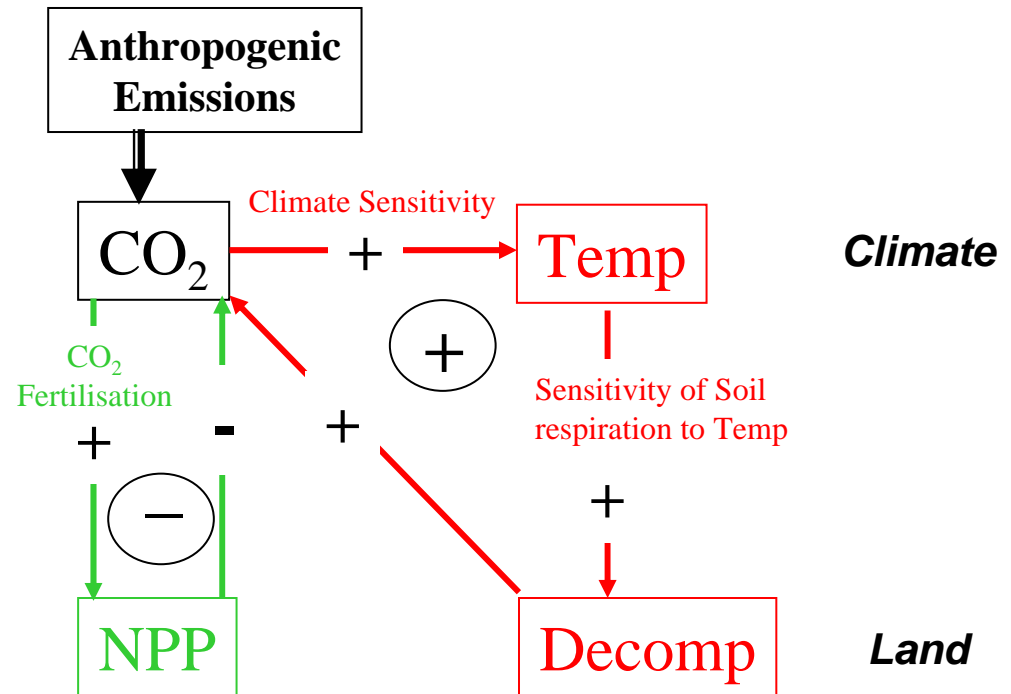


Beware neglecting the “outliers” !

Uncertainties in Carbon Cycle Feedbacks



Climate-Land Carbon Cycle Feedbacks



Modelled GCM feedbacks are competition between CO₂-fertilisation of growth (negative feedback), and accelerated decomposition in warmer climate (positive feedback).

Key unknowns: Climate sensitivity to CO₂

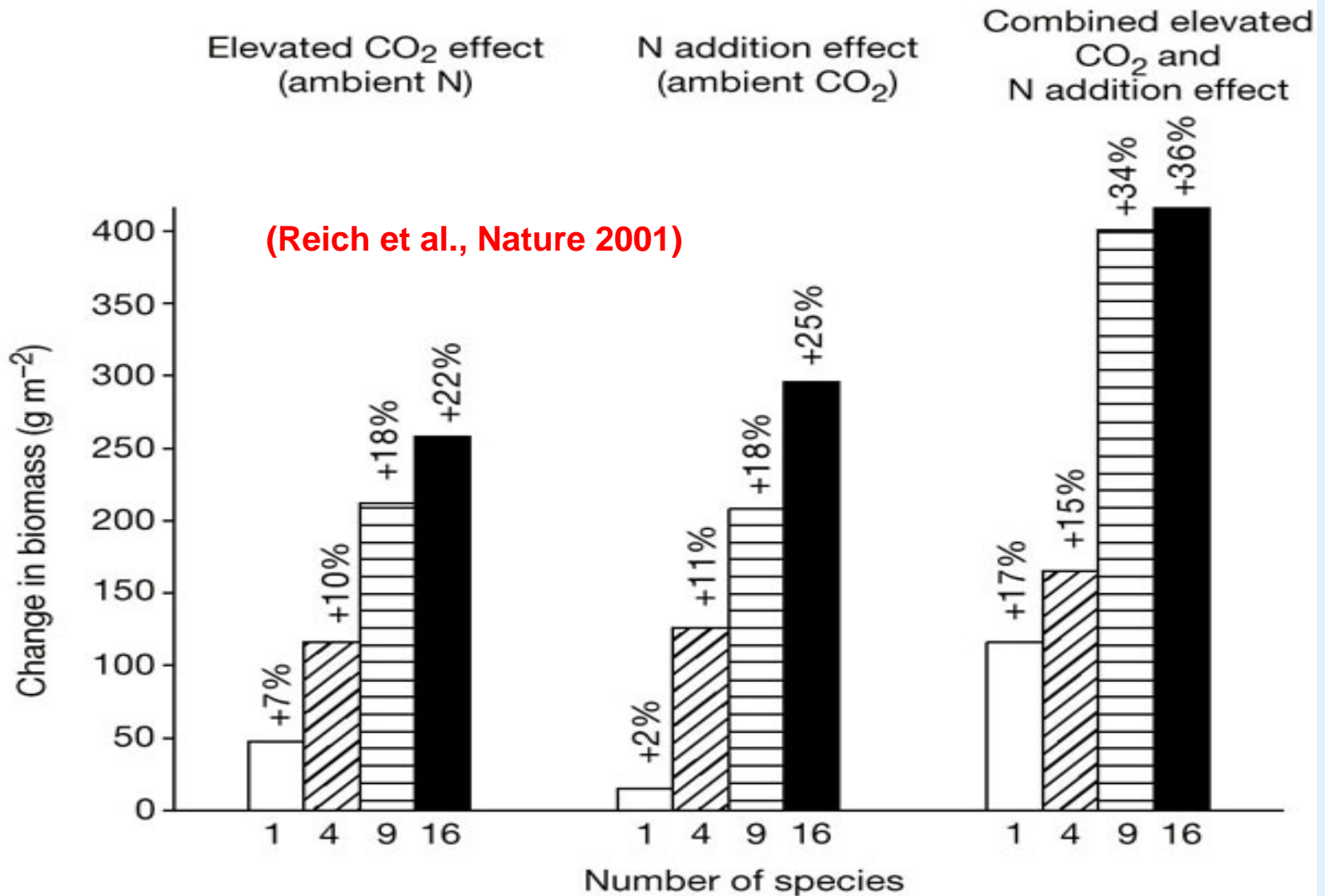
Soil respiration sensitivity to temperature.

CO₂-fertilisation of growth

**How will nitrogen cycling
influence the land carbon sink ?**

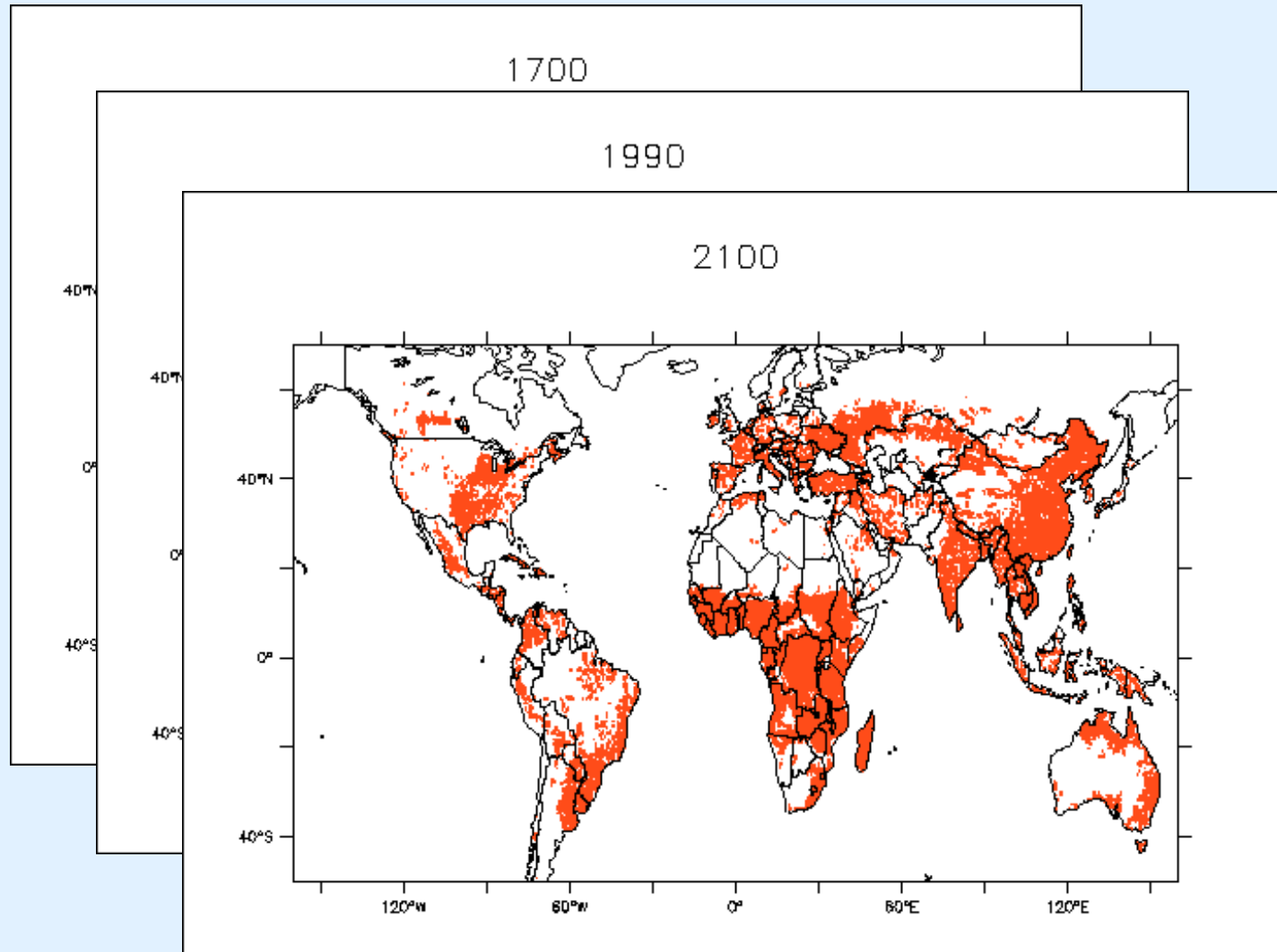
**How does biodiversity affect
the resilience of ecosystems
to climate change ?**

Evidence that Plant diversity enhances ecosystem responses to elevated CO₂ and nitrogen deposition

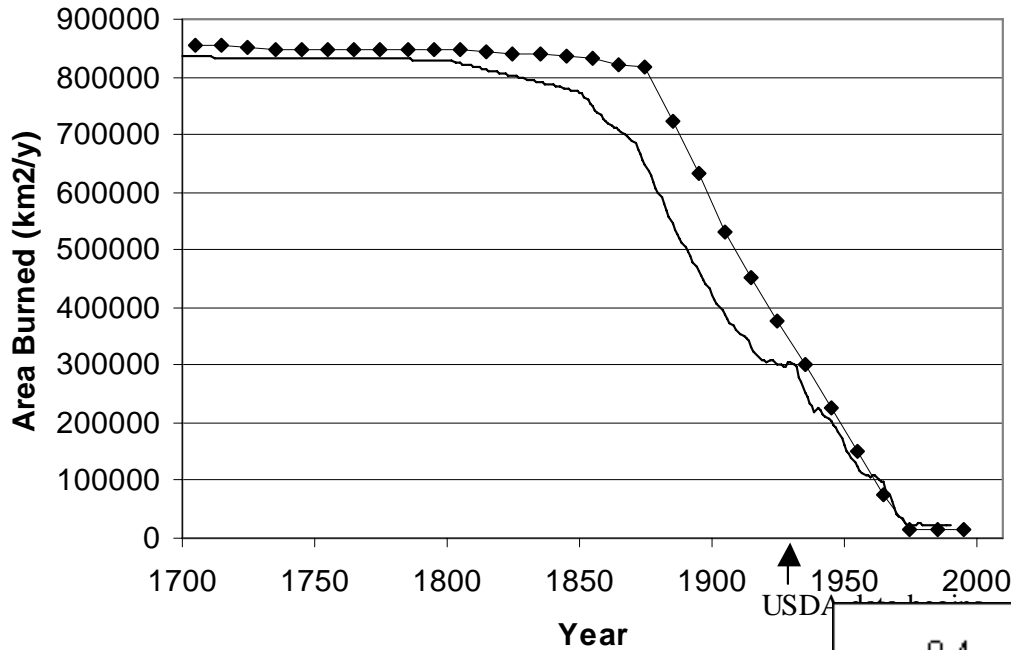


**How important is
land-management
for carbon and
water cycling ?**

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

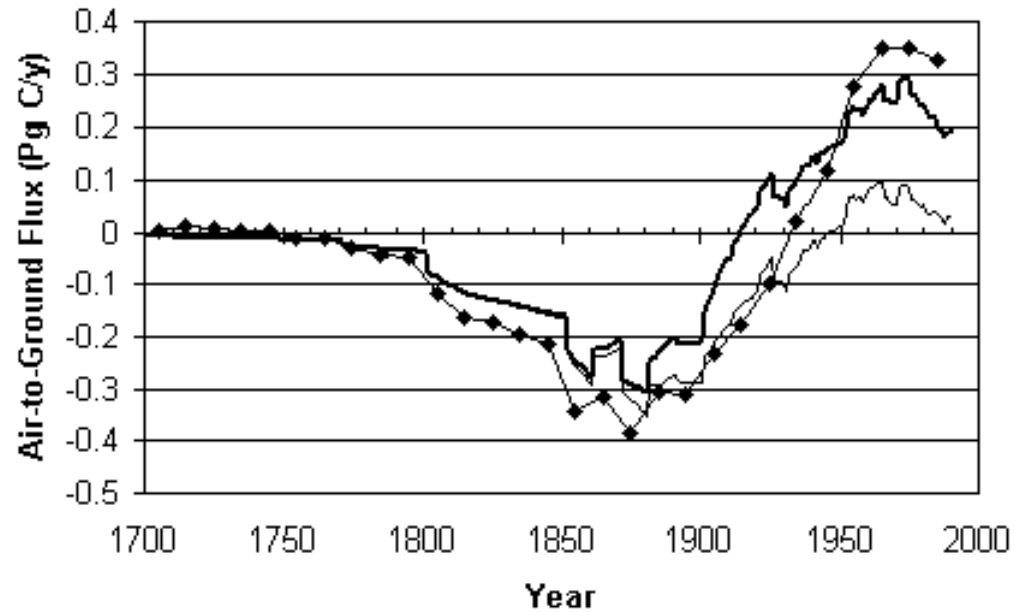


U.S. Fire History



..may account for....

U.S. Land Carbon Sink



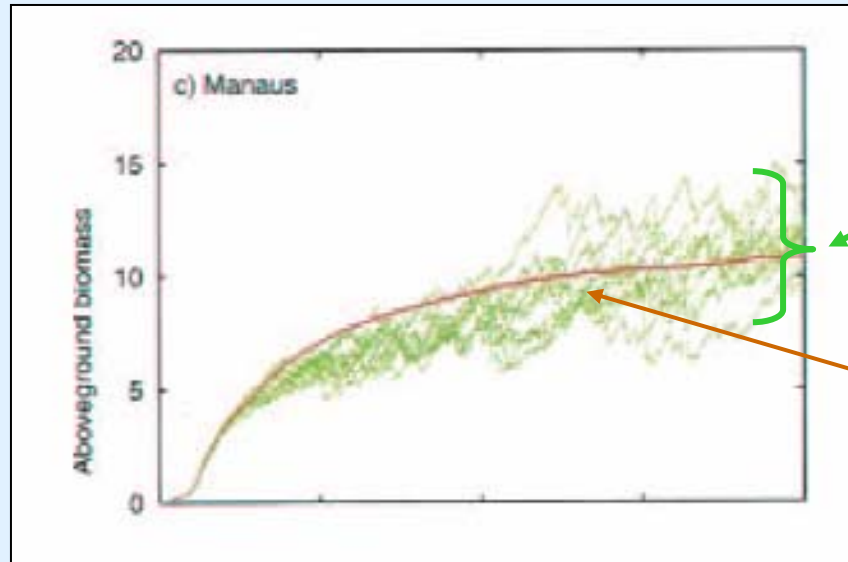
**Importance of
including
land-management
effects...**

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

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

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

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

..enables modelling of land-management effects

**How will fire frequency change
under global warming ?**

Forest Fires

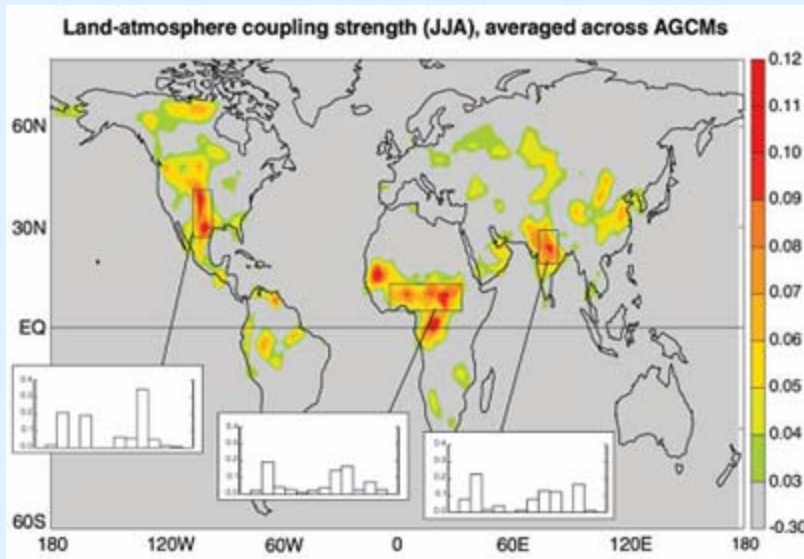


- 1 to 2% of the land surface is estimated to burn annually (GBA 2000).
- There have been dramatic regional changes in fire frequency due to land management.
- How will climate change affect fire frequency ?

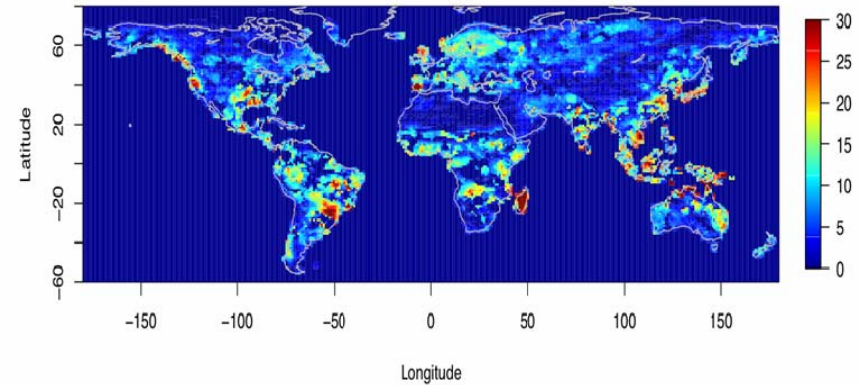
**Where does knowing the state
of the land surface improve
the forecasting of rainfall ?**

Land-atmosphere feedback strength from Models and EO data

Koster et al., 2004

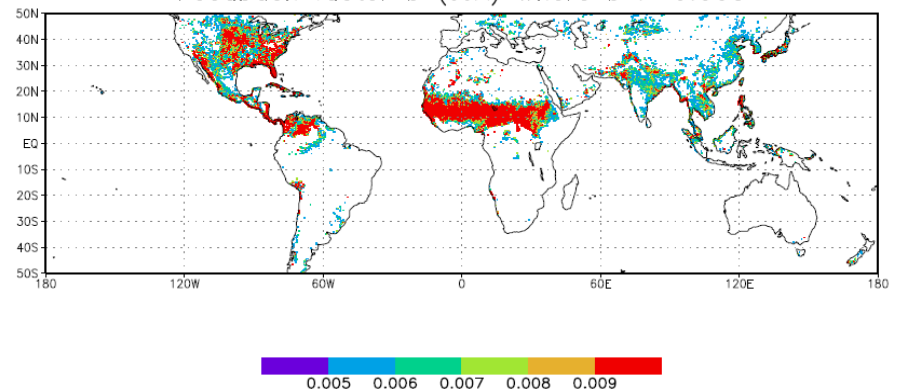


STDV explained by addition of vegetation



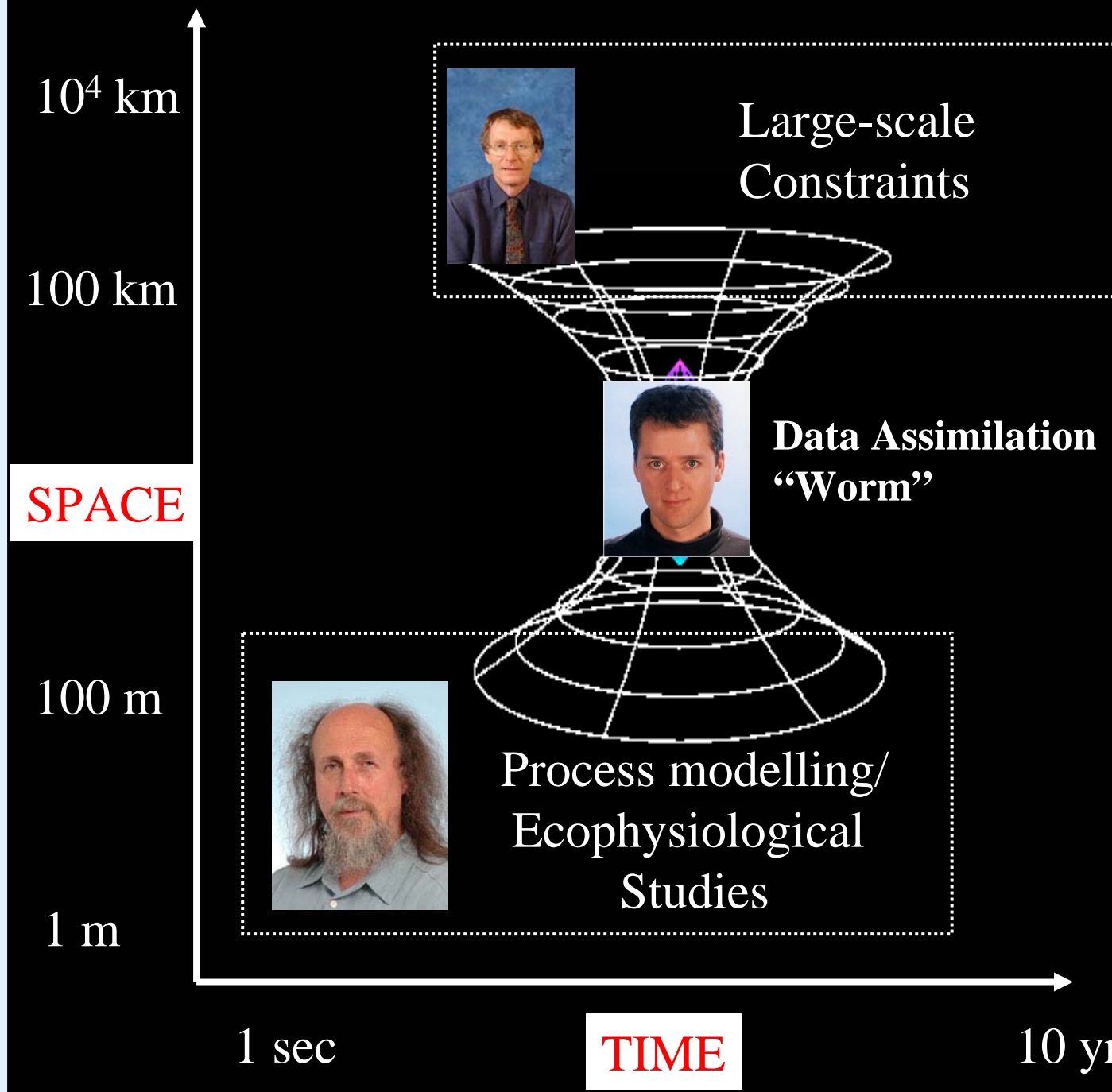
CLASSIC EO-based estimates

Feedback factor b (JJA) where $b > 0.005$

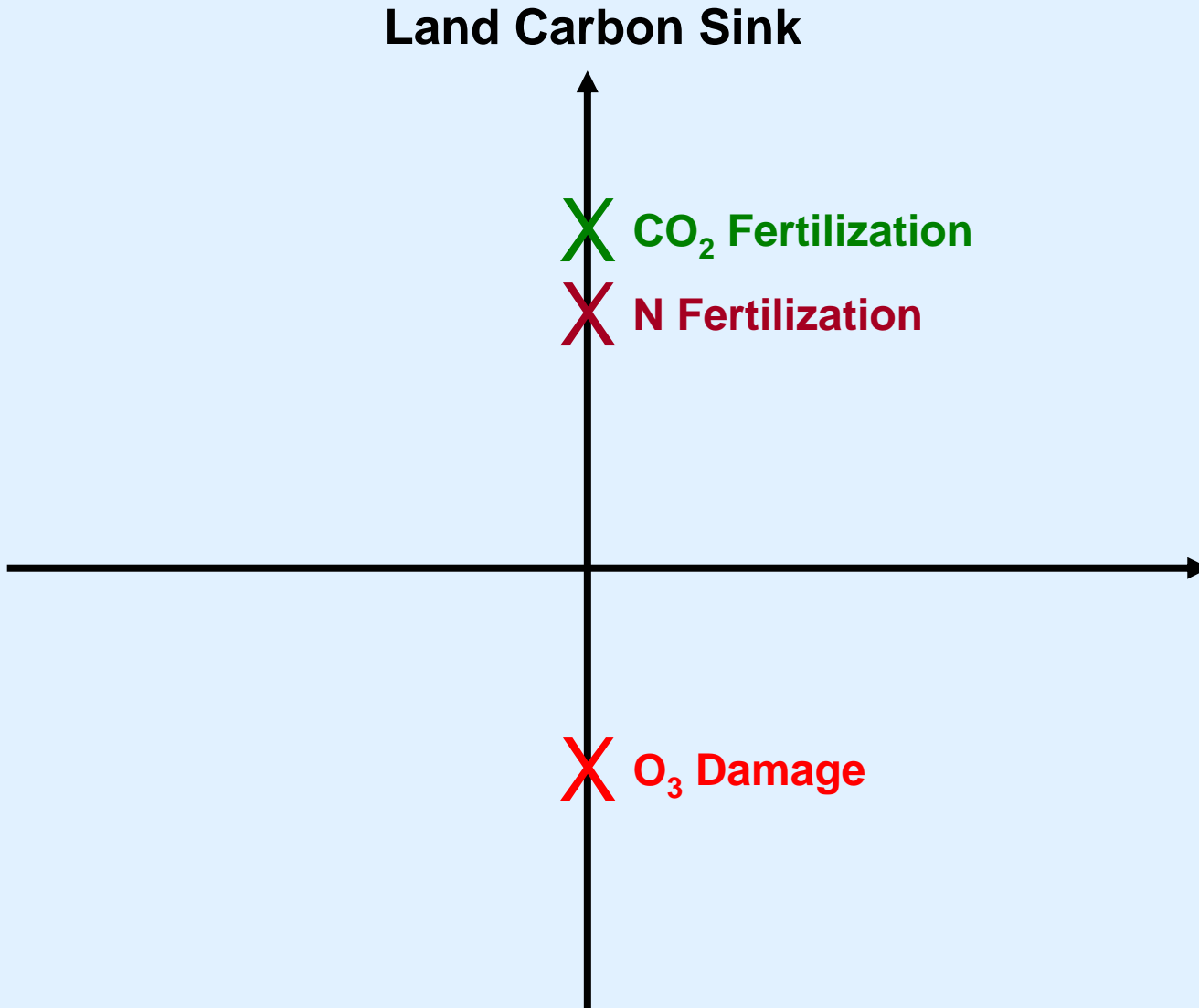


**How should we use
observational data to
constrain predictions ?**

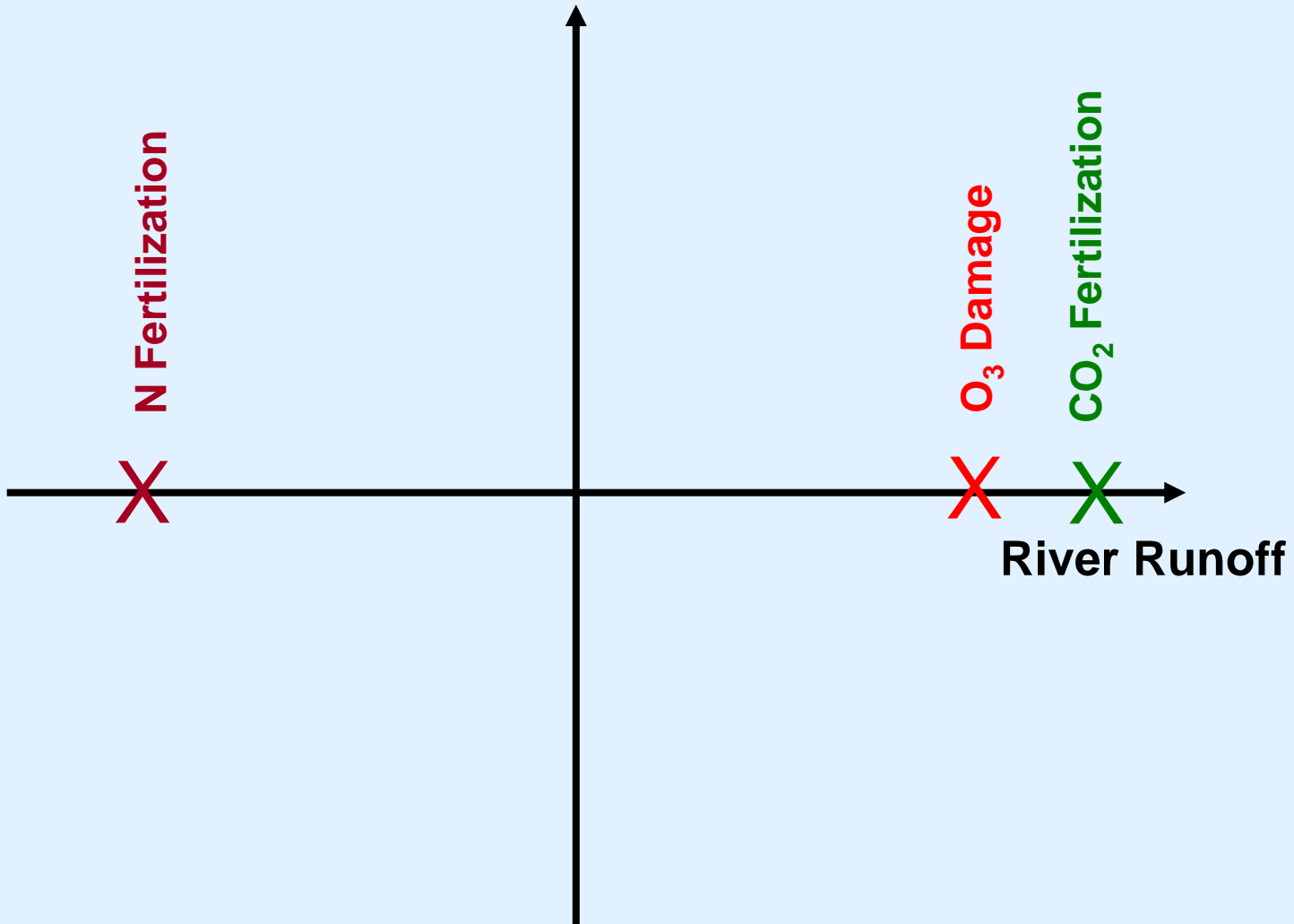
Spanning Time & Space Scales through Model-Data Fusion



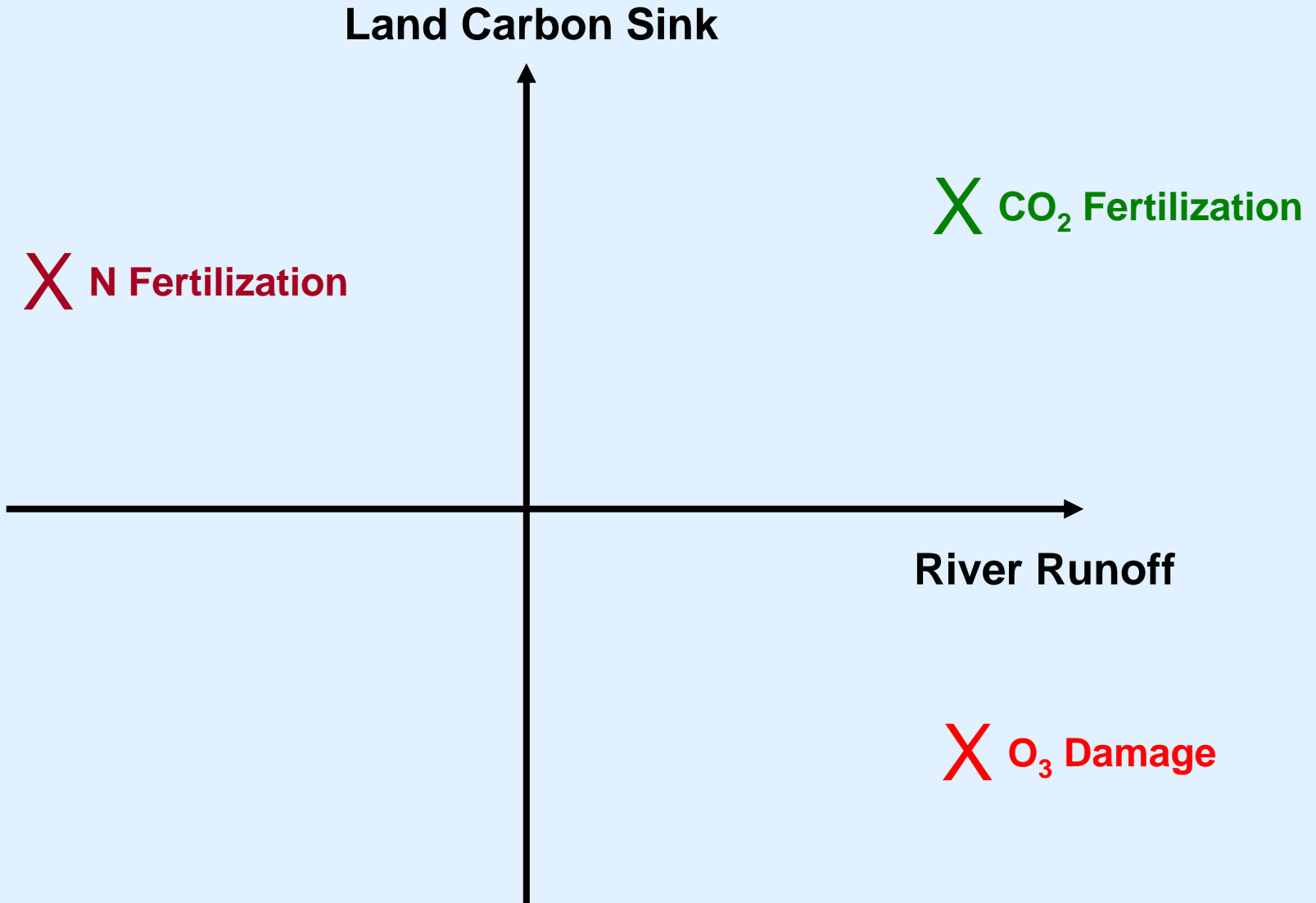
The Value of Multiple Constraints



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The Value of Multiple Constraints

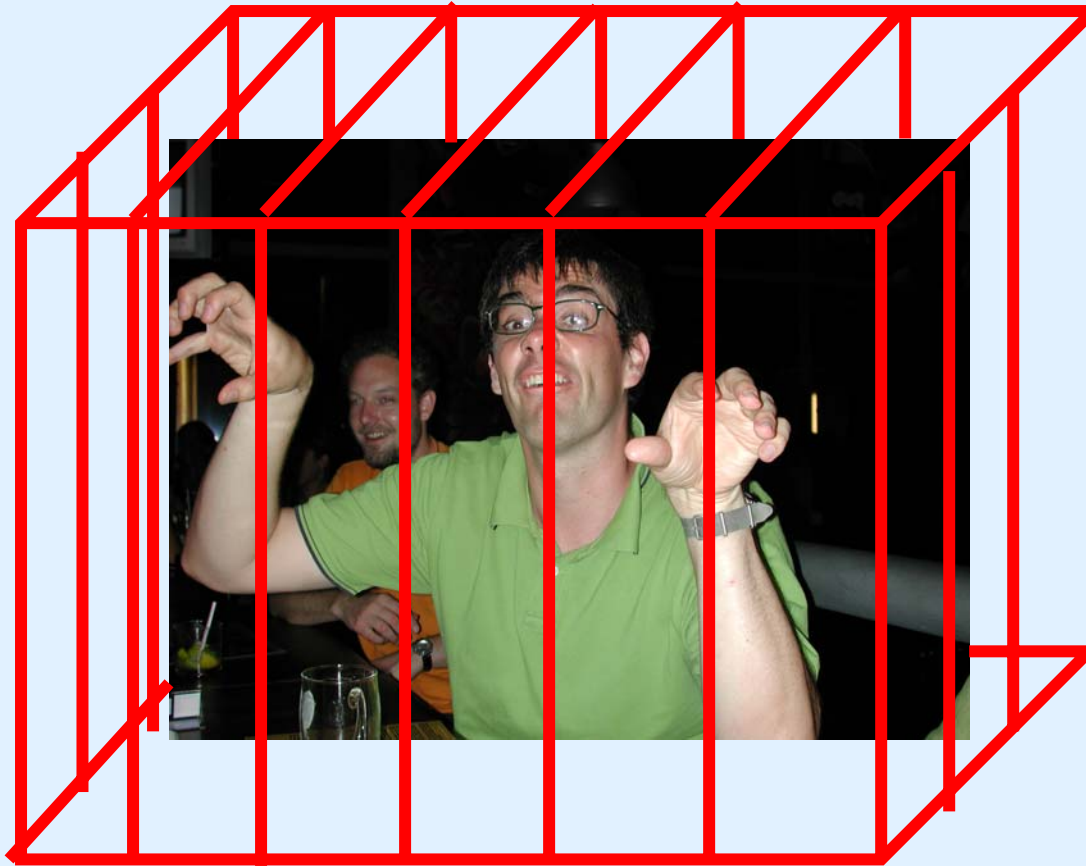


Some Big Questions to Ask JULES

- 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 ?

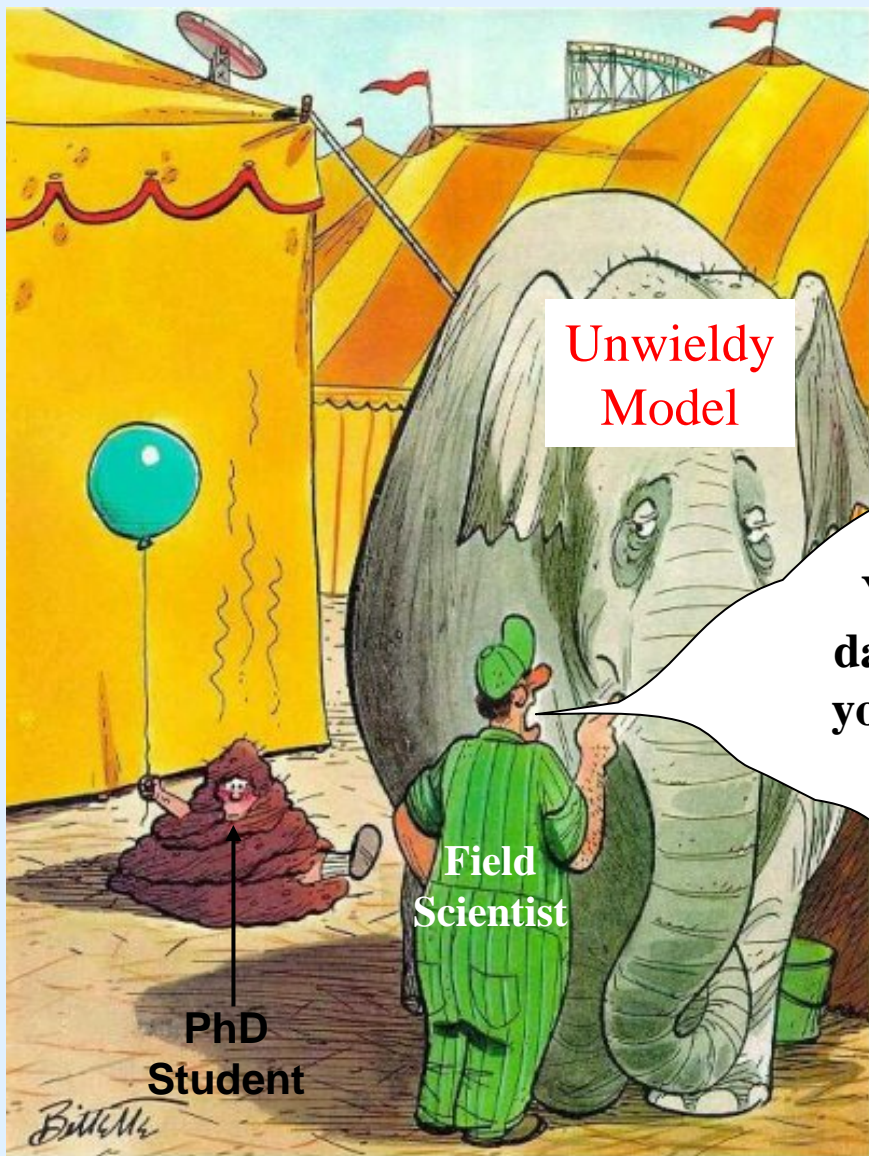
Outdated Views of Models and Data

- The Modeller's View



..modeller constrained by a “data cage”

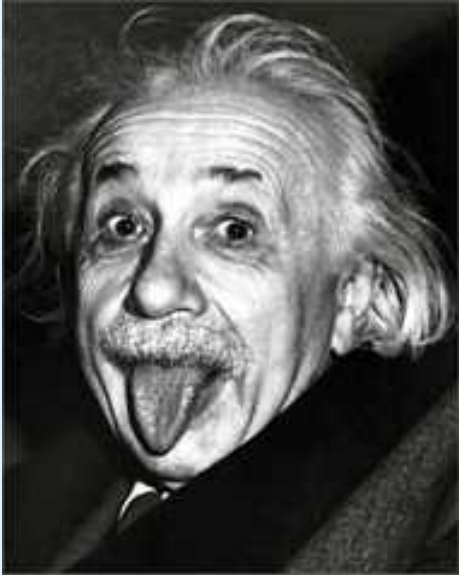
Outdated Views of Data and Models – The Field Scientist's View



You've eaten all my data.....and what have you done with my PhD student?

...models “process” valuable data and turn it into something with much less information content....

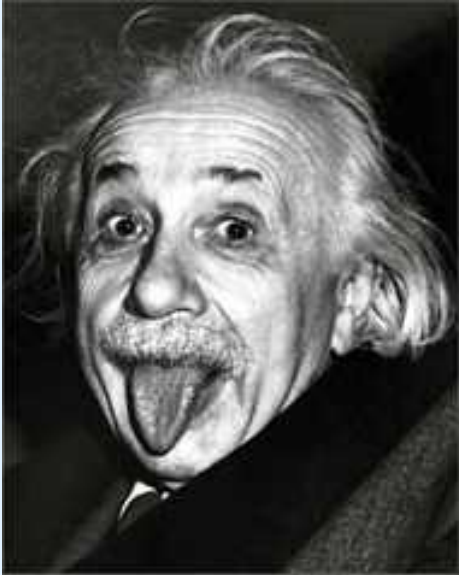
Quotes about Modelling



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



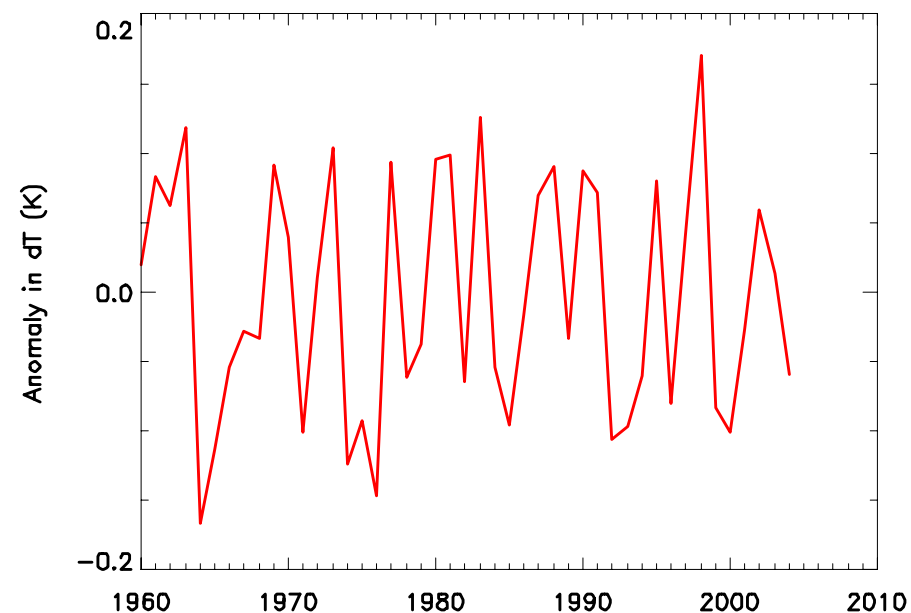
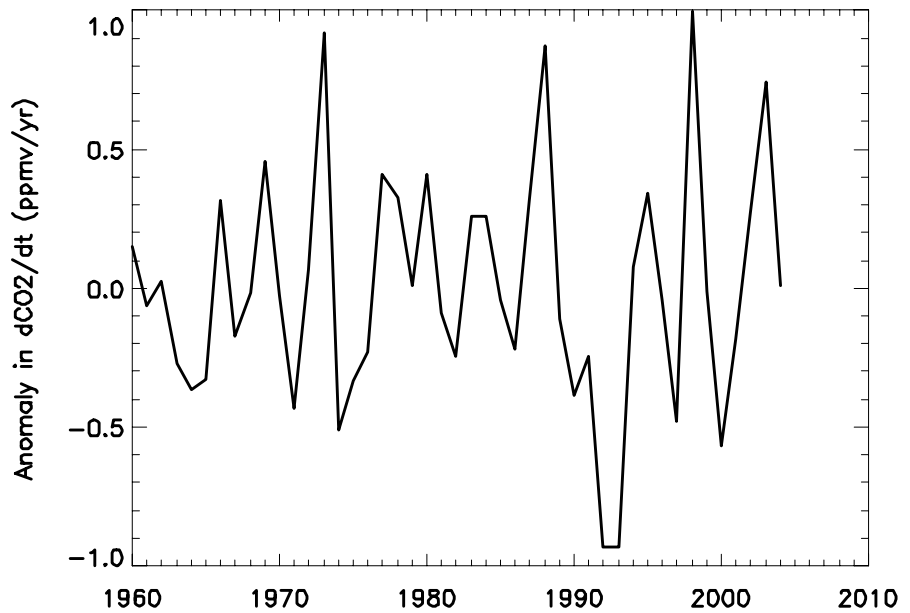
Richard Feynman

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

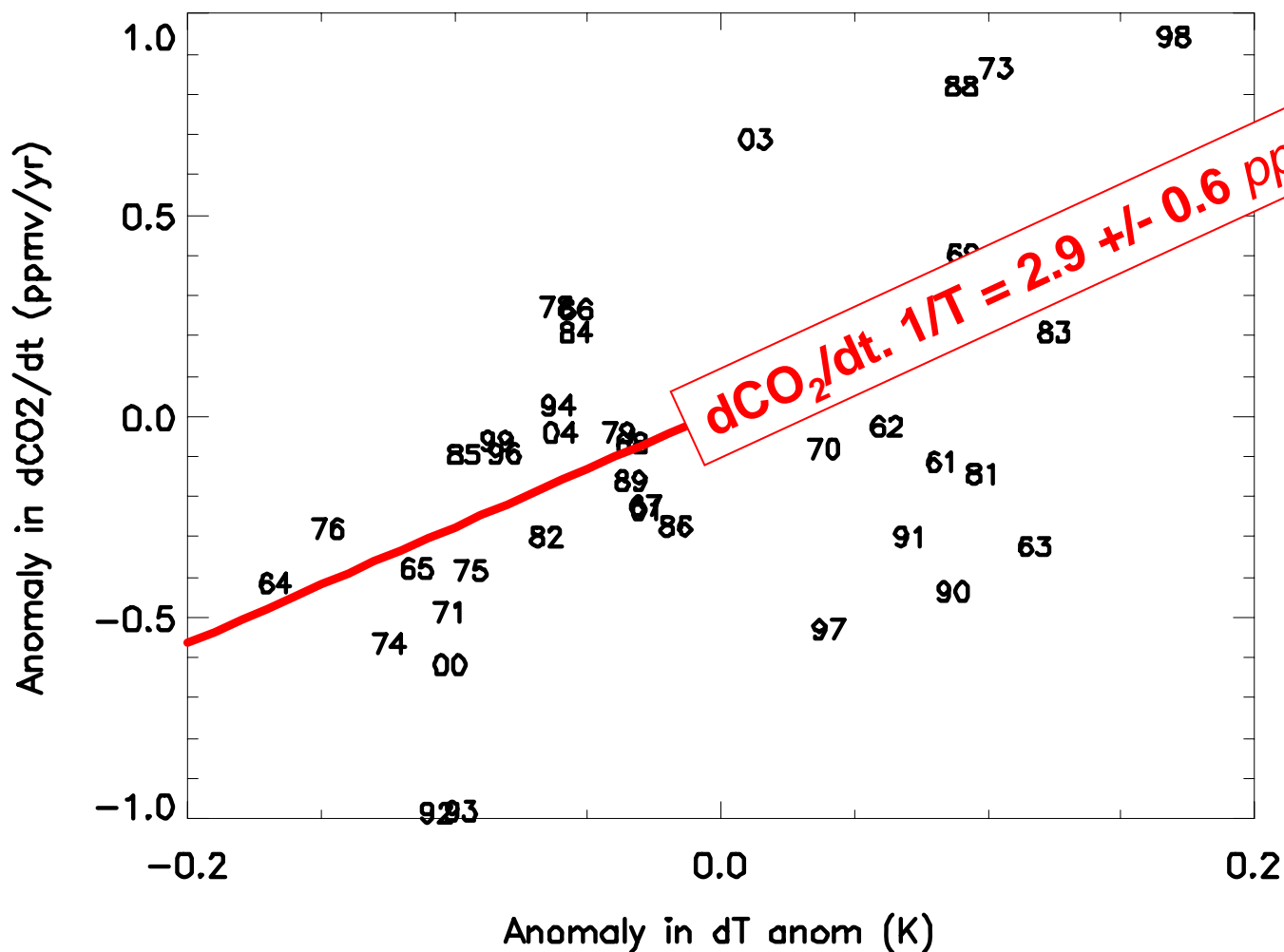
If it doesn't agree with experiment, it's wrong.”

Observational Constraints from **Interannual Variability**

Relationship between Interannual Variability in CO_2 and Global Mean Temperature



Relationship between Interannual Variability in CO₂ and Global Mean Temperature



Inferring Carbon Cycle Sensitivity to Climate from Interannual Variability

