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 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

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<tr>
<th>Model range of climate-carbon cycle feedback</th>
<th>Impact on Airborne Fraction of Total Emissions</th>
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<td>Climate response</td>
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<td>Soil decomposition</td>
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<td>Transient climate sensitivity</td>
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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

(Reich et al., Nature 2001)
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....
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

..enables modelling of land-management effects

Morecroft et al., 2001
How will fire frequency change under global warming?
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

CLASSIC EO-based estimates

STDV explained by addition of vegetation

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

Large-scale Constraints

Data Assimilation “Worm”

Process modelling/Ecophysiological Studies

SPACE

10^4 km
100 km
100 m
1 m

TIME

1 sec
10 yr
The Value of Multiple Constraints

Land Carbon Sink

CO₂ Fertilization
N Fertilization
O₃ Damage
The Value of Multiple Constraints

- CO₂ Fertilization
- N Fertilization
- O₃ Damage
- River Runoff
The Value of Multiple Constraints

Land Carbon Sink

- N Fertilization
- CO₂ Fertilization
- O₃ Damage

River Runoff
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”
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”
“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.”

Richard Feynman
Observational Constraints from Interannual Variability
Relationship between Interannual Variability in CO$_2$ and Global Mean Temperature
Relationship between Interannual Variability in CO$_2$ and Global Mean Temperature

dCO$_2$/dt $\cdot$ 1/T = 2.9 ± 0.6 ppmv/yr/K
Inferring Carbon Cycle Sensitivity to Climate from Interannual Variability

Results from C^4MIP GCM Models

- 60 GtC K^{-1}
- 290 GtC K^{-1}

Interannual \( \frac{d\text{CO}_2}{dT} \) (ppmv K^{-1})

\( \gamma \) (GtC K^{-1})