Uncertainty in the Amazon "die-back" result.

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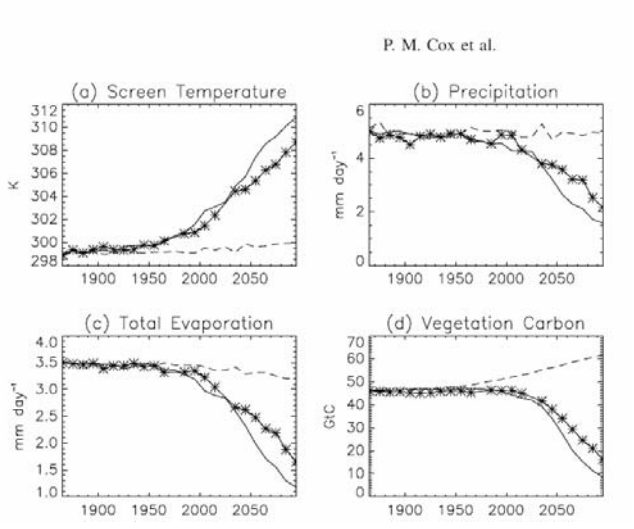
- Peter Cox: Exeter/Hadley Centre
- Paul Moorcroft: Harvard University

The concern…..!



From Cox et al 2004.

Original HadCM3LC simulations are the continuous black lines.

Overview of this talk

- Introduction to IMOGEN system
- Response to
  - GCM uncertainties : QUMP
  - Initial State : CRU vs. HADCM3
  - Altered gas exchange : “LIGHT-MOD”
  - Altered vegetation dynamics: “ED”
  - A little of this work is still “in progress” due to computational requirements…..

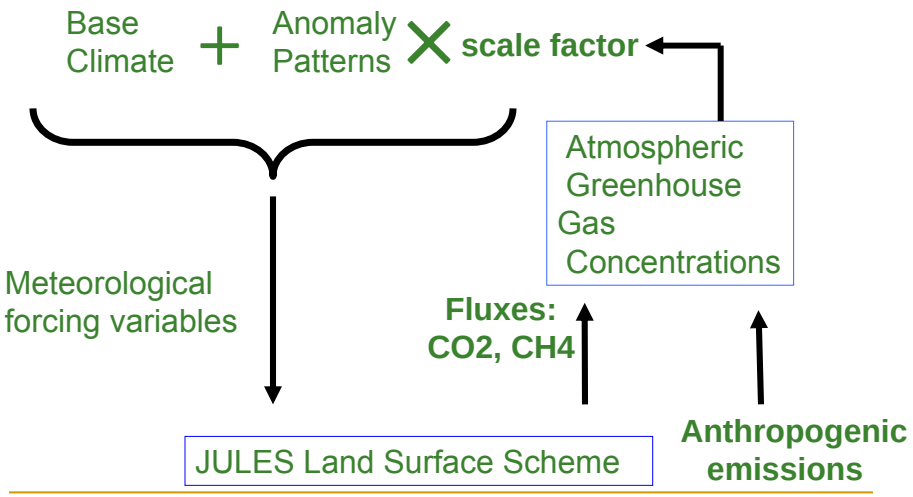
IMOGEN/GCM analogue model: 1

- Investigated monthly predicted surface climate from HadCM3.
- Found that by month and place, most variables are almost linear in global temperature increase, ΔT.
- Suggests can estimate surface climate by multiplying spatial patterns by ΔT.
- ΔT calculated as a history of radiative forcing, itself a function of atmospheric GHGs.

Why use IMOGEN/GCM analogue model?

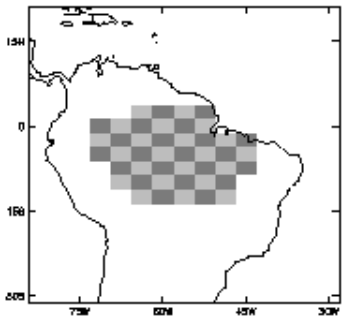
- Can “drop in” different land surface models with much more ease than in to HadCM3 itself.
- Runs much faster than the GCM for different experiments of land surface response.
- Can make simulations for a range of different emission scenarios.
- Also contains a global carbon cycle.
- Can have a “base climate” using observations (most notably CRU).

Tools for climate research (IMOGEN)

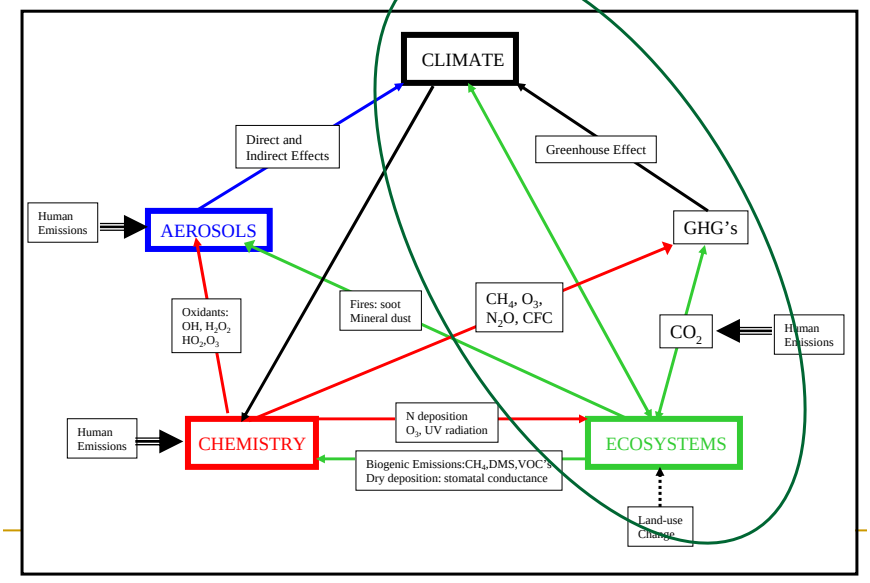


Simulation structure for use here

- CLIMATE
  - CRU climate + HADCM3 anomalies
- Carbon cycle
  - Feedback OFF until DGVMs calibrated away from Amazonia.
- CO_2 from Cox *et al*. (2000)
- Non CO_2 GHGs and sulphates switched “off”.



Climate System: At present concentrating on the carbon cycle components but other factors require inclusion.



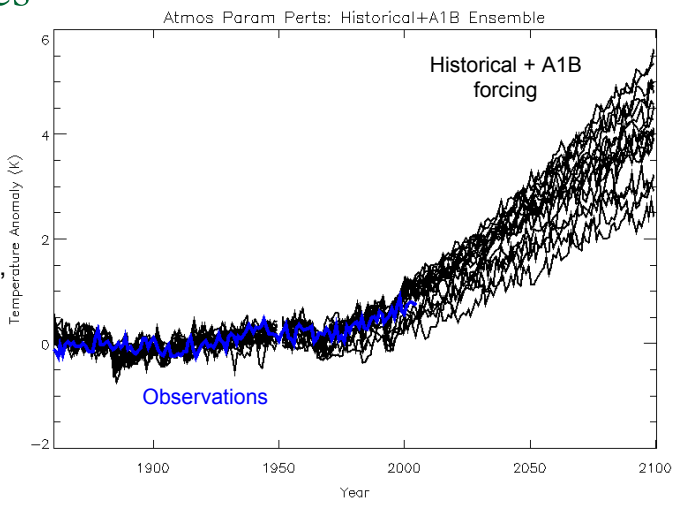
QUMP: "Perturbed Physics" Approach

- Take a climate model (HadCM3)
- Ask experts which of the parameters in the model are (a) uncertain and (b) important
- Run simulations with different values of those parameters

- Cannot sample the space of all possible climate models, but we can try to sample the space of all versions of HadCM3

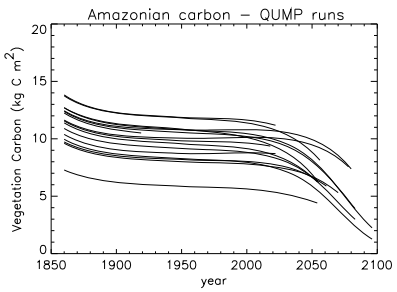
Coupled Atmosphere-Ocean Ensembles

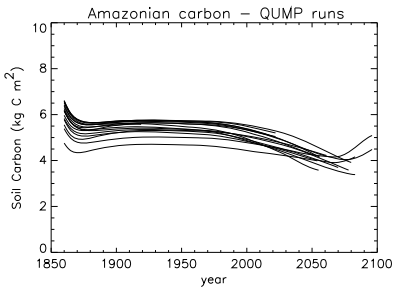
- Perturbations to atmosphere-model parameters that sample uncertainties in the atmospheric, cloud, land surface and sea ice physics schemes.



QUMP results

- All QUMP simulations exhibit Amazonian drying.
- Most appear to initiate "die-back".
- All runs should have finished by tomorrow – sorry!





Light-mod: Radiation interception: big leaf *vs* multilayer approach

Beer's law

$I = Io * e^{-k * LAI}$

No scattering: i.e. sum of reflected and transmitted light

Two stream approximation (Suits, 1972; Sellers, 1995) :

Vertical profiles:

upward and downward diffusive radiative fluxes

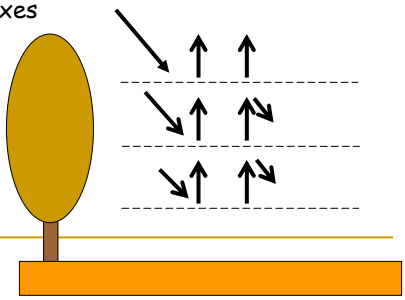
Takes into account:

Leaf and soil scattering

LAI and Leaf angle distribution

Angle of incident radiation

Diffuse and direct radiation



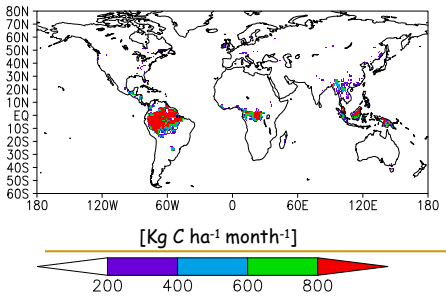
Initial results from global/IMOGEN implementation

Comparison of **GPP** and **NPP**

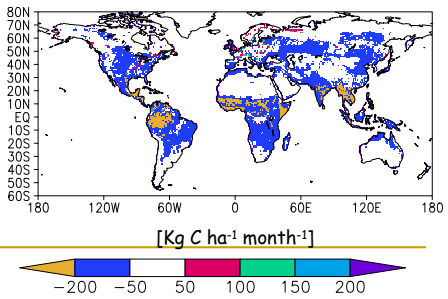
big leaf (BL) & multilayer (ML) approach

Mean June from 1986-1995

GPP (ML)- GPP (BL)



NPP (ML)- NPP (BL)

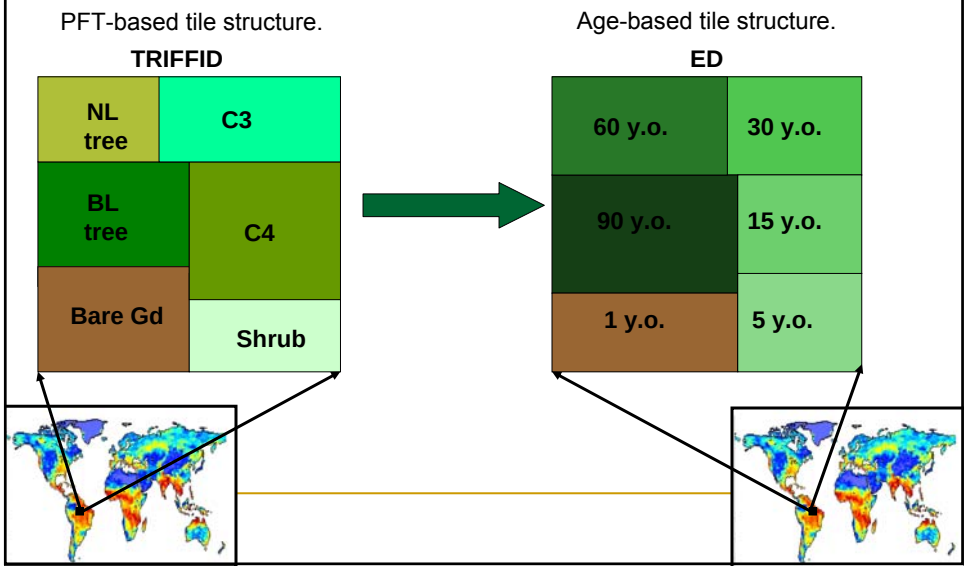


Vegetation Dynamics

- Question : How does the representation of vegetation dynamics affect the die-back response?
- Change from “area based” model to “quasi-individual based” model.

Ecosystem Demography Model (ED)

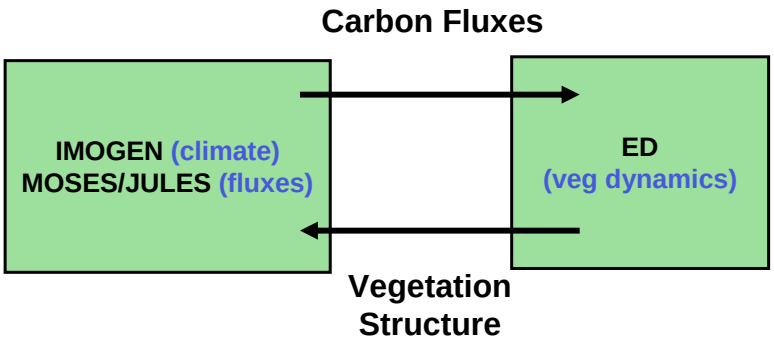
Moorcroft et al. (2001)



Advances of ED approach

- 1. Representation of vertical competition for light between PFTs.
- 2. Simulation of vegetation succession
- 3. Recover from disturbance (fire, deforestation)
- 4. Parameterisation of competition using observable plant traits

ED-IMOGEN coupling



Gas exchange same as Cox *et al*. (2000) simulations, but with different vegetation dynamics

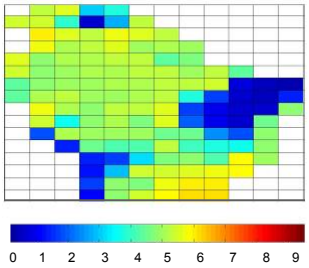
Analysis of initial model results

- Comparison with basic contemporary data…
- …can ED-IMOGEN reproduce:
  - 1. The observed forest distribution (greenness)?
  - 2. The observed biomass distribution?
  - 3. The seasonal LAI patterns
- How do ED-IMOGEN predictions of dieback differ from TRIFFID-IMOGEN predictions

Spatial distributions of contemporary forest.

EVI EO data

ED-IMOGEN LAI Predictions



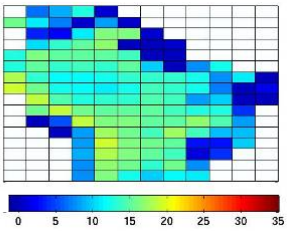
ED represents current forest cover with CRU climatology

Source: NASA/Huete Lab, University of Arizona
Enhanced vegetation index from MODIS satellite.

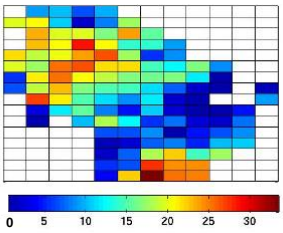
Biomass estimates

Models

TRIFFID

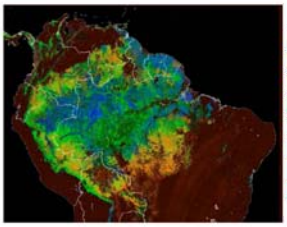


ED



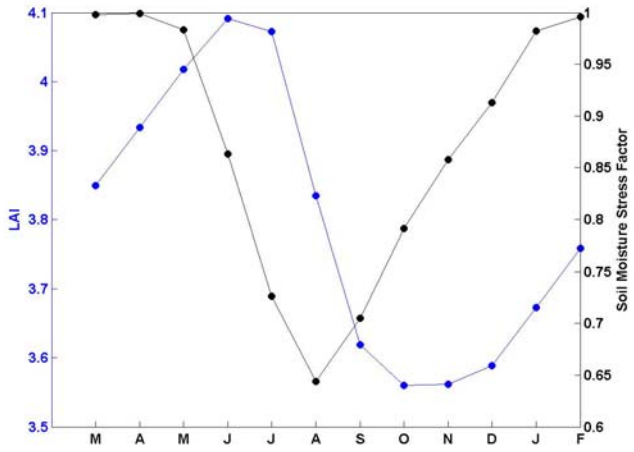
Biomass : Kg m^{-2}

Observations

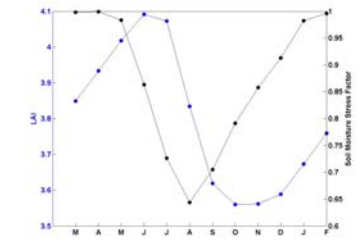


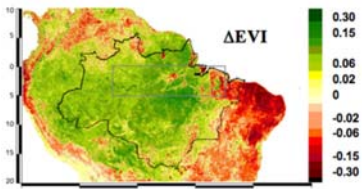
Source: Saatchi *et al.* GCB, 2007
544 biomass plots
19 separate EO data layers

Seasonal patterns of LAI and soil moisture stress.

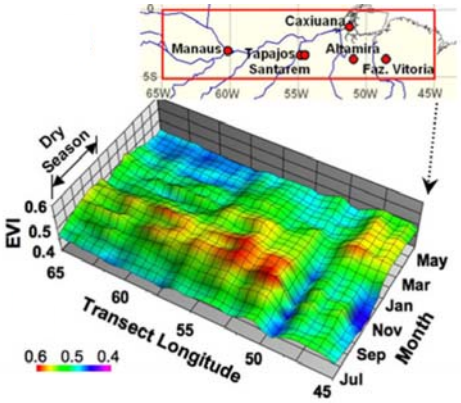


Seasonal patterns of LAI do not match EO or flux tower data.





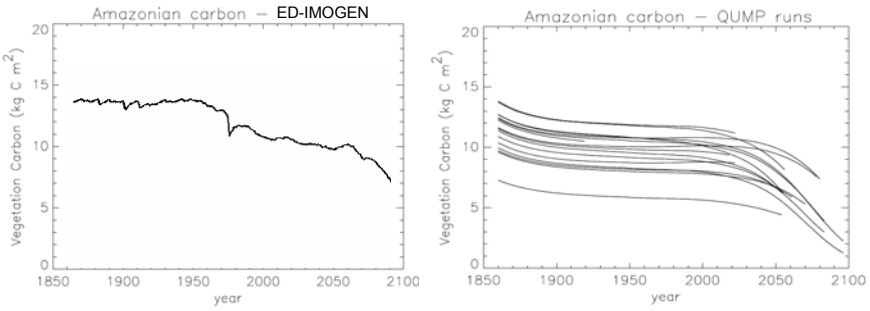
Change in greenness from June-October



Source: Huete *et al*., GRL 2006.

Also: Carswell *et al.*, 2002; da Rocha *et al.*, 2004; Goulden *et al.*, 2004; Loescher *et al*., 2004; Saleska *et al.*, 2004

Dieback simulation: Initial Results



ED-IMOGEN does not predict total die-back of Amazon vegetation, despite using the same climate and physiology
Possibly (?) due to co-existence of grass and drought-deciduous trees

Conclusions of early ED-IMOGEN simulations

- Uncalibrated ED-IMOGEN represents contemporary forest cover well.
- Biomass estimates are within the observed ranges.
- There are still dry season reductions in LAI, in conflict with plot level data.
- Forest decline begins earlier than TRIFFID simulations, but is not as abrupt.
- Due to it's 'disturbance driven' structure ED is ideal for investigating other agents of change, such as fire risk and deforestation.

Conclusions

- Uncalibrated ED-IMOGEN represents contemporary forest cover well.
- ED simulates drought-induced mortality, which decreases the LAI compared to TRIFFID.
- Biomass estimates are within the observed ranges.
- There are still dry season reductions in LAI, in conflict with plot level data. (waiting for simulation to run to produce figure).
- Forest declines begins in year **(statement about transient simulation)
- Further studies with ED-IMOGEN will assess the impact of fire, mortality parameters and rooting depth.

Next steps: Overall

- Shown four key areas of uncertainty: a) initial state, b) canopy light interception, c) different GCM predictions (via QUMP) and d) new DGVM.
- But just showing uncertainty is not enough anymore in climate research – “data assimilation”, “process understanding”, “parameter constraint”.
- How can we determine which simulations are the correct ones for the likely fate of Amazonia?

Next steps: Investigate other GCMs

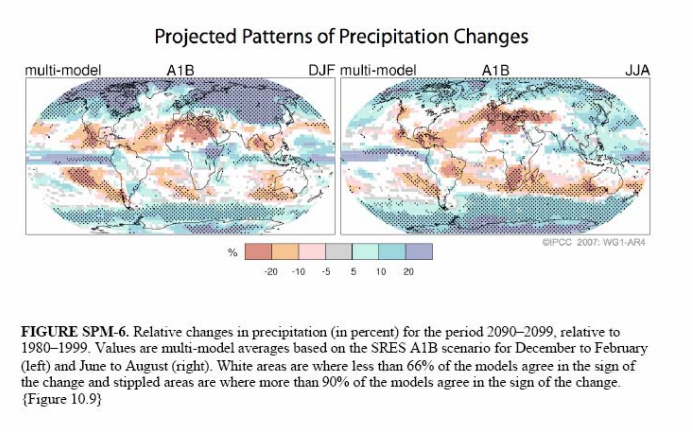


FIGURE SPM-6. Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. {Figure 10.9}

Probabilistic framework

- QUMP simulations are weighted by the Hadley Centre “Climate Prediction Index”.
- Data assimilation will be able to determine low probability simulations. Evolving climate change signal will aid with this.
- FLUXNET measurements / satellite imagery to constrain land surface response?