Uncertainty in the Amazon “die-back” result.

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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, $\Delta T$.
- Suggests can estimate surface climate by multiplying spatial patterns by $\Delta T$.
- $\Delta T$ 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.
- CO₂ from Cox *et al.* (2000)
- Non CO₂ GHGs and sulphates switched “off”.

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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.

![Graph showing temperature anomaly over years with observations and model simulations.](image-url)
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
\[ I = I_0 \times e^{-k \cdot LAI} \]
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

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

Carbon Fluxes

IMOGEN (climate)
MOSES/JULES (fluxes)

Vegetation Structure

ED (veg dynamics)

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

[Map showing vegetation index with color scale]

ED-IMOGEN LAI Predictions

[Heatmap showing LAI predictions with color scale]

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

[Graph showing TRIFFID biomass distribution]

ED

[Graph showing ED biomass distribution]

Observations

AG Biomass Kg m²

- No Class
- 0-15
- 15-20
- 20-25
- 25-30
- 30-35
- 35-40
- >40

[Map showing biomass distribution with color scale]

Source: Saatchi et al. GCB, 2007
544 biomass plots
19 separate EO data layers
Seasonal patterns of LAI and soil moisture stress.

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

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

Source: Huete et al., GRL 2006.

Change in greenness from June-October
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 its ‘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

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?