Committed Terrestrial Ecosystem changes due to climate change

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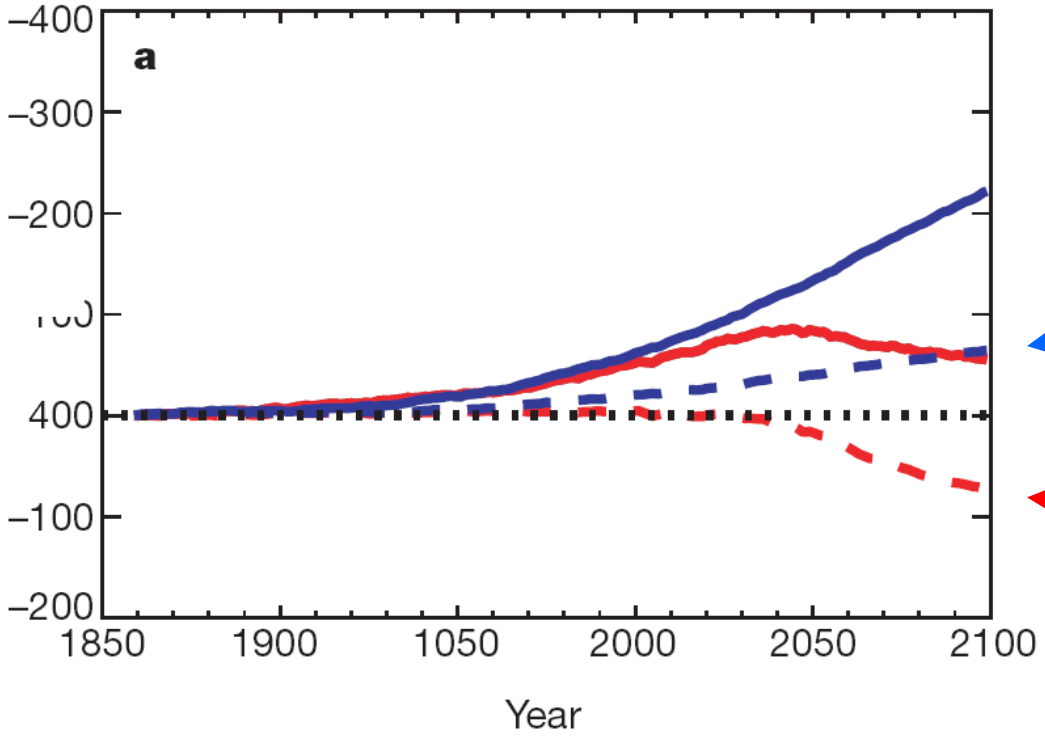
Overview

- Recap
  - Climate change and impacts on ecosystems
    - Amazon forest dieback
- Concept of committed changes to ecosystems
    - Ecosystems have inertia
    - Continue to change post-stabilisation
- Explore multi-model uncertainty
  - DGVMs and the IMOGEN framework
  - What's robust and where does ecosystem uncertainty lie?
  - Importance of local feedbacks and coupled modelling

Future vegetation changes

- Early climate-carbon cycle GCM simulation showed significant loss of Amazon forest under climate change.



Amazon biomass:

No climate change

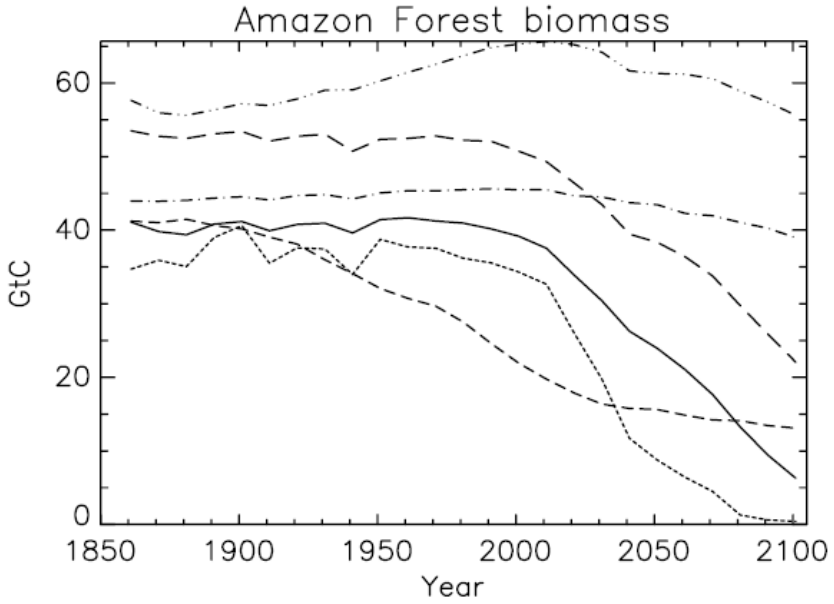
climate change

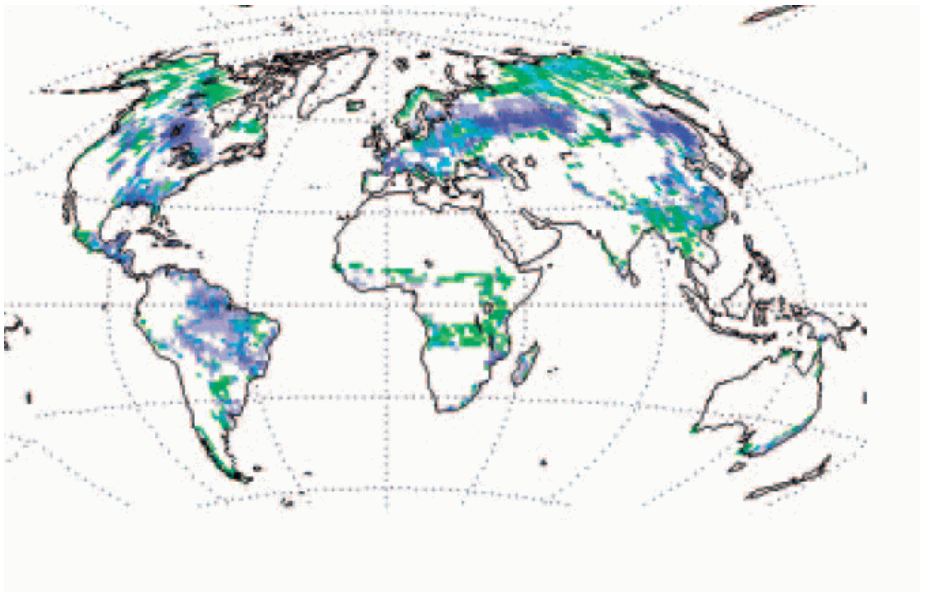
Effect of global warming on changes in land carbon storage. The red lines

Cox et al., 2000, Nature

Future vegetation changes

- Not just a feature of this model
  - Also happens across different vegetation models (Cox et al., 2004, TAC)
  - Also happens for different GCMs (Scholze et al., 2006, PNAS)

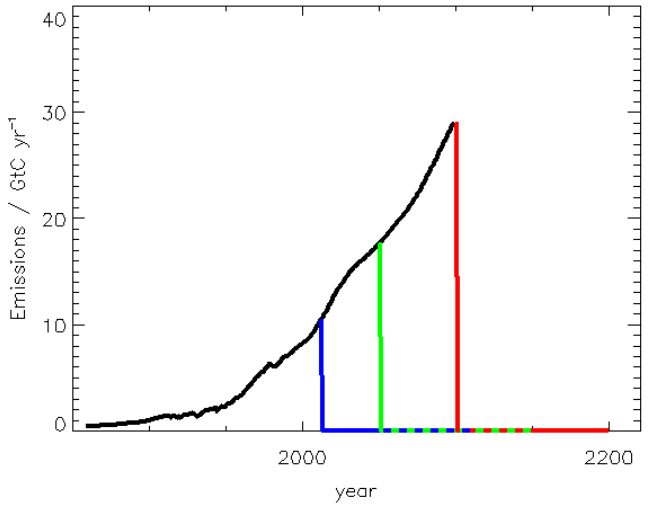


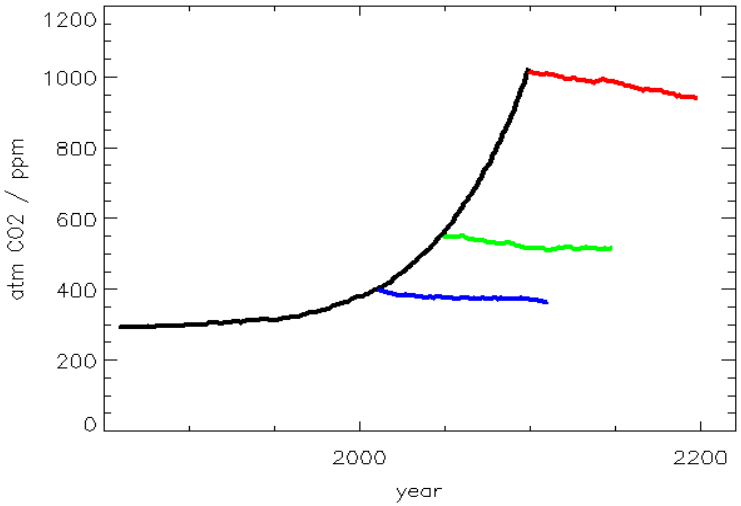


Committed ecosystem changes

- But ecosystems have a long timescale to respond to environmental changes (in terms of composition/coverage)
  - Continue to respond after forcing stabilises

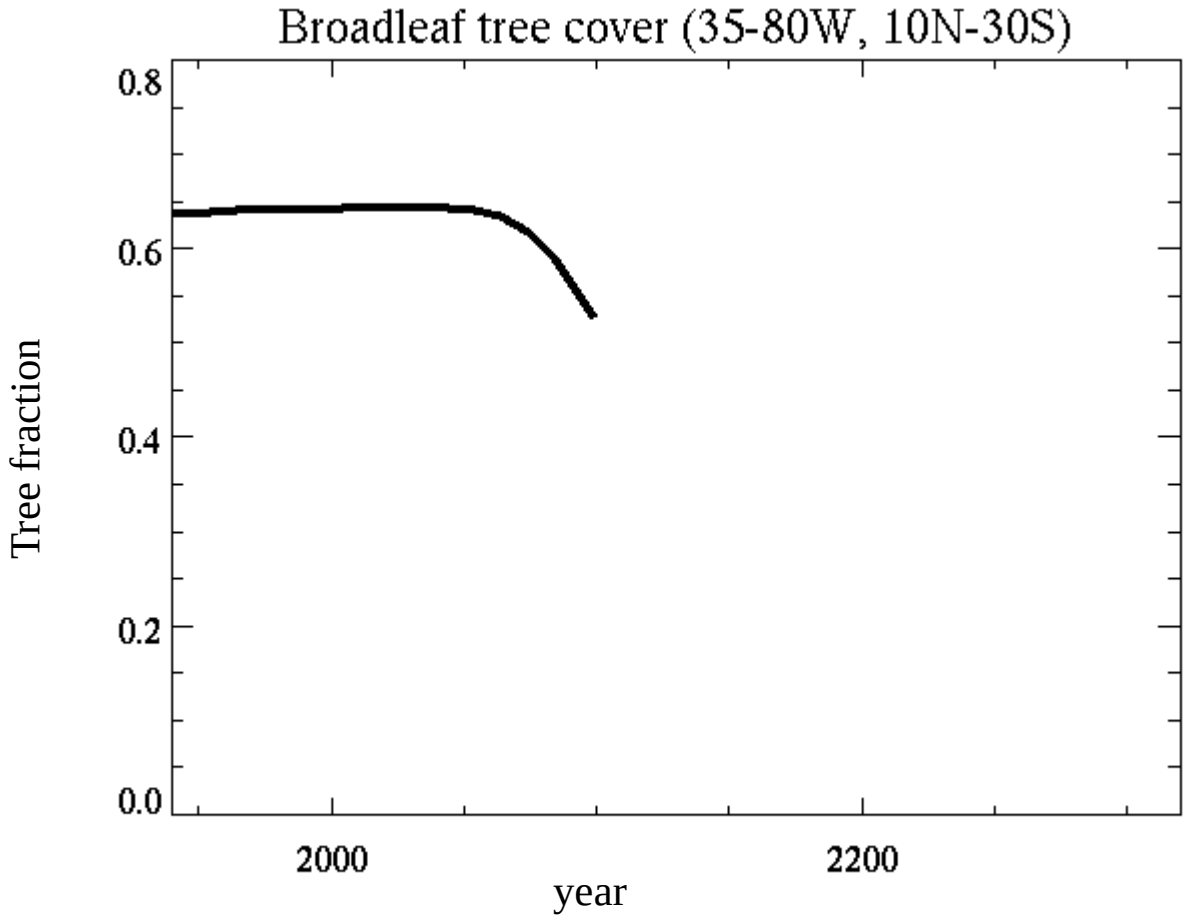
- Start with business-as-usual A2 emissions scenario
  - At 2012, 2050, 2100 cut emissions to zero





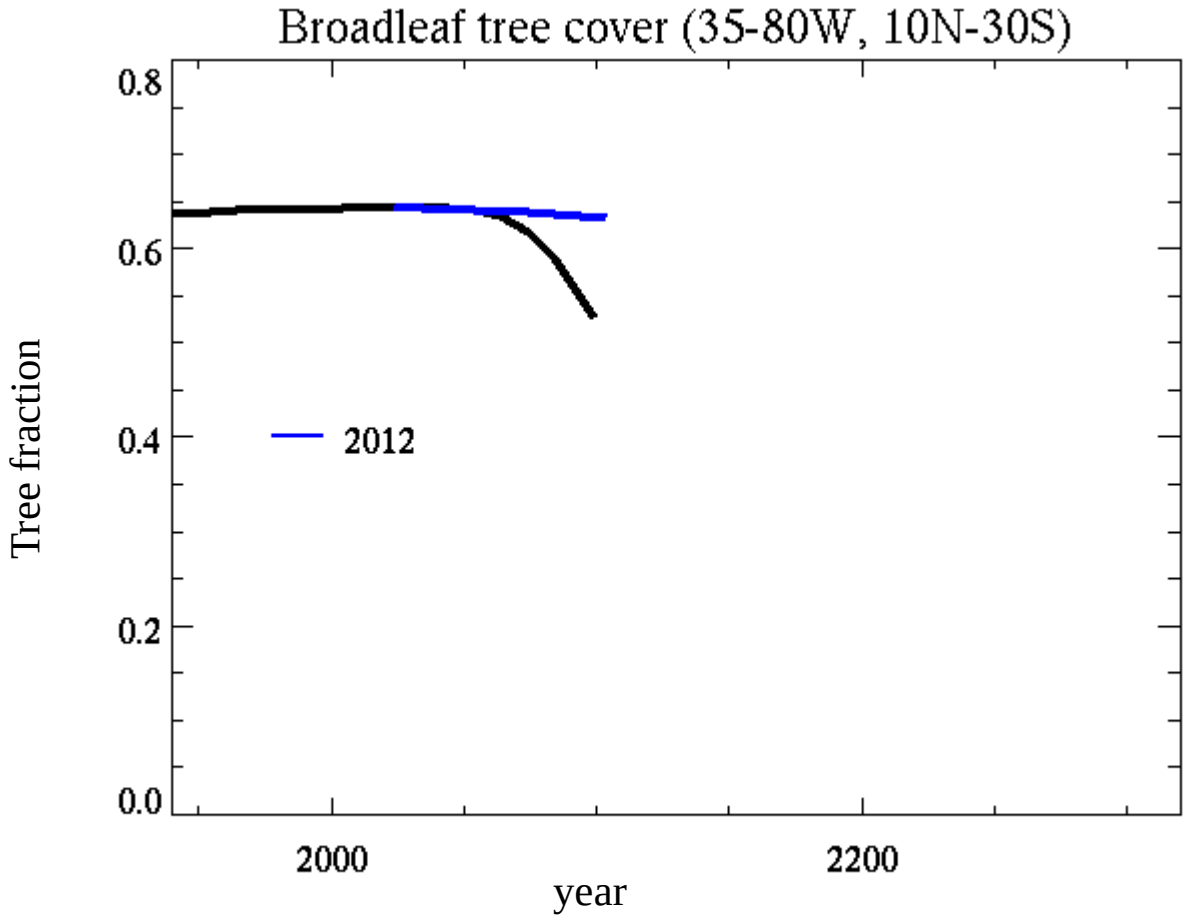
Lowe et al., 2009, ERL

Response of Amazon forest



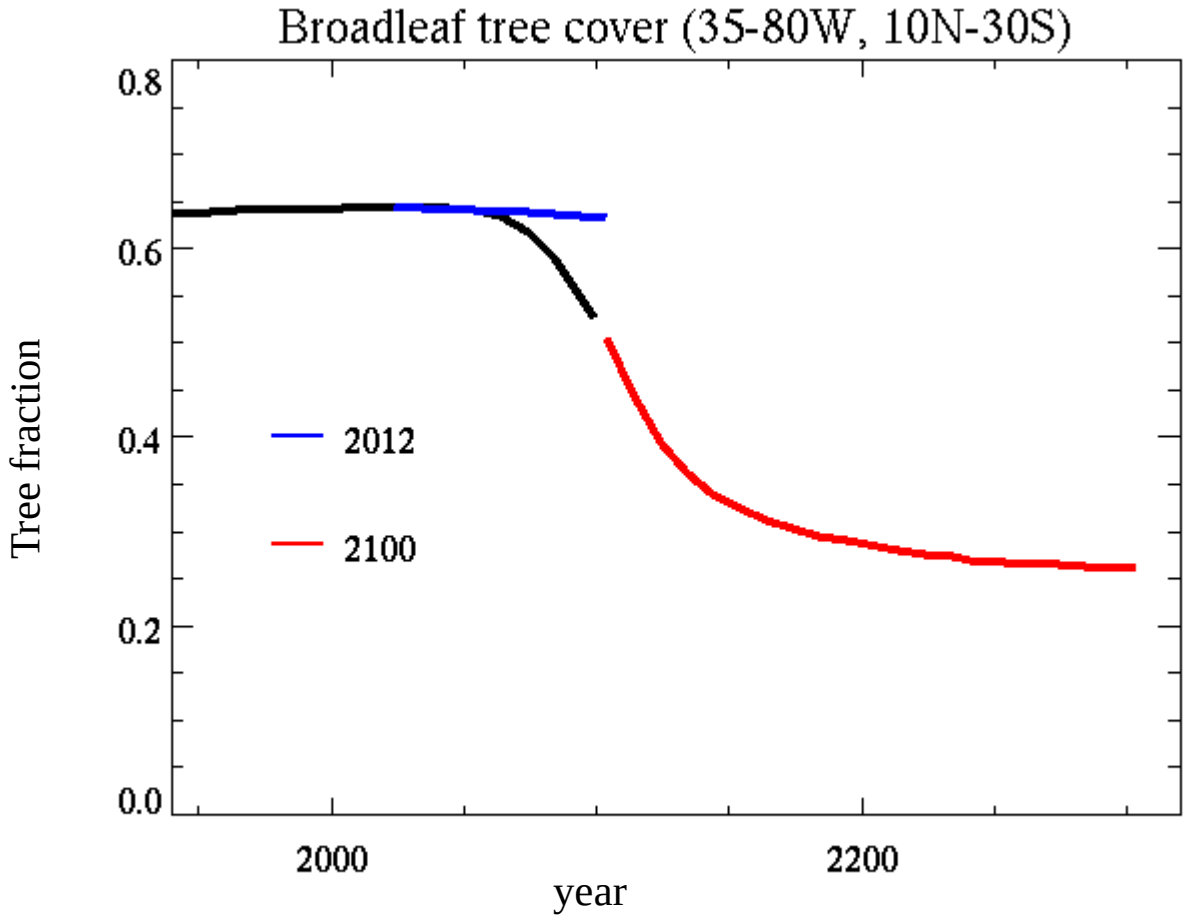
Significant future dieback predicted for “business as usual” A2 scenario

Response of Amazon forest



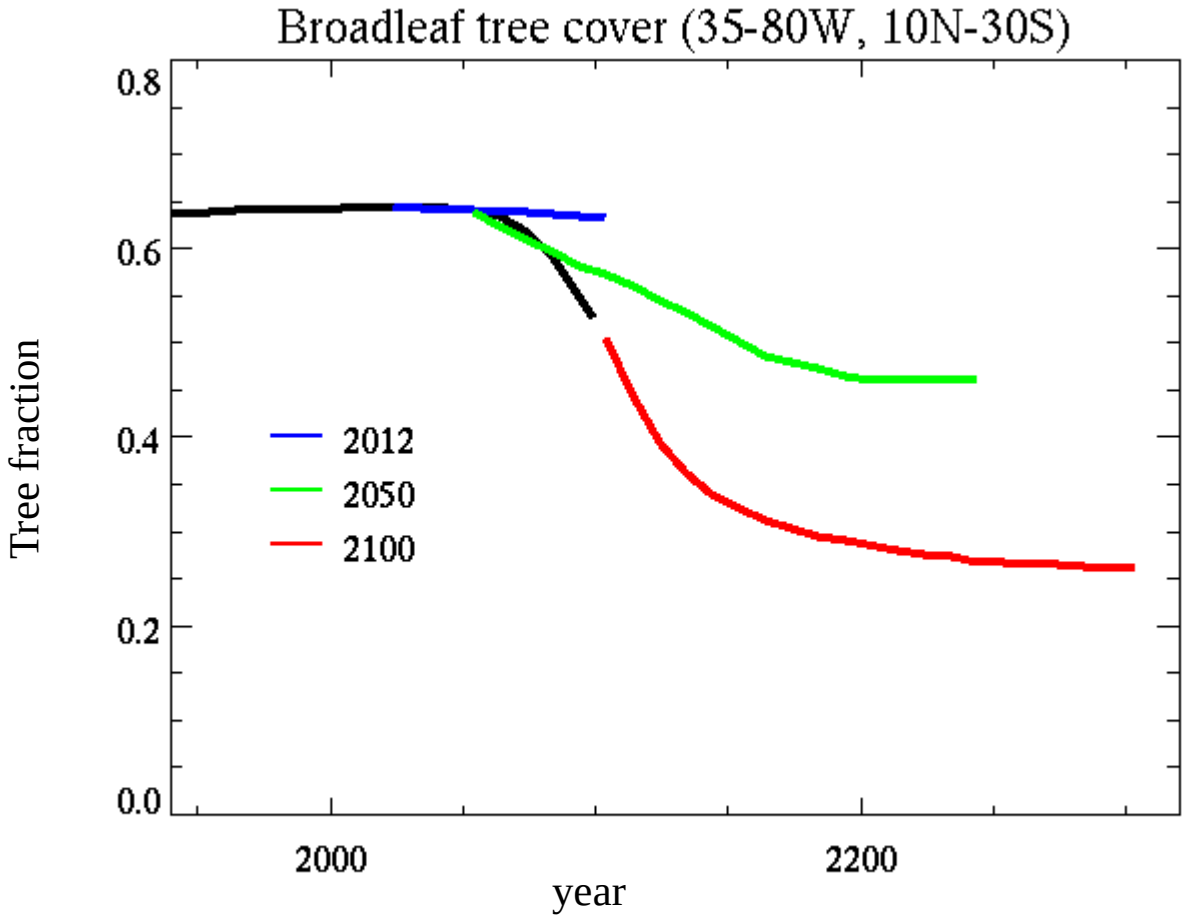
Emissions cuts at 2012 prevent future dieback

Response of Amazon forest



Emissions cuts at 2100 don't allow forest to recover
- continued severe dieback

Response of Amazon forest



Emissions cuts at 2050:

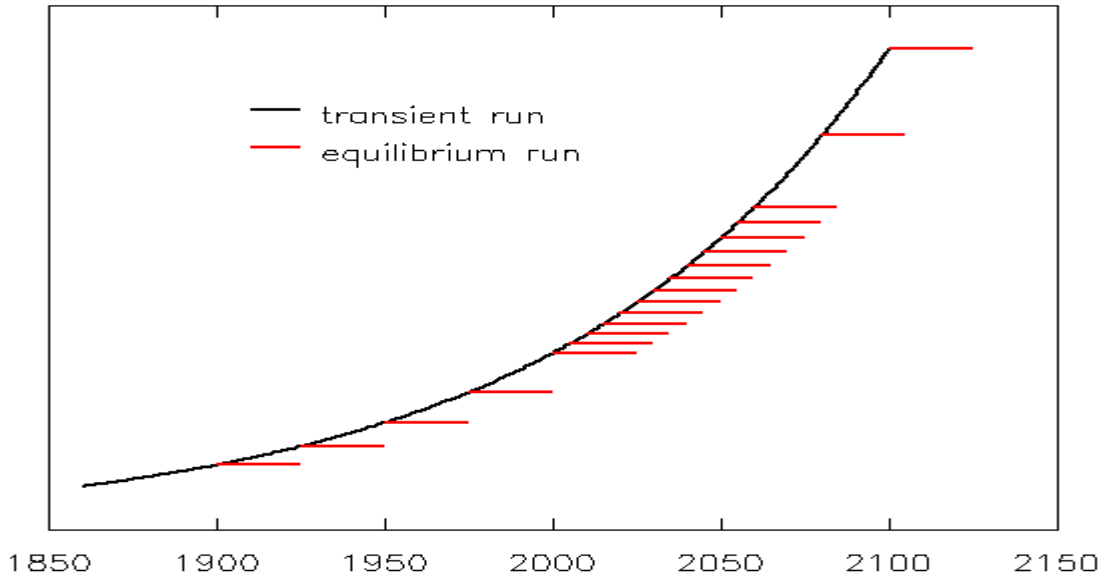
- still see significant future dieback
- even though none apparent at time of cuts!

Must have crossed some climate threshold beyond which dieback is “committed”

Committed ecosystem changes

- Concept of “committed changes” common in climate science
  - Temperature, sea-level rise, ice sheets…
- Continue to respond after stabilisation of forcing
- Any component with “inertia” could exhibit this
  - Ecosystems no exception
  - No reason to suppose actual state at any time is in equilibrium with climate

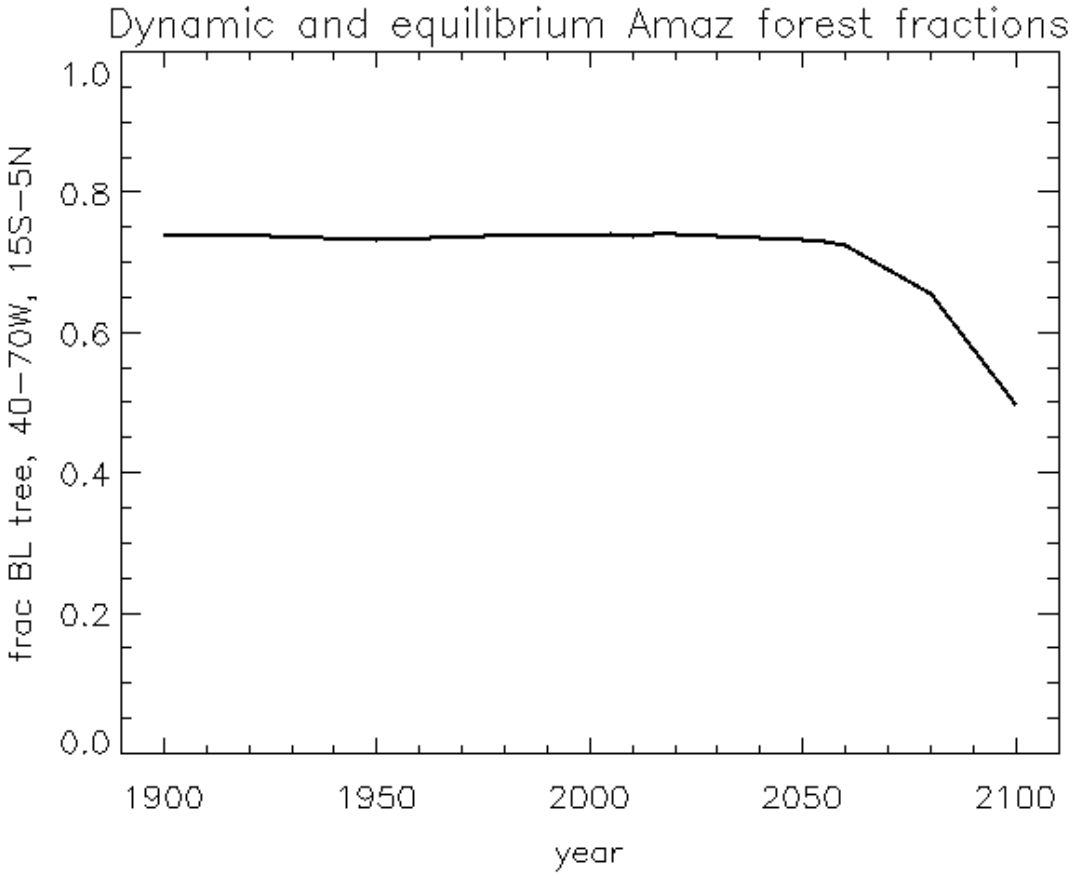
Exploring ecosystem equilibria



- Vegetation model, TRIFFID, has rapid spin-up equilibrium mode
- Run for 25 years following many points along transient path
  - Obtain the equilibrium (committed) vegetation state corresponding to the “realised” state

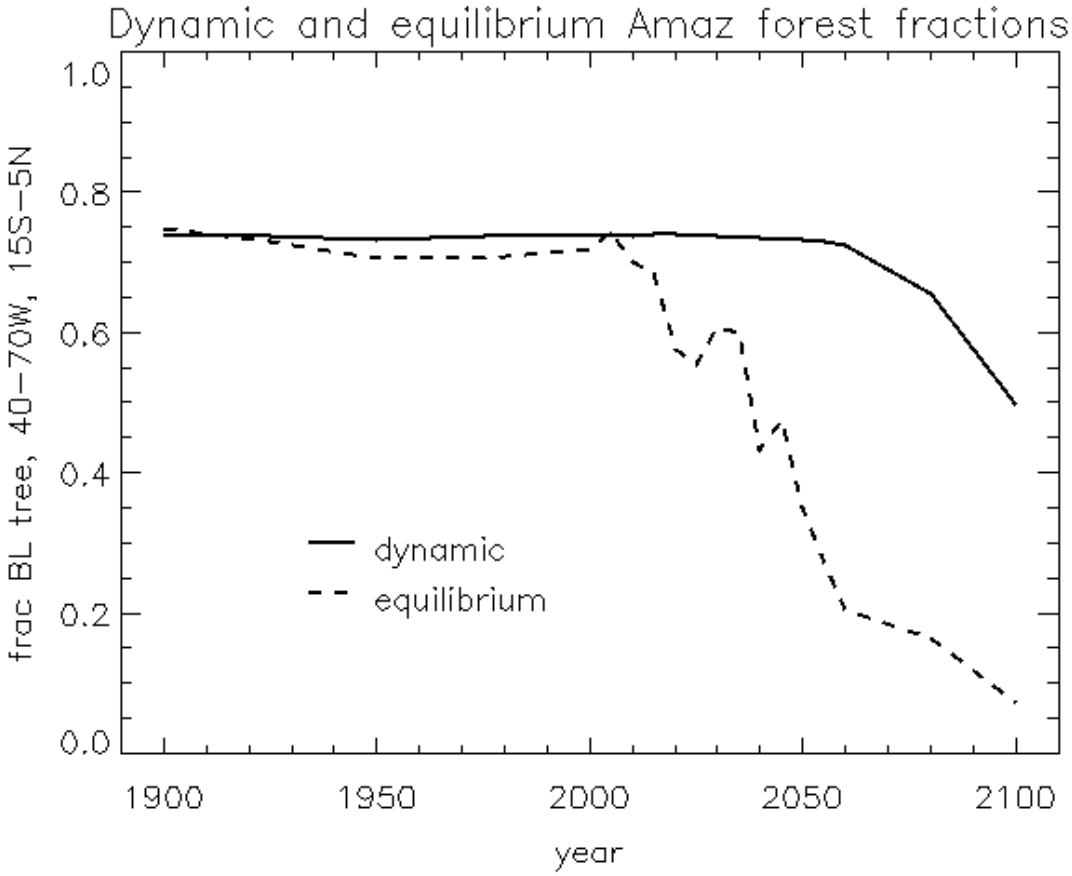
Amazon case study

- Transient run shows significant dieback
  - Becomes apparent after 2050



Amazon case study

- Transient run shows significant dieback
  - Becomes apparent after 2050
- Much greater committed changes
  - Starting early 21st century



- **But single-model study**
  - **clearly magnitude of this is model dependent**

DGVM intercomparison

- 2 axes of uncertainty
  - Climate (GCM)
  - Vegetation response to it (DGVM)
- Here explore the DGVM axis

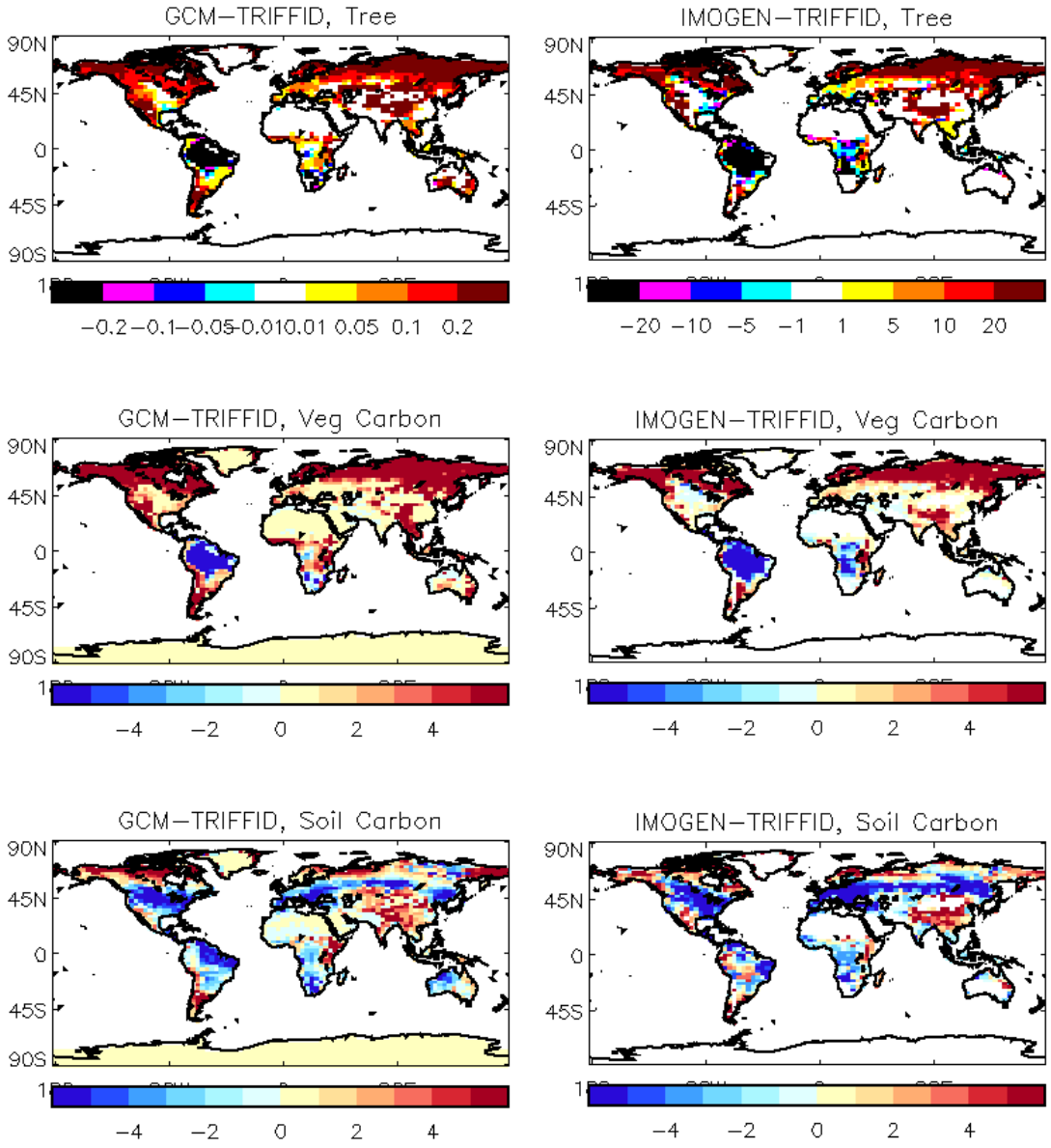
- Use the IMOGEN framework
  - Climate pattern-scaling approach to run land-surface models offline
  - Run 5 DGVMs to equilibrium vegetation cover
    - ΔT = 1,2,3,4,5 degrees

- Note – not funded work. Many thanks to all groups involved for providing results.
  - Hyland, LPJ, ORCHIDEE, Sheffield-DGVM, TRIFFID

IMOGEN vs GCM runs

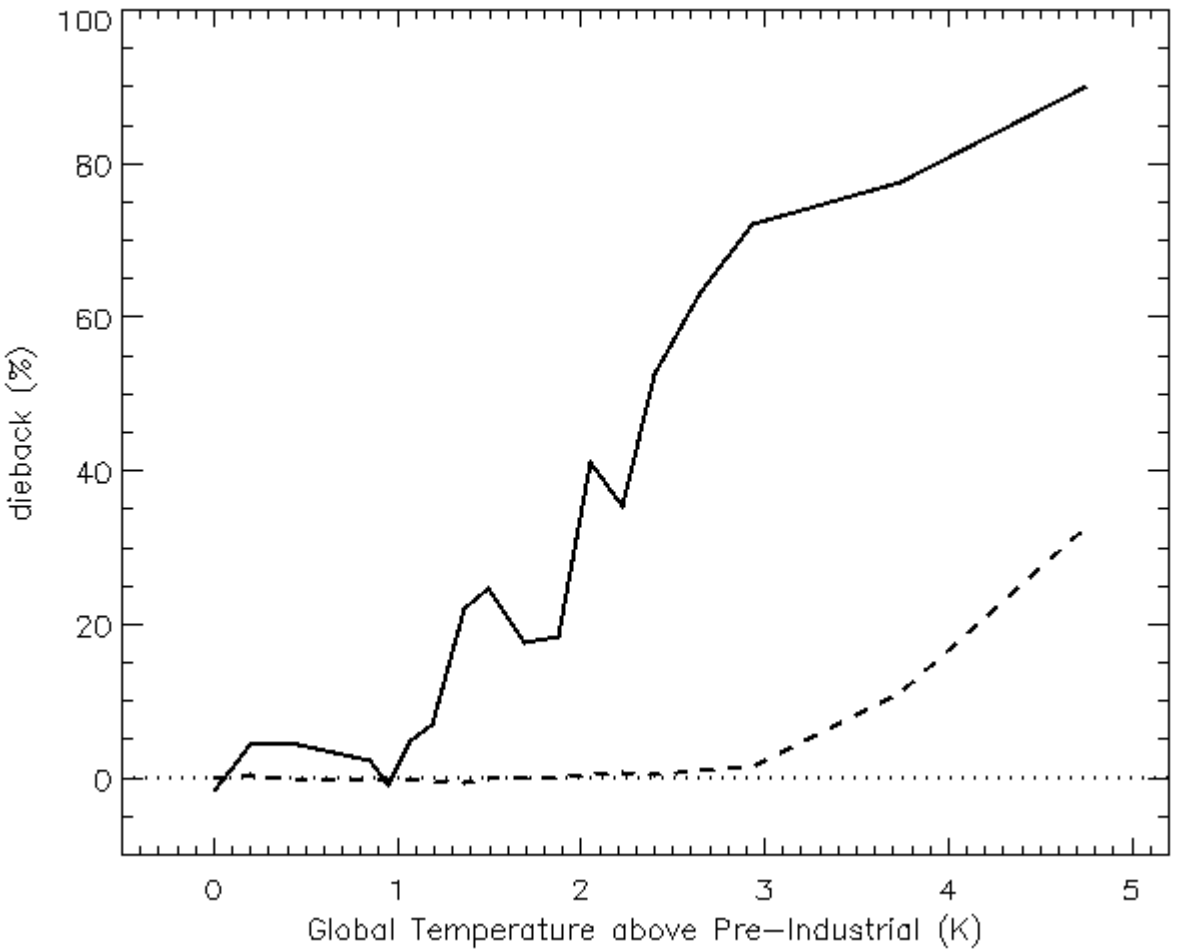
- Compare the IMOGEN runs with TRIFFID against original GCM runs with TRIFFID

- Maps for committed changes at 5 degrees
  - Tree cover
  - Veg carbon
  - Soil carbon
- Very similar patterns*
  - * see caveat later



GCM results in climate space

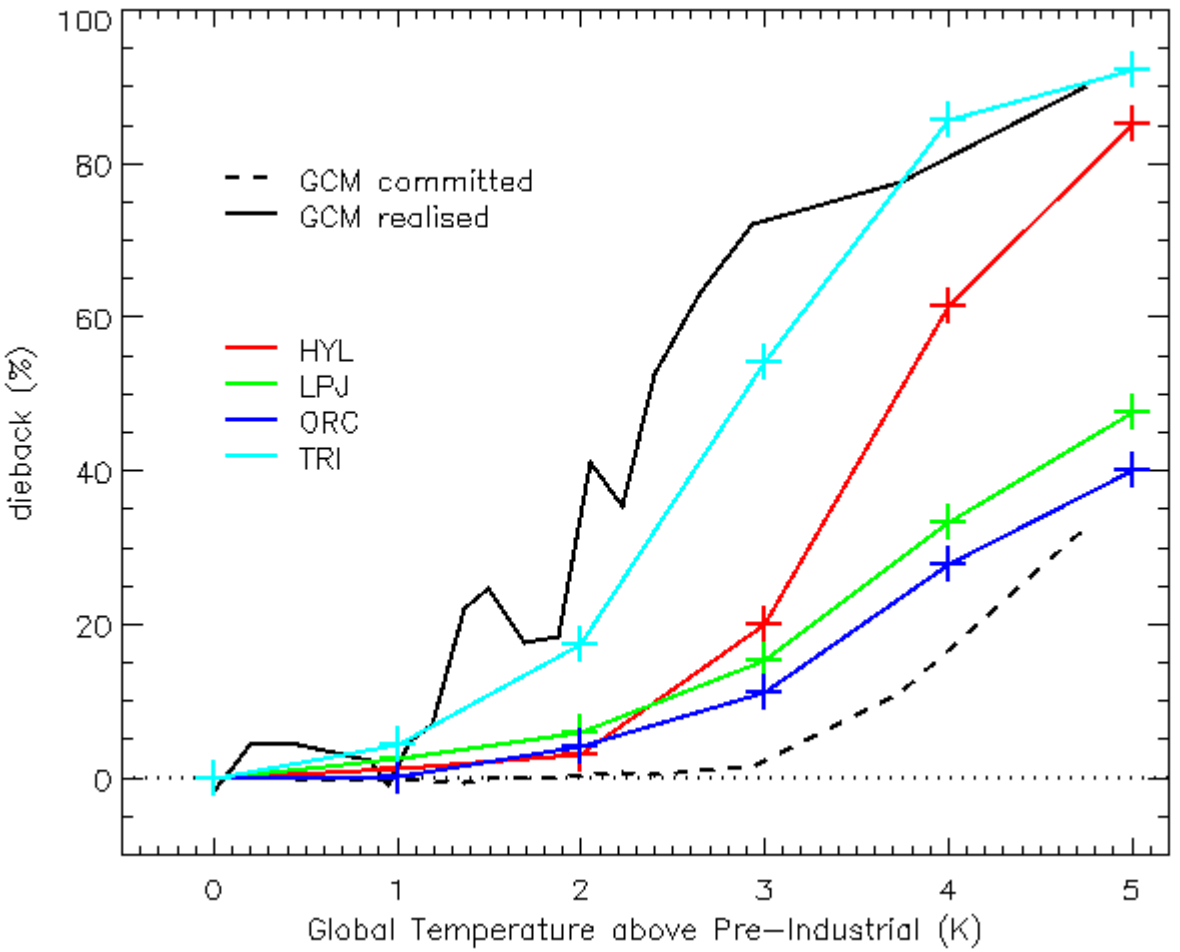
- Same results as before
  - %-dieback (positive upwards)
  - against global temperature change.



Jones et al., 2009, Nature Geoscience

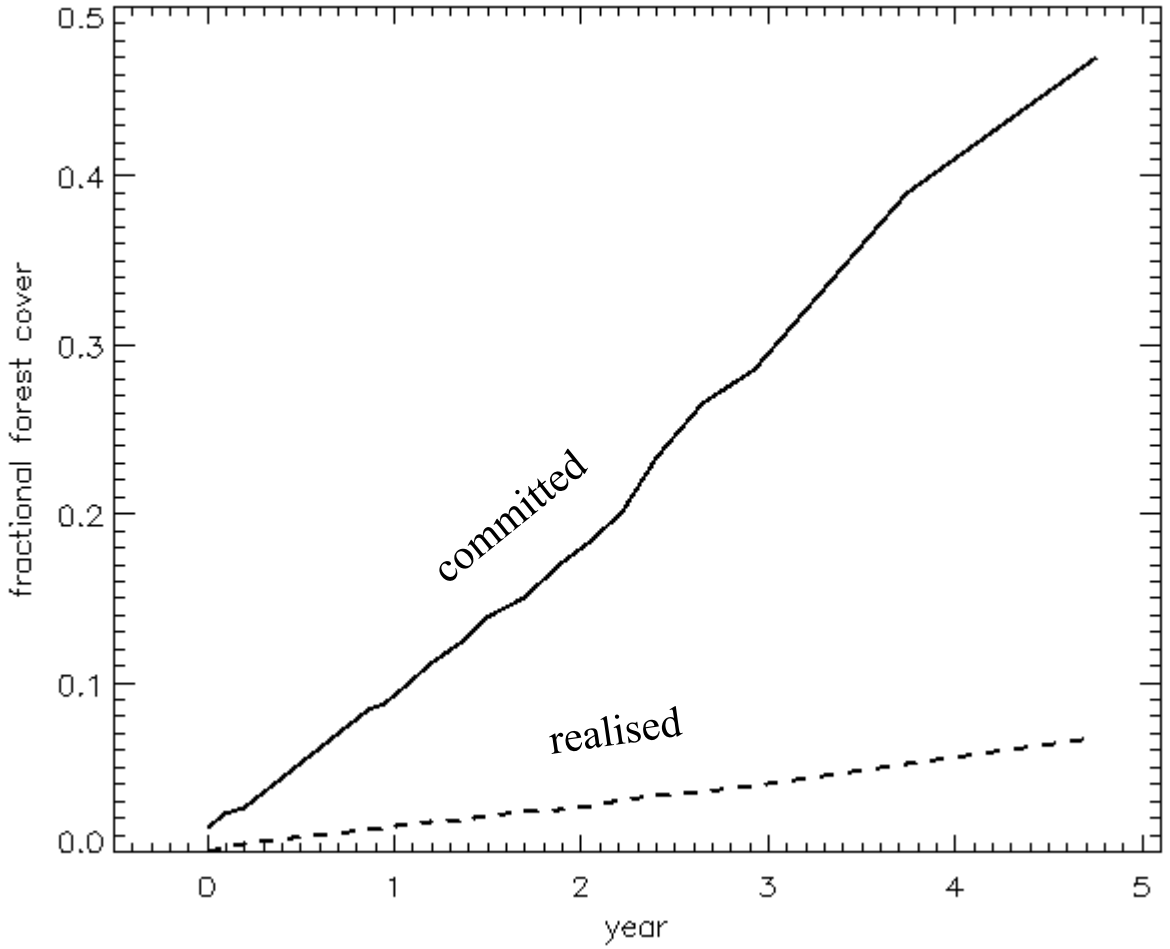
DGVM results – Amazon dieback uncertainty

- All DGVMs see committed dieback
  - Increases for greater climate change
  - All greater than REALISED state in GCM
  - TRIFFID has greatest dieback
  - Remember – all DGVMs see *identical* climate here



Boreal forest results

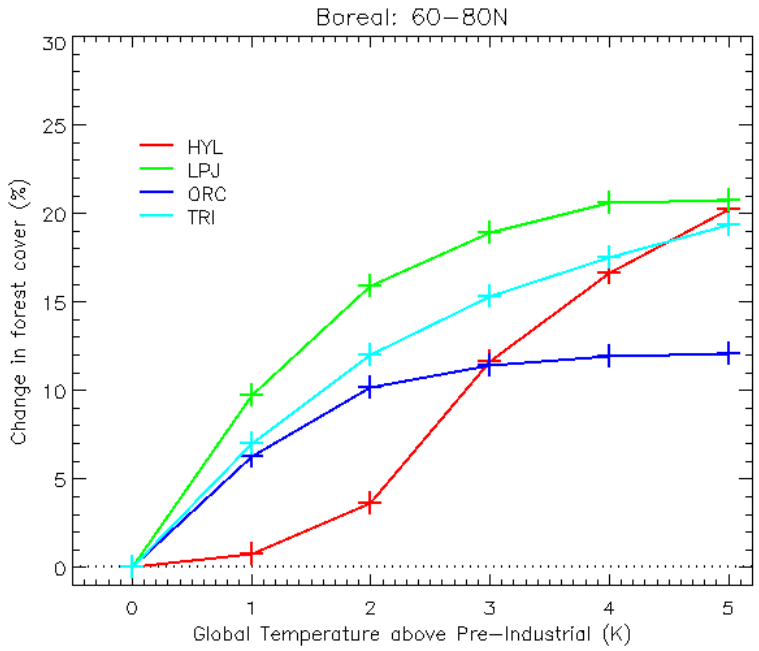
- GCM simulated large expansion of Boreal forest
  - Defined here as tree cover between 45N-80N
  - Transient (realised) response slow, therefore small.
  - Committed response continues for centuries



Jones et al., 2009, Nature Geoscience

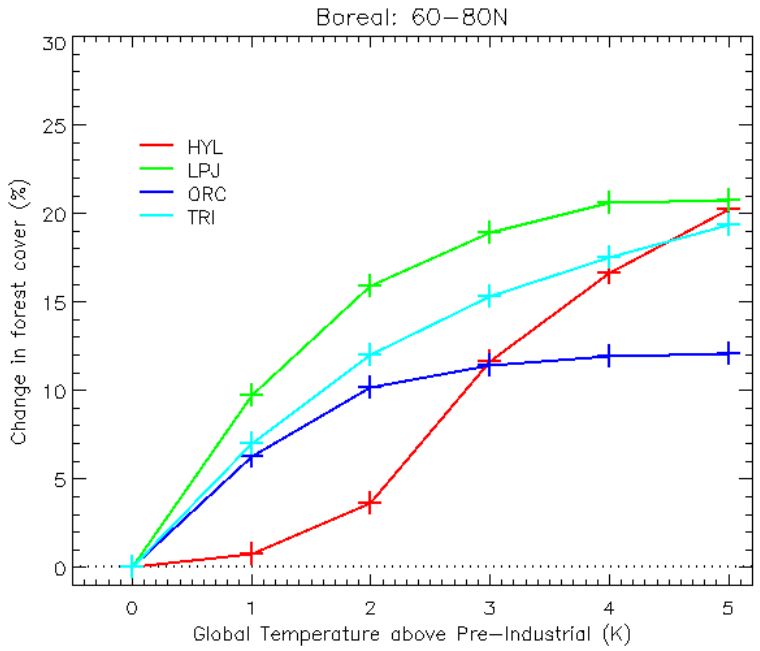
Boreal/temperate forest commitments

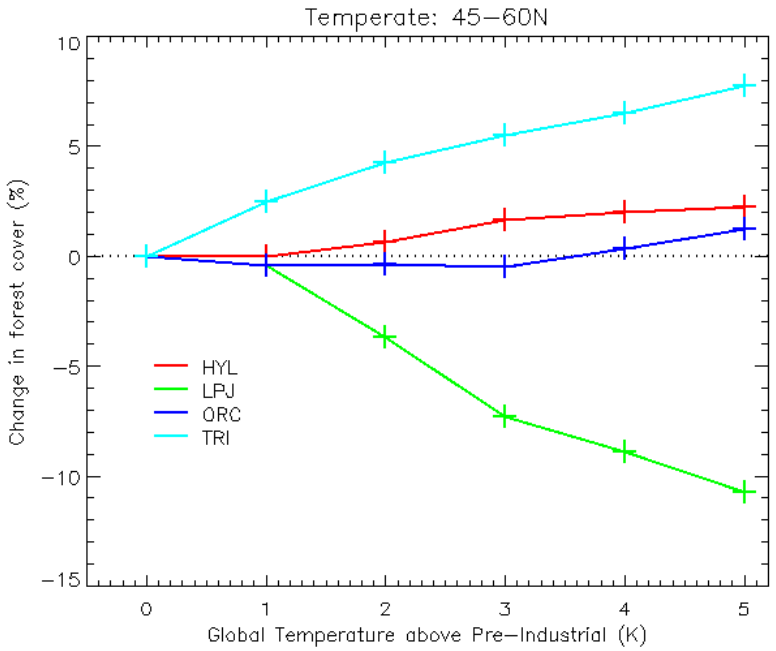
- DGVM response markedly different for Boreal forest (>60N) and temperate forest (45-60N)
  - All see Boreal expansion (northward shift of tree line)



Boreal/temperate forest commitments

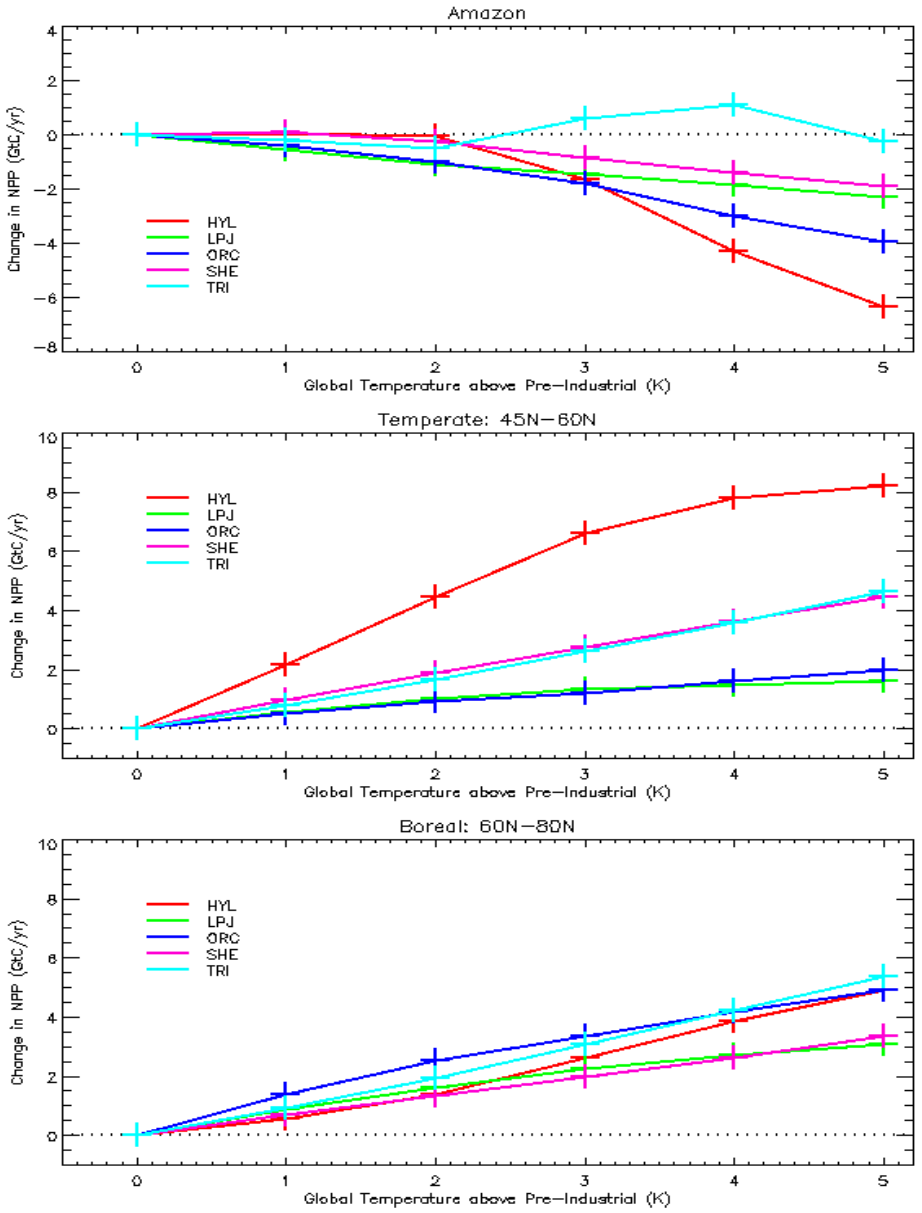
- DGVM response markedly different for Boreal forest (>60N) and temperate forest (45-60N)
  - All see Boreal expansion (northward shift of tree line)
  - Differ in sign of temperate response
    - LPJ sees greatest boreal expansion AND greatest temperate loss…





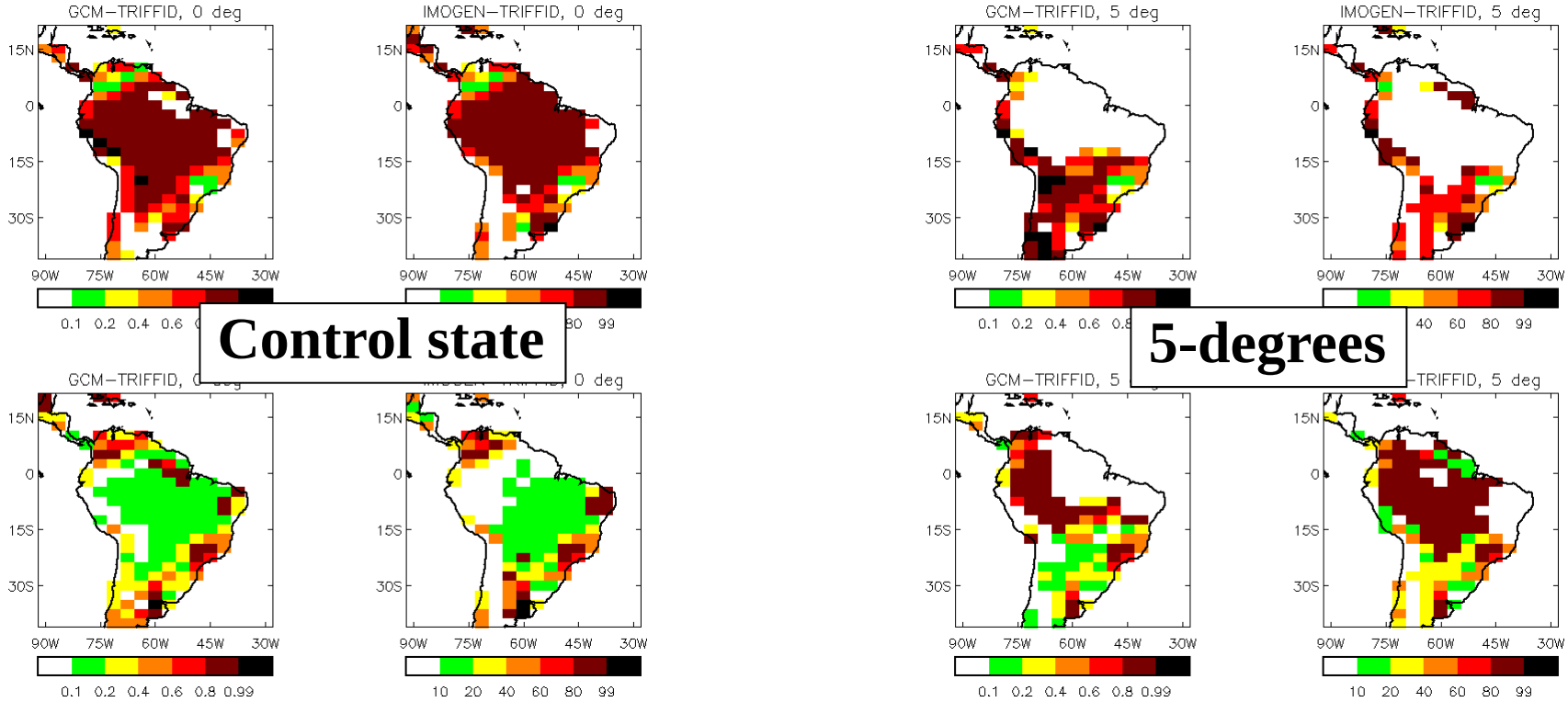
NPP: what drives the vegetation changes?

- Amazon:
  - All models simulate lower NPP. Except TRIFFID!
    - See next slide
  - All models see increase in temperate productivity – including LPJ
    - Large spread in magnitude
    - Fire not yet investigated
  - All models agree closely on increased Boreal productivity



Local feedbacks

- Some interesting aspects requiring more investigation
  - TRIFFID showed largest Amazon dieback, but was only model with unchanged NPP
  - GCM-TRIFFID simulates desertification. IMOGEN-TRIFFID simulates grass cover.
    - Hence NPP not decreased in offline runs.
    - … importance of coupled GCM-vegetation modelling. Offline runs useful but can't do it all…



Summary of results

- We explored the DGVM axis of uncertainty.
- So what's robust and what's uncertain?
  - **Boreal forest expansion**
    - strong agreement on magnitude of NPP increase. Spread in forest expansion, due to veg dynamics
  - **Amazon dieback**
    - general agreement on some dieback. Uncertainty in magnitude. This comes from uncertainty in both response of NPP to climate and veg dynamics
  - **Temperate forest**
    - agree on increased productivity, but uncertain in magnitude.
    - Disagree on sign of forest cover changes
      - Representation of PFTs? Inclusion of fire disturbance?

Conclusions

- Ecosystems exhibit significant commitment to change after climate stabilisation
- Response continues for decades or centuries after climate stabilised
- Quantitative nature of results very model dependent

- We have explored DGVM uncertainty
  - Amazon forest could be committed to large-scale loss before any is apparent
  - Boreal forest will expand northwards – probably for centuries after stabilisation
  - Uncertainty is very large in temperate forest response and southern edge of boreal forest – disturbance processes require more study

  - Work in hand (Chris H.) to explore GCM axis…

- Definitions of Dangerous Climate Change for slowly-responding components need to consider commitments, not just instantaneous state

References and contact

- CO_2 recovery from overshoot is described in:
  - Lowe et al., 2009, *ERL*, **4**, "How difficult is it to recover from dangerous levels of global warming?"
- Committed ecosystem changes are described in:
  - Jones et al., 2009, *Nature Geoscience, **2**,* "Committed terrestrial ecosystem changes due to climate change"
- DGVM intercomparison of these 5 DGVMs under transient climate change in:
  - Sitch et al., 2008, GCB, **14**, "Evaluation of the terrestrial carbon cycle, … using fiveDynamic Global Vegetation Models (DGVMs)"

more info – email: chris.d.jones@metoffice.gov.uk