Forests in JULES: sinks, spaghetti and spots

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Met Office Hadley Centre

JULES meeting, Edinburgh, 19-20 June 2013

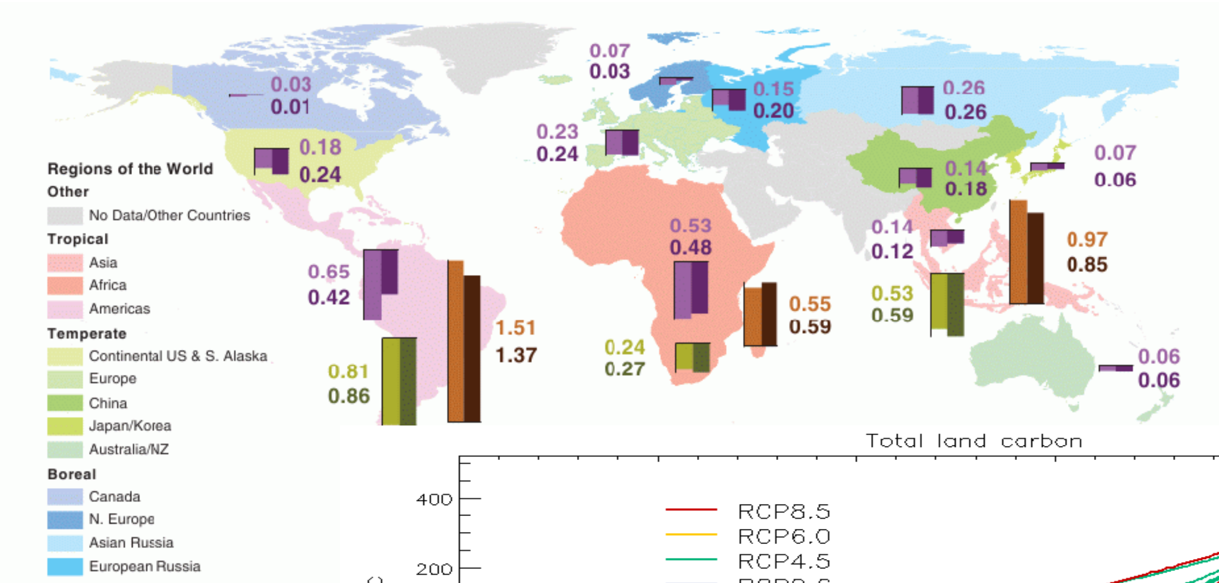
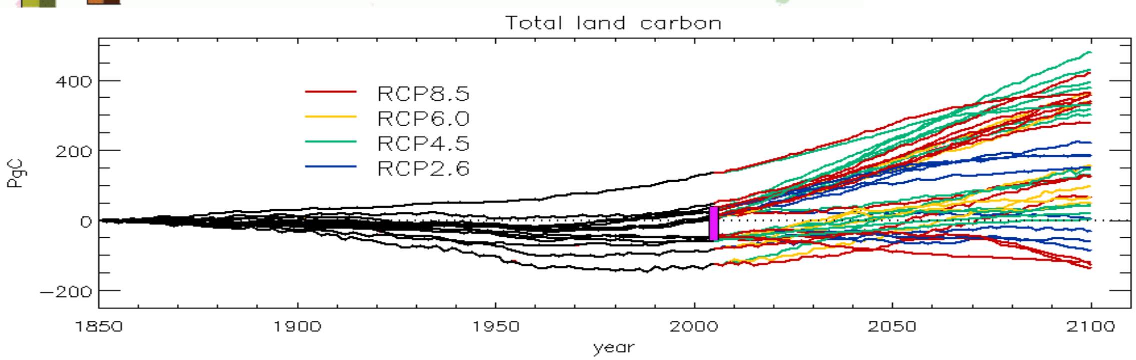
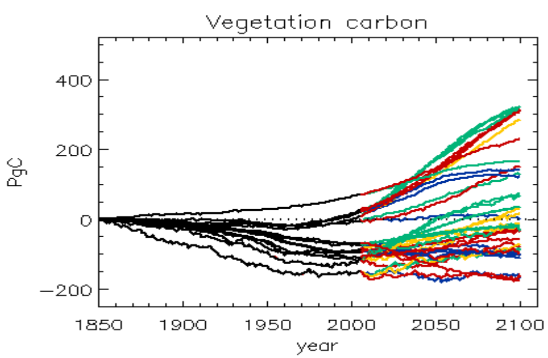
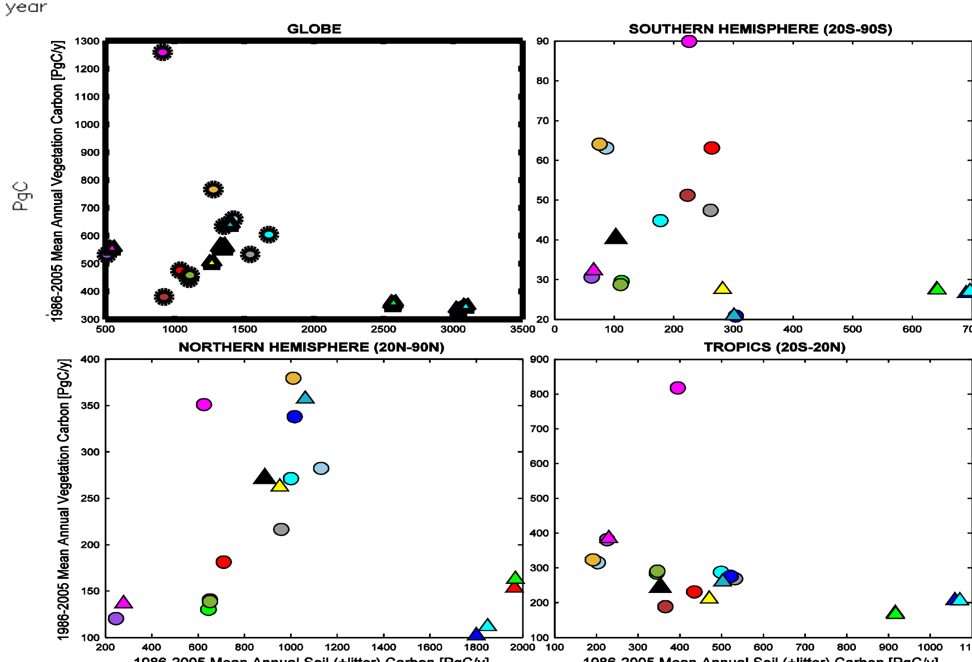


Fig. 1. Carbon sinks and sources (Pg C y
bars in the down-facing direction repre
upward-facing direction represent C sou







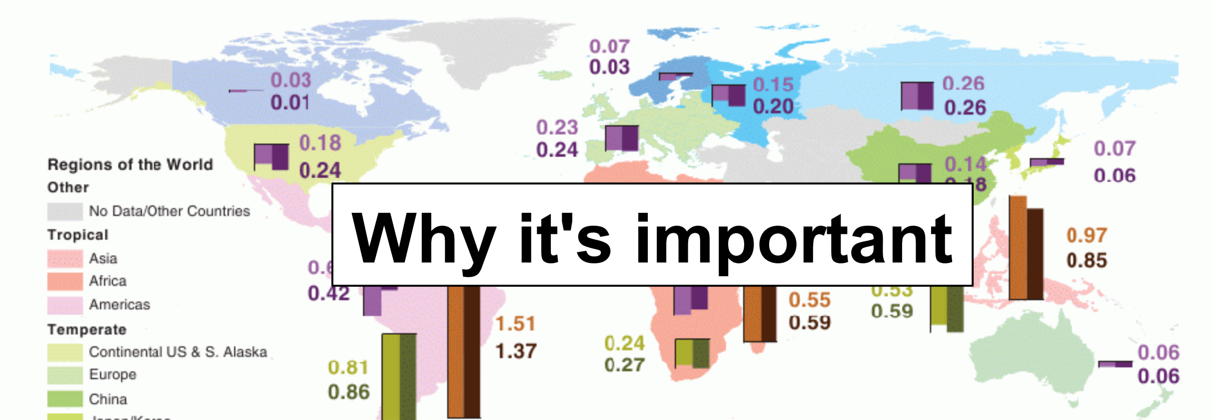


Fig. 1. Carbon sinks and sources (Pg C y
bars in the down-facing direction repre
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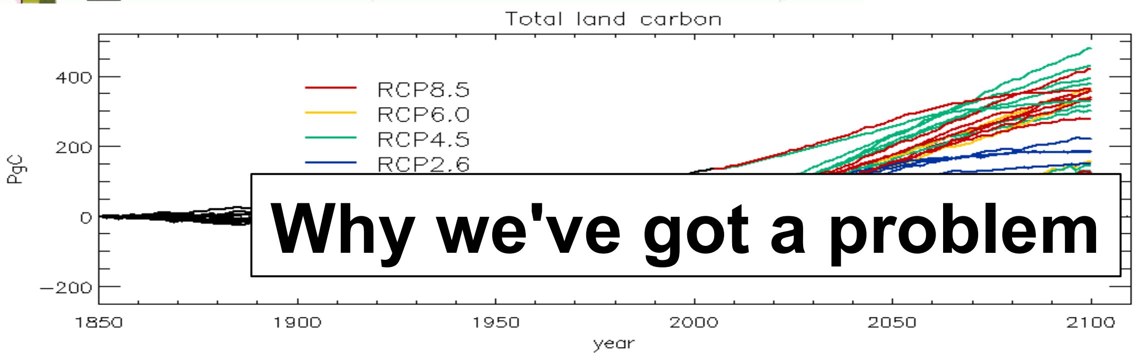
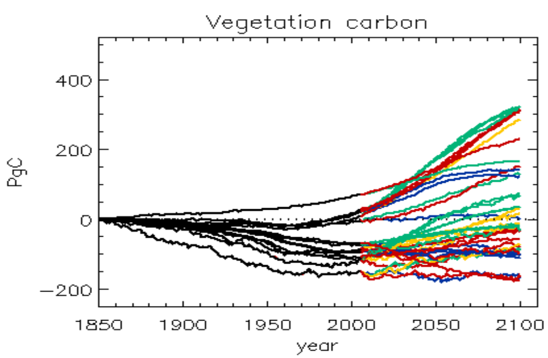
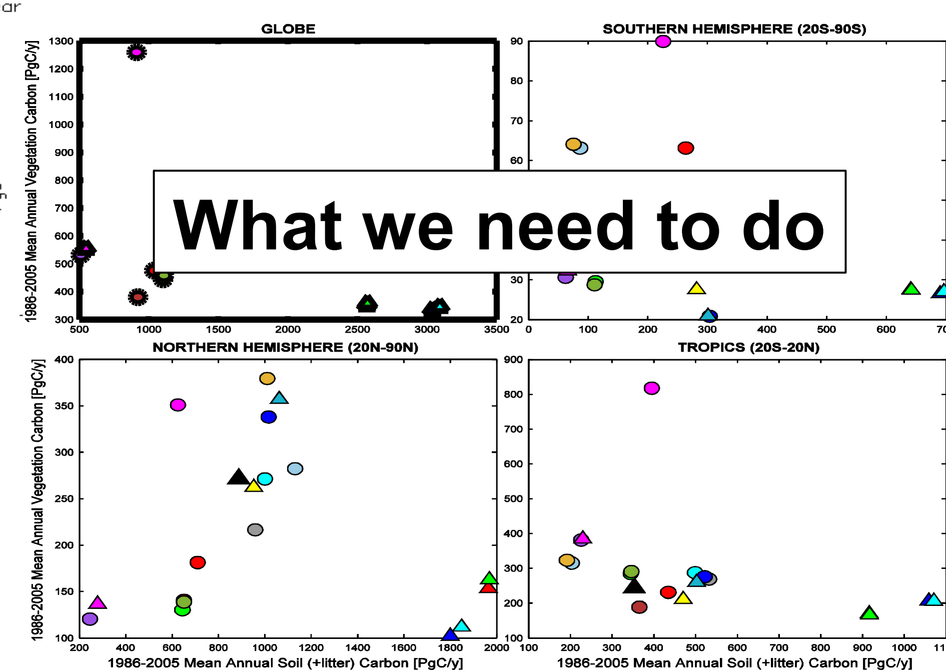
Why it's important



Why we've got a problem





What we need to do

Overview

Global carbon budgets and projections

- Importance of land carbon and forests

Drivers of changes

- Natural and managed forests
- Processes in JULES

Model evaluation

- Current and future

A large and persistent carbon sink in the world's forests

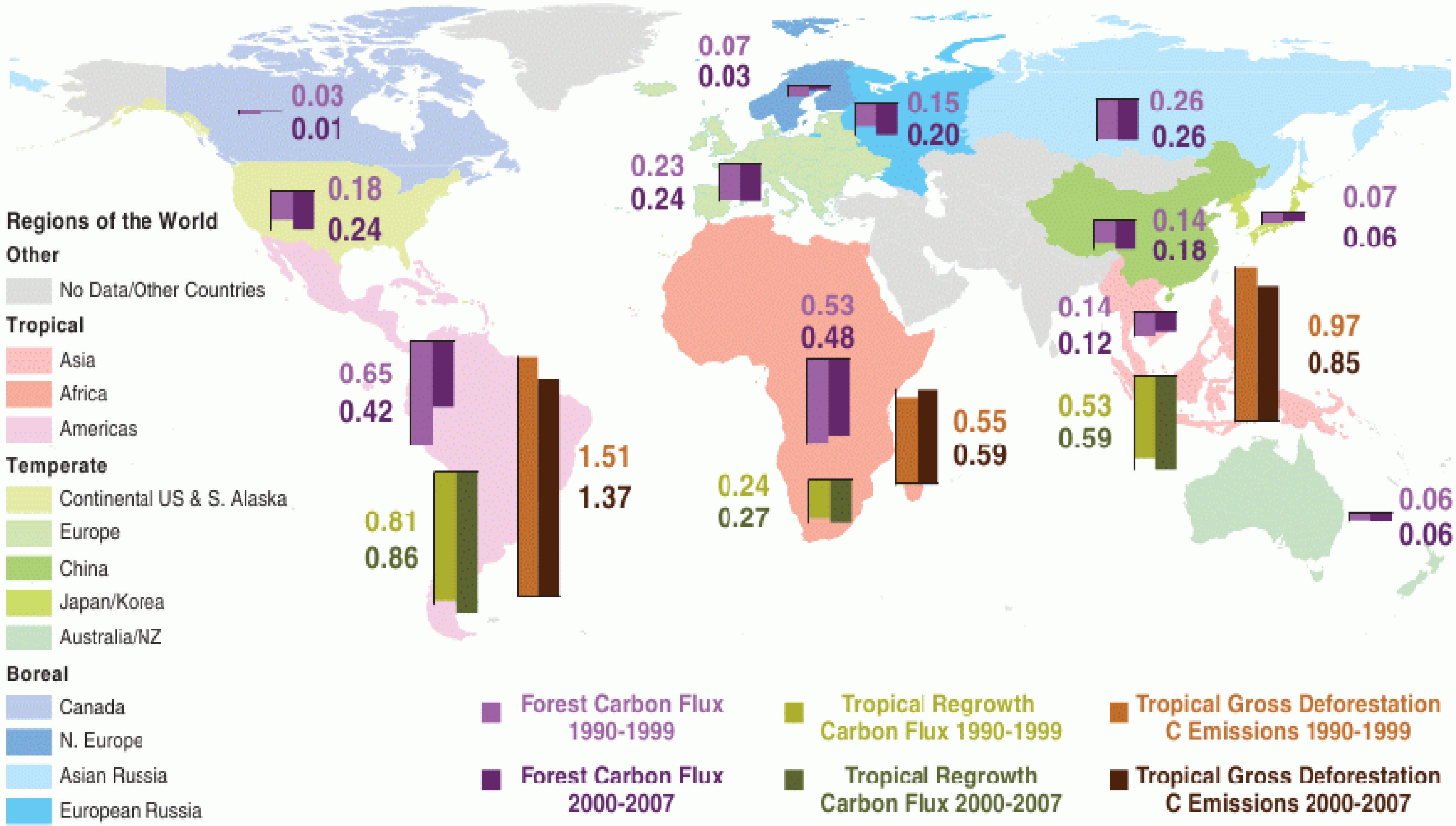
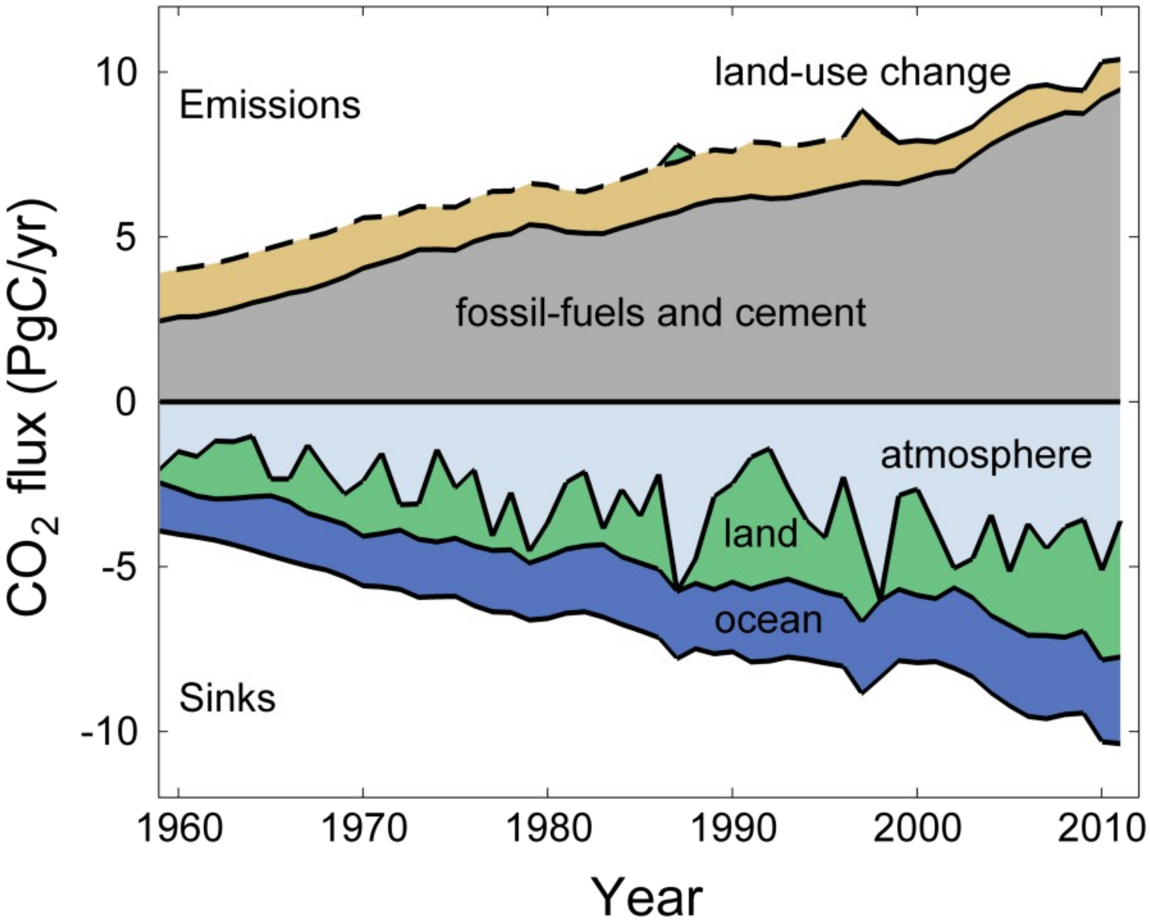


Fig. 1. Carbon sinks and sources (Pg C year^{-1}) in the world's forests. Colored bars in the down-facing direction represent C sinks, whereas bars in the upward-facing direction represent C sources. Light and dark purple, global established forests (boreal, temperate, and intact tropical forests); light and dark green, tropical regrowth forests after anthropogenic disturbances; and light and dark brown, tropical gross deforestati

Pan et al., 2011

Global Carbon Budget

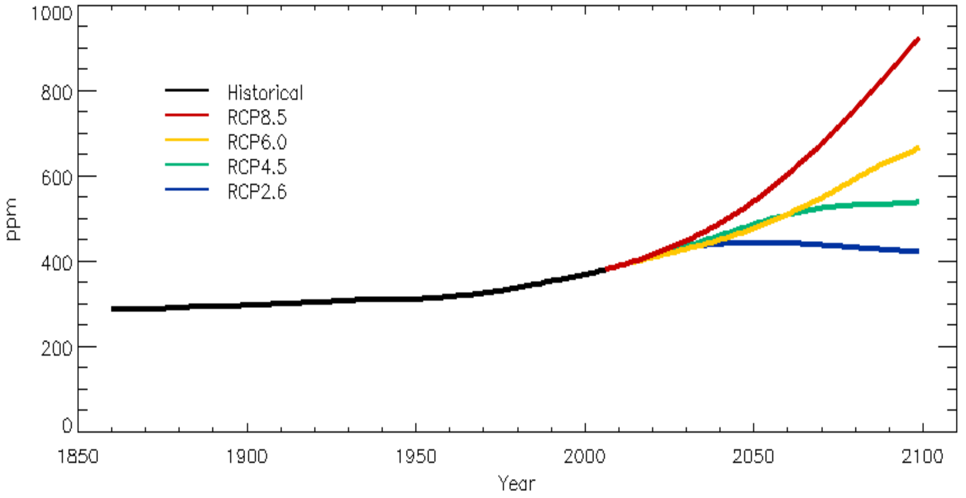
Emissions to the atmosphere are balanced by the sinks
Averaged sinks since 1959: 44% atmosphere, 28% land, 28% ocean

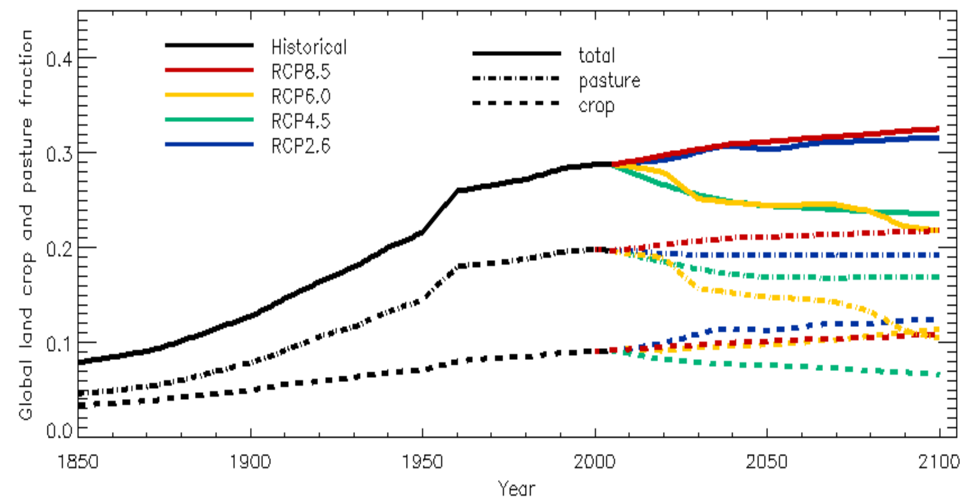


Land sink more variable
In models more uncertain
About 50% magnitude and most of variability comes from tropical forests

Future projections

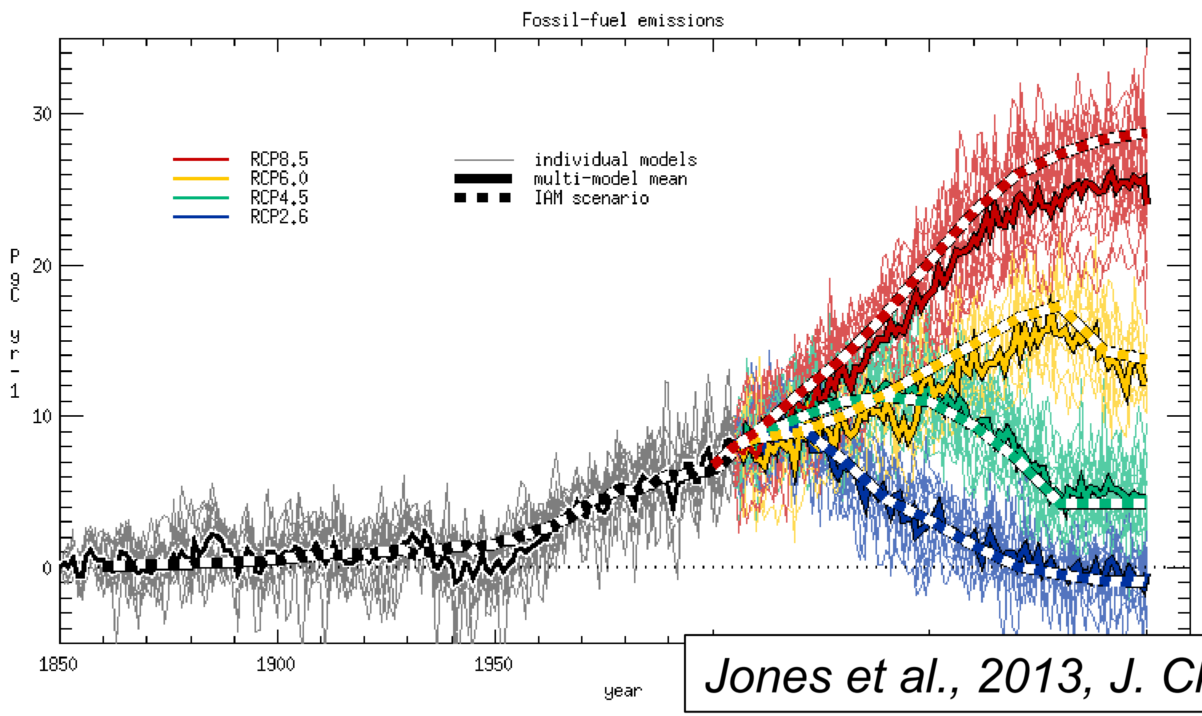
- Based on new RCP scenarios
  - CO2 concentrations and land-use
  - CMIP5 models (incl. HadGEM2-ES) used to diagnose fossil fuel emissions to follow these trajectories





Compatible fossil fuel emissions

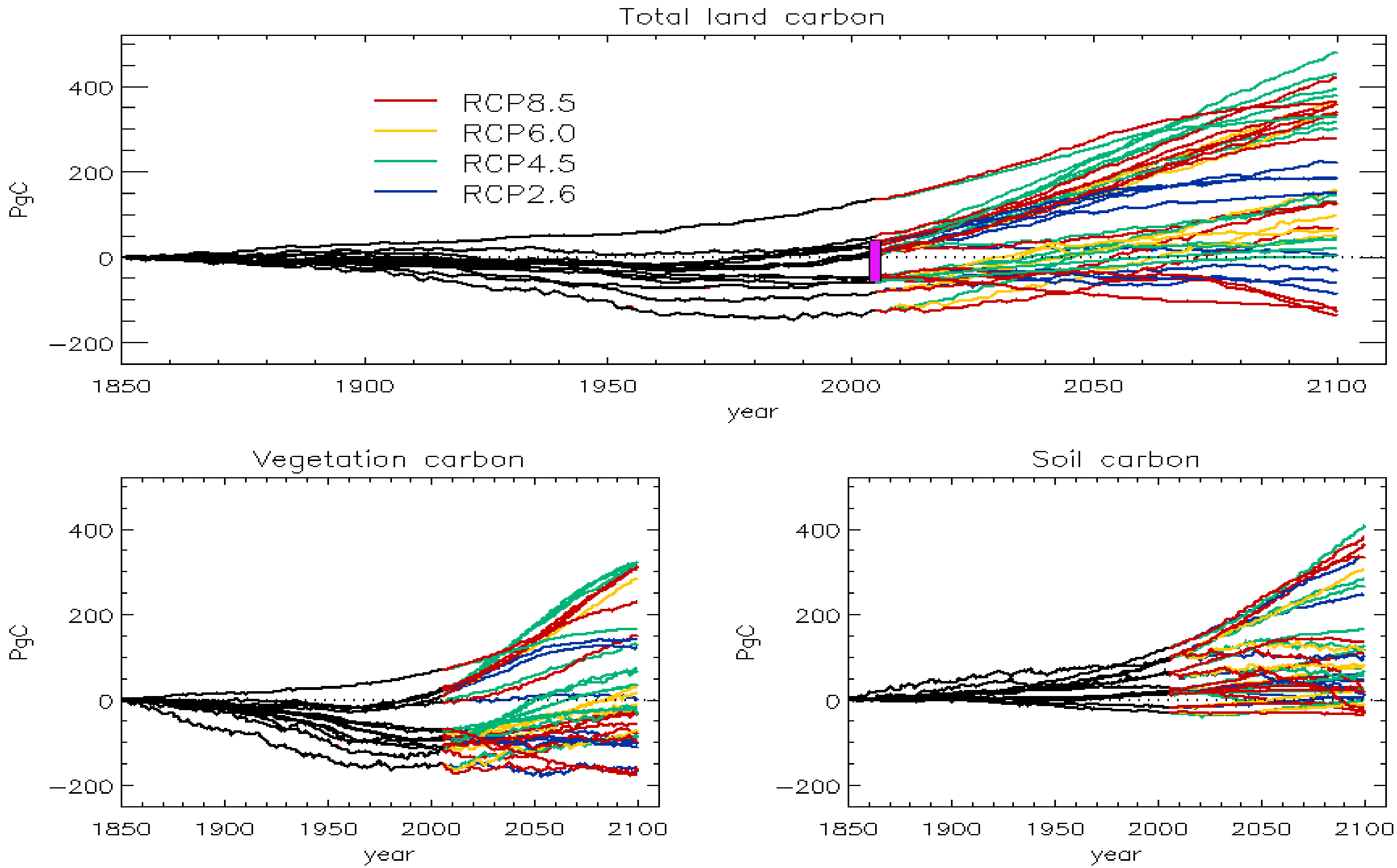
- ESMs simulate land/ocean carbon fluxes
  - Diagnose emissions required to follow RCP pathway



Jones et al., 2013, J. Clim.

CMIP5 land carbon cycle results

- Land uptake – model disagreement



Forests

So, forests are:

- Big
- Important for past, present and future carbon budget
- Uncertain
  - Large model spread in their representation
- Sensitive to direct human forcing and environmental changes
- Complicated!

Drivers of land carbon changes

C4MIP included

- CO_2
- Climate

CMIP5 includes:

- Land use change

Generally not included

- Land-use/management details
- Nitrogen (deposition)
- Fire
- [permafrost]

Drivers of land carbon changes

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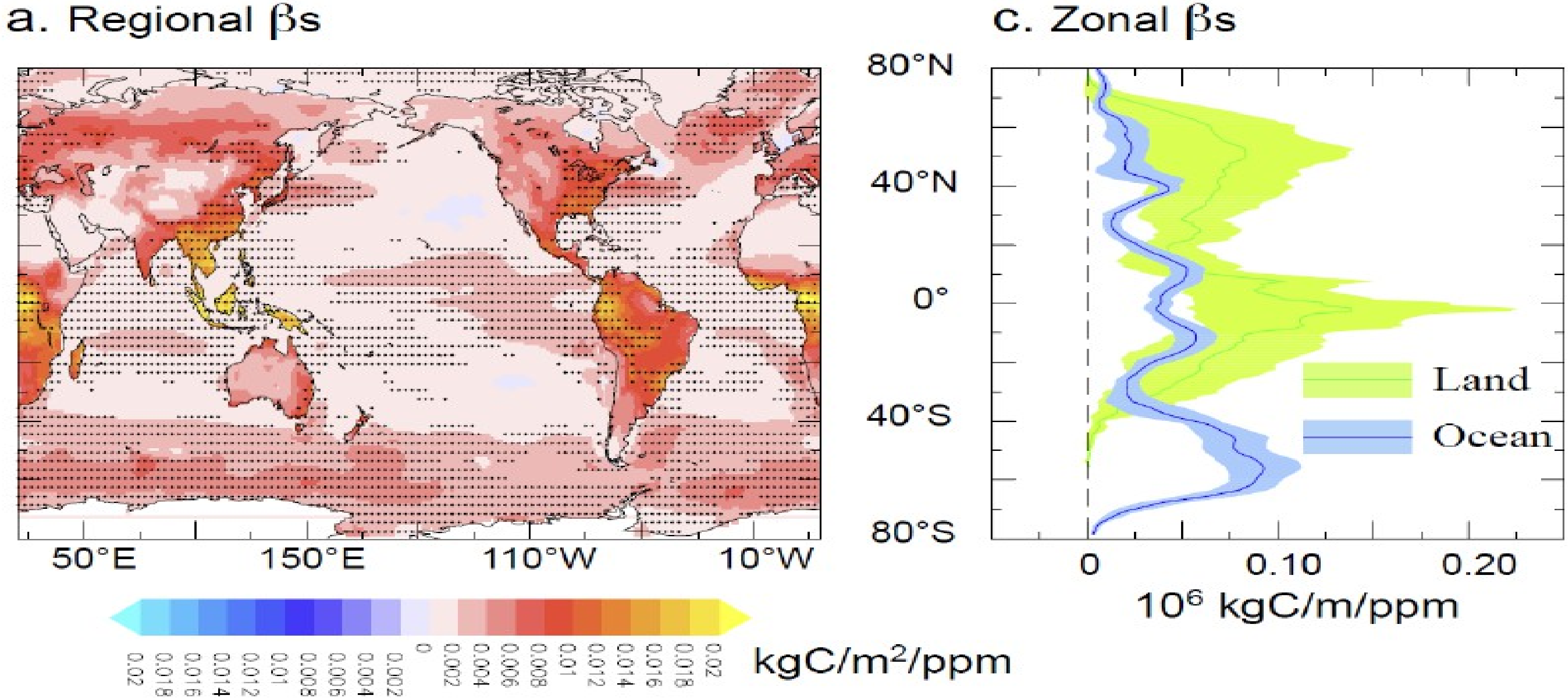
forests

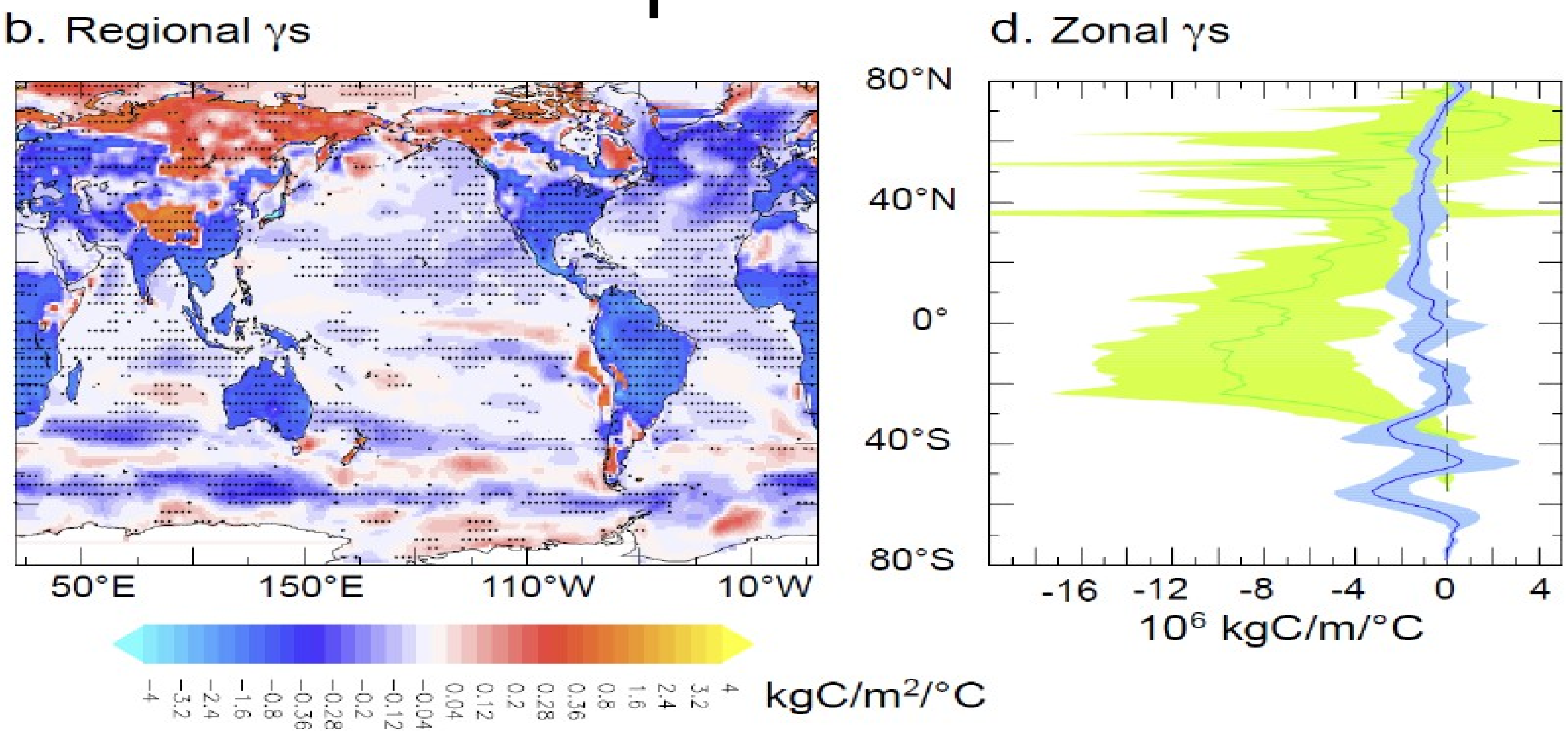
Response to CO2



Positive everywhere (enhanced carbon uptake)

- Land stronger than ocean
- Stronger over forests
- Large spread
- Evaluation data? Tropical FACE?

Response to climate

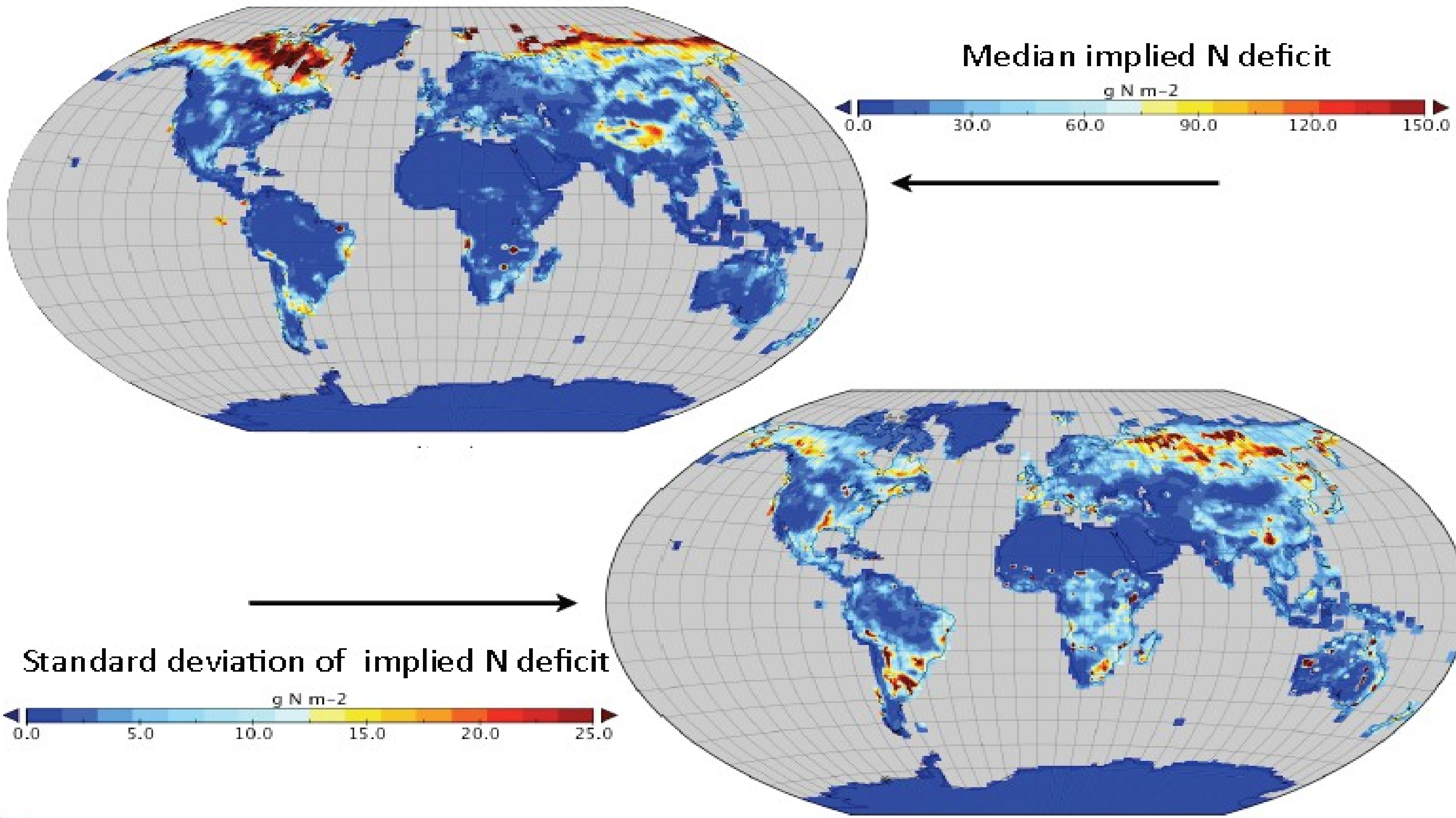


Mixed sign (mainly negative – reduced carbon uptake)

- Land stronger than ocean
- Stronger over forests
- Large spread – high-latitudes disagree on sign
- Evaluation data?

Response to Nitrogen

Spatial pattern of implied N deficit* (HadGEM2-ES, RCP8.5, 2100)



*Obtained from 16 estimates with varying N deposition, biol. fixation, C:N ratios and background N availability

Role of model evaluation

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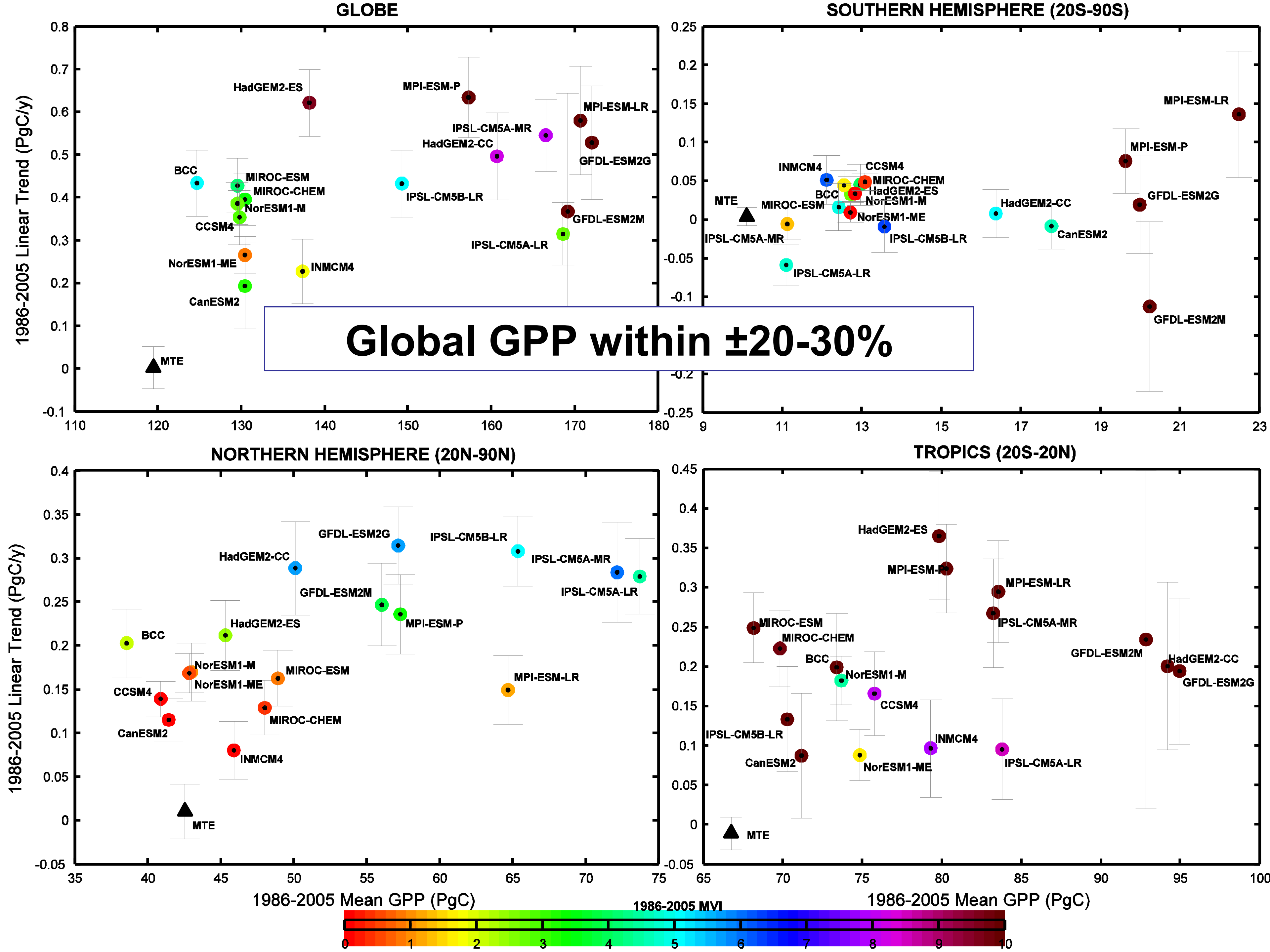
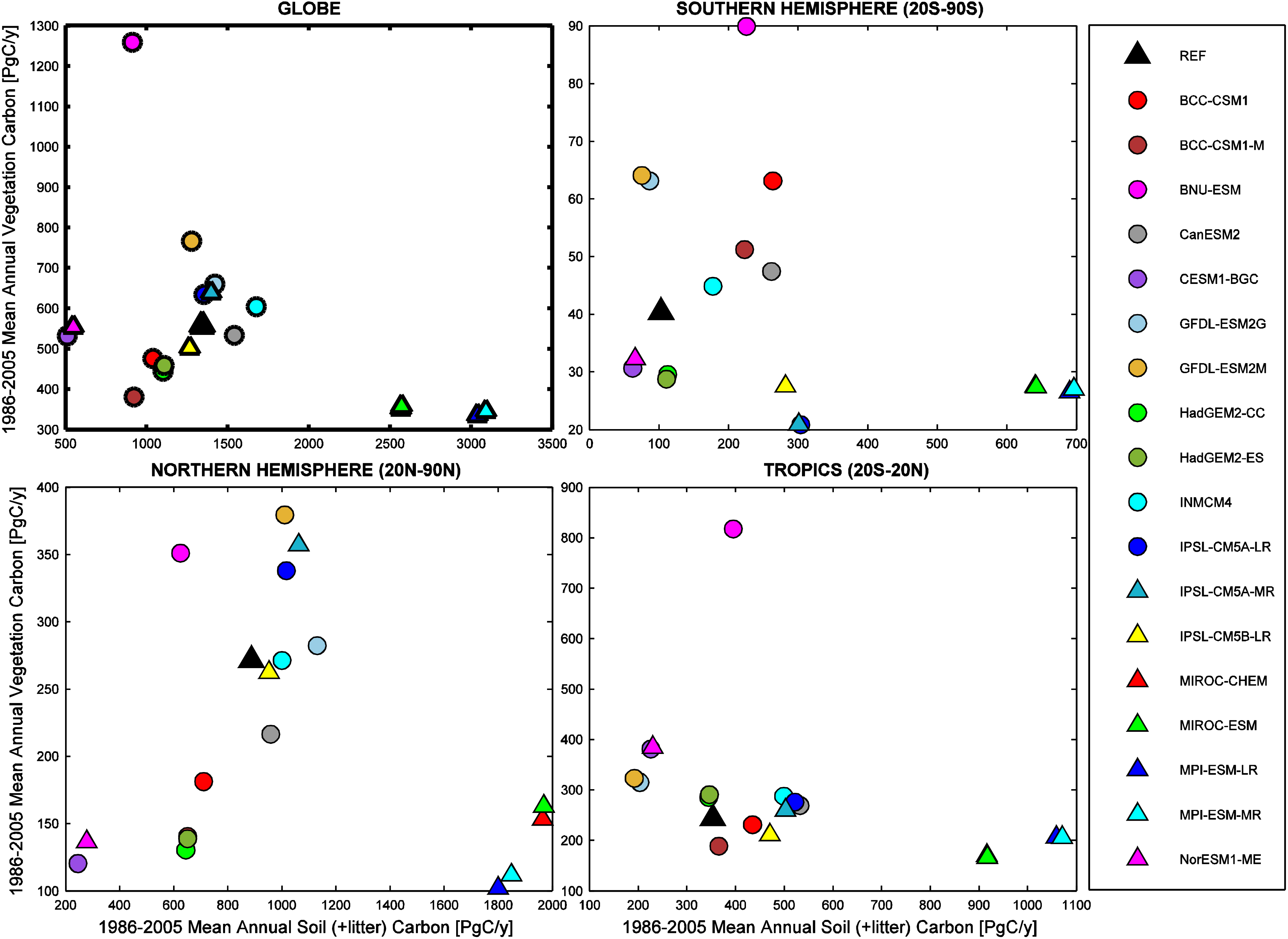
Hadley Centre

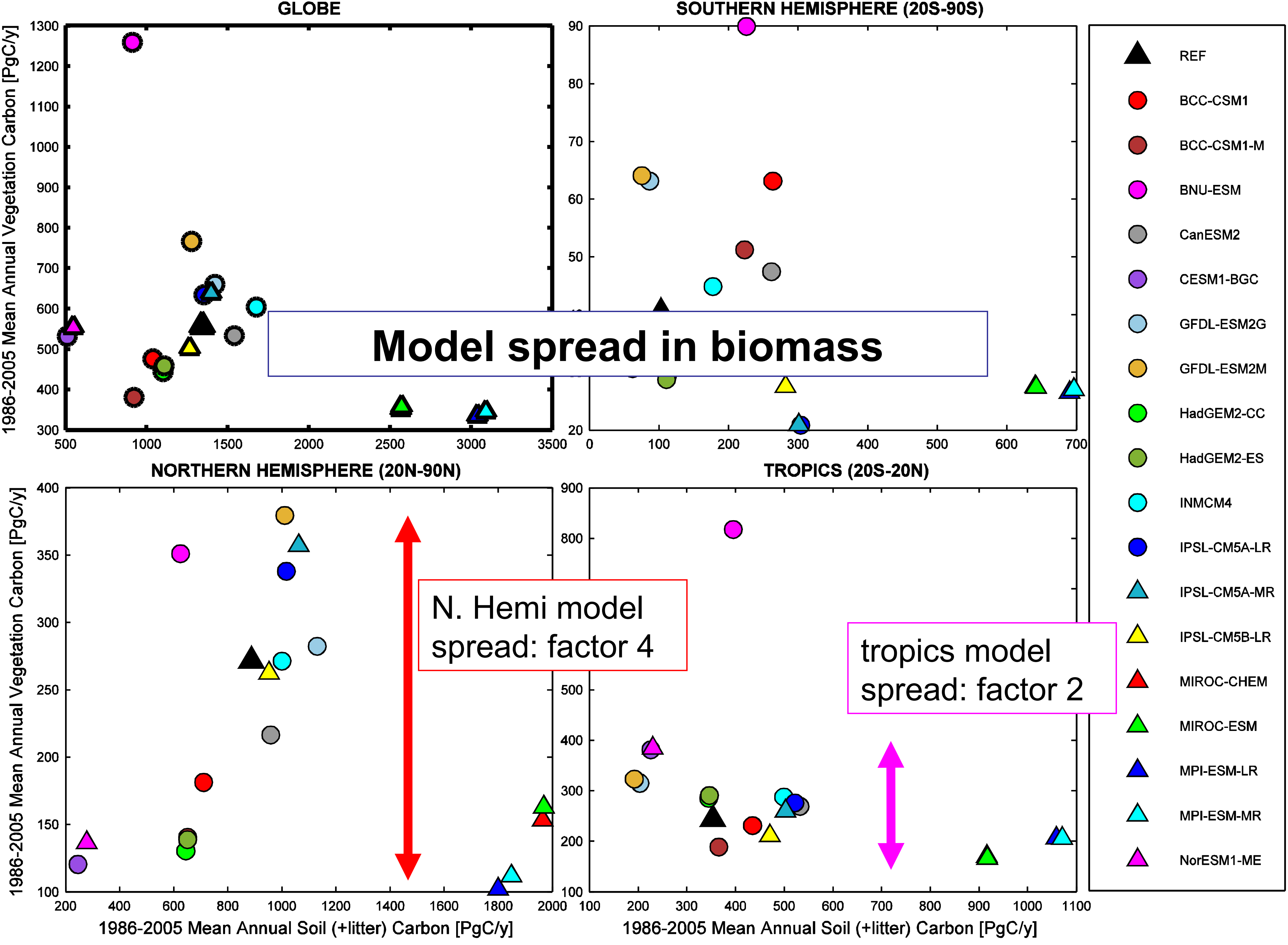
Evaluation becoming more important as models become more complex

- Need to evaluate stores and fluxes of carbon
- Lots of activity on former...
- ...but little on latter
  - Which is ultimately what we want to know
  - This is where models have huge spread/uncertainty
- Also need to evaluate dynamical response
  - Not just stationary state


GLOBE
SOUTHERN HEMISPHERE (20S-90S)
NORTHERN HEMISPHERE (20N-90N)
TROPICS (20S-20N)
1986-2005 Linear Trend (PgC/y)
1986-2005 Mean GPP (PgC)
Global GPP within ±20-30%
1986-2005 MVI
MTE
BCC
CCSM4
CanESM2
GFDL-ESM2G
GFDL-ESM2M
HadGEM2-CC
HadGEM2-ES
INMCM4
IPSL-CM5A-LR
IPSL-CM5A-MR
IPSL-CM5B-LR
MIROC-CHEM
MIROC-ESM
MPI-ESM-LR
MPI-ESM-P
NorESM1-M
NorESM1-ME



GLOBE
SOUTHERN HEMISPHERE (20S-90S)
NORTHERN HEMISPHERE (20N-90N)
TROPICS (20S-20N)
1986-2005 Mean Annual Vegetation Carbon [PgC/y]
1986-2005 Mean Annual Soil (+litter) Carbon [PgC/y]
REF
BCC-CSM1
BCC-CSM1-M
BNU-ESM
CanESM2
CESM1-BGC
GFDL-ESM2G
GFDL-ESM2M
HadGEM2-CC
HadGEM2-ES
INMCM4
IPSL-CM5A-LR
IPSL-CM5A-MR
IPSL-CM5B-LR
MIROC-CHEM
MIROC-ESM
MPI-ESM-LR
MPI-ESM-MR
NorESM1-ME



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SOUTHERN HEMISPHERE (20S-90S)
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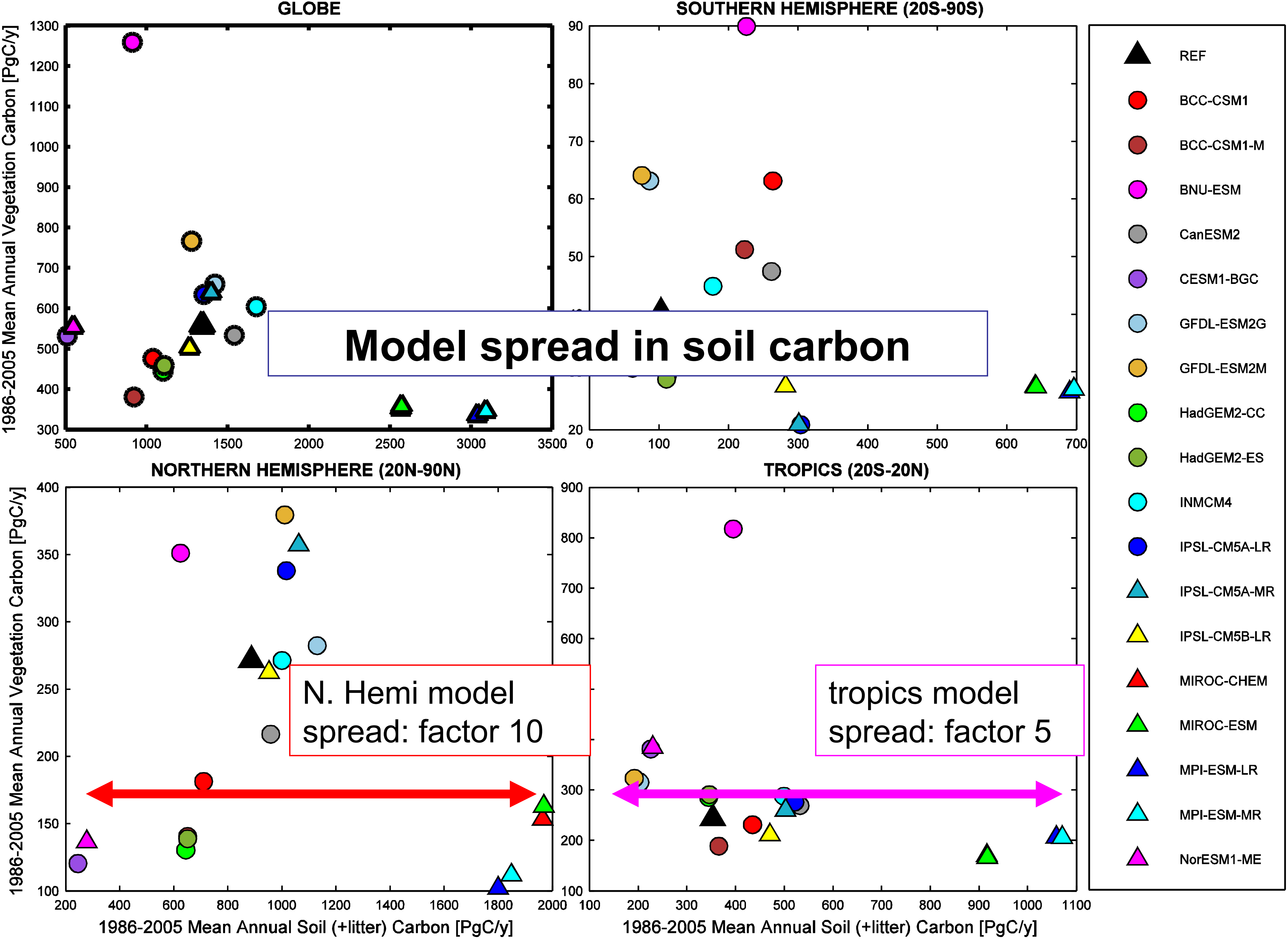
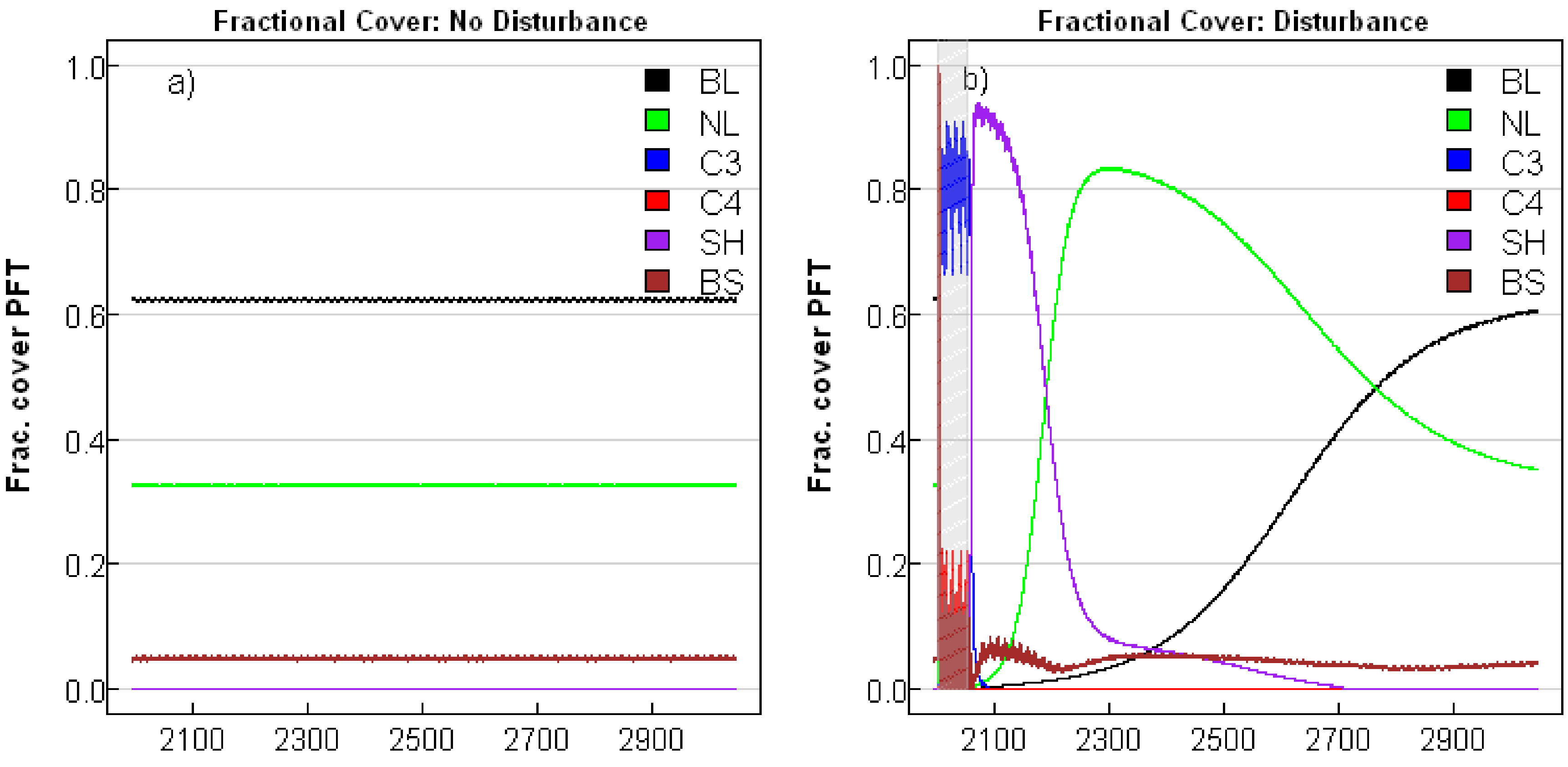
TROPICS (20S-20N)
1986-2005 Mean Annual Vegetation Carbon [PgC/y]
1986-2005 Mean Annual Soil (+litter) Carbon [PgC/y]
Model spread in biomass
N. Hemi model spread: factor 4
tropics model spread: factor 2
REF
BCC-CSM1
BCC-CSM1-M
BNU-ESM
CanESM2
CESM1-BGC
GFDL-ESM2G
GFDL-ESM2M
HadGEM2-CC
HadGEM2-ES
INMCM4
IPSL-CM5A-LR
IPSL-CM5A-MR
IPSL-CM5B-LR
MIROC-CHEM
MIROC-ESM
MPI-ESM-LR
MPI-ESM-MR
NorESM1-ME

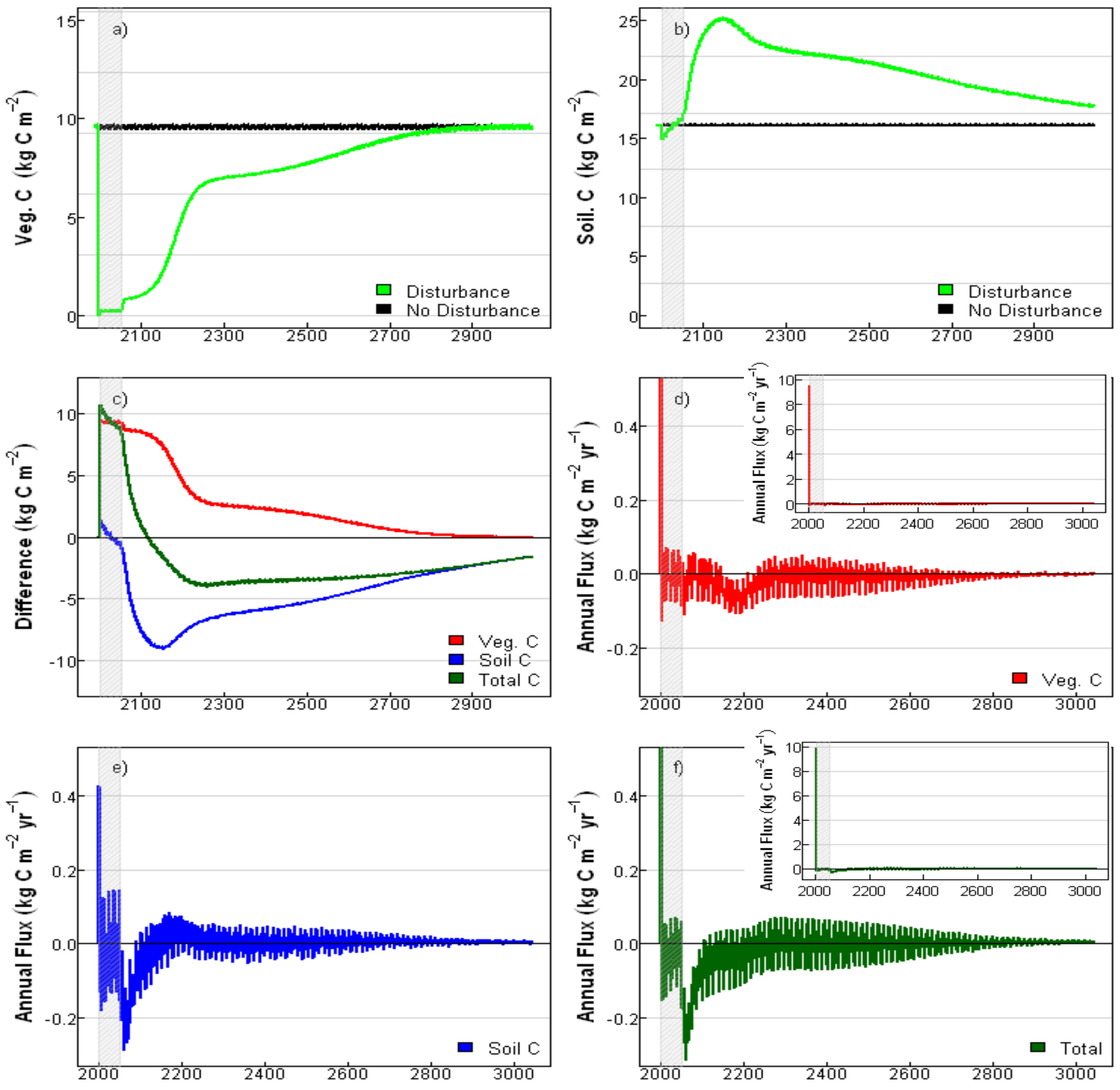


GLOBE
SOUTHERN HEMISPHERE (20S-90S)
NORTHERN HEMISPHERE (20N-90N)
TROPICS (20S-20N)
1986-2005 Mean Annual Vegetation Carbon [PgC/y]
1986-2005 Mean Annual Soil (+litter) Carbon [PgC/y]
Model spread in soil carbon
N. Hemi model spread: factor 10
tropics model spread: factor 5
REF
BCC-CSM1
BCC-CSM1-M
BNU-ESM
CanESM2
CESM1-BGC
GFDL-ESM2G
GFDL-ESM2M
HadGEM2-CC
HadGEM2-ES
INMCM4
IPSL-CM5A-LR
IPSL-CM5A-MR
IPSL-CM5B-LR
MIROC-CHEM
MIROC-ESM
MPI-ESM-LR
MPI-ESM-MR
NorESM1-ME

Idealised disturbance/recovery in JULES – vegetation succession dynamics



And hence carbon fluxes



Compare with Houghton

	Harvard*		Hyytiala**		Manaus***	
	JULES	Houghton	JULES	Houghton	JULES	Houghton
C in undisturbed veg. (Mg C/ha)	95.71	135.00	84.30	90.00	61.59	200.00
C in crops (Mg C/ha)	2.22	5.00	2.07	5.00	4.04	5.00
C in undisturbed soil (Mg C/ha)	161.00	134.00	233.69	206.00	53.16	98.00
Minimum soil C (Mg C/ha)	148.75	101.00	216.77	155.00	45.97	74.00
Recovery time vegetation (years)	749	50	950	50	+954	40
Time to min. soil C (years)	5	30	6	50	2	20
Recovery time soil from min. (years)	+1039	40	+994	35	+1002	40

Key difference is in recovery times

Evaluation requirements

- Dataset development of fluxes
  - Site level, gridded
- Stores
  - Biomass and soil carbon
- Transient changes and sensitivities
  - Recovery from disturbance
  - FACE, manipulation experiments
- Innovative use of obs/models
  - More than just beauty-contest comparisons

Conclusions

Land surface models are key to future projections of carbon storage and emissions to meet targets

- Forests are key aspect
  - Managed and natural
  - Tropical, temperate, boreal
- Large model spread
  - Need to improve existing processes
  - Missing processes too – N, fire, PFTs/dynamics
- Much better evaluation required
  - Beyond fluxes – focus on stores required
  - Importance of successional dynamics