Disturbance, mortality and turnover in global vegetation modelling

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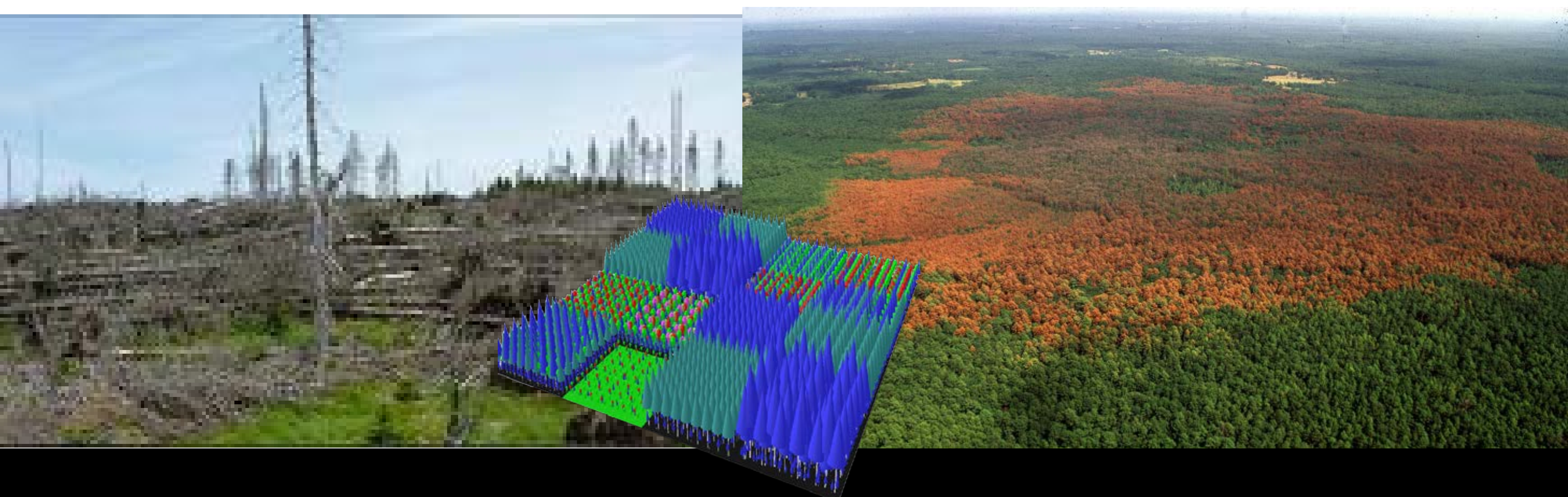
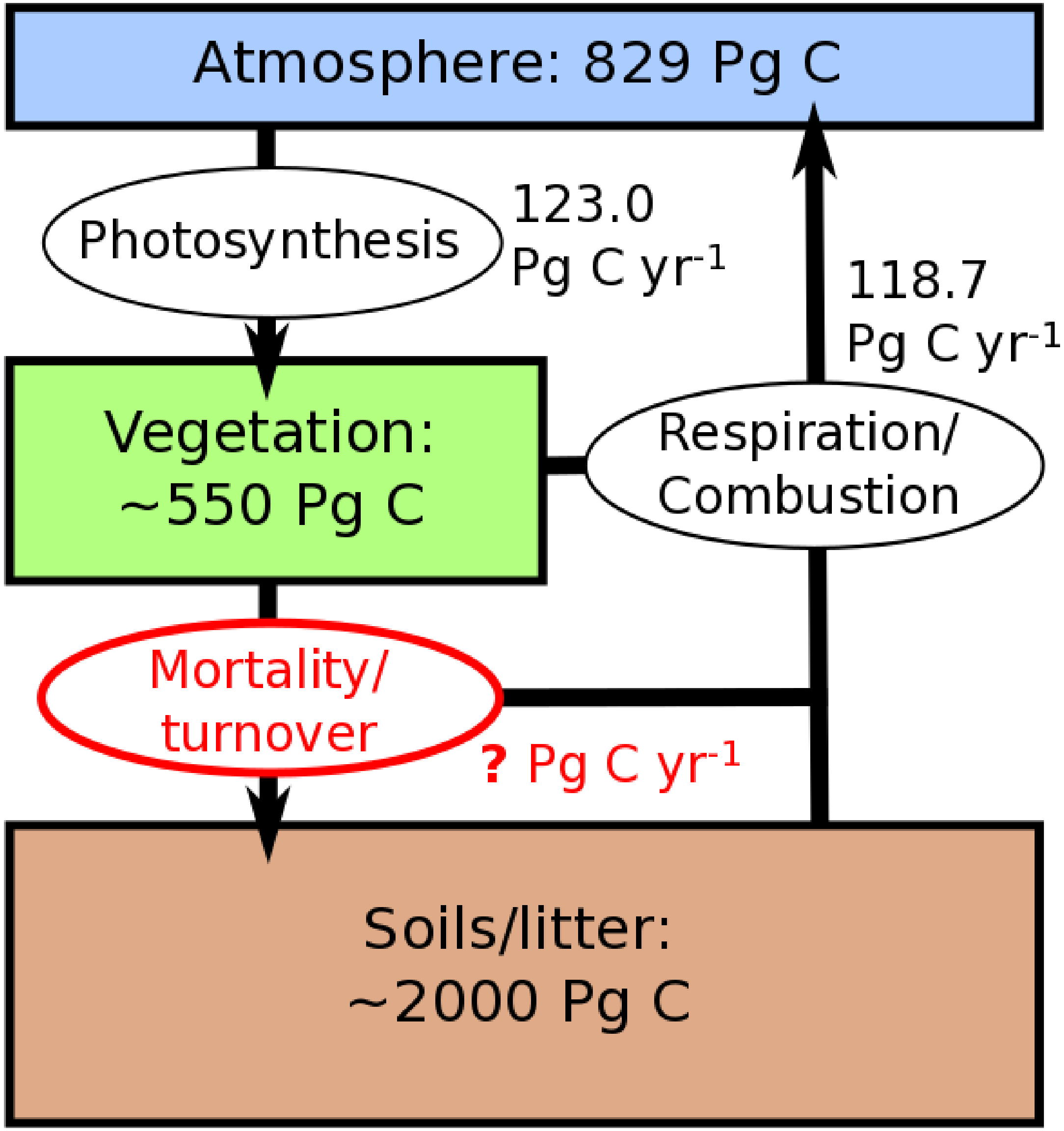


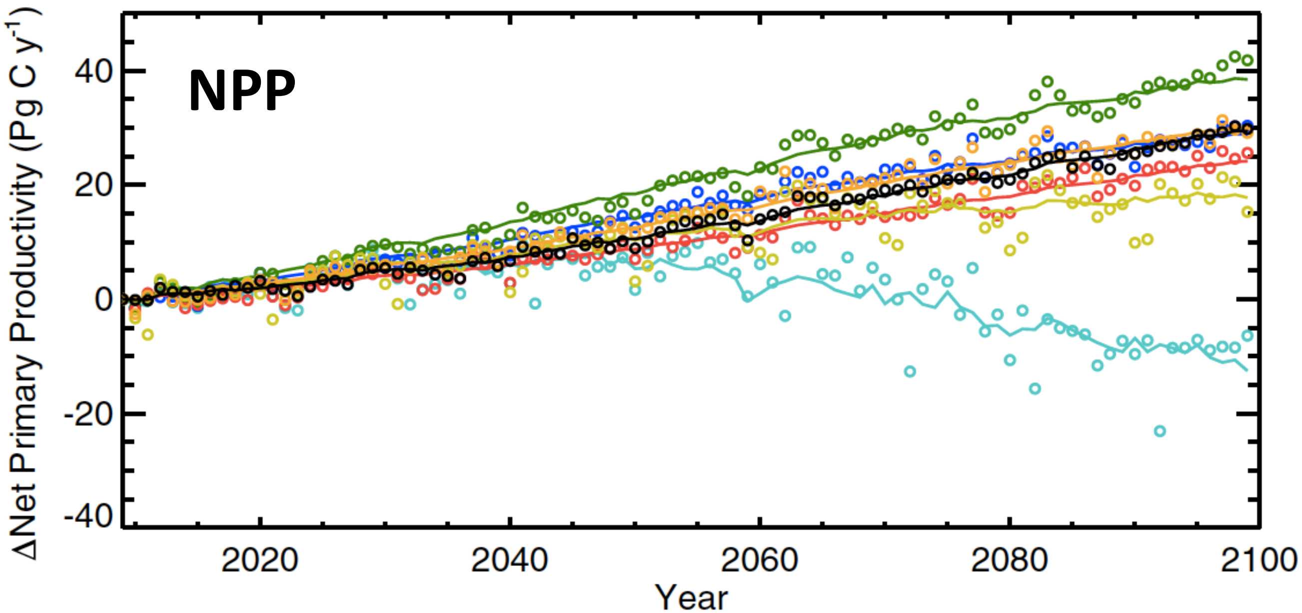
Drivers of carbon storage change



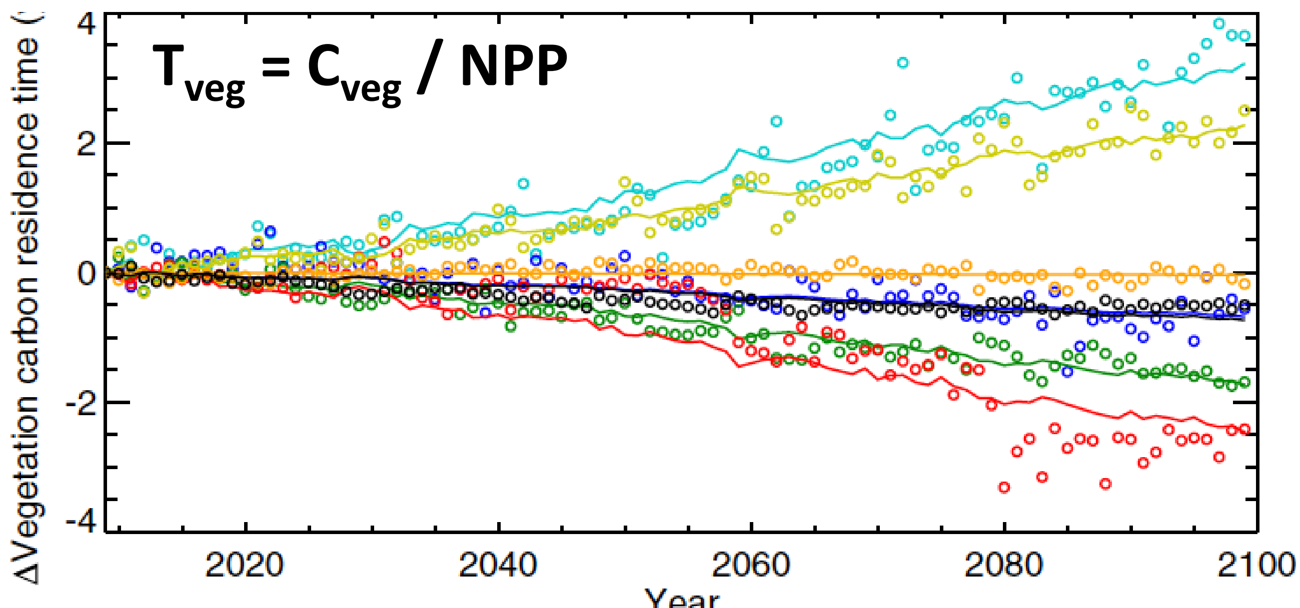
Changes in vegetation turnover rate fundamentally change the carbon storage capacity of ecosystems

Numbers, Ciais et al. (2013)

Drivers of carbon storage change



Huge uncertainty remains how CO_2 will affect vegetation productivity and carbon storage



But mortality and other turnover processes are the main unknown behind future vegetation carbon storage projections

Friend et al. (2014)

Drivers of carbon storage change

What are the drivers of carbon turnover in vegetation?

Leaf and root senescence (phenology)

Plant mortality (intrinsic)

Drought
Pathogens
Competition
Other env. stresses

Disturbance (extrinsic mortality)

Fire
Wind-throw
Insect outbreak
Logging

Very poor understanding of global picture of these fluxes.

Part 1: Modelling forest disturbances

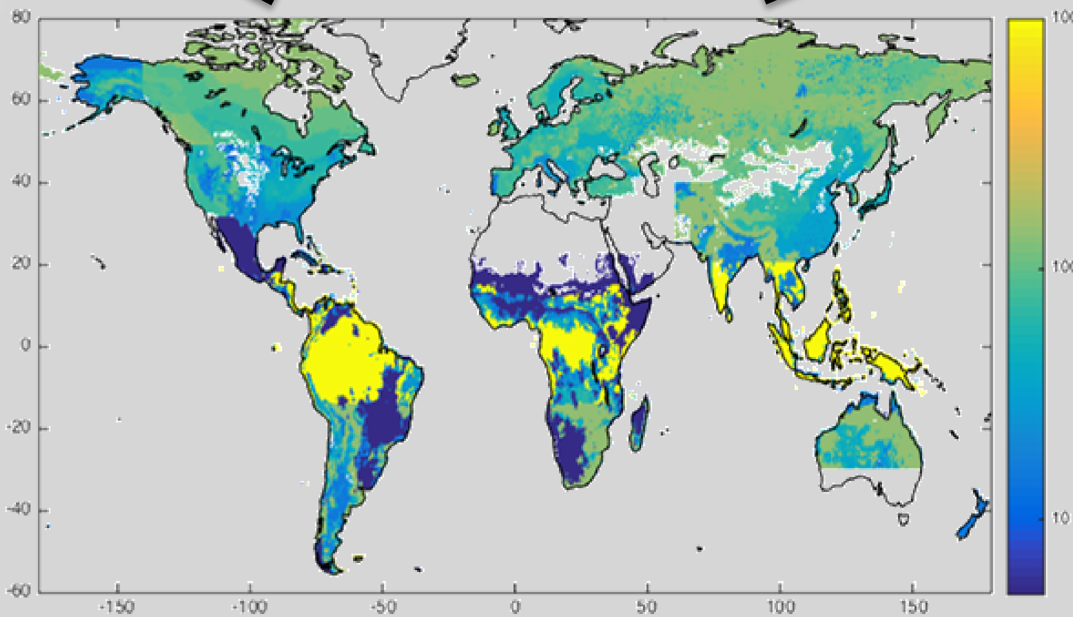
Part 2: Turnover in ecosystem models

Forest disturbance

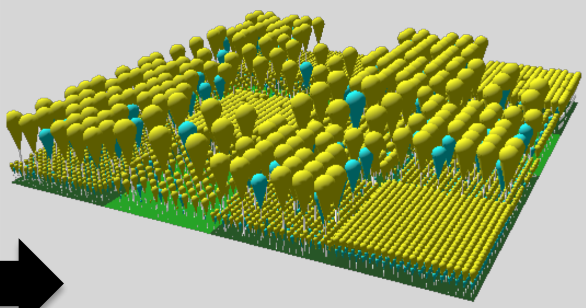
Global forest stand age dataset based on inventories (Poulter et al., in prep.)

Satellite data of forest loss at 30m resolution (Hansen et al., 2013)

Influence of disturbance (*l* ≥ 30 m) on global carbon storage not known



Global forest disturbance return time



LPJ-GUESS Dynamic Global Vegetation Model

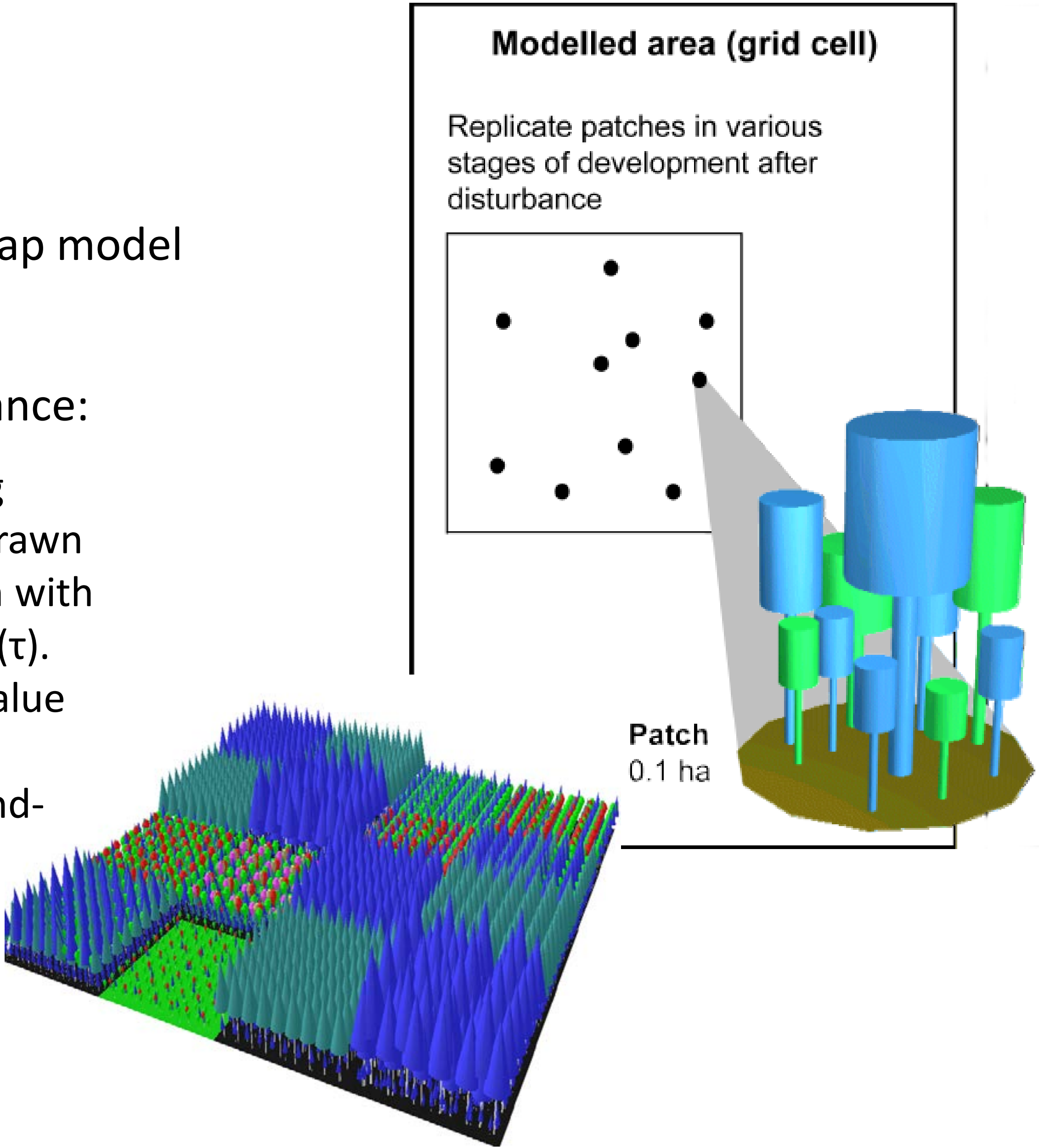
LPJ-GUESS introduction

Key model features

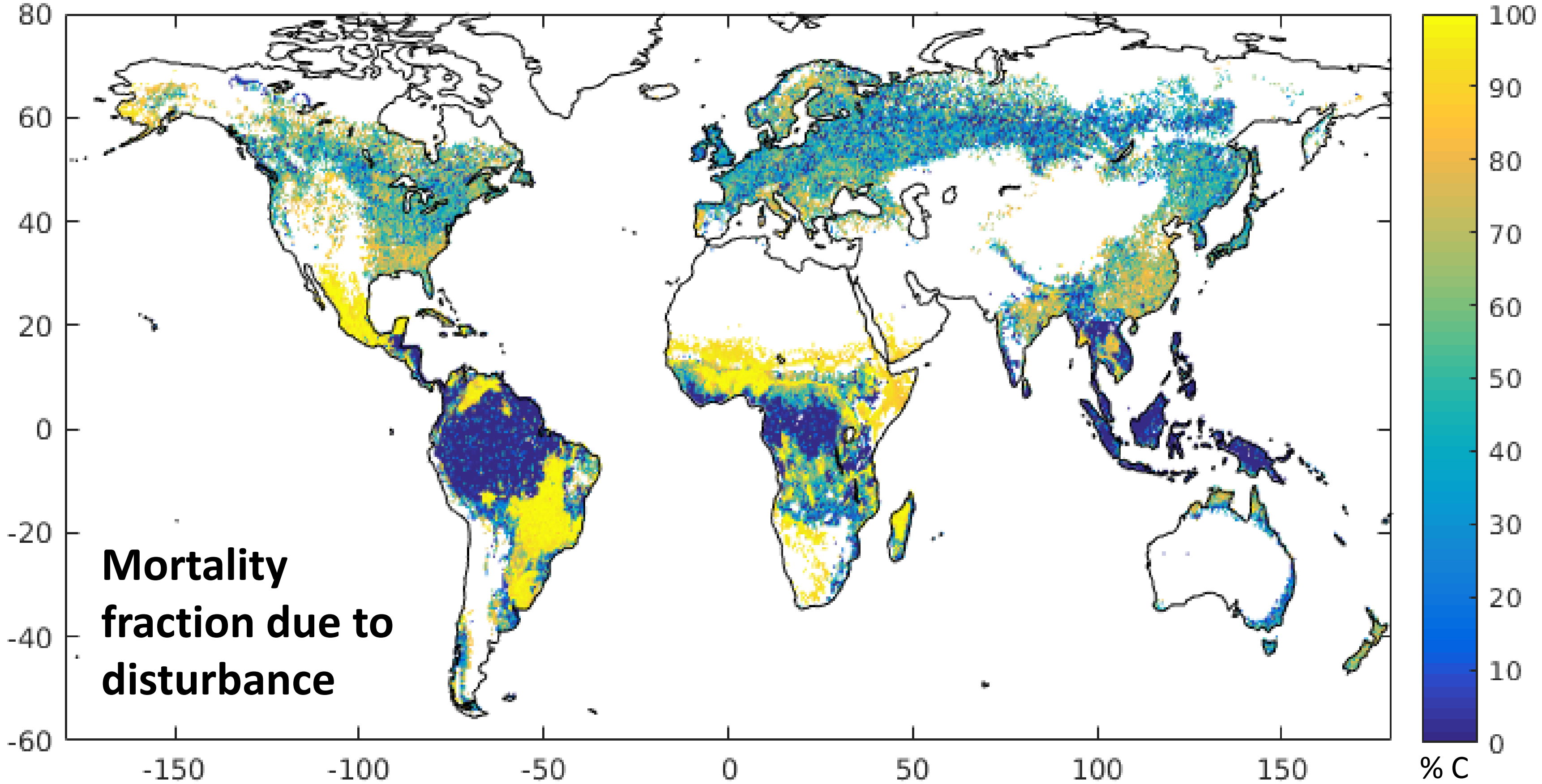
- Age-structured vegetation
- Cohort-based mortality
- Forest dynamics based on gap model
- C-N interactions

Stochastic background disturbance:

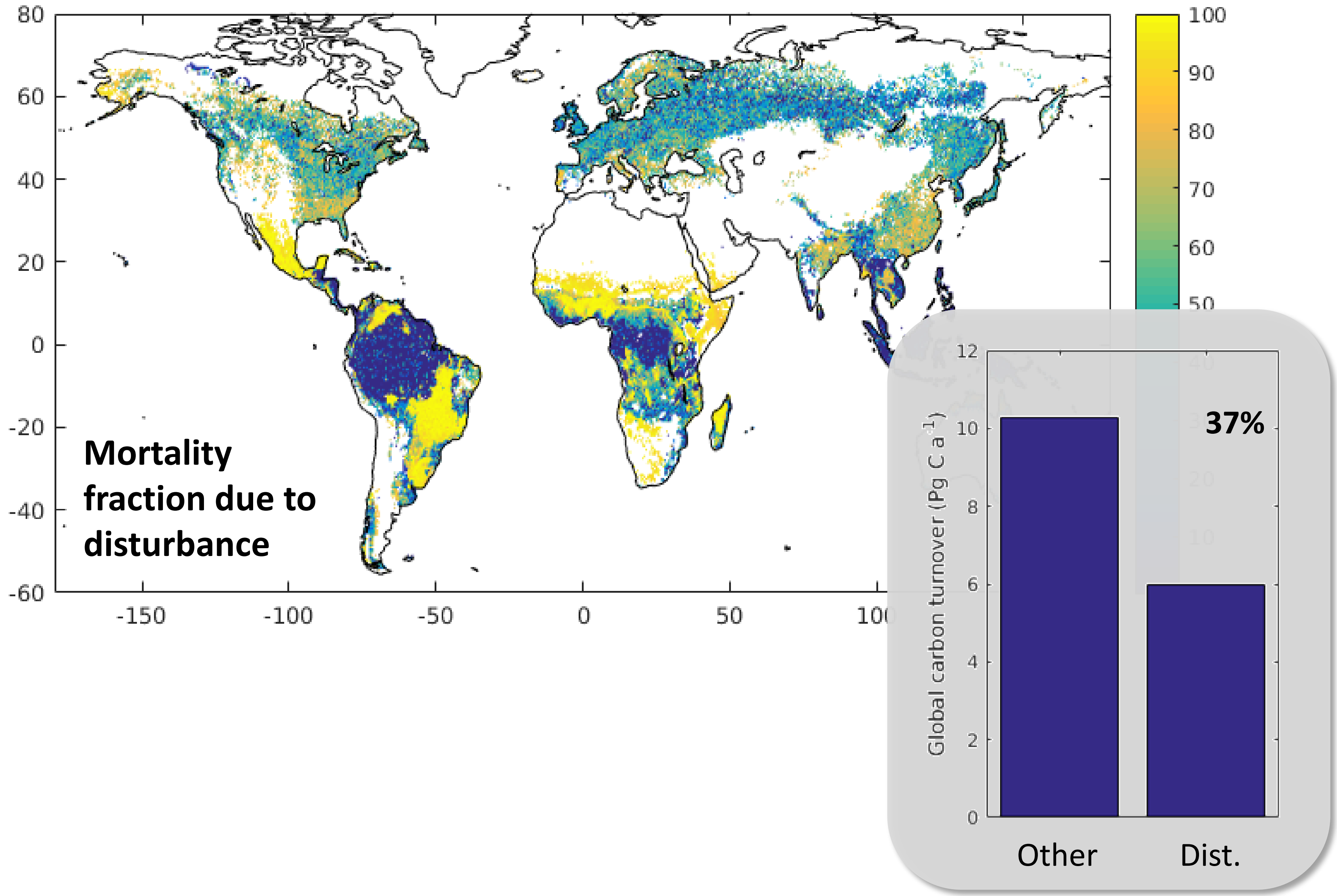
- Likelihood of stand-destroying disturbance in any one year drawn from a probability distribution with a characteristic return period (τ).
- 100 years is standard global value for LPJ-GUESS.
- Intended to represent e.g. wind-throw, insect attack, logging.



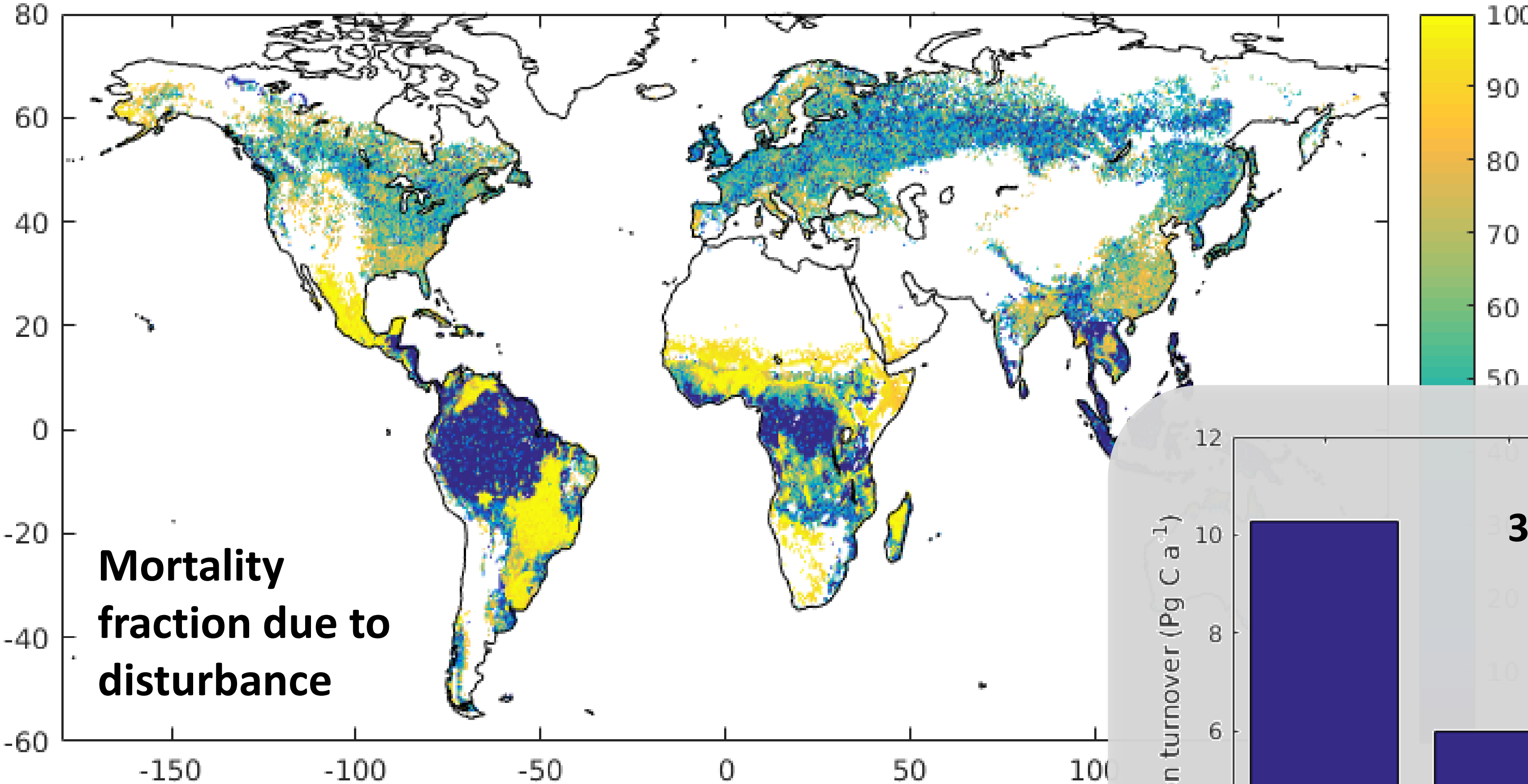
Forest disturbance

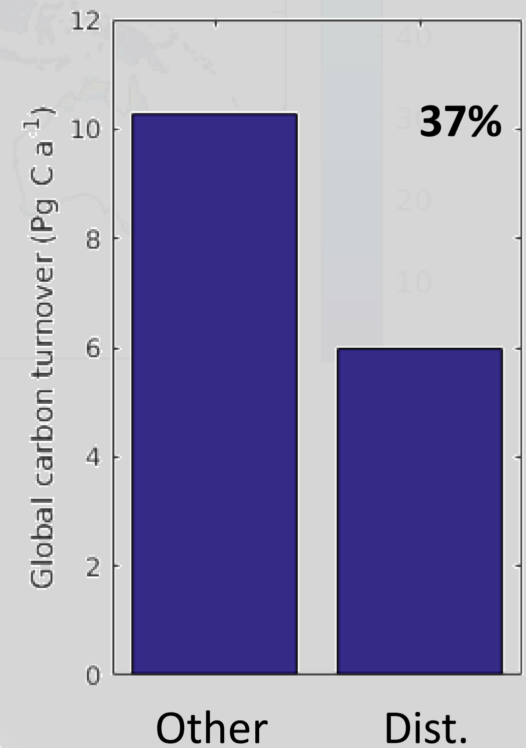


Forest disturbance



Forest disturbance

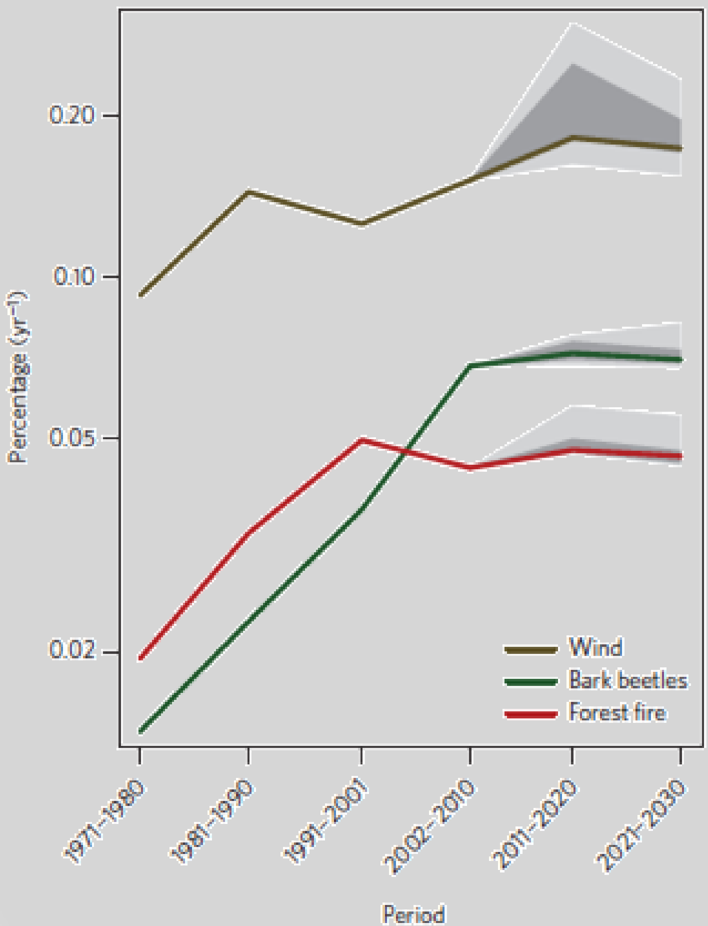




1/3 of forest vegetation carbon loss due to disturbance.

Forest disturbance

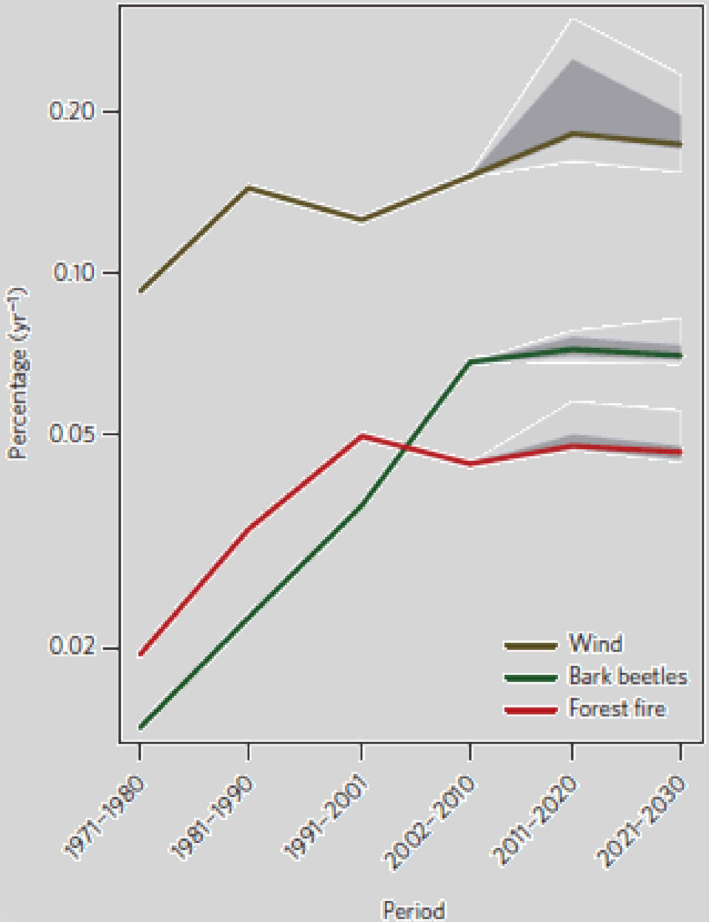
But disturbances have distinct drivers and rates are increasing in at least some regions



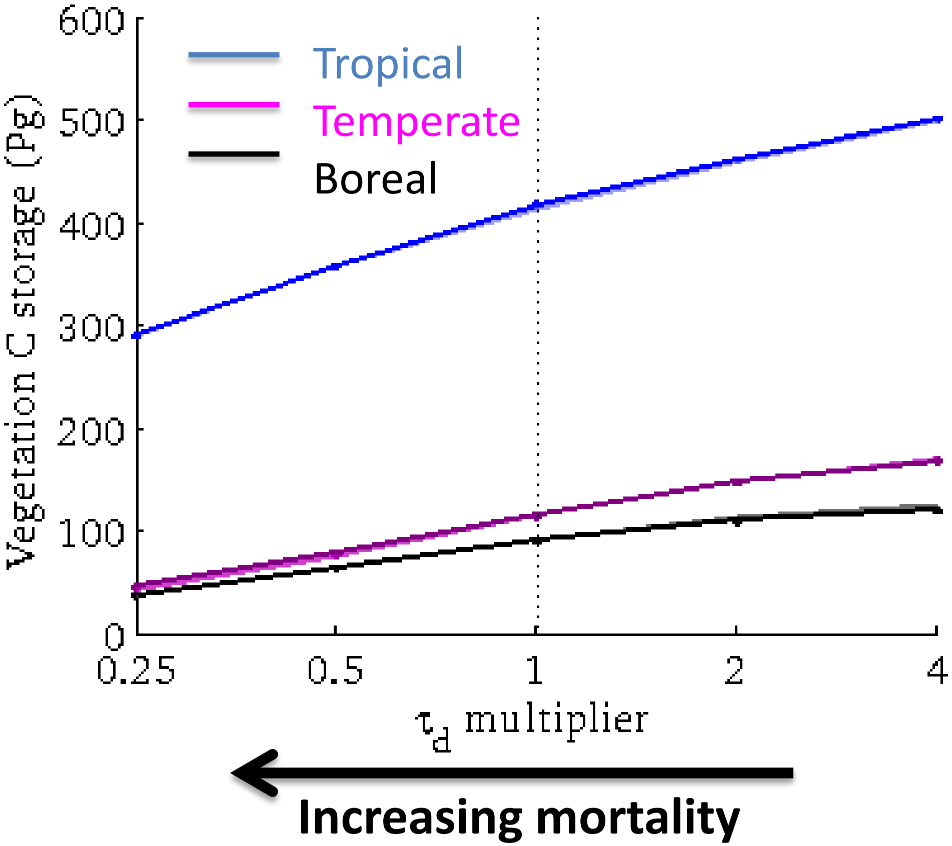
Seidl et al. (2014)

Forest disturbance

But disturbances have distinct drivers and rates are increasing in at least some regions

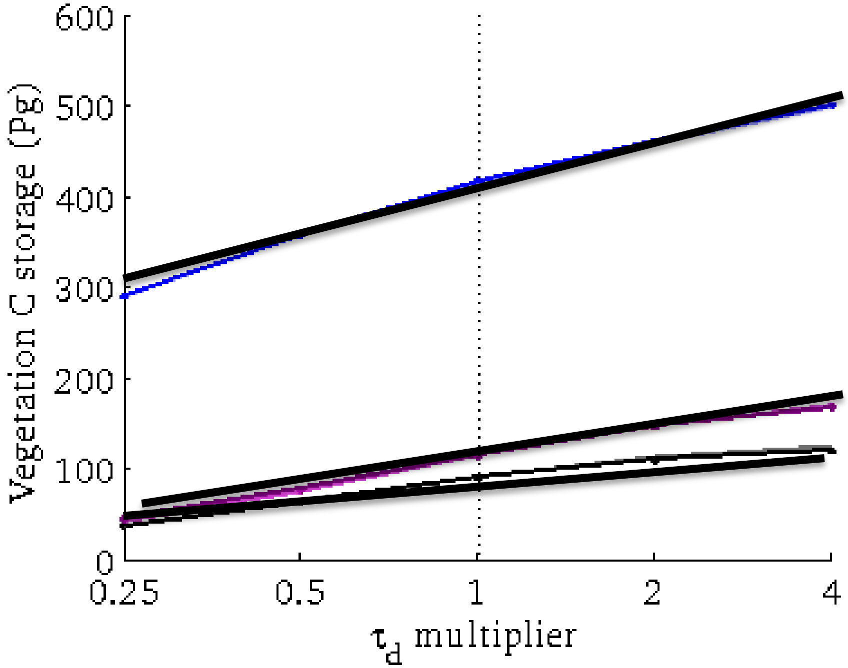


Seidl et al. (2014)



Global doubling of disturbance **releases ca. 160 Pg C** (75 ppmv CO_2)
15 years of current anthro. emissions

Effect of changing disturbance rate: Carbon storage



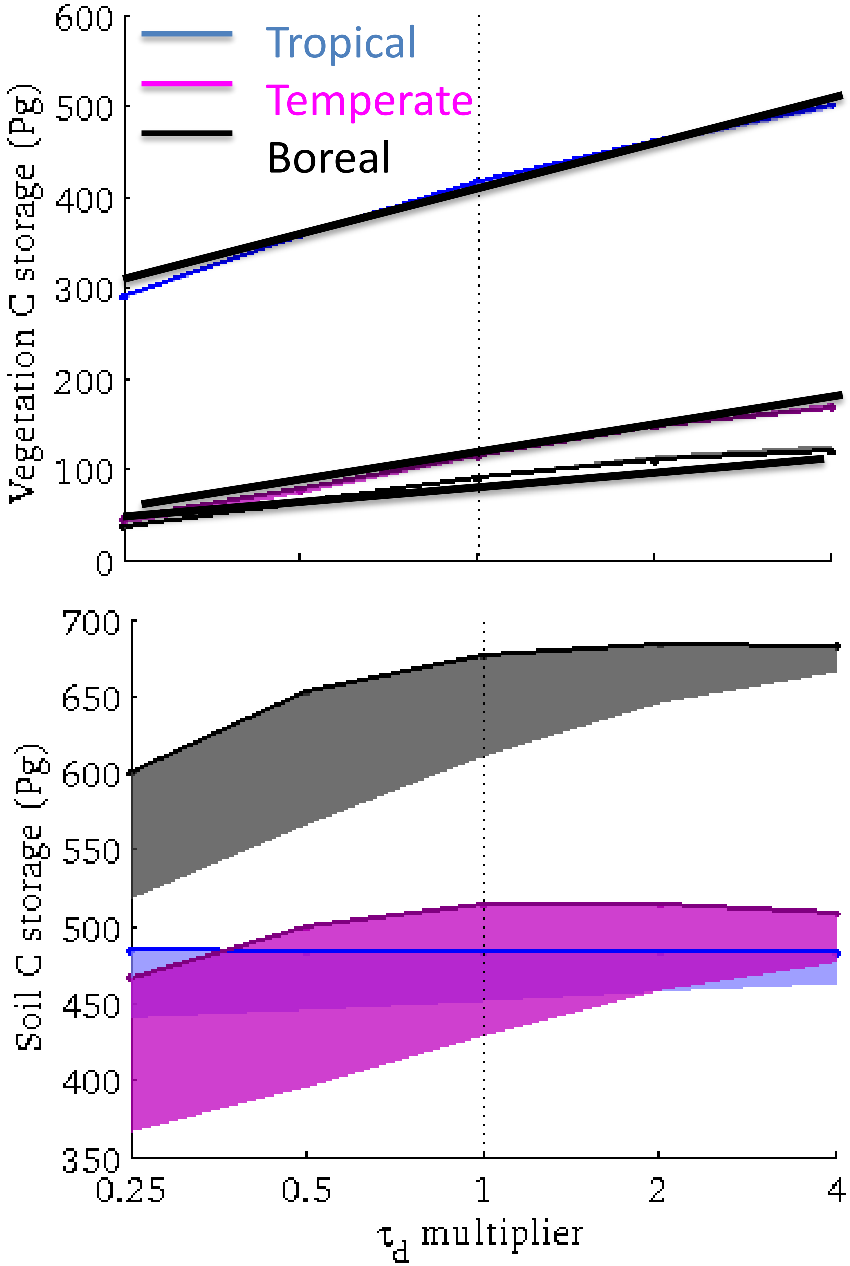
Effect on vegetation carbon is quasi log-linear

Whatever the actual disturbance rate, changes in τ have large effects on C storage

Not strongly sensitive to N feedbacks from soil

Figures, Pugh et al. (in prep.)

Effect of changing disturbance rate: Carbon storage



Effect on vegetation carbon is quasi log-linear

Whatever the actual disturbance rate, changes in τ have large effects on C storage

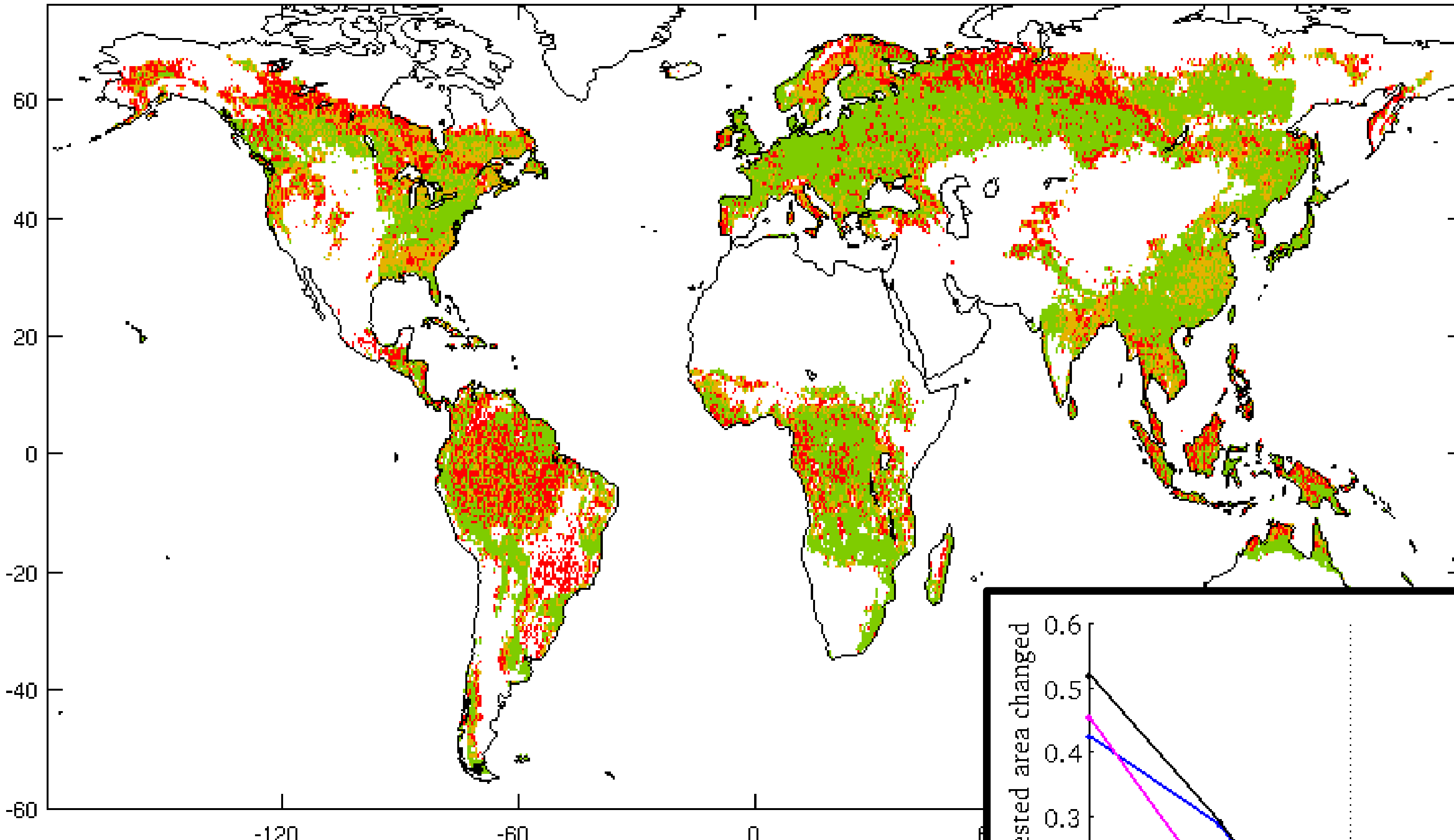
Not strongly sensitive to N feedbacks from soil

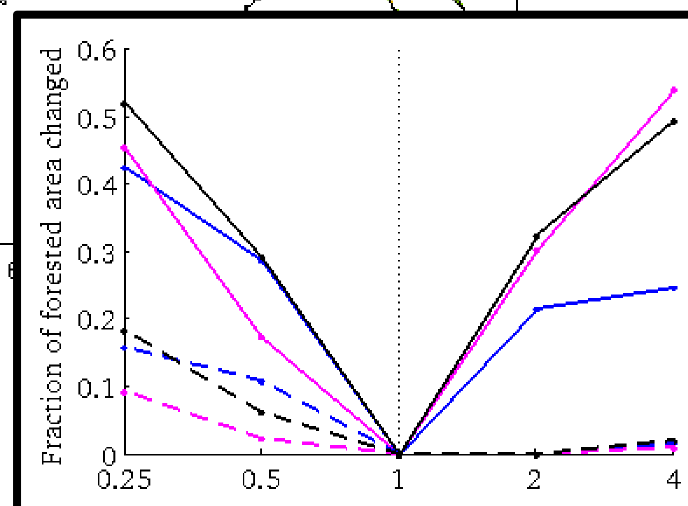
Soil C is a large contributor at high latitudes, and with large uncertainties based on vegetation biomass fate.

Figures, Pugh et al. (in prep.)

Effect of changing disturbance rate: Forest composition

Disturbance-induced changes in dominant plant type





= Grid-cells containing forest

= Dominant PFT changes with 2x disturbance rate

= Dominant PFT changes with 4x disturbance rate

Figures, Pugh et al. (in prep.)

Forest disturbance: Take-home messages

Disturbance accounts for a large portion of global vegetation turnover

Disturbances are crucial drivers of ecosystem composition

Disturbance rate changes have a large impact on carbon storage

Important because drivers of disturbance differ from other forms of mortality

Part 1: Modelling forest disturbances

Part 2: Turnover in ecosystem models



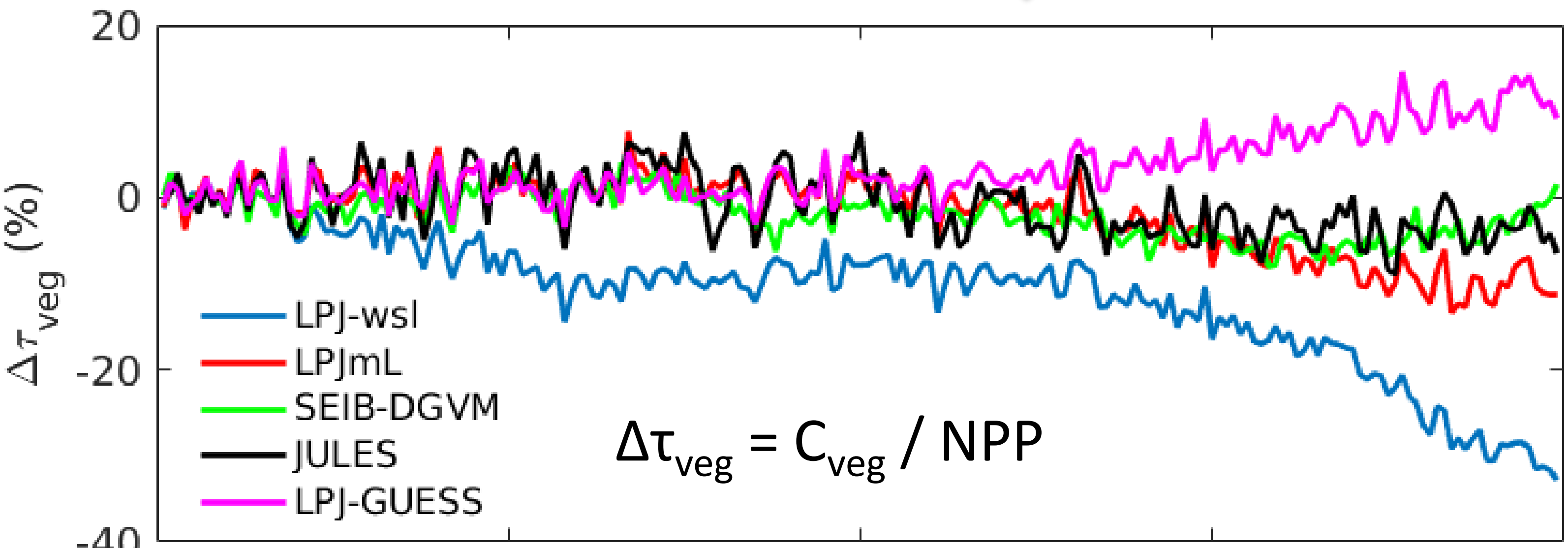
Turnover inter-comparison: First results

Aim: To understand the differences in vegetation turnover between global ecosystem models, and evaluate where possible

PRELIMINARY!

7 models:
JULES, SEIB-DGVM, LPJ-GUESS, LPJmL, LPJ-wsl, CABLE-POP, ORCHIDEE

Similar wide spread of turnover time change as in Friend et al. (2014)



$\Delta\tau_{veg} = C_{veg} / NPP$

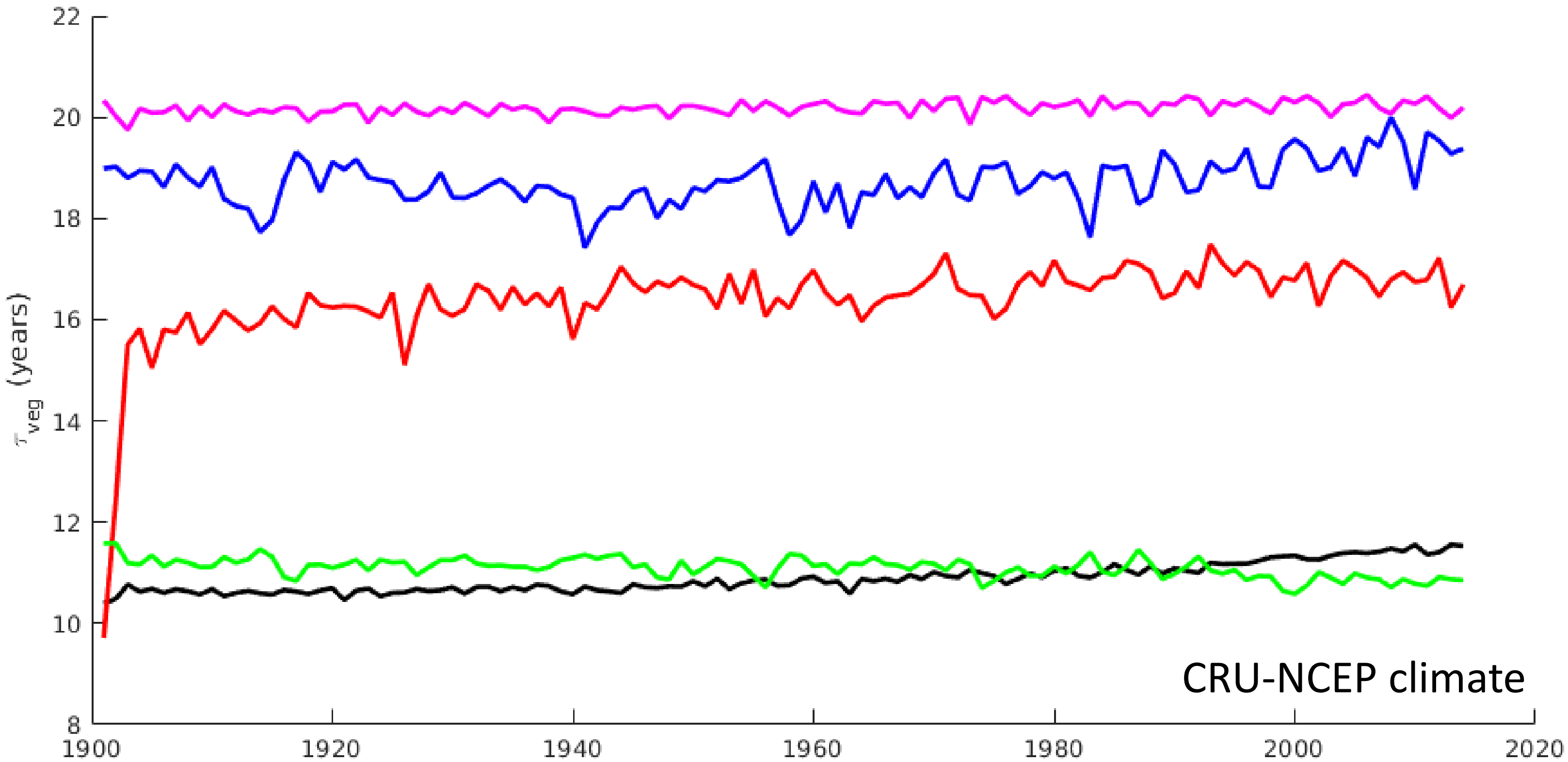
IPSL climate, RCP 8.5

Turnover inter-comparison: First results

$T_{veg} = C_{veg} / F_{all}$

F_{all} is total turnover flux from vegetation

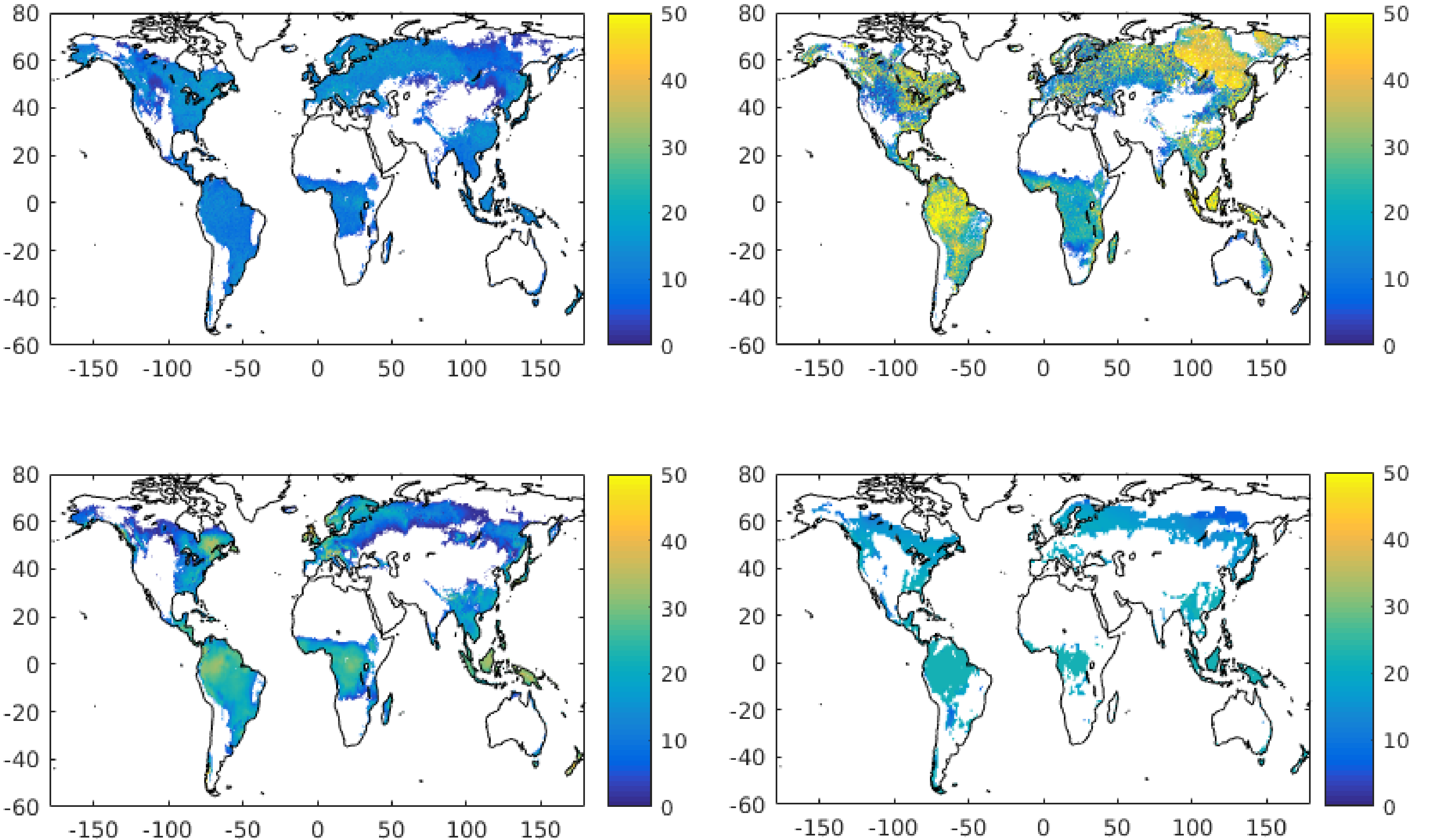
Global mean, across forest vegetation



Absolute turnover times of forest vegetation vary by a factor of two

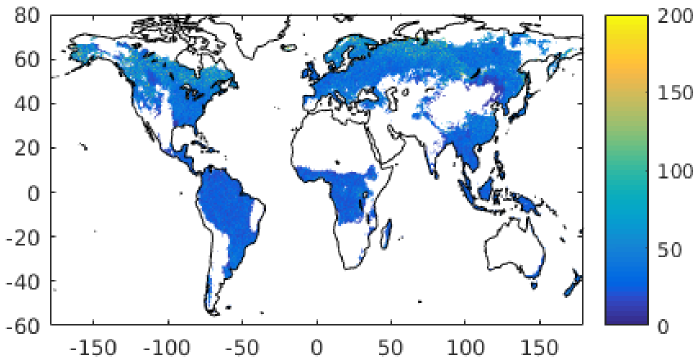
Turnover inter-comparison: First results

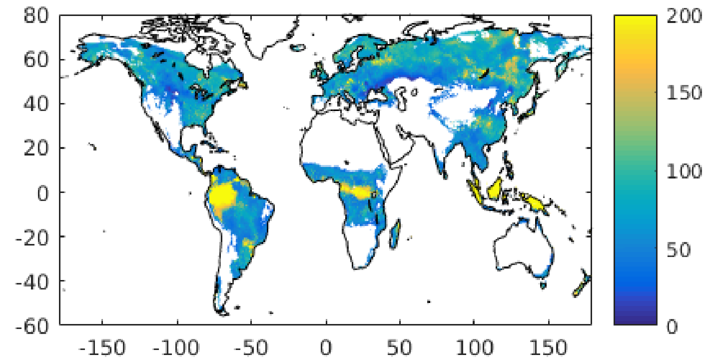
$$\mathbf{T_{veg} = C_{veg} / F_{all}}$$

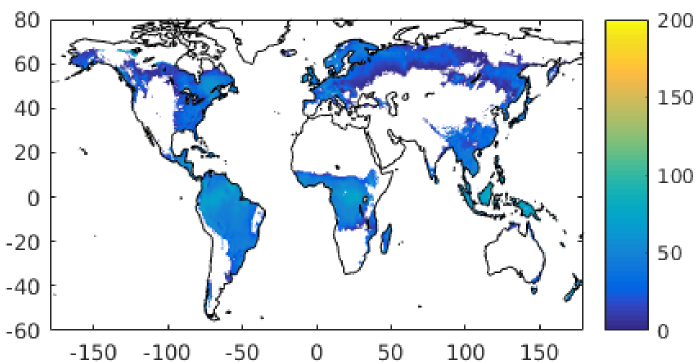


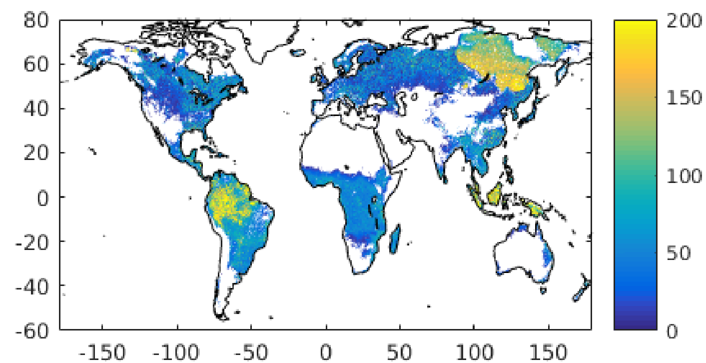
Also no model consensus on τ_{veg} patterns

Turnover inter-comparison: First results



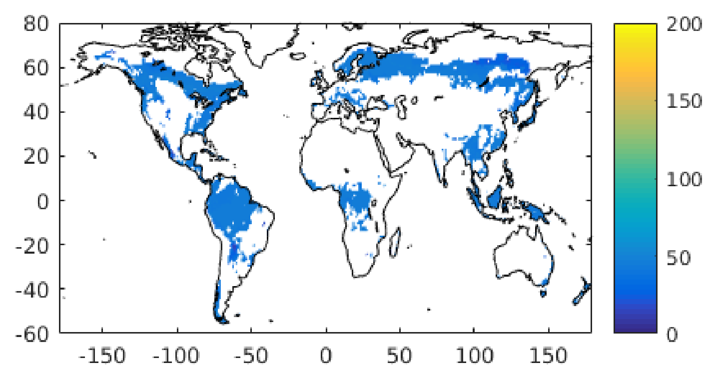






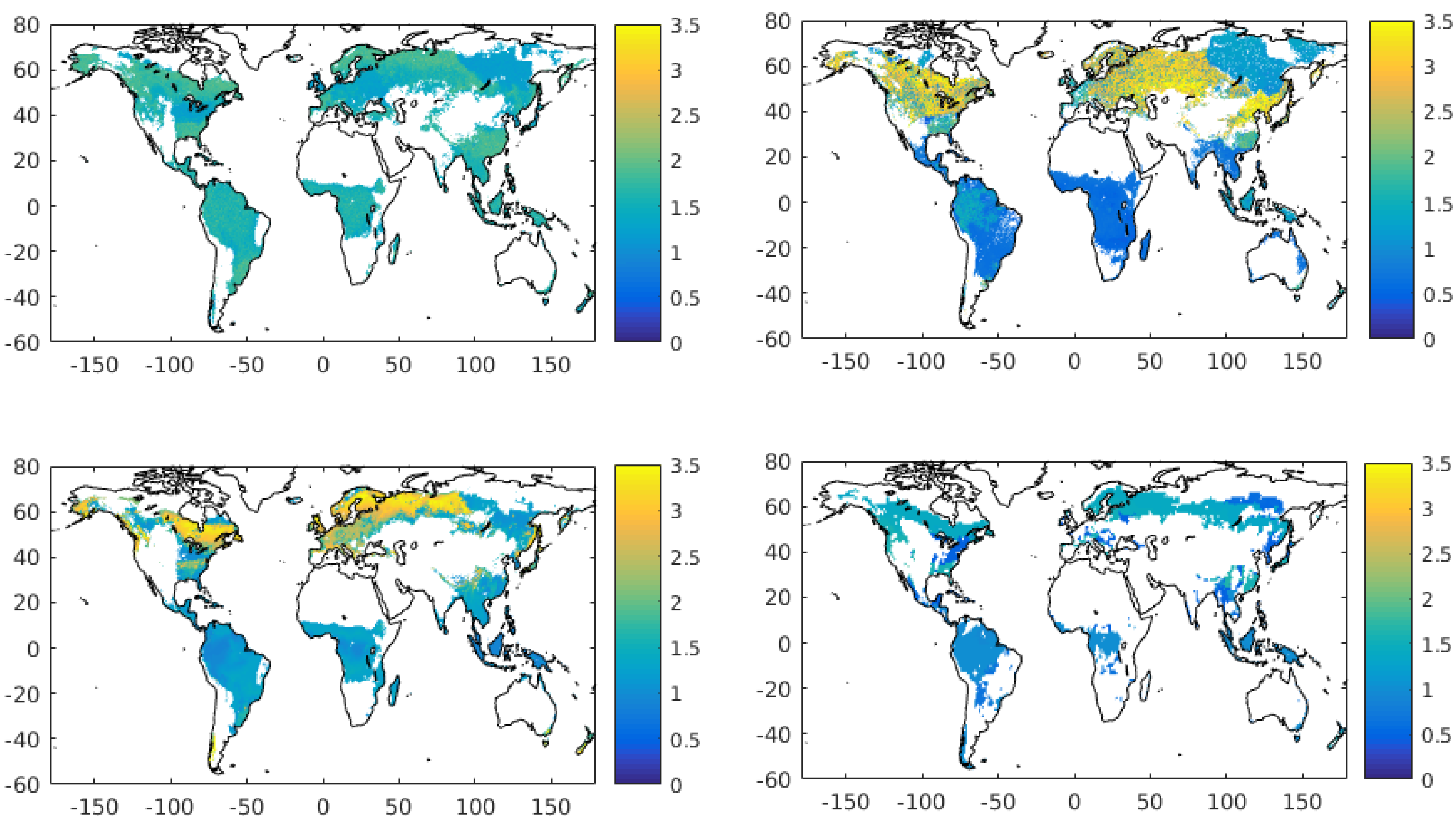
$$T_{veg,mort} = C_{wood} / F_{mort}$$

Differences in mortality rates area strong driver of model differences



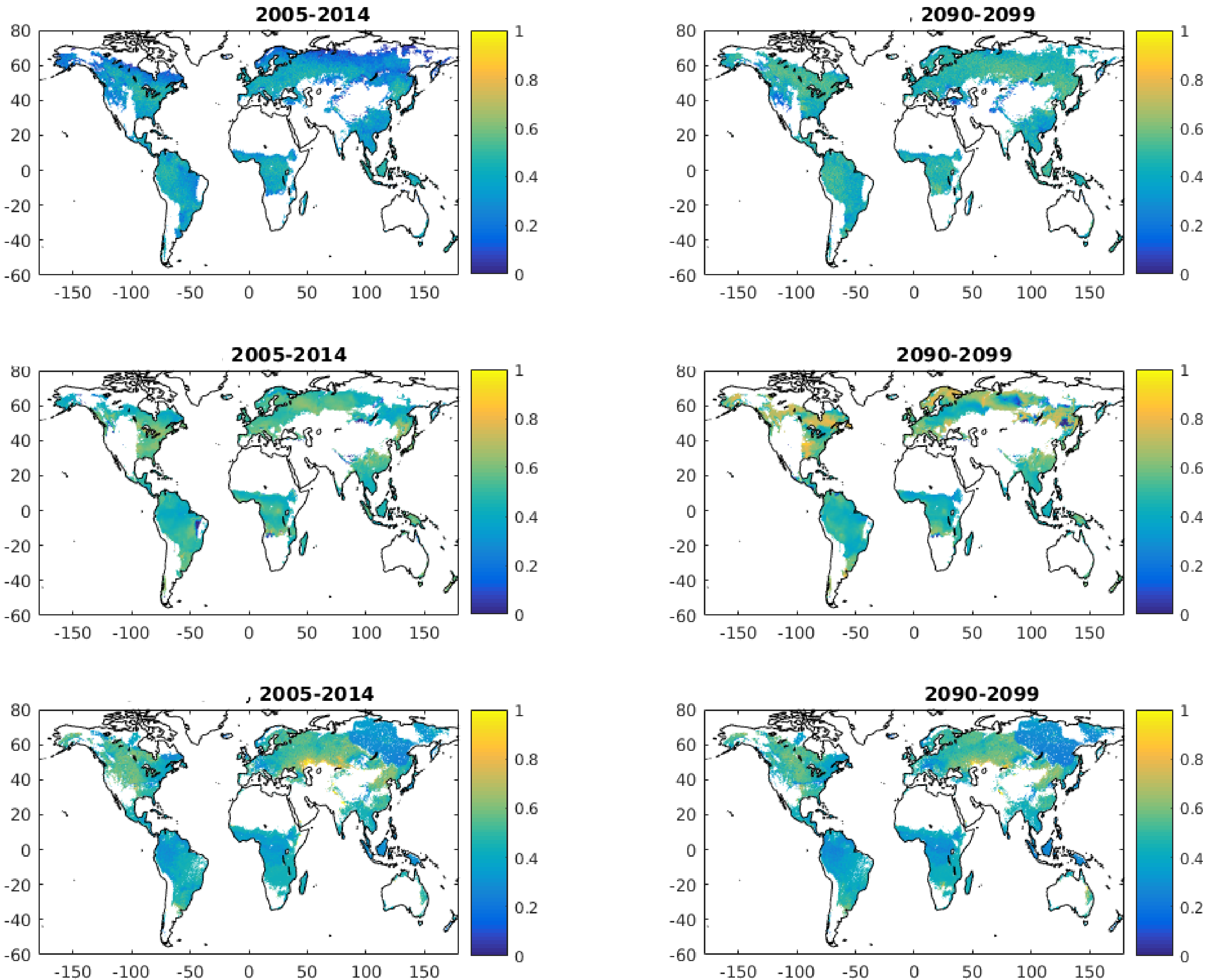
Turnover inter-comparison: First results

$$T_{leaf+root,phen} = (C_{leaf}+C_{root}) / (F_{leaf}+F_{root})$$



Phenology, as much as mortality, is driving differences in temperate/boreal

Turnover inter-comparison: First results



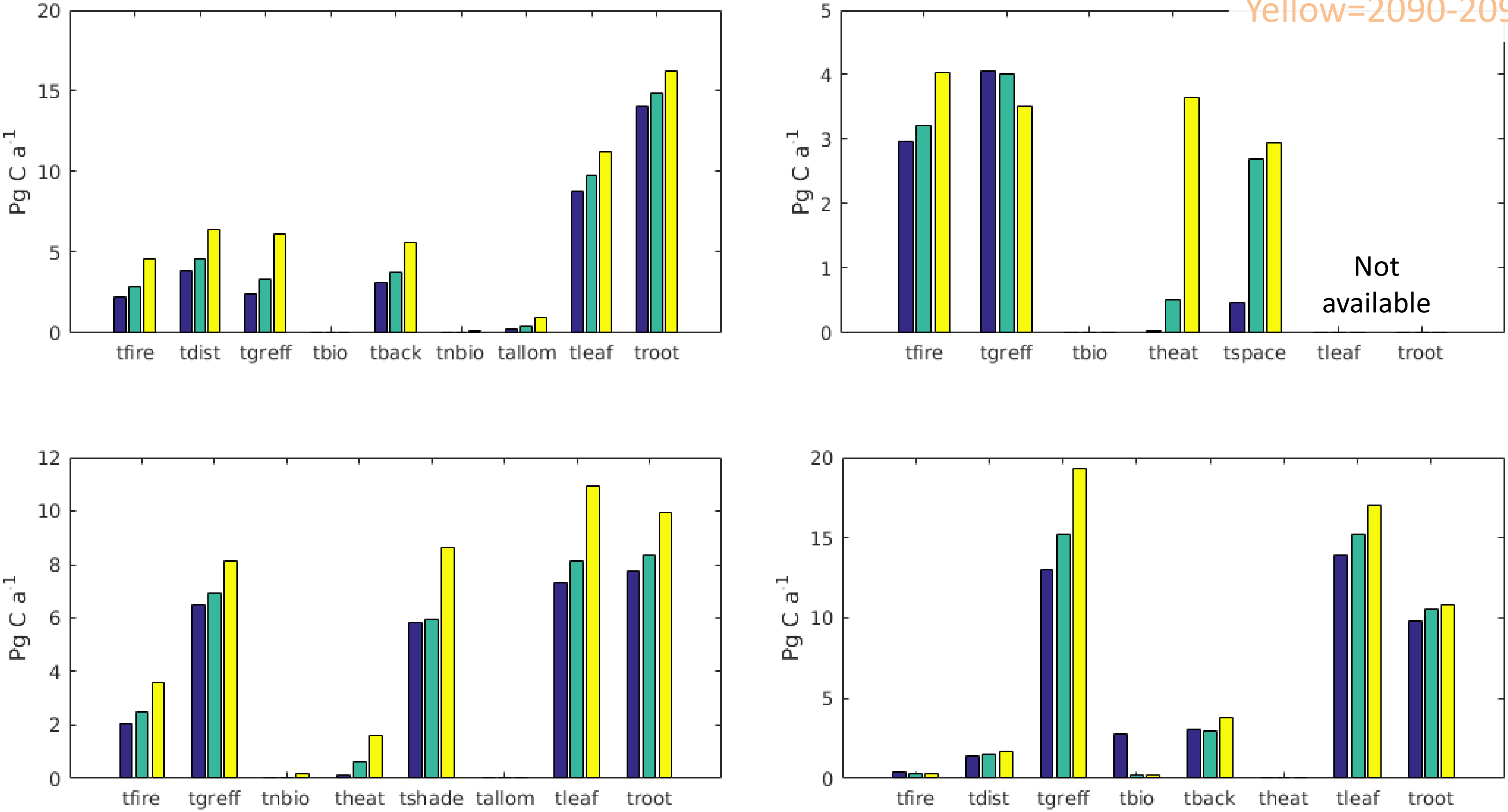
Fraction of turnover due to mortality now and in the future

Large regional shifts in importance of mortality
Biome shifts?
Or stress effects?

Turnover inter-comparison: First results

Breakdown of turnover fluxes by mechanism

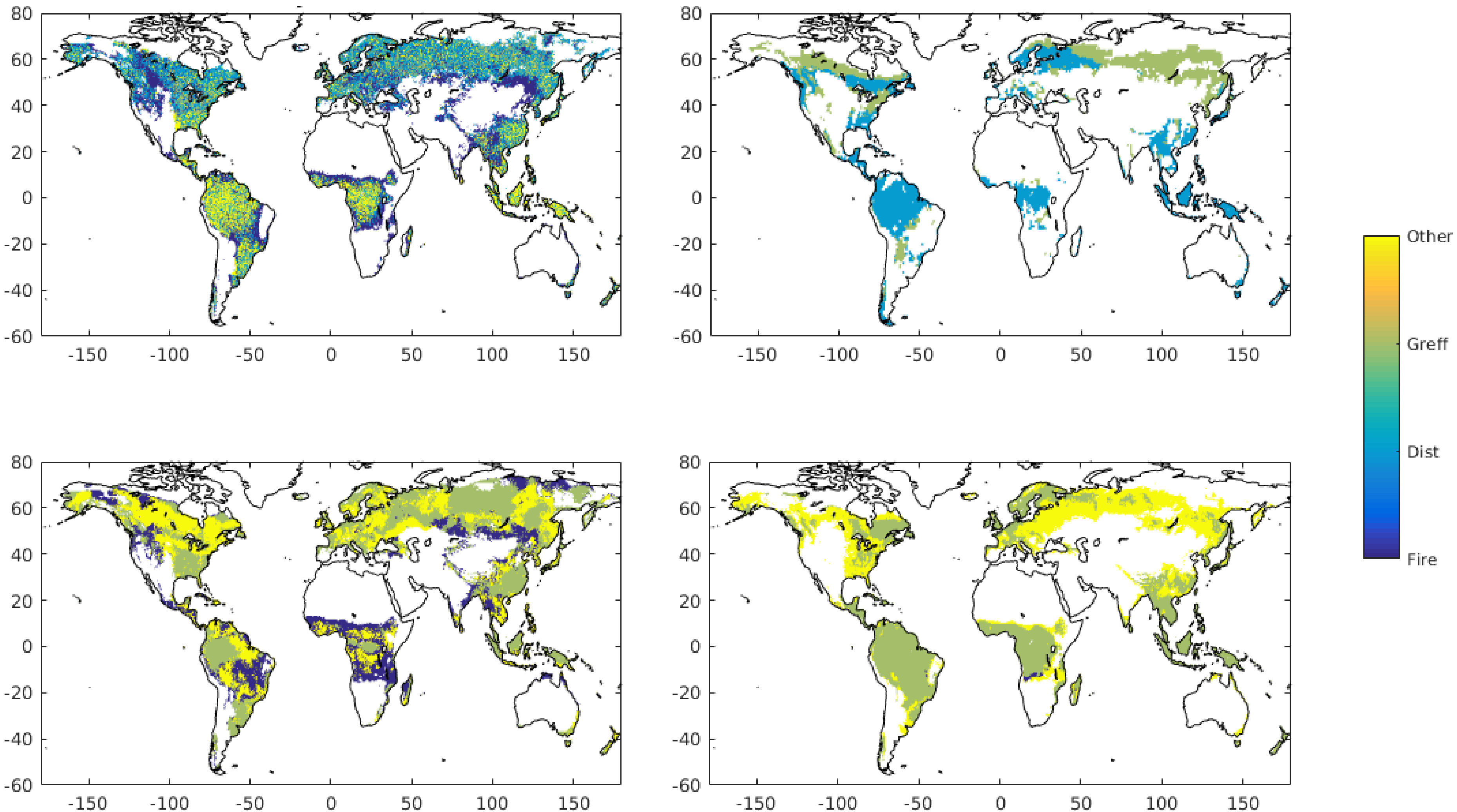
Blue=1901-1910
Aqua=2005-2014
Yellow=2090-2099



Driving mechanisms differ greatly – even between models with the same basic mechanisms

Turnover inter-comparison: First results

Dominant mortality mechanism (2005-2014)



Not just in terms of magnitude, but also spatially.

Turnover inter-comparison: Next steps

Attribution of model response to mechanisms

Plan to evaluate against:

- Drought mortality (Steinkamp et al., 2015; Allen et al., 2010)
- Global turnover estimates from observations (Carvalhais et al., 2014)
- Forest inventory observations of mortality (Amazon; e.g. Brienen et al., 2015)
- Burnt area (MODIS/GFED)

Turnover inter-comparison: Take-home messages

Model disagreement on absolute size, spatial patterns and environmental response of vegetation turnover

Phenology, as well as mortality, appears a strong driver of vegetation turnover

Further work will analyse reasons for differences and carry out evaluation where possible.