
Fire, climate, and the global carbon cycle
NCEAS/KITP, 29/05/2008
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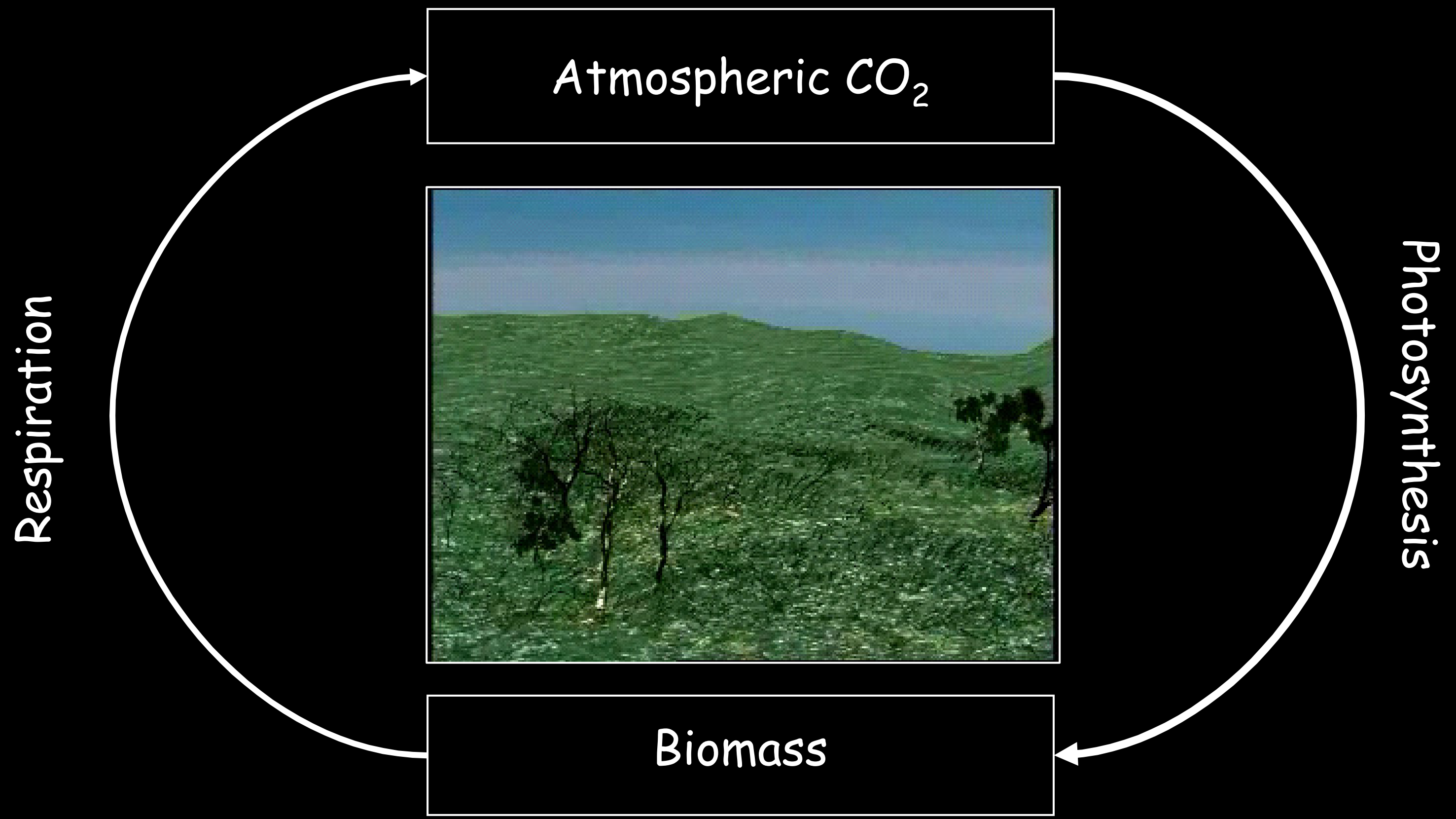
Outline

- Global fire patterns based on satellite data
- Conceptual model for explaining large-scale fire activity
- Quantifying global fire emissions
- Relations between climate and deforestation (fires)
- Climate is more than CO_2: example from the boreal region how fires may influence climate

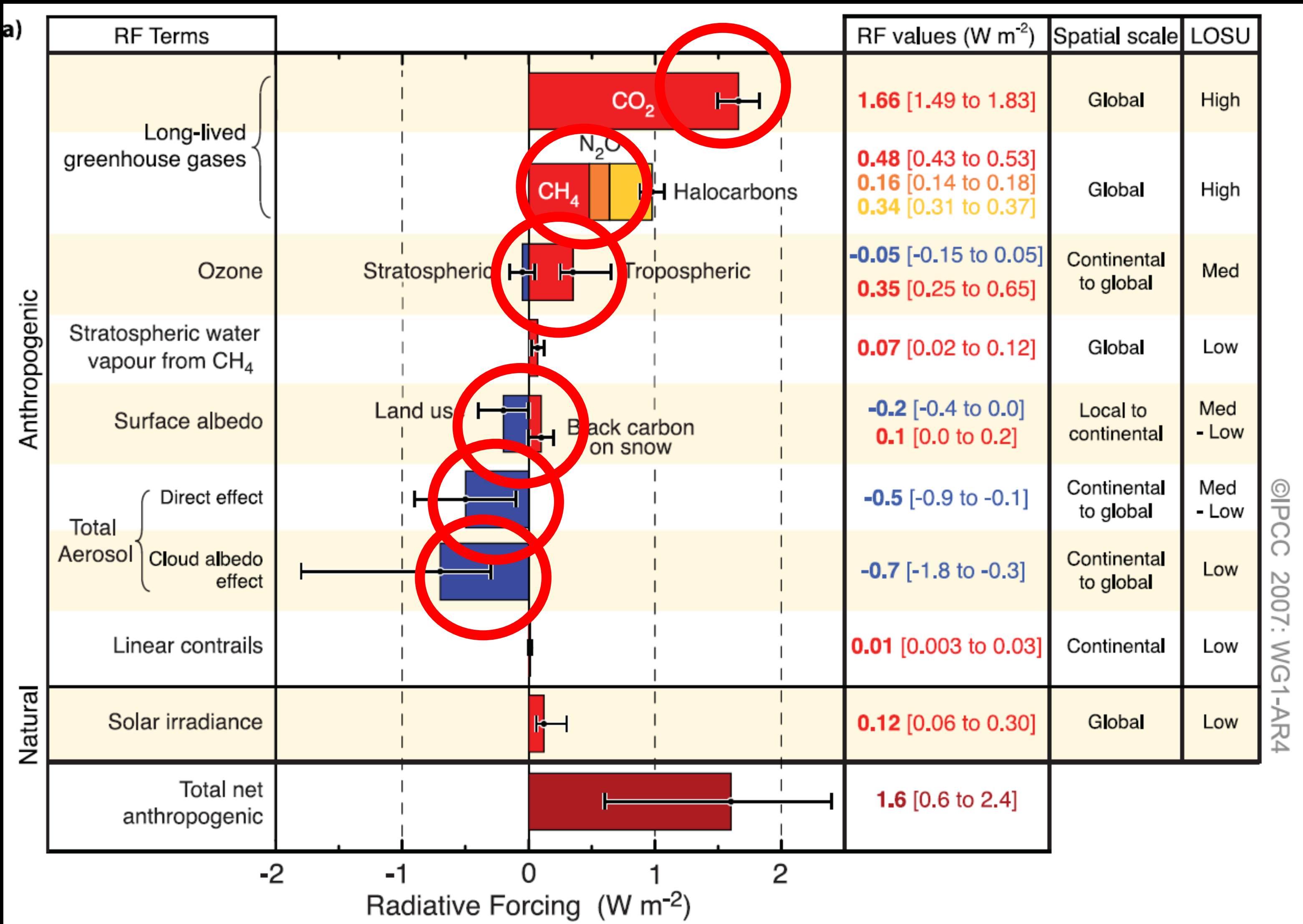
What is fire? (from an atmospheric perspective)



"From a CO_2 perspective, fire is not much more than fast respiration"

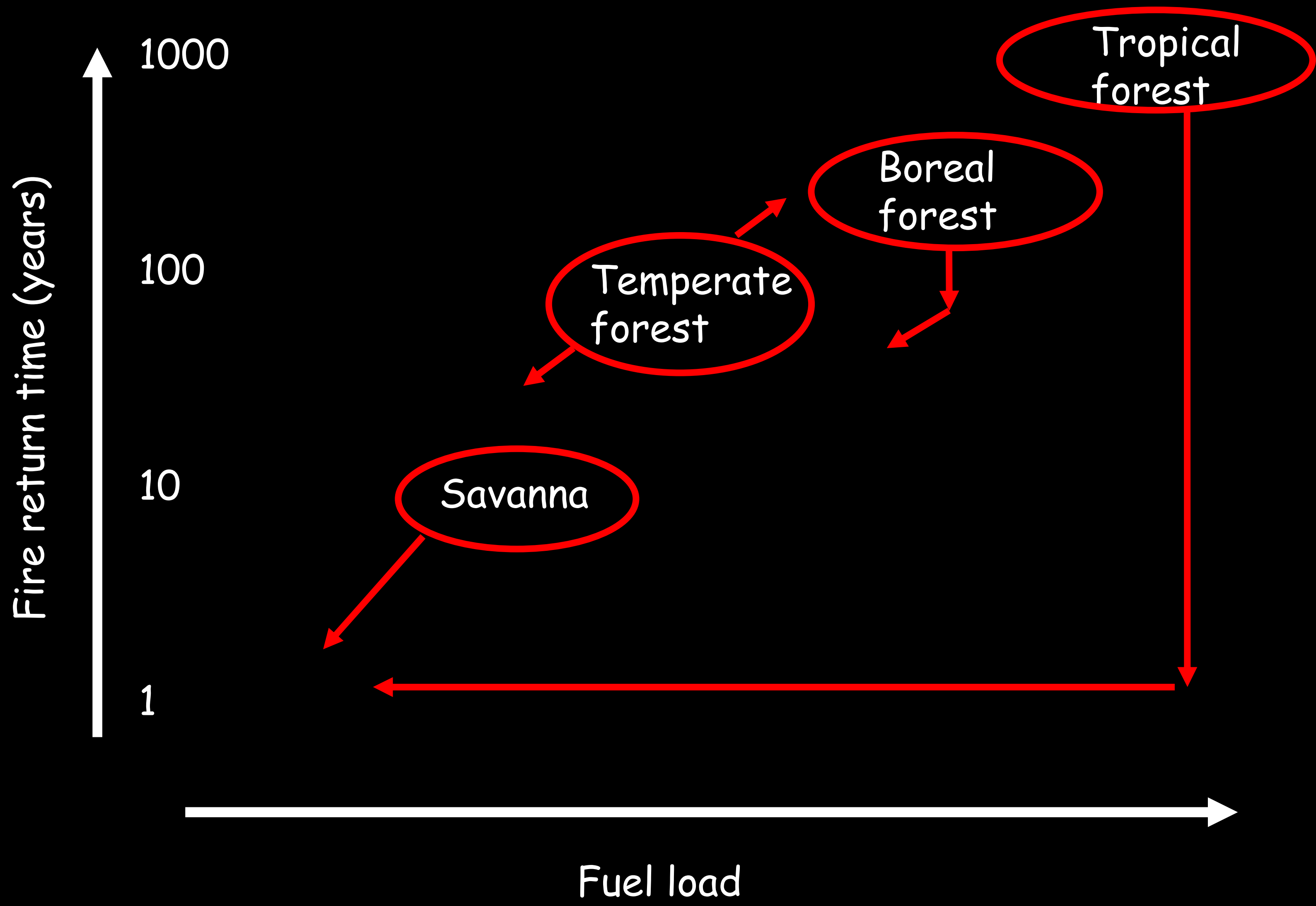
Radiative forcing: change in available energy at top of atmosphere (compared to 1750)

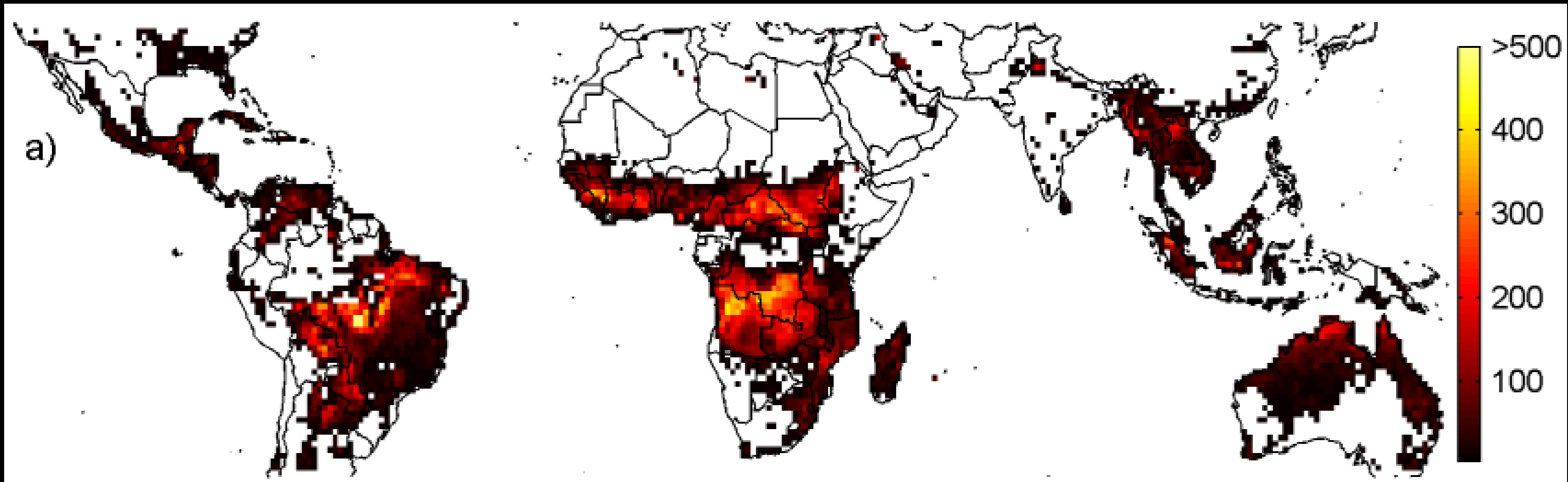
Colder ← → Warmer



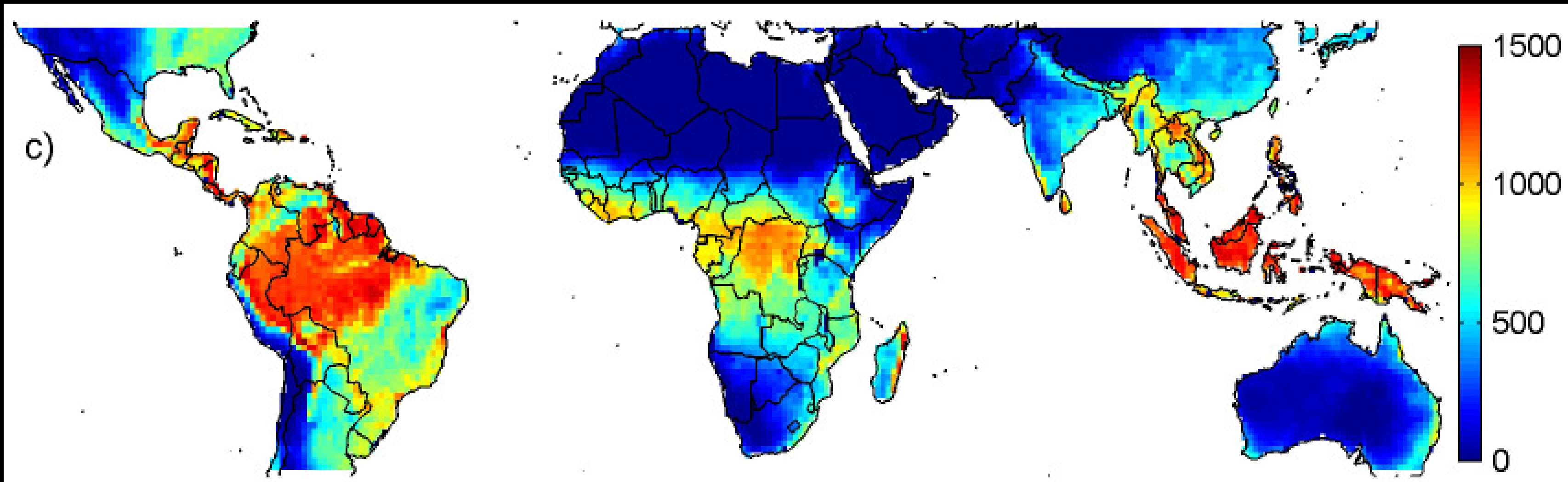



Human influence on fire regimes



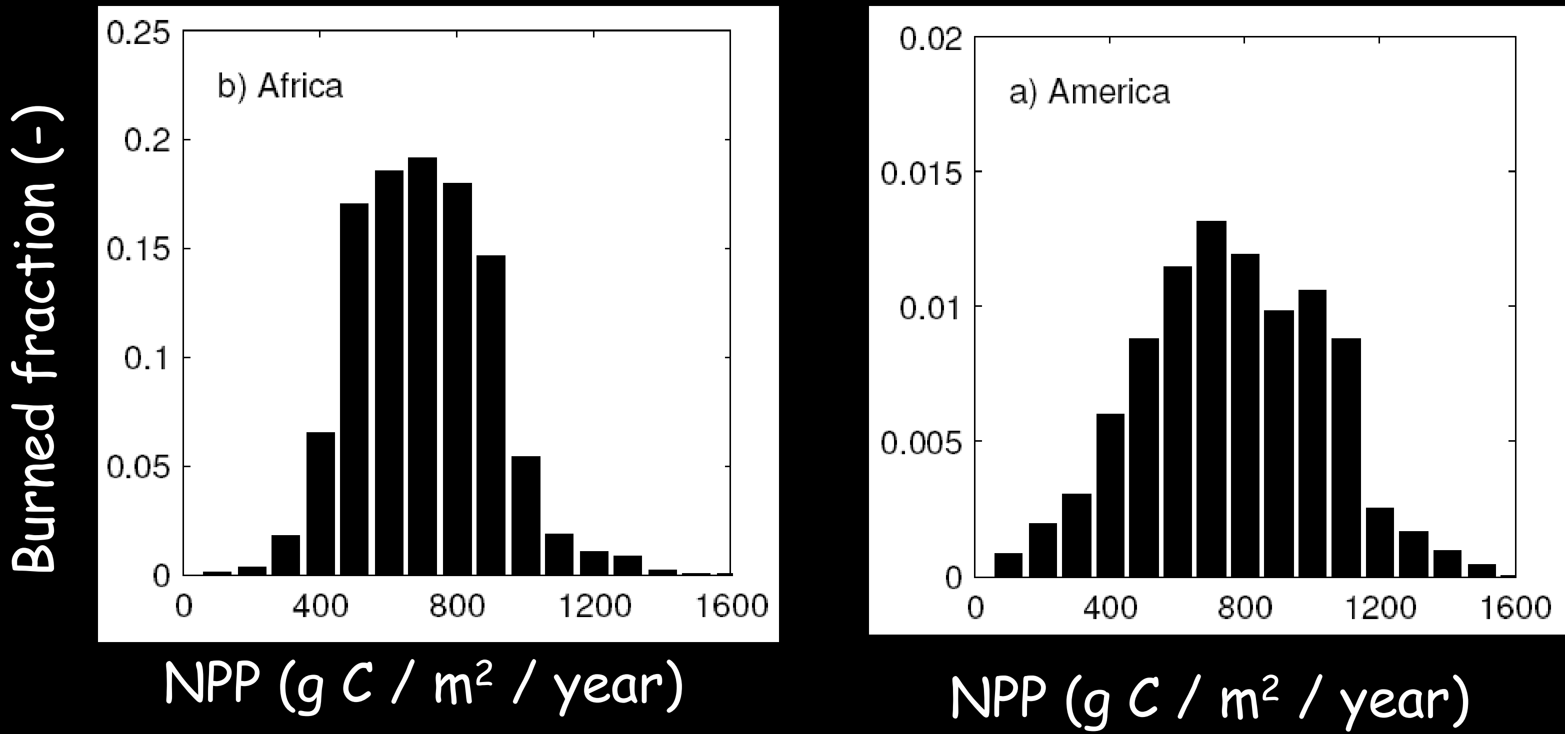


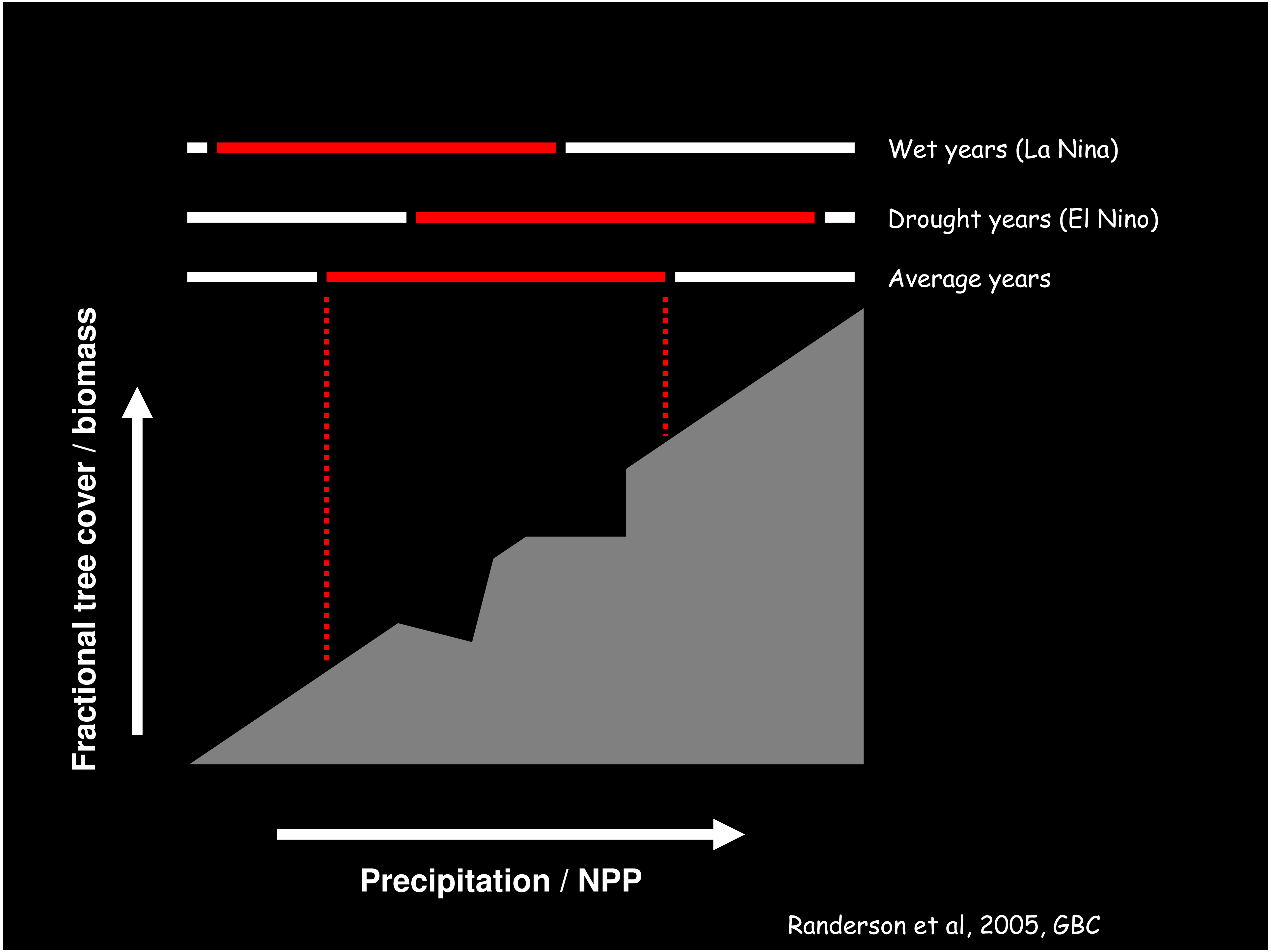
TRMM-VIRS fire counts, Giglio et al, 2003, IJRS

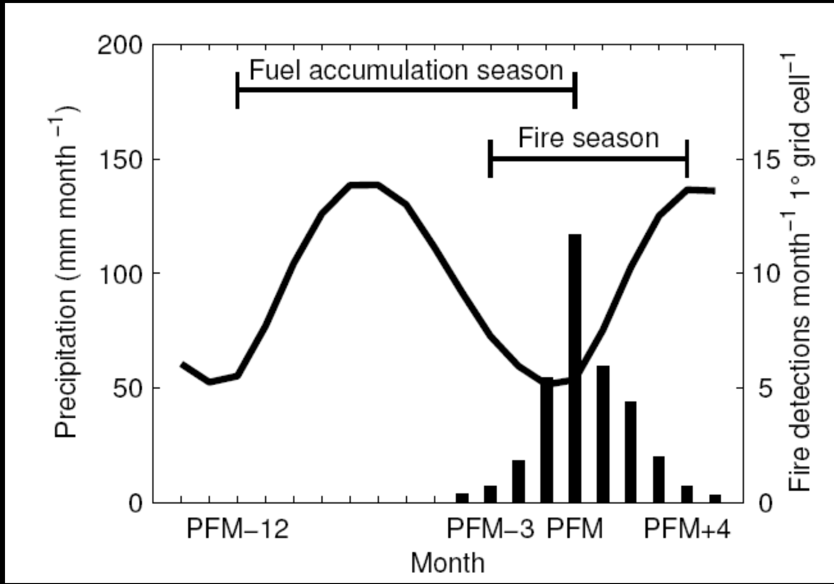


1998-2006 CASA net primary production (NPP)

Fire activity over a productivity gradient

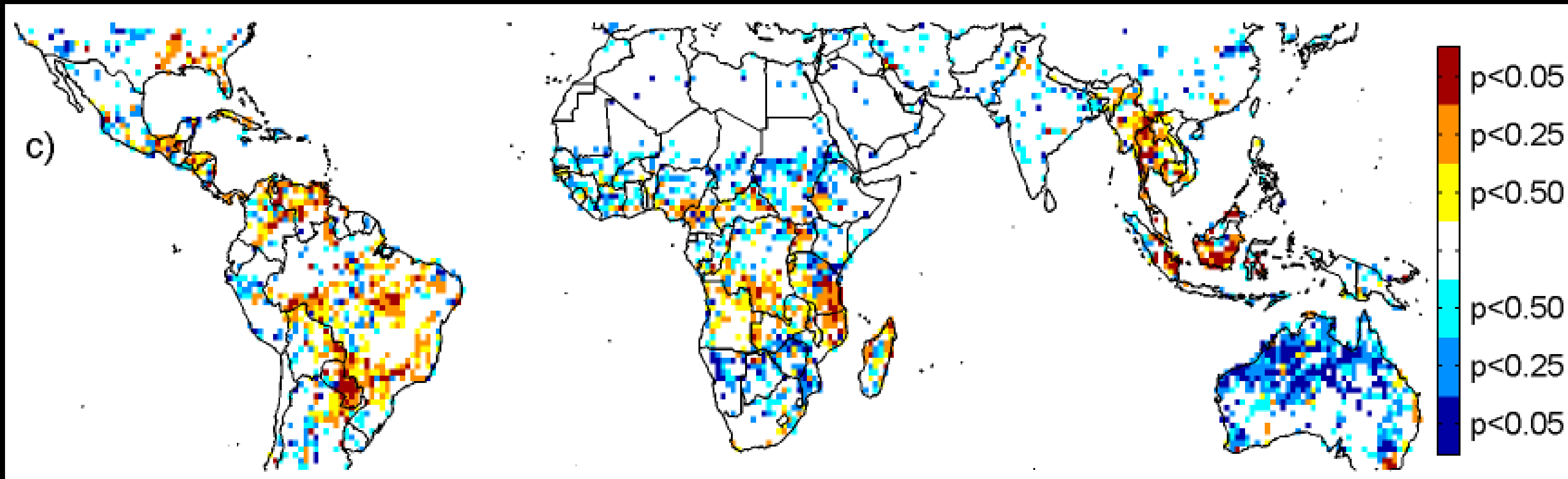



Wet years (La Nina)
Drought years (El Nino)
Average years
Fractional tree cover / biomass
Precipitation / NPP
Randerson et al, 2005, GBC



Red: droughts lead to increased fire activity

Blue: droughts lower fire activity



Van der Werf et al, in press, GBC

Implications?
Need to quantify emissions!

Emissions =

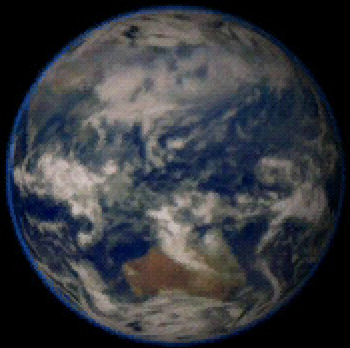
burned area

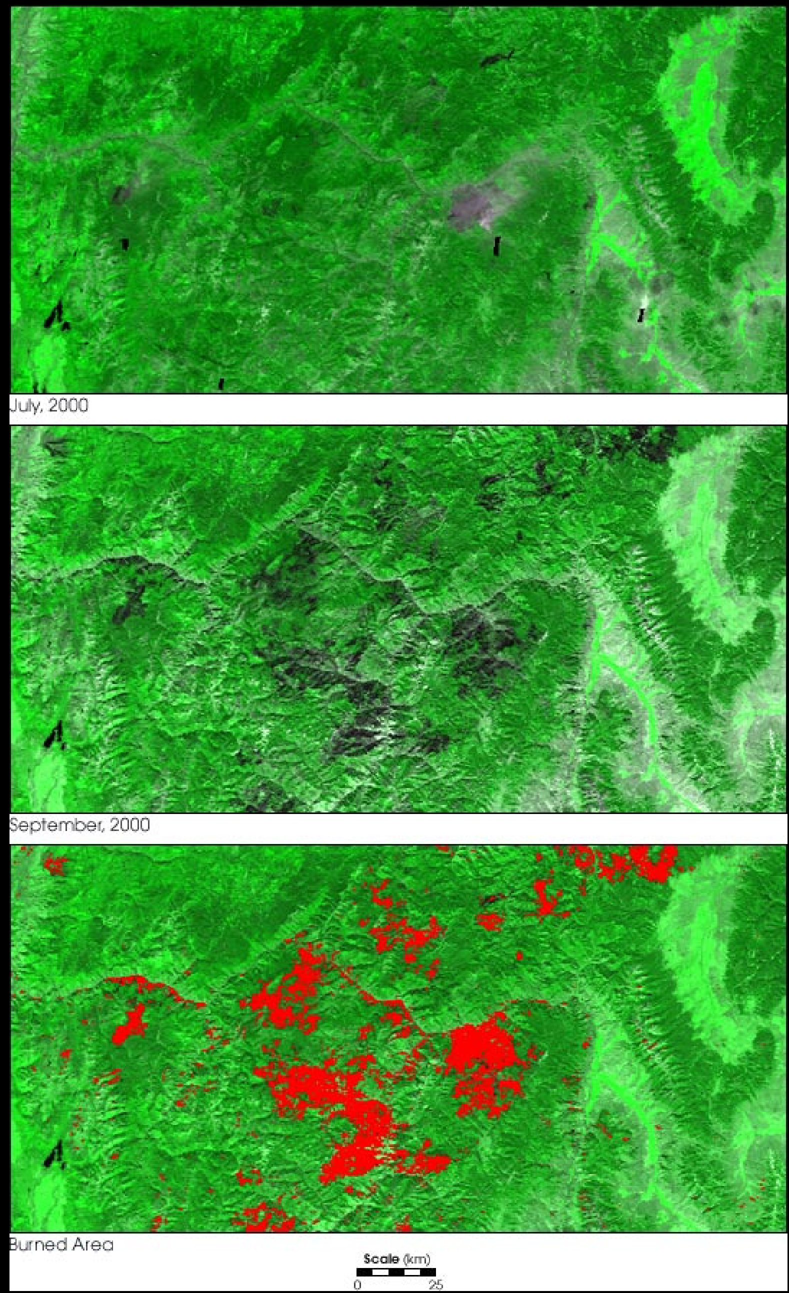
x

Biomass / fuel load

x

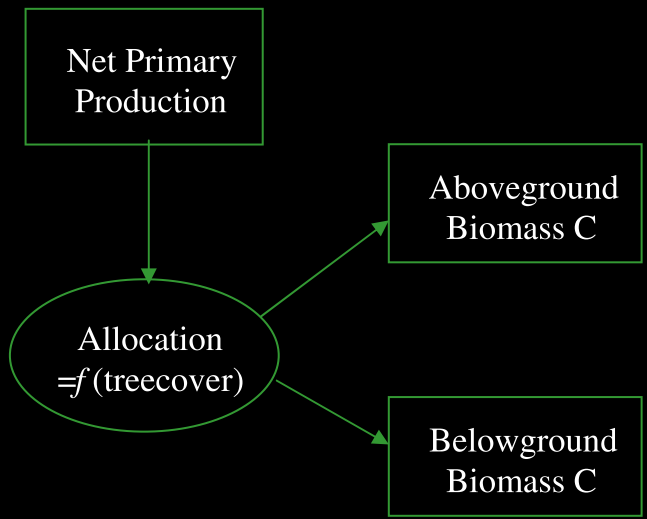
combustion completeness

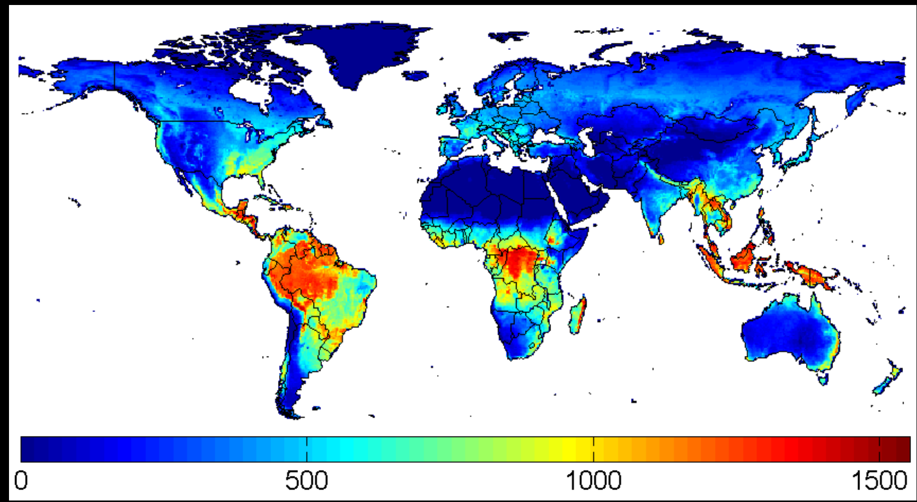




Step 1: modeling biomass buildup (NPP)

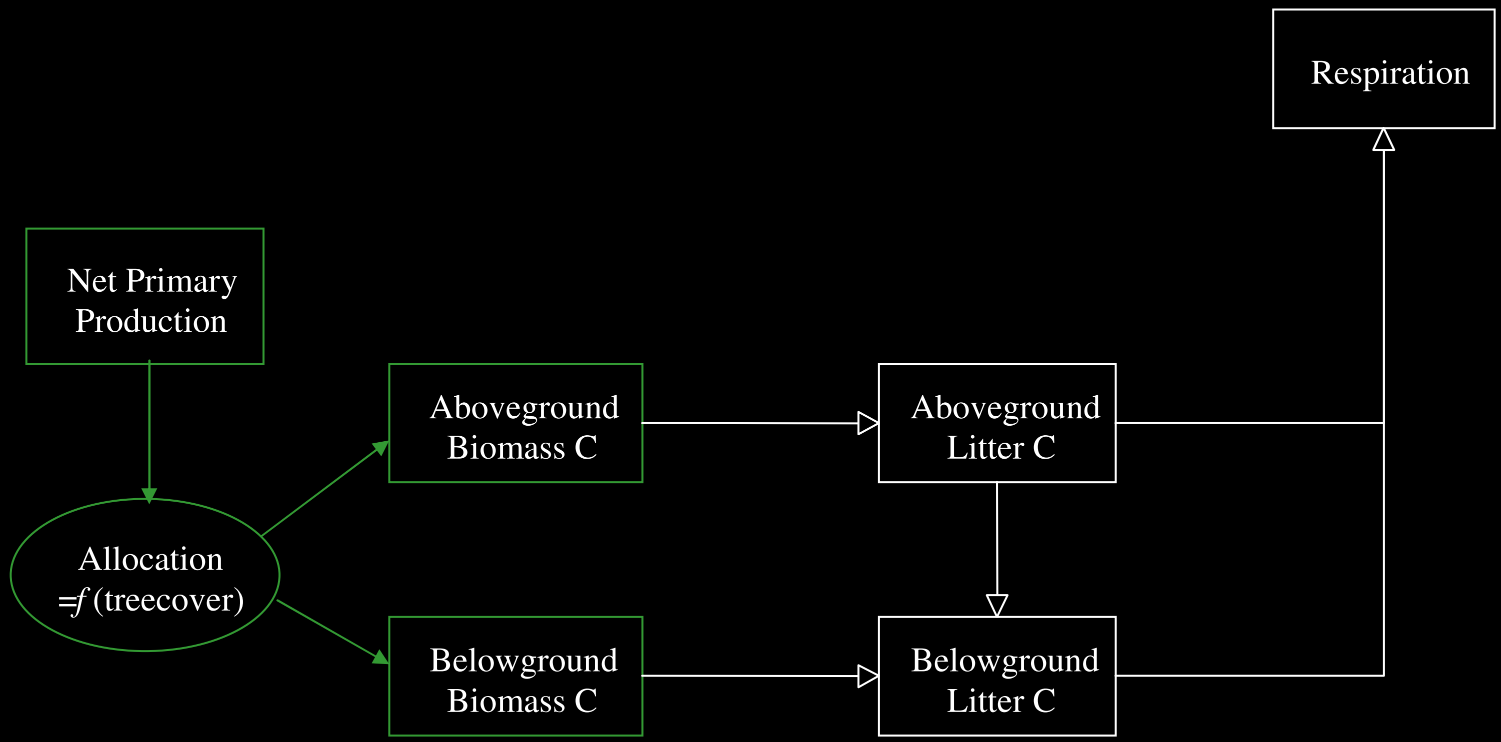
$$NPP = PAR \times FPAR \times LUE_{(T,\theta)}$$



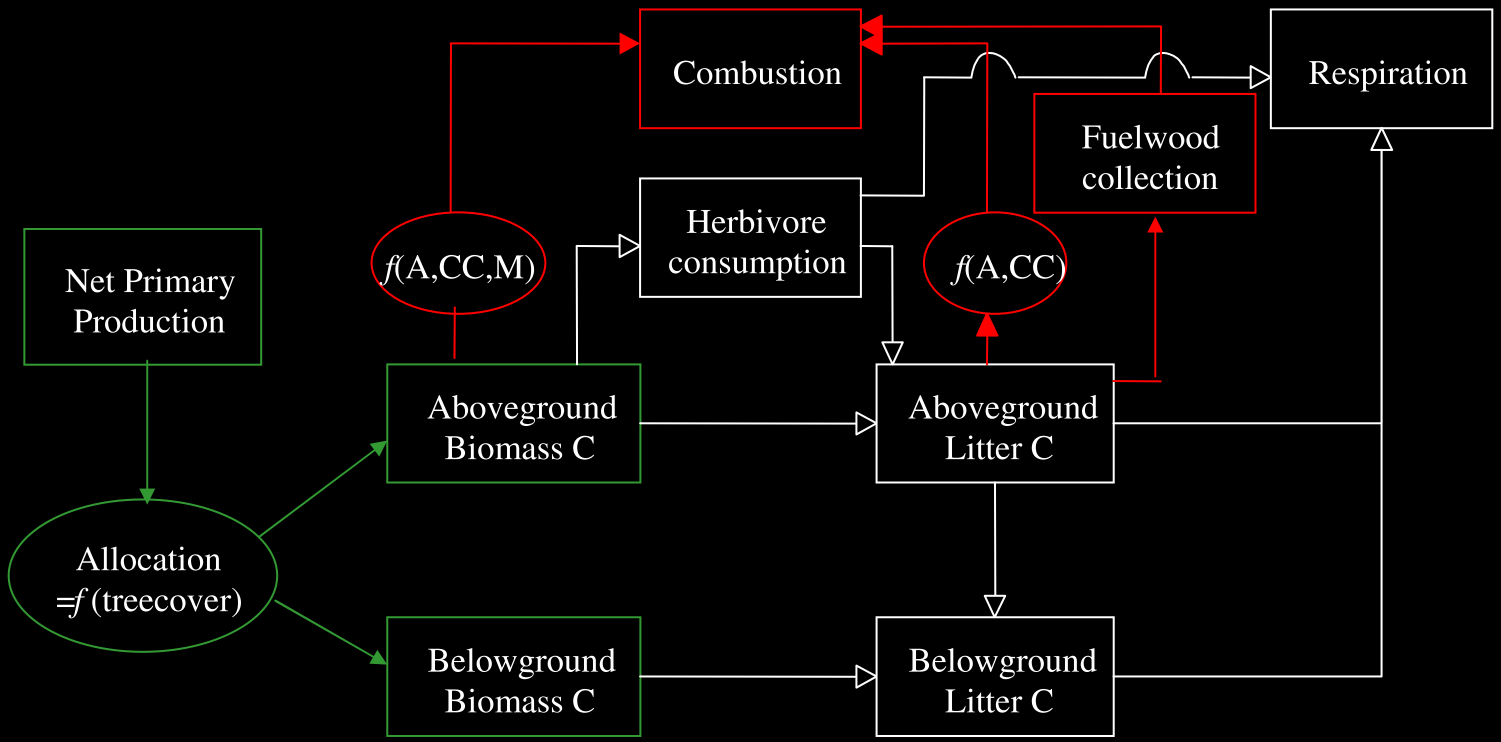


g C / m² / year

Step 2: modeling the main carbon loss pathway (respiration)

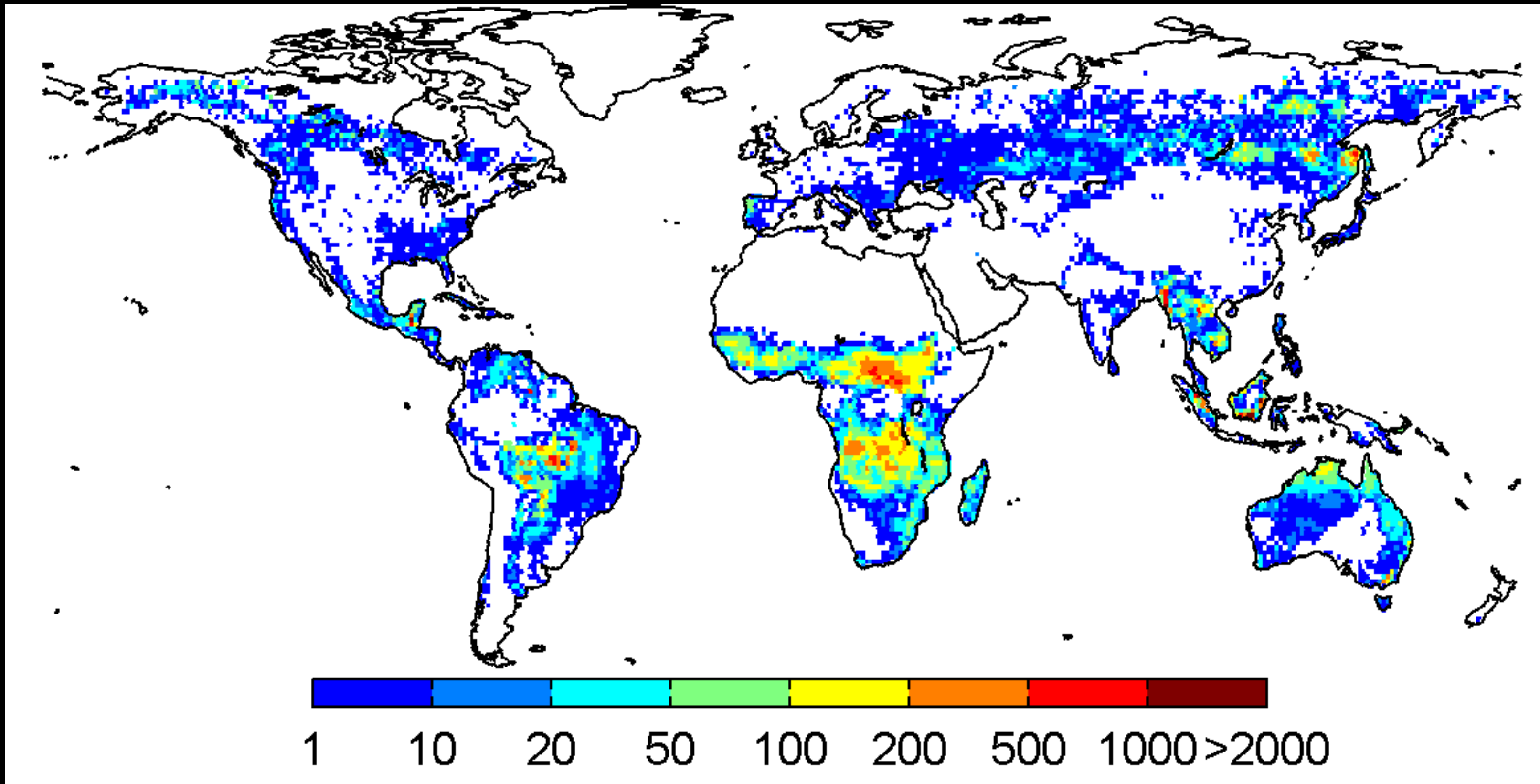


Step 3: adding fire as another pathway how carbon can be released to the atmosphere



A = Area burned   CC = combustion completeness   M = fire induced mortality

Global fire emissions pattern

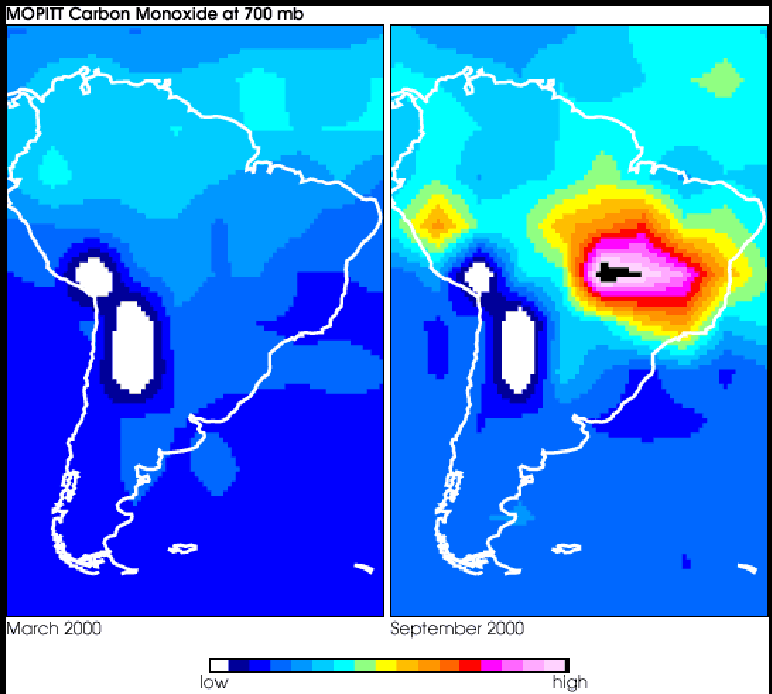


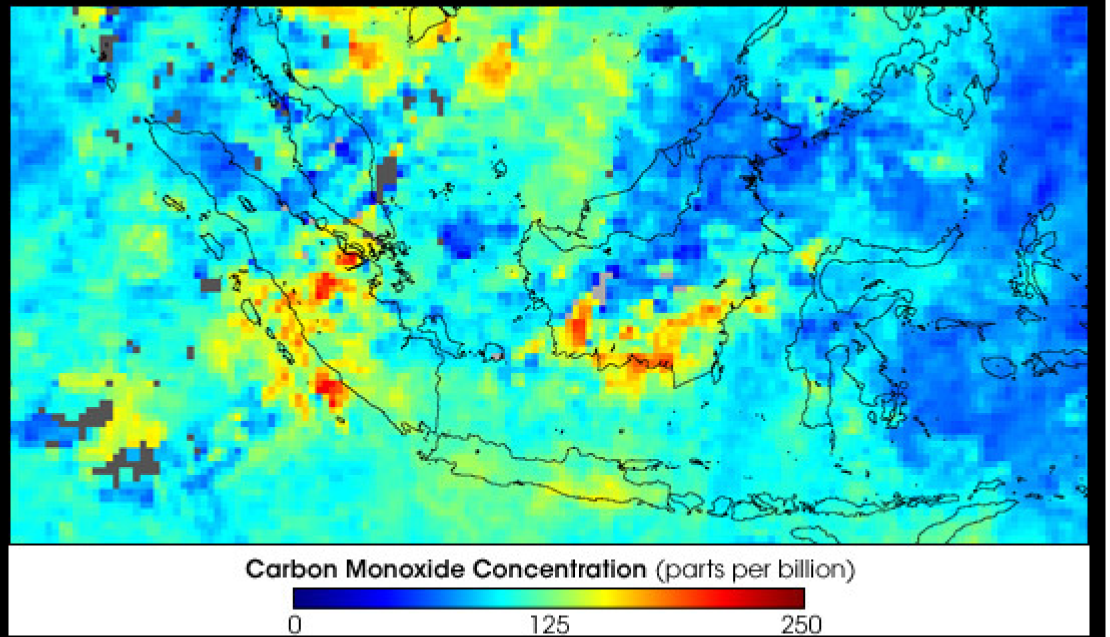
Mean annual fire carbon emissions, averaged over 1997 – 2006 (g C /m² / year).

Global average total = 2.5 Pg C / year. FF now > 8 Pg C / year. Substantial uncertainty!

Van der Werf et al, 2006, ACP

Reducing uncertainties: compare transported CO emissions to atmospheric CO concentration





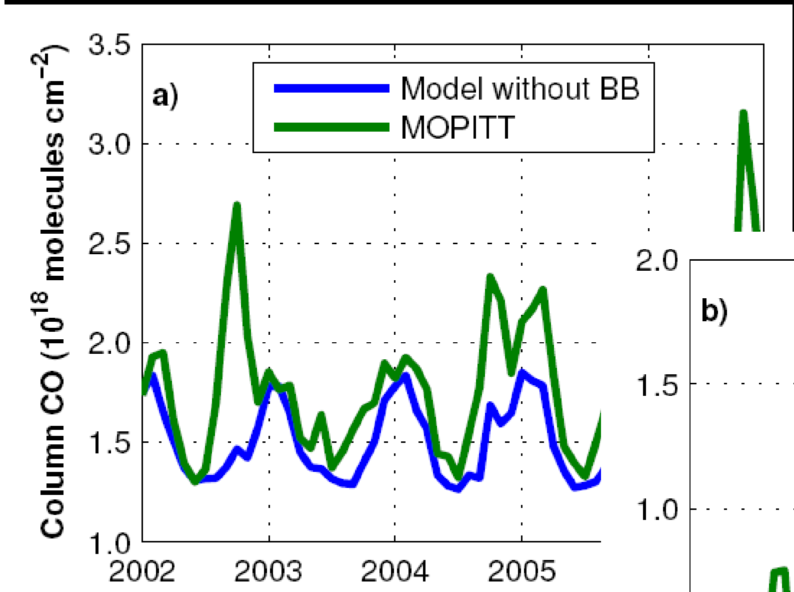
MOPITT

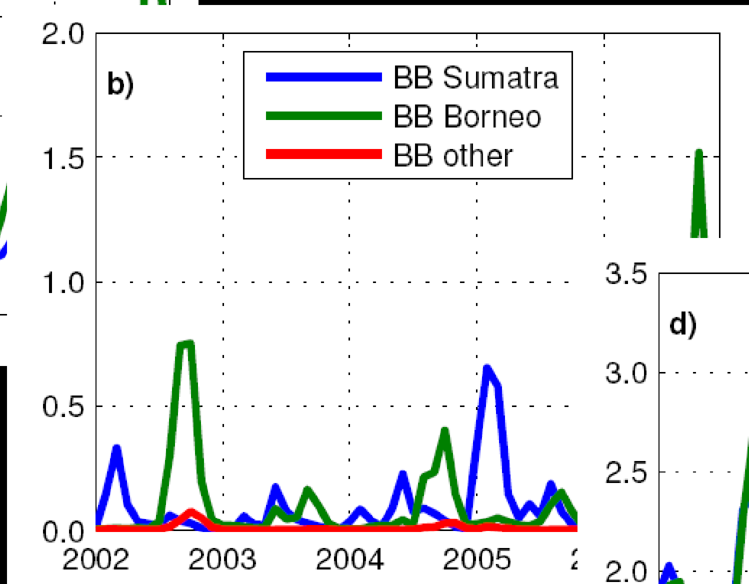
Reducing uncertainties: compare transported CO emissions to atmospheric CO concentration

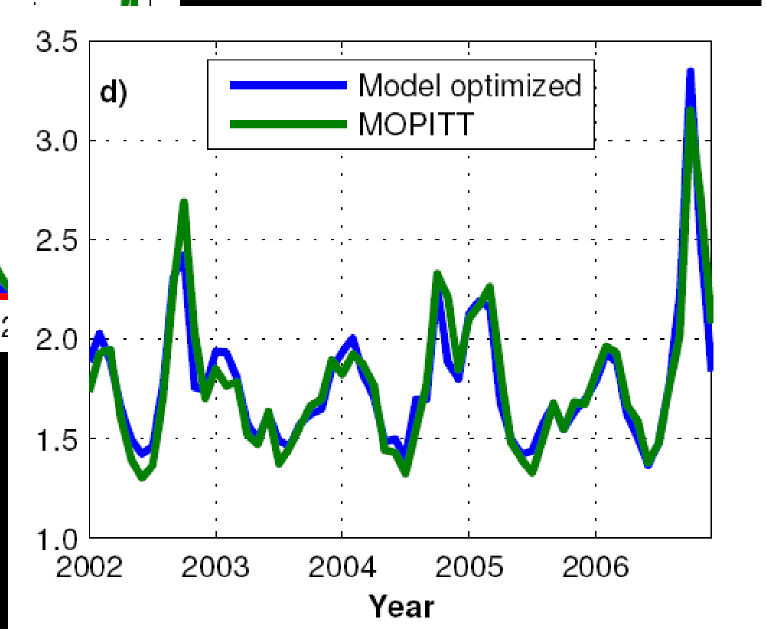
Equatorial Asia

CO from MOPITT

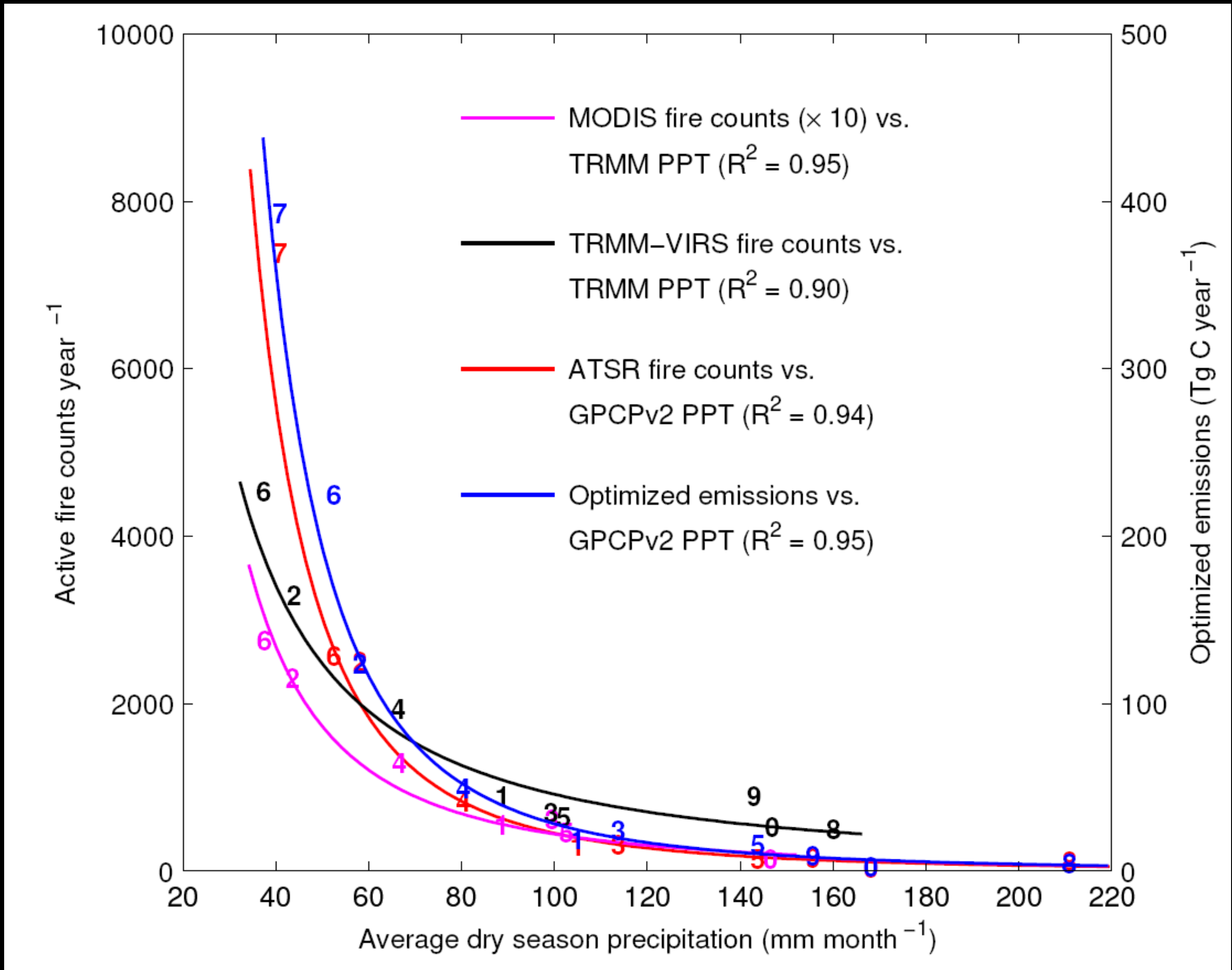
BB = biomass burning



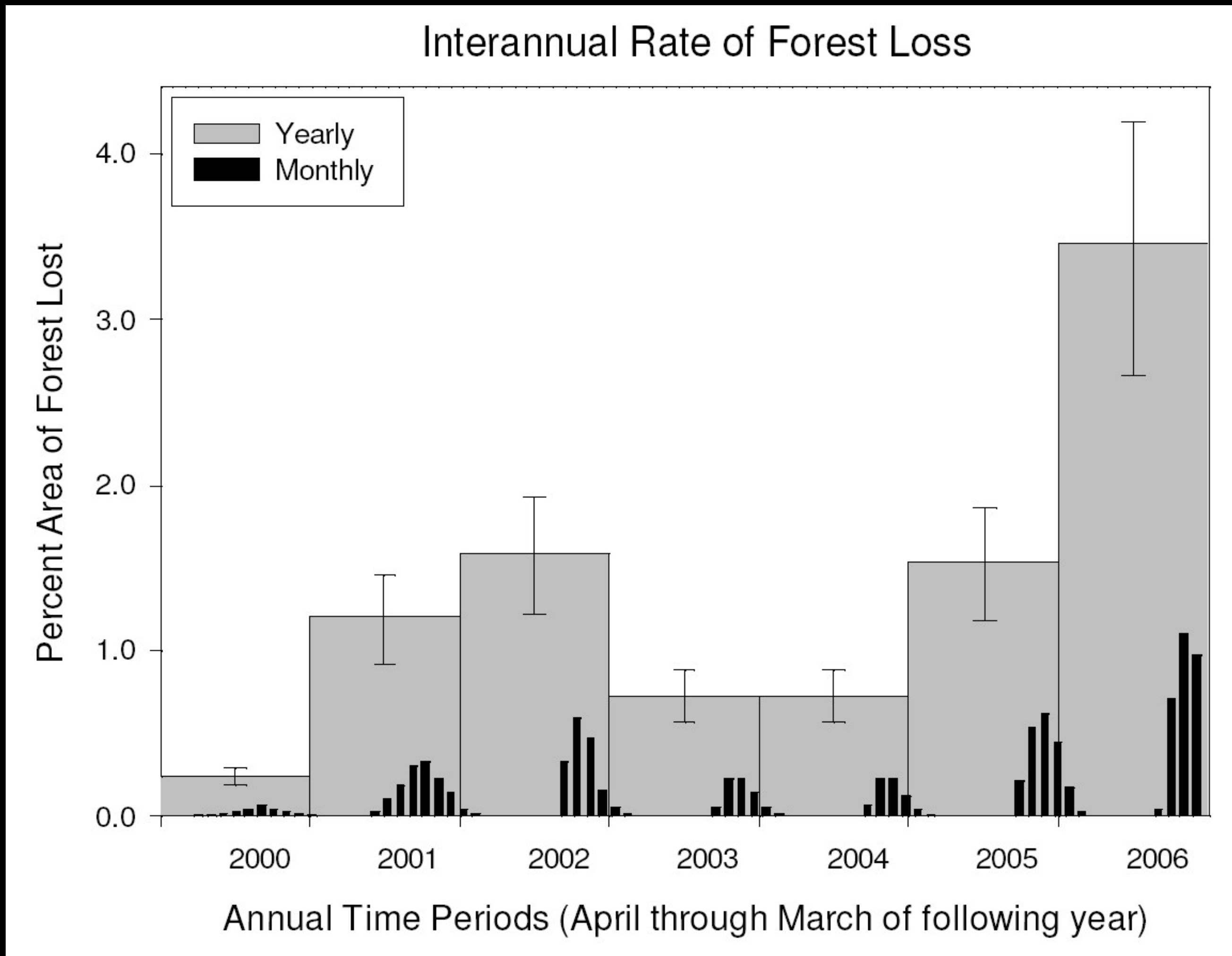




Non-linear relation between drought and fire emissions in southern Borneo



Non-linear relation between drought and forest loss in southern Borneo

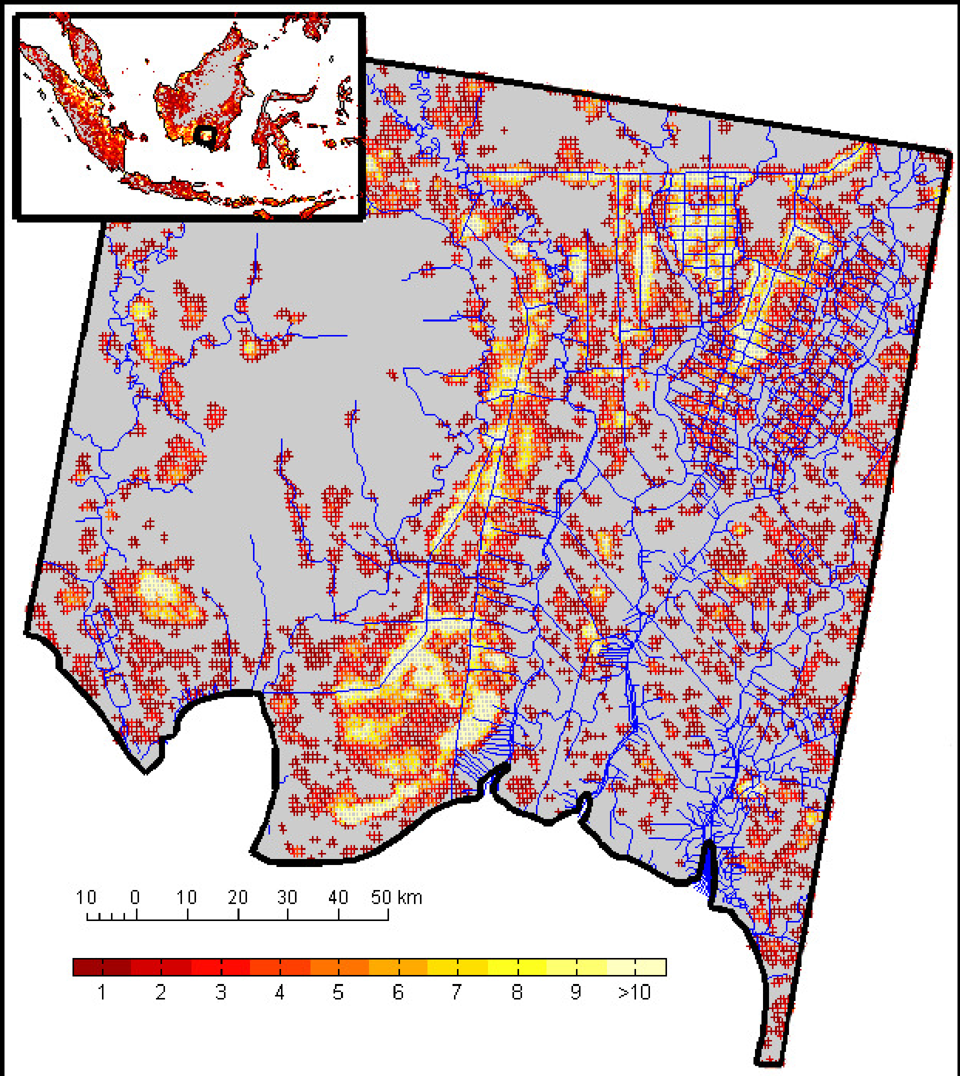


Based on MODIS. Jan Dempewolf, UMD

Page et al., 2002, Nature

Murdiyarso et al., 2004, AEE

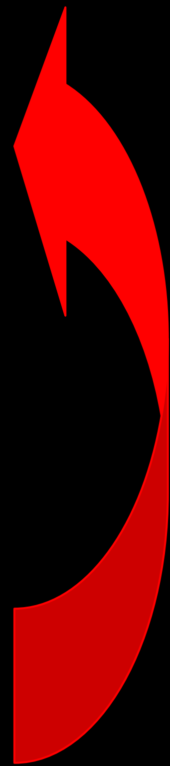
Causes for the non-linear relation



- Threshold
- During droughts, fires can occur further away from drainage, making a larger area of peat vulnerable to fire
- During droughts, forest loss is higher (accidental / intentional?)

This points towards a human-driven carbon-climate feedback

- Droughts lead to higher deforestation rates as humans take advantage of climatic conditions
- Higher deforestation rates lead to higher CO_2 concentrations
- Higher CO_2 concentrations may lead to more drought



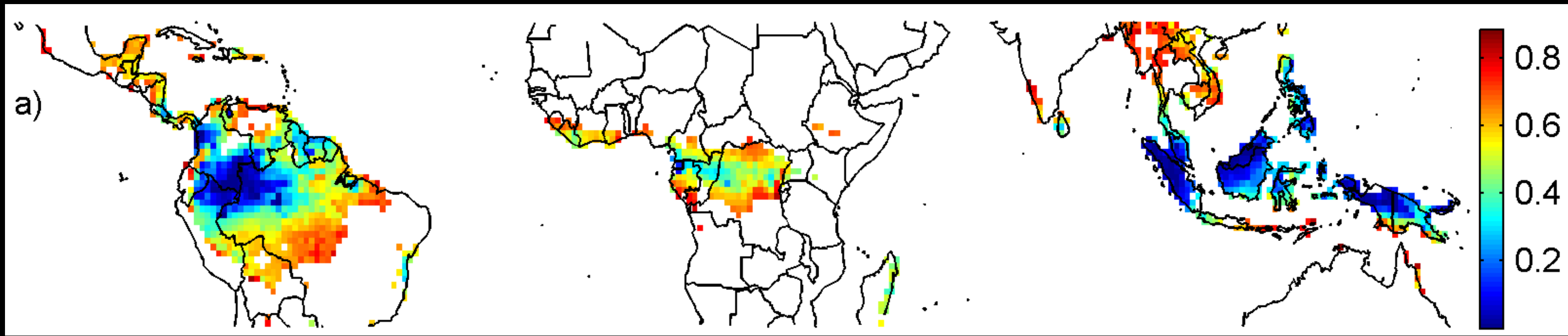
Building on the importance of drought…

$$FDP_{x,y,t} = \sqrt{\left(\#DM_{x,y,t}/8\right) \times \left(1 - \left(PPT_{DM_{x,y,t}}/100\right)\right)}$$

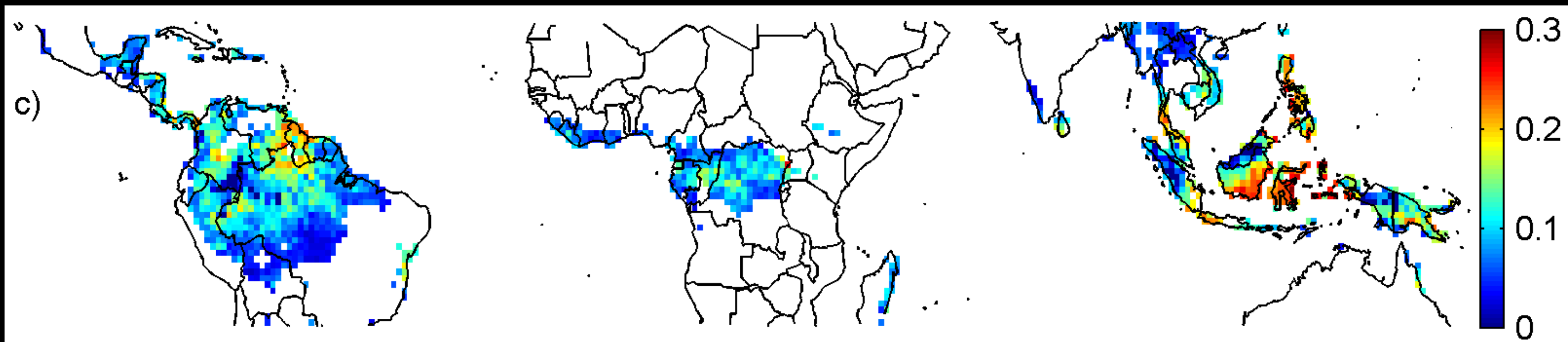
FDP = "fire deforestation potential"

DM = dry month, PPT = precipitation

1998 – 2006 mean:

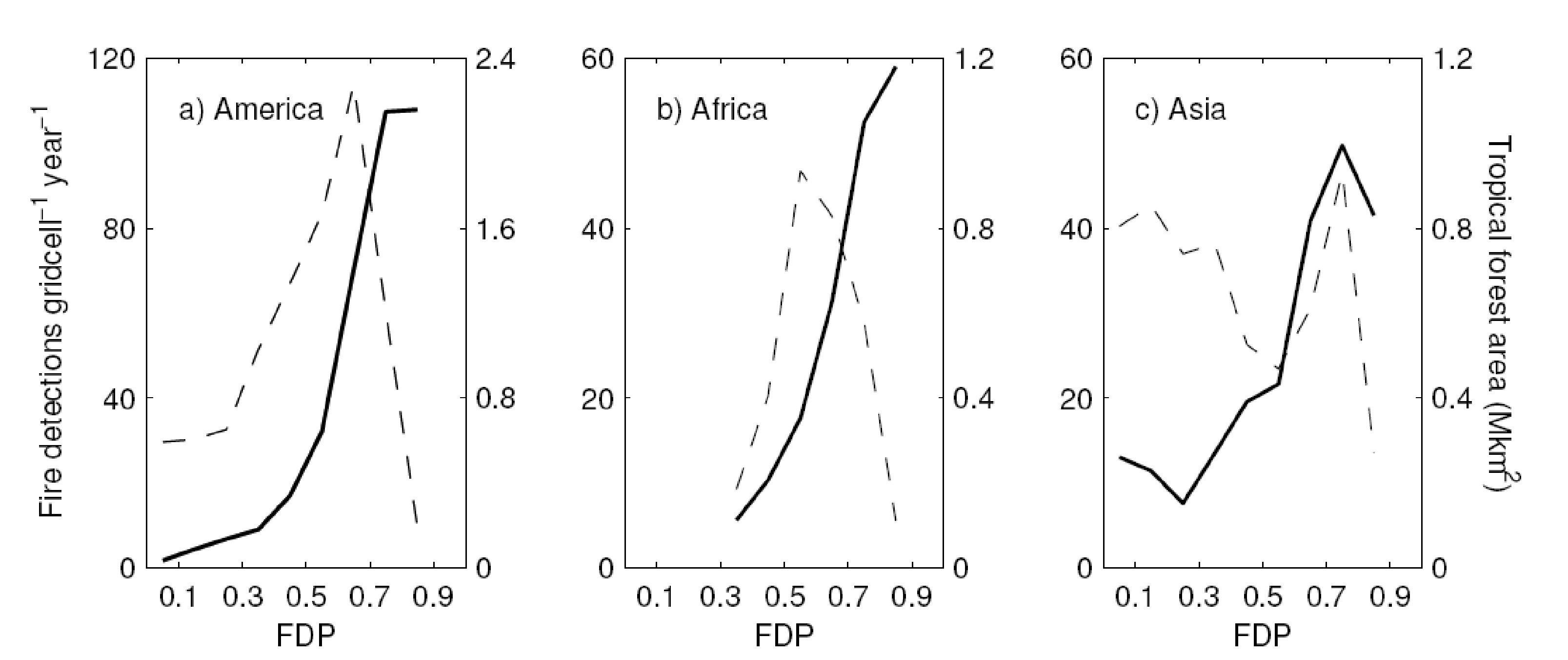


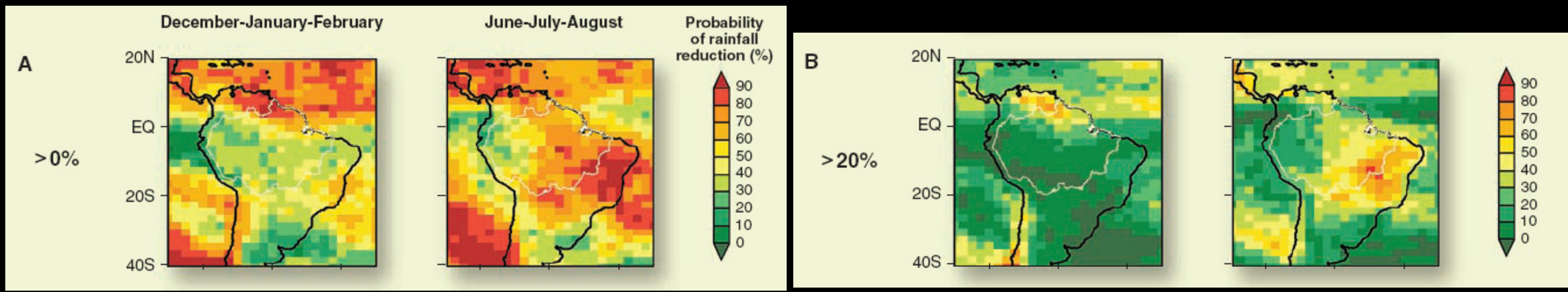
1998 – 2006 standard deviation:



Van der Werf et al, in press, GBC

Good relation between potential and actual deforestation. Natural brake on deforestation in the Amazon?





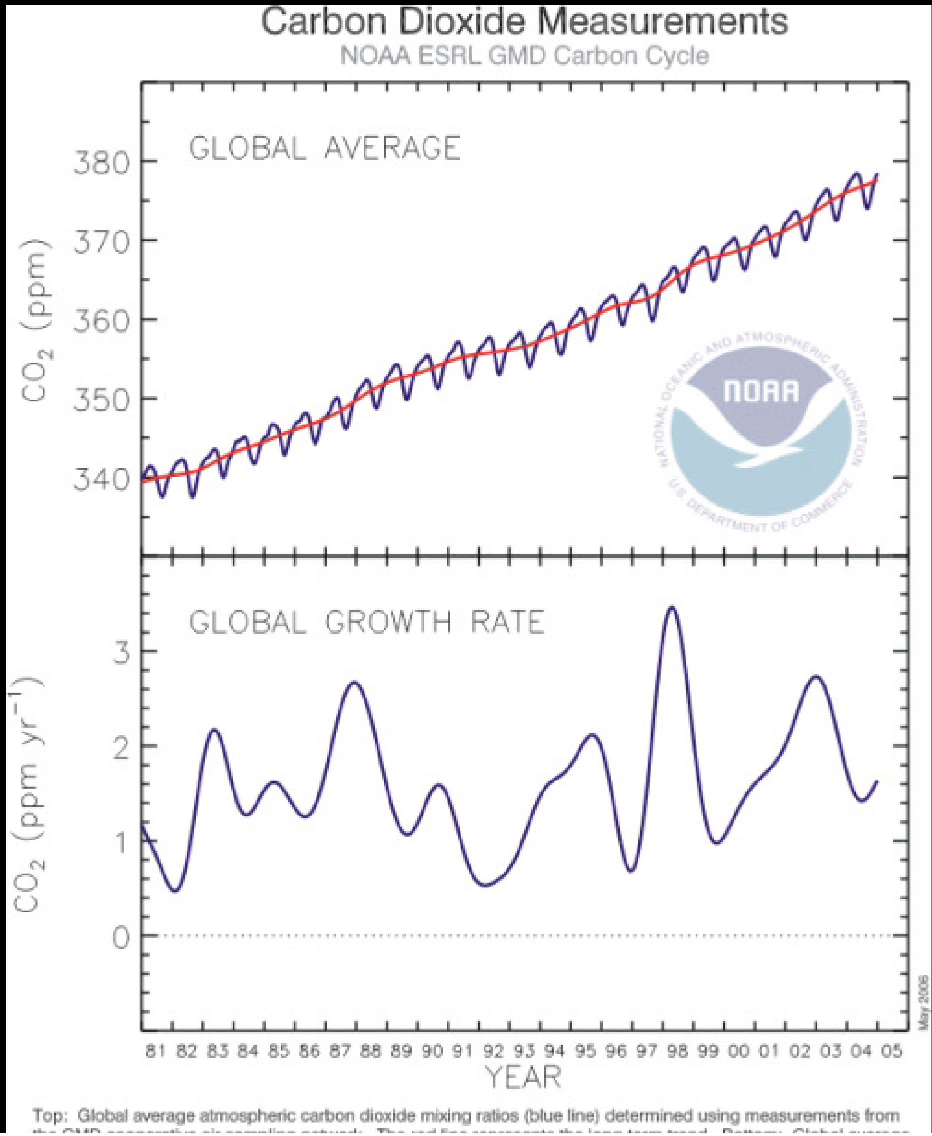
Malhi et al, 2008, Science

So humans seem to take advantage of drought conditions to more efficiently use fire as a tool for deforestation

Drought + humans = high deforestation emissions

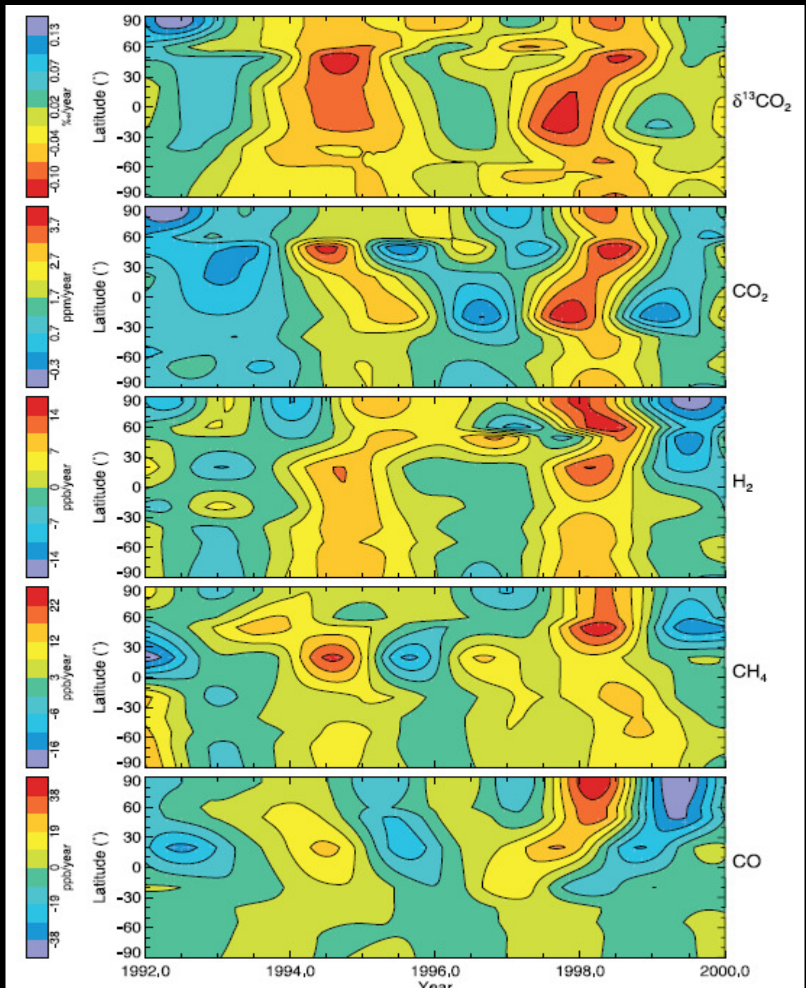
Global implication?

IAV in CO_2 growth rates

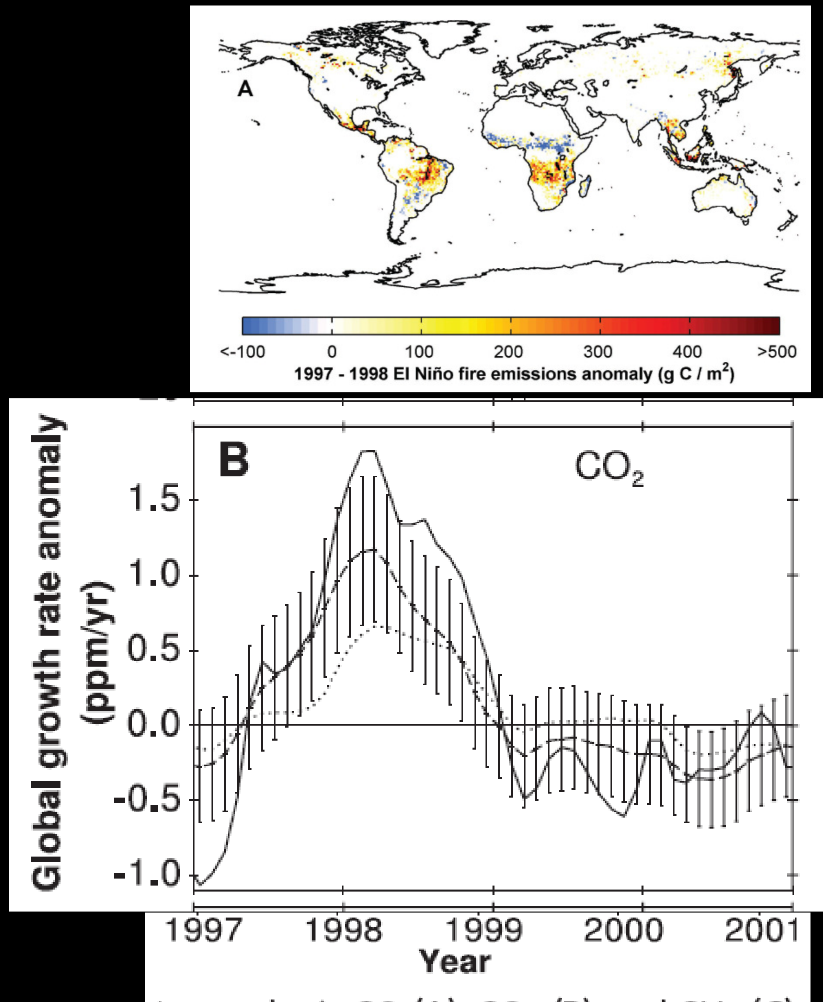


- IAV not related to FF emissions
- Oceans play minor role
- High growth rates during El Nino periods, low growth rated during La Nina or after volcanic eruptions
- El Nino: warm and dry in tropics
- Often explained by offset between photosynthesis (drought: plants sad) and respiration (warm: microbes happy)

Fires explain part of the IAV in CO_2 and CH_4 growth rates



Langenfelds et al., 2002, GBC;



van der Werf et al., 2004, Science

Summary

- Simple conceptual model can explain spatial and interannual fire activity patterns at extreme parts of the PPT or NPP range, human influence dominates in intermediate ecosystems

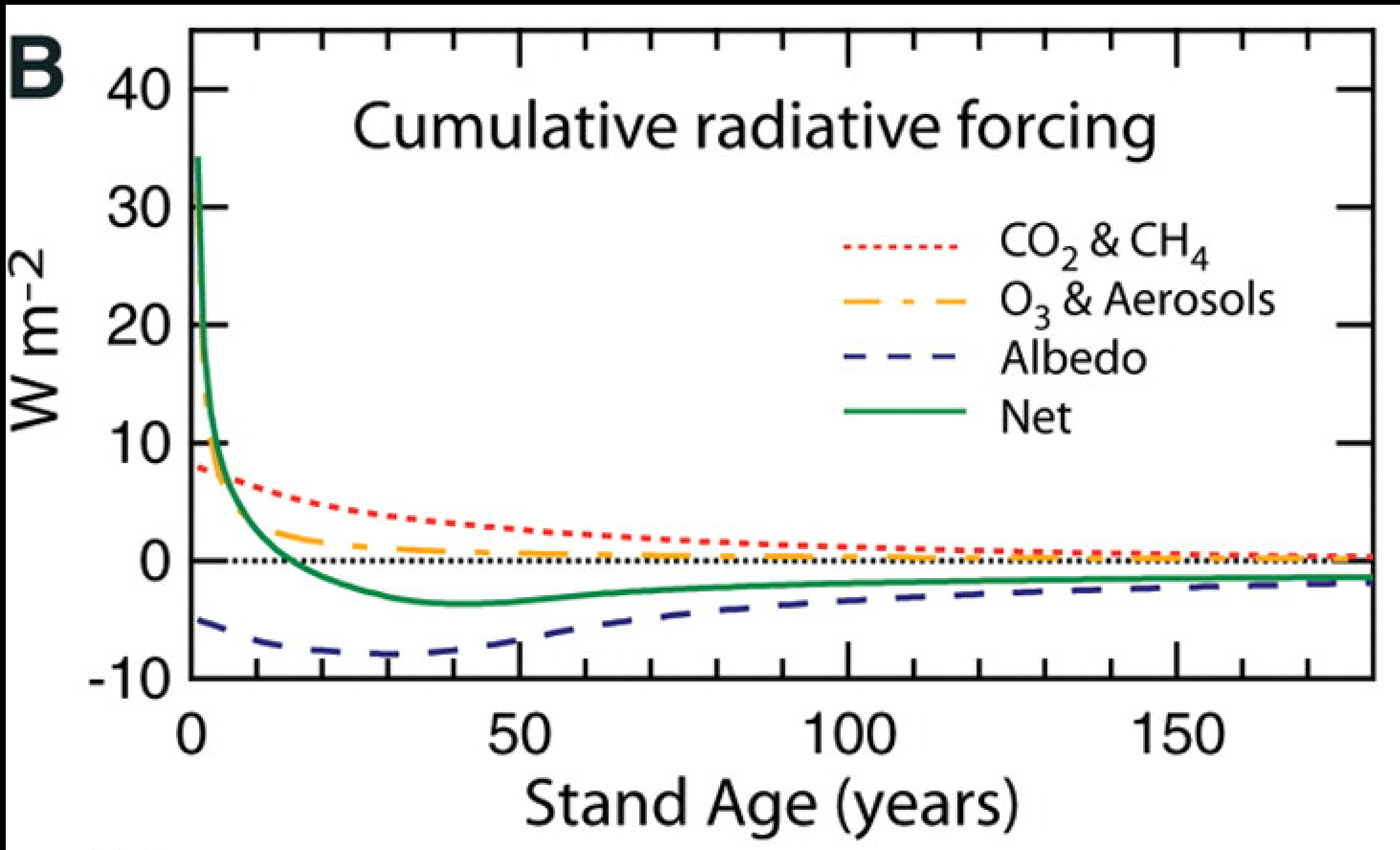
- Global carbon emissions are ~2.5 Pg C / year, but net (deforestation) emissions "only" ~0.5 Pg C / year (but uncertain) with important implications for the effectiveness of REDD programs to slow climate change

- During drought periods, humans take advantage of climatic conditions to use fire more effectively as a tool for deforestation, leading to a positive feedback between climate and fire and implicating that fires can explain part of the interannual variability in CO_2 and CH_4 growth rates

And finally: (boreal) fires and climate

Warmer

Colder



Boreal fires may actually have a cooling effect!

Randerson et al, 2006, Science

Thank you!