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Deforestation Fires Increase Amazon Forest Productivity through Changes to Diffuse Radiation

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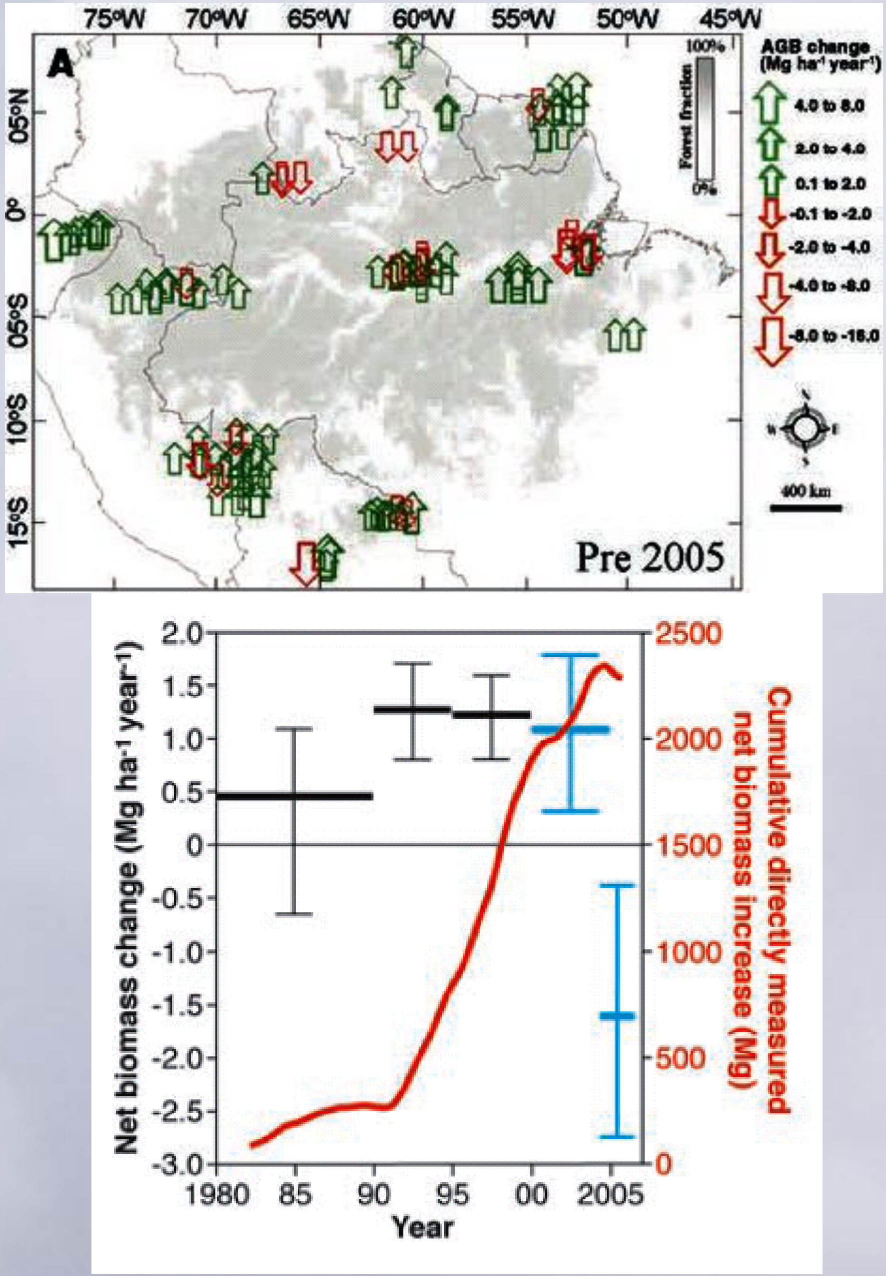
Increased Amazonian carbon storage

Increased carbon storage (0.4 Pg C a^{-1}, 5-10% of fossil fuel emissions) observed in undisturbed forests across Amazonia during the last few decades.

Cause of this important observed carbon sink remains unknown:

CO_2, temperature, cloud cover, solar radiation, rainfall....



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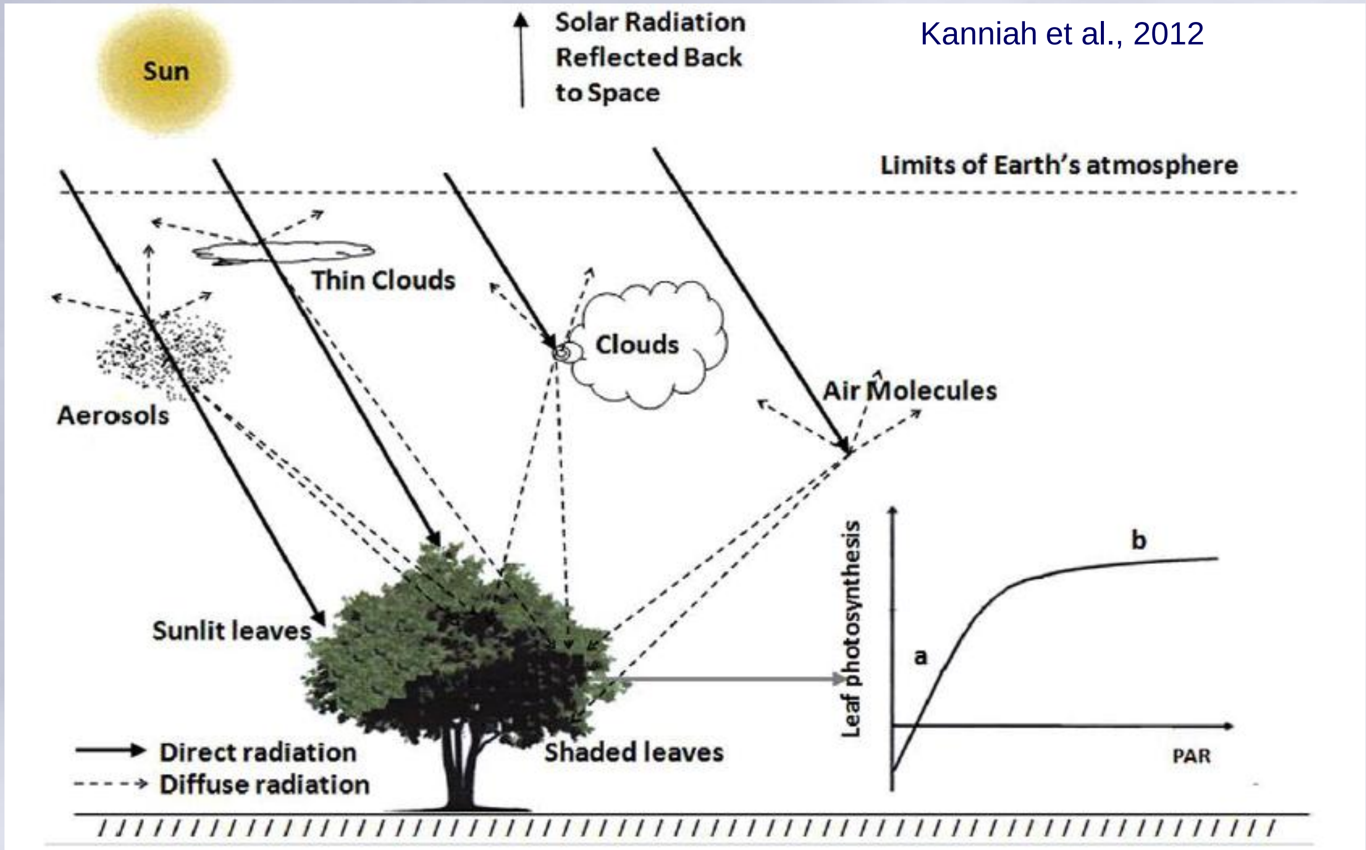
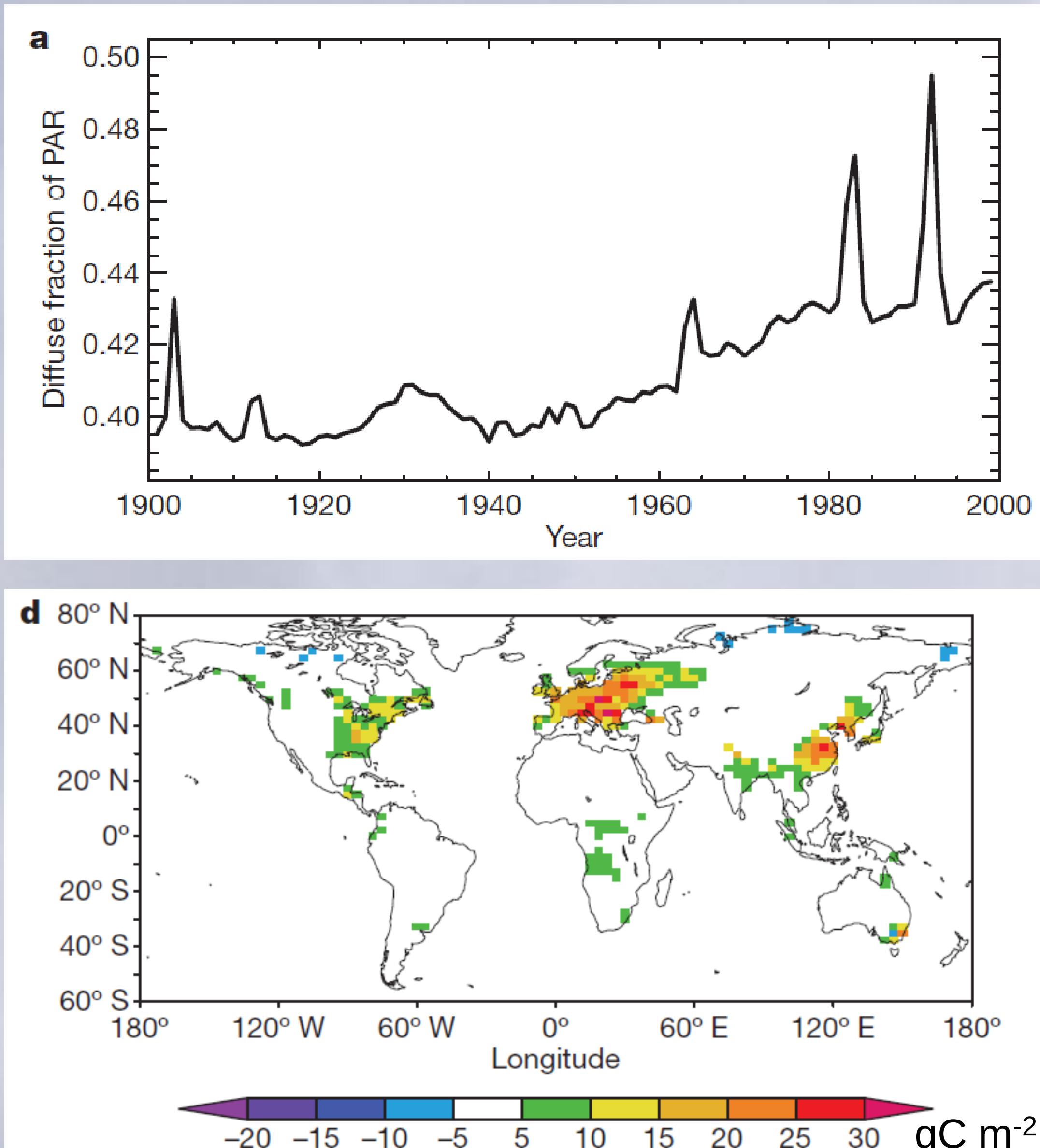
Diffuse radiation and plant productivity



Net effect on photosynthesis depends on the balance between the reduction in total radiation and increase in its diffuse fraction

Global dimming, diffuse radiation and the land carbon sink



gC m^{-2} yr^{-1}

Increases in diffuse fraction of radiation due to fossil fuel aerosol emissions have enhanced the global land carbon sink by 24% between 1960 and 1999

Mercado et al., 2009

<u>Aim</u>: to quantify the increase in plant photosynthesis due to diffuse radiation changes caused by large-scale biomass burning

Methodology

GFEDv3

Deforestation emissions

Meteorology

ECMWF

GLOMAP
(Spracklen et al., 2005)
(Mann et al., 2010)

Aerosol model

Clouds, albedo, GHGs

ISCCP, ECMWF

Radiation model

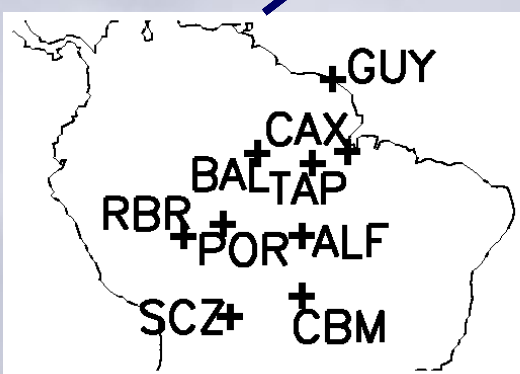
Edwards-Slingo
(Edwards & Slingo, 1996)
(Rap et al., 2013)

EU WATCH

Meteorology

Land-surface model

JULES
(Mercado et al., 2007)
(Best et al., 2011)
(Clark et al., 2011)



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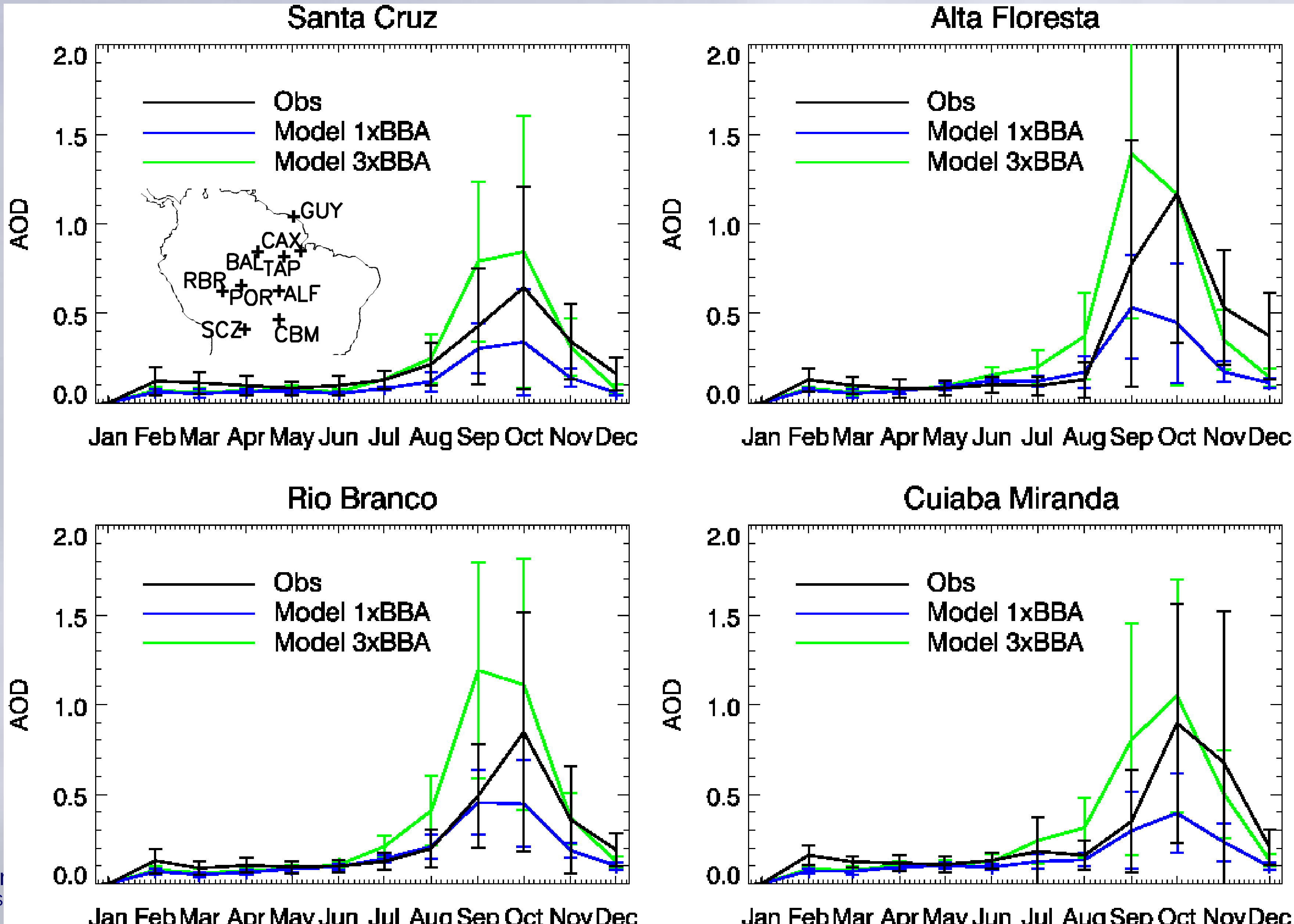
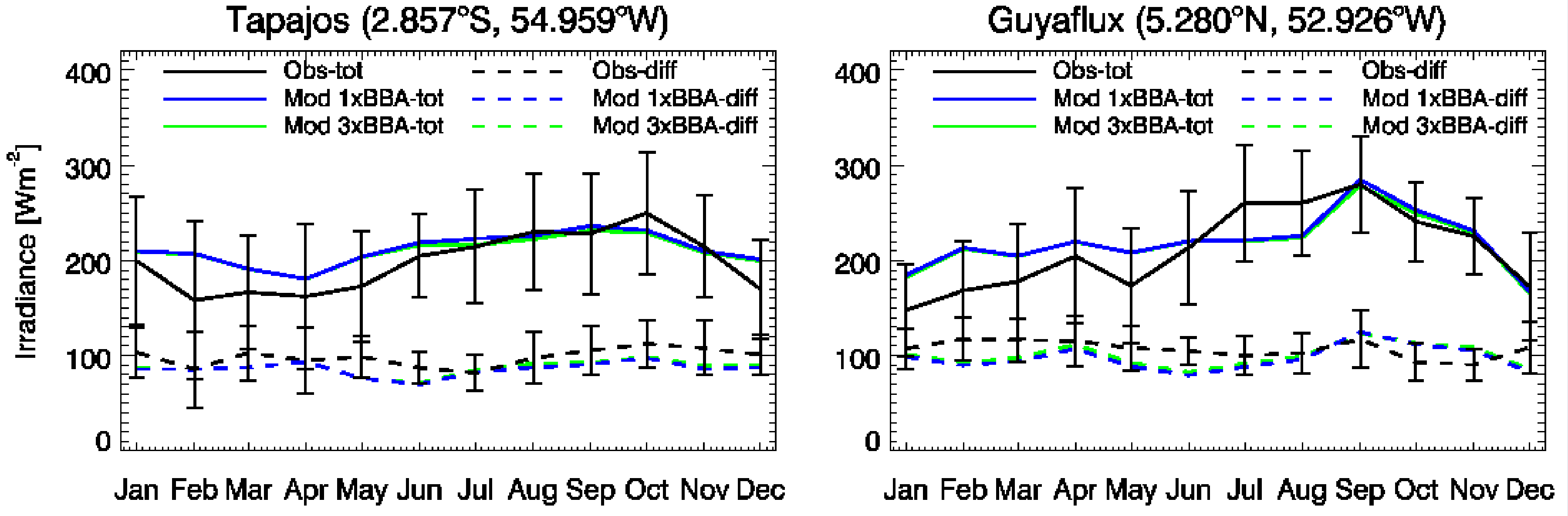
Evaluation of Aerosol Observational Depth



Evaluation of radiation & GPP

- **Radiation and GPP measurements**:
  - Tapajos: 2002-2005, every 60 mins
  - Guyaflux: 2006-2007, every 30 mins

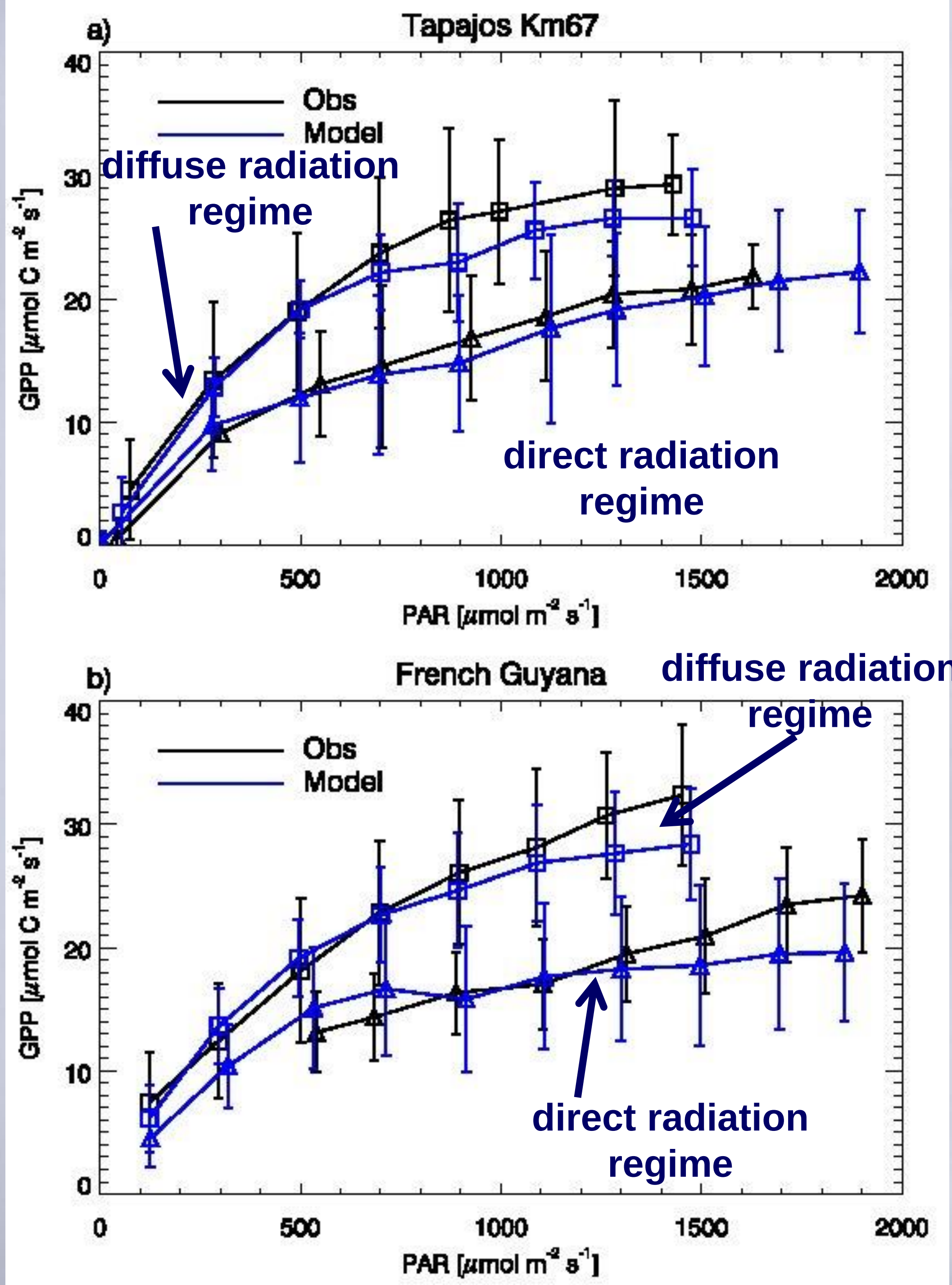


Evaluation of simulated GPP as a function of PAR

Plant productivity increases with irradiance

Photosynthesis is more efficient under diffuse light

JULES captures key properties



Simulations

- Period covered: 1998-2007
- 5 simulations:
  - Control case: everything ON
  - No deforestation fires
  - No biomass burning aerosol (BBA)
  - 3×BBA
  - 6×BBA

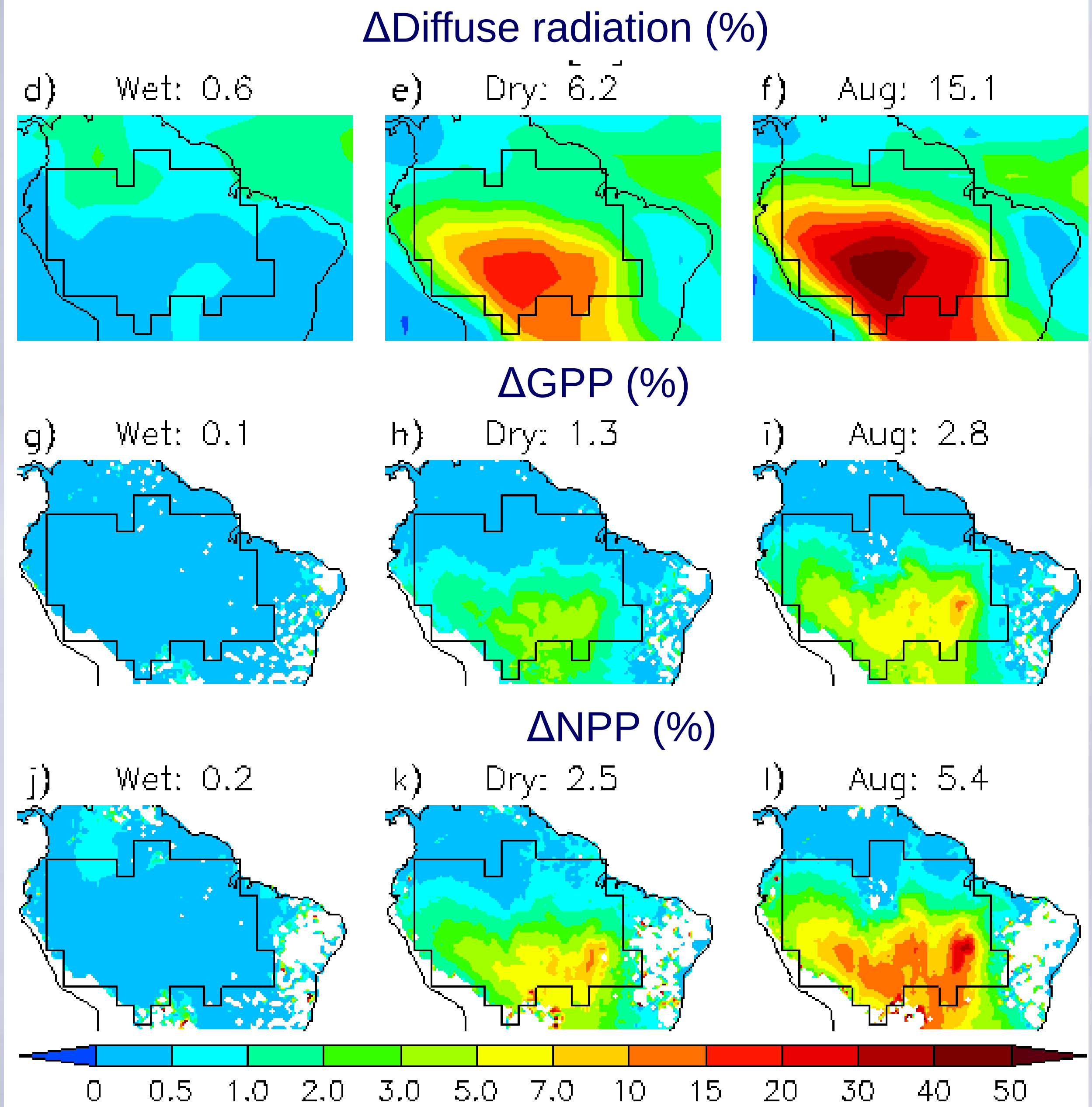
Large regional impact of fire smoke

Regional increases:
- 50% in diffuse radiation
- 7% in GPP
- 15% in NPP

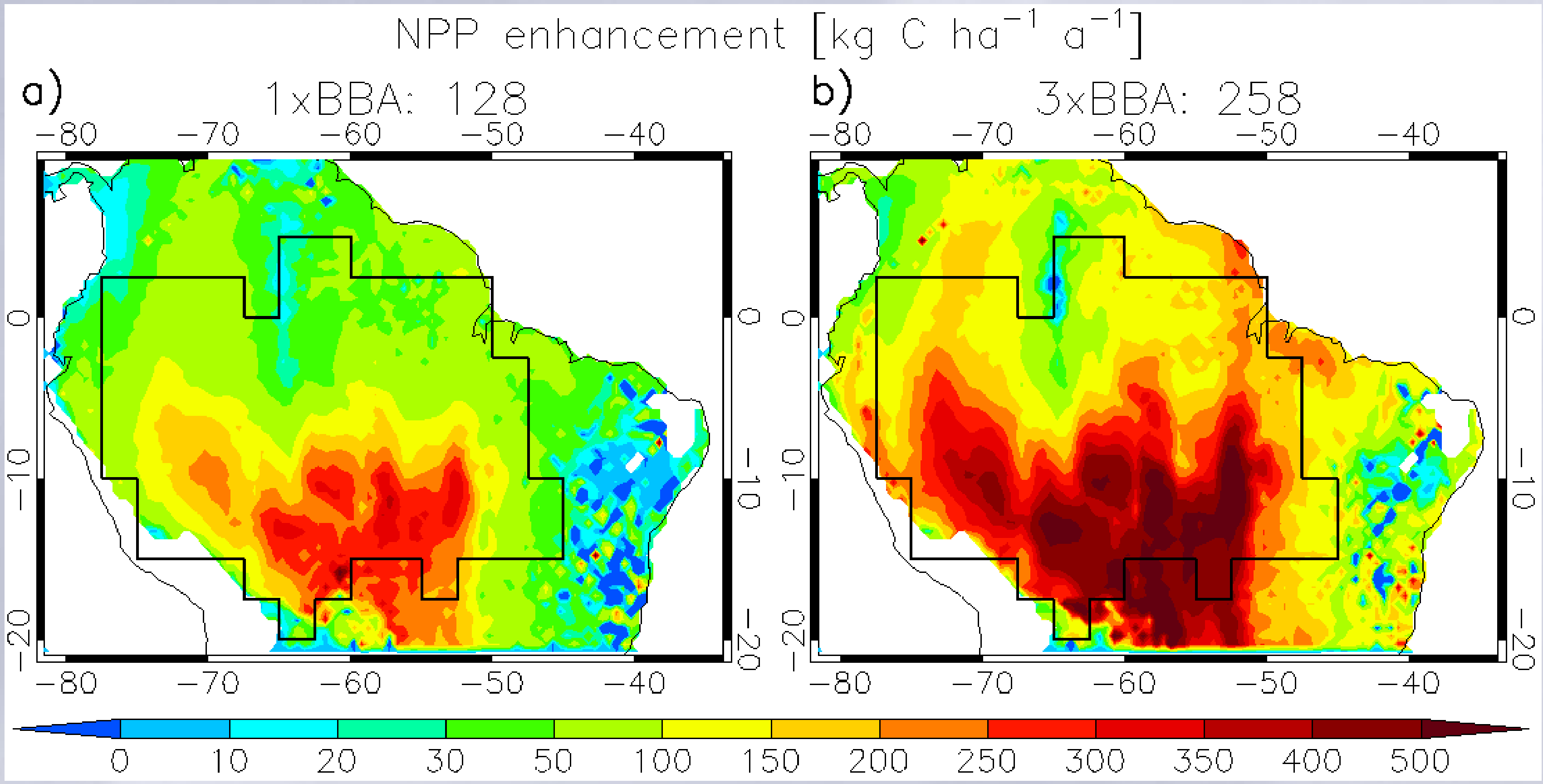
• Basin-wide annual mean increases:
- 3–7% in diffuse radiation
- 0.8 - 1.6% in GPP
- 1.4 - 2.8% in NPP

• For comparison, the annual CO_2 fertilization effect:
- 0.3% increase in GPP
- 0.6% increase in NPP

Dry: Jun-Nov
Wet: Dec-May



NPP enhancement due to diffuse radiation



Amazon-basin NPP enhancement estimated at 78 - 156 Tg C a^{-1}

Offsets 25-35% of the annual rate of carbon loss from fire emissions

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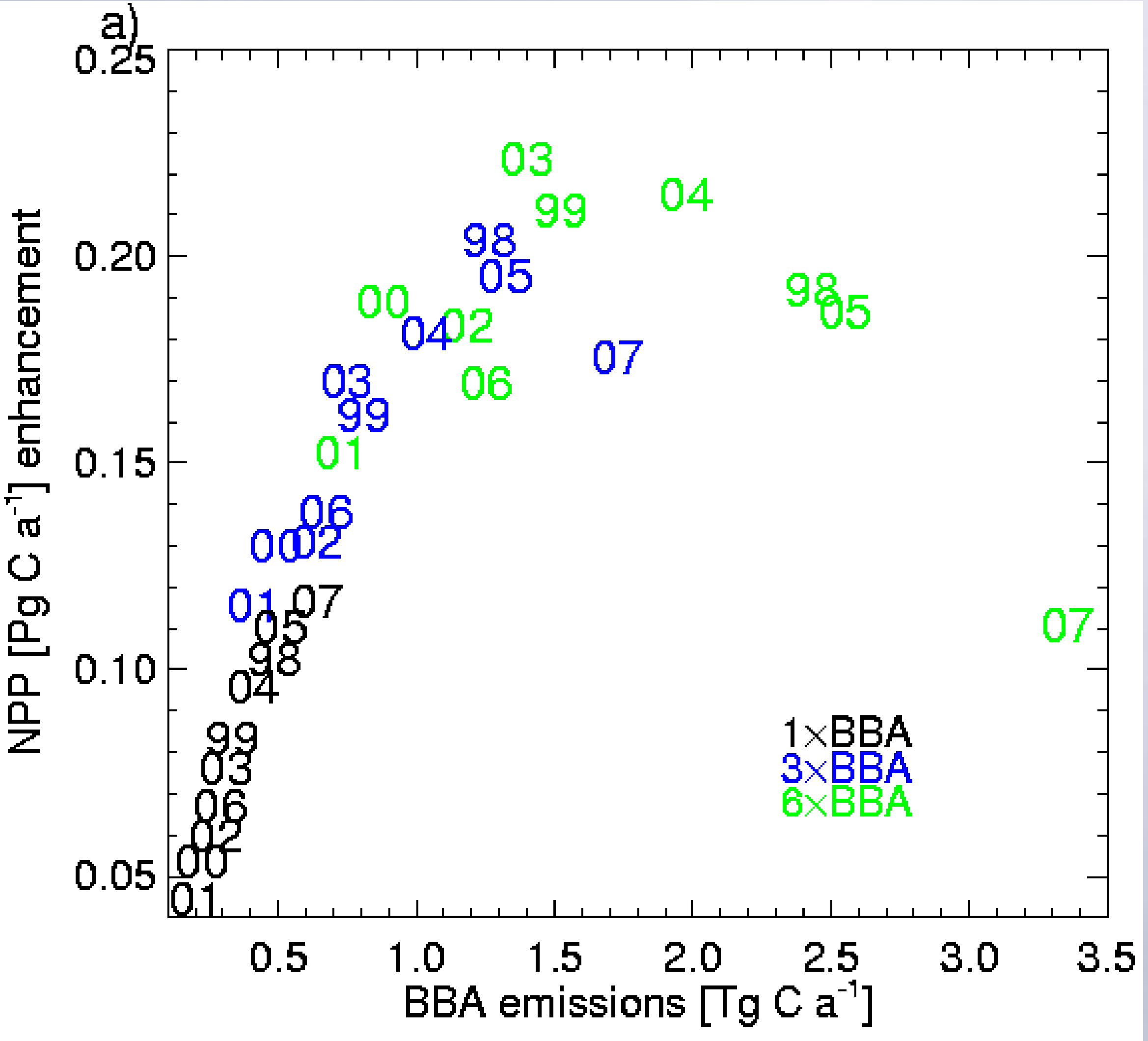
Non-linear relationship between aerosol emission and enhancement to NPP



Conclusions

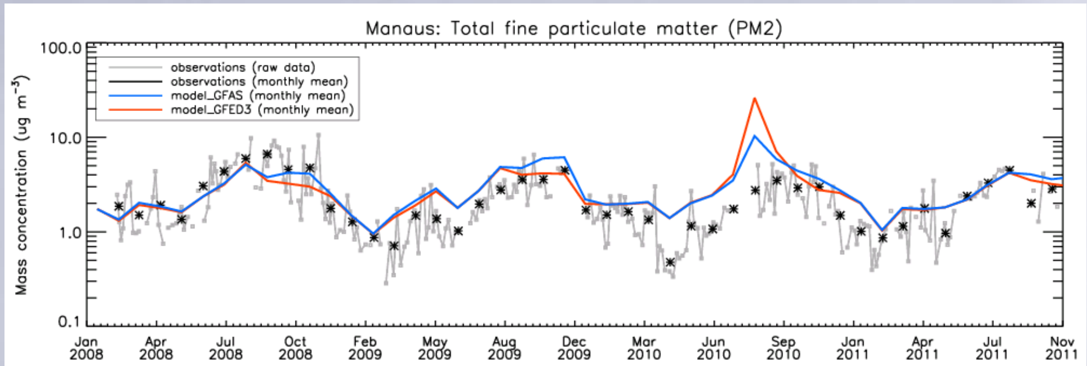
• Deforestation fires have increased diffuse radiation increasing dry season NPP by 7-15% (1-3% basin wide annual mean).

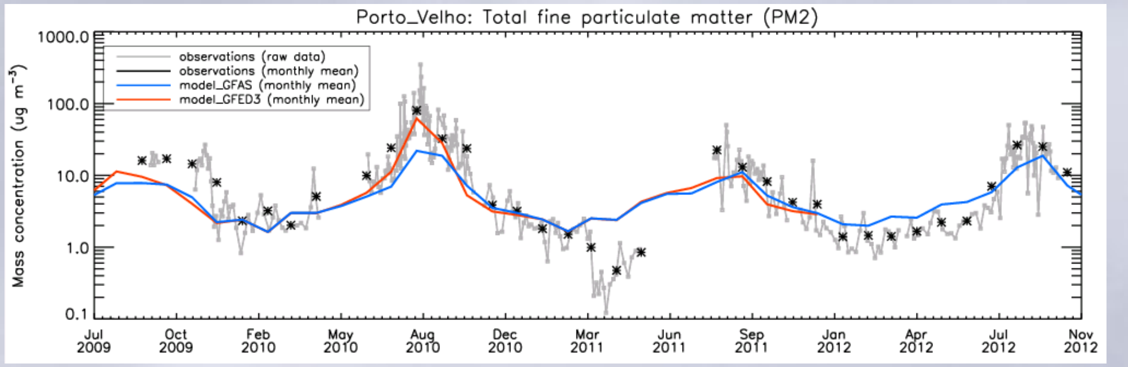
• Amazon-basin NPP enhancement is 78-156 Tg C a^{-1} offsetting 25-35% of the carbon loss from fire emissions.

• Accounts for 8-16% of the observed carbon storage increase across mature Amazonian forests.

Rap et al., Fires increase Amazon forest productivity through changes to diffuse radiation, submitted.

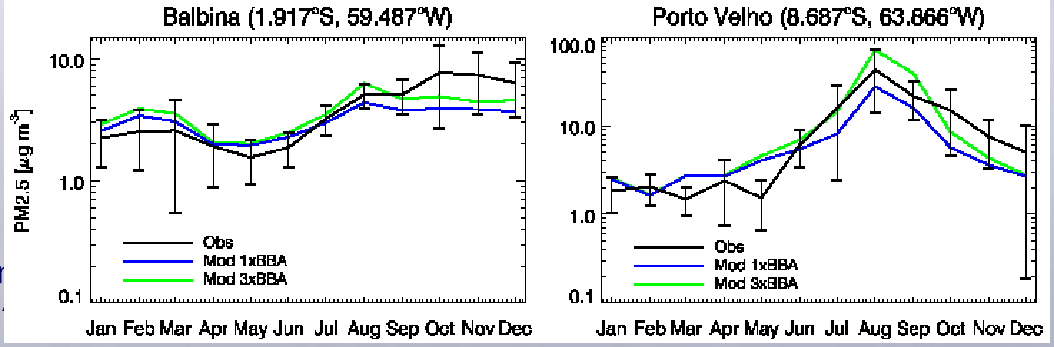
Evaluation of GLOMAP over the Amazon





Porto Velho:
r^2 PM2 model (GFED) = 0.91

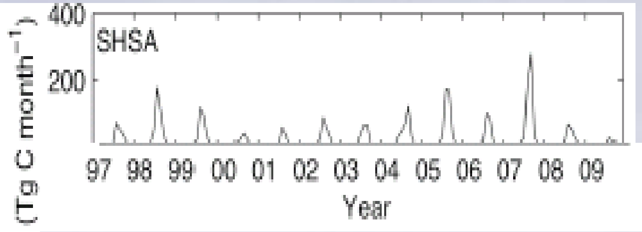
- The model captures the inter-annual and seasonal cycles of PM2.5



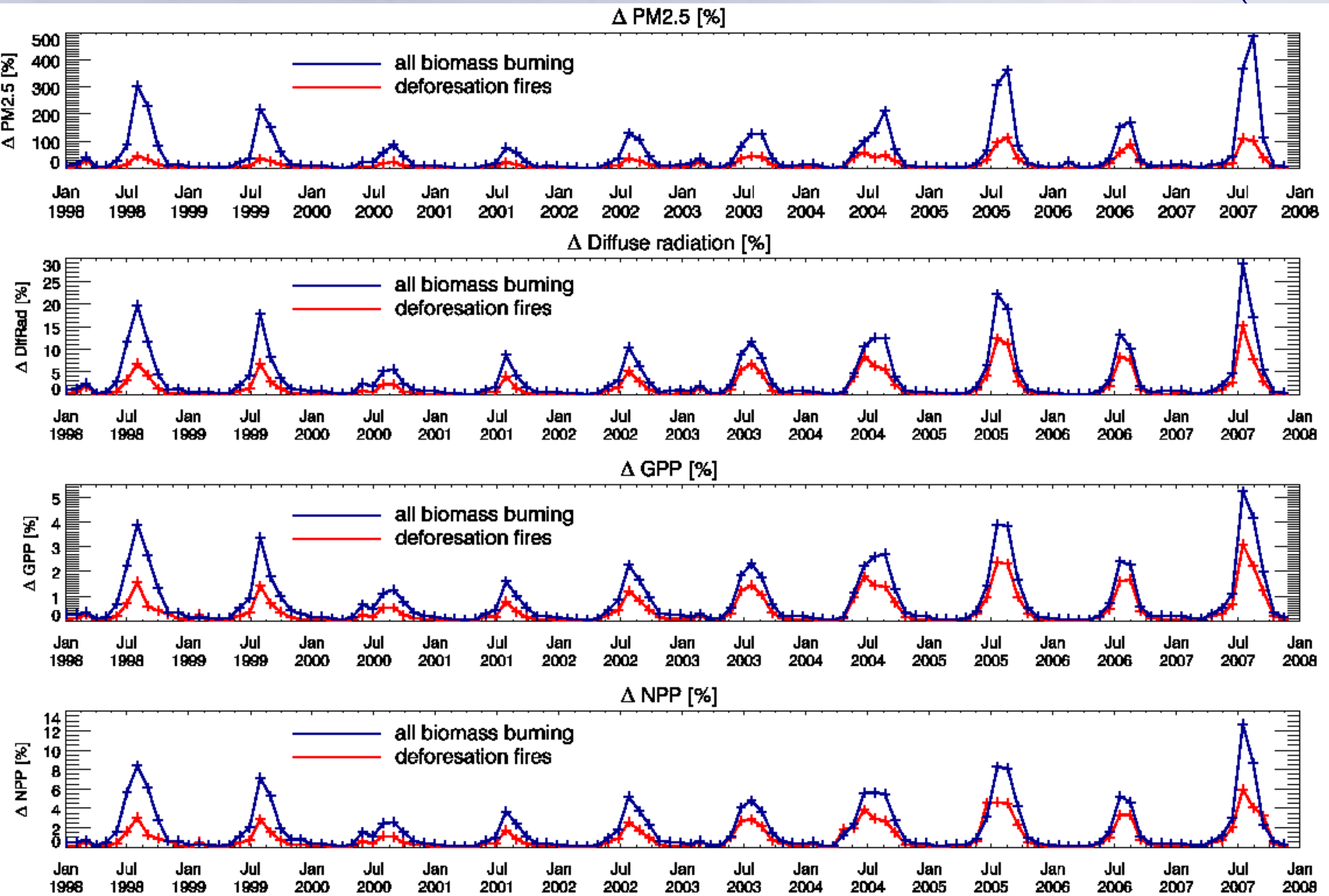
Results: Inter-annual variation

- 1998, 2005, 2007: years of large deforestation fires

Monthly fires emission



(van der Werf, ACP, 2010)



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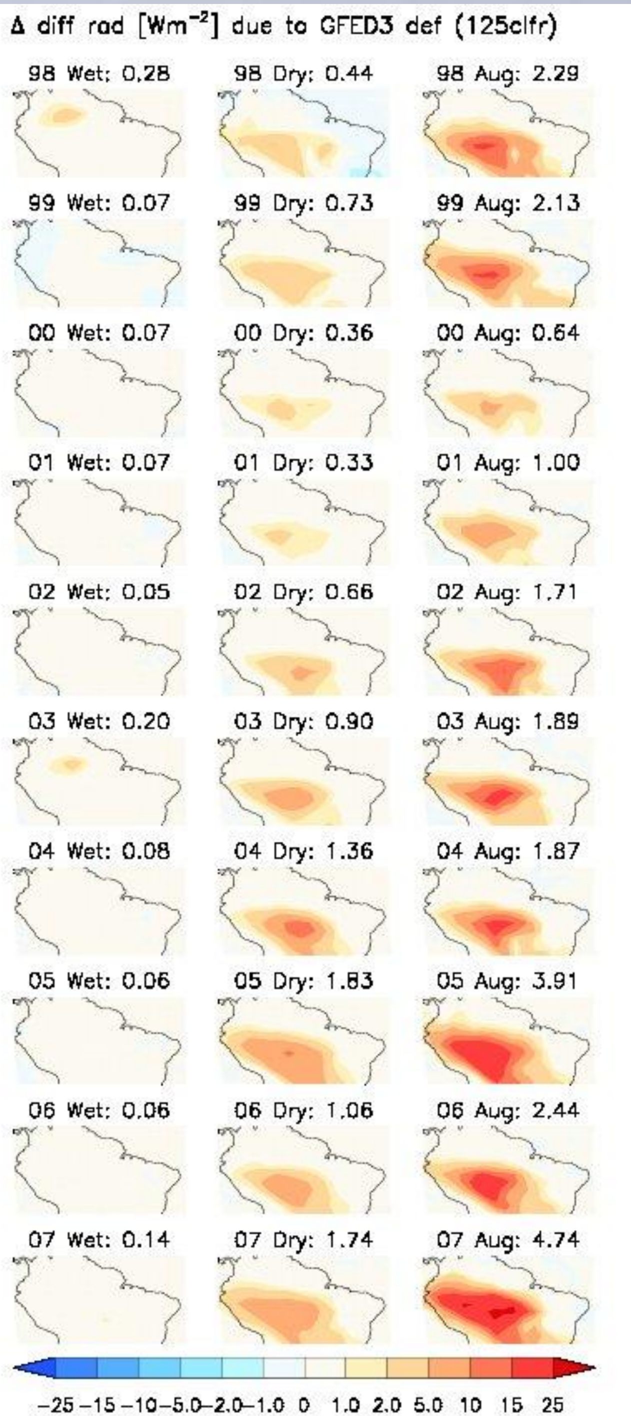
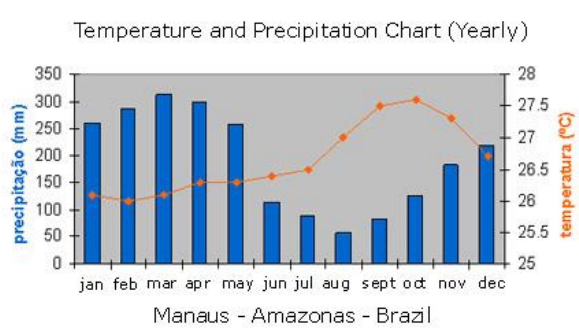
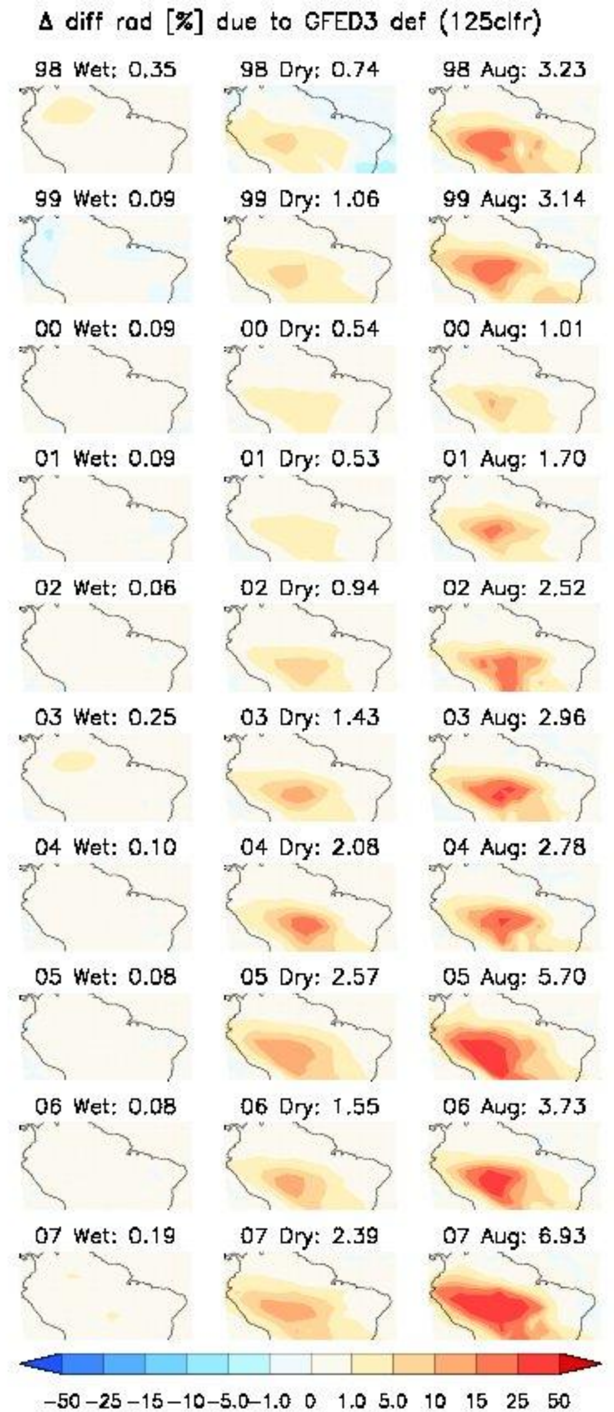


Diffuse radiation change due to deforestation

- substantial increases in diffuse radiation in the dry season
- more than 25 Wm^{-2} local increases in Aug

<u>Dry</u>: Jun-Nov
<u>Wet</u>: Dec-May





Results

Dry: Jun-Nov
Wet: Dec-May

- virtually no effect during the wet season (emission seasonal cycle and cloud masking)

- substantial increases during the dry season

- In August, local increases of:
  - 30% in diffuse radiation
  - 5% in GPP
  - 10% in NPP