School of Earth and Environment
INSTITUTE FOR CLIMATE & ATMOSPHERIC SCIENCE

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Plant productivity response to diffuse radiation changes caused by secondary organic aerosol

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NERC SCIENCE OF THE ENVIRONMENT

Biogenic Secondary Organic Aerosol

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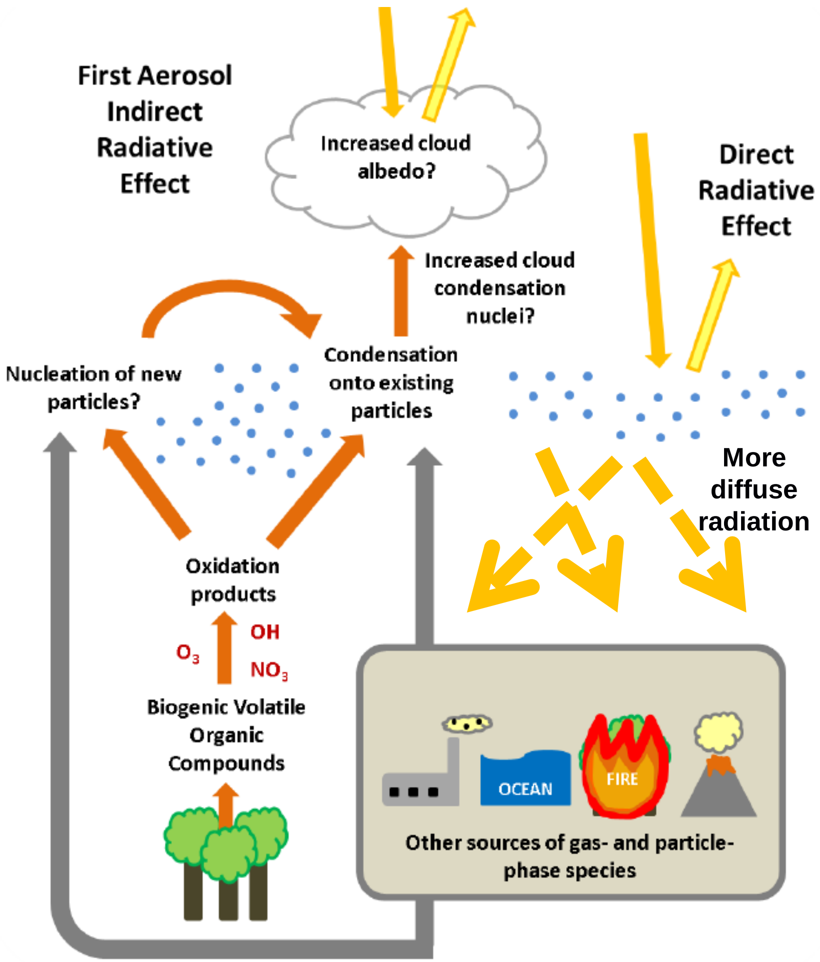
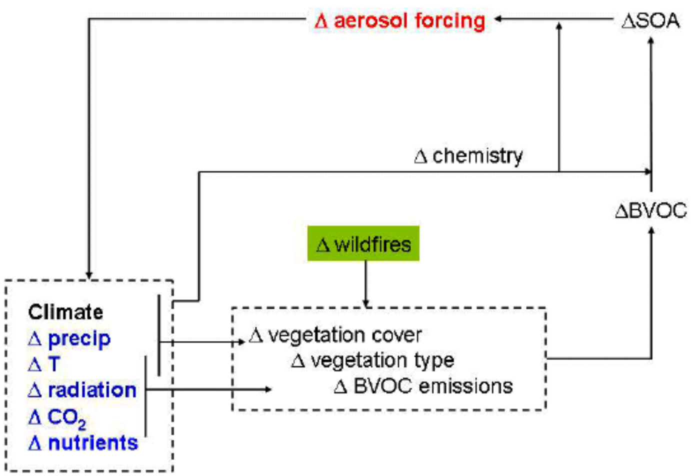
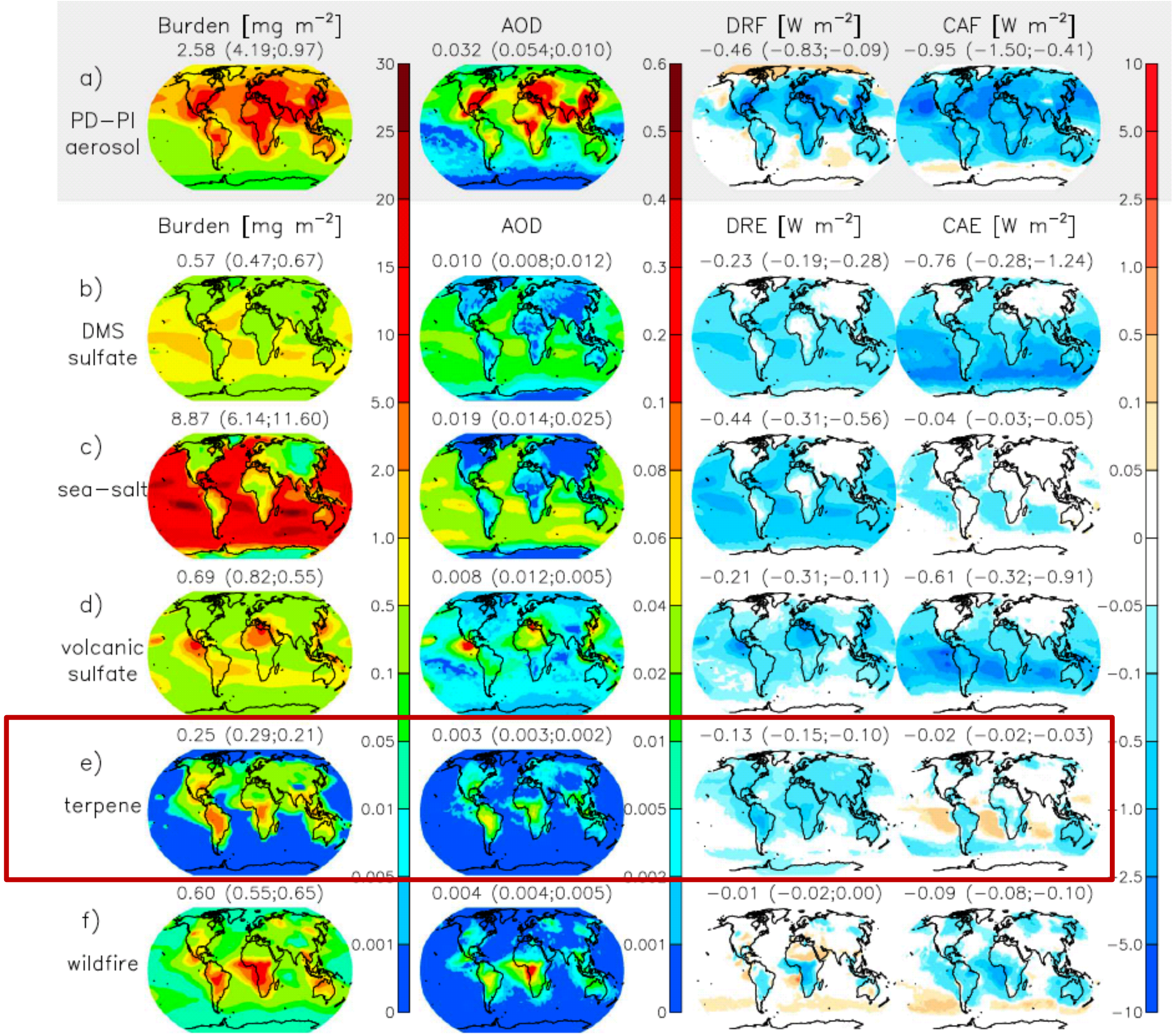


(Scott et al., ACP, 2014)



(Carslaw et al., ACP 2010)

Radiative effects of natural aerosol



(Rap et al., GRL, 2013)

Biogenic Secondary Organic Aerosol (SOA)

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(Scott et al., ACP, 2014) looked at direct and first indirect effect from SOA, including both isoprene and monoterpenes

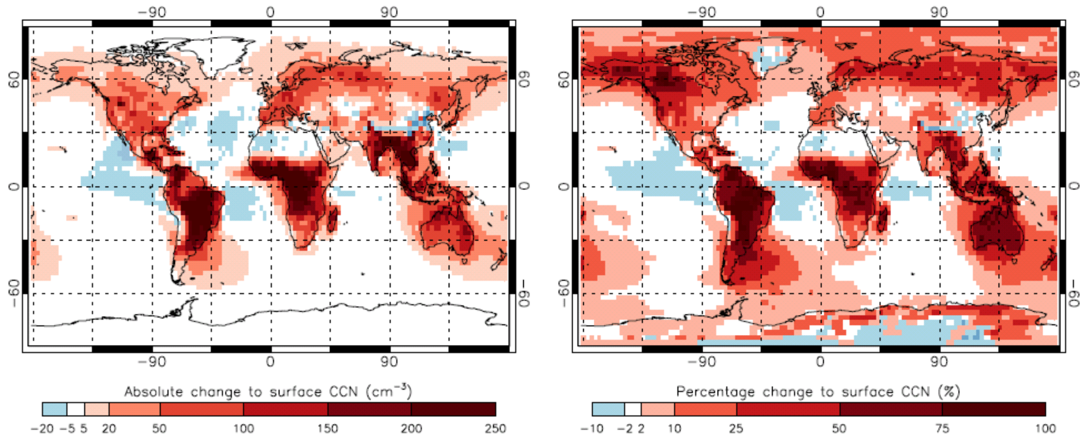


Fig. 1. Simulated annual mean absolute (left) and percentage (right) change to surface cloud condensation nuclei (CCN) numb tration, calculated at 0.2 % supersaturation, resulting from the emission of both monoterpenes and isoprene when the ACT mec

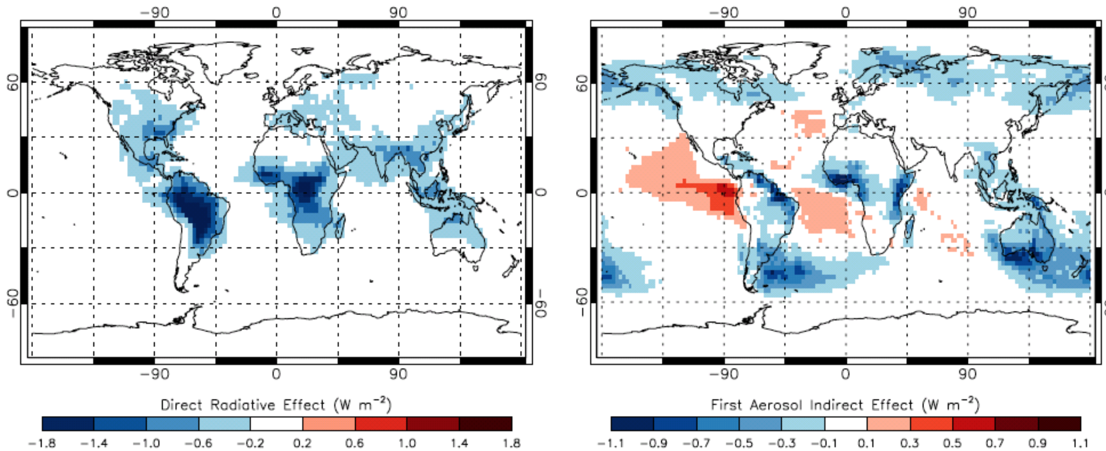
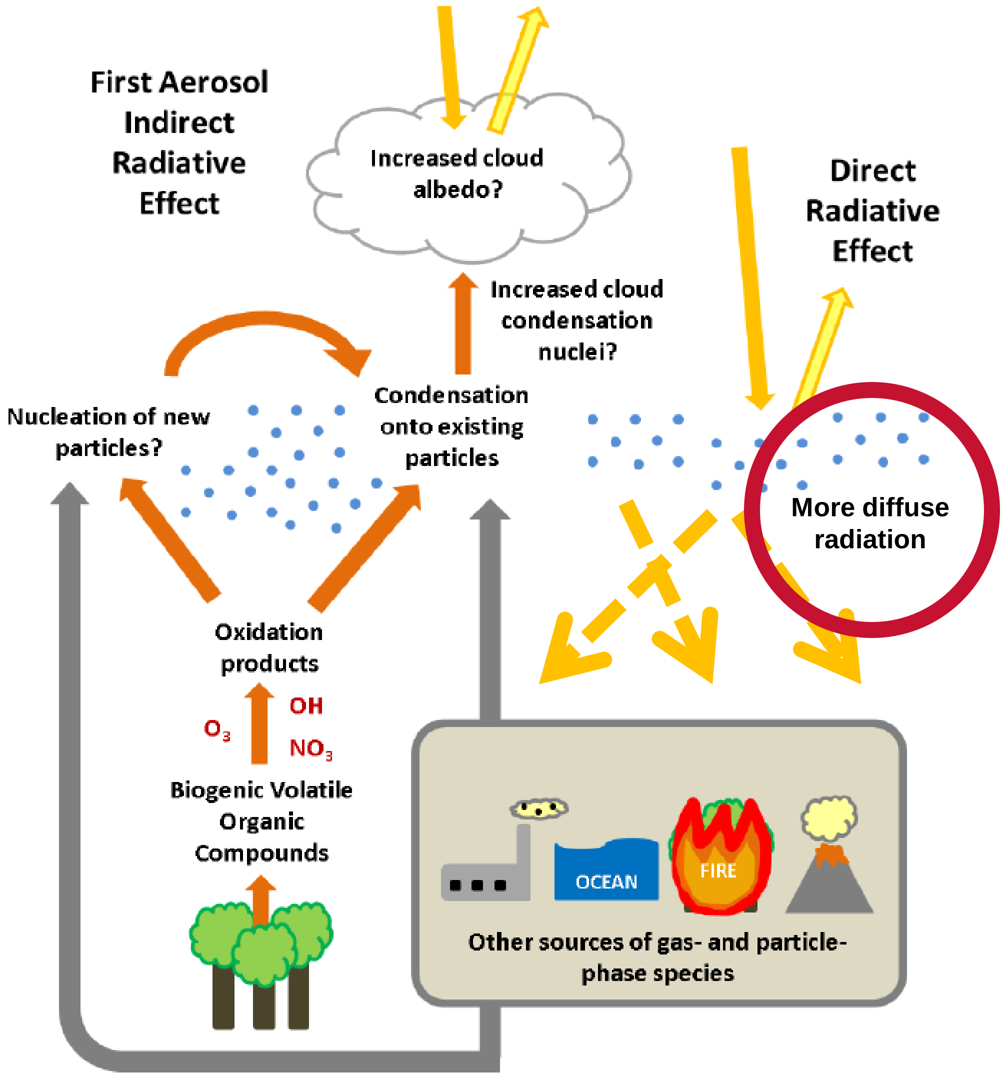


Fig. 7. Annual mean all-sky DRE (left), and first AIE (right) associated with the perturbation in cloud droplet number concentration. biogenic SOA (expt. 4) relative to an equivalent simulation with no biogenic SOA (expt. 1).

This work



How does SOA affect plant productivity via changes in the surface radiation regime?

Diffuse radiation and plant productivity

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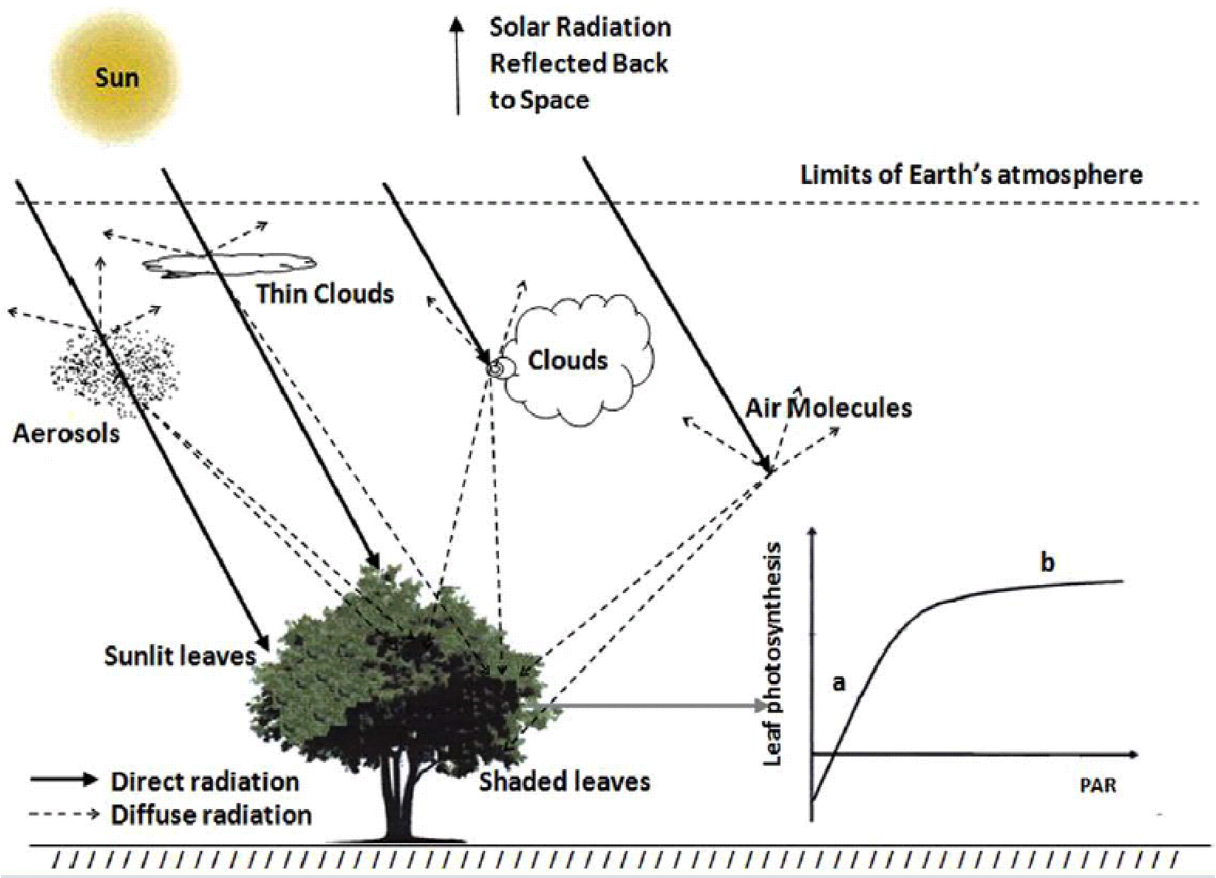

(Kanniah et al., *Progress Phys. Geog.*, 2012)

- plant productivity increases with irradiance
- photosynthesis is more efficient under diffuse light

Changes in radiation have a net effect on photosynthesis that depends on the balance between the reduction in total radiation and the increase in its diffuse fraction

Global dimming and the land carbon sink

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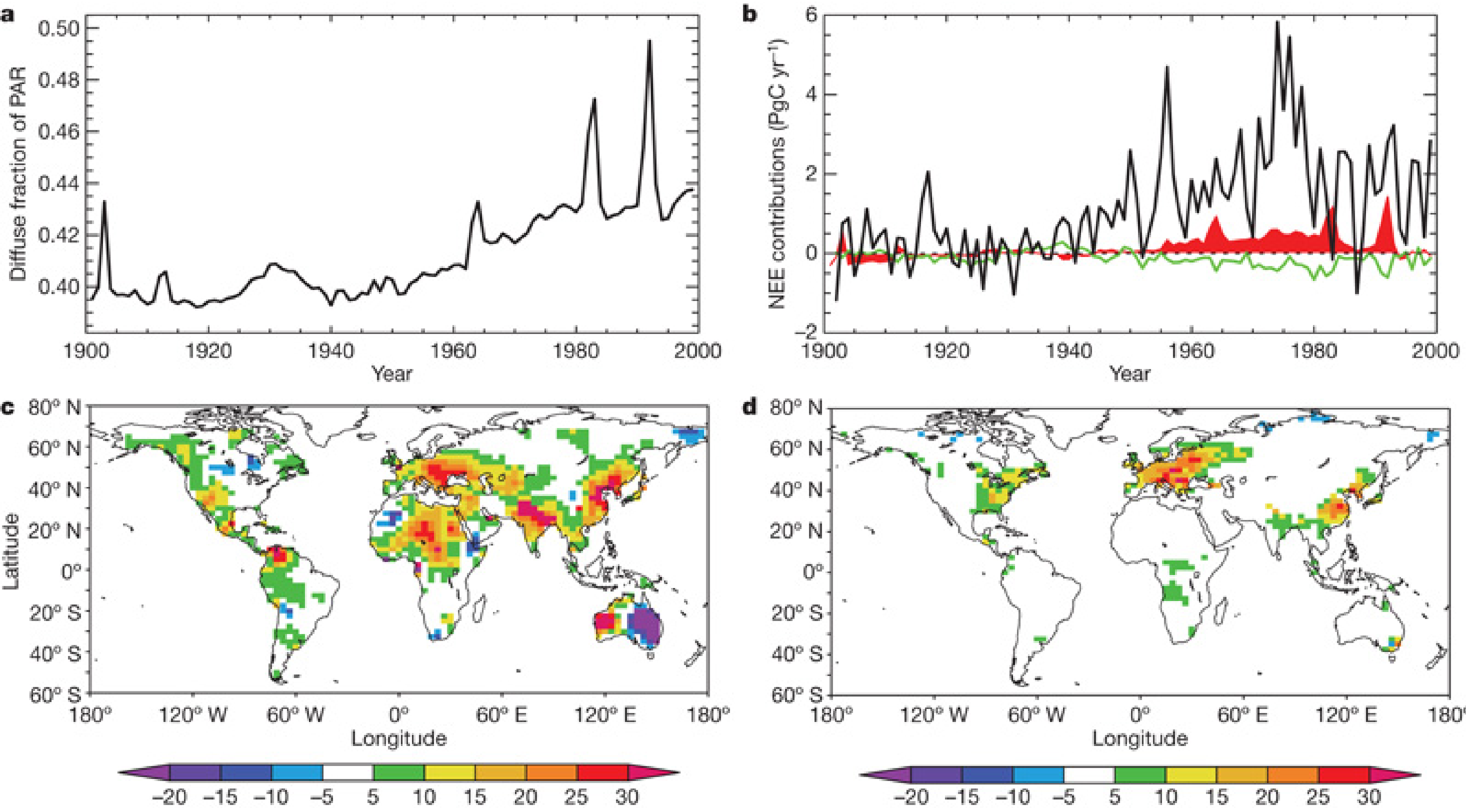

- a) increase in diffuse fraction during the 20th century
- b) the diffuse fraction increase influence on land carbon sink becomes important after 1950
- c) 1950-1980 changes in diffuse fraction
- d) 1950-1980 impact on regional land sink
- increases in diffuse fraction have enhanced the global land carbon sink by 24% between 1960 and 1999

(Mercado et al., Nature, 2009)

Biomass burning and plant productivity

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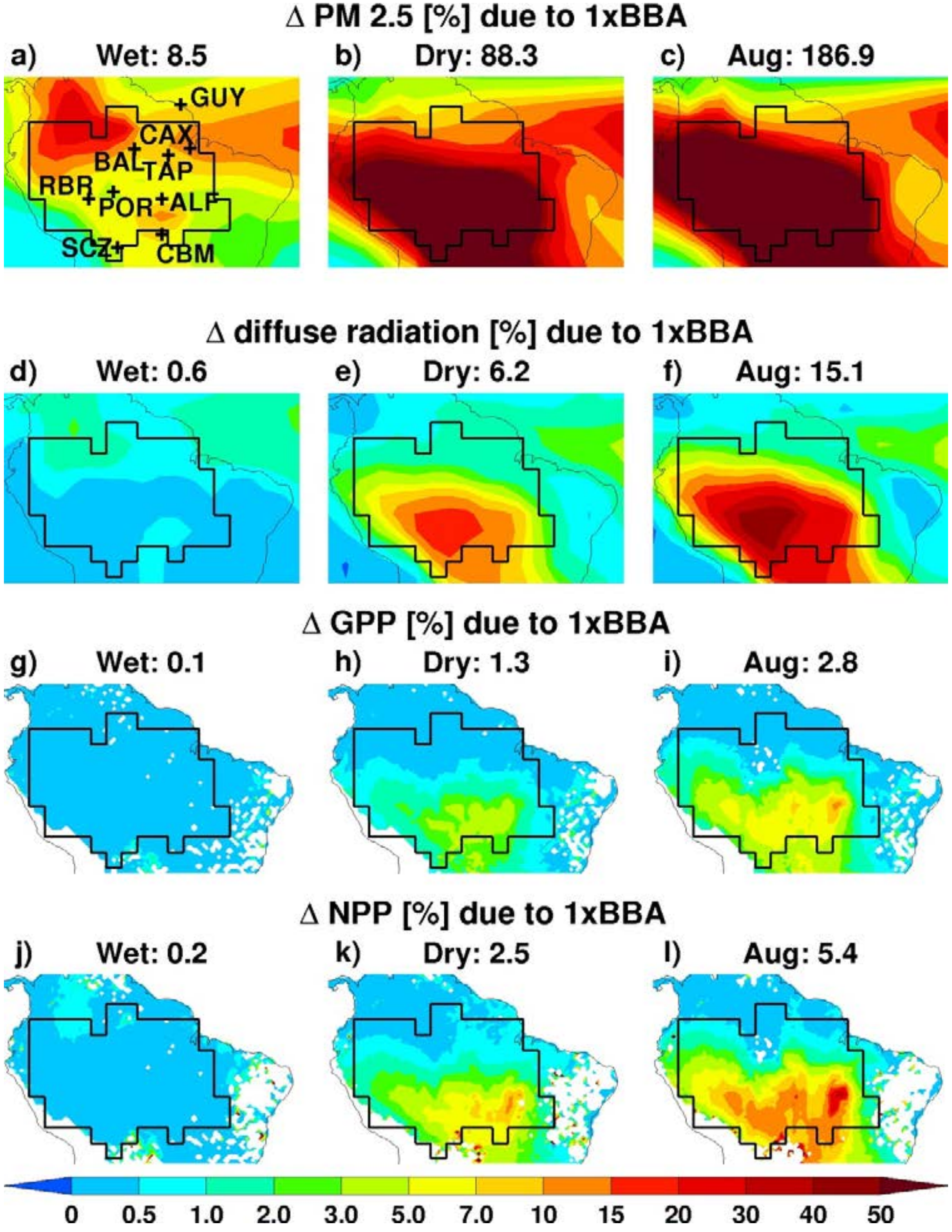

Amazon-basin NPP enhancement due to diffuse fertilisation from BBA estimated at 78 - 156 Tg C a^{-1}

- offsets 33-65% of the annual rate of carbon loss from fire emissions

- offset fraction from 40-50% in low fire years to 25-30% in large fire years

- diffuse radiation fertilisation efficiency seems to saturate at ~ 1.5 Tg C a^{-1} BBA emissions

- diffuse radiation fertilisation mitigates ~40-50% of the moisture generated decline in NPP in dry years

[Rap et al, GRL, 2015]

Methodology

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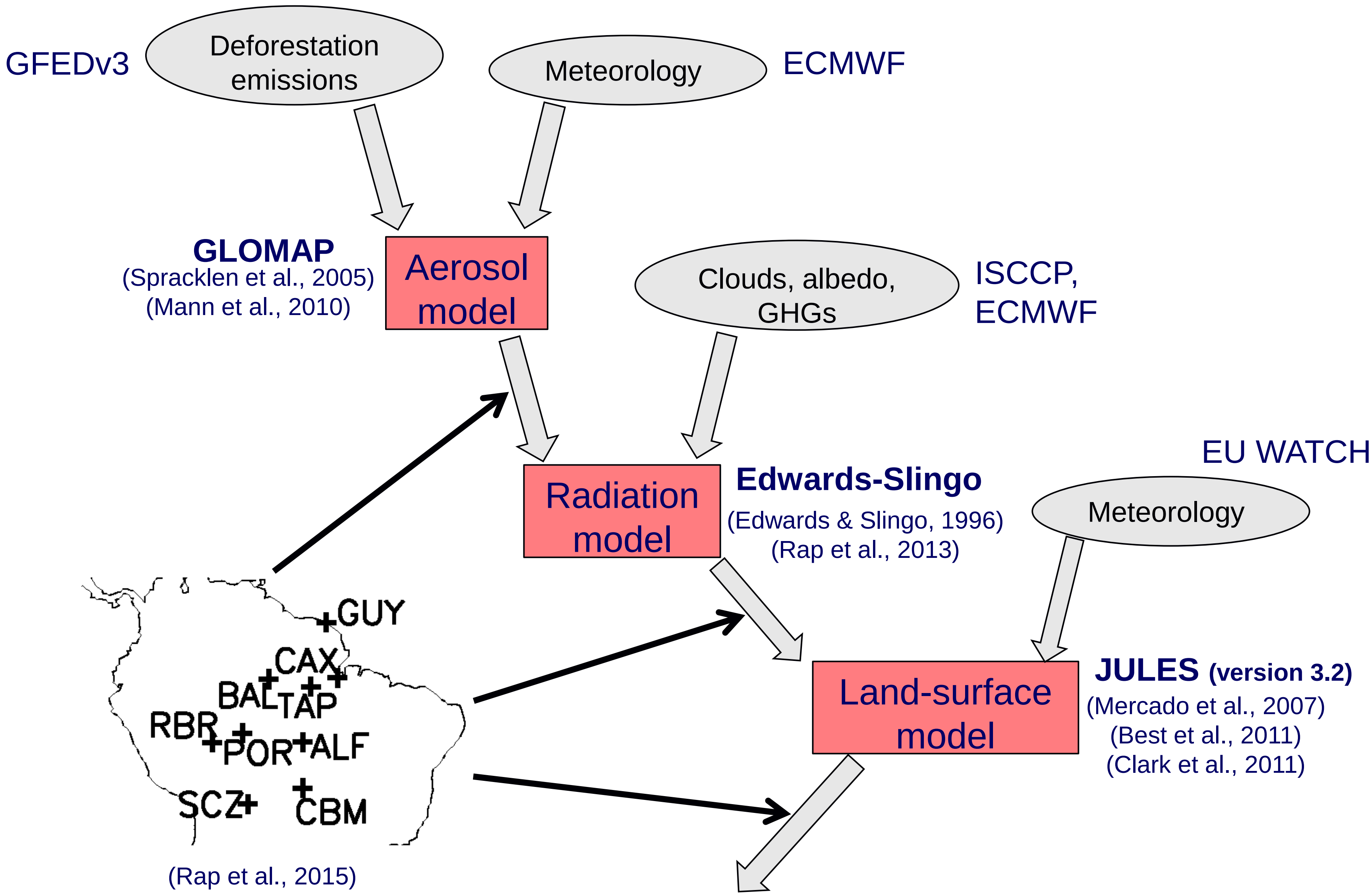

GPP response to PAR regimes

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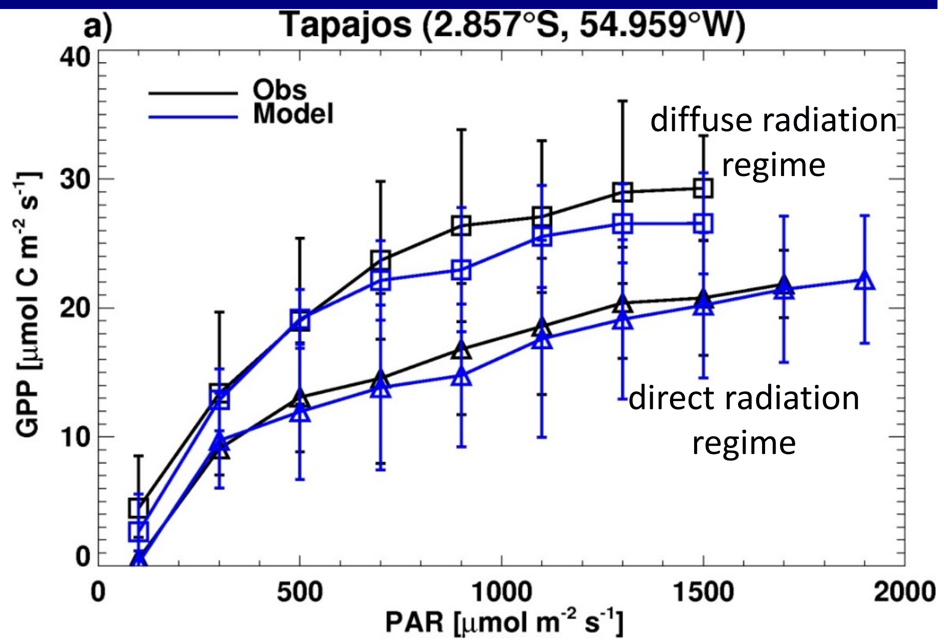
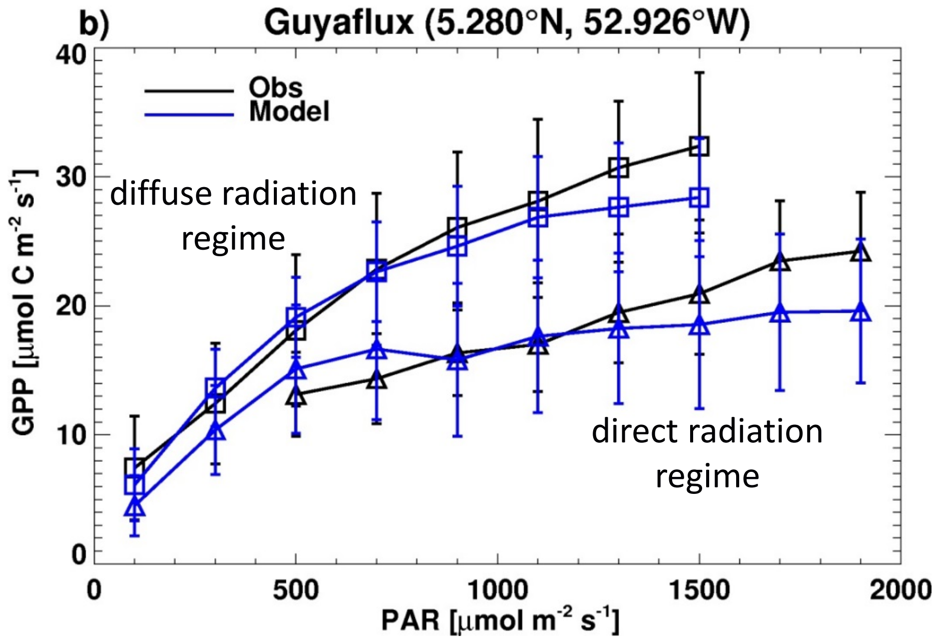
Model and observations

• GPP increases with increased PAR, saturating at high PAR

• for the same amount of PAR, both observed and simulated GPP are increased by ~45% under diffuse compared to direct light conditions

• the model simulates the observed increase in photosynthesis in tropical forests of the Amazon basin under diffuse sunlight.





[Rap et al, GRL, 2015]

Evaluation of SOA emissions

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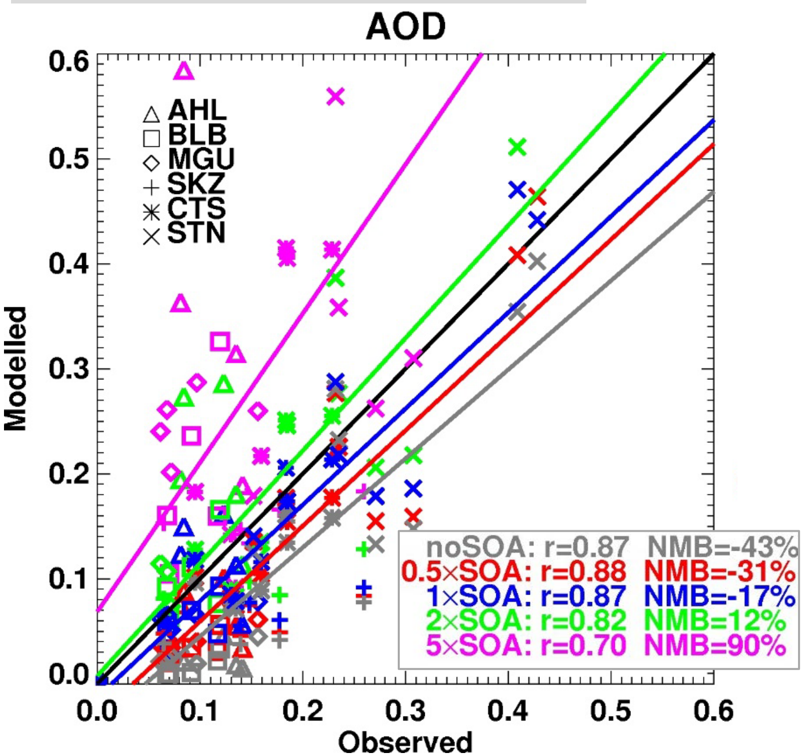
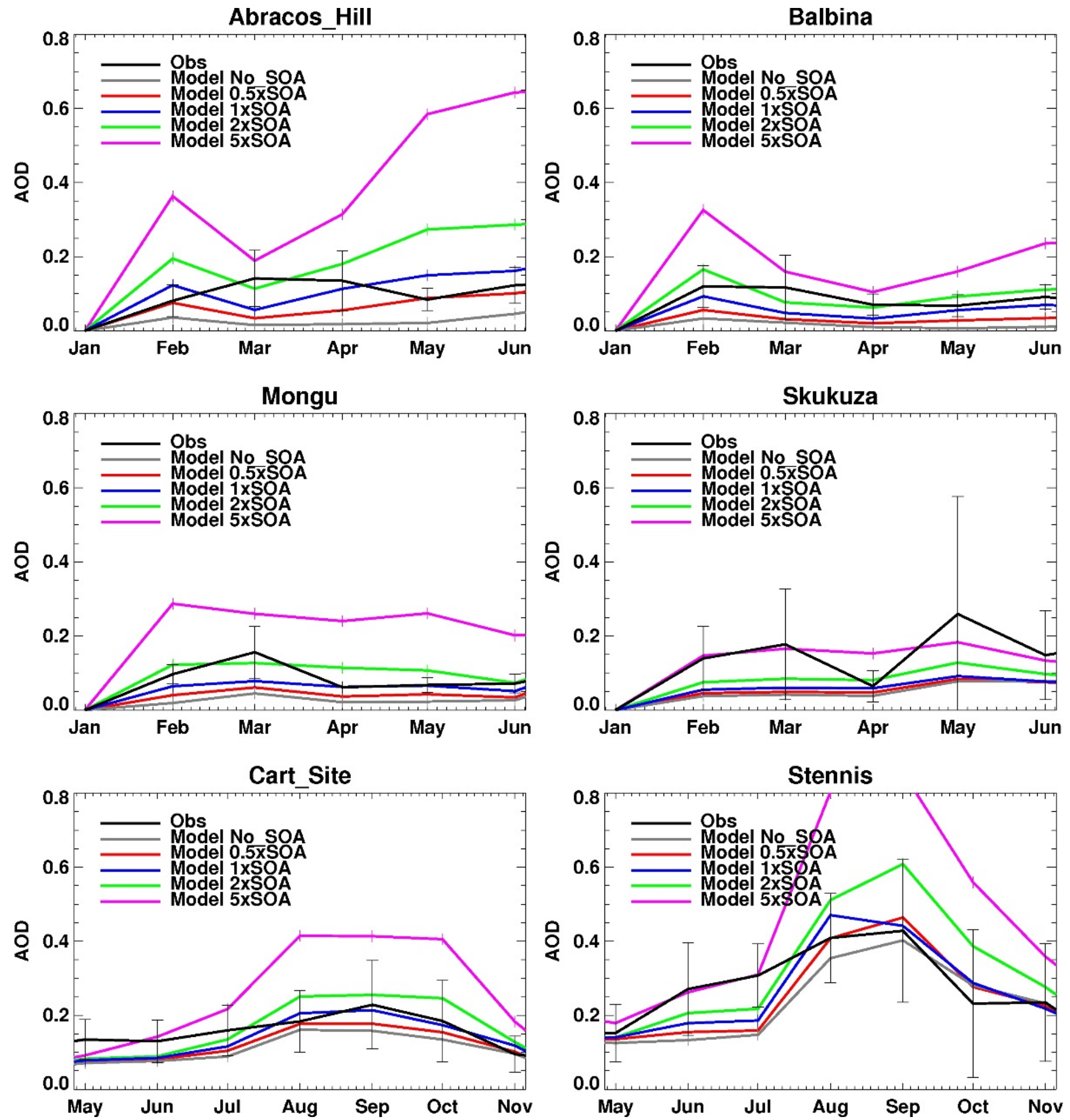
CCN

Simulation		NMB (%) against subset of CCN dataset
	No SOA	−44.4
	0.5 × SOA	−16.4
	SOA	−16.0
ACT	2 × SOA	−16.7
	5 × SOA	−17.2

[Scott *et al.*, 2014]





Seasonal SOA changes on radiation

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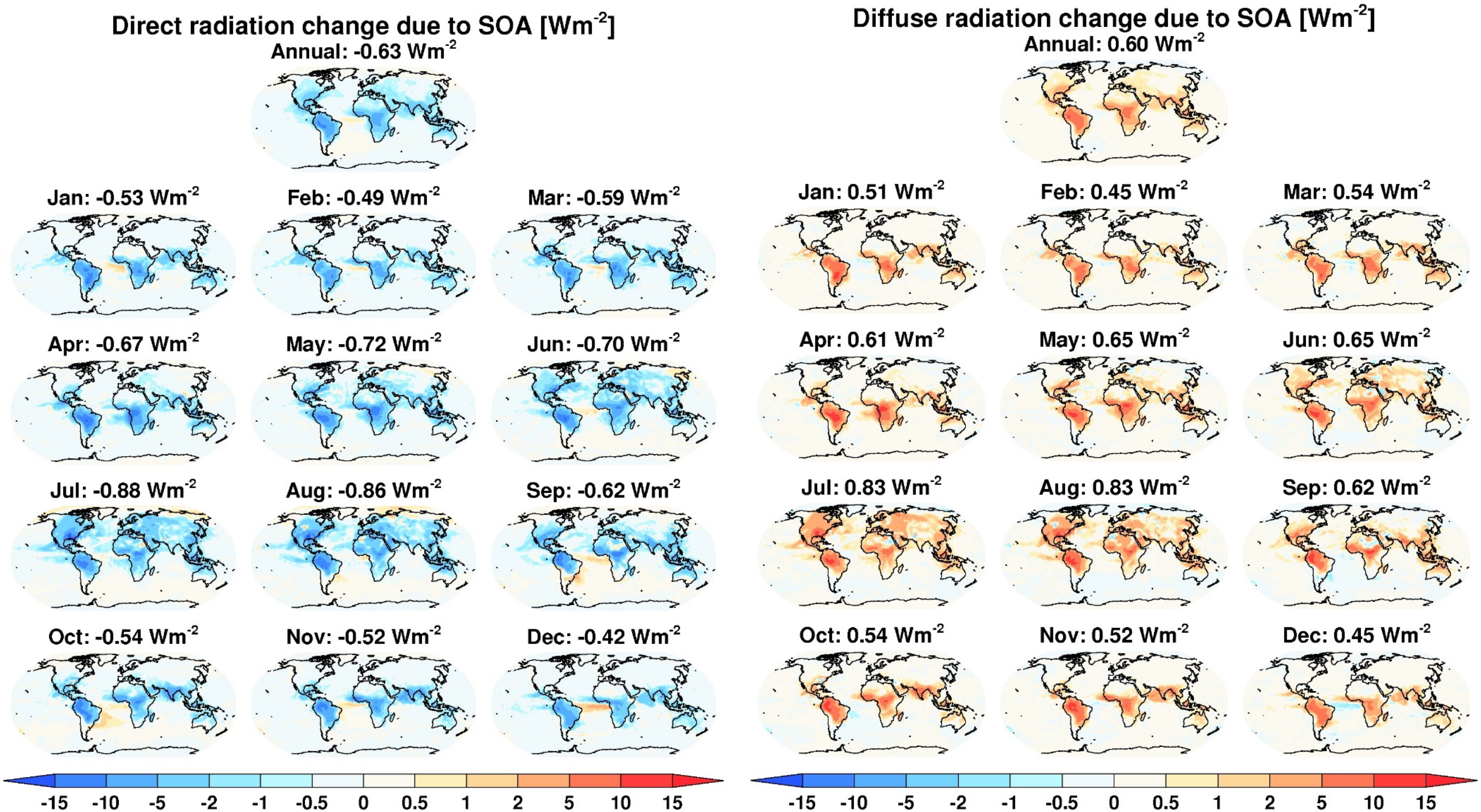

SOA changes on surface radiation

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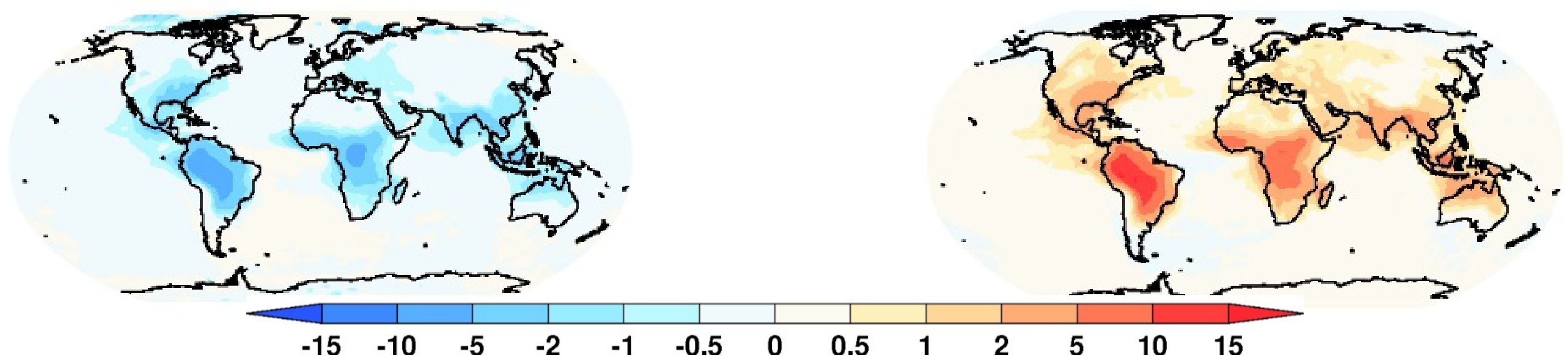
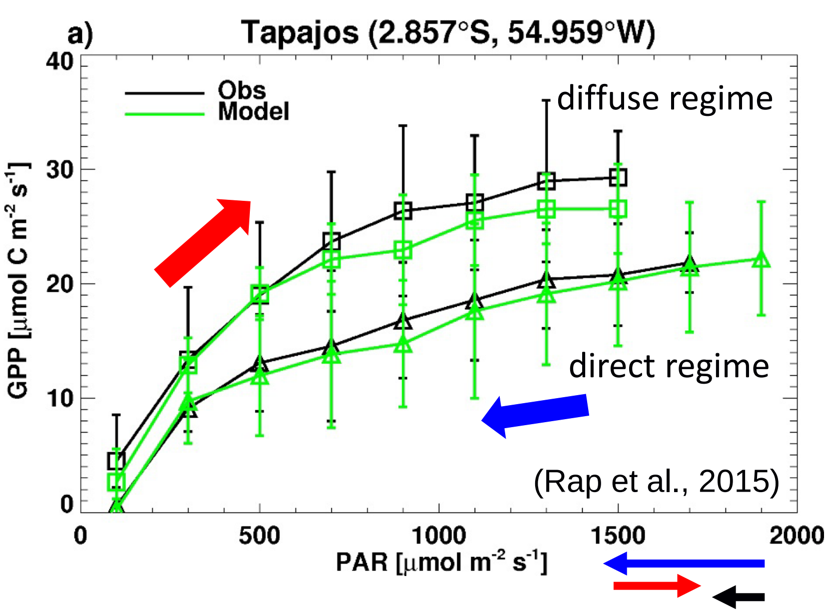
2 competing effects

Reduction in direct radiation | **Increase in diffuse radiation**

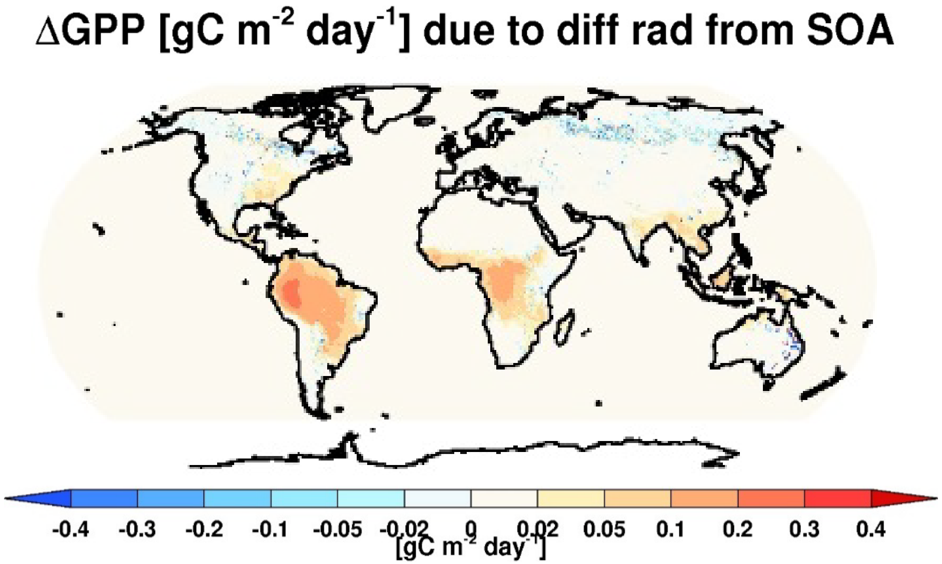
Annual: -0.41% | **Annual: 0.83%**



The net effect on GPP depends on the balance between the **reduction in direct** & **increase in diffuse** radiation



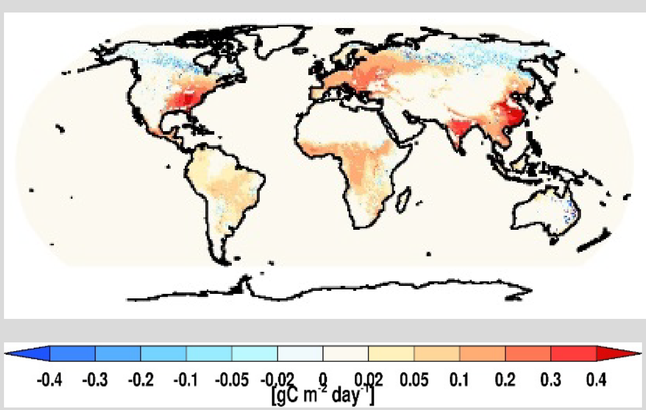
SOA changes on GPP

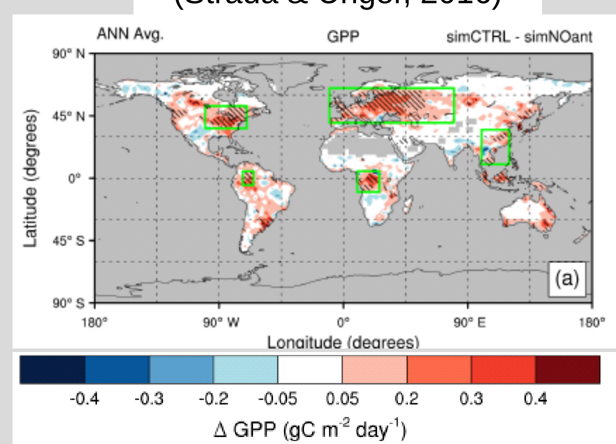


- Substantial increases over tropical regions
- Slight decreases over boreal regions

GPP changes caused by anthropogenic aerosol pollution

(Strada & Unger, 2016)





SOA changes on NPP

(NPP = GPP – respiration)

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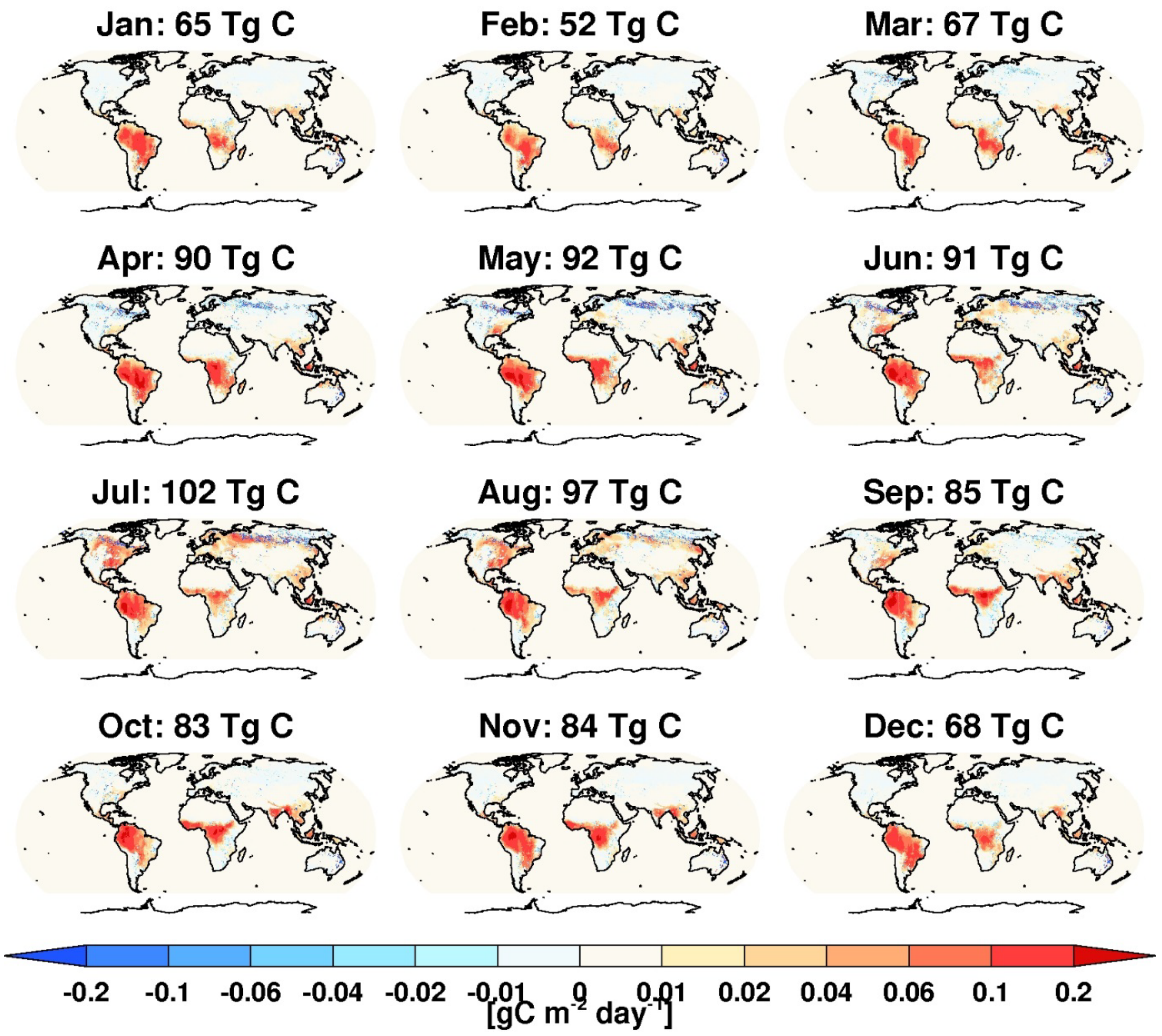

- virtually all NPP increase comes from tropical regions (over 10% NPP increase locally)
- small reductions in high latitudes

- **July**: largest monthly enhancement (~100 Tg C)
- **February**: smallest enhancement (~50 Tg C).

NPP enhancement

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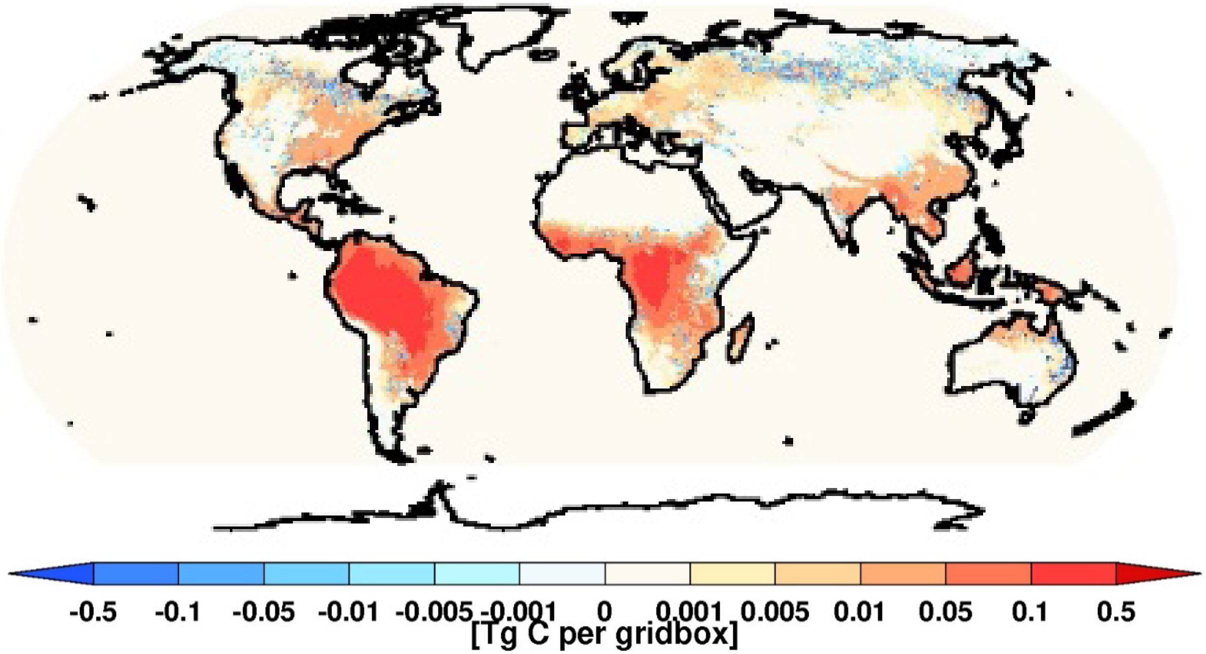
Annual total NPP enhancement: **0.98 Pg C** a^{-1}



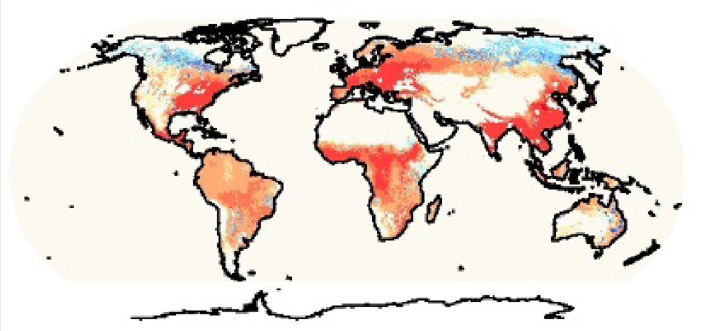
- Diffuse fertilisation from SOA leads to a global NPP enhancement of 0.98 Pg C a^{-1}

- SOA flux is ~30 Tg C a^{-1}
- NPP enhancement is ~30× the SOA source

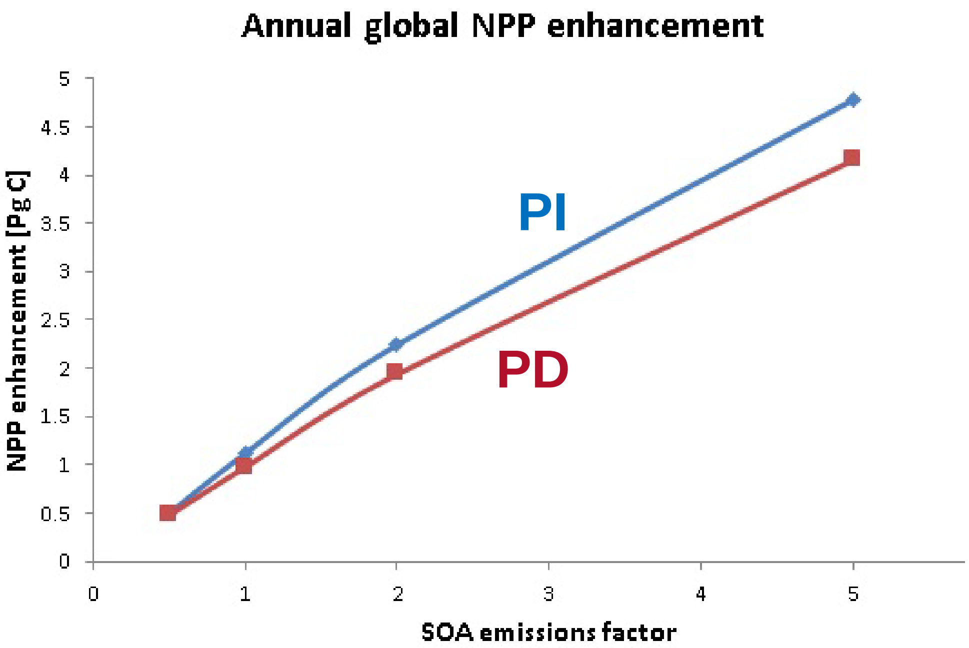
- Total BVOC flux ~600 Tg C a^{-1} (isoprene & monoterpene), [Guether et al., 1995] inventory
- NPP enhancement is ~2× the BVOC source

- the 2013 Global Carbon Emissions (fossil fuels, cement, land-use change) were 9.9 Pg C (Gt C)
- NPP enhancement is 10% of the global anthropogenic C source

NPP enhancement due to anthropogenic aerosol: 2.17 Pg C a^{-1}



Sensitivity to emission factor: PI vs PD



NPP enhancement [Pg C]

SOA emission factor	PI	PD
0.5×	0.50	0.48
1×	1.12	0.98
2×	2.24	1.94
5×	4.78	4.15

- NPP enhancement increases non-linearly with increasing SOA yields
- Diffuse fertilisation effect was bigger in the PI compared to the PD

Thank you for your attention

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