Quantifying the natural aerosol diffuse radiation fertilisation effect

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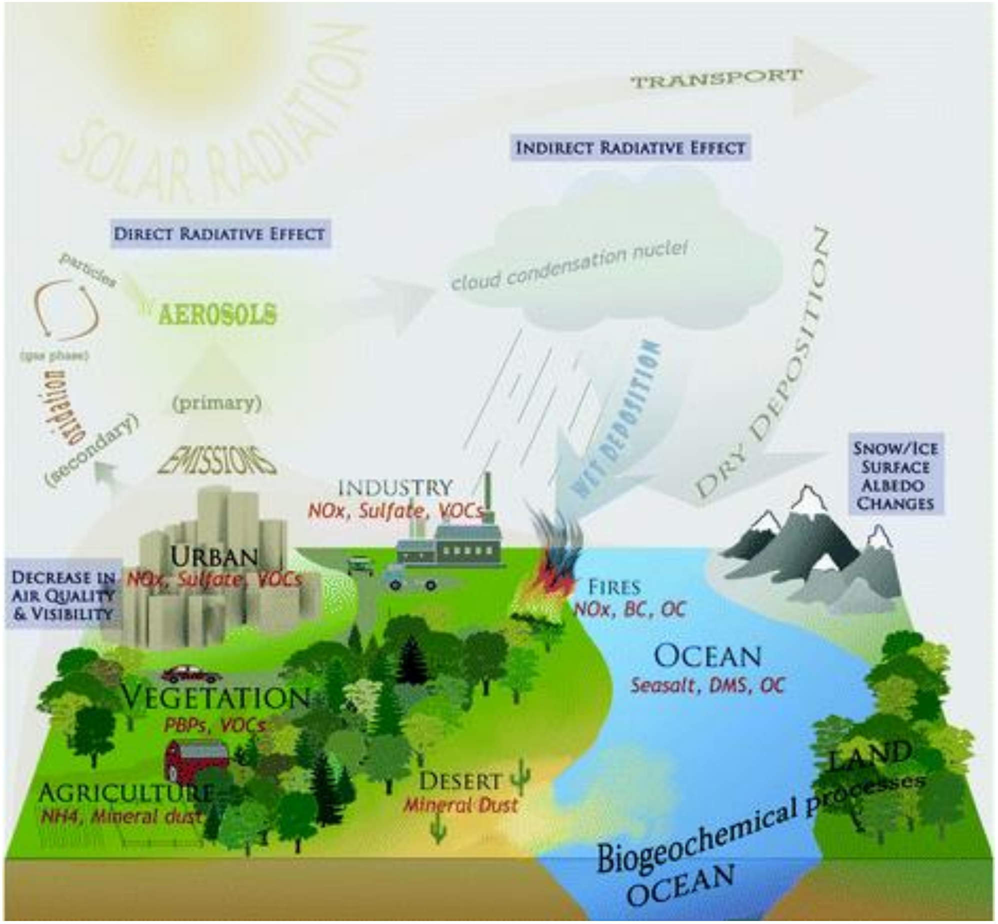
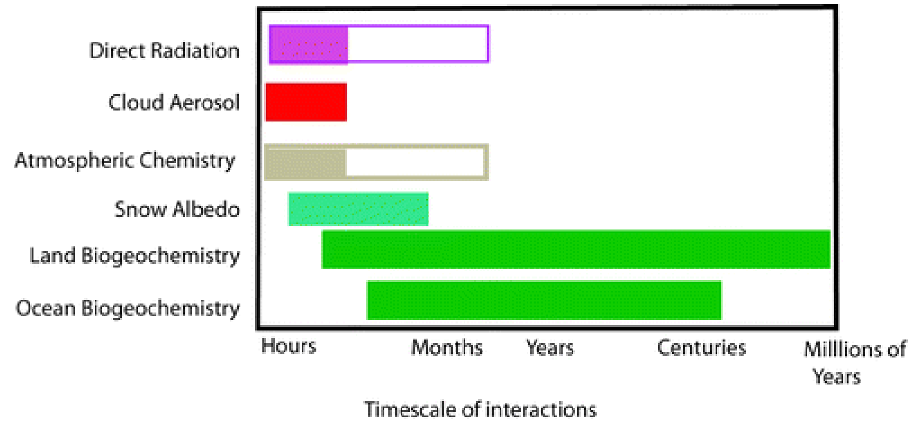
Aerosol & biosphere-atmosphere interactions



(Mahowald et al., 2011)

Aerosol particles affect:

- atmospheric radiative fluxes
  - Direct effects
  - Indirect effects
- atmospheric chemistry
- land and ocean biogeochemistry



Natural aerosol radiative effects

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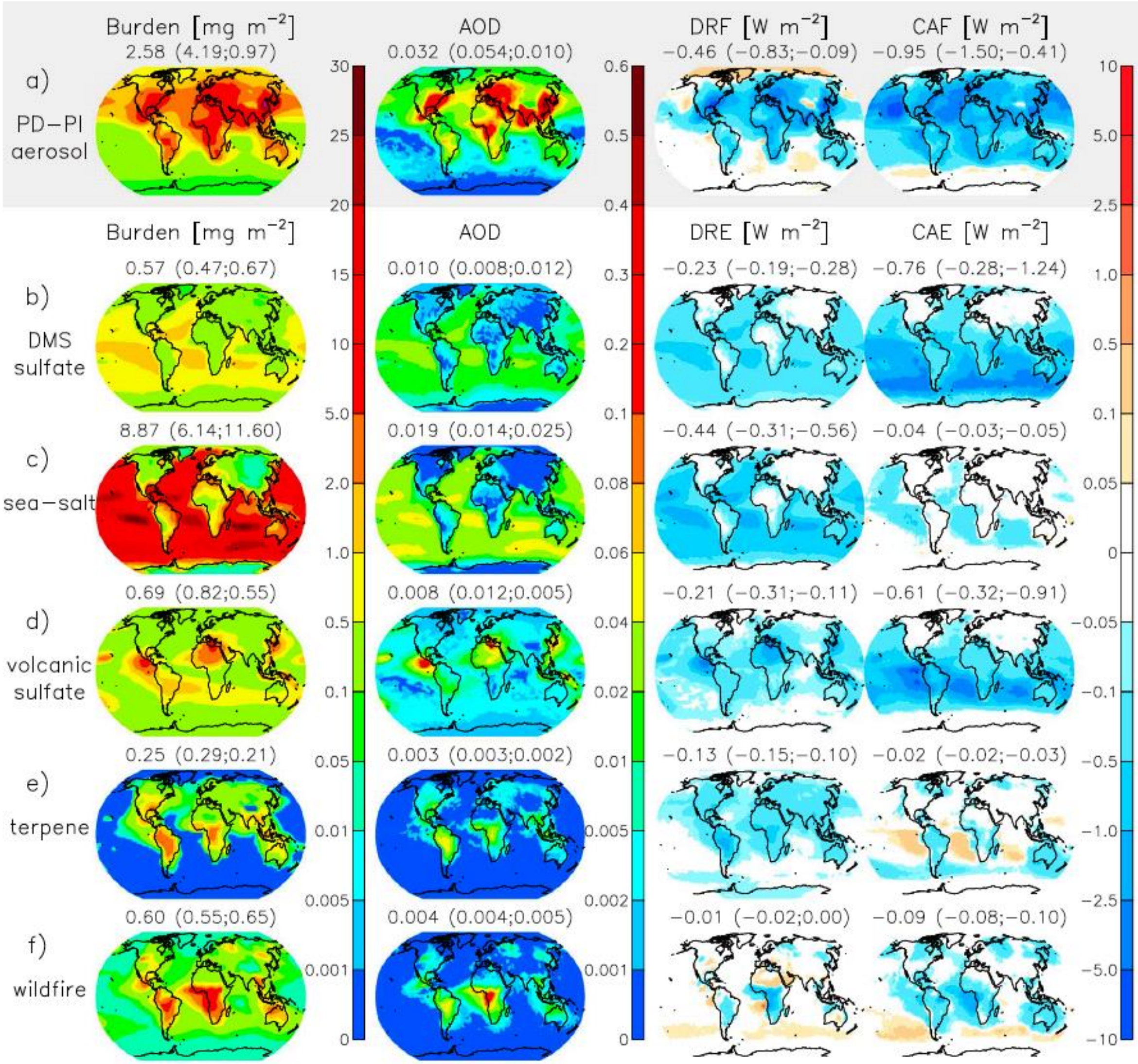

(Rap et al., 2013)

- largest DRE for sea-salt: -0.25 Wm^{-2}
- largest CAEs for DMS- (-0.94 Wm^{-2}) & volcanic (-0.62 Wm^{-2}) sulfate
- sea-salt CAE much lower than existing estimates
- substantial variability in *CAE/DRE ratio*
- substantial variability in natural aerosol radiative efficiency [W/g]: secondary vs. primary aerosol species

	DRE eff	CAE eff
DMS	-614	-1649
Sea-salt	-79	-14
Volcanic	-435	-898
Terpene	-560	-200
Wildfire	-100	-233

Diffuse radiation and plant productivity

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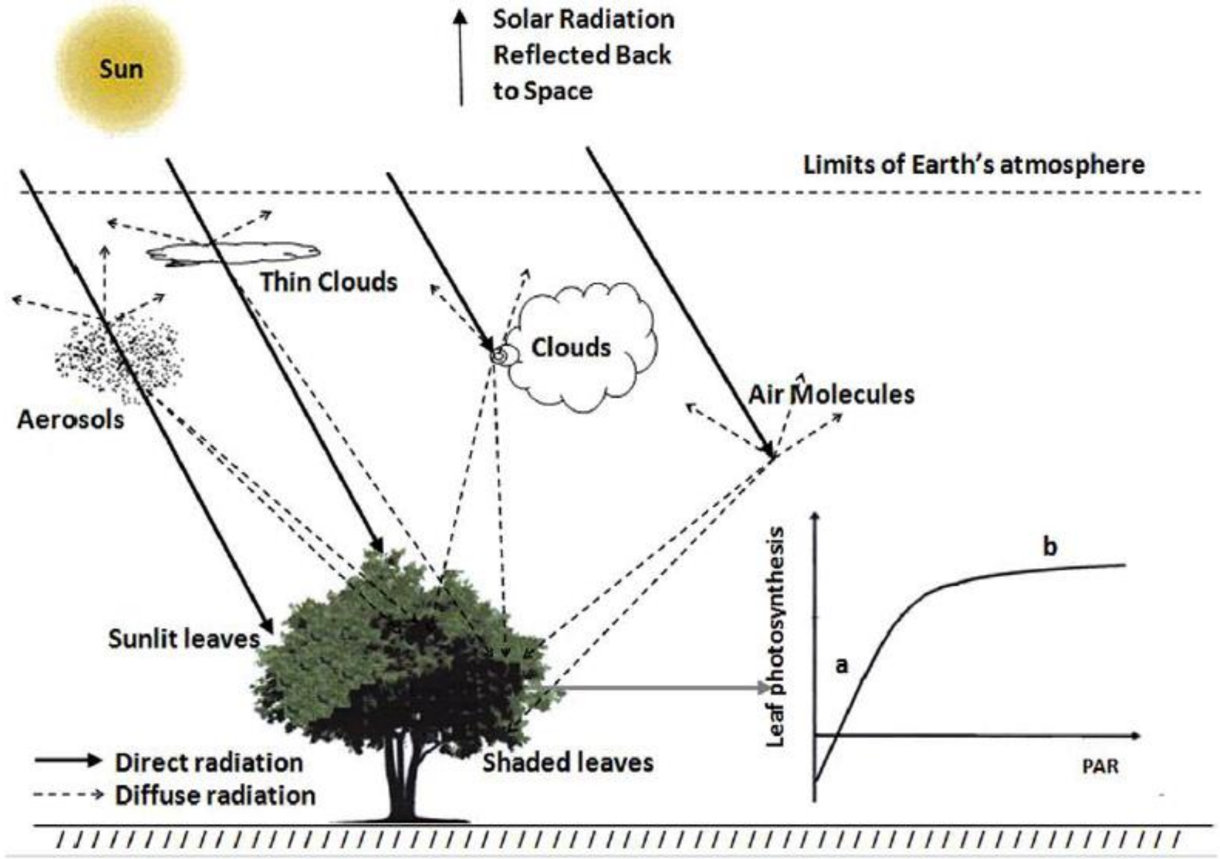

(Kanniah et al., *Progress Phys. Geog.*, 2012)

- 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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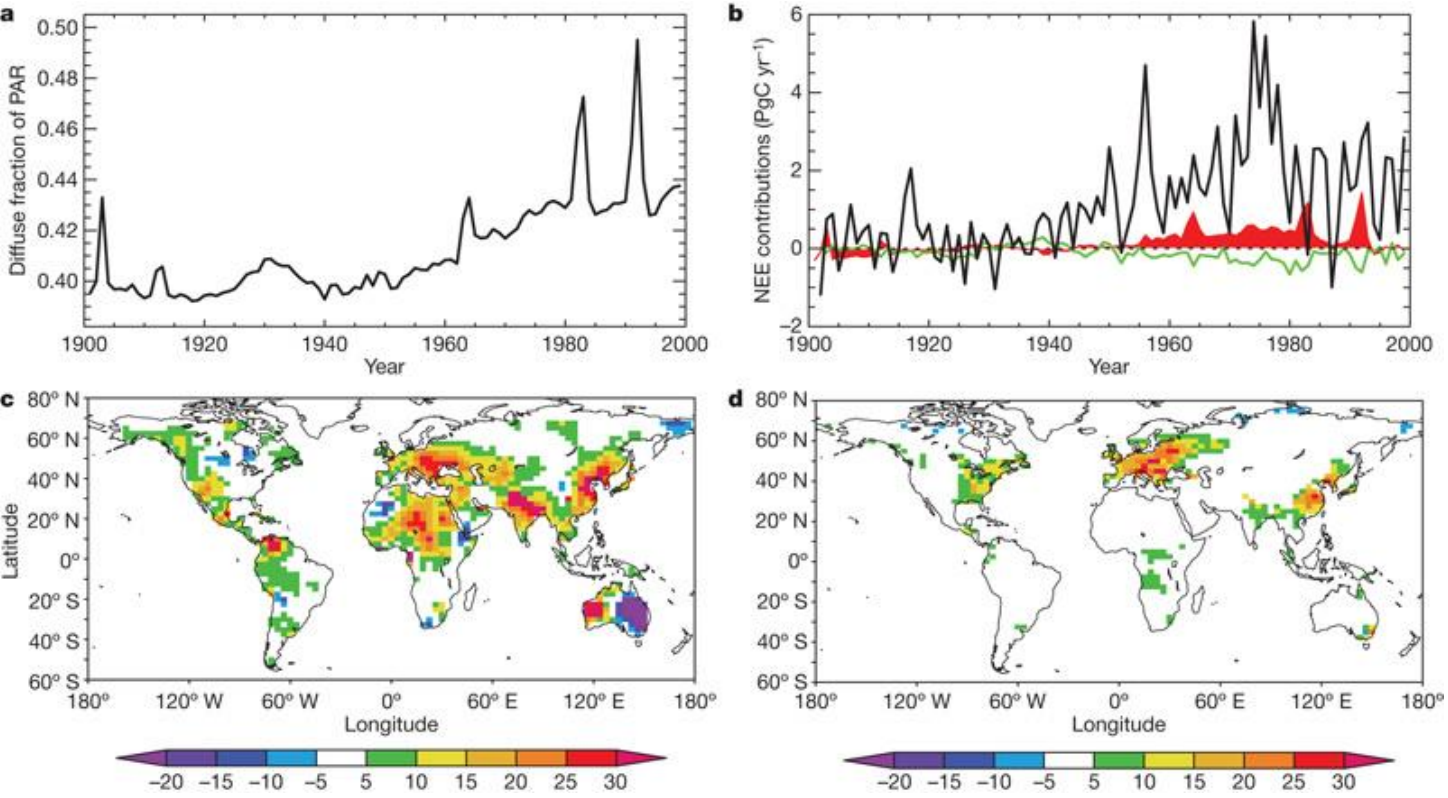

(Mercado et al., 2009)

- 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

Methodology

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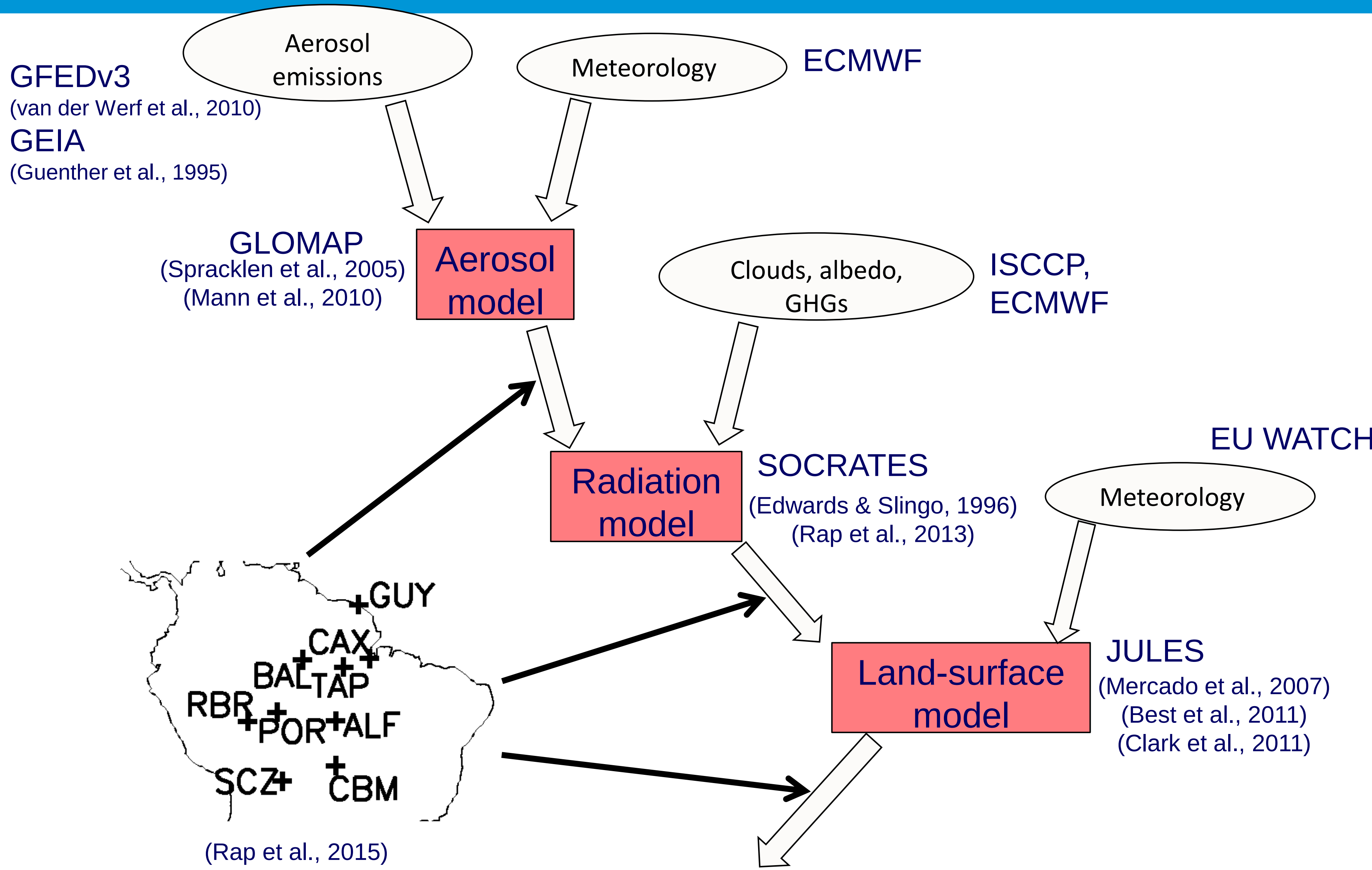

GPP response to PAR regimes
- Model and observations -

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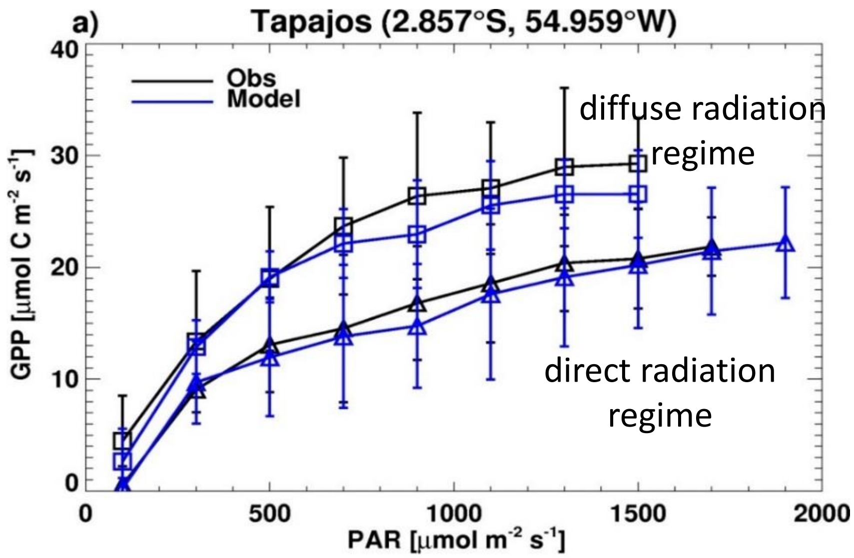
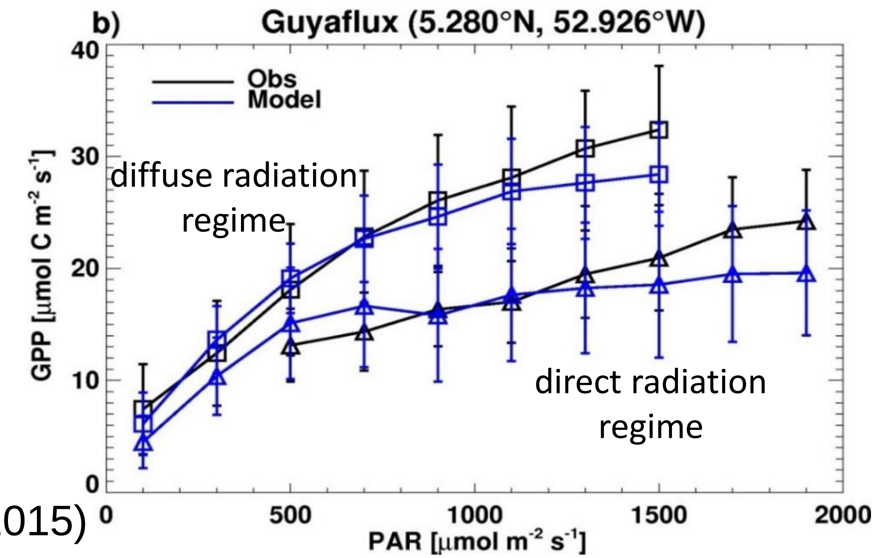
• GPP increases with increased PAR, saturating at high PAR

• 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, 2015)

Amazon biomass burning aerosol

- Model and observations -

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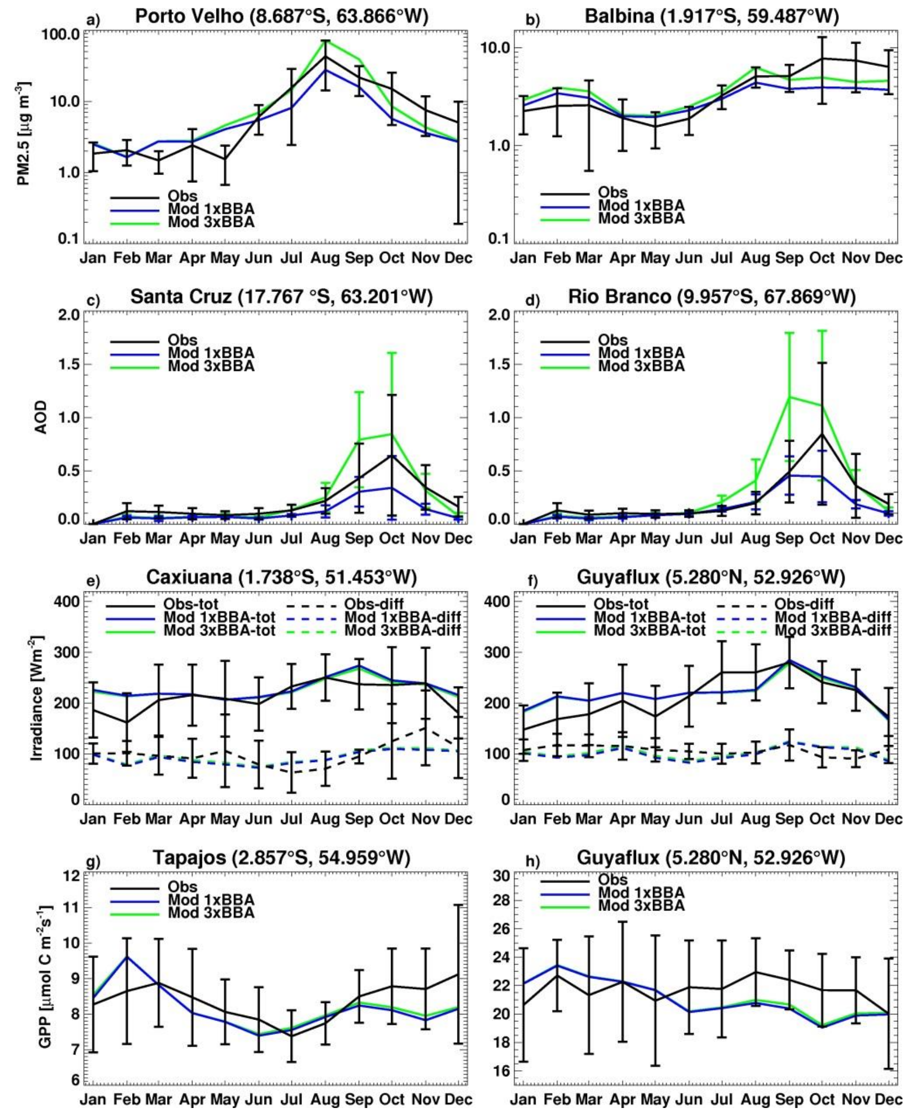

- 1×BBA simulated AOD underestimates the observed values (normalized mean bias (NMB) = −41%)
- 3×BBA typically overestimates AOD (NMB = 19%)
- We use these two simulations as a rough lower and upper bound estimate of BBA emissions.

<u>Radiation and GPP measurements</u>:

- Tapajos: 2002-2005, every 60 mins
- Guyaflux: 2006-2007, every 30 mins

(Rap et al., 2015)

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Impact of Amazon fires on PM2.5, surface radiation, GPP and NPP

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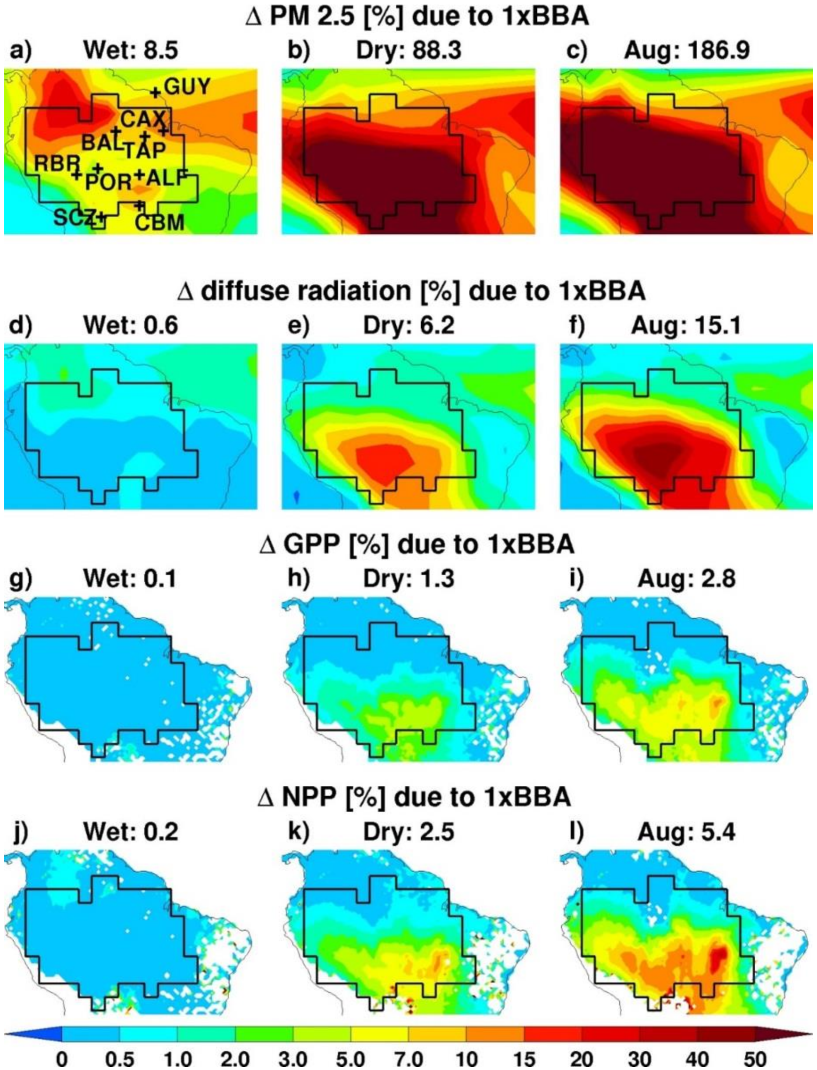
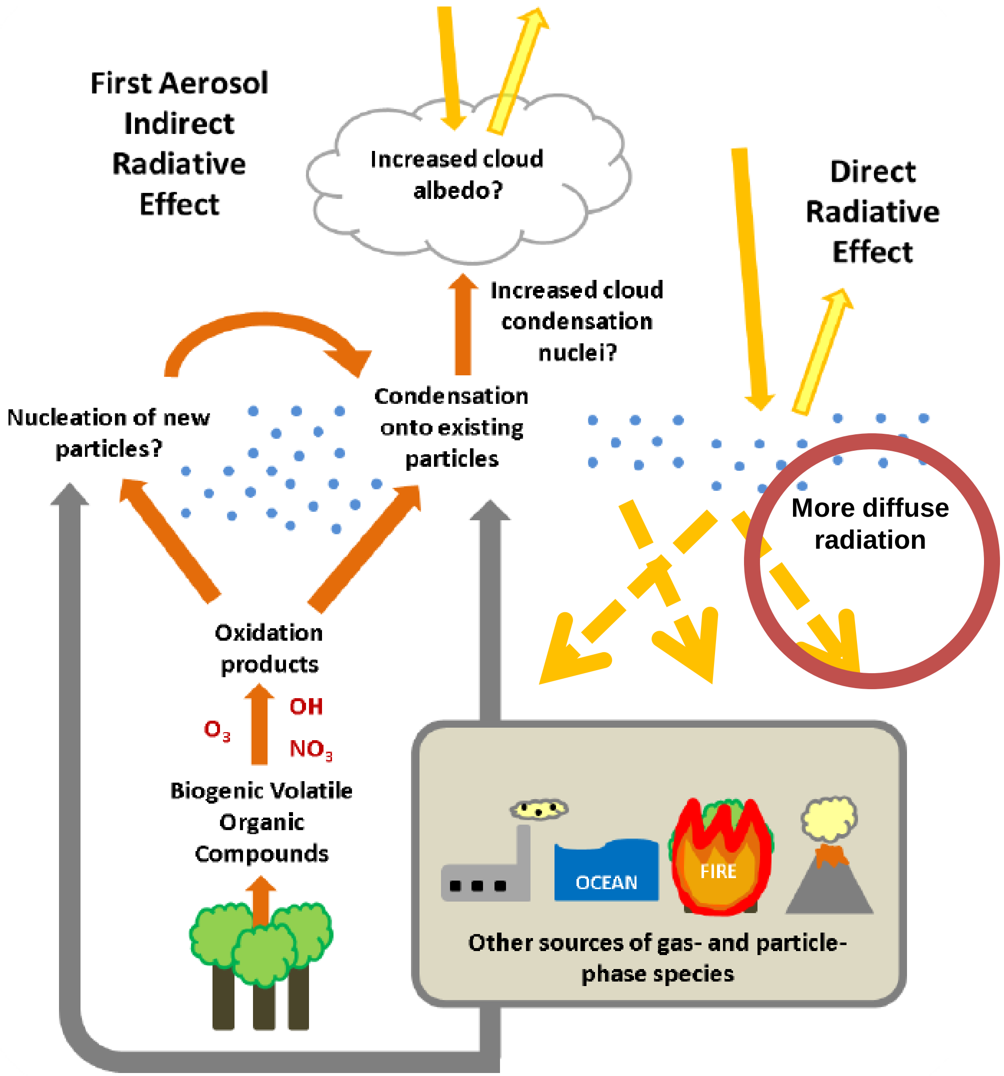


(Rap et al., 2015)

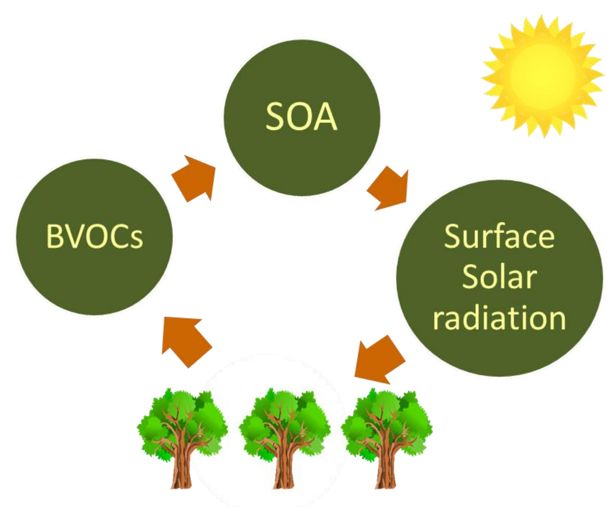
- The Amazon-basin NPP enhancement is ~115 Tg C a^{-1}, offsetting ~50% of the annual regional carbon emissions from biomass burning
- This NPP increase occurs during the dry season and mitigates ~40-50% of the moisture generated decline in NPP in dry years
- We estimate that 30-60 Tg C a^{-1} of this NPP enhancement is within woody tissue, accounting for 8-16% of the observed carbon sink across mature Amazonian forests

Secondary Organic Aerosol (SOA)



(Scott et al, 2014)

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



BVOC emissions

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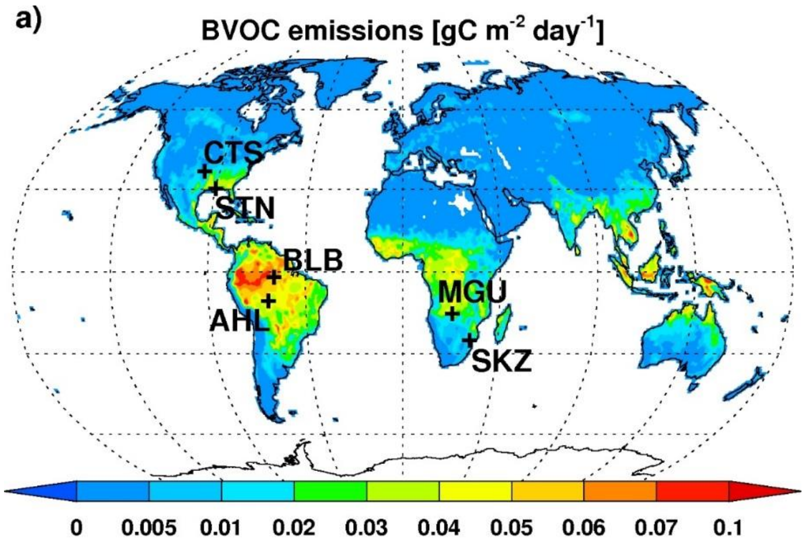
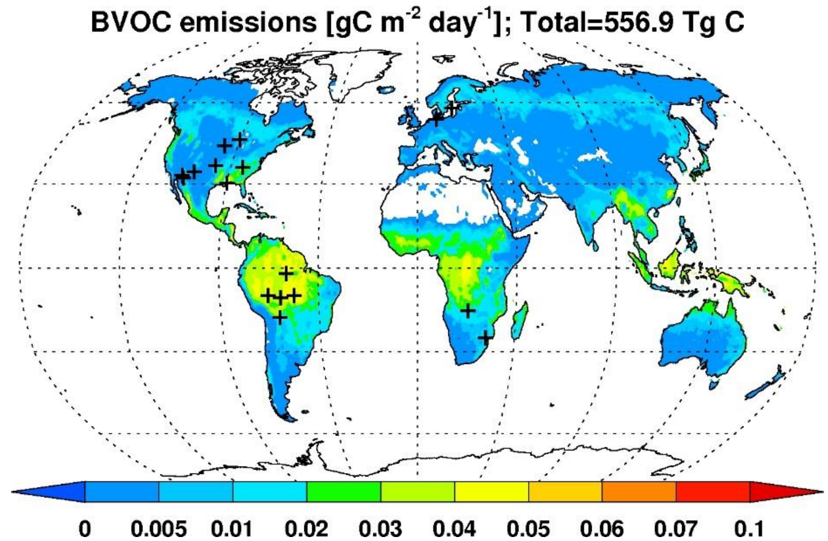
GEIA database:



- Isoprene 503 Tg C a^{-1}
- Monoterpenes 127 Tg C a^{-1}

JULES:



- Isoprene 515 Tg C a^{-1}
- Monoterpenes 42 Tg C a^{-1}

SOA production rate:

- 13-121 Tg a^{-1} (AEROCOM, Tsigaridis et al., 2014)
- 18-185 Tg a^{-1} (range of our sensitivity simulations)
  - best estimate is 55 Tg a^{-1}
  - best agreement with observed AOD for 37-74 Tg SOA a^{-1}
  - consistent with AeroCom models estimate: median=51 Tg a^{-1}, mean=59 Tg a^{-1}, σ=38 Tg a^{-1} (Tsigaridis et al. 2014)

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Evaluation of SOA emissions
- modelled & observed AOD -

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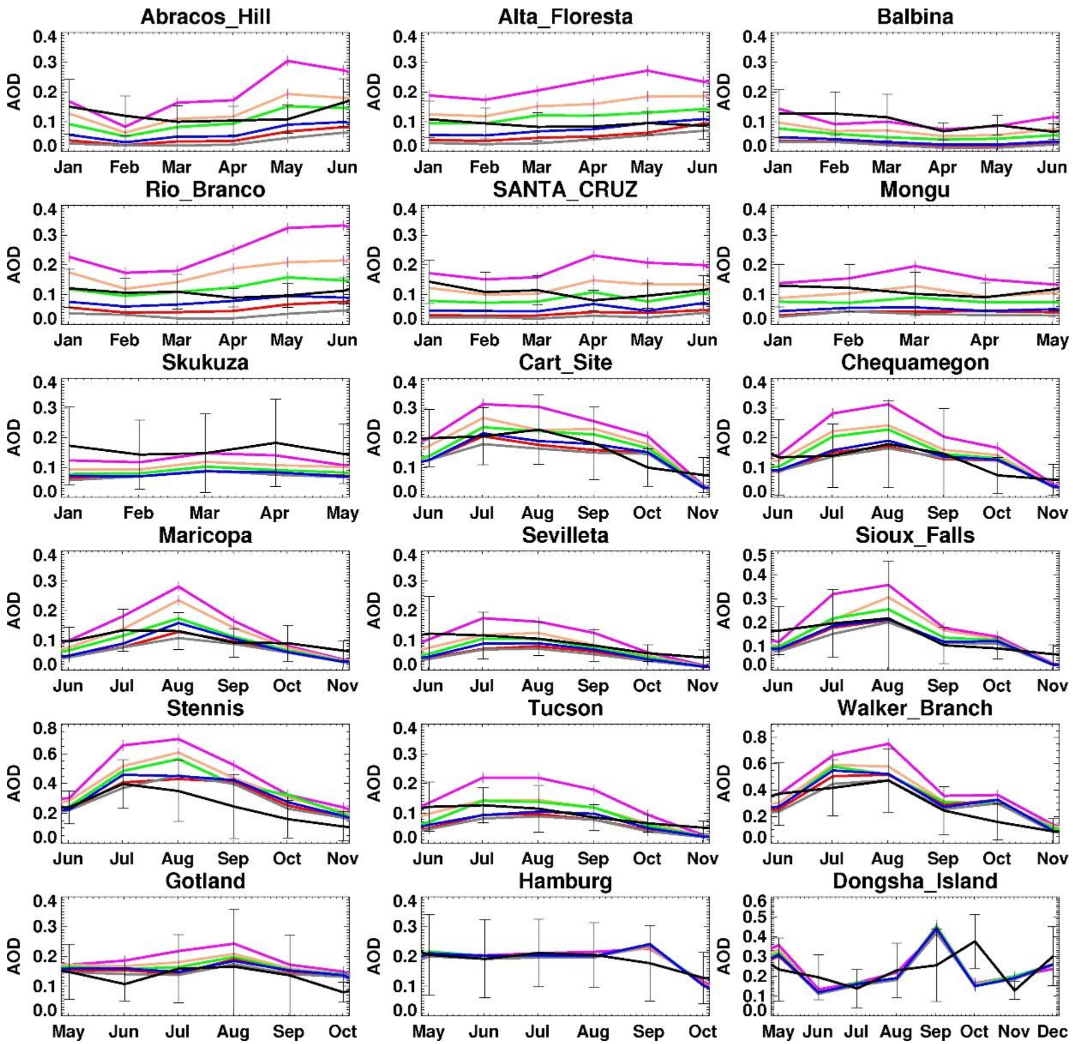
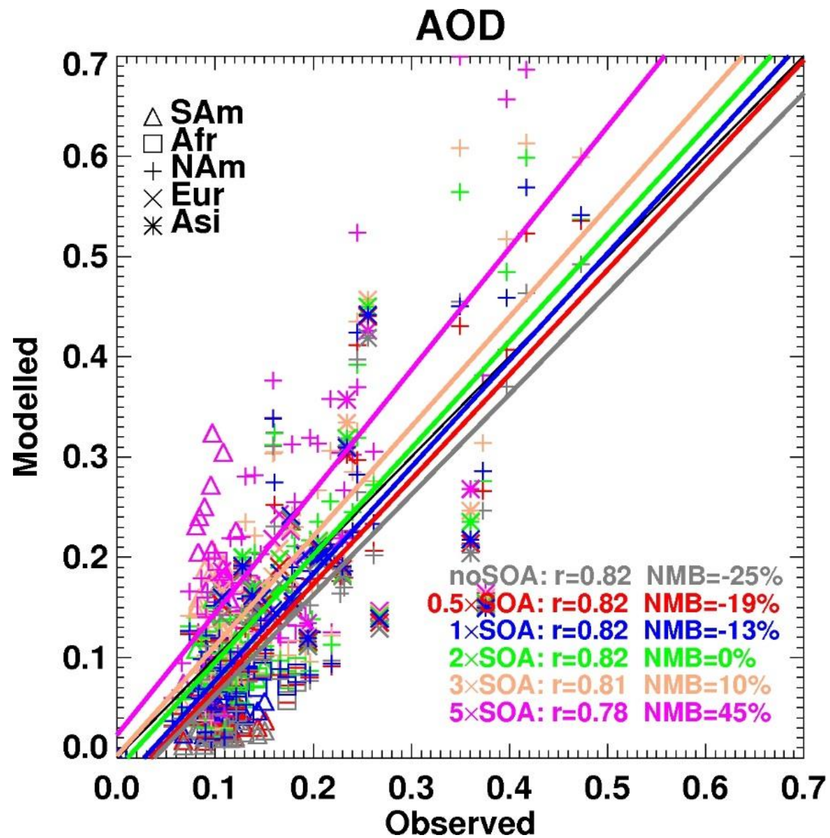


(Rap et al, 2017, submitted)



- best agreement with AERONET AOD measurements for the 2xSOA simulation

SOA changes on surface radiation
- 2 competing effects -

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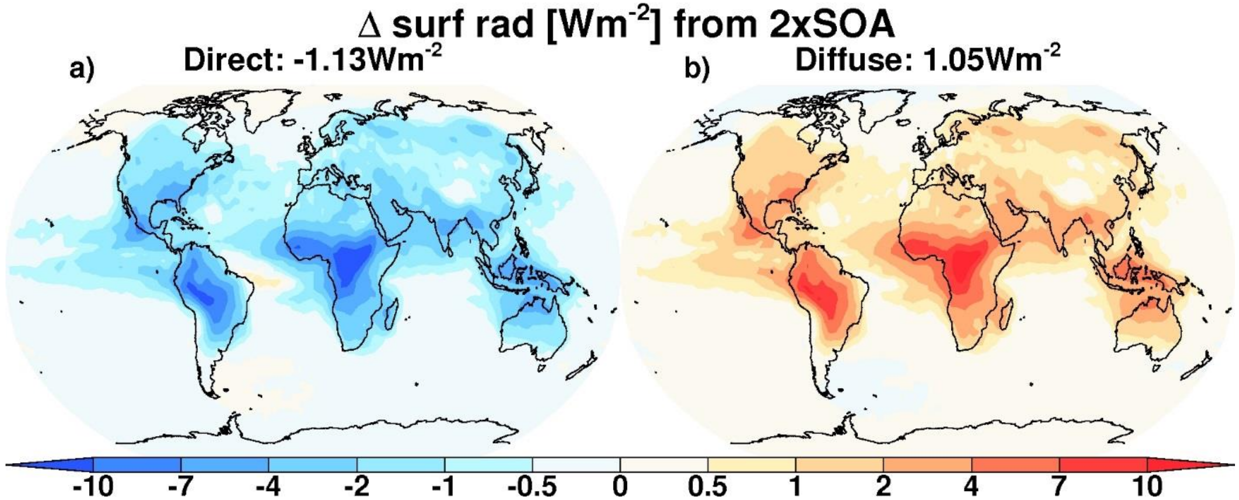
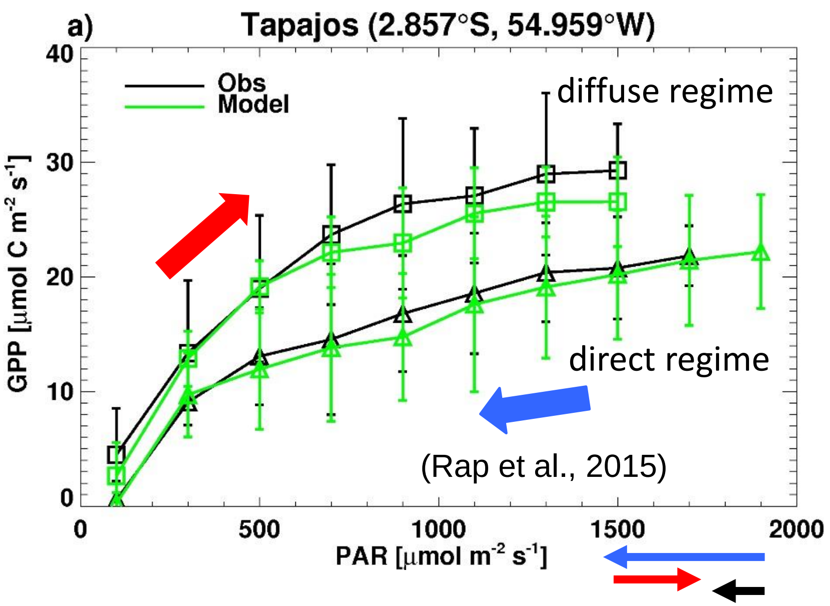
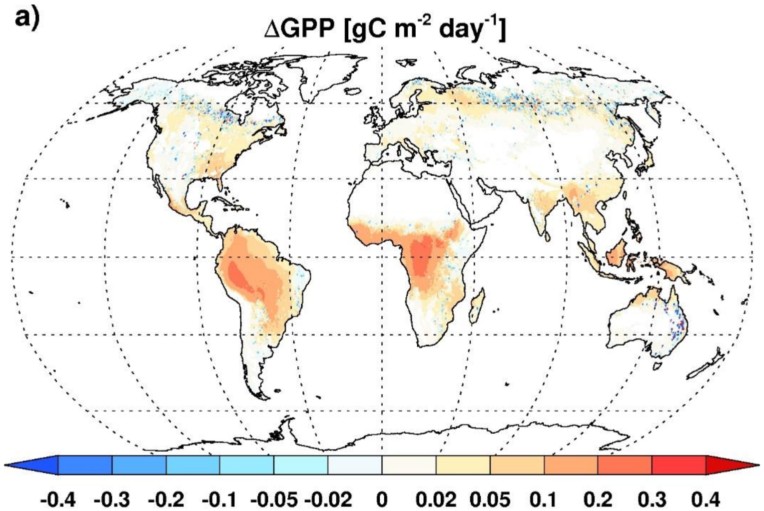
Reduction in direct radiation | **Increase in diffuse radiation**



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



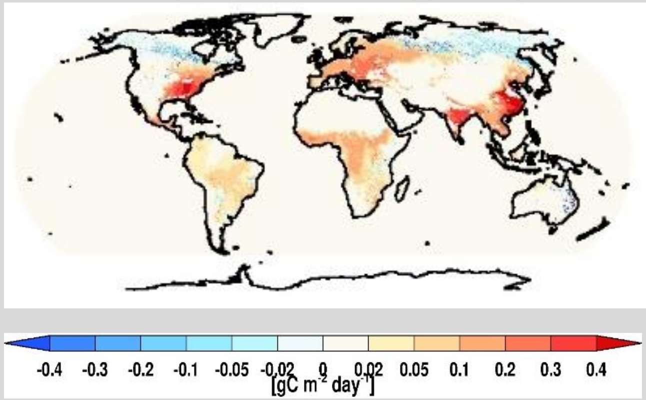
SOA changes on GPP

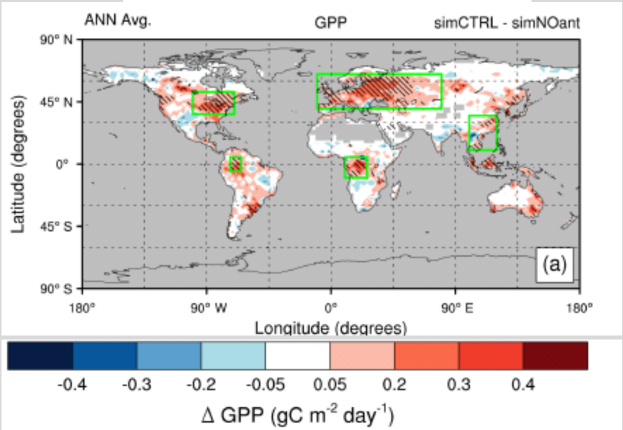


- Substantial increases over tropical regions
- Slight decreases over some boreal regions

GPP changes caused by anthropogenic aerosol pollution

(Strada & Unger, 2016)





NPP enhancement from SOA

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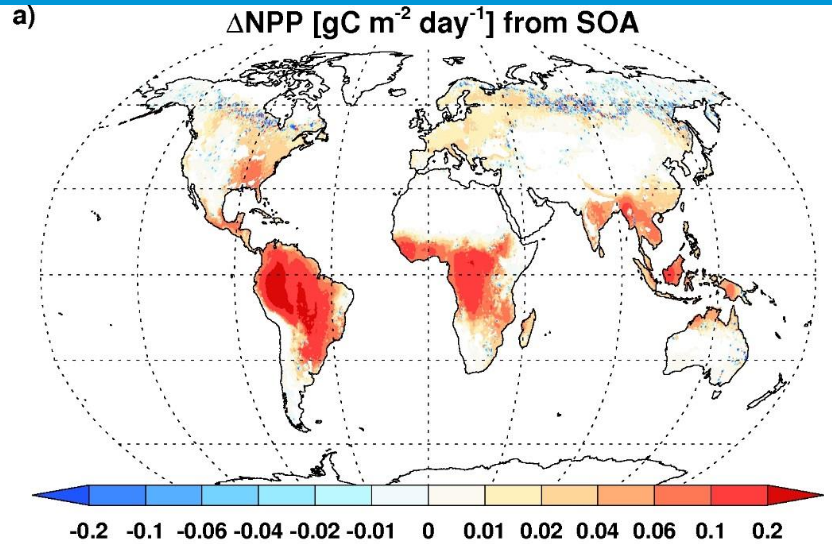
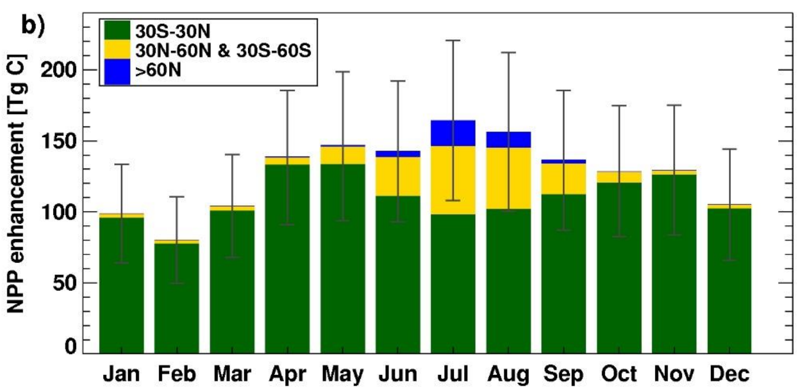
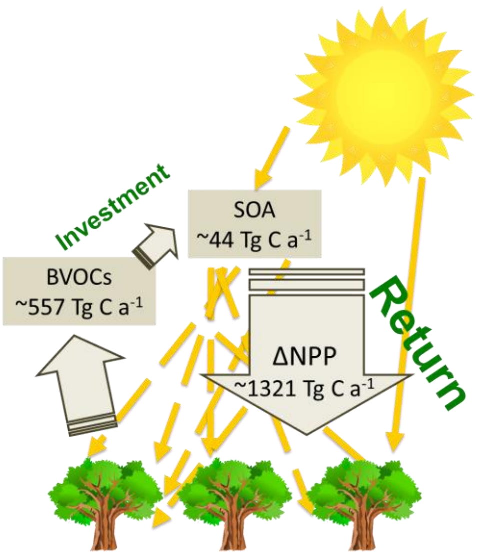




(Rap et al, 2017, submitted)



- Annual mean global NPP enhancement of 1.32 Pg C a^{-1} (0.61-1.95 Pg C a^{-1}, when allowing for uncertainty in SOA formation)
- Most of the NPP enhancement comes from lower latitudes (30°N-30°S)
- Largest increase in July, partly due to a substantial contribution from mid 30°-60° (30%) and boreal 60°N-90°N (10%) latitudes

The terrestrial biosphere benefits from the emission of BVOCs, with an NPP enhancement that is ~2.5 times greater than the initial carbon investment on what is emitted to the atmosphere.

Natural aerosol – radiative effects and diffuse radiation fertilisation

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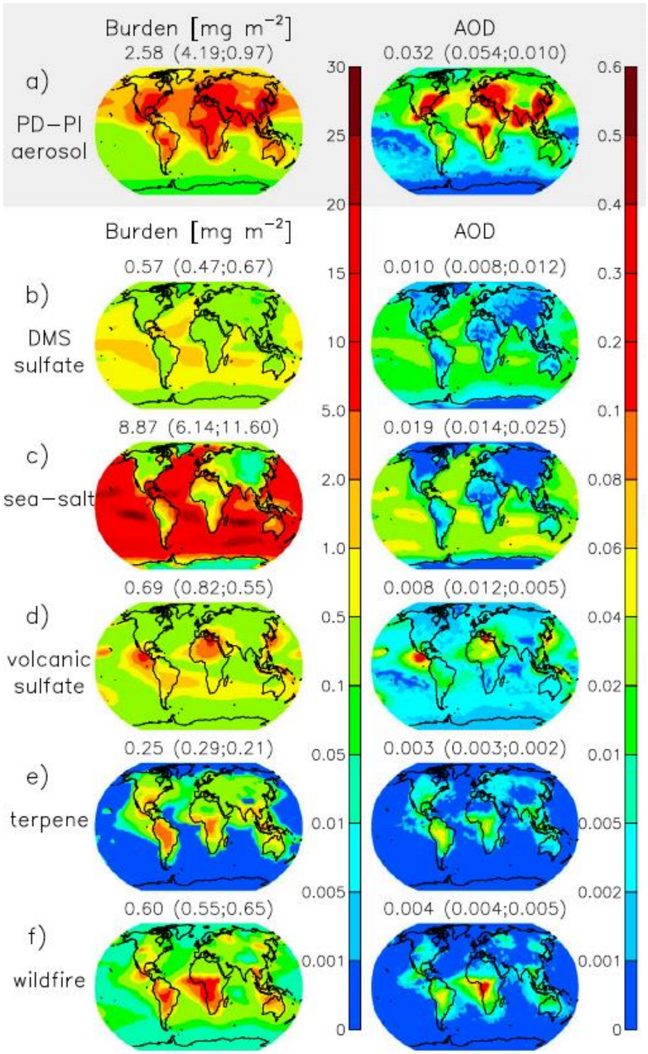

! **Preliminary results**

	Direct RE [Wm^{-2}]	Indirect RE [Wm^{-2}]	ΔNPP [$Pg\ C\ a^{-1}$]
Anthropogenic	-0.46	-0.95	2.17
DMS	-0.23	-0.76	0.15
Sea-salt	-0.44	-0.04	0.34
Volcanic	-0.21	-0.61	0.38
Biogenic SOA	-0.33	-0.04	1.32
Wildfires	-0.01	-0.09	0.25