Isoprene -derived secondary organic aerosols under future climate conditions

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NCAR ACOM/ASP

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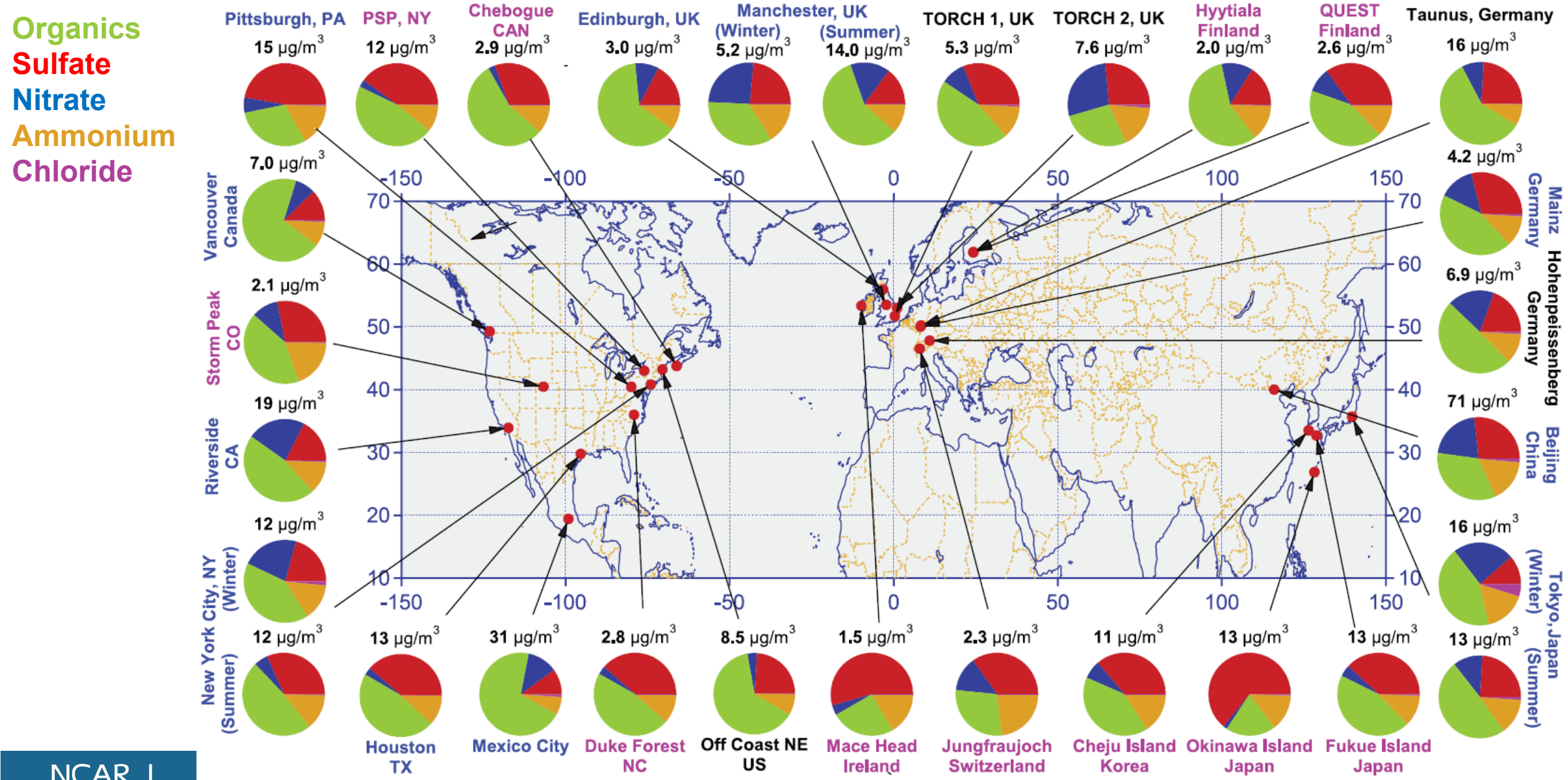
Organic aerosol contributes substantial mass fractions of submicron aerosols



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Zhang et al. (2007)

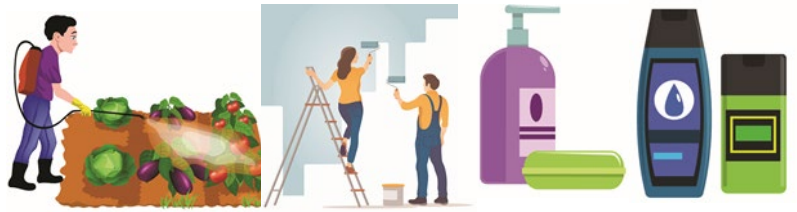
Organic aerosols are generated from multiple sources

Biogenic emissions

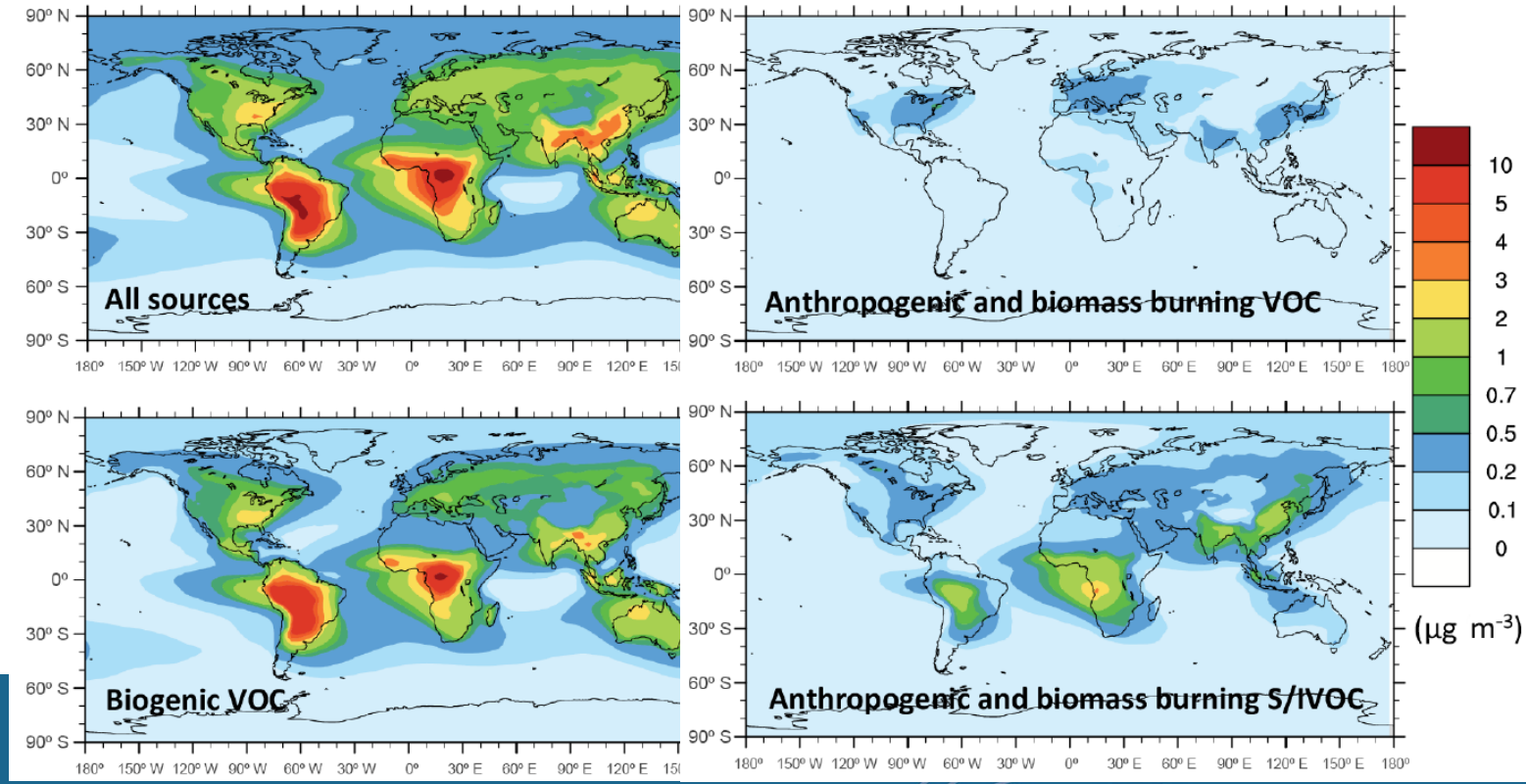
Anthropogenic emissions

Biomass burning emissions

Volatile chemical products



- The largest contribution to organic aerosol production is from biogenic sources

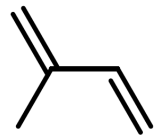


VOC: Volatile Organic Compound

Hodzic et al. (2016)

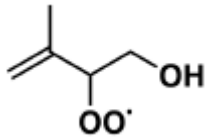
Isoprene -epoxydiol -derived secondary organic aerosol (IEPOX -SOA)

Gas



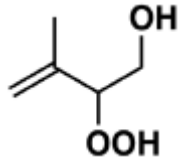
Isoprene

OH



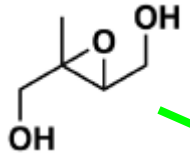
ISOPOO

HO_2



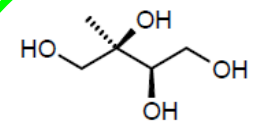
ISOPOOH

OH

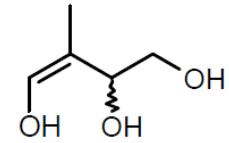


IEPOX

H^+

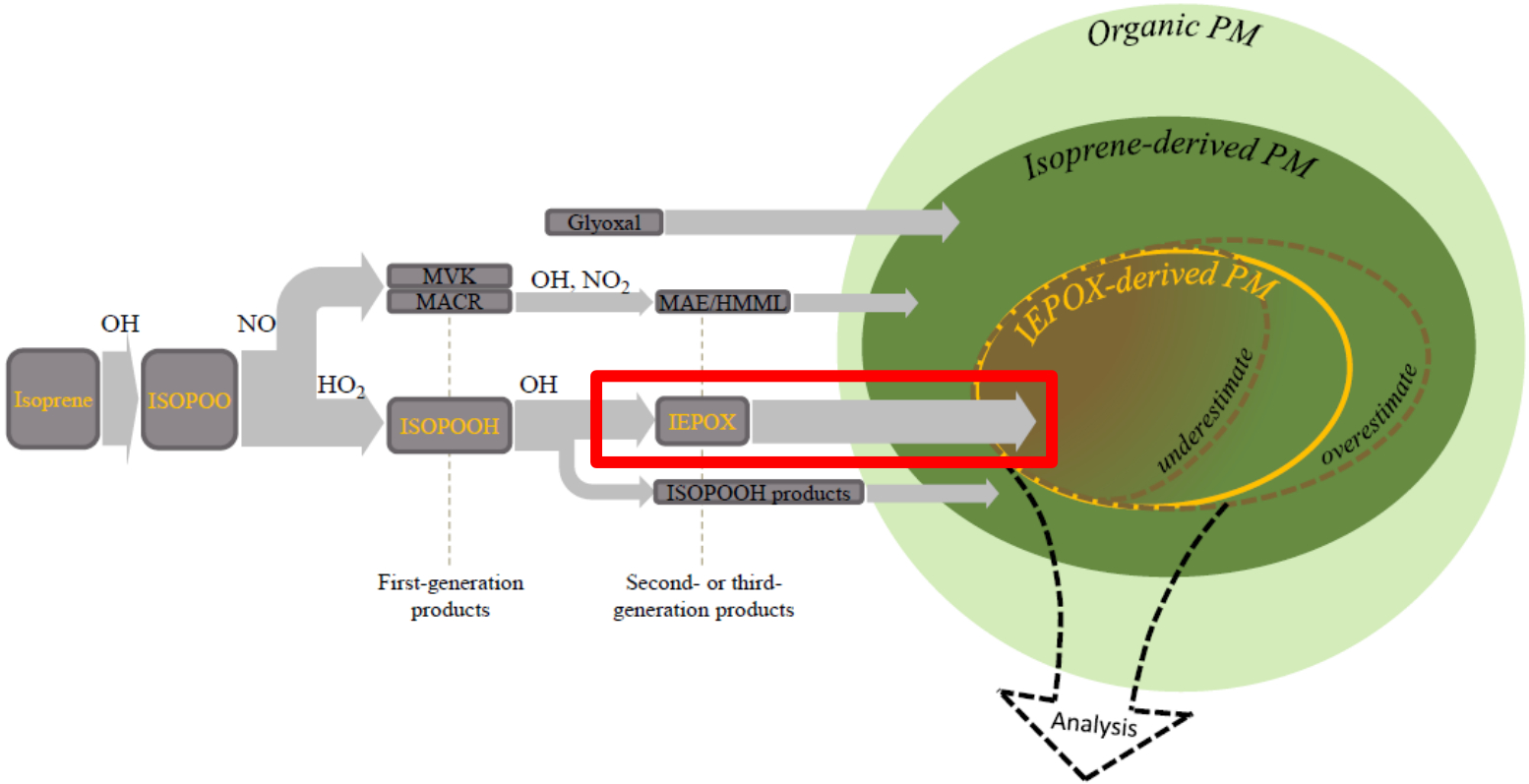


2-methyltetrol



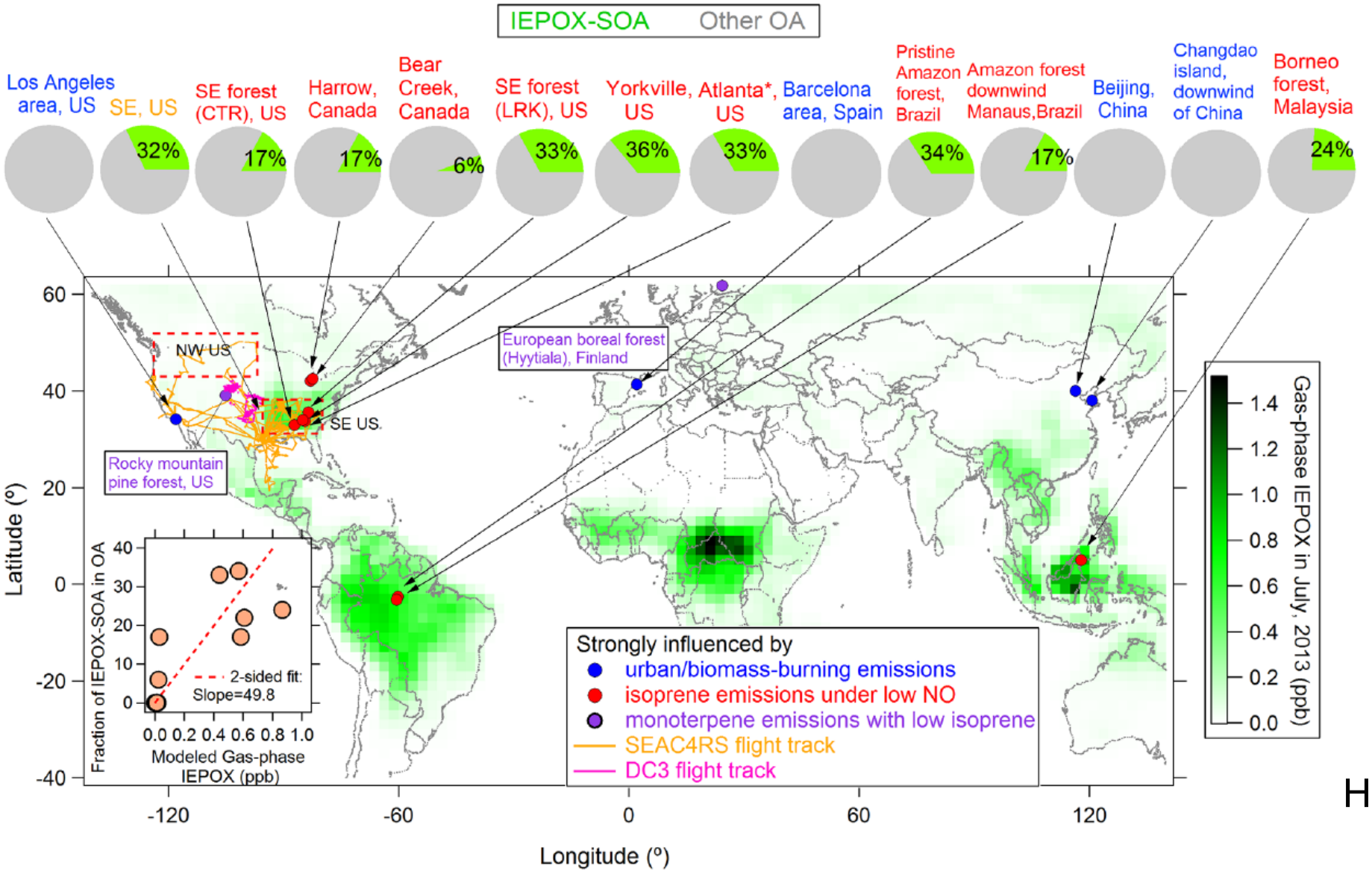
C5-alkene triols

Aerosol



de Sa et al. (2017)

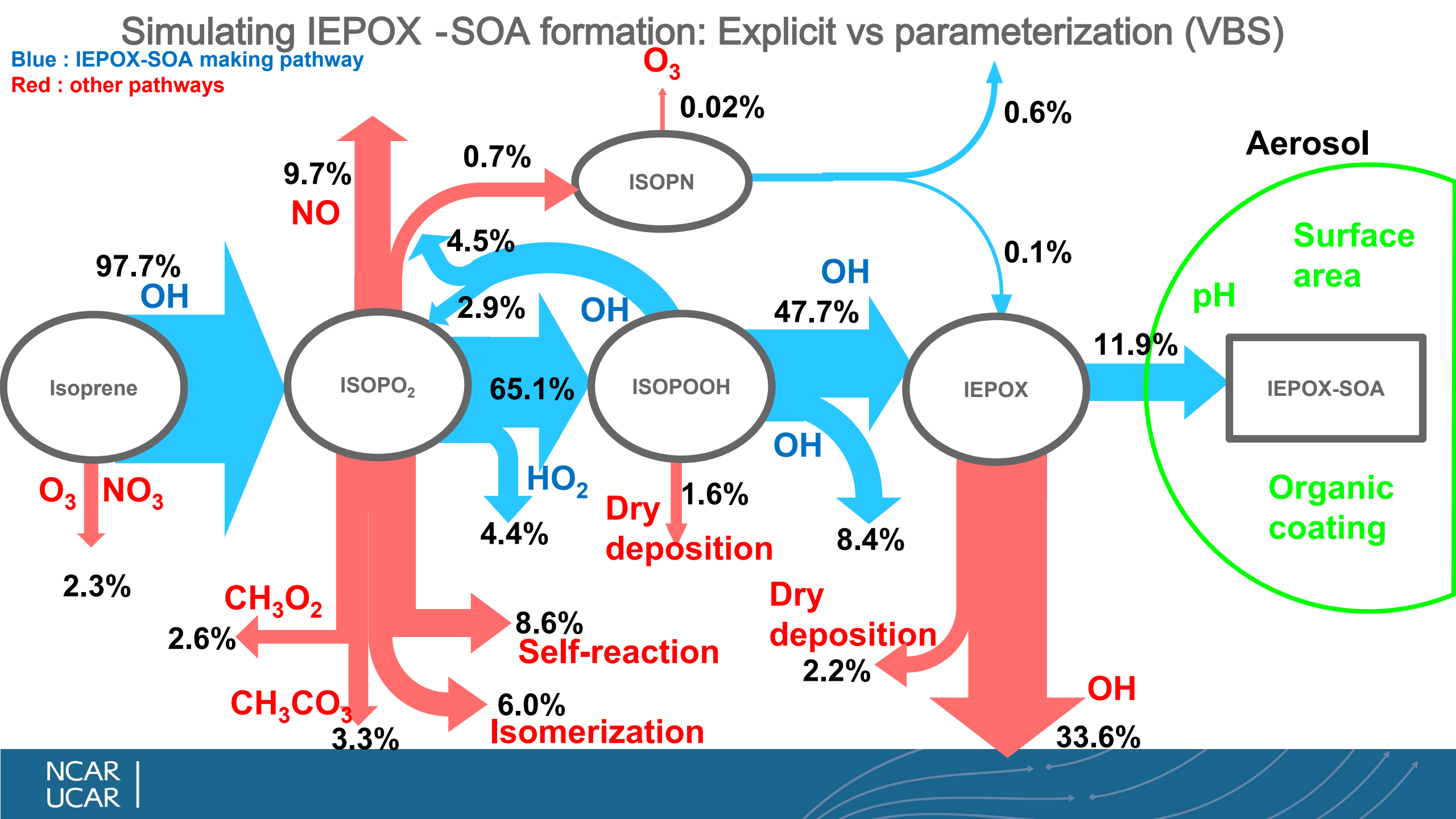
IEPOX-SOA can contribute to total OA concentrations by as much as 36%, especially for forested regions under low NO across the globe



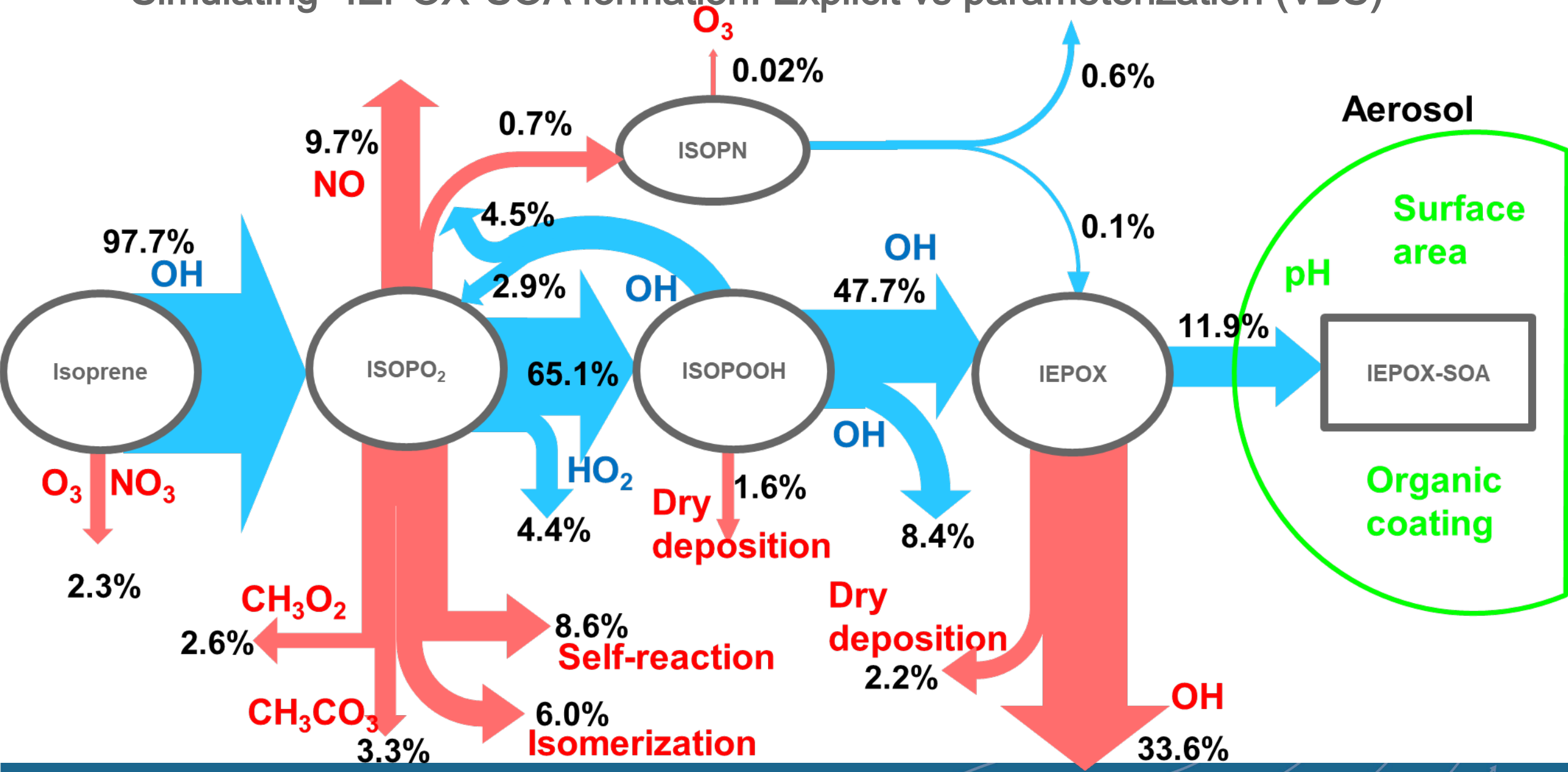
Hu et al. (2015)

Simulating IEPOX -SOA formation: Explicit vs parameterization (VBS)

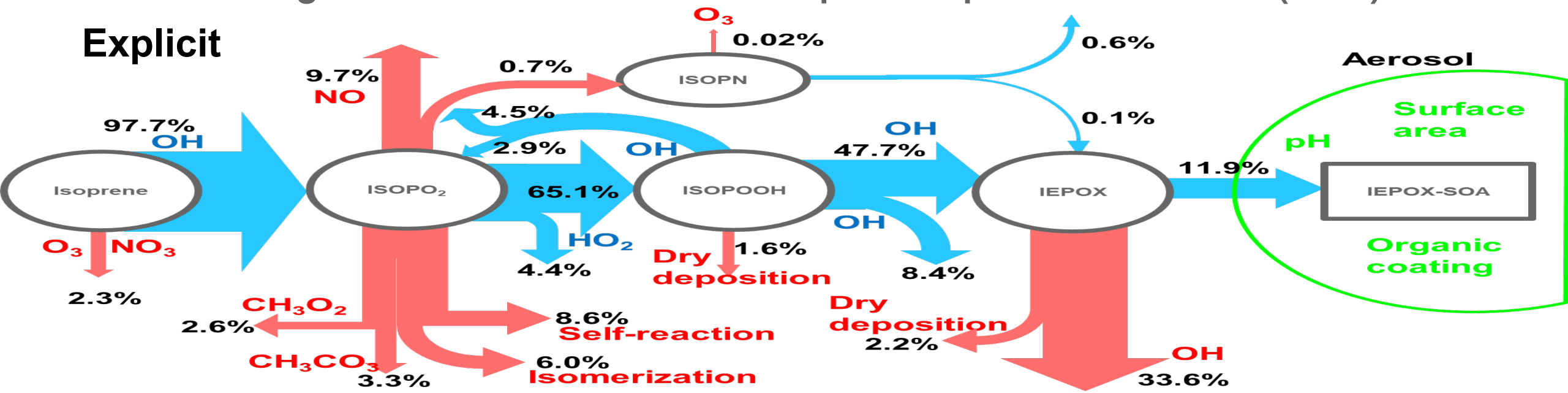
Blue : IEPOX-SOA making pathway
Red : other pathways



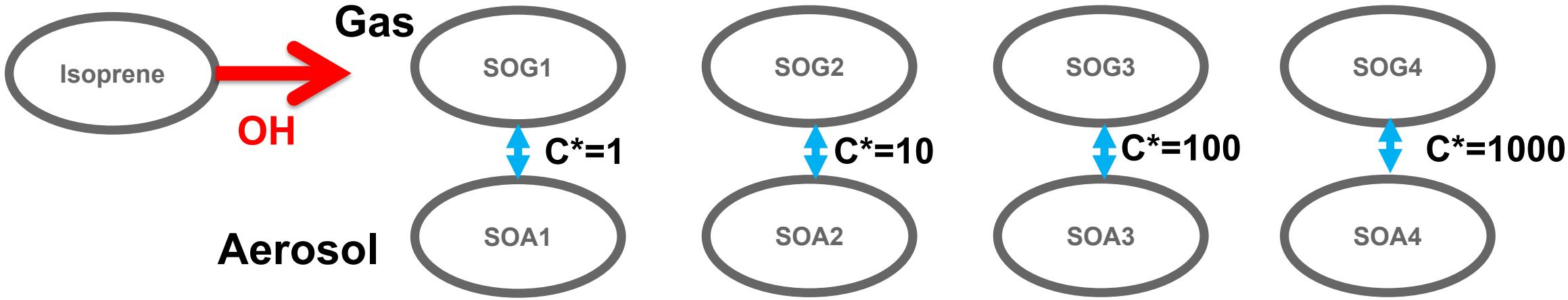
Simulating IEPOX-SOA formation: Explicit vs parameterization (VBS)



Simulating IEPOX-SOA formation: Explicit vs parameterization (VBS)



Volatility basis set (VBS) approach



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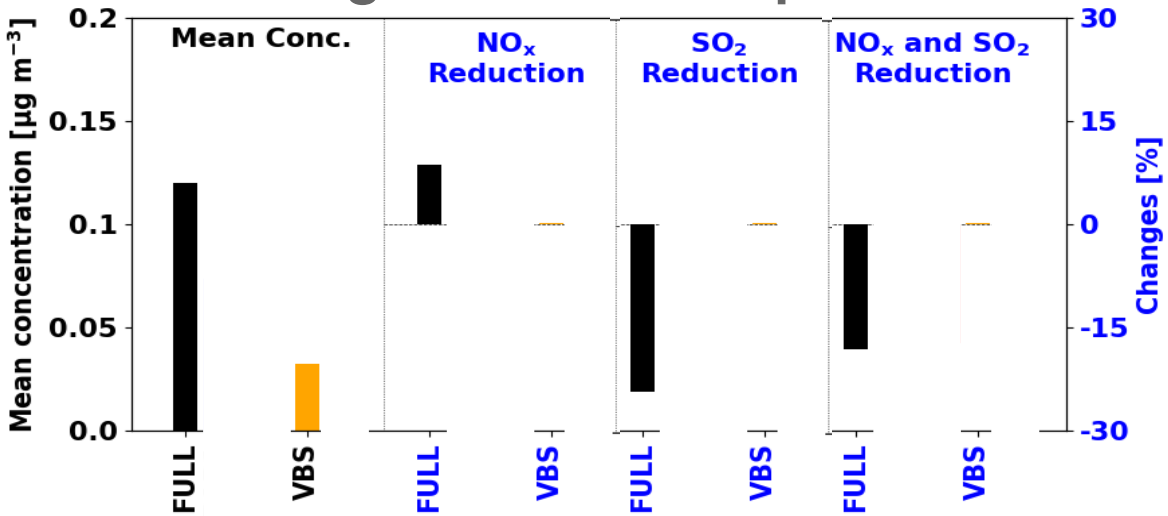
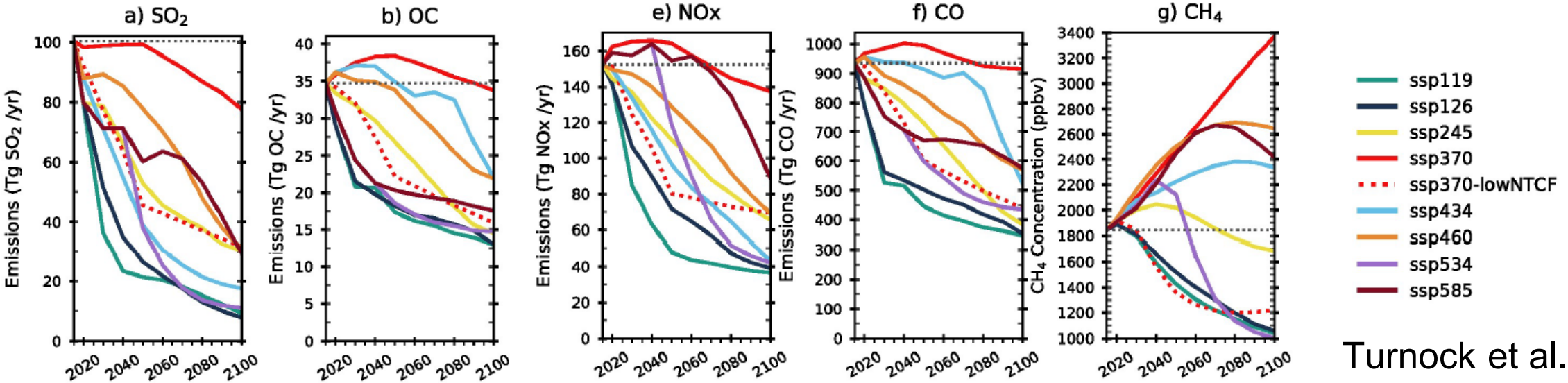
C*: Saturation vapor pressure

The widely used parameterization (VBS) scheme does not capture the response to emission changes due to simplified chemistry



Jo et al. (2019)

Correct sensitivity to emission change is critically important for future prediction of SOA



Turnock et al. (2020)

Objective: Investigate the future IEPOX -SOA change using the explicit isoprene chemistry, and compare it with the isoprene SOA predictions by the VBS parameterization

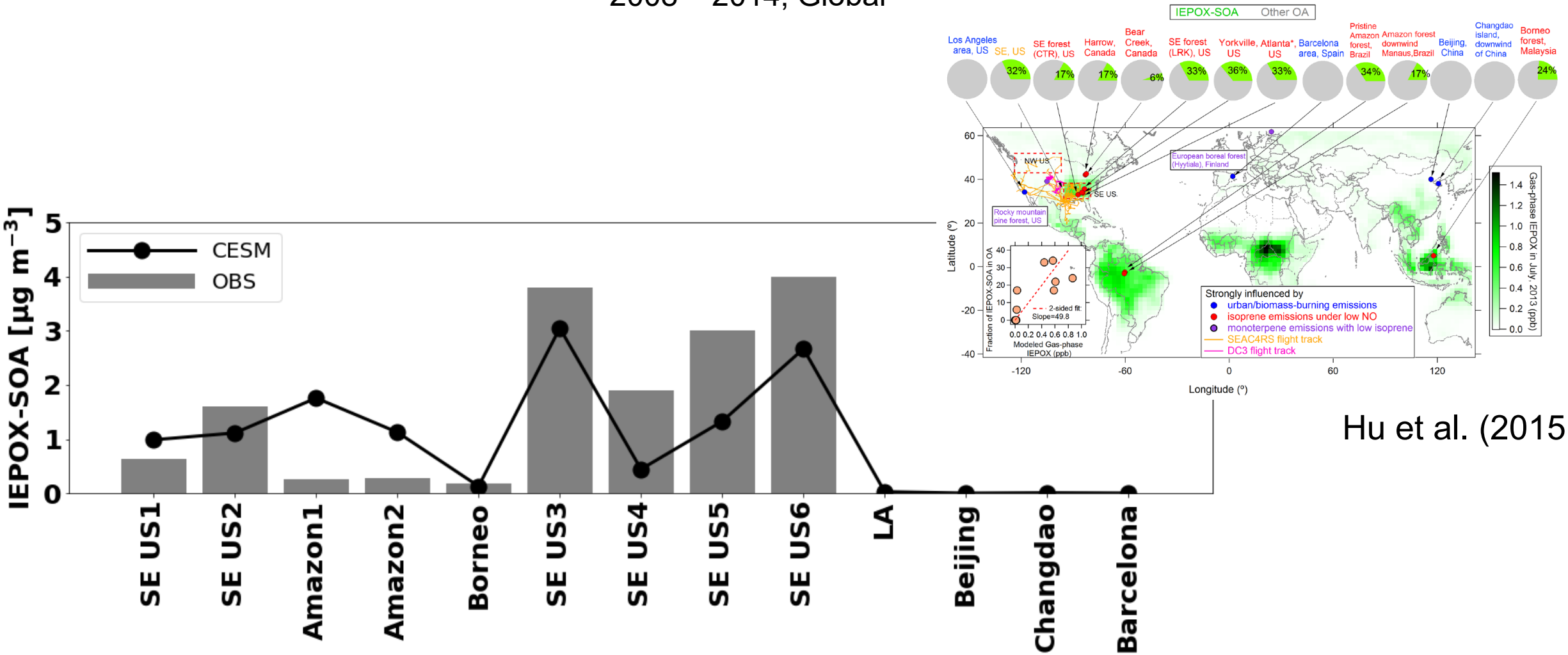
- CESM 2.1.0 release version (CAM6-chem)
  + detailed isoprene gas-phase mechanism (MOZART-T2 chemistry, Schwantes et al., 2020)
  + MOSAIC thermodynamic model for aerosol pH calculation (Zaveri et al., 2020)
  + IEPOX reactive uptake on acidic aerosols
  + NO_x-dependent yields for the VBS parameterization
  + reduced tropical isoprene emissions (emission factors of tropical tree PFTs are decreased by half)

- F case run
  – coupled atmosphere and land models
  – prescribed SST and ice from observational dataset (present) and WACCM results for CMIP6 (future, conducted by Mike Mills)

- Under present (2005-2014) and future (2045-2054; 2091-2100) climate
- Four Shared Socioeconomic Pathways (SSPs) used – SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5

Model evaluation against global surface aerosol mass spectrometer dataset

2008 – 2014, Global

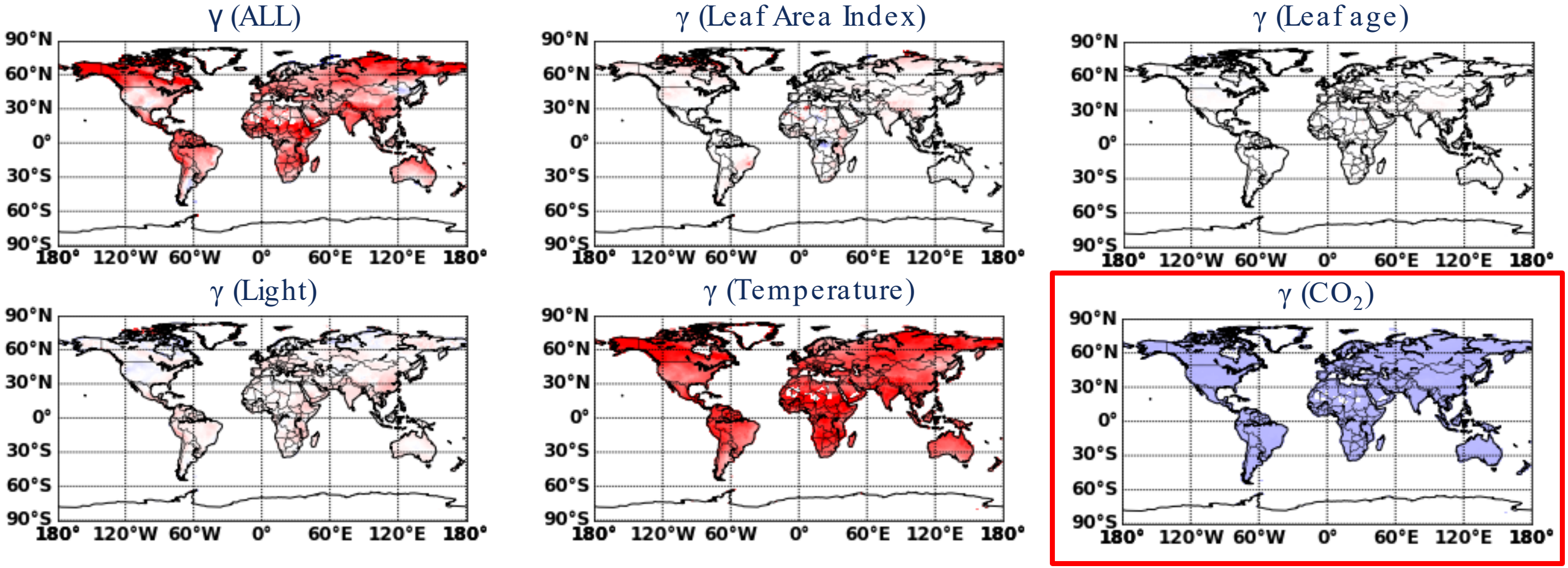


Hu et al. (2015)

$R^2 = 0.65$

Factors affecting isoprene emission changes under future climate (SSP5 -8.5)

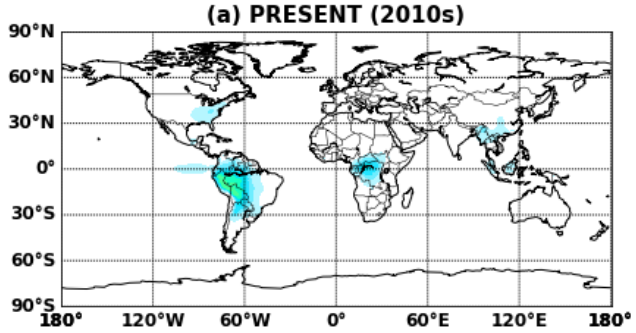
Ratio (SSP5-8.5 / Present)

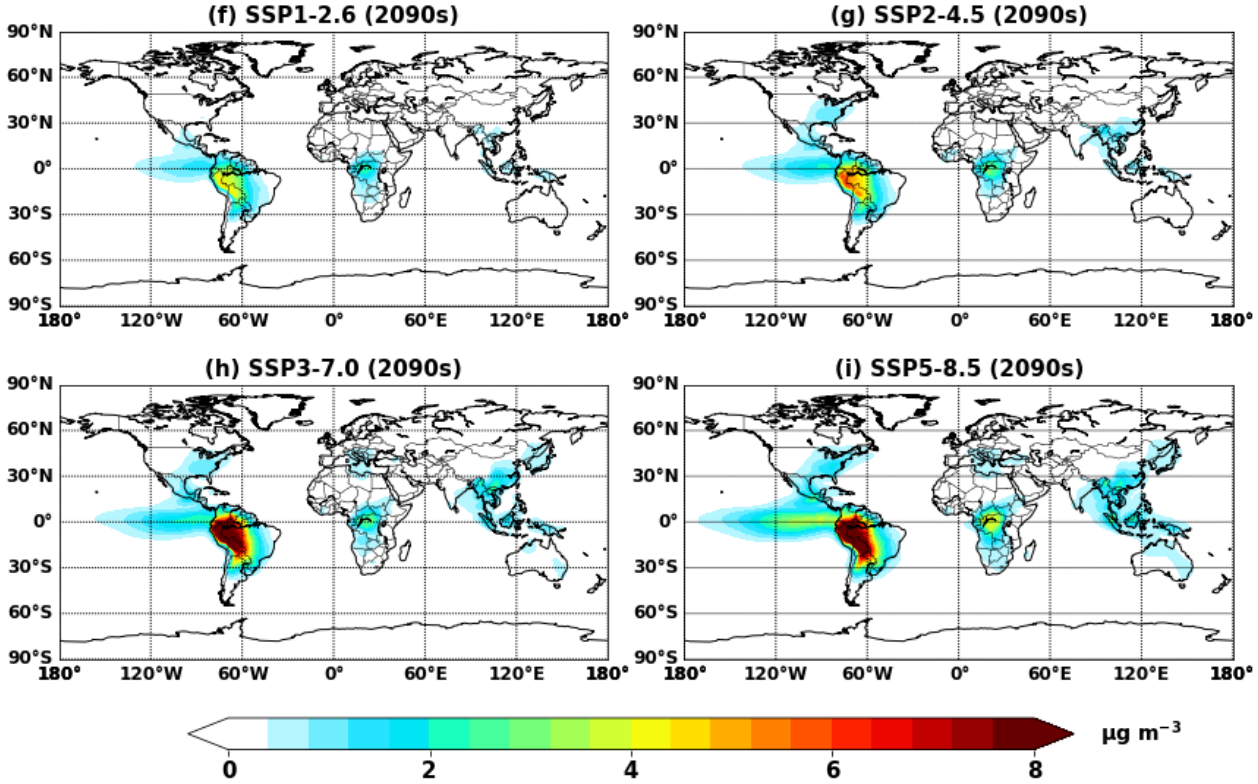


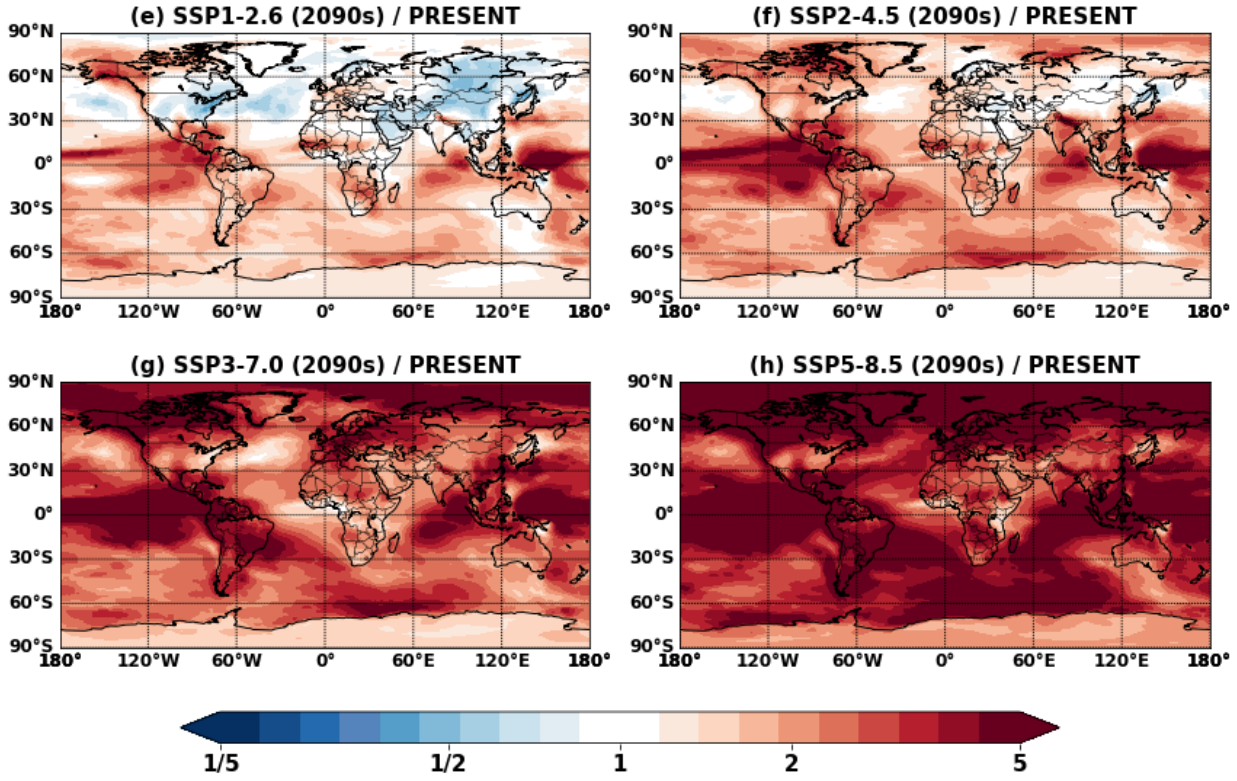
Based on MEGANv2.1 (Guenther et al., 2012) biogenic emission module in CESM2.1.0

Global mean IEPOX -SOA concentrations at the surface (2010s and 2090s) simulated by explicit chemistry

- Without CO_2 inhibition effect







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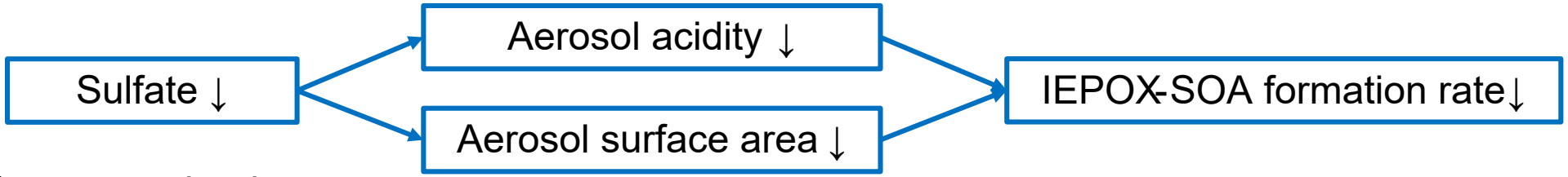
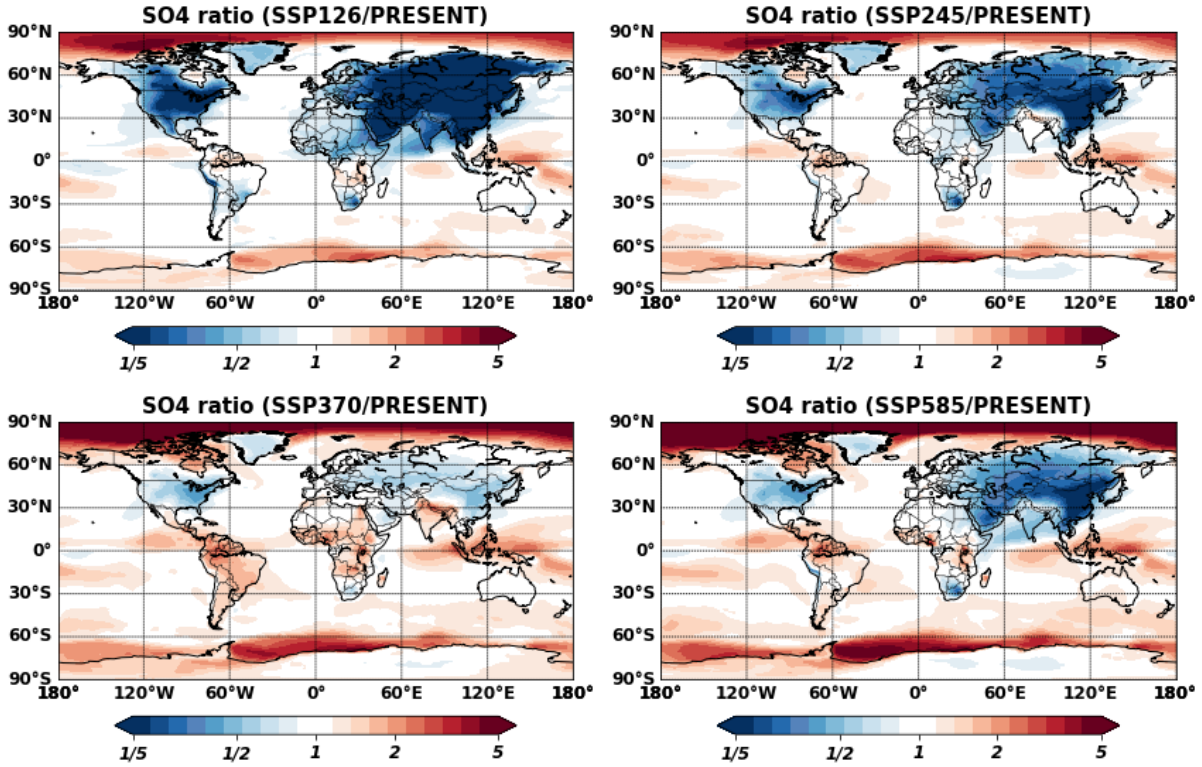
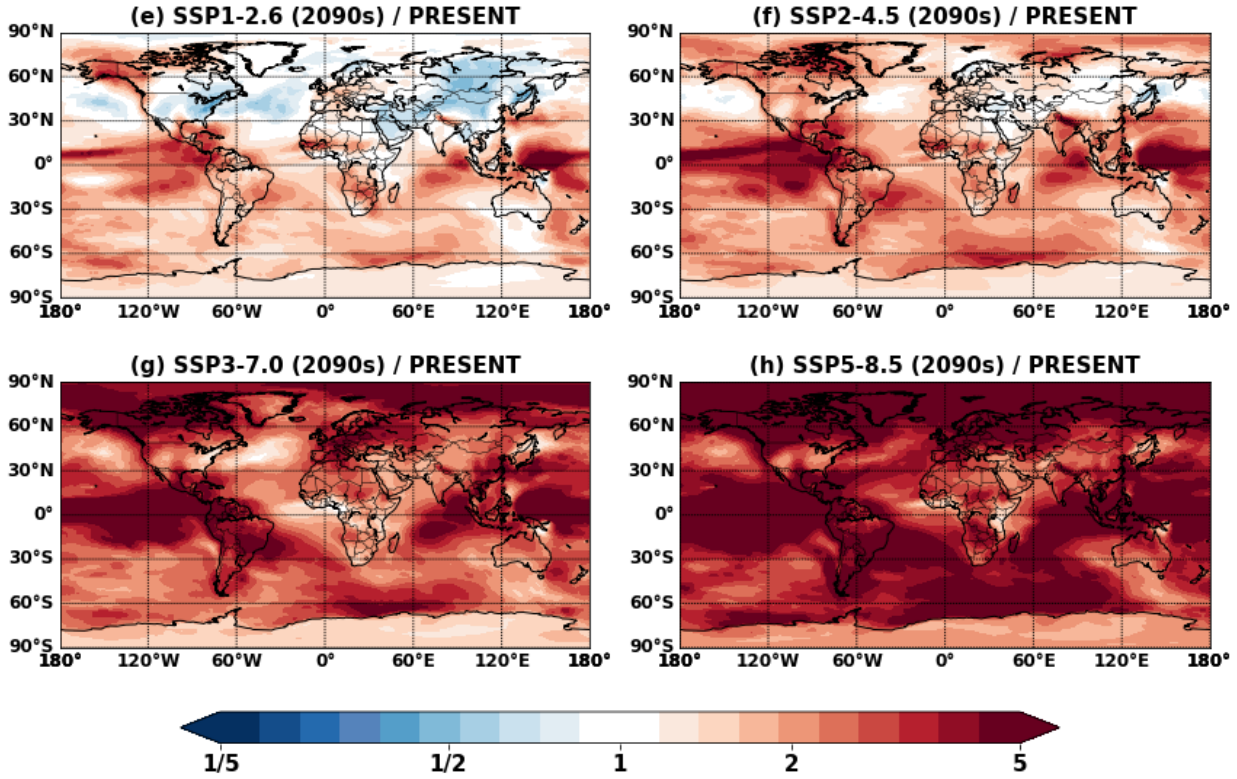


- Sulfate aerosol ratio





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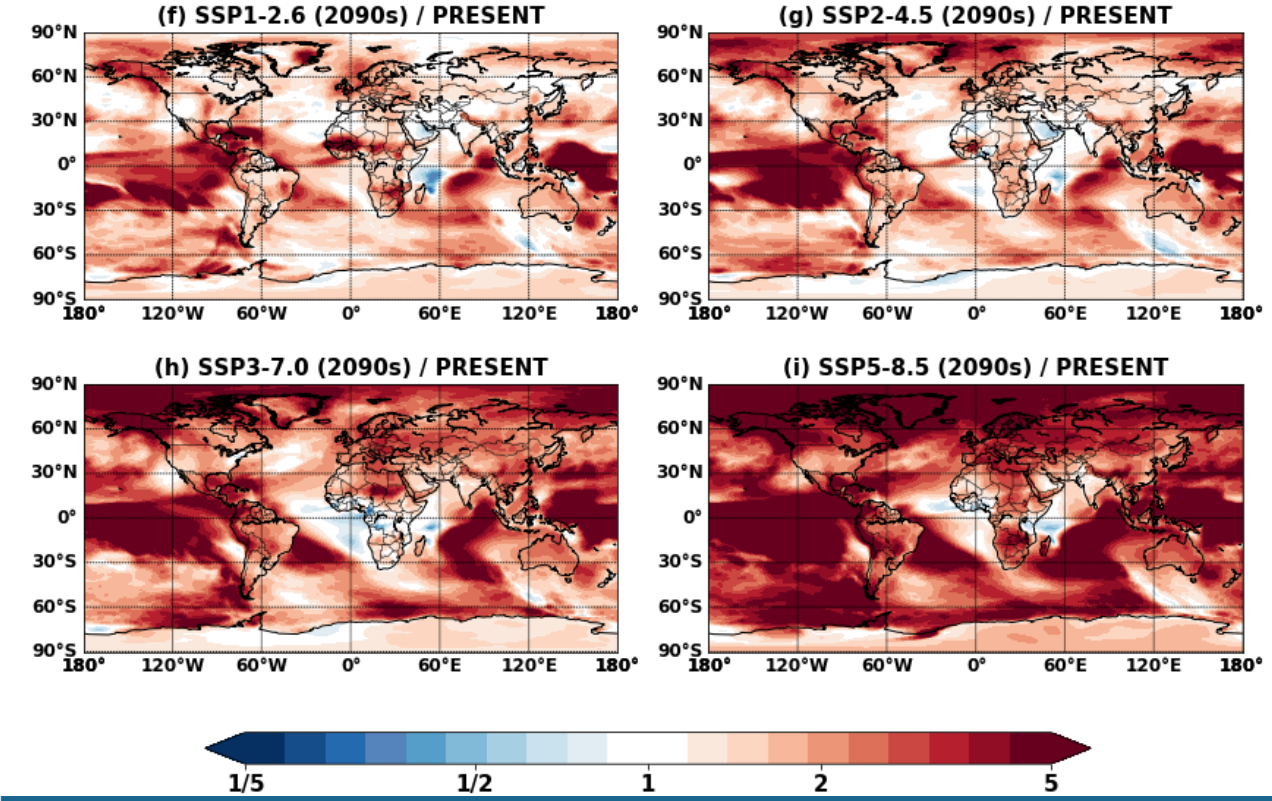
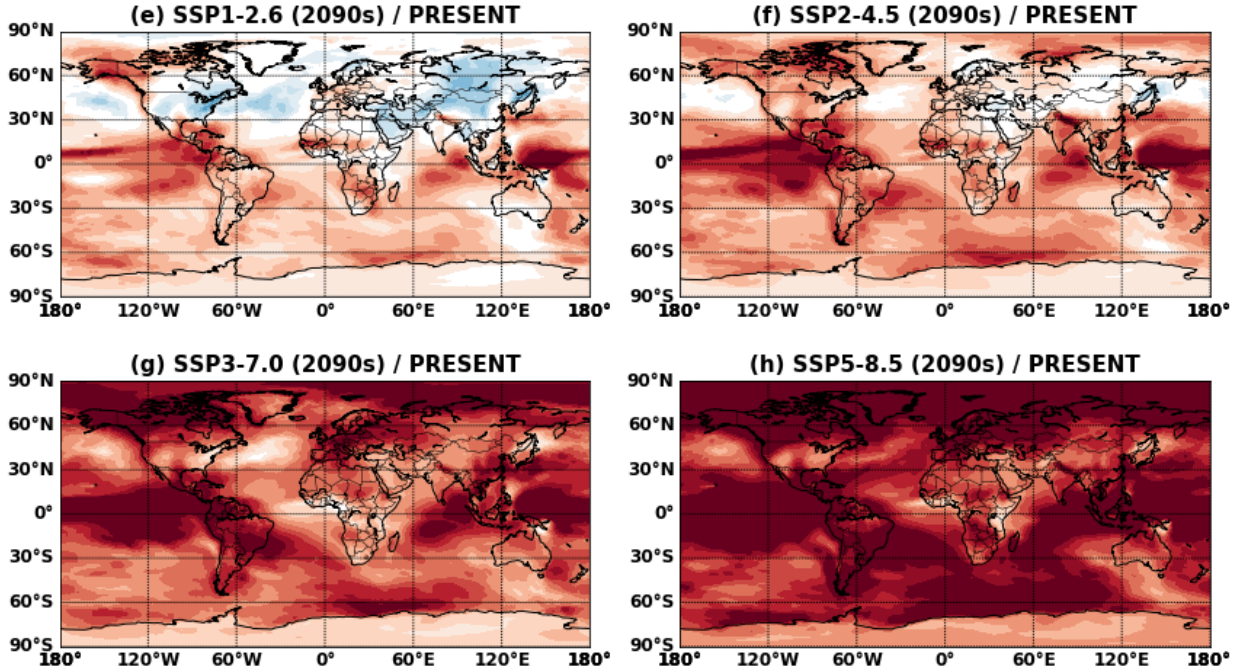
VBS parameterization



Explicit chemistry



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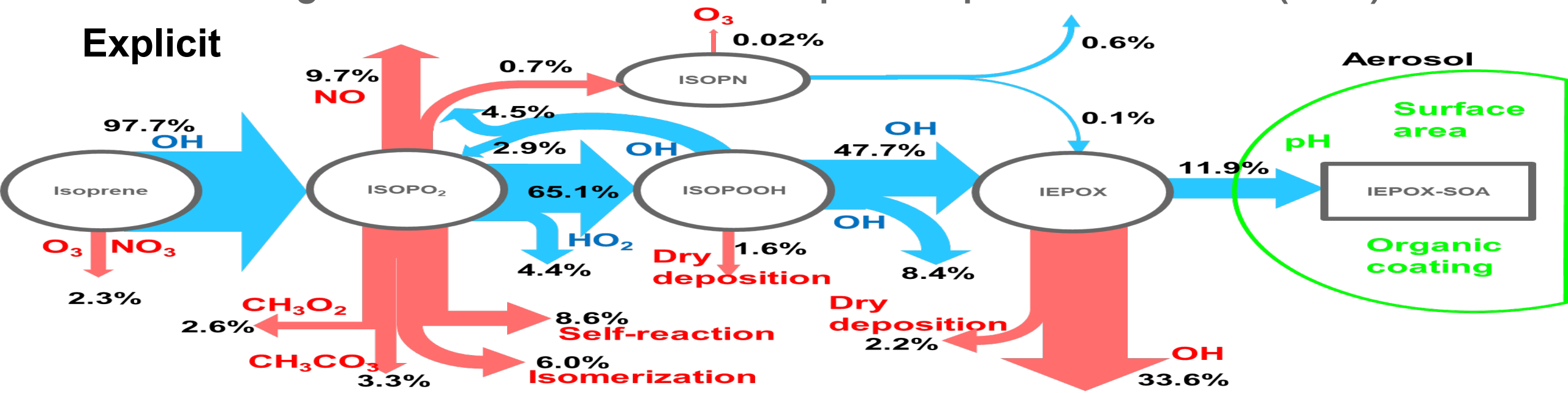

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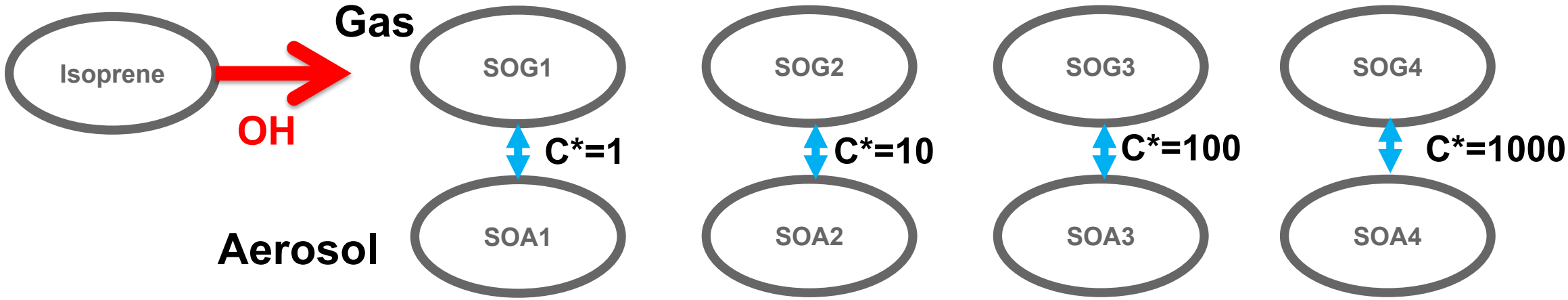


Global tropospheric IEPOX -SOA burden under present and future climate

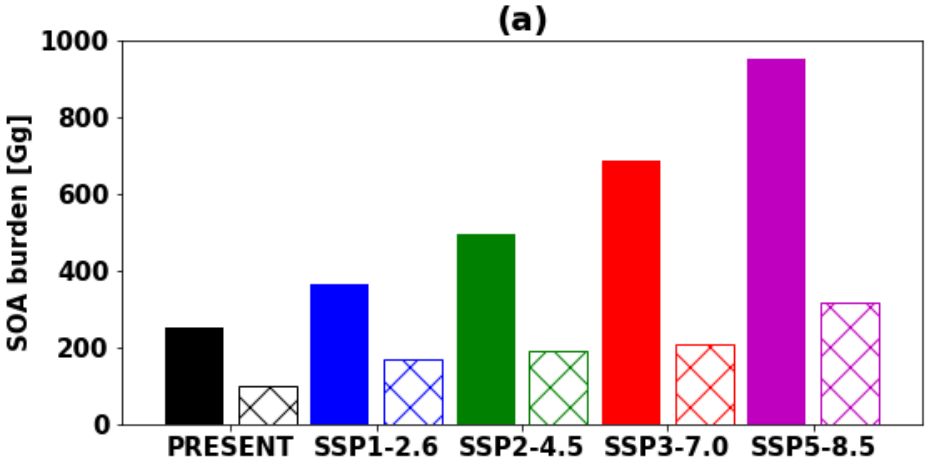
Explicit

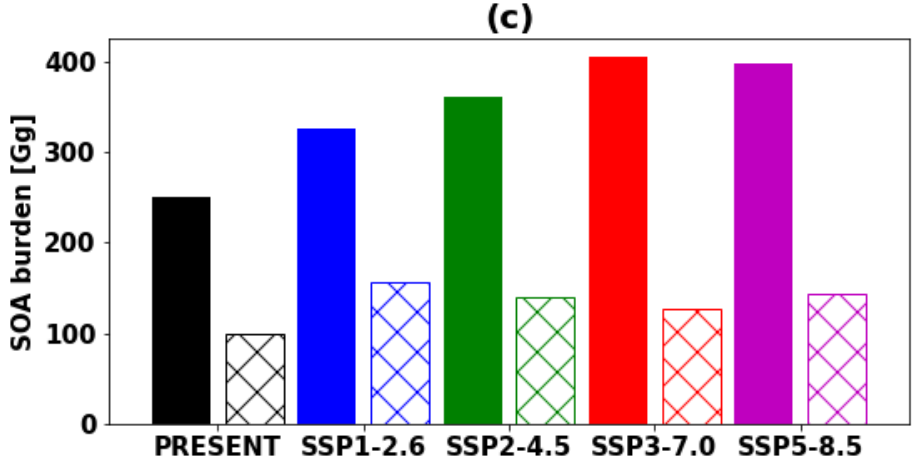
VBS

Without CO_2 inhibition

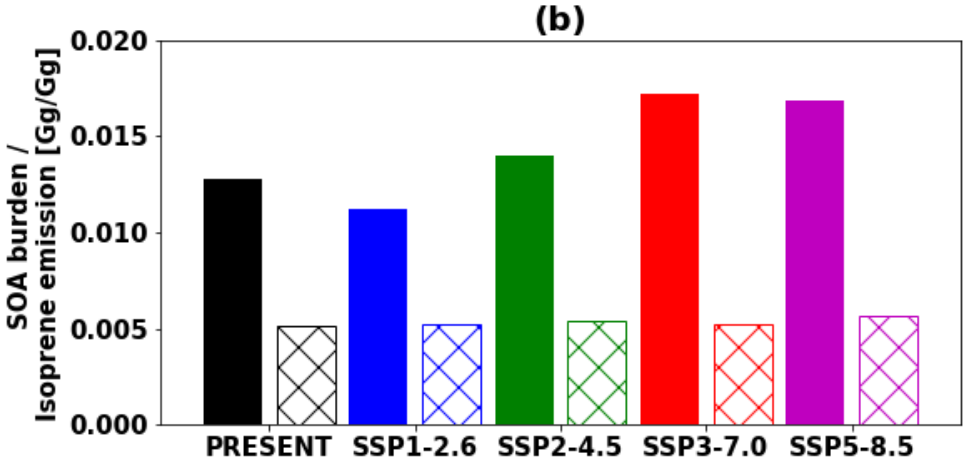
With CO_2 inhibition

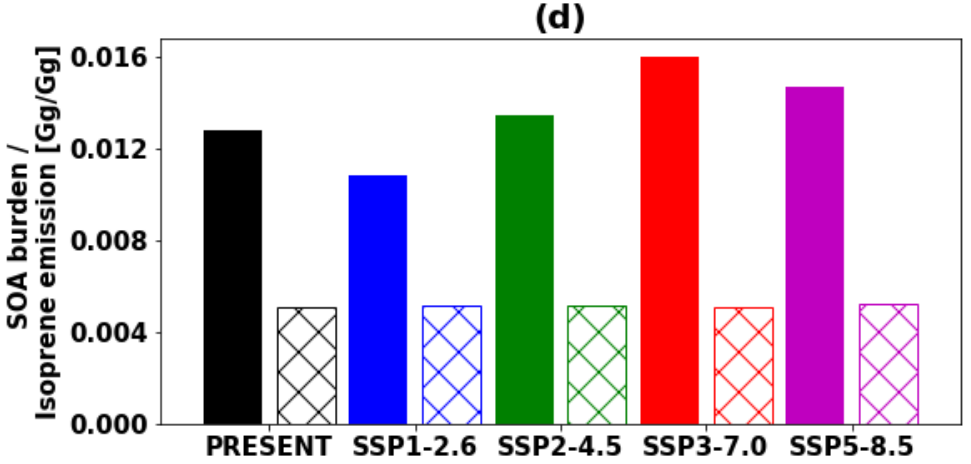
SOA burden [Gg]





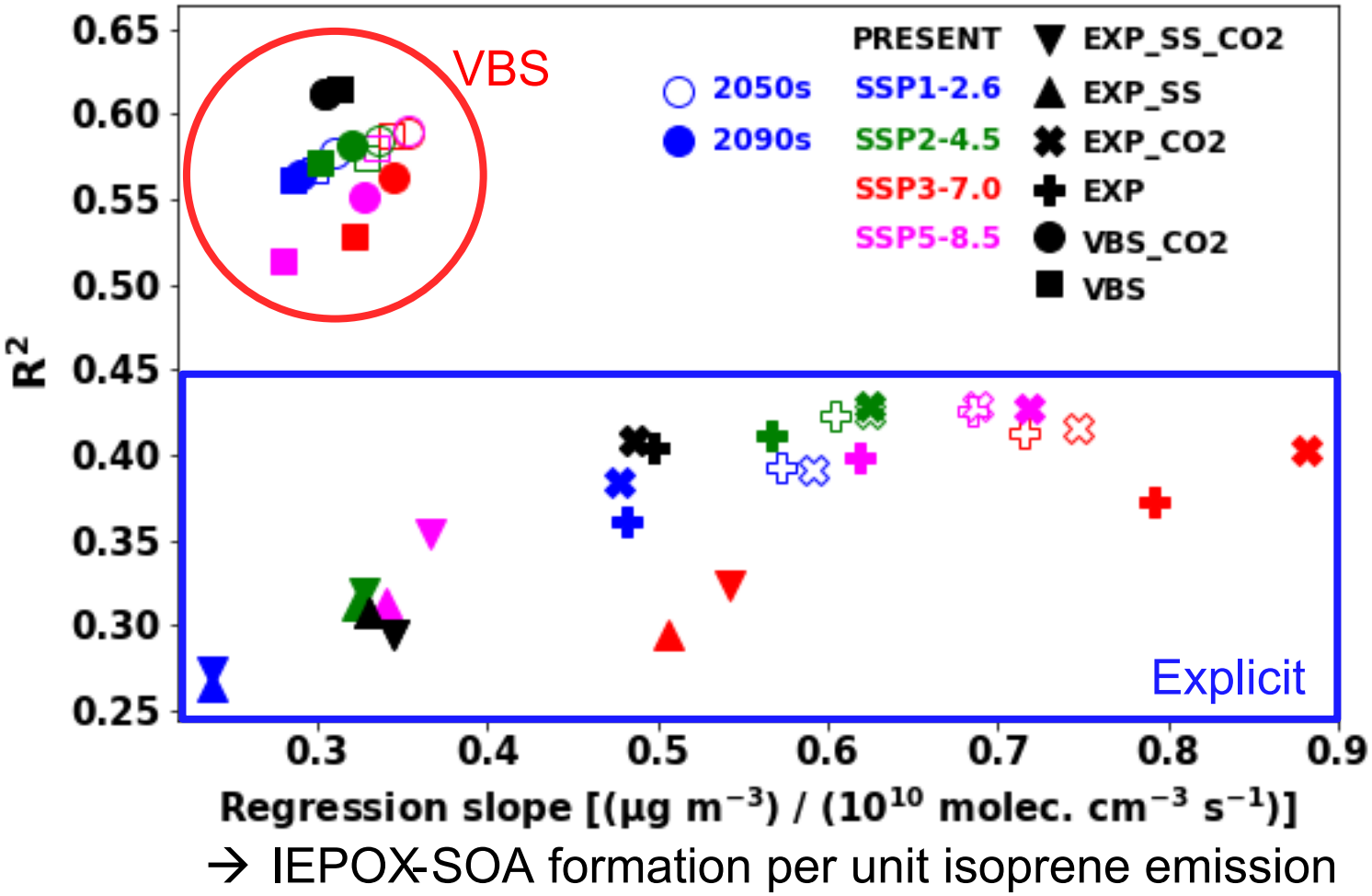
SOA burden [Gg] / Isoprene emission [Gg]



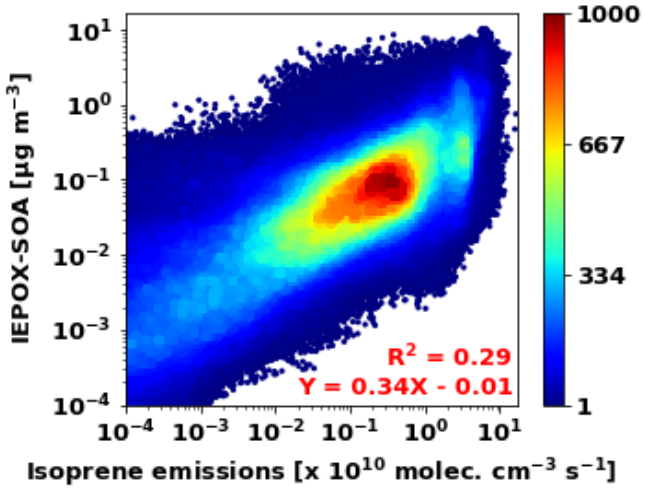


Temperature & isoprene emissions

Global tropospheric IEPOX -SOA burden under present and future climate



→ IEPOX-SOA formation per unit isoprene emission



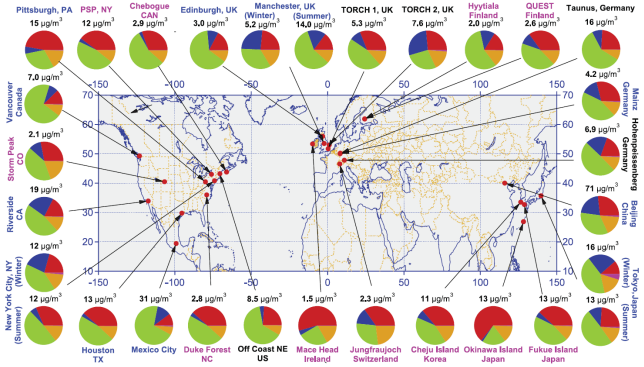
- Lower R^2 between IEPOX-SOA concentrations and isoprene emissions

→ There are other factors affecting IEPOX-SOA formation (e.g. chemistry) in addition to isoprene emissions

- The VBS parameterization shows nearly constant IEPOX-SOA formation efficiencies across different SSP scenarios

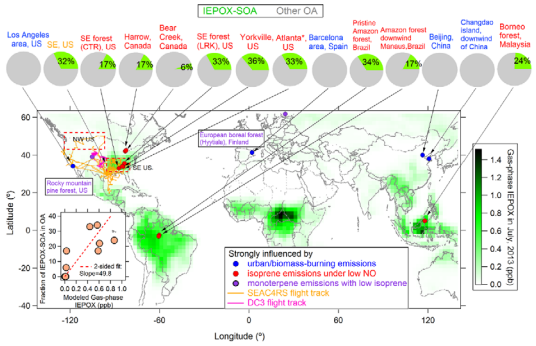
Summary

Organic aerosol contributes substantial mass fractions of submicron aerosols

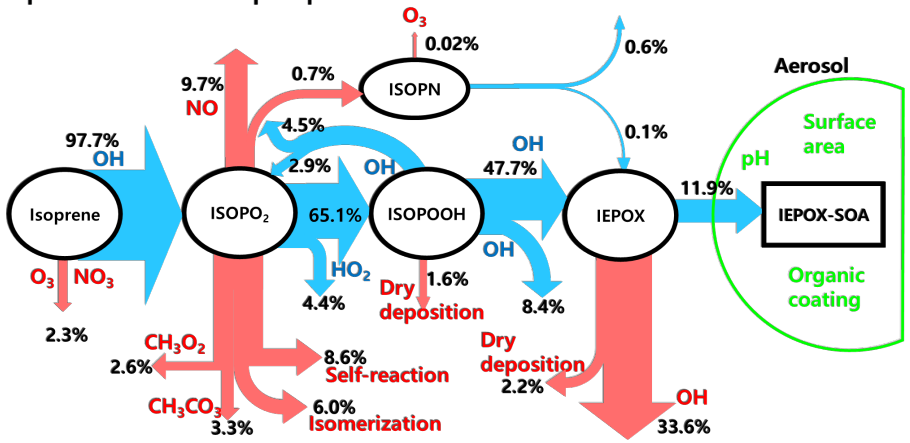


IEPOX-SOA can contribute to total OA concentrations by as much as 36%, especially for forested regions under low NO across the globe

Biogenic emissions

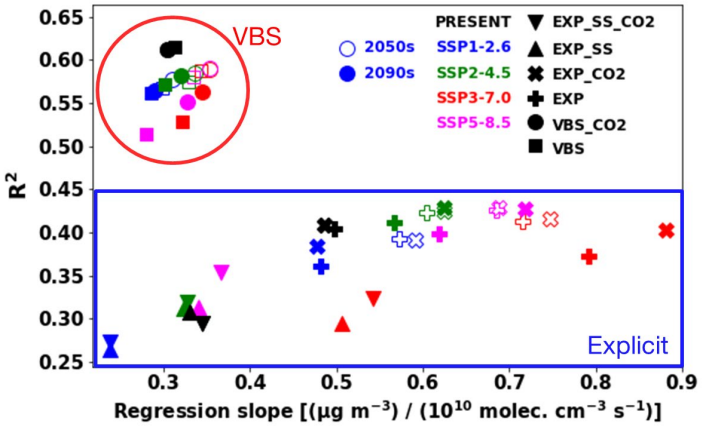


IEPOX-SOA formation depends on oxidants, aerosol pH and other properties

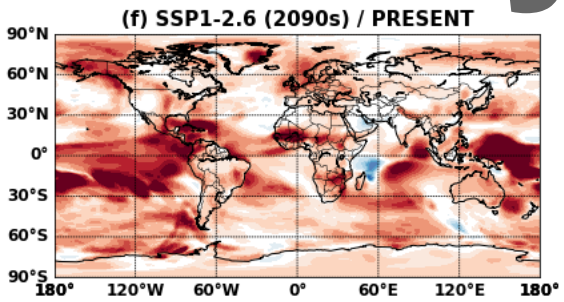


Thank you!

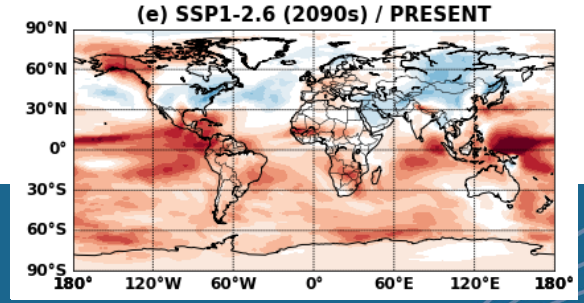
The ex
for pre
concentrations



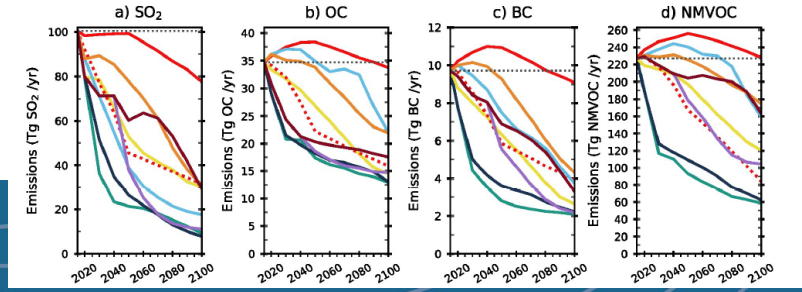
VBS



Explicit



Detailed chemistry will be very important for aerosol simulation in future climate with different emissions



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