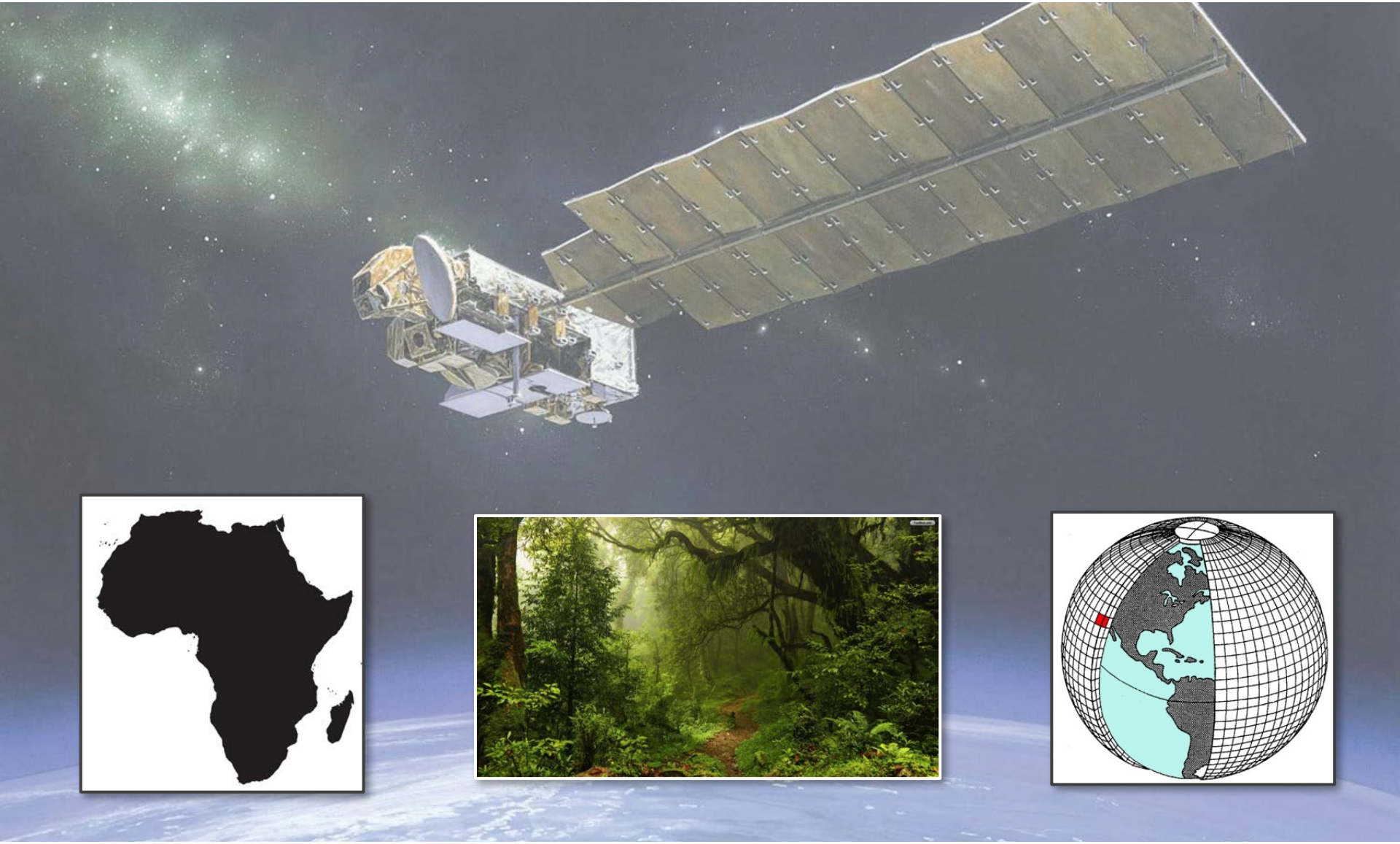
Trees and Atmospheric Chemistry

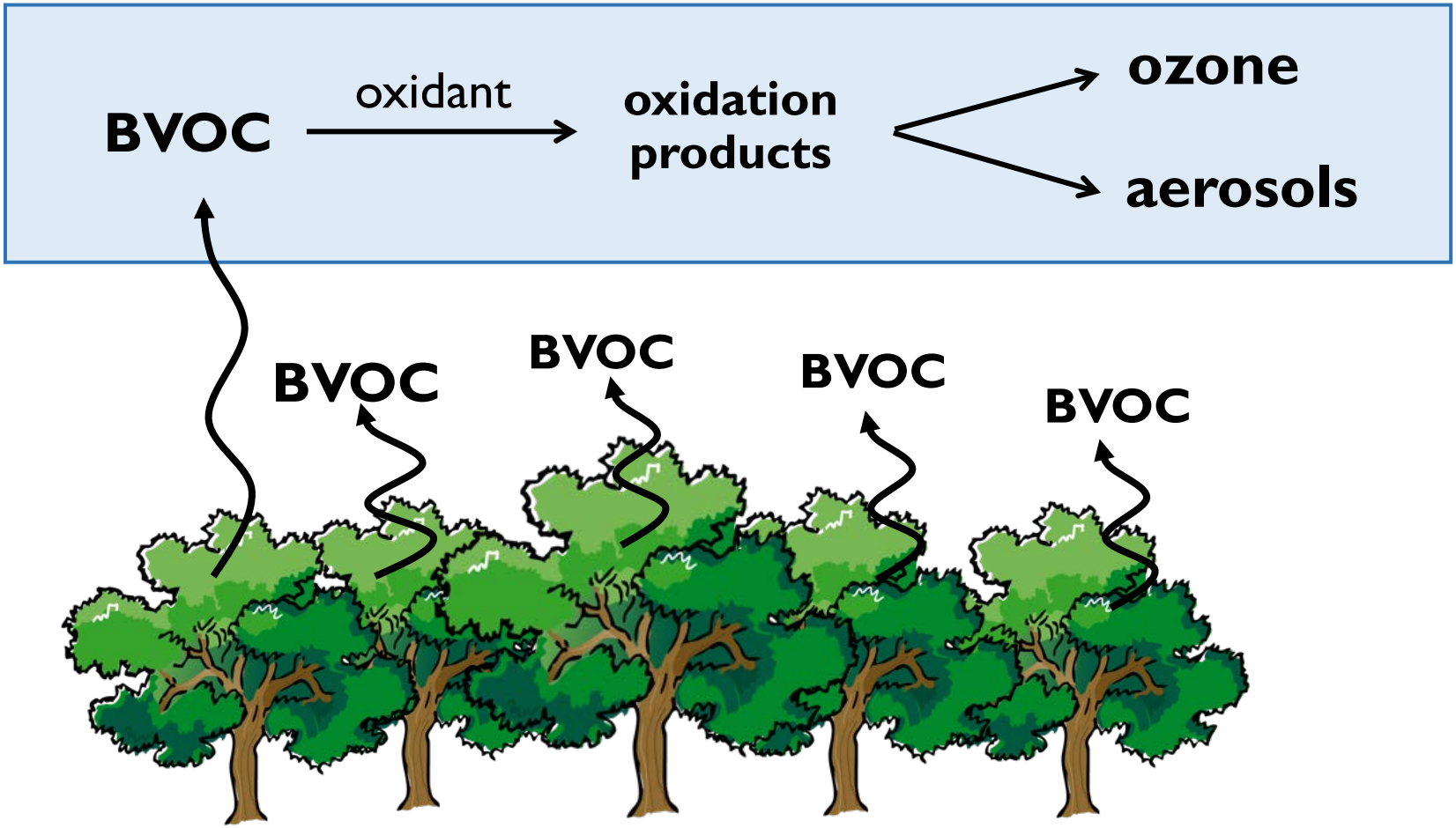


Eloïse A Marais

7 November 2017

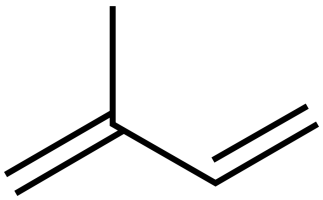
EES, St. Andrews

Biosphere-Atmosphere Interactions



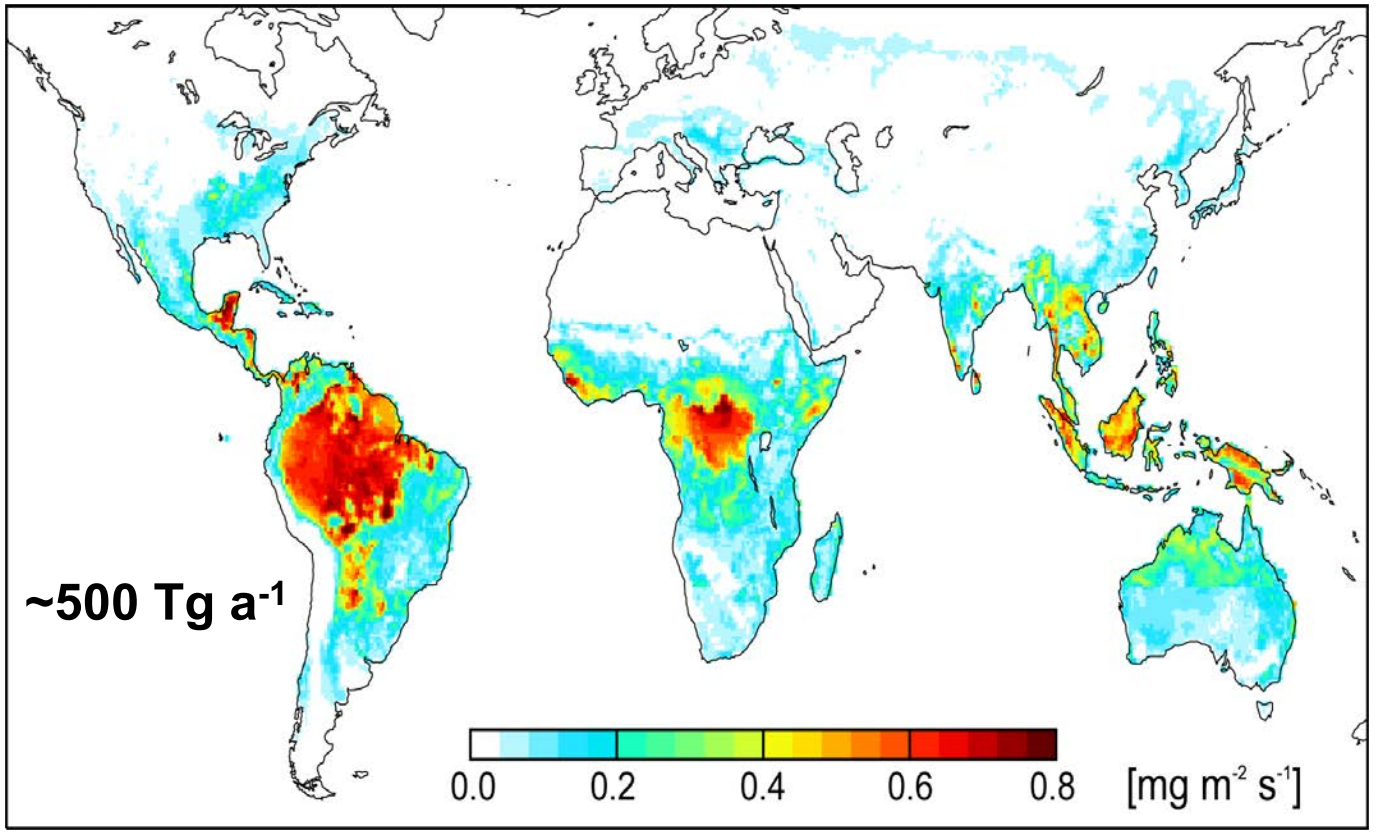
BVOCs: Biogenic volatile organic compounds

Biogenic Emissions of Isoprene



Isoprene

Most isoprene is emitted by tropical trees

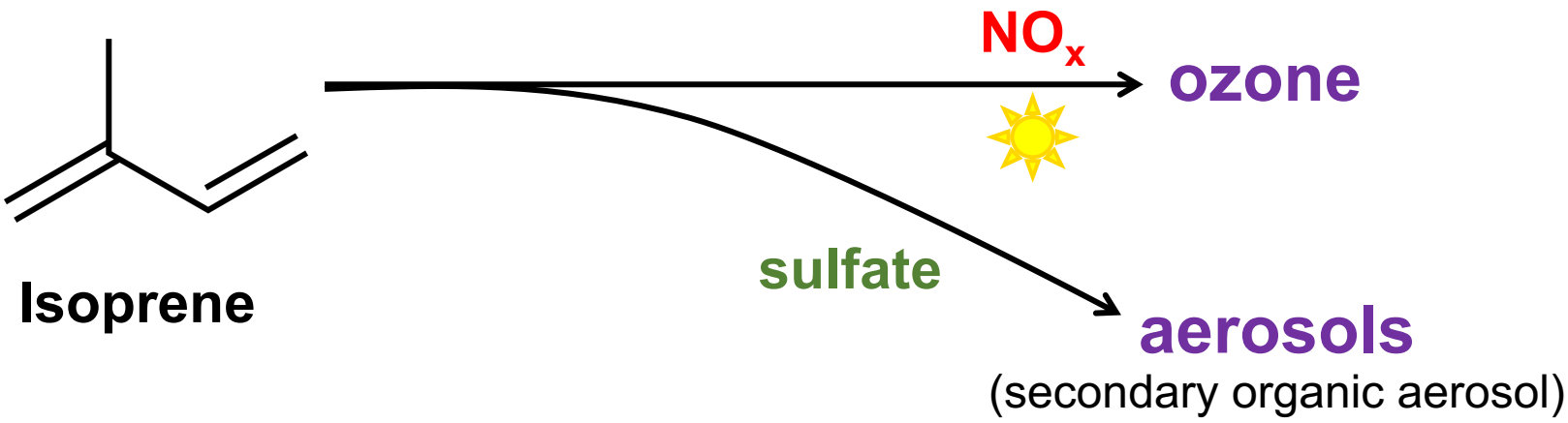


[Guenther et al., 2012]

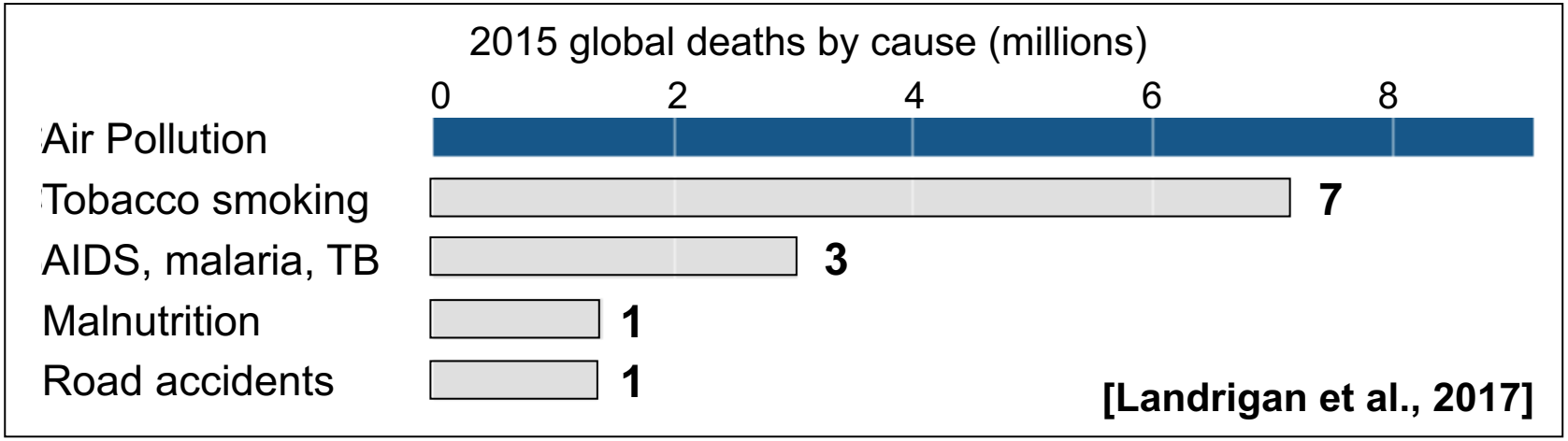
Factors that affect emissions:

plant type, temperature, light, soil moisture, CO_2, plant physiology

Isoprene Impacts Air Quality



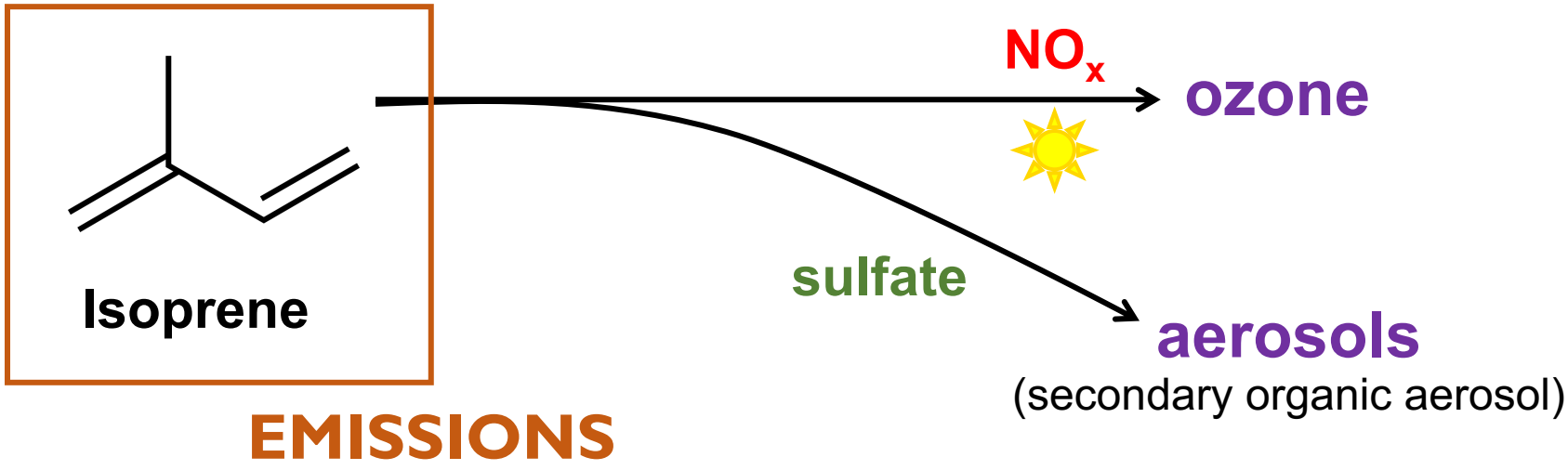
Air pollution (mostly fine aerosols) is detrimental to health



<u>Isoprene also affects climate:</u>

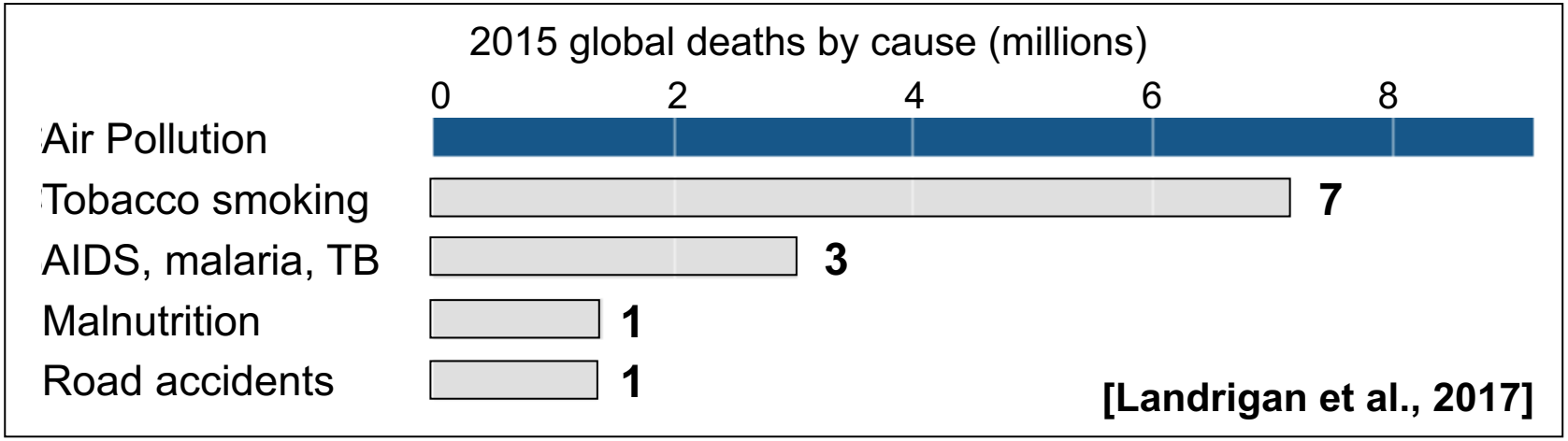
ozone is a greenhouse gas and aerosols absorb and scatter radiation

Isoprene Impacts Air Quality



EMISSIONS

Air pollution (mostly fine aerosols) is detrimental to health



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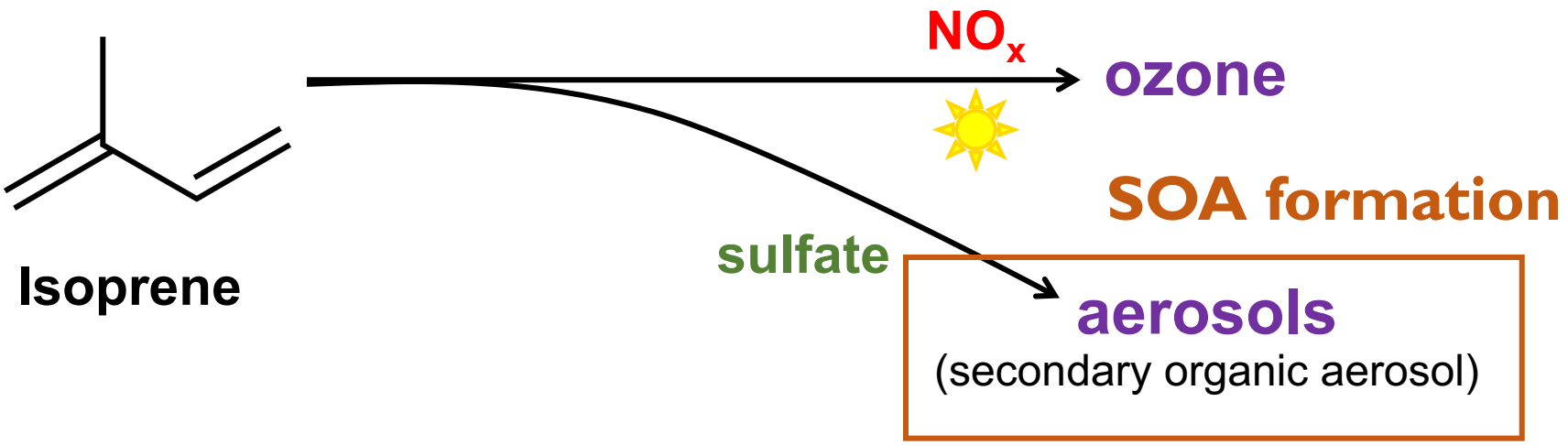

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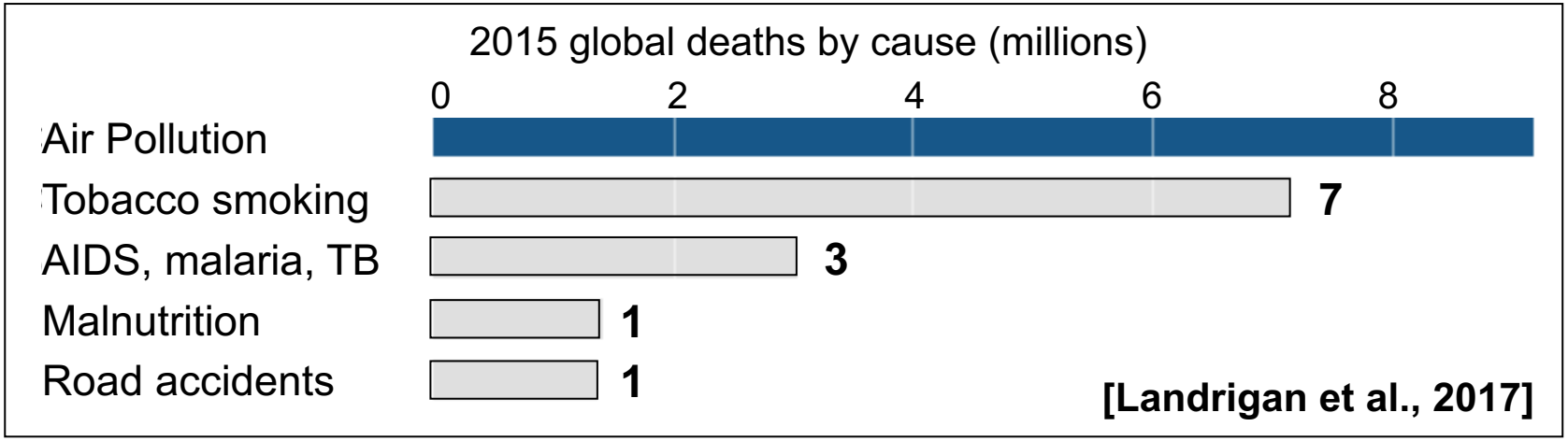


Isoprene also affects climate:

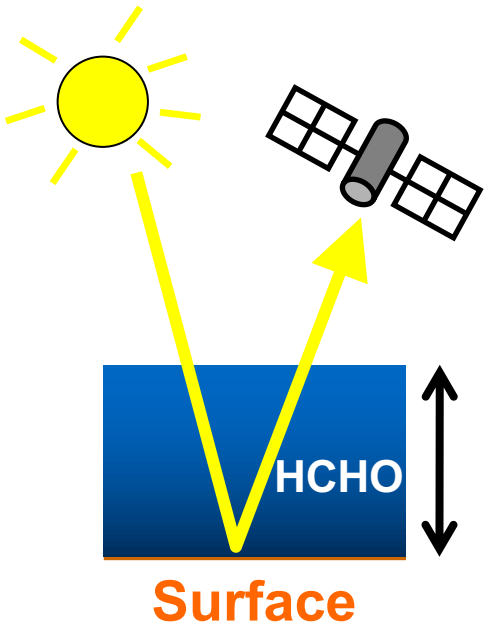
ozone is a greenhouse gas and aerosols absorb and scatter radiation

Top-down Estimate of Isoprene Emissions

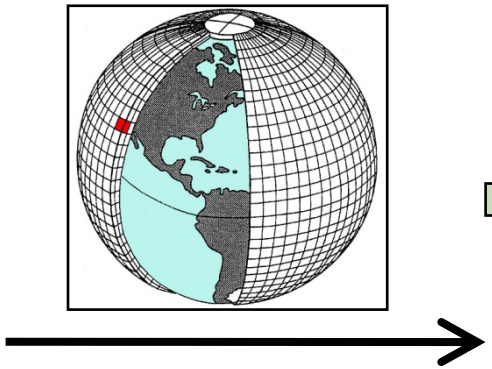
Isoprene $\xrightarrow{OH}$ **HCHO** $\xrightarrow[OH]{\text{photolysis}}$ CO, HO_2

Use a chemical transport model to convert HCHO columns to isoprene emissions

Satellite HCHO



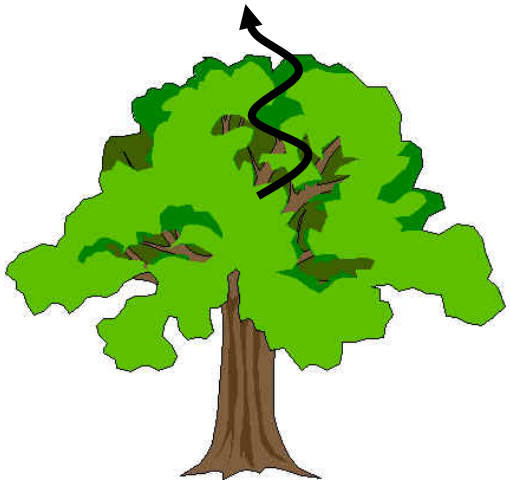
GEOS-Chem



HCHO yield from isoprene

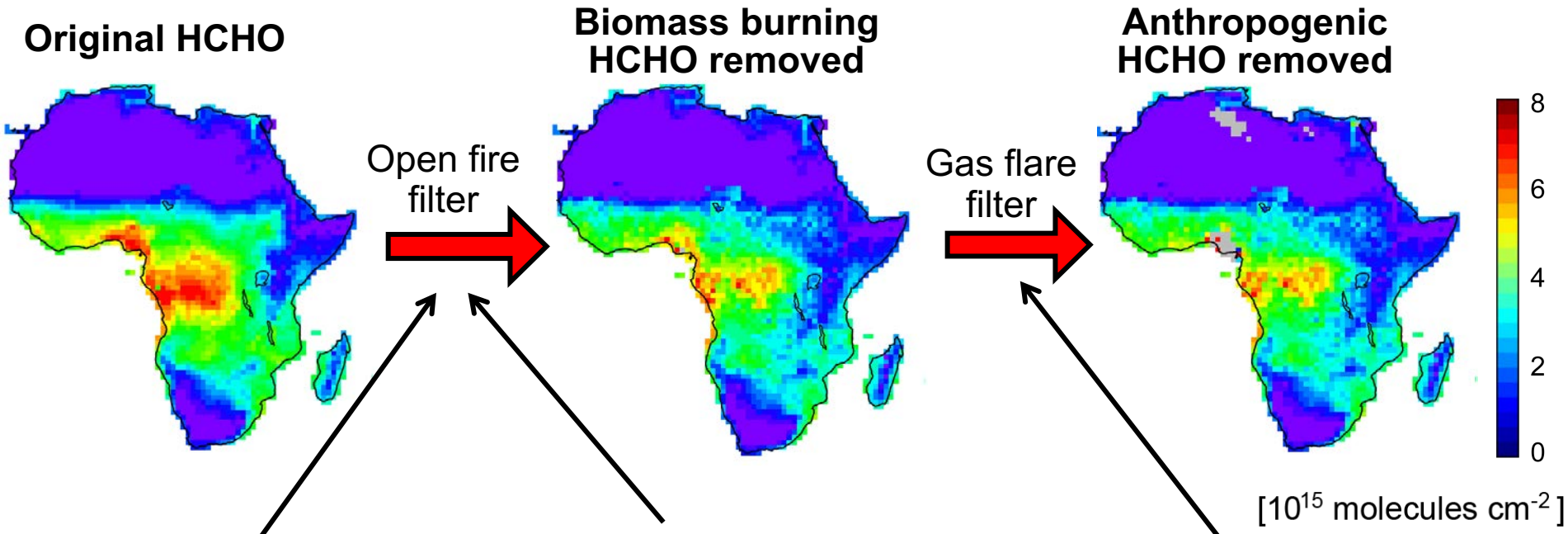
Satellite-derived Isoprene Emissions

isoprene

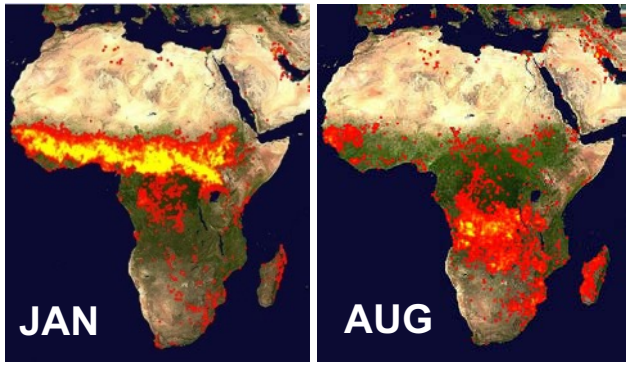


[Palmer et al., 2003; Millet et al., 2008]

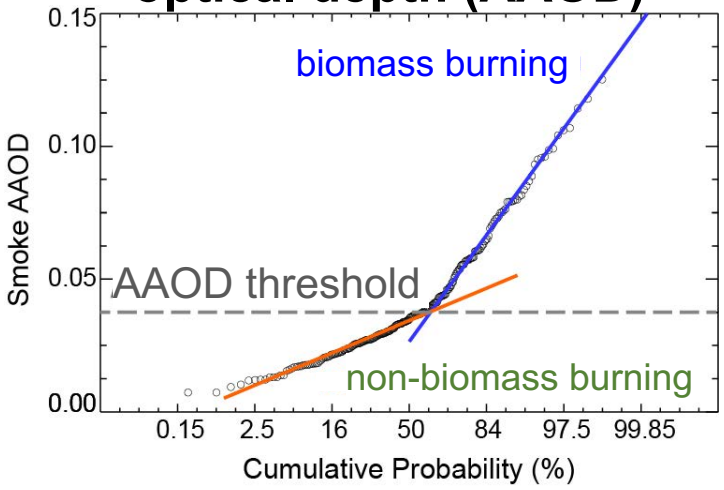
Isolate Biogenic Formaldehyde (HCHO)



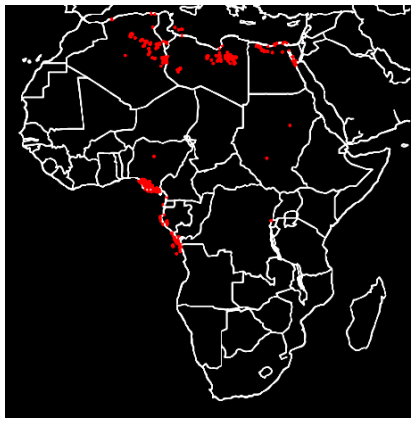
Satellite fire counts



Satellite smoke aerosol optical depth (AAOD)



Satellite gas flares

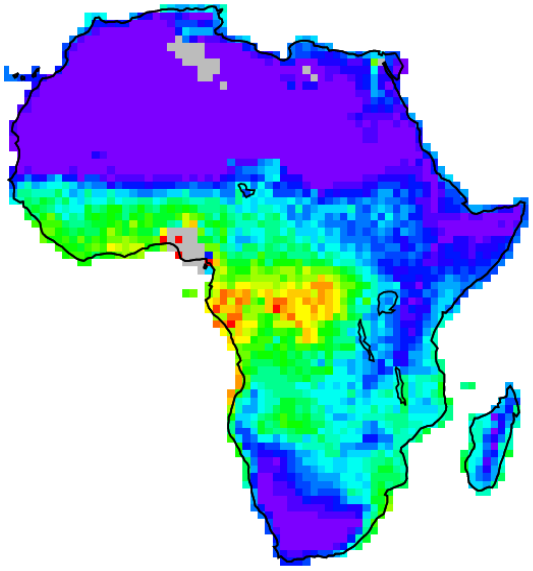


[Marais et al., ACP, 2012]

Convert HCHO to Isoprene Emissions

Yields of HCHO from isoprene depend on ambient concentrations of NO_x

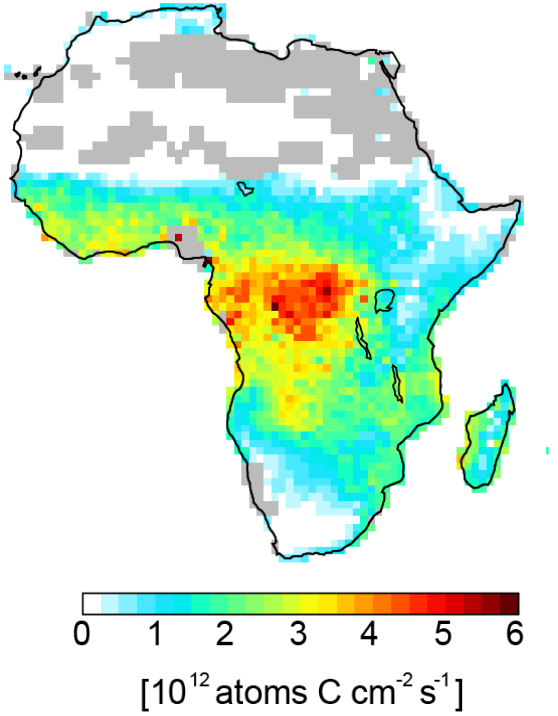
Satellite biogenic HCHO



HCHO yields from isoprene

GEOS-Chem

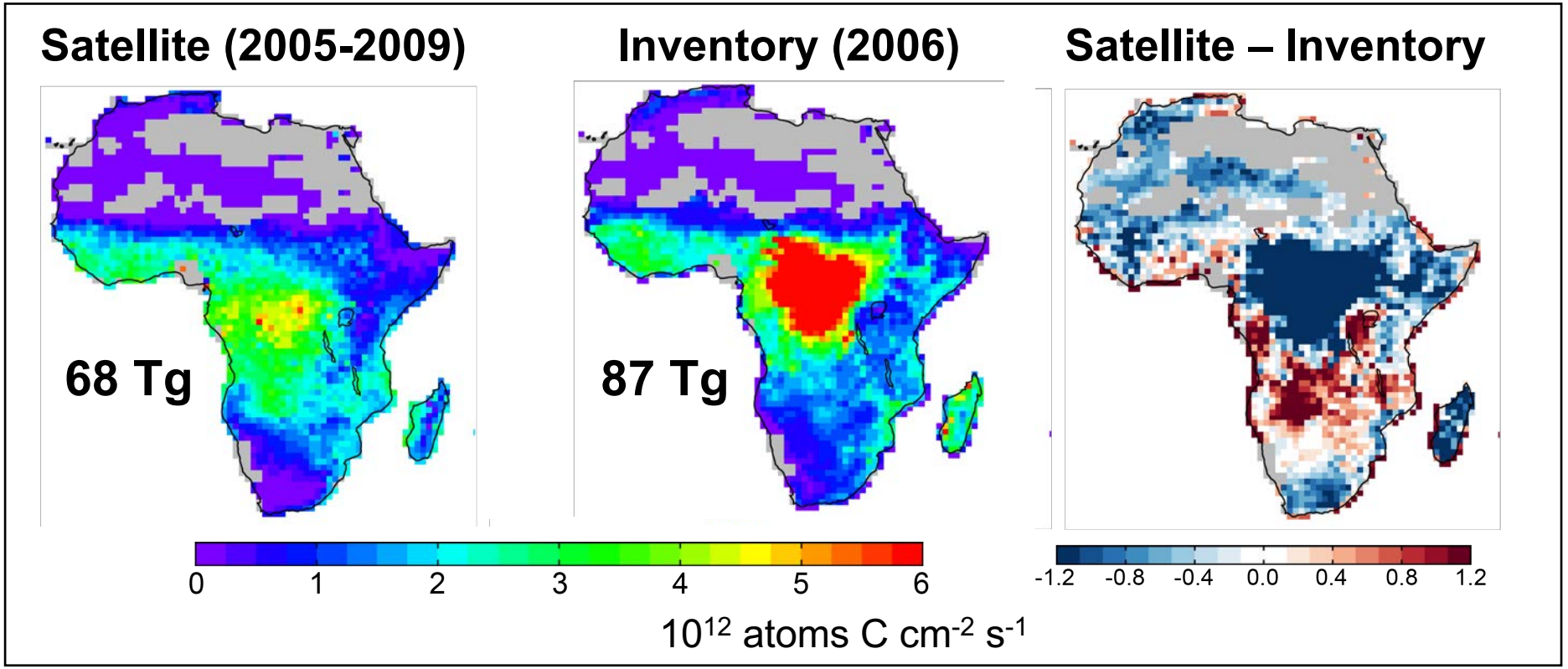
Satellite-derived isoprene emissions



[Marais et al., ACP, 2012]

Evaluate State-of-Science Emission Inventory

Large regional differences between satellite and inventory emissions



Maps: Annual means

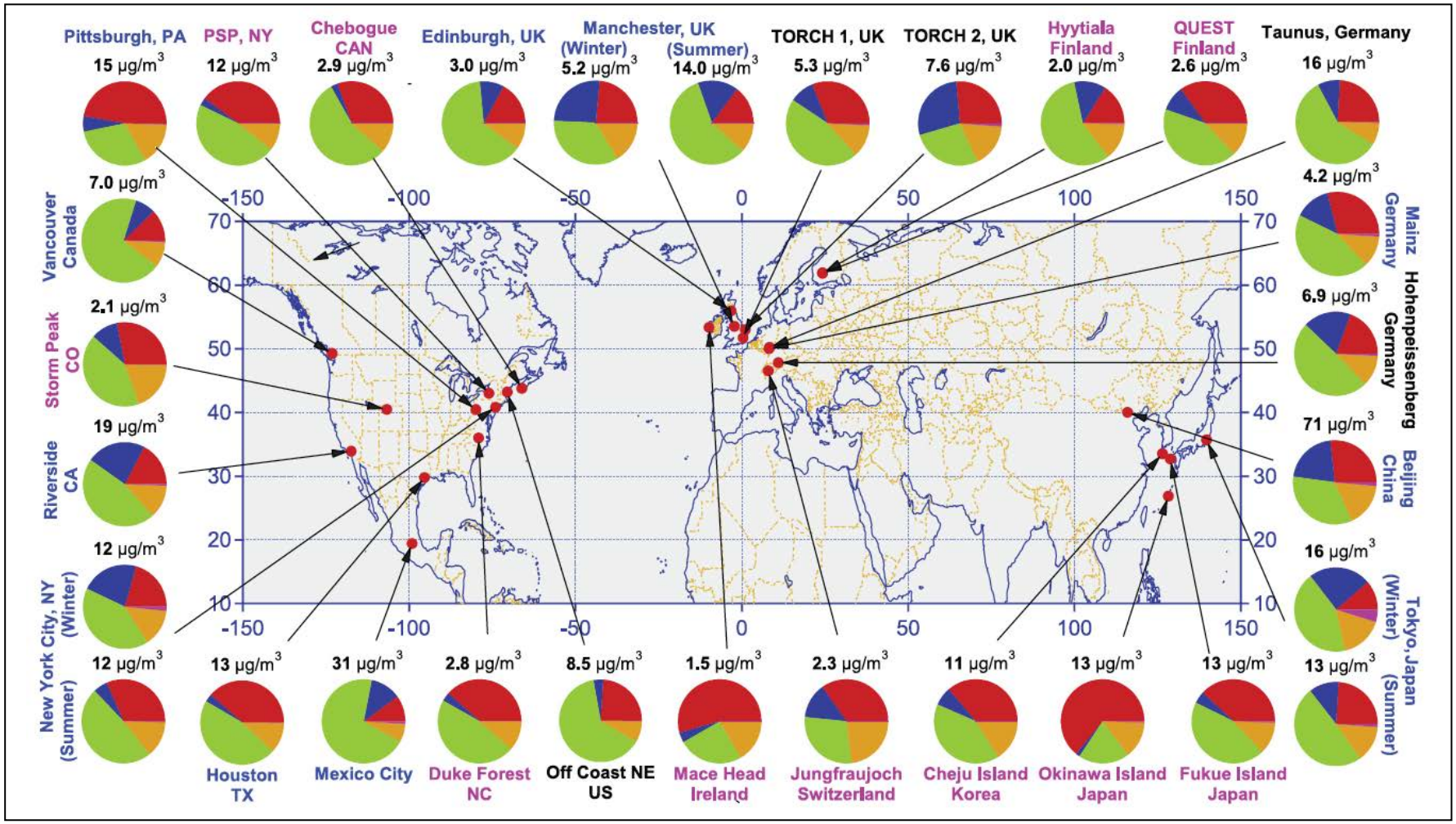
Values Inset: Annual total isoprene emitted

[Marais et al., ACP, 2012]

Implication: Impacts ability to determine contribution of isoprene to local and regional air quality and climate

Isoprene Organic Aerosol Formation

Organic aerosol (OA) is ubiquitous in the atmosphere

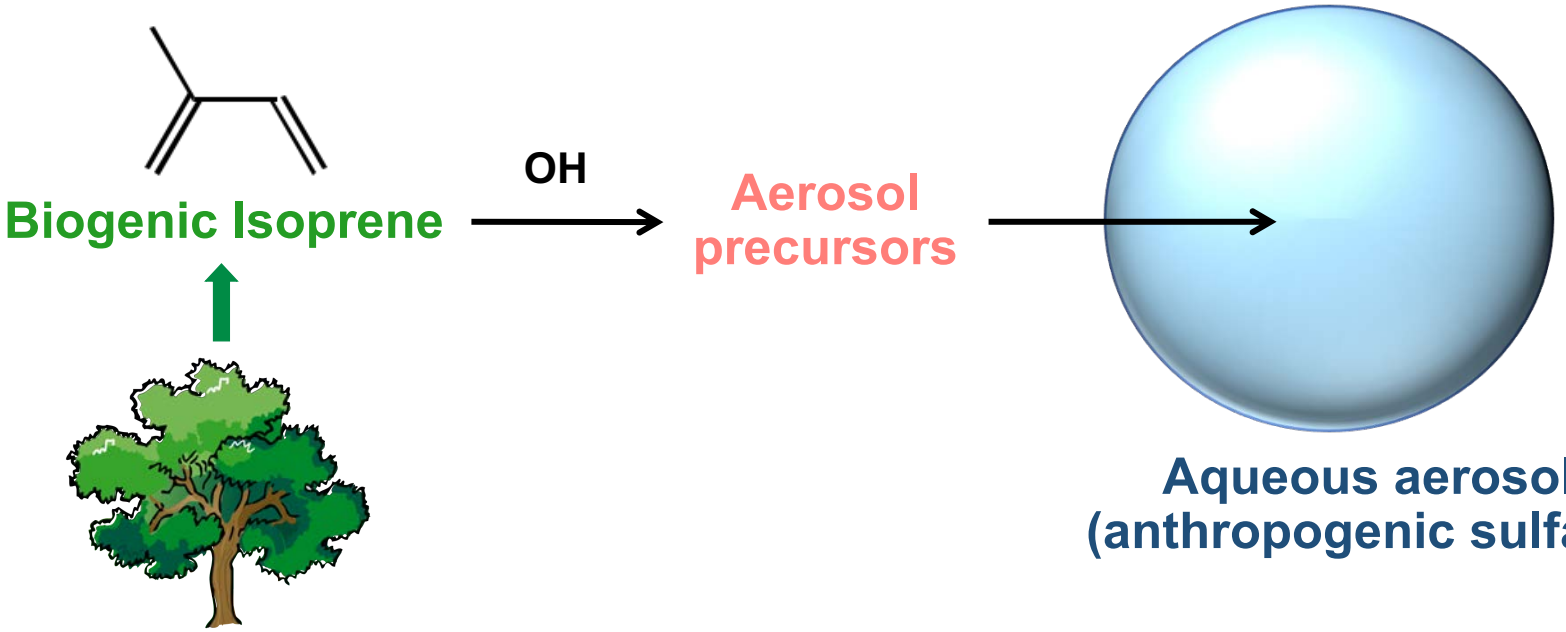


Sulfate **Nitrate** **Ammonium** **Organics (OA)**

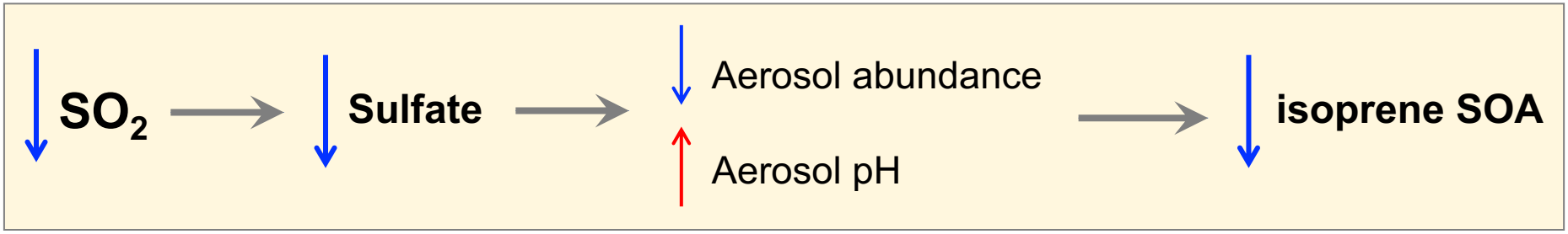
[Zhang et al., 2007]

Updated Mechanism for Aerosol Formation

Couple isoprene secondary organic aerosol (SOA) mechanism to detailed gas-phase chemistry in the GEOS-Chem model



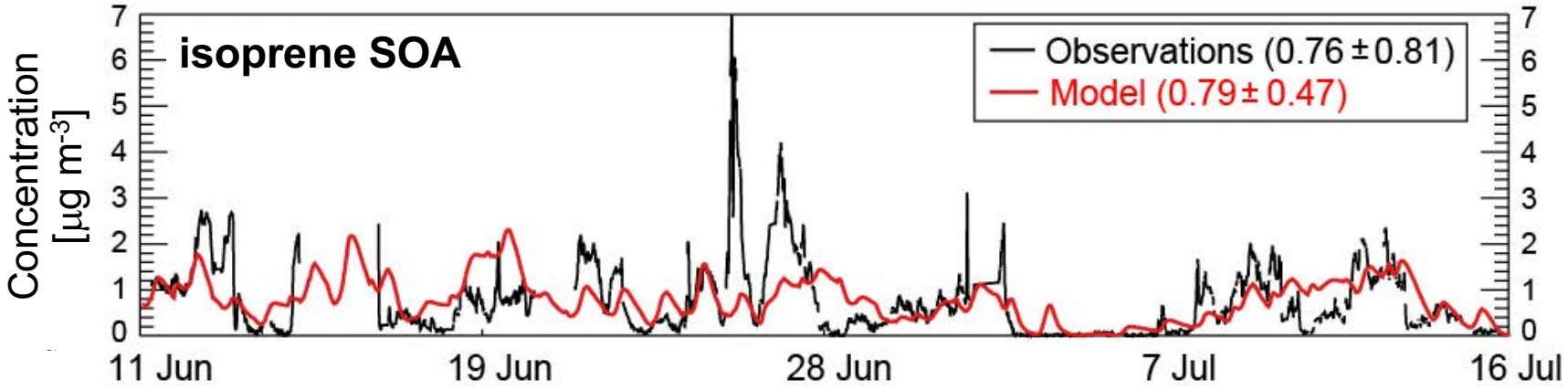
Anthropogenic sulfate influences formation of isoprene SOA



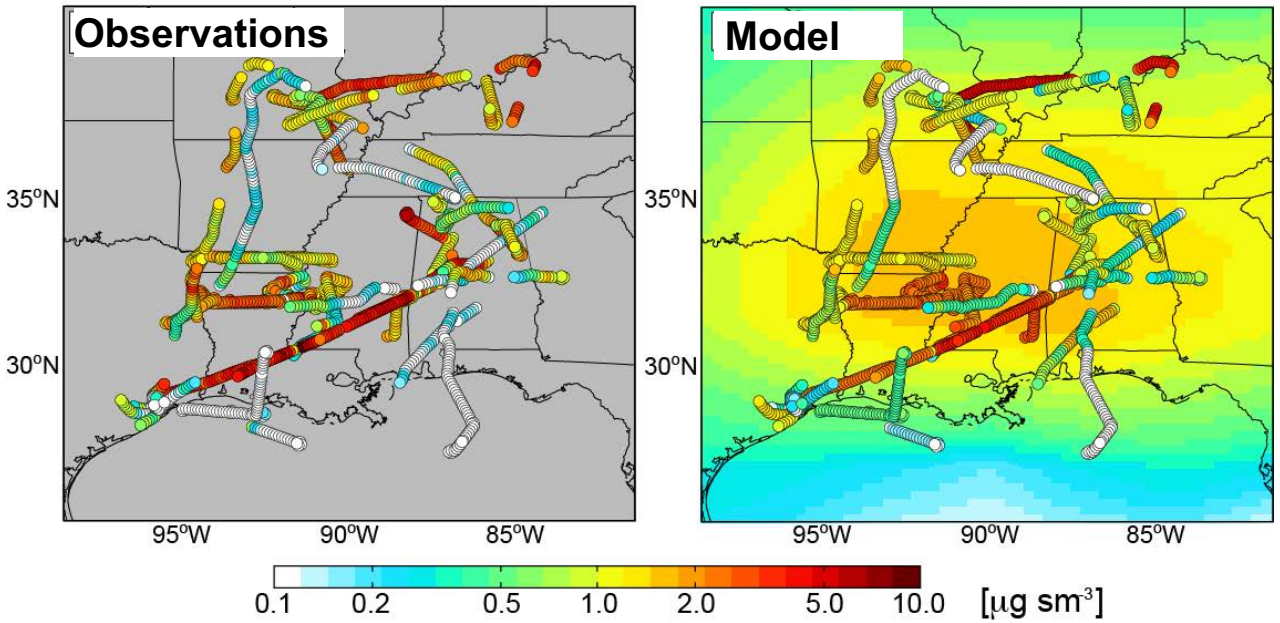
[Marais et al., ACP, 2016]

Extensive Model Validation in Southeast US

Reproduce mean isoprene SOA at surface site in Southeast US



Consistent spatial variability in the Southeast US boundary layer



Mean isoprene SOA:

Observations:

1.4 ± 1.4 μg sm^{-3}

Model:

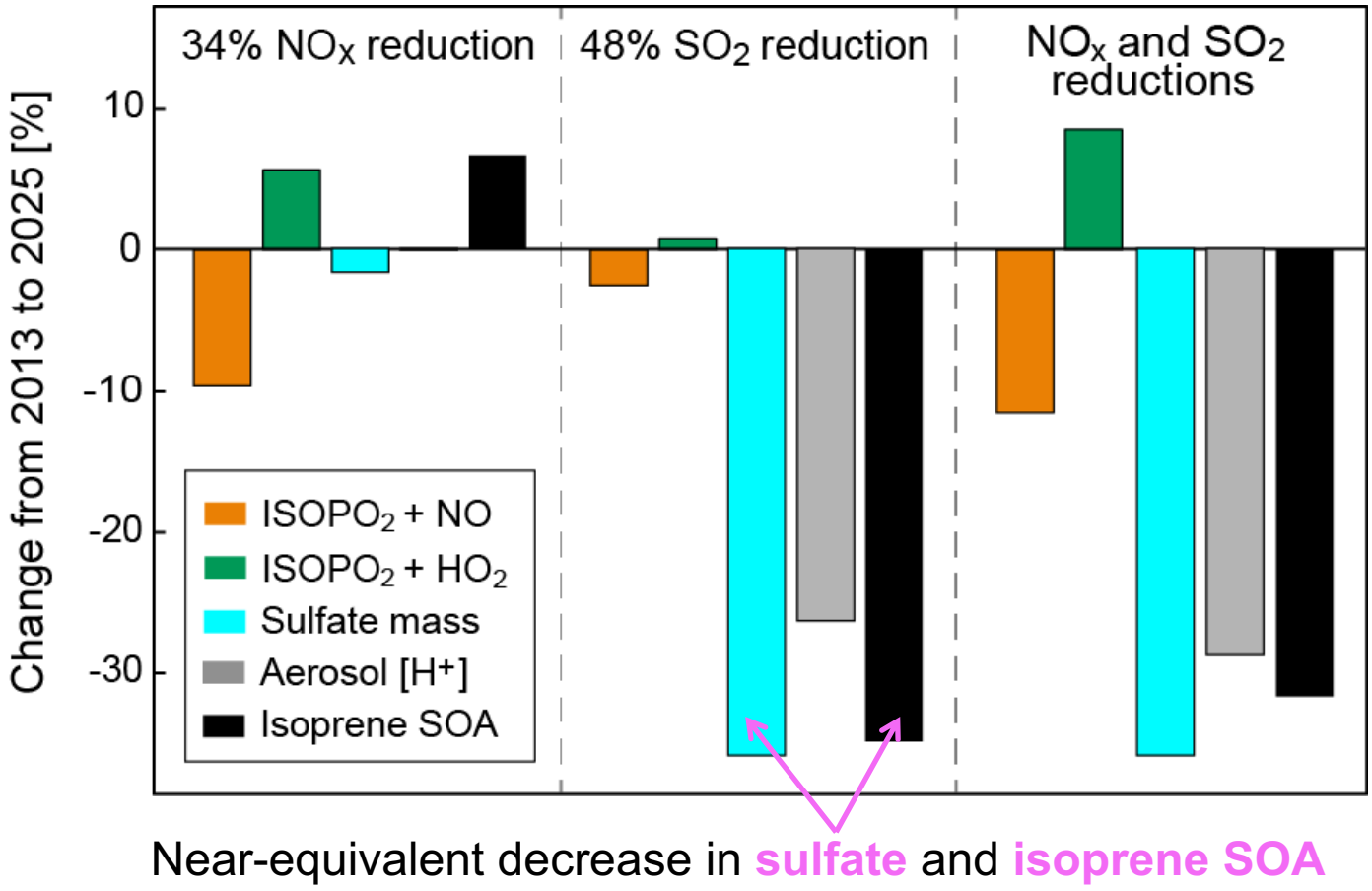
1.3 ± 1.2 μg sm^{-3}

[Marais et al., ACP, 2016]

Model Used to Inform Future Air Quality

Test the effect of future SO_2 and NO_x emission controls on isoprene SOA

Changes in sulfate, aerosol pH, and isoprene SOA



Near-equivalent decrease in **sulfate** and **isoprene SOA**

Policy implication: Dual benefit from targeting SO_2 sources

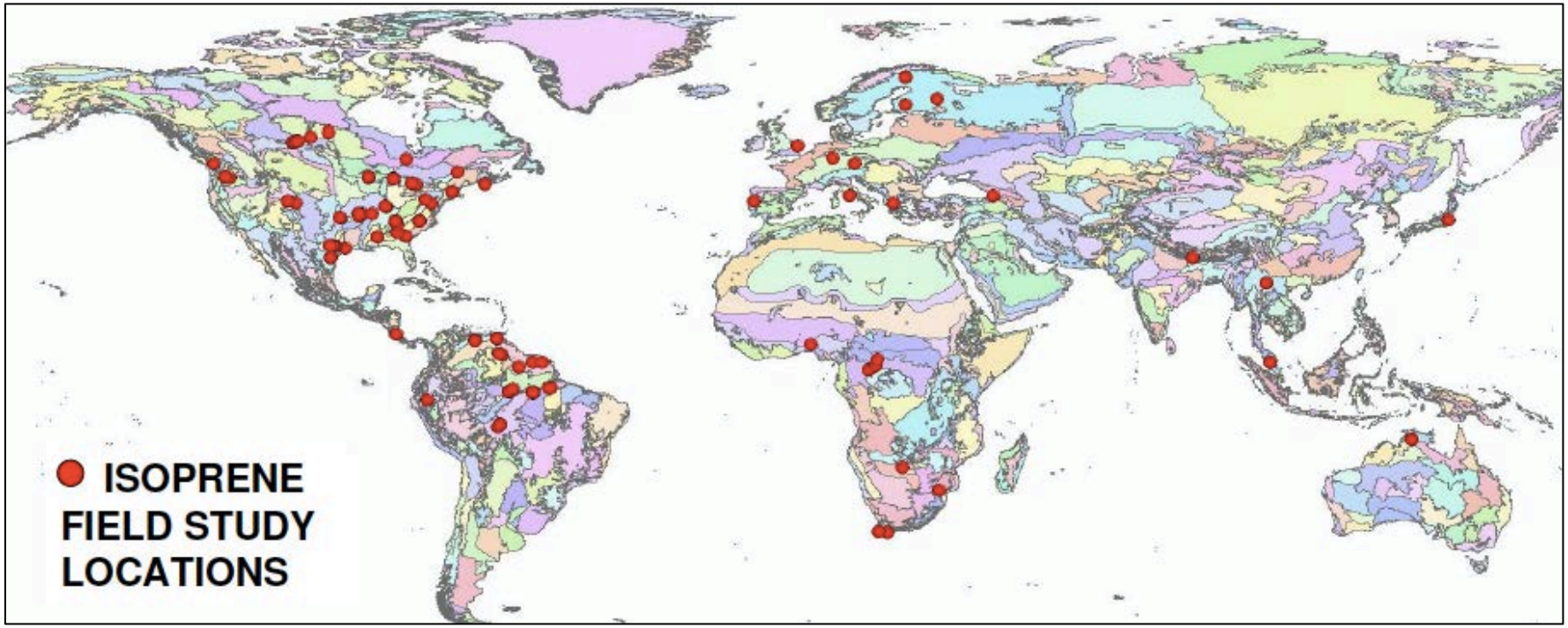
[Marais et al., ACP, 2016]

Supplementary Slides

Isoprene Emissions are Poorly Constrained

Majority of isoprene emission models rely on the **same algorithm**

Few observations in key locations (Africa) to constrain models

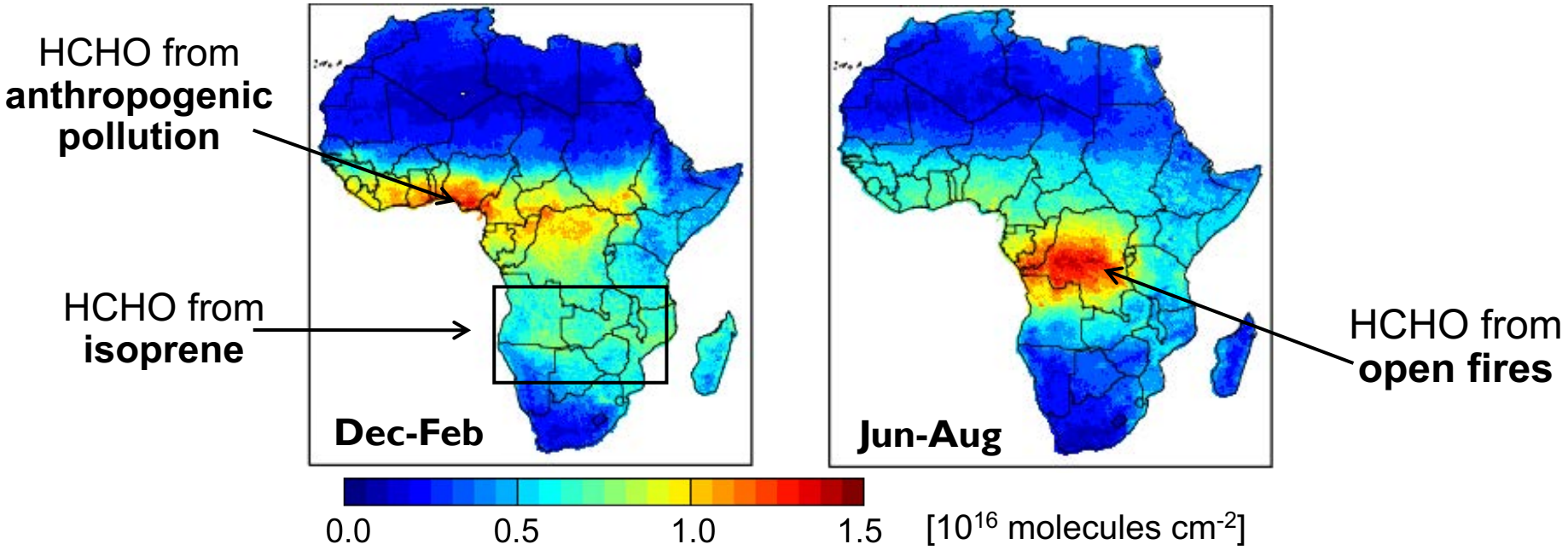


[Guenther et al., 2006]

Satellite observations provide global coverage of the isoprene oxidation product formaldehyde (HCHO)

Top-down Estimate of Isoprene Emissions

Satellite observations of HCHO over Africa



[Data source: Harvard-Smithsonian retrieval group]

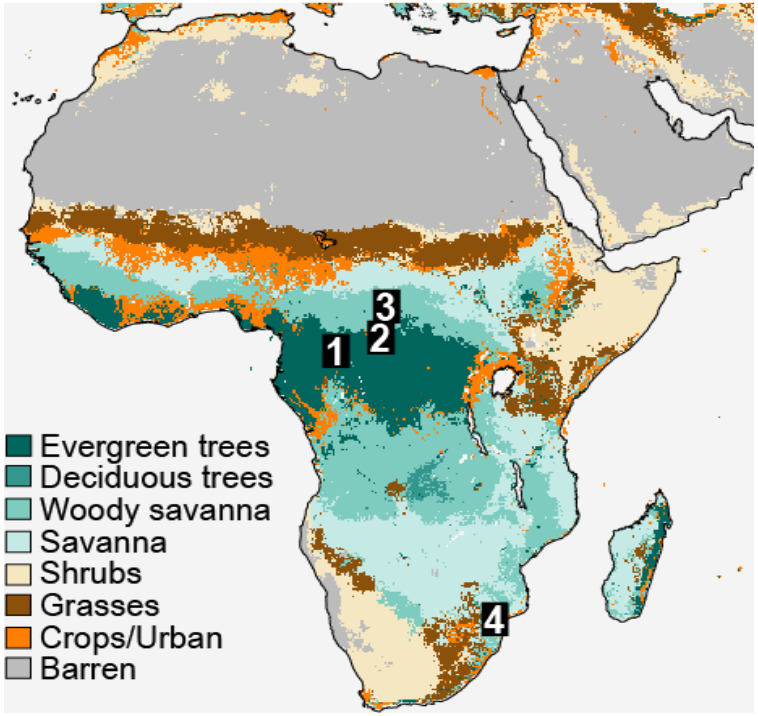
Filter out biomass burning and anthropogenic contribution

Convert biogenic HCHO columns to isoprene emissions

Ground-Based Observations to Arbitrate

Satellite-derived emissions more consistent with flux measurements than a state-of-the-science emission inventory

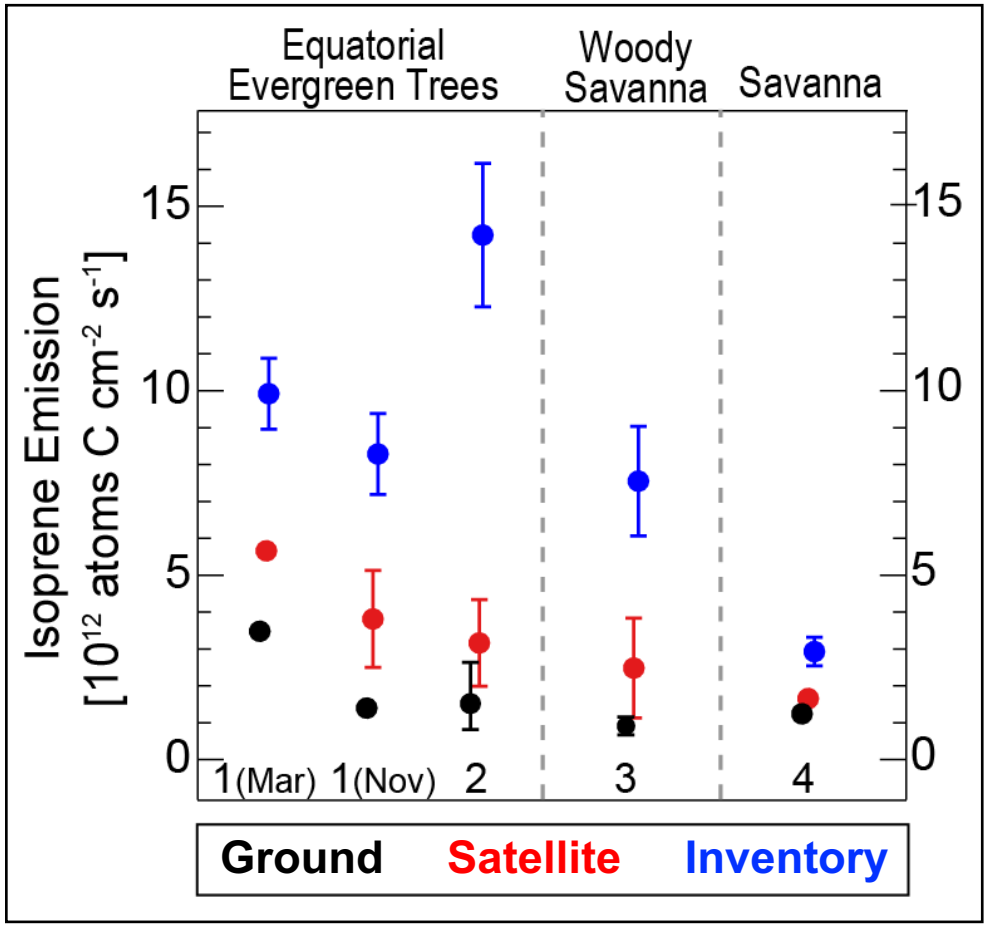
Flux measurement locations



Tower sites: 1 and 4

Aircraft: 2 and 3

Comparison of isoprene fluxes



[Marais et al., ACP, 2014]