Marine Organic Aerosols in CAM5/MAM7

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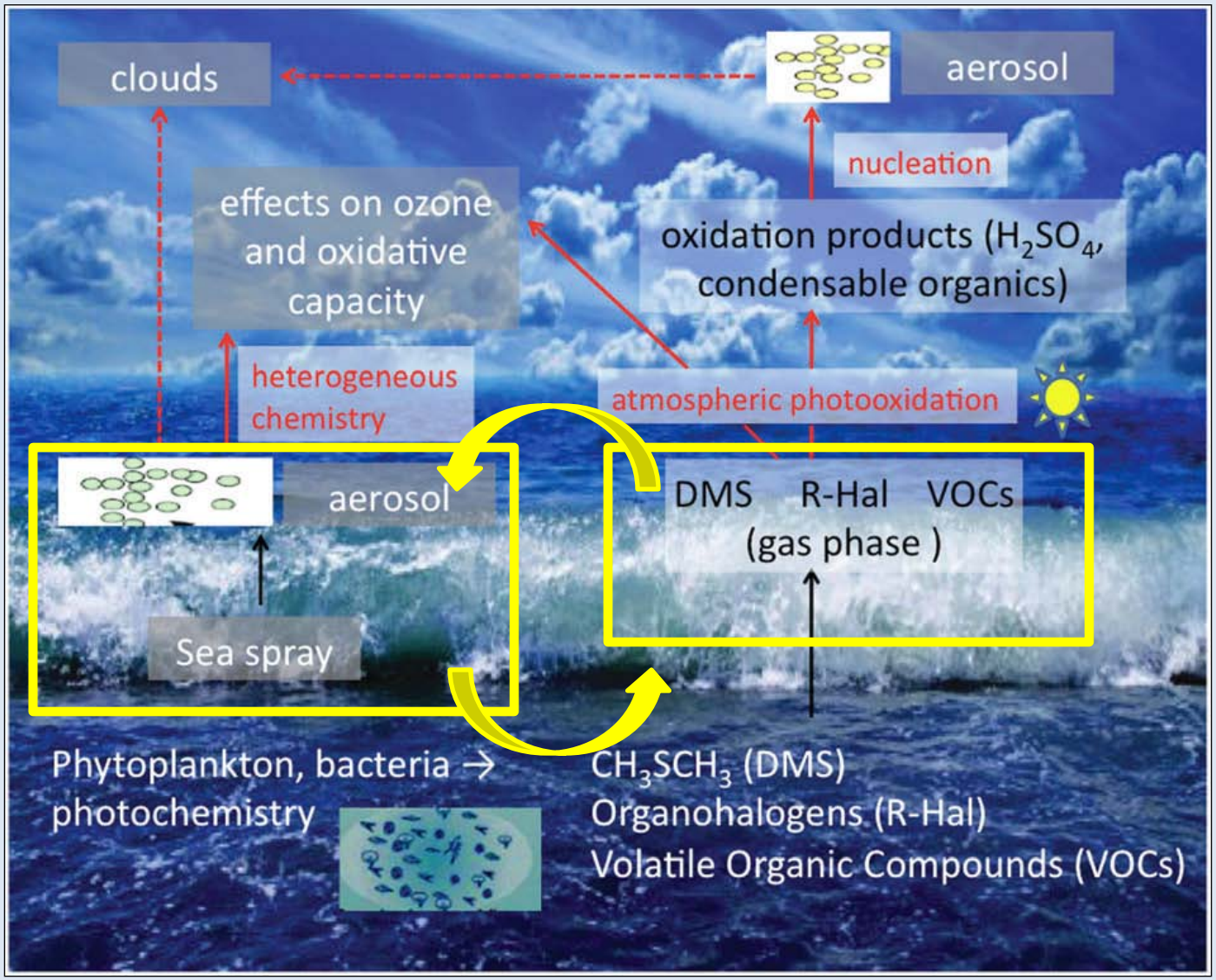
Motivation

- Improved representation of sea spray aerosol in climate and air quality modes
- Emission, photochemical aging, and removal
- Aerosol optics, aerosol-cloud interaction, chemistry of the marine boundary layer
- Influences the Earth's radiative budget directly and indirectly

Objectives/deliverables

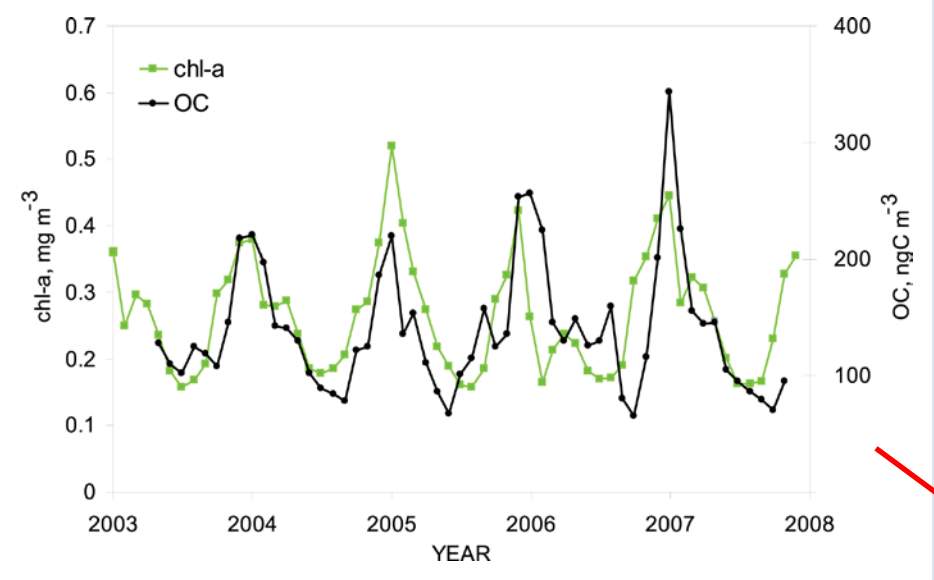
- Emissions of primary marine organic aerosols
- Emissions of phytoplankton-produced isoprene and monoterpenes
- Easily upgradable/inter-changeable
- Air quality (EPA CMAQ), mesoscale (WRF-Chem), CTM (GEOS-Chem) , GCM (CAM5)

Interaction of the Major Types of Oceanic Emissions with the Lower Atmosphere



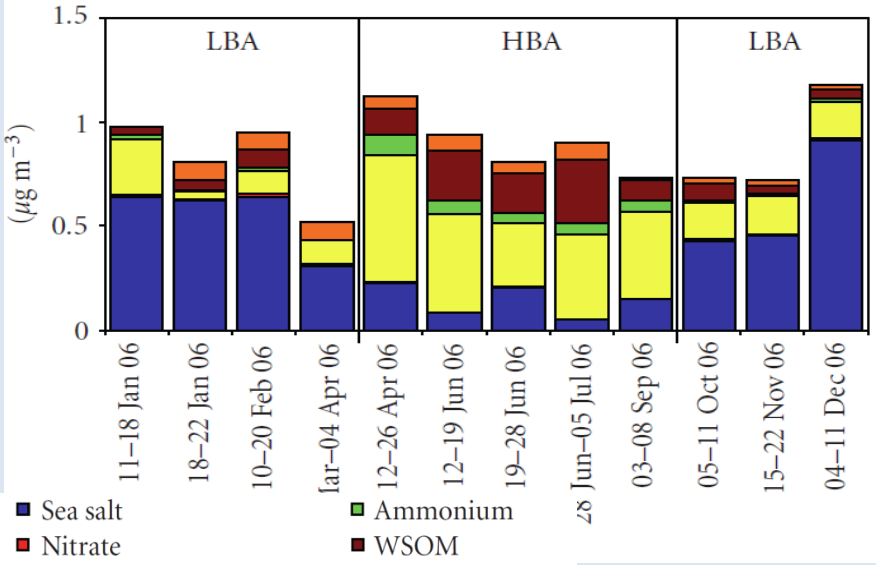
[Carpenter et al., Chem Soc Rev, 2012]

A Direct Evidence of Marine Organic Aerosols

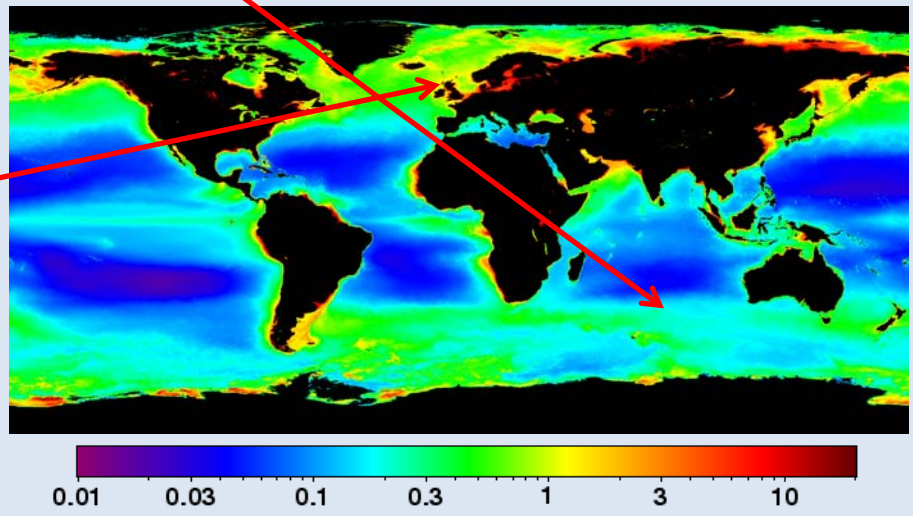


[Sciare et al., JGR., 2009]

- Plenty of indirect implications
- Long term measurements of OC at Amsterdam Island
- Submicron marine aerosol chemical composition at Mace Head

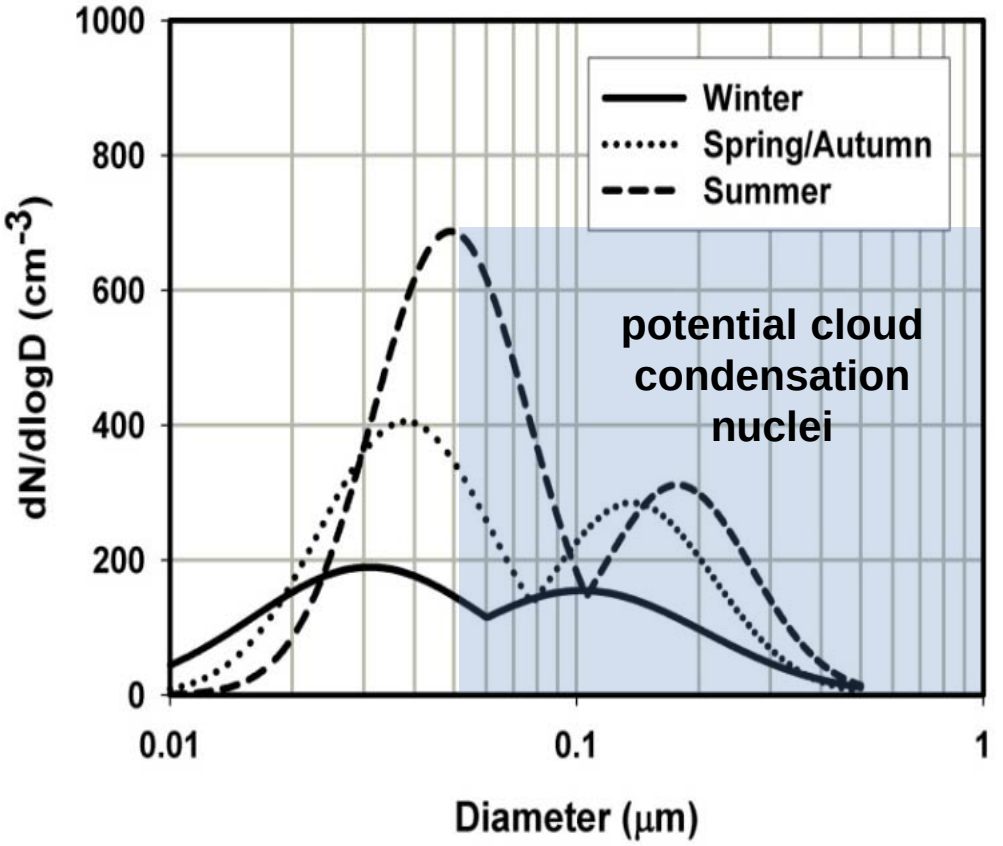


[Rinaldi et al., AMET , 2010]

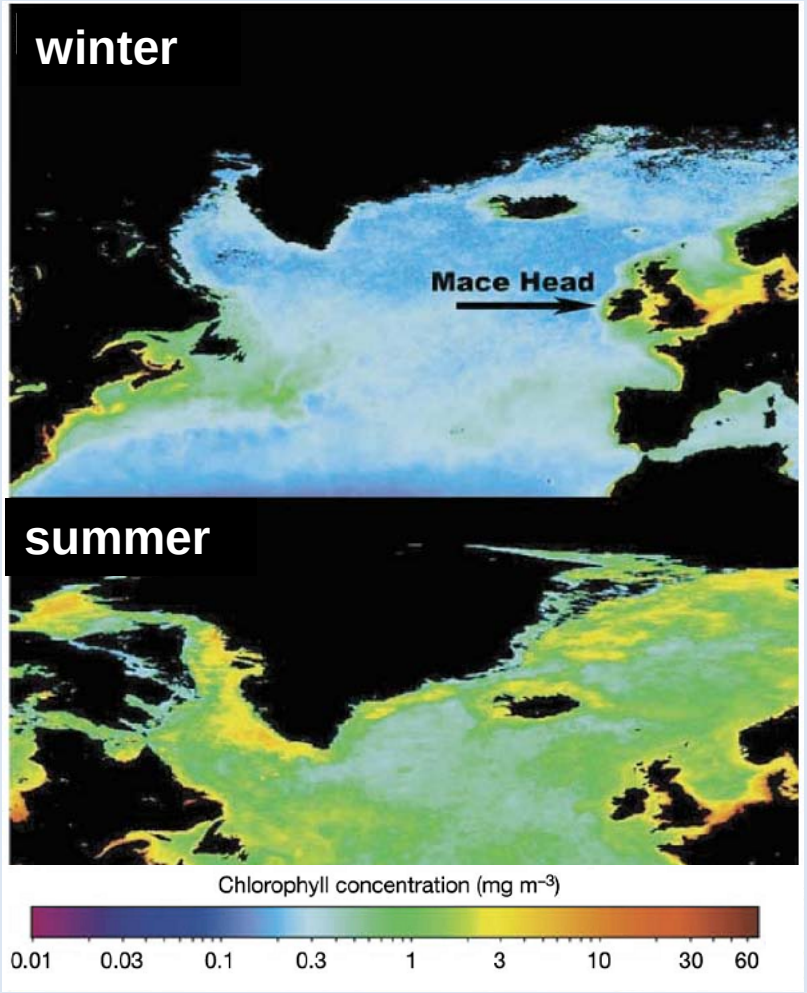


Chlorophyll - a concentration (mg m^{-3})

A Direct Evidence of Marine Organic Aerosols

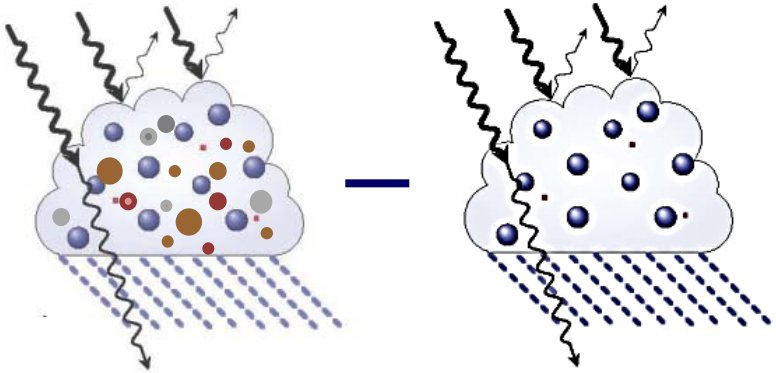


[Yoon et al., JGR, 2007]

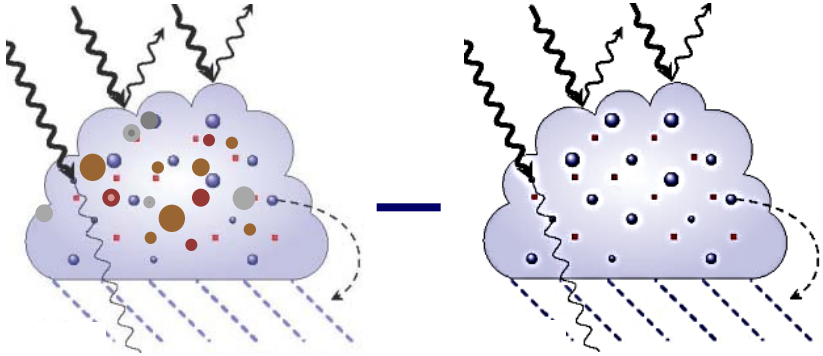


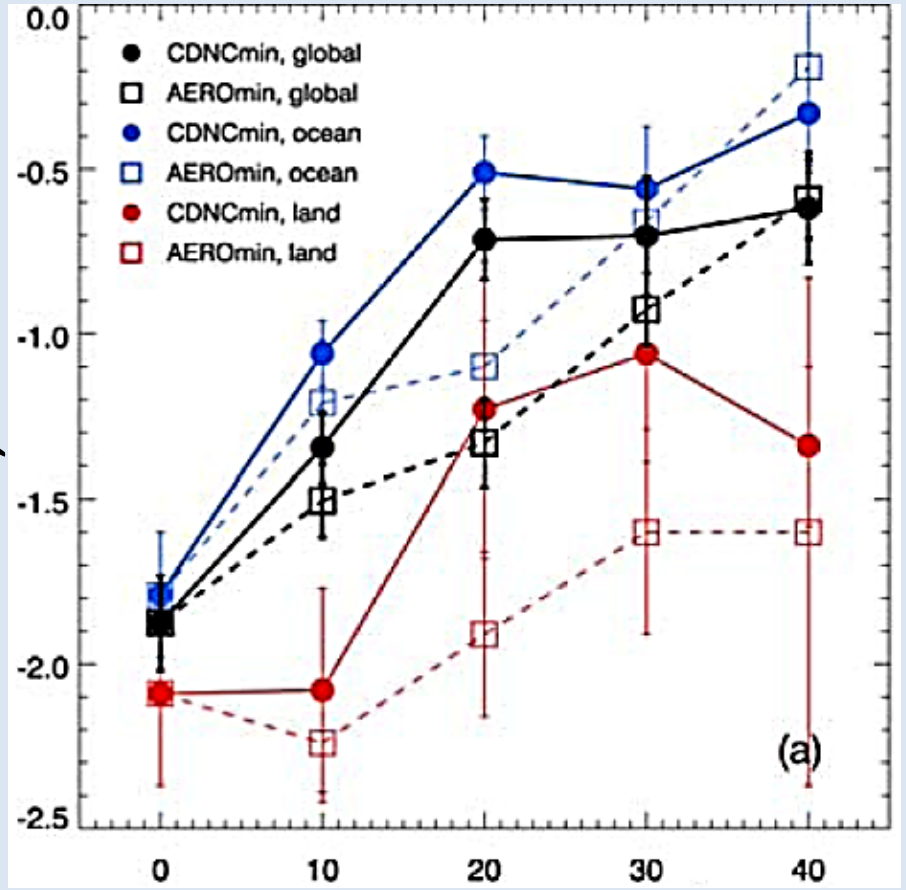
Ocean-Atmosphere Interactions

"Background" CDNC ~ 10 to 20 cm^{-3}



"Background" CDNC ~30 to 40 cm^{-3}

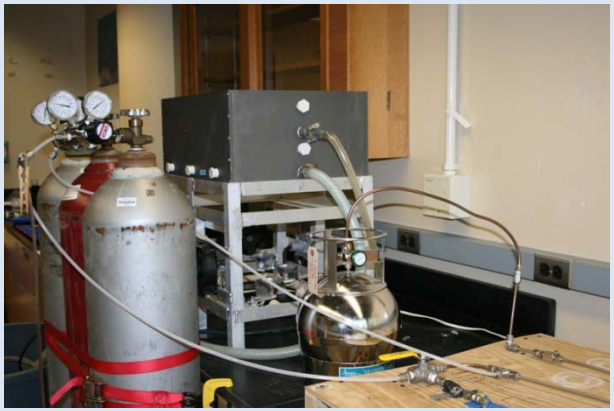




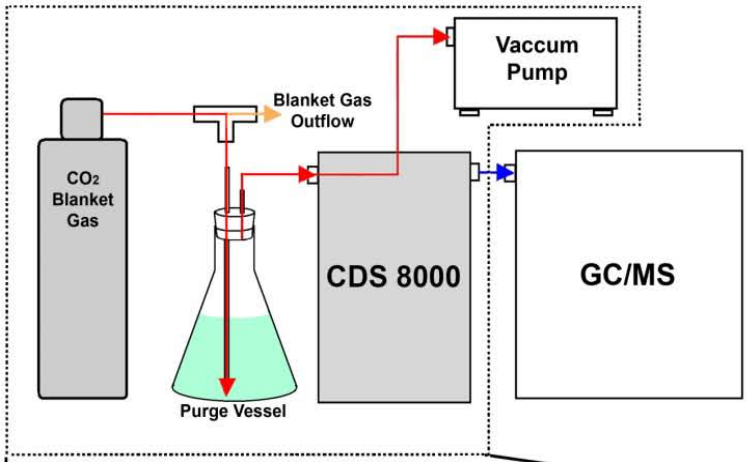
[Hoose et al., GRL, 2009]

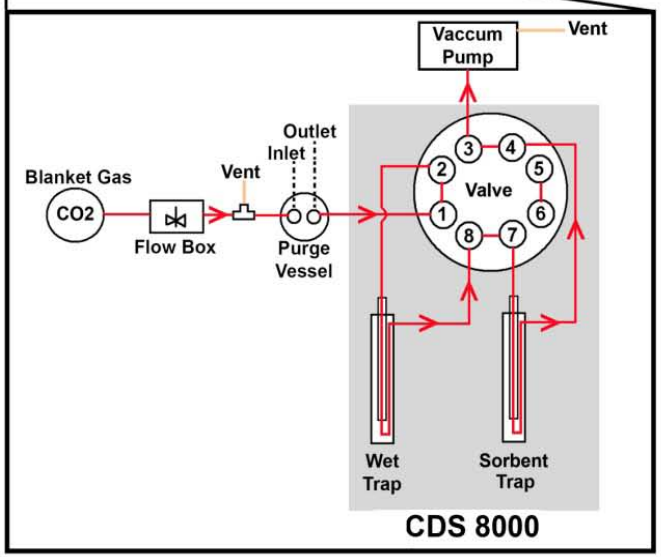
Light And Species Dependent Production Rates Of Marine VOCs

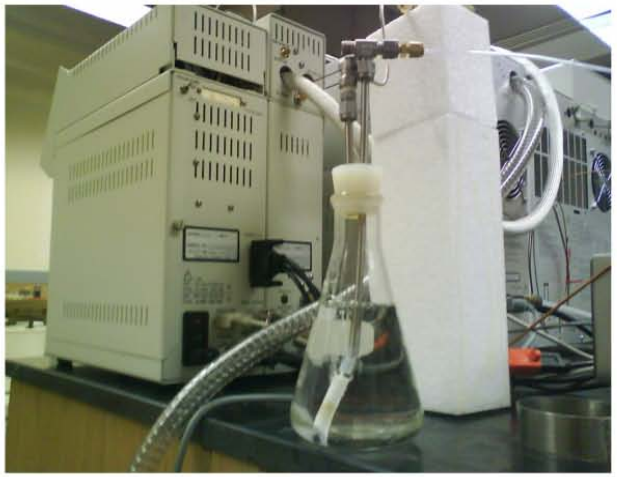
Laboratory grown phytoplankton monocultures: diatoms *Thalassiosira weissflogii* (*T. weiss.)* (CCMP 1336) and *Thalassiosira pseudonana* (*T. pseud.)* (CCMP 1335), prymnesiophyte strains- *Pleurochrysis carterae* (*P. carter.)* (CCMP 645); dinoflagellate strains- *Karenia brevis* (*K. brevis*) (CCMP 718, CCMP 2229) and *Prorocentrum minimum* (*P. minim.*) (CCMP 1329); cryptophyte strains- *Rhodomonas salina* (*R. salina*) (UTEX 2423)



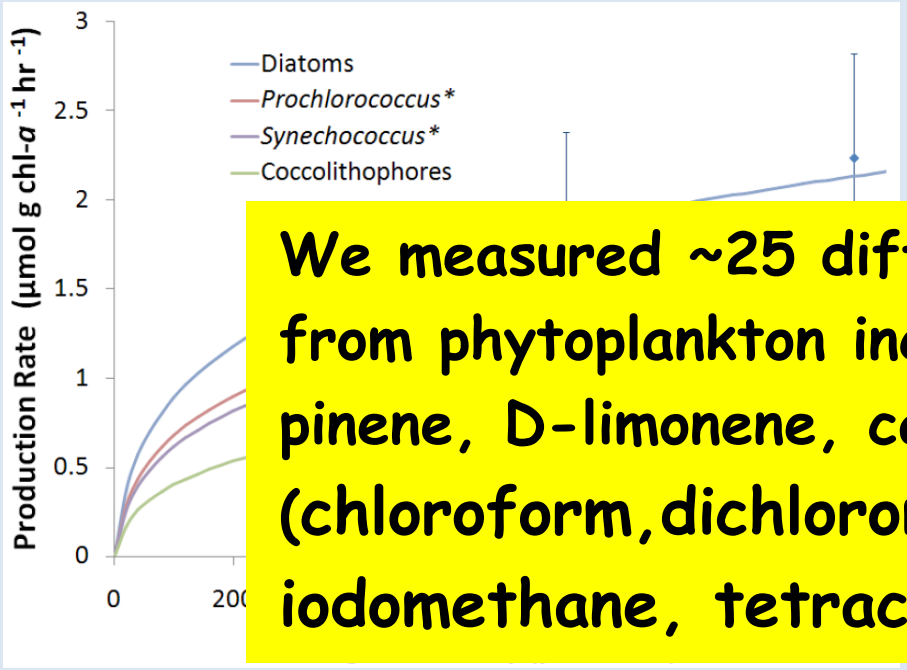
Experimental Setup







Secondary Organics of Marine Origin

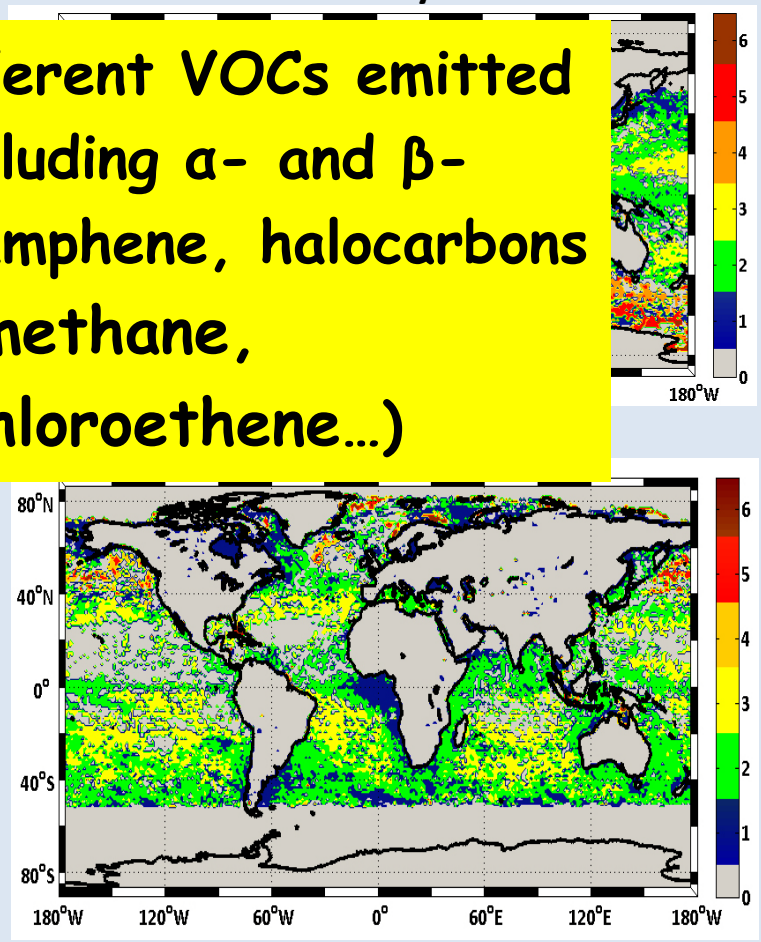


We measured ~25 different VOCs emitted from phytoplankton including α- and β-pinene, D-limonene, camphene, halocarbons (chloroform, dichloromethane, iodomethane, tetrachloroethene…)

[Gantt et al., ACP, 2009]

Phytoplankton Functional Groups

January



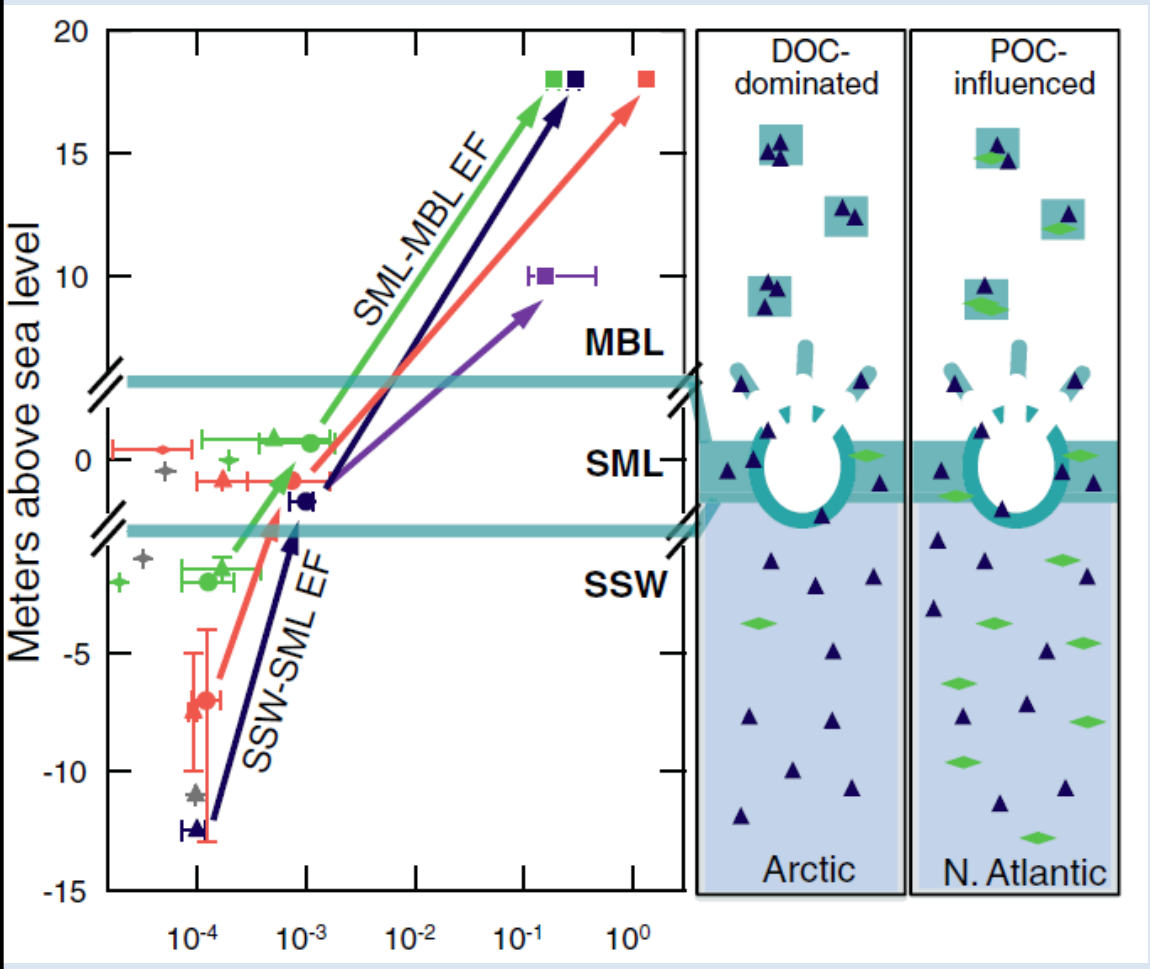
[Maps are created after Alvain et al., GGC, 2008]

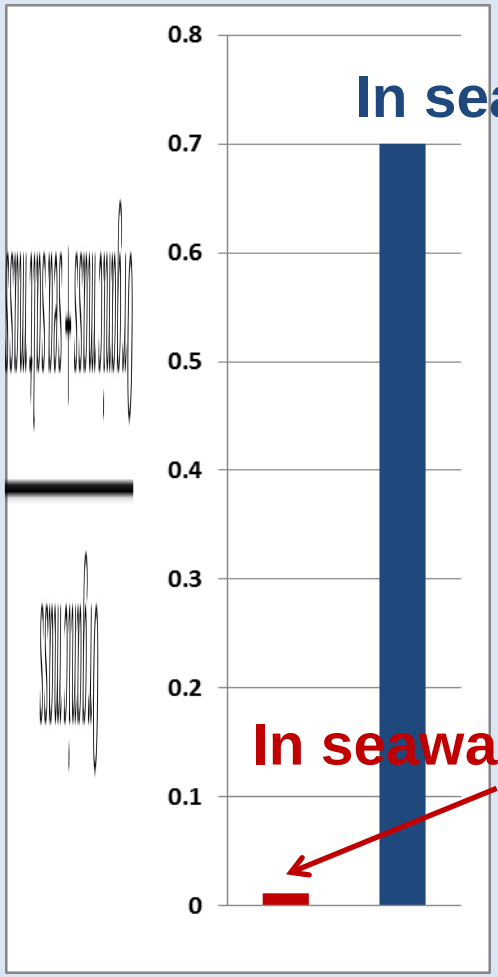
Total column isoprene emission:

$$E_{iso} = SA * H_{max} * [\text{Chl} - a] * F_{iso} * \int_0^{H_{max}} pdh$$

H_{max} - dynamic euphotic depth
F_{iso} - emission fraction
p - isoprene production rate

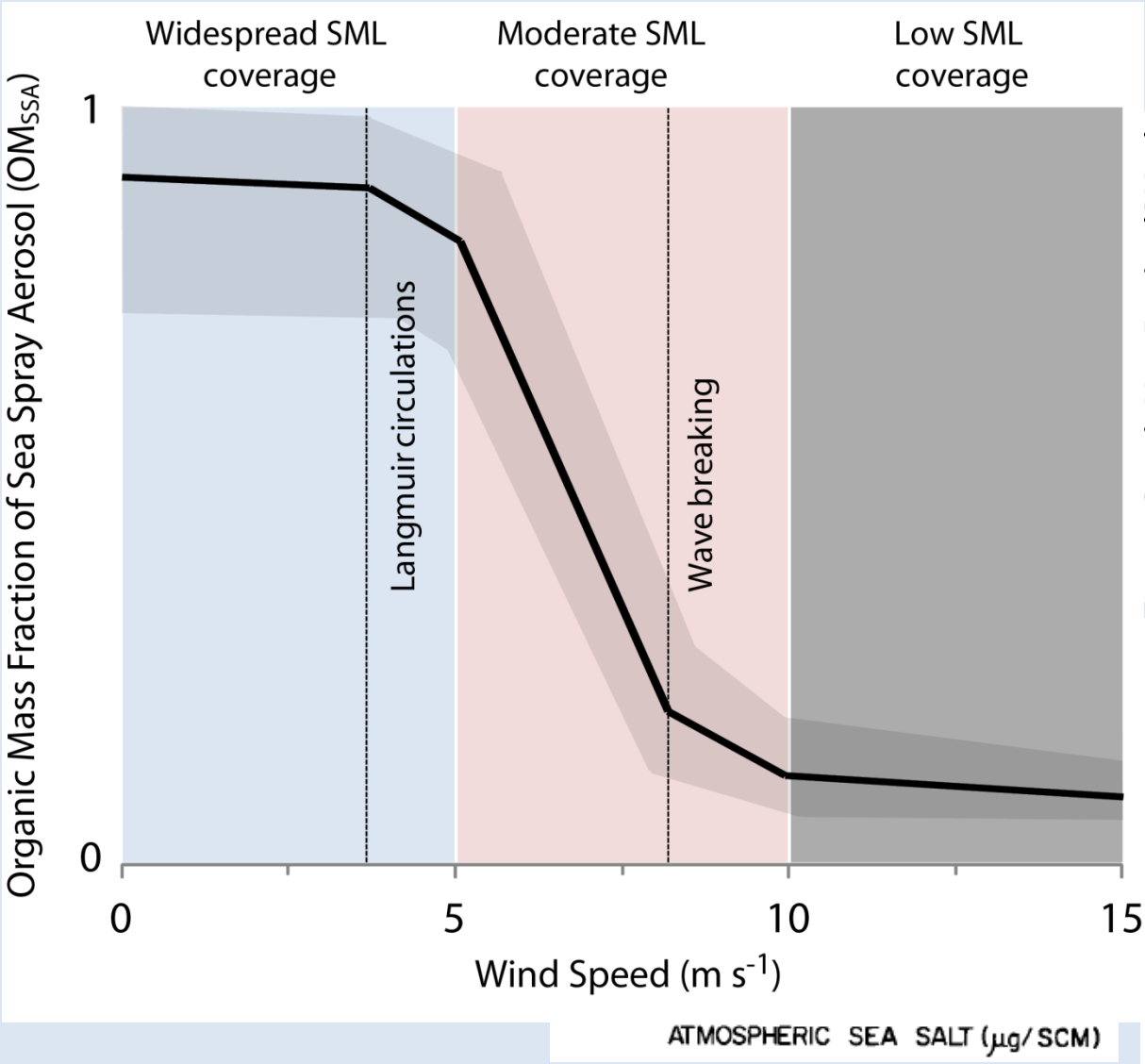
Primary Organics of Marine Origin





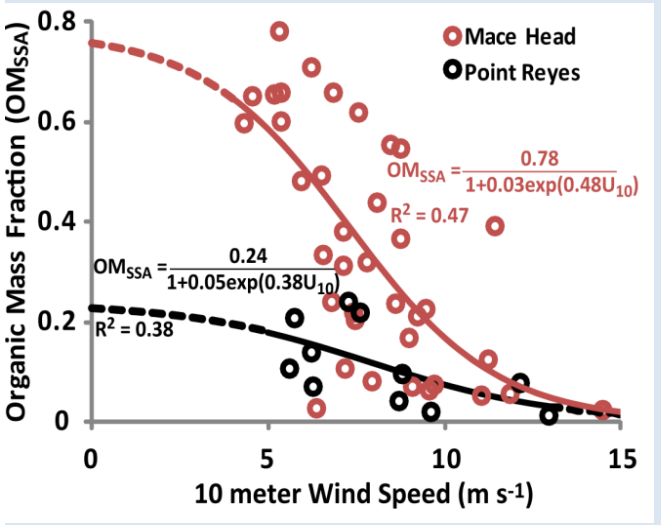
[Russell et al., PNAS, 2010]

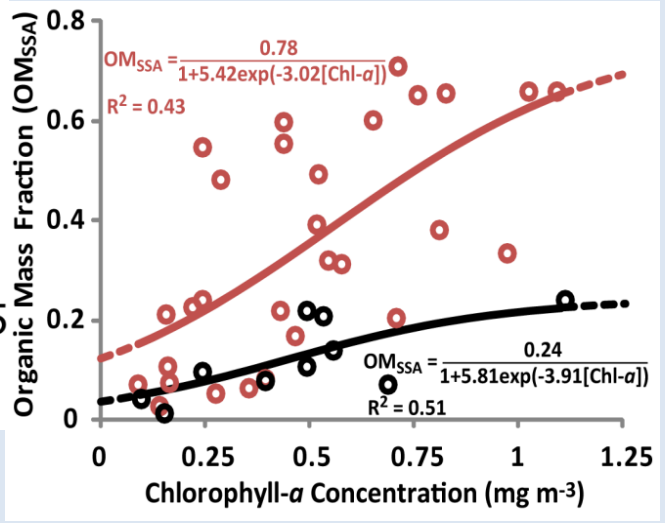
Improved Representation of Primary Organic Emissions



ATMOSPHERIC SEA SALT (µg/SCM)

[Hoffman and Duce, 1974]





Implementation Of Marine Organics In CAM5

Model Configurations

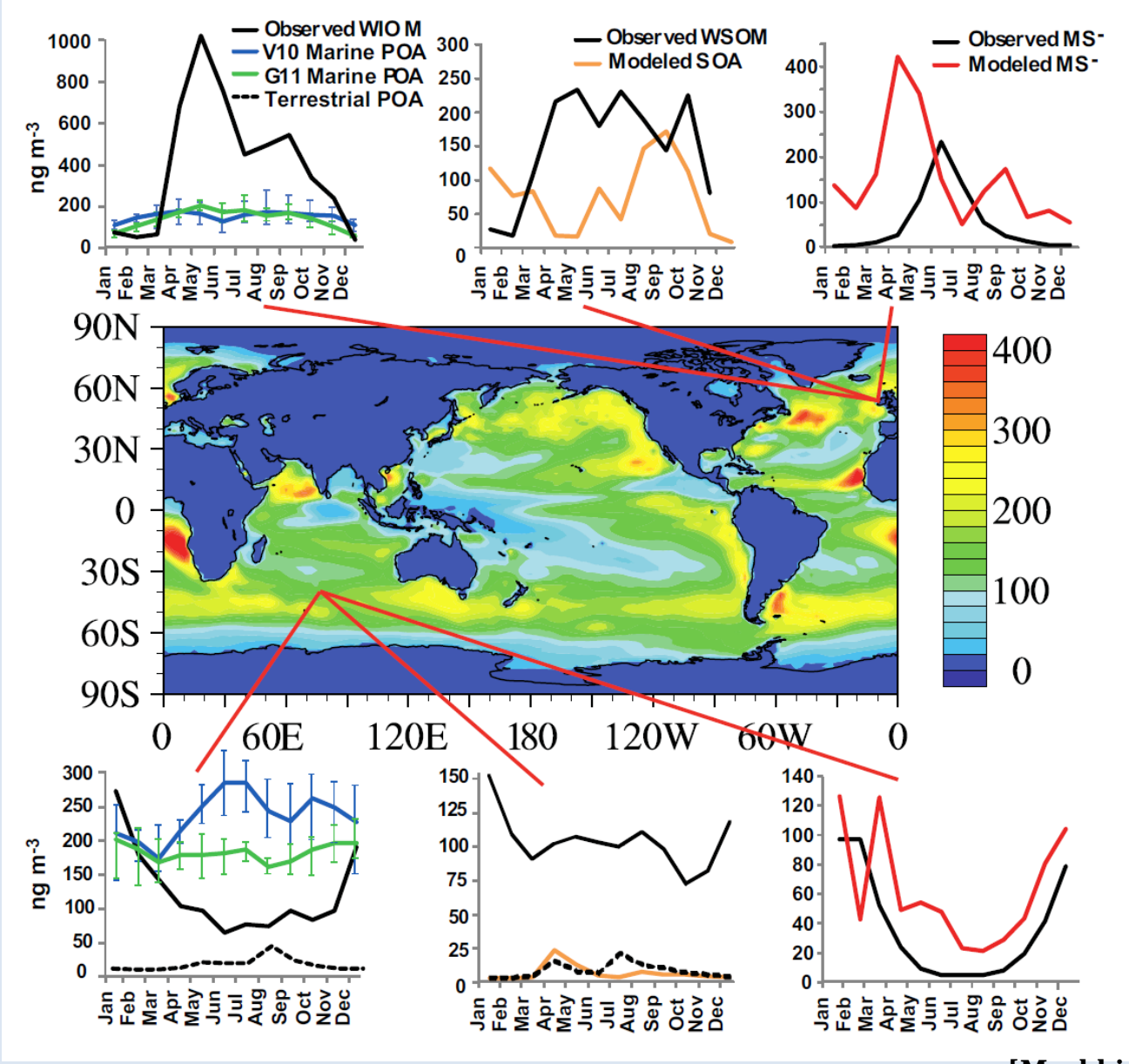
- Horizontal Resolution: 1.9° x 2.5°; Vertical: 30 layers
- Aerosol: 5 sub- and 2 super-micron modes
- Simulation: 5 years; Spin up period: 3 months
- Mårtensson et al. [2003] for 0.02 < Dp < 2.5 μm
- Gong [2003] for 2.5 < Dp < 20 μm
- SOA from isoprene, monotrpenes & MSA (CH_3SO_3H)

Marine Organic Aerosols in CAM5

Sub-micron ← → Super-micron

Mode	Accumulation	Atiken	Primary Carbon	Sea salt	Fine Soil Dust	Coarse Sea salt	Coarse Soil Dust
Aerosol component	Sulfate, Ammonium, POM, SOA, BC, Sea salt, Marine POM & SOA	Sulfate, Ammonium, SOA, Sea salt, Marine POM & SOA	POM, BC	Sea salt, Sulfate, Ammonium, Marine POM	Dust, Sulfate, Ammonium	Sea salt, Sulfate, Ammonium, Marine POM	Dust, sulfate, Ammonium

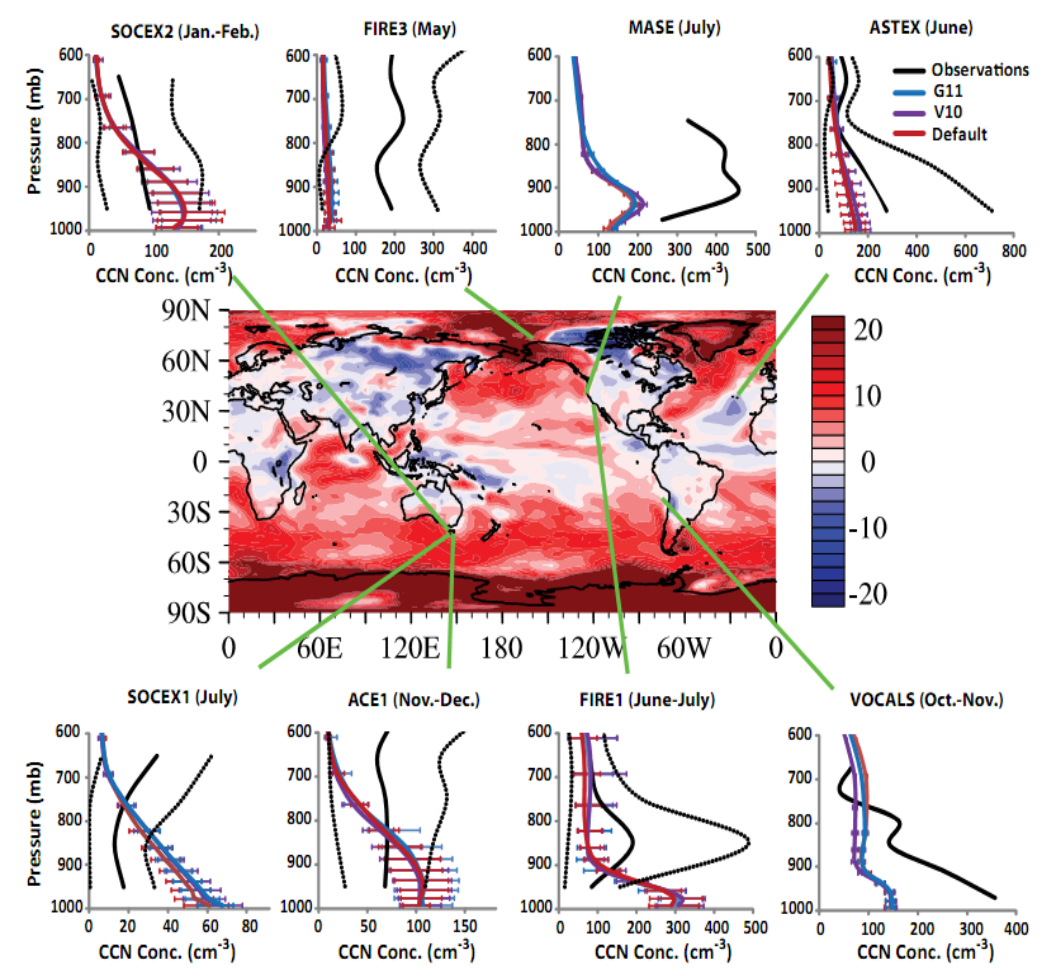
Surface Concentration of Marine OA (ng m^{-3})



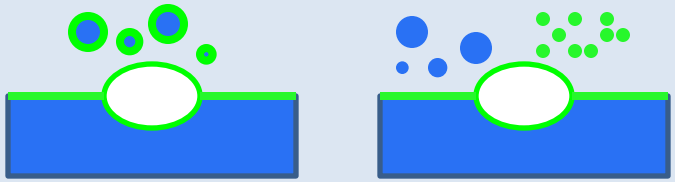
[Meskhidze et al., ACP, 2011]

Ocean Derived Organic Aerosols: Effect on CCN

Percentage change in CCN (# cm^{-3})



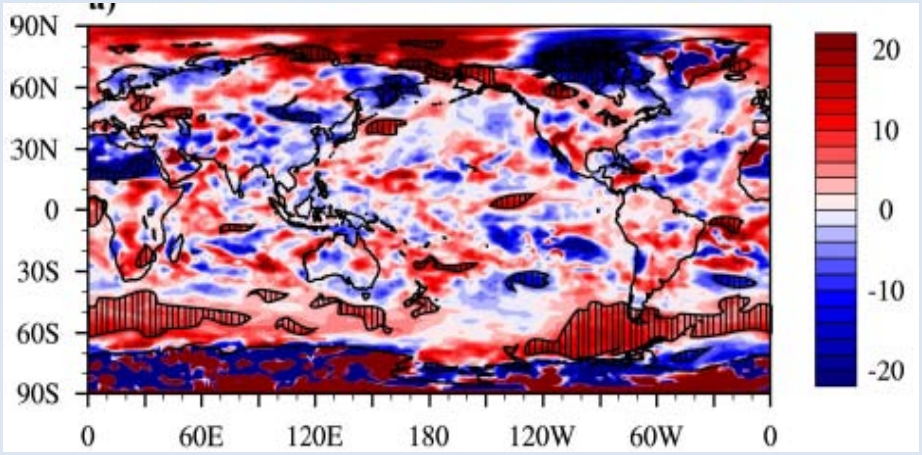
- Organic sea spray added to the model as additional mass (**internally-mixed**) and as additional mass and number (**externally-mixed**)
- Reduction in hygroscopicity parameter (κ) is compensated by increased number of aerosols
- Laboratory measurements vs. ambient data



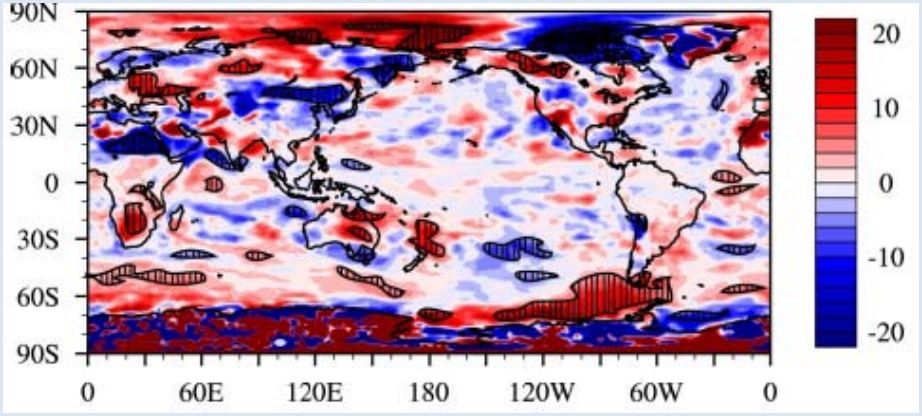
[Meskhidze et al., ACP, 2011]

Ocean Derived Organic Aerosols: Climate Impact

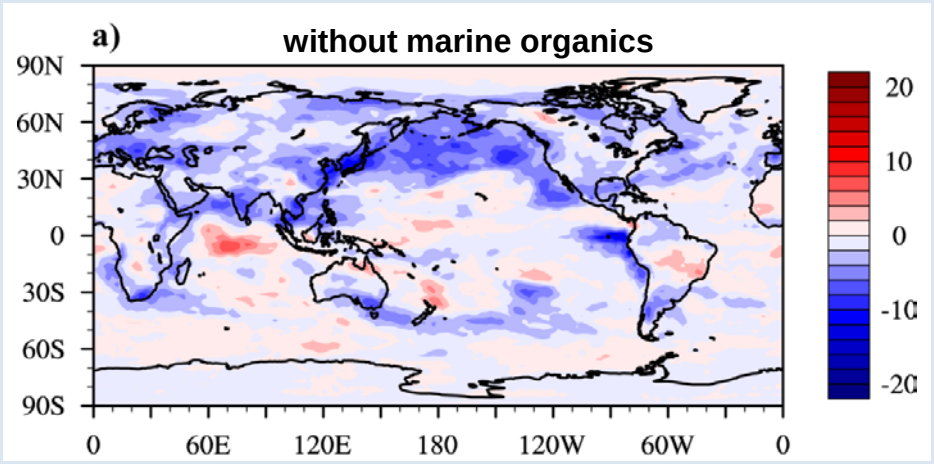
Percentage change in cloud droplet number

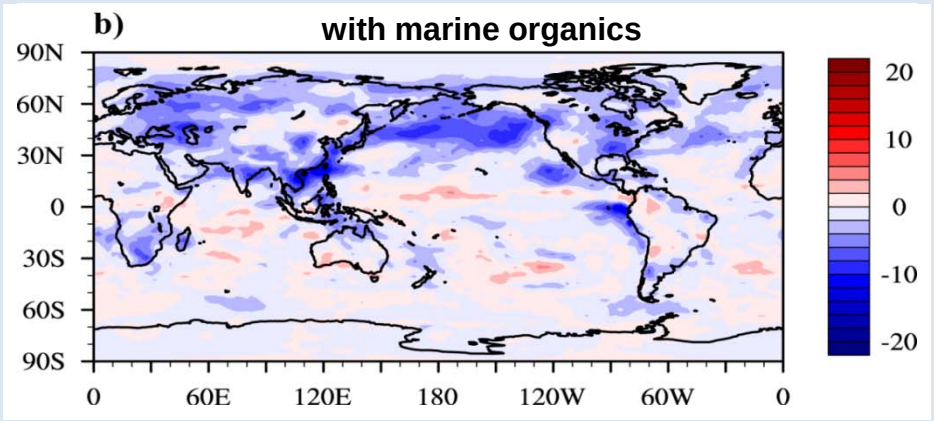


Percentage change in Liquid water path



Aerosol indirect forcing (W m^{-2})





Difference: **0.1 W m^{-2} (7%)**

[Gantt et al., ACP, 2012a]

Summary

- Organics contribute 0.5 $\mu g\ m^{-3}$ on average but > 3.5 $\mu g\ m^{-3}$ during episodic events to sea spray aerosol
- Assuming an external mixture of organics and sea-salt, cloud condensation nuclei and cloud droplet number concentration increase by up to 20%
- A change in the model-predicted aerosol indirect forcing of ~0.1 $W\ m^{-2}$ (7%) is possible by including organic sea spray aerosol
- A top-down marine POA emission scheme that best simulates the monthly to hourly concentrations has an global submicron emission rate of 6.3 $Tg\ yr^{-1}$

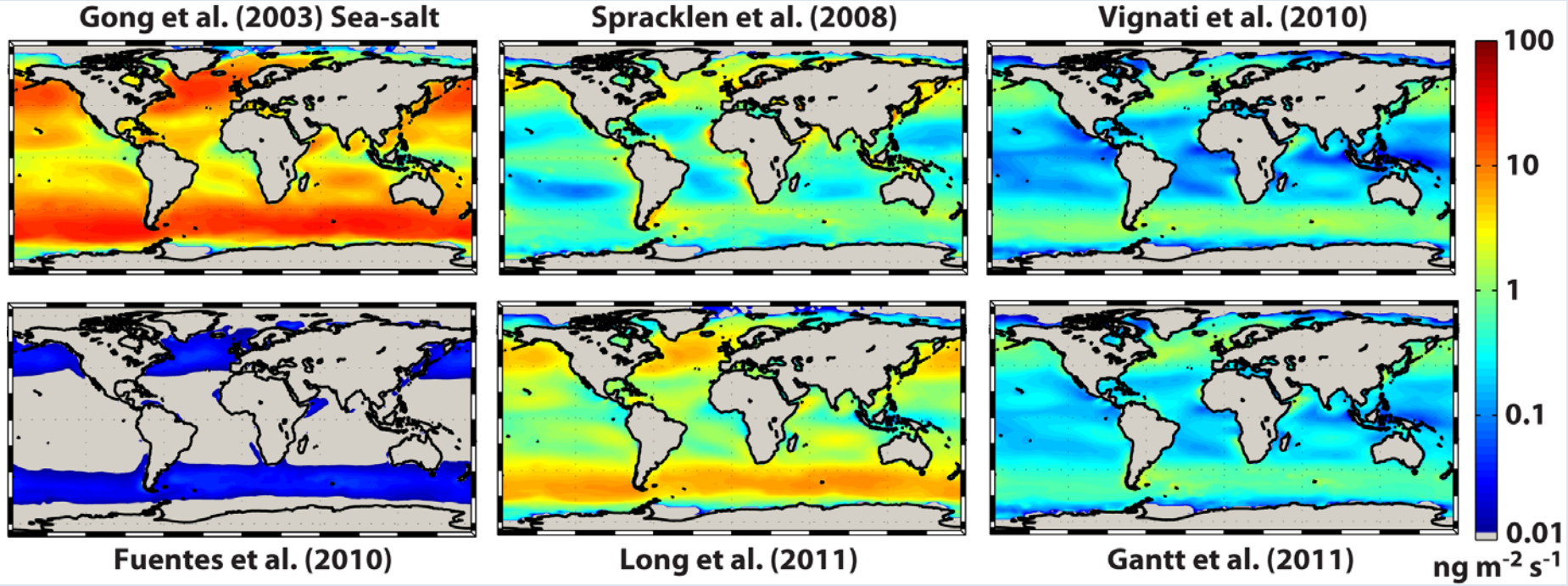
My Take on Near Future Research on Marine Organics

- It is very complex and convoluted with lots of uncertainties
- Extensive lab measurements for phytoplankton emitted BVOC and POA due to bubble bursting are needed
- More field campaigns in clean marine environments (coastal vs. open ocean)
- Improvements to model representation of sources and sinks of marine organics
- Improved satellite retrievals of marine aerosols

Thank you!

Questions?

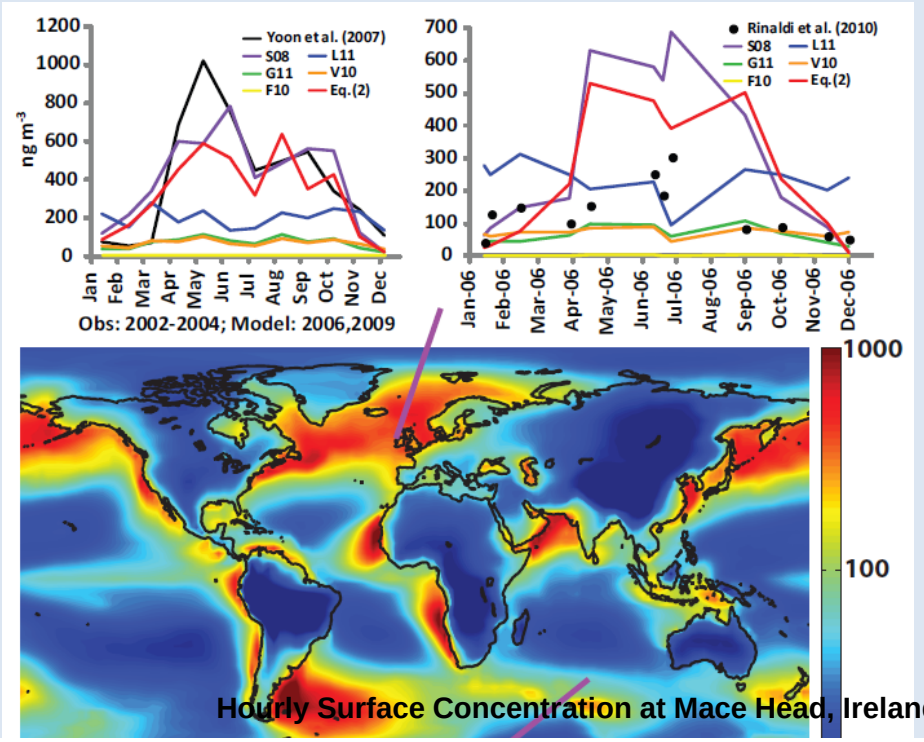
Annual Average Marine POA Emissions (GEOS-Chem)



[Gantt et al., ACP, 2012b]

Parameterization	Global mass submicron (Tg)	
G03 (sea-salt)	73.6	
S08	8.3	Spracklen et al. (2008)
V10	2.9	Vignati et al. (2010)
F10	0.1	Fuentes et al. (2010)
L11	11.9	Long et al. (2011)
G11	2.9	Gantt et al. (2011)
Eq. (3)	6.3	Gantt et al. (2012b)

Model Evaluation of Concentrations



[Gantt et al., ACP, 2012b]