How well do we model primary marine aerosols, and why?

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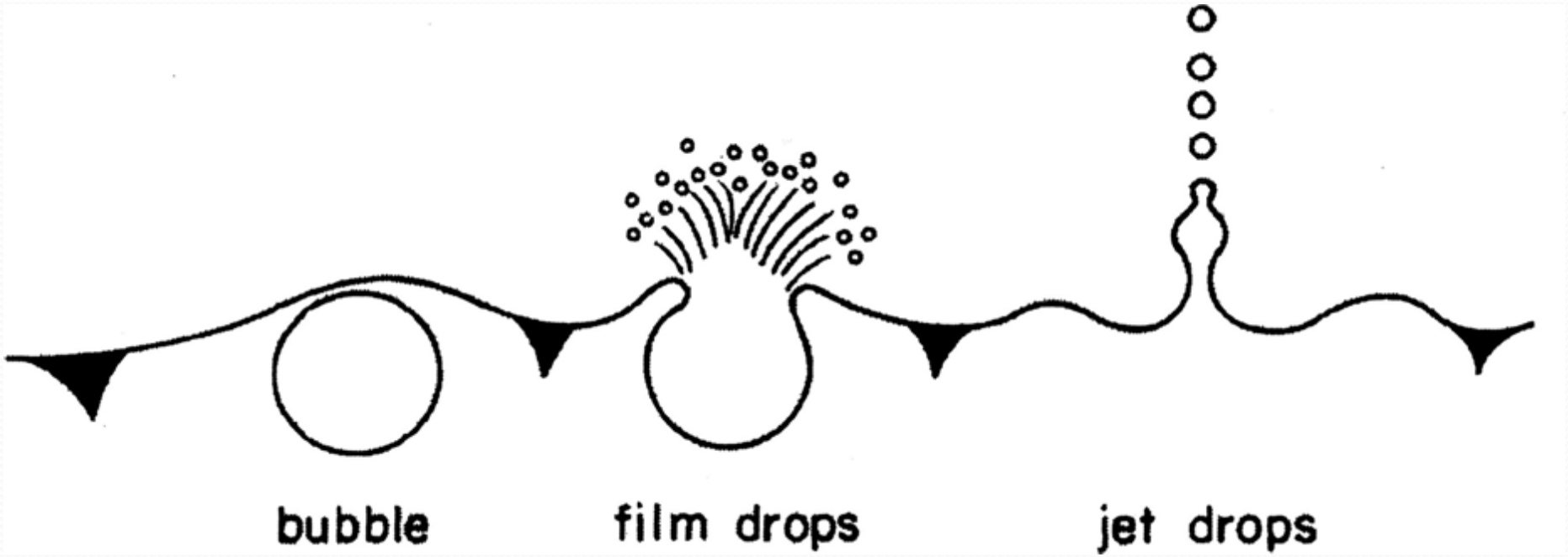
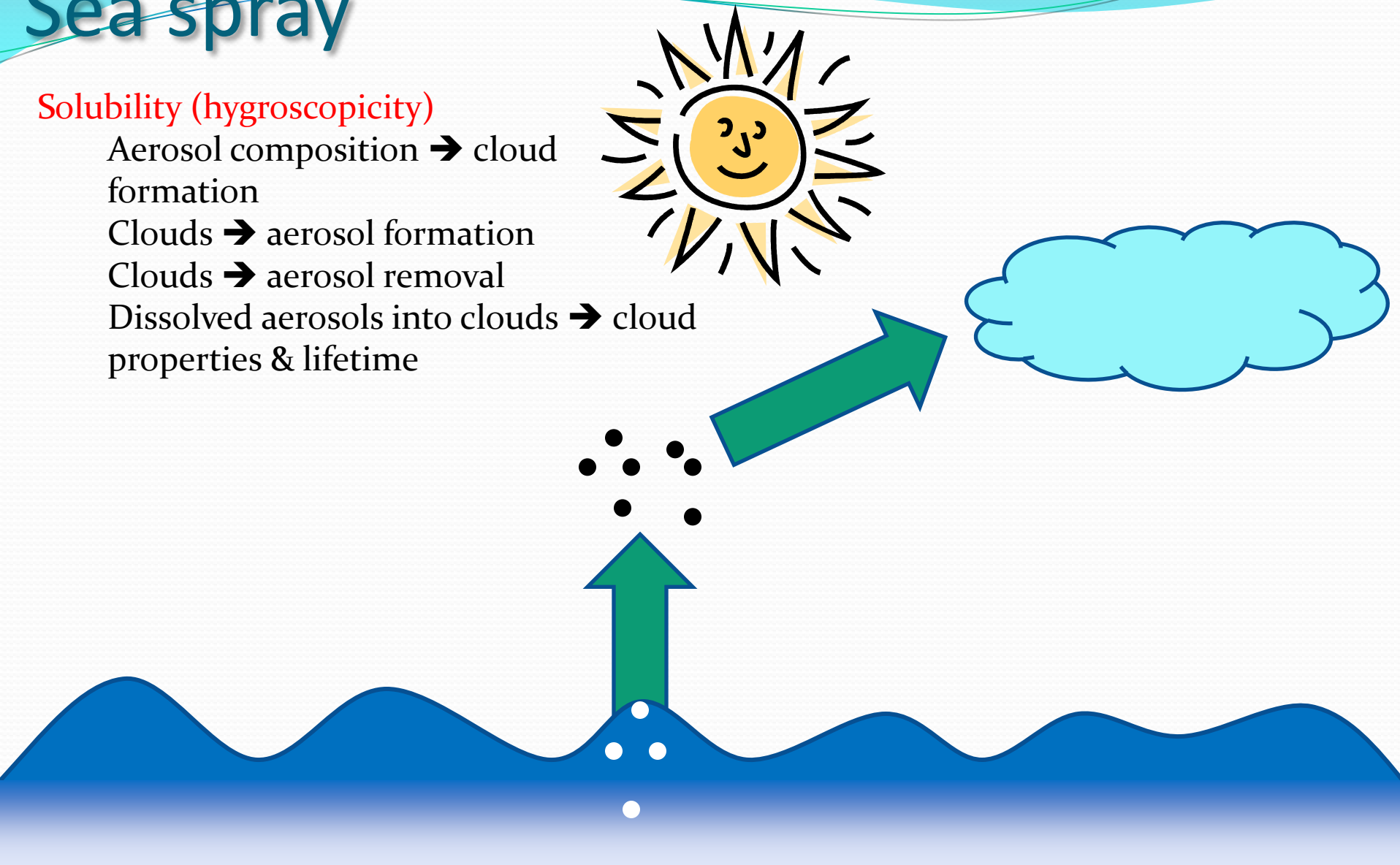
Sea spray



Sea spray

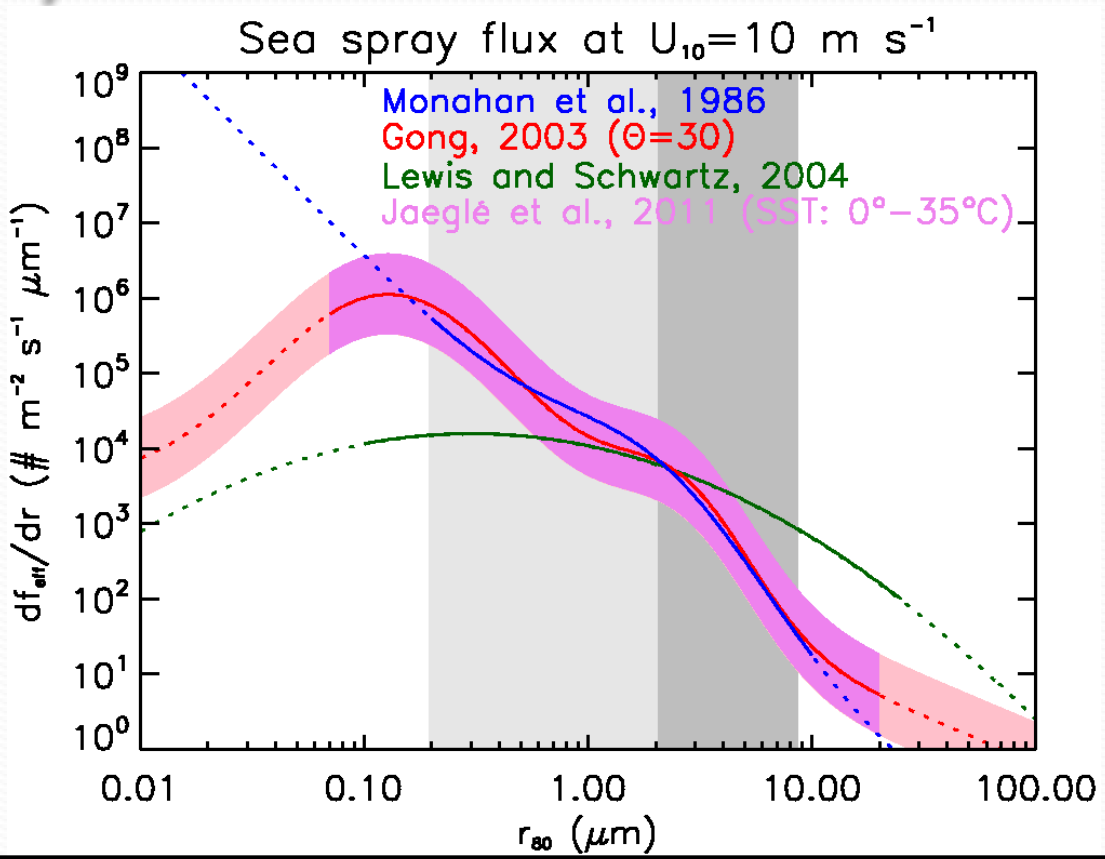
Solubility (hygroscopicity)

- Aerosol composition ➔ cloud formation
- Clouds ➔ aerosol formation
- Clouds ➔ aerosol removal
- Dissolved aerosols into clouds ➔ cloud properties & lifetime



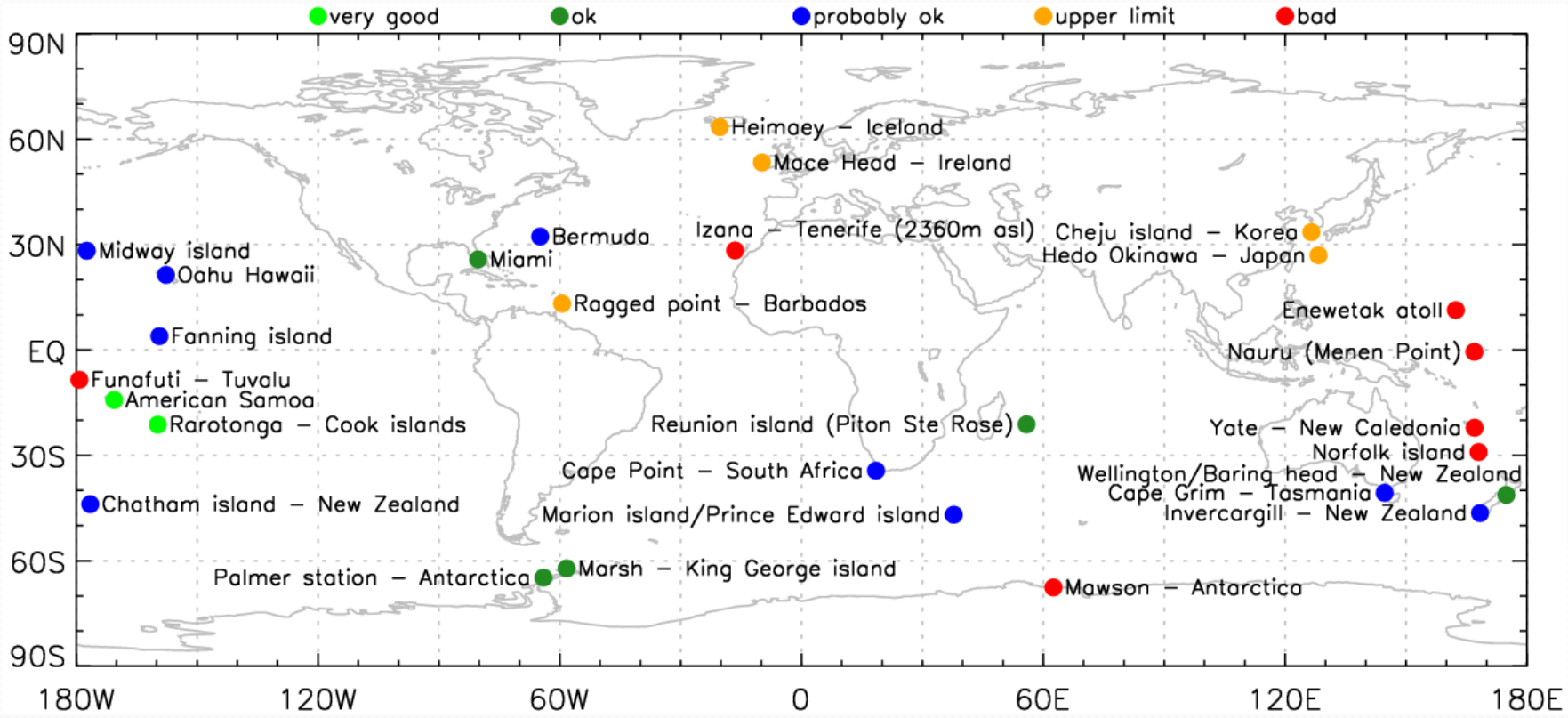
Tsigaridis et al., JGR, 2013

Sea spray source



	Fine mode	Coarse mode
SS1	0.1-1μm	1-4μm
SS2	0.1-1μm	1-10μm
SS3	0.1-0.5μm	0.5-4μm

Sea salt comparison with measurements



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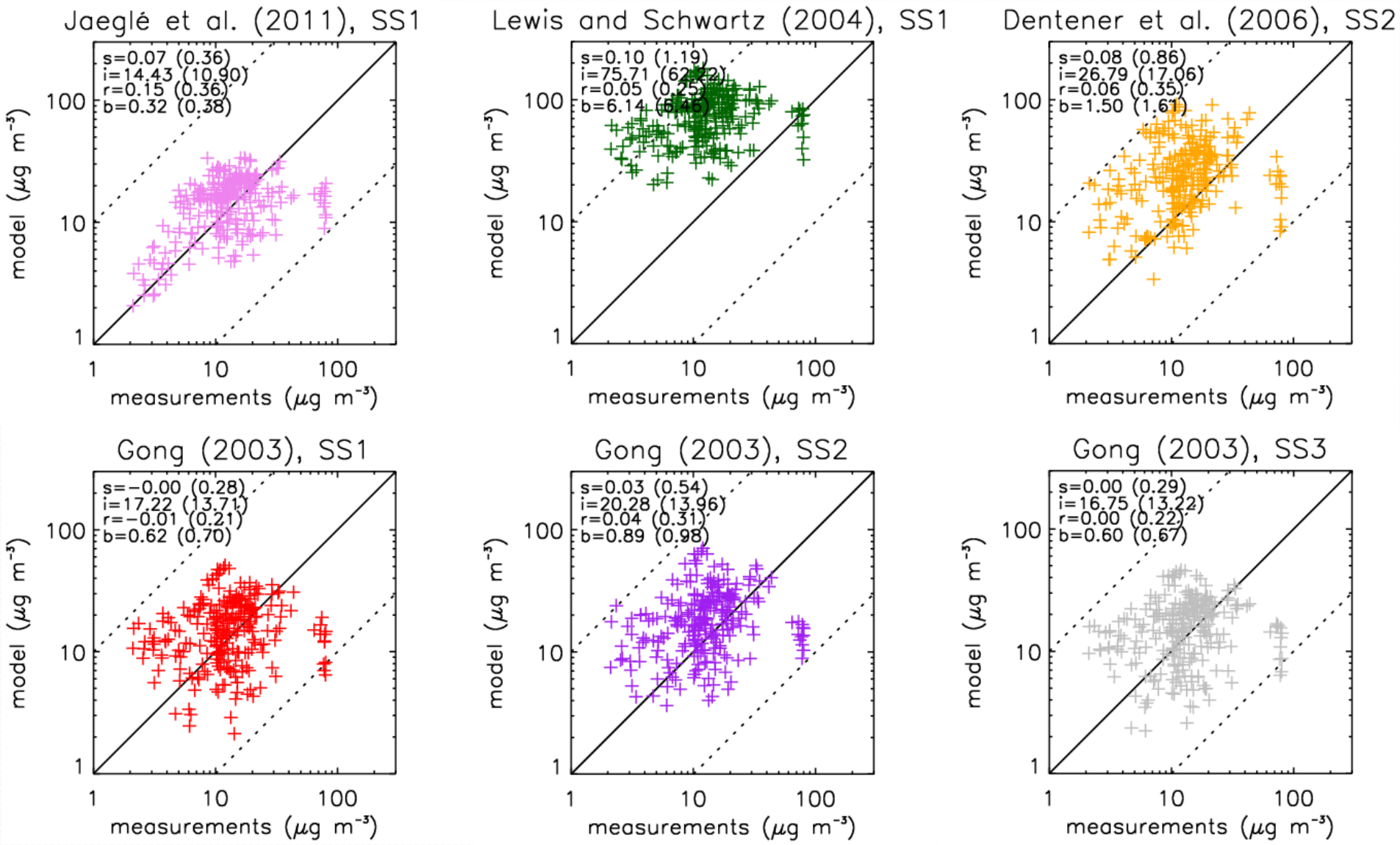
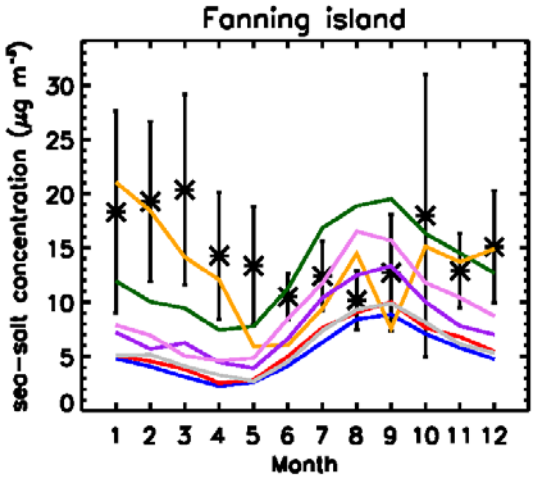
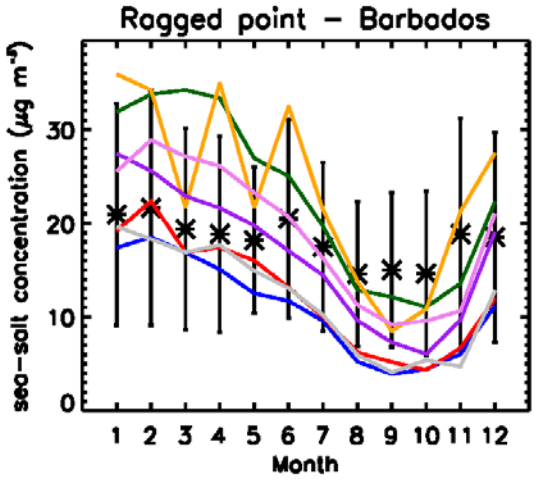
Sea salt comparison with measurements

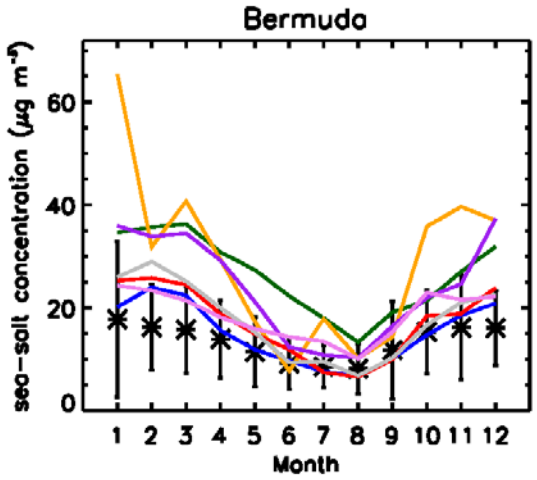


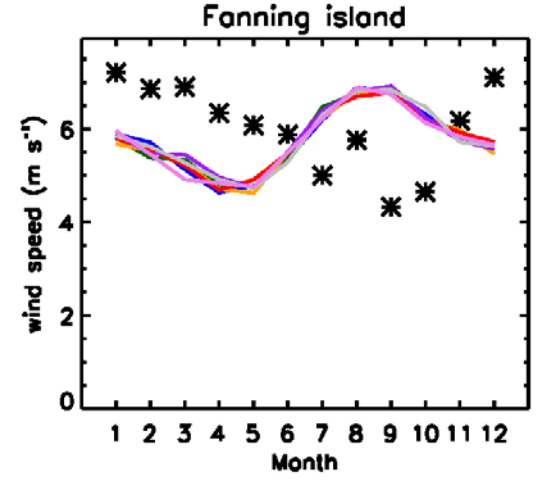
Sea salt vs. wind speed

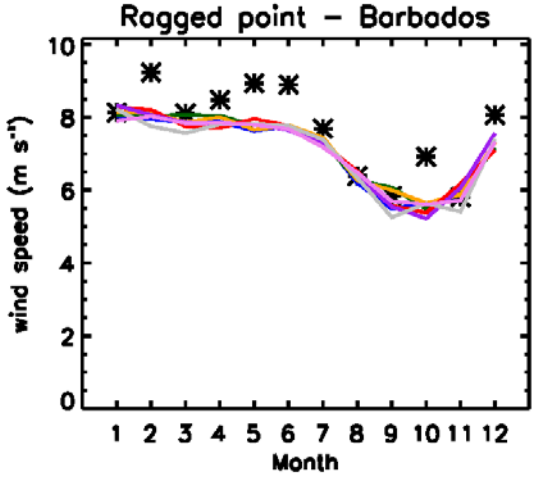
Tsigaridis et al., JGR, 2013

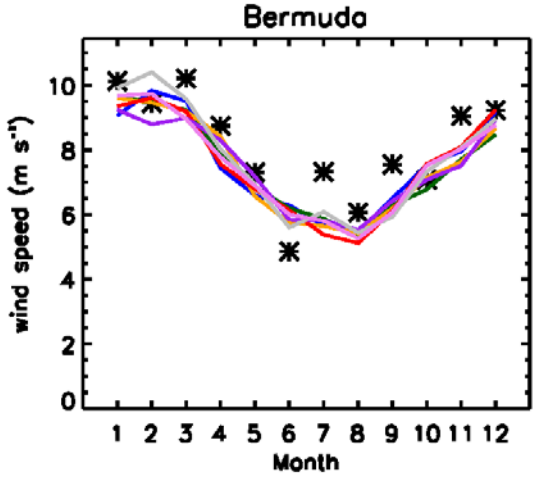






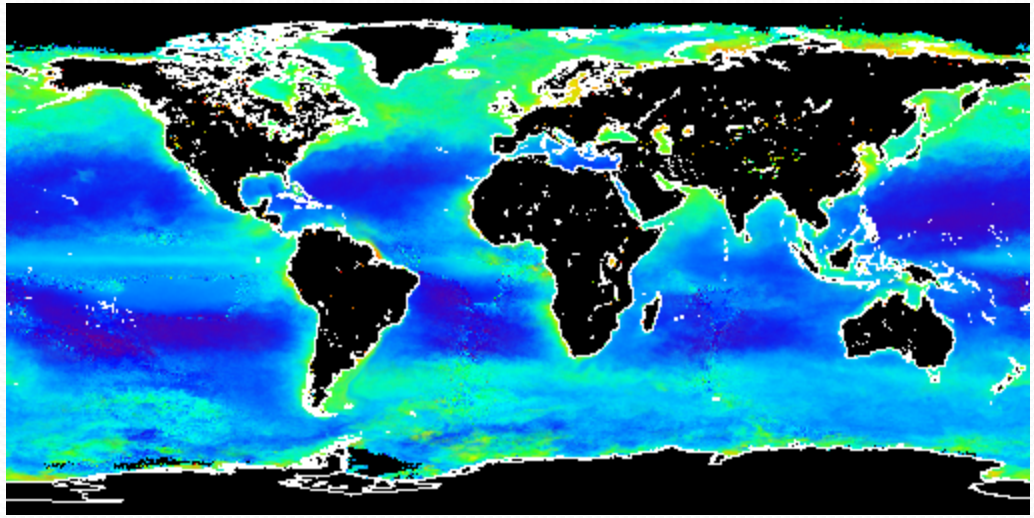






Sea-spray organic enrichment

SeaWiFS, 2000



O'Dowd et al., 2008

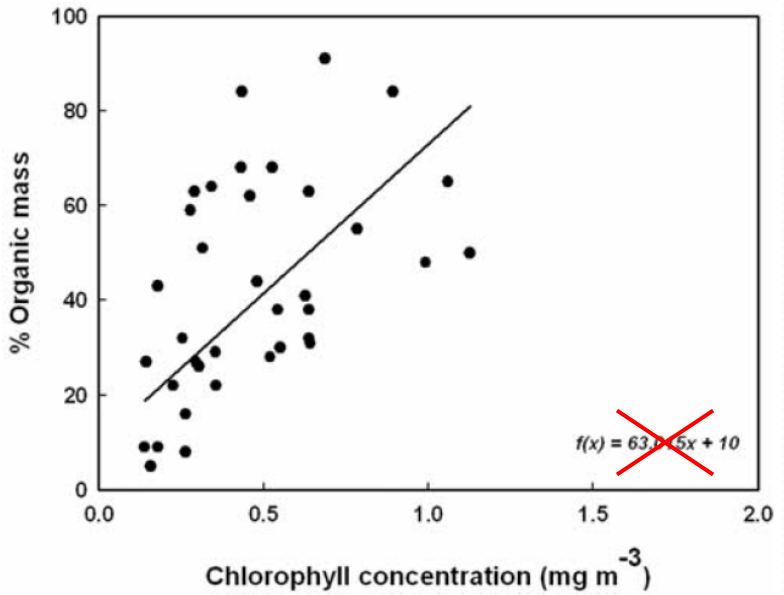


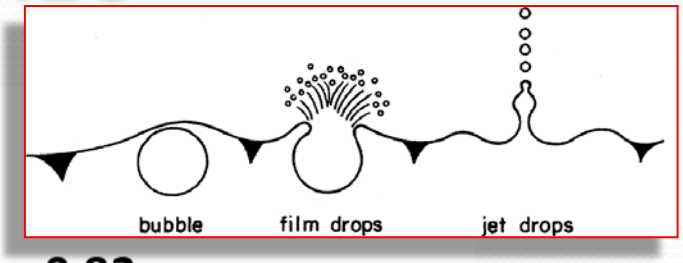
Figure 2. Correlation between fractional WIOC component of sea-spray as a function of grid-average chlorophyll-a concentration.

Vignati et al., 2010

$$\%\ \text{organic mass} = 43.5 * \text{Chl}\ [\text{mg m}^{-3}] + 13.805,$$
$$\text{Chl} < 1.43\ \mu\text{g m}^{-3}$$

Gantt et al., 2011

Organic enrichment vs. size



$$OM_{SSA} = \frac{0.82}{1+0.03\exp(6.81D_p)} + 0.03$$

Models' sea salt (sea spray) fine/coarse threshold

Organic Mass Fraction (OM_{SSA})

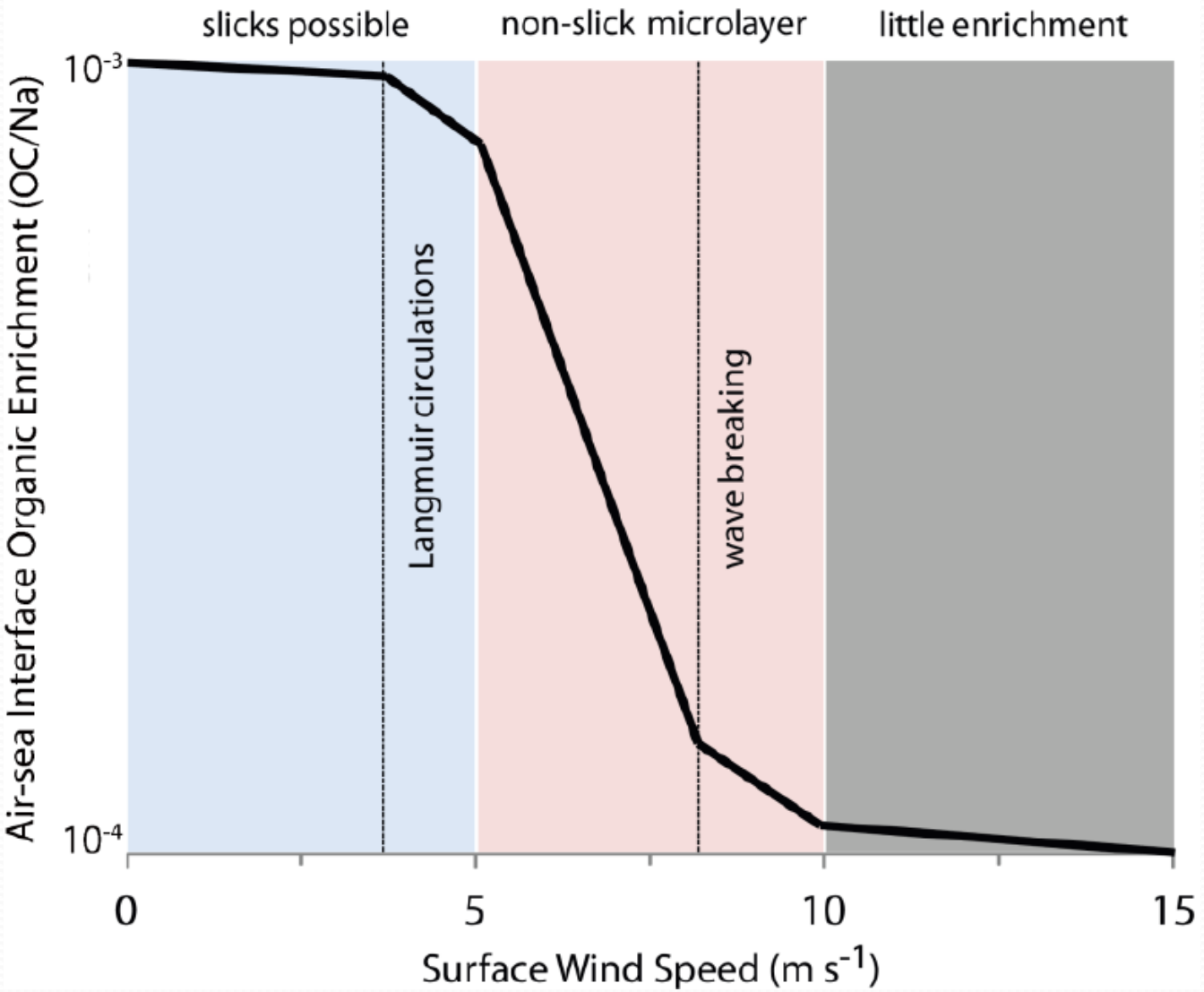
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

0.1
1
10

Aerosol Diameter (µm)

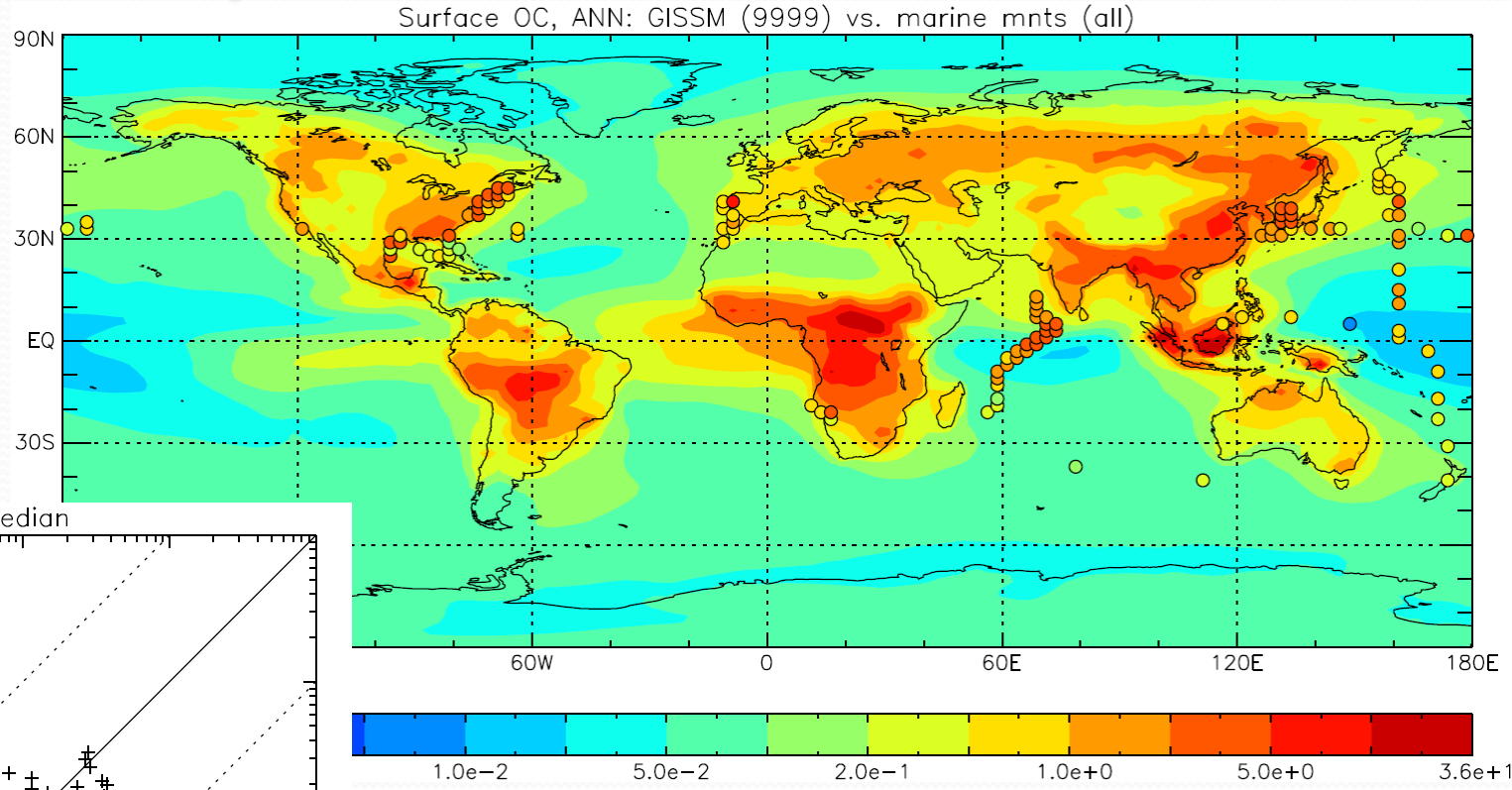
Gantt and Meskhidze, 2011

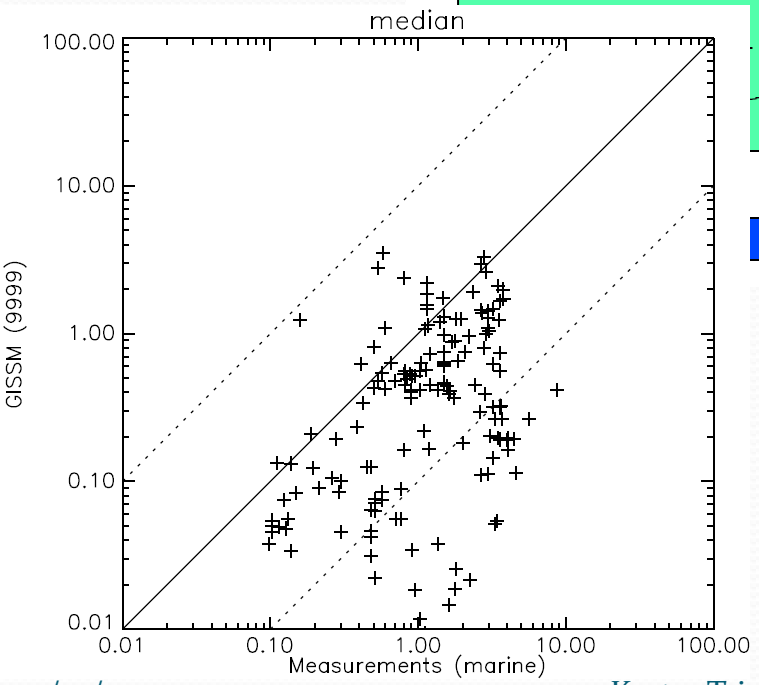
Organic enrichment vs. wind speed



Tsigaridis et al., JGR, 2013

Organics comparison with measurements

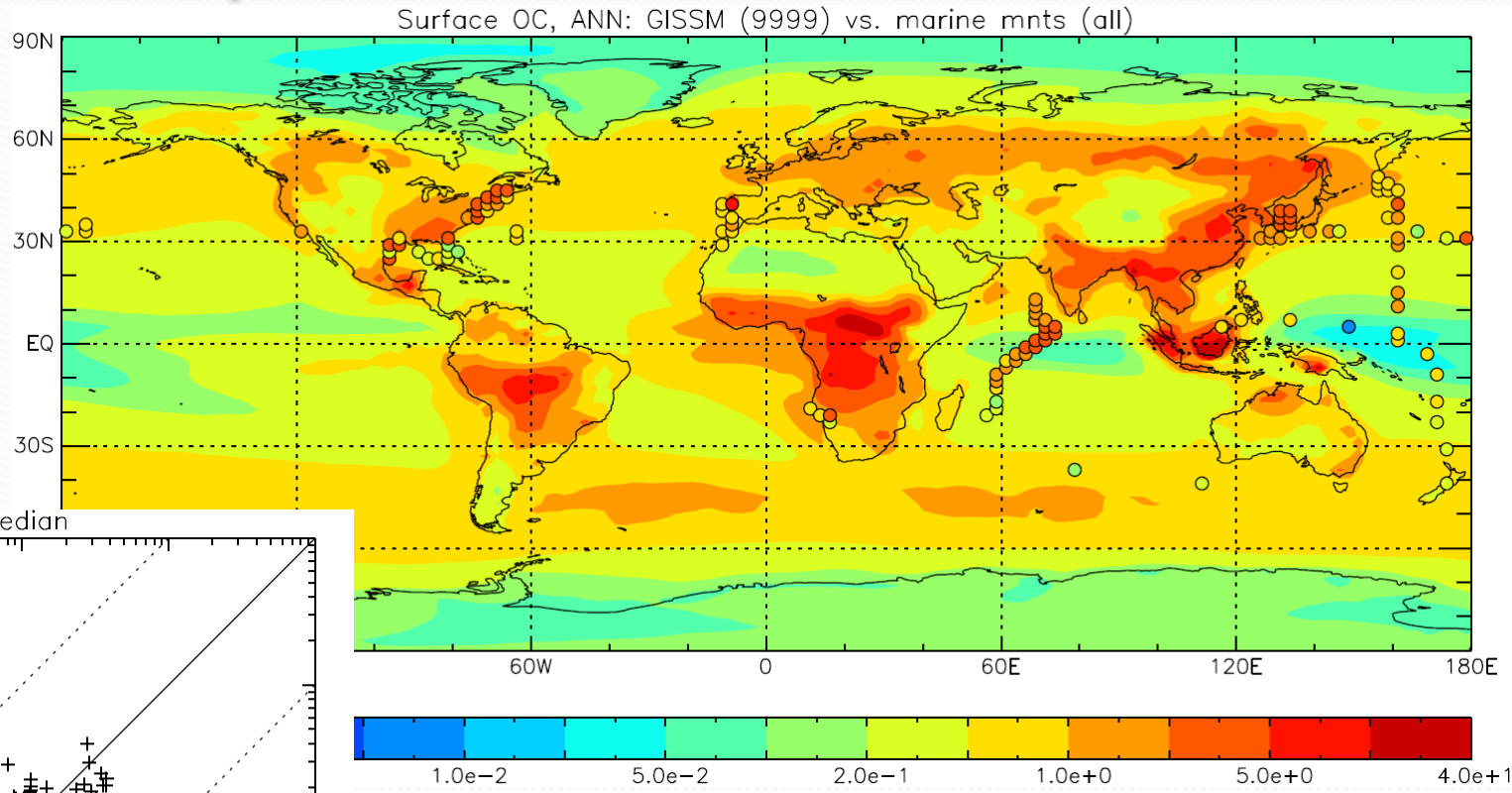


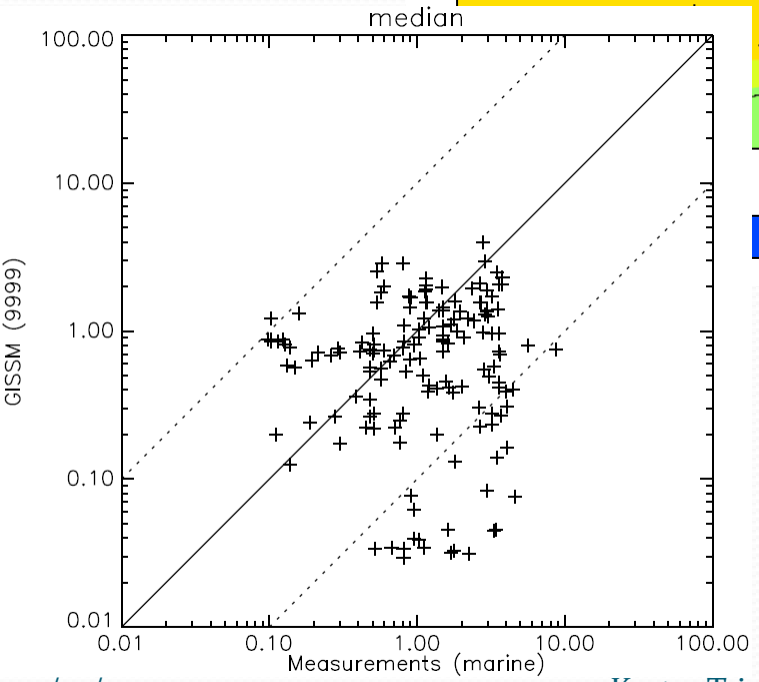


Without oceanic organics

Tsigaridis et al., JGR, 2013

Organics comparison with measurements





With oceanic organics

Oceanic aerosol budget

Tracer	Source (Tg a^{-1})	Lifetime (days)	Reference
Sea salt	24+6273		Vignati et al., 2010
Sea salt	31+6259		Myriokefalitakis et al., 2010
Sea salt	59+2229	1.03, 0.5	Jaeglé et al., 2010
Sea salt	1500		Long et al., 2011
Oceanic OA	1.4+12.6		Duce et al., 1983
Oceanic OA	5.5+2.5 (TgC a^{-1})		Spracklen et al., 2008
Oceanic OA	75 (TgC a^{-1})		Roelofs, 2008
Oceanic OA	2.9+19.4 (TgC a^{-1})		Gantt et al., 2009
Oceanic OA	8.2+9	2.2	Vignati et al., 2010
Oceanic OA	7-8	4.5	Myriokefalitakis et al., 2010
Oceanic OA	29 (TgC a^{-1})		Long et al., 2011
Oceanic OA	17.7 (TgC a^{-1})		Westervelt et al., 2011

Tsigaridis et al., JGR, 2013

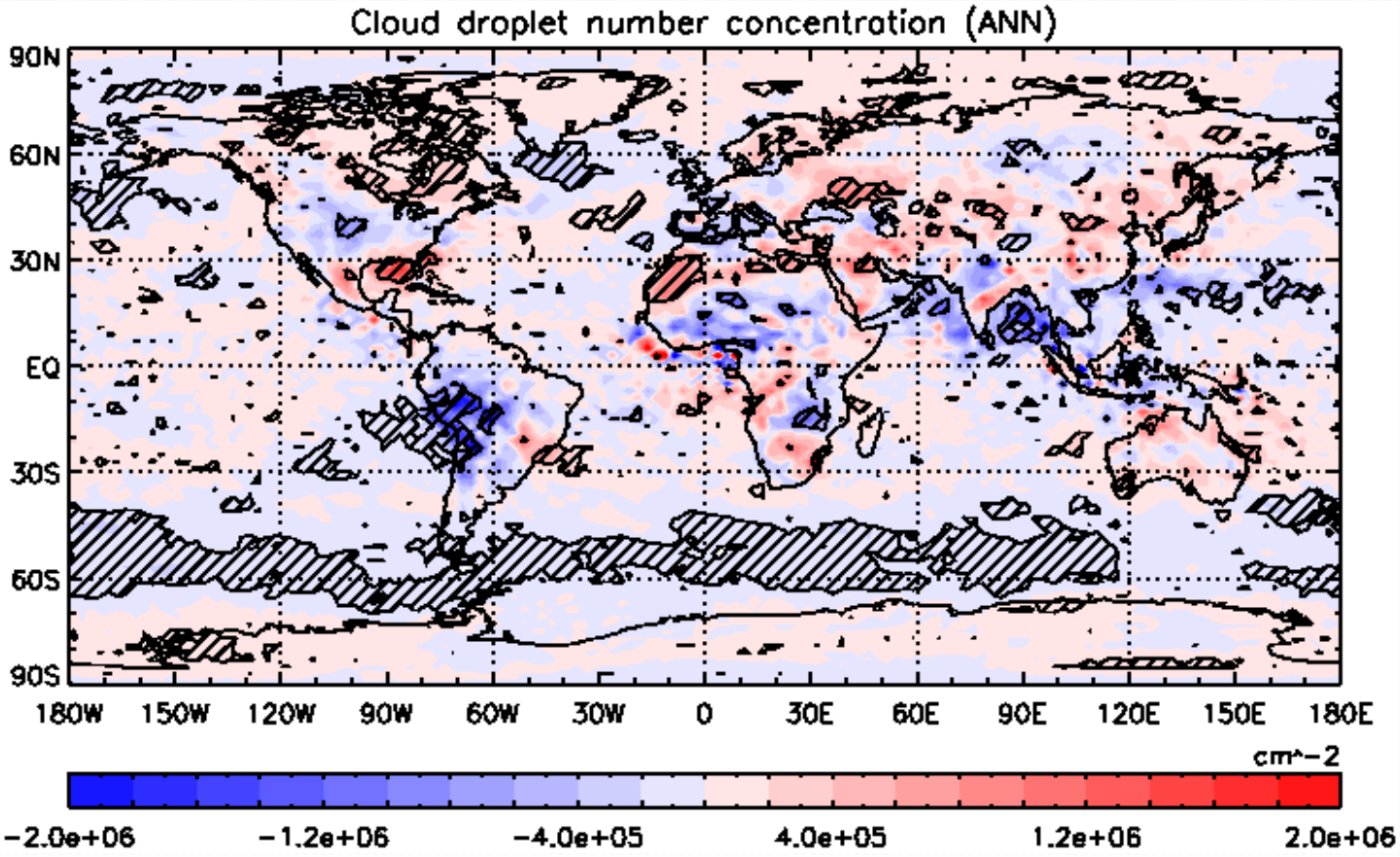
Oceanic aerosol budget

		Source (Tg a^{-1})		Lifetime (days)	
		Fine	Coarse	Fine	Coarse
Sea salt	SS1 – Gong	360 (280)	2330	1.4 (1.5)	1.1
	SS2 – Gong	360 (280)	5100	1.4 (1.5)	0.4
	SS3 – Gong	36 (28)	2660	1.4 (1.5)	1.1
	SS1 – Jaegle	310 (250)	2020	1.3 (1.4)	1.1
Organics	SS1 – Gong	75	-	1.5	-
	SS2 – Gong	75	-	1.5	-
	SS3 – Gong	7.5	-	1.5	-
	SS1 – Jaegle	65	-	1.4	-

	Fine mode	Coarse mode
SS1	0.1-1μm	1-4μm
SS2	0.1-1μm	1-10μm
SS3	0.1-0.5μm	0.5-4μm

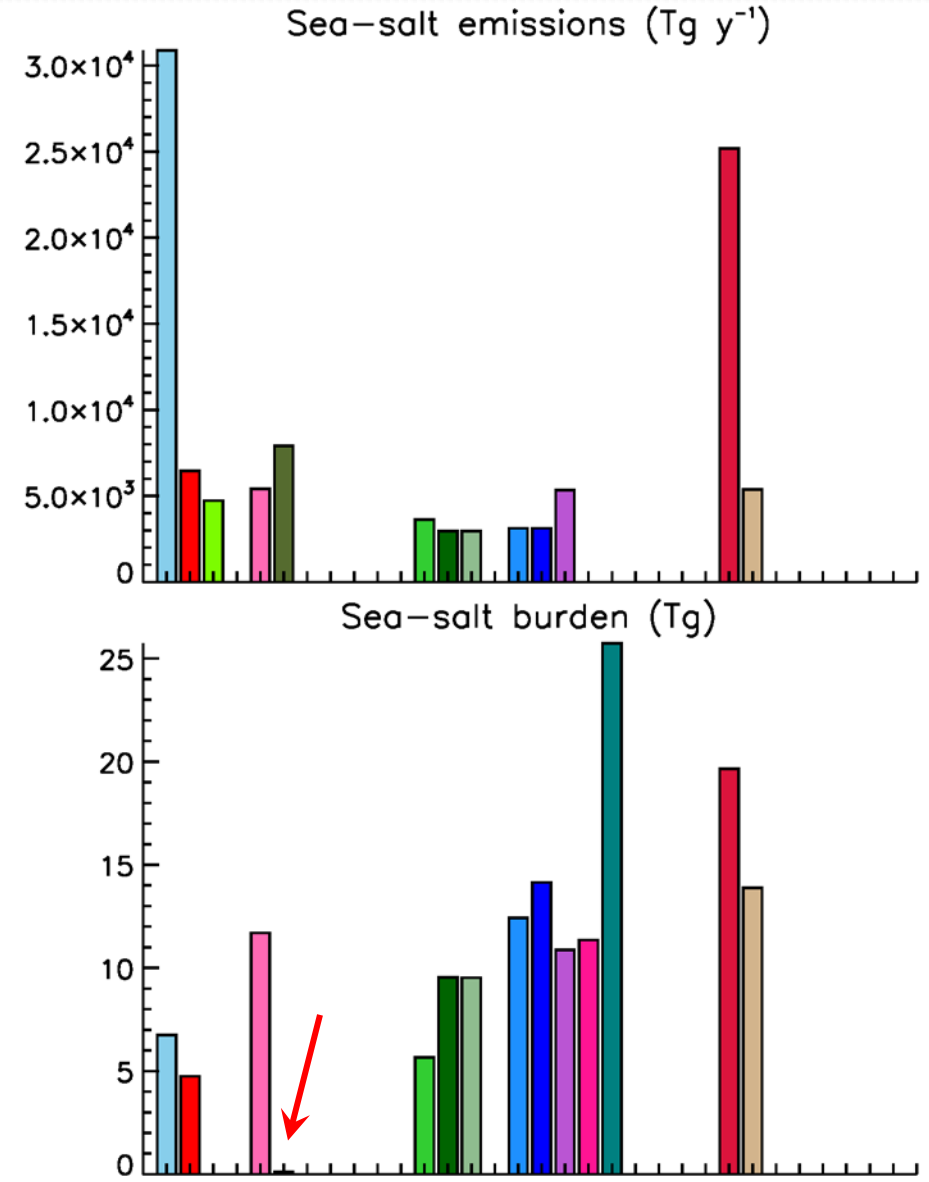
Tsigaridis et al., JGR, 2013

CDNC changes



AeroCom models

BCC
CAM4-Oslo
CAM5-MAM3
CanAM-PAM
ECHAM5-HAMMOZ
ECHAM5-SALSA
ECMWF-GEMS
EMAC
GEOS-Chem
GEOS-Chem-APM
GISS-CMU-VBS
GISS-MATRIX
GISS-modelE-G
GISS-modelE-I
GISS-TOMAS
GLOMAPbin
GLOMAPmode
GMI
GOCART
HadGEM2
IMAGES
IMPACT-A
IMPACT-B
IMPACT-C
LMDz-INCA
MPIHAM-v2
OsloCTM2
SPRINTARS
TM4-ECPL-C
TM4-ECPL-F
TM4-ECPL-FNP
TM5



Concluding remarks

- Sea salt sources differ by an order of magnitude in different global models
- Sea spray sources, size distribution and mixing state are critically important on oceanic OA fluxes
- Oceanic OA sources are very uncertain and differ by an order of magnitude between models; sea spray sources are among the ones to blame
- Sea salt number and size distribution? Removal?
- How far can we go with chlorophyll *a*?

Extras

Sea spray source

Gong (2003)

$$\frac{dF}{dr} = 1.373 u_{10}^{3.41} r^{-A} \left(1 + 0.057 r^{3.45}\right) \times 10^{1.607 e^{-B^2}}, \qquad (2)$$

where $A = 4.7(1 + \Theta r)^{-0.017 r^{-1.44}}$ and $B = (0.433 - log\, r)/0.433$ and Θ in A is an adjustable parameter that controls the shape of the sub-micron size distributions.

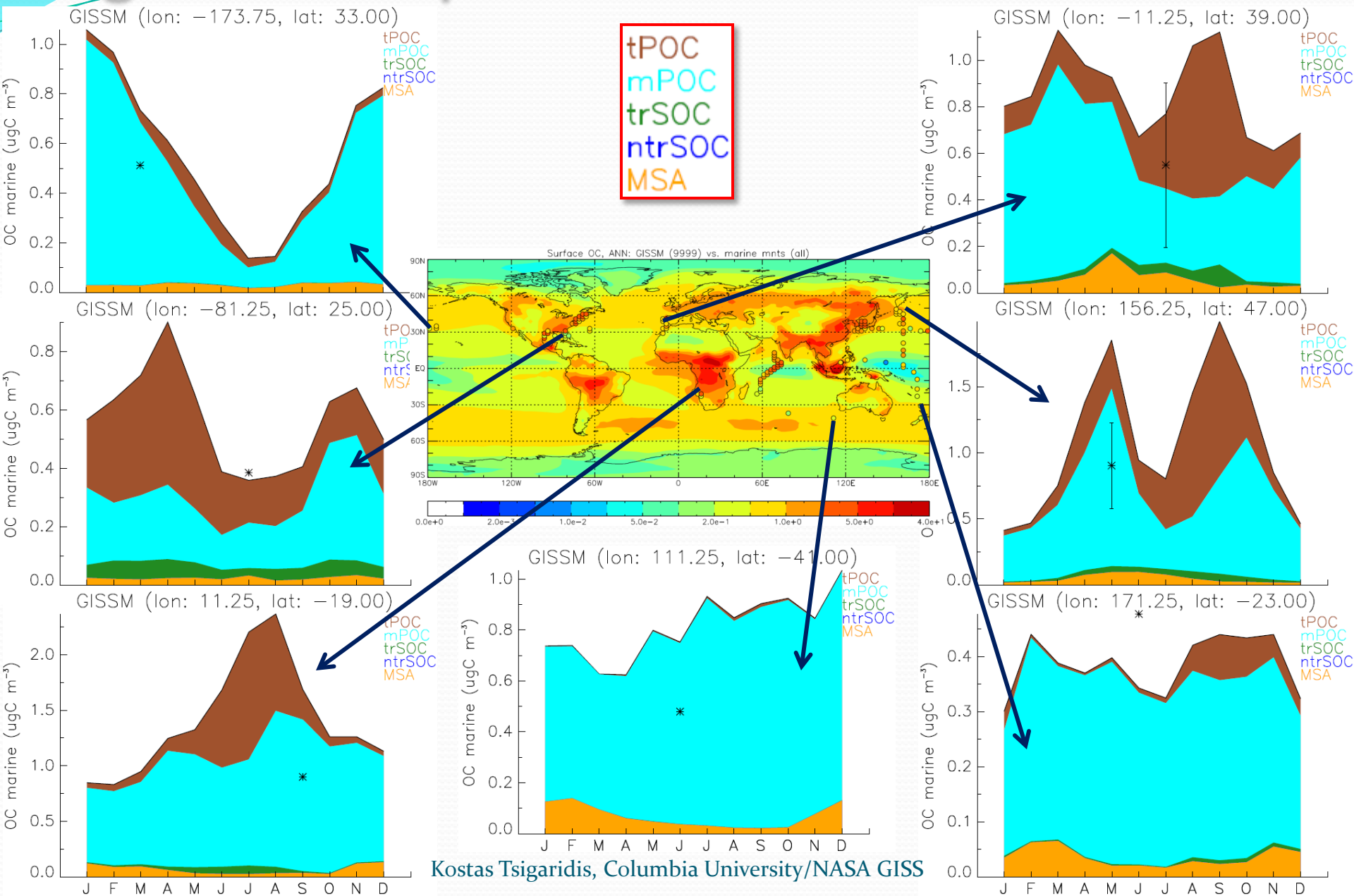
Sea salt size distribution (dry radius)

Fine (µg)	Source ($Tg\ a^{-1}$)	Coarse (µg)	Reference
0.1-1	1734	1-4	Koch et al., 2006
0.05-0.5	24+6273	>0.5	Vignati et al., 2010
0.05-0.5	31+6259	>0.5	Myriokefalitakis et al., 2010
0.01-0.5	59+2229	0.5-4	Jaeglé et al., 2010
0.011-0.25*	1500	0.25-6*	Long et al., 2011
0.005-0.04 0.04-0.15 0.15-0.5	0.7 14.8 100+3427	0.5-5	Meskhidze et al., 2011

* Approximate values based on wet size at 80%RH: 0.022-0.5 and 0.5-12. They are the composite of 8 bins.

Organics comparison with measurements

Tsigaridis et al., JGR, 2013



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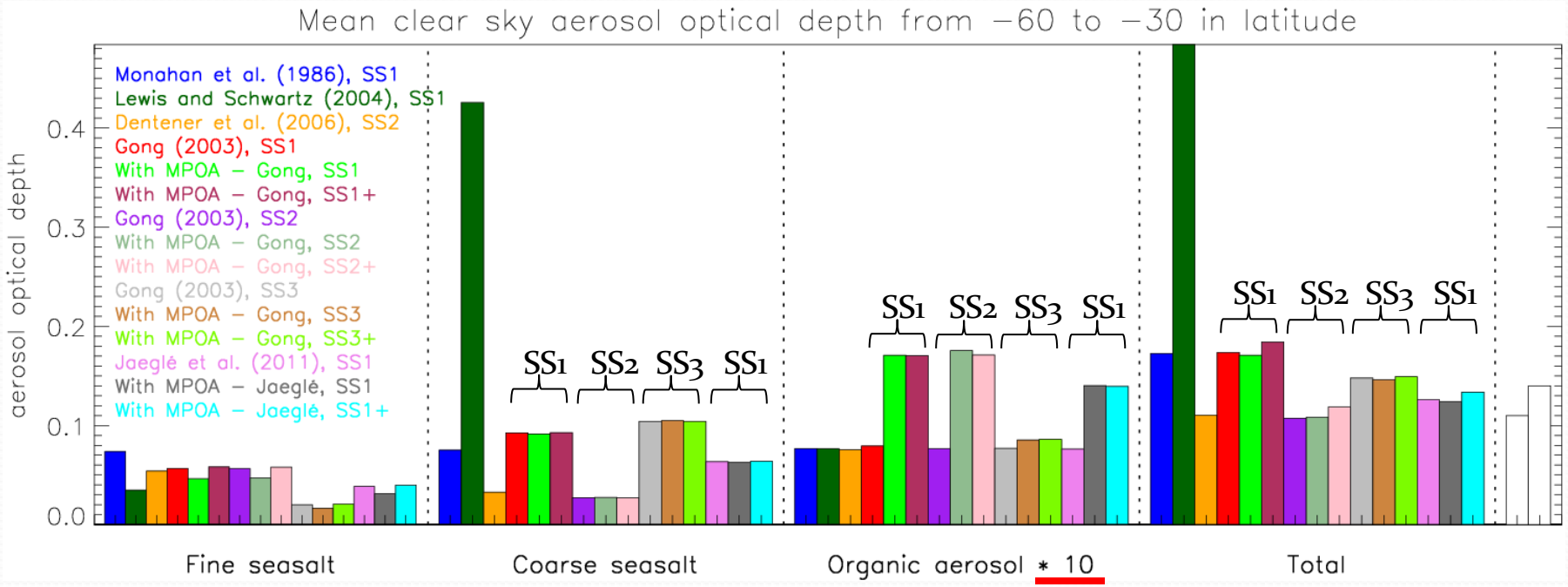
Southern Ocean aerosol optical depth

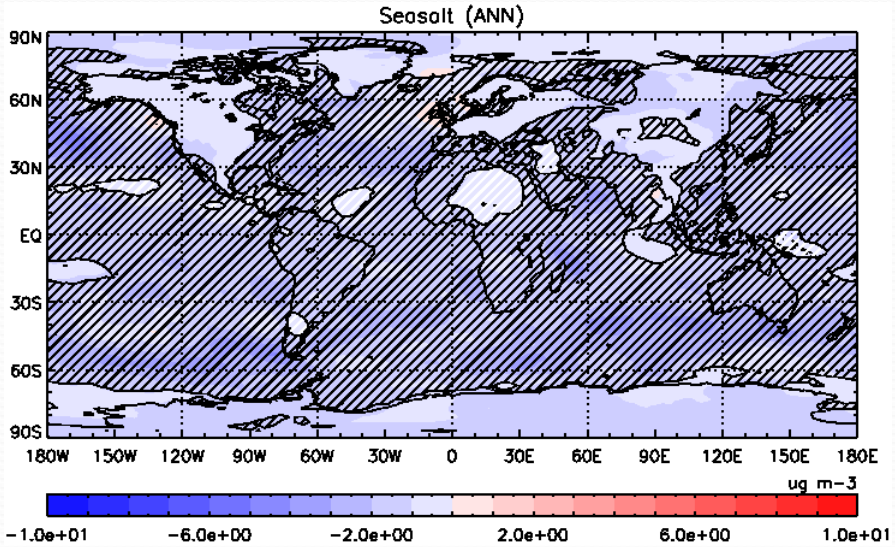


	Fine mode	Coarse mode
SS1	0.1-1μm	1-4μm
SS2	0.1-1μm	1-10μm
SS3	0.1-0.5μm	0.5-4μm

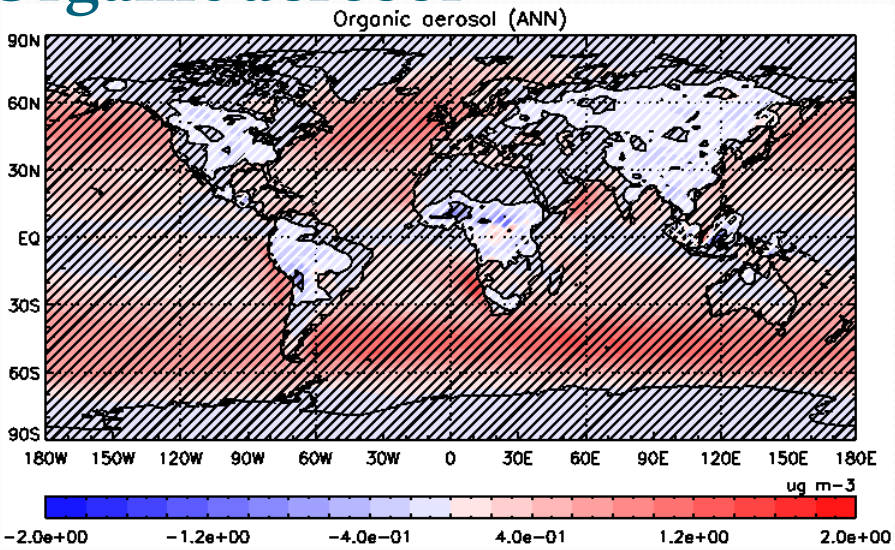
Tsigaridis et al., JGR, 2013

Aerosol concentration changes

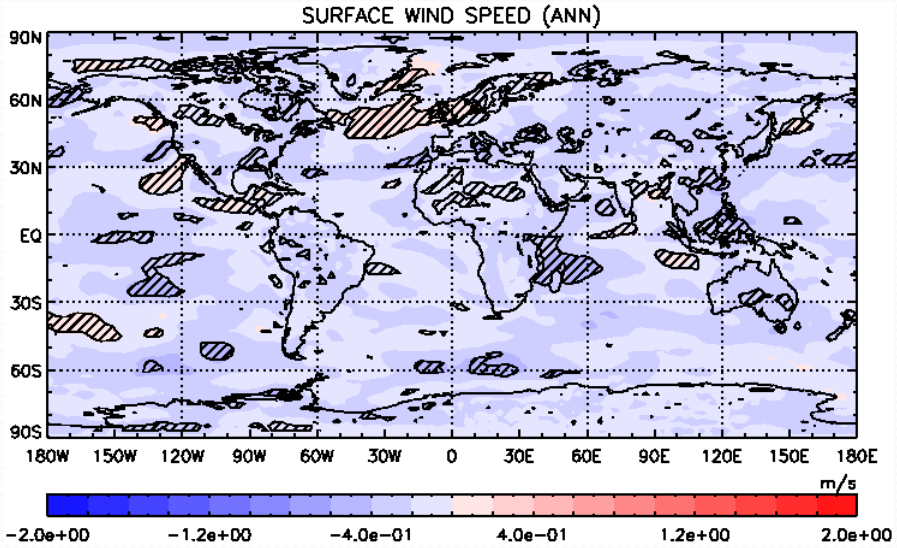
Sea salt



Organic aerosol

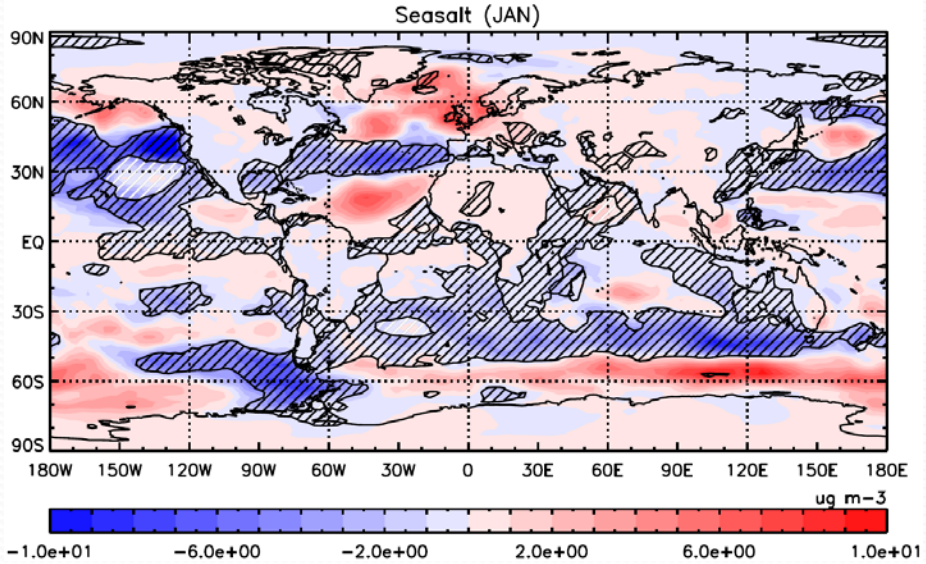


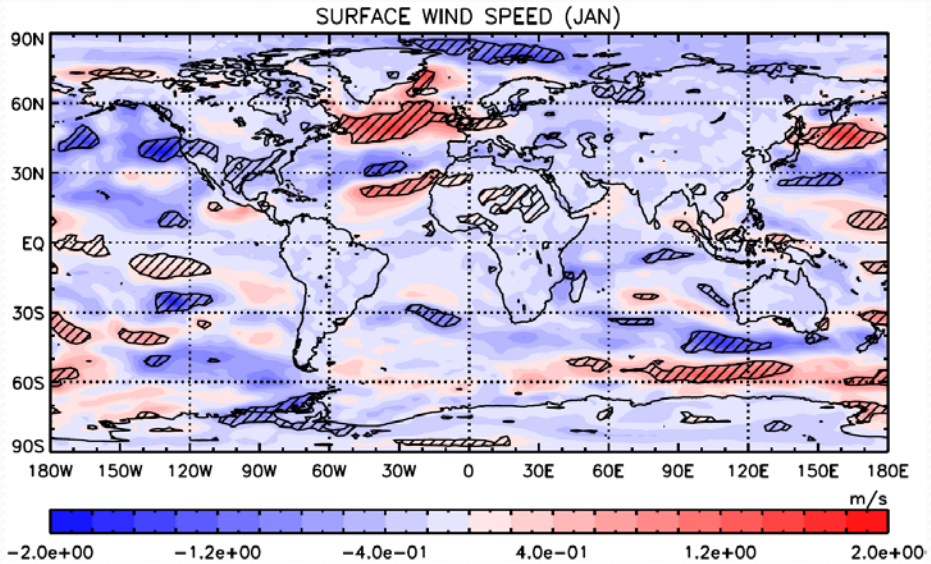
Wind speed

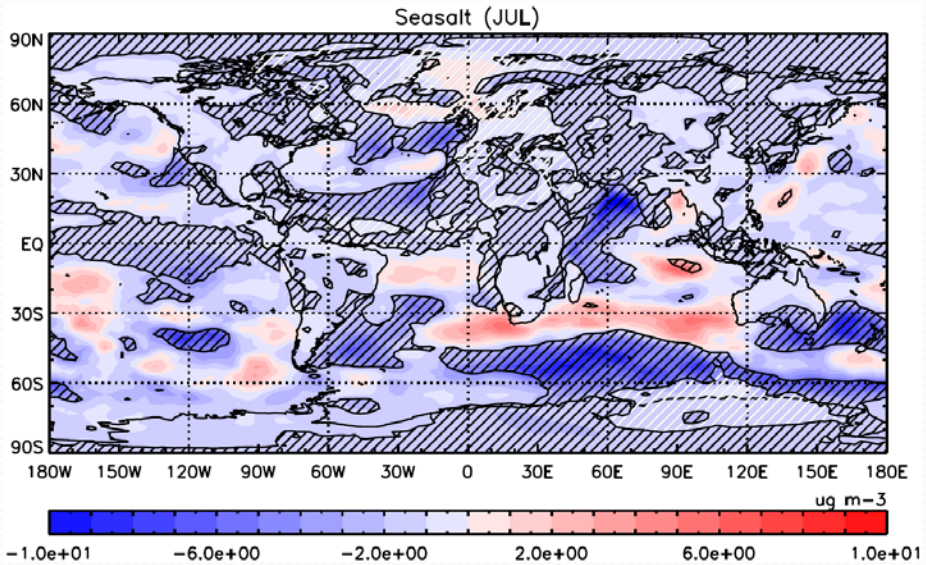


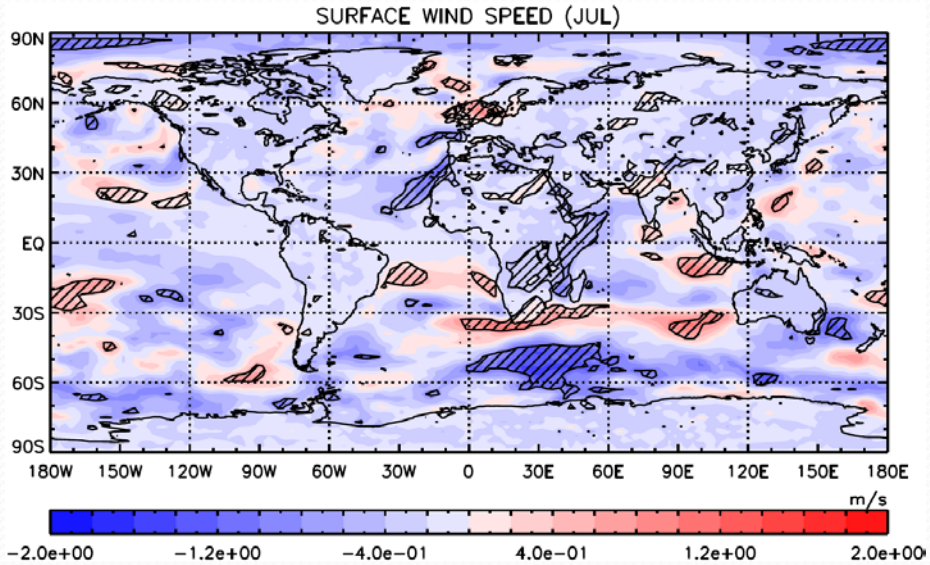
Tsigaridis et al., JGR, 2013

Sea-salt vs. wind speed

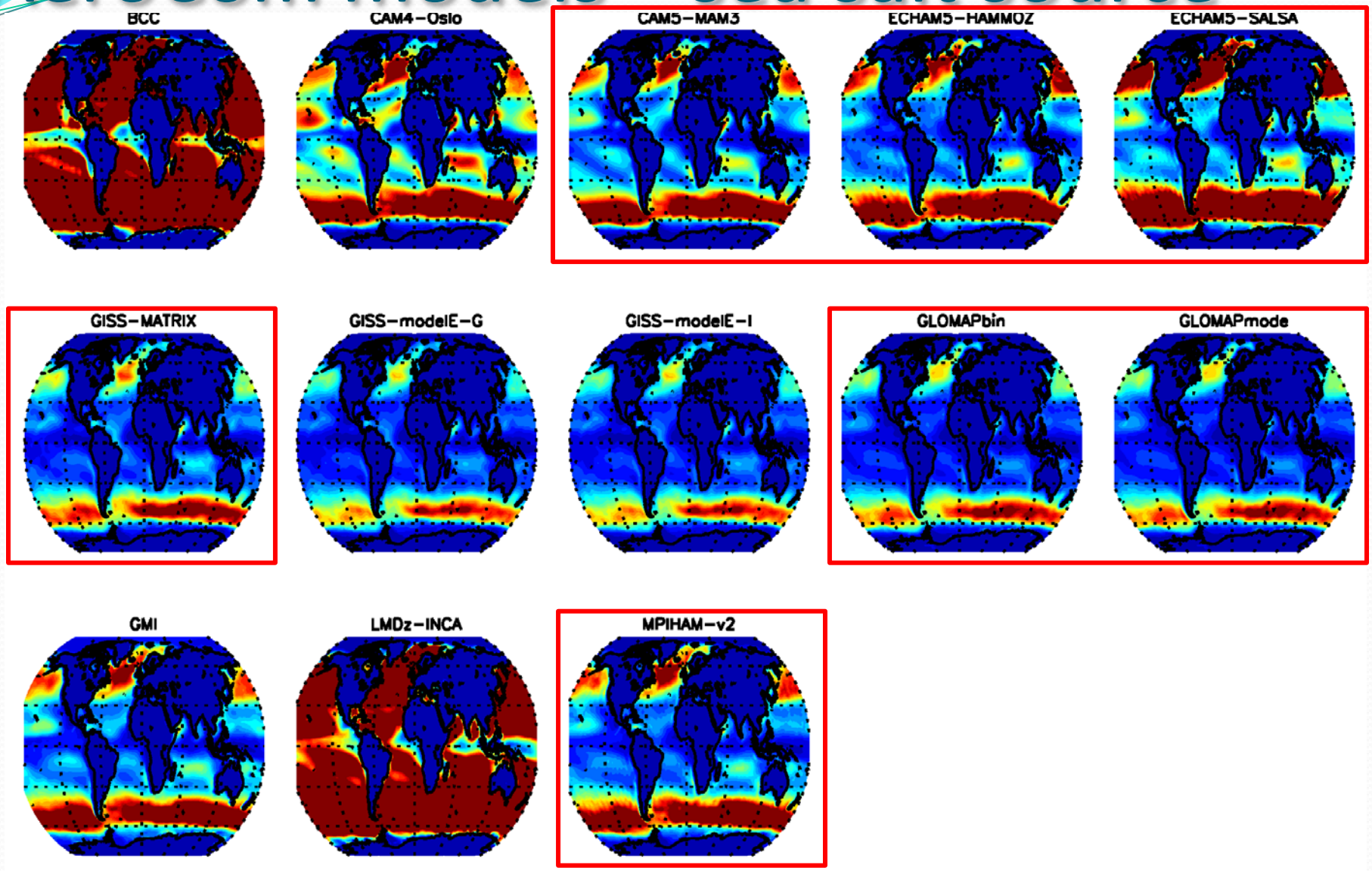








AeroCom models – sea salt source



AeroCom models – sea salt load