Meteorological Service of Canada
Environment Canada

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Sea-salt Production and its Global Budget

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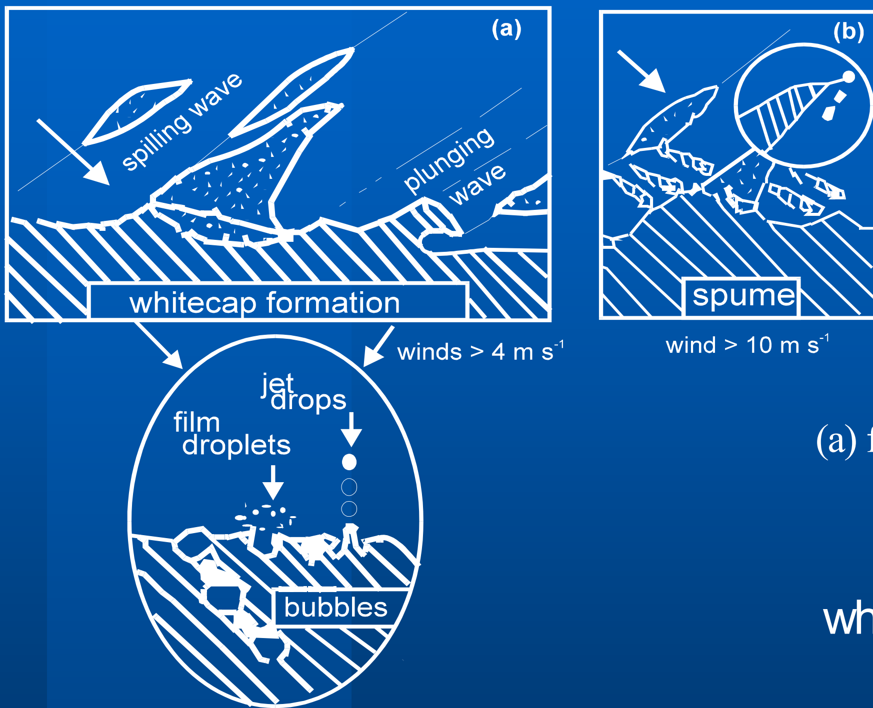
Meteorological Service of Canada

Source Functions (1)



[Monahan *et al.* 1986]

By two mechanisms:

$$\frac{dF_{SS}(r)}{dr} = \frac{dF_0(r)}{dr} + \frac{dF_1(r)}{dr}$$

(a) for indirect mechanism (through bubbles):

$$\frac{dF_0}{dr} = 1.373 U_{10}^{3.41} r^{-3} \left(1 + 0.057 r^{1.05}\right) \times 10^{1.19 e^{-B^2}}$$

where $B = (0.380 - \log r) / 0.650$

(b) for direct mechanism (through spume):

$$\frac{dF_1}{dr} = \begin{cases} 0 & r < 10\ \mu m \\ 8.60 \times 10^{-6} e^{2.08 U_{10}} r^{-2} & 10\ \mu m \le r \le 75\ \mu m \\ 4.83 \times 10^{-2} e^{2.08 U_{10}} r^{-4} & 75\ \mu m \le r \le 100\ \mu m \\ 8.60 \times 10^{6} e^{2.08 U_{10}} r^{-8} & r \ge 100\ \mu m \end{cases}$$

Source Functions (2)

Smith *et al.* [1993]

$$\frac{dF}{dr} = \sum_{i=1,2} A_i \exp\left[-f_i \left(\ln\left(\frac{r}{r_{0i}} \right) \right)^2 \right]$$

where A is strongly dependent on wind speed. For the jet mode, $Log(A)=0.0676\ u_{10} + 2.34$, and for the spume mode Log(A) $=0.959\ u_{10}^{0.5}-1.476$. f_i is the mode width (3.1 and 3.3) and r_{0i} mode radius (2.1 and 9.2 µm).

Source Functions (3)

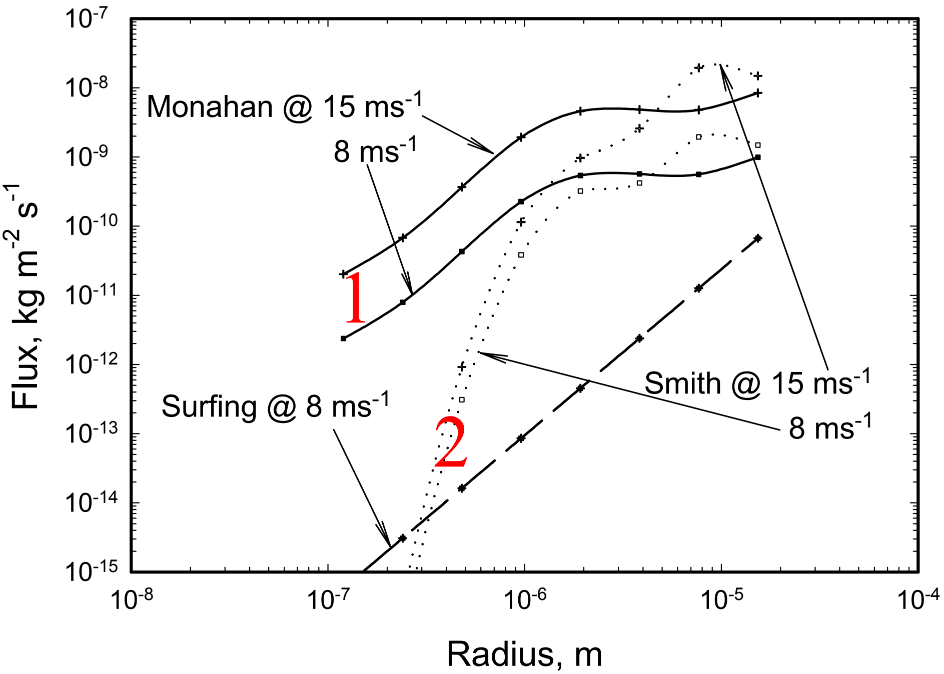
Vignati et al 2001

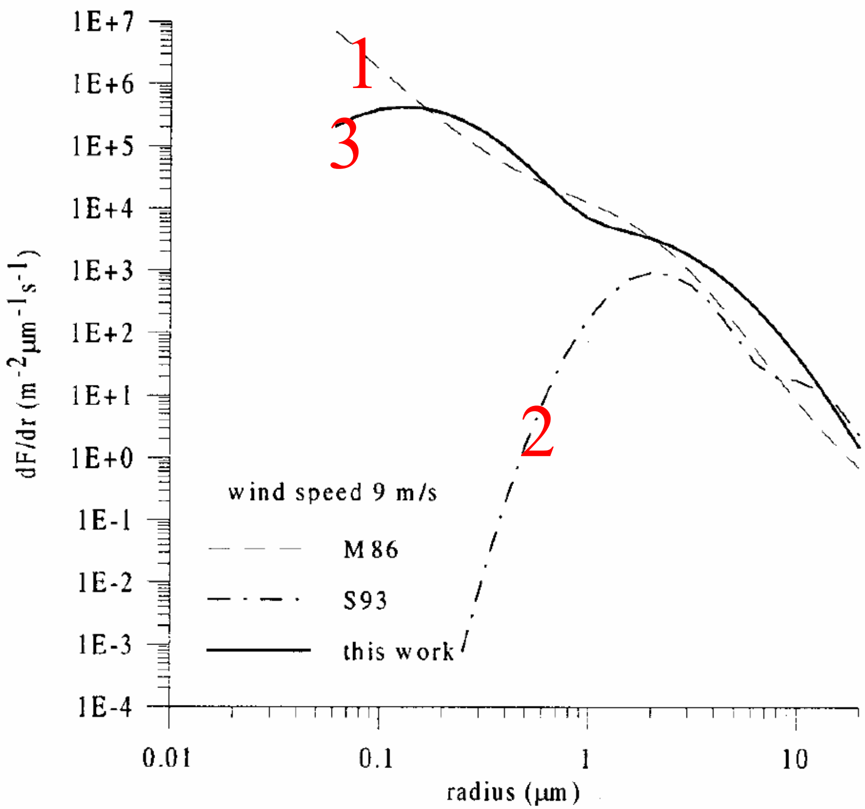
Table 1. Effective Source Function Used in CAT, OD97, Is Formulated as the Sum of Three Lognormal Distributions[a]

Number N, cm^{-3}	Radius R, μm	Standard Deviation σ
$10^{(0.095U+0.283)}$	0.2	1.9
$10^{(0.0422U+0.288)}$	2	2
$10^{(0.069U-3.5)}$	12	3

[a] $F(\log r) = N/\sqrt{2\pi} \log \sigma \exp(-(\log r - \log R)^2/2 \log^2 \sigma)$, where r is the particle radius. The geometric mean radius R applies for RH equal to 80%; U is the wind speed in m s^{-1}.

Comparison of Source Functions





Source Functions (4)

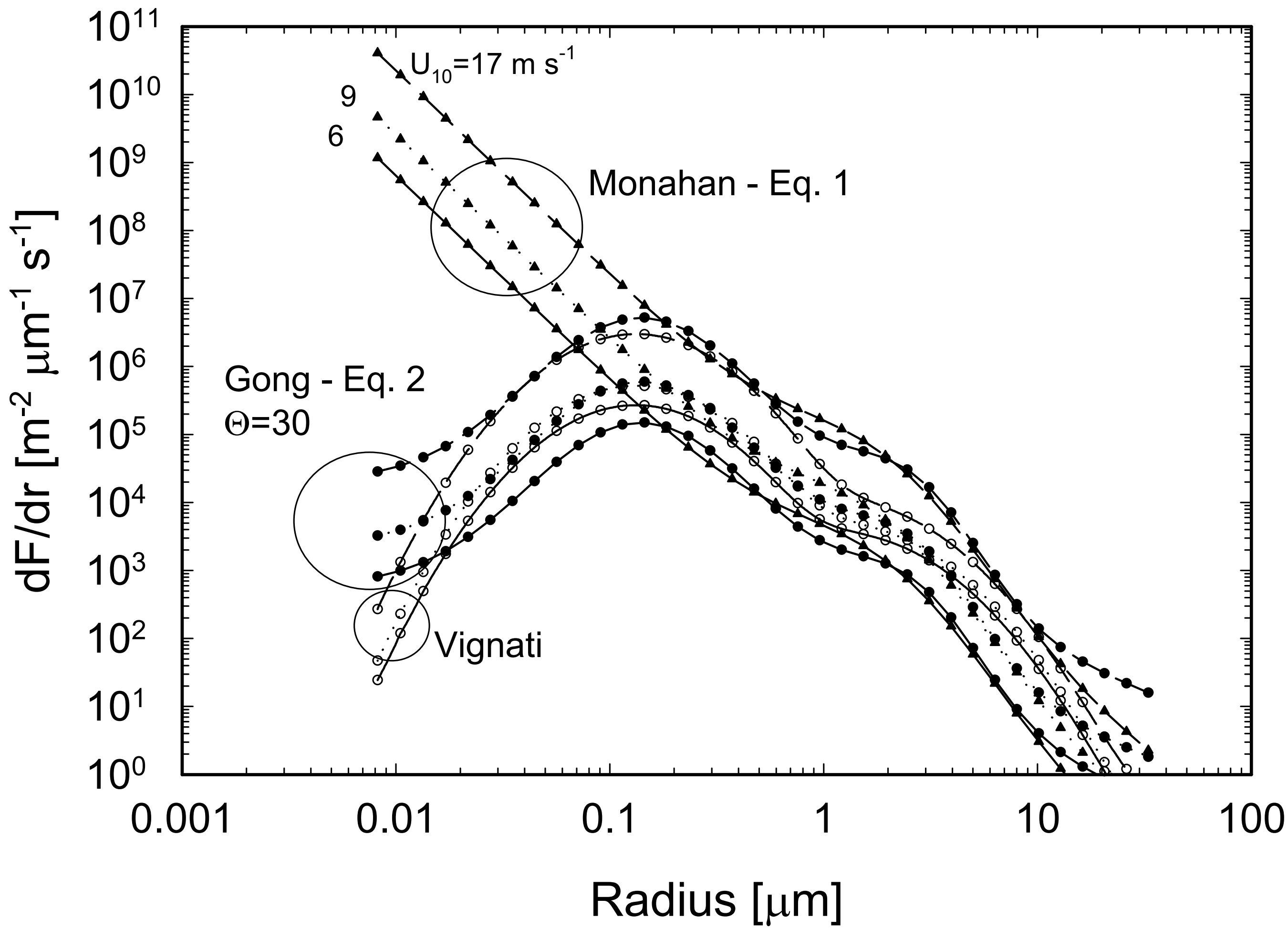
Gong 2003

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

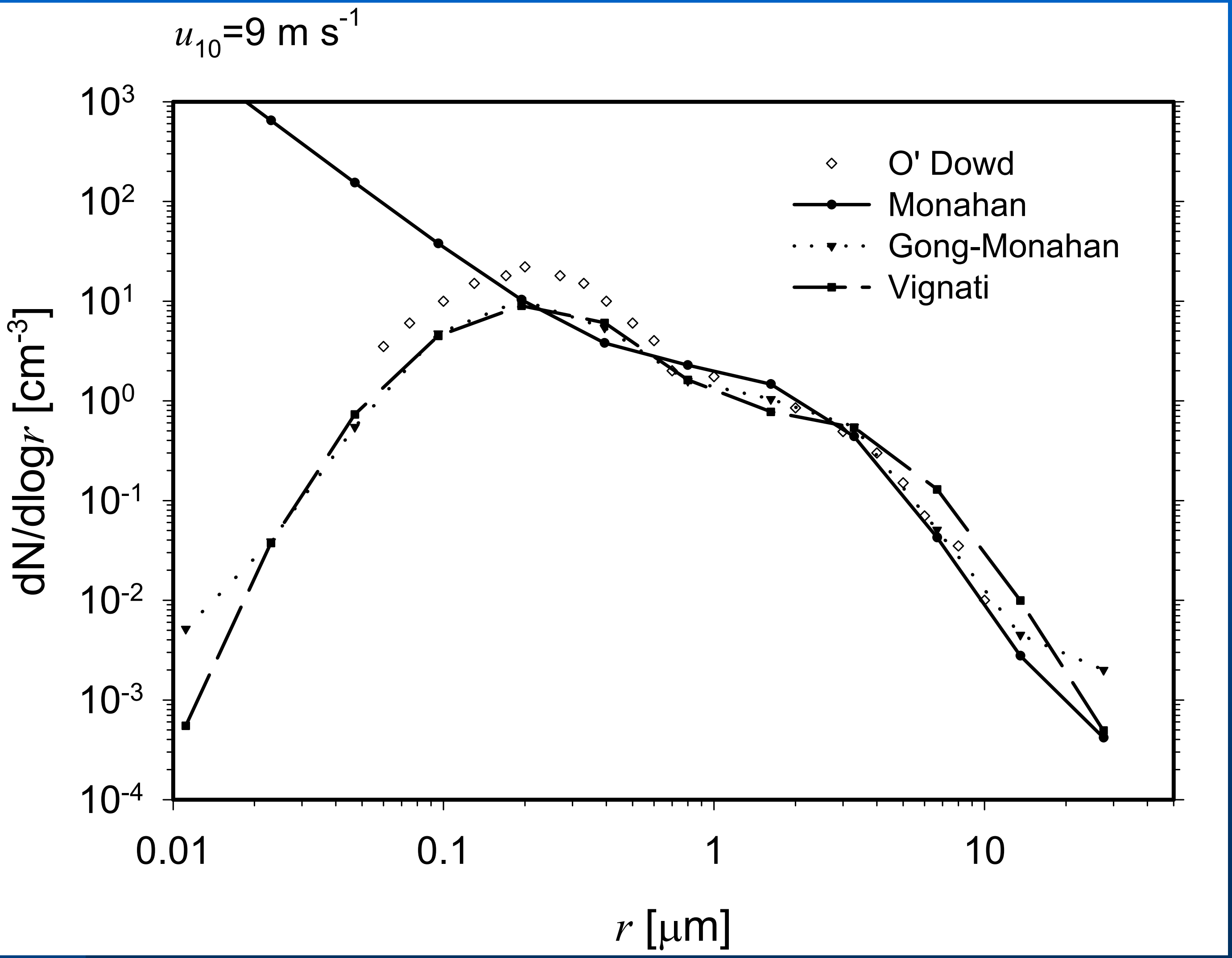
where $A = 4.7(1 + \Theta r)^{-0.017 r^{-1.44}}$

$B=(0.433-\log r)/0.433$ and Θ in A is an adjustable parameter

Comparison of Source Functions



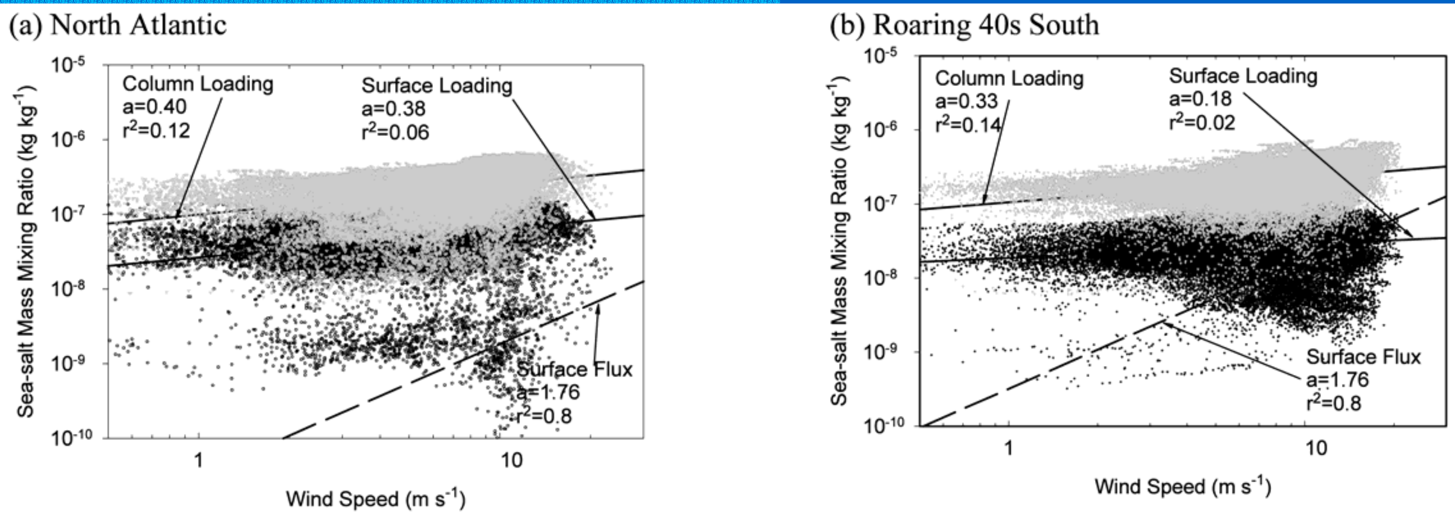
Comparison with Observations

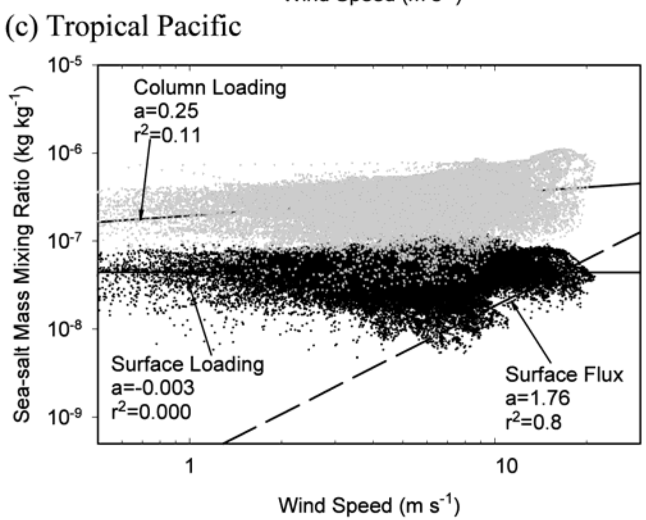


Model Configurations – CAM/GCM

Aerosols	12 bin sectional model: *r*=0.005 – 20.48 μm [dry]
Sources	**Sulphate:** anthropogenic SO_2 and SO_4 (GEIA 1B: 2-level) oceanic DMS concentration (Kettle *et al.* 1999) land H_2S (Benkovitz *et al.* 1994) **Sea-salt:** Monahan 1986, Vignati 2001, Gong 2003 **BC/OC:** fossil fuel (Cook *et al.*) bio-mass (Liousse and Penner *et al*) boreal (Lavoue *et al*) **Soil Dust:** size-segregated (Marticorena and Bergametti 1995)
Prognostic Variables	Aerosol mass mixing ratio in each size bin, cloud water and ice, DMS, SO_2, H_2S and H_2SO_4[g]
Clear-sky processes	Nucleation, condensation, coagulation, on-line S chemistry with MOZART's OH and NO_3
Wet Processes	Below- and In-cloud scavenging (Gong *et al* 2003) Explicit cloud scheme (Lohmann and Roeckner 1996) Cloud activation and cloud S chemistry with MOZART's O_3, H_2O_2 and HNO_3, and NH_3 Brasseur et al. 1998) in stratoform and convective clouds (von Salzen et al. 2000)
Dry Deposition	Size-dependent particle and SO_2 (Zhang *et al* 2001)
Resolution	128×64×32, 15 min

Global 3-D Simulations (1)





Obs.

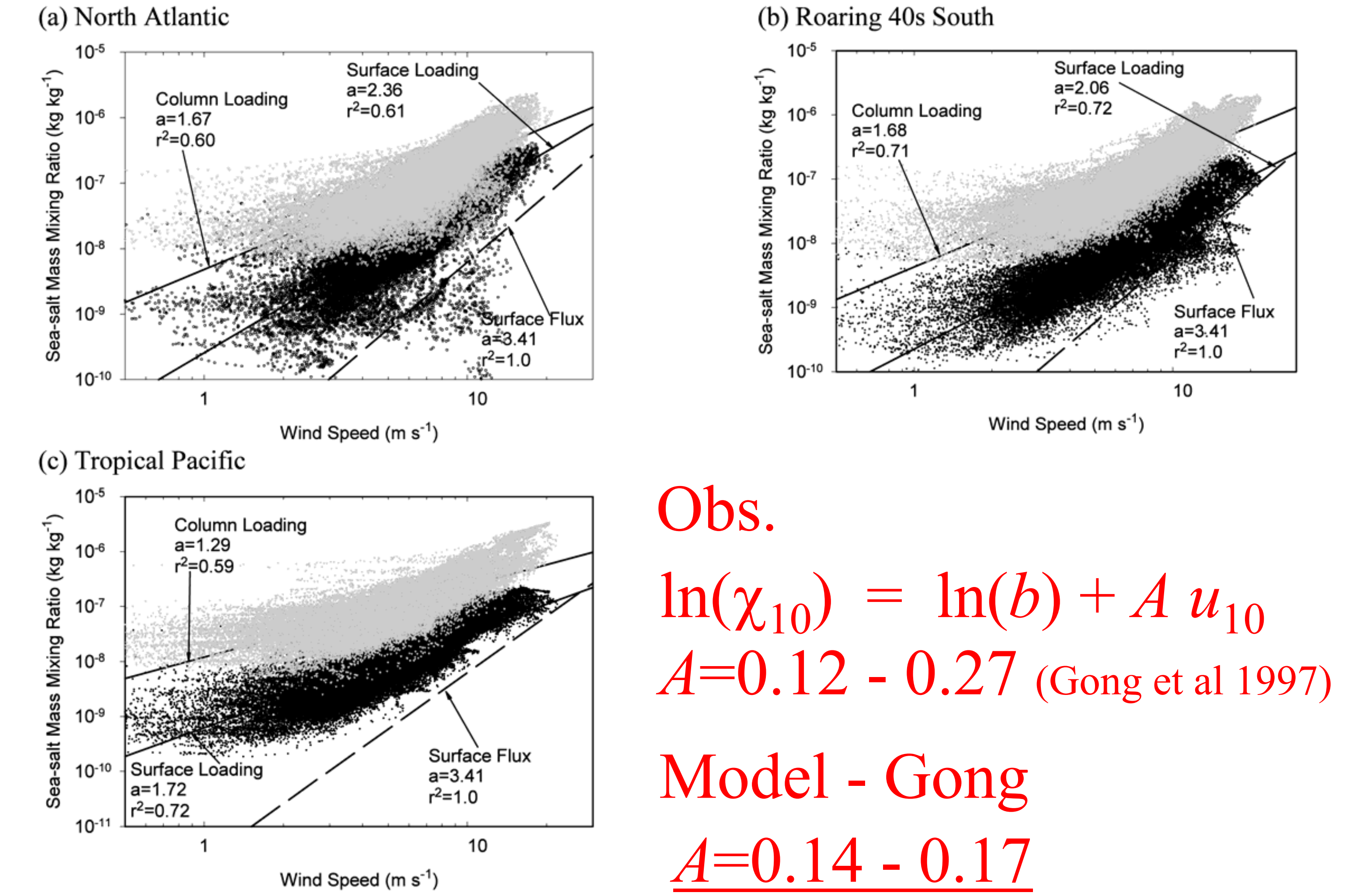
$$\ln(\chi_{10}) = \ln(b) + A\, u_{10}$$

A=0.12 - 0.27 (Gong et al 1997)

Model - Vignati

A=0.00 - 0.03

Global 3-D Simulations (2)



Obs.

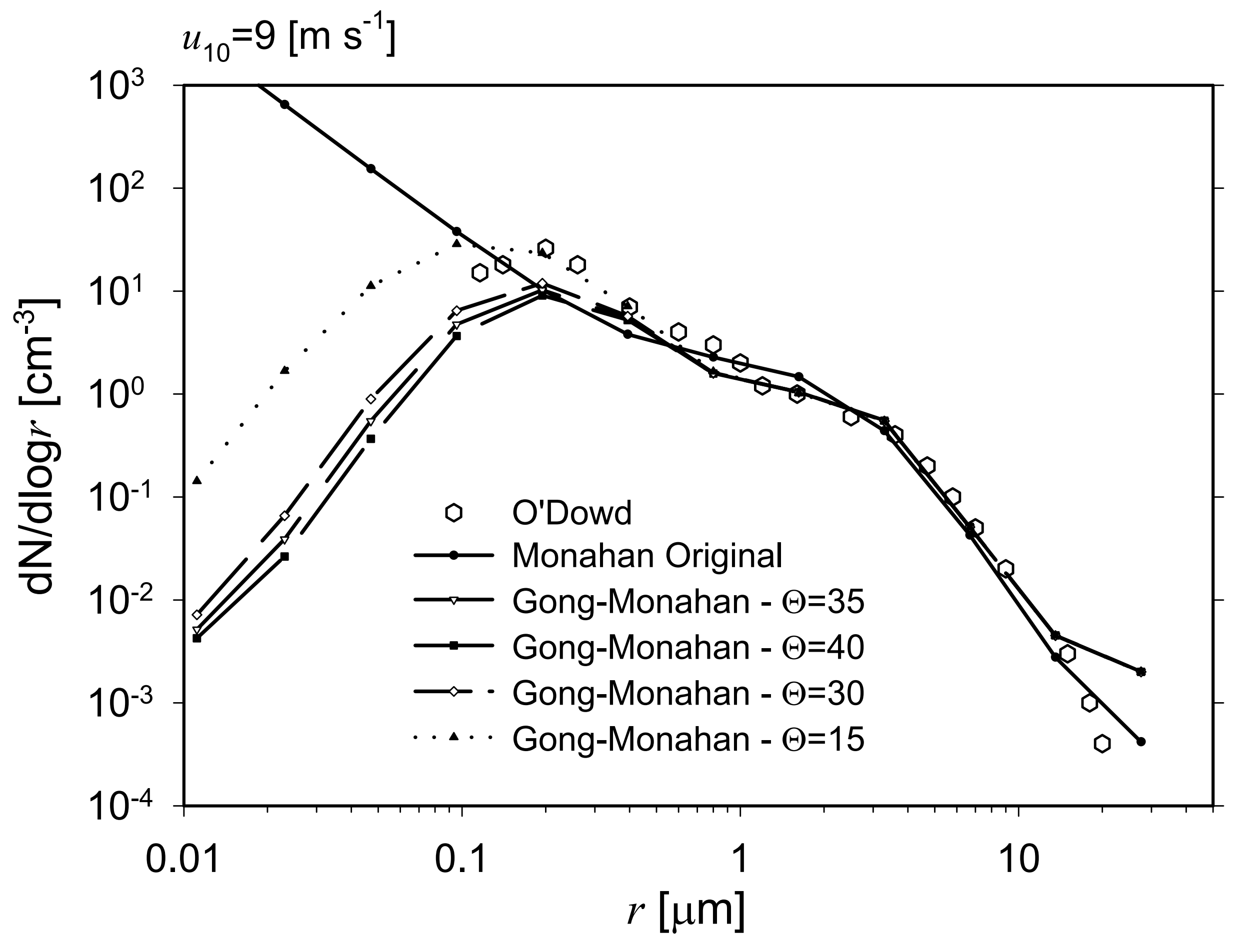
$$\ln(\chi_{10}) = \ln(b) + A\, u_{10}$$

A=0.12 - 0.27 (Gong et al 1997)

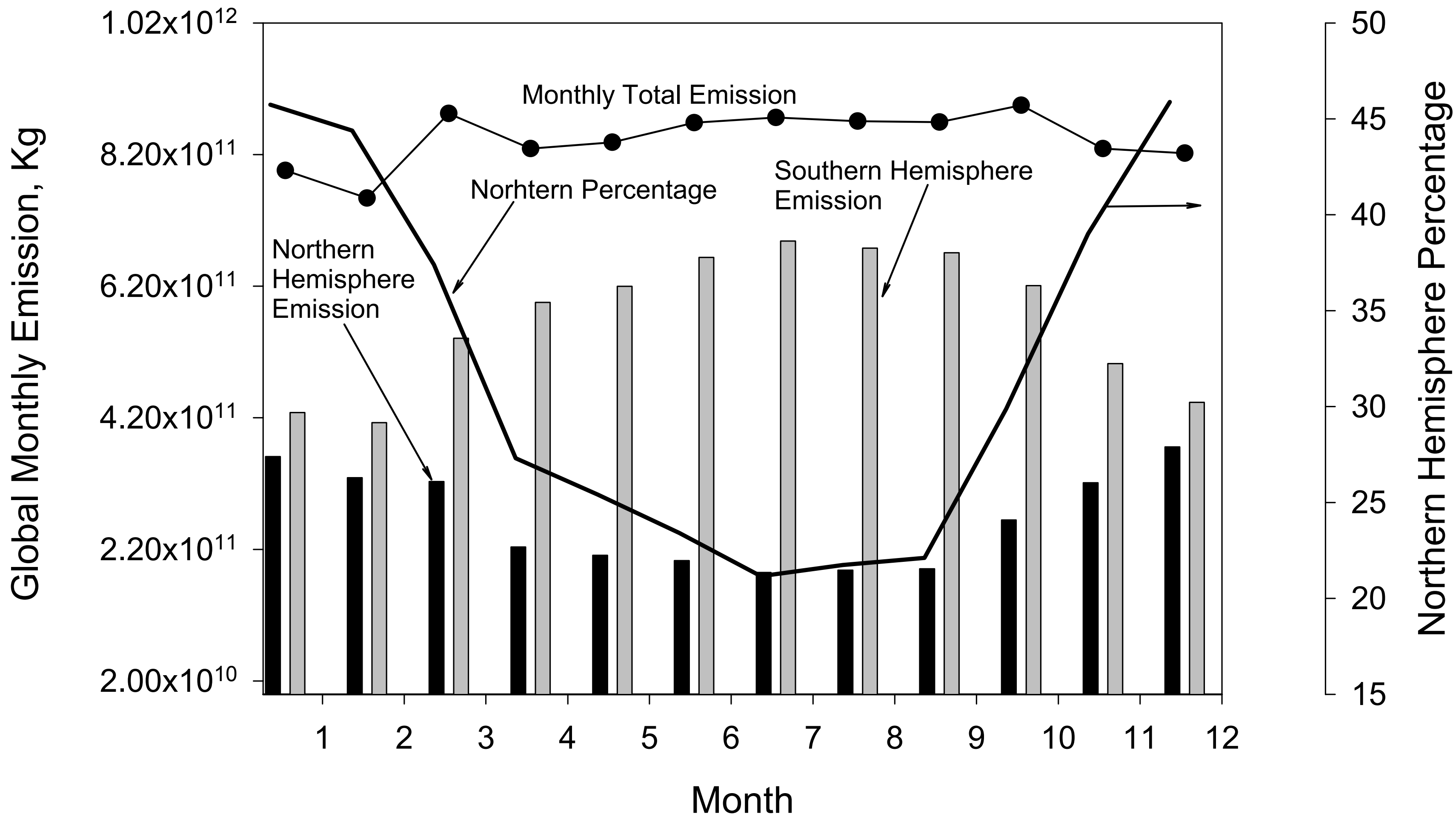
Model - Gong

<u>A=0.14 - 0.17</u>

Impact of Θ on Sea-salt Flux



Global Sea-salt Budgets



Gong et al 2003

Global Annual Sea-salt Budgets

Budgets kg	Flux		Dry Deposition		Below-cloud		In-cloud	
	Northern	Southern	Northern	Southern	Northern	Southern	Northern	Southern
d < 1.0 μm	5.834×10^{10}	1.255×10^{11}	-2.533×10^{10}	-5.188×10^{10}	-1.644×10^{10}	-3.416×10^{10}	-1.097×10^{10}	-2.061×10^{10}
d > 1.0 μm	3.156×10^{12}	6.789×10^{12}	-2.953×10^{12}	-6.364×10^{12}	-1.646×10^{11}	-3.583×10^{11}	-4.626×10^{10}	-8.397×10^{10}
Sub Total	3.215×10^{12}	6.915×10^{12}	-2.978×10^{12}	-6.416×10^{12}	-1.810×10^{11}	-3.925×10^{11}	-5.722×10^{10}	-1.046×10^{11}
Land Percent	1.22%	0.75%	2.19%	0.97%	4.72%	2.20%	5.43%	1.96%
Sub-micron Percent	1.81%	1.81%	0.85%	0.81%	9.08%	8.70%	19.17%	19.71%
Total	1.013×10^{13}		-9.394×10^{12}		-5.735×10^{11}		-1.618×10^{11}	

The land percent is due to the coastal regions and depends on the model resolutions.

[Erickson and Duce 1988] of 1.0 - 3.0×10^{13} kg

Gong et al 2003

Factors for Sea-salt Production

- Production Scheme
- Surface Wind Speed and Frequency Distributions
- Integration Scheme for Size Distributions

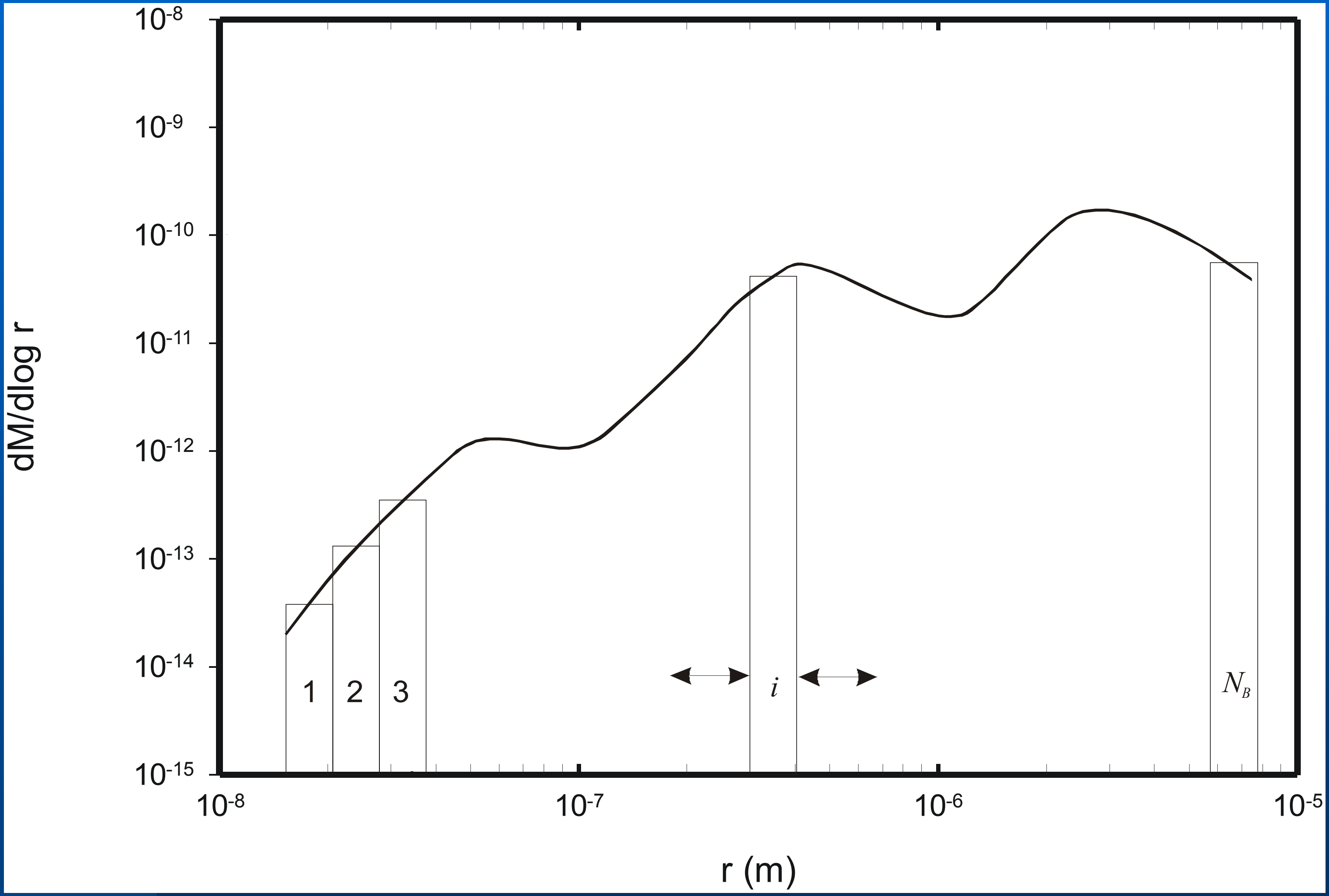
AEROCOM Parameters

Scheme: Gong 2003

Wind Speed: ECWMF 6 hr, $1° \times 1°$

Size Distribution: 24 bins 0.005 – 20.48 μm

Size Configuration



Sea-salt flux with ECMWF Wind

Kg	Submicron	Super-micron	Global Total	Sub/Total	Sup/Total
Jan	7.81E+09	1.87E+12	1.88E+12		
Feb	8.10E+09	1.94E+12	1.95E+12		
Mar	8.45E+09	2.02E+12	2.03E+12		
Apr	7.85E+09	1.88E+12	1.89E+12		
May	8.16E+09	1.96E+12	1.96E+12		
Jun	7.84E+09	1.88E+12	1.89E+12		
Jul	8.34E+09	2.00E+12	2.00E+12		
Aug	8.45E+09	2.02E+12	2.03E+12		
Sep	7.96E+09	1.91E+12	1.91E+12		
Oct	8.14E+09	1.95E+12	1.96E+12		
Nov	7.23E+09	1.74E+12	1.74E+12		
Dec	8.02E+09	1.92E+12	1.93E+12	0.4%	99.6%
Annual	9.63E10	2.31E13	**2.32E13**	0.4%	99.6%

1.01E13 → Gong et al 2003