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Sea Spray Aerosol Production

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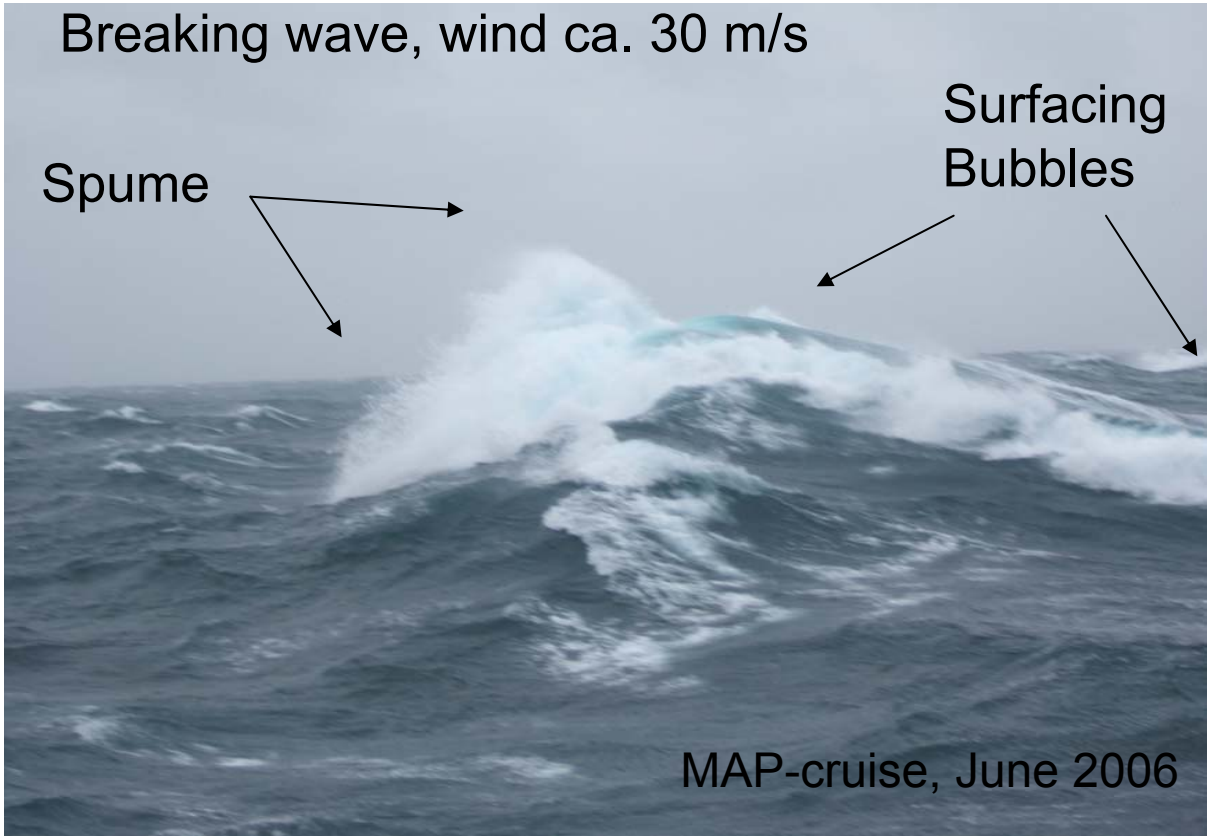
Highway 1, 12 december 2010

Sea-spray aerosol (SSA) consists of a suspension, in air, of particles that are directly produced at the sea surface



Focus on bubble-mediated production (r80< a few μm)

Sea spray aerosol production

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Appendix: Formulations

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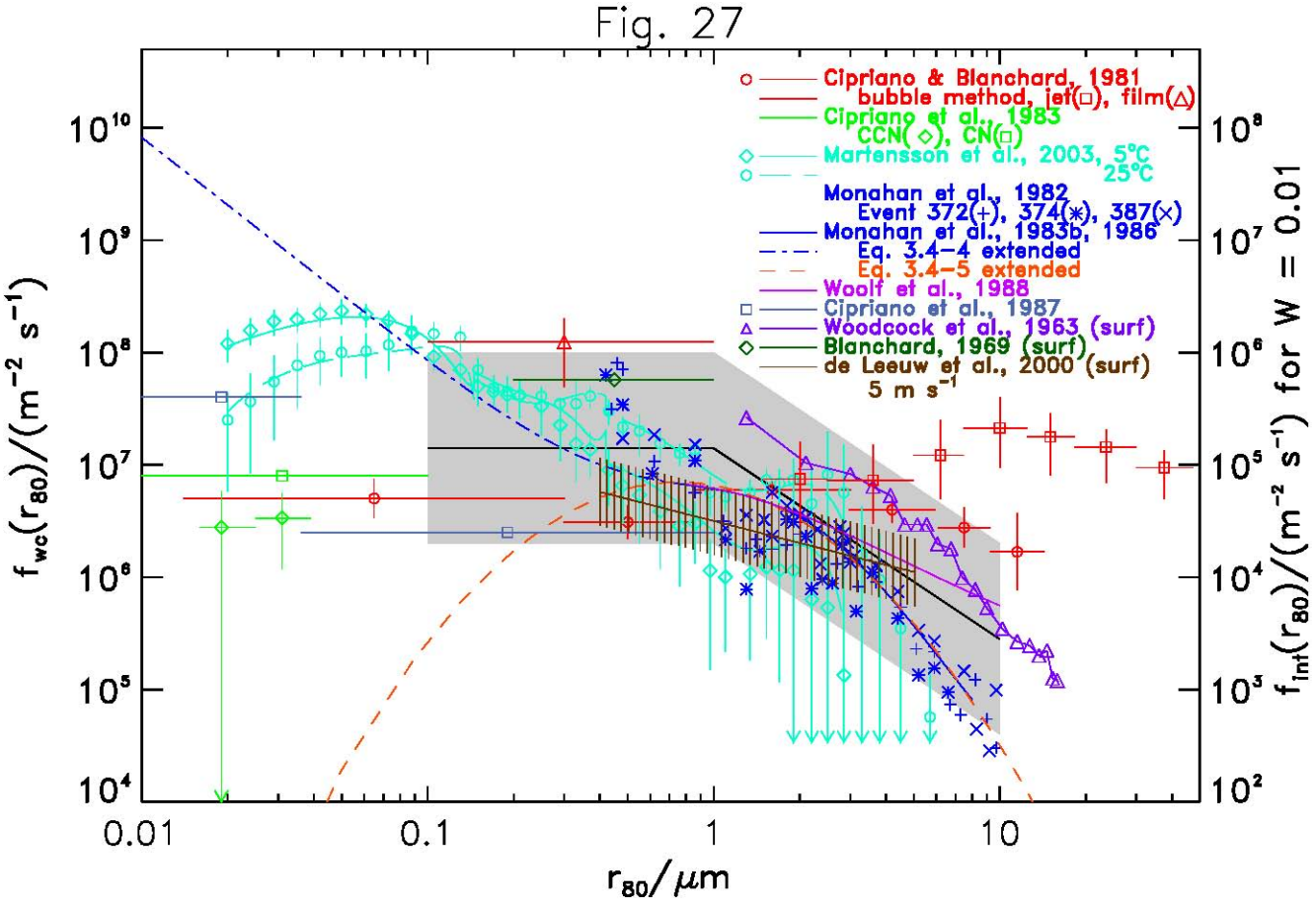
Estimates of primary marine aerosol production: small and medium particles, Lewis and Schwartz (2004)



Lewis and Schwartz, (2004):

Shaded area indicates uncertainty limits (factor 7)

Based on a very large number of published determinations!

The starting point for our review was Lewis and Schwartz (2004)

Methods

1. **Whitecap method**
   1. Determination of the Oceanic Whitecap Fraction
      1. In situ
      2. Satellites
   2. Determination of the SSA particle Flux per White Area
      1. Laboratory experiments
      2. Surf zone
   3. SSA production flux formulations
2. **Micrometeorological methods**
   1. SSA production flux formulations
   2. Gradient method
3. **Chemical Composition of Sea-Spray Aerosol**

Often the SF is written as a product of an amplitude function and a shape function:

$$\frac{dF(r_{80},a,b,..)}{d\log r_{80}} = f(a,b,..)\,g(r_{80})$$

$$\frac{dF_{M86}}{dr_{80}} = 1.373U_{10}^{3.41}\,r_{80}^{-3}\left(1+0.057r_{80}^{1.05}\right)\times 10^{1.19e^{-B^2}}$$

Monahan et al., 1986 (whitecap)

$$F_N = 10^{0.20\overline{U}_{10}-1.71}$$

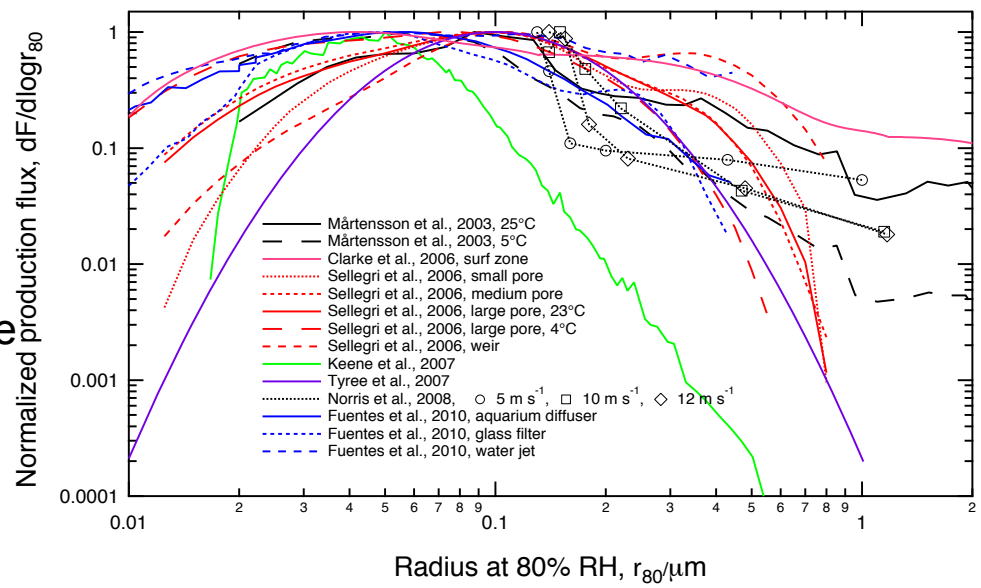
Nilsson et al., 2001 (first application of EC method over open ocean.)

The Whitecap method forms the basis for most of the parameterizations that currently are mostly used in global transport and global circulation models (GTM & GCM)

Whitecap Method

$$\frac{dF}{d\log r_{80}} = W \times \frac{dF_{\mathrm{wc}}}{d\log r_{80}}$$

- Ocean Flux = Whitecap fraction × Flux per white area
- Whitecap fraction determined by field observation: photography, satellite
- Flux per white area determined by lab experiment or field observation (surf zone)
- The whitecap method assumes that the flux per white area is constant, independent of conditions.
- There is little field or laboratory demonstration of this and much evidence against it.



Size distributions of SSA production flux normalized to maximum value in representation *dF*/*d*log*r*80 as a function of *r*80 from laboratory experiments

Note different conditions (production method, water temperature,wind speed)

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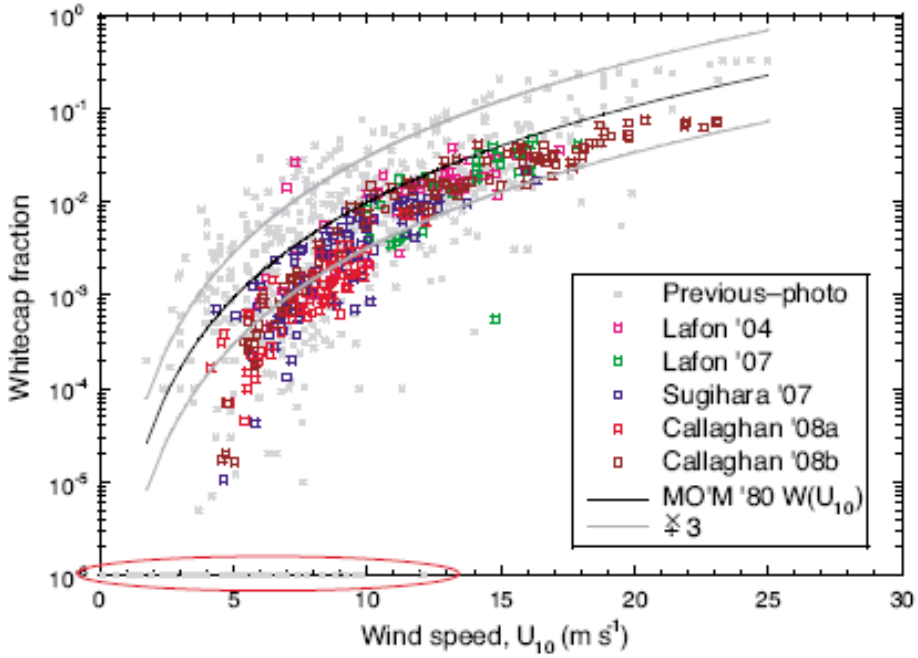
RECENT PHOTOGRAPHIC DETERMINATIONS OF WHITECAP FRACTION



•Spread in observations shows influence of factors other than wind speed.
•Note many zero's in prior data. New photographic observations tend lower; better statistics, no zero's.
•Monahan–O'Muircheartaigh fit based on prior data is widely used; gray lines are factor of 3 above/below to guide the eye.

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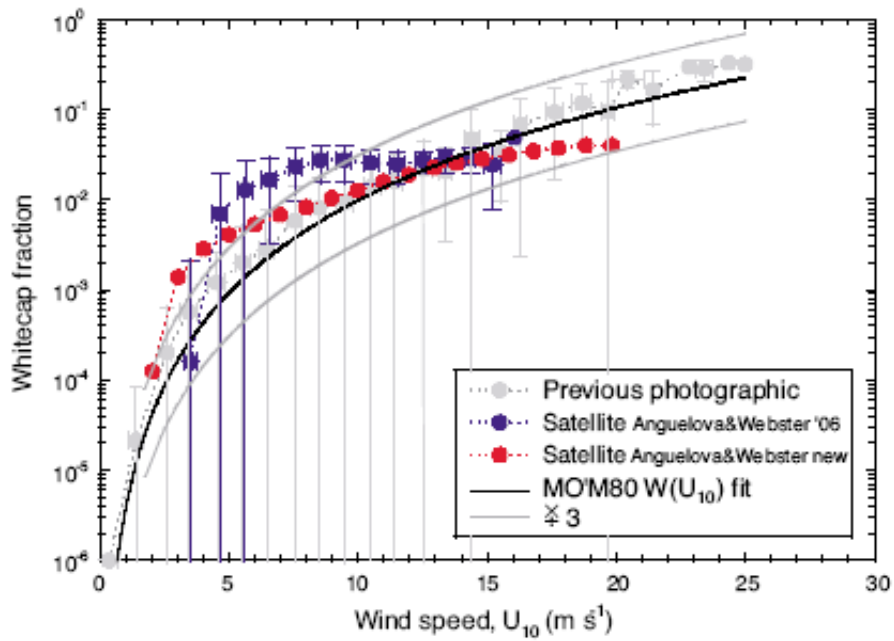
RECENT SATELLITE DETERMINATIONS OF WHITECAP FRACTION



Satellite observations give widespread coverage over large
Satellite observations tend ***higher***; better statistics, no zero's.

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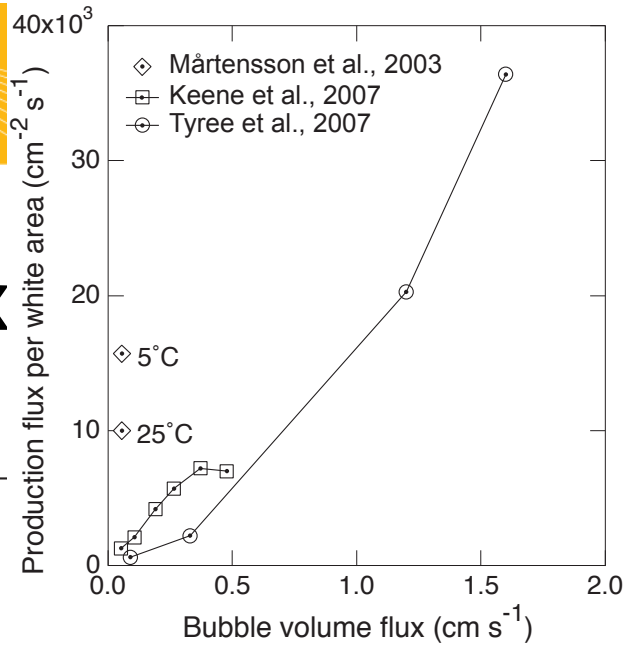
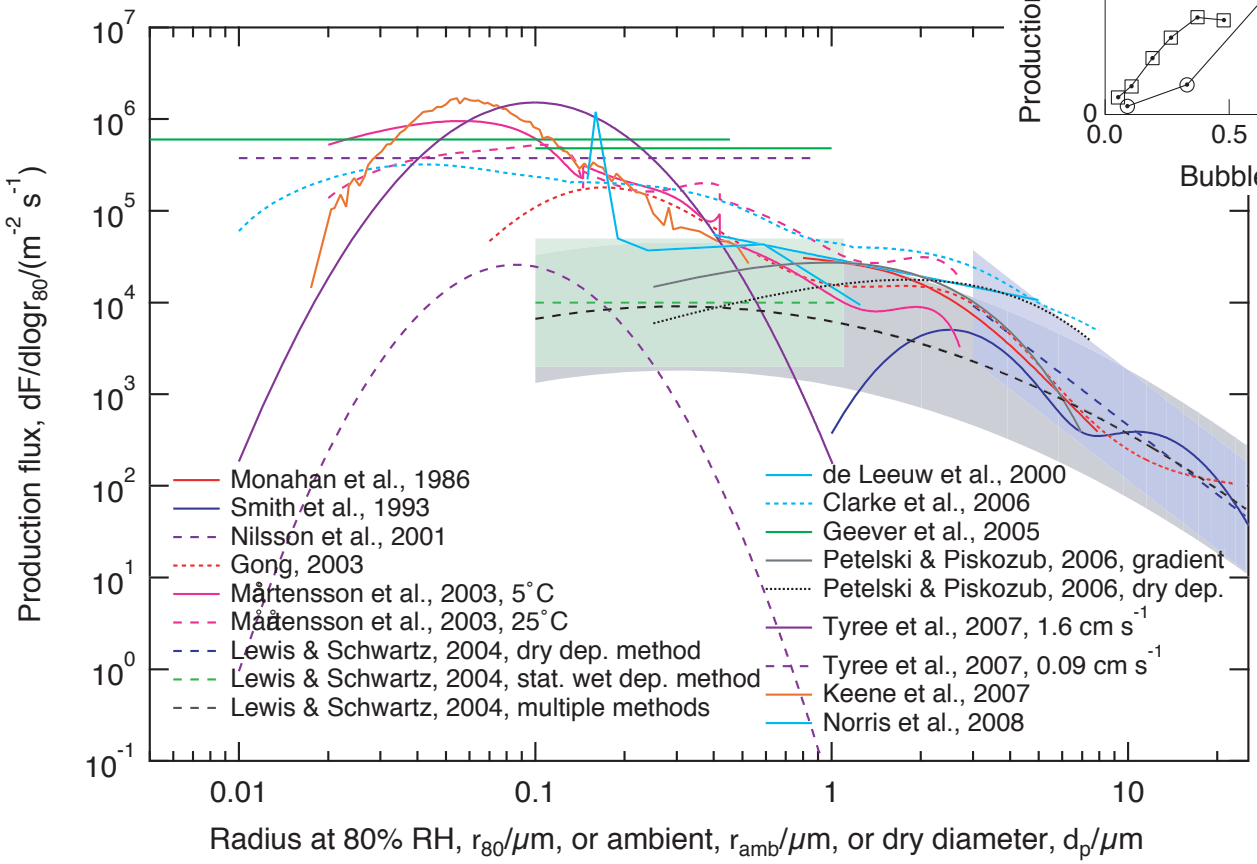
Prior and recent production flux





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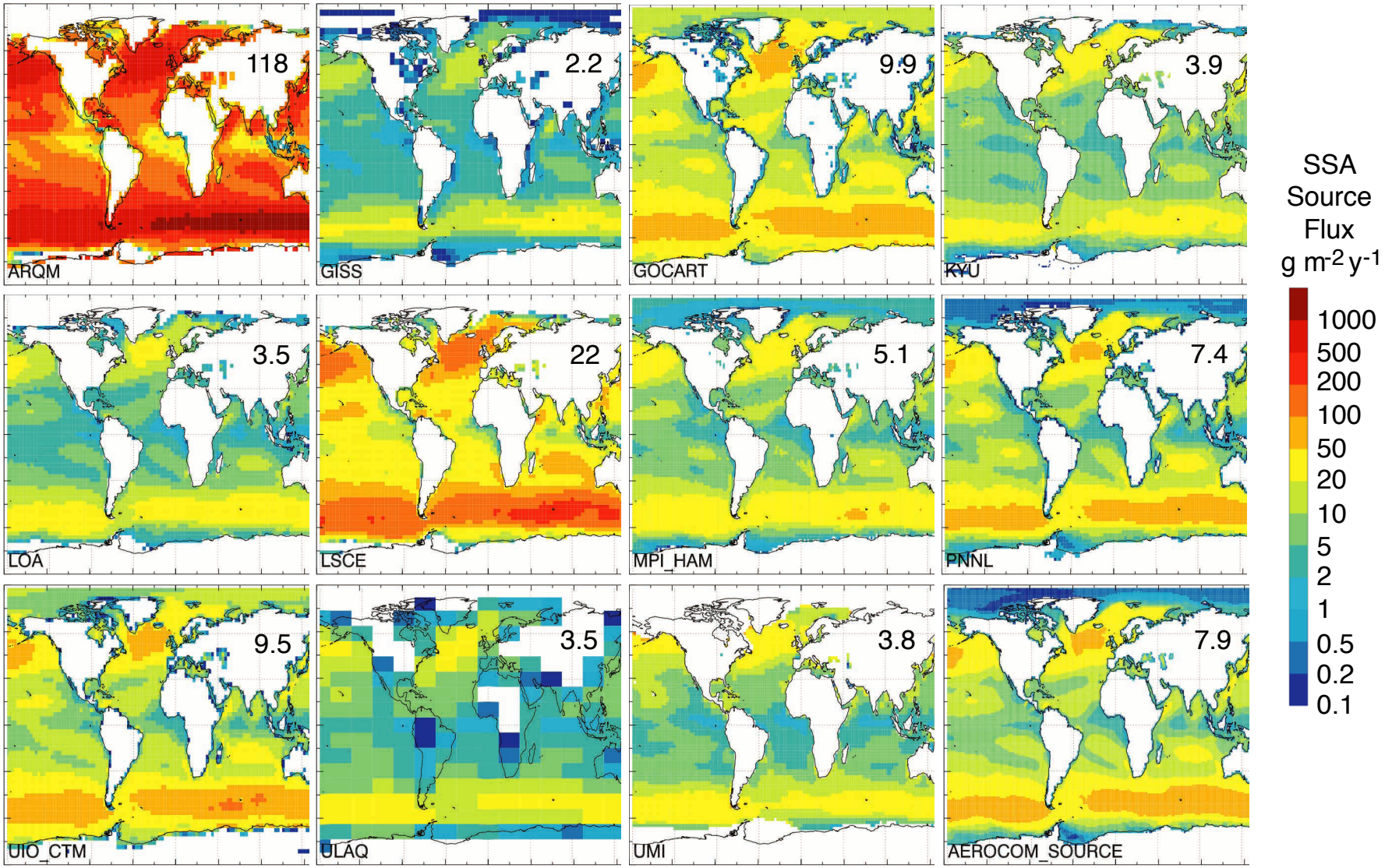
Conclusions (1)

- A major finding of recent work is the recognition of the large contribution of organic substances to SSA particles, especially in locations of high biological activity, which becomes increasingly important with decreasing particle size, and which may be dominant for $r_{80} < 0.25$ μm
- Recent flux determinations show higher production than in the best estimates based on older data (LS04), increasing with decreasing $r_{80} < 1$ μm;
- Determinations of the SSA production flux have been made at sizes smaller than those previously examined, with some formulations extending to particle size as low as $r_{80} = 0.01$ μm;
- The best estimate for the production flux of SSA particles with $r_{80} > 1$ μm remains as that given by *LS04* based on multiple methods, with uncertainty a multiplicative factor of 4 to 5

Conclusions (2)

- Recent advances in determination of the whitecap fraction *W*, also central to evaluation of the SSA production flux by the whitecap method, by both photographic methods and satellite retrievals may eliminate some of the subjectivity in measurement of this quantity, but direct relation to SSA production is lacking.
- Results from laboratory experiments depend on how the white area is produced as well as conditions:
  the basic assumption of the whitecap method is not valid;
- Despite the many gains in understanding in recent years, the uncertainty in the SSA production flux remains sufficiently great that present knowledge of this quantity cannot usefully constrain the representation of emissions of SSA in chemical transport models or climate models that include aerosols.


118
ARQM
2.2
GISS
9.9
GOCART
3.9
KYU
3.5
LOA
22
LSCE
5.1
MPI_HAM
7.4
PNNL
9.5
UIO_CTM
3.5
ULAQ
3.8
UMI
7.9
AEROCOM_SOURCE
SSA
Source
Flux
g m-2 y-1
1000
500
200
100
50
20
10
5
2
1
0.5
0.2
0.1

Thank you for your attention