ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUT

oceanflux sea-spray
support to science element

esa

Using satellite data to determine sea spray aerosol production (OSSA)

Gerrit de Leeuw[1,2,3], Hannele Korhonen[4], Jurgita Ovadnevaite[5], Astrid Manders-Groot[3], Larisa Sogacheva[1], Hanna Lappalainen[1,2], Martijn Schaap[3], Colin O'Dowd[5], Simon Pinnock[6]

Affiliations:
1. FMI, Helsinki
2. Dept Physics, Univ Helsinki
3. TNO, Utrecht
4. FMI, Kuopio
5. NUIG
6. ESA

NUI Galway
OÉ Gaillimh

ICAP, ESA-ESRIN, Frascati, 17 May 2012

TNO

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

oceanflux sea-spray
support to science element

esa

The Oceanflux Sea Spray Aerosol (OSSA) project

The aim of OSSA is:

1.To exploit the use of (European) satellites to improve the parameterization of sea spray source function

2.To use this source function in a global model to determine direct and indirect effects of sea spray aerosol

Duration:	24 months
Start:	1 November 2011
End:	31 October 2013
Partners:	FMI, NUIG, TNO
Sponsor:	European Space Agency ESA

OSSA website:

http://oceanflux.fmi.fi/

NUI Galway
OÉ Gaillimh

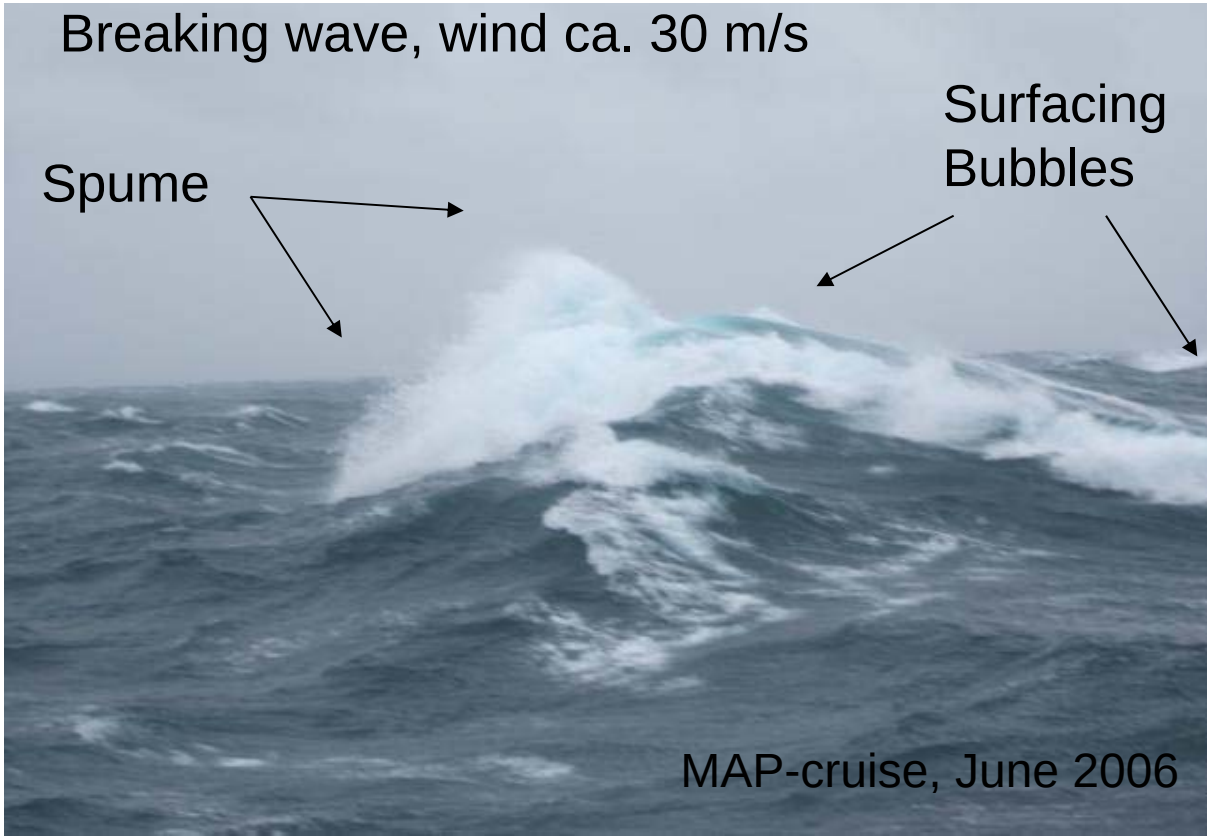
TNO

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

oceanflux sea-spray
support to science element

esa

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



NUI Galway
OÉ Gaillimh

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

TNO

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

oceanflux sea-spray
support to science element

esa

A brief review of current knowledge on the production of sea spray aerosol

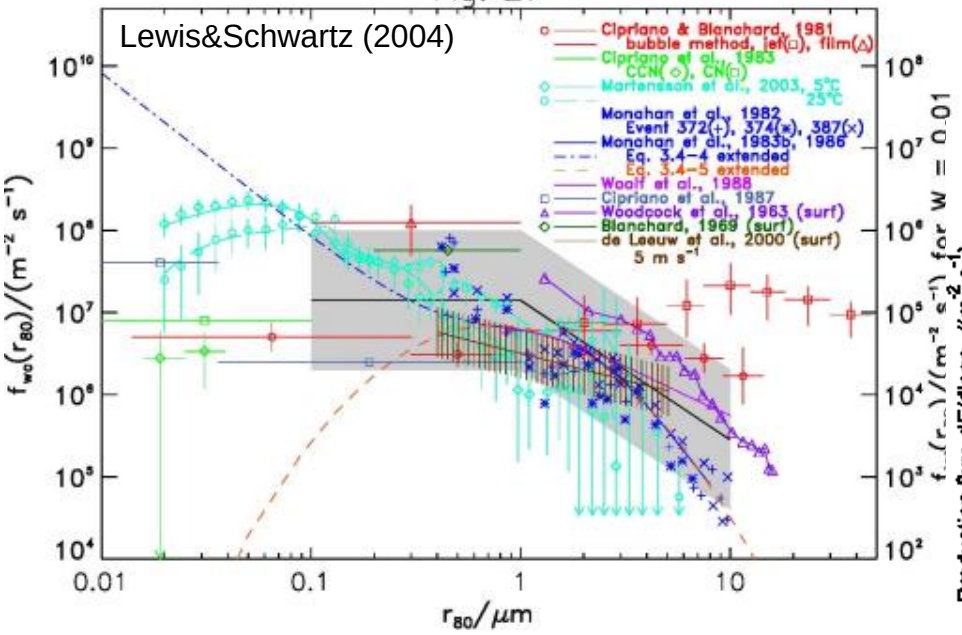
Issues

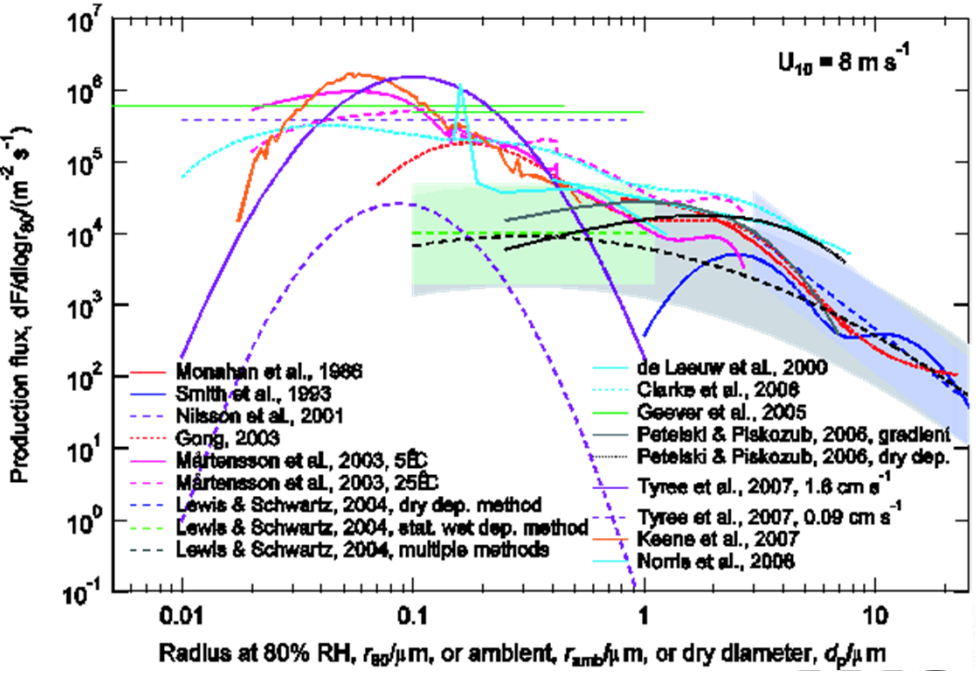
- **Source strenght**
  - How many particles are produced as function of particle radius
  - Effect of environmental parameters
    - Wind speed or whitecap fraction or wave parameters (which?) or …
    - Sea surface temperature (or bulk?)
    - Salinity
- **Composition**
  - Effect on source strength
  - Fraction of organic matter, as function of environmental paramters
  - Effect on physical properties (size distribution, CCN, optical)
- **Effects on climate**
  - DARF
  - Cloud properties

Background

Sea Spray *Production* was reviewed by de Leeuw et al. (2011), taking the comprehensive review by Lewis and Schwartz (2004) as starting point:

Fig. 27
Lewis&Schwartz (2004)





Conclusions of de Leeuw et al., (2011) and their relevance for OSSA:

- Large contribution of organic substances to sub-micron SSA particles;
- Higher production fluxes of sub-micron particles than in the best estimates based on older data (LS04);
- Recent advances in determination of the whitecap fraction *W* 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;
- 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.

de Leeuw, G., E.L. Andreas, M.D. Anguelova, C.W. Fairall, E.R. Lewis, C. O'Dowd, M. Schulz, S.E. Schwartz. *Rev. Geophys.*, *2011*

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)

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

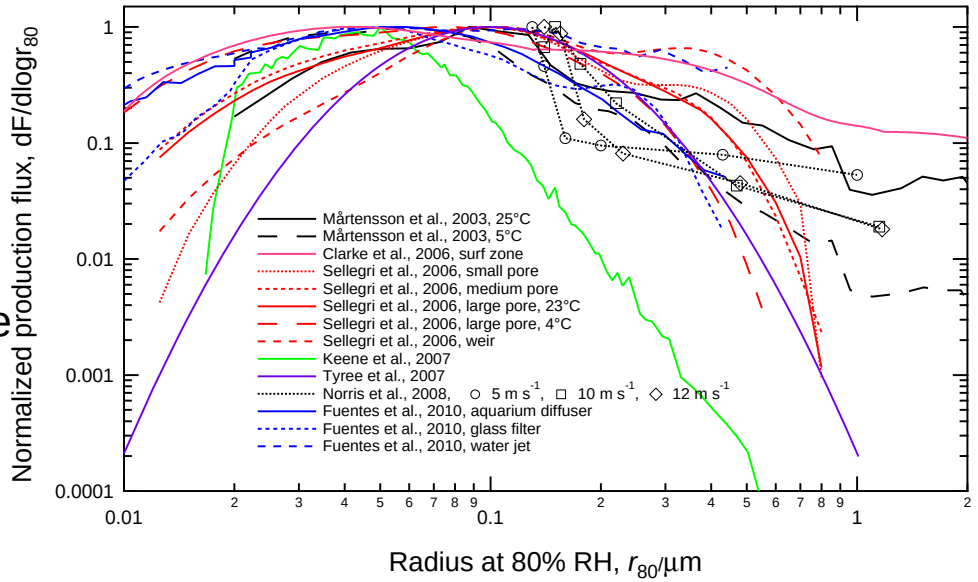
Nilsson et al., 2001 (first application of EC method over open ocean.)

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.



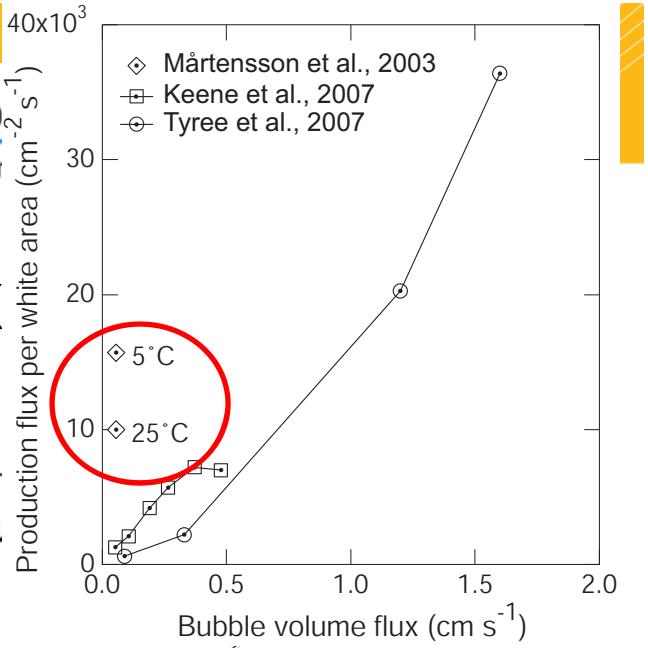
Size distributions of SSA production flux normalized to maximum value in representation *dF*/*d*log*r*80 as a function of *r*80 from laboratory experiments

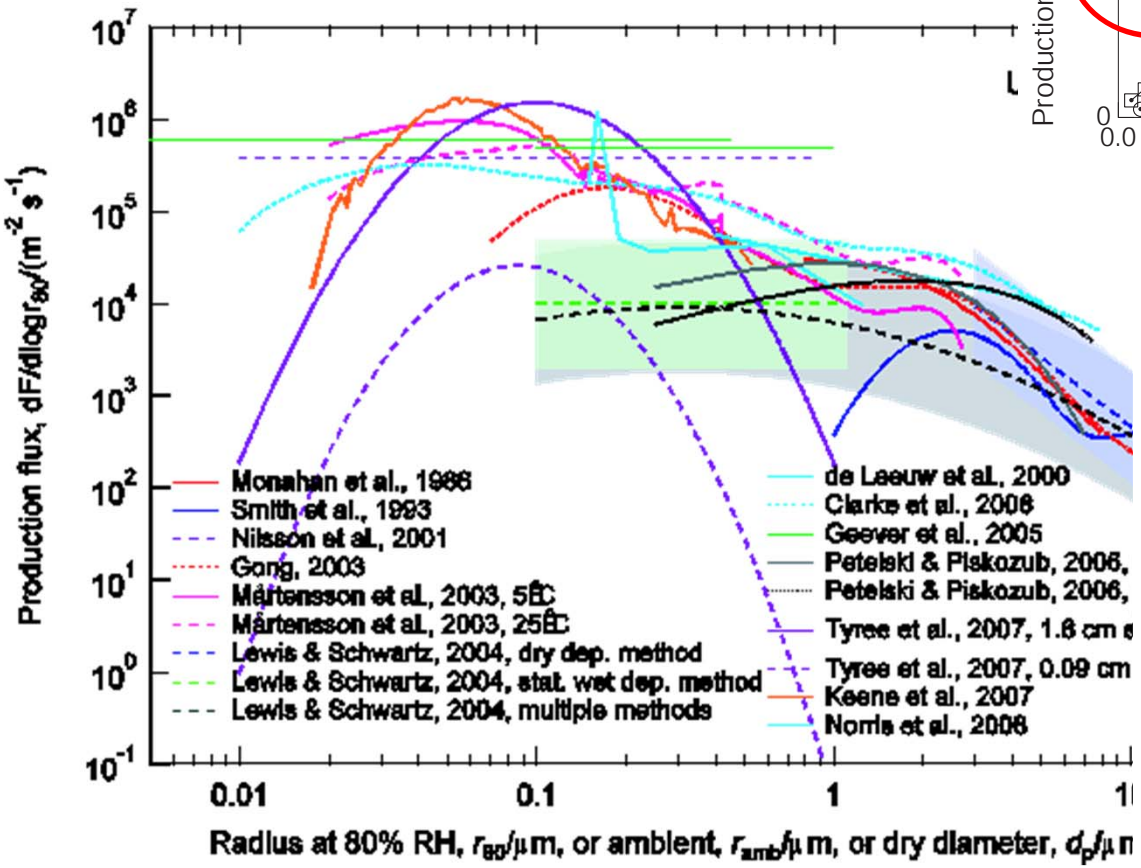
Note different conditions (production method, water temperature,wind speed)

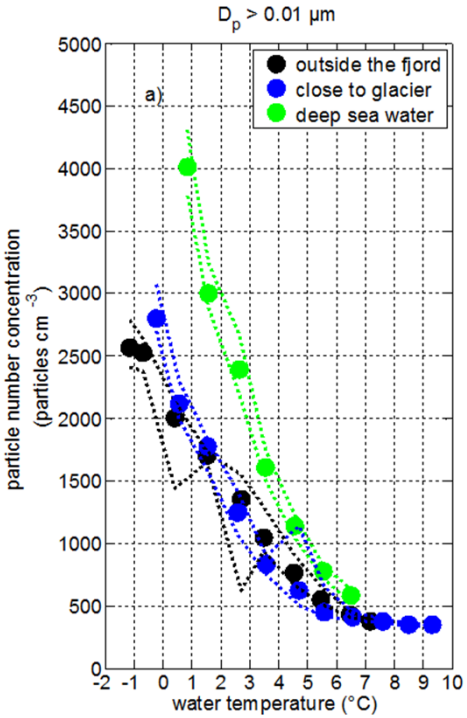
ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

oceanflux sea-sp
support to science eler

Prior and recent production flux







NUI Galway
OÉ Gaillimh

de Leeuw, G., E.L. Andreas, M.D. Anguelova, C.W. Fairall, E.R. Lewis, C. O'Dowd, M. Schulz, S.E. Schwartz. *Rev. Geophys.*, *2011*

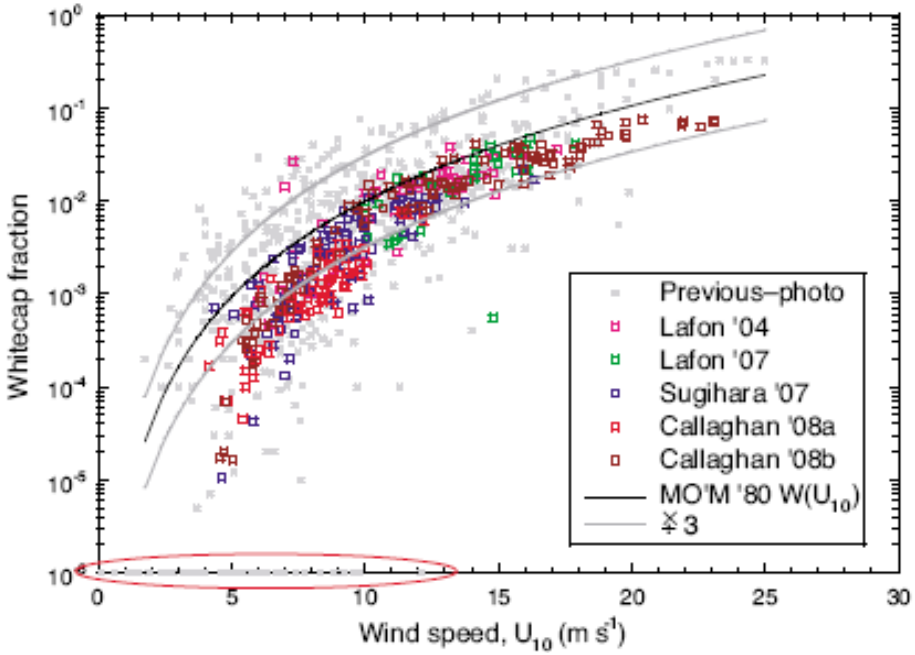
Zabori et al., ACPD

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

oceanflux sea-spray
support to science element

esa

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.

NUI Galway
OÉ Gaillimh

de Leeuw, G., E.L. Andreas, M.D. Anguelova, C.W. Fairall, E.R. Lewis, C. O'Dowd, M. Schulz, S.E. Schwartz. *Rev. Geophys.*, *2011*

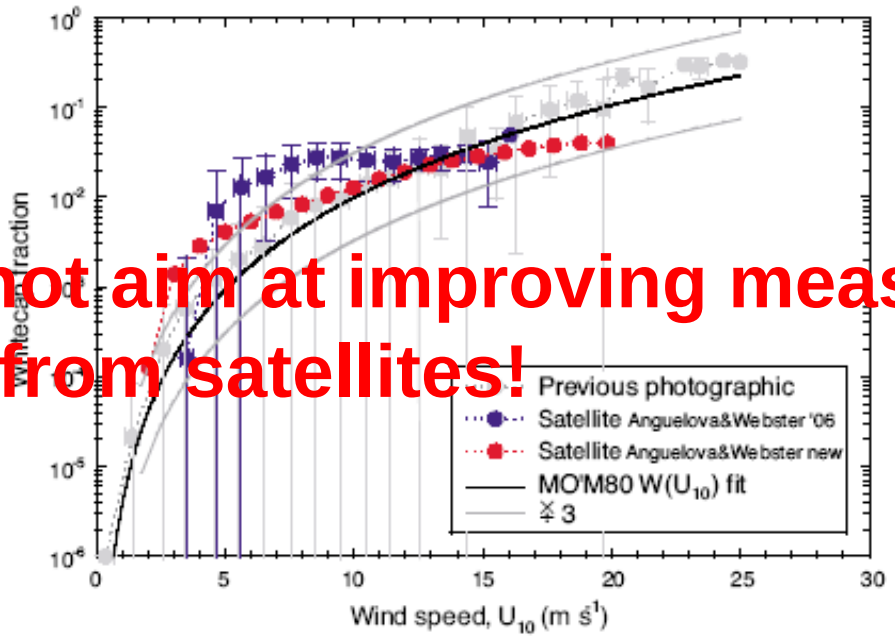
TNO

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

oceanflux sea-spray
support to science element

esa

RECENT SATELLITE DETERMINATIONS OF WHITECAP FRACTION



OSSA will not aim at improving measurements of Whitecaps from satellites!

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

NUI Galway
OÉ Gaillimh

de Leeuw, G., E.L. Andreas, M.D. Anguelova, C.W. Fairall, E.R. Lewis, C. O'Dowd, M. Schulz, S.E. Schwartz. *Rev. Geophys.*, *2011*

TNO

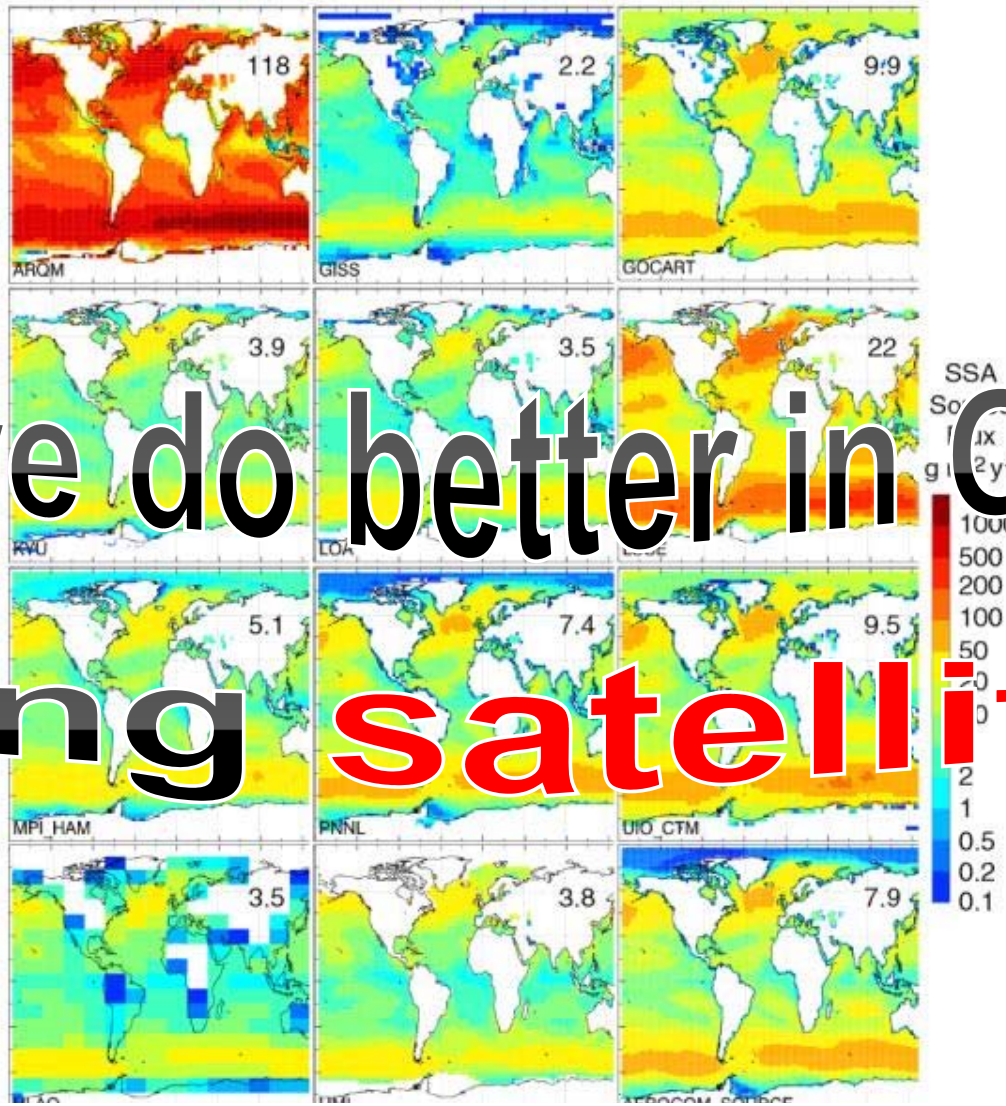
ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

oceanflux sea-spray
support to science element

esa

Can we do better in OSSA?

Using satellites?



de Leeuw, G., E.L. Andreas, M.D. Anguelova, C.W. Fairall, E.R. Lewis, C. O'Dowd, M. Schulz, S.E. Schwartz. *Rev. Geophys.*, *2011*

NUI Galway
OL Gaillimh

ICAP, ESA-ESRIN, Fra

TNO

OSSA objective

- The objective of the *OceanFlux*/Sea-Spray Aerosol project is to exploit (European) multi-mission satellite data to improve the characterization of the SSSF for the purpose of reducing uncertainty in SSA emissions, SSA atmospheric burden and the resulting climatically important direct and indirect radiative effects.

- An important issue in OSSA is the interaction with (potential) users, e.g., climate modelers, who are invited to attend workshops and provide feedback through questionnaires.

Tasks (1)

- Assess the utility of the available sources of (European) (and other) satellite and GCM information on the biogeophysical parameters controlling SSA emission for characterization of the size- and composition-dependent SSSF (3000).
- Investigate the relationship of these parameters to *in-situ* SSA measurements via SSSF parameterization and CTM modeling (5100).
- Develop an improved parameterization of the SSSF making best use of all available European satellite information, supplemented with physical atmospheric or ocean model data where necessary (5200).

Tasks (2)

- Integrate the new SSSF in the aerosol microphysics of a GCM to predict the global and seasonal distribution of SSA (6100).
- Validate the global SSA distribution against ground based sun photometer and satellite aerosol optical depth measurements (6100).
- Calculate, through further global GCM modelling, the direct (solar light scattering) and indirect (cloud albedo and cloud lifetime) radiative effects of SSA (6200, 6300).

Uncertainties in the SSSF, global SSA distribution and direct and indirect radiative effects will be fully characterized.

Satellites for sea spray production

What kind of data can we use?

- Wind speed
- Oceancolour for organic matter
- Sea surface temperature
- Wave information
- Salinity?

What data sets are suitable?

- In situ
- Ground-based remote sensing
- Satellite

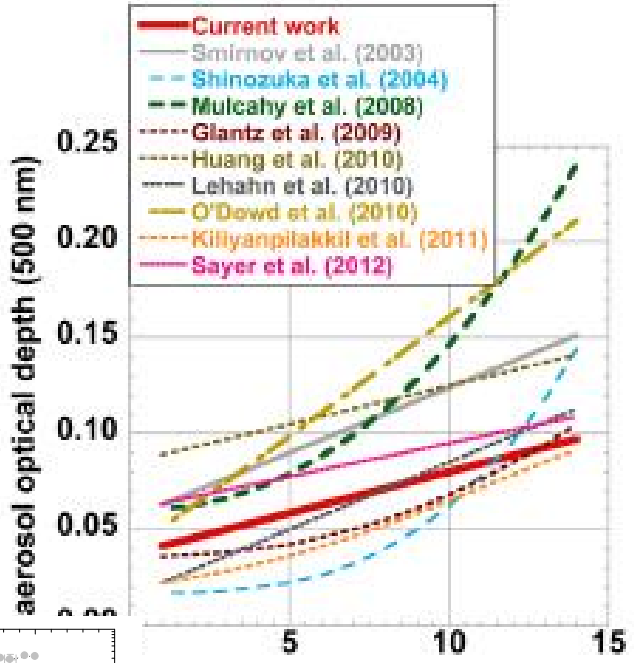
ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

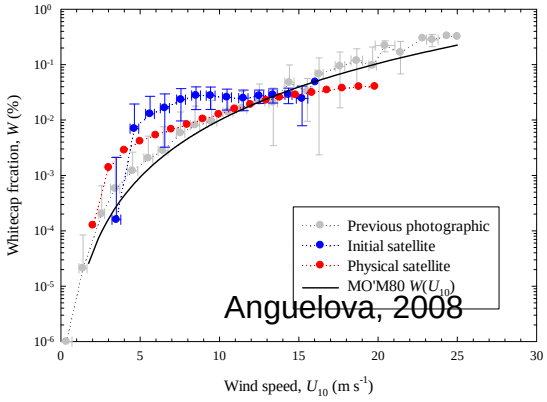
oceanflux sea-spray
support to science element

esa

Use of EO data in SSA production studies

- Correlate AOD with wind speed
- Model evaluation
- Combine EO, model & in situ data to improve parameterizations
- Direct measurements of whitecap fraction – global





Anguelova, 2008

Direct measurements of whitecap fraction not used in OSSA: uncertainties large and not understood; work in progress at NRL and at TNO

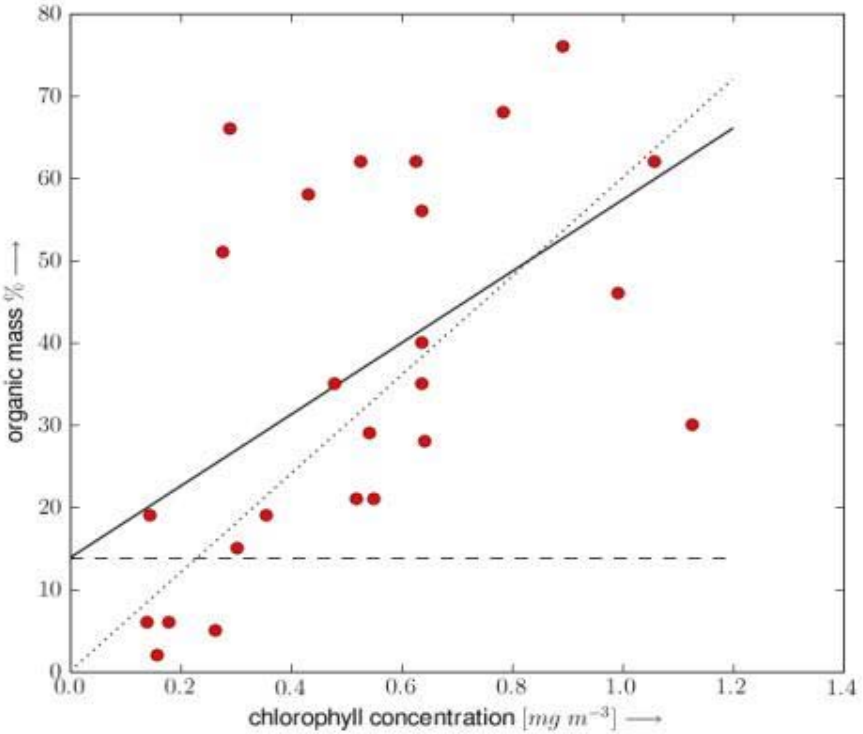
ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

oceanflux sea-spray
support to science element

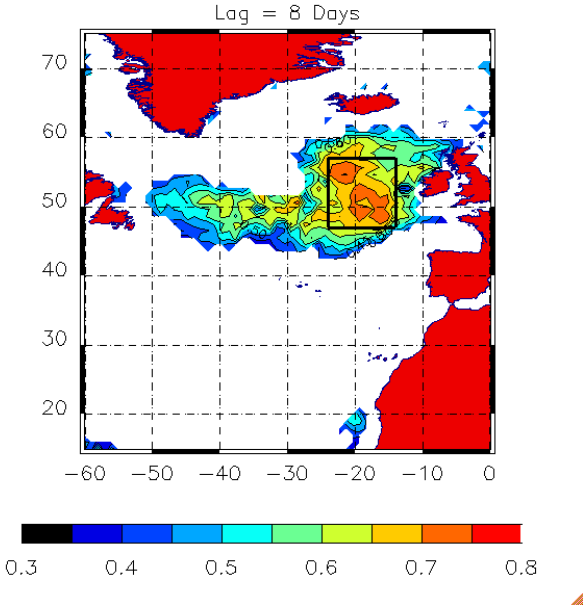
esa

Parameterization of OM fraction

Based on O'Dowd et al. (2004)



~2/3 of global emission of OM due to bias
(Albert et al. Atm Env 2012)



OM bio proxy correlation analysis reveals effects of algae blooms on OM at Mace head
(Rinaldi et al, in preparation)

NUI Galway
OL Gaillimh

TNO

Meskhidze et al.

Parameterization OM fraction in SSA as function of U10, Chl-a

$$\mathrm{OM_{SSA}}(\text{chl-}a, U_{10}, D_p) = \frac{1}{1+\exp(-2.63[\text{chl-}a]+0.18U_{10})} \Big/ \left(1+0.03\exp(6.81D_p)\right) + \frac{0.03}{1+\exp(-2.63[\text{chl-}a]+0.18U_{10})} \qquad (1)$$

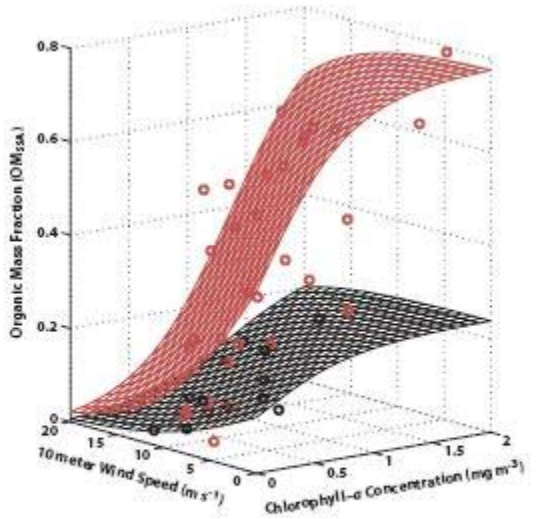
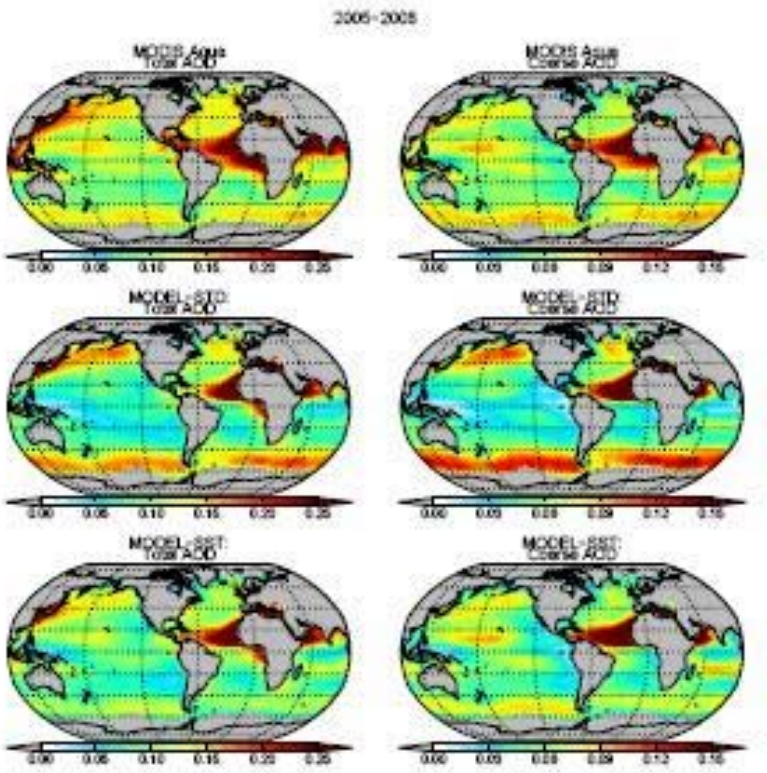


Fig. 3. Organic mass fraction of sea spray aerosol as a function of both 10 m wind speed and [Chl-*a*] for (a) Mace Head (red) and Point Reyes (black) with the surface regression based on Eq. (1) in the same color scheme for each site.

Based on Gantt et al. (2011) & Facchini et al., (2008)

Water temperature (Jaeglé et al., 2010)



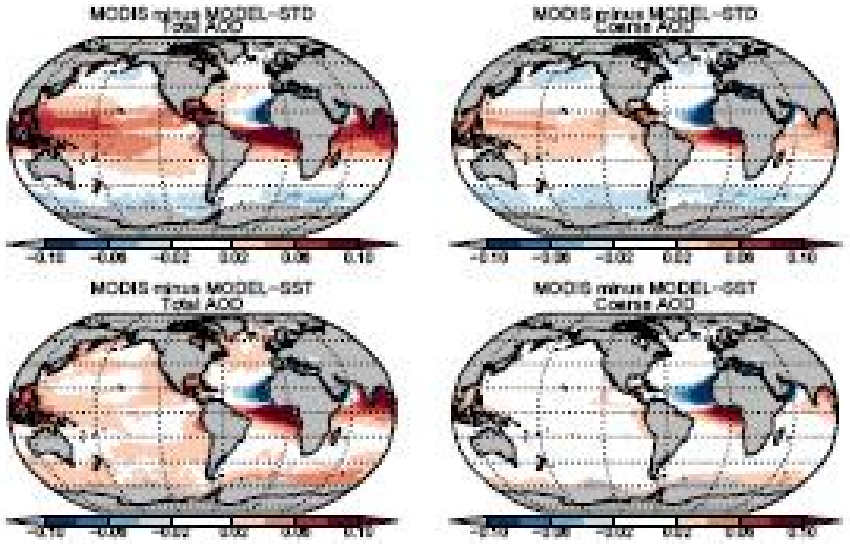


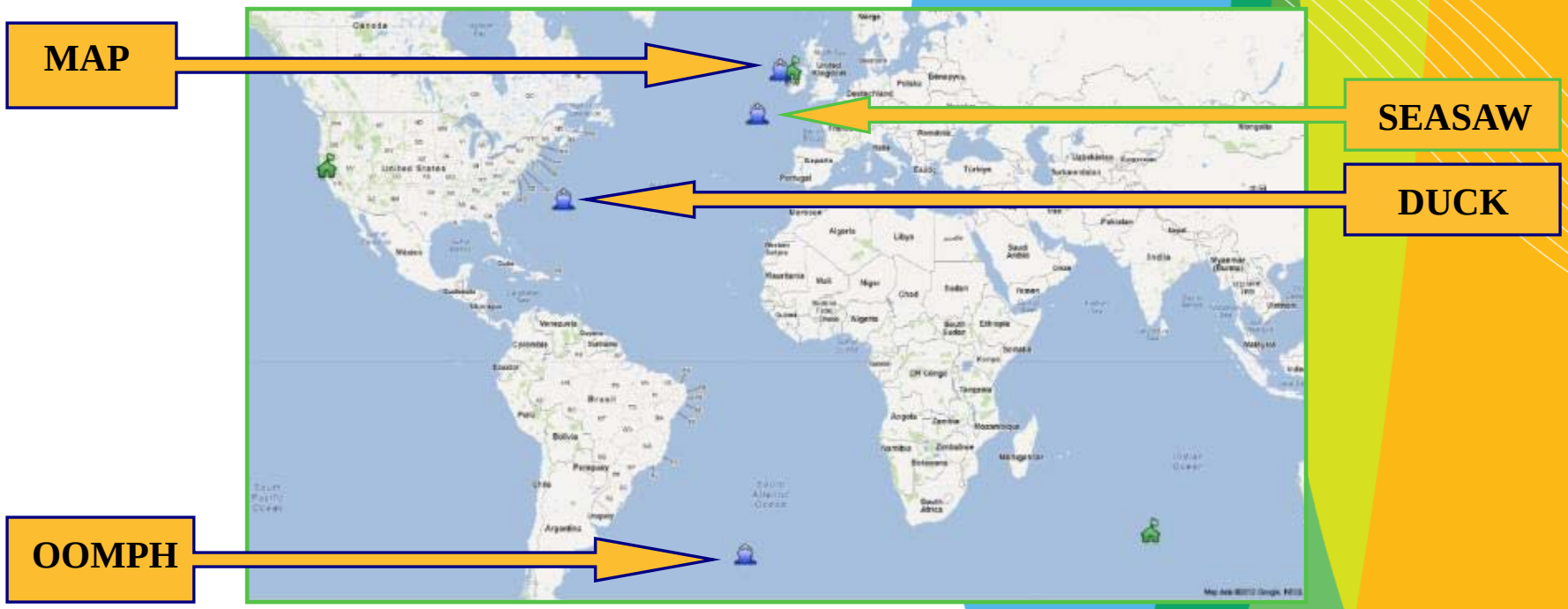
Fig. 9. Difference between annual mean MODIS Aqua and GEOS-Chem total AOD (left column) and coarse mode AOD (right column) for 2005–2008. Top panels: MODIS minus MODEL-STD. Bottom panels: MODIS minus MODEL-SST.

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUT

oceanflux sea-spray
support to science element

esa

SSSF development



MAP: white cap parameterization based on wind speed and wave history along with EO data
OOMPH: Aerosol chemistry data for the validation and evaluation of the SSSF
DUCK: SSSF improvement by Micrometeorological Method
SEASAW: SSSF improvement by Micrometeorological Method

NUI Galway
OÉ Gaillimh

TNO

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

oceanflux sea-spray
support to science element

esa

SSSF validation and evaluation

- **Point Reyes**

Mace Head

Amsterdam Island

Point Reyes: Evaluation and validation of the SSSF
Amsterdam Island: Evaluation and validation of the SSSF, evaluation of the SSSF seasonality
Mace Head: Evaluation and validation of the SSSF, evaluation of the SSSF seasonality, ***HR-ToF-AMS*** (parameterization of the SSSF dependence on the wind speed and wave history, parameterization of the primary organic enrichment in the SSSF), ***Hygroscopicity*** data (water uptake capabilities of the spray aerosol as a function of OM enrichment), ***CCN*** properties of sea-spray aerosol

OE Gaillimh

TNO

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

oceanflux sea-spray
support to science element

esa

SSSF validation and evaluation

- **Point Reyes**

Mace Head

Amsterdam Island

Point Reyes: Evaluation and validation of the SSSF
Amsterdam Island: Evaluation and validation of the SSSF, evaluation of the SSSF seasonality
Mace Head: Evaluation and validation of the SSSF, evaluation of the SSSF seasonality, ***HR-ToF-AMS*** (parameterization of the SSSF dependence on the wind speed and wave history, parameterization of the primary organic enrichment in the SSSF), ***Hygroscopicity*** data (water uptake capabilities of the spray aerosol as a function of OM enrichment), ***CCN*** properties of sea-spray aerosol

OE Gaillimh

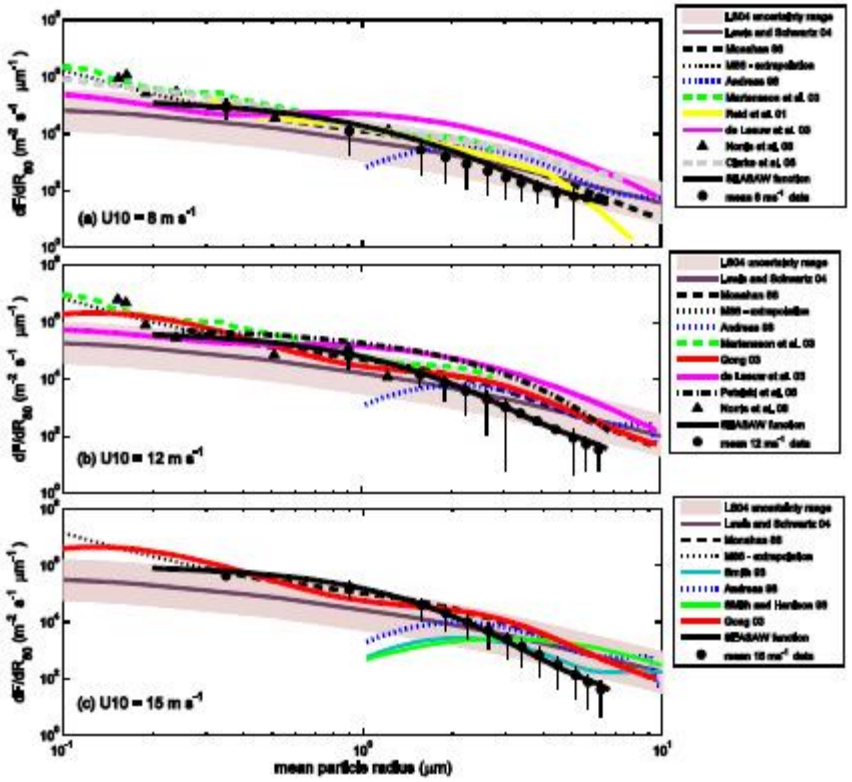
TNO

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

oceanflux sea-spray
support to science element

esa

Micrometeorological flux, open ocean



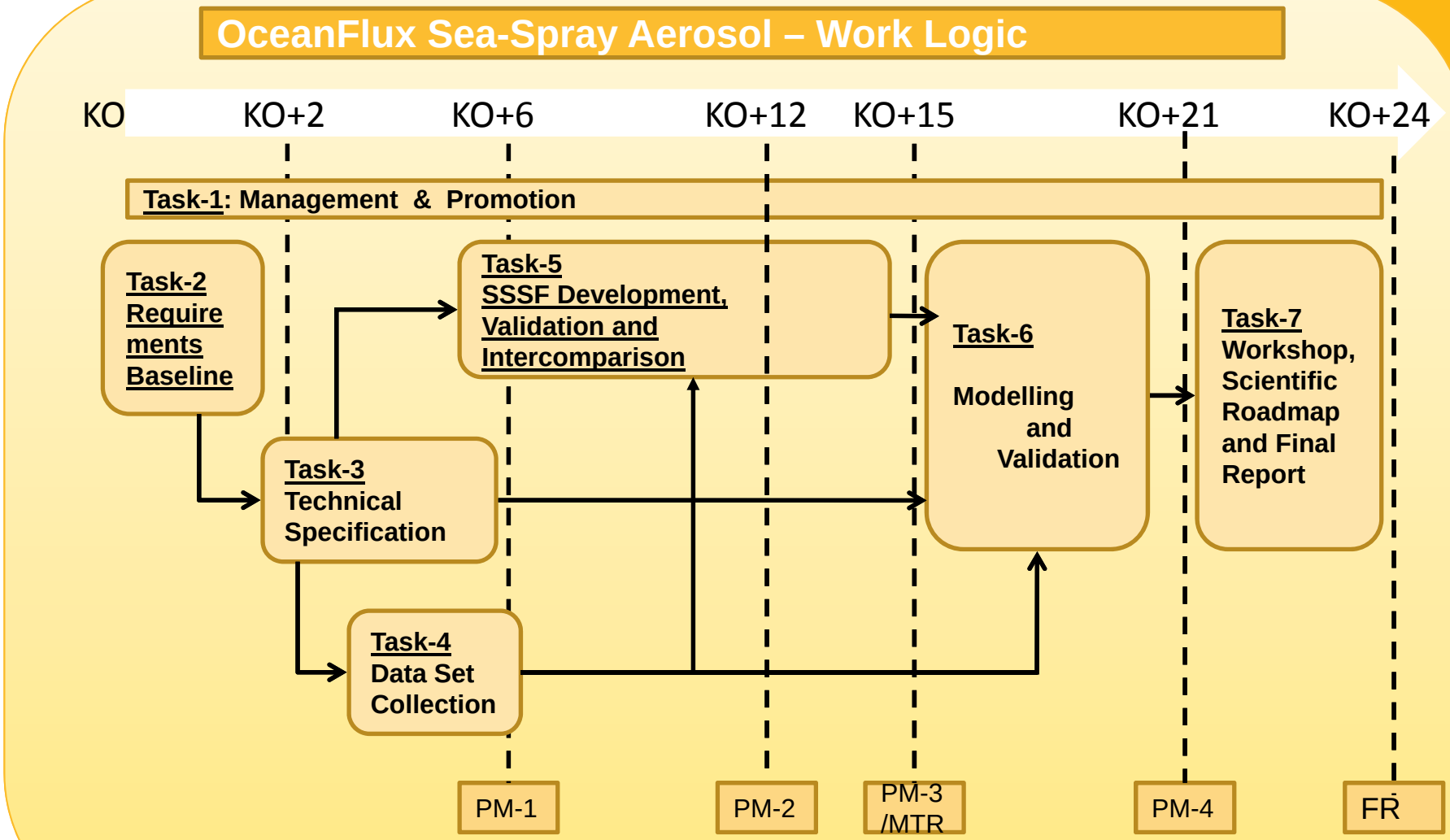
Norris et al., JGR 2012:

Black line and data points (filled circles)

But there are problems with the ec method:

- Intermittent
- Wave induced flow
- RH correction
- Ship motion
- etc

The OSSA project



ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

oceanflux sea-spray
support to science element

esa

Thank you for your attention

To follow the project, see
OSSA website:

http://oceanflux.fmi.fi/

Brochure

Acknowledgements: OSSA is supported by the European Space Agency ESA as part of the Support to Science Element progam Oceanflux

NUI Galway
OÉ Gaillimh

TNO