OceanFlux Sea Spray Aerosol (OSSA): a new formulation for production fluxes and implications for climate studies

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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

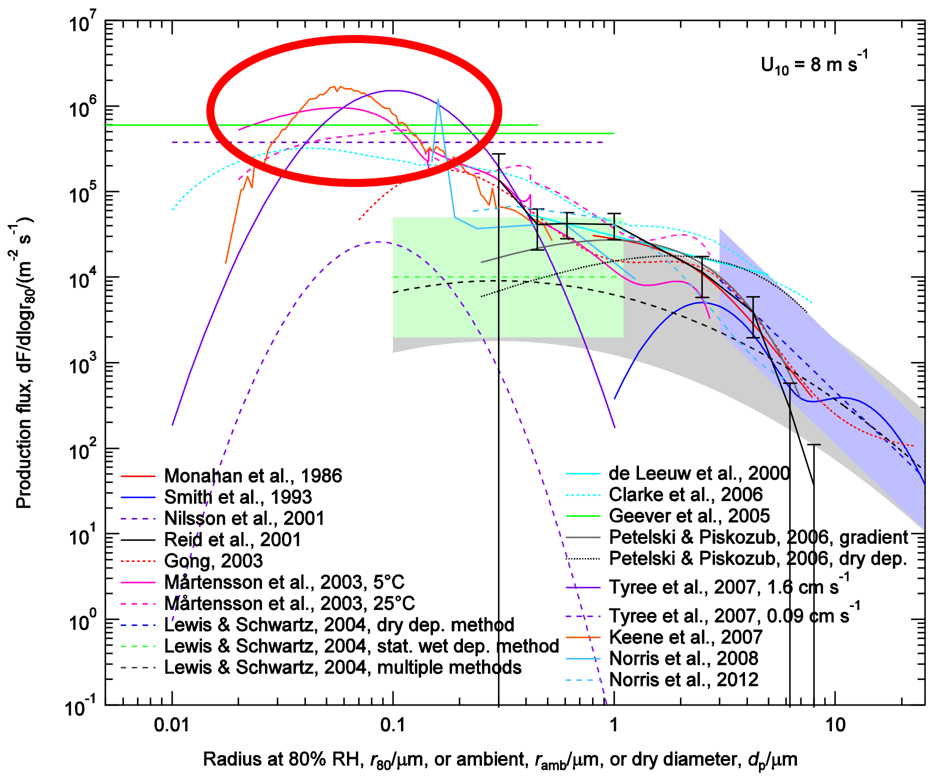
Duration:	24 (+2) months
Start:	1 November 2011
End:	31 December 2013
Partners:	FMI, NUIG, TNO
Sponsor:	European Space Agency ESA

OSSA website:

http://oceanflux.fmi.fi/

Production flux: the number of sea spray aerosol (SSA) particles produced at the sea surface, per m^2 and per second. Current parameterizations vary by an order of magnitude!

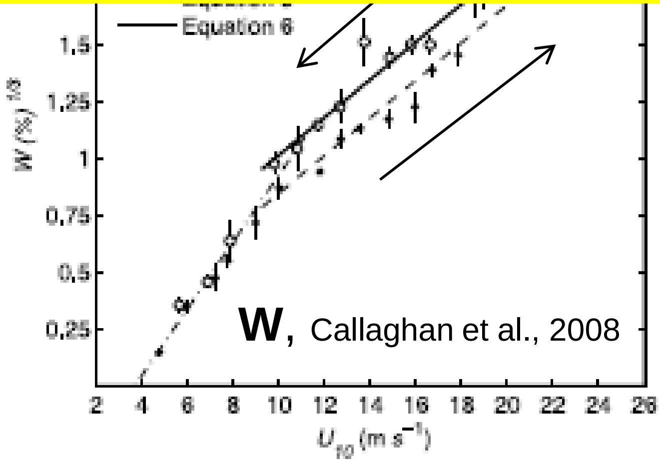
Current parameterizations use wind speed, friction velocity whitecap fraction, SST, ..

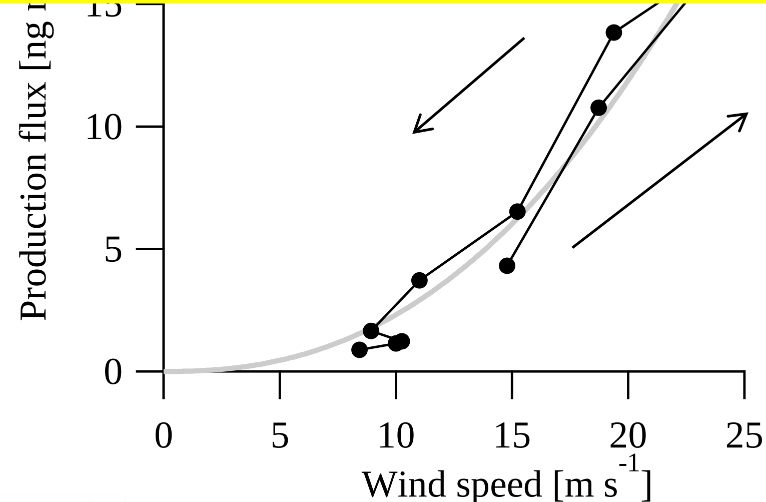


(de Leeuw et al, 2011)

Effects of rising and waning wind

Inclusion of wave state (through Reynolds number) removes these effects



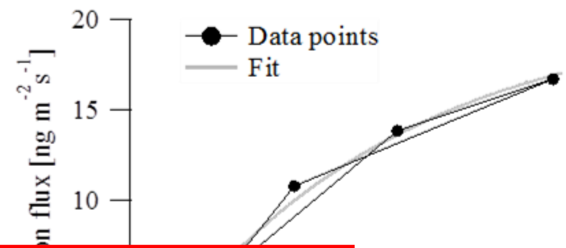


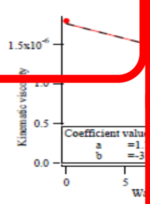
Reynolds number:

$Re_{Hw} = u_* H_s / v_w$

$= C_D^{1/2} U_{10} H_s / v_w$

Includes: wind, wave, SST, salinity





All available from satellite observatons

SSA flux vs. Re_{Hw},

Ovadnevaite et al., ACPD, 2013; & refs cited

Howeve, because our experimental data set is very sparse, we also use model data constrained by satellite observatons

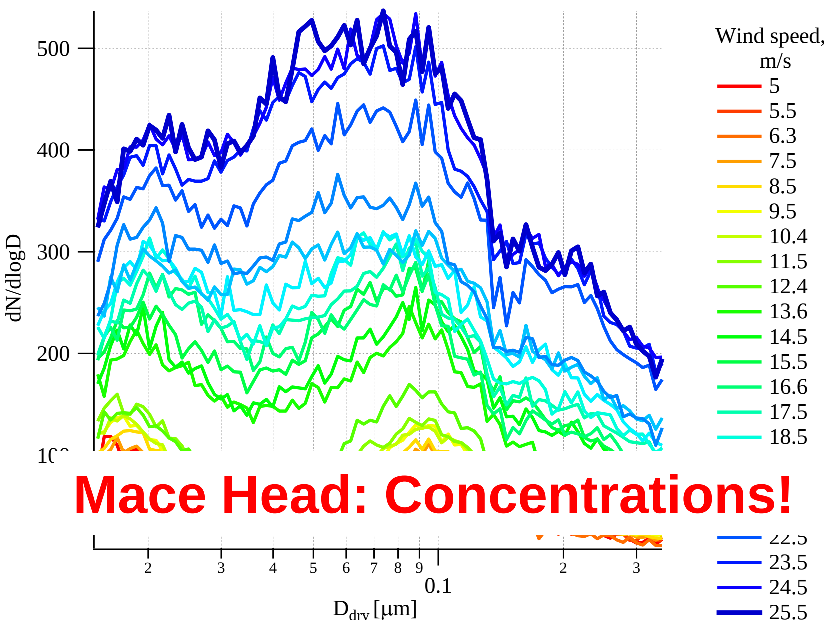
OSSA data sets: aerosols

Mace Head size distributions

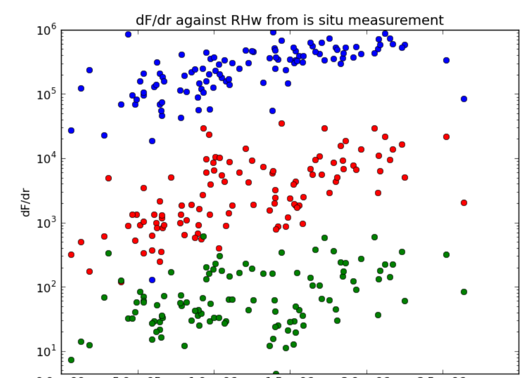
- Ovadnevaite et al., 2012; 2013
- Coastal
- SMPS: Size distributions 3-350 nm dry (RH<20%)
- HR-ToF-AMS: composition
- Wind speed 3-26 m/s

SEASAW fluxes

- Norris et al., 2012; 2013
- SOLAS cruise N. Atlantic
- Eddy covariance measurements
- Radius range 0.17-9.5 µm (RH 80%)
- Wind speed 3-18 m/s



Mace Head: Concentrations!



r_{80}=0.35 µm

r_{80}=2.2 µm

r_{80}=5.1 µm

SEASAW: fluxes!

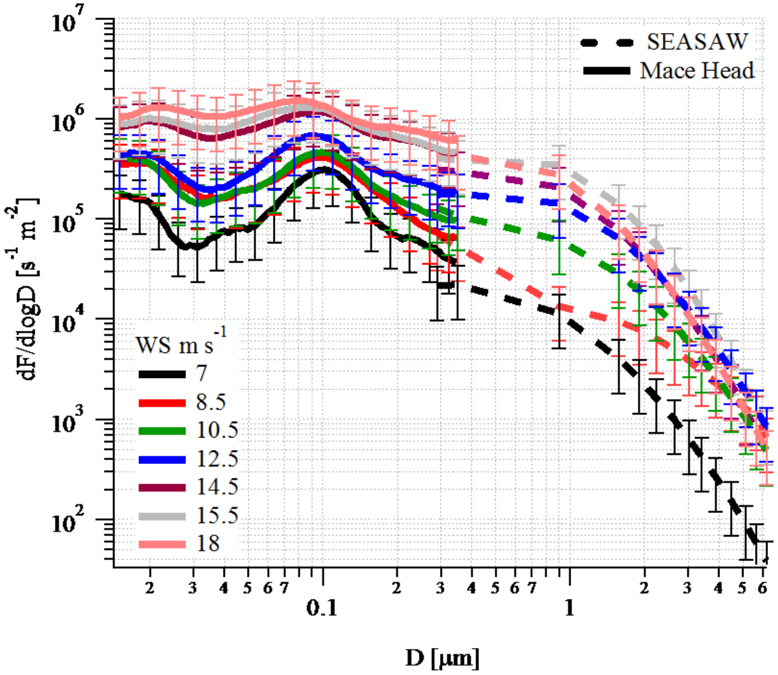
Combining the data sets:

Convert Mace Head concentrations to fluxes:

$$F_{eff}(D) = \frac{N(D) \times H_{MBL}}{\tau}$$

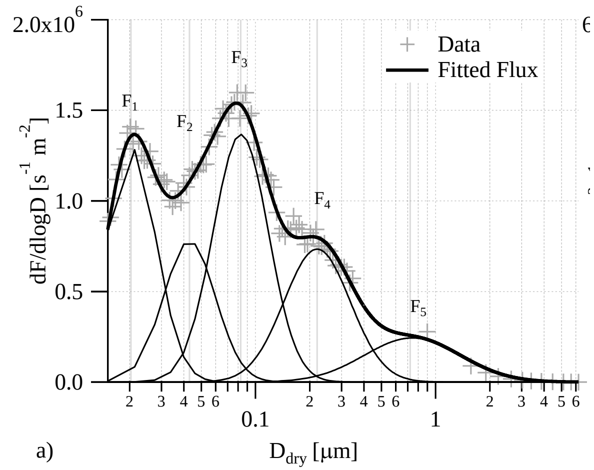
In view of the good fit of both data sets, they were used to fit them together in terms of a sum of lognormal size distributions:

$$\frac{dF}{dlogD} = \sum_{i=1}^{5} \frac{F_i(R_{Hw})}{\sqrt{2\pi} D ln\sigma_i} \exp\left(-\frac{1}{2}\left(\frac{\ln\left(\frac{D}{CMD_i}\right)}{ln\sigma_i}\right)^2\right)$$



Flux parameterization: the OSSA source function

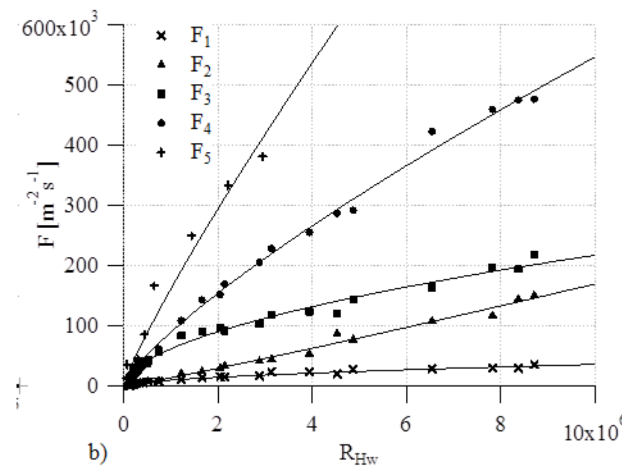
i	σ_i	CMD_i	$F_i(R_{Hw})$
1	1.37	0.02	$4.58*(R_{Hw}-1e^5)^{0.556}$
2	1.5	0.048	$0.0045*(R_{Hw}-1e^5)^{1.08}$
3	1.42	0.102	$33.05*(R_{Hw}-1e^5)^{0.545}$
4	1.53	0.279	$1.3*(R_{Hw}-1e^5)^{0.79}$
5	1.85	1.035	$1.02*(R_{Hw}-2e^5)^{0.87}$



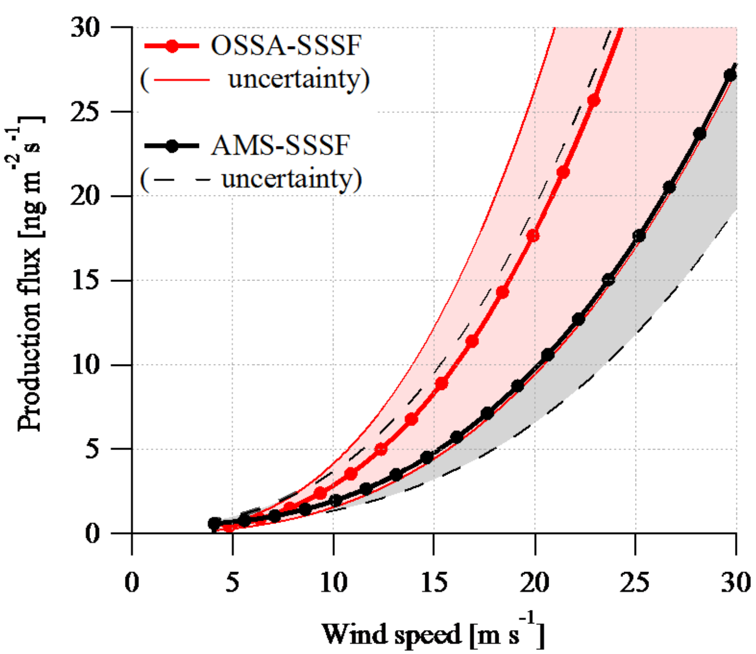
Note that each mode has a different dependence on Re_{Hw}!

This indicates different production mechanisms (Monahan et al., 1986)

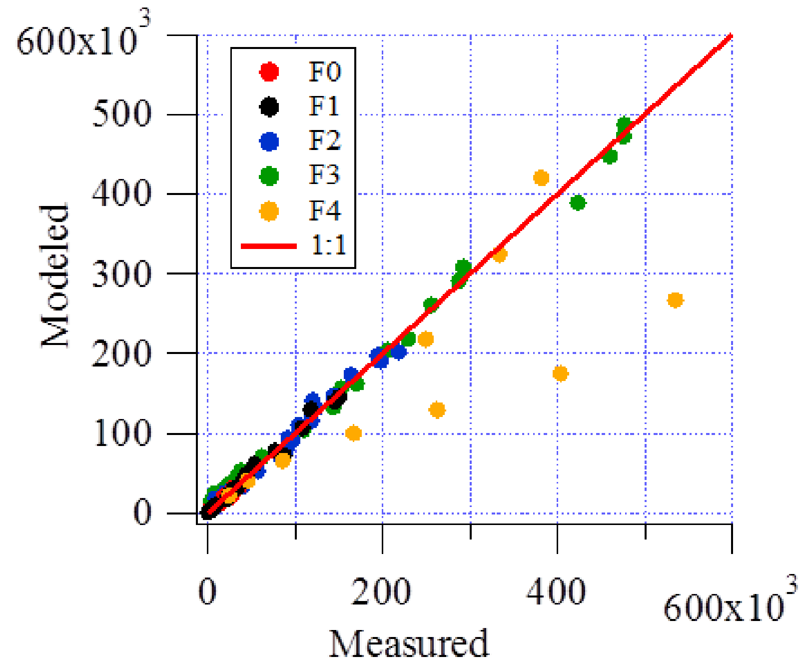
The OSSA source function includes uncertainties!



Validation: Comparison with collocated mass fluxes



Production flux as function of wind speed



Flux mode amplitudes at different wind speeds

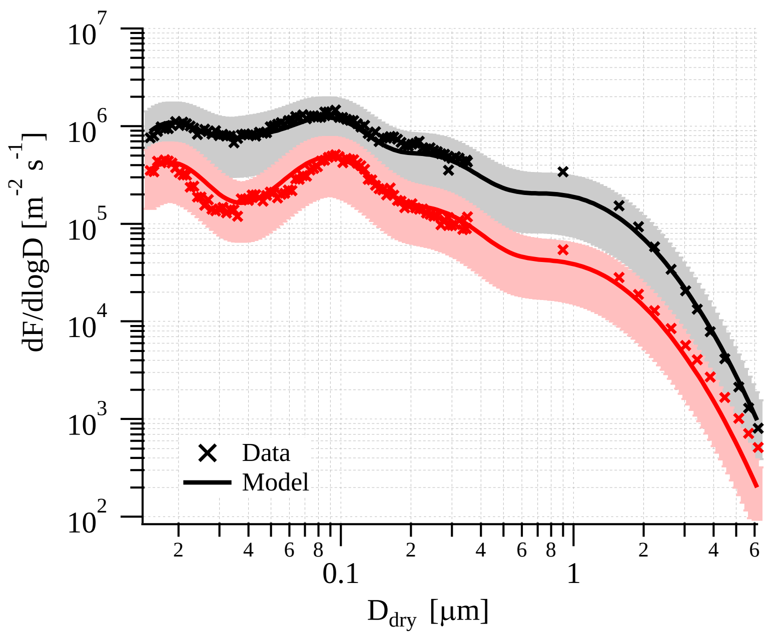
oceanflux sea-spray
support to science element

FMI

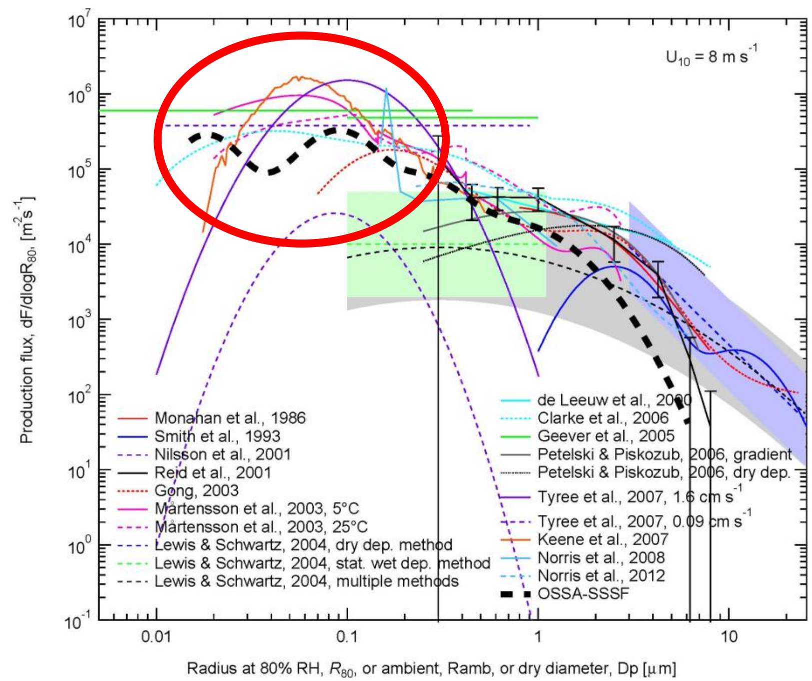
stse
support to science element

esa

Evaluation



Parameterization vs original data



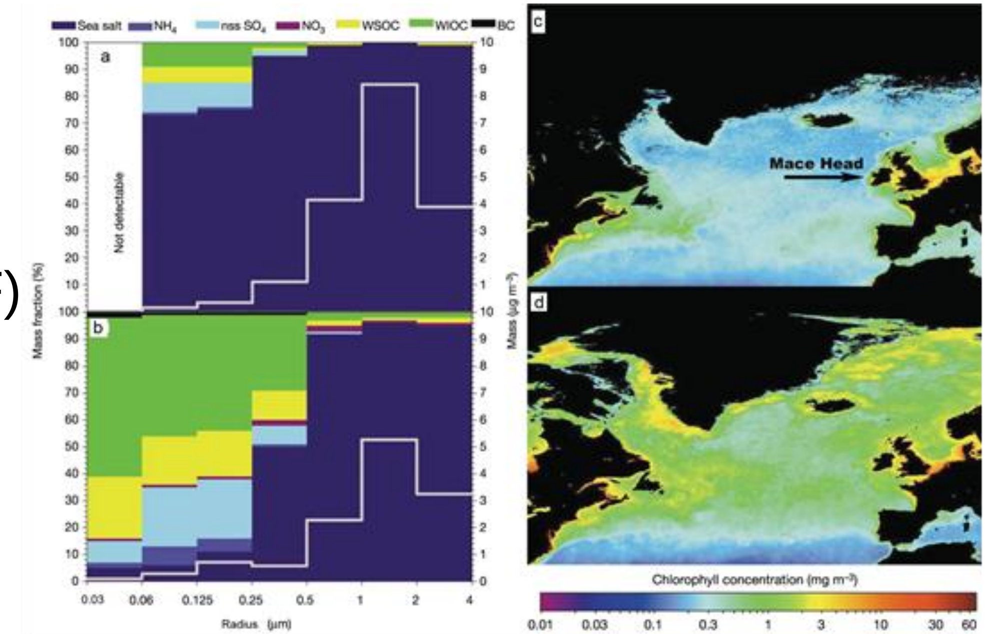
Comparison with other source functions

NUI Galway
OÉ Gaillimh

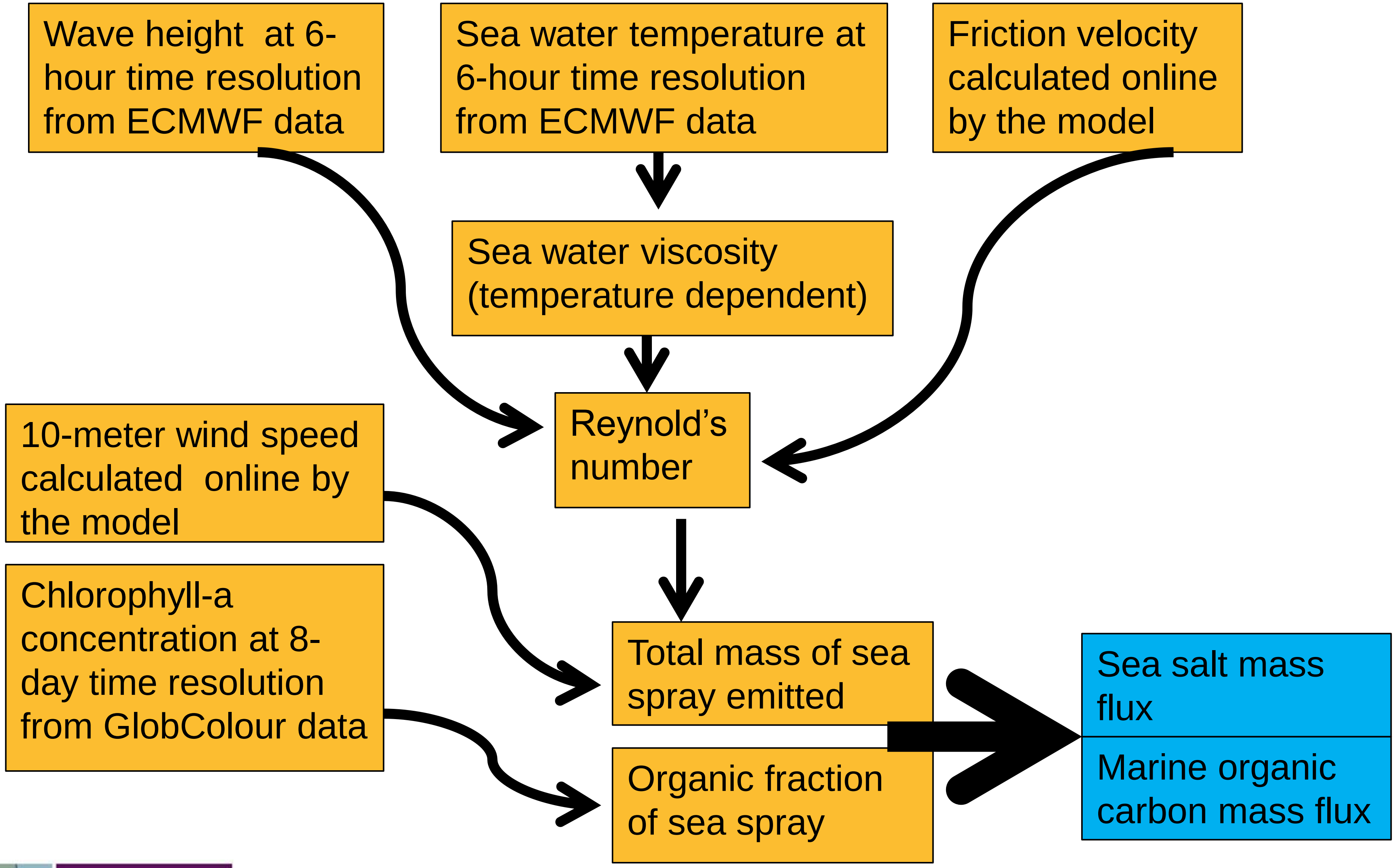
TNO

Use of OSSA SSSF to determine direct and indirect radiative effects of SSA

- The OSSA SSSF is based on observations in non-productive waters:
  - Low Chl concentrations
  - Organic matter fraction (OMF) in SSA is small
- In productive waters the OMF is important in sub-micron particles
- This fraction is important since it determines both radiative properties and CCN activiation of SSA particles



O'Dowd et al., 2004; Facchini et al., 2008

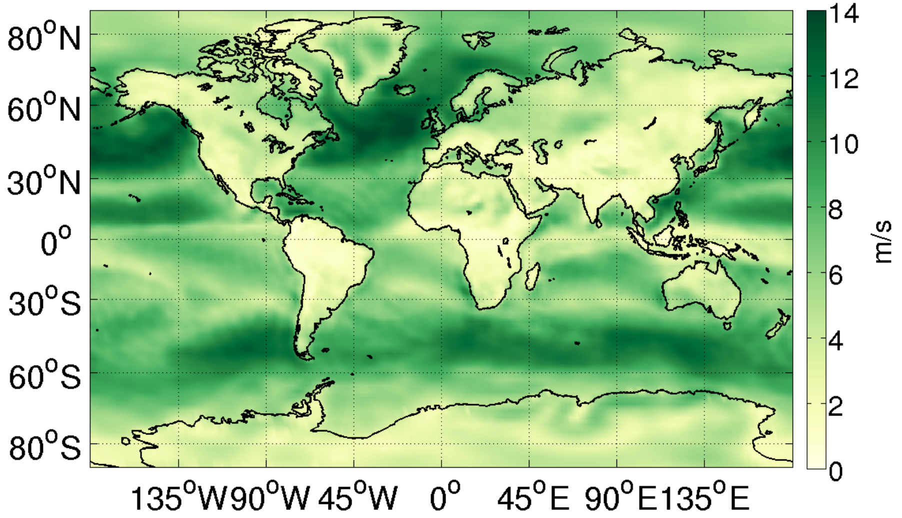

Wave height at 6-hour time resolution from ECMWF data
Sea water temperature at 6-hour time resolution from ECMWF data
Friction velocity calculated online by the model
Sea water viscosity (temperature dependent)
Reynold’s number
10-meter wind speed calculated online by the model
Chlorophyll-a concentration at 8-day time resolution from GlobColour data
Total mass of sea spray emitted
Organic fraction of sea spray
Sea salt mass flux
Marine organic carbon mass flux

SSA direct and indirect radiative effects:

implementation OSSA SSSF in the global aerosol-climate model ECHAM5-HAM

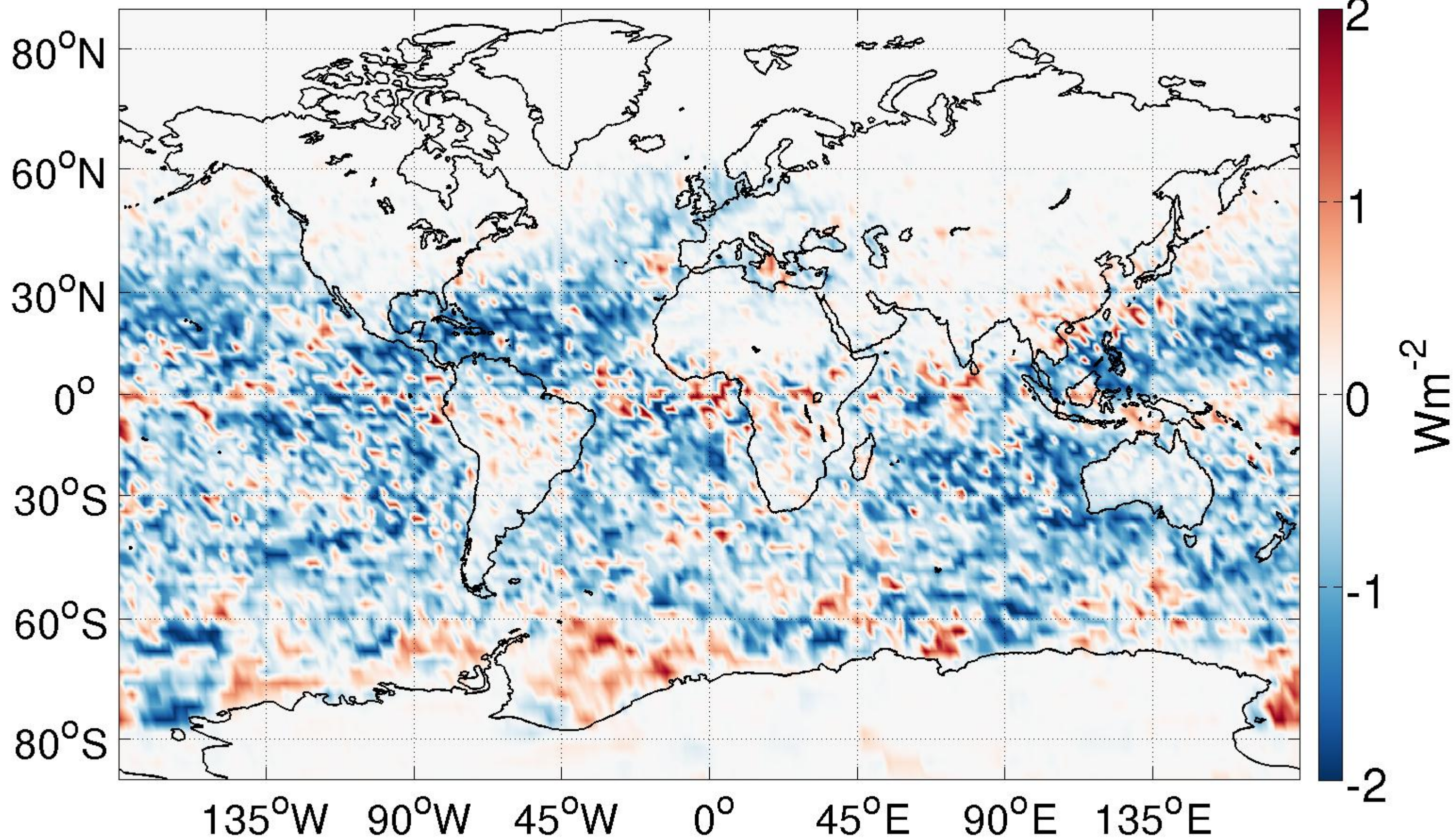
- **The atmospheric core model ECHAM is developed at Max Planck Institute for Meteorology**
- **Horizontal resolution is about 1°×1° (~200 km × 200 km)**
- **The model meteorology is nudged towards ERA Interim data in the runs of this project**

Monthly-mean 10-meter wind speed from the model



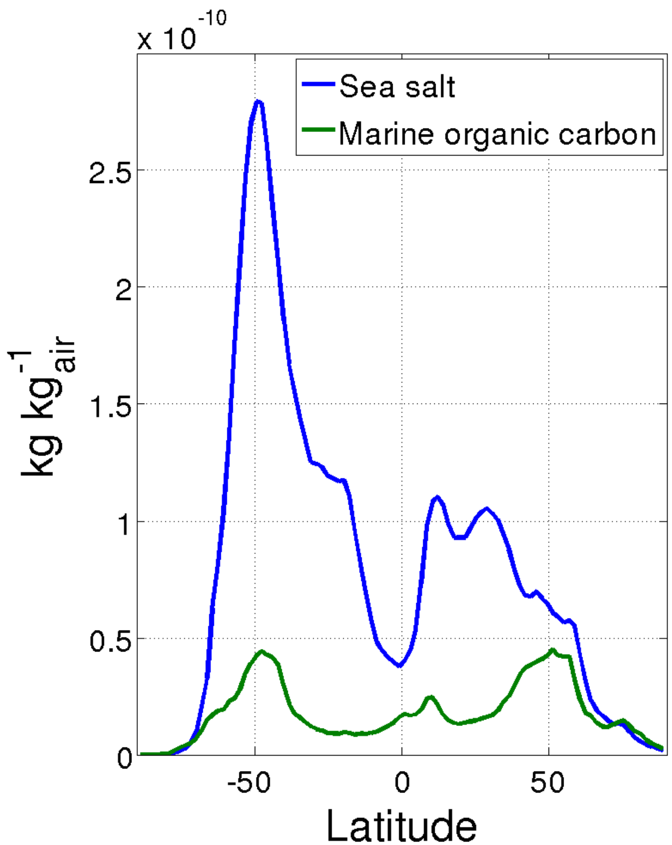
Radiative effects of sea spray in January 2005

Direct effect of sea spray aerosol (preliminary results)

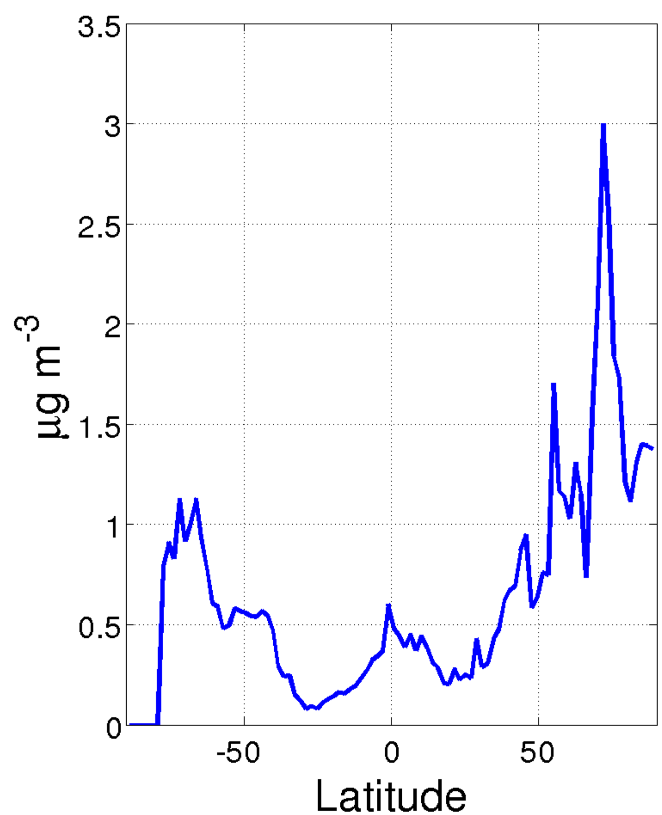


January 2005 (preliminary results)

Sea spray concentration (30-700 nm in diameter) at the lowest model level



Chlorophyll-a concentration in surface water



Summary of the global simulations

- **New sea spray parameterization implemented into global aerosol-climate model ECHAM5-HAM**
  - The model includes detailed aerosol microphysics model SALSA
  - Evaluation of both direct and indirect effects of sea spray aerosol possible
- **Both sea salt and marine organic carbon emissions are modeled**
- **The simulations have just been started, and only preliminary results are available**

Next steps

- **Simulate 5-model years (+1 year spinup) with and without sea spray emissions**
- **Compare model AOD with satellite and sun photometer measurements**
- **Compare sea spray aerosol concentrations against in-situ measurements**
- **Calculate direct and indirect radiative effects of sea spray aerosol**
- **Conduct sensitivity simulations to evaluate the global effects of the uncertainty of the emission flux**

Conclusions

- The OSSA sea spray aerosol source function (OSSA SSSF) has been developed using two independent data sets obtained over the North Atlantic Ocean in non-productive waters:
  - Mace Head, coastal
  - SEASAW cruise, open ocean
- Different techniques, different physical principles
- Parameterisation in terms of Reynolds number Re_{Hw}, depends on:
  - Wind speed
  - Wave state (wave height)
  - SST
  - Salinity
- The use of Re_{Hw} eliminates effects of wind history
- Re_{Hw} is evaluated using re-analysis data constrained by satellite observations
- The OSSA SSSF has been implemented in ECHAM-HAM-SALSA to evaluate the direct and indirect effects of SSA
- ECHAM results will be evalauted using satellite data for aerosols and clouds

Satellite data used:
- Wave height
- Ocean Colour (OC)
- Aerosol and cloud properties
- (SST)
- (Wind info)

Sea Spray Aerosol workshop

30 Sep & 01 October, 2013

Harbour Hotel, Galway, Ireland

Thank you for your attention

To follow the project, see
OSSA website:

http://oceanflux.fmi.fi/

Brochure

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