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, ..
Effects of rising and waning wind

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

Reynolds number:
\[ \text{Re}_{Hw} = \frac{u \cdot H_s}{v_w} = C_D^{1/2} U_{10} H_s / v_w \]

Includes: wind, wave, SST, salinity

All available from satellite observations

However, because our experimental data set is very sparse, we also use model data constrained by satellite observations.

SSA flux vs. \( \text{Re}_{Hw} \)  
Ovadnevaite et al., ACPD, 2013; & refs cited
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
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:

\[ \frac{dF}{d\log D} = \sum_{i=1}^{5} \frac{F_i(R_{Hw})}{\sqrt{2\pi Dln\sigma_i}} \exp\left(-\frac{1}{2}\left(\frac{D}{CMD_i}\right)^2\right) \]

\[ \left(\frac{D}{CMD_i}\right) = \left(\frac{ln(D)}{ln\sigma_i}\right) \]
Flux parameterization: the OSSA source function

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!

<table>
<thead>
<tr>
<th>i</th>
<th>$\sigma_i$</th>
<th>CMD$_i$</th>
<th>$F_i(R_{Hw})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.37</td>
<td>0.02</td>
<td>$4.58*(R_{Hw}-1e^5)^{0.556}$</td>
</tr>
<tr>
<td>2</td>
<td>1.5</td>
<td>0.048</td>
<td>$0.0045*(R_{Hw}-1e^5)^{1.08}$</td>
</tr>
<tr>
<td>3</td>
<td>1.42</td>
<td>0.102</td>
<td>$33.05*(R_{Hw}-1e^5)^{0.545}$</td>
</tr>
<tr>
<td>4</td>
<td>1.53</td>
<td>0.279</td>
<td>$1.3*(R_{Hw}-1e^5)^{0.79}$</td>
</tr>
<tr>
<td>5</td>
<td>1.85</td>
<td>1.035</td>
<td>$1.02*(R_{Hw}-2e^5)^{0.87}$</td>
</tr>
</tbody>
</table>
Validation: Comparison with collocated mass fluxes

Production flux as function of wind speed

Flux mode amplitudes at different wind speeds
Evaluation

Parameterization vs original data

Comparison with other source functions
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 activation 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)

10-meter wind speed calculated online by the model

Reynold’s number

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
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 evaluated 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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