A BIOTIC MARINE SOURCE OF ORGANIC AEROSOLS:
FROM FIELD MEASUREMENTS IN THE AUSTRAL OCEAN
TO MODEL ESTIMATES OF ITS CONTRIBUTION AT A GLOBAL SCALE

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DIRECT & INDIRECT radiative forcing of marine Aerosols - State-of-the-art

Motivations

Contribution of each of these 3 sources (sea salt, S-biogenic, C-biogenic) to CCN number & properties in the marine atmosphere

Phytoplankton

Cloud Albedo (indirect radiative forcing)

Light Scattering (direct radiative forcing)

SO₂, DMSO, VOC

DMS

ORGANICS, SEA SALTS

Cloud Albedo

Climatic Feedback?
AEROSOL monitoring activities
Austral Ocean (Indian Ocean sector)

- operated by LSCE (France)
- operated by CSIRO (Australia)
- co-operated by LSCE (France) and SAWS (S. Africa)
- operated by LGGE (France)

National – International programs / networks

- IPEV - AERORACE (Amsterdam + Crozet)
- ORE - AERONET (Amsterdam + Crozet)
- GAW – Global Station (Amsterdam + Cape Point)
- GAW – Regional Station (Crozet)
- OPEV - ORE CESOA (Amsterdam + Crozet)
- IPEV - AERORACE (Amsterdam + Crozet)
- SOLAS – AERORACE (Amsterdam + Crozet)
- EL CID (2001-2003) (Amsterdam + Crozet)
- OOMPH (2005-2008) (Amsterdam + Crozet)
Experimental / Aerosol chemical composition measurements

Atmospheric Sampling Station
(37.5°S - 77.3°E)

Sampling site
Global fixed station in WMO RA I - Africa

Scientific base

2 x 4-stage DEKATI Impactor
(PM$_1$, PM$_{2.5}$, PM$_{10}$, TSP)
(since 2003)
(EBC, OC, WSOC, ions)

2 x Bulk filter sampling
(since 2003)
(EBC, OC, WSOC, ions)

1 x 11-stage MOUDI Impactor
(since 2006)
(OC, WSOC, ions)

Aethalometer Magee Scientific AE8
(EBC)
Equivalent Black Carbon (EBC)

Max of Radon (continental air masses) in June-July
Max of EBC in August (e.g. at the max. of biomass burning in the Austral Africa)

Monthly mean EBC a factor of 3-5 lower to N. Hemisphere burden (N. Atlantic / Ireland / Mace Head)

* Calculated using a Mass Attenuation efficiency of 19m²/g given by the constructor (Magee Scientific)
Summer max. of OC (at 250ngC/m³)

Background levels (∼ 100ngC/m³)

Summer max. mainly related in WIOC (with summer/winter Amplitude of 4)

C-AEROSOLS
Most of organic aerosols are located in the submicron size range
Importance of « long-range » transport of biogenic marine organic aerosols
Seasonal cycle of OC at remote marine sites

Back trajectory chlorophyll-a correlates well with observed OC at Mace Head and Amsterdam Island. Models under-predict OC by factor of 5-20 at all three sites.
Derive oceanic OC emissions driven by oceanic chlorophyll-a

Correlation between observed OC and remote sensed chlorophyll-a suggests an oceanic source driven by biological activity. We scale chlorophyll-a to produce OC emissions.

\[ \text{OC}_{\text{emis}} = A \cdot \text{[Chl-a]} \]

Annual Mean OC emission (2001-2005)
Biologically driven oceanic OC emissions reduce low model bias

We implement these biologically driven OC emissions in the GEOS-chem model. We modify emission factor ‘A’ to find the best match between observed and simulated OC.

A biological oceanic OC source of 8 Tg / yr is required to match observed OC.
Seasonal cycle of OC at remote marine sites

(a) Amsterdam Island (37S, 77E)

(b) Azores (38N, 27W)

(c) Mace Head (53N, 9W)

- **Observed**
- **GLOMAP** \{ No marine OC \}
- **GEOS-chem** \{ source \}
- **GEOS-chem (1 Tg/yr OC)**
- **GEOS-chem (8 Tg/yr OC)**
- Back trajectory weighted
- SeaWiFS chlorophyll-a
Simulated 2001-2005 surface OC concentrations

No oceanic source

8 Tg / yr oceanic source

With oceanic source / without source

Oceanic OC source leads to large increases in simulated OC in the Southern Ocean.
Mechanism of oceanic carbon emission

Our method does not allow us to evaluate the mechanism for the OC emission. Can use observed water insoluble OC (WIOC) to water soluble OC ratios to give information about the likely source mechanism.

8 Tg of OC would require ~ 250 Tg of oceanic isoprene - many orders of magnitude greater than current emission estimates

Observed OC at all 3 sites is ~80% WIOC suggesting a predominately primary ocean source.
Sources of Organic Carbon (OC) aerosol

Secondary organic aerosol
- Biogenic volatile organic carbon species (VOCs)
- Oceanic organics

Primary emission
- Biomass burning
- Fossil fuels
- Anthropogenic VOCs

Global OC budget is very uncertain. Our inferred oceanic OC source is significant compared to other known sources.
Conclusions

Evidence of an important source of biogenic marine organic aerosols in the Austral Ocean

• Submicron size range & mainly water insoluble (suggesting a primary origin for these organics).

• A global emission of ~8 Tg C / year, scaled with chlorophyll-a gives best model prediction.

• Further work needed 1) to better characterize (experimentally) this organic source, 2) to quantify the implications of this significant global source of organic aerosol.

Thanks for your attention