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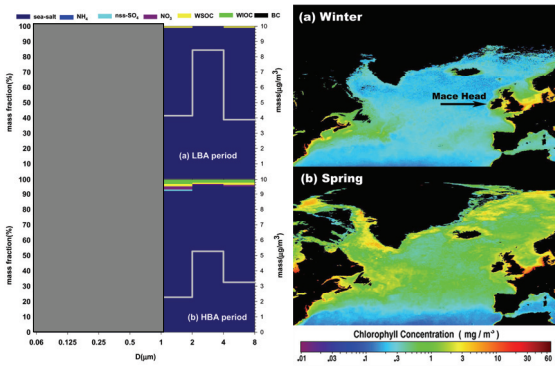
Fine Mode Marine Aerosol: Production, Composition and Impacts

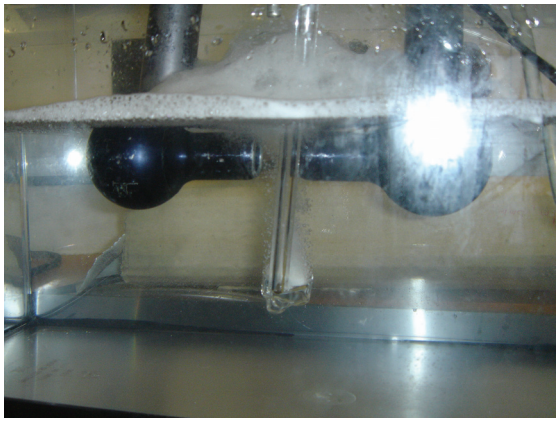
Professor Colin O'Dowd

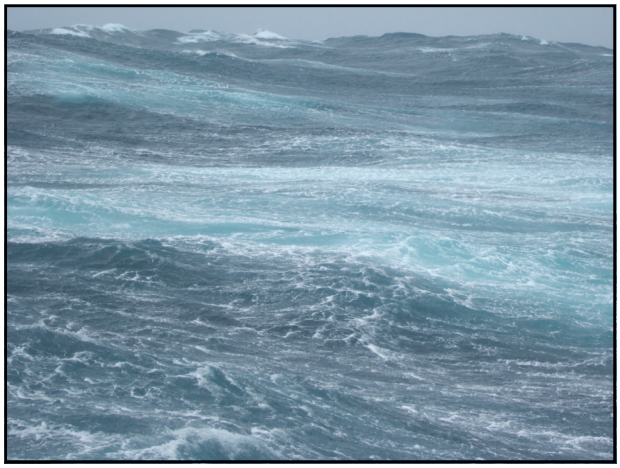
Centre for Climate & Air Pollution Studies, NUI Galway, Ireland

O'Dowd et al, Nature, 2004, Cavalli et al, JGR, 2005



Although the atmospheric measurements point to a primary source, on their own, they cannot be conclusive





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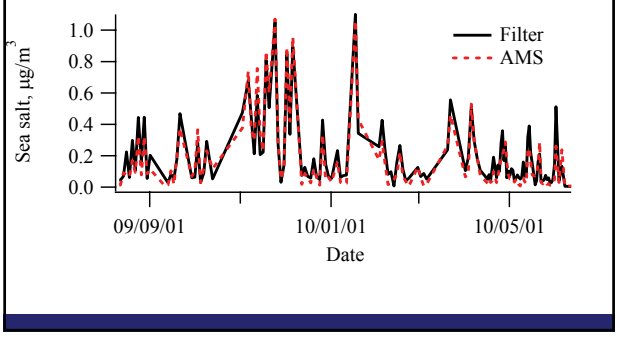
Sea Salt Plumes



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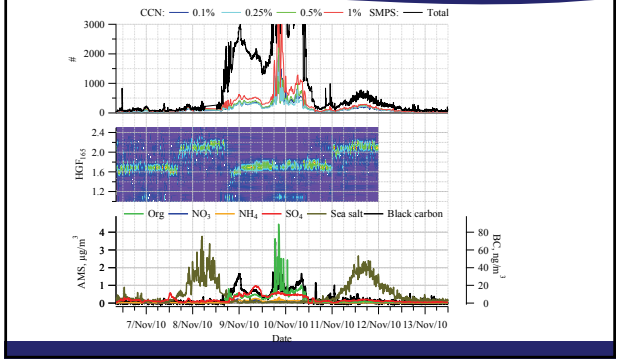
Sea Salt Plumes



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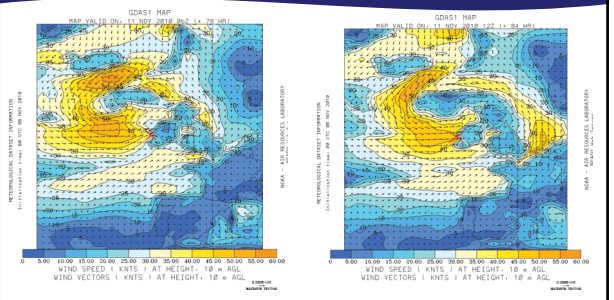
Sea Salt Plumes



a) 06:00 UTC 11 November.
Local wind speed = 18.3 m/s, wind speed derived from NOAA 17.5-20 m/s

b) 12:00 UTC 11 November.
Local wind speed = 24.1 m/s, wind speed derived from NOAA 22.5-25 m/s

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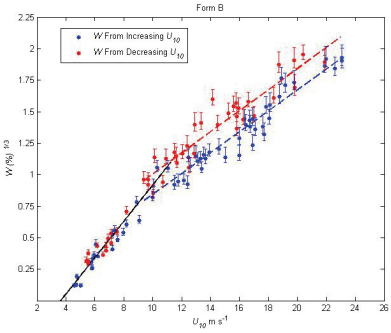
Sea-Salt Production Flux



Ovadnevaite et al., JGR, 2012

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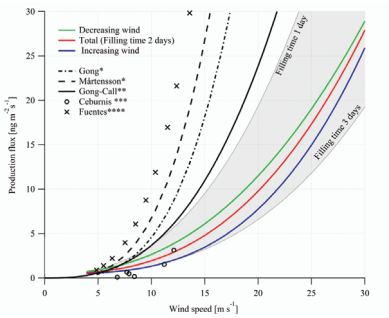
Sea-Salt Production Flux



Ovadnevaite et al., JGR, 2012

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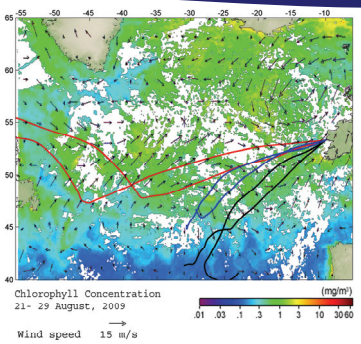
Primary Organic Matter Plumes



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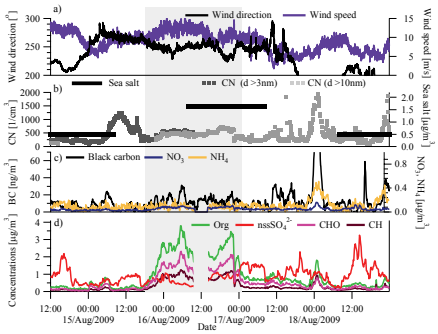
Primary Organic Matter Plumes



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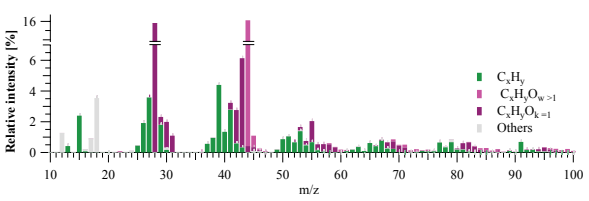
Chemical Characterisation

The **organic mass comprised 77% of the total submicron** non-refractory mass and such plumes were associated with regions of high biological activity and moderately-high wind speeds over the N.E. Atlantic. High-resolution mass spectra analysis revealed a **unique marine organic aerosol fingerprint**, when compared to anthropogenic organic aerosol, and in particular, anthropogenic hydrocarbons.



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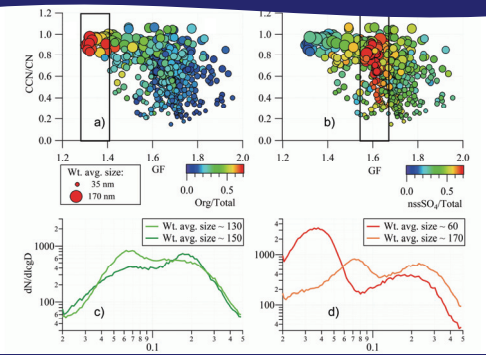
Sea Spray Water Uptake and Activation



Ovadnevaite et al. 2011b GRL

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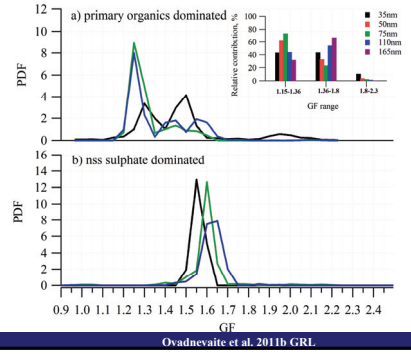
Sea Spray Water Uptake and Activation



Ovadnevaite et al. 2011b GRL

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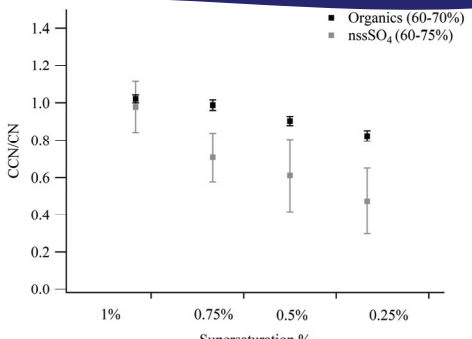
Sea Spray Water Uptake and Activation



Ovadnevaite et al. 2011b GRL

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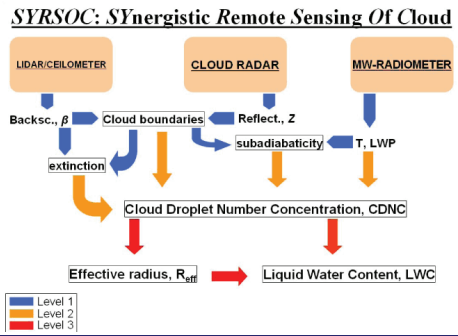
Ground-Based Sensing of Cloud Microphysics



Martucci & O'Dowd, AMT, 2011

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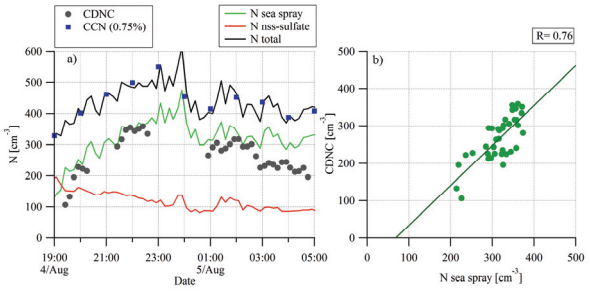
Sea Spray Impact on Clouds



Ovadnevaite et al. 2011b GRL

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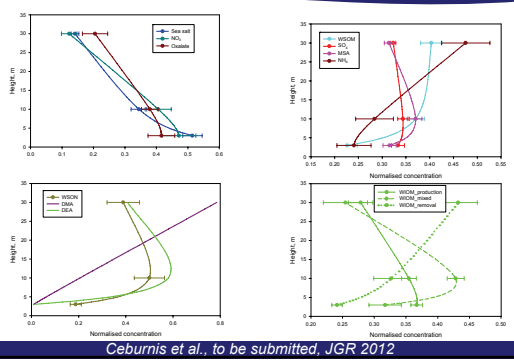
Chemical Composition Gradients



Ceburnis et al., to be submitted, JGR 2012

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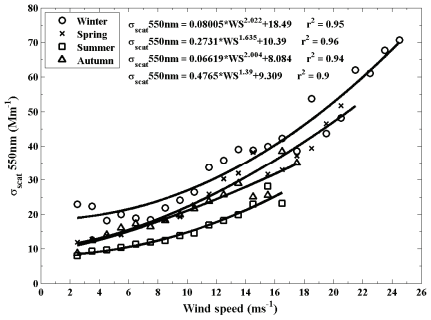
WP4000: NE Atlantic scattering coefficient



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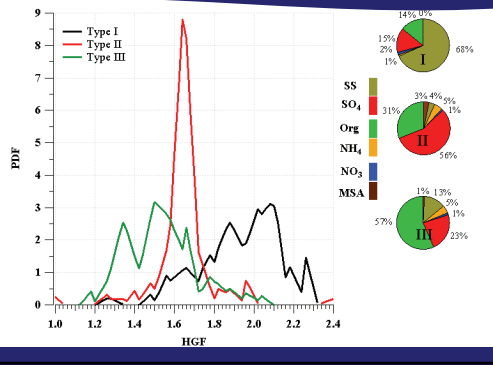
Parameterising Hygroscopic Growth Factor



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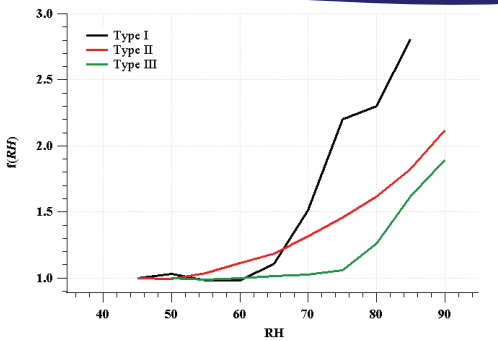

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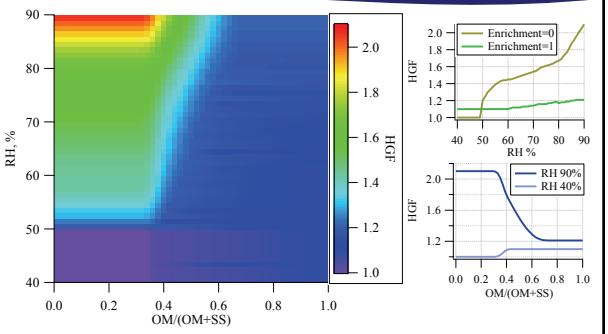

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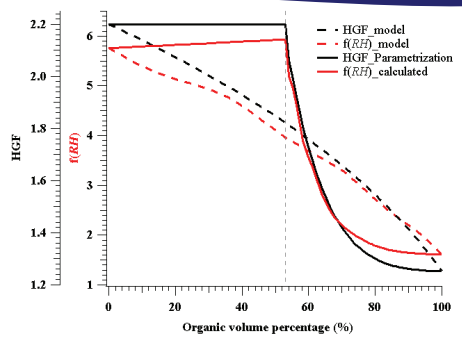
Parameterising Hygroscopic Growth Factor (Model means ZSR Mixing Rule)



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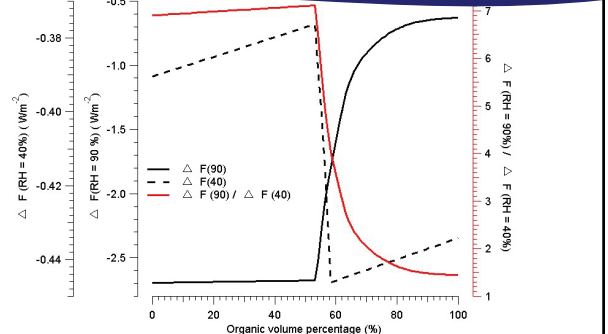
Parameterising Hygroscopic Growth Factor



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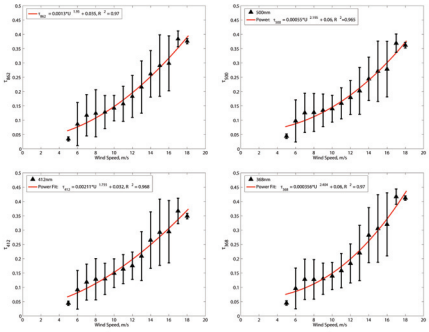
Aerosol Optical Depth



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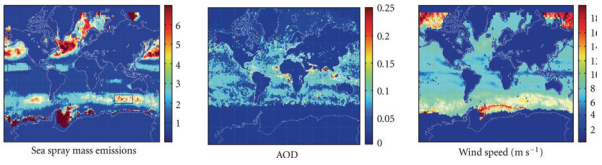
Aerosol Optical Depth



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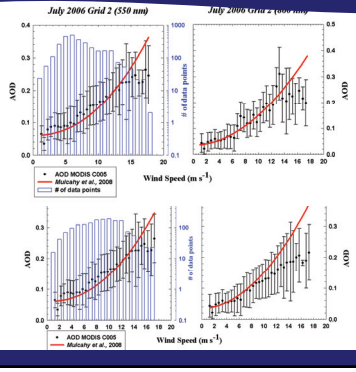
Aerosol Optical Depth



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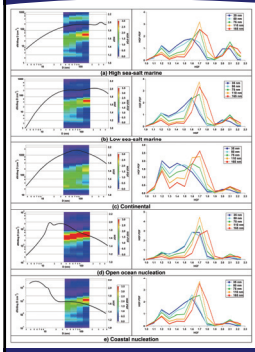
Number Budget: 2 years k-means clustering analysis



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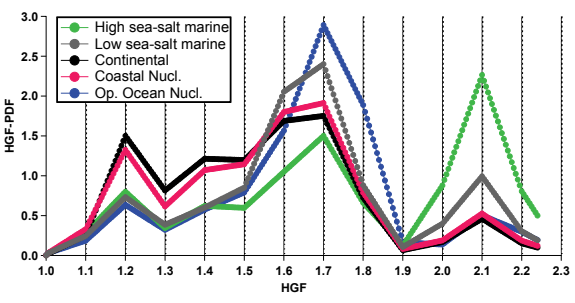
Number Budget



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Number Budget

Cluster Category	Hygroscopic Growth Factor Mode			
	NH Mode	LH Mode	MH Mode	SS Mode
High sea-salt marine	1.19±0.7 (13%)	1.42±0.6 (12%)	1.69±1.4 (35%)	2.1±2 (40%)
Low sea-salt marine	1.19±0.6 (11%)	1.47±0.6 (19%)	1.68±2 (52%)	2.1±0.9 (17%)
Continental	1.19±1.1 (15%)	1.43±1.17 (45%)	1.68±1.3 (30%)	2.1±0.4 (10%)
Coastal nucleation	1.19±1 (19%)	1.42±1 (20%)	1.65±1.9 (50%)	2.1±0.4 (10%)
Open ocean nucleation	1.19±0.5 (9%)	1.52±0.8 (26%)	1.7±2.2 (54%)	2.12±0.5 (11%)

Table 1. Relative contributions of different HGF modes to total number concentrations of analysed sizes.

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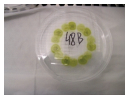
Bubble Bursting Experiments at Mace Head

Aerosol size

Scanning Mobility Particle Sizer (SMPS)
&
Humidified Tandem Differential Mobility Analyser (HTDMA)

Aerosol growth

Circulating water jet in tank



Berner Impactors

Aerosol chemical composition

Aerosol Mass Spectrometer (AMS)

Diatom (*Leptocylindrus danicus*)

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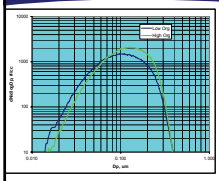
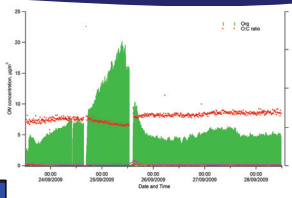
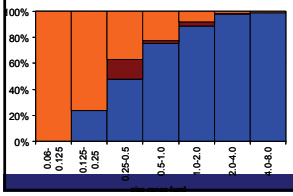
WP4000: Emiliania huxleyi







OM Berner 6.5 ug/m3
OM AMS 8.7 ug/m3

no evidence for "refractory" organics

Number conc. increased by 25%
Volume by 60%

OM mass ~5 times

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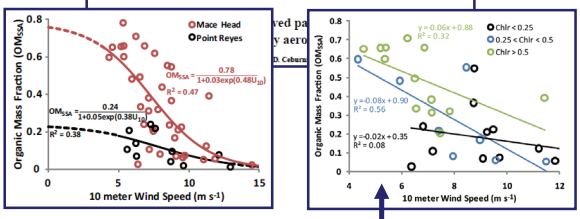
Enrichment versus wind speed

Atmos. Chem. Phys., 11, 8777–8790, 2011
www.atmos-chem-phys.net/11/8777/2011/
doi:10.5194/acp-11-8777-2011

Atmospheric Chemistry and Physics



The correlation persists even when the data are binned for homogeneous Chl-a concentration

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Examples of recent SS-OM Parameterisation

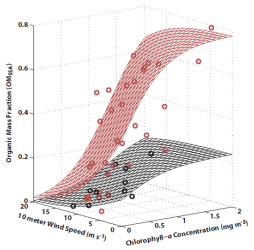
Mace Head Atmospheric Research Station (53.33 N, 9.90 W) on the Atlantic coast of Ireland
Point Reyes National Seashore (38.12 N, 122.91 W) on the Pacific coast of California.

Mace Head measurements of the ~50–100 h average chemical composition of aerosols with an aerodynamic diameter <1.5 μm were taken during periods of "clean sector" conditions.

Point Reyes near San Francisco, CA measurements of the chemical composition of aerosols with diameters <2.5 μm were taken as part of the United States' Interagency Monitoring of Protected Visual Environments (IMPROVE) network.

OM_{SSA} =WIOM/(WIOM + sea-salt)

$$OM_{SSA}(Chl-a, U_{10}) = \frac{OM_{SSA}^{max}}{1+\exp(-2.63[Chl-a]+0.18U_{10})}$$



Organic mass fraction of sea spray aerosol as a function of both 10m wind speed and [Chl-a] for Mace Head (red) and Point Reyes (black).

Gantt et al. 2011 ACP

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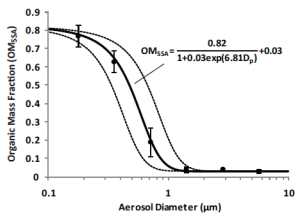
Examples of recent SS-OM Parameterisation



$$OM_{SSA}(Chl-a, U_{10}, D_p) = \frac{\frac{1}{1+\exp(-2.63[Chl-a]+0.18U_{10})}}{1+0.03\exp(6.81D_p)} + \frac{0.03}{1+\exp(-2.63[Chl-a]+0.18U_{10})}$$

Gantt et al. 2011 ACP

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Remote Sensing – GLOBECOLOUR/My Ocean 1998-2010

Processing 1 (the simple mean):
Monthly Chlorophyll maps were computed averaging all valid pixels in the daily Chlorophyll maps provided by GLOBCOLOR / MyOcean data set for the period 1998 to 2010.

Processing 2:
To avoid distortions due to the uneven distribution of valid pixels, data voids in the sequence of daily maps were first filled using MSSA, then monthly maps were computed averaging filled chl fields.

Multi-channel SSA (or M-SSA) is a natural extension of SSA to a multivariate time series of vectors or maps, such as time-varying scalars.

SSA is a nonparametric method thattries to overcome the problems of finite sample length and noisiness of sampled time series not by fitting an assumed model to the available series, but by using a data-adaptive basis set. An, iterative form of **SSA (MSSA)**is used to analyze univariate (multivariate) datasets with uneven sampling or missing observations. Gaps are filled-in by utilizing temporal correlations in the dataset.

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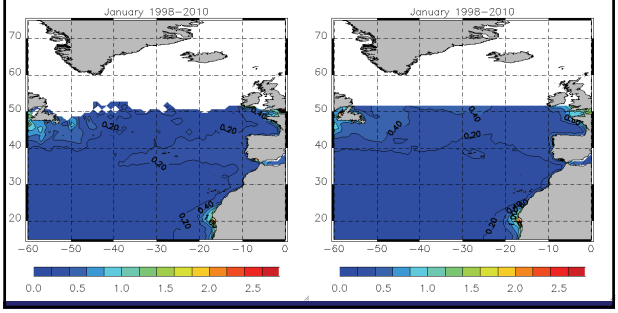
Remote Sensing – GLOBECOLOUR/My Ocean 1998-2010

MSSA | no MSSA



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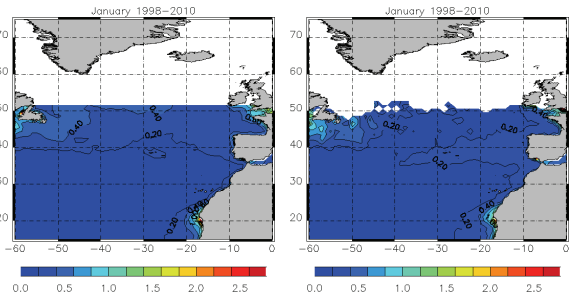
Remote Sensing – GLOBECOLOUR/My Ocean 1998-2010

MSSA | no MSSA



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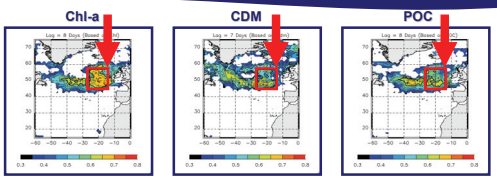
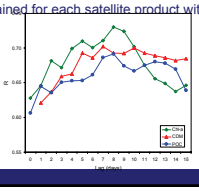
OM Bio-Proxy Correlation analysis

Chl-a | CDM | POC



Correlation maps were obtained for each satellite product with OM_{SS} and for each time lag



Correlation coefficient at 50-60 N and 10-20 W as a function of the time lag

Max correlation at:
- 8 days for Chl-a
- 7 days for CDM
- 8 days for POC

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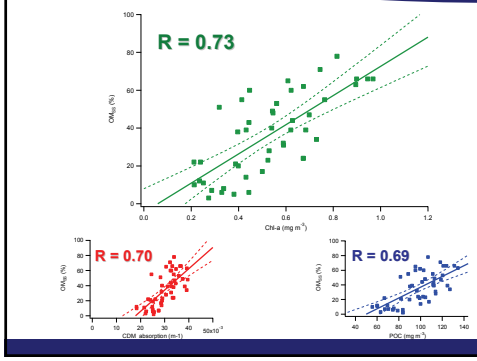

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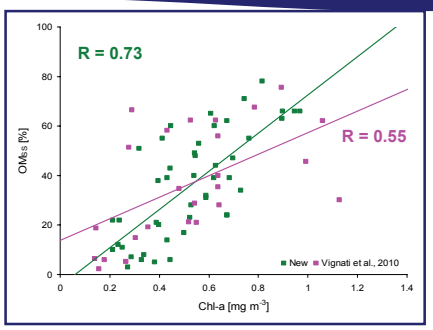

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Proposed New organic-inorganic SS Source Function

$OM_{SS} = K_1 * Chl\text{-}a + K_2 * WS + K_0$

$K_0 = 39.9 \pm 11.9$
$K_1 = 57.9 \pm 10.4$
$K_2 = -4.56 \pm 1.1$
$R = 0.82$