

**PML**

Plymouth Marine  
Laboratory

Marine Matters

# Calcifying plankton and their modulation of the north Atlantic, sub-arctic and European shelf-sea sinks of atmospheric carbon dioxide from Satellite Earth observation

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# Coccolithophore effects from Earth observation

- We have studied the impact of coccolithophores from the perspective of two gases, CO<sub>2</sub> and DMS
- We're interested in CO<sub>2</sub> in relation to the oceanic sink of atmospheric CO<sub>2</sub>
- We're interested in DMS in relation to its contribution to cloud condensation nuclei and resulting effect on climate
- We use Earth observation to identify coccolithophore blooms, then model the effect on pCO<sub>2w</sub> and [DMS], and hence fluxes
- Work is ongoing – progress report!

# Coccolithophore CO<sub>2</sub> from Earth observation

- Coccolithophores form about 50% of the open ocean carbonate pump, sequestering CO<sub>2</sub> in the sea bed
- However, the immediate effect of coccolithophore growth is the addition of CO<sub>2</sub> to surface waters, slowing CO<sub>2</sub> drawdown
- They may also be sensitive to, and hence an indicator of, climate change
- Earth observation can detect coccolithophores, and so gives an opportunity to estimate and monitor their effects

# Coccolithophore CO<sub>2</sub> from Earth observation

- RAGNARoCC is a NERC project to study radiatively active gases such as CO<sub>2</sub> in the north Atlantic
- CaNDyFloSS is a NERC project which aims to study CO<sub>2</sub> and nutrient dynamics and fluxes on shelf seas
- At PML we have estimated the effect of coccolithophores on CO<sub>2</sub> fluxes in the north Atlantic using the SeaWiFS satellite sensor
- Within RAGNARoCC and CaNDyFloSS, we will build on this work to use the MODIS sensor and extend the spatial and temporal coverage
- We will quantify the effect of coccolithophores on fluxes in the North Atlantic, European shelf seas and the Barents Sea in the Arctic since 2000



# Coccolithophore CO<sub>2</sub> from Earth observation



- *Emiliana Huxleyi* is a cosmopolitan species of coccolithophore that produces calcium carbonate scales, or coccoliths. When conditions are right, it produces huge blooms.
- When *E. Hux.* grows and divides at a high rate, the cells shed their liths into the water, where they act like millions of tiny mirrors, vastly increasing the reflectance of the water
- This increased reflectance is easily visible from space

# Coccolithophore CO<sub>2</sub> from Earth observation

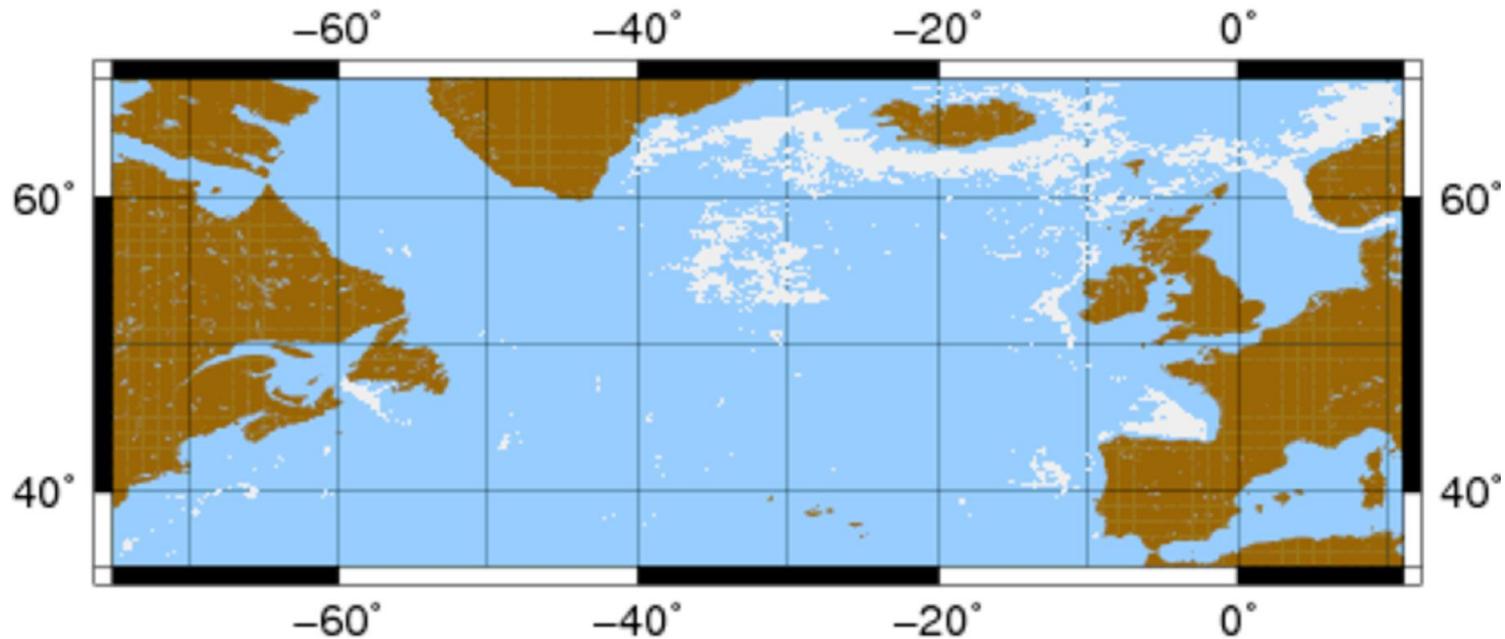
- The calcification reaction



increases the concentration of CO<sub>2</sub> in the water and reduces bicarbonate concentration and alkalinity

- The increase in surface water CO<sub>2</sub> concentration causes flux from atmosphere to ocean to decrease, or that from ocean to atmosphere to increase
- The overall effect is to decrease the north Atlantic sink of CO<sub>2</sub>

# Coccolithophore CO<sub>2</sub> from Earth observation

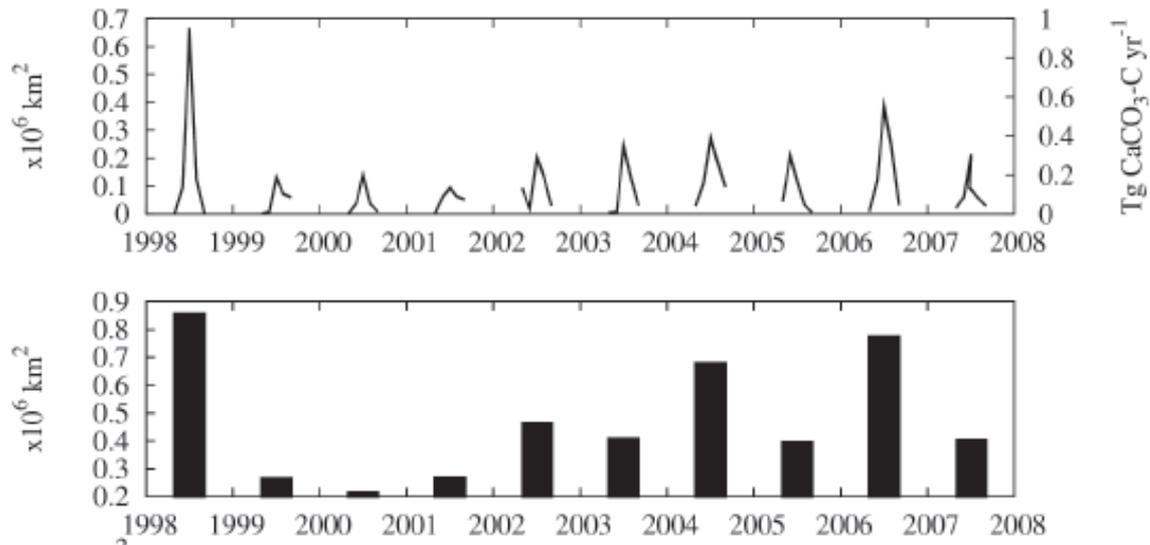


Coverage of coccolithophores detected in waters >200m deep using SeaWiFS between 1998 and 2007

# Coccolithophore CO<sub>2</sub> from Earth observation

## Annual surface coverage and net CaCO<sub>3</sub> production

- Mean annual coverage 474,000 ± 103,000 km<sup>2</sup> yr<sup>-1</sup>
- Mean net production is 0.14 ± 1.71 Tg CaCO<sub>3</sub>-C yr<sup>-1</sup>
- Surface coverage is correlated with ENSO ( $r^2 = 0.75$ ,  $p < 0.02$ )

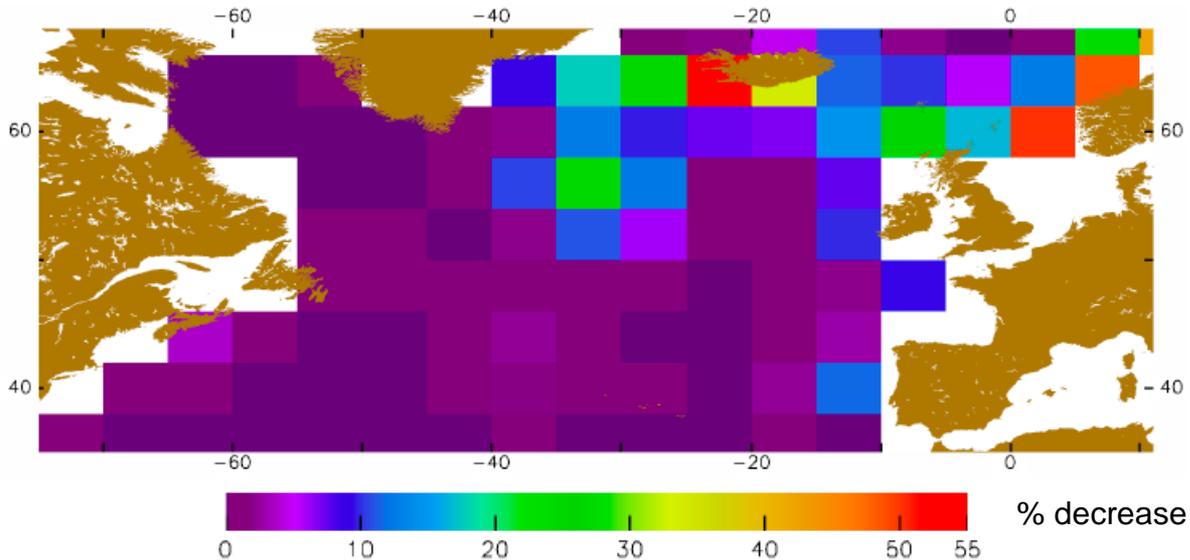


**Shutler, J. D., Land, P. E.,** Brown, C. W., Findlay, H. S., Donlon, C. J., Medland, M., Snooke, R., Blackford, J. C., (2013) Coccolithophore surface distributions in the North Atlantic and their modulation of the air-sea flux of CO<sub>2</sub> from 10 years of satellite Earth observation data, *Biogeosciences*, 10, 1-11, doi:10.5194/bg-10-1-2013.

# Coccolithophore CO<sub>2</sub> from Earth observation

## Modulation of pCO<sub>2w</sub>, air-sea flux and annual sink

- Monthly average impact: air-sea flux reduced by up to 55%
- Estimated reduction in annual north Atlantic sink is 3-28%

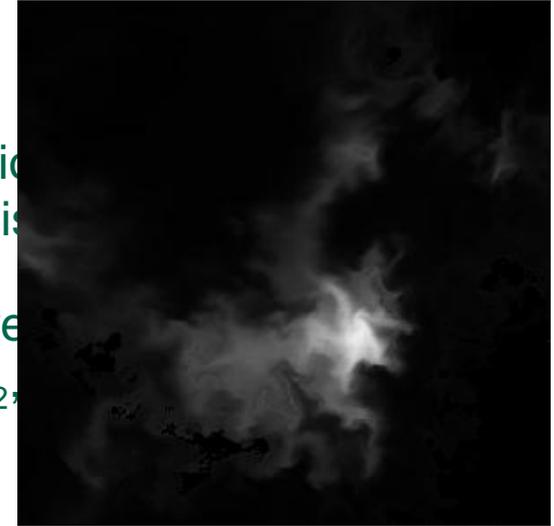


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# Coccolithophore CO<sub>2</sub> from Earth observation

## Correction of satellite data

- The MODIS sensor provides estimates of particulate inorganic carbon (PIC), a measure of phytoplankton biomass
- Assuming this PIC is all newly produced, we can estimate the resultant increase in CO<sub>2</sub> flux
- In strong coccolithophore blooms, the MODIS ocean colour bands can saturate, resulting in a 'hole' in the PIC products where the bloom is strongest
- Visual inspection revealed 35 potential examples in the North Atlantic in 2004
- We have developed a method to fill these gaps using high resolution MODIS data
- North Atlantic data are being reprocessed for RAGNARoCC

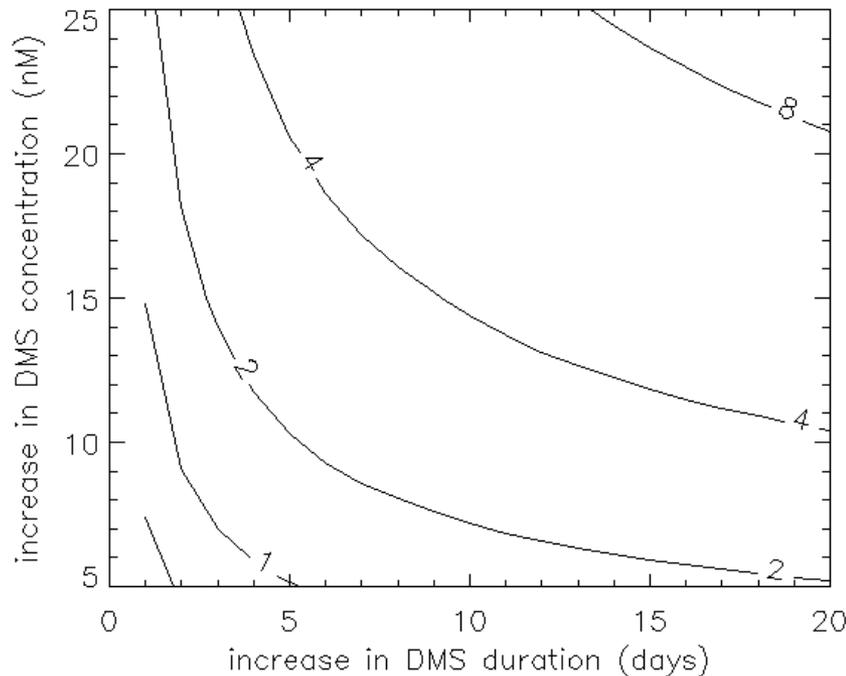


# Coccolithophore DMS from Earth observation

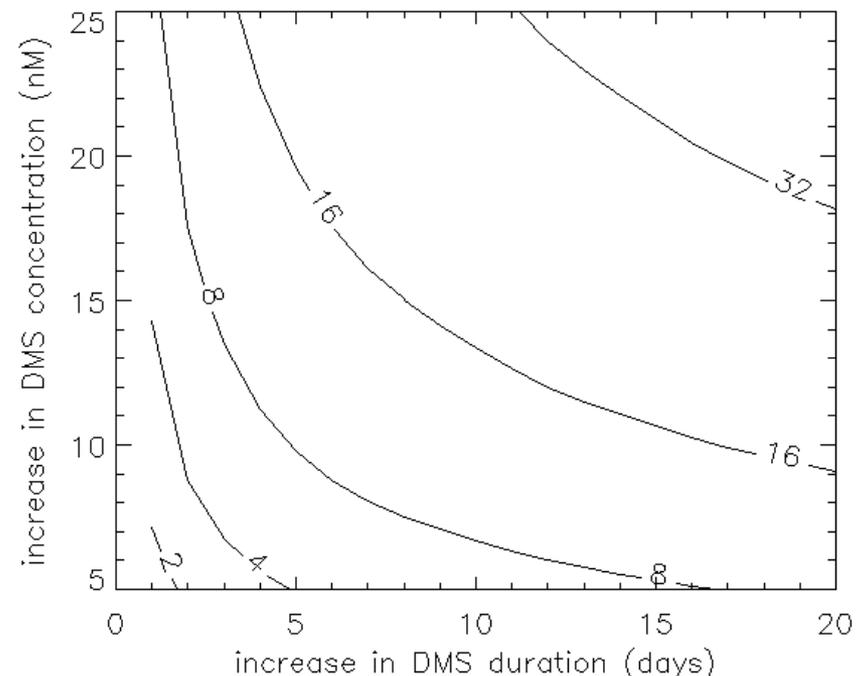
- Coccolithophores have a large intracellular concentration of DMS, the main source of sulphur to the remote marine atmosphere and thought to be important to aerosol formation and climate
- Elevated DMS concentrations have been observed in coccolithophore blooms, though little is known about the magnitude or duration of this effect
- We have performed a sensitivity analysis, examining the effect of coccolithophores observed from space on DMS fluxes
- The effect is small compared with annual fluxes over the whole north Atlantic, but is more important regionally and seasonally

# Coccolithophore DMS from Earth observation

## Percentage increase in DMS flux due to coccolithophores



N Atlantic annual mean flux



NE quadrant July mean flux

Land, P. E., Shutler, J. D., Bell, T. G., Yang, M., (2014) Exploiting satellite Earth observation to quantify current global oceanic DMS flux and its future climate sensitivity, *J. Geophys. Res.:Oceans* 10/2014; DOI: 10.1002/2014JC010104

# Conclusions

- We used Earth observation, model and in situ data to estimate the effect of coccolithophores on CO<sub>2</sub> and DMS fluxes in the N Atlantic
- It is important to account for the effect of calcification on the N Atlantic CO<sub>2</sub> sink
- If not estimated, it should at least be included as a source of uncertainty
- Coccolithophores seem less important to DMS fluxes, but further work is needed to constrain the effect