Simulated Distribution of Marine Dimethyl Sulfide using Explicit *Phaeocystis*

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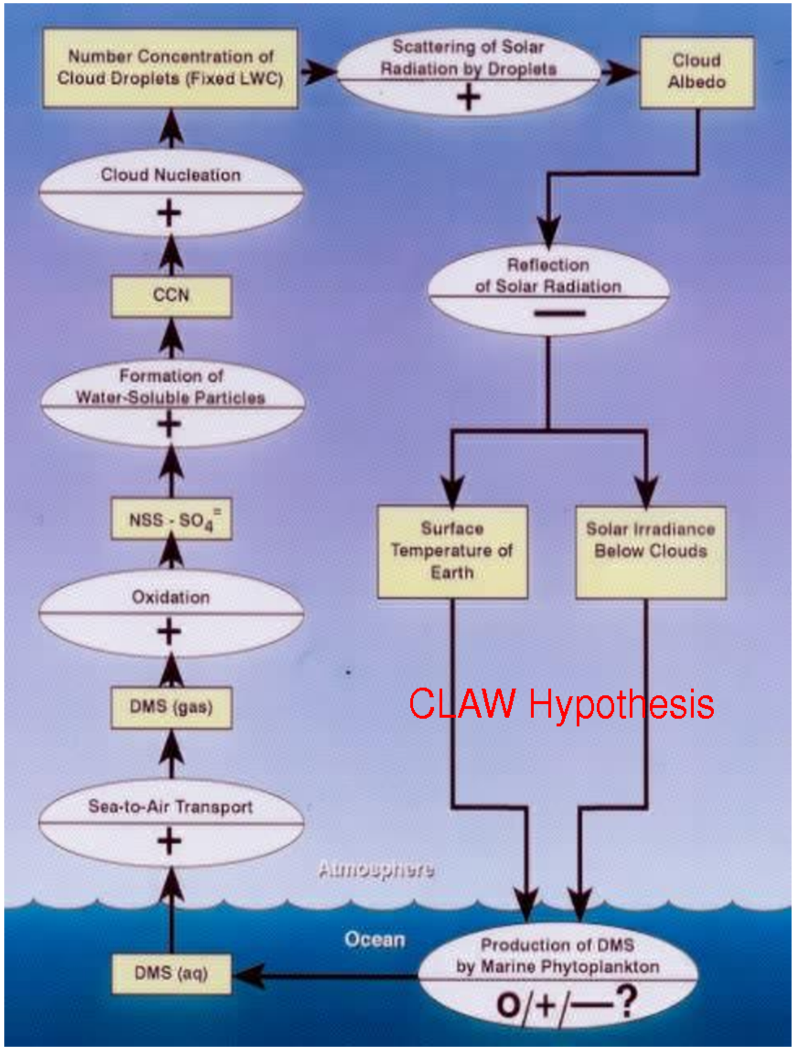
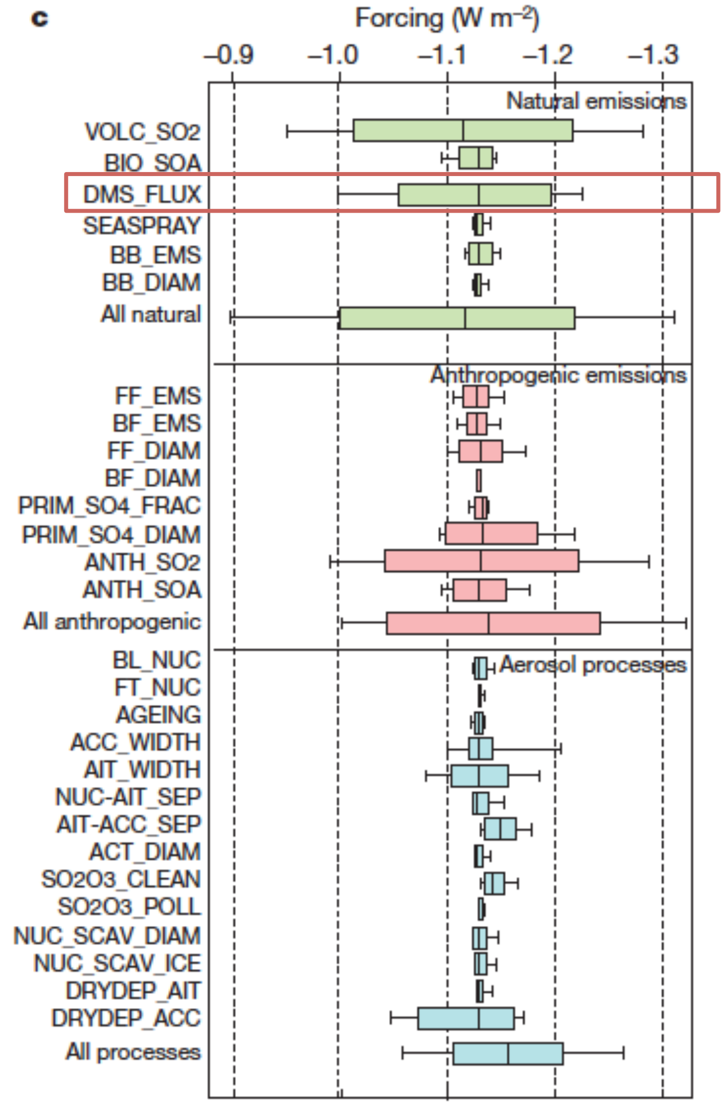
Background

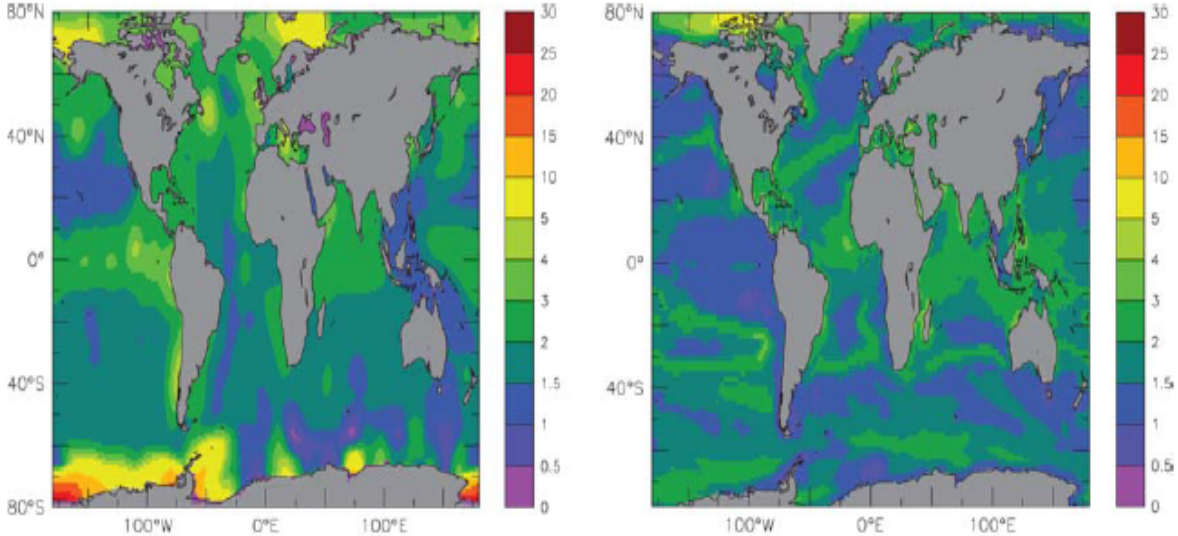


The CLAW Hypothesis
(Charlson et al., 1987)



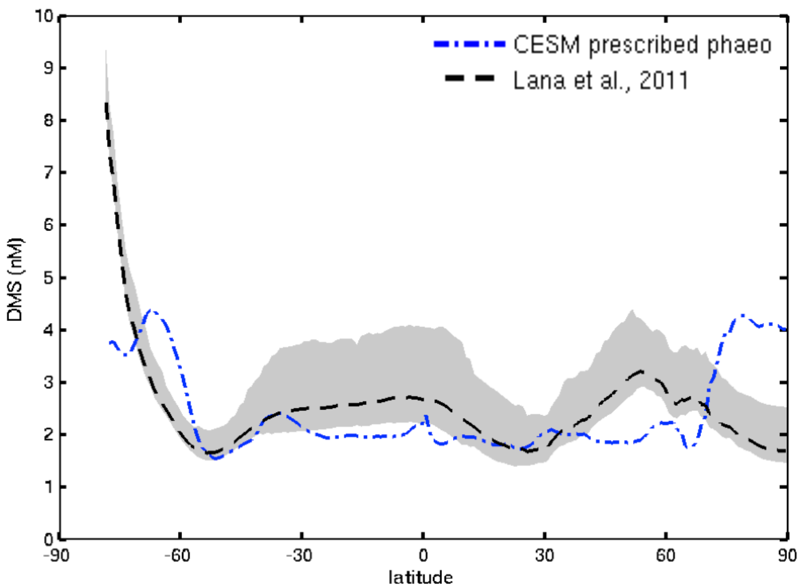
Magnitude and sources of uncertainty in aerosol first indirect forcing (Carslaw et al., 2013)

Background



(a) DMS Kettle (nM) (Vogt et al., 2010) (b) DMS PlankTOM5 (nM)

The underestimated DMS concentrations at high latitudes are potentially due to the absence of an explicit *Phaeocystis* group (Vogt et al., 2010)



(Wang et al., submitted)

In the earlier DMS module, *Phaeocystis* was simulated implicitly as a fraction of the global small phytoplankton. The simulated time and location of DMS peaks are biased.

Previous studies

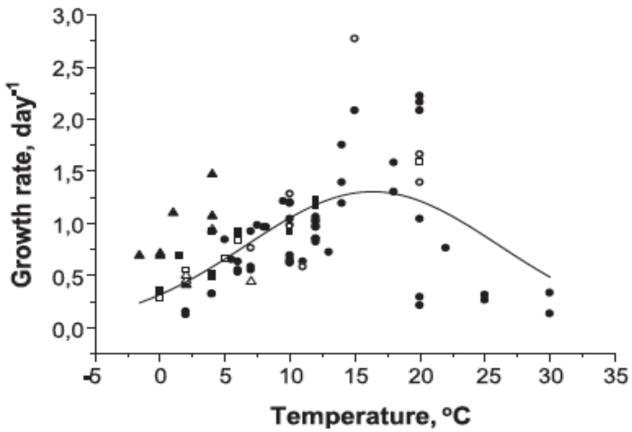
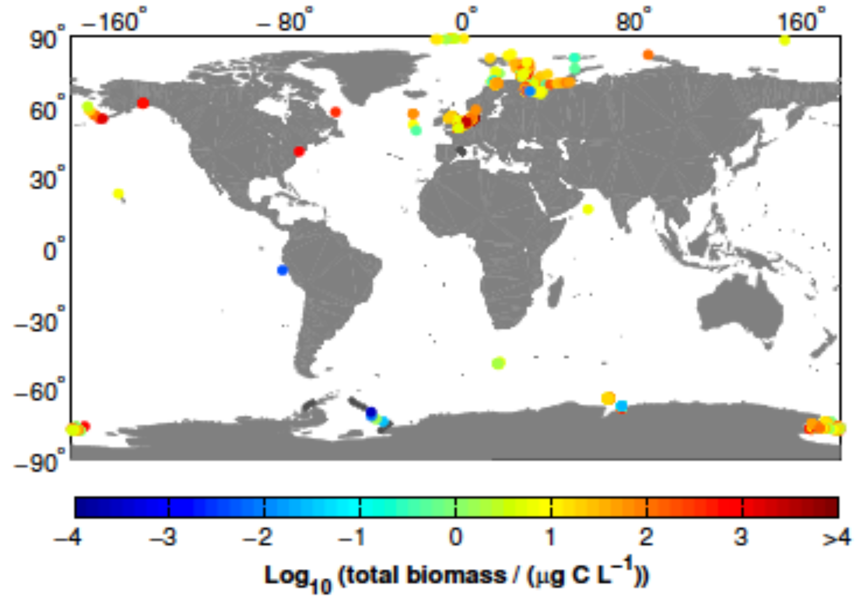
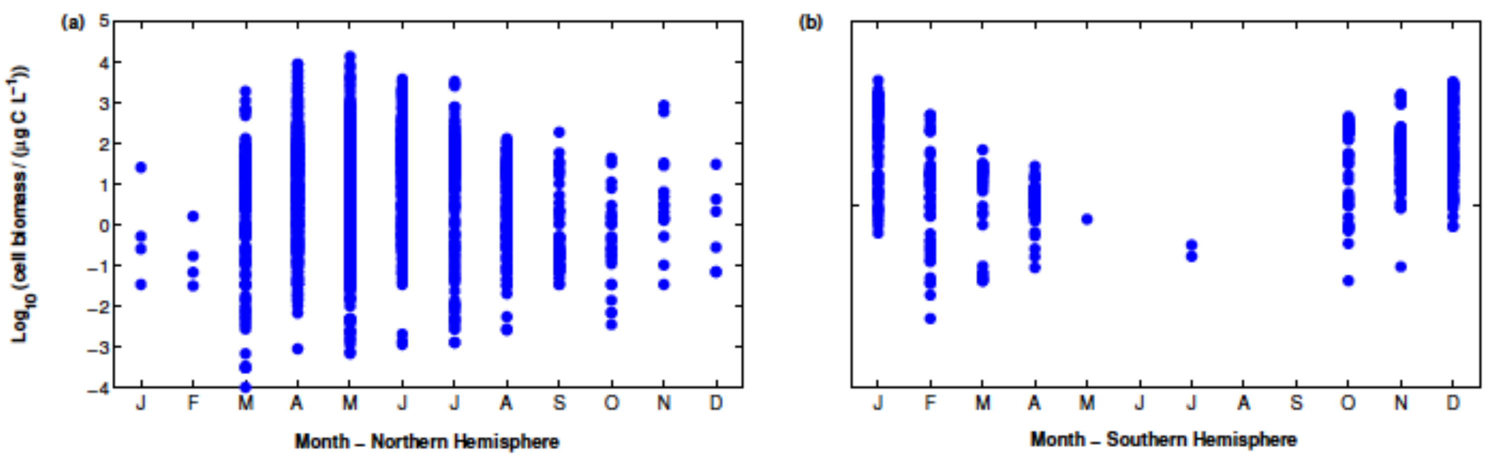


Fig. 3. Relationship between *Phaeocystis* specific growth rate μ and temperature (μ=ln2*υ, with υ=division rate). The closed and the open symbols represent colony cells and solitary cells data, respectively. Squares, circles and triangles represent data for *P. pouchetii*, *P. globosa* and *P. antarctica*, respectively.

(Schoemann et al., 2005)



(Vogt et al., 2012)



(Vogt et al., 2012)

Incorporating *Phaeocystis*

- Two groups of *Phaeocystis*: One group for northern species, combining *P. globosa* and *P. pouchetii*; One group of *P. antarctica*
- Only the blooming colonial form considered

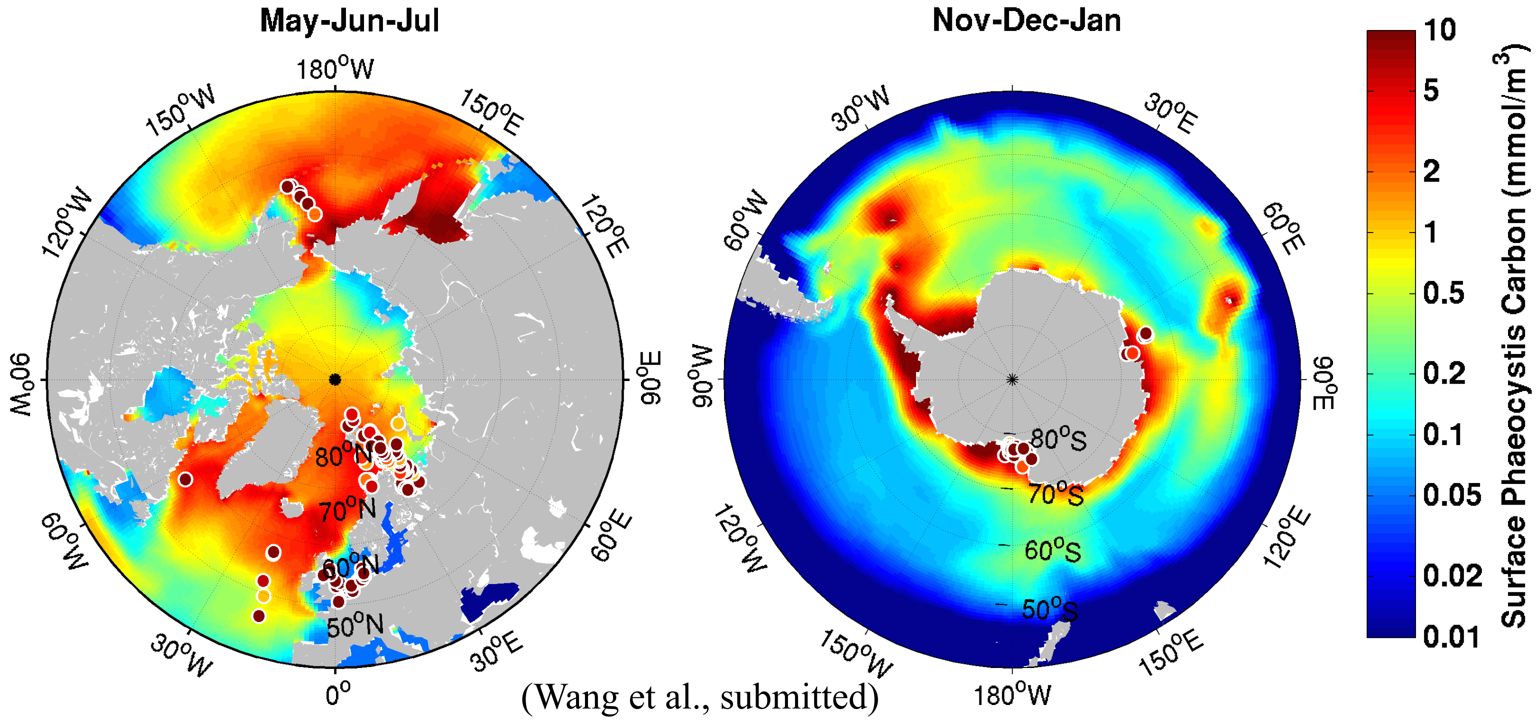
$$PCmax = PCmax \times min(1, \frac{(thres - TEMP)}{(thres - Tpeak)})$$

$$PCmax \; = \; max(PCmax, 0)$$

$$graze = Zumax \times zooC \times \frac{phaeoC}{(phaeoC + diatC + Zgrz)}$$

- The values of T_{peak} are 16.3 °C and 5 °C in NH and SH, respectively
- Grazing on *Phaeocystis* or diatoms is influenced by the total biomass of both groups
- In general, our preferred physiological parameters suggest that *Phaeocystis* is well adapted to low-light and nutrient-rich conditions

Simulated *Phaeocystis*



(Wang et al., submitted)

- In general, the model does a reasonable job reproducing the observed seasonality and spatial distributions of *Phaeocystis*
- Simulated *Phaeocystis* biomass cannot reproduce the extreme high concentrations sometimes reported in field studies due to averaging in large grid and underestimated surface nutrients
- Incorporating *Phaeocystis* has minor impacts on global primary production and export production

DMS module

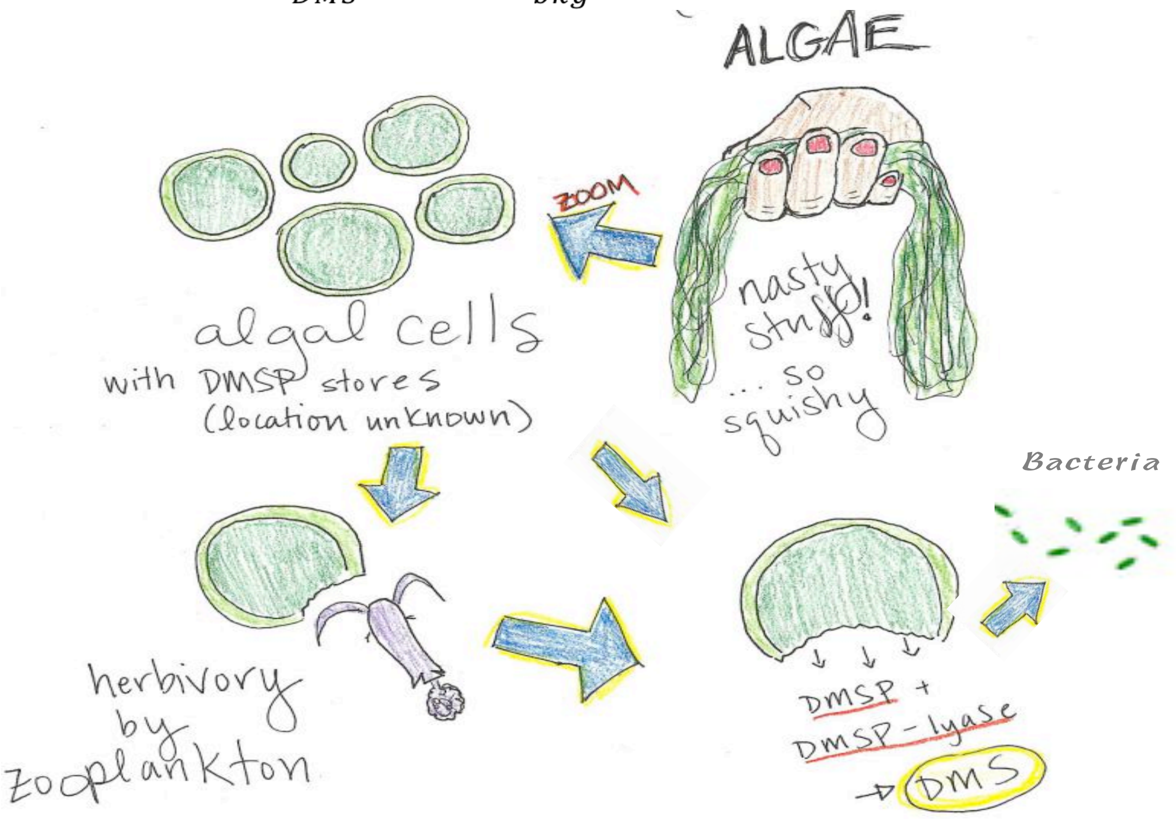
$$Prod^{DMSP} = scale \times \left(\sum_i Prod_i^{DMSP} + Prod_Z^{DMSP} + Prod_{phaeo-dir}^{DMSP}\right)$$

$$Prod^{DMS} = yield \times k \times Prod^{DMSP}$$

$$Loss^{DMS} = Loss_B^{DMS} + Loss_{bkg}^{DMS} + Loss_{photo}^{DMS}$$

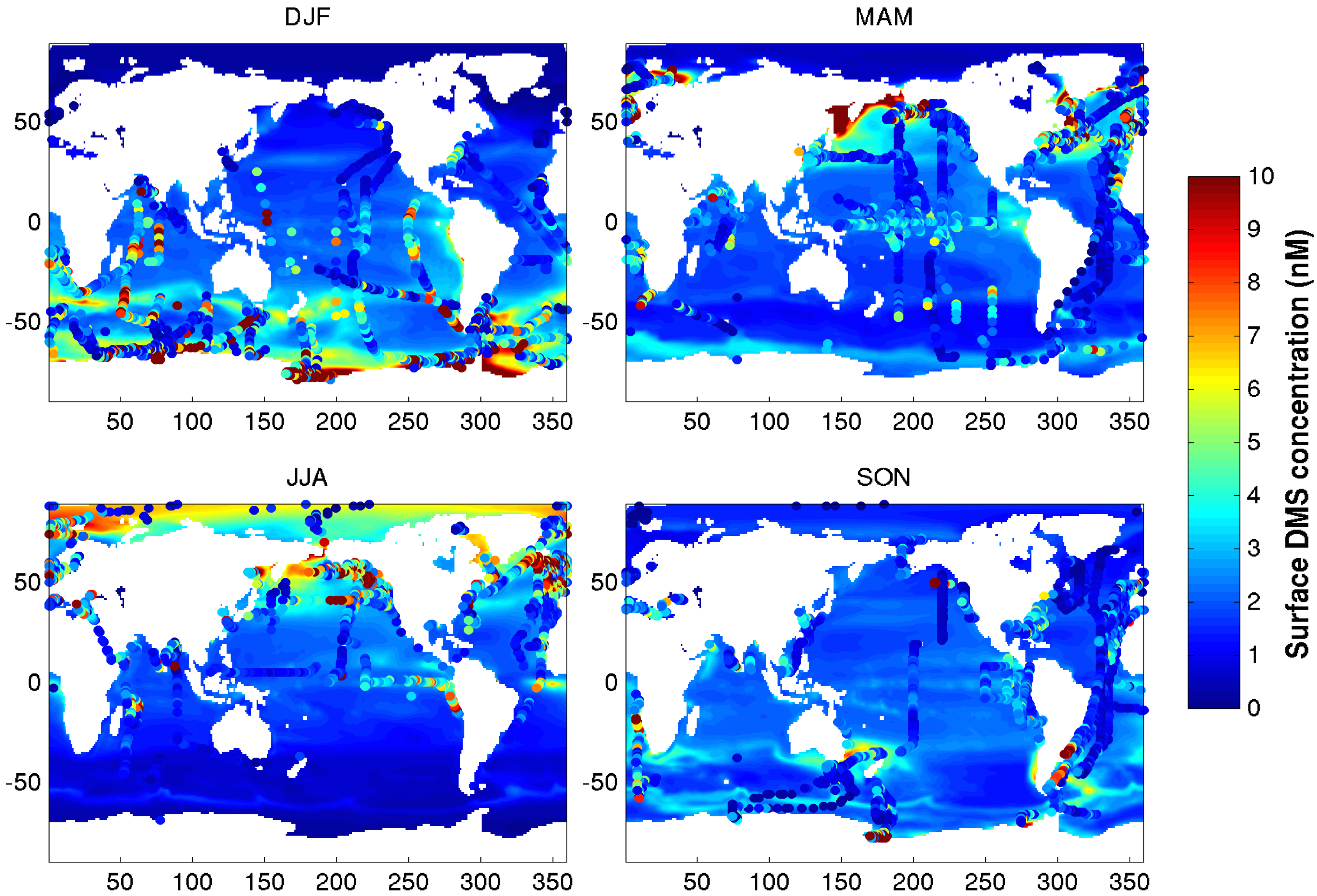
$$Loss^{DMSP} = Loss_{DMS}^{DMSP} + Loss_{bkg}^{DMSP}$$

Simulations:
POP and CICE: ~ 1°
Hindcast simulations
Spinup: 580yr
Run time: 40 yr
Analysis: 1990 – 2009
Explicit Phaeocystis



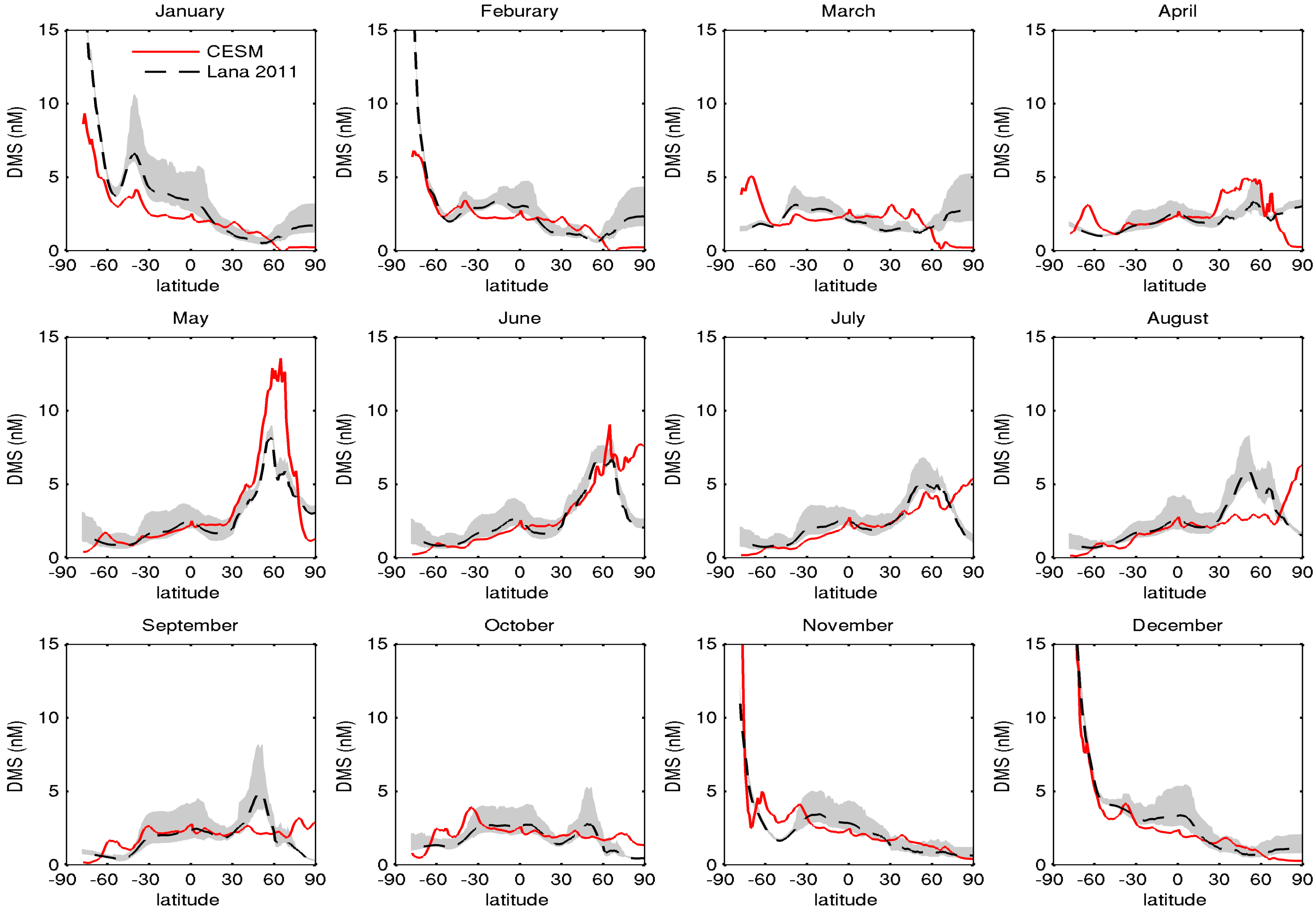
(Modified based on https://culturingscience.wordpress.com)

Simulated DMS



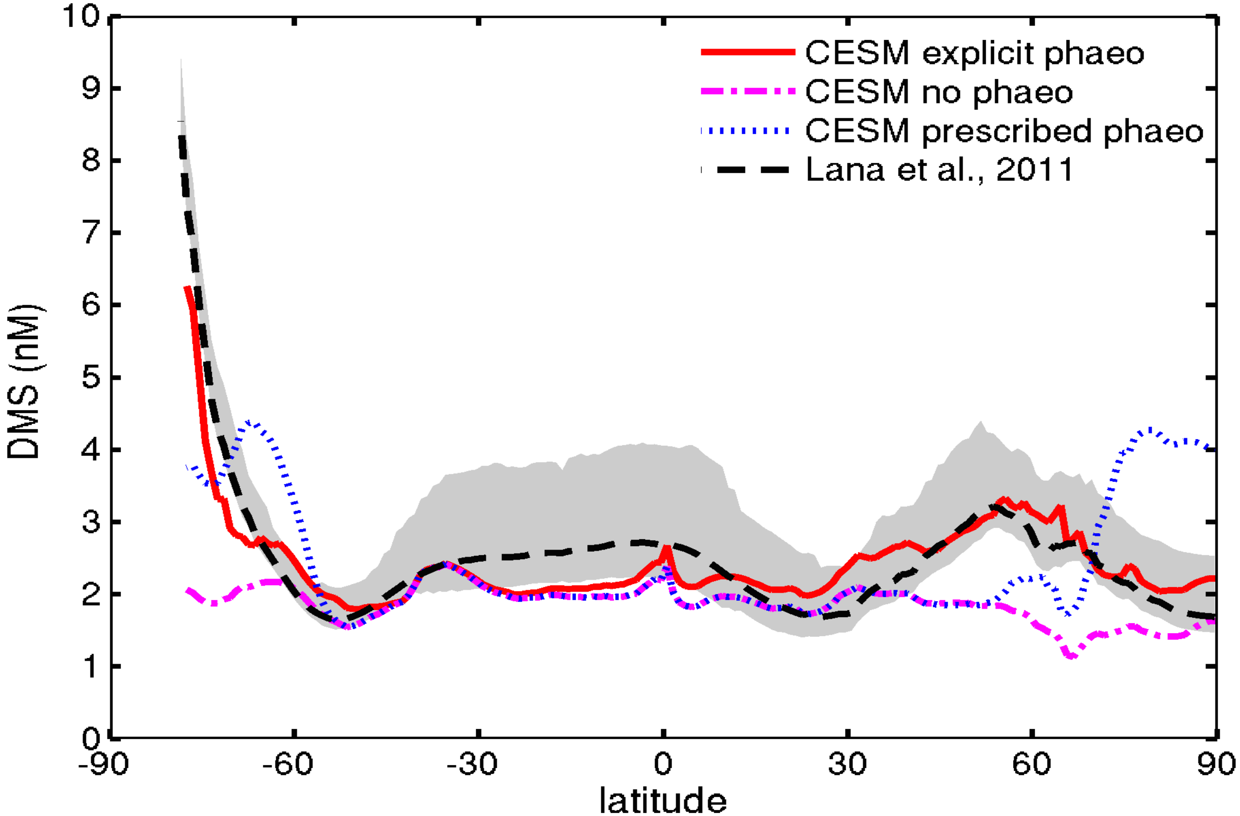
DMS maximum in the North Pacific in May and along the Antarctic coast in December, in agreement with *Lana et al*. (2011)

Simulated DMS



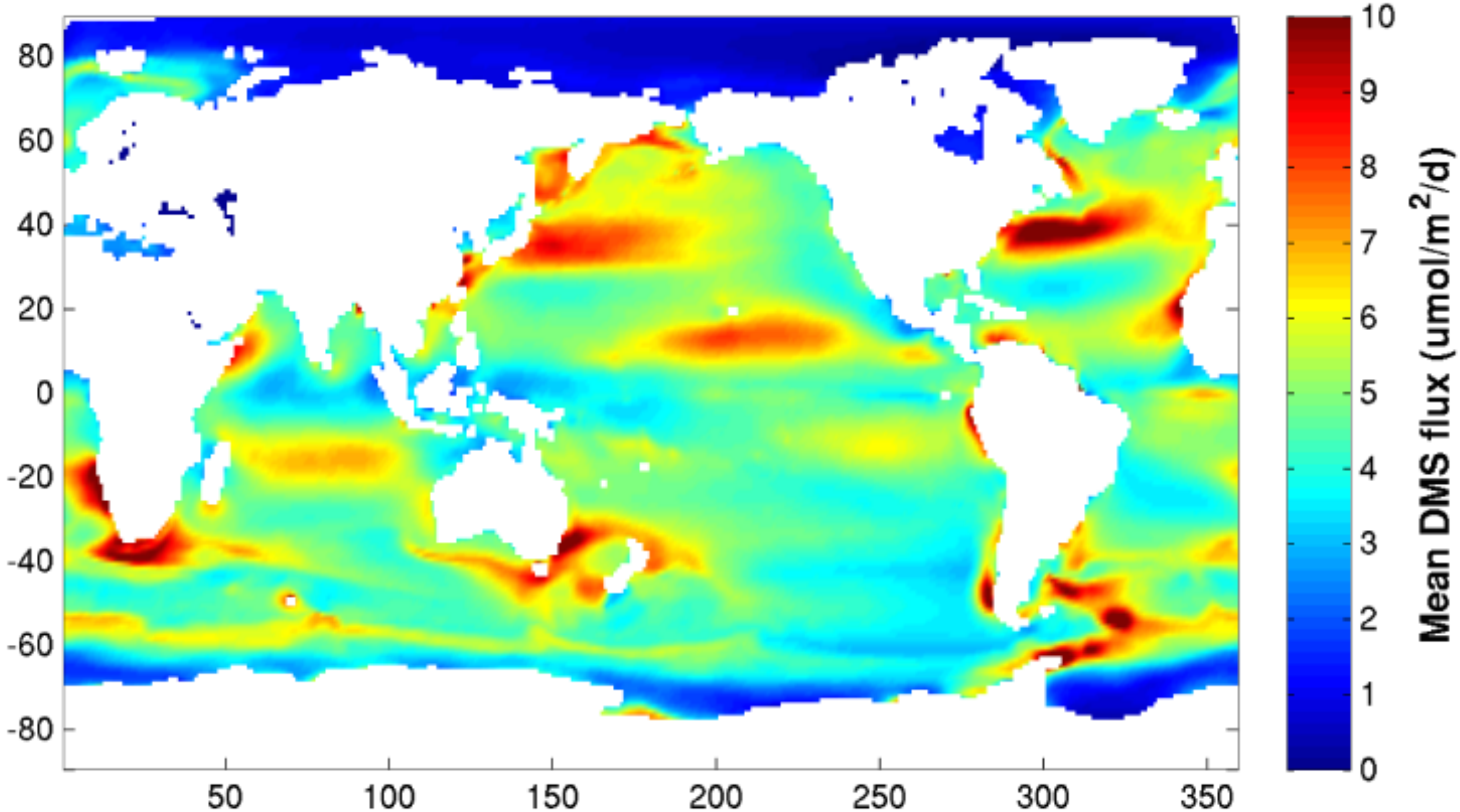
Simulated DMS shows strong bloom behavior at high latitudes, but weak seasonal cycling at low latitudes

Zonal DMS distributions



- The simulated average DMS concentration for the surface ocean is 2.26 nM, comparable to data-based estimate of 2.34nM
- Zonal mean DMS is clearly improved, and matches the observation-based estimate closely, with observed DMS peaks between 50° − 60° N and south of 60° S well reproduced
- *Phaeocystis* account for 17% of annual surface DMS production across the globe while contributing only 6.5% of primary production.

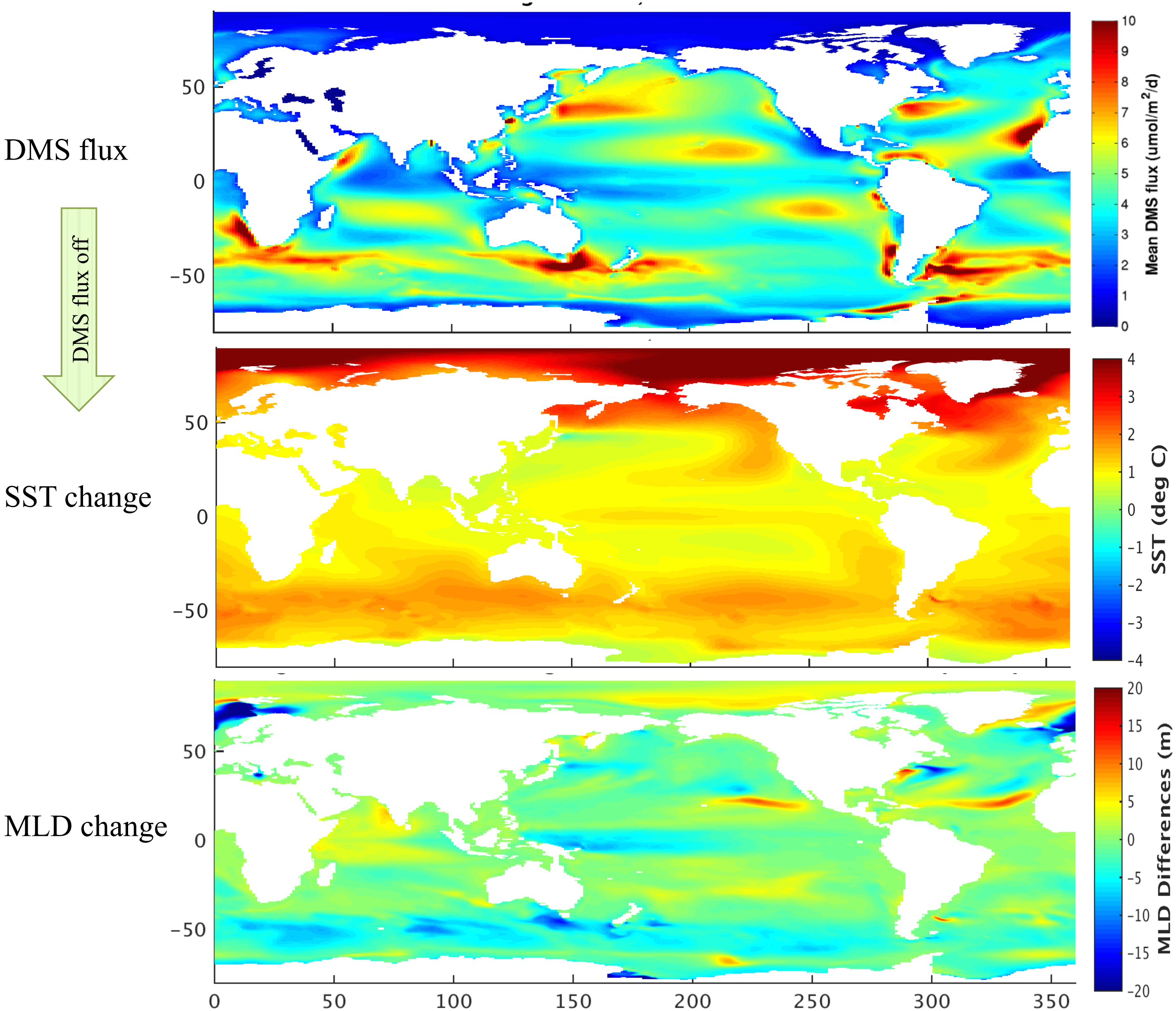
Annual DMS flux



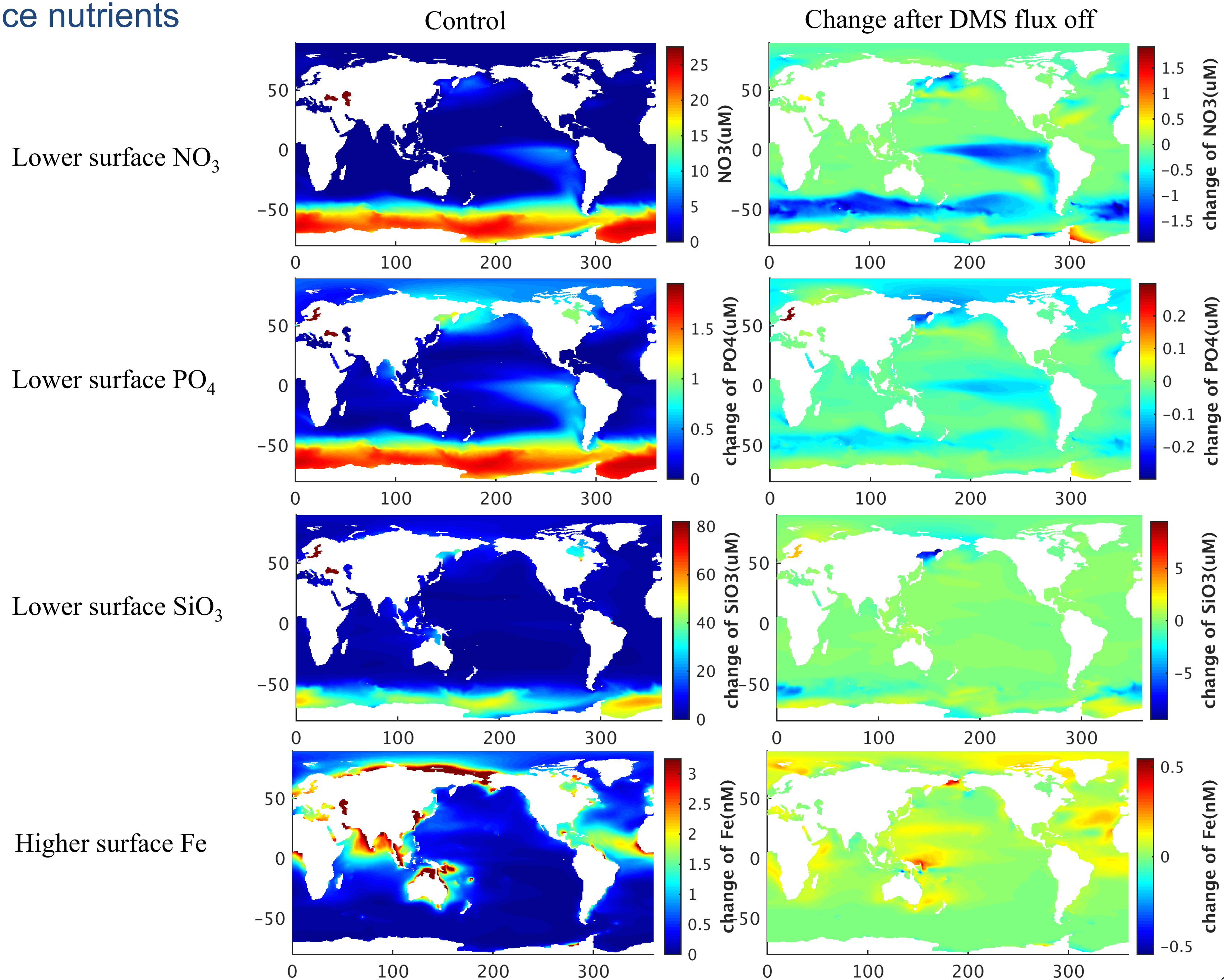
- The global annual DMS flux is 20.3 Tg S/yr in our simulation, falling on the lower side of previous estimates
- Cause: the multicomponent sea-air gas transfer parameterization developed in *Elliott*, (2009), which considers Henry's Law solubility and reduces DMS bubble transfer channel accordingly

More simulations

2100 time slices with and without DMS emission to atmosphere (average of the last 50 year)



Surface nutrients



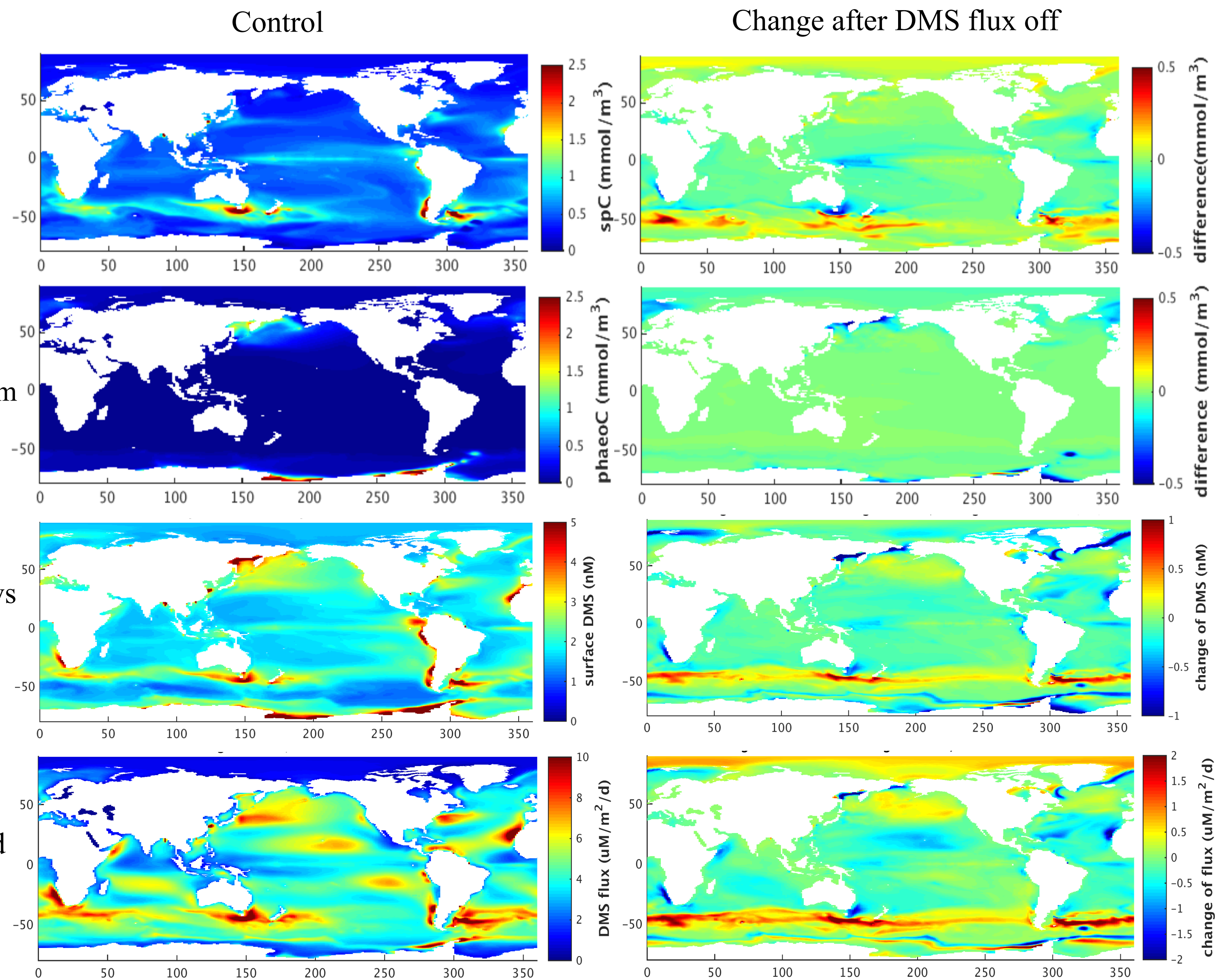
Phytoplankton and DMS

Small phytoplankton
Increase 40 - 60 °S

Phaeocystis decrease
Similar change to diatom

DMS difference follows
marine ecosystems

DMS flux also affected
by wind and sea ice



There is no uniform feedback patterns. CLAW is complicated.

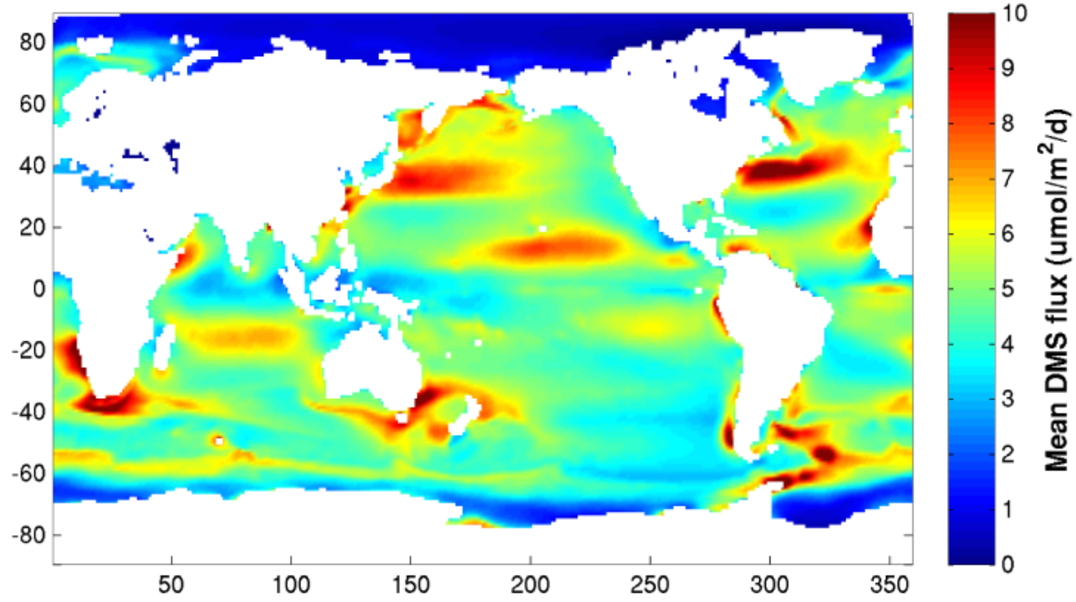
Summary

- Simulated *Phaeocystis* biomass generally agrees with observations
- Given the new explicit *Phaeocystis* representation, the DMS distribution shows significant improvements, especially regarding the amplitude and location of high latitude peaks
- The simulated mean surface DMS value is 2.26 nM, comparable to data-based estimate.
- The total oceanic DMS emission to the atmosphere is 20.3 Tg S/yr
- Fully coupled CESM simulations suggest nonuniform feedback patterns, combining responses of atmospheric conditions and marine ecosystems

Thank you!

Annual DMS flux

Latitude	*Lana et al.* (2011)	Simulated DMS flux	without *Phaeocystis*
90 – 80 N	0.0	0.0	0.0
80 – 70 N	0.1	0.2	0.1
70 – 60 N	0.2	0.2	0.1
60 – 50 N	0.9	0.6	0.4
50 – 40 N	1.5	1.0	0.7
40 – 30 N	1.5	1.4	1.1
30 – 20 N	1.4	1.4	1.2
20 – 10 N	2.6	2.0	1.7
10 – 0 N	2.6	1.8	1.5
0 – 10 S	2.2	1.8	1.6
10 – 20 S	3.5	2.1	1.9
20 – 30 S	3.0	1.7	1.6
30 – 40 S	2.7	2.1	2.1
40 – 50 S	2.8	1.8	1.7
50 – 60 S	2.1	1.5	1.3
60 – 70 S	0.9	0.7	0.6
70 – 80 S	0.1	0.1	0.1
80 – 90 S	0.0	0.0	0.0
Total	28.1	20.3	17.9



- The global annual DMS flux is 20.3 Tg S/yr in our simulation, lower than the estimated flux of 28.1 Tg S/yr by *Lana et al*. (2011) using the piston scheme suggested by *Nightingale et al.* (2000).
- Cause of the difference: the multicomponent sea-air gas transfer parameterization developed in *Elliott*, (2009), which considers Henry's Law solubility and reduces DMS bubble transfer channel accordingly