Investigating why DMS production consistently decreases in acidified ocean experiments

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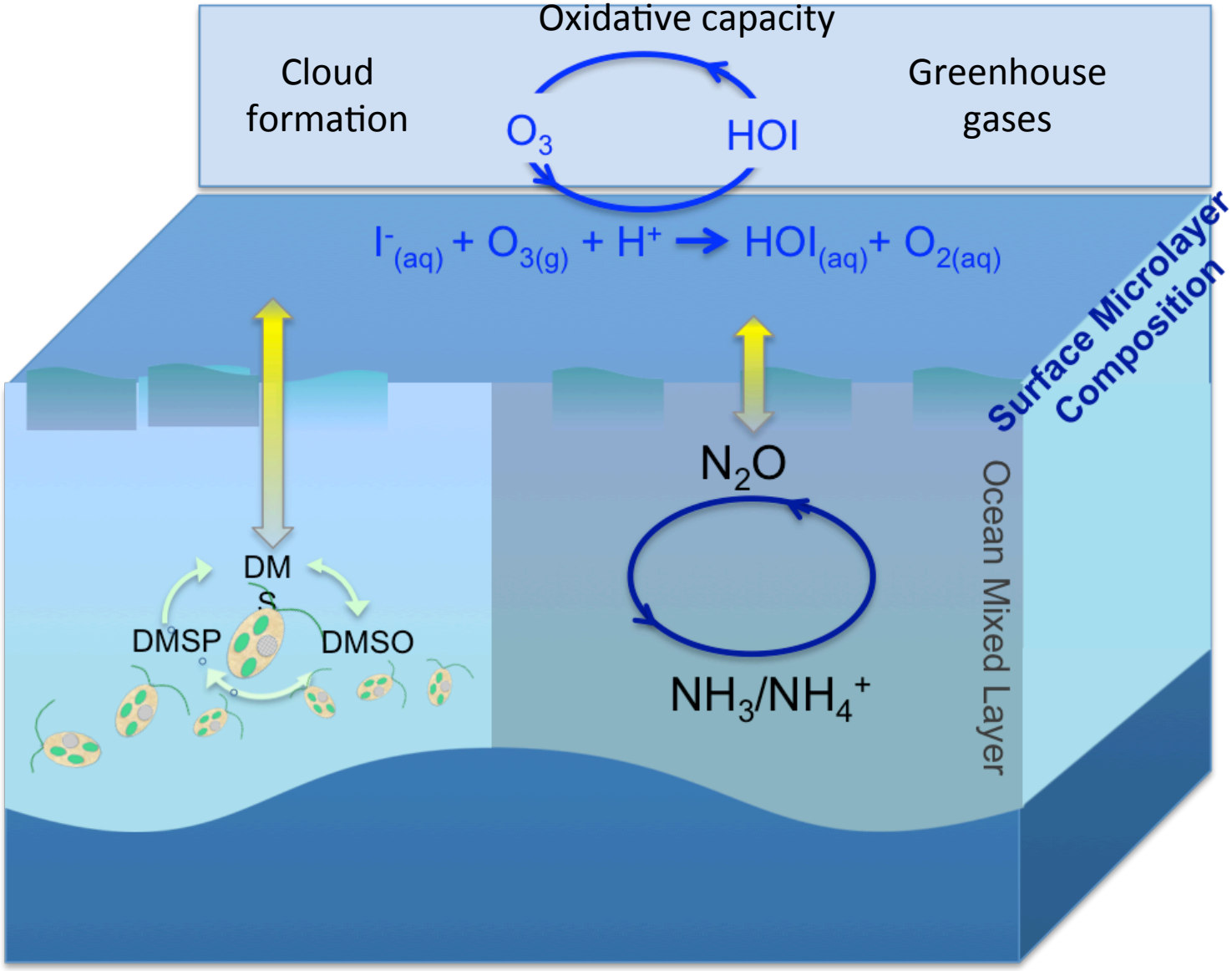
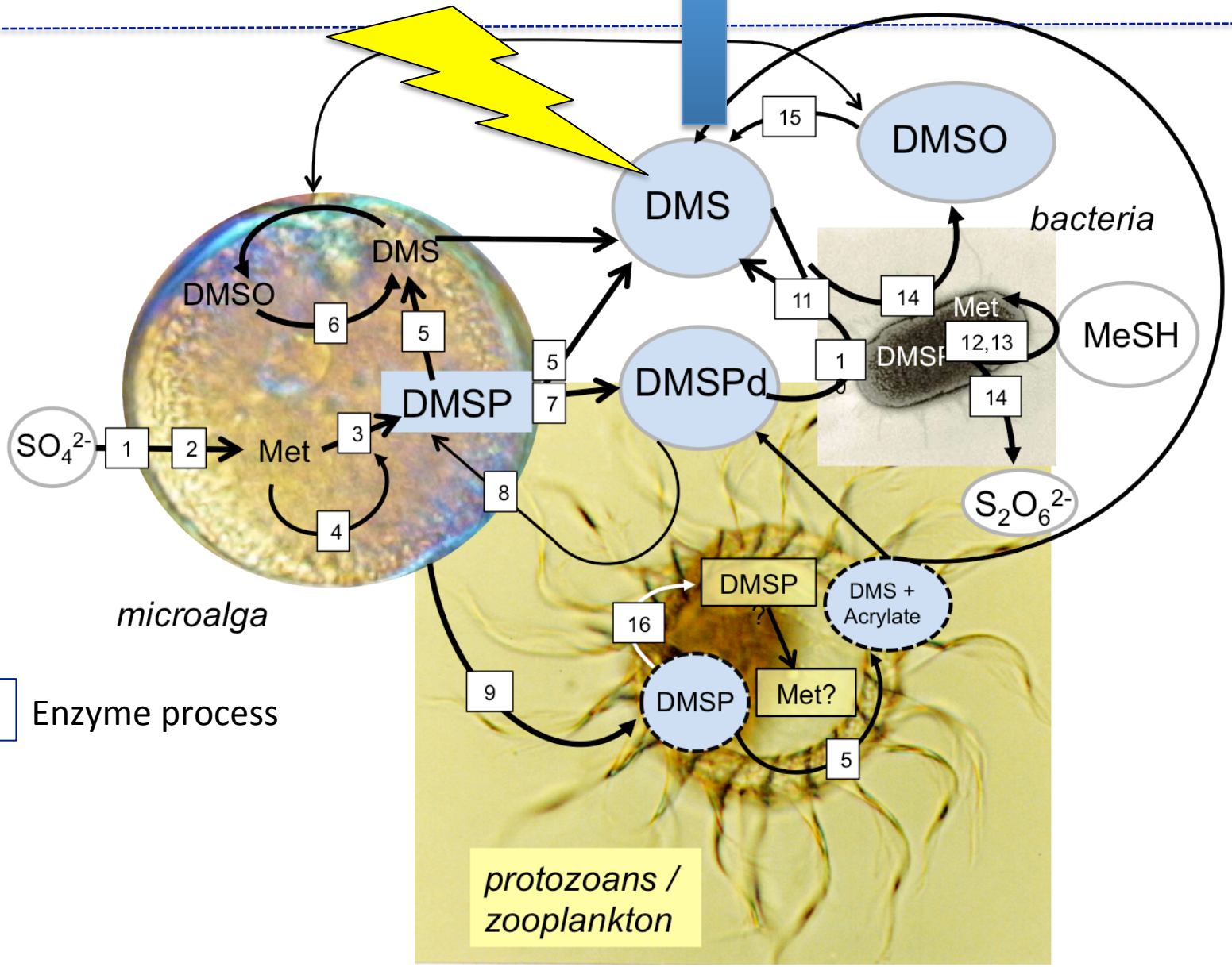
Potential impacts of OA on air-sea trace gas exchange

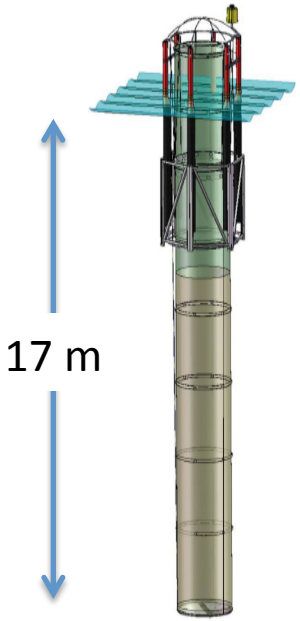


Microbial DMS, DMSP and DMSO cycling



Carpenter et al. 2012. Chem. Soc. Rev.

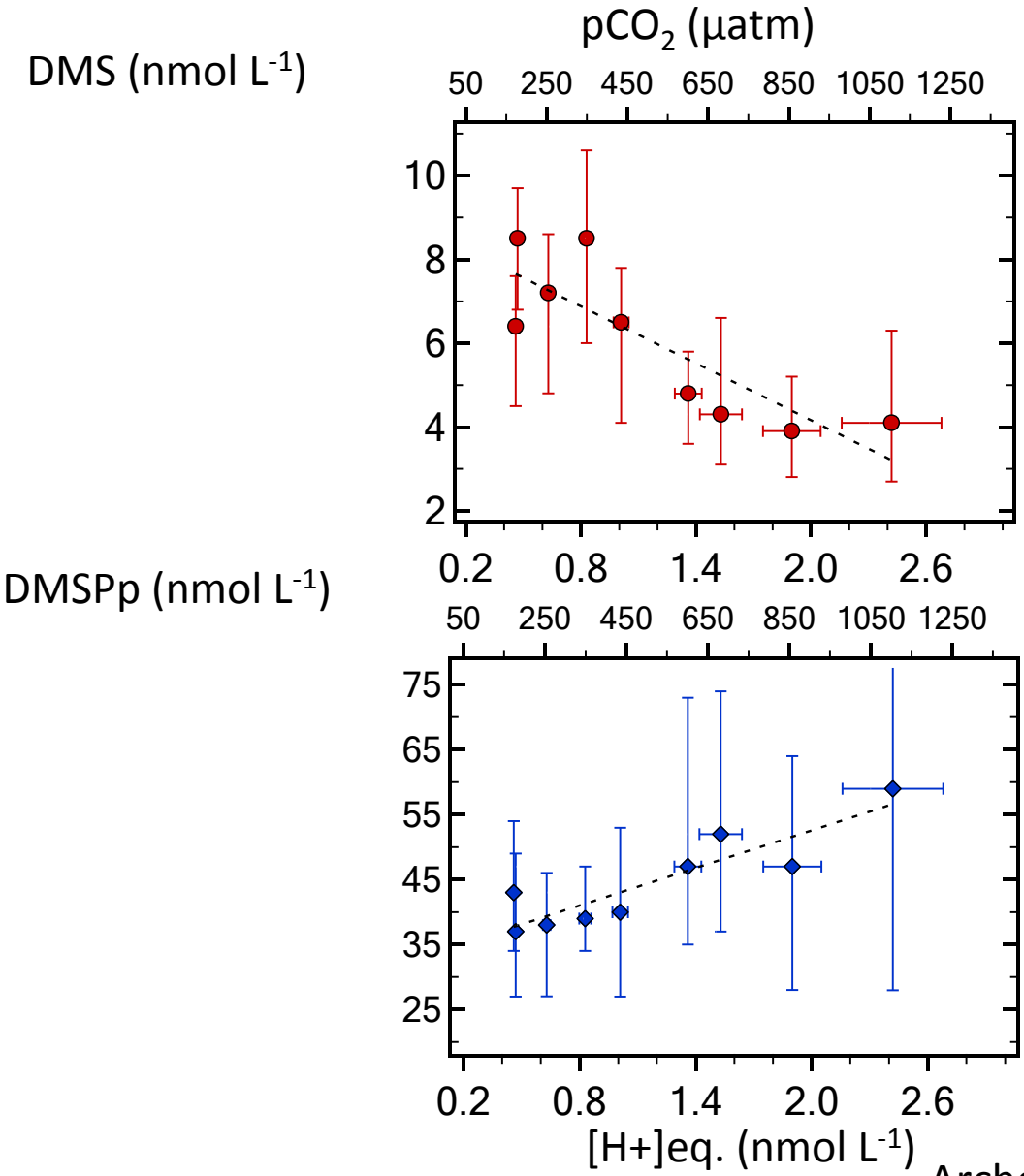
Acidification in a bag: a ‘community-level response’



- 9 mesocosms: 50 - 60 m^3
- CO_2-saturated seawater additions
- pCO_2 gradient : 190 to 1300 µatm
- 33 days

Svalbard – EPOCA mesocosm experiment

Arctic experiment: [DMS] vs. [H^+]



35 ± 11 % decrease in [DMS] at 750 µatm

Despite a 30 % increase in [DMSP]

Archer, et al. 2013. Biogeosciences

Responses of DMS by different communities

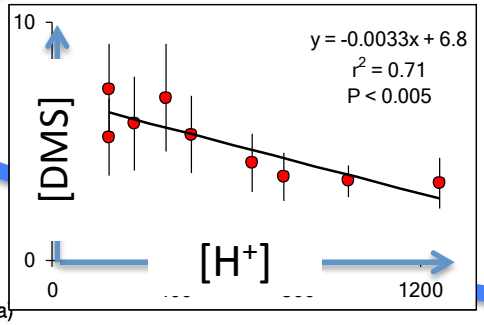
Summary of mesocosm studies of OA on DMS and DMSP

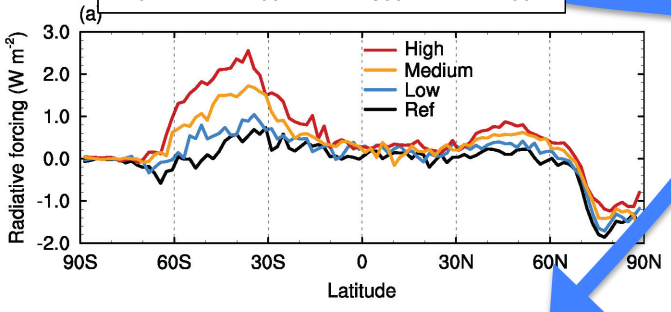
Location	pCO_2 range (ppmv) (and temperature)	% DMS change from present	% DMSP change from present	Study
Norwegian coastal mesocosm	300 vs 750 (7 to 9°C)	~ 40 % lower	40 % lower (P< 0.05) [1]	Avgoustidi 2007
Norwegian coastal mesocosm	300 vs 750 vs 1050 (9 to 12 °C)	not different at P < 0.05 [1]	not significantly different at P < 0.05 [1]	Vogt et al. 2008
Norwegian coastal mesocosm	350 vs 750 (7 to 10 °C)	54% lower	24 % lower [3]	Hopkins et al 2010
Norwegian coastal mesocosm	280 to 1400 (cool-temperate)	~50 % lower	reduced	Webb et al. 2012
Baltic coastal mesocosm	280 – 1400 (cool-temperate)	~10 % lower	?	Webb et al. 2012
Korean coastal mesocosm	400 vs 900 (14-11°C) and 900 ppm + 3 °C	80 % higher 60 % higher	increased DMSP:POC	Kim et al. 2010
Arctic coastal mesocsoms	190 to 750 ppmv (2 – 5 °C)	35 (±11) % lower [4] (P< 0.005)	30 (± 3) % higher [4] (P< 0.005)	Archer et al. 2013
Korean coastal mesocosm	200 to 800 (14-11°C)	50 % lower	50 % decrease	Park et al. 2013

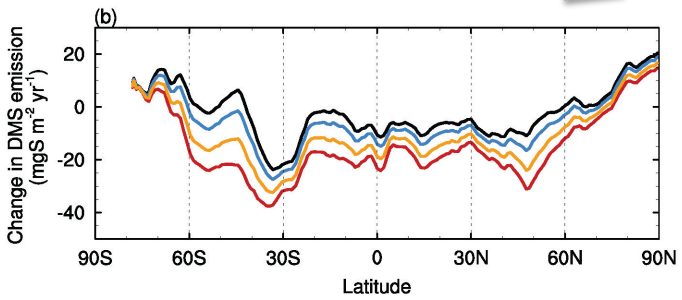
Archer, et al. 2013. Biogeosciences

What might the atmospheric implication be?

Global warming amplified by reduced sulphur fluxes as a result of ocean acidification. Six et al. *Nature Climate Change 2013.*





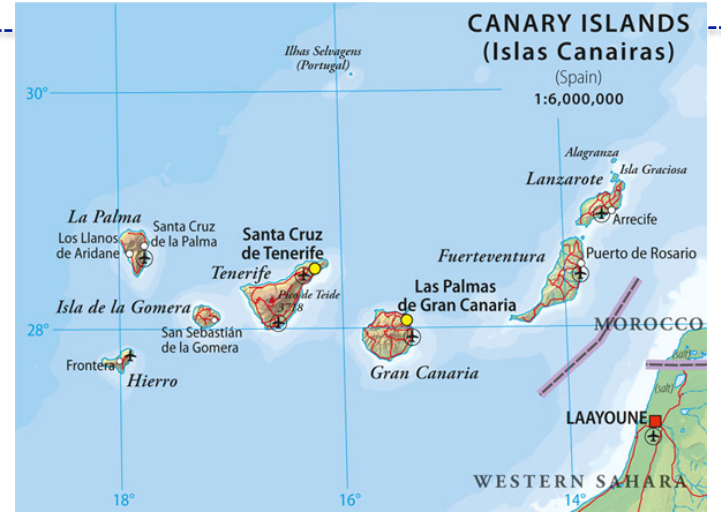


MPI-ESM

2x atmospheric CO_2 - 3.71 W m^{-2}

17% reduced global DMS emission – 0.40 W m-2

Acidification in the tropical Atlantic



2nd Attempt

Three phases in the experiment

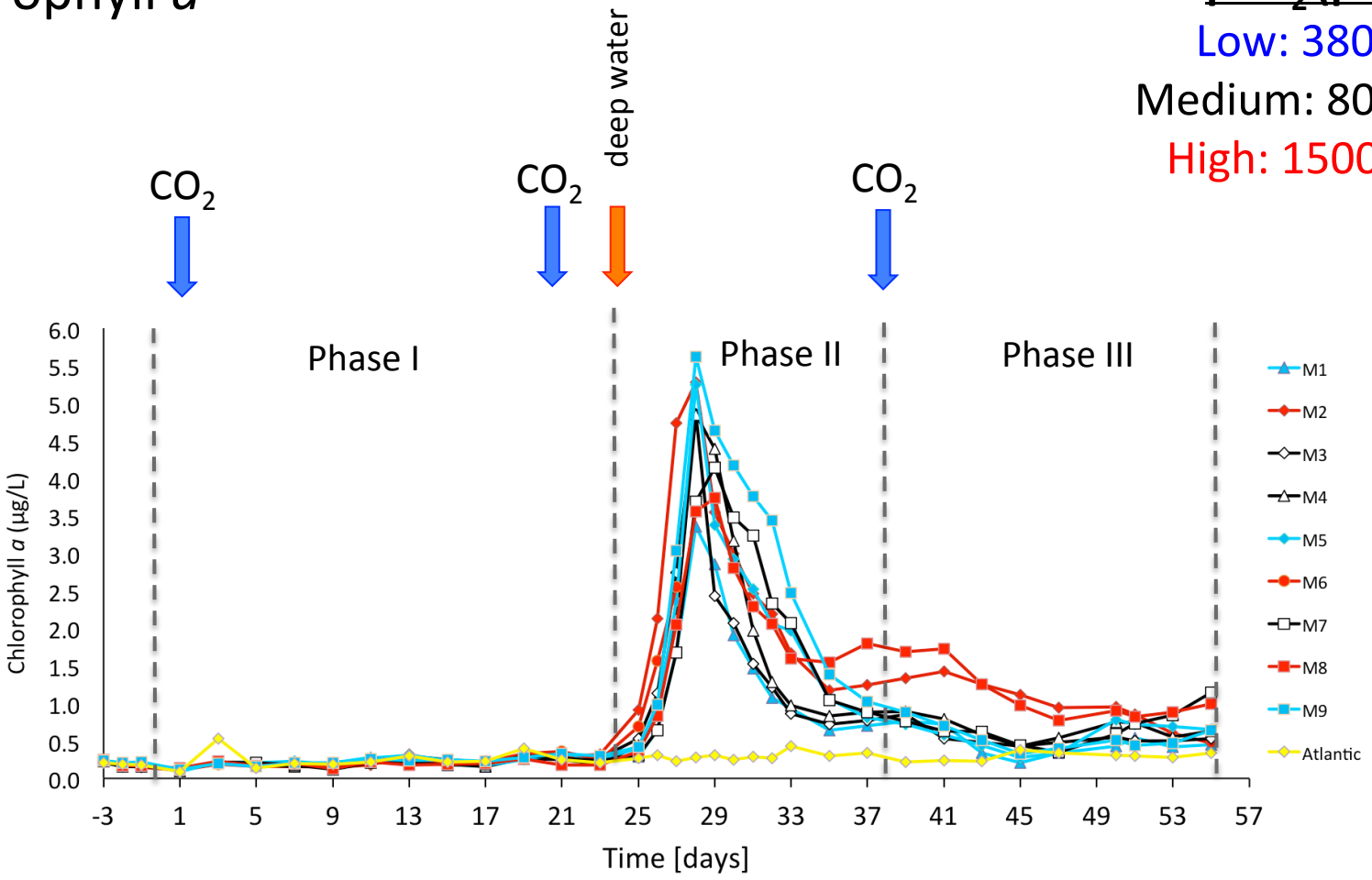
Chlorophyll *a*

pCO_2 (µatm)

Low: 380-600

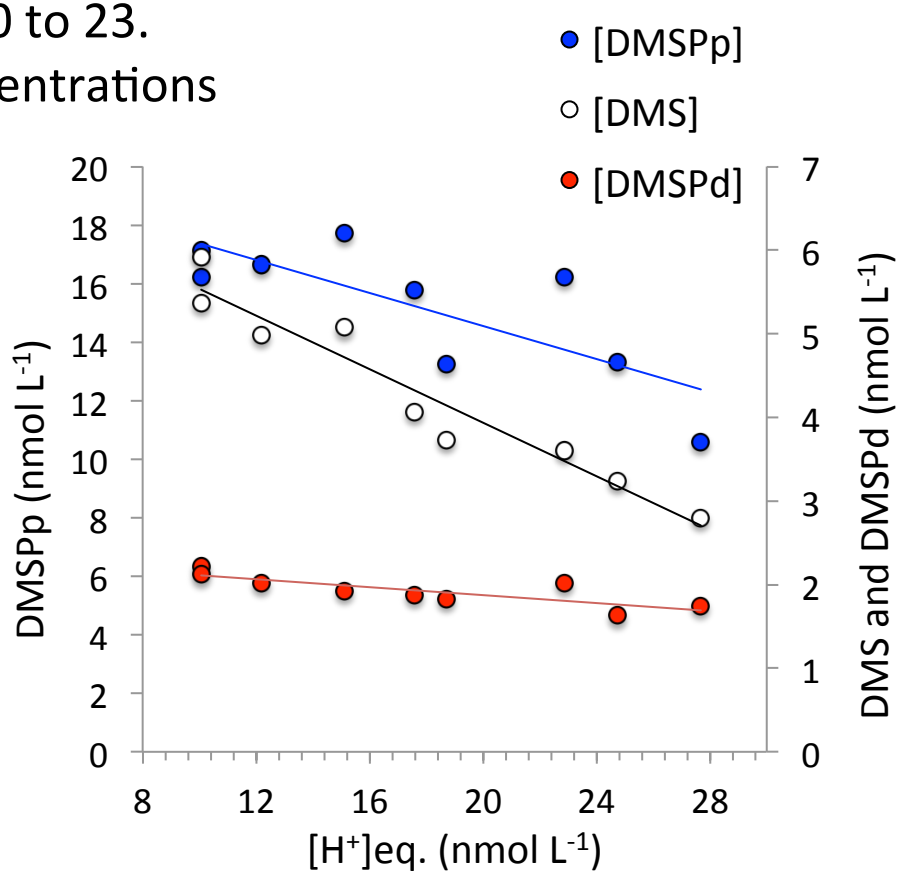
Medium: 800 -1250

High: 1500-2000



The community DMS response

Phase 1: days 0 to 23.
averaged concentrations



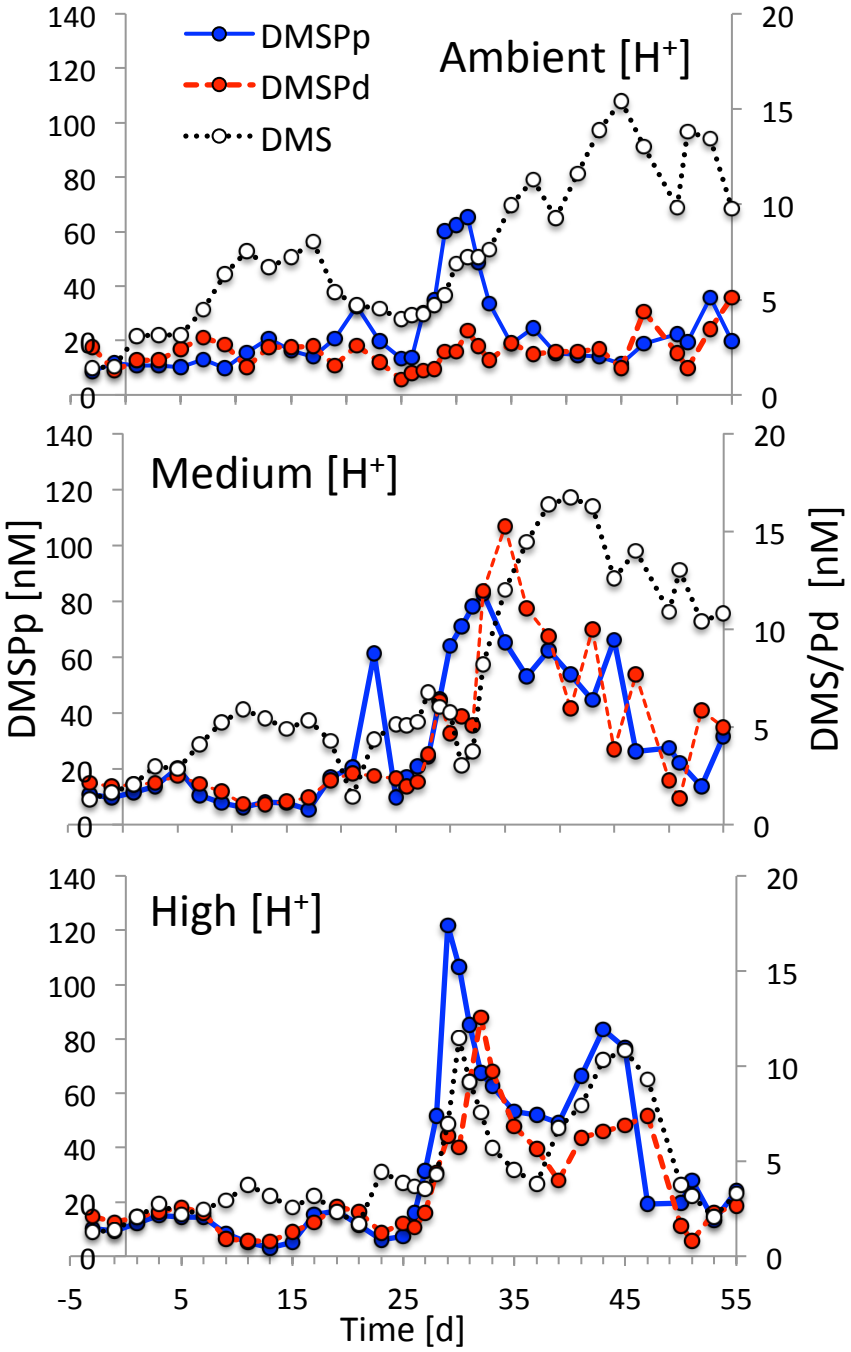
Suggests a 30 % decrease in [DMS] at 750 µatm

Temporal progression DMS, DMSPp and DMSPd

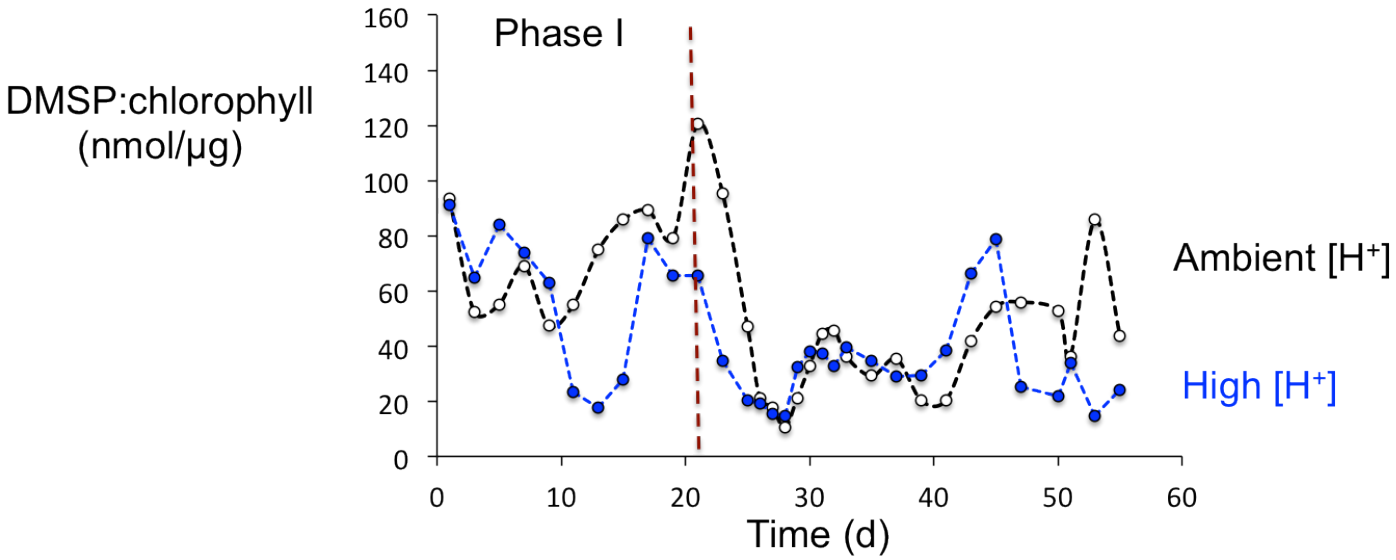
Higher DMS at ambient [pCO_2] in early and late phases

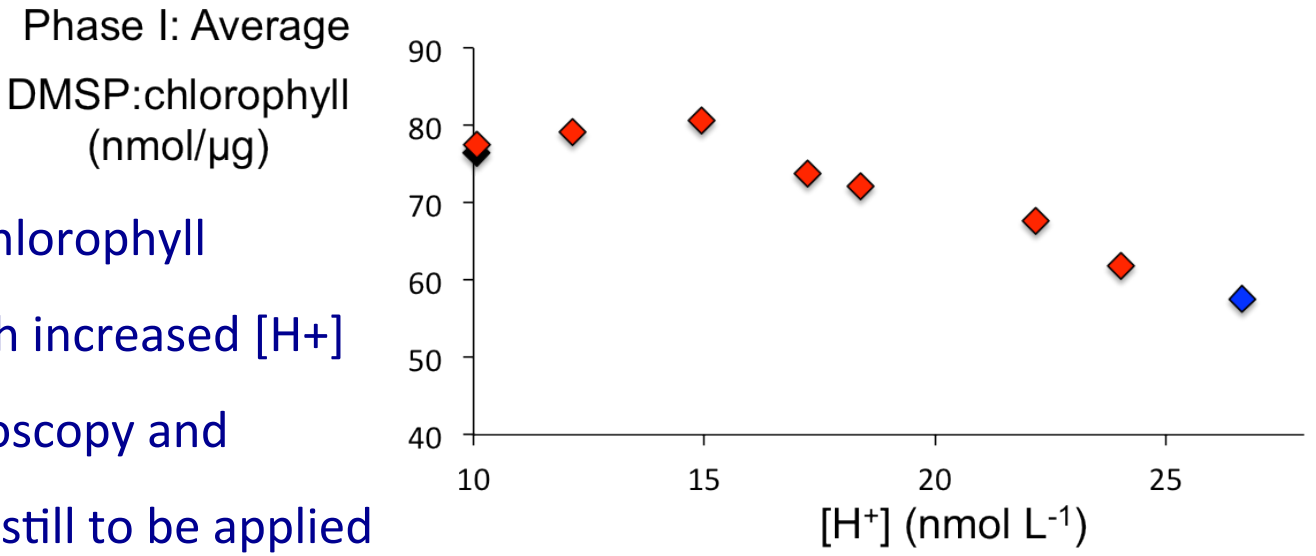
Closer coupling with increased [H^+]

Heterotrophic processes more reliant on DMSP and DMS at higher [H+]?



Phytoplankton component: ecophysiological response

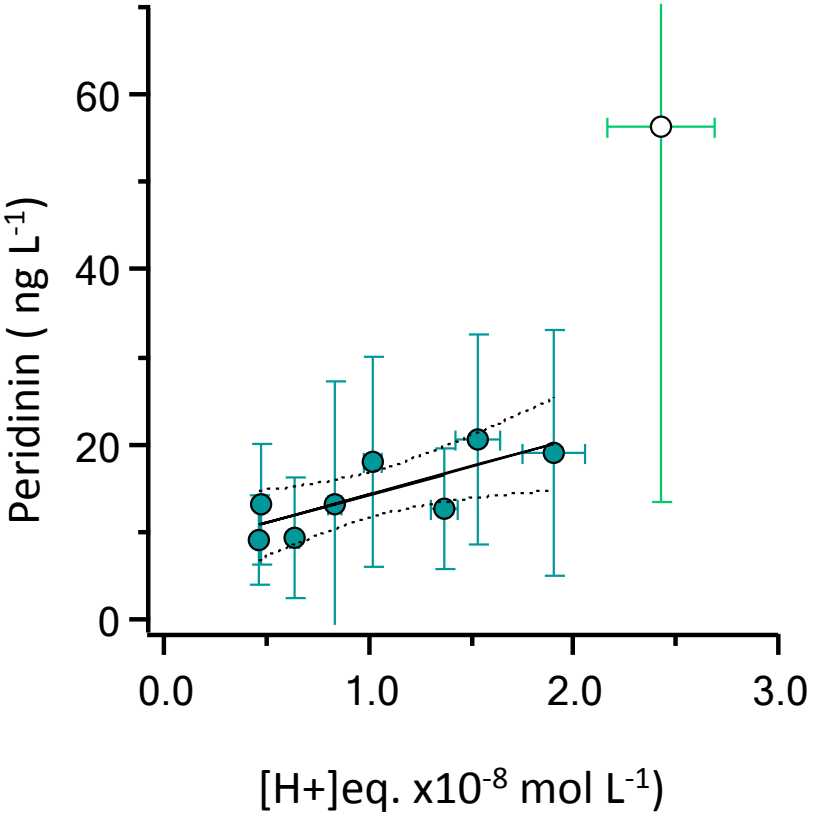


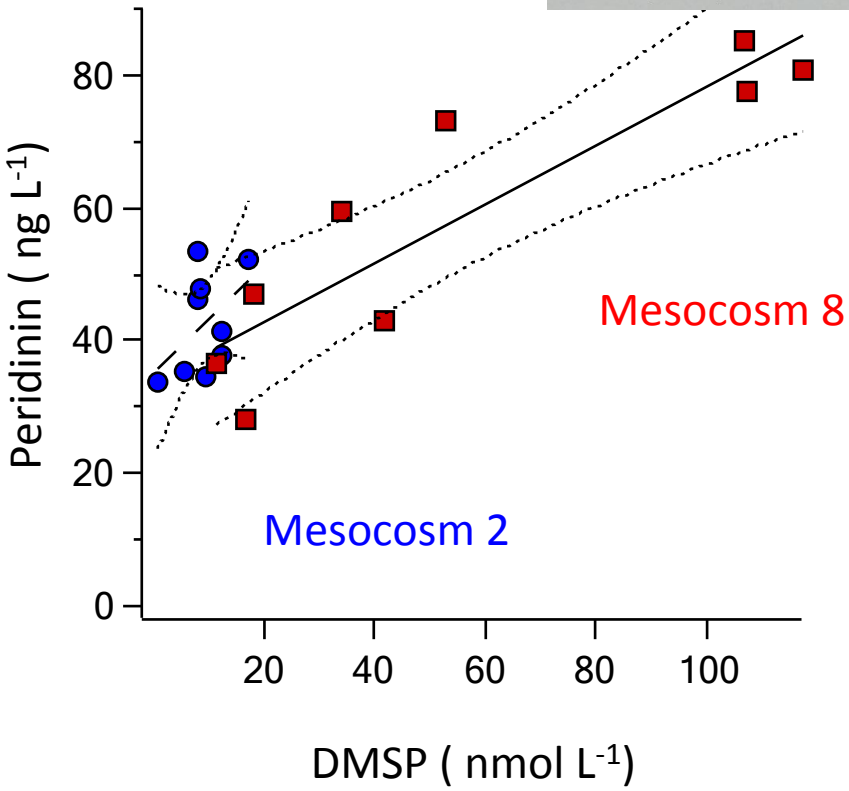


- No obvious trend in chlorophyll
- Decreasing Fv/Fm with increased [H+]
- Flow cytometry, microscopy and 18S-rRNA sequencing still to be applied

Arctic Mesocosm: phytoplankton ecophysiological response

- Peridinin is a marker pigment for dinoflagellates
- Dinoflagellates are strong producers of DMSP





Bacterial component: catabolism of DMSP

^{35}S-DMSP

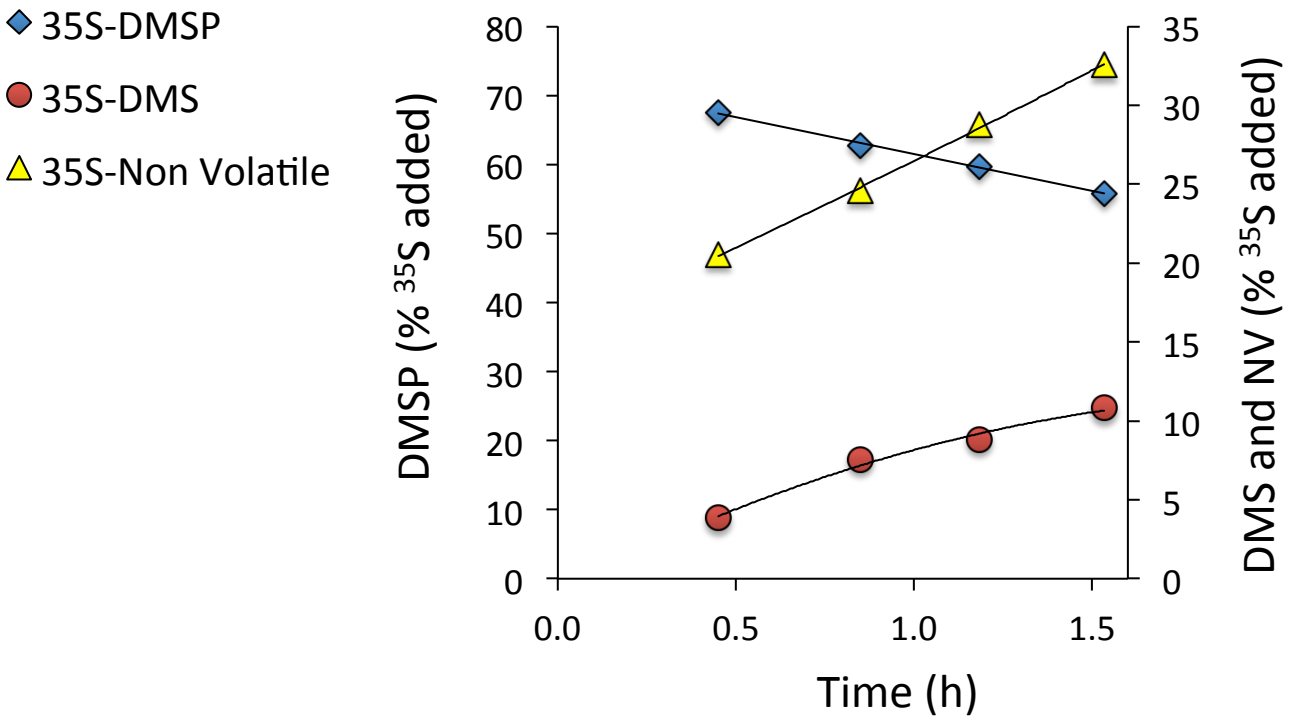
↓

^{35}DMSP decrease: DMSP loss coefficient

↙ ↘

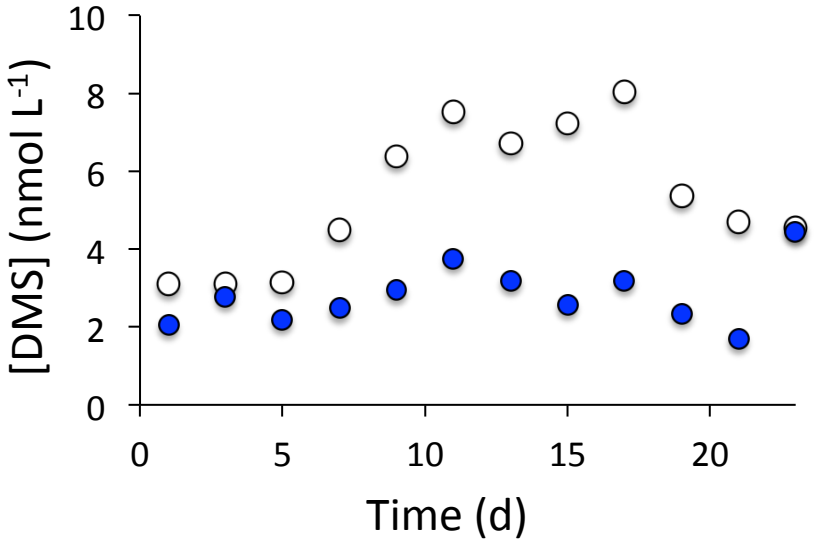
^{35}S-DMS production: DMS yield (%)

^{35}S-non-volatile products: assimilation by cells / $^{35}SO_4^{2-}$



Are bacteria influencing production of DMS?

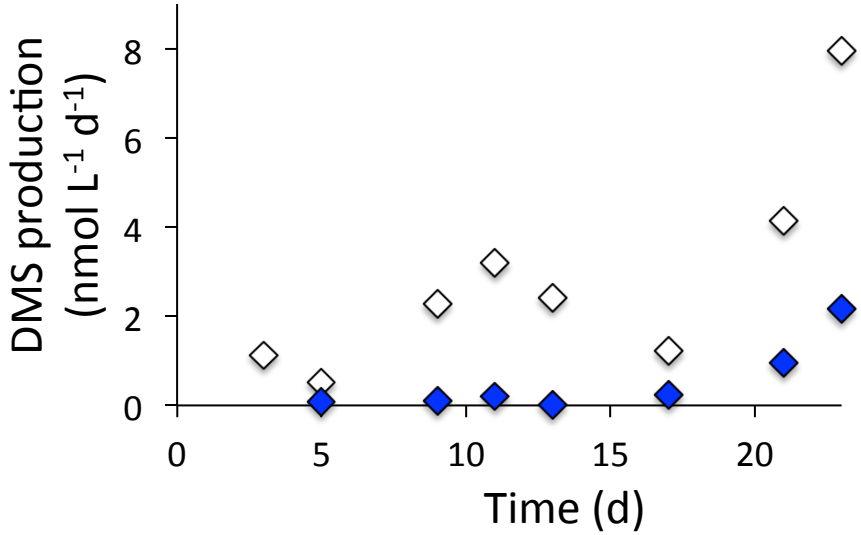
Phase I: Mesocosm DMS concentrations



Low (M1)

High (M8)

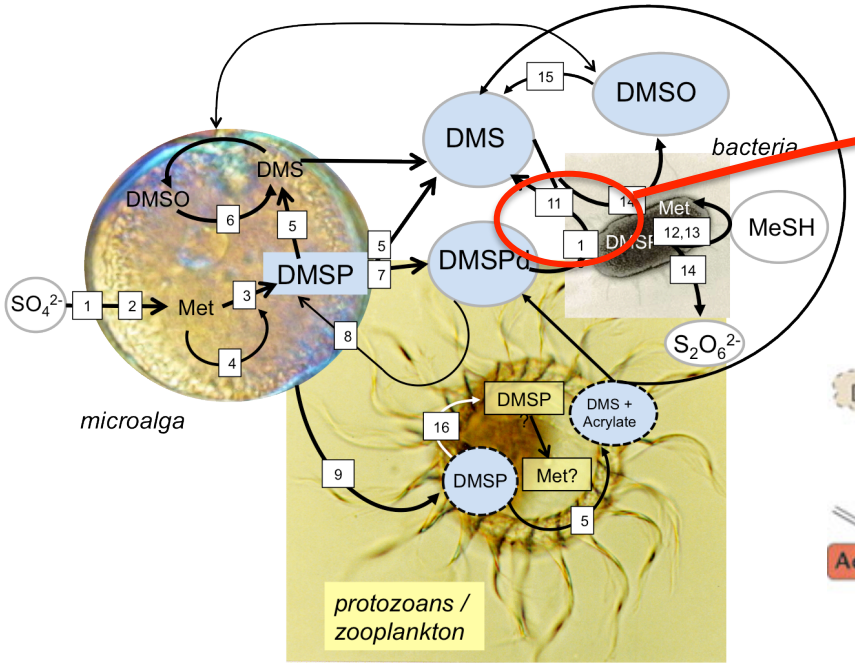
Phase I: ^{35}S-based DMS production rates

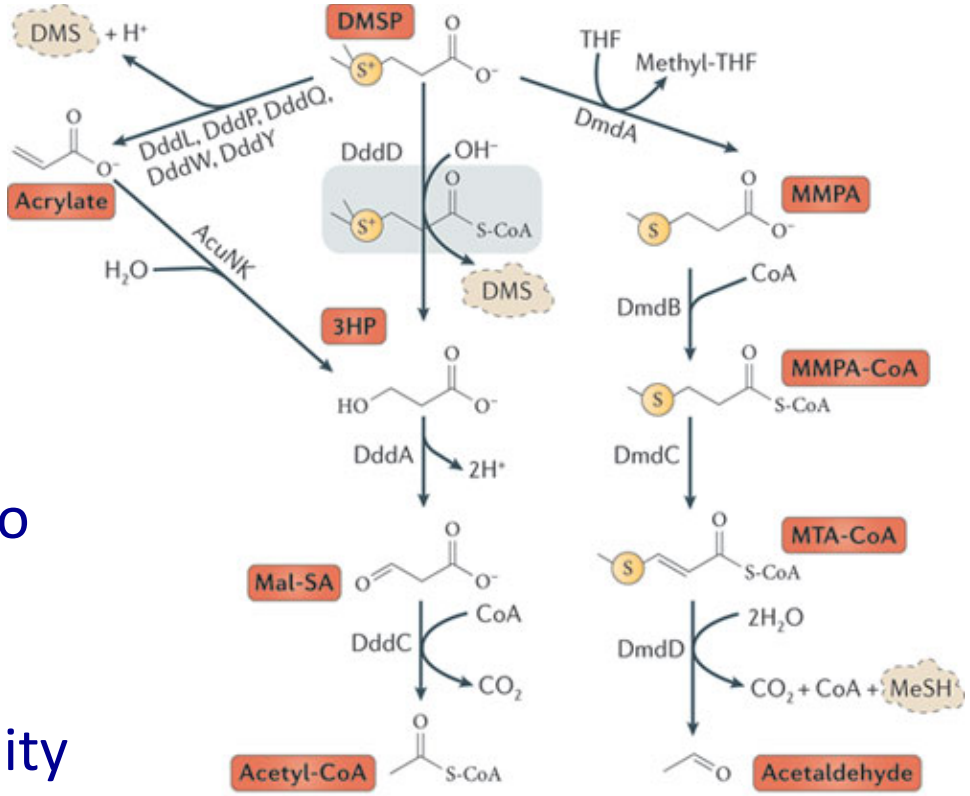


Low (M1)

High (M8)

Regulation of DMS production at the molecular level





- qPCR approach
- Link ^{35}S-DMSP metabolism to gene expression
- Influences of DMSP availability and OA

Curson et al. 2011

Regulation of DMS production at the molecular level

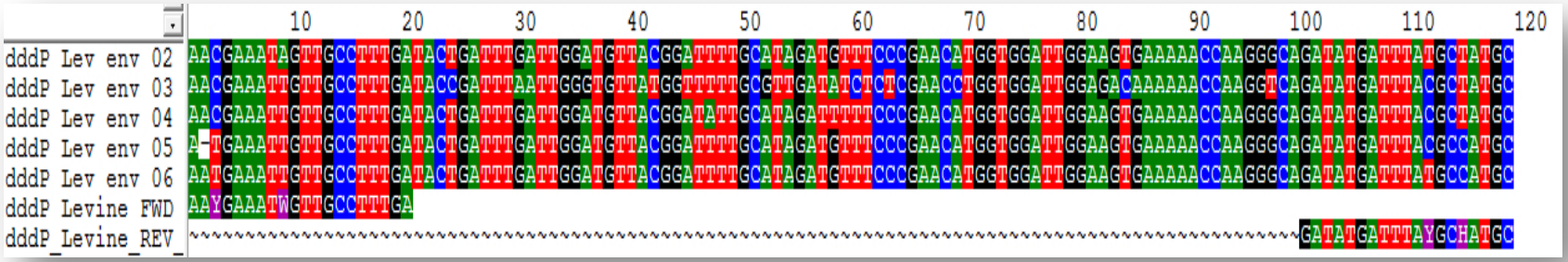
1

Molecular response in *Ruegeria pomeroyi*

DMSP addition: dddP vs. dmdA exprression

2

DMSP catabolism genes in the Gulf of Maine – *dddP*



- *dddP* primers (Levine et al., 2012, Env. Micro)
- 118 bp PCR product
- Mini clone library constructed
- Less variability among sequences than for DmdA
- Best matches in GenBank (75-79% similar)

3

Meta- transcriptomics: expression of S-cycling genes

With 16S sequencing to find out who is there and when

Next steps

1. Ecosystem modeling: individual mesocosms in Canaries
2. Incorporation of key processes into coupled ocean-atmosphere model
3. Mesocosm Expt. 8th to 29th September 2015

- Low nutrient 'warm water' summer community
- Temperature and pCO_2 treatments
- ^{13}C tracer approach to track production and fate of DMSP

Bigelow Seawater Facility