Concurrent DMS and CO_2 air/sea gas transfer

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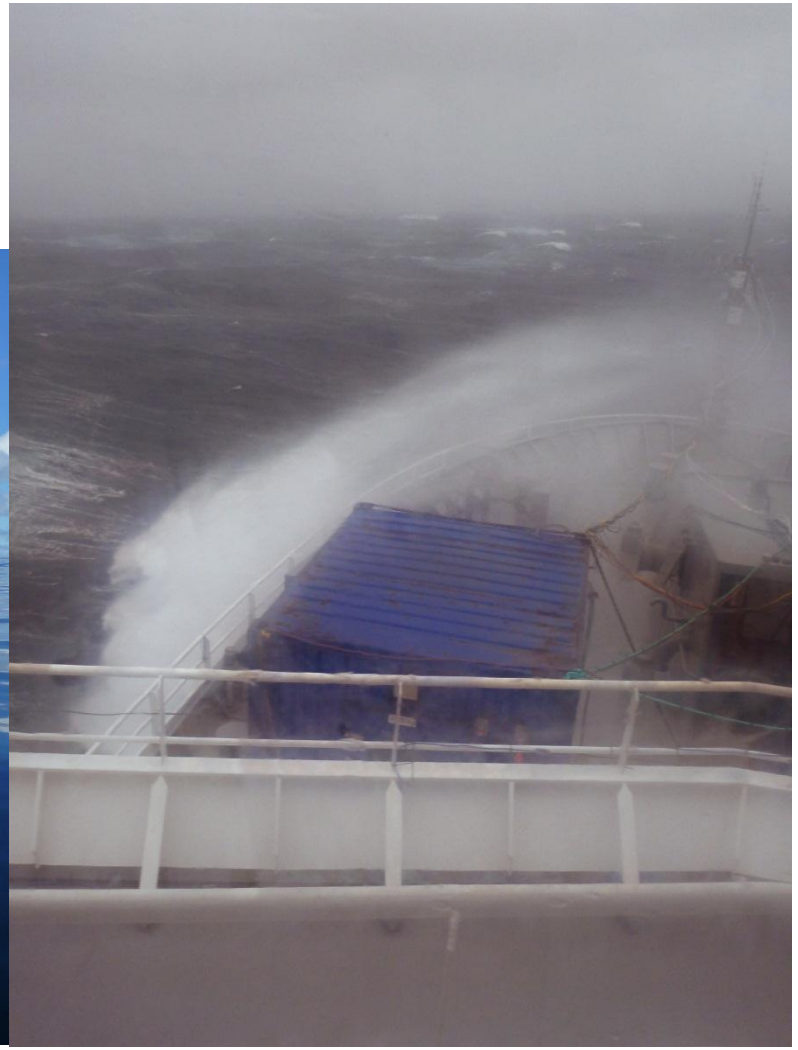
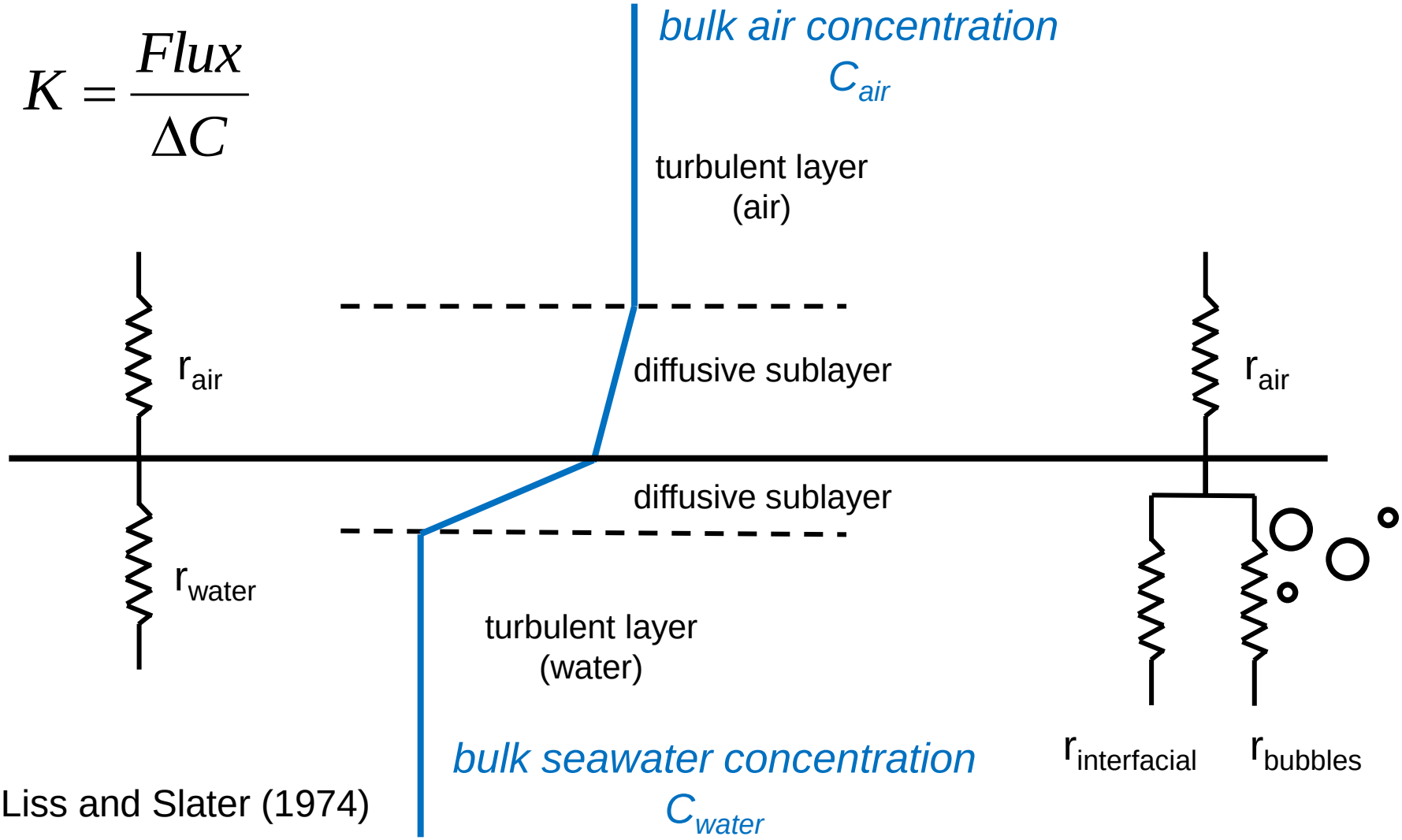


Conceptual View of Gas Transfer

$$K = \frac{Flux}{\Delta C}$$



Liss and Slater (1974)

Motivation(s)…

•Biogeochemical budgets of climate-relevant gases:

DMS, NH_3, CH_3Br, CH_3Cl, $CHBr_3$, CO_2, N_2O, CH_4, O_2

Long term goal…

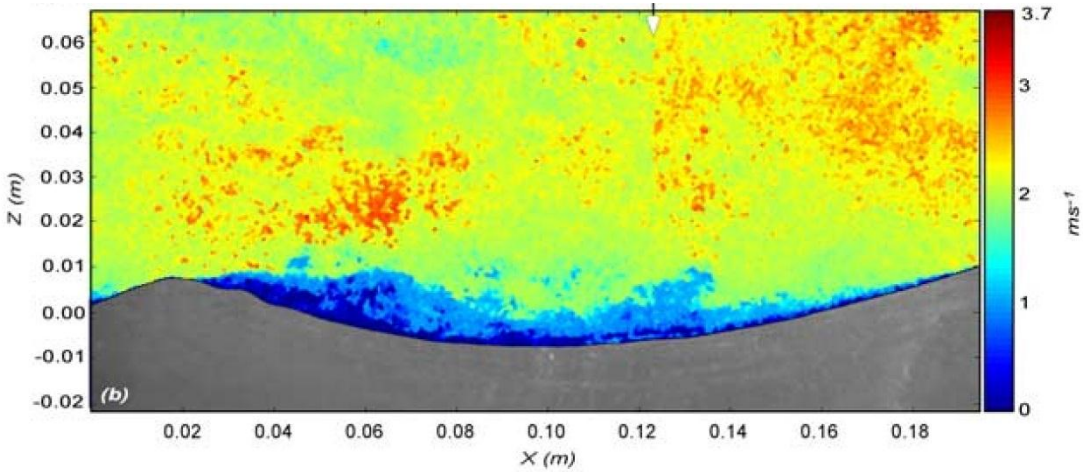
• Physically-realistic parameterizations coupling heat, momentum and gas fluxes.

Tracers for measuring gas exchange:

	DMS	CO_2
$\Delta C/C_{air}$	Large	Small
Solubility	Moderate	Relatively insoluble
Major control(s) on air/sea gas transfer	Interfacial stress	Interfacial stress Bubbles

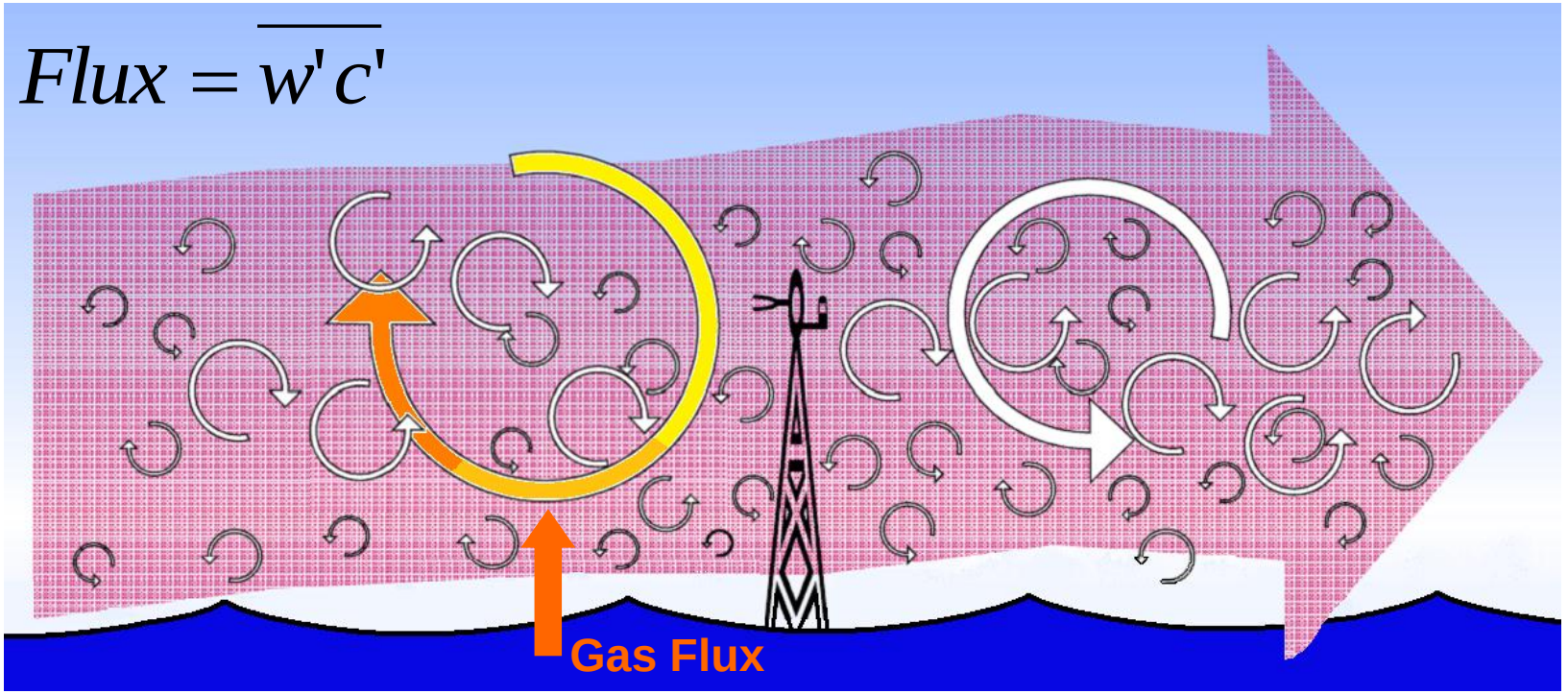
The air/water interface

- Dynamic, heterogeneous
  - Diffusivity / viscosity (Sc)
  - Buoyancy-driven turbulence
  - Shear-driven turbulence
  - Waves
  - Wave breaking (bubbles)
  - Surface tension (surfactants)
- Range of spatial/temporal scales
- Different gases will not be affected equally by these processes!



Interactions between waves and wind using Particle Image Velocimetry (Veron et al., 2008)

Micrometeorological technique: Eddy Covariance

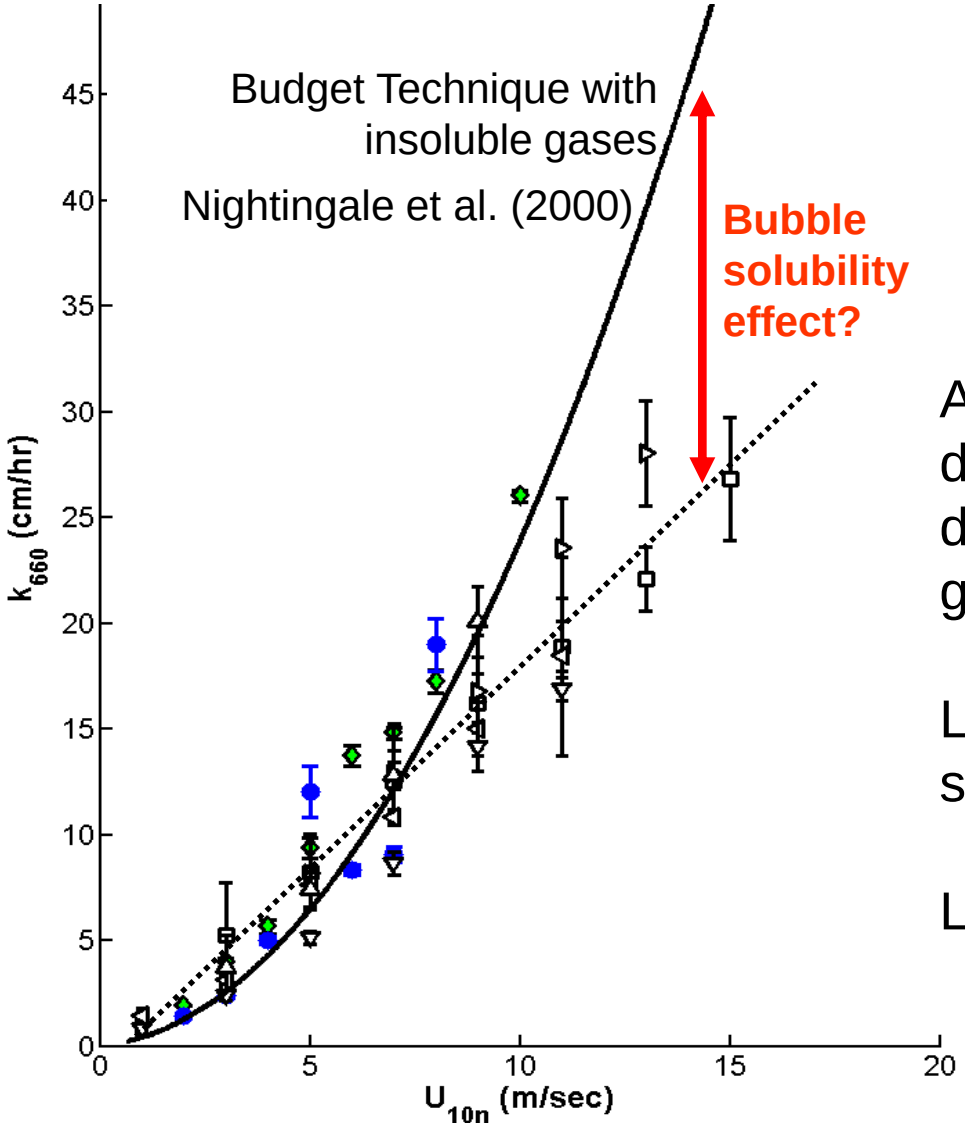


- Covariation in vertical wind (*w*) and gas of interest (*c*)
- Timescale = minutes-hours
- Flux footprint extends ~1 km upwind
- Assumes horizontal spatial homogeneity

$$K = \frac{Flux}{\Delta C}$$

Previous DMS Eddy Covariance Data

(Univ. of Hawaii and Univ. of California, Irvine)



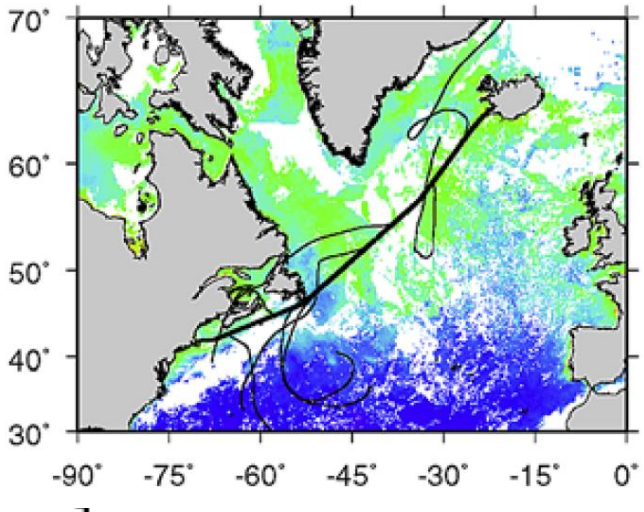
At high wind speeds, divergence between different solubility gases

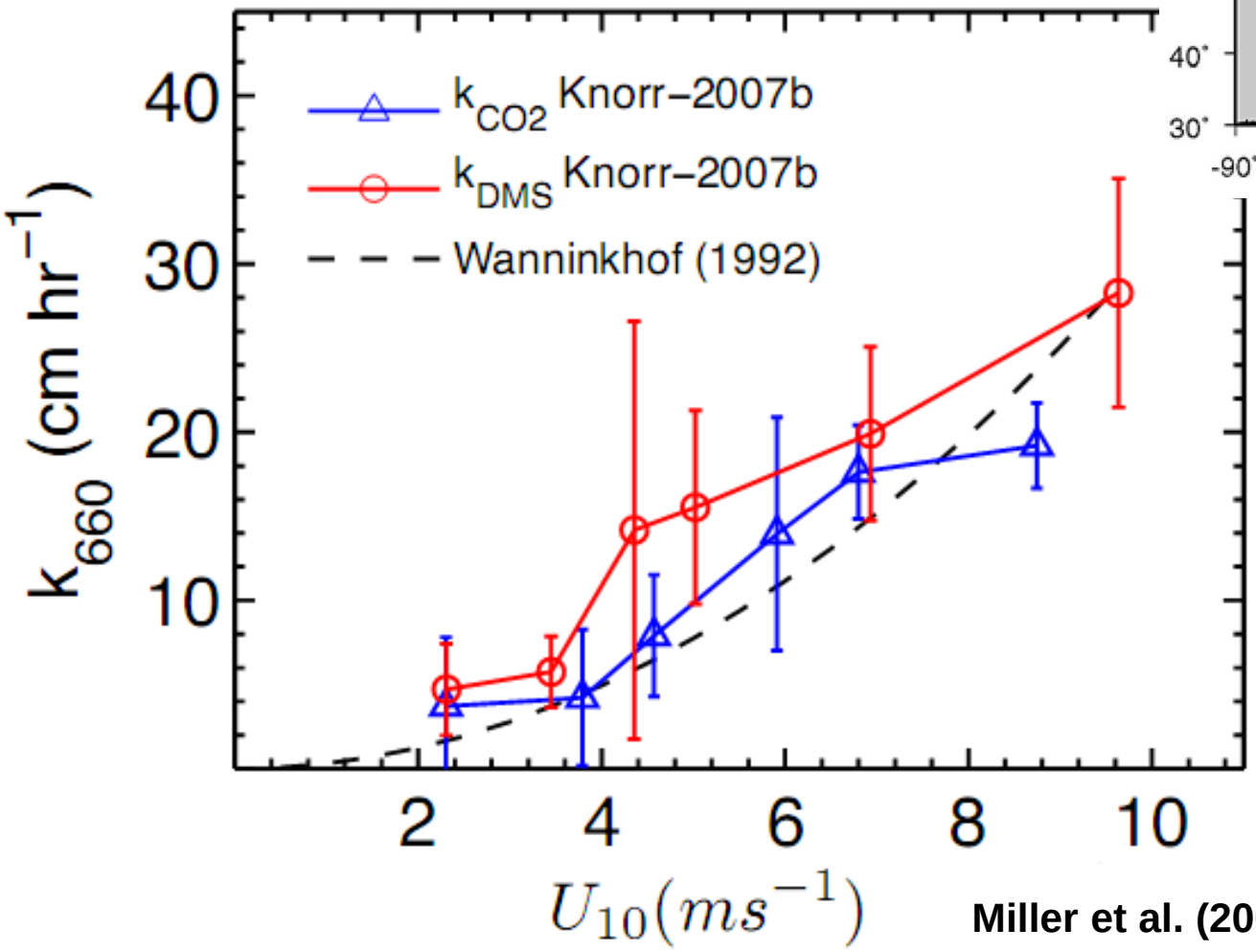
Limited high wind speed data

Linear k_{DMS} vs U?

calm (buoyancy) → moderate wind (shear stress) → rough (waves, bubbles)

Previous concurrent k_{CO2} and k_{DMS} data



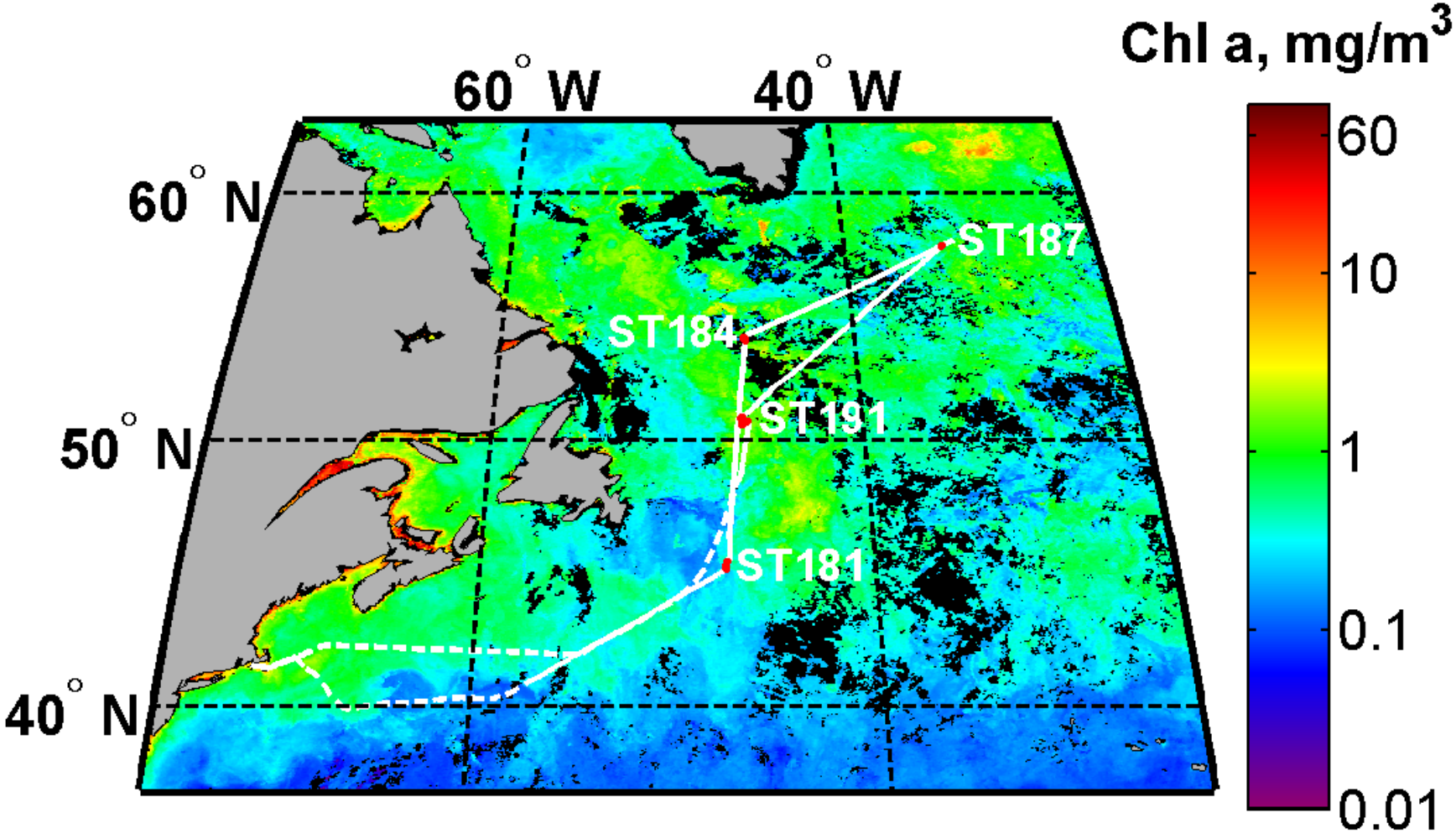


No divergence observed in 2007 N. Atlantic dataset

Only low-intermediate winds

Miller et al. (2009)

R/V Knorr: North Atlantic (June/July 2011)

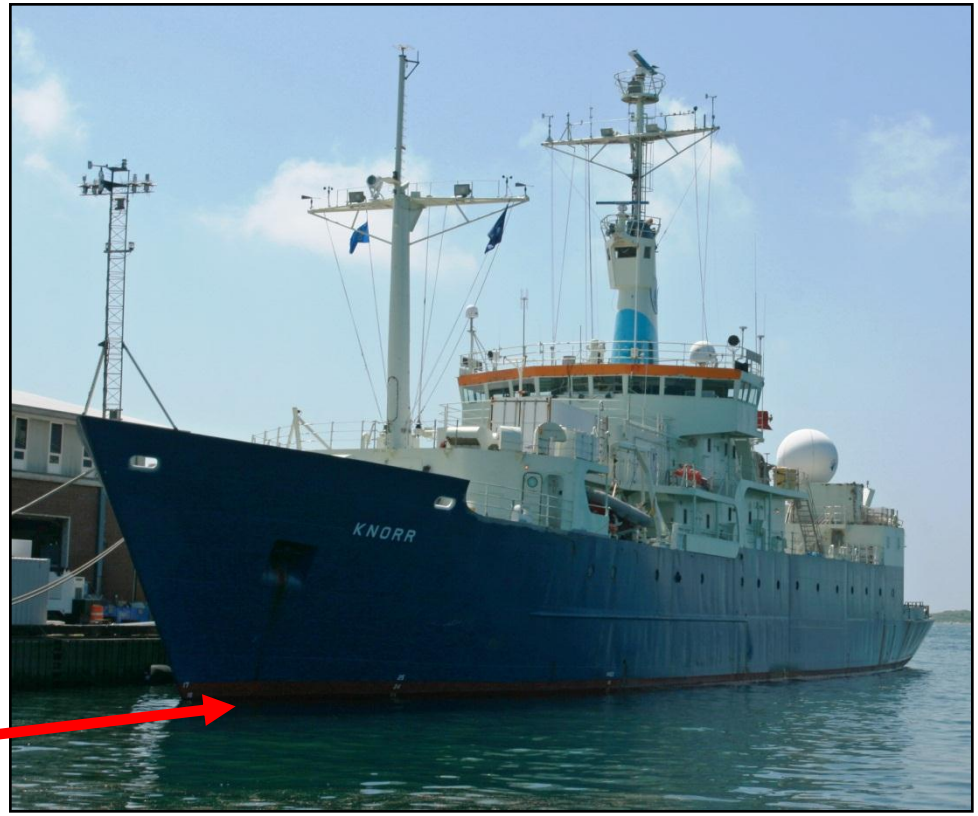


Knorr 2011 Setup
Eddy Covariance Flux
ΔC

3-D Winds
(Sonic Anemometer)

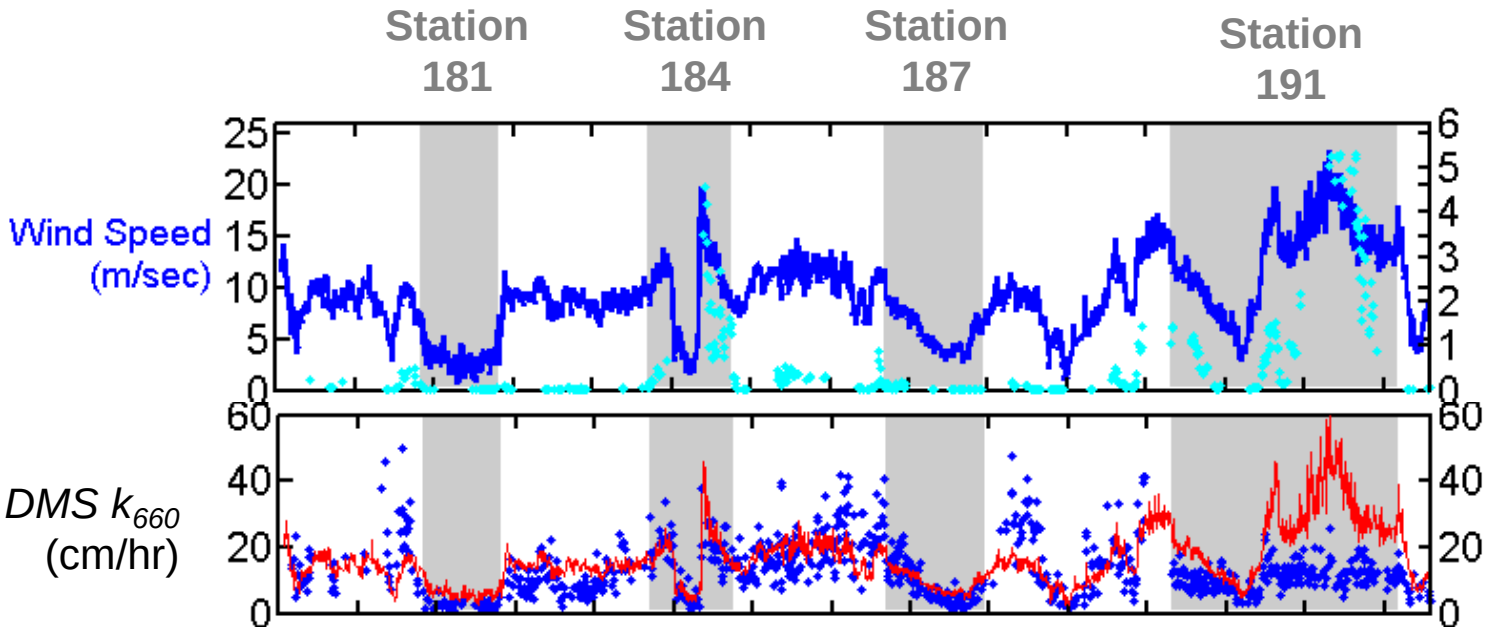
Motion
Pak II

Atm.
Air Inlet



DMS: mass spectrometry (CIMS)
CO_2: Closed path IRGA

Seawater
Ship's Inlet



10 min average data

k_{660} vs Wind Speed (U_{10})

CO_2

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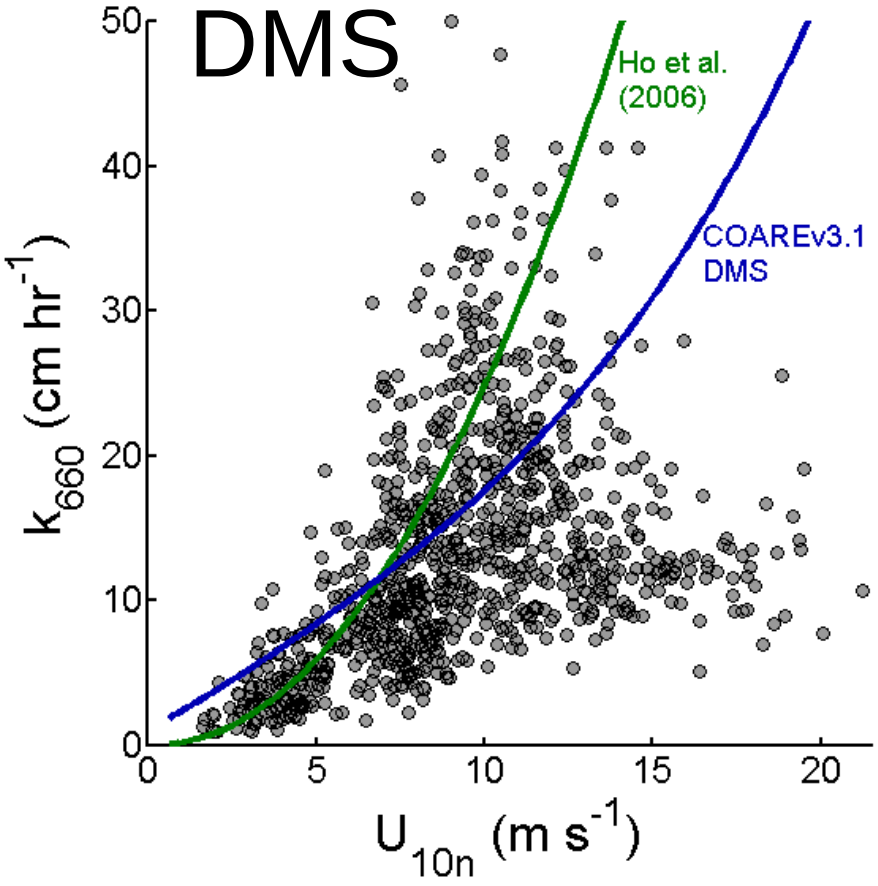
DMS



k_{CO2} scatter is greater than k_{DMS} scatter
10 min average data

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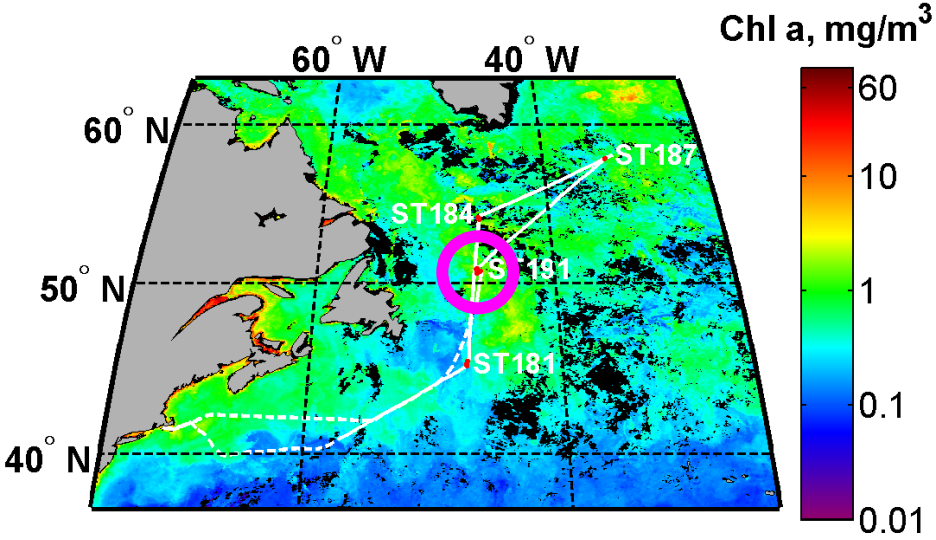
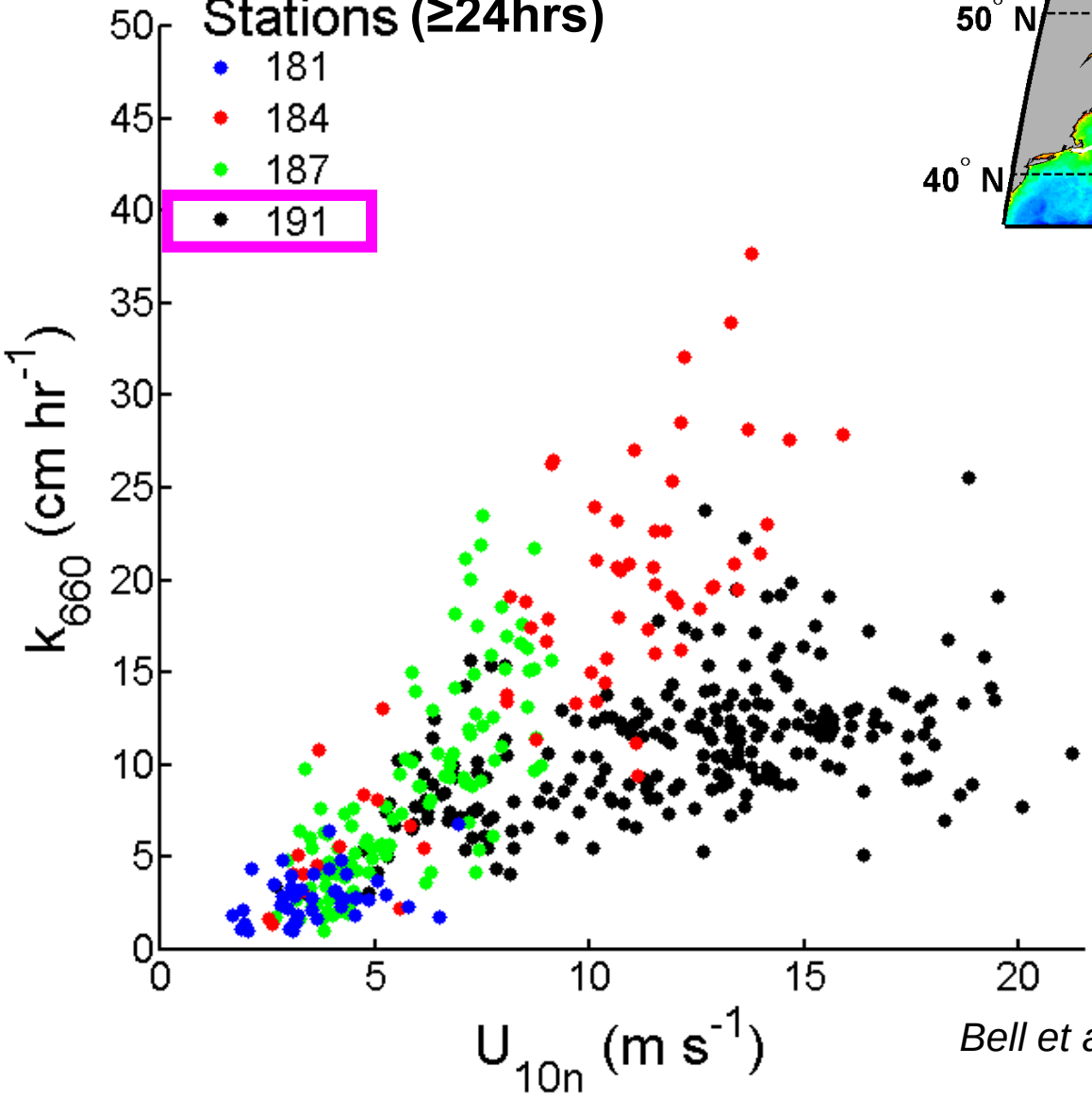
$k_{DMS} < k_{CO2}$

bubbles?

k_{CO2} and k_{DMS} < COAREv3.1

Station Data: k_{DMS}





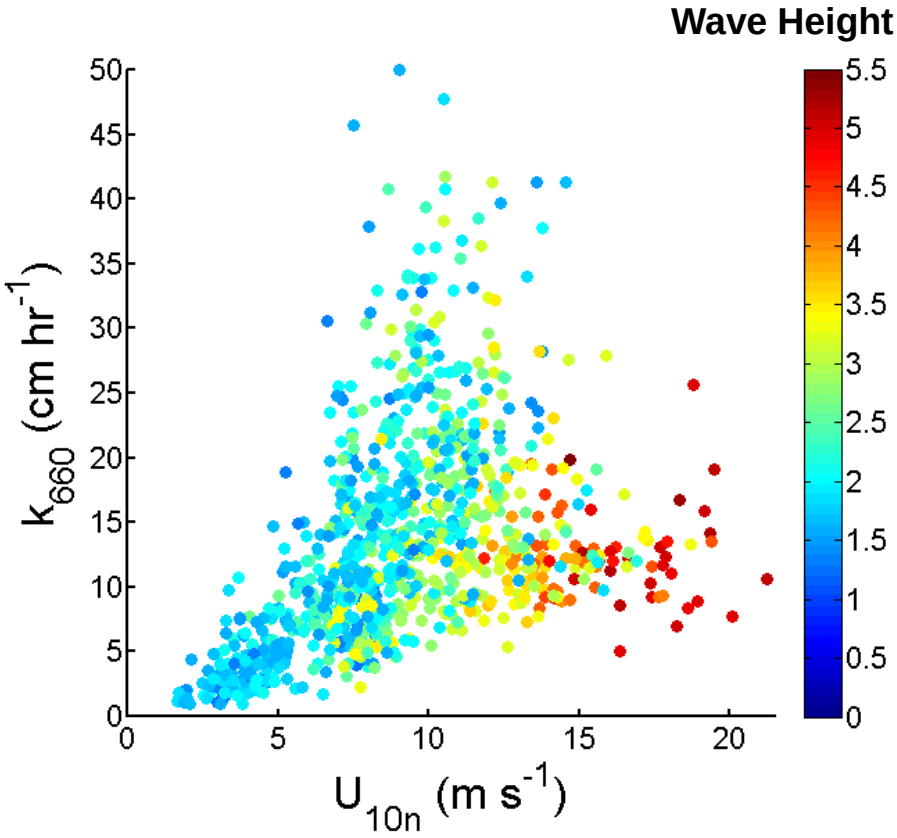
Spatial/temporal variations in k_{DMS} *vs.* U_{10} relationship

Station 191 is different (at high wind speeds)

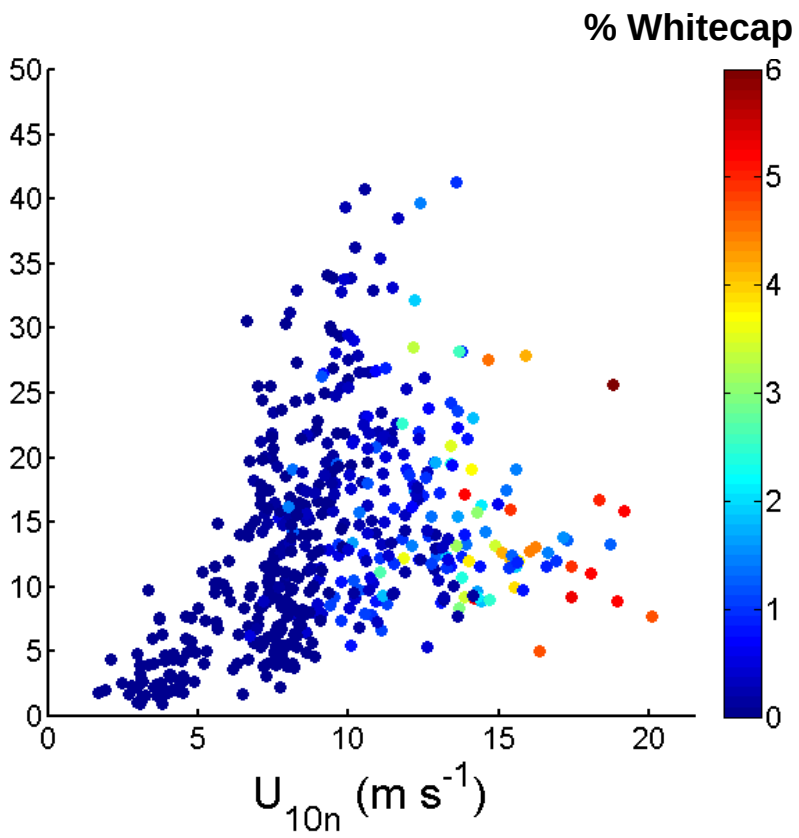
Bell et al., ACPD (2013)

k_{DMS} vs. waves and whitecaps

Bell et al., ACPD (2013)

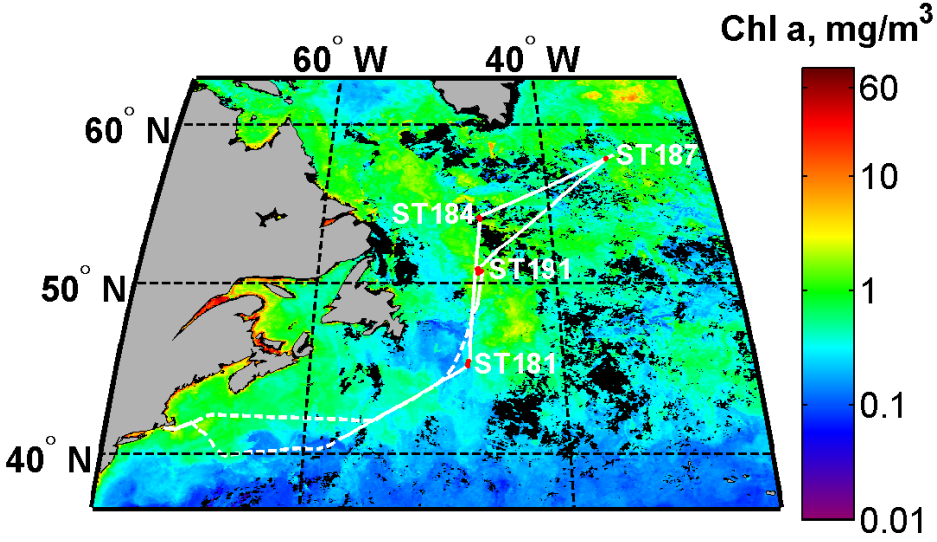


Suppression of kDMS when large waves were present.



As expected, no relationship with % whitecaps

Station Data: k_{CO2}



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Station 191 variations in k_{DMS} *vs.* U_{10} relationship are not observed in k_{CO2} data

Compensated by bubble flux?

Conclusions:

- Wind speed is not the sole factor controlling gas transfer
- Evidence for wave effects on $k_{interfacial}$?
- Evidence for bubble effects on k_{CO2}?
- Role for surfactants?
- Multiple gases help understand fundamental gas transfer processes.

Eric Saltzman

Warren De Bruyn

Cyril McCormick

Scott Miller

…a team effort!

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