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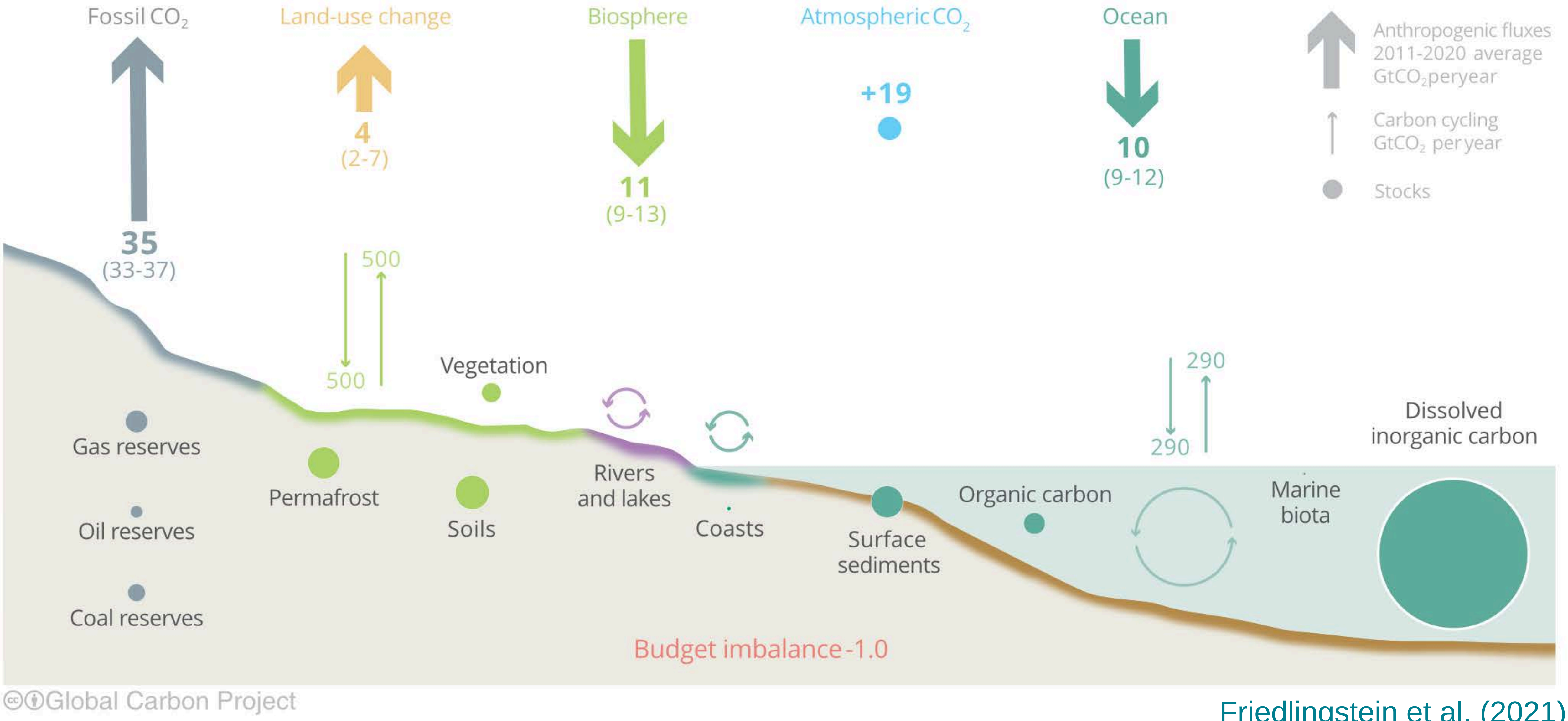
The importance of SST and in situ observations for improving global air/sea CO_2 flux estimates

T.G. Bell, M. Yang, L. Marie, Y. Dong, T. Smyth, V. Kitidis, I. Brown, J. Shutler, G. Tilstone

amt4oceansatflux

Why measure air-sea CO_2 fluxes?



Friedlingstein et al. (2021)

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Satellite-based estimates of air-sea CO_2 flux

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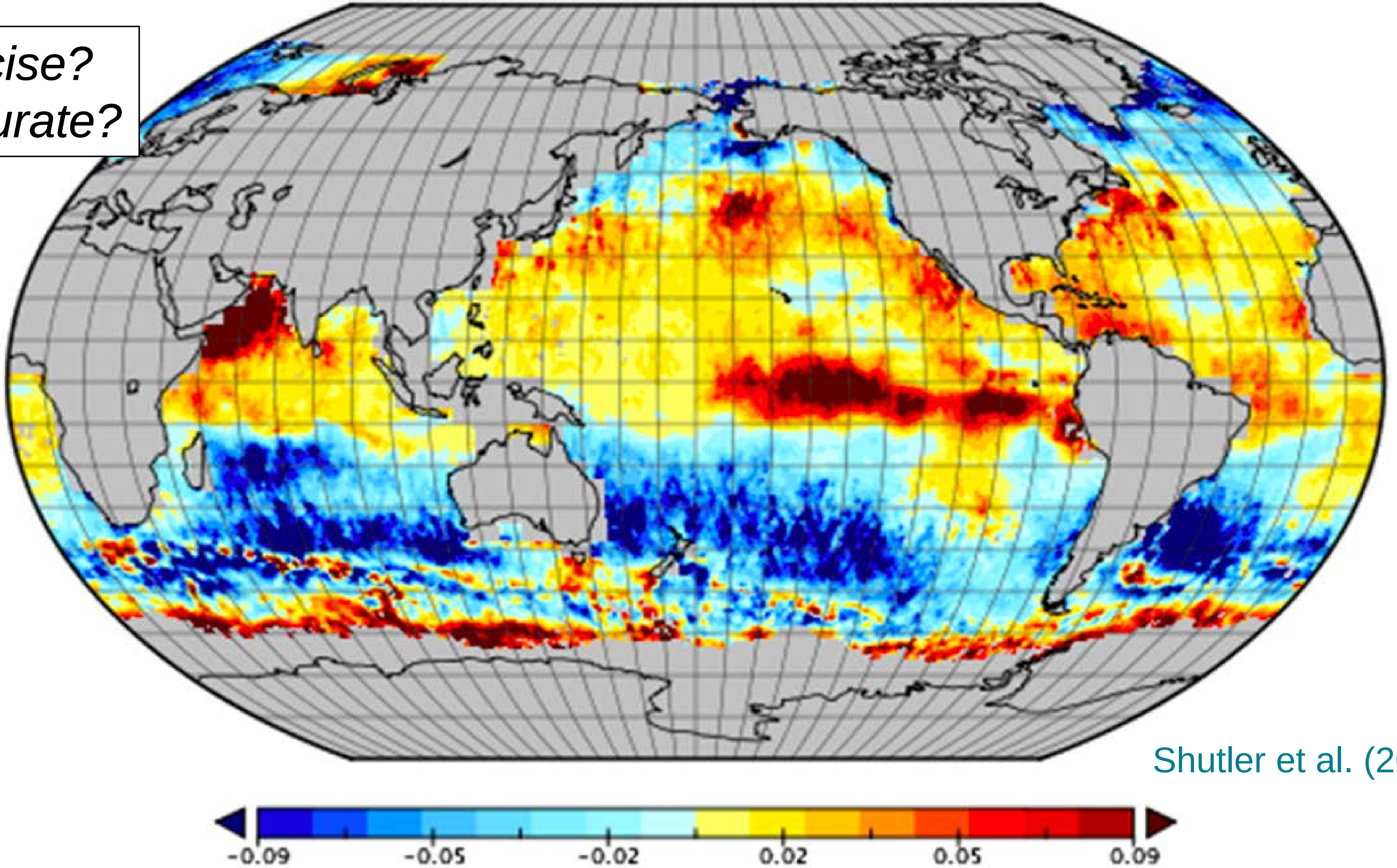
How precise?
How accurate?



Shutler et al. (2016)

Air-sea CO_2 flux ($gC\ m^{-2}\ day^{-1}$) for August 2000

Estimating air-sea CO_2 fluxes

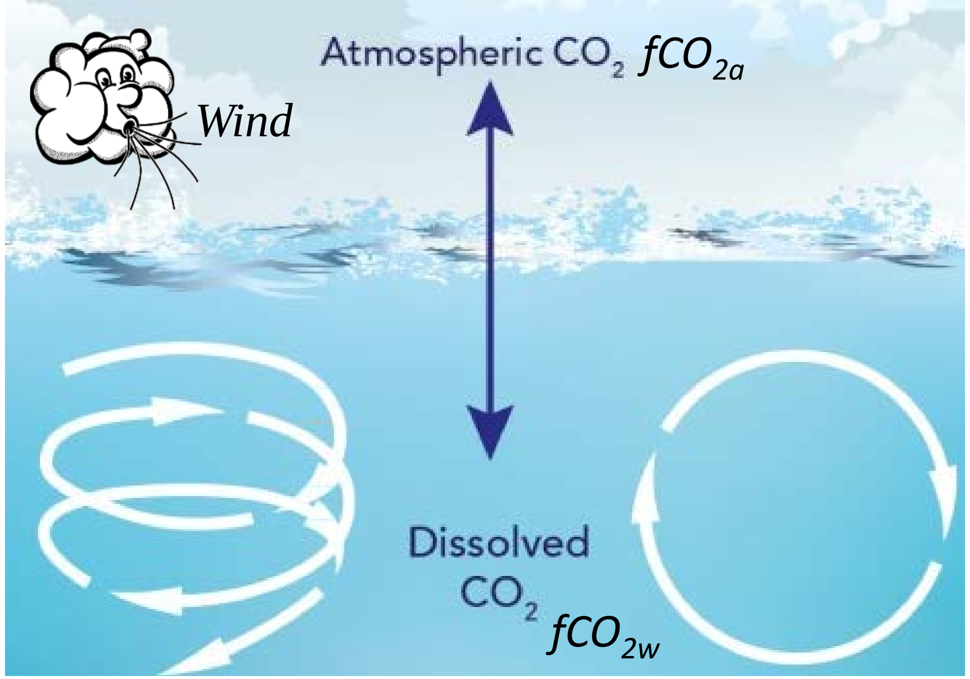
Indirect measurements of oceanic/atmospheric variables to calculate flux

$$\text{Flux} = K.\Delta C$$

$$\text{Flux} = K(\alpha_w fCO_{2w} - \alpha_i fCO_{2a})$$

α (solubility), function of temperature

K (gas transfer velocity), function of physical forcing(s)



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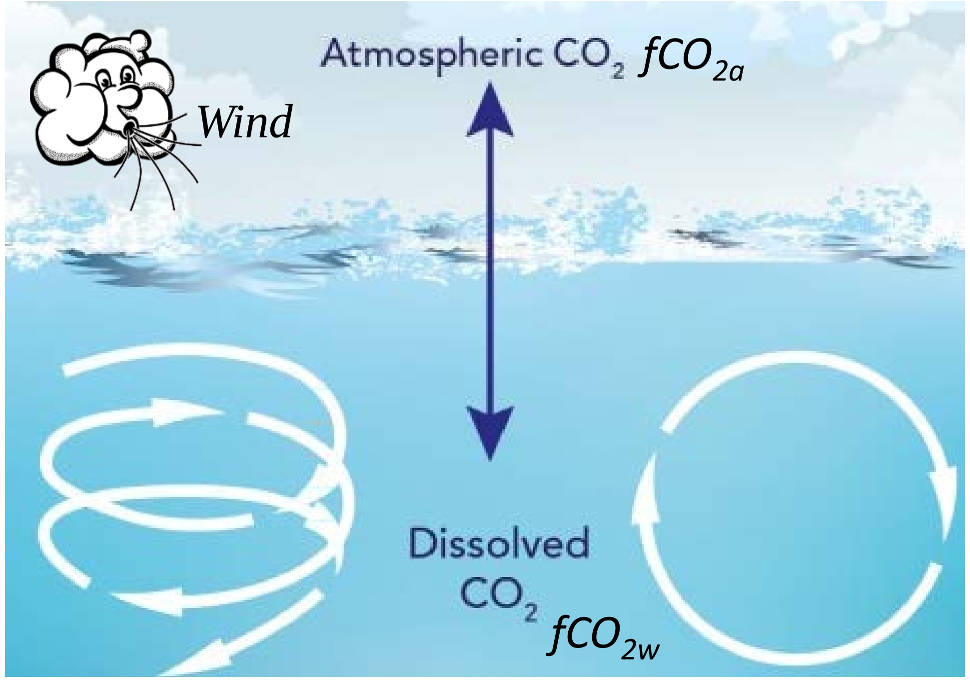
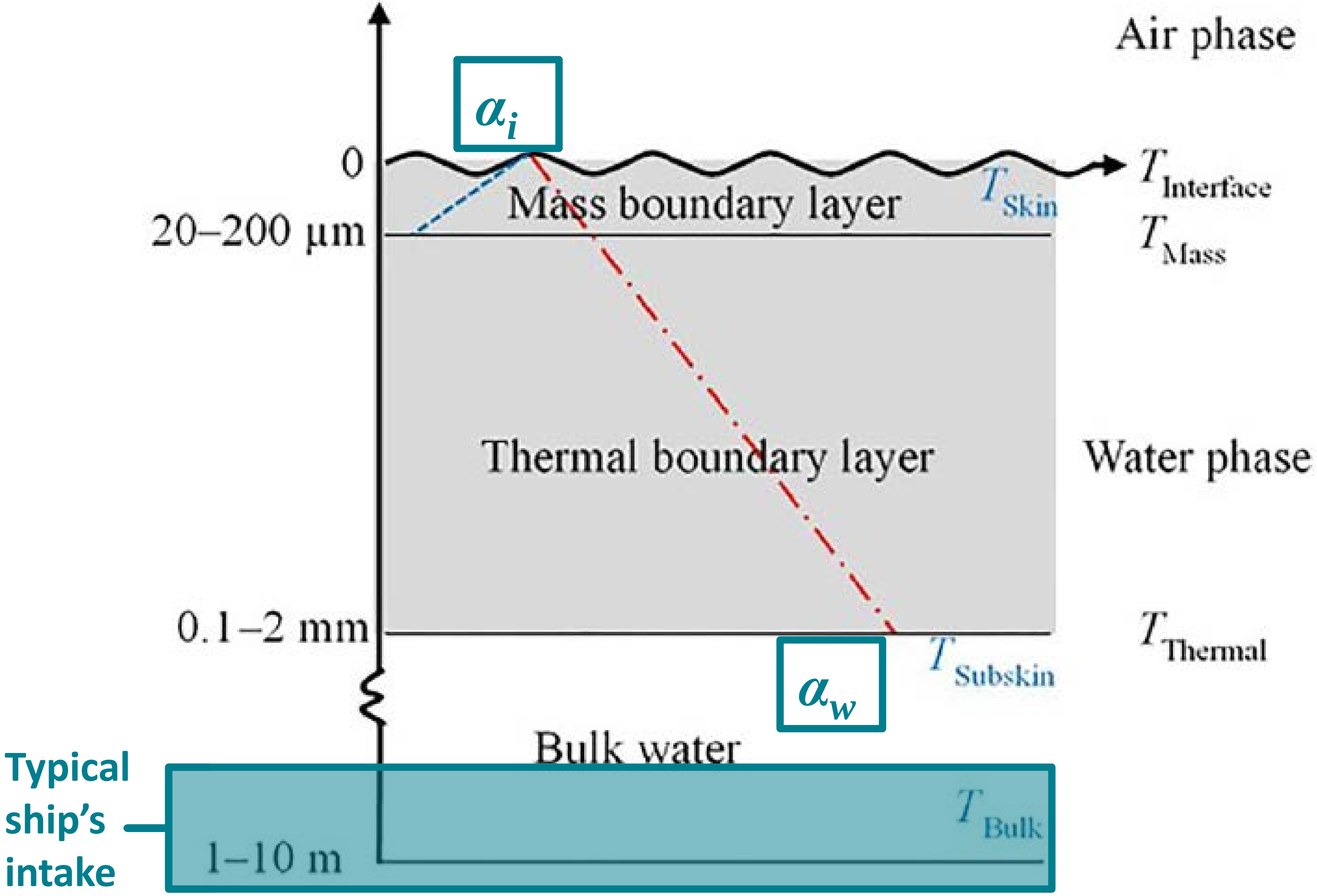
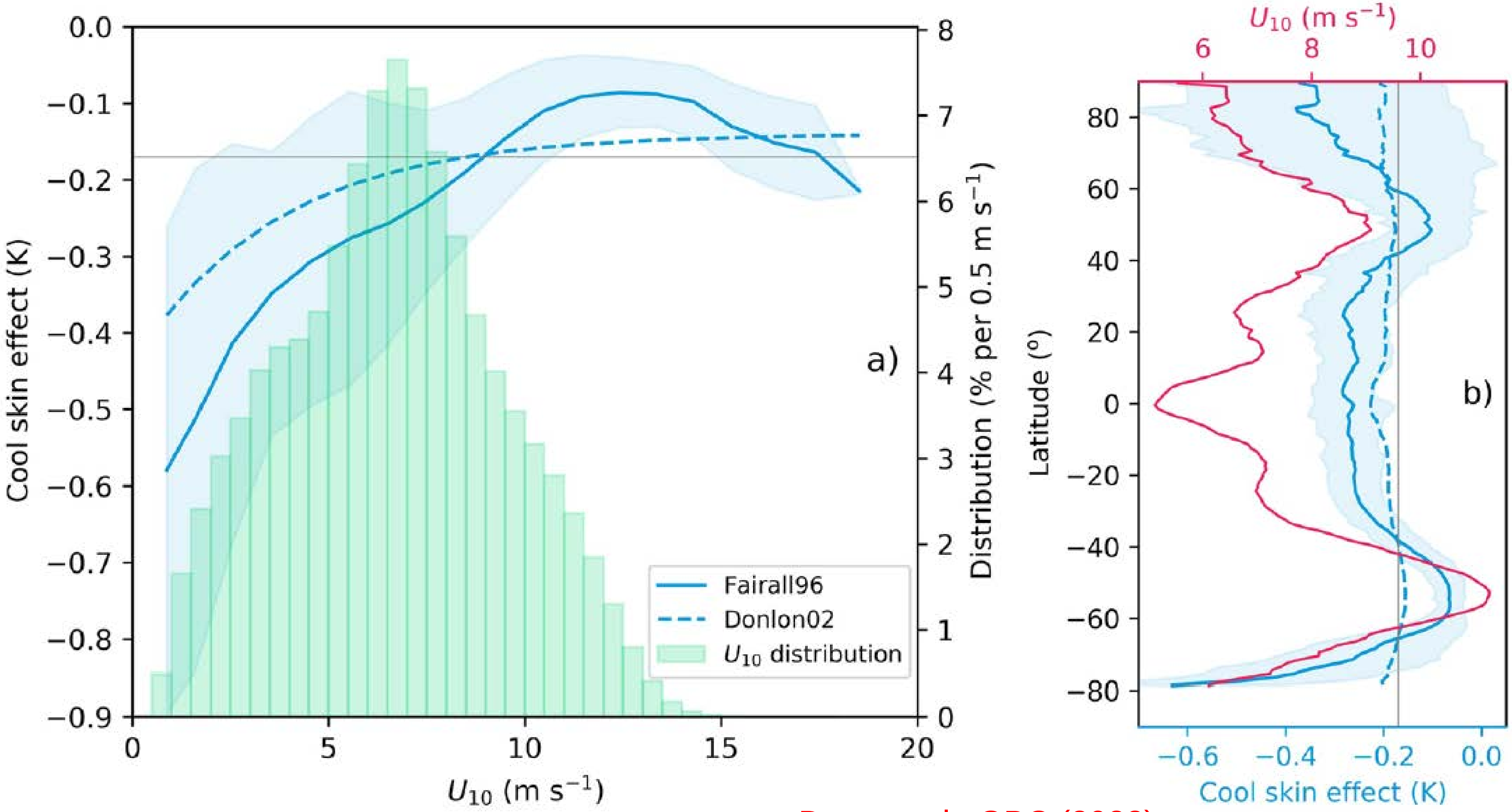




….AND seawater warms inside ships!

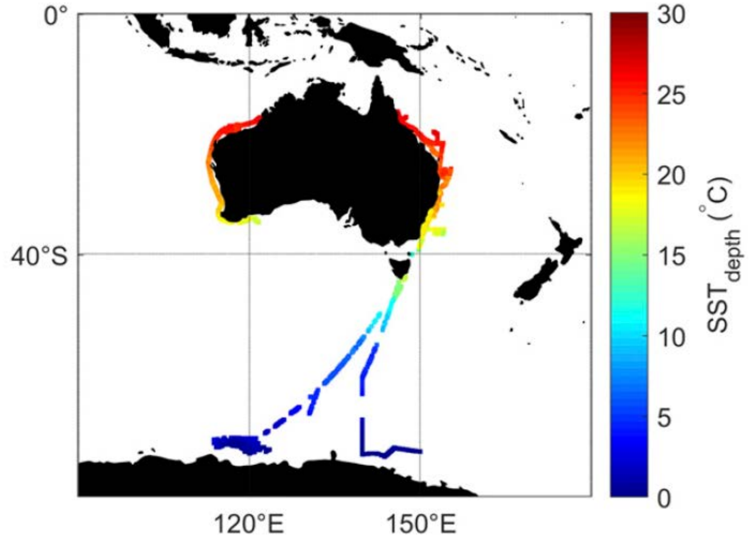
$$fCO_{2w} = fCO_{2w\_equ}\, e^{0.0423(T_{w\_bulk} - T_{equ})}$$

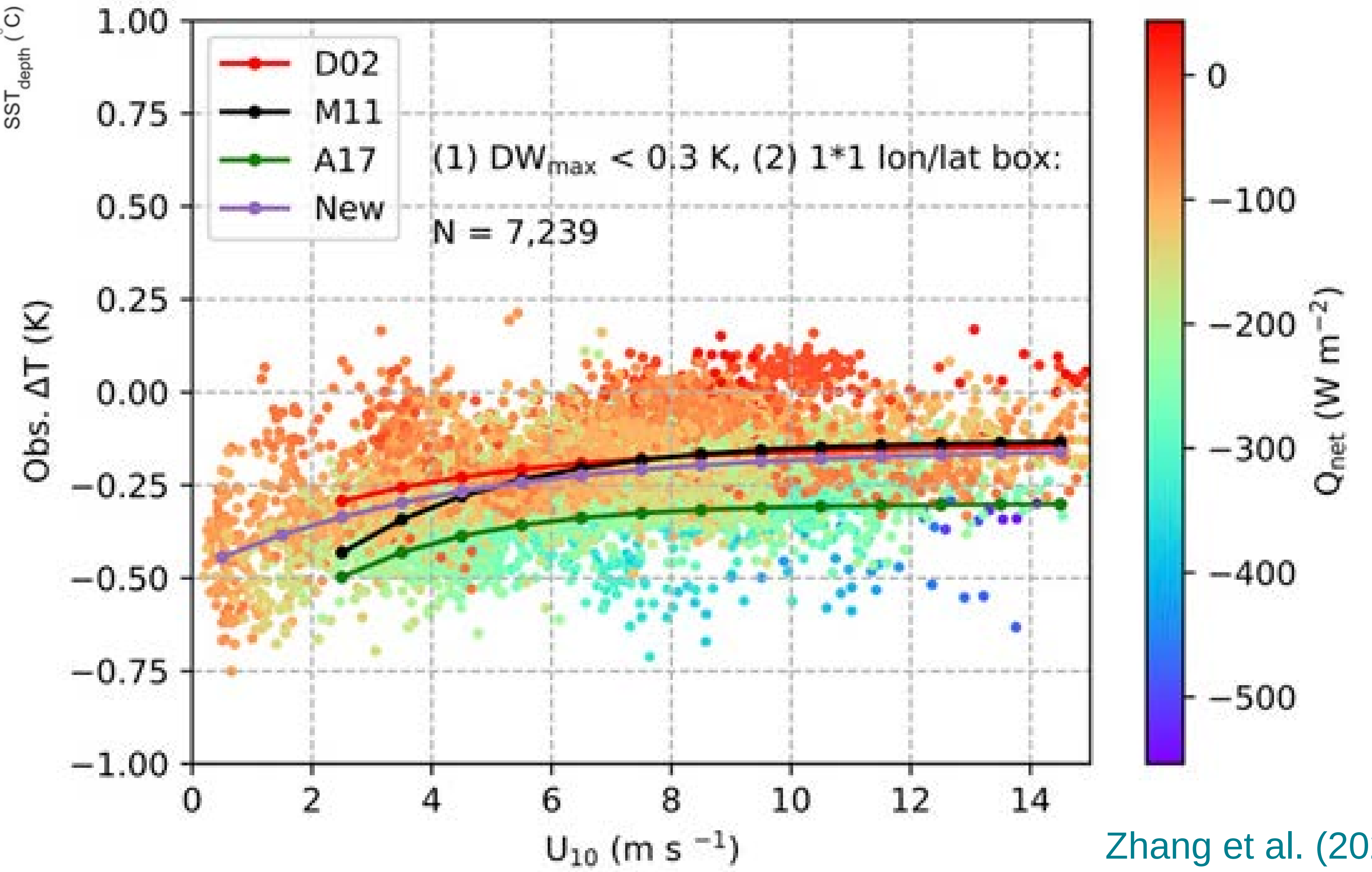
Choice of cool skin model



Dong et al., GBC (2022)

ISAR cool skin observations





Zhang et al. (2020)

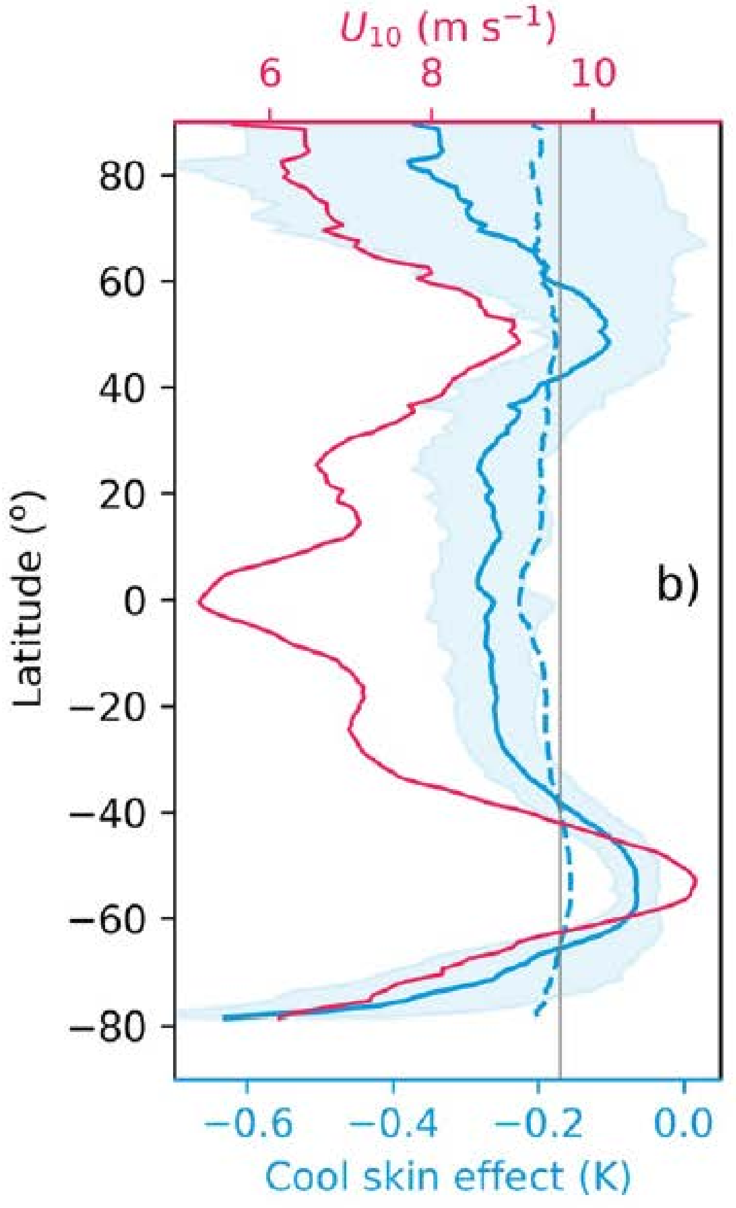
Is the cool skin correction important?

Dong et al., GBC (2022):

- Global ocean uptake estimate:

No temperature correction	1.7±0.4 Pg C yr^{-1}
With temperature corrections	2.2±0.4 Pg C yr^{-1}

- 30% enhancement in carbon uptake!
- Cool skin correction responsible for ¾ of this adjustment
- Independent ocean carbon inventory estimate = 2.1±0.4 Pg C yr^{-1}



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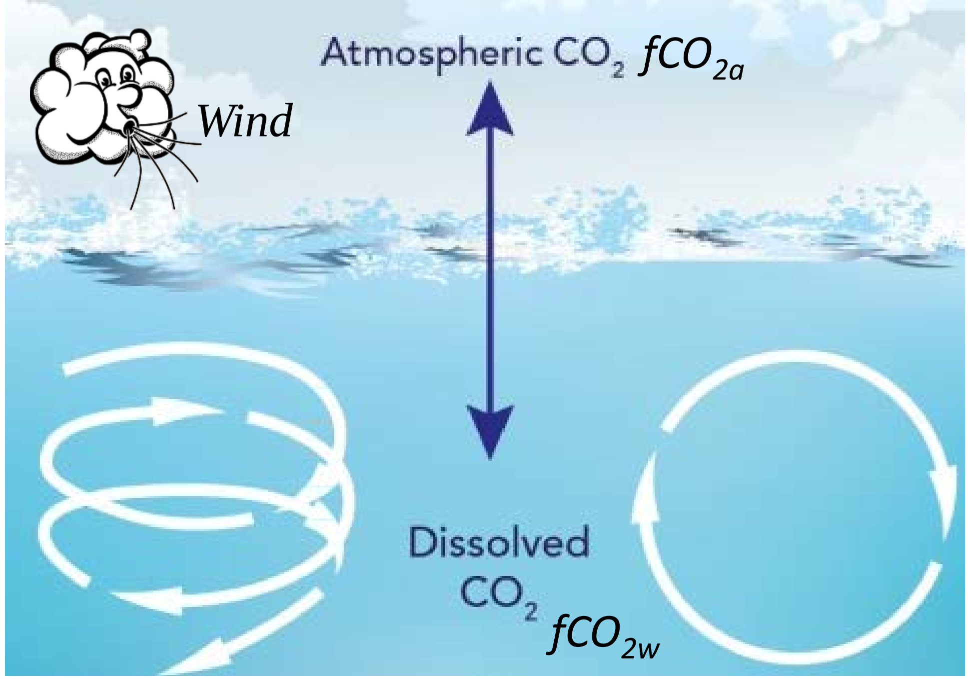
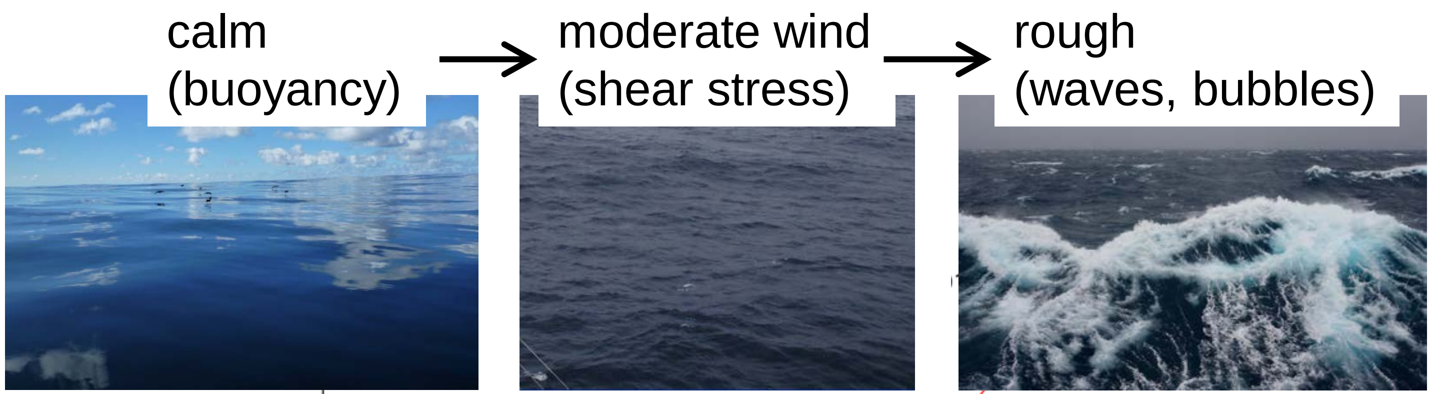
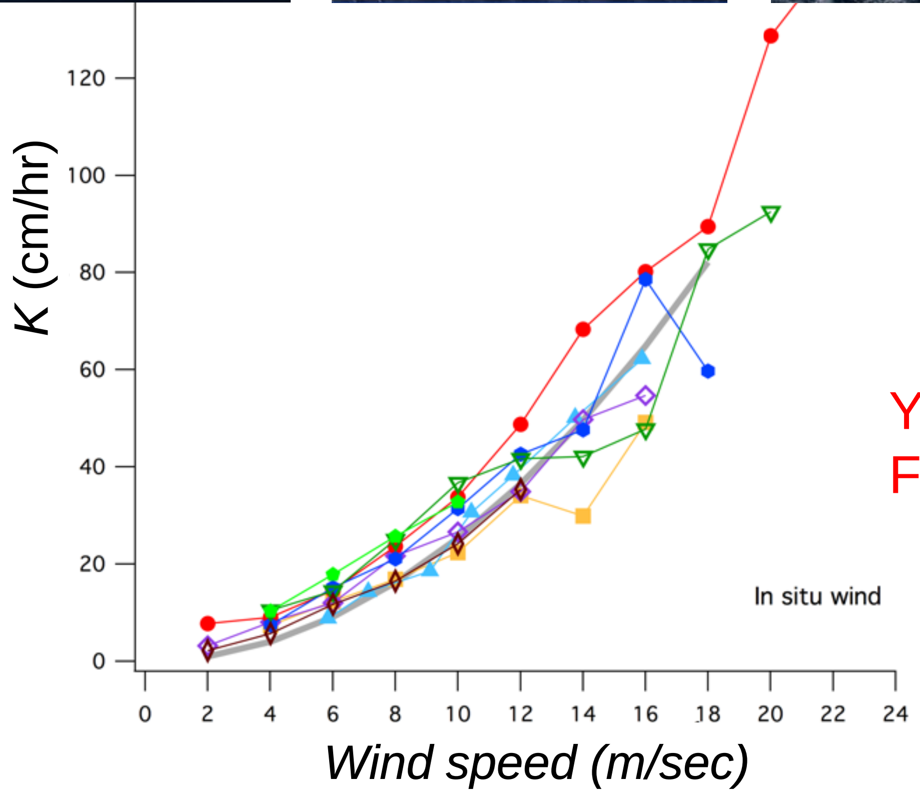


K (gas transfer velocity) uncertainty





Yang et al., Frontiers (2022)

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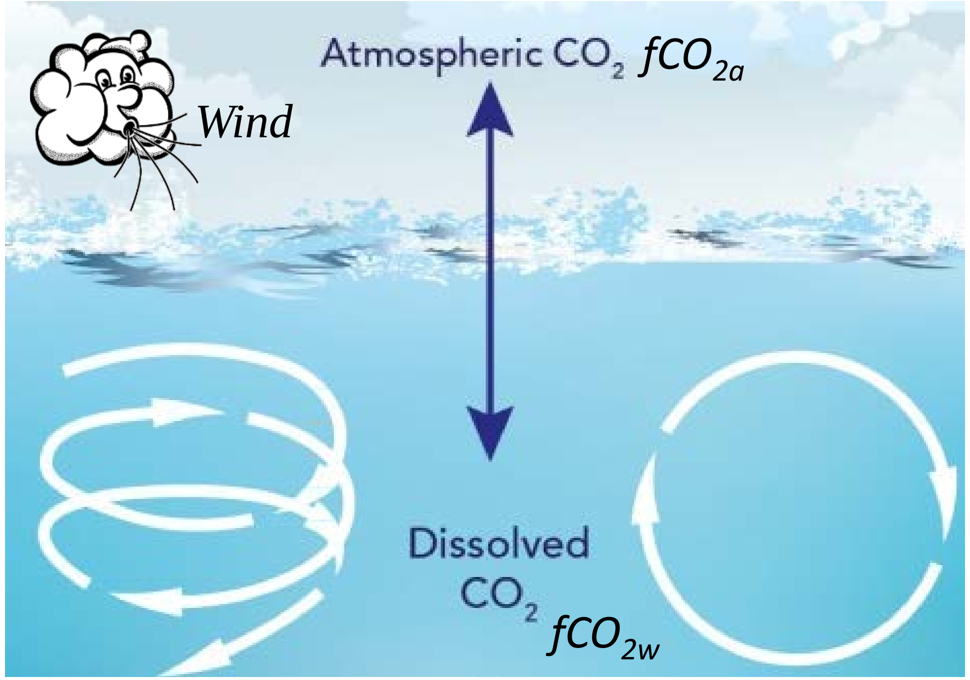
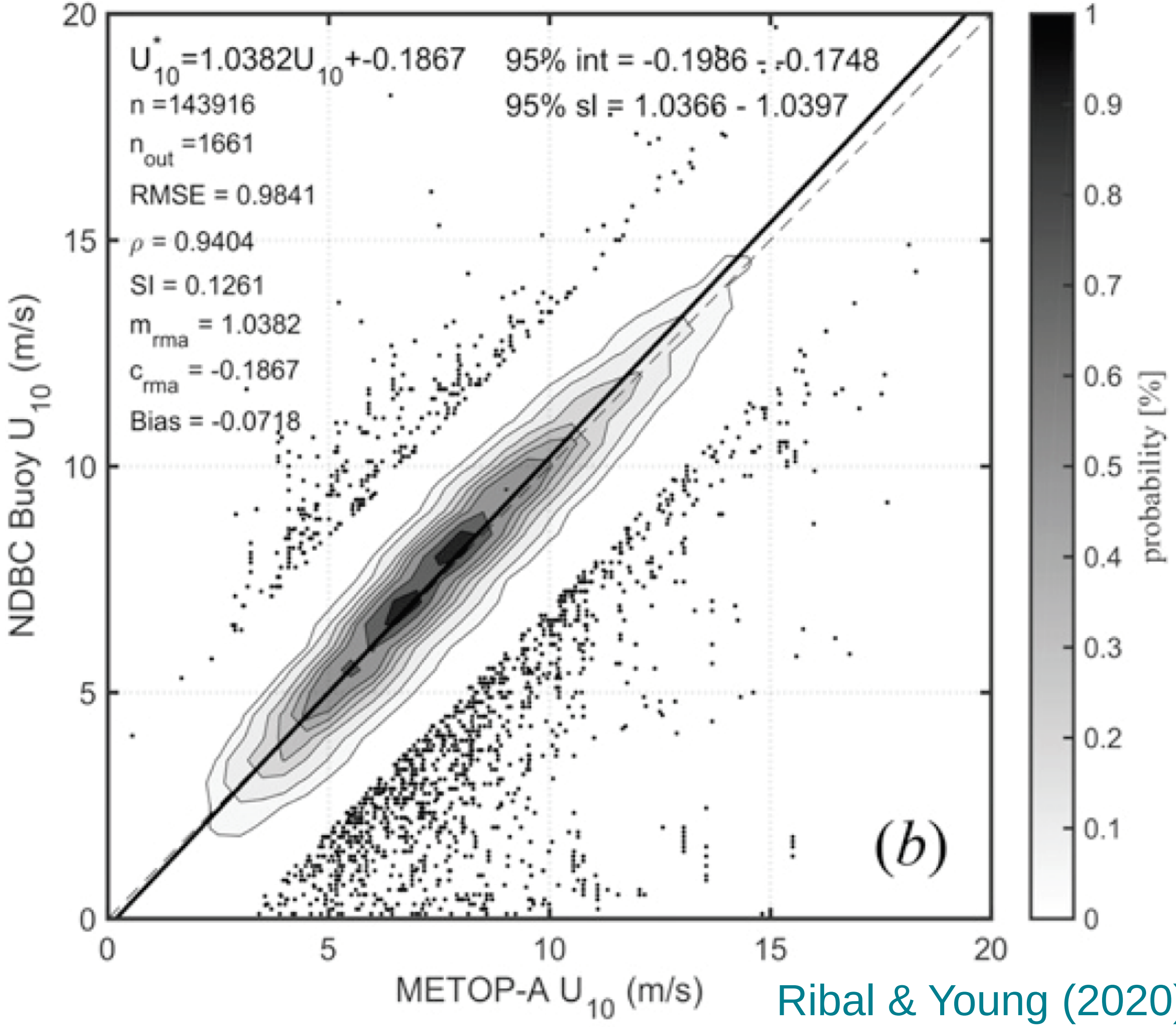
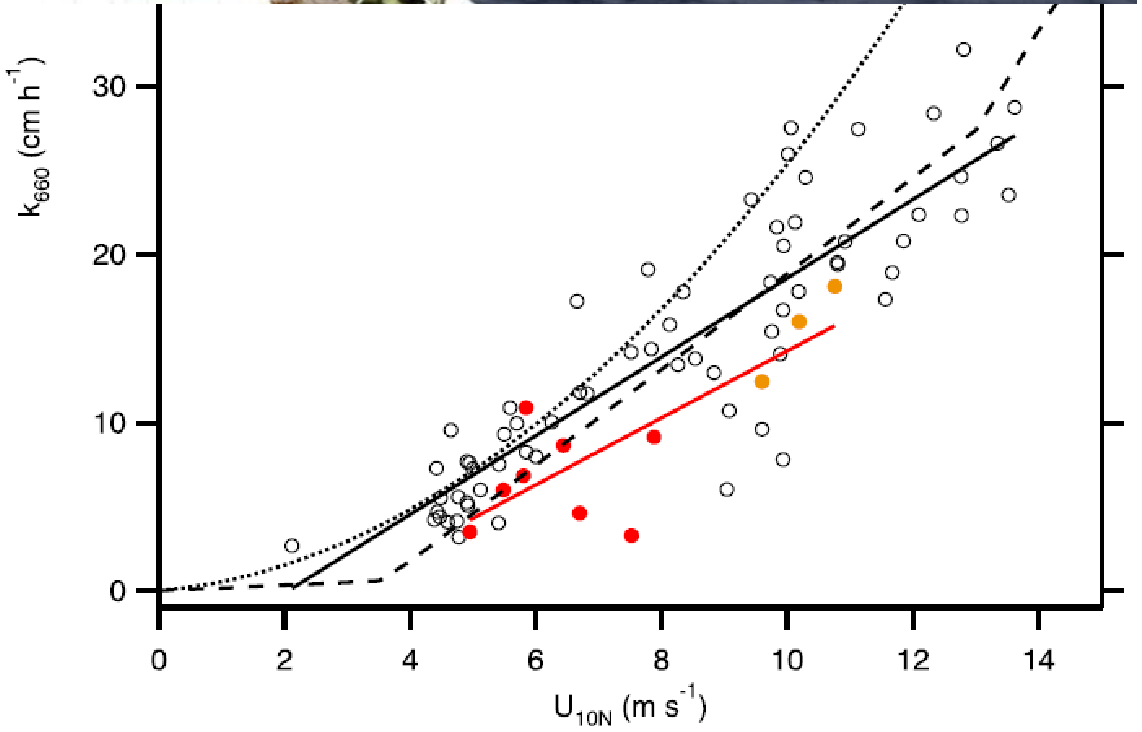


Satellite wind speed (U_{10}) uncertainty

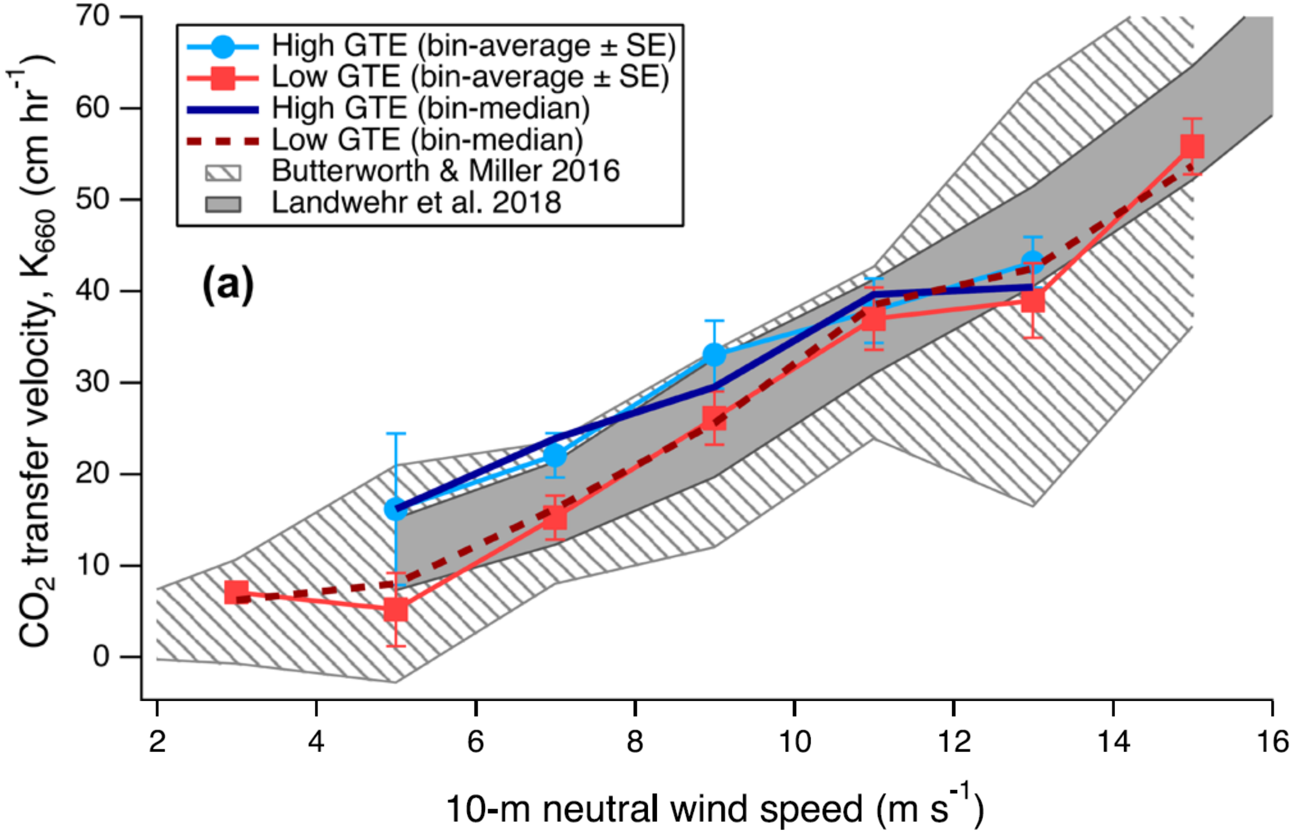


Ribal & Young (2020)

Impact of surfactants on sea surface



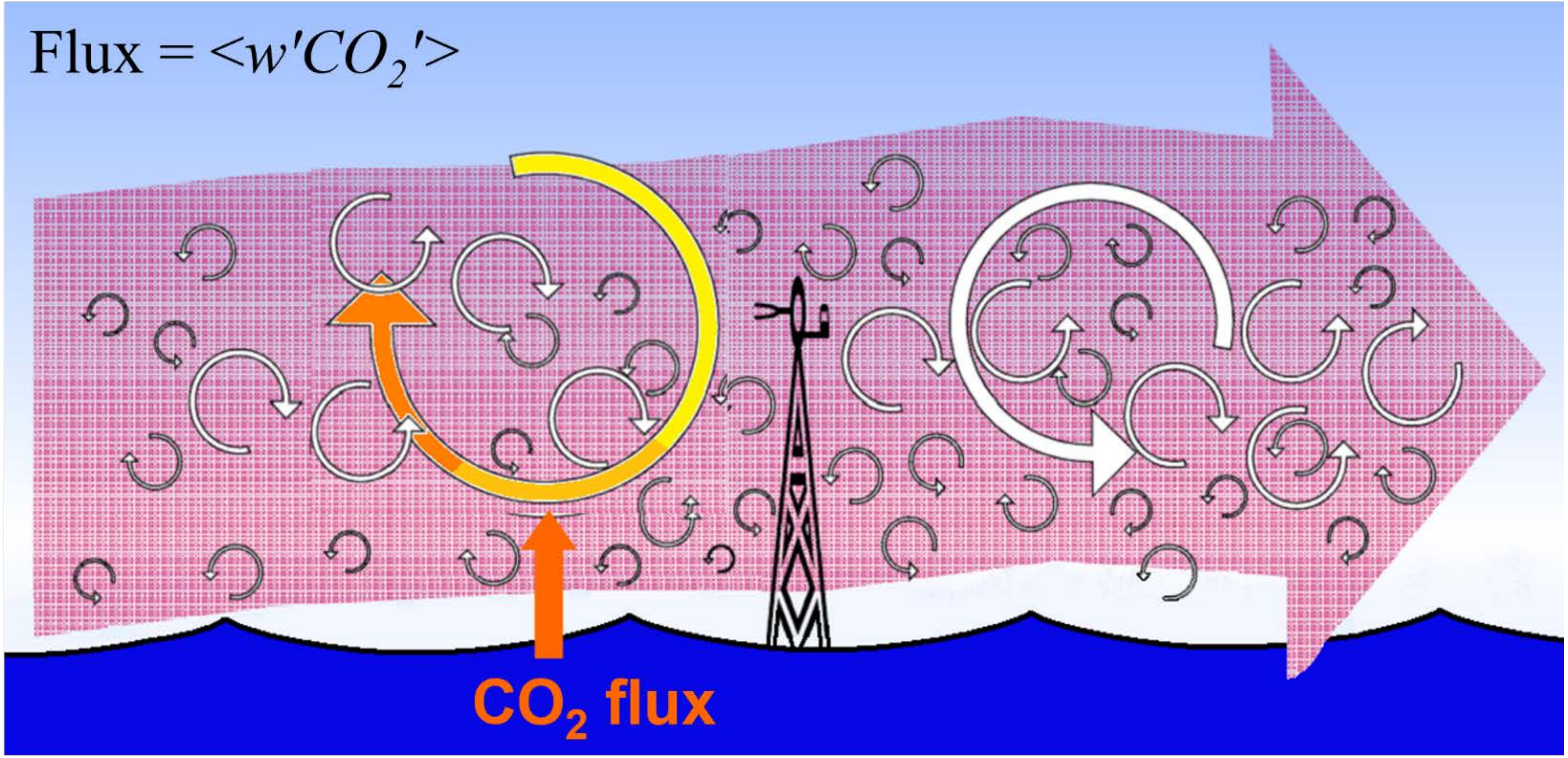
Salter et al. (2011)



Yang et al., Nature Sci. Rep. (2021)

Measuring air-sea CO_2 fluxes

Direct measurements (eddy covariance) – independent estimate of flux



Combined observations are a tool to investigate processes: $K = \text{Flux} / (\alpha_w fCO_{2w} - \alpha_i fCO_{2a})$

Autonomous air-sea CO_2 flux systems

Eddy covariance CO_2 fluxes

Seawater pCO_2

Flux observations:

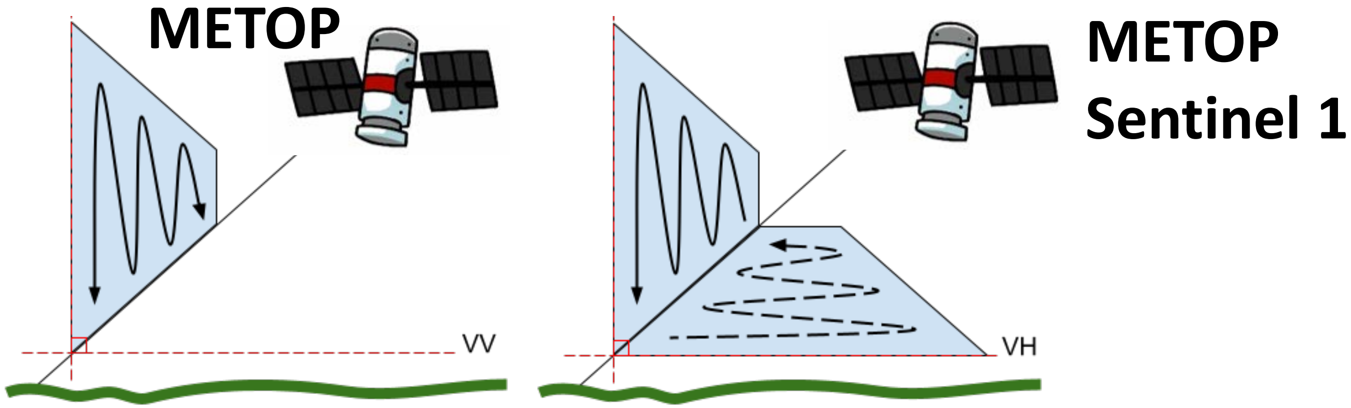
-Closed path

-Dried

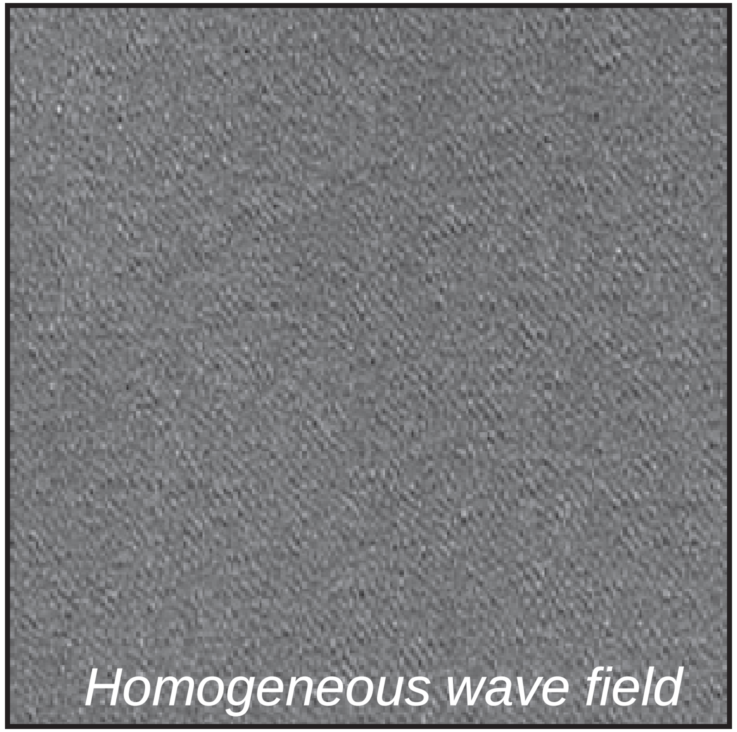
-Licor/Picarro

See Dong et al., ACP (2021)

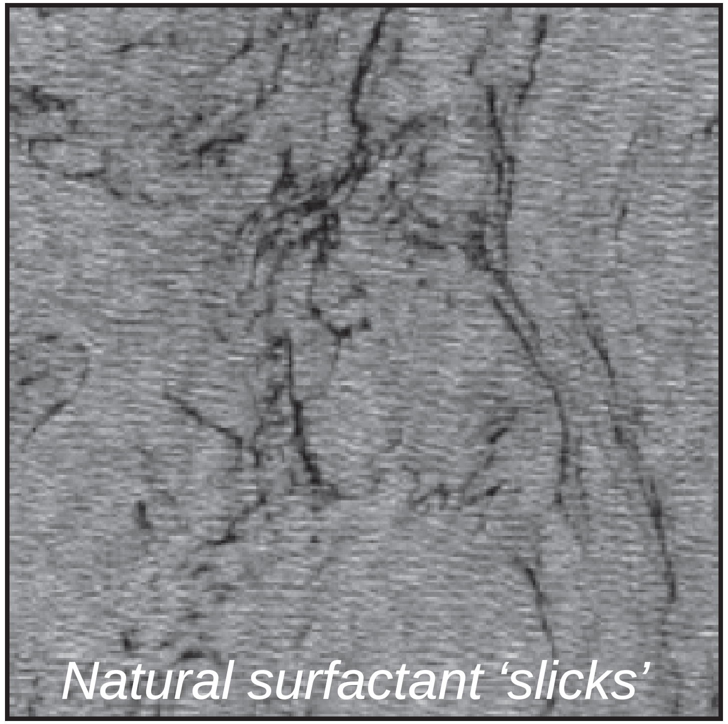
Sea surface scattering



Kudryavtsev et al. (2014)



Homogeneous wave field

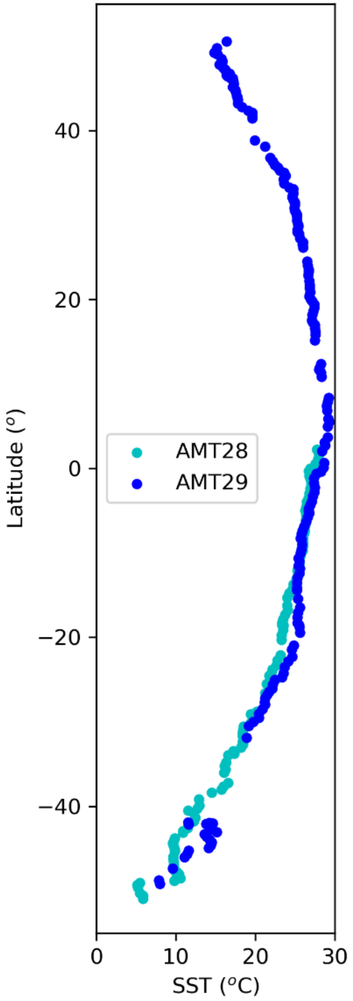


Natural surfactant 'slicks'

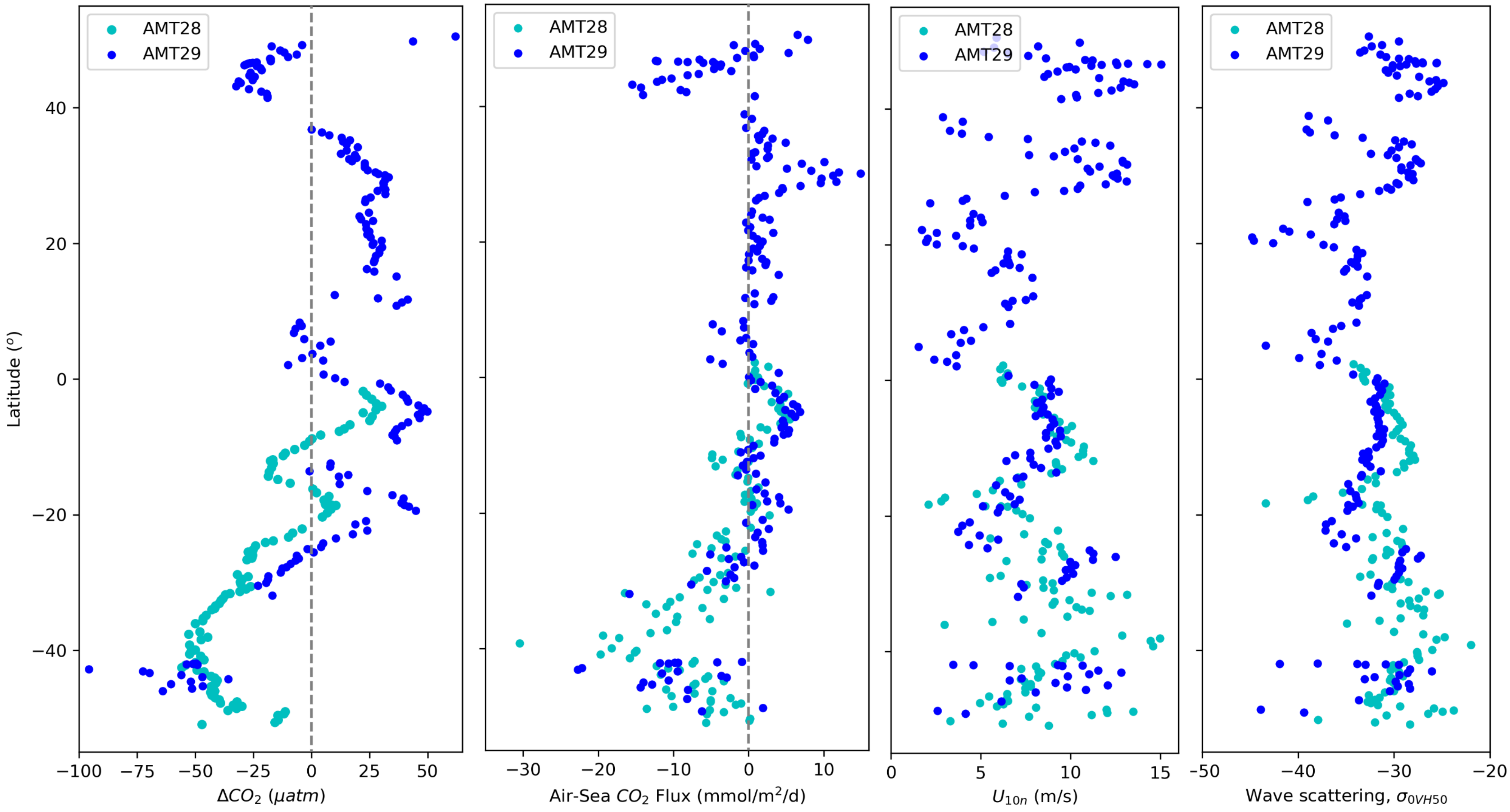
Wang et al. (2019)

- Scattering, σ_0 (C-band radar)
- Cross Polarisation (Horizontal/Vertical)
- Angles: 30º-50º
- Measures roughness (waves, whitecaps, etc.)

Atlantic Meridional Transect (AMT)



Latitudinal trends



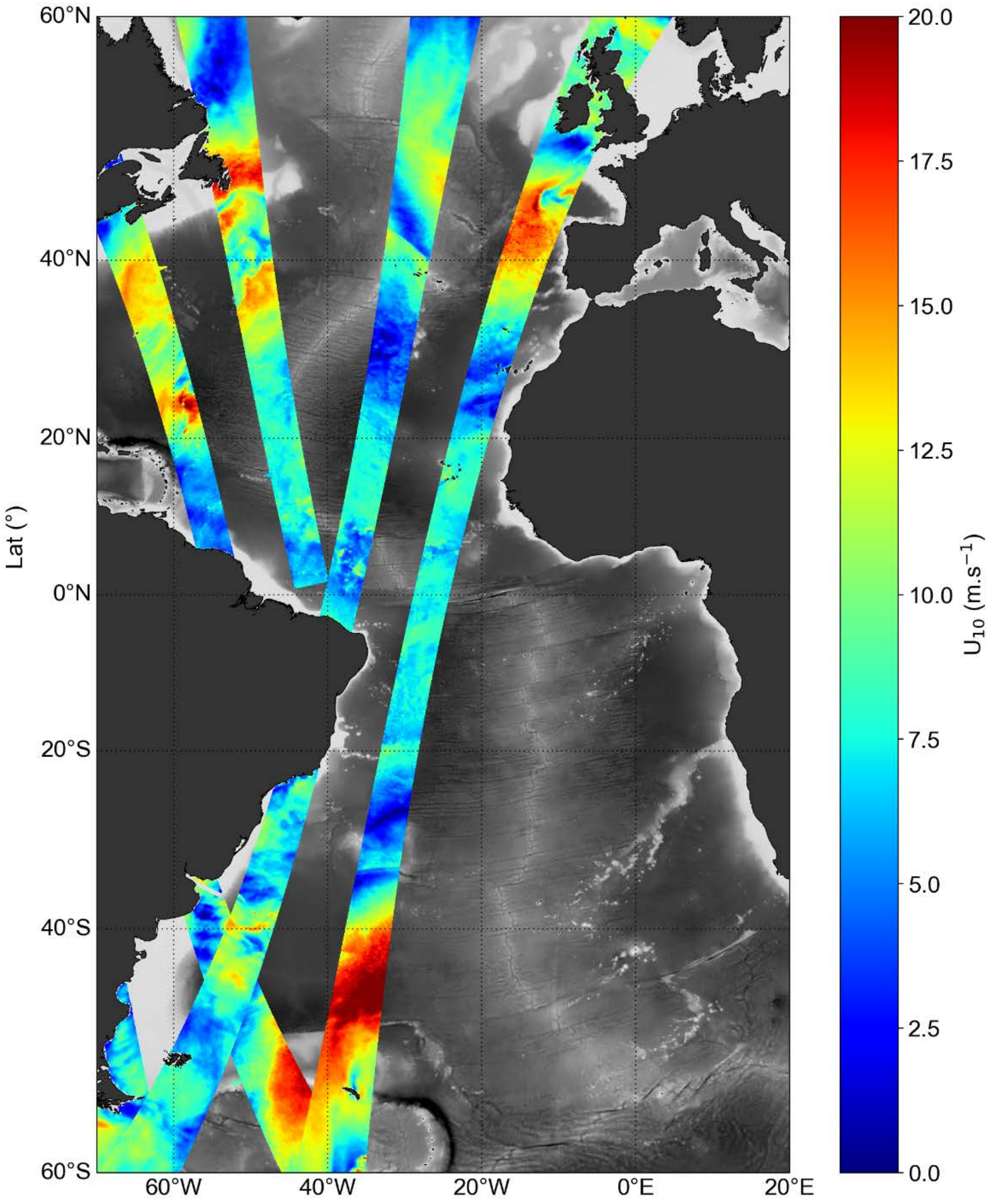
Summary and Outlook

- Cool skin temperature correction enhances global CO_2 uptake estimates by >20%
- Theoretical adjustment though! Needs verification

- K vs *in situ* radar backscatter (σ_0) relationship similar strength to K vs wind speed relationship
- Cross polarization σ_0 (VH) and 50^0 angle are optimal
- Reasonable comparison between satellite σ_0 and in situ observations
- In situ *K* vs. METOP σ_0 VV
  - Few observations
  - Corroborates in situ σ_0 and K relationship

Future: - More in situ observations needed

- Investigation of satellite σ_0 potential



METOP: 22^{nd} Nov. 2019