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Air-sea gas transfer velocity for gases of different solubility (CO_2, O_2 and CH_4)

Anna Rutgersson, Erik Sahlée, Andreas Andersson, Antonin Verlet-Banide, Eva Podgrajsek, Anna Sjöblom
Uppsala University, Sweden

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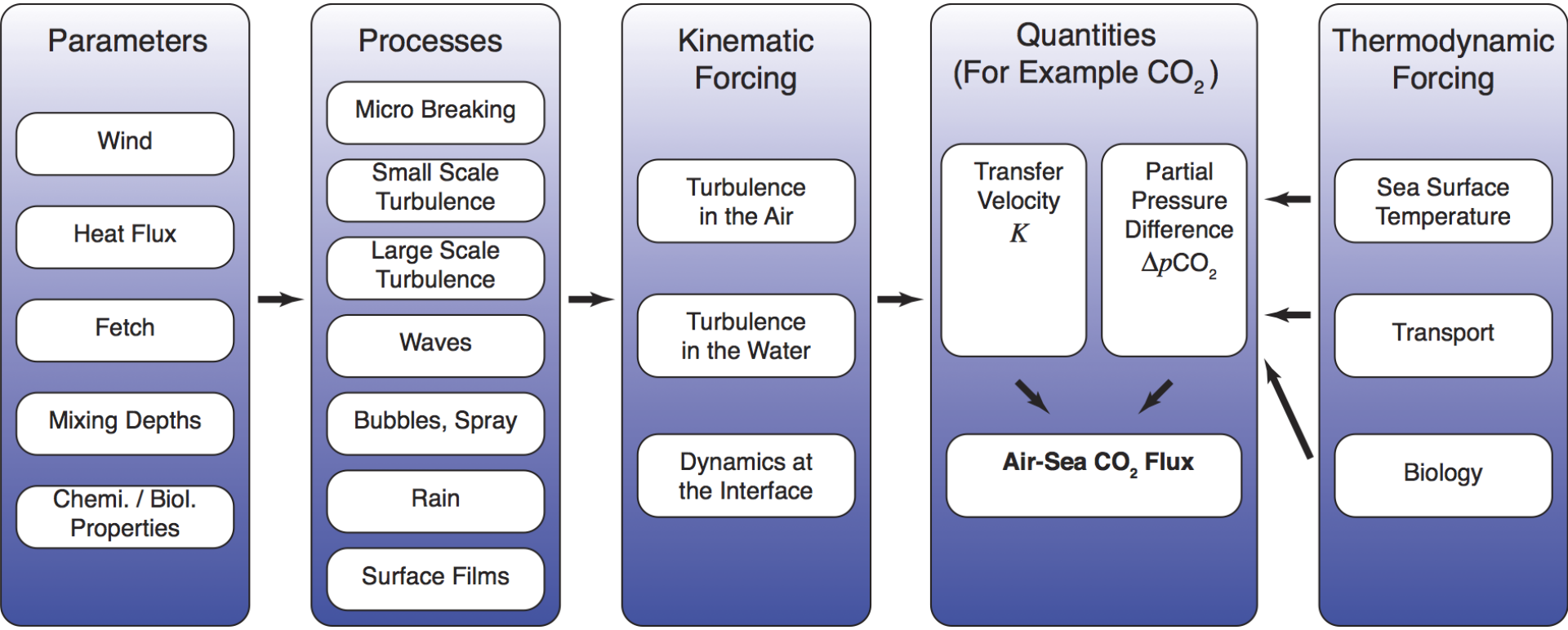
What controls the exchange?



COST735 book (Garbe and Rutgersson et al)

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Types of water basins:

- Open ocean
  - Spray, bubbles
  - waves

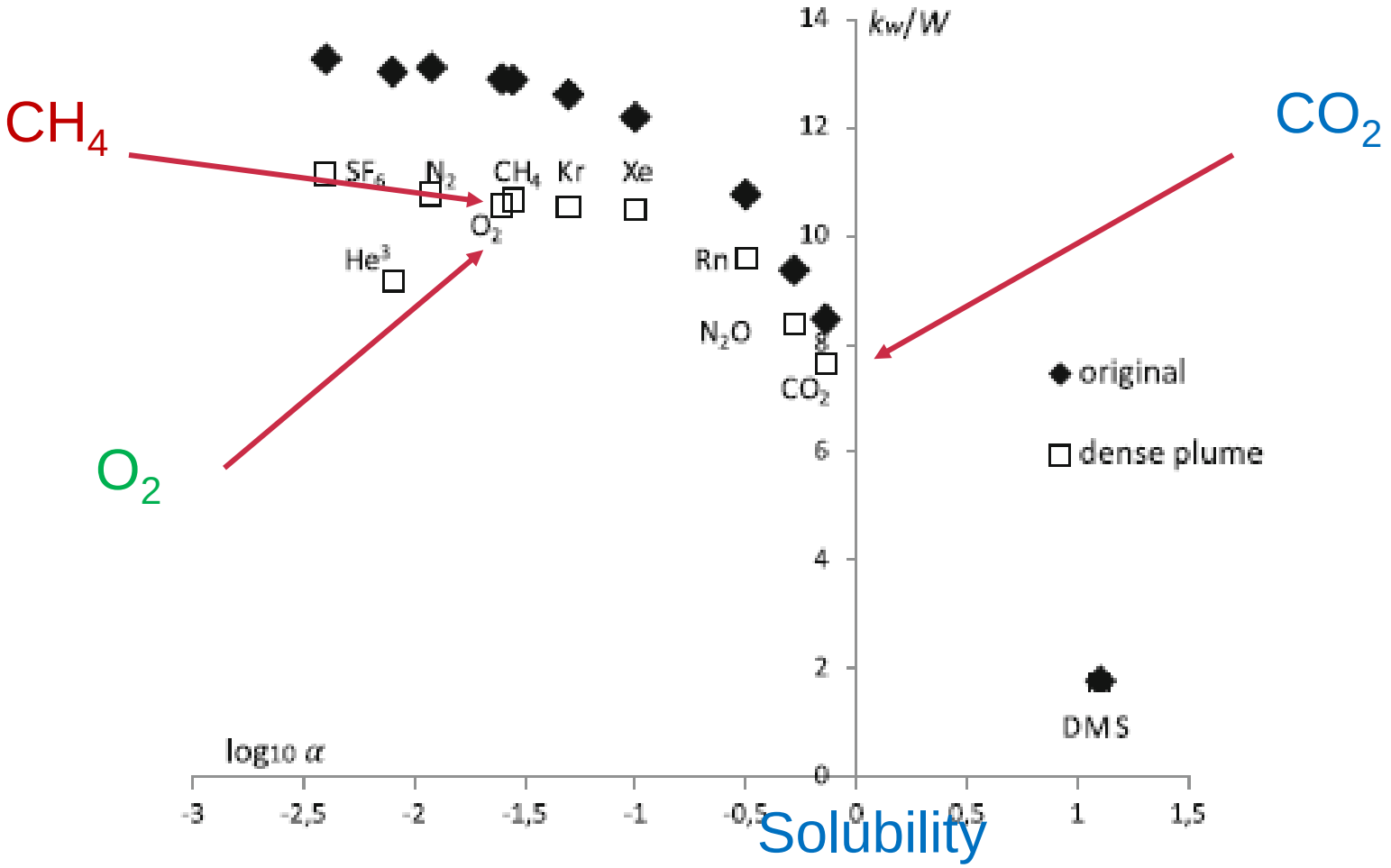
  → Wind speed, Waves
- Marginal and coastal seas
  - Spray, bubbles, waves
  - buoyancy

  → Wind speed and waves, Temperature difference
- Shore areas
  - Spray, bubbles, waves
  - buoyancy
  - surfactants

  → Wind speed and waves, Temperature difference, Chem/biol properties
- Lakes
  - buoyancy
  - Surfactants

  → Temperature difference, Chem/biol properties, Wind speed?

Sensitivity of gas transfer velocity to whitecap coverage



COST735 book (Garbe and Rutgersson et al) based on models from Woolf et al (2007)

Controls of diffusive fluxes:

For vertical flux of gas (here for CO_2). Using EC method

$$F_{CO2} = \overline{w'c'} \text{ (turbulent vertical flux)}$$

$$F_{CO2} = kK_0(pCO_{2w} - pCO_{2atm})$$

Observations of fluxes.

Calcuate fluxes

$$k = \frac{\overline{w'c'}}{K_0(pCO_{2w} - pCO_{2atm})}$$

$$k_{660} = \frac{\overline{w'c'}}{K_0(pCO_{2w} - pCO_{2atm})}\sqrt{\frac{Sc}{660}}$$

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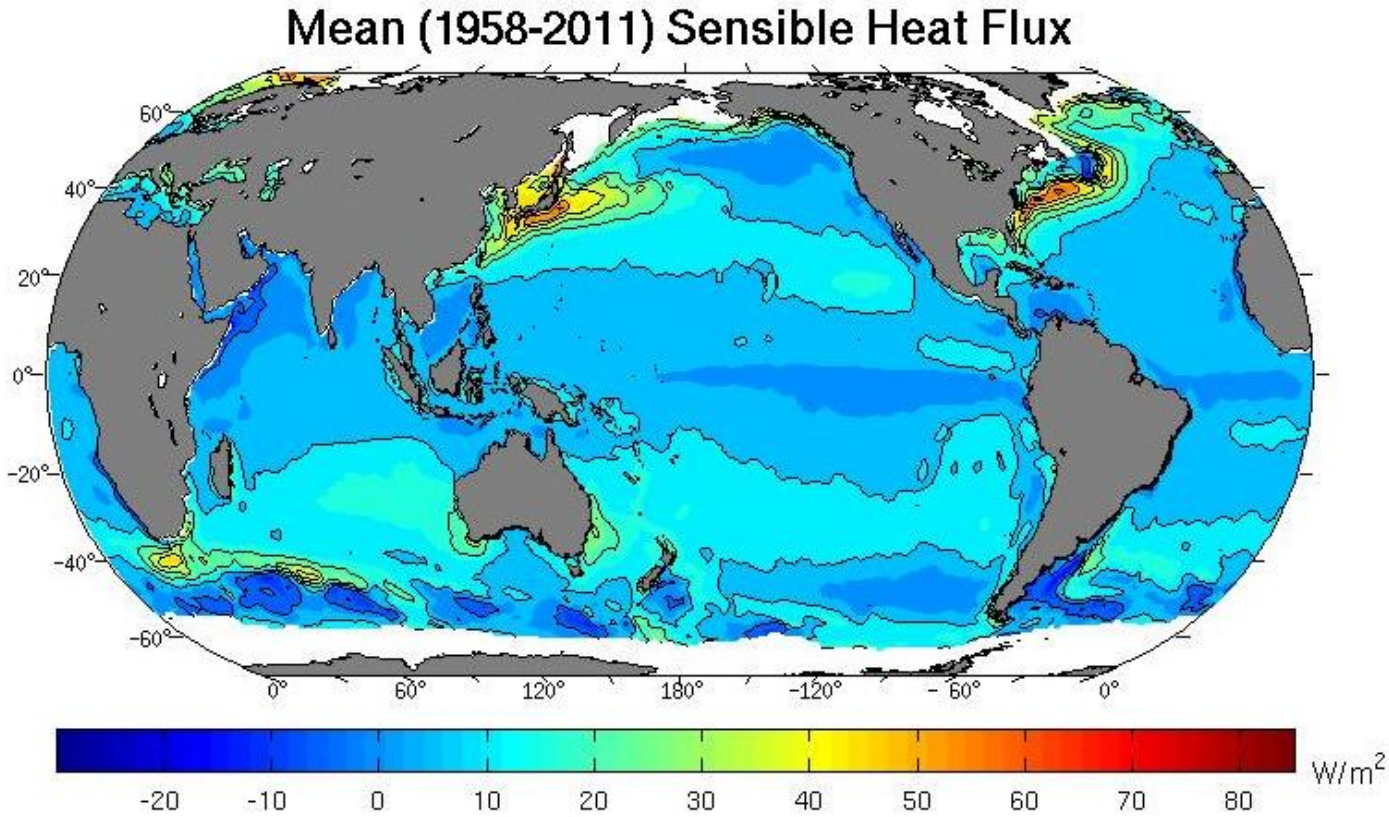
Heat flux globally (indicates air-sea temeprature difference):



From WHOI OAflux

The Östergarnsholm-site, CO_2 and O_2

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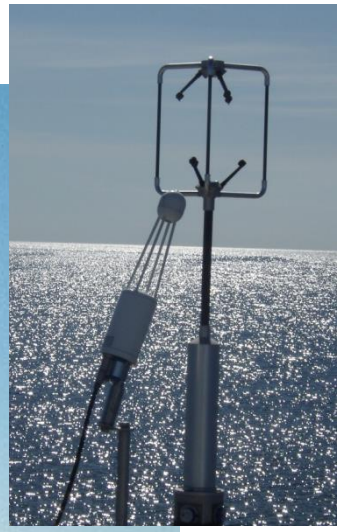
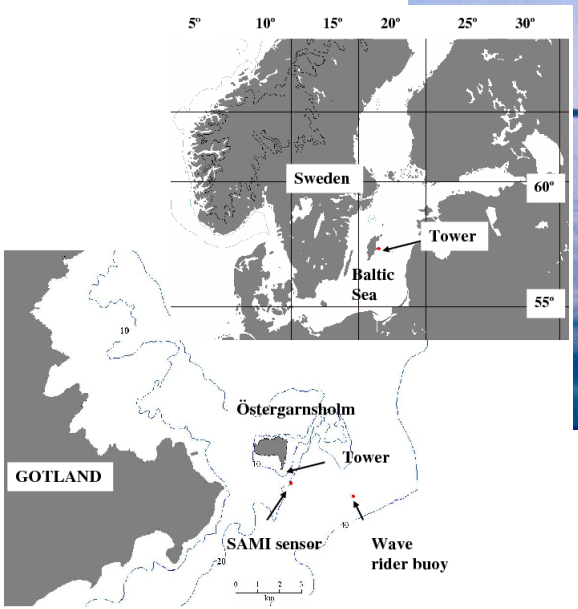
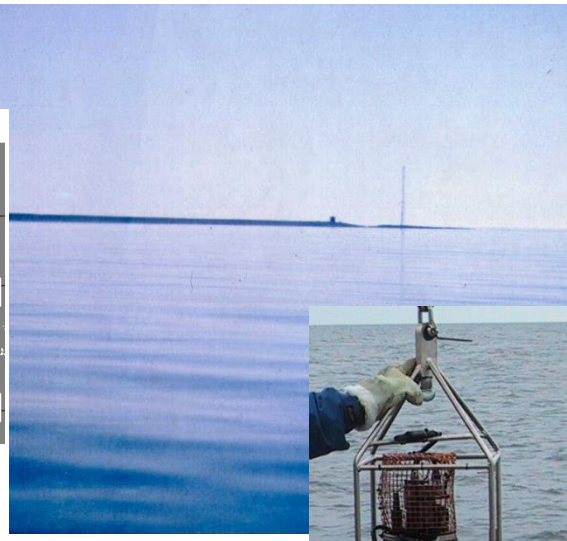


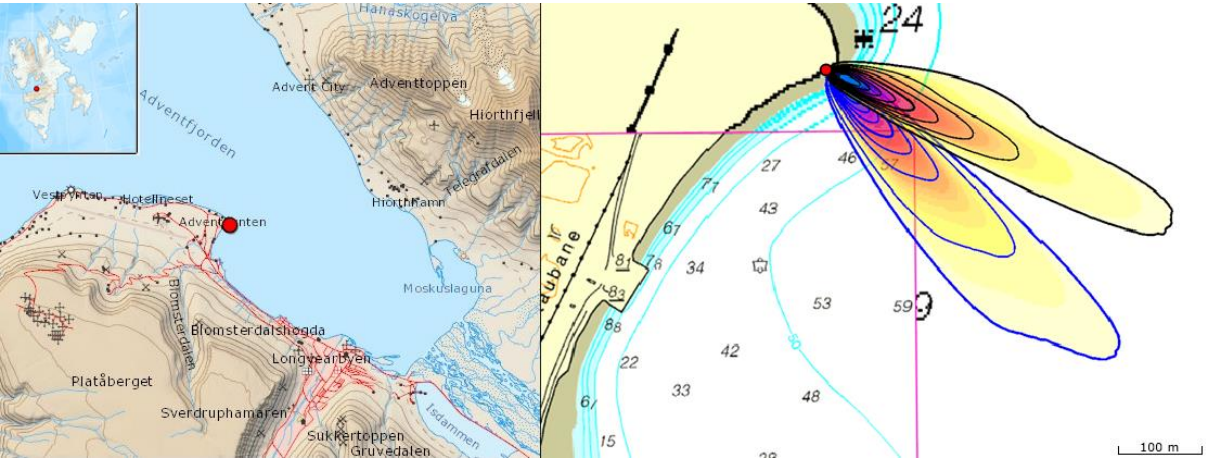




Data for air-sea interaction investigations, meteorological data as well as buoy data (wave, pCO_2 etc). Has been shown to well represent open sea conditions.

integrated carbon observation system

Adventsfjorden, a Svalbard fjord, CO_2



Arctic conditions, large air-sea temperature differences.

Tower on the shore during 2 months.

Water sampling

Swedish lake system, used at two lakes (Tämnaren, Erken), CO_2 and CH_4

Relatively low winds

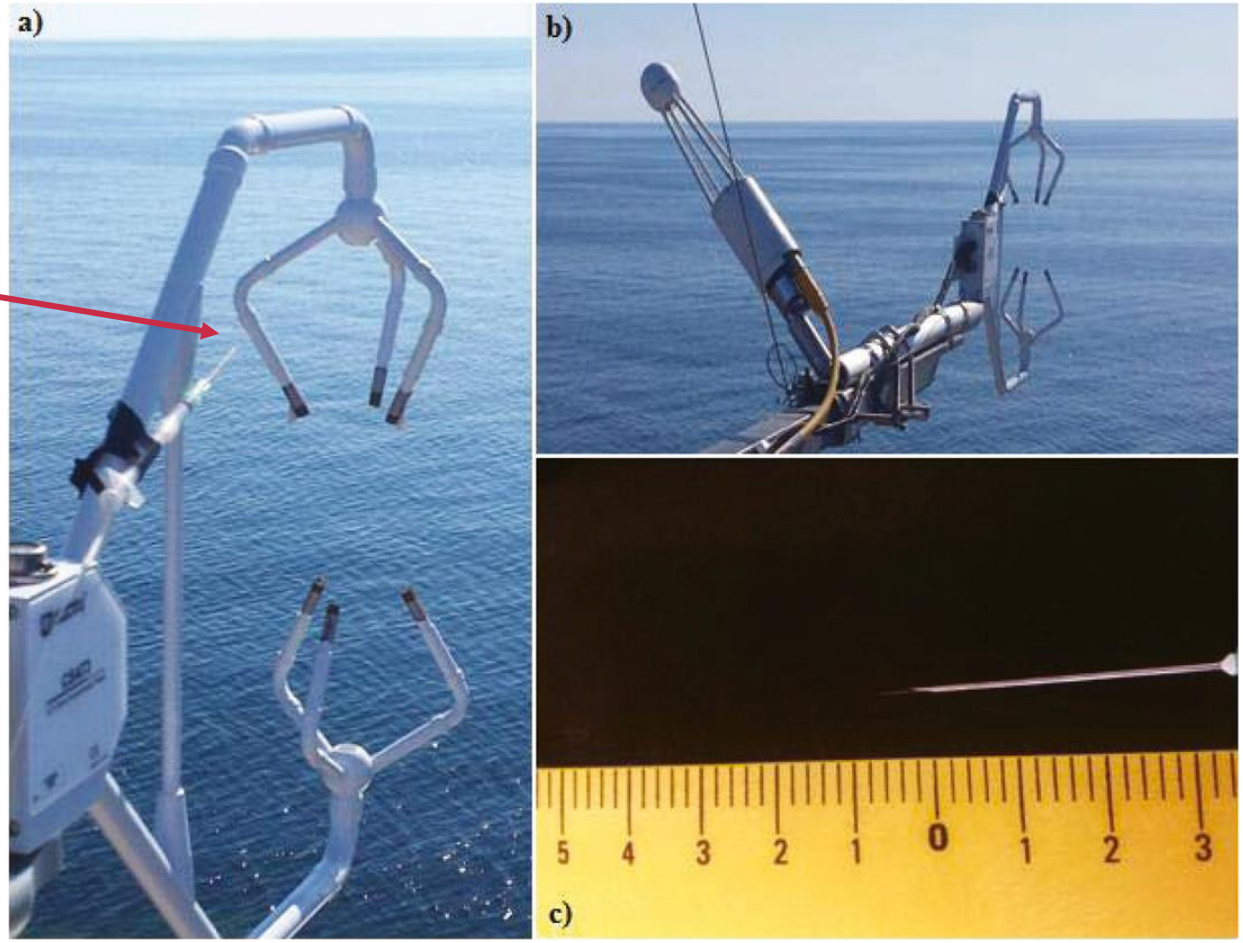
Carbon dioxide and methane

Fast response oxygen optode

Fast response oxygen optode Microx TX3 (PreSens Precision Sensing GmbH)

Uses luminescence lifetime technique

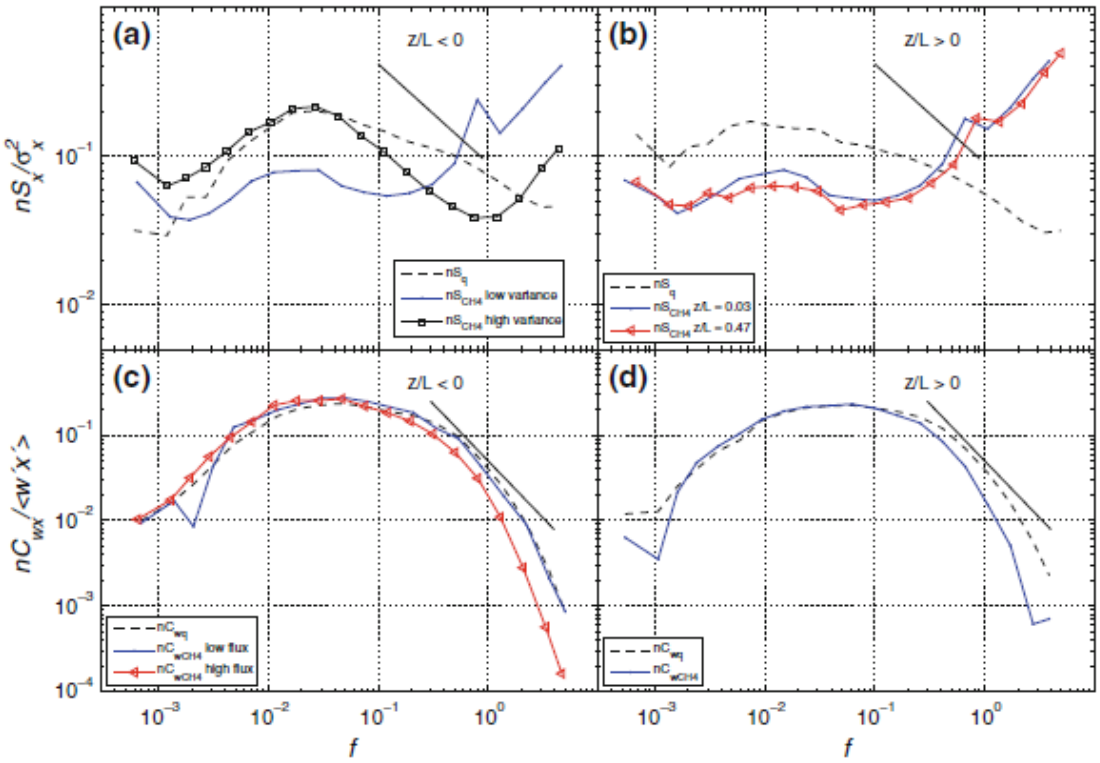
No cross-sensitivity



Andersson, Rutgersson and Sahlée (2014) Using a High-Frequency Fluorescent Oxygen Probe in Atmospheric Eddy Covariance Applications, J. Ocean and Atmospere Techn., 31, 2498

Methane fluxes, LI-7700, open path system

IR gas analyser, good results for fluxes, some drop in high-frequency response



Podgrajsek, E. et al. (2014). *J. Geophys. Res. Biogeosciences,*119, 236–248
Sahlée et al., (2013) BLM

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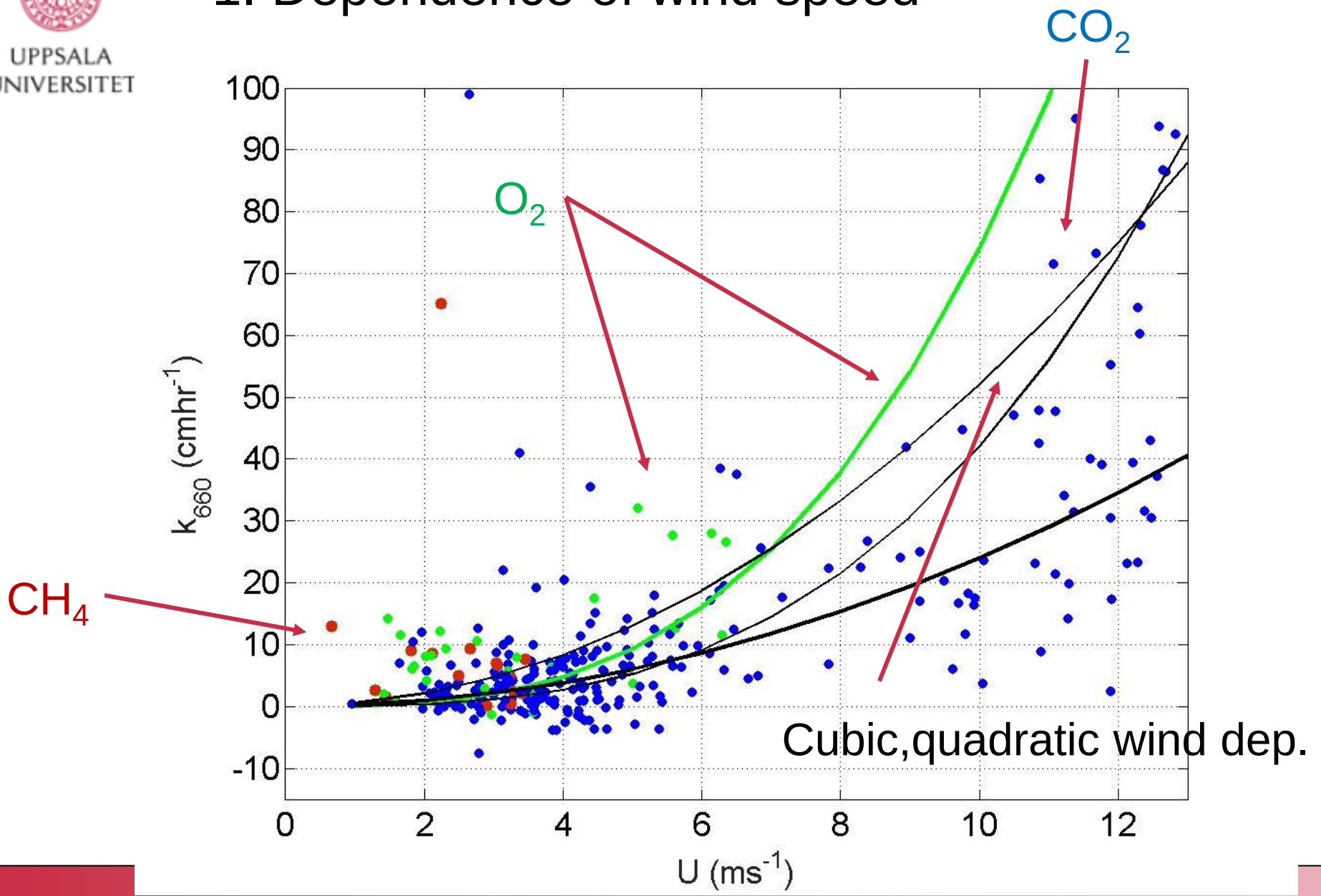
1. Dependence of wind speed



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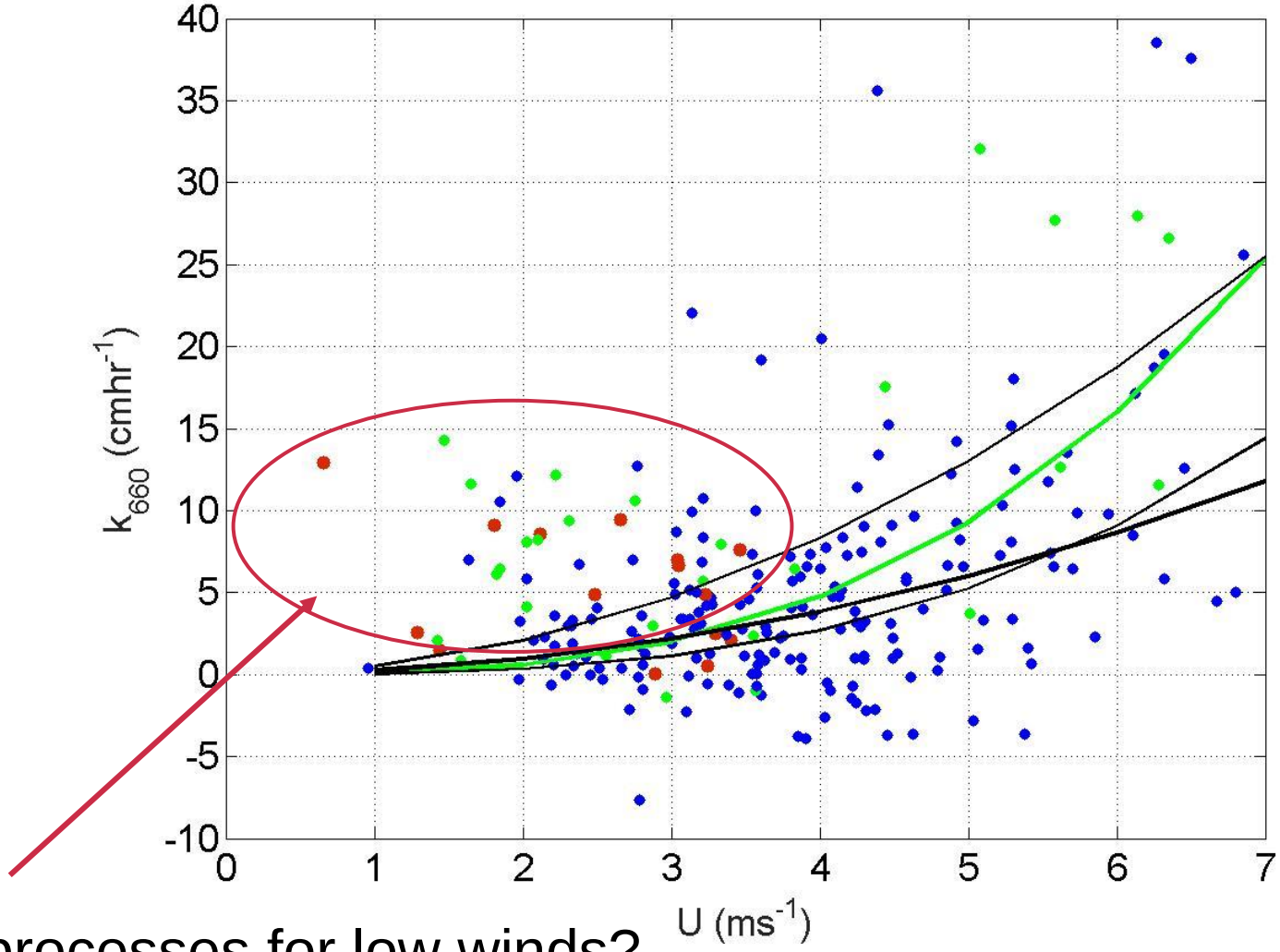
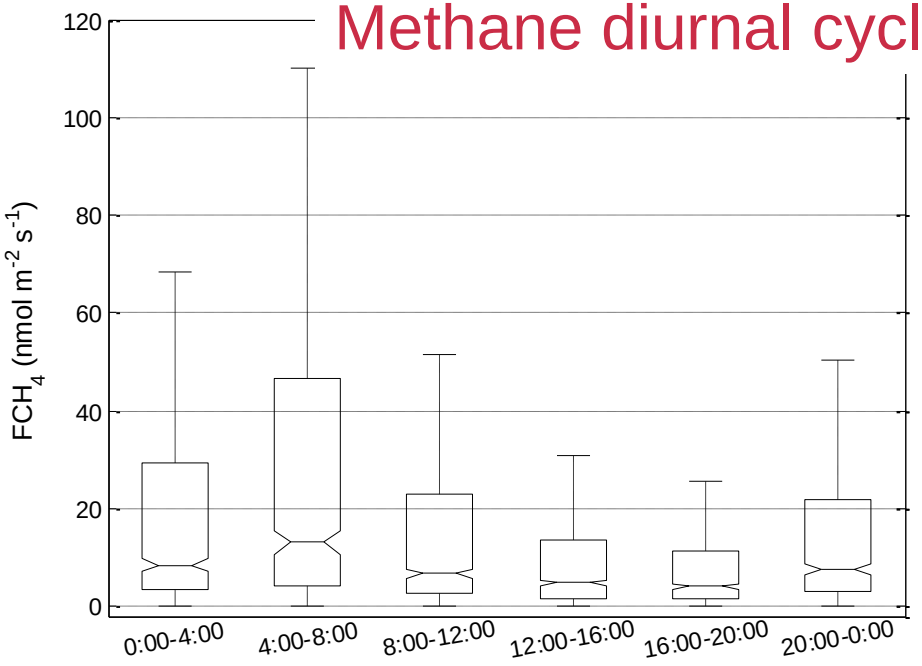
1. Dependence of wind speed, larger for oxygen



Other processes for low winds?

2. Dependence on convection, Lake

Methane diurnal cycle

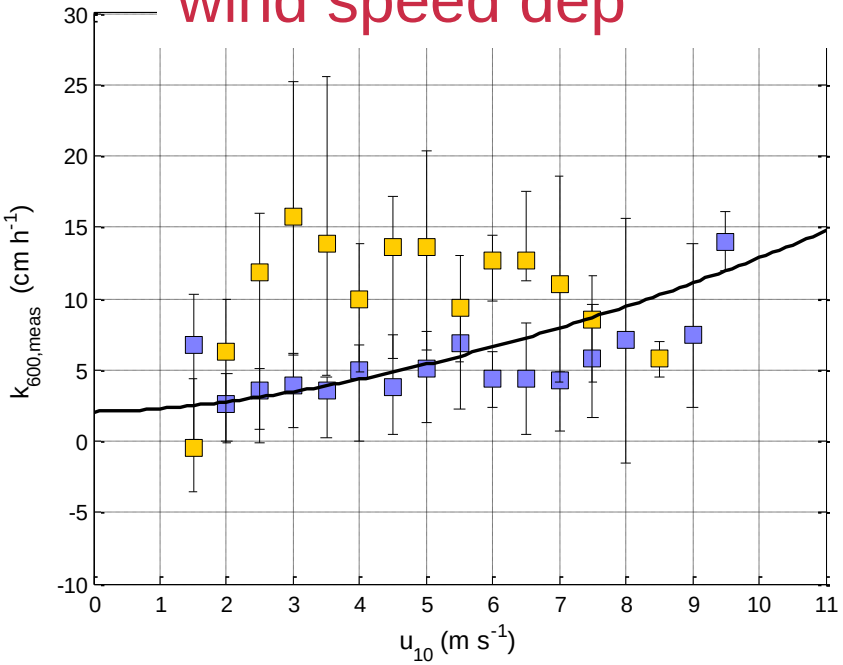


Diurnal cycle for methane

CO2 controlled by water-side convection

Methane and carbon dioxide flux increased for water-side convection

Carbon dioxide CO2 wind speed dep



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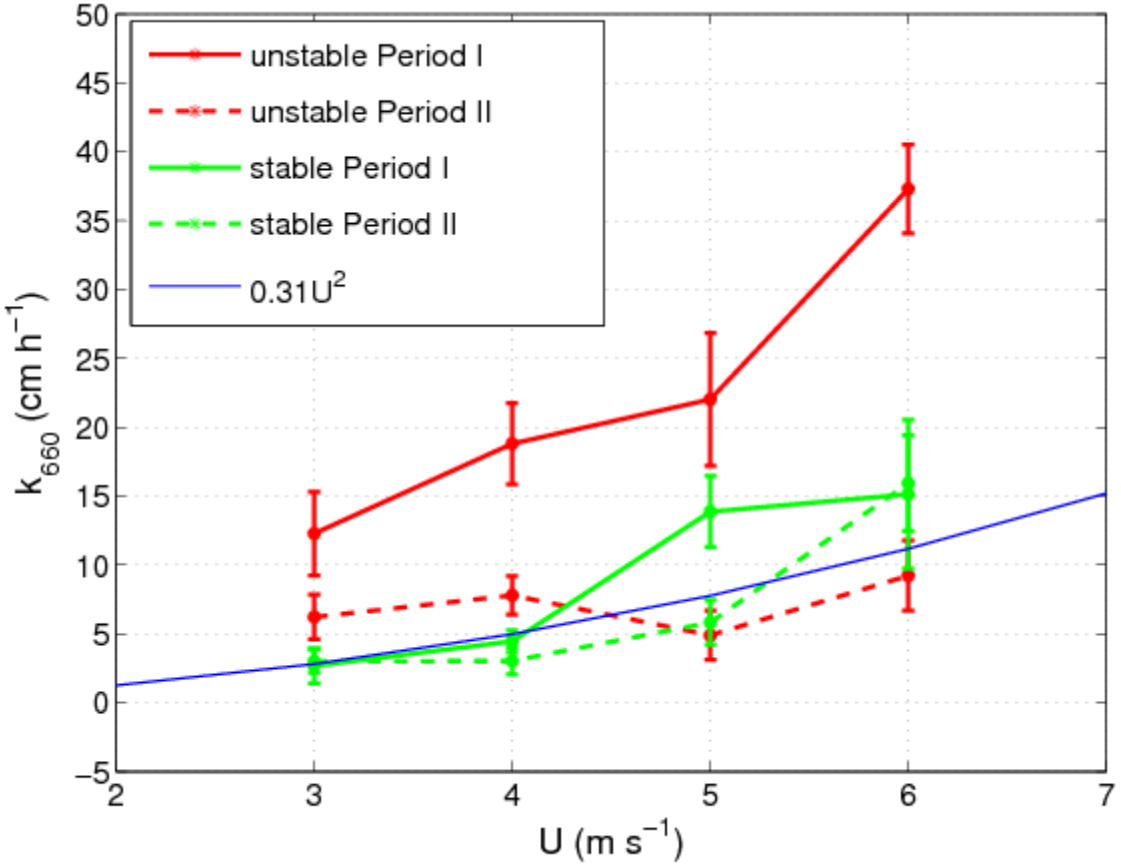
Larger transfer velocity for larger mixed layer depth, define convective velocity scale



$$w = \left(z_{ml} B\right)^{1/3}$$

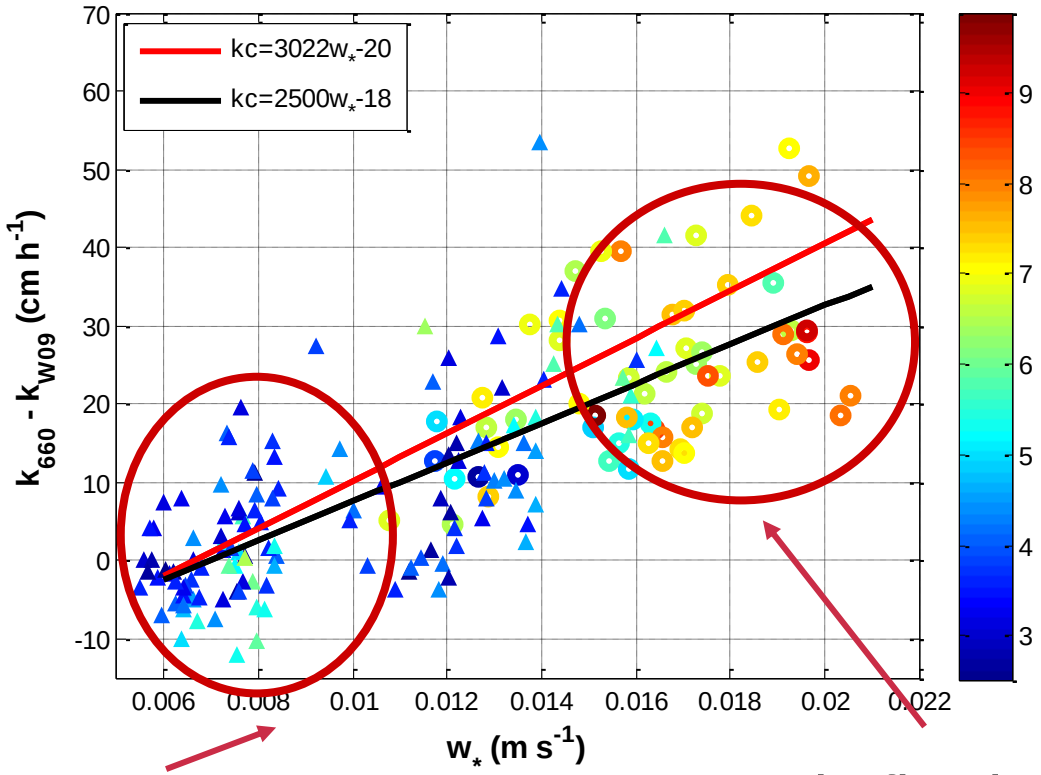
$$B = buoyancy\ at\ the\ surface$$

$$z_{ml} = mixed - layer\ depth$$

B refers to the buoyancy in the water due to cooling and evaporation (colder saltier water is heavier)

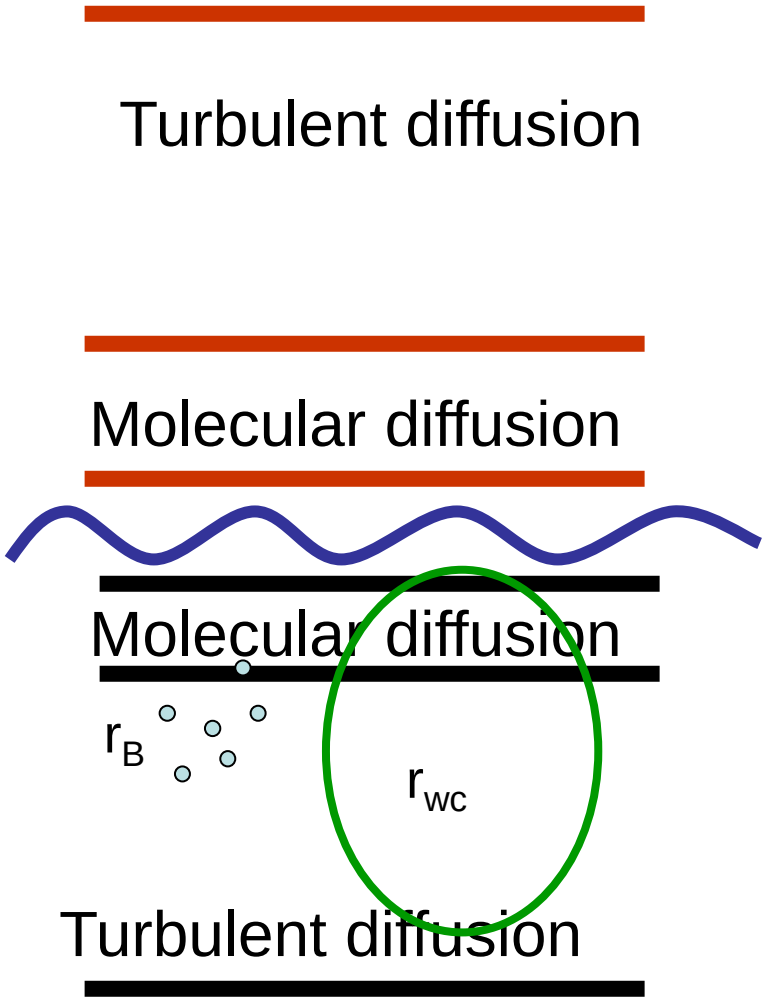
From Rutgersson and Smedman (2010)

2. Dependence on water-side convection



Baltic Sea

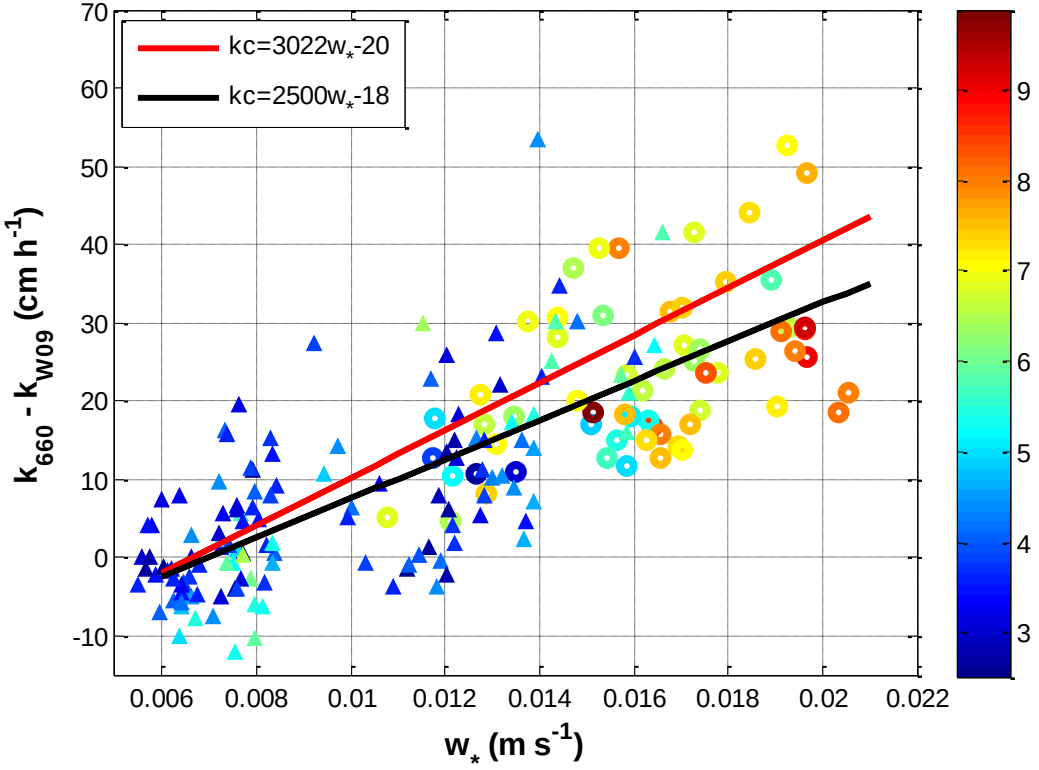
Arctic fjord

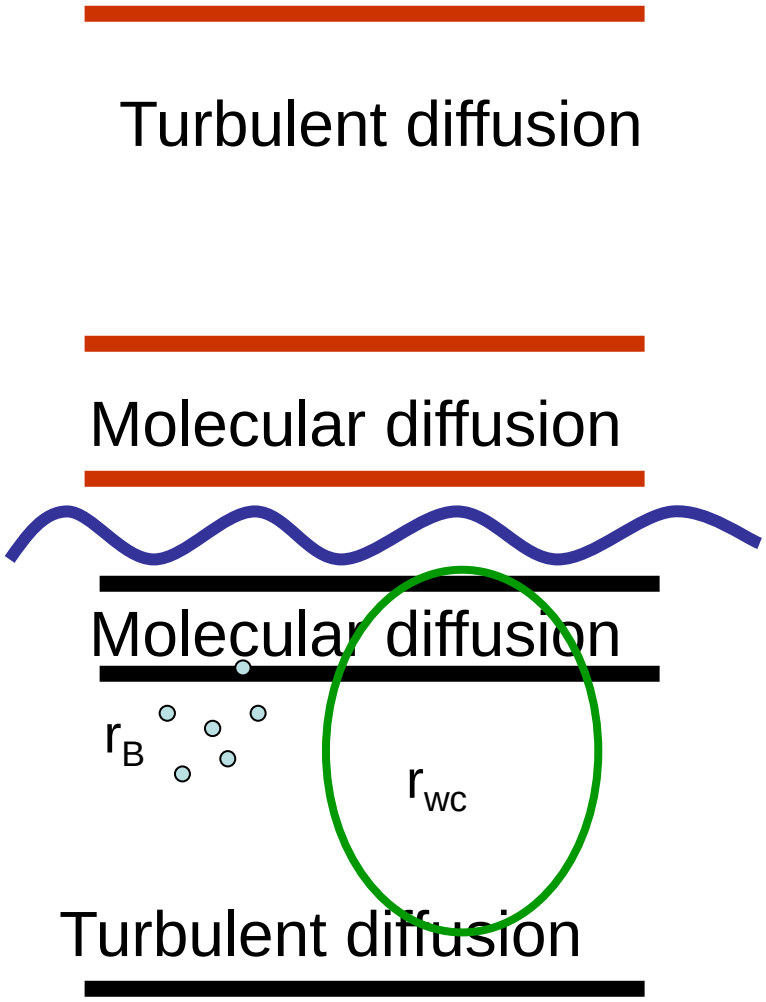


Wind speed and convection, w*
convective velocity scale

Andersson, Rutgersson, Sjöblom, Falck and Sahlée (2016) Air-sea gas transfer for high Arctic fjords.

2. Dependence on water-side convection





Carbon dioxide flux increased for water-side convection in Arctic fjord and inlands sea for waterside convection.

Andersson, Rutgersson, Sjöblom, Falck and Sahlée (2016) Air-sea gas transfer for high Arctic fjords.

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Studies show for different type of gas and basins

	Wind	**Convection**	**Surfactants**
Lake CO_2	**Weak**	**Yes**	Yes?
Lake CH_4	**Weak**	**Yes**	Yes?
Marginal Sea O_2	**Strong**	**?**	No?
Marginal Sea CO_2	**Yes**	Yes	No?
Arctic fjord, CO_2	**Yes**	**Strong**	No?

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Conclusions

- Need more studies in a variety of basins+conditions for different gases for better understanding of processes (more measurements…).
- Limited size basins with land influence non-wind-driven processes more important.
- Different solubility different processes acts differently.

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Thank you!