UPPSALA UNIVERSITET

Remote sensing algorithms for sea surface CO_2 and CO_2 flux

a Swedish National Spaceboard project focusing the Baltic Sea

Anna Rutgersson[1], Tiit Kutser[2], Melissa Chierici[3], Gaelle Parard[1], Sindu Parampil[1], Erik Sahlée[1], Maria Norman[1]

[1]Air-Water Exchange Platform, Uppsala University, anna.rutgersson@met.uu.se
[2]Estonian Marine Institute
[3]University of Gothenburg and IMR, Tromsø, Norway

RYMDSTYRELSEN Swedish National Space Board

integrated carbon observation system

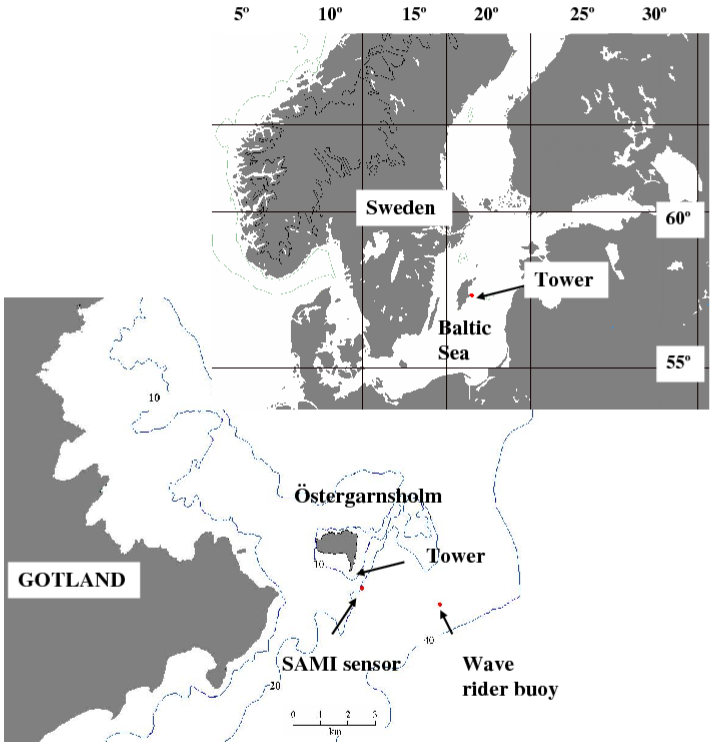
Baltic Earth
Earth System Science for the Baltic Sea Region

From a global perspective: Why Baltic Sea?

1. Representative of coastal regions

   (contribution of marginal seas and shelf areas to the ocean carbon cycle is disproportionally large).

2. Highly variable
   - river runoff
   - upwelling
   - atmopshere more variable (stratification, sea-breeze circulation, coastal jets etc).



UPPSALA UNIVERSITET

Do we need to consider water-side convection when calculating air-sea gas transfer?

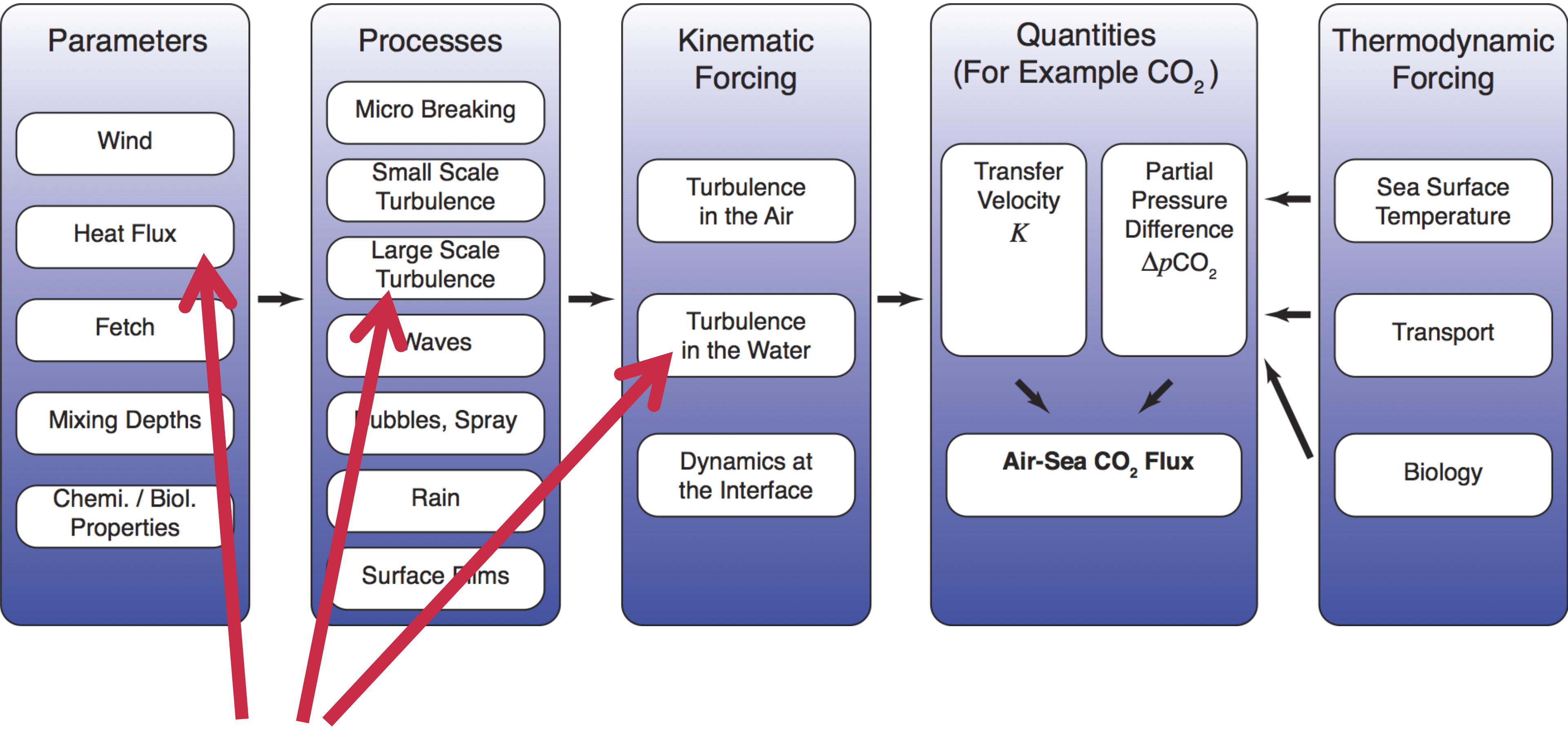
Transfer velocity for different gases.

Anna Rutgersson

also Erik Sahlée, Eva Podgrajsek, Maria Norman, Andreas Andersson

UPPSALA UNIVERSITET

What controls the exchange?



COST735 book

UPPSALA UNIVERSITET

Wind-speed dependent transfer velocity

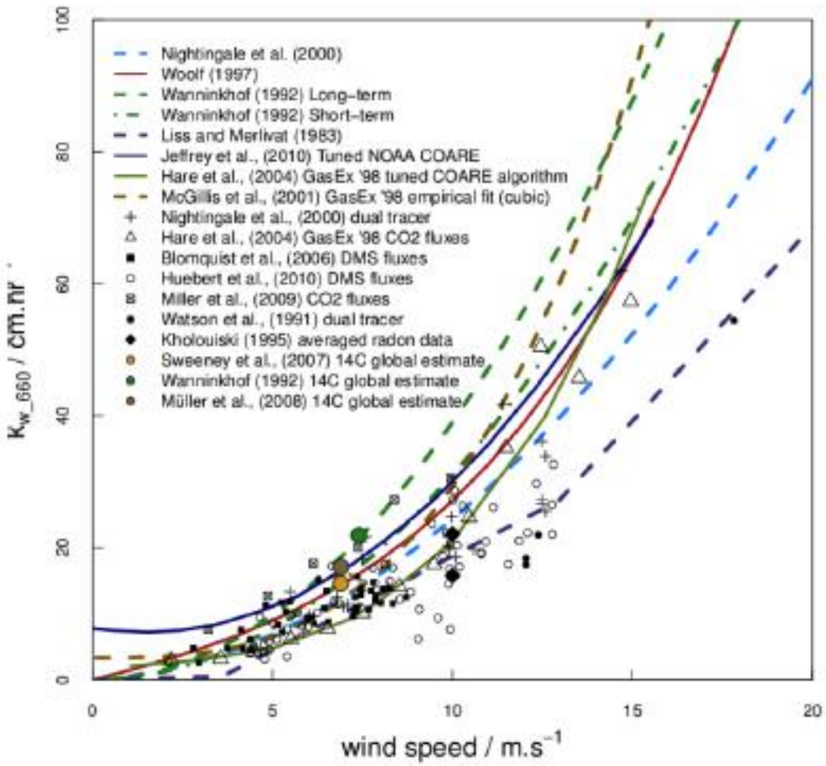


Fig. 4 A comparison of different windspeed relationships of the transfer velocity *k*.

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

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

$$k \propto U^x$$

$$x = 1,2,3,\ldots$$

Time scale of various processes

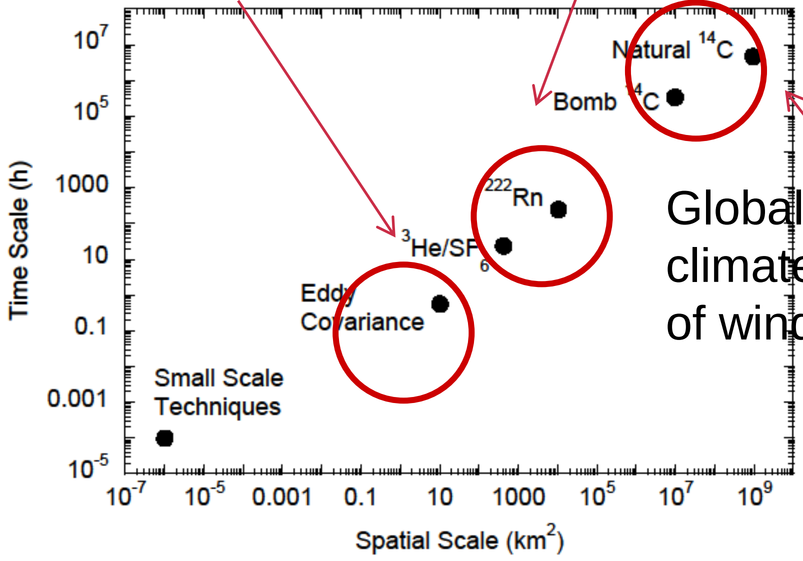
Non-linear dependence of various parameters.

What is the relevant timescale when estimating k?

For smaller scales – we need to include more processes

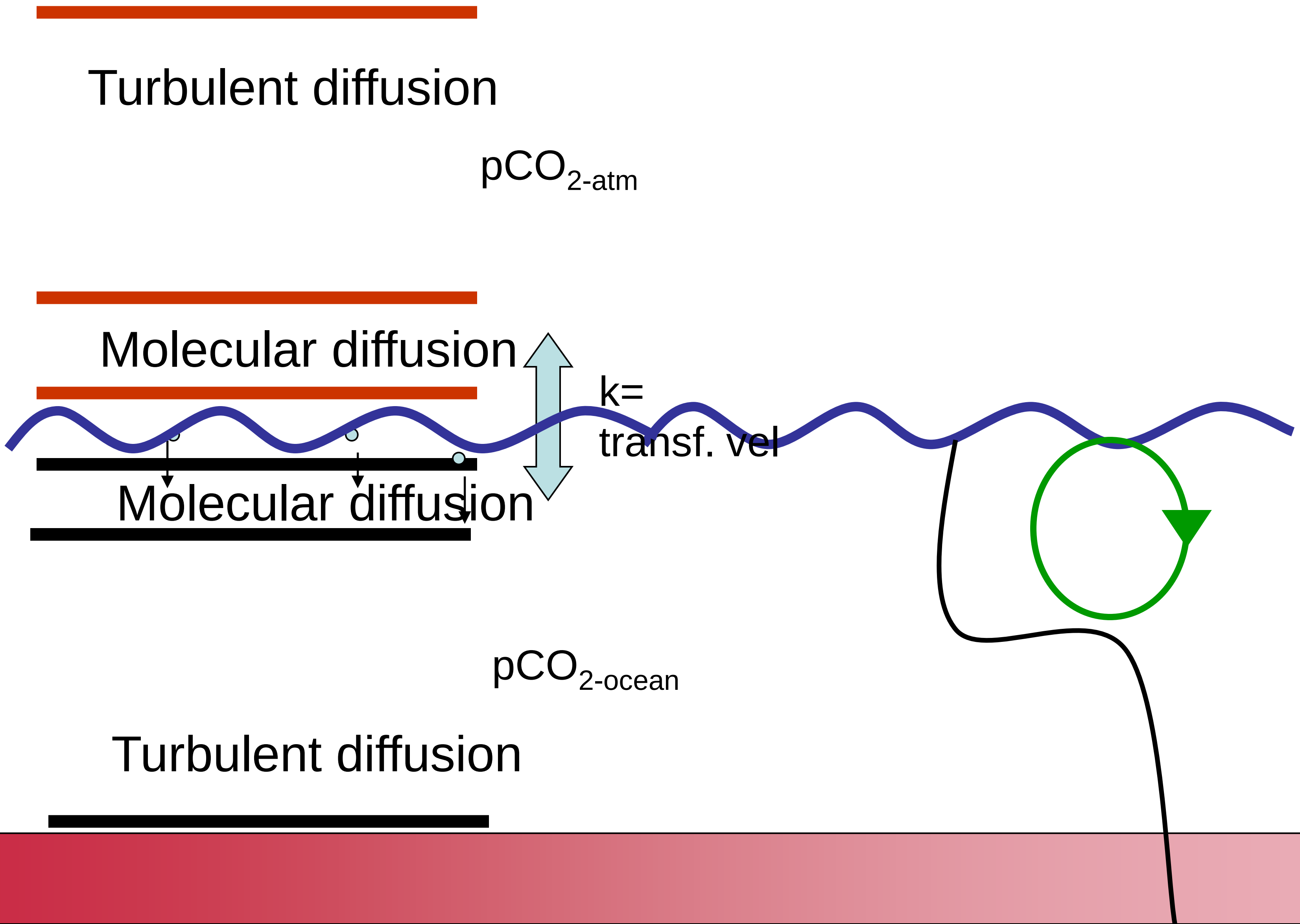
Coastal zone
daily cycle
upwelling

Basin estimates
Synoptic scale
variability



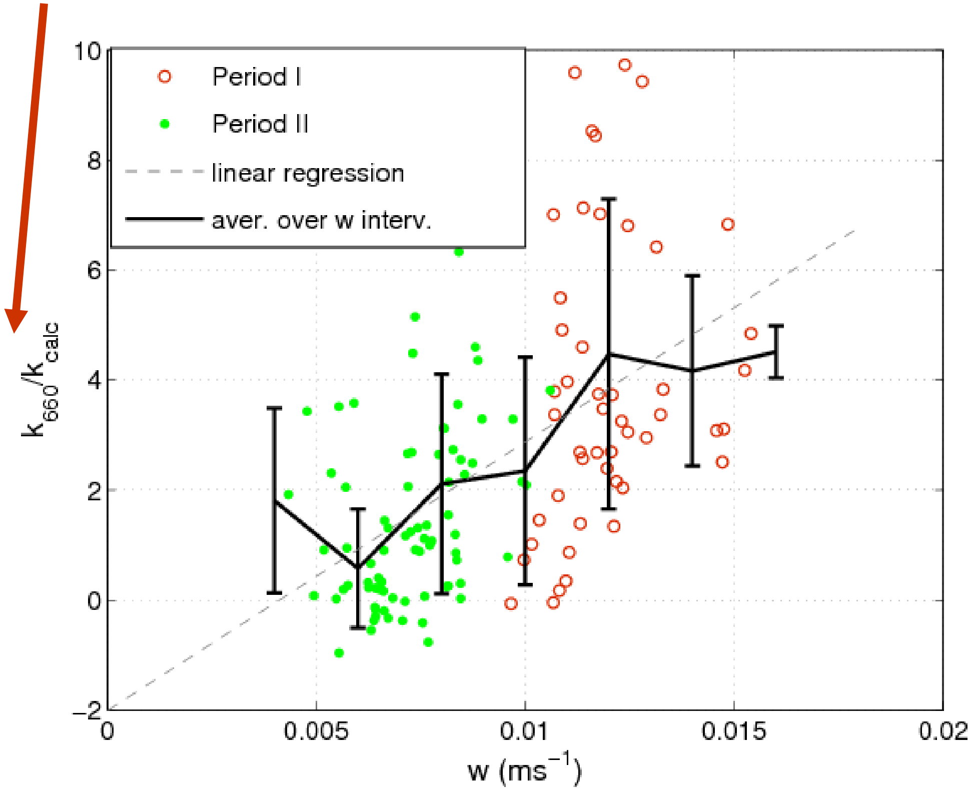
Global budget
climate distr.
of winds

Water-side convection



Convective velocity scale

Transfer velocity
normalised
by wind speed



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

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

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

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

UPPSALA UNIVERSITET

How can this be described?

- **Additional resistance in the water** (Rutgersson et al, 2011)

$$\frac{1}{r_w} = \frac{1}{r_{wt} + r_{wm}} + \frac{1}{r_B} + \frac{1}{r_{wc}}$$

$$k = \frac{u_{*a}}{r_w + r_a \alpha}$$

$$\frac{1}{r_{wc}} = \gamma \sqrt{\frac{u_{*w}}{w}} = enhancement\ by\ convection$$

Strength of buoyancy realtive to shear induced turbulence

UPPSALA UNIVERSITET

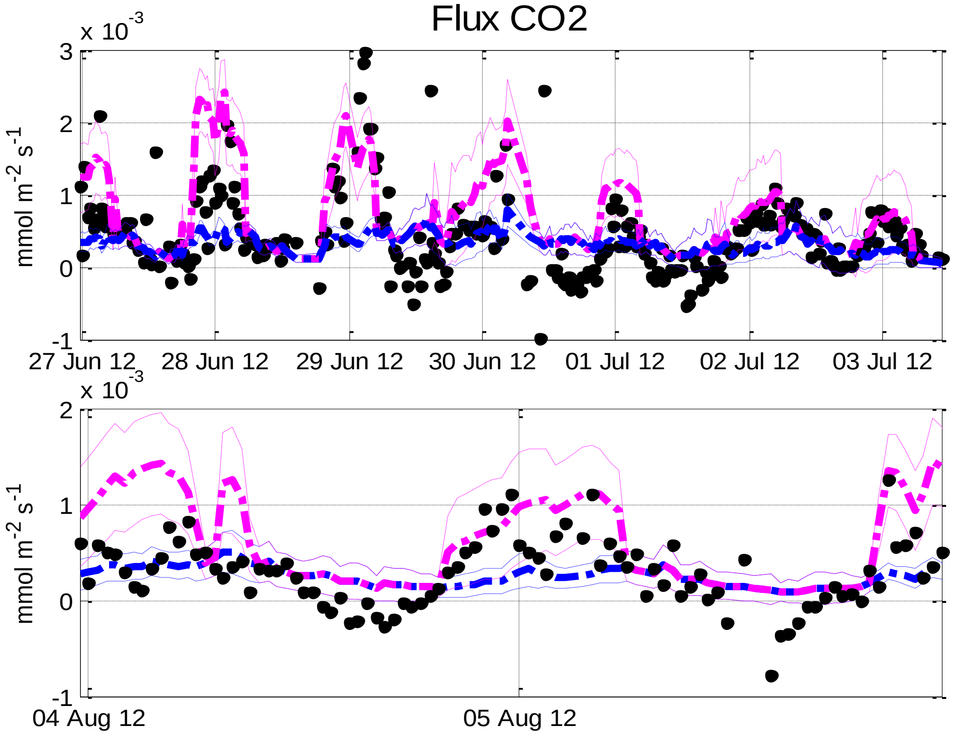
Methods

- Different scale basins (Lakes, Baltic Sea)
- Different scalars (carbon dioxide, methane, oxygen, water vapor)

UPPSALA UNIVERSITET

Lake studies

Strong diurnal cycle for methane and carbon dioxide (Podgrajsek et al, 2013a; 2013b)



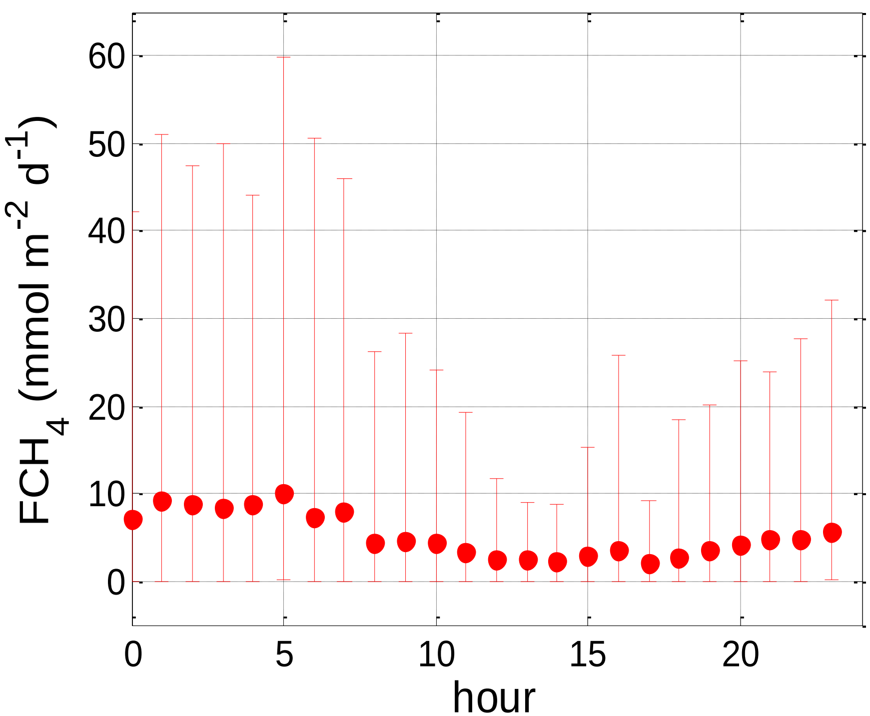
Flux
black=measured
Blue=wind (Cole and Caraco 1998)
Pink=wind+conv
(Rutgersson and Smedman 2010)

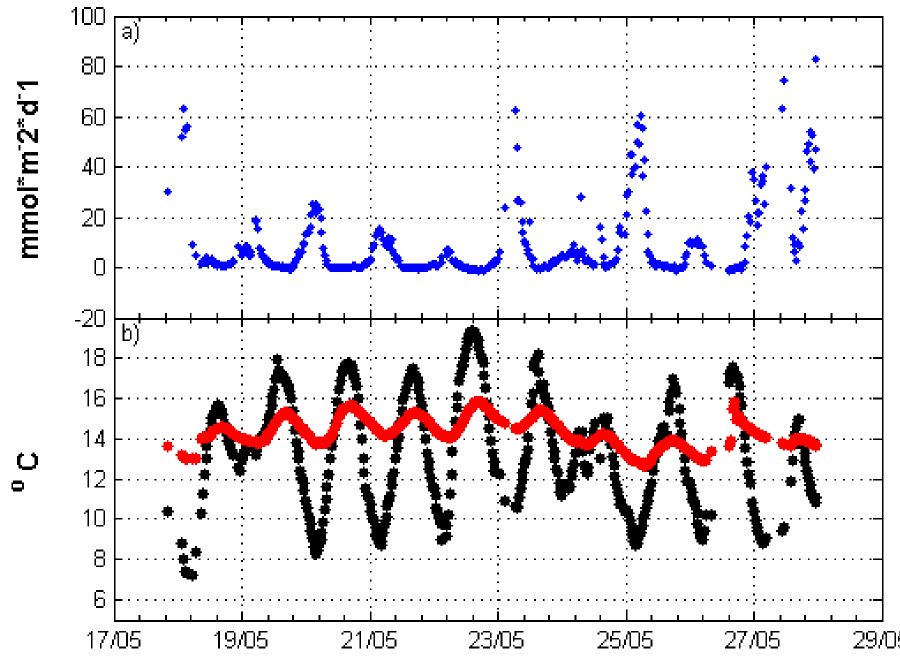
Carbon dioxide

Lake studies

Strong diurnal cycle for methane and carbon dioxide (Podgrajsek et al, 2013a; 2013b)

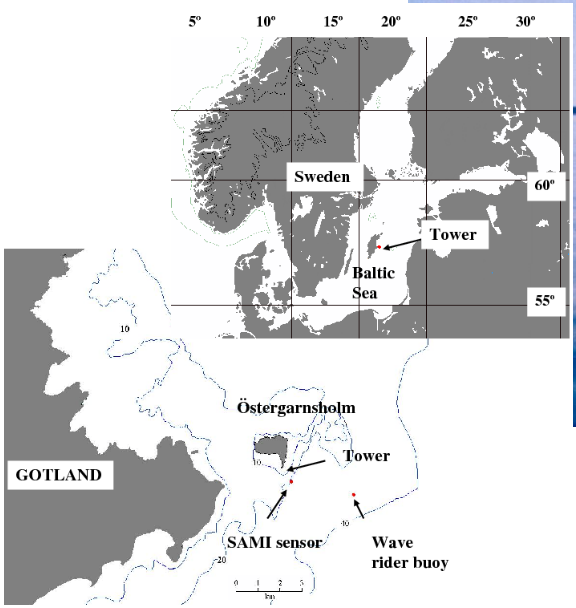
Methane

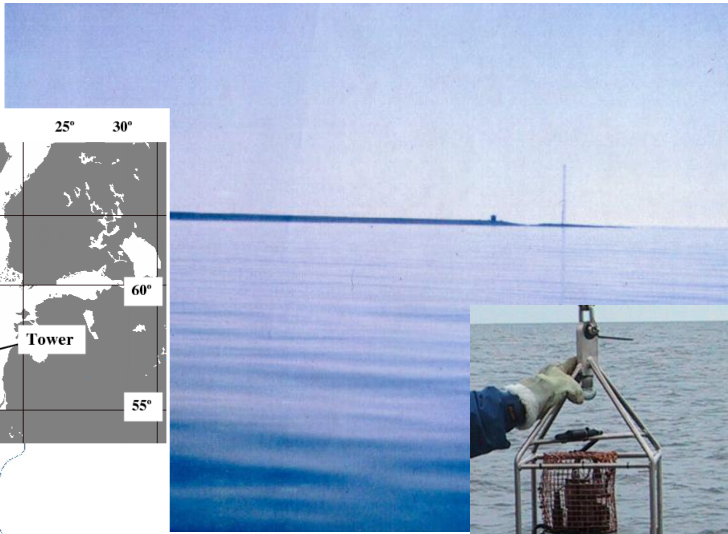




UPPSALA UNIVERSITET

Baltic Sea studies, the Östergarnsholm-site





Data for air-sea interaction investigations, meteorological data as well as buoy data (wave, pCO2 etc). Has been shown to well represent marine conditions.

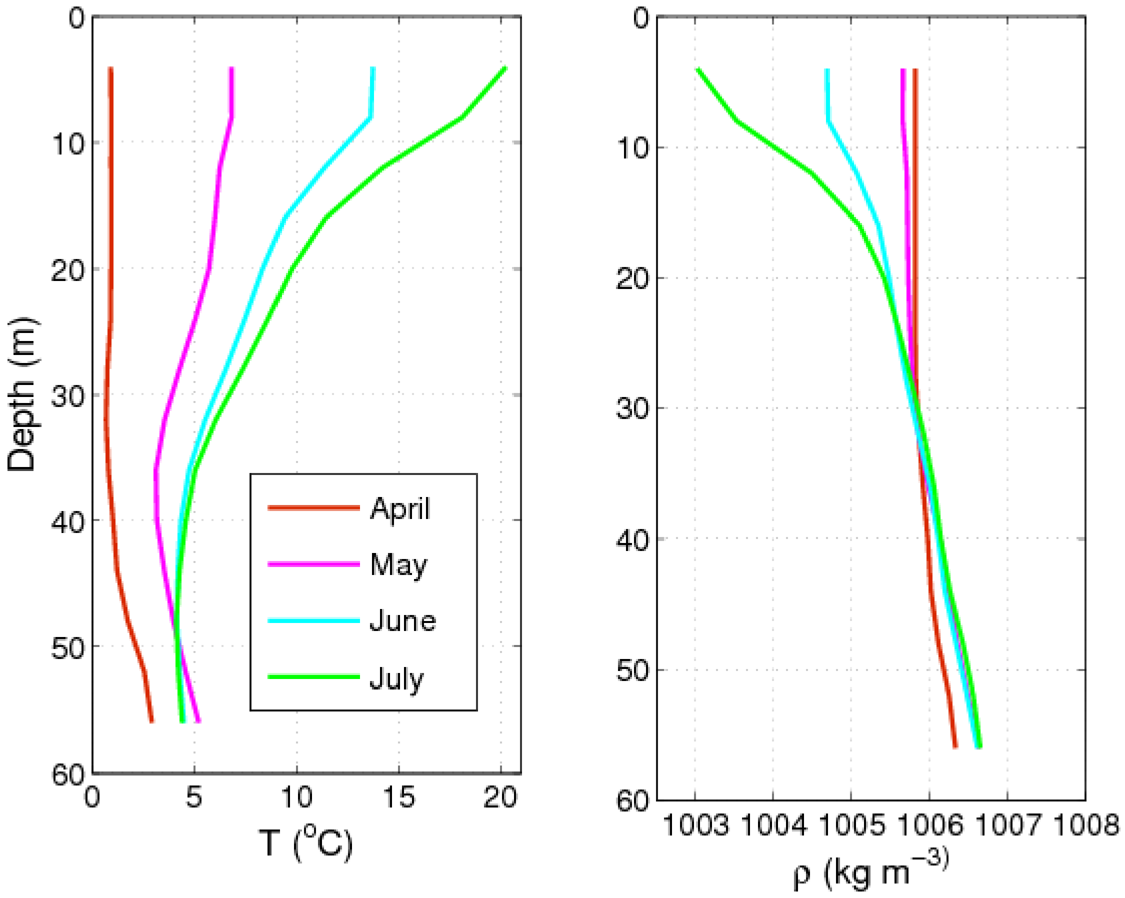
icos integrated carbon observation system

Mixed layer depth

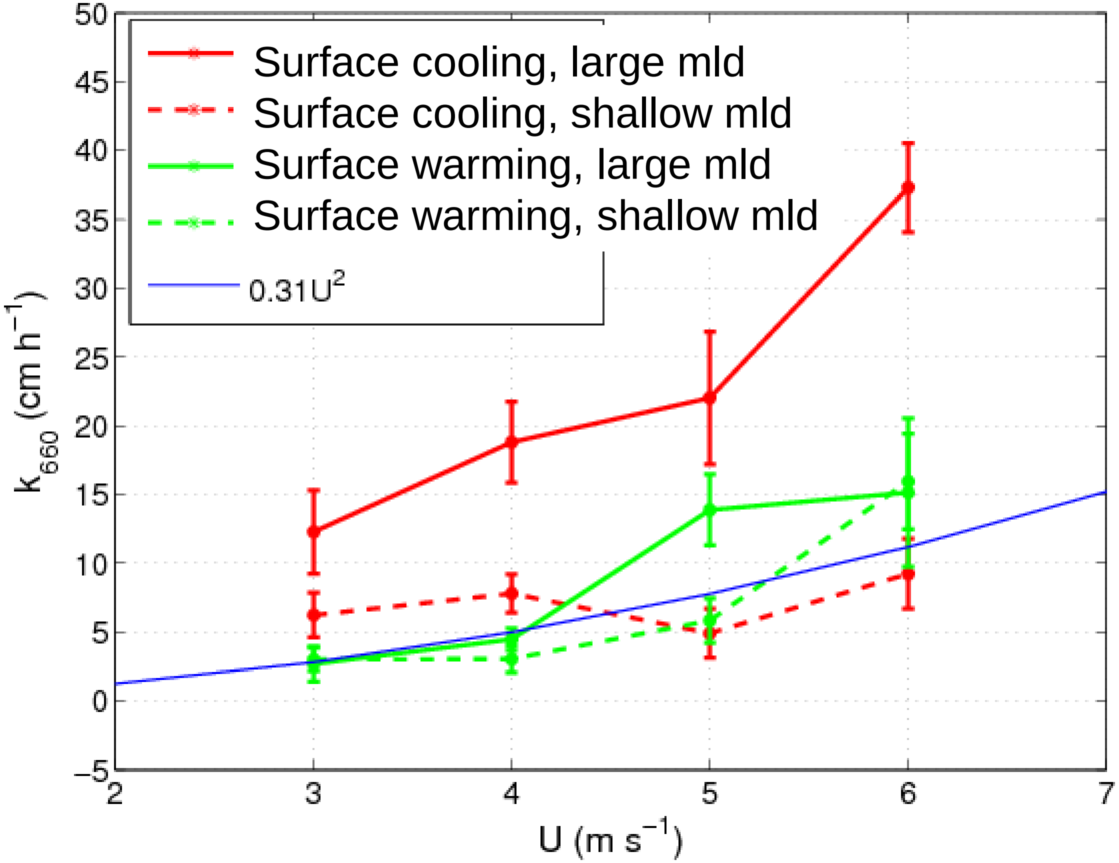
Period I: April to May (z_{ml}>40m)

Period II: June to July (z_{ml}<20m)

- Mixed layer depth from HIROMB (3D ocean model for Baltic Sea)



Larger transfer velocity for convection in the water and larger mixed layer depth



Important for intermediate wind speeds

Rutgersson et al., 2011; Rutgersson and Smedman 2010

Transfer velocity for varying solubility. EC measurements of Oxygen (Presens MicroTX).

Larger k for higher winds (prelimenary results)

UPPSALA UNIVERSITET

Final comments

- When we increase the resolution in time and space – we need knowledge of the relevant processes.
- Impact of surface heat flux underestimated (buoyancy as forcing parameter). Impact also seen in the open ocean (for example GASEX01, McGillis et al, 2004).
- Other gases, additional knowledge

UPPSALA UNIVERSITET

THANK YOU!

References:

Andersson, A., Rutgersson, A. and E. Sahlée. Transfer velocity of oxygen. In manuscript.

McGillis, W. R., et al. (2004), Air-sea CO_2 exchange in the equatorial Pacific, J. Geophys. Res., 109, C08S02, doi:10.1029/2003JC002256.

Podgrajsek, E., Rutgersson, A. and E. Sahlée, 2013a. Diurnal cycle of lake methane fluxes. Geophys. Res. Lett. Under revision

Podgrajsek, E., Sahlée, E. and A. Rutgersson, 2013b. Transfer velocity of CO_2 in lakes. In manuscript.

Rutgersson, A., Smedman, A., 2010. Enhanced air–sea CO_2 transfer due to water-side convection. J. Mar. Syst. 80, 125–134.

Rutgersson, A., Smedman, A., Sahlée, E., 2011. Oceanic convective mixing and the impact on air–sea gas transfer velocity. Geophys. Res. Lett. 38, L02602.