# Installation of a new Eddy Covariance system for measuring air-sea $CO_2$ exchange

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## Introduction

Air-sea $CO_2$ fluxes are usually calculated from gradients across the sea surface. The required parameters from the ocean carbonate system are measured from ships and buoys. These platforms allow for a flexible sampling design but are restrictive in terms of temporal resolution and extent. The Eddy Covariance (EC) technique produces high-resolution direct flux measurements over extended periods of time, even under conditions that prevent ship-based sampling, and are therefore a valuable alternative or addition to the existing platforms. We explore the possibility of installing an EC system on a sensor platform that was specially designed to facilitate scientific pilot studies (Fig. 1). This platform is situated 500 m outside Ostend harbor (Belgium) and is equipped with its own power source and communication infrastructure.

## Environmental settings

- Several years of wind data from a nearby weather station show that roughly 40% of the wind measurements in a typical season come from over sea (Fig. 2). These directions are sufficiently evenly distributed over the year to measure fluxes in all seasons (Fig. 3).
- Moisture is a complicating factor in flux calculations (Burba 2007) and potentially presents an additional problem in an oceanic context because of salt deposition (Fig. 4).

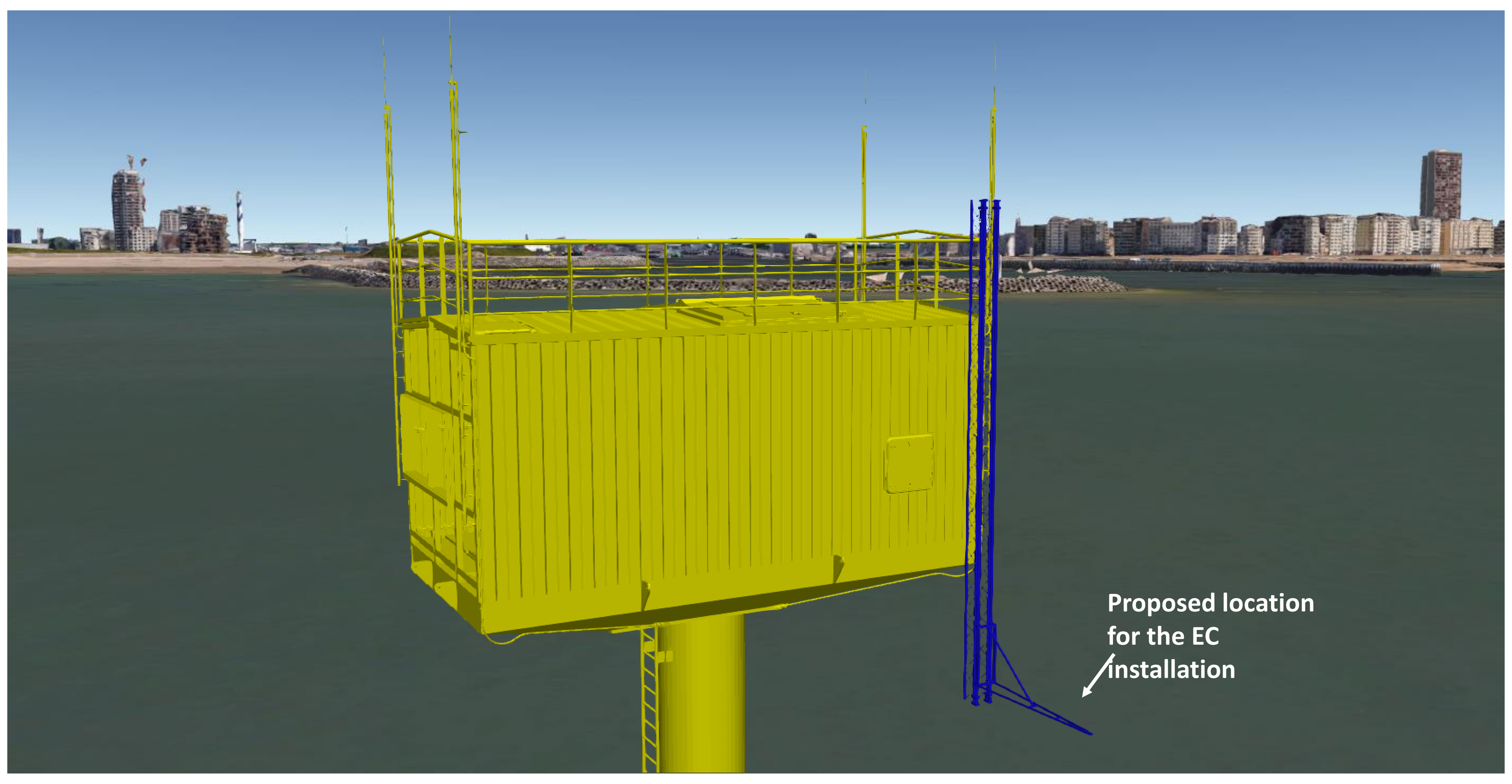


Fig. 1: The Blue Accelerator platform outside Ostend harbor, viewed from North, with the proposed construction for the EC system in blue. This construction consists of a vertical truss/pylon and a horizontal arm that carries the anemometer and gas intake at the end. This arm is depicted in the measurement position and can move up along the truss to the roof level, and swing towards the container to provide access to the EC system for maintenance and calibration.

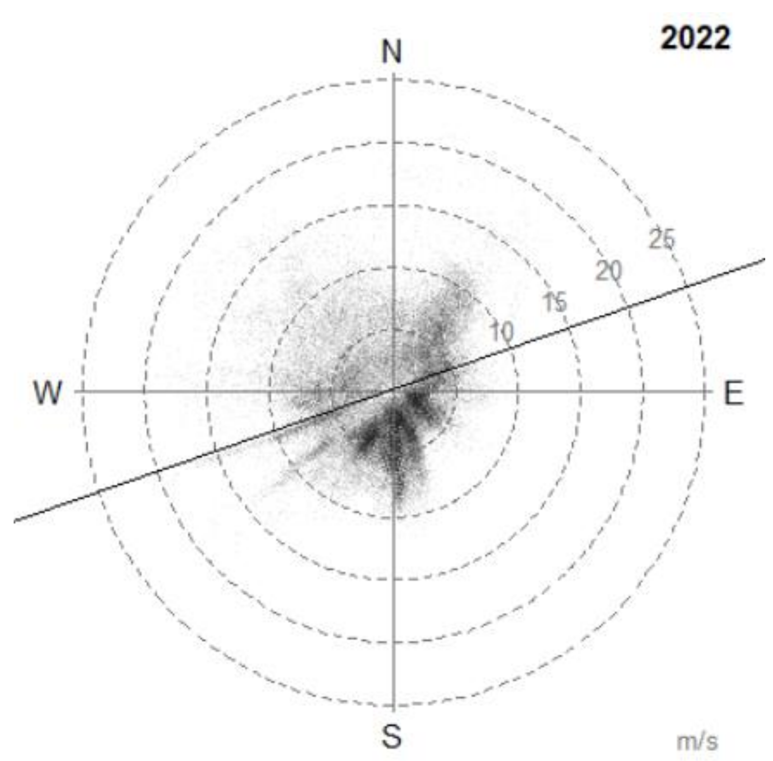


Fig. 2: Left: Polar plot of wind velocities near Ostend harbor. The straight line from WSW to ENE indicates the direction of the coastline and the sector of wind directions that are theoretically useful for measurements of air-sea gas exchange. Winds from above the line blow from sea, those below the line blow from land. Data from Meetnet Vlaamse Banken

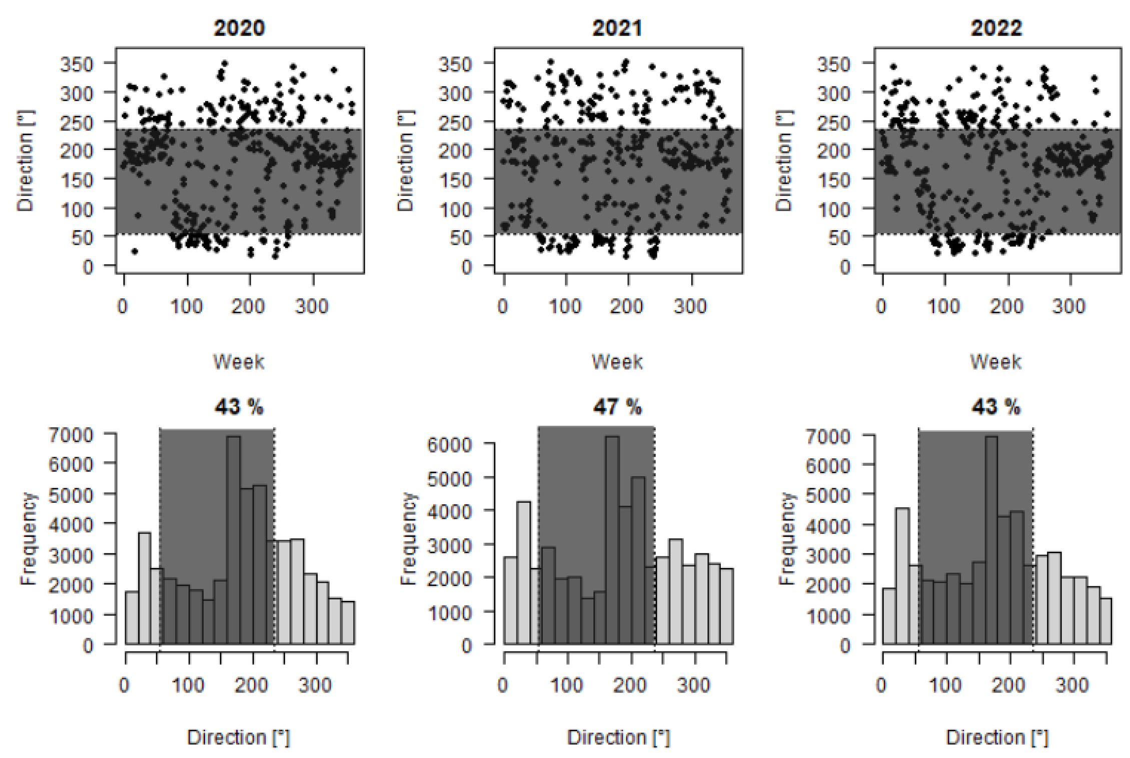


Fig. 3: Seasonal distributions (upper) and corresponding frequency distributions (lower) of the wind directions for a given year. The dark zone indicates wind directions from over land that are not useful for air-sea exchange measurements. The percentages above the frequency distributions indicate the fraction of measurements that is useful for air-sea exchange. Data from Meetnet Vlaamse Banken

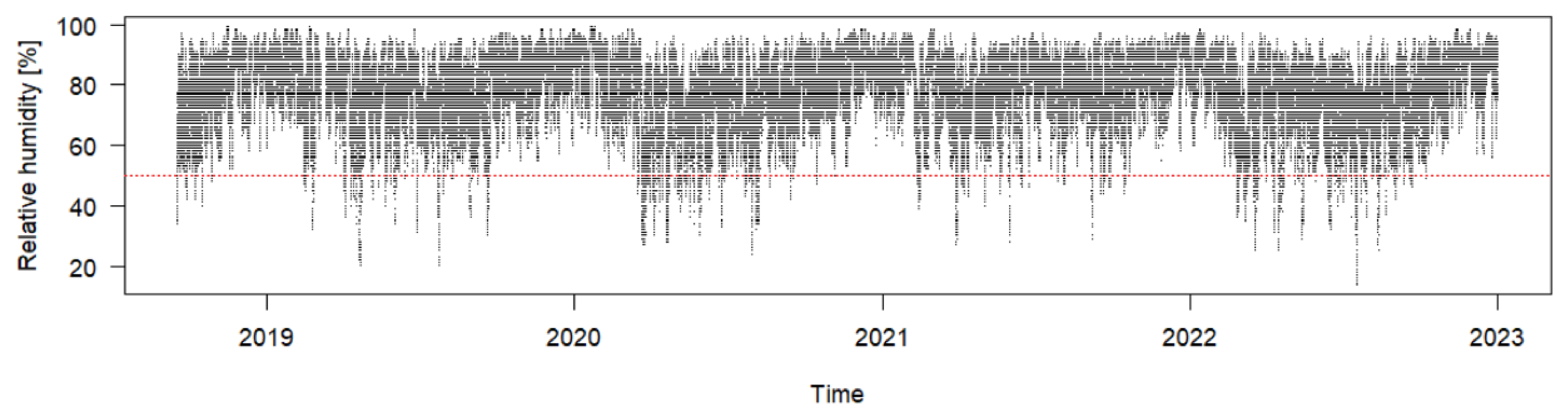


Fig. 4: Time series of air humidity near Ostend harbor, obtained from Meetnet Vlaamse Banken. The red dashed line indicates the 50% limit suggested by Burba (2007) to include an air-drying system in the EC setup.

## Interference of the platform

A simple k-ω model (i.e. Reynolds-Averaged Navier Stokes; RANS model) was set up to assess wind patterns around the container platform, and to find the optimal position for the EC system. Simulations were performed in OpenFOAM. The model was run to steady-state in a design with combinations of three wind velocities (5, 10, and 15 m/s) and four wind directions (W ⇨ NE in steps of 45°). Apart from the wind direction and speed, all parameters were kept constant in the different simulations (cf. Model setup and parameters). Variation in wind speed and turbulent kinetic energy near the platform were qualitative evaluated (Fig. 5 and 6).

**Model setup and parameters:**

Model domain (x,y,z):
- 100 x 100 x 50 m

Grid resolution:
- 1 m near boundaries
- adaptive hexmesh near structures

Boundaries:
- bottom = no-slip
- sides + top = slip
- velocity forced upon inlet
- pressure = zerogradient

Integrator:
- simpleFoam, incompressible fluid

Wind speeds (U) and directions:
- U = 5, 10, 15 m/s
- 270, 315, 360, and 45°

Kinematic viscosity:
- $\nu_t = 1.48 \times 10^{-5}\ m^2/s$

Turbulence kinetic energy (k):
- $k = 1.5\ (U\ T_i)^2$,
- with turbulence intensity ($T_i$) of 5%

Dissipation rate (ε):
- $\varepsilon = (0.09^{3/4}\ k^{3/2})/(0.07\ L)$,
- with characteristic length scale (L) of 50m

Specific dissipation rate (ω):
- $\omega = \varepsilon/k$

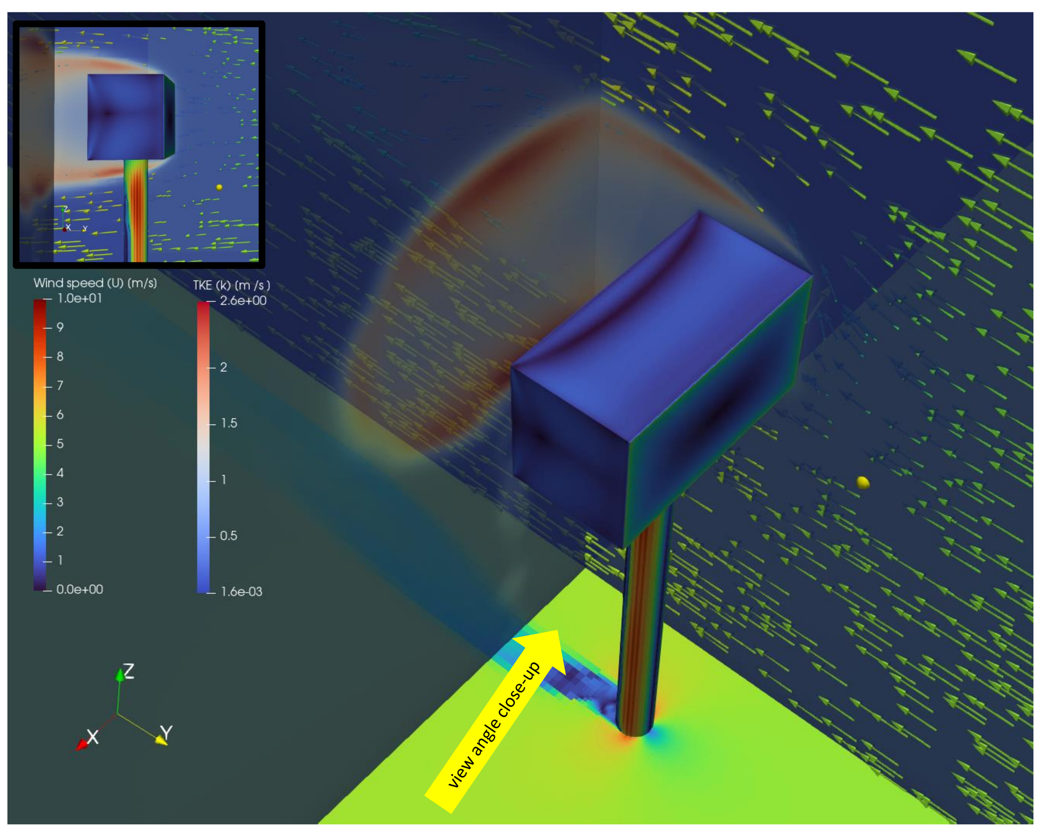


Fig. 5: Simulation result for north wind of 10 m/s (negative y-direction). The colors on the bottom, the wall of the platform, and the arrows indicate wind speed (left-hand color bar). The color of the vertical slices indicate turbulent kinetic energy (k; right-hand color bar). The deflection of the velocity vectors (arrows) in the vicinity of the EC sensors (yellow dot) shows the influence of the platform on the measurements. The close-up under a different angle (yellow arrow) illustrates this best. Down-wind of the platform the turbulence kinetic energy (k) increases substantially, whereas no increase in k is visible up-wind of the container near the sensor location.

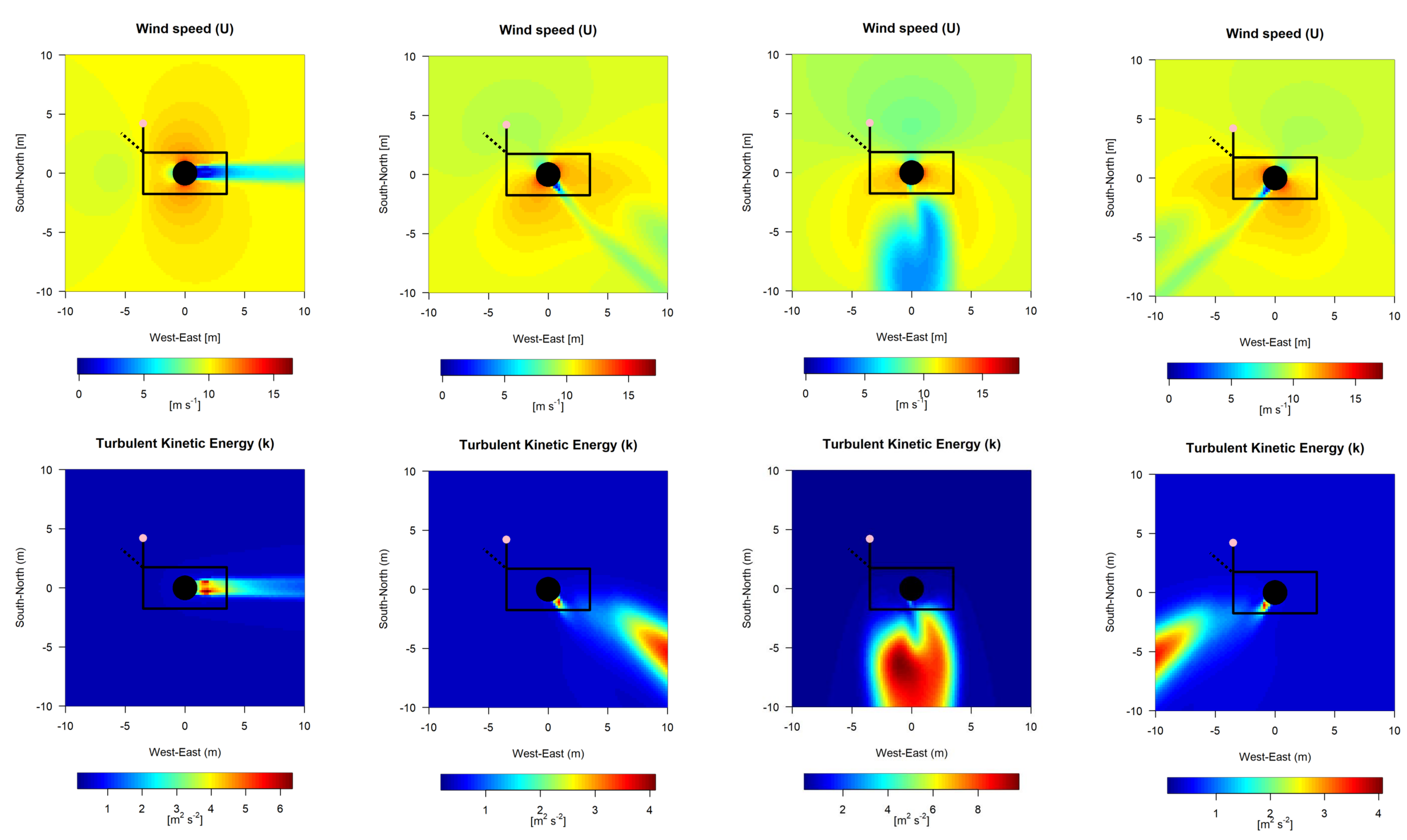


Fig. 6: Horizontal slice (top view) through the position of the EC system (pink dot) for different wind directions, ranging from west (left) to north-east (right), at wind speeds of 10 m/s on the up-wind boundary. The container and pile of the platform are indicated in black. An alternative arm configuration, pointing in northwestern direction is indicated with a dotted line. The upper graphs show the wind speed. The lower graphs give the turbulence kinetic energy.

## Conclusion

- A seasonal study of air-sea $CO_2$ fluxes by means of an eddy covariance system near Ostend harbor is feasible.
- The system should be installed near the Northwest corner of the platform to optimize for wind direction.
- Some influence from the container on the EC measurements is to be expected. The largest effects appear to be on velocity, not turbulent kinetic energy. Large Eddy Simulation (LES) models may provide a way to reflect in depth on this interference.
- A horizontal arm that accommodates the sensors should be at least 2.5 m long. No clear advantage exists for an arm pointing north, over one that points in northwestern direction.

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