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integrated carbon observation system

Baltic Earth
Earth System Science for the Baltic Sea Region

Using land-based stations for air-sea interaction studies, experience from the Östergarnsholm station

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Air-sea fluxes, eddy covariance technique.

1. Site problems
   - Flow distortion
   - **Land influence**
   - Motion influence
2. Method problems
   - **Stationarity and divergence**
   - Homogeity
   - Webb correction
3. Sensor problems
   - Salt contamination

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

- Assume surface flux
- Representing flux footprint

Marine micrometeorological sites

- Ships
- Buoys
- Off-shore platforms
- **Land-based sites**

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- Limited flow distortion
- No motion correction
- Relatively easy to access

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- Possible land influence

Land-based marine micrometeorological sites

Key question – what do the fluxes represent?

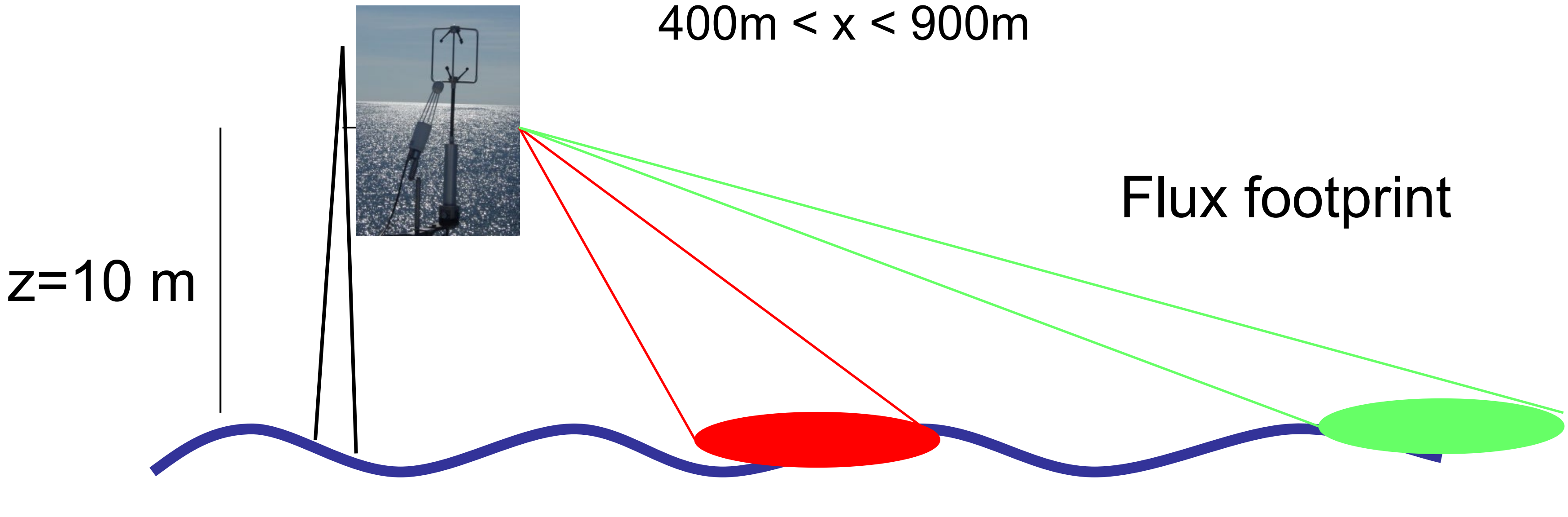
Östergarnsholm site
No archipelago.
Ideal bottom topography.
Shallow island.
Relatively undisturbed site.

Land disturbances of different scales

1. Mesoscale processes (sea-breeze, Low-level jets, upwelling,…)
2. Heterogeneous footprint
3. Disturbed wave field
4. Limited fetch
5. Shore zone (combined land-sea footprint)
6. Downwind topography

Concept of foot-print, measurements ”see” some distance upwind

Unstable atmospheric conditions: 60% of fluxes originates at 400m < x < 900m



Stable atmospheric conditions: 60% of fluxes originates at 1.5km < x < 5km

Högström et al (2008)

Suggestion: define the data based on how much land-influence we have.

CAT1. Open sea, undisturbed wave field, water side measuring system representative of the flux footprint of the tower. Meso-scale circulation systems might influence the station, but the data can be considered stationary and homogeneous.

CAT2. Disturbed wave field resulting in physical properties different from open sea conditions and likely also heterogeneity of water properties in the foot-print region. In a near surface region the biogeochemical properties can vary even if the physical does not (run-off, biological activity).

CAT3. Mixed land/sea footprint of the data, very heterogeneous conditions, not possible with few water-side measurements to fully represent water-side conditions.

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Define categories

CAT1. Marine station, undisturbed wave field, water side
measuring sys … nt of the tower.
Meso-scale ci … station, but the
data can be considered stationary and homogeneous.

1. Open sea conditions

CAT2. Distur … l properties
different from … so heterogeneity of
water propert … ar surface region
the biogeochemical properties can vary even if the physical does not.

2. Coastal sea conditions

CAT3. Mixed l … ry heterogeneous
conditions, not … asurements to fully
represent water-side conditions.

3. Shore conditions

Define categories Ö-holm

1. Physical (stress, heat and humidity fluxes; waves, SST)
2. Biogeochemical (carbon; runoff, biological activities)

Sector	Physical	Biogeo-chemical
45<WD<80	2	2
80<WD<160	1	1
160<WD<220	1	2
220<WD<295	2	2
295<WD<355	3	3
355 over 45	x	x

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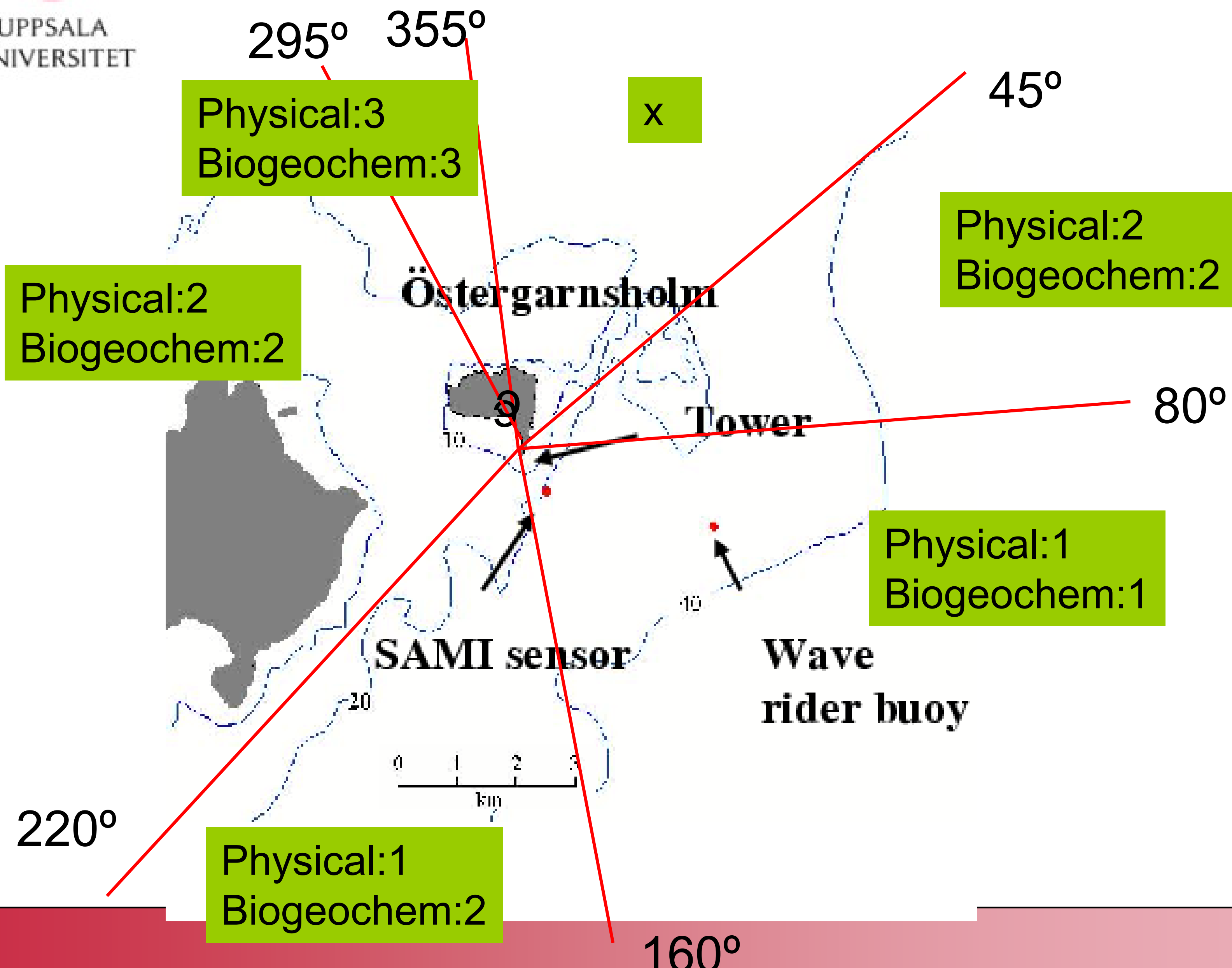
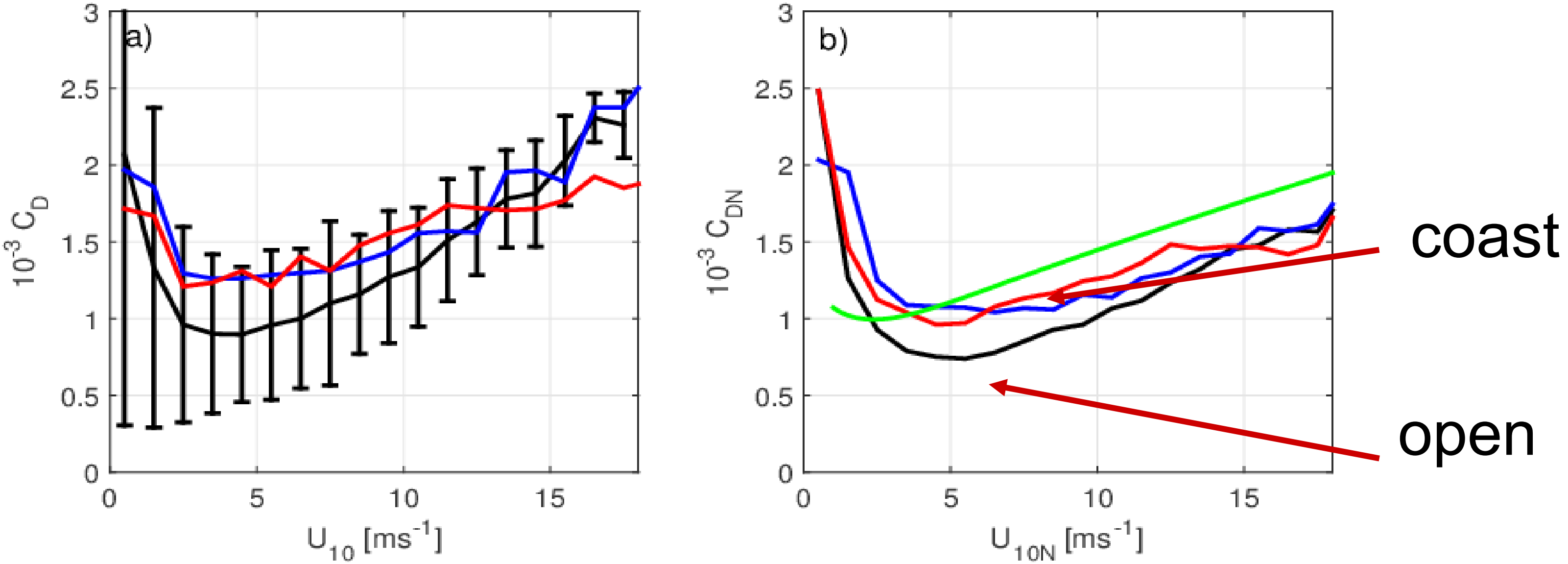
Sectors, suggestion



Use Östergarnsholm, data

Drag coefficient (open:black; coast:blue; shore:red; COARE:green)

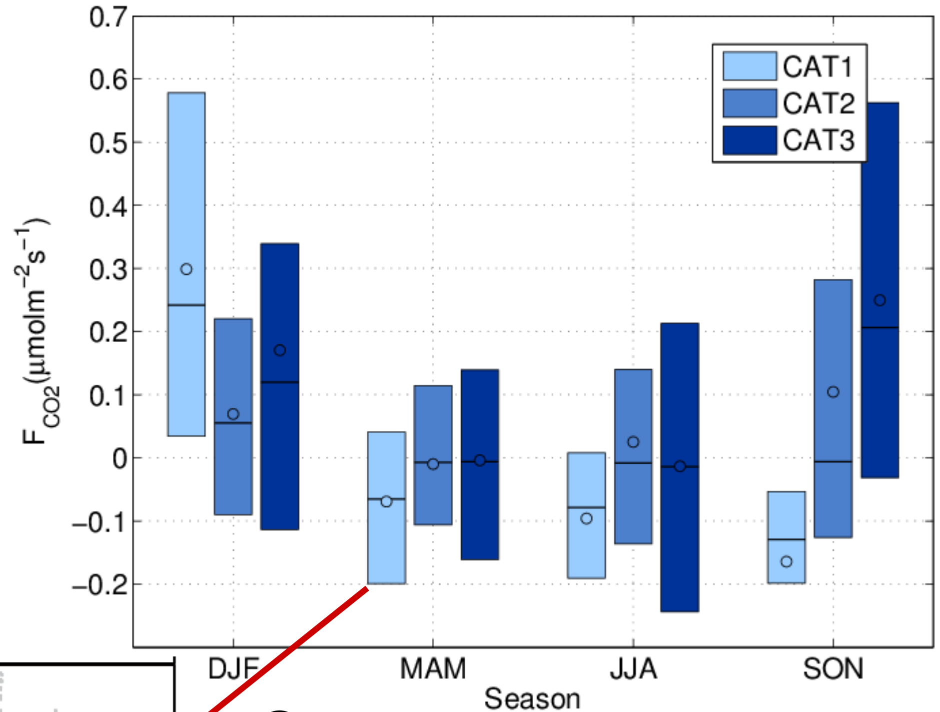


Below 10m/s:
Higher drag coefficient in the coastal sector – younger waves giver larger drag.

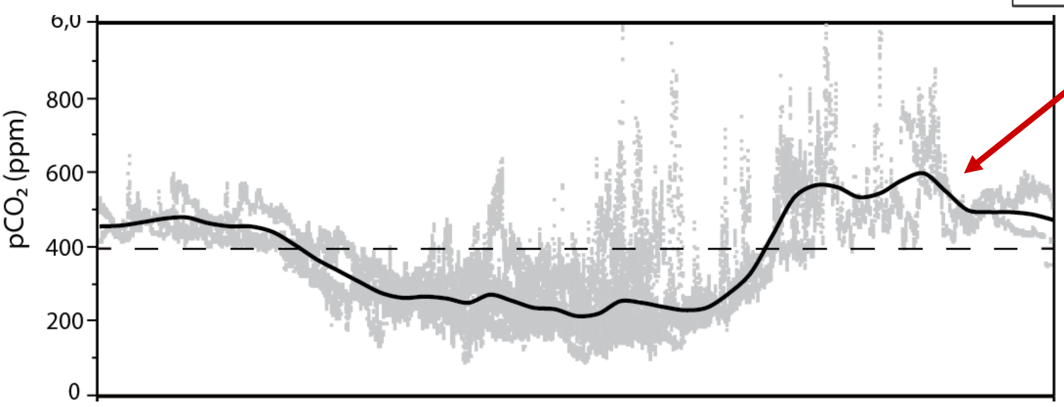
Use Östergarnsholm, data

Flux of carbon dioxide

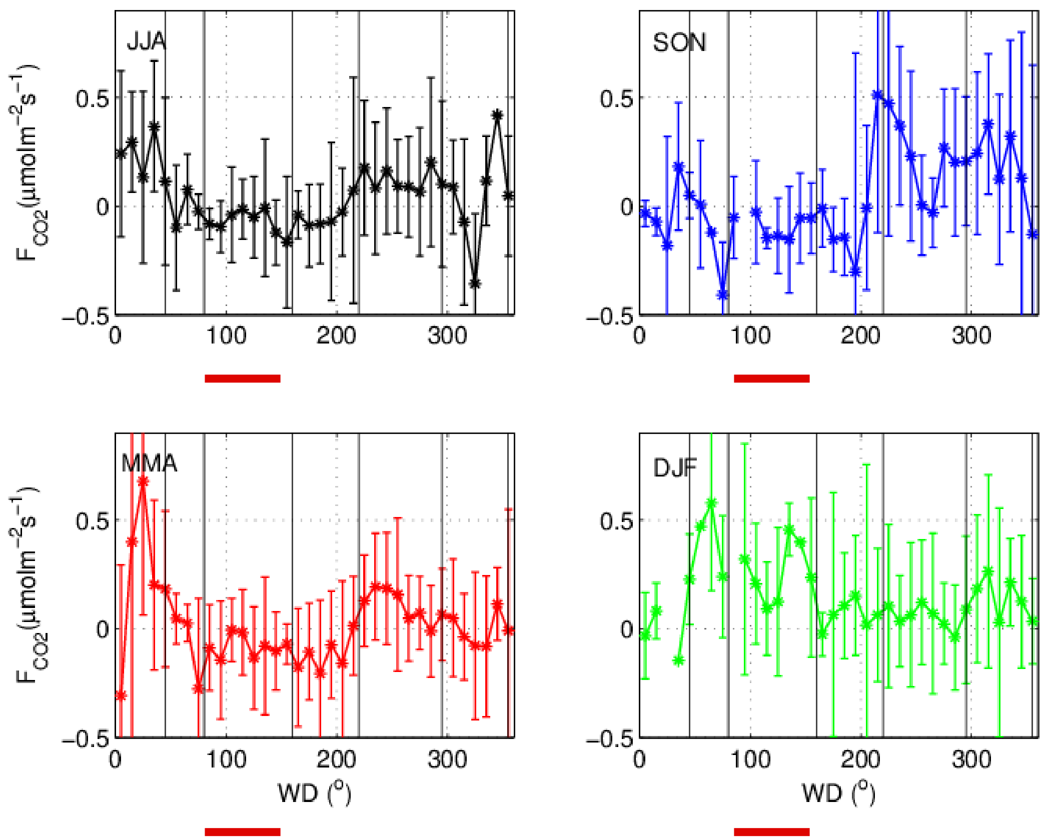
Different seasonal cycle, for different sectors



Open sea



Use Östergarnsholm, data



Choise of sectors - reasonable

Vertical divergence

Eddy covariance technique:

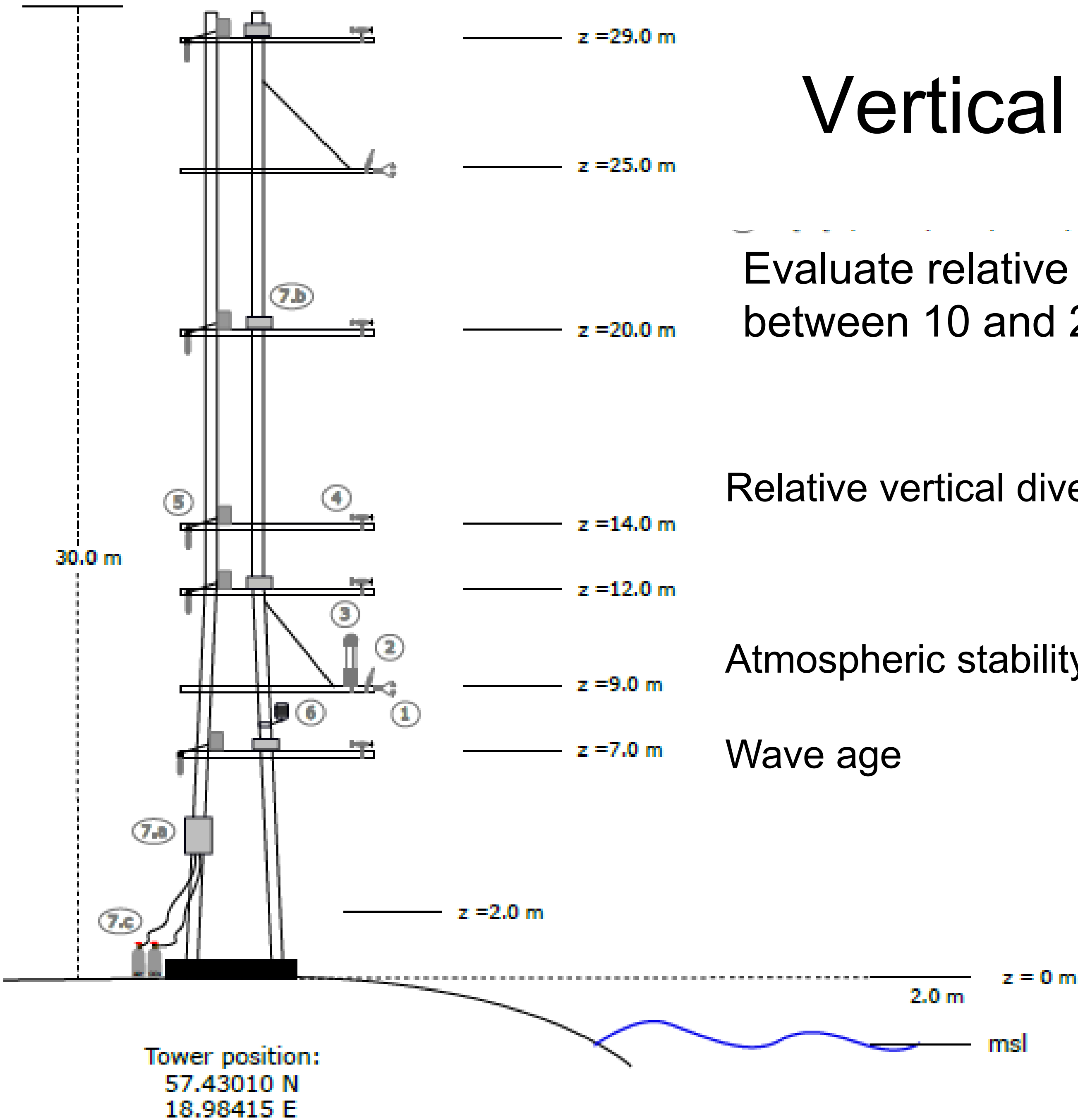
Assume measured fluxes represent surface fluxes.

Divergence can be caused by:

Horisontal pressure gradient (stress)

Advection (stress, heat, mass)

Vertical divergence



Evaluate relative difference of fluxes between 10 and 25 m.

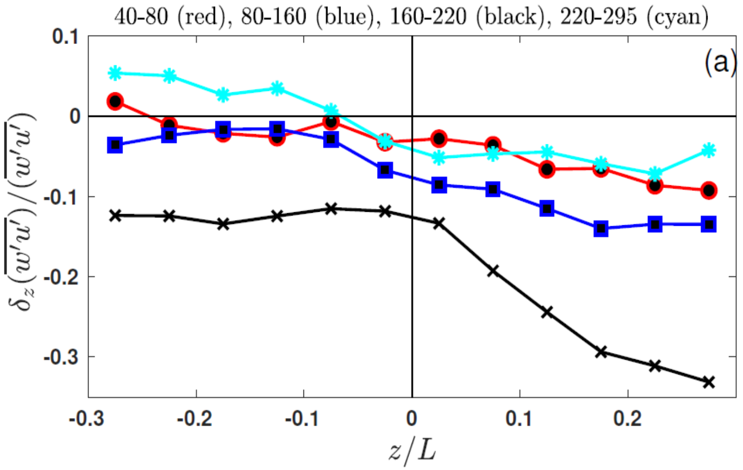
Relative vertical divergence $\delta \frac{\overline{w'c'}}{\overline{\overline{w'c'}}}$

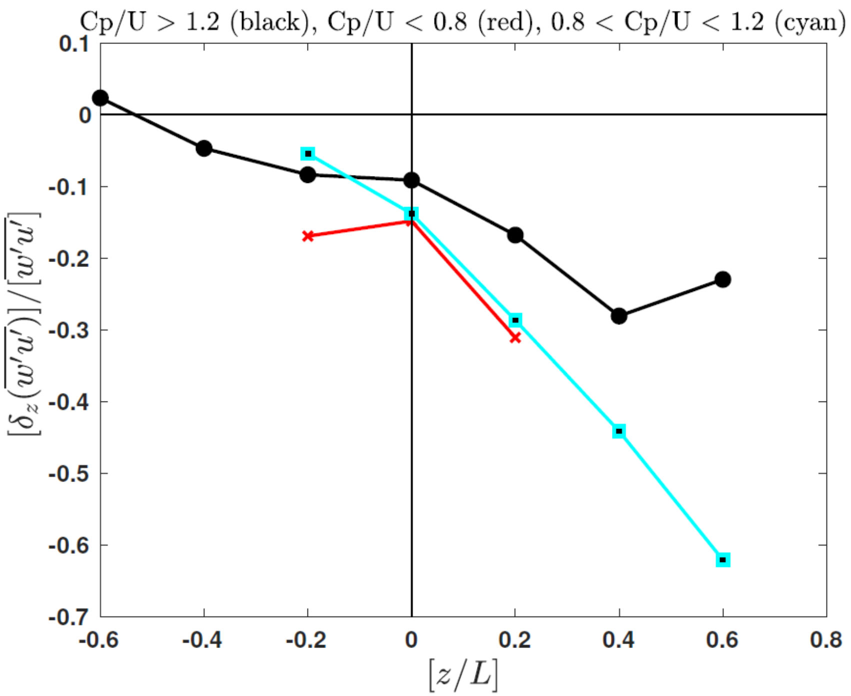
Atmospheric stability z/L

Wave age cp/U

Vertical stress flux divergence depend on:

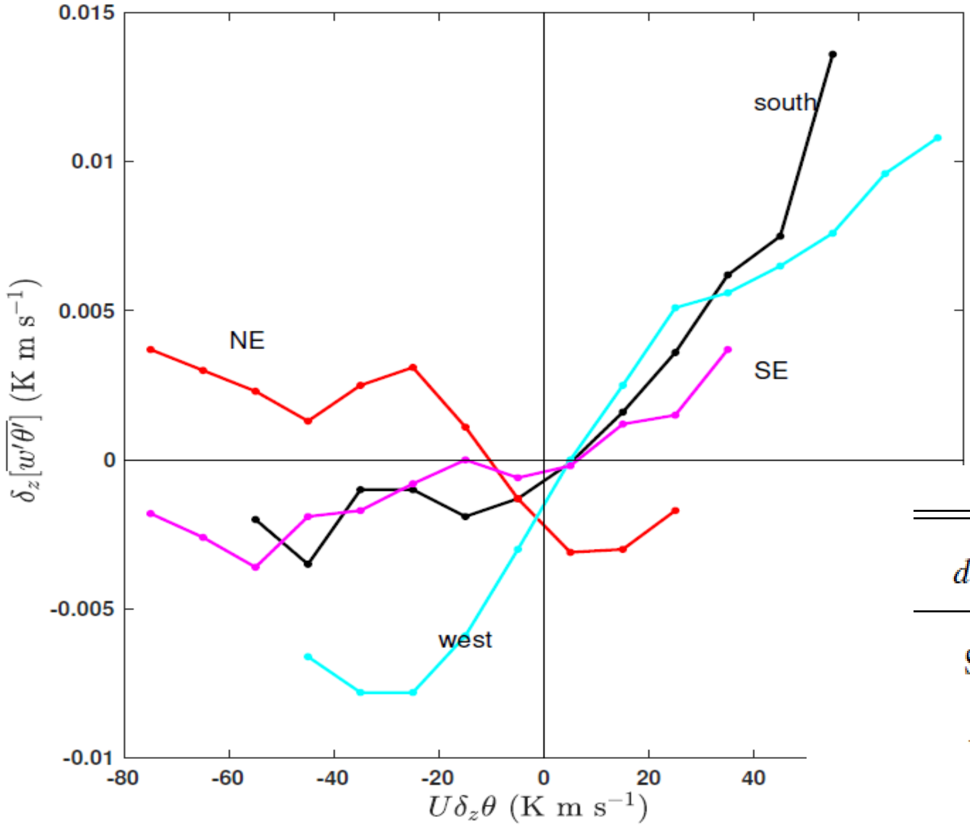
Wind direction, atmospheric stability (z/L) and wave age (cp/U)





Vertical heat flux divergence depend on:

Wind direction, atmospheric stability (z/L)



direction	divergence (%)	C_h regression	$C_h(z/L)$
Southerly	17 (14)	1.1 (0.9)	1.6 (0.8)
Westerly	32 (18)	1.05 (0.66)	1.1 (0.65)
South-easterly	5 (10)	1.27 (0.76)	1.3 (0.8)

Conclusions

- Land-based marine micrometeorological data should be defined based on magnitude of land disturbance:
  - Open sea
  - Coastal
  - Shore area

- Flux divergence can cause underestimation of flux of up to 20% (stress and heat flux), for CO_2-flux we do not know

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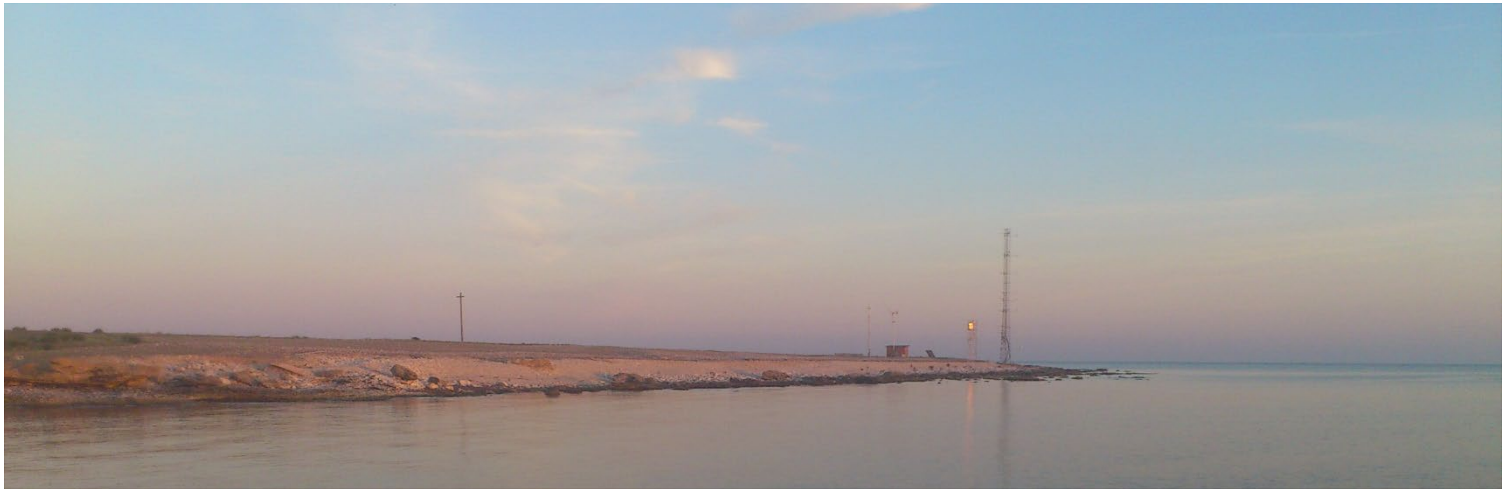
Thank you!



References

Mahrt, L., E. Nilsson, H. Pettersson and A. Rutgersson (2020) Sea-surface stress driven by small-scale non-stationary winds. Bound. Layer Met., https://doi.org/10.1007/s10546-020-00518-9

Mahrt, L., E. Nilsson, H. Pettersson and A. Rutgersson (2021) Vertical divergence of the atmospheric momentum flux near the sea surface at a coastal site. JPO

Mahrt, L., E. Nilsson, H. Pettersson and A. Rutgersson (2022) The surface heat flux at a coastal site, to be submitted

Rutgersson, A., et al (2020) Using land-based stations for air–sea interaction studies, Tellus A: Dynamic Meteorology and Oceanography, 72:1, 1-23, DOI: 10.1080/16000870.2019.1697601