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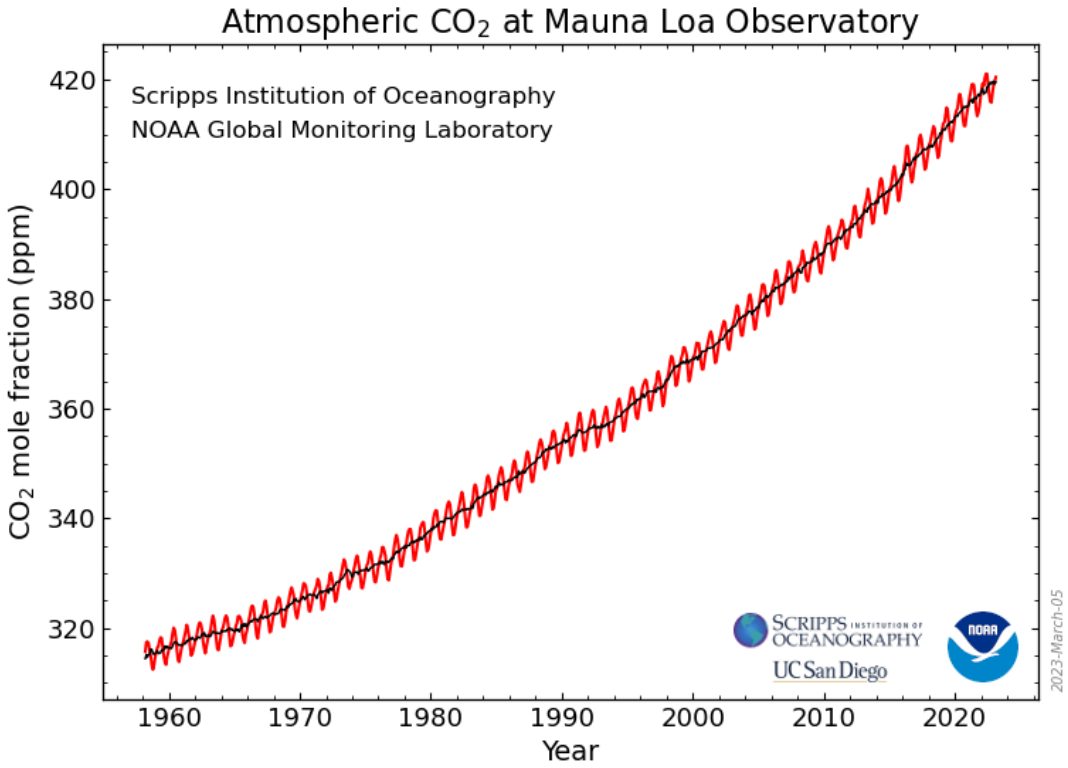
Air-sea CO_2 exchange at Utö in the Baltic Sea

Based on M. Honkanen, M. Aurela, J. Hatakka, L. Haraguchi, S. Kielosto, T. Mäkelä, J. Seppälä, S.-M. Siiriä, K. Stenbäck, J.-P. Tuovinen, P. Ylöstalo and L. Laakso (2024). '**Interannual and seasonal variability of the air-sea CO_2 exchange at Utö in the coastal region of the Baltic Sea**'. EGUsphere 2024: pp. 1–31.

1.10.2024 **Martti Honkanen**

Carbon dioxide (CO_2)

- Important greenhouse gas
  - Global warming
  - Ocean acidification
- Oceans absorb a quarter of the CO_2 emissions
- The air-sea CO_2 exchange depends on
  - CO_2 gradient in the interphase
  - Gas transfer velocity



Utö Atmospheric and Marine Research Station

- Located in the southern edge of the Archipelago Sea
- Long history of measurements
  - Meteorology (1881–)
  - Sea water T and S profiles, sea ice (1900–)
- New marine station founded in 2014 by FMI and SYKE
  - Combining biological, chemical and physical measurements
- Collaboration with ICOS, ACTRIS, industry, defense & NATO

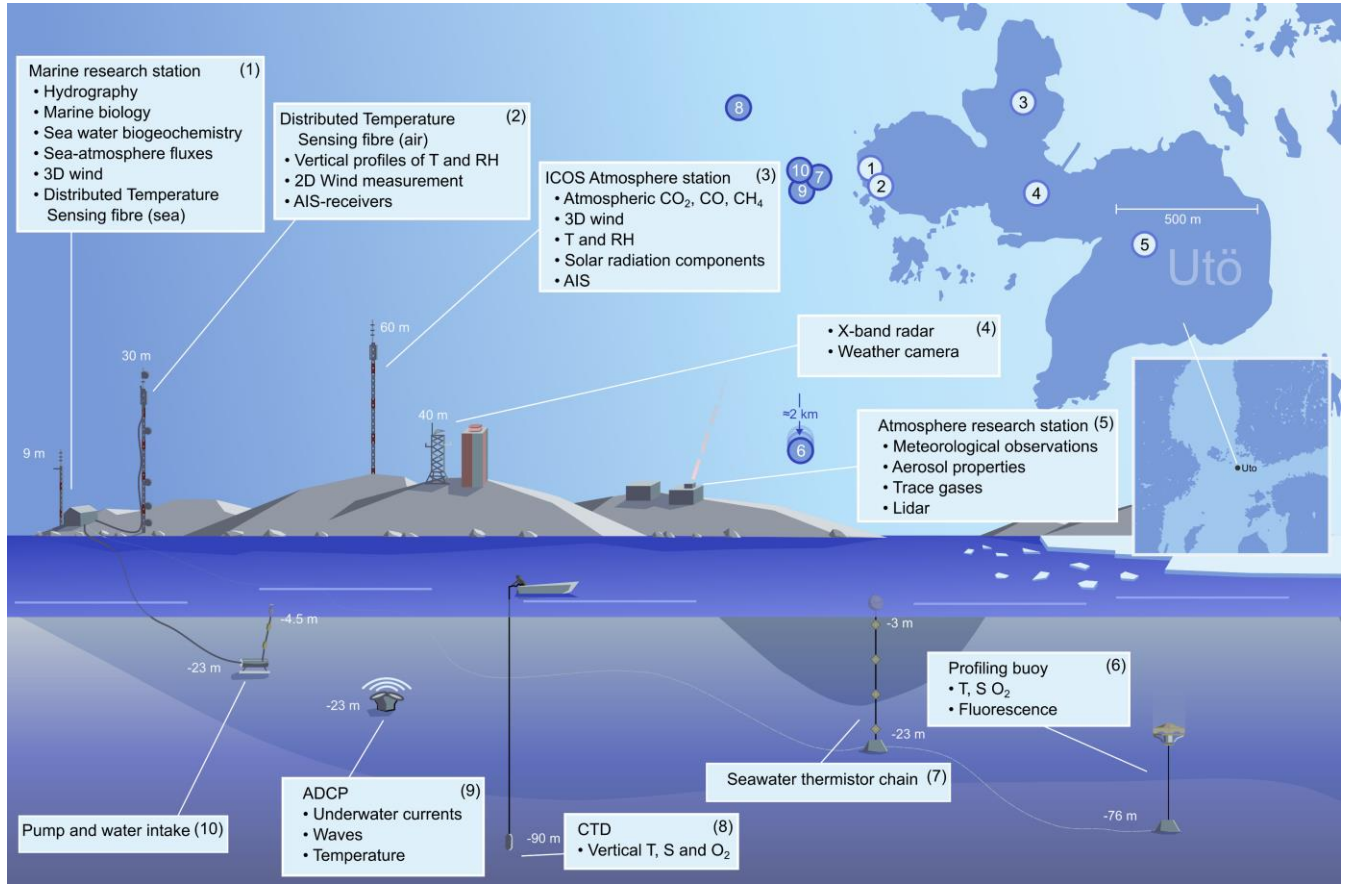


Fig. by Simo-Matti Siiriä

Marine CO_2 measurements at Utö

- Eddy covariance flux tower
  - Direct measurement of the air-sea CO_2 flux
- Flow-through water sampling
  - pCO_2: Equilibrator + infrared gas analyzer
    - Together with the wind speed, used for filling the gaps in the EC flux data
  - Colorimetric pH determination
  - DIC and TA samples in SYKE campaigns
- Supporting observations:
  - Chl-a fluorescence
  - O_2 concentration
  - Phytoplankton species, nutrients, meteorology, waves etc.

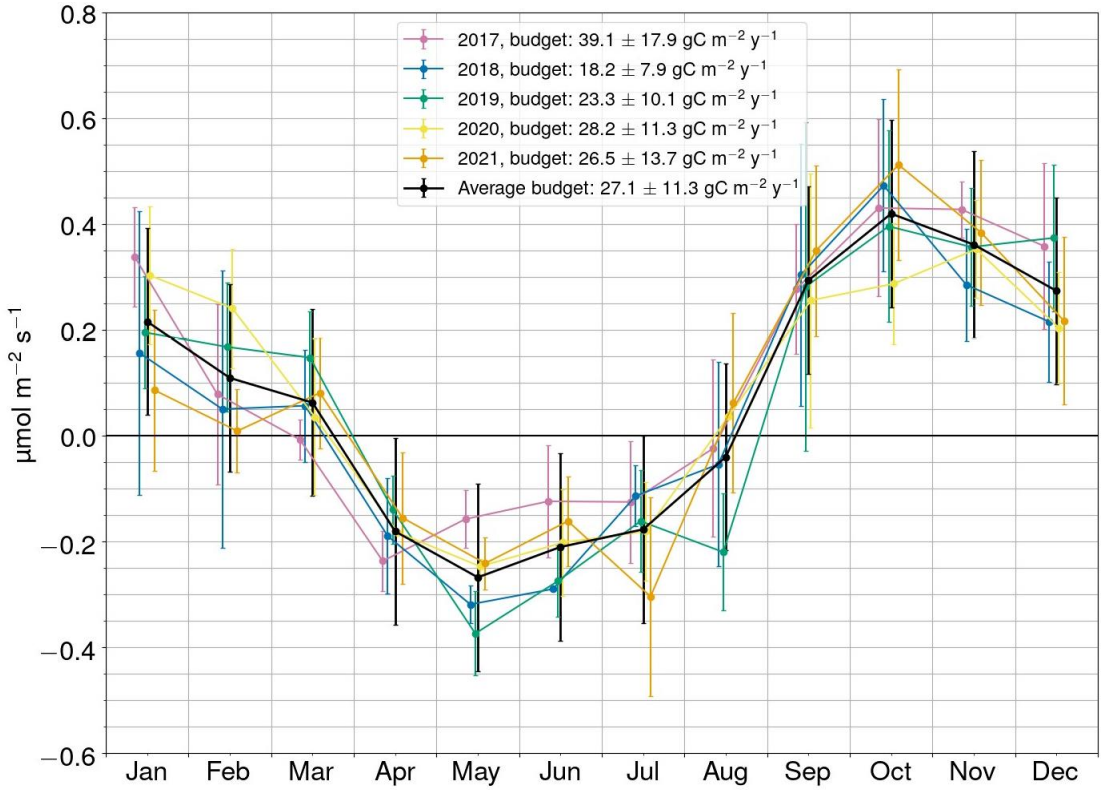
Photo by Martti Honkanen

Annual seawater pCO_2 cycle

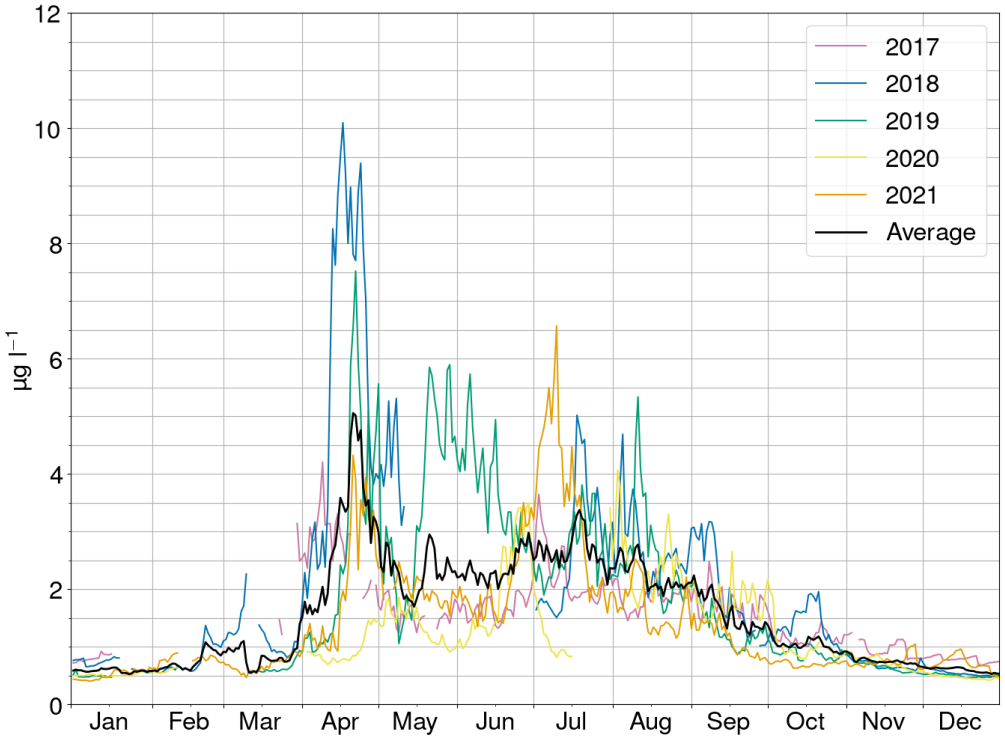
- Fluxes are driven partly by the air-sea pCO_2 gradient
- General pCO_2 annual cycle:
  - Quick drawdown by spring bloom
  - Late summer blue algal drawdown
  - Mineralization and mixing of CO_2 rich water in fall
  - Equilibrating with air in winter
- During the summer 2017, the pCO_2 stayed relatively high

Air-sea CO_2 fluxes

- General flux annual cycle:
  - Spring – summer: Sink
  - Autumn – Winter: Source
- The sea acts as a net source of atmospheric CO_2
  - On average, 27 gC m^{-2} y^{-1}
  - **Positive net exchange possibly indicating carbon inflow from land ecosystems**
- The highest source in 2017
  - Small summer fluxes, compared to the average
- Interannual variability on the budget: 18—39 gC m^{-2} y^{-1}



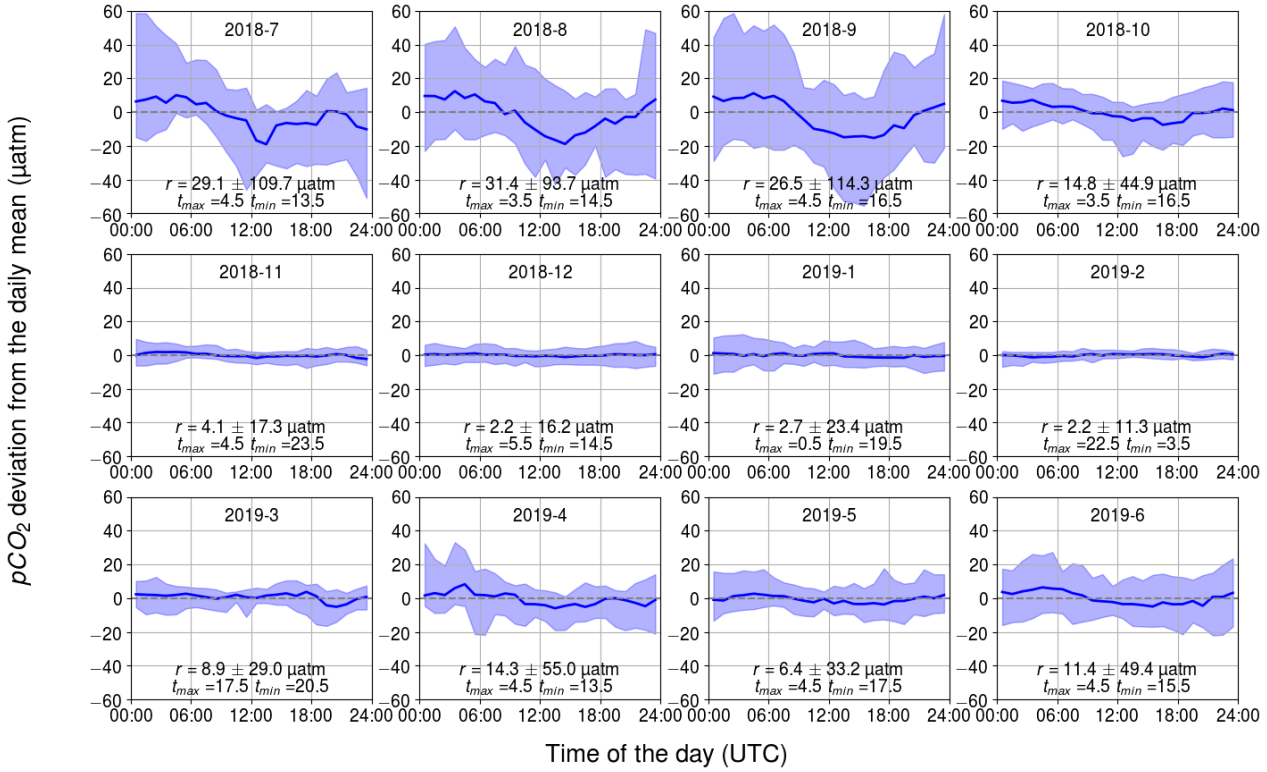
Using biology to explain interannual air-sea CO_2 flux variation



- 2017 and 2018 summers differ greatly in terms of Chl-a and pCO_2 dynamics
- Chl-a not presenting whole algal community
  - Plankton imaging and cyanobacterial analysis at Utö (Kraft et al., 2024) can provide more information on coupling the biology and inorganic carbon

Diurnal pCO_2 variability

- Sinusoidal signal during productive season, ca. 30 µatm
  - Based on oxygen data: Most pCO_2 diurnal signal is driven by biological transformations
- Importance of high frequency measurements:
  - Up to 12 % error in net air-sea CO_2 exchange if used data only specific time of the day



M. Honkanen, J. Müller, J. Seppälä, G. Rehder, S. Kielosto, P. Ylöstalo, T. Mäkelä, J. Hatakka and L. Laakso (Nov. 2021). '**The diurnal cycle of pCO_2 in the coastal region of the Baltic Sea**'. Ocean Science 17: pp. 1657–1675.

Conclusions

- Utö Atmospheric and Marine Research Station tracks the carbonate system using multidisciplinary instrumentation
  - The air-sea CO_2 fluxes at Utö are measured using
    - The eddy covariance flux tower
    - Flow-through sampling of pCO_2
- The sea acts as a net source of atmospheric CO_2 at Utö
- Useful to couple the coastal carbonate system research with biological measurements
- Terrestrial inputs of carbon needs more attention
  - Requiring long term high frequency measurements

Photo by Ismo Willström