The Surface Ocean-Lower Atmosphere Study (SOLAS): Contributing to our understanding of air/sea exchange in the Atlantic

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SOLAS is an international research initiative aiming "to achieve quantitative understanding of the key biogeochemical-physical interactions and feedbacks between the ocean and atmosphere, and of how this coupled system affects and is affected by climate and global change."

- Integrated topics (e.g., upwelling systems, polar oceans, coastal waters, Indian Ocean)
- Evaluating the environmental efficacy and impacts of geoengineering
- Science & Society: impacts of ship-plume emissions on ocean biogeochemistry, blue carbon, open-ocean stewardship
Quantifying air/sea CO$_2$ exchange in the Atlantic

- Atlantic Meridional Transect (AMT) program
- Decade of ocean and atmosphere CO$_2$ measurements

Air/sea CO$_2$ Flux = $K\Delta f$CO$_2$

$K = $ Gas Transfer Velocity

Kitidis et al. (2016)
Wind speed control of gas transfer?

- Calm (buoyancy)
- Moderate wind (shear stress)
- Rough (waves, bubbles)

Breviere et al. (2015)
Flux = KΔC

K = Flux/ΔC

- Direct measure of flux using covariation in vertical winds and gas concentrations
- Tool for understanding processes controlling K
- Validation of other flux estimates (e.g. from satellite)
Penlee Point Atmospheric Observatory (PPAO)

- Meteorology and air/sea CO₂ and CH₄ fluxes
- Gases (SO₂, O₃, CO₂, CH₄)
- Periodic aerosol number and size distribution
- Aerosol composition
- Rainwater collection

~20m above mean sea level

http://www.westernchannelobservatory.org.uk/penlee/
Continuous measurements = good statistics!
Opportunity to investigate processes in the flux ‘footprint’
What controls $K$ other than wind?
Surfactants, turbulence, waves, bubbles

Seasonal uptake and outgassing of CO$_2$
Air-sea CO₂ flux (gC m⁻² day⁻¹) for August 2000
Back to AMT: Installation of CO$_2$ flux system on JCR
CO₂ fluxes hot off the press (ship)!

Preliminary data

AMT-28 (Oct 2018)
Conclusions and Recommendations

Conclusions:
Long-term continuous eddy covariance measurements offer opportunity to:
1. Investigate processes controlling CO₂ air/sea fluxes
2. Validate satellite products and test inversion model estimates

Recommendations:
CO₂ / Gas Exchange:
- Distributed network of continuous flux measurements?
- Atmospheric CO₂ retrievals (XCO₂) – use with inverse models?
- Make use of other satellite data products to interpret gas flux measurements (waves, bubbles, surfactants)
- Application of geostationary satellites to timeseries stations?
- Can we decouple retrievals of wind speed from retrievals of waves/sea surface scattering?

Other ‘SOLAS-topic’ recommendations:
- Improve satellite retrievals of concentrations and fluxes of other gases (e.g. DMS)
- Assessment of ship emissions (particles, SOx, NOx) and impacts on ocean biogeochemistry – new global IMO regulation in 2020
- Links between ocean ecosystems, aerosols and clouds (e.g. NASA NAAMES)
Use of shipboard CO₂ measurements provide improved North Atlantic flux estimates in comparison to use of surface site data alone.

Could satellite XCO₂ data constrain estimates further?
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SOLAS Open Science Conference
21 - 25 April 2019, Sapporo, Japan
Registration until 28 Feb 2019!

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Yang, Bell et al. (2018)
Biogeosciences Discussions

This graph shows the relationship between friction velocity (m s^{-1}) and specific CO₂ uptake (K_{CO₂,660} (cm hr^{-1})). The data points are categorized into different conditions:

- **Open water**
- **Plymouth Sound**
- Poly fit Open water (95% confidence interval)
- Landwehr et al. 2018

The y-axis represents the specific CO₂ uptake, while the x-axis represents the friction velocity. Different colors and symbols are used to distinguish between the categories.
Seawater $f\text{CO}_2$ database (SOCAT)

\begin{align*}
\text{Seawater } f\text{CO}_2 \\
\text{(μatm)}
\end{align*}

Air/sea $CO_2$ Flux = $K\Delta f\text{CO}_2$

Bakker et al. (2016)
Air-sea CO$_2$ flux (gC m$^{-2}$ day$^{-1}$) for August 2000

Shutler et al. (2016)