ExOIS Forum

Quantifying CO_2 Transport Across the Air-Sea Interface and Small-Scale Mixed Layer Turbulent Processes

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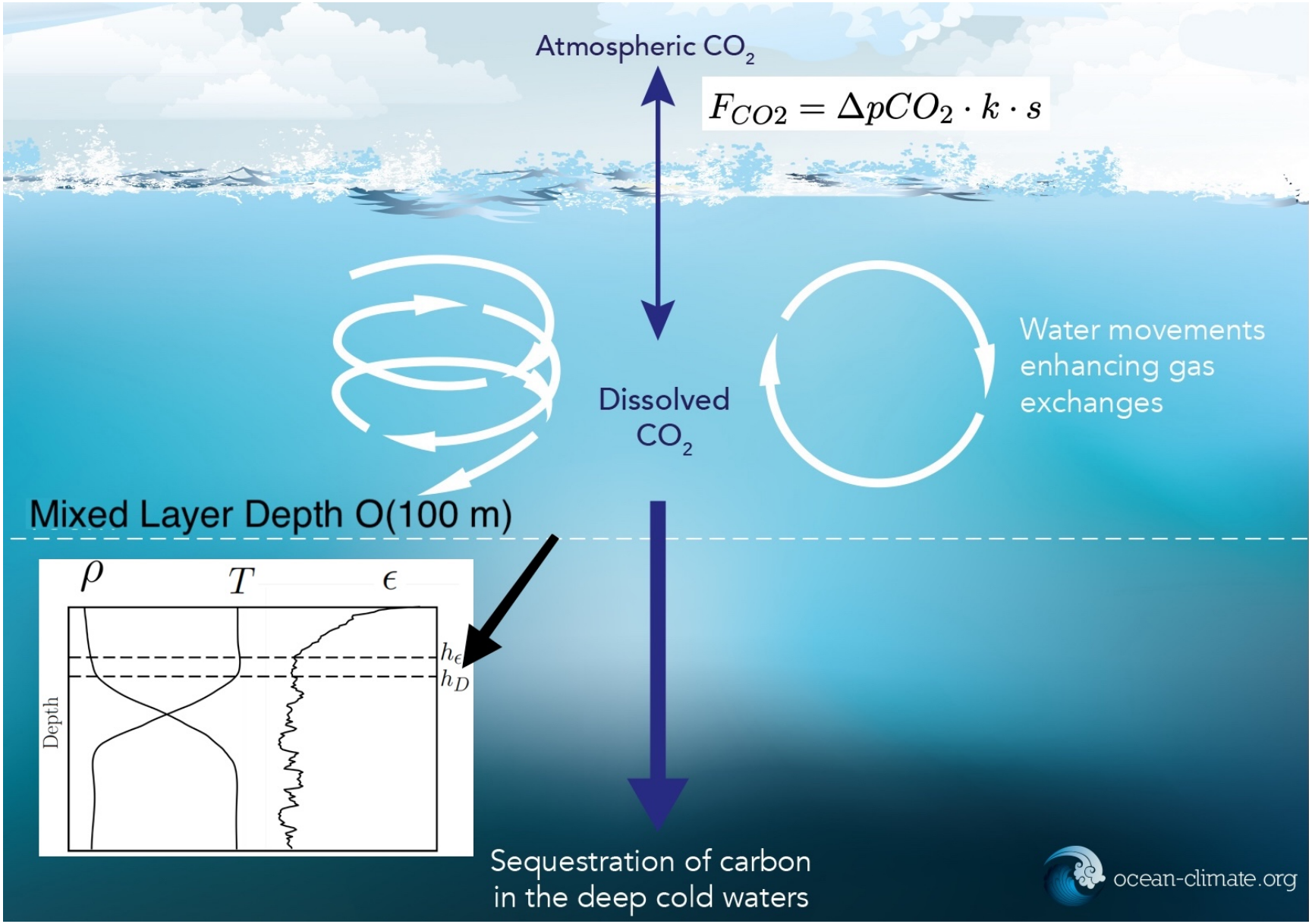
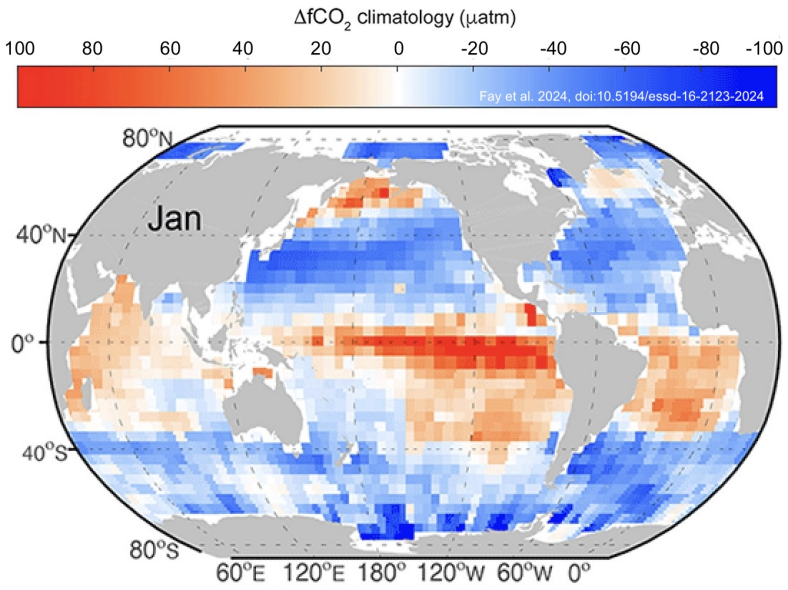
AirSea Lab

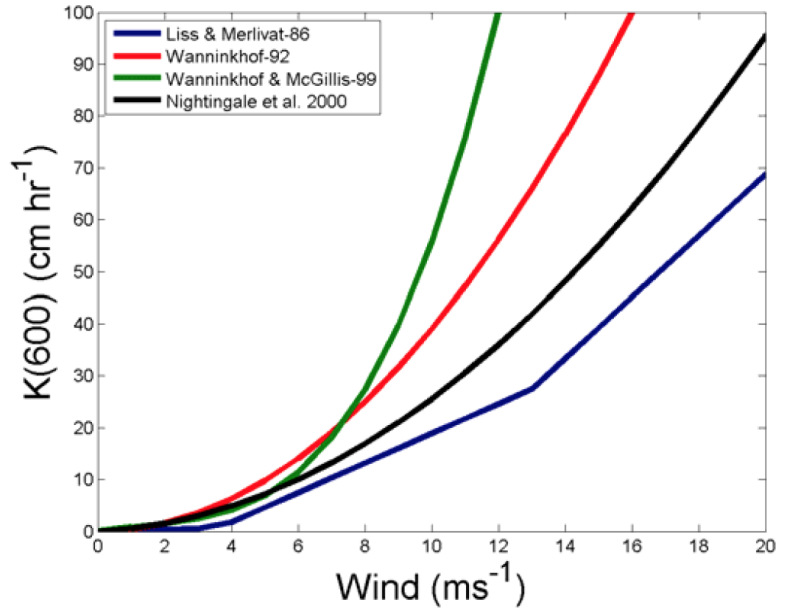
Ollscoil na Gaillimhe
University of Galway

Fluxes of CO_2



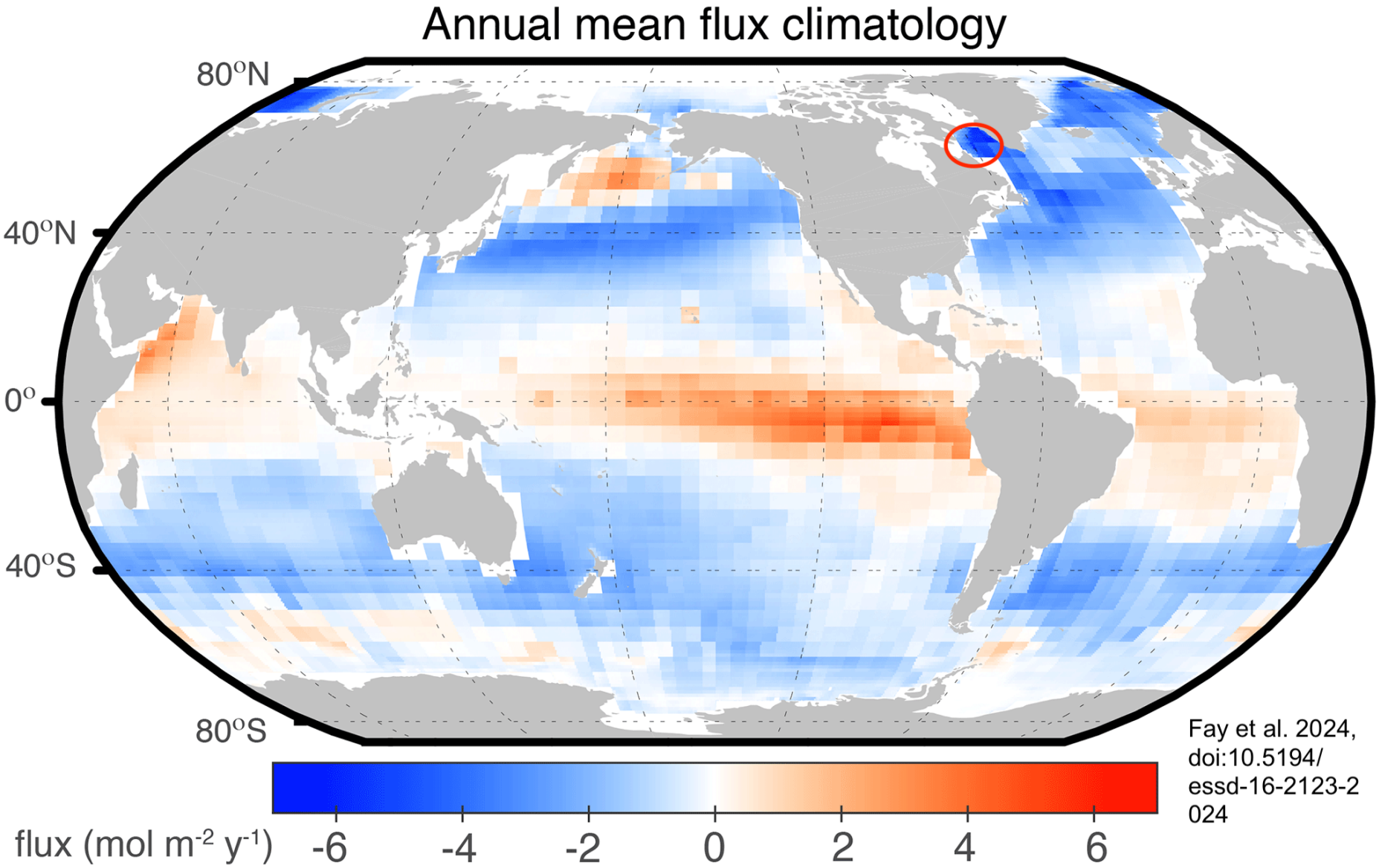
Determining Air-Sea CO_2 Fluxes



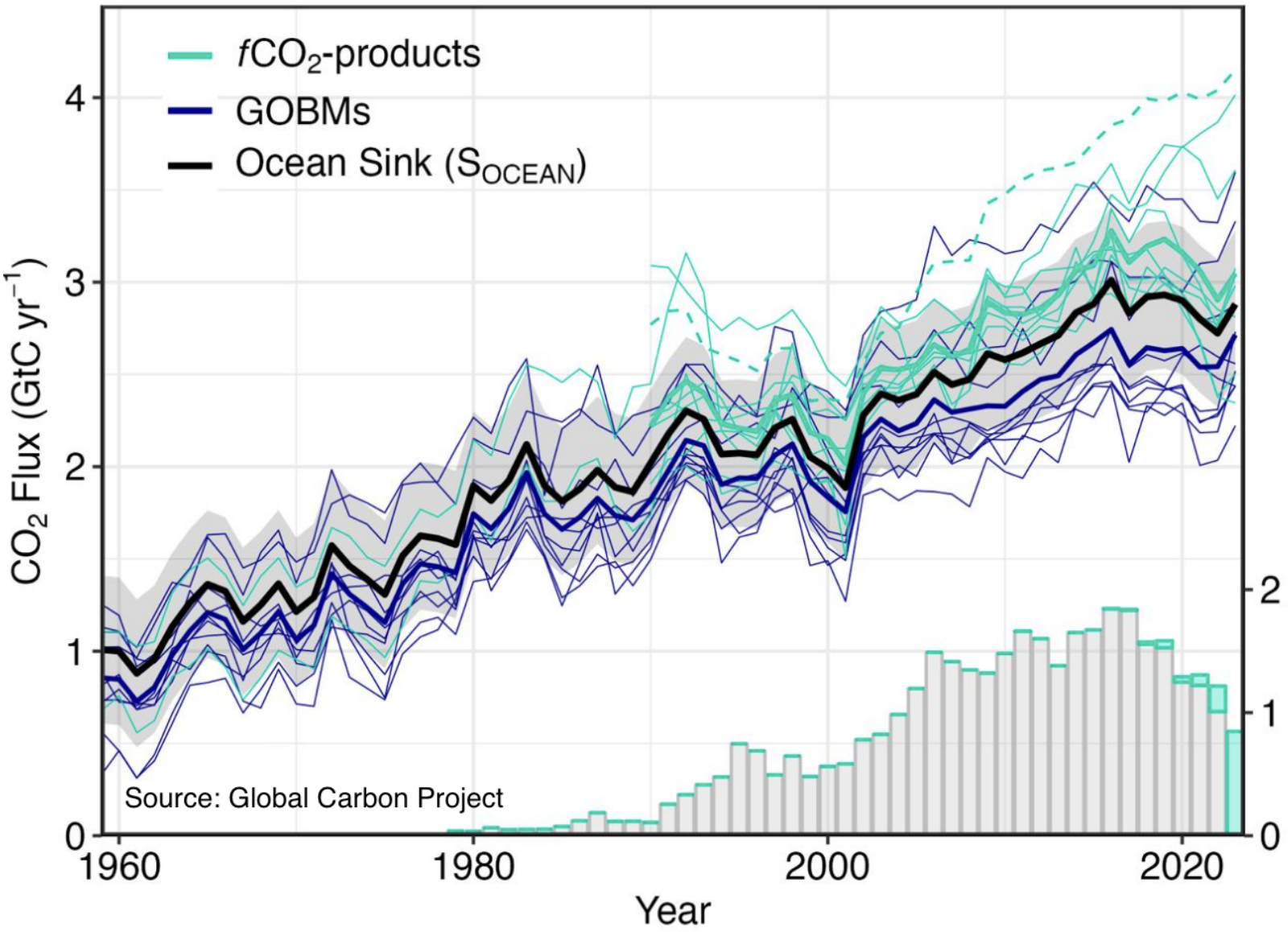


- The air-sea CO_2 flux is parameterised according to: $F = s \cdot \Delta pCO_2 \cdot k$ where
  - s (solubility of CO_2 in seawater): readily calculated from experimentally determined coefficients
  - ΔpCO_2 (partial pressure difference of CO_2 between the ocean and atmosphere): can be measured from a ship with some effort
  - k (the transfer velocity in $\mathrm{cm\,h^{-1}}$): represents ocean turbulence in the flux equation where $k(\epsilon)$ and where $\epsilon(U_{10})$ where ϵ is the dissipation rate of TKE and U_{10} is the wind speed

Global Ocean Uptake of Carbon

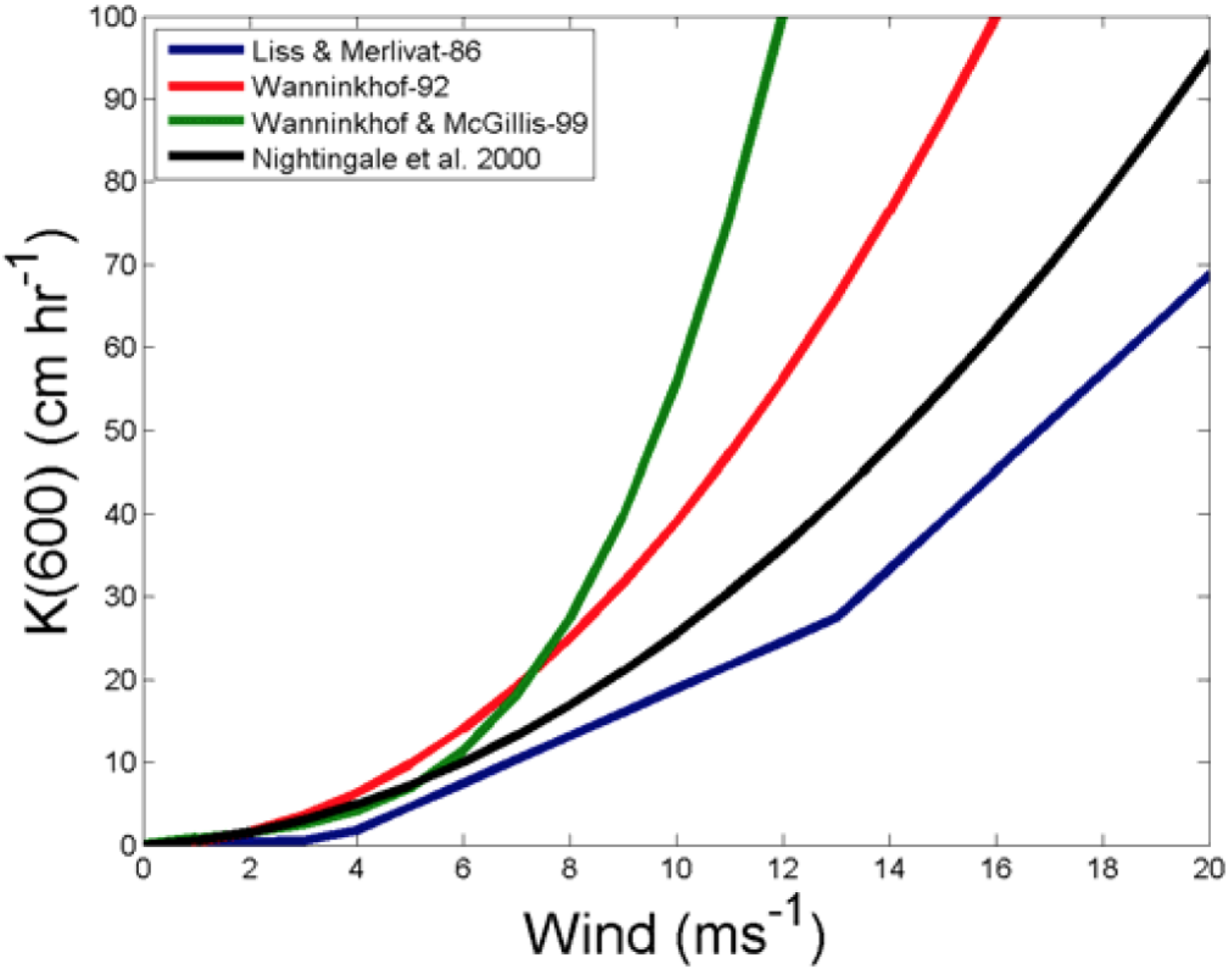


Ocean Sink of CO_2



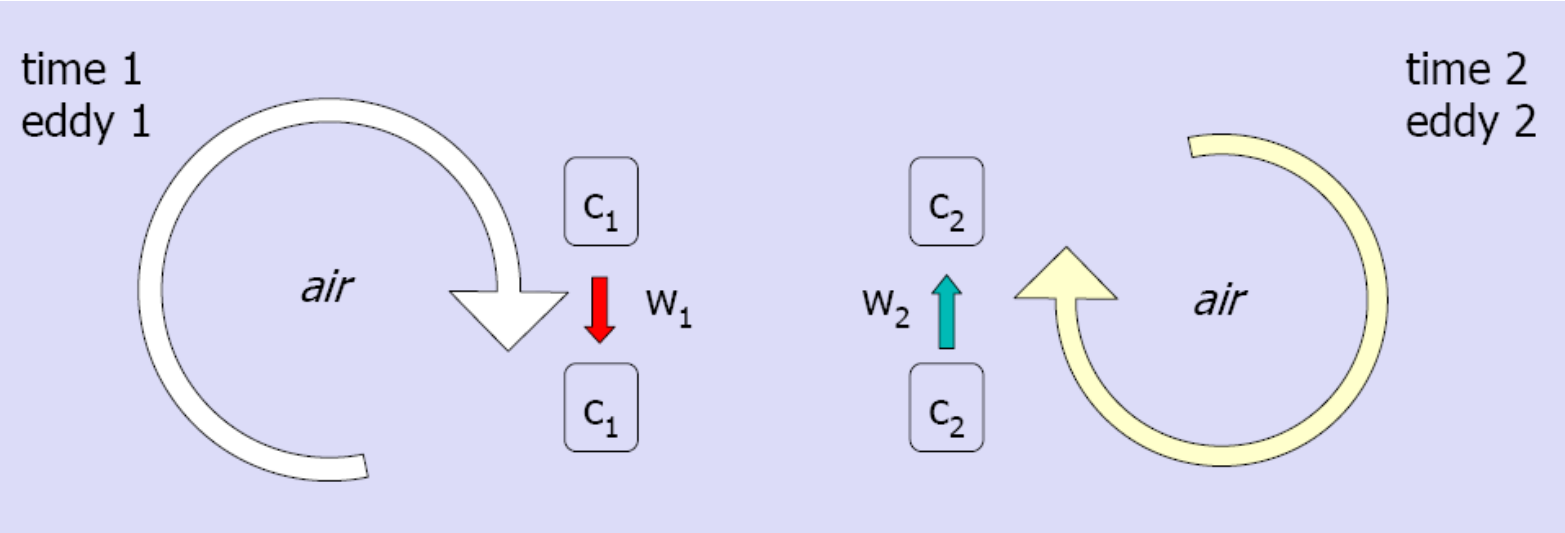
The ocean carbon sink amounts to 2.9 ± 0.4 Gt C yr^{-1}in 2023

Transfer Velocity



- How do we avoid using parameterisations of the transfer velocity?
- We use the eddy covariance method for **directly** measuring air-sea fluxes

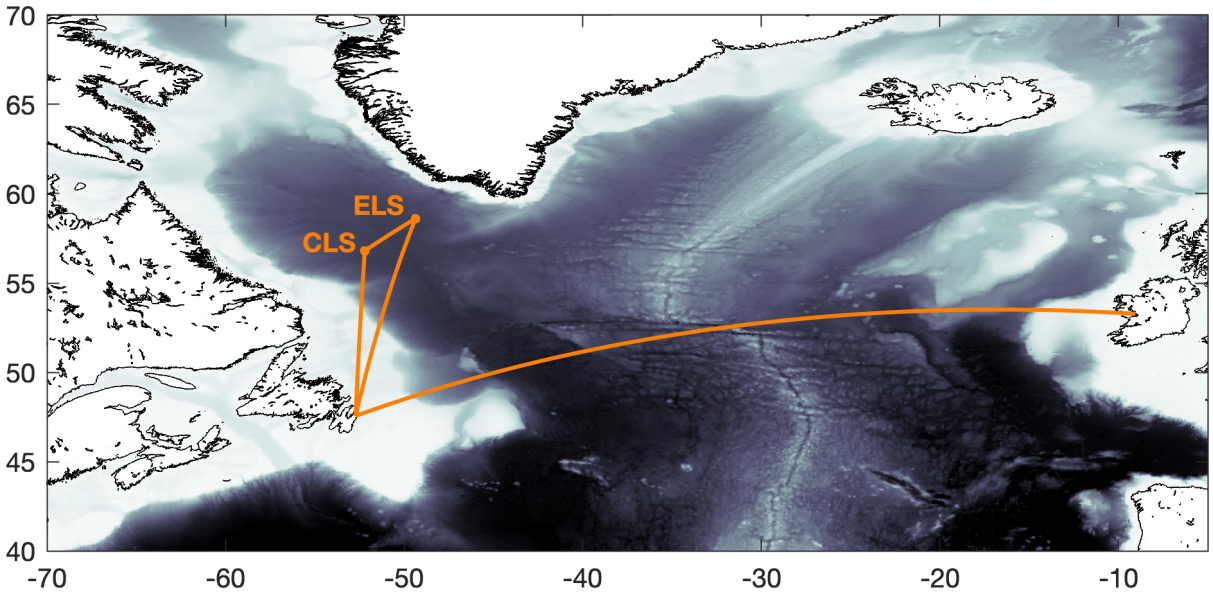
What is eddy covariance?

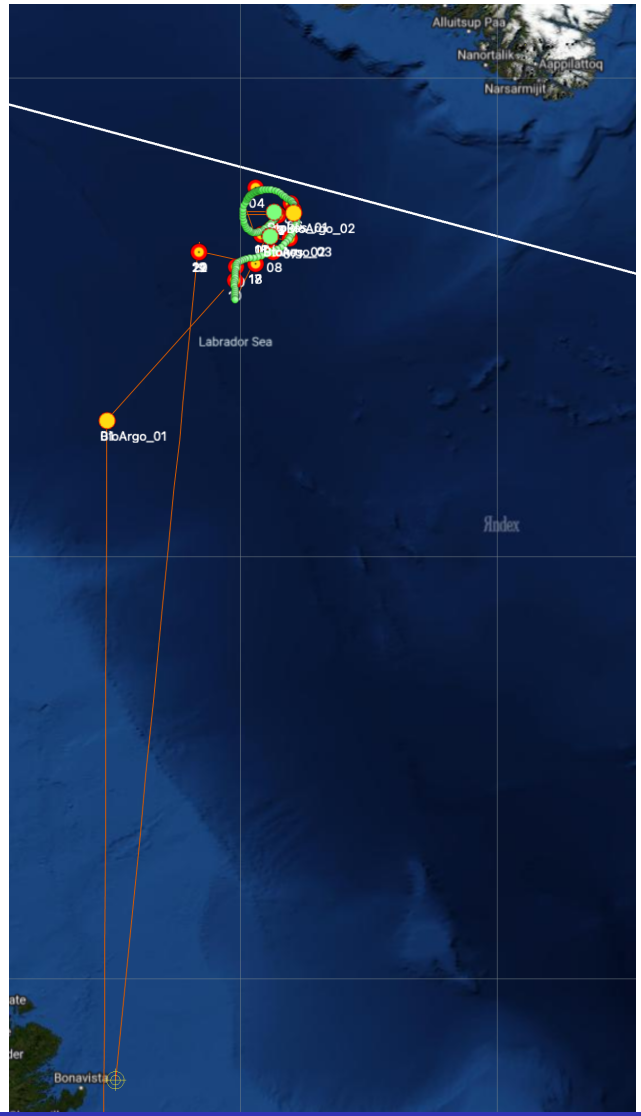


- Eddy 1 moves air parcel c_1 down at a velocity w_1
- Eddy 2 moves air parcel c_2 up at a velocity w_2
- Each parcel of air c has concentration of CO_2 temperature, humidity, aerosol density
- Knowing w and c provides the flux $F =< w^{'} c^{'} >$
- E.g. if $c_1 = 2$ molecules and $c_2 = 3$ molecules $\Rightarrow$ net upward flux of 1 molecule
- Eddy covariance: covariance between concentration and vertical wind speed

Labrador Sea Cruise May 2024

A collaboration with Dalhousie and Memorial Universities to study the biological carbon pump





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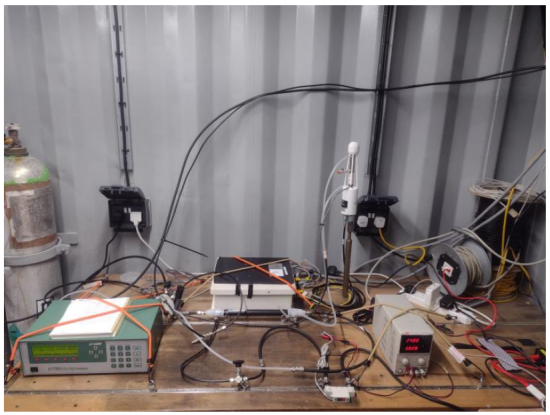
Eddy Covariance Setup

EC analysis: Sensor Setup

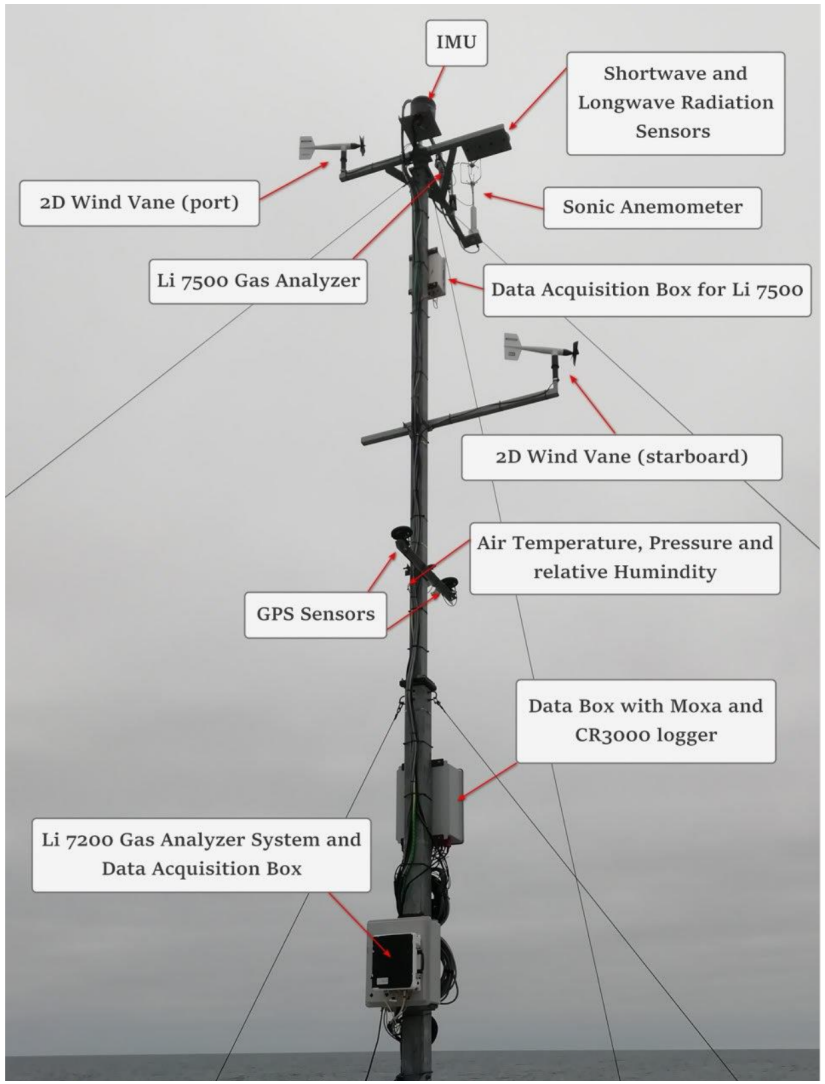
BELAS Labrador Sea 2024

Sensor	Position	Inlet
LI-7000	Container	dry
LI-7500	Container	dry
LI-7500	Mast	wet
LI-7200	Separate system on mast	dry

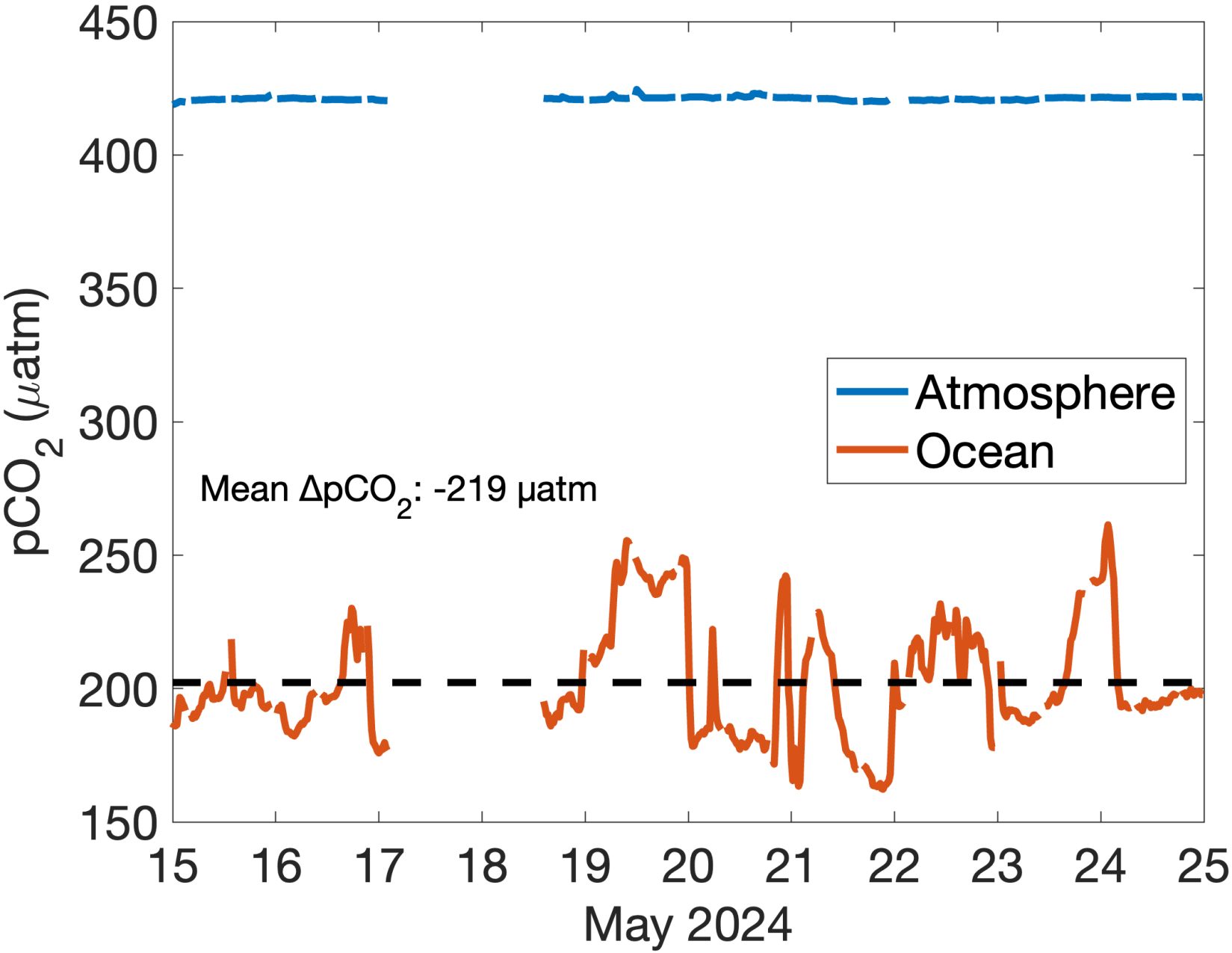
LI-7200 in box on the mast



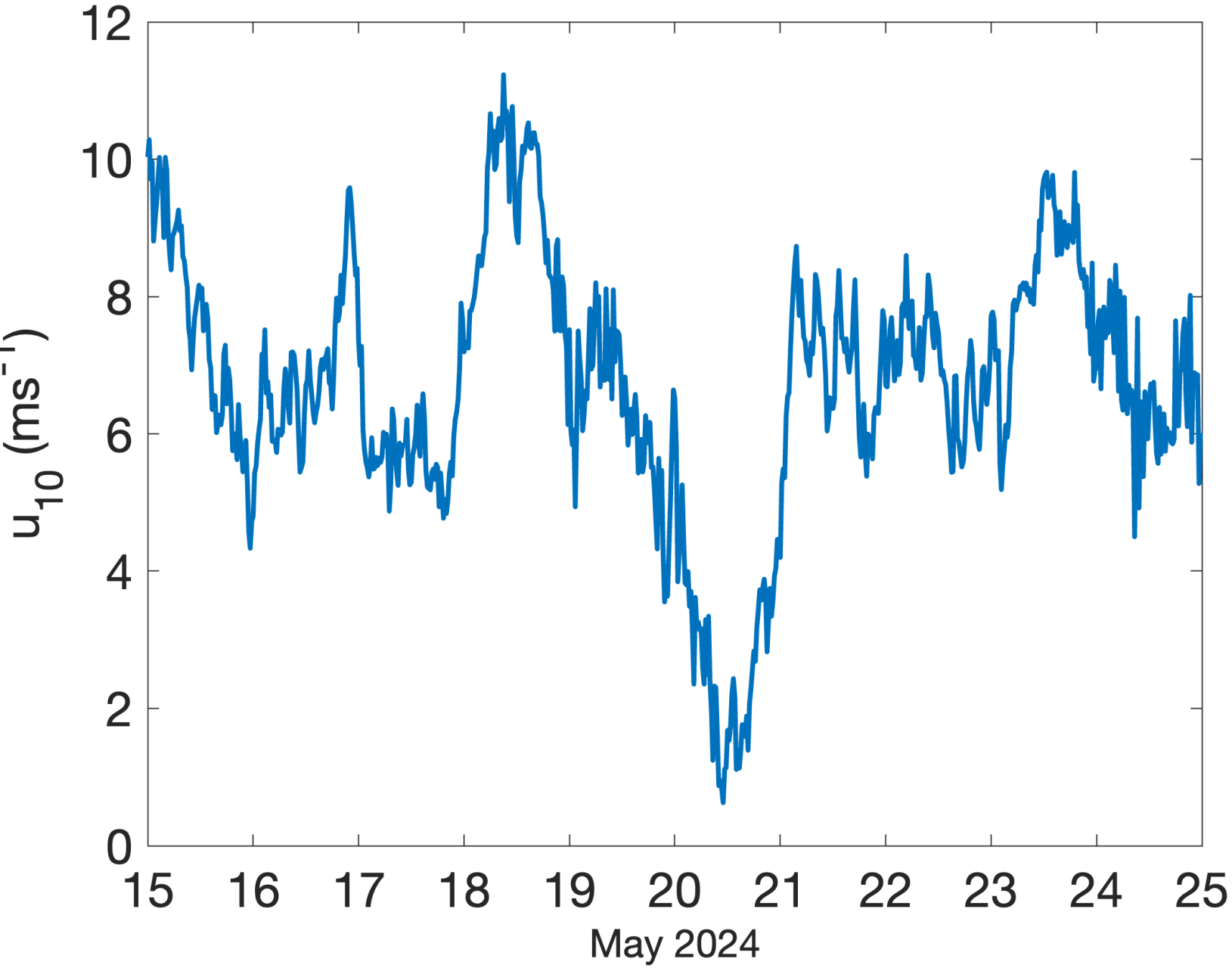
LI-7000 on the left and LI-7500 on the right in the bow container



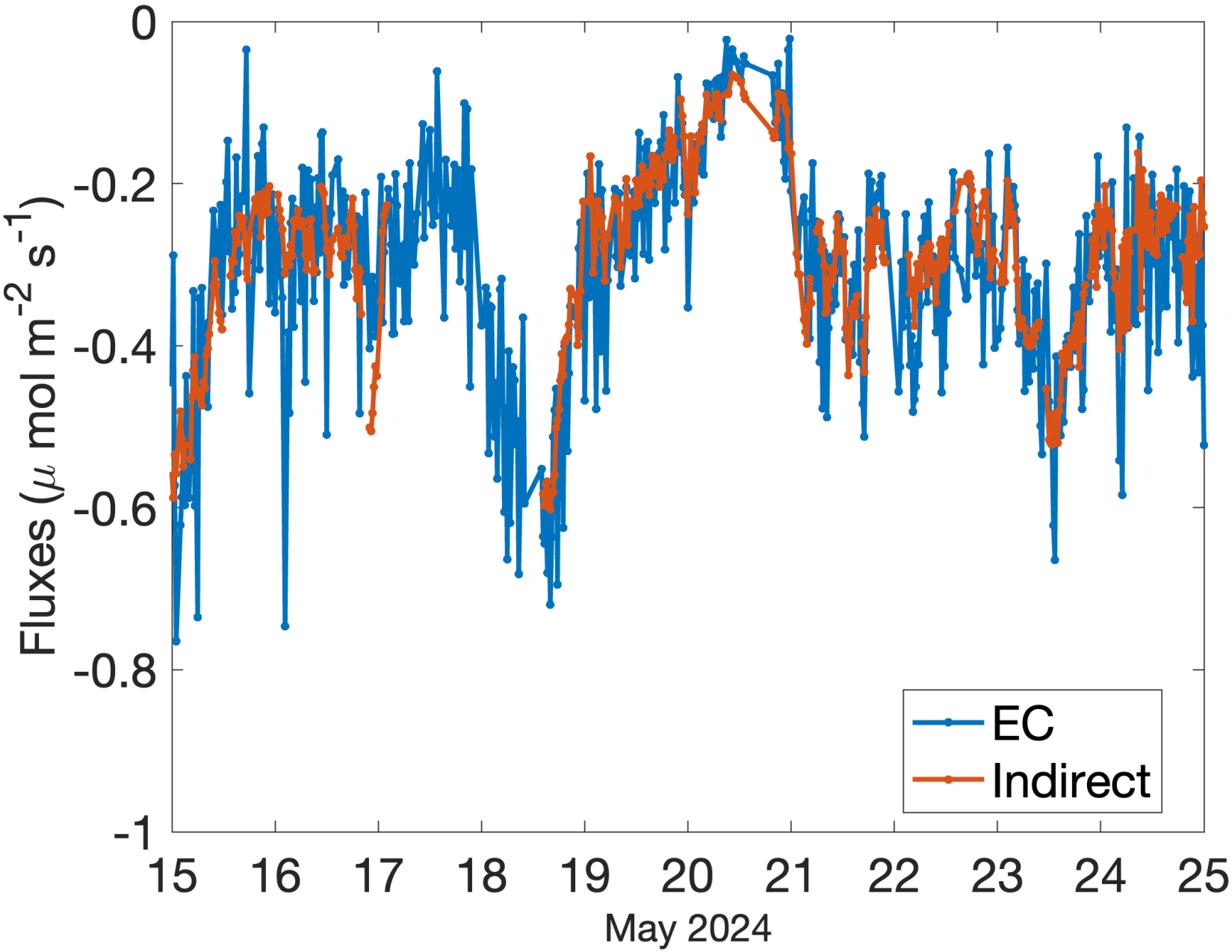
Labrador Sea Cruise: ΔpCO_2



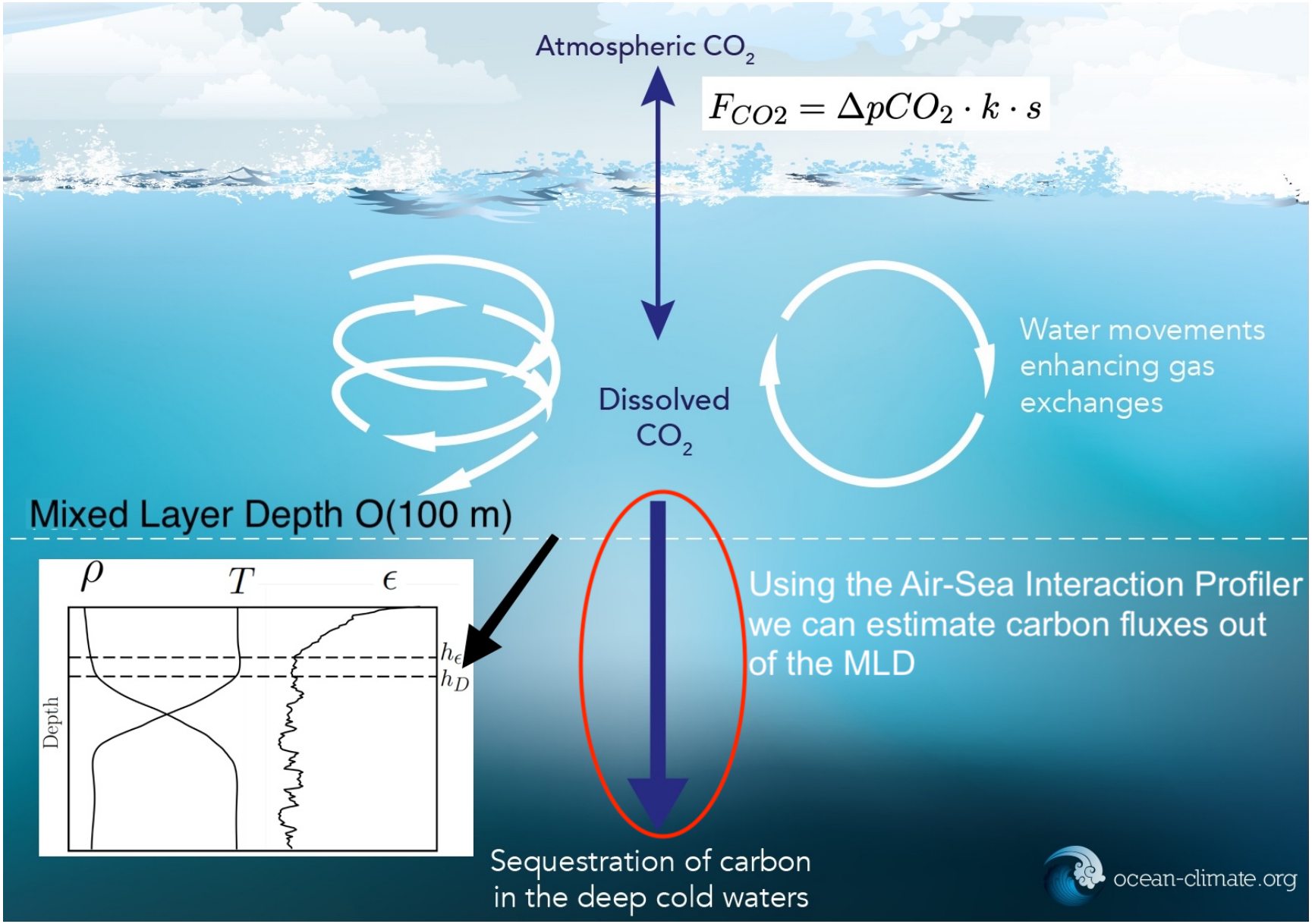
Labrador Sea Cruise: Wind Speed



Labrador Sea Cruise: EC and Indirect Flux Comparison

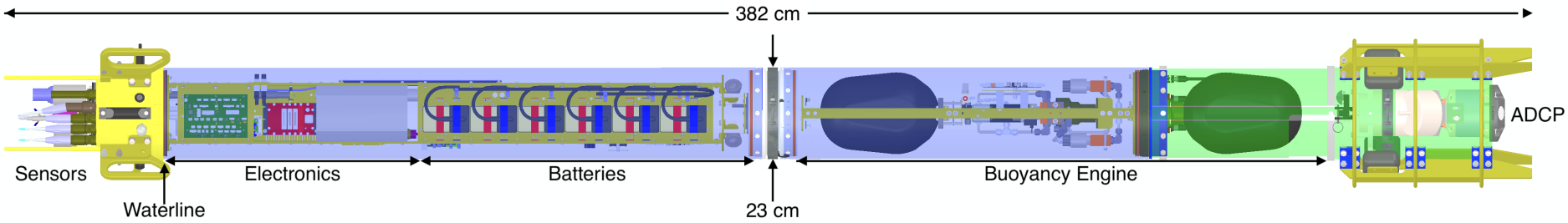


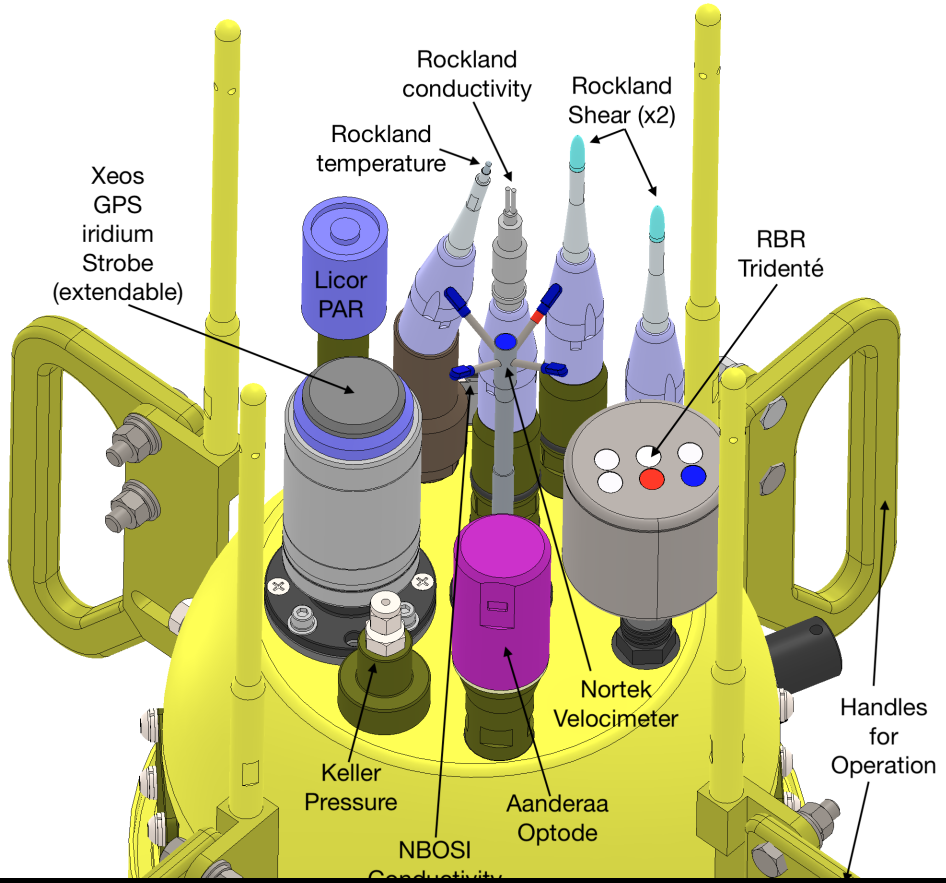
Fluxes of CO_2



Air-Sea Interaction Profiler

The ASIP is an autonomous vertically ascending profiler





- Shear probes x2
- Microstructure T
- Microstructure S
- RBR Tridenté (BS/Chl/FDOM)
- Oxygen optode
- Vectrino ADV
- PAR
- Pressure
- Reference CTD

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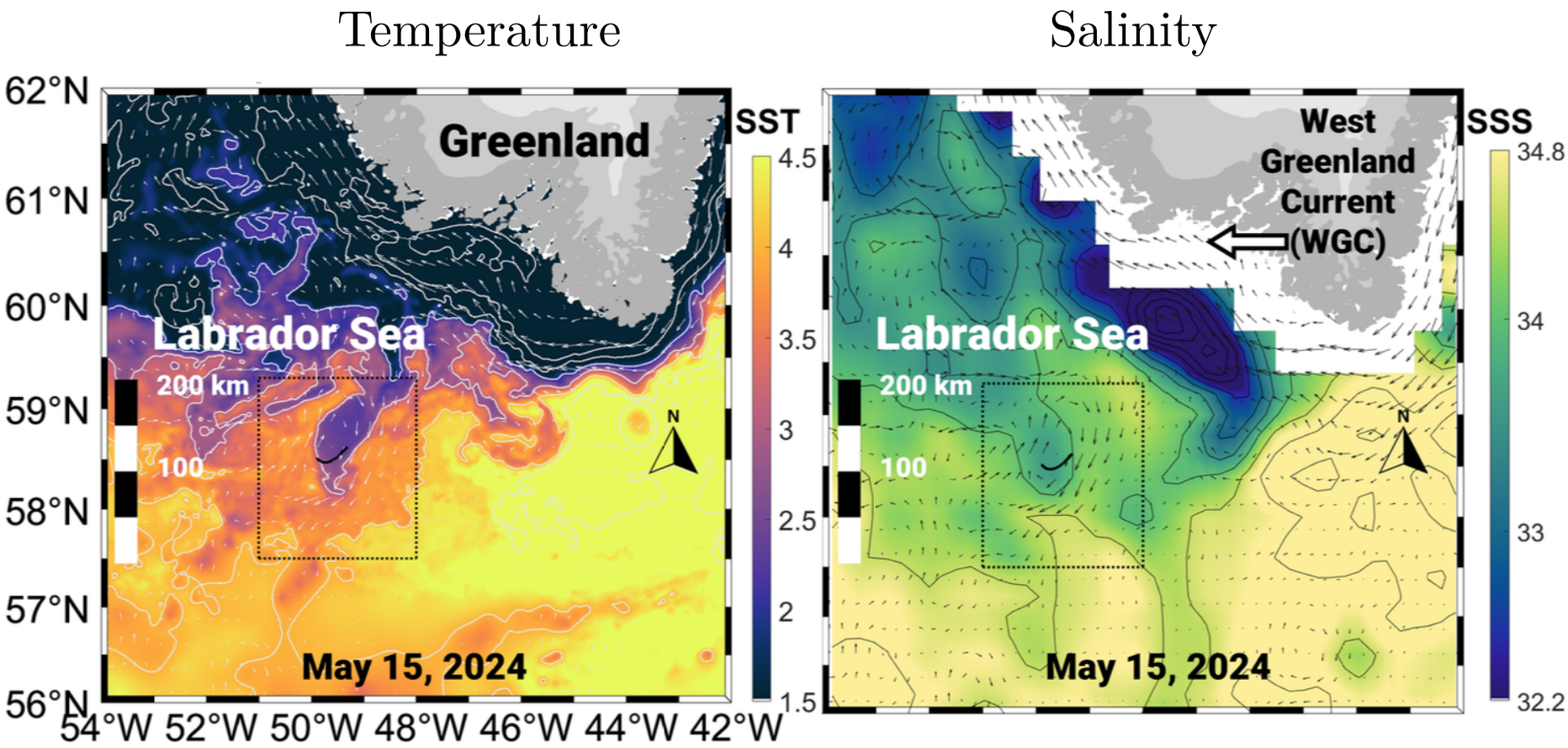
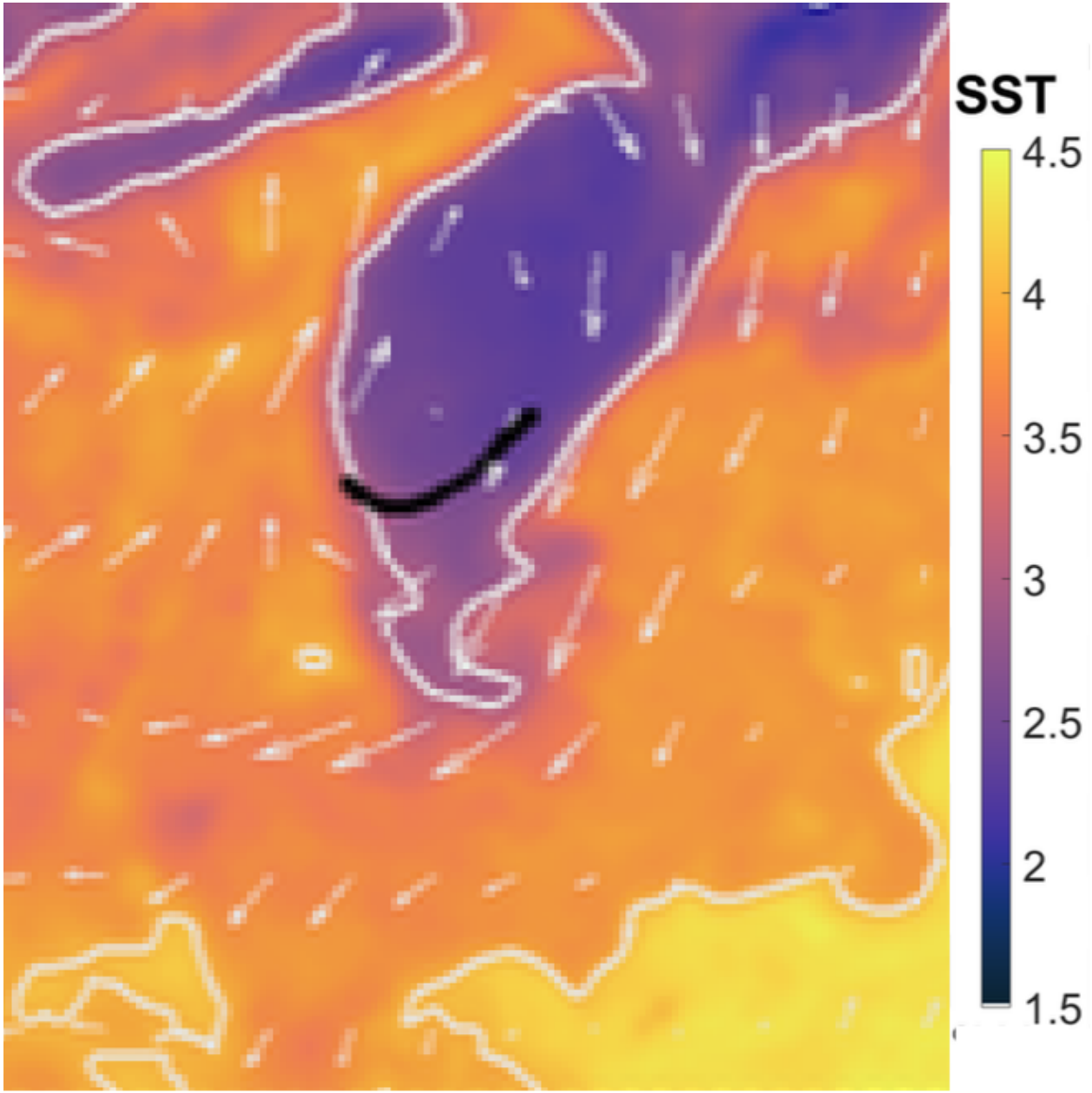
Labrador Sea Cruise: Satellite TS Data



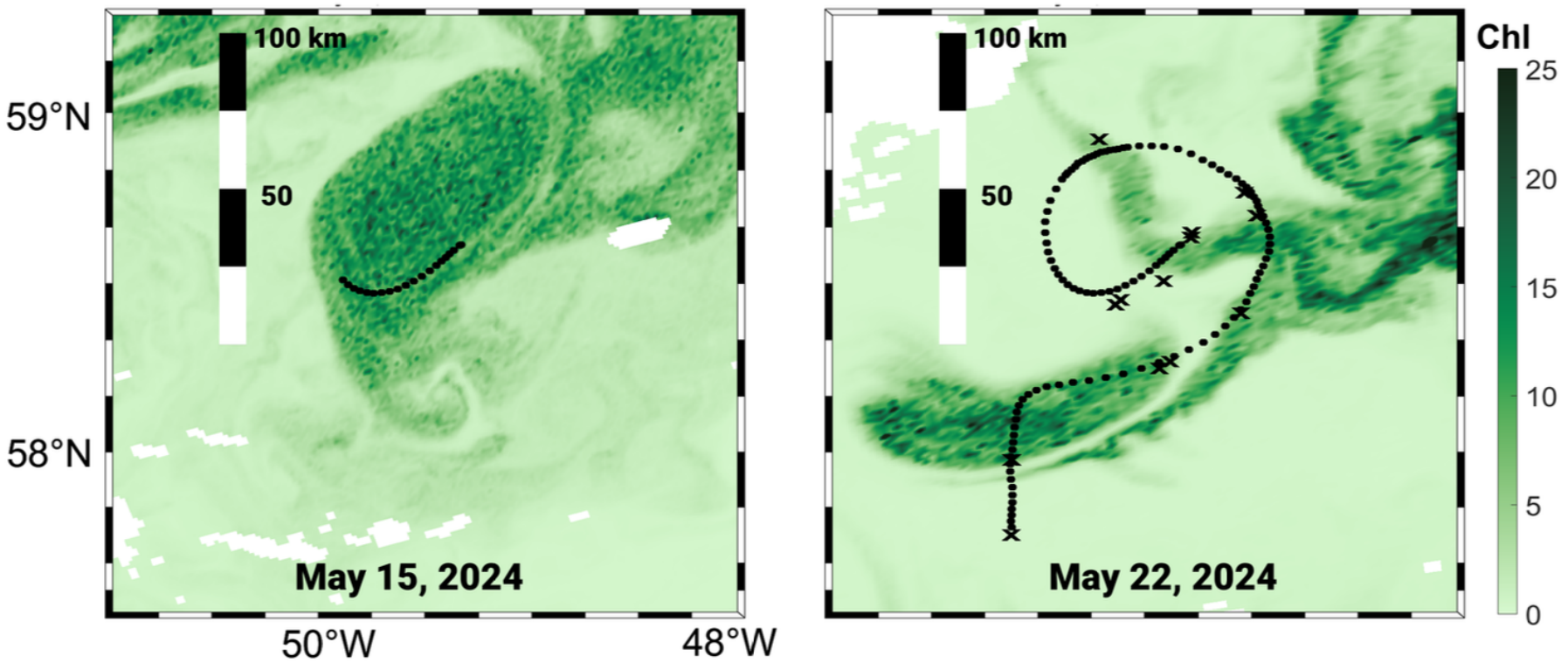
- ASIP was initially deployed on May14 and the satellite image of temperature confirns that it was located inside an eddy

Labrador Sea Cruise: Satellite TS Data



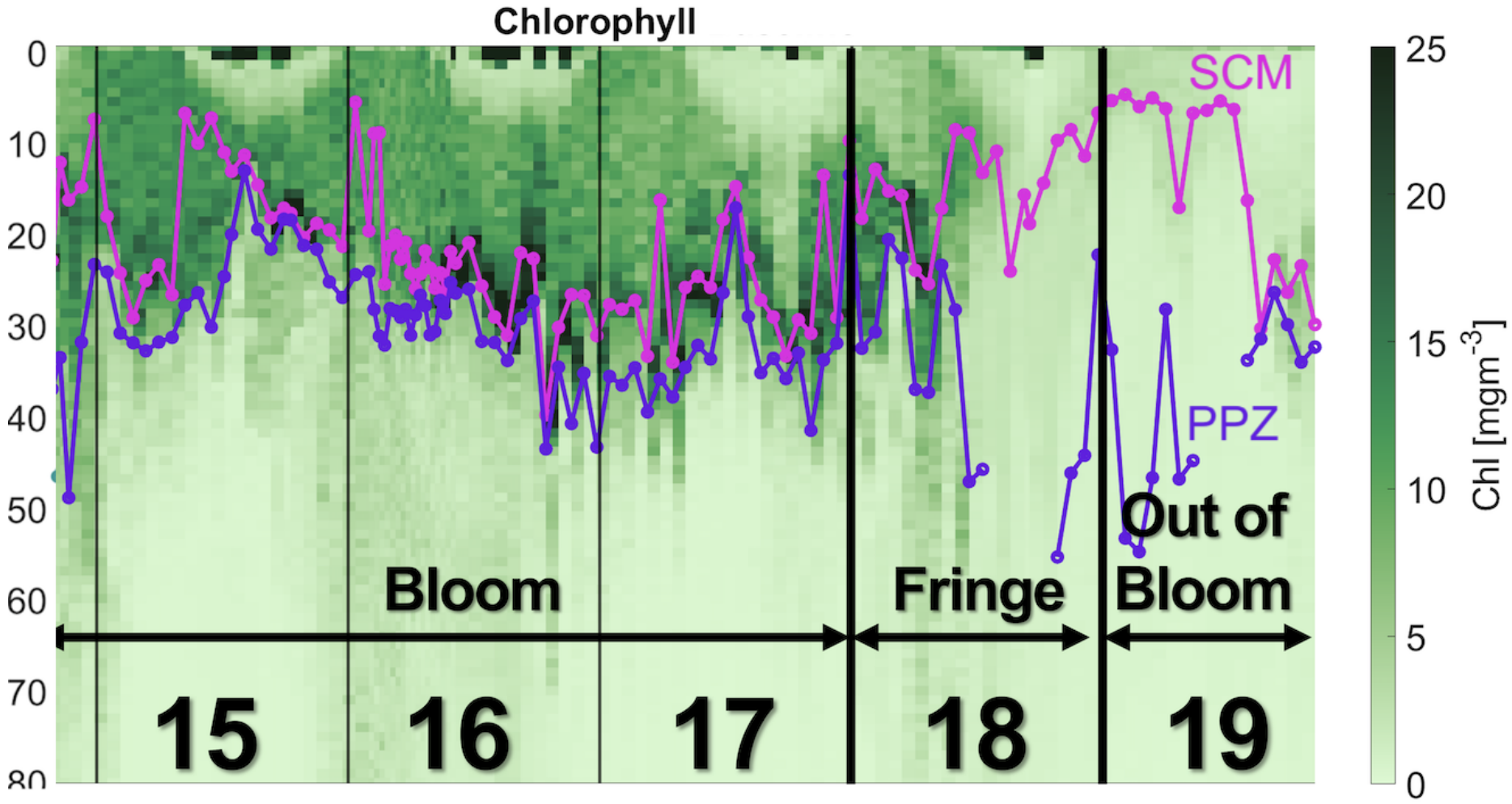
- ASIP track after about 1 day
- ASIP was programmed to profile hourly to a depth of 100 m

Labrador Sea Cruise: Satellite Chl Data

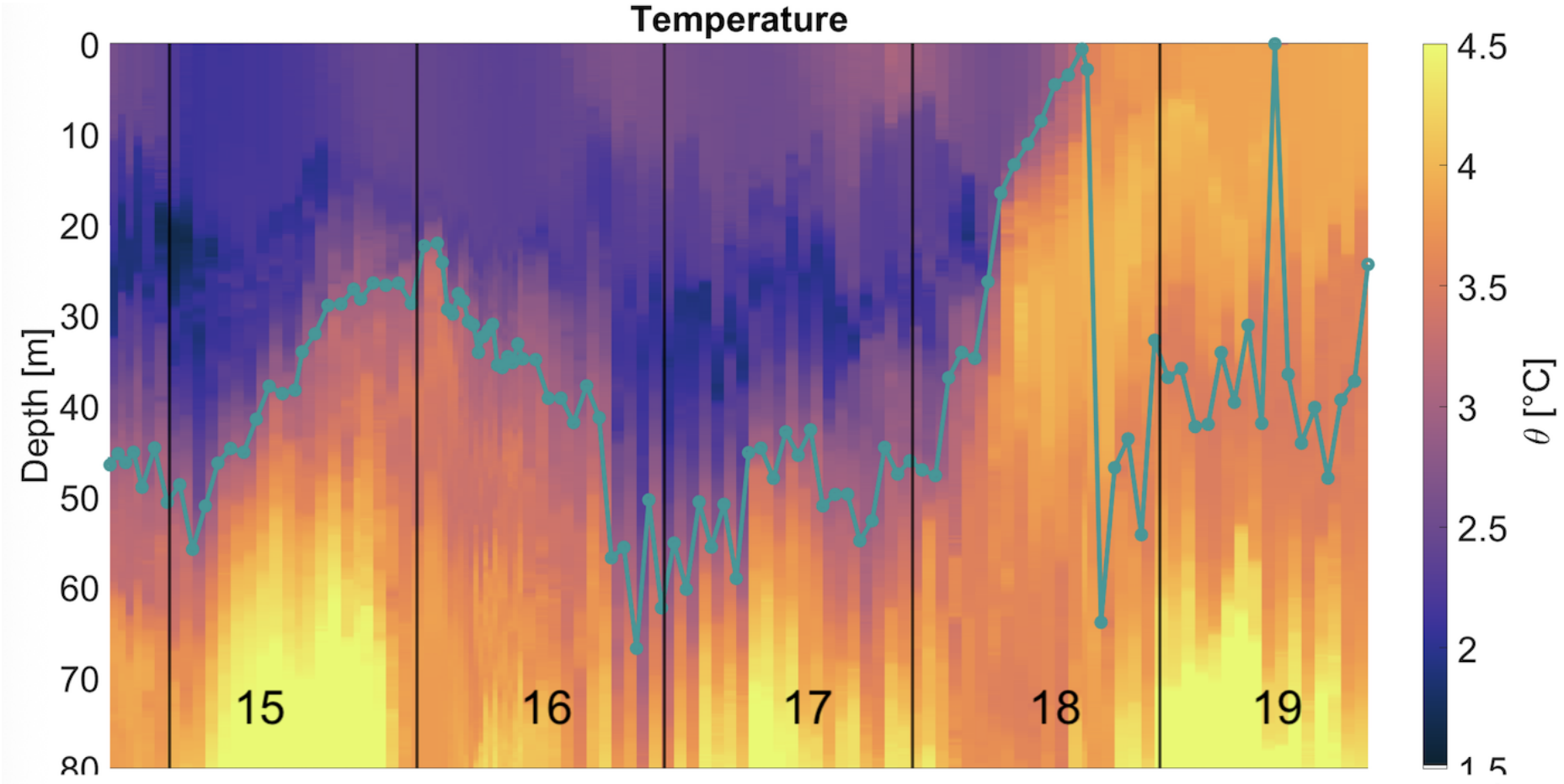


- Satellite Chl data confirms elevated Chl values inside eddy
- Due to cloud cover there were no images available between May15 and May22
- The physical situation had changed between the two satellite images; note that ASIp was recovered on May19

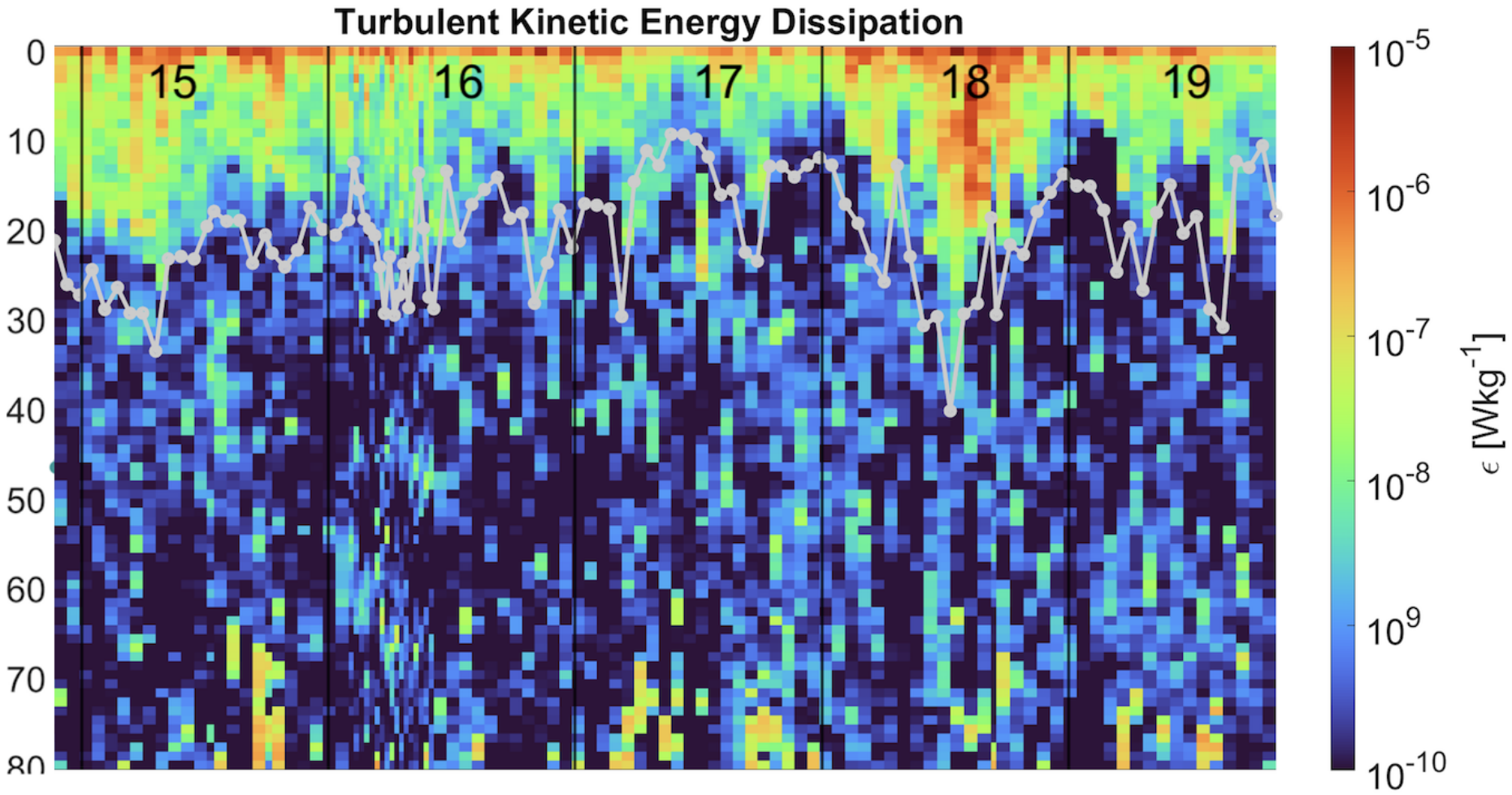
Labrador Sea Cruise: ASIP Chlorophyll Data



Labrador Sea Cruise: ASIP Temperature Data



Labrador Sea Cruise: ASIP Turbulence Data



- Mixed layer depth estimated with ϵ
- Enhanced turbulence on May18 associated with edge of eddy

Conclusions

- Air-sea fluxes are critical for mCDR verification
- Export fluxes are critical for mCDR verification
- Eddy covariance allows us to **directly** quantify air-sea fluxes of CO_2
- ASIP is a bespoke novel instrument designed to study the small-scale processes in the upper ocean
- ASIP allows us to quantify mixed layer processes and potentially quantify abyssal fluxes of CO_2