# Recent observations of the Southern Ocean surface $fCO_2$ and carbon sink in autumn with focus on the coast off the Dronning Maud Land, Kong Håkon VII Hav

Agneta Fransson,
Norwegian Polar Institute

Melissa Chierici (IMR), Ylva Ericson (NPI)

Norway-South Africa SANOCEAN collaboration:
Laura de Steur, Tore Hattermann, Sebastien Moreau, Hanna Kauko (NPI)
Murat Ardelan, Nicolas Sanchez (NTNU),
Sandy Thomalla, Tommy Ryan-Keogh (Council of Science and Industrial Research, CSIR),
Warren Joubert, Thato Mtshali, Pedro Monteiro (CSIR)
Margret Ogundare, Asmita Singh, Roy Alakendra (Stellenbosch Univ.),
DML/NPI and SANOCEAN project SOPHY-CO2

ICOS INTEGRATED CARBON OBSERVATION SYSTEM



Photo: Agneta Fransson, NPI

# Norwegian RV Kronprins Haakon (KPH) Southern Ocean Ecosystem cruise

26 Feb-11 April 2019, from Punta Arenas, Chile
via seasonal ice zone off the Dronning Maud Land
and Kong Håkon VII Hav
to Cape Town, South Africa

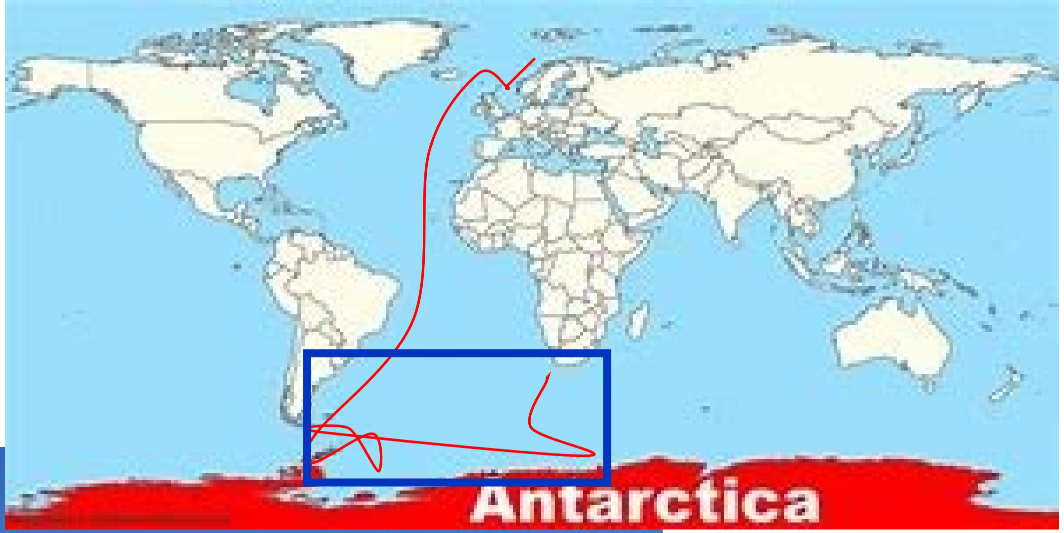



Photo: Agneta Fransson, NPI

ICOS INTEGRATED CARBON OBSERVATION SYSTEM

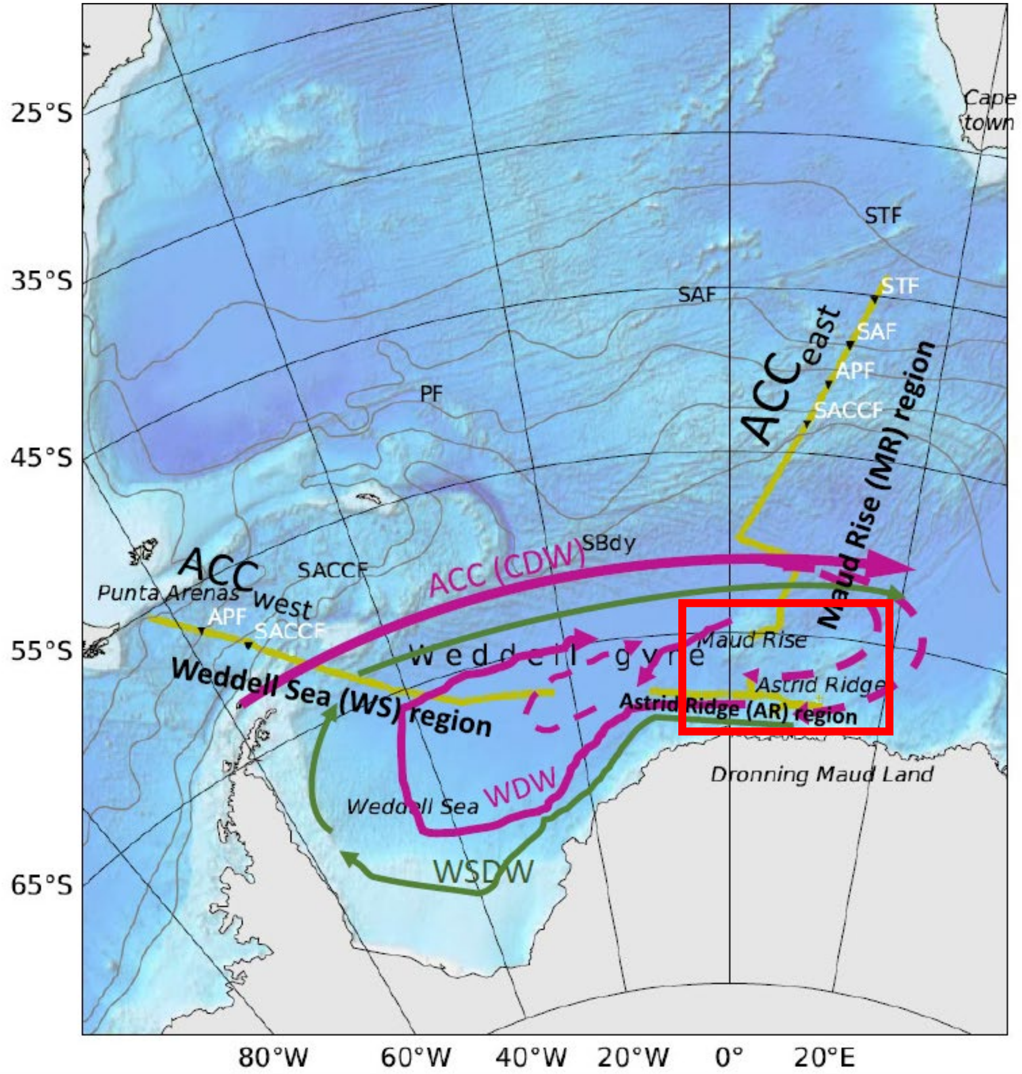



Figure in Ogundare, Fransson et al, submitted 2020

# SOPHY-CO2

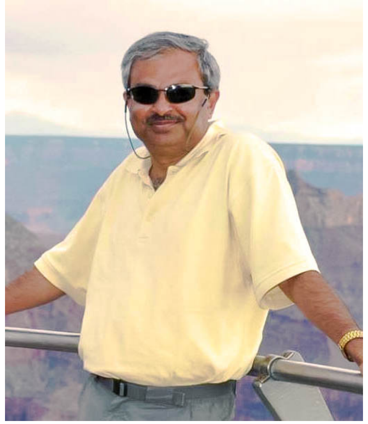
«Southern Ocean phytoplankton community characteristics, primary production, $CO_2$ flux and the effects of climate change"



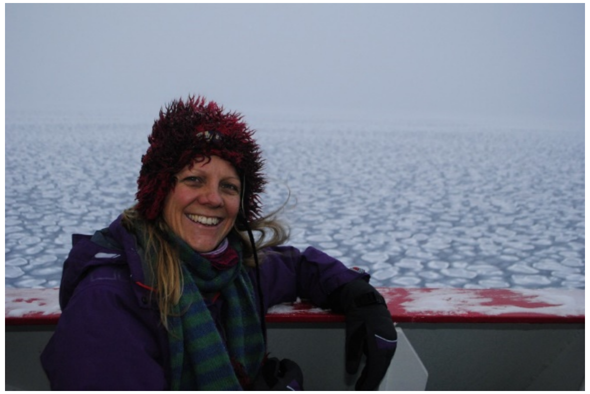




Black/white photos: Caeyers, UiT








# Motivation

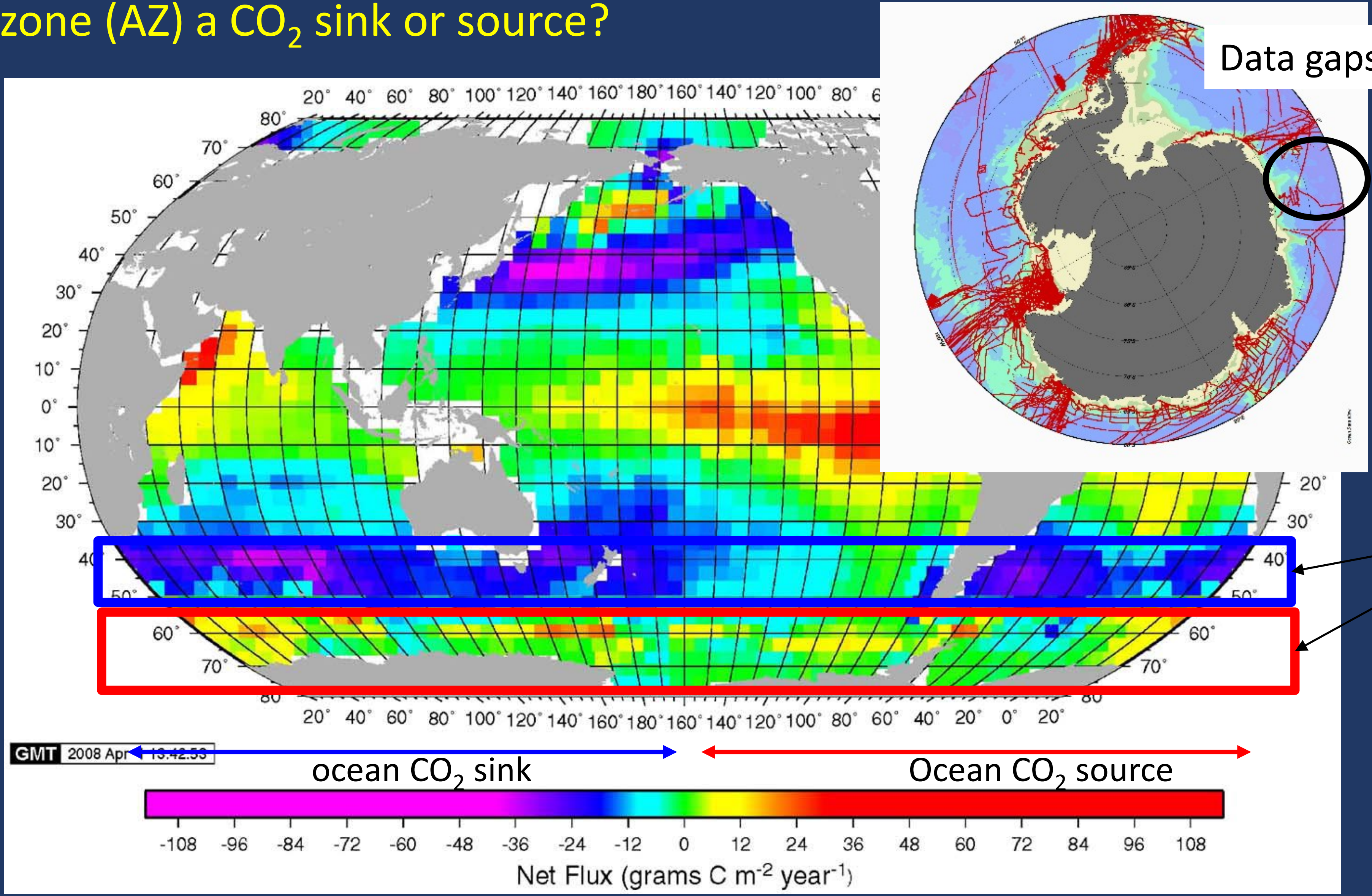
- Oceans have taken up about 30% of anthropogenic $CO_2$
- Southern Ocean (SO): 40% uptake of total anthropogenic $CO_2$
- Chemical changes such as pH decrease, ocean acidification
- Previous estimates of air-sea $CO_2$ fluxes and climatologies are mainly based on spring/summer data (Takahashi et al 2009)
- Few studies in the ice-covered SO and few data in autumn
- Need for seasonal and interannual studies of the $CO_2$ chemistry, with the effects of sea-ice formation and meltwater, primary production and mixing of water masses
- Effects of climate change: warming, increased ice melting, increased storms

# Role of Southern Ocean for global carbon: $CO_2$ climatology

## Is the Antarctic zone (AZ) a $CO_2$ sink or source?

The Southern Hemisphere oceans, south of 14°S to Antarctica, is the largest $CO_2$ sink taking up about 1.1GtC/y→ 40% of total anthropogenic $CO_2$ uptake

Major sink area is the Circumpolar Sink Zone (CSZ) 40-50 °S




CSZ

AZ

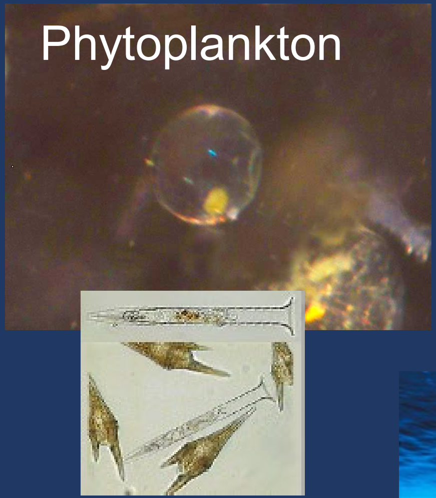
2 mill observations

Takahashi et al., 2009

# $CO_2$ : distribution, concentrations and variability are related to processes in the ocean; physical, biological, chemical and air-sea gas exchange

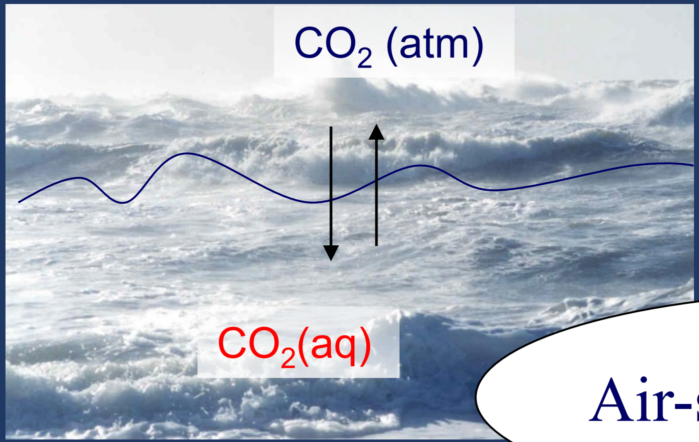

Ocean circulation (currents)

## Biological processes



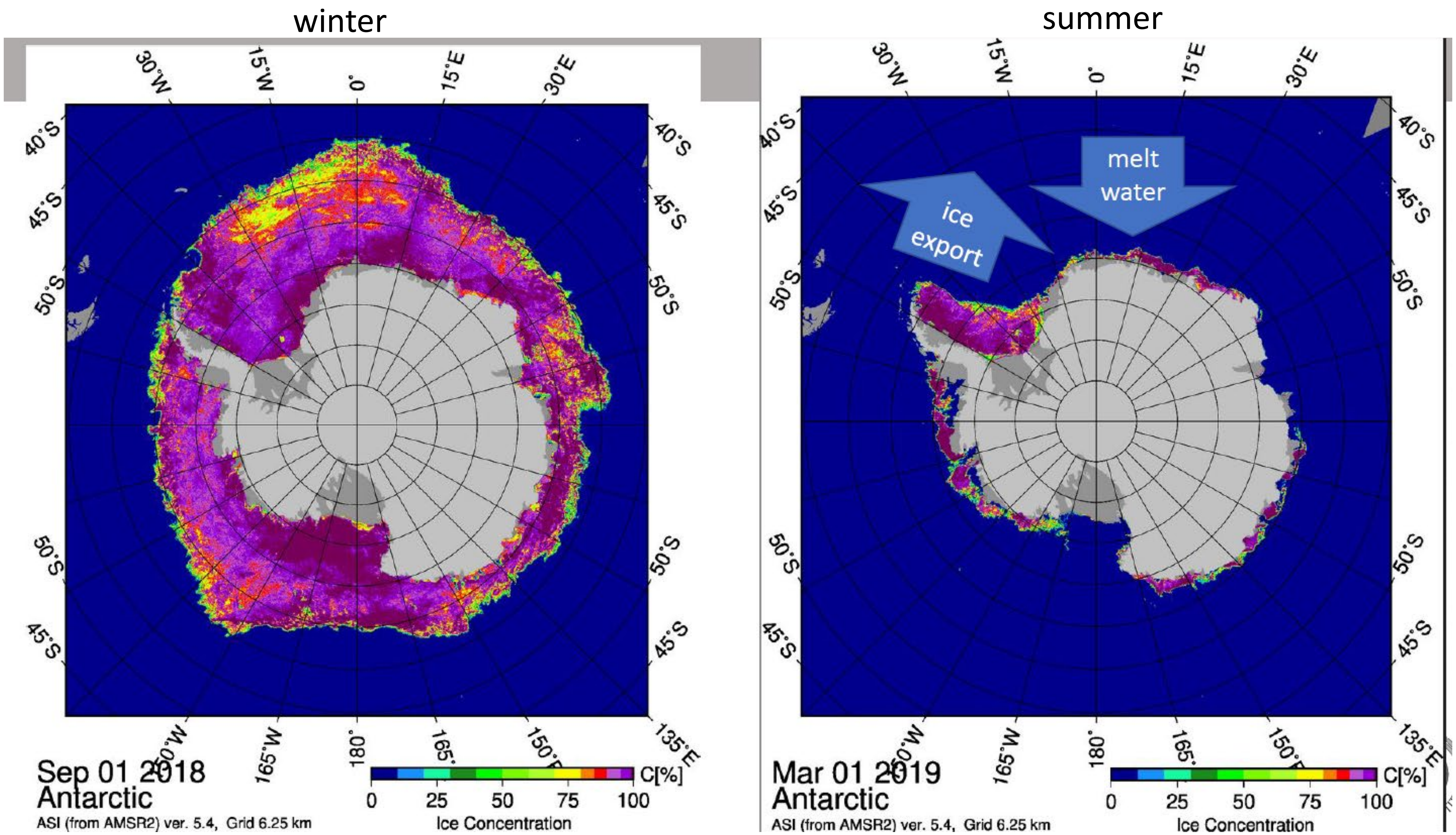

zooplankton

Birds, seals whales




Air-sea gas exchange

# Seasonal sea ice in Antarctica




Courtesy: T. Hattermann
Zhou et al 2014

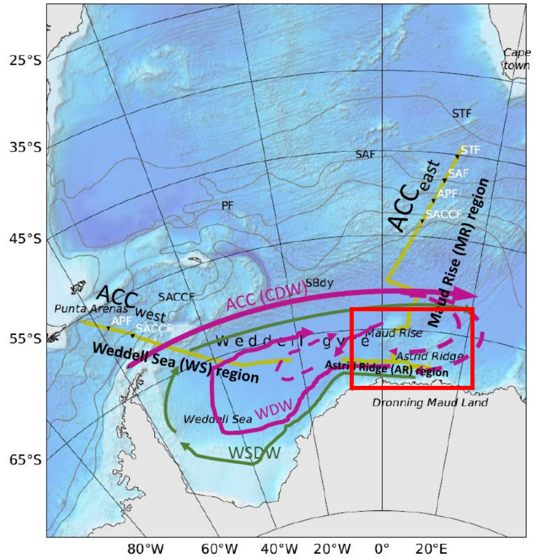
Photo: A. Fransson, NPI

# How do processes and climate change affect the potential for ocean $CO_2$ uptake of atmospheric $CO_2$

- Changes in temperature: **warming** → $CO_2$ increases/source
- Changes in salinity: **freshening** (sea-ice and ice-shelf melt) → $CO_2$ decreases/sink
- **Primary production** → $CO_2$ decreases/sink
- Wind-induced **upwelling**, vertical mixing of $CO_2$-rich subsurface water → $CO_2$ increases/source

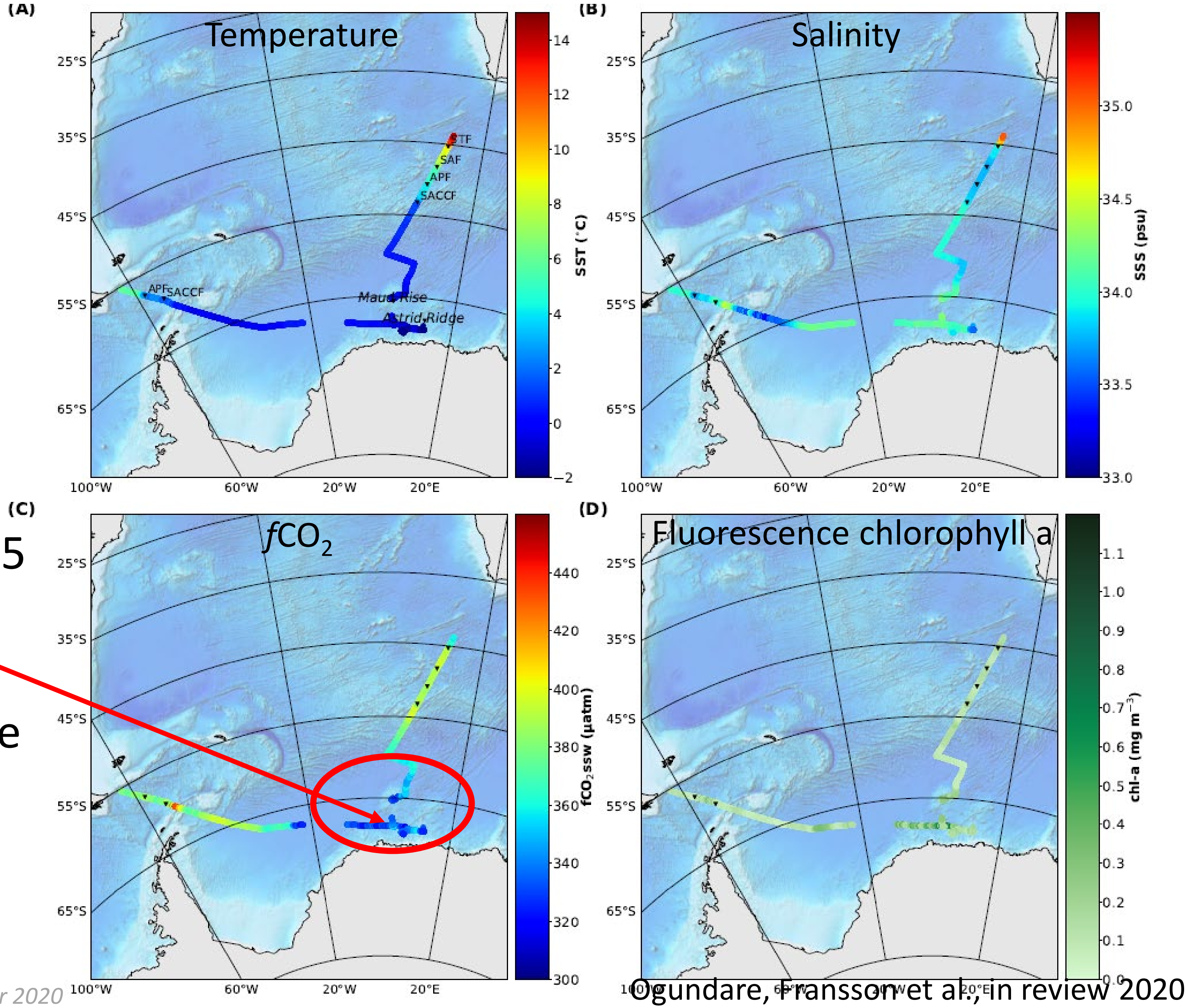
Increased ocean $CO_2$ → increased **ocean acidification**, can have serious effects on marine organisms and chemical reactions in the ocean, essential for life

# Surface water observations along the KPH cruise track in autumn




Surface water $fCO_2$ undersaturated compared to atmospheric $fCO_2$ ( ~405 µatm) → potenial **$CO_2$ sink**

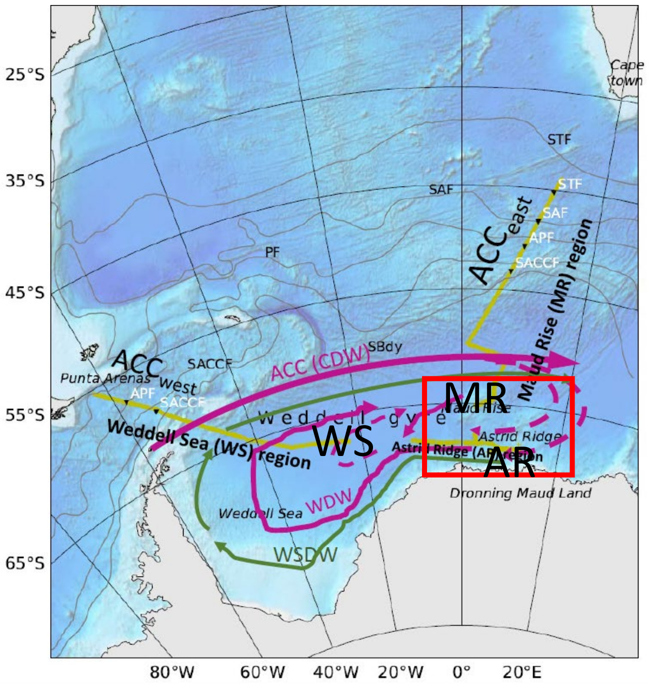
- corresponded to colder water and higher chlorophyll a fluorescence

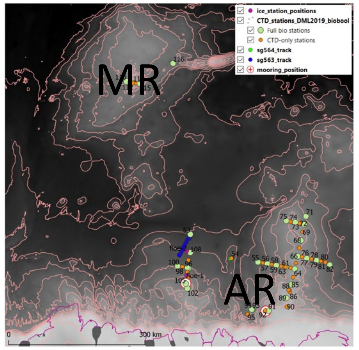



Agneta Fransson NPI, ICOS Science meeting, 29 October 2020

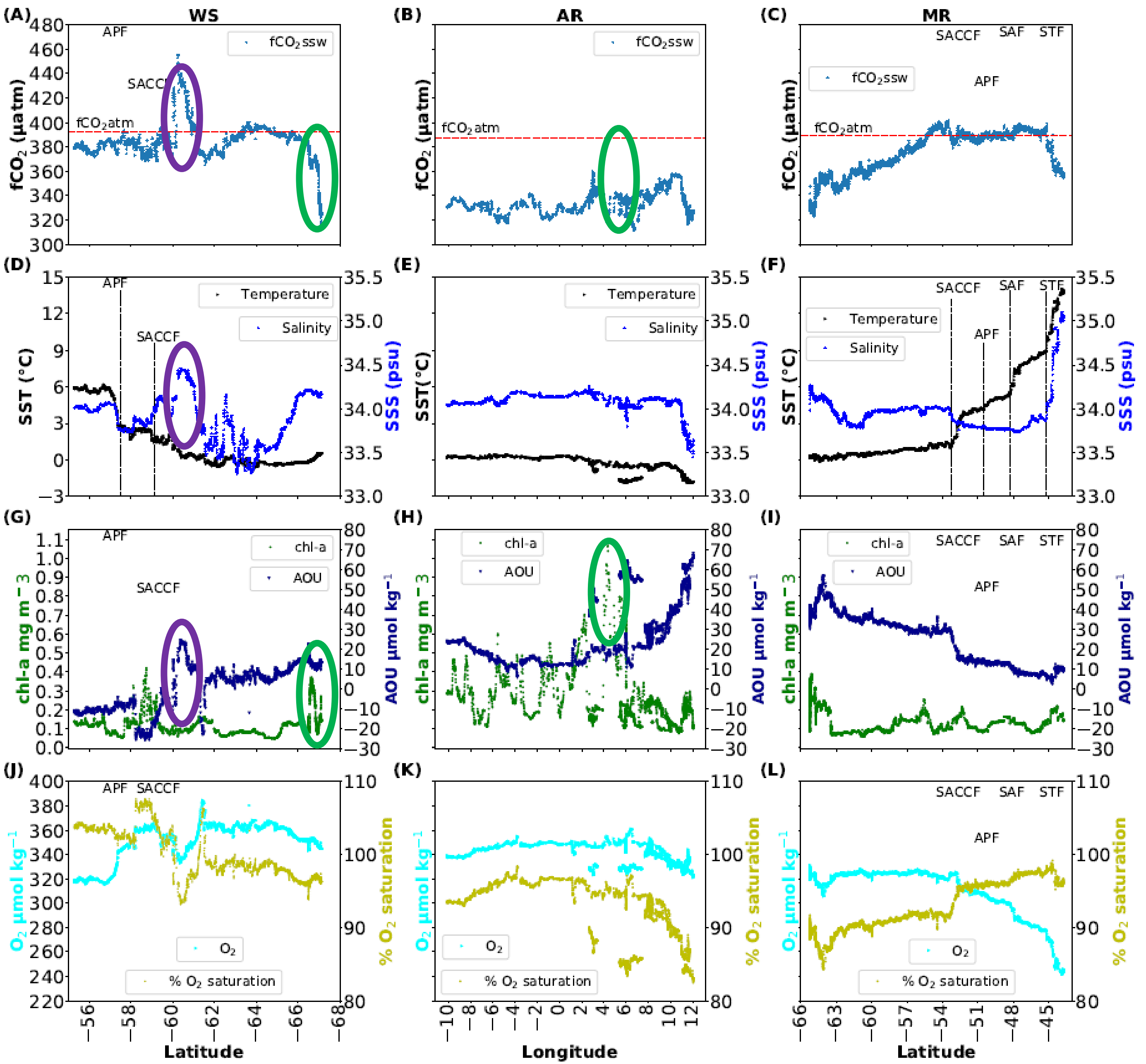
Ogundare, Fransson et al., in review 2020

# Surface $fCO_2$, SST, SSS, chl a, oxygen in




Weddell Sea (WS) Astrid Ridge (AR) Maud Rise (MR)




- $fCO_2$ undersaturated (<405 µatm) in most areas
- Peak in $fCO_2$ >440 µatm in WS near front
- Coinciding with increased salinity and apparent oxygen utilisation (AOU) due to upwelling of $CO_2$-rich subsurface water, lower oxygen
- Lowest $fCO_2$ at 66-68°S in WS and coast/AR
- Coinciding with higher chl a

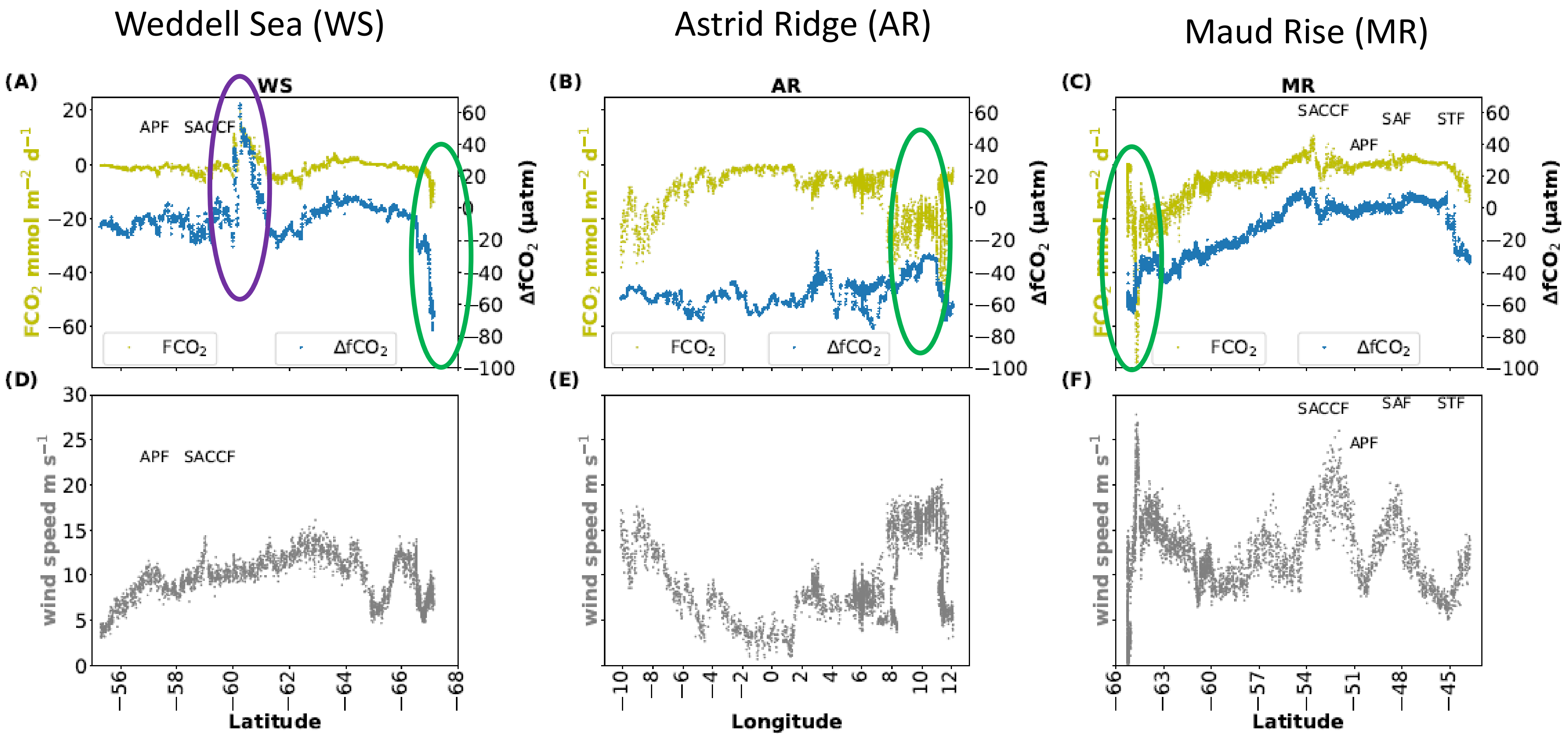
*Agneta Fransson NPI, ICOS Science meeting, 29 October 2020*

Ogundare, Fransson et al., in review

# $\Delta fCO_2$ ($fCO_{2sw}$-$fCO_{2air}$), sea-air $CO_2$ flux ($FCO_2$) and wind speed

- $\Delta fCO_2$ is negative (undersaturated) in most areas, and $CO_2$ flux close to zero
- except in WS at 60°S, a $CO_2$ source (positive flux)
- and at 66-68°S, in WS, MR and eastern AR, the ocean is a potential $CO_2$ sink (negative flux)

Wanninkhof, (2014), flux formulation using quadratic wind speed

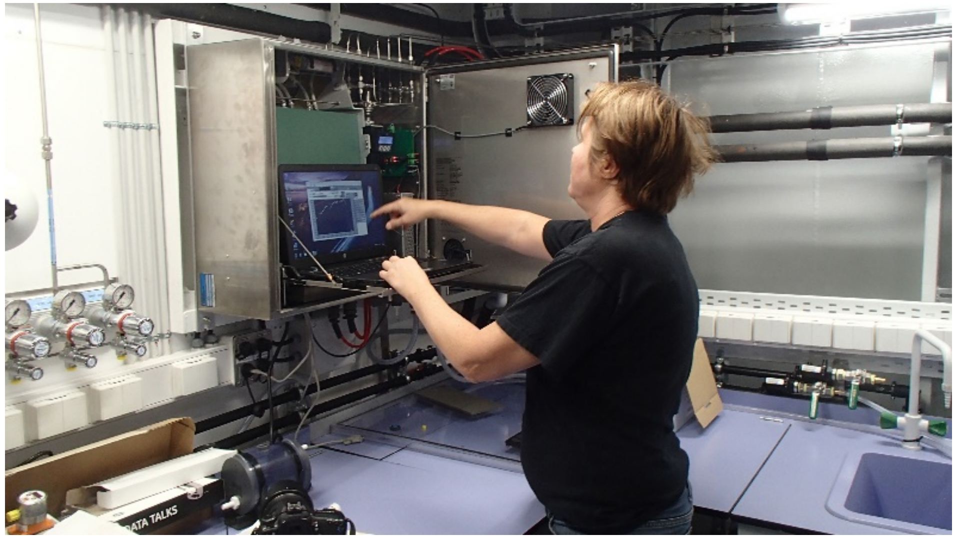



Ogundare, Fransson et al., in review

# Lab work onboard RV Kronprins Haakon

Chemical analyses of carbonate chemistry: pH, dissolved inorganic carbon (DIC), total alkalinity (AT) and dissolved oxygen in Drylab

Continuous $pCO_2$ oxygen, fluorescence measurements from KpH water intake in clean water lab





Photos: A. Fransson NPI/M. Chierici IMR

# Water sampling

- Underway surface-water sampling
- Water column sampling using Niskin bottles on rosette with CTD (salinty, temperature, depth)

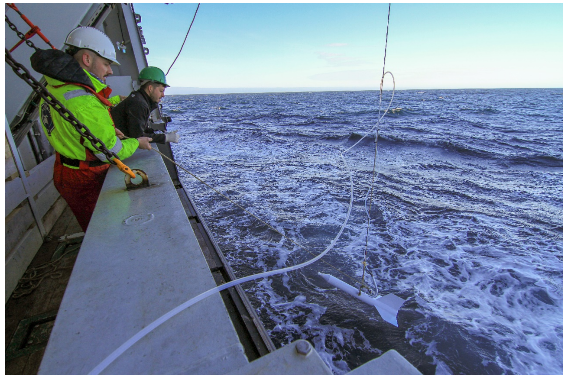


Photo: A. Fransson, NPI

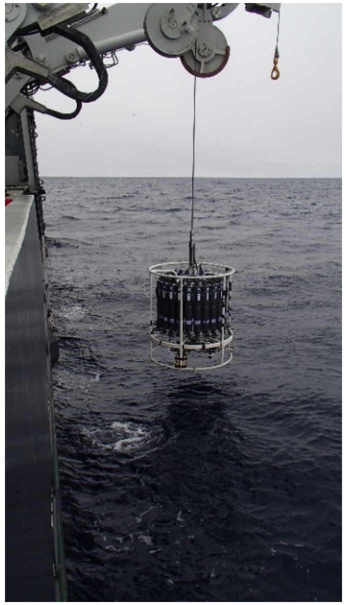


Photo: R. Caeyers, UiT

Photo: A. Fransson, NPI

# Summary

- Surface water *f*$CO_2$ is mostly lower than the atmospheric value (about 405 µatm) throughout the Kong Håkons VII Hav in autumn.
- Largest ocean $CO_2$ sink at about 66-68 °S in the seasonal ice zone, and not a $CO_2$ source as suggested by the climatology.
- Explanations: previous or ongoing primary production, and also due to colder and fresher surface water.
- $CO_2$ source in WS at about 60°S likely due to upwelling
- Results show the importance of observations in autumn/winter, effect of climate change

# Data workshop at Fram Centre in Tromsø, 2019

# Thanks for the attention!

SOPHY-CO2

Photo: Robin Hjertenes, IMR Kronprins Haakon