Role of the Southern Ocean in the Earth System

A NERC funded programme

RoSES

www.RoSES.ac.uk @RoSES_ocean

Dr. Elaina Ford
British Antarctic Survey, Natural Environment Research Council,
- UK Research and Innovation

NERC SCIENCE OF THE ENVIRONMENT | UK Research and Innovation

The Role of the Southern Ocean in the Earth System – RoSES – is a programme funded by the UK's Natural Environment Research Council (NERC) through UK Research and Innovation (UKRI) and aims to substantially reduce uncertainty in 21st century global climate change projections through improved assessment of the Southern Ocean carbon sink. It is a five-year programme, funded from 2017 to 2022.

RoSES (Twitter: @RoSES_ocean, website www.roses.ac.uk) currently consists of three projects, below. A fourth will be funded in due course on: Developing key policy-informing metrics of the integrated efficiency of the SO carbon sink and its role in 21st-century global climate change.

Here we present the aims and objectives of these three projects, and their links to the ORCHESTRA programme – "Ocean Regulation of Climate by Heat and Carbon Sequestration and Transports". ORCHESTRA and RoSES are coordinated centrally by the British Antarctic Survey, they meet together annually have a common Programme Advisory Board.

CUSTARD

Carbon Uptake and Seasonal Traits in Antarctic Remineralisation Depth

Principal Investigator: Dr Adrian Martin, National Oceanography Centre

Team: Stephanie Henson, Richard Sanders, Sari Giering, Geraldine Clinton-Bailey, Alex Beaton, Peter Brown, Andrew Yool (NOC), Mark Moore, Tom Bibby (U. Southampton), Dorothee Bakker (UEA), Heather Bouman (U. Oxford), Simon Ussher, Angie Milne (U. Plymouth), Hugh Venables (BAS), Peter Landschützer (MPI, Hamburg) + *postdocs and students to be recruited*

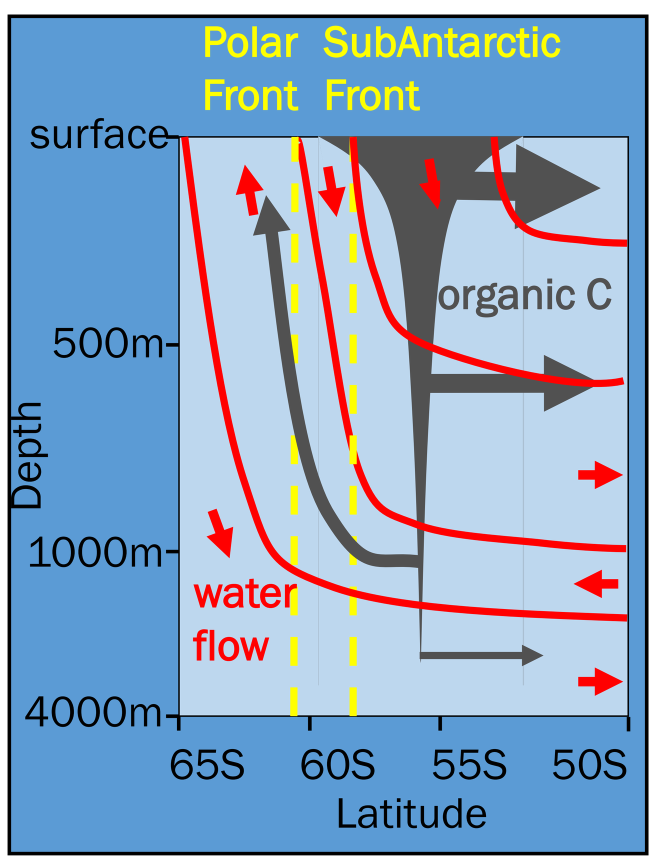
#RoSES_CUSTARD

Aims

The upwelling of water within the Antarctic Circumpolar Current (ACC) represents a boundary between two 'limbs' of circulation in the Southern Ocean (SO). The upper limb comprises the northward transport of upwelled waters before the waters subduct between the Polar and Sub-Antarctic Fronts. This upper limb is a key junction in the marine carbon cycle. First, carbon dioxide (CO_2) in the cold upwelled waters is released to the atmosphere as the water is warmed, and solubility reduces. Second, interplay between remineralisation and the circulation means that the fate of carbon fixed by the surface phytoplankton will differ according to how deep it penetrates before being remineralised; shallow remineralisation leads to carbon exiting the S. Ocean in the upper limb, likely upwelling further north within decades. Conversely deep remineralisation results in carbon entering the lower limb with the potential for it being retained in the ocean for hundreds of years. The depth of remineralisation is affected by seasonality; in plankton production (the spring bloom) but also in biogeochemically-controlled physiology and community.

We hypothesise that the seasonal interplay of upper limb surface biogeochemistry, circulation and remineralisation controls how long carbon entering the ocean is kept out of the atmosphere.

To test this, CUSTARD will simultaneously observe the air-sea CO_2 flux, and resolve the biogeochemical influences on phytoplankton ecophysiology and the attenuation of the sinking organic carbon flux throughout the year in the remote Southern Ocean, while having the ability to track the subsequent fate of carbon under different scenarios of remineralisation.



Objectives

- Determine the seasonal air-sea flux and macronutrient drawdown
- Quantify the link between iron, silicate and remineralisation depth
- Observationally determine the seasonal cycle in remineralisation depth
- Examine the link between seasonality in remineralisation depth and the trajectory of carbon from the surface out of the upper limb

Figure showing potential segregation of organic carbon across water masses entering/leaving the Southern Ocean

PICCOLO

Processes Influencing Carbon Cycling: Observations of the Lower limb of the Antarctic Overturning

Principal Investigator: Prof Karen Heywood, UEA University of East Anglia

Co-PI: Tom Bell, PML Plymouth Marine Laboratory

Team: Dorothee Bakker, Carol Robinson, Rob Hall (UEA), Mingxi Yang, Giorgio Dall'Olmo, Angus Atkinson (PML), Simon Ussher (U. Plymouth), Mike Fedak, Lars Boehme (St Andrews), (Will Homoky) Oxford, Clara Manno, Keith Nicolls (BAS) + *postdocs and students to be recruited.*

#RoSES_PICCOLO

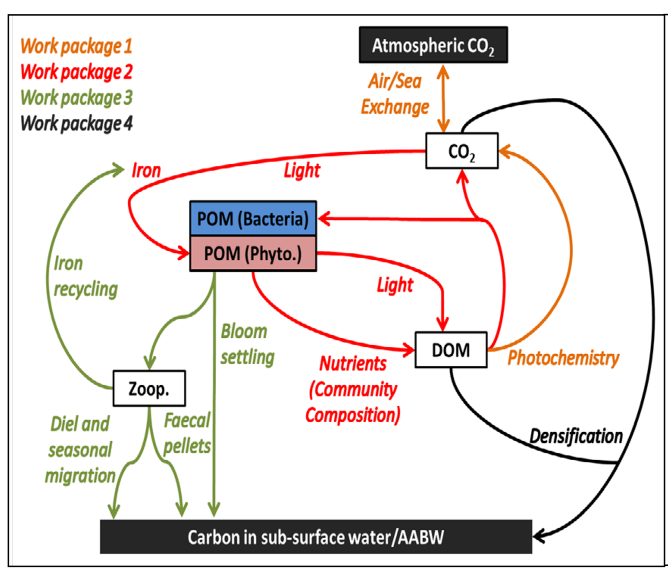
Aims

Our deficient understanding of Southern Ocean carbon uptake means that projections of future climate change are hindered. This is because net carbon uptake is determined by poorly-understood biogeochemical and biological processes in the lower limb of Antarctic overturning circulation. PICCOLO is an ambitious multi-disciplinary project that will make ground-breaking over-winter observations and use cutting-edge autonomous technologies to elucidate these processes. Multi-season observations in the deep Weddell Gyre, on the continental shelf and under sea ice will quantify rates of carbon uptake, transformation and export as water interacts with the atmosphere, cryosphere and biosphere and then sinks off the shelf into the abyss. PICCOLO will provide a comprehensive understanding of lower limb carbon processes, and will provide the key biogeochemical information needed to improve future Earth System models.

PICCOLO deliberately focuses on the biological and biogeochemical processes that ORCHESTRA cannot study, targeting the seasons and regions of water mass transformation that the summertime ORCHESTRA sections will simply enclose. Key unknowns in ice-covered regions include physical controls on air/sea/ice gas transfer and how seawater CO_2 is regulated by biological processes, photochemical reactions and changing salinity. We have very limited understanding of the relative importance and control that iron, light, sea ice and grazers have upon biological carbon dioxide uptake and export in the Weddell Sea.

Objectives

(i) Obtain first-of-a-kind, systematic, year-round measurements of the processes controlling the rate of carbon uptake in the lower limb of the Southern Ocean overturning circulation;
(ii) Use these observations to define the key processes that must be correctly characterised in models of the SO carbon system, quantify their contribution to the system's efficiency, and assess how models must represent their mechanistic operation.



PICCOLO work packages and carbon-relevant processes that determine CO_2 uptake efficiency in surface waters:
i) primary production (CO_2 uptake into phytoplankton particulate organic matter, POM);
ii) organic matter transformations into dissolved organic matter (DOM), bacterial POM and CO_2;
iii) POM and DOM removal. Organic forms of carbon may be cycled through grazers, repackaging and modulating nutrient export and recycling. Nutrients, light and sea ice control these processes.

SONATA

Southern OceaN optimal Approach To Assess the carbon state, variability and climatic drivers

Principal Investigator: Prof. Corrine Le Quere UEA University of East Anglia

Team: Parv Suntharalingam, Andrew Manning (UEA), Andy Watson, Ute Schuster (U. Exeter), Anna Jones, Neil Brough, Emily Shuckburgh (BAS), Pete Brown, Elaine McDonagh, Brian King (NOC). + *postdocs and students to be recruited.*

#RoSES_SONATA

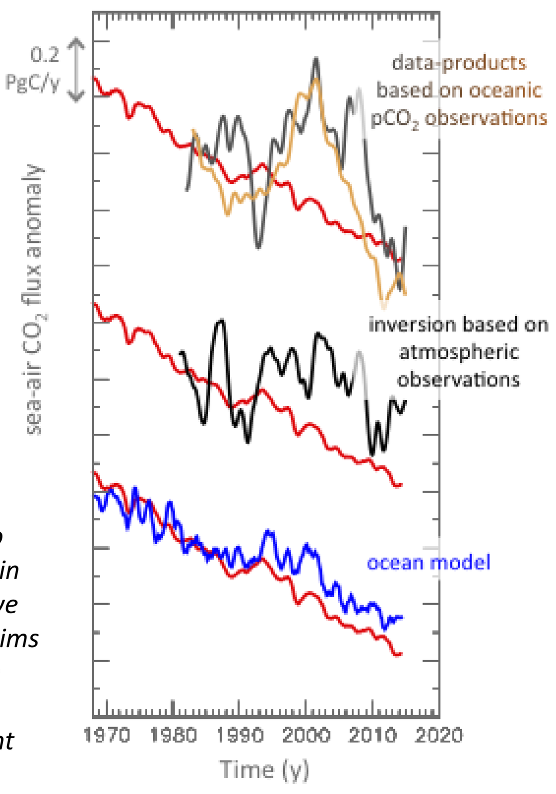
Aims

SONATA is a synthesis and analysis project that builds on the integration of information from oceanic measurements, atmospheric measurements, and model simulations.

The overriding objectives of SONATA are to design and implement an optimal approach to assess the state, variability and climatic drivers of the contemporary SO carbon sink, and establish a legacy strategy to track the SO carbon sink in the future.

Objectives

- Determine the mean state and seasonality of the Southern Ocean carbon sink: provide a calibration to pH-based estimates from float data, and to use historical and new hydrographic data of interior dissolved inorganic carbon (DIC) and total alkalinity (TA) to reconstruct wintertime surface fCO_2 concentrations.
- Determine the geographical distribution of the Southern Ocean carbon sink: This will be done by putting together a new, dense, 3-dimensional (3-D) database of atmospheric CO_2 concentrations. This database will then be used in an atmospheric inversion framework to quantify the geographical distribution, particularly regarding the differences in SO carbon fluxes associated with the upper and lower limbs.
- Identify the trends and climatic drivers of the Southern Ocean carbon sink: combining analysis using existing and new oceanic and atmospheric data-based estimates, with expected fingerprints of climatic drivers from a series of new hindcast ocean model simulations developed specifically to reproduce the effects of observed variability in underlying processes and drivers.
- Design and implement a strategy to monitor the Southern Ocean carbon sink by integrating existing and new data-products and model simulations, and design an optimal sampling strategy to reduce remaining uncertainties.



At present, different methods to assess the trend and variability in the Southern Ocean CO_2 sink give very different results. SONATA aims to understand and reduce these differences, and provide an integrated assessment of current knowledge.

ORCHESTRA

OCEAN • CLIMATE • CARBON

Ocean Regulation of Climate by Heat and Carbon Sequestration and Transports

Principle Investigator: Dr. Emily Shuckburgh, British Antarctic Survey
@ORCHESTRAproj
www.bas.ac.uk/projects/orchestra

ORCHESTRA is a multi-institute collaboration between the British Antarctic Survey, National Oceanography Centre, British Geological Survey, Plymouth Marine Laboratory, Centre for Polar Observation and Modelling, Sea Mammal Research Unit at the University of St Andrews and the UK Met Office, along with numerous national and international partners.

It is a five-year programme that complements the RoSES projects and aims to advance our understanding of, and capability to predict, the Southern Ocean's impact on climate change via its uptake and storage of heat and carbon. It is making new measurements in the Southern Ocean using a range of techniques, as well as deployments of autonomous surface and underwater vehicles, meteorological aircraft, and other innovative techniques for collecting data. It is also developing and using advanced ocean and climate simulations to improve our ability to predict climate change in coming decades.