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

Update on the evolution of the Southern Ocean CO_2 sink viewed from models

Team:

UEA: Modelling: Corinne Le Quéré, Erik Buitenhuis, Anthony De-Gol, Becci Wright
Data/inversions: Parv Suntharalingam, Andrew Manning, Zhaohui Chen, Penelope Pickers

U. Exeter: Andy Watson, Ute Schuster, Neill Mackay, Aimee Coggins

BAS: Anna Jones, Neil Brough, Emily Shuckburgh (Elaina Ford, Nina Fox)

NOC: Pete Brown, Elaine McDonagh, Brian King

Project partners:

UKESM: Colin Jones

GCP: Pep Canadell

International Advisory Board:

MPI: Christian Rödenbeck

AWI: Judith Hauck

NOAA/AOML: RiK Wanninkhof (link to SOCCOM)

Objectives of SONATA are to determine:

- the mean state and seasonality
- the geographical distribution
- the trends and climatic drivers
- and propose a strategy to monitor

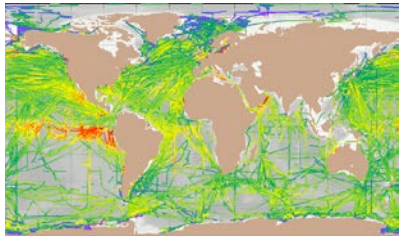
the Southern Ocean carbon sink

Workpackages overview:

WPI view from the ocean

data-products based on oceanic pCO_2 observations

ocean fCO_2 data



The reinvigoration of the Southern Ocean carbon sink

Peter Landschützer,[1*] Nicolas Gruber,[1,2] F. Alexander Haumann,[1,2] Christian Rödenbeck,[3] Dorothee C. E. Bakker,[4] Steven van Heuven,[5†] Mario Hoppema,[3] Nicolas Metzl,[6] Colm Sweeney,[7,8] Taro Takahashi,[9] Bronte Tilbrook,[10] Rik Wanninkhof[11]

WPII view from the atmosphere

inversion based on atmospheric observations

atmospheric CO_2 data

Saturation of the Southern Ocean CO_2 Sink Due to Recent Climate Change

Corinne Le Quéré,[1,2,3*] Christian Rödenbeck,[1] Erik T. Buitenhuis,[1,2] Thomas J. Conway,[4] Ray Langenfelds,[5] Antony Gomez,[6] Casper Labuschagne,[7] Michel Ramonet,[8] Takakiyo Nakazawa,[9] Nicolas Metzl,[10] Nathan Gillett,[11] Martin Heimann[1]

WPIII processes and drivers of change

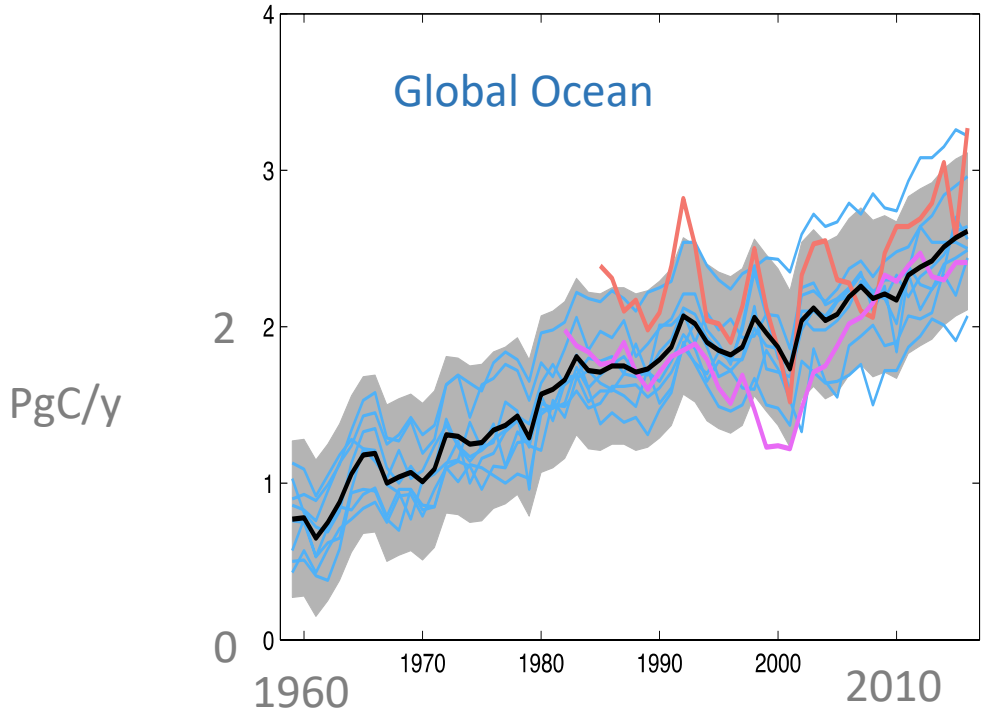
ocean models

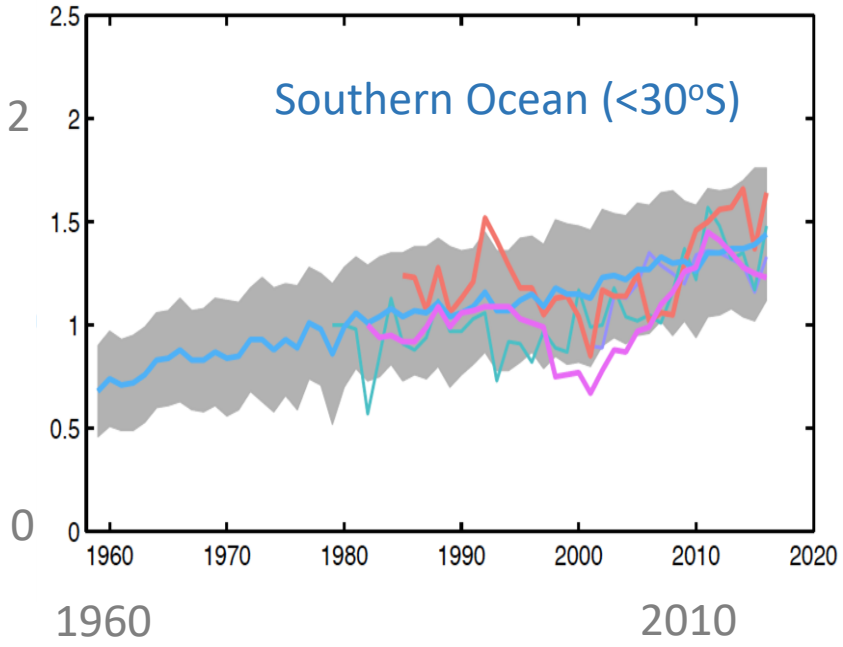
WPIV integration

Monitoring & OSSES

Comparison of models and SOCAT-based flux products used in the Global Carbon Budget

➔ models have skills for the global ocean
➔ models show very little variability in the Southern Ocean
➔ flux products have uncertainties and could too variable (less likely)





SOCAT-based flux products from Rödenbeck and from Landschutzer

7 Global Ocean Biogeochemistry models, resolution of ~2 degrees

Global Carbon Budget 2017
Le Quéré et al. ESSD 2018

Models: CCSM-BEC | CSIRO | MITgem-REcoM2 | MICOM-HAMMOC | NEMO-PISCES (CNRM)| NEMO-PlankTOM5 | NorESM-OC; pCO_2-based products from C. Rödenbeck and P. Landschützer with SOCATv5

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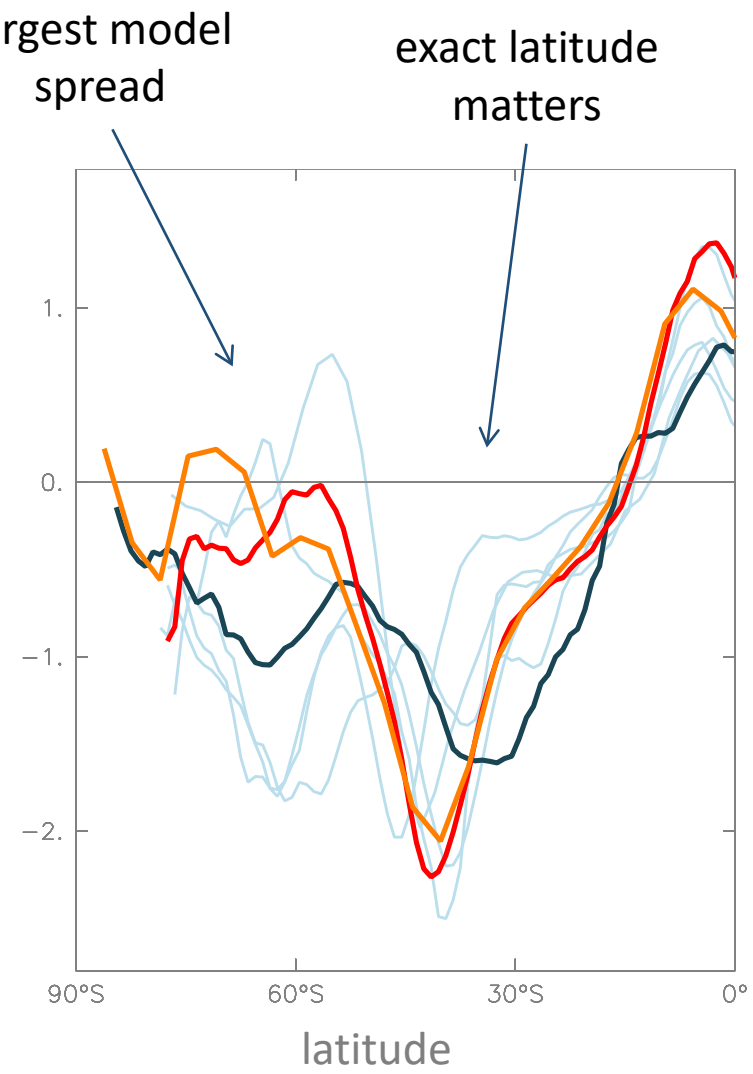
latitudinal spread in the Southern Ocean CO_2 sink



Ocean CO_2 sink <30°S for last decade

SOCCOM estimate of 0.1 PgC/yr

1 PgC/yr

SOCAT-based flux products from Rödenbeck and from Landschutzer

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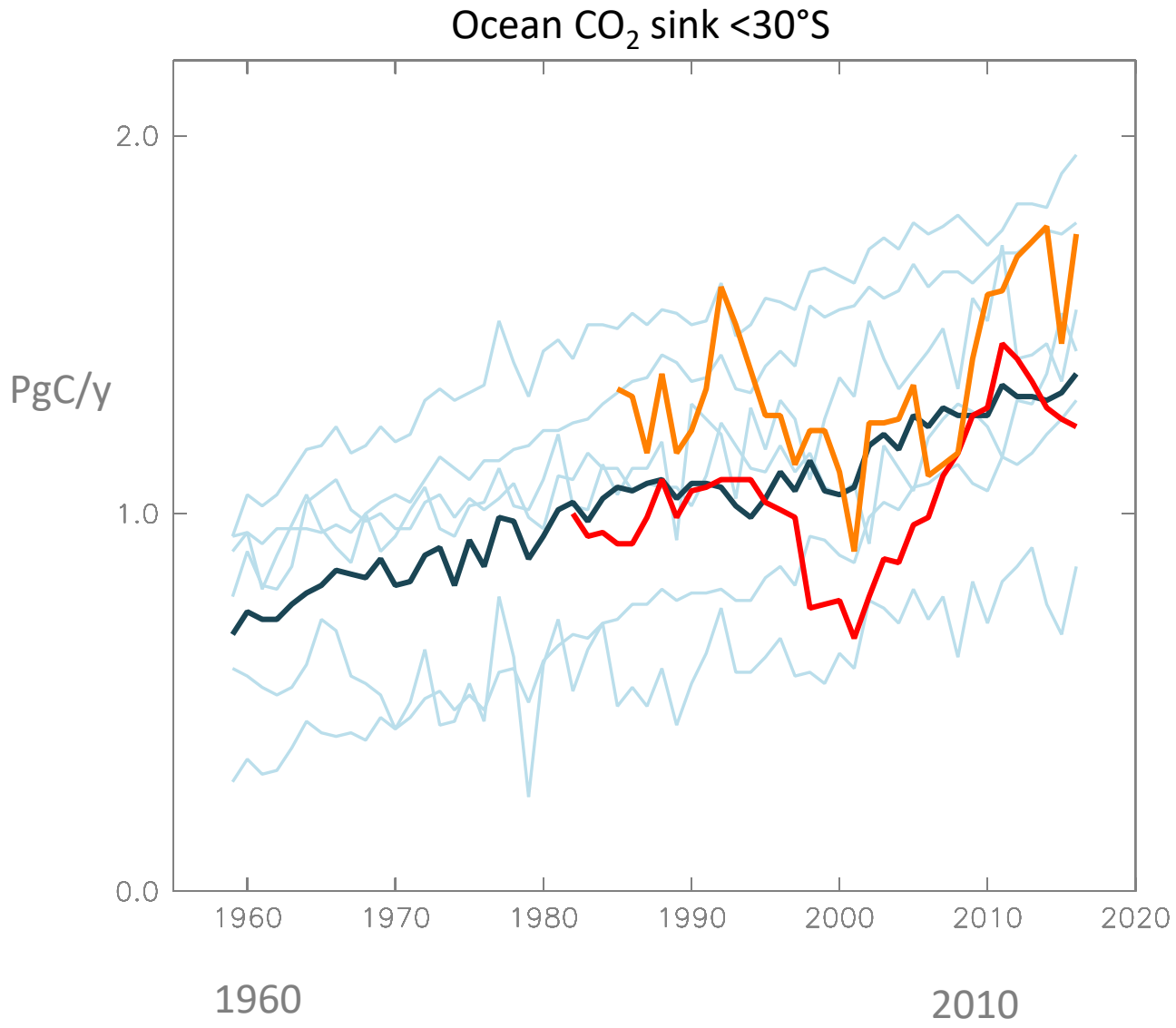
decomposition of drivers using models



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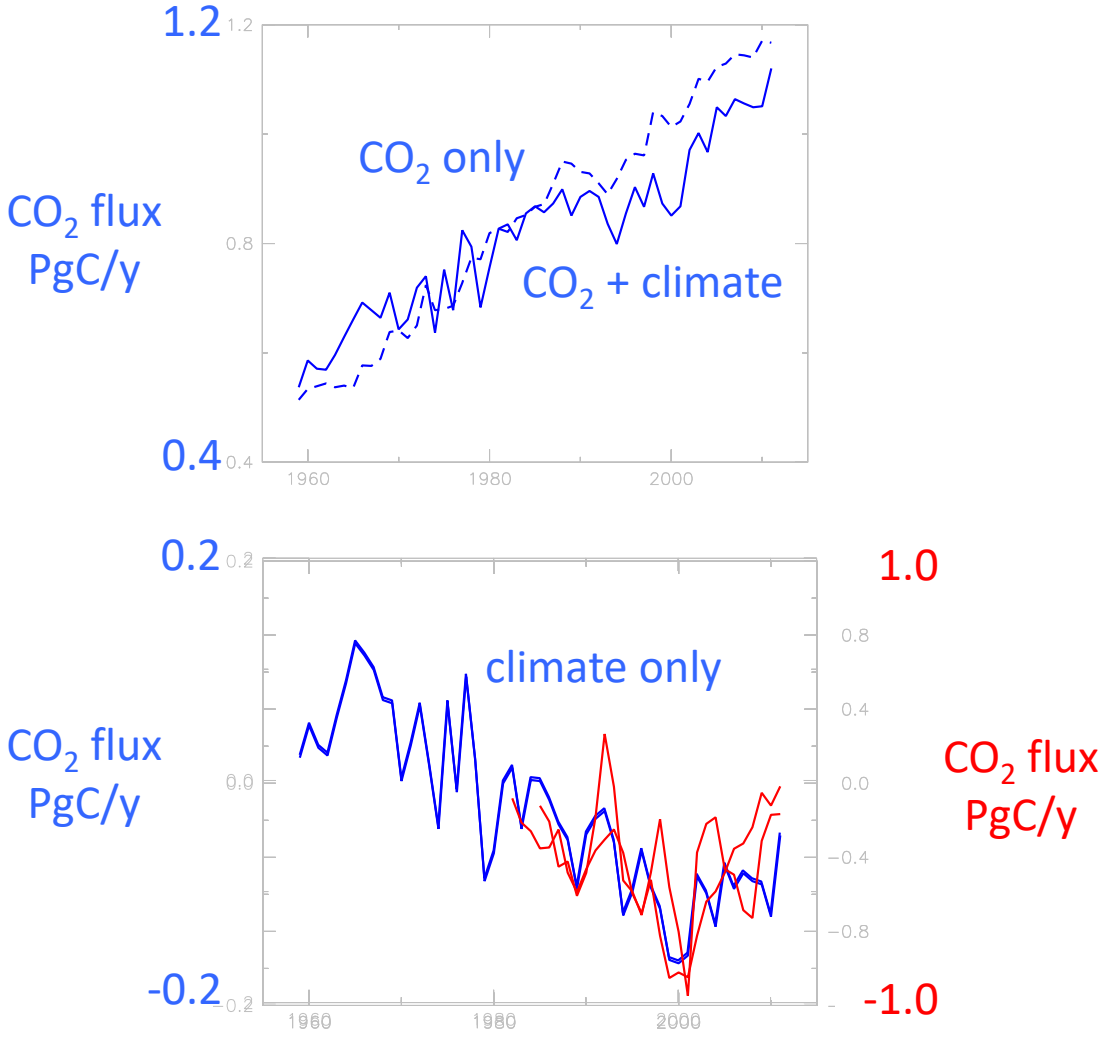


To decompose the drivers we did model simulations forced with:

- rising CO_2 only
- rising CO_2 and climate change and variability

There is a marked reduction in CO_2 sink caused by climate change and variability in the model simulations

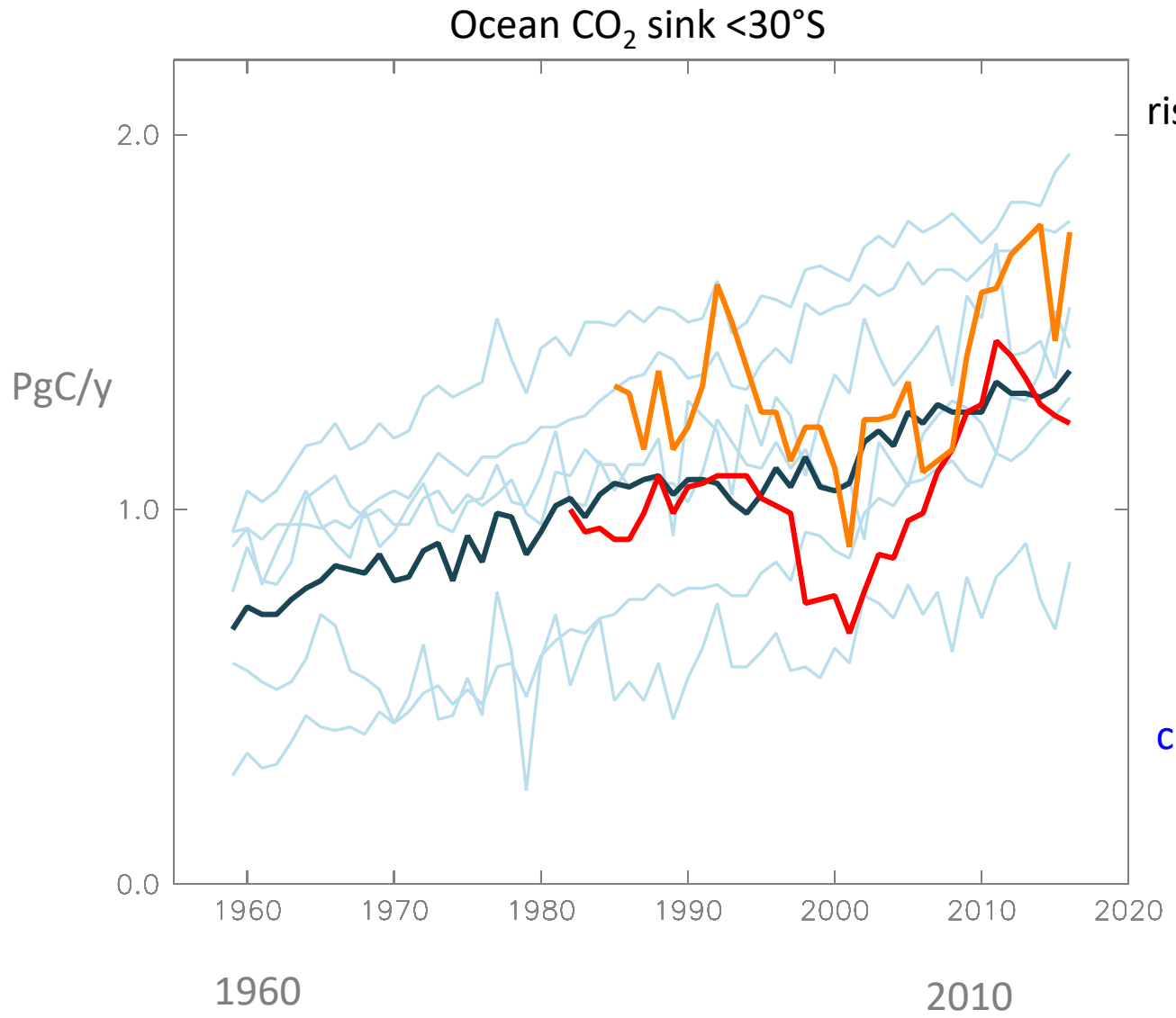
The effects of climate variability on the CO_2 sink are similar to that of the flux products

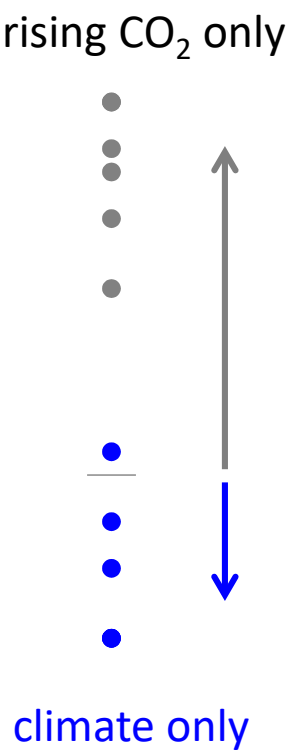
➔ the amplitude is 5 times too small

Models: NEMO-PlankTOM5

pCO_2-based products from C. Rödenbeck and P. Landschützer with SOCATv5

decomposition of drivers using models





average offset of CO_2 sink due to climate change and variability (models):

- 40% last 56 years
- 10% last 30 years

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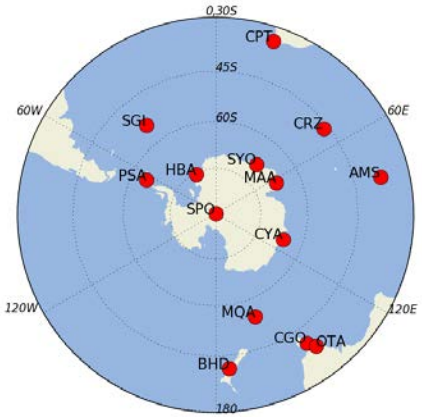
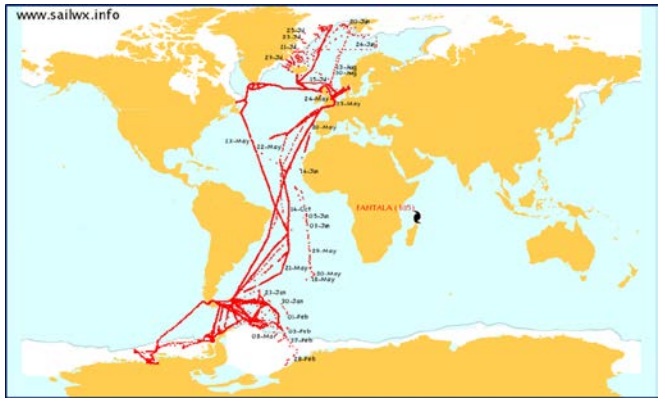
use of existing and new atmospheric CO_2 data
see posters by Chen et al and Jones et al

Big questions to be answered:

- What is the real variability in the SO?
- Why are models so much more rigid than the flux products?
- Is the outgas of natural CO_2 about to resume?

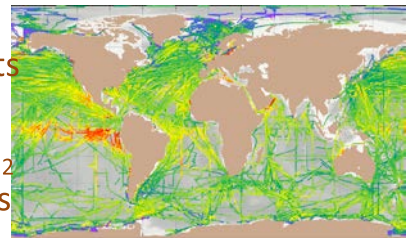




WPI view from the ocean

ocean fCO_2 data

data-products based on oceanic pCO_2 observations



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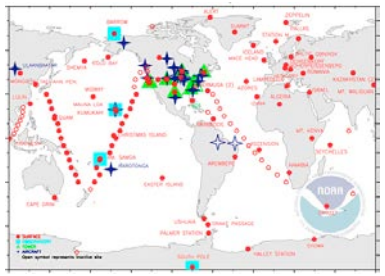

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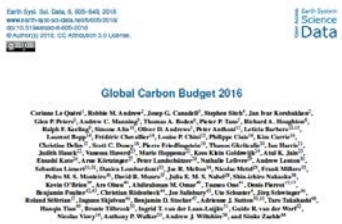
WPIII processes and drivers of change



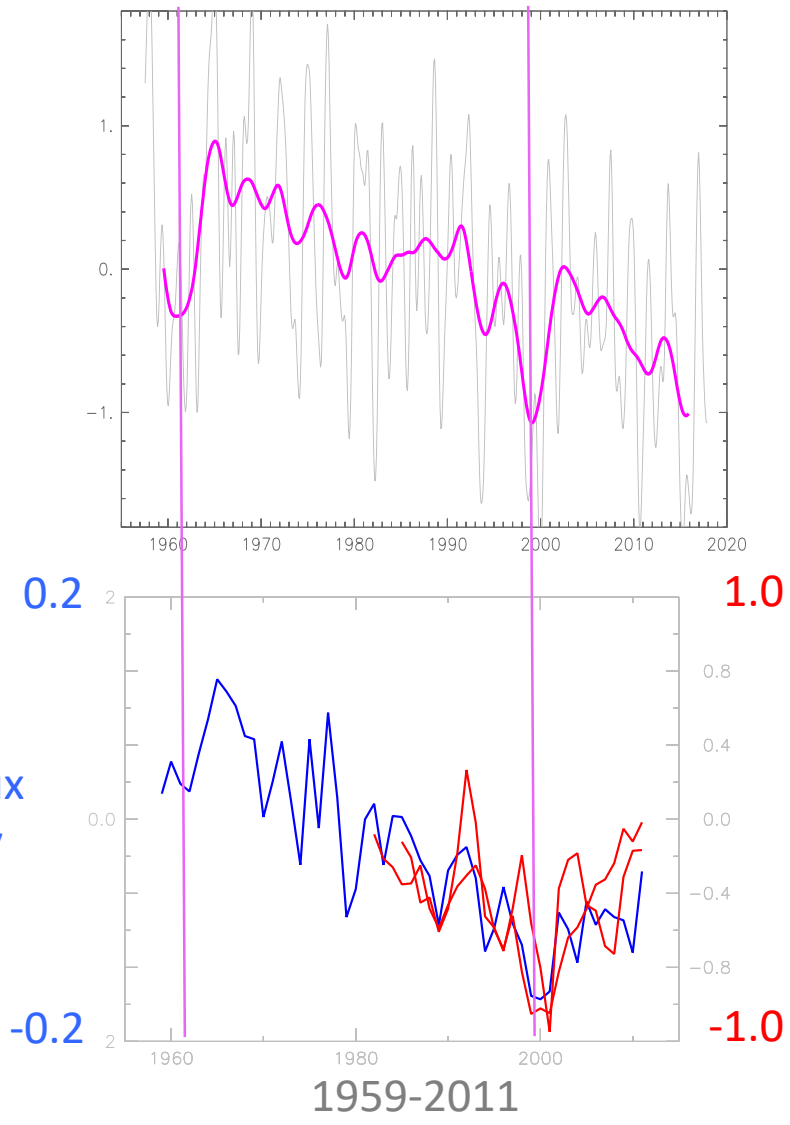
ocean models

WPIV integration

Monitoring & OSSES

University of East Anglia
University of Exeter
British Antarctic Survey
National Oceanography Centre
Natural Environment Research Council
NERC
SONATA

Insights from the Southern Annular Mode (SAM)



SAM (G. Marshall Index; 5-year smooth, inverted)

NEMO-PlankTOM

CO_2 flux PgC/y

CO_2 flux PgC/y

2 pCO_2-based flux products using SOCATv5

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Objectives of SONATA:

- Determine the mean state and seasonality of the Southern Ocean carbon sink
- Determine the geographical distribution of the Southern Ocean carbon sink
- Identify the trends and climatic drivers of the Southern Ocean carbon sink
- Design and implement a strategy to monitor the Southern Ocean carbon sink
- Design an optimal sampling strategy to reduce remaining uncertainties and constrain the evolution of the Southern Ocean carbon sink in the future

WPI view from the ocean

WPIa New calibrations of pH from biogeochemistry floats.

- deploy the ORCHESTRA floats with oxygen and pH sensors simultaneously
- collect calibration information (DIC and TA) over a region that follows the floats over a period of 30 day

WPIb New estimates of seasonal (especially wintertime) fluxes from existing data.

- construct new estimates of wintertime MLD, and estimate expected wintertime DIC & TA, adjusted for loss of carbon due to seasonal production and MLD dynamics.

WPII view from the atmosphere

WPIIa Atmospheric observations

- new in situ CO_2 observational programme in remote locations
- data mining of CO_2 measurements
- data in support of process analysis (APO)

WPIIb Atmospheric inverse analysis

- with GEOS-Chem incl sensitivity and uncertainty

WPIII processes and drivers of change

WPIIIa New hindcast simulations with global NEMO-PlankTOM model

- coarse resolution optimised for Southern Ocean CO_2 variability
- eddy-permitting resolution (G06)
- contribution to OMIP
- model analysis, including OMIP and GCP models

WPIIb Fingerprint analysis

- simulations with and without climate change and ozone change
- check for patterns of change and/or variability in vertical and horizontal gradients in space and time

WPIV integration

WPIVa Monitoring of the state of the Southern Ocean

- bayesian approach using all estimates and their uncertainties
- annual updates with the Global Carbon Budget

WPIIb Optimal strategy to keep track of the Southern Ocean sink

- oceanic OSSEs
- atmospheric OSSEs