Global observational synthesis to constrain recent changes in the ocean carbon uptake

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A Lenton, R J Matear, T J O'Kane, M Chamberlain, T Ziehn, R M Law

Motivation – Models and Obs

Earth Syst. Sci. Data, 8, 605–649, 2016
www.earth-syst-sci-data.net/8/605/2016/
doi:10.5194/essd-8-605-2016

Open Access Earth System Science Data

Global Carbon Budget 2016

Corinne Le Quéré[1], Robbie M. Andrew[2], Josep G. Canadell[3], Stephen Sitch[4], Jan Ivar Korsbakken[2], Glen P. Peters[2], Andrew C. Manning[5], Thomas A. Boden[6], Pieter P. Tans[7], Richard A. Houghton[8], Ralph F. Keeling[9], Simone Alin[10], Oliver D. Andrews[1], Peter Anthoni[11], Leticia Barbero[12,13], Laurent Bopp[14], Frédéric Chevallier[14], Louise P. Chini[15], Philippe Ciais[14], Kim Currie[16], Christine Delire[17], Scott C. Doney[18], Pierre Friedlingstein[19], Thanos Gkritzalis[20], Ian Harris[21], Judith Hauck[22], Vanessa Haverd[23], Mario Hoppema[22], Kees Klein Goldewijk[24], Atul K. Jain[25], Etsushi Kato[26], Arne Körtzinger[27], Peter Landschützer[28], Nathalie Lefèvre[29], Andrew Lenton[30], Sebastian Lienert[31,32], Danica Lombardozzi[33], Joe R. Melton[34], Nicolas Metzl[29], Frank Millero[35], Pedro M. S. Monteiro[36], David R. Munro[37], Julia E. M. S. Nabel[28], Shin-ichiro Nakaoka[38], Kevin O'Brien[39], Are Olsen[40], Abdirahman M. Omar[40], Tsuneo Ono[41], Denis Pierrot[12,13], Benjamin Poulter[42,43], Christian Rödenbeck[44], Joe Salisbury[45], Ute Schuster[4], Jörg Schwinger[46], Roland Séférian[17], Ingunn Skjelvan[46], Benjamin D. [illegible], Hanqin Tian[49], Bronte Tilbrook[50], Ingrid T. v[illegible], Nicolas Vioyy[14], Anthony P. Walker[53]

Recent variability of the global ocean carbon sink

P. Landschützer[1,2], N. Gruber[1], D. C. E. Bakker[2], and U. Schuster[3]

[1]Institute of Biogeochemistry and Pollutant Dynamics, ETH Zürich, Zürich, Switzerland, [2]Centre for Ocean and Atmospheric Sciences, School of Environmental Sciences, University of East Anglia, Norwich, UK, [3]College of Life and Environmental Sciences, Hatherly Laboratories, University of Exeter, Exeter, UK

SOCAT · SURFACE OCEAN CO_2 ATLAS ·

Dorothee's excellent SOCAT talk

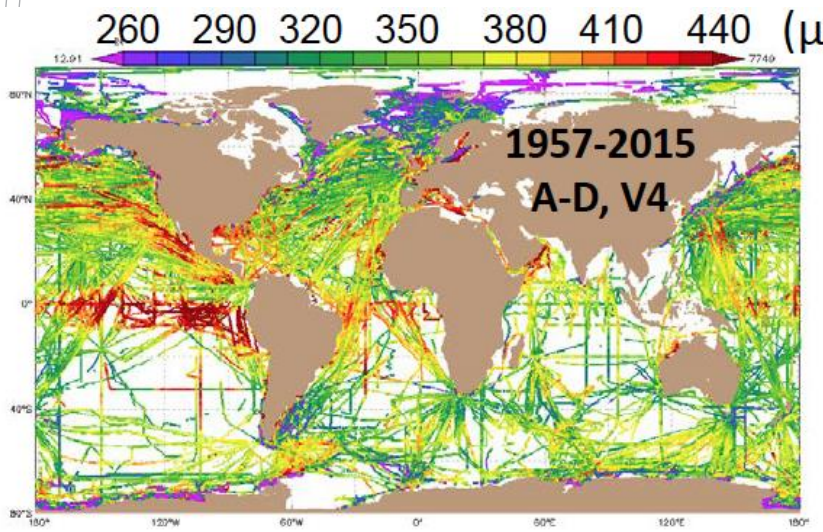
ACE CRC

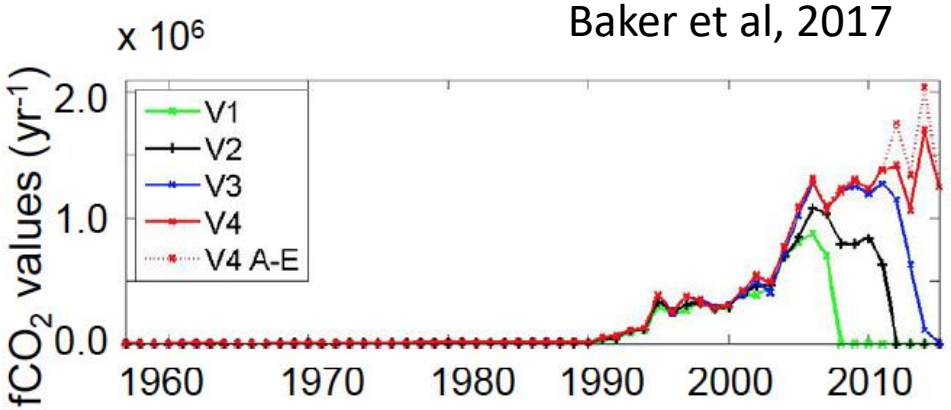
CSIRO

Motivation –Models or Obs?

- However, the limited observations of the ocean carbon cycle necessitate some degree of interpolation and/or large-scale spatial and temporal averaging.

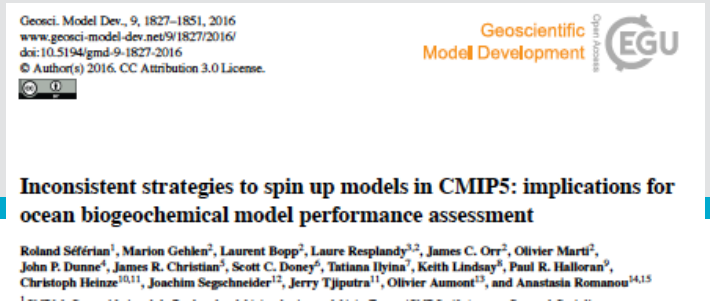
- This has the potential either to bias or alias the results toward a dynamically inconsistent ocean state thereby making understanding the drivers of these changes challenging.





Baker et al, 2017

Motivation – Models or Obs?



Geosci. Model Dev., 9, 1827–1851, 2016
www.geosci-model-dev.net/9/1827/2016/
doi:10.5194/gmd-9-1827-2016

Geoscientific Model Development

Inconsistent strategies to spin up models in CMIP5: implications for ocean biogeochemical model performance assessment

Roland Séférian[1], Marion Gehlen[2], Laurent Bopp[2], Laure Resplandy[3,2], James C. Orr[2], Olivier Marti[2], John P. Dunne[4], James R. Christian[5], Scott C. Doney[6], Tatiana Ilyina[7], Keith Lindsay[8], Paul R. Halloran[9], Christoph Heinze[10,11], Joachim Segschneider[12], Jerry Tjiputra[11], Olivier Aumont[13], and Anastasia Romanou[14,15]

Models have issues also - often large biases and unphysical states

To answer this question we better global state estimates that allow us to really understanding the processes

This allows us to understand the processes and mechanisms

Can we the use the increasing observations?

Physics drives changes?

LETTER

doi:10.1038/nature21068

Recent increase in oceanic carbon uptake driven by weaker upper-ocean overturning

Tim DeVries[1,2], Mark Holzer[3,4] & Francois Primeau[5]

NEWS & VIEWS RESEARCH

CLIMATE SCIENCE

Ocean circulation drove increase in CO_2 uptake

The ocean's uptake of carbon dioxide increased during the 2000s. Models reveal that this was driven primarily by weak circulation in the upper ocean, solving a mystery of ocean science. SEE LETTER P.215

Physics drives changes?

LETTER

doi:10.1038/nature21068

Recent increase in oceanic carbon uptake driven by weak

Tim DeVries[1]

Is getting getting a better representation of the physics or ocean state the key to bringing models and observations together?

ARCH

Ocean circulation drove increase in CO_2 uptake

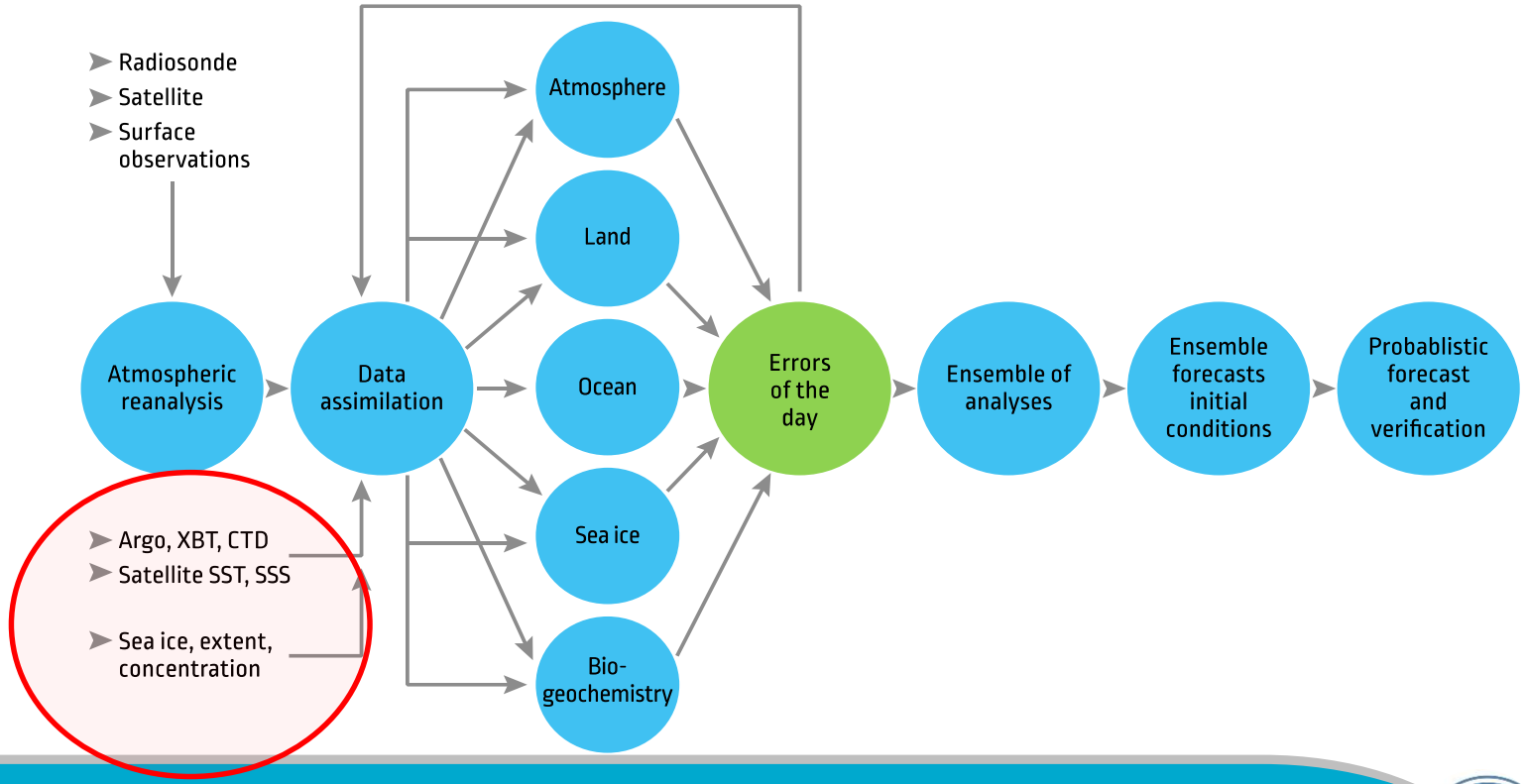
The ocean's uptake of carbon dioxide increased during the 2000s. Models reveal that this was driven primarily by weak circulation in the upper ocean, solving a mystery of ocean science. SEE LETTER P.215

Goal:

CLIMATE ANALYSIS FORECAST ENSEMBLE system

Simulate the response of the ocean carbon cycle in a framework dynamically consistent with the physical changes

Coupled Data Assimilation - > Forecasts



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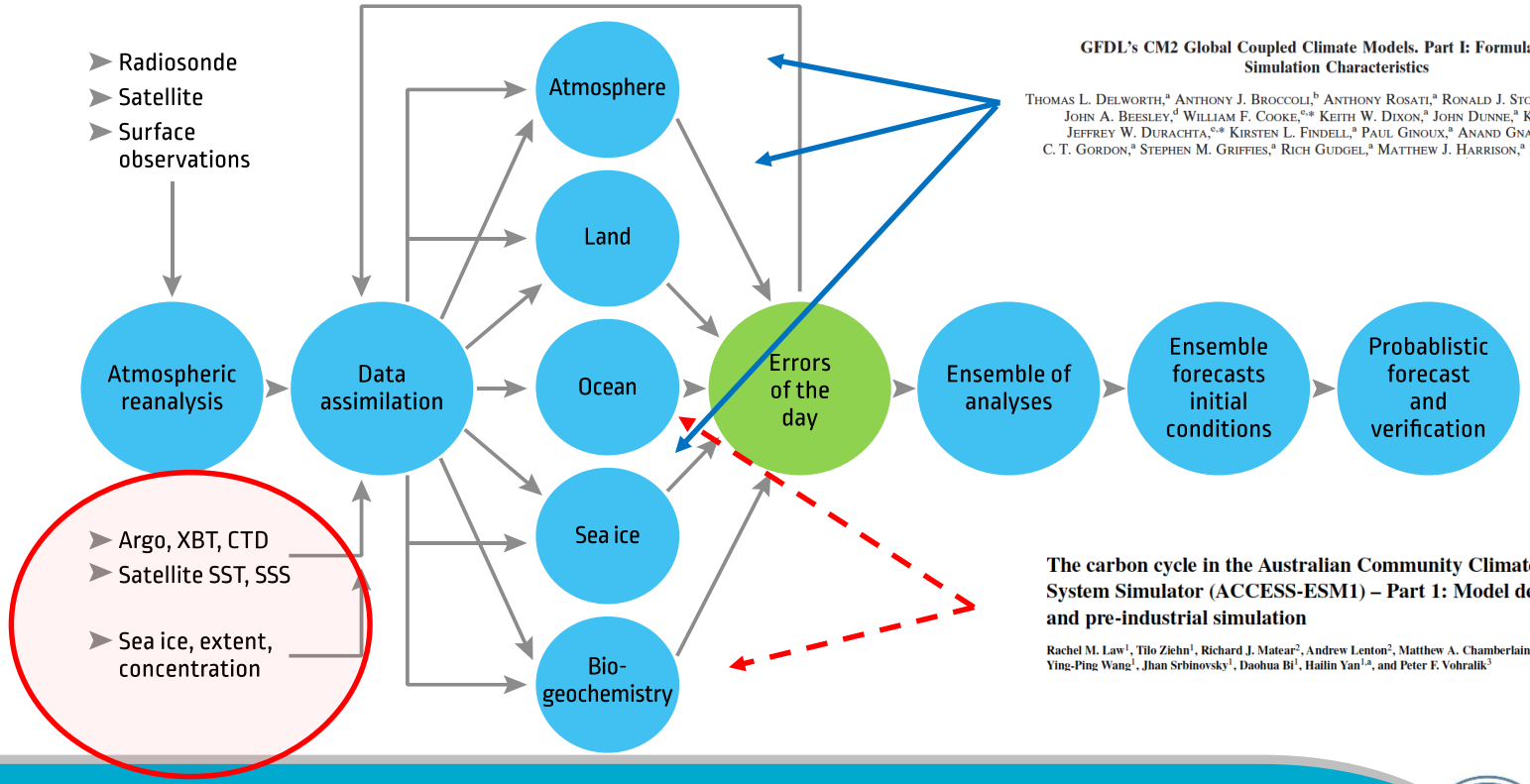


GFDL's CM2 Global Coupled Climate Models. Part I: Formulation and Simulation Characteristics

Thomas L. Delworth,[a] Anthony J. Broccoli,[b] Anthony Rosati,[a] Ronald J. Stouffer,[a] V. Balaji,[c] John A. Beesley,[d] William F. Cooke,[e,*] Keith W. Dixon,[a] John Dunne,[a] K. A. Dunne,[f] Jeffrey W. Durachta,[e,*] Kirsten L. Findell,[a] Paul Ginoux,[a] Anand Gnanadesikan,[a] C. T. Gordon,[a] Stephen M. Griffies,[a] Rich Gudgel,[a] Matthew J. Harrison,[a] Isaac M. Held,[a]

The carbon cycle in the Australian Community Climate and Earth System Simulator (ACCESS-ESM1) – Part 1: Model description and pre-industrial simulation

Rachel M. Law[1], Tilo Ziehn[1], Richard J. Matear[2], Andrew Lenton[2], Matthew A. Chamberlain[2], Lauren E. Stevens[1], Ying-Ping Wang[1], Jhan Srbinovsky[1], Daohua Bi[1], Hailin Yan[1,a], and Peter F. Vohralik[3]

Simulations

Physical Coupled Model spun up for 1000+ years

-> used to build covariance matrices

Physical assimilation to remove model biases 2002 -2016

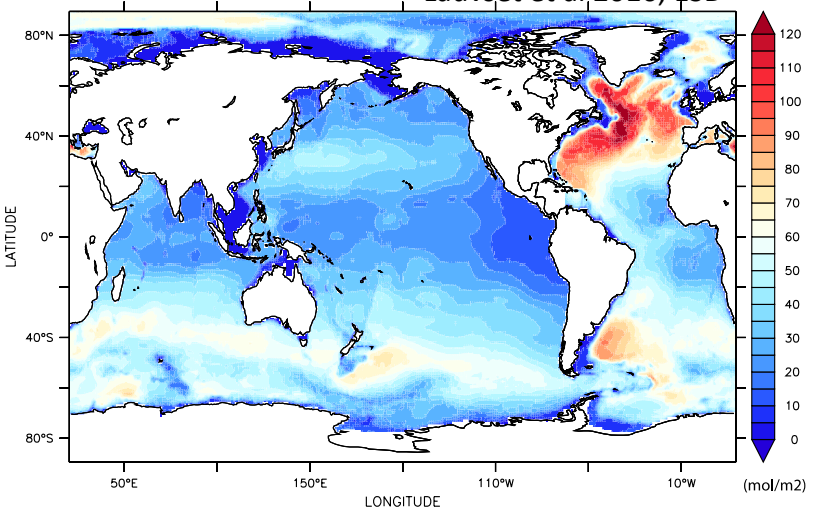
-> why 2002 – data!!!

BGC initialized with GLODAP V2 in 2002, observed Chla

Driven with GCP atmospheric history between 2002 and 2016

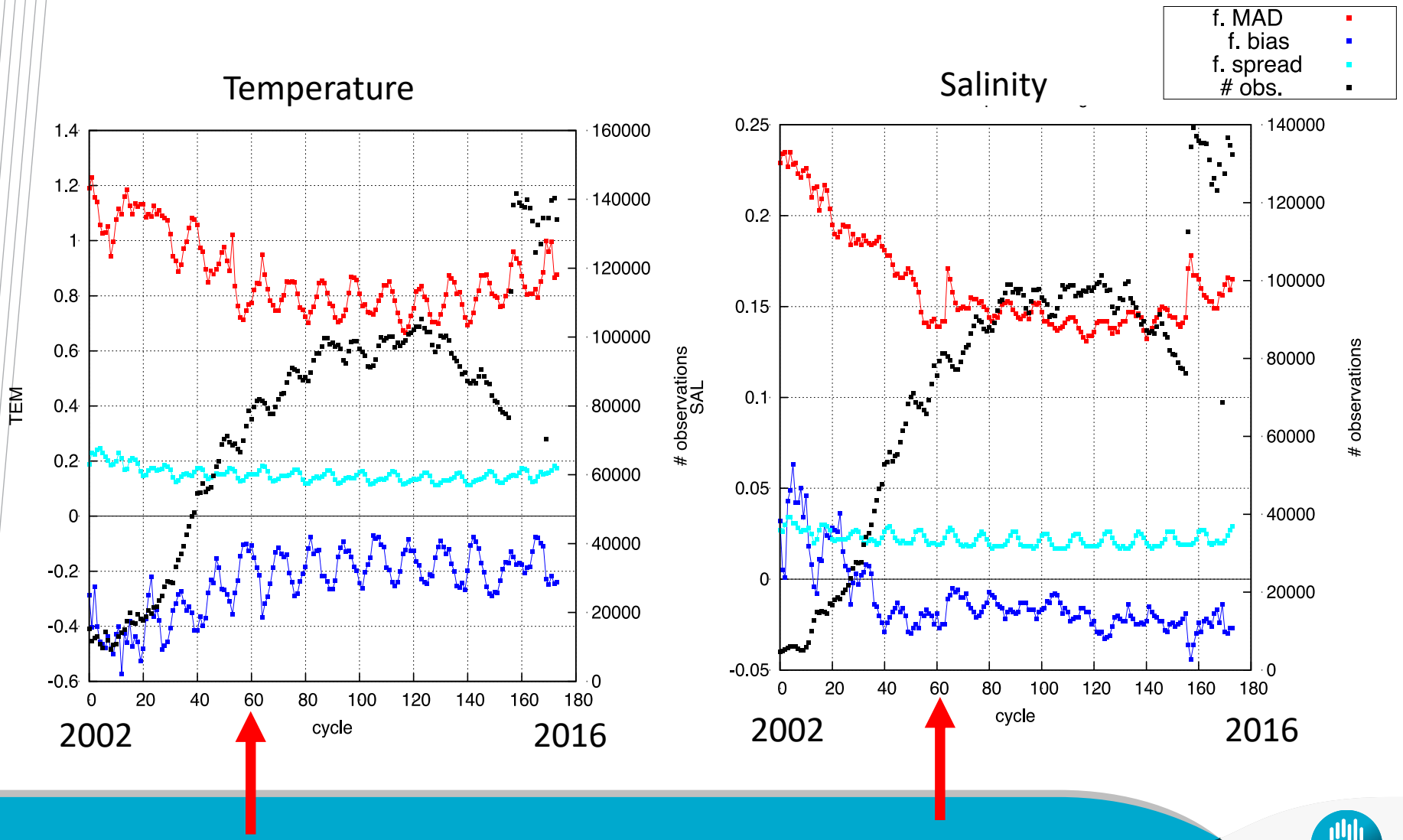
Focus on 2006 onwards ->

Lauvset et al 2016, ESD



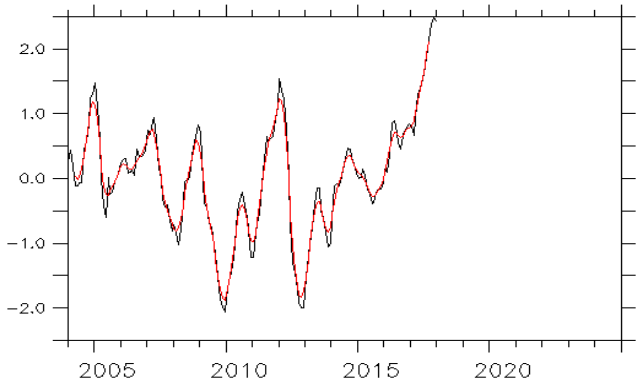
Anthopogenic Carbon (2002)

Physically Assessment- Total Ocean

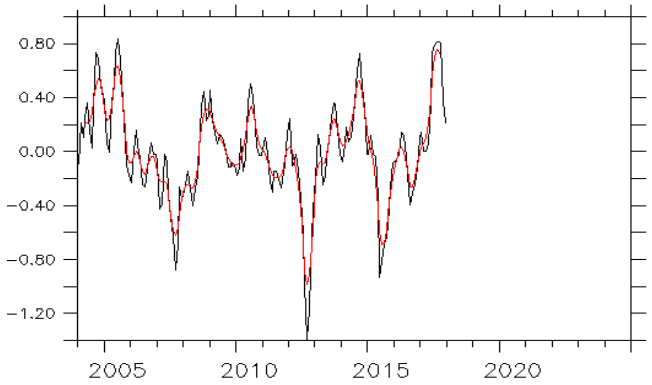


Physically Assessment – Major Climate Modes

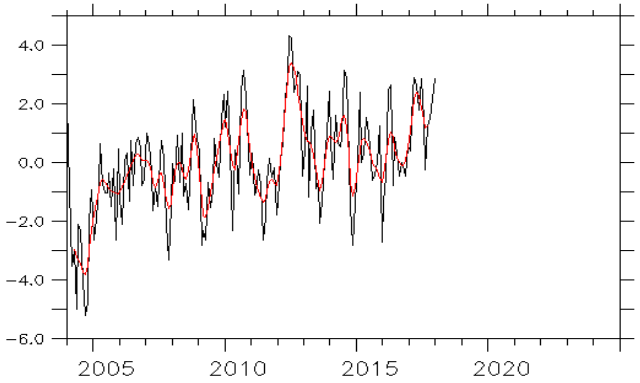
Nino 3.4



Indian Ocean Dipole



Southern Annular Mode

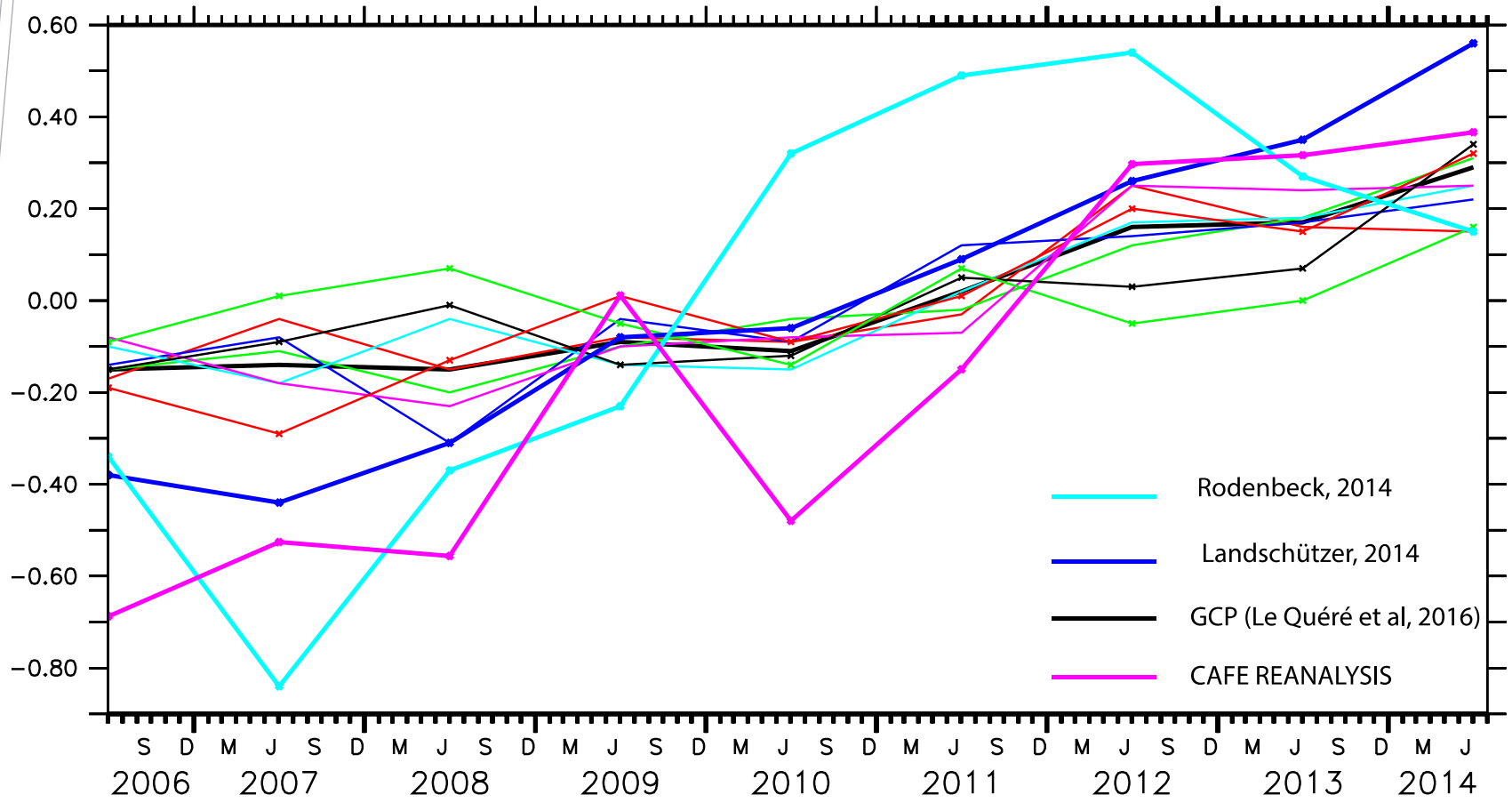


Major Climate Modes Well Reproduced

Observations

Model

Global Responses Anomalies 2006-2014

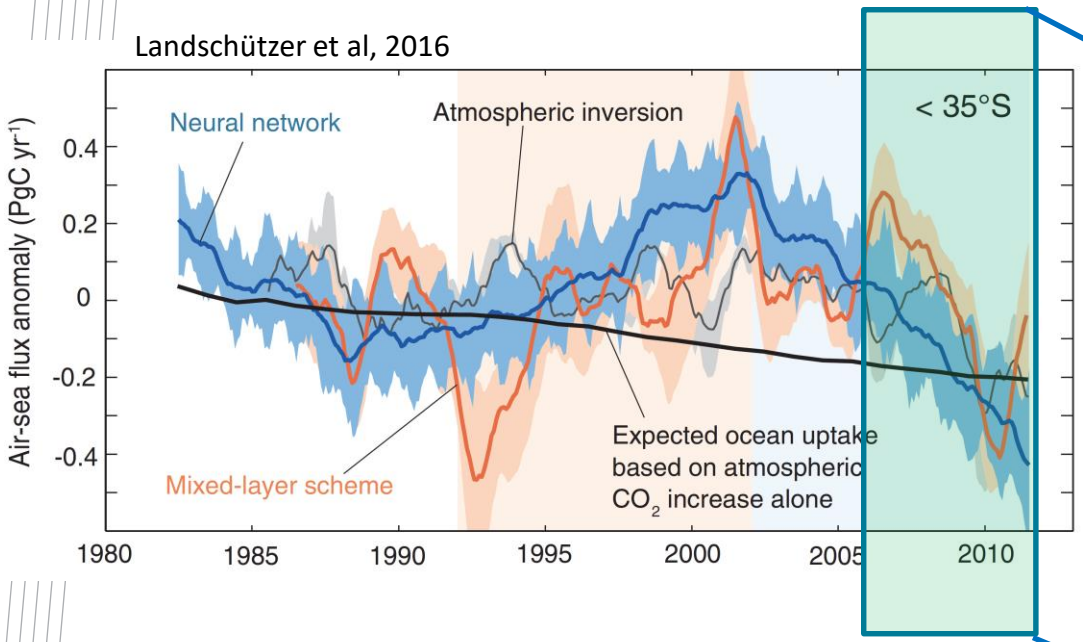


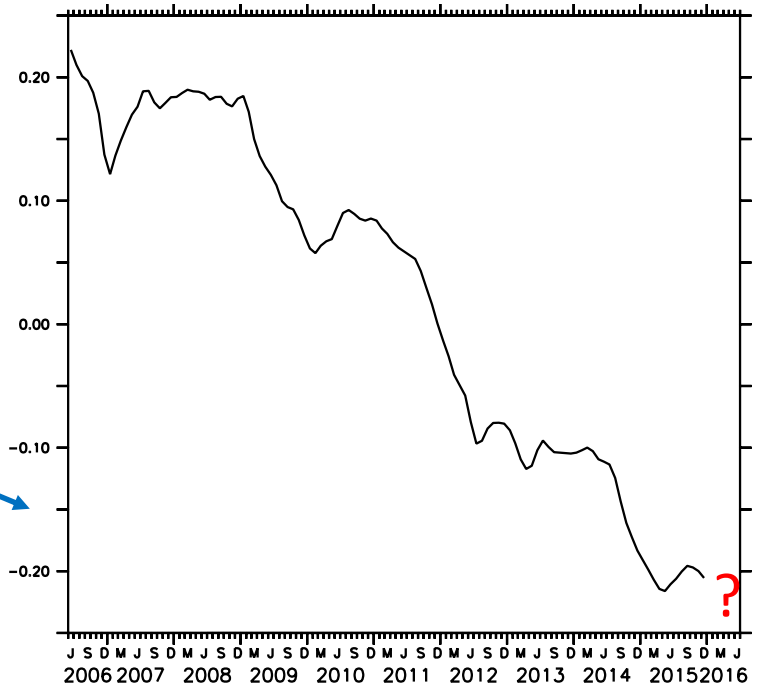
Models: Buitenhuis et al ,2010, Aumont and Bopp, 2006, Doney et al 2009, Assman et al; 2010, Oke et al 2014, Hauck, 2013, Séférian et al, 2013

Results: Southern Ocean

Southern Ocean 35S ->

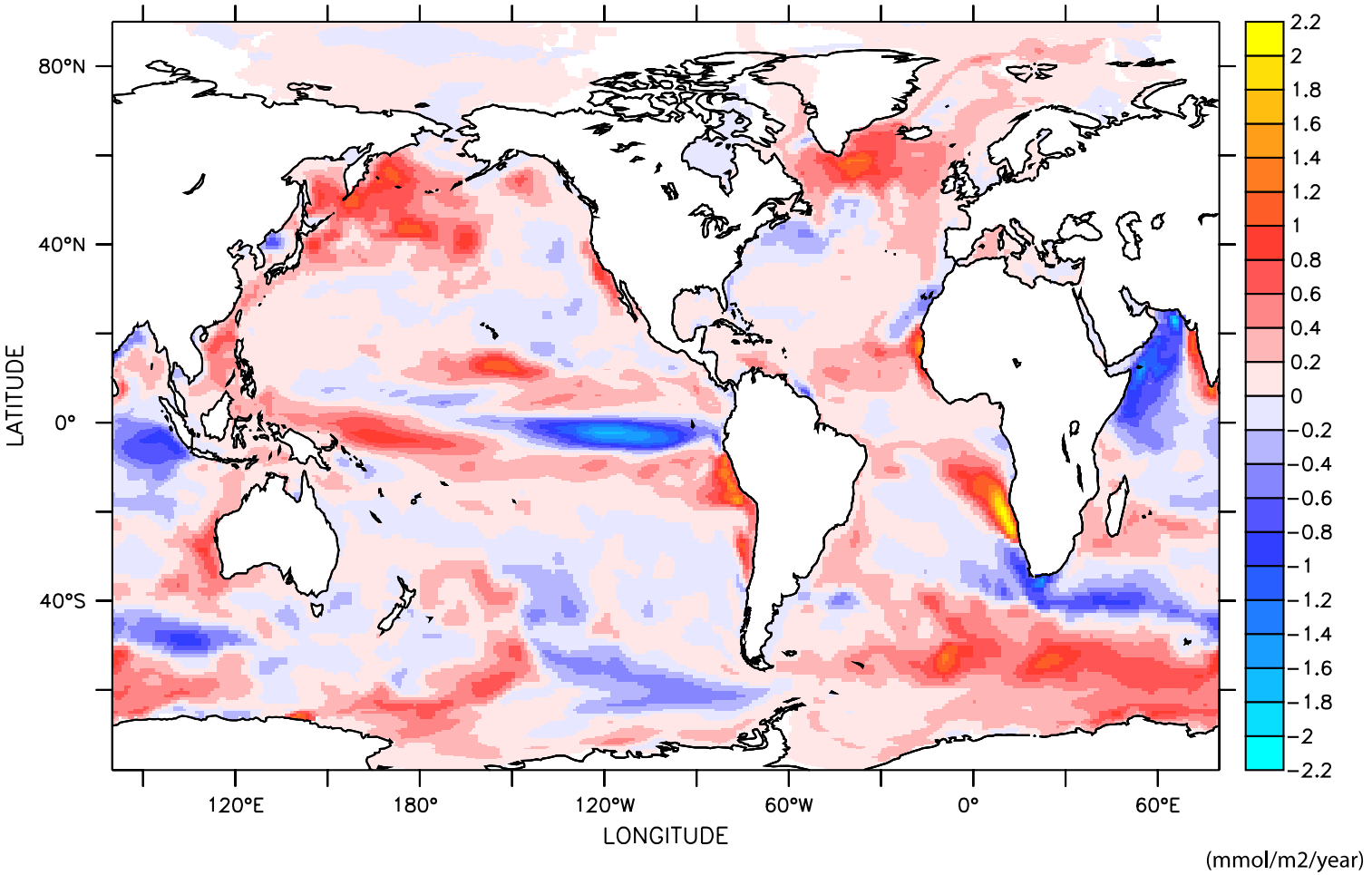
Landschützer et al, 2016





Similar variability and phase over the period 2006-2013
-> argues for continuation

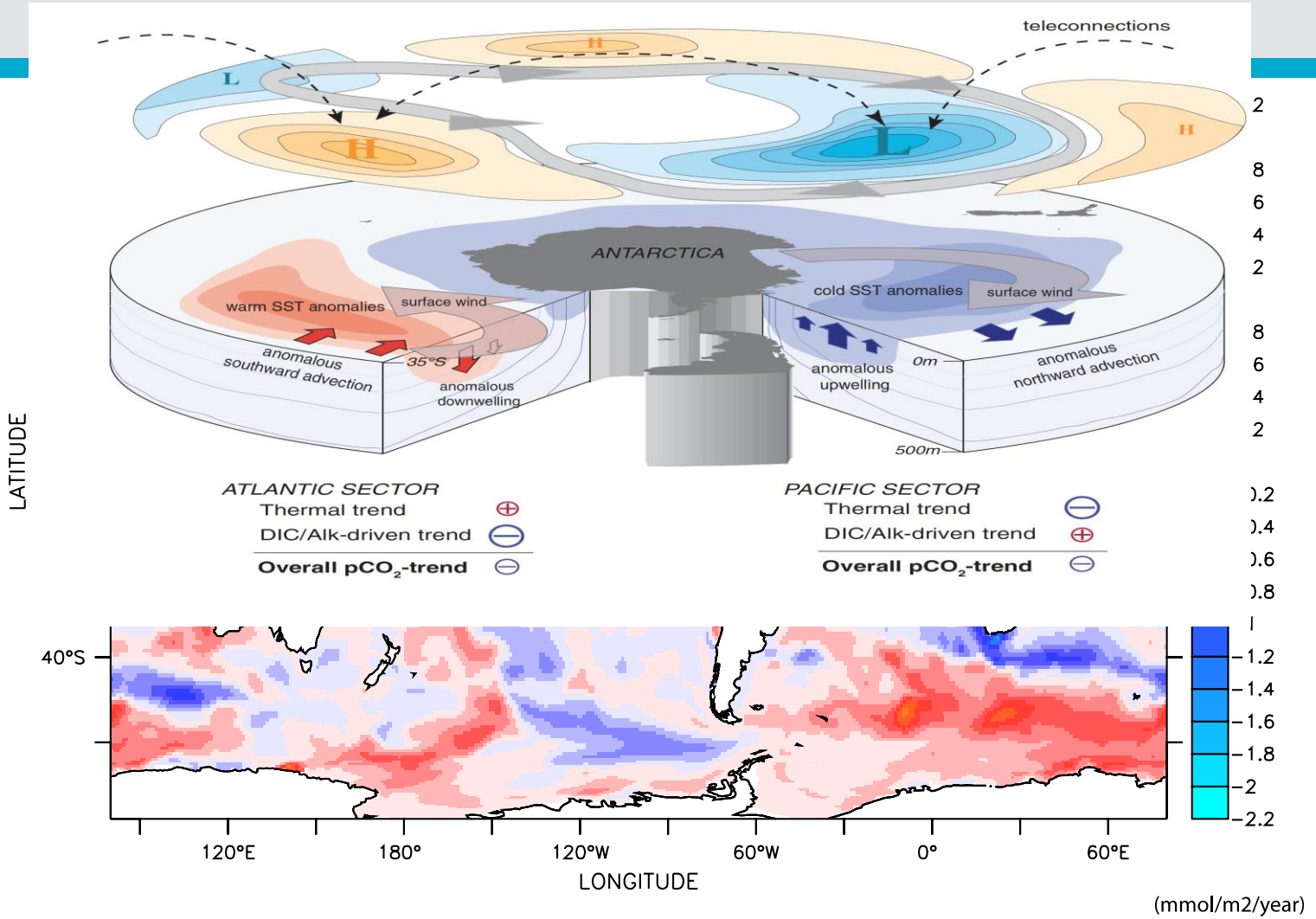
Results – Global Trends



Linear Trends in Carbon Fluxes (2006-2016)

Results – Global Trends

Landschützer et al, 2016



Linear Trends in Carbon Fluxes (2006-2016)

Conclusions

Early Stages……

Improving the state estimation improves the carbon response and closes the gap between models and observations

Hopefully this will a product for the Global Carbon Budget Update

More work to do : SOCAT, SOCCOM, atmospheric observations and others

Allows to probe mechanisms and improve our representation of processes e.g. biological pump

Can’t go back much more than a decade and requires computer resources

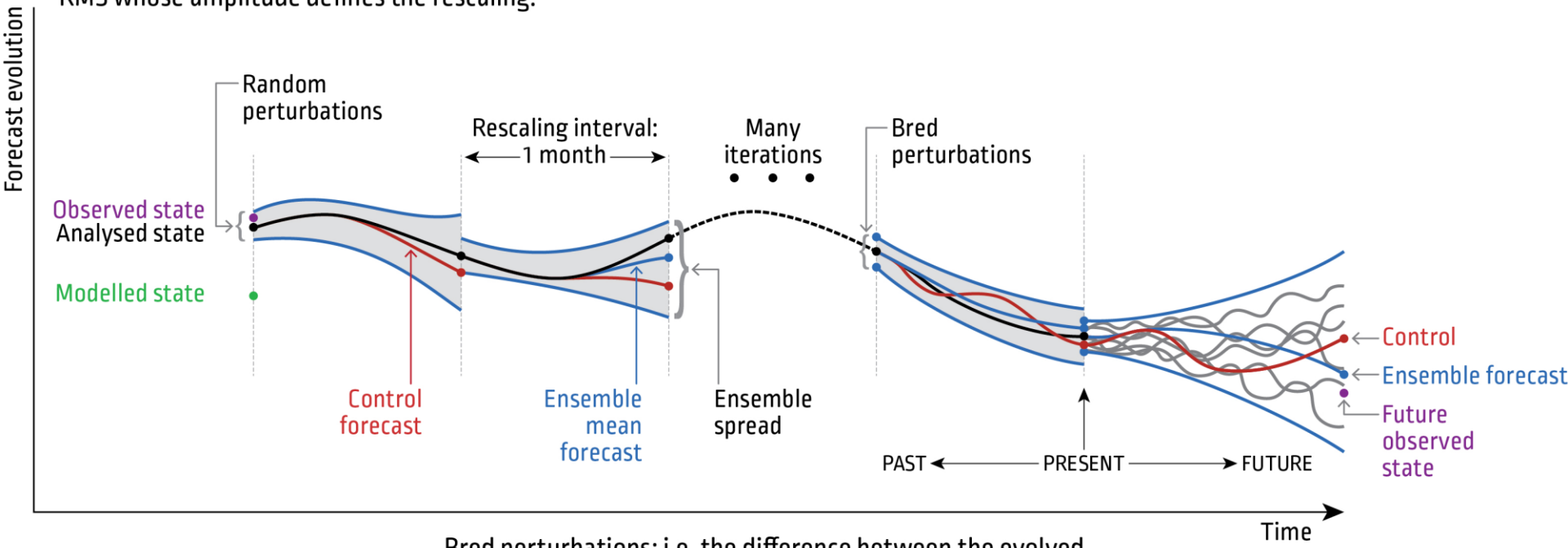
RECCAP -2 ? Exciting – seasonality improved

More information/future

GOAL -> Forecasts, in the land and ocean

Methodology

Random initial perturbations with prescribed RMS whose amplitude defines the rescaling.



Bred perturbations: i.e. the difference between the evolved perturbed forecasts and the control, renormalised via the norm defined by the RMS of the initial perturbations and the length of the rescaling interval.