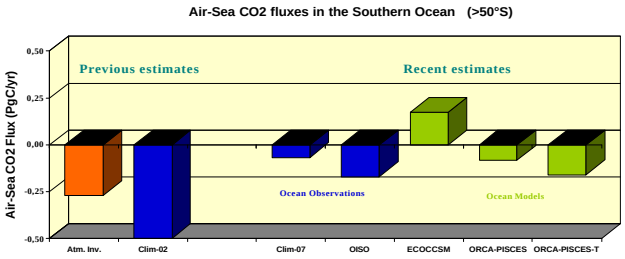
Air-Sea CO_2 Fluxes in the Southern Ocean: different methods, converging results?

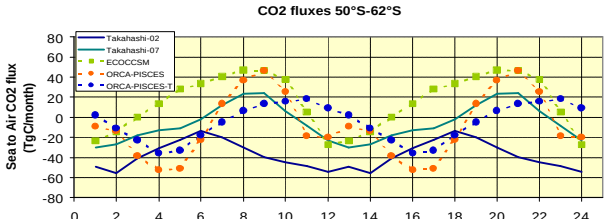
N. Metzl[1*], A. Lenton[1], O. Aumont[1,2], P. Bousquet[3], N. Gruber[4], C. Le Quéré[5], C. Lo Monaco[1], N. Lovenduski[6], B. Mc Neil[7], P. Peylin[3], T. Takahashi[8], B. Tilbrook[9]

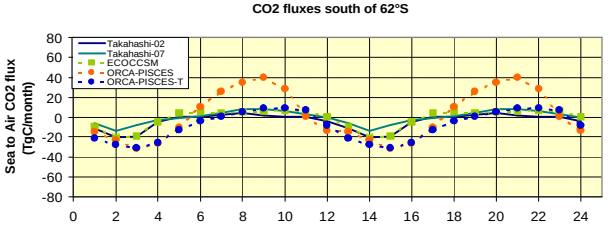
*metzl@ccr.fr 1 Institut Pierre Simon Laplace, LOCEAN/IPSL, UPMC, Paris, FRANCE; 2 IRD, Brest, FRANCE; 3 Institut Pierre Simon Laplace, LSCE/IPSL; UVSQ, Gif/Yvette, FRANCE; 4 Institute of Biogeochemistry and Pollutant Dynamics, ETH Zurich, SWITZERLAND; 5 School of Environmental Sciences, UEA, Norwich, UK; 6 Department of Atmospheric and Oceanic Sciences, UCLA, Los Angeles, Ca, USA; 7 University of New South Wales, Sydney, AUSTRALIA; 8 Lamont-Doherty Earth Observatory, Palisades, NY, USA; and 9 Antarctic CRC and CSIRO, Hobart, AUSTRALIA

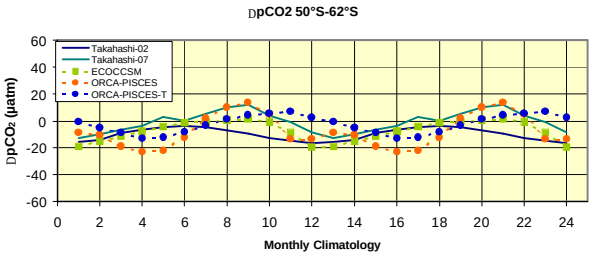
MOTIVATION

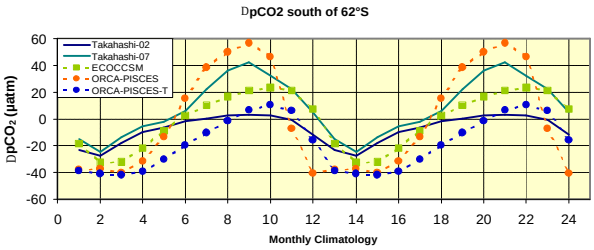
The large, cold, windy and icy circumpolar Southern Ocean, south of the Polar Front (~50°S), plays an important role in the global carbon cycle and climate change. Future scenarios for the Southern Ocean highlight large changes, strong feedbacks and potential high-latitude vulnerabilities. Currently our knowledge of contemporary seasonal air-sea CO_2 fluxes in the Southern Ocean needs to be improved in order to better understand the response of the carbon cycle to changes in oceanic processes and atmospheric forcing, now and in the future. A well-represented seasonal cycle also plays an important role in preconditioning the oceanic response on non-seasonal timescales.











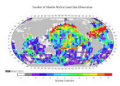
RESULTS

Historically the magnitude of the Southern Ocean flux has been suggested to be a sink of between 0.2 - 0.9 PgC/yr both from observations and modelling studies (e.g. *Bousquet et al (2000), Takahaski et al (2002)*). In recent years winter observations collected in the Southern Ocean (e.g *Metzl et al (2006)*) have been incorporated in an updated global data synthesis *(Takahashi et al, 2007)* and recent ocean biogeochemical simulations analysed. A synthesis of these studies, presented here, suggests that a clear picture of the seasonal cycle is beginning to emerge, one of a strong winter outgassing (related to deep mixing) close in magnitude to the strength of the summer sink (driven by biological processes). This leads to a reduced flux estimate, close to equilibrium, of ±0.15 PgC/yr. These changes are not driven by differences in gas transfer formulations but changes in ?pCO_2.

While a consistent large-scale picture is emerging for the present day, the responses of these simulations will diverge over longer timescales due to the unique evolution of ΔpCO_2 in each model. Understanding the seasonal response of biological and physical processes in each simulation requires investigation of all of the components that drive the ocean carbon cycle (e.g. DIC, Alkalinity, macro and micro nutrients, etc). To extract the maximum information from the limited Southern Ocean observations such an analysis needs to be performed at the regional scale.

METHODS - Observational

Takahashi et al Climatology (*2007*) - incorporates more than 2.7 million measurements of surface pCO_2 collected over the last 4 decades. These values are corrected to a reference year of 2000 and interpolated onto a global 4°x 5° global grid.

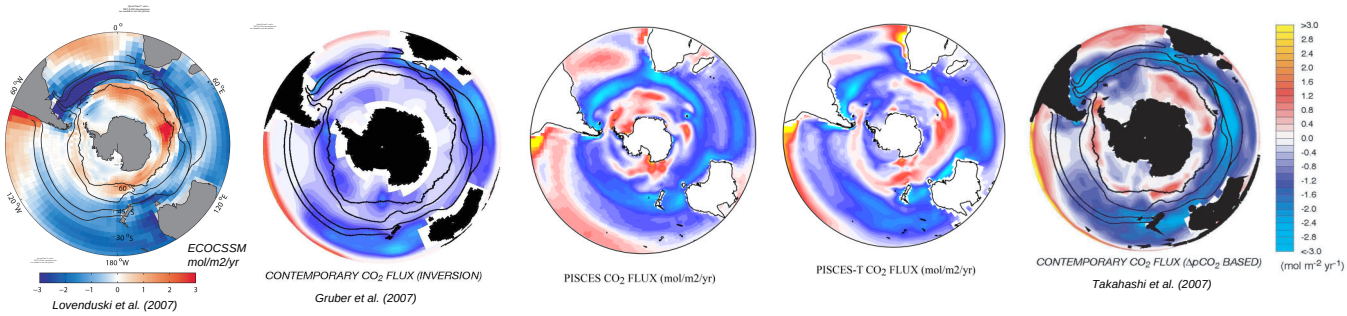


METHODS - Simulations using NCEP-R1

PISCES/ ORCA2-LIM - PISCES includes 4 Plankton Functional Types (Nanophytoplankton, Diatoms, meso and micro zooplankton) and co-limitation by P, Si, Fe and light (*Aumont et al, 2003*). It is coupled to an ocean model (ORCA), ~2°x1° resolution in the Southern Ocean and ice model (LIM).

PISCES-T/ ORCA2-LIM - The same as PISCES but with a different representation of meso-zooplankton processes and a temperature-dependance of particle remineralization (*Buitenhuis et al. 2006*).

ECO-CCSM - ECO comprises several nutrient phytoplankton, zooplankton classes and detritus, as well as ecosystem parameterisations and Fe cycling (*Moore et al, 2004*). This is coupled to the CCSM ocean model with a horizontal resolution of ~4°x 1°.



References:

Aumont, O. et al (2003). An ecosystem model of the global ocean including Fe, Si, P co-limitations, Global Biogeochem. Cycles, 17, doi:10.1029/2001GB001745.

Bousquet, P. et al (2000) Regional Changes in Carbon Dioxide Fluxes of Land and Oceans Since 1980, Science, Vol 290(5495) pp1342-1346

Buitenhuis,E. T. et al (2006) Biogeochemical Fluxes through mesozooplankton, Global Biogeochemical Cycles, 20, doi: 10,1029/2005GB002511

Gruber, N. K. et al. (2007) Oceanic sources and sinks for atmospheric CO_2, Global Biogeochemical Cycles,(in revision)

Lovenduski, N. S. et al. (2007) Enhanced CO2 outgassing from a positive phase of the Southern Annular Mode, GBC, (submitted)

Metzl, N, et al (2006) Summer and winter air-sea CO_2 fluxes in the Southern Ocean, Deep-Sea Research 53 (1548-1563)

Moore J. K. et al (2004) Upper ocean ecosystem dynamics and iron cycling in a global 3-D model, Global Biogeochem. Cycles, 18, 4, GB4028, 10.1029/2004GB002220

Takahashi, T. et al (2002). Global sea-air CO2 flux based on climatological surface ocean pCO2 and seasonal biological and temperature effects Deep-Sea Research II 49(1601-1622).

Takahashi, T. et al (2007). Climatological mean surface ocean pCO2 and net sea-air CO2 flux over the global oceans: Progress since 2002, JGR (in prep).