JGOFS Open Science Conference
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Constraining Fluxes at the Top: Advances in Quantifying Air-Sea Carbon Dioxide Fluxes during the JGOFS Decade

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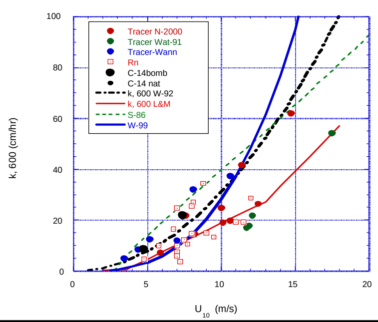
Commentator: Richard A. Feely NOAA/PMEL

Outline:
- New techniques for determining gas transfer velocity
- Parameterization of pCO_2 from SST, SSS, Chl and nutrients
- Estimation of global CO_2 air-sea fluxes

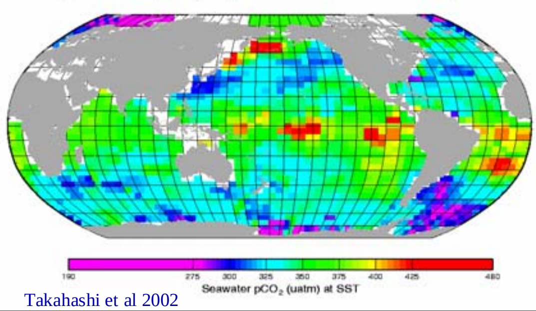
$$F_{av} = (k\ s\ \Delta pCO_2)_{av}$$

Gas transfer velocity
Function of:
Surface turbulence (wind speed)
Physical properties of gas and water

Thermodynamic component
Function of:
Temperature, Salinity, TCO_2
Biology (photosynthesis/respiration)
Transport (horizontal/vertical)



(B) Climatological pCO_2 in Surface Water for February 1995

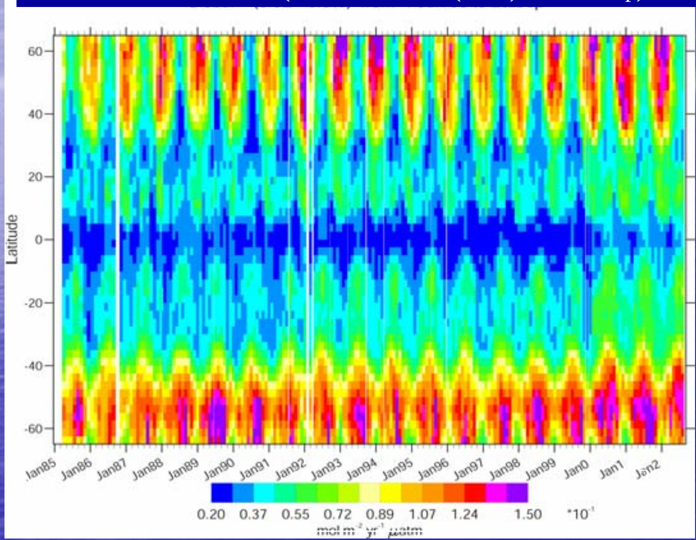


Takahashi et al 2002

CO_2 transfer velocity & exchange coefficient (K=ks):

Monitoring using satellite wind speed (Geosat, SSM/I, ERS, QSCAT…) 1985-2002

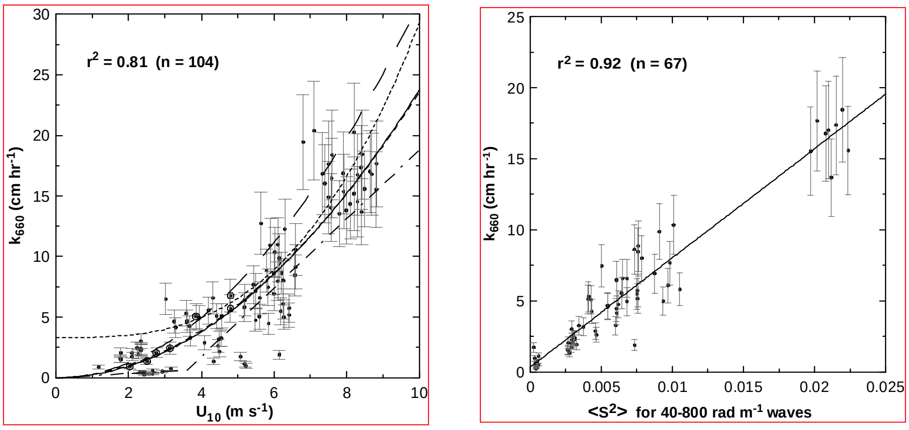
K over Global ocean (k-U Wanninkhof(1992) relationship)



Geosat altimeter | **SSMI** Microwave radiometer | **ERS1 and ERS2** scatterometer | **QSCAT** scatterometer

(Boutin et al., 2003)

Gas Transfer Velocity: Wind Speed and Mean Square Slope Dependence



Data from 1997 NSF CoOP Coastal Air-Sea Exchange Experiment [Frew et al., 2003]

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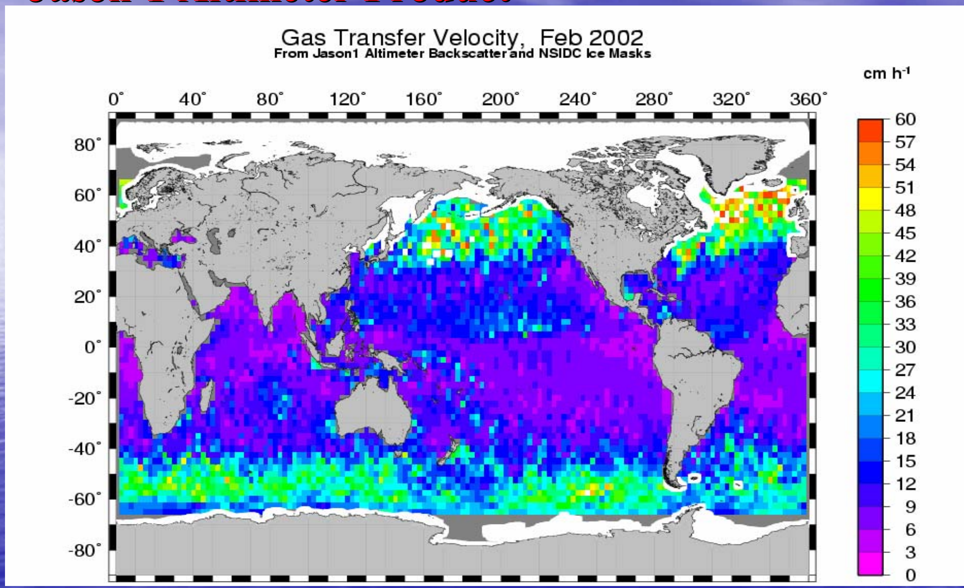
Jason-1 Altimeter Product



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CO_2 gas transfer velocity: summary and issues

- Monitoring of k using satellite wind speed (Geosat, SSM/I, ERS, QSCAT…) 1985-present
  and a given k-U relationship: Strong k variability (including interannual)

  Issue: Need for intercalibration of U retrieved from various instruments

- K deduced from various k-U relationships differ (Boutin et al., GRL, 2002):

  Issue: Calibration of k-U relationships still needed

- Use of altimeter measurements and k-MSS relationship (Glover et al., 2002)

k-MSS estimates close to k-U Liss and Merlivat estimates
(k-altimeter relationship calibrated with laboratory (wind/wave tank) measurements).

Issue: Calibration of k-MSS relationships still needed

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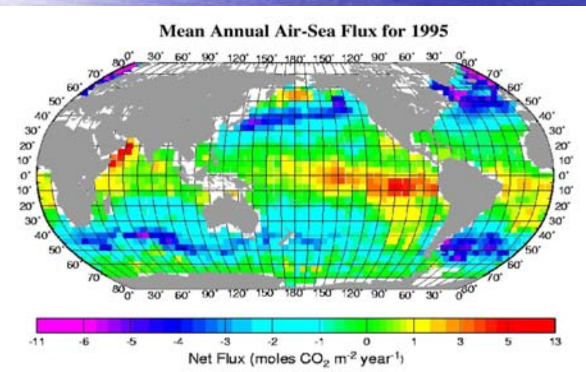
-Boutin, Etcheto et al., JGOFS 2003

Joint Global Ocean Flux Program

Major scientific question for the JGOFS program:

1. How much carbon is sequestered by the open- oceans?



Takahashi et al. CO_2 Air-sea Flux Climatology based on a 40-yr database of over 1,400,000 measurements of surface seawater pCO_2

Global Oceanic Uptake

-1.5 ± 0.4 Pg C yr^{-1}

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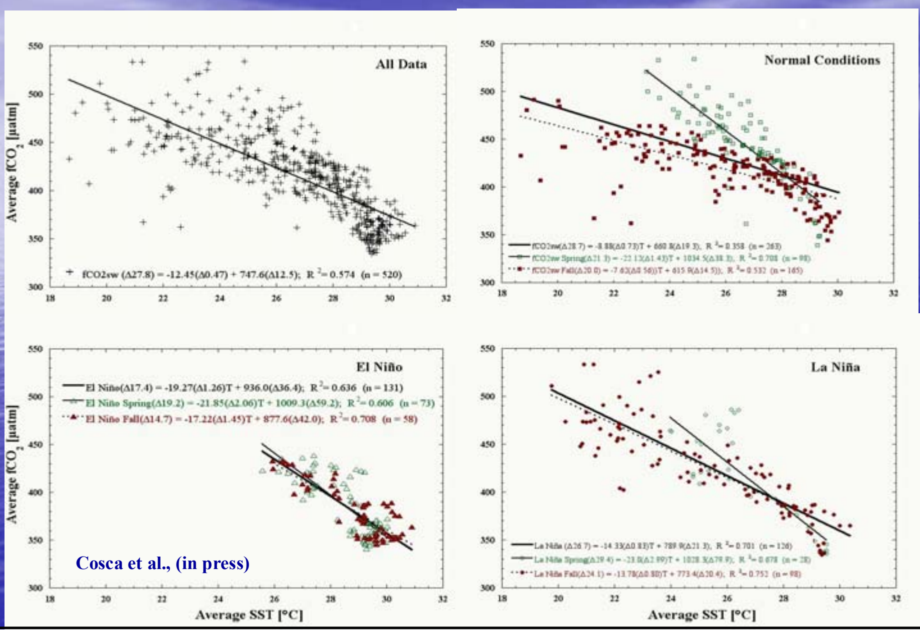
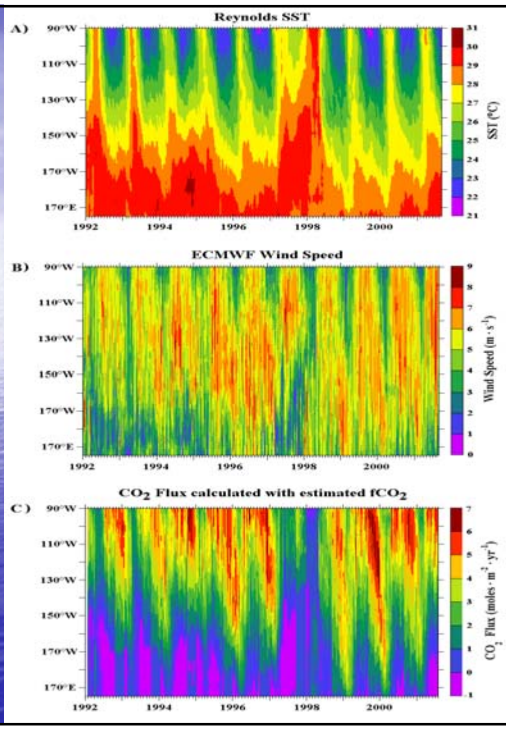
pCO_2 versus Temperature in the Equatorial Pacific
89 Data Sets Collected Between March 1992 and July 2001





Large-Scale Observational Results: 1992-2002

El Niño: 0.2-0.4 Pg C year^{-1}

Non El Niño: 0.7-0.9 Pg C year^{-1}

La Niña: 0.8-1.0 Pg C year^{-1}

Average: 0.6 ± 0.2 Pg C year^{-1}

from Feely et al. JGR (submitted)

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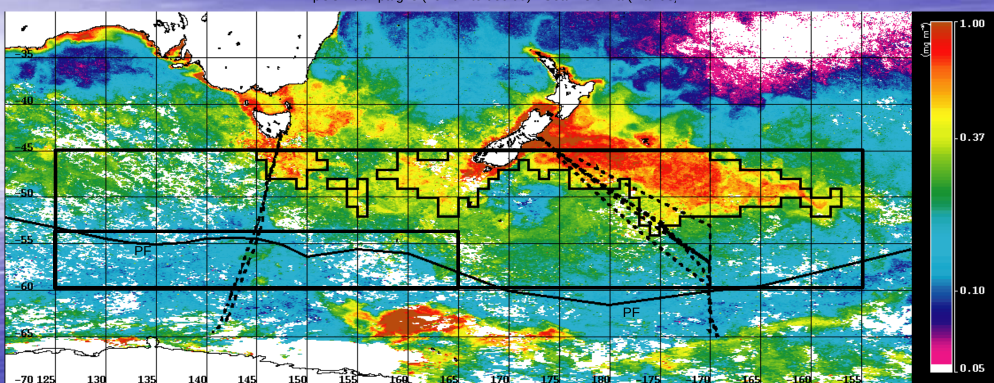
Influence of Chl and SST on pCO_2 observed during AESOPS and Astrolabe campaigns

pCO2 campaigns (nov 97 to dec 99) - Seawifs chl a (mar 98)

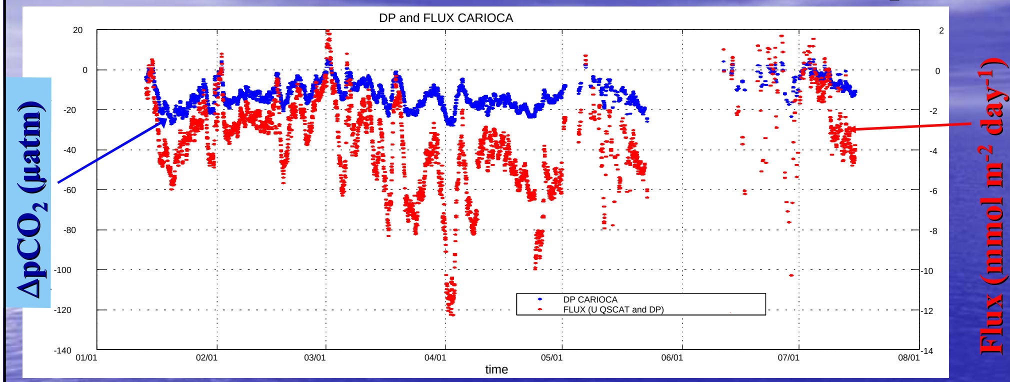


130 140 150 160 170 180 -170 -160

***see POSTER Session 1 Theme 2, Boutin et al.:** Air-sea CO2 fluxes in the Southern Ocean inferred from satellite data)*

Boutin, Etcheto et al., JGOFS 2003

CARIOCA ΔpCO_2 and CO_2 Flux deduced from QSCAT winds and K-U Wanninkhof (1992) relationship



Air sea flux from CARIOCA pCO_2, atmospheric pCO_2 derived from atmospheric pressure measured onboard the buoy, satellite (QSCAT) wind speed and K-U Wanninkhof relationship.

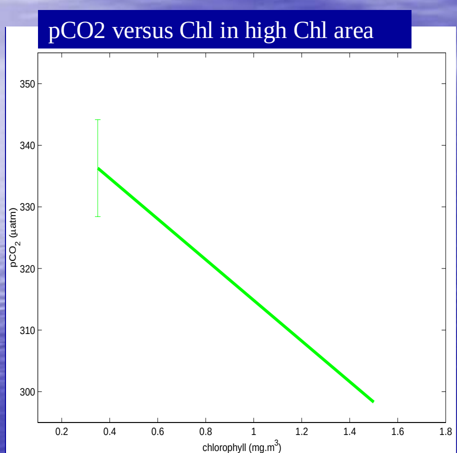
From January to July 2002:

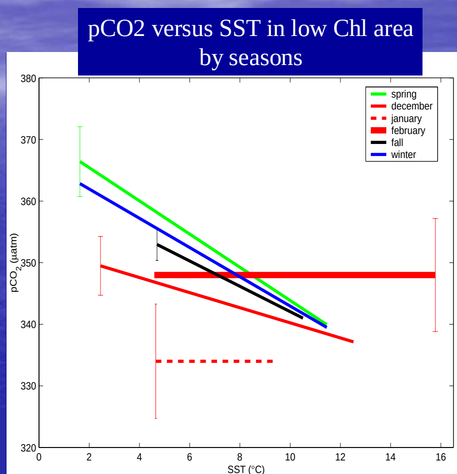
Mean ΔP = -12.6 µatm

Mean Air-sea flux = -3.8 mmol m^{-2} day^{-1}

10/16/2003 ***POSTER Session 1 Theme 1, Etcheto et al.:*** *Recent results from CARIOCA drifters in the Southern Ocean*

pCO_2 regressions South of Tasmania and New Zealand





see POSTER Session 1 Theme 2, Boutin et al.: *Air-sea CO_2 fluxes in the Southern Ocean inferred from satellite data)*

Boutin, Etcheto et al., JGOFS 2003

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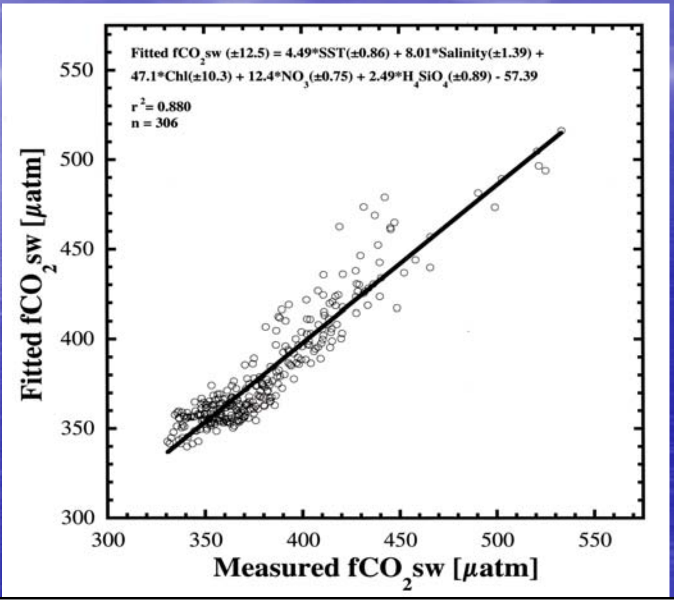
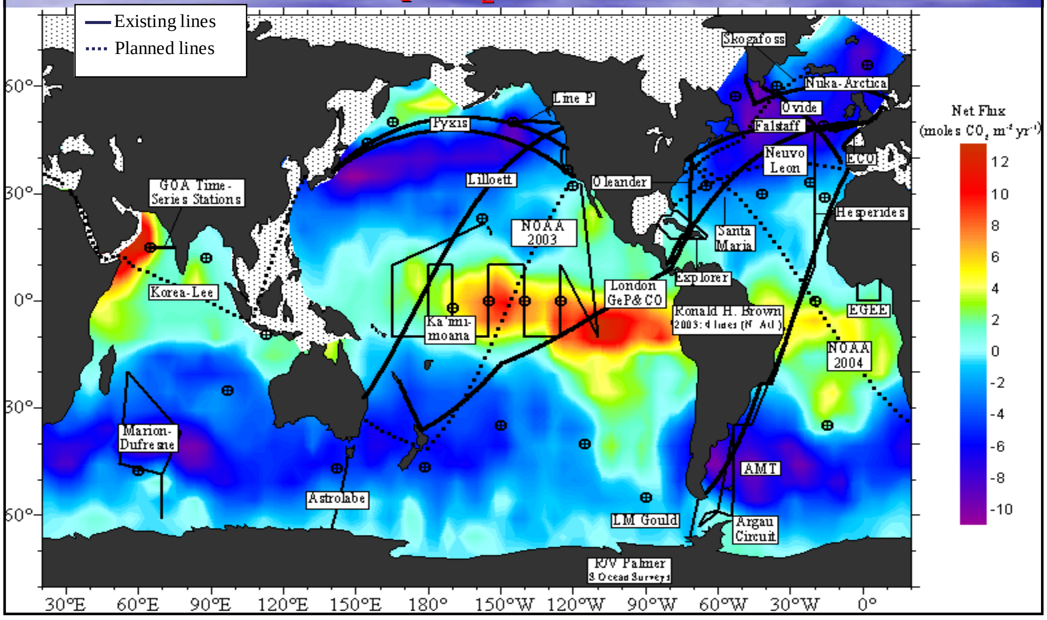
MLR Regression pCO_2 versus SST, SSS, Chla, NO3 and SiO4 in the Equatorial Pacific using 89 Data Sets Collected Between March 1992 and July 2001

Cosca et al. (in press)



Global map of existing and planned near-surface pCO_2 measurements



Current Satellite Sensors

Wind speed: (2 scatterometers in the air)

-Scatterometer: QSCAT 1999-TBD
Seawinds on ADEOS2 2003-TBD

Sea Surface Temperature:

-Visible/IR radiometer: AVHRR 1982-TBD
GOES -TBD
Meteosat 2nd generation 2002

-Microwave radiometer: TMI (40S-40N) 1997-TBD
AMSR-E on AQUA 2002-TBD
AMSR on ADEOS2 2002-TBD

Ocean Color: (6 radiometers in the air)

-Visible/IR radiometer: Seawifs 1997-2003
MODIS on Terra 2001-2005
MERIS on ENVISAT 2002-2007
MODIS on AQUA 2002 -2007
POLDER 2 & GLI on ADEOS2 2003-TBD

Sea Surface Height anomalies: (3 altimeters)

-Altimeter: Topex-Poseidon 1992 -TBD
Jason 1991-TBD
RA on ENVISAT 2002-TBD

Conclusions

- **Remote sensing can be a powerful tool to monitor time and space variations of several parameters influencing CO_2 distribution and air-sea fluxes (wind speed, SSH, SST, Chl).**
  - Remote sensing can help interpret and extend in space and time in situ measurements
  - Remote sensing can provide constraints for biogeochemical modelling

- **In situ measurements are essential to:**
  - Validate remotely sensed and parameters derived from remote sensing measurements covering various oceanographic provinces at various time scales.
  - Determine the processes contolling variations of parameters observed by remote sensing: measurements of parameters not accessible from space.

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