SO GasEx results and satellite techniques for determining Southern Ocean CO_2 sources/sinks

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Outline

SO GasEx

Mixed layer carbon budget, calculation of air-sea CO_2 flux

Preliminary physical, chemical and biological observations

Satellite techniques for oceanic pCO_2

Explanation and first Southern Ocean maps

Comparison with other climatologies (Takahashi, 2009; McNeil, 2007)

Part 1: Southern Ocean GasEx

GasEx 2001: Lagrangian study of CO_2 exchange

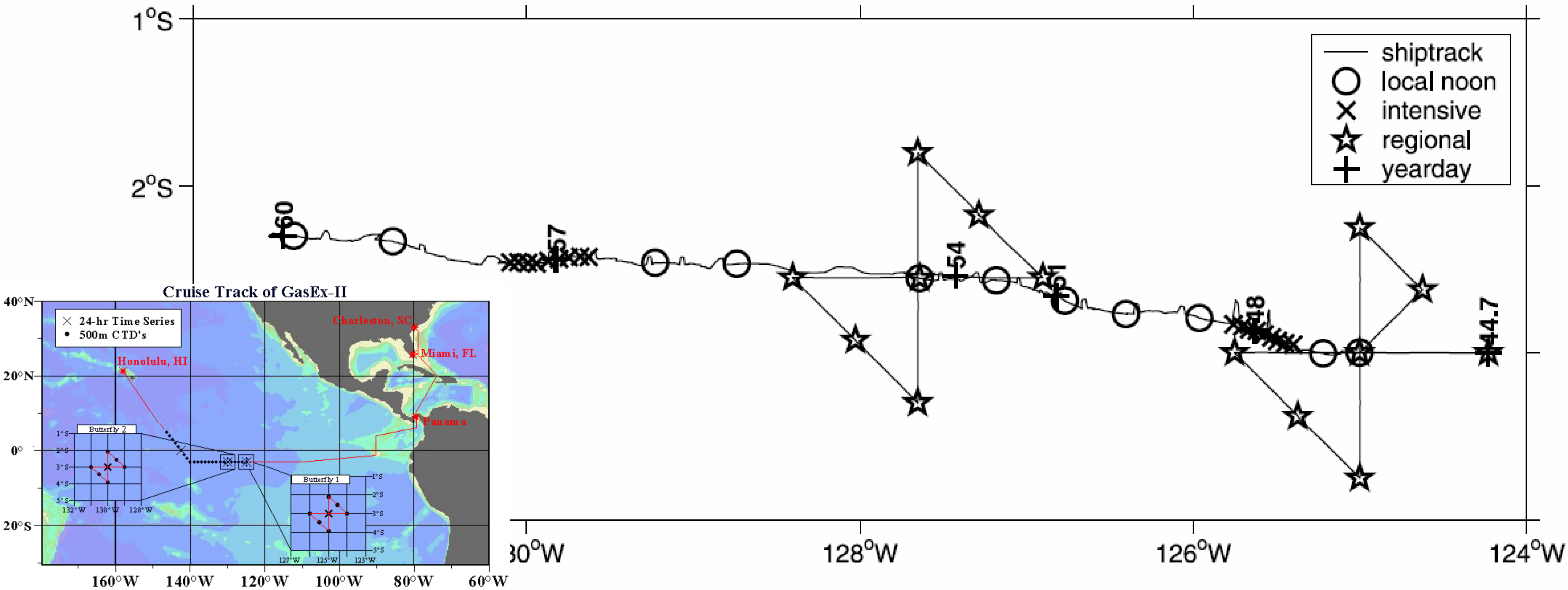
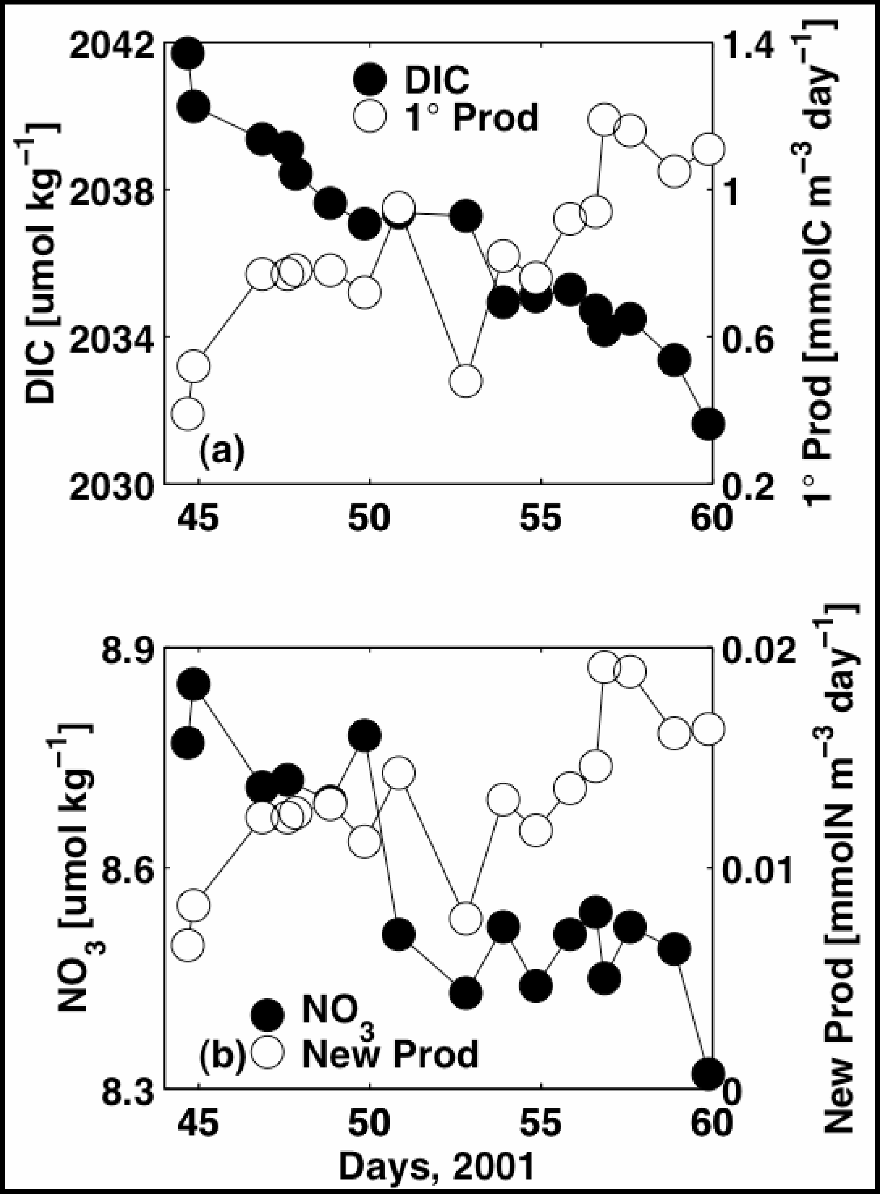


Figure 1. Ship track (solid line) and CTD/O_2 cast positions during GasEx-2001 including noon casts following the instrument array drift (circles), casts taken following the array during the two intensive observation periods (crosses), and casts taken mostly away from the array during the two regional butterfly surveys (stars). Select times along the track indicated in yeardays (pluses with numbers).

Johnson et al., 2004

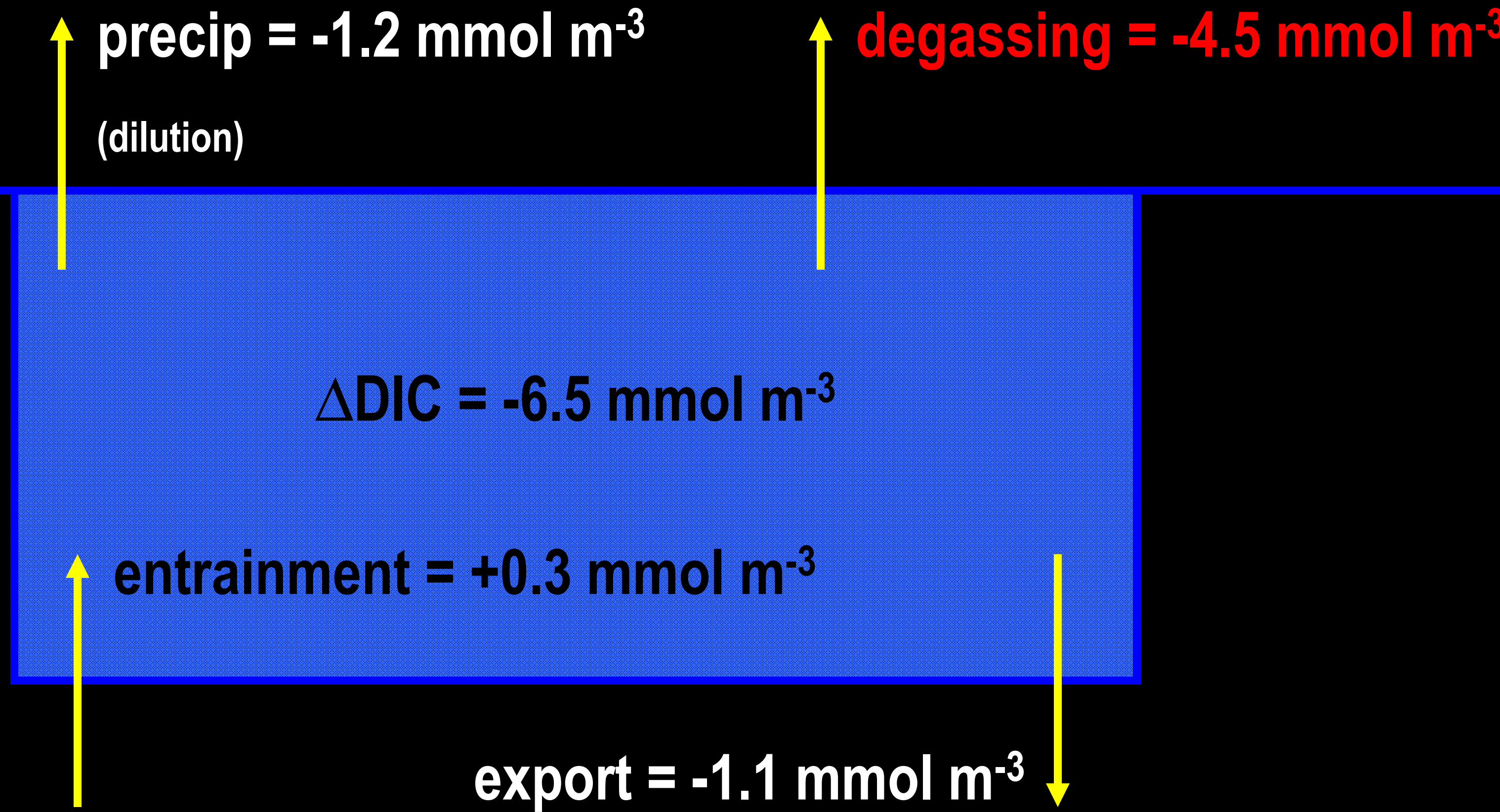
Mixed layer carbon and nutrient dynamics: GasEx2001



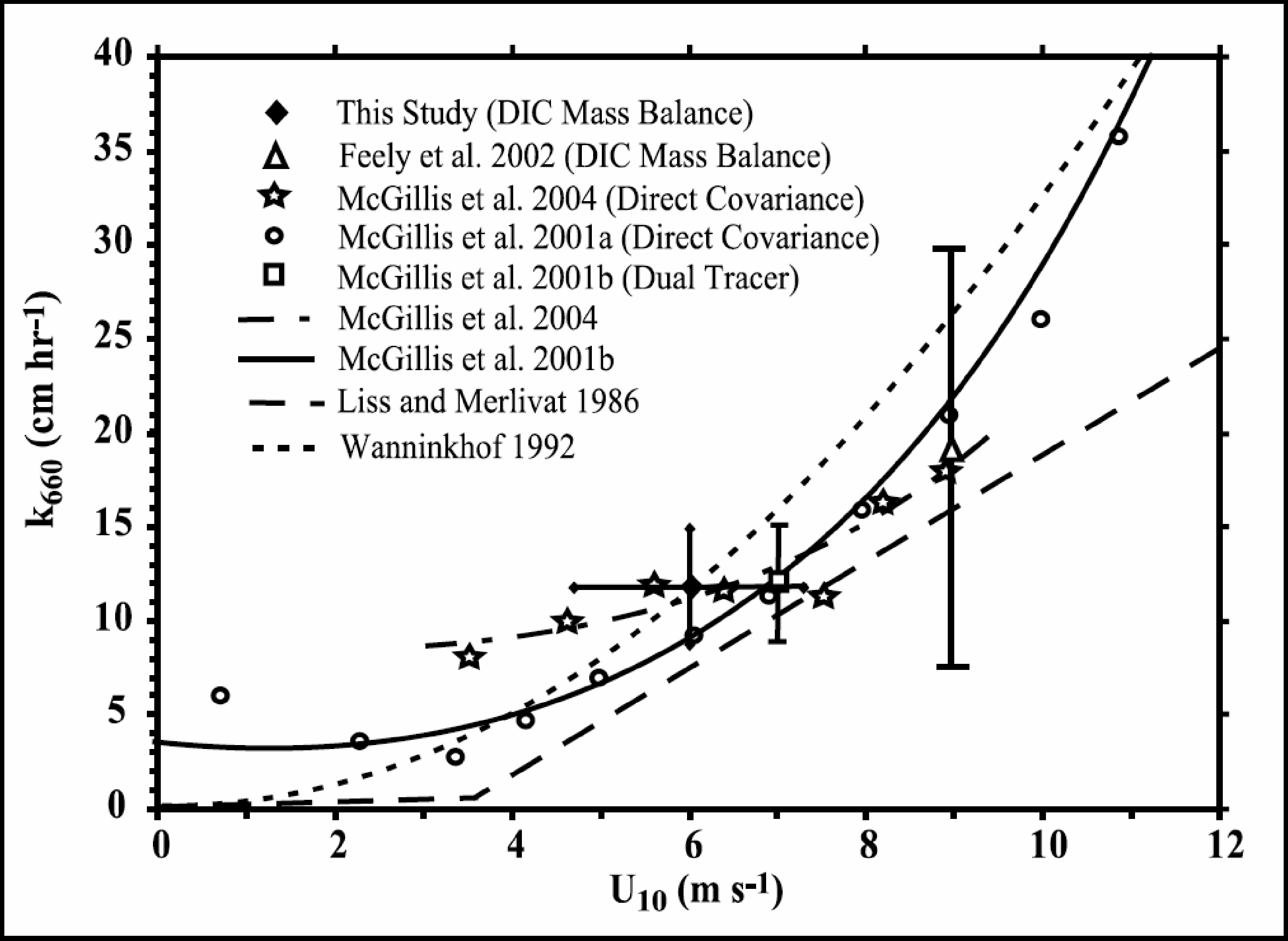
Strutton et al., 2004

Constructing a mixed layer carbon budget

$$F = k\,\alpha\,\Delta pCO_2$$



Validation of the gas transfer velocity

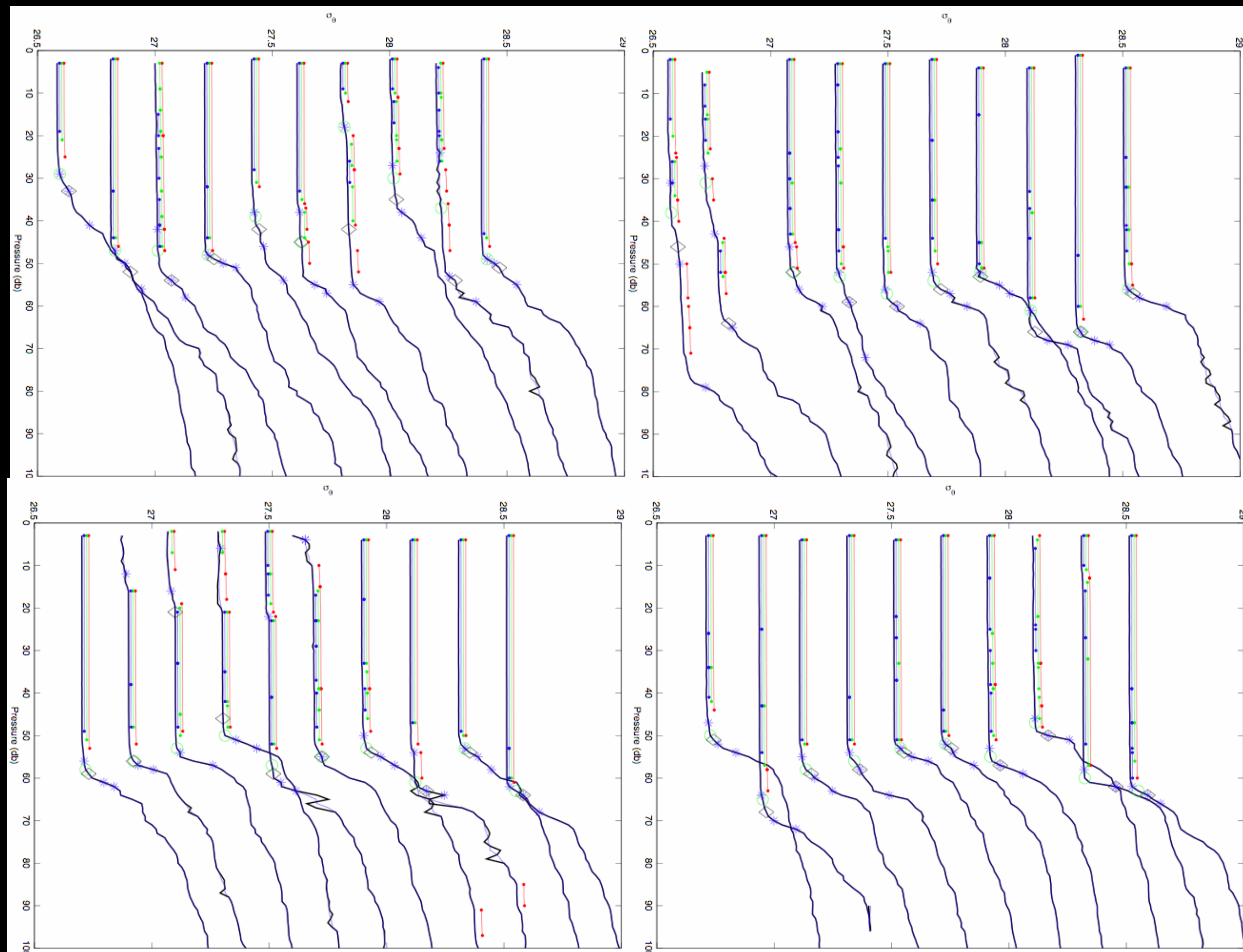


Sabine et al., 2004

SO GasEx: Modeled mixed layer depth

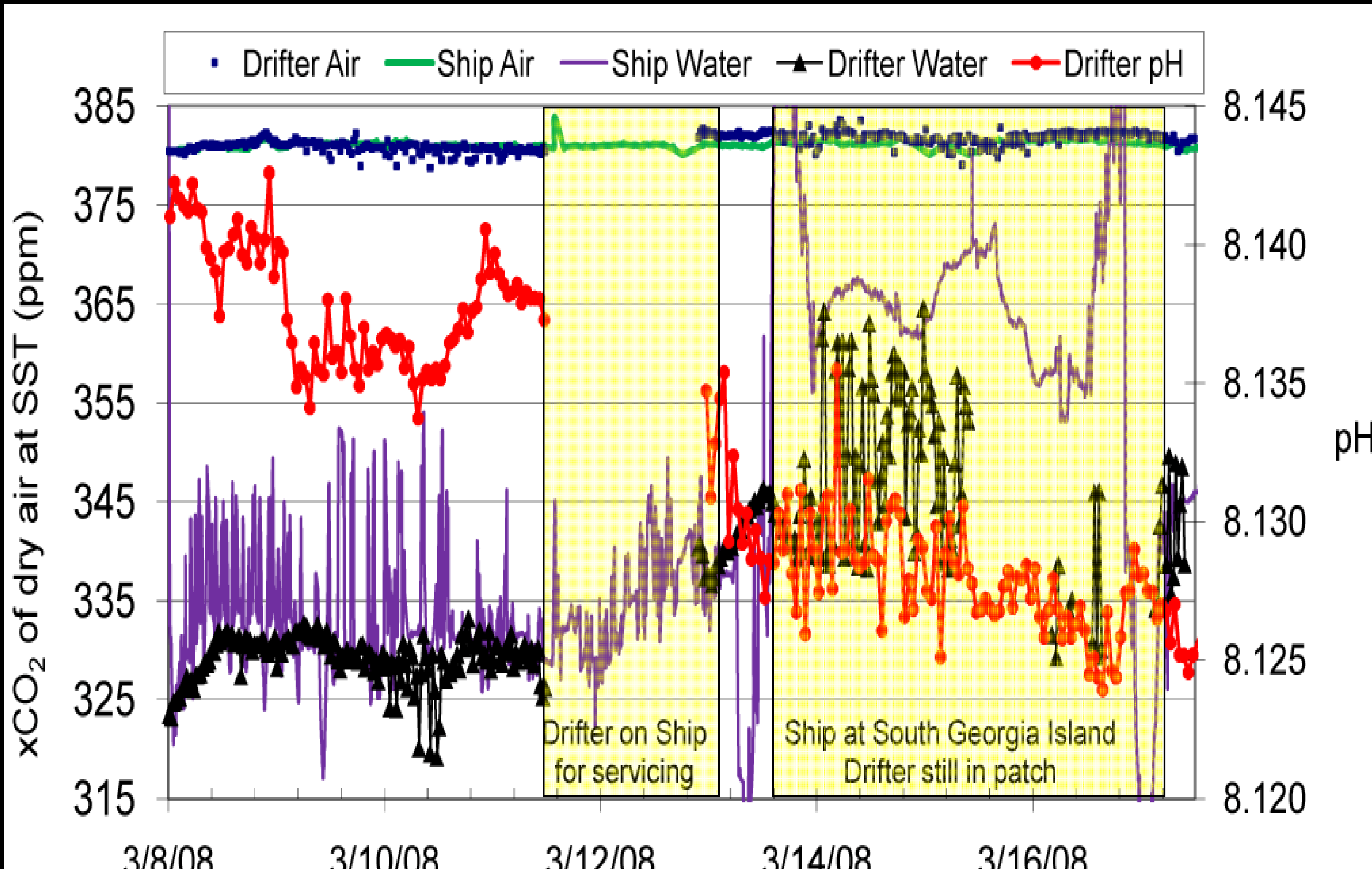
Dwivedi,
Haine and
Del Castillo,
submitted.

SO GasEx: Measured mixed layer depth



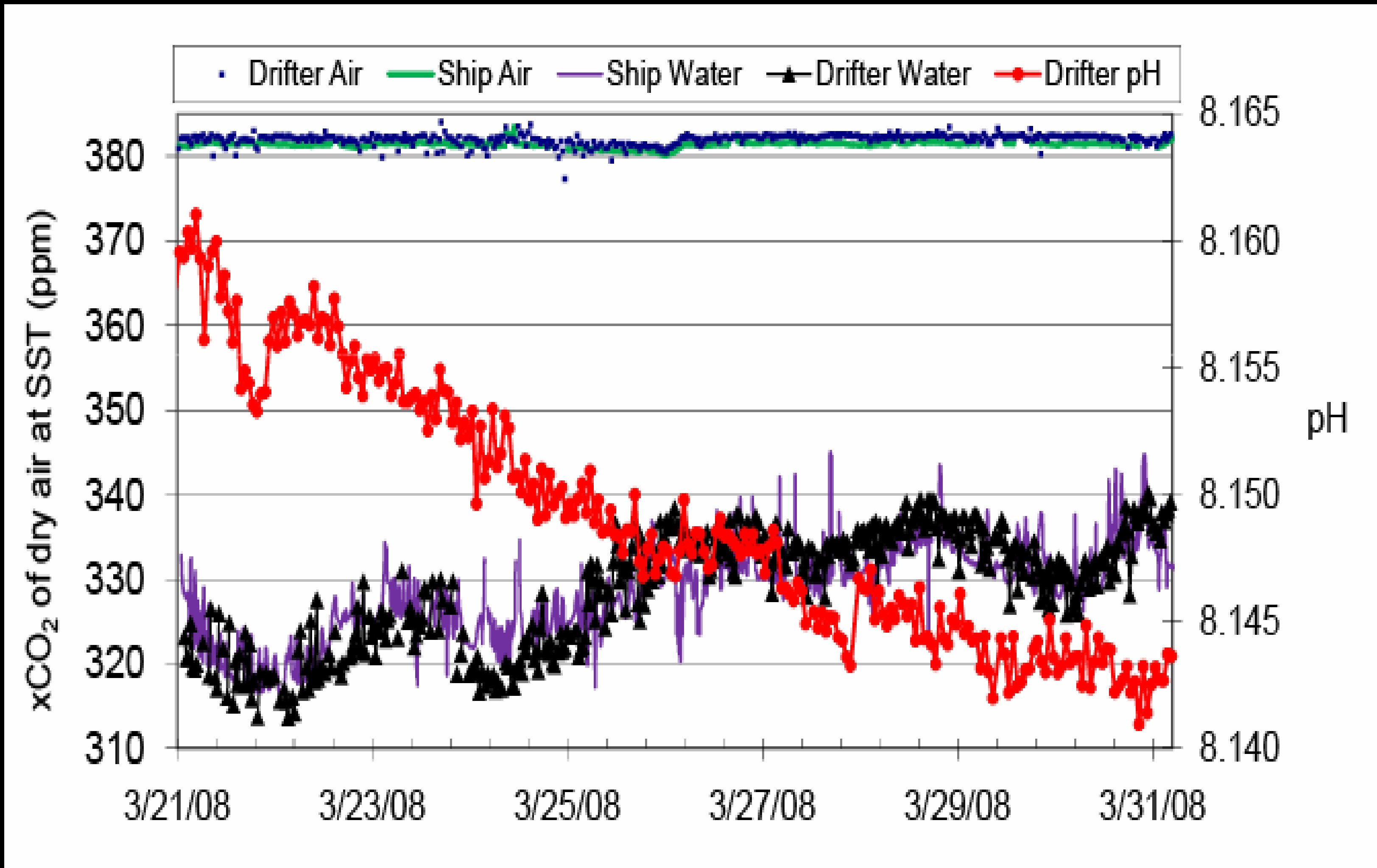
From Dave Hebert

SO GasEx: Mooring- and ship-based pCO_2



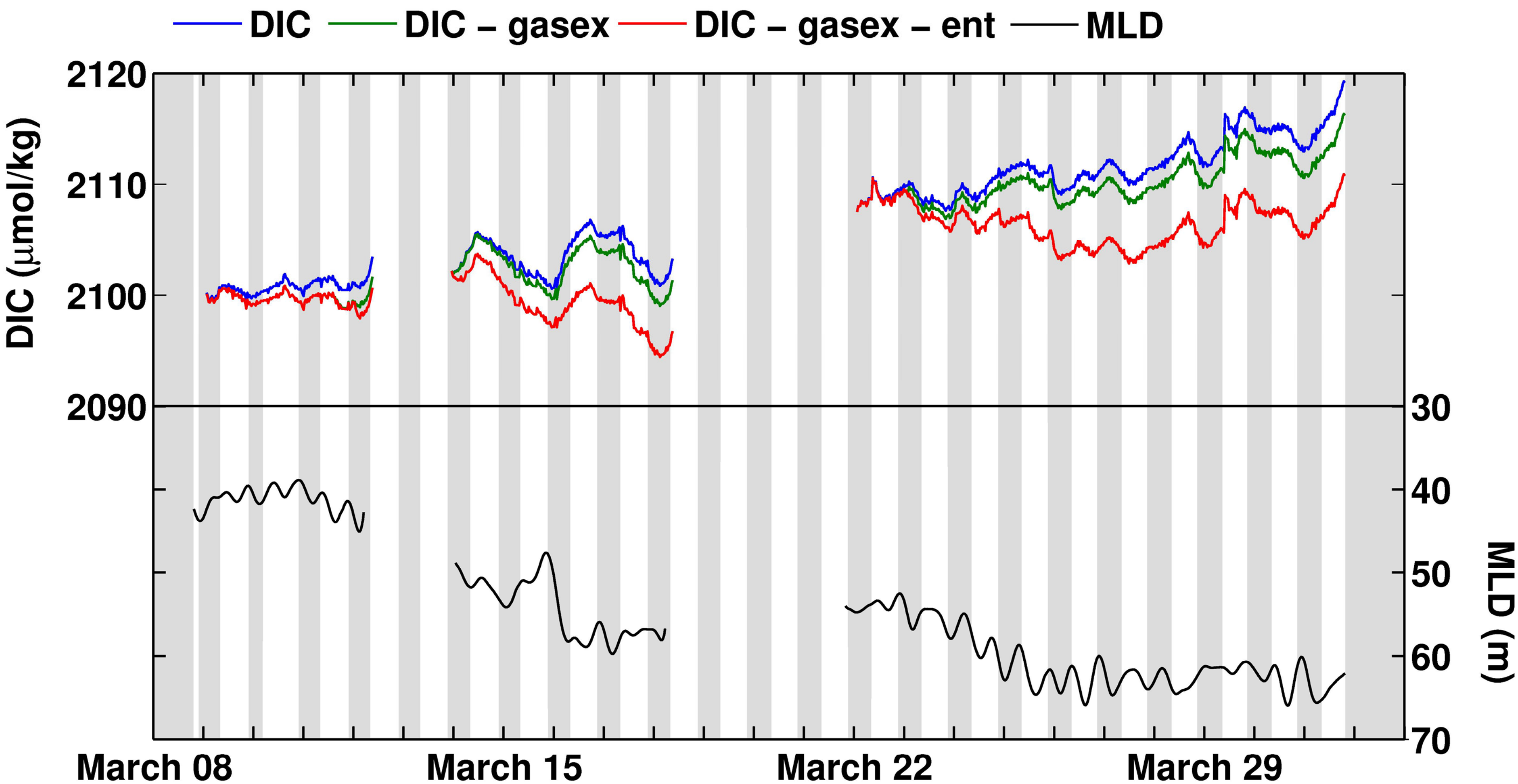
From Sabine et al.

SO GasEx: Mooring- and ship-based pCO_2



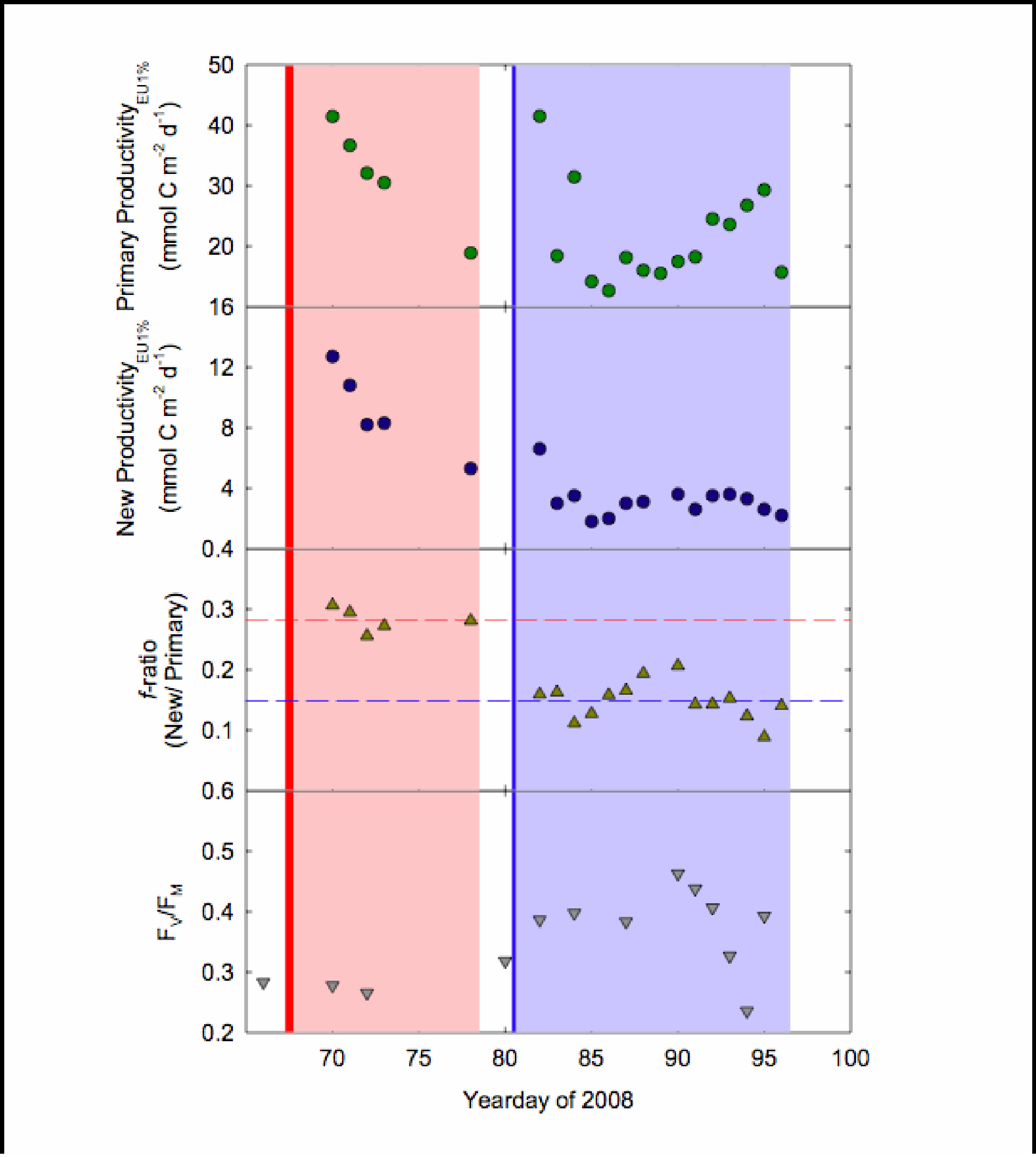
From Sabine et al.

SO GasEx: Mooring-based carbon chemistry



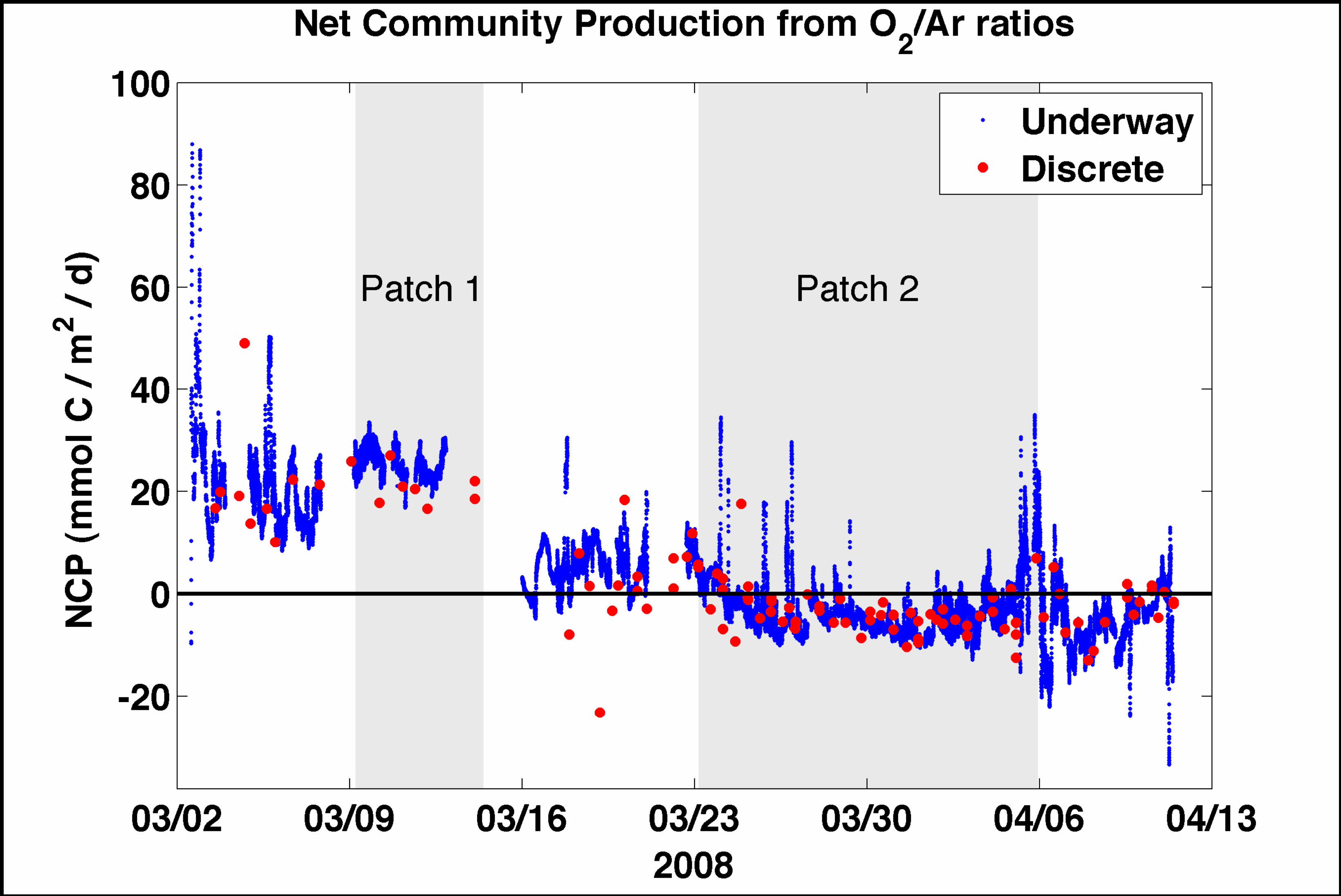
Moore and DeGrandpre (5m data)

SO GasEx: ^{14}C and ^{15}N productivity measurements



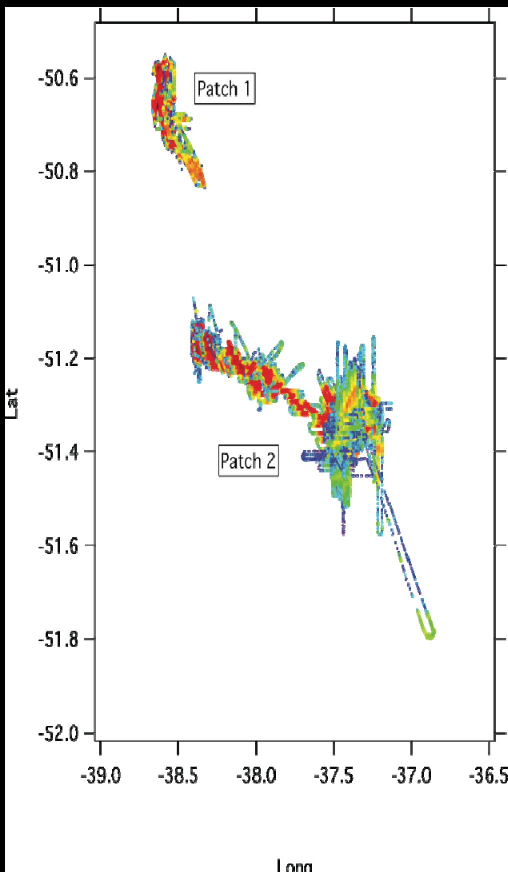
Lance, Strutton, Vaillancourt and Hargreaves

SO GasEx: O_2/Ar measurements

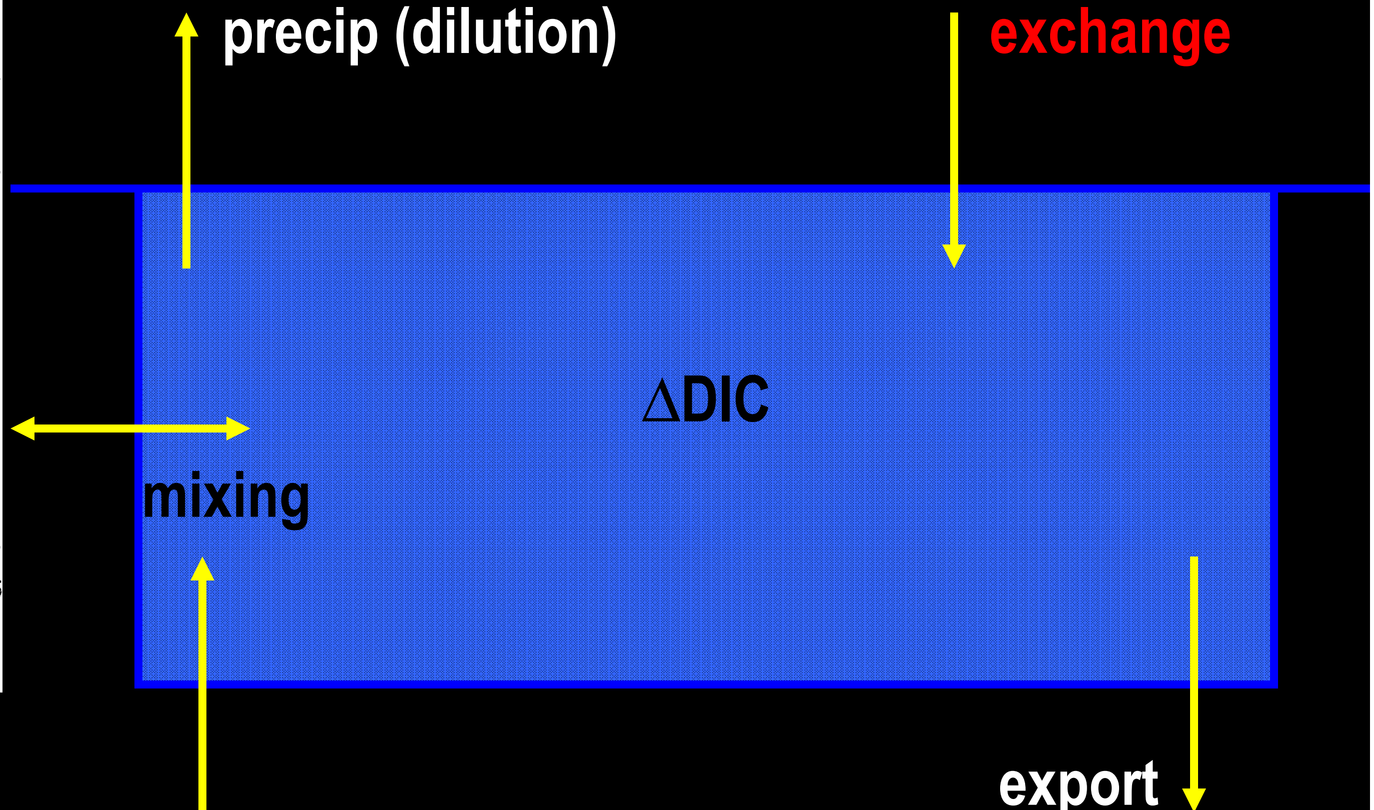


Hamme and Bender

Constructing a mixed layer carbon budget



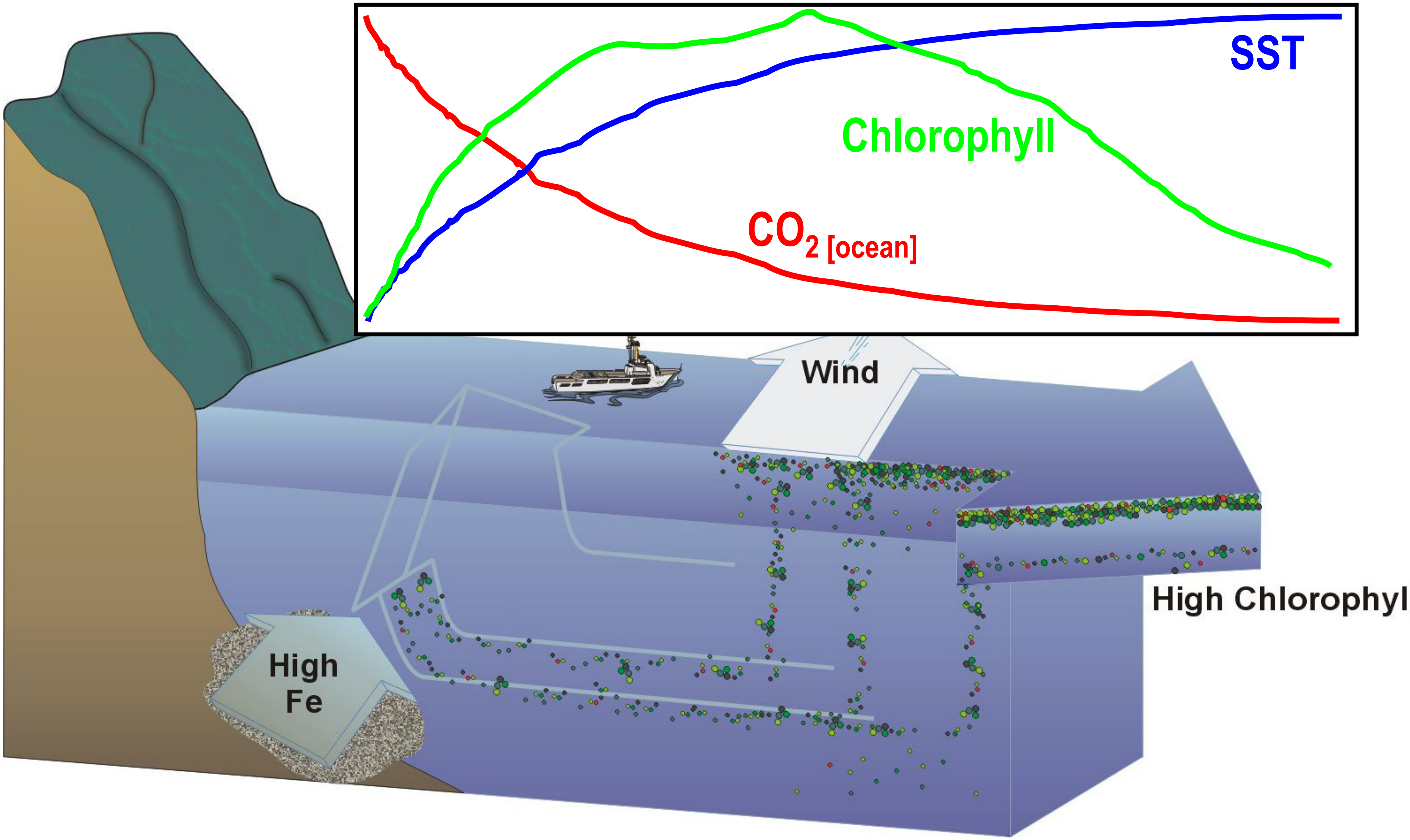
$F = k\,\alpha\,\Delta pCO_2$



Part 2: Satellite techniques for oceanic pCO_2

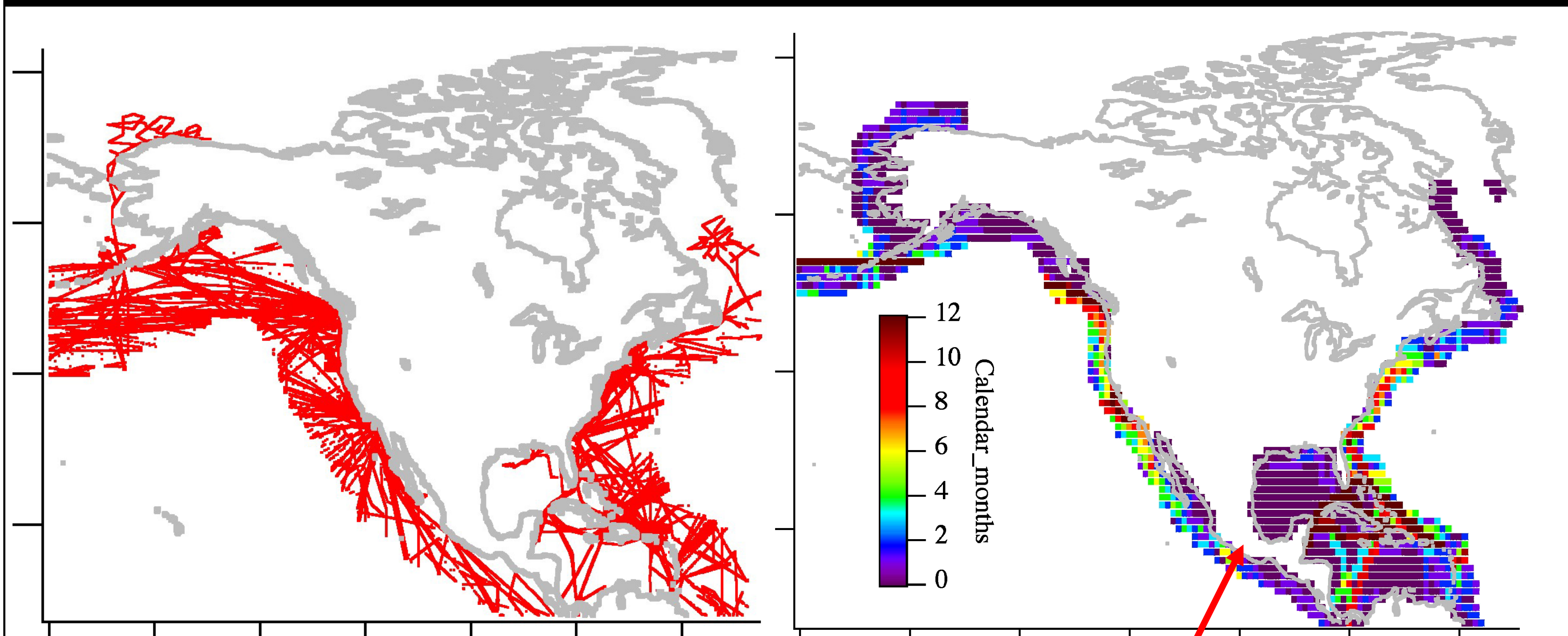
Global CO_2 flux

Global CO_2 data coverage



SST
Chlorophyll
$CO_{2\ [ocean]}$
Wind
High Chlorophyll
High Fe

North American west coast almost neutral



9 Tg C yr^{-1} source to the atmosphere

Overview of satellite algorithm development

Calculate fluxes

Central America changes from 9 Tg $year^{-1}$ source to 1.5 Tg $year^{-1}$sink

Chavez *et al*., SOCCR 2007:

8°N to 55°N, -13 Tg C $year^{-1}$

This analysis:

5°N to 50°N, -30 Tg C $year^{-1}$

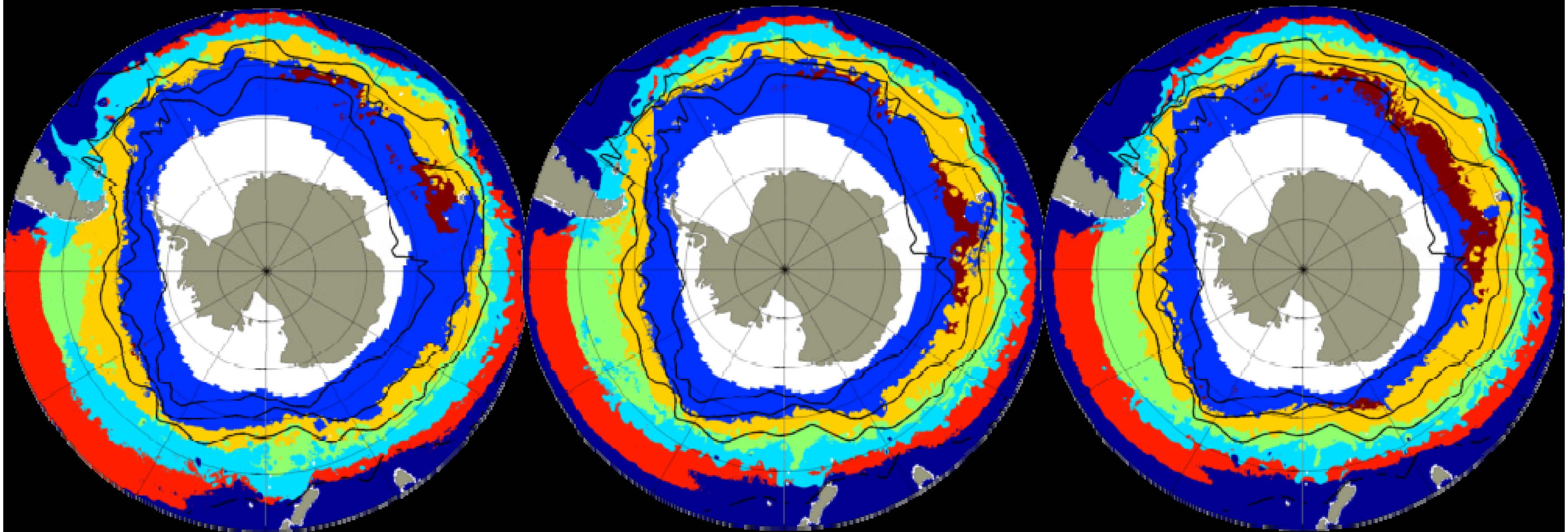
Why might this better than other observational methods?

In some (many) places there **are no observations:**
_______ pCO_2 from co-varying parameters is a way forward

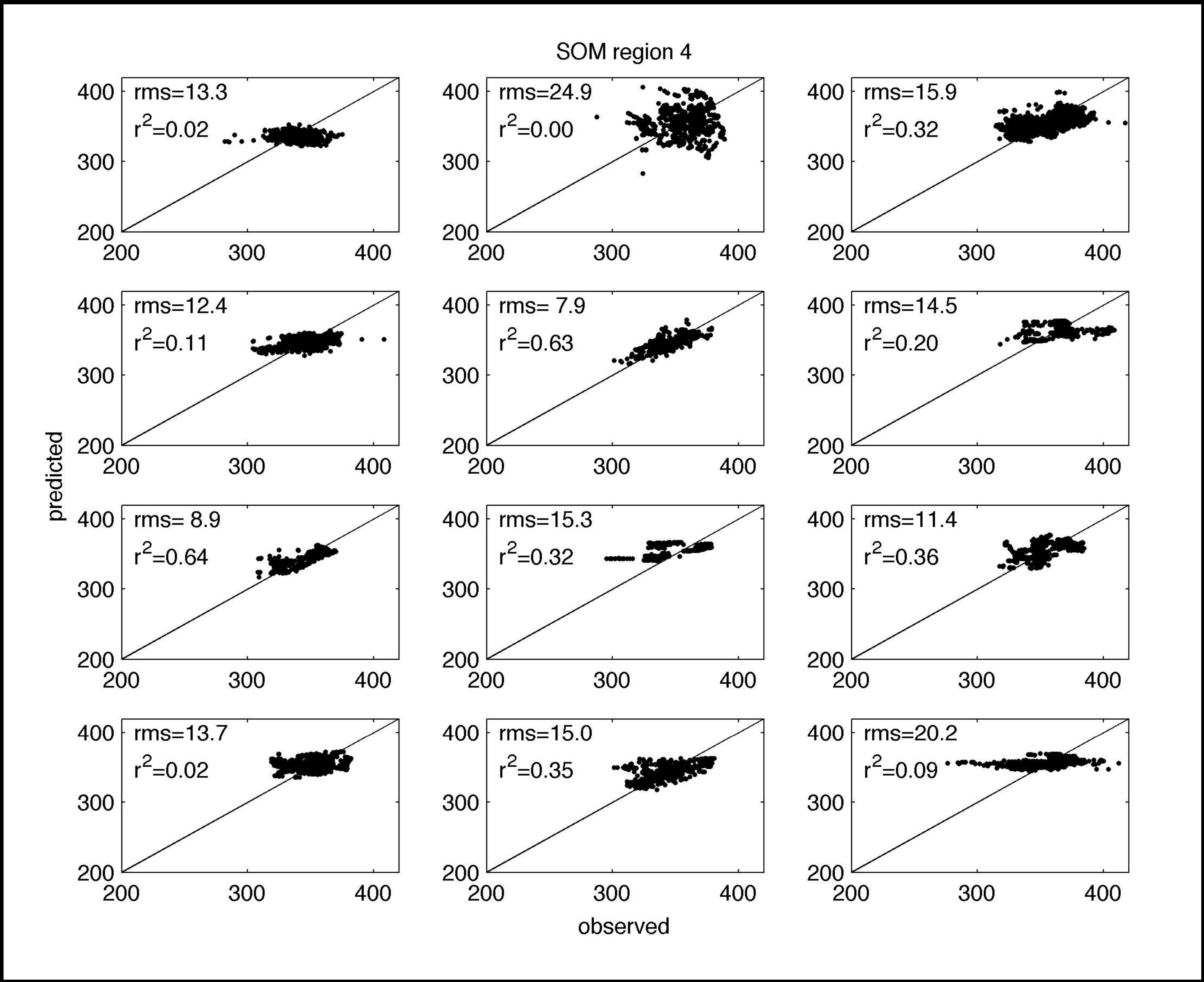
We can investigate smaller spatial scales:
Limited by the resolution of the satellite data (kilometers), not sparse observations (~10^2 to 10^3 km)

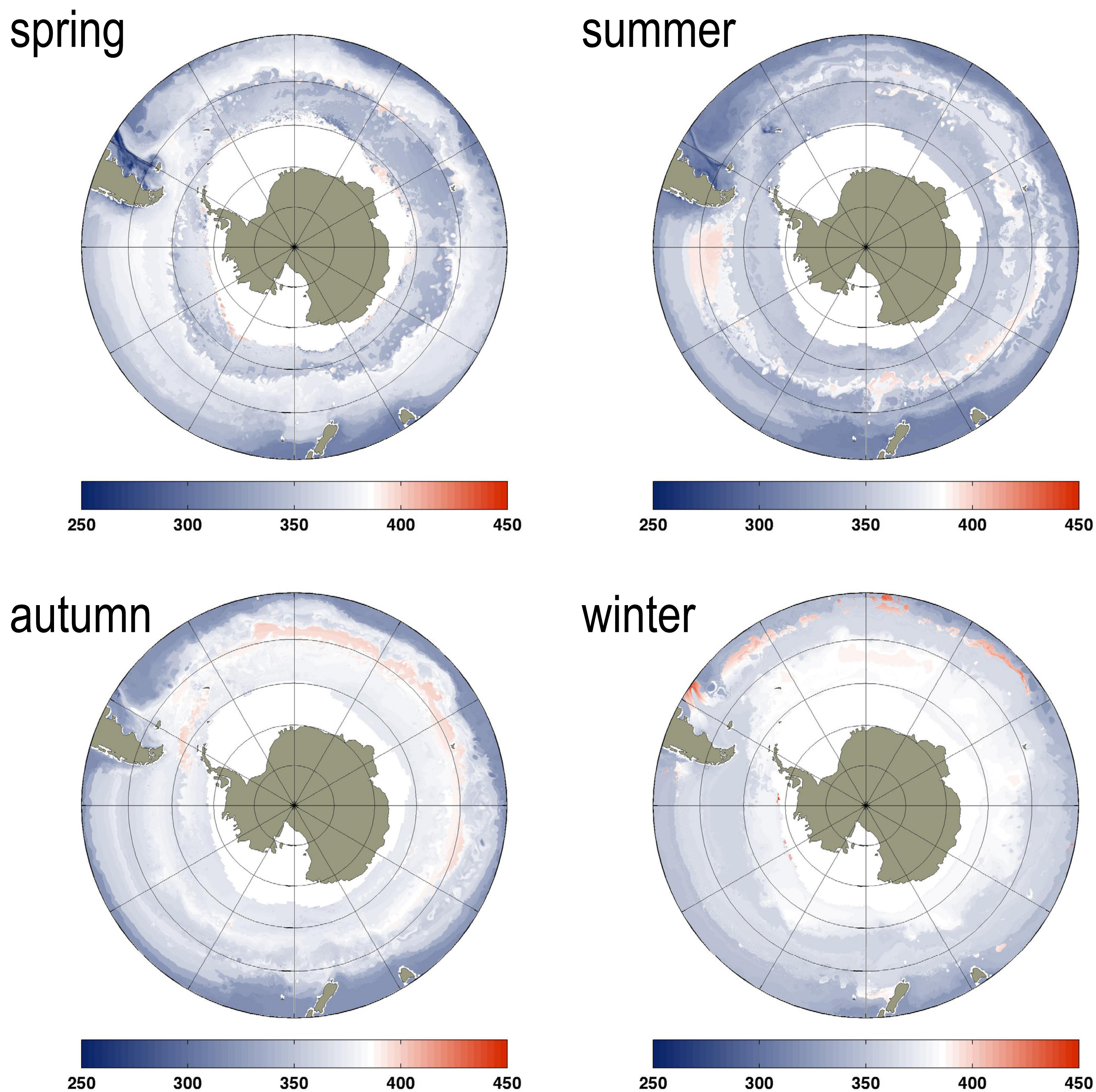
We can investigate seasonal and interannual variability:
Links to long term changes in forcing: Southern Ocean winds

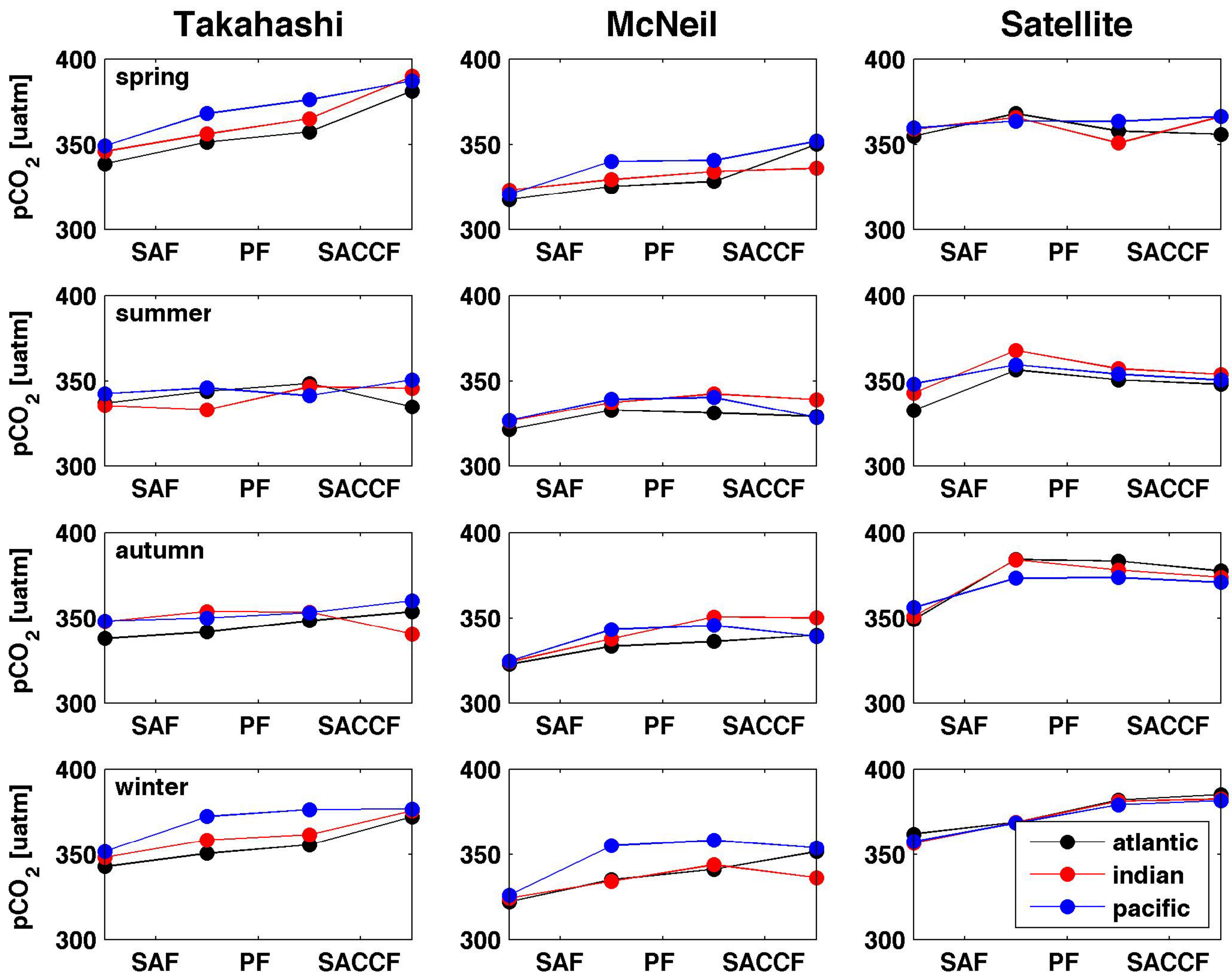
Southern Ocean Self Organized Maps (SOMs)



Accuracy of regional algorithms

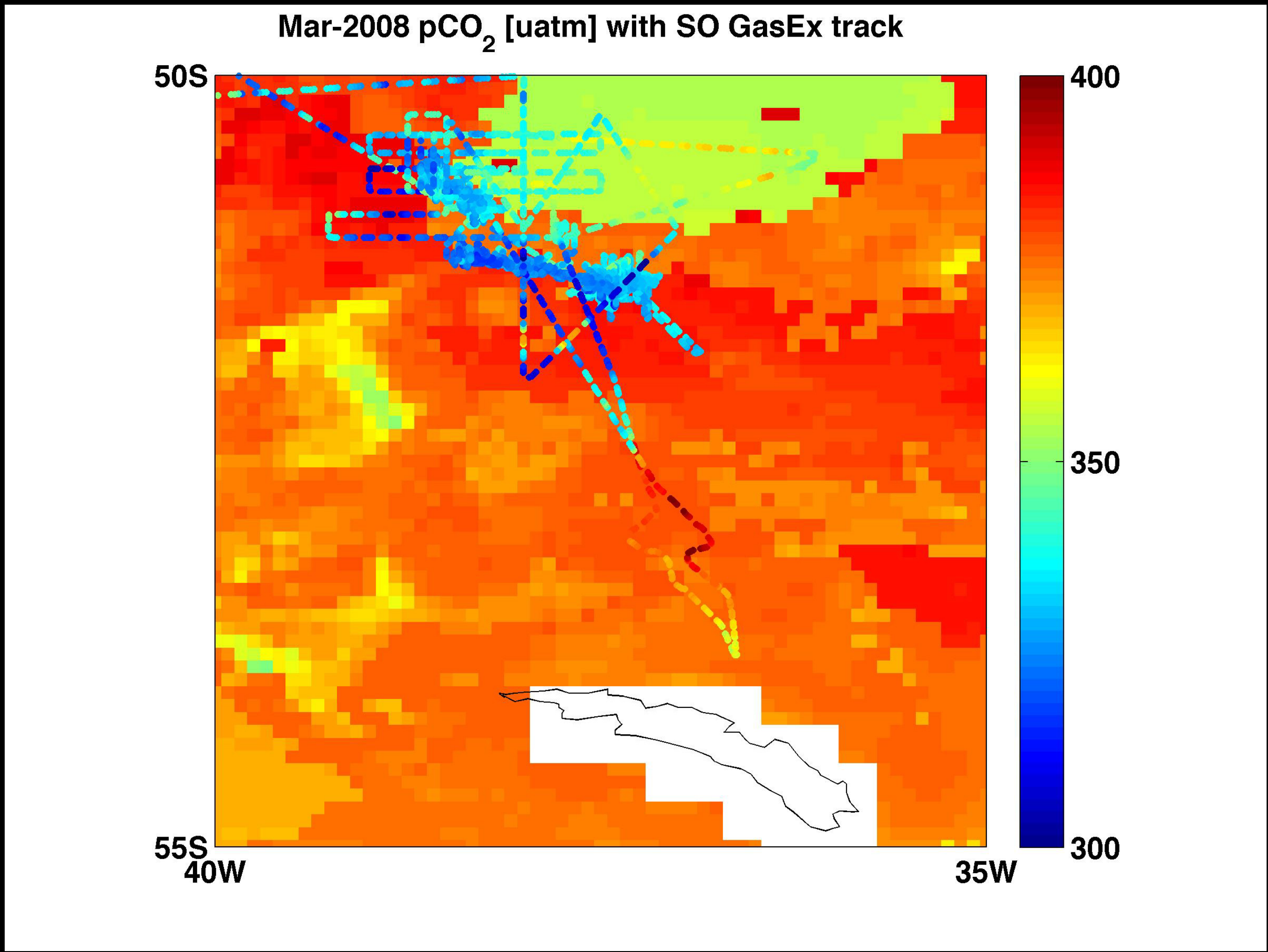



spring
summer
autumn
winter
250
300
350
400
450

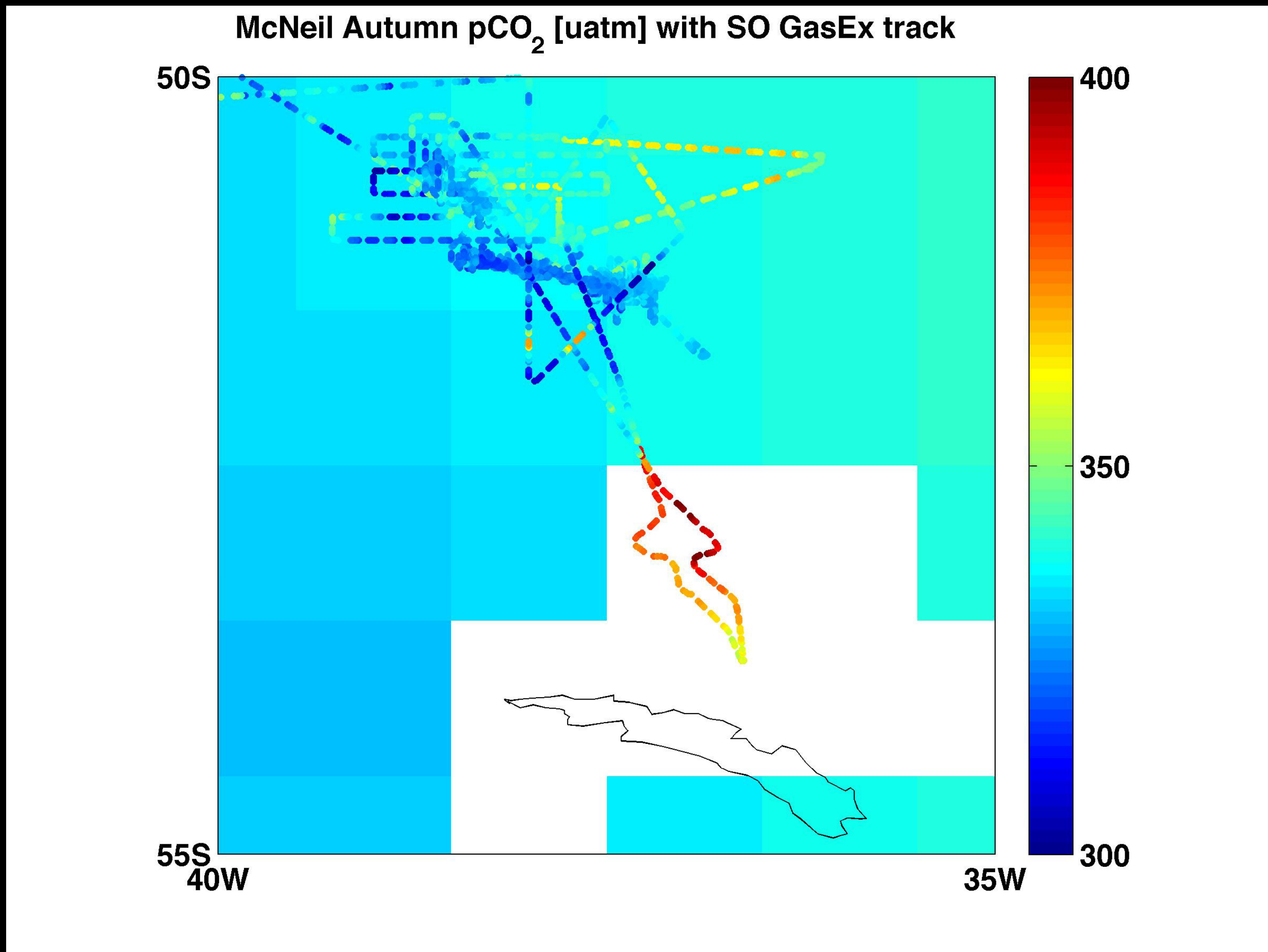


Takahashi
McNeil
Satellite
spring
summer
autumn
winter
pCO2 [uatm]
400
350
300
SAF
PF
SACCF
atlantic
indian
pacific

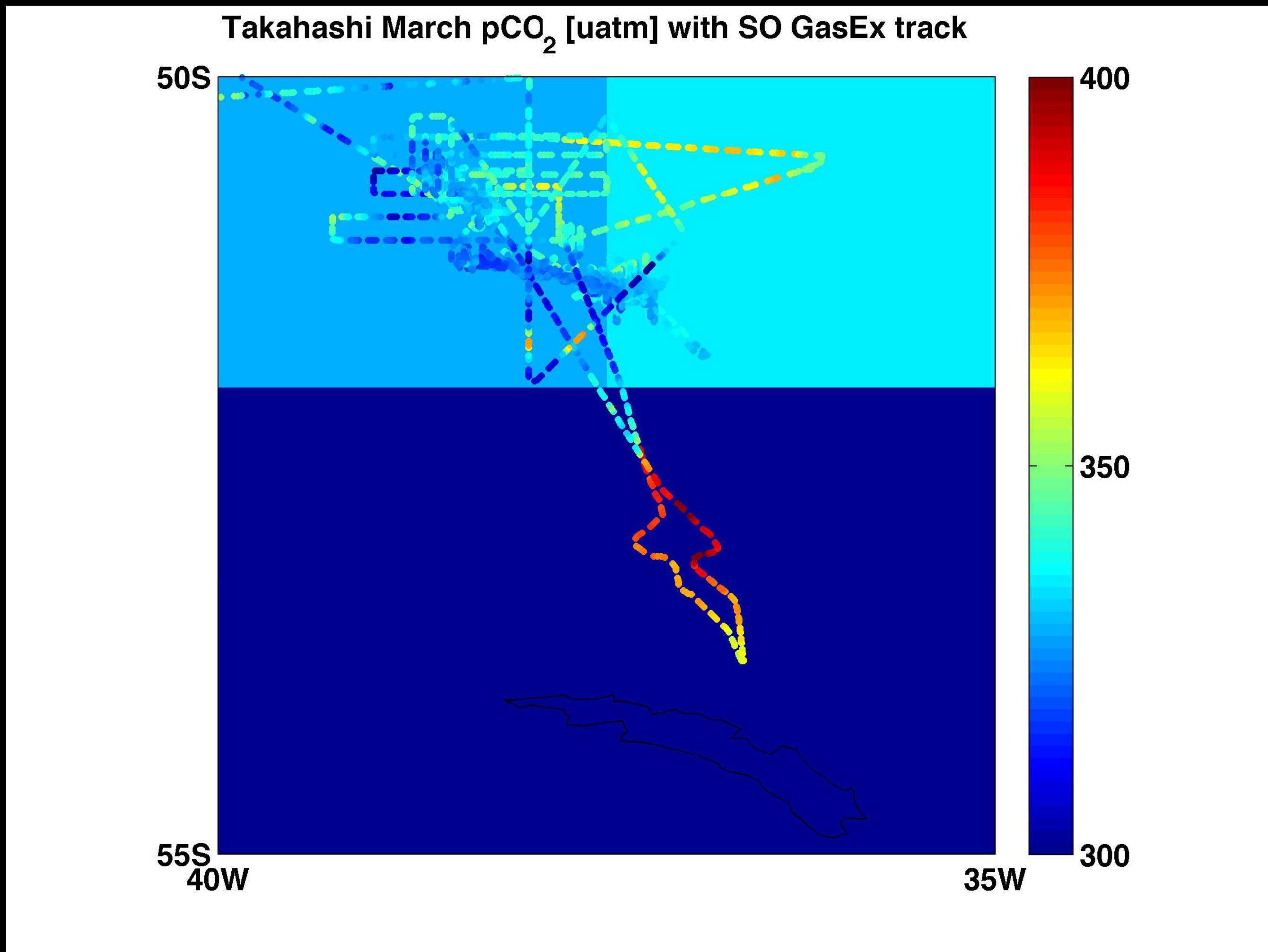
SO GasEx observations *cf* satellite predictions



SO GasEx observations *cf* McNeil



SO GasEx observations *cf* Takahashi



Expanded observations

Conclusions and future work

Despite 3 million global observations of pCO_2, uncertainties remain:

In the link between ΔpCO_2 and fluxes

In pCO_2 for many regions: In particular the Southern Ocean

Field efforts are helping to refine the gas transfer velocity

Measurement campaigns are helping to fill in some data gaps

Satellite algorithms offer a way to fill gaps and better quantify spatial and temporal variability

Next: Seasonal and interannual variability

More rigorous comparison with climatologies and models.

[redacted]

Estimating pCO_2

$$\begin{bmatrix} alk \\ DIC \\ t_0 \\ mixing \\ \ldots \end{bmatrix} = \begin{bmatrix} p_0 \\ latitude \\ longitude \\ seasonality \\ \ldots \end{bmatrix} \begin{bmatrix} 1 & a_1 & a_2 & a_3 \\ 1 & b_1 & b_2 & b_3 \\ 1 & c_1 & c_2 & c_3 \\ 1 & d_1 & d_2 & d_3 \\ \ldots & & & \end{bmatrix} \longrightarrow pCO_2$$

Develop and apply regional algorithms