Spacebased Carbon Dioxide Fugacity in Sea

Xiaosu Xie and W. Timothy Liu

Jet Propulsion Laboratory , California Institute of Technology, Pasadena, CA

Email: xiaosu.xie@jpl.nasa.gov, w.timothy.liu@jpl.nasa.gov

1. Background

The air-sea exchange in CO2 (F) is

$F=k\alpha(\Delta pCO2)$

where k is CO2 gas transfer (piston) velocity, α is solubility of CO2 in seawater, and $\Delta pCO2=pCO2_{sea}-pCO2_{air}$.

The difference between the fugacity (fCO2) and partial pressure (pCO2) of CO2 is generally negligibly small compared with the uncertainties of measurement accuracy. In this study, we do not distinguish between the two parameters. Relations between $pCO2_{sea}$ and oceanic parameters are developed with co-incident measurements on cruises in the past studies. As shown in Fig. 1, the correlation coefficients between climatological annual cycle of $pCO2_{sea}$ and the oceanic parameters change from positive to negative over various regions. The significance of the parameters in affecting the fugacity varies with location and season. A single universal linear or polynomial regression, as derived in the previous studies, would not work over global ocean across all seasons.

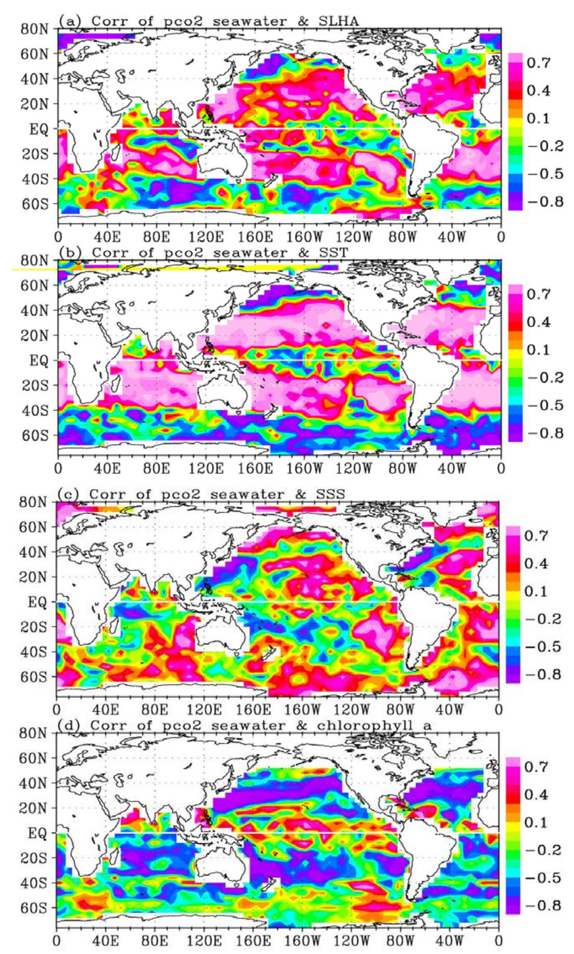


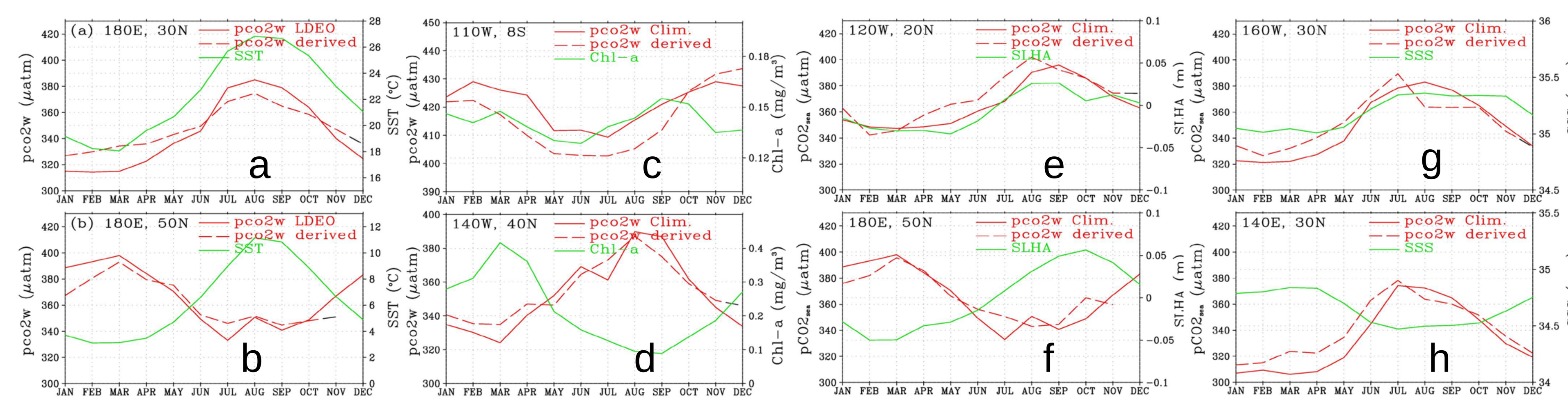
Fig. 1 Correlation coefficients between $pCO2_{sea}$ and (a) sea level height anomaly (SLHA), (b) sea surface temperature (SST), (c) sea surface salinity (SSS), and (d) Chl-a, derived from the gridded climatological data by Takahashi et al. (2009) and the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) Chl-a.

2. Statistical Model

A statistical model was developed using support vector regression to derive weekly $pCO2_{sea}$ from SST measured by the Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E), SLHA from merged altimeter data, Chl-a from SeaWiFS, and climatological salinity. The day of year, longitude and latitude are also included in the training as input.

Fig. 2 shows that the statistical model picks up seasonal and geographical dependence of the relation between $pCO2_{sea}$ and the oceanic parameters.

Fig. 2 Time series of climatological $pCO2_{sea}$ (solid red), derived $pCO2_{sea}$ (dashed red), and SST (green) at (a) 180ºE, 30ºN, and (b) 180ºE, 50ºN. Derived $pCO2_{sea}$ (dashed red) and Chl-a (green) at (c) 110ºW, 8ºS, and (d) 140ºW, 40ºN. Derived $pCO2_{sea}$ (dashed red) and SLHA (green) at (e) 120ºW, 20ºN, and (f) 180ºE, 50ºN. Derived $pCO2_{sea}$ (dashed red) and SSS (green) at (g) 160ºW, 30ºN, and (h) 140ºE, 30ºN.



3. Validation

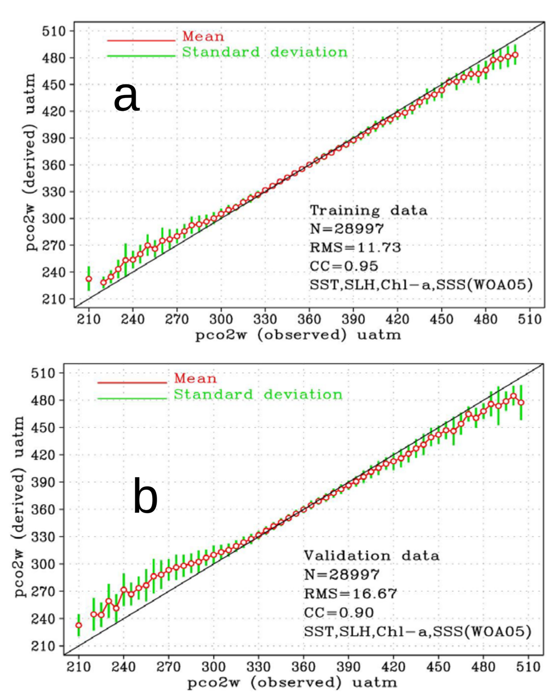


Fig. 3 Bin average of derived $pCO2_{sea}$, as a function of observed $pCO2_{sea}$ for (a) training, and (b) validation data. Standard deviation is superimposed on each bin average as error bars.

4. Spring Bloom

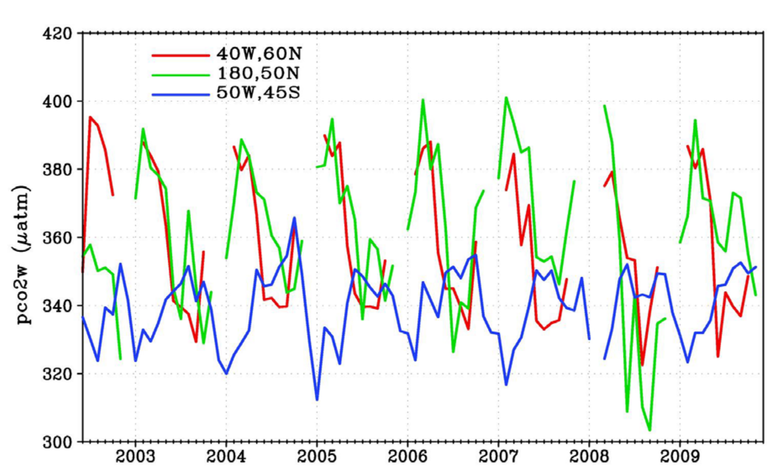


Fig. 4 Time series of derived $pCO2_{sea}$ at 40ºW, 60ºN (red), 180º, 50ºN (green), and 50ºW, 45ºS (blue). $pCO2_{sea}$ at high latitudes of Pacific and Atlantic shows spring bloom and reaches minima during summer.

5. Interannual Signal (El Nino)

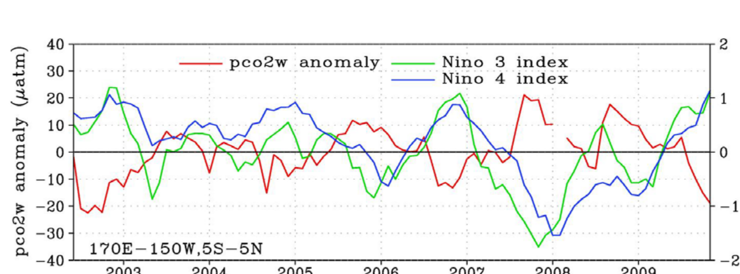


Fig. 5 Time series of interannual anomalies of derived $pCO2_{sea}$, with annual cycle removed, averaged between 170ºE - 150ºW, 5ºS - 5ºN (red), compared with Nino 3 (green) and Nino 4 (blue) index. The $pCO2_{sea}$ anomalies at the equatorial Pacific are highly correlated with the ENSO cycle.

6. Decadal Signal (Pacific Decadal Oscillation)

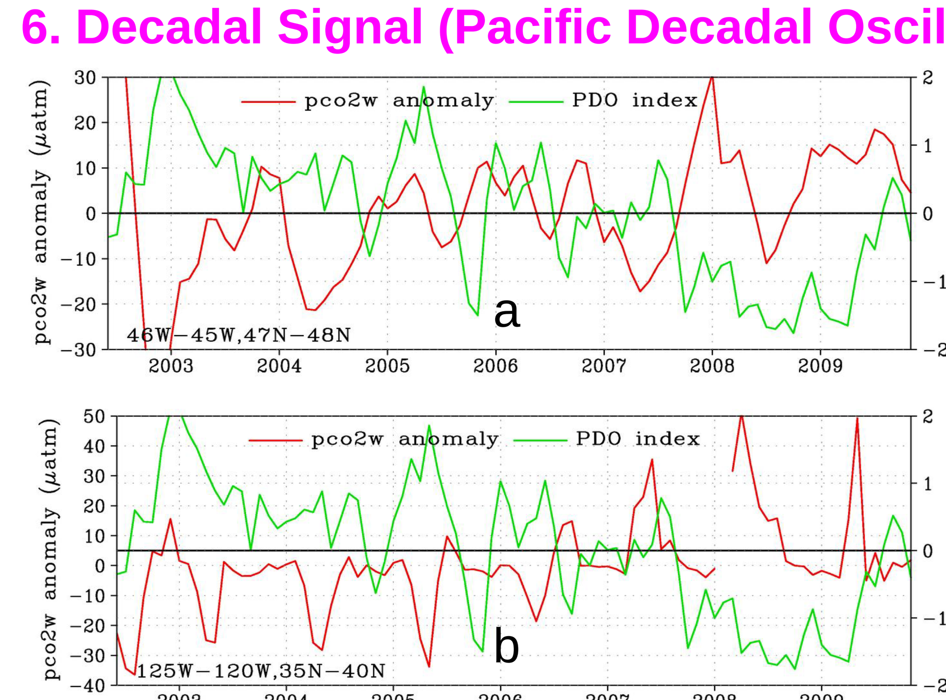


Fig. 6 Time series of interannual anomalies of derived $pCO2_{sea}$ (red) averaged between (a) 46ºW - 45ºW, 47ºN - 48ºN, and (b) 125ºW - 120ºW, 35ºN - 40ºN and PDO index (green). The $pCO2_{sea}$ anomalies at the California coast in Pacific and east of Grand Banks in Atlantic are negatively correlated with the PDO index.

7. Comparison with climatology

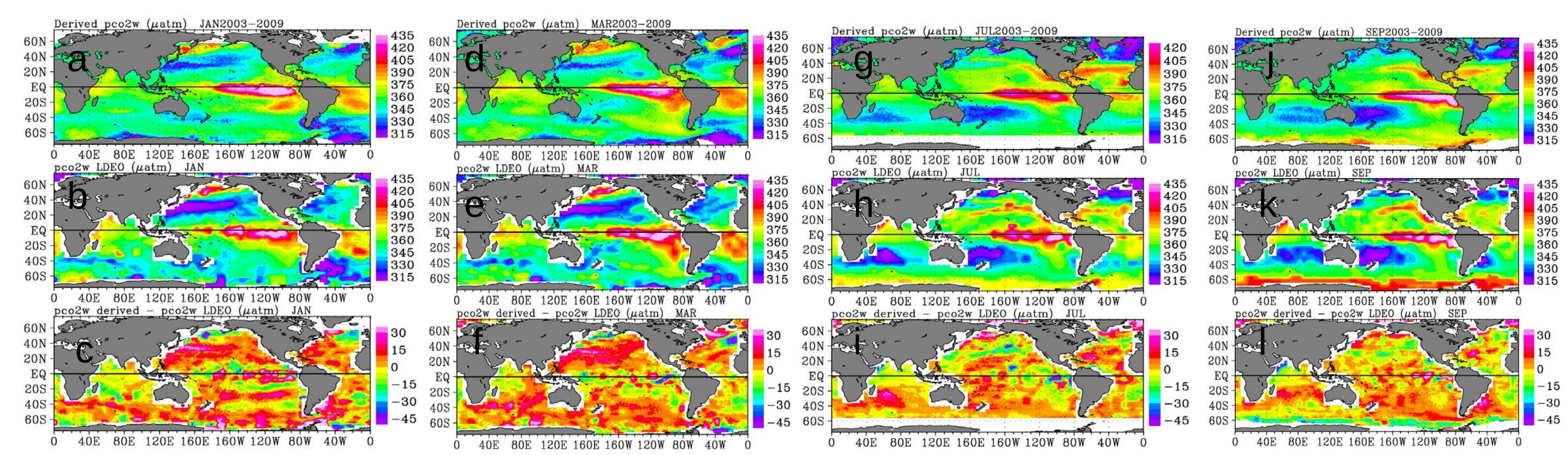


Fig. 7 Average of derived $pCO2_{sea}$, for (a) January, (d) March, (g) July, and (j) September 2003-2009. Climatilogical $pCO2_{sea}$ for (b) January, (e) March, (h) July, and (k) September. Difference of derived and climatoligical data for (c) January, (f) March, (i) July, and (l) September. It shows that the model retrieved $pCO2_{sea}$ agrees with climatology where there are sufficient training data.

8. Summary

- A statistical model to estimate ocean surface carbon dioxide fugacity ($pCO2_{sea}$) was developed.
- Comparison of 28997 validation data and coincident retrieved data gives a rms difference of 16.7 for a range of 300 µatm.
- 8 years of fugacity at weekly and half degree resolution over global oceans are derived.
- Data from the model pick up annual, interannual (ENSO), and decadal (PDO) variations.
- 8 year means show major features of climatology.
- More pCO2 data are being seeked to fill geographic gaps for improving the model.