README FILE

Global sea-air CO_2 fluxes determined from a ΔpCO_2 climatology and monthly anomalies in SST and wind

Introduction

This file describes the method and data used to create the global monthly sea-air CO_2 flux product. The basic principle of the approach is that we use the monthly sea-air CO_2 flux climatology from Takahashi et al. (2009) as the basis to estimate interannual variability in sea-air CO_2 fluxes. Then applying subannual relationships between sea surface temperature (SST) and partial pressure of CO_2 in surface water (pCO_{2SW}) from this climatology we estimate the pCO_{2SW} for the other years from the sea surface temperature anomaly compared to the SST for reference year 2000. Details can be found in Lee et al. (1998) and Park et al. (2006, 2010a, 2010b).

In equation form we derive the surface water pCO_2 for each month ($pCO_{2SW_{ym}}$):

$$pCO_{2SW_{ym}} = [pCO_{2SW_{2000m}} + (\delta pCO_{2SW}/\delta SST)_{2000m} \times \Delta SST_{ym-2000m}]$$

where *ym* is the year and month, and subscript *2000m* refers to the month in 2000.

The flux in turn is determined from:

$$F_{ym} = k_{ym} K_{0\,ym} \{pCO_{2SW_{ym}} - pCO_{2AIR_{2000m}}\} = k_{ym} K_{0\,ym} \Delta pCO_{2_{ym}}$$

The solubility $K_{0\,ym}$ is determined from monthly SST and climatological salinity estimates using the solubility equations of Weiss (1974). We estimate the monthly gas transfer velocity, k_{ym} from the second moment of monthly mean wind speed and the gas transfer coefficient:

$$k_{ym} = 0.22 \times \langle U_{10\,ym}^2 \rangle (Sc_{ym}/660)^{-0.5}$$

where $\langle U_{10\,ym}^2 \rangle$ the second moment of the wind at 10m above sea surface representing the variance of the 6-hourly wind speeds for each grid cell over *ym*, and Sc is Schmidt number. The proportionality coefficient of 0.22 is derived from the coefficient of 0.26 for monthly mean wind speed ($\langle U_{10} \rangle$) and $\langle U_{10}^2 \rangle / \langle U_{10} \rangle^2$ of 1.2 (0.26/1.2 = 0.22) used by Takahashi et al. (2009). The coefficient of 0.26 differs from that of 0.39 proposed by Wanninkhof (1992) and is based on an updated global gas transfer velocity based on the partitioning of the global bomb-^{14}C inventory between atmosphere and ocean utilizing an global ocean circulation model (Sweeney et al. 2007). In the polar regions where sea-ice forms seasonally, k_{ym} was multiplied by (1–f), where f is the fractional sea-ice cover.

Details on inputs used in this product

1. The time period covered is from 1982-2009
2. The basis ΔpCO_2 climatology is that of Takahashi et al. (2009). The data is obtained from www.ldeo.columbia.edu/res/pi/CO2/carbondioxide/pages/air_sea_flux_2009.html. This product is at monthly resolution on a 4˚ by 5˚ grid.

3. For each grid cell optimum subannual relationships are created to determine $(\delta pCO_{2SW}/\delta SST)_{2000m}$. Optimum subannual pCO_{2SW}-SST relationships are made from at least three consecutive monthly values according to the annual patterns of pCO_{2SW} and SST in each grid cell. Therefore, each grid cell has from one to four subannual relationship(s). Mean correlation coefficient (R2) for total grid cells is 0.83 ± 0.14.

Total # of grid cells: (except the central and eastern Equatorial Pacific)	1665	
# grid cells with 1 subannual relationship:	292	(18 %)
# grid cells with 2 subannual relationships:	405	(24 %)
# grid cells with 3 subannual relationships:	845	(51 %)
# grid cells with 4 subannual relationships:	123	(7 %)

4. The SST's are the NOAA Optimum Interpolation (OI) Sea Surface Temperature (SST) V2 processed from 1982 onward. The monthly 1^o x 1^o data (180x360) is binned and averaged onto a 4^o x 5^o grid. The original data source is: (http://www.cdc.noaa.gov/data/gridded/data.noaa.oisst.v2.html)

5. The wind speed is the 6-hour (4 times a day) NCEP/DOE Reanalysis 2 product in Gaussian grid processed from 1982 onward. The statistical analysis uses all wind data within each 4x5 cell, properly masked for land. NCEP Reanalysis 2 data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at: http://www.cdc.noaa.gov/data/gridded/data.ncep.reanalysis2.html

6. The monthly fractional sea-ice cover values for each $4^o \times 5^o$ grid cell are obtained from the NCEP/DOE reanalysis 2 surface ice concentration fields (ftp://ftp.cdc.noaa.gov/Datasets/ncep.reanalysis2/gaussian_grid/). The original data are re-gridded to a $4^o \times 5^o$ grid and averaged for each month in each grid cell. Following the convention in Takahashi et al. (2009) each grid cell is regarded as a sea-ice-free area when the ice cover value is less than 0.1. In the case that the ice cover value is over 0.9, we assume that each grid cell has 10% ice-free open water (f = 0.9) because of leads and polynyas where CO_2 is exchanged across the sea-air interface (Takahashi et al., 2009).

7. For the central and eastern Equatorial Pacific ($10^oS–6^oN$, $165^oE–280^oE$ (= 80^oW)) where we have significant data we used the equations updated and extended through 2008 from those of Feely et al. (2006) who provide unique algorithms between pCO_{2SW}-SST for El Niño and Non-El Niño periods for three different time periods. Mean atmospheric pCO_2 values for estimating ΔpCO_2 in each grid cell of the central and eastern Equatorial Pacific are obtained from GLOBALVIEW-CO2, 2009.

References

Feely, R. A., T. Takahashi, R. Wanninkhof, M. J. McPhaden, C. E. Cosca, and S. C. Sutherland (2006), Decadal variability of the air-sea CO_2 fluxes in the equatorial pacific ocean, J. Geophys. Res., 111, doi:10.1029/2005JC003129

GLOBALVIEW-CO2. (2009), Cooperative Atmospheric Data Integration Project - Carbon Dioxide. CD-ROM, NOAA ESRL, Boulder, Colorado [Also available on Internet via anonymous FTP to ftp.cmdl.noaa.gov, Path: ccg/co2/GLOBALVIEW].

Lee, K., R. Wanninkhof, T. Takahashi, S. Doney, and R. A. Feely (1998), Low interannual variability in recent oceanic uptake of atmospheric carbon dioxide, Nature, 396, 155–159.

Park, G.-H., K. Lee, R. Wanninkhof, and R. A. Feely (2006), Empirical temperature-based estimates of variability in the oceanic uptake of CO_2 over the past 2 decades, J Geophys. Res., 111, doi:10.1029/2005JC003090.

Park, G.-H., R. Wanninkhof, and J. Triñanes (2010a), Procedures to create near real-time seasonal air-sea CO_2 flux maps. NOAA Tech. Memo., OAR AOML–98, 14pp.

Park, G.-H., R. Wanninkhof, S. C. Doney, T. Takahashi, K. Lee, R. A. Feely, C. L. Sabine, J. Triñanes, and I. D. Lima (2010b), Variability of global net sea-air CO_2 fluxes over the last three decades using empirical relationships, Tellus, 62B, in press.

Sweeney, C., E. Gloor, A. R. Jacobson, R. M. Key, G. McKinley, J. L. Sarmiento, and R. Wanninkhof (2007), Constraining global air-sea gas exchange for CO_2 with recent bomb C-14 measurements, Global Biogeochemical Cycles, 21, doi:10.1029/2006GB002784.

Takahashi, T., S. C. Sutherland, R. Wanninkhof, C. Sweeney, R. A. Feely, D. W. Chipman, B. Hales, G. Friederich, F. Chavez, C. Sabine, A. Watson, D. C. E. Bakker, U. Schuster, N. Metzl, H. Y. Inoue, M. Ishii, T. Midorikawa, Y. Nojiri, A. Koertzinger, T. Steinhoff, M. Hoppema, J. Olafsson, T. S. Arnarson, B. Tilbrook, T. Johannessen, A. Olsen, R. Bellerby, C. S. Wong, B. Delille, N. R. Bates, H. J. W. de Baar, and (2009), Climatological mean an decadal change in surface ocean pCO_2, and net sea-air CO_2 flux over the global oceans, Deep-Sea Res., Part II, 56, 554–577.

Wanninkhof, R. (1992), Relationship between gas exchange and wind speed over the ocean, J. Geophys. Res., 97, 7373–7381.

Weiss, R. F. (1974), Carbon dioxide in water and seawater: The solubility of a non-ideal gas, Mar. Chem. 2, 203–215.