TransCom 3: Seasonal CO2 Flux Estimates from Atmospheric Inversions (Level 2)

Get Data

Summary:

This data set provides model outputs and seasonal mean CO_2 fluxes from the Atmospheric Carbon Cycle Inversion Intercomparison (TransCom 3), Level 2 inversion experiment. Inversion methods can be used to estimate surface CO2 fluxes from atmospheric CO2 concentration measurements, given an atmospheric transport model to relate the two. This Level 2 experiment inverted for the spatial and temporal pattern of the residual CO2 sources and sinks.

There were 12 atmospheric tracer transport models utilized in this experiment. The data inverted were mean CO2 concentration data from 75 sites from the GLOBALVIEW-CO2 2000 data set for the period 1992-1996. The seasonal inversion consists of a 3 year forward simulation (365 days per year) containing 4 presubtracted tracers, 11 SF6 tracers, and 22 CO2 tracers (11 terrestrial, 11 oceanic) (Gurney et al., 2000). Carbon fluxes were estimated for each month of an average year determined as the mean of the 1992-1996 time period from an intercomparison of 12 different atmospheric tracer transport models.

This data set provides the following TransCom 3, Level 2 products:

- Input Data (see the companion file transcom3_level1_readme.pdf for more detail):
    - 1990 and 1995 fossil-fuel pre-subtraction emission maps: The annual mean emissions from fossil-fuel burning, hydraulic cement production, and gas flaring in 1990 and 1995, respectively.
    - Neutral biosphere pre-subtraction maps: Net ecosystem production (NEP) pre-subtraction carbon exchange flux maps, one for each month.
    - Ocean exchange pre-subtraction maps: Net ocean pre-subtraction carbon exchange flux maps, one for each month.
    - Terrestrial carbon basis functions: Terrestrial carbon basis function flux maps, one for each terrestrial region.
    - Ocean carbon basis functions: Ocean basis function flux maps, one for each ocean region and month.
    - SF6 basis functions: SF6 basis function flux maps, one for each land region.
- Model Output from atmospheric transport models:
    - Original netCDF model submissions files of forward CO2 tracer simulations.
    - Monthly mean CO2 concentrations for each region/month combination.
- A basis function map:
    - Reflects both geographical and mechanistic elements.
- Cyclo Inversion Code provides information on:
    - The calculation of the inverse fluxes.
    - Land and ocean regions prior flux estimates.
- Estimated Fluxes (control-inversion results)

There are six compressed data files (.gz format) with this data set.

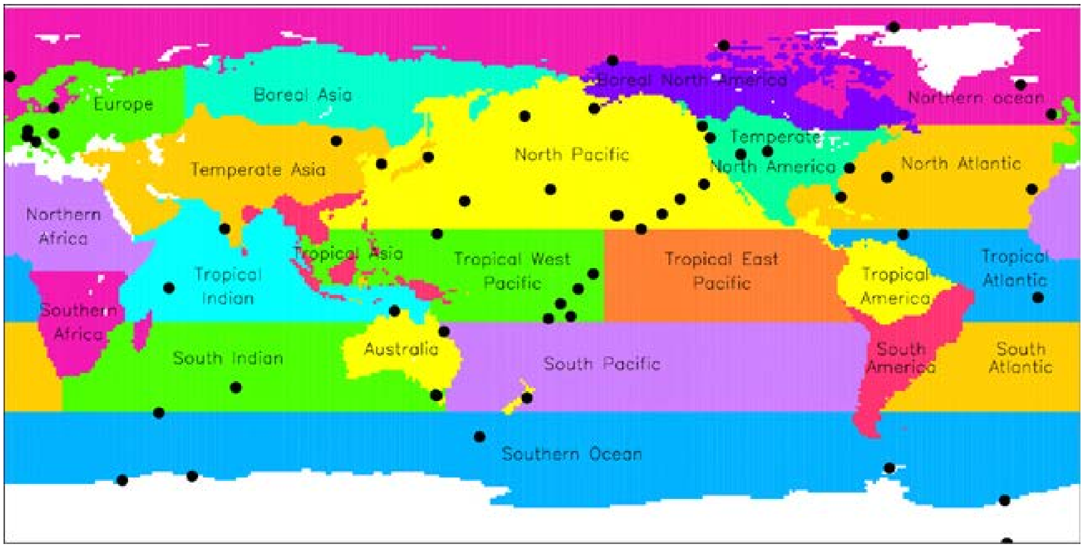

Figure 1: Regions used in the inversion and the locations of the 76 CO_2 observational records used. Multiple records exist at some locations (Gurney et al., 2002). Note: The station at Darwin, Australia (on the map, Darwin is the most northern point in Australia), was not included in the Level 2 experiment, thus there were only 75 stations used (Gurney et al., 2002).

Data Citation:

Cite this data set as follows:

Gurney, K.R., and A.S. Denning. 2013. TransCom 3: Seasonal CO2 Flux Estimates from Atmospheric Inversions (Level 2). ORNL DAAC, Oak Ridge, Tennessee, USA. http://dx.doi.org/10.3334/ORNLDAAC/1198

Table of Contents:

1. Data Set Overview

Project: TransCom

The TransCom Project was created to quantify and diagnose the uncertainty in inversion calculations of the global carbon budget that result from errors in simulated atmospheric transport, the choice of measured atmospheric carbon dioxide data used, and the inversion methodology employed. The project is part of a larger International Geosphere-Biosphere Programme (IGBP), Global Analysis, Interpretation, and Modeling (GAIM) research project which aims to develop coupled ecosystem-atmosphere models that describe time evolution of trace gases with changing climate and changes in anthropogenic forcing.

There are three completed phases of TransCom. The first phase examined the atmospheric concentration response to surface emissions of fossil fuel CO_2 and the activity of terrestrial ecosystems. The second phase, TransCom 2, examined the transport of sulfur hexafluoride (SF_6) emissions using 11 tracer transport models. The third phase, TransCom 3, Atmospheric Carbon Cycle Inversion Intercomparison, conducted a series of experiments in which leading chemical tracer transport models from around the world were used to calculate the global carbon budget of the atmosphere. There are three experiments in TransCom 3: Level 1 annual mean inversion experiments (archived at the ORNL DAAC), Level 2, seasonal cycle inversion experiments, and Level 3, interannual control inversion experiment.

This data set is from TransCom3, Level 2. The experiment inverted for the spatial and temporal pattern of the residual CO_2 sources and sinks. There were 12 atmospheric tracer transport models utilized in this experiment and each ran a series of forward CO_2 tracer simulations (Gurney et al., 2000) as greens functions in order to construct model-specific response functions used to perform the inversion. The data inverted were mean CO_2 concentration data from 75 sites from the GLOBALVIEW-CO2 2000 data set for the period 1992-1996.

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TransCom 3, Level 2 Models (refer to the companion file transcom3_level1_readme.pdf for additional information regarding the models and contributors)

Model	Modeler
CSU	Gurney and Denning
dUCB2	Fung and John
UCI (s,b)	Prather, Pak, Lee and Hannegan
JMA	Maki
MATCH: CCM3	Bruhwiler
MATCH: NCEP	Chen
MATCH: MACCM2	Law
NIES	Maksyutov
NIRE CTM-964	Taguchi
TM25	Bousquet and Peylin
TM25	Bousquet and Peylin
GCTM5	Baker

Related Data Set:

Gurney, K. R., and A. S. Denning. 2008. TransCom 3: Annual Mean CO2 Flux Estimates from Atmospheric Inversions (Level 1). Data set. Available on-line [http://daac.ornl.gov/] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A. doi:10.3334/ORNLDAAC/895.

2. Data Description:

There are six compressed files (.gz) with this data set. When the zip files are expanded, the data files are organized under subdirectory files and are in text (.txt) and NetCDF (.nc) format.

Compressed file names:

input_data_L2_all.tar.gz

original_netCDF_model_submissions.tar.gz

model_results_L2_gmatricies_all.tar.gz.

basis_function_map_all.tar.gz

inversion_results_invout_all.tar.gz

process.tdi.all.2.f

inversion_code_L2_all.tar.gz

Input Data Files

Data used to run the forward simulations are provided in the compressed file: **input_data_L2_all.tar.gz.** This file contains four files:

input.new.dat	The input.new.dat file contains the following data: fossil-fuel CO_2 pre-subtraction emissions (for 1990 and 1995, respectively); neutral biosphere pre-subtraction; ocean ex-change pre-subtraction; terrestrial carbon basis functions; ocean carbon basis functions; and SF_6 basis functions.
statlocs.revised.all.dat	CO2 monitoring station list (245 stations)
read.statlocs.f	A FORTRAN code to read the statlocs.revised.all.dat file (station location data).
takahashi_data.pdf	Information about the net oceanic pre-subtraction carbon exchange maps

Model Output Files

Original netCDF model submissions files of forward CO2 tracer simulations. A total of 268 tracers were simulated by each model. The results were used to construct model-specific response functions for use in the control inversion.

The files are provided in the compressed file **original_netCDF_model_submissions.tar.gz**. When expanded, this file contains 12 files, one for each model, under the subdirectory **original_netCDF_model_submissions.**

Subdirectory: original_netCDF_model_submissions
CSU.tar.gz
MATCH.CCM3.tar.gz
NIES.tar.gz
TM3.tar.gz
GCTM.tar.gz
MATCH.MACCM2.tar.gz
NIRE.tar.gz
UCB.tar.gz
JMA.tar.gz
MATCH.ncep.tar.gz
TM2.tar.gz
UCI.tar.gz

Model Response Functions.

These files (from each of the models) contain monthly mean CO2 concentrations for each region/month combination, for 245 stations. Eight additional sites were added, for a total of 253 stations. The files are provided for the 245 sites, and also with the eight additional sites. The files are in the compressed file **model_results_L2_gmatricies_all.tar.gz**. When expanded, this file contains 28 files under the subdirectory **model_results_L2_gmatrices_all**.

There are two files per model in NetCDF (.nc) format.

File naming convention for results run with 245 sites:

model name.investigator.L2.monthly mean.nc.

Example file name: **CSU.gurney.L2.monmean.nc**

File naming convention for results run with 253 sites:

model name.investigator.L2.253.monthly mean.nc

Example file name: **CSU.gurney.L2.253.monmean.nc**

Subdirectory: model_results_L2_gmatrices_all
Model Response Function File for 245 Stations for Each Model
CSU.gurney.L2.monmean.nc
GCTM.baker.L2.monmean.nc
GISS.prather.L2.monmean.nc
JMA-DTM.maki.L2.monmean.nc
MATCH.chen.L2.monmean.nc
MATCH.law.L2.monmean.nc
NIRE.taguchi.L2.monmean.nc
MATCH.bruhwiler.L2.monmean.nc
TM2.lsce.L2.monmean.nc
TM3.heimann.L2.monmean.nc
PCTM.zhu.L2.monmean.nc
GISS.fung.L2.monmean.nc
NIES.maksyutov.L2.monmean.nc
Model Response Function File for 253 Stations for Each Model
CSU.gurney.L2.253.monmean.nc
GCTM.baker.L2.253.monmean.nc
GISS.fung.L2.253.monmean.nc
GISS.prather.L2.253.monmean.nc
JMA-CDTM.maki.L2.253.monmean.nc
MATCH.bruhwiler.L2.253.monmean.nc

MATCH.chen.L2.253.monmean.nc
MATCH.law.L2.253.monmean.nc
NIES.maksyutov.L2.253.monmean.nc
NIRE.taguchi.L2.253.monmean.nc
PCTM.zhu.L2.253.monmean.nc
TM2.lsce.L2.253.monmean.nc
TM3.heimann.L2.253.monmean.nc
Two additional files are included with this subdirectory:
PCTM.zhu.L2.Gmat.253.txt
instuctions.txt file

Basis Function Map

A basis function map constructed to reflect both geographical and mechanistic elements. Information regarding the basis map construction, the basis function data file, a readme, the final smoothed basis map, and the GLOBALVIEW stations overlaid on the basis function map are provided in the compressed file **basis_function_map_all.tar.gz**. When expanded, this file contains eight files under the subdirectory **basis_function_map_all:**

Subdirectory: basis_function_map_all	
basis_map_construction.pdf	Provides an explanation of the methodology used to construct the basis function map
make.map.new.f	A spatial smoother routine used to generate source/sink regions with smooth, continuous boundaries
newmap.adj.jpg	Shows terrestrial regions, no smoothing applied
smoothmap2.final.2.jpg	The final smoothed basis function map
smoothmap.fix.2.bin	Basis function data file
smoothmap.readme.txt	Readme for basis function data file
supp.figure.1.jpg	Shows GLOBALVIEW stations overlaid on the basis function map
vegmap.ncar.present.jpg	The landcover classification map used as the starting point for source/sink region boundaries.

Cyclo Inversion Code

These are files used in the process of calculating the inverse fluxes and the control-inversion set-up. The files are in the compressed file **inversion_code_L2_all.tar.gz**. When expanded, this file contains the subdirectory **inversion_code_L2_all**. This subdirectory contains three files and a subdirectory **L2inv**:

Subdirectory: inversion_code_L2_all	
dat75.varunc.nc	CO2 concentration data from GLOBALVIEW 2000. One of two data files (the 2nd used is list_dat75.dat) used in the process of calculating the inverse fluxes
list_dat75.dat	A file of the 75 GLOBALVIEW 2000 stations. One of two data files (the other file is dat75.varunc.nc) used in the process of calculating the inverse fluxes
priors.L1and0.3.2Tak.nc	The land region prior flux estimates incorporate results from recent inventory studies and are identical to values used in the annual mean inversion (Level 1). The ocean region prior flux estimates were prescribed as zero for each month.
Subdirectory: L2inv.zip-- contains folder L2inv with the following two files:	
control.results	Control-inversion intercomparison
control.tdi.results	Time-dependent control-inversion

Estimated Fluxes (Cyclo Inversion (control) Results)

These are the estimated fluxes from the model output. The files are in the compressed file named **inversion_results_invout_all.tar.gz**. Within this file, there are 27 files under the subdirectory **inversion_results_invout_all.** The inversion is described as a "control inversion" because the simulations only used the observational data from the GLOBALVIEW 2000 data set for input data.

The 12 post.sources files are the individual model mean posterior fluxes for all 22 basis function regions. The files include columns for region, time, flux value, and an uncertainty.

The 12 vardump files are the complete error covariance files for each model. The file **process.tdi.all.2.f** is the source code that reads the vardump files. The key piece of code starts on line 495.

Subdirectory: inversion_results_invout_all
post.sources.CSU.gurney
post.sources.GCTM.baker
post.sources.GISS.fung
post.sources.GISS.prather
post.sources.JMA-CDTM.maki
post.sources.MATCH.bruhwiler
post.sources.MATCH.chen
post.sources.MATCH.law
post.sources.NIES.maksyutov
post.sources.NIRE.taguchi
post.sources.TM2.lsce
post.sources.TM3.heimann
vardump.CSU.gurney
vardump.GCTM.baker
vardump.GISS.fung
vardump.GISS.prather
vardump.JMA-CDTM.maki
vardump.MATCH.bruhwiler
vardump.MATCH.chen
vardump.MATCH.law
vardump.NIES.maksyutov
vardump.NIRE.taguchi
vardump.TM2.lsce
vardump.TM3.heimann

Additional files in the subdirectory: inversion_results_invout_all	
t3_grid.tar.gz	An Interactive Data Language (IDL) gridding routine that will map the model mean of a collection of model flux output.
make.output.l2.f	A new routine for writing Level 2 output to netCDF format.
post.modflux.txt	Regional monthly flux data for each model

Companion Files

- transcom3_level1_readme.pdf -Additional information about the experimental protocol and results.
- http://transcom.project.asu.edu/index.php -The TransCom project web site.

Site boundaries: (All latitude and longitude given in decimal degrees)

Site (Region)	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Global)	-180	180	90	-90

Time period:

- The data set covers the period 1990/01/01 to 1996/12/31.

Platform/Sensor/Parameters measured include:

- COMPUTER MODEL / ANALYSIS / TRACE GASES/TRACE SPECIES
- COMPUTER MODEL / ANALYSIS / CARBON DIOXIDE
- COMPUTER MODEL / ANALYSIS / SULFUR COMPOUNDS

3. Applications and Derivation

Contributors to TransCom 3 followed a detailed protocol (Gurney et al., 2000) which contains three different experimental designs. The first level (Level 1, archived by ORNL DAAC) focused on annual mean carbon sources and sinks and required a limited number of tracers using supplied input fields of regional carbon exchange. The second level (Level 2, this data set) expanded on the first by including an inverse calculation of the strength of the seasonal cycle in regional fluxes and required a much larger number of CTM tracers.

Level 1and Level 2 experiments used the the GLOBALVIEW-CO2, 2000 data for the inversion, however, Level 2 only used 75 of the 76 sites.

4. Quality Assessment

The uncertainty attached to each data value from C(D), was derived from the monthly residual standard deviation (RSD) of individual observations around a smoothed time series as given by GLOBALVIEW. This choice was based on the assumption that the distribution of RSD (higher RSD values for northern and continental sites and lower RSD values for Southern Hemisphere oceanic sites) reflects the high-frequency variations in transport and regional flux that large-scale transport models are unable to accurately simulate.

The number of inverted regions was limited to reduce random error, and the need to limit the computation burden of the forward model simulations. This was a trade-off between random error and bias.

Biases caused by transport error across all models or representation error are potential limitations to this method. However, only random errors were characterized in this study. Furthermore, interpretation is somewhat limited by examination of a single 5-year mean and the use of the single station network used.

For further discussion on the results and a comparison of results from the TransCom 3 level 1 annual results and this Level 2 seasonal experiment, please refer to Gurney et al., 2004.

5. Methods

Experimental Description

This Level 2 experiment inverted for the spatial and temporal pattern of the residual CO2 sources and sinks. There were 12 atmospheric tracer transport models utilized in this experiment. The data inverted were mean CO2 concentration data from 75 sites from the GLOBALVIEW-CO2 2000 data set for the period 1992-1996.

Experimental Steps (Refer to Gurney et al, 2002, 2003 for more details):

1) Forward simulations were run in each of the 12 models using the flux data from flux sources (described below). This provided a measure of model-model transport responses.

2) The inversion was set-up:

A) prior estimates of the fluxes in each of the 264 region/month flux combinations were determined from independent estimates of terrestrial and oceanic exchange from each of the 22 regions (see Figure 1 for the regions). Land region estimates were from recent inventory studies. Ocean estimates were prescribed as zero for each month.

B) Five-year, mean CO2 measurements for 1992-1996 at 75 sites were inverted. The data were from the GLOBALVIEW-CO2, 2000 data set.

Input Data

Input data for the forward simulations:

- 1990 and 1995 fossil-fuel pre-subtraction emission maps: The annual mean emissions from fossil-fuel burning, hydraulic cement production, and gas flaring in 1990 and 1995, respectively.
- Neutral biosphere pre-subtraction maps: Net ecosystem production (NEP) pre-subtraction carbon exchange flux maps, one for each month.
- Ocean exchange pre-subtraction maps: Net ocean pre-subtraction carbon exchange flux maps, one for each month.
- Terrestrial carbon basis functions: Terrestrial carbon basis function flux maps, one for each terrestrial region.
- Ocean carbon basis functions: Ocean basis function flux maps, one for each ocean region and month.
- SF6 basis functions: SF6 basis function flux maps, one for each land region.

The input data above are provided in the compressed file **input_data_L2_all.tar.gz**.

Input data for the Inversion:

- Mean CO2 measurement data from the GLOBALVIEW CO2 2000 data set: The only data used in the control inversion simulations.

These data are provided in the compressed file **inversion_code_L2_all.tar.gz.**

Refer to the companion file transcom3_level1_readme.pdf for more details.

Forward Simulations

Twelve transport models ran a series of forward CO2 tracer simulations (Gurney et al., 2000) as greens functions in order to construct model-specific response functions used to perform the inversion for seasonal carbon sources and sinks. Tracers were simulated by each model, four of which were ‘‘background’’ global fluxes and 264 of which were region/month fluxes, representing a combination of 12 months and the 22 land and ocean regions. Theses fluxes compromised the "basis functions". These responses were converted to a single 12-month stationary response by compositing like months (summing all Januaries, all Februaries, etc., in the 3-year span) and detrending (removing the concentration trend resulting from the constant emissions in the forward simulations).

The background fluxes consisted of:

- 1990 and 1995 fossil fuel emission fields
- An annually balanced, seasonal biosphere exchange and air-sea gas exchange (Andres et al., 1996; Randerson et al., 1997; Takahashi et al., 1999; A.L. Brenkert, 1998)
- Carbon dioxide emission estimates from fossil-fuel burning, hydraulic cement production, and gas flaring for 1995, on a one degree grid cell basis, available at http://cdiac.esd.ornl.gov/ndps/ndp058a.html.

The monthly mean CO2 concentrations for each region/month combination, for the 245 and 253 stations are provided in the file **model_results_L2_gmatricies_all.tar.gz.**

Basis Function Map (Taken from Gurney, 2002)

A basis function map was constructed from the above simulations that reflected both geographical and mechanistic elements. The terrestrial and oceanic portions of the world were each broken into 11 separate source/sink regions.

The 11 land basis region boundaries were constructed to enclose vegetation of similar seasonal structure and carbon exchange based on vegetation classification. Ocean basis regions were chosen to approximate circulation features such as gyres and upwelling regions. Unit emissions of 1 Gt C yr-1 were specified from each region. Subregional-scale variations in emissions rates were prescribed for land regions according to simulated net primary production from the CASA model. This assumes that carbon fluxes follow the distribution of vegetation productivity. Emissions from ocean regions were prescribed as spatially uniform, except that sea-ice was masked out using seasonally varying fractional ice cover distributions.

Prior estimates of the fluxes in each of the 264 region/month flux combinations were determined from independent estimates of terrestrial and oceanic exchange. The land region prior flux estimates incorporate results from recent inventory studies and are identical to the annual mean values used in the annual mean inversion (Gurney et al., 2003). Where more than one estimate for a given region was considered, a midpoint of the estimate spread was used. The land region prior fluxes were only available as annual mean values and were distributed evenly over those months considered the most likely to capture the emission or uptake implied by the prior flux. The ocean region prior flux estimates were prescribed as zero for each month.

For information on the construction of the basis map, refer to the compressed file **basis_function_map_all.tar.gz**.

Inversion (Taken from Gurney, 2002)

The inversion required prior flux and uncertainty estimates from the steps described above.

Mean measurements for each month from the period 1992-1996 were inverted from data at 75 sites taken from the GLOBALVIEW- 2000 data set (GLOBALVIEW-CO2, 2000). Gaps in the data were filled by extrapolation from marine boundary layer measurements. Sites were chosen where the extrapolated data accounted for less than 30% of the 1992–1996 period.

The process of calculating the inverse fluxes, prior flux estimates, and data used for the inversion, are provided in the file **inversion_code_L2_all.tar.gz.** Inversion model results are provided in the file **inversion_results_invout_all.tar.gz.**

Specific information about the experimental protocol and results are provided in two companion files:

- http://daac.ornl.gov/daacdata/transcom/level_1_annual_co2/comp/transcom3_level1_readme.pdf, and
- http://daac.ornl.gov/daacdata/transcom/level_1_annual_co2/comp/transcom3_level1_experimental_protocol.pdf

Data Access:

This data set is available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

Data Archive:

Web Site: http://daac.ornl.gov

Contact for Data Center Access Information:

E-mail: uso@daac.ornl.gov

Telephone: +1 (865) 241-3952

7. References:

Andres, R. J. , G. Marland, I. Fung, and E. Matthews. 1997. Geographic Patterns of Carbon Dioxide Emissions from Fossil-Fuel Burning, Hydraulic Cement Production, and Gas Flaring on a One Degree by One Degree Grid Cell Basis: 1950 to 1990. NDP-058. Carbon Dioxide Information analysis Center (CDIAC), Oak Ridge National Laboratory, Oak Ridge, TN.

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Gurney, K. R., and A. S. Denning. 2008. TransCom 3: Annual Mean CO2 Flux Estimates from Atmospheric Inversions (Level 1). Data set. Available on-line [http://daac.ornl.gov/] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A. doi:10.3334/ORNLDAAC/895.

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Takahashi, T., R. H. Wanninkhof , R. A. Feely, R. F. Weiss, D. W. Chipman, N. Bates, J. Olafsson, C. Sabine, and S. C. Sutherland. 1999. Net sea-air CO2 flux over the global oceans: An improved estimate based on the sea-air pCO2 difference. Proceedings of the 2nd CO2 in Oceans Symposium, Tsukuba, Japan, January 18-23, 1999.