

## **Global inversion output for RECCAP – frequently asked questions (FAQ)**

### **RECCAP Background and the new inversion intercomparison**

The LSCE laboratory (Philippe Peylin et al.) have been collecting carbon flux estimates from recent inversions performed by groups around the world. There was general agreement that inverse methods had advanced since the TransCom CO<sub>2</sub> inversion intercomparison (T3) (Gurney et al., 2002 etc) and that the more recent inversions should be assessed. This is a global effort and is partnering, to some extent, with ongoing inversion work under the NACP (led by Andy Jacobson and colleagues) and the CarboEurope endeavor (Ciais et al. XXXX).

The Global Carbon Project is performing a synthesis activity called the Regional Carbon Cycle Assessment and Processes (RECCAP) aimed at establishing mean carbon balance estimates at the regional scale, a comparison of top-down and bottom-up flux estimates and evaluation of regional ‘hot spots’ of carbon flux activity. RECCAP is hoping to synthesize some of the results from the inversion intercomparison effort.

### **What process was used to compile and synthesis these CO<sub>2</sub> inversions?**

For the broader intercomparison effort, led by LSCE, an invitation was made through the Transcom email list for groups to submit their inversion output to LSCE. This is an ongoing process with results available at <https://transcom.lsce.ipsl.fr/>

To aid with flux comparisons, all inversion output has been regridded onto a 1x1 degree grid, preserving land/ocean boundaries. Flux estimates are not expected to be reliable at this scale, but this has enabled common region masks to be applied to all inversions.

From the submitted inversions, only those which span at least 5 years have been provided for RECCAP analysis. This is necessary as the RECCAP effort places considerable analysis emphasis on interannual variability and a consistent time period for calculating long-term means.

The TransCom 3 experimental results are included in the RECCAP analysis but only the T3 model mean will be represented rather than the individual models submitted through that experiment. In addition to the T3 mean, ten other inversions are included in the RECCAP analysis. Five of these are similar in methodology to the T3 case, solving for regions and using monthly mean data. The remaining inversions typically solve for fluxes at grid-cell resolution (with some correlation scale) and mostly use observations at the times of their observations. Some inversions include interannually varying transport while others do not. These differences are summarised in the table below. Further information about each inversion is given in the file `inversion_description.xls`.

<b>Inversion</b>	<b>No. regions</b>	<b>IAV transport</b>	<b>Observations</b>
Transcom mean	22	No	Monthly mean
JMA	22	Yes?	Monthly mean
MATCH	116	No	Monthly mean
CCAM	146	No	Monthly mean

NIES	64	Yes	Monthly mean
NICAM			Monthly mean
Carbontracker-US	156	Yes	Raw
Carbontracker-EU	156	Yes	Raw
LSCE (Peylin)	Grid-cell	Yes	Monthly mean
LSCE (Chevallier)	Grid-cell	Yes	Raw
Jena	Grid-cell	Yes	Raw

### **What inversion output has been provided to region chapters?**

Monthly mean ‘total’ and ‘natural’ fluxes for a number of masked regions for each inversion and for the T3 mean. Natural = Total – fossil where the fossil emissions are as used/estimated by each inversion. Most inversions assume known fossil emissions but note that different inversions have used different global fossil estimates.

Most chapter regions have been provided with sub-region fluxes (1x1 gridded results). These are unlikely to be credible except where atmospheric CO<sub>2</sub> data is most dense (e.g. Europe, North America). We advise analysing your total region first before any attempt is made to interpret sub-region fluxes.

*Uncertainties.*

### **Can we use other ‘top-down’ flux estimates in our chapter?**

Yes, if you have access to other inversions such as those focussed on your region, please make use of these in your chapter. Please attempt to gather the same information regarding inversion setup, station list, etc that is provided with the inversions coming from the LSCE-led effort.

### **What are the main differences between inversion methods?**

*Solution method*

*Priors*

*Observing sites used:* Previous work (Law et al, 2003, Gurney et al., 2008) has shown that the fluxes estimated by the inversion can be very sensitive to which sites are included in an inversion. This is particularly true for regions that are constrained by very few sites. For example, the mean flux in the South Pacific can change by most of a PgC/y depending on the inclusion of Easter Island data. The sensitivity of the inversion to particular sites also needs to be considered when analysing the interannual variability in fluxes. Real interannual variability may be masked by variations due to changes in the availability of observations through the inversion period. Most inversions try to minimise this spurious variability by only using sites that are available for the full period of the inversion, or by making use of the interpolated data in the GLOBALVIEW data product.

To facilitate comparisons between inversions, the sites used by all inversions are summarised in site\_table\_reccap.xls. Sites are listed alphabetically, in general using

the site codes of GLOBALVIEW

([http://www.esrl.noaa.gov/gmd/ccgg/globalview/co2/co2\\_sites.html](http://www.esrl.noaa.gov/gmd/ccgg/globalview/co2/co2_sites.html)). Many site locations are listed more than once, since multiple CO<sub>2</sub> records are available for many sites (either collected by different labs, or representing separate flask and in-situ records). Some inversions chose only to use the most complete record at a given location while others include all available records. It is unlikely that one choice is better than the other. There are differences in calibration etc between laboratories. These are not accounted for in inversions, but their impact is unlikely to be significant compared to other transport and representation uncertainties in modelling any given site (Rödenbeck et al., 2006).

*Type of observed CO<sub>2</sub> used for each site:* There are a variety of ways the CO<sub>2</sub> data from any given site has been used, depending in part on whether flask or in-situ data are available; some inversions use monthly mean data while others use the data at the appropriate sampling time. Various degrees of selection have been applied to the data. An indication of how the data have been used is given in the `site_table_reccap.xls` file through a series of codes.

Code	Explanation
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*Temporal resolution*

M	Monthly mean data used
D	Daily mean data used
H4	Four hour mean data used
H4 (hrs)	Four hour mean data used only for the hours indicated (UT)
H	Hourly data used
H (hrs)	Hourly data used only for the hours indicated (UT)
F4	Flask samples are used as a 4 hour average around sampling time
F	Flasks samples are used at the sampling time

*Data selection*

GV	Globalview CO <sub>2</sub> used. Globalview CO <sub>2</sub> is derived from a fitted curve to CO <sub>2</sub> observations and is intended to represent baseline conditions
GV E	The use of Globalview CO <sub>2</sub> data includes extrapolated data. This fills in missing data by applying a mean seasonal offset for the site from marine boundary layer CO <sub>2</sub> concentration. Many inversions give periods of extrapolated data less weight than periods with observations.
*	Consecutive hours that differ by greater than 1 ppm are removed
o	Outliers (mismatch between observations and model > 3 sigma) are removed
JMA	Data are removed when inconsistent with the inversion through an iterative procedure (Maki et al., 2010)

Site locations may be represented by model output interpolated to the site location or by the nearest model grid-cell. For coastal sites, the nearest ocean grid-cell is often chosen as being more representative of the baseline air that is usually sampled by flask records at coastal sites.

Some inversions include ship data. This may be used at the actual location and time of sampling (as in the CarbonTracker inversions) or it may be binned into latitude and/or longitude bins as in the GLOBALVIEW POC\* records and the JMA use of JMA ship data.

*Uncertainty attached to CO<sub>2</sub> observations:* The inversion methods used require an uncertainty to be attached to each CO<sub>2</sub> observation. This provides a relative weighting for each observation and determines how much the estimated fluxes will be adjusted to try and match the observation. This uncertainty accounts for measurement errors as well as representation uncertainty, that is the ability of the transport model to represent a site. In general, inversions place smaller uncertainties on remote, ocean sites than on continental sites.

### **Why are the flux estimates for our region so different between inversions?**

The flux estimates for any given region are dependent on which observations are available in or close to that region, how the CO<sub>2</sub> data have been included in the inversion and what prior information is assumed about that region. These can be compared across inversions to try and understand the differences in estimated fluxes. It is also important to be aware that the estimates from poorly constrained regions will have large uncertainties so that many differences between inversions may not be significant.

### **Which inversion should we believe (if any)?**

#### **References**

- Baker D.F., R. M. Law, K. R. Gurney, P. Rayner, P. Peylin, A. S. Denning, P. Bousquet, L. Bruhwiler, Y.-H. Chen, P. Ciais, I. Y. Fung, M. Heimann, J. John, T. Maki, S. Maksyutov, K. Masarie, M. Prather, B. Pak, S. Taguchi, and Z. Zhu, 2006: TransCom 3 inversion intercomparison: Impact of transport model errors on the interannual variability of regional CO<sub>2</sub> fluxes, 1988–2003, *Global Biogeochem. Cycles*, 20(1), GB1002, doi:10.1029/2004GB002439.
- Gurney, K.R., R.M. Law, A.S. Denning, P.J. Rayner, D. Baker, P. Bousquet, L. Bruhwiler, Y.H. Chen, P. Ciais, S. Fan, I.Y. Fung, M. Gloor, M. Heimann, K. Higuchi, J. John, T. Maki, S. Maksyutov, K. Masarie, P. Peylin, M. Prather, B.C. Pak, J. Randerson, J. Sarmiento, S. Taguchi, T. Takahashi and C.W. Yuen, 2002: Towards robust regional estimates of CO<sub>2</sub> sources and sinks using atmospheric transport models. *Nature*, 415, 626-630.
- Gurney, et al., “Interannual variations in regional net carbon exchange and sensitivity to observing networks estimated from atmospheric CO<sub>2</sub> inversions for the period 1979 to 2006,” *Global Biogeochemical Cycles*, 22, GB3025, doi:10.1029/2007GB003082, 2008.
- Law, R.M., Y.-H. Chen, K. R. Gurney and Transcom 3 modellers, 2003: Transcom 3 CO<sub>2</sub> Inversion Intercomparison: 2. Sensitivity of annual mean results to data choices. *Tellus*, 55B, 580-595, doi:10.1034/j.1600-0560.2003.00053.x.
- Maki, T., M. Ikegami, T. Fujita, T. Hirahara, K. Yamada, K. Mori, A. Takeuchi, Y. Tsutsumi, K. Suda and T. J. Conway, 2010: New technique to analyse global distributions of CO<sub>2</sub> concentrations and fluxes from non-processed observational data, *Tellus B* (in press).
- Rödenbeck, C., T. J. Conway, R. L. Langenfelds, 2006: The effect of systematic measurement errors on atmospheric CO<sub>2</sub> inversions: a quantitative assessment. *Atmos. Chem. Phys.*, 6, 149-161.