Intergovernmental Oceanographic Commission

Workshop Report No. 216

Surface Ocean CO_2 Atlas (SOCAT) Project – 2nd Technical Meeting

Paris, France
16-17 June, 2008

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Abstract:
At the Surface Ocean CO_2 Variability and Vulnerability workshop at UNESCO, Paris in April 2007, participants agreed to assemble a global surface CO_2 data set of all publicly available ocean surface fCO_2 data in a common format. This is an activity that has been called for by several international groups for many years, and has now become a priority activity for the marine carbon community. This data set will serve as a foundation upon which the community will continue to build in the future, based on agreed data and metadata formats and standard 1st level quality-control procedures, building on earlier agreements established at the 2004 Tsukuba workshop on Ocean Surface pCO_2 Data Integration and Database Development.

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1. INTRODUCTION AND STATUS REPORT

1.1 BACKGROUND ON THE SOCAT PROJECT
(M. Hood, B. Pfeil, A. Olsen, D.C.E. Bakker)

At the "Surface Ocean CO_2 Variability and Vulnerability" (SOCOVV) workshop at UNESCO, Paris in April 2007, co-sponsored by IOCCP, SOLAS, IMBER, and the Global Carbon Project, participants agreed to assemble a global surface CO_2 data set of all publicly available ocean surface fCO_2 data in a common format. (The fugacity of carbon dioxide, or fCO_2, is the partial pressure of CO_2 (pCO_2) corrected for non-ideal behaviour of the gas.) This is an activity that has been called for by several international groups for many years, and has now become a priority activity for the marine carbon community. This data set will serve as a foundation upon which the community will continue to build in the future, based on agreed data and metadata formats and standard 1st level quality-control procedures, building on earlier agreements established at the 2004 Tsukuba workshop on "Ocean Surface pCO_2 Data Integration and Database Development". This activity also supports the SOLAS and IMBER science plans and their joint carbon implementation plan.

This data set is meant to serve a wide range of user communities and it is envisaged that, in the future, 2 distinct data products will be made available in this Surface Ocean CO_2 Atlas (SOCAT):

- a 2nd level quality controlled global surface ocean fCO_2 data set following agreed procedures and regional review, and
- a gridded SOCAT product of monthly surface water fCO_2 means on a 1° x 1° grid with no temporal or spatial interpolation using the 2nd level quality-controlled global surface ocean fCO_2 data set.

The extended 1st level quality-controlled data set builds on the work started in 2001 as part of the EU ORFOIS project by Dorothee Bakker , which now continues as part of the EU CarboOcean project, where Benjamin Pfeil and Are Olsen have compiled the publicly-available surface CO_2 data held at CDIAC (Carbon Dioxide Information Analysis Center) and elsewhere into a common format database based on the IOCCP recommended formats for metadata and data reporting. This compilation currently includes data from more than 10 countries, producing an initial database composed of more than 1250 cruises from 1968 to 2007 with approximately 4.5 million measurements of various carbon parameters, available in a common format, 1st level quality-controlled data set.

A small technical meeting, henceforth called the SOCAT-1 meeting, was held in Bremen, Germany, on 5 December 2007 (associated with the 3rd CarboOcean Annual Meeting) to agree on 1st level QC for the data set and to decide on a way forward for the 2nd level QC issues.

The IOCCP, along with CarboOcean and the SOLAS-IMBER Joint Carbon Group, agreed to hold a 2nd technical workshop (SOCAT-2, this meeting) to develop internationally agreed 2nd level quality-control procedures and to discuss the coordination of regional scientific groups to conduct the 2nd level quality control (QC) analyses. The goals for this meeting were to:

- Reach international agreement on 2nd level QC procedures
- Identify approaches for gridding and interpolation
- Identify major science issues for each basin and globally
- Develop a short report for distribution to all relevant networks.

A list of participants is provided in Annex I and the agenda is in Annex II of this report, and the report of the SOCAT-1 meeting is given in Annex III.

1.2 OVERVIEW OF SOCAT-1; GOALS FOR SOCAT-2
(D.C.E. Bakker)

Dorothee Bakker, chair of the SOCAT-2 meeting, provided an overview of the decisions made in the 1st technical workshop (December 2007) and outlined the major issues that need to be discussed for the 2nd level quality control.

Establishing surface ocean and atmosphere carbon observing systems for constraining the net annual air-sea CO_2 flux per ocean basin to < 0.2 Pg C yr^{-1} (SOLAS/IMBER joint carbon implementation plan) was adopted as an overall goal during the SOCOVV workshop. The idea for a Surface Ocean CO_2 Atlas (SOCAT) emerged during discussions on Observation Strategies (Working Group 2) and Data and Scientific Synthesis (Working Group 3) during SOCOVV. A number of action items were identified to advance this goal, and Bakker provided an update on these actions:

1. Determine which global fCO_2 data sets being compiled by different groups should be considered the global standard data set (Sabine, Pfeil). The analysis provided this summary for the following compilations:
   - The Takahashi et al. (2008) data set – quality controls and adjustments are not fully documented (see report: Takahashi, T., S.C. Sutherland, and A. Kozyr. 2007. Global Ocean Surface Water Partial Pressure of CO_2 Database: Measurements Performed During 1968 - 2006 (Version 1.0). ORNL/CDIAC-152, NDP-088. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee, 20 pp.)
   - Data set of John Callahan (NOAA/PMEL) – not in a common format and not publicly available.
   - Data set of Joellen Russell (Uni. Arizona, USA) – more than 3 million data points; adjustments not well documented and compilation not publicly available.
   - Data set of Pfeil and Olsen (Bjerknes Centre, Norway) – more than 4.5 million data points in common format that are documented and traceable, with 1st level QC carried out (missing values, outliers) and with calculation of fCO_2

2. Establishment of a standard, global surface ocean fCO_2 data set, based on agreed data and metadata formats and standard 1st and 2nd level QC. The decision was made to use the common format, well-documented data set of Pfeil and Olsen with 1st level QC based on agreements from the ad-hoc SOCAT-1 meeting. The 2nd level QC issues are being discussed at the SOCAT-2 meeting.

3. Initiation of regular data product development. To be discussed at this meeting.

4. Identify approaches for gridding and interpolation in order to estimate flux and surface CO_2 using satellite and proxy techniques (Sabine). To be discussed at this meeting.

5. Establishment of regional groups to address regional QC and synthesis issues. Specifically, the groups will look at the available data and QC issues, identify missing data, compare methods for creating fCO_2 maps, exchange findings on a global level, coordinate regional QC into a global synthesis, and identify key process-related scientific questions that require large-scale joint synthesis efforts. The following groups were established:
   - Atlantic + Arctic (Schuster; Lefèvre)
   - Pacific (Feely for 30N-30S; others under development)
   - Indian (Sarma)
   - Southern Ocean (Tilbrook)
   - Coastal seas (Chen, Borges)

- Global focal points (Bakker, Pfeil, Sabine, Metzl, Olsen)

Bakker reminded the group of the goals of this 2nd technical workshop (SOCAT-2) and the issues that must be covered in the two days (see Agenda in Annex II). She also added that the group needs to set goals for a realistic date for the release of the 2nd level QC data set, to begin discussions on how the gridded data product will be developed, to decide how the 2nd level QC data set would be regularly updated, and to look ahead to the scientific analyses and outcomes that might come from the SOCAT data set and gridded products, with a possible goal of having new results to present at the International Carbon Dioxide Conference – 8, scheduled for September 2009.

1.3 STATUS OF THE DATA SET
(B. Pfeil and A. Olsen)

Benjamin Pfeil and Are Olsen provided a status report on the SOCAT data set. The last updated version (version 1.1, June 12 2008) is now available to data contributors. All the data in the date set are public, and the data set contains 1370 cruises from 1968 to 2007, with approximately 4.5 million CO_2 measurements. Included in the data set are all publicly available underway data from CDIAC, NOAA/AOML, NOAA/PMEL, LDEO, CARINA, WDC-MARE and data delivered directly by PIs. Some data have been excluded from the data set: data from NOAA/AOML from 2006 and 2007 that has not yet been submitted to CDIAC; data with known issues (e.g. problems with the temperature sensor); data with intellectual property rights (most CARBOOCEAN data); and data with only atmospheric CO_2 measurements.

Figures in Annex IV show the spatial overview (cruise tracks), spatial distribution (number of points as a function of latitude / longitude), and the temporal distribution (number of data points over time) of the SOCAT data (version 1.1).

Pfeil provided an overview of the 1st level QC procedures carried out on the data set. All input data were put in a common file format (tab delimited text file), the time and latitude / longitude position of data points were made uniform, the naming of parameters was standardized, and NaN was used for all missing values. Essential missing parameters like salinity and atmospheric pressure were added from standard data collections since they are needed for re-computations of fCO_2. Obvious outliers for all non-carbon parameters were flagged or sometimes corrected by examining the neighboring stations. For example, treatment of unrealistic values included correction of negative values (e.g., a salinity value of -35.23) based on neighboring data. Unrealistic values in SST, salinity and atmospheric pressure were either deleted or interpolated from the neighboring data.

Where possible, fCO_2 was recomputed (see Annex V for details of the fCO_2 re-calculations applied for this data set). Cruise labels were standardized using Expocodes.

Pfeil pointed out several known issues with this 1st level QC data set that must still be addressed:

- Detailed metadata are missing for some cruises.
- Some cruises may have been reported more than once.
- Expocodes still to be assigned for one vessel.
- Problem with Expocodes for commercial vessels (when vessels are sold, change names, change country flag, etc.).
- Expocodes for moorings and time series need to be decided upon.
- Identification of cruises from iron fertilization experiments needs to be carried out in order to avoid inclusion of purposefully perturbed CO_2 conditions in the data set.

- Incomplete checking of non-carbon parameters for unrealistic values (also see page 11).

Metadata are differentiated between basic metadata for each cruise (cruise inventory table) and the detailed metadata as provided by the PI. The cruise inventory table includes
- Cruise name as reported by the data holder
- Expocode
- Research vessel
- PI
- Data source (e.g. CDIAC, NOAA, WDC-MARE etc)
- Date added to the collection
- Bounding box (spatial distribution of the data)
- Start and end date of the cruise
- Number of observations
- Metadata (links to detailed metadata as reported by the PI)

This is linked to the detailed CDIAC Mercury Metadata report provided by the PI.

An international cruise labeling convention was assigned for all cruises, which consists of
- Country code
- Vessel code
- Start date of the cruise: yyyymmdd

The advantage of this is easy identification of a cruise. Basic information on the cruise can be obtained by referring to the label.

On the Bjerknes website(http://www.carbon-synthesis.org/front_content.php?idcat=371) are available:
- The SOCAT data set version 1.1 in Ocean Data View
- The SOCAT data set version 1.1 in a tab delimited text file
- all MATLAB scripts
- documentation
- the cruise inventory table and detailed metadata per cruise

Discussions:
The group agreed that the Expocodes for commercial vessels should be updated in the data set every time the ship's IMO identification changes as a result of change of flag, name and/or ownership. However, the EXPOCODE should not be changed for data already collected. For moorings and time series stations, it was agreed that the OceanSITES formats would be adopted.

The group also brought up the issues of how to distinguish different data sets from the same cruise, and how to deal with future data variables (e.g., Total CO_2). Pfeil noted that it was straightforward to re-write the scripts to add new variables as they become available.

ACTION ITEM 1: Coordinate with OceanSITES on the Platform Names / Codes for time series stations (Pfeil, Olsen, Kozyr, Hood).

2. 2nd LEVEL QUALITY CONTROL ISSUES

2.1 ASSESSMENTS OF UNCERTAINTY
(A. Körtzinger and C. Sabine)

Arne Körtzinger provided an overview of previous intercomparison experiments for surface fCO_2 systems to provide insight into the sources of uncertainty in surface CO_2 data from underway ships. He pointed out that when systems are run side-by-side in identical, carefully controlled conditions, it is possible for different systems to agree to within 2 µatm. This has been demonstrated in three international intercomparison experiments. Often, the major source of uncertainty is bad temperature data, resulting from sensors in the seawater inlet or the equilibrator that were not calibrated accurately. However, the reality is that these systems are not run in identical or controlled conditions, and it is likely that the difference between systems is around 4-5 µatm.

From these intercomparison experiments, we can now identify potential sources of error, some of which are minor, others of which are very difficult to address. Known sources of error include

- Calibration error of (secondary) gas standards;
- Suboptimal xCO_2 (mixing ratio) calibration routine (calibration function, number of standards, cell pressure measurement in the non-dispersive infrared analyser);
- Differences in data reduction algorithms;
- Inconsistent calibration of in-situ and equilibrator temperature (T) sensors;
- Temporal mismatch of in-situ and equilibrator T measurements (adds spurious variability);
- Improper calibration of inlet temperature sensor, often a thermosalinograph (comparison with CTD casts);
- Improper location of intake temperature sensor (e.g. downstream of pump);
- Loss in accuracy with moist gas xCO_2 measurement (e.g. with LI-COR 6262 or 7000);
- Contamination problem with dry air xCO_2 measurements through equilibrator venting (slight continuous under-pressure);
- Existence of undetected gas leaks (e.g., with Nafion dryers);
- Incomplete drying of sample air (exhaustion of desiccants, malfunction of dryers, etc.);
- Uncertainty in equilibrator pressure ;
- Deterioration of signal with drop in seawater and/or gas flow rates;
- Respiration of organic matter accumulating in particle filters; and
- Respiration of organic matter in the seawater line (has been demonstrated to be significant for O_2 (oxygen) on research vessels and VOS (voluntary observing ships);

Körtzinger highlighted some things we can do to address these errors:

- Make sure complete metadata information is available;
- Perform 1st level quality control (time, location, parameter range, missing parameters, 'flyers' etc.);
- Exclude data sets on the basis of justifiable minimal criteria (as in Taro Takahashi's approach);
- Calculate pCO_2 or fCO_2 for all data sets from xCO_2 using a uniform procedure;
- Compare *in-situ* temperature measurements (thermosalinograph) with calibrated temperature measurements from co-located CTD casts;
- Compare atmospheric xCO_2 with Globalview-CO_2 data set for plausibility; try to correlate steep changes in atmospheric xCO_2 with changes in meteorological parameters (e.g., barometric pressure, wind direction);
- Inspect key variables vs. time or latitude/longitude for each data set (e.g., ΔT in situ – equilibrator, ΔP equilibrator – barometric) and correlations between them (very labor intensive);
- Inspect data visually data set by data set (very labor intensive).

Körtzinger also pointed out that it would be difficult to use crossovers between cruises for offset identification, because the spatiotemporal variability scales of pCO_2 are such that the match in space and time would have to be extremely close.

Discussions:
The group agreed that the uncertainty for most surface fCO_2 data from VOS ships is probably at least 4-5 µatm.

The group discussed possible ways of identifying offsets and potentially bad data. The main points of this discussion have been merged with those from the discussion on page 10 in the section on Crossover and Other Checks.

2.2 DATA FLAGS
(R. Wanninkhof)

Rik Wanninkhof provided an overview of flag issues, which build on experience from GLODAP and CARINA as well as on agreements about data and metadata reporting from an informal meeting (http://www.aoml.noaa.gov/ocd/gcc/uwpco2/workshops/) held in Miami in 2002, which were later adopted by the international community at the IOCCP workshop "Ocean Surface pCO_2, Data Integration and Database Development" (Tsukuba, 2004). The IOCCP Recommended Format for fCO_2 Metadata and Data from Underway Systems is on the IOCCP web-site: www.ioccp.org under Data and Products. This is the format now used by CDIAC for its metadata forms. Wanninkhof reminded the group that 2007 Guide to Best Practices for Ocean CO_2 Measurement (available at CDIAC: http://cdiac.ornl.gov/oceans/Handbook_2007.html) contains a Standard Operating Procedure (SoP) for Determination of pCO_2 in air that is in equilibrium with a continuous stream of sea water.

Wanninkhof reviewed the WOCE flag designations for Data and Cruise QC flags. The data QC flags are:

2 = Good (measurement meets specified accuracy or precision)
3 = Questionable (measurement might not meet specified accuracy or precision but probably is useful for some / many purposes)
4 = Bad (measurement has no interpretive value and value is not reported)

For surface water fCO_2 data with a WOCE flag 3, a set of sub-QC flags is used by several groups to indicate the problem with the particular measurement and to provide the user with additional information if the data are to be used, where 1= outside standard range; 2 = questionable/interpolated sea surface temperature; 3 = questionable equilibrator temperature; 4 = anomalous ΔT (± 1°C); 5 = questionable SSS; 6 = questionable pressure; 7 = low equilibrator gas flow; 8 = questionable air values (e.g. possible stack gas contamination); 9 = interpolated standard; and 10 = other, see metadata.

Discussions:
It was recognized that the vast majority of users of the SOCAT products will never refer to the data flags, but will instead accept the data that this group says are useable. The system of flags should be as simple as possible. After discussing the proposed structure, the group agreed to the following flag system:

I. Cruise Flags:
Category A (11): A good cruise:
1) followed approved methods / SoP criteria
2) metadata documentation complete

3) 2nd level QC performed and deemed acceptable

Category B (12): An acceptable cruise:

1) followed methods / SoP criteria
2) metadata documentation complete
3) no 2nd level QC could be performed because data were obtained in a region or time where no other data were available for comparison

Category C (13): An acceptable cruise:

1) did not follow methods / SoP criteria
2) metadata documentation complete
3) 2nd level QC performed and deemed acceptable

Category D (14): Un-documented data

1) inadequate information about methods / procedures
2) metadata documentation incomplete

Category F (15): (F for "failure") Failed QC checks (do not show in data set).

The initial status of data contributed to data set that has not yet undergone 2nd level QC would be labeled as "N" (19). These category labels will later be given numerical values but in such a way that they will not be confused with WOCE flags. Suggested numerical values are between brackets.

II. Data Flags:

The group agreed to use the WOCE flags: 2 = Good, 3 = Questionable, and 4 = Bad for individual data points. The group decided not to retain the sub-flag system use by some groups in their internal QC. The group agreed that only fCO_2 data flagged as 2 and 3 would be retained in the SOCAT data products, while level 4 data would be eliminated.

2.3 CROSSOVER AND OTHER CHECKS FOR UNDERWAY DATA (U. Schuster and A. Olsen)

Ute Schuster provided an overview of crossover analyses carried out for the *MV Santa Maria* and *MV Falstaff* lines, showing results of comparisons between the ship values and NCEP / NCAR reanalysis products for SST, sea-level pressure, wind speed, and air temperature. Schuster's results showed that the comparisons involve a lot of work. Other parameters may be used depending on how much time the PI has to put into the analysis.

Are Olsen presented examples of crossover analyses from the *Nuka* and *Skogafoss* lines, and described the automated crossover analyses used in the CARINA project. He noted that much of the work can be automated, and Matlab routines developed for the CARINA project may facilitate this process. Tests were carried out that showed that the automated scripts work just as well as user-supervised analyses, but expert judgment on the quality of the crossovers remains essential. Olsen suggested that the automated routine used for CARINA may be adapted to manage surface fCO_2 crossovers, although interpretation of the results will be much more difficult than for inorganic carbon data from below 2000 m due to much larger spatial and temporal variability of fCO_2 in the surface ocean.

Olsen suggested that another approach for fCO_2 data comparison would be to establish MLR algorithms for fCO_2 as a function of temperature, mixed-layer depth (such as from the FOAM UK Met Office reanalysis), and Chlorophyll a (from SeaWiFS and MODIS) and check observations against calculated fCO_2 ranges for the period and region. He emphasized that this MLR technique is only intended to detect offsets that would require further investigation.

Combined discussions on 2nd level QC procedures:

- Comparison of atmospheric CO_2 - It was agreed that a valuable first check would be to compare the available shipboard atmospheric CO_2 measurements (especially xCO_2 in dry air) with GlobalView data. The group agreed that these data should be provided as a separate data set for QC purposes, but not included in the surface fCO_2 data set itself. If the measured atmospheric xCO_2 is systematically biased, this could mean that calibration is off and that fCO_2 in water has a similar bias.
- Variations in fCO_2 normalized to a constant temperature - Another option for data where the fCO_2 variability is largely temperature driven is to compute fCO_2 at a constant temperature and look at the seasonal variations in a given area. This would make it possible to use cross-over analysis to identify major offsets and then to do a closer inspection to see if the variability is real or a data problem. This is something that is best done by the regional groups.
- Use Multiple Linear Regressions (MLR) – It may be useful to perform a MLR on all the data in a given area to look at the residuals on a cruise-by-cruise basis to see if anything stands out. The regression could be on temperature or salinity, and this could be done regionally in an automatic way on the already-assembled data set. This would not be particularly useful in data sparse areas, and it would probably be time consuming to prepare the code, although it is not necessary to worry about the precision of the regressions since the goal is simply to identify flyers. MLR will need to be examined closely for each region to determine the applicability to a particular area, the data or data products available, and the amount of work involved.
- The group also agreed that crossover analyses might be useful in certain regions, if much of the work could be automated as was done for CARINA. The Matlab scripts used by CARINA are a good starting point, but they would need to be adapted to surface fCO_2. It is likely that the crossover results will have to be interpreted manually.
- The cruise flag will indicate which data have been examined by 2nd level QC. Accompanying comments will describe the procedures followed.

Based on discussions of 1st and 2nd level QC procedures, the group summarized procedures remaining to be carried out:

Additional 1st level QC procedures

- Check unrealistic ship speed to find GPS failures.
- Check ΔT=inlet temperature – equilibrator temperature (size, sign as expected, spikes) (automated), e.g. 2°C as upper limit for flagging. Plot equilibrator temperature versus sea surface temperature; good way to find outliers. Put negative flag on any fCO_2 for high ΔT

List of priorities for 2nd level QC

- Atmospheric CO_2 data (especially in open ocean regions, e.g., the Southern Ocean) (co-locate with GlobalView data, gridded/interpolated) within spline fit. (automate) (LAS to co-locate) (within 2-3 ppm), use with care (regional groups to look at differences). Shipboard atmospheric xCO_2 will be available as a companion file to SOCAT in future versions of the data set.

Suggested regional and experimental tools for 2nd level QC

- Check sea surface temperature (SST) (reanalysis products, satellite, CTDs) (automate)
- Look at fCO_2 at a constant temperature (subtropical, only works in some regions). Plot data as a function of time after correcting for temperature, should be within 40 uatm bandwidth (at least in subtropics of Pacific) (visual, lots of work).
- MLR (multiple linear regression) approaches using SST, salinity, nitrate or mixed layer depth. Plot MLR as function of sea surface temperature and salinity, find outlier

cruises. Likely to work in temperature controlled regions, e.g., the subtropics. Note: this approach will not be applicable to all regions.

- Crossovers to help identify potential issues (adopt CARINA procedures). This approach may not work very well for highly variable surface water fCO_2.
- Despiking, dangerous, no one keen

ACTION ITEM 2: Develop a separate data set of xCO_2 in dry air and fCO_2 in air to compare with long-term atmospheric monitoring stations and GlobalView. This is not a top priority and should be left to future SOCAT versions (Pfeil, Olsen, Hankin, Malczyk).

ACTION ITEM 3: Test the MLR approach in one area and assess this approach. (Regional groups)

2.4 QUALITY-CONTROLLING NON-CARBON DATA
(B. Pfeil)

Benjamin Pfeil referred to his earlier presentation on the status of the data set and indicated the 1st level QC checks that were applied to the non-carbon variables already. Much more remained to be done for the QC of the non-carbon data (see list above), but other commitments have prevented him from dedicating much time to this.

Discussions:
The group agreed that many of these activities are time consuming. Automating these activities as much as possible is critical. It was suggested that we could make more use of the LAS system, and that the group needed to develop a list of the checks to be done for the non-carbon data. It was suggested that a toolbox should be created and made available such that individual investigators can use it to send clean data to the data center. However, some 1st level QC will always need to be done at a higher level (e.g., the data assembly center), since it will ensure a more coherent global data set.

2.5 LIVE-ACCESS SERVER AND SHARED DATA MANAGEMENT STRATEGIES FOR OCEAN CARBON OBSERVATIONS
(S. Hankin and J. Malczyk)

Steve Hankin provided a demonstration of the LAS for the Takahashi 2008 collection, http://ferret.pmel.noaa.gov/OCDMS/index.htm and an initial preview of the SOCAT data version 1.0. He noted that the server was working, although there were still some bugs to track down and the latest version of the data set needed to be entered. He also provided an example of how LAS might be used to compare data from the Takahashi climatology and the SOCAT data set. Of particular interest were the generation of on-the-fly anomaly maps that may be generated by comparing observations to a climatology or other data set. (On the fly means that a smaller data set can be extracted online from a larger data set.) Finally, Hankin provided some thoughts on what would be possible with a shared data set:

1. Support for 2nd level QC:
    - Able to download by region – e.g., N. Pacific; regions can overlap;
    - Able to upload flags, altered (recalibrated) values, QC “scripts” that may be applied to other regions;
    - Able to track additions to metadata - who uploaded? when? what was altered?
    - Able to add new fields (e.g., wind shear)
2. “Releases” and/or “tags” (versions)
    - major (external) and minor (internal)
    - each observation can be audit-tracked

- compare scientific conclusions by version

3. Comparison support
   - between cruises on repeat tracks
   - time-track visualizations and anomalies
   - cross-over points
4. On-the-fly gridding

Given an agreement on gridding techniques, LAS can create gridded fields on the fly:

- Choose the data subset and constraints (e.g., Central Pacific Spring, excluding El Niño years)
- Choose gridding technique and parameter values
- Choose grid resolution

Discussions:

It was noted that initial comparisons between the Takahashi climatology and the SOCAT data set reveal that Takahashi has significantly more Pacific data. It was not clear if those data are publicly available, but have simply not yet been contributed to CDIAC. LAS may help us to identify data sets missing in SOCAT.

The group needs to decide on definitions for the regions to allow LAS to have a drop-down menu to extract data by region. For the coastal areas, the definition is done by bathymetry (<200 meters is defined as coastal). The LAS and SOCAT data set have the necessary bathymetry data to do this. The group must also decide what to do with cruises that cross from one region to another, or from the open ocean to the coastal zones.

ACTION ITEM 4: Decide on regional definitions and how to deal with cruises that cross boundaries (Regional groups, Pfeil, Olsen, Hankin, Malczyk)

2.6 RECORD-KEEPING FOR SECONDARY QC PROCEDURES (R. Key)

Bob Key advised the group to record everything, or at least enough so that someone 10 years from now can figure out exactly what was done to the data. This includes

- Origin of the data
- Data sets included, with appropriate cruise names or code numbers.
- Methods used – a formal publication-quality level of detail including methods, software used, etc.
- Detailed results about how the data were treated, including a description by data set with an emphasis on anomalies, tabulated results of all tests with supporting graphics, a consistent sense of the offset by all data contributors, and a consistent offset type (additive or multiplicative) used by all, if applicable.
- Where applicable, robust adjustments applied to data, including a publication quality table (web or manuscript) that includes EXPOCODES and internal identifiers for automated application, a special code to indicate data that were not tested (which must be different from the indicator for data that have been tested, but no adjustment recommended), and a "Master" cruise indicator if used.
- Summary Documents – white papers with as much detail as practical, and publication level summary.

Discussions:

In response to questions about how to deal with errors found in the data set, Key advised that the PI should be contacted and asked to fix it and to resubmit the data. The original data should always be kept unchanged.

2.7 GRIDDING AND INTERPOLATION PROCEDURES
(C. Sabine and U. Schuster)

Chris Sabine and Ute Schuster led an open discussion about the basic gridding procedures the group would use. They reminded the group that the goals set out by the 2007 SOCOVV meeting were to develop both a regularly updated 2nd level QC data set and a monthly 1° x 1° gridded data product with no interpolation. In discussions with potential users of the data, this gridded product was agreed to be more useful for more people than an interpolated product, and to remain truer to the original data. It was agreed that the data set would not include CO2 air-sea fluxes, since PIs will calculate this in different ways.

The binning statistics to the 1° x 1° gridded monthly data product may need some careful consideration to determine whether some weighting scheme should be used to differentiate between data from a single cruise that made measurements every minute versus a more sparse data set that made measurements every hour. It was suggested that some information about the fraction of the month that is covered by the different data sets would also be useful. There needs to be some information for all bins that will allow a user to identify, for example, the number of data points, the number of cruises and the standard deviation of the data.

The group stressed that the 2nd level QC data set need to be clearly identified in LAS with respect to version number and level of QC, so that someone using the LAS knows exactly which version of the 2nd level QC data set was used.

ACTION ITEM 5: Develop a recommended procedure for providing information about binning (e.g., the number of data points, the number of cruises and the standard deviation of the data.) (Sabine, Schuster, Wanninkhof)

2.8 DATA SHARING ISSUES
(C. Sabine, B. Pfeil)

Drawing from the status report provided by Benjamin Pfeil, Chris Sabine led a discussion on the data currently included in the SOCAT data set. Some data provided to Takahashi for the climatology has not been approved for public sharing, citing a two-year embargo period that is more-or-less traditional for research programs. Some CarboOcean PIs have adopted this two-year period, while other CarboOcean data are released more quickly.

With this in mind, the SOCAT data set will be approximately 2 years behind for some data (e.g., the data set for 2nd level QC to be published in late 2009 will have all available data up to the end of 2007). The group agreed that it would be helpful to set a goal for science publications that would come from using the SOCAT data set, and to work back from that goal in order to determine at what point we will freeze the data for 2nd level QC for the first version. While ambitious, the group agreed that the 8th International Carbon Dioxide Conference (13-19 September 2009, Jena, Germany) would be the best opportunity. The group agreed that all data to be included in the first-release SOCAT data set should be sent to CDIAC no later than 1 September 2008, and the 2nd level QC data set will be frozen on 15 September. The data set for 2nd level QC will then be sent to LAS, which can do the gridding on-the-fly to any specified grid size.

The group agreed it would be desirable to continue acquiring new data as they become available after the 1 September 2008 deadline in order to have them ready for the next version of the data set. It would be best to carry out 1st level QC on the data as soon as possible after submission and to contact data contributors about any problems.

Benjamin Pfeil also pointed out that many data sets may be publicly available, but are not yet in CDIAC. A special effort will be made before the 1 September 2008 deadline to identify those cruises and contact the data contributors as soon as possible.

ACTION ITEM 6: Benjamin Pfeil, Maria Hood and Alex Kozyr will identify data contributors whose data are probably publicly available, but not yet at CDIAC.

3. REGIONAL GROUP REPORTS

The regional group chairs established at the 2007 SOCOVV meeting were asked to provide an update on regional group activities, including members of the group, identification of missing data sets in their regions, possible approaches to 2^{nd} level QC and scientific synthesis priorities.

3.1 INDIAN OCEAN GROUP REPORT
(N. Metzl for V.V.S.S. Sarma)

Group members:
V.V.S.S. Sarma (Chair, NIO, India), A. Murata (JAMSTEC, Japan), C. Sabine (PMEL, NOAA, USA), N. Metzl (Paris, France), C. Goyet (Univ. Perpignan, France), B. Tilbrook (CSIRO, Australia)

Data set identification:
The group has not yet examined the SOCAT version 1.1 data set for missing data.

Scientific synthesis issues and priorities:
The Indian Ocean is very much undersampled compared to the rest of the world ocean (Annex 4). Seasonal sampling has only been carried out for one year in the Arabian Sea (1995), which happened to be an unusually warm year. Good seasonal and inter-annual coverage exists at the French time-series station in the southwestern Indian Ocean. The rest of the region (more than 90%) has been sampled mostly only once or twice. Interannual variability of fCO_2 in the Indian Ocean is completely unknown. The work of Nicolas Metzl suggests that there is a significant effect of the Indian Ocean Dipole (IOD) on CO_2 parameters, but the nature and mechanisms of the variability are unknown. Sarma has applied a simple MLR model to understand the influence of the IOD on CO_2 fluxes and primary productivity (PP) and observed that the fluxes were decreased by about 30% during an IOD year. In the case of Bay of Bengal, nothing much known is at all, including how river runoff affects dissolved inorganic carbon cycling, how biological controls (such as PP and bacterial respiration), change due to river runoff, etc. Hence, little is known about how climatic events and land-driven processes influence different factors controlling fCO_2 in the Indian Ocean.

Dr. Murata of JAMSTEC reports that the Japanese vessel, *R/V Mirai*, is scheduled to visit the eastern equatorial Indian Ocean every year for servicing or deployment of TRITON buoys, and says that it may be possible to install an underway-surface fCO_2 system on the ship for these cruises. Sarma has proposed a couple of cruises in the Bay of Bengal during the next few years. The Japanese vessel *Hakuo Maru* is also arriving in the India Ocean this year, and will make a deep meridional section across the Indian Ocean from 15°N to Antarctica.

Murata and Sabine have observations of several new repeat hydrography sections in the Indian Ocean, and comparisons with the 1995 WOCE cruise sections will allow for an examination of how the Indian Ocean is responding to the anthropogenic forcing.

A new time-series station in the central Bay of Bengal will be operational by the end of this year and is expected to continue for another decade. A coastal time series in the Bay of Bengal has already been operating for the past 9 months. Carbon measurements are planned in the Arabian Sea time series. Therefore, it would be interesting to compare time-series variations of carbon parameters in the northern (Arabian Sea and Bay of Bengal) and southwestern Indian Ocean (French time series).

While we may expect better seasonal and spatial coverage, it will not be possible to create a 1° x 1° grid with the current data coverage.

The following key questions should be addressed in the future to better understand fCO_2 cycling in the Indian Ocean:

1. The highest priority should be given to examine seasonal and inter-annual variability of fCO_2 in different regions such as the Bay of Bengal, the equatorial Indian Ocean and the South Indian Ocean.
2. Efforts should be focused towards examining the influence of Indian Ocean Dipole on surface pCO_2 and the influence of different processes such biological, thermal, and mixing effects, as well as air-sea exchange.
3. More in situ buoys, such as NOAA/PMEL, should be moored in different locations to cover temporal variability.

3.2 PACIFIC OCEAN GROUP REPORT
(R. Feely)

Group members:

- Equatorial and tropical Pacific Group (30 ˚S- 30 ˚N): Dick Feely (Chair).
- South Pacific Group: Bronte Tilbrook (Chair).

Other sub-regions and group members are not yet established.

Data sets identified:
The group has not yet examined the SOCAT version 1.1 data set for missing data.

Scientific synthesis issues and priorities:
For the Pacific Ocean, the goal of surface CO_2 measurement projects is to quantify the daily-to-interannual and decadal variability in air-sea CO_2 fluxes and understand the mechanisms controlling these fluxes. The approach used is to make autonomous surface fCO_2 measurements using research and volunteer observing ships (VOS) to get spatial coverage at seasonal time scales and use a network of surface moorings to get high-frequency temporal resolution. There are currently 7 ships in the Pacific (variable from year to year) with an additional 7 open-ocean moorings and 1 coastal mooring. NOAA, LDEO, JMA, IOS, and CSIRO have been maintaining fCO_2 systems on research and VOS ships in the Pacific Ocean for many years.

3.3 ATLANTIC OCEAN GROUP REPORT
(U. Schuster and N. Lefèvre)

Group members:
Ute Schuster and Nathalie Lefèvre (Co-Chairs): other group members not yet established.

Data set identification:
The group has not yet examined the SOCAT version 1.1 data set for missing data.

Scientific synthesis issues and priorities:
In the North Atlantic, the priorities are:

- to identify variability on seasonal, annual, and interannual variability in CO_2 air-sea fluxes to a higher precision as done so far, and
- to identify the underlying causes for the variability, including changes in e.g. sea surface temperature, biological activity, circulation changes, and the North Atlantic Oscillation .

The North Atlantic is an ocean basin where a high number of measurements are available now, and continuous measurements on research vessels, VOS, moorings, and buoys is continuing. However, some geographical regions, as the south-eastern tropical region, are undersampled in comparison with others, making basin-wide estimations still uncertain. Where sufficient measurements are available, the MLR technique will be used to identify flyers. Additionally, with a relatively high density of measurements (compared to other ocean basins), the use of cross-over analyses will be explored as a tool for quality control.

In the equatorial and Southern Atlantic, data coverage is still low , and 2nd level quality control will be very difficult.

3.4 SOUTHERN OCEAN GROUP
(N. Metzl for B. Tilbrook)

Group members:
Bronte Tilbrook and Nicolas Metzl (Co-Chairs): other group members not yet established.

Data set identification:
The SOCAT data set version 1.1 (April '08) has been explored for the Southern Ocean (south of 30°S). Not surprisingly, compared to Northern Hemisphere, the S.O. is clearly undersampled and large regions have never been sampled (or the data are not yet in SOCAT, see Annex 4, figures 1 and 2). Most of the cruises in S.O.-SOCAT have been conducted since 1986 (only 11 cruises reported before 1984). During the austral winter season (July-September), SOCAT contains very few cruises, especially south of 50°S. However, it is recognized (Figure 1) that three sectors have been better sampled: Drake Passage (Western Atlantic sector), the sections between Tasmania/New-Zealand and Antarctica (Western Pacific sector, including the Ross Sea) and regions around sub-Antarctic French Islands (Western Indian sector).

QC issues:

For QC issues, five topics have been explored using SOCAT, that may also help in selecting/producing QC1 and QC2 for other regions:

1. Detecting bad or missing data and information in the data base: for example, Julian day not included for all cruises, the number of digits for hydrography incorrect for some cruises, etc.. This should be checked as QC1 for all cruises, not only the S.O. region. The easiest way would be to ask all contributors to check their data (e.g. by selecting name of cruises in SOCAT) and send back comments to B. Pfeil.
2. Check differences between Equilibrium Temperature and SST: this is especially important in cold waters of the Southern Ocean as well as in large SST gradients when crossing frontal zones. In the SOCAT data set we identified some cruises that present very large differences between Equilibrium Temperature and SST (differences between 5°C and 20°C). It has been noted that for some of these cruises, recomputed fCO2 is not reported; therefore these data should be deleted. Such comparison (plots Teq versus SST) should be performed for all regions.

3. Comparison of atmospheric xCO_2 recorded on board to independent atmospheric xCO2 data: this is especially interesting in the Southern Ocean as the spatio-temporal variability of atmospheric CO_2 is relatively low in the southern hemisphere. Examples of such comparisons have been presented (south Indian region), which help verify the quality of the standards and data processing as well as long-term analysis. The comparison has been done using atmospheric xCO_2 data from monitoring stations (using the original xCO_2 data, not using the GlobaView 2D (time/latitude) interpolated product). It has been noted that for some cruises such a comparison is difficult, mostly because of pollution by the ship.

4. Identifying intercomparison cruises: For the S.O., four intercomparisons have been identified.

- Several groups that provided data to SOCAT (S.O. region) were involved in the intercomparion cruises onboard *Meteor* (1996, see section 2.1 in this report; also Körtzinger et al., 2000). During this cruise, the differences between systems fromCSIRO (Australia), MRI (Japan) and IPSL (France) was about +/- 2 µatm.
- Intercomparison conducted during a cruise on the *Aurora Australis* (2003, south of Tasmania) between CSIRO (Australia) and Ulg (Belgium) systems: difference was about +/- 4 µatm.
- Intercomparison conducted during OISO-8 cruise on the *Marion-Dufresne* (Dec-1998, South Indian sector) between systems of IPSL (France) and Ulg (Belgium) : difference about +/- 5 µatm
- Intercomparison conducted onboard *L'Astrolabe* (Jan-2008, south of Tasmania) between CSIRO ("old system") and the GO-CSIRO ("new instrument"). Specify type of this new system. What is the main difference with the old system.): difference 0.2 +/- 2.2 µatm.

These results are in the range (4-5 µatm) of the uncertainty for most surface pCO_2 data (see discussion in section II of this report). The good results obtained during the recent comparison in January 2008 with the GO system (now used by many groups) suggest that such intercomparisons should be performed more regularly (when possible) to verify "old systems" and thus help to verify historical data in SOCAT.

5. Identifying Cross-over for intercomparison: this concept is tricky (see report SOCAT-I meeting), and we think it is especially tricky for the S.O. because of high mesoscale variability in frontal zones and in the Seasonal Ice Zone (where large daily changes and small-scale, variations (i.e. few km), are common during austral summer). Using Cross-over analysis for QC is not recommended for the S.O. region.

Scientific synthesis issues and priorities:

The scientific issues have been separated following temporal scale (here referring mostly to data-based analysis).

Past and recent past activities

Seasonality: In the sub-Antarctic zone and Polar Front zone, several analyses have been published over the last ten years, and in these sectors, the pCO_2 seasonality is relatively well known. At higher latitudes (south of the Polar Front) the seasonality, as well as the climatology of pCO_2, have been improved only in recent years. This is mainly because of new data collected during the austral winter season (high fCO_2). Although winter data are sparse, a simple interpolation of SOCAT recomputed fCO_2 data clearly shows that fCO_2 is higher south of 50°S. On an annual scale, the summer CO_2 sink is balanced by the winter source. Recent estimates suggest that the net annual air-sea CO_2 flux is low (range 0-0.2 PgC/yr south of 50°S) compared to previous data-based and modelling approaches.

Interannual variability: a few studies analyzed the interannual variability in the Southern Ocean. These were mainly based on cruise to cruise comparison (e.g. two periods) and chosen to highlight and understand large pCO_2 anomalies (in summer only and often associated to warm anomalies and biological activity at local/regional scales). A synthesis of 22 cruises (1991-2003) has been recently composed to evaluate the interannual variability of pCO_2 in the subtropical and sub-Antarctic regions south of Tasmania; this analysis suggests that pCO_2 anomalies are likely related to large-scale climate indices (SAM, ENSO).

Decadal variability: detecting the decadal change (or stability) of ocean pCO_2 obviously needs long-term and accurate observations. Only very recently some groups (in Japan, France, USA and New-Zealand) have been able to explore the decadal trends of ocean pCO_2 and compare with the rate observed in the atmosphere. In short, all studies show that ocean pCO_2 increases in the S.O. but the rates are different depending the location and period. The decadal rates deduced from the data range between 10 to 20 µatm/decade in the region 30°S-50°S, and between 18 to 24 µatm/decade south of the Polar Front.

Present and near future activities

Although the results listed above indicate encouraging progress in the S.O. regions, it is worth recalling that most of these analyses were conducted at local or regional scales. It is expected that the SOCAT data set will help to investigate the spatio-temporal variability of pCO_2 at a basin scale. In this context several issues have been identified:

Re-Investigate the seasonal variability in all S.O. regions, especially at high latitudes including the complex seasonal ice zone where pCO_2 temporal variability (when observed) is very high, both rate (~ order of 1 week) and size of change (> 50 µatm). A better understanding of the processes controlling the seasonal variability in all sectors is also needed to improve biogeochemical parameterization of ocean models.

Understanding the interannual to decadal variability: Recent studies based on atmospheric CO_2 observations as well as ocean modelling suggest that the Southern Ocean CO_2 sink has been saturated for about two decades (or is no longer keeping pace with atmospheric CO_2 increases). This is due to an intensification of the Southern Annular Mode (SAM) which increases ventilation of carbon-rich deep water. Detecting the interannual to decadal change of the S.O. carbon uptake from in-situ observations and at basin scale is challenging, as the data are sparse. The few studies that have documented decadal trends of pCO_2 (see above) show that the rate of increase in surface water pCO_2 is not far from the atmospheric change (given the uncertainties). Both the SOCAT data set and derived accompanying monthly Atlas will help to identify key regions where such a decadal analysis could be performed and compared. In this context, we also expect to separate the anthropogenic signal and natural or climate induced variability. For this, an important new goal would be to create a synthesis of both DIC and TA data that have been also measured in the surface waters during several cruises.

Interpolation and extrapolation methods: As we expect to estimate air-sea CO_2 fluxes at basin-scale, for both seasonal and long-term analysis, interpolation/extrapolation methods need to be investigated in the S.O. where data are sparse in space and time. Unfortunately, simple regression techniques (e.g. pCO_2 versus SST, Chla, etc.) are not able to reconstruct pCO_2 fields in the S.O. Indeed, it has been shown that there is no simple relationship with SST (especially at high latitude). Methods based on MLR approaches or neural networks (NN) that used SST, Chl-a, MLD, etc, have been tested in the North Atlantic, but not in the S.O.; these are attractive approaches but cloud cover often limits the use of satellite products in the S.O. (e.g. Chla). Therefore, new approaches have to be developed or adapted (e.g. linking pCO_2 data with altimetry).

High winds and changes in the winds: an important source of uncertainty in CO_2 flux estimates from observations is the gas transfer velocity, especially at the high wind speeds of the Southern Ocean. It is expected that recent experiments conducted in the Southern Ocean (e.g. GasEx III, 2008) will offer new results and reduce the uncertainties attached to the gas exchange coefficient. The effects of sea ice dynamics on air-sea CO_2 fluxes are poorly known.

Other topics for the S.O. group: Based on the SOCAT data, it should be possible after selecting specific data to address new questions relevant for the S.O. region: the role of mesoscale (eddies, fronts), the role of sea-ice, comparing naturally fertilized areas (Islands in circumpolar regions, sea-ice regions), identifying large pCO_2 anomalies as a proxy in Climate change, etc.

3.5 COASTAL REGIONS
(A. Borges and A. Chen)

Group members:
Alberto Borges and Arthur Chen (Co-Chairs); Potential group members contacted include Abdir Omar, Arthur Chen, Bruno Delille, Burke Hales, Dorothee Bakker, Fiz Fernandez Perez, Francisco Chavez, Helmuth Thomas, Joe Salisbury, Magdalena Santana-Casiano, Minhan Dai, Nick Bates, Nick Hardman-Mountford, Simone Alin, Ute Schuster, Vedula V.S.S. Sarma, Wei-Jun Cai.
Several more potential candidates have been identified during SOCAT-2.

Data set identification:
The group has not yet examined the SOCAT version 1.1 data set for missing data.

Scientific synthesis issues and priorities:
One of the major scientific issues to be addressed by an enhanced global coastal data set is to reconcile opposing views on carbon cycling in the coastal ocean; namely, that continental shelves act as sinks and near-shore ecosystems act as sources of CO_2 to the atmosphere. The direction of the flux changes both spatially and seasonally, and the controls on this are not fully understood. The impact of rivers is of particular interest.

Quality control of coastal data is even more complicated than in open oceanic waters. There are large areas of the world's coastal zones that do not have data. Where data do exist, they are often of poor quality. In many cases, very simple measurement techniques are used, and many scientists working in these areas do not know the difference between xCO_2 (mixing ratio) and fCO_2, and do not record atmospheric pressure or humidity. Mooring data indicate that typical day-to-day variability in fCO_2 data is up to 50 µatm, and that sub-daily variability can be up to 25 µatm (due to tidal advection of water masses with different chemical signatures). This will make the cross-over approach very difficult or impossible. Atmospheric xCO_2 cannot help due to continental influence. One way to QC the data is to use quality checked open oceanic data and assume the same quality on the coastal part of the transect. A simple averaging approach without interpolation of data, as decided for the open ocean regions, is also recommended for the coastal region. A 1°x1° resolution of grids is considered too coarse, while a 1/4°x1/4° resolution of grids is assumed over-ambitious. Hence, a grid resolution of 1/2°x1/2° seems a good compromise. LAS should be able to handle 1°x1° grids for the open ocean and 1/2°x1/2° grids for the coastal ocean. It is also recommended that LAS should be able to filter data for depths 0 m to 200 m to extract the coastal ocean data.

ACTION ITEM 7. Regional group chairs will establish their groups (Atlantic, Pacific sub-regions, Southern) and all groups will look through the SOCAT version 1.1 data set to identify data sets that are missing and provide that information to Pfeil. Pfeil, Kozyr, and

Hood will contact data contributors to include those data in the SOCAT data set before the 1 September deadline.

4. SUMMARY AND ACTION ITEM LIST

The group offered its congratulations and thanks to Benjamin Pfeil and Are Olsen for the extraordinary amount of work they have done to get the SOCAT data set to its present stage. The next steps will require input from the regional groups, including identifying missing data sets and looking at the data to see which 2nd level QC checks may be performed in each region (deadline 1 September 2008). The regional groups are asked to carry out 2nd level QC after this date, aiming for a first release of the 2nd level QCed SOCAT data set and SOCAT gridded product by late 2009. The above will require a significant time commitment on the part of the regional groups, and it is not clear that there is either sufficient time or commitment to do this adequately. Having funds to support working group meetings would be extremely helpful, but is unlikely before September 2008. It was also strongly suggested that the groups should identify new science that can be generated from the data set, both regionally and globally, to encourage scientists in the regional groups to put in effort to the QC procedures, and to work towards strong scientific SOCAT presentations (e.g., at the ICDC-8 Conference in September 2009) and publication.

ACTION ITEM 1: Coordinate with OceanSITES on the Platform Names / Codes for time series stations (Pfeil, Olsen, Kozyr, Hood).

ACTION ITEM 2: Develop a separate data set of xCO_2 in dry air to compare with long-term atmospheric monitoring stations and GlobalView. The fCO_2 in air and the difference between fCO_2 in air and water should be added to the main data set eventually, but should be left to future SOCAT versions (Pfeil, Olsen, Hankin, Malczyk).

ACTION ITEM 3: Test the MLR approach in one area to see how difficult this is. (Regional groups)

ACTION ITEM 4: Decide on regional definitions and how to deal with cruises that cross boundaries (Regional groups, Pfeil, Olsen, Hankin, Malczyk)

ACTION ITEM 5: Develop a recommended procedure for providing information about binning (e.g., the number of data points, the number of cruises and the standard deviation of the data.) (Sabine, Schuster, Wanninkhof)

ACTION ITEM 6: Benjamin Pfeil, Maria Hood and Alex Kozyr will identify data contributors whose data are probably open for data sharing but not yet at CDIAC.

ACTION ITEM 7. Regional group chairs will establish their groups (Atlantic, Pacific sub-regions, Southern) and all groups will look through the SOCAT version 1.1 data set to identify data sets that are missing and provide that information to Pfeil. Pfeil, Kozyr, and Hood will contact data contributors to include those data in the SOCAT data set before the 1 September deadline.

ANNEX I

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ANNEX 2

AGENDA

Monday, 16 June 2008

0900 - 0910	Welcome, Opening, Announcements (Maria)
0910 - 0930	Overview of SOCAT-1 Meeting and decisions for 1st level QC data set; goals for SOCAT-2 (Dorothee)
0930-1030	Overview of actions from 1st level QC and discussions (status of level 1 QC data set; treatment of unrealistic values; input on draft technical document, Matlab files, metadata, public data not to be included, etc.). (Benjamin / Are)
1030-1100	*Break*
1100-1130	Overview of issues for 2nd level QC data set (need for consistent data set, assessment of uncertainties per cruise, flags, crossovers, etc.) (Benjamin / Are / Dorothee, etc.)
1130-1200	Assessment of uncertainty per cruise / getting data to a certain level of certainty (Chris, Arne)
1200-1230	Flags (Denis/ Rik)
1230-1400	*Lunch*
1400-1430	Crossover checks (Are, Ute, others with experience)
1430-1500	Quality controlling non-carbon variables (Benjamin)
1500-1530	Tools in the Live Access Server (Steve / Jeremy)
1530-1600	Break
1600-1630	Guidelines for documenting 2nd level QC (Bob)
1630-1700	Gridding and interpolation procedures for gridded data set (Chris, Ute)
1700-1730	Data sharing issues ? What should be included in this 1st version of the data set with 2nd level QC? How should this data set be built upon in the future ? (Chris)
1730-1800	Summary of 2nd level qc issues and open discussion (Dorothee)

Tuesday, June 17, 2008

0930 -1000	Overview of Day 1 decisions (Dorothee)
    1000-1030 1030-1100 1100-1130 1130-1200 1200-1230 1230-1400 1400-1430	Regional QC and science issues (each group should identify major science issues, major data QC issues, describe experience with QC (if any) and who will carry out tasks.) (20 minutes presentation / 10 minutes discussion) Atlantic (Ute and Nathalie) *Break* Pacific (Dick) Indian (Nic to present report of Sarma) Southern Ocean (Nic) *Lunch* Coastal Regions (Alberto and Arthur)
1430 - 1530	Issues for bringing it all together (Bob, Alex, Benjamin, etc.)
1530 - 1600	*Break*
1600-1700	Open discussions and summary decisions on 2nd level QC (Dorothee)
1700-1730	Dates for tasks, public release of 2nd level QC, science meeting follow-up (Maria, Dorothee)
1730	Close of meeting.
1800 - 2000	Joint Reception SOCAT / CARINA; Miollis Coffee Bar

ANNEX 3

SUMMARY OF SOCAT-1

Summary of SOCAT-1 meeting, Bremen, 5 December 2007

I. On the 1st level QC data set:

- Cut-off for data included in this 1st version data set on 31/12/2007. Freeze set of 1st level QC data, until 2nd level QC has been completed.
- Technical issues on the 1st level QC data set by Taro and Ray have been resolved.
- 1st level QC is not a full data QC. Only outliers in salinity and atmospheric pressure have been removed.
- Parameters in the 1st level QC data set: all the measured CO2 parameters in water and air, equilibrator temperature, sea surface temperature, atmospheric pressure, as well as salinity from the World Ocean Atlas and atmospheric pressure from NCEP reanalysis, as well as fCO2 calculated in a consistent way from other CO2 parameters.
- Data will be co-located with bathymetry, especially useful for coastal regions.
- Naming of cruises with EXPO codes (country, ship, year, month, date of sailing).
- The data will be archived at CDIAC and will be made accessible to the data PIs and the regional groups for 2nd level QC.
- The data will be put onto a Live Access Server by the PMEL group before the spring meeting. The LAS will catch problems in the data. The LAS will be live during the meeting.
- Advise all data PIs of data calculation routines and a description of the methods in January 2008 with a month for comments. Distribution via an email from IOCCP, link on IOCCP website and an announcement in the IOCCP Newsletter.
- Ask all PIs if they agree that their data are included (Wanninkhof).
- Encourage the PIs to update the metadata (eg. publications).
- Any further issues?

II. Suggestions on the 2nd level QC:

- Regional groups have been established at the Paris meeting. The groups will lead the 2nd level QC and the science based on the data synthesis.
- Need for consistent 2nd level QC
- How to do this in practical terms?
- Assessment of uncertainty per cruise (Sabine).
- Get the data to a certain level of certainty (Körtzinger).
- Add flags to the data sets. Design a formal table for all flags, such that flags can be assigned in a consistent and transparent manner (Watson). Flags could be based on the accuracy of the analyser, the number of standards etc.
- Crossover concept tricky.
- How critical should one be?
- Identify unrealistic values
- Document everything!
- Use atmospheric xCO2 for QC
- If regions are identified, use at least 10º overlaps (Key)
- 2nd level QC ready by September 2008

III. Meeting of the group leaders on approaches for 2nd level QC in May-June 2008:

- Main aim: Discuss approaches for 2nd level QC (see also section II above)

- Identify approaches for gridding/ interpolation. LAS may help.
- Identify science issues.

IV. Action items:

1. Circulate report of the Bremen meeting among participants. Ask absent group leaders for input (Maria Hood, Dorothee Bakker) (December 2007).

2. Contact PIs via IOCCP (January 2008) (Maria Hood, Dorothee Bakker, Are Olsen, Benjamin Pfeil). Make the items below available to data PIs (Benjamin Pfeil, Are Olsen):
    - Draft technical document with description of methods of 1st level QC and calculation of surface water fCO2,
    - Matlab routines for 1st level QC and calculation of surface water fCO2,
    - Original surface CO2 cruise data files,
    - Metadata,
    - List of cruises with EXPOcodes and original cruise names.
    - Ask data PIs within a month:
    - To comment on the draft technical document and the Matlab routines for 1st level QC and calculation of fCO2.
    - To contact Benjamin Pfeil, if their public data should NOT be included in the data synthesis.
    - To check whether the database has the final version of their data.
    - To check and update the metadata, e.g. publications, information on calibration, information on ice cover.

3. Put 1st level QC data on to Live Access Server by March 2008 (Chris Sabine).

4. Make 1st level QC data set available to the group leaders in March 2008 (Benjamin Pfeil, Are Olsen), if possible via the Live Access Server.

5. Organize a meeting for the group leaders by June 2008 (Maria Hood, Dorothee Bakker).

6. 2nd level data QC ready by late 2008.

7. Plan a scientific meeting in 1-2 years for all data PIs.
    - E.g. Discussion of interpolation methods. LAS can assist in making a gridded product at a 1° by 1° resolution with finer resolution in coastal regions.
    -

8. Prepare scientific papers for the global CO_2 meeting in summer 2009 (Jena).

ANNEX 4

SOCAT VERSION 1.1 DATA DISTRIBUTION GRAPHICS (B.PFEIL)

Figure 1. Spatial Overview of the Data in SOCAT v1.1

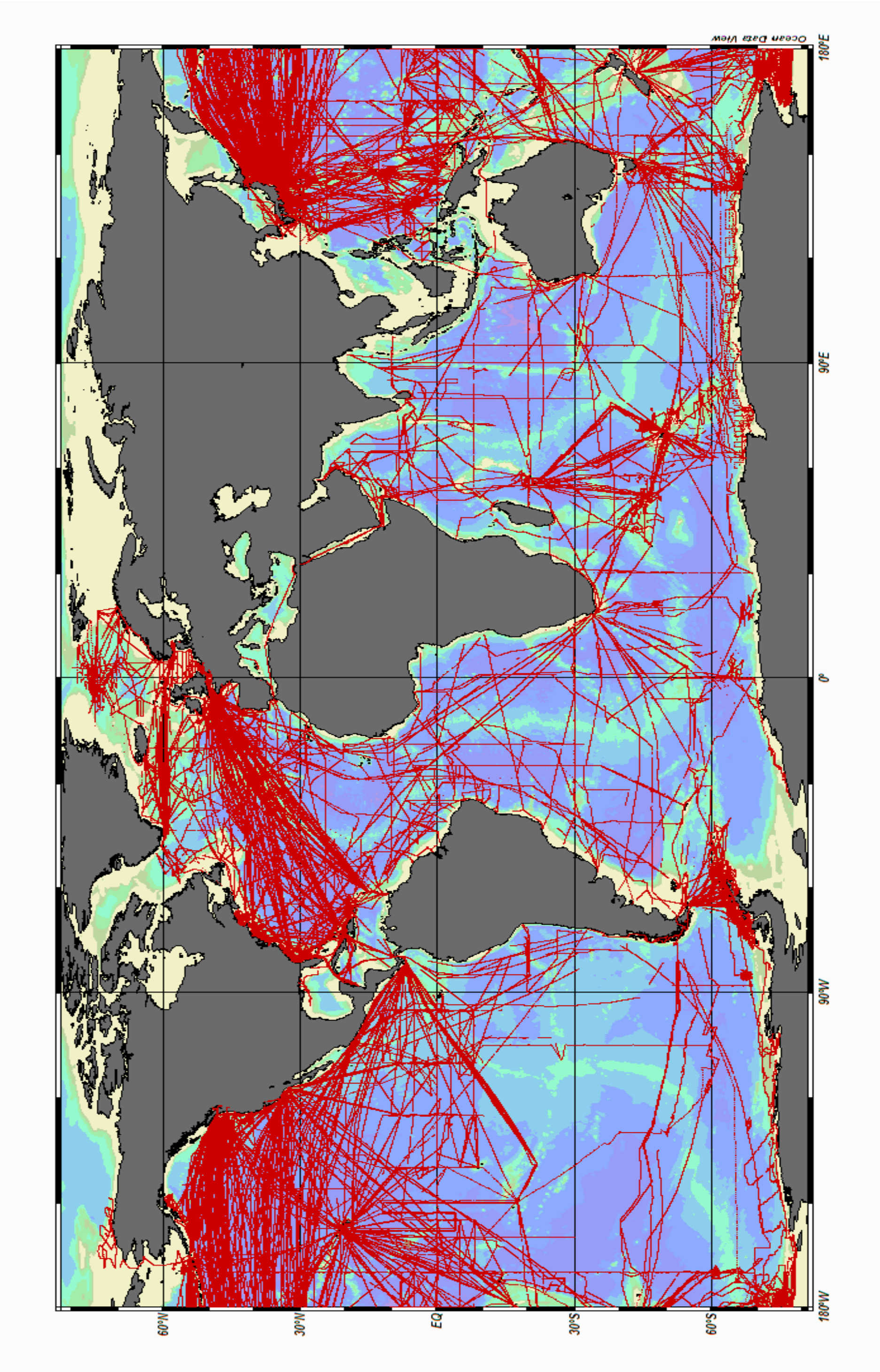


Figure 2. Spatial Distribution of the data in SOCAT v1.1

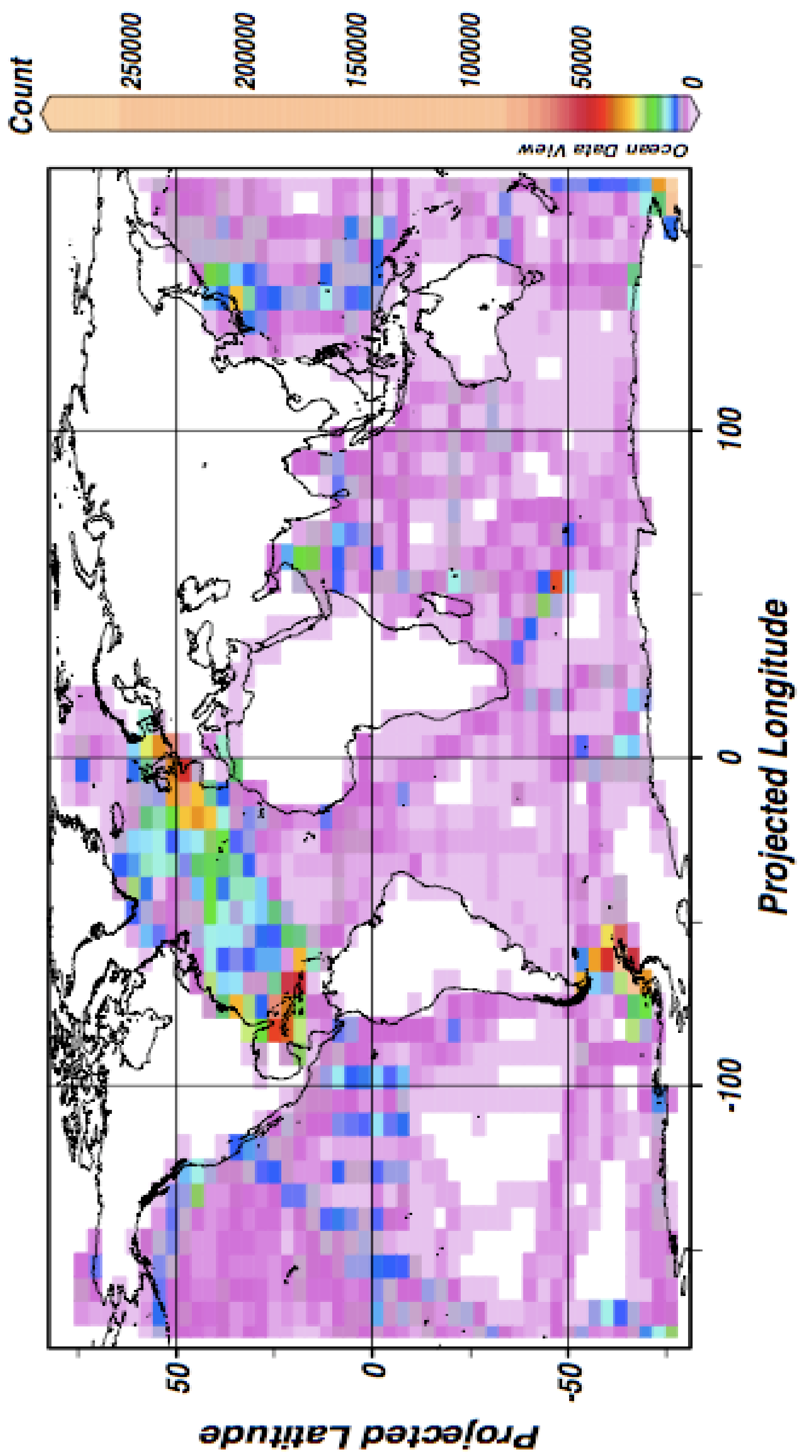
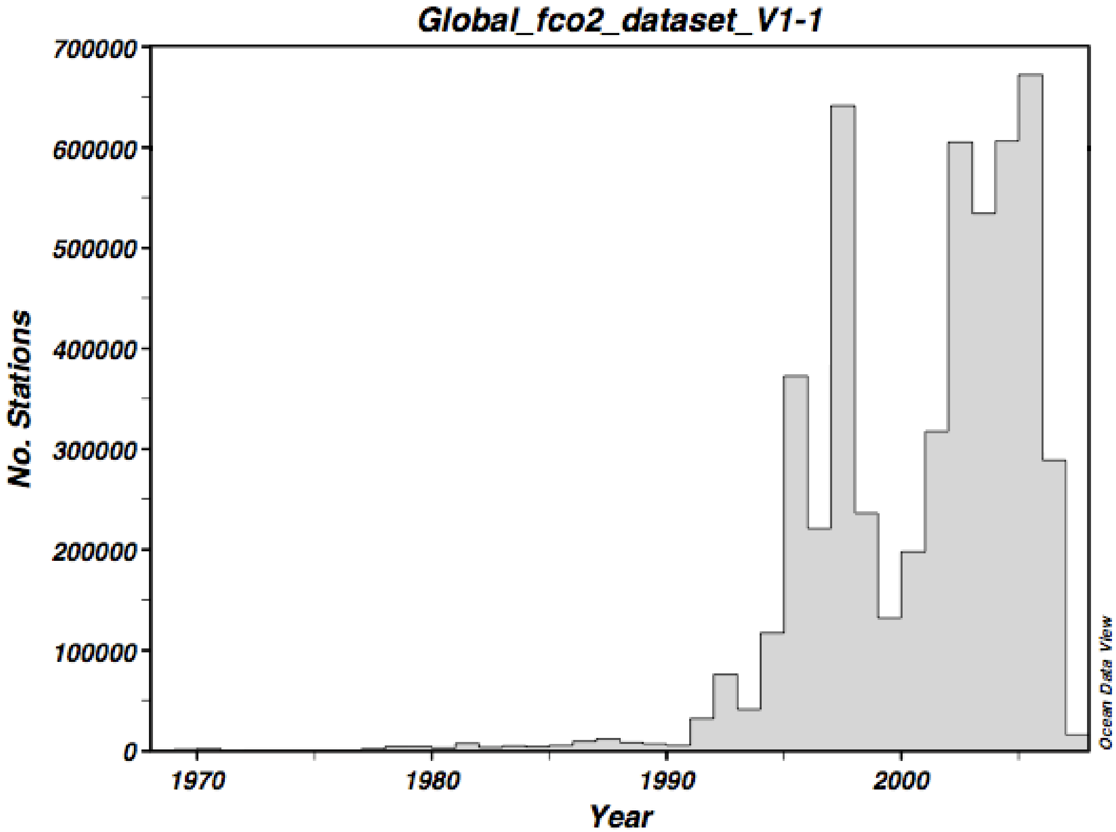


Figure 3. Temporal Distribution of the data in SOCAT v1.1



ANNEX 5

CALCULATIONS USED FOR THE 1ST LEVEL QC DATA SET

Uniform Format Data Set for the Surface Ocean CO_2 Atlas (SOCAT)

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August 2008

Introduction

Over the last few decades several million measurements of the surface ocean CO_2 concentration have been made, in particular following the advent of infrared based measurement devices which determines the CO_2 concentration in an air headspace in equilibrium with a continuous stream of sea water. The concentration can be expressed as the mole fraction of CO_2 in the headspace (xCO_2), the CO_2 partial pressure (pCO_2), and the fugacity of CO_2 (fCO_2) in the headspace, which takes into account the non-ideal behavior of CO_2 gas. It is this latter which should be used for gas exchange calculations. Conversion between these can be carried out using a set of standard procedures (DOE, 1994, Dickson et al., 2007).

Unfortunately investigators have reported data differently. Some have reported xCO_2, some pCO_2, and some fCO_2 of the surface seawater. Given this, and given that the format of the files have varied, it has always been a time consuming task to handle and use data from publicly available data repositories like CDIAC (Carbon Dioxide Information Analysis Center).

To alleviate this situation a uniform format global surface ocean fCO_2 data set has been developed, as encouraged by both the Surface Ocean – Lower Atmosphere Study (SOLAS) and the International Ocean Carbon Coordination Project (IOCCP) at the workshop on "Ocean Surface pCO_2 Data Integration and Database Development", Tsukuba 2004. This document briefly describes the work that has been done.

Equations

To ensure consistency we decided to recompute fCO_2 data whenever possible using a set of standard equations.
Calculations were carried out according to *Recommendation for autonomous underway pCO_2 measuring systems and data reduction routines* by Pierrot et al, 2008, which follows the DOE handbook (DOE, 1994).

Unless otherwise specified, reported xCO_2 data were assumed to be dry mole fractions standardized by each investigator with respect to calibration gas runs at the temperature of equilibration. Calculation of CO_2 partial pressures from these data follows:

$$(pCO_2)^{wet}_{equT} = (xCO_2)^{dry}_{equT}(P_{equ} - pH_2O) \tag{1}$$

where $(xCO_2)^{dry}_{equT}$ is the CO2 mole fraction and pH_2O is the water vapor pressure at the equilibrator temperature.

Water vapor pressure is calculated according to Weiss and Price (1980):

$$pH_2O = \exp(24.4543 - 67.4509(100/T) - 4.8489\ln(T/100) - 0.000544S) \tag{2}$$

The correction for difference in intake and equilibrator temperatures was carried out using the emperical relationship derived by Takahashi et al. (1993)

$$(pCO_2)_{SST}^{wet} = (pCO_2)_{equT}^{wet} \exp\{0.0423(SST - equT)\} \qquad (3)$$

where SST is the sea surface temperature in the same units as *equ*T. Note, our approach here differs from that of Pierrot et al. (2008) who suggest that the conversion to intake temperatures are done on the fCO_2 values. We chose to do it on the pCO_2 values since the Takahahsi et al. (1993) relationship were derived using pCO_2. The difference between these two approaches is very very small. If only fCO_2 at the equilibrator temperature was provided, the conversion to in situ temperature was carried out using these.

Although several approaches are available (e.g., Copin-Montégut, 1988; Goyet et al., 1993; Takahashi et al., 1993; Weiss et al., 1982), the one of Takahashi et al. (1993) was preferred as it does not require knowledge of the alkalinity and TCO2 of the waters and was determined for isochemical conditions, while the others were not.

The conversion of pCO_2 to fCO_2 values is carried out according to:

$$(fCO_2)_{SST}^{wet} = (pCO_2)_{SST}^{wet} \exp\left\{\frac{\left[B(CO_2,SST) + 2\left(1-\left(x_{CO_2}\right)_{equT}^{wet}\right)^2 \delta(CO_2,SST)\right]P_{equ}}{R \times SST}\right\} \qquad (4)$$

where P_{equ} is the pressure (atm) of the equilibrator, and SST is the sea surface temperature (in K). R is 82.0578 cm^3 atm mol^{-1} K^{-1}. $B(CO_2,T)$ and $\delta(CO_2,T)$ are the virial coefficients for CO_2 (Weiss, 1974).

$B(CO_2,T)$ in cm^3 mol^{-1} is given by:

$$B(CO_2,SST) = 1636.75 + 12.0408\ SST - 3.27957\ 10^{-2}\ SST^2 + 3.16528\ 10^{-5}\ SST^3$$
(5)

and $\delta(CO_2,T)$ in cm^3 mol^{-1} by:

$$\delta(CO_2,SST) = 57.7 - 0188\ SST$$

Implementation
The sea surface CO_2 concentration data in the files were reported in 11 different ways, and the large majority of the files contained CO_2 data expressed in at least two different manners (e.g. xCO_2 and fCO_2).

Ideally we would like to have always computed or recomputed fCO_2 values from dry mole fractions along with reported equilibrator and intake temperatures, equilibrator pressure, and surface salinity using the set of equations given above. However, on many occasions not all of the required data were reported in the data files, and this necessitated the use of different starting points for our calculations and/or the use of data from external sources. In particular, atmospheric pressure and/or salinity data were sometimes missing. When pressure was missing we used 6 hourly sea level pressure data from the NCEP/NCAR reanalysis project (Kalnay et al., 1996). When salinity was not reported we used climatological monthly mean salinity data from the World Ocean Atlas 2005 (Antonov et al., 2005). The salinity has only a minor effect on the calculations as it only influences the fCO_2 through the water vapor pressure (see eqs 1 and 2).

Table 1 lists the various starting CO_2 parameters for our recalculations, the additional supplied data, and what external data were required for the calculation. This list also gives the order of preference for our recalculations. That is, if (1) was possible this was used. If (1) was not possible but (2) was, then (2) was used. If neither (1) nor (2) was possible, but (3) was, then this was used and so on. The philosophy behind this scheme was to (a) start out as close to dry xCO_2 values as possible and (b) to limit use of external data unless absolutely required (i.e. when no in situ fCO_2 data could be obtained without resorting to WOA salinities or NCEP/NCAR pressures.). If fCO_2 data were provided, but no xCO_2 or pCO_2, like from for instance a CARIOCA buoy, the fCO_2 values were retained.

Finally, if either atmospheric pressure or NCEP/NCAR were used, 3 hPa were added to account for the overpressure normally maintained in ships (Takahashi and Sutherland, 2007).

We note that even though 11 different types of surface CO_2 data were reported, only 5 were used for the recalculations. The others were incorrectly classified or somewhat obscure (for instance xCO_2 at sea surface temperature at 100% humidity) and could not be used in either equation 1 or 3 directly. However, no data were lost since all the data sets containing non-usable parameters also had parameters that could be used for recalculations.

Table 1: Reported CO_2 Parameters Used for the Calculations in Order of Preference

Preference[b]	CO_2 parameter	required extra var.	number of occurrences	occurrences in %
1	dry xCO_2 at eq or intake temp[a]		3,144,803	67.19
2	pCO_2 at eq. or intake temp[a]		278,690	5.96
3	fCO_2 at eq or intake temp[a]		573,859	12.26
4	pCO_2 at eq or intake temp but no pressure[a,c]	pressure	617,377	13.19
5	xCO_2 but no pressure and SSS[a]	SSS & pressure	65,060	1.39
	total		4,679,789	

[a]Some xCO_2/pCO_2/fCO_2 data were reported at intake temp. For these, the correction to intake temperature was not carried out. It is clear from the data file what data were reported at intake temperature and what data were reported at equilibrator temperature.
[b]Number is also used within the output data file for identifying which reported CO_2 variable was used for calculations. See Table 2.
[c]In case pCO_2 at eq or intake temperature was reported without an accompanying pressure it was assumed that the pCO_2 was reported at 1 atm, i.e. NCEP/NCAR sea level pressure was only used for the conversion to fCO_2

Reported data

All scripts and in- and output data have been made available along with this report. Transparency is essential for assuring the best quality data product and we encourage all to evaluate our calculations to identify any errors.

The data file contains all of the reported data, the NCEP/NCAR pressures and the WOA salinities. In addition bottom depth from ETOPO2 (http://www.ngdc.noaa.gov/mgg/global/global.html) has been included for identification of shelf and coastal data.

The file also contains an identifier which shows what input parameter was used. It should also indicate whether the original data were provided at equilibrator or intake temperature.

Table 2: Parameters Reported in the Output File:

Abbreviation	Description	unit
intake_depth	water intake depth	m
sst	sea surface temperature	deg C
sss	sea surface salinity	PSU
fCO2_rec	recomputed fCO_2	µatm
eq_t	temperature at equilibration	deg C
atm_press	atmospheric pressure as reported	hPa
equ_press	equilibrator headspace pressure as reported	hPa
Press	pressure used for recomputing (if atmospheric pressure, 3hPa has been added)	hPa
win_dir	wind direction as reported	deg
wind_speed	wind speed as reported	m/s
Jday	Julian day as reported	
ship_speed	ship speed	knot
ship_dir	ship heading direction	deg
Hum	humidity	%
WOA_sss	salinity extracted from WOA 2005	PSU
NCEP_slp	atmospheric pressure extracted from NCEP/NCAR 6 hourly data	hPa
ETOPO_z	Bottom depth from ETOPO2v2c, http://www.ngdc.noaa.gov/mgg/global/etopo2.html	M
XCO2_w_sst_wet	xCO_2 water at sea surface temperature in wet air	µmol/mol
XCO2_w_eqt_wet	xCO_2 water at equilibrator temperature in wet air	µmol/mol
XCO2_w_sst_dry	xCO_2 water at sea surface temperature in dry air	µmol/mol
XCO2_w_eqt_dry	xCO_2 water at equilibrator temperature in dry air	µmol/mol
XCO2_w_eqt_dry_n	xCO_2 water at equilibrator temperature in dry air. Duplicate*	µmol/mol
fCO2_insitu_from_XCO2	fCO_2 recomputed from xCO_2, salinity and either atmospheric pressure or pressure at equilibration provided in the file	µatm
fCO2_insitu_from_XCO2_WOA	fCO_2 recomputed from xCO_2, salinity data used from WOA 2005	µatm
fCO2_insitu_from_XCO2_NCEP	fCO_2 recomputed from xCO_2, atmospheric pressure used from NCEP/NCAR	µatm
fCO2_insitu_from_XCO2_WOA_NCEP	fCO_2 recomputed from xCO_2, salinity used from WOA 2005 and atmospheric pressure used from NCEP/NCAR	µatm
pCO2_theta_w_sst	pCO_2, water at sea surface temperature in wet air Duplicate*	µatm
pCO2_w_eqt	pCO_2, water at equilibrator temperature in wet air	µatm
pCO2_w_sst_wet	pCO_2, water at sea surface temperature in wet air	µatm
pCO2_w_sst_wet_n	pCO_2, water at sea surface temperature in wet air Duplicate*	µatm
fCO2_insitu_from_pCO2	fCO_2 recomputed from pCO_2, salinity and either atmospheric pressure or pressure at equilibration provided in the file	µatm
fCO2_insitu_from_pCO2_NCEP	fCO_2 recomputed from pCO_2, salinity provided atmospheric pressure used from NCEP/NCAR	µatm
fCO2_w_corr20	fCO_2, water corrected to 20 deg C sea surface	µatm

	temperature in wet air	
fCO2_w_corr25	fCO_2, water corrected to 25 deg C in wet air	μatm
fCO2_w_eq	fCO_2, water in wet air at equilibrator temperature	μatm
fCO2_w_sst_wet	fCO_2, water at sea surface temperature in wet air	μatm
fCO2_insitu_from_f CO2	fCO_2, recomputed from fCO_2 salinity and either atmospheric pressure or pressure at equilibration provided in the file	μatm
Id_CO2_used	Identifies which reported CO_2 value was used for the calculations (see Table 1 for details)	
station	number of measurements during a cruise	
identifier	Important for later data handling, which will enable easier tracking of changes.	

* Duplicate: Will be corrected in next version.

References

Antonov, J.I., Locarnini, R.A., Boyer, T.P., Mishonov, A.V., Garcia, H.E., 2006.

World Ocean Atlas 2005, Volume 2: Salinity. Levitus, S., ed, NOAA Atlas NESDIS 62, U.S. Government Printing Office, Washington, D.C., 182 pp.

Copin-Montégut, C., 1988. A new formula for the effect of temperature on the partial pressure of CO_2 in seawater. Marine Chemistry 25 (1), 29-37.

DOE, 1994. Handbook of methods for the analysis of the various parameters of the carbon dioxide system in sea water. Version 2, Dickson, A.G., Goyet, C., eds, ORNL/CDIAC-74.

Dickson, A.G., Sabine, C.L., Christian, J.R, 2007. Guide to best practices for ocean CO_2 measurements. PICES Special Publication 3,191pp.

Goyet, C., Millero, F.J., Poisson, A., Shafer, D.K., 1993. Temperature dependence of CO2 fugacity in seawater. Marine Chemistry 44 (2-4), 205-219.

Kalnay, E. et al, 1996. The NCEP/NCAR 40-year reanalysis project. Bulletin of American Meteorological Society 77, 437-470.

Pierrot, D., Neill, C., Sullivan, K., Castle, R., Wanninkhof, R., Lüger, H., Johannessen, T., Olsen, A., Feely R.A., Cosca, C.E., 2008. Recommendations for Autonomous Underway pCO_2 Measuring Systems and Data Reduction Routines. Deep-Sea Research Part II. To be published.

Takahashi, T., Olafsson, J., Goddard, J.G., Chipman, D.W., Sutherland, S.C., 1993. Seasonal-Variation of CO2 and Nutrients in the High-Latitude Surface Oceans – a Comparative-Study. Global Biogeochemical Cycles 7 (4), 843-878.

Weiss, R.F., 1974. Carbon dioxide in water and seawater: the solubility of a non-ideal gas. Marine Chemistry 2, 203-215.

Weiss, R.F., Jahnke, R.A., Keeling, C.D., 1982. Seasonal effects of temperature and salinity on the partial pressure of CO2 in seawater (Pacific Ocean). Nature 300 (5892), 511-513.

Weiss, R.F., Price, B.A., 1980. Nitrous oxide solubility in water and seawater. Marine Chemistry 8, 347–359.

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16	Workshop on the Western Pacific, Tokyo, 19-20 February 1979.	E, F, R
17	Joint IOC/WMO Workshop on Oceanographic Products and the IGOSS Data Processing and Services System (IDPSS); Moscow, 9-11 April 1979.	E
17 suppl.	Papers submitted to the Joint IOC/WMO Seminar on Oceanographic Products and the IGOSS Data Processing and Services System; Moscow, 2-6 April 1979.	E
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28	FAO/IOC Workshop on the effects of environmental variation on the survival of larval pelagic fishes. Lima, 20 April-5 May 1980.	E
29	WESTPAC Workshop on Marine Biological Methodology; Tokyo, 9-14 February 1981.	E
30	International Workshop on Marine Pollution in the South-West Atlantic; Montevideo, 10-14 November 1980.	E (out of stock) S
31	Third International Workshop on Marine Geoscience; Heidelberg, 19-24 July 1982.	E, F, S
32	UNU/IOC/UNESCO Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the context of the New Ocean Regime; Paris, France, 27 September-1 October 1982.	E, F, S
32 Suppl.	Papers submitted to the UNU/IOC/ UNESCO Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the Context of the New Ocean Regime; Paris, France, 27 September-1 October 1982.	E
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36	IOC/FAO Workshop on the Improved Uses of Research Vessels; Lisbon, Portugal, 28 May-2 June 1984.	E
36 Suppl.	Papers submitted to the IOC/FAO Workshop on the Improved Uses of Research Vessels; Lisbon, 28 May-2 June 1984	E
37	IOC/UNESCO Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs; Colombo, 8-13 July 1985.	E
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40 Suppl.	First International Tsunami Workshop on Tsunami Analysis, Prediction and Communications, Submitted Papers; Sidney, B.C., Canada, 29 July-1 August 1985.	E
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44 Suppl.	IOC-FAO Workshop on Recruitment in Tropical Coastal Demersal Communities, Submitted Papers; Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986.	E
45	IOCARIBE Workshop on Physical Oceanography and Climate; Cartagena, Colombia, 19-22 August 1986.	E
46	Reunión de Trabajo para Desarrollo del Programa "Ciencia Oceánica en Relación a los Recursos No Vivos en la Región del Atlántico Sud-occidental"; Porto Alegre, Brasil, 7-11 de abril de 1986.	S
47	IOC Symposium on Marine Science in the Western Pacific: The Indo-Pacific Convergence; Townsville, 1-6 December 1966	E
48	IOCARIBE Mini-Symposium for the Regional Development of the IOC-UN (OETB) Programme on 'Ocean Science in Relation to Non-Living Resources (OSNLR)'; Havana, Cuba, 4-7 December 1986.	E, S
49	AGU-IOC-WMO-CPPS Chapman Conference: An International Symposium on 'El Niño'; Guayaquil, Ecuador, 27-31 October 1986.	E
50	CCALR-IOC Scientific Seminar on Antarctic Ocean Variability and its Influence on Marine Living Resources, particularly Krill (organized in collaboration with SCAR and SCOR); Paris, France, 2-6 June 1987.	E
51	CCOP/SOPAC-IOC Workshop on Coastal Processes in the South Pacific Island Nations; Lae, Papua-New Guinea, 1-8 October 1987.	E
52	SCOR-IOC-UNESCO Symposium on Vertical Motion in the Equatorial Upper Ocean and its Effects upon Living Resources and the Atmosphere; Paris, France, 6-10 May 1985.	E
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55	IBCCA Workshop on Data Sources and Compilation, Boulder, Colorado, 18-19 July 1988.	E
56	IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Cleveland, Australia, 24-30 July 1988.	E
57	IOC Workshop on International Co-operation in the Study of Red Tides and Ocean Blooms; Takamatsu, Japan, 16-17 November 1987.	E
58	International Workshop on the Technical Aspects of the Tsunami Warning System; Novosibirsk, USSR, 4-5 August 1989.	E
58 Suppl.	Second International Workshop on the Technical Aspects of Tsunami Warning Systems, Tsunami Analysis, Preparedness,	E

No.	Title	Languages
	Observation and Instrumentation. Submitted Papers; Novosibirsk, USSR, 4-5 August 1989.	
59	IOC-UNEP Regional Workshop to Review Priorities for Marine Pollution Monitoring Research, Control and Abatement in the Wider Caribbean; San José, Costa Rica, 24-30 August 1989.	E, F, S
60	IOC Workshop to Define IOCARIBE-TRODERP proposals; Caracas, Venezuela, 12-16 September 1989.	E
61	Second IOC Workshop on the Biological Effects of Pollutants; Bermuda, 10 September-2 October 1988.	E
62	Second Workshop of Participants in the Joint FAO-IOC-WHO-IAEA-UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region; Accra, Ghana, 13-17 June 1988.	E
63	IOC/WESTPAC Workshop on Co-operative Study of the Continental Shelf Circulation in the Western Pacific; Bangkok, Thailand, 31 October-3 November 1989.	E
64	Second IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Phuket, Thailand, 25-31 September 1989.	E
65	Second IOC Workshop on Sardine/Anchovy Recruitment Project (SARP) in the Southwest Atlantic; Montevideo, Uruguay, 21-23 August 1989.	E
66	IOC ad hoc Expert Consultation on Sardine/ Anchovy Recruitment Programme; La Jolla, California, U.S.A., 1989	E
67	Interdisciplinary Seminar on Research Problems in the IOCARIBE Region; Caracas, Venezuela, 28 November-1 December 1989.	E (out of stock)
68	International Workshop on Marine Acoustics; Beijing, China, 26-30 March 1990.	E
69	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Leningrad, USSR, 28-31 May 1990.	E
69 Suppl.	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Submitted Papers; Leningrad, USSR, 28-31 May 1990.	E
70	IOC-SAREC-UNEP-FAO-IAEA-WHO Workshop on Regional Aspects of Marine Pollution; Mauritius, 29 October - 9 November 1990.	E
71	IOC-FAO Workshop on the Identification of Penaeid Prawn Larvae and Postlarvae; Cleveland, Australia, 23-28 September 1990.	E
72	IOC/WESTPAC Scientific Steering Group Meeting on Co-Operative Study of the Continental Shelf Circulation in the Western Pacific; Kuala Lumpur; Malaysia, 9-11 October 1990.	E
73	Expert Consultation for the IOC Programme on Coastal Ocean Advanced Science and Technology Study; Liège, Belgium, 11-13 May 1991.	E
74	IOC-UNEP Review Meeting on Oceanographic Processes of Transport and Distribution of Pollutants in the Sea; Zagreb, Yugoslavia, 15-18 May 1989.	E
75	IOC-SCOR Workshop on Global Ocean Ecosystem Dynamics; Solomons, Maryland, U.S.A., 29 April-2 May 1991.	E
76	IOC/WESTPAC Scientific Symposium on Marine Science and Management of Marine Areas of the Western Pacific; Penang, Malaysia, 2-6 December 1991.	E
77	IOC-SAREC-KMFRI Regional Workshop on Causes and Consequences of Sea-Level Changes on the Western Indian Ocean Coasts and Islands; Mombasa, Kenya, 24-28 June 1991.	E
78	IOC-CEC-ICES-WMO-ICSU Ocean Climate Data Workshop Goddard Space Flight Center; Greenbelt, Maryland, U.S.A., 18-21 February 1992.	E
79	IOC/WESTPAC Workshop on River Inputs of Nutrients to the Marine Environment in the WESTPAC Region; Penang, Malaysia, 26-29 November 1991.	E
80	IOC-SCOR Workshop on Programme Development for Harmful Algae Blooms; Newport, U.S.A. 2-3 November 1991.	E
81	Joint IAPSO-IOC Workshop on Sea Level Measurements and Quality Control; Paris, France, 12-13 October 1992.	E
82	BORDOMER 92: International Convention on Rational Use of Coastal Zones. A Preparatory Meeting for the Organization of an International Conference on Coastal Change; Bordeaux, France, 30 September-2 October 1992.	E
83	IOC Workshop on Donor Collaboration in the Development of Marine Scientific Research Capabilities in the Western Indian Ocean Region; Brussels, Belgium, 12-13 October 1992.	E
84	Workshop on Atlantic Ocean Climate Variability; Moscow, Russian Federation, 13-17 July 1992	E
85	IOC Workshop on Coastal Oceanography in Relation to Integrated Coastal Zone Management; Kona, Hawaii, 1-5 June 1992.	E
86	International Workshop on the Black Sea; Varna, Bulgaria, 30 September – 4 October 1991	E
87	Taller de trabajo sobre efectos biológicos del fenómeno «El Niño» en ecosistemas costeros del Pacífico Sudeste; Santa Cruz, Galápagos, Ecuador, 5-14 de octubre de 1989.	S only (summary in E, F, S)
88	IOC-CEC-ICSU-ICES Regional Workshop for Member States of Eastern and Northern Europe (GODAR Project); Obninsk, Russia, 17-20 May 1993.	E
89	IOC-ICSEM Workshop on Ocean Sciences in Non-Living Resources; Perpignan, France, 15-20 October 1990.	E
90	IOC Seminar on Integrated Coastal Management; New Orleans, U.S.A., 17-18 July 1993.	E
91	Hydroblack'91 CTD Intercalibration Workshop; Woods Hole, U.S.A., 1-10 December 1991.	E
92	Réunion de travail IOCEA-OSNLR sur le Projet « Budgets sédimentaires le long de la côte occidentale d'Afrique » Abidjan, côte d'Ivoire, 26-28 juin 1991.	E
93	IOC-UNEP Workshop on Impacts of Sea-Level Rise due to Global Warming. Dhaka, Bangladesh, 16-19 November 1992.	E
94	BMTC-IOC-POLARMAR International Workshop on Training Requirements in the Field of Eutrophication in Semi-enclosed Seas and Harmful Algal Blooms, Bremerhaven, Germany, 29 September-3 October 1992.	E
95	SAREC-IOC Workshop on Donor Collaboration in the Development of Marine Scientific Research Capabilities in the Western Indian Ocean Region; Brussels, Belgium, 23-25 November 1993.	E
96	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Zanzibar, United Republic of Tanzania, 17-21 January 1994.	E
96 Suppl.	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Submitted Papers 1. Coastal Erosion; Zanzibar, United Republic of Tanzania 17-21 January 1994.	E
96 Suppl	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Submitted Papers 2. Sea Level; Zanzibar, United Republic of Tanzania 17-21 January 1994.	E
97	IOC Workshop on Small Island Oceanography in Relation to Sustainable Economic Development and Coastal Area Management of Small Island Development States; Fort-de-France, Martinique, 8-10 November, 1993.	E
98	CoMSBlack '92A Physical and Chemical Intercalibration Workshop; Erdemli, Turkey, 15-29 January 1993.	E
99	IOC-SAREC Field Study Exercise on Nutrients in Tropical Marine Waters; Mombasa, Kenya, 5-15 April 1994.	E
100	IOC-SOA-NOAA Regional Workshop for Member States of the Western Pacific - GODAR-II (Global Oceanographic Data Archeology and Rescue Project); Tianjin, China, 8-11 March 1994.	E
101	IOC Regional Science Planning Workshop on Harmful Algal Blooms; Montevideo, Uruguay, 15-17 June 1994.	E
102	First IOC Workshop on Coastal Ocean Advanced Science and Technology Study (COASTS); Liège, Belgium, 5-9 May 1994.	E
103	IOC Workshop on GIS Applications in the Coastal Zone Management of Small Island Developing States; Barbados, 20-22 April 1994.	E
104	Workshop on Integrated Coastal Management; Dartmouth, Canada, 19-20 September 1994.	E
105	BORDOMER 95: Conference on Coastal Change; Bordeaux, France, 6-10 February 1995.	E
105 Suppl.	Conference on Coastal Change: Proceedings; Bordeaux, France, 6-10 February 1995	E
106	IOC/WESTPAC Workshop on the Paleographic Map; Bali, Indonesia, 20-21 October 1994.	E
107	IOC-ICSU-NIO-NOAA Regional Workshop for Member States of the Indian Ocean - GODAR-III; Dona Paula, Goa, India, 6-9 December 1994.	E
108	UNESCO-IHP-IOC-IAEA Workshop on Sea-Level Rise and the Multidisciplinary Studies of Environmental Processes in the Caspian Sea Region; Paris, France, 9-12 May 1995.	E
108 Suppl.	UNESCO-IHP-IOC-IAEA Workshop on Sea-Level Rise and the Multidisciplinary Studies of Environmental Processes in the Caspian Sea Region; Submitted Papers; Paris, France, 9-12 May 1995.	E
109	First IOC-UNEP CEPPOL Symposium; San José, Costa Rica, 14-15 April 1993.	E
110	IOC-ICSU-CEC regional Workshop for Member States of the Mediterranean - GODAR-IV (Global Oceanographic Data Archeology and Rescue Project) Foundation for International Studies, University of Malta, Valletta, Malta, 25-28 April 1995.	E
111	Chapman Conference on the Circulation of the Intra-Americas Sea; La Parguera, Puerto Rico, 22-26 January 1995.	E
112	IOC-IAEA-UNEP Group of Experts on Standards and Reference Materials (GESREM) Workshop; Miami, U.S.A., 7-8 December 1993.	E
113	IOC Regional Workshop on Marine Debris and Waste Management in the Gulf of Guinea; Lagos, Nigeria, 14-16 December 1994.	E
114	International Workshop on Integrated Coastal Zone Management (ICZM) Karachi, Pakistan; 10-14 October 1994.	E
115	IOC/GLOSS-IAPSO Workshop on Sea Level Variability and Southern Ocean Dynamics; Bordeaux, France, 31 January 1995	E
116	IOC/WESTPAC International Scientific Symposium on Sustainability of Marine Environment: Review of the WESTPAC Programme, with Particular Reference to ICAM, Bali, Indonesia, 22-26 November 1994.	E
117	Joint IOC-CIDA-Sida (SAREC) Workshop on the Benefits of Improved Relationships between International Development Agencies, the IOC and other Multilateral Inter-governmental Organizations in the Delivery of Ocean, Marine Affairs and Fisheries Programmes; Sidney B.C., Canada, 26-28 September 1995.	E
118	IOC-UNEP-NOAA-Sea Grant Fourth Caribbean Marine Debris Workshop; La Romana, Santo Domingo, 21-24 August 1995.	E
119	IOC Workshop on Ocean Colour Data Requirements and Utilization; Sydney B.C., Canada, 21-22 September 1995.	E
120	International Training Workshop on Integrated Coastal Management; Tampa, Florida, U.S.A., 15-17 July 1995.	E
121	Atelier régional IOC-CERESCOR sur la gestion intégrée des zones littorales (ICAM), Conakry, Guinée, 18–22 décembre 1995	F
122	IOC-EU-BSH-NOAA-(WDC-A) International Workshop on Oceanographic Biological and Chemical Data Management, Hamburg, Germany, 20-23 May 1996	E
123	Second IOC Regional Science Planning Workshop on Harmful Algal Blooms in South America; Mar del Plata, Argentina, 30 October–1 November 1995.	E, S
124	GLOBEC-IOC-SAHFOS-MBA Workshop on the Analysis of Time Series with Particular Reference to the Continuous Plankton Recorder Survey; Plymouth, U.K.,4-7 May 1993.	E
125	Atelier sous-régional de la COI sur les ressources marines vivantes du Golfe de Guinée ; Cotonou, Bénin, 1-4 juillet 1996.	E

No.	Title	Languages
126	IOC-UNEP-PERSGA-ACOPS-IUCN Workshop on Oceanographic Input to Integrated Coastal Zone Management in the Red Sea and Gulf of Aden. Jeddah, Saudi Arabia, 8 October 1995.	E
127	IOC Regional Workshop for Member States of the Caribbean and South America GODAR-V (Global Oceanographic Data Archeology and Rescue Project); Cartagena de Indias, Colombia, 8-11 October 1996.	E
128	Atelier IOC-Banque Mondiale-Sida/SAREC-ONE sur la Gestion Intégrée des Zones Côtières ; Nosy Bé, Madagascar, 14-18 octobre 1996.	E
129	Gas and Fluids in Marine Sediments, Amsterdam, the Netherlands; 27-29 January 1997.	E
130	Atelier régional de la COI sur l'océanographie côtière et la gestion de la zone côtière ;Moroni, RFI des Comores, 16-19 décembre 1996.	E
131	GOOS Coastal Module Planning Workshop; Miami, USA, 24-28 February 1997	E
132	Third IOC-FANSA Workshop; Punta-Arenas, Chile, 28-30 July 1997	S/E
133	Joint IOC-CIESM Training Workshop on Sea-level Observations and Analysis for the Countries of the Mediterranean and Black Seas; Birkenhead, U.K., 16-27 June 1997.	E
134	IOC/WESTPAC-CCOP Workshop on Paleogeographic Mapping (Holocene Optimum); Shanghai, China, 27-29 May 1997.	E
135	Regional Workshop on Integrated Coastal Zone Management; Chabahar, Iran; February 1996.	E
136	IOC Regional Workshop for Member States of Western Africa (GODAR-VI); Accra, Ghana, 22-25 April 1997.	E
137	GOOS Planning Workshop for Living Marine Resources, Dartmouth, USA; 1-5 March 1996.	E
138	Gestión de Sistemas Oceanográficos del Pacífico Oriental; Concepción, Chile, 9-16 de abril de 1996.	S
139	Sistemas Oceanográficos del Atlántico Sudoccidental, Taller, TEMA;Furg, Rio Grande, Brasil, 3-11 de noviembre de 1997	S
140	IOC Workshop on GOOS Capacity Building for the Mediterranean Region; Valletta, Malta, 26-29 November 1997.	E
141	IOC/WESTPAC Workshop on Co-operative Study in the Gulf of Thailand: A Science Plan; Bangkok, Thailand, 25-28 February 1997.	E
142	Pelagic Biogeography ICoPB II. Proceedings of the 2nd International Conference. Final Report of SCOR/IOC Working Group 93; Noordwijkerhout, The Netherlands, 9-14 July 1995.	E
143	Geosphere-biosphere coupling: Carbonate Mud Mounds and Cold Water Reefs; Gent, Belgium, 7–11 February 1998.	E
144	IOC-SOPAC Workshop Report on Pacific Regional Global Ocean Observing Systems; Suva, Fiji, 13-17 February 1998.	E
145	IOC-Black Sea Regional Committee Workshop: 'Black Sea Fluxes' Istanbul, Turkey, 10-12 June 1997.	E
146	Taller Internacional sobre Formacíon de Capacidades para el Manejo de las Costas y los Océanos en le Gran Caribe, La Habana, – Cuba, 7–10 de Julio de 1998 / International Workshop on Management Capacity-Building for Coasts and Oceans in the Wider Caribbean, Havana, Cuba, 7–10 July 1998	S/E
147	IOC-SOA International Training Workshop on the Intregration of Marine Sciences into the Process of Integrated Coastal Management, Dalian, China, 19-24 May 1997.	E
148	IOC/WESTPAC International Scientific Symposium – Role of Ocean Sciences for Sustainable Development Okinawa, Japan, 2-7 February 1998.	E
149	Workshops on Marine Debris & Waste Management in the Gulf of Guinea, 1995-97.	E
150	First IOCARIBE-ANCA Workshop Havana, Cuba, 29 June-1 July 1998.	E
151	Taller Pluridisciplinario TEMA sobre Redes del Gran Caribe en Gestión Integrada de Áreas Costeras Cartagena de Indias, Colombia, 7-12 de septiembre de 1998.	S
152	Workshop on Data for Sustainable Integrated Coastal Management (SICOM) Maputo, Mozambique, 18-22 July 1998	E
153	IOC/WESTPAC-Sida (SAREC) Workshop on Atmospheric Inputs of Pollutants to the Marine Environment Qingdao, China, 24-26 June 1998	E
154	IOC-Sida-Flanders-SFRI Workshop on Ocean Data Management in the IOCINCWIO Region (ODINEA project) Capetown, South Africa, 30 November-11 December 1998.	E
155	Science of the Mediterranean Sea and its applications UNESCO, Paris 29-31 July 1997	E
156	IOC-LUC-KMFRI Workshop on RECOSCIX-WIO in the Year 2000 and Beyond, Mombasa, Kenya, 12-16 April 1999	E
157	'98 IOC-KMI International Workshop on Integrated Coastal Management (ICM), Seoul, Republic of Korea 16-18 April 1998	E
158	The IOCARIBE Users and the Global Ocean Observing System (GOOS) Capacity Building Workshop, San José, Costa Rica, 22-24 April 1999	E
159	Oceanic Fronts and Related Phenomena (Konstantin Fedorov Memorial Symposium) – Proceedings, Pushkin, Russian Federation, 18-22 May 1998	E
160	Under preparation	
161	Under preparation	
162	Workshop report on the Transports and Linkages of the Intra-americas Sea (IAS), Cozumel, Mexico, 1-5 November 1997	E
163	Under preparation	
164	IOC-Sida-Flanders-MCM Third Workshop on Ocean Data Management in the IOCINCWIO Region (ODINEA Project), Cape Town, South Africa, 29 November – 11 December 1999	E
165	An African Conference on Sustainable Integrated Management; Proceedings of the Workshops. An Integrated Approach, (PACSICOM), Maputo, Mozambique, 18 –25 July 1998	E, F
166	IOC-SOA International Workshop on Coastal Megacities: Challenges of Growing Urbanization of the World's Coastal Areas; Hangzhou, P.R. China, 27 –30 September 1999	E
167	IOC-Flanders First ODINAFRICA-II Planning Workshop, Dakar, Senegal, 2-4 May 2000	E
168	Geological Processes on European Continental Margins; International Conference and Eight Post-cruise Meeting of the Training-Through-Research Programme, Granada, Spain, 31 January – 3 February 2000	E
169	International Conference on the International Oceanographic Data & Information Exchange in the Western Pacific (IODE-WESTPAC) 1999, ICIWP '99, Langkawi, Malaysia, 1-4 November 1999	***under preparation***
170	IOCARIBE-GODAR-I Cartagenas, Colombia, February 2000	***under preparation***
171	Ocean Circulation Science derived from the Atlantic, Indian and Arctic Sea Level Networks, Toulouse, France, 10-11 May 1999	E
172	(*Under preparation*)	
173	The Benefits of the Implementation of the GOOS in the Mediterranean Region, Rabat, Morocco, 1-3 November 1999	E, F
174	IOC-SOPAC Regional Workshop on Coastal Global Ocean Observing System (GOOS) for the Pacific Region, Apia, Samoa, 16-17 August 2000	E
175	Geological Processes on Deep-water European Margins, Moscow-Mozhenka, 28 Jan.-2 Feb. 2001	E
176	MedGLOSS Workshop and Coordination Meeting for the Pilot Monitoring Network System of Systematic Sea Level Measurements in the Mediterranean and Black Seas, Haifa, Israel, 15-17 May 2000	E
177	*(Under preparation)*	
178	*(Under preparation)*	
179	*(Under preparation)*	
180	Abstracts of Presentations at Workshops during the 7th session of the IOC Group of Experts on the Global Sea Level Observing System (GLOSS), Honolulu, USA, 23-27 April 2001	E
181	*(Under preparation)*	
182	*(Under preparation)*	
183	Geosphere/Biosphere/Hydrosphere Coupling Process, Fluid Escape Structures and Tectonics at Continental Margins and Ocean Ridges, International Conference & Tenth Post-cruise Meeting of the Training-through-Research Programme, Aveiro, Portugal, 30 January-2 February 2002	E
184	*(Under preparation)*	
185	*(Under preparation)*	
186	*(Under preparation)*	
186	*(Under preparation)*	
187	Geological and Biological Processes at deep-sea European Margins and Oceanic Basins, Bologna, Italy, 2–6 February 2003	E
188	Proceedings of 'The Ocean Colour Data' Symposium, Brussels, Belgium, 25-27 November 2002	E
189	Workshop for the Formulation of a Draft Project on Integrated Coastal Management (ICM) in Latin America and the Caribbean (LAC), Cartagena, Colombia, 23–25 October 2003 Taller de Formulación de un Anteproyecto de Manejo Costero Integrado (MCI) en América Latina y el Caribe (ALC), Cartagena, Colombia, 23–25 de Octubre de 2003	E F ***(electronic copy only)***
190	First ODINCARSA Planning Workshop for Caribbean Islands, Christchurch, Barbados, 15–18 December 2003	E ***(electronic copy only)***
191	North Atlantic and Labrador Sea Margin Architecture and Sedimentary Processes — International Conference and Twelfth Post-cruise Meeting of the Training-through-research Programme, Copenhagen, Denmark, 29–31 January 2004	E
192	Regional Workshop on Coral Reefs Monitoring and Management in the ROPME Sea Area, Iran I.R., 14–17 December 2003	E ***(under preparation)***
193	Workshop on New Technical Developments in Sea and Land Level Observing Systems, Paris, France, 14–16 October 2003	E ***(electronic copy only)***
194	IOC/ROPME Planning Meeting for the Ocean Data and Information Network for the Central Indian Ocean Region	***(under preparation)***
195	Workshop on Indicators of Stress in the Marine Benthos, Torregrande-Oristano, Italy, 8–9 October 2004	E
196	International Coordination Meeting for the Development of a Tsunami Warning and Mitigation System for the Indian Ocean within a Global Framework, Paris, France, 3–8 March 2005	E
197	Geosphere-Biosphere Coupling Processes: The TTR Interdisciplinary Approach Towards Studies of the European and North African Margins; International Conference and Post-cruise Meeting of the Training-Through-Research Programme, Morocco, 2-5 February 2005	E
198	Second International Coordination Meeting for the Development of a Tsunami Warning and Mitigation System for the Indian Ocean, Grand Baie, Mauritius, 14–16 April 2005	E
199	International Conference for the Establishment of a Tsunami and Coastal Hazards Warning System for the Caribbean and Adjacent Regions, Mexico, 1–3 June 2005	E
200	Lagoons and Coastal Wetlands in the Global Change Context: Impacts and Management Issues — Proceedings of the International Conference, Venice, 26–28 April 2004 (*ICAM Dossier N° 3)*	E
201	Geological processes on deep-water European margins - International Conference and 15th Anniversary Post-cruise Meeting of the Training-Through-Research Programme, Moscow/Zvenigorod, Russian Federation, 29 January–4 February 2006	E
202	Proceedings of 'Ocean Biodiversity Informatics': an international conference on marine biodiversity data management Hamburg, Germany, 29 November–1 December 2004	E
203	IOC-Flanders Planning Workshop for the formulation of a regional Pilot Project on Integrated Coastal Area Management in Latin America, Cartagena de Indias, Colombia, 16–18 January 2007	*E* ***(electronic copy only)***
204	Geo-marine Research along European Continental Margins, International Conference and Post-cruise Meeting of the Training-through-research Programme, Bremen, Germany, 29 January–1 February 2007	E
205	IODE/ICAM Workshop on the development of the Caribbean marine atlas (CMA), United Nations House, Bridgetown, Barbados, 8–10 October 2007	E ***(electronic copy only)***
206	IODE/JCOMM Forum on Oceanographic Data Management and Exchange Standards, Ostend, Belgium, 21–25 January 2008	*(Under preparation)*
207	SCOR/IODE Workshop on Data Publishing, Ostend, Belgium, 17–18 June 2008	*(Under preparation)*
208	JCOMM Technical Workshop on Wave Measurements from Buoys, New York, USA, 2–3 October 2008 (IOC-WMO publication)	*(Under preparation)*

No.	Title	Languages
209	Collaboration between IOC and OBIS towards the Long-term Management Archival and Accessibility of Ocean Biogeographic Data, Ostend, Belgium, 24–26 November 2008	*(Under preparation)*
210	Ocean Carbon Observations from Ships of Opportunity and Repeat Hydrographic Sections (IOCCP Reports, 1), Paris, France, 13–15 January 2003	E ***(electronic copy only)***
211	Ocean Surface pCO_2 Data Integration and Database Development (IOCCP Reports, 2), Tsukuba, Japan, 14–17 January 2004	E ***(electronic copy only)***
212	International Ocean Carbon Stakeholders' Meeting, Paris, France, 6–7 December 2004	E ***(electronic copy only)***
213	International Repeat Hydrography and Carbon Workshop (IOCCP Reports, 4), Shonan Village, Japan, 14–16 November 2005	E ***(electronic copy only)***
214	Initial Atlantic Ocean Carbon Synthesis Meeting (IOCCP Reports, 5), Laugavatn, Iceland, 28–30 June 2006	E ***(electronic copy only)***
215	Surface Ocean Variability and Vulnerability Workshop (IOCCP Reports, 7), Paris, France, 11–14 April 2007	E ***(electronic copy only)***
216	Surface Ocean CO2 Atlas Project (SOCAT) 2nd Technical Meeting Report (IOCCP Reports, 9), Paris, France, 16–17 June 2008	E ***(electronic copy only)***