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SUMMARY
Surface and deep ocean carbon chemistry data sets have been collated in collaboration with other projects and made available that can be used to validate model output from WP3.3.The completion of CARINA and SOCAT means that work on integrating satellite and reanalysis data into the observations data sets (Task 3.1.2) is progressing rapidly. The data available to the MONARCH-A community in the CARINA and SOCAT data sets enable that basin-wide fields of pH and air-sea fluxes can be quantified (Task 3.1.3).

MONARCH-A CONSORTIUM

Participant no.	Participant organisation name	Short name	Country
1 (Coordinator)	Nansen Environmental and Remote Sensing Center	NERSC	NO
2	The University of Sheffield	USFD	UK
3	Universität Hamburg	UHAM	NO
4	Centre National de la Recherche Scientifique	CNRS	FR
5	Scientific foundation Nansen International Environmental and Remote Sensing Center	NIERSC	RU
6	Universitetet i Bergen	UiB	NO
7	Danmarks Tekniske Universitet	DTU	DK
8	Institut Francais de Recherche pour l'Exploitation de la Mer	IFREMER	FR

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1 Introduction

So far in WP3.1 we have focused on getting the needed datasets from in-situ observations – CARINA and SOCAT – ready for the international scientific community, in particularly the MONARCH-A community.

2 The CARINA data set

The CARINA (CARbon dioxide IN the Atlantic Ocean) data synthesis project is an international collaborative effort of the EU IP CARBOOCEAN, and US partners. It has produced a merged internally consistent data set of open ocean subsurface measurements for biogeochemical investigations, in particular, studies involving the carbon system. The CARINA database includes data from 188 cruises in the Southern Ocean, Atlantic Ocean, and Arctic Ocean. The salinity, oxygen, nutrient, inorganic carbon system and CFC data have been subjected to extensive quality control and adjustments have been made when necessary. The CARINA data set has been quality controlled and is publically available from the Carbon Dioxide Information Analysis Centre (http://cdiac.ornl.gov/oceans/CARINA/) along with software to handle the data. The data and the quality controls are described in a special issue of the Earth System Science Data Journal (http://www.earth-syst-sci-data-discuss.net/special_issue2.html). Note especially the publication of (Key *et al.*, 2010) on the overall data set and (Jutterström *et al.*, 2009), (Olsen *et al.*, 2009), and (Tanhua *et al.*, 2009) for the Arctic Ocean, Nordic Seas, and Atlantic Ocean data respectively. These publications describe the core of the CARINA data set which will be important in addressing the potential change in the ocean inorganic carbon cycle, either as an increased C-transport from Russian River systems into shelf regions and into the open ocean, through deep water formation in the Greenland Sea and general inorganic C-uptake in the Arctic regions. The overall uncertainty in the dissolved inorganic carbon and alkalinity in the CARINA data base is 4-5 μmol kg^{-1}, for more details on this see (Tanhua *et al.*, 2009b). Figures 1 and 2 below show maps of the data distribution in the Arctic Ocean and in the Nordic Seas respectively.

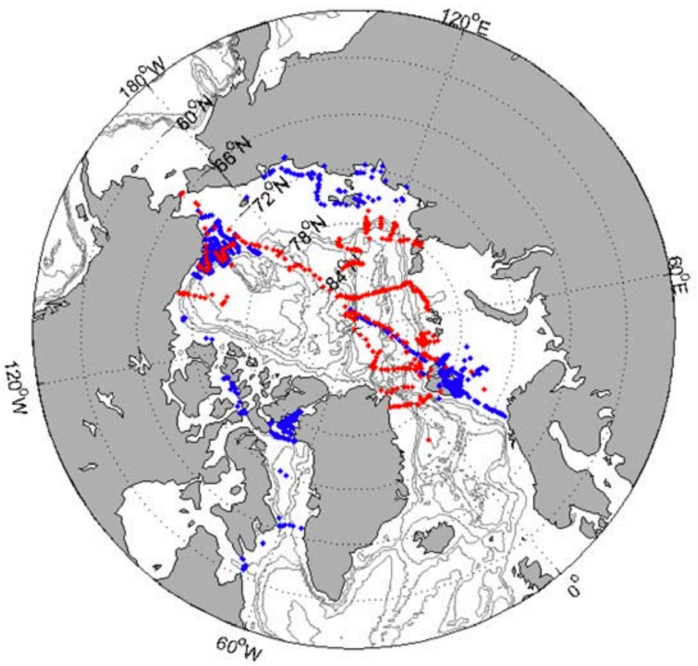


Figure 1: Showing the quality controlled CARINA data for the Arctic, as described in (Jutterström et al.*, 2009). These data are now publically available.*

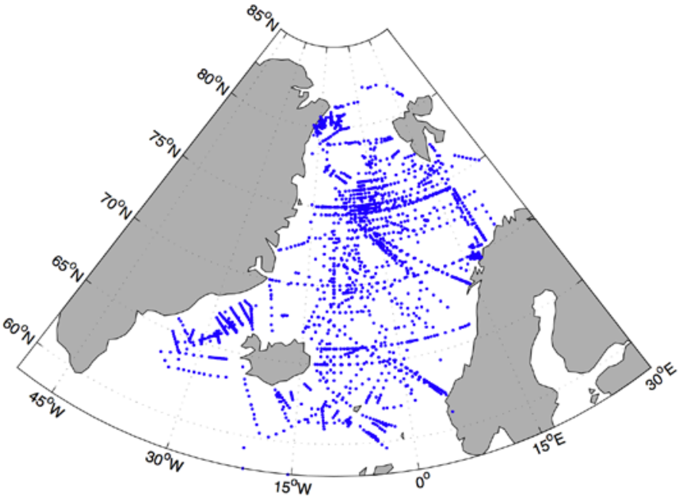


Figure 2: Showing the data from the Nordic Seas published in (Olsen et al.*, 2009), containing the CARINA data quality assessment and now publically available.*

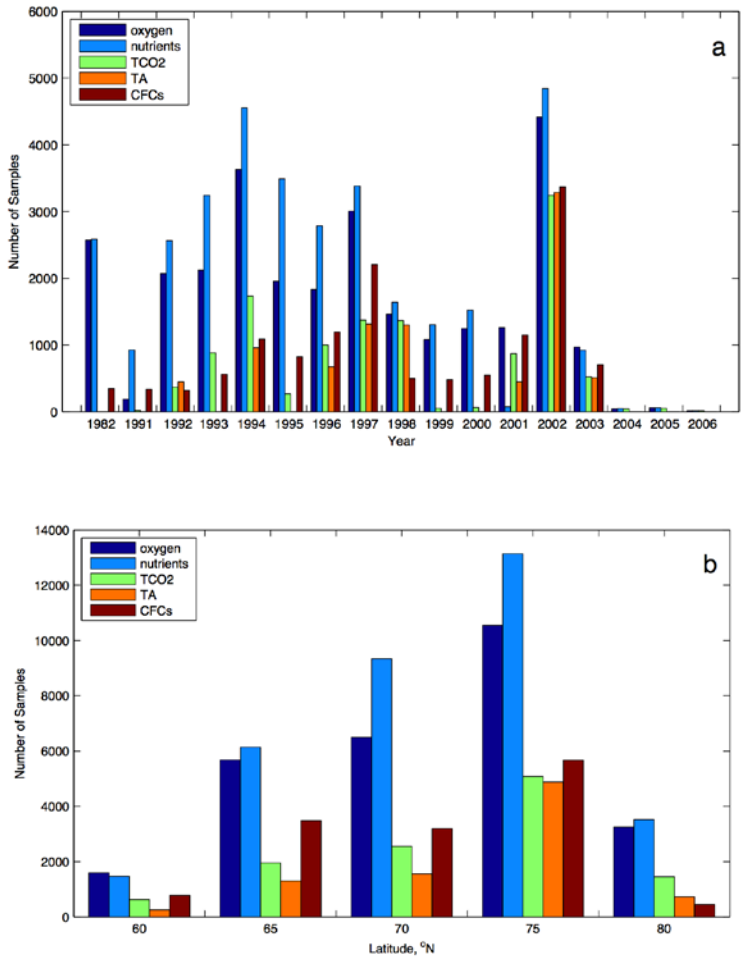


Figure 3: Data distribution of Nordic Seas CARINA data, number of samples by (a) year and (b) latitude, binned into 5º latitude bands. Data that were found to be of too poor quality to be included in the CARINA product are

not included. The count for nutrients reflects measurements of any or several of the triplet nitrate, phosphate, and silicate. Similarly, the count for CFC reflects measurements of any or several of CFC-11, CFC-12, CFC-113, and CCl_4. Note that X-axis jumps from 1982 to 1991 in (a). Interpolated or calculated values have not been included.

When it comes to the number of measurements the carbon parameters – which are of highest importance for MONARCH-A – increase with time from 1982 and peaks in 2002 (Fig. 3a). In the Nordic Seas the data density is highest around 75ºN (Fig. 3b), mostly due to the repeat hydrographic section at this latitude. It is also noteworthy that there is a seasonal bias in the measurements with significantly more data in the summertime than in the wintertime (Fig. 4). Seasonal distribution also varies greatly with the year, and no year has measurements in all months or even all seasons.

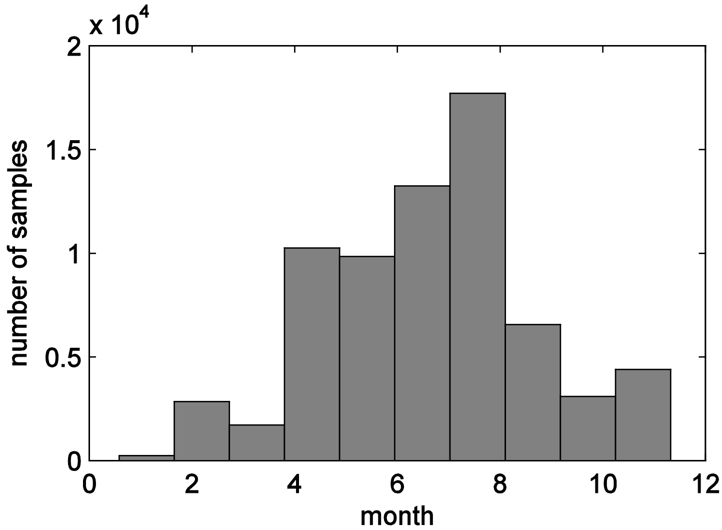


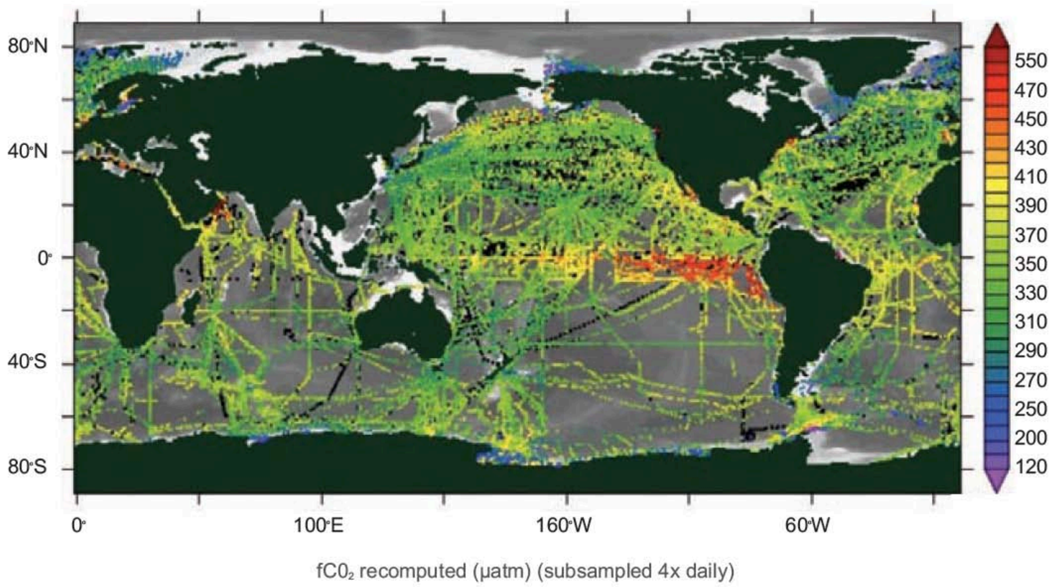
Figure 4: Figure showing the seasonal data distribution in the Nordic Seas and Arctic Ocean part of the CARINA data set.

2.1 Derived parameters in the CARINA data set

From the data in CARINA it is possible to derive pH (note that pH is also measured, but not as frequently as total carbon and alkalinity is), the carbonate saturation for both calcite and aragonite, and the carbonate ion (CO_3^{2-}) concentration. These parameters are highly relevant for ocean acidification studies and will be important for the remaining work in WP3. When total carbon, alkalinity, and fCO_2 are given, pH can be calculated with an estimated total error ranging from ±0.0021 to ±0.0062 depending on the combination of measured variables (Zeebe and Wolf-Gladrow, 2001). The accuracy of pH measurements is assumed to be 0.002 (Zeebe and Wolf-Gladrow, 2001).

3 The SOCAT data base

By 2007 surface water CO_2 data had been archived in a variety of formats in data bases around the world; each with its own rules for access. Also many data had not been made public and some were at risk of being lost for future research. The Surface Ocean CO_2 Atlas (SOCAT) has been created to improve access to global surface water CO_2 data in April 2007 at the Surface Ocean CO_2 Variability and Vulnerabilities' workshop. The SOCAT initiative is a large, international synthesis effort by marine carbon scientists. The SOCAT data set brings together, in a common format, all publicly available, surface water fCO_2 (fugacity of CO_2) data from the coastal seas and global oceans, including the Arctic Ocean. The methods in SOCAT are transparent and fully documented with documentation and Matlab scripts available from the SOCAT website (http://www.socat.info/) (Bakker *et al.* submitted to EOS). The work on the SOCAT data base is practically finished and a map of the global data distribution is shown in Fig. 5. The data has gone through secondary quality controls, but the publication of the online data base is delayed. It is estimated that the entire data base will be publically available by September 2011. The data can be made available to people working in MONARCH-A before this time so there is no expected delay in the MONARCH-A work for which the SOCAT data are required (mainly tasks 3.1.2 and 3.1.3). For additional information the contact person for SOCAT is Benjamin Pheil at the University of Bergen (Benjamin.Pheil@uni.no).



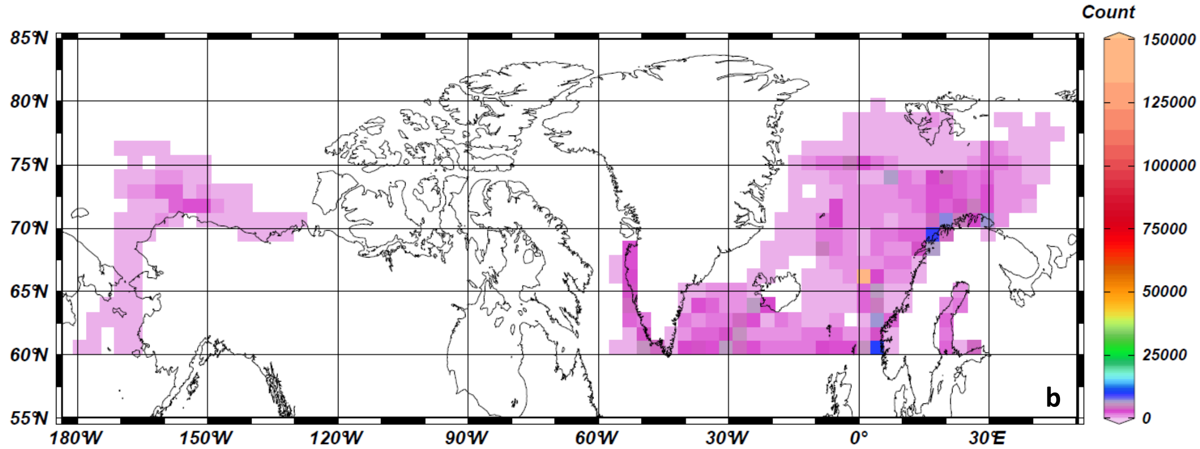


Figure 5: a) Map (from SOLAS news issue 12, 2011) showing all fCO_2 data collected in the period of time from 17 of November 1968 until 6 of November 2008. b) Map of the data count north of 60ºN in the period 1972-2007. Note that the highest data density is found near the Norwegian coastline and that there are no data in the Arctic Ocean proper. The SOCAT database is available for MONARCH-A, but still not released to the public. It is planned released in September 2011 according to present plans. Further delays may occur. Responsible persons for collecting and quality controlling the data are Are Olsen (UNIRESEACH) and Benjamin Pheil (UiB), for live access version, Jeremy Malczyk and Steve Hankin NOAA/PMEL in Seattle, USA and for the fCO_2 data, the global fCO_2 measuring community.

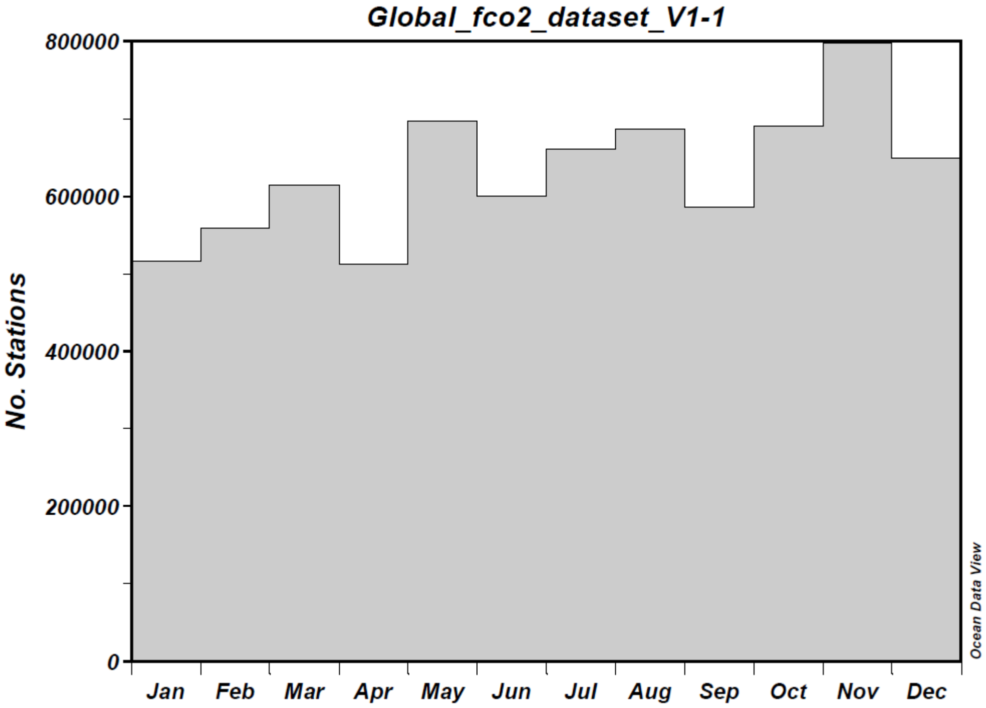


Figure 6: Monthly distribution of data measurements in SOCAT. Note that opposed to CARINA there is no large seasonal variation in the number of measurements in SOCAT. This is due to many measurements being made by voluntary observation ships (VOS) which operate all year.

Globally there is not much seasonal or monthly variation in the number of measurements in the SOCAT data fCO_2 data set (Fig. 6). But it is somewhat different for the high northern latitudes where the wintertime conditions prevent as many measurements being made in the mid-winter months (Fig. 7). There is still a reasonable seasonal coverage in SOCAT data in the regions relevant for MONARCH-A, and there is enough data that fields can be calculated and used for comparing model output with observations. In SOCAT the amount of data increases strongly after 1995 in all ocean regions, and in the northern high latitudes (north of 60ºN) also increase strongly after 2005 (Fig. 8). In the region relevant for MONARCH-A there are almost no data prior to 1995.

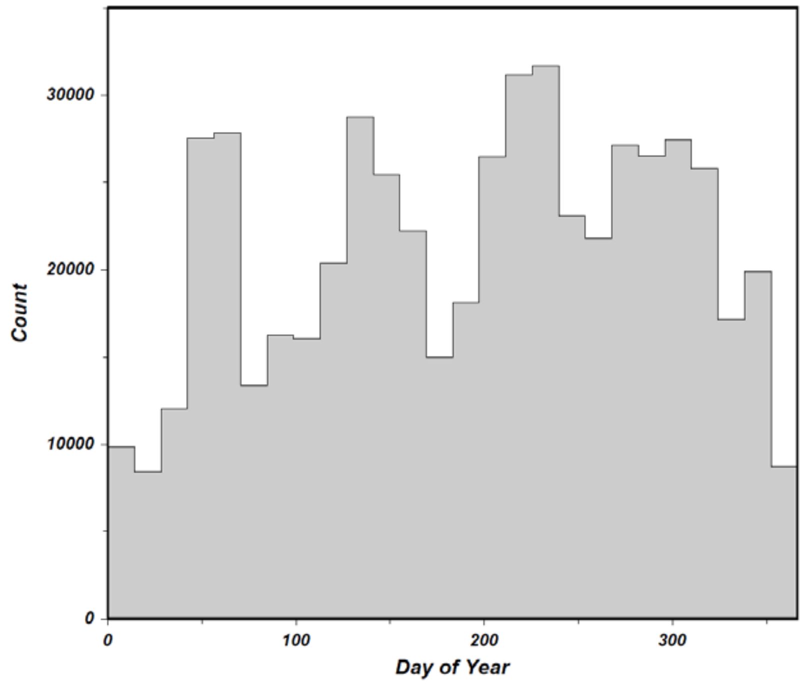


Figure 7: Seasonal distribution of data in SOCAT north of 60ºN. The highest measurement frequency is found in spring and early fall.

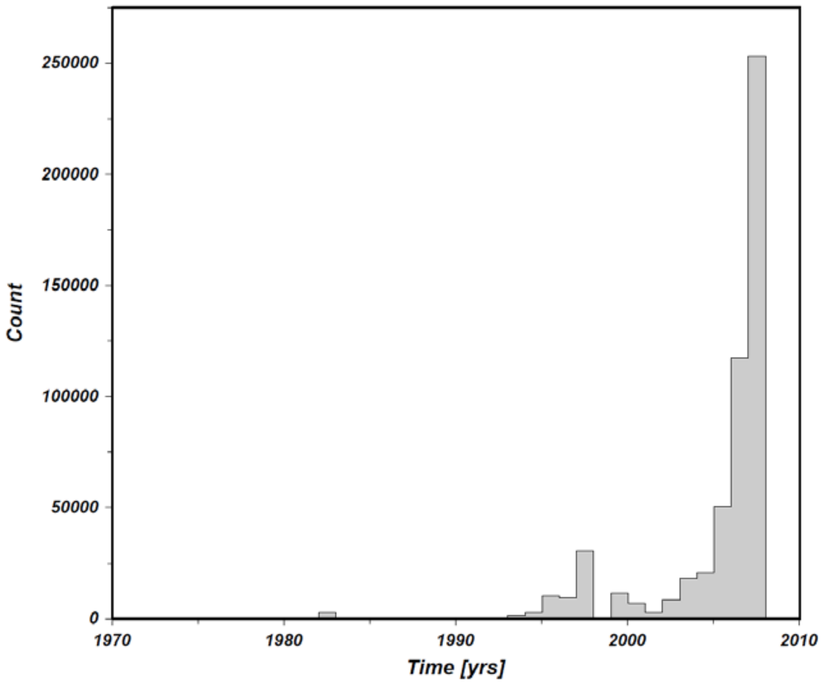


Figure 8: Number of measurements by year between 1972 and 2007 for the areas north of 60ºN.

4 In Conclusion

- The completion of CARINA and SOCAT means that work on integrating satellite and reanalysis data into the observations data sets (Task 3.1.2) is progressing rapidly.
- The data available to the MONARCH-A community in the CARINA and SOCAT data sets ensure that basin-wide fields of pH and air-sea fluxes can be calculated and analyzed (Task 3.1.3).
- There now exists surface and deep ocean carbon chemistry data sets that can be used to validate model output from WP3.3.

5 References

The publications mentioned in the text, and listed below, are references and not directly resulting from Monarch-A.

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