Coriolis Ocean database for ReAnalysis

CORA3 Documentation

VERSION 1.0

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Dataset overview

1.1 History of the dataset

The program Coriolis has been setup at Ifremer at the beginning of the 2000's in the wake of the development of operational oceanography in France. The project was launched in order to provide ocean in situ measurements to the French operational ocean analysis and forecasting system (Mercator-Océan) and to contribute to a continuous, automatic, and permanent observation networks. The Coriolis data centre has been set up to gather, qualify [4] and distribute data from the global ocean both in real and delayed time. The Coriolis database is a real time dataset as it is updated every day as new data arrive. On the contrary, the CORA database corresponds to an extraction of all in situ temperature and salinity profiles from the Coriolis database at a given time. All the data is then re-qualified.

CORA is meant to fit the needs of both re-analysis and research projects. However, dealing with the quantity of data required by re-analysis projects and the quality of data required by research projects remains a difficult task. Several important changes have been made since the last release CORA02, both in the production procedure (to be able to release yearly reanalysis) and quality checks applied to the data. These changes are fully described in this document.

1.1.1 Previous versions of CORA

Two previous versions of CORA have already been released by the Coriolis data center: CORA01 in 2007 and CORA02 in 2008. CORA01 contains data from 2002 to 2006 while CORA02 is from 1990 to 2007. To produce such a dataset the Coriolis data center proceeded basically in three steps:

1. Data passed through a statistical quality check based on objective analysis method (see [6] for further details).This statistical check produced alerts on doubtful profiles.
2. All doubtful profiles were visually checked, and profiles were flagged - if necessary - in the Coriolis database.
3. Data was extracted from the Coriolis database (to produce netcdf files).

1.1.2 Main changes for the CORA3 version

- A new procedure is now used to produce the dataset: This procedure fully described in section 2.1 was set up to be able to extract only new and updated data from the Coriolis database at each new release of CORA.

- A new set of quality checks is performed on the data. These quality checks are described in section 2.2
- A check of duplicates was re-run on the whole dataset (see section 2.3)
- An XBT bias correction has been applied. This correction is described in section 2.4
- The CORA3 release has been extended for the period 1990-2010.

1.2 Data sources

Data submitted to, or obtained by, the Coriolis Data Centre which contains profiles of temperature and/or salinity were potential data source for CORA3 database. The CORA3 database thus corresponds to the Coriolis database at the date of the CORA3 retrieval. For CORA3, the data retrieval has been spread over time (see table 1.1).

Data Span	Date of retrieval
1990-2008	25-May-2010
2009	09-September-2010
2010	22-03-2011

Table 1.1: Dates of retrieval for CORA3

The Coriolis centre receives data from Argo program, French research ships, GTS data, GTSPP, GO-SUD, MEDS, voluntary observing and merchants ships, moorings, and the World Ocean Database (not in real time for the last one and for CTD only). CORA thus contains data from different types of instruments: mainly Argo floats, XBT, CTD and XCTD, and Mooring.

1.3 Organisation of the dataset

1.3.1 Files formats - structure

Files structure is the same as for the distribution of the Argo profiles data and it is fully described in the argo-dm-user manual, section 2.2. Each netcdf files contains N_PROF profiles and a profile contains measurements of different variables (e.g. temperature, salinity) performed at N_LEVELS different pressures or immersion taken as the instrument is being dropped or risen vertically in the water column. For surface-only data, the profile consists of a single measurement. For moored buoys and drifting buoys, a profile is a discrete set of concurrent measurements from the instruments placed at different depths.

All the variables in a file are defined for Argo float profiles, but most of these variables still have the same signification for other types of profile (e.g. XBT or CTD profiles).

> *Guidance for the users*
> Each profile has a unique identifier in the Coriolis database and the CORA database which is the DC_REFERENCE number. Please, refer to this DC_REFERENCE number if you want to make a feedback on a specific profile to the Coriolis data centre. The variable PLATFORM_NUMBER is the platform identifier that is assigned for the life of the platform (e.g. Profiling floats, moored buoys, ...). For measurements collected from research vessels or merchant ships-of-opportunity the PLATFORM_NUMBER is the vessel/ship identifier.

1.3.2 Type of files and data type

The data are stored in 7 netcdf files types: PF, XB, CT, OC, MO, BA, and TE. Files are stored in yearly directories. There is one file per day and per type. The file name is of the form:

CO_DMQCGL01_YYYYMMDD_PR_TT.nc

This file contains all the raw data of the date YYYYMMDD and of the data type TT.

- PF files : data from Argo floats directly received from DACS (real Time and delayed mode if available). These data have a nominal accuracy of 0.01° and 0.01 PSU and are transmitted with full resolution.
- XB files : XBT or XCTD data received from research and opportunity vessels have accuracy within 0.03° to 0.1° for temperature and 0.03 to 0.1 PSU for salinity.
- CT files : contains CTD data from research vessels (accuracy on the order of 0.002° for temperature and 0.003 PSU for salinity after calibration) but also data from sea mammals equipped with CTD (accuracy is on the order of 0.01° for temperature and 0.02 PSU for salinity but can be lower depending of the availability of reference data for post-processing, see [1]) and received from MNHN and some sea Gliders.
- OC files : Others CTD and XCTD data coming from the high resolution CTD dataset of the World ocean database 2009.
- MO files : Mooring data are mostly from TAO TRITON RAMA and PIRATA mooring and have accuracy generally comparable to Argo floats (except for S near surface).
- TE and BA files : The two last categories are for all the data transmitted trough the GTS (data from Argo floats not yet received at the DACS, mooring, XBT,...). This transmission system imposes limitation on the accuracy: data is truncated two and one places beyond decimal point for TE and BA type respectively.

Guidance for the users : How to find a particular data type in CORA3?
This classification of the data in netcdf files depend mainly on the data sources and resolution. However, it can be difficult for the user to find all the data from one type of instrument (e.g. CTD) as it is found in different types of files (e.g. CT, OC, TE files for CTD instruments). The variable WMO_INST_TYPE in the netcdf raw files can help to distinguish the different instrument types (see table A.1). However the same WMO_INST_TYPE can be attributed to different types of instrument platform (e.g. the WMO_INST_TYPE 830 standing for CTD is attributed to CTD launched from vessels or ships, CTD attached to sea mammals, some mooring buoys etc...). To facilitate the identification of a particular type of data a PROBE_TYPE code was attributed to each profile (see table A.2 for definition of codes). The PROBE_TYPE variable can be found in the Index files (see section 1.3.3) and be used to select a particular type of data.

1.3.3 The Index files

An Index for the raw data of CORA3 is available (./RAW/Index). The index is organized as follow: There is one index file per month (e.g. index_cora3.2_01_1990.nc) containing only the main information about the profile (e.g. LONGITUDE, LATITUDE, JULD, PROBE_TYPE, PLATFORM_NUMBER, etc...), the name of the corresponding raw file (FILE_NAME) and the profile number in the raw file (NUM_PROF_IN_FILE). As the index files can be read very quickly, this allows the user to make his own data selection or to pick up a single profile in the raw database. The PROBE_TYPE variable was added to the index files (but not in the raw files) to facilitate the identification of a particular type of data (see table A.2).

1.4 Data quality

1.4.1 Quality flags

Each measurement for each profile is associated with a control quality flag ranging from 0 to 9. Basically, a flag 1 stand for good data, a flag 4 stand for bad data. See table 1.2 for a complete description. Quality flags are set at the different steps of the quality control procedure (see section 2.2).

Quality Code	Meaning
0	No QC was performed
1	Good data
2	Probably good data
3	Bad data that are potentially correctable
4	Bad data
5	Value changed
6	Not used
7	Not used
8	Interpolated value
9	Missing value

Table 1.2: Quality flags and their definition

Guidance for users: How to use flag values?
It is advised to keep only stations for which:

$$POS\_QC \neq 3 \text{ or } 4 \text{ and } JULD\_QC \neq 3 \text{ or } 4$$

and for each station it is advised to keep only measurements for which:

$$\begin{cases} PRES\_QC \\ DEPH\_QC \end{cases} = 0, 1 \text{ or } 2 \text{ and PARAM\_QC } = 1 \text{ or } 2$$

Quality flags exist both for the PARAM (TEMP_QC, PSAL_QC,...) and the PARAM_ADJUSTED (TEMP_ADJUSTED_QC, PSAL_ADJUSTED_QC,...). Thus if one uses the adjusted values of salinity (PSAL_ADJUSTED) it should check the flag PSAL_ADJUSTED_QC to determine if the salinity value is good or not.

1.4.2 Adjusted parameter versus parameter

CORA3 database not only contains the raw parameters (temperature, salinity, pressure or depth as received from the instrument) but also the adjusted parameters if it exists (temperature, salinity, pressure or depth corrected from a drift or an offset etc...). The parameters can be adjusted in real time in an automated manner (in this case the variable DATA_MODE is equal to 'A') or in delayed mode (the variable DATA_MODE is equal to 'D'). For Argo data, the adjusted parameter are mainly the salinity and pressure. The salinity is corrected in delayed mode by the PI of the float by comparing the observed value to neighboring historical CTD trough the Owens and Wong method ([13]; [2]; [10]). For some of Argo floats (mainly APEX floats), the pressure parameter also need adjustments. Pressure corrections started to be applied by the Argo Dacs in the year 2009. For the CORA3 database, the adjusted parameters for Argo data are those received at the GDACs at the date of the retrieval (see table 1.1). The user should refer to the section1.4.2.1 to evaluate the state of pressure corrections for APEX floats in CORA3. The adjusted parameters present in CORA3 for XBT data have been calculated following the method described in section 2.4.

Guidance for the users: How to use adjusted parameters?
It is advice to take the PARAM_ADJUSTED values instead of the PARAM values each time the PARAM_ADJUSTED values exist. The user should then take the PARAM_ADJUSTED values for the whole profile if the variable DATA_MODE ='A' or 'D'.

1.4.2.1 Particular case of pressure correction for Argo floats

While PROVOR and SOLO floats internally correct for pressure offsets, APEX floats do not make any internal pressure corrections. APEX floats return "raw" pressures, which are stored in the variable PRES in the Argo files. Pressure adjustment should be applied both in real-time and delayed mode to all APEX floats by using the surface pressure values returned by the APEX floats and stored in the Argo technical files. Most of the Dacs started to apply such a pressure correction during the year 2009. As the CORA3 dataset was extracted in 2010-2011 (see table 1.1), thus it is important to give an insight of pressure correction state in the CORA3 dataset. Figure 1.1 gives the state of corrections for APEX float profiles that need pressure correction in CORA3 : 62% of pressure profiles are adjusted, in real time (data Mode ='A') or delayed mode (data Mode ='R').

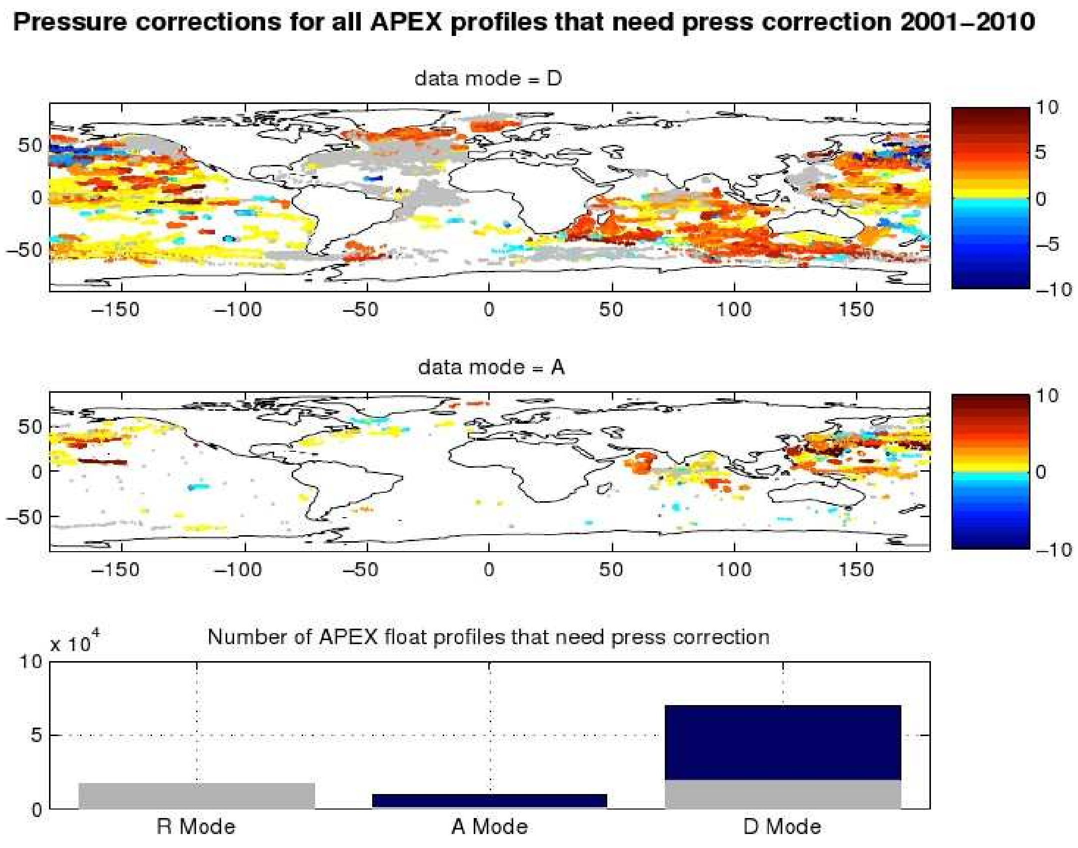

Figure 1.1: Pressure corrections for all APEX profiles that are correctable and need pressure correction for (top) profiles adjusted in delayed mode (Data Mode ='D') and (middle) profiles adjusted in real time (Data Mode ='A'). The bottom panel shows the repartition of Apex float profiles that need pressure correction among Data Mode='R' (no adjustement) Data Mode='A' and Data Mode ='D'. In grey if PRESS-PRESS_ADJUSTED =0

Among APEX floats, some of them (floats with Apf-5, Apf-7, or Apf-8 controllers) set negative surface pressure to zero,thus making the pressure data unadjustable. Truncated Negative Pressure Drift (TNPD) refers to the part of a float's time series from which surface pressure reads continuously zero without reverting back to positive values during at least 6 months. In delayed mode, PI of the float are asked to flag the data (TEMP, PRES and PSAL) of TNPD floats to 4 when float data show observable T/S anomalies that are consistent with increasingly negative pressure drift and to flag the data of TNPD floats to 2 otherwise (see the Argo quality control manual for more details). Figure 1.2 shows the number of profiles with TNPD in CORA3 and the percentage of data whith quality flags set to 3 or 4 for TNPD floats in the CORA3 database.

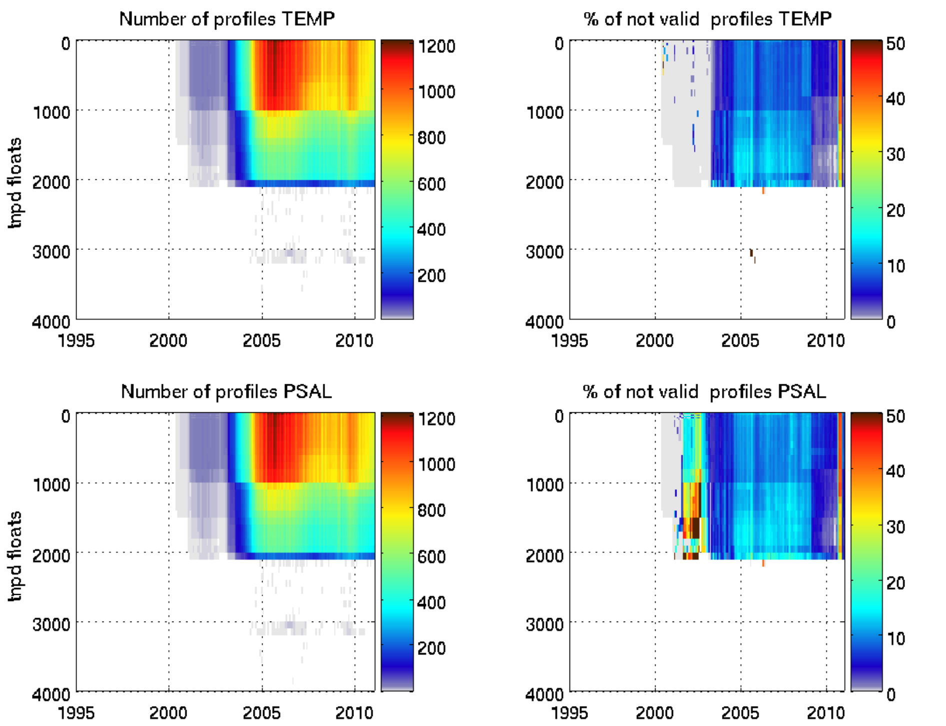

Figure 1.2: Number of TNPD profiles per month at a given depth (left) and the percentage of the data that is not usable (because quality flags are bad -ie 3 or 4) in CORA3 (right)

1.5 Goals and uses of the dataset

1.5.1 Research

CORA database is meant to investigate specific scientific questions. Achieving this goal will lead to the improvement of the quality of the dataset, by detecting abnormal data. That will benefit subsequently to the Coriolis data centre. Using the CORA database to estimate global ocean temperature, heat and freshwater still need careful comparison and sensitivity studies as these global quantities are very sensitive to any sensor drift or systematic instrumental bias (see Von [11]). Although our quality controls are meant to detect such instrument problems, they can still miss unknown drifts or bias.

1.5.2 Ocean model validations

CORA can be used to construct elaborated products such as climatologies of heat content, depth of the thermocline or 20°C isotherms, or climate indices (niño3.4, MOC, PDO…). Such products are especially useful for validating ocean model outputs and improve their quality or assess their results.

1.5.3 Data assimilation in ocean models

An important application of such a database is also its use in ocean reanalyses. Throughout the world, several reanalyses projects are underway which aim at providing a continuous space-time description of the ocean, synthesizing the information provided by various observation types (remotely sensed and in situ) and the constraints provided by the physics of numerical ocean models. In France, global ocean reanalysis activity is a joint collaboration between Mercator-Océan, Coriolis data centre and several oceanographic and atmospheric research laboratories in the framework of GLORYS (Global Ocean ReanalYsis and Simulations) project. This project contributes also to the production of coordinated reanalyses at the European level in the context of MyOcean EU funded FP7 project, in collaboration with Italian, English, French and Canadian partners. The goal of GLORYS is to produce a series of realistic eddy resolving global ocean reanalyses. Several reanalyses are planned, with different streams. Each stream can be produced several times with different technical and scientific choices. Version 1 of Stream 1 (GLORYS1V1) covering the Argo era (2002-2008) has been produced using the previous version of the CORA (version 2.1) data set and is available on request from products@mercator-ocean.fr. Further information and results can be found in [5].

Finally, the CORA dataset is a product of the MyOcean catalog and aims to be a reference as a dataset produced by the in situ TAC of this European project.

Description of data processing

2.1 Data flow

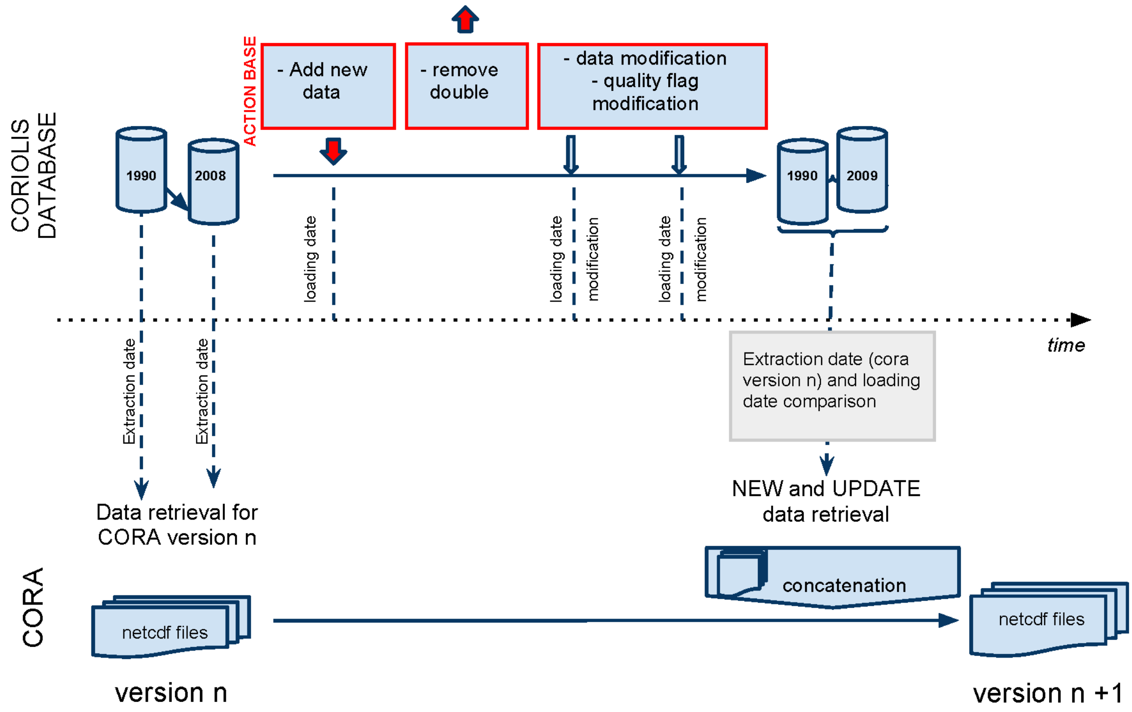

Figure 2.1: Process used to update the CORA database

Figure 2.1 describes the process used to update the CORA dataset. CORA data are retrieved from the Coriolis database which is constantly evolving because new data is submitted, some data are reprocessed, other data are adjusted in delayed mode (Argo platform data), quality flag are modified in the Coriolis database after quality checks have been performed, etc.... Basically, all new and modified data since the previous version of CORA are retrieved from the Coriolis database. This subset of new and updated data are then re-qualified. Other quality checks are performed on the whole CORA dataset to ensure data quality consistency.

2.2 Quality checks

2.2.1 Real-time and Near-real-time channel

Data received by the Coriolis data centre from different sources are put through a set of quality control procedures [4] to ensure a consistent dataset. Real time and near real time tests encompass the checks that are done between one day and one month after the data have been loaded in the Coriolis database. All the data managed by the Coriolis data centre are first going through automatic QC (see Argo Quality Control Manual, section 2) and are then visually checked. Once a day a statistical analysis is performed with all data available (RTQC).The statistical test is based on an objective analysis run [3] with a three weeks window (see [6] for further details). Residuals between the raw data and the gridded field are computed by the analysis. Residuals larger than a defined value produce alerts that are then checked visually and control quality flags are changed if necessary. Finally, once a month, the statistical test based on the objective analysis is re-run (NRTQC), new alerts are produced and visually checked.

2.2.2 CORA channel

Beside RT and NRT tests, several other quality checks have been developed or applied to produce CORA3 in order to reach the quality level required by the physical ocean re-analysis activities. These checks include some simple systematic tests, a test against climatology and a re-run of the statistical analysis involving an objective analysis method . Visual quality control (QC) is performed on all the suspicious temperature and salinity profiles. After these visual checks it is decided to change or not the control quality flag.

2.2.2.1 Systematic test on new and updated data

A profile fails a systematic test when pressure is negative, T and S values are outside an acceptable range depending on depth and region, T or S are equal to zero at bottom or surface, values are constant along depth, values are outside the 10 climatological range, if there is large salinity gradient at the surface (more than 5 PSU within 2dB) or a systematic bias. Each time a profile failed a systematic test it was visually checked.

2.2.2.2 Tests on the whole database

A test against climatology that we call Anomaly Method was also applied. In this case, a profile failed the test if at least 50% of its data points lie outside the 5 σ climatological range. This allows detecting smaller deviations compare to the 10 σ check. The statistical test based on an objective analysis is re-run with a three weeks window. Residuals between the raw data and the gridded field are computed by the analysis. Residuals larger than a defined value produce alerts that are then checked visually. This method combines the advantage of a collocation method since it takes into account all neighboring sensors, and the comparison with climatology. Finally, Argo floats pointed out by the altimetric test ([7] and ftp://ftp.ifremer.fr/ifremer/argo/etc/argo-ast9-item13-AltimeterComparison/) were systematically verified over all their life period and quality control flags were modified when necessary.

2.3 Elimination of duplicate profiles

The source of profiles with multiple occurrences in the Coriolis database is the multiple paths they can use to transit from the sensor to the data centre. For example an XBT profile can be send trough the TE channel whose precision is lower than the XB channel usually preferred for XBT data. And sometimes the data uses both of them and it results that two profiles are stored in the data centre with different meta data, different format type (BA, CT, MO, OC, TE, XB, PF), values potentially truncated and most of the time a little shift in the date or the position due to different precisions. Hopefully a duplicate profile check is performed on the Coriolis database but it seems that some profiles pass trough mostly because the real time duplicate check procedure can sometime experiment some failures and thus is not run for a short while. A duplicate check is then performed again on the whole CORA database.

CORA dataset has been cleaned from most of the duplicate profiles but we cannot guarantee a complete suppression of them because used criterion have been set to a compromise between a loose detection which results in a major amount of suppression and a restrictive definition of double profiles aiming to discard the fake ones but which could lead to miss some of the duplicate profiles. Those criterion are also of pretty low-level complexity to avoid the creation of multiple kind of redundant case that could overlap each other or mask some duplicates.

	Couple with same type (ex: BA BA or TE TE)	**Couple with different type (ex: BA TE, BA OC)**
delta date = +/-	0,00001 days (0,864s)	0,042 days (1h28s) - exception for TE PF : 24h -
Delta longitude = +/-	0,0001°	0,1°
delta latitude = +/-	0,0001°	0,1°
Platform number	Can be different	Must be the same

Table 2.1: Criterion table for redundant profiles detection

If profiles are too different to be redundant there is no suppression of profile. To distinguish which are (practically) similar and the fake one we set up empirical threshold in mean and standard deviation for temperature and salinity (see table 2.2)

	TEMP	**PSAL**
Maximal mean difference	0.4°C	0.5 PSU
Maximal standard deviation difference	1°C	1 PSU

Table 2.2: Thresholds used to eliminate fake doubles

One of the most important parts of this process is the choice about which profile will be deleted between two copies. The first criterion is the number of physical parameter provided. For example if a profile contains values of temperature and salinity it will be preferred to a simple temperature profile. If the first criterion is not decisive we use a choice table, which gives best format type. This table has been based on the definition of precision of each format type standard of data.

As shown on the previous figure some of the format couple are not determined, therefore a third test help to choose which profile has to be deleted: it is a test on the length of the profiles (resolution and amplitude). Practically we compare relative difference in amplitude and resolution and we use the bigger to determine which profile is the best. Then if this test does not permit to make a choice we evaluate the number of occurrences in the list of redundant profiles itself, if one of the two profiles appears many times then it will be chosen for suppression in order to break as much as possible couples with as less as possible loss of information. Finally if none of those steps is conclusive an arbitrary decision is made about the suppression of one of the two profiles. redundancies

	OC	BA	XB	CT	PF	MO	TE
OC	?	delete BA	not a double	delete OC	not a double	not a double	delete TE
BA		?	delete BA	delete BA	delete BA	delete BA	delete BA
XB			?	not a double	not a double	not a double	delete TE
CT				?	not a double	not a double	not a double
PF					?	not a double	delete TE
MO						?	delete TE
TE							?

Table 2.3: Table of choice

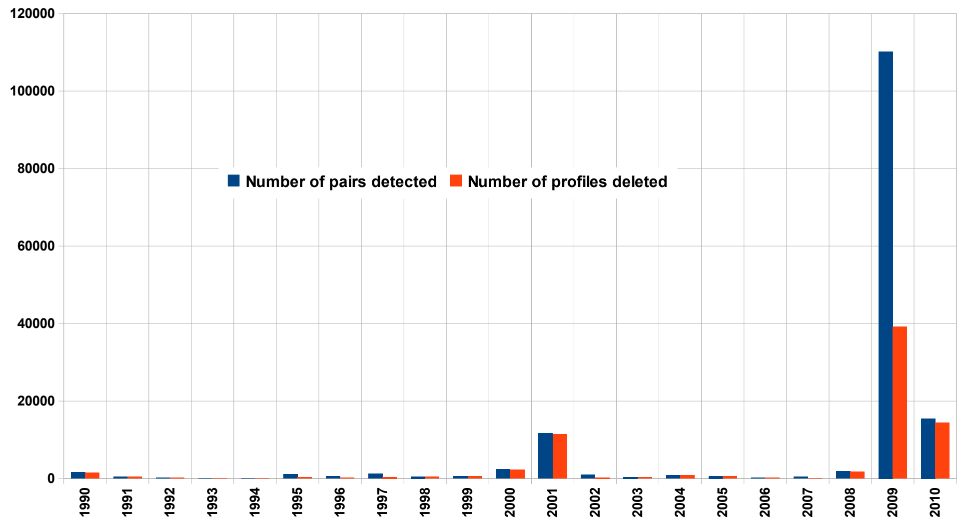

Figure 2.2: Number of pair detected and profiles deleted

2.4 XBT bias correction

Different issues with the data of eXpendable BathyThermograph (XBTs) exist and, if not corrected, they are known to contribute to anomalous global heat content variability (e.g. [12]). The XBT system measures the time elapsed since the probe entered the water and thus inaccuracies in the fall rate equation result in depth errors. There are also issues of temperature offset but usually with little dependence on depth. The correction applied on CORA3 dataset is an application of the method described in [8]. This correction is divided in two parts: first the computation of the thermal offset then the correction of depth. To evaluate the temperature offset and the error in depth the reference used are all the co-localised profiles (e.g. in a 3km ray, +/-15 days temporal frame, a maximum average temperature difference of 1°C and a bathymetric difference inferior to 1000m) that are not XBT and with quality flags different from 3 and 4 (suspicious and bad quality). Those references thus gather CTD, Argos profilers and mooring buoys. Figure 2.3 gives the number of XBT with co-localised profiles that can be found each year.

What is an XBT profile in CORA3? It is a profile either in XB, BA or TE files with a WMO_INST_TYPE that refers to an XBT probe (see table A.1). Profiles in XB files with a WMO_INST_TYPE unknown (999) and no salinity data (to avoid XCTD) are also considered as XBT.

Profiles with a WMO_INST_TYPE unknown in BA or TE files cannot be qualified of XBT since many different instruments types are gathered in those files. As information on the XBT type is missing for a large part of XBT profiles in the XB files, we decided not to apply the Hanawa ([9]) fall-rate for XBT depth computed with the old fall rate equation. This differs from [8], where the Hanawa correction was first applied when possible. Thus, the only correction we made for the XBT in the CORA3 database is statistical.

- The temperature offset correction:

This correction aims to give a value of correction for each profile as a function of the year and the category of XBT: shallow XBT or deep XBT (e.g. maximal depth >=500m). The values are computed by the difference of each XBT profile with its reference profile in the layer 30-50m (below the mixed layer and where depth errors are not important enough to explain the observed bias). Solely low temperature gradient points (e.g. <0.0025 °C/m) are used to compute those corrections. XBT and reference profiles are interpolated on standard levels from 0 to 1000m and a resolution of 10m before the calculation. The final offset is the median of all those differences.

- The depth error correction:

Results of this depth correction are second order polynomial coefficients depending of the year, the depth and the category of XBT profile. In this second step there are not two but four different categories: deep and hot, deep and cold, shallow and hot, shallow and cold (e.g. maximal depth ≥ 500m and mean temperature ≥ 11°C). To evaluate the error in depth we use the following formula:

$$dZ = \frac{T - T_{ref}}{\partial_z T_{ref}} \tag{2.1}$$

Some cursors such as a minimum number of collocations per level and a maximum value of depth error allow improving the quality of the median profile gotten from the raw depth errors in each of the four categories. Then we fit a second order polynomial on the median depth errors and we get three coefficients:

$$Z_{true} - Z = aZ^2 + bZ + c \tag{2.2}$$

The c coefficient is replaced by the mean of the depth error in the layer 30-200m to ignore the noise due to the mixed layer. The values of the coefficient are given in table A.3.The difference between the XBT profile and the reference profile before and after applying the correction is plotted in figure 2.4.

> *Guidance for the users: How to use XBT with thermal offset and depth corrected?*
> For XBT profiles (PROBE_TYPE=10 in the index files) the corrected values are reported in the ADJUSTED fields: TEMP_ADJUSTED field for the temperature corrected from the thermal offset and DEPH_ADJUSTED for the depth corrected.
> The depth correction which stretches the values of depth can lead to negative depth value on the first level of some profiles (depending on the year, on the category of XBT and on the value of the first level). Those negative depth values have been kept in the DEPH_ADJSUTED field but the quality flag has been set to 4. Those negative values concern between 50 and 70% of the profiles each year. Users are free to reject or not this first level (notice that the correction applied in the first layer is not that relevant).
> It appeared to us that some XBT profiles of the CORIOLIS and CORA databases have values of depth incorrectly stored in the field PRES. As we were not able to find the origin of this error, we computed the depth correction assuming that we had a depth and not pressure information. However to allow future corrections, for those XBT, we let the corrected depth in the PRES_ADJUSTED parameter.

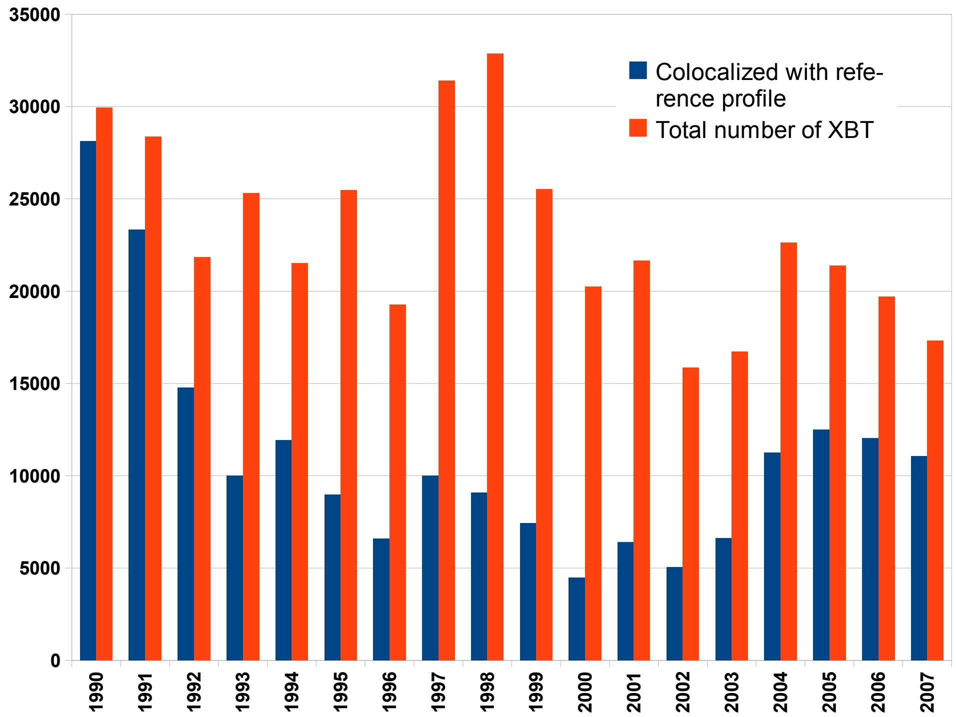

Figure 2.3: Number of XBT profiles colocalized with a reference profile

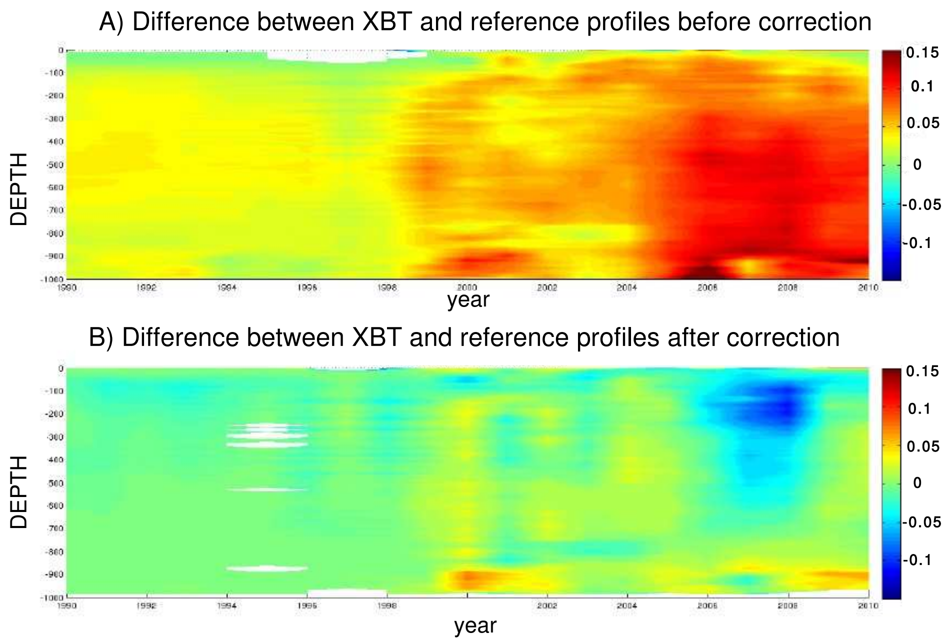

Figure 2.4: Difference between XBT and reference profiles before (A) and after (B) corrections

CHAPTER 3

Description of the dataset

This section gives an overview of the CORA3 dataset. Figures 3.1 - 3.21 give the spatial distribution of the different data types (table A.2) for each year between 1990-2010. Figures 3.22 -3.33 represent the number of profiles per month at a given depth and the percentage of the data that is not usable (because quality flags are bad -ie 3 or 4) for each data type.

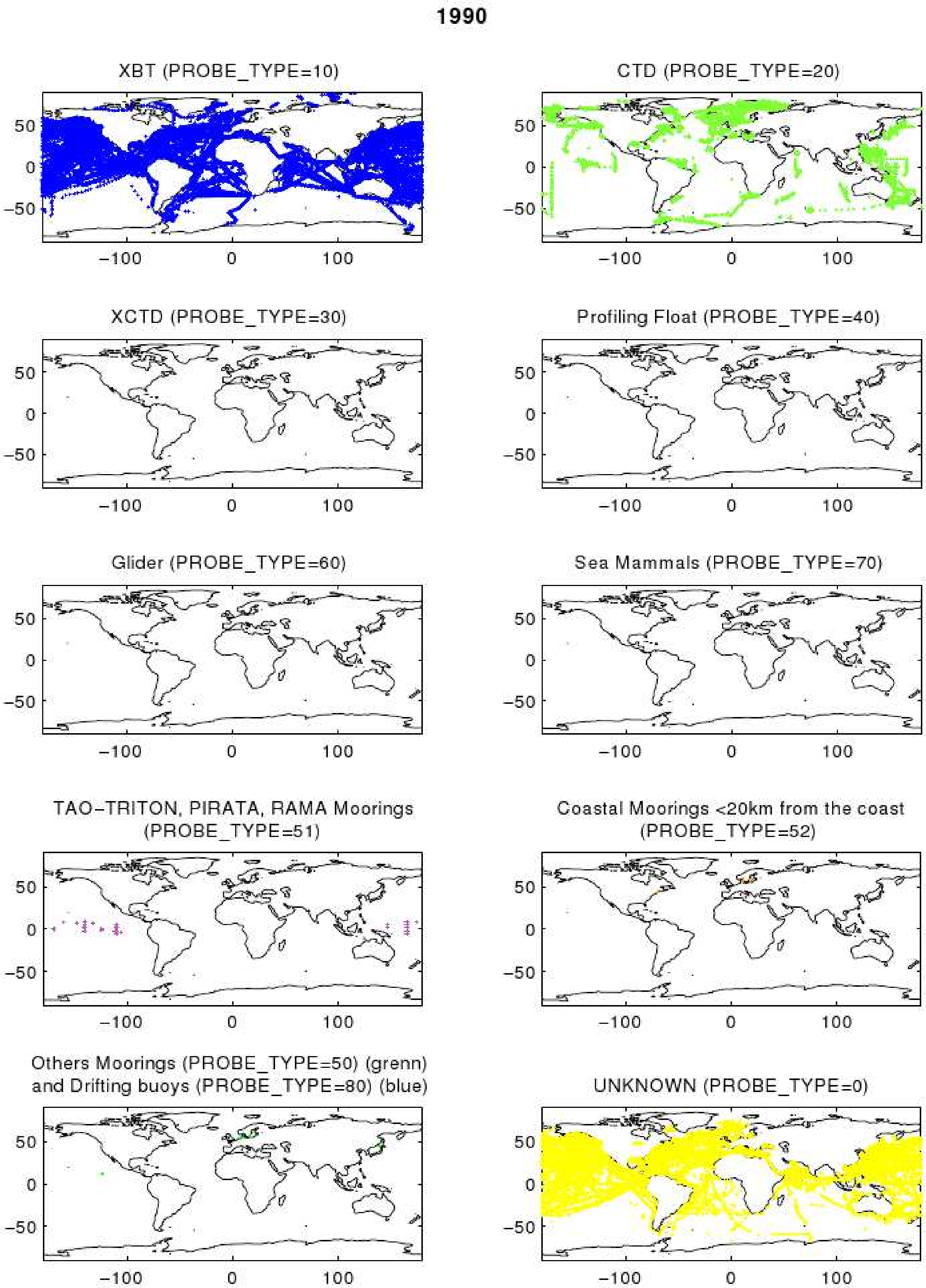

Figure 3.1: Spatial distribution of the different type of data (see table A.2) for the year 1990

1991

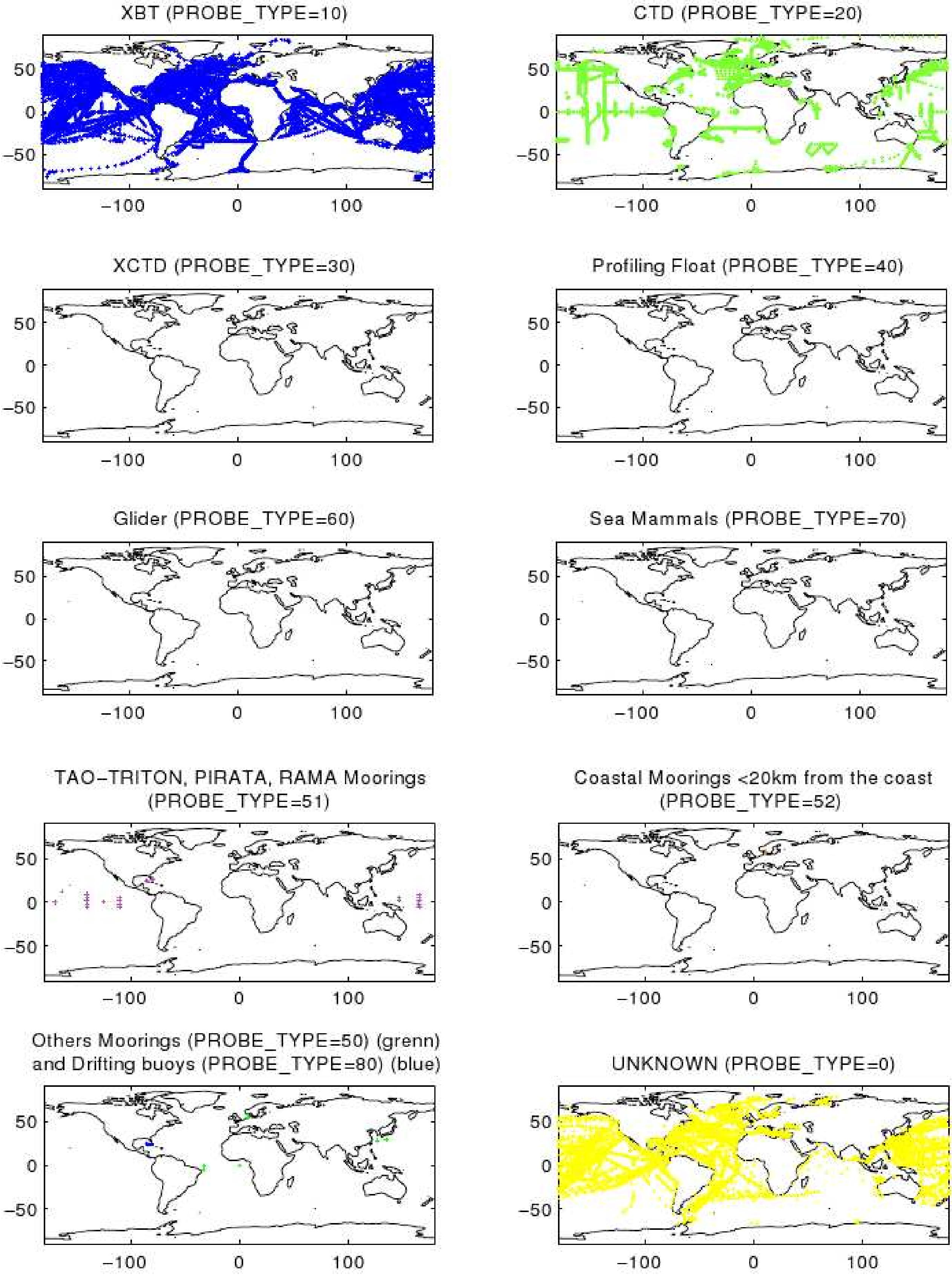

Figure 3.2: same as fig. 3.1 for the year 1991

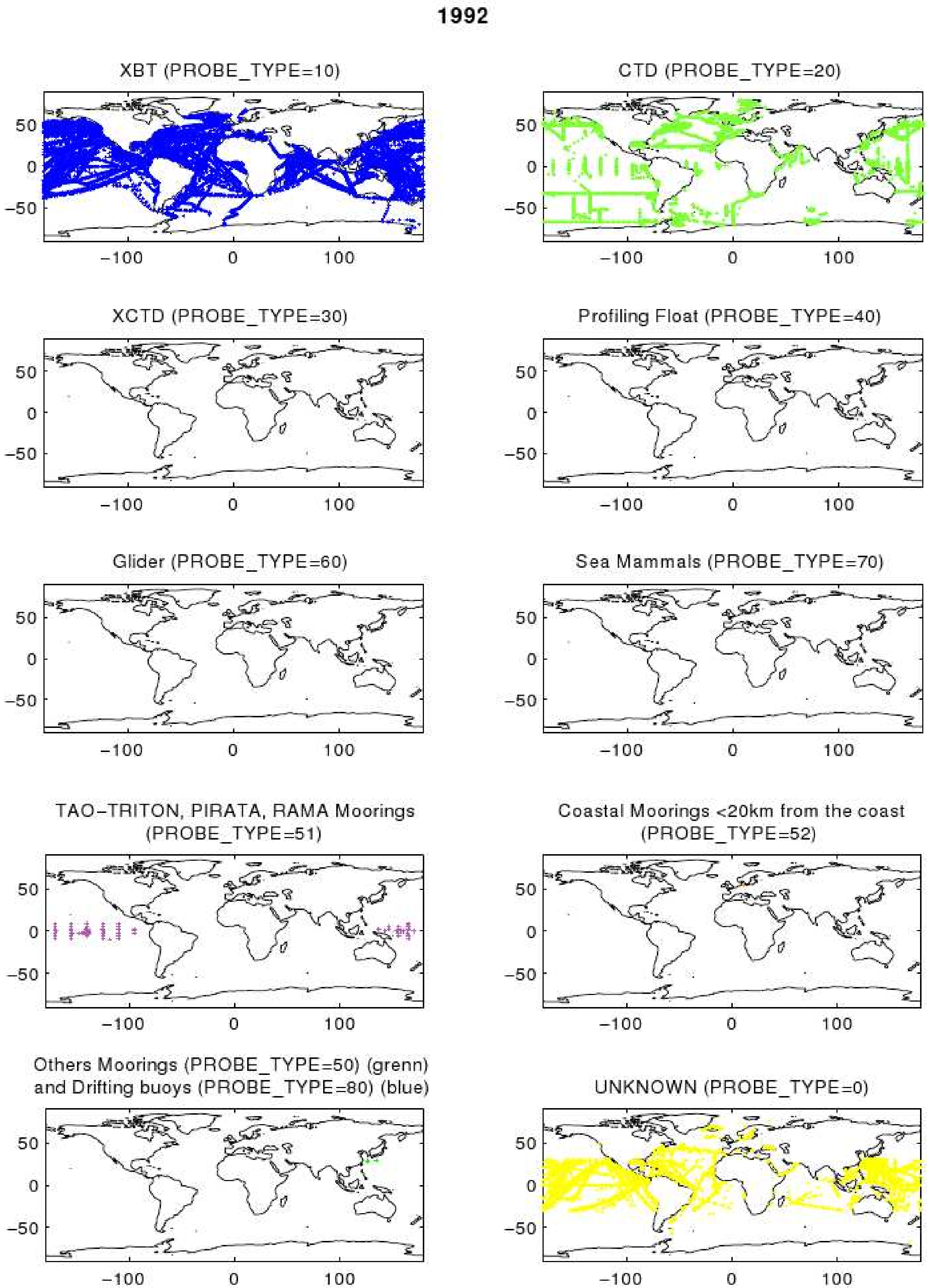

Figure 3.3: same as fig. 3.1 for the year 1992

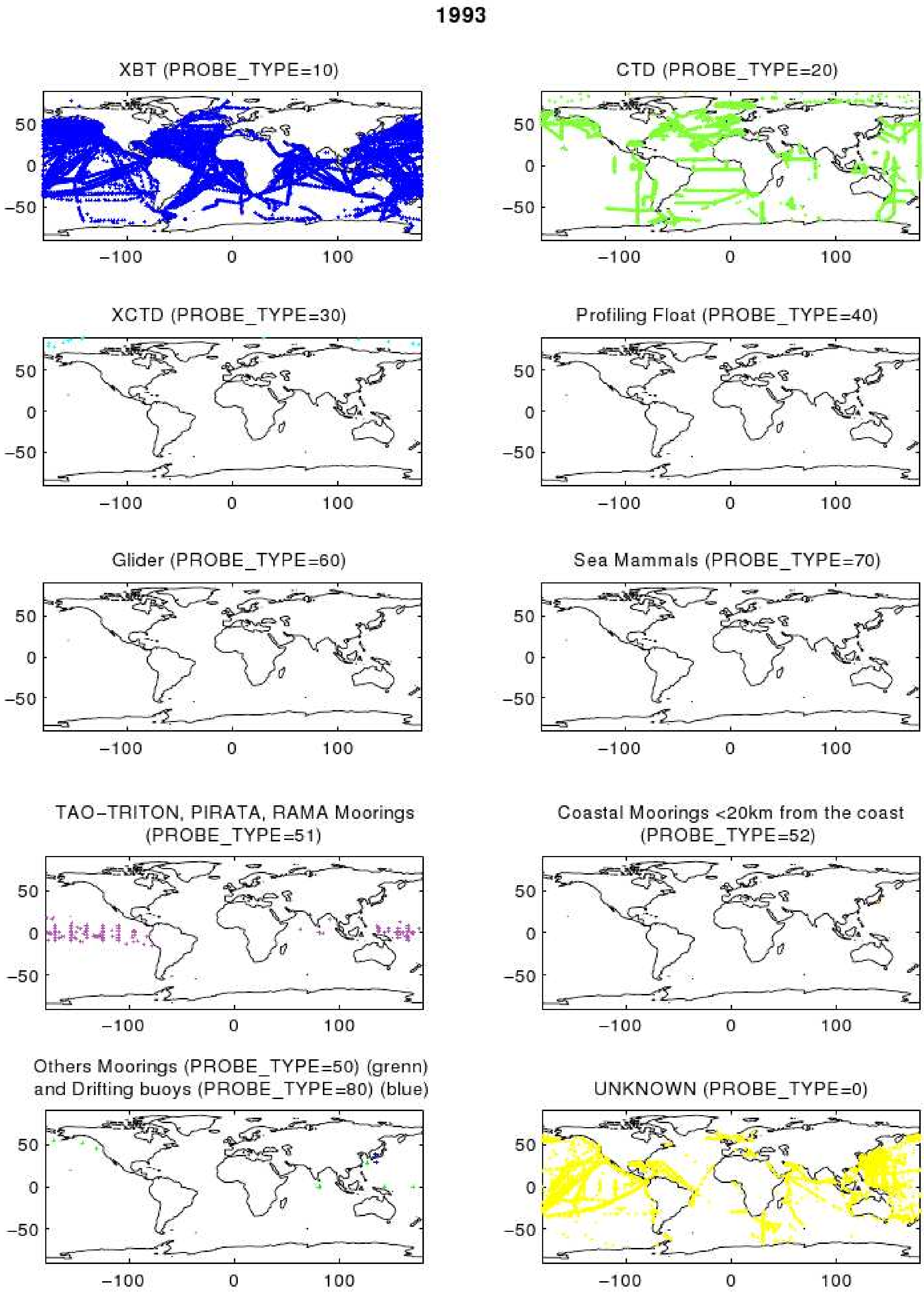

Figure 3.4: same as fig. 3.1 for the year 1993

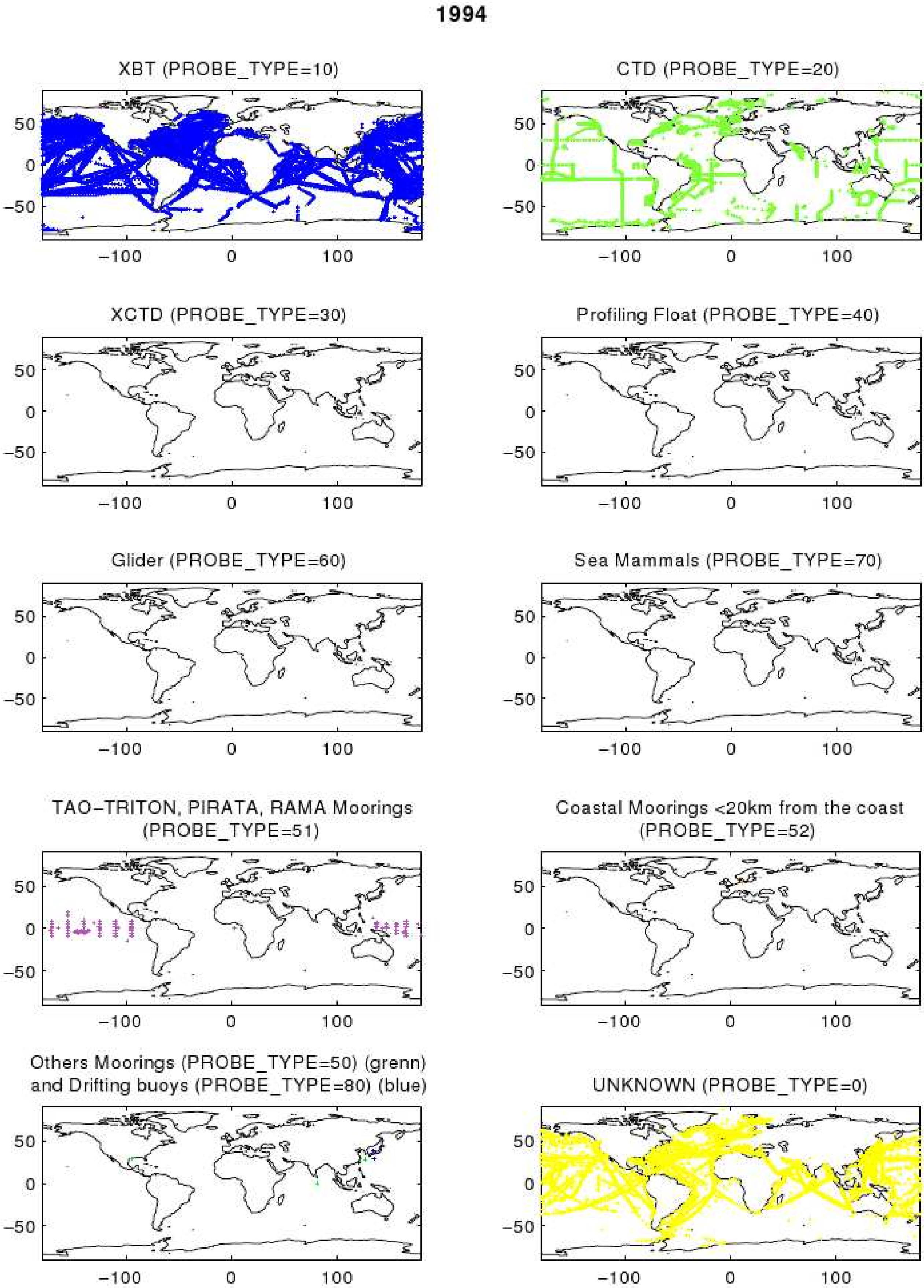

Figure 3.5: same as fig. 3.1 for the year 1994

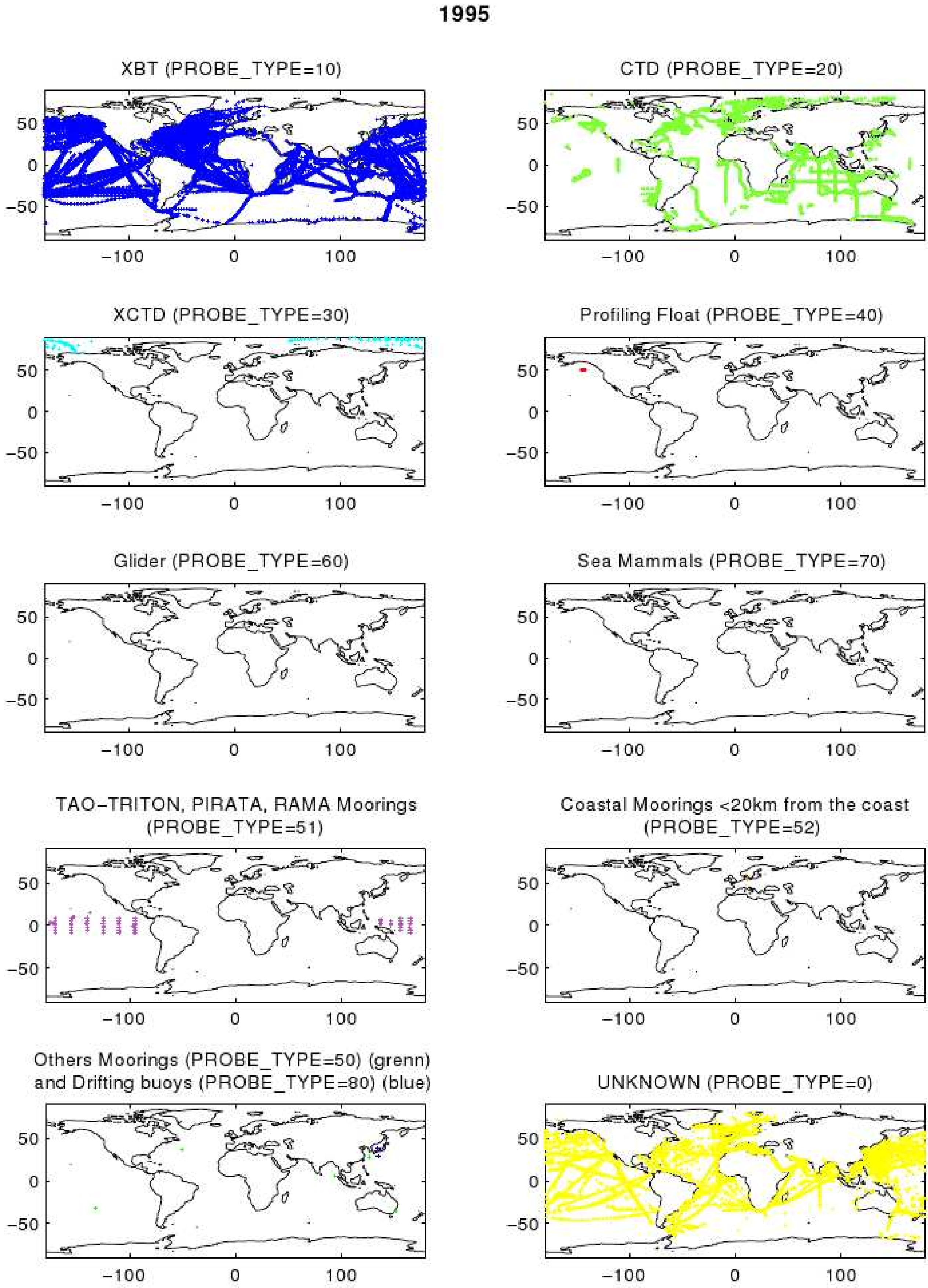

Figure 3.6: same as fig. 3.1 for the year 1995

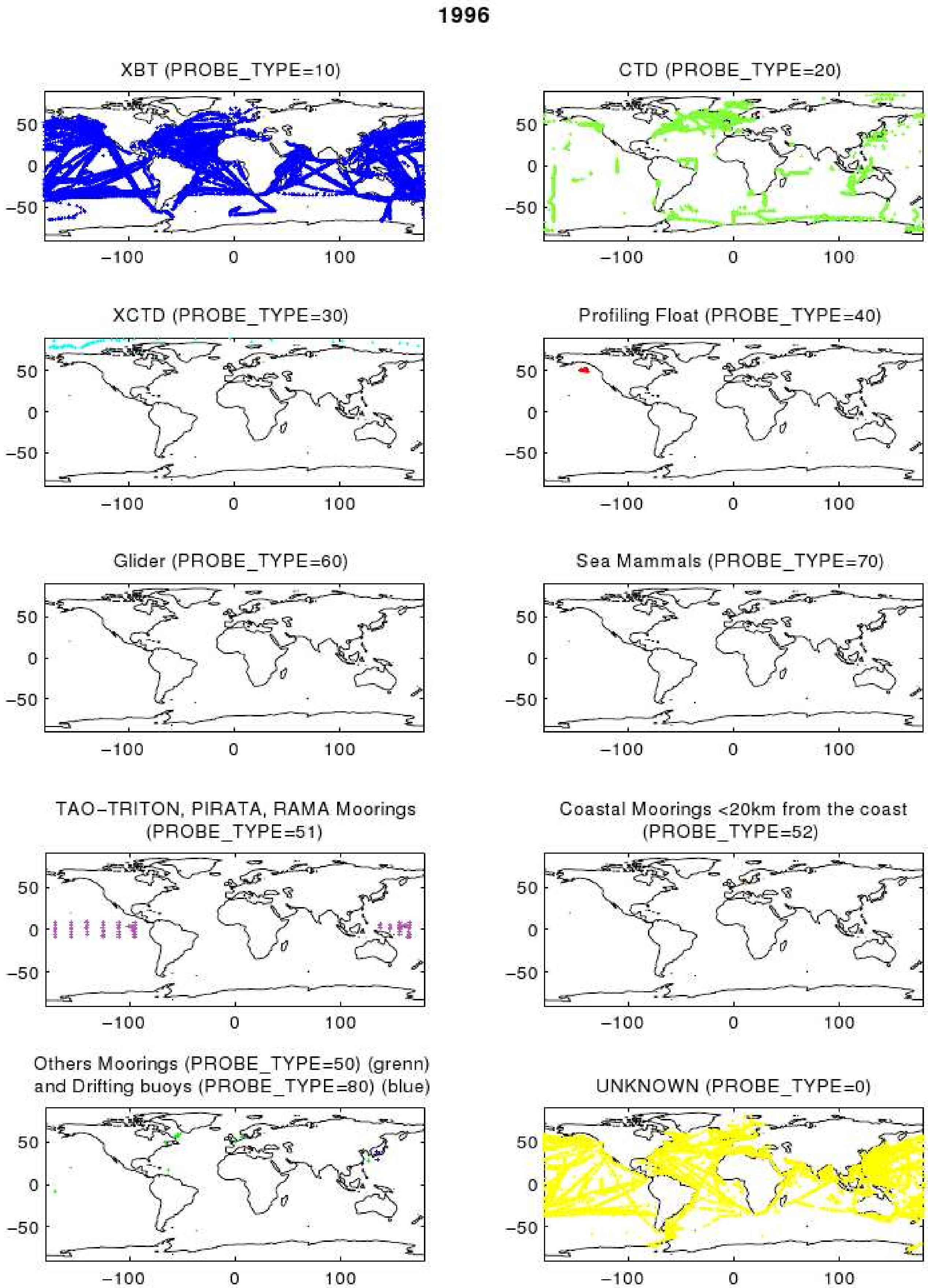

Figure 3.7: same as fig. 3.1 for the year 1996

1997

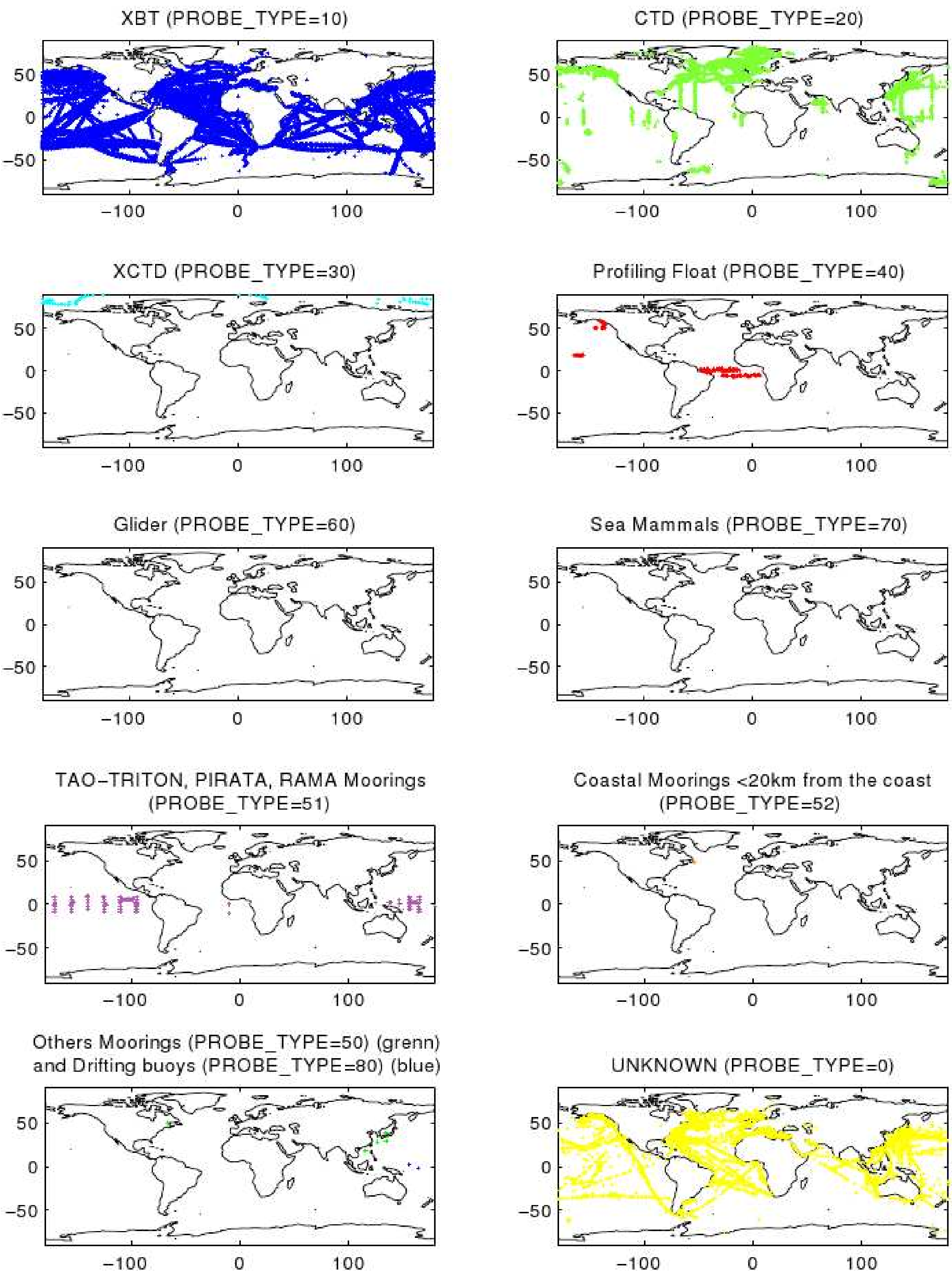

Figure 3.8: same as fig. 3.1 for the year 1997

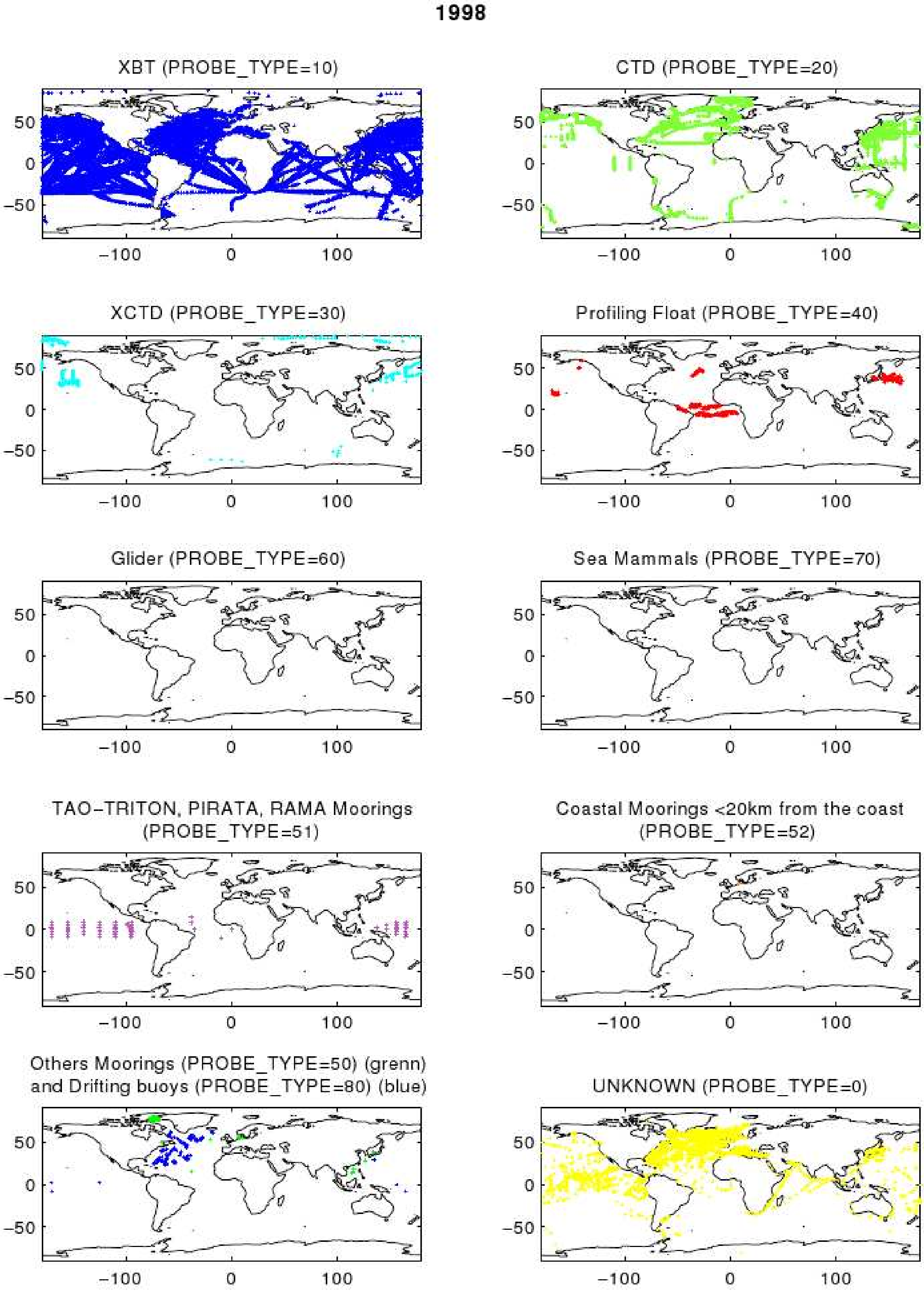

Figure 3.9: same as fig. 3.1 for the year 1998

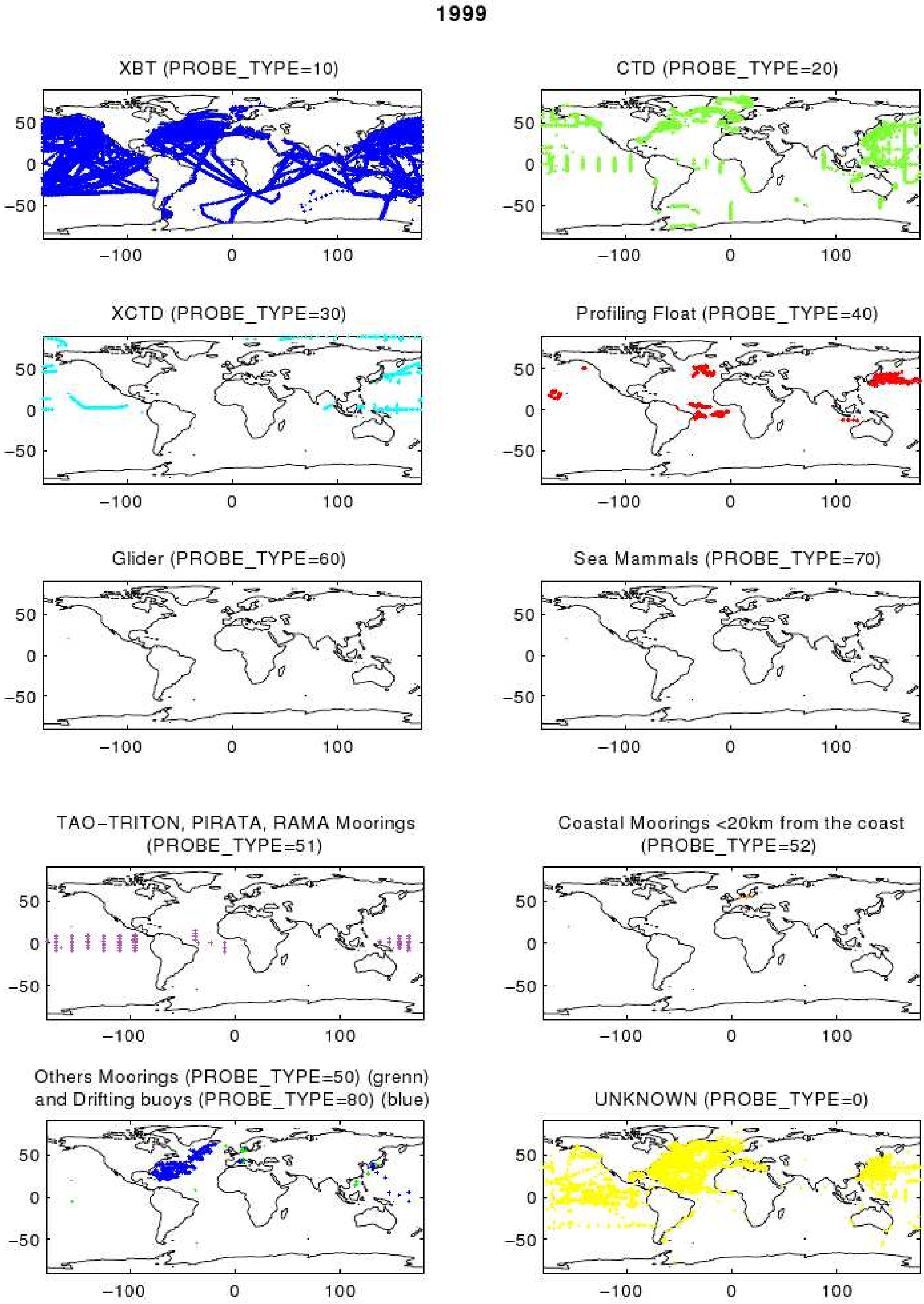

Figure 3.10: same as fig. 3.1 for the year 1999

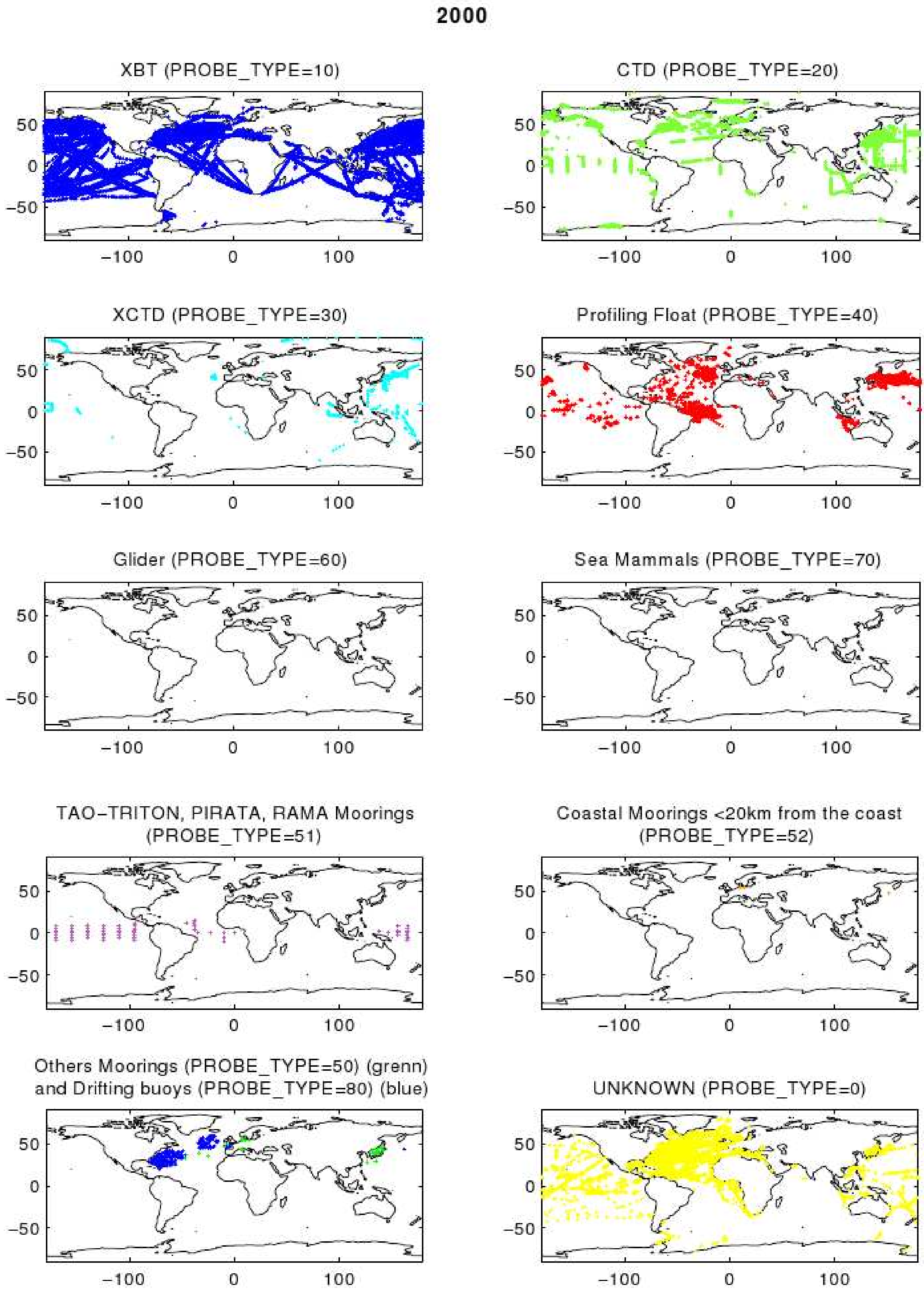

Figure 3.11: same as fig. 3.1 for the year 2000

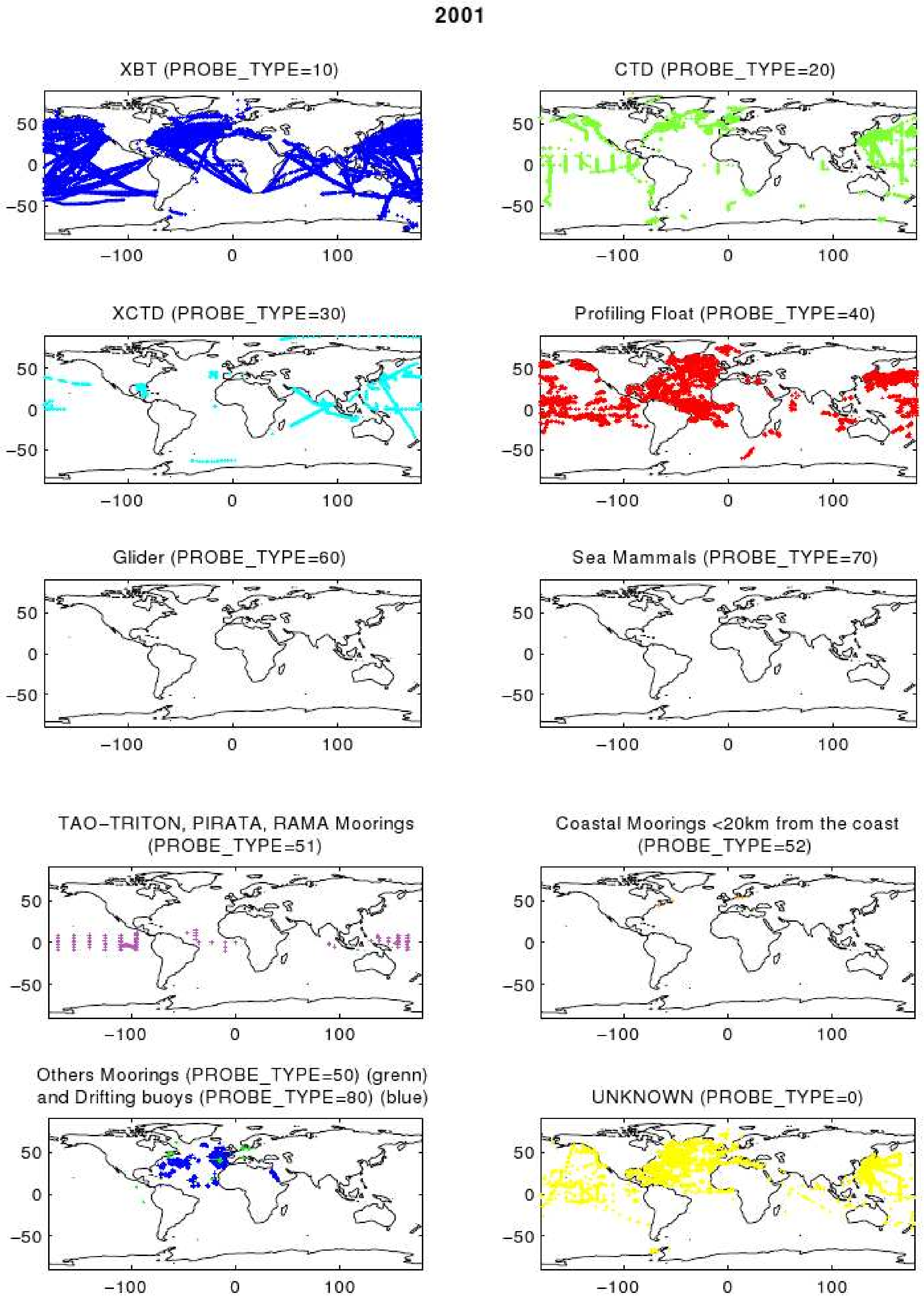

Figure 3.12: same as fig. 3.1 for the year 2001

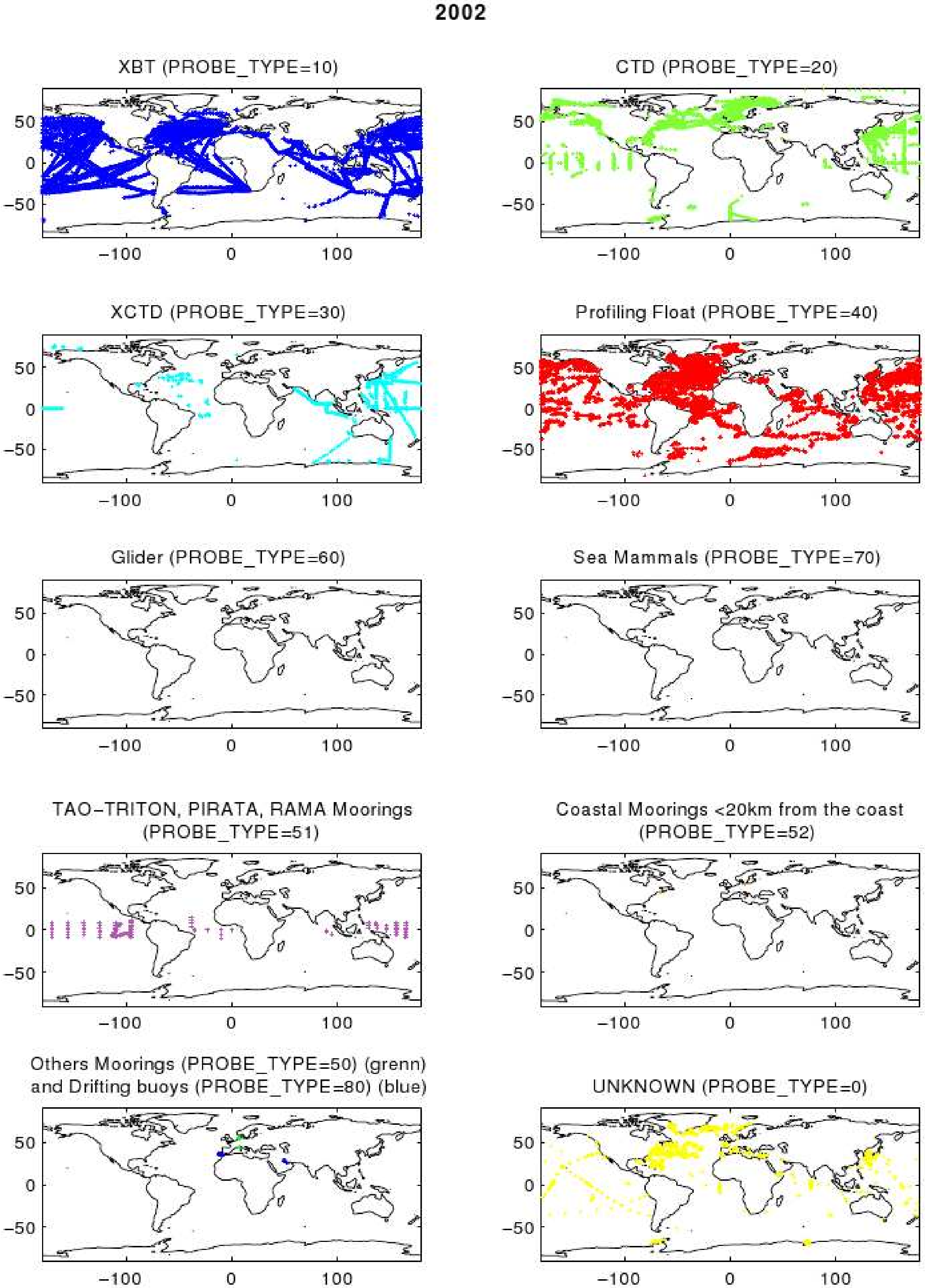

Figure 3.13: same as fig. 3.1 for the year 2002

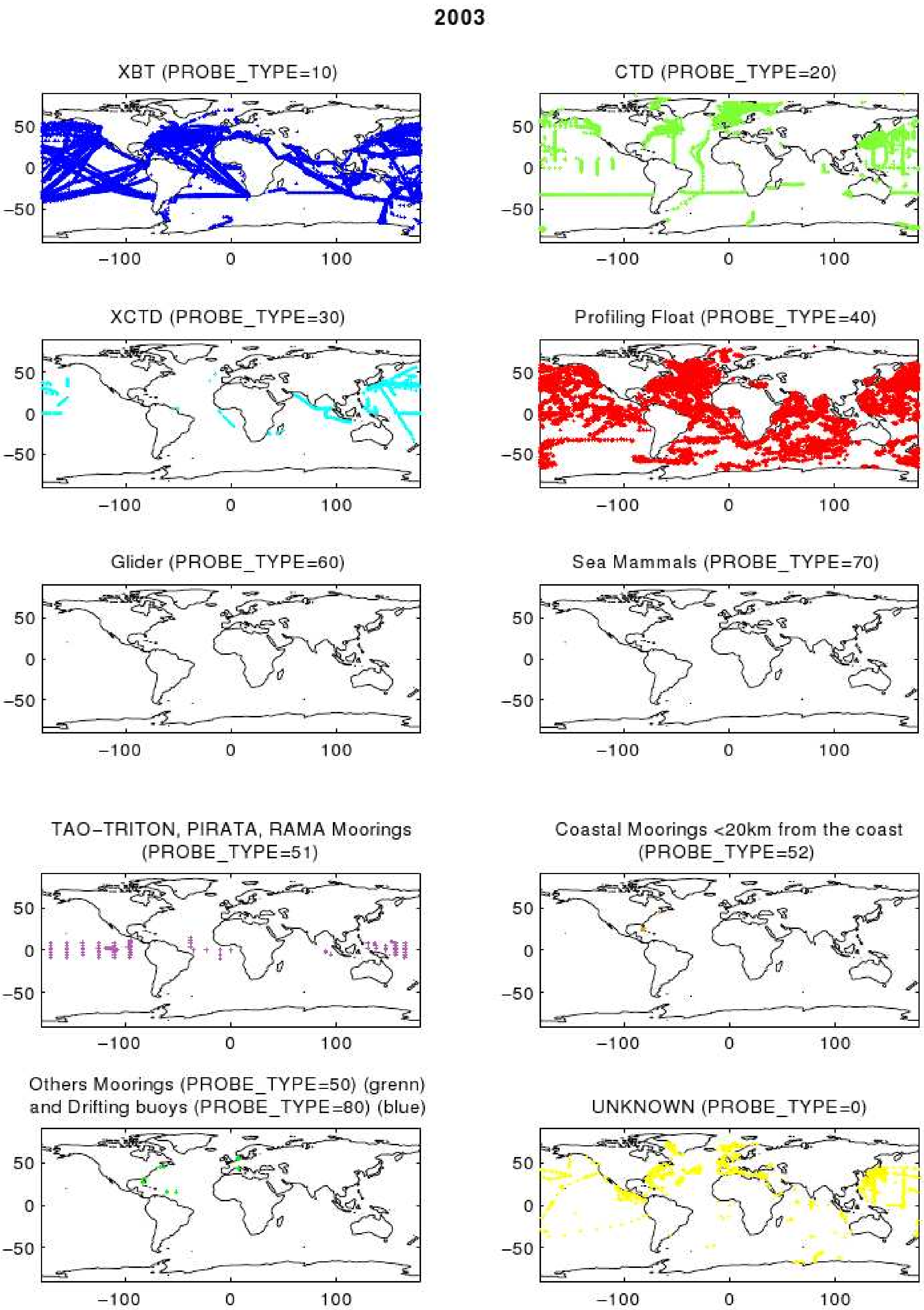

Figure 3.14: same as fig. 3.1 for the year 2003

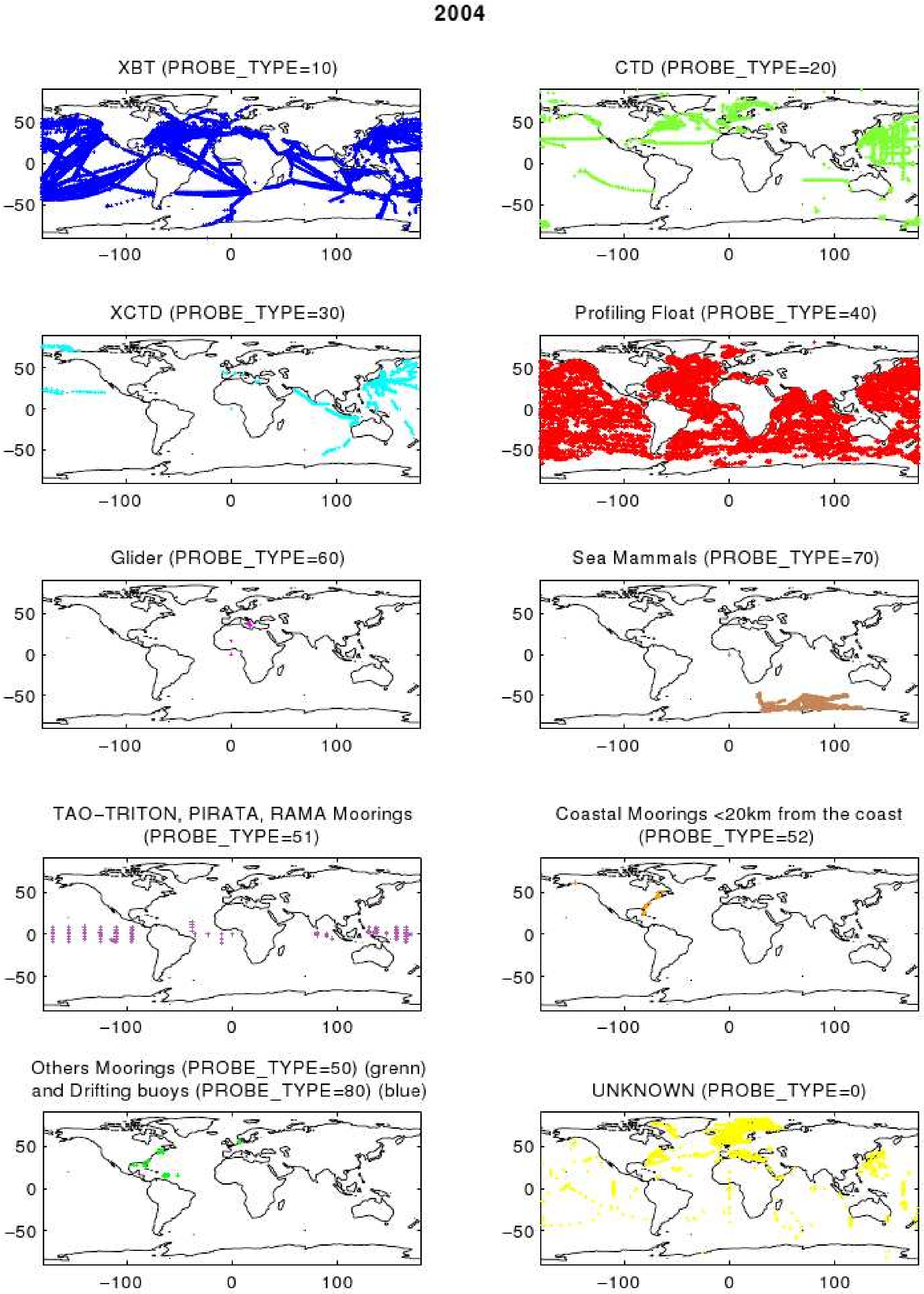

Figure 3.15: same as fig. 3.1 for the year 2004

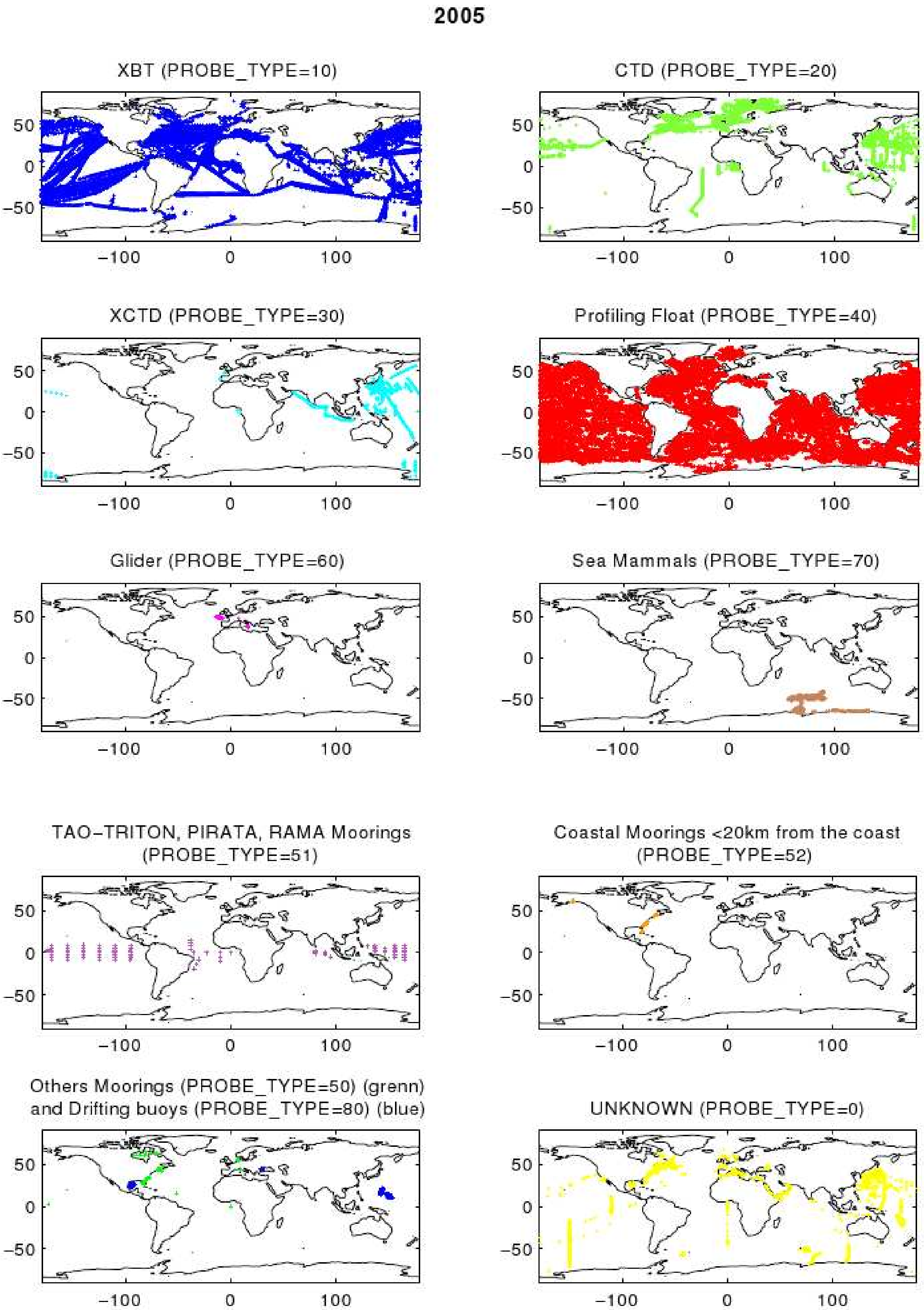

Figure 3.16: same as fig. 3.1 for the year 2005

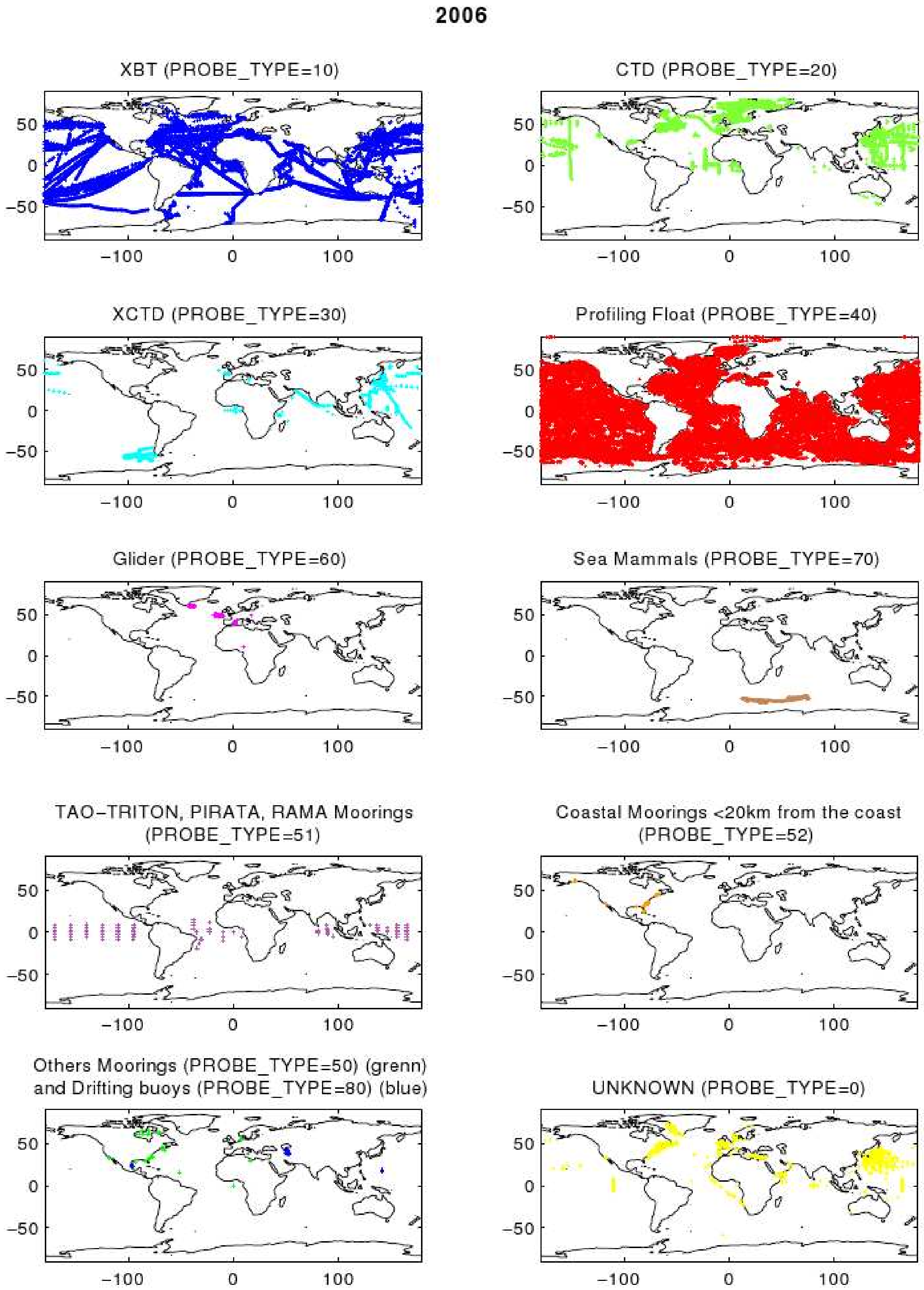

Figure 3.17: same as fig. 3.1 for the year 2006

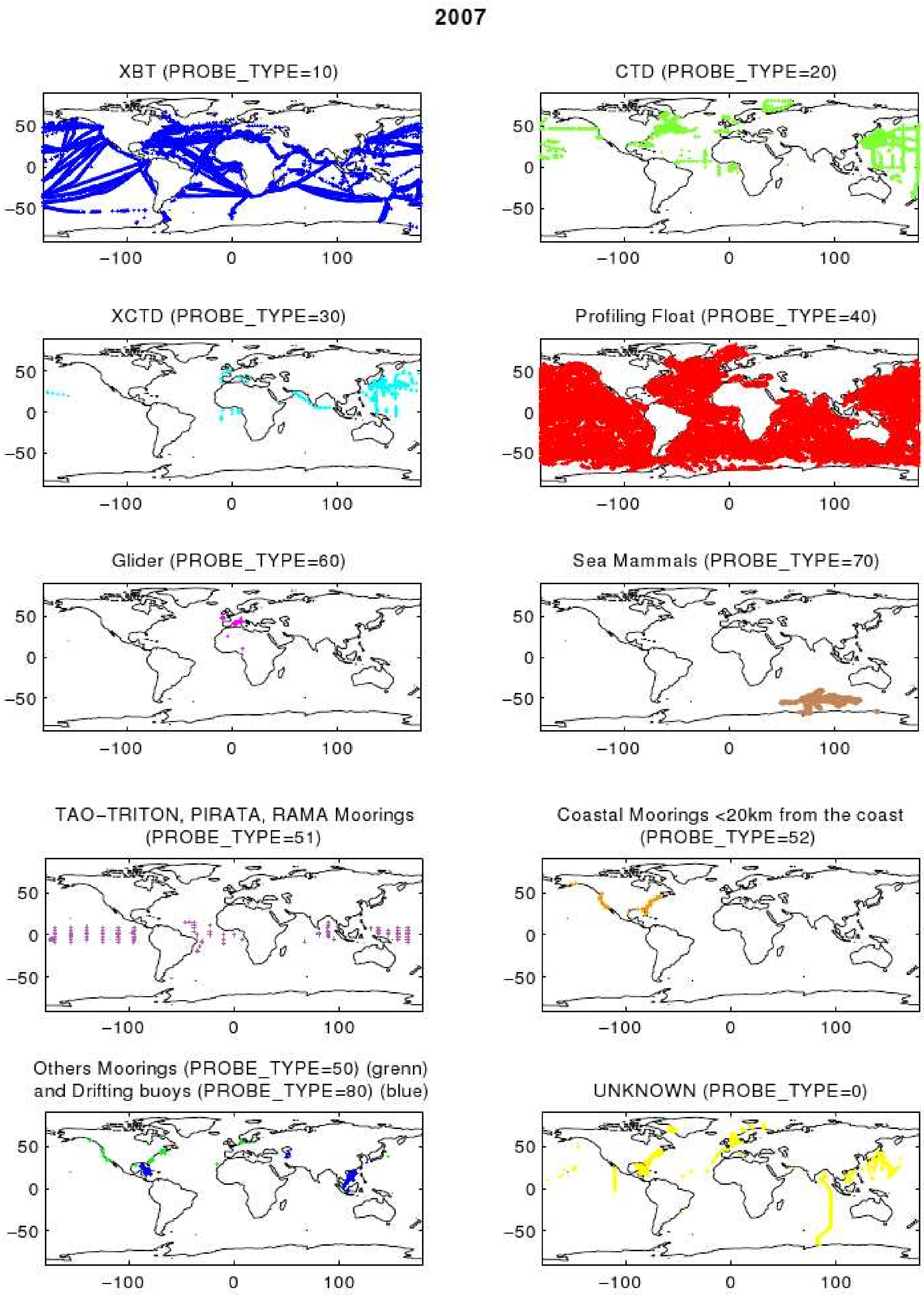

Figure 3.18: same as fig. 3.1 for the year 2007

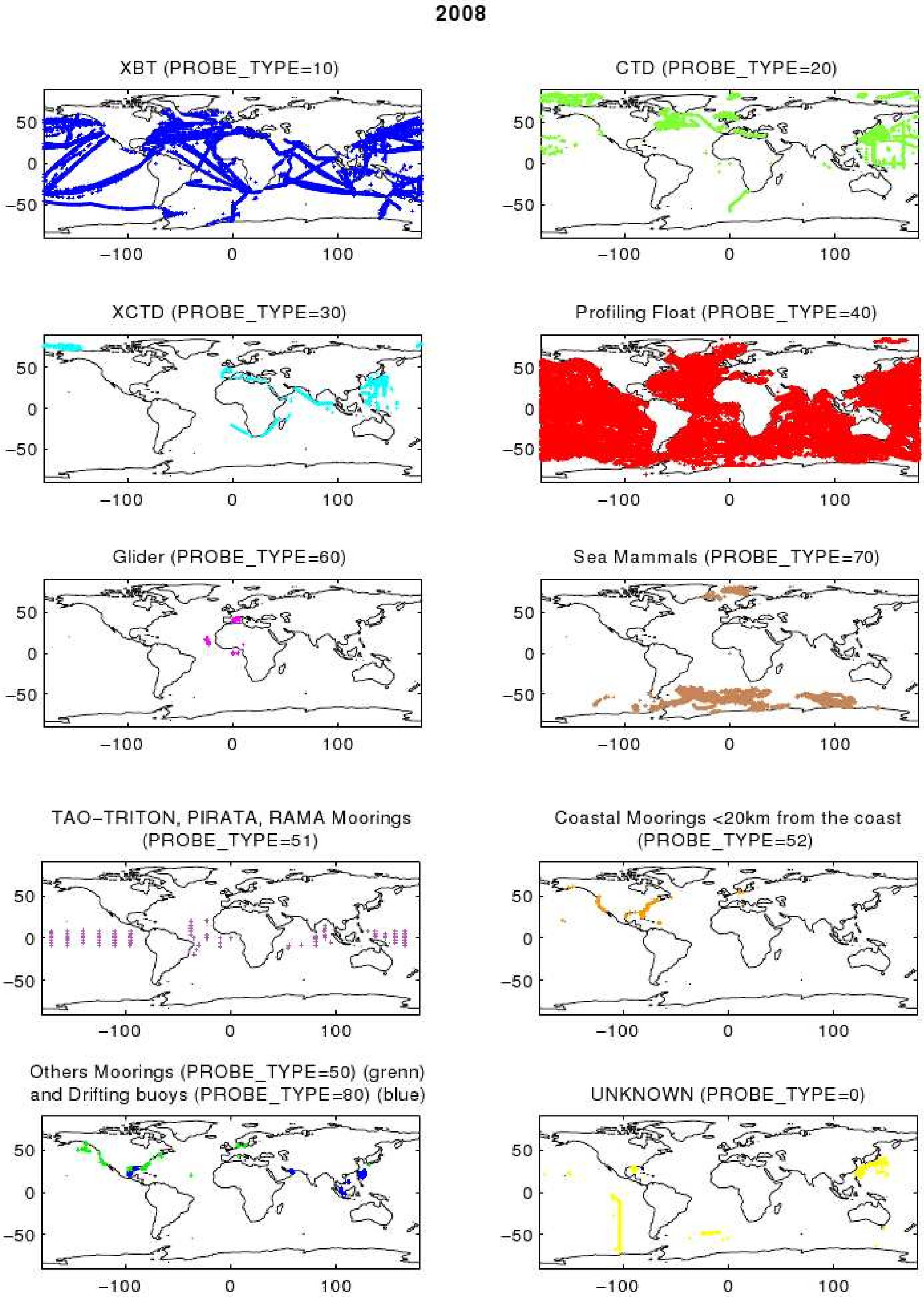

Figure 3.19: same as fig. 3.1 for the year 2008

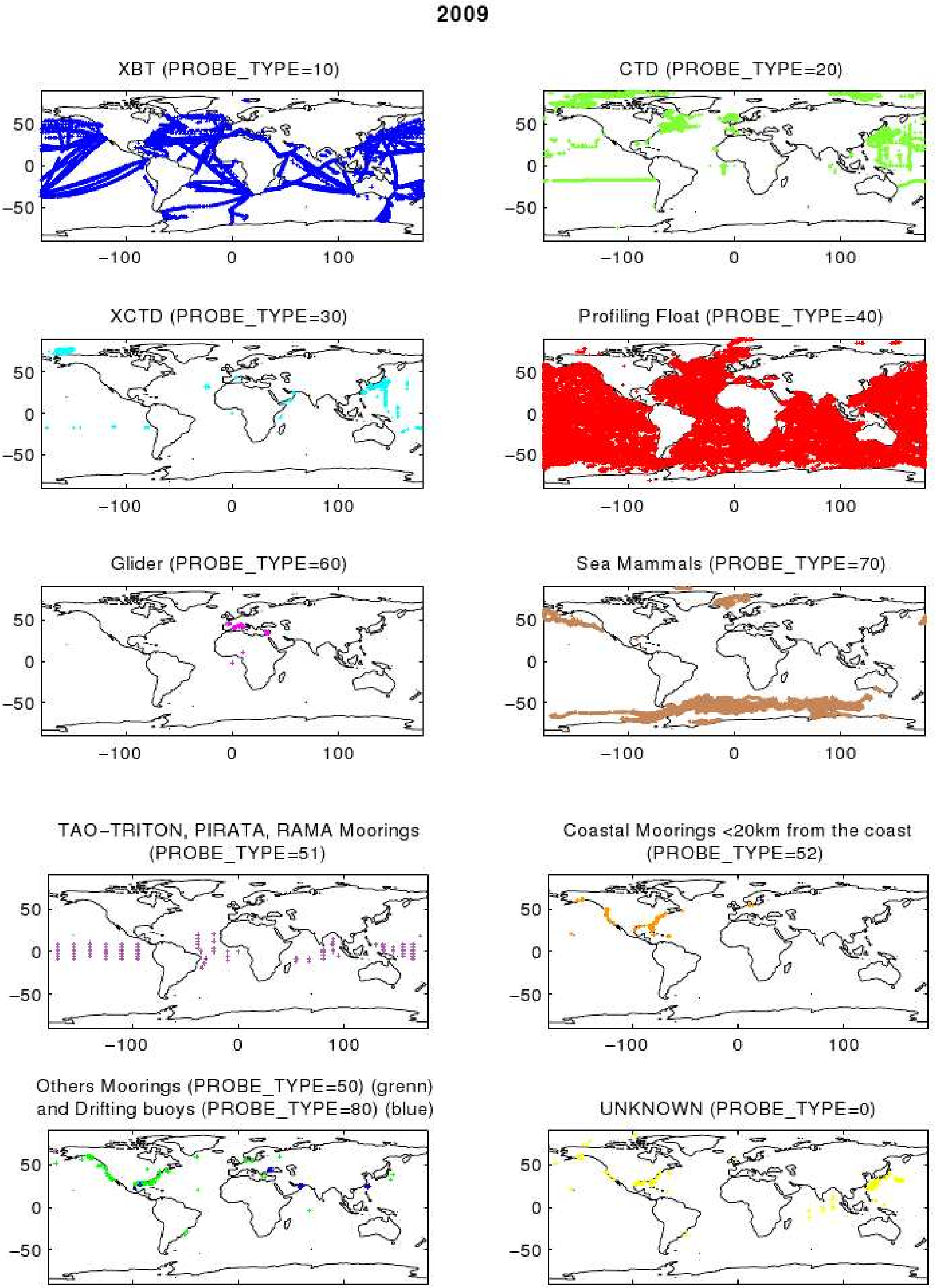

Figure 3.20: same as fig. 3.1 for the year 2009

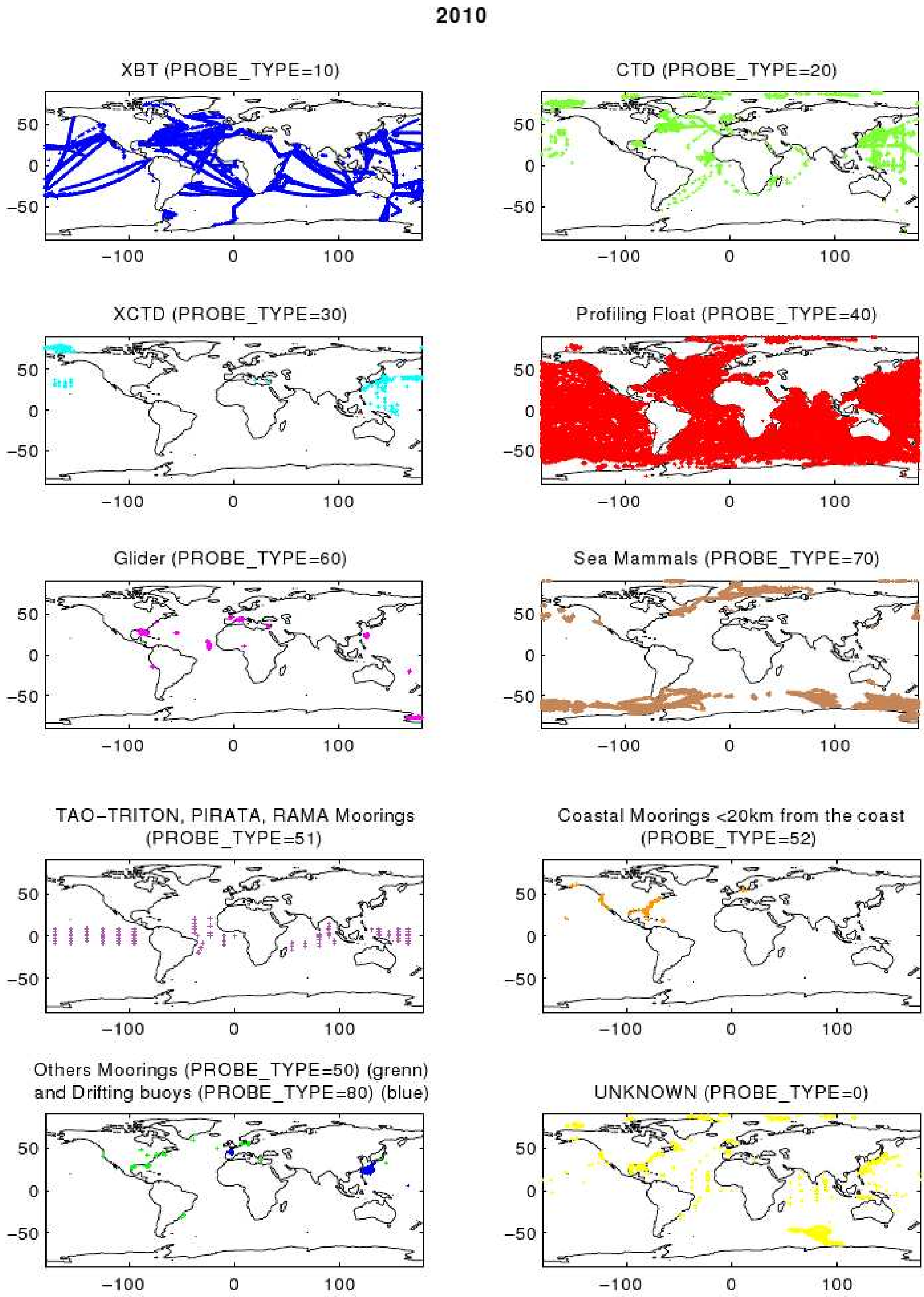

Figure 3.21: same as fig. 3.1 for the year 2010

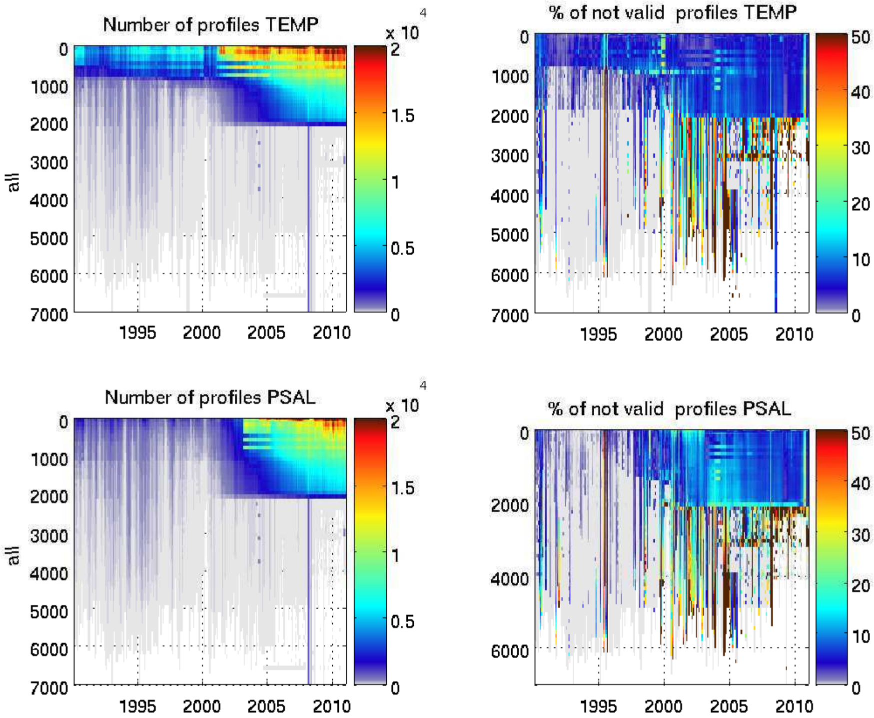

Figure 3.22: Number of profiles per month at a given depth (left) and the percentage of the data that is not usable (because quality flags are bad -ie 3 or 4) in CORA3 (right)

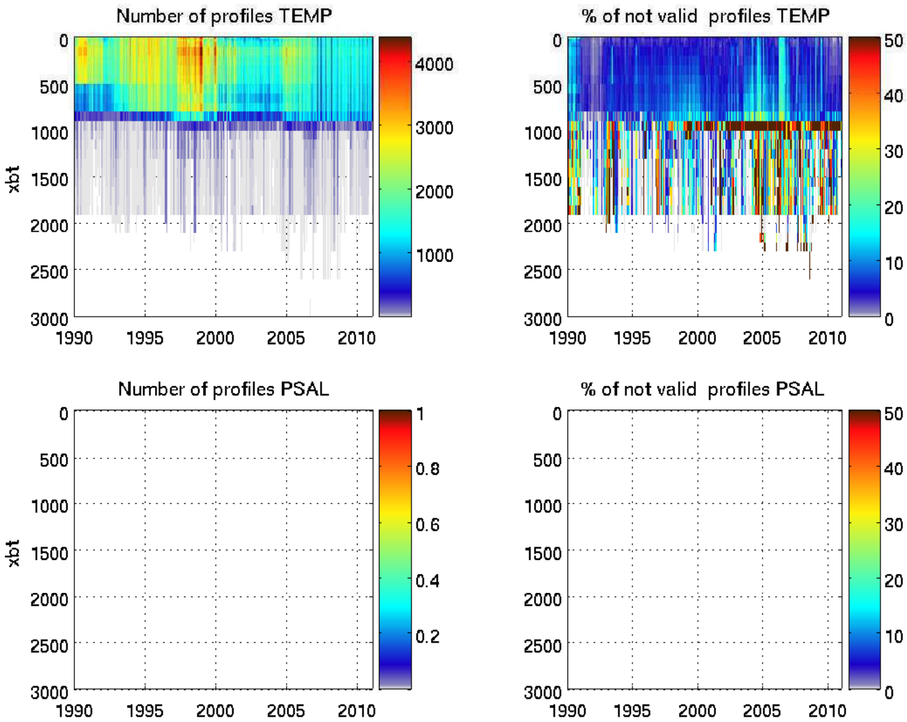

Figure 3.23: same as fig. 3.22 for XBT data only

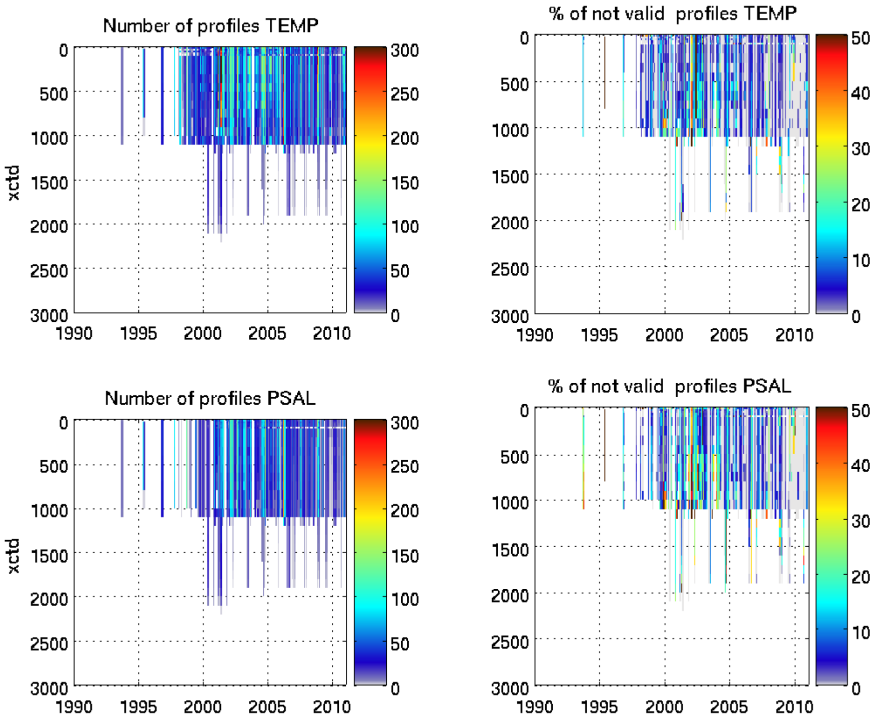

Figure 3.24: same as fig. 3.22 for XCTD data only

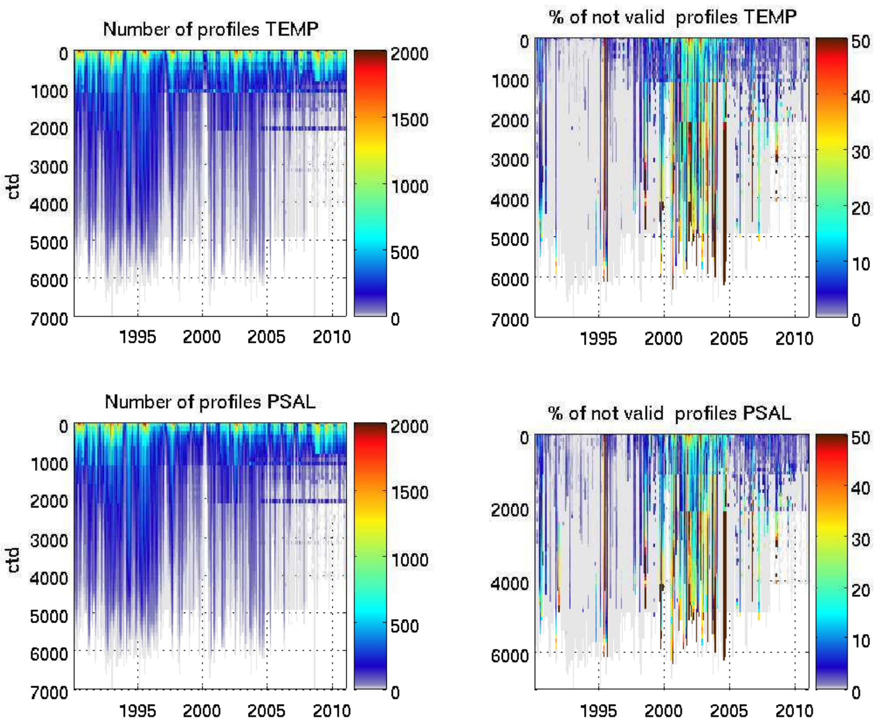

Figure 3.25: same as fig. 3.22 for CTD data only

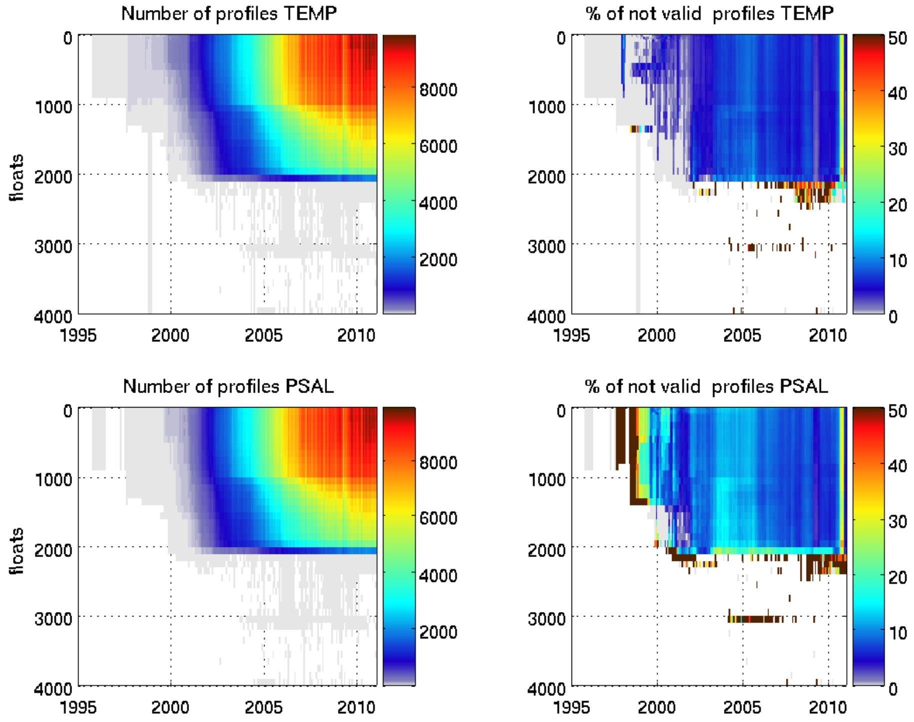

Figure 3.26: same as fig. 3.22 for float data only

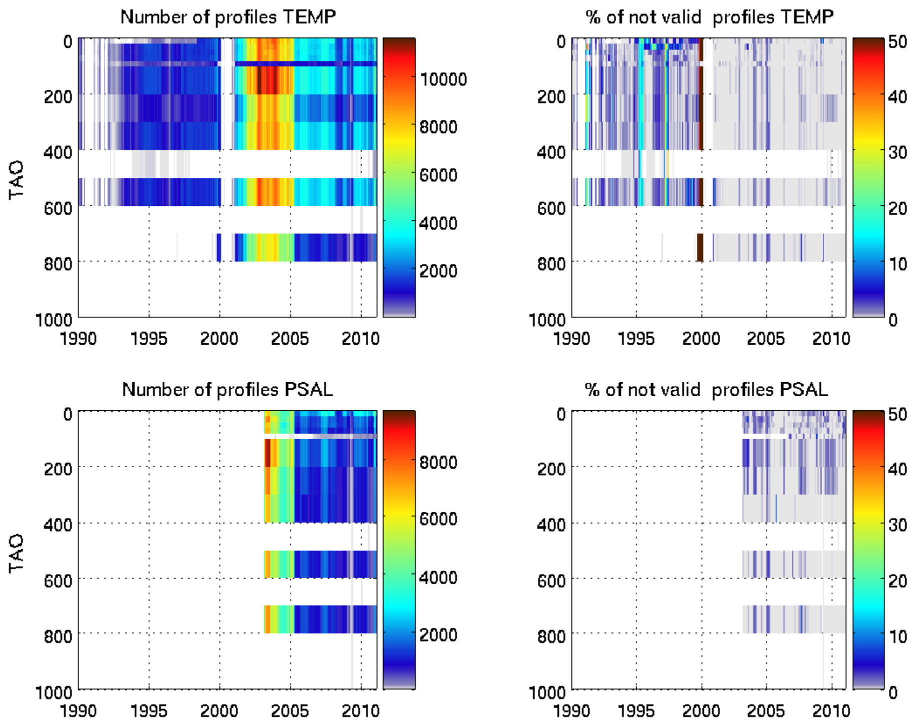

Figure 3.27: same as fig. 3.22 for TAO data only

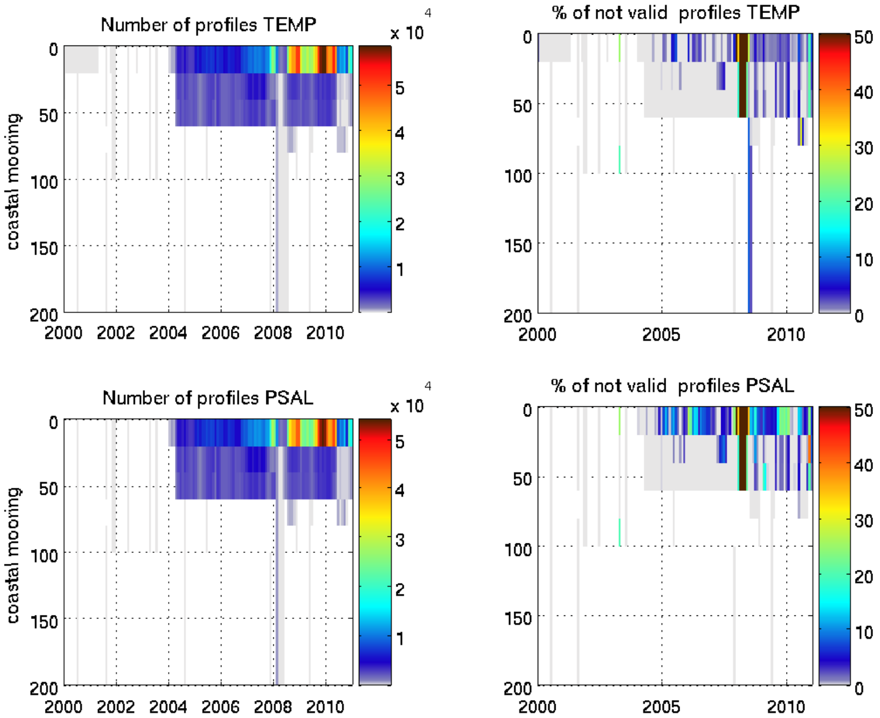

Figure 3.28: same as fig. 3.22 for coastal mooring data only

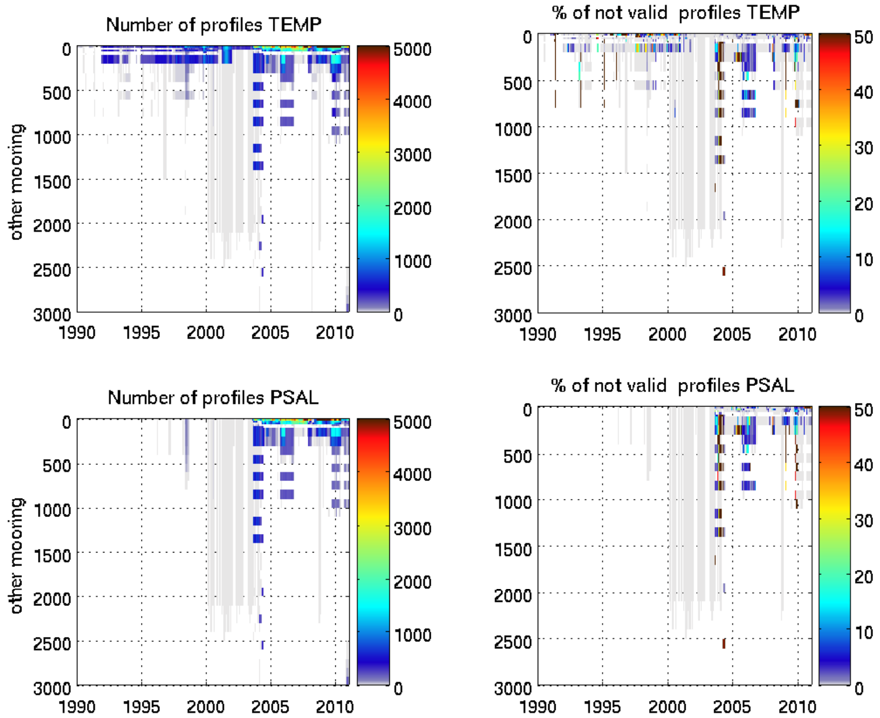

Figure 3.29: same as fig. 3.22 for other mooring data only

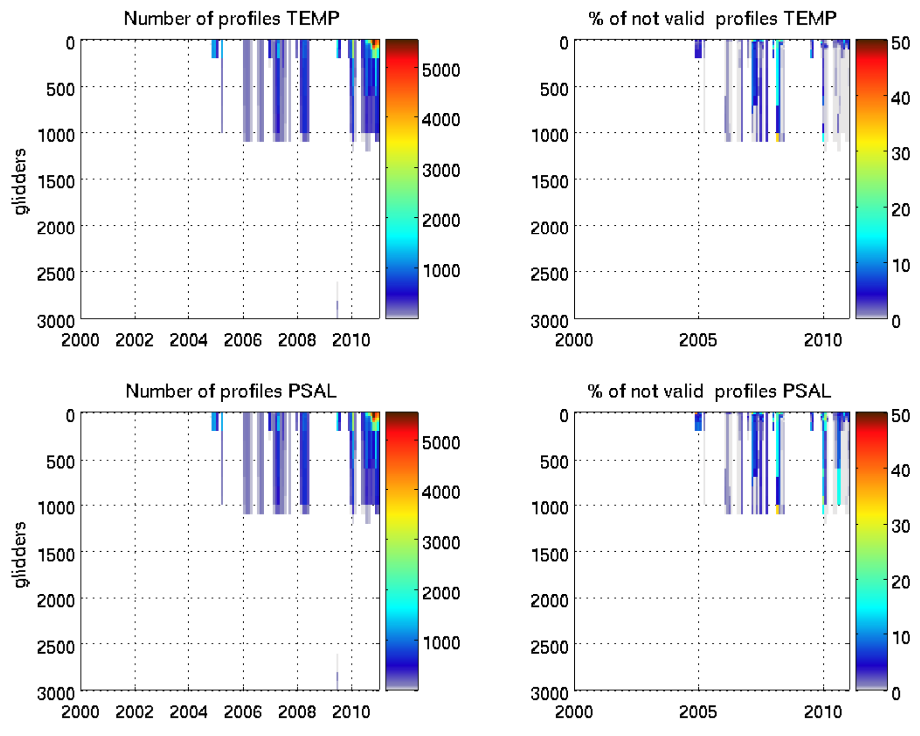

Figure 3.30: same as fig. 3.22 for glidder data only

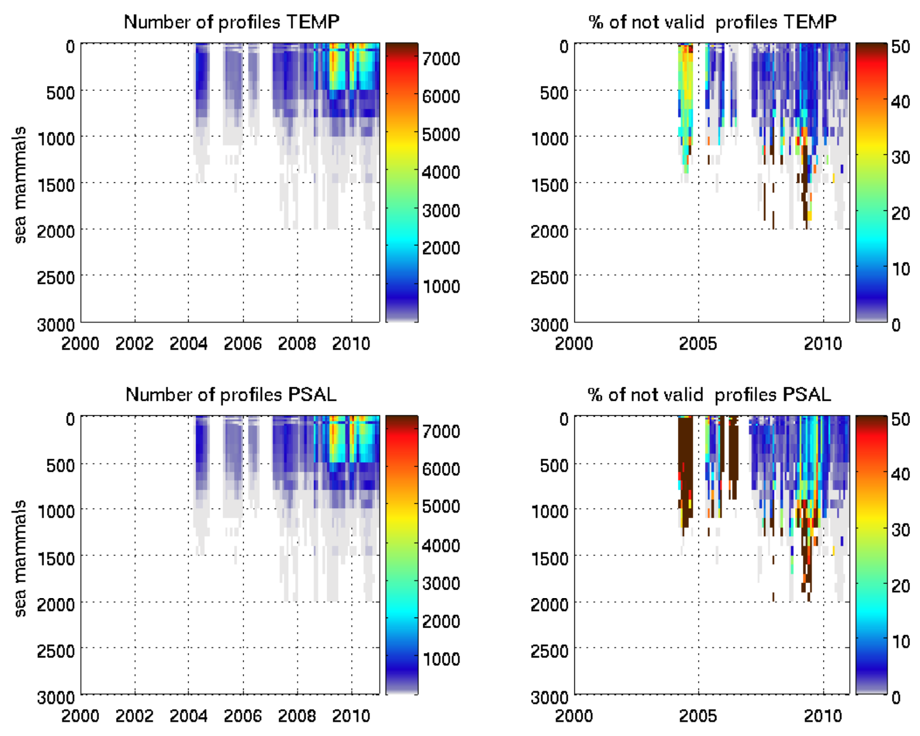

Figure 3.31: same as fig. 3.22 for sea mammals data only

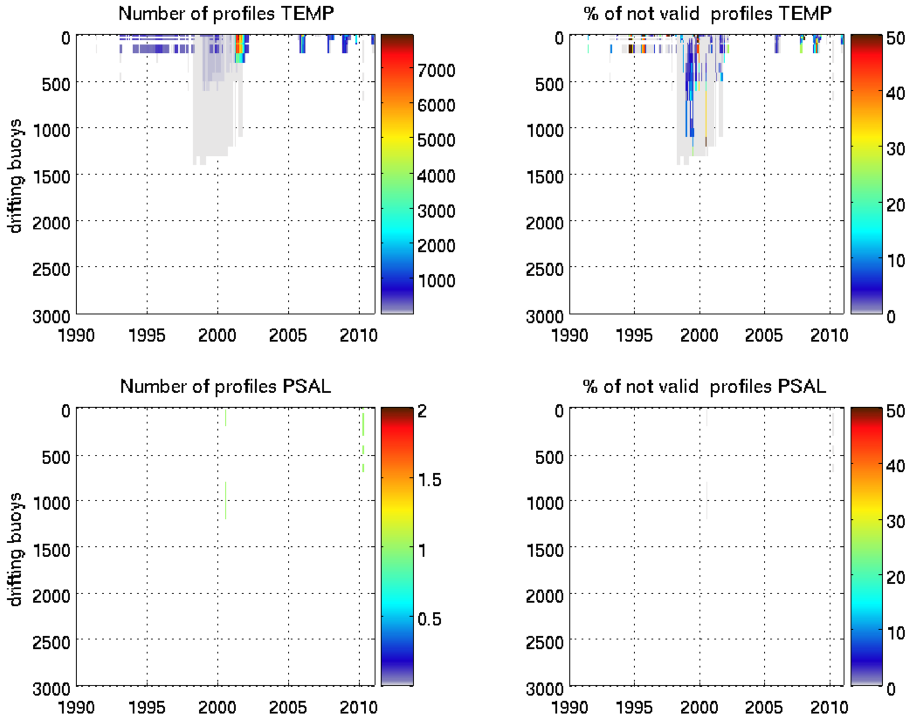

Figure 3.32: same as fig. 3.22 for drifting buoys data only

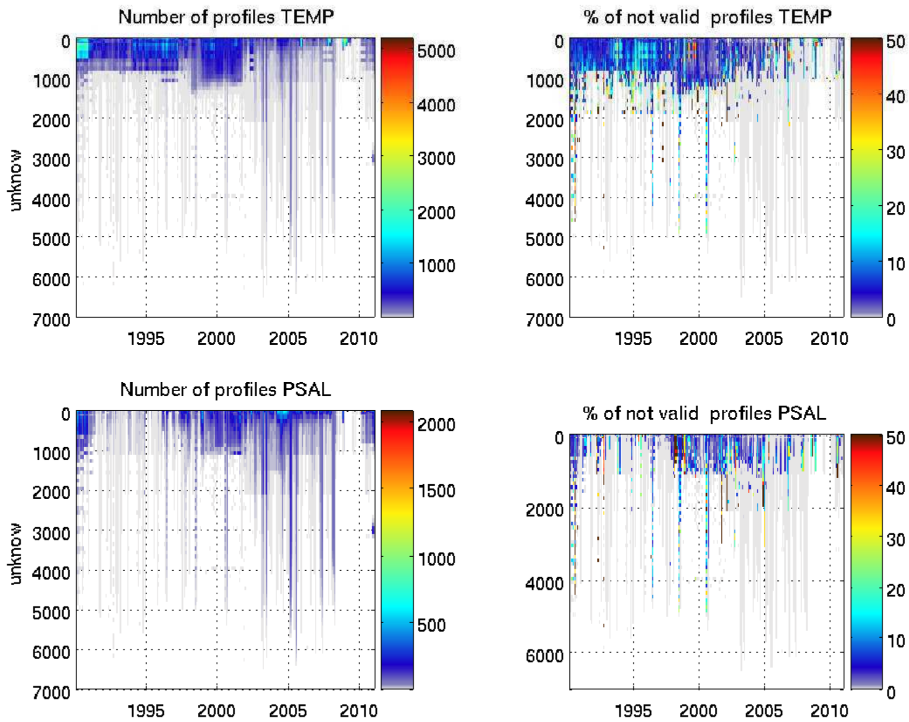

Figure 3.33: same as fig. 3.22 for unknown type data only

APPENDIX A

Tables

WMO_INST_TYPE	Description	WMO_INST_TYPE	Description
001	Sippican T-4	700	Sippican XCTD standard
002	Sippican T-4 new eq.	710	Sippican XCTD deep
009	T-04 460m T-04 1500F	720	Sippican AXCTD
011	Sippican T-5	730	Sippican SXCTD
019	T-05 1830m	741	TSK XCTD
021	Sippican Fast Deep	742	TSK XCTD-2
022	inconnu022	743	TSK XCTD-2F
031	Sippican T-6	751	TSK AXCTD
032	Sippican T-6 new eq.	800	MBT Mechanical Bathy Thermograph
039	T-06 460m	810	Hydrocast
041	Sippican T-7	820	Thermistor Chain
042	Sippican T-7 new eq.	830	CTD
049	T-07 760m	831	Profiling Float (PF) - Generic
051	Sippican Deep Blue	840	PF, PROVOR, no conductivity sensor
052	Sippican Deep Blue new eq.	841	PF, PROVOR, SBE conductivity sensor
059	T-DB 760m	842	PF, PROVOR, FSI conductivity sensor
060	inconnu060	843	PF, Polar Ocean Profiling System (POPS), PROVOR SBE
061	Sippican T-10	844	PF, ARVOR, Seabird conductivity sensor
069	T-10 200m	845	PF, APEX, no conductivity sensor
071	Sippican T-11	846	PF, APEX, SBE conductivity sensor
079	T-11 460m	847	PF, APEX, FSI conductivity sensor
081	Sippican AXBT (300m probes)	850	PF, SOLO, no conductivity sensor
201	TSK T-4	851	PF, SOLO, SBE conductivity sensor
202	TSK T-4 new eq.	852	PF, SOLO, FSI conductivity sensor
211	TSK T-6	853	PF, SOLO2 (SCRIPPS), Seabird conductivity sensor
212	TSK T-6 new eq.	856	PF, NINJA, SBE conductivity sensor
221	TSK T-7	858	PF, NINJA, TSK conductivity sensor
222	TSK T-7 new eq.	860	PF, NEMO, SBE conductivity sensor
229	TSK T-7	861	PF, NEMO, FSI conductivity sensor
231	TSK T-5	995	Instrument attached to marine mammals
241	TSK T-10	999	Unknown
251	TSK Deep Blue		
252	TSK Deep Blue		
401	Sparton XBT-1		
411	Sparton XBT-3		
421	Sparton XBT-4		
431	Sparton XBT-5		
451	Sparton XBT-6		
460	Sparton XBT-7 (old)		
461	Sparton XBT-7		
462	Sparton XBT-7		
481	Sparton XBT-10		
491	Sparton XBT-20		
501	Sparton XBT-20DB		

Table A.1: WMO INSTRUMENT TYPES and their definition

PROBE_TYPE	Description
10	XBT
20	CTD
30	XCTD
40	PROFILING FLOAT
51	TAO-TRITON PIRATA RAMA MOORINGS
52	COASTAL MOORINGS (< 20km from the coast)
50	OTHER MOORINGS
60	GLIDERS
70	INSTRUMENT ATTACHED TO SEA MAMMALS
80	DRIFTING BUOYS
0	UNKNOWN

Table A.2: PROBE TYPES: Codes and definitions

	HOT and DEEP			HOT and SHALLOW			COLD and SHALLOW			COLD and DEEP		
	a	b	c	a	b	c	a	b	c	a	b	c
1990	-7.1143e-07	0.0083645	0.69065	2.1037e-05	-0.0010439	0.68068	4.2526e-06	0.0063198	0.79734	4.2959e-06	0.0043327	0.65858
1991	1.3984e-06	0.0073466	0.68601	1.0786e-05	0.0030236	0.67179	3.9592e-07	0.0071839	0.77337	3.4361e-06	0.004904	0.60144
1992	1.0472e-06	0.0074213	0.65338	1.0847e-05	0.0028244	0.65256	7.6253e-06	0.0030343	0.51567	5.3715e-06	0.0034703	0.60528
1993	2.9732e-07	0.0080382	0.61483	3.1862e-07	0.0071422	0.61035	1.9661e-05	-0.0036154	0.33827	2.8472e-06	0.0051036	0.54112
1994	1.5963e-06	0.007318	0.58377	1.6427e-05	0.00087699	0.62846	1.0832e-05	0.0083538	1.0879	3.1558e-06	0.0049934	0.56838
1995	3.3509e-06	0.0060772	0.51941	1.0886e-06	0.0018374	0.22987	0.00016299	-0.011499	3.5574	8.3509e-06	0.00048441	0.57517
1996	8.0693e-06	0.0057776	1.1429	4.4181e-05	-0.0043531	0.42843	4.6105e-06	-0.0096887	0.005048	2.2101e-06	0.0046373	0.53954
1997	1.0653e-05	0.00095079	0.89169	-2.0466e-05	0.024874	-0.46646	2.9297e-05	0.032902	-1.8837	1.2932e-05	-0.0011347	0.86702
1998	-6.2216e-07	0.0075039	0.27032	-3.7186e-06	0.011031	1.2913	-7.2406e-05	0.031521	0.58015	1.0817e-06	0.0049313	0.45446
1999	6.2702e-06	0.0043985	1.4626	7.5043e-06	0.00023827	-0.59822	5.3383e-05	-0.0034839	0.79974	1.4228e-06	0.0047577	0.62921
2000	5.4507e-06	0.013707	3.2011	-0.00018074	0.077799	3.0092	0.00014598	-0.0086735	3.0833	7.7839e-06	0.0027011	3.3757
2001	-2.3193e-06	0.014295	2.1633	4.0522e-07	-0.00050234	-1.0727	-0.00036536	0.11583	5.7531	1.6803e-05	-0.016518	0.89113
2002	2.0987e-05	0.0026797	2.0622	5.0699e-05	0.022176	4.2065	0.00017235	-0.039704	3.4083	1.4325e-05	-0.0071179	2.4769
2003	1.0295e-05	0.0033341	1.5199	-1.7672e-05	0.017371	1.4836	-0.00015894	0.042183	0.27333	6.6755e-07	-0.00012579	1.7853
2004	5.4394e-05	-0.029327	0.50069	3.9714e-05	0.0062092	1.0057	-7.9741e-06	0.00072145	2.3911	-1.0725e-06	0.0026358	2.1516
2005	-1.2825e-06	0.012921	1.6975	4.2472e-05	0.0086823	1.9908	5.625e-05	-0.024077	-0.52684	2.8511e-05	-0.010609	1.815
2006	2.4648e-05	-0.0031966	0.13278	-3.3885e-06	0.0085185	0.43597	2.5282e-05	-0.027834	0.28719	-1.0889e-05	0.016215	1.8422
2007	-2.8851e-05	0.044312	1.098	-1.9285e-05	0.024406	3.571	0.00020061	-0.080332	-1.4409	-1.4928e-05	0.02117	2.1417
2008	-2.1199e-05	0.038473	1.0583	-7.5197e-09	0.009879	1.4405	3.8229e-05	-0.035406	-1.5448	-1.5126e-05	0.027662	1.5466
2009	-1.3035e-06	0.02052	1.8746	-3.6274e-05	0.030775	4.2302	1.5642e-05	0.0060667	0.71466	2.3378e-05	-0.0050675	2.2219
2010	3.8618e-06	0.01673	0.69743	-7.7101e-05	0.038386	1.6881	1.7455e-05	-0.010886	-2.3344	3.0286e-05	-0.011257	1.3605

Table A.3: Coefficients of the parabolic correction and the depth offset for XBT

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