THE OGS MEDITERRANEAN DRIFTER DATASET: 1986-2016

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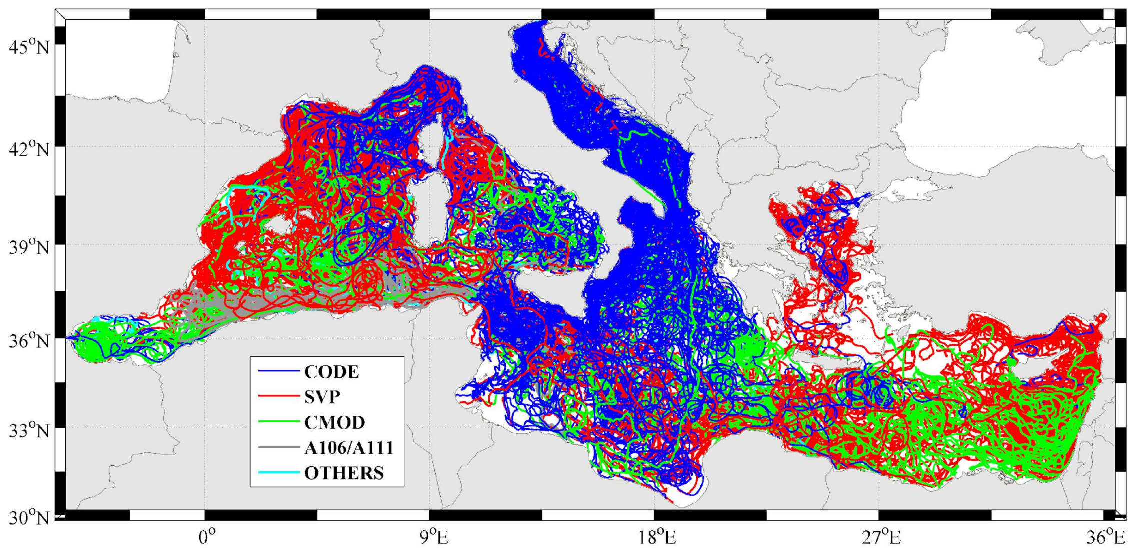

Approved for release by: ……………………………………………

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1. Introduction

The OGS Mediterranean drifter database consists of drifter data collected in the Mediterranean Sea from various institutions and countries since 1986. Surface drifters are autonomous observing platforms that provide a Lagrangian trajectory from which ocean currents can be inferred. Due to their Lagrangian nature, drifters move with the currents and can cover substantial geographical areas allowing the descriptions of the circulation in specific Mediterranean sub-basins and providing novel insights on the near-surface dynamics (Poulain et al., 2012). During their life, drifters can also provide other variables of interest, such as Sea Surface Temperature (SST) or air pressure.

The MAOS (Mobile Autonomous Oceanographic Systems) group of the OGS oceanographic section (OCE) mainly works with autonomous instruments, including a variety of different drifters. The drifter data reported in this document were collected in the Mediterranean Sea and other regions of interest (Southern Ocean, Senegal coast). The data come from OGS-MAOS own projects, from the main global ocean observing networks, from other research institutes and data centers (see Section 4). These data were cleaned from eventual outliers and elaborated with standard procedures (editing and interpolation; see Section 3). In this report, we present the contents of the OGS MedSVP_db24 drifter database for the period spanning 1986-2016. The results of these elaborations (interpolated drifter products) are available upon request for scientific applications (see Section 5).

2. Drifter types and telemetry

The majority of the drifters collected in MedSVP_db24 are of three types (Table 1): Surface Velocity Program (SVP) drifters which are the standard design of the Global Drifter Program (Lumpkin and Pazos, 2007), CODE drifters which were developed by Davis (1985) in the early 1980's to measure coastal surface currents, and Compact Meteorological and Oceanographic Drifters (CMOD) or XAN-1 drifters (Selsor, 1993) which were mainly operated by the U.S. Navy.

SVP drifters (Figures 1, A1) consist of a surface buoy that is tethered to a holey-sock drogue, centered at a nominal depth of 15 m, that holds the drifter almost motionless with respect to the horizontal layer studied (for details on the SVP design, see Sybrandy and Niiler (1991) and Appendix A). They have a drag area ratio of the drogue to the tether and surface buoy in excess of 40. A tension sensor, located below the surface buoy where the drogue tether is attached, indicates the presence or absence of the drogue. Measurements of the water-following capabilities of the SVP have shown that when the drogue is attached, they follow the water to within 1 cm/s in 10 m/s winds (Niiler et al., 1995).

CODE drifters consist of a slender, vertical, 1-m-long negatively buoyant tube with four drag-producing vanes extending radially from the tube over its entire length and four small spherical surface floats attached to the upper extremities of the vanes to provide buoyancy (Poulain, 1999; Figure 1). Comparisons with current meter measurements (Davis, 1985) and studies using dye to measure relative water movements (D. Olson 1991, personal communication) showed that the CODE drifters follow the surface currents to within 3 cm/s, even during strong wind conditions.

CMOD drifters are sonobuoys which consist of a 60-cm-long aluminum cylindrical hull with a floatation collar (35-cm overall diameter). They are drogued with the sonobuoy case on a 100-m-long (4-m for a few of them) tether, resulting in a wet to dry area ratio of about 5 (Matteoda and Glenn, 1996).

Table 1. Quantity of drifter data in the OGS MesSVP_db24 database for the period 1986-2016.

Drifter types	Number of drifter tracks	Drifter days	Max life (days)	Mean life (days)	Mean half life (days)
CODE	776	44230	364	56.7	35
SVP	661	56329	576	81.3	54
CMOD	226	10576	219	46.8	38
A106/A111	17	1184	164	69.7	66
OTHER	65	1638	182	25.2	11
TOTAL	1743	113958			

Model A106 drifters are similar in design to the CODE drifters; model A111 house the transmitter, antenna and batteries within a vertical cylinder. These systems were fitted with a holey sock drogue centered at a nominal depth of 10 m (Font et al., 1998; Salas et al., 2001) but no sensor indicated the drogue presence. Other drifter types included in MedSVP_db24 database (Figure 1) are: the Mini Drifter Iridium (MD03i; http://albatrosmt.com/wp-content/uploads/2014/09/MiniDrifterIridium_MD03i.pdf), the Ocean Drifter iridium buoy (ODi; http://albatrosmt.com/wp-content/uploads/2014/09/ODi_IridiumOceanDrifterSolar.pdf) and the MLi (http://www.sondara.com/fichas/boya-mli.pdf). As part of the TOSCA (Tracking Oil Spills and Coastal Awareness Network) project (2012) OGS, in collaboration with other European research institutes and universities, deployed in the Mediterranean a number of peculiar drifters (I-sphere, Oilspill prototypes, prototype surface drifters from the Institute of Marine Sciences, Albatros) depicted in Figure 1. Further information about these drifters and their technical characteristics can be found in Gerin et al. (2012, 2013).

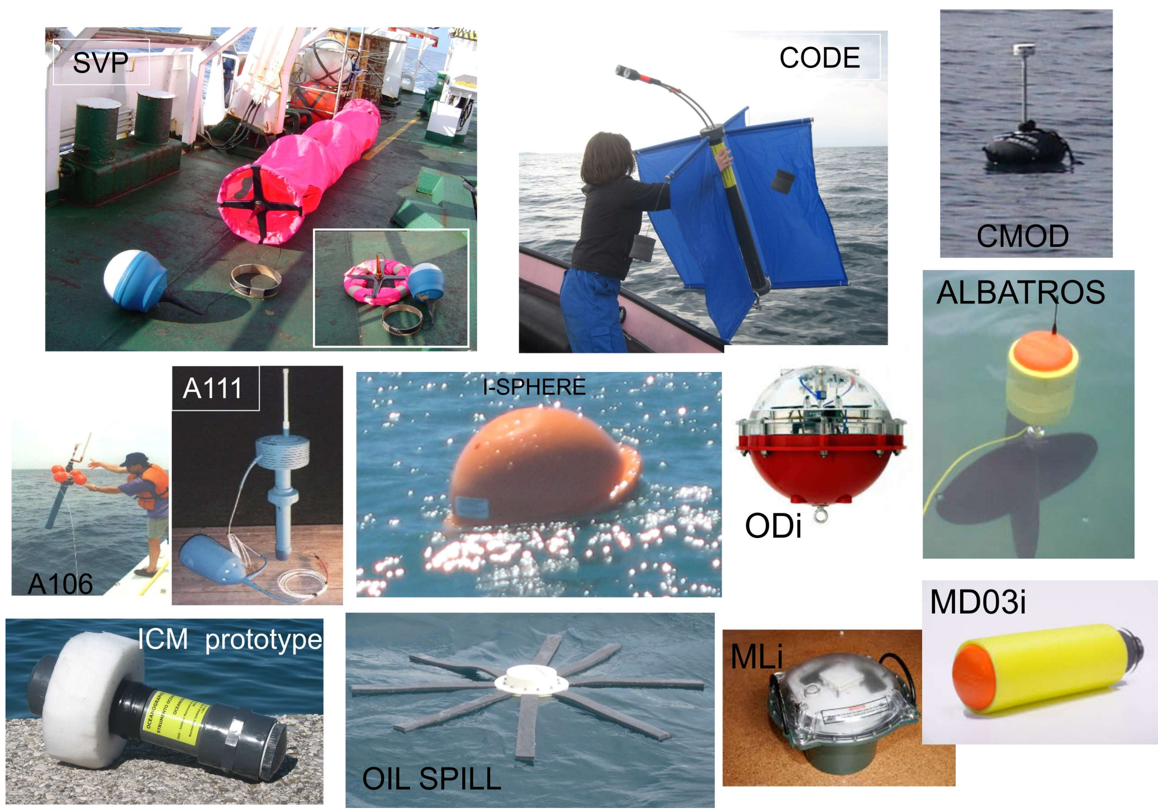

Figure 1. Drifter types deployed in the Mediterranean Sea since 1986.

Depending on the drifter model, the instrument can be localized by two positioning systems: the Argos Data Collection and Location System (DCLS) onboard polar-orbiting satellites and/or with Global Positioning System (GPS). This second method allow to obtain a more accurate (~10 m) and more frequent (hourly or even every 5 minutes) location. Drifter data (sea surface temperature, voltage, drogue presence indicator, etc.) can be transmitted on land through several communication systems: by using radio or satellite links (i.e.: mobile communication, Argos, Iridium or Globalstar).

3. Data processing

3.1 Raw data and raw packet validation

3.1.1 Raw data acquisition

The raw data collection and storage are automatic procedures (preprocessing) executed every morning (or with higher frequency during some experiments). The raw data are downloaded via telnet, ftp o http (shared pages) or received by means of sms (one message per drifter) or by e-mail (multiple drifter per e-mail). Immediately after the data collection, a backup is executed. The file received via e-mail is split in different parts corresponding to different drifters, and saved in files identified by the Argos number (drifter ID) or by the IMEI number (Iridium) and the ESN number (for SPOT devices), whenever the Argos number is lacking.

3.1.2 Database

A PostgreSQL database was chosen to organize and manage the large amount of drifter information and the related decoding and deployment data. This kind of database guarantees good performances and high data security level.

3.1.3 Raw packet validation

The raw data collected by the different kind of drifters have their own peculiarity and need to be processed to obtain files with common characteristics from which the decoding procedure can start. First of all, the exceeding spaces, the spurious characters, such as question marks or different carriage returns (from UNIX standard) are removed. Then, each file is split into parts related only to a specific mission (since a file can include data of different deployments/missions and/or its data can be generated with various decoding).

The deployment information (decoding, time, latitude, longitude and other metadata) are retrieved from the database for each drifter and the integrity of the sent packets is checked (i.e. number of bits, number of blocks, CRC, ...). Incomplete packets are discarded.

3.2 Decoding and Metadata

At the moment, the database includes about 70 different decoding. For each drifter, a dedicated Matlab script interrogates the database and automatically generates a specific Matlab script for its decoding.

In particular, the information derived from the database are:

- decoding type (from 1 to 70);
- a flag which indicates if the code of the packet is decimal or hexadecimal;
- a flag which indicates the necessity to combine a chain of bits from the packet and then to split it;
- the position of the parameters in the packet or in the chain;
- the formula to apply to obtain engineering data (i.e.: SST=(0.08*value)-5.00).

Duplicated packets and packets before the beginning of the mission are eliminated. Packets are then ordered by Argos or Iridium time. In the end, the packets are decoded and saved in Matlab binary files.

Additionally, the scripts which decode the raw data also extract the Metadata of each deployment from the database. These data are then saved in the same output Matlab file.

3.3 Automatic editing

Drifter data are edited to remove spikes generated by malfunction or failure of the sensors (GPS, temperature, Argos localization system).

A specific script for the automatic editing was created to remove location errors (Figures 2, 3, 4 and 5). In particular, the automatic editing replaces the decoded data with NaN (see Gerin and Bussani, 2011 for details) in case of:

- positions outside a specific area (such as the Mediterranean or Black Seas);
- GPS data acquired before the beginning of the experiment;

- duplicated data due to message repetitions or to data introduced manually into the file (as in the case of manual download of packets);
- duplicated GPS position acquired at different times;
- speeds larger than a threshold (150 cm/s for the Argos positions and 300 cm/s for the GPS position; the deployment position is considered good);
- speeds larger than a threshold from a polynomial fit of degree 4 (only for GPS data; fit calculated every 20 points);
- position data collected at wrong time (Figure 5);
- positions on land;
- temperature data lower than 2°C and major than 35°C;
- temperature data which gradient is major than 1/8°C;
- voltage values major than 1V with respect to the linear fit.

The edited data are saved in a new Matlab file together with a QC flag indicating the reason of the discarded data.

Time, position, positioning system (Argos or GPS) and QC flag are automatically incorporated in the database.

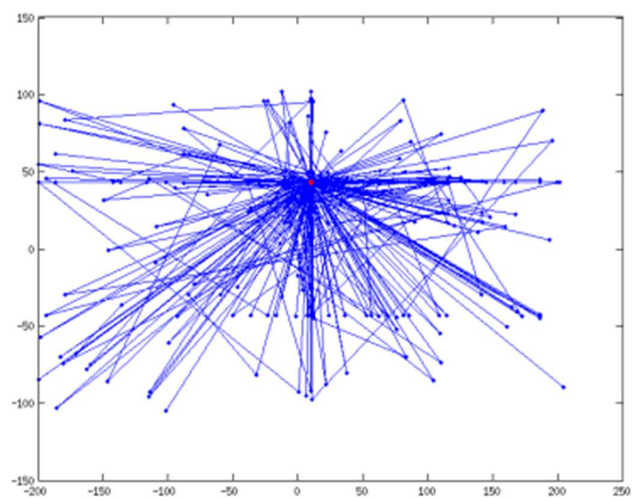

Figure 2: GPS (blue) and Argos positions (red). GPS locations of the first generation of drifters with GPS include strong noise. Coordinates in degrees.

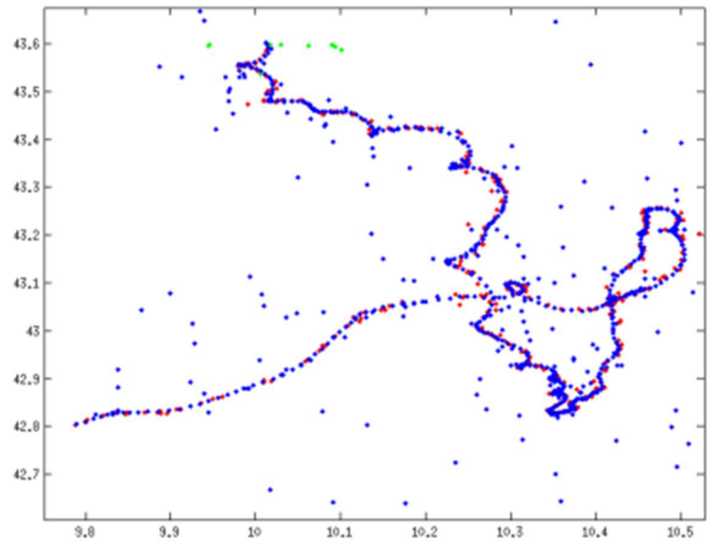

Figure 3: Same as Figure 2 after the first 4 steps of the editing procedure.

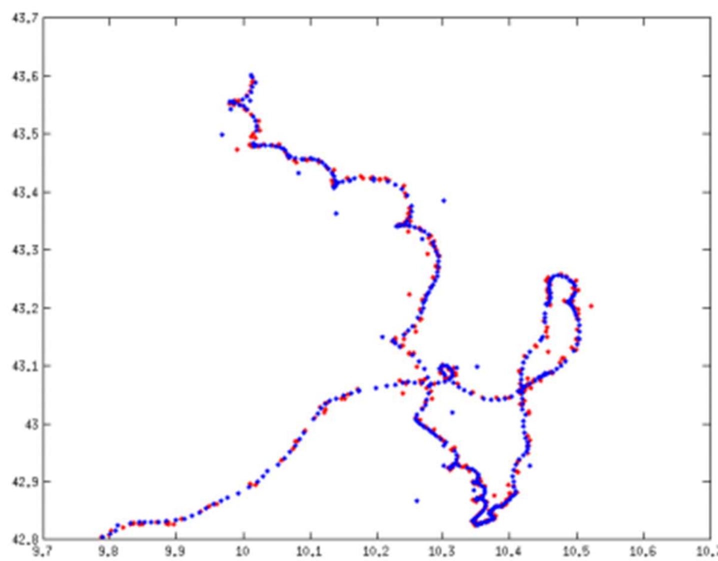

Figure 4: Same as Figure 3 after the removal of the extreme speeds.

3.4 Manual editing and drogue presence

The automatic editing procedure eliminates the majority of the spikes. Nevertheless, some erroneous data require a visual check and the decision of an operator in order to be removed manually. A recurrent case is when there are important temporal gaps or when a drifter has stranded. If the temporal interval between the raw observation exceeds 4 days, the drifter trajectory is split in two parts which are considered as two different deployments. However, for the oldest drifters (1986-1999) this splitting procedure was not applied.

In case of stranding, the automatic editing discards only the data on land and cannot recognizes the exact moment when the drifter goes ashore. As a consequence, the drifter track can depict a star-like shape (Figure 6).

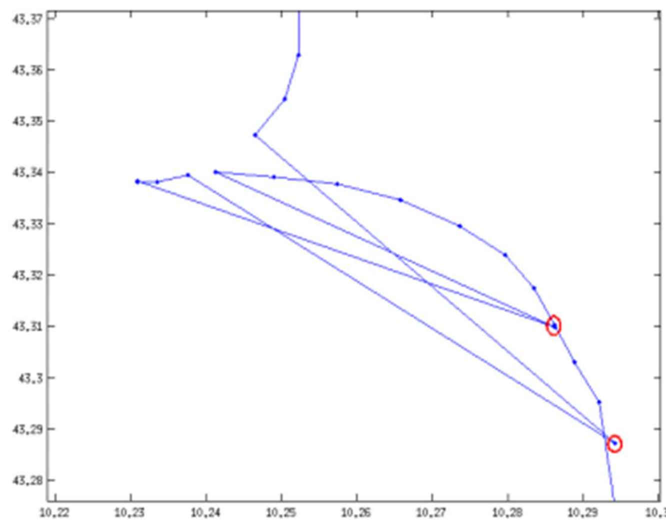

Figure 5: Potential good GPS positions collected at wrong times. These data are discarded by the automatic editing.

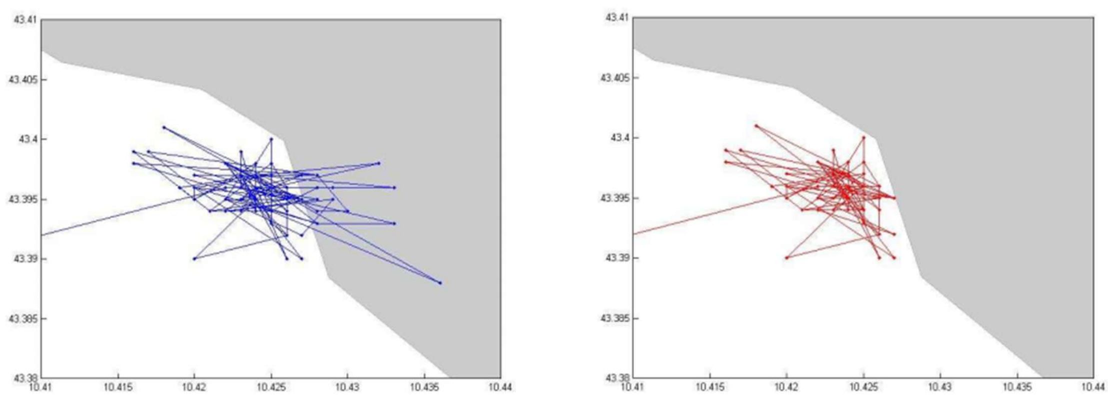

Figure 6: Star-like trajectory depicted by a stranded drifter. Raw data on the left and remaining data after the automatic editing on the right.

The operator has to recognize the time of stranding with the assistance of a dedicated Matlab script. The manual editing procedure does not directly replace the data by NaN after the identified time. Instead, the time of stranding value is saved in a file *_info_manual_editing.mat which is retrieved during the automatic procedure to replace the position data after the identified stranded time with NaNs. This strategy was adopted to have the possibility to discern the automatic edited data from the manual edited data. Additionally, it allows to easily reprocess the data without considering the manual editing procedure simply by removing (or renaming) the *_info_manual_editing.mat file.

The manual editing procedure allows also to evaluate the status of the drogue (presence/absence) for the SVP drifters and, eventually, to visually define the date of drogue lost. The drogue presence is analyzed using two different methods: the SVP drogue detection system (hereafter defined as DDS; see Appendix A for more details) and the correlation between the residual drifters and wind velocities (defined hereafter as CORWIND; see Appendix B for more details).

Drogue presence information is saved in the drifter metadata and in particular as three parameters (flag_lost_drogue, lost_drogue_time, lost_drogue_wind) detailed in Appendix C.

3.5 Interpolation

Edited data of position, temperature, voltage and drogue presence are then interpolated at 30 minute uniform intervals using a kriging optimal interpolation method (Hansen and Poulain, 1996). More details about the interpolation method are given in Appendix D. The velocities are then calculated as finite differences of the interpolated position.

Data are finally subsampled at 1, 2, 3 and 6 h and the 2-h subsampled data are low-pass filtered with a hamming filter with cut-off period at 36 h, in order to eliminate tidal and inertial variability, and then they are subsampled every 6 hours. All the data at 30 minutes, 1, 2, 3, 6 h and the 6-h filtered data are then saved in dedicated folders as Matlab files.

4. Collection of additional drifter data

Drifter data were retrieved not only from the OGS own projects but also from the databases collected by other research institutions and by international data centers. In this context, the main effort of the MAOS-OGS drifter team is to retrieve a data version as raw as possible, in order to apply to all the data the same processing. The most important sources are:

- Global Drifter Program (GDP): is a branch of the NOAA's Global Ocean Observing System and maintains, since 1980, a global array of 5°x5° SVP drifting buoys to meet the need for an accurate and globally dense set of in-situ observations of mixed layer currents. The drifter data are processed and archived by the NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML). Generally, GDP data are available in 6-hourly interpolated format at the web-page http://www.aoml.noaa.gov/phod/dac/dacdata.php. These products are too much 'refined' for the purposes of the OGS Mediterranean drifter database, therefore the OGS-MAOS team have requested and obtained the possibility to download the raw data from GDP for the Mediterranean area using an ftp procedure.
- SOCIB: is a multi-platform distributed and integrated system, located in the Balearic Islands, that provides streams of oceanographic data and modeling services to support operational oceanography in a European and international framework (http://www.socib.es/?seccion=home). SOCIB maintains a sustained drifter program, in the framework of the GDP, consisting on periodic deployments of SVP platforms to attend scientific needs. Drifter available files are downloaded via ftp from SOCIB database in NetCDF format; an automated procedure controls every day the eventual presence of new drifters and, sends an email report to the MAOS-OGS team. In this way, the new SOCIB drifter data can be added automatically in near real time to the OGS Mediterranean drifter database.
- CORIOLIS: is a system for operational oceanography developed in France with the contribution of seven research institutes. Two of these institutes (Ifremer and Shom) share their drifter data in delayed time on the CORIOLIS web-portal, where the raw data can be downloaded in Excel tables after an authorized authentication.

All these data, obtained from various sources, were processed with the techniques illustrated in Section 3.

5. Database Statistics

In this Section we show some statistics on the OGS MedSVP_db24 drifter database related to drifter types and telemetry and to the results the SVP DDS analysis; temperature data are not considered in this context.

The interpolated and low-pass filtered tracks of the OGS MedSVP_db24 drifter database in the period 1986-2016 are depicted in Figure 7. It can be seen that CODE drifters mostly cover the Adriatic, northern Ionian, Sicily Channel, Tyrrhenian and Liguro-Provençal sub-basins, whereas the SVP units dominate in the Eastern Mediterranean, in the Aegean and in the Liguro-Provençal sub-basins. CMOD drifter are found in both the eastern and western Mediterranean basins, but they were operated only in the years previous to 2000 (see Figure 8 left panel). Drifters A106/A111 (17 units, see Table 1) provided data mainly in the southern Algerian sub-basin during the period 1996-1997 (see Figure 8).

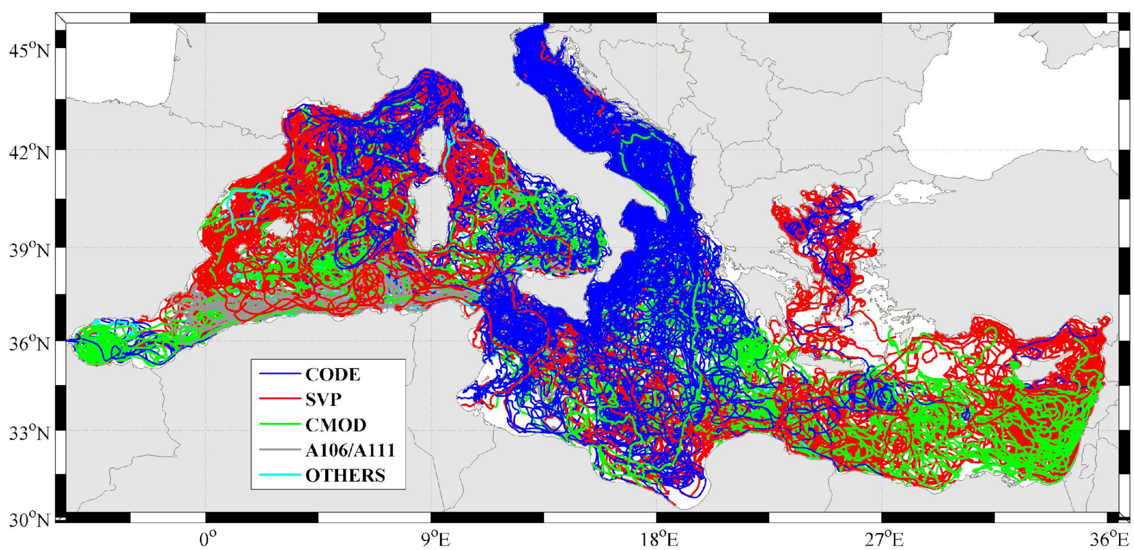

Figure 7. Composite diagram of the interpolated (6h) and low-pass filtered drifter tracks in the OGS Mediterranean dataset in the period 1986-2016. Different colors correspond to different drifter types.

The quantity of drifters corresponding to the different types as well as ancillary information about the drifter lifetimes are summarized in Table 1. The temporal distribution of drifter data is intermittent (Figure 8 left panel). The larger number of drifter were operated in 2003 (217 units) and in 2012 (187 units). A huge number of SVP drifters were employed in the Mediterranean Sea since 2002. The different drogue depths of the SVPs collected in MedSVP_db24 are shown in Figure 8 (right panel);

the standard and most common drogue depth is 15 m (470 units). The maximum operating life is observed for the SVPs (about 600 days), followed by CODEs (about 350 days; Table 1; Figure 9); the larger mean half-life is detected for the SVPs (54 days) with respect to 35 days for the CODEs.

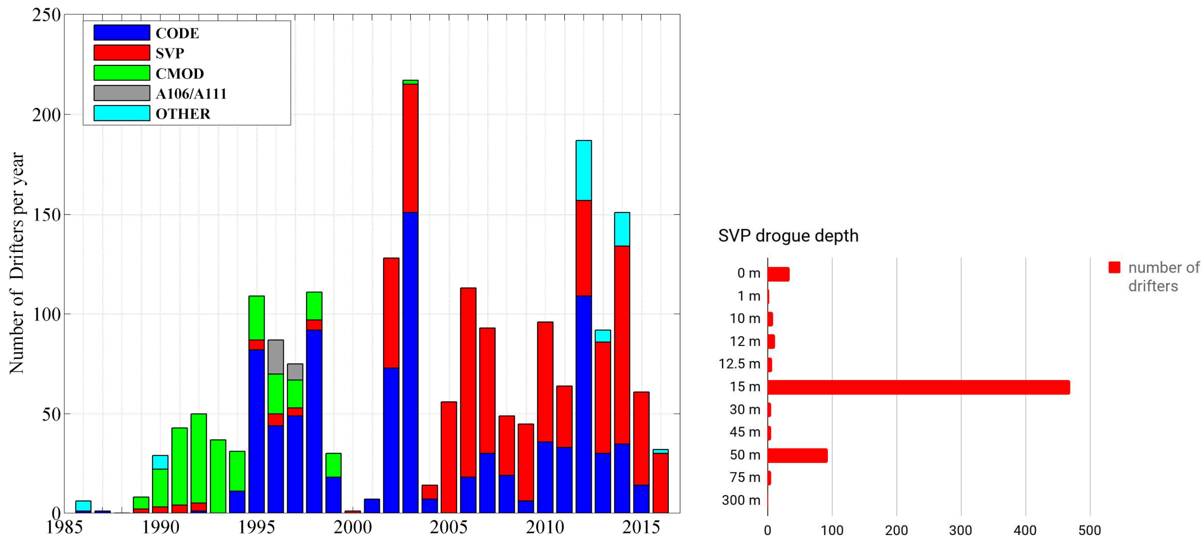

Figure 8. Temporal distribution of the Mediterranean OGS dataset (number of drifters per year), spanning 1986-2016 (left panel); different colors correspond to different drifter types. Drogue depth of the SVP drifters (right panel).

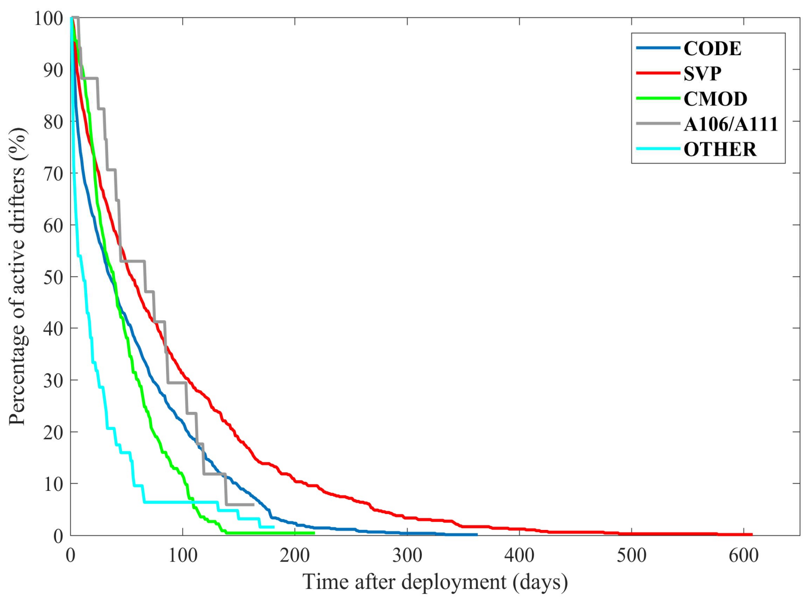

Figure 9. Survival rate for Mediterranean OGS dataset sorted by drifter types.

The majority of Mediterranean drifters uses Argos satellite telemetry (Figure 10); the Iridium telemetry was introduced in 2010 and has been employed more frequently in the successive years. The different positioning systems employed in the Mediterranean Sea are summarized in Figure 11: Argos positioning was used before 2000; since 2001 some drifter units were ‘also equipped’ or ‘only equipped’ with GPS receivers to obtain more accurate and more frequent positions (see Section 2).

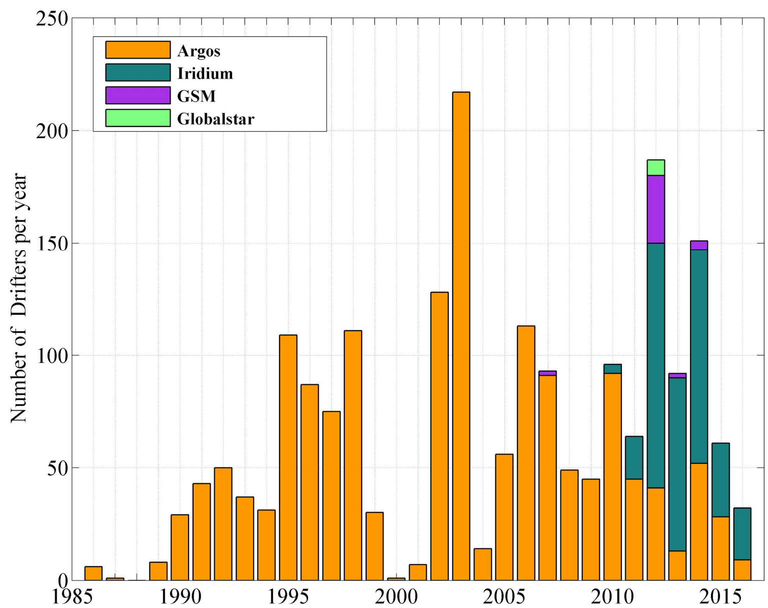

Figure 10. Temporal distribution of the Mediterranean OGS dataset (number of drifters per year), spanning 1986-2016. Colors correspond to different telemetry systems.

5.1. Drogue presence statistics

The Mediterranean SVP drifter dataset in the period 1986-2016 is composed of 534 instruments equipped with the drogue centered at depth <= 15m depth (Figure 12). Colors indicate the drifter tracks of the three different categories based on the information derived from the DDS (for more details see Appendix A): 231 instruments keep the drogue attached during all their life (defined hereafter as ‘drogued’ drifters; red tracks in Figure 12) and represent 43.3% of the dataset (Figure 13a); 131 instruments have lost the drogue during their life (defined hereafter as LOST-DROGUE), they lived a first part of their life with the drogue (red tracks) and a second part without the drogue (defined hereafter as 'undrogued'; blue tracks in Figure 12); these LOST-DROGUE drifters constitute 24.5% of the dataset (Figure 13a); 172 instruments for which no drogue information is available (defined hereafter as 'NO-DROGUE-INFO'; green tracks in Figure 12) represent 32.2% of the dataset (Figure 13a). Therefore, using only the information derived from SVP DDS the drogue status is unknown for 32% of the dataset (for more details see Appendix B). In order to retrieve a part of these data and to check the accuracy of the DDS, a simple methodology, suggested by Rio (2012), was used to extract the residual currents from drifters and to correlate these currents with the wind velocities (CORWIND statistics; Appendix B).

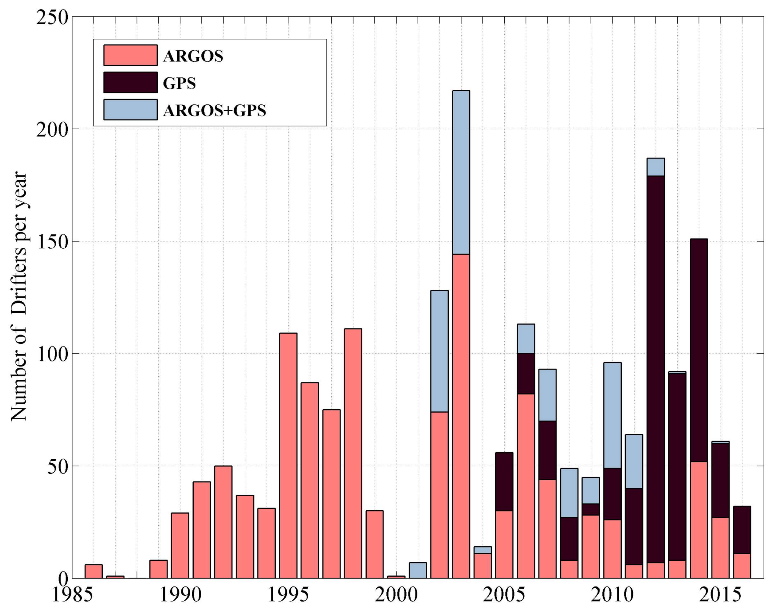

Figure 11. Temporal distribution of the Mediterranean OGS dataset (number of drifters per year), spanning 1986-2016. Colors correspond to different drifter positioning systems.

CORWIND can be estimated for 319 instruments of which: 202 instruments keep the drogue attached during all their life and represent 37.8% of the dataset (Figure 13b); 117 instruments have lost the drogue during their life and constitute 21.9% of the dataset (Figure 13b); the remaining 40.3% still has no information on the drogue status because of the short lifetime of the drifters (drifters with less than 25 days of data were excluded from the calculation; for more details see Appendix B) or the temporal limit of the wind database (available until May 2016).

The combined use of the DDS and CORWIND allows to reduce the number of unknown drifters from 32.2% (Figure 13a) to 20% (Figure 13c).

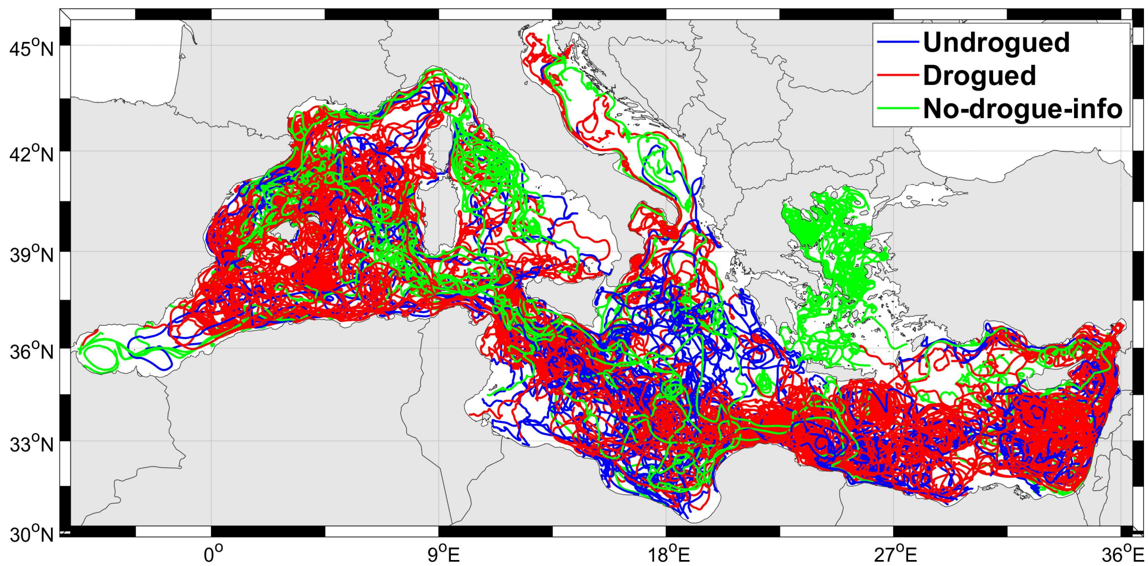

Figure 12. SVP drifter (holey sock drogue centered at depths <= 15 m depth) tracks in the Mediterranean Sea in the period 1986-2016.

If we look at similar statistics in terms of number of observations (Figure 14), we can conclude that CORWIND allows to reduce the number of unknown observations from 17.7% (27628 observations; Figure 14a) to 2.1% (3359 observations; Figure 14b). In other words, 88% of the data for which the drogue status is unknown has been now classified as either drogued or undrogued drifter data.

Figure 13d summarizes the drogue presence information available for the entire MedSVP_db24 SVP drifter database.

CORWIND was also used to check the results of the SVP drogue detection system for the instruments analyzed with both methods (254 instruments; 47.6% of the total in Figure 15). Among all these drifters analyzed both by DDS and CORWIND, 66.5% of the drifters are drogued according to both methods, 28.3% have a lost drogue date equal for both the methods and only 5.1% have a different lost drogue date. The time difference between DDS and CORWIND for this 5.1% (Figure 16) shows that the dates defined by CORWIND generally precede those defined by DDS, except in one case, when the CORRWIND data exceeds 7 days the DDS date. From these statistics we can conclude that the SVP drogue detection system in the Mediterranean Sea provides correct information in the 94.8% of the cases analyzed.

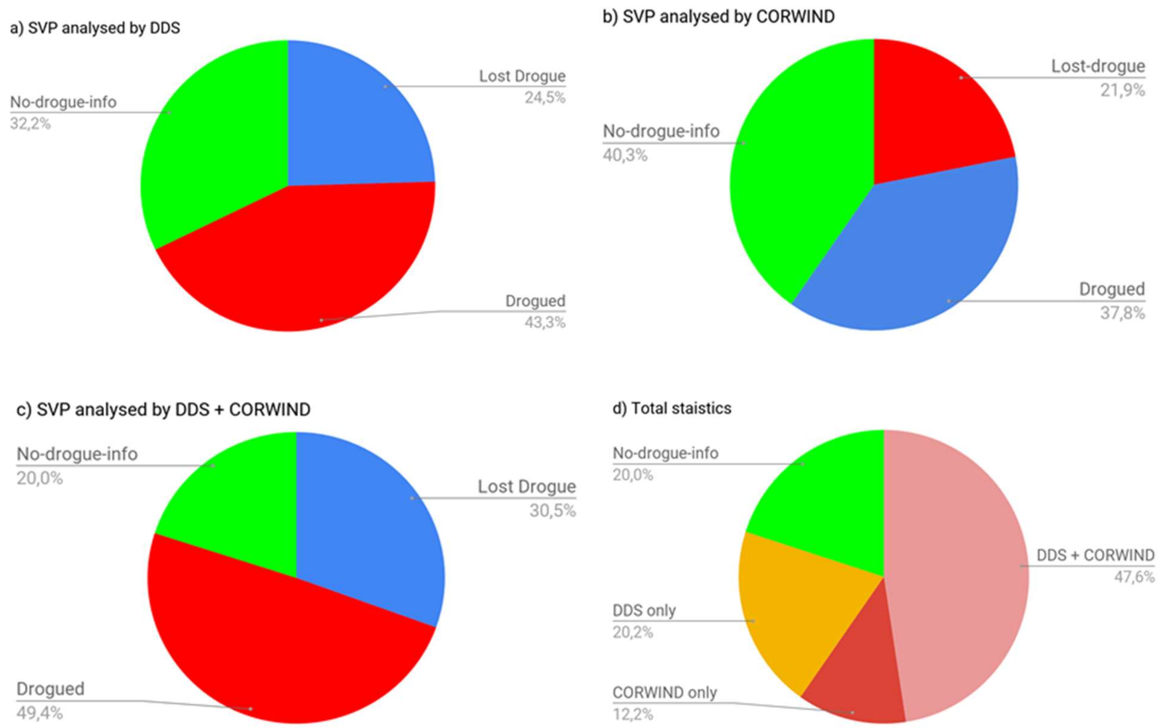

Figure 13. Cake diagrams of the SVP dataset based on the number of instruments Drogued, Lost Drogue and NO-DROGUE-INFO, analyzed by DDS only (a), by CORWIND only (b) and analyzed using together DDS and CORWIND results (c); summary of the number of drifters analyzed (or not analyzed) by DDS and CORWIND .

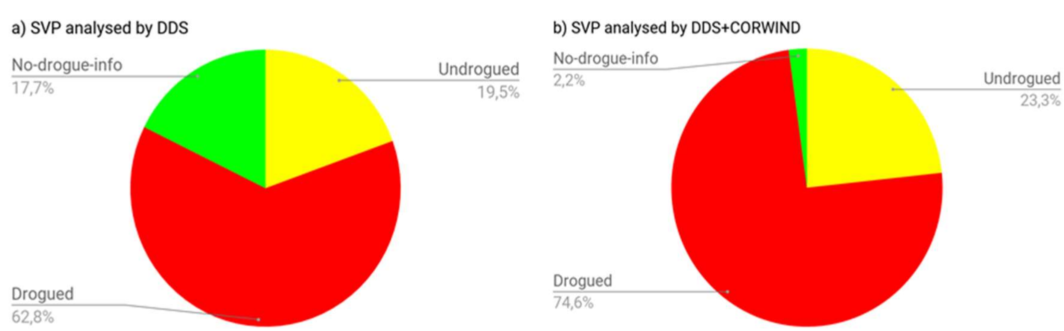

Figure 14. Cake diagrams of the SVP dataset (number of observations) analyzed only by DDS (a) and analyzed by DDS and CORWIND (b).

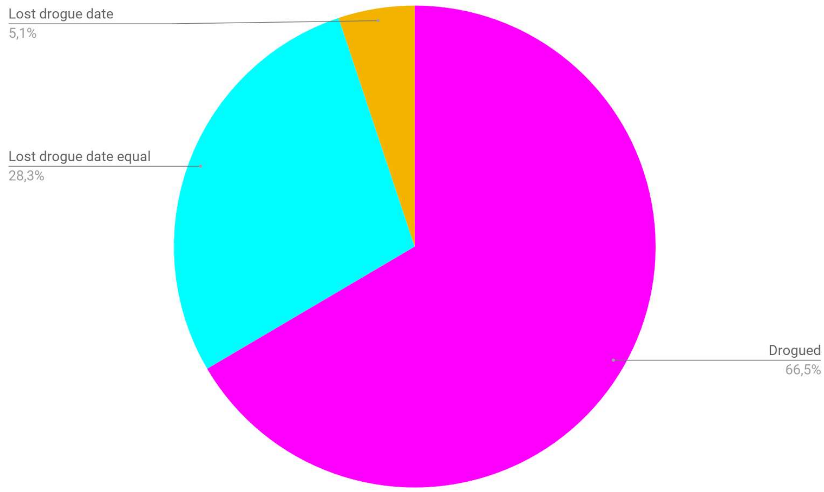

Figure 15. Cake diagrams of the SVP instruments analyzed both from DDS and CORWIND.

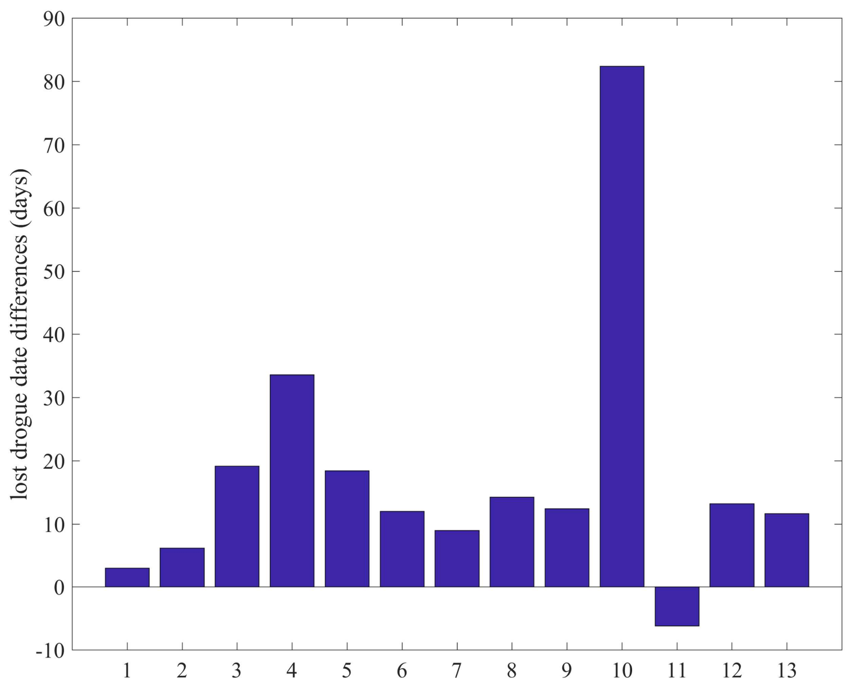

Figure 16. Time differences between the lost drogue date defined by CORWIND and that defined by DDS.

6. Scientific applications

The estimation of accurate ocean surface currents is crucial for a wide and growing range of applications – offshore industry, search and rescue, oil spill monitoring, etc..- (Rio et al., 2014a). In this context, the OGS Mediterranean drifter dataset has been used in recent years for several scientific applications:

- in the framework of the Globcurrent project (http://www.globcurrent.org/), to obtain an estimate of the Ekman currents, in the Mediterranean Sea; the results of the Globcurrent Ekman model were compared with those obtained from the OGS Ekman model described in Poulain et al. (2012);
- to estimate the Mean Dynamic Topography (MDT) of the Mediterranean Sea currently available to the oceanographic community (Rio et al., 2014b). The MDT is the missing component needed to reconstruct the full dynamical signal from the altimetry data;
- to derive tidal currents throughout the Mediterranean Sea (Poulain et al., 2017);
- to assess the amplitude of Stokes drift in the motion of drifters in the Mediterranean (Prigent et al., 2017).

Appendix A: SVP drogue detection system

SVP drifters (Figure A1) which have lost their drogues can be identified using the SVP DDS. In the first version of SVP drifter model (Sybrandy and Niiler, 1991) the drogue loss was detected by a change in the immersion behavior of the surface float through the use of a surface float submergence sensor. For more recent buoys, this was replaced by a tension sensor, located below the surface buoy where the drogue tether is attached, which indicates the presence or absence of the drogue (Poulain et al., 2012). When the drogue is attached, the wind slip is ~ 0.1% of the wind speed for winds up to 10 m/s; when it is lost, slip increases to ~1% of the wind speed, according to Pazan and Niiler (2001), and ~3% according to Rio (2012).

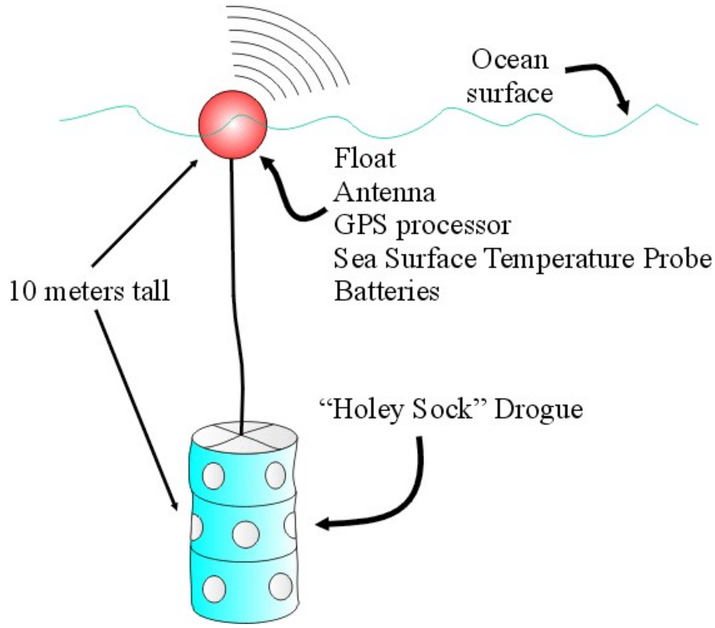

Figure A1: Schematic representation of an SVP drifter.

The determination of drogue presence cannot be done with an automatic procedure, because the DDS data assume distinct values and different meanings depending on the drifter manufacturer and on the year of production. Some examples of the information obtained from the DDS are given in Figure A2: e.g. Figure A2a shows a drifter with the drogue on; Figure A2b shows an example of a malfunctioned DDS from which it is impossible to decide if the drifter lost its drogue and when. The most common characteristic for DDS is that the loss of drogue causes a discontinuity (sharp drop or rise) in the time series of DDS values (as in Figure A2c). The evaluation of DDS time series is carried out during the manual editing procedure, when an operator visually checks each SVP separately and eventually selects the date of drogue loss.

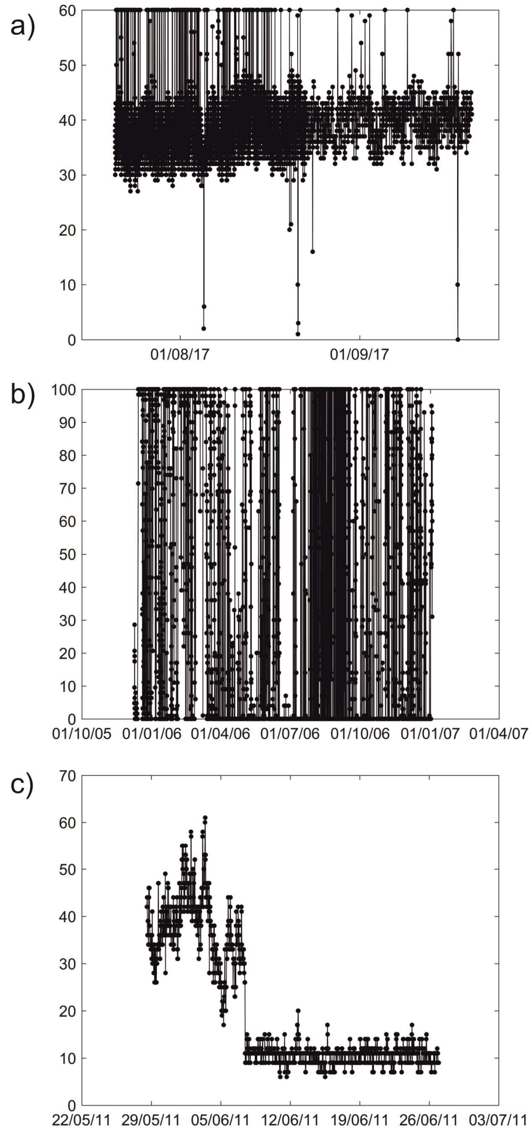

Figure A2. Drogue sensors time series for a drifter drogued (a), a malfunctioned sensor (b), and a drifter that lost its drogue (c).

Appendix B: Detecting the drogue presence from wind slippage

The OGS MedSVP_db24 drifter database is composed of a significant number of drifters without clear information about the drogue presence (32% of the dataset; see Figure 13a). The main reasons of this lack of information are the malfunctioning of the DDS or the unavailability of details about the drogue presence in the metadata. Furthermore, recent studies have documented the possible failure of the SVP DDS (Grodsky et al., 2011; Rio, 2012; Lumpkin et al, 2013). As a consequence, a large number of undrogued buoys can "contaminate" the dataset of the drogue-on SVP. In order to retrieve the drogue presence information about drifters with un unknown drogue status and to check the accuracy and/or the potential failure of the DDS, we applied the method described in Rio (2012). This method uses altimetry and wind products to extract the direct wind slippage from the drifter velocities. The altimetry data used in this study are the gridded (1/8º Mercator projection grid) Ssalto/Duacs daily, two-satellite, delayed time product from AVISO, available since 1993. The wind data used are the new Cross-Calibrated, Multi-Platform (CCMP) V2.0 ocean surface wind velocity products available from Remote Sensing Systems for the period July 1987 – May 2016.

The current measured by a drifter ($\boldsymbol{u_{dr}}$) is given by the sum of various contributions, including the geostrophic currents ($\boldsymbol{u_g}$), the Ekman currents ($\boldsymbol{u_e}$), the wind generated slip ($\boldsymbol{u_s}$) and a number of other ageostrophic currents ($\boldsymbol{u_a}$) associated with the internal oscillations, tide currents, Stokes drift, internal ocean dynamics, etc. The sum of the Ekman and slip velocities is defined as the wind-driven component ($\boldsymbol{u_{wind\text{-}driven}} = \boldsymbol{ue} + \boldsymbol{u_s}$) and it is estimated using a simple regression model already used in in Poulain et al. (2012). The $u_{residual}$ drifter component along each single trajectory was estimated by removing from the drifter velocities both the geostrophic velocity (u_g), derived from altimeter, and the wind-driven velocity ($u_{wind\text{-}driven}$):

$$\boldsymbol{u_{residual} = u_{dr} - u_{wind\text{-}driven} - u_g}$$

Residual velocities from drifters with the drogue attached are expected to be poorly correlated with the wind, while residual velocities from undrogued drifters includes the wind slippage and are expected to show a significant correlation with the wind. The cross-correlation (Kundu, 1976) between the residual drifter and the wind velocities was computed using a 100-point window and, when the length of the drifter vector allows it, in addition to 100-point window, the cross-correlation was also computed with 200 and 300 point windows. Some examples of the CORWIND results are shown in Figures B1 and B2. According to the DDS time series (Figure B1a), drifter 33023401068380 kept its drogue for all its life. On the contrary, CORWIND increases significantly (Figure B1b) and the correlation angle (direction between the wind and the residual drifter velocities; Figure B1c) gets close to 0° on 8 January 2012 (vertical dashed line in Figures B1b, c), suggesting that this drifter lost its drogue on that date. In this situation CORWIND helps us to correct the DDS data. In the second example (Figure B2), according to the DDS, the drifter 330234011045330 is drogued until 26 November 2013 (black vertical solid line), but CORWIND increases and the direction decreases to 0° about a month before (23 October, see black vertical dashed line in Figures B2b, c), suggesting to modify the DDS time of drogue loss.

The determination of CORWIND and the related correlation angle for the MedSVP_db24 database considerably help to retrieve essential information on the drogue presence. Detailed statistics are presented in Section 5.

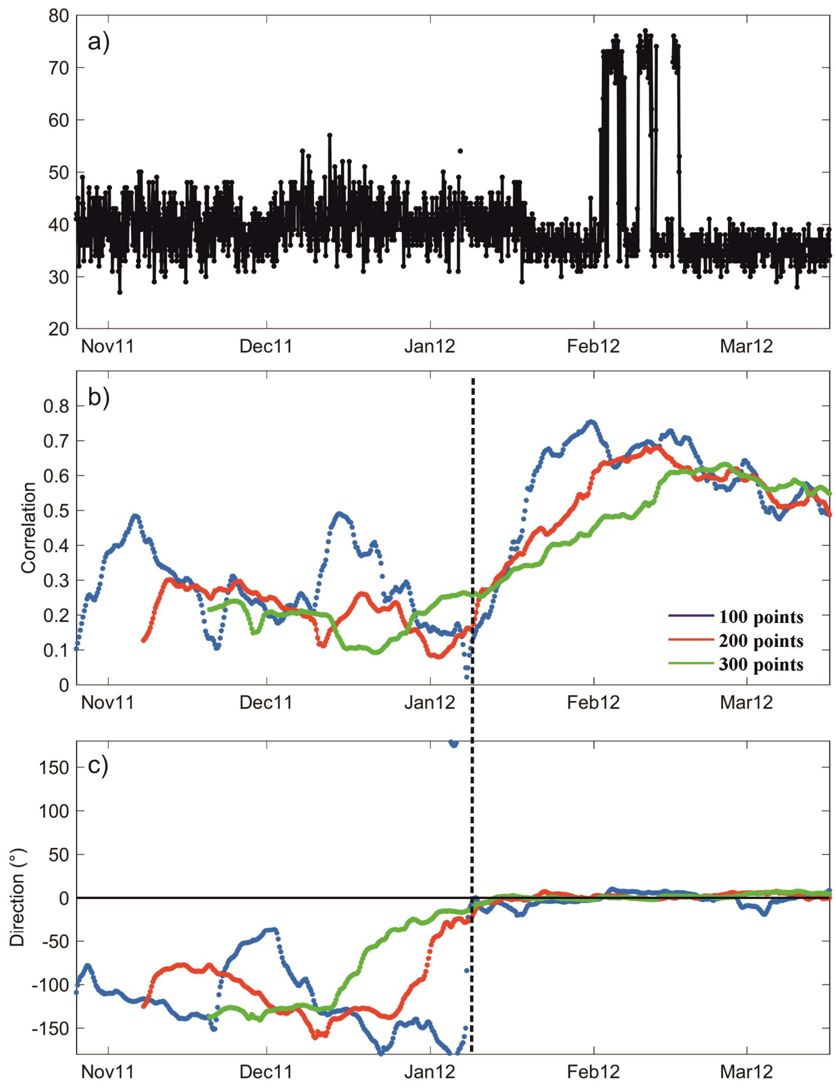

Figure B1. Drogue sensors time series (a), correlation coefficient (b) and correlation angle (c) for the drifter 33023401068380. The complex correlation is computed for 100 (blue) 200 (red) and 300 (green) point windows.

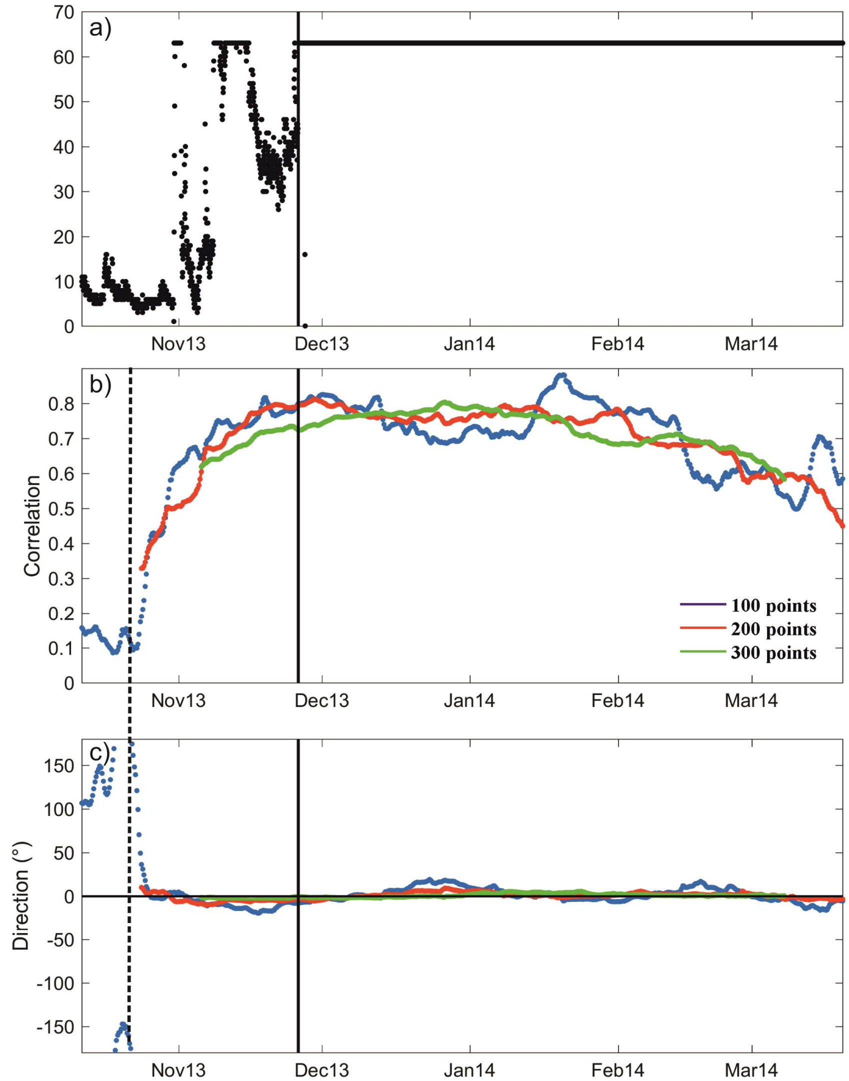

Figure B2. Drogue sensors time series (a), correlation coefficient (b) and correlation angle (c) for the drifter 330234011045330. The complex correlation is computed for 100 (blue) 200 (red) and 300 (green) point windows.

Appendix C: The parameter flag_lost_drogue

The drogue presence information derived from DDS and from CORWIND are currently summarized in the Metadata of the MedSVP_db24 database, where for each SVP drifter there is a flag expressed in binary code that describes the drogue presence. The lost drogue dates derived both from the sensor (lost_drogue_time) and from the wind correlation (lost_drogue_time_wind) are recorded.

The parameter flag_lost_drogue is expressed in binary code and the eight positions, from left to right, specify:

1: N/C

2: N/C

3: 1 means analyzed by CORWIND;

4: 1 means that the drifter has lost the drogue according to CORWIND;

5: 1 means checkable by DDS;

6: 1 means analyzed by an OGS operator

7: 1 means that the drifter lost the drogue according to DDS;

8: 1 means checked by AOML;

Some examples of the parameter flag_lost_drogue are reported hereafter. First, we describe the flag for a drifter analyzed by DDS only:

- Drogue on: flag_lost_drogue=00001101 or flag_lost_drogue=00001100

the drogue presence is checkable (1 in the fifth position) then the DDS worked and gave right information; the drogue presence was checked by OGS (1 in the sixth position) then the drifter was processed with the manual editing procedure described in Section 3.4; the drogue is on (0 in the seventh position); the drogue presence is also available on the AOML system (1 in the eighth position) or not (0 in the eighth position). The parameter lost_drogue_time is empty.

- Drogue off: flag_lost_drogue=00001111 or flag_lost_drogue=00001110

the drogue presence is checkable (1 in the fifth position); the drogue presence was checked by OGS (1 in the sixth position); the drifter lost its drogue (1 in the seventh position); the drogue presence is also available on the AOML system (1 in the eighth position) or not (0 in the eighth position). The parameter lost_drogue_time contains the date of drogue lost; in this situation the drifter is defined as 'drogued' in the time period between the deployment date and the date of drogue lost, whereas it is defined as 'undrogued' for time periods consecutive to the drogue lost date.

- No drogue information: flag_lost_drogue=00000100

the drogue presence is not checkable (0 in the fifth position) then the DDS information are not available; the drifter was analyzed by OGS (1 in the sixth position) and the manual editing procedure detected the lack of drogue presence information; the seventh position is not applicable (0 in the seventh position); the eighth position is not applicable (0 in the eighth position). The parameter lost_drogue_time is empty.

Second, we describe the flag for a drifter analyzed by CORWIND only:

- Drogue on: flag_lost_drogue=00100100

the drogue presence is checkable by CORWIND (1 in the third position) then the wind data are concurrent with drifter data and the complex correlation can be computed; the drogue presence was checked by OGS (1 in the sixth position) but the DDS doesn't give information (0 in the fifth position); the drogue is on according to CORWIND (0 in the fourth position); the drogue presence is also available on the AOML system (1 in the eighth position) or not (0 in the eighth position). The parameters lost_drogue_time and lost_drogue_time_wind are empty.

- Drogue off: flag_lost_drogue=00110100

the drogue presence is checkable by CORWIND (1 in the third position); the drogue presence was checked by OGS (1 in the sixth position) but the DDS doesn't give information (0 in the fifth position); the drifter lost its drogue (1 in the fourth position). The parameter lost_drogue_time_wind contains the drogue lost date; in this situation the drifter is defined as 'drogued' in the time period between the deployment date and the drogue lost date, whereas it is defined as 'undrogued' for time periods consecutive to the drogue lost date.

- No drogue information: flag_lost_drogue=00000100

the drogue presence is not checkable by CORWIND (0 in the third position); the drifter was analyzed by OGS (1 in the sixth position) the manual editing procedure detected the lack of drogue presence information. parameters lost_drogue_time and lost_drogue_time_wind are empty.

Third, we describe the flag for a drifter analyzed by DDS and by CORWIND:

- Drogue on for both DDS and CORWIND: flag_lost_drogue=00101101 or flag_lost_drogue=00101100

the drogue presence is checkable by CORWIND (1 in the third position) and by DDS (1 in the fifth position); the drogue presence was checked by OGS (1 in the sixth position) then the drifter was processed with the manual editing procedure described in the Section 3.4; the drogue is on according to CORWIND (0 in the fourth position) and according to DDS (0 in the seventh position); the drogue presence is also available on the AOML system (1 in the eighth position) or not (0 in the eighth position). The parameters lost_drogue_time and lost_drogue_time_wind are empty.

- Drogue off for both DDS and CORWIND: flag_lost_drogue=00111111 or flag_lost_drogue=00111110

the drogue presence is checkable by CORWIND (1 in the third position) and by DDS (1 in the fifth position); the drogue presence was checked by OGS (1 in the sixth position); the drifter lost its drogue according to CORWIND (1 in the fourth position) and according to DDS (1 in the seventh position); the drogue presence is also available on the AOML system (1 in the eighth position) or not (0 in the eighth position). The parameters lost_drogue_time and lost_drogue_time_wind contain the drogue lost date; in this situation the drifter is defined as 'drogued' in the time period between the deployment date and the drogue lost date, whereas it is defined as 'undrogued' for time periods consecutive to the drogue lost date. The dates lost drogue estimated by DDS and by CORWIND can coincide or can be different; in the second case the users can decide which date use for their estimations.

- No SVP: flag_lost_drogue=NaN

When the type of drifter analyzed is different form SVP, the parameter flag_lost_drogue is not applicable.

Appendix D: Interpolation of the drifter positions

The kriging method is an optimum interpolation technique based on the correlation of the data. The interpolated value is the weighted mean of the neighboring observed values (Hansen and Poulain, 1996). The weights are determined by minimizing the mean square difference between the true values at the interpolated times and their estimates. In practice, the method is based on the Structure Function (SF), which is defined as

$$S_{ij} = ½ < (x_i - x_j)^2 >,$$

where x_i and x_j are the observations of the same drifter at time t_i and t_j, and $< >$ is an ensemble or time average.

Empirical values of the SF were estimated from the observations themselves. Using the MedSVP_db24 dataset (1912 edited files), we estimated the SF for latitude (Figure D1) and longitude (Figure D2) for the Argos and GPS positions separately.

The SF is generally smaller for latitude compared to longitude. There are two main reasons for that: 1) at the latitudes of the Mediterranean Sea, a degree of longitude corresponds to a smaller distance than a degree of latitude, and 2) for large time there might be some saturation in the dispersion due to the fact that the Mediterranean basin has a smaller meridional extension. For small time lags (< 10 h) the SF is essentially quadratic, whereas for long time lags (>50 h) it becomes linear with time. The difference between the Argos and GPS curves is due to the different times and locations sampled by the Argos and GPS drifters. Indeed, if we restrict our analysis to the drifters with both Argos and GPS (133 tracks, out of a total of 1912), the SF results for the Argos and GPS positions are very similar (Figures D3 and D4).

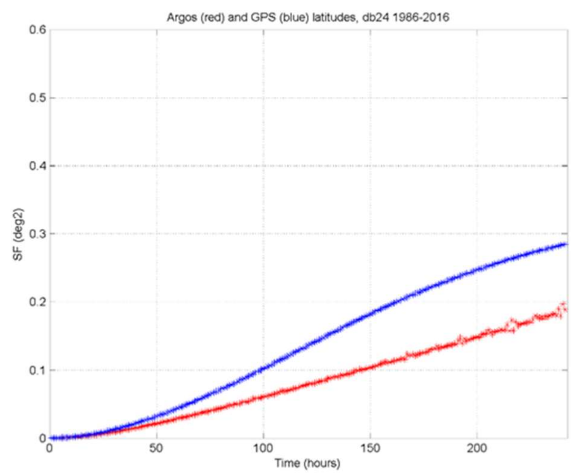

Figure D1. Structure function versus time for the drifter Argos and GPS latitudes.

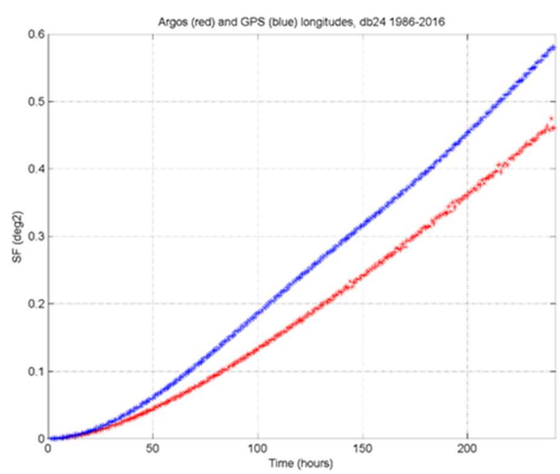

Figure D2. Same as Figure D1 but for longitudes.

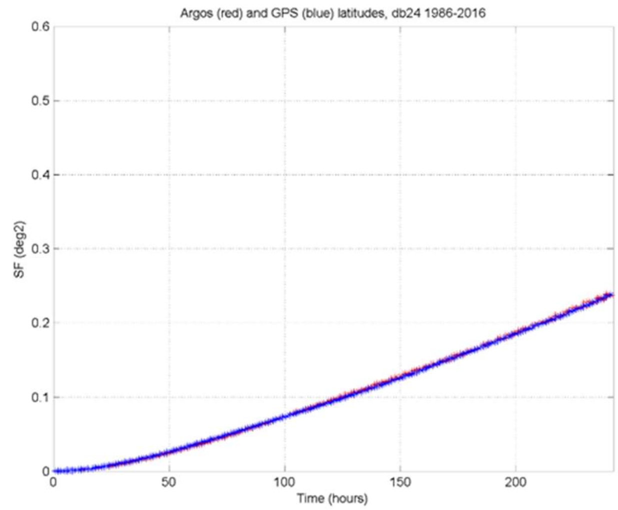

Figure D3. Structure function computed with the latitude data of drifters with both Argos and GPS positions.

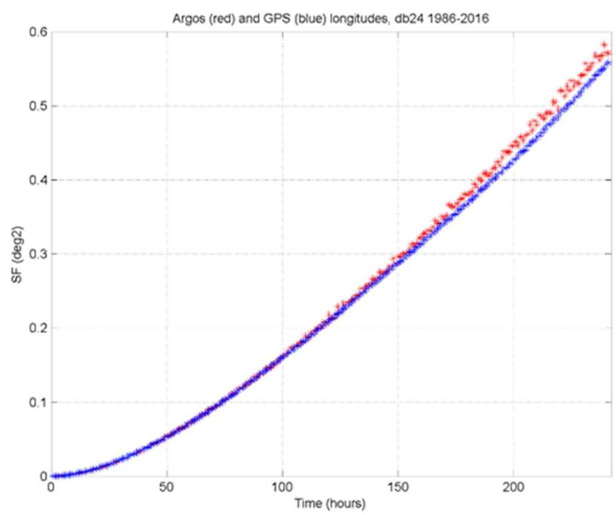

Figure D4. Same as Figure D3 but for longitudes.

We decided therefore to estimate the SF using all the pairs of Argos positions and all the pairs of GPS positions, combined. The results are depicted for time lags as large as 10 days in Figure D5. It should be noted that the most important part of the SF corresponds to time lags smaller than a few days because interpolation over longer periods was avoided by splitting the drifter trajectories when data gaps longer than 4 days occurred. The SF for latitude and longitude corresponding to time lags bounded by 3 and 2 days are depicted in Figures D6 and D7, respectively.

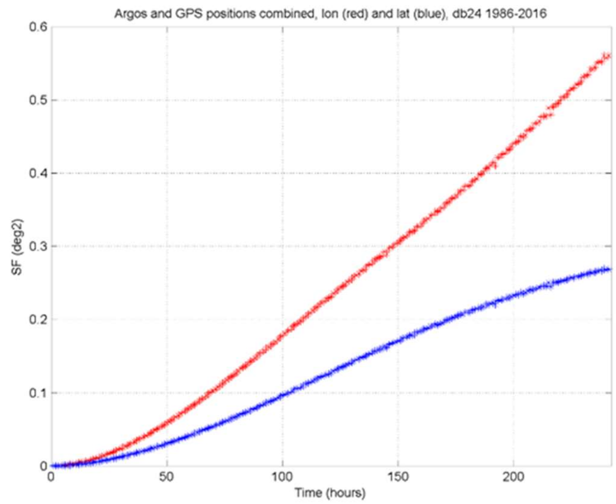

Figure D5. Structure function versus time for the drifter positions using combined Argos and GPS pairs.

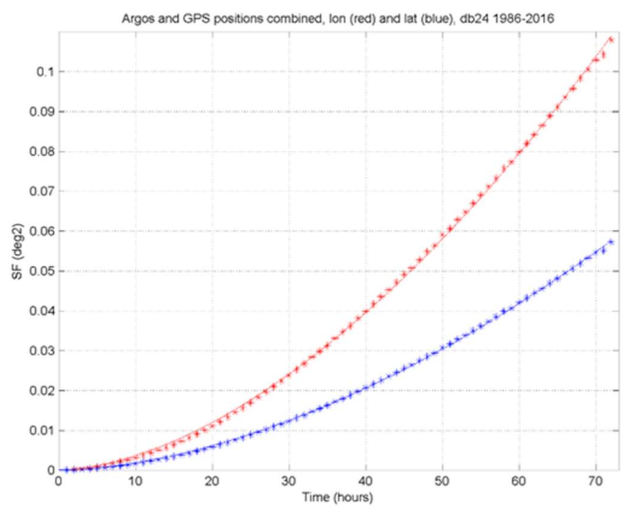

Figure D6. Structure function versus time for the drifter positions using combined Argos and GPS pairs for lags up to 3 days. Solid curves indicate the analytical functions obtained by least squares fit.

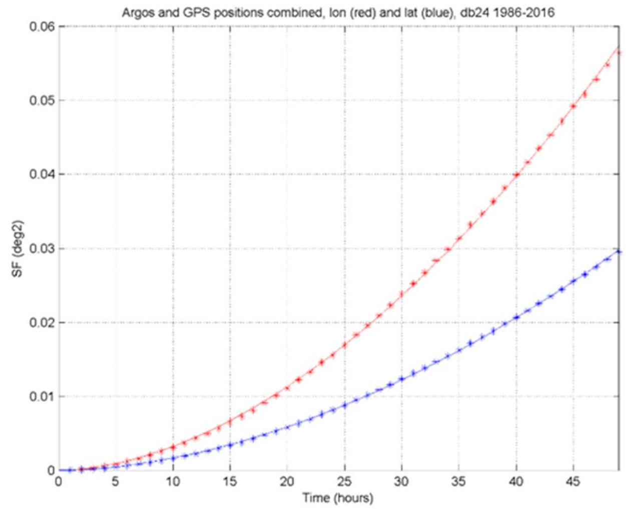

Figure D7. Same as Figure D6 but for time lags up to 2 days.

Since the kriging method requires the knowledge of the SF at all possible time lags needed for the interpolation, we must fit analytical functions to the empirical curves shown in Figures D6 and D7. Following Hansen and Poulain (1996) we fitted the following model to the data:

$$S(\tau)= \alpha\, \tau^{\beta},$$

in which τ denotes time and α and β are parameters to be determined by least squares fit. Using the Matlab function *fit.m* we obtained the solid curves depicted in Figures D6 and D7 and the coefficients listed in Table D1.

Table D1. Coefficients of the analytical SF obtained by least squares fit considering the empirical SF up to 2 and 3 days.

	α		β	
	2 days	3 days	2 days	3 days
Latitude	0.008	0.008	1.81	1.75
Longitude	0.016	0.016	1.81	1.72

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