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# Southern Ocean Time Series (SOTS) Quality Assessment and Control Report Wetlabs FLNTUS instruments Version 2.0

Fluorescence and optical backscatter records

2009-2016

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IMOS
Integrated Marine Observing System

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## Important disclaimer

# Contents

# Acknowledgments

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# Executive summary

The Southern Ocean Time Series (SOTS) Observatory located at 140°E and 47°S provides high temporal resolution observations in sub-Antarctic waters. It is focused on the sub-Antarctic Zone because waters formed at the surface in this region slide under warmer subtropical and tropical waters, carrying $CO_2$ and heat into the deep ocean, where it is out of contact with the atmosphere. This process also supplies oxygen for deep ocean ecosystems, and exports nutrients that fuel ~70% of global ocean primary production. The sub-Antarctic Zone and these processes are expected to change with global warming, but the potential impacts of these changes are not yet known.

This report details the quality control applied to the bio-optical data collected from the SOTS moorings between 2009 and 2016. The quality controlled datasets are publicly available via the IMOS Data Portal. This report should be consulted when using the data.

# 1 Introduction

The Southern Ocean Time Series (SOTS) Observatory provides high temporal resolution observations in sub-Antarctic waters. Observations are broad and include measurements of physical, chemical and biogeochemical parameters from multiple deep-water moorings in the sub-Antarctic Zone southwest of Tasmania (Figure 1). The emphasis is on seasonal and inter-annual variations of lower atmosphere and upper ocean properties and their influence on exchange with the deep ocean. The continuous time-series information allows the study of ocean physics and chemistry, climate change, carbon cycling and biogeochemical controls on marine productivity. These moorings provide cost-effective observations and overcome the infrequent availability of ships in the region. The Southern Ocean Time Series is an Australian contribution to the international OceanSITES global network of time series observatories and is one of the few comprehensive Southern Ocean sites globally. More information on the SOTS facility is available on-line at www.imos.org.au.

The Southern Ocean (south of 30°S) is responsible for ~40% of the total global ocean uptake of human-induced $CO_2$ emissions, and 75% of the additional heat that these emissions have trapped on Earth. The Southern Ocean Time Series site is focused on the sub-Antarctic Zone because waters formed at the surface in this region, the Sub-Antarctic Mode and Antarctic Intermediate waters, slide under warmer subtropical and tropical waters and carry this $CO_2$ and heat into the deep ocean, out of contact with the atmosphere. This process also supplies oxygen for deep ocean ecosystems, and exports nutrients that fuel ~70% of global ocean primary production. The sub-Antarctic Zone and these processes are expected to change with global warming but the potential impacts of these changes are not yet known.

The Southern Ocean Time Series site southwest of Tasmania is comprised of a number of elements including a deep ocean sediment trap mooring (SAZ), a surface biogeochemistry mooring (Pulse) and an air-sea flux mooring (SOFS). Located in the sub-Antarctic Zone near 140°E, 47°S, the site is particularly vulnerable to the extreme weather events that typify the area including very large waves, strong currents and severe storms, presenting significant technical and engineering challenges.

SOTS (red star in Figure 1) is located in a low current region, north of the Subantarctic Front (SAF) that marks the northern edge of the Antarctic Circumpolar Current. SOTS is located in deep waters (>4500 m) west of the Tasman Rise (the shallow region south of Tasmania; with waters less than 2000m deep, shown in blue). SOTS exhibits oceanographic properties representative of the Australian sector of the sub-Antarctic Zone (from ~90 to 145 °E; Trull et al., 2001). Waters flowing southward in the East Australian Current reach this region by transiting through channels in the Tasman Rise (Herraiz-Borreguero et al., 2011).

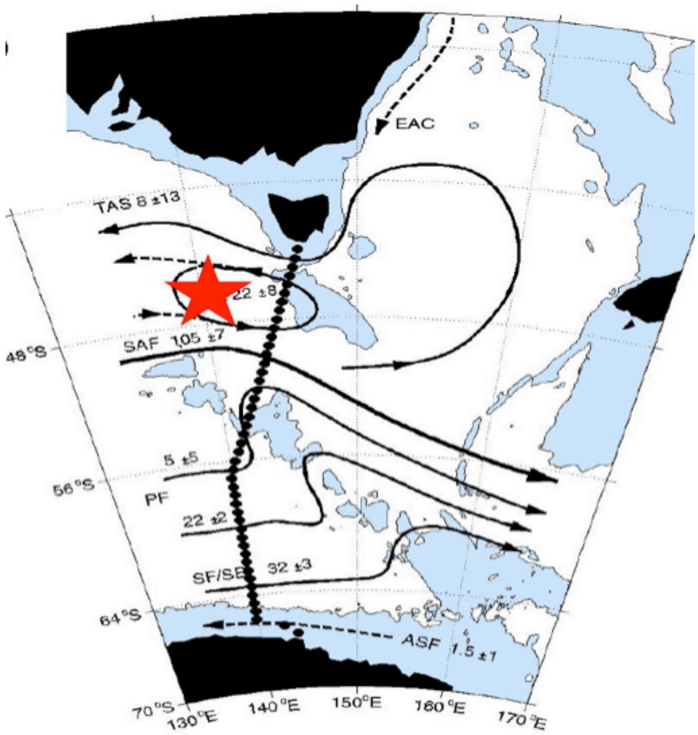



**Figure 1 Location of the SOTS observatory; Figure adapted from Herraiz-Borreguero et al., 2011**

# 2 Moorings description

The Southern Ocean Time Series moorings are the Pulse biogeochemistry mooring, the Sub-Antarctic Zone (SAZ) sediment trap mooring, and the Southern Ocean Flux Station.

- The Pulse biogeochemistry mooring is used to measure upper ocean carbon cycle and phytoplankton productivity processes. Measured parameters include temperature, salinity, dissolved oxygen, total dissolved gases, nitrate, chlorophyll and turbidity. This mooring also collects water samples for measurements of dissolved carbon and nutrients, and phytoplankton microscopic identification.

- The SAZ sediment trap mooring collects sinking particles to quantify carbon fluxes, and provides current meter measurements and a deep ocean CTD to measure heat contents below the depth of Argo profiling float measurements.

- The SOFS meteorological tower mooring has dual sets of radiometers, temperature and humidity sensors, precipitation gauges and sonic anemometers, and a $pCO_2$ sensor provided by NOAA providing the measurements necessary for computing air-sea fluxes of $CO_2$, heat, momentum and mass. Surface photosynthetically active radiation and surface UV are also measured to help assess light available for phytoplankton production. In the 2016-17 year, we combined the SOFS and Pulse capabilities into a single prototype mooring known as FluxPulse-1.

- All three moorings are anchored to the ocean floor 4.5 kilometres below the surface. The SOFS and Pulse moorings are s-tether designs that are longer than this, and correspondingly their surface floats move in large 'watch circles'. In contrast, the SAZ mooring is a stiff subsurface mooring with all components more than 700m below the surface. The moorings record hourly sensor observations until they are swapped with a duplicate mooring the following year.

- Data collected from the Pulse and SOFS are relayed back by satellite. The sub-surface data are stored and downloaded when the moorings are retrieved (approximately a year later). All data are available via the Australian Ocean Data Network (AODN) Portal.

# 3 Summary of instruments

Four different FLNTUS instruments were deployed at SOTS between 2009 and 2015, on two different mooring designs. Instruments on the Pulse mooring were deployed at 30m depth, in a downward looking configuration mounted on the bottom plate of the RAS water sampler and instrument package. Instruments on the SOFS (and FluxPulse-1) moorings were mounted on the base of the 2.7m diameter meteorological surface float, at ~0.5m depth, also in a downward looking configuration. All sensors had an integral “bio-wiper” (as indicated by the S designation for the FLNTUS instruments) which rotated a plastic wiper past the sensing window prior to measurement (see Figure 2). In addition, copper metal sheet was added surrounding the instruments to further discourage bio-fouling (beginning in 2012). Nonetheless, some bio-fouling did occur, especially the growth of gooseneck barnacles which hung within the sensor view, as discussed further below (see Figure 3).

**Figure 2 Recovered FLNTUS sensor with bio-wiper**

The FLNTUS measures both chl-a fluorescence and total backscattering at 700 nm. Fluorescence is stimulated with a blue LED emitting light at 470 nm, and backscatter is stimulated with a red LED emitting light at 695 nm. The two measurements are made extremely close in time but are not expected to interfere with each other. The instrument detects fluorescence and backscatter in a cone-shaped field of view in the water column, with the source beam and detector view angled towards each other (see Figure 4). The in-water centroid angle for the backscatter measurement of the FLNTUS is reported as 142° by the manufacturer (WET Labs ECO Centroid Angles for Back Scatter Measurements, July 2016).

**Figure 3 Gooseneck barnacle growth around recovered FLNTUS instrument**

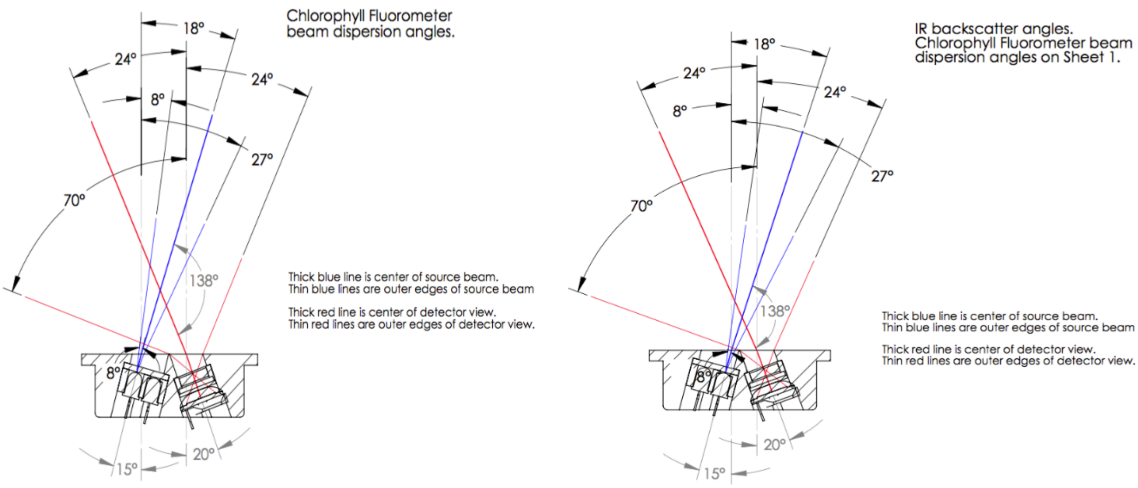



**Figure 4 FLNTUS sensor configurations and beam dispersion angles for fluorescence and backscatter measurements, reproduced from WET Labs data sheets**

The FLNTUS was programmed to measure in different intervals for different deployments, see Table 1 for details. For the most part, the instrument was programmed to make hourly burst measurements, with 5 measurements per burst (over 5 seconds).

**Table 1 Instrument deployment details**

| Deployment | FLNTUS serial number | Fluorescence calibration factors | Backscatter calibration factors | No of measure-ments /burst | Frequency of final data |
|---|---|---|---|---|---|
| **Pulse-6-2009** | 1215 | Dark = 54; Scale = 0.0121 | Dark = 47; Scale = 0.0057 | no bursts | hourly |
| **Pulse-7-2010** | 1215 | Dark = 54; Scale = 0.0121 | Dark = 47; Scale = 0.0057 | no bursts | hourly |
| **SOFS-1-2010** | 1186 | Dark = 72; Scale = 0.0120 | Dark = 47; Scale = 0.0061 | no bursts | variable: mainly 10 and 50 minute intervals |
| **Pulse-8-2011** | 1215 | Dark = 54; Scale = 0.0121 | Dark = 47; Scale = 0.0057 | 5 | hourly |
| **SOFS-2-2011** | 1186 | Dark = 72; Scale = 0.0120 | Dark = 47; Scale = 0.0061 | 5 | hourly |
| **Pulse-9-2012** | 1596 | Dark = 48; Scale = 0.0072 | Dark = 50; Scale = 0.0024 | 5 | hourly |
| **SOFS-3-2012** | 1802 | Dark = 50; Scale = 0.0282 | Dark = 51; Scale = 0.0060 | $9 \pm 1$ | hourly |
| **Pulse-10-2013** | 1186 | Dark = 72; Scale = 0.0120 | Dark = 47; Scale = 0.0061 | 5 | hourly |
| **SOFS-4-2013** | 1802 | Dark = 50; Scale = 0.0282 | Dark = 51; Scale = 0.0060 | 5 | hourly |
| **Pulse-11-2015** | 1186 | Dark = 72; Scale = 0.0120 | Dark = 47; Scale = 0.0061 | 5 | hourly |
| **SOFS-5-2015** | 1802 | Dark = 50; Scale = 0.0282 | Dark = 51; Scale = 0.0060 | 5 | hourly |
| **FluxPulse-1-2016** | 1215 | Dark = 54; Scale = 0.0121 | Dark = 47; Scale = 0.0057 | 5 | hourly |

# 4 Instrument handling and data processing summary

Instrument clocks were set to UTC. Instruments logged to their internal memories, except for Pulse-6 and Pulse-7 deployments which were logged in voltage by an associated Seabird SBE16+ CTD, and for SOFS-1 which was logged as counts serially using a Campbell Scientific CR1000 logger. Data acquired for periods when the instruments were out of the water were flagged as bad (flag=4) before initiation of the QC tests applied here, with these flags carried through to the final data products.

For conversion of counts to scientific units, the instrument calibrations carried out by the manufacturer were used (these have associated precision of ~10%). The individual calibration coefficients are provided with each deployment (netcdf) file. The calculation of the particulate backscatter requires correction for backscatter from seawater (as detailed in section 5.2), and this requires temperature and salinity estimates. These were obtained from the co-located subsurface Seabird SBE16+ CTDs on the Pulse moorings and the co-located surface Seabird SBE37 CTDs on the SOFS and FluxPulse.

# 5 QC specifics

The hierarchy of tests recommended by Integrated Ocean Observing System (IOOS) Quality Assurance or Real-Time Oceanographic Data (QARTOD; https://ioos.noaa.gov/project/QARTOD) was adapted for FLNTUS quality control.

## 5.1 QC tests and flags used

**Table 2 QC tests recommended by QARTOD (their Table3-2) for real-time quality assurance for coastal and oceanic ocean optics observations. Column to the right indicates whether tests were implemented for the FLNTUS sensor**

| | | | *FLNTUS:* |
|---|---|---|---|
| **Group 1** *Required* | Test 1 | Timing/Gap Test | *YES* |
| | Test 2 | Syntax Test | *YES* |
| | Test 3 | Location Test | *YES* |
| | Test 4 | Gross Range Test | *YES* |
| | Test 5 | Decreasing Radiance, Irradiance, and PAR Test | *N/A* |
| **Group 2** *Strongly Recommended* | Test 6 | Photic Zone Limit for Radiance, Irradiance, and PAR Test | *N/A* |
| | Test 7 | Climatology Test | *YES* |
| | Test 8 | Spike Test | *YES* |
| | Test 9 | Rate of Change Test | *N/A* |
| | Test 10 | Flat Line Test | *YES* |
| **Group 3** *Suggested* | Test 11 | Multi-Variate Test | *No* |
| | Test 12 | Attenuated Signal Test | *N/A* |
| | Test 13 | Neighbor Test | *No* |

**Table 3 Flags used in FLNTUS quality control**

| **Flag** | **Description** |
|---|---|
| Not evaluated = 0 | Raw data |
| Pass, Good data = 1 | Data have passed the highest level of quality control for *both* fluorescence and backscatter |
| Probably good data = 2 | Data have passed the highest level of quality control for the respective measurement (i.e. fluorescence or backscatter) but not for both |
| Suspect or of high interest = 3 | Data have failed one or more tests indicating bio-fouling or some other interference not considered instrument failure |
| Fail = 4 | Data have failed one or more tests indicating instrument or mooring failure (mooring adrift or out of the water, batteries flat,…) |

## 5.2 Applied tests and calibrations

Specifically, the order of tests was changed in such a way that calibrations were only necessary for the final test, so tests were run on uncalibrated data as much as possible. Given the uncertainty regarding fluorescence calibrations for chlorophyll-a (e.g., see Roesler et al., 2017), this was the most conservative approach. Additionally, the fact that most of the data had 5 measurements (or more) per burst (~each hour) allowed for a first level of quality control to be conducted on the level of raw burst data.

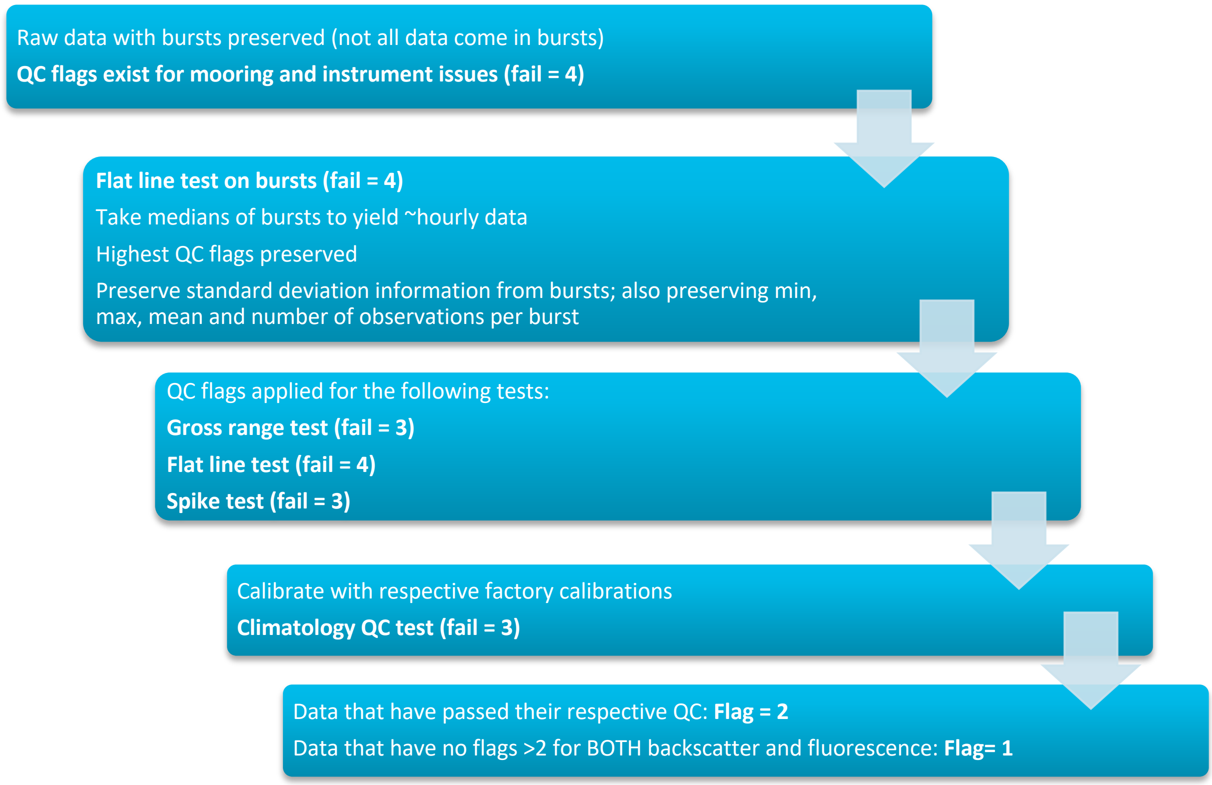



**Figure 5 Flow chart of tests and other data manipulations applied in order. Higher flags are never overwritten by lower flags except in the last step, where flag=2 is applied before flag=1**

*Note that all tests were performed separately for fluorescence and backscatter measurements, but in two instances (gross range test and the final flag=1 step in the flow chart above) the test results from one measurement are used to flag the other.*

### Flat line test:

The flat line test was applied in two instances: first on the burst level (if data were recorded in bursts), and at a later stage on the uncalibrated data. The two tests are expected to catch issues with sensor performance:

- The flat line test on the burst level is implemented to catch instrument problems, i.e. if a sensor is stuck on a single value for the duration of a burst, hence fail = 4. The test flags all bursts where the following applies:

*sum(absolute(difference(data points in burst))) = 0.*

- The flat line test on the uncalibrated (~hourly) data is also expected to identify problems stemming from sensor issues, hence fail = 4. Because this test is done on the hourly, and thus "smoothed" data, it is run on a 24-hour time window, with the expectation that some variability should be observed over 24 hours if the sensor were performing correctly. The criteria for a failed test are the same as above:

*sum(absolute(difference(hourly data points in 24-hour data window))) = 0*.

If there is a data gap such that the first and last data point in a data window are more than 26 hours apart, the test is not performed and the data are flagged as "probably good", i.e. flag=2.

## Gross range test:

The gross range test checks whether the ~hourly, uncalibrated data are within a reasonable range. All data <0 or >2000 counts are flagged as "probably bad" (flag=3). The assumption is that the sensor is performing correctly in these cases, but bio-fouling of some sort (e.g. gooseneck barnacles in the field of view) is affecting the signal.

Since scatterers such as these barnacles have a stronger effect on the backscatter signal than on fluorescence, but are also expected to confound the fluorescence signal, fluorescence data are also flagged (flag=3) where the backscatter signal failed this test.

## Spike test:

The spike test is implemented to identify spikes in the data, presumably from interference from bio-fouling or fish. Because the test is run on the ~hourly and thus "smoothed" data, spikes are not expected to be caused by sinking particles (of phytoplankton or detrital matter) passing through the field of view of the sensor. Such particles could cause spikes in single measurements in a burst, but these spikes within bursts are effectively eliminated by the approach of taking the median of burst measurements. Given horizontal currents averaging ~20 cm $s^{-1}$ and the small field of view of the sensor, it is highly unlikely that a particle remains in the field of view for the duration of a burst. Spikes that remain in the ~hourly data are thus not expected to hold valuable information about phytoplankton aggregates, hence flag=3.

The spike test is implemented as follows:

1) A running median with a window size = 25 (~1 day) is calculated.
2) The standard deviation (stdev) of the whole deployment is calculated, using only data not previously flagged 3 or 4.
3) The difference (diff) between each individual data point and the running median for the respective point is calculated.
4) The test is failed if absolute(diff) > (3*stdev), and flag=3.

## Climatology test:

The climatology test is similar to the gross range test, except that it is performed on the calibrated data. With regards to chl-a, it is expected that the factory calibration over-estimates chl-a values by a factor ~7 (see Roesler et al., 2017). Hence the upper limit for factory-calibrated chl-a is set rather high for the region, at 10 mg $m^{-3}$. All chl-a data <0 or >10 mg $m^{-3}$ are flagged as “probably bad”, i.e. flag=3.

For backscatter, the climatology test is performed on the calculated particle backscattering coefficient $b_{bp}$ (see details of calibration and conversion to $b_{bp}$ below). All $b_{bp}$ <0 or >0.01 $m^{-1}$ are flagged as “probably bad”, i.e. flag=3.

**Table 4 Thresholds and window sizes for the respective QC tests**

| Name of test | Fail criteria for fluorescence | Fail criteria for backscatter |
|---|---|---|
| **Flat line test on bursts** | abs(diff(data in burst)) = 0 | abs(diff(data in burst)) = 0 |
| **Gross range test on hourly data** | data <0, data >2000 counts | data <0, data >2000 counts |
| **Flat line test on hourly data** | window size = 24 (1 day);<br>abs(diff(data in window)) = 0 | window size = 24 (1 day);<br>abs(diff(data in window)) = 0 |
| **Spike test on hourly data** | window size for running median = 25 (~1 day);<br>abs(single data point – running median) >3*standard deviation (of the whole time series where flags <3) | window size for running median = 25 (~1 day);<br>abs(single data point – running median) >3*standard deviation (of the whole time series where flags <3) |
| **Climatology test on calibrated data** | chl-a <0, chl-a >10 mg $m^{-3}$ | $b_{bp}$ <0, $b_{bp}$ >0.01 $m^{-1}$ |

## Calibrations for chl-a and the particle backscattering coefficient $b_{bp}$:

Chl-a is calibrated using the factory-supplied scale factor and dark counts for the respective sensor (differs with serial number):

$$chl\text{-a}\ (mg\ m^{-3}) = scale\ factor * (counts - dark\ counts)$$

The particulate backscattering coefficient $b_{bp}$ is derived from the backscatter measurement (in turbidity units of NTU) in the following steps:

- Calibration of turbidity based on factory-supplied scale factor and dark counts:

$$turb\ (NTU) = scale\ factor * (counts - dark\ counts)$$

- Conversion to the volume scattering function $\beta$ at 700 nm based on a conversion factor supplied by Wetlabs:

$$\beta\ (m^{-1}\ sr^{-1}) = turb * 0.002727$$

- Calculation of $b_{bp}$, with the volume scattering function of seawater and salts, $\beta_{sw}$, following Zhang et al. (2009):

$$b_{bp}(m^{-1}) = 2 * \pi * \chi_p * (\beta - \beta_{sw})$$

where $\chi_p$ for a backscattering angle of 142° is taken to be 1.17 (based on 1.167 reported for 140° Sullivan and Twardowski, 2009).

## Combining fluorescence and backscatter flags:

Given that both $b_{bp}$ and chl-a are measured by the same sensor and extremely close in time, it is reasonable to assume that confounding factors affecting one measurement are also affecting the other. For this reason, $b_{bp}$ and chl-a are flagged as "good", i.e. flag=1, only when *both* measurements have successfully passed all outlined QC tests. This strict criterion leaves only the highest quality data flagged as "good". Data that have only successfully passed the QC tests for the respective measurement (i.e. chl-a has passed the chl-a tests, $b_{bp}$ has passed the $b_{bp}$ tests) are flagged "probably good", i.e. flag=2.

## 5.3 Flag statistics

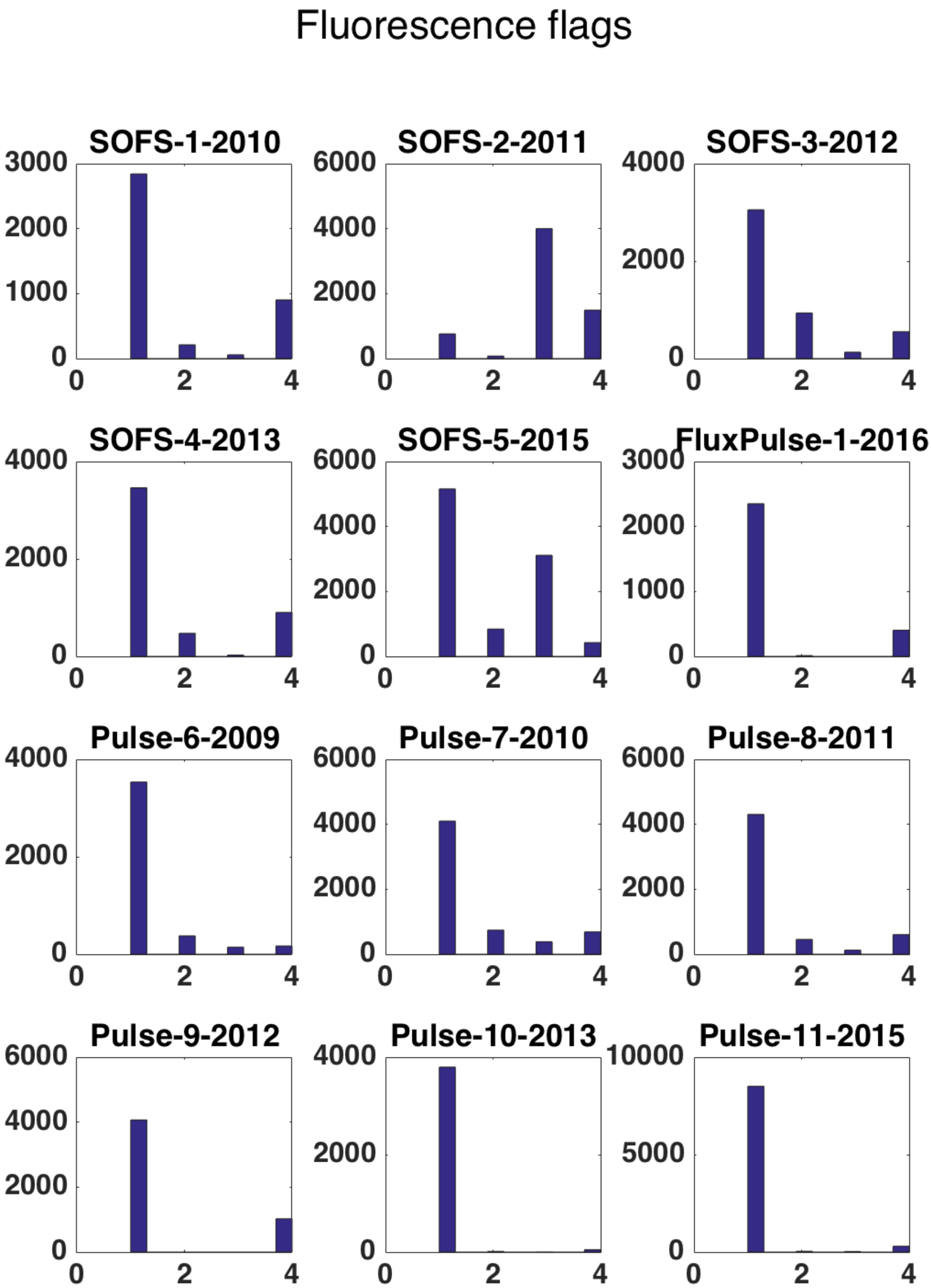



Figure 6 Counts of flags applied to fluorescence data after all QC tests were run

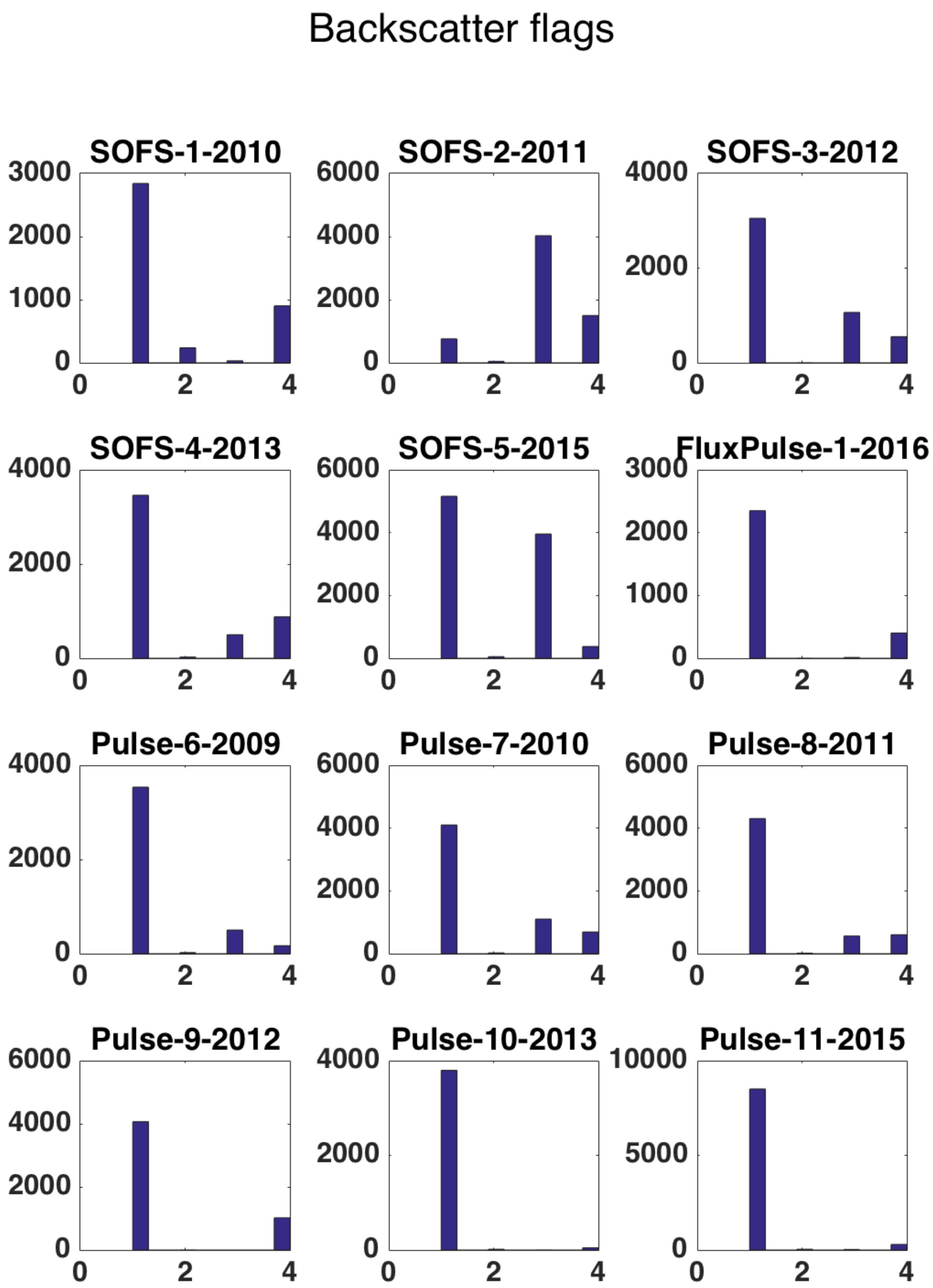



**Figure 7 Counts of flags applied to backscatter data after all QC tests were run**

## 5.4 Discussion and Recommendations

**Recommended QARTOD tests that were not performed:**

A number of QARTOD tests were deemed not applicable to the FLNTUS dataset. The two obvious tests in this category are those that relate to depth profiles, i.e.

- “Decreasing Radiance, Irradiance, and PAR Test” (Test 5 in Table 1) and
- “Photic Zone Limit for Radiance, Irradiance, and PAR Test” (Test 6 in Table 1). Since the FLNTUS data are from a discrete depth, these tests are not applicable.

- “Rate of Change Test” (Test 9) was also not deemed applicable in the mooring situation where hourly data are reported. At the SOTS site, it is possible that different water masses (with different scattering and fluorescence properties that are not related to the previous measurements) may move through within an hour, making a rate of change test inapplicable.
- “Attenuated Signal Test” (Test 12) was attempted but found to not be practical for the FLNTUS data set, because low standard deviations can occur during periods of data which otherwise appear to be good, e.g. in displaying daily cycles and being within expected ranges.
- “Multi-Variate Test” (Test 11), e.g. exploring the $b_{bp}$/chl-a ratio, may prove useful in the future, when greater confidence in expected values is achieved by more extensive calibration of each parameter to regional particle characteristics.
- “Neighbor Test” (Test 13), which could make use of nitrate measurements where available, or of PAR measured at multiple depths to derive an attenuation coefficient, which should be related to chl-a and $b_{bp}$. However, these tests were beyond the scope of the present QC effort, given that those parameters are also currently undergoing evaluation.

### How good are the “good” data?

As outlined above, the tests are designed to flag malfunctions of the instrument and mooring, as well as issues with bio-fouling or other interferences (e.g. from fish). While the tests as currently implemented do a reasonable job at catching the majority of suspect data, they cannot be expected to catch everything because the thresholds are set in such a way that they err on the side of “flagging too little” rather than “too much”. This means that more rigorous QC can always be applied on top of what was performed so far, as evident in some of the data plots in Section 6. Known issues with data escaping a fail or suspect flag exist in the following areas:

- There is currently no test that specifically searches out data where some object appears to have covered the detector for some time, e.g. where there is a low signal and reduced variability.
- There is also an issue with solitary data points escaping flagging in sections where a generally high noise level, for example in the backscattering signal, indicates bio-fouling. The remaining data points in such sections tend to be isolated, and are easily identified by visual inspection (e.g. see SOFS-2 data for fluorescence in Section 6). However, they are not caught with the current QC routine.

The current QC does also not flag fluorescence data that are affected by non-photochemical quenching (NPQ). Non-photochemical quenching manifests as a decrease in chl-a fluorescence when light levels are high. The signal is clearly discernible in the fluorescence data, and may indeed provide an additional avenue for future QC of the fluorescence sensor such that the absence of a daily cycle in chl-a fluorescence is an indicator of bio-fouling. Depending on the desired application of the chl-a data, however, the user may wish to not include data affected by NPQ.

It is now established that the Wetlabs factory calibrations for chl-a overestimate Southern Ocean phytoplankton chl-a by a factor ~7 (e.g., see Roesler et al., 2017). The provided chl-a data should thus not be taken as “true” values, but are nonetheless useful to report for inter-comparison purposes with other campaigns, for example Bio-Argo and SOCCOM floats. It may be possible in the future to derive a regional calibration for the SOTS moorings based on shipboard data. In the meantime, application of the “slope factor” reported by Roesler et al. (2017) for the Southern Ocean may be a reasonable approximation.

The IMOS community is presently working on recommendations for calibration of optical instruments, for example, yearly fluorescence sensor calibrations performed with fluorescein, or against well-maintained and characterized “golden unit” instruments. Dark counts and scale factors can both drift with time, and therefore instruments should be calibrated regularly. Improved calibration of instruments would likely reduce the number of negative data points in the chl-a data and would allow for seamless time-series analyses, although we note that we observe reasonably good agreement for overlapping data from the FLNTUS instruments covered in this report, see Figures 8-10.

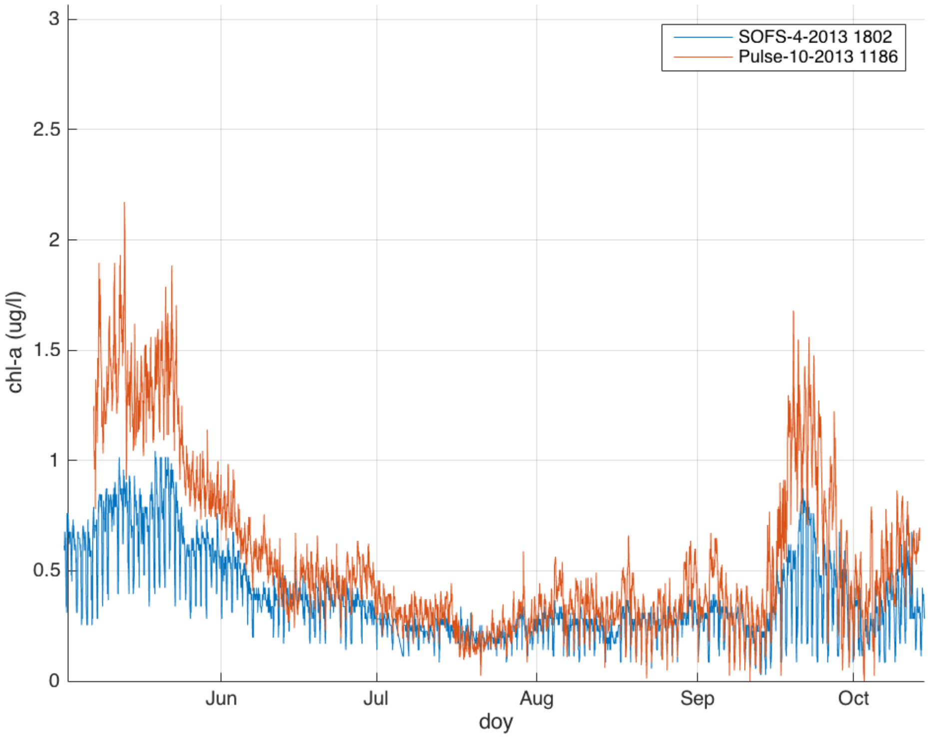



**Figure 8 Comparison of overlapping data from two different FLNTUS instruments**

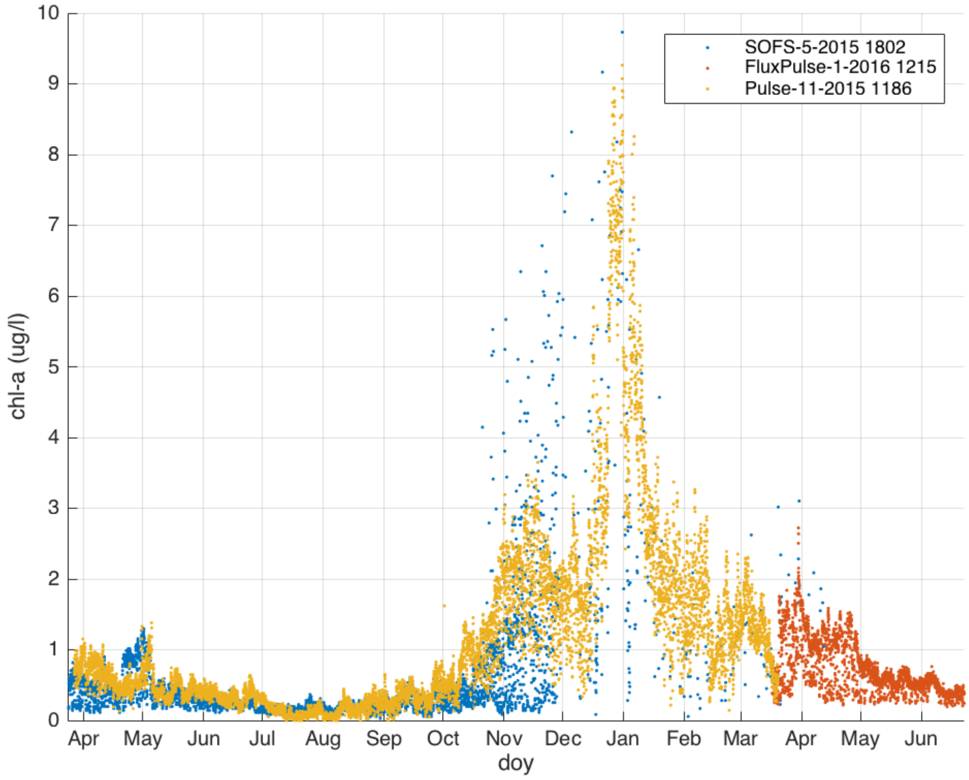



**Figure 9 Comparison of overlapping data from three different FLNTUS instruments**

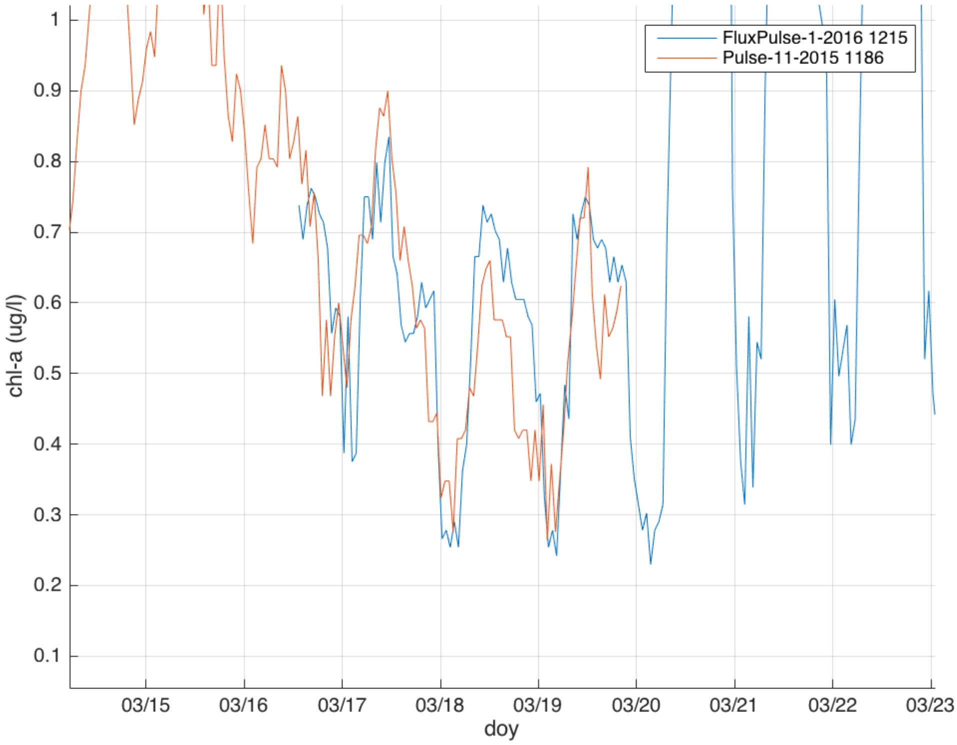
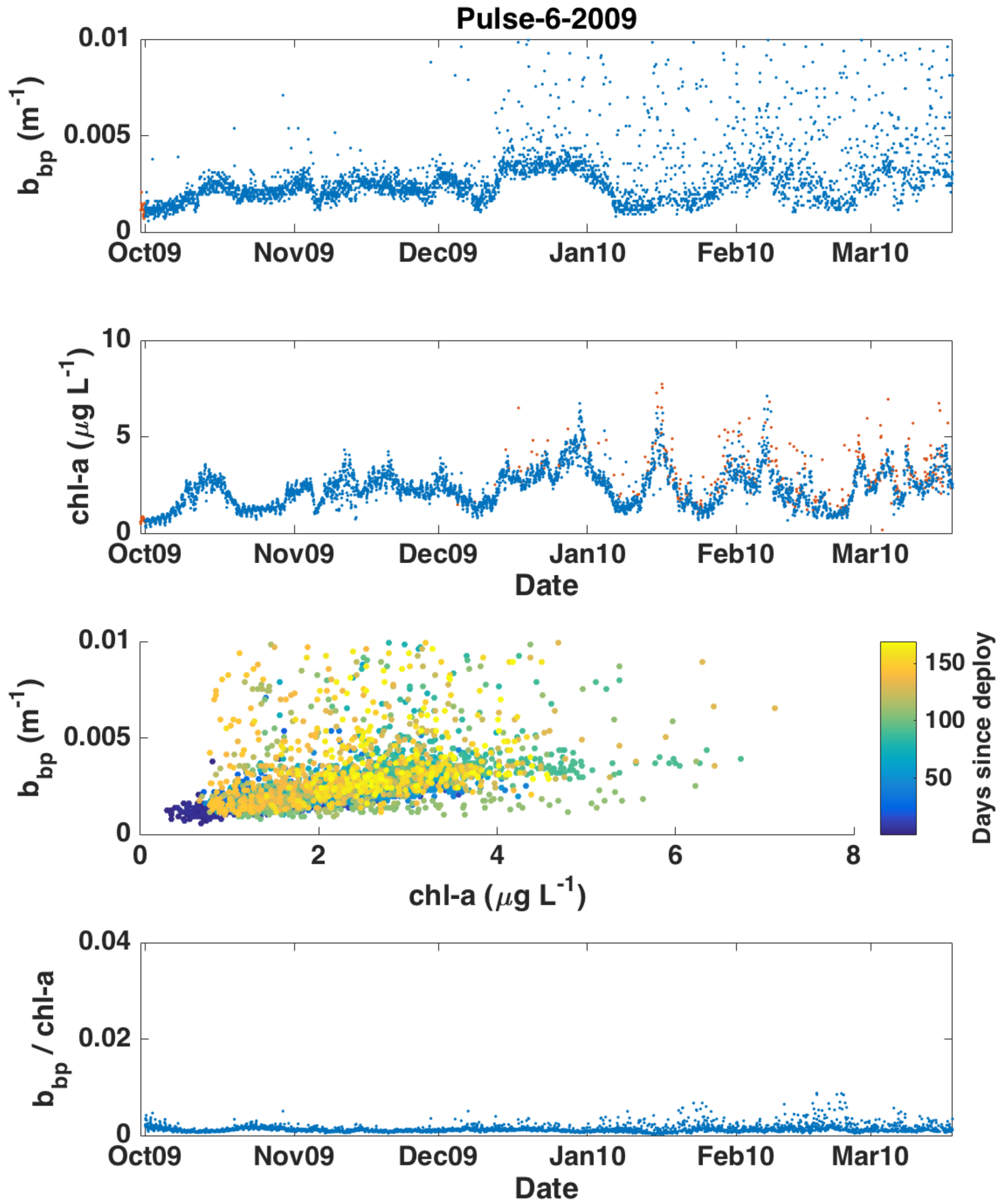
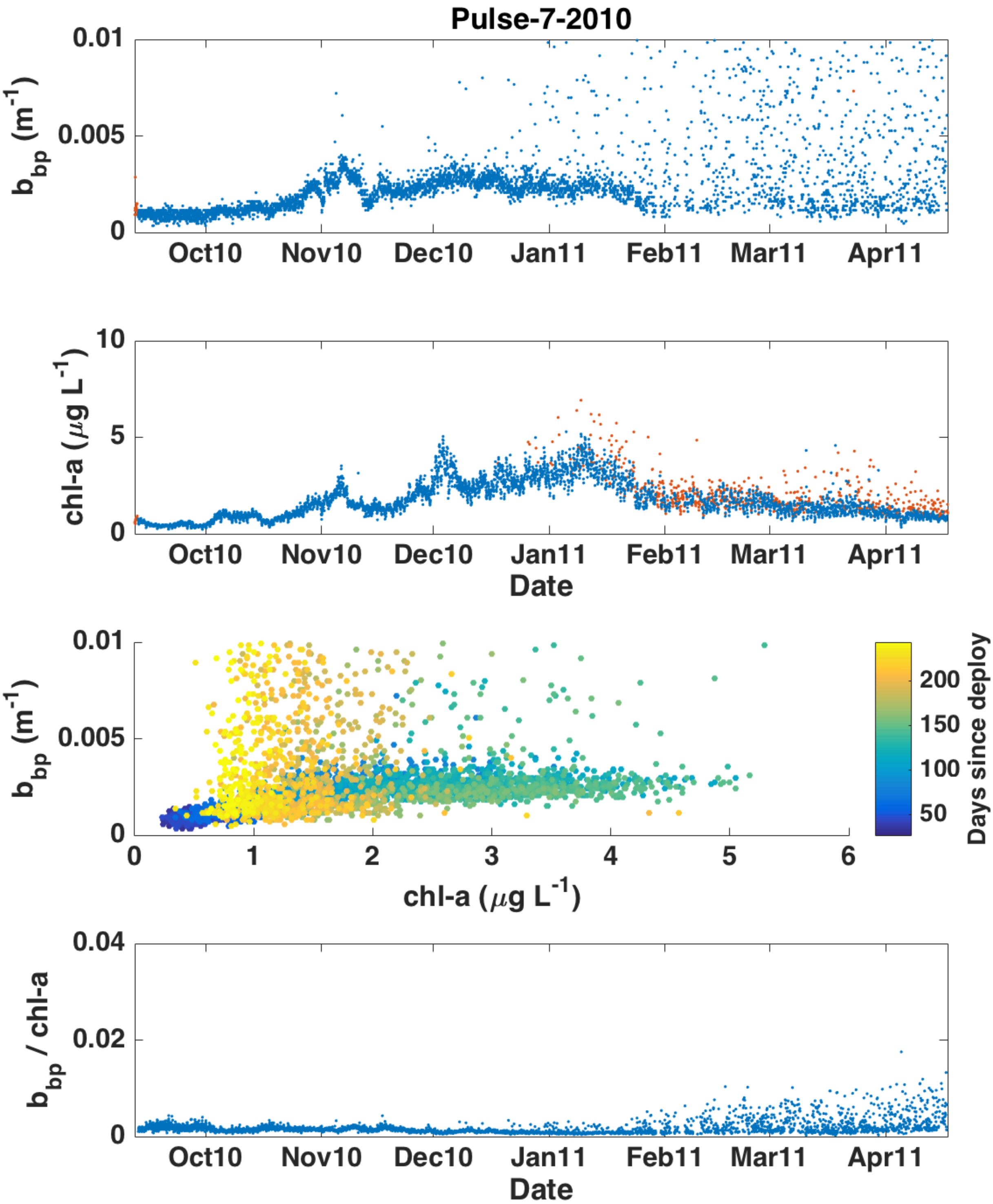


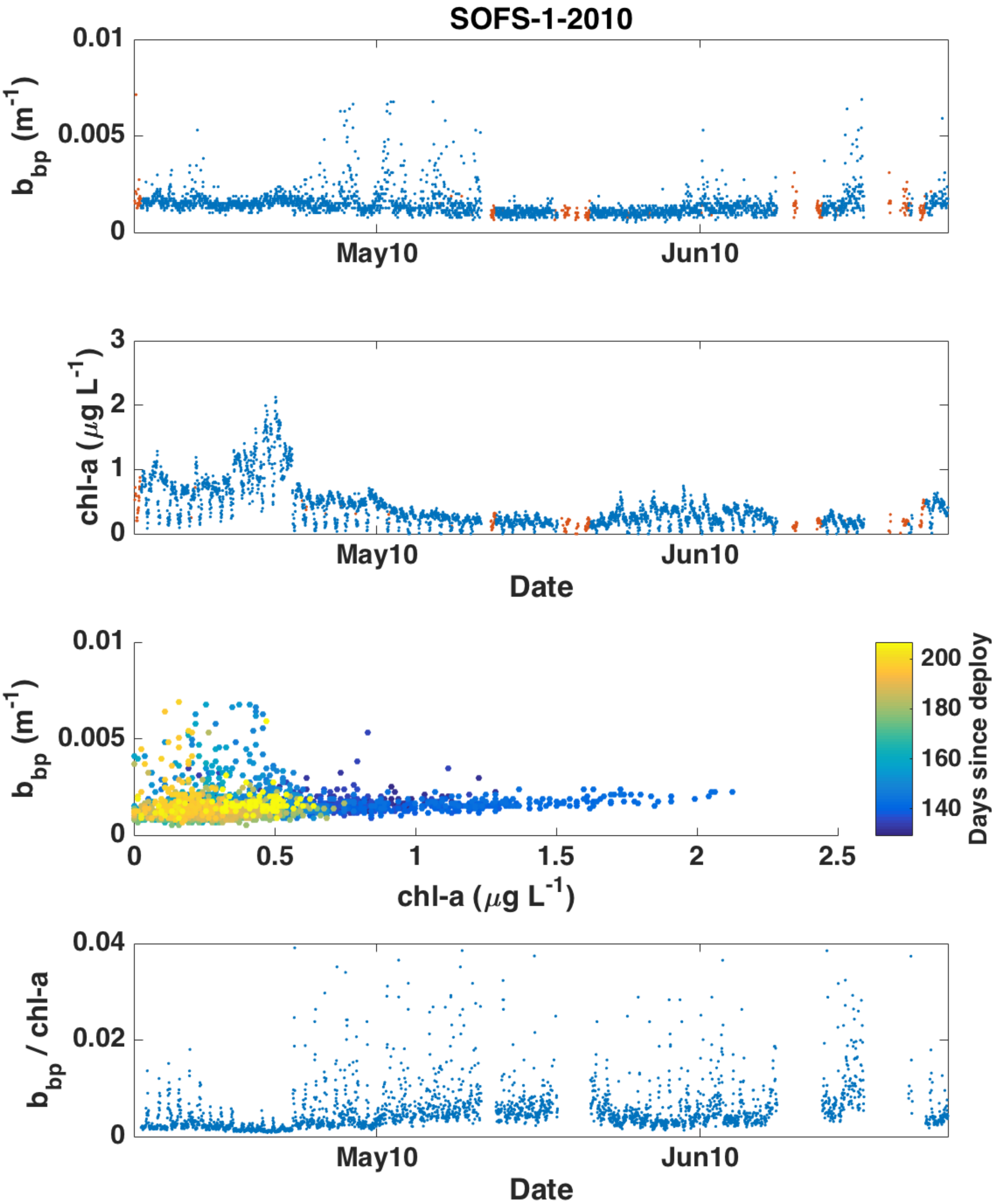

**Figure 10 Comparison of overlapping data from two different FLNTUS instruments**

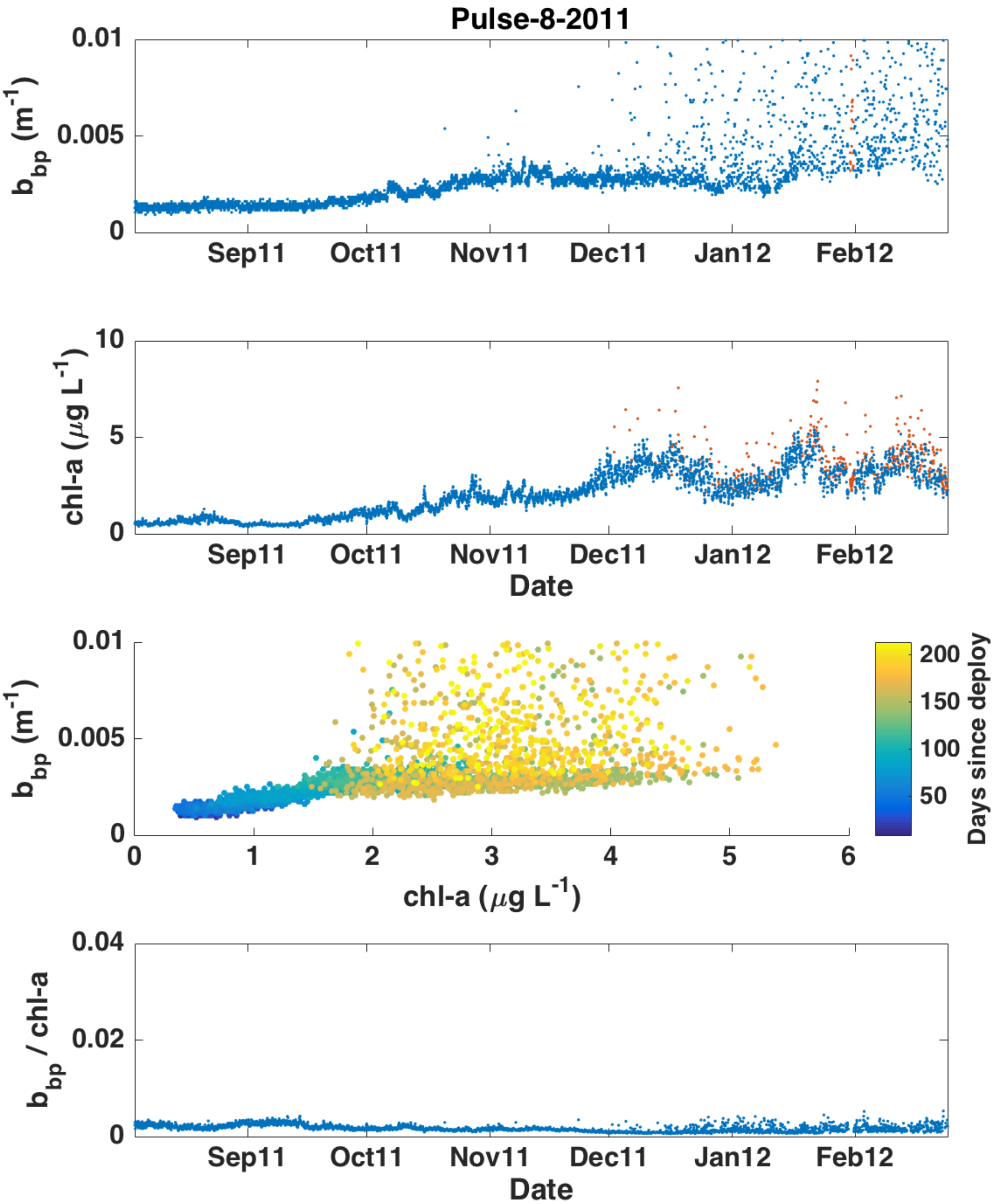
# 6 Data plots for each deployment

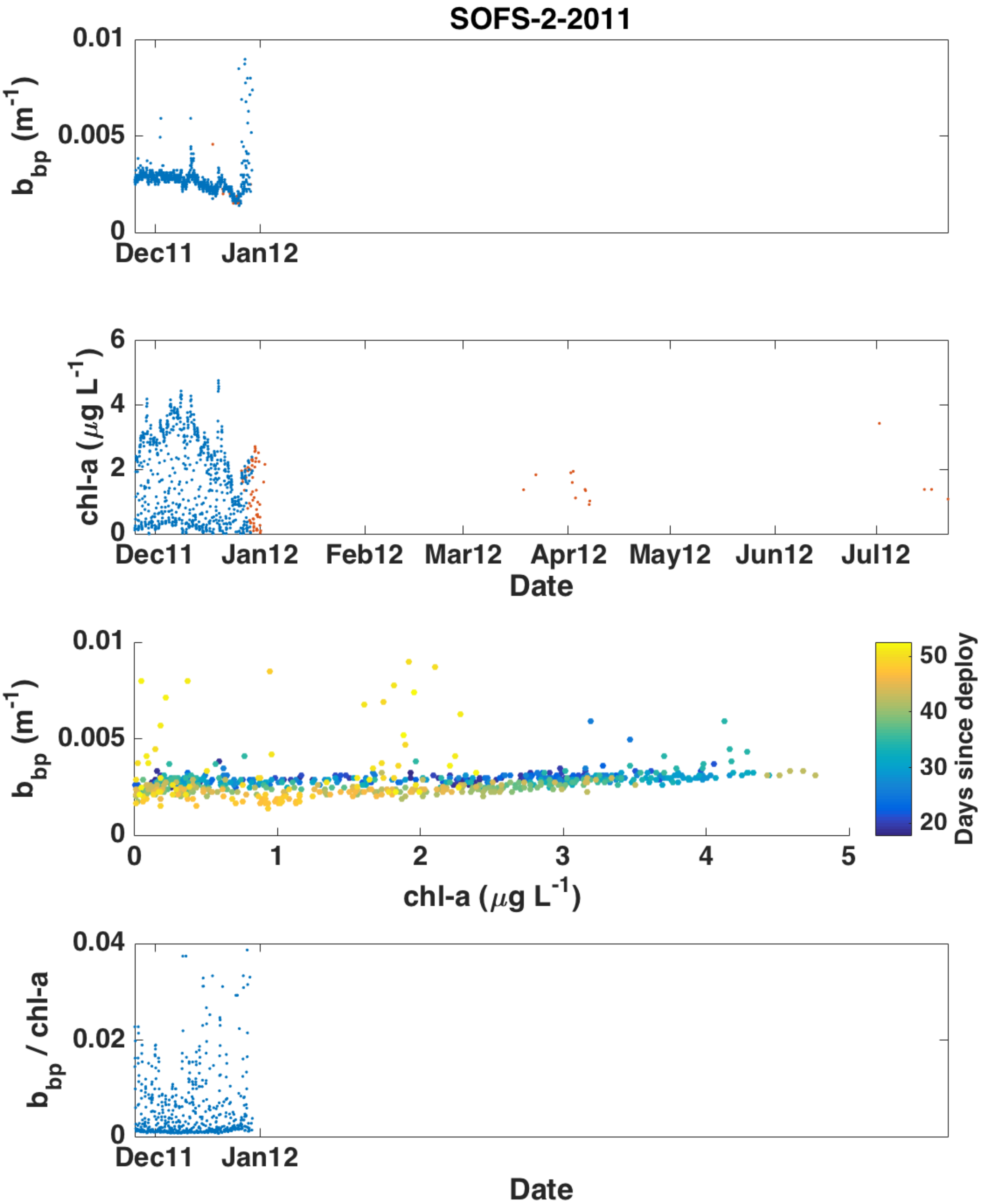
Blue colours indicate flag =1; brown colours flag = 2. Higher flag data excluded.

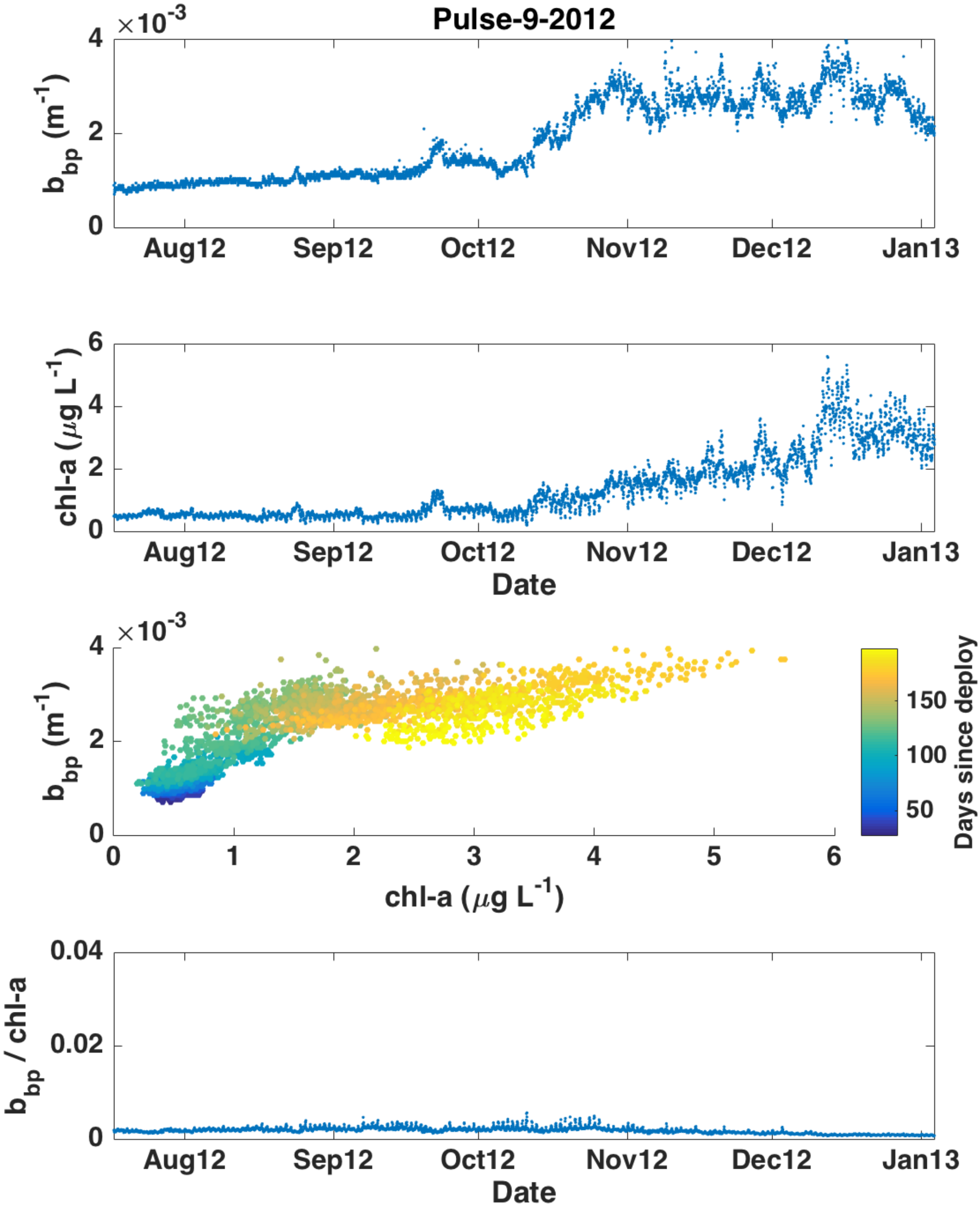


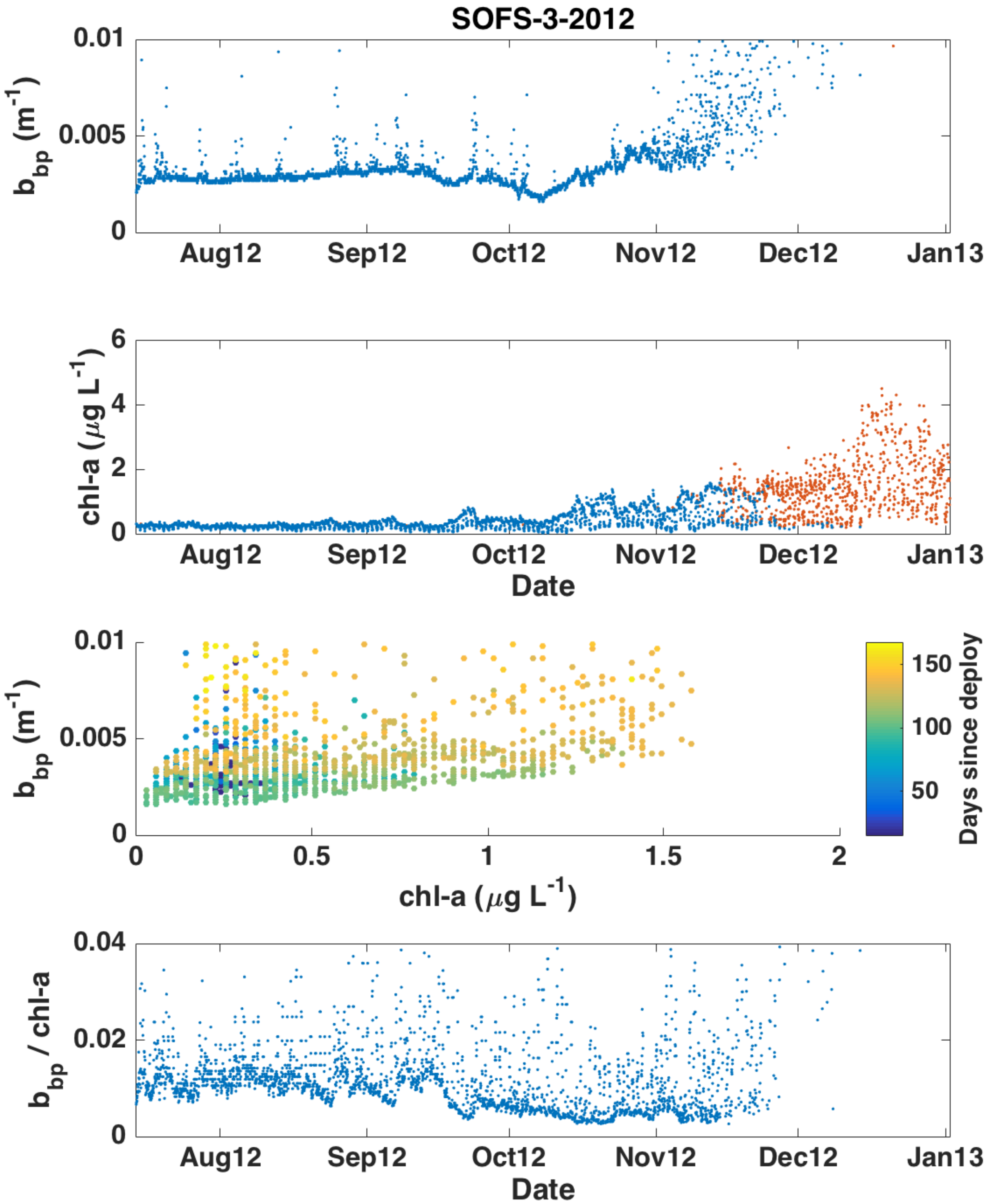

Pulse-7-2010
0.01
0.005
0
$b_{bp}$ ($m^{-1}$)
Oct10
Nov10
Dec10
Jan11
Feb11
Mar11
Apr11
10
5
0
chl-a ($\mu$g $L^{-1}$)
Date
0.01
0.005
0
$b_{bp}$ ($m^{-1}$)
0
1
2
3
4
5
6
chl-a ($\mu$g $L^{-1}$)
200
150
100
50
Days since deploy
0.04
0.02
0
$b_{bp}$ / chl-a
Date

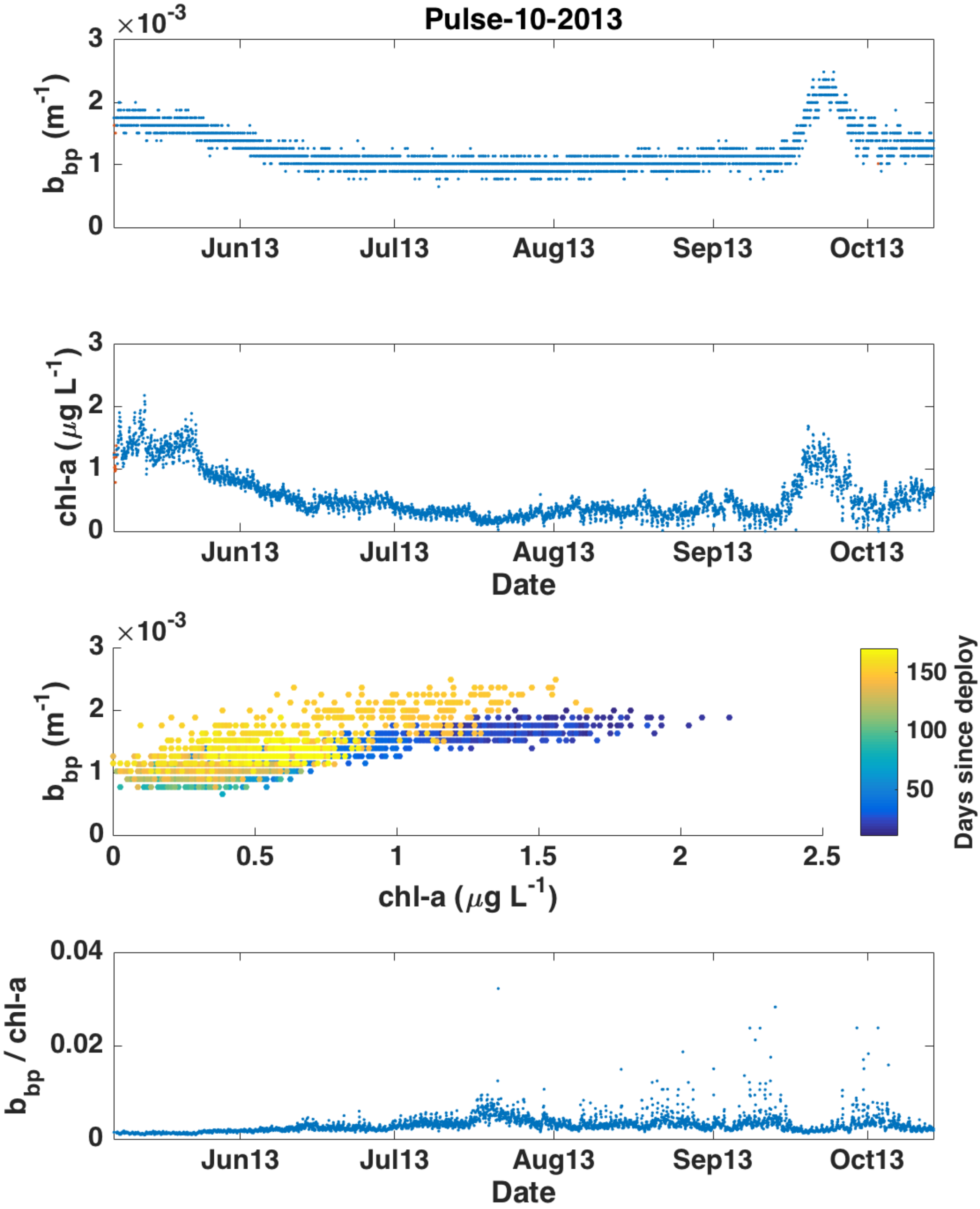

SOFS-1-2010
0.01
0.005
0
May10
Jun10
3
2
1
0
May10
Jun10
Date
0.01
0.005
0
0
0.5
1
1.5
2
2.5
200
180
160
140
Days since deploy
0.04
0.02
0
May10
Jun10
Date

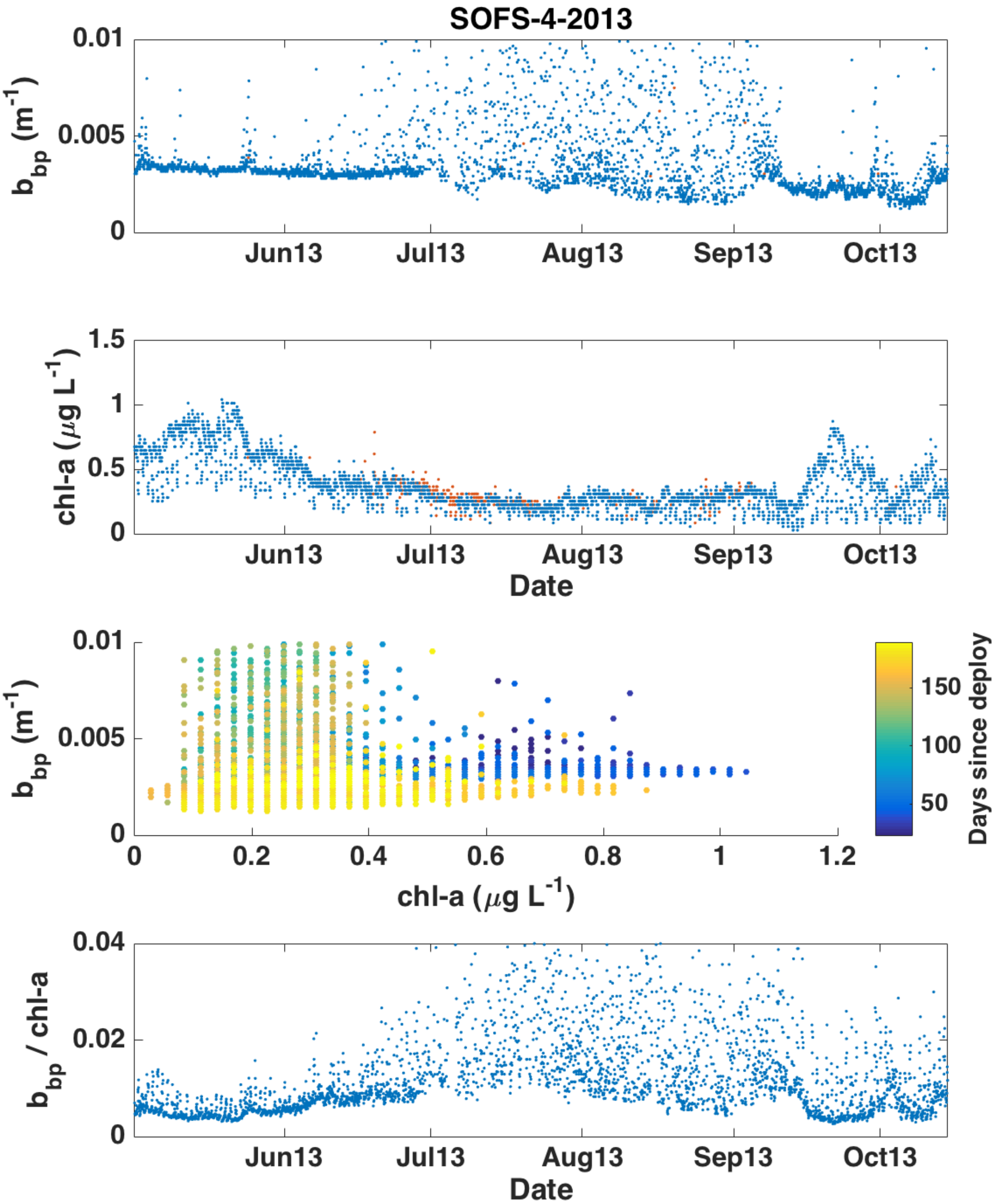

Pulse-8-2011
bbp (m-1)
0.01
0.005
0
Sep11
Oct11
Nov11
Dec11
Jan12
Feb12
chl-a (μg L-1)
10
5
0
Date
0
1
2
3
4
5
6
200
150
100
50
Days since deploy
0.04
0.02
bbp / chl-a

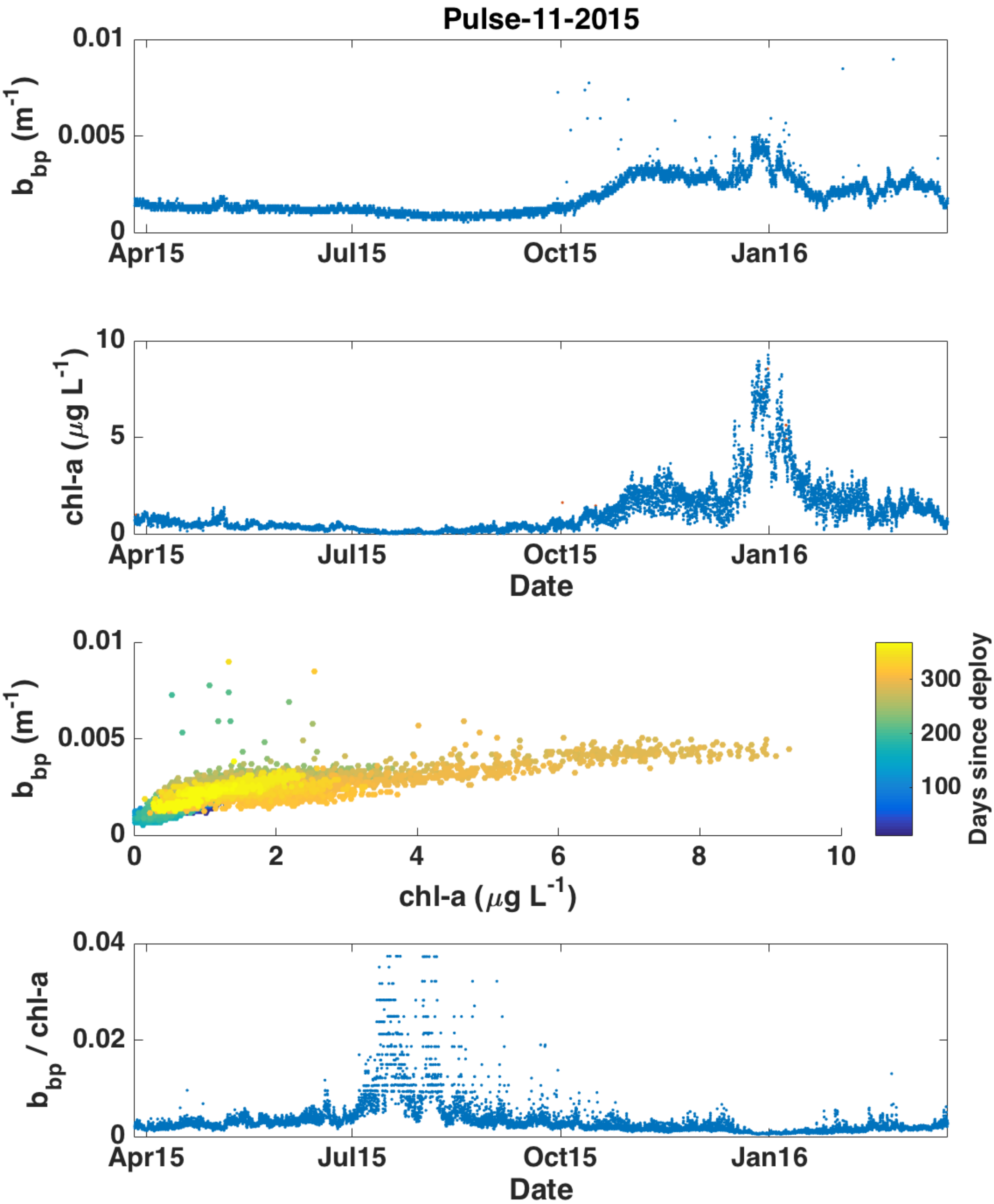

SOFS-2-2011
0.01
0.005
0
$b_{bp}$ ($m^{-1}$)
Dec11
Jan12
6
4
2
0
chl-a ($\mu$g $L^{-1}$)
Dec11
Jan12
Feb12
Mar12
Apr12
May12
Jun12
Jul12
Date
0.01
0.005
0
$b_{bp}$ ($m^{-1}$)
0
1
2
3
4
5
chl-a ($\mu$g $L^{-1}$)
50
40
30
20
Days since deploy
0.04
0.02
0
$b_{bp}$ / chl-a
Dec11
Jan12
Date


Pulse-9-2012
$\times 10^{-3}$
$b_{bp}$ ($m^{-1}$)
Aug12
Sep12
Oct12
Nov12
Dec12
Jan13
chl-a ($\mu g\ L^{-1}$)
Date
Days since deploy
$b_{bp}$ / chl-a

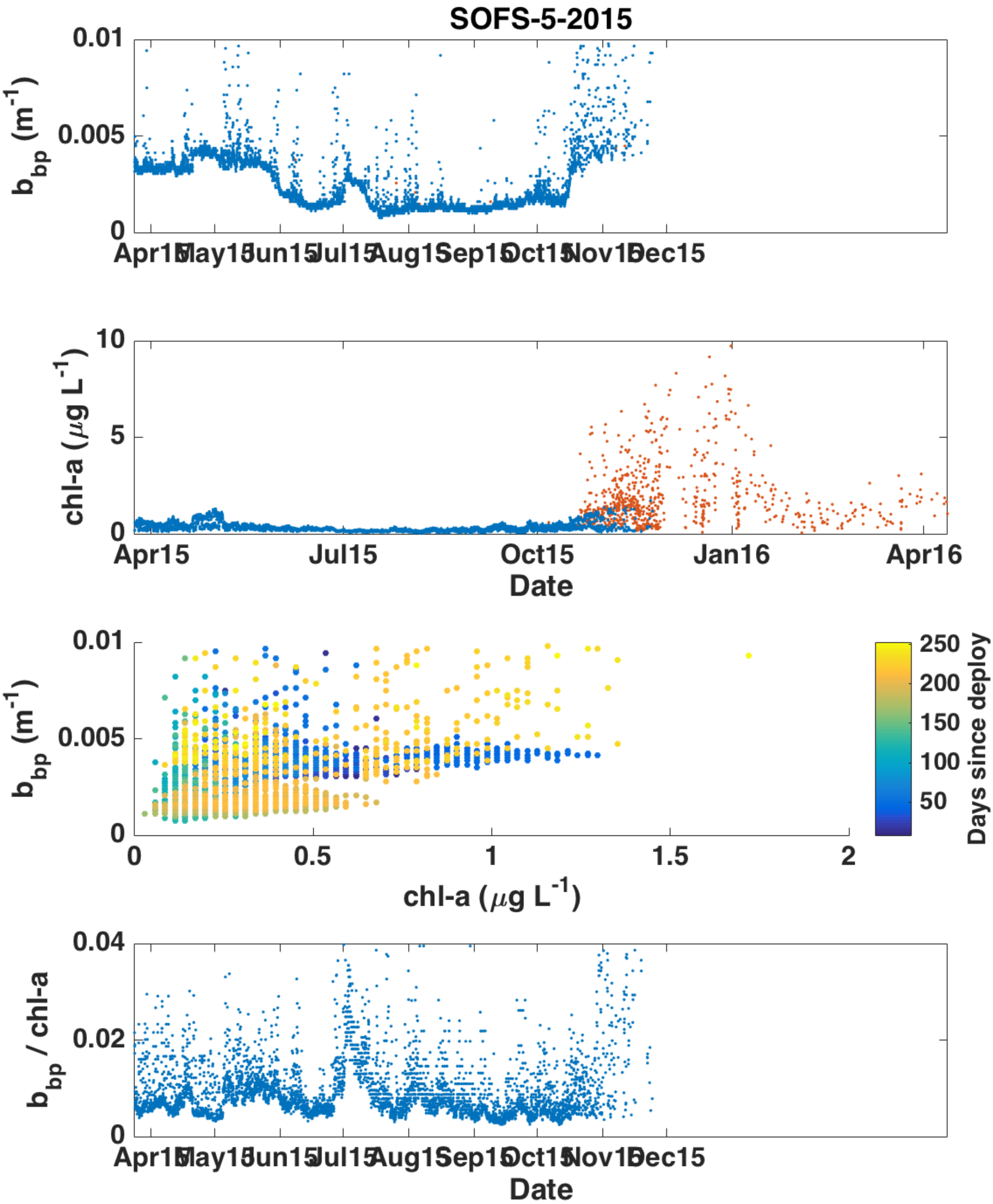

SOFS-3-2012
b_bp (m^-1)
0.01
0.005
0
Aug12
Sep12
Oct12
Nov12
Dec12
Jan13
chl-a (μg L^-1)
6
4
2
0
Date
0.5
1
1.5
2
150
100
50
Days since deploy
b_bp / chl-a
0.04
0.02

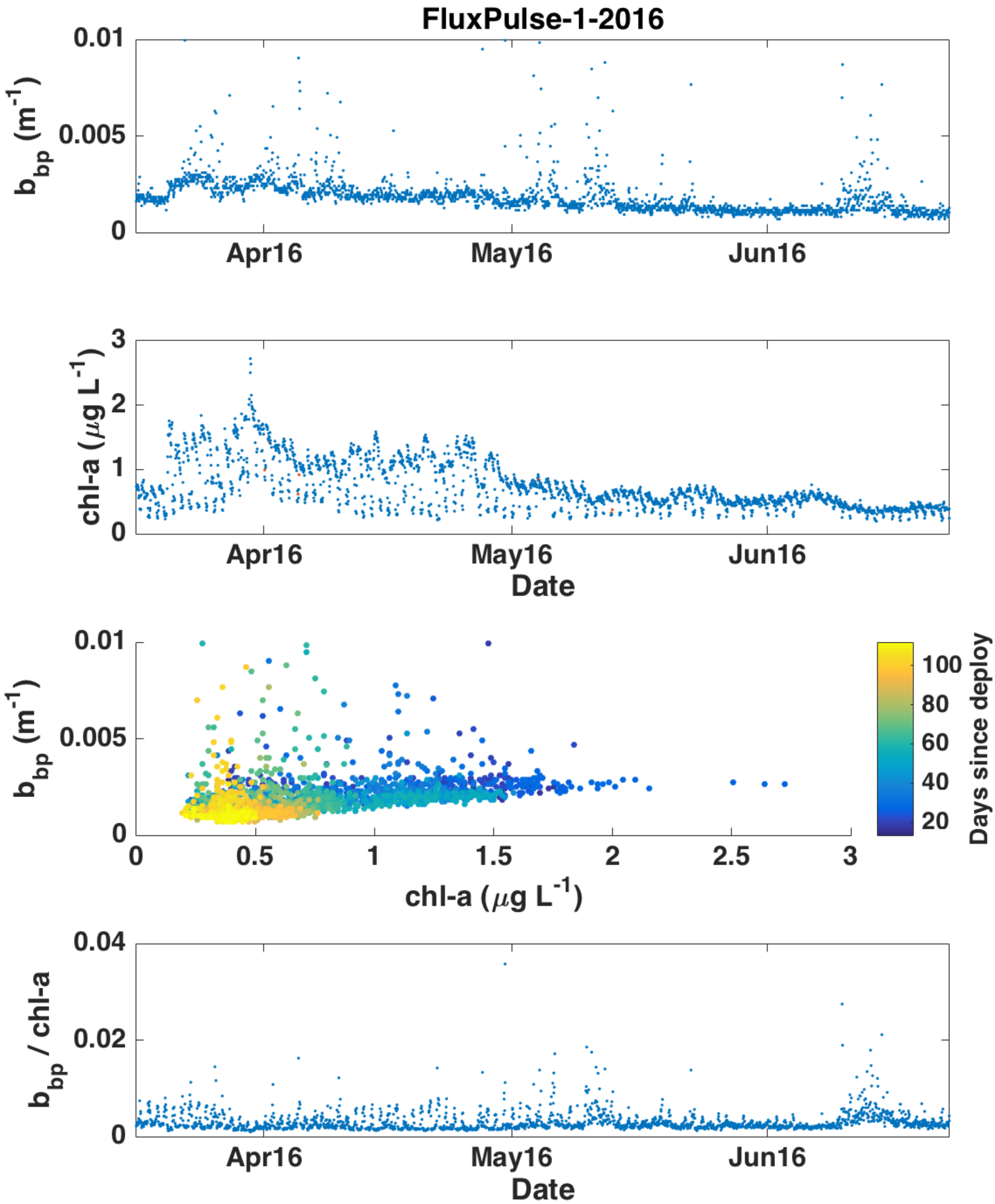

Pulse-10-2013
×10^-3
b_bp (m^-1)
chl-a (μg L^-1)
Jun13
Jul13
Aug13
Sep13
Oct13
Date
Days since deploy
150
100
50
b_bp / chl-a
0.04
0.02
0
0.5
1
1.5
2
2.5
3


SOFS-4-2013
0.01
0.005
0
$b_{bp}$ ($m^{-1}$)
Jun13
Jul13
Aug13
Sep13
Oct13
1.5
1
0.5
0
chl-a ($\mu$g $L^{-1}$)
Date
0
0.2
0.4
0.6
0.8
1
1.2
chl-a ($\mu$g $L^{-1}$)
150
100
50
Days since deploy
0.04
0.02
$b_{bp}$ / chl-a



Pulse-11-2015
0.01
0.005
0
$b_{bp}$ ($m^{-1}$)
Apr15
Jul15
Oct15
Jan16
10
5
0
chl-a ($\mu$g $L^{-1}$)
Date
chl-a ($\mu$g $L^{-1}$)
0
2
4
6
8
10
Days since deploy
100
200
300
0.04
0.02
$b_{bp}$ / chl-a


SOFS-5-2015
0.01
0.005
0
$b_{bp}$ ($m^{-1}$)
Apr15
May15
Jun15
Jul15
Aug15
Sep15
Oct15
Nov15
Dec15
10
5
0
chl-a ($\mu$g $L^{-1}$)
Apr15
Jul15
Oct15
Jan16
Apr16
Date
0.01
0.005
0
$b_{bp}$ ($m^{-1}$)
0
0.5
1
1.5
2
chl-a ($\mu$g $L^{-1}$)
250
200
150
100
50
Days since deploy
0.04
0.02
0
$b_{bp}$ / chl-a
Apr15
May15
Jun15
Jul15
Aug15
Sep15
Oct15
Nov15
Dec15
Date


FluxPulse-1-2016
$b_{bp}$ ($m^{-1}$)
0.01
0.005
0
Apr16
May16
Jun16
chl-a ($\mu g\ L^{-1}$)
3
2
1
0
Apr16
May16
Jun16
Date
$b_{bp}$ ($m^{-1}$)
0.01
0.005
0
0
0.5
1
1.5
2
2.5
3
chl-a ($\mu g\ L^{-1}$)
Days since deploy
100
80
60
40
20
$b_{bp}$ / chl-a
0.04
0.02
0
Apr16
May16
Jun16
Date

# 7 Accessing the data

Data are provided on-line from the Australian Ocean Data Network in CF compliant netcdf format files, with one file per deployment.

# 8 References


Herraiz-Borreguero, L., Rintoul, S.R. (2011), Regional circulation and its impact on upper ocean variability south of Tasmania (Australia). Deep-Sea Research II 58:2071-2081.

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Sullivan, J.M. and Twardowski, M.S. (2009), Angular shape of the oceanic particulate volume scattering function in the backward direction. Applied Optics 48(35): 6811-6819.

Trull, T.W., Bray, S.G., Manganini, S.J., Honjo, S., François, R. (2001), Moored sediment trap measurements of carbon export in the Subantarctic and Polar Frontal Zones of the Southern Ocean, south of Australia. Journal of Geophysical Research 106: 31489-31510.

Zhang, X., Hu, L, He, M.X. (2009), Scattering by pure seawater: Effect of salinity. Optics Express 17(7): 5698-4710

# Appendix A Names of MATLAB files used for processing

Data processing routines are available from the authors. The following 4 mfiles are run in the indicated order:

- **QC_sens_routine1.m**: loads data from netcdf files; takes burst data and makes it into ~hourly data; applies flat line QC test on burst data; output saved as structure in a mat file
- **QC_sens_routine2.m**: loads the mat file produced with QC_sens_routine1.m and applies the QC tests on the ~hourly, uncalibrated data; output saved under a different name in the same mat file
- **sensor_QC_getcalib.m**: loops through the netcdf files and finds the respective calibration data for the sensors; saves the output in the mat file mentioned above
- **QC_sens_routine3.m**: loads the output from QC_sens_routine2.m and from sensor_QC_getcalib.m (i.e. the mat file) and applies the factory calibrations to the data, then runs the climatology QC tests and finally applies flags 2 and 1; output saved in same mat file under the same name; option to produce (and export) plots of the QC-controlled data

The following 3 files are custom functions used by the mfiles above:

- moving.m: used to calculate moving medians etc.
- files_w_ext.m: finds and lists files with the same extension in a given folder
- betasw_ZHH2009.m: calculates the seawater and salt contribution to the volume scattering function

# Appendix B Document Version Control

| Version | Date | Change Description | Author |
|---|---|---|---|
| | June 2017 | Original version | C Schallenberg, P Jansen, TW Trull |
| 2.0 | February 2019 | doi and version number added to citation | C Schallenberg |

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