Oceans and Atmosphere

Southern Ocean Time Series (SOTS) Quality Assessment and Control Report PAR Instruments



Photosynthetically available radiation records

2009-2016

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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 CO2 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 photosynthetically available radiation (PAR) 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.

# 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 <http://www.imos.org.au/>.

The Southern Ocean (south of 30°S) is responsible for ~40% of the total global ocean uptake of human-induced CO2 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 CO2 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). The SOTS site 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).

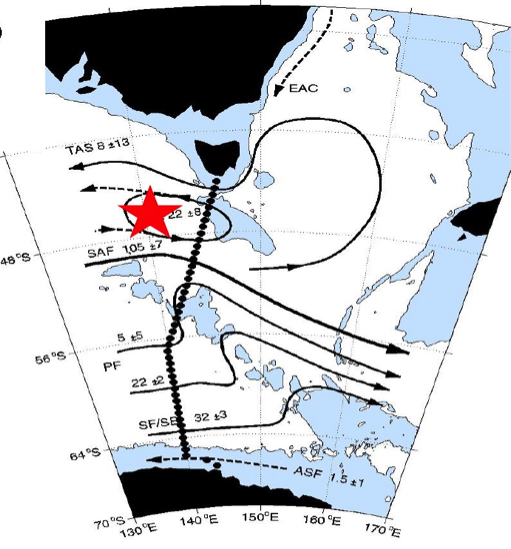


Figure 1 Location of the SOTS observatory; Figure adapted from Herraiz-Borreguero et al., 2011

# 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 pCO2 sensor provided by NOAA providing the measurements necessary for computing air-sea fluxes of CO2, 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.

- Surface 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.

# Summary of Instruments

A total of ten different instruments for measuring PAR were deployed at SOTS between 2009 and 2015. These instruments were deployed on two different mooring designs, at varying depths ranging from the surface to a depth of 50m (Refer to table 1 for the deployment depth of each sensor). All instruments were mounted facing upwards.

The PAR sensors deployed at SOTS can be divided into two main functional categories, cosine and spherical. Cosine sensors measure PAR as a downwelling vector quantity, whereas spherical sensors measure PAR as a scalar quantity.

Cosine (also known as planar) sensors receive downwelling light through a flat surface and measure downwelling PAR as a vector quantity. These sensors tend to underestimate PAR as would be experienced by phytoplankton, as they are incapable of receiving upwelling light or light reflected off of particles in the water. However, they work well in measuring PAR out of the water or at the surface. These sensors also possess cosine correction, in the form of a material that diffuses light, reducing errors introduced by light hitting the sensor from lower incident angles. As these sensors receive light through a flat surface they can be wiped to prevent biofouling. Of the cosine sensors deployed at SOTS, only the WET Labs cosine sensors had a wiper attached.

Spherical sensors use a spherical surface to diffuse incoming light before it reaches the sensor. This is intended to provide a more accurate representation of the way in which a cell in the water would receive light. This structure means that sensors mounted at or above the surface may receive light reflecting from the ocean surface. Additionally, biospherical sensors are more susceptible to biofouling as the spherical surface cannot be wiped whilst the sensor is deployed.

Cite Kirk text book

Table 1. Instrument deployment details for cosine sensors

|  |  |  |  |
| --- | --- | --- | --- |
| **Producer** | **Model** | **Serial no.** | **Deployments and Depth** |
| Alec Electronics | DEFI-L | 082V023 | Pulse-10-2013 (50m)  Pulse-11-2015 (50m) |
| WET Labs | ECO-PAR | 134 | Pulse-8-2011 (28m)  Pulse-10-2013 (28m)  Pulse-11-2015 (28m) |
| WET Labs | ECO-PAR | 135 | Pulse-6-2009 (28m)  Pulse-7-2010 (28m)  Pulse-9-2013 (28m) |
| Licor | LI-190 | Q47470 | SOFS-4-2013 (Surface - in air)  SOFS-5-2015 (Surface - in air) |
| Licor | LI-190SA | Q40966 | SOFS-1-2010 (Surface - in air)  SOFS-2-2011 (Surface - in air)  SOFS-3-2012 (Surface - in air) |

Table 2. Instrument deployment details for spherical sensors

|  |  |  |  |
| --- | --- | --- | --- |
| **Producer** | **Model** | **Serial no.** | **Deployments and Depth** |
| Alec Electronics | MDS-MKV/L | 201318 | SOFS-1-2010 (40m)  SOFS-2-2011 (40m)  SOFS-4-2013 (20m)  SOFS-5-2015 (20m) |
| Alec Electronics | MDS-MKV/L | 201319 | SOFS-2-2011 (10m)  SOFS-4-2013 (40m)  SOFS-5-2015 (40m) |
| Alec Electronics | MDS-MKV/L | 200341 | Pulse-6-2009 (Surface)  Pulse-7-2010 (Surface)  Pulse-8-2011 (50m)  Pulse-10-2013 (Surface) |
| Alec Electronics | MDS-MKV/L | 200664 | Pulse-6-2009 (27m)  Pulse-7-2010 (50m)  Pulse-8-2011 (27m) |
| Alec Electronics | MDS-MKV/L | 200665 | Pulse-6-2009 (50m)  Pulse-7-2010 (27m)  Pulse-8-2011 (Surface)  Pulse-10-2013 (50m)  Pulse-11-2015 (20m) |

# Summary of Instrument Handling and Data Processing

All Alec Electronics sensors logged to their internal memories. Licor sensors were logged by a CR1000 data logger. The WET labs sensors were logged both internally and by an SBE16plusV2. Data obtained from periods when the instruments were out of the water were given a flag value of 5 before initiation of the QC tests applied here, with these flags carried through to the final data products.

Sensor calibrations are based on different relationships between logged counts and PAR for each sensor type.

The Wet Labs sensors are logarithmic sensors, with counts converted to PAR using the following formula:

(equation 1.)

Where Im is an immersion correction, a0 is (can’t remember which is reference and which is sensitivity) and a1 is …

The Licor and Alec Electronics sensors are all proportional sensors. PAR is converted from logged counts using the following formula:

(equation 2.)

Where A is … and B is ….

More detail on the specifics of these calibrations can be found in Appendix B.

# 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 PAR data quality control. Some of the tests were decided not to be applicable to the PAR data and were not conducted, as described in section 5.4.

## QC tests and flags

Table 3. QC tests recommended by QARTOD for real-time quality assurance for coastal and oceanic ocean optics observations.

|  |  |  |  |
| --- | --- | --- | --- |
| **Test Group** | **Test no.** | **Test Name** | **Conducted** |
| Group 1  *Required* | Test 1  Test 2  Test 3  Test 4  Test 5 | Timing/Gap Test  Syntax Test  Location Test  Gross Range Test  Decreasing Radiance, Irradiance, and PAR Test | Yes  Yes  Yes  Yes  N/A |
| Group 2  *Strongly Recommended* | Test 6  Test 7  Test 8  Test 9  Test 10 | Photic Zone Limit for Radiance, Irradiance, and PAR Test  Climatology Test  Spike Test  Rate of Change Test  Flat Line Test | N/A  Yes  No  Yes  Yes |
| Group 3  *Suggested* | Test 11  Test 12  Test 13 | Multivariate Test  Attenuated Signal Test  Neighbour Test | No  No  Yes |

Table 4. Flags used in PAR quality control

|  |  |
| --- | --- |
| **Flag** | **Description** |
| Pass, Good data = 1 | Data have passed the highest level of quality control |
| Probably good = 2 | Data was unable to be evaluated by at least one test, but also was not flagged as suspect or fail by any other tests |
| 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,…) |
| Sensor active but not deployed = 5 | Data obtained when the sensor was out of water or not at the assigned depth |

## Applied tests

I haven’t implemented any flags for these first three tests but can do so fairly easily, except maybe syntax test, not really sure how that works

**Test 1. Timing/Gap Test:**

The timing/gap test was implemented to check that all measurements were made at the correct time intervals

**Test 2. Syntax test:**

The syntax test was conducted to ensure that all measurements were made in the correct data format.

**Test 3. Location Test:**

The location test is used to check that all measurements were taken at the correct location.

**Test 4. Gross Range Test:**

The gross range test checks whether the data are within a reasonable range of values. All data with a value less than 0 or higher than 10000 μmol m−2 s−1 are flagged as a fail. Any value above 4500 μmol m−2 s−1 is flagged as suspect.

Any point with a value greater than 10000 was assigned a flag of 4. Any flag with a value between 4500 and 10000 was assigned a flag of 3.

**Test 7. Climatology:**

The climatology test functions similarly to the gross range test, but threshold values change seasonally. To create bounds for this test, estimates of PAR at each depth were created from modelled incident solar irradiance at the surface, using the clear water value of the diffuse attenuation coefficient (Kd = 0.04).

The solar irradiance model used the solar constant value of 1361 W m-2 and then created a seasonal cycle based on the Earth’s orbit and the solar altitude at different times of year. It factors in the absorbance of solar radiation due to the atmosphere.

Solar radiation values were calculated for each PAR measurement using the *suncycle.m* Matlab function (see Appendix A). This function calculates the solar radiation from a latitude, longitude and date. Before being used to calculate PAR, all solar radiation values were converted from units of W m-2 to μmol m−2 s−1 by multiplying by a factor of 4.57 (McCree 1972).

PAR was calculated using the following formula:

(equation 3.)

These PAR values represent the amount of light that would theoretically reach the sensors on a sunny, clear-sky day with completely clear water. Given that the water will not be completely clear, any values of PAR that fall above the estimated PAR are flagged as a fail.

This test becomes less useful during dawn and dusk as light conditions are not well represented by the solar radiation model and the test begins to flag a large number of values that may be of good quality. Therefore, all low PAR values were flagged as unevaluated given that this test cannot accurately be applied to them.

Any data point showing a value higher than the modelled PAR value at that depth was assigned a flag of 4. All data points that were below a PAR value of 3 μmol m−2 s−1 were assigned a flag value of 2.

**Test 9. Rate of Change Test:**

This test was applied to the night-time data from all sensors. The aim here being to catch any sensors that exhibit sensor drift, which should be easily detectable using night values where no light is available. The night time PAR data was converted to nightly means and each night was assigned a standard deviation value calculated as the standard deviation of that point and the following six points. Any sensor that was shown to vary between two nights by more than three standard deviations was flagged as a fail.

(equation 4.)

Any points returning TRUE for equation 4 were assigned a flag of 4. Any points that were unable to be evaluated due to not having enough subsequent points to create a window of 7 points in order to calculate a standard deviation were assigned a flag value of 2.

**Test 10. Flat Line Test:**

The flat line test was applied across all sensors. This test was only run on daytime data as all sensors would be expected to flat line somewhat during the night. If a sensor returned 5 consecutive measurements within a tolerance value of 0.1, the 5th value was flagged as a fail.

The flat line test was implemented using a rolling window of 5 data points. The following formula was applied to each set of data points:

(equation 5.)

The final data point in any set of 5 points that returned TRUE for equation 5 was assigned a flag of 4. Any points that were unable to be evaluated due to not having enough subsequent points to create a window of 5 points were assigned a flag value of 2.

**Test 13. Neighbour Test:**

The neighbour test used all PAR sensors deployed on the same mooring and compared their records. The theory is that all sensors should show similar trends with time, with the sensors at greater depths given a more attenuated signal. The test thus consisted of comparing each sensor to those mounted below them on the mooring. If the readings from a sensor were observed to drop below multiple deeper sensors the data was flagged as a failure. If a sensor only fell below one other sensor it becomes difficult to say with certainty which sensor was at fault, so in this scenario both data points are listed as suspect.

Any sensor returning a daily mean PAR value that was lower than more than one deeper sensor was given a flag of 4. If the value was lower than that from a single deeper sensor then both data points were given a flag of 3. Any sensor that could not be compared to other sensors was considered unevaluated and assigned a flag value of 2.

## Flag statistics

Table 5. Flag counts from each deployment for each test

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| TEST | DEPLOYMENT | FLAG = 1 | FLAG = 2 | FLAG = 3 | FLAG = 4 |
| Gross Range | Pulse 6  Pulse 7  Pulse 8  Pulse 9  Pulse 10  Pulse 11  SOFS 1  SOFS 2  SOFS 3  SOFS 4  SOFS 5  **TOTAL** |  | N/A  N/A  N/A  N/A  N/A  N/A  N/A  N/A  N/A  N/A  N/A  **N/A** |  |  |
| Climatology | Pulse 6  Pulse 7  Pulse 8  Pulse 9  Pulse 10  Pulse 11  SOFS 1  SOFS 2  SOFS 3  SOFS 4  SOFS 5  **TOTAL** |  |  |  |  |
| Rate of Change | Pulse 6  Pulse 7  Pulse 8  Pulse 9  Pulse 10  Pulse 11  SOFS 1  SOFS 2  SOFS 3  SOFS 4  SOFS 5  **TOTAL** |  |  |  |  |
| Flat Line | Pulse 6  Pulse 7  Pulse 8  Pulse 9  Pulse 10  Pulse 11  SOFS 1  SOFS 2  SOFS 3  SOFS 4  SOFS 5  **TOTAL** |  |  |  |  |
| Neighbour | Pulse 6  Pulse 7  Pulse 8  Pulse 9  Pulse 10  Pulse 11  SOFS 1  SOFS 2  SOFS 3  SOFS 4  SOFS 5  **TOTAL** |  |  |  |  |
| Flag Totals | Pulse 6  Pulse 7  Pulse 8  Pulse 9  Pulse 10  Pulse 11  SOFS 1  SOFS 2  SOFS 3  SOFS 4  SOFS 5  **TOTAL** |  |  |  |  |

Will put plots here once flagging is done

## Discussion and recommendations

Recommended QARTOD tests that were not performed:

Some of the recommended QARTOD tests were decided to not be applicable to the PAR data. As all of the sensors are mounted at discrete depths on the mooring, tests related to depth profiles (Test 5 and test 6 in table 2) were not conducted.

Given that PAR values can change rapidly within a short period of time the “Spike Test” was also not deemed to be applicable. It would be difficult to differentiate a spike due to a problem with a sensor from natural changes in PAR such as a cloud covering or uncovering the sun.

Similarly, it was decided that applying the “Attenuated Signal Test” would be too complicated as it would be difficult to distinguish the attenuation of the signal due to biofouling from attenuation due to cloudiness.

An attempt was made to create a multivariate test that functioned in a similar way to the climatology test, using chlorophyll values to estimate Kd and therefore PAR at different depths. However, there was not enough good quality chlorophyll data from the SOTS site to cover all the PAR measurements. It was thought that perhaps a fixed value of the highest chlorophyll concentration observed at the SOTS site could be used as a lower bound, below which PAR could not fall. However, this would only work on a clear day, as high chlorophyll in combination with clouds could push the PAR values below this bound. Ultimately it was decided that this particular test would be too complicated to implement.

**How good do I think the data is?**

The main obstacle to quality control of this dataset is the fact that it is difficult to remove the impact of cloudy days on PAR at the SOTS site. This QC effort could be significantly improved if this was addressed.

Ways in which the tests could be more strict

* Doesn’t really flag the issues with SOFS 1, eg data not as high as it should be, some kind of calibration issue I think. Not low enough to fall into neighbour test. Still enough variation in the signal. Although I guess this is kind of a calibration issue rather than a sensor issue so maybe it’s ok we don’t catch it as long as we mention it?
* Depends how complex a neighbour test I get up and running but could comment on a more elaborate one

**Known issues not represented in the QC flags**

As mentioned earlier, it is thought that biospherical sensors mounted at the surface may also receive light reflected from the surface of the water. This is shown in the SOTS data with surface biospherical sensors producing PAR values much higher than those recorded by surface cosine sensors. This QC effort did not include a flag to indicate the fact that this issue is present in the data, but it is a factor that is important to take note of in any future analysis using the SOTS PAR data.

There were also known issues with the LiCor sensor deployed on SOFS 1. Due to calibration issues(? Check the details of this with Pete) the values recorded by this sensor were much lower than those recorded by a similarly placed sensor on all other deployments. Also make sure there’s no way of catching sensors that are lower than they should be?

Plots showing some of the issues discussed above

* Surface biospherical data and surface cosine data (also make note of sofs 1 licor
* Plots showing dip in 27m sensor compared to 50m sensor

# Data Plots for Each Deployment

Will put finished plots here once flagging is done

* Daily max and mean for each deployment or sensor?
* Could show the whole data set but I imagine will look pretty messy

# 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.

# 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.

Kirk, J.T.O. (1994), Light and Photosynthesis in Aquatic Ecosystems. Cambridge University Press, Cambridge.

McCree, K.J. (1972), Test of current definition of photosynthetically active radiation against leaf photosynthesis data. Agricultural Meteorology 10: 443-453.

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.

Names of R and Matlab files used for processing

Numbering is included in the style (Appendix A, Appendix B).

* 1. Insert text [style = Appendix Heading 2]

Sensor Calibration Sheets

Attached below are the calibration sheets for all PAR sensors deployed at the SOTS site.

|  |  |  |
| --- | --- | --- |
|  | | |
| CONTACT US  t 1300 363 400  +61 3 9545 2176  e csiroenquiries@csiro.au  w www.csiro.au  At CSIRO, we do the  extraordinary every day  We innovate for tomorrow and help improve today – for our customers, all Australians and the world.  Our innovations contribute billions of dollars to the Australian economy  every year. As the largest patent holder  in the nation, our vast wealth of intellectual property has led to more  than 150 spin-off companies.  With more than 5,000 experts and a burning desire to get things done, we are Australia’s catalyst for innovation.  CSIRO. WE IMAGINE. WE COLLABORATE.  WE INNOVATE. |  | For further information  Insert Business Unit name  Insert contact name t +61 0 0000 0000  e first.last@csiro.au  w www.csiro.au/businessunit  Insert Business Unit name  Insert contact name t +61 0 0000 0000  e first.last@csiro.au  w www.csiro.au/businessunit  Insert Business Unit name  Insert contact name t +61 0 0000 0000  e first.last@csiro.au  w www.csiro.au/businessunit |