frontiers

Supplementary Material

ProVal:

A new autonomous profiling float for high quality radiometric measurements

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A. The PROVOR CTS5

The PROVOR CTS5 was developed under a collaboration between NKE and the *Laboratoire d'Océanographe de Villefranche* (LOV) with the objective to build the next generation of Argo floats dedicated to new and more challenging applications. It has the same mechanical characteristics as the previous version (CTS4) with an overall length of about 2.20 m, a weight of 35 kg and a variable buoyancy of up to 2.5 L. As other PROVOR floats, the CTS5 is larger than other Argo floats such as Navis (Sea-Bird Scientific) or Apex (Teledyne Marine) floats and has greater capacity for carrying payload. This is especially valuable for the ProVal application for which the stability and verticality of the float are essential to perform high quality radiometric measurements. The PROVOR CTS5 differs from the CTS4 (Leymarie et al., 2013), currently used for the BGC-Argo program, by its new electronics boards. The CTS5 uses a double electronic board architecture: a navigation board to control the float itself and an acquisition board, interlinked with the first one, which controls data collection and processing. On the CTS5, the navigation board, named APMT (standing for *Automate Profileur Multi-Taches*) provides extended capabilities as compared to the CTS4. The navigation board manages the buoyancy of the float (i.e. drive the hydraulic system), the positioning of the float through a GPS receiver, the telemetry and the safety of the float. The software embedded on the navigation board allows for customization of the float mission. For example, it allows for up to 10 different profiling patterns executed one after another in a continuous loop. For each pattern, according to Argo standards, the user can define: the parking depth, the profile starting depth, the overall duration of the pattern or the meeting time at surface (synchronization mode) which could be defined with a precision of one minute.

All these parameters can be modified remotely thanks to two-way Iridium communication. An *end of life* mode triggered by the user through Iridium communication might force the float to stay at surface thus allowing its recovery if needed. APMT navigation-board implements also a new Iridium RUDICS (Router-Based Unrestricted Digital Internetworking Connectivity Solutions) protocol for telemetry. This protocol and the hardware capabilities of the APMT board allow a very high speed satellite communication with an average of 13 ko/min. As pressure data are needed for navigation, the APMT board also manages the CTD (SBE41CP, SeaBird Scientific) in the same way as usual PROVOR floats.

The APMT board is connected to and exchanges data with the acquisition board, named payload, developed by the OSEAN Company in collaboration with the LOV and taking advantage of a previous development (Hello et al., 2011). The acquisition board implements eight RS232 serial ports, each associated with a power switch, so that eight sensors can be controlled independently. The embedded software enables complex acquisition schemes defined with tunable XML parameter files while onboard resources allow advanced data processing if required. Sampling can be defined independently for each sensor and at any depth for each phase of the navigation (i.e. descent, parking, ascent and surface). Raw data can be recorded as individual frames or averaged over a given number of data frames. Data are tagged with time and with the latest pressure received from the CTD by the navigation-board (every 2s during the ascent phase).

The combination of the Provor CTS5 and of the *payload* board results from the need to improve mission flexibility of floats, either for integrating different types of sensors or to improve the observation capacity. The double board configuration is designed for such an objective. The navigation-board and its software usually remain unchanged and guarantee the robustness of the float whereas the acquisition-board is capable of hosting new sensors and on-board data processing that can answer specific scientific questions.

B. Navigation behavior

In this section we show the same plot as Figure 5-a in section 3.2 but for the 30 profiles used for OLCI match-ups which are supposed to coincide with good weather condition. As expected, tilt values are lower for these 30 profiles than for the entire database presented in section 3.2. For example, the amount of data with a tilt lower than 10°, in the Southern Ocean, increases from 51 to 60% for the "buoy" mode and from 41% to 61% for ascent data.

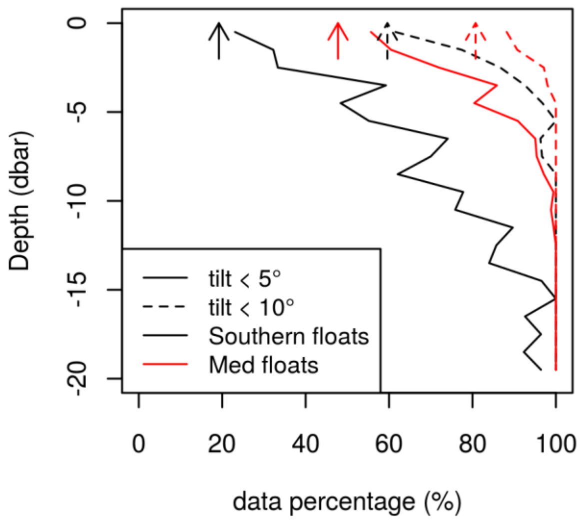

Figure a : Same plot as Figure 5 in section 3.2 but for the 30 profiles used for OLCI match-ups. Percentage of the data point below 5° (solid lines) and 10° (dashed lines) as a function of depth for the Southern Ocean (black) and the Mediterranean Sea (red). Arrows represent values during "buoy" mode.

C. Match-ups Profiles

In this section we show Irradiance and Radiance data collected by ProVal floats, in the shallowest 25 m for the 30 profiles selected for OLCI match-ups in section 3.6.

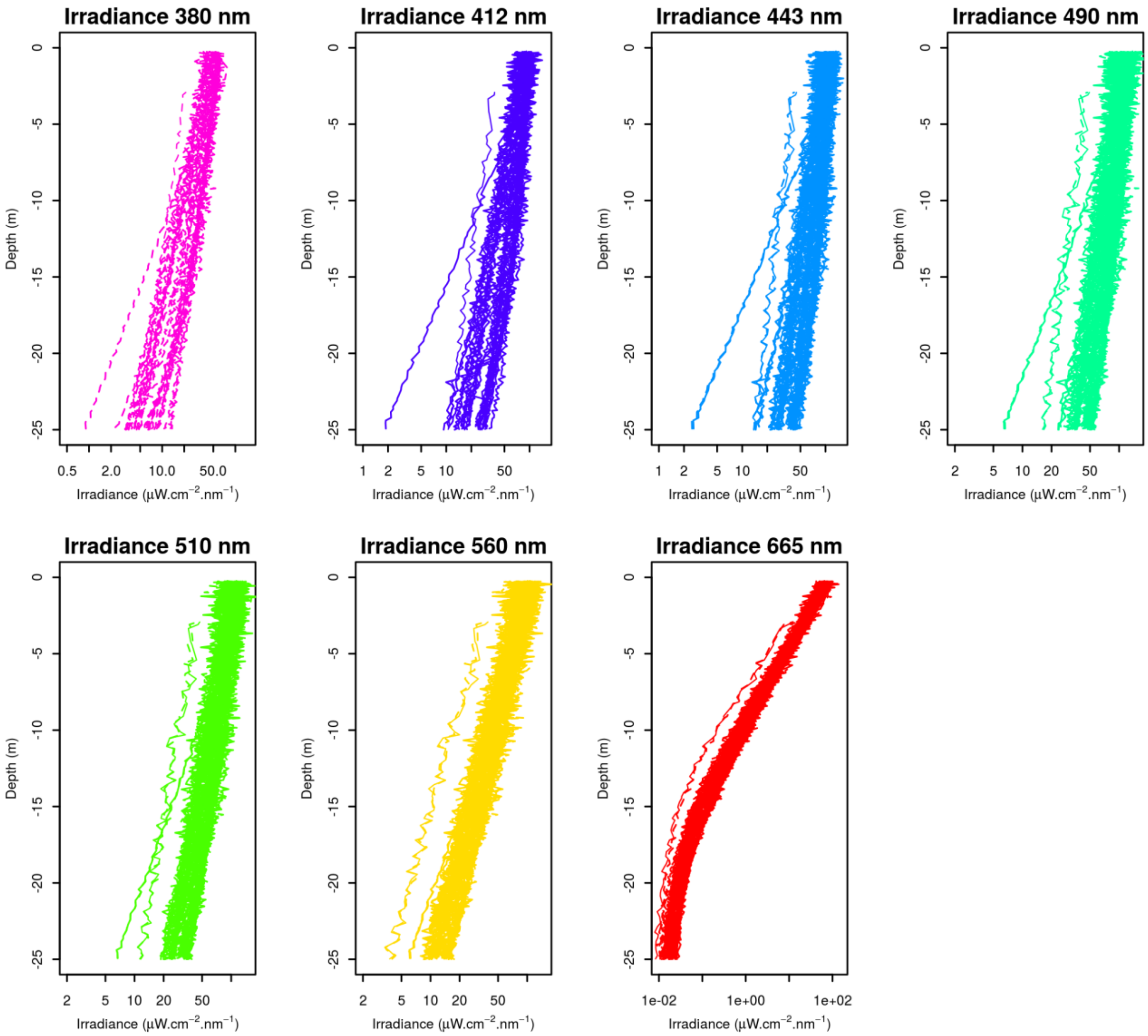

Figure b : Irradiance data in the shallowest 25 m for the 30 profiles selected for OLCI match-ups. Data with tilt > 10° are flagged.

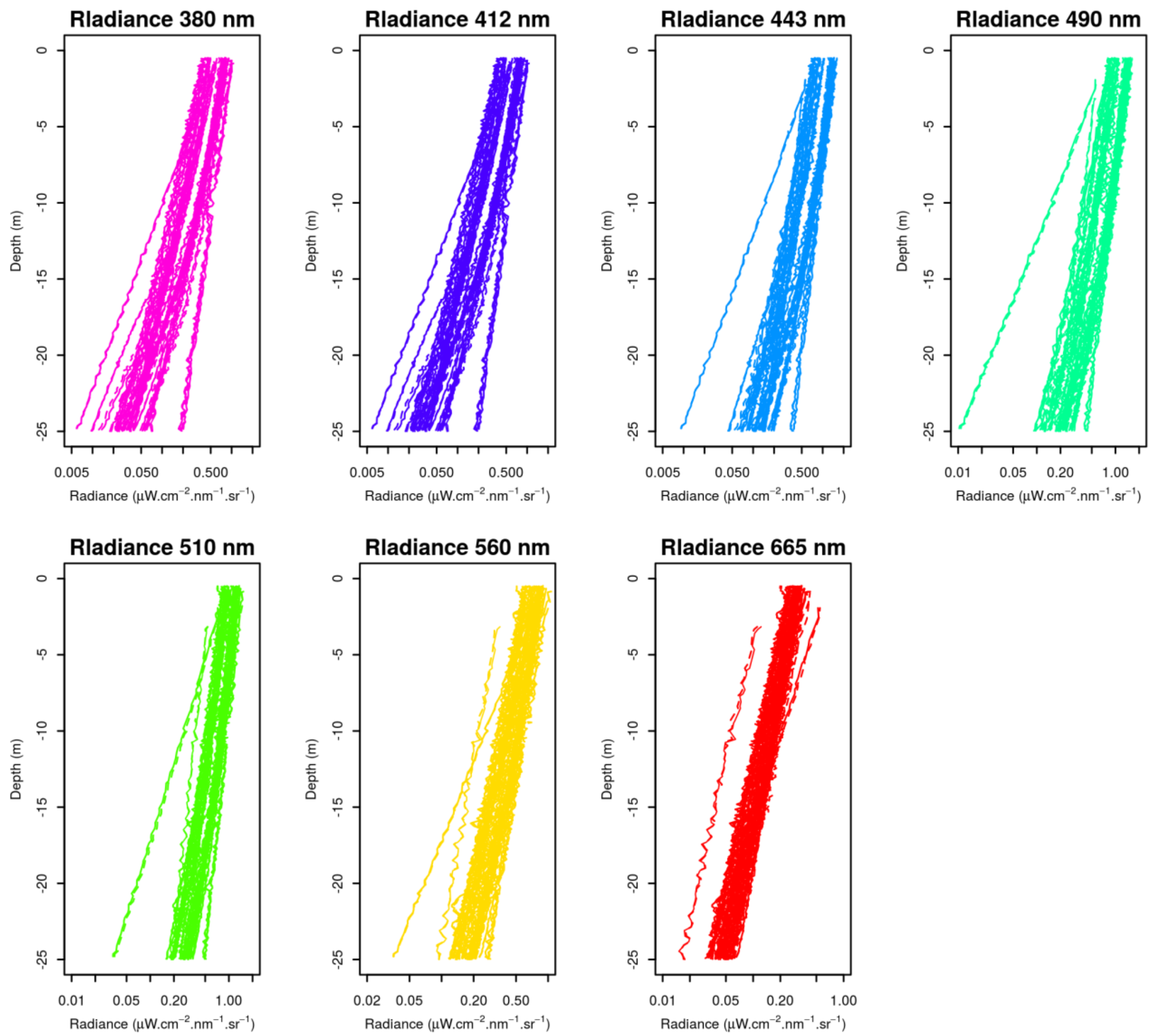

Figure c : Radiance data in the shallowest 25 m for the 30 profiles selected for OLCI match-ups. Data with tilt > 10° are flagged.

D. Match-up analysis

Normalized remote sensing reflectance (ρ_{wN}) spectra from OLCI were compared to the median of the four spectra provided by a ProVal float, according to section 3.6. We show here the result of the linear regression for each area. In the Mediterranean Sea, a slope of 0.932 (± 0.014) for all gathered wavelengths is found. This is substantially less than the value of 0.968 found for both areas. In the Southern Ocean, a slope of 1.11 (± 0.047) is found.

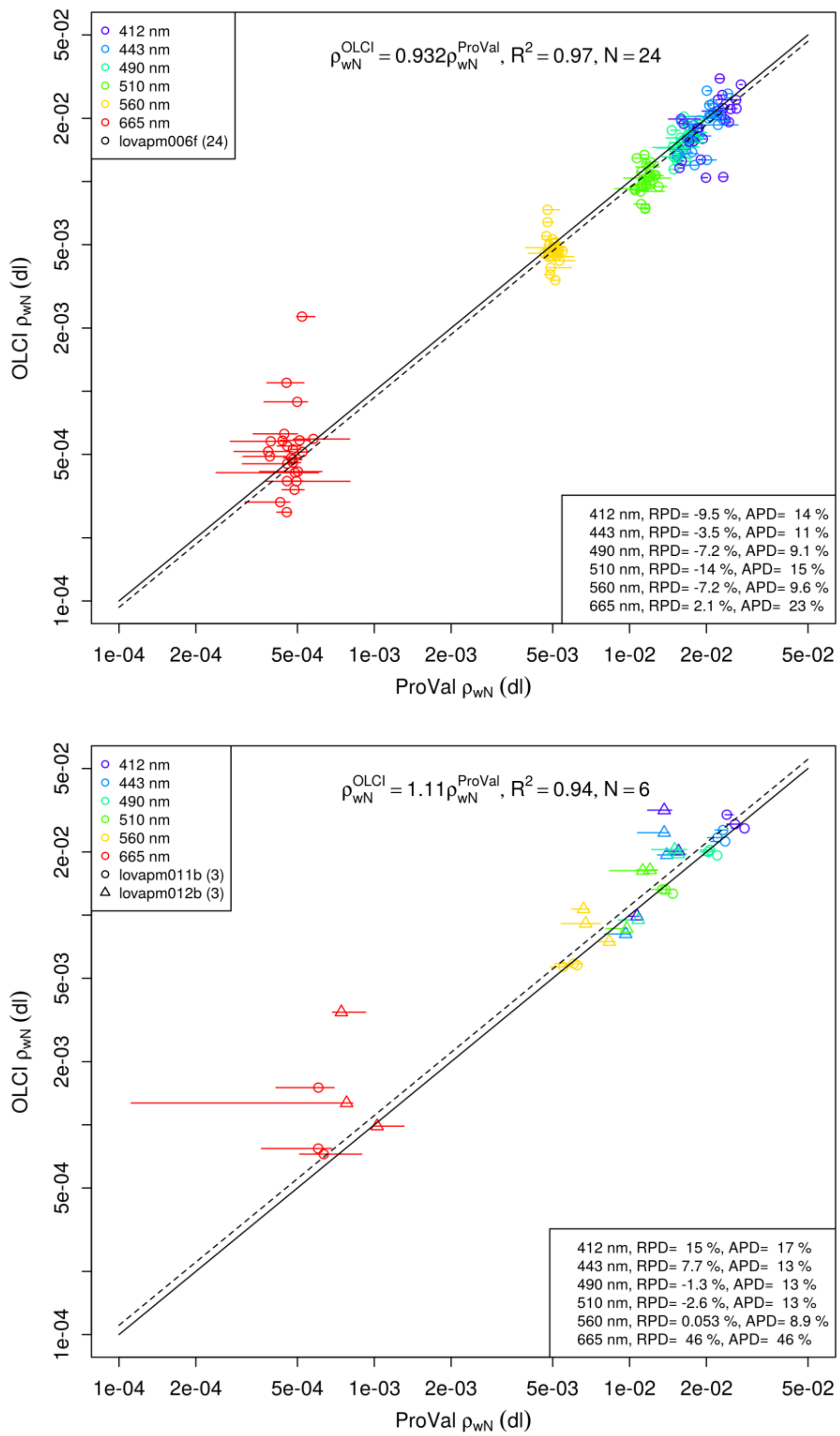

Figure d : normalized reflectance ρ_{wN} from OLCI and ProVals for top: Mediterranean (*lovapm006f*) and bottom: Southern Ocean floats (*lovapm011b* and *lovapm012b*). Error bars on the ProVal data are given by the minimum and maximum of the four normalized reflectance values. Solid line represents the 1:1

line while the dashed line is the linear regression. The number of match-ups for each float are given in brackets in the top-left legend.

E. Shading Estimation by Monte Carlo

Shading estimations was realized by using a 3D Monte Carlo code, named SimulO (Babin et al., 2012; Doxaran et al., 2016; Leymarie et al., 2010). A 3D backward Monte Carlo approach is used by merging two different simulations. In a first simulation (Figure e-a), called the “true case”, light propagates from a sensor point toward above water through a water column that is optically defined by a given set of Inherent Optical Properties (IOPs). Photons are followed from this (virtual) sensor point until their absorption by the medium or until their exit through the surface, above which no absorption and scattering occur (vacuum). The second simulation (Figure e-b), called the “shaded case”, uses the same water body but now includes the float structure as well. The structure (including the sensor itself) obstructs a certain amount of photon trajectories, thus causing shading on the sensor. Under both simulations, the photons that leave the surface are summed up into photon counters with finite solid angles as a function of their zenith and azimuth angles. The number of photons summed in each solid angle element of the above water hemisphere are compared between the two simulations, providing an estimate of the shading effect.

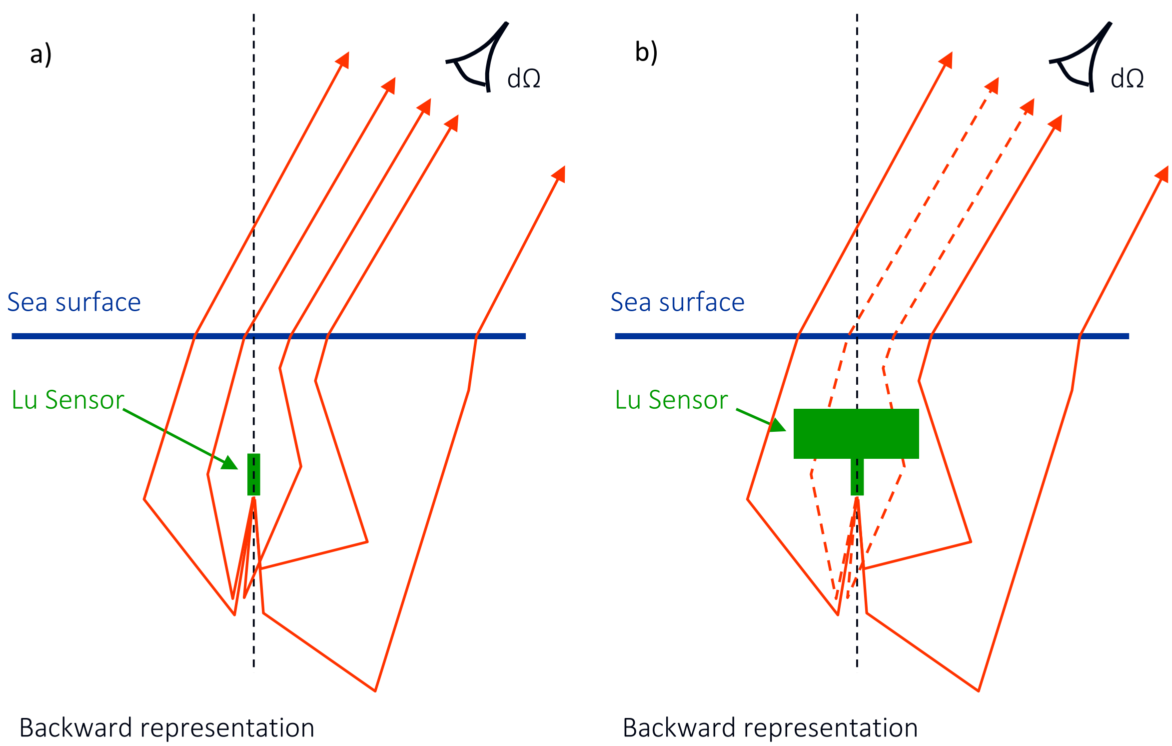

Figure e : description of the shading estimation method using two Backward Monte Carlo Simulation. a) First simulation with a transparent sensor. b) Second simulation with a real sensor which obstructs photons trajectories.

F. References

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