

The Argo CTD -- SBE 41/41CP CTD Module for Autonomous Profiling Floats (available exclusively through float manufacturers)

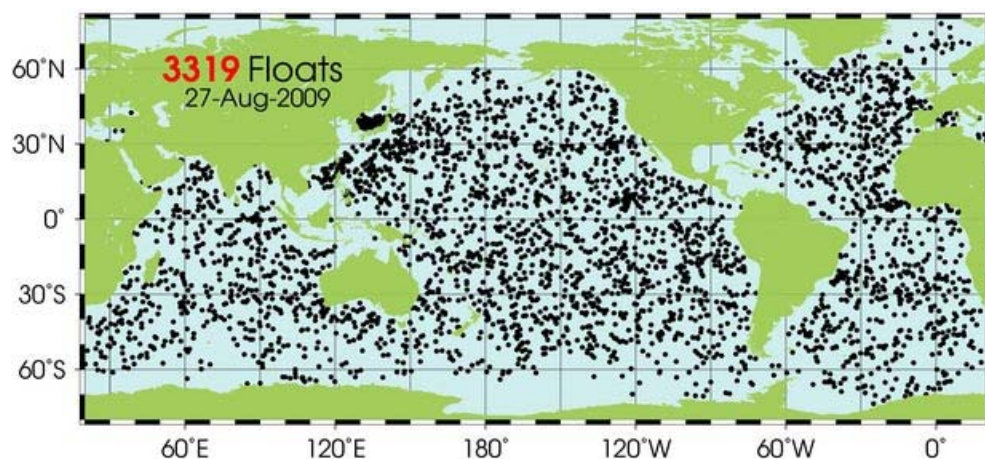
Introduction

The **SBE 41** CTD module was originally developed in 1997 for integration with a sub-surface oceanographic float called **ALACE** (Autonomous Lagrangian Circulation Explorer) (Davis, et. al., 1992). ALACE floats were neutrally buoyant at depth, where they were carried by currents until periodically increasing their displacement and slowly floating to the surface. At the surface, the ARGOS satellite system could determine its current position (http://www.argosinc.com/system_overview.htm). The long time-series of successive position data on hundreds of individual floats gave insights into deep ocean circulation.

Early in the evolution of ALACE floats, researchers added temperature and conductivity sensors to the float to obtain a temperature/salinity profile during the float's ascent to the surface. The ALACE float soon became known as **PALACE** (Profiling ALACE), and PALACE floats transmitted temperature and salinity data in addition to providing drift track data. However, the quality of the salinity data on early PALACE floats deteriorated quickly due to fouling. The Sea-Bird SBE 41 CTD module was developed in response to the scientific need for highly accurate salinity measurements that remained stable for the three to five year operational life of the PALACE float. The results have been truly remarkable. Today, SBE 41s are producing salinity data accurate to within 0.005 [PSU] for more than 3 years. The value of near-real-time oceanographic data transmission from multiple floats is evidenced by the ability of oceanographers to monitor and predict the influence of El Niño weather patterns on the surface of the North Atlantic Ocean (Riser, 1998).

The success of PALACE floats and the SBE 41 led to the **Argo Program**, which began in 1999 (<http://www.argo.ucsd.edu/>). The program goal was to establish and maintain a working population of 3000 floats dispersed throughout the world, transmitting near-real time temperature and salinity from the upper 2000 meters of the ocean. That goal was reached by the end of 2007; there are more than 3300 deployed floats as of August 2009, as shown on the float distribution map below.

Today, Sea-Bird manufactures approximately 1000 SBE 41/41CP CTDs per year, supplying more than 90% of the annual Argo program requirement as well as a growing market in non-Argo float applications.



Float deployment from vessel

Features and Specifications of the SBE 41/41CP Design

- The SBE 41/41CP uses the proven MicroCAT Temperature, Conductivity, and Pressure sensors. The CTD is shipped fully calibrated, and has demonstrated excellent long-term stability, eliminating the need for post-deployment tampering of the calibration to force agreement with the local TS.

Sensor	Calibration Standard	Accuracy	Stability
Temperature	ITS-90	0.002 deg C	0.0002 deg C/year

Conductivity	IAPSO Standard Seawater	0.002 (equivalent salinity)	0.001 / year (equivalent salinity)
Pressure	Deadweight tester & pressure reference	2 dbars	0.2 dbar

- The SBE 41/41CP has carefully engineered anti-foul protection, with anti-foulant devices, a U-shaped flow path, and a pump.
 - On the float's ascent, as the float approaches 10 – 5 decibars beneath the ocean's surface, the pump turns off. The U-shaped flow path prevents sea surface oils and contaminants from being ingested while proceeding through the ocean surface skin and sitting at the surface during data transmittal.
 - Between profiles the pump is off. The U-shaped flow path prevents water flow through the system caused by waves or currents; minute amounts of anti-foulant concentrate inside the conductivity cell to minimize bio-fouling.
- The SBE 41/41CP has proven TC-Ducted flow over the temperature sensor and into the conductivity sensor. Salinity spiking is minimized because the TC-Duct and pump precisely coordinate the T and C responses.
- The SBE 41/41CP premium strain-gauge pressure sensor has thermistor correction for ambient temperature effects.
- The SBE **41** pump delivers 40 ml/sec flow for 2.5 seconds per measurement of T, C, & P, and exhausts through a zero-thrust port. The SBE **41CP** pump delivers 30 ml/sec flow continuously during the profile.

The CTD sensors and electronics (shown below) are mounted to an Argo top end cap (satellite whip antenna not shown).



Photo A: Sea-Bird CTD module with guard installed.



Photo B: Module with guard removed to show conductivity cell.



Photo C: Module showing mounted PCB.



Photo D: Opposite side of Photo C, showing pressure sensor.

SBE 41 or 41CP?

Both the SBE 41 and 41CP measure conductivity, temperature, and pressure, and can be equipped to also measure dissolved oxygen (see *Recent Developments* below). The sensors on the SBE 41 and 41CP are identical; the difference lies in the circuitry and sampling protocols:

- The **SBE 41** spot samples on command. It has no internal memory, and transmits the data to the float controller as each measurement is made. The float controller stores the data, and transmits it when the float reaches the surface. This system is typically used with low bandwidth satellite telemetry such as Argos, which can accommodate only a limited stream of data.
- The **SBE 41CP** is designed to perform a **Continuous Profile**, sampling at 1 Hz as the float ascends to the surface, and storing the data in internal memory. The float controller requests and transmits the data when the float reaches the surface. The SBE 41CP can spot sample on command in addition to / in combination with continuous sampling. For example, a float can be programmed to spot sample in deep water, where parameters of interest are fairly stable, and then to perform a continuous profile as the float ascends through shallower depths, providing the desired level of detail while minimizing the data to be transmitted.

For both the SBE 41 and 41CP, the system can be programmed to transmit all the data, or just the parameters of interest (C, T, P; T and P; P only; or C, T, P, and D.O.).

Recent Developments

• **SBE 43I Oxygen Sensor integrated with Argo CTDs**

A number of SBE 43I oxygen sensors have been integrated with SBE 41/41CPs on deployed floats. The SBE 43I uses the same sensing technology and calibration techniques as the [SBE 43](#) (modular sensor for conventional CTDs, in production since 2001), but is optimized for use on Argo floats, with lower power consumption, smaller mass, and better dynamic accuracy ([click here](#) for more details).

• **Surface Temperature and Salinity Sensor (STS) integrated with Argo CTDs**

The trade-off for achieving sensor stability over the lifespan of the Argo floats was the forfeiture of very near surface temperature and salinity information to prevent ingestion of sea surface oils and contaminants into the conductivity cell. With increasing interest in measuring surface salinity in the world's oceans, Sea-Bird developed an integrated system that continues to gather high accuracy salinity and temperature data using the pumped SBE 41CP CTD between 2000 – 5 decibars, while co-deploying a free-flow sensor called STS in the upper 20 db to capture the surface temperature and salinity conditions. STS is a free-flushing sensor, and is expected to ingest sea surface oils and contaminants that may alter the sensor calibration over time. To correct any drift in STS, both the SBE 41CP CTD and the STS take measurements near the float park depth and again in the upper ocean, just before the SBE 41CP pump is turned off, and then STS continues sampling through the ocean surface. STS data can then be corrected by recalibrating it based on the comparison measurements to the clean data from the SBE 41CP ([click here](#) for more details).

SBE 41/41CP Manufacturing and Calibration



Argo CTD Calibration Baths and Controller



Argo "CTD heads" in various stages

Additional Information

(At right, Module mounted on a float at WRC)

[Argo Float Druck Pressure Sensor Micro-Leak Problem and Warranty Replacement \(2009\)](#)

Information on performance of SBE 41 / 41CP:

- [Accuracy and Stability of Argo SBE 41 and SBE 41CP CTD Conductivity and Temperature Sensors](#) (2008)

Information on development of a Surface Temperature Salinity sensor:

- [Measurement of Salinity and Temperature Profiles through the Sea Surface on Argo Floats](#) (December 2008)



- [STS: An Instrument for Extending Argo Temperature and Salinity Measurements through the Sea Surface](#) (March 2008)

General information about Argo floats, go to:

- [Teledyne Webb Research Corp.](#)
- [WOCE Subsurface Float Data Assembly Center \(WFDAC\)](#).
- [Robot buoys are taking the ocean's pulse](#), Seattle Times, April 2, 2008.

Information on Oxygen sensors integrated with the SBE 41 / 41CP:

- [SBE 41 brochure / specification sheet](#)
- [Assessing the Calibration Stability of Oxygen Sensor Data on Argo profiling floats using routine WOCE monitoring data from HOT](#) (2008)
- [A Year of Oxygen Measurements from Argo Floats](#) (2003)



References

Davis, R.E., D.C. Webb, L.A. Regier, and J. Dufour (1992) "[The Autonomous Lagrangian Circulation Explorer \(ALACE\)](#)", Journal of Atmospheric and Oceanic Technology, V9, 264-285.

Riser, S.C. (1998). "The Distribution of 18-Degree Water in the North Atlantic During the Autumn of 1997 and the Winter of 1998", AGU 1998 Ocean Sciences Meeting Presentation OS11J-04.

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