Evaluation of property change of pressure sensor installed on TRITON buoys

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Abstract A property change of strain gauges type pressure sensor installed on TRITON buoys was investigated for correction of pressure and salinity data. Output data from pressure sensors on deck after recovery indicated overestimated value as a result of hysteresis of pressure sensor. A value of overestimate surpasses 10 dbar in the most remarkable case, and it becomes an error of 0.005 psu by salinity conversion. It is critical for our aim of salinity measurement accuracy (0.02 psu). Moreover, sensor calibration data reveals larger influence of hysteresis under actual high-pressure condition. It is also obvious that hysteresis occurs at a stage put in high-pressure installed depth, at least 10 days mooring, and its value is different among each sensor. This result suggests that removal of a bias, which corresponds to hysteresis induced by calibration data, become effective.

Keywords: TRITON buoy, pressure sensor, hysteresis, salinity

1. Introduction

For the purpose of understanding for heat and fresh water budget on the western Pacific warm pool, the TRIangle Trans-Ocean buoy Network (TRITON) has been developed by Japan Marine Science and Technology Center, now Japan Agency for Marine-Earth Science and Technology (Kuroda and Amitani, 2001)[1]. The major advantage of the TRITON buoy is use of various meteorological sensors and Conductivity-Temperature-Depth (CTD) and CT sensors; the former enable us to calculate heat and momentum fluxes at the sea surface, and the latter is used to calculate salinity.

Salinity observations in the past were mainly conducted with CTD casts from research vessels, because it is difficult to keep conductivity sensor property. Moorings for salinity worry us with temporal property change of conductivity sensors. The property change of conductivity sensor misleads us into false interpretation for salinity variation. However, as a study of warm pool advanced, importance of a salinity variation in that region for large-scale air-sea interaction has been pointed out, and long-term mooring observation of salinity has been required.

During Tropical Ocean and Global Atmosphere / Coupled Ocean and Atmosphere Response Experiment (TOGA/COARE) period, moorings for salinity were carried out in the warm pool by National Oceanic and Atmospheric Administration / Pacific Marine Environmental Laboratory (McPhaden *et al*. 1990)[2]. Investigation of conductivity sensors installed on these moorings, Freitag *et al*. (1999)[3] showed that conductivity sensors installed in upper layer had a positive drift due to scouring effect by strong currents. This property change of conductivity sensor was also detected from TRITON moorings for a longer term (Matsumoto *et al*., 2001[4], Ando *et al*., 2005[5]). In previous study we demonstrated property change of conductivity sensors installed on TRITON buoys, and discussed about correction method of conductivity data because of acquisition of more precise salinity value.

As a next stage, we evaluate property change of pressure sensors in this paper. Since pressure is one of the parameters, which were used in salinity calculation, more precise pressure value brings more precise salinity value. This paper consists of five sections. Information for sensor and calibration system is shown with data description in section 2. As one evaluation of property change of pressure sensors, we show result of deck offset investigation in section 3. The property change under high-pressure condition is described in section 4. Finally, conclusions are summarized in section 5.

2. Data and calibration system

TRITON buoys have been deployed in western Pacific since 1998, and original planned array of 18 buoys, which contain 2 buoys in eastern Indian Ocean have been completed now (Fig. 1). Normally, 2 CTD and 10 CT sensors are installed on each 1-year mooring. The schematic figure of the TRITON mooring is shown in Fig. 2. Each CTD sensor is installed at 300 m and 750

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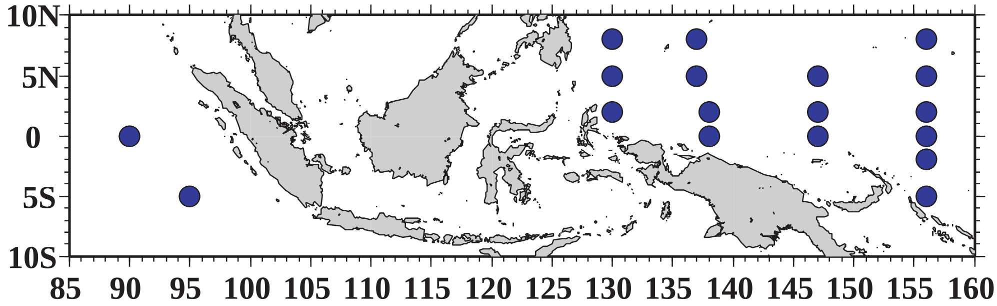

Figure 1: The location of TRITON moorings.

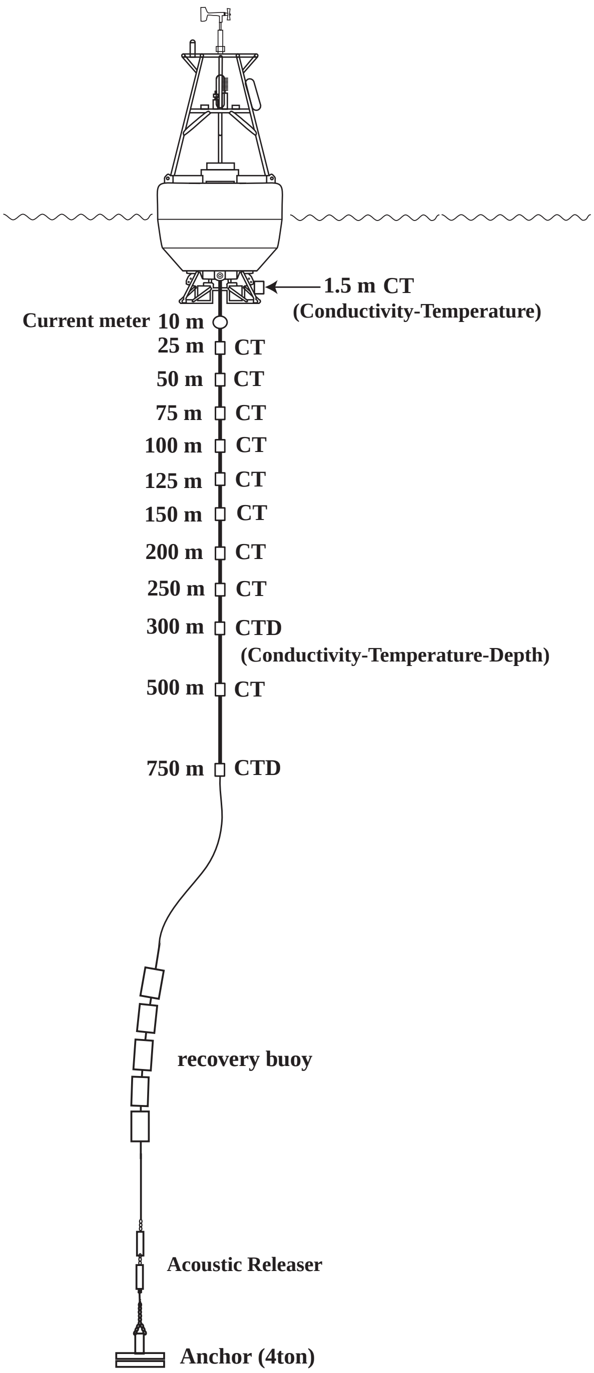

Figure 2: The schematic figure of a TRITON buoy.

m. Total 99 CTD sensors installed on 51 TRITON moorings deployed from 1998 to 2002 were used in this study.

We use Sea-Bird Electronics MicroCAT (SBE-37IM) with optional strain gauges type pressure sensor developed by Druck, Inc. Specifications of the pressure sensor are listed Table 1. The initial accuracy of the pressure sensor is 0.1 % of full-scale range, which corresponds to about 3 dbar.

Pre-deployment and post-recovery calibrations are carried out at Mutsu institute for Oceanography in Japan Agency for Marine-Earth Science and Technology. The calibration system is shown in Fig. 3. Calibration for pressure sensor is carried out through comparison with a reference sensor (Paroscientific digiquartz pressure sensor 42K-105; accuracy is about 0.2 dbar) in 5 points generated pressure with Budenberg Dead-Weight Tester model 480LA. The calibration points are 14.7 psia, 314.7 psia, 514.7 psia, 1014.7 psia, and 1514.7 psia. At the pre-deployment calibration, we decide coefficients for pressure observation, whereas we derive property change of pressure sensor at the post-recovery calibration.

3. Deck offset

Since CTD sensors installed on TRITON buoy usually start at a few days before deployment for initial check, pressure sensors measure deck pressure at that period. Because it is switched on during a few days after recovery of the buoy, pressure sensors continue measuring deck pressure as same as before deployment. The output value of the pressure sensor is set in convenience to become zero under a standard atmospheric pressure. The output value of pressure sensor on a deck appropriately calibrated becomes zero ideally. However, the output value on a deck is caused by accuracy of sensor and an atmospheric pressure change, and does not always become zero. We call the difference “deck offset”, but define it concretely with a daily mean value of pressure on a deck.

Table 1: Specifications of the pressure sensor installed on TRITON buoys.

Measurement Range	Initial Accuracy	Typical Stability (per month)	Resolution
0 to 3500 m	0.1% of full scale (about 3 dbar)	0.004% of full scale (about 0.1 dbar)	0.002% of full scale (about 0.05 dbar)

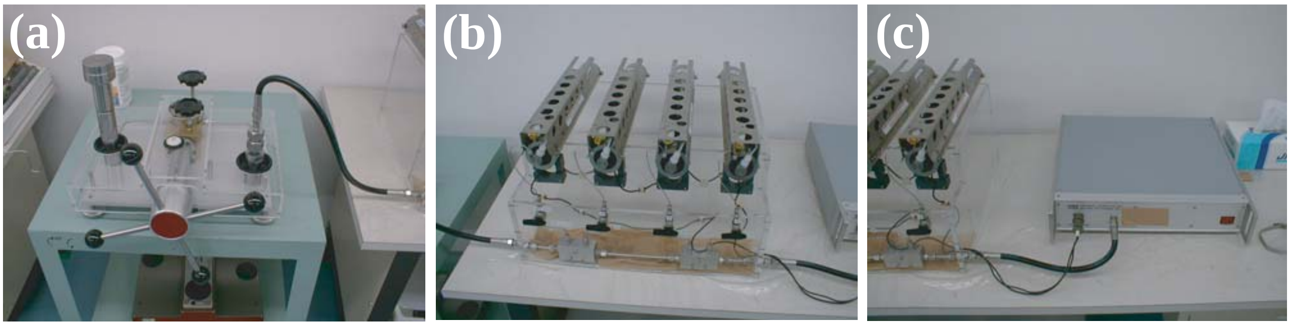

Figure 3: The pressure sensor calibration system. (a) Budenberg Dead-Weight tester model 480LA. (b) Pressure sensors (SBE-37IM). (c) Reference sensor (Paroscientific degiquartz pressure sensor 42K-105)

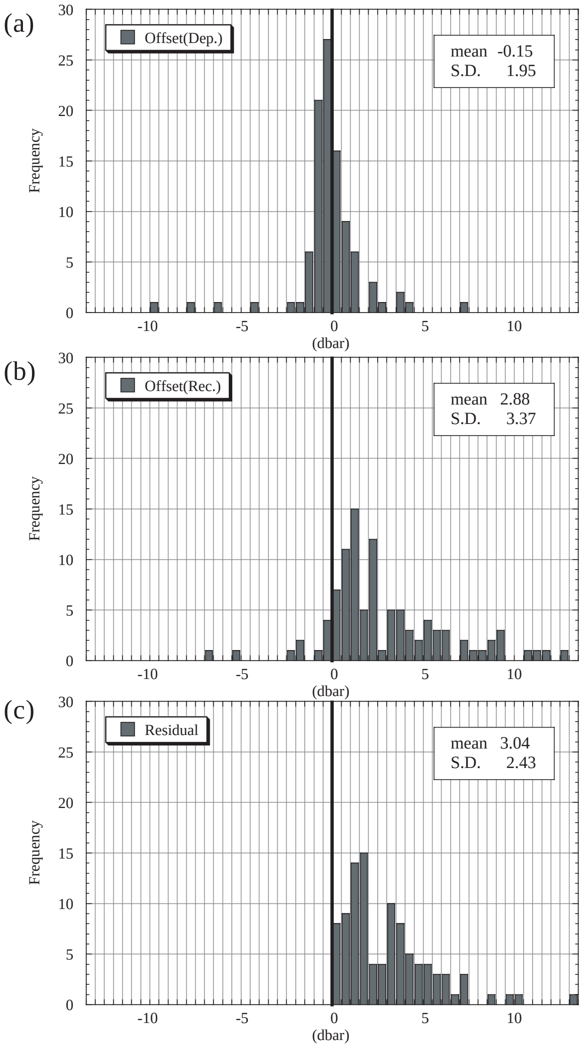

Figure 4: Frequency distributions of deck offset of pressure sensor. (a) Before deployment. (b) After recovery. (c) Differences of the both (off set after recovery minus that before deployment).

Frequency distributions of deck offset before deployment and after recovery are shown in Fig. 4 with that of differences of both. Deck offset before deployment (Fig. 4a) is distributed a lot in the vicinity of zero and most fit within 3 dbar of sensor accuracy. This means that pre-deployment calibration was appropriately carried out. On the other hand, frequency distribution of deck offset after recovery (Fig. 4b) reveals two significant features. One is shift of both of the mean and the median to positive direction, and the other is a large individual difference of deck offset. These features suggest that there is a property change of pressure sensor during mooring period. Moreover, frequency distribution of offset after recovery minus before deployment (Fig. 4c) indicates that all sensors changed in quality to overestimated pressure. The largest value of the overestimated pressure is over 10 dbar.

Figure 5 shows time series of pressure at 750 m on 5N 156E. As shown in this figure, amplitude of pressure variation is usual around 5 dbar. The overestimated value of 10 dbar is larger than this usual amplitude of pressure variation. A 10-dbar difference from actual pressure value at 750 m induces a 0.005-psu difference from actual salinity. Therefore, this pressure difference becomes critical for salinity measurements of the order of 0.01 psu, which affects aim accuracy (0.02 psu) of TRITON. Values of the overestimated pressure become large with increasing depth and dispersive more with increasing mooring days (Fig. 6). This property change of pressure sensor after recovery suggests hysteresis caused by condition of high pressure during moorings.

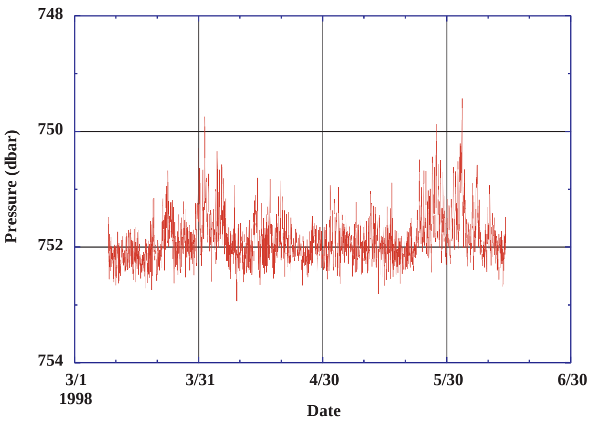

Figure 5: Time series of pressure measured with sensor installed at 750 m on 5N 156E from 01 March 1998 to 30 June 1998.

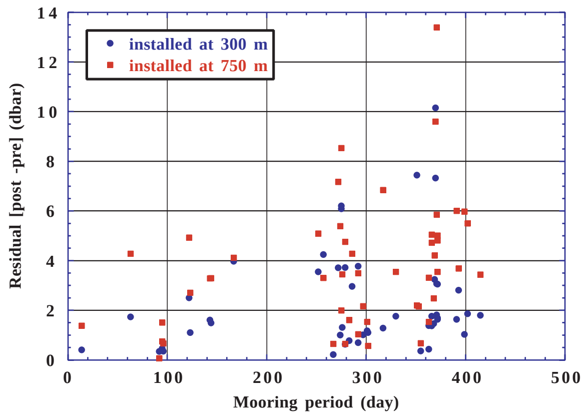

Figure 6: The time dependence of deck offset of pressure sensor. The blue closed circle indicates deck offset for sensors installed at 300 m, and the red closed rectangle indicates that for sensors installed at 750 m.

4. Hysteresis under high pressure

In the previous section, property change of pressure sensor after recovery under atmospheric pressure called hysteresis was investigated from pressure data on deck. However, we have to evaluate hysteresis under high pressure for understanding influence of hysteresis under actual pressure (not atmospheric pressure).

Some statistical quantities of hysteresis at 5 points of the calibration pressures are shown in Fig. 7. Although the calibration is done both at compression and decompression process, a clear difference in hysteresis induced from both is not seen. There is no large difference in hysteresis in sections from 14.7 psia to 314.7 psia, and the value is a few dbar on average. Values of hysteresis, however, become large with increasing pressure over 314.7 psia and show 6 dbar at 1014.7 psia and 12 dbar at 1514.7 psia, in average. This result suggests that an

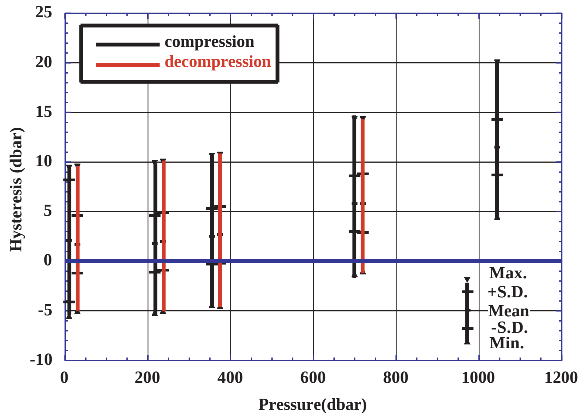

Figure 7: Statistical quantities of hysteresis of pressure sensors at 5 points of the calibration pressure; 14.7, 314.7, 514.7, 1014.7 and 1514.7 psia. The black line indicates for compression phase and the red line indicates for decompression phase.

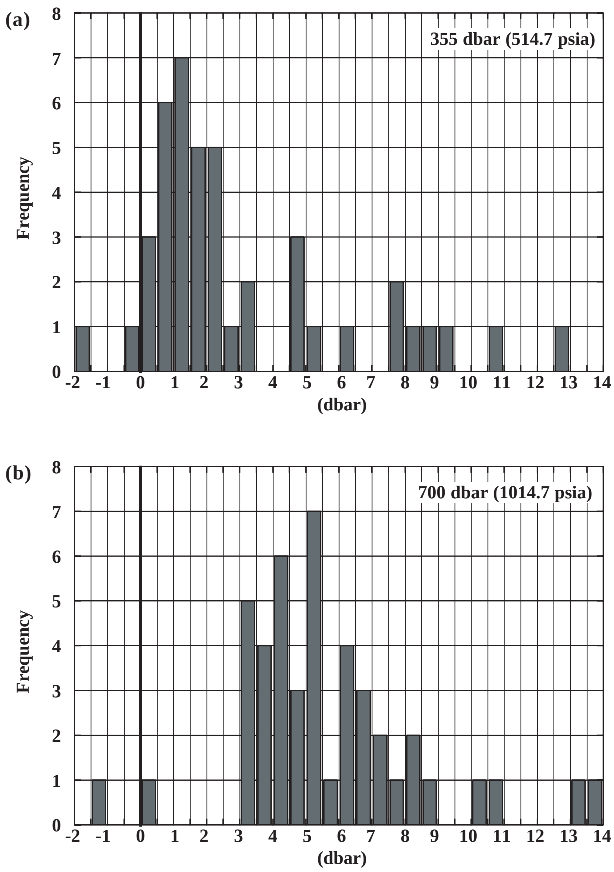

Figure 8: Frequency distribution of hysteresis of pressure sensor installed at (a) 300 m and (b) 750 m.

evaluation of actual influence of hysteresis at installed depth is inadequate only by deck offset under atmospheric pressure.

Since pressure sensors of TRITON buoy were installed at 300 m and 750 m as described section 2, we

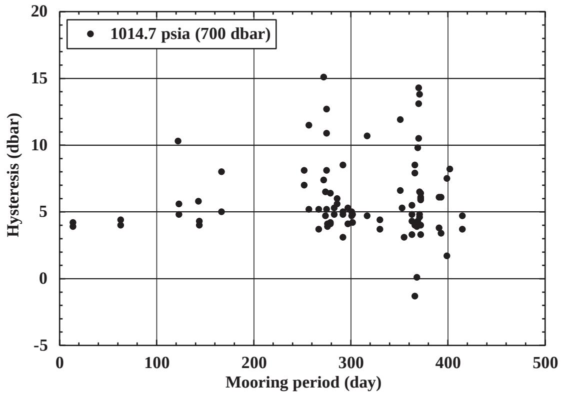

Figure 9: The time dependence of hysteresis of pressure sensor at pressure of 1014.7 psia.

investigate hysteresis on corresponding calibration pressure according to installation depth. By frequency distribution of hysteresis of pressure sensors installed 300 m (Fig. 8a), it was shown that average is 3.0 dbar and median is 1.6 dbar. On the other hand, concerning to hysteresis of pressure sensors installed 750 m (Fig. 8b), average is 5.6 dbar and median is 5.2 dbar. As shown in these figures, it is obvious that a value of hysteresis of pressure sensor installed deeper layer become large. A characteristic of hysteresis as a function of the mooring days is indicated in Fig. 9. It shows that hysteresis does not depend on the mooring days and occurs at a stage put in high-pressure condition, at least 10 days mooring. In addition, it is clear that value of hysteresis is different with a sensor by the same mooring days.

5. Summary

We investigate property changes of strain gauges type pressure sensor installed on TRITON moorings. It is apparent from deck offset analysis that our pre-deployment calibration was successfully performed and property of recovered pressure sensors changed to indicate overestimated pressure, which is called hysteresis. A value of overestimate surpasses 10 dbar in the most remarkable case, and it becomes an error of 0.005 psu by salinity conversion. It is critical for our aim of salinity measurement accuracy (0.02 psu).

Calibration data revealed that hysteresis under high-pressure condition work more effective compare with that under atmospheric pressure. A value of hysteresis under 700 dbar surpasses 5 dbar on average and 13 dbar in the most remarkable case. The result suggests that hysteresis has a larger value if a pressure sensor is installed in a higher pressure.

Hysteresis is appeared at least 10 days mooring and does not seem to depend for a mooring period. Rather values of hysteresis are different with an individual sensor, and it becomes important to grasp a property change of a pressure sensor individually.

As for the correction to get more highly precise data, the bias removal induced by calibration data is proper if we consider a property change of a pressure sensor described above. In addition if more highly precise observation or observation in deeper depth is need, the use of a digiquartz type pressure sensor is effective.

Acknowledgments

We would like to thank the staff who maintain the TRITON buoys. The deployment and recovery of TRITON buoys have been carried out R/V MIRAI and R/V KAIYO. We also wish to acknowledge efforts of captain and crew of these vessels.

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(Received December 22, 2004)