序

気象研究所海洋研究部では1979年以来、気象庁及び神戸海洋気象台の協力の下に、海洋大循環の解明のための一手段として、流速計を用いた海中設置型の係留系による直接測流観測を実施してきた。これらの観測に用いた流速計は、1990年代後半まではアーンデラー社製のもので、測定原理としてはローターとベーンを用いて器械的に流速(スピード)と流向を測定するものであった。当時、アーンデラー社製品の評価は高く、全世界で類似製品のうち90％に及ぶ普及率であった。しかし、その測定原理の故に、微弱な流速に対しては感度が悪いという欠点があり、当研究部の観測でも流速の弱い海洋深層での測流においては相対的に低い測定精度であった。

1990年代以降、器械的運動を伴わない新たな測定原理による流速計が次々と開発された。当研究部においても経常研究「西太平洋における中・深層循環の定量化」(平成10〜14年度)での赤道域における深層測流の開始を機に、超音波の位相のずれを測定原理とするFSI社製の流速計を次期の主力とすべく整備していった。ここで問題はそれら新旧２種の流速計のキャリブレーションであった。それを行うために、赤道域での深層測流用係留系において約１年に及ぶ比較観測を延べ５回にわたって、上記経常研究及び後続の「高解像度（渦解像）海洋大循環モデルの開発とそれによる水塊の形成、維持、及び変動機構の解明」（平成15〜19年度）において実施した。その内の１回ではさらに他の新機種２台を加えて４機種による比較観測を行った。

本技術報告はそれらの比較観測結果を示すものである。そこから見えてくるのは、旧来型はもちろんのこと、新機種においてもそれぞれに特有の測定誤差を含んでいるということである。特に、大きな水圧のかかる深海では予想外に大きな誤差を生じる場合もあることが示された。これらのテスト結果は深層測流を行っている研究者には貴重な情報である。旧来型の流速計もまだ多く使用されているのが実情であり、その誤差に関する情報は内外の関係者に役立つものと考えられる。

これらの観測の実施に当り、多大のご協力をいただいた、気象庁、神戸海洋気象台の関係者の方々、また、一部流速計の借用を快諾していただいた企業の方々にこの場を借りて御礼申し上げる。

海洋研究部長　石崎　廣

Preface

In the Oceanographic Research Department of the Meteorological Research Institute (MRI), we have long made direct observations of *in situ* currents at various depths to elucidate the ocean general circulation, by means of moored current meter systems since 1979, under the cooperative efforts by Japan Meteorological Agency (JMA) and Kobe Marine Observatory (KMO). The current meters used until the 1990s were manufactured by Aanderaa Instruments, and use a mechanical rotor and vane system to measure current speed and direction. In those days, the Aanderaa current meters were well appreciated, having a worldwide market share greater than 90%. However, they have a low sensitivity to weak currents because of the principle behind their current measurements. Therefore, in our measurements of deep-sea currents, they were not accurate because the current speeds there were usually very weak.

In the 1990s, development began of current meters based on new principles of measurement, without mechanical movement. One of them was a current meter using the phase shift of supersonic waves as the principle for current measurements, manufactured by Falmouth Scientific Inc. (FSI; Cataumet, MA, USA). In our research department we prepared this kind of current meters as the next generation of current meters in time to take advantage of the start of mooring observations near the equator in 1998. However, there arose the problem of calibration between the two kinds of current meters. To accomplish this calibration, we made parallel observations five times in the deep mooring system near the equator, with each set of observations lasting about one year. In one of the five comparisons, two other types of current meters were added, so four types of current meters were used for that set of parallel observations.

This report presents the results of the comparisons from the parallel observations. We found that even the new types of current meters have their own inherent measurement errors. In particular, a few cases showed that unexpectedly large errors occurred in the deep ocean under conditions with extreme pressure. We think the results of our comparison contain important information for researchers occupied in field observations at home and abroad. The classic type of current meter is often used even today, in addition to the new types, so that information about their operating characteristics is useful.

The parallel observations were carried out as part of two projects funded by MRI's

ordinary budget: ‘Quantitative study of the intermediate and deep circulation in the western Pacific’ (1998–2002) and ‘Development of high-resolution (eddy-resolving) ocean general circulation model, and study on formation, maintenance, and variation mechanisms of water masses based on the model’ (2003–2007). We thank the people at JMA and KMO for their cooperative efforts in carrying out the observations. We also thank Alec Electronics Company for providing us two other types of current meters for our parallel observations.

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概　　要

4 種類の流速計（RCM8：アーンデラー社製・ローターとベーンタイプ、3D-ACM：FSI 社製・超音波位相差、Compact-EM (EM)：アレック電子社製・電磁式、RCM11：アーンデラー社製・超音波ドップラー式）のデータの比較を、赤道近傍の約 1 年間の深層測流観測結果をもとに行った。また、4 回の RCM8 と 3D-ACM の比較観測結果もあわせて解析した。平均流速は、RCM8 が最も弱く、RCM11 は、3D-ACM と EM よりやや弱かった。3D-ACM と EM の平均的な流速と流向はよく一致していた。RCM8 の流向には、他の流速計と比較して系統的に非対称的な差があった。すなわち、RCM8 と他の流速計の流向の差（RCM8 の流向－他の流速計の流向）は、流速との間（2～10 cm s^{-1}）に負の相関があった。流速が弱いほど、流向の差が大きい。さらに、RCM8 と 3D-ACM の比較では、10 cm s^{-1} より強い流れの時における流向の差が零ではなく、15°～30°の範囲で 安定して存在する場合があった。時間平均流の流向差は、これらの差を反映している。3D-ACM と EM の流向については、異なったトレンド及び突然の背景誤差変移がみられた。

Abstract

We compared the data from four types of current meter: rotor and vane (model RCM8; Aanderaa), acoustic phase shift (3D-ACM), electromagnetic (Compact-EM [EM]), and Doppler backscatter (RCM11; Aanderaa). The data were obtained from deep-ocean moorings near the equator for a period of one year. We also analyzed data from four additional parallel observations by RCM8 and 3D-ACM meters. The mean current speed of the RCM8 meter was the lowest, and that of the RCM11 was lower than the EM and 3D-ACM. The mean current speed and direction data of the 3D-ACM and EM current meters were in good agreement. There was a systematically asymmetric difference in the current direction indicated by the RCM8 as compared to the other meters; that is, the difference in direction between the RCM8 and the others is inversely correlated with the current speed in the medium velocity range of 2 to 10 cm s^{-1}. We found that the lower the current speed, the greater the difference in direction. Furthermore, a comparison of paired RCM8 and 3D-ACM meters indicated that the difference in direction for large speeds exceeding 10 cm s^{-1} was consistently high, ranging from 15° to 30° in some situations, not near zero. The time-averaged difference in direction reflects these differences. Two current meters, models 3D-ACM and EM, exhibited different temporal trends and abrupt offsets in direction during the observations.

Contents