MEAN SEA SURFACE HEIGHT OF THE WORLD OCEAN USING ARGO FLOAT AND ALTIMETRY

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ABSTRACT

TOPEX/Poseidon and Jason-1 observe sea surface height anomaly from mean sea surface height temporally averaged from 1993 to 1999. To reconstruct absolute sea surface height, mean sea surface height averaged for the same period, is needed. In this study, we combined Argo and satellite altimetry, and made mean sea surface height in the world ocean. Obtained mean sea surface height by this approach has two characteristics. Firstly, it fits to satellite anomaly because it is time mean value from 1993 to 1999. Secondly, it is located along satellite orbit where altimeters observe sea surface height anomaly. The mean sea surface height field obtained in the present study revealed significant difference from one estimated using climatology of temperature and salinity profiles in World Ocean Atlas 2005, especially in the western part of each open ocean.

1. INTRODUCTION

Altimeter data measured by TOPEX/Poseidon (T/P) and Jason-1 are sea surface height anomalies (SSHA) from mean SSH (MSSH) field averaged for a certain period (actually 1993-1999), since we do not know an accurate geoid at present. Therefore, MSSH field is needed to reconstruct actual SSH field using altimeter SSHA. However, the lack of an accurate MSSH field still prevents us to compute accurate SSH from SSHA measured by satellites.

In order to obtain MSSH, various attempts have been made so far. Among them, [5] constructed MSSH field of the North Atlantic using historically archived hydrographic data. However, they pointed out the mismatch between SSHA and MSSH because of different averaging period for MSSH. A unique method to construct MSSH was proposed by [3]. In their method, so-called 'match-up' data in time-space domain between hydrographic data and altimeter data were used to calculate MSSH. However, inadequate numbers of hydrographic data prevented them from MSSH estimation without additional mathematical treatments, such as extrapolation for temperature and salinity (T/S) data, horizontal interpolation of SSHA, and an optimal interpolation using climatological T/S data.

In the present study, we use the Argo float data instead of ship observation data as hydrographic data, since Argo float data distribute densely in time-space domain in the world ocean. Purpose of this study is to estimate new MSSH field of the world ocean using altimeter data and Argo float data, based on the method proposed by [3].

Section 2 explains the used data. In Section 3, analysis method is described, and MSSH is estimated by applying match-up conditions to Argo float data and altimeter data. A summary is presented in Section 4.

2. DATA

The altimeter data were those measured by TOPEX/Poseidon and Jason-1 along its orbits, distributed by AVISO (Archiving, Validation and Interpretation of Satellite Oceanographic) data center. These data were given as SSHA based on its time MSSH from 1993 to 1999, with spatial resolution 7km along its orbits every 10days in all most oceans. The period used in this study was from September 1992 to October 2002 (TOPEX/Poseidon) and from August 2002 to December 2008 (Jason-1). Conventional geophysical and atmospheric corrections (tides, wet and dry tropospheric corrections, ionospheric correction, sea state bias, instrumental drift and bias) were applied to the data, as recommended by AVISO.

Argo profile data provided by GDAC (Global Data Archive Center) from January 2000 to December 2008 in the world ocean was used, including two types of data (real time mode and delayed time mode). Eliminated profiles with less than 10 sampling layers, and deleted profile whose physical property was flagged as bad or probably bad. We removed profiles which took obviously abnormal values of temperature and salinity. The selected data were used after each profile was interpolated vertically on 1 dbar grid using the Akima spline in [1], and in situ density was calculated from the interpolated temperature and salinity data. When Argo T/S profiles were unavailable below 1500 dbar, we used the climatological T/S profiles of the World Ocean Atlas 2005 ([4] and [2], hereafter WOA05) on 1° x 1° (latitude x longitude) grid. SSH dataset was prepared through integration of specific volume anomaly profile from reference level (2000db).

3. RESULT

By subtracting SSHA from SSH estimated using temperature and salinity profile, we can obtain MSSH as follows;

$$\mathrm{MSSH}\ (r) = \mathrm{SSH}\ (t, r) - \mathrm{SSHA}\ (t, r) \qquad (1)$$

only when two measurements, altimeter and Argo float, satisfy exact coincidence of observation in time and place. However, we cannot expect the exact coincidence in place and time between satellite altimetry and Argo float observation. So it is needed to loosen match-up condition from exact coincidences. This match up condition comes from temporal and spatial behavior of SSH variation, because obtained MSSH directly depends on SSH difference accompanied with gap from exact coincidence. Here, we estimated temporal and spatial decorrelation scales of SSH, where spatial lag correlation coefficient of SSHA along orbit drops to 0.9. Its spatial scales are ranging from 10 to 50km along ascending and descending orbit, and temporal scales are from 1 to 6days (not shown).

Match up between Argo and satellite altimeter was done under the match up condition. When there are plural match-up data at a given altimetry foot point, averaged MSSH and standard deviations are calculated. MSSH is estimated at each of altimeter foot points. Obtained MSSH is shown in Fig 1. As you can see, the MSSH located at each foot points covers in the world ocean almost uniformly, although a little bit dense in Kuroshio and its extension region, less along 15S of Atlantic Ocean. And it indicates well-known patterns such as higher MSSH in subtropical and lower in subarctic gyre and around the Antarctic Continent. As for subtropical region, top of MSSH is 320cm in North Pacific Ocean, 270cm in South Pacific Ocean, 260cm in North Atlantic Ocean and 290cm in Indian Ocean. All of them take maximal value, and their places are just equator side of western boundary current in common (see Fig 2). Bottom is 150cm at center of subarctic gyre in North Pacific. In terms of arctic region south of Antarctic circumpolar current, MSSH is over 50cm. Compared to MSSH calculated from T/S climatology data of WOA05, MSSH at top and bottom is heavily smoothed from 10 to 30cm, although the difference is within 10cm around the Antarctic Continent and South of Greenland. This difference simply comes from difference of temporal smoothing span (7-years and several decades to hundred years) and spatial smoothing span (10 to 50km (not shown) and more heavily). Magnified Fig 1 to see MSSH field in four western boundary current regions (Fig 2). It is seen that spatial pattern of MSSH along satellite orbit form western boundary current such as Kuroshio. Especially, recirculation gyres appear clearly south of Kuroshio and Gulf Stream. The standard deviations of MSSH can be regarded as a kind of error of obtained MSSH. Although the standard deviations are less than 4cm at almost all the updated points, a few large values exceeding 8cm can be seen in Kuroshio and Gulf Stream region, which may reflect existence of energetic eddies there (not shown).

4. SUMMERY

In this study, we obtained new MSSH along altimeter orbits in the world ocean, by match-up between altimeter and Argo data. This MSSH distributed along satellite foot points, and each MSSH was mean value averaging from 1993 to 1999, which fit to satellite anomaly, because of the same averaging period. Western boundary current were reproduced under the assumption of geostrophy, and large MSSH difference from 10 to 30cm were found around there through the comparison with climatological data. This was simply because of temporal smoothing period and spatial smoothing span. Total accuracy was 5cm.

This field is expected to use for reconstruction of SSH every 10days for all altimeter mission from 1992 to on going because it allows us to add altimeter SSHA to this MSSH strictly, from reason described above. However, reproduced SSH from this approach is SSH based on concept of no motion current (2000db here), and this is disadvantage of this MSSH.

REFERENCES

1. Akima, H. (1970), A new method of interpolation and smooth curve fitting based on local procedures, *J. ACM*, 17, 589-602.
2. Antonov, J.I., R.A. Locarnini, T.P. Boyer, A.V. Mishonov, and H.E. Garcia (2006), *World Ocean Atlas 2005*, vol. 2, *Salinity*, *NOAA Atlas NESDIS 62*, edited by S. Levitus, 182pp., U.S. Gov. Print. Of., Washington, D.C.
3. Kuragano, T., and A. Shibata (1997), Sea surface dynamic height of the Pacific ocean derived from TOPEX/POSEIDON altimeter data: Calculation method and accuracy, *J. Oceanogr.*, 53, 585-599.
4. Locarnini, R.A., A.V. Mishonov, J.I. Antonov, T.P. Boyer, and H.E. Garcia (2006), *World Ocean Atlas 2005*, vol. 1, *Temperature*, *NOAA Atlas NESDIS 61*, edited by S. Levitus, 182pp., U.S. Gov. Print. Of., Washington, D.C.
5. Willebrand, J., R.H. Käse, D. Stammer, H.H. Hinrichsen, and W. Krauss (1990), Verification of Geosat sea-surface topography in the Gulf-Stream extension with surface drifting buoys and hydrographic measurements, *J. Geophys. Res.*, 95, 3007-3014.

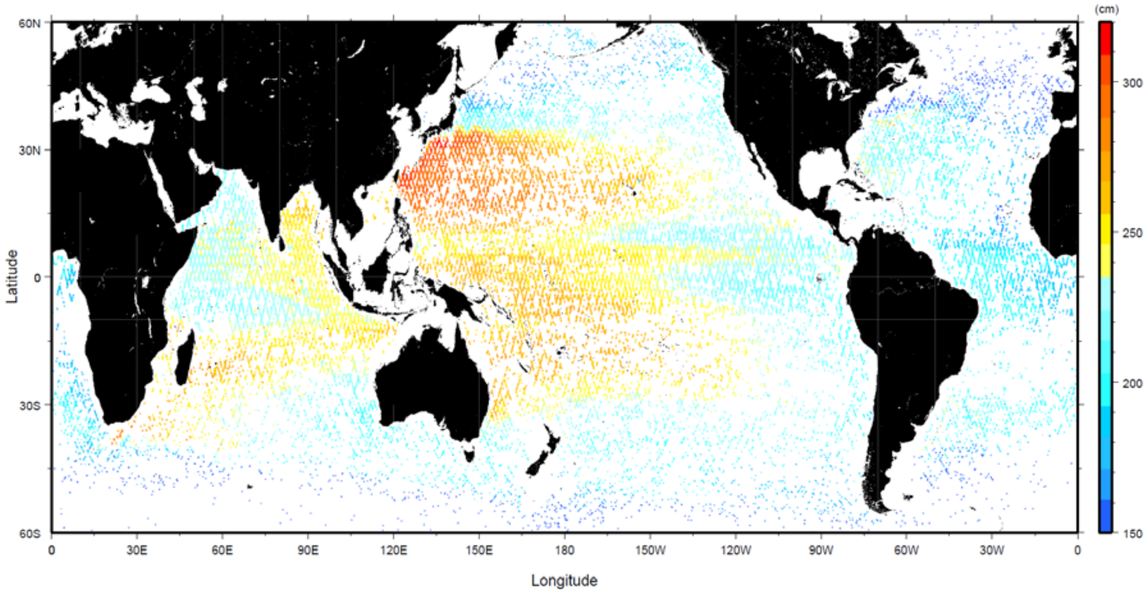

Figure 1. Obtained MSSH (cm) at satellite foot points averaged from 1993-1999 (refers to 2000db).

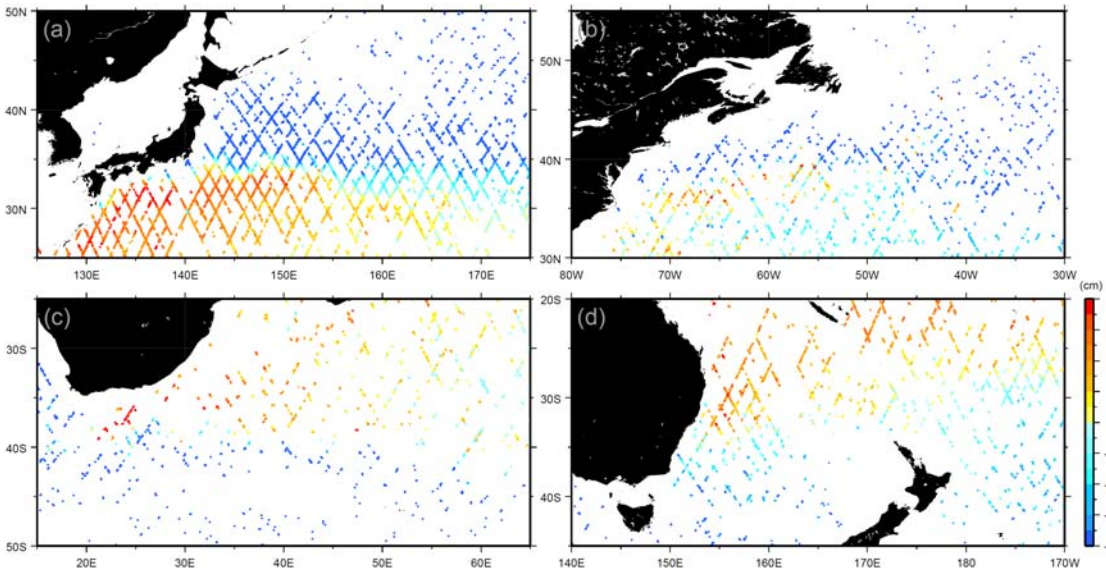

Figure 2. Relative value of obtained MSSH (cm) in Fig 1 in four western boundary current regions. The standard level through (a) to (d) is 270cm, 220cm, 240cm and 240cm, respectively.