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First accuracy assessment of the HY-2A altimeter sea surface height observations: Cross-calibration results

Lifeng Bao [a,*], Peng Gao [a,b], Hailong Peng [c], Yongjun Jia [c], C.K. Shum [a,d], Minseng Lin [c], Qi Guo [d]

[a] State Key Laboratory of Geodesy and Earth's Dynamics, Institute of Geodesy and Geophysics, Chinese Academy of Sciences, 340 Xudong Dajie, Wuhan 430077, China

[b] Graduate School of the Chinese Academy of Sciences, Beijing 100049, China

[c] National Satellite Ocean Application Service (NSOAS), 8 Dahuisi, Beijing 100028, China

[d] Division of Geodetic Science, School of Earth Sciences, The Ohio State University, Columbus, OH 43210, USA

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Abstract

Since the launch of China's first altimetry and scatterometry satellite, Haiyang-2A (HY-2A), various validation studies of HY-2A radar altimetry using preliminary data products have been conducted. Here, we present the first comprehensive result assessing HY-2A's altimeter data quality and the altimetry system performance using an improved HY-2A Geophysical Data Record (GDR) product (Institute of Geodesy and Geophysics reprocessed GDR product version A, GDR_IGGA). The main improvements include altimeter timing and waveform retracking, and tropospheric, ionospheric, and sea-state bias (SSB) corrections, which resulted in more accurate HY-2A sea surface height observations. Jason-2 altimeter observations are used for the cross calibration of the HY-2A altimeter over the oceans between ±60° latitude bounds, primarily due to the limitation of Jason-2 coverage. The statistical results from single- and dual-satellite altimeter crossover analysis demonstrated that HY-2A fulfills its mission requirements. We uncovered a mean relative bias of −0.21 cm (with respect to Jason-2), and a standard deviation of 6.98 cm from dual-satellite crossover analysis. In addition, we present the results of a detailed analysis on variance reduction studies for the various geophysical corrections from HY-2A and compared them with Jason-2. The wave-number spectra of HY-2A and Jason-2 sea-level anomalies show similar spectral content, verifying the performance of HY-2A altimetry to be similar to Jason-2. Open issues and the remaining HY-2A data problems have been identified, allowing prospective future studies for further improvement of its accuracy.

Keywords: HY-2A altimeter; Altimetry; Cross calibration; Crossover analysis; Sea surface height

1. Introduction

Haiyang-2A (HY-2A) is the first altimetry and scatterometry satellite mission of the China National Space Administration (CNSA), and it is dedicated to the studies of physical oceanography and geodesy. The satellite mission has a scientific and operational requirement to monitor ocean vector wind fields, sea level, sea surface temperature, waves, currents, tides, and storms to provide timely disaster and weather forecasting information. Onboard instrument systems include a microwave imager (microwave brightness temperature), a dual-frequency (Ku- and C-band) radar altimeter (sea level, wave height, and wind speed), and a Ku-band scatterometer (sea surface

* Corresponding author.
E-mail addresses: baolifeng@whigg.ac.cn (L. Bao), gaopengwhigg@hotmail.com (P. Gao), phl@mail.nsoas.gov.cn (H. Peng), jiayongjun@mail.nsoas.gov.cn (Y. Jia), ckshum@osu.edu (C.K. Shum), mslin@mail.nsoas.gov.cn (M. Lin), guo.376@osu.edu (Q. Guo).

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vector wind field). HY-2A is also the first China–France collaborative satellite mission on satellite oceanography and operational ocean climatology. The cooperation includes supplying of near real-time satellite data by NSOAS (National Ocean Satellite Application Service, China) to CNES (Center National d'Etudes Spatiales, France) and other meteorological agencies, and for CNES to supply DORIS (Doppler Orbit Determination and Radiopositioning Integrated on Satellite) orbital tracking data, for HY-2A operational orbit and precise orbit determination. In addition to the CNES DORIS instrument, HY-2A has a geodetic (Global Positioning System (GPS) receiver onboard and is equipped with laser corner retroreflectors for global satellite laser ranging (SLR) tracking of the satellite. The medium-orbital ephemeris (MOE) and the precise orbital ephemeris (POE) will be used by NSOAS to generate Level 1 and Level 2 altimetry products, which will then be used by CNES to enhance its multi-mission altimetry sea-level products computed and distributed by AVISO (Archivage Validation Interprétation des Données des Satellites Océanographiques). DORIS tracking data are available through the International DORIS Service (IDS). HY-2A was launched by CNSA using the Long March CZ-4B launcher to a Sun-synchronous orbit with a mean orbital altitude of 970 km on 16 August 2011. The HY-2A satellite mission is operated by NSOAS for a nominal mission lifetime of 5 years. The mission phases of the HY-2A include a 14-day near-repeat orbit with a mean altitude of ~971 km and a geodetic mission phase of 168-day repeat with a mean altitude of ~973 km.

The HY-2A mission complements the global satellite altimetry network and, with its distinct and polar region-observing orbits, contributes to the generation of long-term climate records. A global accuracy assessment of the altimetry sea-level measurements is a crucial prerequisite for the use of the data for climate studies. Establishing that the accuracy requirement has been met is another prerequisite before releasing the Geophysical Data Records (GDRs) to the science community (Fu and Cazenave, 2001). Before 2020, there will be at least two planned HY-2-series altimetry satellites in operation. The quantitative analysis to assess the accuracy of the HY-2A altimetry-derived sea-level heights in the form of an error budget – covering the altimetry and radiometer instrument; the data processing procedure; and various instruments, media, and geophysical corrections – is imperative to validate or improve the future HY-2 altimeter data and the HY-2 series of satellite missions.

The radar altimeter was designed to provide accurate surface height measurements over the ocean, and have been used for innovative measurements of the water-level height of the world's hydrologic bodies, ice sheet and glacier elevation change, and solid Earth deformation (Shum et al., 1995). These datasets have been used, for example, for the studies of the marine geoid, tides, currents, and present-day sea-level rise. To assess the data quality from the altimeters, generally, the sea surface height (SSH) products can be analyzed using altimeter crossover analysis, and/or the comparison with in situ observations from Global Navigation Satellite System (GNSS) buoys, and/or tidal gauge observations over oceans and large lakes (Ménard et al., 1999; Shum et al., 2003; Chambers et al., 2003; Dorandeu et al., 2004; Francis et al., 2005; Cheng et al., 2010; Haines et al., 2010; Crétaux et al., 1990; Cancet et al., 2012; Watson et al., 2012; Bonnefond et al., 2012). Thus, calibration and validation of satellite altimeter data are critical and necessary, as the results of the analysis and comparisons performed have led to and will lead to the improvement of sensor calibrations and the geophysical algorithms that are the key to producing robust science data processing system and climate data records (Lillibridge et al., 2013).

There are two ultra-stable oscillators (USOs) on the HY-2A satellite, side A and side B. During its first stage of mission life, due to the frequent orbit control and other uncertain factors, the performance of the side A oscillator is not stable. Therefore, the backup side B oscillator has been activated on 15 April 2013. In this paper, we present the results of statistical analysis applied to cycle 44–54 of the HY-2A 1-Hz GDR data product with the stable side B oscillator (product version: GDR_IGGA, which was reprocessed by the Institute of Geodesy and Geophysics, Chinese Academy of Sciences, based on the GDR products provided by NSOAS). The main improvements include updated geophysical corrections, datation, and waveform retracking. The objective is intended to provide a comprehensive and reliable assessment of HY-2A GDR data product quality.

The performance assessment of HY-2A was derived from the calibration and cross calibration with other altimeters, including crossover analysis of HY-2A, crossover analysis of HY-2A and Jason-2, comparison of the respective geophysical corrections, and the wave-number spectra of sea-level anomaly (SLA) from HY-2A and Jason-2 products. It is demonstrated that the HY-2A mission fulfills the requirements of high-precision altimetry, a mean relative range bias of about −0.21 cm. Finally, a standard deviation of about 6.98 cm, with respect to Jason-2, is determined. Additionally, potential improvements and open issues are identified, with the objective of still making progress in terms of altimeter data quality

2. Data editing and validation

Since its successful launch on 16 August 2011, HY-2A has been measuring the global SSH every 14 days. The reference ellipsoid used in the HY-2A mission is adopted as the WGS84 ellipsoid. In this study, the altimeter data products of HY-2A (cycle 44–54, from 25 May 25 2013 to 19 October 2013) were provided by NSOAS (data product version 2013), including the raw 20-Hz 128-sample waveform data and the 1-Hz GDR product. The data processing is operational: they are processed within 30 days after obtaining the satellite data. In NSOAS's SGDR (Sensor Geophysical Data Record) product, 20-Hz orbital altitudes