Available online at www.sciencedirect.com

ScienceDirect

Polar Science 8 (2014) 10–23

http://ees.elsevier.com/polar/

Comparison of tide model outputs for the northern region of the Antarctic Peninsula using satellite altimeters and tide gauge data

Fernando A. Oreiro [a,b,*], Enrique D'Onofrio [a,b], Walter Grismeyer [a], Mónica Fiore [a,b], Martín Saraceno [c,d,e]

[a] Servicio de Hidrografía Naval, Ministerio de Defensa, Av. Montes de Oca 2124 (C1270ABV), Ciudad Autónoma de Buenos Aires, Argentina
[b] Instituto de Geodesia y Geofísica Aplicadas, Universidad de Buenos Aires, Argentina
[c] Centro de Investigaciones del Mar y la Atmosfera (CONICET), Argentina
[d] Departamento de Ciencias de la Atmósfera y los Océanos, Universidad de Buenos Aires, Argentina
[e] Instituto Franco-Argentino de Estudios sobre el Clima y sus Impactos (IFAECI, CNRS/CONICET-UBA), Argentina

Received 5 July 2013; revised 18 October 2013; accepted 2 December 2013
Available online 11 December 2013

Abstract

This study compares the common harmonic constants of the O_1, K_1, P_1, Q_1, M_2, S_2, N_2, and K_2 tidal constituents from eight global and four regional tide models with harmonic constants from satellite altimeter and tide gauge data for the northern region of the Antarctic Peninsula (58°S–66°S, 53°W–66°W). To obtain a more representative comparison, the study area was divided into three zones with different physical characteristics but similar maximum tidal amplitude variations: Zone I (north of 62°S), Zone II (south of 62°S and west of the Antarctic Peninsula), and Zone III (between 62°S and 64.3°S, and east of 58.5°W). Root sum square (RSS) values are less than or equal to 3.0, 4.2, and 8.4 cm for zones I, II, and III, respectively. No single model shows superior performance in all zones. Because there are insufficient satellite altimetry observations in the vicinity of Matienzo Base (64.9761°S, 60.0683°W), this station was analyzed separately and presents the greatest values of both root mean square misfit and RSS. The maximum, minimum, and average amplitude values of the constituents that follow in importance after the eight common tidal constituents, and which have amplitudes greater than 1 cm, are also analyzed.

Keywords: Sea-surface height; Tide modeling; Antarctic Peninsula; Coastal satellite altimetry

1. Introduction

Knowledge of tides not only contributes to many practical applications in the marine environment, such as navigation and contaminant-dispersion modeling, but is also important in a wide range of scientific studies. For example, microstructure studies have shown a correlation between the rate of turbulent dissipation and tide cycles (Polzin et al., 1997; Ledwell et al., 2000), and there is increasing evidence that tides may provide a significant source of energy for the mixing that takes place in the deep ocean (Munk and Wunsch, 1998; Egbert and Ray, 2000, 2001). At the coast, the tide contributes significantly to vertical

* Corresponding author. Servicio de Hidrografía Naval, Ministerio de Defensa, Av. Montes de Oca 2124 (C1270ABV), Ciudad Autónoma de Buenos Aires, Argentina. Tel.: +54 11 58421558.

E-mail addresses: mareas@hidro.gov.ar, foreiro@hidro.gov.ar (F. A. Oreiro).

1873-9652/$ - see front matter © 2013 Elsevier B.V. and NIPR. All rights reserved.
http://dx.doi.org/10.1016/j.polar.2013.12.001

mixing, redistributing nutrients and oxygen and therefore influencing marine life (Romero et al., 2006), and to CO_2 exchange between ocean and atmosphere (Bianchi et al., 2005). In the Antarctic Ocean, tides interact with the floating ice sheet (Legrésy et al., 2004; Brunt et al., 2010), influence the ice-sheet grounding zone, modify sea-ice formation in front of ice shelves, and probably also play a role in iceberg formation (King et al., 2011).

In some studies, the tidal signal is regarded as noise and must therefore be removed. This is the case for satellite measurements of ice-shelf-surface height (laser altimetry) and ice motion (Interferometric Synthetic Aperture Radar, inSAR), where tides are the primary cause of the time-dependent ice-shelf-height signal, which requires accurate removal of the tidal signal (Padman et al., 2001). For fixed stations, such as mooring sites, it is possible to remove the tide using numerical filters. Because of the sampling rate of satellites, the signal retrieved can be affected by aliasing. Aliasing refers to the effect whereby different signals become indistinguishable (or aliases of one another) when sampled. It also refers to the distortion that results when the signal reconstructed from samples differs from the original continuous signal. According to the Nyquist criterion, aliasing occurs when the variability in a signal occurs at scales smaller than twice the sampling interval (Bendat and Piersol, 1971). A direct consequence of the aliasing effect is that short-scale signals may appear in the measurements at longer or even infinite scales (Chen and Lin, 2000). Thus, direct filtering is not feasible and requires the use of both global and regional models.

During the past 20 years, the accuracy of such global and regional models has been improved. However, model results in Antarctica and near coasts are less accurate than in the rest of the ocean (Padman et al., 2002; Lyard et al., 2006). Several reasons may account for this lack of accuracy, such as bathymetric uncertainties, the quality and amount of tidal data assimilated into the models, and an inadequate number of tidal constituents. Furthermore, the limited availability of direct tide observations in Antarctica (see http://www.psmsl.org/products/data_coverage/) indicates the need for ongoing research on this topic. Although there is a history of reports of direct tide observations in the Antarctic region (Lutjeharms et al., 1985; Pedley et al., 1986; Foldvik et al., 1990; Levine et al., 1997), these have limited spatial coverage. Since the launch of the Topex–Poseidon mission in 1992, spatial coverage has improved; however, satellite altimeter measurements at high latitudes are scarcer than in other regions of the ocean, due to ice coverage during most of the year. With more than 20 years of data now available, the number of altimetry observations in Antarctica has allowed the precise harmonic constants of tide to be obtained in certain regions.

The aim of this work is to compare harmonic constants from 12 of the most up-to-date global and regional tide models with harmonic constants from satellite altimeter and tide gauge data for the northern region of the Antarctic Peninsula (58°S–66°S, 53°W–66°W; Fig. 1). An evaluation of the performance of tide models in this area will contribute to the development of more accurate results in oceanographic and climatic studies. In addition, tide models can be used to detide altimetry data in order to compute large-scale patterns of sea-surface height (SSH) and associated geostrophic velocities (e.g., Saraceno et al., 2010).

A new harmonic analysis methodology is implemented that allows the use of sea-level heights with missing data and uneven sampling intervals. Time series from 20 coastal tide gauges are used; 3 of these series are longer than six years, 13 are longer than a month, and 4 are longer than a fortnight.

2. Tide gauge records and model output

2.1. Tide gauge records

In the Antarctic Peninsula, tide observations have been conducted mainly in the vicinity of the scientific bases located in the northwestern part of the Antarctic Peninsula (Fig. 1). These observations were made using float tide gauges, water-level recorders with pressure sensors, and tide poles. Table 1 presents information for the time series analyzed for each tide station, including latitude, longitude, period, length in days, and type of measuring device. The full record available at each station was used, despite missing data in some cases, because a longer series allows more precise harmonic constants to be calculated. All data used were obtained by the Argentine Naval Hydrographic Service, apart from those measured by the Hydrographic and Oceanographic Service of the Chilean Navy in Arturo Prat Base. Measurements made with float tide gauges and pressure sensors were performed according to the standards of the Argentine Naval Hydrographic Service, with an error of ±1 cm, whereas for tide poles the error is ±3 cm. According to the University of Hawaii Sea Level Center, Prat Base data appear to be of good quality (ftp://ilikai.soest.hawaii.edu/rqds/atlantic/doc/qa730a.dmt).