Abstract

This paper presents a data-derived surface current forecast model based on statistical decomposition techniques [1] on the observations of high-frequency radar-derived surface currents, local winds, and sea surface height anomalies (SSH) off southern San Diego. The regional surface circulation mainly consists of tide-, wind-, and low-frequency pressure gradient-coherent components, and residual currents, which lead us to use tidal harmonic analysis, response functions using wind stress and pressure gradients, autoregressive analysis, respectively, in the forecast model. These basic functions have been consecutively added, and the performance of corresponding forecast models is evaluated.

Introduction

As one of geophysical boundary flows at the air-sea interface, coastal circulation is associated with complex interactions of geophysical forces (tide, wind, sea height, flux, and low-frequency forcing) and their interfaces in coastal regions has been addressed with in situ observations, numerical simulations, and theories such as environmental sensing and data analysis, computation fluid dynamics, and theoretical studies on geophysical fluid dynamics, respectively. Particularly, coastal dynamics is vital for tracking of water-borne materials (e.g., search and rescue, oil spill, and tsunami), beach erosion, sea level rise, and fishery science [e.g., [9]; add more].

In the awareness of importance of ocean physics and bio-geochemistry, the forecasting skill and models have been developed with regional numerical models and concurrent in-situ observations along with data assimilation techniques [2]. Among them, the statistical and dynamical data analysis have elucidated the coastal ocean dynamics [3, 4]. [7] proposed a stochastic forecast model based on harmonic analysis for tide-coherent surface currents and autoregressive process (e.g., Gauss-Markov method) for residual surface currents in order to derive surface circulation for search and rescue missions. Primary distinction of this study is to present a near-real time forecast model based on observations of surface currents, tide gauges, along-track altimeter, and local wind data by accumulating them as regression basis functions and evaluate the performance of the forecast model in terms of individual basis functions.

Data Analysis

Data

Surface currents

Hourly surface current maps off southern San Diego are obtained from AVISO around southern San Diego. Moreover, along-track and optimally interpolated sea surface height anomalies obtained from satellite altimeter (TOPEX) off southern San Diego are used to estimate the pressure gradients in the cross-shore and along-shore directions.

Sea surface heights

The sea surface elevation at tide gauges in San Diego Bay and Los Angeles are analyzed to derive along-shore geostrophic coherent components. Moreover, along-track and optimally interpolated sea surface height anomalies obtained from satellite altimeter (TOPEX) off southern San Diego are used to estimate the pressure gradients in the cross-shore and along-shore directions.

Auto-regressive model

The auto-regressive model is applied to residual surface currents ($u_m$) by regressing time-lagged basis functions. The result is:

$$w_m(t) = \sum_{i=1}^{n} \alpha_i \cdot w_m(t-i) + \epsilon_m(t)$$

where $w_m(t)$ denotes the $m$th time-lagged of residual currents, $w_m(t)$ (two subscripts separated by comma indicate the decomposed components and the number time lags), and $\alpha_i$ indicate the noise level of imputes (e.g., $u_{m1}$, $u_{m2}$, and $w_m$), in equations below to constitute the regularized matrix ($A_j x_j$).

Wind response function

The tidal residual surface currents are decomposed with the wind response function and auto-regressive model:

$$w_m(t) = \sum_{i=1}^{n} \left( \sum_{k=1}^{R} \frac{a_{jk}}{b_{jk}} \tau^j \right) + \epsilon_m(t)$$

where $R$ denotes the cross-track geostrophic currents.

Forecast analysis

The hindcast analysis derives forcing-response relationships using the regional numerical models and concurrent in-situ observations: Three HF radars [R1 (Point Loma), R2 (Imperial Beach), and R3 (Coronado Islands)] for surface currents, two stations at the Scripps Pier (W1, SIO) and Tijuana River Valley (WR, TDF) for wind, and one mooring (T) for both subsurface currents (ADCP) and surface currents. Moreover, along-track and optimally interpolated sea surface height anomalies obtained from satellite altimeter (TOPEX) off southern San Diego. Considering the primary components in the regional surface circulation [tide-, wind-, and low-frequency pressure gradient-coherent components, and residual currents] and tidal harmonic analysis, response functions using wind stress and pressure gradients, and autoregressive analysis, respectively, in the forecast model.

Acknowledgement

Sung Yong Kim is supported by the Basic Science Research Program through the National Research Foundation (NRF), Ministry of Education (2013R1A1A2057849), the Human Resources Development of the Korea Institute of Energy Technology Evaluation and Planning (KETEP), Korea Trade, Industry and Energy (ps 201302400203030), Republic of Korea. Surface current data are provided from the Southern California Coastal Ocean Observing System (SCCOOS). Available online at http://www.sccoos.org at Scripps Institution of Oceanography (SIO). Wind data at the Tijuana River (Tidal Linkage) are maintained by the SystemWide Monitoring Program of the Scripps Institution of Oceanography. Surface current data are provided by the National Ocean Technology Center (NOTC). terrestr. Res. Res. Prog. (2012), 389–433, 2003.

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