Analysis of NASA Ocean Pathfinder Altimetry for Ocean Circulation and Climate Research

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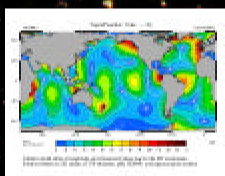
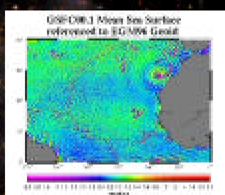
Altimetry Upgrades

Introduction

Over the past decade, satellite altimeter data sets have been invaluable to the NASA physical oceanography program and the ocean science community, in general. The need for high quality, documented and easy-to-use global measures of ocean topography, provided in a consistent reference frame and processing environment has grown for scientific research, environmental monitoring, and academic applications.

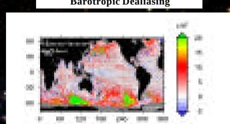
The NASA Ocean Altimeter Pathfinder Project was initiated at GSFC in 1995 (http://neptune.gsfc.nasa.gov/ocean.html) and is currently a collaboration with JPL to create such a data base for all altimeter satellites. While significant progress has been made in providing a consistent, cross-mission data set, further improvements to the complete data set are proposed. Progress continues in model development and instrument validation which in some cases, significantly improves our ability to isolate subtle, yet highly significant long period signals.





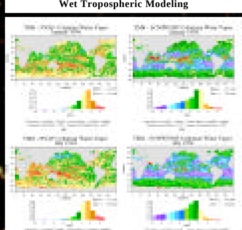
The GSFC00.1 mean sea surface (Wang, 1999) is a 2'x2' resolution field based on current versions of Pathfinder GEOSAT, ERS, and T/P altimetry. Improvements were made to the cross-track gradient correction due to the improved modeling of the local geoid.

Barotropic Dealiasing



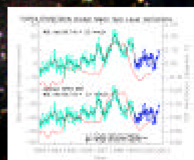
A barotropic model, based on Ponte's (1993, 1997) has been optimized in terms of friction, bathymetry, and no slip conditions to better handle steep topography. The model is driven by 12 hour NCEP operational wind and pressure fields from 1993 - 1995. The model friction has been adjusted to explain both TOPEX sea level and certain bottom pressure recorders. This model adequately removes some of the trackiness in both T/P and ERS data that was due to fast ocean response to wind and pressure (other than IB), aliasing into longer periods. The image above shows the explained variance which is derived by data variance minus data-model residual variance. This model will be applied to T/P and ERS Pathfinder data over the next few months. For more details, see poster F.9 .

Wet Tropospheric Modeling

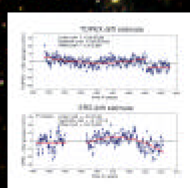


NASA's Water Vapor Project (NVAP) has assembled many available observations of global atmospheric water vapor (*e.g.*, data from the global radiosonde network , SSM/I, and TOVS) and blended these data types into a set of global water vapor products (Randel et al., 1996). We have evaluated the global relative accuracy of the NVAP data set, as well as the ECMWF model through a direct comparison with TOPEX microwave radiometer (TMR) measurements (Simpson, et al., 2000). Employing the NVAP data set in the coastal and archipelago regions where the radiometer is not reliable will enable the recovery of these observations.

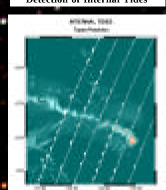
Monitoring Global Mean Sea Level

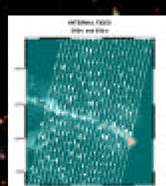


Global mean sea level variations are computed from T/P and ERS altimetry (Nerem et al., 1994). Each asterisk represents a 10 day estimate (11.6 days for ERS) of the global mean sea level variation with respect to the 1993 - 2000 average. The solid black line is a 60-day Hanning filter. The red line is the Reynolds' sea surface temperature. The dark blue asterisks identify the transition from TOPEX ALT A to ALT B that is currently being evaluated. The sea level variations for TOPEX are re-evaluated with an updated SWH based on comparisons with ERS-1, ERS-2, POSEIDON, and in-situ measurements (Queffeulou, 2000). The sea level variations are biased by 40 mm to view both series. In order to measure such low frequency, small amplitude signals, precise calibration of the altimetry series to determine instrument drift is critical. The altimetry series for both ERS and T/P are compared to a global network of 108 WOCE tide gauge stations (courtesy of Gary Mitchum). These comparisons indicate a 7 mm bias between TOPEX ALT A and ALT B. Examining ERS; there appears to be a residual instrument bias between Phase C and ERS-2, and the downward trend in 1999 can be attributed to underestimation of the ionosphere during this period of solar maximum. A revised ERS SPTR correction is to be released this year (Francis, 2000) which is expected to reduce inter-mission biases.



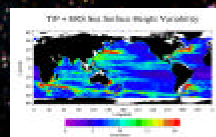
Detection of Internal Tides



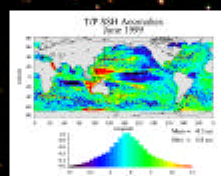


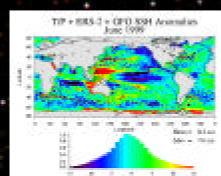
Analysis of ERS and T/P satellite altimetry reveals short-wavelength fluctuations in the ocean surface tide that are attributable to internal tides (Ray and Mitchum, 1996). In the figures above high-pass filtered M2 amplitudes are plotted along ascending T/P tracks and descending ERS tracks. A significant fraction of the semidiurnal internal tide generated at the Hawaiian Ridge is phase-locked to the astronomical potential and can modulate the amplitude of the surface tide by ~ 5 cm. For more details, see poster F.1 .

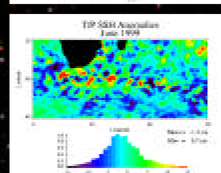
Multi-Mission SSH Mapping

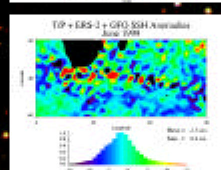


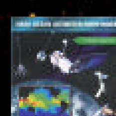
High resolution maps of ocean topography are generated employing techniques to adjust altimetry from multiple missions into the T/P reference frame (Le Traon, et al, 1995). The above figure is the mesoscale sea surface height variability at 1/4 degree resolution from the combination of ERS-1 Phase C&G, ERS-2, and T/P altimetry from 1993-1999. The maps below illustrate the improved detection of mesoscale features comparing sea surface height anomalies (June 1999) from T/P only at 1x1 degree resolution, and the joint solution from T/P, ERS-2, and GFO enabling a 1/4 degree resolution height field.









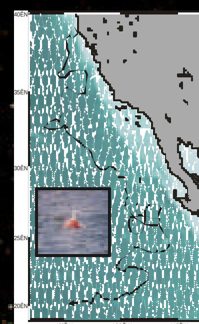


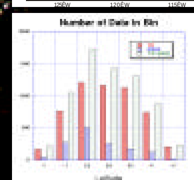
Estimation of the Near Surface Ocean Circulation

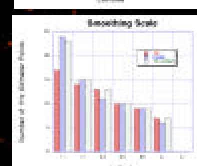
A number of recent studies have demonstrated the potential for estimating the near surface ocean circulation using satellite altimeter data (Niiler and Ralph, 1998; Lagerloef et al, 1999, and Picaut et al, 1990). Most of these studies have focused on the steady state circulation and used only T/P altimeter measurements. In this presentation we examine the potential for estimating the time dependent circulation and evaluate the impact of ERS altimeter data on the solution.

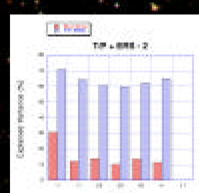
Our study utilizes the WOCE/TOGA surface drifters that have been distributed around the globe over the past decade. In particular, coverage in the North Pacific has been quite dense and therefore we focus our study on this region. We use the drifter data as a surface validation.

In order to develop a surface current model from the altimeter and wind observations, an evaluation of the individual contributions of the wind driven Ekman and geostrophic currents was conducted using the drifter data. A regression analysis on the drifter observations was carried out based upon geostrophic estimates from altimetry and Ekman estimates from surface wind fields. The results of these analysis are shown in the figures below. As anticipated, the geostrophic flow dominates the drifter observations throughout the North Pacific. ERS-2 and T/P altimeter data provide similar results, as does a blended analysis. More importantly, the analysis suggests that the altimeter and wind fields can account for more than 70% of the drifter variance throughout the Pacific. For more details, see poster A.7 .





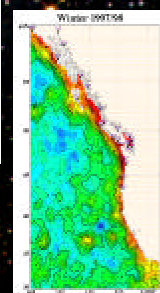


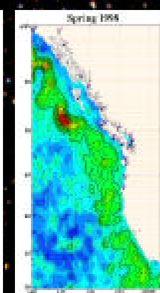


Science Contributions

Applications of the Pathfinder data have been over a wide range of subject areas from large scale ocean changes to inland water variations. Some examples of recent results developed by investigators that have employed the Pathfinder data sets in their research activities are displayed below.

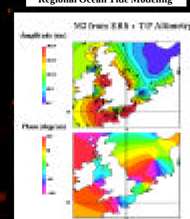
Seasonal ERS -2 & T/P Sea Level Anomalies





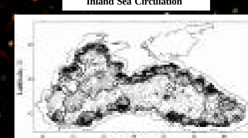
During the winter of 1997/98 a band of record high sea levels are observed along the west coast of North America due to a combination of wind set up and the northward propagation of coastal Kelvin waves from El Nino forcing. In February of 1998 the along-shore winds have reversed direction (the so-called spring transition), resulting in these sea levels to drop dramatically, and a band of high sea levels moved offshore as Rossby waves and eddies at higher latitudes. Courtesy of Bill Crawford, Mike Foreman, and Josef Cherniawsky.

Regional Ocean Tide Modeling



Combined ERS-1, ERS-2, and T/P altimetry are employed for tidal studies in shallow water regions. RMS comparison with 63 pelagic tide gauges in the northwest European shelf region for the M2 constituent is 2.73 cm for the joint solution. Courtesy of Ole Andersen. For more details, see poster F.5 .

Inland Sea Circulation



Root mean square sea level deviation are measured in the Black Sea with ERS altimetry. Values smaller than 4 cm are denoted by a dotted line; contour intervals are 0.25 cm. Courtesy of G. Korotaev.

References

W. Crawford, J.Cherniawsky Anticyclonic Eddies in the Eastern Gulf of Alaska, 1958 - 2000. JGR-Oceans submitted.

R. Francis, Identification and Correction of Clock Asymmetry in the ERS-1 and ERS-2 Radar Altimeters, ERS-Envisat Symposium, Oct. 16 - 20, 2000.

G. Korotaev , O. Saenko C. Koblinsky, Satellite Altimetry Observations of the Black Sea Level, JGR-Oceans in press.

G. Lagerloef, G. Mitchum , R. Lukas, et. al, Tropical Pacific Near-Surface Currents Estimated from Altimeter, Wind, and Drifter Data, JGR-Oceans 104: (C10) 23313-23326, Oct. 15, 1999.

P.Y. Le Traon , P. Gaspar,F. Ogor ,J. Dorandeu , Global Adjustment of ERS-1 Data using TOPEX/POSEIDON as a Reference, Technical Report CNES/CLS GO/94/522.

G. Mitchum An improved Calibration of Satellite Altimetric Heights using Tide Gauge Sea Levels with Adjustment for Land Motion, Marine Geodesy, 23:145-166, 2000.

S. Nerem , E. Schrama,C. Koblinsky, B. Beckley, A Preliminary Evaluation of Ocean Topography from the TOPEX/POSEIDON Mission,J. Geophys. Res., 99(C12), 24565-24583, 1994.

P. Niiler, P. Ralph, Wind Driven Currents in the Tropical Pacific, J.Physical Oceanography 29: (9) 2121-2129, Sept. 1999.

J. Picaut, A. Busalacchi, M. Mcphaden , et al., Validation of the Geostrophic Method for Estimating Zonal Currents at the Equator from Geosat Altimeter Data, JGR-Oceans 95: (C3) 3015-3026 March 15, 1990.

R. Ponte, P. Gaspar Regional Analysis of the Inverted Barometer Effect over the Global Ocean using TOPEX/POSEIDON Data and Model Results, JGR-Oceans, 1999.

P. Queffeulou Quality of Long-Term Satellite Wind and Wave Measurements, ERS-Envisat Symposium,Oct,2000.

D. Randel, T. Vonder Haar, M. Ringerud G. Stephens, T. Greenwald, C. Combs, A new global water vapor dataset, Amer. Meteor. Soc., vol. 77, no. 6, 1996, 1233-1246.

R. Ray, A Global Ocean Tide Model from TOPEX/POSEIDON Altimetry:GOT99.2, NASA/TM-1999-209478.

J. Simpson, J. Berg, C. Koblinsky, G. Hufford, B. Beckley, The NVAP Global Water Vapor Data Set: Independent Cross-Comparison and Multi-Year Variability, Remote Sensing of Environment,inpress.

Y. Wang, The Satellite Altimeter Data Derived Mean Sea Surface GSFC98, GRL 27:5 701 - 704, March 2000.