Web-based Altimeter Service

Philip S. Callahan, Brian Wilson, Zhangfan Xing, Rob Raskin, Kenneth Oslund

Jet Propulsion Laboratory, California Institute of Technology

Abstract

We are developing a web-based system to allow updating and subsetting of altimeter data. This is crucial to the expanded use and improvement of altimeter data. The service aspect is necessary for altimetry because the result of most interest – sea surface height anomaly (SSHA) – is composed of several components that are updated individually and irregularly by specialized experts. This makes it difficult for spaceflight projects engaged in ongoing data processing to provide the most up-to-date products. Some components are the subject of ongoing research, so the ability for investigators to make products for comparison or sharing is important. The service will allow investigators/producers to get their components into widespread use much more quickly. For coastal altimetry, the ability to subset the data to the area of interest and insert specialized models or data processing results is crucial.

We will describe the basic structure of the web service and the steps toward implementation. We are integrating web and grid workflow features with algorithms developed to produce improved Geophysical Data Records (GDRs) with retracking (RGDRs) for TOPEX. TOPEX RGDRs in a netCDF format that has been coordinated with Jason data are the initial basis of the service. The service allows individual users to produce their own GDRs and SSHA data sets using data components that they select from known sources or supply themselves, do time and space subsetting, and select variables of interest from the netCDF files.

Altimeter Data Uses and Characteristics

Altimeter data have become a standard tool in ocean modeling and climate investigations. Much recent effort has been devoted to operational or short-term uses of altimetry such as hurricane ocean heat studies, el Nino monitoring, and evaluation/prediction of currents for pollution transport or rescue operations. However, the altimeter data will remain crucial to climate studies, and long-term accuracy and consistency of the data are crucial to this use. There are now five long time series of data – TOPEX-Jason, ERS-1/2, GFO – with a growing series from the latest altimeter OSTM (Jason-2) that span nearly 20 years.

The current estimate of global sea level rise is approximately 3.2 +/-0.4 mm/yr (http://sea-level.colorado.edu/index.php). Enough data have now accumulated so that regional estimates of sea level rise can also be made. These show an irregular pattern with rates up to nearly 10 mm/yr, but the possibility of geographically correlated errors in the data make the rates less certain than the global result.

Retrievals of Sea Surface Height (SSH) from altimeter data are different from other types of Earth science data in that they require several highly accurate, specialized measurements and correction models (referred to here as components). The expertise for producing these components is spread among institutions, and there may be good alternatives for some of the components that should be compared and evaluated before full adoption in the standard data products.

Significant advances have been made over the last several years in improving the accuracy of TOPEX and Jason data, particularly in the orbits and the geophysical models used with the data (information on the latest advances can be found at http://www.aviso.oceanobs.com/en/home/index.html, particularly the picks for CALVAL and OST/ST). These efforts have been leveraged to improve the other altimeter data sets as well. To quantify trends of 1 mm/yr requires accuracy and consistency to better than 1 cm over 10 years and across instruments and missions. In addition to consistency, the key error characteristic of altimeter data is geographically correlated error, i.e., error with a large spatial scale persisting over time. Geographically correlated errors will appear as patterns on a time-averaged map of sea surface height (SSH) or SSH Anomaly (SSHA, the difference of SSH from a reference surface, usually a long term mean sea surface or geoid). These systematic errors are difficult to detect and correct. The primary detection method is the comparison of large data sets created with different versions of a particular component.

TOPEX and Jason orbits are approaching 1 cm accuracy (or at least consistency; Desai, et al., 2003, 2004) when they are calculated with the same gravity field and model assumptions. Other 1 cm effects include the sea state bias correction (SSB, related to significant wave height; Chambers et al., 2003), tide models (open ocean; much larger as the ocean becomes shallower), and atmospheric pressure effects. Instrument corrections for both the altimeter and the microwave radiometer (provides a correction for the wet troposphere delay) are subject to calibration errors and drifts and are also at this accuracy level. Thus, the use of the most up to date and consistent corrections and understanding of system behavior is essential to perform accurate climate change studies.

In order to investigate climate signals at the 1 mm/yr level, it is essential that improvements in one data set be propagated appropriately to all measurements. The largest or most significant improvements are likely to come from continuing improvements to gravity models resulting in better orbits, particularly reducing geographically correlated errors. Other improvements can come from atmospheric models for the dry tropospheric delay and inverse barometer effect, radiometer calibration for the wet tropospheric effect, and improved sea state bias. All of the changes have significant geographic and seasonal signals, so correcting these effects can be crucial to detecting regional signals in changes. Such regional effects will be of increasing interest in policy and mitigation responses to climate change.

Efforts to improve accuracy and studies using altimeter data have concentrated on global scales so far. Much more use of the data in coastal studies could be made if local tidal models, as well as other corrections that have local variations (tropospheric corrections) not well-accounted for in global models, were used. Coastal studies are especially important for investigating the interaction of physical and biological ocean processes as well as for their economic and social importance.

Altimeter Data Records

Altimeter Geophysical Data Records (GDRs) contain all the information necessary to study the SSH or SSHA. GDRs include the instrument-corrected altimeter range, precision orbit(s), environmental corrections, geophysical corrections, tide models, and nominal mean surface fields (Chelton et al, 2001). During the mission, a Project data system produces GDRs with algorithms and models developed during the early phases of the mission. After the initial calibration/validation phase, the data processing is likely to be updated only in the case of problems or major findings. The focus of the Project is on global data, so the models and corrections are developed at that scale. The GDRs are used to study oceanographic phenomena. Some investigators may also use GDRs with other data to improve orbit determination, environmental corrections, tide models, and improved instrument corrections. As these investigations progress at varying rates and different groups develop different models, it is desirable to compare the results directly on large data sets and thereby verify the improvement in the accuracy of the GDRs. There is also no general mechanism for investigators to incorporate local component information or models for regional analysis.

Currently, altimeter products are updated by Projects on a lengthy and irregular schedule so that these improvements are only slowly coming into widespread use. Overall, it is extremely difficult to combine the best global correction models with high-resolution local components, perform regional or local studies, evaluate improved components over long time-series, and share results with the ocean community. Studies are usually more piecemeal, performed only at a few major centers, and not easily repeatable.

Altimeter Service Features and Implementation

To enable more rapid application of data improvements and better community access we are developing a web-based service and tools to allow frequent and easy updating and customization of altimeter data products. It is also hoped that this will serve as a prototype for the International Altimeter Service that has been called for by the community (IAS-Planning Group commissioned by IAG, IOC/GLOSS in October 2003 http://iag.dgfi.badw.de/?ias-pg).

The approach embodied in the web service concept is in many ways different than that described by Blanc in the Community White Paper: "Evolution in data and product management for serving operational oceanography, a GODAE feedback" and Gregg in "Ocean and Coastal Data Stewardship", although it needs many of the same underpinnings such as complete metadata, well-defined formats, and connectivity. The difference in concept is that the service assumes that users are interested in making specialized "products" that are updated much more frequently or have much greater variation than those from Production Centers. Furthermore, the service envisions that users will share their own improved altimeter components either as data files or, ultimately, as a computational service.

A key part of the Altimeter Service and a difference from previous data system models is having data producers provide updated or local models and data. In order for this to succeed, producers need to register their components with the Altimeter Service and agree to provide the product either on demand or in a way that can be integrated into the basic altimeter data record structure. It is highly desirable that the external providers perform the computing of the component with their resources.

The web-based altimeter service enables users to:

- **Select** a **time** range (or orbit cycle range) and a latitude/longitude **region** (or the globe);
- **Select** the desired choices of **components** from a menu, some of which can be remote data or model components that have been registered with the Altimeter Service;
- **Register** their own **component** corrections and models by providing a few items of information and URL's pointing to the data files;
- **Reprocess** (update) altimeter GDR data on demand, using the selected components;
- **Retrieve** the updated GDR containing the parameters of interest in netCDF;
- **Compare** SSH or SSHA from their GDR update to prior runs or known GDR versions;
- **Visualize** the key parameters SSH and SSHA on a map or via Google Earth or as a time series.

A functional flow of the system is shown in Figure 1.

TOPEX GDRs with retracking (RGDRs; Callahan and Rodriguez, 2004) in a netCDF format that has been coordinated with Jason data are the initial basis of the service. It will later be expanded to include Jason data as those become available in netCDF format. The capabilities are being implemented using flexible scientific workflows (XML workflow documents) so that the portal can be modified rapidly, kept up to date, and easily integrate new capabilities developed by users (by authoring and uploading new workflow documents). The workflows may involve distributed computing in that some of the data components can be retrieved on demand from a remote site, or an entire component model could be executed remotely using a Web Service call. The Altimeter Service is based on the SciFlo distributed dataflow engine developed by B. Wilson and collaborators with prior NASA support (Wilson et al., 2005). SciFlo is already being used to bring together multi-instrument Earth science data sets as part of two other collaborative science projects (Yunck et al., 2007 and Paradise et al., 2009). Updating algorithms are being written in python or with python wrappers on existing Fortran or C code.

To facilitate regional GDR processing and analysis, datasets will be space/time subsettable, including the input base GDR, all available component models, and all reprocessed (updated) GDR versions. The netCDF format will facilitate appending of updated data elements (the old value of a data element will be stored in "element_old") or selection of data elements.

A user could evaluate a new component by globally reprocessing a year or two of cycles, or choose a small region on the globe and reprocess the data in that region over the entire time series of the TOPEX and JASON altimeters. The data visualizations and map overlays will be available in Keyhole Markup Language (KML) to drive Google Earth.

References

Callahan, P.S., Rodriguez, E. 2004, *Marine Geodesy*, 27, pp, "Retracking of Jason1 Data".

Chambers, D.P., S.A. Hayes, J.C. Ries, T.J. Urban, 2003, *J. Geophys Res.*, 108, 3305, "New TOPEX Sea State Bias Models and their Effect on Global Mean Sea Level".

Chelton, D.B., J.C. Ries, B.J. Haines, L.L. Fu, P.S. Callahan, "Satellite Altimetry", in Satellite Altimetry and Earth Sciences, L.L. Fu and A. Cazenave (Eds), Academic Press, 2001.

Haines, B. J., W. I. Bertiger, S. D. Desai, D. Kuang, T. Munson, L. Young, and P. Willis, Initial orbit determination results for Jason-1: Towards a 1-cm orbit, J. Inst. Navigation, 50 (3), 171-180, 2003.

Haines, B. J., Y. E. Bar-Sever, W. I. Bertiger, S. D. Desai, and P. Willis, One centimeter orbit determination for Jason-1: New GPS-based strategies, J. Marine Geodesy, 27 (1-2), 299-318, 2004.

Paradise, S., B. Wilson, and A. Braverman (2009), "*The Aerosol Measurement and Processing System (AMAPS)*", submitted to Earth Science Informatics.

Wilson, B., B. Tang, G. Manipon, D. Mazzoni, E. Fetzer, A. Eldering, A. Braverman, E. Dobinson, and T. Yunck, "GENESIS SciFlo: Scientific Knowledge Creation on the Grid Using a Semantically-Enabled Dataflow Execution Environment", peer-reviewed Proceedings of the 17th international conference on Scientific & Statistical Database Management (**SSDBM**), Santa Barbara, CA, 2005.

Yunck, T., E. Fetzer, T. Mannucci, C. Ao, F. Irion, B. Wilson and G. Manipon, *Use of Radio Occultation to Evaluate Atmospheric Temperature Data from Spaceborne Infrared Sensors*, *JTAO*, 2007.

The research described here was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. *NASA sponsorship is acknowledged.*

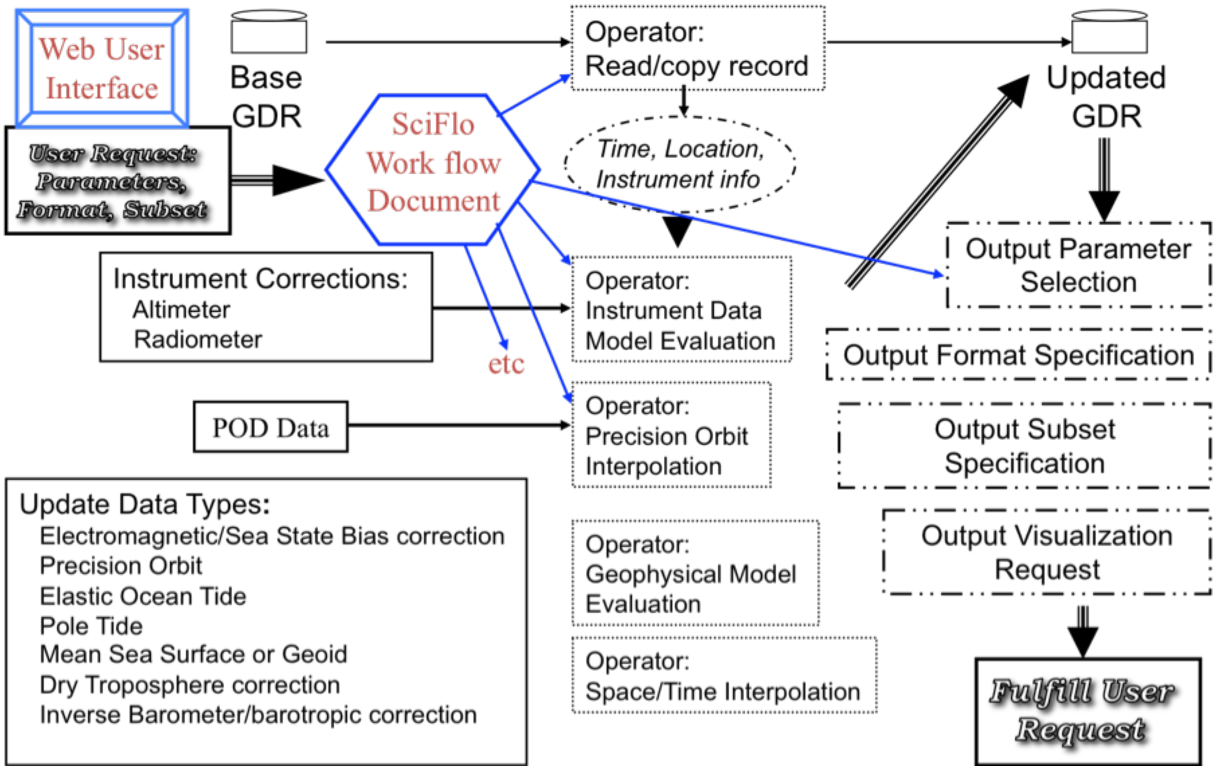

Figure 1: Functional Flow of Web-based Altimeter Service.