River Dynamics, Lake Level Variability And Near-Real Time Reservoir Monitoring

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ABSTRACT: Satellite radar altimetry is a valuable tool in providing surface height (stage) measurements of inland water targets. Clearly demonstrating a non-ocean application, hydrological-based altimetric studies have been ongoing for well over a decade.The technique has been utilized in many interdisciplinary projects seeking surface elevation for lakes, rivers and wetlands, in many cases providing new datasets for regions where traditional gauge data is completely lacking. This proposal seeks to explore several inland water investigations using data from the current tandem (Jason and TOPEX/POSEIDON) mission, as well as data from the original TOPEX/POSEIDON (T/P) archive. The tandem mission is a unique opportunity to use the improved spatial and emporal resolution of stage data to greatly enhance knowledge of the dynamics of the Amazon River. The addition of ERS-2 (and later GFO and ENVISAT) data further improves overall resolution. This multi-sensor outlook also provides a more global view of the status of lake and reservoir water storage. This NASA-funded program consists of a technical project which is linked to an on-going, semi-operational, near-real time reservoir monitoring program that has evaluation of regional drought and irrigation potential as part of its overall goal. Two science programs are also proposed with objectives aimed at exploring river dynamics and climate variability/change issues. Central to all three programs is an investigation of the performance of the Jason instrument.

Objectives

1. To determine the overall performance of the Jason altimeter over inland water targets. To develop data evaluation methods to maximize accuracy and resolution, to provide feedback to the SWT community and to the reservoir monitoring program, and to advise on the role of altimeters within hydrology in regards to near-real time data, operational hydrology programs, and future missions.
2. To investigate the dynamics of the Amazon River. To use the synergistic multi-sensor datasets to update and determine stage variations along the main stem. To use the increased spatial resolution to enhance existing knowledge of the water surface gradient along river reaches. To examine the temporal variability of the deduced gradients in lieu of flood-wave and tributary influences. Through collaborative efforts, contribute specifically to studies of basin hydrology (floodplain storage) and sediment dynamics.
3. To examine the correlations between observed lake/reservoir stage variations and climatic indices (e.g. ENSO, NAO). The long-term goals are the evaluation of regional vulnerability to droughts and floods and the utilization of near-real time elevation data. The focus will have a global outlook using time series of stage variations from the Jason and TOPEX/POSEIDON missions.

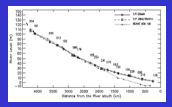
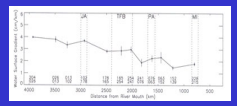



Figure. TOPEX/POSEIDON elevation profile (left) of the Amazon River for 1st June 1996 with satellite pass numbers above each point. Accuracy of various geoid models becomes apparent in the translation to varying orthometric systems. Spatial variability of the average (1993-1999) water-surface gradient for 1st June is shown to the right. Each value represents the reach between adjacent T/P satellite crossings. The approximate location of arches and buried bedrock ridges are indicated in capitals (JA=Jutai Arch, TTB=Titled Fault Block, PA=Purus Arch, MI=Monte Alegre intrusion and ridge).

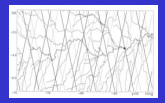
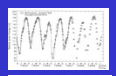
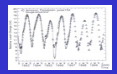




Figure. Location of the original (bold) and new TOPEX/POSEIDON ground tracks across the Amazon Basin. Example time series are taken from pass 183 (solid circle) and show T/P stage variations for the river channel (top) and its floodplain (bottom) in comparison with gauge data (solid symbol).

Technical Program - Jason Performance Evaluation

Objectives

The objectives of this program are to evaluate the performance of the Jason radar altimeter, namely:

- To explore the merits and limitations of the IGDR, GDR and SDR datasets
- To examine any improvements over minimum target size via the availability of 20Hz elevation data
- To investigate data anomalies, particularly noted here is the current rejection of data within the ground-processing software that rejects "calm-water" data (i.e. non-ocean like radar echoes) from the IGDR and GDR data streams.
- To investigate various retracking methods to enhance the accuracy of the elevations
- To search for new methods of data filtering – particularly of relevance to inland water
- To perform a stage validation via the acquisition of ground-based gauge data and a comparison of Jason and T/P lake-stage measurements during the verification phase.
- To seek out any data interpretation methods that will improve the quantity and quality of the elevation data over inland water targets
- To compare instrument performance with contemporary missions, ERS-2, GFO and ENVISAT.
- To look at problems arising from the use of varying reference datum and reference tracks across the missions, within the repeat-track methods that deliver time series of elevation variations.
- In regards to the altimeter and wide-swath ocean altimeter (WSOA) onboard the OSTM, an examination of the potential to retrieve coherent echoes with a view to interferometric mapping of river surfaces.
- To report the findings to the reservoir monitoring program and the Jason1 SWT.

Specifics

Data from the Jason mission in the form of IGDR, GDR and SDR datasets (post January 2002) will be utilized. Comparison of stage accuracy with T/P will be performed with synergistic data from the verification phase (January–August, 2002). Ground-based gauge data for Jason validation exercises will be freely obtained for North America (USA, Canada) via the USGS and various on-line databases, and for South America from collaborative sources. Data from the original T/P (1992-2002) and ERS-2 missions (1995-2003) are already archived/on-line for comparative studies.

Science Program 1 - River Dynamics

Objectives

- With relevance to the instrument performance study (Technical Program above), to examine the performance of the Jason altimeter over the Amazon River crossings. Includes the determination of elevation (stage) accuracy, inter-comparison with historical T/P studies, and the evaluation of the potential of the 20Hz Jason data. Validation of Jason stage accuracy to be performed with ground-based gauge data. Second validation via T/P data during the verification phase (January –August, 2002, both spacecraft in the same orbit, ~1minute apart) is also included.

- To determine the stage amplitude variations and timing of peak flows at the new river locations offered by the current T/P orbit (post September, 2002).
- To compute a higher resolution river profile based on data from the Jason1 and T/P tandem mission (September, 2002 – 2003), incorporating the latest GRACE geoid model.
- To computer high-water river gradients for river reaches defined by inter-track spacing distances.
- To examine the results for further evidence of the three structural highs (Purus Arch, Titled Fault Block, and Jutaí Arch – Fig.1) which are situated transversely to the river path direction.

- To investigate the spatial and temporal variability of the river-reach gradients to further investigate the controlling effects of the main basin tributaries and transient peak flow flood wave.

- To incorporate stage measurements from the ERS-2 mission. This mission offers a further ~50 river location crossings, but subject to stage accuracy and performance across the terrain. To support investigations of sediment transport. This is based on a collaborative effort with UCSB who are examining the relationships between stage and gradient (Radar Altimetry), discharge (ground-based observations), inundation patters (SAR) and suspended sediment concentration and dynamics (via MODIS) along the main stem for the period 2000-2003.,

- To support investigations of water storage within the basin. Support is via collaborative effort with UCLA (PI: D.Alsdorf, Hydrological Modeling of the Central Amazon Basin using Remotely Sensed Data, NASA NRA-00-OES-05) The UCLA project is a combined remote sensing effort to develop a water mass-balance and transport model investigating floodplain storage (of biogeochemical and ecological significance). Association with this proposal ensures delivery of the new and updated T/P stage variations along the main stem in addition to the already available archived results.

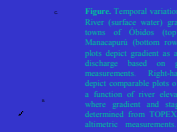


Figure. Temporal variation in Amazon River (surface water) gradient at the towns of Óbidos (top row) and Manacapuru (bottom row). Left-hand plots depict gradient as a function of discharge based on ground-based measurements. Right-hand graphs depict comparable plots of gradient as a function of river elevation (stage), where gradient and stage are both determined from TOPEX/POSEIDON altimetric measurements. The plots show both clockwise and anti-clockwise hysteresis effects as the gradient increases/decreases with varying stage throughout the season

Specifics

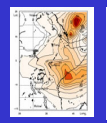
The definition of the Amazon main stem includes, from West to East, the Marañon, the Solimões and the Amazon rivers. With a reduced 157km track spacing at the equator, the combined Jason/TP satellite ground tracks cross ~35 differing main stem locations, though not all will be obtainable due to topographic limitations.
Data from the Jason, T/P GDR and archived T/P will be utilized in the first half of the program. The original archive T/P time series data set will be updated to cover its full 10-year time span. After inter calibration/validation exercises between Jason and T/P within the verification phase, the Jason stage measurements will be used to extend the T/P archive to ~2005. The performance of the ERS-2 radar altimeter and its follow-on mission, ENVISAT, is currently being investigated under other funded programs (NAG5-8747, NAG5-10191). Incorporation of the results from the ERS-2 mission (WAP data: 1996-2003) is expected into this project. Exploration of the GFO dataset and incorporation of both GFO and ENVISAT results will be time dependent.
Data reduction techniques for Jason will be based on the outcome of the Technical Program. Previously published repeat track techniques will be used to determine stage variability along the main stem, and thus determine the tuning of peak flows. Distances between satellite crossings will be computed via the use of ERS-1 geo-referenced radar Landsat mosaics within a GIS-based system (Birkett et al., 2002 for details) where a transect tool will be utilized to follow the river channel center (or thalweg). The velocity of the peak-flow flood wave will then be estimated using the timing of the peak flows and the estimates of the track separation distances. Low-water gradients are more representative of average channel bed slope but due to instrument limitations, high flow gradients will be computed.

Science Program 2 - Lake Level Variability

Objectives

The long-term goal of this project is to utilize climatic indices in the form of predicted sea surface temperature (SST) together with near-real time and archived altimetry data over lakes and reservoirs, to aid in the forecast of regional drought and flood. There are five main objectives:

- To utilize the surface status (elevation) of lakes and reservoirs as a proxy indicator of precipitation and as a direct measure of hydrological drought and flood.
- To note current hydrological (water surface) status, variability and trends.
- To utilize the stage variations to seek correlations with known drought/flood episodes.
- To further examine the relationships in terms of short-term climate events.
- To deduce the vulnerability of these regions to short-term climatic events and to look towards the future role of combined satellite data and predictive SST forecasts.





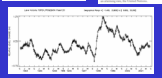




Figure. 1997/1998 rainfall anomaly over East Africa bringing floods and 1-2m rise of stage in the East African Lake Victoria (top). Landsat images showing drought conditions in Afghanistan and the drying of the Jehil Reservoir (bottom). Stage and radar backscatter variations (for Jehil) as observed by TOPEX/POSEIDON.

Specifics

Precipitation excess/deficit does not always produce a flood or drought situation, as other factors such as water usage, hydrology and topography play a role. A 'flood hazard' occurs at the observation site, but a 'drought hazard' will be indicative of decreased precipitation within a select region of the catchment region i.e. at the primary origin of inflow. Thus, ground-based information (situation reports) will go hand-in-hand with observation of all available global targets of varying types (reservoir/open-lake/closed-lake).

Time series of lake and reservoir stage variations (1992-2005) from the combined Jason/TP archive will be utilized. These products will be directly obtainable from the currently funded USDA NRT-RM program. Due to target size limitations, the focus will center on ~100 large lakes within North and South America, Asia, Eastern Europe and Asia with separate results from the African continent incorporated from another on-going program (PI: C. Birkett, NAG5-10191). Short-term climatic events will focus on ENSO, but Indian Ocean and Atlantic sea surface temperature (SST) anomalies will also be studied. Correlations will focus on monthly NINO3/ATL/Indian Ocean anomalies with mean annual or mean monthly lake level variations. Current drought/flood information is obtainable from web-based sources such as the Red Cross/Red Crescent Society and the Dartmouth Flood Observatory.

For the ~10-15year time series of stage variations, method will be based on,

- The derivation of a mean annual stage signal for each target
- Derivation of seasonal stage anomalies (departures from the mean)
- Identification of areas that depict large anomalies and corroboration with flood/drought reports.
- Correlation with climate anomalies via monthly indices such as NINO3 and ATL, and with Indian Ocean SST and SST gradient anomalies. Comparison will be on a month-to-month basis, or at peak stage periods.
- Noting the magnitude/timing/duration of the region's response and seasonal phase lags.
- Noting of any large-scale geographical similarities between response and climate event.
- A search for consistencies between response and event, determining the effect of combined climatic events.
- A review of the decade's short-term climatic events in terms of known precipitation anomalies.

Via interaction with the Technical Program (Jason Performance Evaluation) and the USDA NRT-RM program, this project will ensure the use of the best overall time series of stage variations obtainable from the altimeter missions. In this regards, time series of the seasonal and inter-annual observations of the radar backscatter (sigma0) signal will also be examined for data loss estimates and effects, due to ice coverage during freeze/thaw transitions for study lakes at high northern latitudes.