Application of Multiple RA Data Sets to Serve Inland water Projects: (A) Water Accounting across the Balonne floodplain, Australia

Charon Birkett (1) and Ben Gouweleeuw (2)

CONTACTS: cmb@essic.umd.edu (Tel: 301-405-9296), Ben.Gouweleeuw@csiro.au

(1) ESSIC, University of Maryland at College Park, (2) Land and Water Division, Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia

Supported by NASA Jason-2/ OSTM Grants NNX08AT88G and NNX13AH15

Jason-2/OSTM PI Meeting, Boulder, Colorado, October 8-11th, 2013

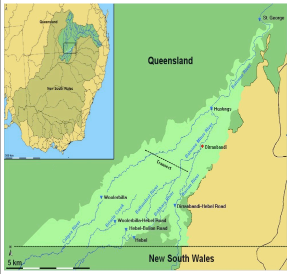
1. Introduction

This NASA-funded program includes several inland water science investigations that utilize a suite of archival (T/P, Jason-1, ERS, ENVISAT), current (Jason-2/OSTM, SARAL) and potential future (Jason-3, Sentinel-3) radar altimeter data sets. The science focus includes river and wetland hydraulics and dynamics, and the utilization of lake levels as a proxy indicator of climate change. A multi-altimeter approach provides a more global and long-term outlook, combining the temporal and spatial resolution merits of each instrument, while the exploration of additional synergistic data such as NASA's ICESat-1 mission offers a multi-sensor approach for the determination of river discharge. A strong instrument performance and validation theme runs throughout the proposed program. This presentation centers on one of the science investigations that utilizes Jason-2/OSTM in its first phase. The region in question is the Balonne River floodplain in Queensland, Australia. Here, there are competing environmental and agricultural/industrial demands on predominantly limited water resources. The region has many small storage tanks and irrigation ponds but the amount of water stored in such pools is a a vital but often missing factor in the water accounting assessments.

KEY REQUIREMENT = AN INVENTORY OF STORED WATER HEIGHTS AT HIGH SPATIAL RESOLUTION

Seasonal rainfall is low, but the plain occasionally receives floodwaters which recharge the many shallow ponds. In 2010 the region experienced one of its largest flooding events. Here we provide a radar altimetric assessment of surface water heights using Jason-2/OSTM over one of the large-scale irrigation developments, and show how the measurements aided the regional water accounting as the flood waters receded.

2. The Balonne Floodplain



The Lower-Balonne floodplain, Southern Queensland, Australia. Situated North of the New South Wales and Queensland borders with gauging stations highlighted (triangles). St. George station is upstream and measures inflow onto the floodplain. All other gauges are downstream and measure outflow off the floodplain. Inset shows Murray-Darling Basin (shaded), the Balonne catchment (dark green) and the Balonne floodplain (rectangle).

The Lower Balonne floodplain (~3,580km^2, maximum elevation range 62m) lies in the Condamine-Balonne catchment. It is situated in the upper northern headwaters of the Murray-Darling basin. On average, minor flood events occur every 2yrs, with major flood events occurring every 10ys alternating with multi-year droughts. All events contribute a significant source of water and provide flows into a heavily regulated system of river extraction and off-channel open water storages for crop irrigation. Storage tanks range in size from 1-20km^2 and storage depth is maximized (~4.5m average) by moving water from one to another, to reduce evaporative losses. Storage water height gradually declines over 1-2 growing seasons in support of crop irrigation.

HOW MUCH WATER IS DIVERTED DURING THESE FLOOD EVENTS? ARE ALL DIVERSIONS REPORTED? WATER ACCOUNTING IS HAMPERED WHEN FLOW GAUGES ARE IMMERSED AND THE ENTIRE AREA IS INACCESSIBLE.

A drought-breaking flood occurred in Queensland in March 2010. The 'worst flood in 120yrs" it caused millions of dollars worth of damage to infrastructure. The flood peaked at 252GL/day at the St. George Station.

3. Water Storage from In Situ and Satellite Imagery

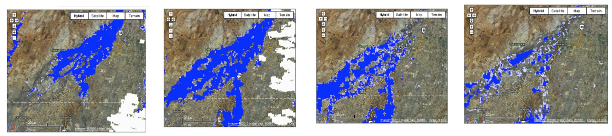
• *In situ* gauge observations. Daily mean, minimum and maximum flows, plus stage/discharge rating curves. ***Good spatially integrated flow at a point within relatively narrow error bounds, but less accurate at high discharge and complete failure during immersion in high flows.***

• Primarily daily optical (Terra/Aqua MODIS 500m) data supplemented by daily passive microwave (Aqua AMSR-E, 37GHz, 14x8km^2) imagery for surface water extent mapping, employing edge detection techniques, in cloud free scenes of varying spatial resolution. Imagery superimposed on Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) (pixel=90m, assuming error ±2m). ***Imagery - Good spatial distribution but low/moderate resolution and cloud interference at optical wavelengths. DEM – restricted by horizontal and vertical accuracy.***

Daily Gauge inflow = St. Georges Station
Daily Gauge outflow = Summary of all other gauges

Net Gauge water volume (time t) = net Gauge water volume (t-1) + inflow (t) – outflow (t) – losses (t)

Image Derived Surface Water Volume = superimposition of water extent map over the DEM.

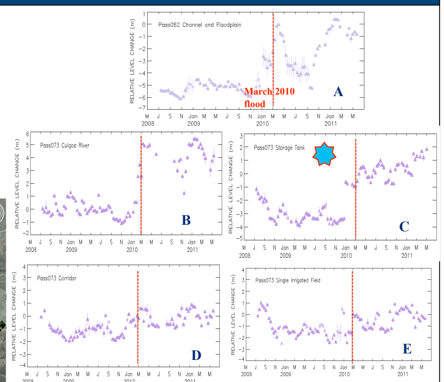


Progression of the March 2010 flood extent (in blue) on the lower Balonne floodplain for March 10th, March 17th, March 24th and 2nd April. White surface =cloud. Overland flows move south and south-east at the peak flow and during flood recession a week later. MODIS: Surface water extent using Open Water Index (OWI) based on Global Vegetation Moisture Index (GVMI) and the Enhanced Vegetation Index (EVI). OWI converted to Open Water Likelihood (OWL). AMSR-E: Surface water extent using the Polarization Ratio (PR) based on vertically- and horizontally- polarized brightness temperatures. PR related to water fraction within a pixel using OWL map from MODIS. Downscaling of AMSR-E via DEM to MODIS 500m resolution.

4. Jason-2/OSTM Results

Location of the Jason-2/OSTM reference ground tracks for ascending/descending passes 073/062. Sections of pass073 cover the north-eastern edge of a large-scale water storage development on the Lower Balonne floodplain. On pass 073 the largest water storage tanks are ~20km^2.

Radar Altimetry: Good on-board (acquisition and tracking) and post-processing (retracking), over gently sloping terrain, calm waters, and small water bodies. Limited along-track (330m) and across-track (315km) resolution, and limited target size. Ground tracks do not precisely repeat and the instrument footprint may contain dry land. Errors on individual heights ~30cm (calm waters/low SWH).

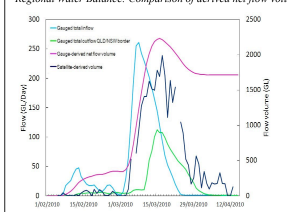


Time series of surface water level variations as monitored by the NASA/CNES Jason-2/ OSTM radar altimeter on ascending pass 073 and descending pass 062. Utilizing 20Hz GDR ice-retracker ranges. Standard repeat track techniques. Checks on radar backscatter coefficient variation for water/type detection. Error bars reflect the root mean square error on the mean of the average height for a particular date. The x-axis is in intervals of 2 months.

A=Southern Floodplain, two 5-6m fluctuations, 2010+2011 flood events.
B=Culgoa River, similar to Southern Floodplain, 2010 event more sustained
C=Storage Facility, 3-4m increase then 2-3m rise, plus smaller fluctuations
D=Over-land flow corridor, Slight increasing 2m trend, small fluctuations
E=Irrigated Field, similar to the corridor

5. Discussion

Regional Water Balance: Comparison of derived net flow volume



COMPARABLE PEAKS BETWEEN GAUGE AND SATELLITE BUT THERE IS A DISCREPANCY BETWEEN WATER VOLUME ESTIMATES DURING THE FLOOD RECESSION

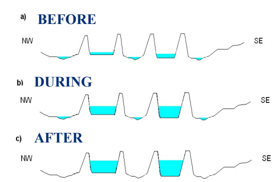
WHERE DOES THE WATER GO?

i) Leaves the floodplain un-gauged?

ii) Infiltrates into the soil or evaporates?

iii) Harvested in open storage structures?

~1,550±160GL OF STORED WATER IS NOT ACCOUNTED FOR. CLEARLY IT DID NOT REMAIN AS SURFACE WATER ON THE FLOODPLAIN OR IT WOULD HAVE BEEN DETECTED BY THE SATELLITE IMAGERY…..



Flood scenario: A time series of 3 NW-SE transects (left image) over the floodplain, a) rising limb, b) peak inundation and c) no river flow. While storage volume increases, surface water extent remains virtually unchanged for the satellite sensor due to the storage wall's steep gradient. (Vertical scale exaggerated here).

Imaging satellite sensors miss the harvested water volume.

The latter remains largely undetected in the satellite imagery due to minim areal extent variation (steep gradient of constructed storage dam walls) i.e., water levels decline but area remains approximately constant

HISTORICAL ESTIMATES – OPEN STORAGE STRUCTURES, 1,200GL CAPACITY, TOTAL SURFACE AREA 267km^2, MEAN DEPTH 4.5m

2010 FLOOD EVENT

1,550GL = MISSING STORED WATER, maximum/1-month average INUNDATION EXTENT =3,200/1,250km^2
???GL = UGAUGED LOSSES, IMAGERY SHOWED EXTENDED SHEETS OF WATER BY-PASSING THE MAIN GAUGES
0GL = SOIL INFILTRATON MINIMAL DUE TO SATURATED GROUND
375GL = MAXIMUM EVAPORATION LOSSES PENMAN POTENTIAL EVAPORATION (8-10mm/day over 30days and 1,250km^2)
791GL = MARCH 2010 REPORTED WATER TAKES

RADAR ALTIMETRY SUGGESTS A POTENTIAL 5-6m STORAGE DEPTH or 1,600GL
COULD WATER TAKES BE GREATER THAN ASSUMED?

6. Conclusions

• Water accounting requires accurate and timely water height information in the open reservoirs. Satellite radar altimetry can provide this information to a certain degree of accuracy. Near real time altimetry data offers a potential operational tool but the spatial resolution is currently limited. Combined Jason-2/SARAL/Sentinel-3 may offer improvements over a single altimeter.

• Jason-2/OSTM has the ability to capture the water height information within the larger irrigation developments. Major fluctuations agree with the high flow events and with water moving slowly downstream over several months. Minor fluctuations agree with irrigation practices and storage top-ups. Results suggest possible storages of 5-6m, larger than the historical average, and therefore greater 'water takes' from the floodplain.

• For water accounting the full spectrum of *in situ* and satellite data are required and the longer-term will look to the SWOT mission (launch 2019, swath, 50m restn, 11day repeat) to improve sufficient spatial resolution of water heights.

7. References

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