SLR energy density modelled and measured at Jason-2 and at the Herstmonceux station

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Introduction

The Jason-2 satellite was launched in the summer of 2008 to follow on from the TOPEX/Poseidon and Jason-1 missions. It continues to monitor global ocean circulation and the tie between the oceans and atmosphere, improve global climate predictions and monitor events such as El Nino conditions and ocean eddies. In addition, Jason-2 carries the Time Transfer by Laser Link (T2L2) payload for the precise characterization of the USO (ultra-stable oscillator) used by the DORIS positioning system. T2L2 also offers the capability to compare ground clocks at different stations (Exertier et al.,2010), particularly those in common view, with an accuracy of better than 100ps. The T2L2 unit uses two photo detectors. The first is linear and records the incident energy of incoming laser pulses and the background from the Earth's albedo. It is used to provide a gate to the second non-linear detector in geiger mode which is used to trigger the event timer and make the T2L2 measurement. In front of each detector is a graded neutral density filter with a profile that accounts for the distance to the satellite and the atmospheric attenuation. This is used to minimise the dynamic energy received during a pass. The raw energy density data is corrected for this filter to give a measurement in J/m^2, in the plane perpendicular to the line of sight.

The SLR station at the Space Geodesy Facility in Herstmonceux measures return signal strength as return rate, which is the number of satellite track returns over the number of opportunities for detection. This value was calculated in 10 second bins by comparing the full rate data files with the raw files archived at the facility. This probability of detection was converted to number of photoelectrons using a Poisson distribution. This was then scaled for detector quantum efficiency and converted to joules using the Planck constant and the wavelength of the laser, 532nm. Further corrections were made for the telescope receive efficiency, the laser semi-train and applied filters (ND and spectral). Finally the values were scaled for the area of the telescope to give energy density. The radar link budget (Degnan, 1993) allows the estimation of energy density at the Herstmonceux station and the Jason-2 satellite. This required known parameters such as the laser energy, the effective telescope area and the transmission and receive telescope efficiencies. Other parameters were estimated from empirical data, such as the laser divergence and atmospheric transmission. Finally, the retro-reflector array cross section was calculated using the far field diffraction pattern, the velocity aberration and the satellite attitude.

These energy densities, measured at Jason-2, measured by SLR at Herstmonceux and estimated by the radar link budget, are compared in this report with the aim of drawing conclusions on the performance of the retro-reflector array cross section and the Herstmonceux station.

Results

The energies, simultaneously measured at the Jason-2 satellite and at the Herstmonceux station, when plotted and compared in time show similar features on a pass by pass basis. Figure 1 shows two example passes, the top plots in red are energies measured at Jason-2 and averaged in 4 second bins. The bottom plots in green

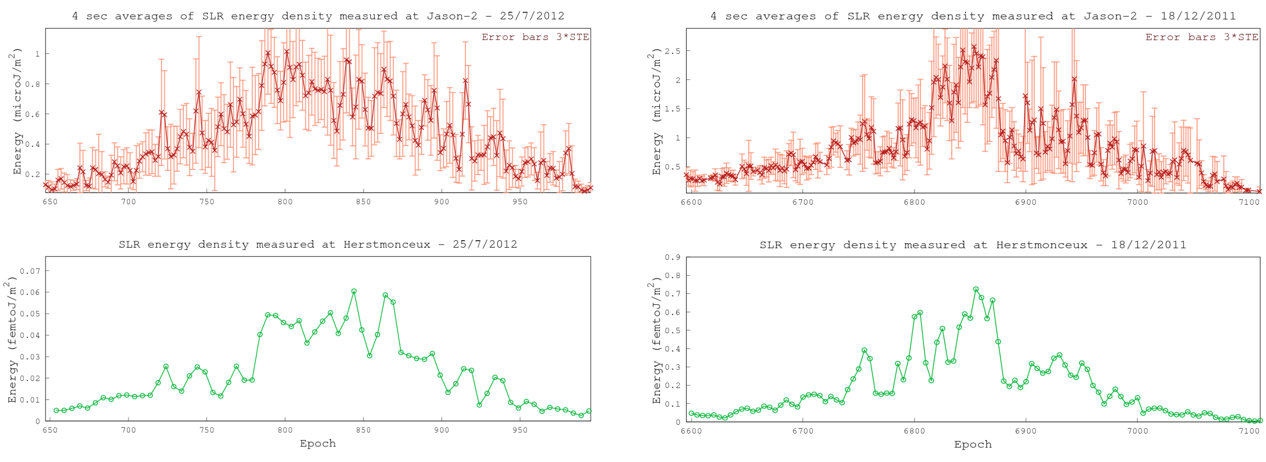

Figure 1. Energies recorded during two example Jason-2 passes, at the satellite (red) and at the station (green).

are energies recorded from 10 seconds of SLR data from the Herstmonceux station.

Figure 2a) shows in red the full history of 4 second averages of Herstmonceux laser shots recorded at the Jason-2 satellite plotted against range. The data is binned and averages are plotted with error bars 6 x standard error. 2b) shows the equivalent plot of calculated energies from the radar link budget using observed visibility values for each pass. Comparing the plots, the observed values are greater than the expected by a factor of 5 or more. Figure 2c) shows the 2-way SLR energy densities measured at the Herstmonceux station plotted against range and averages are plotted with 3 x standard error. 2d) is the equivalent link budget plot, which over estimates the recorded values by a factor of 3 or more.

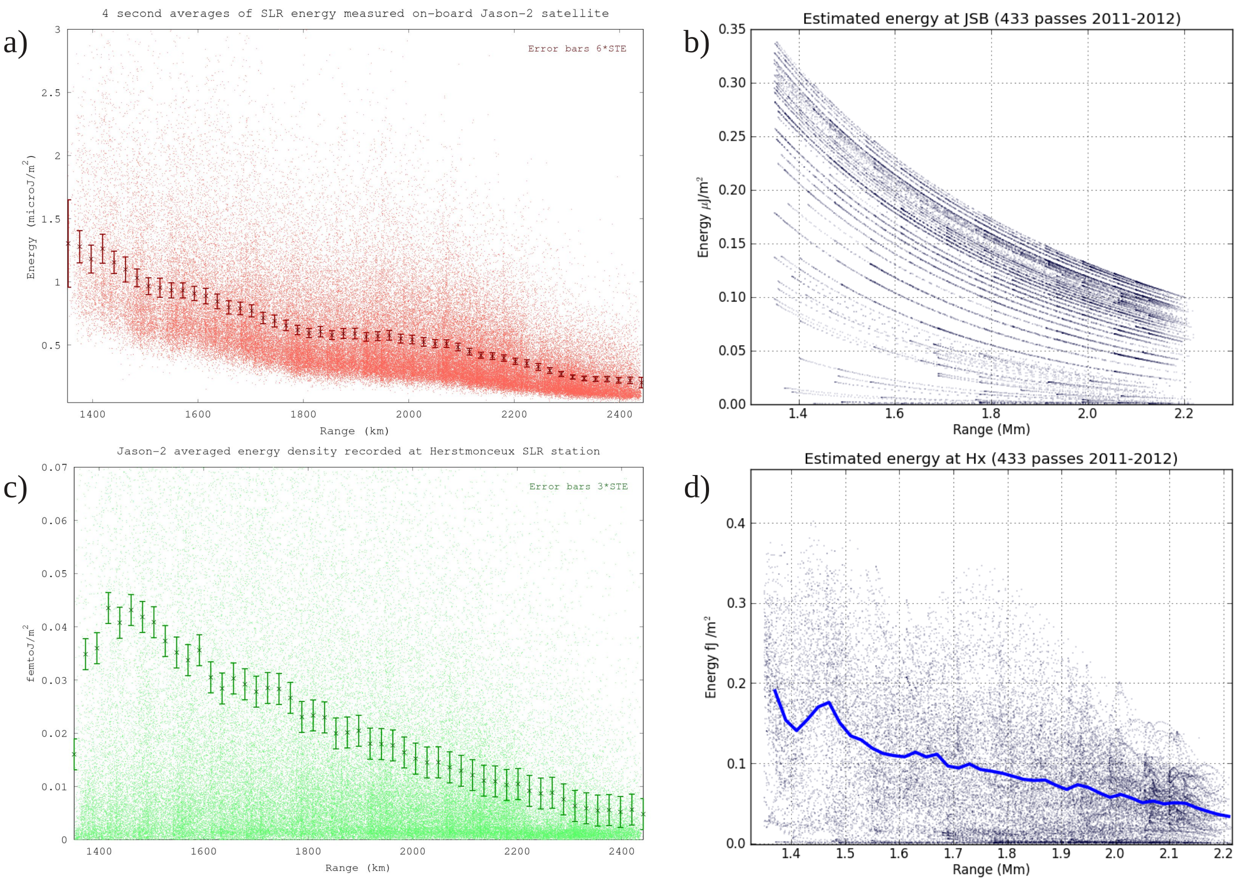

Figure 2. Recorded energies against range. a) recorded at Jason-2. b) estimated one-way energy at Jason-2. c) recorded at Herstmonceux. d) estimated two-way energy for Herstmonceux.

Rearranging the radar link equation to give energy density equivalent to that recorded at Herstmonceux gives $E_{Hx}=\frac{n_{pe}hc\eta_q}{\lambda A_r \eta_r}=E_T\eta_t G_t \sigma\left(\frac{1}{4\pi R^2}\right)^2 T_a^2$. Where η_{pe} is the number of photoelectrons, η_q is the detector quantum efficiency, A_r is the effective area of the telescope, η_r and η_t are the receive and transmission efficiencies, E_T is the laser pulse energy, G_t is the transmitter gain, σ is the satellite optical cross section and T_a is the one-way atmospheric transmission. The energy density at Jason-2, E_J, is also measured and equal to the one-way components of the link budget. Substituting the square $E_J^2=\left(E_T\eta_t G_t\left(\frac{1}{4\pi R^2}\right)T_a\right)^2$ in to the expression above for E_{Hx} and rearranging for σ gives $\sigma=\frac{E_{Hx}E_T\eta_t G_t}{E_J^2}$.

Figure 3 plots the optical cross section σ calculated using the expression above from energies simultaneously recorded at Jason-2 and at Herstmonceux and plotted against range. The values were binned in range and averages and 3 x standard errors are plotted. These values are approximately between 500 and 2000 square

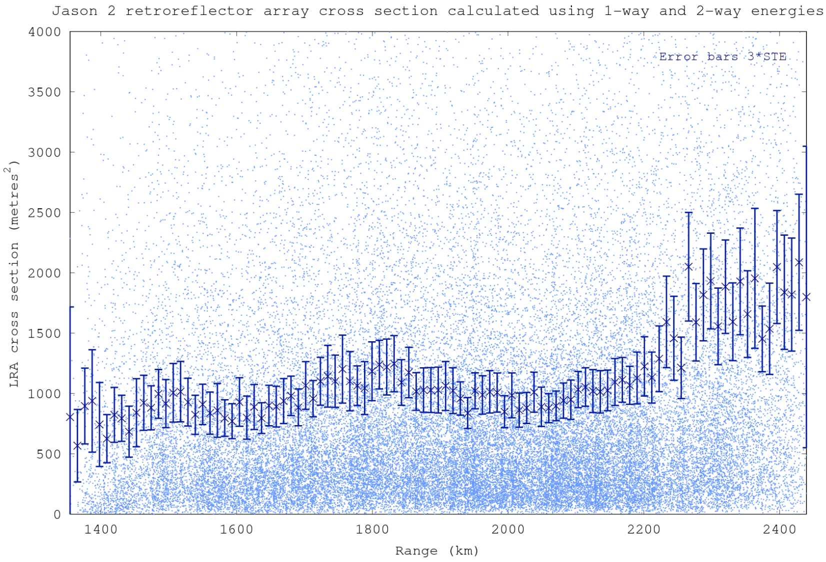

Figure 3. Jason-2 optical cross section calculated using the energies recorded at Jason-2 and the Herstmonceux SLR station.

metres. The expected average value for the cross section for Jason-2 is 800 000m^2 (Arnold, 2003), more than 2 orders of magnitude greater.

Conclusions

The simultaneously recorded energy density datasets look promising since they contain similar features on an individual pass by pass basis. Comparing the whole history of both datasets shows on average a correlated relationship between the two measurements. Using the 1-way and 2-way energy density records should allow a direct calculation of the satellite optical cross section. However, our radar link budget calculations currently give low energy density values at Jason-2, by a factor of 5, and high return values at Herstmonceux, by a factor of 3. The cross section of the Jason-2 array, calculated from the 1-way and 2-way measurements, is consequently much less than the expected value. Possible causes for this disagreement could be incorrect treatment of the atmospheric transmission or an inaccurate value used for transmission gain.

References

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