SLR energy density estimations and measurements for the Herstmonceux station

Matthew Wilkinson, Jose Rodriguez
SGF, Herstmonceux
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Reprocessed return energies

- Return rates were recalculated using fullrate data files, raw range files and corresponding records of the applied filters.
- Reversing part of the link equation gives the number of photo-electrons per shot from the probability of detection.
- This is then scaled by the QE of the detector, the wavelength and Planck constant, the applied filters, receive optical efficiencies and the area of the telescope.
Reprocessed return energies

- The data set begins in June 2009 when the narrowband oven filter was last retuned.
- The dataset is not perfect and includes laser services, SPAD swaps and optic changes.
- Energy densities were calculated for both SLR systems, although the kHz laser was operational for less than half of the period.
Starlette return energy densities
Herstmonceux Link-budget

The link budget uses measurement, modelling and estimation:

• The beam divergence was measured using a scanning method (Burris et al.).
• Pointing errors were estimated as an average bias based on observer experience.
• Atmospheric transmission was estimated from local visibility measurements and the values were tested with photometry star calibrations.
• An average value of cirrus cloud was assumed.
• Satellite cross-section was calculated by diffraction modelling and velocity aberration.
• For spherical LRA targets, the retroreflectors were assumed to be evenly distributed.
• For Jason-2, actual retroreflector positions + attitude law were calculated.

Average Lageos return energy densities

Estimated 2-way energy densities at the 2kHz Hersmoneux SLR station from Lageos

Estimated 2-way energy densities at the 12Hz Hersmoneux SLR station from Lageos
Average **Starlette** and **Stella** return energy densities
Average Ajisai return energy densities
Average Etalon return energy densities

SLR return energy densities from the 12Hz system

SLR return energy densities from the 2kHz system
Laser energy from and at Jason-2

- From its launch in 2008, as part of the OCA/CNES time transfer by laser link (T2L2) payload, Jason-2 recorded energy densities of incoming SLR laser pulses.
- Both detectors have a graded neutral density filter to minimise the dynamic energy received during a pass.
- The raw data is corrected for this filter to give a measure of J/m², in the plane perpendicular to the line of sight.
Average Jason-2 return energies
1-way laser energy densities at Jason-2
Turbulent, asymmetric distribution

- Energy measurements at Jason-2 show a asymmetric distribution with the majority of values concentrated at the lower end.
- This is explained by turbulence-induced scintillation.
- A log-norm distribution with the variance of the logarithm of the intensity as sole parameter (no curve fit) describes perfectly the empirical PDF.

![HERL laser energy distribution at Jason-2](image-url)
Lunar Reconnaissance Orbiter (LRO) energies

- The Lunar Orbiter Laser Altimeter (LOLA) is an instrument on NASA’s LRO which detects incoming laser signals and records the pulse energy.
- The Herstmonceux station began one-way tracking soon after its launch in June 2009.
- The clear aperture of the telescope is 1.9 cm
Lunar Reconnaissance Orbiter (LRO) energies

1-way energy densities from Hersmonceux SLR measured by the LOLA detector on LI

Estimated 1-way energy densities from the 14Hz Hersmonceux SLR station detected at LRO
Conclusions

• The SGF, Herstmonceux has a varied selection of laser pulse energy density measurements in its possession.

• We are beginning to make sense of the data by comparing the results with our best estimates using the radar link equation.

• However further progress is needed, particularly on the large 2-way estimation and measurement disagreements.
Conclusions

• Poor performance of the SLR system could also be the cause of some of the disagreements observed.

• Other known errors include:
  • Diffraction calculation. Even retroreflector spacing is assumed and the intensity is artificially concentrated on centre of FFDP resulting in cross-section underestimation.
  • Scintillation effects in the data and to pointing.
Thankyou

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