Beam Divergence Measurements at ILRS SLR stations

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It is now essential that ILRS stations are able to estimate, or measure, the angular divergence of laser pulses emitted during satellite laser ranging. With this divergence value, along with the laser pulse energy, it is possible to calculate the energy density at satellite heights. This is of high interest to satellite mission operators, particularly those with on-board equipment that could be sensitive to incident laser light.

A procedure to measure beam divergence was drafted by the NESC and is available to download http://ilrs.gsfc.nasa.gov/docs/2016/BeamDiv_procedure_201606.pdf

Stations were requested to use this procedure, or an alternative method if necessary, to determine beam divergence. The results from the SLR beam divergence measurement campaign, carried out over the summer of 2016, were presented at the NESC meeting during the 20th ILRS Laser Workshop held in Potsdam, Germany. Most stations were able to use the beam divergence procedure and get good results, particularly after some practice. These are presented in the **figure #1**.

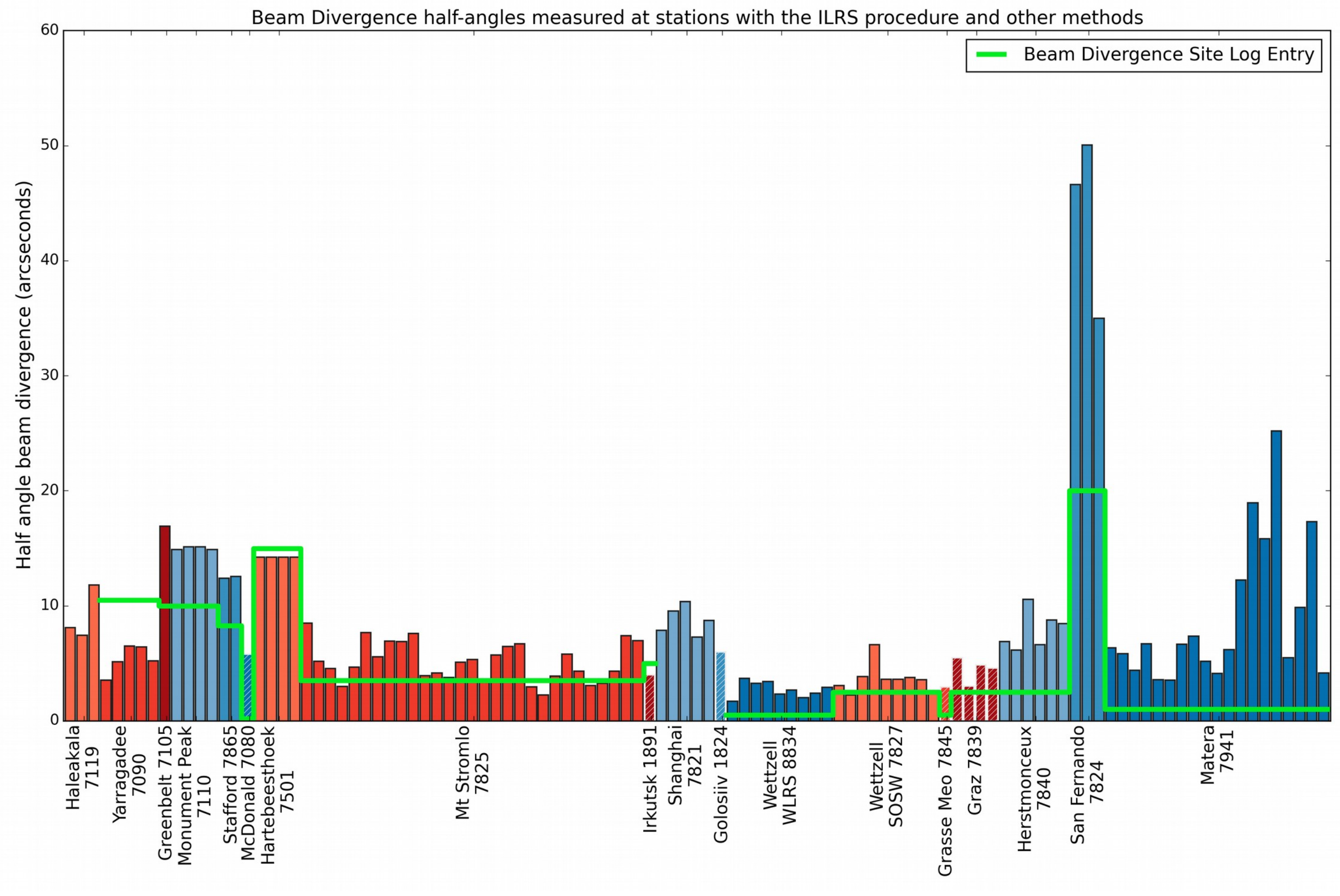

Figure #1

Some stations however we not able to carry out the procedure for reasons including:

- Faulty energy sensor/meter
- High energy detection threshold
- Limited telescope pointing/tracking accuracy

Data was provided by some stations using alternative methods. These stations were McDonald, Irkutsk, Golosiiv, Grasse and Graz (these are included in these plots and shown with white hash lines). The methods used included:

- Satellite scanning
- Optical system ray tracing
- Measurements in the focal plane

Mount Stromlo, Australia carried out many measurements, see **figure #2**. There is some variability in the results and it seems that lower values were recorded for the GNSS satellites. The chart suggests that taking multiple measurements on different satellites on different nights will give a better average reading than a single measurement.

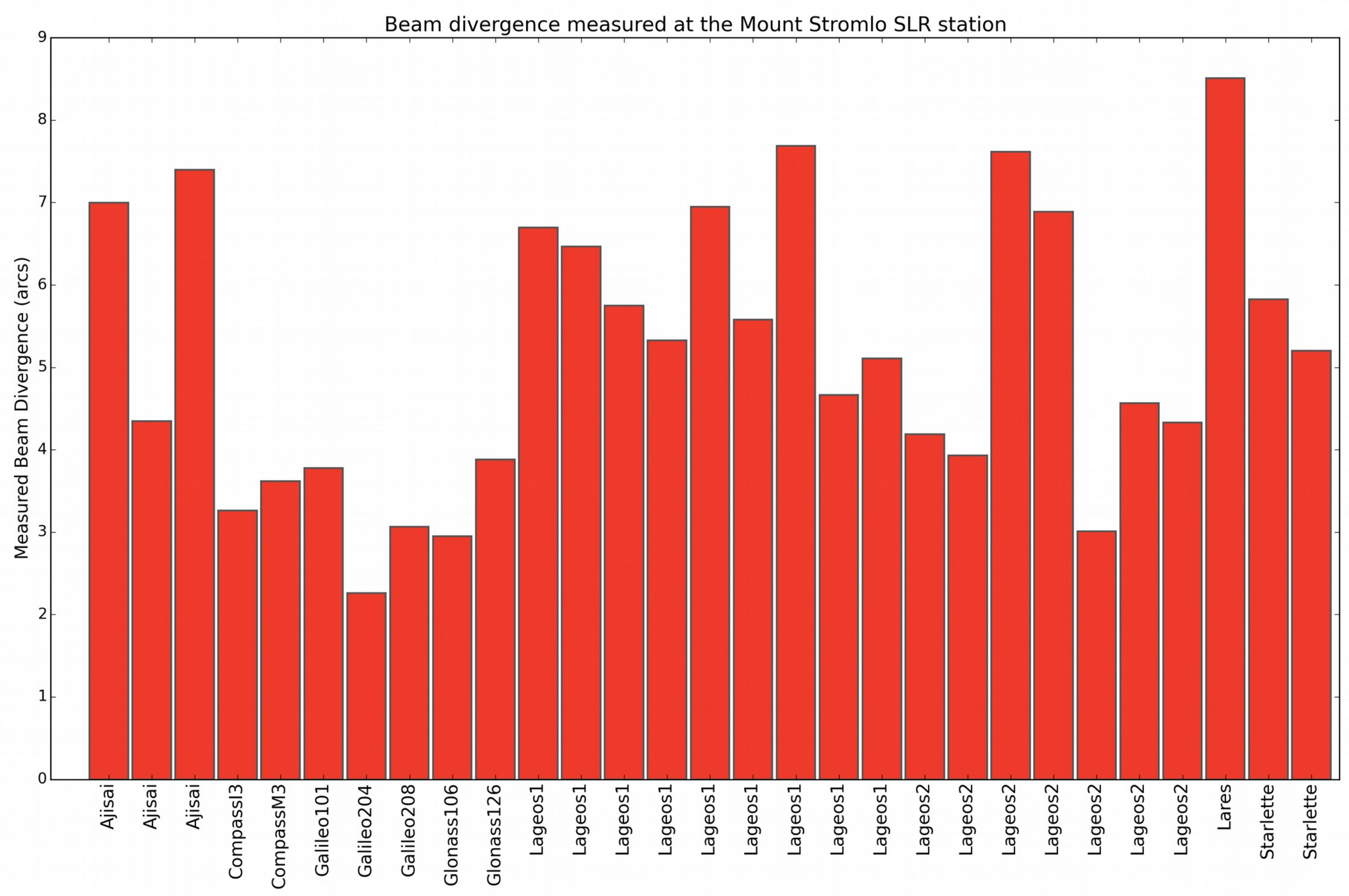

Figure #2

Matera, Italy also took many measurements, see **figure #3**. The results show the two different beam divergence settings used.

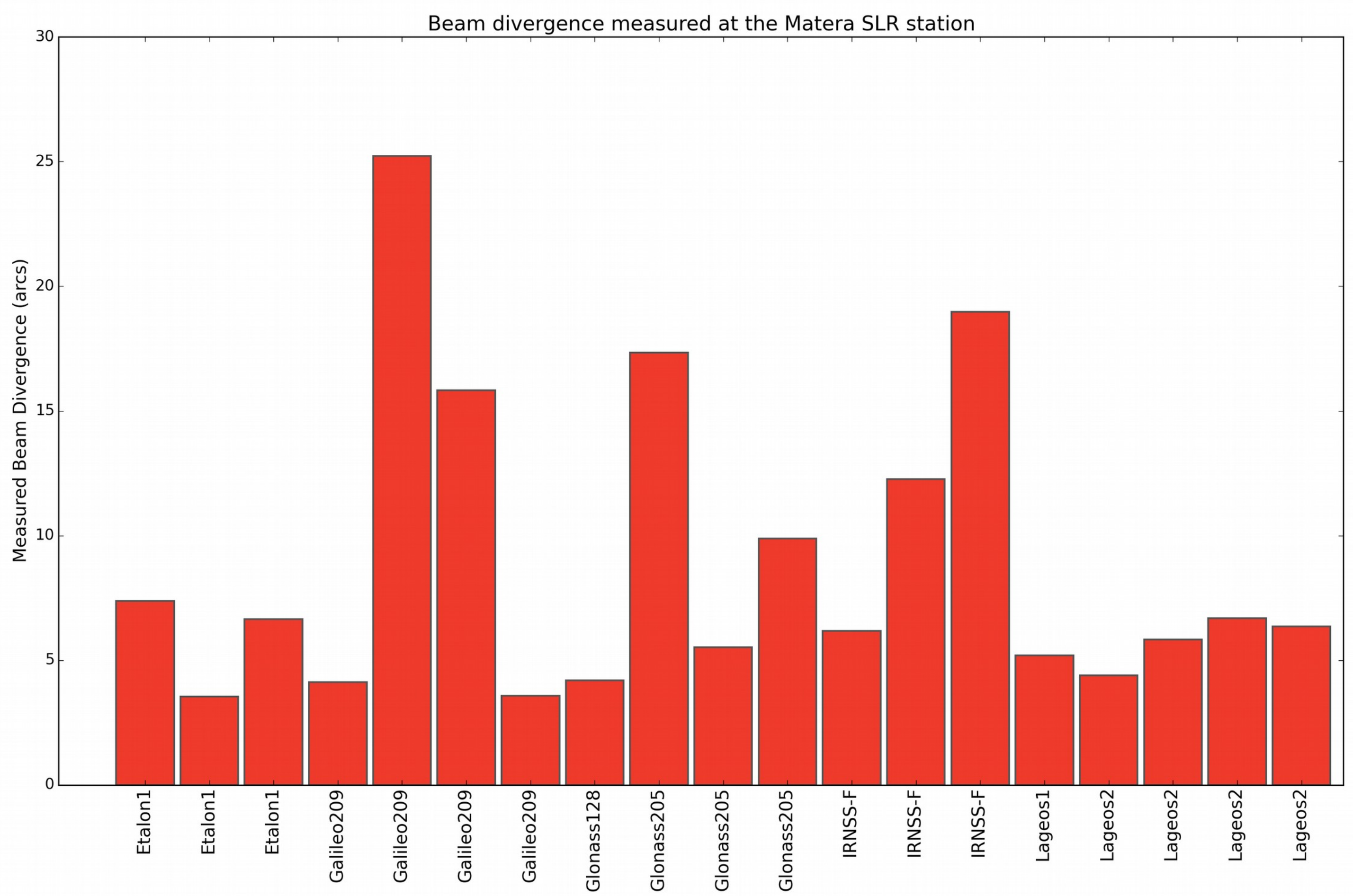

Figure #3

The procedure includes a secondary part where an operator can change the beam divergence setting and making a quick comparative measurement. This was carried out at Herstmonceux, UK for a number of satellites at different times by 2 observers. The trend fit can now be used to relate the arbitrary beam expander setting value to a real divergence value. See **figure #4**.

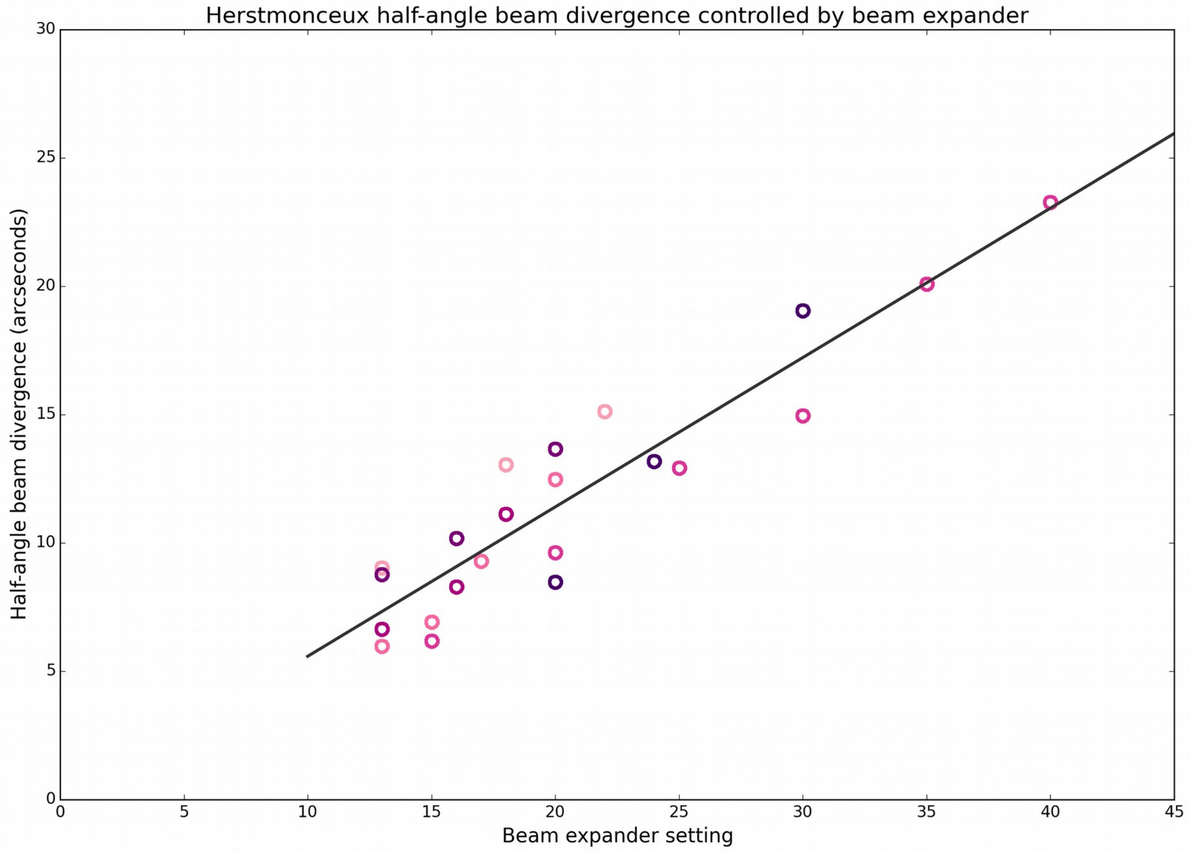

Figure #4

Figure #5 is the averaged values for each station. Included is a green line indicating the stated beam divergences in the ILRS Site Logs. The beam divergence procedure is giving generally close agreement with the ILRS Site Log entries. For some stations, the site log entries are lower values than measurements taken using the beam divergence procedure.

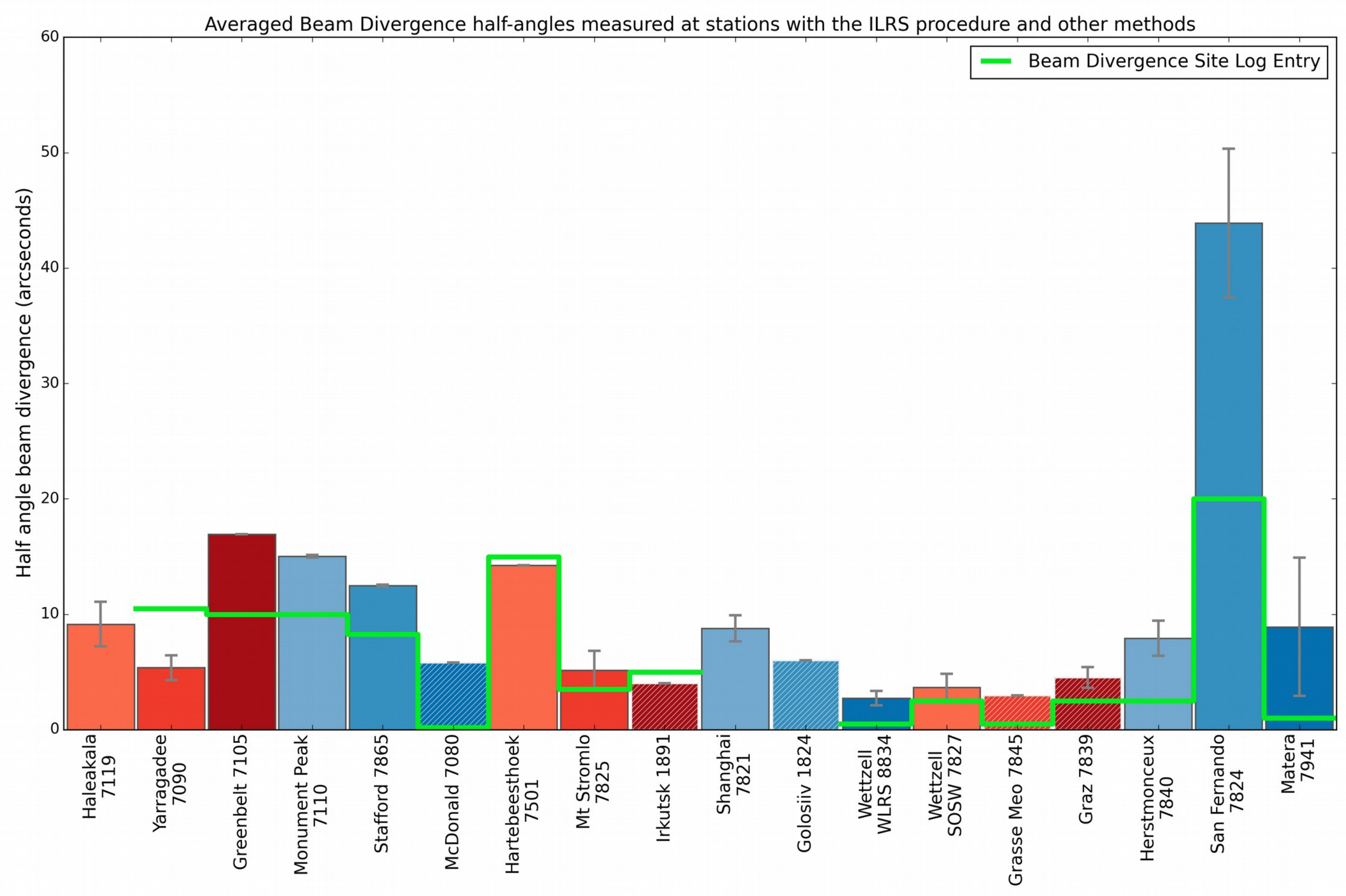

Figure #5

Figure #6 shows the single-shot energy density from each station at a height of 1336km (Jason-2 height), calculated using these beam divergence values and the laser pulse energies from the ILRS Site Logs. The y-axis has been limited, the Wettzell result is 0.28 microJ/cm^2 and the Grasse result is 0.65 microJ/cm^2.

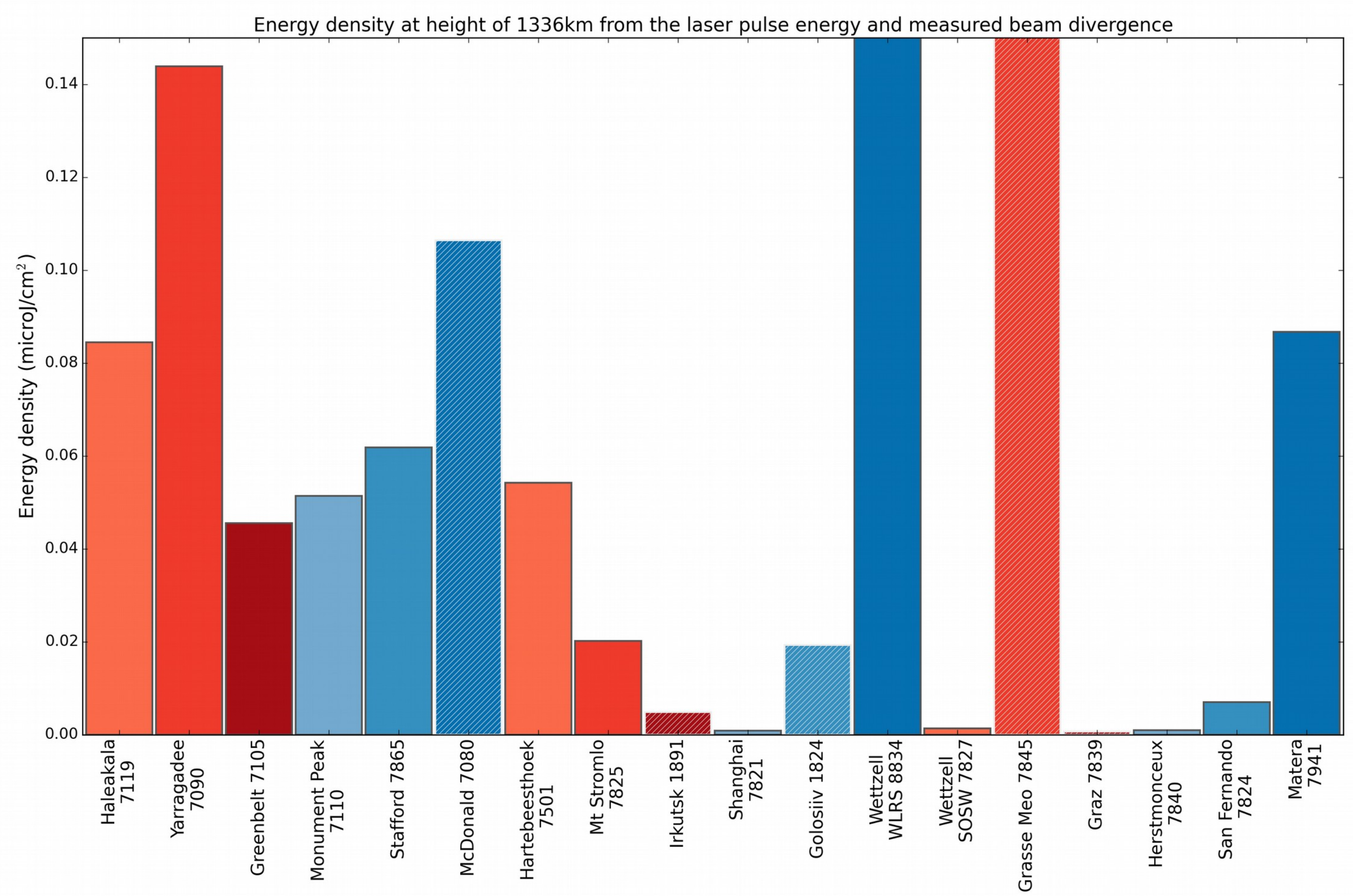

Figure #6

An alternative way to look at energy densities at satellite heights would be to make measurements at the satellite. The Jason2 mission has recorded energies of SLR pulses since its launch in 2008 as part of the OCA/CNES time transfer by laser link (T2L2) payload.

Figure 7 shows the average energies for individual stations recorded at Jason-2 for the year 2015. The energies were normalised to the Jason2 height in the zenith (1336 km) and corrected for atmospheric attenuation.

My thanks to P. Exertier and OCS and CNES colleagues for providing this data.

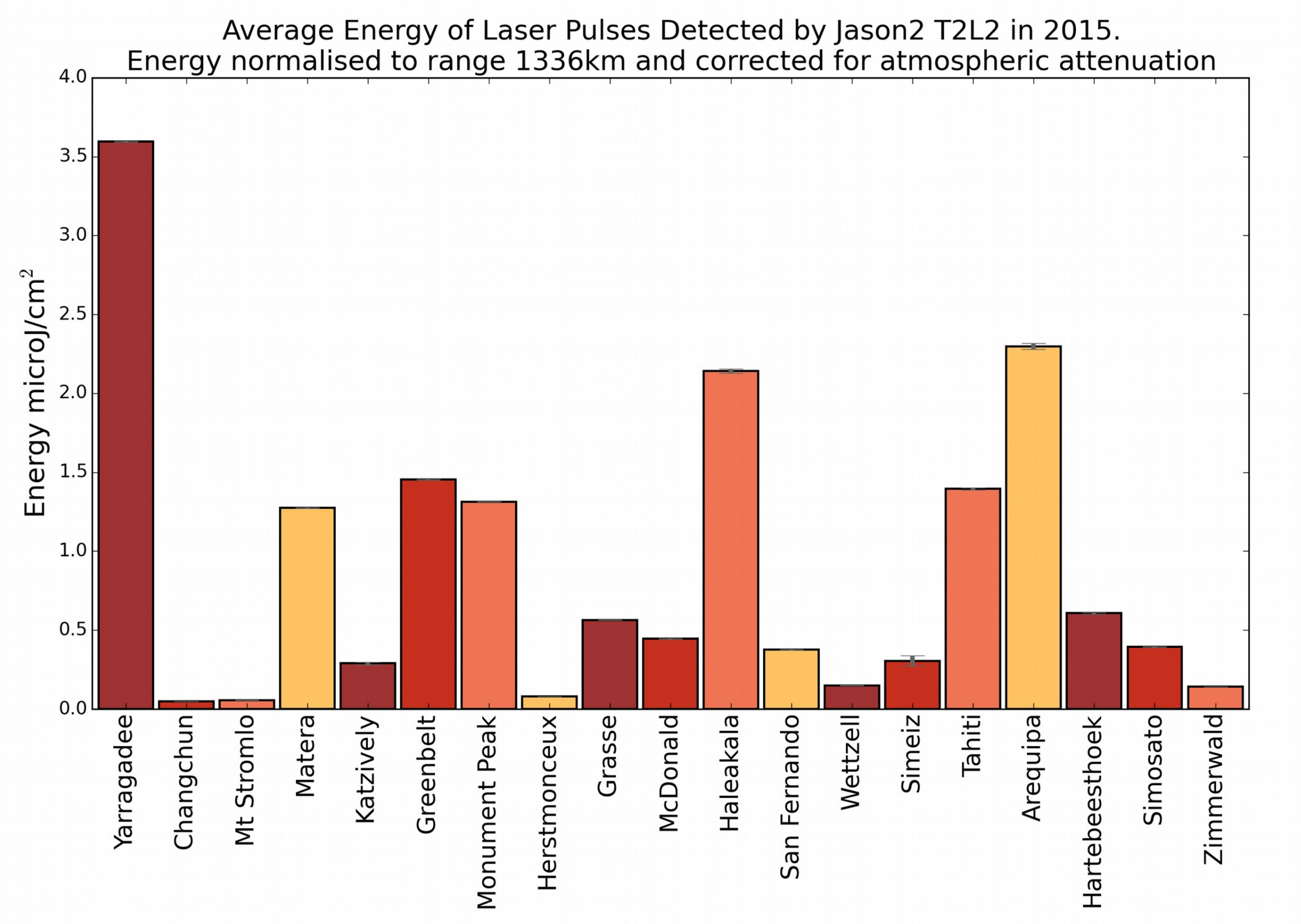

Figure #7