Relative signal strengths from SLR tracking of the different retro-reflector targets onboard HEO satellites using the fullrate data set

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NATURAL ENVIRONMENT RESEARCH COUNCIL

Summary

- Introduction
- Different High Earth Orbiting (HEO) satellite targets
- Return rates from fullrate data
  - Defining the 'return rate' and forming a value
  - What variables affect the return rate?
  - Reducing the impact of these variables
- Analysis of the Herstmonceux and Yarragadee fullrate data from 2007
- Plots of return rate against elevation and corrections
- Comparison of CompassM1 target and individual retro-reflectors to the other HEO satellites
- Conclusion

Introduction

- The ILRS Missions Working Group requested a tracking campaign for March 2009 encouraging stations to increase tracking of the CompassM1 satellite and the other HEO satellites.

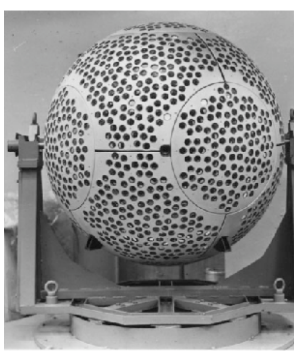
- The aim was to test and compare the effectiveness of the relatively small array of un-coated cubes on the COMPASS-M1 satellite with respect to the three GLONASS, two GIOVE, two GPS and two ETALON geodetic satellites currently supported.

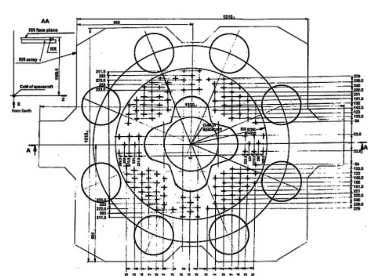
- This work follows a preliminary report presented at the Missions Working Group and Analysis Working Group meetings in April 2009 at the EGU.

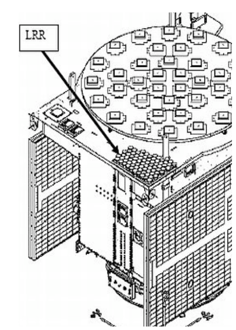
The CompassM1 retro-reflector array. 31.6 x 28cm, 42 cubes of 33mm diameter of fused silica.

Introduction

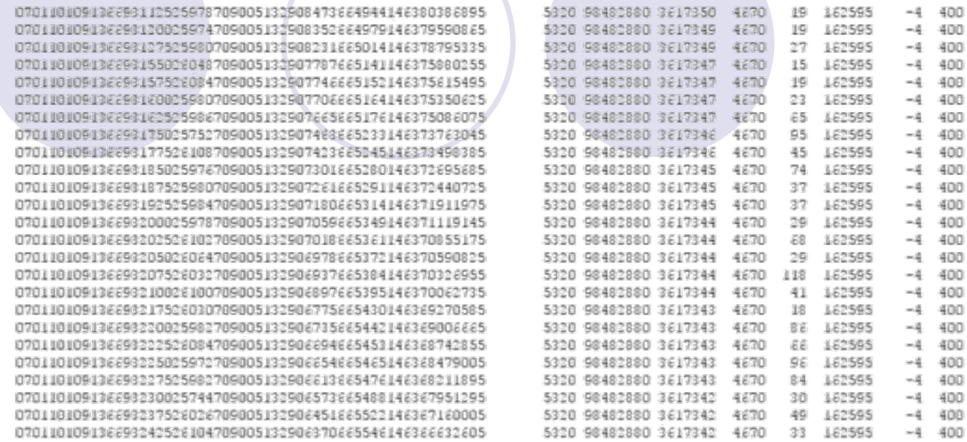
- CompassM1 is the only HEO satellite to use un-coated retro-reflectors
- The GPS, Giove, Etalon and Glonass retro-reflectors were built by the Russian Institute for Space Device Engineering. Each is made from fused-quartz with the back reflective surfaces coated with aluminium.
- For the different satellites, the retro-reflector arrays are arranged in different shapes and sizes.







Relative signal strengths



- The fullrate data files on CDDIS and EDC from contributing stations contain all successful returns from satellite laser ranging separated into satellite and station folders.

- A return rate can be calculated as the number of observation entries in the fullrate file within a time interval over the expected number of shots during this period.

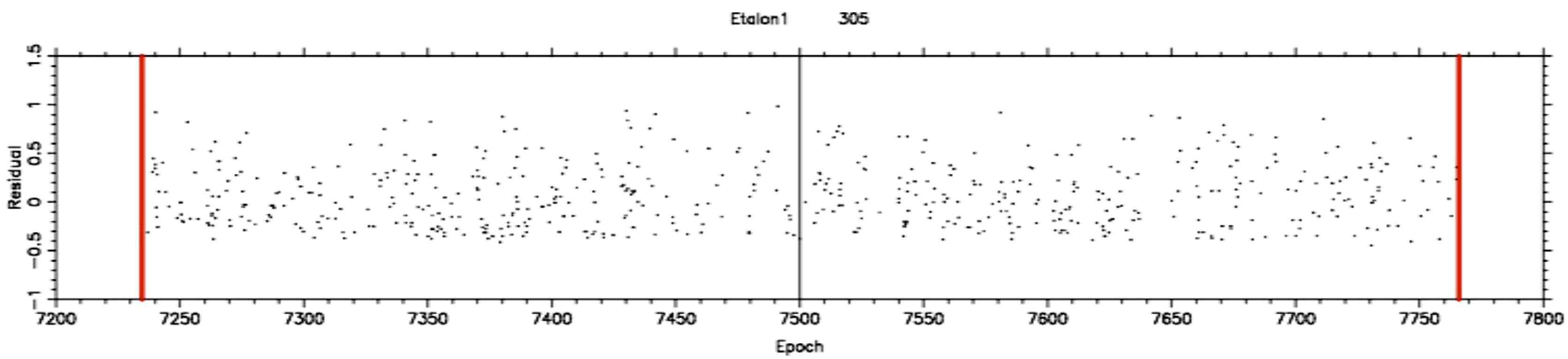
$$\text{Return rate} = \frac{\text{Number of observations}}{\text{Number of laser fires}}$$

- The fullrate data used is this study was from **2007 onwards**.

- The CompassM1 and GioveB datasets include data from the beginning of SLR tracking, December 2008, and May 2008 respectively.

Relative signal strengths

- Return rates in this investigation use the maximum and minimum epochs in a bin and the interval between the two to calculate the number of expected fires, dependant on the firing rate.



- Instead of the 300 second normal point bin, a 60 second bin was used to best avoid any gaps in data. Further to this data gaps of greater than 15 seconds were removed.

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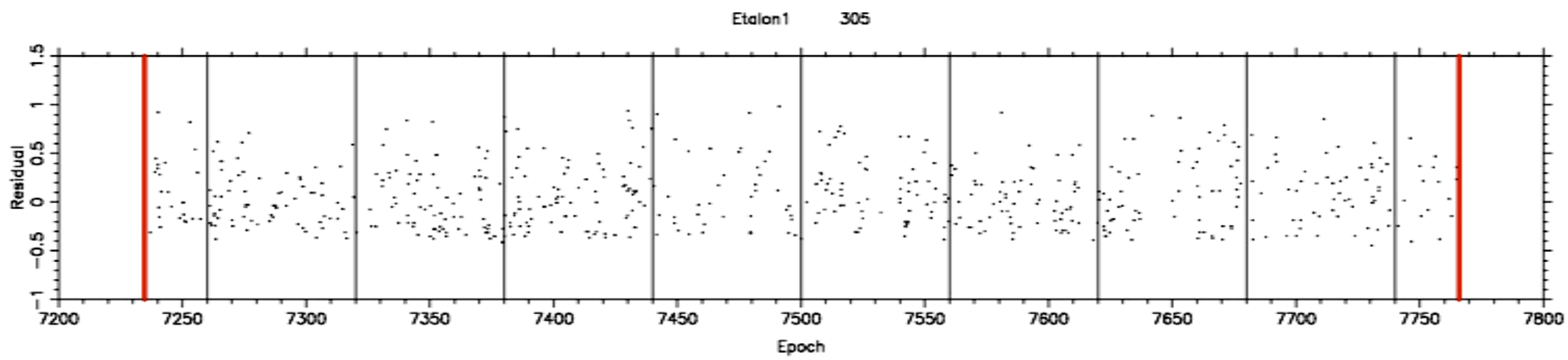

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Relative signal strengths

- There are a number of factors that influence the observed return rate:
  - Individual station ability
    - **Separate analysis for individual stations**
  - Atmospheric transparency
    - **Averaged over large amounts of data**
  - Beam divergence
    - **Settings kept the same for all HEOs over time**
  - Satellite range
    - **To be corrected for**
  - Filtering of the return signal and detection thresholds
    - **Data entries removed so that the all data is comparable**
  - Retro-reflector targets
    - **Remaining dominant variable in analysis**

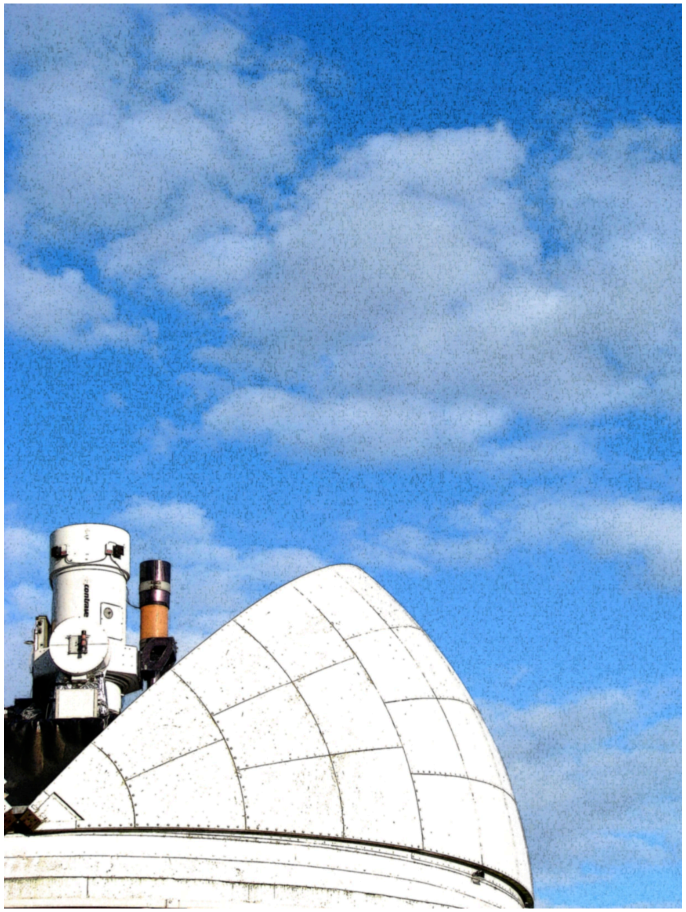
Relative signal strengths

- In the following plots the resulting return rates are presented plotted against elevation.
- The Etalon satellite datasets are combined together.
- The GPS datasets are combined together
- The Glonass datasets (Glonass99, Glonass 102 and Glonass 109) are combined together.
- The Giove satellites have different retro-reflector targets and are treated independently.

Relative signal strengths

Herstmonceux, UK

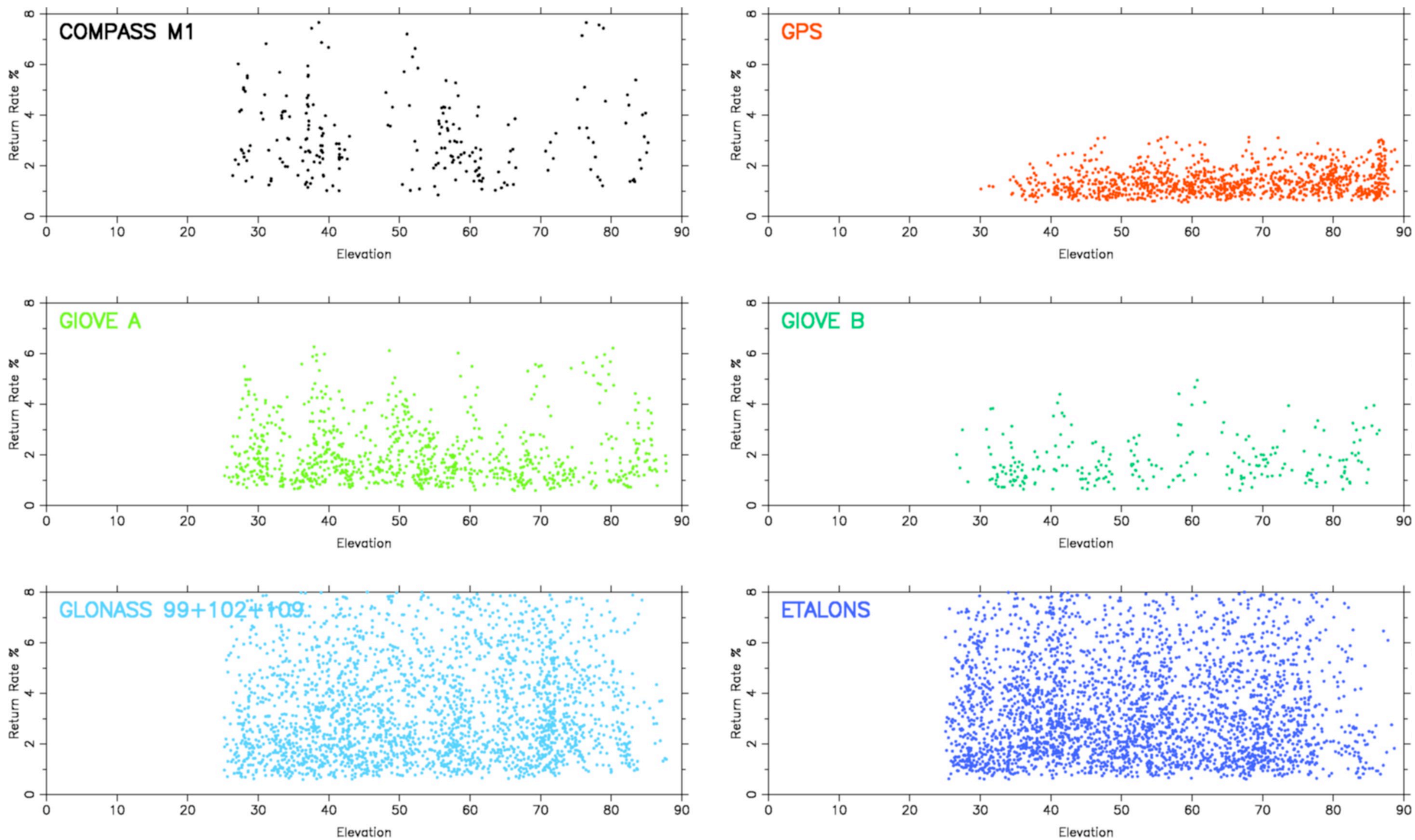
- Herstmonceux firing rate is effectively 24Hz using the semi-train.
- All Daytime data is excluded in this analysis as this was collected using the Narrowband filter
- All kHz tracking is excluded
- All data collected using Neutral Density filters was excluded.



Relative signal strengths

Herstmonceux, UK

Return rates from the Herstmonceux SLR station from 2007



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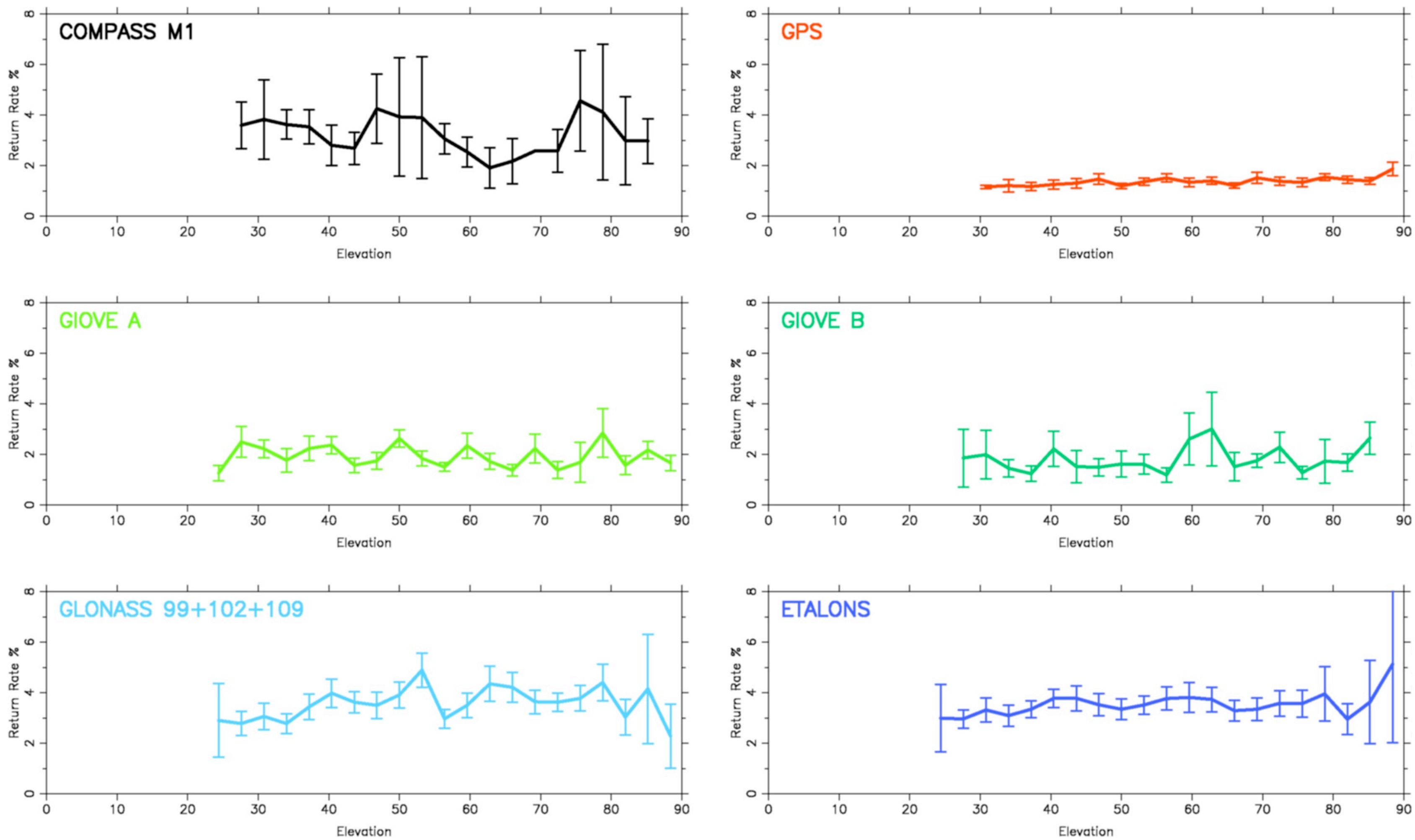
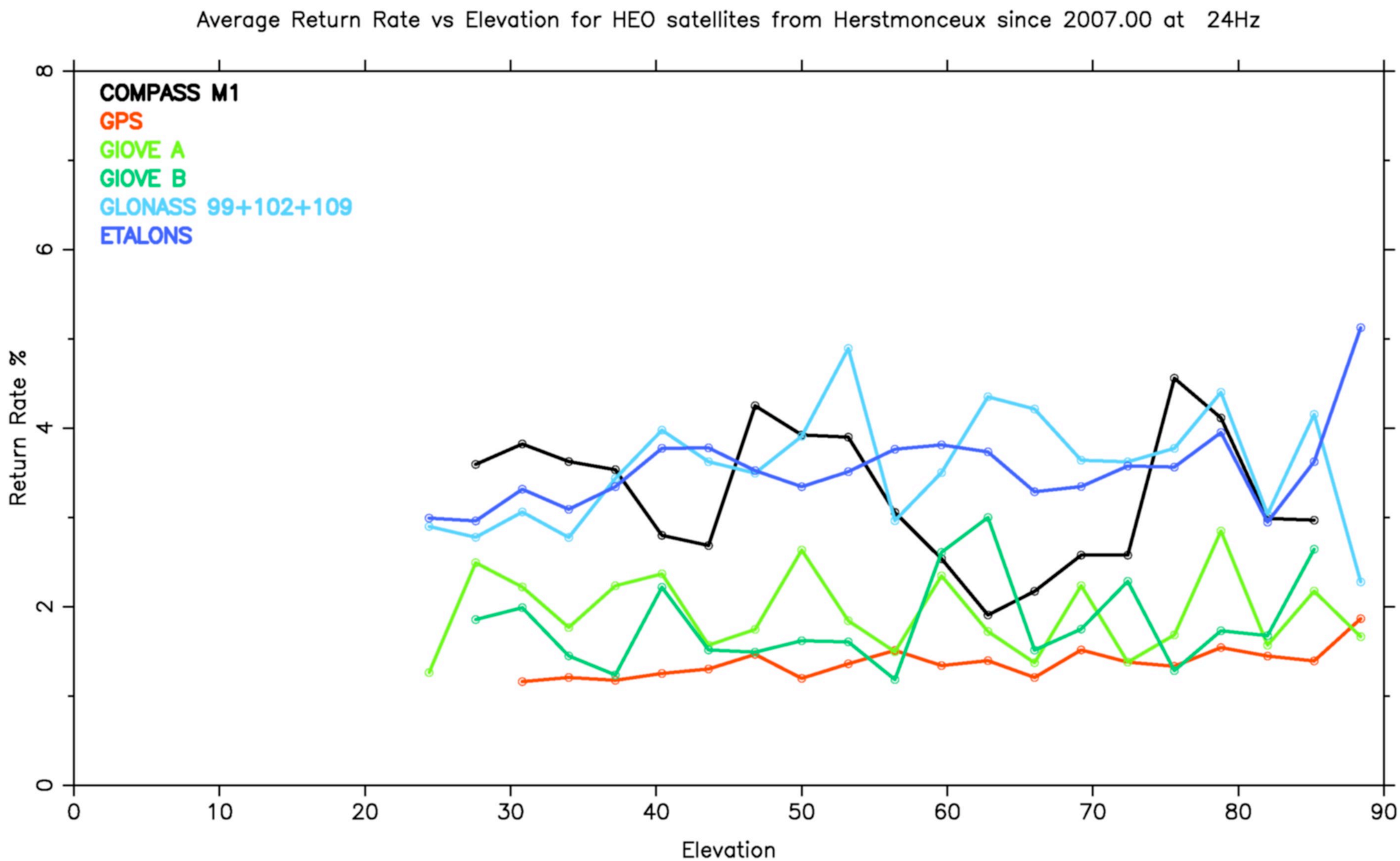


Relative signal strengths Herstmonceux, UK



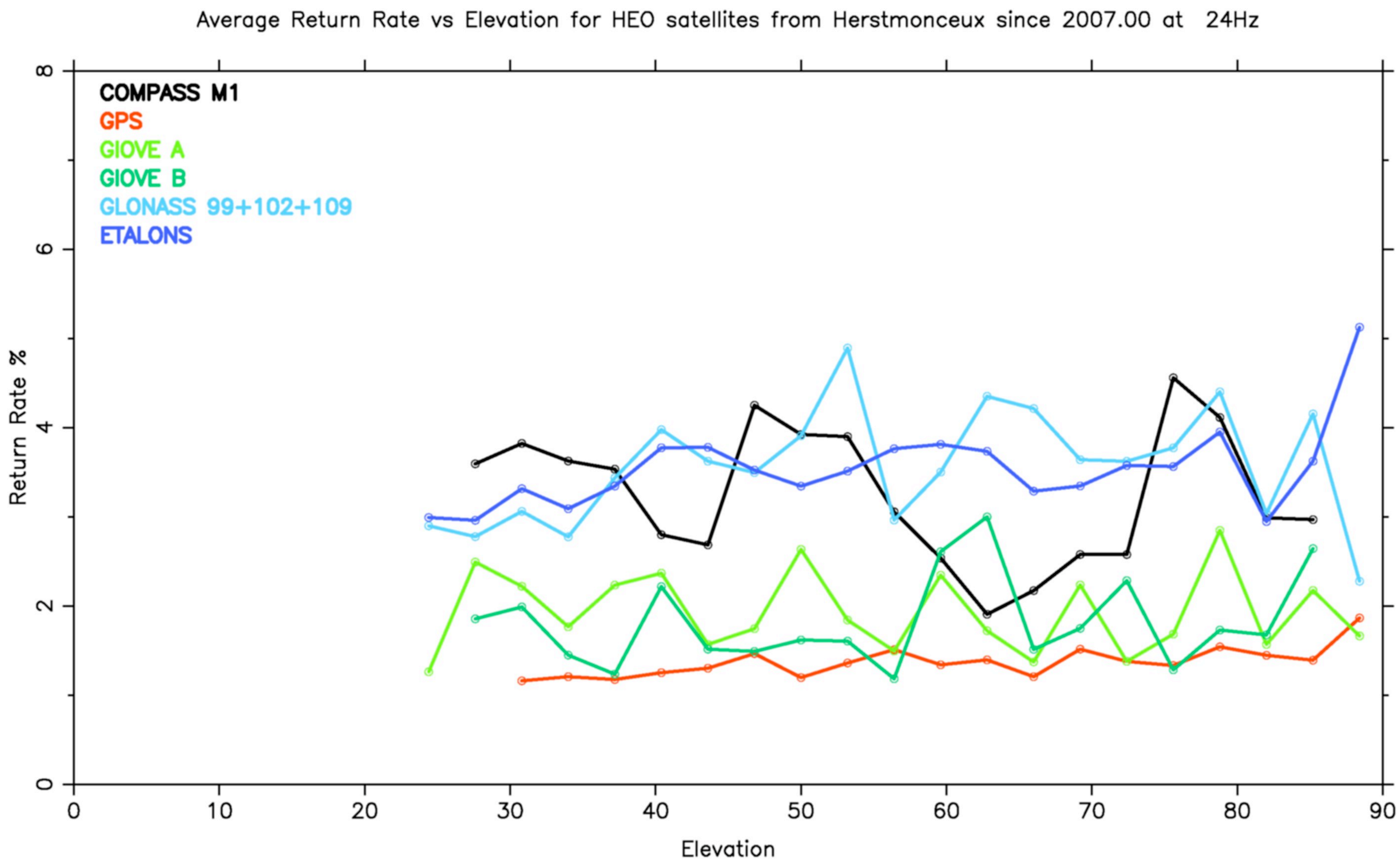
Relative signal strengths

- Return rate is dependent upon the satellite range as a R^4 relation. The distances to the satellites are:

CompassM1	21 500 km
Etalon 1 + 2	19,135 km
GioveA	23 916 km
GioveB	23 916 km
Glonass99 + 102 + 109	19,140 km
GPS35 + 36	20,030 km

- The return rates can therefore each be scaled according to the average range. The following results are normalised to a distance approximately that of Compass M1 range in the Zenith.

Relative signal strengths   Herstmonceux, UK



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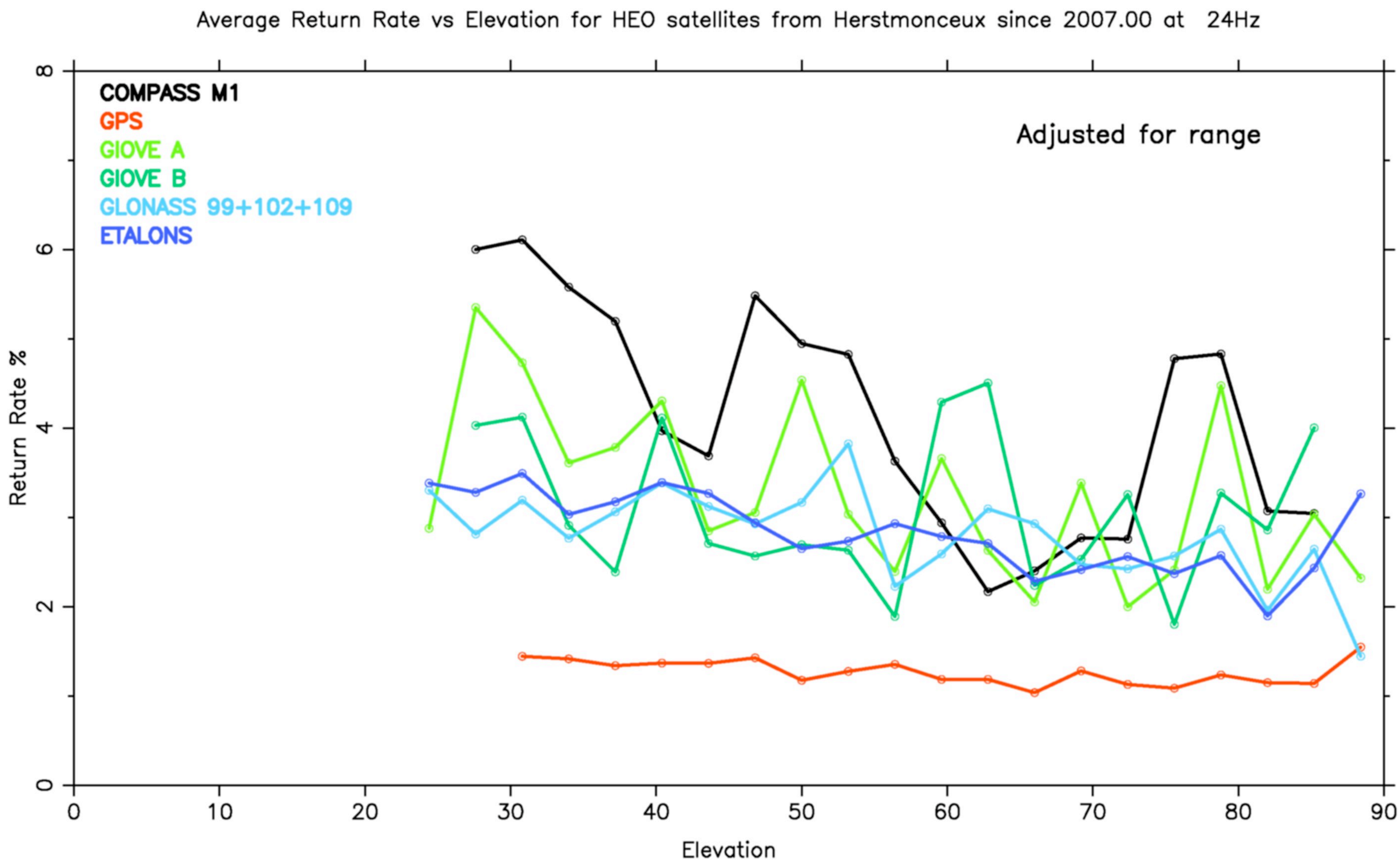


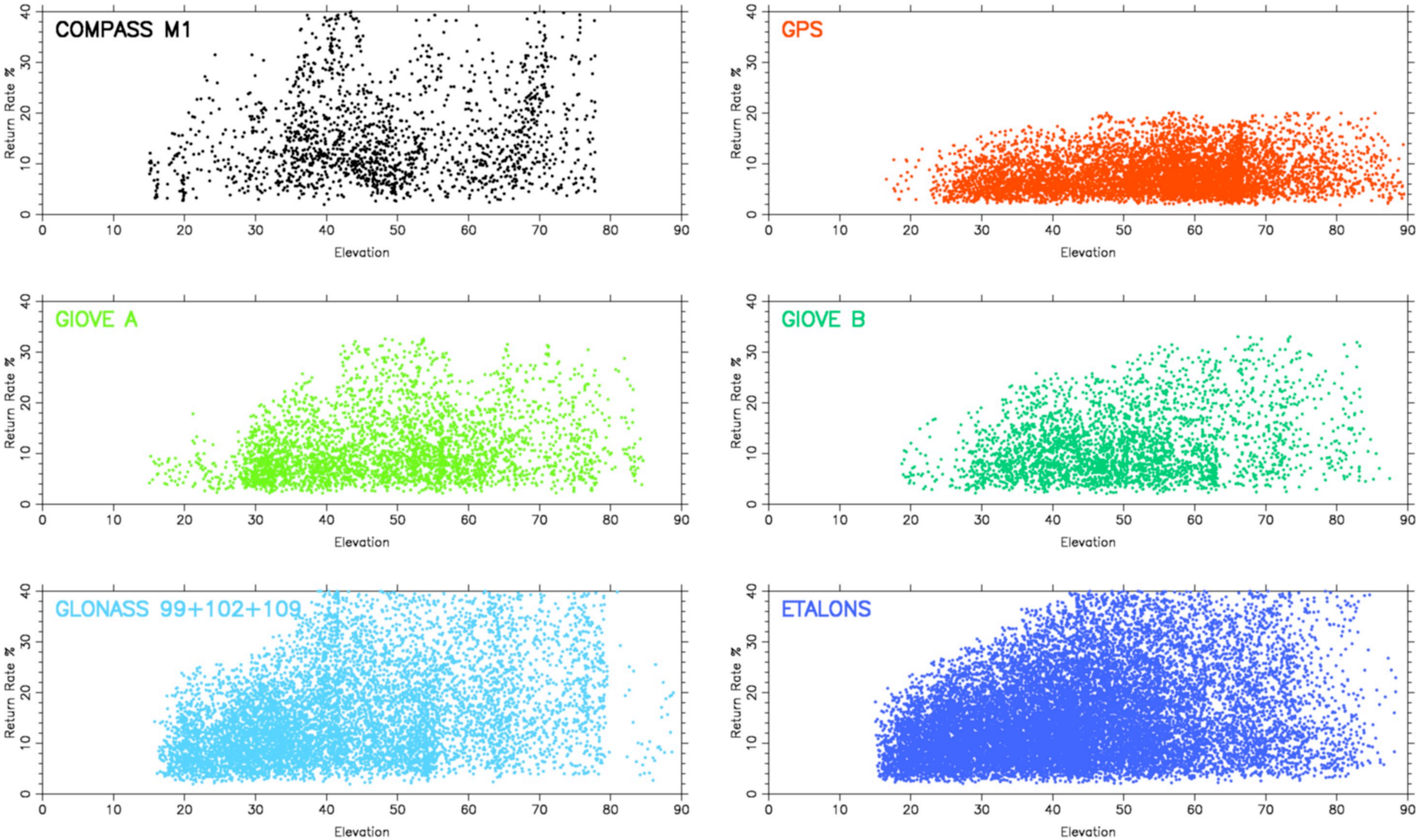
Relative signal strengths

Yarragadee, Australia

- Yaragadee is the most productive site in the ILRS network.
- In July 2009 a new MCP tube was installed using a voltage of 3000V and allowing daytime HEO observations. This data was not included in this analysis.
- The previous MCP used a voltage of 3600V which was increased to 3700V for most GPS passes and some other difficult GNSS passes.
- In this period no daytime observations of HEOs were made.
- The firing rate is 4Hz for HEO satellites.
- ND filters would only rarely be used.

Relative signal strengths Yarragadee, Australia

Return rates from the Yarragadee SLR station from 2007



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Yarragadee, Australia

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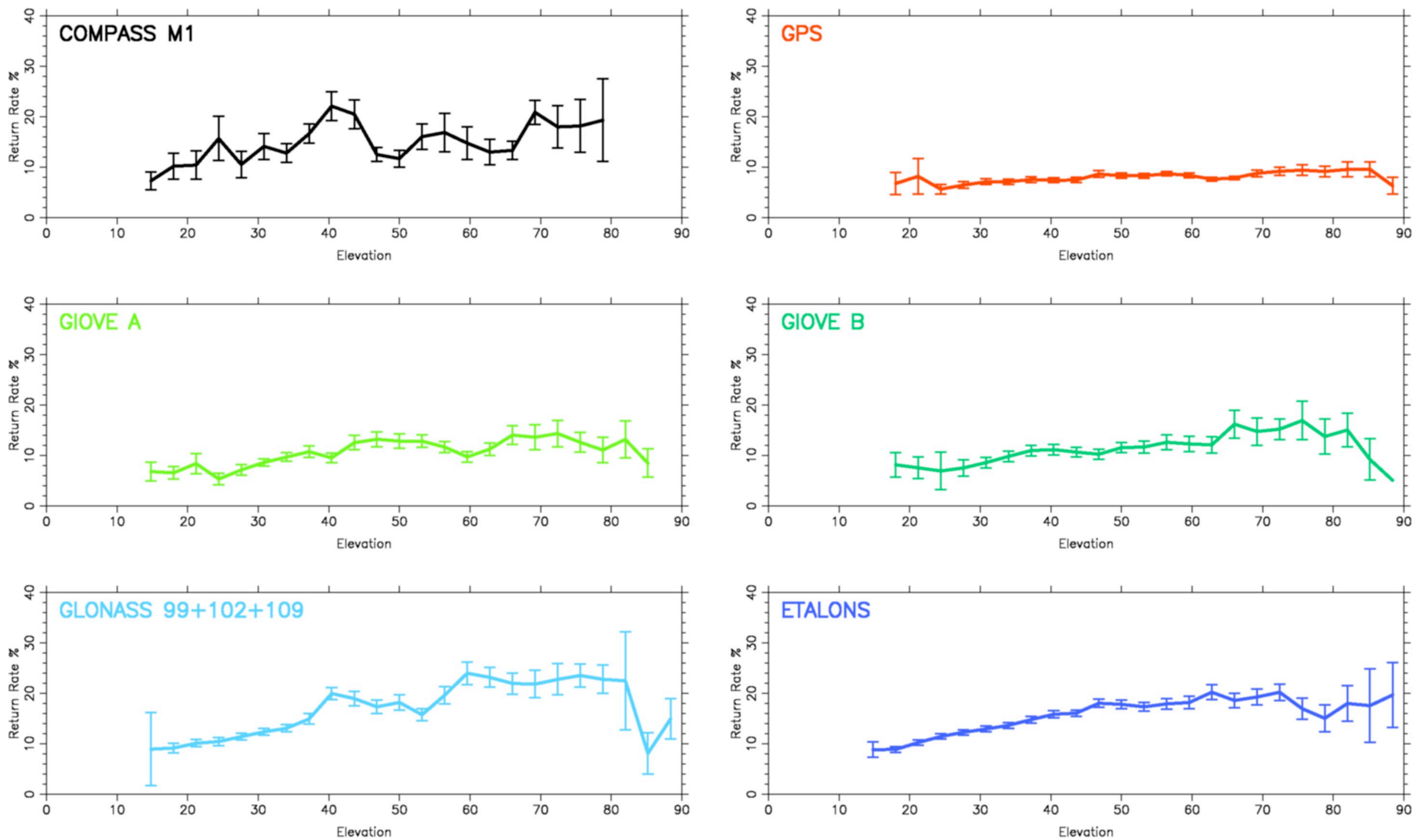

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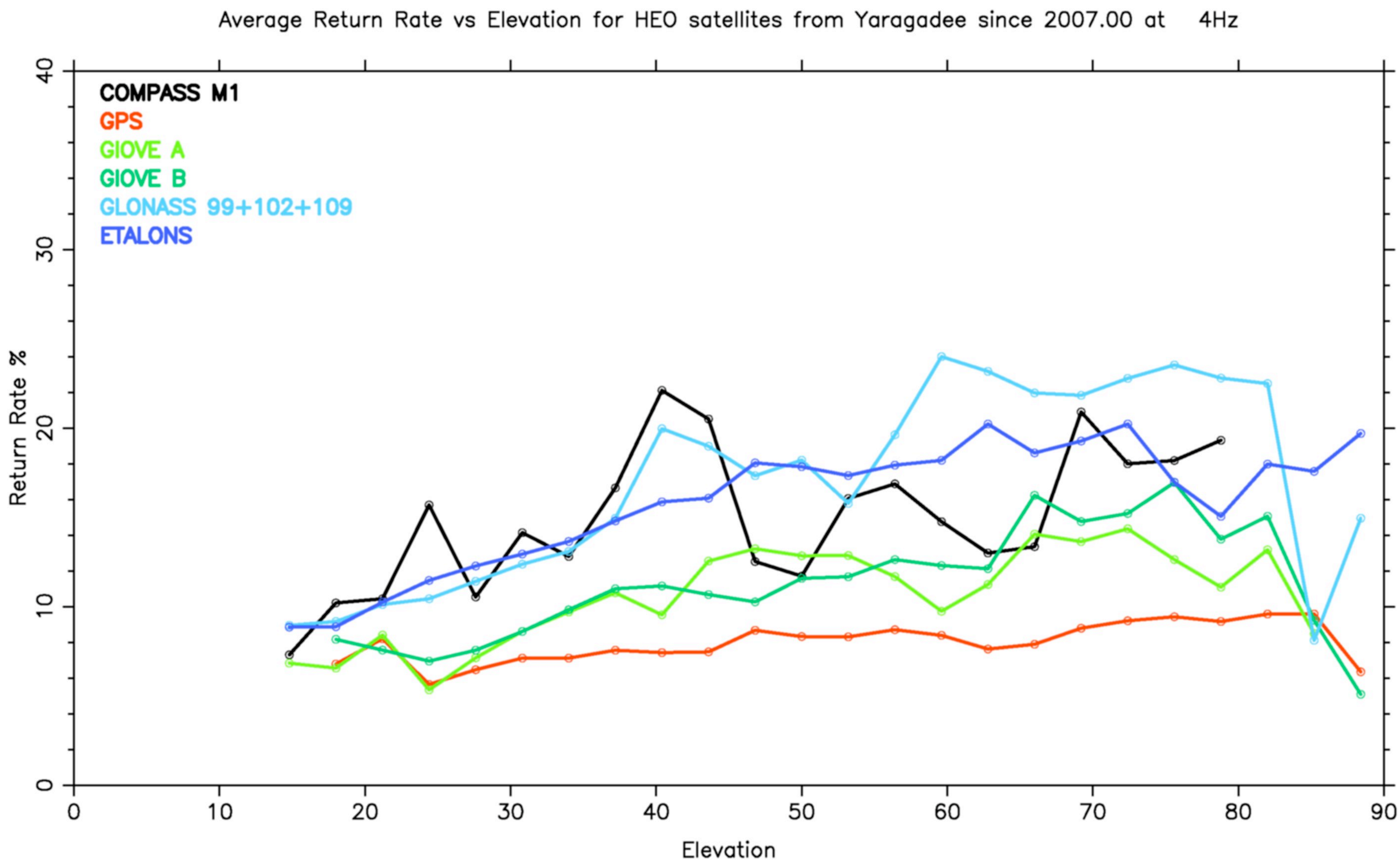
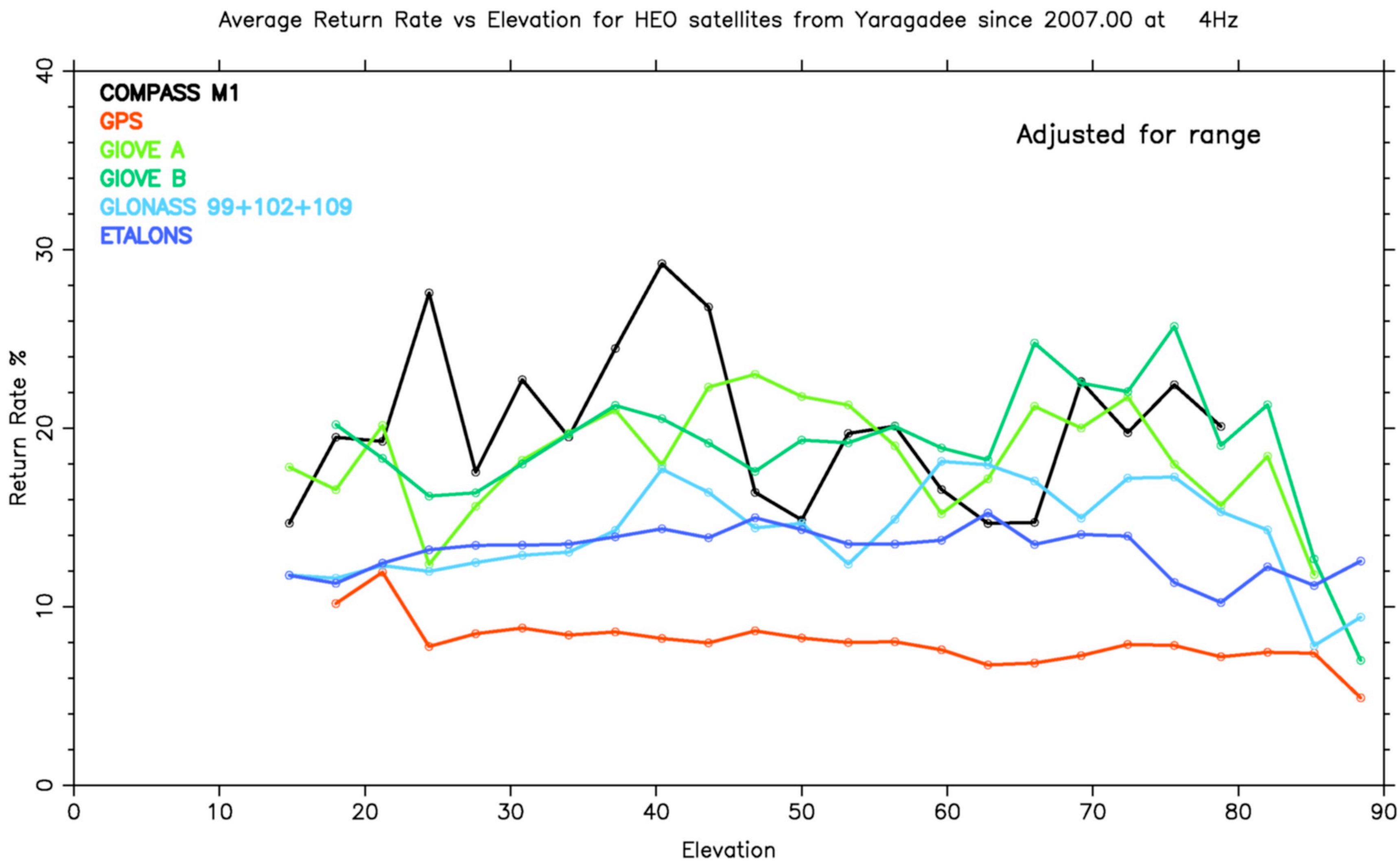


Relative signal strengths — Yarragadee, Australia



Relative signal strengths

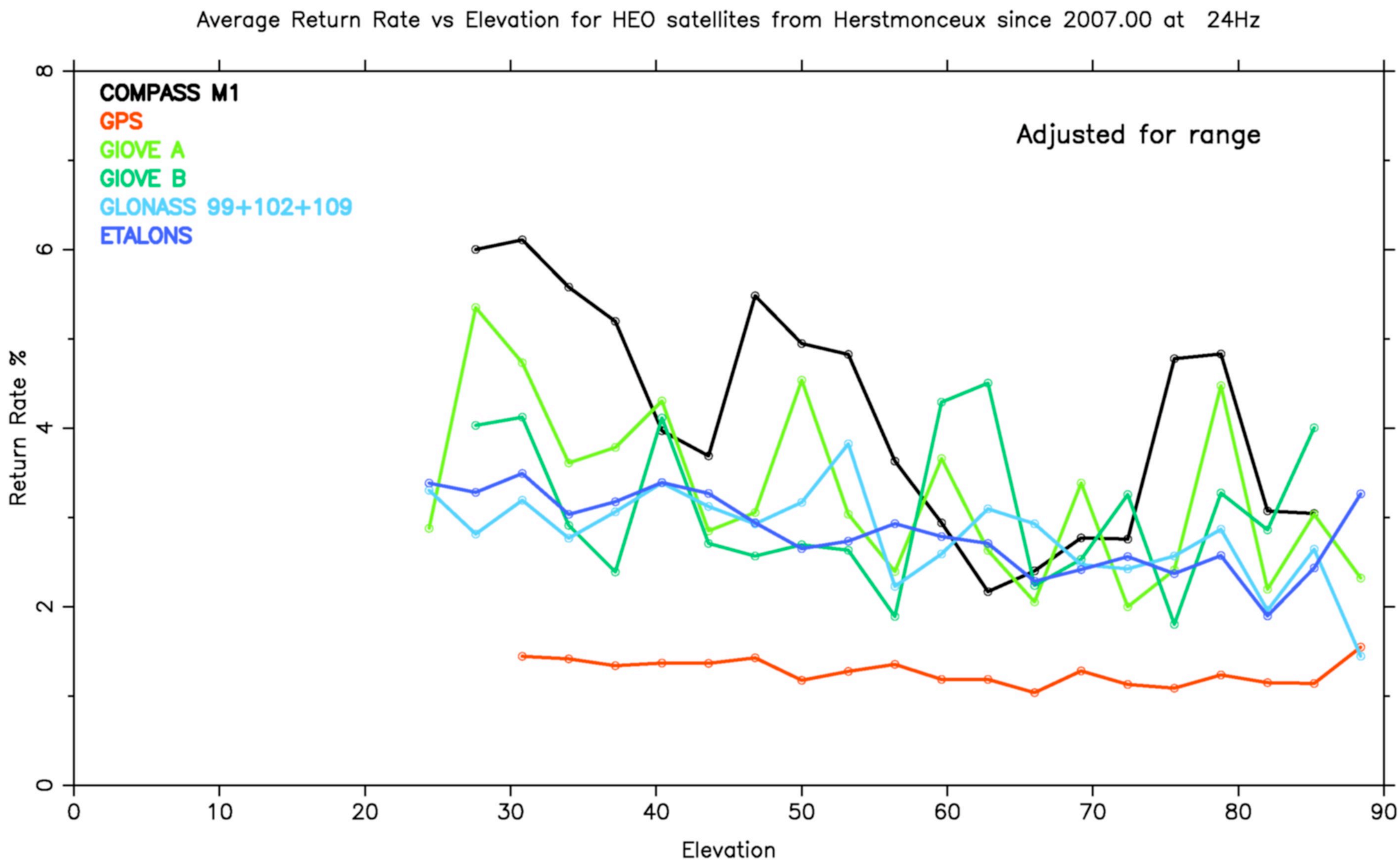
- The retro-reflector targets have the following:

	No. cubes	Cube Diameter	Retro Target Area
CompassM1	42	3.3cm	359.2cm^2
Etalon 1 + 2	65.8 effectively ± 3.9#	2.86cm*	422.7cm^2
GioveA	76	2.86cm*	488.2cm^2
GioveB	67	2.86cm*	430.4cm^2
Glonass99 + 102 + 109	112	2.86cm *	719.5cm^2
GPS35 + 36	32	2.86cm *	205.6cm^2

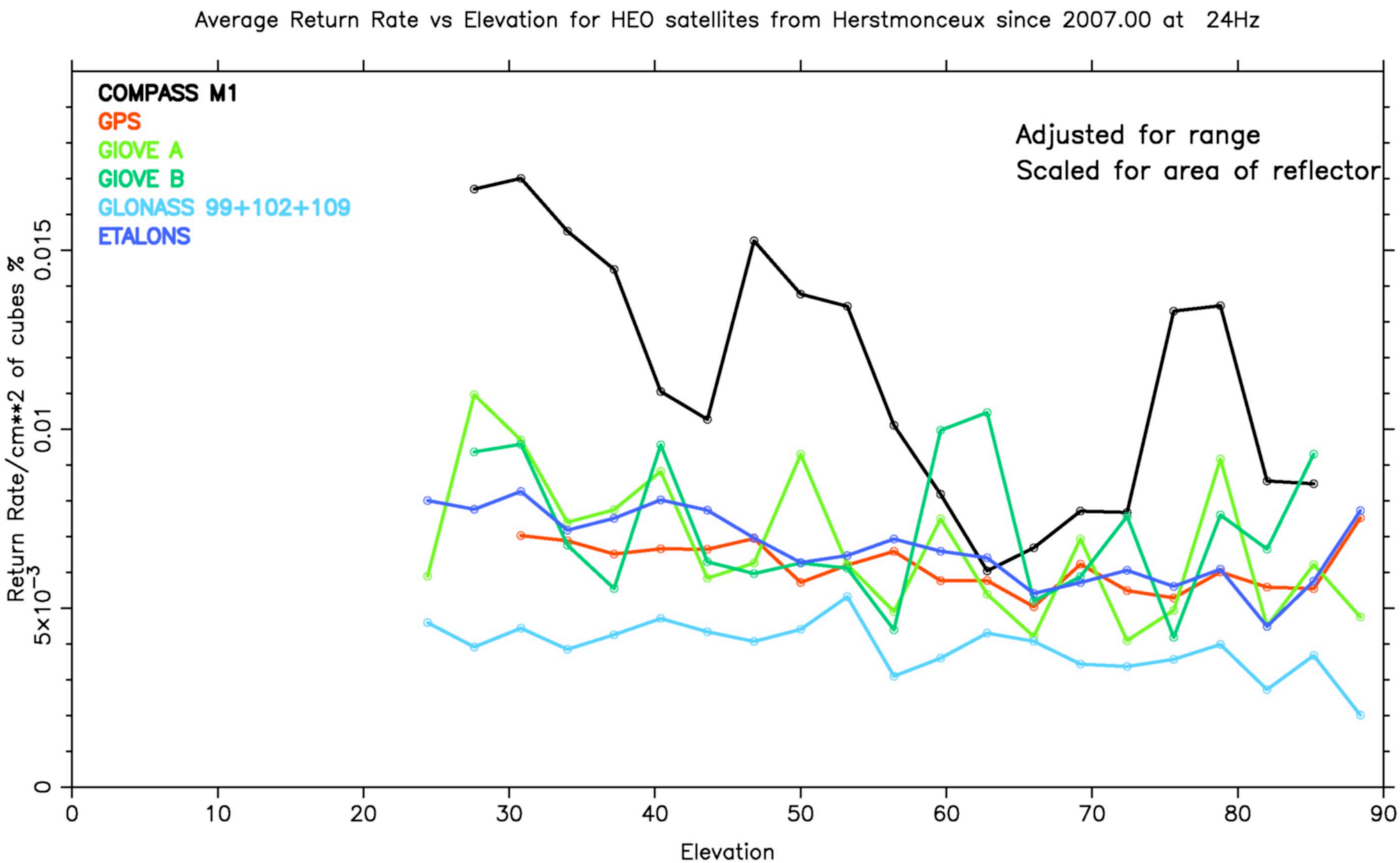
Mironov et al “Etalon-1,-2 Center of Mass Correction and Array Reflectivity” 8th ILRS Workshop, Maryland, 1992

* Degnan, J.J., Pavlis, E.C., "Laser Ranging to GPS Satellites with Centimeter Accuracy", GPS World, Vol. 5, no. 9 Sept. 1994

Relative signal strengths Herstmonceux, UK



Relative signal strengths — Herstmonceux, UK



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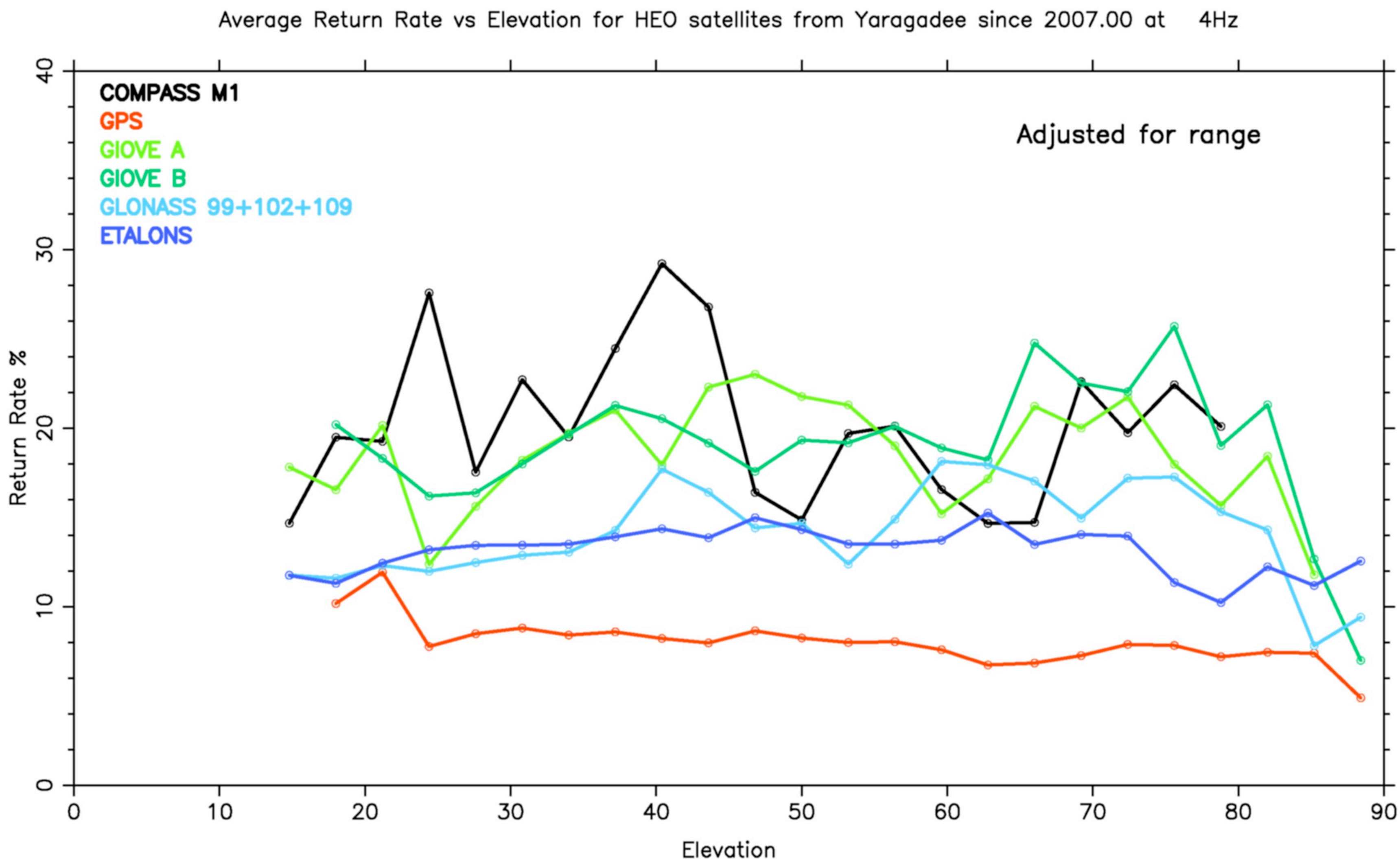

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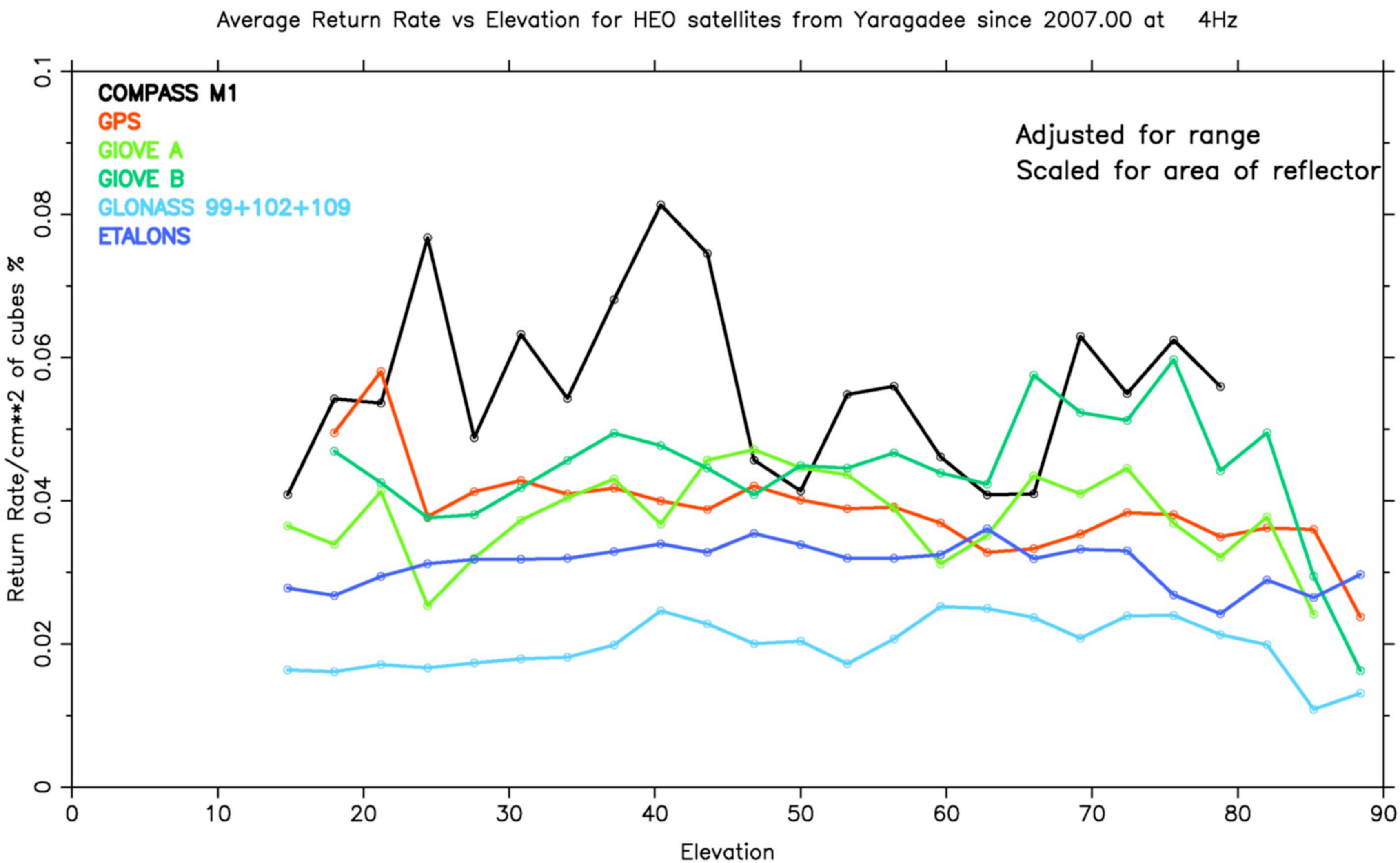

Relative signal strengths

- Estimate of return signal as a percentage of that from the CompassM1 target and per cm^2 of the targets

	Target Area cm^2	Herstmonceux %	Herstmonceux per cm^2 %
Etalon 1 + 2	422.7	66.3 ± 12.5	56.4 ± 18.5
GioveA	435.1	78.7 ± 14.4	57.9 ± 14.4
GioveB	383.6	66.9 ± 17.7	55.9 ± 17.7
Glonass99 + 102 + 109	719.5	66.3 ± 12.8	33.1 ± 12.8
GPS35 + 36	205.6	28.7 ± 12.3	50.2 ± 12.3

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	Target Area cm^2	Yarragadee %	Yarragadee per cm^2 %
Etalon 1 + 2	422.7	66.5 ± 5.4	56.3 ± 11.4
GioveA	435.1	93.8 ± 7.0	69.0 ± 7.0
GioveB	383.6	95.3 ± 7.1	79.6 ± 7.1
Glonass99 + 102 + 109	719.5	70.6 ± 6.0	35.2 ± 6.0
GPS35 + 36	205.6	37.4 ± 5.8	65.4 ± 5.8

Relative signal strengths

- Estimate of return signal as a percentage of that from the CompassM1 target and per cm^2 of the retro-reflector areas

	Target Area cm^2	Yarragadee %	Yarragadee per cm^2 %
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GioveA	435.1	93.8 ± 7.0	69.0 ± 7.0
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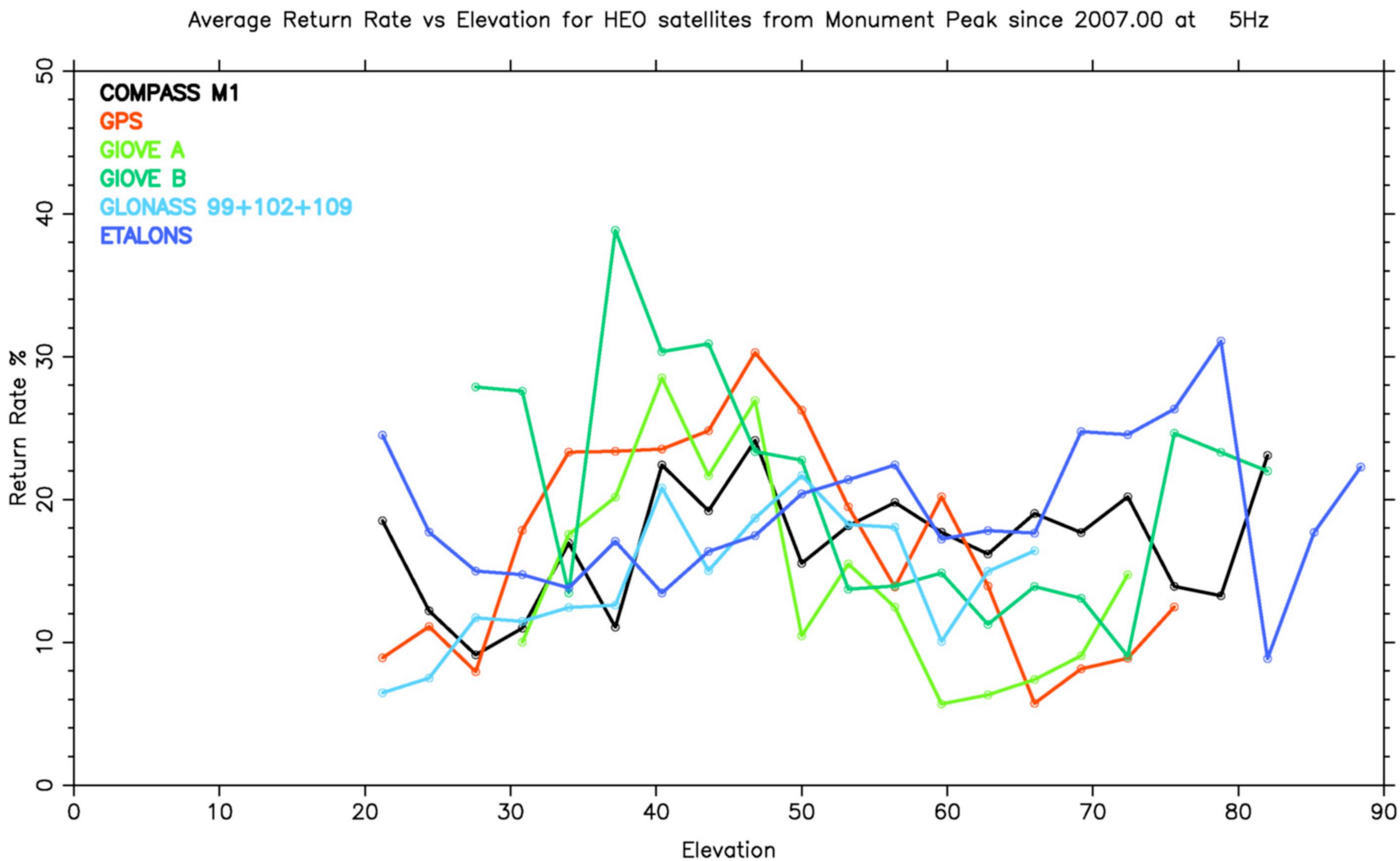
Relative signal strengths **Monument Peak, USA**



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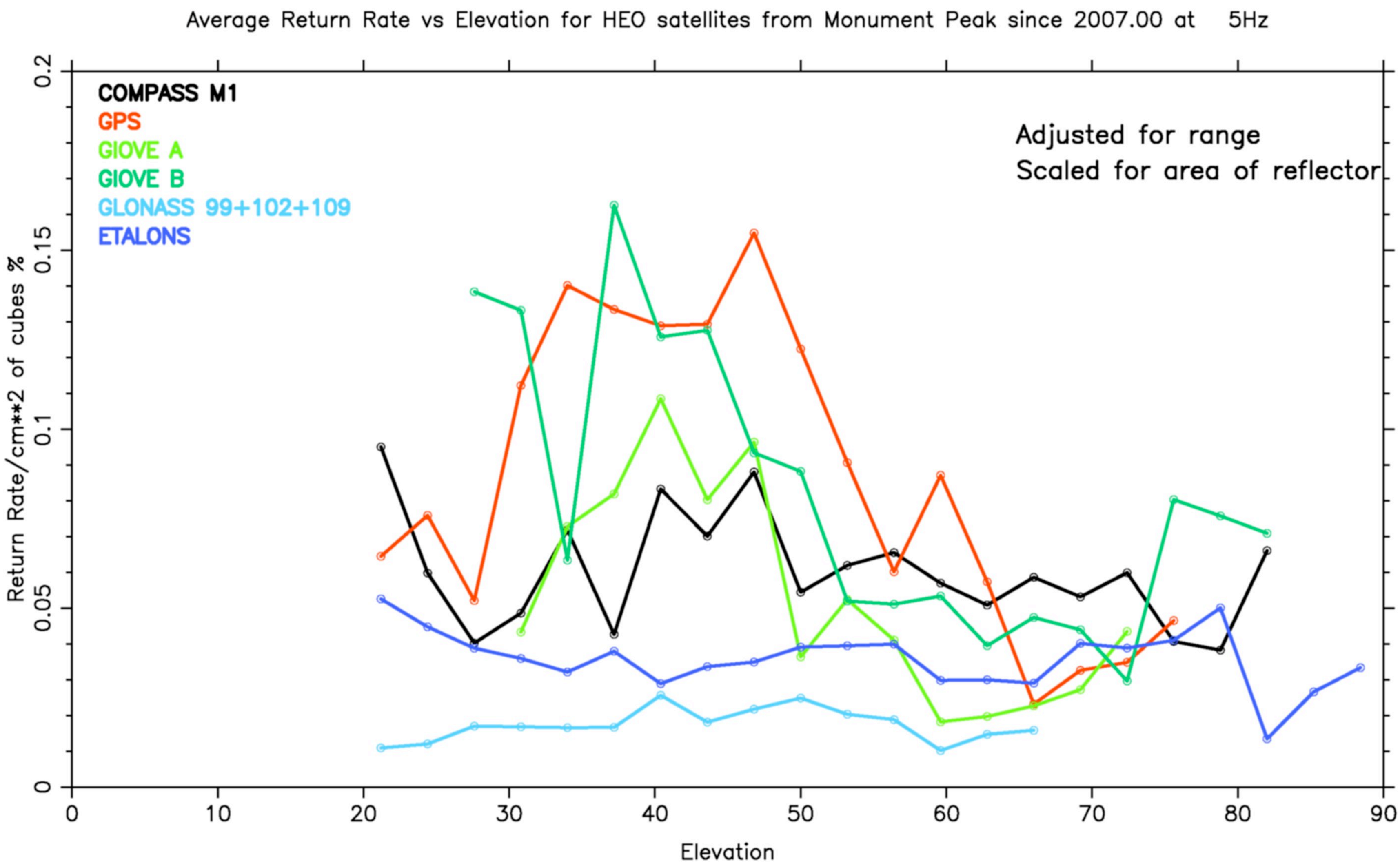

Relative signal strengths

- Estimate of return signal as a percentage of that from the CompassM1 per cm^2 of the retro-reflector targets

	No. cubes	Herstmonceux per cm^2 %	Yarragadee per cm^2 %	Monument Peak per cm^2 %	McDonald per cm^2 %
Etalon 1 + 2	65.8	56.4 ± 18.5	56.3 ± 11.4	58.4 ± 15.7	56.5 ± 20.4
GioveA	76	57.9 ± 14.4	69.0 ± 7.0	98.7 ± 16.7	75.1 ± 16.5
GioveB	67	55.9 ± 17.7	79.6 ± 7.1	104.1 ± 15.9	86.2 ± 18.6
Glonass99 + 102 + 109	112	33.1 ± 12.8	35.2 ± 6.0	29.3 ± 12.8	31.9 ± 17.9
GPS35 + 36	32	50.2 ± 12.3	65.4 ± 5.8	171.7 ± 14.7	103.5 ± 17.5

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Conclusions

- Analysis of the full rate dataset confirms the experience of the SLR observer that the GPS is a more difficult target and the new CompassM1 satellite is more successful.

- The return signal from the CompassM1 target is approximately 1.5 times stronger than the Glonass, Etalon and GioveB targets and 3 times stronger than the GPS targets.

- The CompassM1 has the highest return rate per unit array area.

- The return signals from the Etalon, GPS and Giove satellites per cm^2 are approximately 50% of the CompassM1 signal.

- The Glonass satellite return signal per cm^2 is approximately 30%.