Evaluation of potential systematic bias in GNSS orbital solutions.

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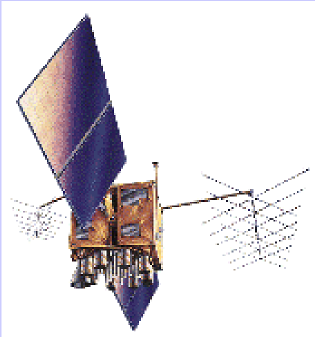
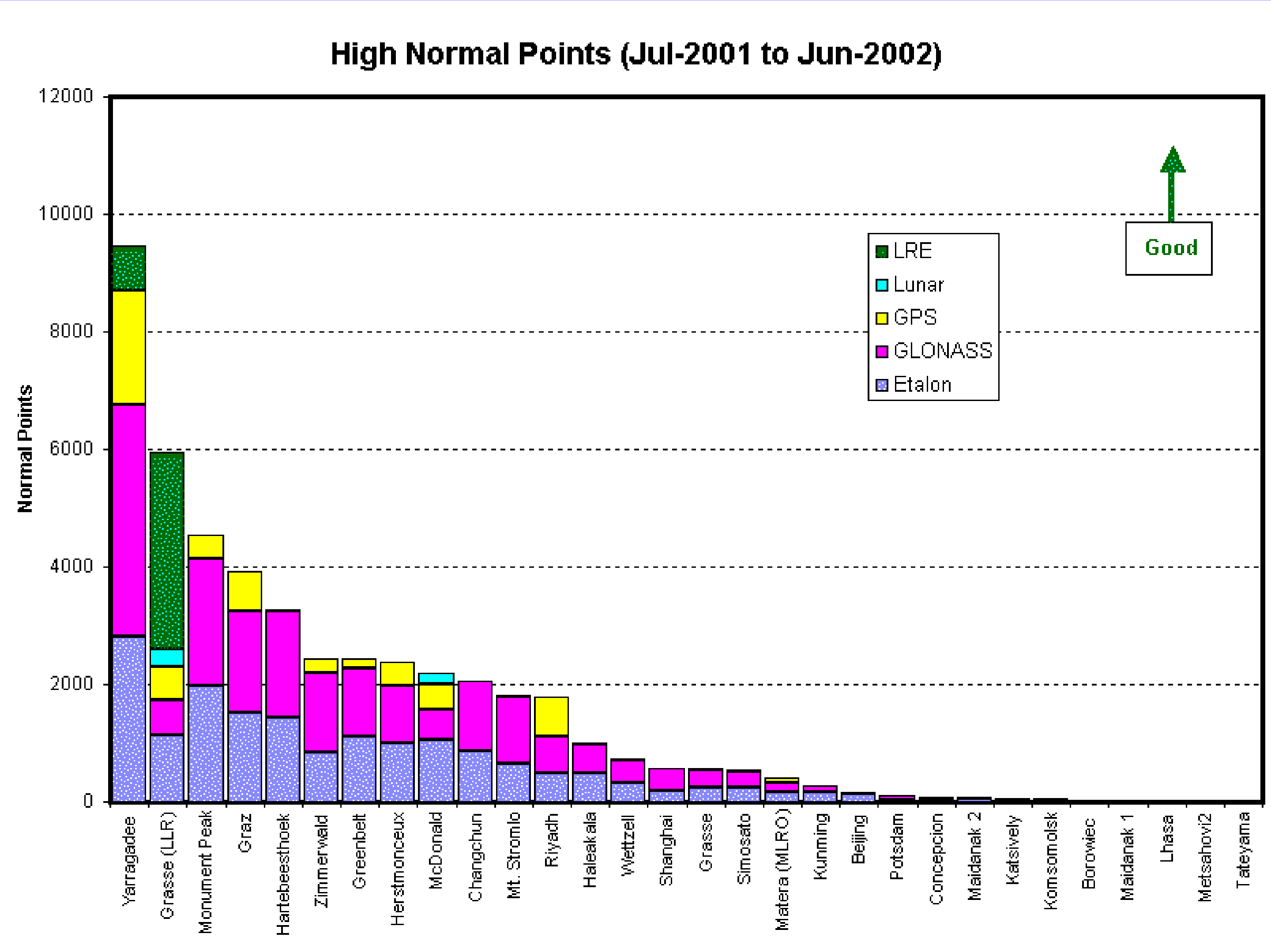


Introduction

- During routine orbit determination of GNSS spacecraft using radiometric data, the radial component of the orbit is *inferred* from the time-like observations and a knowledge of *GM*
- We can use precise laser range observations to carry out independent checks on the accuracy, particularly of the radial component, of published orbits of a subset of the GPS and GLONASS navigational satellites.

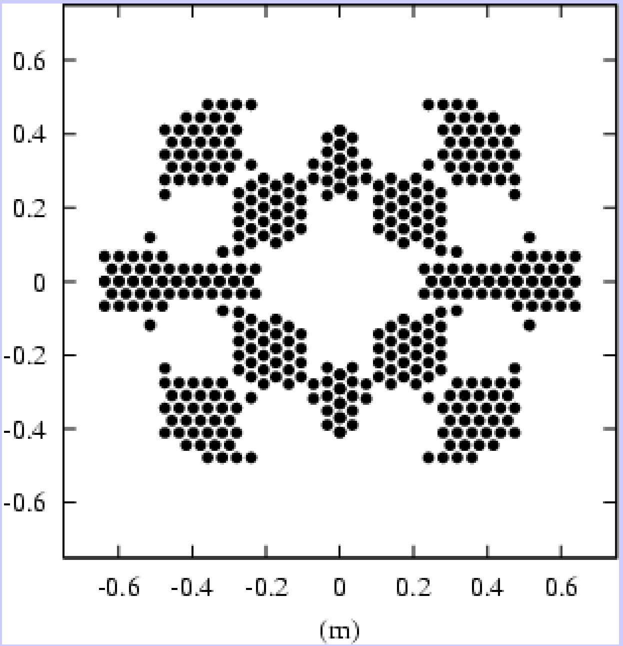
The satellites

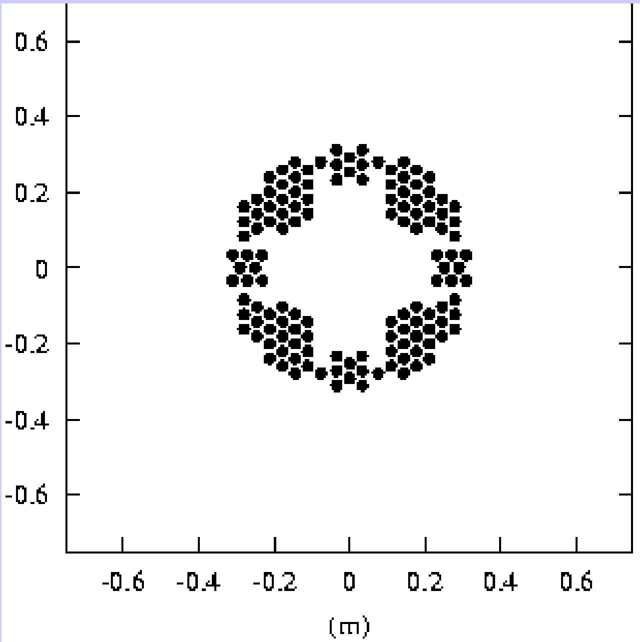
ILRS supports tracking of 2 GPS and three GLONASS satellites;



GLONASS Reflector Arrays

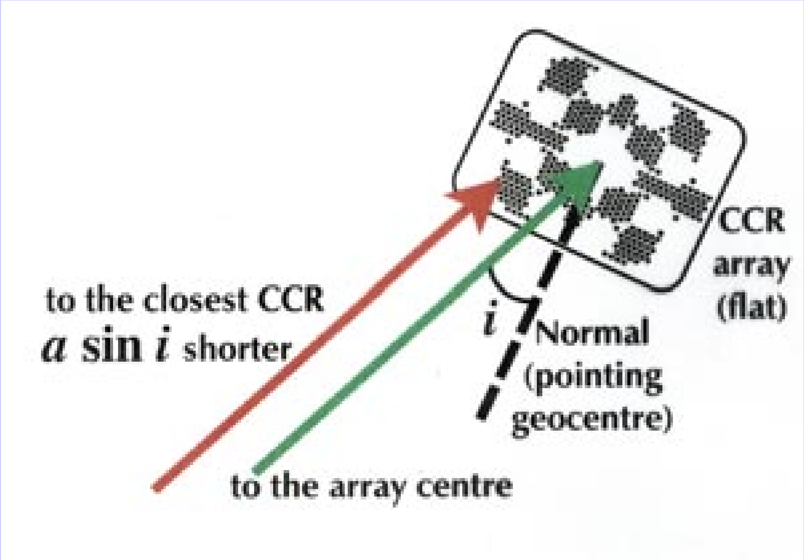
- Early satellites in the GLONASS constellation carried very large (1m x1m) reflector arrays, giving a good link budget but presenting a new challenge for precise interpretation of range data;
- For the GPS and new GLONASS satellites, the arrays are small and systematic effects much reduced, at the expense of a strong link budget.



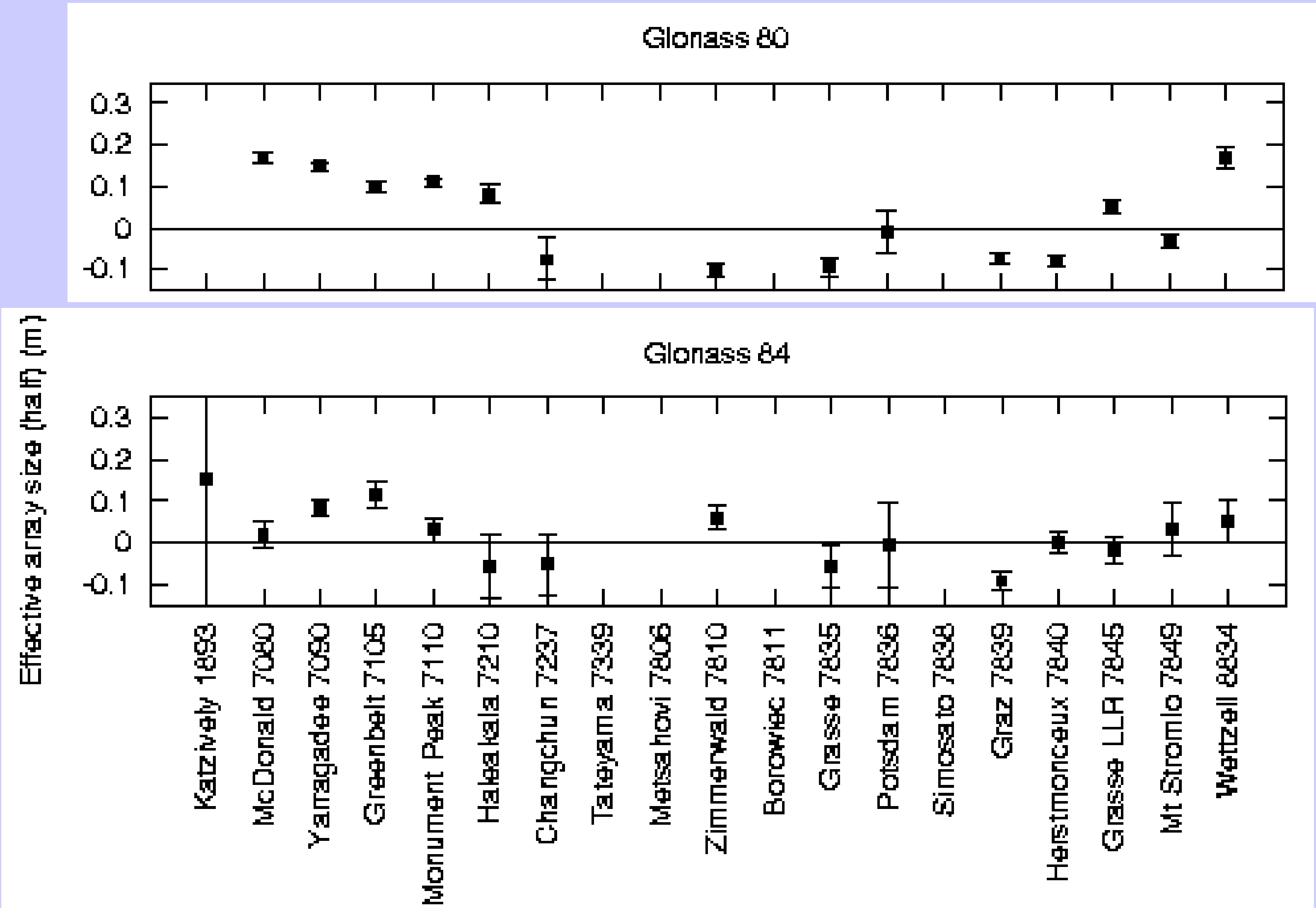


Laser Ranging to Flat Array

- Laser range measurements to the flat arrays on GLONASS and GPS satellites can cause attitude-dependent offsets from the centres of the array.
- These effects are now fairly well understood and depend upon the characteristics of the tracking station (Otsubo *et al,* 2001) .
- They may be detected through precise orbit determination:



‘range ambiguity’ due to flat arrays



Using SLR data to monitor radiometric orbits

Two methods can be employed:

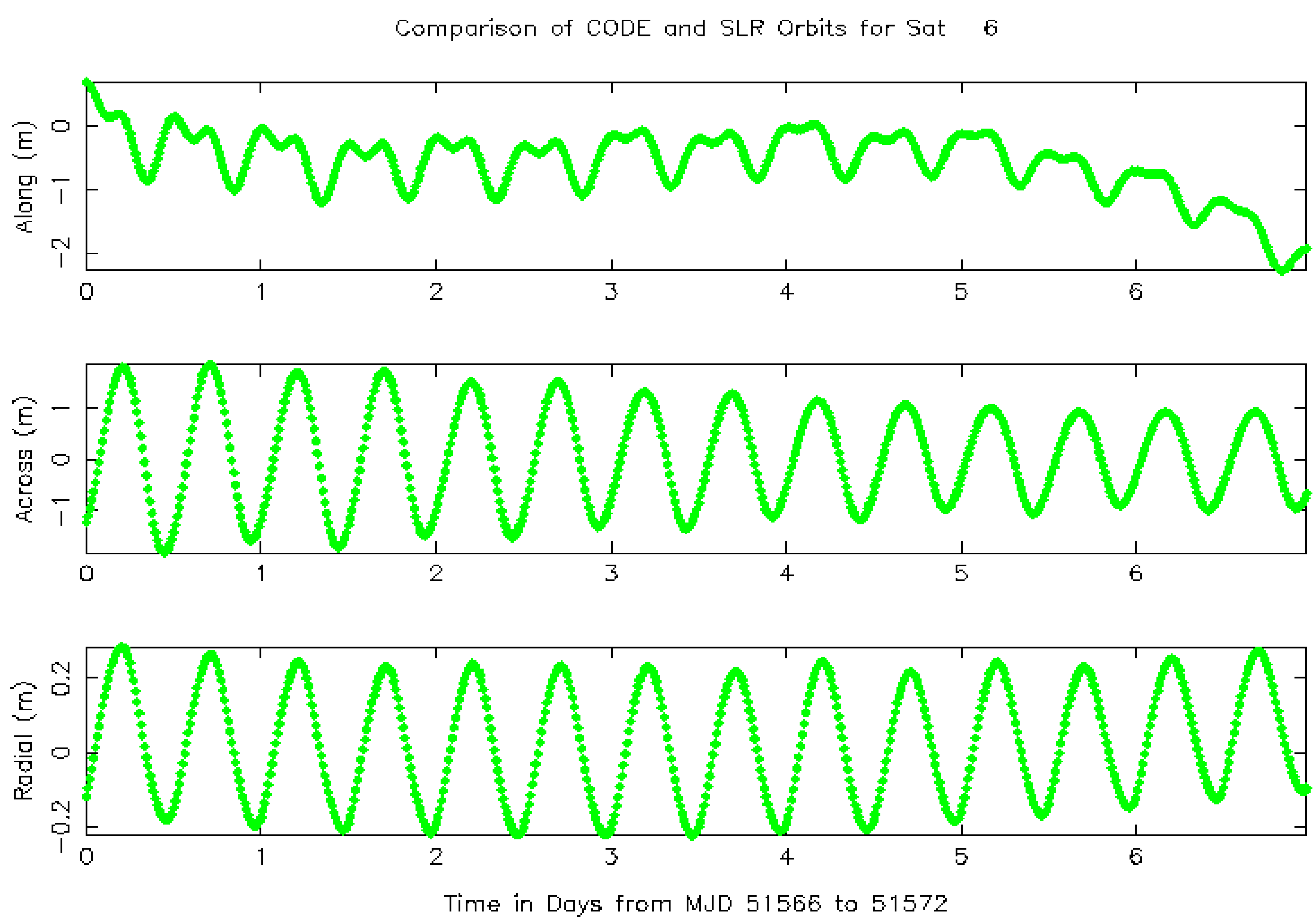
- _ Compute independent orbits using SLR data alone and compare with radiometric orbits;
- _ Compare laser ranges directly with satellite-station distances derived from microwave orbits (*cf* CODE daily analyses)

- For GLONASS, sufficient SLR data exists to compute orbits and compare 3D point-by-point with radiometric orbits;
- For GPS, often too few laser measurements for this approach.

SLR-orbit comparisons

- 7-day orbital arcs fitted to SLR data: adjustment of a standard set of parameters.
- Daily IGS/IGLOS orbits available from CDDIS public ftp site.
- 15-minute Coordinate differences are mapped to in- and out-of-plane directions:
- **Results**: RMS of Along- and Across-track differences ~ 50cm; Radial ~ 10 - 20cm

Differences between SLR and radiometric orbits: 7-day arc for GPS36

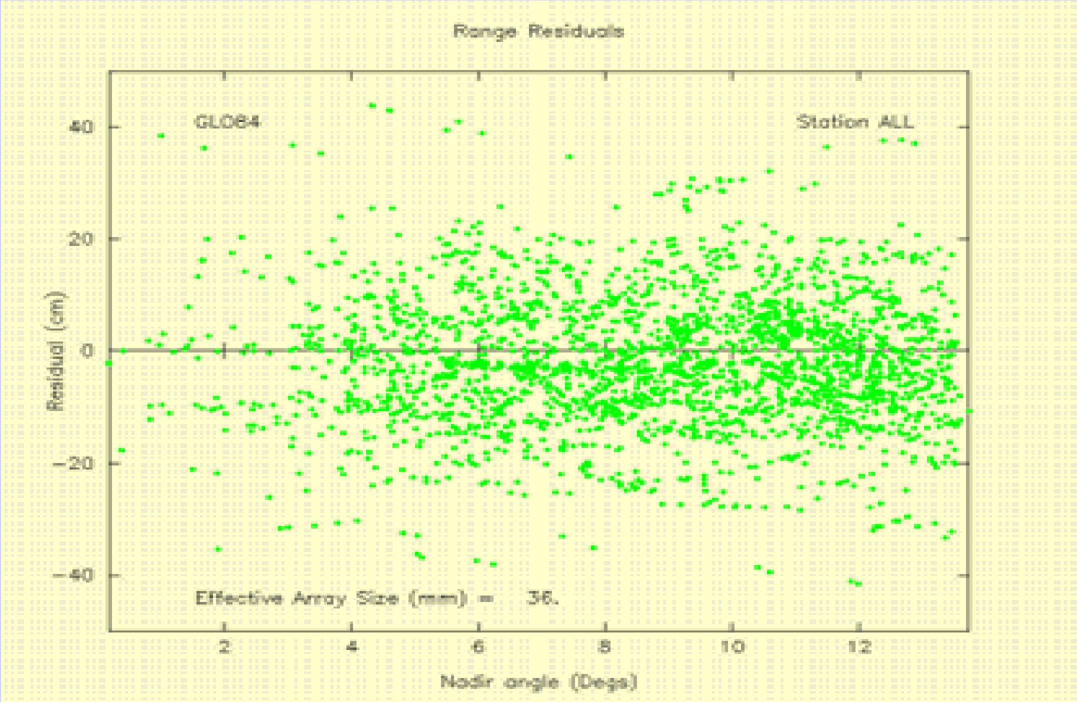


Direct comparison

- Orbital comparisons of course contain error contribution from both the SLR and radiometric orbital solutions;
- "cleaner" is a direct comparison of precise SLR normal points with station-satellite distance determined from radiometric orbit;
- Range differences are (close to) a measure of orbit radial error.

SLR ranges - satellite range deduced from radiometric orbit (GL84)

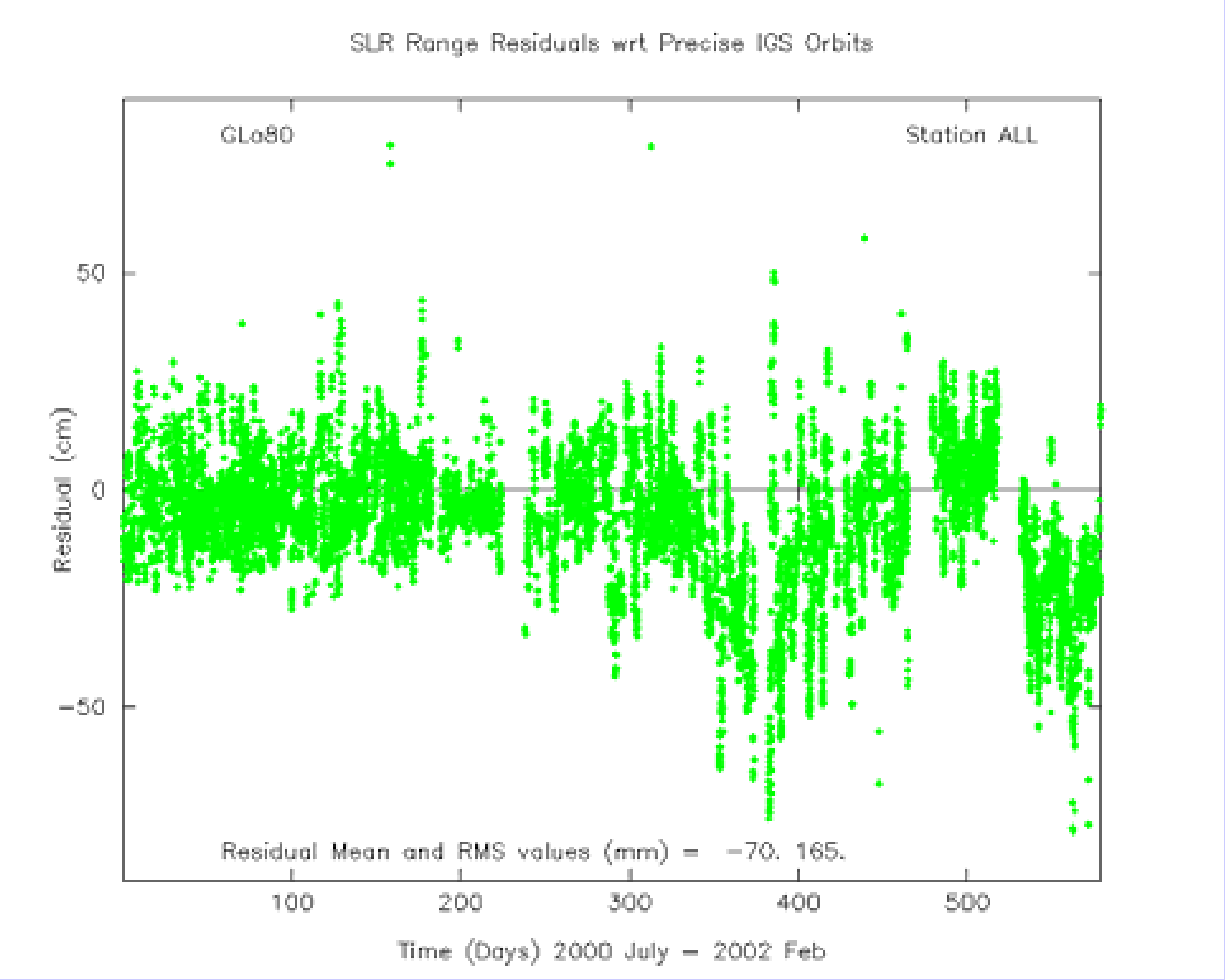
Each point represents a precise SLR normal point range wrt computed range to the satellite array centre using the IGLOS orbit. Range "residuals" are plotted against impact angle at the satellite. Data span 2001 February - 2002 July



Long term radial bias monitor

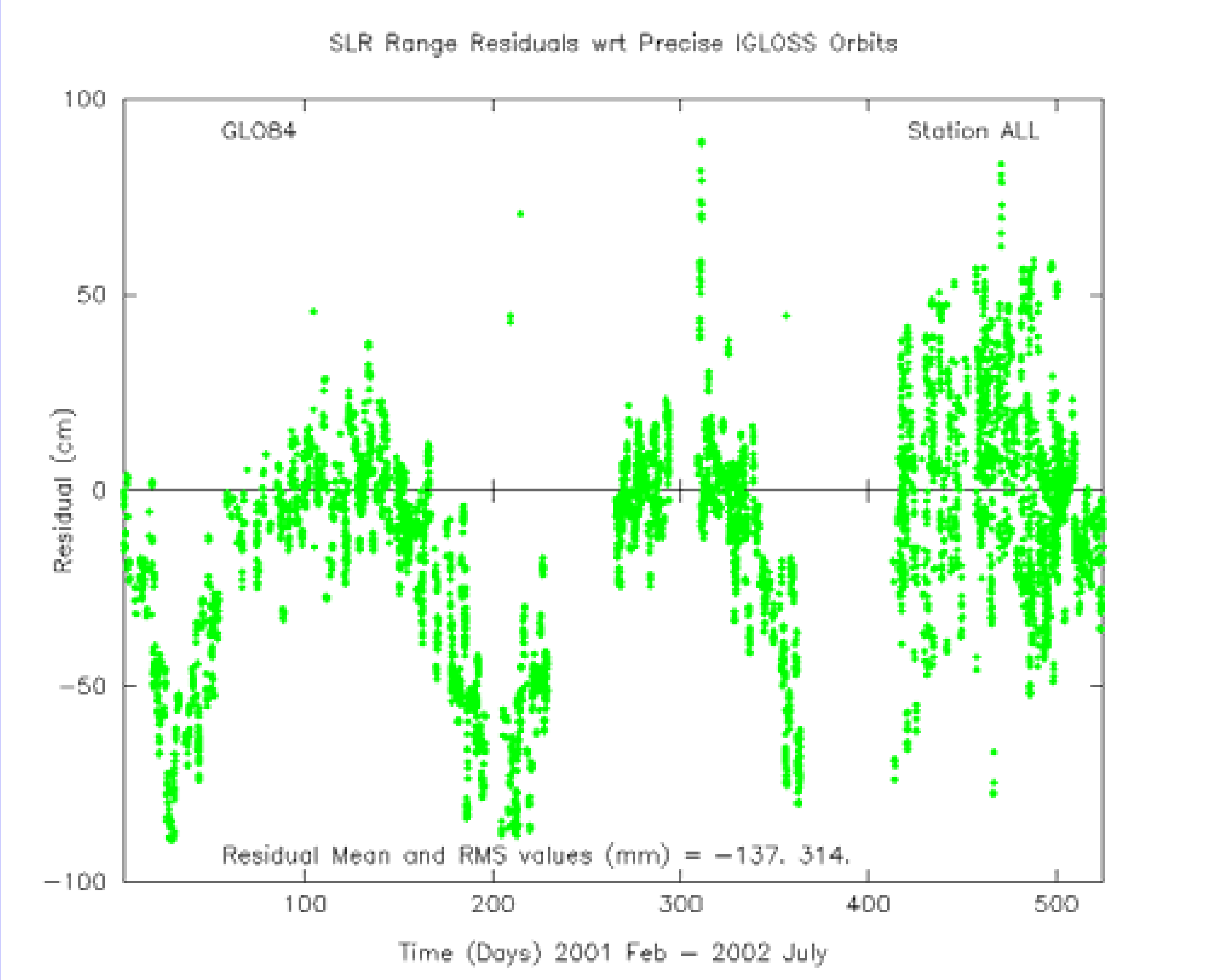
- It is then possible to monitor long-term radial trends in the 7-day IGLOS (*ESA*) and IGS (*CODE*) orbits;
- Carried out for GL80, GL84, GL86 and GL87, when available during the period 2000 July to 2002 July (GL80 ceased operational service in Feb 2002);
- Carried out for GPS35 and GPS36 for the period 1999 January to 2000 May

Time series of GLONASS-80 results
2000 July-2002 February

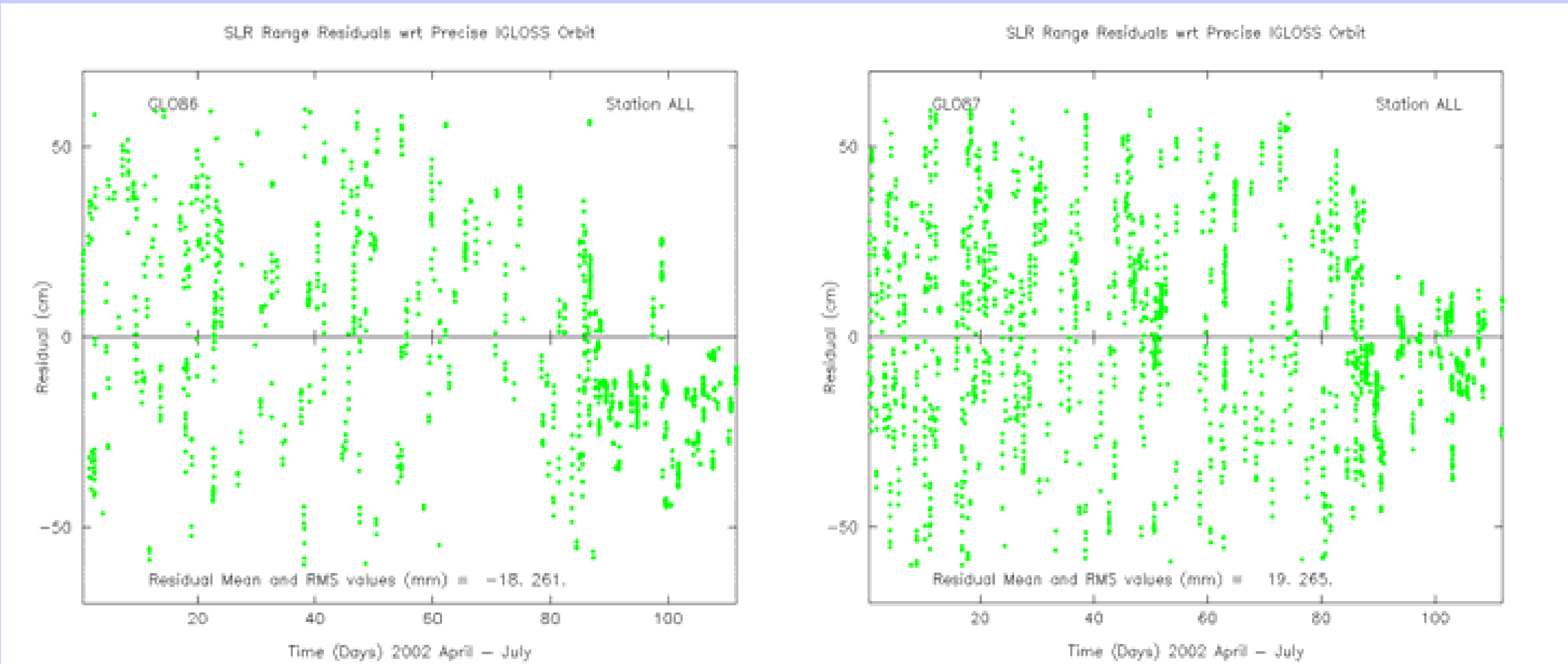


Time series of GLONASS-84 results

2001 February - 2002 July.

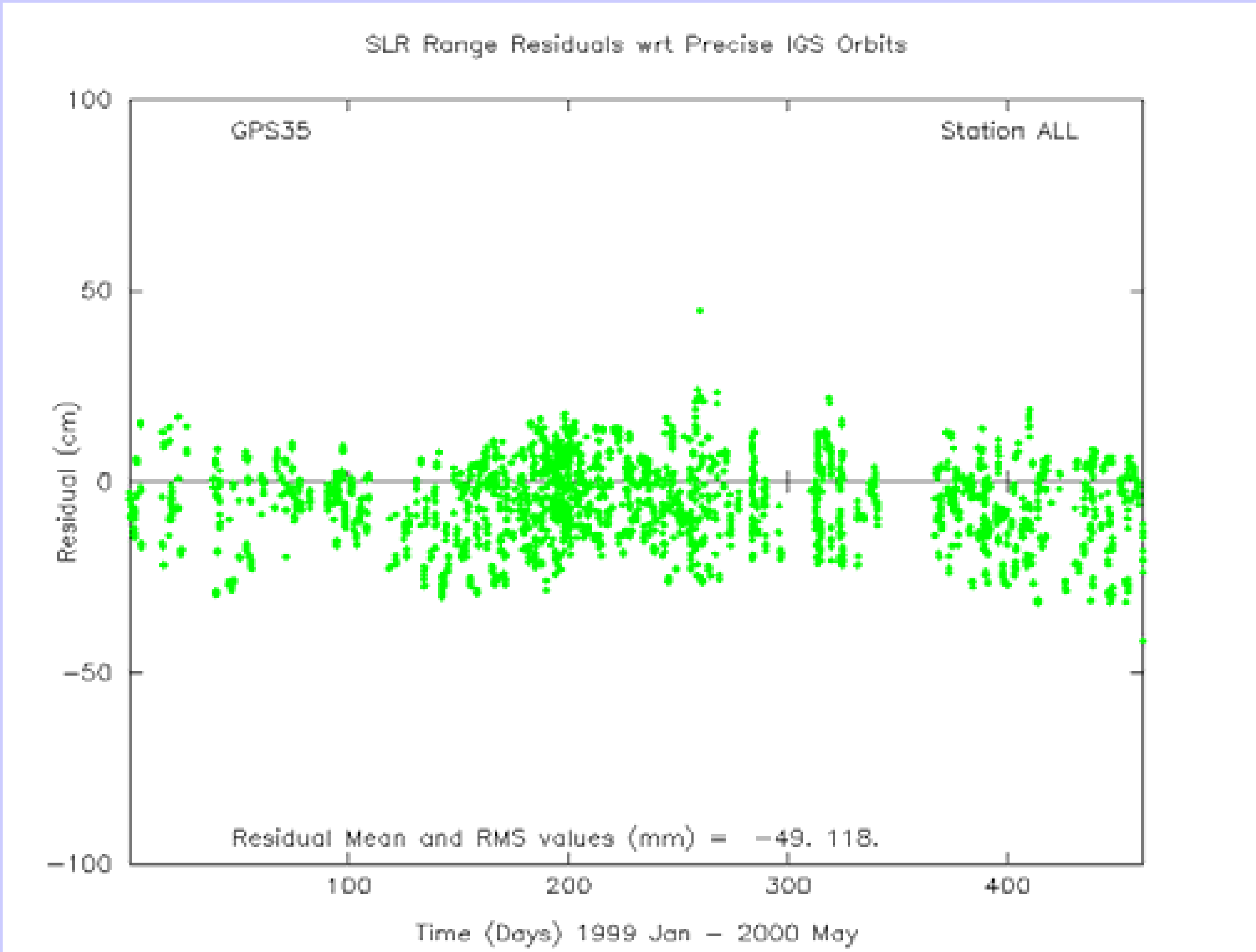


Time series of GLONASS-86 and 87 results 2002 April - 2002 July.



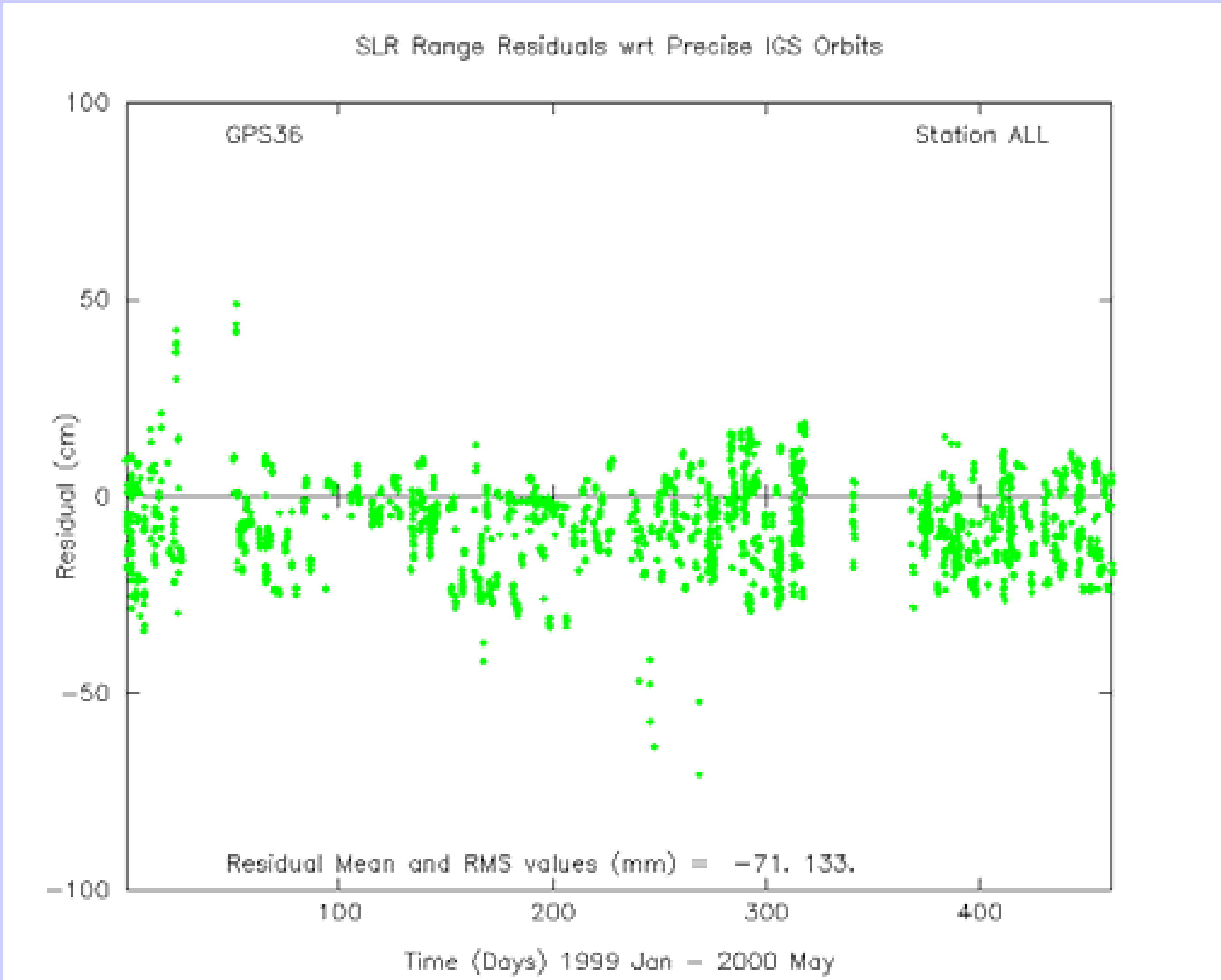
Time series of GPS35 results

1999 January - 2000 May

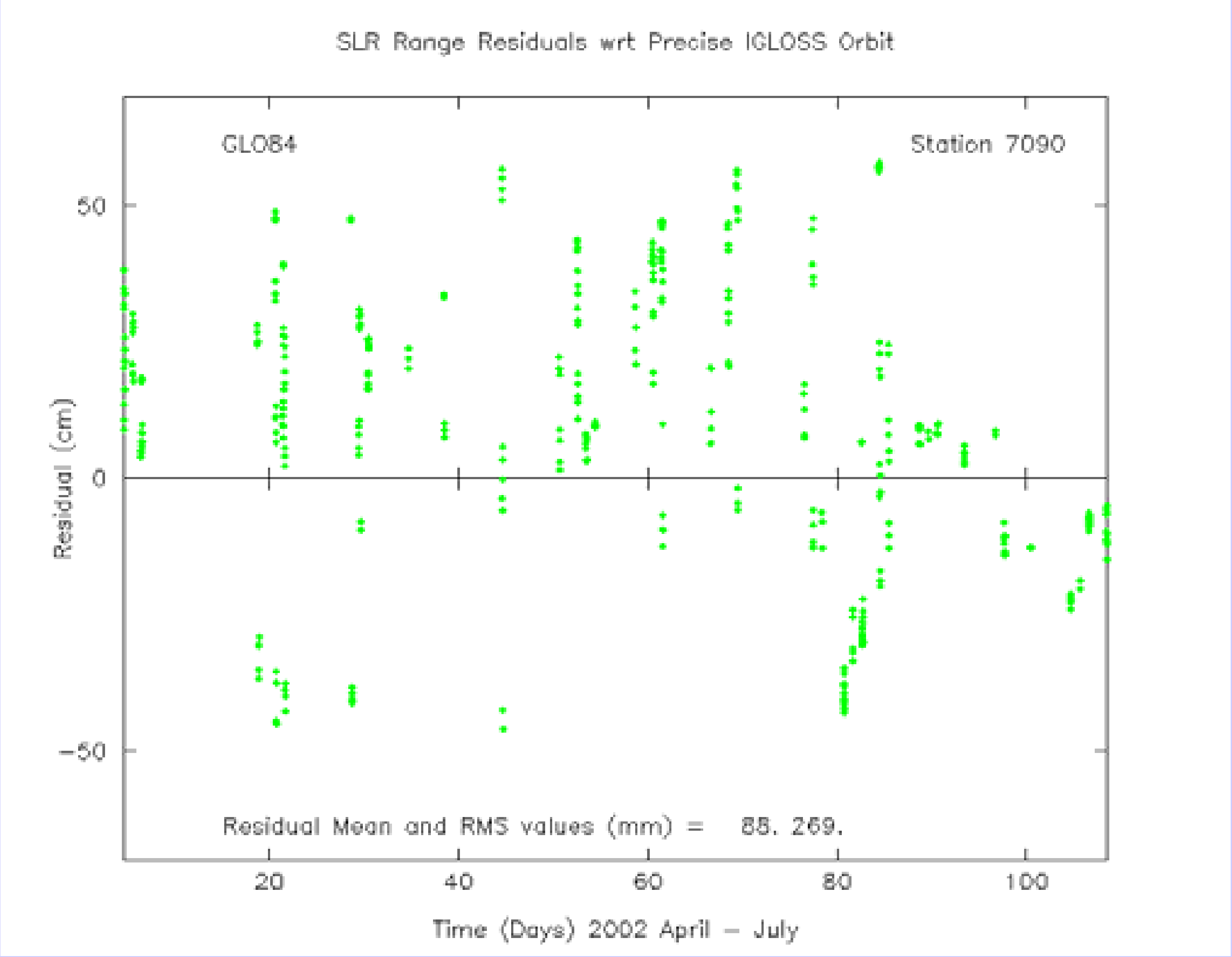


Time series of GPS36 results

1999 January - 2000 May



Also possible to monitor trends using a single prolific station



Conclusions

- GPS orbital solutions appear to be the more accurate, but a persistent ~5cm radial bias exists;
  - Perhaps the location of the GPS laser arrays needs revision
- Long-term systematic radial bias in the radiometric orbits is very variable for GLONASS;
  - Significant, 60cm level, radial bias with "annual" periodicity is seen in two of the GLONASS satellites (ILRS GL80, plane 1, slot 1 and ILRS GL84, 3/24)
- Consideration should be given to whether a combination of ILRS and IGS/IGLOS data during operational orbit determination processing could significantly improve the orbital accuracy.