CoM values for Geodetic SLR targets:

Current accuracy and prospects

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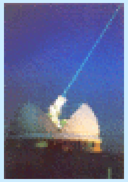

NATURAL ENVIRONMENT RESEARCH COUNCIL

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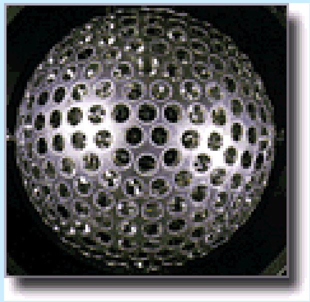
Scope

- Summary of table of ILRS-recommended CoM values for LAGEOS and for ETALON for each ILRS station;
- Report on new work for mm-level CoM corrections for LEO satellites;
- Closure of work on non-linear effects in some time-of-flight counters.

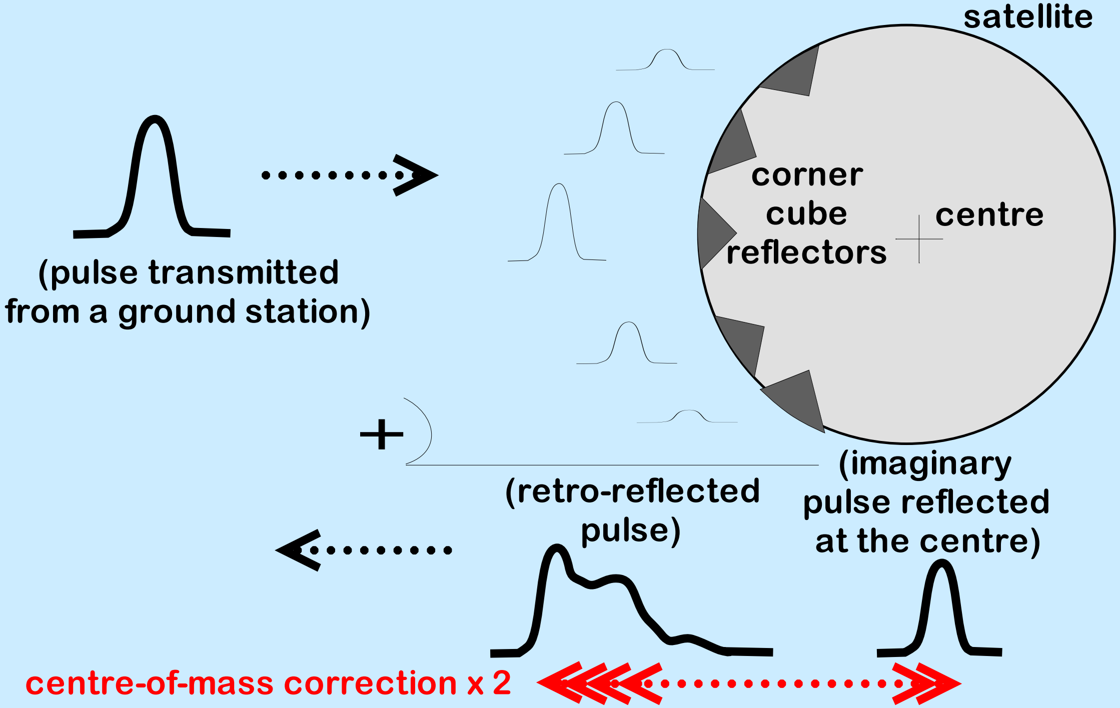
ETALON

Centre of Mass corrections:

Satellite ‘signature' contribution



LAGEOS



On average, over many shots, returning pulse-shape can be modelled as a convolution of laser pulse-shape with the satellite response function.

Magnitude of effect

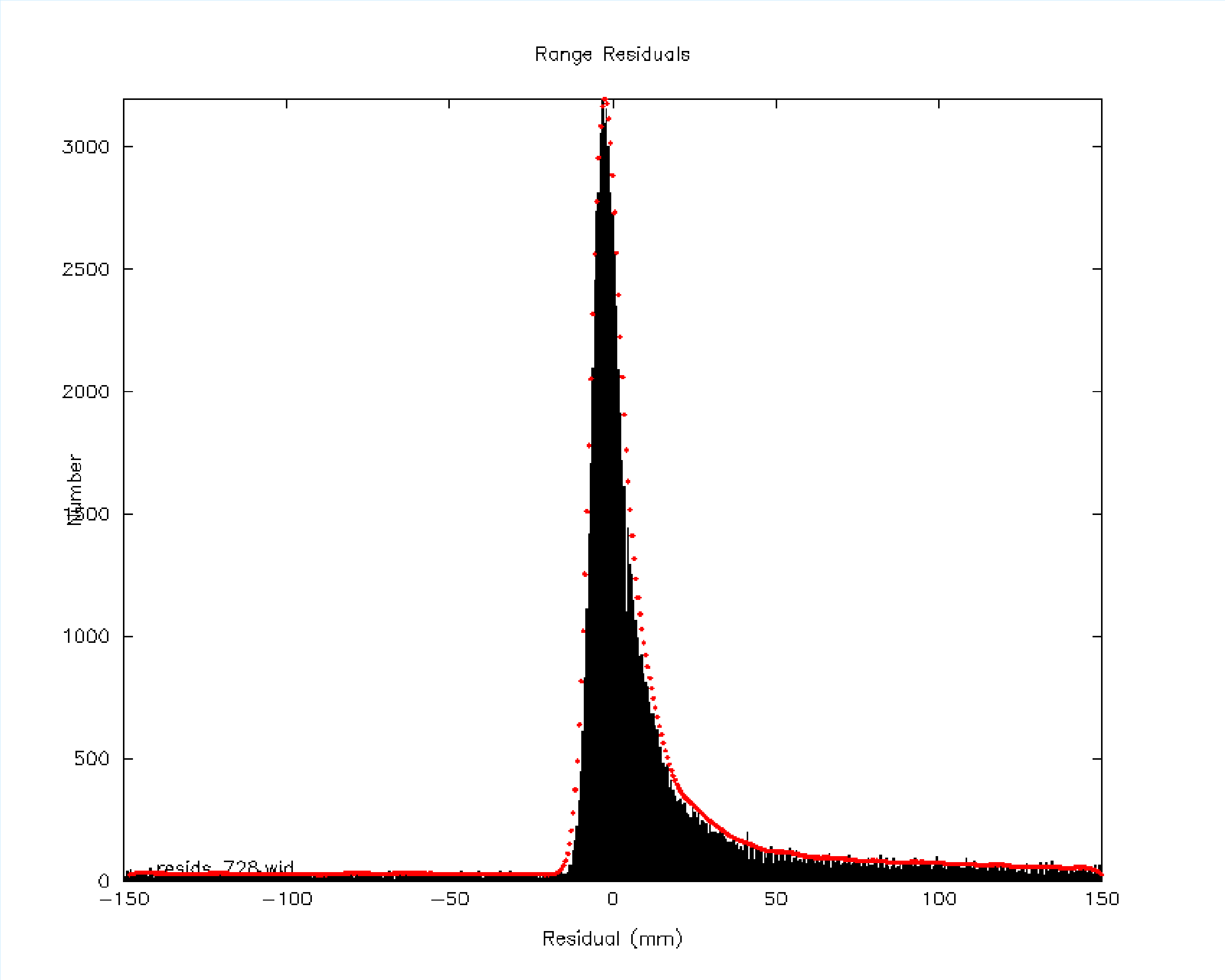
- Depending upon the stations' technology, there is a range of appropriate CoM values;

- For LAGEOS the total range is **~6mm** (Minott *et al*, 1993, Otsubo & Appleby, 2003)
- For ETALON the total range is **~5cm**

- Station technology:
  - multi-photon returns:
  - photomultiplier or first-photon detection
  - single photon return

- Development of a model, illustrated using a low return-energy system (single photons) on LAGEOS:

Real data from a pass at **<< single photons**.
σ = 8.5mm: (data will be rejected at -12 and +25mm



For this case, possible to compute **from the model** an **average** CoM value accurate to ~1mm (=245mm)

Centre of mass corrections >> single photons

- For NASA systems, for example, returns peak at several hundreds of photons (est. from link models for LAGEOS, e.g. Degnan, 1993)
- Models for CoM depend upon characteristics of electronic discriminators;
- Cannot use statistical method for CoM as for single-photon systems
  - But can **estimate** from the model distributions (leading edge), to give LAGEOS CoM 248   2 mm
  - This compares with ground tests on LAGEOS-2 giving 249 mm (Minott, 1993)
  - For ETALON, get 603   5 mm

In summary:

There exist different CoM values dependent on the stations' technology.

- Single photon systems have smallest uncertainty: **1 or 2mm**

CoM for high-energy systems have an estimated uncertainty of 2mm (LAGEOS) and 5mm (ETALON)

  - take account of unknown effect of discriminators at different stations;
  - effect is to increase effective pulse-length

- Tables of values have been produced:

- CoM for LAGEOS for typical single photon station 245mm

- Com for typical, majority, high-energy station 248mm
  - or use 249mm as measured for MCP on LAGEOS-2 in lab.

CoM for compact arrays on LEO

- Recent analytical work (Neubert, 2009) has achieved sub-mm-level corrections for the CHAMP, GRACE (etc.) compact retro-arrays
  - Improves upon current simple correction (~5mm precision)
- Formulae for CoM values for each of the (4) cubes on the array relative to the array ref. pt.
- In most orientations, only one cube contributes to return signal

CoM for compact arrays on LEO (2)

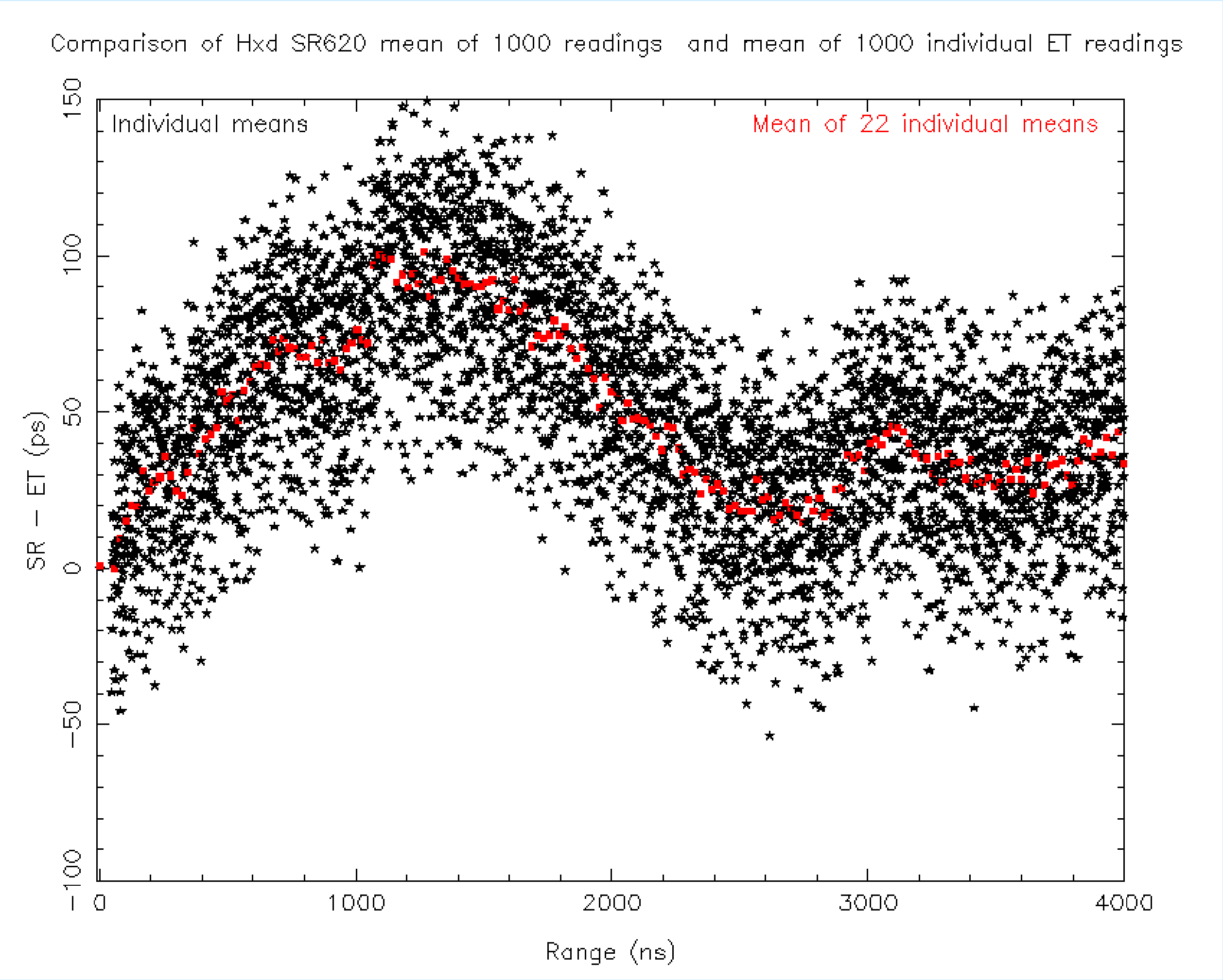
- If more than one cube contributes, Neubert derives a weighted solution and an approximate FFDP that provides a CoM value at 1mm accuracy
  - Should be applicable to the 9-cube arrays on JASON, ENVISAT
  - Potentially valuable too for pre-processing kHz
- Part of correction is very sensitive to satellite attitude:
  - For 1mm accuracy, use (quaternion) attitude data to get 15 arc-min attitude accuracy

Time-of-flight counter ‘calibration’

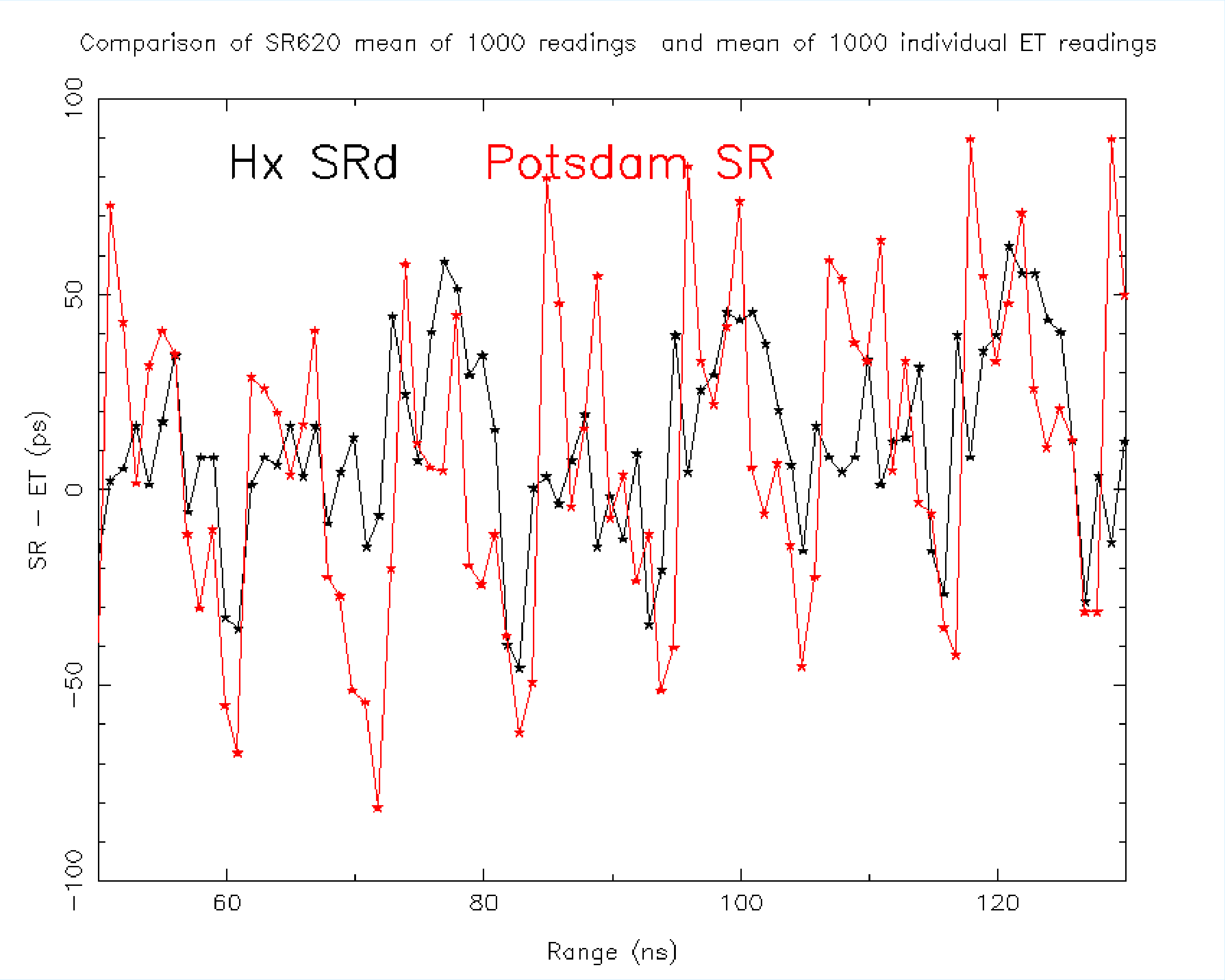
- Work (Appleby & Gibbs) reported at Canberra (2006), EGU (2007), UAW (2007) was based on measurement of non-linear behaviour of Stanford counters;

- Effects (~5mm) at close (calibration) and far (satellite) ranges do not cancel

- Optimistic that correction tables could be applied to several ILRS stations



Close-range non-linearity – note high-frequency signal:

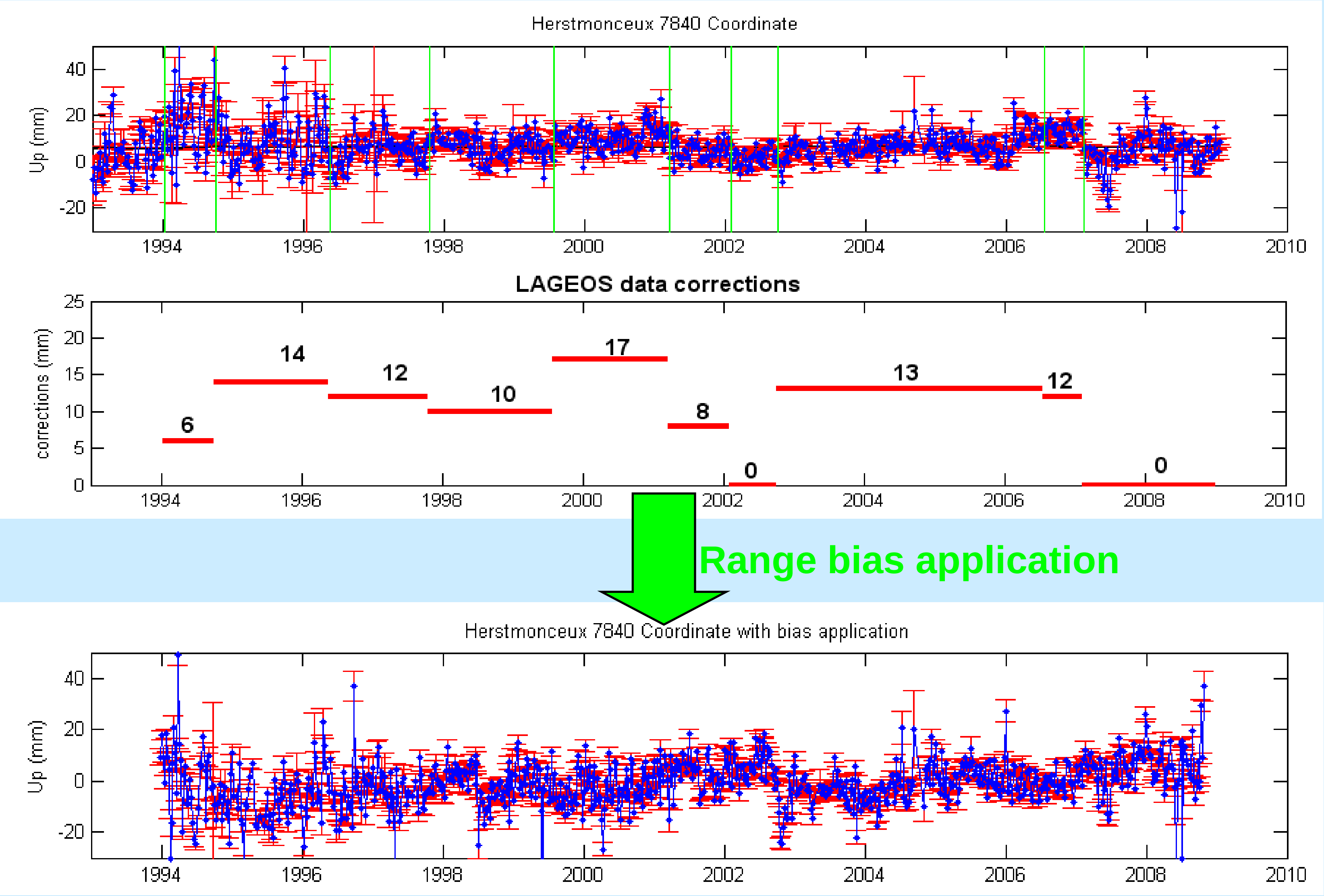


High-frequency signal (P=11ns) from two Stanford counters-note vertical scale –> 70ps=10mm

Problem

- The high-frequency signal often destroys attempts to determine range corrections in historical data:
- Care has been taken to re-construct the electronic delay-circumstances pertaining at the time;
- But error function changes radically in few nsecs, and is a function of the actual device;
- Hence some success but also some extra problems are induced –
  - Following is result from Luceri *et al*, EGU 2009

The Herstmonceux case



Recommendation

- Problem with post-determination of total Stanford errors in 1993-2006 era, ‘even’ at Herstmonceux;
- Thus validity of applying technique to other stations’ counters must be questioned
- ‘Better’ route is solution for satellite-dependent, constrained RB during dynamic solutions;
  - Informed by log-file documentation of epochs of hardware changes

Summary

- ILRS-recommended CoM corrections for LAGEOS and ETALON are available
- Improved-accuracy values for compact arrays on GRACE, CHAMP
  - Application to JASON, ENVISAT, CRYOSAT
- Not recommended is application of 'Stanford' counter corrections, but empirical RB corrections to be made available