USNO Report to the CGSIC Timing Subcommittee

Stephen Mitchell
US Naval Observatory (USNO)
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DoD Directive 4650.05 (2008) and 4650.07 (2012)

- ***The Secretary of the Navy shall direct the U.S. Naval Observatory to:***
  - ***Develop and maintain the standards for Precise Time and Time Interval (PTTI) services, earth orientation parameters, and the celestial reference frame for the DoD Components***
  - ***Provide representation to PNT committees and working groups, as necessary***
  - ***Serve as the DoD PTTI Manager for all DoD systems***

Maintain the Master Clock for DoD and US government PNT systems

USNO Master Clocks

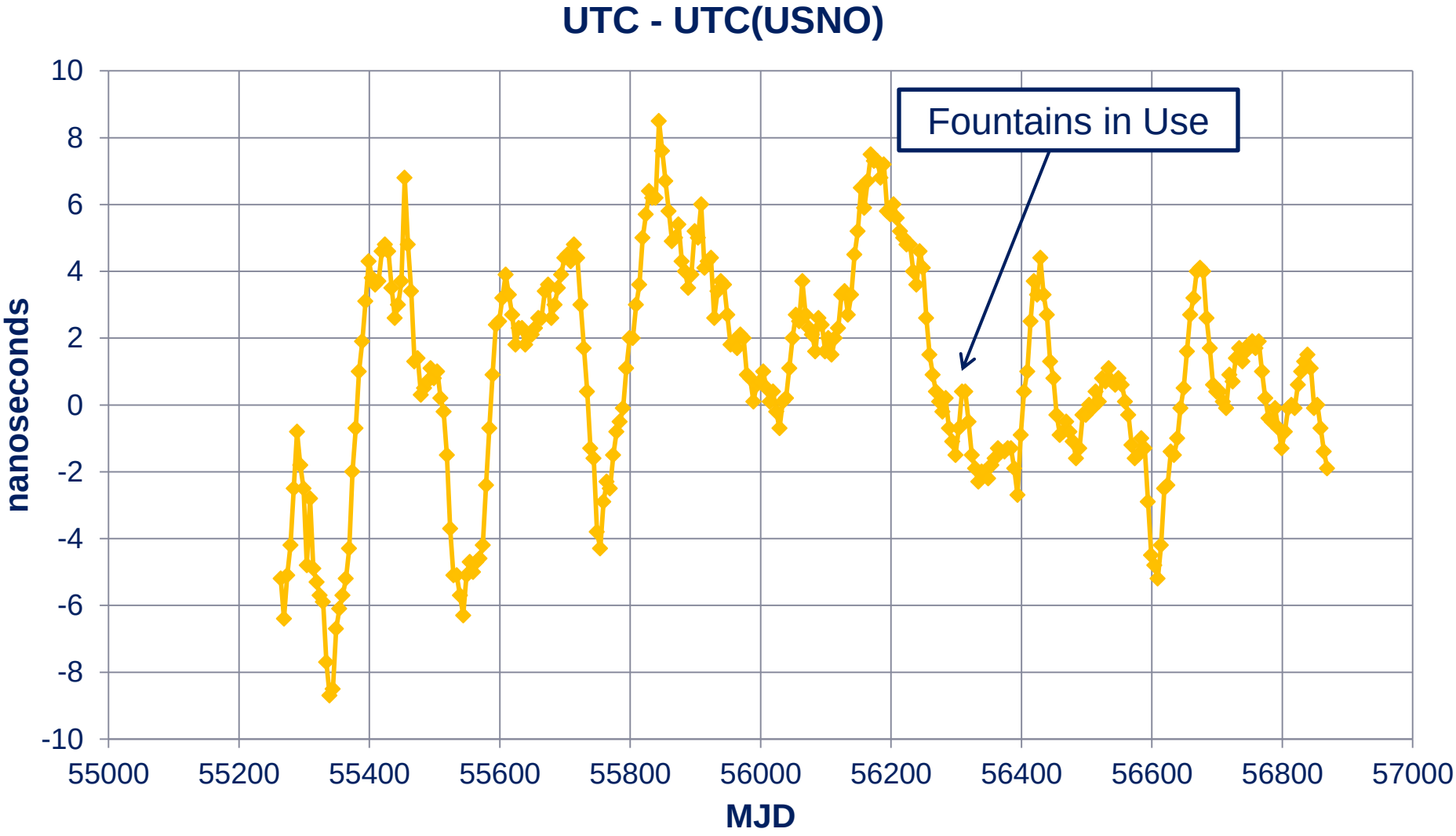
Master Clock
Washington, DC

- *66 High Performance Cesiums*
- *44 Cavity-Tuned Masers*
- *4 Rubidium Fountains*

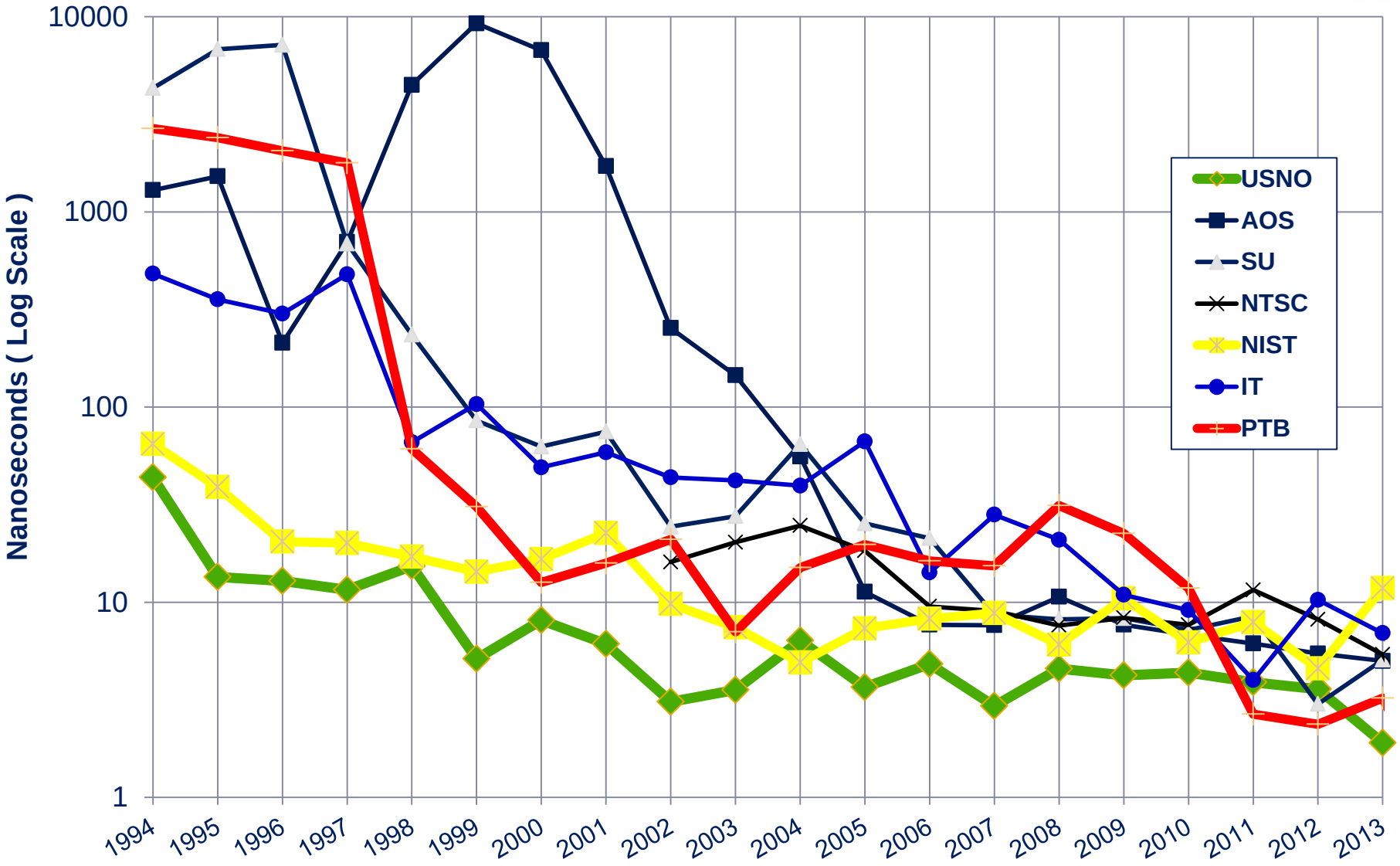
Alternate Master Clock
Schriever AFB

- *12 High Performance Cesiums*
- *4 Cavity-Tuned Hydrogen Masers*
- *2 Rubidium Fountains in test mode*

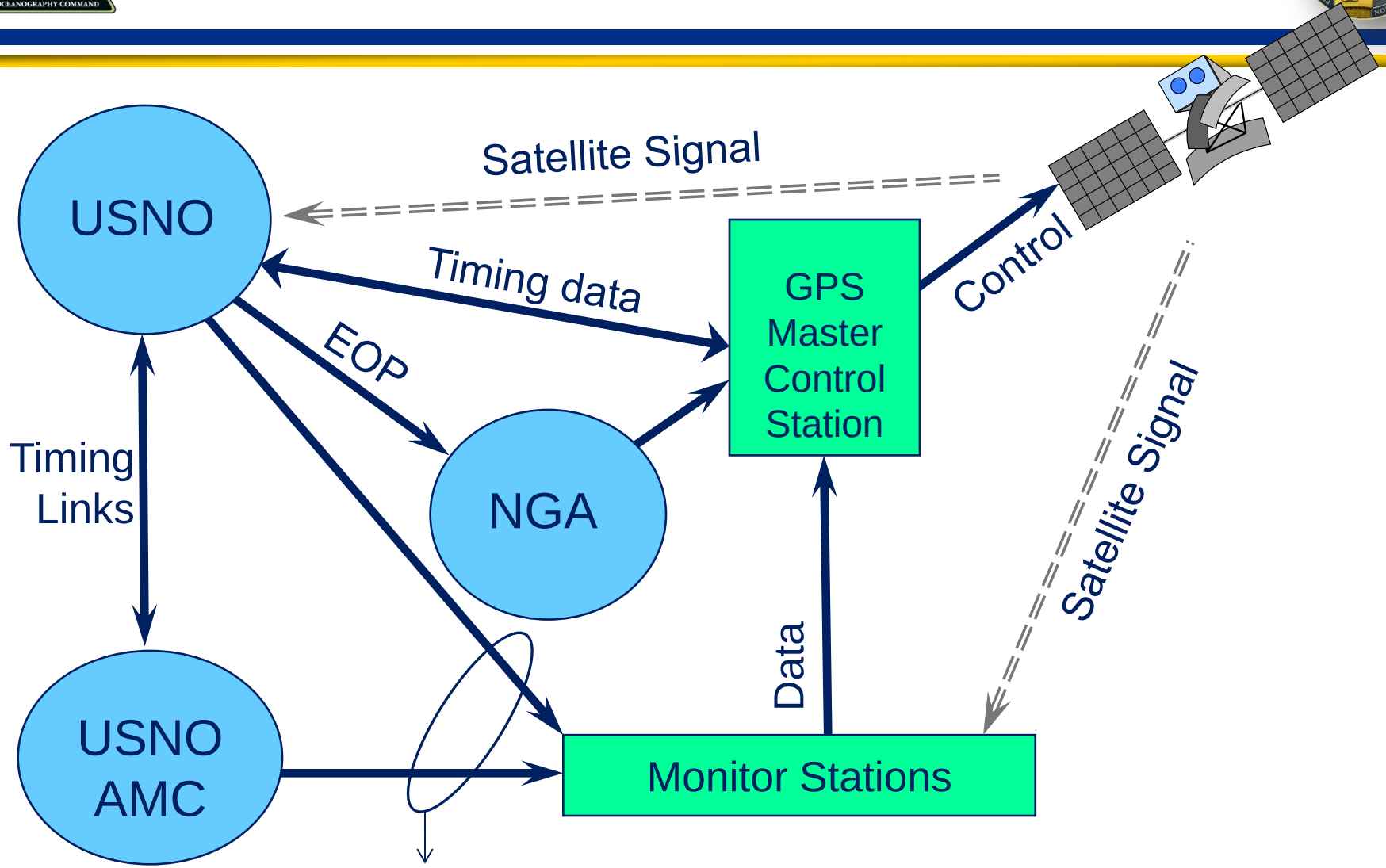
USNO Master Clock and UTC before/after Fountains



UTC - UTC(LAB)
Yearly Root Mean Square (RMS)



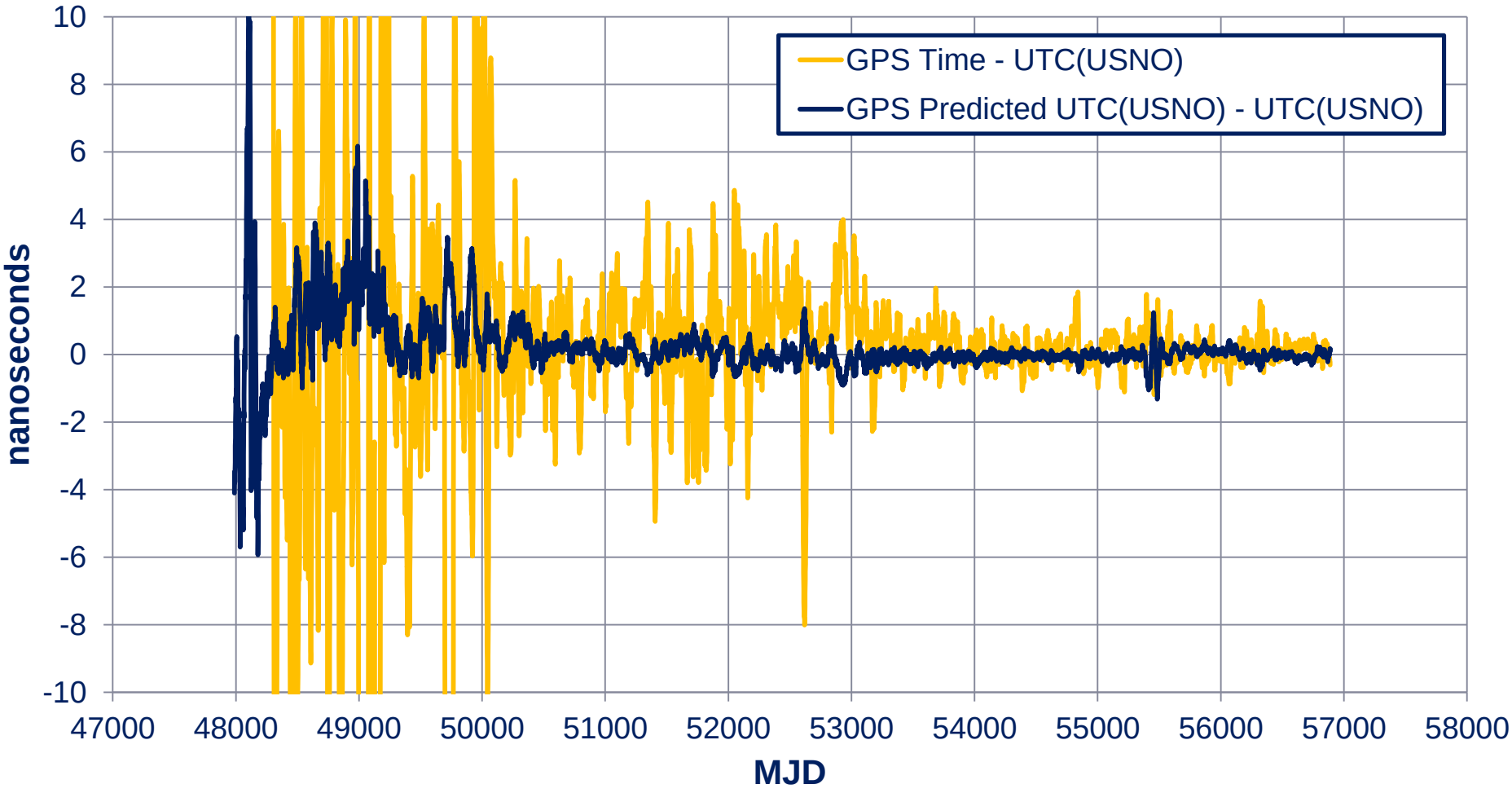
USNO Contribution to GPS



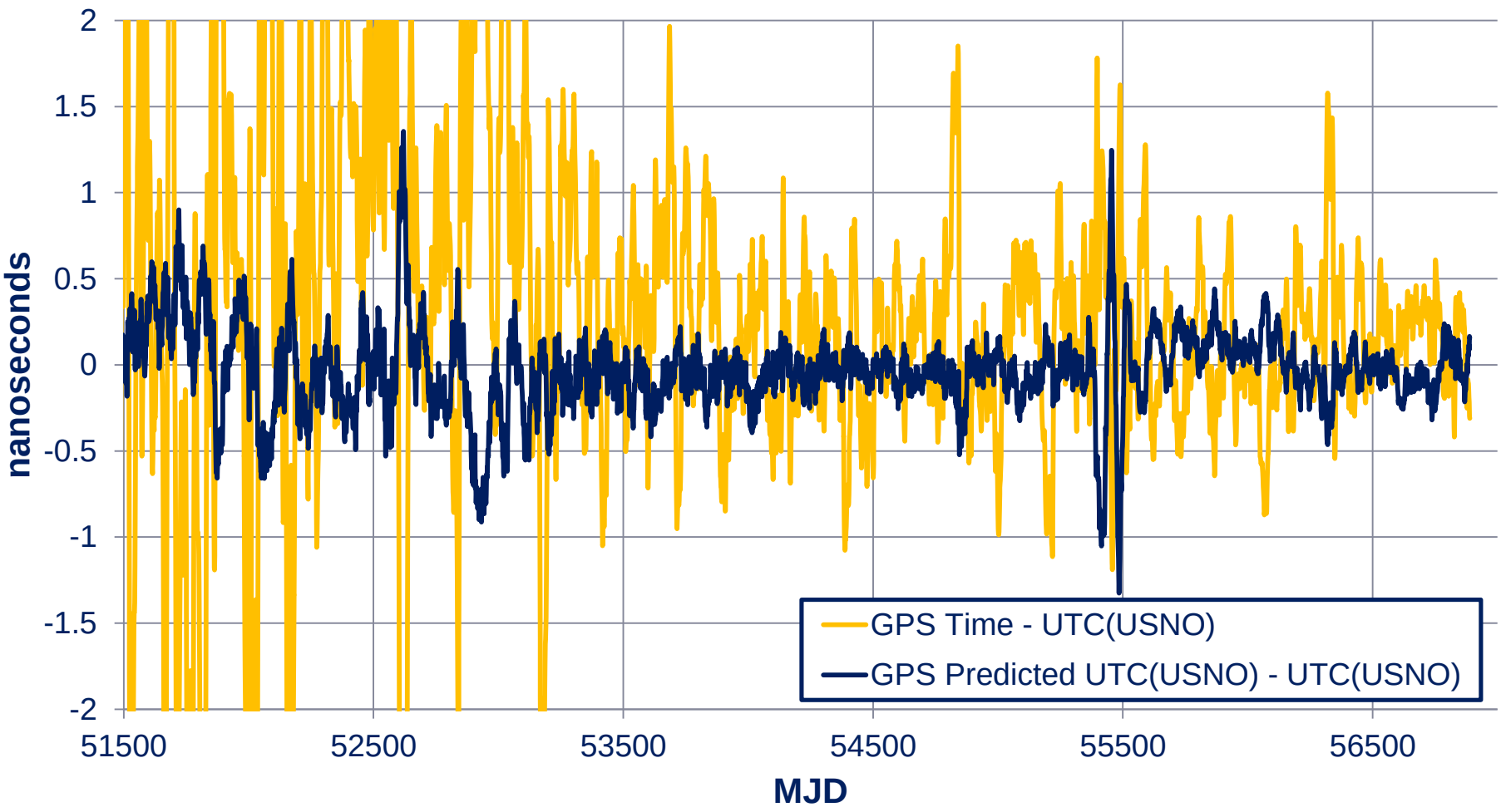
How Exactly Does GPS Keep On Time?

- *First: GPS Time, a Navigational Timescale*
  - *No leap seconds*
  - *Intelligent average of system clocks*
    - *Satellite and ground clocks*
  - *Kalman Filter*
  - *Steered to USNO Master Clock*
    - *USNO tells GPS how far off GPS Time is*
    - *GPS accelerates GPS Time*
      - **The time does not jump**
      - **The frequency does not jump**
      - **The change in frequency does jump**
        - *In other words, it is instantly changed*

GPS Time Delivery, 30-day Averages

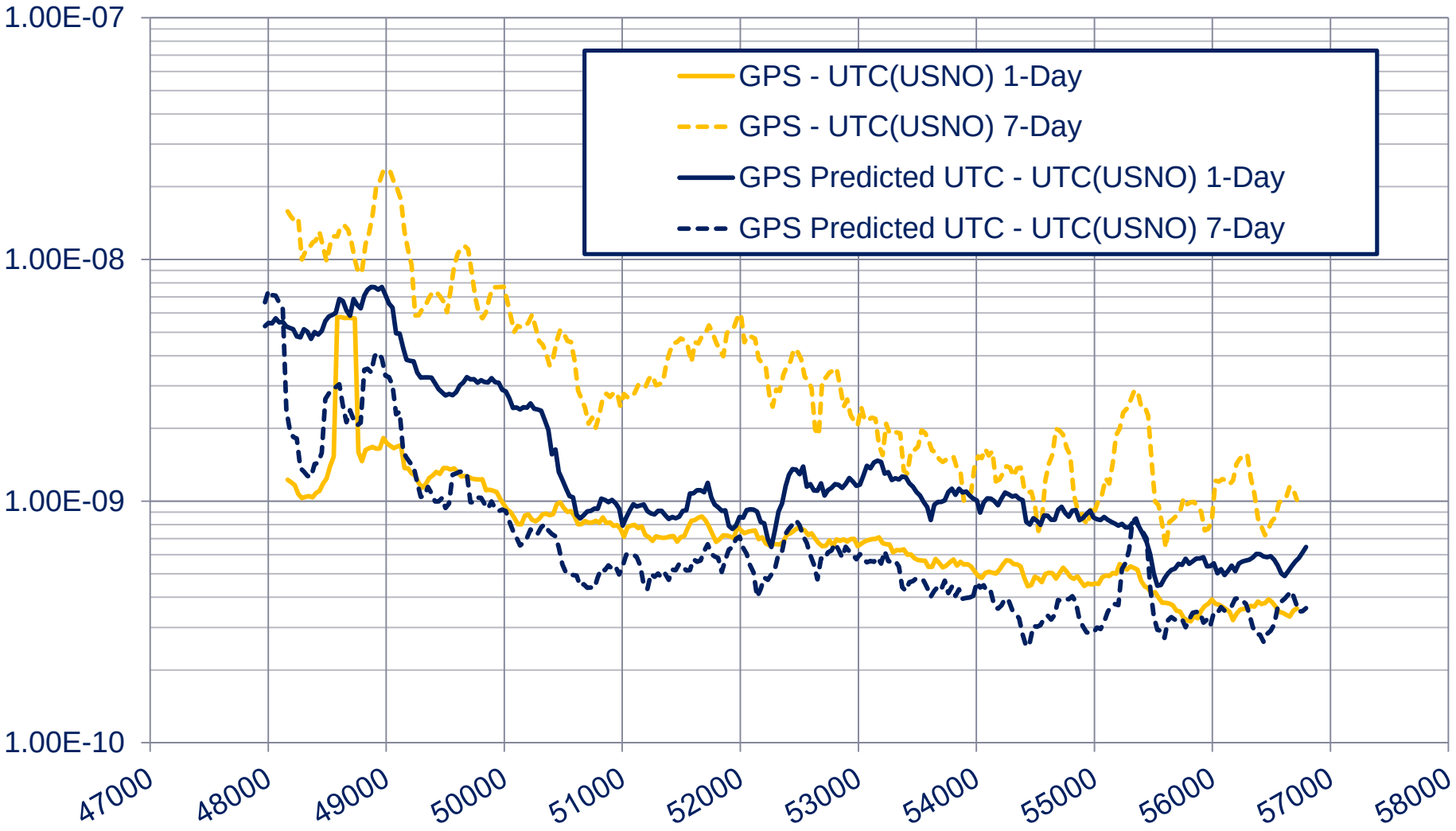


GPS Timing, More Recent History



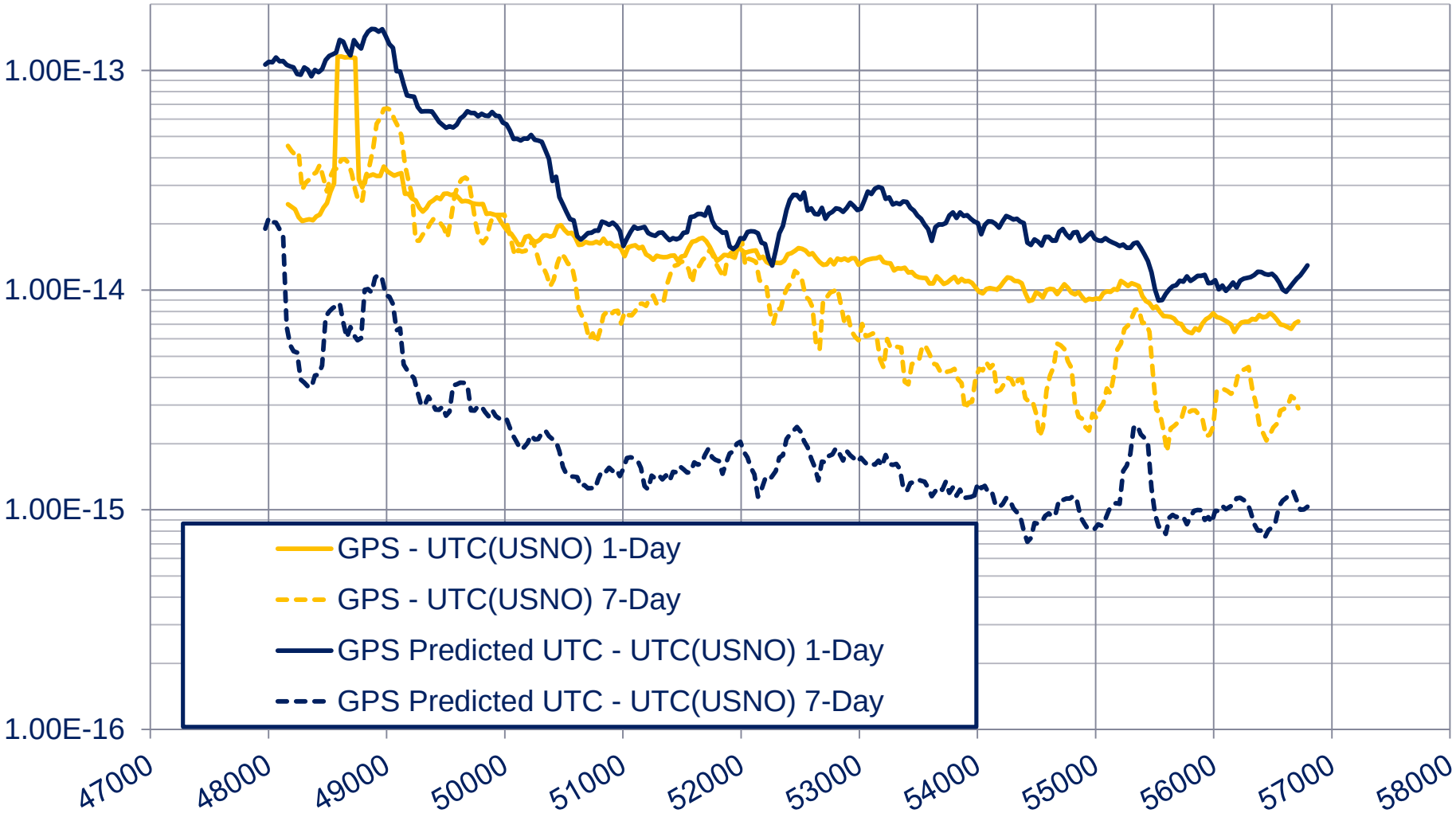
GPS Timing Instability

Time Deviations Over 6-Month Datasets

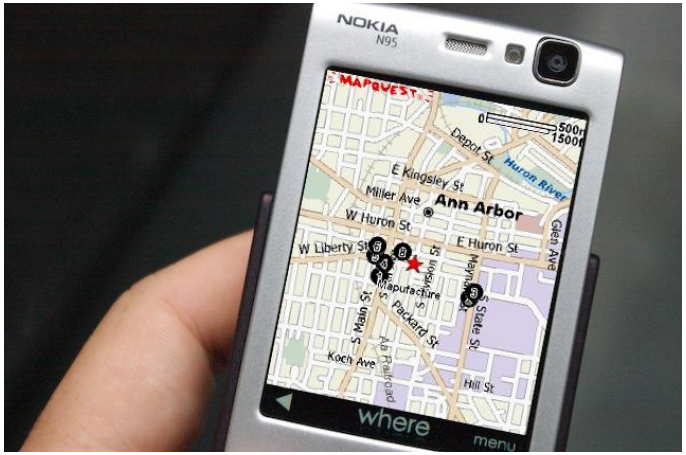


GPS Frequency Instability

Modified Allan Deviations Over 6-Month Datasets



GPS as it is now can do almost everything



But GPS + other GNSS can do more

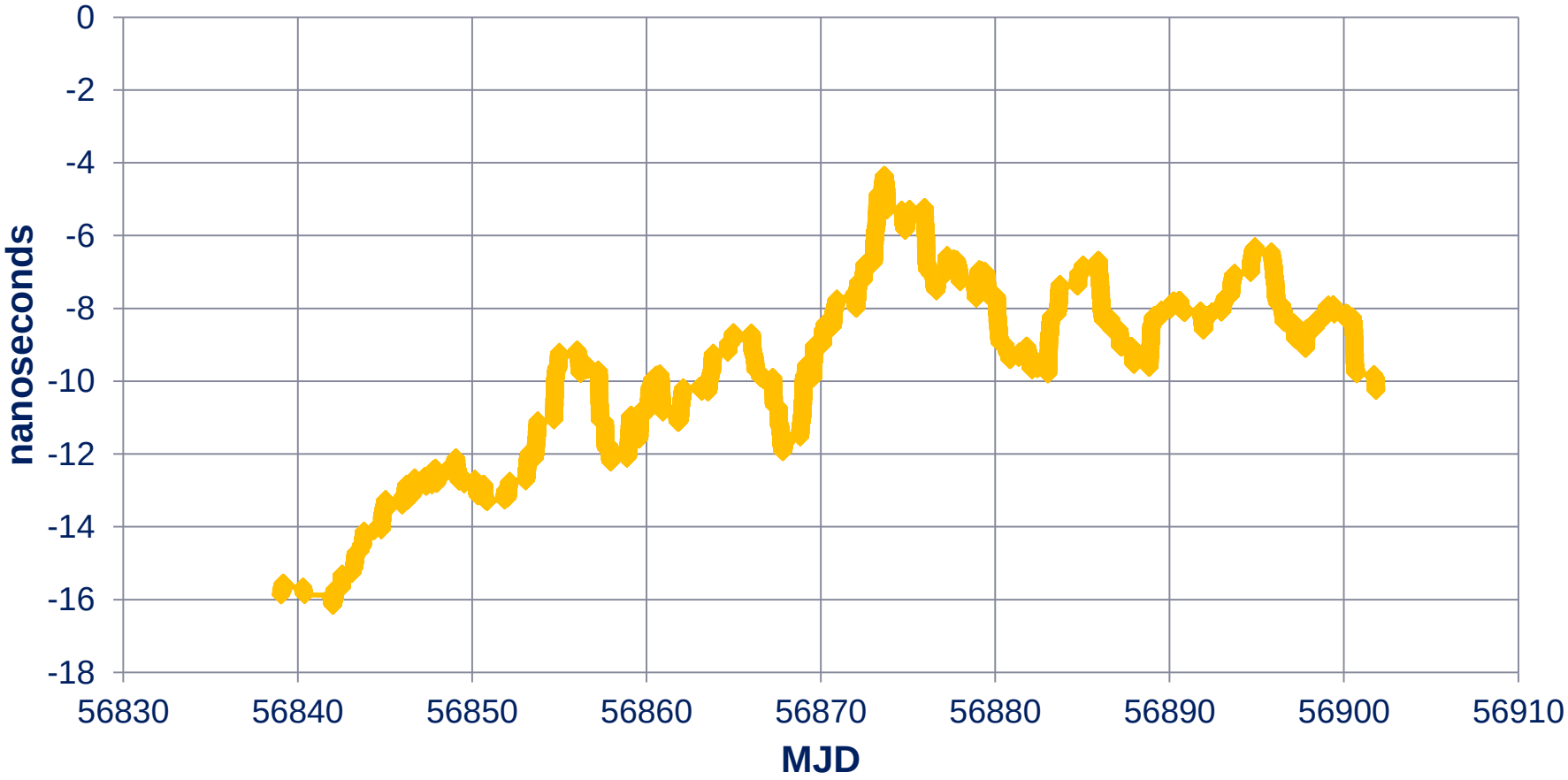
- *Urban canyons, Reliability*
- *Common Time Reference Needed*
- *USNO and Galileo to broadcast the difference between their navigational timescales*
  - *Galileo GGTO, GPS-GALILEO Time Offset*
  - *Parallel operational measurements*
  - *Shared and Compared*
  - *System running in test mode*
- *Bias Measurements being actively measured by USNO*
- *Other GNSS could be incorporated*

USNO Additional GPS III support

- ***USNO will act to coordinate GPS Time with other GNSS systems Time and provide a correction message to GPS***
  - ***USNO is presently providing both GLONASS and Galileo time differences in support of special CNAV testing (not presently being broadcast)***
  - ***USNO is moving into an operational phase coordinating the Galileo to GPS Time Offset (GGTO) information with Galileo system***

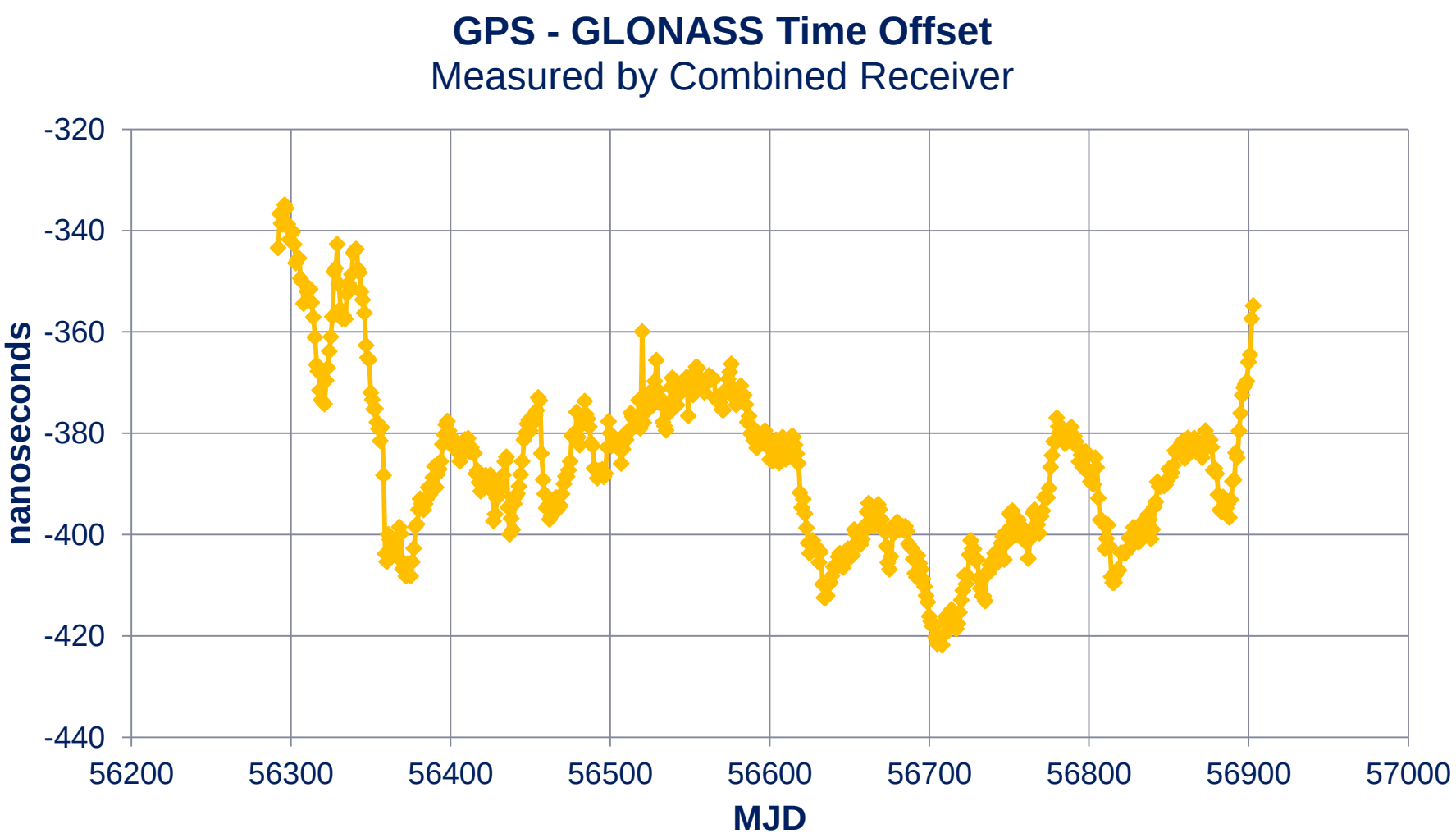
- ***Also supporting OCX, USNO will work with USAF for the determination of the GPS satellite and reference stations inter-signal and inter-frequency biases***
  - ***This is needed to ensure that average constellation biases are removed in a consistent way to ensure accuracy for timing user community***

GALILEO GGTO



The plot contains 30-second bin-averaged GPS – GALILEO data smoothed 3000 points.

GLONASS GGTO



The plot contains 1-day quadratic fit values at the midpoint of the fit

Future Emphasis for Reliable Sub-Nanosecond Timing

1. Stable Timescale Reference
2. Carrier Phase Analysis for GNSS
3. Environmental Control
4. Redundant Independent Receiver Systems
5. Multipath Reduction
6. Calibration, and Recalibration
7. Impedance Matching / Cable Reflections
8. Equipment Design
9. Inter-frequency Bias corrections

ION-PTTI-14

- *PTTI = Precise Time and Time Interval*
  - *Now an ION conference*
- *USNO still posts all papers through PTTI-12*
  - *See http://tycho.usno.navy.mil/ptti*
- *As well as its own subsequent papers and any unsolicited donations*
- *ION holds copyright to "papers as a whole"*

- ***Next meeting is Dec 1-4, 2014***
- ***Boston, Ma***

Another Time

- *USNO also measures the Earth Orientation Parameters, including the Earth's rotational angle UT1, for GPS and other users*
- *USNO serves as the rapid service/prediction center of the International Earth Rotation and Reference Frames Service (IERS)*
- *New Department Heads!*
  - *Christine Hackman, Earth Orientation*
  - *Nancy Oliverson, Astronomical Almanac*
  - *Warren Walls, Time Service*

Summary

- ***USNO specializes in real-time timekeeping***
  - ***UTC realization***
  - ***Dissemination***
  - ***Monitoring***
  - ***Device and analysis R&D***