Assessing the Compatibility of Microwave Geodetic Systems

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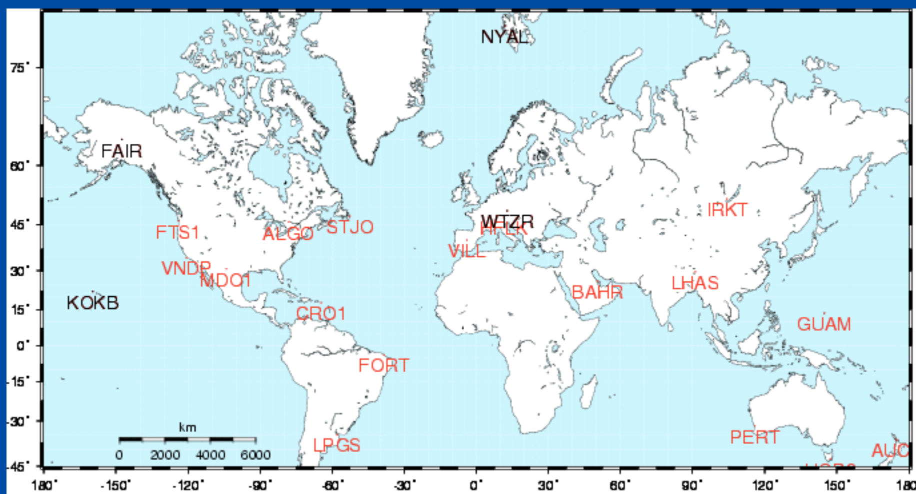
Overview

- Examine the compatibility of VLBI and GPS systems by comparing clock and atmospheric delay estimates from the two systems
- Data Analyzed:
  - End of the CONT96 VLBI experiments
  - Common stations: Fairbanks, Wettzell, Kokee, Nyales20. No GPS at NRAO station.
  - Additional 20 global stations used in GPS analysis

VLBI and GPS Network



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Analysis Technique

- VLBI: CALC+SOLVK Kalman filter
  - Clock process noise consistent with 10^{-14} Alan standard deviation at 1000 seconds; Quadratic terms removed apriori.
  - Atmospheric process noise: Derived from delay-rate variance: Typical random walk values 10 mm/sqrt(hr); variations of factor of three about this value
  - Constant zenith delay based on station height and zero water vapor

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Analysis Technique

- GPS: GAMIT program
  - Clocks estimated epoch-by-epoch relative to Fairbanks/Gilcreek clock
  - Phase clocks aligned with clocks from pseudo-range estimates
  - Atmospheric delay estimated with piece-wise linear function with nodes every 2-hours. Stochastic noise 20 mm/sqrt(hr)
  - Constant apriori zenith delay.

Some effects that might be expected: Clock effects

- GPS is controlled by 10.23 MHz oscillators
- On the Earth's surface these oscillators are set to $10.23x(1\text{-}4.4647x10^{-10})$ MHz (39,000 ns/day rate difference)
- This offset accounts for the change in potential and average velocity once the satellite is launched.
- The first GPS satellites had a switch to turn this effect on. They were launched with "Newtonian" clocks

Corrections terms

- Propagation path curvature due to Earth's potential (a few centimeters)

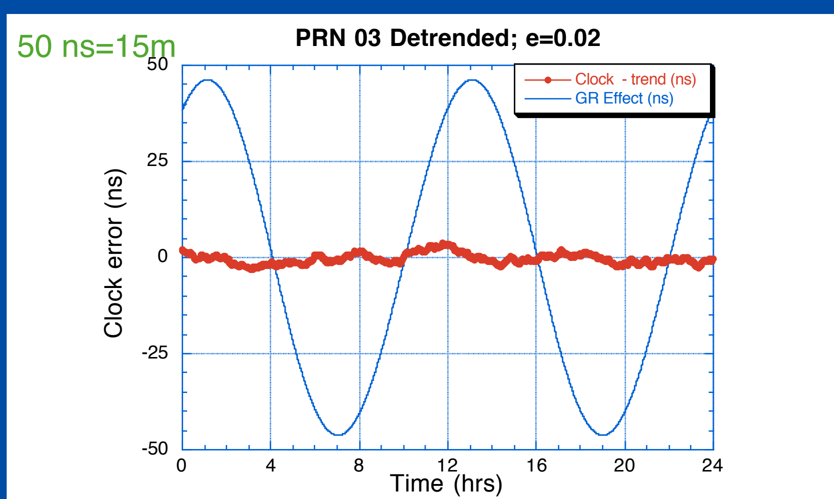
$$\Delta\tau = \frac{2GM}{c^3}\ln\left(\frac{R_r + R_s + \rho}{R_r + R_s - \rho}\right)$$

- Clock effects due to changing potential

$$\Delta t = \frac{2\sqrt{GM}}{c^2} e\sqrt{a}\sin E$$

- For e=0.02 effect is 47 ns (14 m)

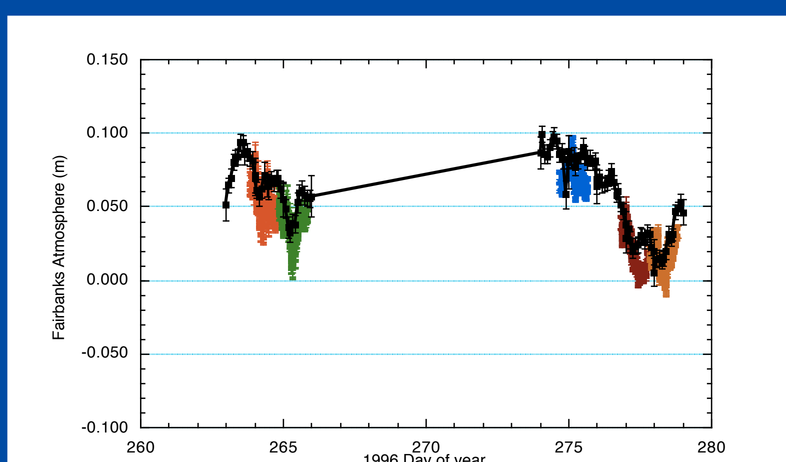
Relativistic Effects (SA off)



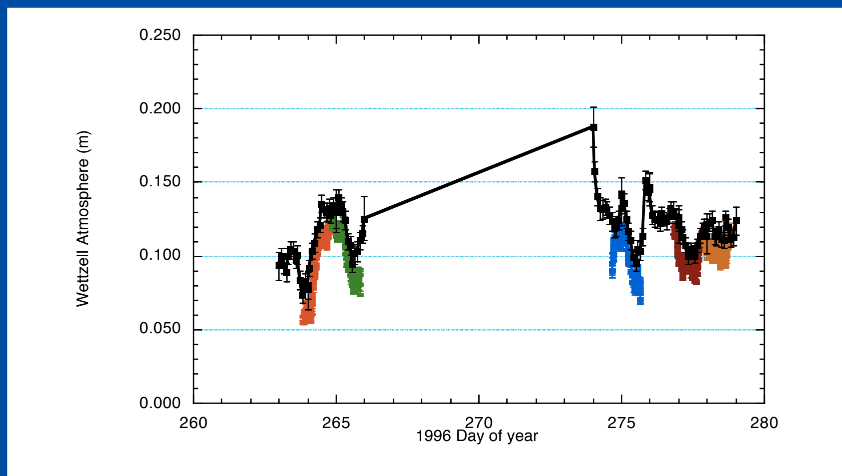
Comparisons

- Atmospheric delays:
  - Easiest comparison because apriori zenith delay chosen as constant and the same apriori used for VLBI and GPS
- Clocks:
  - Clocks are more difficult to compare because:
    - No absolute standard for either system (show clocks relative to Fairbanks/Gilcreek)
    - VLBI has different quadratic removed each day. Clocks relative to ensemble
    - GPS also referred to Fairbanks. Only linear trend removed each day.

Fairbanks Atmospheric delays



Wettzell Atmosphere



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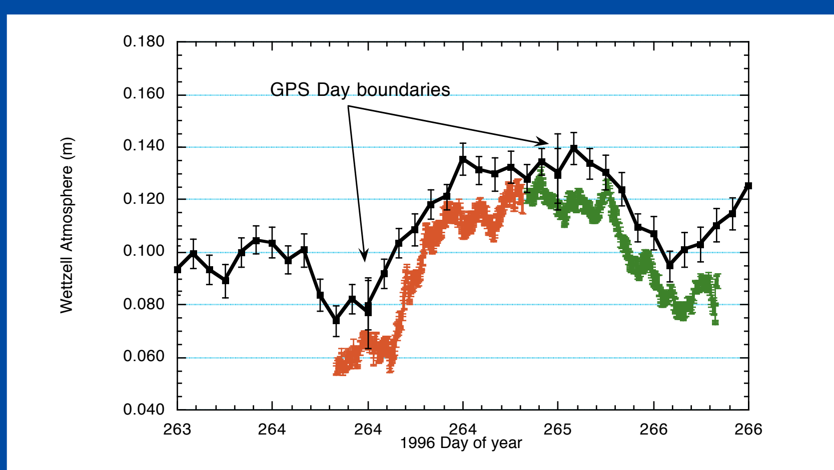
Zoom of Wettzell (Sep 19-20)



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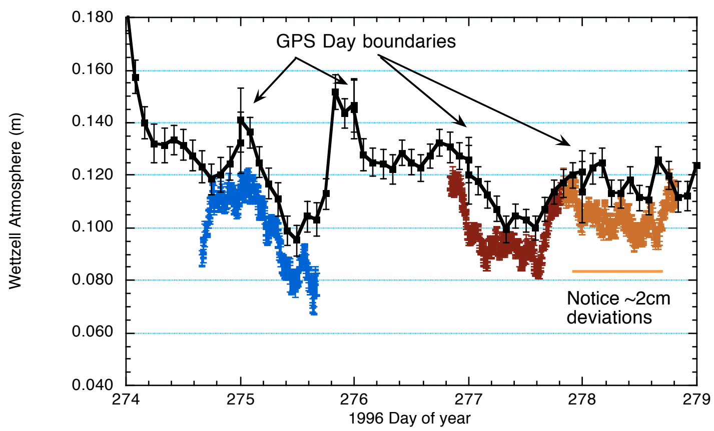
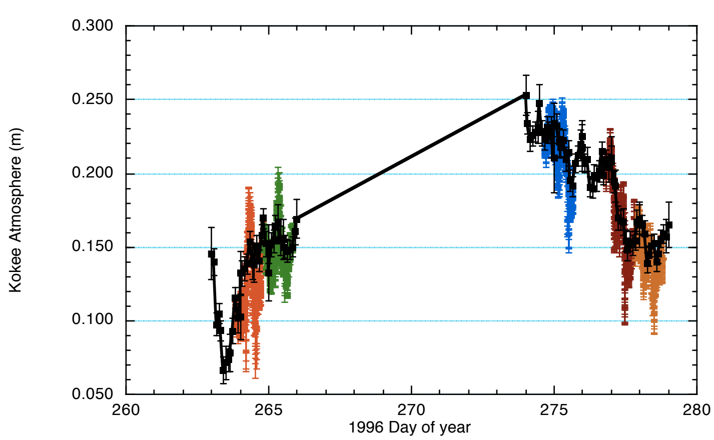
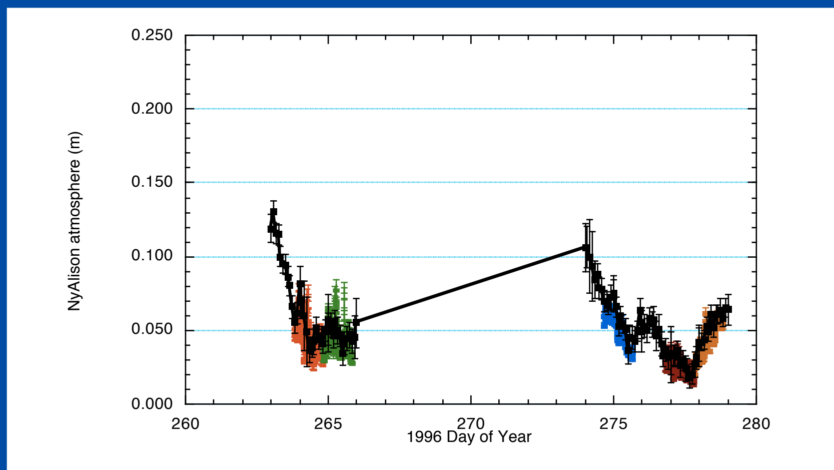
Zoom Wettzell (Sept 30-Oct 2)



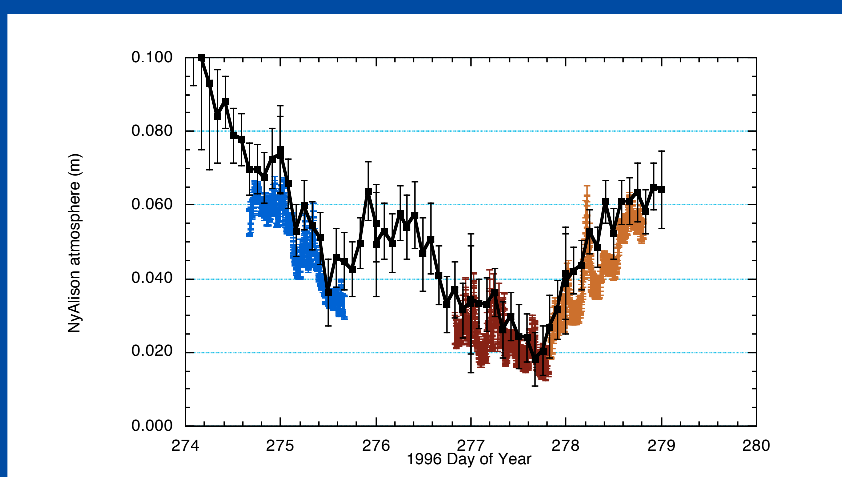
KOKEE Atmosphere



NyAlison Atmosphere



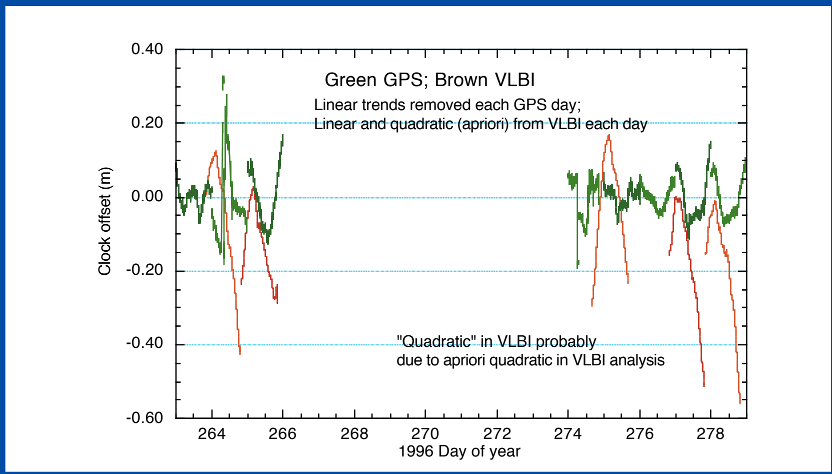
Zoom of NyAlison (Sep 30-Oct 2)



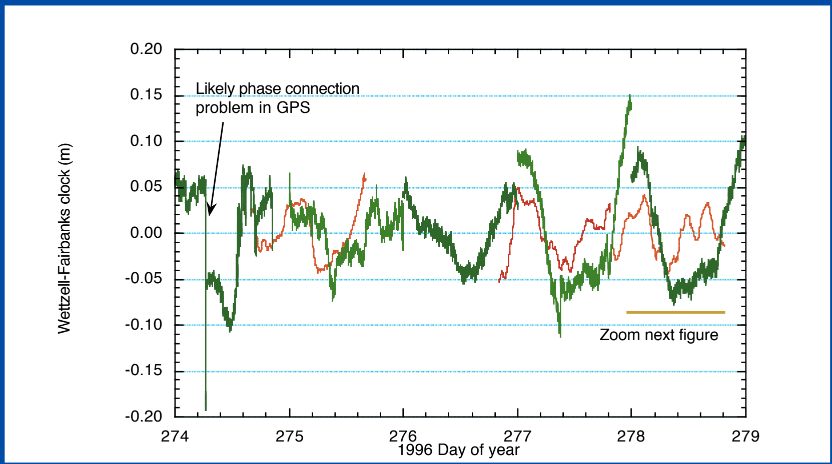
Clock comparisons

- Clock comparison are “complicated” by the removal of trends from VLBI results (can be corrected but currently time-consuming).
- Absolute offsets can not be compared because of VLBI group delay ambiguities; the GPS alignment of phase and range; unknown delays in VLBI and GPS electronics
- Examine difference of Wettzell and Fairbanks clocks

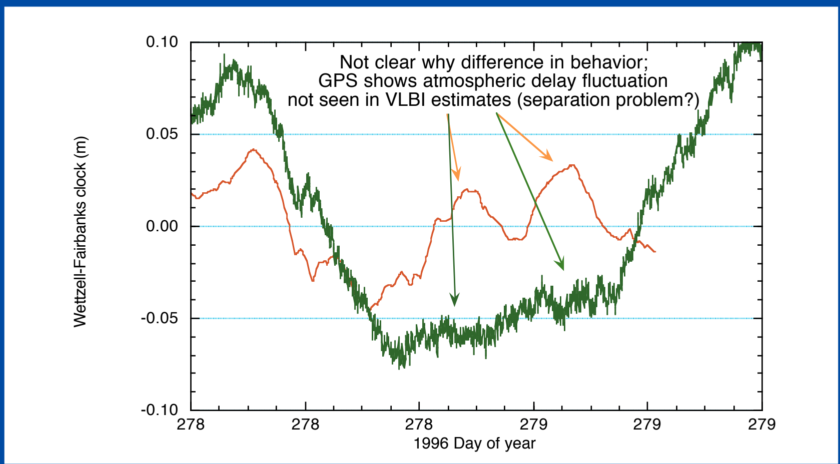
Wettzell-Fairbanks comparison



Wettzell-Fairbanks with VLBI quadratic removed



Zoom area for Wettzell



Conclusions

- Initial study of comparison between VLBI and GPS clock parameters and atmospheric delay estimates.
- Initial results indicate that clocks are comparable quality (no smoothing in GPS)
- Next steps:
  - Accounting for clock rates and accelerations applied to VLBI
  - More consistency in mapping functions and gradients
  - Effects of model changes in GPS (antenna phase centers) on clock comparisons
  - Time dependent process for GPS atmospheres (validation using VLBI data)
- Possible use of GPS atmospheres and clocks in the analysis of VLBI?