QUANTIFYING THE INFORMATION CONTENT IN THE GPS SLANT PATH DELAYS

Yoaz Bar-Sever

We quantify the amount of information on atmospheric water vapor that can be extracted from the GPS line of sight measurement, by comparing these measurements to those made with a collocated pointed water vapor radiometer (WVR). We distinguish between the zero order, first order, and higher order variability of the water vapor distribution, as evident from the GPS line of sight observations. We show that while the GPS observations are capable of capturing the zero and first order (gradient) distribution of water vapor with high accuracy as compared to the WVR-based observations, the higher order information is not captured well and is mostly buried in noise. We conclude that most observations of slant path delays to-date are merely representation of the delay gradients. This fact significantly limits the capability of standard GPS receivers to support atmospheric tomography.

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Validation of GPS LOS Wet Trop

Goal: Characterize the information content in the GPS-based LOS delays
- How much is due to gradients
- How much is higher order variations

Method: Compare GPS-based estimates with those from a collocated WVR

Setup: Lamont ARM site
GPS: AOA Benchmark
WVR: Radiometrics

WVR data: points to all GPS satellites in succession (~5 min cucle)
10° elevation angle cutoff
Interpolate zenith-mapped WVR LOS delays to GPS measurement epoch (5 min)

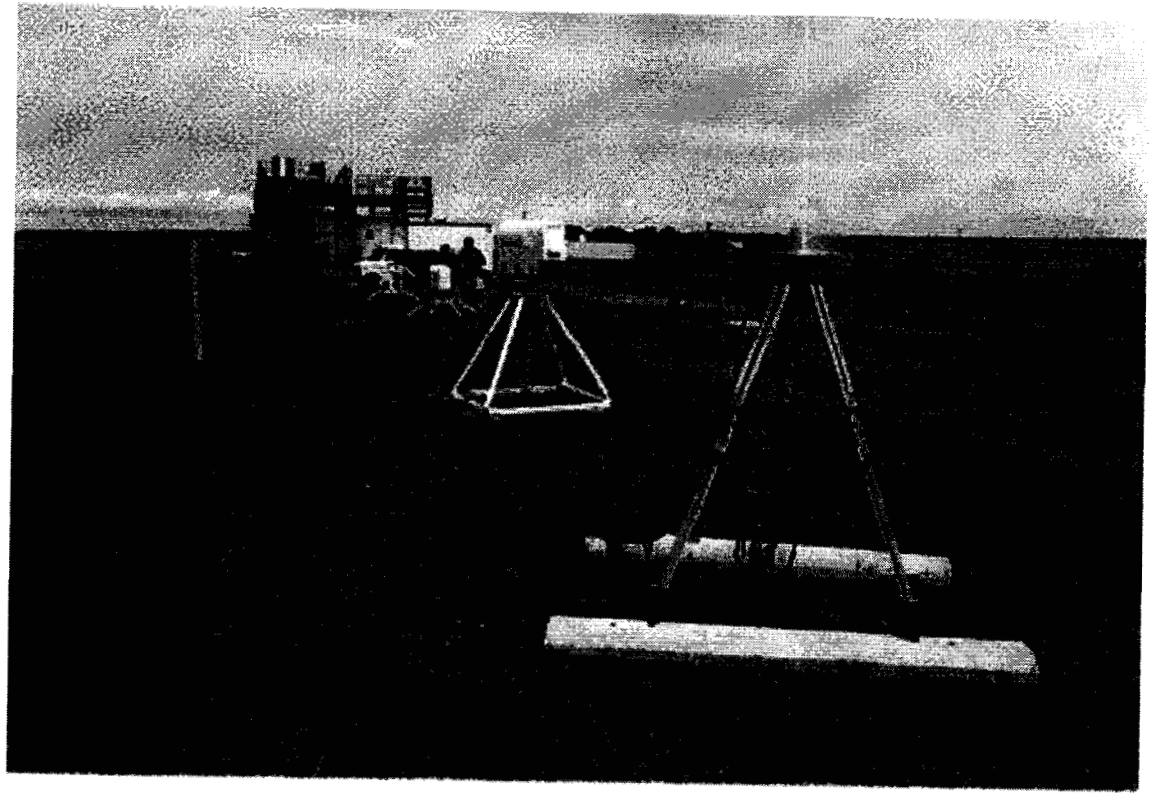
GPS Data Processing

Point positioning: 30 hour arcs centered on noon

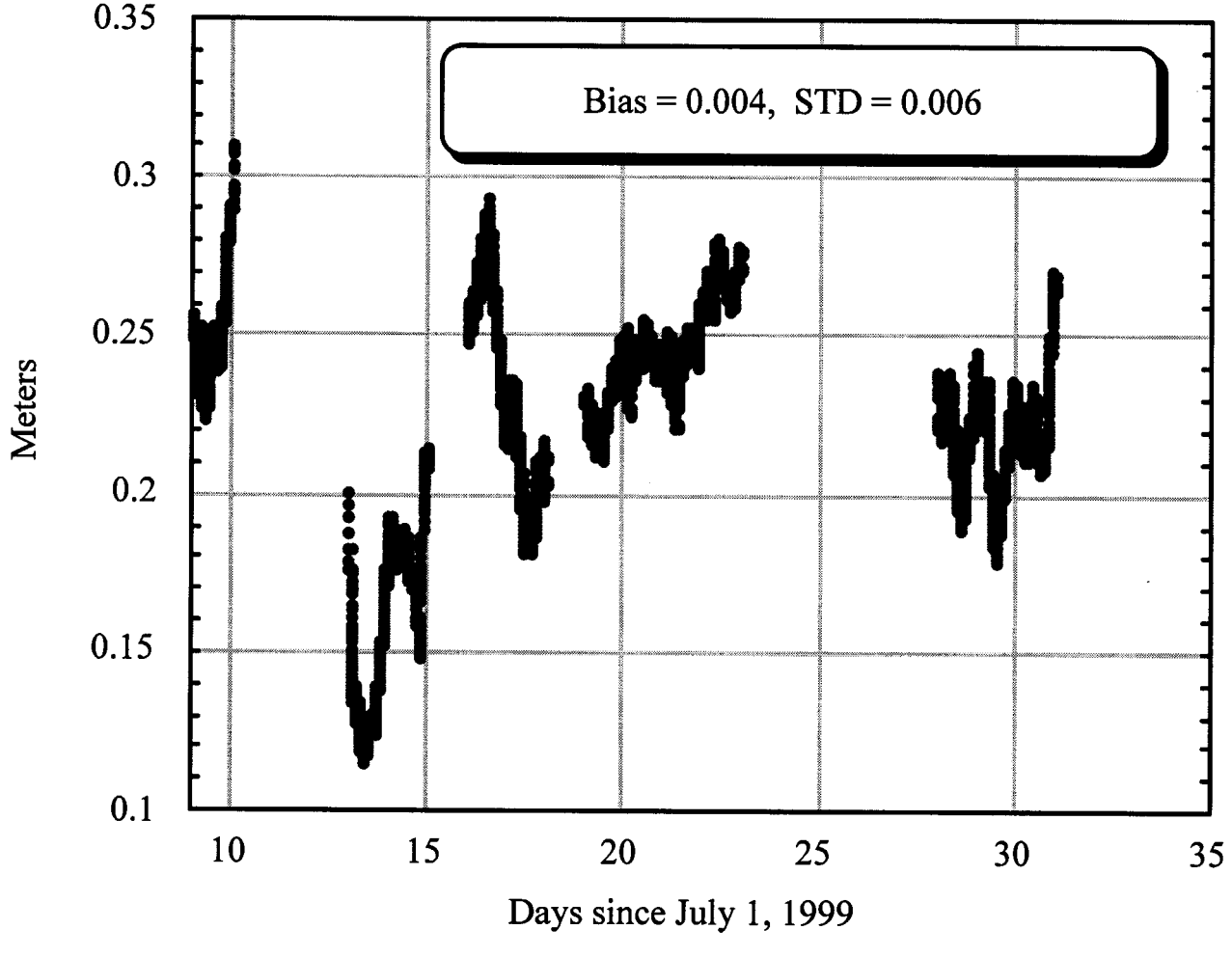
Calibrate antenna phase center/multipath by residual stacking method with three months of data

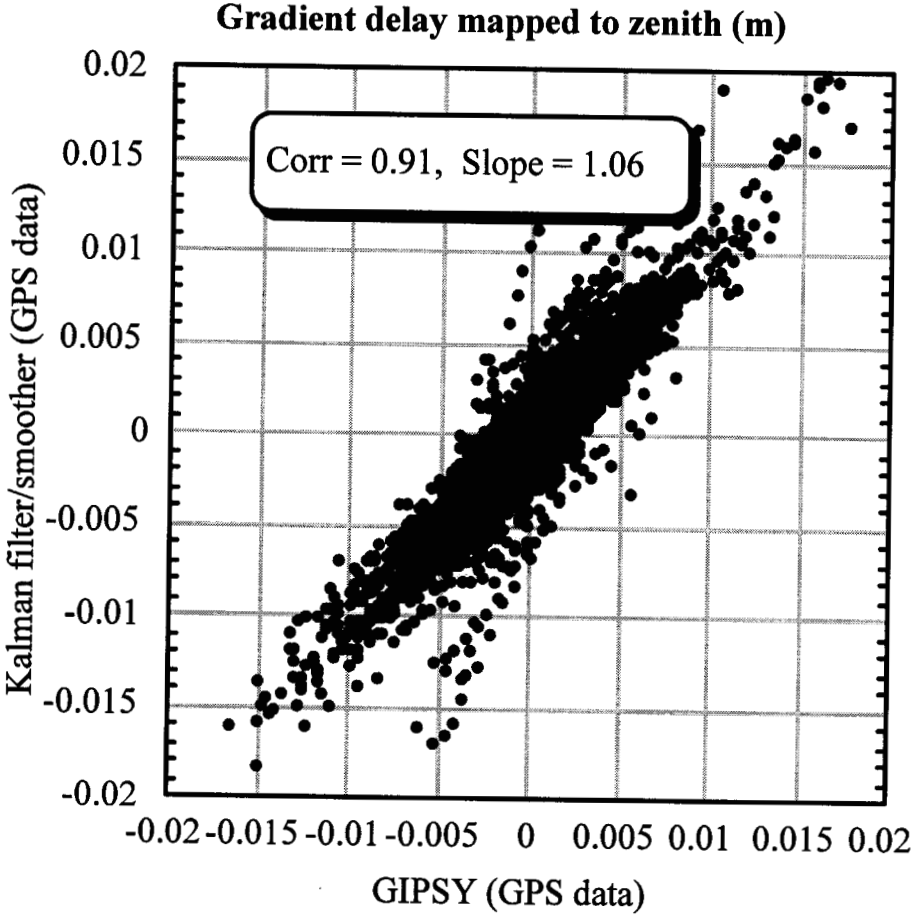
Daily estimation: Estimate everything that is modelable (position, clock, zenith delay, gradients)

Experiment Site

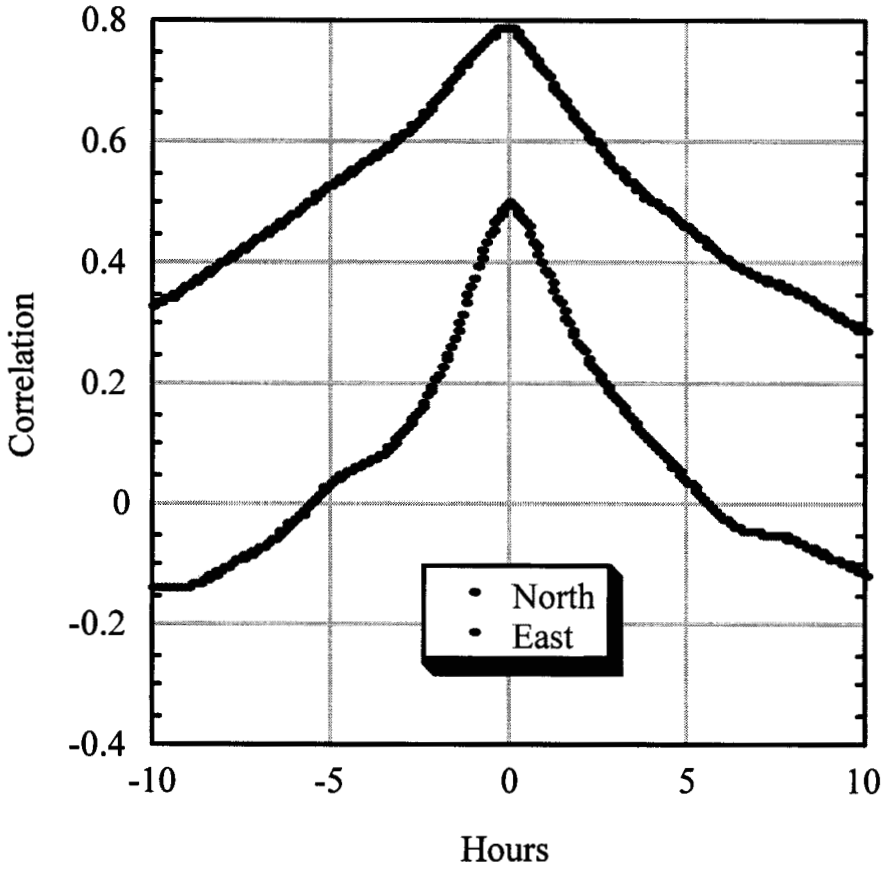


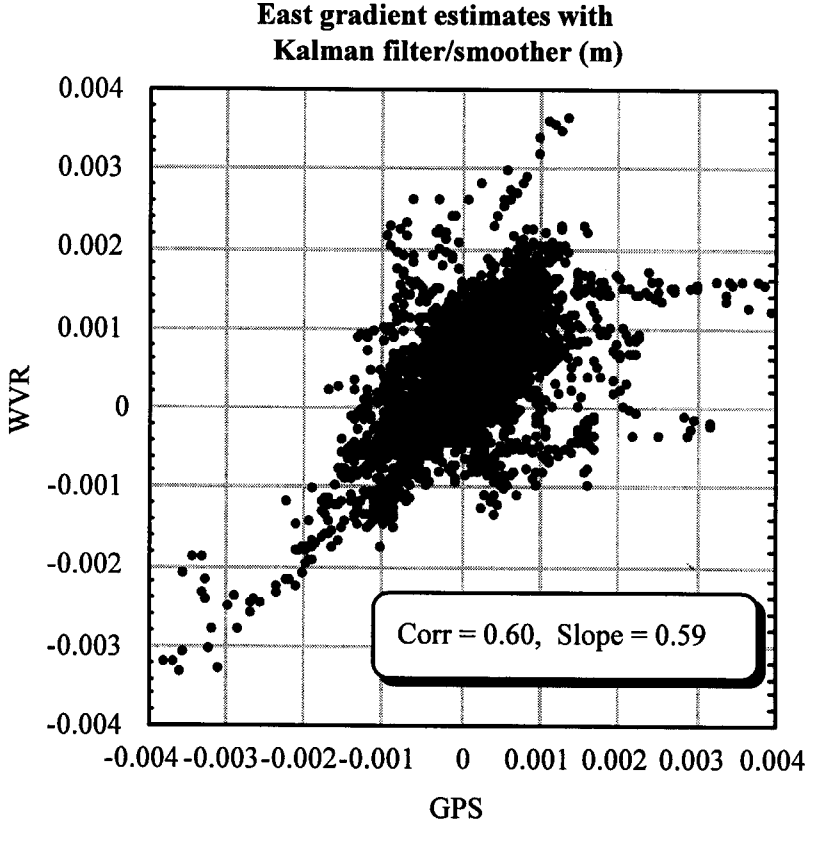
Wet zenith delay estimates from GPS and WVR data using Kalman filter/smoother

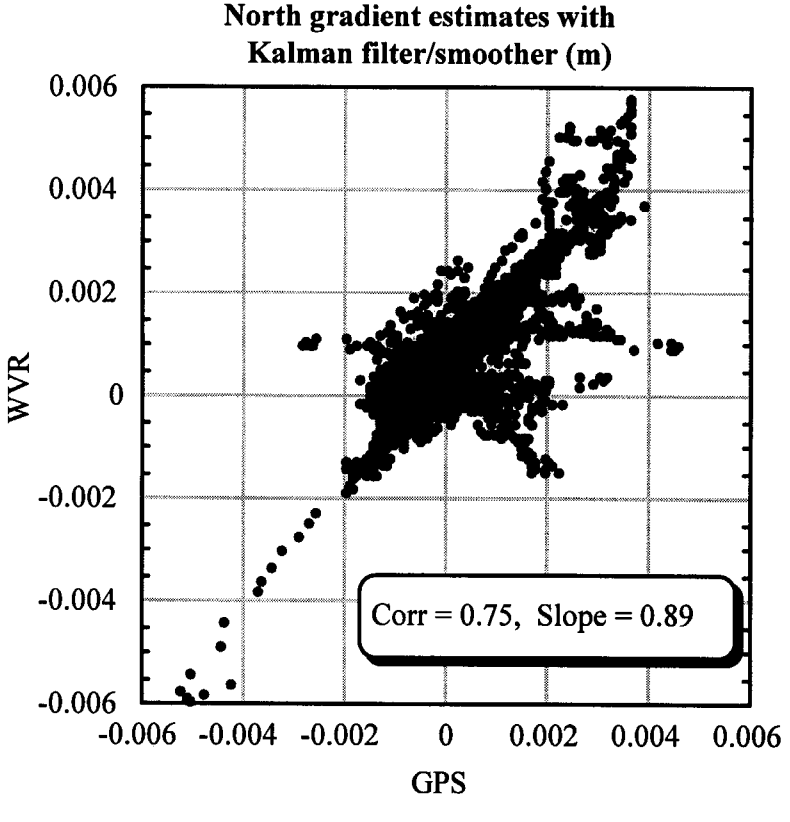


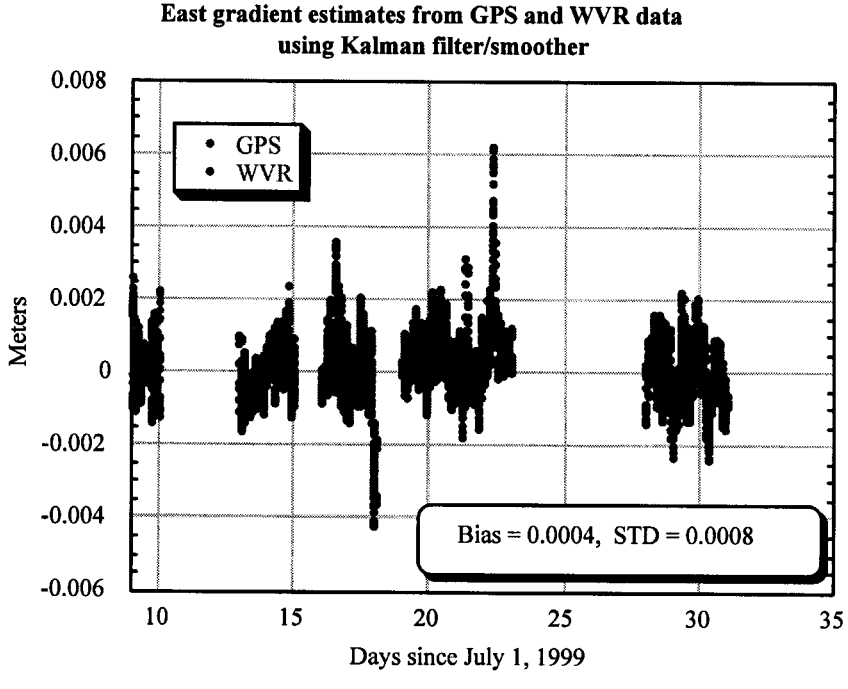

Gradient delay mapped to zenith (m)
Corr = 0.91, Slope = 1.06
Kalman filter/smoother (GPS data)
GIPSY (GPS data)
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
-0.02 -0.015 -0.01 -0.005 0 0.005 0.01 0.015 0.02

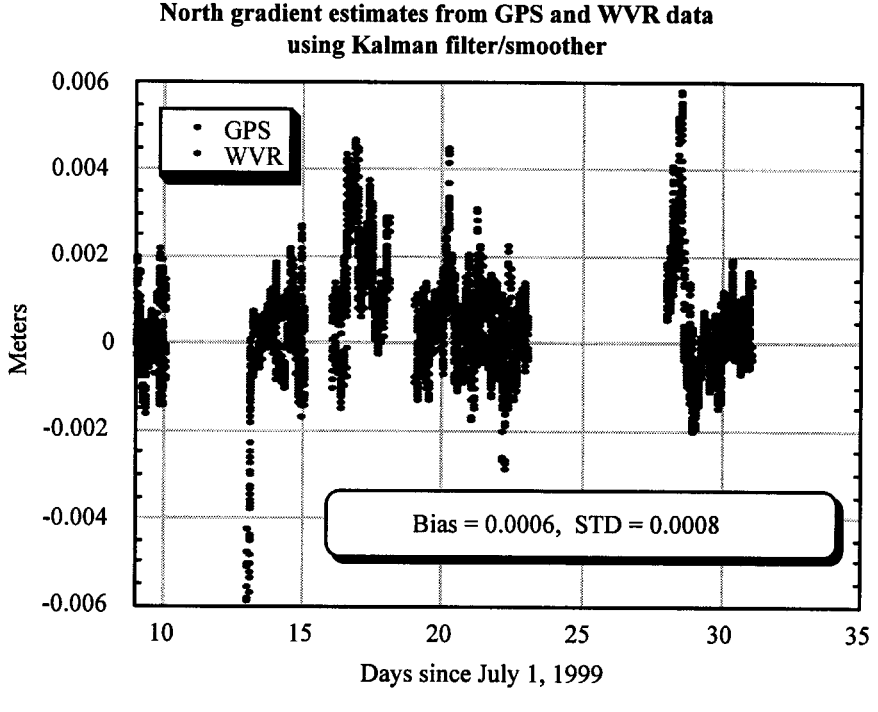
Cross correlation of gradient estimates based on GPS (GIPSY) and WVR (Kalman)

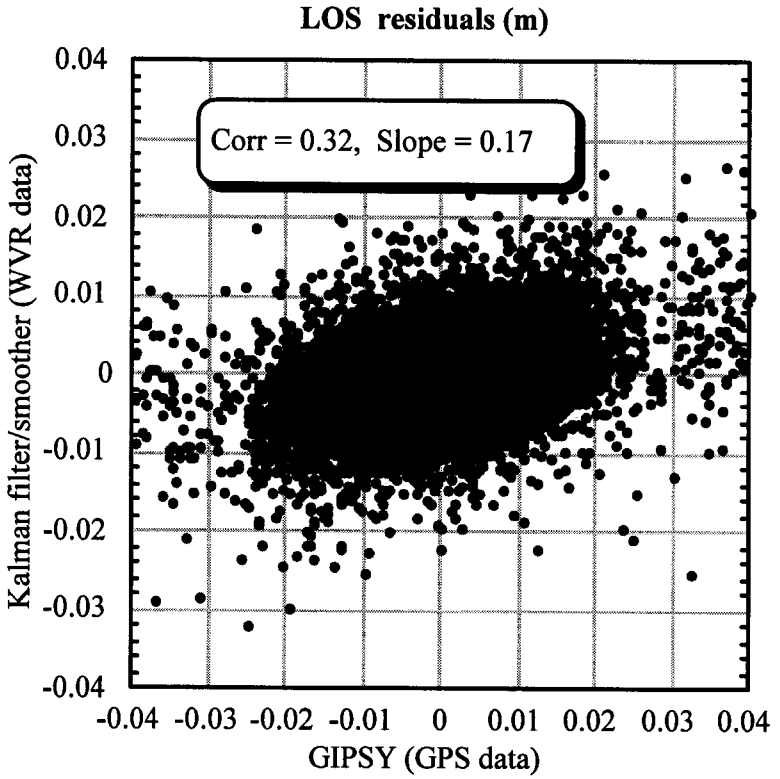


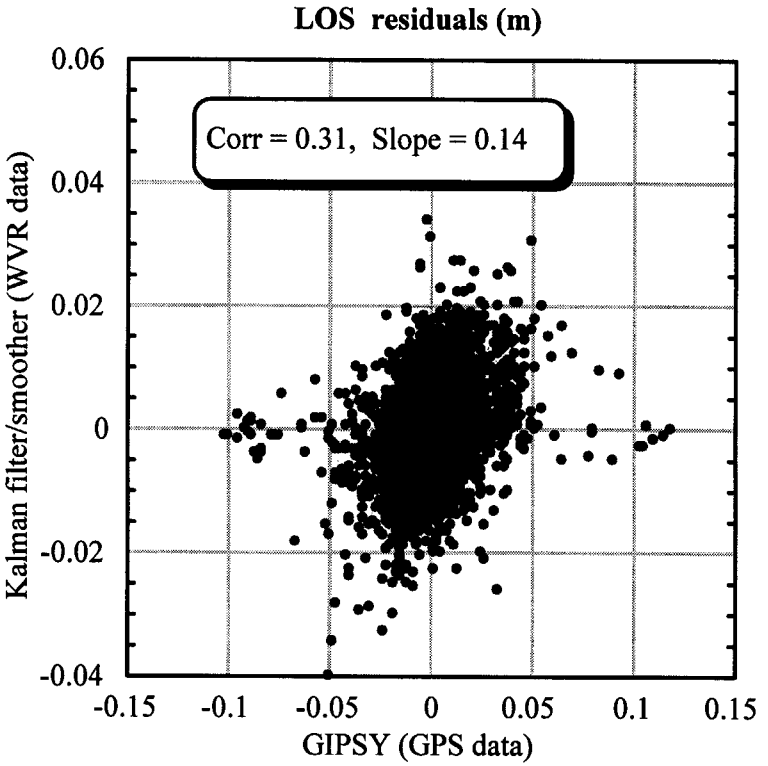

East gradient estimates with
Kalman filter/smoother (m)
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
WVR
-0.004 -0.003 -0.002 -0.001 0 0.001 0.002 0.003 0.004
GPS
Corr = 0.60, Slope = 0.59

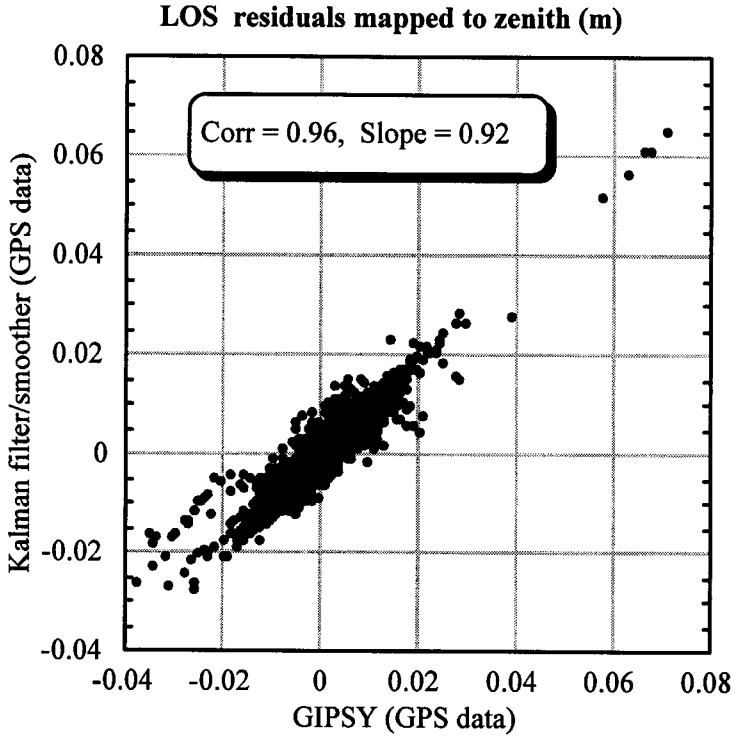

North gradient estimates with
Kalman filter/smoother (m)
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
WVR
-0.006 -0.004 -0.002 0 0.002 0.004 0.006
GPS
Corr = 0.75, Slope = 0.89

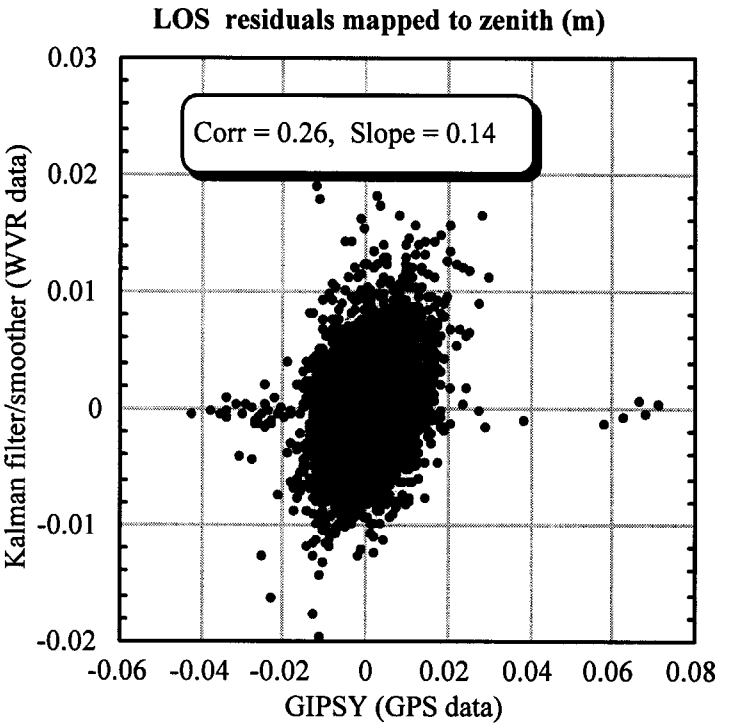

East gradient estimates from GPS and WVR data
using Kalman filter/smoother
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
Meters
GPS
WVR
Bias = 0.0004, STD = 0.0008
10
15
20
25
30
35
Days since July 1, 1999


North gradient estimates from GPS and WVR data
using Kalman filter/smoother
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
Meters
GPS
WVR
Bias = 0.0006, STD = 0.0008
10
15
20
25
30
35
Days since July 1, 1999


LOS residuals (m)
Corr = 0.32, Slope = 0.17
Kalman filter/smoother (WVR data)
GIPSY (GPS data)
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.04 -0.03 -0.02 -0.01 0 0.01 0.02 0.03 0.04


LOS residuals (m)
Corr = 0.31, Slope = 0.14
Kalman filter/smoother (WVR data)
GIPSY (GPS data)
0.06
0.04
0.02
0
-0.02
-0.04
-0.15 -0.1 -0.05 0 0.05 0.1 0.15


LOS residuals mapped to zenith (m)
Corr = 0.96, Slope = 0.92
Kalman filter/smoother (GPS data)
GIPSY (GPS data)
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.04 -0.02 0 0.02 0.04 0.06 0.08


LOS residuals mapped to zenith (m)
Corr = 0.26, Slope = 0.14
Kalman filter/smoother (WVR data)
GIPSY (GPS data)
0.03
0.02
0.01
0
-0.01
-0.02
-0.06 -0.04 -0.02 0 0.02 0.04 0.06 0.08

Conclusions

The GPS LOS delay estimates are dominated by the zero- and first-order approximations for the inhomogeneous troposphere. Higher order effect are not discernable from the post-fit residual data

Possible mitigation: Special hardware to reduce multipath; Atomic clocks

Alternative approach: Parametrize second order variations