Jet Propulsion Laboratory
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Optimization of tropospheric delay estimation parameters by comparison of GPS-based precipitable water vapor estimates with microwave radiometer measurements

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Motivation

- Assess impact of processing parameters on troposphere delay estimates:
  - Random walk parameter σ for zenith delays
  - Arc length (24 hr vs. 30 hr)
  - Nominal troposphere model
  - Mapping function
- Make recommendation for random walk σ
  - Previous recommended value from Bar-Sever and Kroger, *Strategies for GPS-based estimates of troposphere delay*, ION 1996
  - Bar-Sever & Kroger used data from two radiometers in Southern California in 1995

Data sources

- U.S. Department of Energy Atmospheric Radiation Measurement (ARM) Climate Research Facilities
- Microwave water vapor radiometers (WVR)
  - Measure brightness temperature
  - Available products provide precipitable water vapor in the zenith direction
- GPS receivers within 10 km of WVR
- Surface pressure and temperature
- Several years of data from each site

WVR and GPS locations

- 4 sites in Central U.S. (Kansas, Oklahoma) – HKLO, HBRK, PRCO, VCIO
- Papua New-Guinea - PNGM
- Nauru – NAUR
- Alaska – BASC

Comparing WVR and GPS measurements

- Interpolate WVR data at GPS epochs (5 minutes)
- Convert precipitable water vapor from the WVRs to zenith delay:

$$ZWD = PW\left(\frac{10^5}{461\left(3.776e5/T_m + 17\right)}\right)^{-1}$$

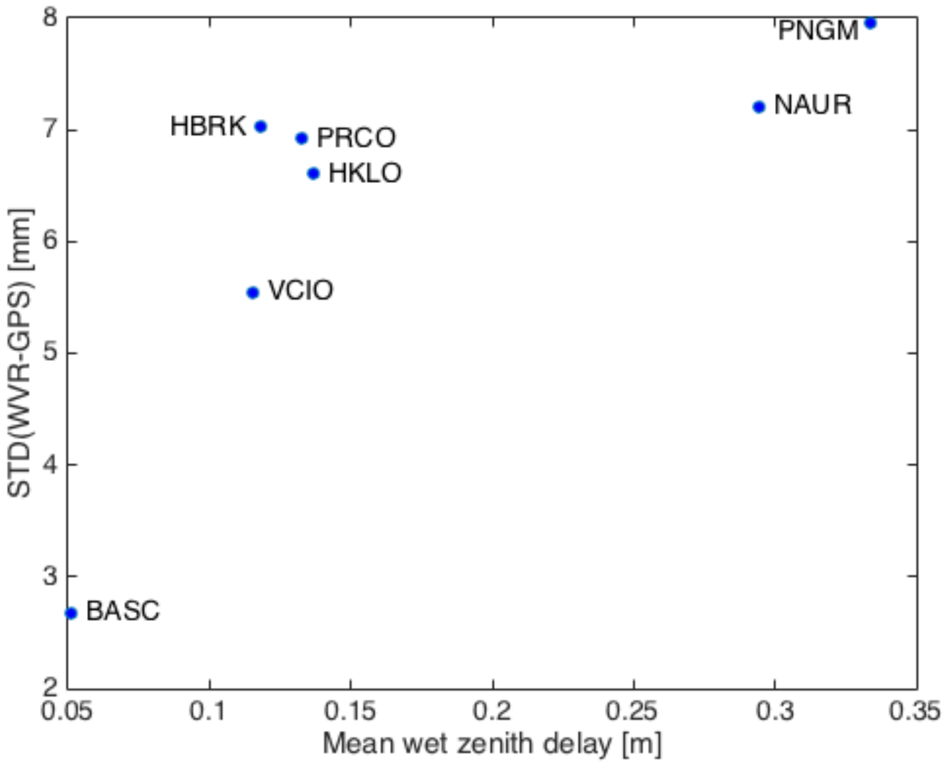
  - Uses measured surface temperatures T

$$T_m = 70.2 + 0.72T$$

- Hydrostatic delay from surface pressure
- Compare to total GPS derived precise point positioning (PPP) delay estimate

Comparing GPS and WVR measurements

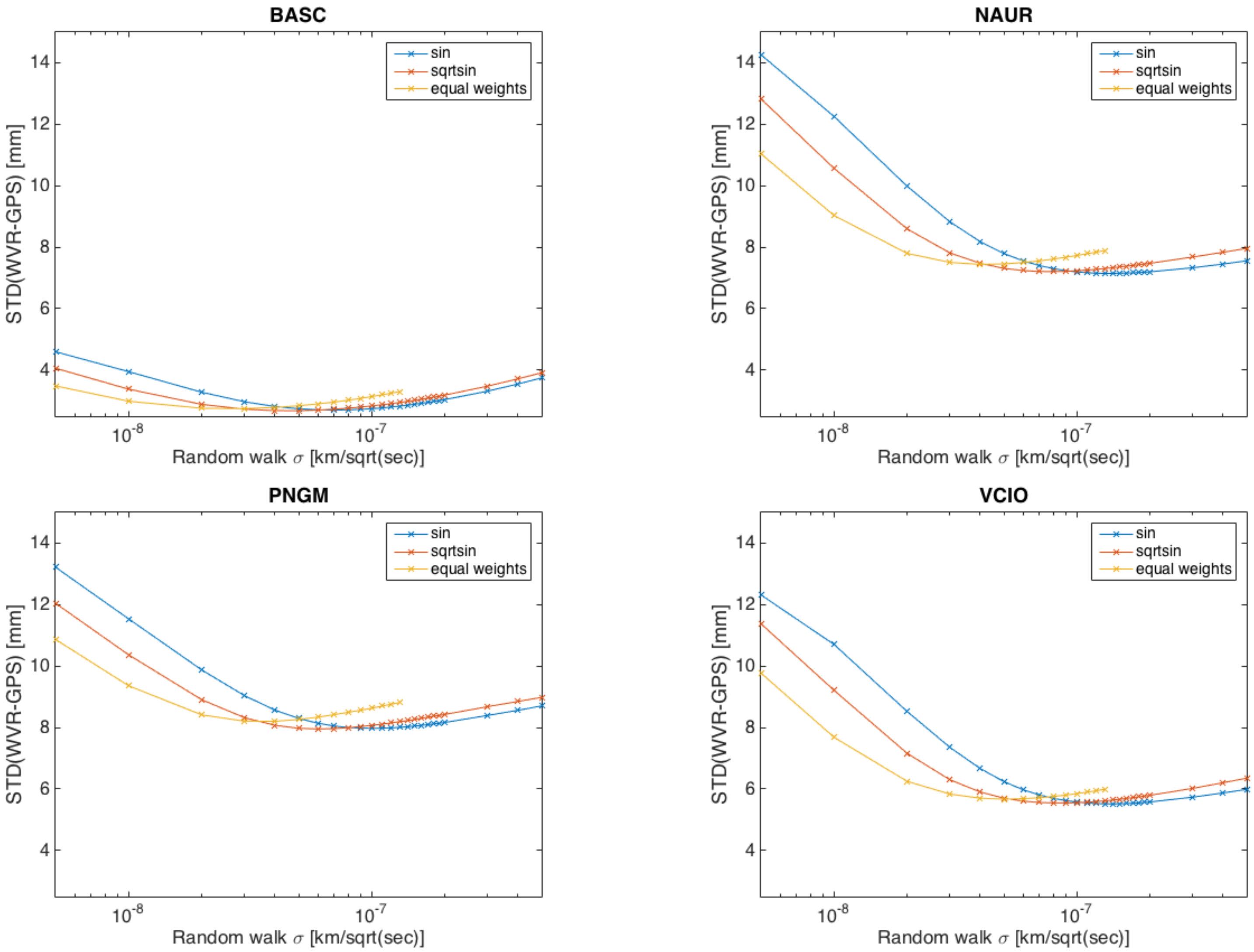
- WVR data unreliable when liquid water content of the atmosphere is high
- Ignoring biases
- Applied 3σ outlier editing for each station
- Larger differences for sites with high overall humidity



Elevation Dependent Data Weights

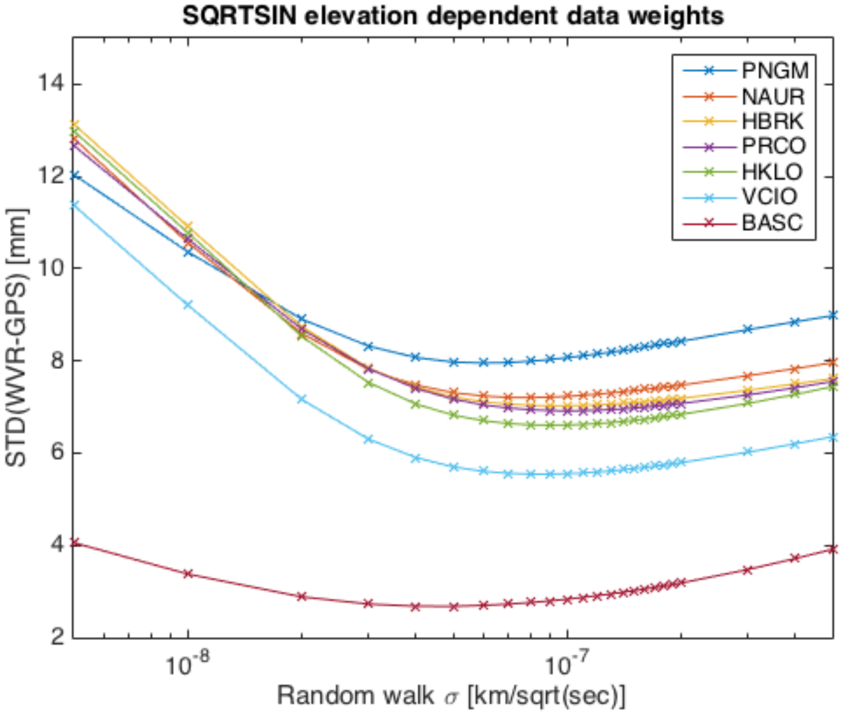
- Lower weights for data at low elevation angles
- Gives lower weights to noisier data
- Relevant to estimation of tropospheric delays
- Investigating three different weight functions: equal weights, SIN, SQRTSIN
- If using SIN, data weight is $\mathrm{w} = \frac{\sin(elevation)}{\sigma}$
- If using SQRTSIN, data weight is $\mathrm{w} = \frac{\sqrt{\sin(elevation)}}{\sigma}$
- Equal weights used in determination of recommended random walk sigma by Bar-Sever & Kroger, 1996

Random walk σ & elevation dependent weights



Random walk σ & elevation dependent weights

- As expected, optimal random walk σ is higher when elevation dependent weights are used
- Optimal σ for different sites can differ by a factor of 2
- Picking a higher σ than the optimal value for wet sites has only small effects on errors



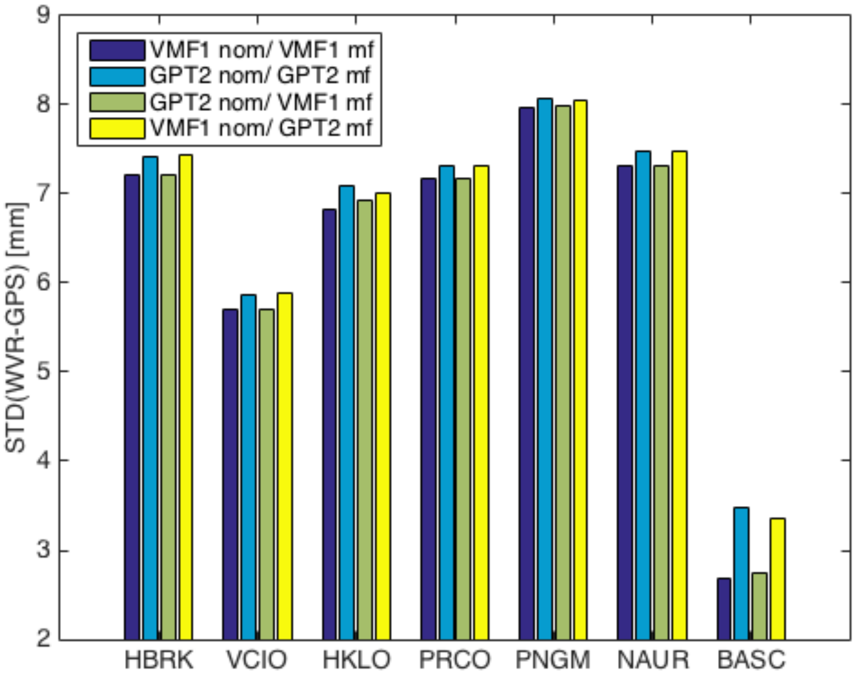
Random walk parameter recommendations

- Median of site-specific values that minimize differences between GPS and WVR
- Equal weights: 5e-8 km/sqrt(sec)

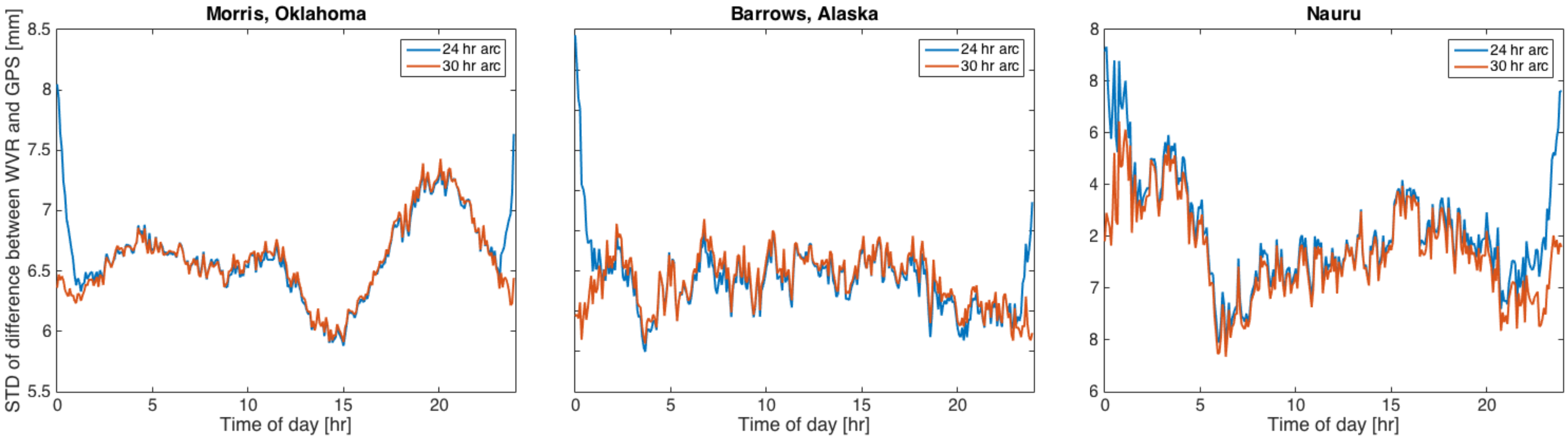
  (same as previous recommendation)
- SQRTSIN weights: 9e-8 km/sqrt(sec)
- SIN weights: 1.4e-7 km/sqrt(sec)
- Increase value for tracking high precipitation events
- Future work: Use similar analysis to determine optimal σ for troposphere horizontal gradients

Nominal troposphere models and mapping functions

- Comparing GPT2w to VMF1
- Mapping function: small improvement from VMF1 compared to GPT2w
  - 0.1 - 0.2 mm for most sites
  - 0.7 mm for BASC
- Nominal wet and dry: tiny improvement with VMF1
  - Mean over all sites: 0.02 mm



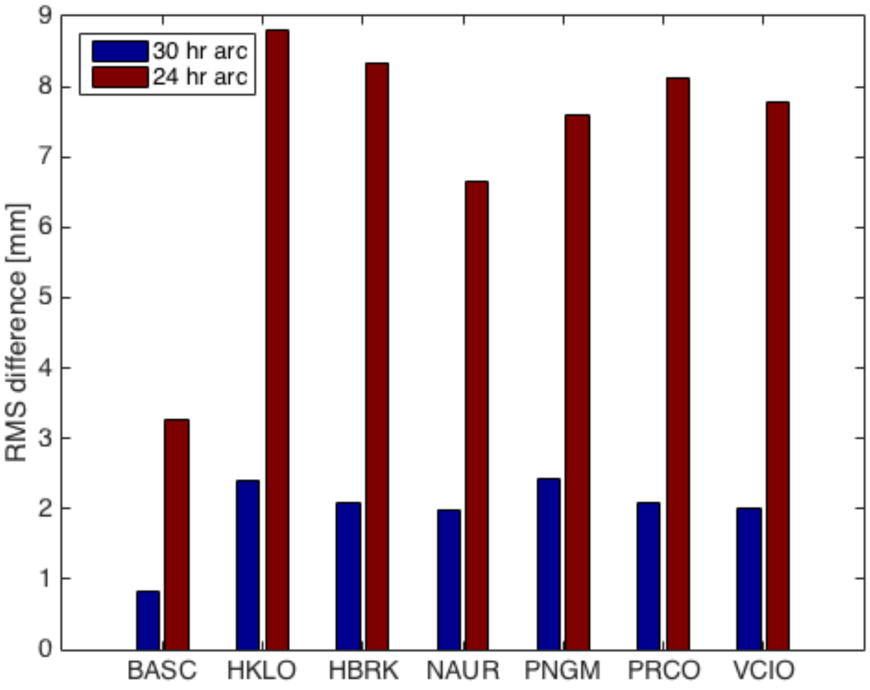
Arc length: 24 hr vs. 30 hr



- Study edge effects by comparing ppp runs with 24 hr and 30 hr data windows
- Uses JPL's orbit and clock products, which are available as daily 30 hr solutions
- 24 hr runs have ~10-20% higher standard deviation of differences with WVR at the beginning and end of the arc
- Increasing the window to 30 hr eliminates edge effects

Day boundary discontinuities

- Differences between GPS zenith delays at midnight epoch for two runs on consecutive days
- Jumps at midnight can be significantly reduced by using longer data window to mitigate edge effects
- Does not include epochs for which WVR data was unavailable or GPS-WVR outliers
- RMS differences are only slightly higher if these epochs are included



Summary

- Recommended random walk σ:
  - Equal weights: 5e-8 km/sqrt(hr)
  - SQRTSIN weights: 9e-8 km/sqrt(sec)
  - SIN weights: 1.4e-7 km/sqrt(sec)
  - Increase for tracking high variability events
- Mapping function: 0.1 – 0.7 mm improvement when using VMF1 instead of GPT2
- Nominal troposphere: difference between using VMF1 and GPT2 very small
- Differences between GPS and WVR increase by ~10-20% at data window boundaries
- Extending data windows by 3 hours on each side is sufficient to eliminate increased GPS/WVR differences at day boundaries and significantly decreases day boundary jumps between GPS runs

Acknowledgements

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- GPS data: NOAA, Geosciences Australia, UNAVCO

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