Use of GPS TEC Maps for Calibrating Single Band VLBI Sessions

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GPS TEC (total electron content) global maps:

- 2.5 x 5.0 degree (lat/long) resolution.
- A map every 2 hrs.
- Available ~1998-present.
- Made by several IGS analysis centers and available at IGS data centers, such as cddis.gsfc.nasa.gov.

Program *gps_iono*:

- Developed for K/Q reference frame sessions, but applicable at other frequencies.
- Uses software from the Institute for Astronomy, University of Berne (from ftp://ftp.unibe.ch/aiub/ionex/source).
- Uses rotated maps (keeps same sun angle).
- Puts a contribution into databases which can be applied in *Solve* solutions.
- Ionosphere treated as a thin shell.
- Used JPL maps for this study.

Modified Single-Layer Model Mapping Function

SLM mapping function:

$$F(z) = \frac{1}{\cos z'} \quad \text{with} \quad \sin z' = \frac{R}{R+H} \sin z$$

R and H are set typically to 6371 and 450 kilometers, respectively.

"Modified" SLM (MSLM) mapping function:

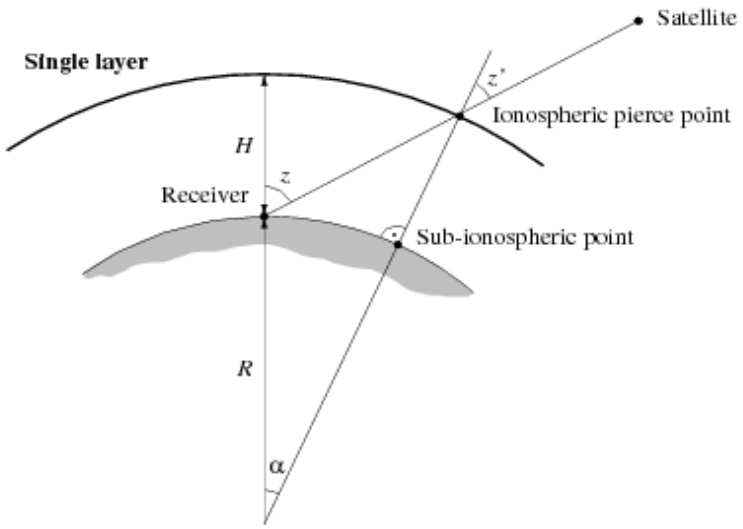
$$F(z) = \frac{1}{\cos z'} \quad \text{with} \quad \sin z' = \frac{R}{R+H} \sin(\alpha\, z)$$

Best fit with respect to the JPL extended slab model (ESM) mapping function is achieved at $H = 506.7$ km and $\alpha = 0.9782$ (when using $R = 6371$ km and assuming a maximum zenith distance of 80 degrees).

$R_0 = 6371$ km is the mean radius of the Earth, and

H is the height of the single-layer above the Earth's mean surface.

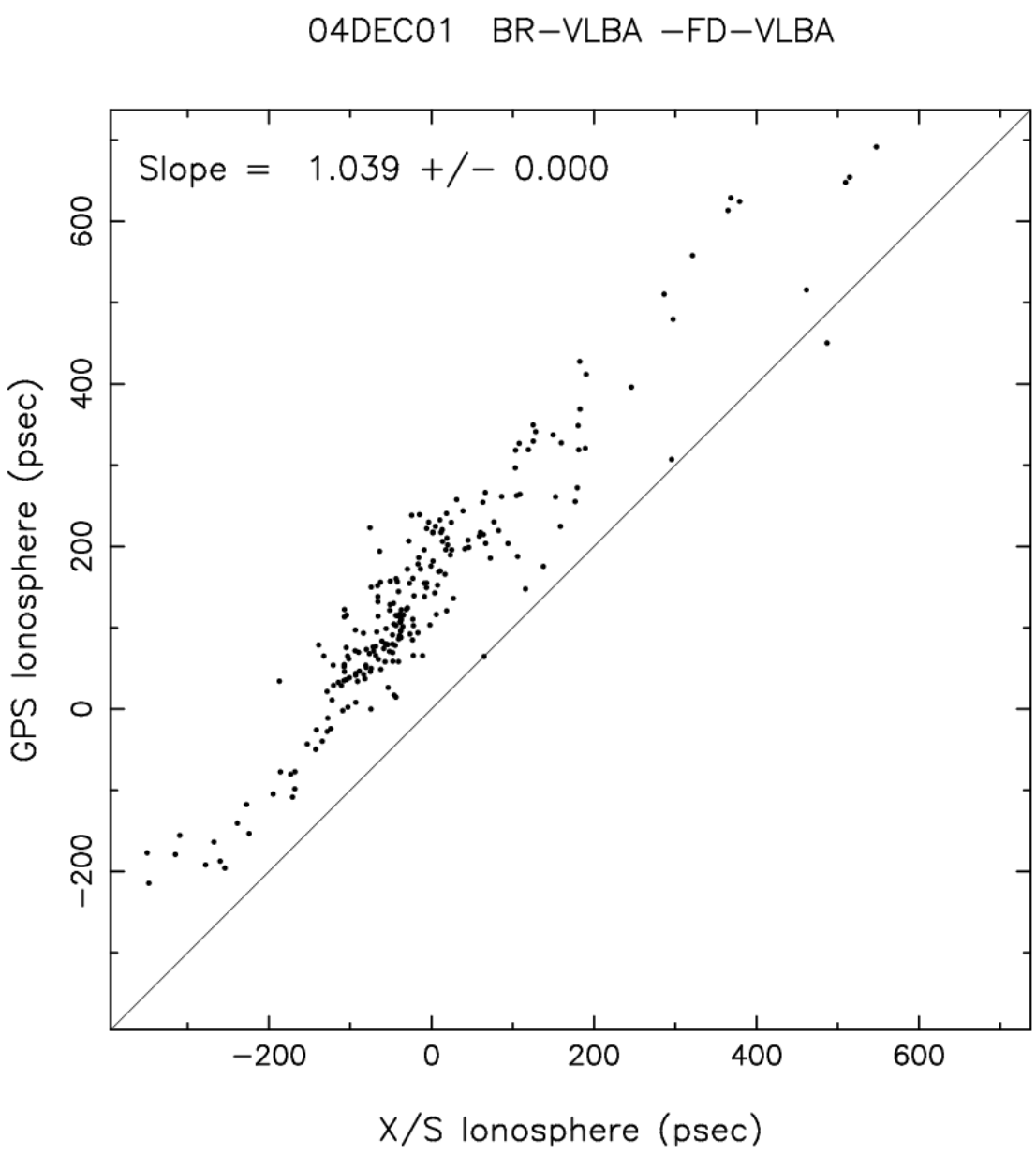
The height H of this idealized layer is usually set to the height of the expected maximum electron density: e. g. $H = 400$ km.

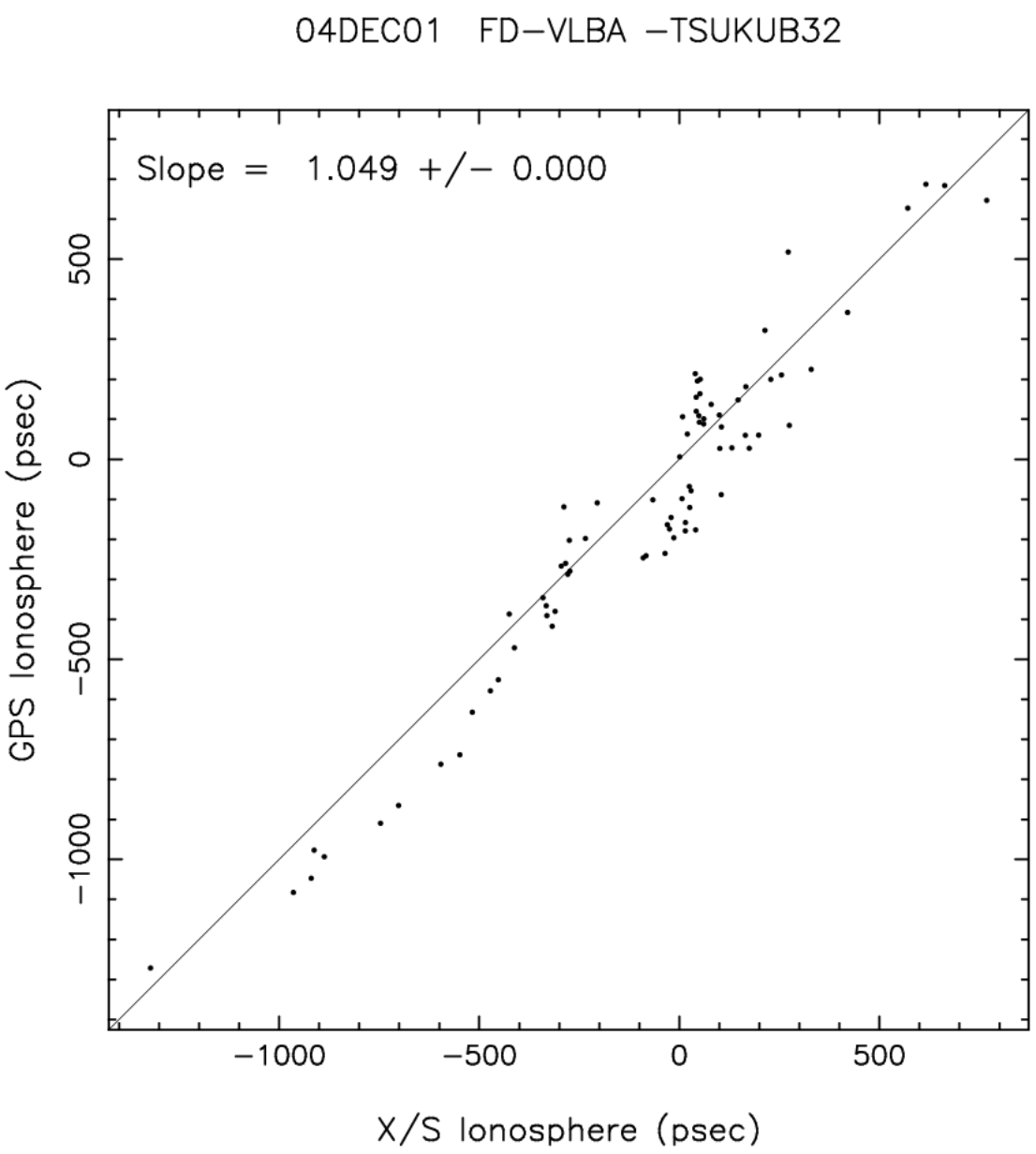


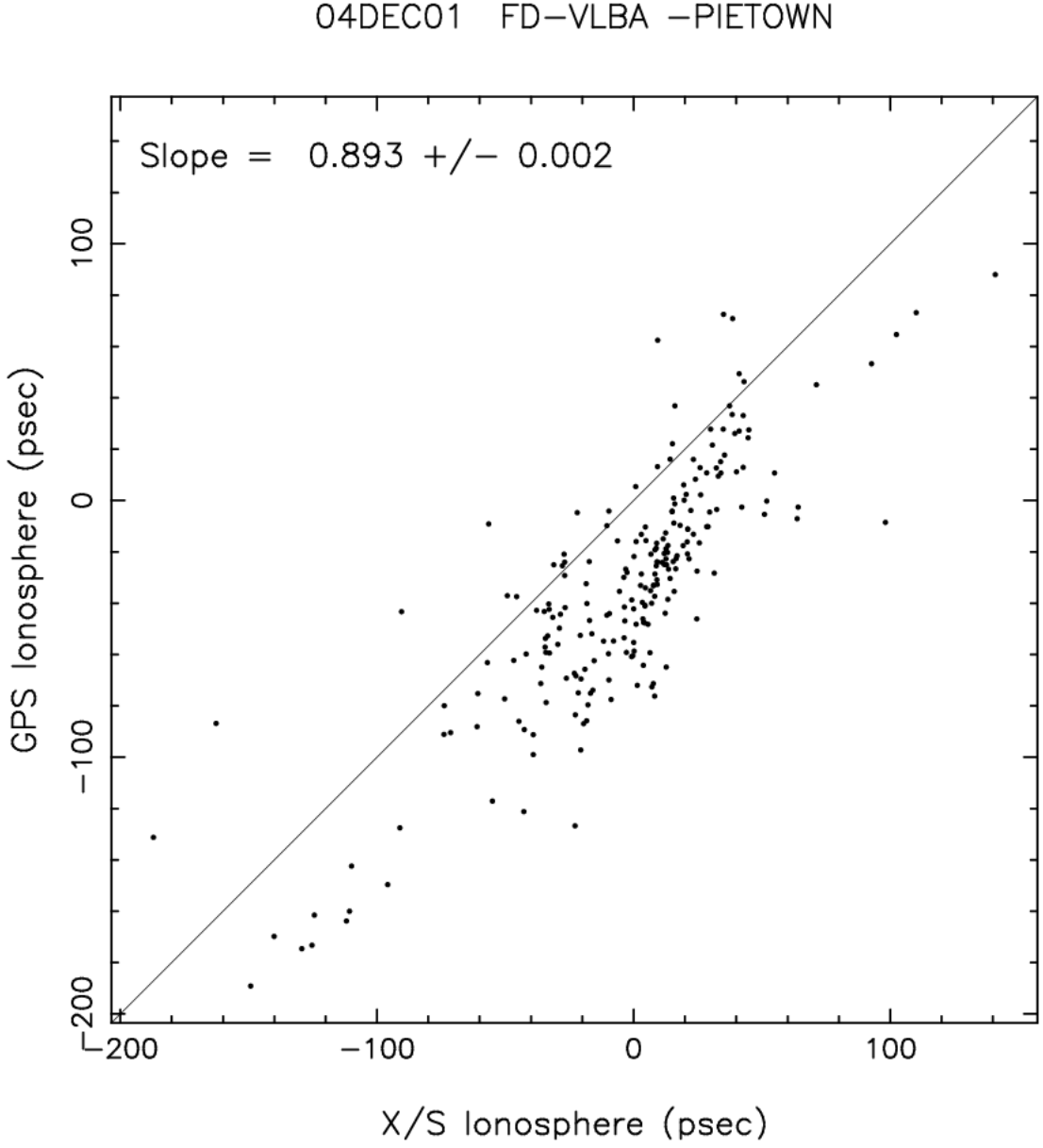
Comparison of GPS Ionosphere corrections with X/S ionosphere corrections:

Plots of X/S ionosphere corrections vs. GPS ionosphere corrections for several baselines of an RDV session.

Slopes should be 1.0, but they vary typically from ~0.8 to ~1.2, and can show large scatter.


04DEC01 BR−VLBA −FD−VLBA
Slope = 1.039 +/− 0.000
GPS Ionosphere (psec)
X/S Ionosphere (psec)
−200
0
200
400
600


04DEC01 FD−VLBA −TSUKUB32
Slope = 1.049 +/− 0.000
GPS Ionosphere (psec)
X/S Ionosphere (psec)
500
0
−500
−1000
−1000
−500
0
500


04DEC01 FD−VLBA −PIETOWN
Slope = 0.893 +/− 0.002
GPS Ionosphere (psec)
X/S Ionosphere (psec)
100
0
−100
−200
−200
−100
0
100

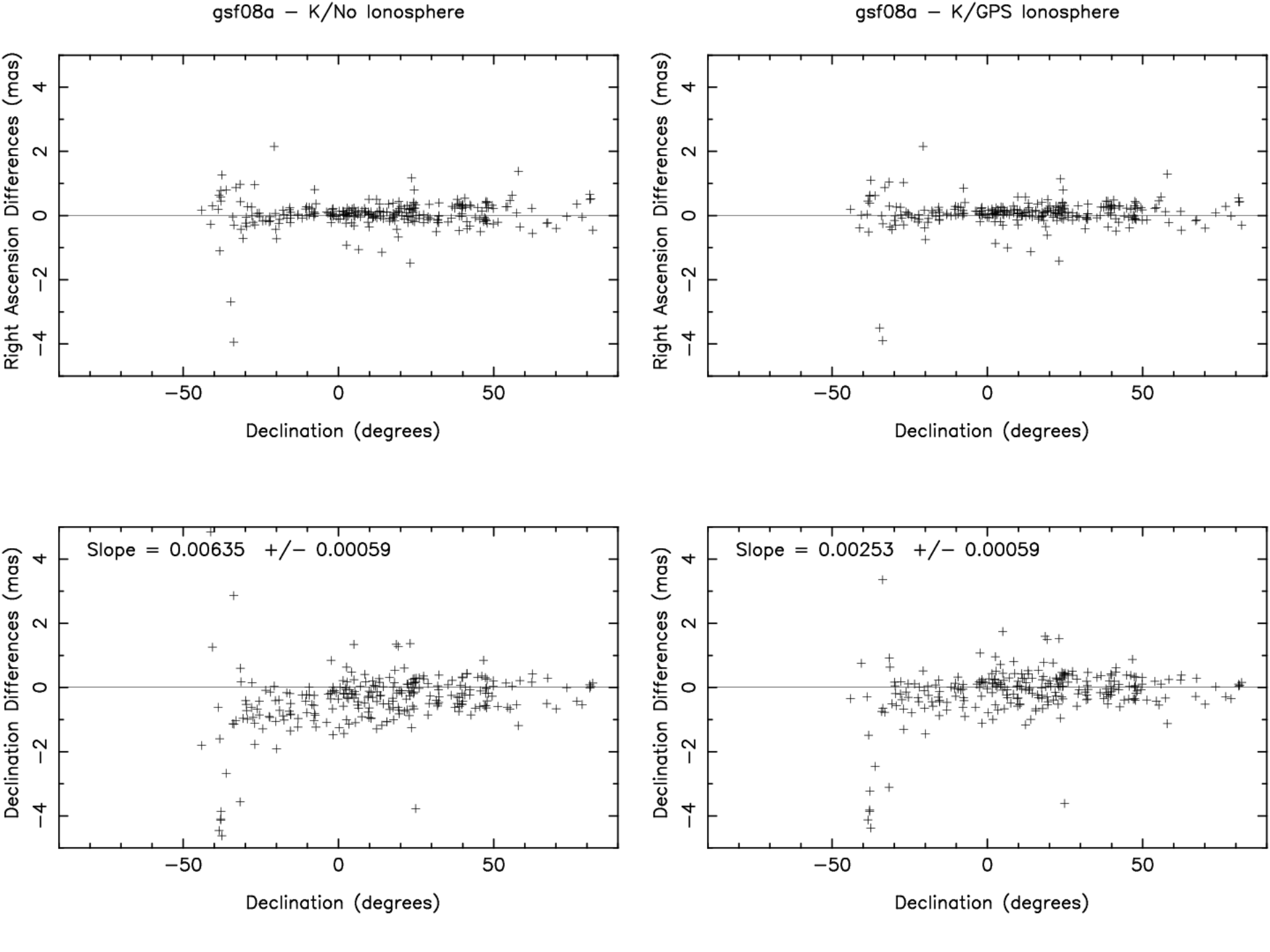
Spatial and temporal resolution is low, but the hope was that GPS ionosphere usage could statistically remove source position biases.

Application of GPS ionospheres to 12 K-band VLBA sessions:

•Without: source declinations show a declination bias (.0064 +/- .0006 mas/degree).

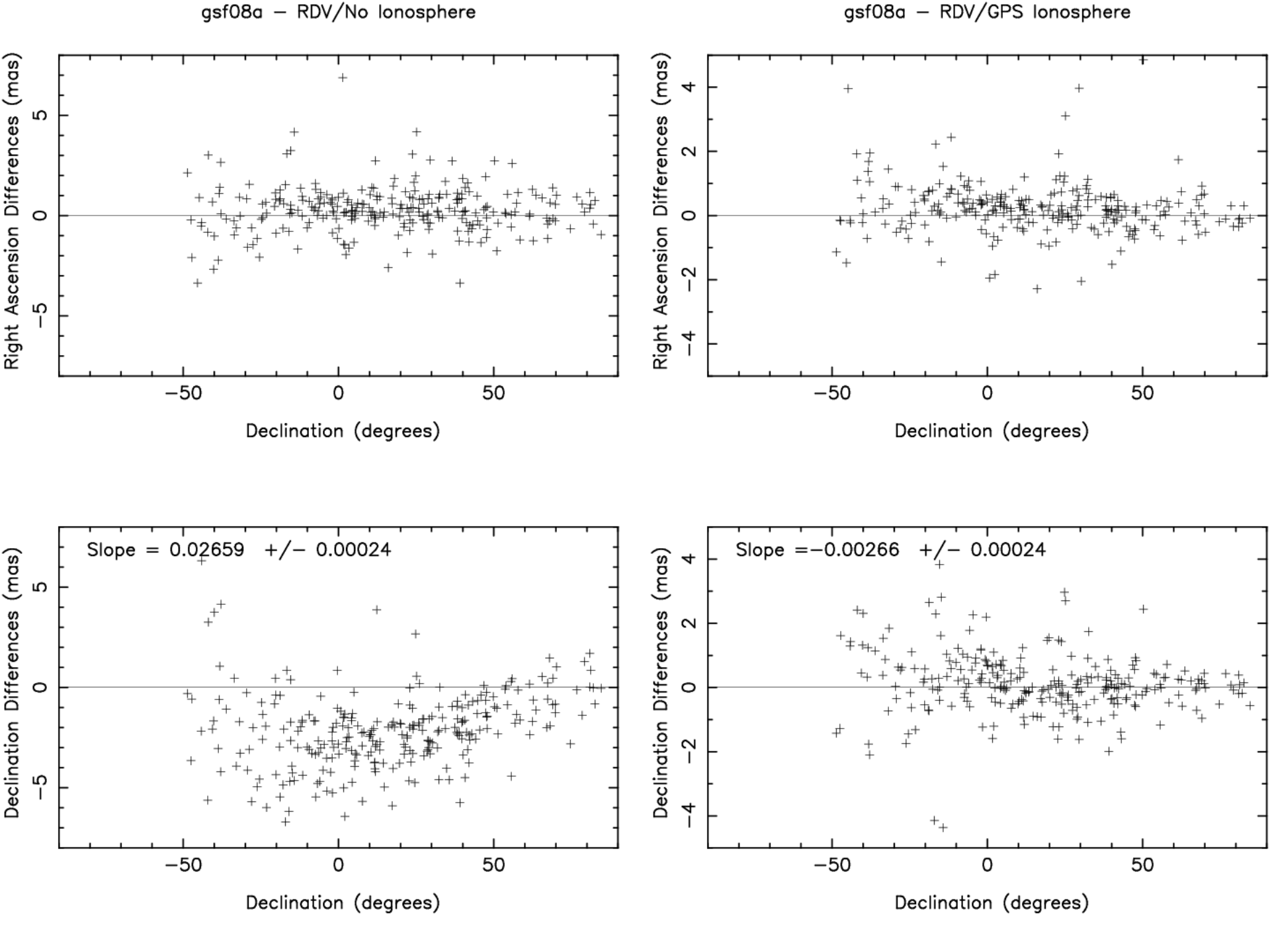
•With GPS ionospheres: removes ~60% of the declination bias (.0025 +/- .0006 mas/degree).

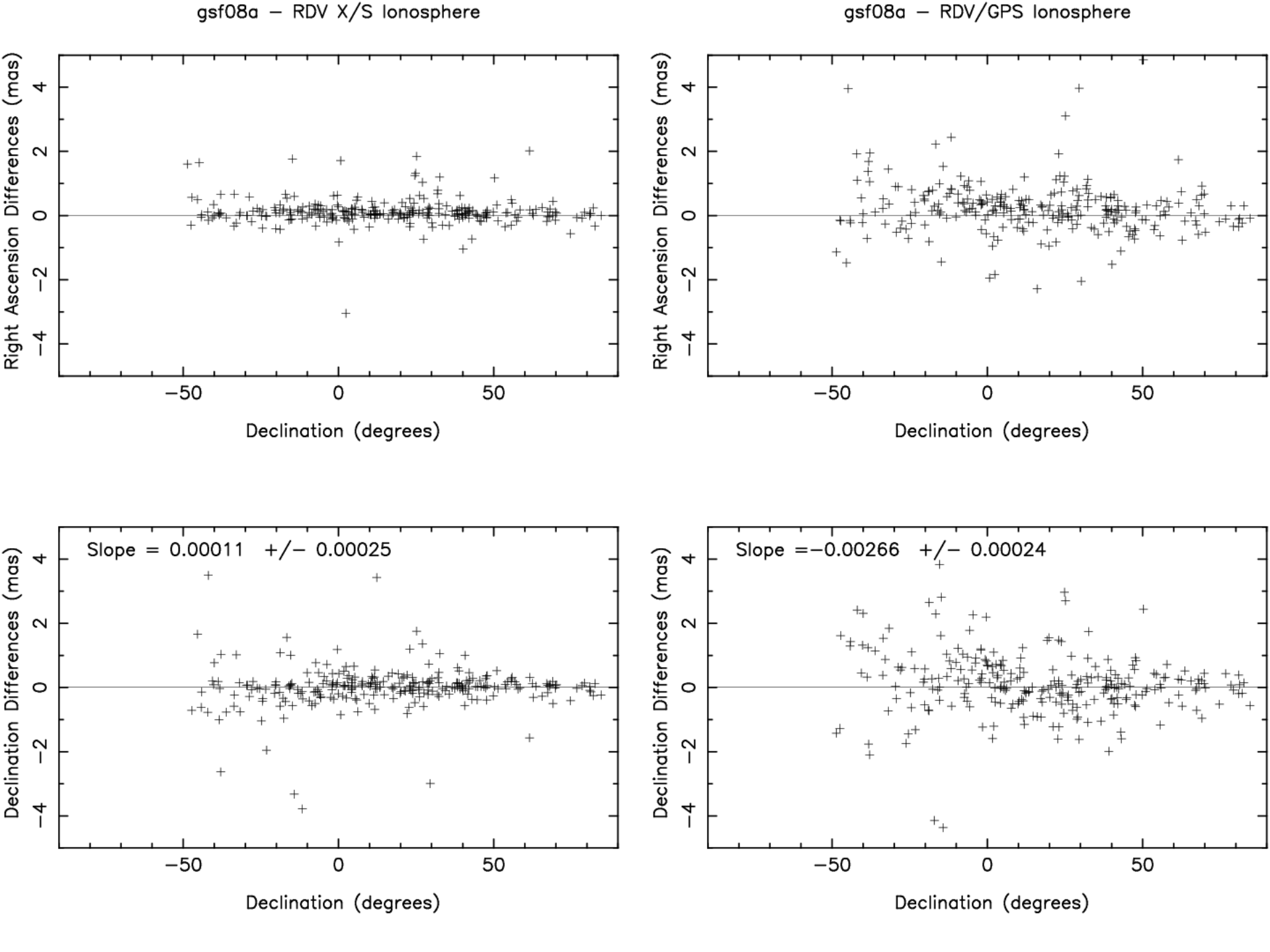
•Similar at Q-band.


gsf08a – K/No Ionosphere
gsf08a – K/GPS Ionosphere
Right Ascension Differences (mas)
Declination Differences (mas)
Declination (degrees)
Slope = 0.00635 +/– 0.00059
Slope = 0.00253 +/– 0.00059
–50
0
50
–4
–2
0
2
4

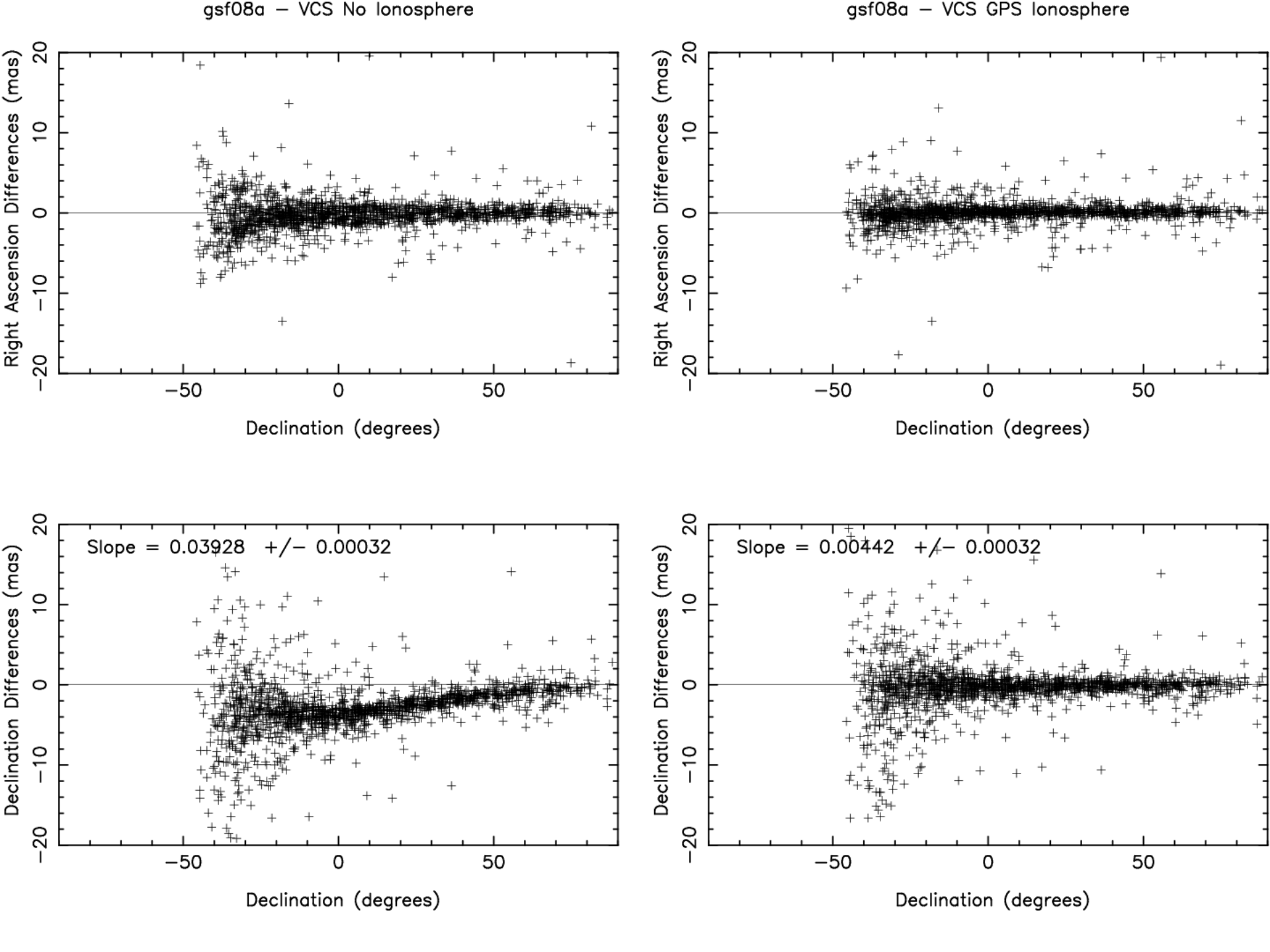
Application of GPS ionospheres to 10 RDV sessions:

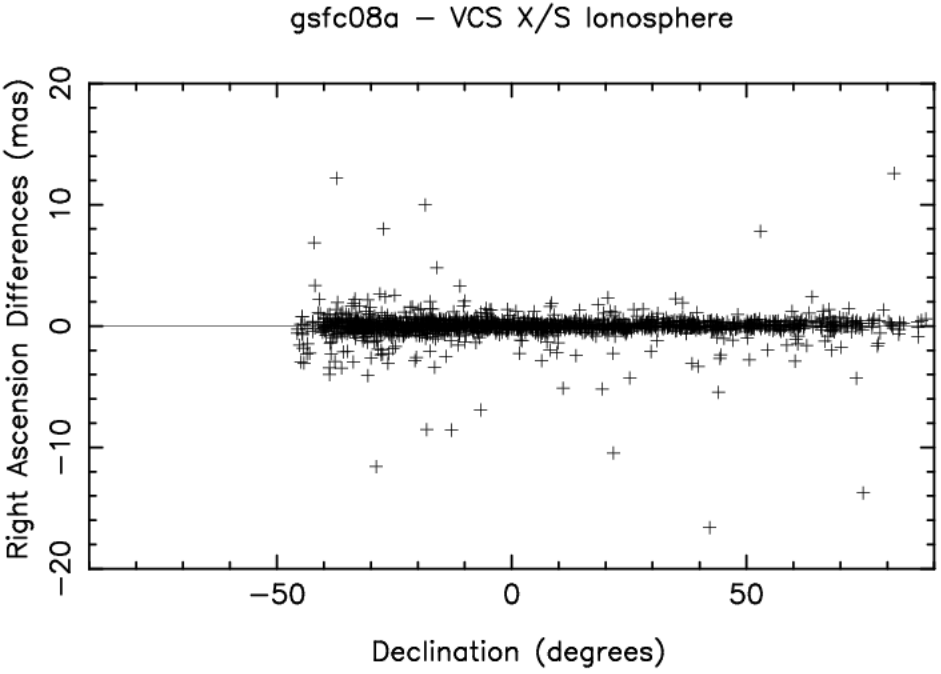
- With no ionosphere - large declination bias.
- With GPS ionosphere - removes most of the declination bias.
- Compared to X/S - adds 0.50/.51 (RA/Dec) mas of noise in an RSS sense.

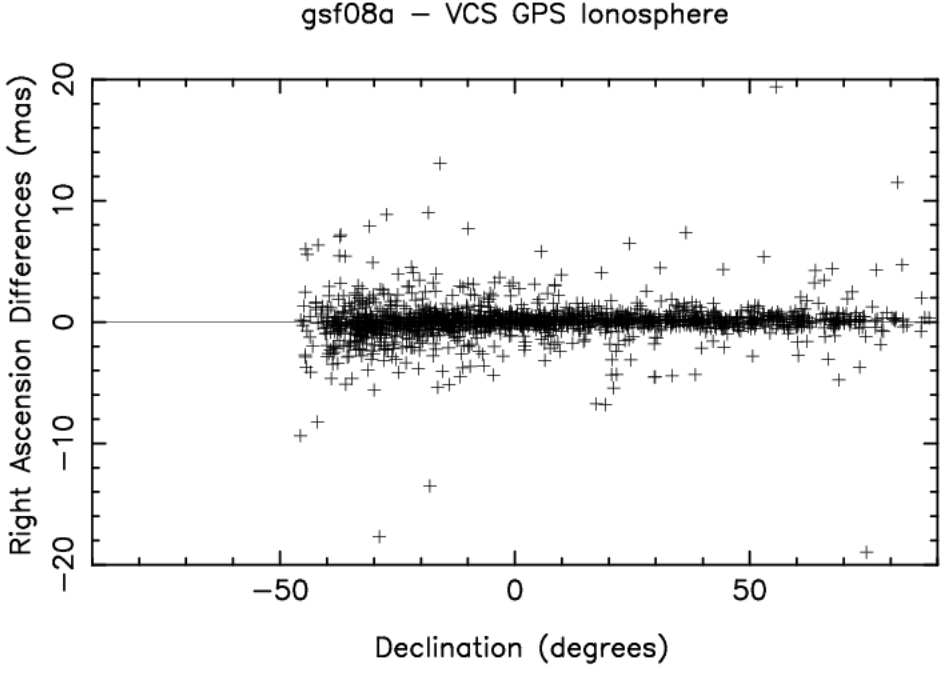

gsf08a – RDV/No Ionosphere
gsf08a – RDV/GPS Ionosphere
Right Ascension Differences (mas)
Declination Differences (mas)
Declination (degrees)
Slope = 0.02659 +/– 0.00024
Slope =–0.00266 +/– 0.00024

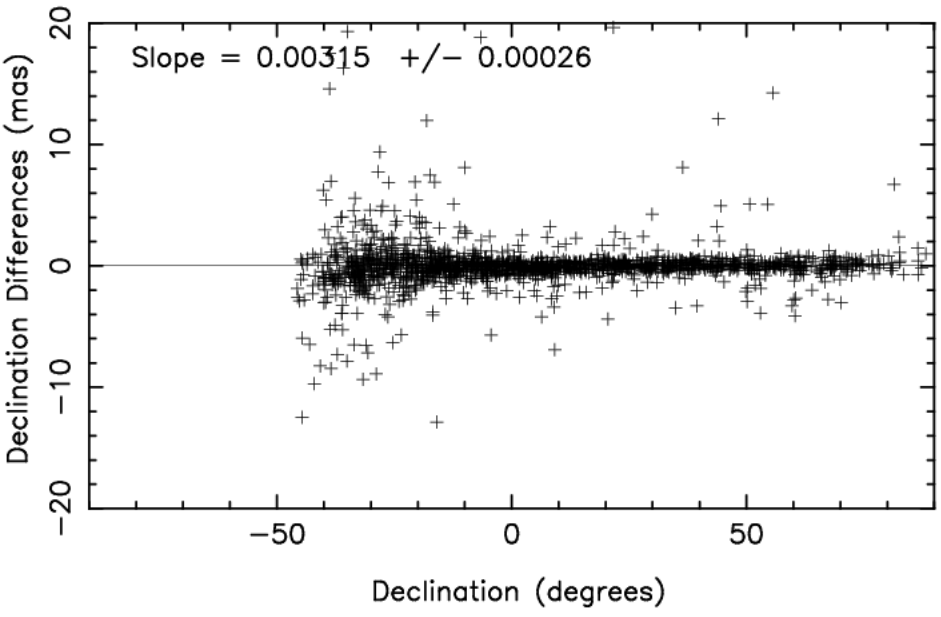

gsf08a – RDV X/S Ionosphere
gsf08a – RDV/GPS Ionosphere
Right Ascension Differences (mas)
Declination Differences (mas)
Declination (degrees)
Slope = 0.00011 +/– 0.00025
Slope =–0.00266 +/– 0.00024

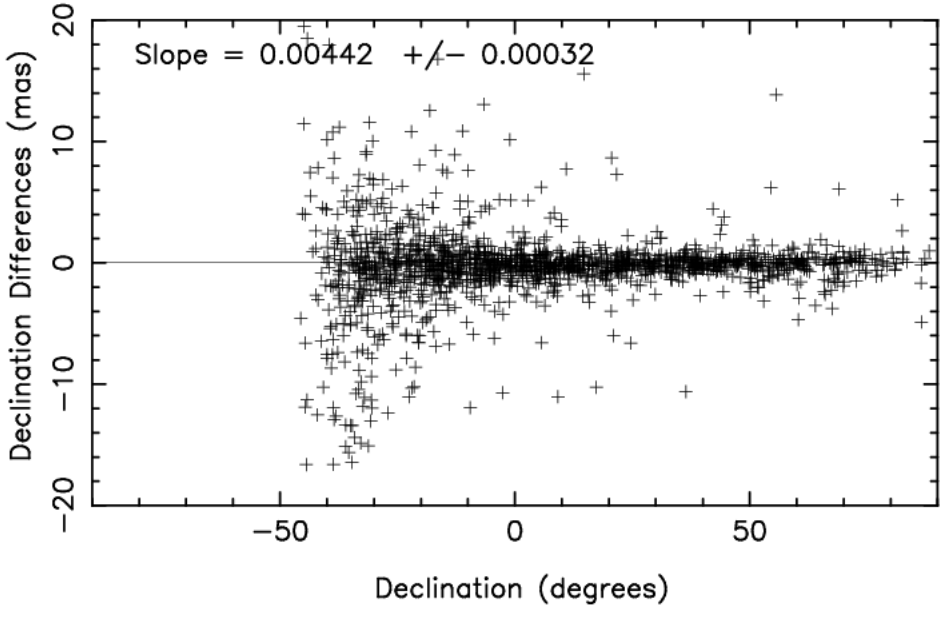
VCS sessions:
We applied GPS ionospheres to 13 VCS sessions (VCS2 - VCS6, 2002 - 2007) to see if some additional sources could be used. The sessions were re-edited using GPS ionosphere calibrations instead of X/S ionosphere corrections. 135 additional sources became available. Many sources that had only a few observations now had many more observations.


gsf08a – VCS No Ionosphere
gsf08a – VCS GPS Ionosphere
Right Ascension Differences (mas)
Declination Differences (mas)
Declination (degrees)
Slope = 0.03928 +/– 0.00032
Slope = 0.00442 +/– 0.00032
20
10
0
–10
–20
–50
0
50


gsfc08a – VCS X/S Ionosphere
Right Ascension Differences (mas)
20
10
0
−10
−20
−50
0
50
Declination (degrees)


gsf08a – VCS GPS Ionosphere
Right Ascension Differences (mas)
20
10
0
−10
−20
−50
0
50
Declination (degrees)


Slope = 0.00315 +/− 0.00026
Declination Differences (mas)
20
10
0
−10
−20
−50
0
50
Declination (degrees)


Slope = 0.00442 +/− 0.00032
Declination Differences (mas)
20
10
0
−10
−20
−50
0
50
Declination (degrees)

Conclusions:

- GPS ionosphere calibrations found to be useful at K and Q bands. May be even more useful at X-band.
- Supplemental X/GPS solutions (VCS, perhaps other sessions) can add at least 135 sources to the detected source catalogs. Some sparsely observed (3,4,5 obs.) sources may have better X/GPS positions when the number of observations increases significantly (20,30,40,etc). X/GPS positions should be useful for calibrator catalogs, where ~.5-1 mas precision is still useful for phase referencing, and should be better than X-only positions.