GNSS Absolute Antenna Calibration at the National Geodetic Survey

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GOALS

Simultaneous multi-frequency, multi-system calibration

2-D (elevation, azimuth) patterns

Calibration values publicly distributed via Internet

Fast, free service

Serve high precision needs of U.S. surveying and geodesy communities

Produce calibrations to International GNSS Service (IGS) standards

NGS METHODOLOGY

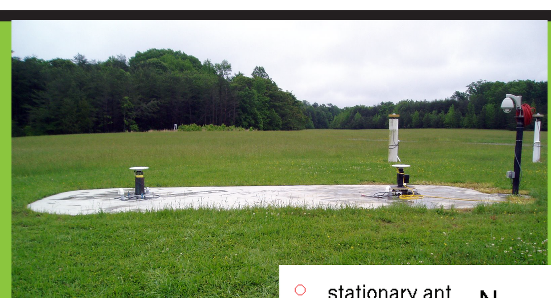
collection

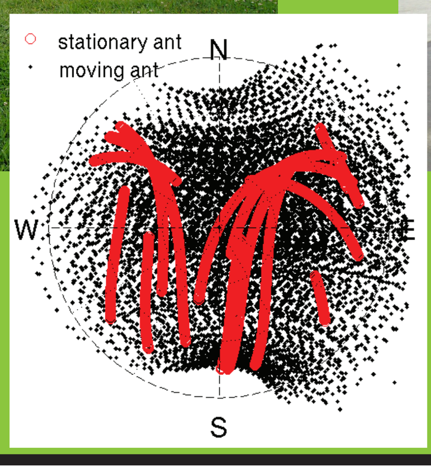
move antenna using Pan Tilt Unit (PTU

2-axis robot requires 4 orientations (N S E W) on PTU for full coverage

full motions to receive data at negative elevation angles

dual-antenna heading receiver = common clock



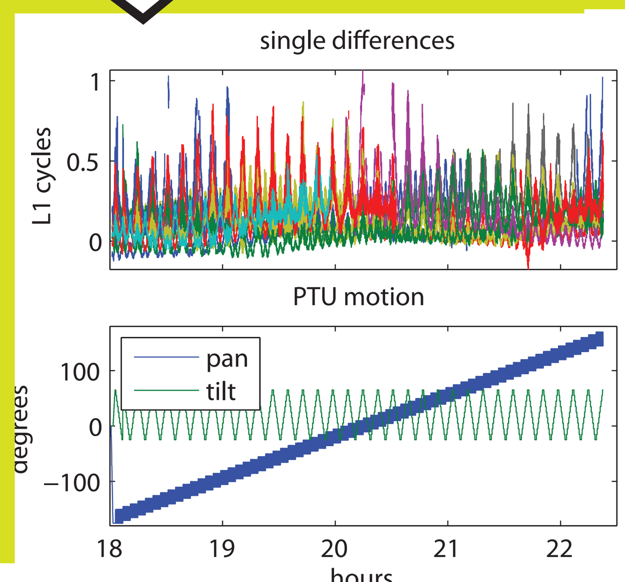


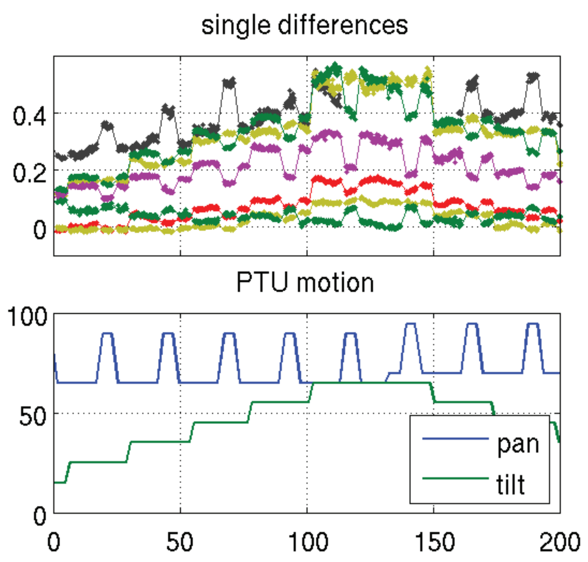
reduction

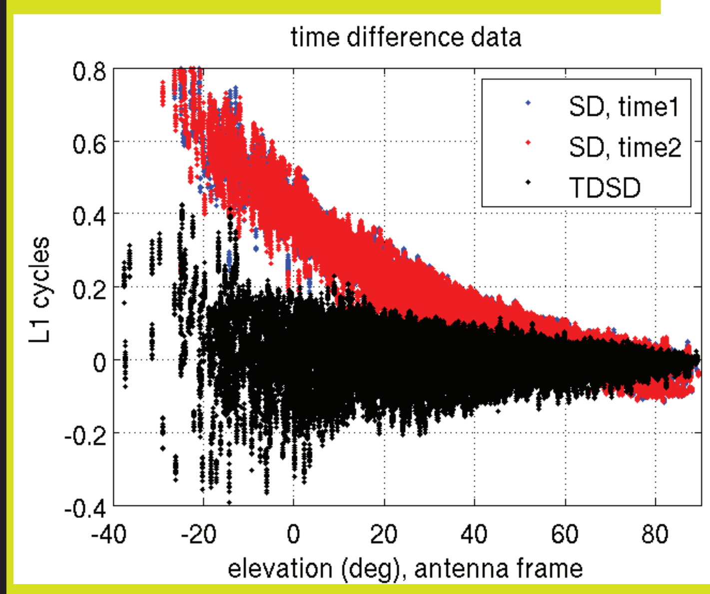
(1) single difference (SD): short baseline = remove atmospheric effects, clocks

cycle slip editing; biases removed

remove modeled factors (phase windup due to antenna motion; robot arm; PC0 at ref antenna for easier data editing)







(2) time difference (TDSD): data pairs <10 sec apart, where antenna is panned +/- 25 deg

* remove PCV at reference

* minimize multipath errors

TDSD are actually a function of differential elevation and azimuth angles

(3) angles: pattern depends on elevation/azimuth angles of reception, e.g. in antenna reference frame

combination

solution

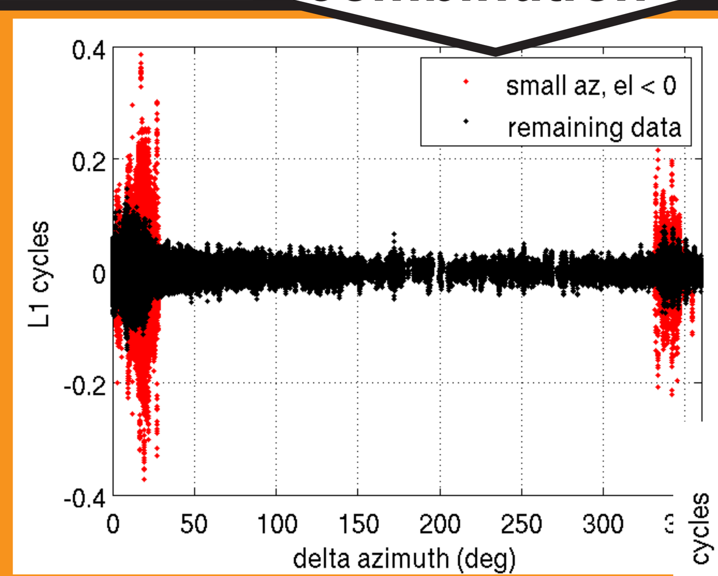
weighted least squares

* PC0 fit to TDSD: projection of antenna boresight onto satellite line of sight

* PCV fit to TDSD-PC0: spherical harmonics, using elevation/azimuth angles in antenna reference frame

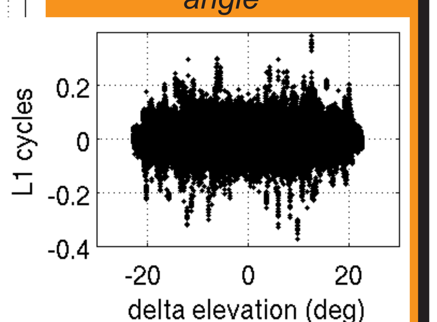
* default degree 8, order 5

* solution dependent on weights



highest scatter TDSD occur when azimuth change is small...

no correlation with change in elevation angle

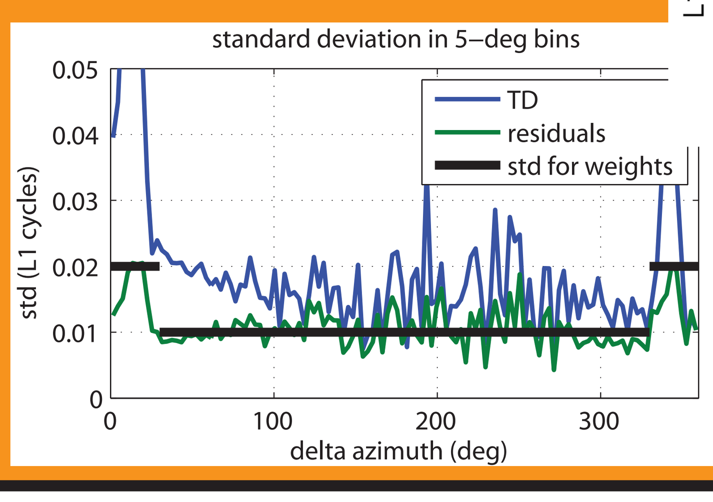


data weights

* standard weights = norm([sinel_t1 sinel_t2])

* deweight pairs where azimuth angle change is small (<30 deg) and at negative elevation angles

* upweight > 80 deg elevation (x 5)



data weights based on azimuth angle change

MULTIPATH

simulation of multipath errors for the following parameters:

* GPS L1 frequency

* AOA D/M chokering gain pattern

* max ARP height = 0.54 m

* only 5% of incoming signal is reflected (95% attenuation)

Multipath assumptions:

spatially uniform (flat field)

slowly varying due to low antenna height

minimized via time pair selection

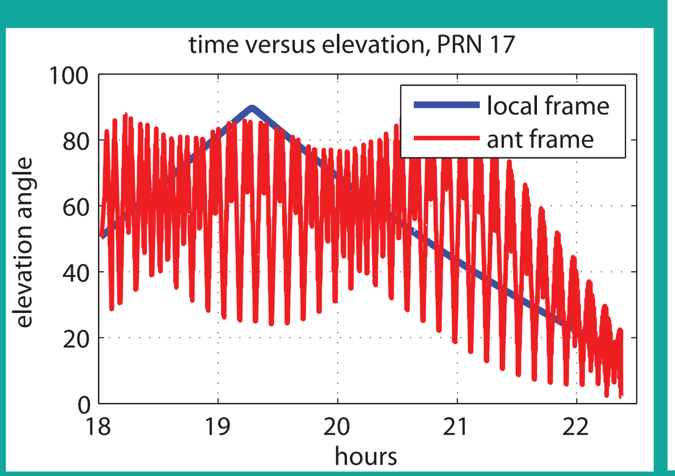
TDSD formed with delta-pan motions so PC0 is fixed height above ground = constant multipath phase

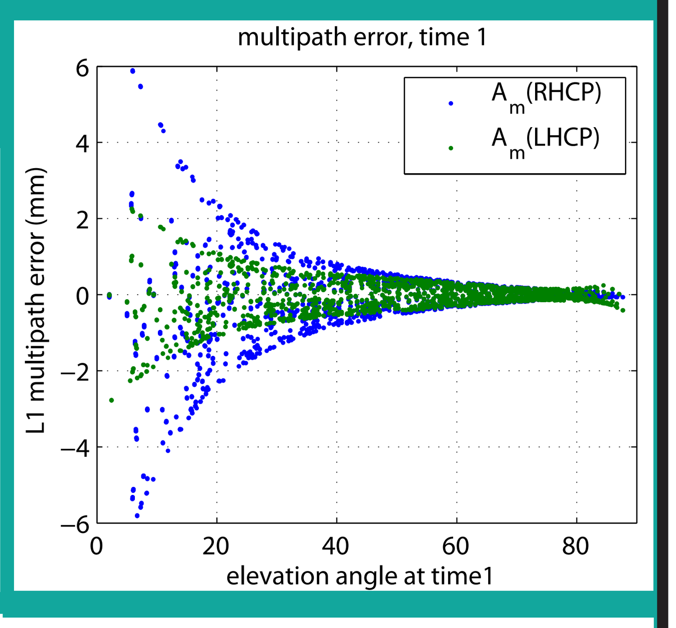
deltaMP term in TDSD may be significant - due to changes in gain pattern between pairs

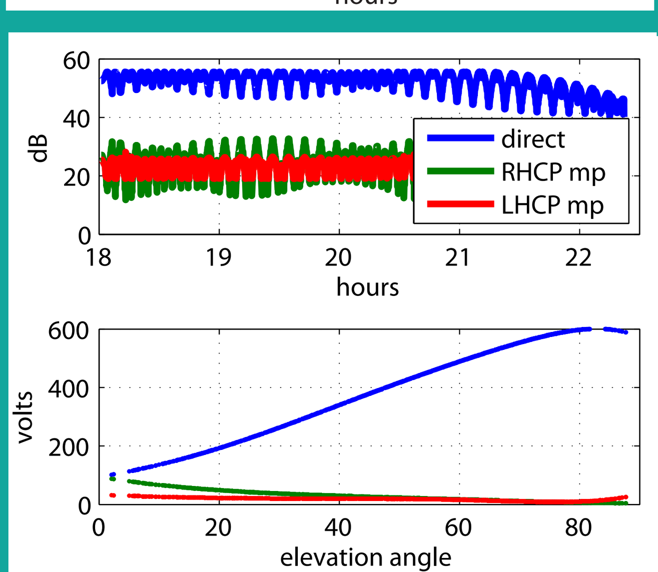
average deltaMP with equivalent delta-pan motions:

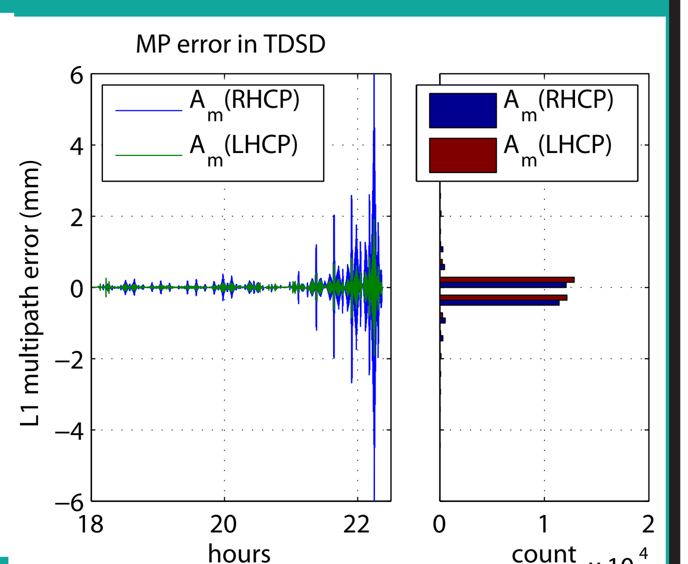
TDSD_pair1 = panA - panB

TDSD_pair2 = panB - panA





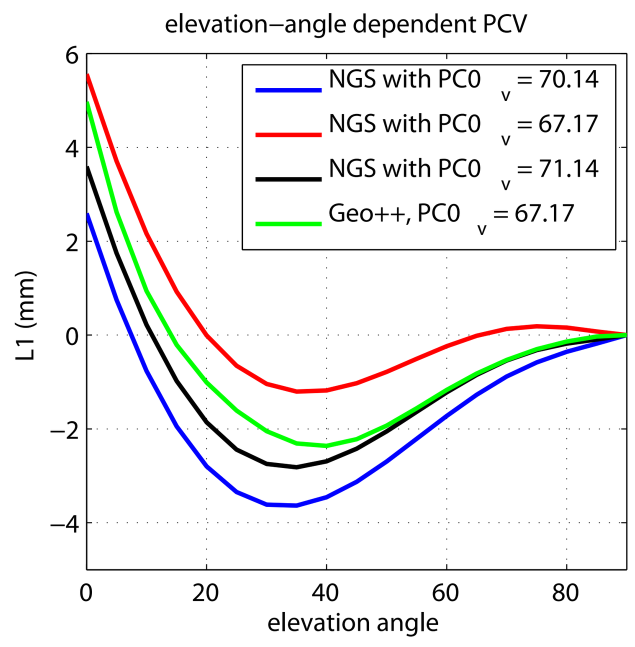


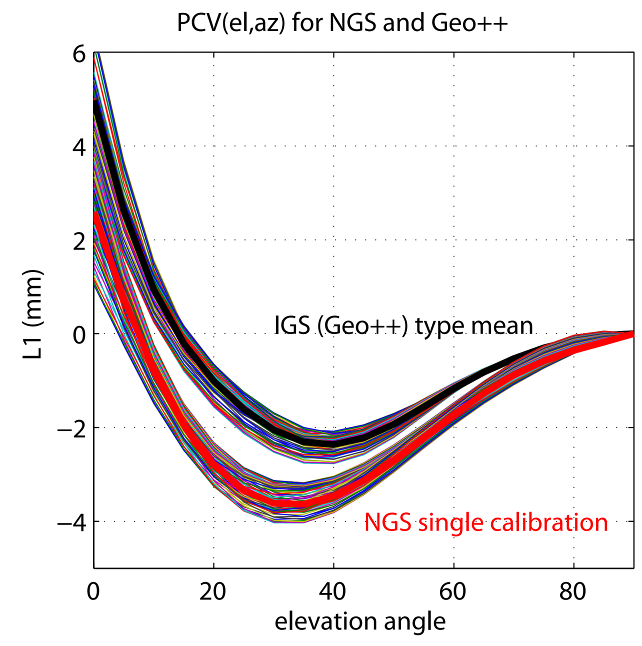


CALIBRATION RESULTS

Trimble Zephyr GNSS Geodetic Model 2

[TRM55971.00 NONE]





original PC0 from NGS Solutions (unshifted)

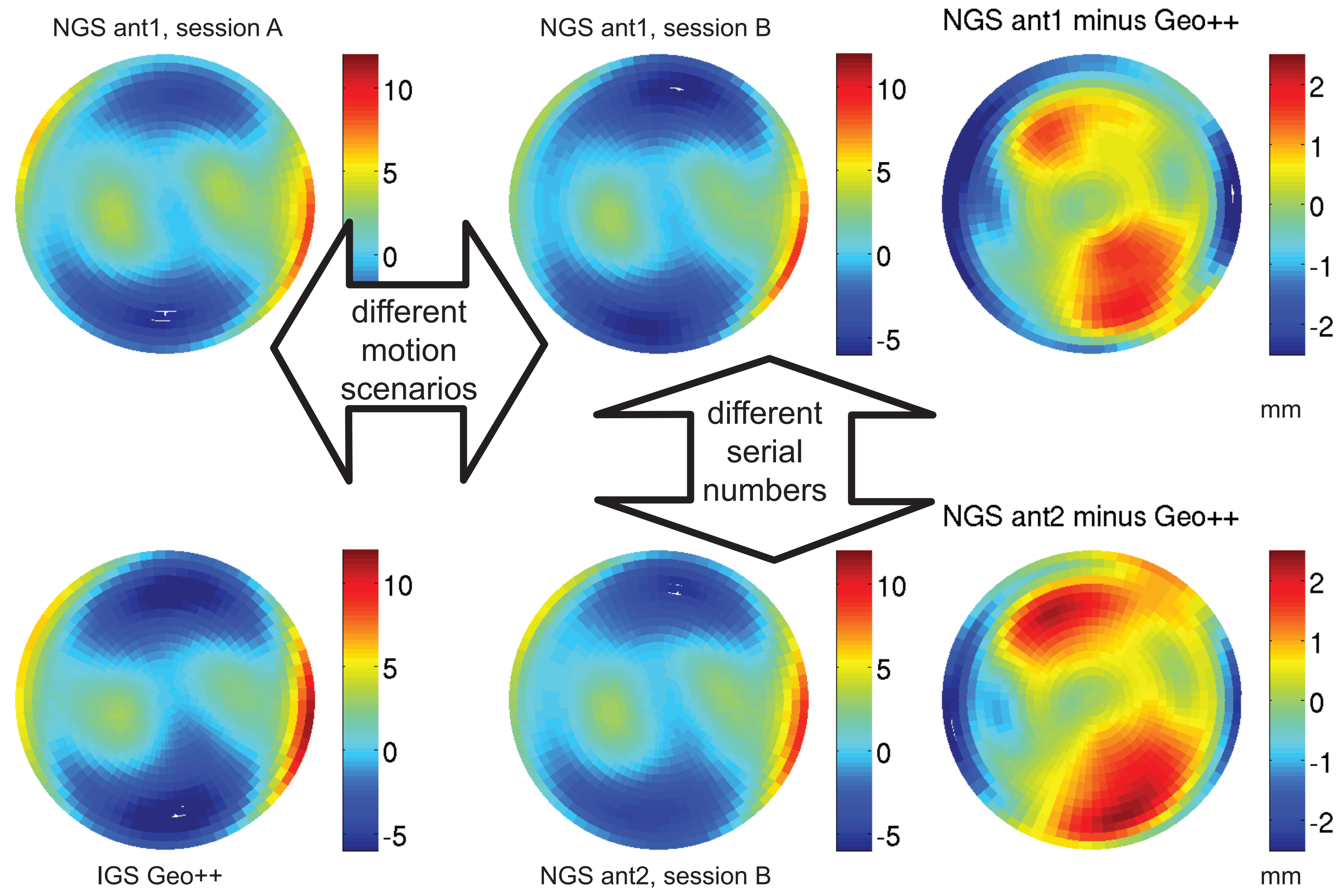
	N	E	V [mm]
NGS	1.37	-0.45	70.14
Geo++	1.07	-0.19	67.17

solution degree 8, order 5

L1 patterns

Ashtech Whopper

[ASH700718B NONE]



all of the above patterns were shifted for PC0_vertical alignment with IGS Geo++ values

original PC0 from NGS Solutions (unshifted)

ant#	session	N	E	V [mm]
1	A	-1.35	0.29	69.53
1	B	-1.85	0.45	68.20
2	B	-1.22	0.23	69.45
Geo++		-1.67	-0.47	69.48

NEXT STEPS

facility refinements

test for max antenna load

engineer 3rd axis rotation device

validation

cross-check with Geo++ calibration of UNAVCO antennas

analysis

refine spherical harmonic solution

- more sophisticated weight matrix
- interpolation for data gaps
- determination of best degree/order

combination for type mean

L2 solutions: fix L2 tracking, or use L2C only

GNSS PC0 + PCV

refine data editing algorithm

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