Campaign GPS processing

Fun with GAMIT, GLOBK, TRACK, and the Queen's nose

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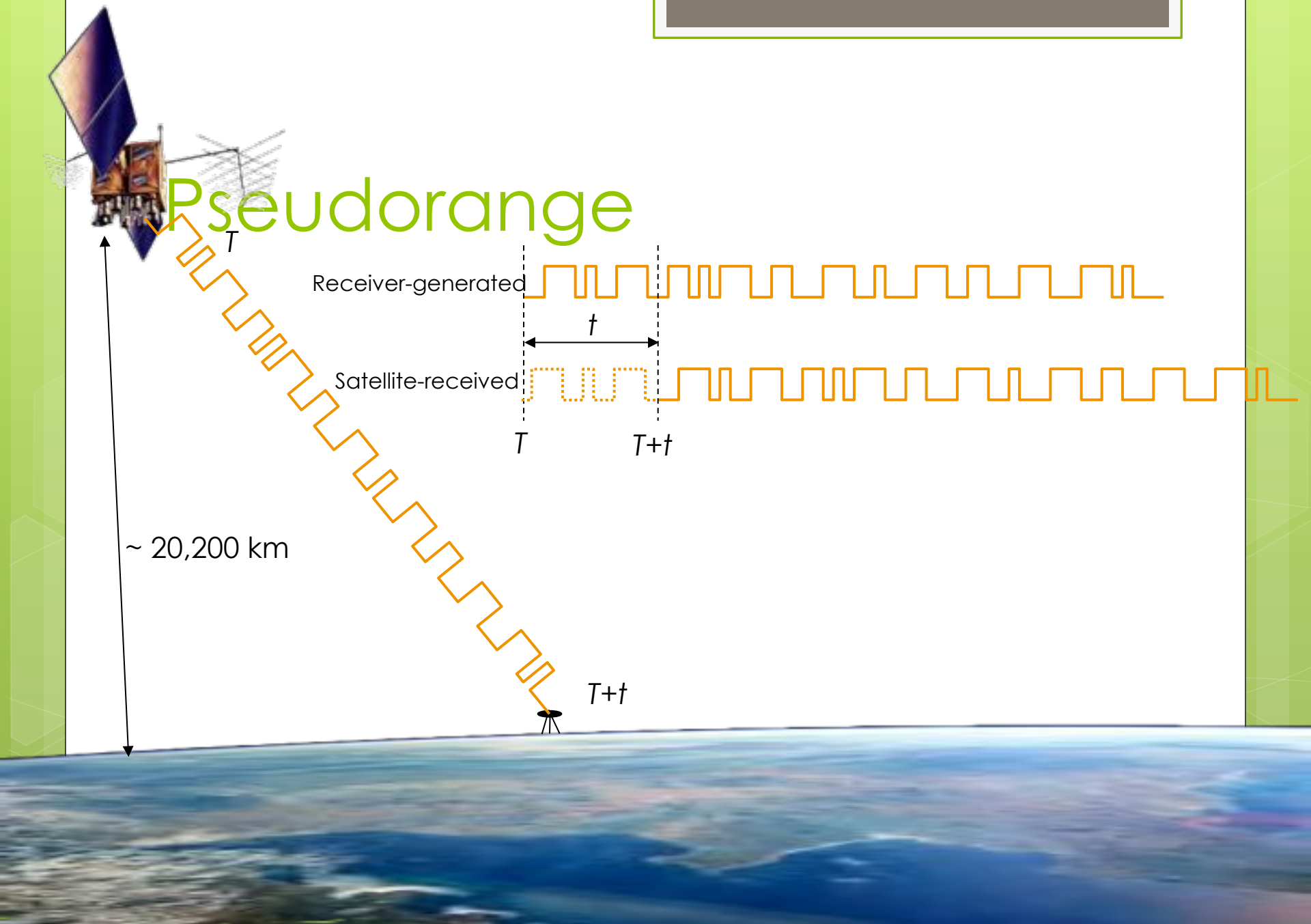
Outline

- What are GAMIT, GLOBK, and TRACK?
- What's GPS?
- Why campaign?
- Occupy San Jacinto.

Let's get this straight…

- GAMIT – positions
- GLOBK – repeatabilities, velocities, time series
- TRACK – kinematic GPS

Pseudorange



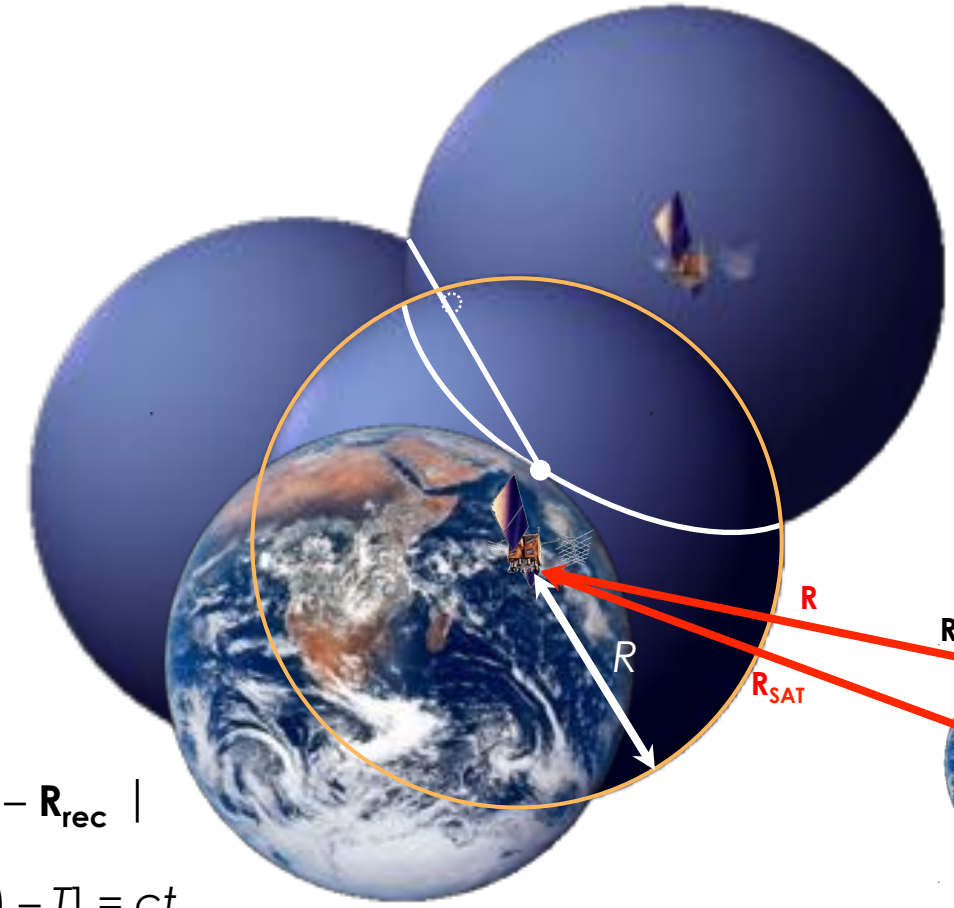
Pseudorange

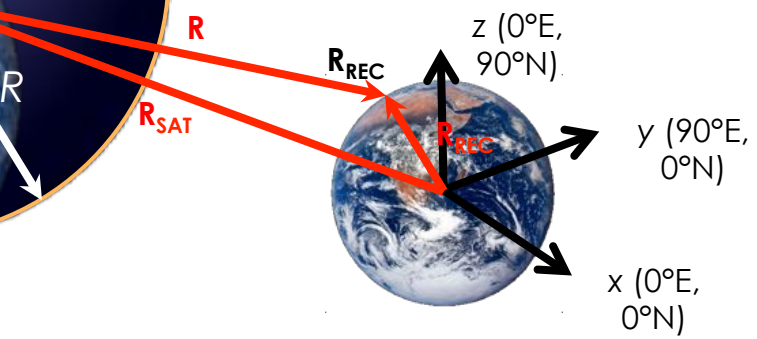
But…

t is travel time (as measured by clocks in the satellite and receiver), which is subject to error between these clocks.

So…

We need a minimum of *four* satellites in order to solve for an additional unknown, the clock bias.



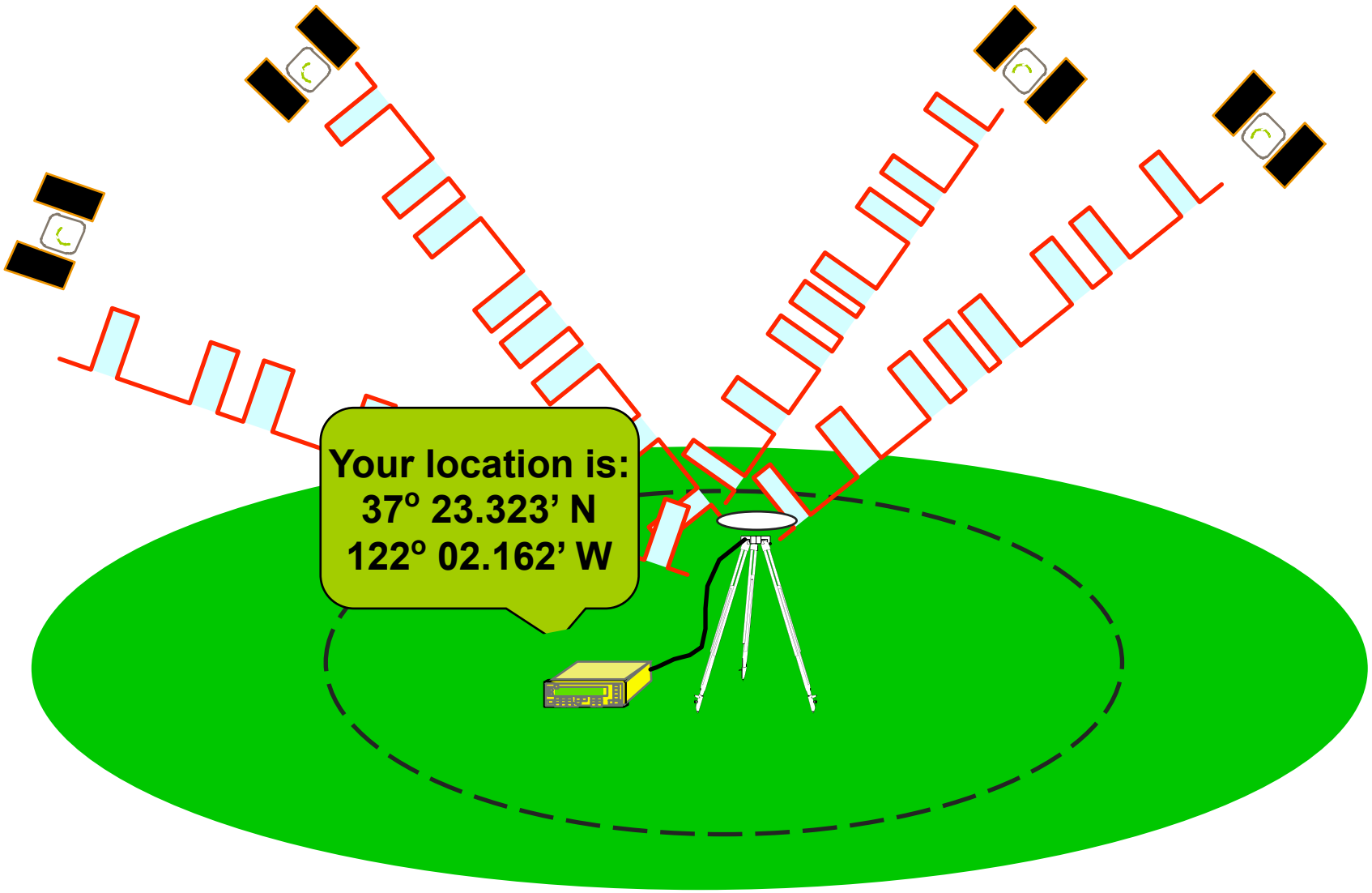


$$R = \left| \mathbf{R}_{sat} - \mathbf{R}_{rec} \right|$$

$$R = c[(T+t) - T] = ct$$

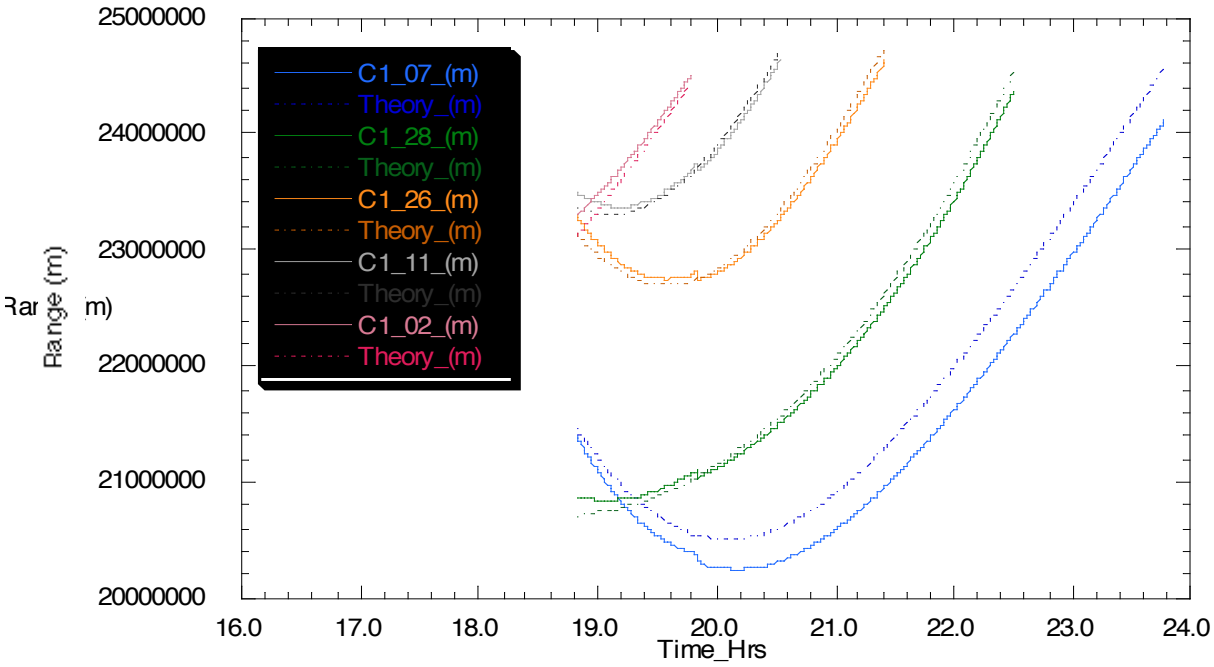
$$(ct_{sat_i-rec})^2 = (x_{sat_i} - x_{rec})^2 + (y_{sat_i} - y_{rec})^2 + (z_{sat_i} - z_{rec})^2$$

Pseudorange



Phase measurements

- High-precision positioning uses the phase observations
- Long-session static: change in phase over time carries most of the information
- The shorter the span the more important is ambiguity resolution



Each Satellite (and station) has a different signature

Limits of GPS Accuracy

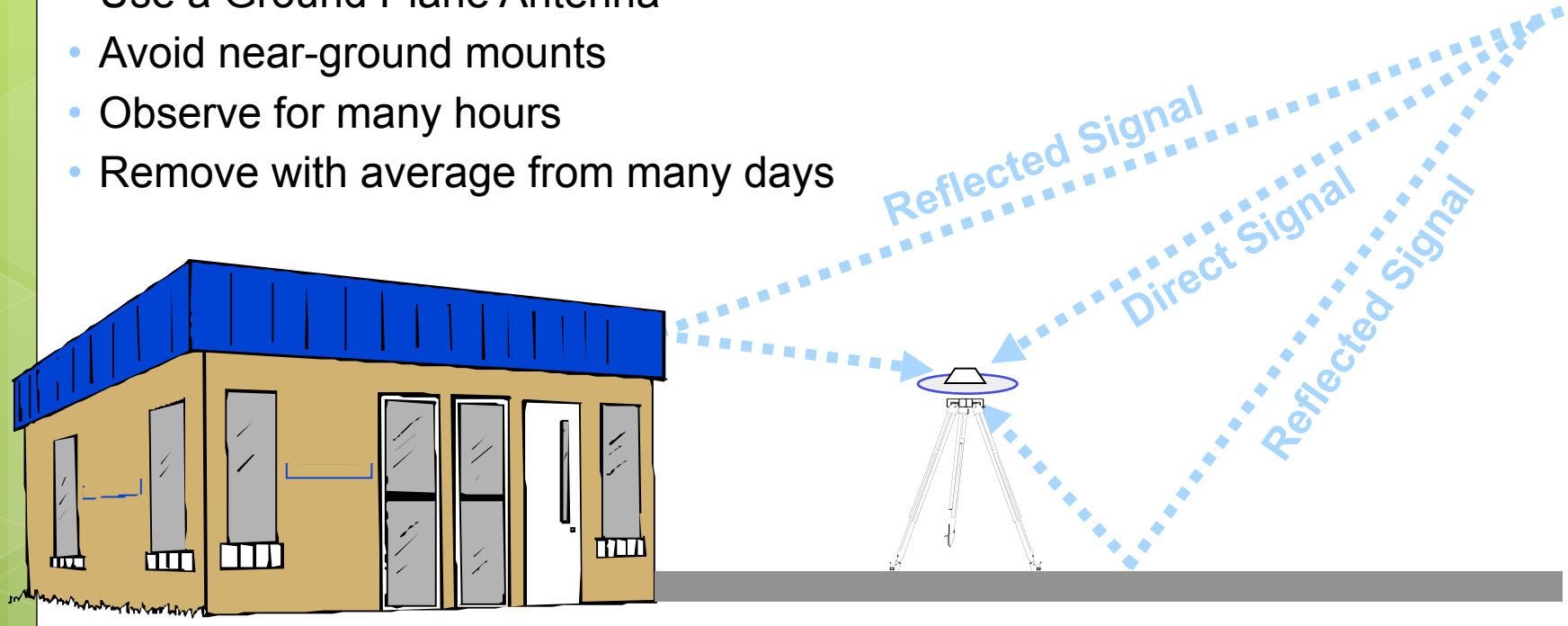
- Signal propagation effects
  - Signal scattering (antenna phase center / multipath)
  - Atmospheric delay (mainly water vapor)
  - Ionospheric effects
  - Receiver noise
- Unmodeled motions of the station
  - Monument instability
  - Loading of the crust by atmosphere, oceans, and surface water
- Unmodeled motions of the satellites
- Reference frame

Multipath

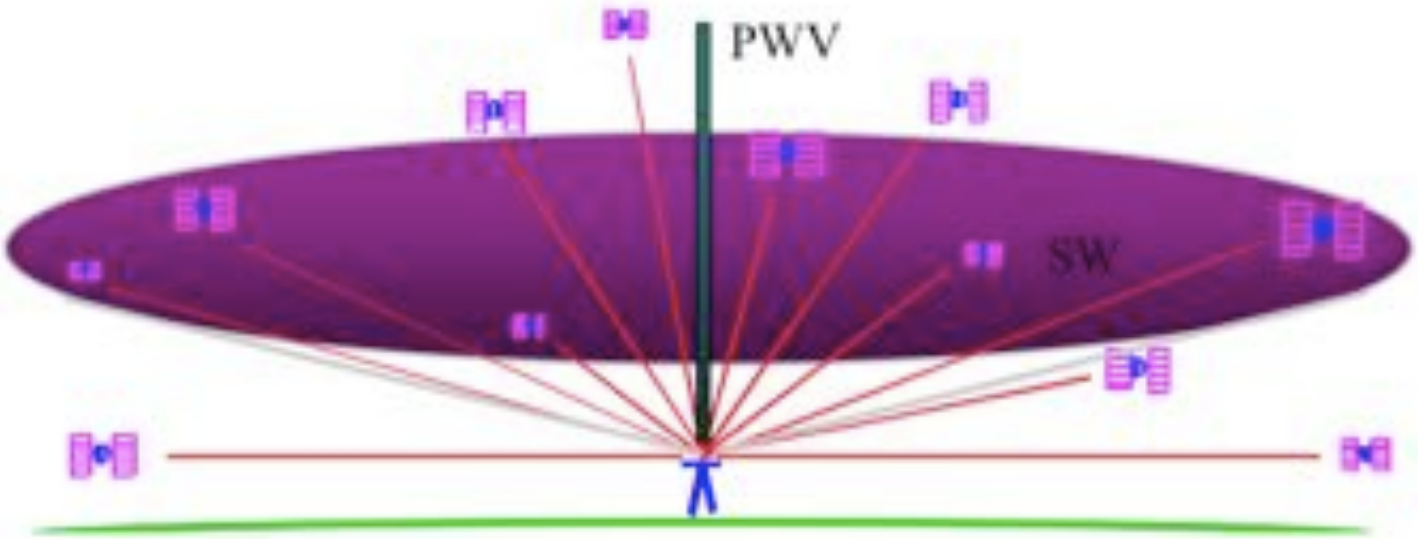
Multipath is interference between the direct and a far-field reflected signal (geometric optics apply)

To mitigate the effects:

- Avoid Reflective Surfaces
- Use a Ground Plane Antenna
- Avoid near-ground mounts
- Observe for many hours
- Remove with average from many days



Atmospheric delay

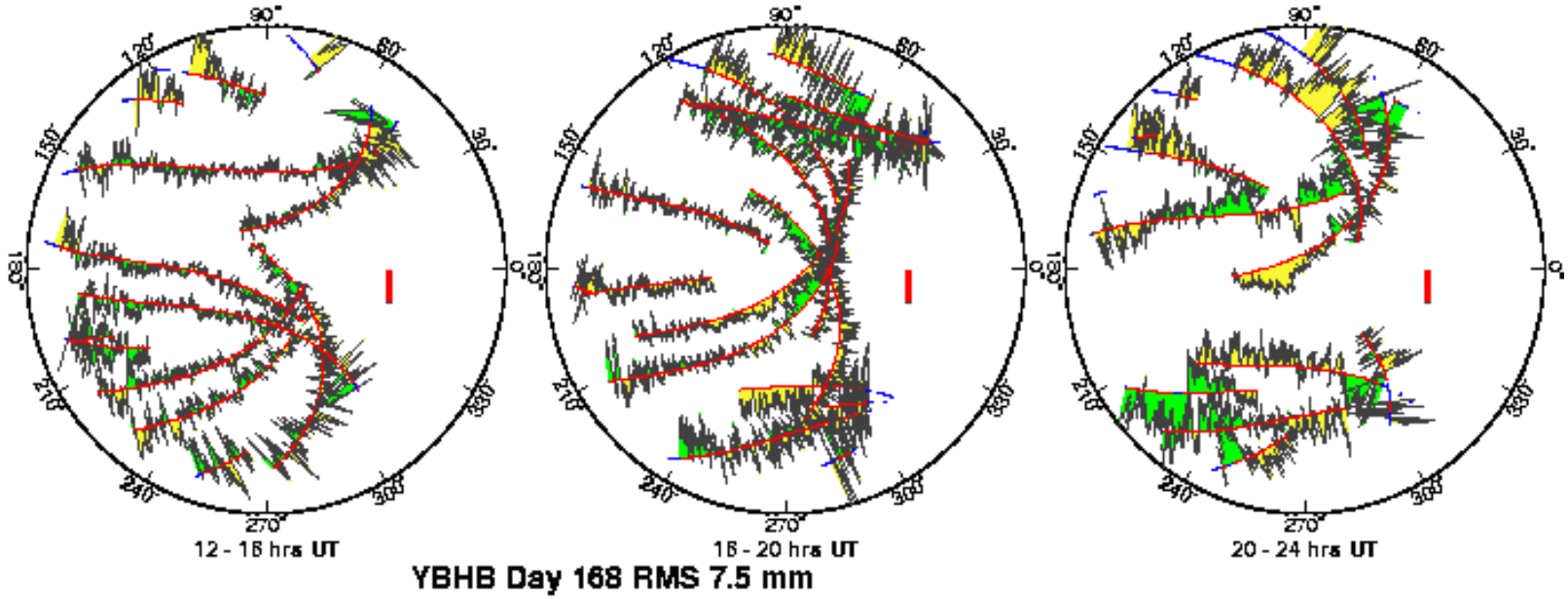


The signal from each GPS satellite is delayed by an amount dependent on the pressure and humidity and its elevation above the horizon. We invert the measurements to estimate the average delay at the zenith (green bar).

(Figure courtesy of COSMIC Program)

Signal propagation

Multipath and Water Vapor Effects in the Observations



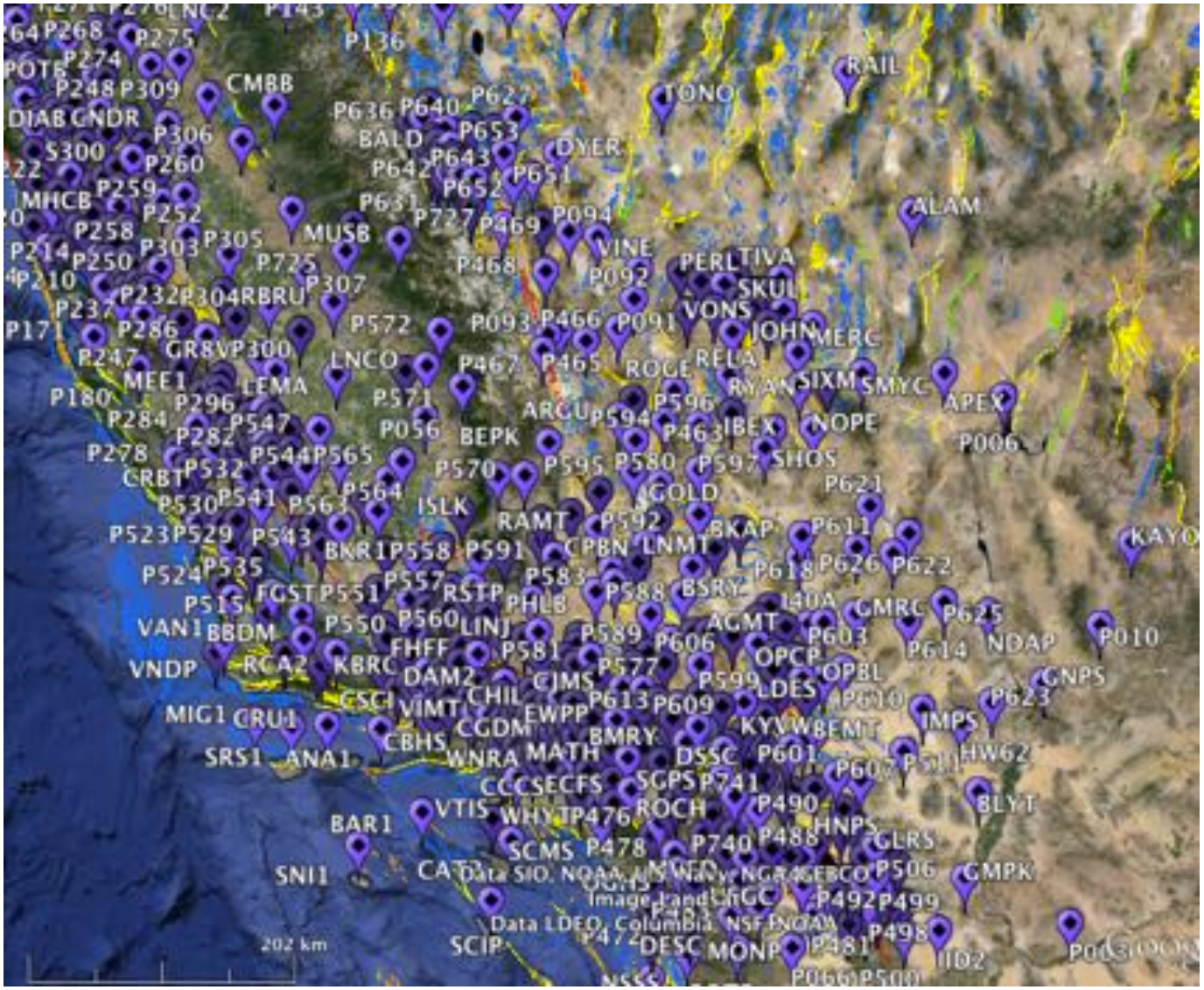
One-way (undifferenced) LC phase residuals projected onto the sky in 4-hr snapshots. Spatially repeatable noise is multipath; time-varying noise is water vapor.

Red is satellite track. Yellow and green positive and negative residuals purely for visual effect.
Red bar is scale (10 mm).

(it's fun)

Why campaign?

Continuous



P136
P275
P274
P248
P309
CMBB
DIAB
CNDR
P306
S300
P260
P259
MHCB
P252
P258
P303
P305
P214
P250
P210
P232
P304
RBRU
P307
P237
P171
P286
GR8V
P300
P247
MEE1
LEMA
P180
P296
P284
P547
P282
P278
CRBT
P532
P544
P565
P530
P541
P563
P564
P523
P529
P543
BKR1
P558
P591
P524
P535
P515
FGST
P551
P557
RSTP
VAN1
BBDM
P550
P560
LINJ
FHFF
P581
VNDP
RCA2
KBRC
DAM2
CJMS
CHIL
MIG1
CRU1
CGDM
EWPP
CBHS
SRS1
ANA1
WNRA
MATH
CCCS
ECFS
VTIS
WHYT
P476
BAR1
SCMS
P478
SNI1
SCIP
DESC
MONP
P481
P066
P500
P636
P640
P627
BALD
P653
P643
P642
P651
P652
P631
P727
P469
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MUSB
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P572
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LNCO
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ARGU
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BEPK
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ISLK
GOLD
RAMT
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CPBN
LNMT
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LDES
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P740
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HNPS
GLRS
P506
GMPK
P492
P499
P498
IID2
TONO
RAIL
DYER
ALAM
VINE
PERL
TIVA
SKUL
VONS
JOHN
MERC
RELA
ROGE
RYAN
SIXM
SMYC
APEX
NOPE
IBEX
SHOS
P006
P621
BKAP
P611
KAYO
P618
P626
P622
I40A
GMRC
P625
AGMT
P603
P614
NDAP
P010
OPCP
OPBL
GNPS
P623
KYVW
BEMT
IMPS
HW62
BLYT
202 km

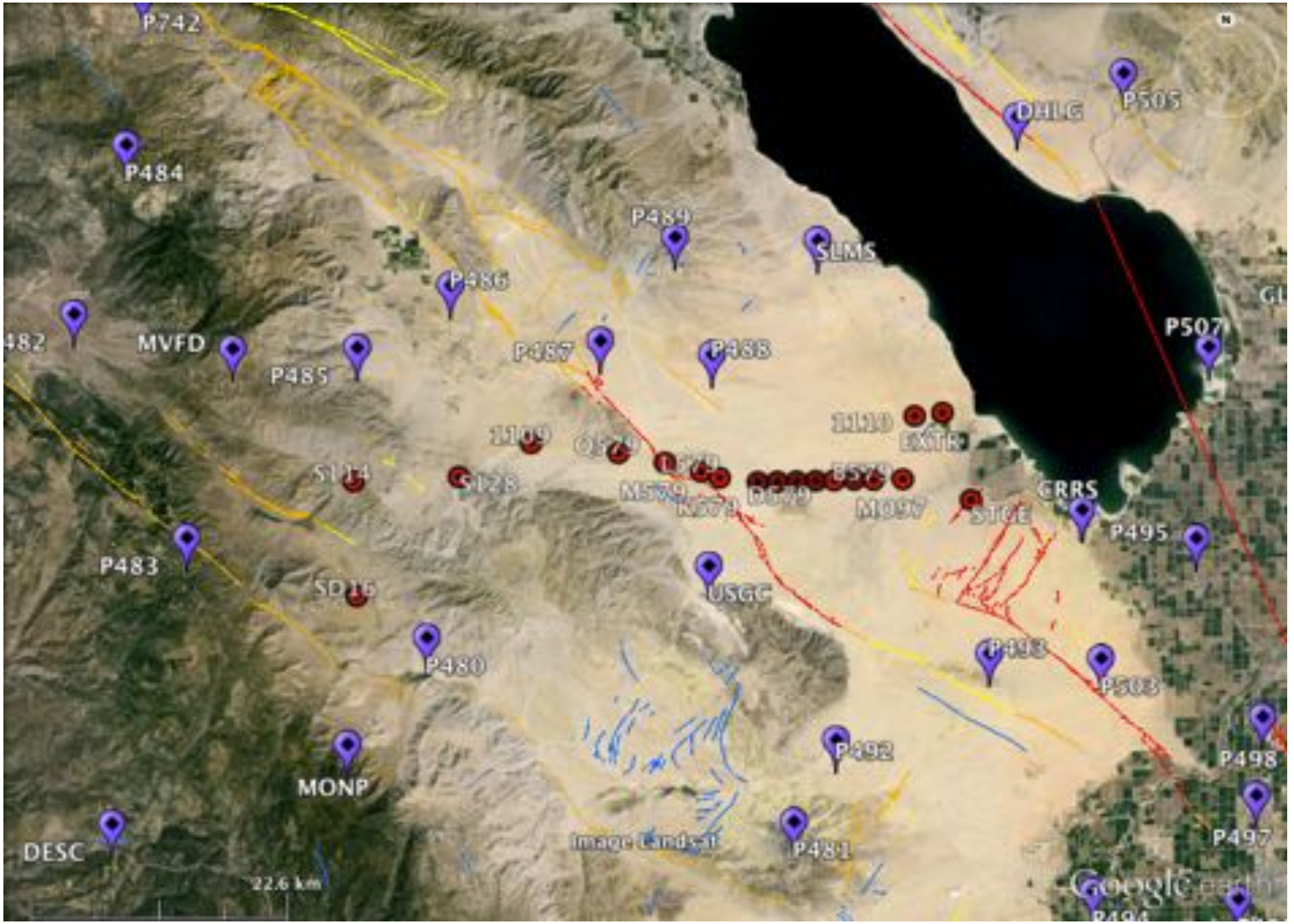
"Special" Characteristics of Survey-mode Data

- Editing is critical: every point counts
- Usually combined with cGPS data to provide continuity and a tie to the ITRF
- Appropriate relative weighting needed in combining with cGPS data
- Antenna meta-data may be more complicated
- Heights may be problematic if different antennas used
- Seasonal errors behave differently than in cGPS data: best strategy is to observe at the same time of the year (unlike cGPS, which has minimal seasonal sensitivity at 1.5, 2.5, 3.5 ….years total span)
- Multipath and atmosphere more of a problem for short occupations.

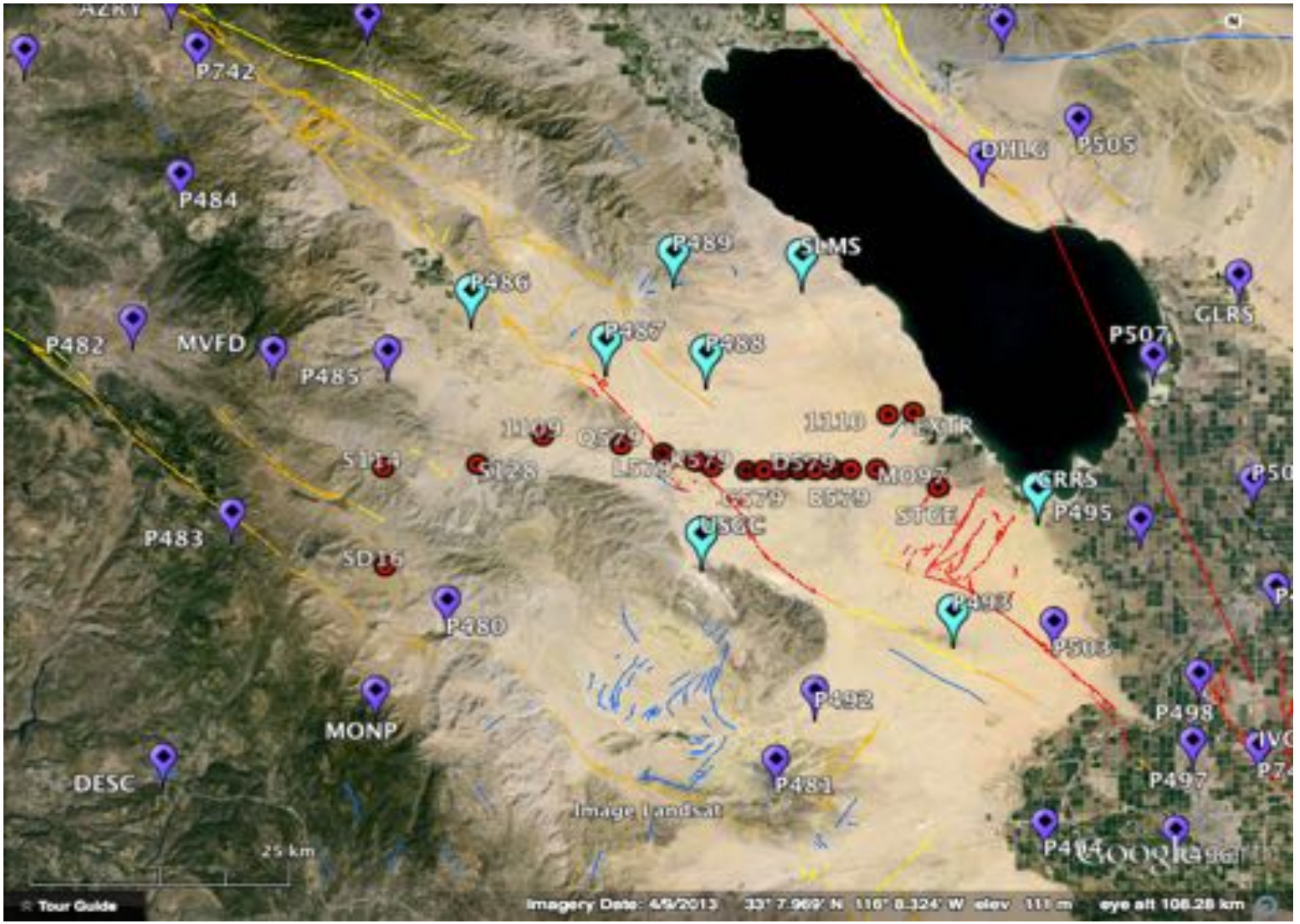
Occupy San Jacinto

Where are we?

Where are we?


P742
P484
P489
SLMS
DHLG
P505
P486
P507
MVFD
P485
P487
P488
P495
P483
USGC
P480
P503
P498
MONP
P492
P497
DESC
P481
22.6 km
Image Landsat
Google earth

Where are we?



P742
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MVFD
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P486
P489
SLMS
P487
P488
DHLG
P505
GLRS
P507
1110
EXTR
1109
Q579
S114
S128
L579
D579
M097
CRRS
P495
STGE
USGC
P483
SD16
P480
P493
P503
P492
MONP
DESC
P481
P498
P497
Image Landsat
25 km
Tour Guide
Imagery Date: 4/9/2013
eye alt 108.28 km

Log sheets

Sheet ___ of ___

GENERAL

4-Char ID: E579 Station (stamping or name): ___

Observer: Chris [CJO] Institution: IGPP/SIO

Campaign: Science 78 array spring 2014

INSTRUMENTATION

Receiver Type: Ashtech Z-12 Serial/ID Number: LP03047

Antenna Type: Ashtech Serial/ID Number: CR519991780 Rev. B

Tribrach Type: Sero Serial/ID Number: Lot # IG1ZT

Power: Battery [X] AC [ ] Solar [ ] Start Voltage: ___ End Voltage: ___

START-UP INFORMATION

Initial Setup

Tribrach bubble centered: Yes No
Crosshairs on target: Yes No
Hockey puck locked down: Yes No
Hockey puck thumbscrew tightened: Yes No
Antenna aligned to True N (15° W of Mag N): Yes No

Antenna Height:

Vert. Meas. Pt.: ___ Rad. Meas. Pt.: ___

Heights [hole #]: 121.4 [10]: 121.4 [6]: 121.4 [2] meters [ ] cm [X] inches [ ]

Start Date/Time (in UTC):

Start Year/Day Number: 2014 -110 Start Time: 01:36 Local Day of Week: Sat

Logging start OK: Yes No (go to Ashtech Screen 8, wait until file size is at least 0.1 EQHR — typically 5-10 min)

SHUTDOWN INFORMATION

End Date/Time (in UTC):

End Year/Day Number: 2014 / 111 End Time: 00:40 Local Day of Week: Sun

Antenna Height:

Heights [hole #]: 121.3 [1]: 121.3 [6]: 121.3 [10] meters [ ] cm [✓] inches [ ]

Final Takedown

Hockey puck thumbscrew tightened: Yes No
Hockey puck locked down: Yes No
Antenna aligned to True N (15° W of Mag N): Yes No
Tribrach bubble centered: Yes No (if No, center before crosshairs check)
Crosshairs on target: Yes No

The Rinex File

- File name: [stid][DDD][#].[YY]o
- E.g., e5791100.14o
- For several occupations in one day, change # from 0 to 1, etc.

Rinex

```
     2.11           OBSERVATION DATA    G (GPS)             RINEX VERSION / TYPE
teqc  2013Mar15                        20140425 00:39:50UTCPGM / RUN BY / DATE
OSX ker:10.8.0|Core 2 Duo|gcc 4.2 -m64|OSX ker:10.8.0+|=+   COMMENT
BIT 2 OF LLI FLAGS DATA COLLECTED UNDER A/S CONDITION       COMMENT
E579                                                        MARKER NAME
EOL                 SIO                                     OBSERVER / AGENCY
LP03047             ASHTECH Z-XII3      CD00                REC # / TYPE / VERS
CRS19991786         ASH7019458_M                            ANT # / TYPE
        0.0000        0.0000        0.0000                  APPROX POSITION XYZ
        1.1638        0.0000        0.0000                  ANTENNA: DELTA H/E/N
     1     1                                                WAVELENGTH FACT L1/2
     7    L1    L2    C1    P1    P2    S1    S2           # / TYPES OF OBSERV
     5.0000                                                 INTERVAL
 SNR is mapped to RINEX snr flag value [0-9]                COMMENT
  L1 & L2: min(max(int(snr_dBHz/6), 0), 9)                  COMMENT
pseudorange smoothing corrections not applied               COMMENT
  2014     4    20     1    37   35.0000000     GPS         TIME OF FIRST OBS
                                                            END OF HEADER

 14  4 20  1 37 35.0000000  0  8G01G15G17G28G26G07G08G09
     68767.54747     46866.96943                                    23389166.5594
        44.7004         19.9004
     -9912.84347     -6925.24544                                    23488941.4724
        44.7004         24.4004
    -12997.46649     -9317.6894
        55.1004         3.6004
     57034.04148     38748.55047  21782661.622    21782661.3374   21782666.5484
        52.7004         43.9004
     94738.40448     59253.56946  21866682.385    21866682.7014   21866690.1404
        51.0004         40.4004
    170652.57447    117263.9654
        44.0004         1.5004
    140823.11048     85522.91446  21502284.826    21502284.5784   21502291.6444
        51.0004         41.8004
    121428.00649     82846.38947  20963108.660    20963108.8624   20963115.1464
        54.1004         46.3004
```

Ingredients

- Campaign rinex files
- Log sheets
- A few chosen continuous stations to "anchor" the solution.

Recipe

- Run sh_setup –yr YYYY
- Set up processing in tables/
  - process.defaults
  - sittbl.
  - sites.defaults
  - Update station.info
- Run gamit
- Post-process with GLOBK

sh_setup

- Run from top directory, containing folder "rinex/"
- Specify year sh_setup –yr 2012
- Creates "tables/" folder in the top (YEAR) directory, and copies the tables that will be necessary for processing.

Inside tables/

- Edit process.defaults
  - Enter your mailto address if you want
  - Session info
  - dopts and copts
- Edit sittbl.
  - Pick one station (preferably a continuous one) to constrain.
  - Check paths

Inside tables/

- Edit sites.defaults
  - Delete all non-commented lines
  - Enter: all_sites expt xstinfo
  - Enter the names of your continuous stations with "expt ftprnx xstinfo".
    - E.g., cact_gps hw78 ftprnx xstinfo
    - NOTE: Leading space!
- Edit sittbl.
  - Pick one station (preferably a continuous one) to constrain.
    - E.g., P488 P488_GPS NNN 0.003 0.003 0.01

Inside tables/

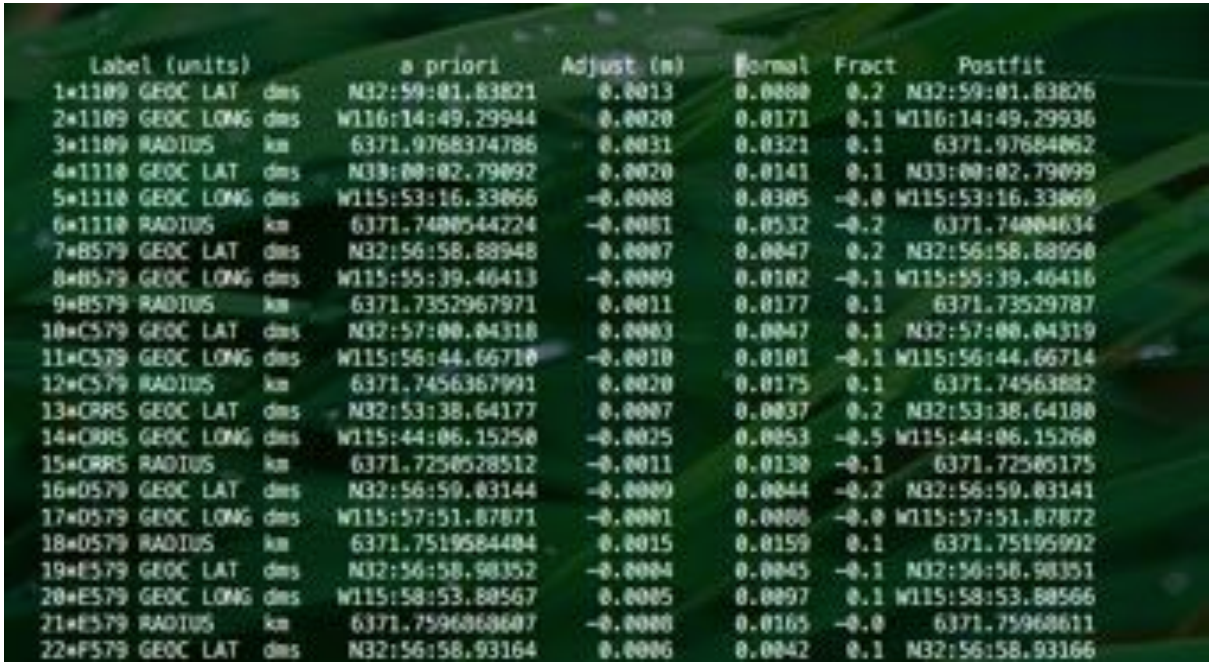
- Tell GAMIT which stations you are going to process
  - sh_upd_stnfo -l sd; mv station.info.new station.info
    - Continuous stations first
  - sh_upd_stnfo -files ../rinex/*.Yyo
    - Then add campaign

Ready to run!

- sh_gamit -expt hw78 -d 2012 125 126 -pres ELEV -orbit IGSF -c
  - Run gamit from the top directory
  - This runs gamit for experiment “hw78”, for days 125 and 126 in the year 2012, with IGSF orbits and plots showing phase vs. elevation.

Results.

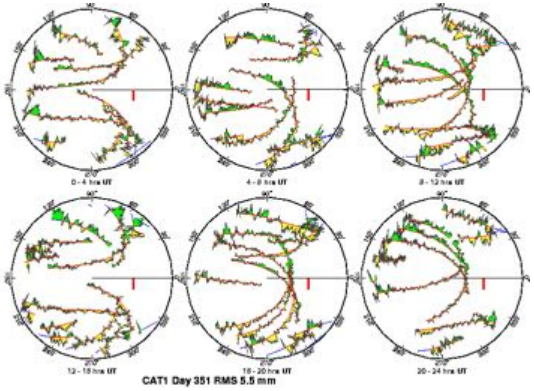
- Look at file [day]/q[expt]a.[day]



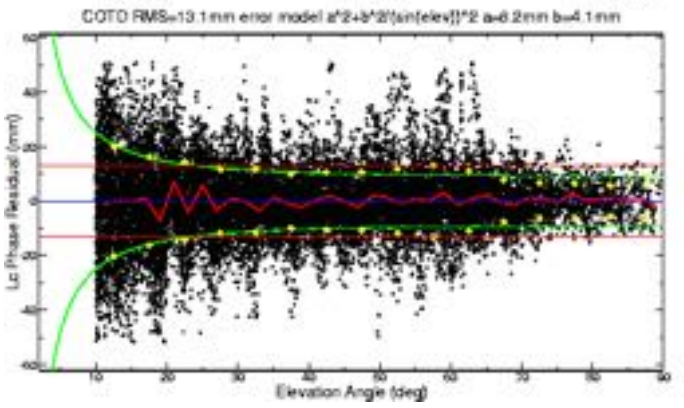
Label (units)		a priori	Adjust (m)	Formal	Fract	Postfit
1*1109 GEOC LAT	dms	N32:59:01.83821	0.0013	0.0080	0.2	N32:59:01.83826
2*1109 GEOC LONG	dms	W116:14:49.29944	0.0020	0.0171	0.1	W116:14:49.29936
3*1109 RADIUS	km	6371.9768374786	0.0031	0.0321	0.1	6371.97684062
4*1110 GEOC LAT	dms	N33:00:02.79092	0.0020	0.0141	0.1	N33:00:02.79099
5*1110 GEOC LONG	dms	W115:53:16.33066	-0.0008	0.0305	-0.0	W115:53:16.33069
6*1110 RADIUS	km	6371.7400544224	-0.0081	0.0532	-0.2	6371.74004634
7*B579 GEOC LAT	dms	N32:56:58.88948	0.0007	0.0047	0.2	N32:56:58.88950
8*B579 GEOC LONG	dms	W115:55:39.46413	-0.0009	0.0102	-0.1	W115:55:39.46416
9*B579 RADIUS	km	6371.7352967971	0.0011	0.0177	0.1	6371.73529787
10*C579 GEOC LAT	dms	N32:57:00.04318	0.0003	0.0047	0.1	N32:57:00.04319
11*C579 GEOC LONG	dms	W115:56:44.66710	-0.0010	0.0101	-0.1	W115:56:44.66714
12*C579 RADIUS	km	6371.7456367991	0.0020	0.0175	0.1	6371.74563882
13*CRRS GEOC LAT	dms	N32:53:38.64177	0.0007	0.0037	0.2	N32:53:38.64180
14*CRRS GEOC LONG	dms	W115:44:06.15250	-0.0025	0.0053	-0.5	W115:44:06.15260
15*CRRS RADIUS	km	6371.7250528512	-0.0011	0.0130	-0.1	6371.72505175
16*D579 GEOC LAT	dms	N32:56:59.03144	-0.0009	0.0044	-0.2	N32:56:59.03141
17*D579 GEOC LONG	dms	W115:57:51.87871	-0.0001	0.0086	-0.0	W115:57:51.87872
18*D579 RADIUS	km	6371.7519584404	0.0015	0.0159	0.1	6371.75196992
19*E579 GEOC LAT	dms	N32:56:58.98352	-0.0004	0.0045	-0.1	N32:56:58.98351
20*E579 GEOC LONG	dms	W115:58:53.80567	0.0005	0.0097	0.1	W115:58:53.80566
21*E579 RADIUS	km	6371.7596868607	-0.0000	0.0165	-0.0	6371.75968611
22*F579 GEOC LAT	dms	N32:56:58.93164	0.0006	0.0042	0.1	N32:56:58.93166

Phase residual plots

- Set with -pres elev in sh_gamit command line (requires GMT)
- Postscript files in day directory, by default converted to gif in /gifs directory and then erased (needs ImageMagik convert program).
- Use to assess multipath, water vapor, and antenna phase center model

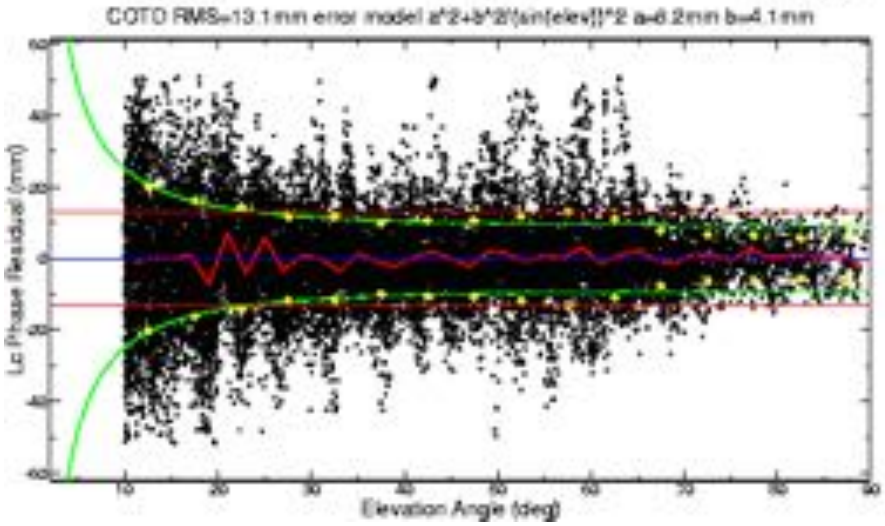


"Sky plot"

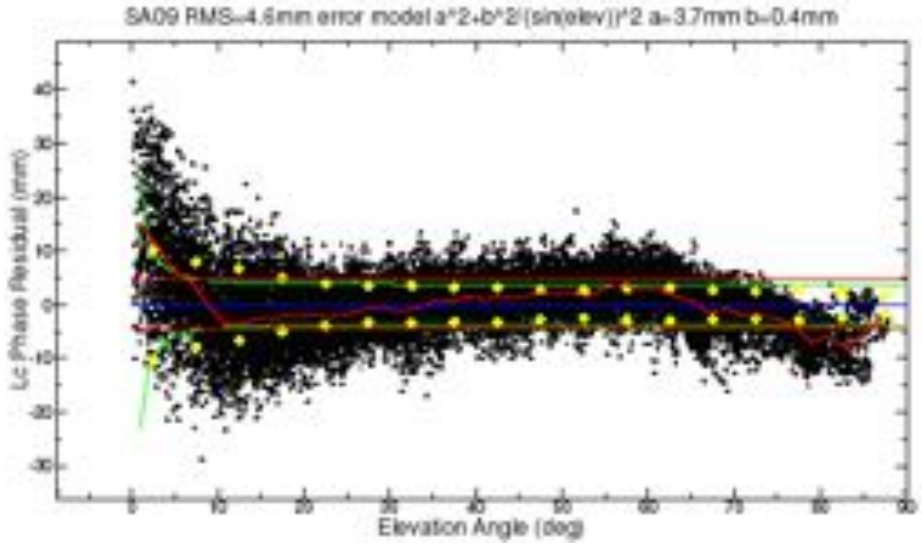


Phase vs elevation angle

Results



Normal pattern: bands are high-frequency multipath; red is smoothing of individual values, showing no strong systematics. Mid-elevation angle noise could be atmospheric delay errors?



Bad pattern: systematic signature of smoothed values indicates a poor model of the antenna phase pattern (perhaps a misidentified antenna in station.info)

(Green lines show the elevation-dependent noise model shown at top and used to reweight the data in solve)

What can go wrong?

- Site missing (not listed)
  - no RINEX data within session span: check RINEX file and/ or makex.expt.infor
  - too few data, x-file too small and not used: check RINEX file size, change minxf in process.defaults
- Site in solution but no data or adjustment
  - a priori coordinates > 10 m off: check range rms in autcln.prefit.sum,
    - run sh_rx2apr differentially for several RINEX files
  - bad receiver: examine RINEX files or initial c-files with cview
- Q-file nrms > 0.2
  - solution over-constrained: check GCX vs GLX nrms, rerun with only one site constrained

Post-processing

- GLOBK
  - Velocities and time series
- GLRED
  - Repeatabilities
- GLORG
  - Fine-tuning and corrections