TECHNISCHE UNIVERSITÄT DRESDEN

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Nadir angle and elevation angle dependent GPS code delay variations

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Older Work on GPS Code Delay Variations

GPS Satellite Antennas

Receiving Antennas

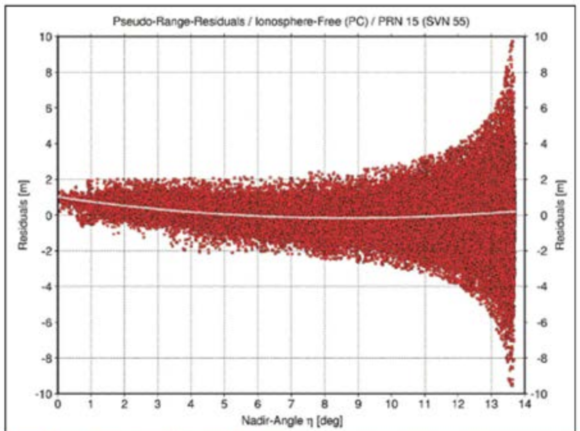
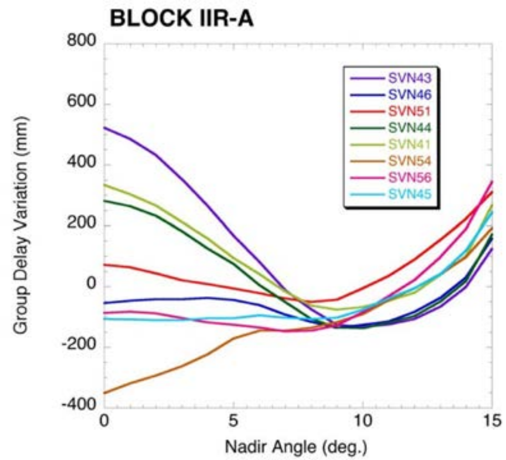
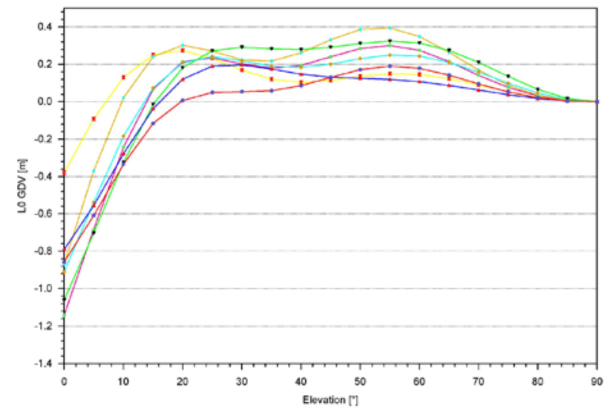


FIGURE 3 Pseudorange residuals on GPS SVN55





Springer and Dilssner 2009:

- derived from ground measurements, iono.-free
- several 10 cm level
- largest: SVN55

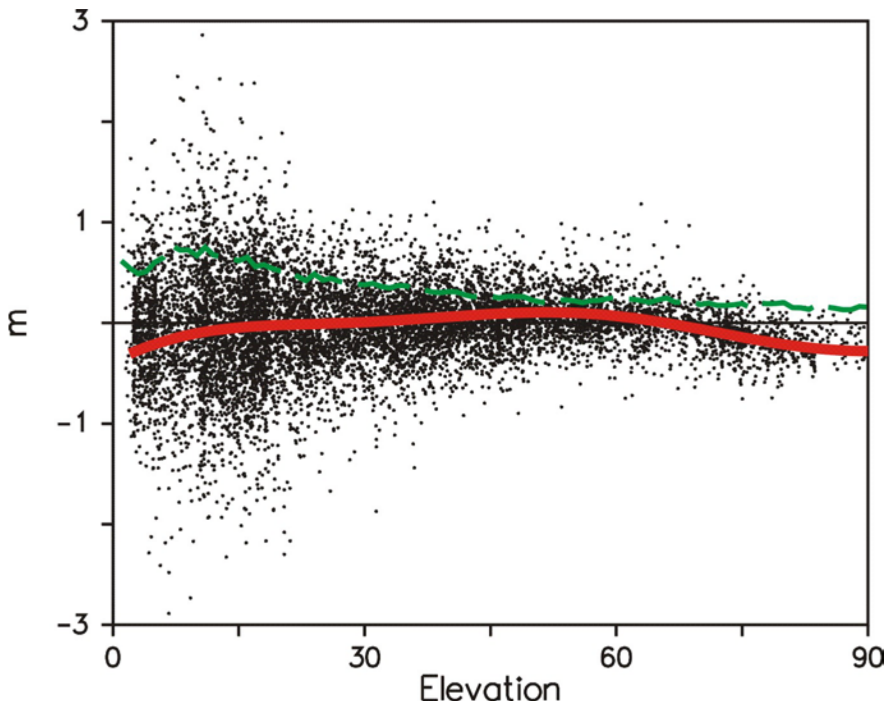
Haines et al. 2012, 2014:

- derived from GRACE measurements, iono.-free
- several 10 cm level
- largest: Block IIR

Wübbena et al. 2008:

- derived from robot calibrations, L1, L2, → iono.-free
- 5 DM type antennas, 2 other CR antennas

MP observable: code / dual-frequency phase



MP values

RMS(MP)

Regression Model

Regression Model: Calibration of code variations with respect to carrier-phases

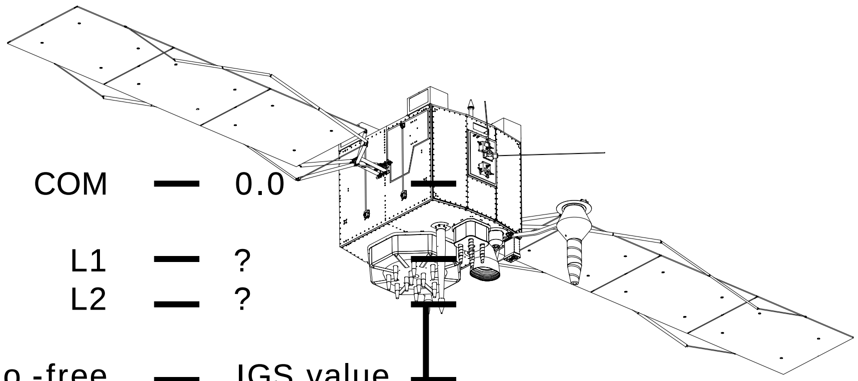
C1 and P2 separately → all linear combinations

Challenges

- **code multipath**
  → low-pass filtering, many different stations
- **dependence on tracking channel characteristics ?**
  → (receiver selection,) majority voting, averaging
- **code / phase, frequency dependent properties**
  → common reference point at antennas
  → phase wind-up
- **separation sat. ant. from rec. ant.**
  (→ absolute calibration values for receiving antennas)
  → reference antenna type

Common reference points for phase observations

at transmitting antenna



COM	—	0.0
L1	—	?
L2	—	?
iono.-free	—	IGS value

Z

at receiving antenna

L2	—	12.0 cm
L1	—	9.1 cm
iono.-free	—	4.6 cm
ARP		0.0

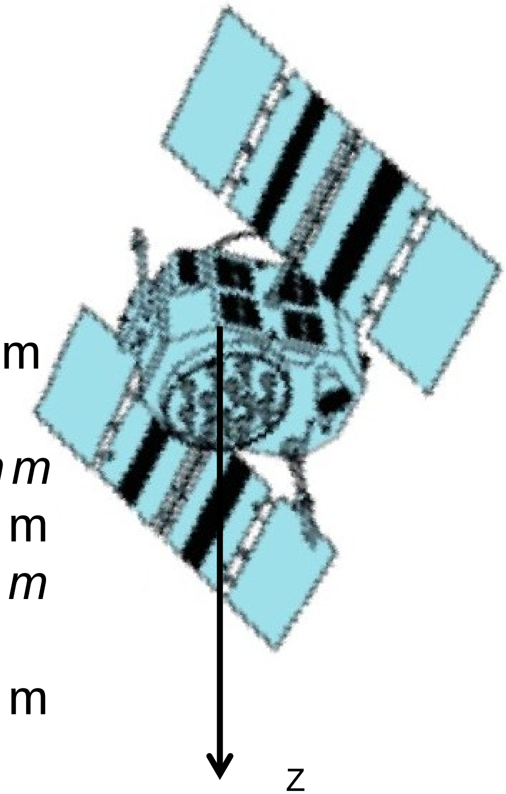
Drawings are simplified: in reality we consider PCO and PCV

the later code corrections will refer to these reference points

Common reference points for phase observations

Example:
Block IIa, SVN40

COM	—	0.00 mm
L2	—	*622.02 mm*
geom. distance COM - antenna	—	1000.00 mm
L1	—	*1377.98 mm*
iono.-free	—	2546.50 mm



→ Modification of IGS08.ATX: new L1/L2 PCO of satellite antennas,
no changes for iono.-free linear combination

Receiving Antennas

4 Dorne-Margolin type

AOAD/M_T
ASH700936?_M
LEIAT504GG
TRM29659.00

9 more antenna types

JAV_RINGANT_G3T
LEIAR25.R3
LEIAR25.R4
SEPCHOKE_MC
TPSCR.G3
TRM41249.00
TRM55971.00
TRM57971.00
TRM59800.00

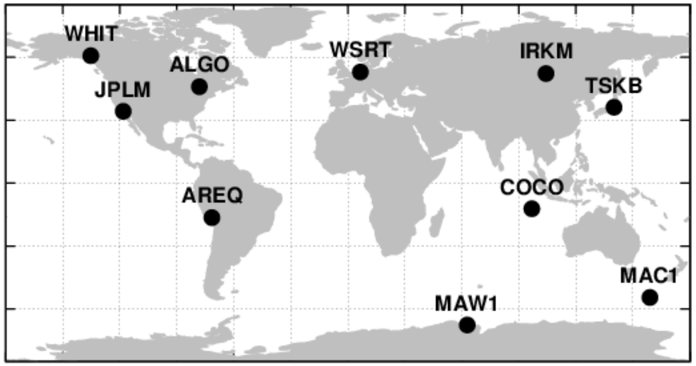
differences of radomes / receiver types ignored

selected code signals: C1, P2

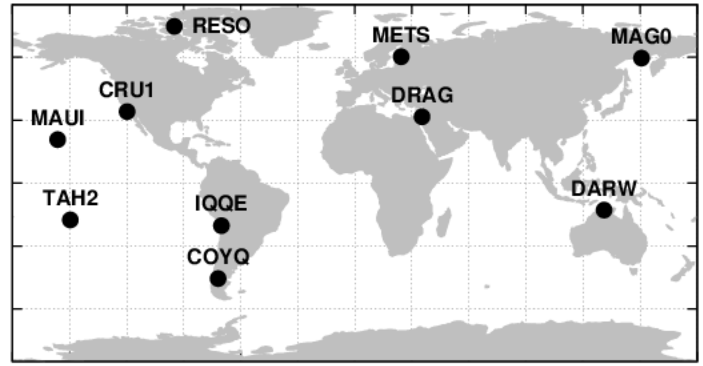
RMS (MP) considered: ele. range 10-90 deg
RMS (MP) < 0.5 m for C1, P2

Station distribution: GPS week 1843 (123-129/15)

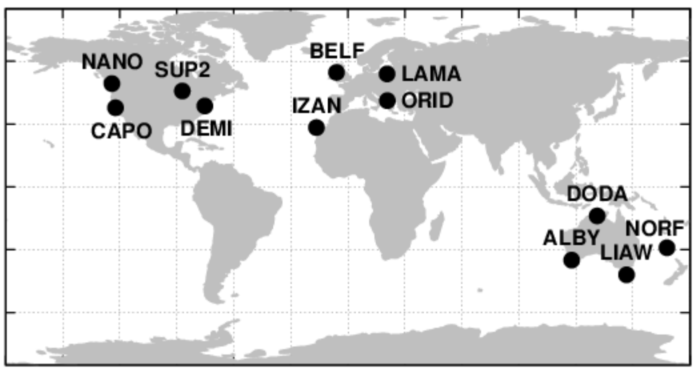
AOAD/M_T



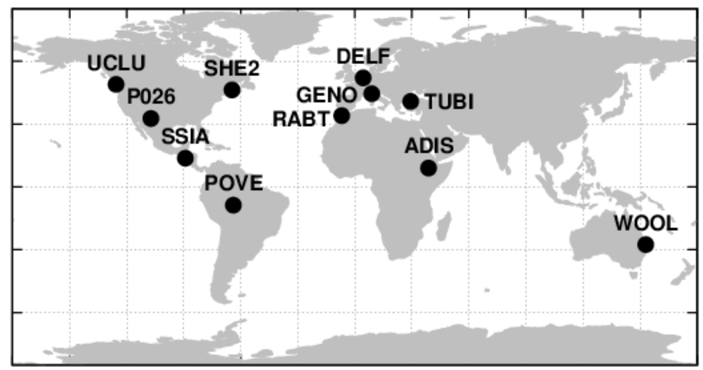
ASH700936?_M



LEIAT504GG



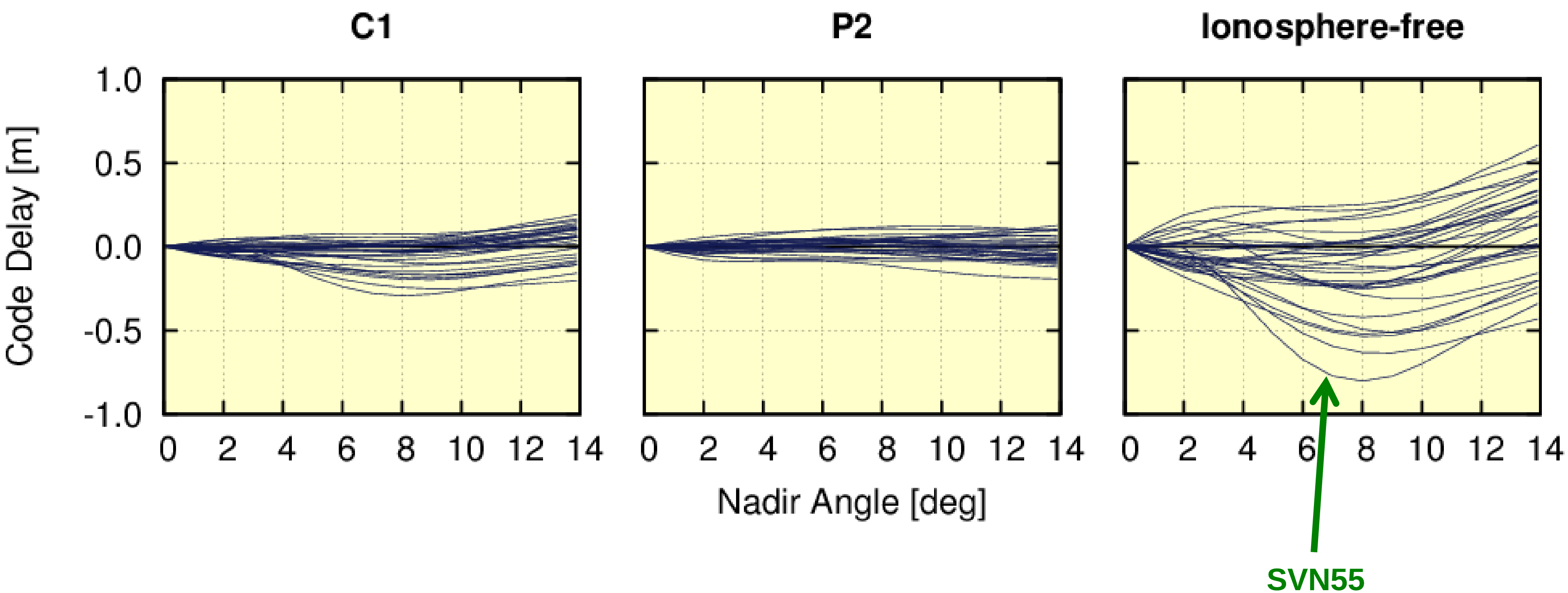
TRM29659.00



43 stations

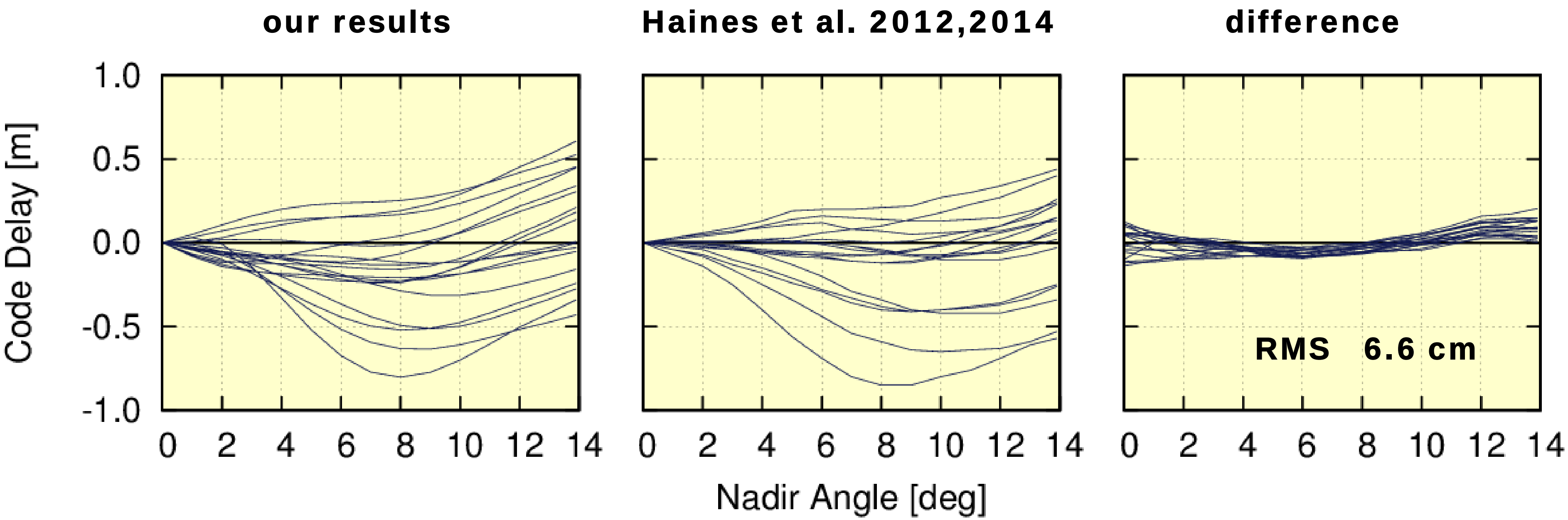
+ 85 other stations with 9 additional types of receiving antennas

Results for satellite antennas – all 43 stations



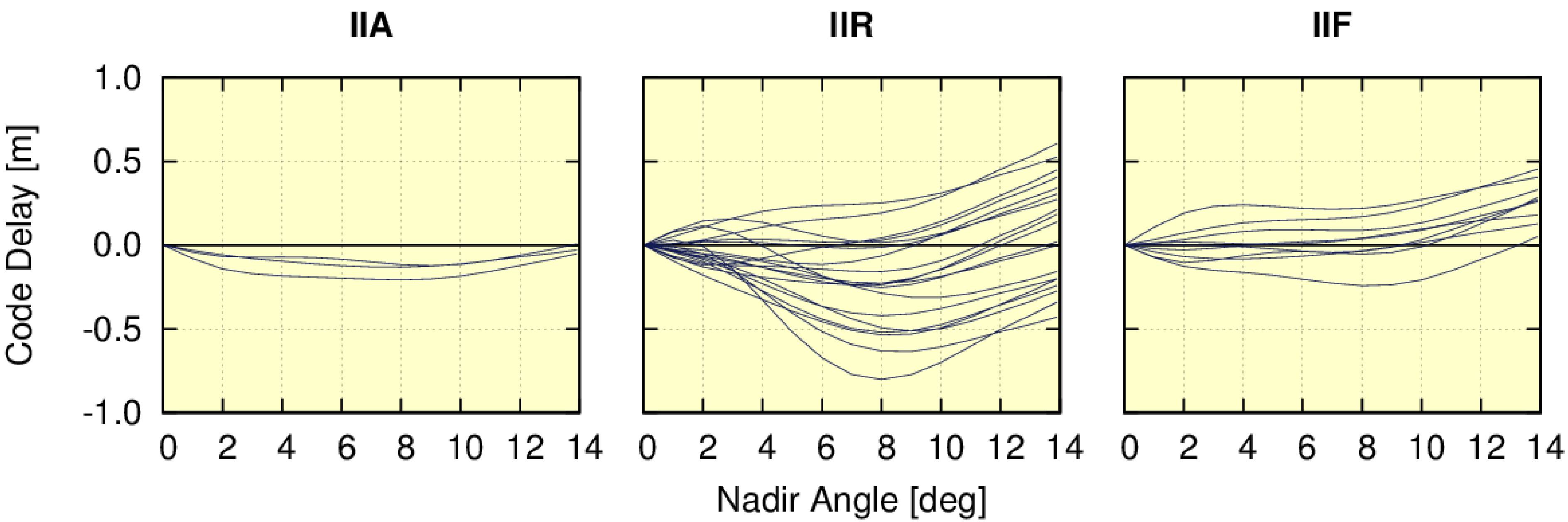
31 SV

Results sat. ant. – comparison with Haines

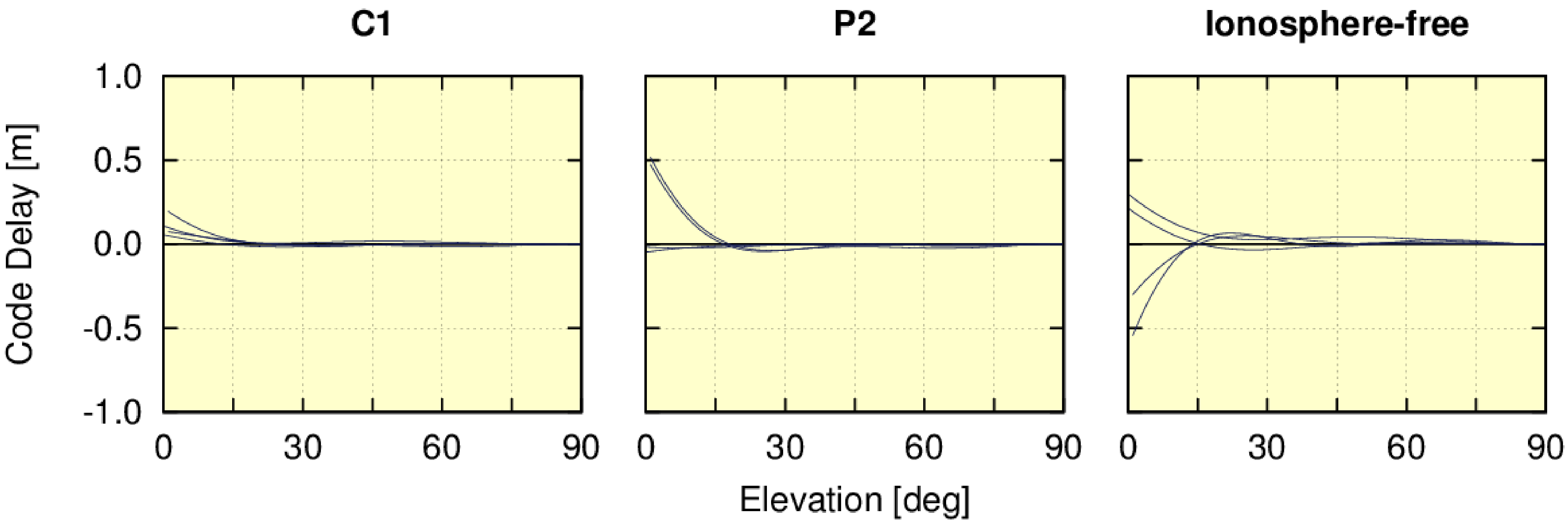


18 identical satellites

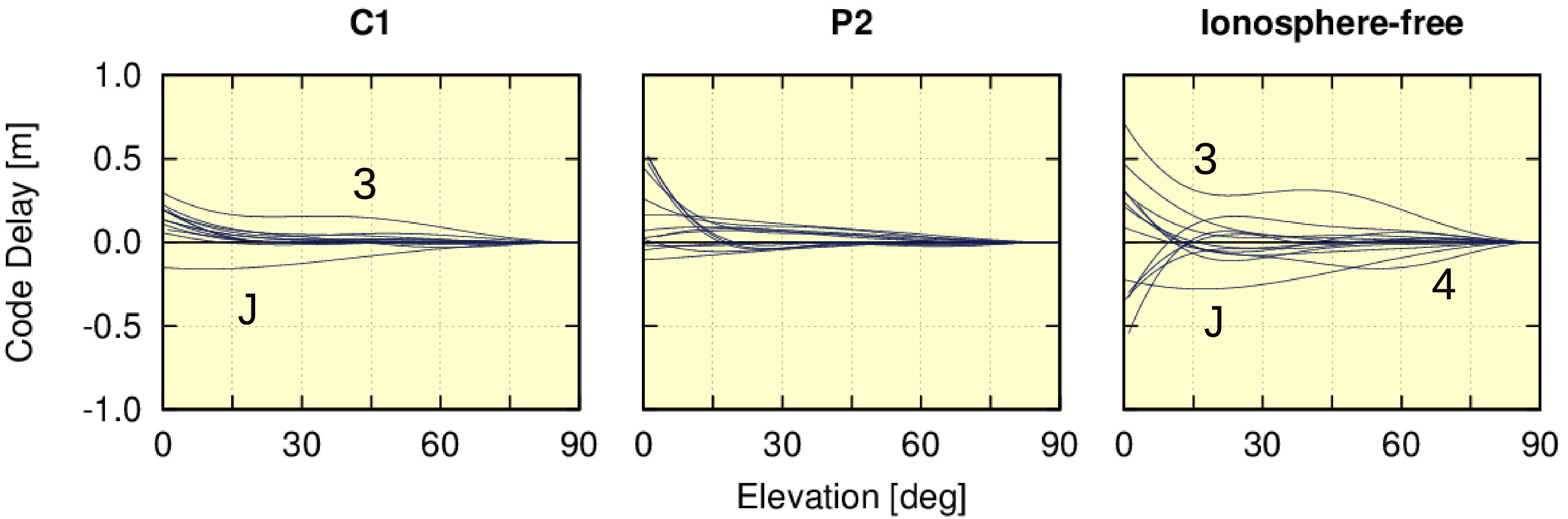
Results – per GPS satellite block



Receiving Antennas: 4 DM type



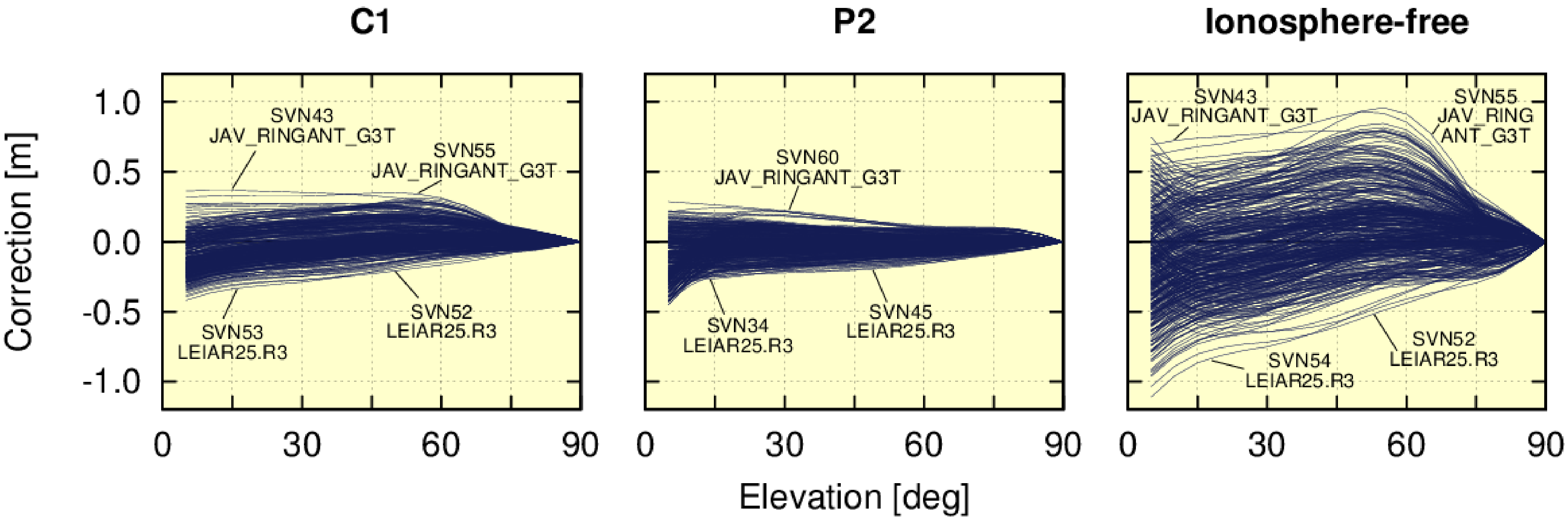
Receiving Antennas: 4 DM + 9 more



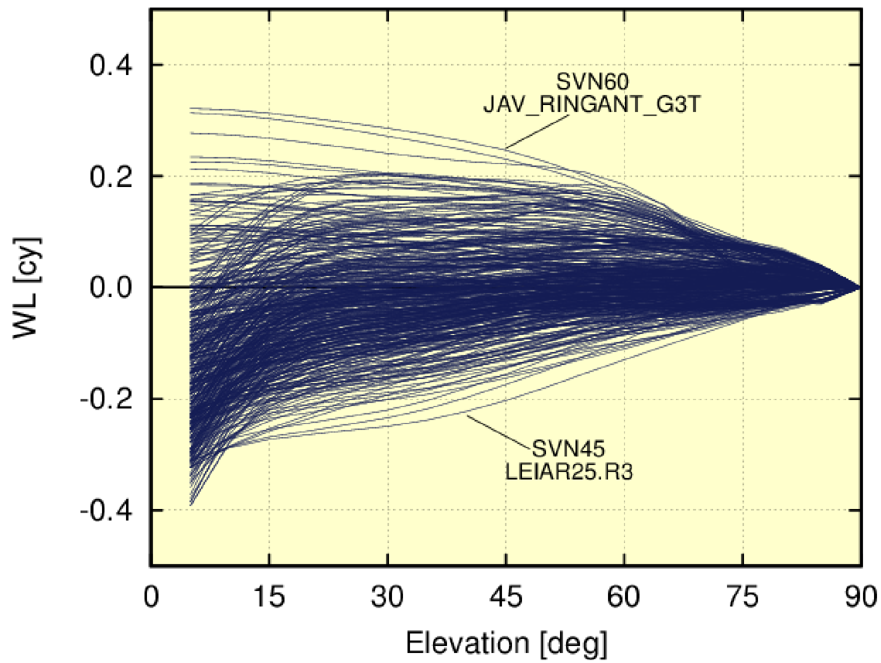
3 - LEIAR25.R3
4 - LEIAR25.R4
J - JAV_RINGANT_G3T

Combined Corrections – Various Combinations

31 SV x 13 antenna types = 403 correction data sets

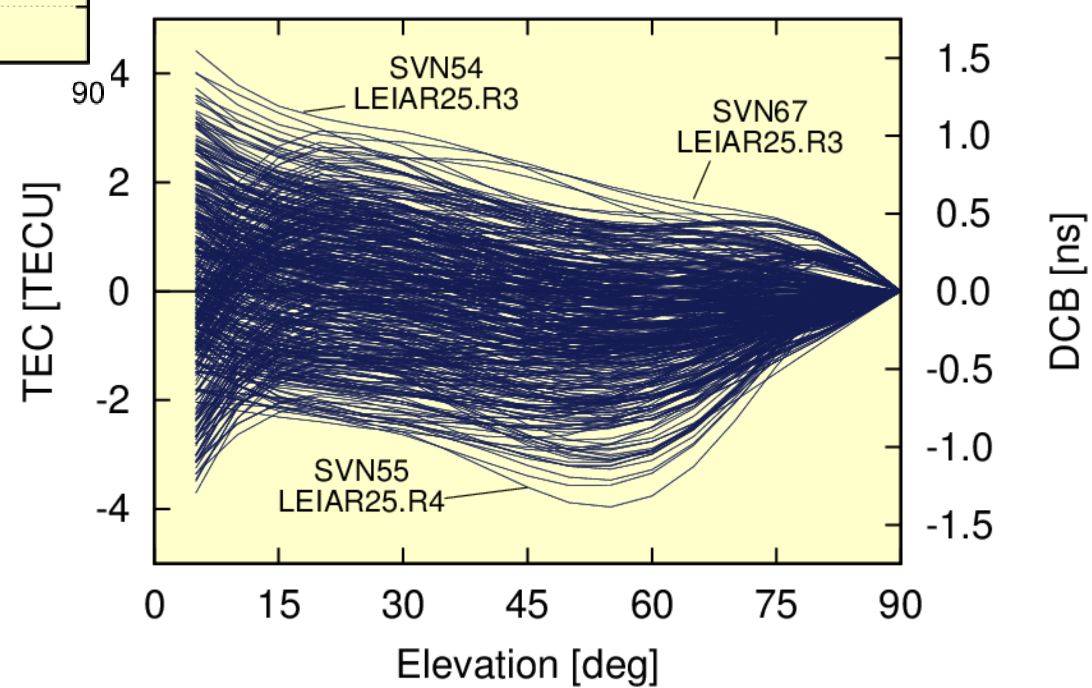


Combined Corrections – Various Combinations



Code contribution to Melbourne-Wübbena LC, widelane cycles

Ionospheric LC or DCB



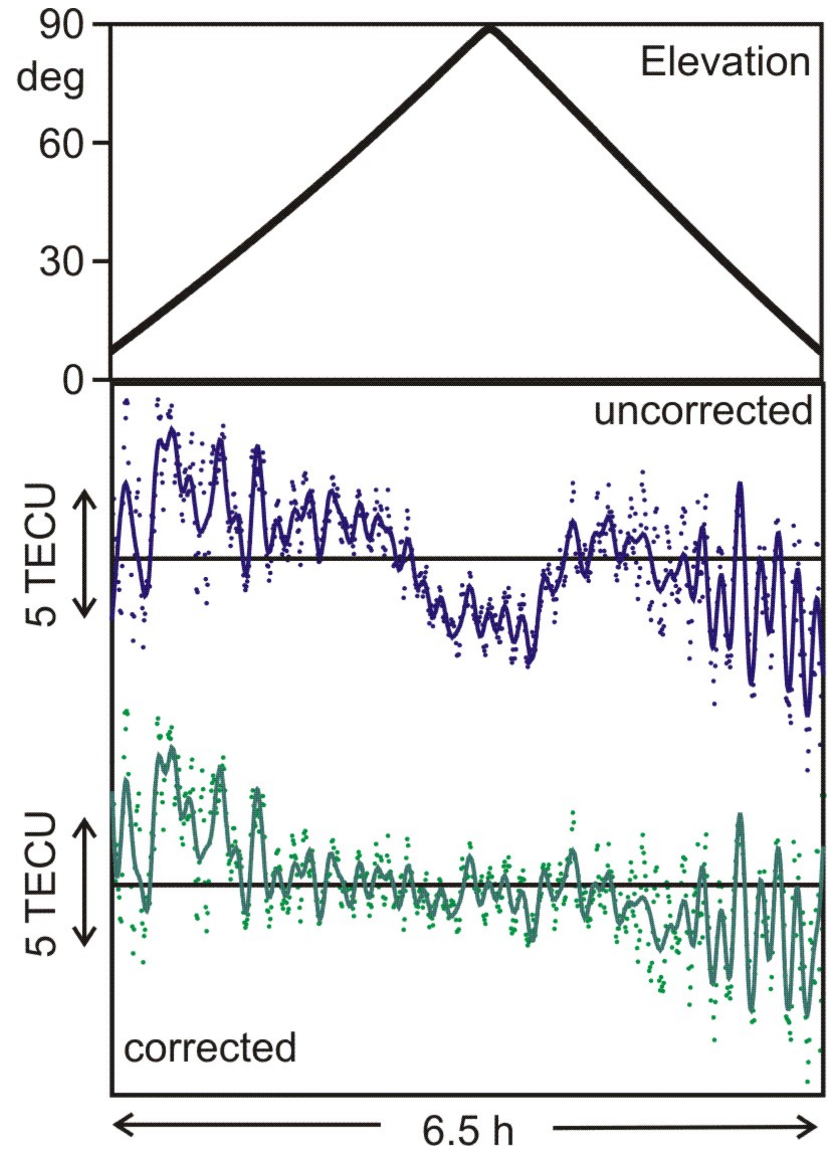
TEC Determination

SVN55
LEIAR25.R4
at IGS station KRGG
DoY 160/2015

Differences:
TEC from phase - TEC from code

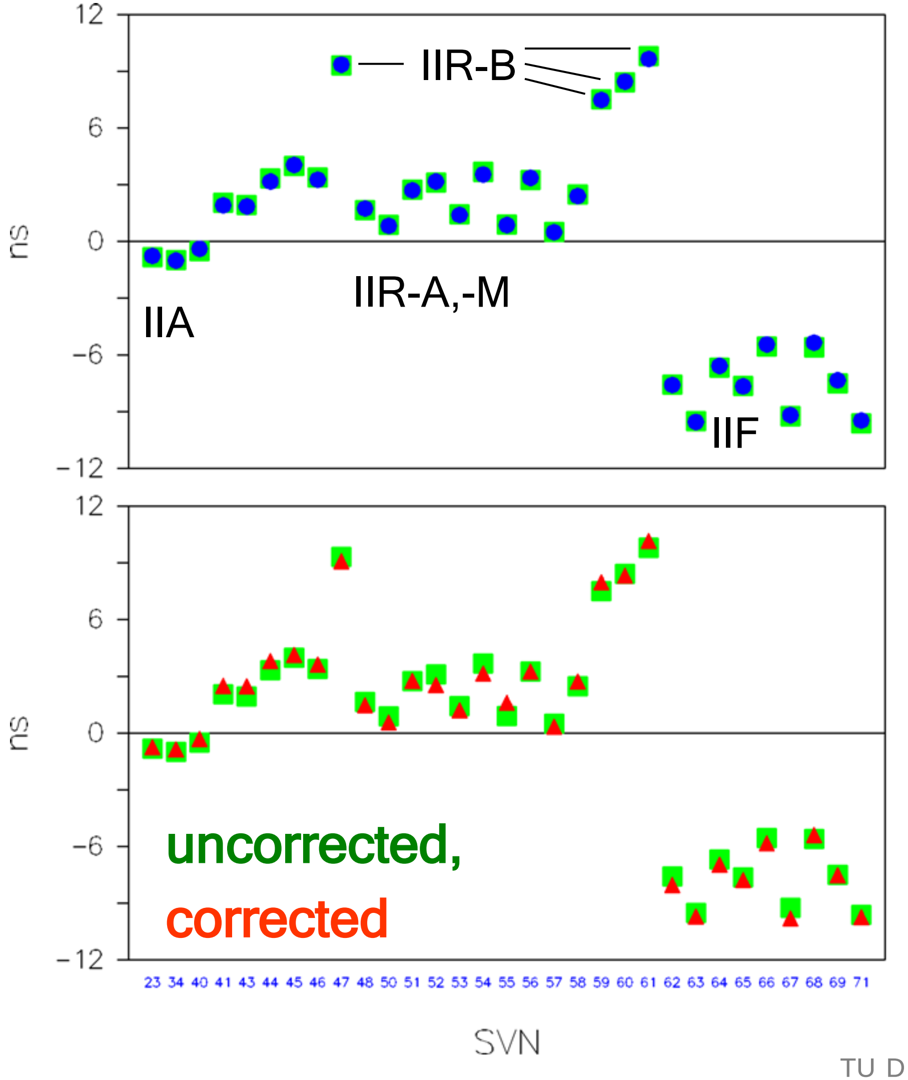
unfiltered, low-pass filtered

code uncorrected, corrected

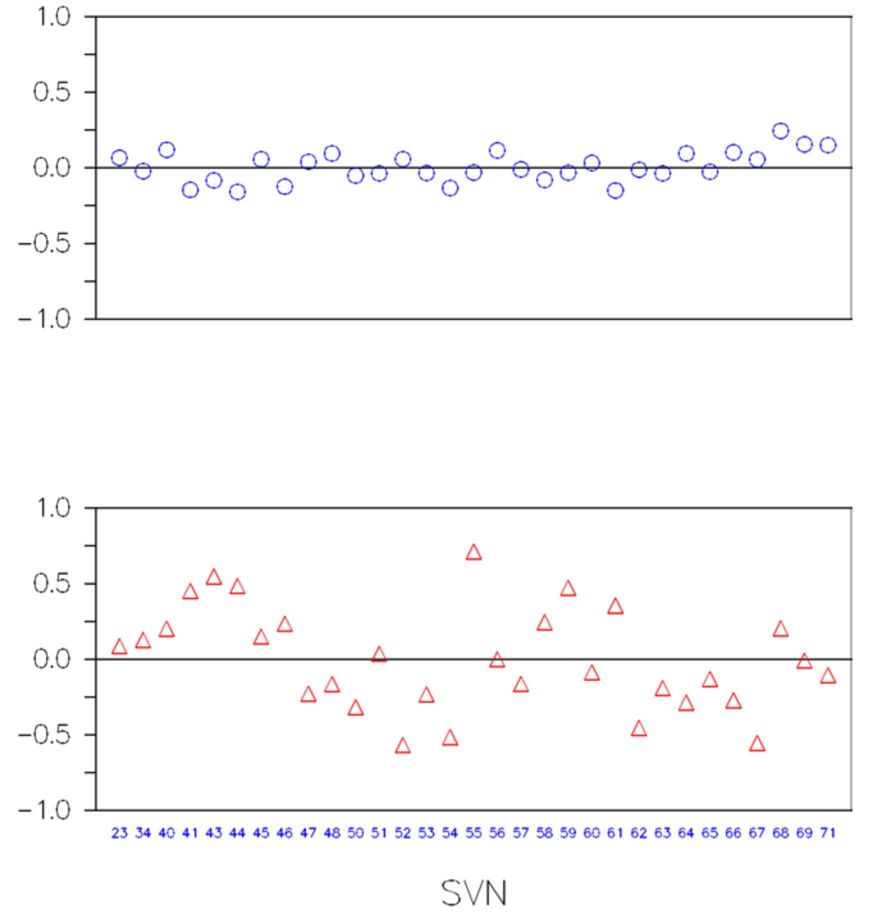


DCB C1P2, own results: DoY 160/2015, 320 IGS stations

own results, Berne: P1P2-P1C1 → C1P2



Differences



Summary, Conclusions

GPS code delay variations

- from MP linear combinations of reference stations
- for C1, P2 → linear combinations

GPS satellites

- good agreement with results from Haines et al. 2012, 2014
- largest corrections for Block IIR

Receiving antennas

- esp. large corrections for some antenna types:
  LEIAR25.R3, LEIAR25.R4, JAV_RINGANT_G3T

Improvements wherever code is used for precise applications

- single-frequency code/phase PPP
- PPP ambiguity fixing
- TEC from code
- ...