TECHNISCHE UNIVERSITÄT DRESDEN

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Nadir- and elevation-dependent GNSS group delay variations

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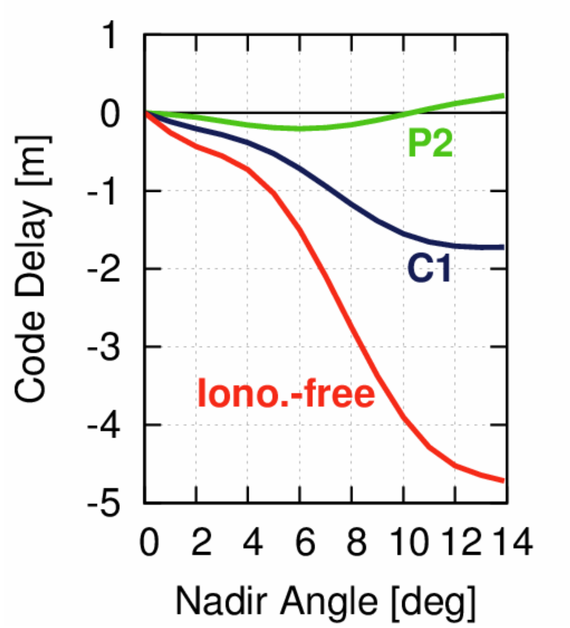
GNSS Group Delay Variations (GDV)

GPS SVN49

- 1st GPS SV with L5 payload
- launched in 2009
- satellite-internal multipath
  → mainly affects code
  → elevation-dependent errors
- never entered service, but still transmits occasionally



How to detect/model GDV?

Code Multipath Observable: MP [m]

$$MP_i = C_i + (m_{ij} - 1) \cdot \Phi_i - m_{ij} \cdot \Phi_j - B$$

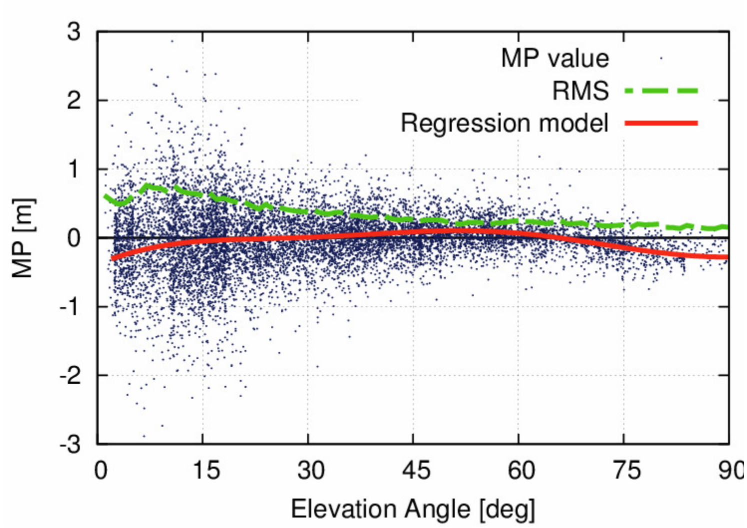
Linear Combination of:

- single-frequency code C_i
- dual-frequency phase Φ_i, Φ_j
- bias term (ambiguities, constant delays) B
- frequency-dependent factor m_{ij}

Free of effects from: orbits, position, clocks, refraction

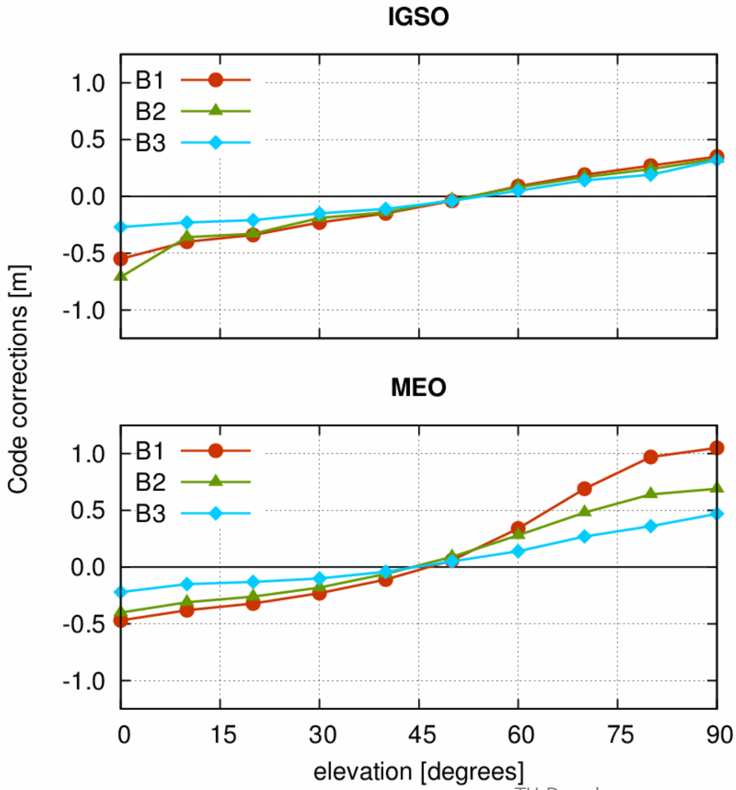
But: code multipath

How to detect/model GDV?



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

Satellites: BDS GDV, 2014

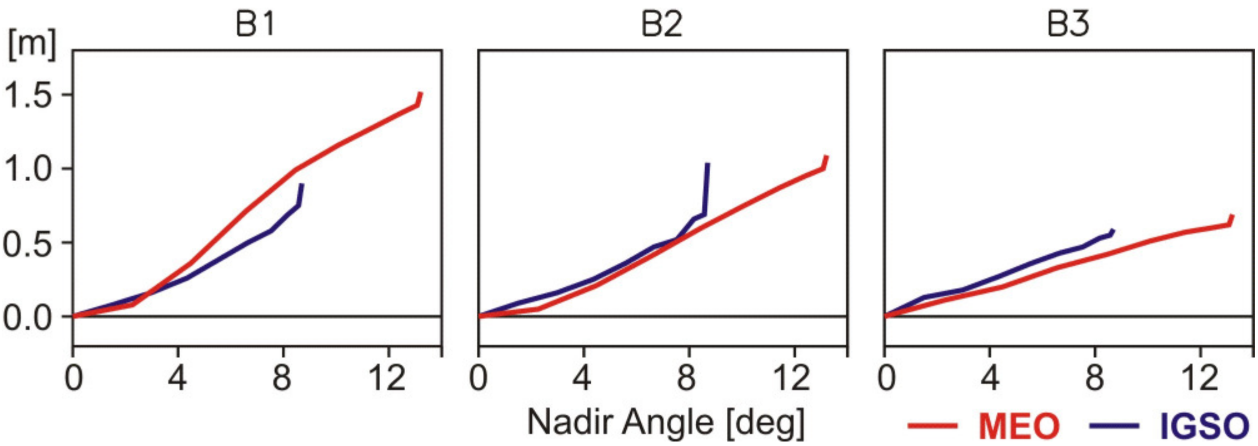


2014:
4 MEO, 5 IGSO

→ GDV on m level

(Wanninger and Beer 2015, GPS Solutions)

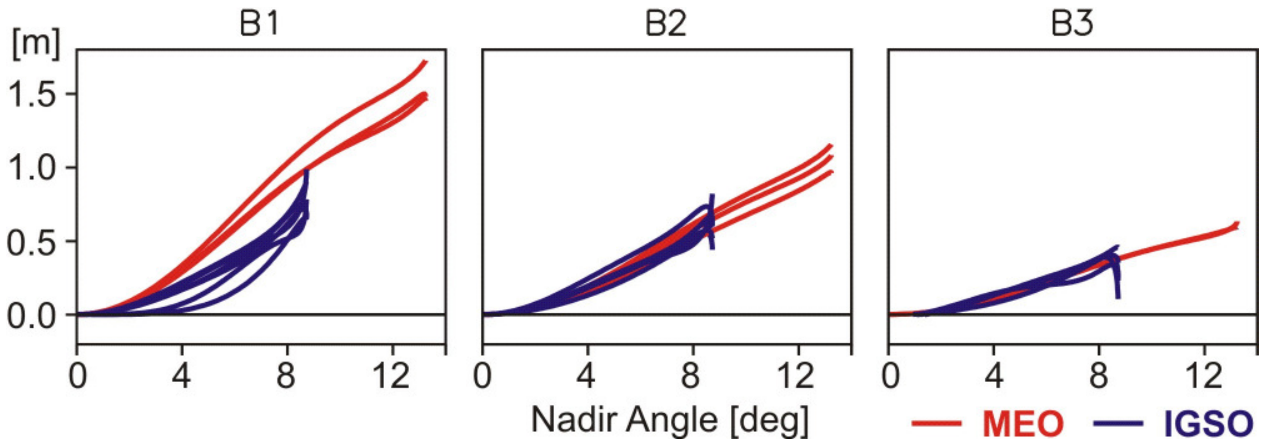
Satellites: BDS GDV, 2014



2014: 4 MEO, 5 IGSO

orbit type specific correction

Satellites: BDS GDV, 2016



2016: 3 MEO, 6 IGSO

satellite individual corrections

Satellites: smaller GDV for all other GNSS

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

Separation of GPS satellite and receiver GDV

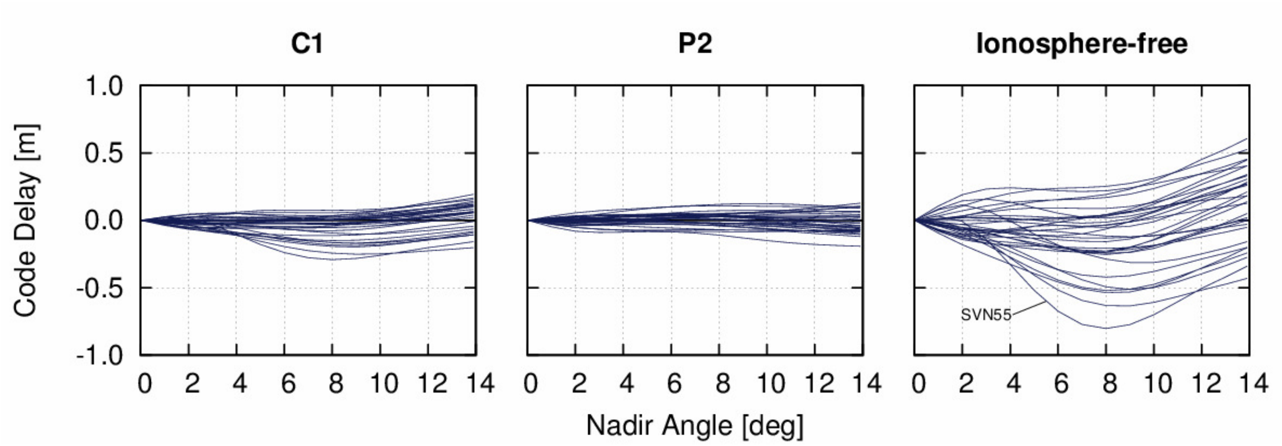
Set of reference antennas, Dorne-Margolin type:

AOAD/M_T
TRM29659.00
LEIAT504 (GG)
ASH700936D_M

→ Satellite GDV refer to this set of receiving antennas

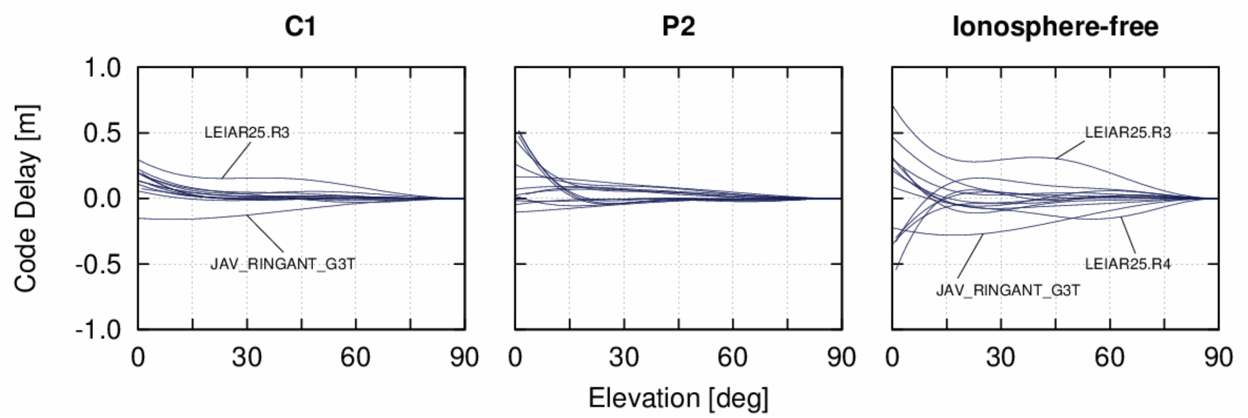
→ All receiving antenna GDV refer to this set of antennas

Results for 31 GPS satellites, 2015



→ GPS GDV: smaller as those of BDS by factor of ~10

Results for 13 receiving antenna types, GPS only



→ GDV of 3 receiving antennas differ significantly from the other geodetic antennas:

JAV_RINGANT_G3T
LEIAR25.R3
LEIAR25.R4

Application of GDV corrections

Not necessary for code-based positioning.

But it improves results of …

PPP-Widelane ambiguity fixing

dual-frequency code/phase Melbourne-Wübbena

Iono.-free single-frequency PPP

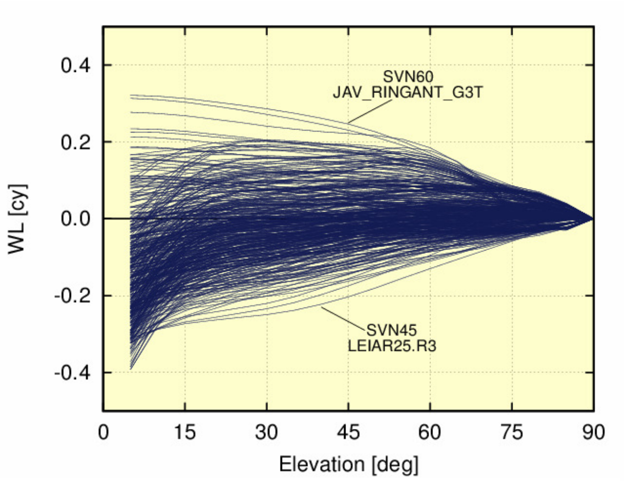
L1 single-frequency code/phase

TEC determination

with dual-frequency code

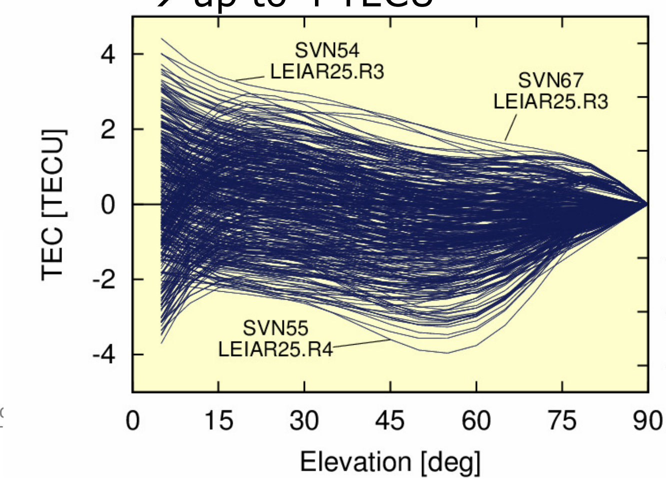
Combined GPS satellite/receiver antenna GDV

31 SV x 13 antenna types = 403 correction data sets



Melbourne-Wübbena LC
→ up to 0.3 widelane cy

Ionospheric LC
→ up to 4 TECU



Summary, Conclusions

GNSS Group Delay Variations (GDV)

- determined from MP linear combinations of reference stations observations
- large GDV for 2nd generation BDS (and GPS SVN49)
- some receiving antenna types differ significantly from other geodetic antennas

Corrections should be applied wherever code is used for precise applications