A new approach for precise orbit determination based on raw GNSS measurements

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Basic considerations

- Basic principle in geodesy:
  - Observations are directly used to estimate parameters
- In GNSS processing this principle is neglected
- Observations are combined beforehand to form derived observations
  - Linear combinations, differences, …

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Why not use them directly?

Principles for precise orbit determination

- Use all available observations as they are observed
  - Code and phase
- No forming of differences
  - Between epochs, receivers, transmitters
- No forming of linear combinations
  - Wide-lane, Ionosphere-free, …
- Known influences are corrected beforehand
  - Relativistic effects, transmitter clock error, phase wind-up, …
- Remaining influences are added as parameters
  - Ionospheric refraction, unknown ambiguities, antenna center variations, …

Goal: kinematic orbits for gravity field determination

Observation equations

Code pseudo range

$$R_i^k - \delta R_i^k = \rho_i^k + c\delta t_i + I_i^k + ACV_i + ACV^k$$

known influences

$$\Phi_i^k - \delta \Phi_i^k = \rho_i^k + c\delta t_i + \lambda n_i^k + I_i^k + ACV_i + ACV^k$$

Phase observation

Observation equations

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Receiver clock error

Ionosphere

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Antenna center Variations Rec/Tra

$$\Phi_i^k - \delta \Phi_i^k = \rho_i^k + c\delta t_i + \lambda n_i^k + I_i^k + ACV_i + ACV^k$$

Phase observation

ambiguity

Building normal equation

- Epoch dependent parameters
  - Position (x,y,z), receiver clock error and ionosphere parameter for each satellite-receiver combination
  - Ionosphere parameter is eliminated
  - 4x4 block remains for each epoch (main diagonal)
- Epoch independent parameters
  - Ambiguities
    - for each continuous track of a satellite
    - for each carrier frequency
  - Antenna center variations
    - Receiver
    - Transmitter

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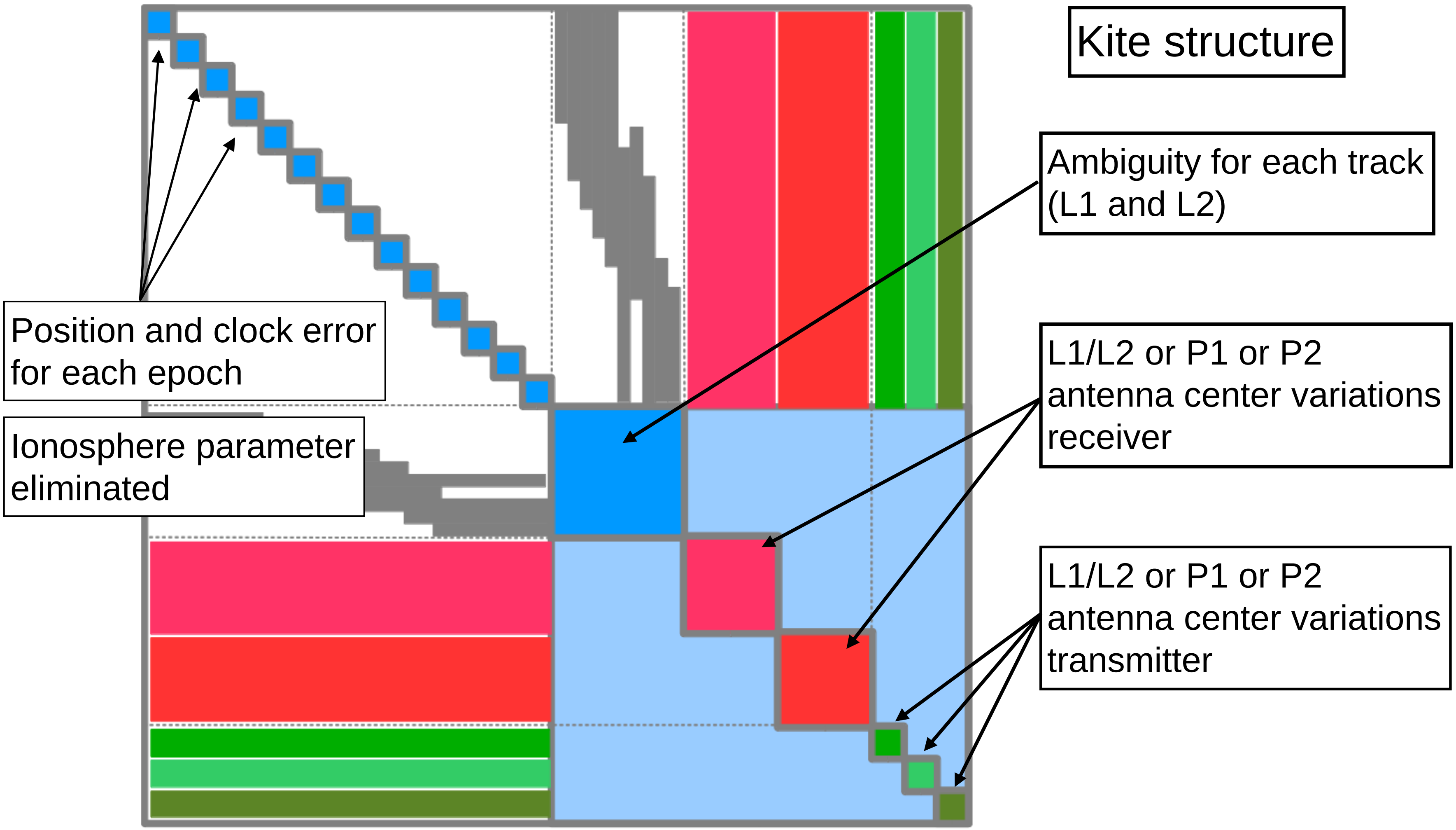
Normal equation



Antenna center variations

For code and phase observations

For receiver

- Spherical harmonics expansion

For transmitters

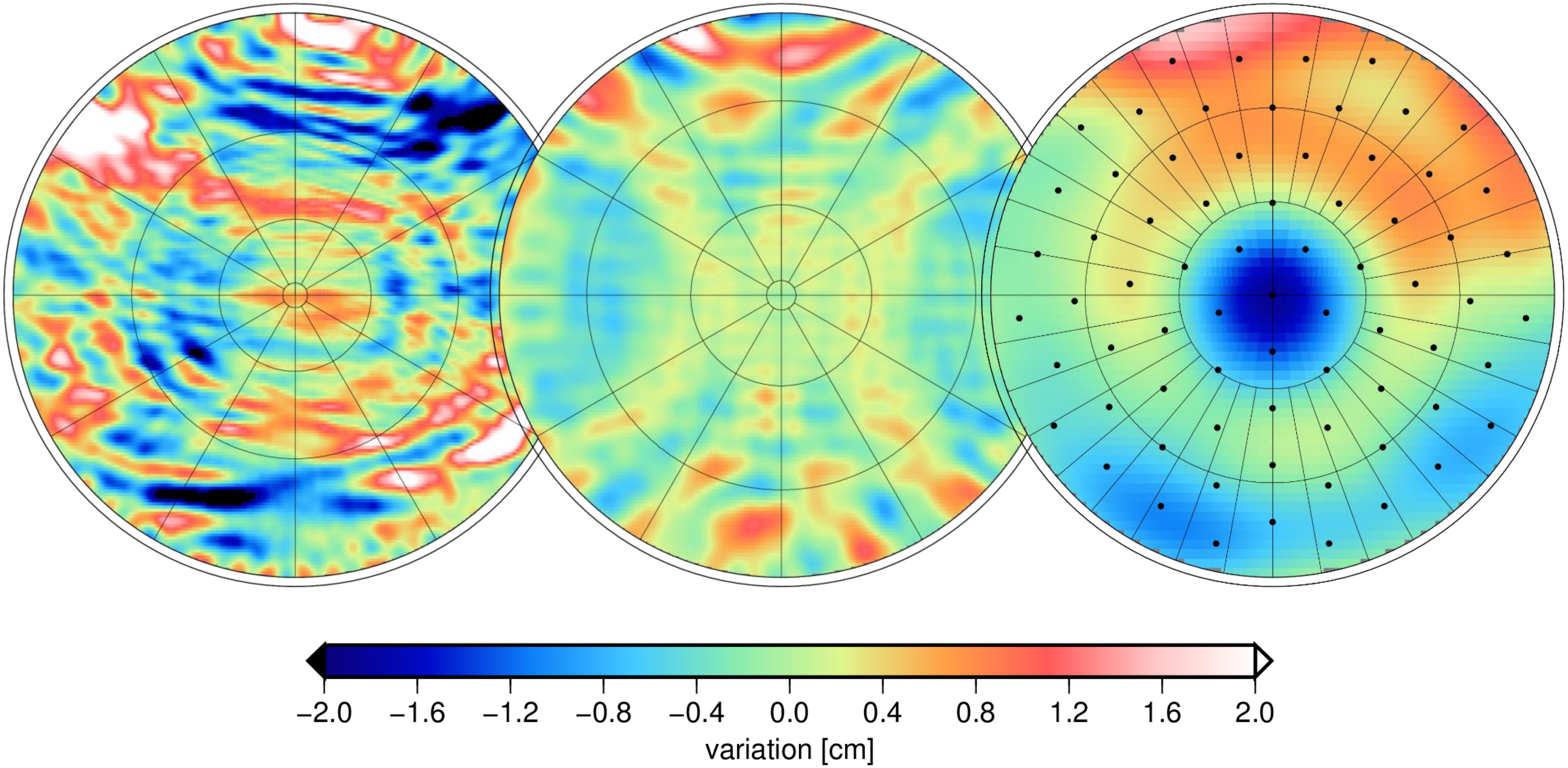
- Radial basis functions

Degree 0 and 1 omitted to avoid singularity
(constant and origin of antenna)

Both representations are <u>azimuth-elevation dependent</u>

Antenna center variations – Example L1/L2

- GOCE
- GRACE A
- SVN 41 (Block IIR-A)



Antenna center variations – Example P1

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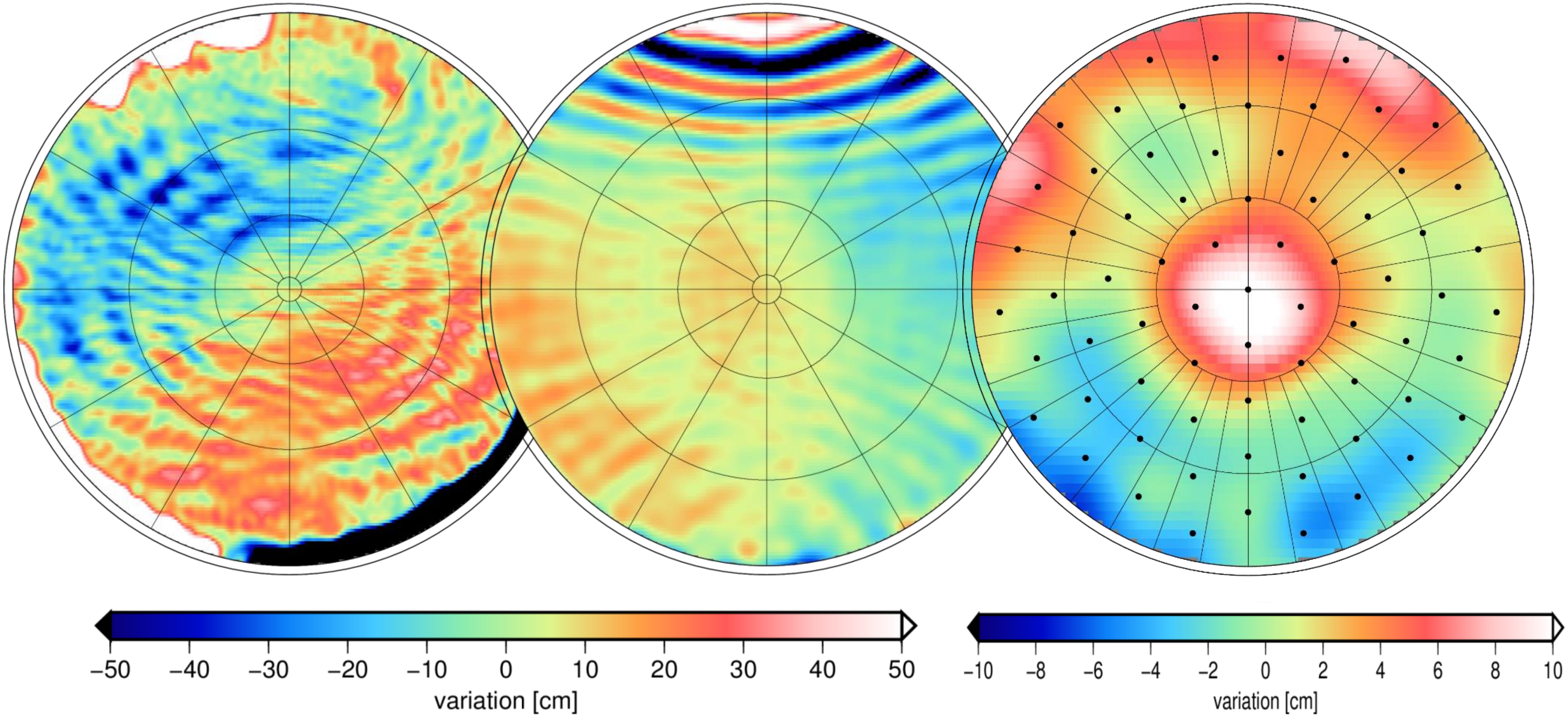
- SVN 41 (Block IIR-A)



Raw GNSS measurements

- Measurements as they are observed

Advantages

- Original noise level
- Parameters are not mixed up
  - Ambiguities on each frequency can be accessed directly
  - Gives possibility to fix them

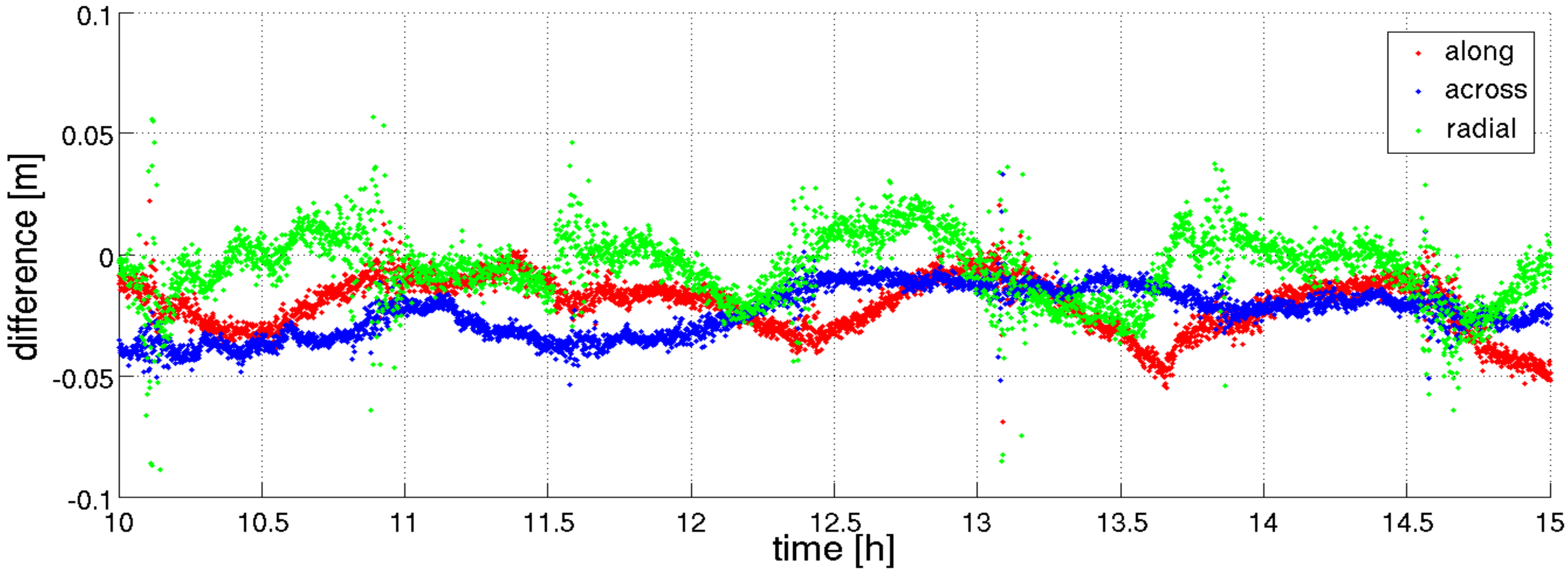
Disadvantages

- Influences are not eliminated/reduced

Results for GOCE

Example: GOCE 02.11.2009 10:00 – 15:00

Compared to official reduced-dynamic orbit

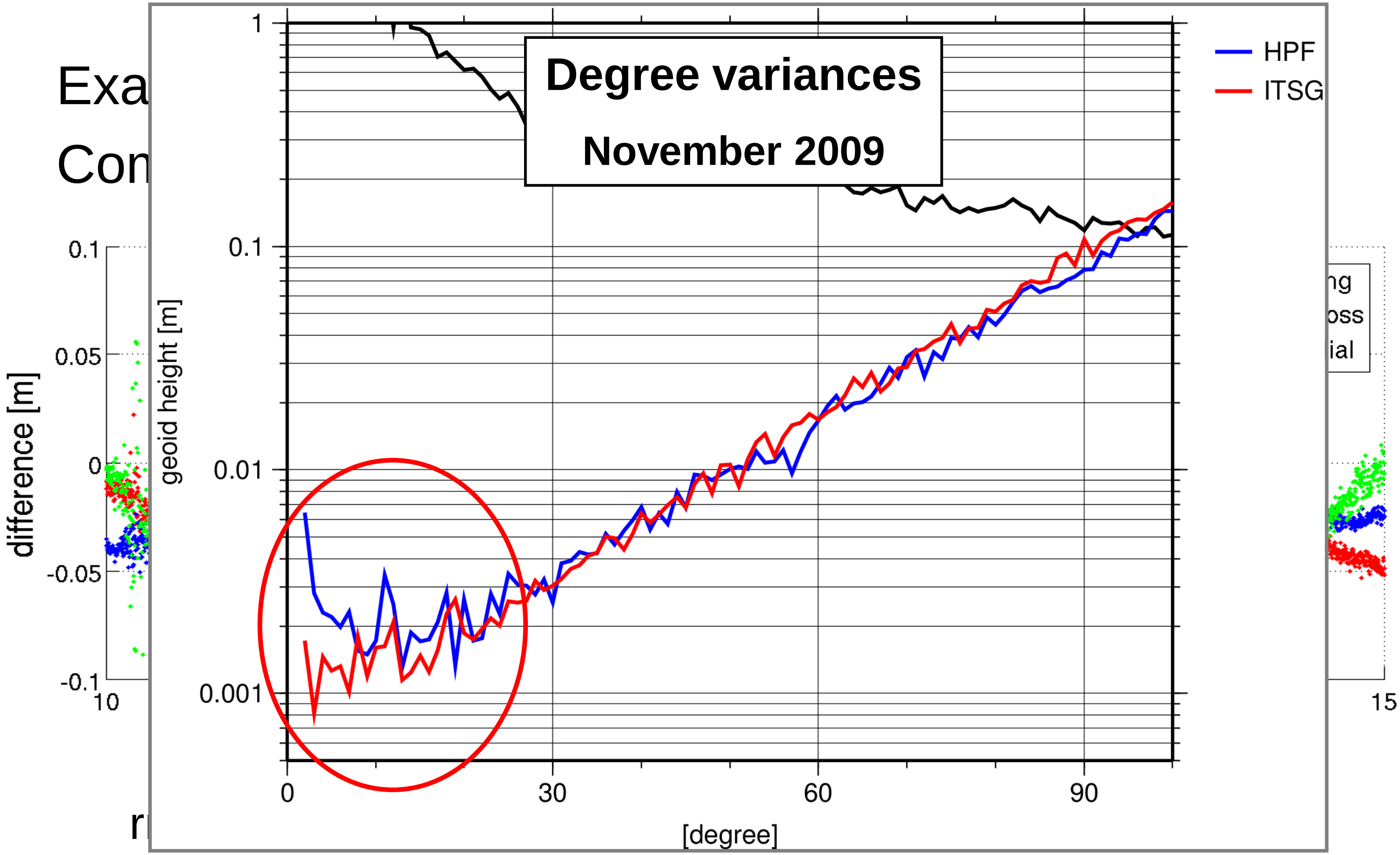


rms: along: 1.7 cm / across: 1.2 cm / radial: 2.3 cm

Results for GOCE

Exa

Con



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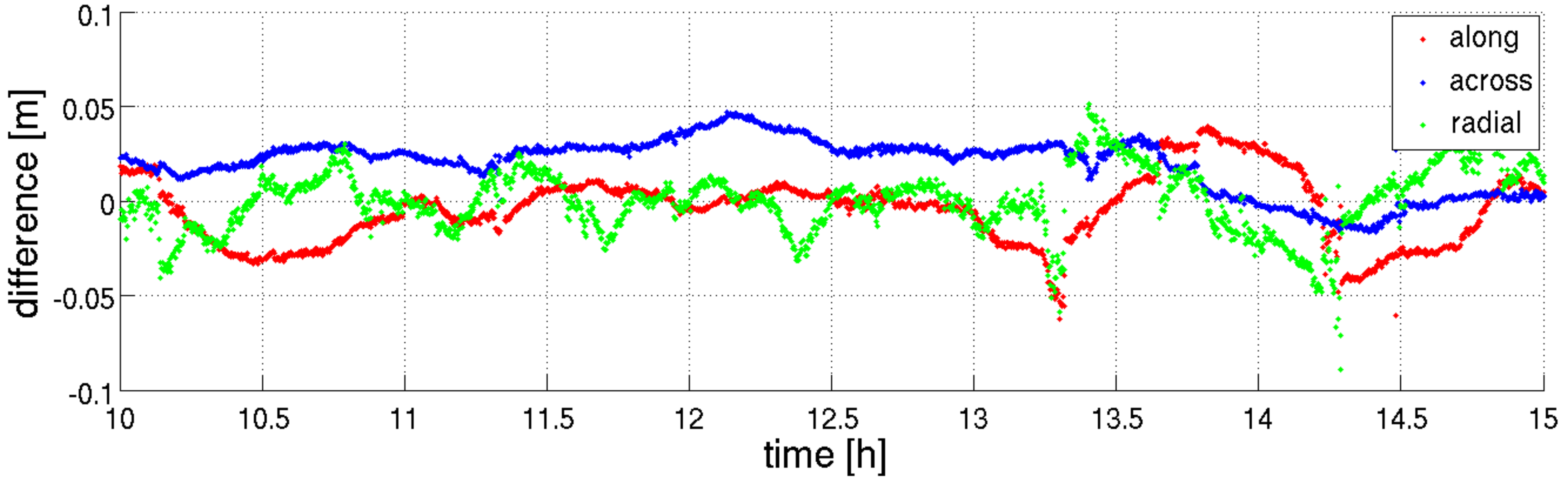
Results for GRACE

Example: GRACE A, 01.05.2008 10:00 – 15:00

Compared to official reduced-dynamic orbit

IGS values for transmitter antenna center variations used

⇨ nadir dependent



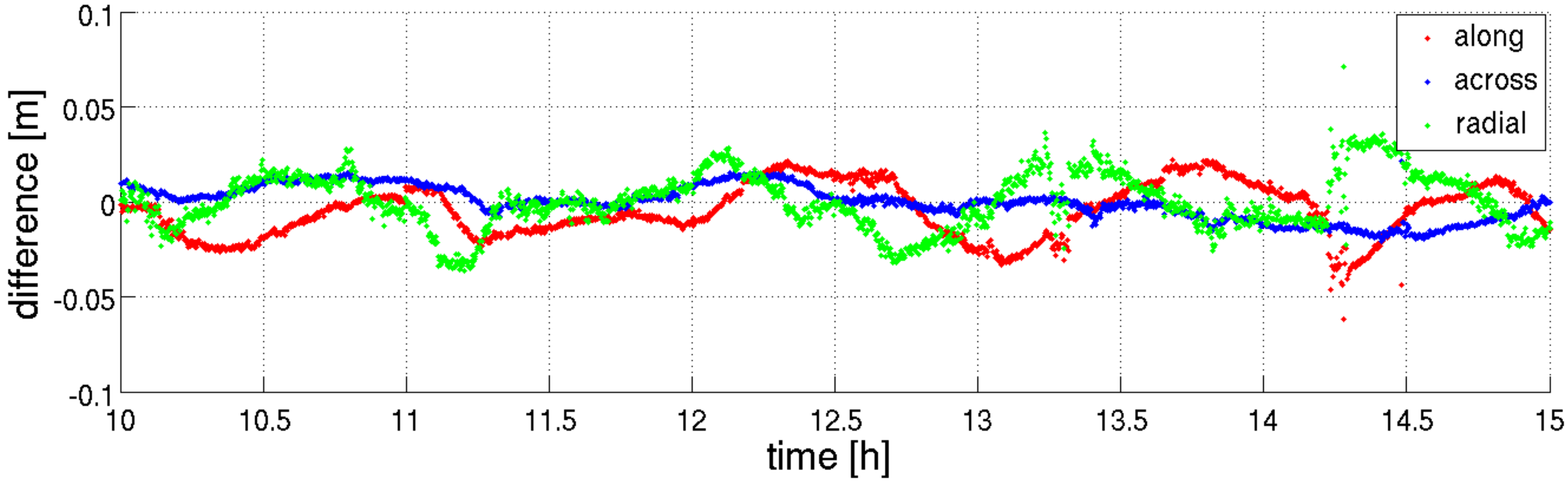
rms: along: 2.3 cm / across: 2.0 cm / radial: 2.7 cm

Results for GRACE

Example: GRACE A, 01.05.2008 10:00 – 15:00

Compared to official reduced-dynamic orbit

Radial basis functions used for transmitter antenna center variations ⇨ azimuth-nadir dependent



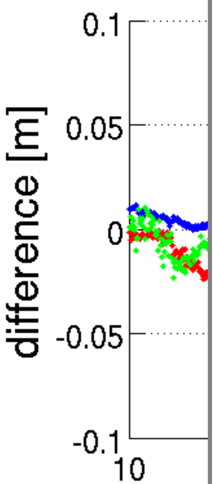
rms: along: 1.8 cm / across: 1.5 cm / radial: 2.0 cm

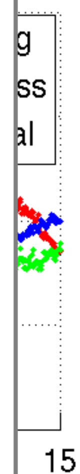
Results for GRACE

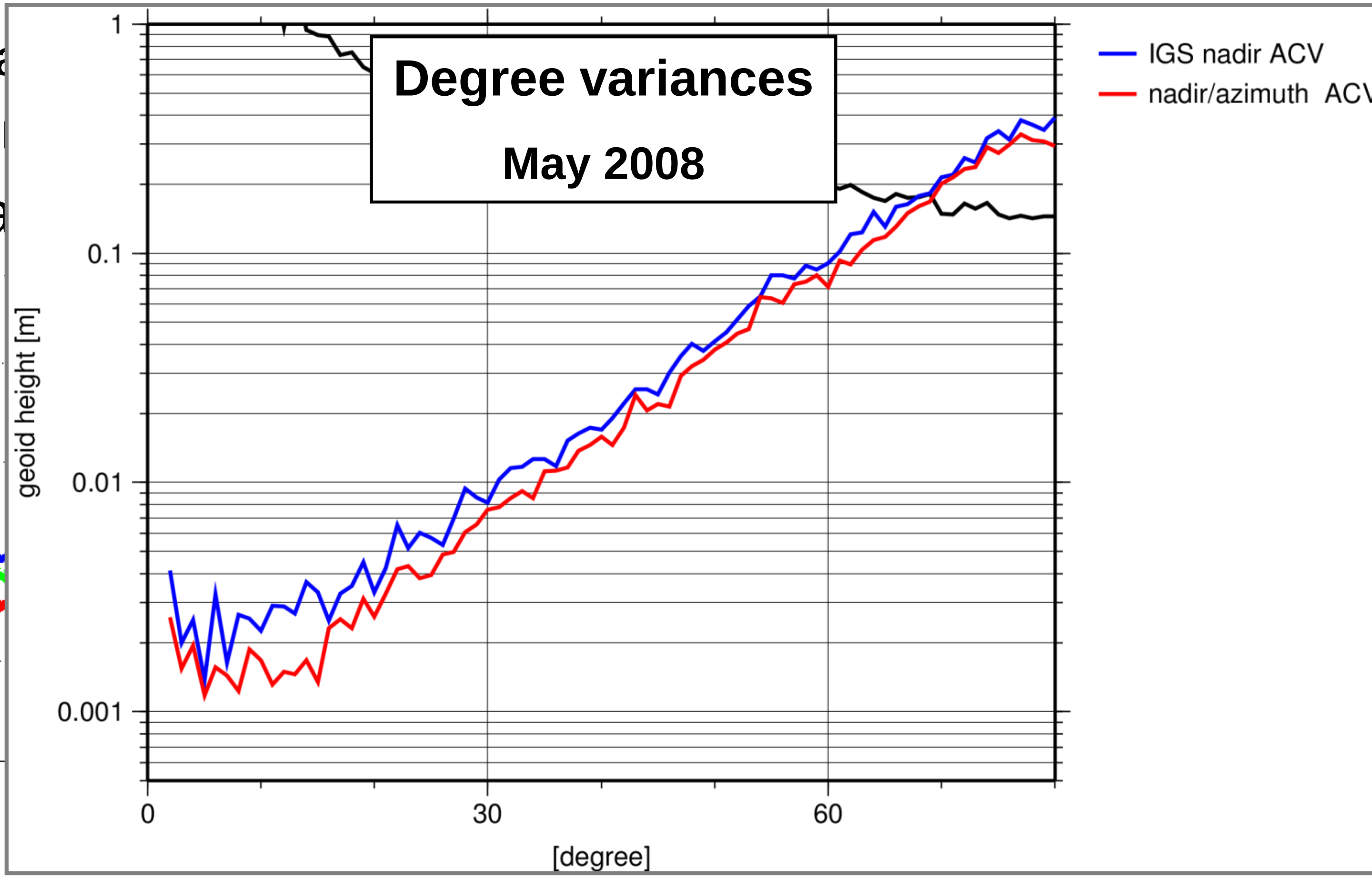
Exa

Co

Ra nter







Conclusions

- Method is straightforward
- Well suited for modernized GNSS environment with additional frequencies (L5,…)
- Ambiguities are directly accessible on each frequency ⇨ integer nature is preserved
- Antenna center variations can be estimated
  - For receivers and transmitters
  - For phase and code observations
- Current results are suitable for gravity field recovery

Conclusions

- Next steps:
  - –Ambiguity fixing
  - –Compute longer time series
    - CHAMP, GRACE, and GOCE
  - –Prepare for SWARM
  - –Validation in terms of position and gravity field results

- The orbits will be published: itsg.tugraz.at

Thank you for your attention!