Institut für Erdmessung

Leibniz Universität Hannover

Mitigation of ionospheric effects on Swarm GPS observations and kinematic orbits

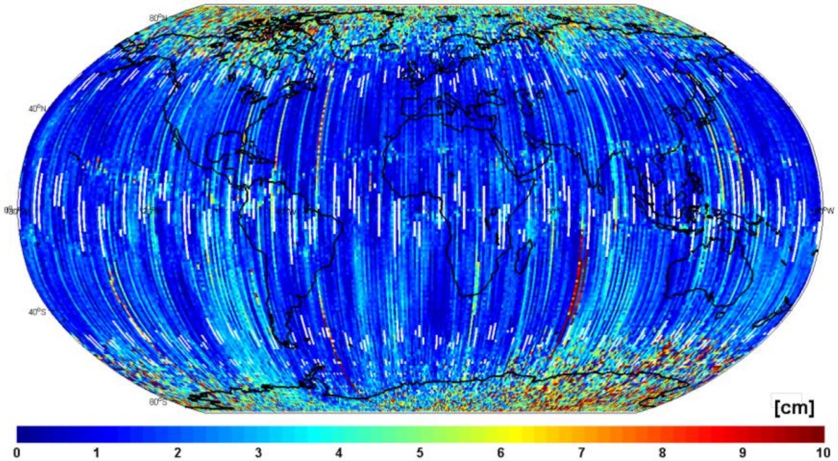
Le Ren & Steffen Schön

Institut für Erdmessung

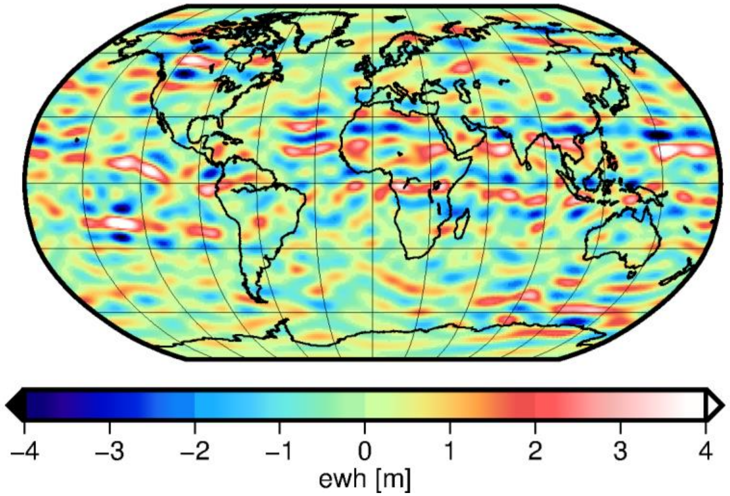
Leibniz Universität Hannover

DynamicEarth SPP 1788

Motivation



Radial residuals in May, 2015, Swarm A



Gravity field in May, 2015, Swarm A

Large high frequency noise at polar and equatorial areas

Systematic errors at geomagnetic bands along ±15° in the gravity field

Strategies to mitigate the impacts of scintillation

- 1) Simple elimination of noisy parts impacts:
  - Strength of the positioning reduced
  - Ambiguity estimation more difficult
  - Low degrees of gravity field solutions affected

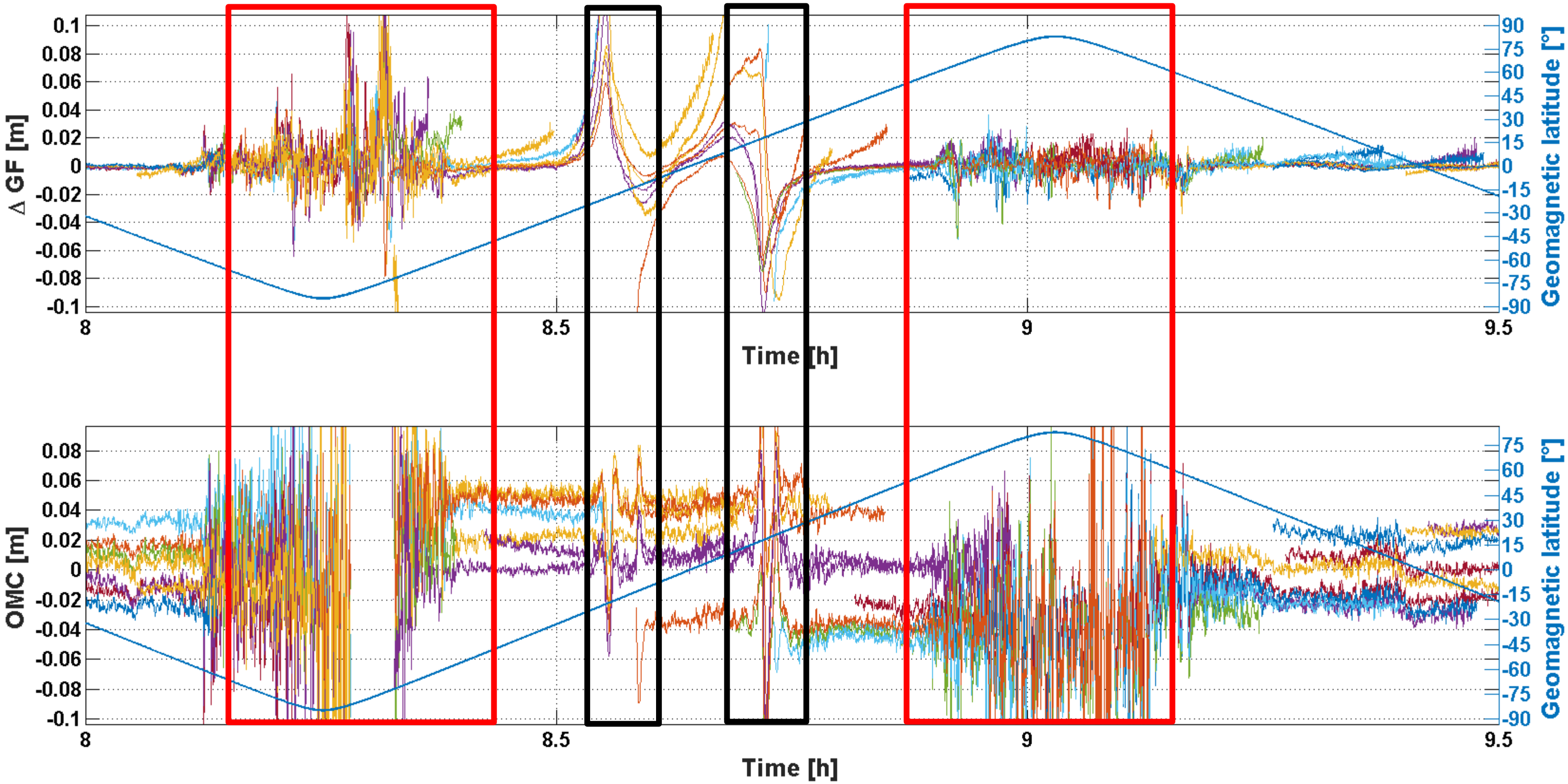
- 2) Downweighting of noisy observations:
  - Many observations are disturbed simultaneous

- 3) Physically based mitigation of the impacts

Structure

1. Impact of ionospheric scintillations
2. Mitigation of the effects at polar areas
3. Mitigation of the effects at equatorial areas
4. Conclusions

1. Impacts of ionospheric scintillations



Two kinds of impact:

- Large high frequency noise at polar areas and some equatorial areas
- Systematic errors at equatorial areas

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Filtering using Mátern family matrix

Step1
- Preprocessing step
- Substraction of the mean and polynomial fitting of the observations

→ OMC or detrended OBS

Step2
- Noise detection in the proprocessed observations
- Rate of change $\left|\frac{d\sigma}{dt}\right|$ with σ ionospheric free linear combination of carrier phase observations
- Empirical threshold 3σ 0.012 ms^{-1}

→ ΔOMC
Δ_4OBS
ΔGF

Step3
- Extraction of the iono-TS: minimal length 250 s
- Filtering with adequate VCM

→ Mátern covariance matri

Step4
- Reconstruction of the observations

Mátern covariance matrix

- An adequate fully populated covariance matrix **W** is built based on the knowledge of the ionospheric spectral density:

$$\mathbf{w}(\tau) = (\alpha\tau)^{\nu} K_{\nu}(\alpha\tau)$$

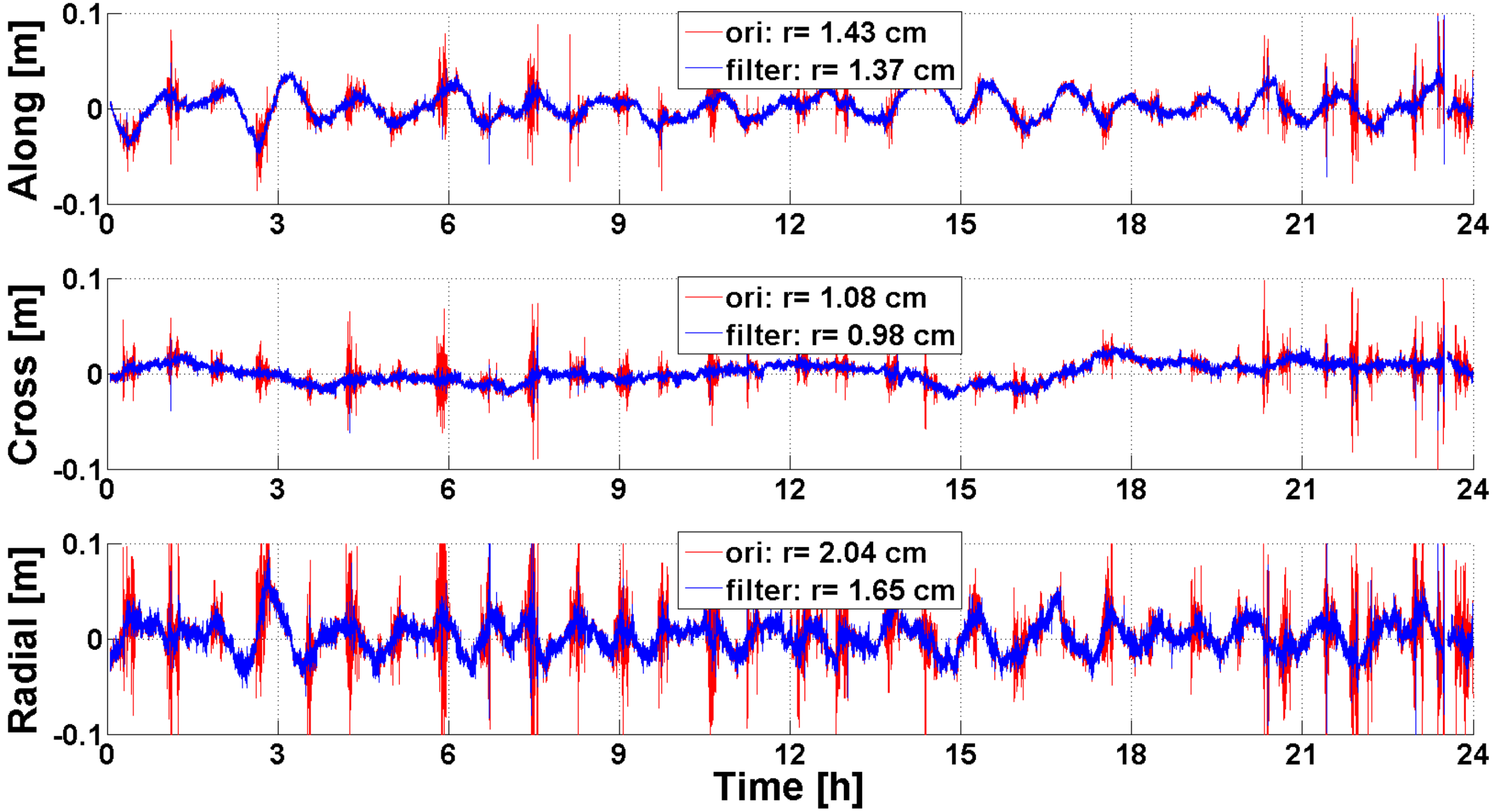
- The filtered time series corresponding to ionospheric scintillations is extracted from the identified time series:

$$\boldsymbol{y}' = \gamma \widehat{\boldsymbol{y}},$$

with $\widehat{\boldsymbol{y}} = \mathbf{w}^{-\frac{1}{2}} \boldsymbol{y}$, $\gamma = \frac{\sigma_{\varphi,ref}}{\sigma \widehat{\boldsymbol{y}}}$, and $\sigma_{\varphi,ref} = 3\,mm$

- The filtered time series have the similar spectral density with the normal observations, when $\alpha = 1.5$ and $\nu = 1$.

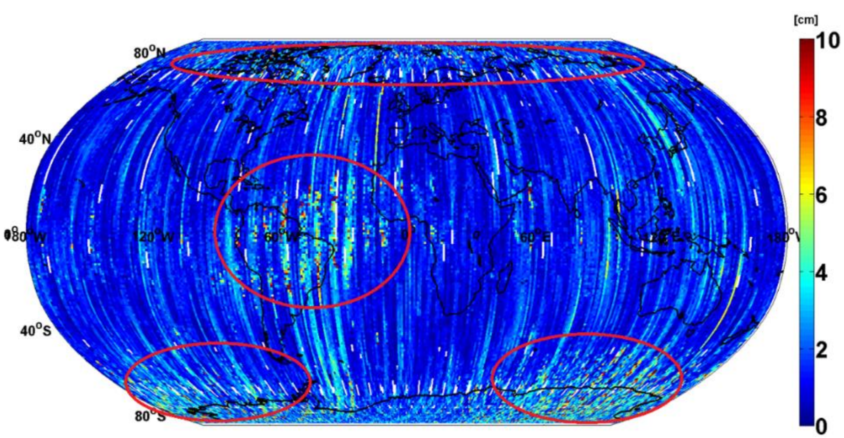
Improved kinematic orbit determination

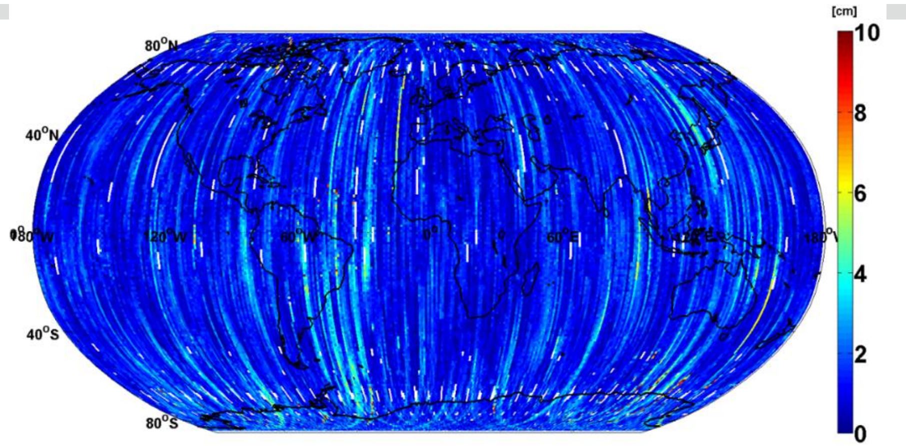


DoY 333, 2015 Swarm A

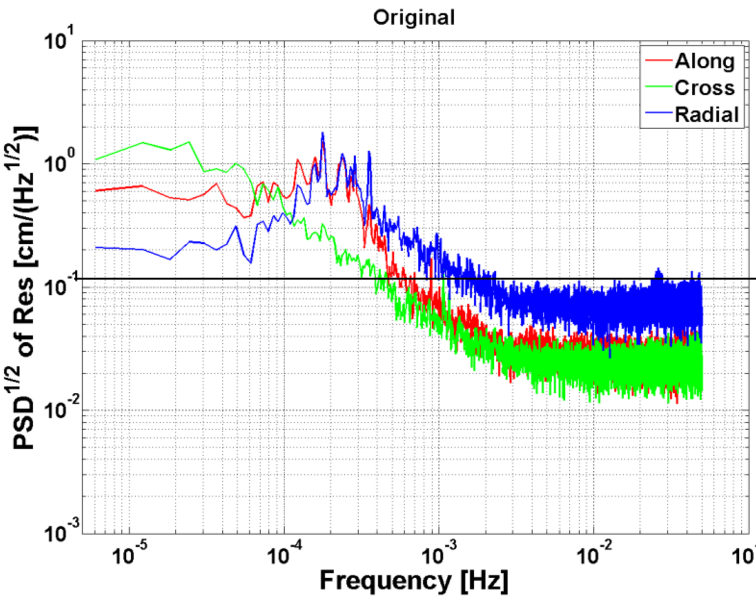
Daily RMSE in radial direction can be reduced by around 20%.

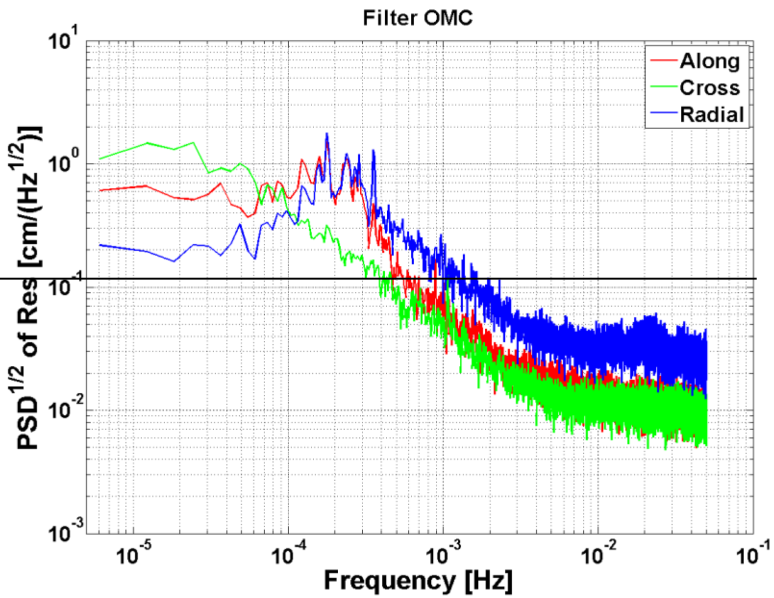
Ionospheric filtering with OMC



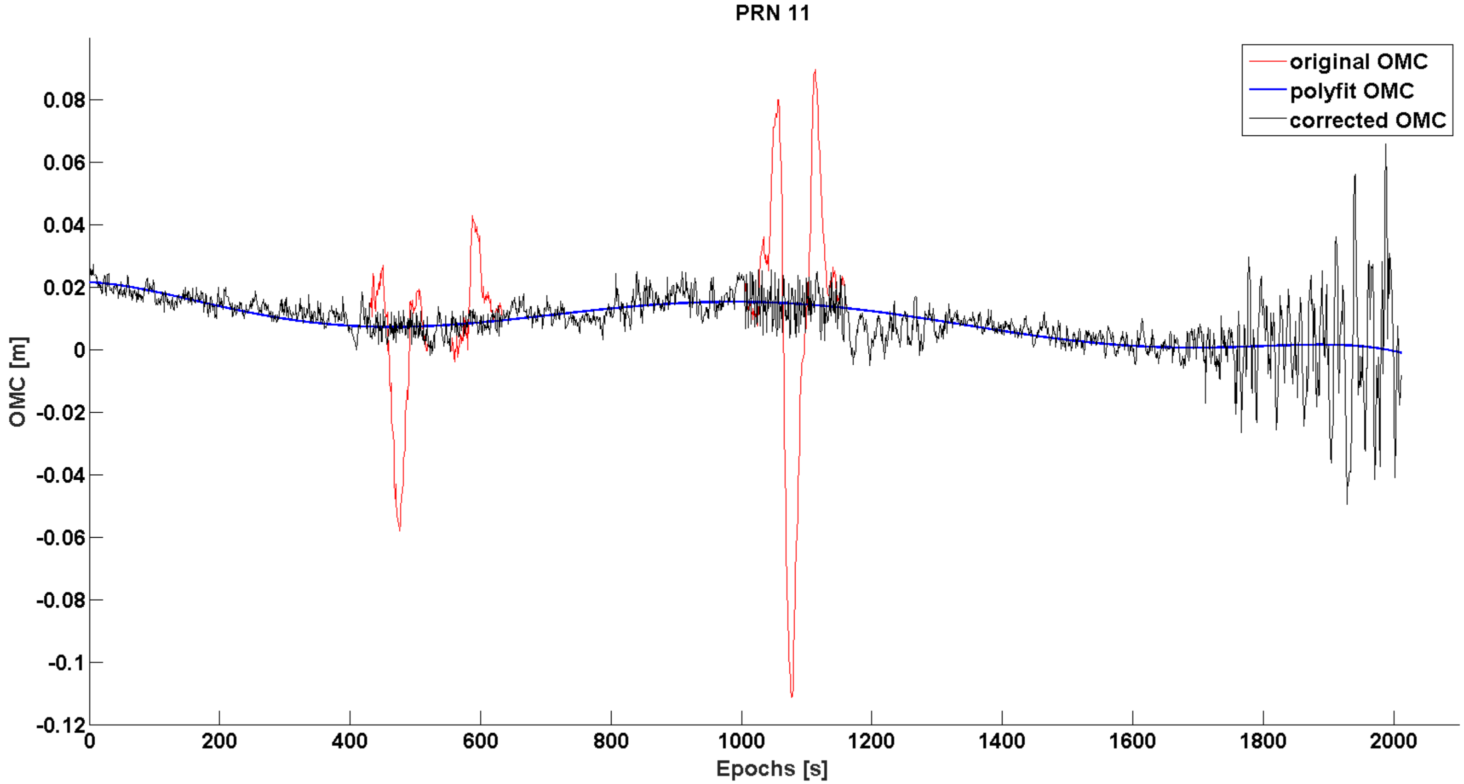


November, 2015, Swarm A





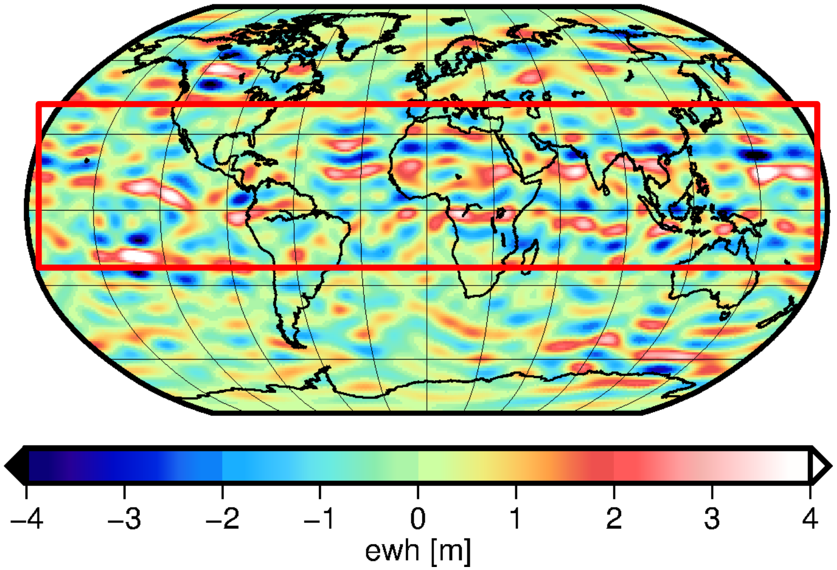
Correction of systematic errors



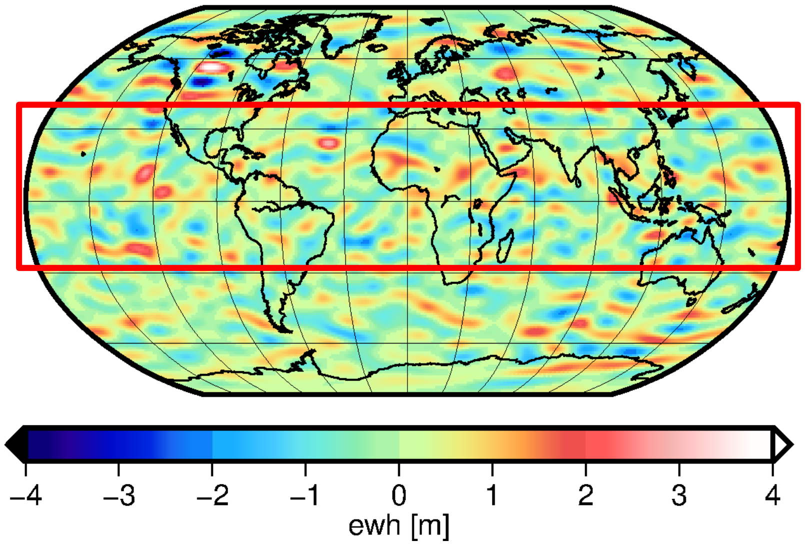
DoY 135, 2015 Swarm A

Using white noise instead of systematic errors

Improved gravity field



Gravity field from original orbits
RMS = 1.047 m



Gravity field from corrected orbits
RMS = 0.718 m

Swarm A, April 2015

5. Conclusions

- Mátern covariance matrices with $\alpha = 1.5$ and $\nu = 1$ are used to mitigate the impact of noise increase due to ionospheric scintillations and these homogenize the observation noise.
- The high frequency noise caused by ionospheric scintillations is strongly eliminated using Mátern covariance matrix, with 20% in the radial direction.
- Systematic errors at equatorial areas can be eliminated using white noise instead, in order to reduce the errors in the gravity field.

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Thank you for your attention

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Le Ren & Steffen Schön
Institut für Erdmessung
Schneiderberg 50
D-30167 Hannover, Germany
E-Mail: ren@ife.uni-hannover.de
Tel: +49 (511) 762 3892
Fax: +49 (511) 762 4006
URL: http://www.ife.uni-hannover.de/

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