

Signatures of the equatorial Ionosphere in kinematic positioning and gravity field recovery

**using Swarm $L3$ residuals and time derivatives of the $L4$
linear combination**

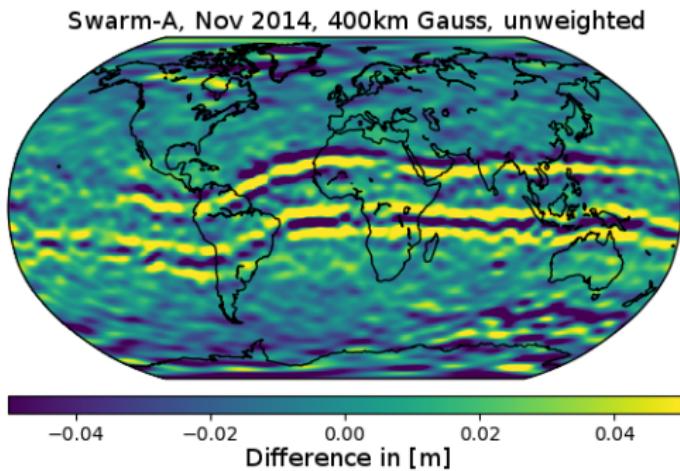


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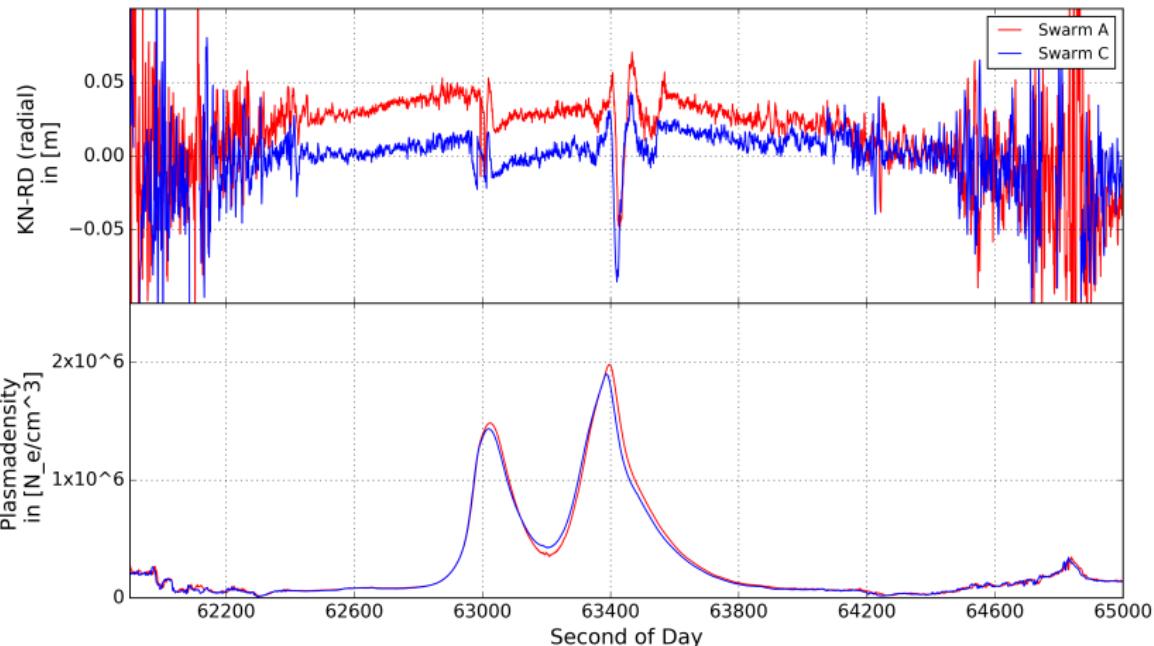
7th Swarm Data Quality Workshop, Delft, 24-27 Oct 2017

Swarm gravity field



Geoid height differences, static GRACE gravity field AIUB-GRACE03S
- Swarm A gravity field, November 2014

Kinematic-Reduced dynamic Orbit (radial) and Plasmadensity



Observation equations

$$L_{1k}^i = \rho_k^i - I_k^i(f_1) + T_k^i + c\delta_k - c\delta^i + \lambda_1 n_{1k}^i$$

$$L_{2k}^i = \rho_k^i - I_k^i(f_2) + T_k^i + c\delta_k - c\delta^i + \lambda_1 n_{2k}^i$$

$$L_{3k}^i = \frac{1}{f_1^2 - f_2^2} (f_1^2 L_{1k}^i - f_2^2 L_{2k}^i) \text{ : ionosphere-free linear combination}$$

$$L_{4k}^i = L_{1k}^i - L_{2k}^i \text{ : geometry-free linear combination}$$

ρ_k^i : Slant range

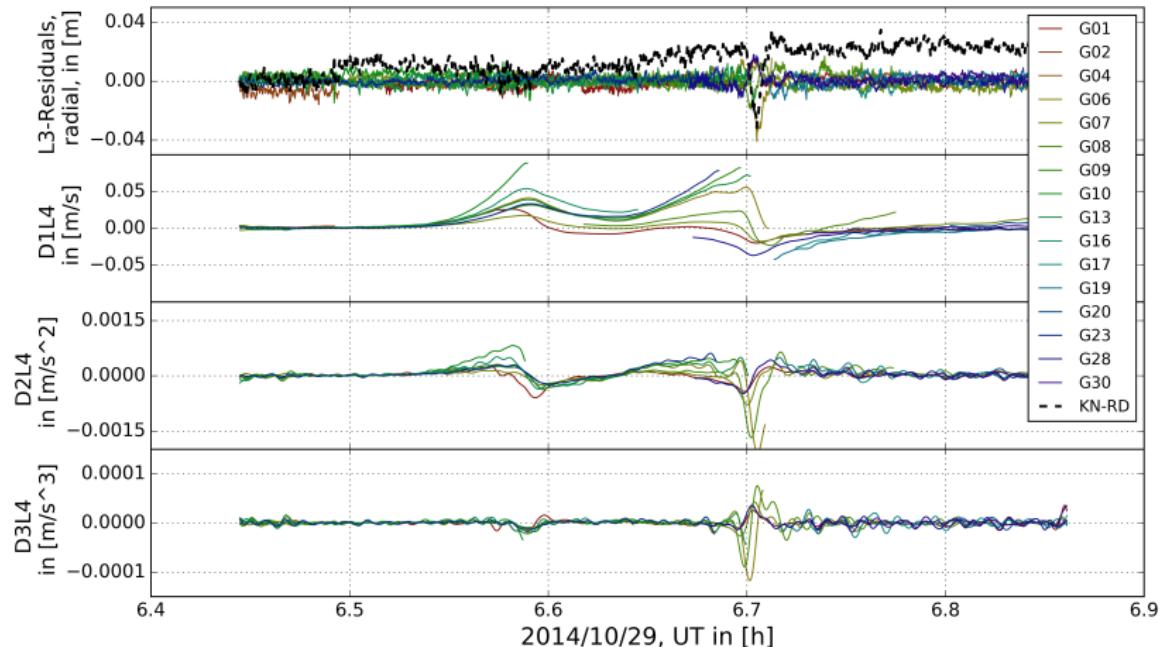
I_k^i : Ionospheric phase delay

T_k^i : Tropospheric delay

δ_k, δ^i : Receiver/transmitter clock correction

n_{1k}^i, n_{2k}^i : ambiguities

Time derivatives of the L4



The Model

- Idea: using the epoch wise variances in the derivatives to detect possible affected epochs.
- $\mathcal{V}(t)$ is the set of visible GPS satellites at epoch t .
- $D^i L_j$ i -th time derivative of linear combination j .
- sd denotes the standard deviation.

$$sd_{L3}(\hat{\mathcal{V}}(t), t) = c_0 + c_1 \cdot sd_{D^1 L_4}(\mathcal{V}(t), t) \\ + c_2 \cdot sd_{D^2 L_4}(\mathcal{V}(t), t) + c_3 \cdot sd_{D^3 L_4}(\mathcal{V}(t), t)$$

Observation specific weighting

We define an observation specific weight:

$$\omega(G_k, t) = sd_{L3}(-G_k, t) / sd_{L3}(t)$$

G_k : GPS-Satellite k

Observation specific weighting

We define an observation specific weight:

$$\omega(G_k, t) = sd_{L3}(-G_k, t)/sd_{L3}(t)$$

G_k : GPS-Satellite k The Observation specific σ is defined as $1/\omega$ and was scaled with a factor of 100.

$$\sigma_{scaled} = (\sigma - 1) \cdot 100$$

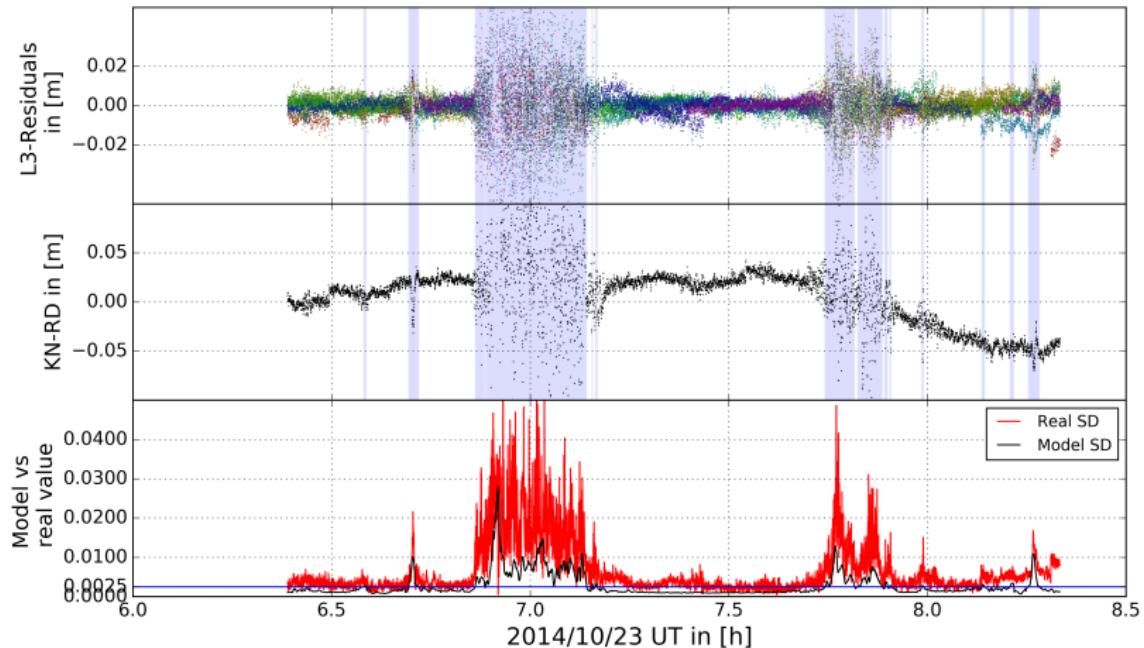
Any $\sigma < 1$ was set to 1.

Evaluation

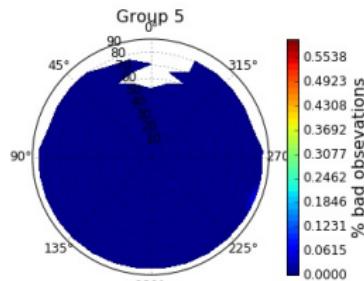
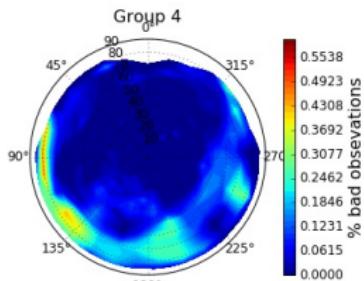
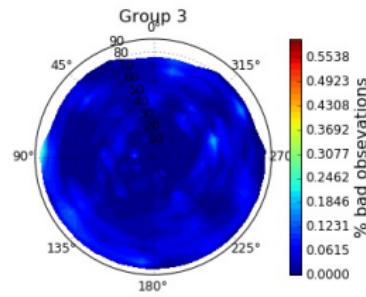
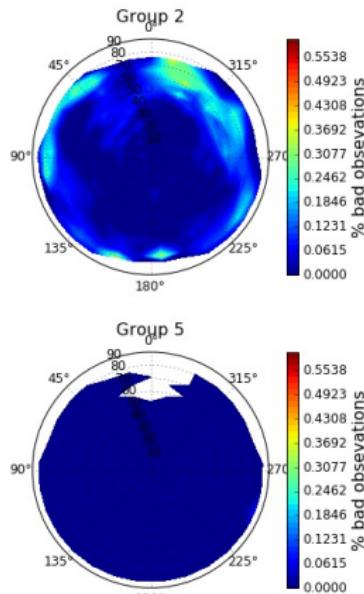
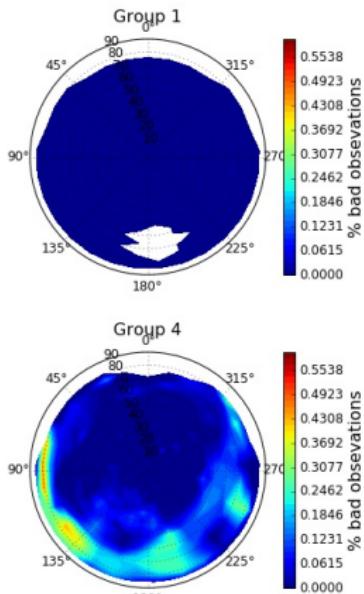
Model trained individually for 30 days in Nov. 2014

	mean	sd	min	max
c_0	0.00094	0.00009	0.00084	0.00133
c_1	-0.0520	0.0115	-0.0820	-0.0300
c_2	9.4031	1.0230	7.9196	12.3240
c_3	73.4637	13.1162	47.7995	108.0637
correlation	0.8249	0.0712	0.6138	0.8942

Detection of affected epochs

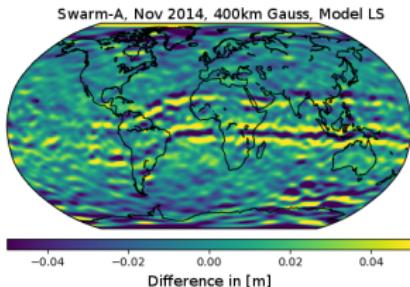
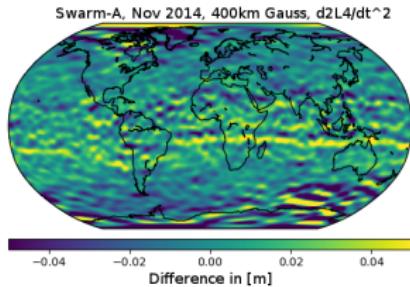
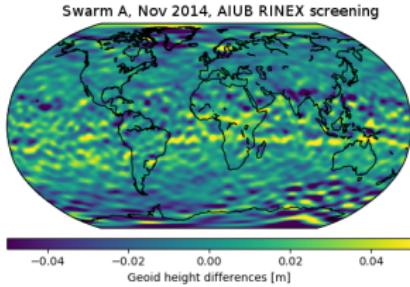
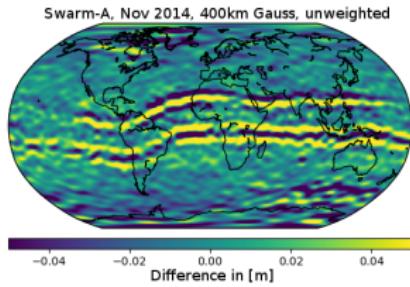


Identification and position of affected Satellites

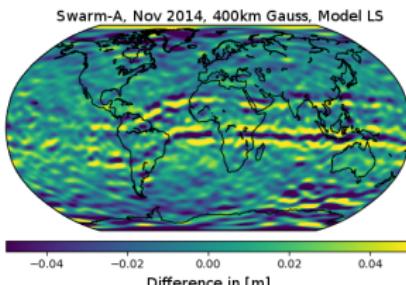
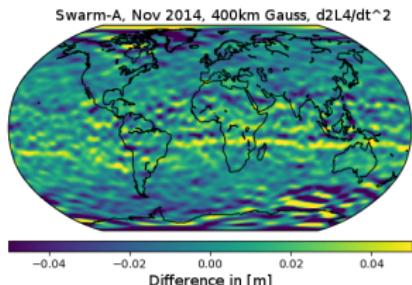
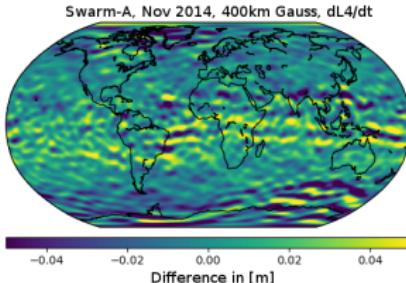
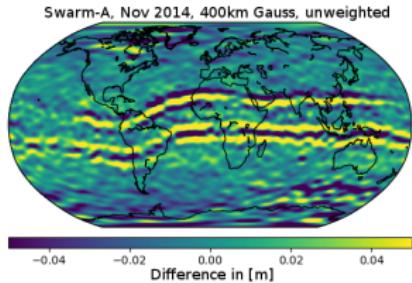


Group	MLAT(UP)
1	-35 → -25
2	-25 → -10
3	-10 → 10
4	10 → 25
5	25 → 35

Observation specific weighting (preliminary results)

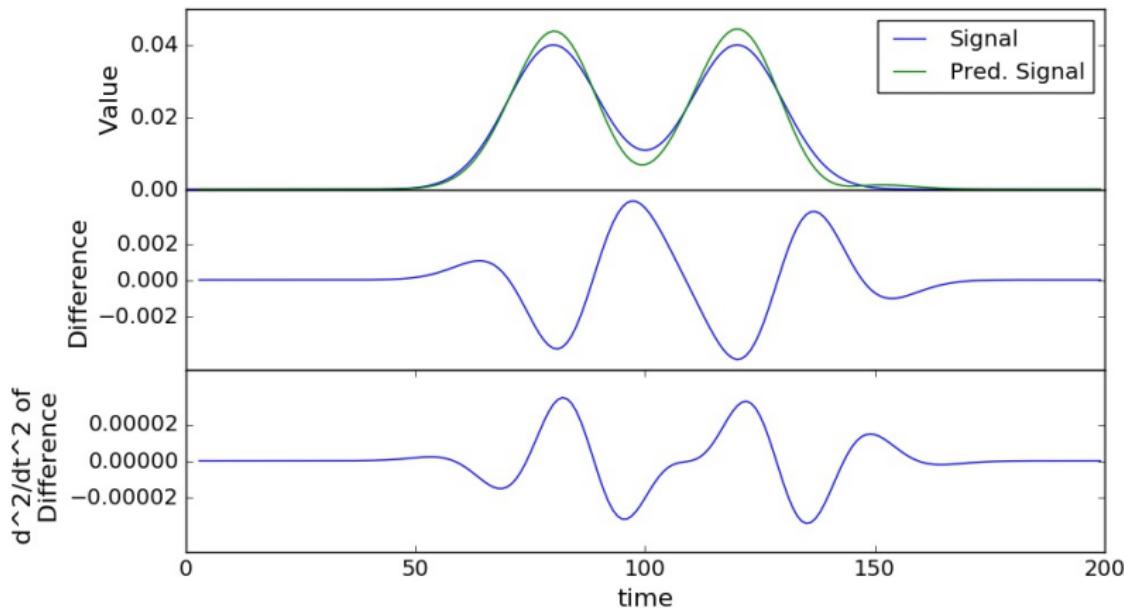


Observation specific weighting (preliminary results)



Further tests

- Threshold for second and third derivative
- How does the receiver work? Extrapolation approach.



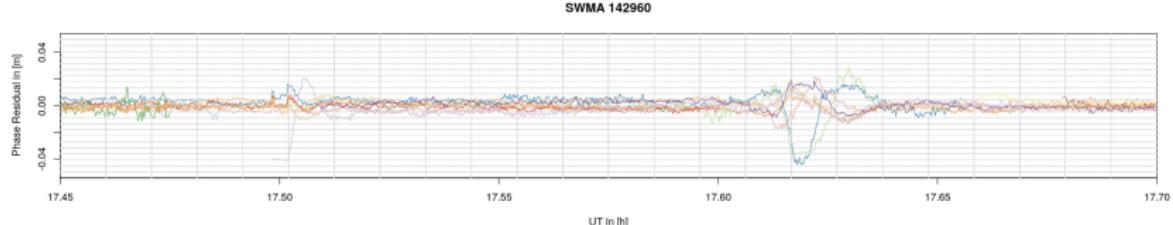
Conclusions

- A high variation in L4 seems to triggers artefacts in kinematic positioning.
- The standard deviation of L3 is predictable by the L4 time derivatives up to a correlation > 0.8 .
- The second time derivative seems to be a better indicator for affected epochs than the first time derivative.

Thank you for your attention.

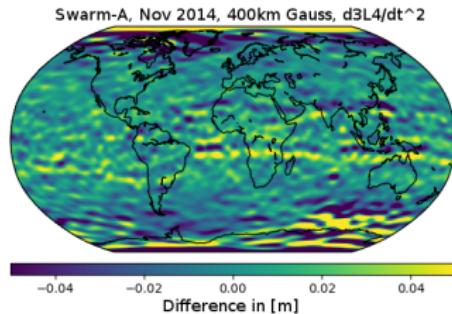
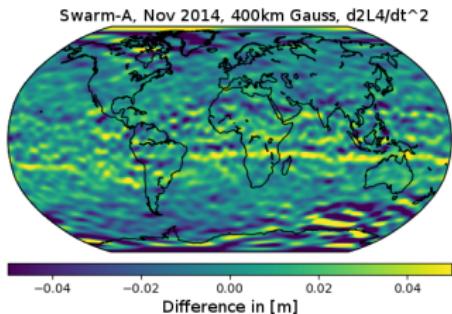
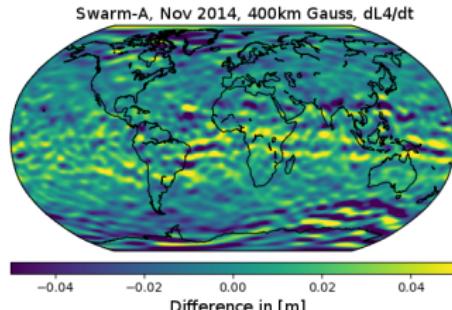
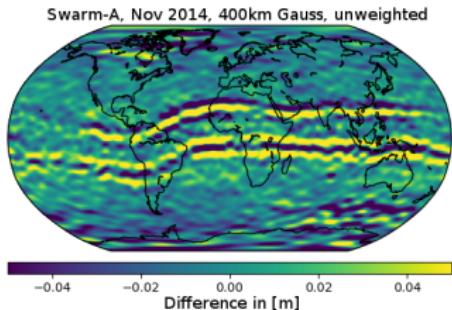
Open for discussion.

L3 and L4 residuals



L3 and L4 residuals during an equatorial pass.

Derivatives only



Model evaluation

