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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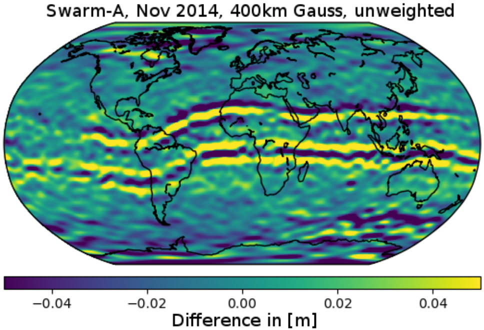
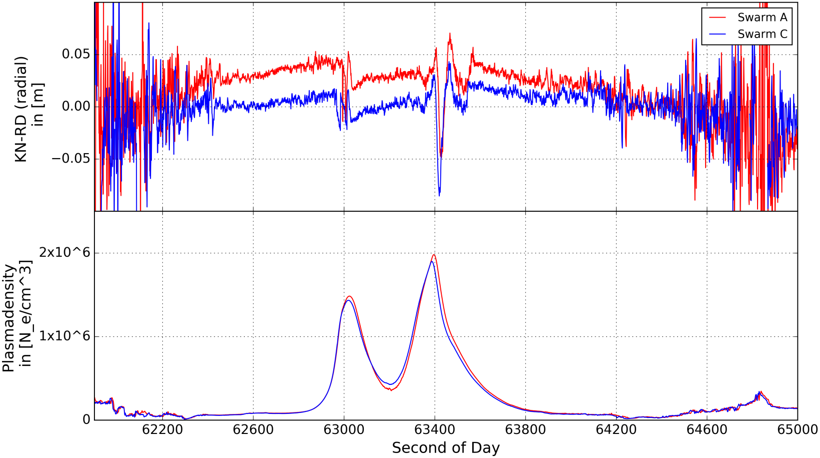
Swarm gravity field



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

Kinematic-Reduced dynamic Orbit (radial) and Plasmadensity



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Observation equations

$$L^i_{1k} = \rho^i_k - I^i_k(f_1) + T^i_k + c\delta_k - c\delta^i + \lambda_1 n^i_{1k}$$

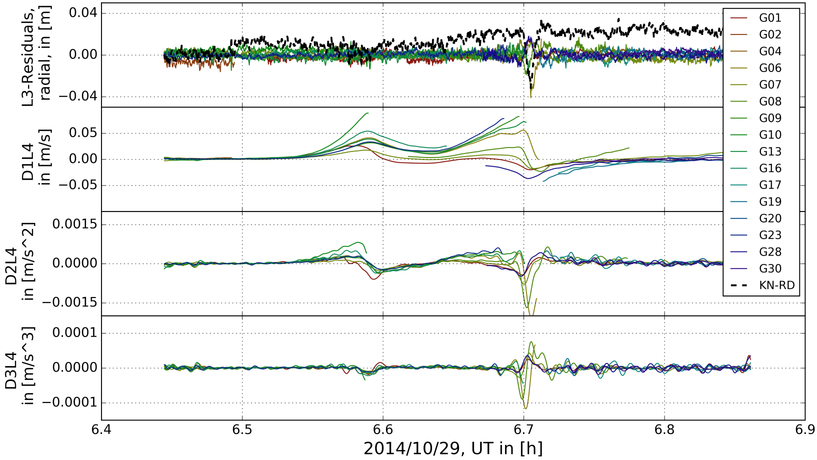
$$L^i_{2k} = \rho^i_k - I^i_k(f_2) + T^i_k + c\delta_k - c\delta^i + \lambda_1 n^i_{2k}$$

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

$$L^i_{4k} = L^i_{1k} - L^i_{2k}$$:geometry-free linear combination

ρ^i_k: Slant range
I^i_k: Ionospheric phase delay
T^i_k : Tropospheric delay
δ_k, δ^i: Receiver/transmitter clock correction
n^i_{1k}, n^i_{2k}: ambiguities

Time derivatives of the L4



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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.

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

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

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

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

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

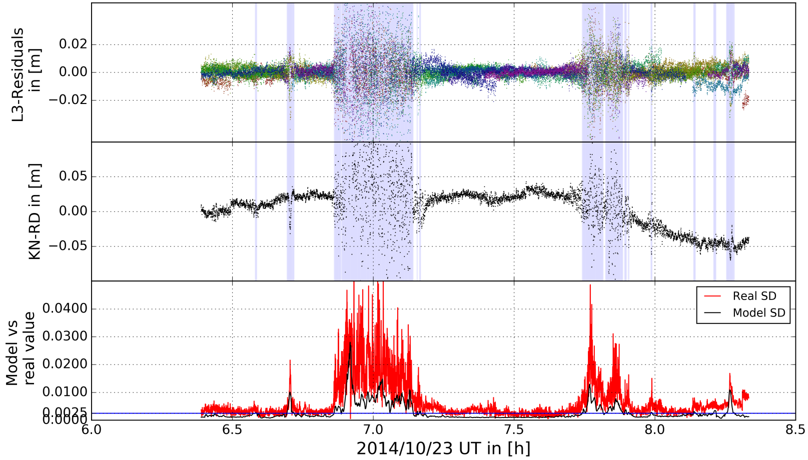
Any $\sigma < 1$ was set to 1.

Evaluation

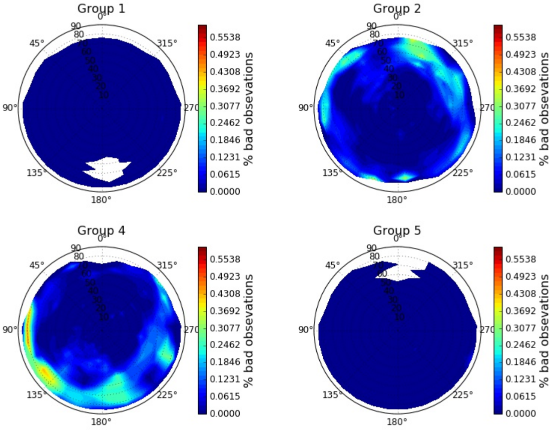
Model trained individally for 30 days in Nov. 2014

	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

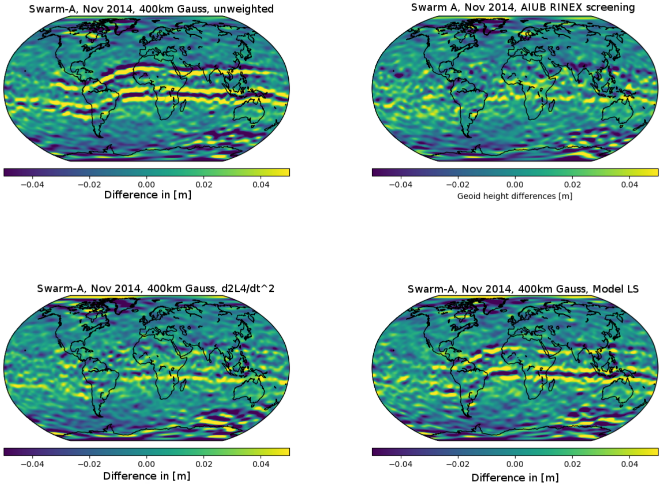


Identification and position of affected Satellites



Group	MLAT(UP)
1	$-35 \to -25$
2	$-25 \to -10$
3	$-10 \to 10$
4	$10 \to 25$
5	$25 \to 35$

Observation specific weighting (preliminary results)



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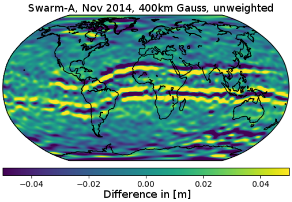
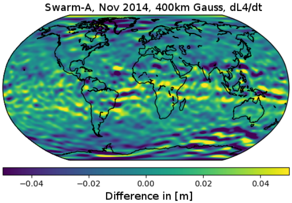
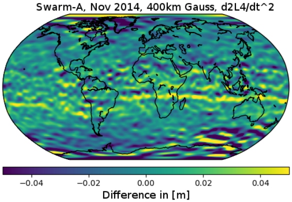
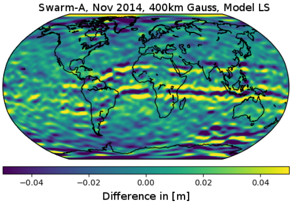
Observation specific weighting (preliminary results)



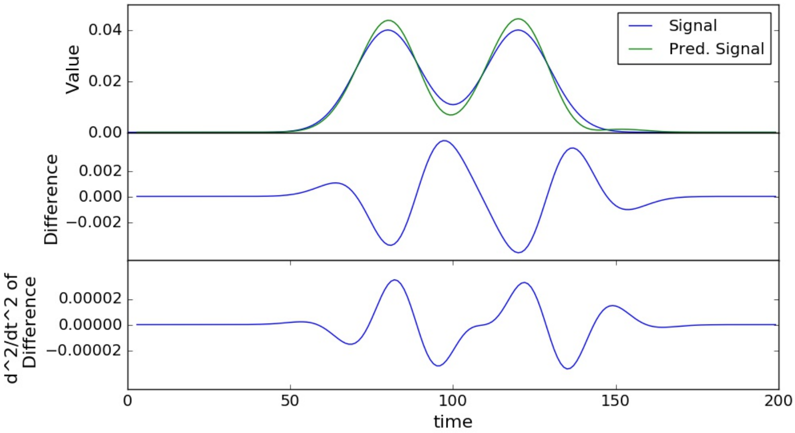






Further tests

- 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.

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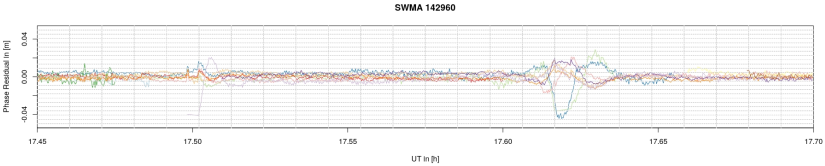
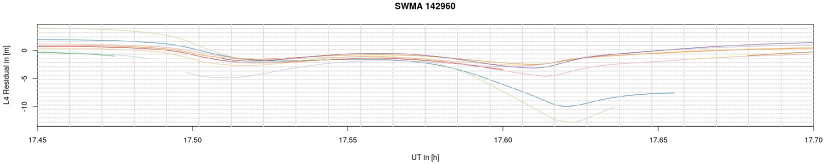
Thank you for your attention.

Open for discussion.

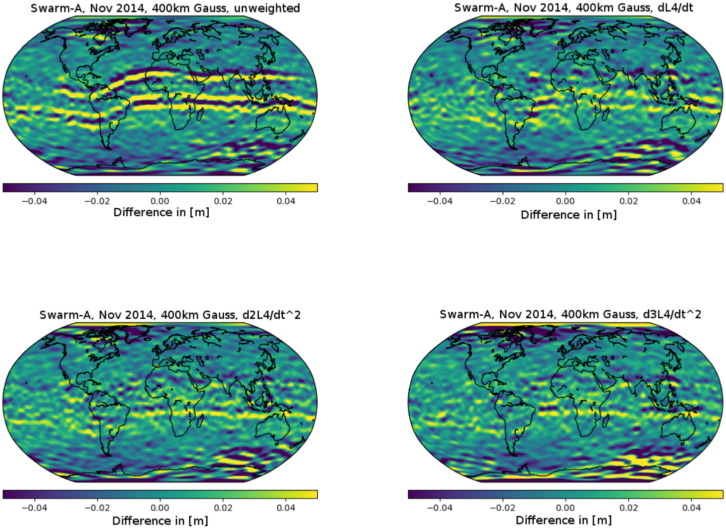
$L3$ and $L4$ residuals





$L3$ and $L4$ residuals during an equatorial pass.

Derivatives only



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Model evaluation