Time-variable gravity field determination from GRACE-FO data at AIUB

Martin Lasser[1], Ulrich Meyer[1], Daniel Arnold[1], Adrian Jäggi[1]

[1] *Astronomical Institute, University of Bern, Switzerland*

GRACE & GRACE-FO Science Team Meeting
Oct. 8-10, 2019
Pasadena, California

Content

Kinematic orbits of GRACE-FO satellites

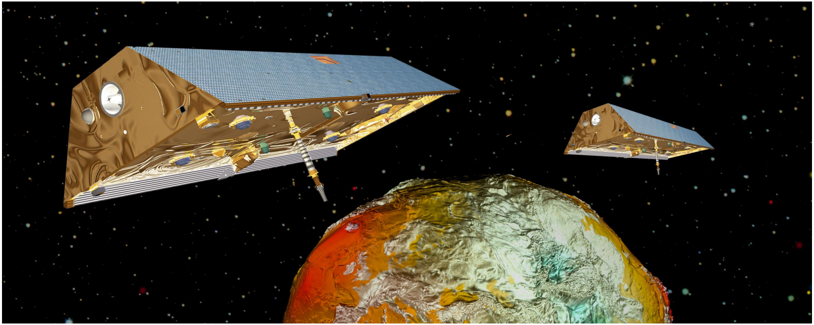
Stochastic behaviour of kinematic positions

Empirical modelling

Inter-satellite link

Impact on gravity field determination

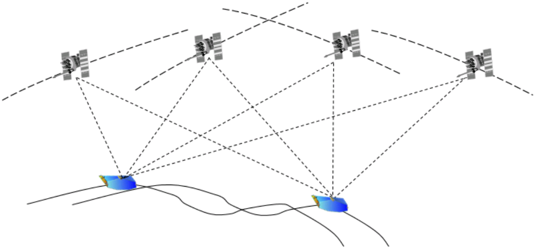
Observations



Credit: DLR

GPS	Inter-satellite link
absolute	relative
3-dim	1-dim
lower precision	very high precision

Kinematic orbits of GRACE-FO satellites



LEO precise orbit determination from GPS data

- 10 s sampling (full sampling used in processing)
- undifferenced PPP solution
- fixing zero-difference ambiguities to integers

→ CODE (Center of Orbit Determination in Europe) phase biases

→ CODE ambiguity-fixed clocks

Integer-fixing of carrier phase ambiguities

SLR residuals for 2018-11 (in comparison with float)

SV	type	mean [mm]	std. dev [mm]
GRACE-C	float	3.1	18.6
GRACE-D	float	-4.5	16.8
GRACE-C	fixed	4.3	10.6
GRACE-D	fixed	1.0	12.0

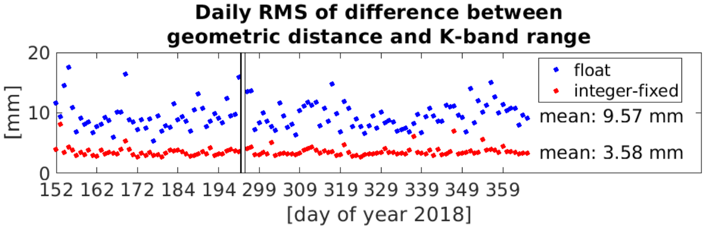
M. Lasser, U. Meyer, D. Arnold, A. Jäggi: Status of GFO data processing at AIUB
GRACE & GRACE-FO Science Team Meeting, Oct. 8-10, 2019, Pasadena, California

Integer-fixing of carrier phase ambiguities

SLR residuals for 2018-11 (in comparison with float)

SV	type	mean [mm]	std. dev [mm]
GRACE-C	float	3.1	18.6
GRACE-D	float	-4.5	16.8
GRACE-C	fixed	4.3	10.6
GRACE-D	fixed	1.0	12.0

K-band range validation of kinematic positions

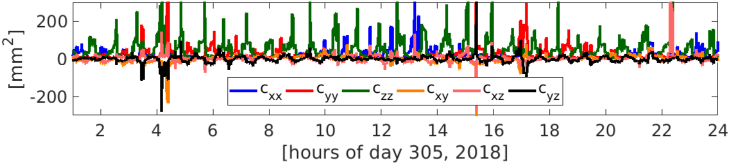


→ Individual arcs feature less scattering

M. Lasser, U. Meyer, D. Arnold, A. Jäggi: Status of GFO data processing at AIUB
GRACE & GRACE-FO Science Team Meeting, Oct. 8-10, 2019, Pasadena, California

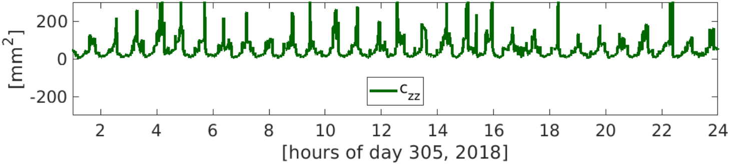
Stochastic behaviour of kinematic positions

- SST-hl tracking geometry varies between poles and the equator
- Epoch-wise covariance information from kinematic PPP: mainly 2/rev; important information on observation quality



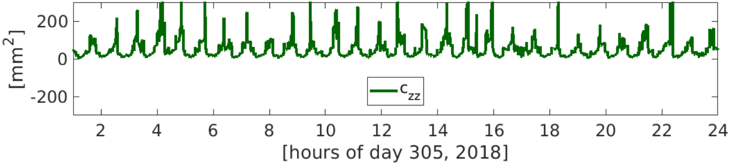
Stochastic behaviour of kinematic positions

- SST-hl tracking geometry varies between poles and the equator
- Epoch-wise covariance information from kinematic PPP: mainly 2/rev; important information on observation quality



Stochastic behaviour of kinematic positions

- SST-hl tracking geometry varies between poles and the equator
- Epoch-wise covariance information from kinematic PPP: mainly 2/rev; important information on observation quality



- Ambiguities feature the correlation between epochs

→ Full covariance matrix from PPP (at least in principle)

→ Integer-fixed: almost no correlations

Empirical modelling

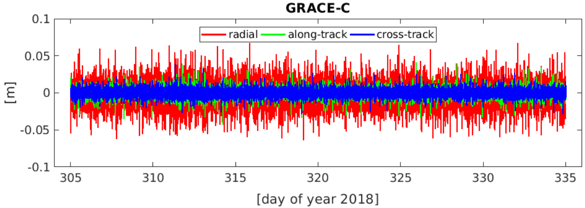
Non linear least squares: $\mathbf{x} = \mathbf{x_0} + (\mathbf{A}^{\mathrm{T}}\mathbf{P}\mathbf{A})^{-1}\mathbf{A}^{\mathrm{T}}\mathbf{P}\delta\mathbf{l}$

→ The observations enter via $\delta\mathbf{l} = o - c$

Empirical modelling

Non linear least squares: $\mathbf{x} = \mathbf{x_0} + (\mathbf{A}^\mathrm{T}\mathbf{P}\mathbf{A})^{-1}\mathbf{A}^\mathrm{T}\mathbf{P}\delta\mathbf{l}$

$\rightarrow$ The observations enter via $\delta\mathbf{l} = o - c$

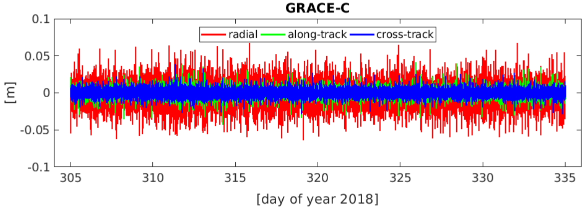


M. Lasser, U. Meyer, D. Arnold, A. Jäggi: Status of GFO data processing at AIUB
GRACE & GRACE-FO Science Team Meeting, Oct. 8-10, 2019, Pasadena, California

Empirical modelling

Non linear least squares: $\mathbf{x} = \mathbf{x_0} + (\mathbf{A}^{\mathrm{T}}\mathbf{P}\mathbf{A})^{-1}\mathbf{A}^{\mathrm{T}}\mathbf{P}\delta\mathbf{l}$

→ The observations enter via $\delta\mathbf{l} = o - c$



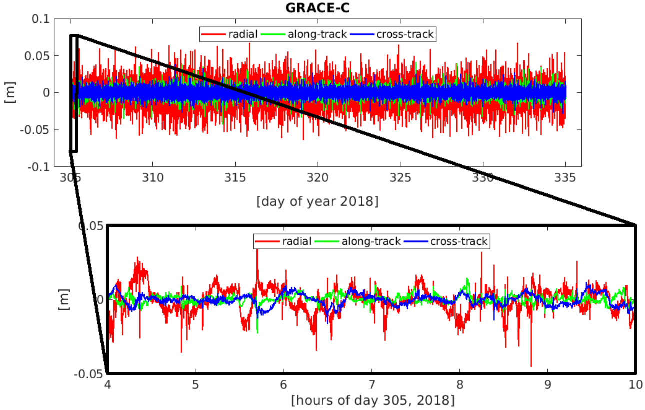
- Residuals feature observation noise (o)
- And mismodelings from the computed component (c)

→ c contains the full a priori force model
(gravity field, tides, AOD, accelerometer, ...)

Empirical modelling

Non linear least squares: $\mathbf{x} = \mathbf{x_0} + (\mathbf{A}^{\mathrm{T}}\mathbf{P}\mathbf{A})^{-1}\mathbf{A}^{\mathrm{T}}\mathbf{P}\delta\mathbf{l}$

$\rightarrow$ The observations enter via $\delta\mathbf{l} = o - c$



Empirical covariance estimation

- Set up (constrained) piecewise constant accelerations (strategy used at AIUB)

In case of a stationary process

- Estimate a mean covariance function from the residuals $\mathbf{e}$.

$$cov(\Delta t_k) = \frac{1}{n} \sum_{i=0}^{n} \mathbf{e}(t_i)\mathbf{e}(t_i + \Delta t_k)$$

- Variance/covariance matrix has a symmetric Toeplitz-structure and the individual elements only depend on the distance in time.

→ Mean covariance function for each month

→ Length of correlation 100 min

Inter-satellite link

The inter-satellite link is much more precise

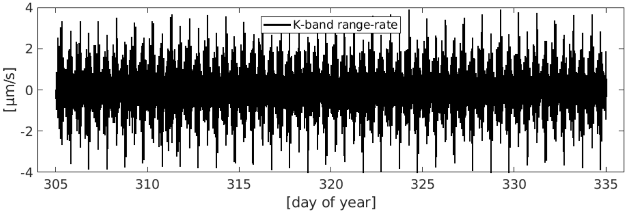
→ dominates the resulting gravity field signal

→ 5 s sampling for K-band, 2 s sampling for LRI

- Assign one factor to weight K-band

→ extended to weight based on its arc-wise residual RMS

- Set up constrained PCA to model stochastic behaviour (mainly a 2/rev signal)



Inter-satellite link

The inter-satellite link is much more precise

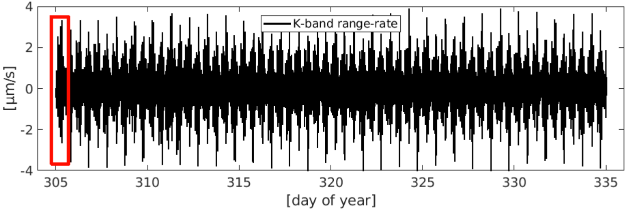
→ dominates the resulting gravity field signal

→ 5 s sampling for K-band, 2 s sampling for LRI

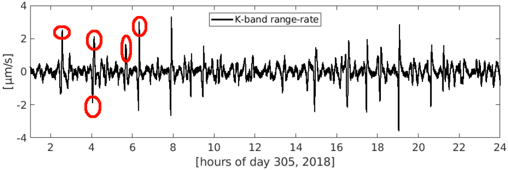
- Assign one factor to weight K-band

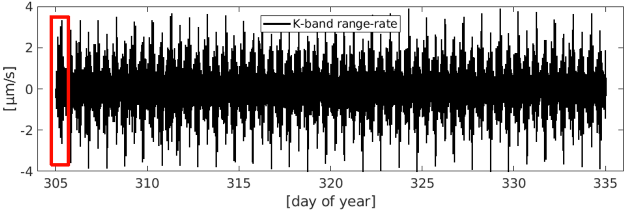
→ extended to weight based on its arc-wise residual RMS

- Set up constrained PCA to model stochastic behaviour (mainly a 2/rev signal)

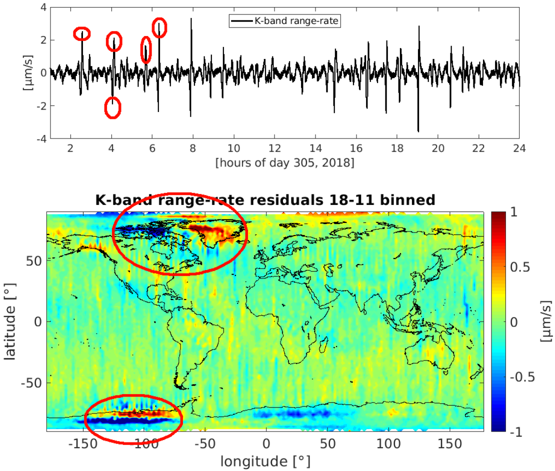


Inter-satellite link





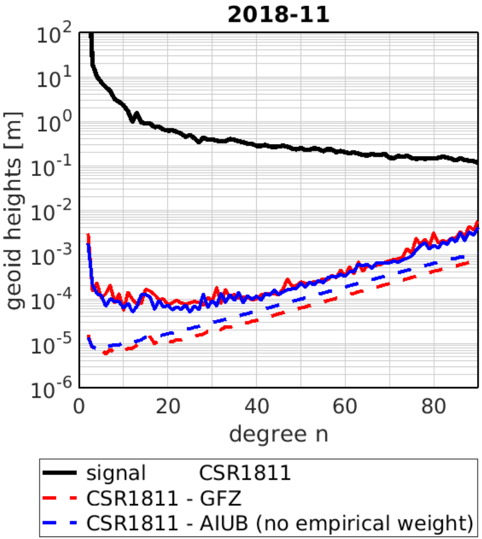
Inter-satellite link



- Large distance in time between reference epoch of background field and observations

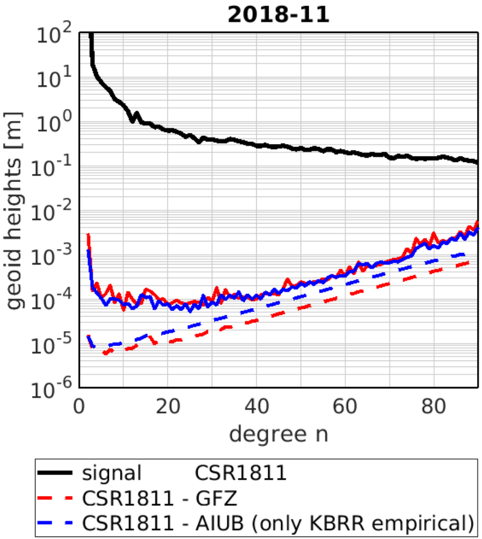
M. Lasser, U. Meyer, D. Arnold, A. Jäggi: Status of GFO data processing at AIUB
GRACE & GRACE-FO Science Team Meeting, Oct. 8-10, 2019, Pasadena, California

Impact on gravity field determination



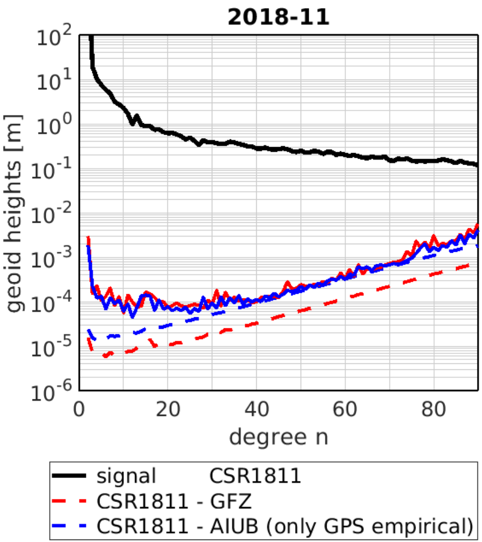
- Formal errors are too optimistic

Impact on gravity field determination



- Slight improvement due to better characterisation of range-rate data
- Noise in background force field modelled through PCA only

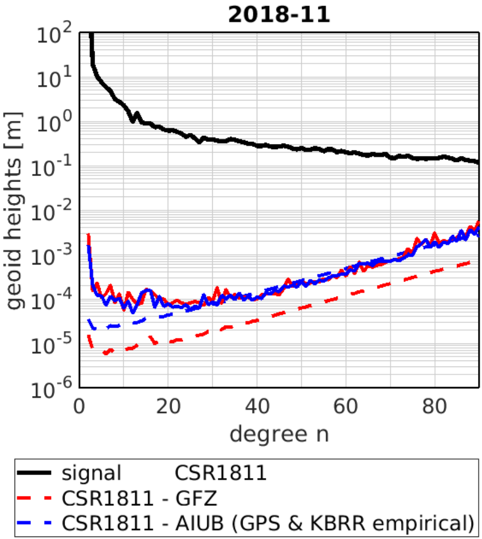
Impact on gravity field determination



- Noise in background force field mainly characterised due to GPS contribution

M. Lasser, U. Meyer, D. Arnold, A. Jäggi: Status of GFO data processing at AIUB
GRACE & GRACE-FO Science Team Meeting, Oct. 8-10, 2019, Pasadena, California

Impact on gravity field determination



- Formal errors in higher degrees realistic
- Low degrees require further inspection

M. Lasser, U. Meyer, D. Arnold, A. Jäggi: Status of GFO data processing at AIUB
GRACE & GRACE-FO Science Team Meeting, Oct. 8-10, 2019, Pasadena, California

Summary

- Integer-fixing of carrier phase ambiguities closer to K-band
- Empirical noise modelling via GPS improves formal errors

→ Extend the procedure to K-band/Laser link

- Processing strategy tested on GRACE-FO

→ (At some point) reprocess GRACE time series

Thank you for your attention.