

The EGSIEM combination service for monthly gravity fields

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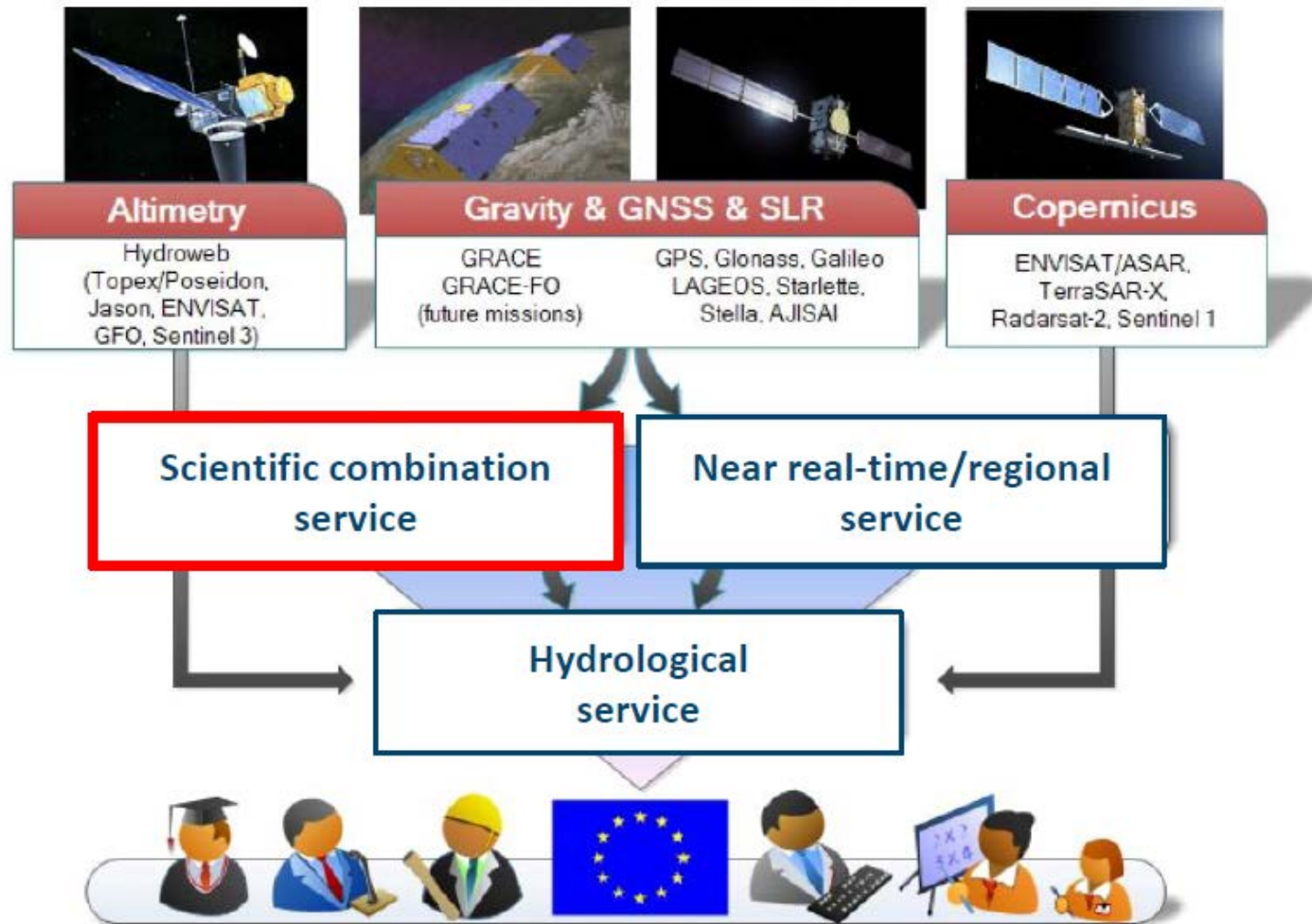
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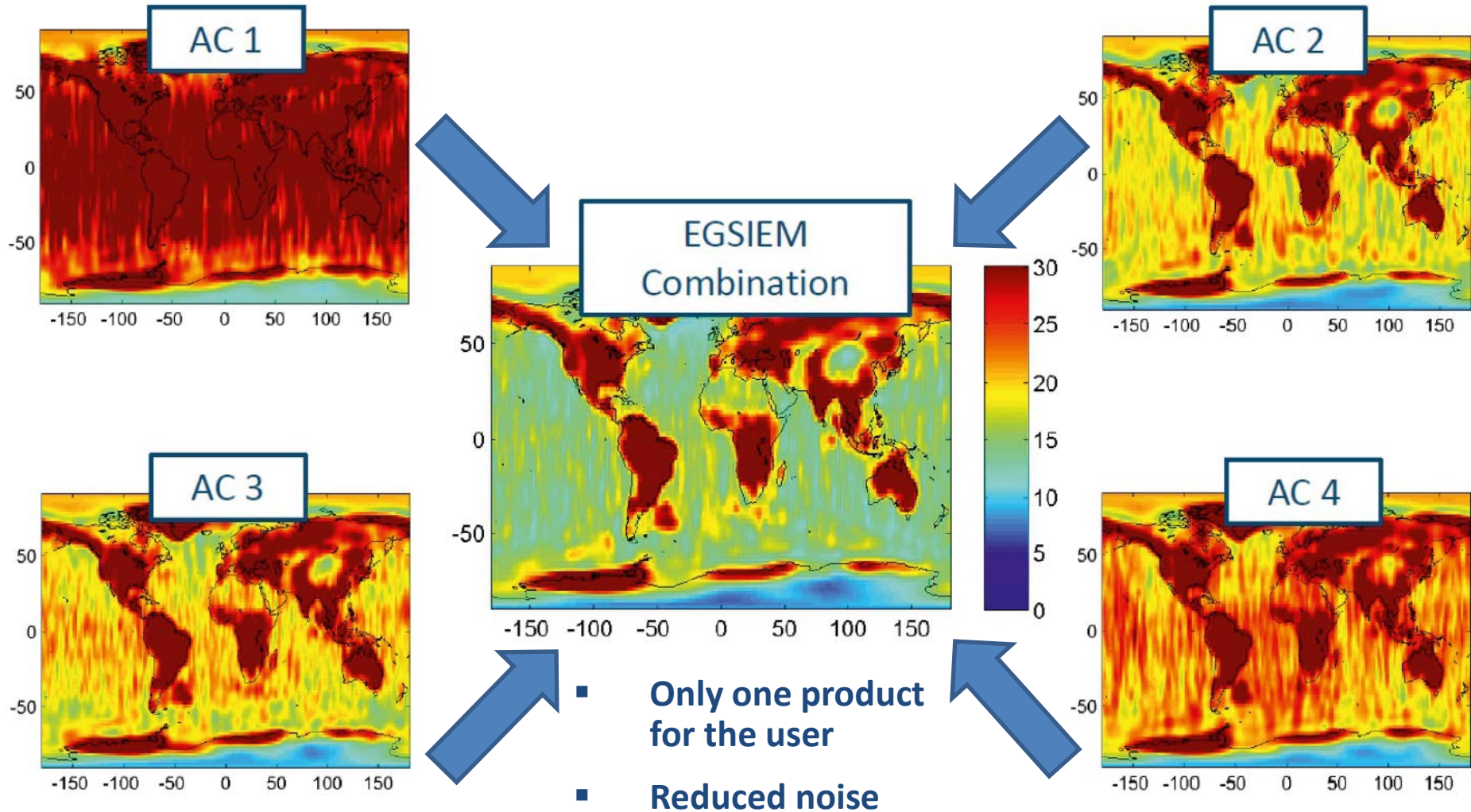
Contents

- The EGSiEM project
- The Scientific Combination Service
- Gravity Field Determination
- The EGSiEM plotter
- User-friendly L3-Products
- Transition to IAG service COST-G

EGSIEM Project – Three services are established



Scientific Combination Service



Scientific Combination Service

- The EGSIM combination service provides monthly GRACE K-band gravity fields combined on solution / normal equation (NEQ) Level.
- To ensure consistency, a set of common standards for reference frame, Earth rotation, force model and satellite geometry were defined.

Why combine results based on the same observations?

Errors in GRACE monthly gravity fields are still dominated by analysis and background model noise, not observation noise => AC-specific errors are reduced by combination!

Linear observation equations:

$$l = Ap + \epsilon$$

Weight matrix:

$$P = C_{ll}^{-1}$$

Solution (least-squares):

$$p = (A^T P A)^{-1} A^T P l$$

Linear observation equations:

$$l = Ap + \epsilon \quad \text{Observations}$$

Weight matrix:

$$P = C_{ll}^{-1}$$

Solution (least-squares):

$$p = (A^T P A)^{-1} A^T P l$$

Linear observation equations:

$$l = A p + \epsilon \quad \text{Observations}$$

Weight matrix:

unknown Parameters

$$P = C_{ll}^{-1}$$

Solution (least-squares):

$$p = (A^T P A)^{-1} A^T P l$$

Linear observation equations:

$$l = A p + \epsilon \quad \text{Observations}$$

Weight matrix:

unknown Parameters

$$P = C_{ll}^{-1} \quad \text{Observation Errors}$$

Solution (least-squares):

Designmatrix

$$p = (A^T P A)^{-1} A^T P l$$

Non-linear case:

$$\mathbf{A} = f(\mathbf{p})$$

A priori:

$$\mathbf{l}_0 = \mathbf{A}_0 \mathbf{p}_0$$

Corrections (least-squares):

$$\Delta \mathbf{p} = (\mathbf{A}_0^T \mathbf{P} \mathbf{A}_0)^{-1} \mathbf{A}_0^T \mathbf{P} (\mathbf{l} - \mathbf{l}_0)$$

Noise Model: Variance-Covariance

$$C_{ll} = \begin{pmatrix} \sigma_{l_1}^2 & \sigma_{l_1 l_2} & \cdots & \sigma_{l_1 l_n} \\ \sigma_{l_2 l_1} & \sigma_{l_2}^2 & \cdots & \sigma_{l_2 l_n} \\ \vdots & & \ddots & \vdots \\ \sigma_{l_n l_1} & \sigma_{l_n l_2} & \cdots & \sigma_{l_n}^2 \end{pmatrix}$$

Noise Model: Variance-Covariance

Variance information

$$C_{ll} = \begin{pmatrix} \sigma_{l_1}^2 & \sigma_{l_1 l_2} & \cdots & \sigma_{l_1 l_n} \\ \sigma_{l_2 l_1} & \sigma_{l_2}^2 & \cdots & \sigma_{l_2 l_n} \\ \vdots & & \ddots & \vdots \\ \sigma_{l_n l_1} & \sigma_{l_n l_2} & \cdots & \sigma_{l_n}^2 \end{pmatrix}$$

Noise Model: Variance-Covariance

Variance information

$$C_{ll} = \begin{pmatrix} \sigma_{l_1}^2 & \sigma_{l_1 l_2} & \cdots & \sigma_{l_1 l_n} \\ \sigma_{l_2 l_1} & \sigma_{l_2}^2 & \cdots & \sigma_{l_2 l_n} \\ \vdots & & \ddots & \vdots \\ \sigma_{l_n l_1} & \sigma_{l_n l_2} & \cdots & \sigma_{l_n}^2 \end{pmatrix}$$

Covariance information: correlations

Problems

Simplified error model:

$$C_{ll_0} = \begin{pmatrix} \sigma_{\text{GPS}}^2 & & 0 \\ & \dots & \\ 0 & & \sigma_{\text{KBR}}^2 \end{pmatrix}$$

Separate estimation (regularization):

$$\begin{pmatrix} \Delta p_o \\ \Delta p_g \end{pmatrix} = (\mathbf{A}_0^T \mathbf{P} \mathbf{A}_0)^{-1} \mathbf{A}_0^T \mathbf{P} (\mathbf{l} - \mathbf{l}_0)$$

Problems

Simplified error model:

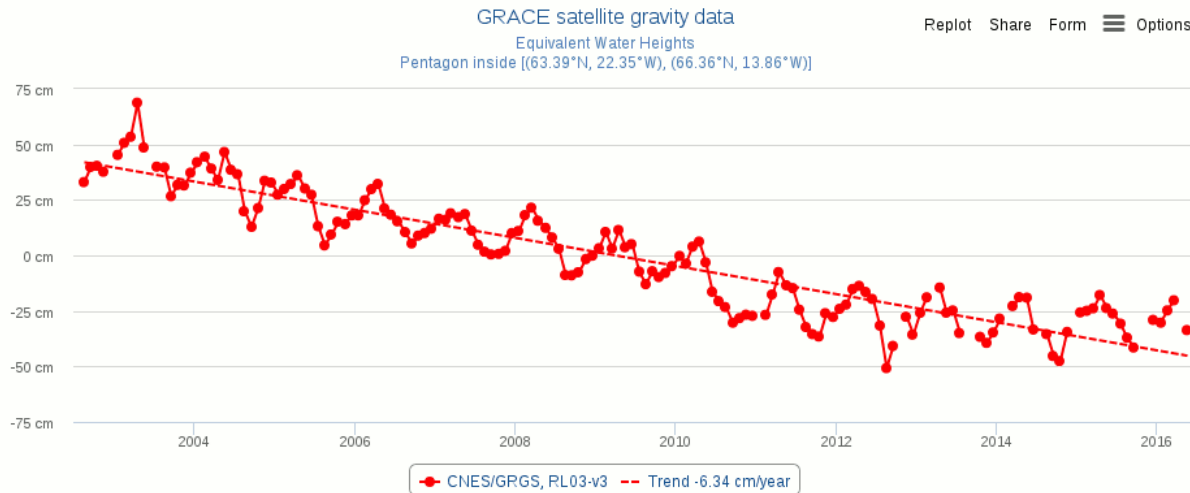
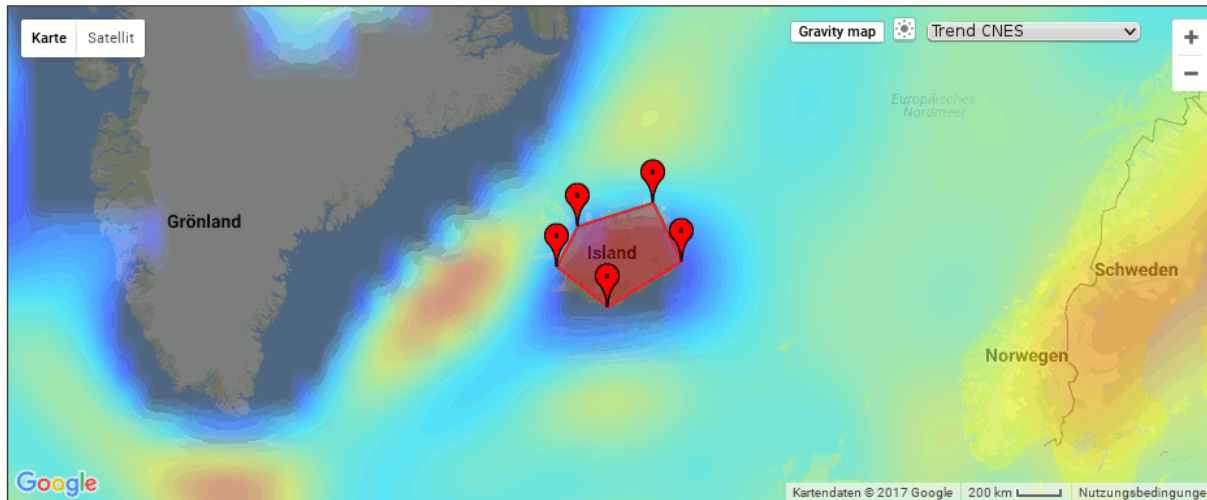
$$C_{ll_0} = \begin{pmatrix} \sigma_{\text{GPS}}^2 & & 0 \\ & \dots & \\ 0 & & \sigma_{\text{KBR}}^2 \end{pmatrix}$$

Separate estimation (regularization):

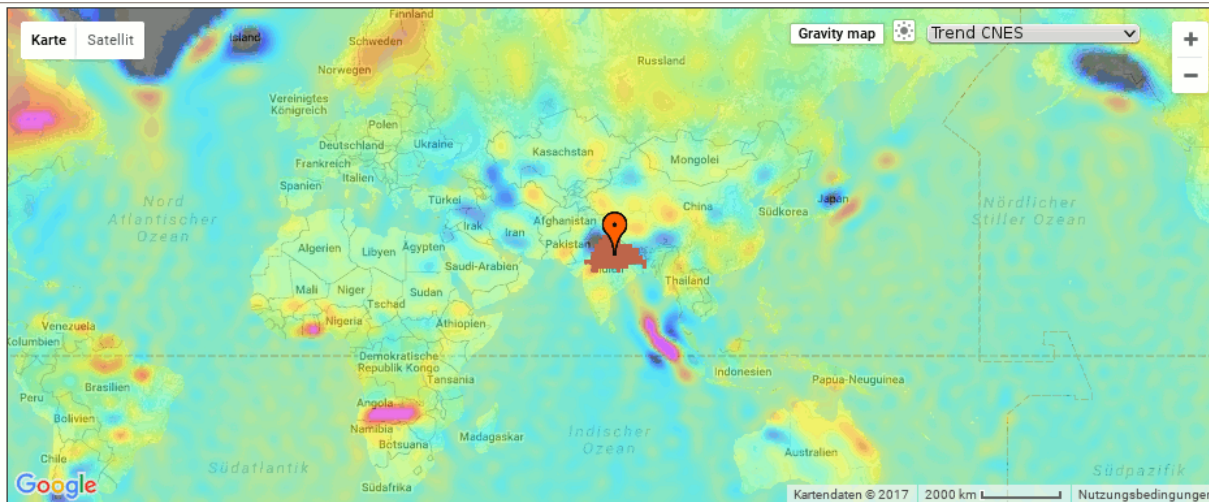
$$\begin{pmatrix} \Delta p_o \end{pmatrix} = \left(\begin{pmatrix} \mathbf{A}_o^T \mathbf{P} \mathbf{A}_o \end{pmatrix} + \begin{pmatrix} \mathbf{I} \end{pmatrix} \right)^{-1} \begin{pmatrix} \mathbf{A}_o^T \mathbf{P} \mathbf{l}_o \end{pmatrix}$$

$$\begin{pmatrix} \Delta p_g \end{pmatrix} = \left(\mathbf{A}_g^T \mathbf{P} \mathbf{A}_g + \begin{pmatrix} \mathbf{I} \end{pmatrix} \right)^{-1} \mathbf{A}_g^T \mathbf{P} \mathbf{l}_g$$

EGSIEM-Plotter (plot.egsiem.eu)

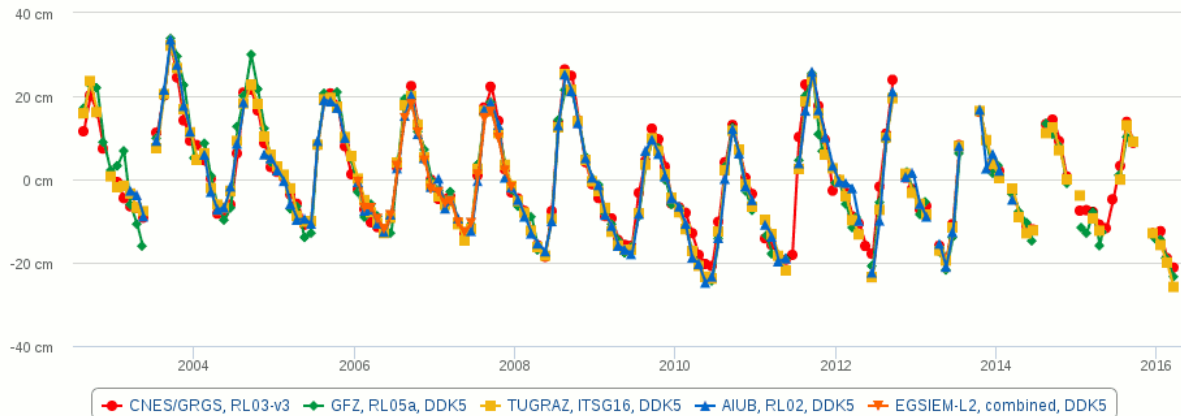


EGSIEM-Plotter (plot.egsiem.eu)

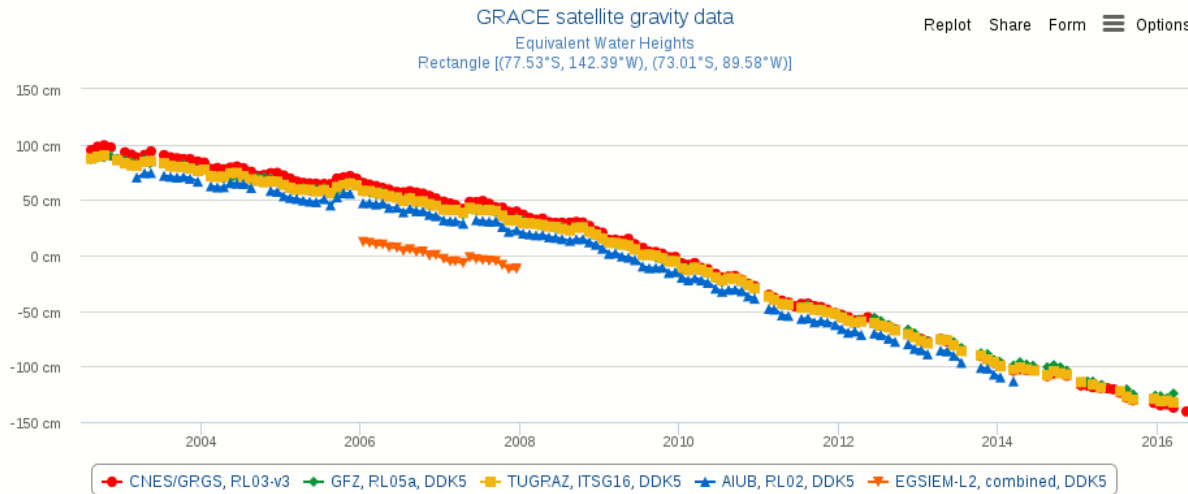
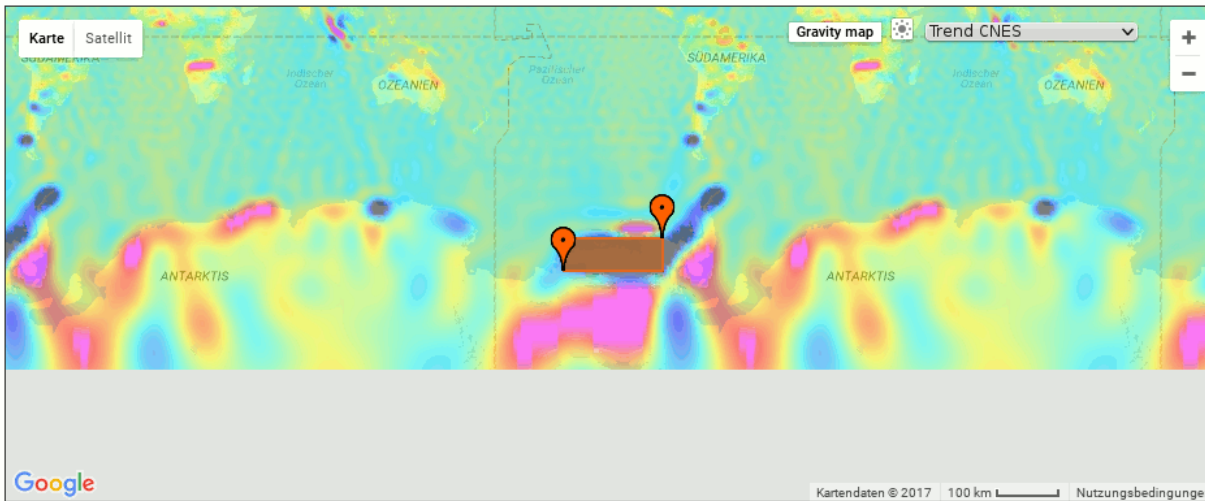


GRACE satellite gravity data
Equivalent Water Heights
Ganges basin

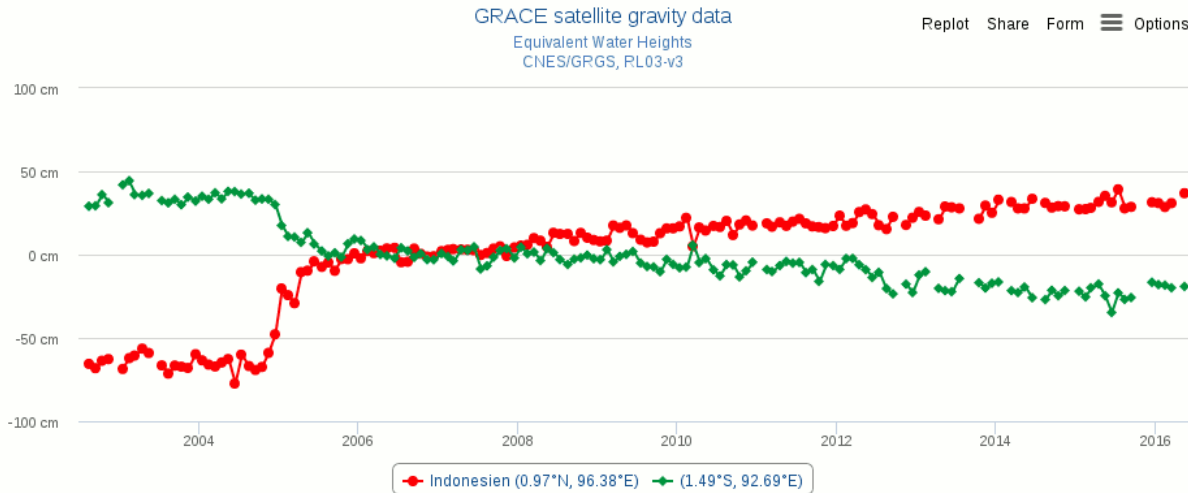
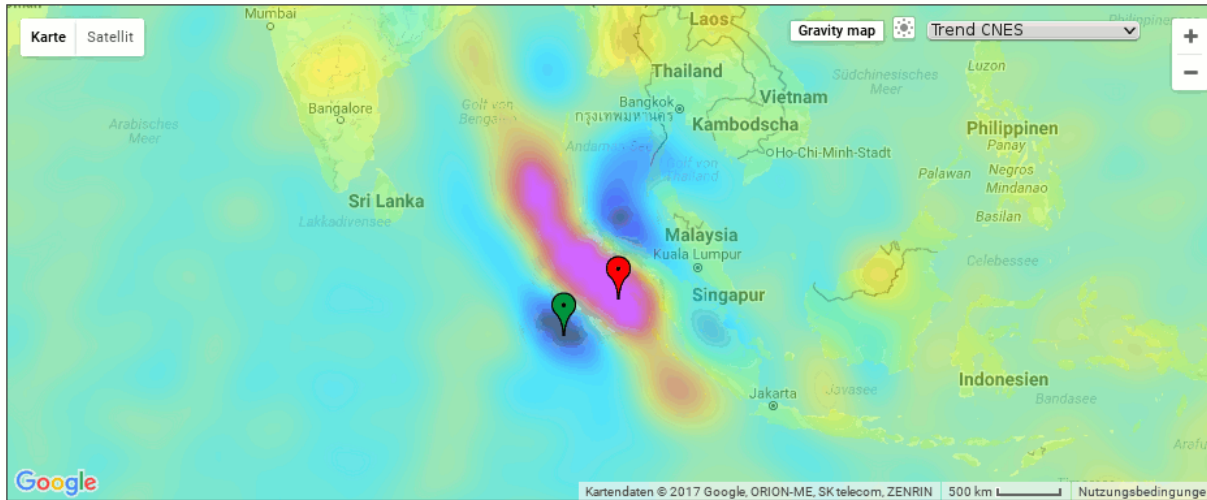
Replot Share Form Options



EGSIEM-Plotter (plot.egsiem.eu)



EGSIEM-Plotter (plot.egsiem.eu)



EGSIEM-Plotter: L3-products

Functional

Water heights ▾

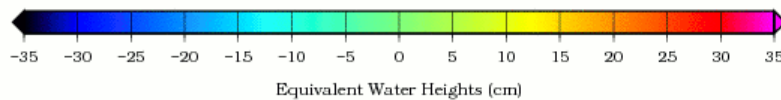
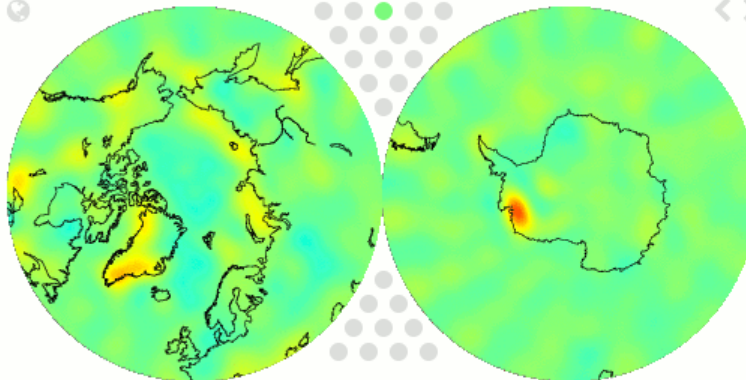
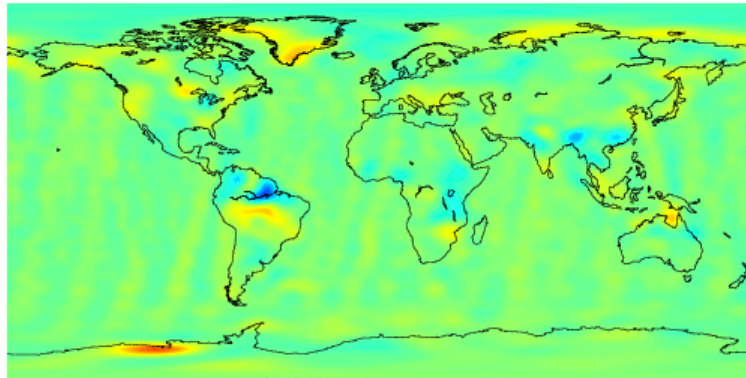
Data center and version

EGSIEM GRACE hydrology DDK3 ▾

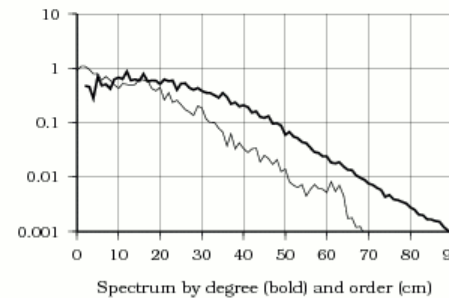
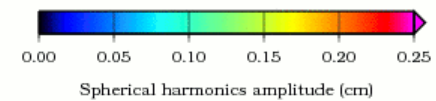
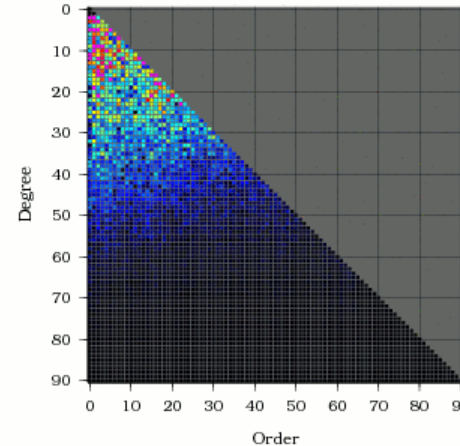
Date

2006 January ▾

EGSIEM graceHydrology monthly DDK3 - 2006/01/01 - 2006/01/31
Equivalent Water Heights comparison to time series mean (degree 2 to 90)
min -24.86 cm / max 23.89 cm / weighted rms 3.16 cm / oceans 1.91 cm



2002 2004 2006 2008 2010 2012 2014 2016 2018



Concluding Remarks

- The products of the EGSIEM combination service are available at:
 - SH-coefficients (Level-2): www.icgem.de
 - grids and de-aliasing (Level-3): www.egsiem.eu
- The combination service will be continued as a Combination Center (COST-G) under the umbrella of the International Gravity Field Services (IGFS) of the International Association of Geodesy (IAG).