EGSIEM

European Gravity Service for Improved Emergency Management

Near real-time GRACE-based flood warning

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ISSI Workshop

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Introduction

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European Gravity Service for Improved Emergency Management

EGSIEM European Gravity Service for Improved Emergency Management

was a H2020 project consisting of eight European partners:

and several associated members:

EGSIEM Objectives

The three ***main objectives*** of EGSIEM were:

- Deliver the best global time-variable gravity products for applications in Earth and environmental science research without using regularization
- Reduce the latency and increase the temporal resolution of the gravity and therefore mass redistribution products using regularization
- Develop gravity-based indicators for extreme hydrological events and demonstrate their value for flood forecasting and monitoring services

Space Gravimetry
GRACE/GRACE-FO

EOSIEM
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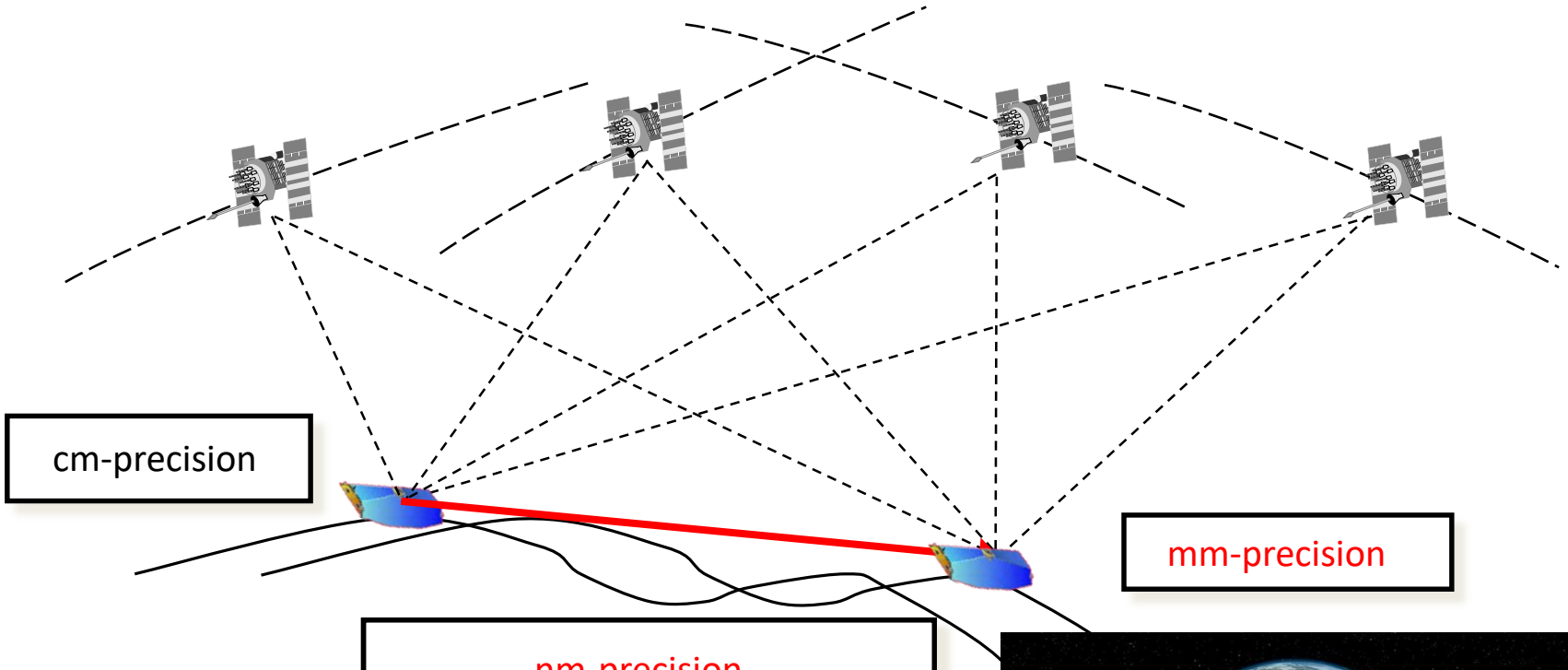

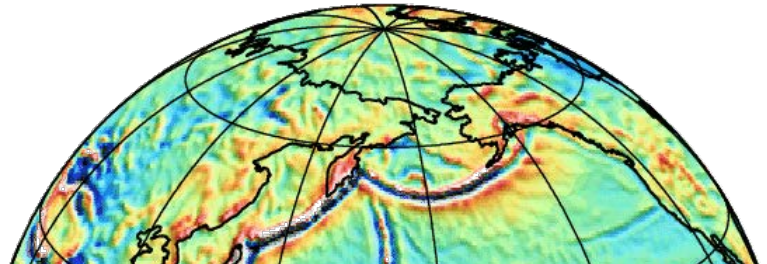

Meaurement Principle

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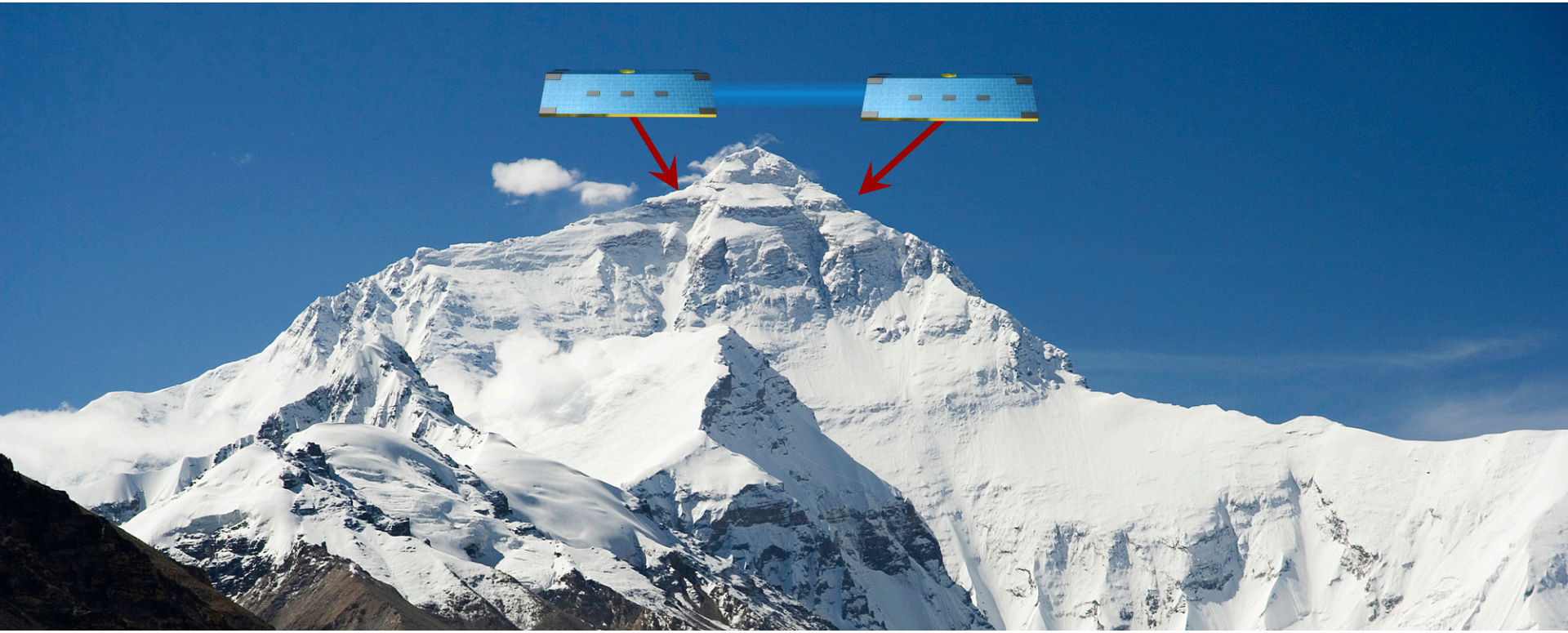
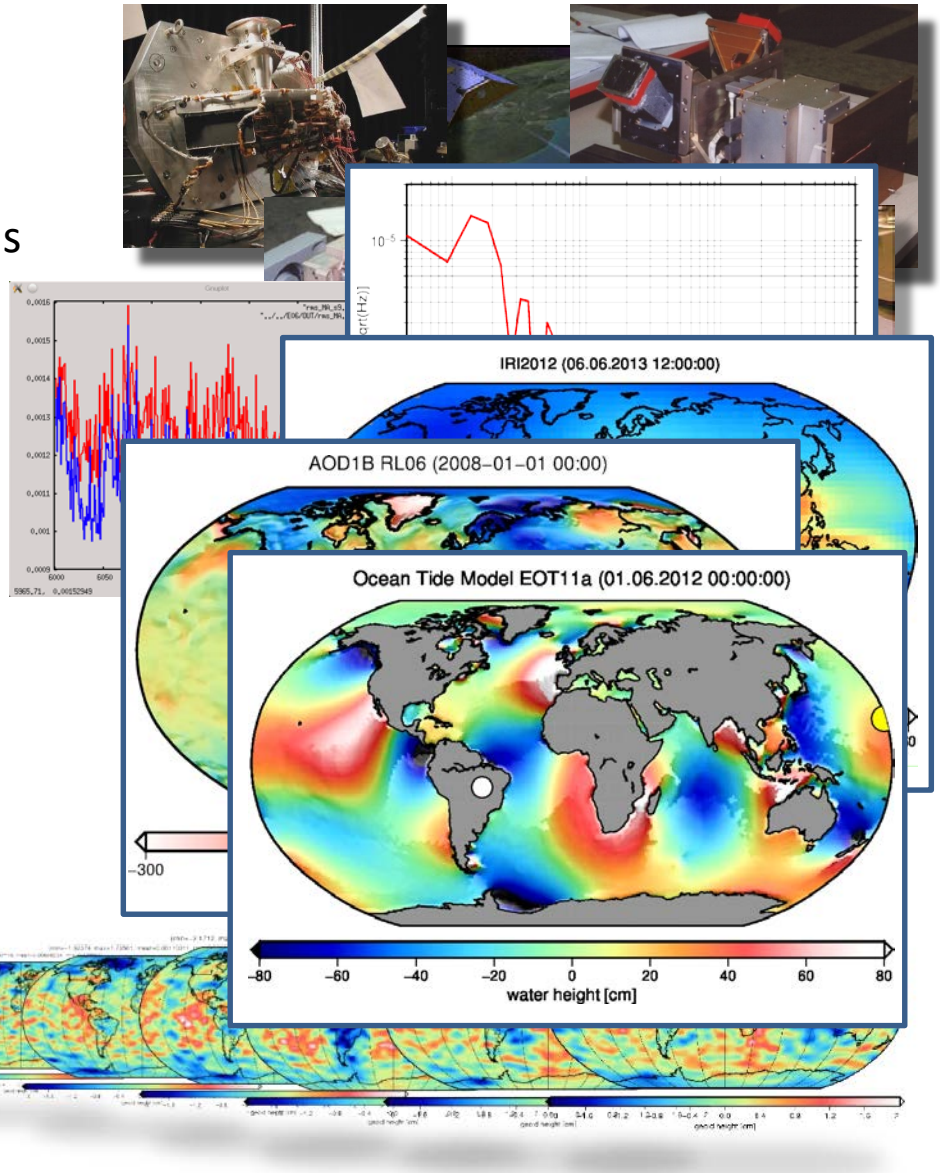


GRACE in a nutshell:

- Process GRACE data to
  a time series of monthly gravity field solutions
- Processing is challenging
  - Interaction of multiple instruments
  - Different noise characteristics
  - Environmental disturbances
    - Ionosphere
    - Atmosphere
    - Ocean currents
    - Tides
  - Large system of equations:
    Computational restrictions
  - Processing is challenging

=> There is not only one truth solution



EGSIEM prototype Services

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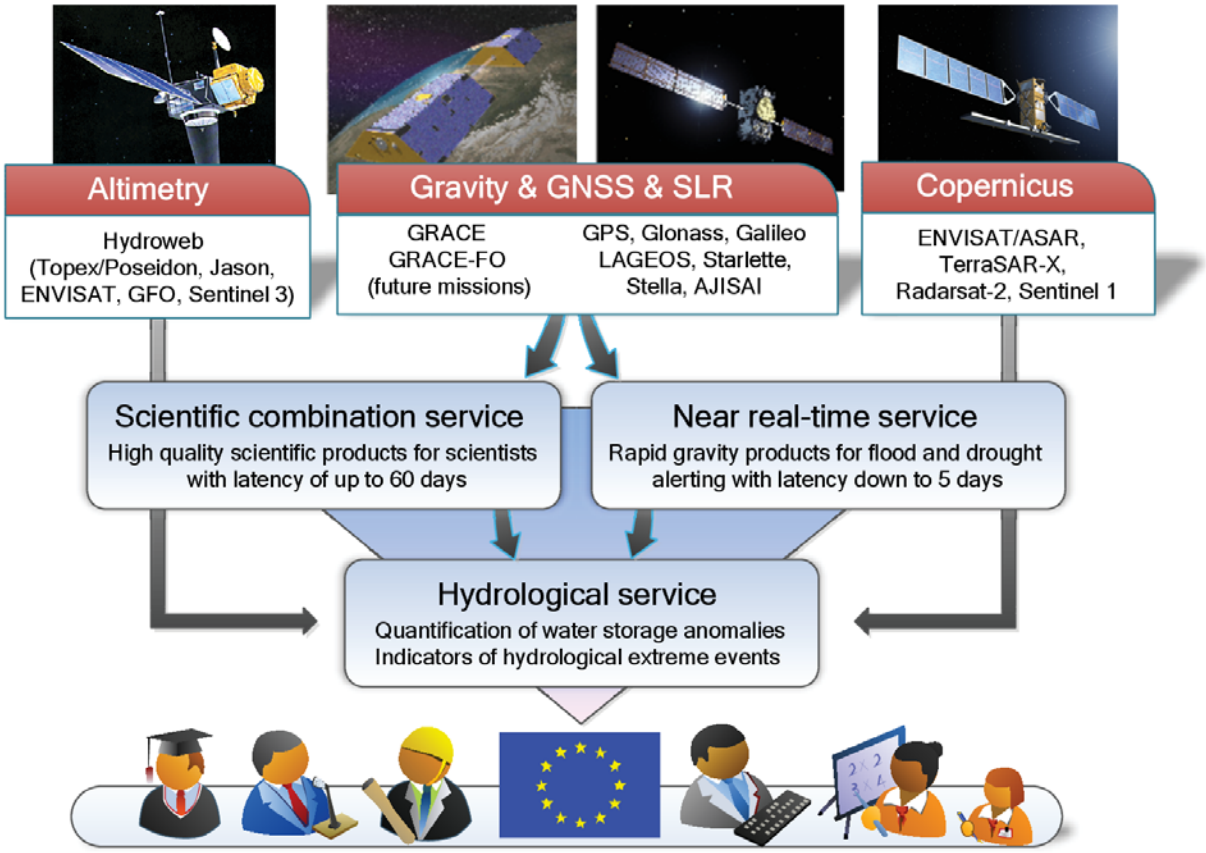

Jäggi et al. (2019)

Gravity Field Analysis

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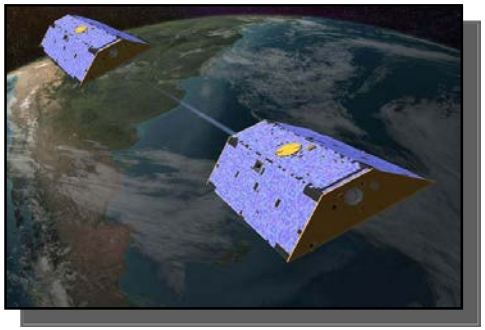

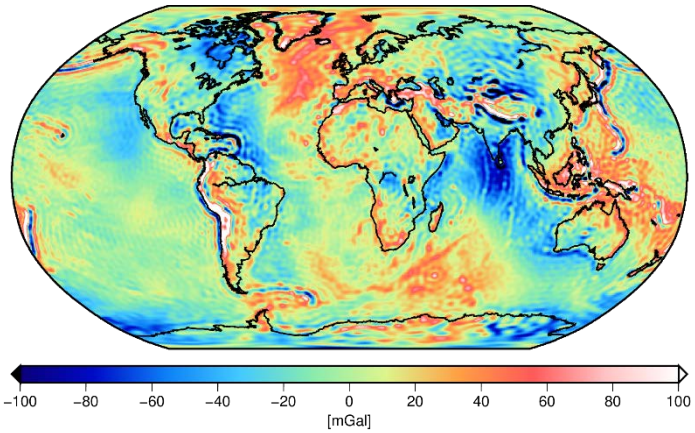

- Improved gravity field solutions by:
  - Harmonization of processing standards
  - Improvements of analysis methods
- EGSIEM Analysis Centers (ACs):
  - GFZ (Direct Approach)
  - CNES (Direct Approach)
  - UBERN (Celestial Mechanics Approach)
  - TUG (Short-Arc Approach)
  - More in the future (COST-G) …

==> Provide different solutions for a combined solution

Scientific Combination Service

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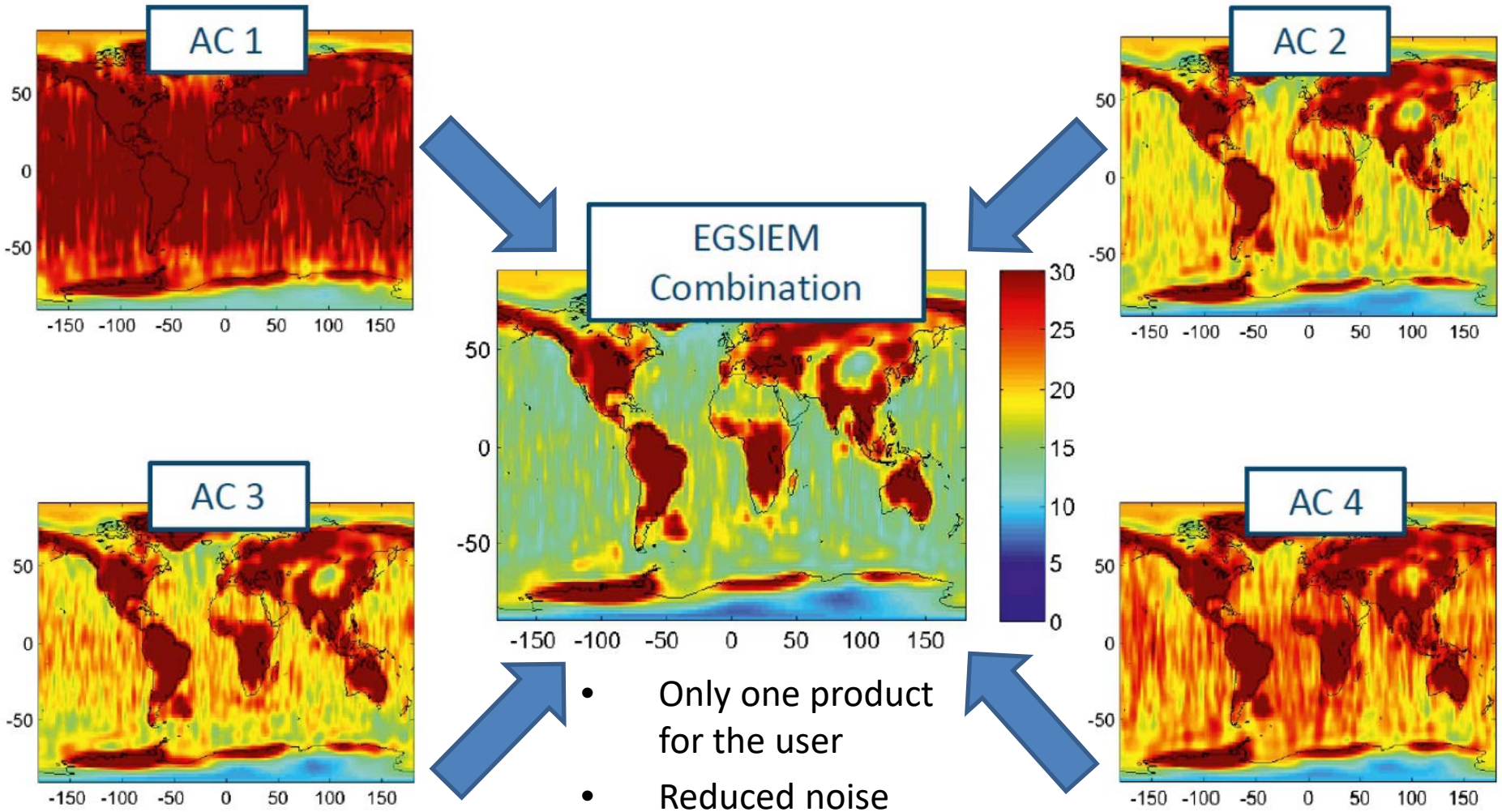
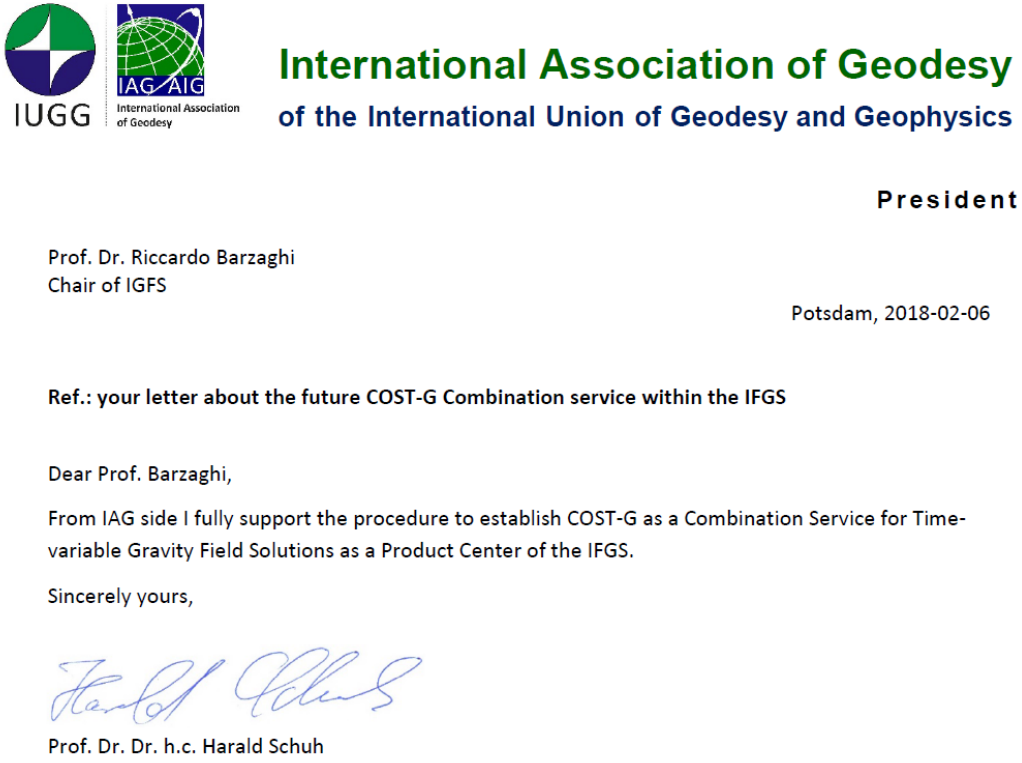


- Only one product for the user
- Reduced noise

Jean et al. (2018)

Future Perspective



International Association of Geodesy
of the International Union of Geodesy and Geophysics

President

Prof. Dr. Riccardo Barzaghi
Chair of IGFS

Potsdam, 2018-02-06

Ref.: your letter about the future COST-G Combination service within the IFGS

Dear Prof. Barzaghi,

From IAG side I fully support the procedure to establish COST-G as a Combination Service for Time-variable Gravity Field Solutions as a Product Center of the IFGS.

Sincerely yours,

Prof. Dr. Dr. h.c. Harald Schuh

- The EGSIEM Scientific Combination Service is continued as **COST-G** (**CO**mbination **S**ervice of **T**ime-variable **G**ravity field solutions). COST-G is a Product Center of the International Gravity Field Service (**IGFS**) of the International Association of Geodesy (**IAG**).
- Currently in preparational phase, kindly supported also by ISSI.
- Official inauguration will be at the 2019 IUGG meeting this summer

COST-G

Near Real-Time Service

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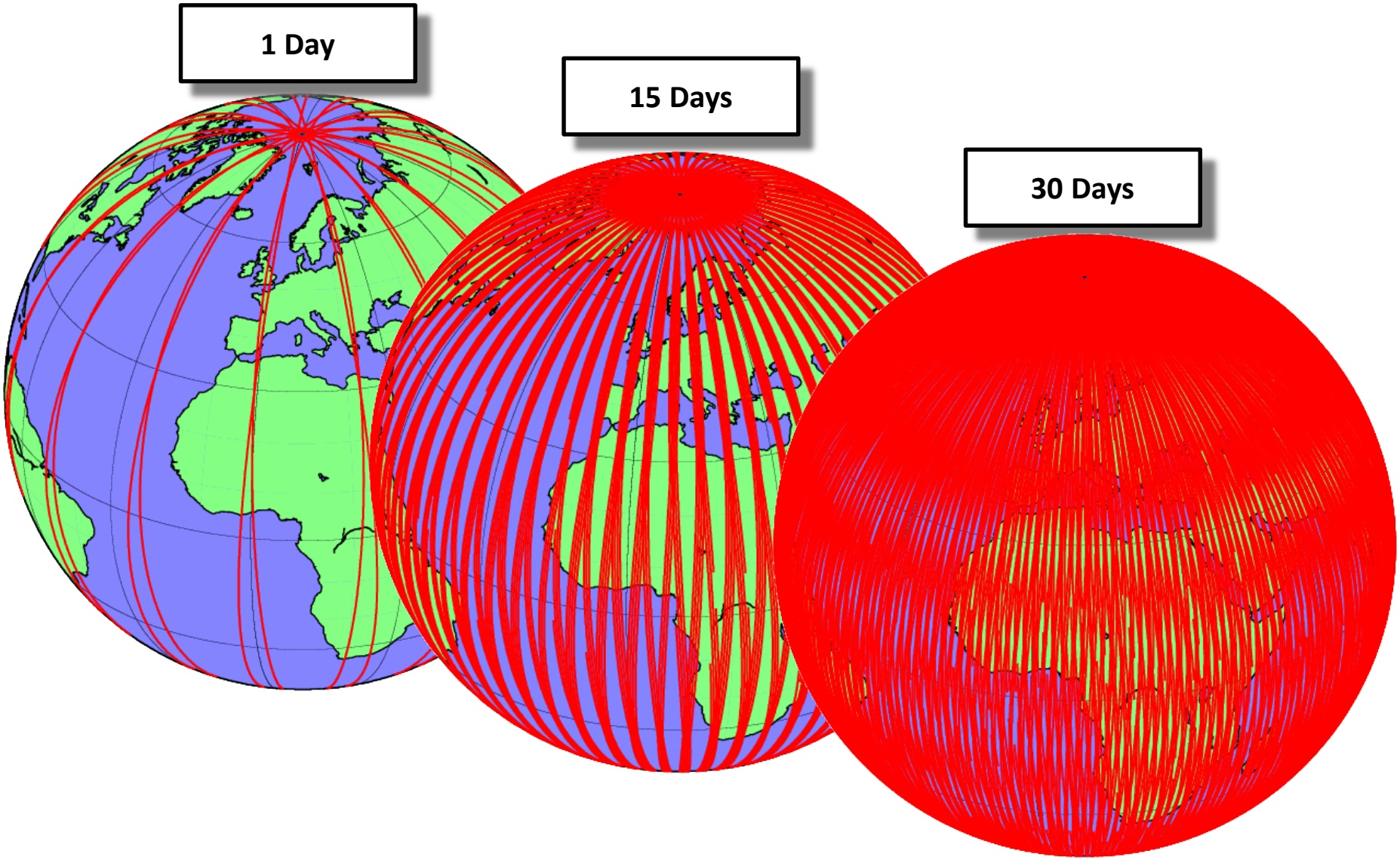

Near Real-Time Service

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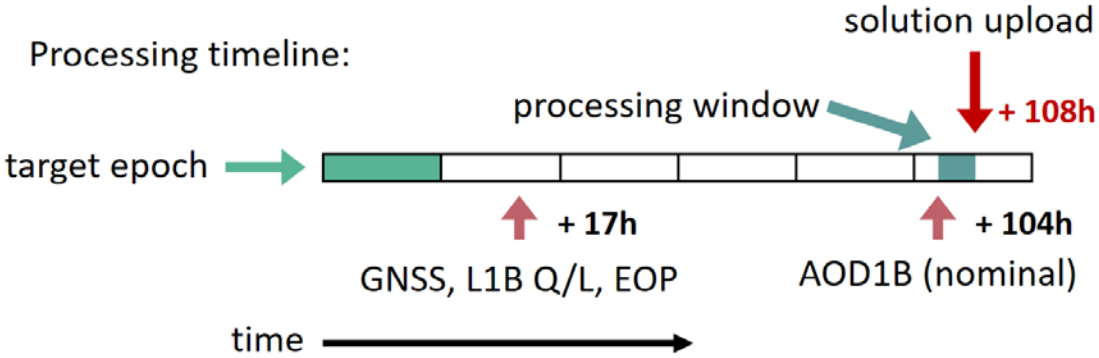
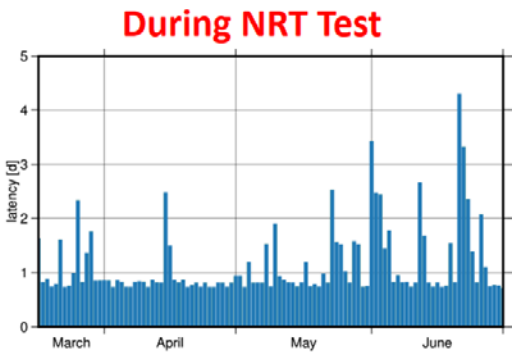
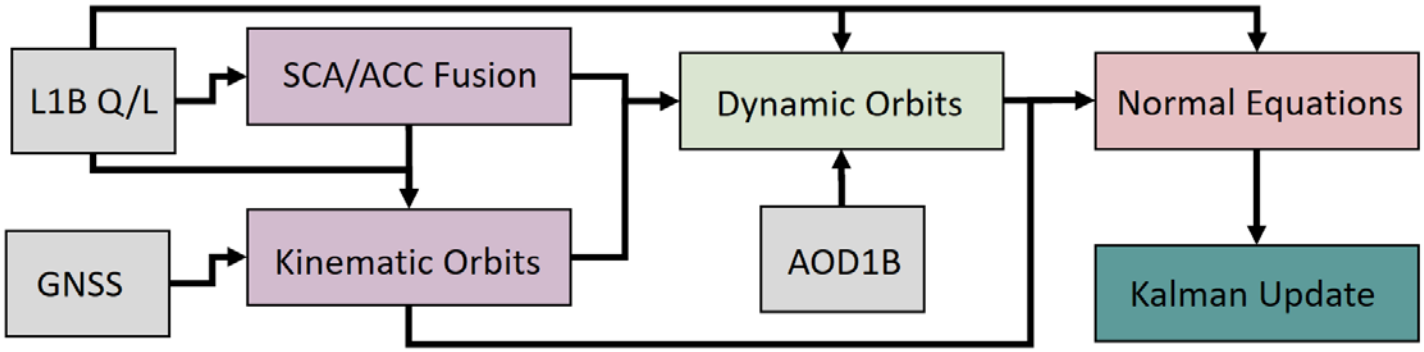
- Processing timeline:





- Processing steps from raw data to final solution:



Solutions from Operational Test-Run

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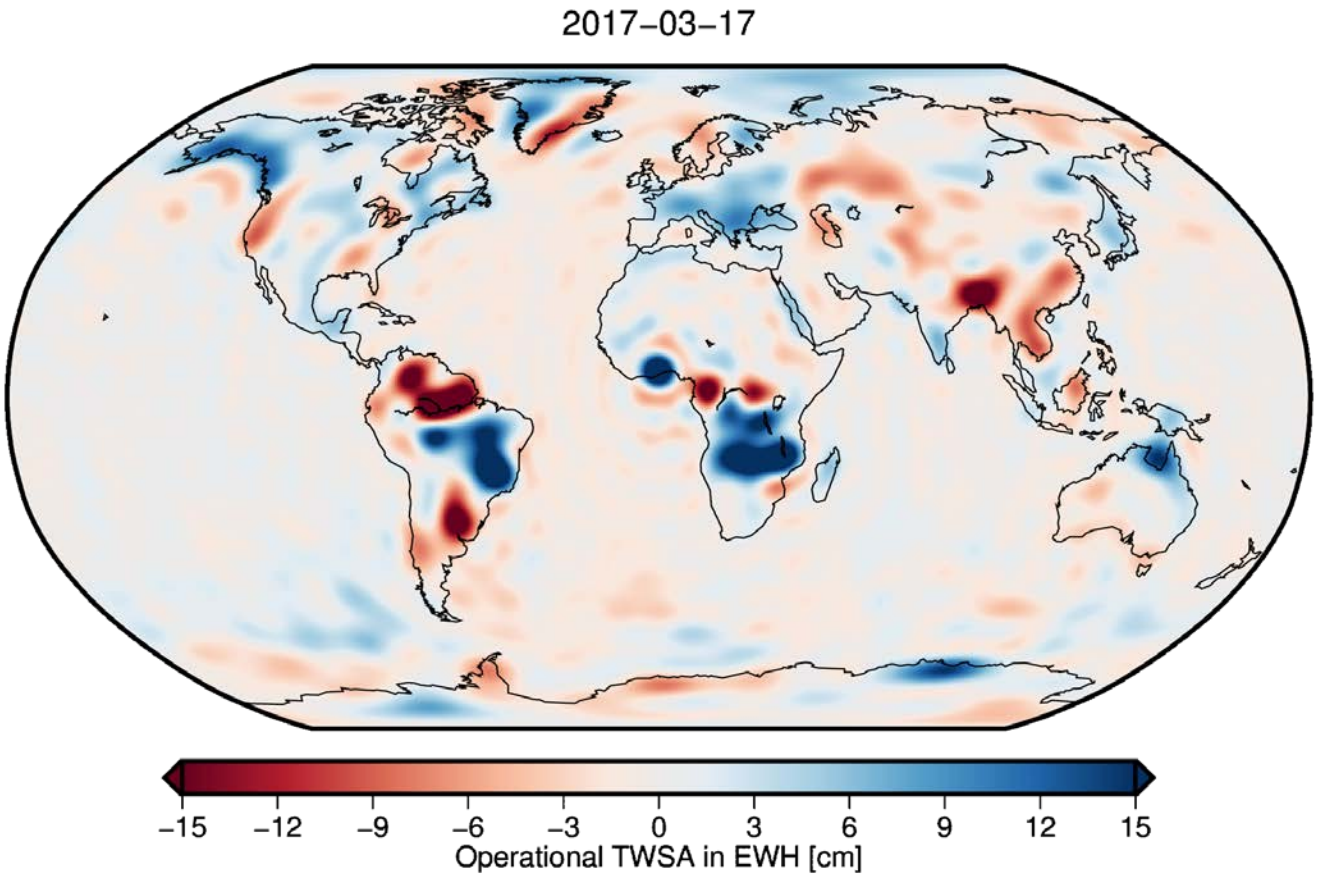

Hydrological Service

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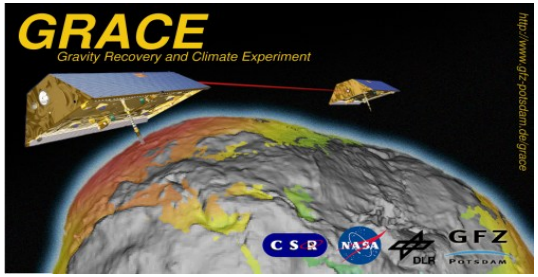
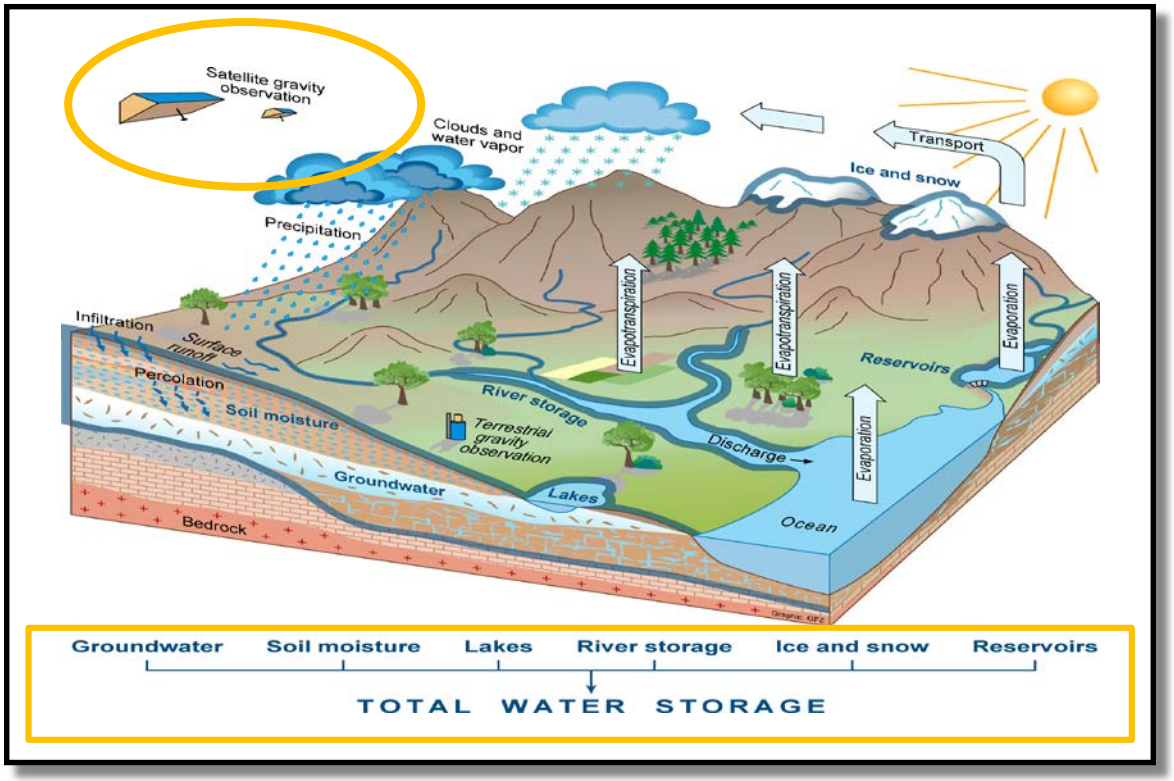


GRACE gravity-based time series of ***total*** water storage anomalies are an integral descriptor of the wetness status of river basins

- GRACE: 2002 – 2017
- GRACE-FO: 2018 – 2023



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Hydrological Service

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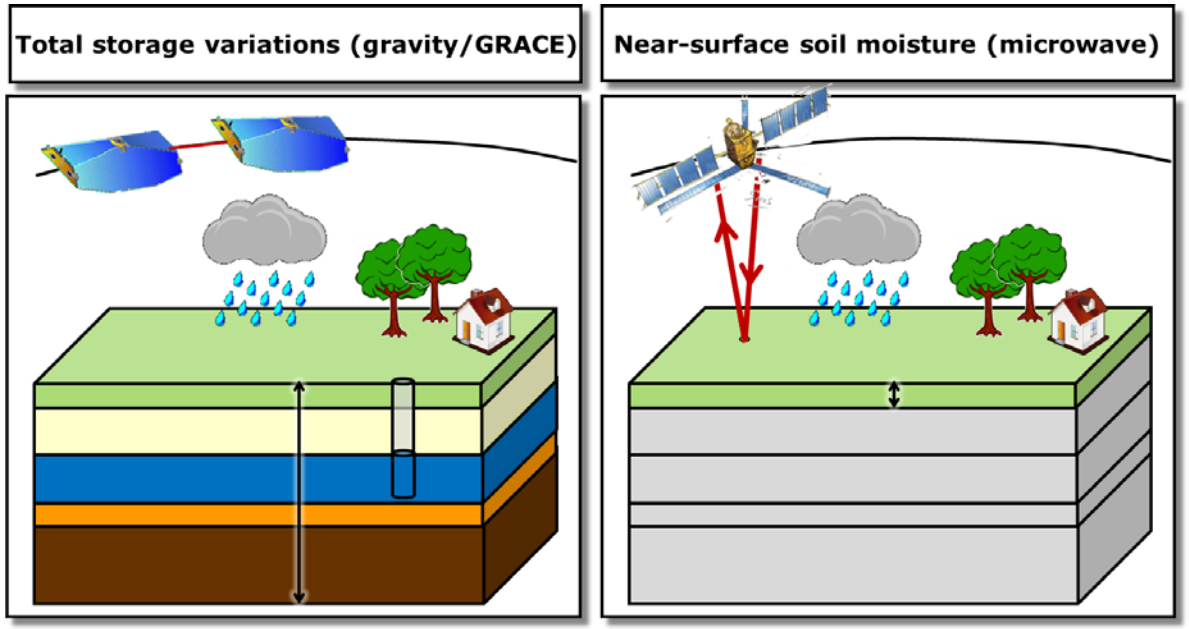
GRACE gravity-based time series of total water storage ***anomalies*** are an integral descriptor of the wetness status of river basins

Hypothesis:
added value for flood monitoring and forecasting



Different sensitivities are expected compared to standard indices based on precipitation or soil moisture.

Hydrological Service

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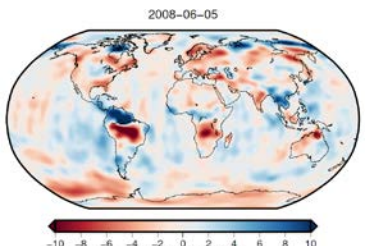
Daily GRACE Total Water Storage Anomalies (TWSA)

Three products from two processing centres:
- TU Graz, ITSG-2018
- TU Graz, ITSG-2016
- GFZ Potsdam



Total water storage anomaly [cm]

Secular

Inter-annual

Seasonal

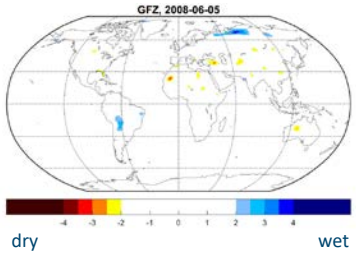
Residual

decomposition

normalize

by standard deviation

Wetness Index



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Example: Ganges-Brahmaputra

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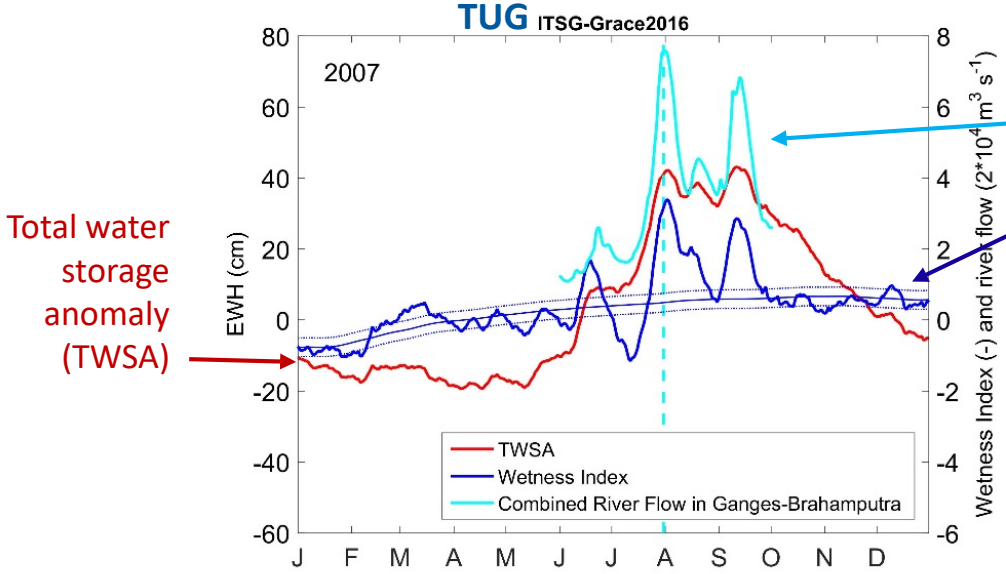
Daily GRACE data track major flood events
in the Ganges-Brahmaputra Delta - example 2007 flood

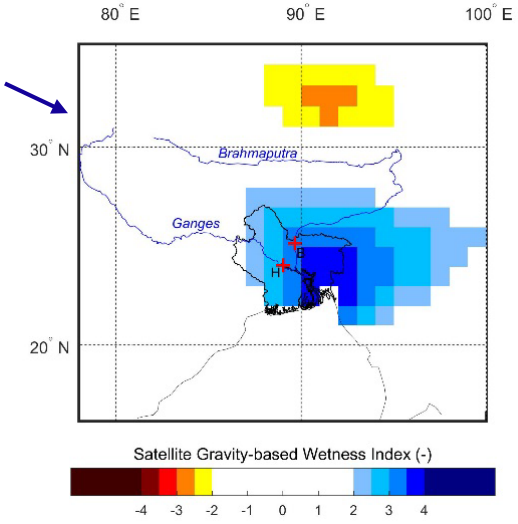


Total water storage anomaly (TWSA)

Discharge

Wetness Index

31 July 2007



Gouweleeuw et al. (2018)

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Example: Danube Basin

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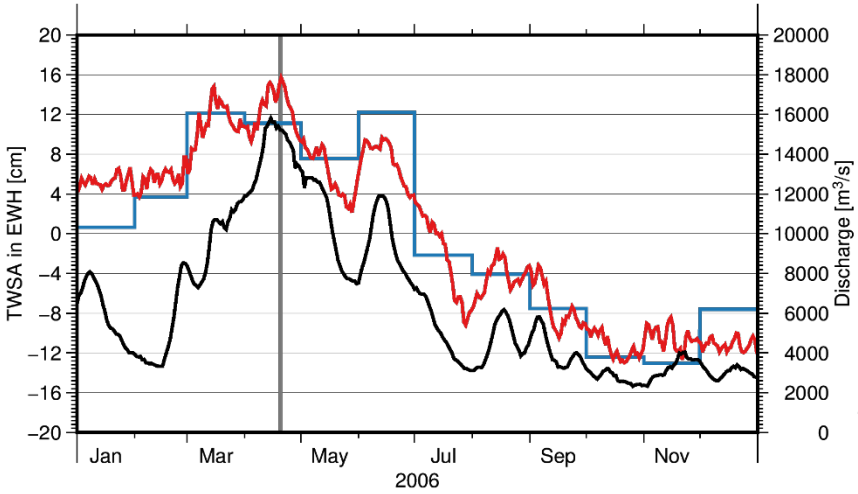
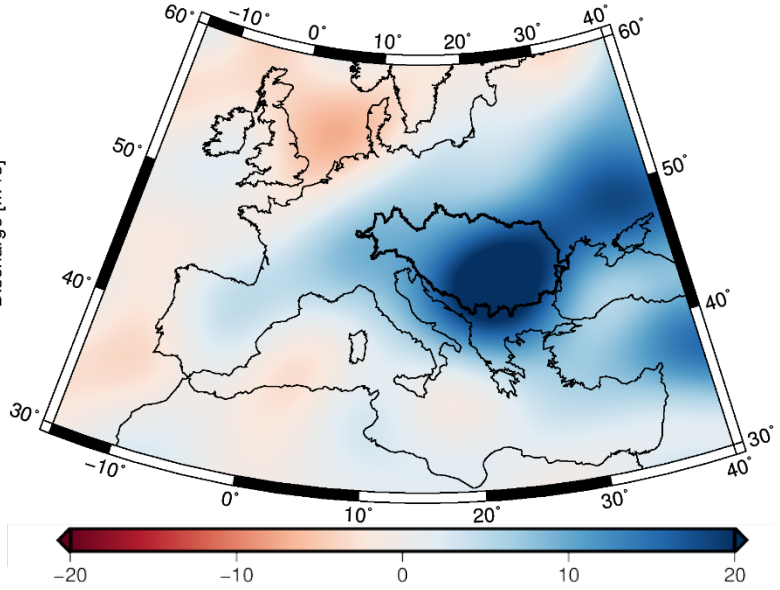
Comparison to monthly GRACE data and river discharge



GRACE daily water storage (ITSG-Grace2016)

GRACE monthly water storage (CSR RL05)

River discharge (station Bazias)



Total water storage anomaly at time of flood peak [cm]

Global-Scale Analysis of Flood Events

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Data Basis:

Dartmouth Flood Observatory

Archive of the Dartmouth Flood Observatory (DFO)

- 2411 river flood events in the GRACE period 2002-2015
- 616 with DFO event area > 100 000 km²
- event duration mostly < 25 days (75% of all events)

Methods:

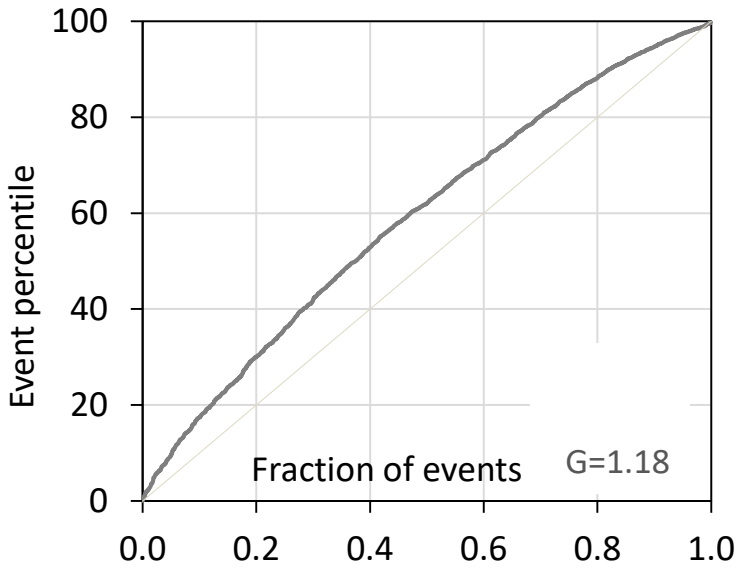
- Calculate area-average GRACE water storage anomaly / wetness index for each event
- Determine percentile of event storage anomaly within full time series (2002-2015)

Global-Scale Analysis of Flood Events

European Gravity Service for Improved Emergency Management

Global-scale analysis of flood events

Percentiles of GRACE-based wetness index for DFO events (2002-2015)



ITSG-Grace2016, all DFO events (n=2411)

G: modified Gini coefficient as a measure of the deviation from a uniform distribution (G=1.0)

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Global-Scale Analysis of Flood Events

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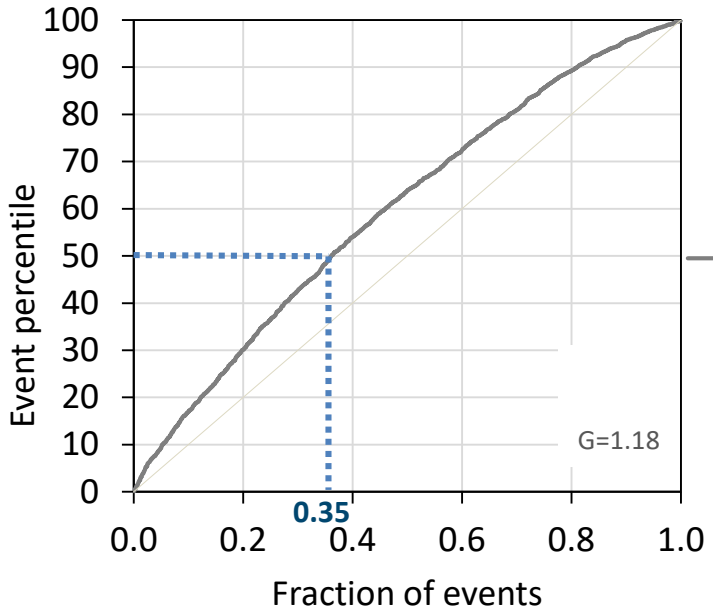
Global-scale analysis of flood events

Percentiles of GRACE-based wetness index for DFO events (2002-2015)



e.g., 65% of the events have a GRACE-based wetness index that is larger than the long-term median wetness index value in the event area

G: modified Gini coefficient as a measure of the deviation from a uniform distribution (G=1.0)

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Global-Scale Analysis of Flood Events

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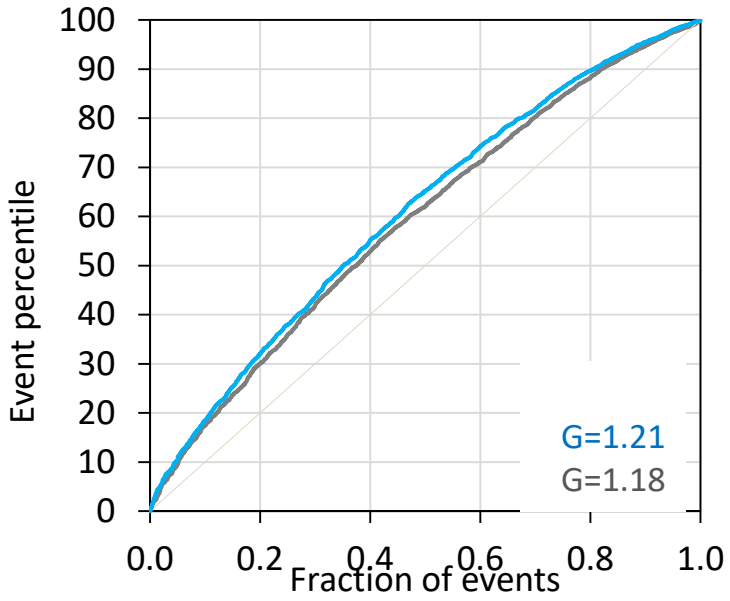
Global-scale analysis of flood events

Percentiles of GRACE-based wetness index for DFO events (2002-2015)



ITSG-Grace2016, all DFO events (n=2411)

ITSG-Grace2018, all DFO events (n=2411)

G: modified Gini coefficient as a measure of the deviation from a uniform distribution (G=1.0)

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Global-Scale Analysis of Flood Events

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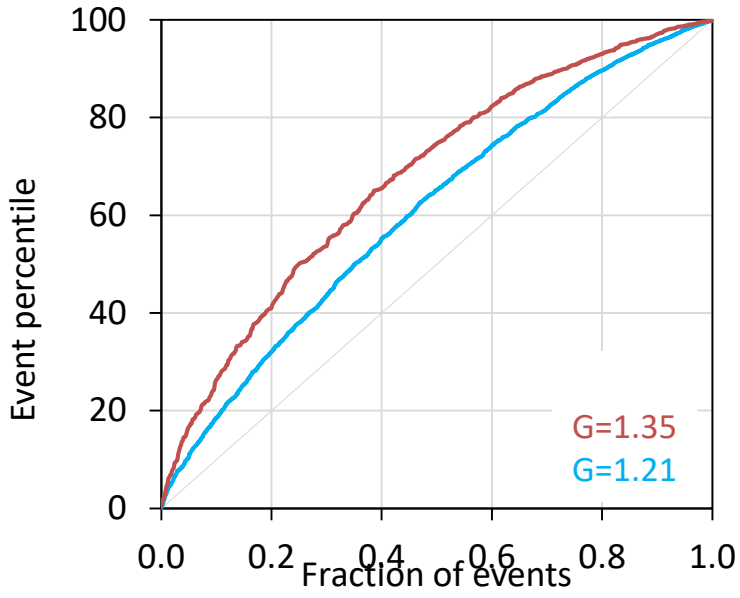
Global-scale analysis of flood events

Percentiles of GRACE-based wetness index for DFO events (2002-2015)



— ITSG-Grace2018, all DFO events (n=2411)

— ITSG-Grace2018, DFO events with area > 100 000 km² (n=616)

G: modified Gini coefficient as a measure of the deviation from a uniform distribution (G=1.0)

Global-Scale Analysis of Flood Events

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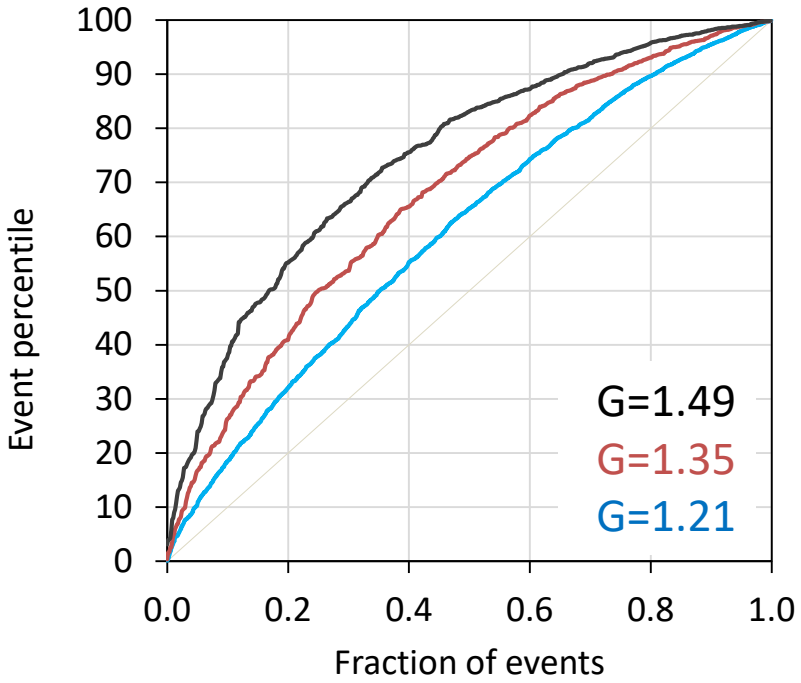
Global-scale analysis of flood events (2002-2015)

Percentiles of GRACE-based wetness index and total water storage anomalies (TWSA) for DFO events



ITSG-Grace2018, all DFO events (n=2411)

ITSG-Grace2018, DFO events with area > 100 000 km² (n=616)

ITSG-Grace2018, DFO events with area > 100 000 km², detrended TWSA only (n=616)

G: modified Gini coefficient as a measure of the deviation from a uniform distribution (G=1.0)

Global-Scale Analysis of Flood Events

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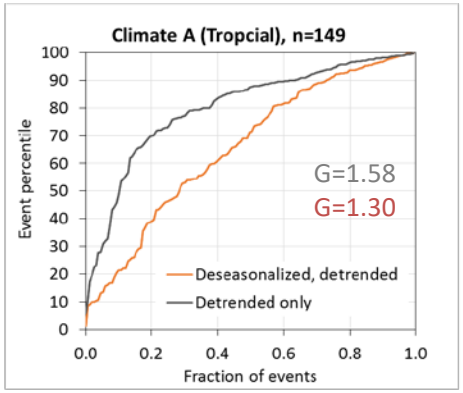
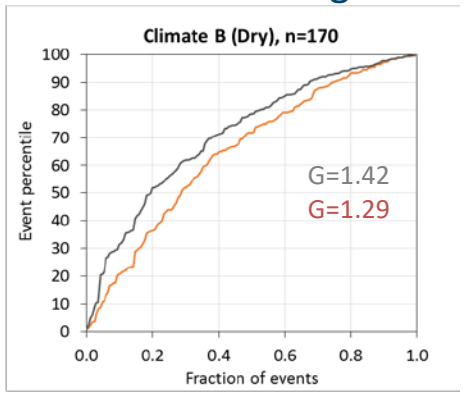
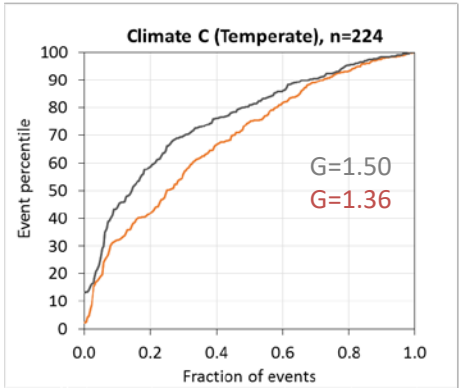
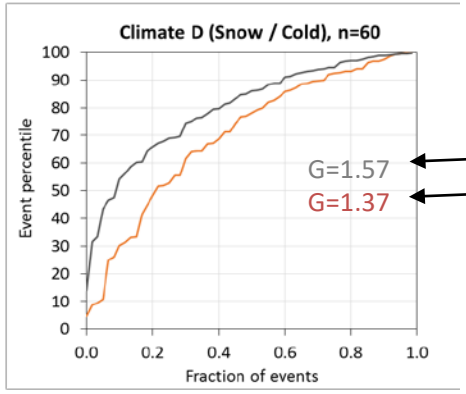
Global-scale analysis of flood events (2002-2015)

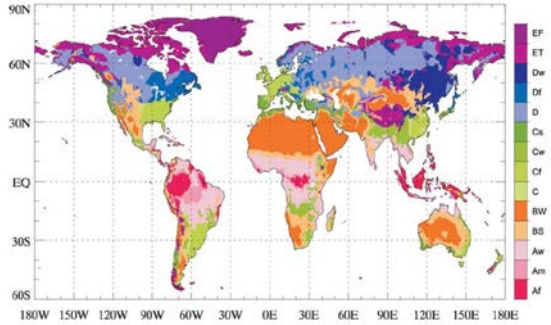
Percentiles of GRACE-based total water storage anomalies (TWSA) for DFO events, sorted for Koeppen climate zones











detrended only
deseasonalized, detrended

G: modified Gini coefficient as a measure of the deviation from a uniform distribution (G=1.0)

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Early Indication of Flood Events

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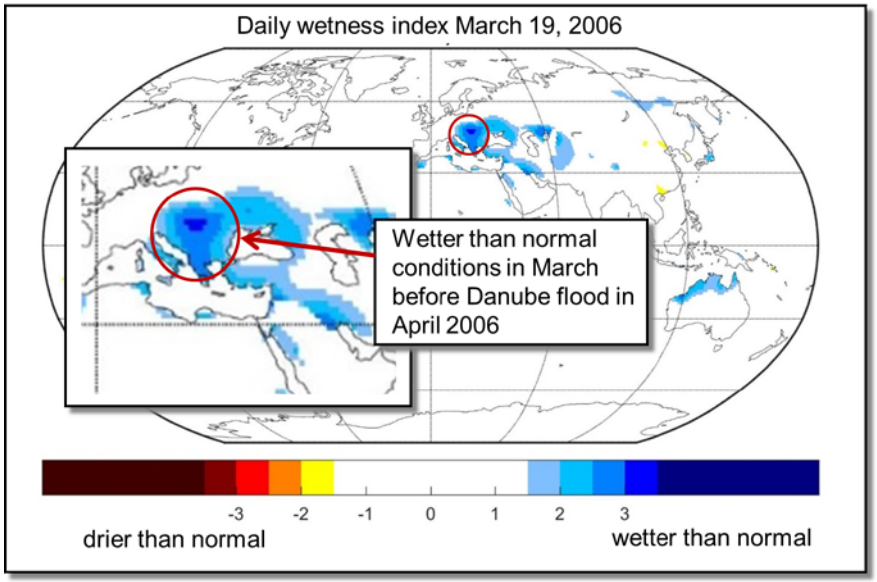
Gravity-based wetness index as early flood indicator

Example Danube Flood 2006

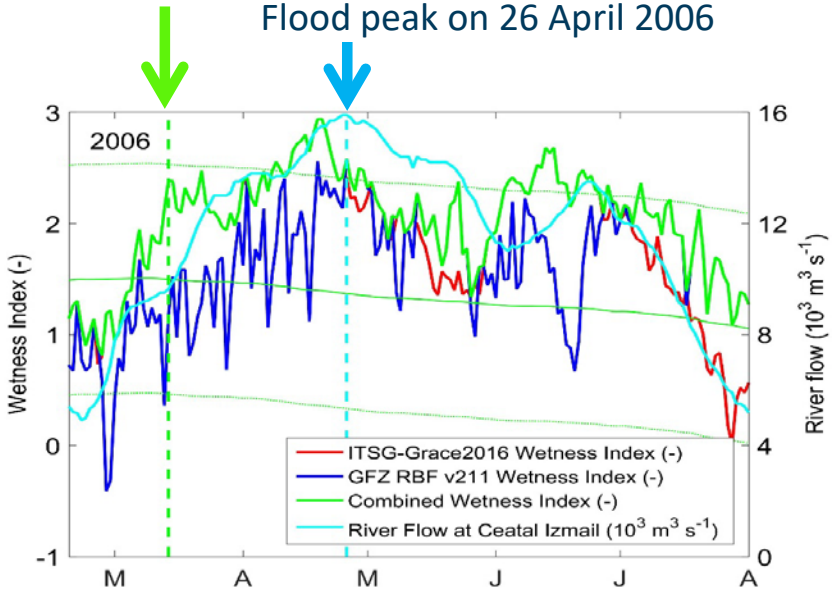
First Peak of Wetness Index on 14 March 2006

Lead time: 43 days



River discharge at Ceatal Izmail (outlet of the Danube Basin)

Flood peak on 26 April 2006



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Early Indication of Flood Events

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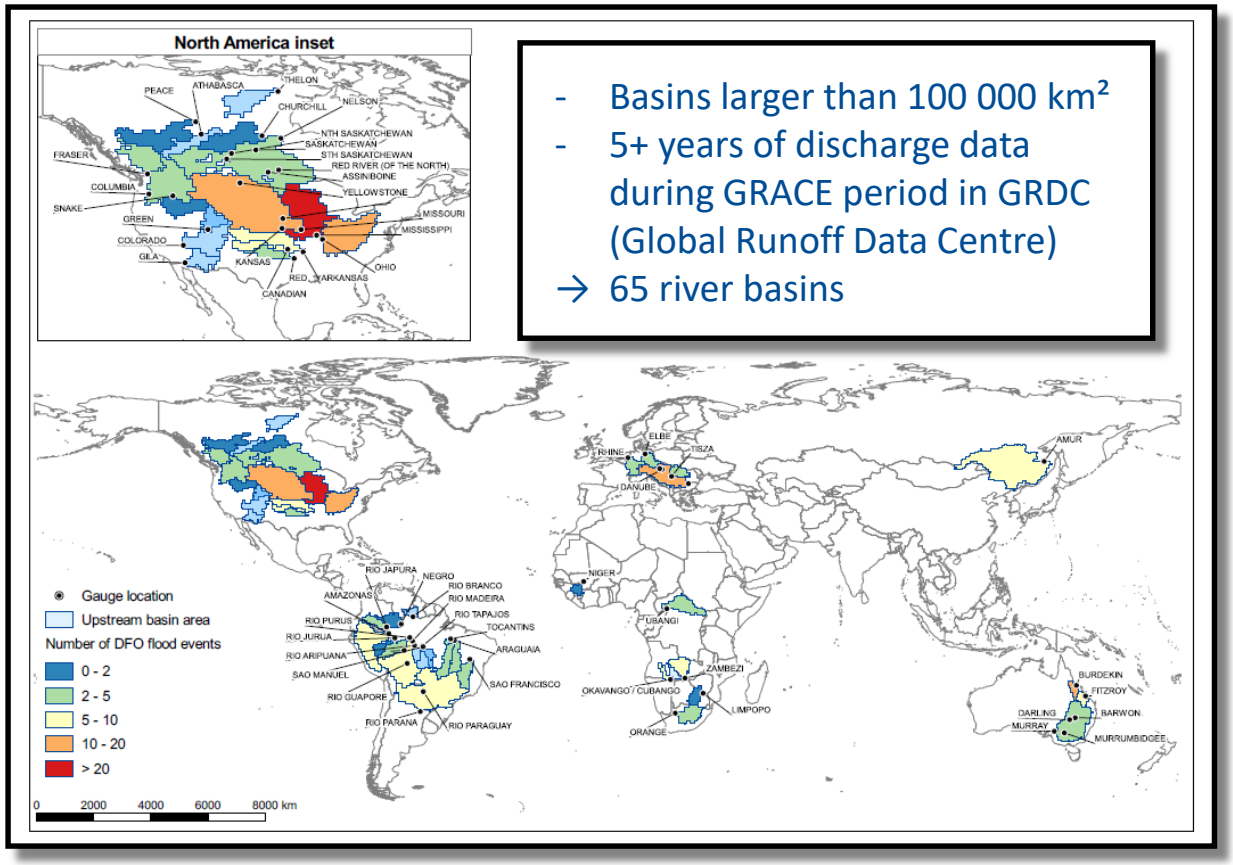
Gravity-based wetness index as early flood indicator

Global-scale analysis



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Early Indication of Flood Events

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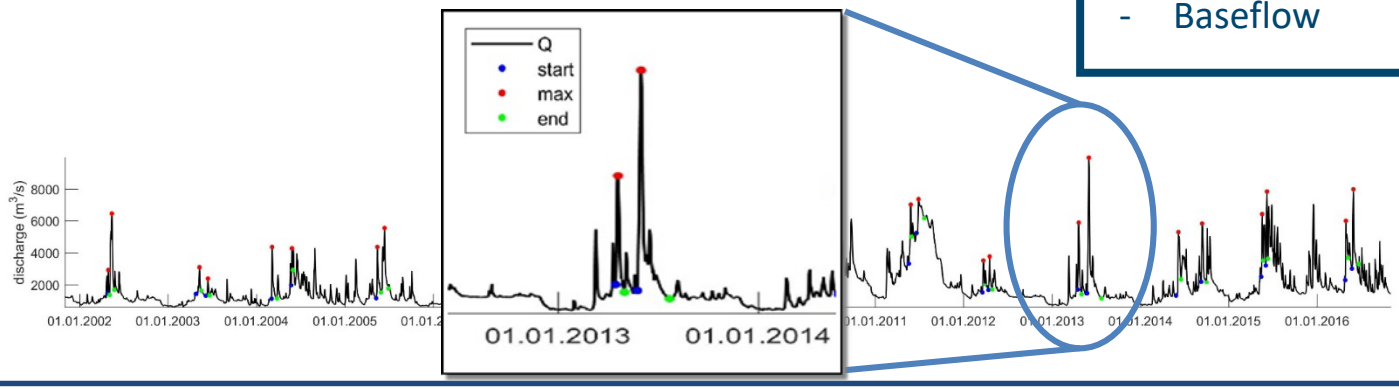
Gravity-based wetness indices as early flood indicators

Global-scale analysis

Flood event characteristics
- Peak discharge
- Flood volume
- Runoff ratio

Wetness indices
at the day before the event starts:
- GRACE-based water storage anomaly
- GRACE-based wetness index (de-seasonalized)
- Near-surface soil moisture (ESA CCI satellite product)
- Antecedent Precipitation Index (API)
- Baseflow



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Early Indication of Flood Events

European Gravity Service for Improved Emergency Management

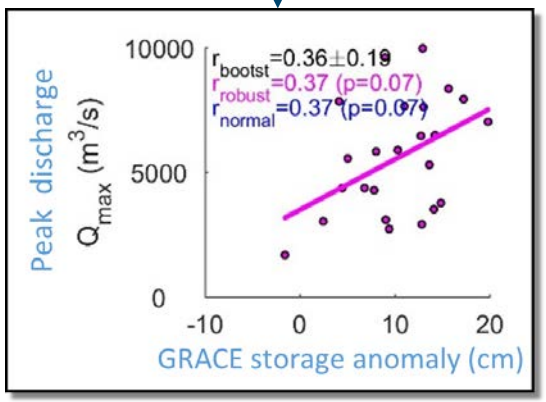
Gravity-based wetness indices as early flood indicators

Global-scale analysis

Flood event characteristics
- Peak discharge
- Flood volume
- Runoff ratio

Correlation analysis

Wetness indices
at the day before the event starts:
- GRACE-based water storage anomaly
- GRACE-based wetness index (de-seasonalized)
- Near-surface soil moisture (ESA CCI satellite product)
- Antecedent Precipitation Index (API)
- Baseflow



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Early Indication of Flood Events

European Gravity Service for Improved Emergency Management

Gravity-based wetness indices as early flood indicators – global-scale analysis

Average **correlations** between flood characteristics and pre-event flood indicators

River basins in temperate climate zone

	Storage anomaly	Wetness index	Soil moisture	Baseflow	Antecedent Precip Index
	GRACE	GRACE	ESA CCI	Gauge	GPCP
Peak discharge	0.32	0.31	0.11	0.45	0.13
Flood volume	0.08	0.09	0.00	-0.04	0.11
Runoff coefficient	0.14	0.14	0.03	-0.07	-0.07

River basins in snow-dominated climate

	Storage anomaly	Wetness index	Soil moisture	Baseflow	Antecedent Precip Index
	GRACE	GRACE	ESA CCI	Gauge	GPCP
Peak discharge	0.48	0.46	0.08	0.50	0.23
Flood volume	0.26	0.13	0.03	0.00	0.09
Runoff coefficient	0.26	0.10	-0.11	-0.08	-0.11

- Gravity-based indices mostly result in higher correlations than other indices
- In snow-dominated basins, correlations tend to be higher
- GRACE storage anomalies correlate higher than wetness index in snow basins

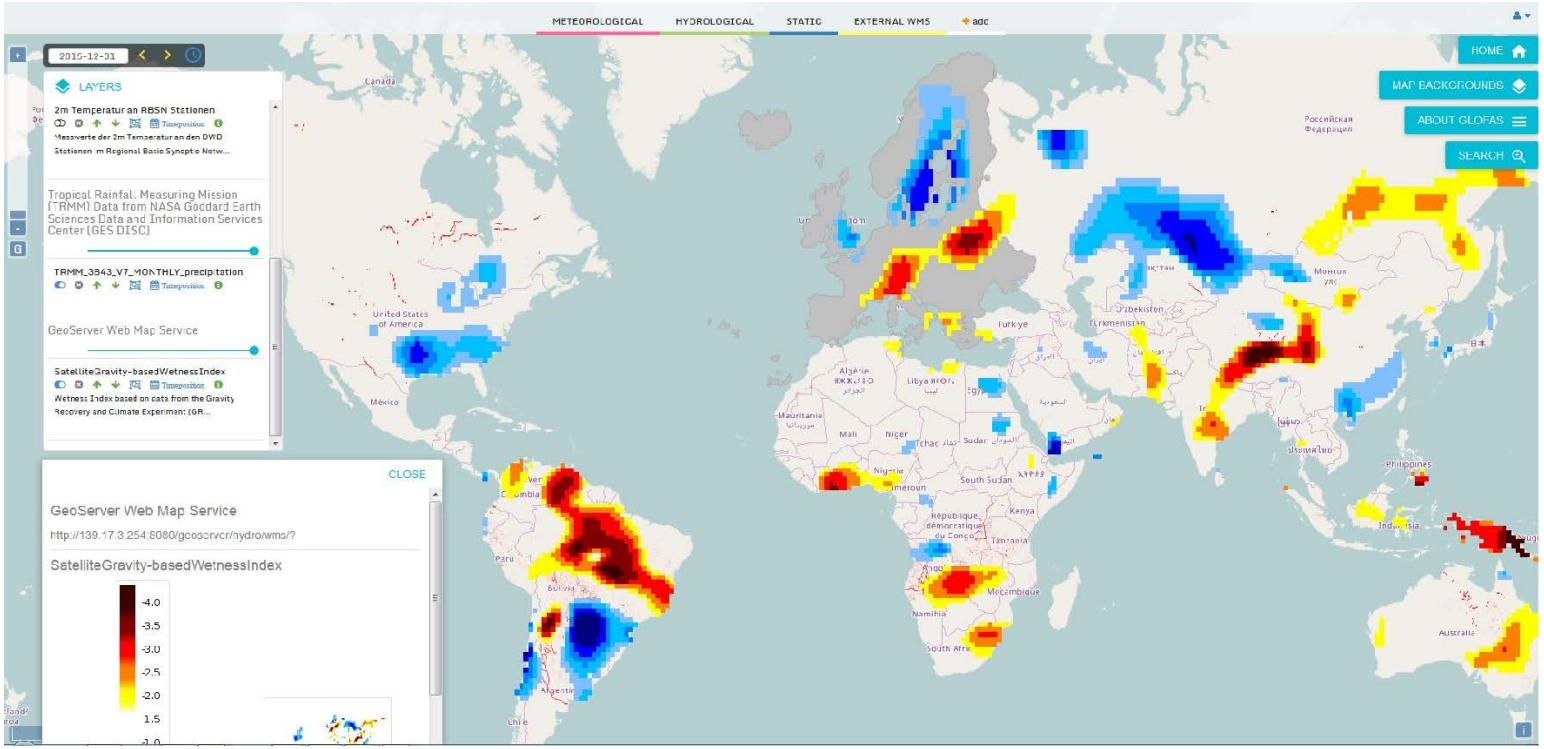
Conclusions

- Daily gravity-based water storage time series can monitor the dynamics of large-scale flood events
- The seasonality of water storage is particularly relevant to explain floods in snow-dominated and semi-humid tropics
- Wetness index derived from daily gravity data shows early flood warning capacity in case studies
- Gravity-based flood indicators outperform classical indices, albeit with overall low correlations to flood characteristics

Outlook

European Gravity Service for Improved Emergency Management

- Integration into automatic flood emergency management services



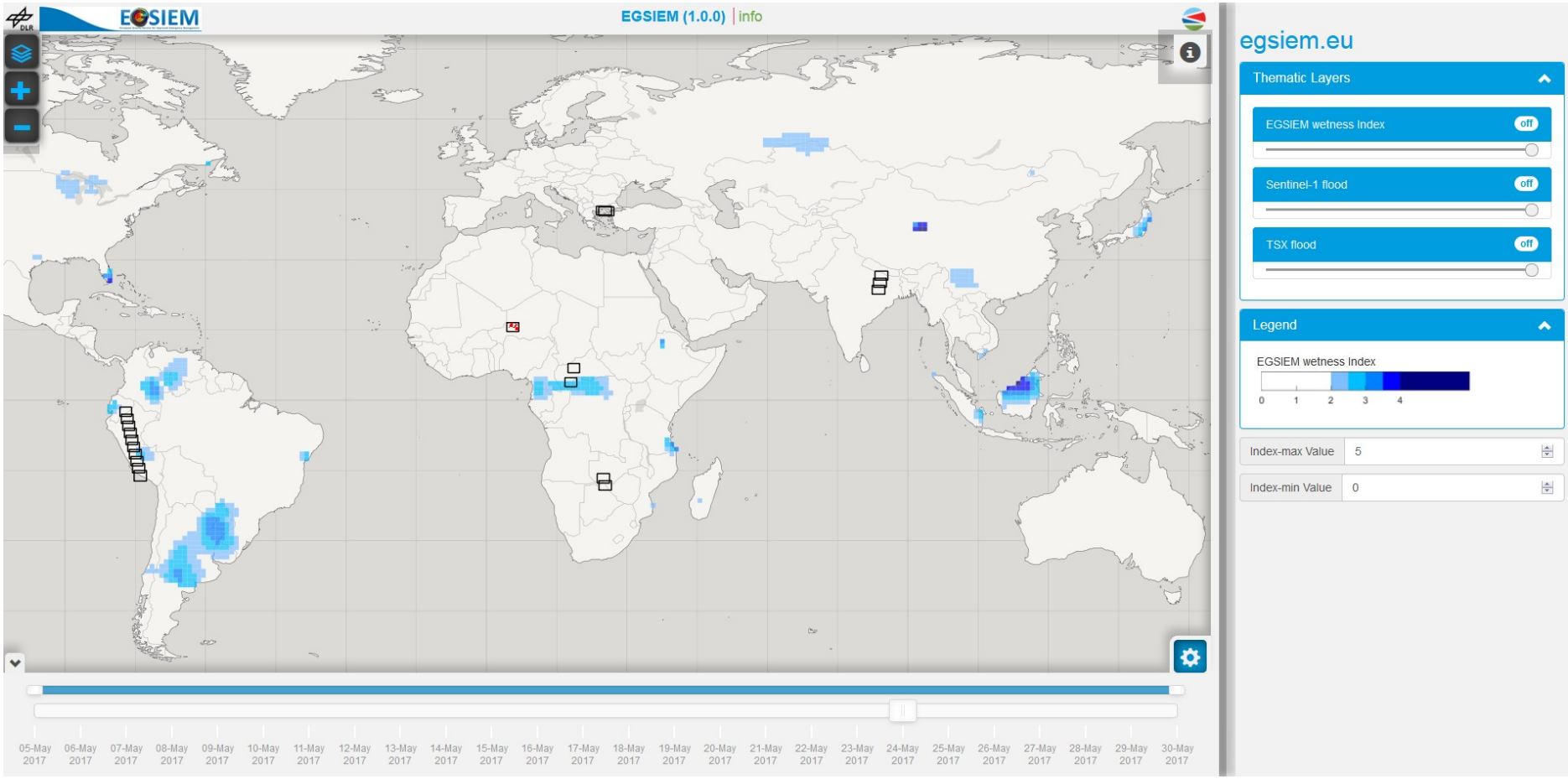
Operational for April 1 to June 30, 2017

HORIZON 2020

Outlook

EGSIEM

European Gravity Service for Improved Emergency Management



EGSIEM

HORIZON 2020

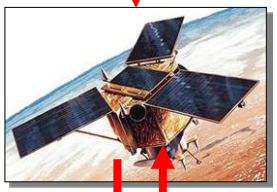
Outlook

EOSIEM
European Gravity Service for Improved Emergency Management

ZKI: Center for satellite-based crisis information @ DLR

ZKI

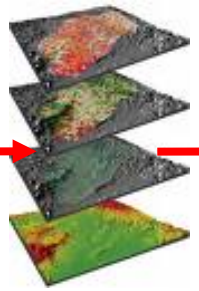
Alarm



Data acquisition

Pre-processing

Rapid Mapping Concept:
Improved Awareness due to Gravity-based Indicators



Analysis

Map Generation

Information

„Science for Society“

From science …

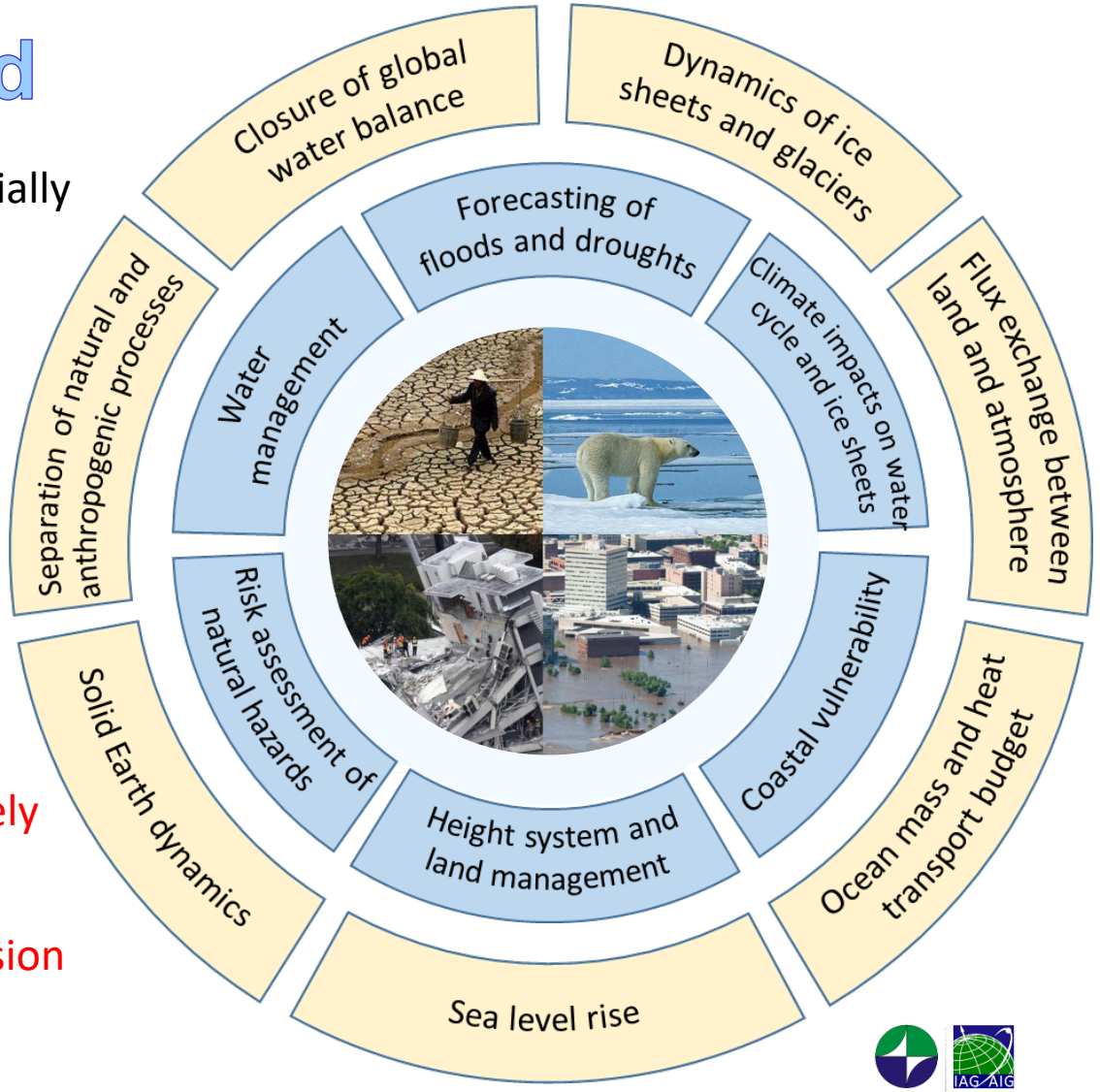
… to societal need

Gravity-derived products can potentially be directly used in many of existing services, e.g. in the Copernicus services …

… but may also be used in many more applications and future services.

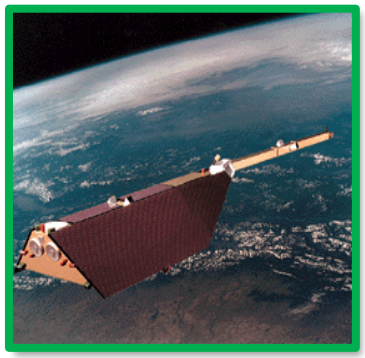
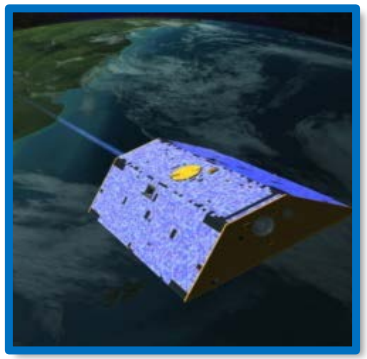
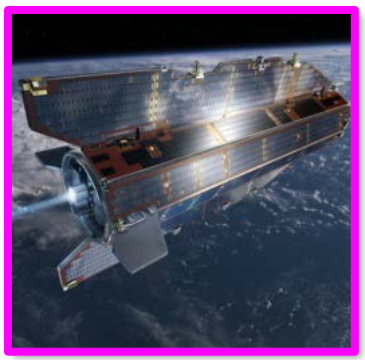
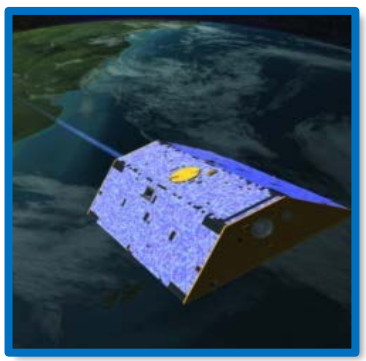
Already today a number of ECVs and services based on Copernicus data rely on gravity observations.

However, no operational gravity mission is planned yet!



Pail et al. (2015)

Continuity of mass transport measurements


CHAMP (GFZ, 2000-2010)

GRACE (NASA/DLR, 2002-2017)

GRACE-FO (NASA/GFZ, 2018-2023)

GOCE (ESA, 2009-2013)

GRACE-2 / Sentinel-??

Gravity missions enabled spectacular results:

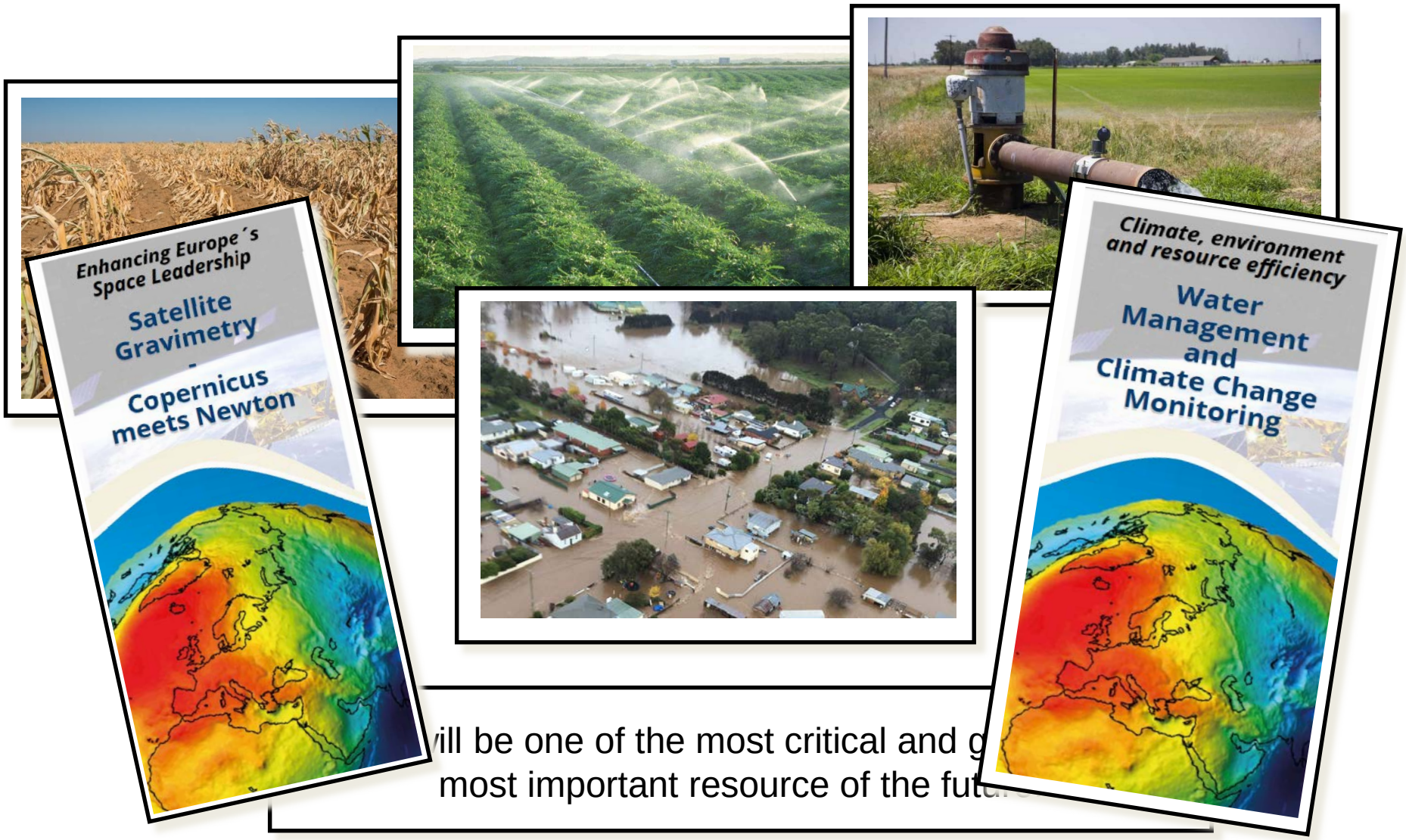
- insights into the global water cycle
- polar and mountain ice mass loss
- changes in ocean surface currents
- unification of height systems
- sea level rise

→ **There is a strong need for sustained observation.**

Outlook

EOSIEM

European Gravity Service for Improved Emergency Management

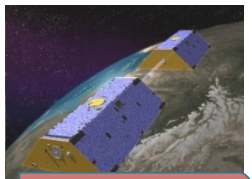


ill be one of the most critical and g
most important resource of the futu

Outlook

EOSIEM
European Gravity Service for Improved Emergency Management


Altimetry


Gravity


Copernicus

Data processing
and dissemination

Gravity: one of the missing links in the Copernicus Earth Observation

Service evolution:

- Atmosphere monitoring
- Marine environment monitoring
- Emergency management
- Land monitoring
- Climate change

Copernicus
Europe's eyes on Earth

Thanks a lot for your attention!