

EGSIEM

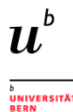
European Gravity Service for Improved Emergency Management

Title: **Improved Level 2 products**

Presenter: TMG

Affiliation: TUG

EGSIEM Meeting Potsdam,
02.06.2016 - 03.06.2016



Leibniz
Universität
Hannover



Horizon2020

Motivation

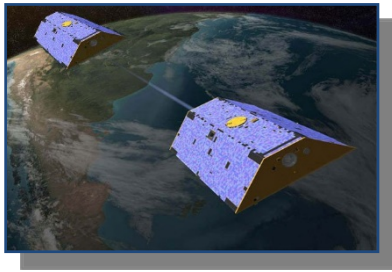
GRACE Level 2 products are complicated to use!

⇒ Generation of user friendly Level 3 products

Can we make the Level 2 products more user friendly too?

GRACE observations

GRACE observes the total mass change



Level 2 should reflect this

Level 2 should include additional models for signal separation

- Hydrology
- Ice sheets
- Glaciers
- Permanent frost
- Ocean tides
- Ocean pole tides
- Barotropic ocean circulation
- Sea level rise
- Atmospheric tides (S1, S2)
- Atmospheric mass redistribution
- Solid Earth tides
- Rotational deformation (pole tides)
- Glacial isostatic adjustment
- Loading deformation
- Degree 1 mass redistribution
- Earthquakes

Ice

Ocean

Atmosphere

Solid Earth

A possible new definition of Level 2 products

GRACE Level 2 product (GSM)

- Gravitational potential generated by the complete mass of the Earth

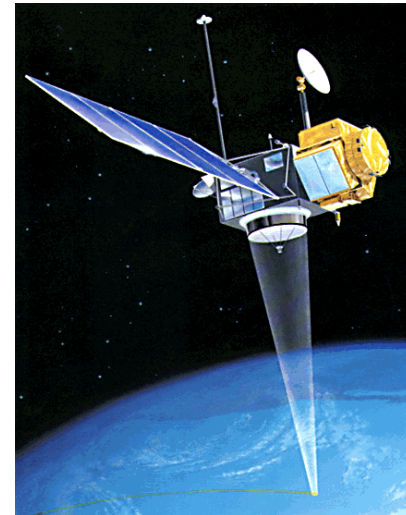
Part of the Level 2 products:

Monthly mean of models for signal separation

- Solid Earth tides
- Rotational deformation (pole tides)
- Glacial isostatic adjustment
- Degree 1 mass redistribution
- Ocean tides
- Ocean pole tides
- Barotropic ocean circulation
- Atmospheric mass redistribution
- Continental hydrology

Regularly used for Altimeter data. Each observation is supplemented by geophysical models, e.g.

- Inverse barometric effect
- Ocean tides
- Geoid



Definition

In the reference system community:

Distinction between:

- “System”: Theoretical definition (Goal: products without noise/errors/problems)
- “Frame”: Realization (Instruments noise, Complicated space-time pattern, Aliasing)

GRACE: only realizations without theoretical definition

Proposal of a theoretical definition:

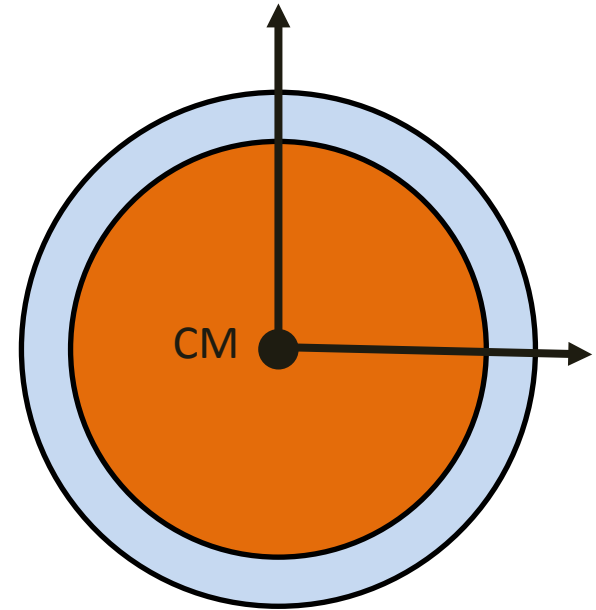
GRACE monthly solution (GSM)

- Gravitational potential generated by the complete mass of the Earth
- Origin is the center of mass (CM)
- Orientation is aligned to ITRS
- Mean mass distribution of the complete month

Geocenter motion

Center of mass (CM)

- The degree 1 terms of the sum of all masses do not change (set to zero)
- If the degree 1 terms of the fluid envelope (ocean, atmosphere, hydrology, ...) changes, the degree 1 terms of the solid Earth changes too



Geocenter motion

Center of mass (CM)

- The degree 1 terms of the sum of all masses do not change (set to zero)
- If the degree 1 terms of the fluid envelope (ocean, atmosphere, hydrology, ...) changes, the degree 1 terms of the solid Earth changes too

Center of solid Earth (CE) / Center of figure (CF)

- The degree 1 terms of the solid Earth do not change
- (only the terms of the fluid envelope changes)

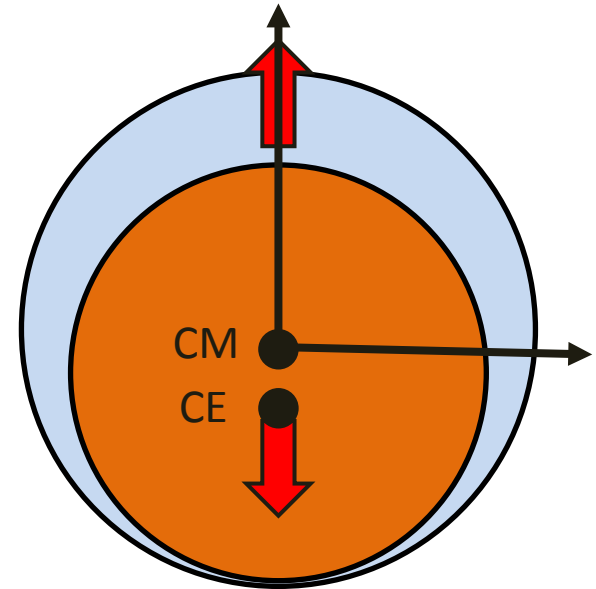
Transformation from CM to CE

Must remove the degree 1 terms of the solid Earth from the degree 1 of the complete mass

⇒ Signal separation problem

⇒ Cannot provided by GRACE only

⇒ Model / external data needed



For hydrology apps.: remove solid earth and ocean

For ocean apps.: remove solid earth and hydrology

Geocenter motion

Center of mass (CM)

- The degree 1 terms of the sum of all masses do not change (set to zero)
- If the degree 1 terms of the fluid envelope (ocean, atmosphere, hydrology) changes, the degree 1 terms of the sum of all masses do not change (set to zero)

GRACE Level 2:

- GRACE monthly solution (GSM) in CM (degree 1 set to zero)
 - Contains all mass variations
- Additional degree 1 products for signal separation
 - Solid earth
 - Ocean
 - Hydrology
 - Atmosphere (Provided by Tellus already)

Center of solid earth (CSE)

- The degree 1 terms of the sum of all masses do not change (set to zero)
- (only the terms of the solid earth)

Transformation

Must remove the degree 1 terms of the sum of all masses

the degree 1 terms of the sum of all masses

⇒ Signal separation

⇒ Cannot be provided by GRACE only

⇒ Model / external data needed

For hydrology apps.: remove solid earth and ocean

For ocean apps.: remove solid earth and hydrology

Definition

In the reference system community:

Distinction between:

- “System”: Theoretical definition (Goal: products without noise/errors/problems)
- “Frame”: Realization (Instruments noise, Complicated space-time pattern, Aliasing)

GRACE: only realizations without theoretical definition

Proposal of a theoretical definition:

GRACE monthly solution (GSM)

- Gravitational potential generated by the complete mass of the Earth
- Origin is the center of mass (CM)
- Orientation is aligned to ITRS
- Mean mass distribution of the complete month

Temporal average

Current definition

Average over all days with GRACE data

$$\bar{c}_{nm} = \sum_{i \text{ with GRACE}} \int_{t_i}^{t_{i+1}} c_{nm}(t) dt$$

Proposal of a new definition

Average over the complete month

$$\bar{c}_{nm} = \int_{t_0}^{t_1} c_{nm}(t) dt$$

What is the consequence?

Example usage of GRACE: Validation/Comparison with other data

- Altimetry
- Ocean bottom pressure recorder
- GPS loading deformation
- Hydrological model

⇒ Computation the temporal average

⇒ Must use the same time span as GRACE data

Which definition did you used?

(Almost) all users treat GRACE products as monthly means

⇒ **Level 2 should respect this**

Temporal average

Current definition

Average over all days with GRACE data

$$\bar{c}_{nm} = \sum_{i \text{ with GRACE}} \int_{t_i}^{t_{i+1}} c_{nm}(t) dt$$

Proposal of a new definition

Average over the complete month

$$\bar{c}_{nm} = \int_{t_0}^{t_1} c_{nm}(t) dt$$

GRACE processing:

Observation model assumes constant gravity field coefficients

Trying to remove all high frequent (submonthly) variations by models

⇒ Reduced Gravity field (GSM) should be constant within the month regardless which days are observed

Concerning only the mean of the background models (GAA, GAB, GAC, ...)

Summary

We should make the GRACE Level 2 products more user friendly

- With a clear theoretical definition

Theoretical definition:

GRACE monthly solution

- Gravitational potential generated by the complete mass of the Earth
- Origin is the center of mass (CM)
- Orientation is aligned to ITRS
- Mean mass distribution of the complete month

- With additional monthly mean of models for signal separation

- | | |
|--|---|
| <ul style="list-style-type: none">• Glacial isostatic adjustment• Degree 1 mass redistribution• Barotropic ocean circulation• Atmospheric mass redistribution• Continental hydrology | <ul style="list-style-type: none">• Solid Earth tides• Pole tides• Ocean tides• Ocean pole tides |
|--|---|