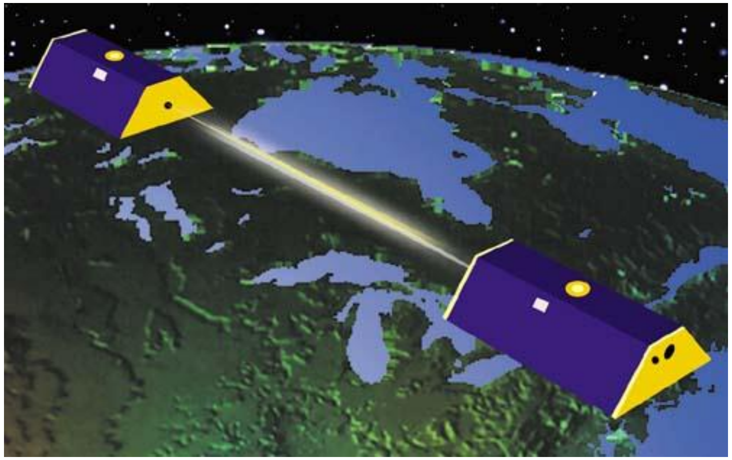
ON VARIABILITY OF GEOID IN EUROPE



Jan Krynski

Grazyna Kloch-Glowka

Malgorzata Szelachowska

Institute of Geodesy and Cartography, Warsaw

krynski@igik.edu.pl

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Outline

- introduction
- GRACE data applied
- methodology
- temporal variations of geoid heights
- modelling of geoid height changes
- prediction of geoid height changes
- conclusions

Introduction (1)

Satellite mission GRACE

Breakthrough in modelling gravity field

- **homogeneity** of data acquired
- **high accuracy and spatial resolution**
- **short acquisition time of data required for developing representative gopotential models**

→ **monitoring temporal variations of gravity field**

→ **temporal variations of geoid**

First use of SST in low-low mode

Advantages of SST

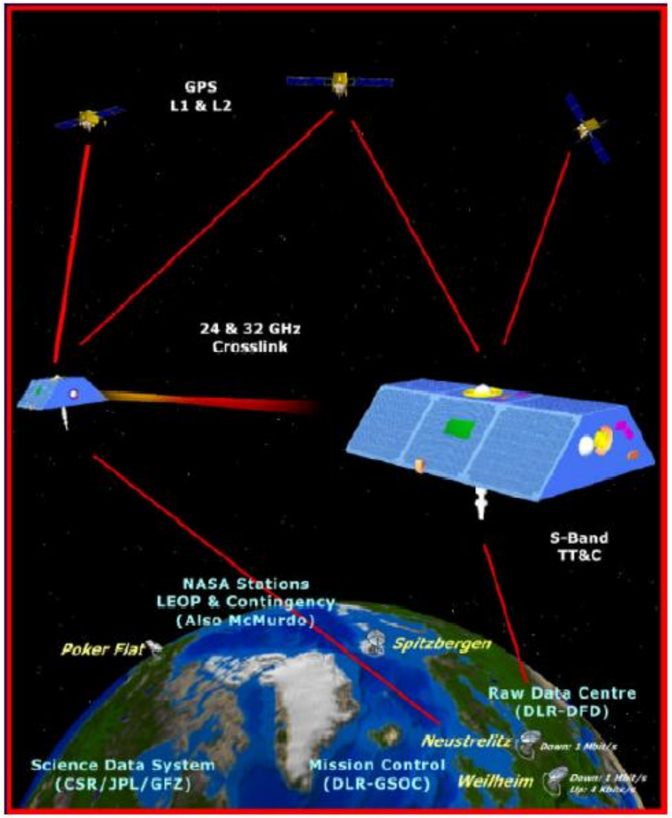
- **problem of terrestrial tracking stations eliminated** *(equipment, time synchronization, uniform coordinates)*
- **easy automatic tracking**
- **atmospheric refraction eliminated**
- **accuracy increase due to differential measurement**

Introduction (2)

Satellite mission GRACE

Gravity Recovery And Climate Experiment

- **launched 17 March 2002 r. (planned for 5 years – lasted >10 years)**
- **NASA & Germany**



Mission dedicated modelling gravity field and geiod with high accuracy and resolution

- **orbit: two almost identical orbits of satellites GRACE-A & GRACE-B**
  - **–** ***i*** **= 89°** *(inclination)*
  - **–** ***e*** **< 0.005** *(eccentricity)*
  - **–** ***H*** **= 485-200 km** *(altitude)*
  - **–** ***d*** **= 220 ± 50 km** *(separation of satellites)*
    (every 30-60 days orbit correction maneuver)

Introduction (3)

Satellite mission GRACE

- **distance between satellites observed with accuracy of 5 μm (10^{-6} m)**

  (DOWR – Dual-One-Way-Ranging technique)

  – phase measurement in two radio bands: K: f = 24.5 GHz
  Ka: f = 32.7 GHz

  at 1 s rate with accuracy of 10^{-4} cycle

  – satellite clocks synchronized with accuracy of 10^{-10} s (0.1 ns)

  – synchronized measurement of GRACE-A – GRACE-B
  and GRACE-B – GRACE-A

  eliminates satellite clock errors since
  the observed phases are summed up

Introduction (4)

Satellite mission GRACE

- **each satellite equipped also with**
  - **dual-frequency 14-channel self-initialising GPS Blackjack receiver**
    (high-low SST positioning with accuracy of 2 cm)
  - **ultra-stable oscillator**
    (for low-low SST positioning)
  - **accelerometer of accuracy of 10^{-10} ms^{-2}**
    (for elimination atmospheric drag and non-gravitational effects)
  - **a pair of cameras orienting with respect to stars (25" accuracy) consisting of optical telescope with a CCD camera**
    (for elimination of orientation errors from measured distance)
  - **system of laser retroreflectors**
    (laser tracking besides GPS tracking)

Introduction (5)

Satellite mission GRACE

Modelling gravity field using GRACE data:

- **varying in time geopotential models**

monthly GGM solutions: (60 x 60) - (120 x 120)
CSR, GFZ, JPL and later AIUB

- determination of variability of harmonics up to 30-50 degree/order

- monitoring variability of mass in atmosphere, hydrosphere, geosphere
e.g. hydrology changes of 1 cm in 1000 km area

10-day GGM solutions of GRGS: (50 x 50)

GRACE data applied

GRACE-derived geopotential models from different centres

- CSR-60
- JPL-120
- GFZ-120
- CNES/GRGS-50

suitability

- **accuracy** of solutions
- spatial **resolution**
- **time coverage**
- **stability** of the solution

→ **JPL**

Data filtering methods

- no filtering
- Gauss filter ψ = 400 km
- Gauss filter ψ = 600 km
- DKK1
- DKK2
- DKK3

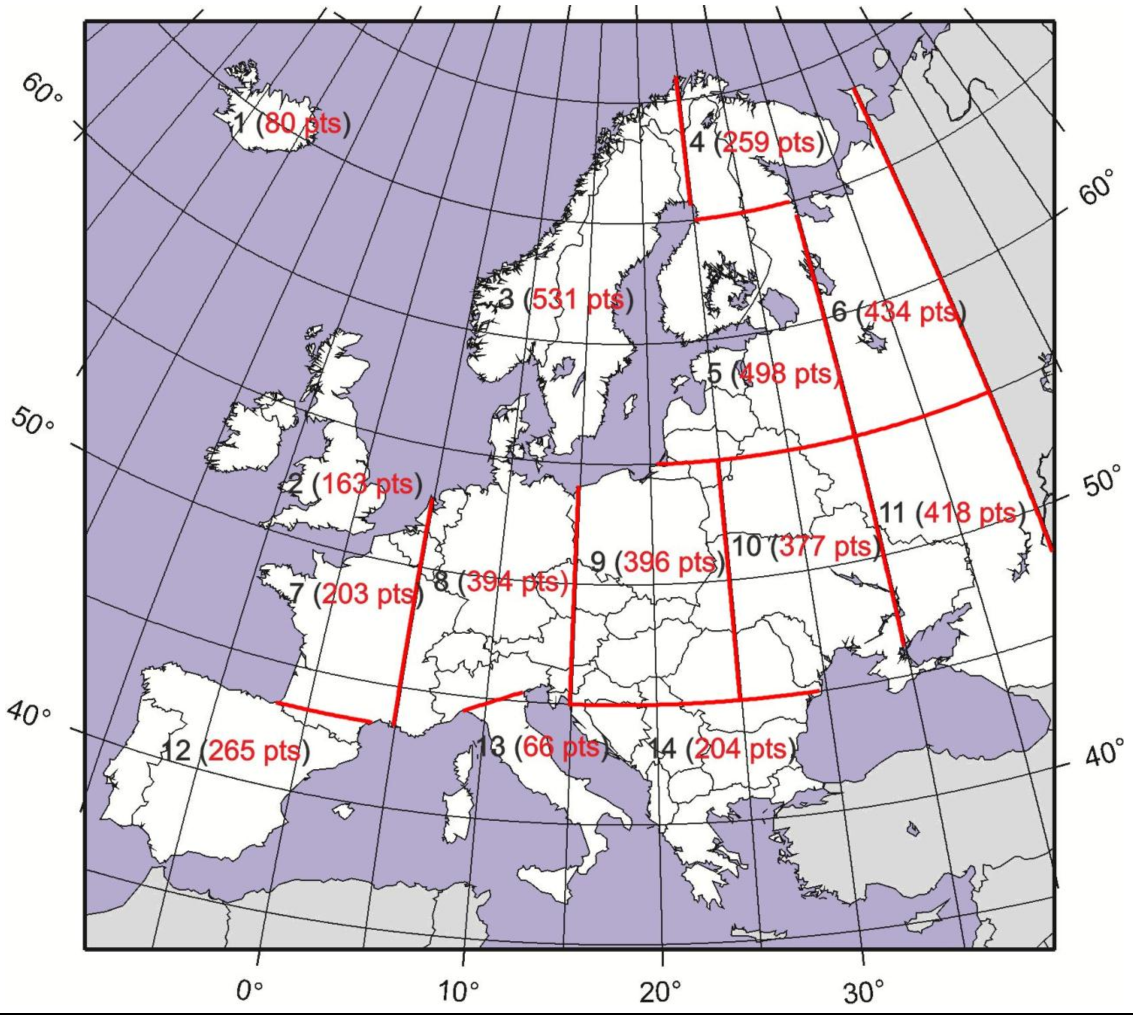
noise investigated

→ **DKK1**

Methodology

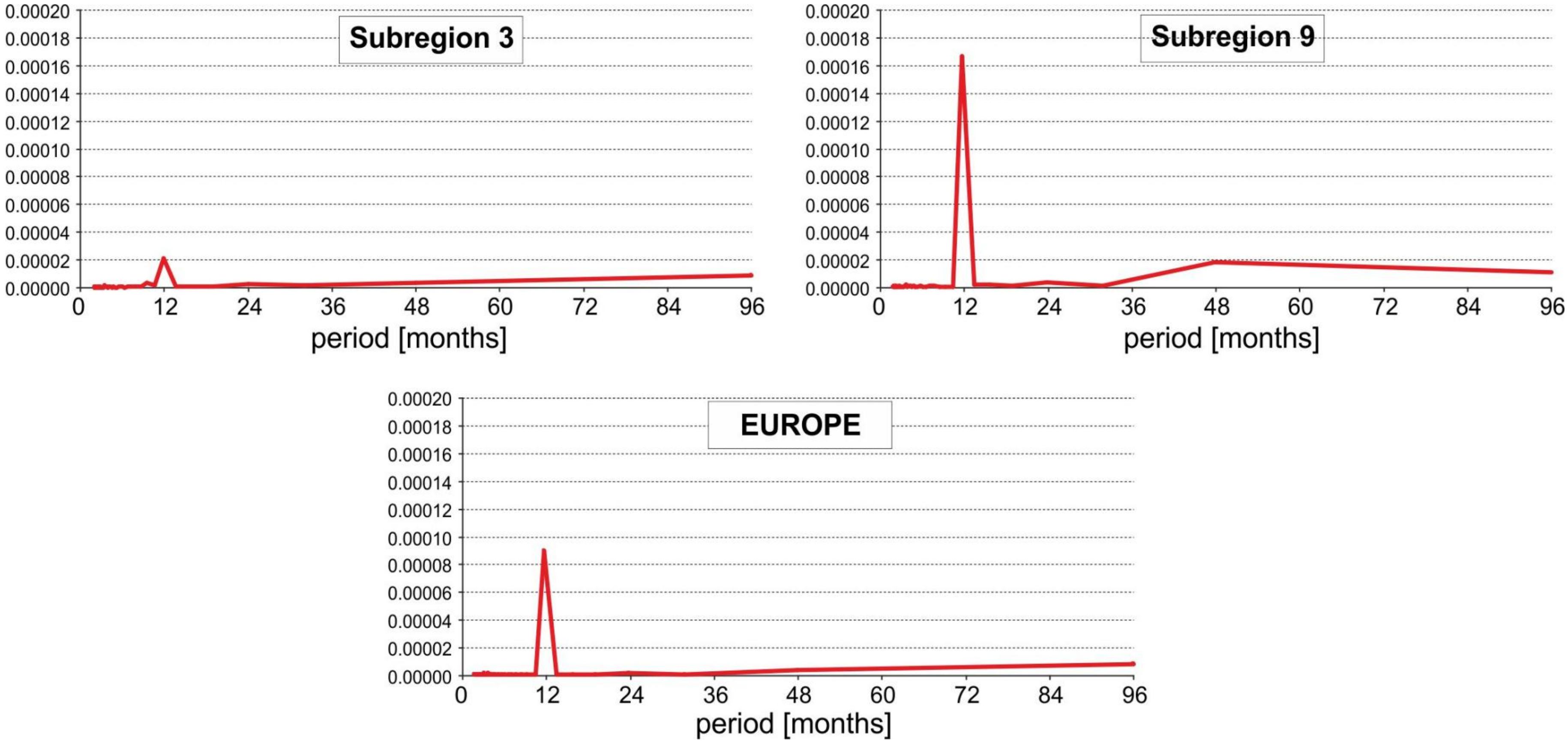
14 subregions of Europe

Number of points (*grid nodes* 0.5° × 0.5°) averaged in subregions



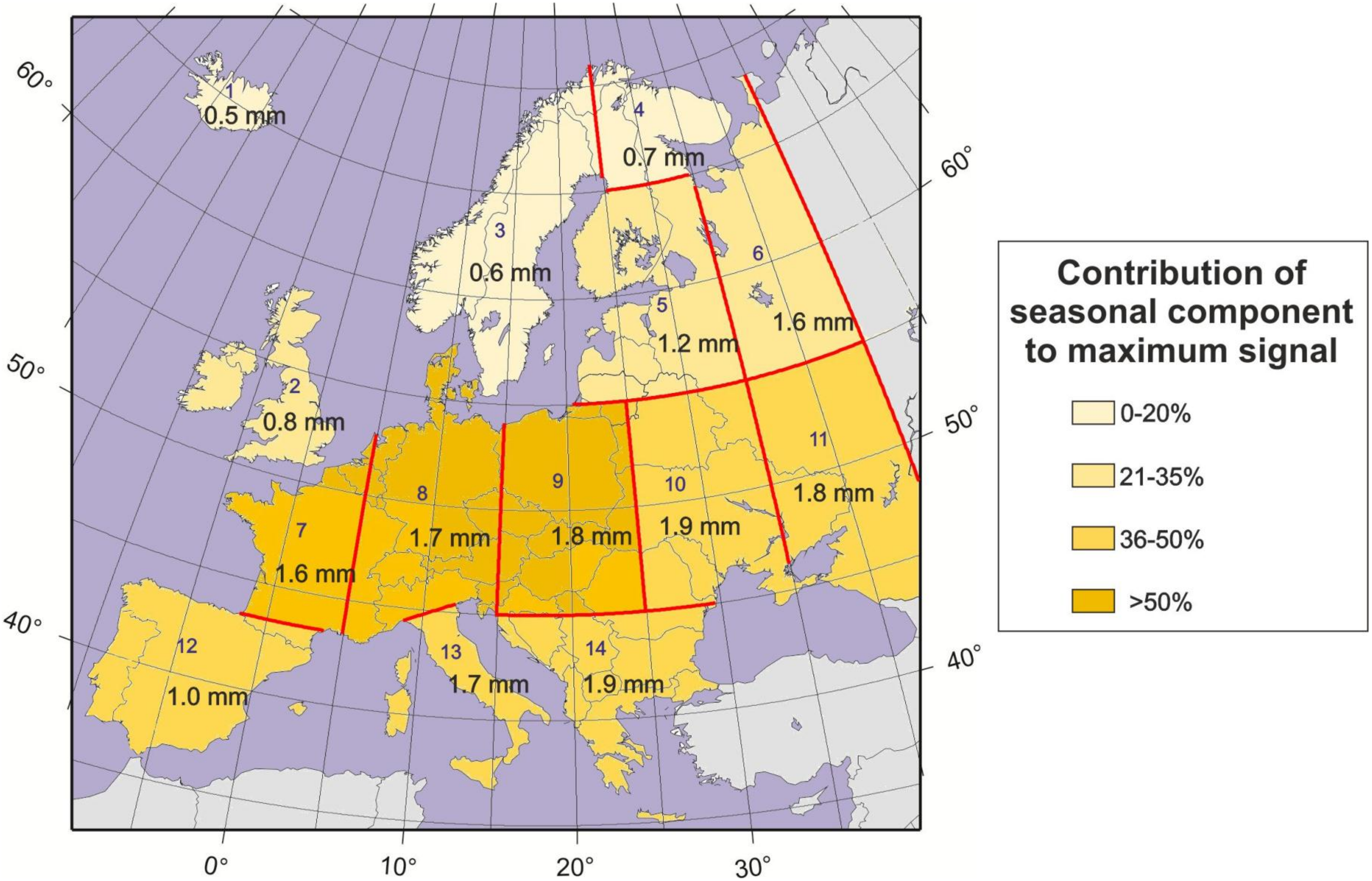
Temporal variations of geoid heights (1)

Periodicity of geoid heights variations



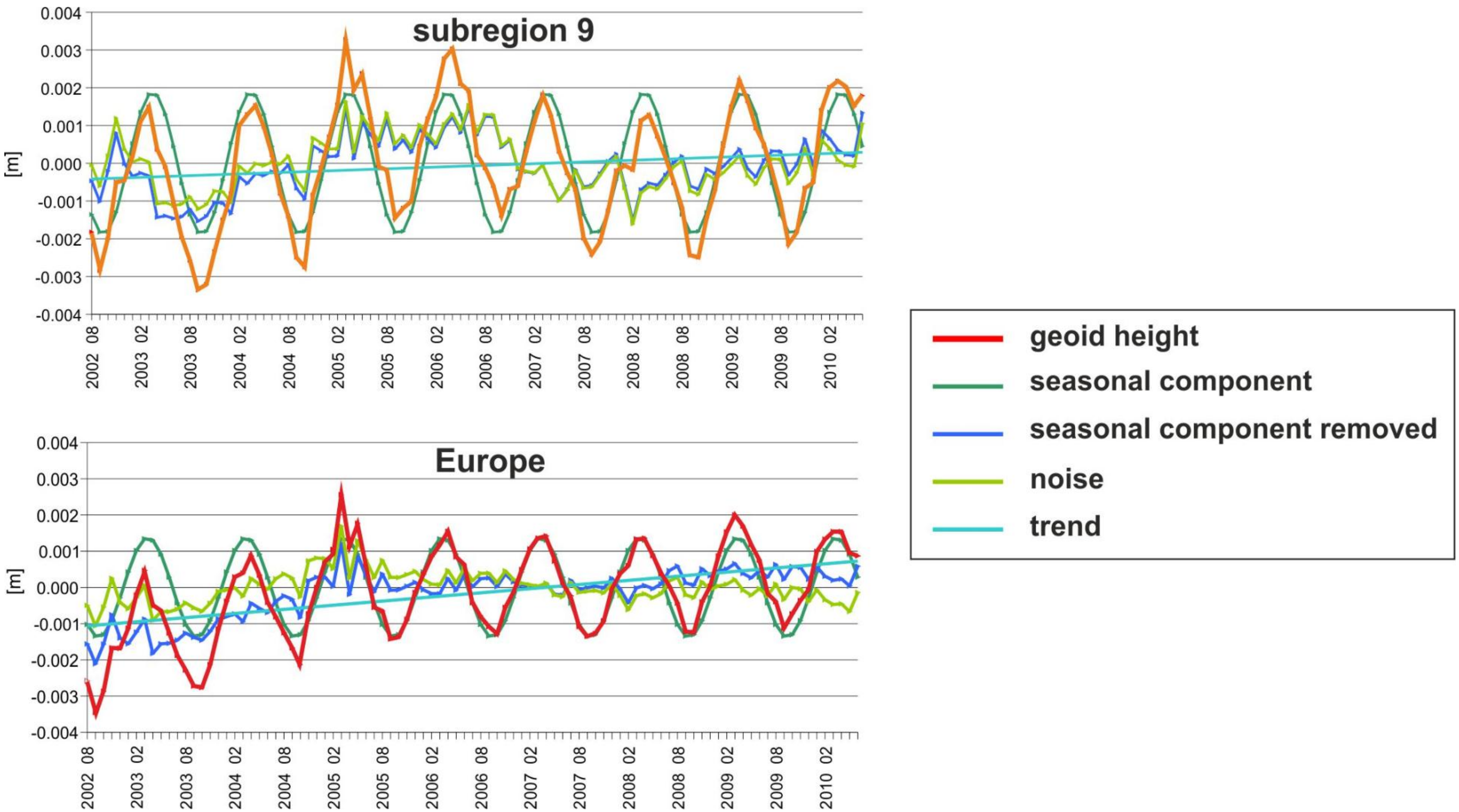
Temporal variations of geoid heights (2)

Amplitudes of seasonal variations of geoid heights



Temporal variations of geoid heights (3)

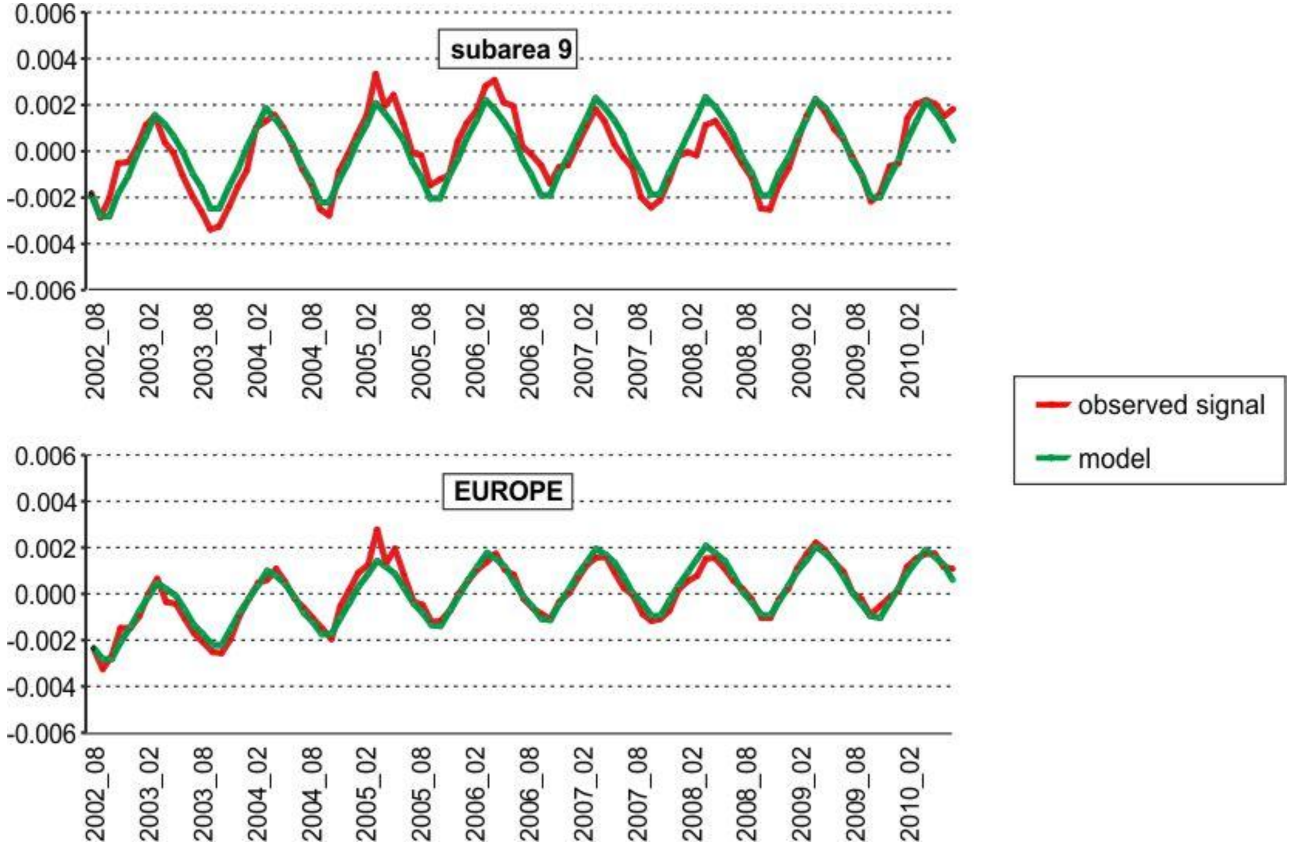
Examples: subregion 9 and Europe



Modelling of geoid height changes (1)

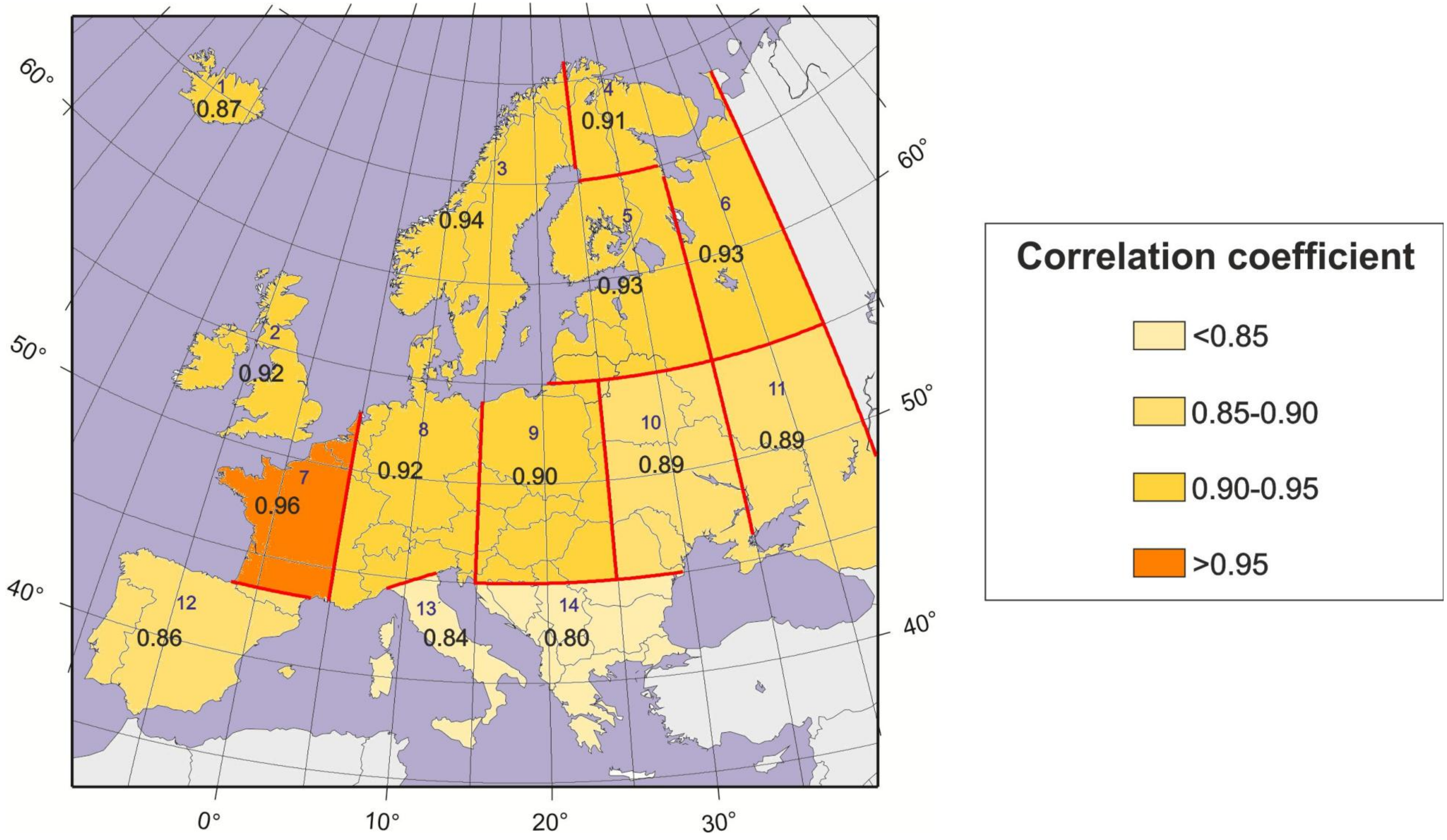
(seasonal component 12-months period and trend expressed by 2nd order polynomial)

Examples: subregion 9 and Europe



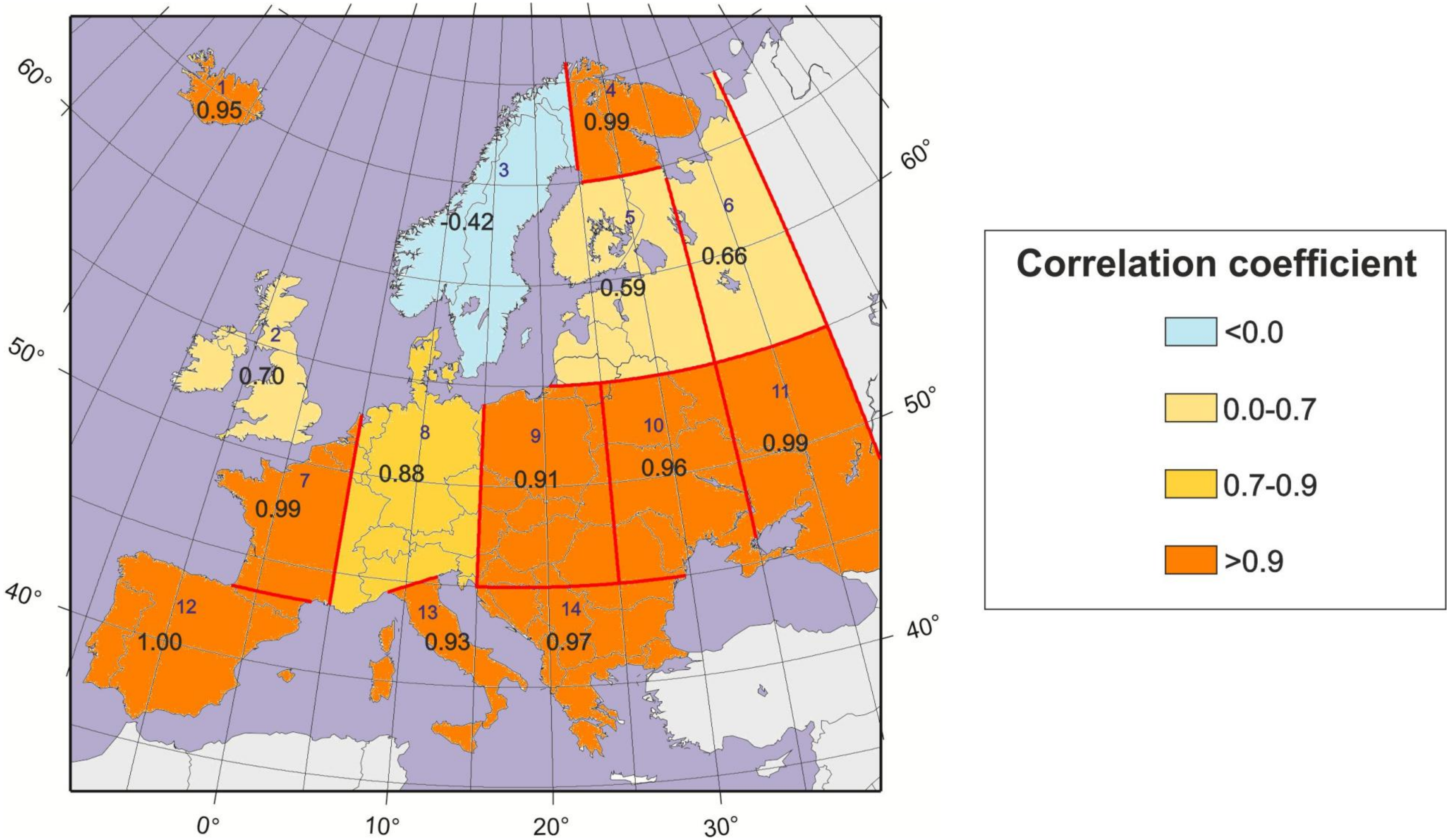
Modelling of geoid height changes (2)

Correlation of observed geoid height variation with a modelled one (optimum model for August 2002 – June 2010)



Prediction of geoid height changes

Correlation of observed geoid height variation with a predicted one (optimum model for July 2010 – October 2010)



Conclusions (1)

GRACE-derived geopotential models carry a unique information for geodynamics

<u>Geoid height variations</u> determined on regional scale may substantially differ from the respective ones determined on local scale

<u>Geoid height variations</u> determined from GRACE data for Europe as well as its 14 subareas besides a trend contain a strong annual component

Models consisting of those components fit very well to the observed data. The estimated seasonal <u>changes of geoid heights</u> in Central Europe are within the range of ±2 mm. Within the period of August 2002 – June 2010, the averaged geoid heights vary, however, in that area by up to 7 mm. Thus, actual geoid height changes exceeding 1 cm can be expected

Conclusions (2)

The concept of static geoid as a reference surface in precise heighting, with the use of contemporary global positioning techniques becomes outdated

There is a growing need for kinematic models of gravimetric geoid

The results obtained show the necessity of urgent launch of GRACE-type mission that could ensure continuation of monitoring gravity field variations with high spatial and temporal resolution