ERROR ANALYSIS OF GOCE DATA FOR SOLID EARTH APPLICATIONS

HOW MUCH CAN WE BELIEVE MODELS OF THE EARTHS' INTERIOR?

MARK VAN DER MEIJDE, ROLAND PAIL, THOMAS FECHER

WITH CONTRIBUTIONS FROM:
JORDI JULIA (UNIV FED RIO GRANDE NORTE, BRAZIL)
MARCELO ASSUMPÇÃO (UNIV SAO PAOLO, BRAZIL)
ANDY NYBLADE (PENNSTATE, USA)
ISLAM FADEL (UT-ITC)
PAVEL DITMAR (TU DELFT)
Resolving earth structure is trying to find something that is invisible…

many approaches and solutions possible

Choices are based on researcher

Errors and uncertainties are unclear

**Question:** what is the uncertainty / reliability of model

Source: van der Meijde et al, 2013
ERROR/UNCERTAINTY ANALYSIS

Three major components to uncertainty analysis

1. Sensor/measurement uncertainty
2. Mathematical and/or modelling uncertainty
3. ‘Application’ uncertainty

Approach:
Simple model, add uncertainties, compare to other techniques
Our starting point:
“simple” models that do not rely on \textit{a priori} constraints or knowledge of area

Method:
- Fitting of Fourier surface through corrected gravity signal

Validation through:
- Comparison with receiver function results (local estimates under seismic station)
- Comparison with global CRUST1, seismic models
- Through validation at known crustal structure, reliability for other parts can be estimated
CRUSTAL MODEL
SOUTH AMERICA

Input layers:
- Gravity anomaly
- Bouguer correction
- Sediment correction
  - Fixed contrast of 200 kg/m$^3$
  - no depth dependence

Final output for further processing

Source: van der Meijde et al, 2013
MOHO MODEL

- Over 65 in Andes to less than 6 km in oceanic basins
- Thickest crust in central Andes
- Brazilian shield is thicker than Guyana shield
- Thinning (?) in basins along Andean Foreland as well as Solimoes and Amazon basins

Source: van der Meijde et al, 2013
COMPARISON WITH SEISMOLOGICAL OBSERVATIONS

- Overall >70% similar
- Stable part 88%
- Andes 60% (especially underestimation)
- Caribbean orogenic zone shows scatter

Source: van der Meijde et al, 2013-90°
SENSOR AND MEASUREMENT UNCERTAINTY

- We used computed "error coefficients", that are consistent with the GOCE variance-covariance matrix, added to the gravity model coefficients, converted to error grids of gravity anomalies.

- The variance-covariance matrix is a result of the sensor characteristics and the ground coverage and satellite altitudes.

- Monte Carlo simulation of this coefficients in this matrix gives possible uncertainty solutions, each one of them equally likely.
OBSERVATIONS

- Maximum error/uncertainty for South America in the crustal thickness due to sensor errors in the order of 1 km crustal thickness
- Error is smaller than widely accepted ‘Earth science uncertainty’
- The error is smooth, and gradually changes. No abrupt changes (= important for analysis of small scale features)
MODEL COMPARISON

- Comparison between
  - gravity only models,
  - gravity based models and,
  - seismological models

- Different data sources, different techniques but all trying to solve the same object
THE DIFFERENT MODELS

Source: van der Meijde et al, 2014
DIFFERENT MODELS AND POINT OBSERVATIONS

Source: van der Meijde et al, 2014
THE DIFFERENCES

Source: van der Meijde et al, 2014
SPECIFIC DIFFERENCES

- Similar modelling approach but with:
  - Different parameterizations
  - Inversion in different domains (spatial vs frequency)

Source: van der Meijde et al, 2014
MOST REMARKABLE DIFFERENCE

- Two seismological models
  - Both widely used
  - Different modelling approach (data driven vs knowledge driven)
  - Difference ranging from -15 km up to +28 km!

Source: van der Meijde et al, 2014
IN SUMMARY

- GOCE error propagation into solid earth science modelling contributes insignificantly to the final model.
- Errors are an order of magnitude smaller than uncertainties resulting from using different modelling approaches.
- Uncertainties resulting from the chosen modelling approach are much larger, in exceptional cases even 28 km.
- Propagation of errors might be influenced by the chosen modelling approach, should be further evaluated.
Inversion is a fantastic tool to provide us an insight into unexplored depths

BUT: it is a tricky business!

Choices in modelling techniques, parameters to include, filtering, conversion criteria, smoothness, etc all play a major role

Small changes in the above mentioned factors can lead to significantly different models

Lack of validation can be a problem → Fixing your model at a few locations doesn’t mean that the rest of the model is good!!!
A good fit in your inversion doesn’t mean that your model is good!

- Always link to earth science content!
  Are your parameters realistic?

- Keep enough points for validation of the model

- How biased are you towards a certain outcome and have selected parameters or method accordingly?