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ERROR ANALYSIS OF GOCE DATA FOR SOLID EARTH APPLICATIONS

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

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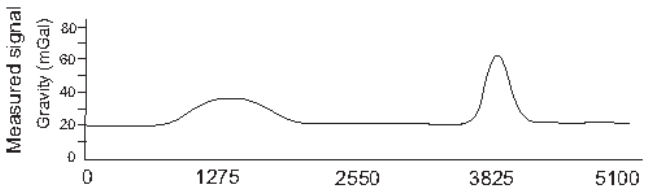
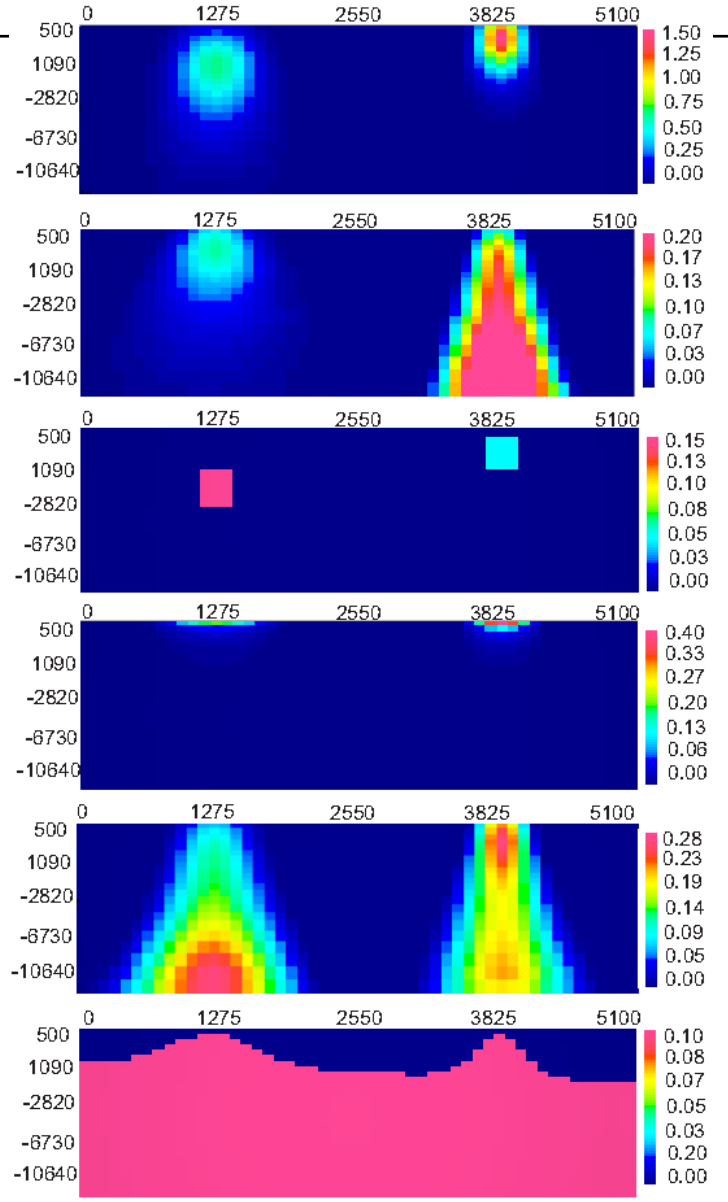
GEOPHYSICAL NON-UNIQUENESS

- 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



A set of models that can fit the measured signal



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

ESTIMATING CRUSTAL THICKNESS

Our starting point:

"simple" models that do not rely on *a priori* constraints or knowledge of area

Method:

- Fitting of Fourier surface through corrected gravity signal

Validation through:

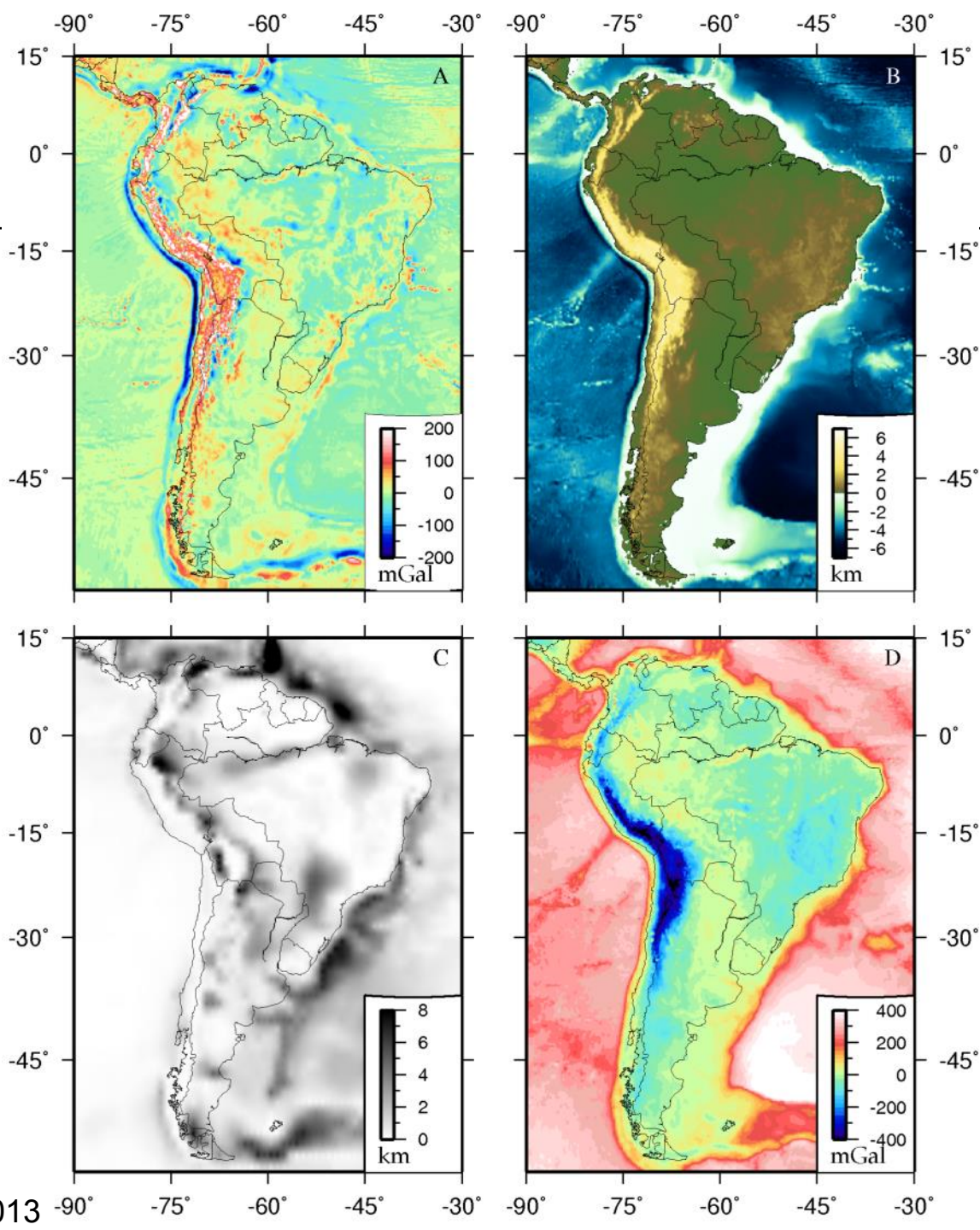
- Comparison with receiver function results (local estimates under seismic station)
- Comparison with global CRUST1, seismic models
- Through validation at known crustal structure, reliability for other parts can be estimated

CRUSTAL MODEL SOUTH AMERICA

Input layers:

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

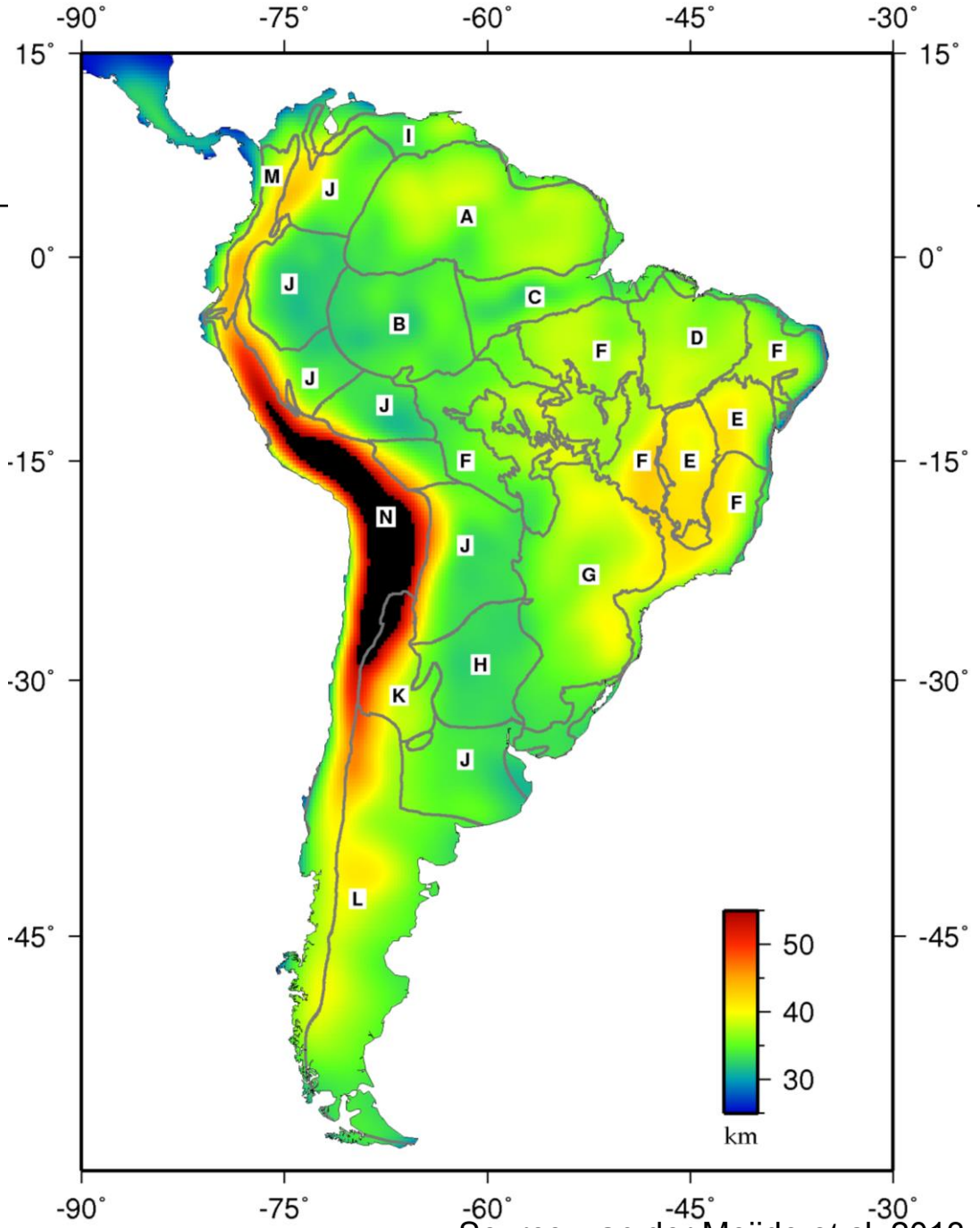
Final output for further processing



Source: van der Meijde *et al*, 2013

MOHO MODEL

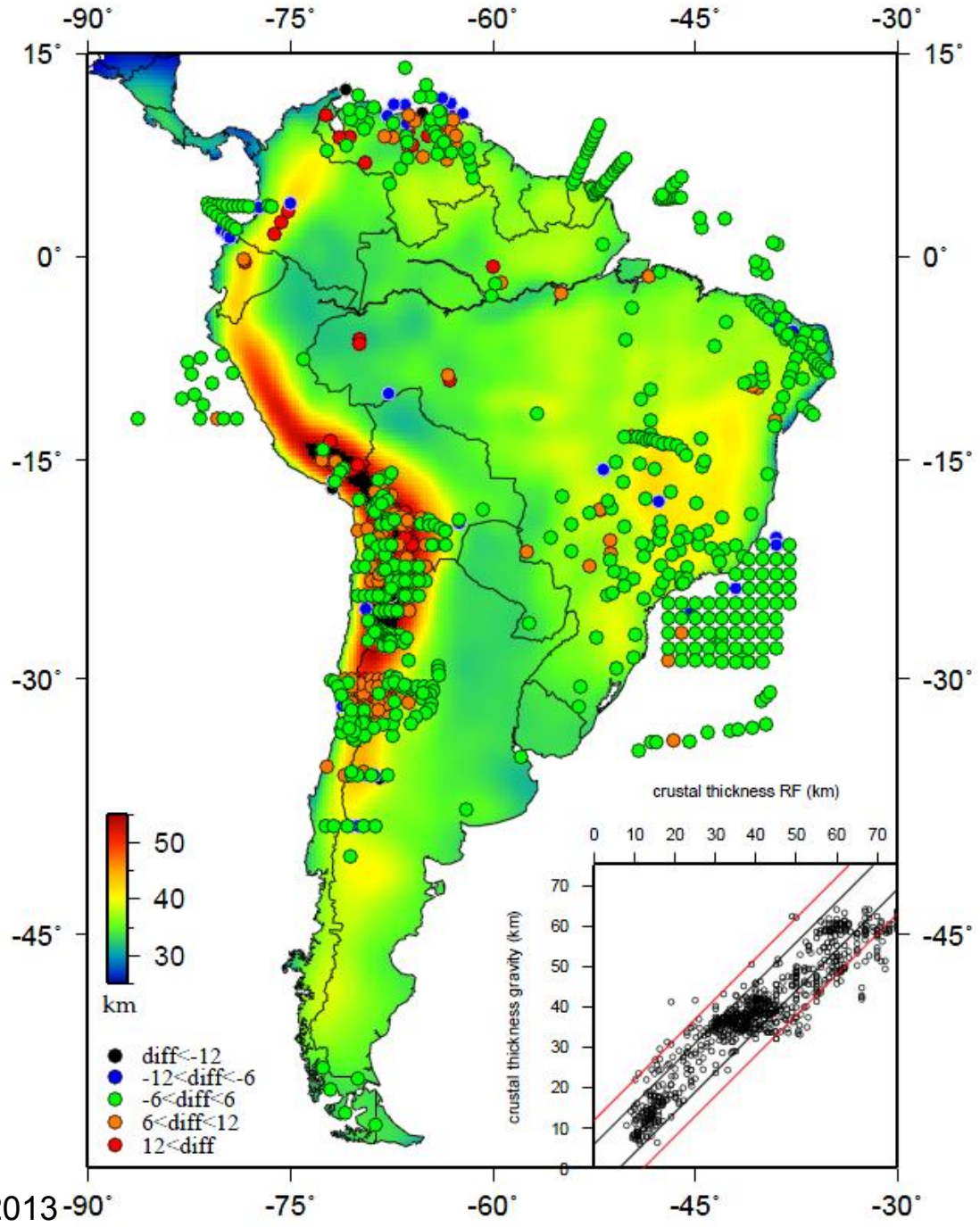
- Over 65 in Andes to less than 6 km in oceanic basins
- Thickest crust in central Andes
- Brazilian shield is thicker than Guyana shield
- Thinning (?) in basins along Andean Foreland as well as Solimoes and Amazon basins



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



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Source: van der Meijde *et a*l, 2013

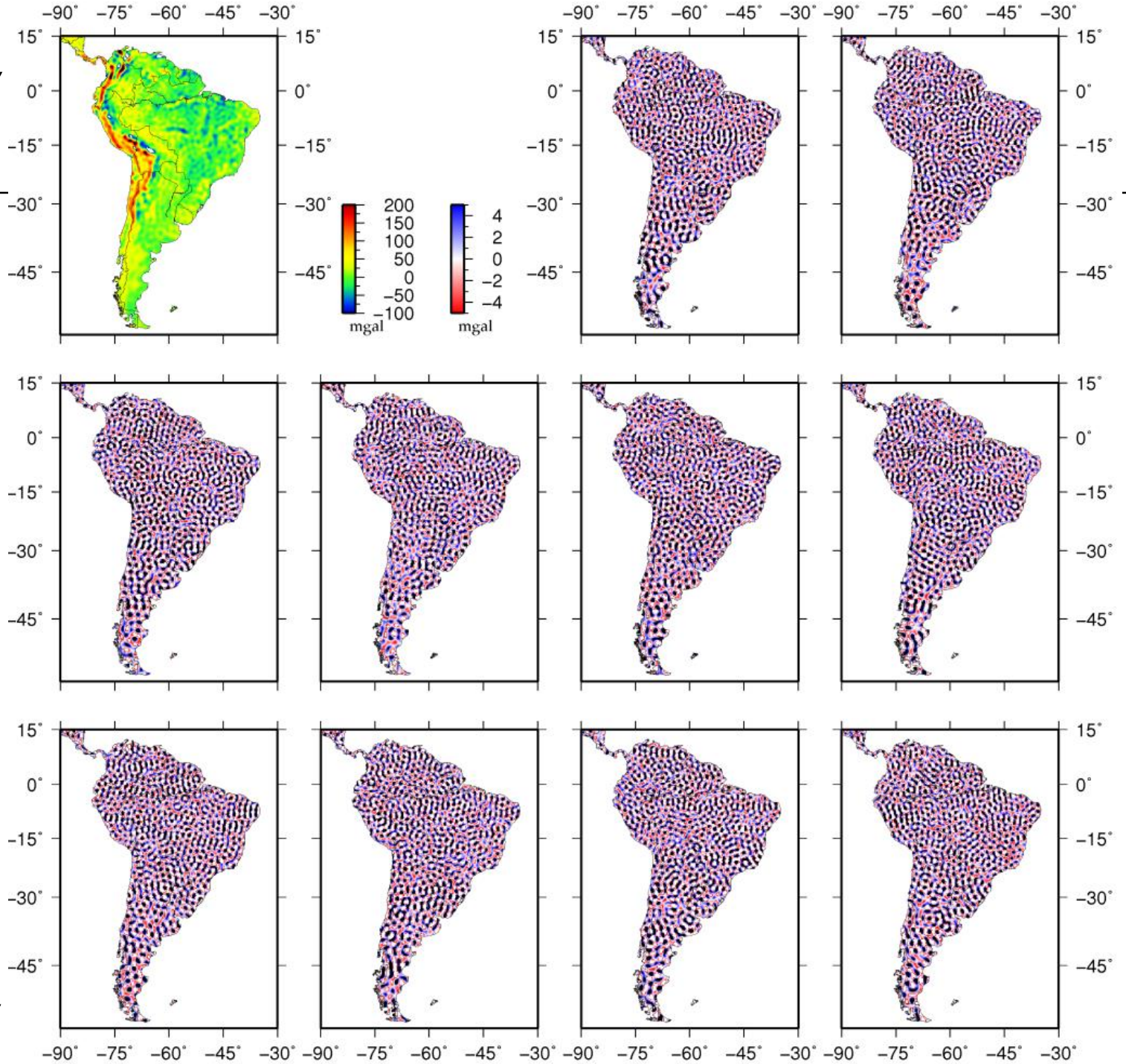
SENSOR AND MEASUREMENT UNCERTAINTY

- 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.

UNCERTAINTY GRIDS



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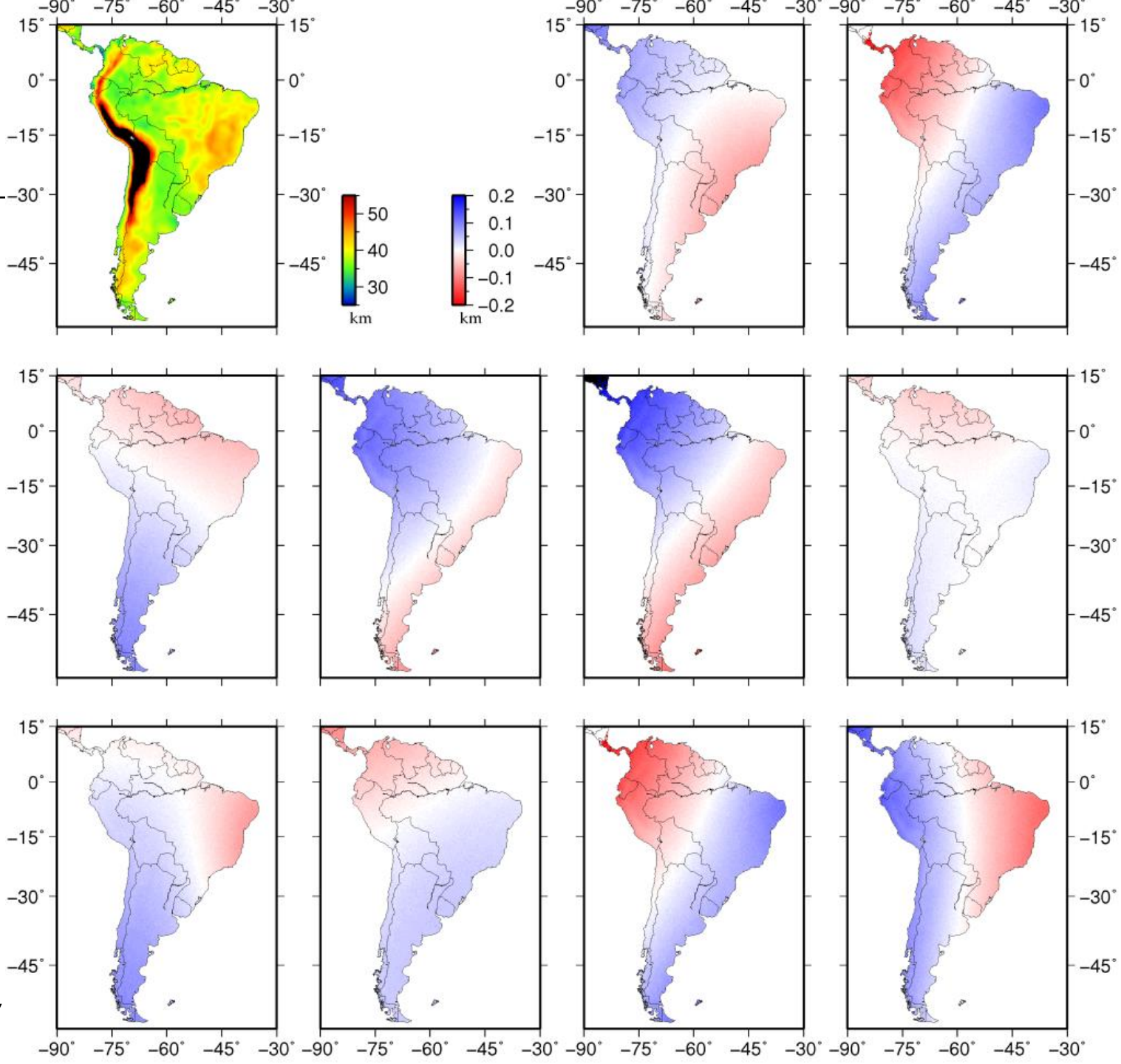
FINAL PROPAGATED ERROR



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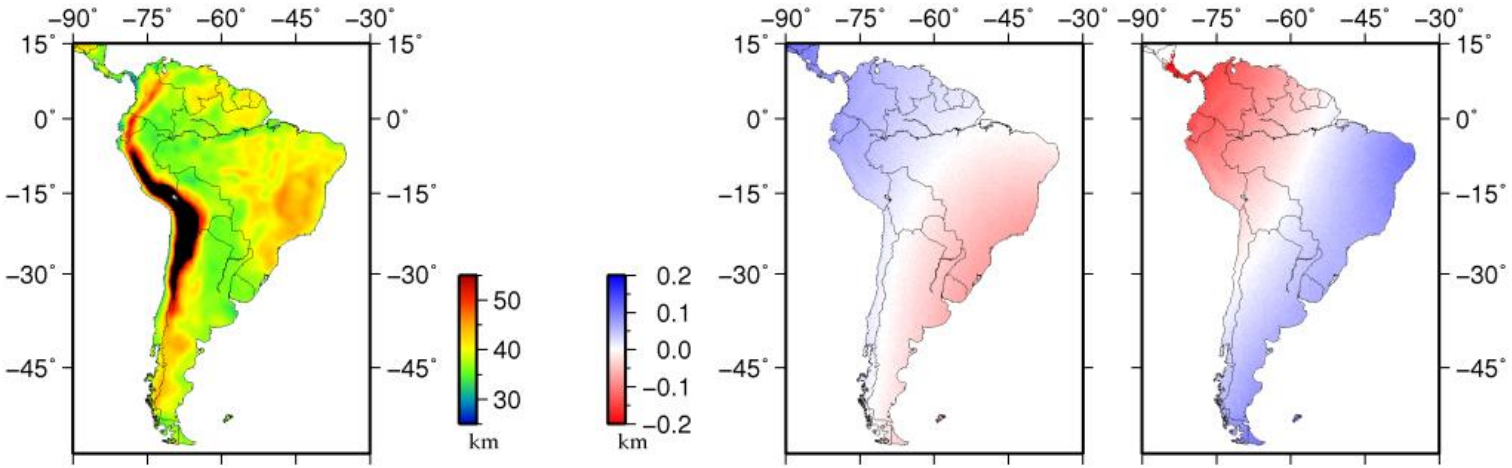
OBSERVATIONS

- 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)



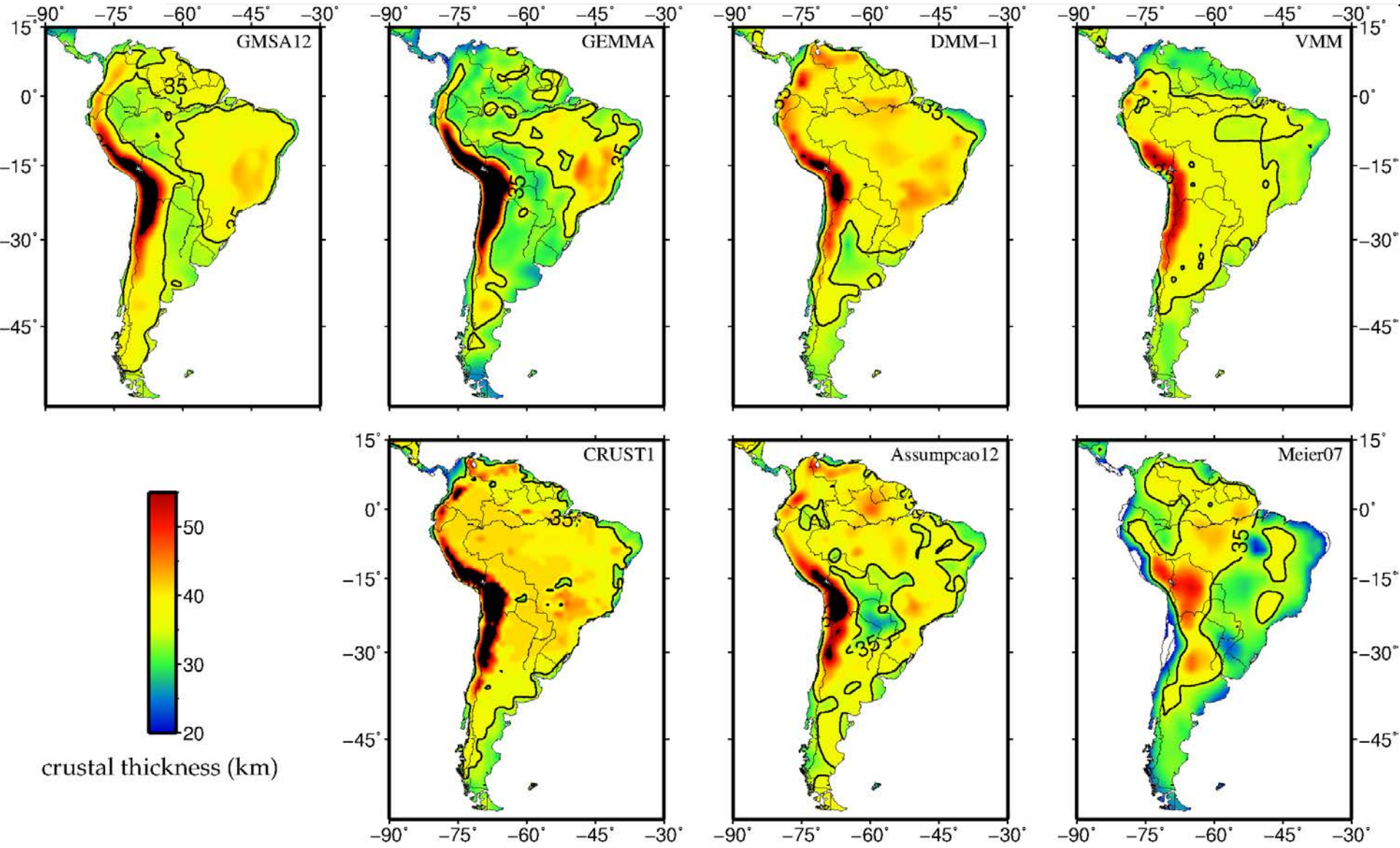
MODEL COMPARISON

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

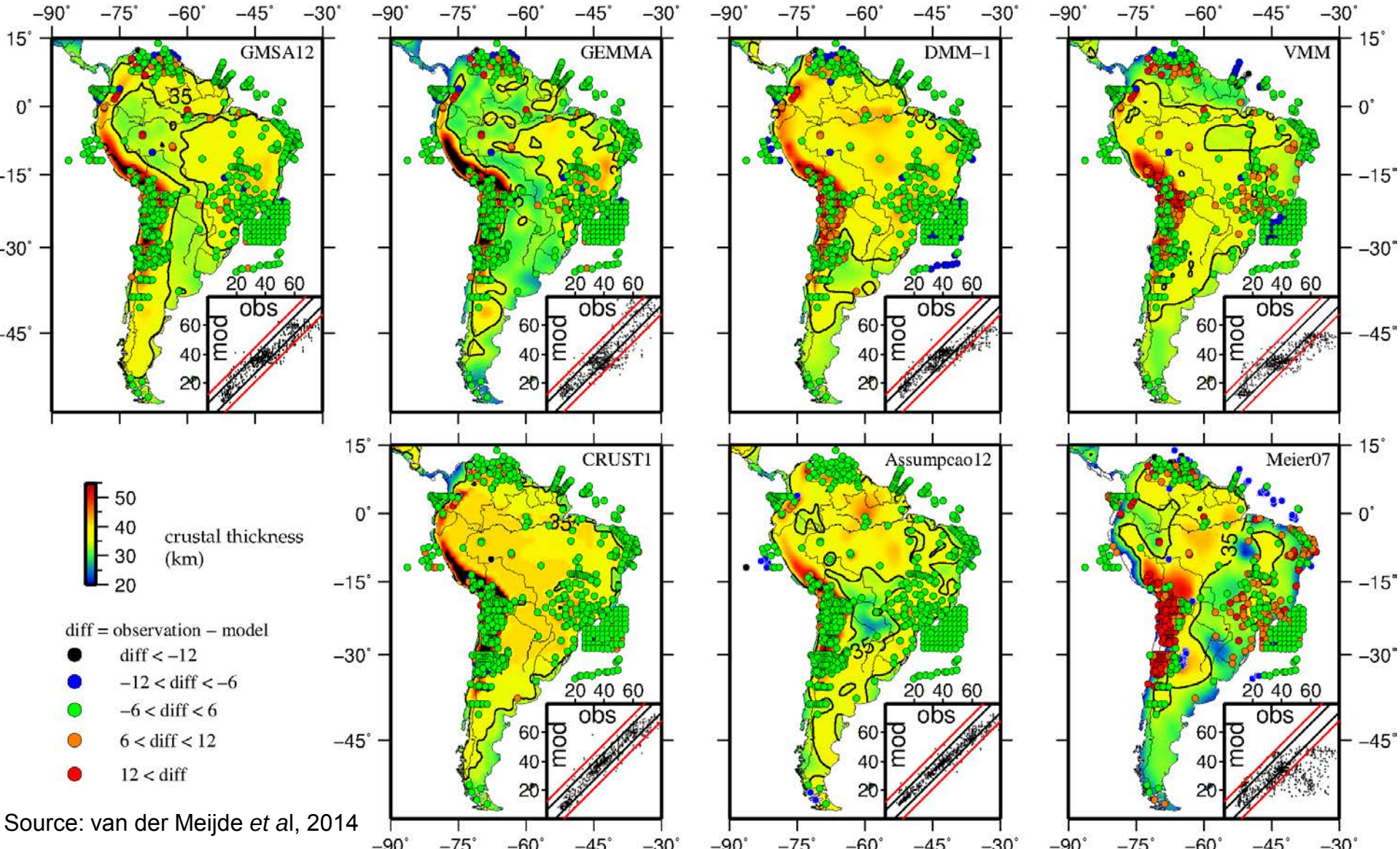
- Different data sources, different techniques but all trying to solve the same object

THE DIFFERENT MODELS

Source: van der Meijde *et a*l, 2014



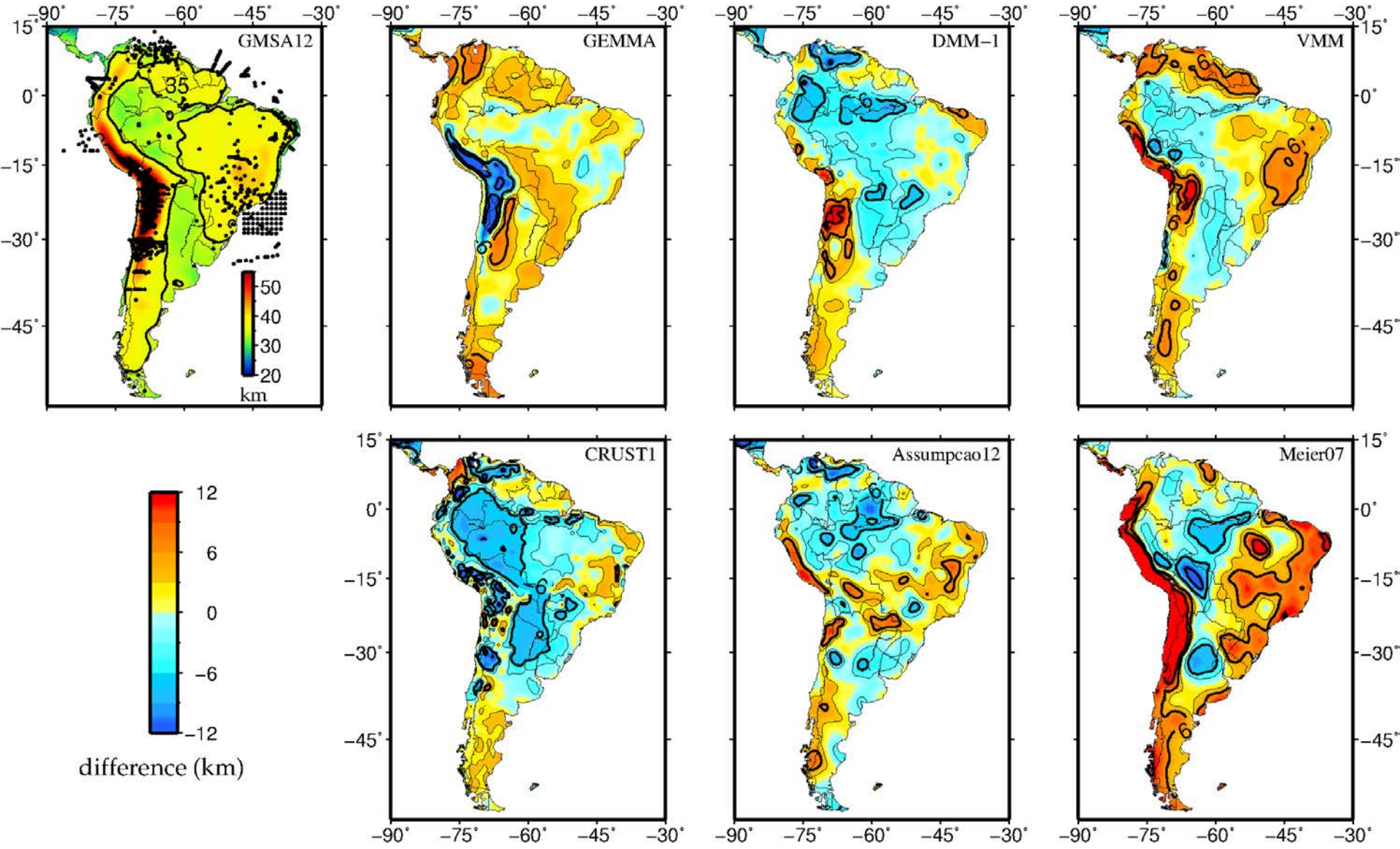
DIFFERENT MODELS AND POINT OBSERVATIONS



Source: van der Meijde *et a*l, 2014

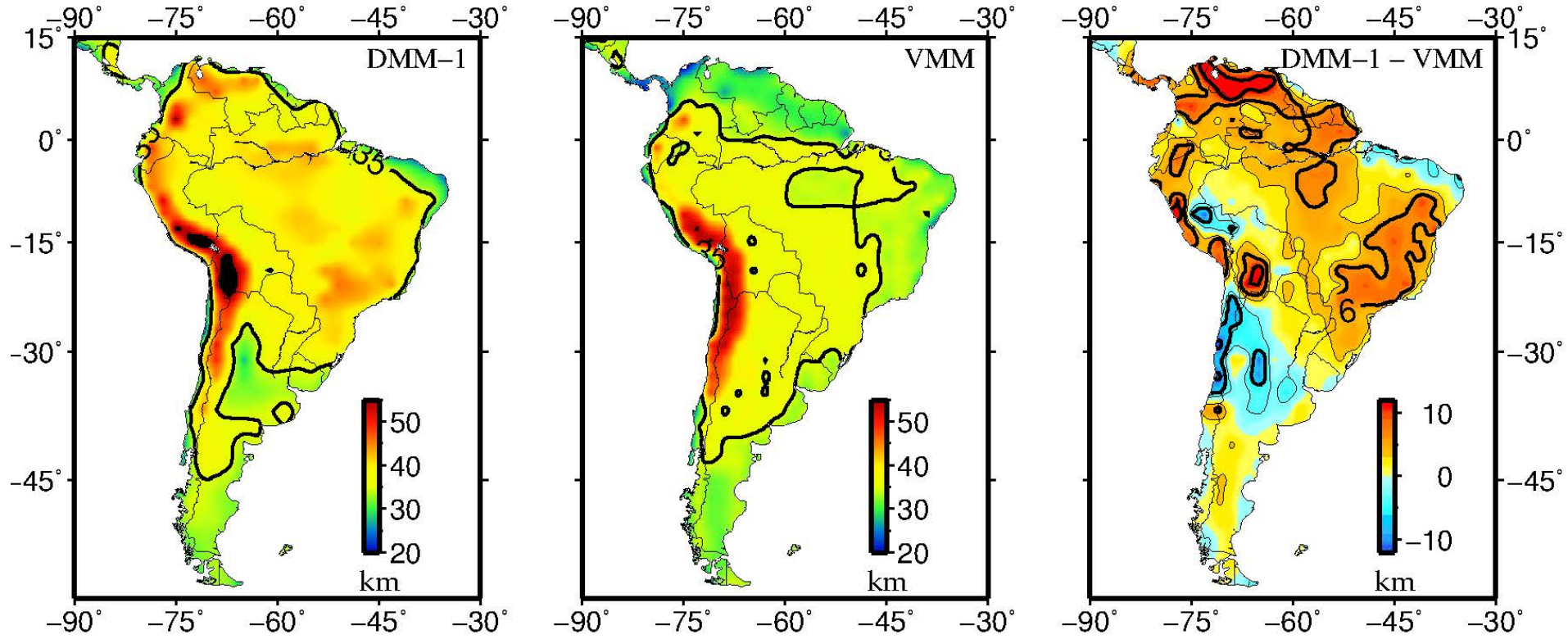
THE DIFFERENCES

Source: van der Meijde *et al*, 2014



SPECIFIC DIFFERENCES

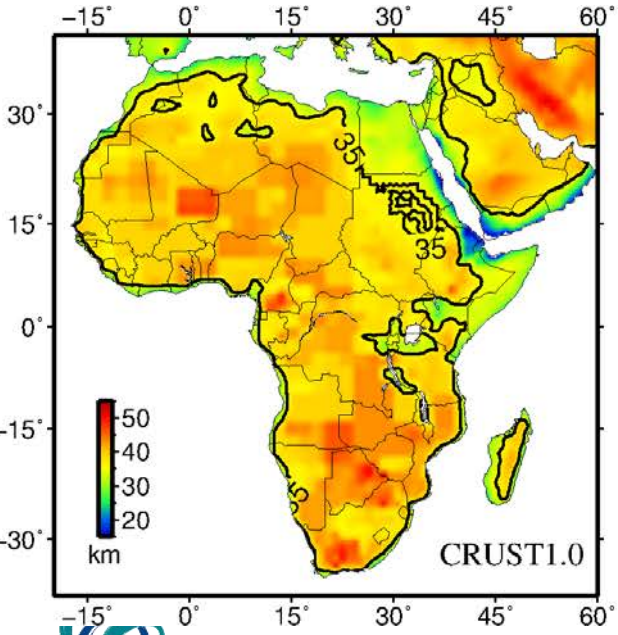
- Similar modelling approach but with:
  - Different parameterizations
  - Inversion in different domains (spatial vs frequency)

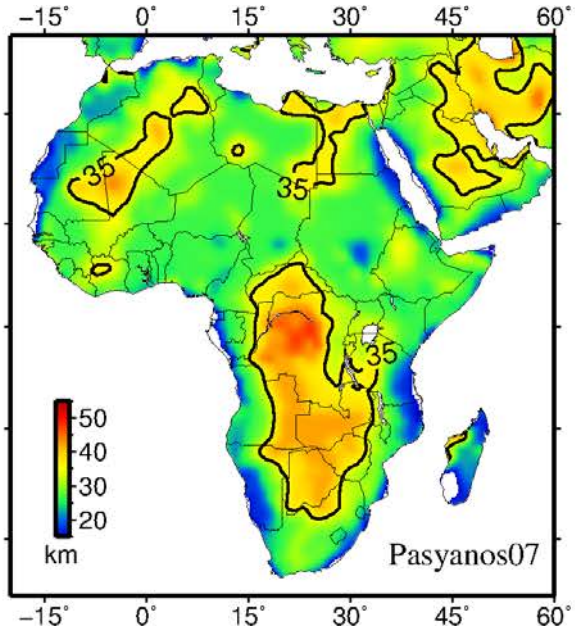


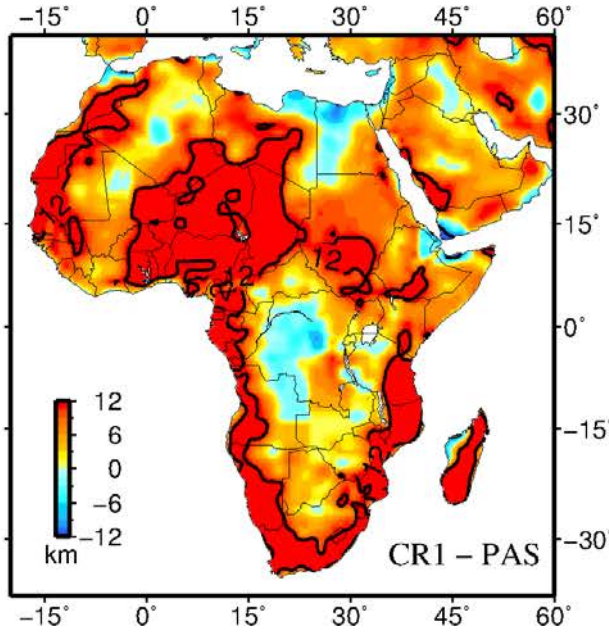
Source: van der Meijde *et al*, 2014

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!







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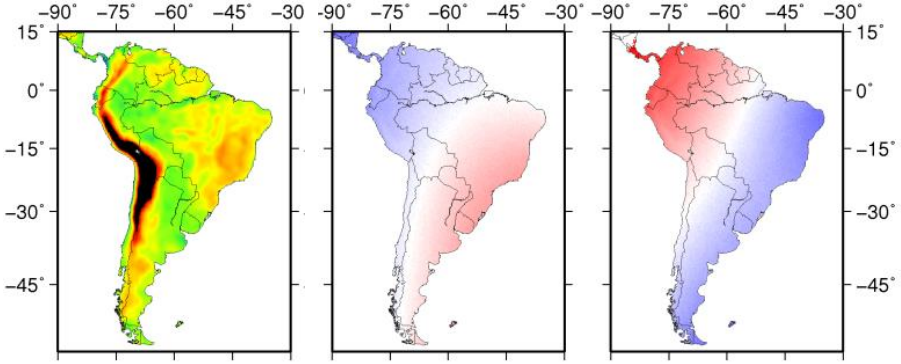
Source: van der Meijde *et al*, 2014

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.



WHAT CAN WE LEARN FROM THIS

- 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!!!

IMPORTANT LESSONS

- 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?