Joint use of MGS-MAG and MGS-ER measurements to better describe and understand the complex magnetic story of Mars

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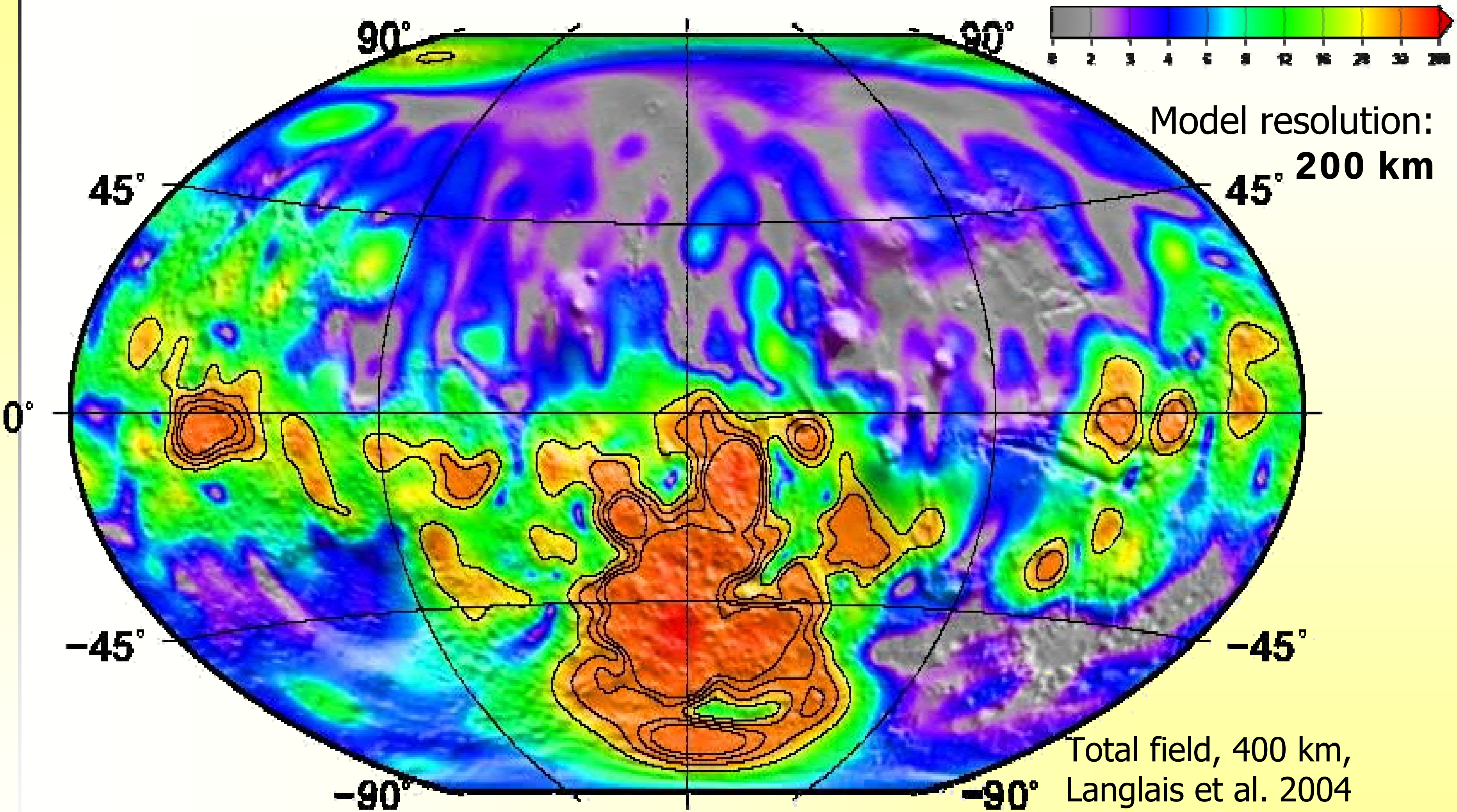
Incomplete Martian magnetic field history



Model resolution:
200 km

Total field, 400 km,
Langlais et al. 2004

Incomplete Martian magnetic field history

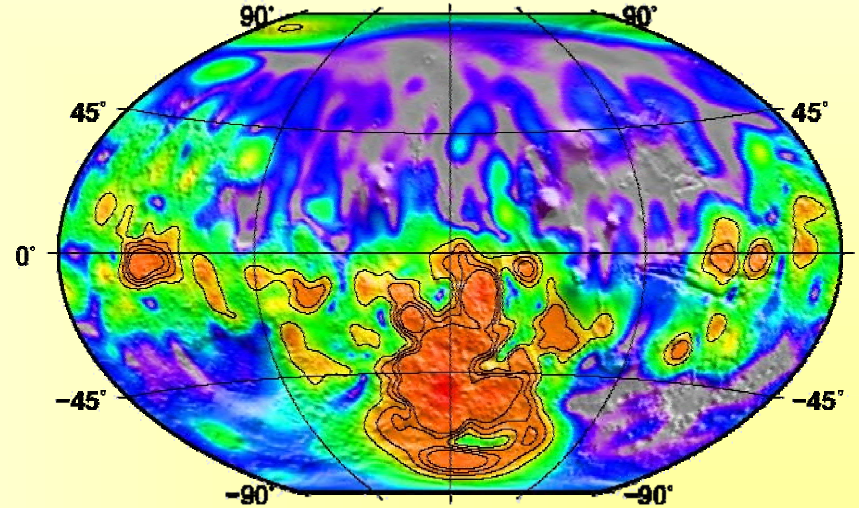
Mars had a dynamo (when did it start and stop?)

Lithospheric rocks cooled or formed in the presence of an ambient magnetic field (where?)

Mars lost its dynamo (when , 4.2 or 3.7 Gyrs ago, and why?)

Lithospheric rocks demagnetized through volcanic or impact events (where and when?)

Sharper, more accurate description of the current field will help to better understand the past magnetic field



Why an improved model?

Few global models of the Martian magnetic field, fewer models of the magnetization

Equivalent Source Dipoles (ESD) are used: at each point, the magnetic field results from the addition of the fields created by each individual source (Mayhew 1979)

Previous ESD model (Langlais et al., 2004):

- binned input data, 1°x1°x10km cells
  - field variations may exceed 700 nT/° (AB, SPO)
  - no external field proxy (MO)
- data limited to 1997-2001 time period
- horizontal resolution ~ 200 km

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New ESD model (preliminary results):

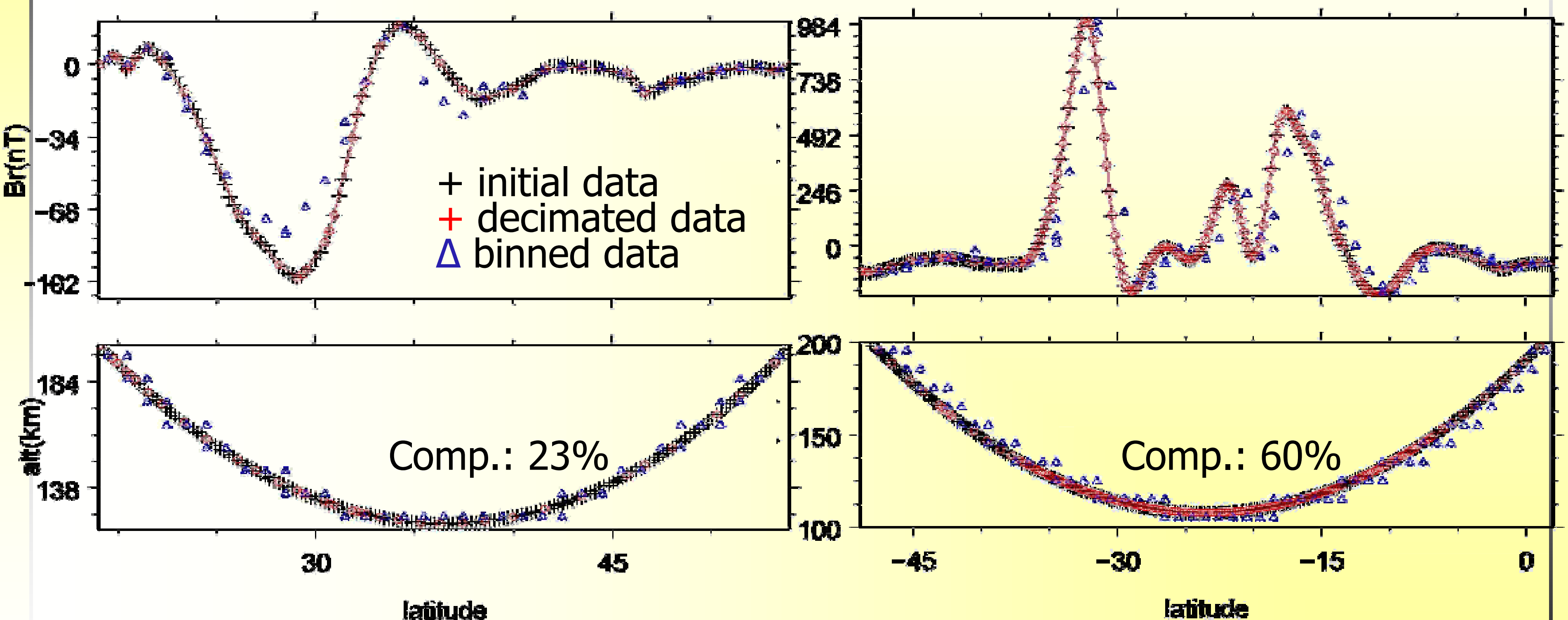
- true (decimated measurements)
  - **improved** removal scheme for outliers
  - **external field proxy** for MO data
  - ER data also used: **new** constraint at low altitude
- horizontal resolution ~ **120 km** (will be better)

Data selection, low altitude (AB, SPO)

550,000 measurements available below 350-km altitude

Decimation: distance between adjacent measurements : 0.8° < d < 5.0°

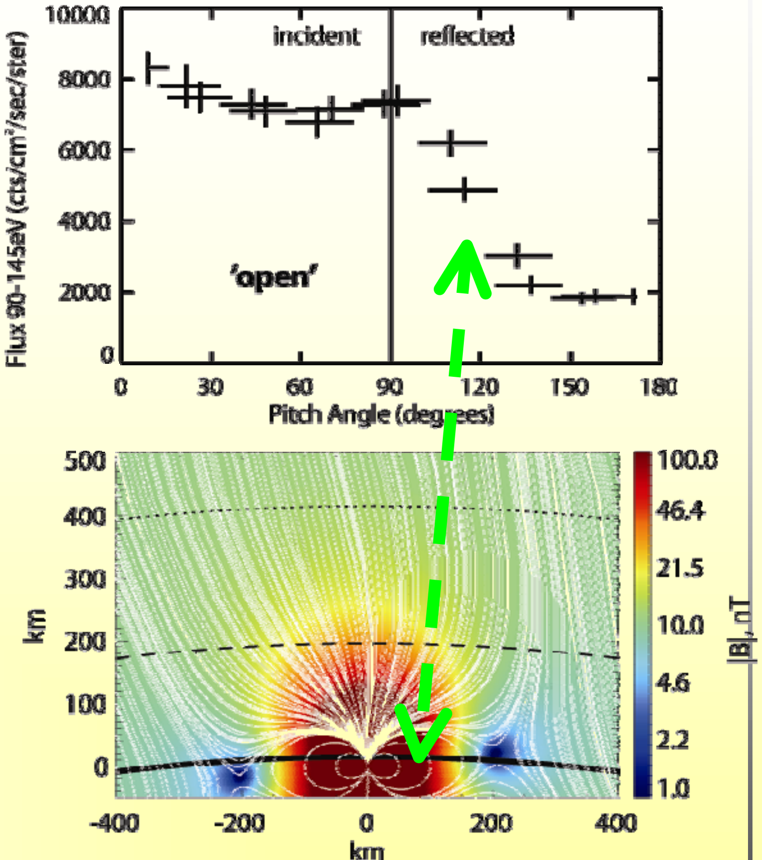
maximum rms (obs. vs. linear extrapolation) < 1.5 nT



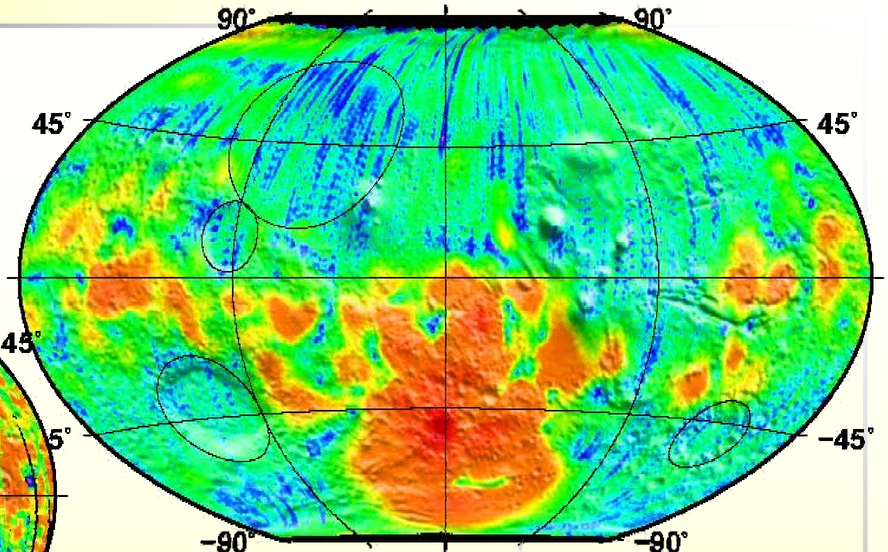
Decimated dataset: 120,000 measurements

ER data – Mirroring and absorption of e-

- Incident electrons with pitch angles further from 90° go deeper in the atmosphere before reflecting → higher chance of absorption (Lillis et al., 2008)
- Pitch angle-dependent attenuation of reflected electrons contains information about the crustal magnetic field that reflects the electrons and the atmosphere which absorbs them.
- ~2.3 million measurements over 7 years.
- Smoothed using 200 km diameter circle
- Spatial resolution: ~200 km
- Sensitivity threshold: 4nT
- No data where field lines are permanently closed

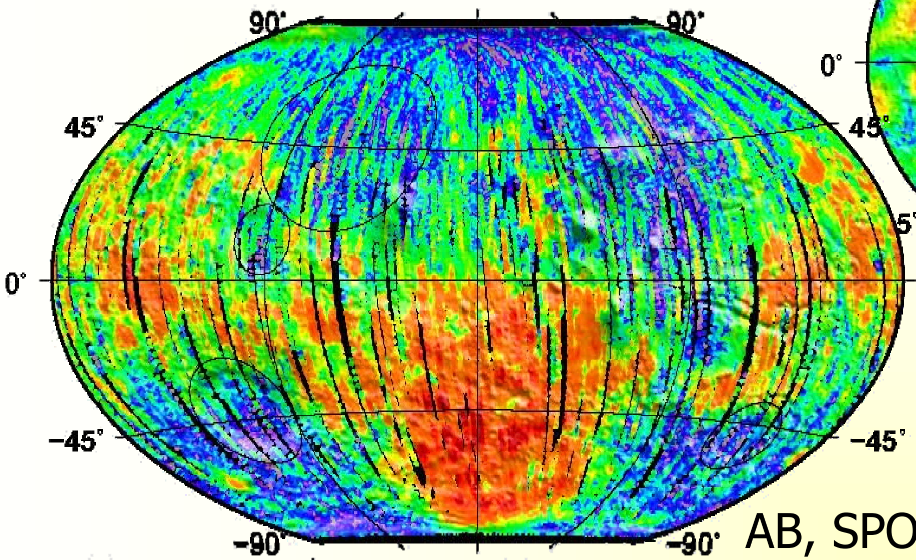


Data summary



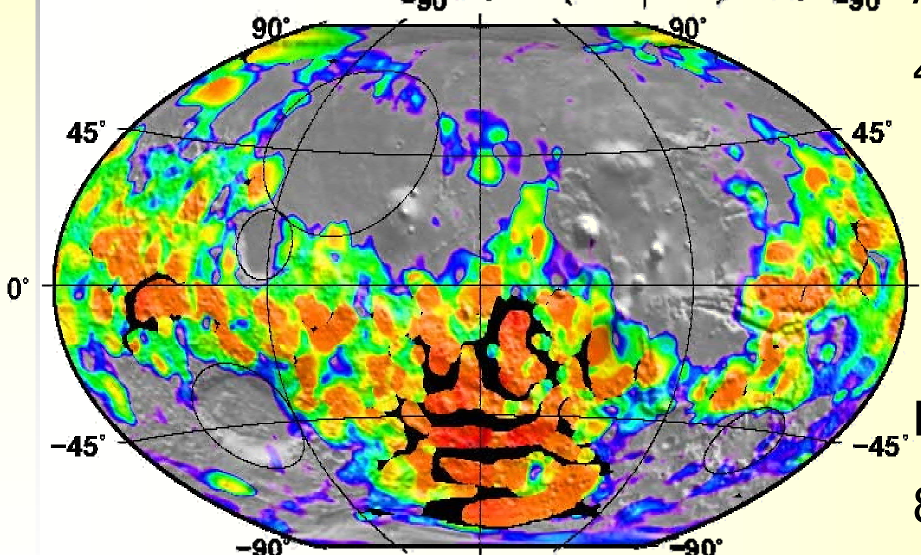
MO (~ 400 km)

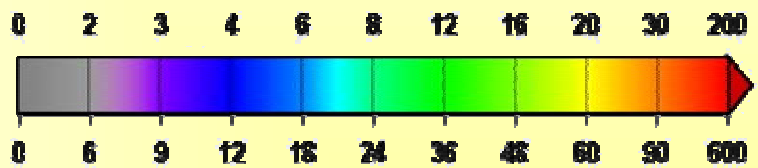
96% cov.



AB, SPO (90 -> 350 km)

42% cov





ER (185 km)

80% cov

Data inversion scheme

The inversion is iterative; L2 norm is used; Conjugate gradient approach, needs to linearize the problem

The use of scalar data requires a priori knowledge of the magnetization vector and associated magnetic field vector at observation location:

step 1: only vector data, a ‘rough’ model M0 is computed

step 2: M0 used as initial model, vector and scalar data used

step 3: rms residuals are computed and evolution is compared

step 4: a model M1 is chosen and replaces model M0 in step 2

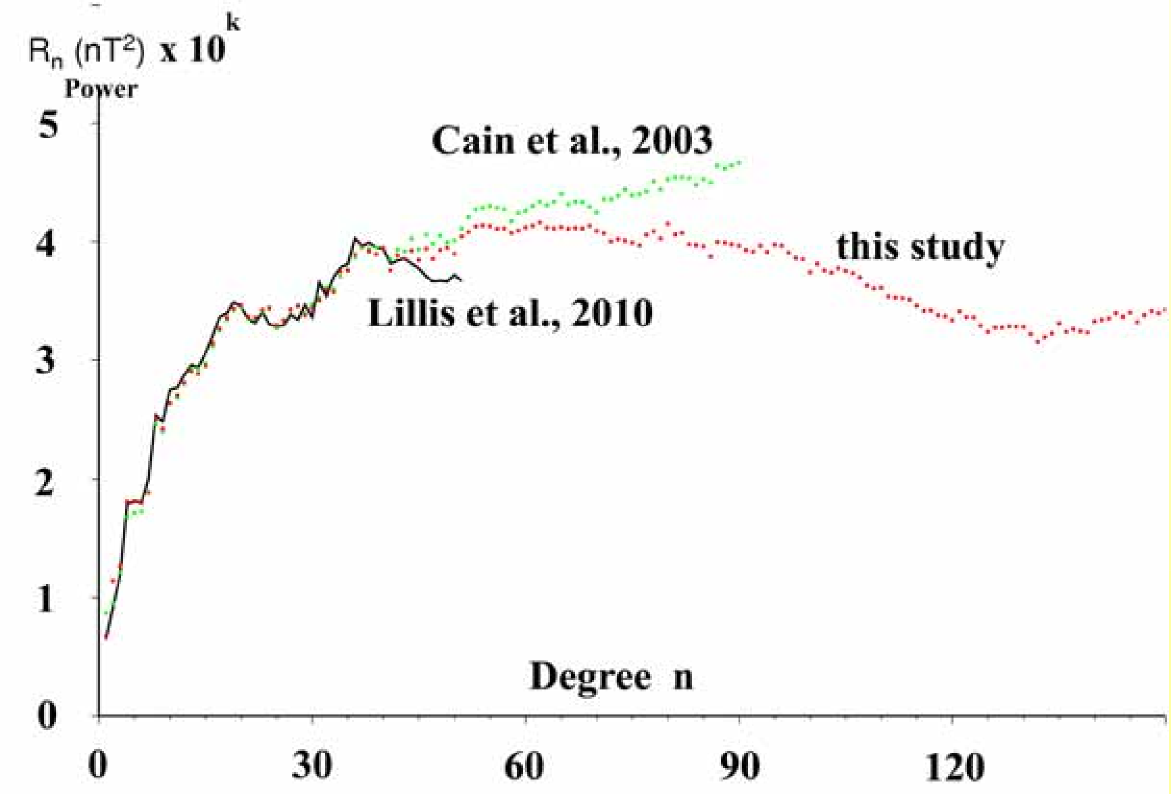
step 5: final model when M1 and M0 do not differ by more than 10^{-3}

Results

Final model: correlation >0.98

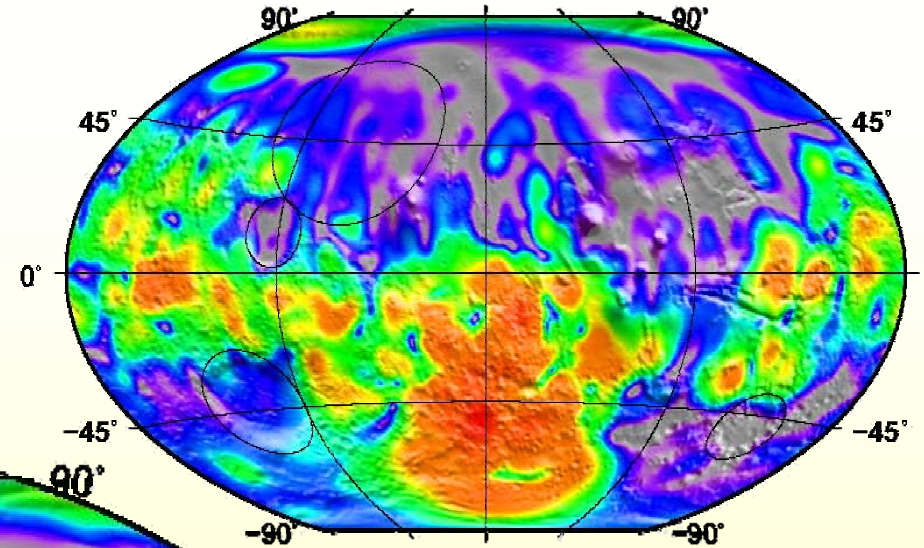
	σ_{Br}	σ_{Bt}	σ_{Bp}	σ_{B}
AB,SPO	22.3	23.2	23.3	24.9
MO	3.9	4.3	4.2	4.3
ER	-	-	-	15.5

Power spectra compared

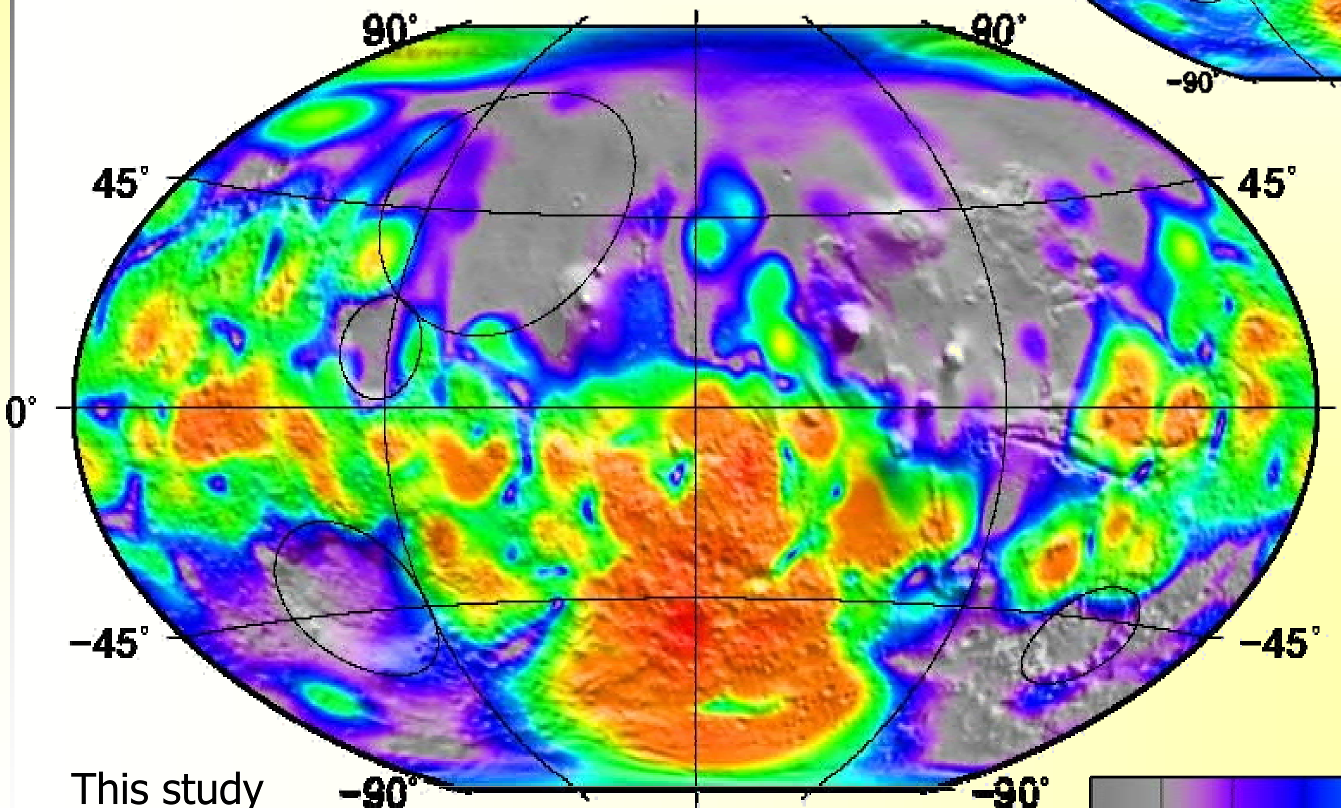


Total field

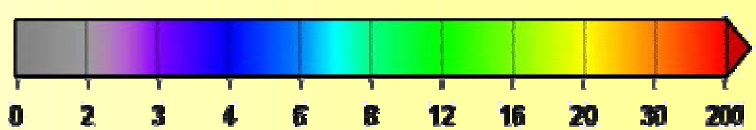
altitude 400 km



Langlais et al., 2004



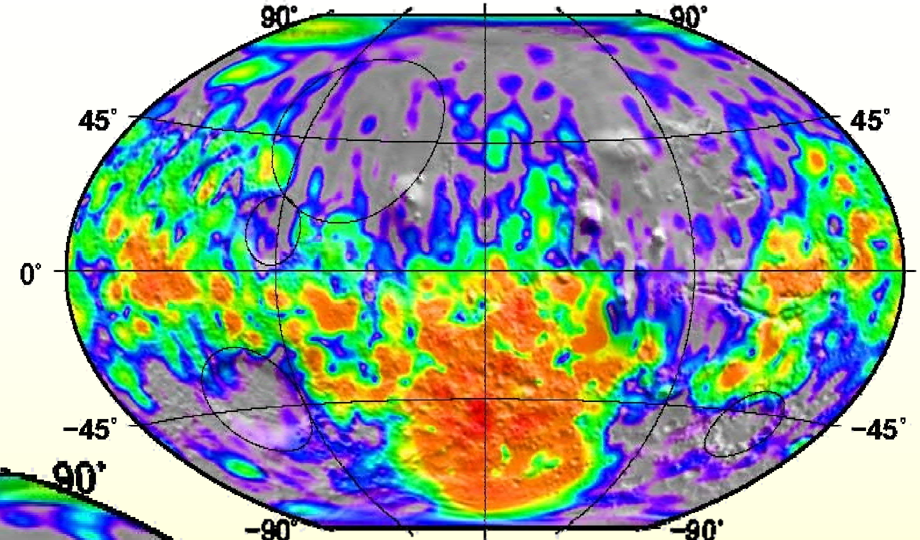
This study



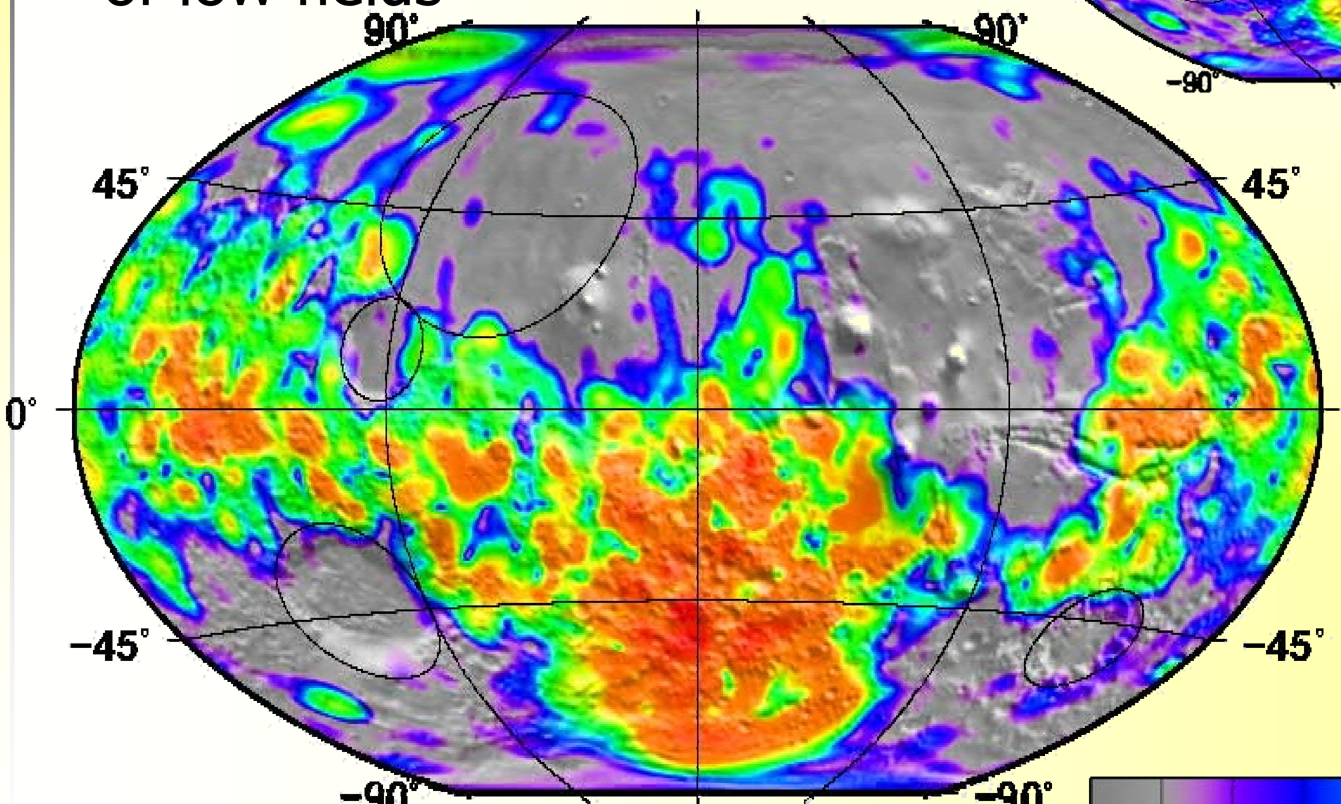
Total field

altitude 200 km

Much less small scale noise, better definition of low fields



Langlais et al., 2004



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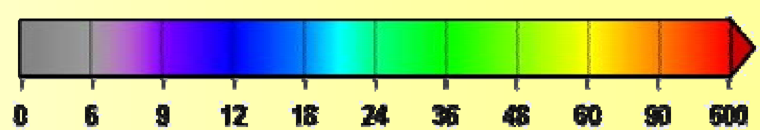
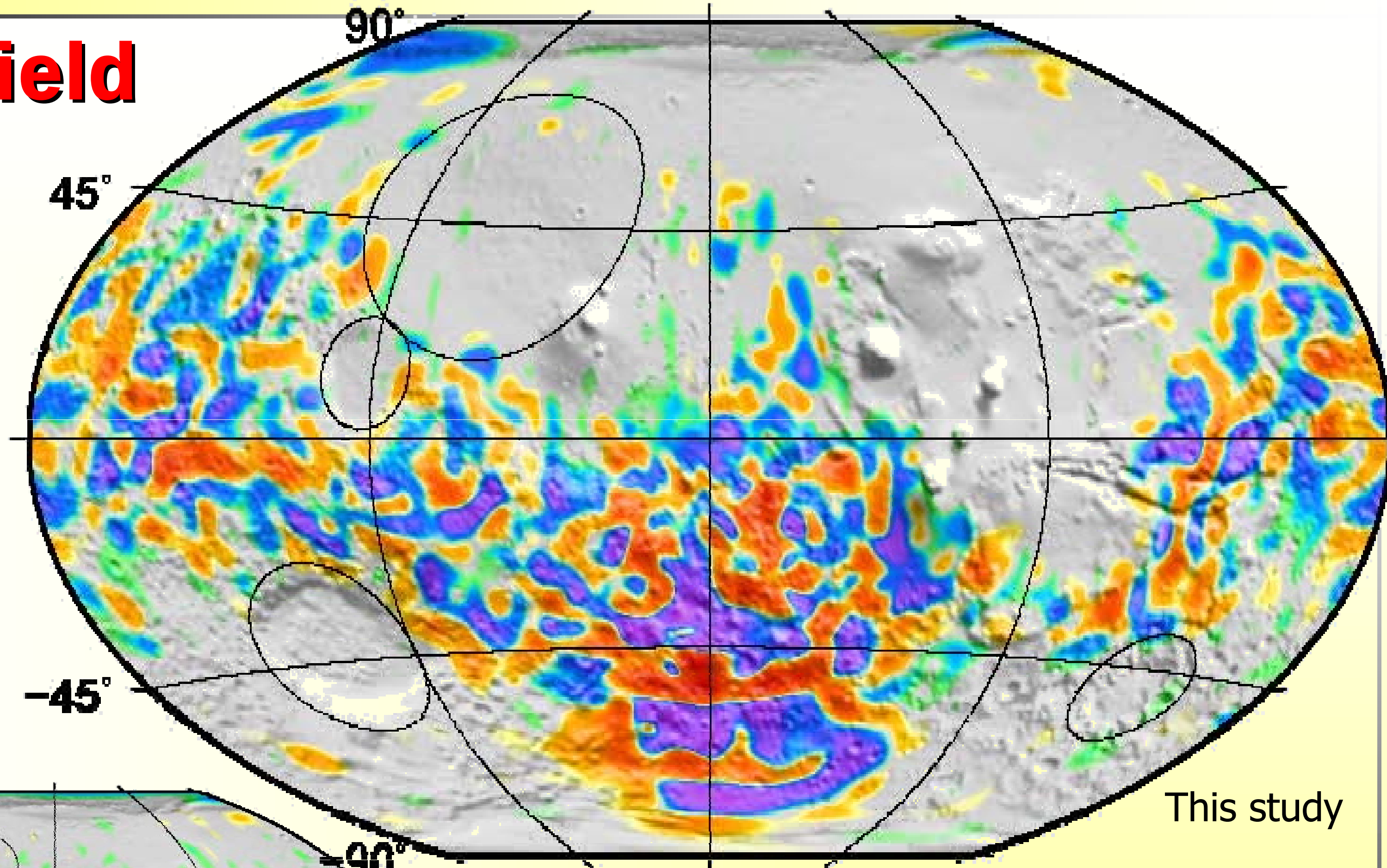


Radial field

200 km



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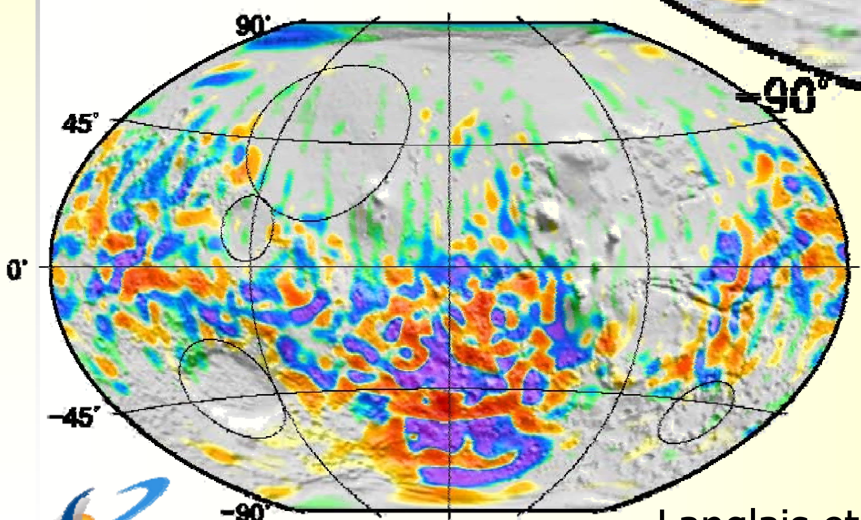
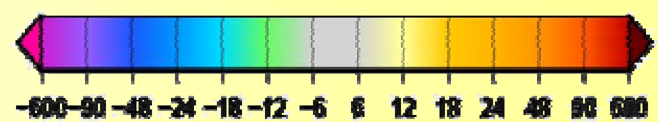
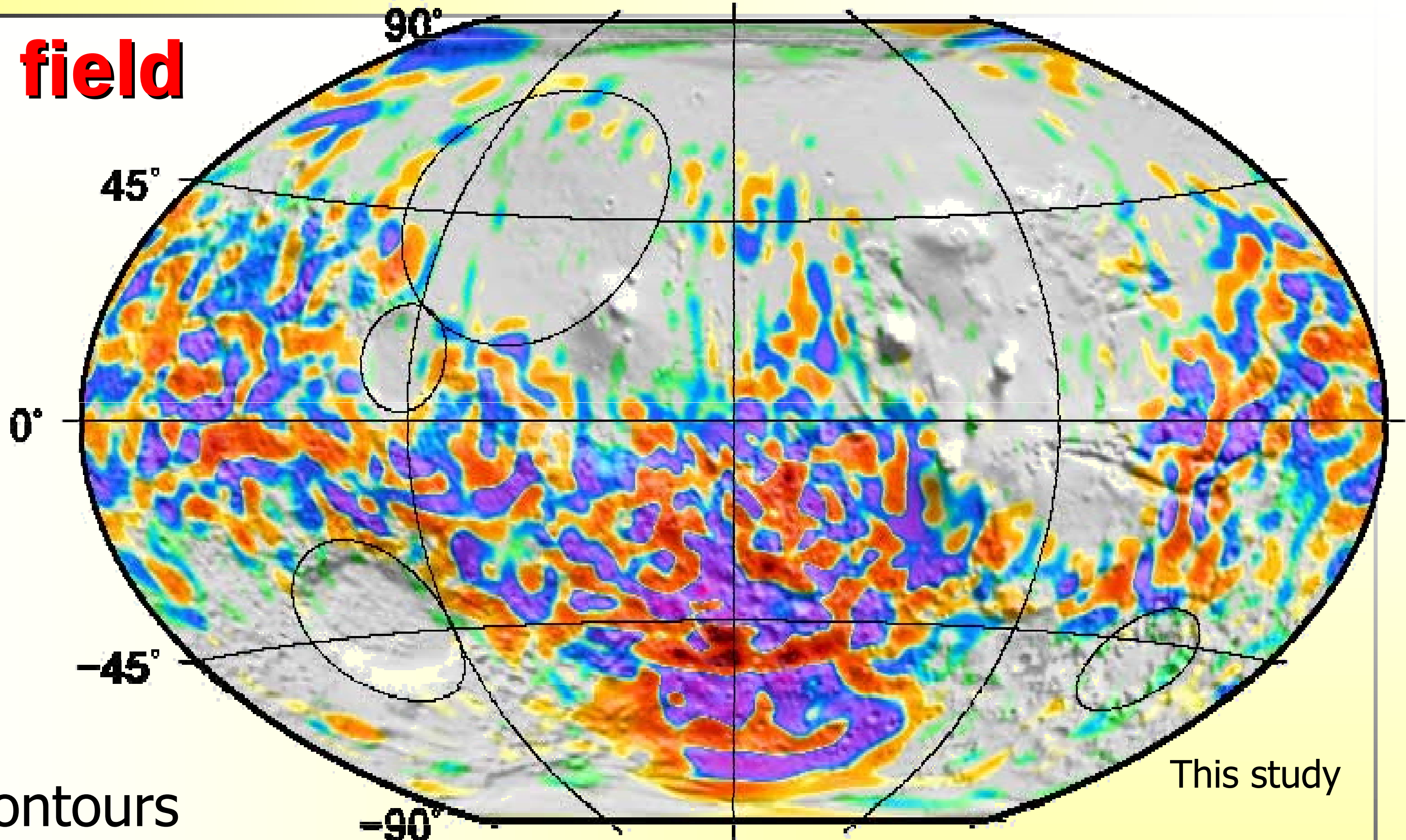


Langlais et al., 2004



Radial field

150 km



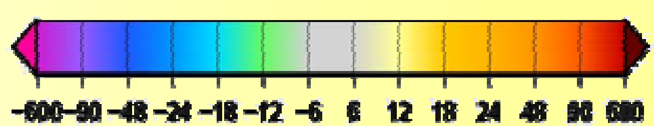
Sharper contours

No small-scale noise

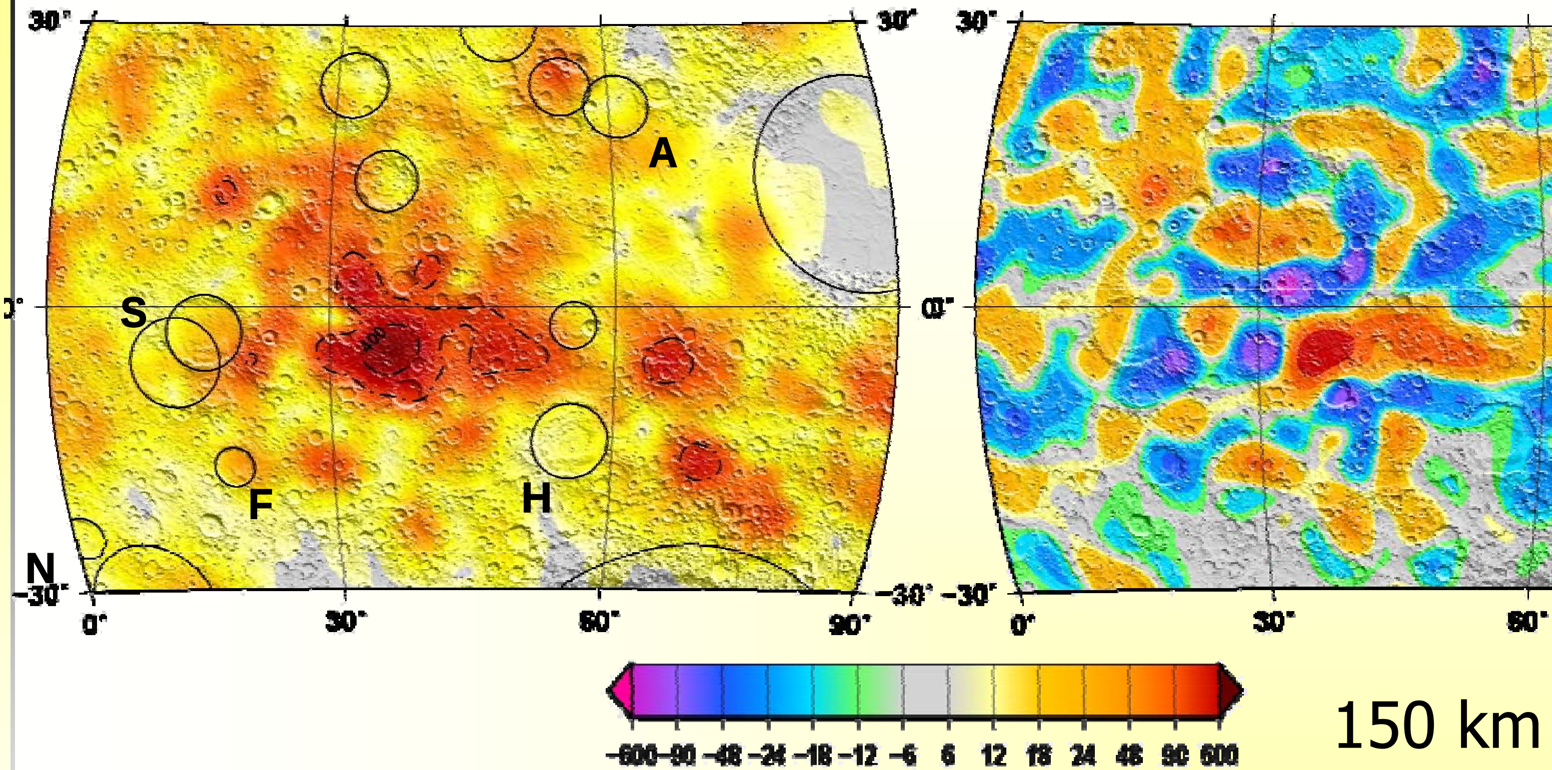
-690/+1120 nT

Extrema: M_r -14/+21 A/m;
M_θ -10/+16 A/m; M_φ -9/+9 A/m

Rms magnetization ~ 1 A/m



Close-up above Terra Sabaea

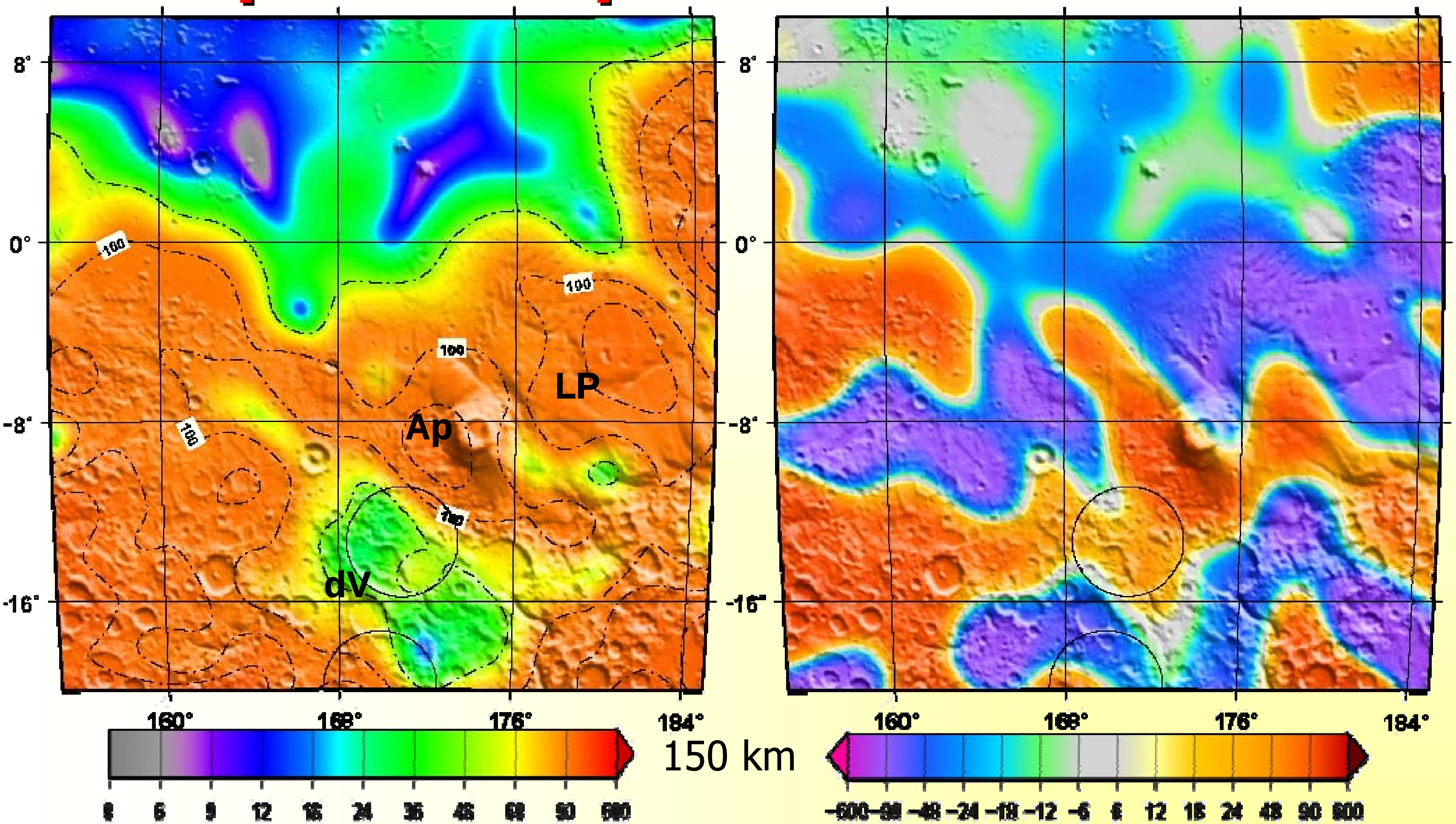


Isidis (3.96 Gyrs) not magnetized. Huygens (3.98 Gyrs) at a minimum. Syrtis Major (3.72 Gyrs) surrounded by weakly magnetized units, Nili Fossae at a minimum.

Antoniadi (3.79 Gyrs) and nearby – unnamed – crater have very different signatures

Schiaparelli (3.92 Gyrs) and overlap, Flaugergues, Newcomb (4.00 Gyrs) are close to magnetic maximum.

Close-up above Apollinaris Patera



Apollinaris Patera (3.81 Gyr) & Lucus Planum (younger) magnetized (Langlais and Purucker, 2007; Hood et al., 2010)

de Vaucouleurs has a weaker signature (3.95 Gyr)

Summary

1/ A new model: more input data, improved spatial resolution, better noise reduction, sharper definition

2/ Global, as well as local and detailed studies are possible at lower altitude, with more confident results.

3/ The magnetic field history of Mars is still not fully understood; dynamo cessation timing is uncertain (~3.7 Gyrs or ~4.2 Gyrs). Other scenario are possible, implying different dynamo regime (see Amit et al. poster, and 2011, PEPI)

4/ More, lower altitude measurements are needed.
MAVEN is awaited!