AGU 2017
GP41A 0964

The Martian crustal magnetic field as seen from MG and MAVEN

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Overview of the new model

The magnetic figure of Mars was essentially constrained by the high quality measurements of Mars Global Surveyor (1996-2006). While the orbital parameters of this mission returned repetitive measurements on the night side (2:00 am) at a nearly constant altitude of 400km, the low altitude measurements were very sparse.

The MAVEN mission (since 2014) is on an elliptical orbit around Mars, which provides a wealth of measurements at different local times and altitudes. With now almost three years of available measurements, it is possible to combine MAVEN and MGS observations and to compute a high resolution model of the martian magnetic field.

This new model supersedes previously published models. It is based on Equivalent Source Dipoles (ESD), a discrete approach which benefits from the varying data distribution. It is converted into a spherical harmonics (SH) model which is stable up to degree 137, and can be used to predict the magnetic field at the surface of Mars with an unprecedented accuracy.

-> Main improvements

- Data selection scheme for MGS MAG Mapping Orbit (M0) measurements, based on night time and on a Martian quiet time index (Langlais et al., 2017)
- Reselection of low altitude measurements (< 600 km), as for MAVEN
- Use of MGS Electron Reflectometry (ER) indirect estimates of the total field (Lillis et al., 2008) at 185 km altitude
- Use of MAVEN magnetic field measurements (until 05/15/2017)
- Increased lateral spatial resolution of the dipole mesh, down 1.91° or ~110 km

-> Data selection

The combined use of MAVEN (Jakosky et al., 2016) and MGS makes it possible to test the quality of the measurements. Selection criteria are based on comparison of true measurements with predicted ones (by a preliminary model), orbit by orbit. About 1/3 of the low altitude MGS orbits are rejected. The same procedure is applied to MAVEN, with a similar proportion of rejected orbits.

-> Power spectrum

The ESD solution is converted into a spherical harmonics model. Model converges up to N=137.

Comparison with other models not using MAVEN data clearly shows that the field is less energetic at small scales than previously thought, with a 1-order-of-magnitude difference at N=137.

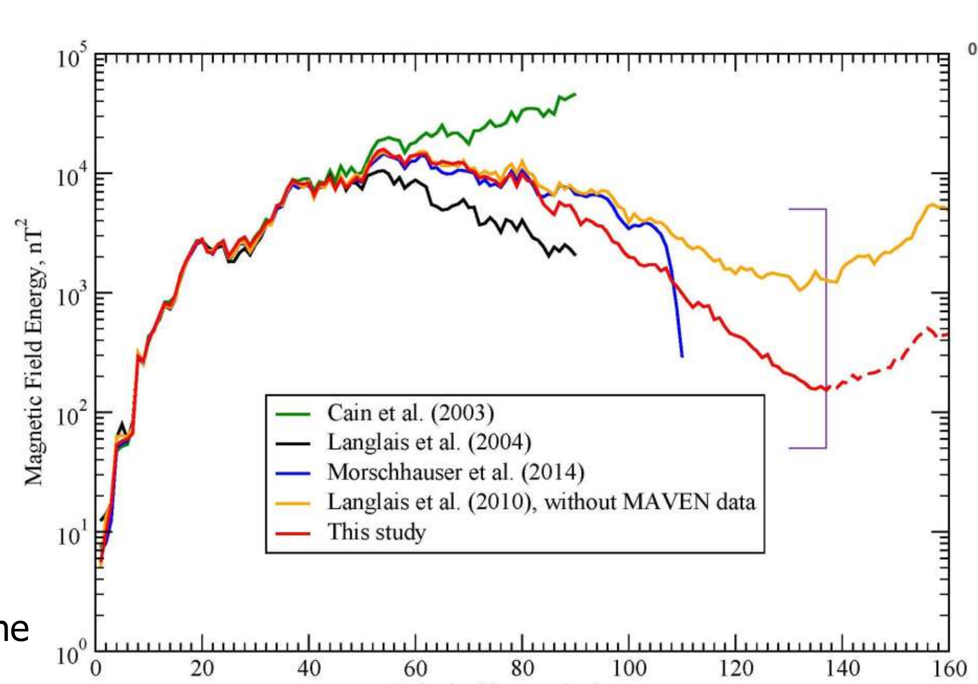

Figure 1: Magnetic energy spectrum of the new model compared to previously published models. Note that Morschhauser et al. (2014) damped their model at N=110.

-> Some numbers

Model statistics indicates that radial field is the best described. Globally correlation coefficients exceed 0.98, except for B_φ, closer to 0.95.

A stable solution is found after 43 iterations.

data	Nobs	σB_r	σB_θ	σB_φ
MGS AB/SPO, below 600 km	101956	14.29	17.48	18.98
MGS MO, ~400km, night side	333670	3.82	3.88	3.86
ER 185 km	178951		11.67 (σB)	
MAVEN, below 600km, night side	158152	8.24	9.30	9.68

Table 1: root mean square differences between the measurements used and that predicted by the ESD model. All values in nT, except for Nobs.

-> Results

We plot the magnetic field (Br and total field) at 200 and 150km, and at the surface (using a SH model based on the ESD solution). The global picture of the magnetic field remains similar (Fig. 3), but the model has a better resolution and the field can be computed at lower altitude (Fig. 4). The ESD model is converted into spherical harmonics and allows to predict the field at the surface (Fig. 5).

Magnetization remains very strong (Fig. 6) and heterogeneous. At a local scale, anomalies are locally better defined (Fig. 7 and 8). All these improvement should ease the interpretation of the models in terms of magnetization properties and correlations with geology.

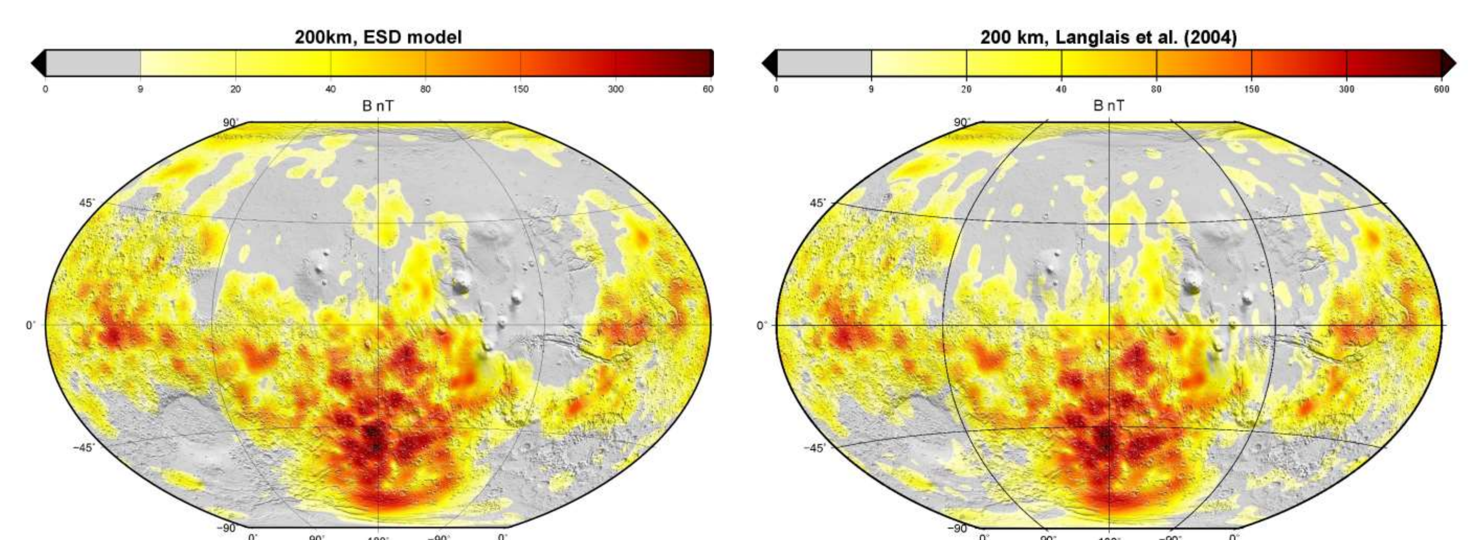

Figure 2: Field intensity predicted at 200 km altitude, from the new ESD model (left) and that published by Langlais et al. (2004). Note that improvement is especially visible over the northern hemisphere plains, where anomalies are better defined.

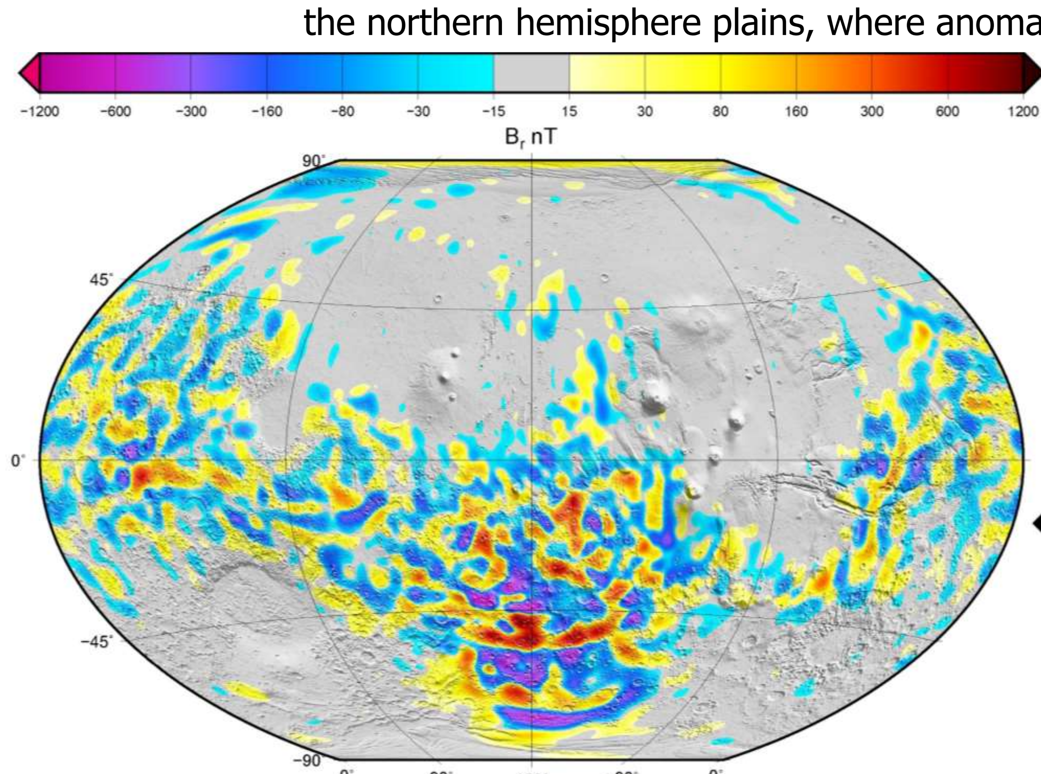

Figure 3: Radial field predicted at 150 km from the new ESD model.

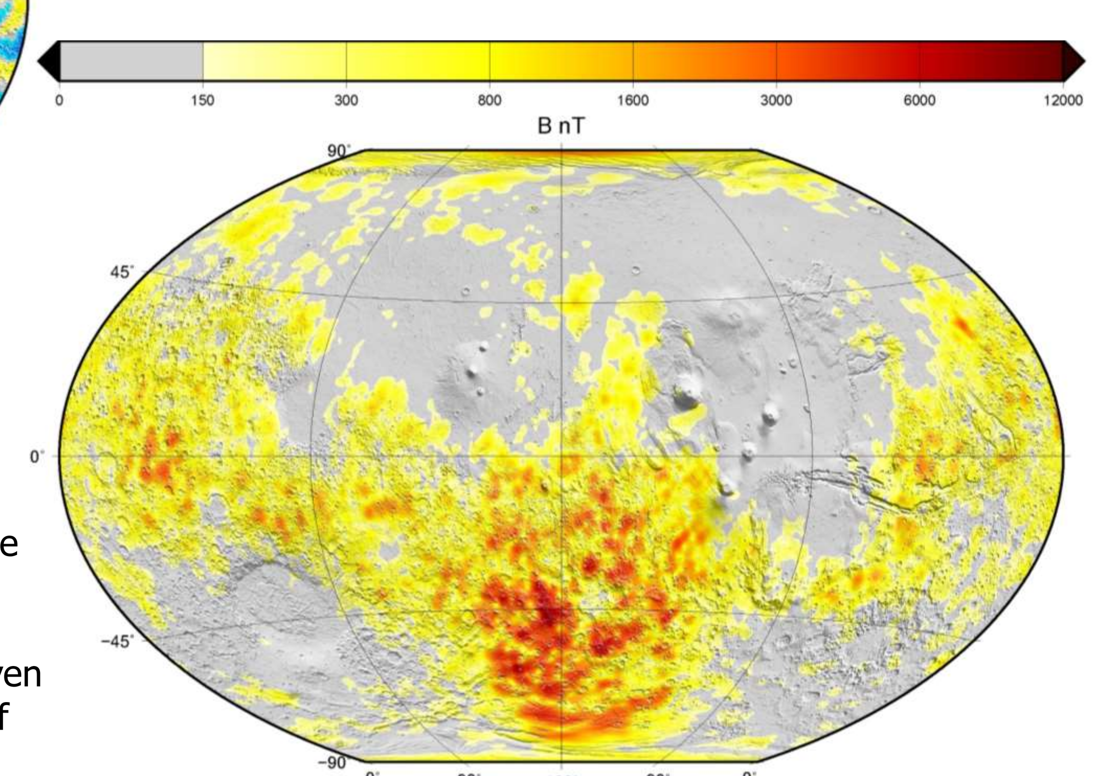

Figure 4: Total field predicted at the surface, using a SH model up to N=137 (based on the new ESD model). At these lengthscales the field may be in excess of 12000 nT locally. The field is very heterogeneously located, even in the highly magnetized southern terrains of Terra Cimmeria and Terra Sirenum.

-> Magnetization maps

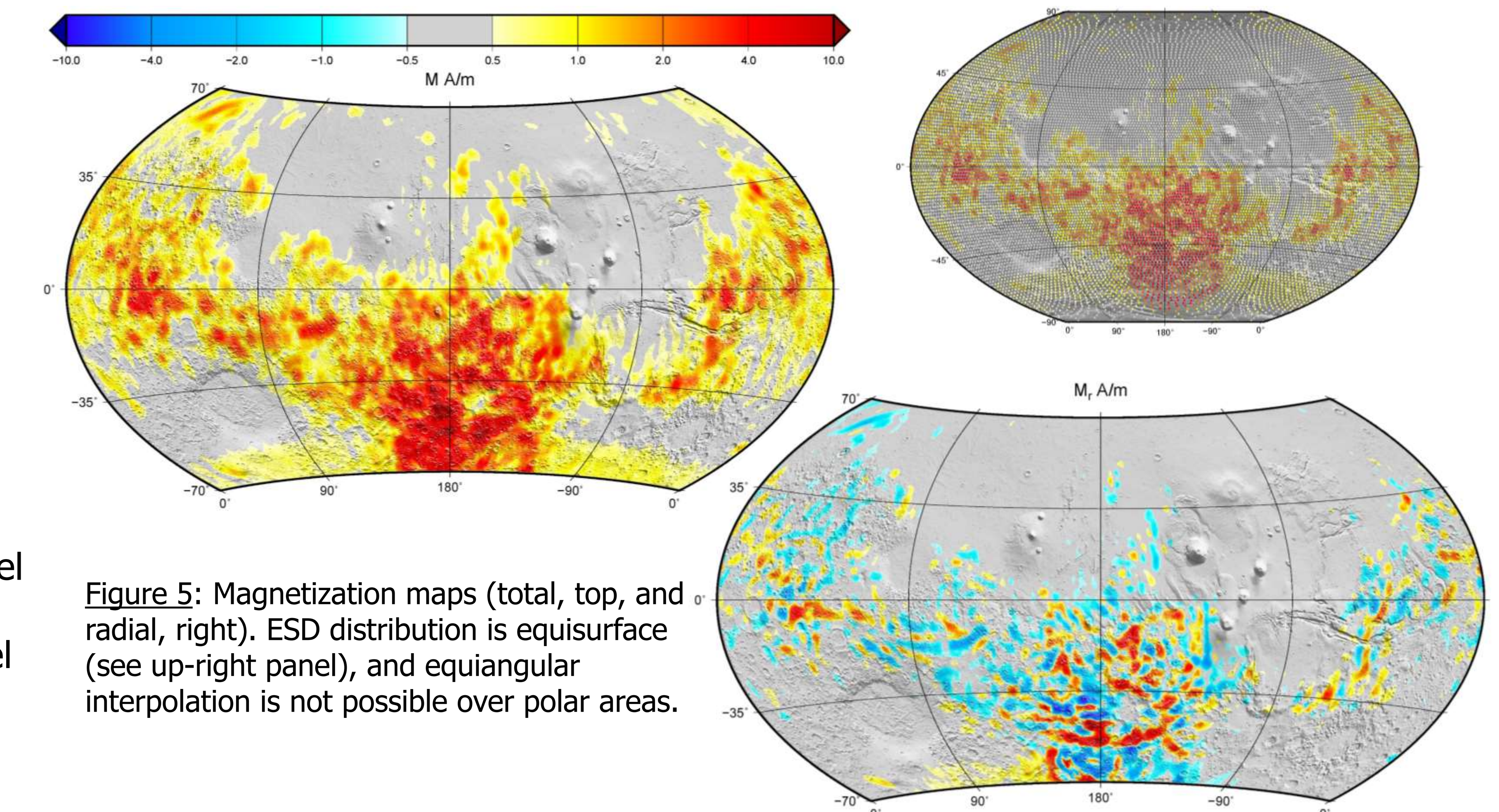

Figure 5: Magnetization maps (total, top, and radial, right). ESD distribution is equisurface (see up-right panel), and equiangular interpolation is not possible over polar areas.

The ESD scheme allows to estimate what is the magnetization under certain assumptions. For a 40-km thickness and a spherical surface of 0.96° radius, magnetization range between +- 15 A/m. Rms magnetization is close to 1 A/m. Only 27% of the surface has a magnetization larger than this value.
To get absolute values, surface measurements, such as those envisaged by the project NEWTON (Diaz-Michelena et al., 2017) are needed.

-> Zoom over specific areas

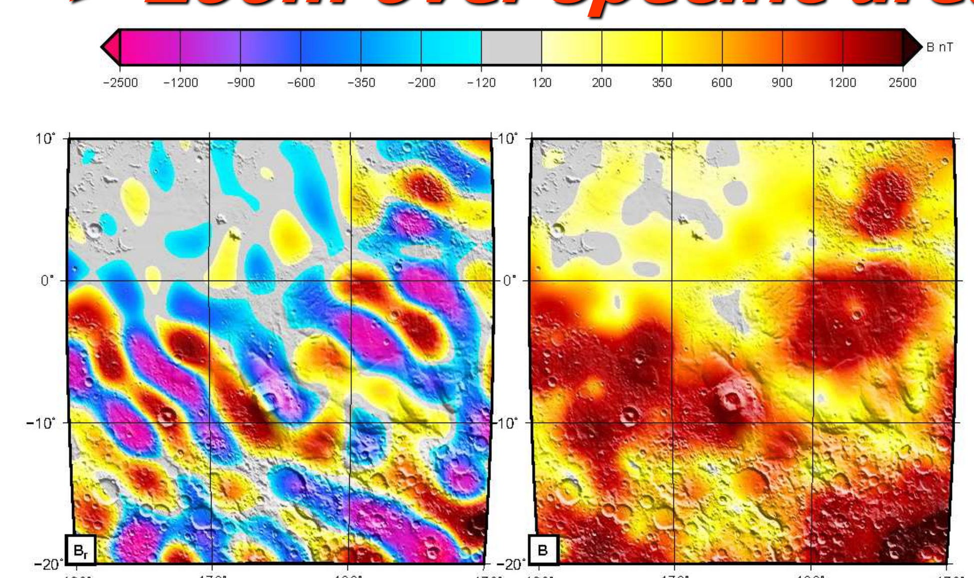

Figure 6: close up over Apollinaris Patera. The late-Noachian volcano has a clear magnetic field signature, exceeding 1500 nT above its caldera. The link with the timing of the dynamo cessation will be investigated.

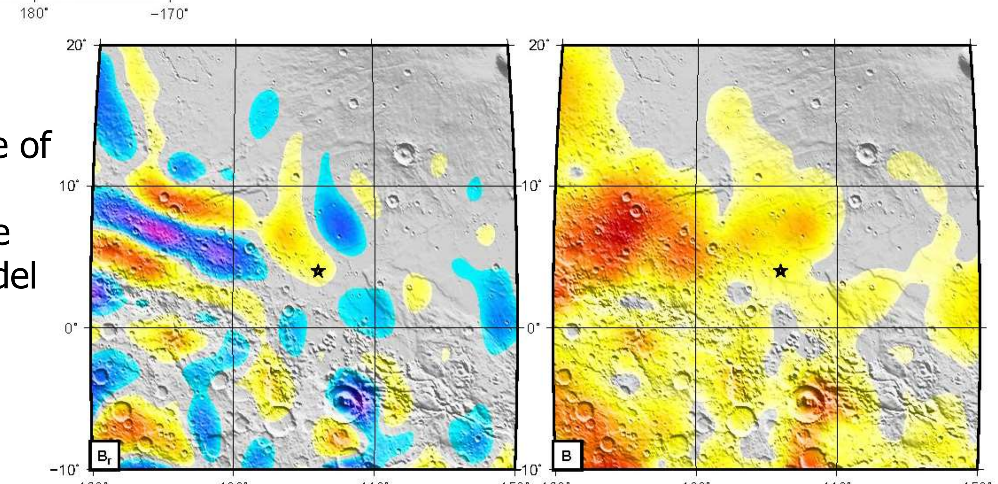

Figure 7: close up over the landing site of InSight (Banerdt et al., 2013 – launch: May 2018), south-west of Elysium. The magnetic field as predicted by our model is close to 300 nT.

-> Concluding remarks and more

This new model will allow to investigate in details the magnetic figure of Mars and its evolution, as it combines field maps at the surface and magnetization contrasts.
A paper is preparation, but the model is ready to be shared with those interested.

REFERENCES: Banerdt et al., LPSC, 2013; Cain et al., JGR, 2003; Diaz-Michelena et al., EPSC, 2017; Jakosky et al., GRL, 2016; Langlais et al., JGR, 2004; Langlais et al., JGR, 2017; Lillis et al., Icarus, 2008; Morschhauser et al., JGR, 2014; *Financial Support was provided by CNES and by the European Union's Horizon 2020 research and innovation programme under grant agreement No 730041 / NEWTON*