A 2015 IGRF candidate model based on Swarm's experimental ASM Vector Mode Data

GP51A-3701

P. Vigneron(1), G. Hulot(1), N. Olsen(2), Jean-Michel Leger(3), T. Jager(3), L. Brocco(1), O. Sirol(1), P. Coisson(1), X. Lalanne(1), A. Chulliat(4), F. Bertrand(3), A. Boness(3) and I. Fratter(5)

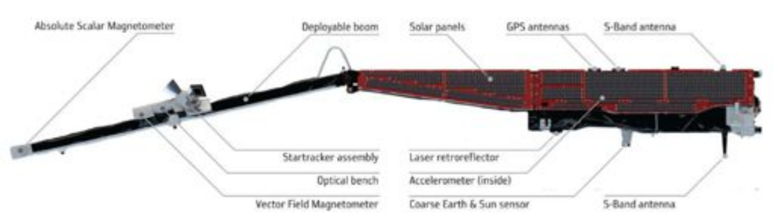
(1) Institut de Physique du Globe de Paris, Paris, France, (2) Technical University of Denmark Space, Kongens Lyngby, Denmark, (3) CEA LETI, Grenoble, France, (4) National Geophysical Data Center, Boulder, CO, United States, (5) CNES French National Center for Space Studies, Toulouse, France

Contact : vigneron@ipgp.fr, gh@ipgp.fr

Abstract

Each of the three Alpha, Bravo and Charlie satellites of the ESA Swarm mission carries an Absolute Scalar Magnetometer (CNES customer furnished ASM instrument designed by CEA-LETI) that provides the nominal 1 Hz scalar data of the mission, but also delivers 1 Hz experimental vector data (ASM-V). Tests during the commissioning and calibration/validation phase have shown that these data and the rigidity of the boom mechanically linking the ASM to the star imager (STR) on Alpha and Bravo were of such good quality that an IGRF candidate geomagnetic field model could possibly be produced from such ASM-only data (without having to resort to any of the nominal vector field magnetometer (VFM) data of the mission). Here, we report on our efforts to build such an IGRF candidate, which intends to provide an image of the January 1, 2015 Geomagnetic Field, alternative to the images provided by IGRF candidate models based on Swarm nominal L1b data, or other data.

ASM-V Data production



Experimental vector ASM-V data used here are derived from L0 quasi-daily files containing the basic vector mode output of the ASM instrument (in EU). Three steps are needed to process these raw files :

1. Calibration parameters of the ASM vector mode (CCDB) are evaluated on a daily basis (see poster GP51A-3698 [1])
2. L0 raw data are converted to physical units using the CCDB previously computed and the magnetic field **B** is then corrected from several stray fields.
3. Finally, **B** is interpolated at UTC times to produce the ASM-V data in the ASM instrument reference frame

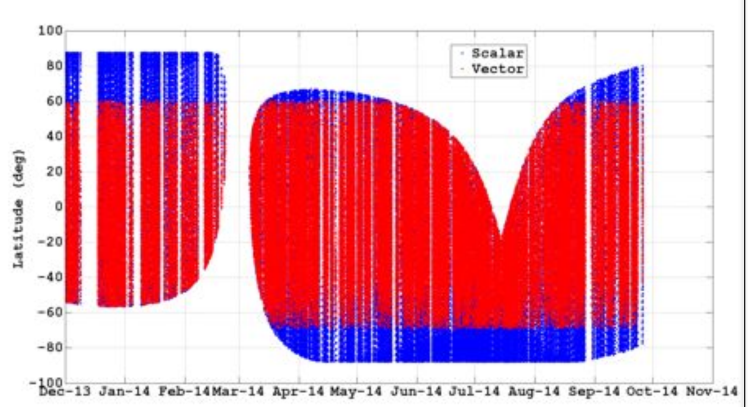
Data selection

◆ Global data selection are first applied with the following criteria

Criteria	Threshold
Satellite(s)	A and B only
Time	From November 29, 2013 to September 25, 2014
Sun exposition	Sun at least 10° below the horizon
Magnetospheric ring-current strenght	RC index < 2 nT/hr
Geomagnetic activity	Kp index < 2$^+$
Merging electric field at the magnetopause	Em < 3.3 mV/m on average over the last 60 minutes

◆ Then the data are split in the following way :

- At QD latitudes poleward of ± 55° : scalar data
- At other latitudes : keep vector data if scalar residuals are less than 0.3 nT and if not flagged as outlier (see [1]), else use scalar data



◆ Data have also been removed if the matching VFM data behaved as a rough outlier w.r.t. CHAOS-4 model (see [2]) to ensure availability of synchronous VFM data

◆ Finally data have been adequatly decimated

◆ Three different dataset were produced at this point : all have the same data coverage (same time on the same satellite). The only difference is the data used : ASMV, VFM or VFM normalized to the scalar ASM data (VFMn). This allows us to produce three different models for comparison.

Inversion

The overall modeling procedure we used is similar to the one used for CHAOS-4 (see [2]) but with a simplified treatment of the magnetospheric field and a steady Secular Variation (SV). The field is assumed to be potential with both internal and external sources. Euler angles that define the rotation between the instrument and the Star Tracker (STR) are co-estimated every 10 days.

		Number of coefficients
Internal sources (max degree 40)		1680
Steady secular variation (max degree 8)		80
External sources	Remote magnetospheric sources	2
	Near magnetospheric ring current	11
Euler angles (every ten days)		180
TOTAL		**1953**

These 1953 parameters are estimated using an Iteratively Reweighted Least-Squares algorithm with Huber weights. No regularization of any sort was applied.

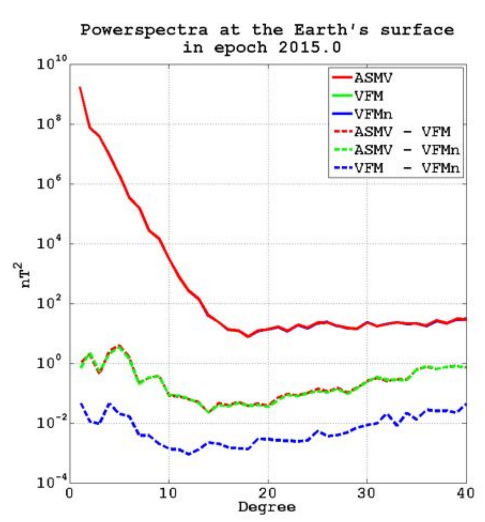
Residuals

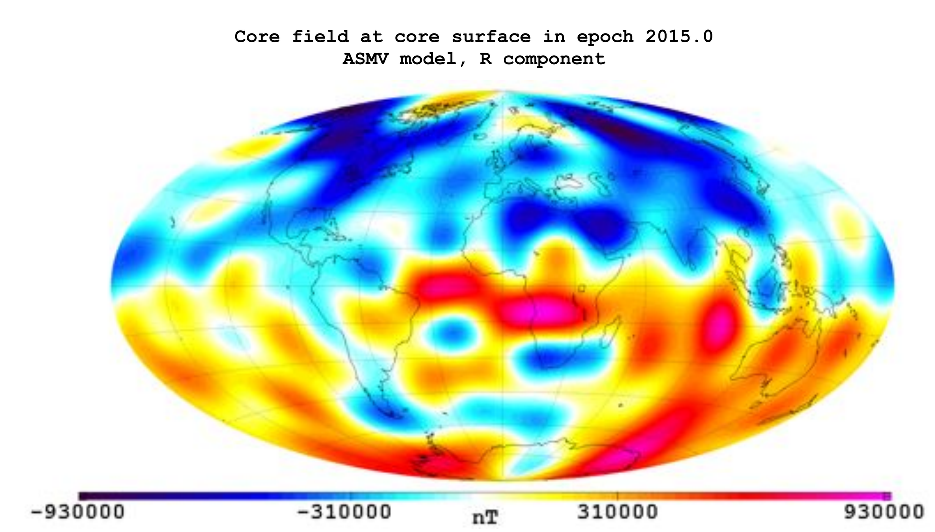
Component	N	Mean (nT) ASM-V	Mean (nT) VFM	Rms (nT) ASM-V	Rms (nT) VFM
F (polar)	49,214	-0.27	+0.00	4.81	4.80
F (non polar) + B_B	223,627	+0.04	+0.02	2.30	2.27
B_r	139,292	-0.02	-0.06	2.45	1.76
B_{theta}	139,292	-0.03	+0.06	3.56	3.18
B_{phi}	139,292	-0.16	-0.13	2.96	2.61

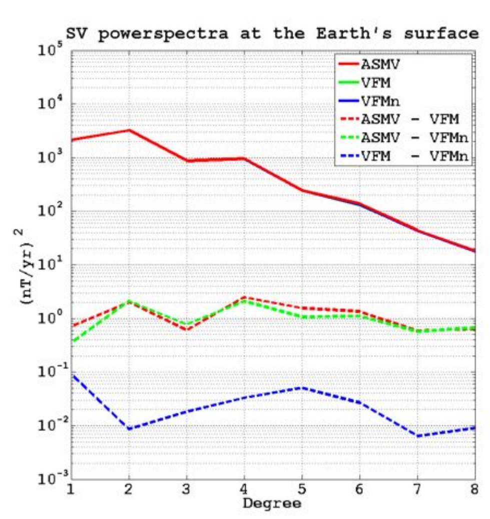
What must be kept in mind when comparing these residuals :

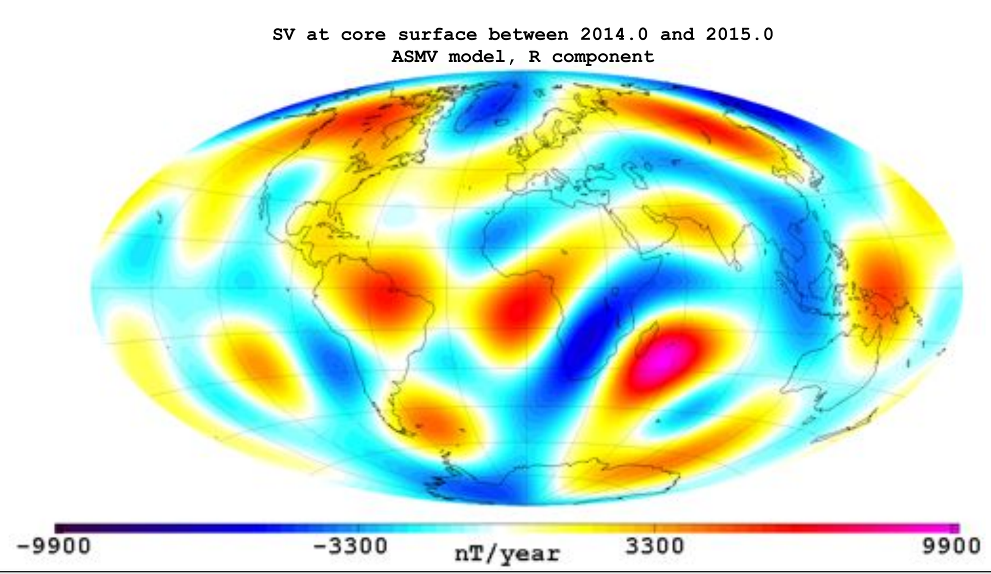
Boom oscillation	the ASM instrument is sitting much further away (2 m) from the STR than the VFM (which shares the same optical bench as the STR)
Noise of the instruments	roughly 2 nT standard deviation for the ASM-V (see [1]) and 0.3 nT for the VFM
VFM-ASM scalar residual issue	Perturbations can affect the VFM data (see poster GP51A-3700 [3])

Power spectra and maps







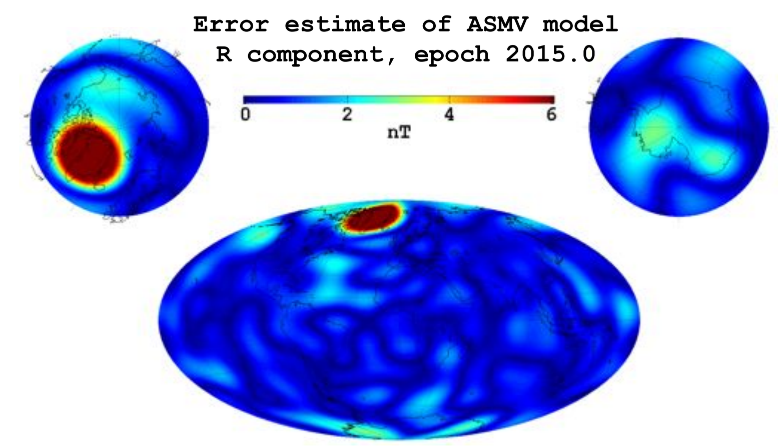


Model assessment

◆ **ASM-V model uncertainties —** the ASM-V dataset was split into two subsets of equal length based on even days (for the first one) and odd days (for the second one). Then, uncertainties in the predictions of the ASM-V model at the Earth's surface were computed, using :

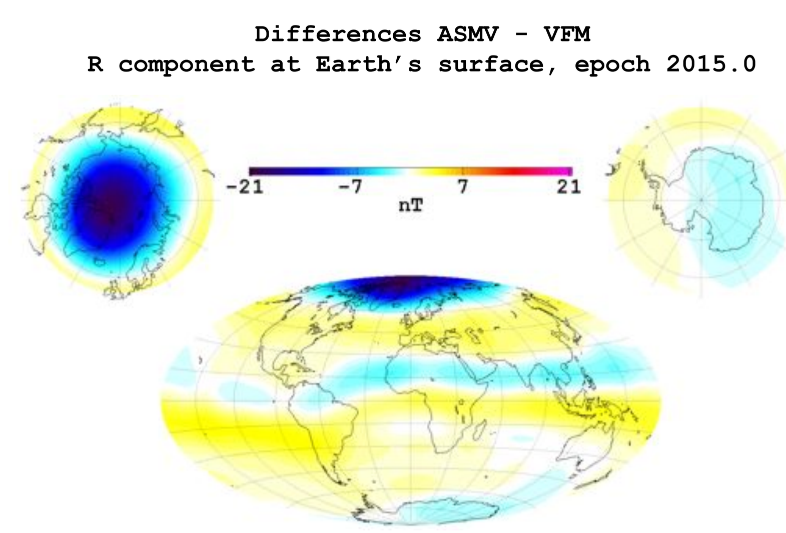
$$\sigma(\theta,\varphi)=\sqrt{\frac{1}{2}\left[\left(B_1(\theta,\varphi)-B(\theta,\varphi)\right)^2+\left(B_2(\theta,\varphi)-B(\theta,\varphi)\right)^2\right]}$$

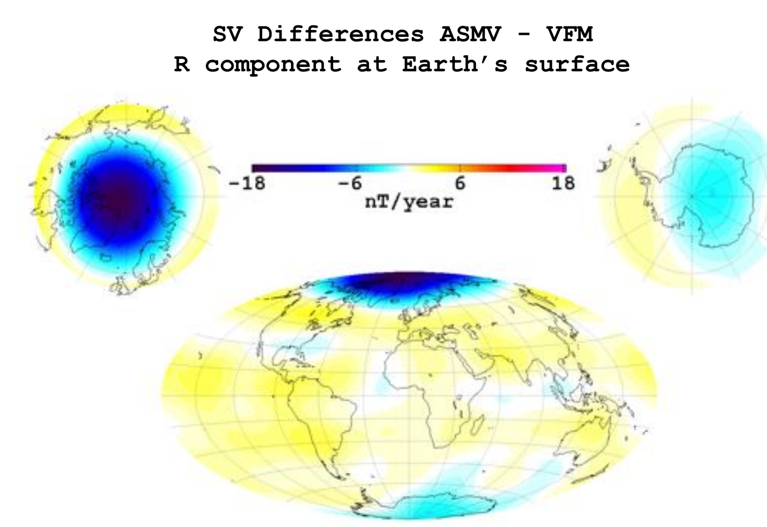
where $\mathbf{B_1}$ (resp. $\mathbf{B_2}$) is the predicted field based on the first (resp. the second) sub-model, while **B** is the predicted field based on the ASM-V model



- The North Pole area contains the highest uncertainties (the color scale is truncated, max value is 12 nT)
- Uncertainties elsewhere are much smaller (typically 1nT to 2 nT)

◆ **ASM-V versus VFM model comparison**





- Disagreements in the field predicted at the Earth's surface by the ASM-V and VFM models for epoch 2015.0 concentrate in the North Pole, and in two equatorial bands
- Disagreements in the SV at the Earth's surface show a similar concentration close to the North Pole, showing that the SV is the cause of the North Pole disagreements in the 2015.0 models
- Analogous maps are obtained when comparing the ASM-V model against the VFMn model

Conclusions

1. ASM-V data and the mechanical link between the ASM and STR instruments are of good enough quality to produce a reliable IGRF candidate model
2. Largest uncertainties in the model arise because of the limited data coverage in the Northern latitude, which affects the SV model and propagates to the 2015.0 candidate model. This effect is seen in the ASM-V uncertainty and in the ASM/VFM model comparison. It is not an ASM-V issue, but a data coverage issue (imposed by the deadline for submission of IGRF candidate models)
3. Disagreement between the directional information provided by the ASM-V data and the VFM data lead to a static zonal disagreement on the order of 2 nT at the Earth's surface. The cause of this disagreement is the combined effect of boom mechanical distorsions and issues possibly affecting the ASM-V data, or the VFM data (see [3])
4. The ASM instrument can be used as a stand alone absolute vector magnetometer to produce reliable global field models

References

[1] GP51A-3698 : In-flight calibration of the experimental Absolute Scalar Magnetometer vector mode on board the Swarm satellites, Jäger, T. et al

[2] Olsen, N., Lühr, H., Finlay, C. and Toffner-Clausen, L. (2014). The CHAOS-4 Geomagnetic Field Model, Geophys. J. Int., 197:815-827

[3] GP51A-3700 : Comparing Swarm's Nominal Level1b Magnetic Data and ASM Vector Field Experimental Data: a Convenient Tool for Understanding Data Quality Issues, Brocco, L. et al