

Using twenty-four years of CLUSTER FGM data to observe the average behavior of the magnetic field and current density in the Earth's magnetosphere.

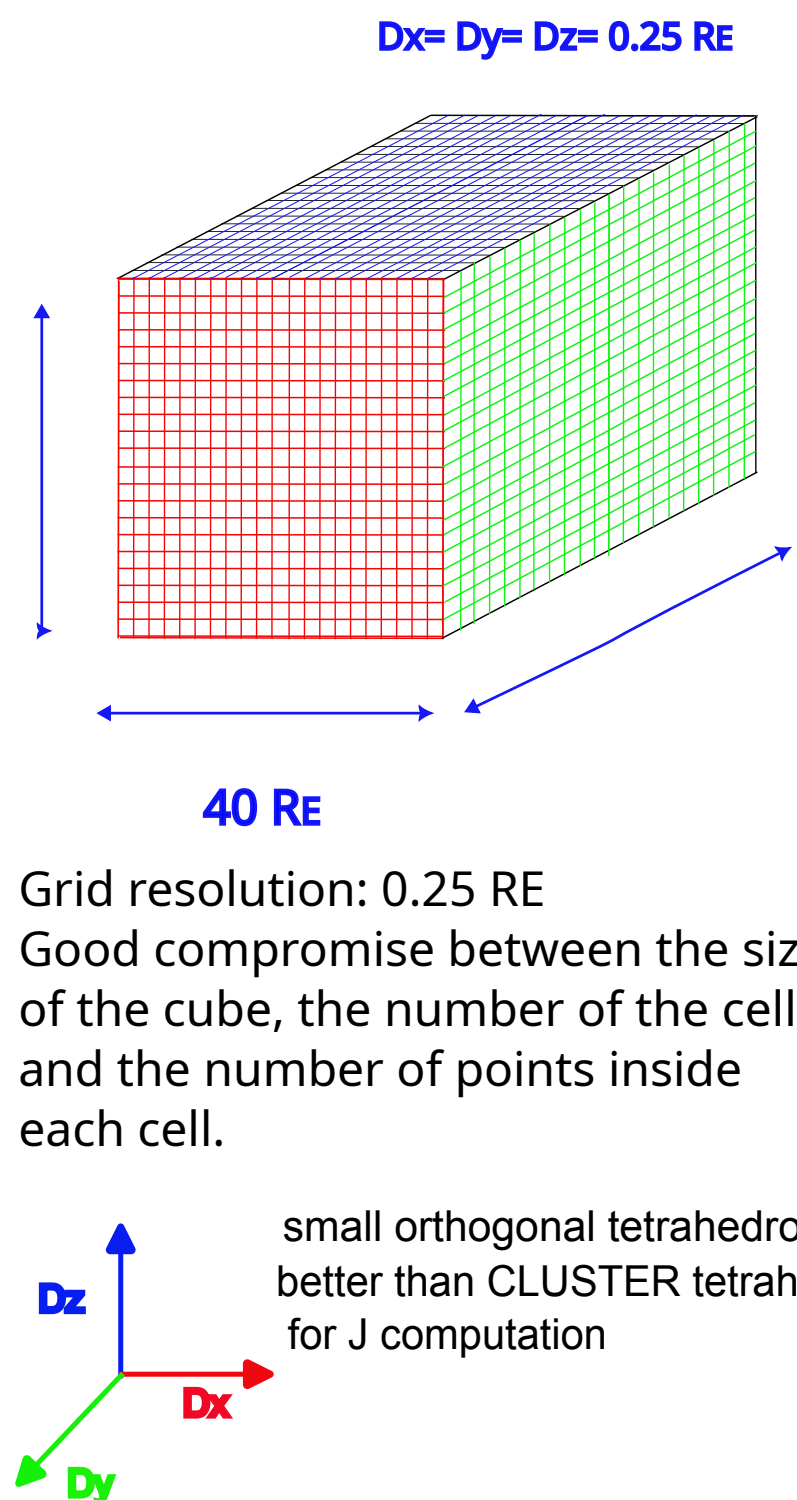
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Data from the CLUSTER FGM magnetometer, recorded over 20 years at ESA's Cluster Science Archives, along with satellite positions, were used to create a giant database of the time- and position-dependent B vector in the GSE system.

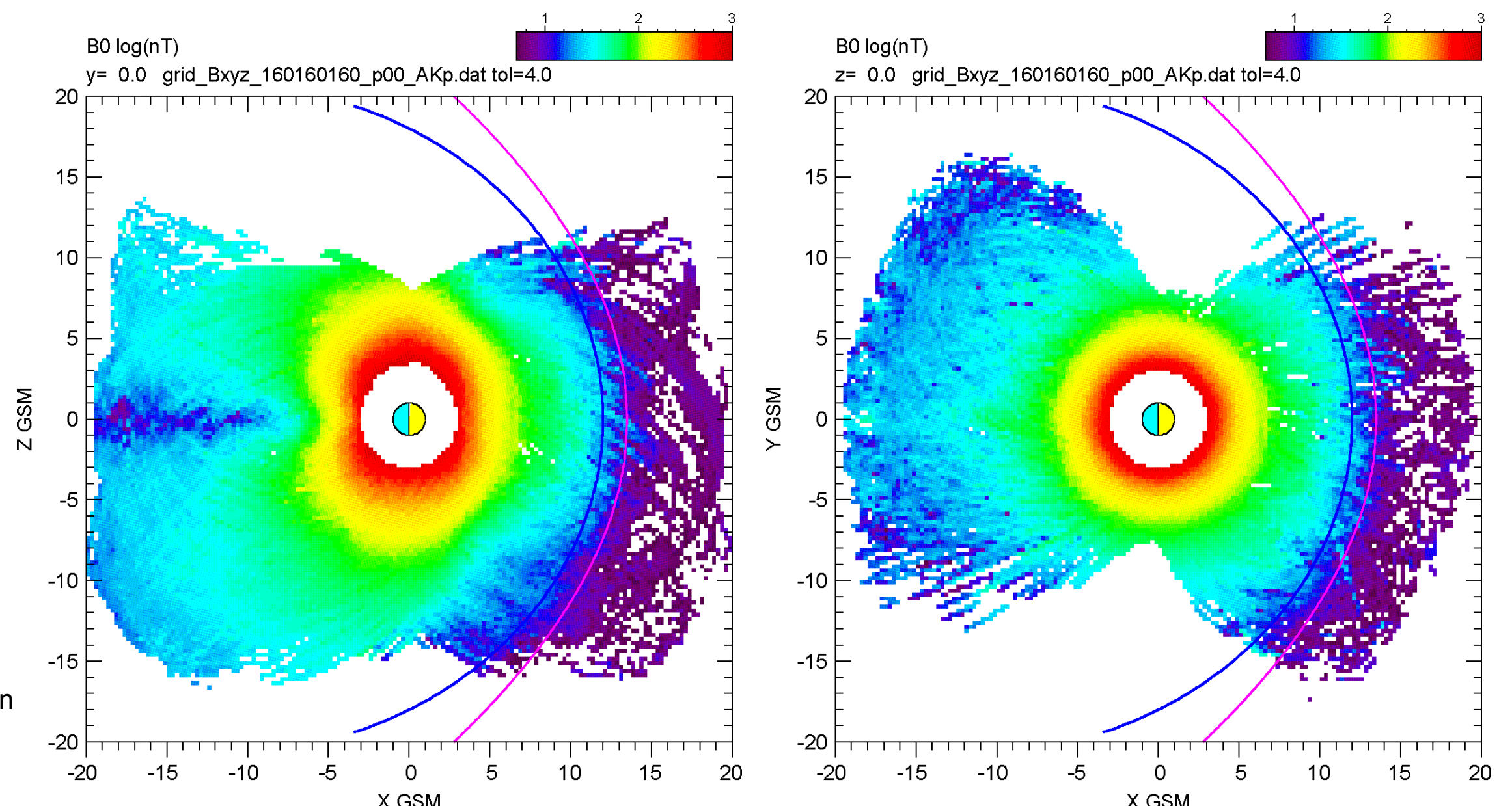
CLUSTER FGM SPIN data base: First record= 2001-01-01 Last record= 2024-09-29 Number of files= 33903 Number of points= 623 005 747 Total size= 70 GB

1 3D grids creation



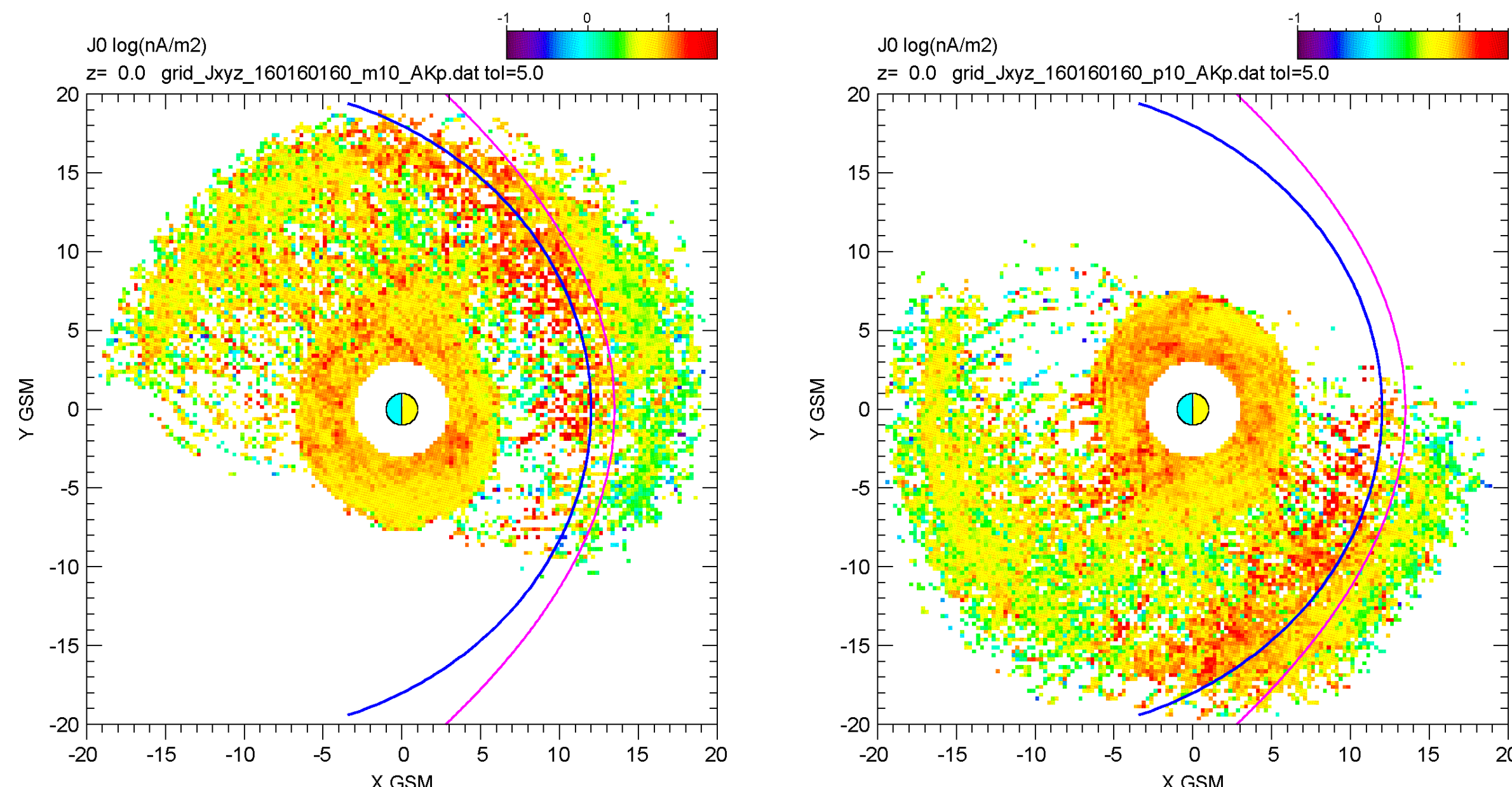
The data are then bin-averaged, as a function of the dipole tilt angle, to form 3D grids with a spatial extent of 40 RE, with spatial resolution of 0.25 RE, in GSM coordinates. The hypothesis is made that the shape of the field depends mainly of the dipole tilt angle. Due to the limit of the used computer, the solar wind parameters are not taken into account.

A first set of grids is computed, containing the B_{ijk} values for each dipole tilt angle. From this set, magnetic field strength maps can be produced.



Intensity of the magnetic fields in X-Z and X-Y GSM plane ($\theta=0$). Results are consistent with what is expected.

A second set of grids is computed, containing the B_{ijk} values after subtracting the IGRF model value. To use the second set of grids, we define a small orthogonal tetrahedron the size of the grid resolution. This allows the calculation of the current density at each grid point, and thus the production of new J_{ijk} grids.



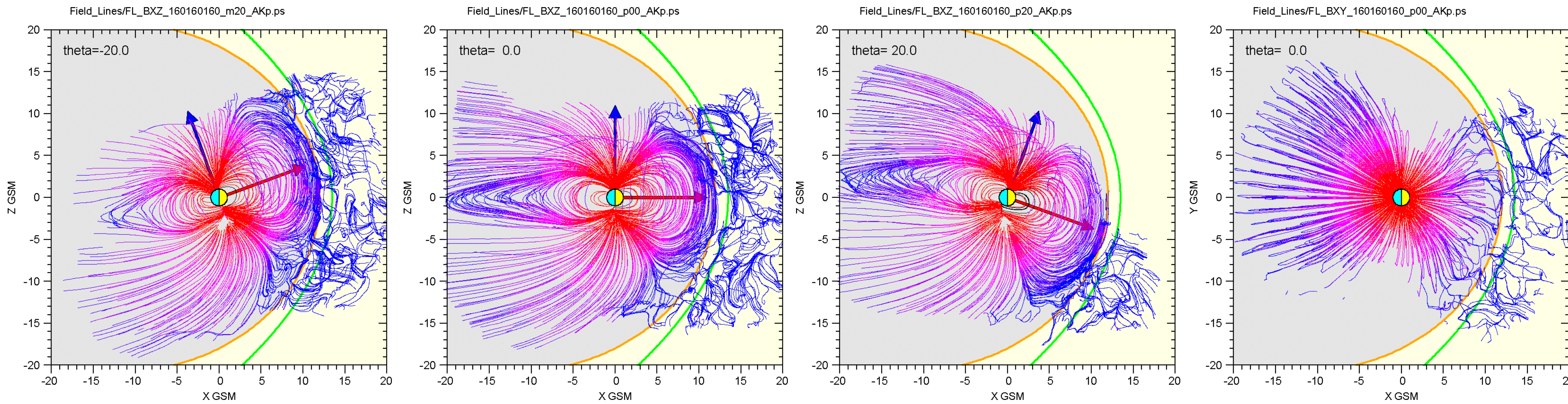
Intensity of the current density in X-Y GSM plane, for $\theta = -10^\circ$ and $\theta = +10^\circ$. Results are consistent with what is expected:
ring current visible, intensity $\approx 5-20 \text{ nA/m}^2$ position around 3-8 RE $\text{Div/Curl} \approx 0.1 - 0.2$

2 SPATIAL INTERPOLATION

Using Franke-Little spatial interpolation, the grids allow the calculation of the B and J vectors at any point in space where they are filled. Interpolation is made from the closest cell. The total number of cells is $[40/0.25]^3 = 4\,096\,000$ points interpolation could be done from all initial points, but with $600 \cdot 10^6$ points, it is too heavy for a small computer...

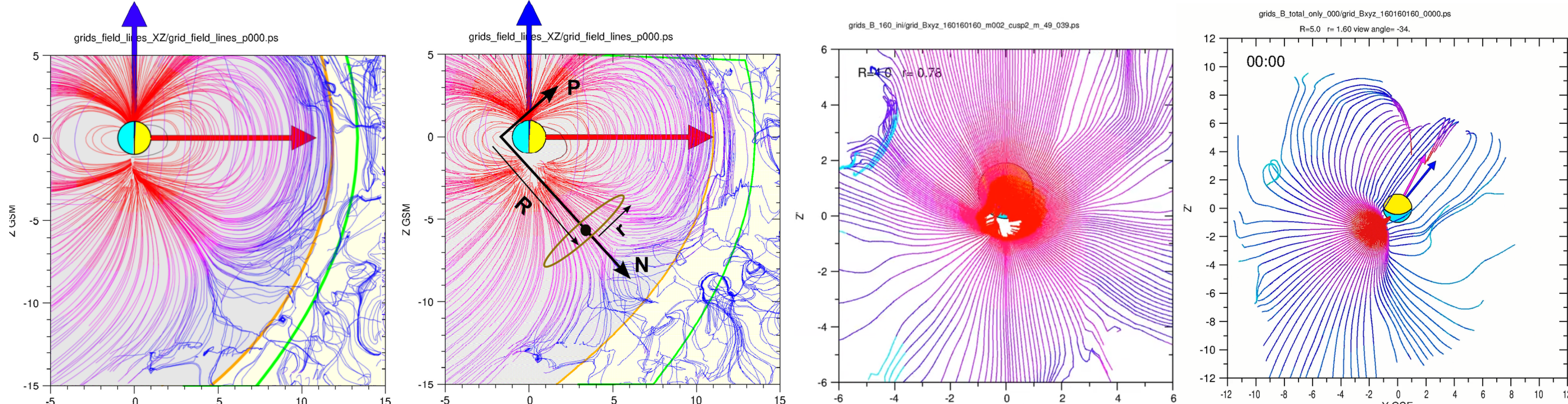
As we can have the value of the field at any point in space, we can calculate field lines with a ray tracing program (TRACE de TSY.)

From a given point, we can calculate the field line starting from this point (and in both directions). By carefully choosing a set of starting points, one can obtain field lines maps as above.



Magnetic field line in the X-Z GSM plane for 3 values of the dipole tilt angle. Results are consistent with what is expected.

Magnetic field line in the X-Y GSM plane.

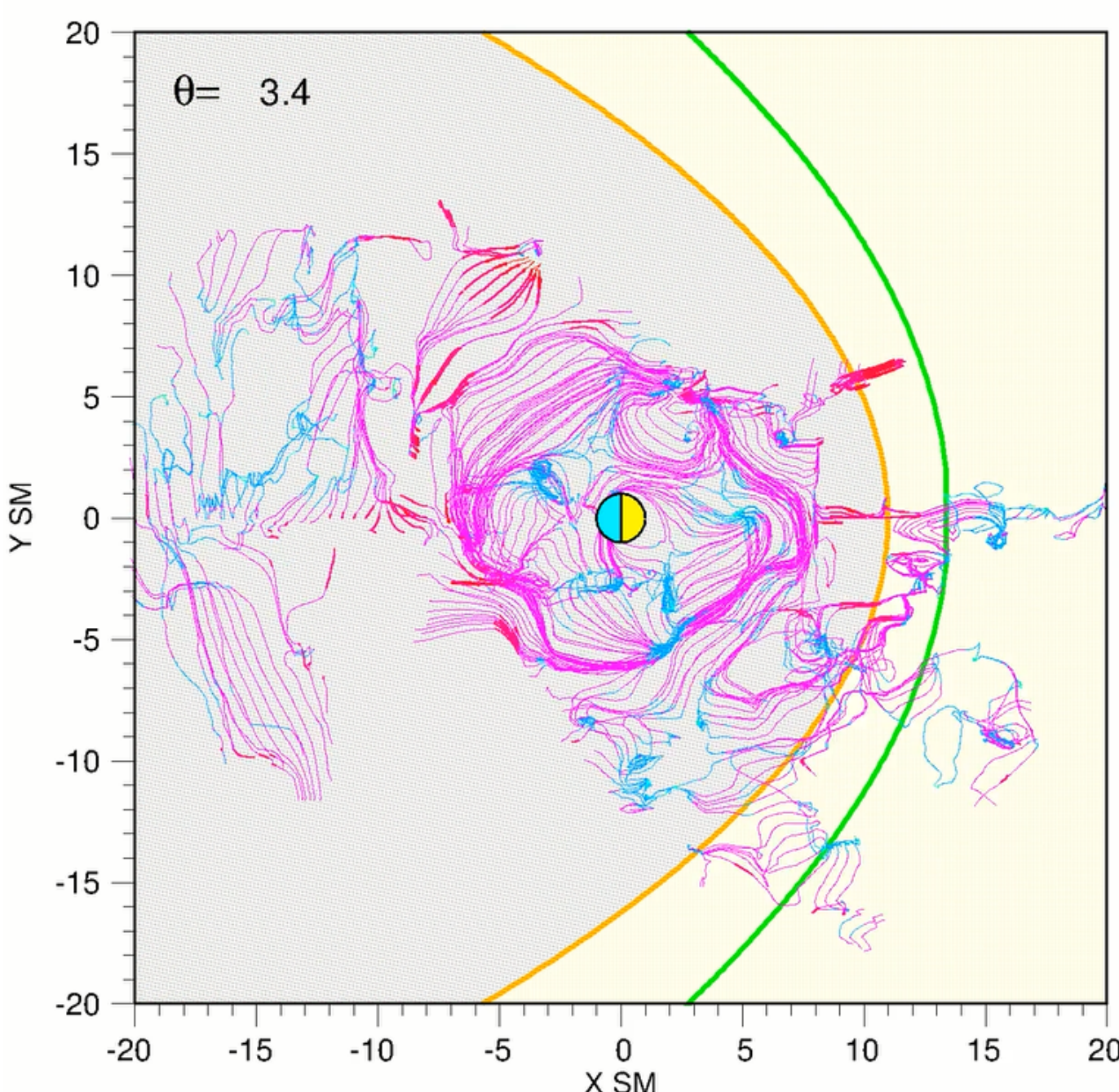


Zoom on the south cusp for $\theta=0$. Cusp is very narrow with field lines in the center.

Definition of the NYP system. A circular line (Position R, radius r) is used to define the starting point of the field lines allowing computation of the cusp field lines in the Y-Z plane.

Field lines of south cusp in (Y_{GSM}, N) plane with $R=4$ and $r=0.78$ ($\theta=0$).

Field lines of south cusp in (Y_{GSE}, N) plane with $R=5$ and $r=1.6$ ($\theta=0$).



Field line of the current in X-Y SM equatorial plane.
-> not so good but ring current still visible.

3 CONCLUSION

- Software to read data base and create 3D grids (+ curl(B) and div(B) computation).
- 3D grids creation for B, J, div(B), (J,B) angle etc.
- 3D interpolation to get B(x,y,z,theta).
- possibility of drawing field lines for B and J.
- production of B and J maps, in intensity and in direction.
- production of B and J field line maps.

In a future work more criteria other than the dipole tilt angle could be added, such as Kp indices or solar wind parameters.
Adding data from other missions (such as THEMIS or MMS) to the main database would expand the regions covered by Cluster and increase the spatial extent and resolution of the 3D grid. However, a powerful computer would be required.

This poster, data bases, MagCube software, images and animations are available here: http://www.scientidev.fr/FTP_server/Publications/Communications
JGR paper is available here: http://www.scientidev.fr/FTP_server/Publications/Articles
The talk given for the twenty year CLUSTER meeting (Darmstadt, 2021) is available here: http://www.scientidev.fr/FTP_server/Publications/Communications