OpenGGCM simulation of the April 24, 2009 interplanetary shock interaction with Earth's magnetosphere: effects of symmetry

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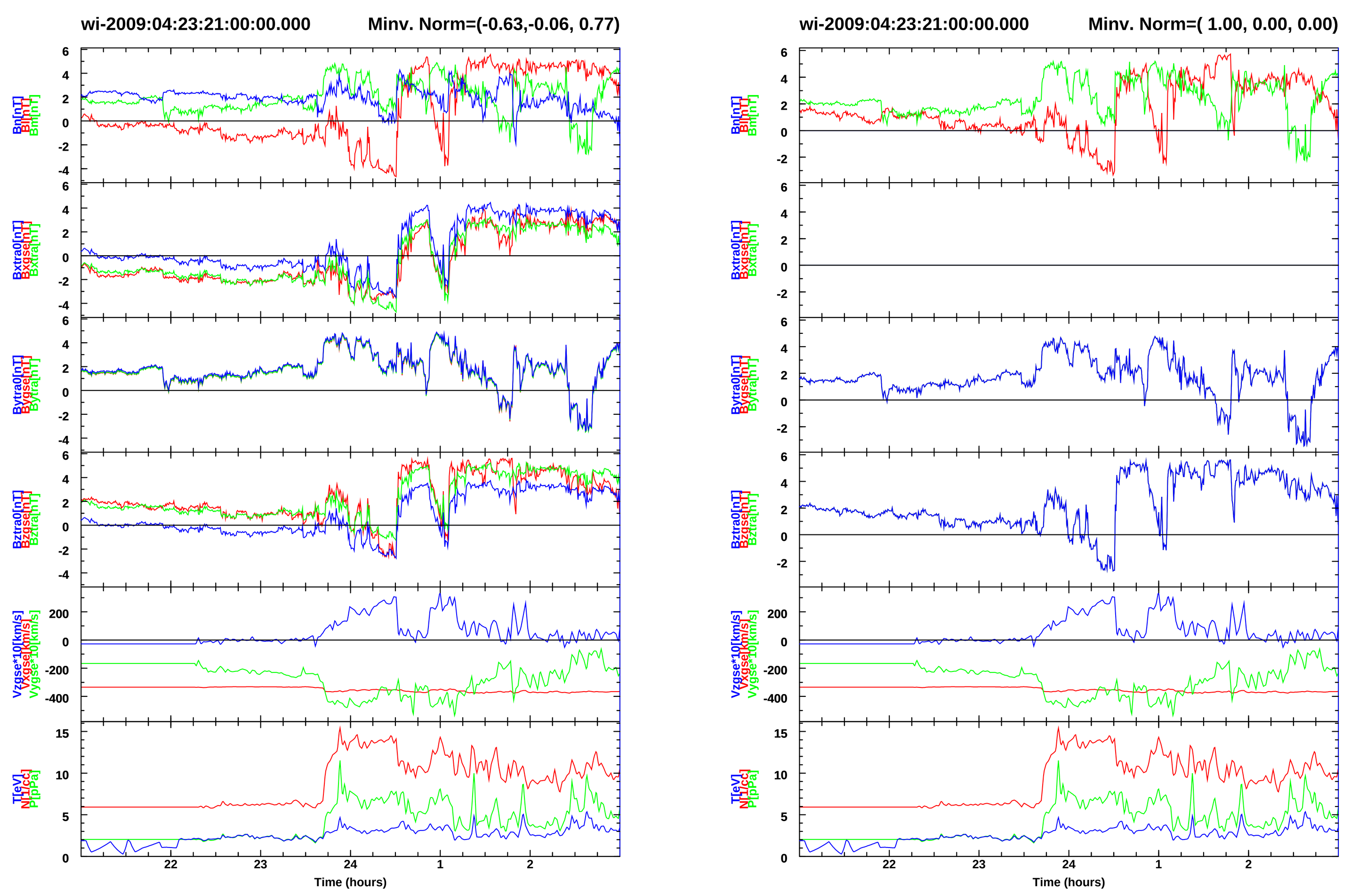
Introduction

In this study we investigate the interaction of an interplanetary (IP) shock with Earth's magnetosphere using OpenGGCM global simulations. We first simulate the April 24, 2009 event using WIND input data. This simulation shows a fairly mild response of the magnetosphere and hardly any response of the nightside ionosphere. Because the IP shock normal had a large angle with the sun-Earth line, we ran a second simulation setting the IMF x-component to zero. A zero IMF B_x should have little consequence for the solar wind - magnetosphere interaction, but it implies that the shock normal now points in the sunward direction. This simulation shows a much stronger response in the tail and in the nightside ionosphere. We interpret these differences by the way the shock induced waves propagate through the magnetosphere, namely that an inclined IP shock essentially pushes the tail and the plasma sheet to one side, whereas in the symmetic case two waves converge onto the plasma sheet causing a compression and the launch of an Earthward disturbance.

Solar wind input

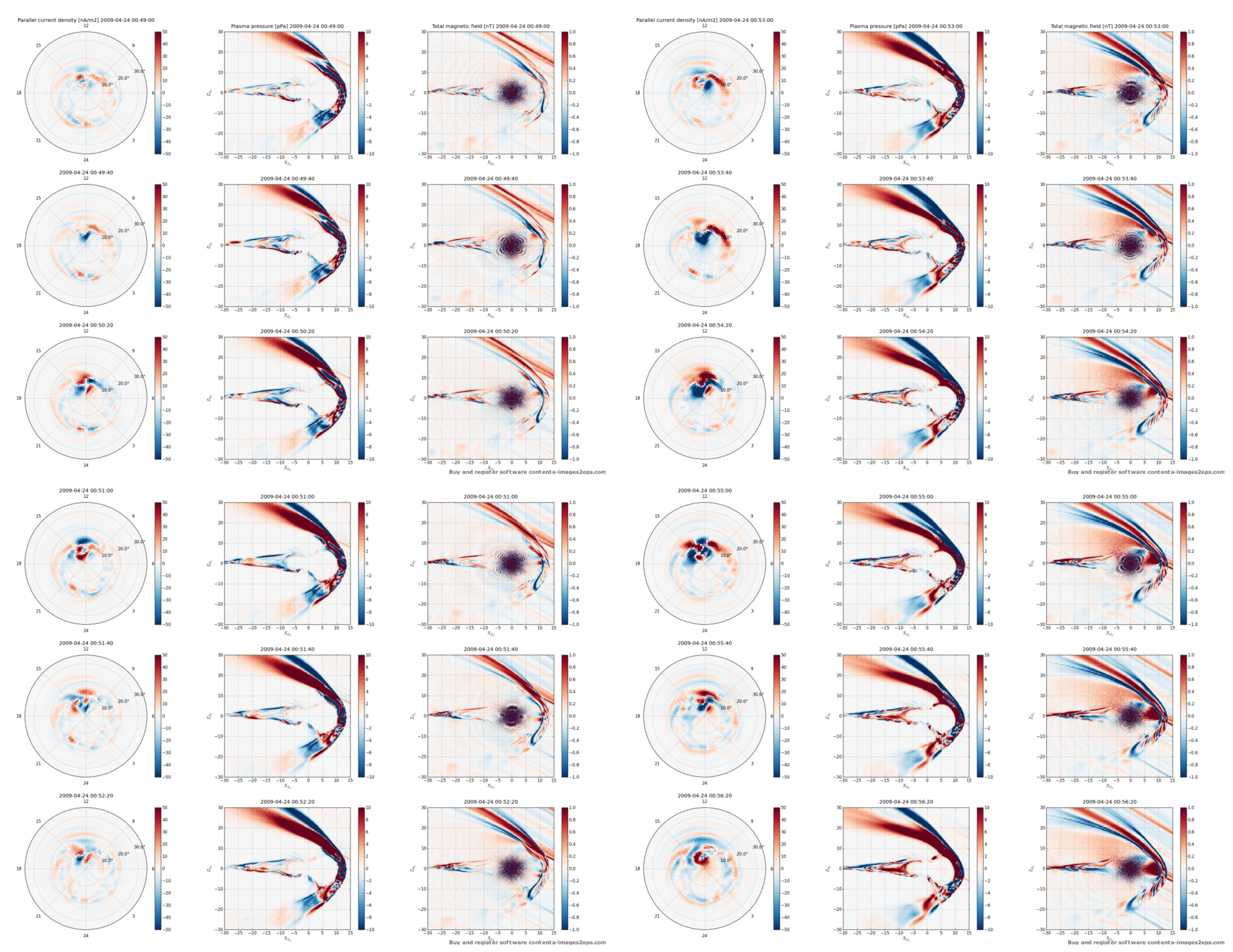


- Solar wind input plotted using data from WIND MFI instrument recorded on April 23-24, 2009.
- First plot is constructed with actual data. In this case, the x-component of the magnetic field is held different than zero. The second plot represents the result of a simulation in the case where $B_x = 0$ for seek of simplicity.
- Clearly a shock event starts close to midnight

Solar wind conditions

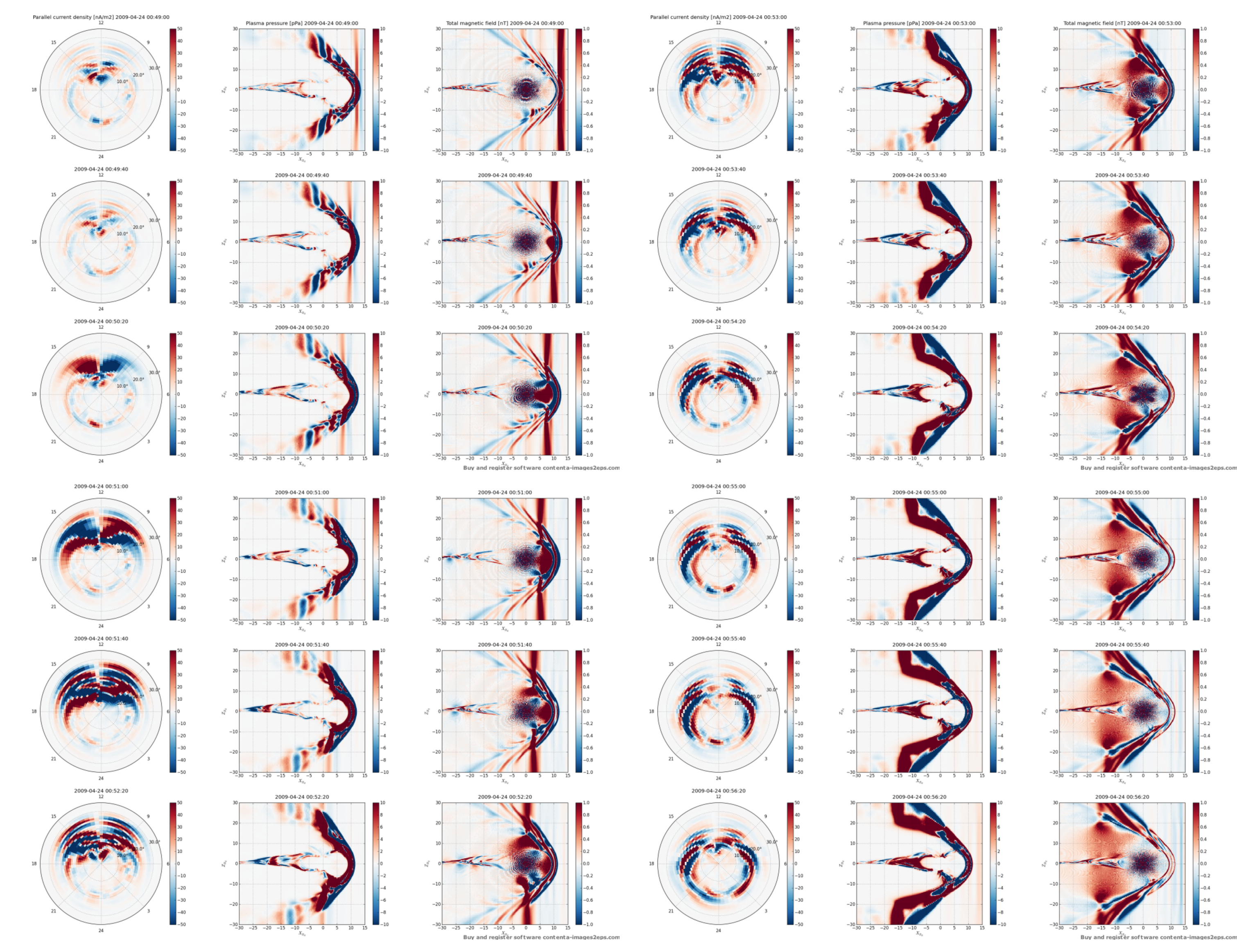
In order to use the Wind data as input for the simulation we propagate the Wind data ballistically at the prevailing solar wind speed (-420 km s^{-1}) to the inflow boundary of the simulation which is located $230R_E$ upstream from Earth. We also compute the most likely normal direction of the solar wind discontinuities using the minimum variance method over the entire interval from 0049 UT to 0056 UT. This assumes that the solar wind roughly consists of layers that are all inclined by the same angle to the Sun-Earth line. Such an assumption is necessary, because we have only very limited information of the true three-dimensional solar wind structure from a single observation point. On the basis of this normal direction we then propagate the solar wind and IMF into the simulation box. Hence we not only obtain a more accurate boundary condition, but we can also propagate the IMF B_x component into the simulation. The alternative, which entails setting the entire inflow boundary to the measured data, implies that the solar wind parameters are independent of Y and Z. In that situation, B_x cannot change, because that would violate Maxwell's equation $\nabla \cdot \mathbf{B} = 0$.

Results with $B_x \neq 0$ in the IMF



12 consecutive frames from left to right in two columns represent WIND data for parallel current density in the ionosphere, plasma pressure, and total magnetic field in the magnetosphere. In this case, the x-xomponent of the IMF is held different than zero. These plots show the difference bwtween two consecutive time outputs. As a result, it is possible to visualize how these quantities change in time.

Results with $B_x = 0$ in the IMF



Same plot sequence for the case in which x-component of the IMF is set to zero. In this case, a not so quiet ionosphere is visible.

Conclusion

- Global simulations predict that shock waves impinging the Earth's magnetosphere with certain inclination do not drive significative currents on either day or night side. The most evident effect is the compression of the tail
- On the other hand, simulations with shock waves hiting the magnetospere symmetrically, i.e., without any inclination, predict that significative currents in both day and night side may be enhanced.

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