VORTICITY IN THE TRANSITION REGION OF A GLOBAL HYBRID-VLASOV SIMULATION

Venla Koikkalainen[1], Minna Palmroth[1,2], Maxime Grandin[2], Emilia Kilpua[1], Ivan Zaitsev[1], Liisa Juusola[2], Abiyot Workayehu[1], Giulia Cozzani[3], Lauri Pänkäläinen[1], Markku Alho[1], Konstantinos Horaites[4], Shi Tao[1], Jonas Suni[1], Yann Pfau-Kempf[5], Urs Ganse[1]

[1] University of Helsinki, Department of Physics, Helsingin yliopisto, Finland.
[2] Finnish Meteorological Institute, Helsinki, Finland.
[3] LPC2E, OSUC, University of Orléans, CNRS, CNES, Orléans, France.
[4] Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, Boulder, CO, USA
[5] CSC – IT Center for Science, Espoo, Finland

VLASIATOR
HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI
MATEMAATTIS-LUONNONTIETEELLINEN TIEDEKUNTA
MATEMATISK-NATURVETENSKAPLIGA FAKULTETEN
FACULTY OF SCIENCE
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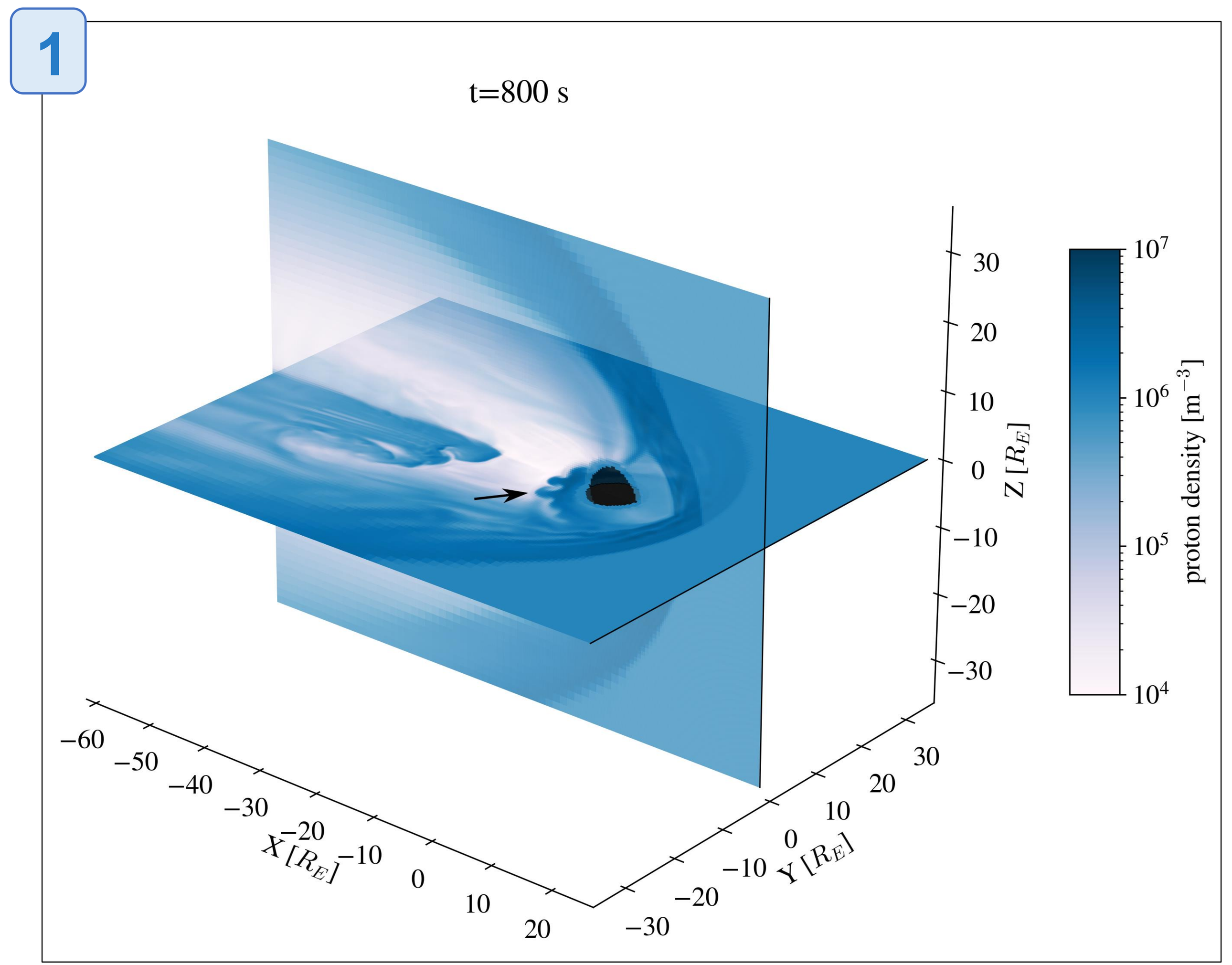

SIMULATION RUN

Solar wind:
Speed: 750 km/s
B: Southward, B_z=-5 nT
Density: 1 cm^{-3} Temperature: 0.5 MK

Maximum resolution: 1000 km
Total run length: 1612 s
Box size: X: -110 to 50 R_E
Y and Z: -58 to 58 R_E

Figure 1: Proton density in the Vlasiator simulation domain, the arrow points out the transition region between the dipole field and the magnetotail, where a wavy density structure forms.

INTRODUCTION

In the transition region between the Earth's dipolar magnetic field and the stretched magnetotail, the features of both domains affect the dynamics of the phenomena that occur. Additionally, the magnetic field is coupled to the Earth's ionosphere, which leads to interaction between the upper atmosphere and magnetic structures at many R_E (Earth radii) away from Earth in the magnetotail.

Our study utilises the global hybrid-Vlasov magnetospheric model Vlasiator (Figure 1) [1], which has recently been complemented with an ionospheric boundary model [2], allowing for the study of magnetosphere-ionosphere coupling. We observe the formation of several Earthward flow channels in the transition region, which create vorticity and density depletions ahead of their path. The flow channels and vorticity couple to the ionosphere, where they create a pattern of field-aligned currents (FACs).

OVERVIEW OF THE FORMATION OF VORTEX FLOW

- The wavelength of the vortices in the transition region is about 4 R_E (Figure 2, top rows)
- In the ionosphere the wavelength of the FAC structure is about 2000 km (Figure 2, bottom row)
- The vortex flows form and dissolve over a time scale of about 300 seconds
- The event begins with magnetic reconnection and fast Earthward flow at the dusk at ~X= -10 R_E
- The features of the event are consistent with it originating from a combination of Earthward bulk flow and the ballooning/interchange instability [3,4]

BALLOONING/INTERCHANGE INSTABILITY

- We observe that the transition region is unstable to the ballooning/interchange instability due to a tailward gradient in residual B_z and flux tube entropy S (Equation A) depletions seen to coincide with the Earthward flow regions (Figure 3).
- The event also has the visual look of the ballooning/interchange instability, which is a plasma analogue to the Rayleigh-Taylor fluid instability.

REFERENCES

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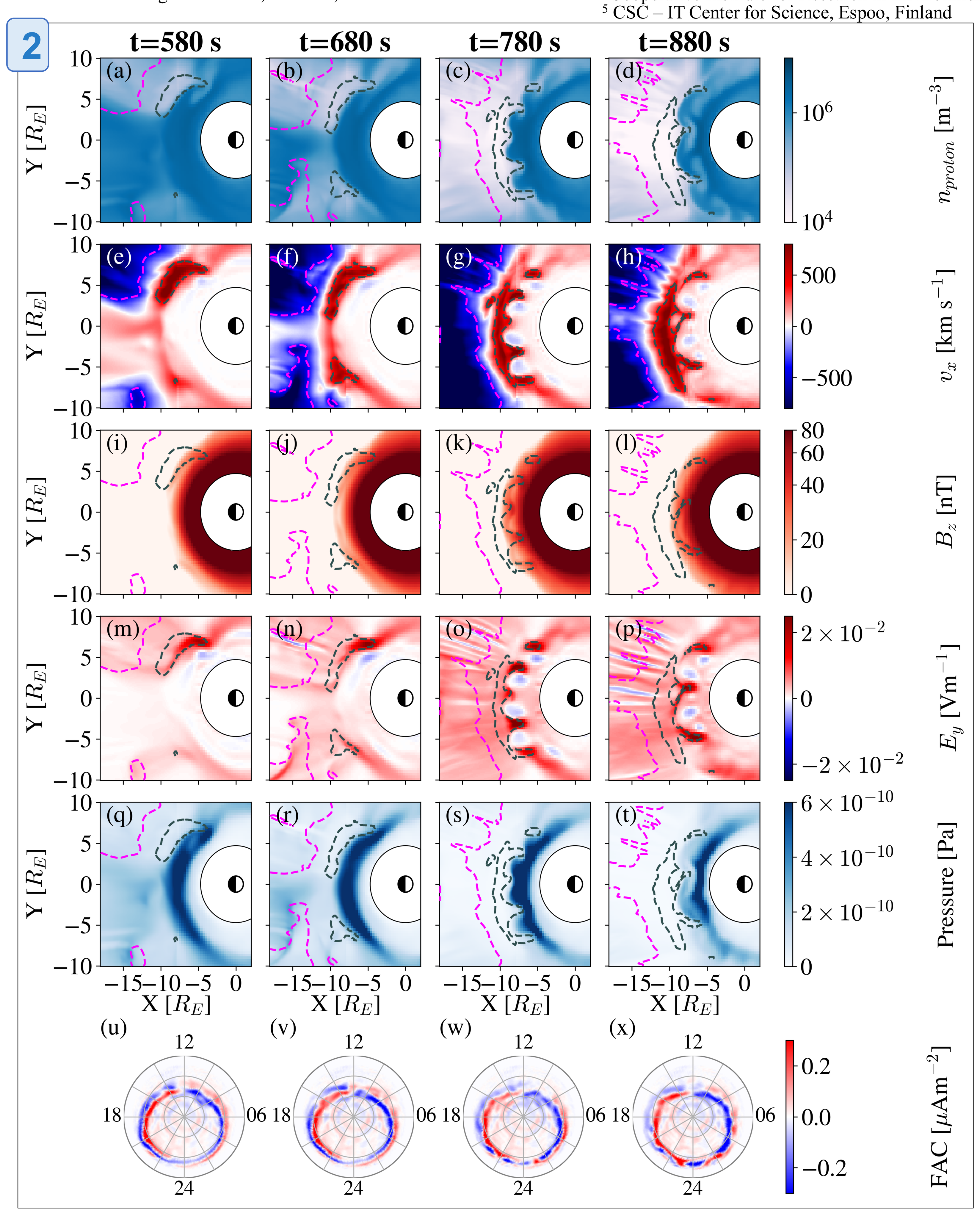

Figure 2: Panels (a-d): proton density. Panels (e-h): ion v_x. Panels (i-l) B_z , Panels (m-p) E_y . Panels (q-t) pressure. The contour lines indicate 400 km s−1 (grey) and -400 km s−1 (pink) velocities. Panels (u-x): FACs on the ionospheric grid of the simulation, in magnetic local time (MLT) coordinates.

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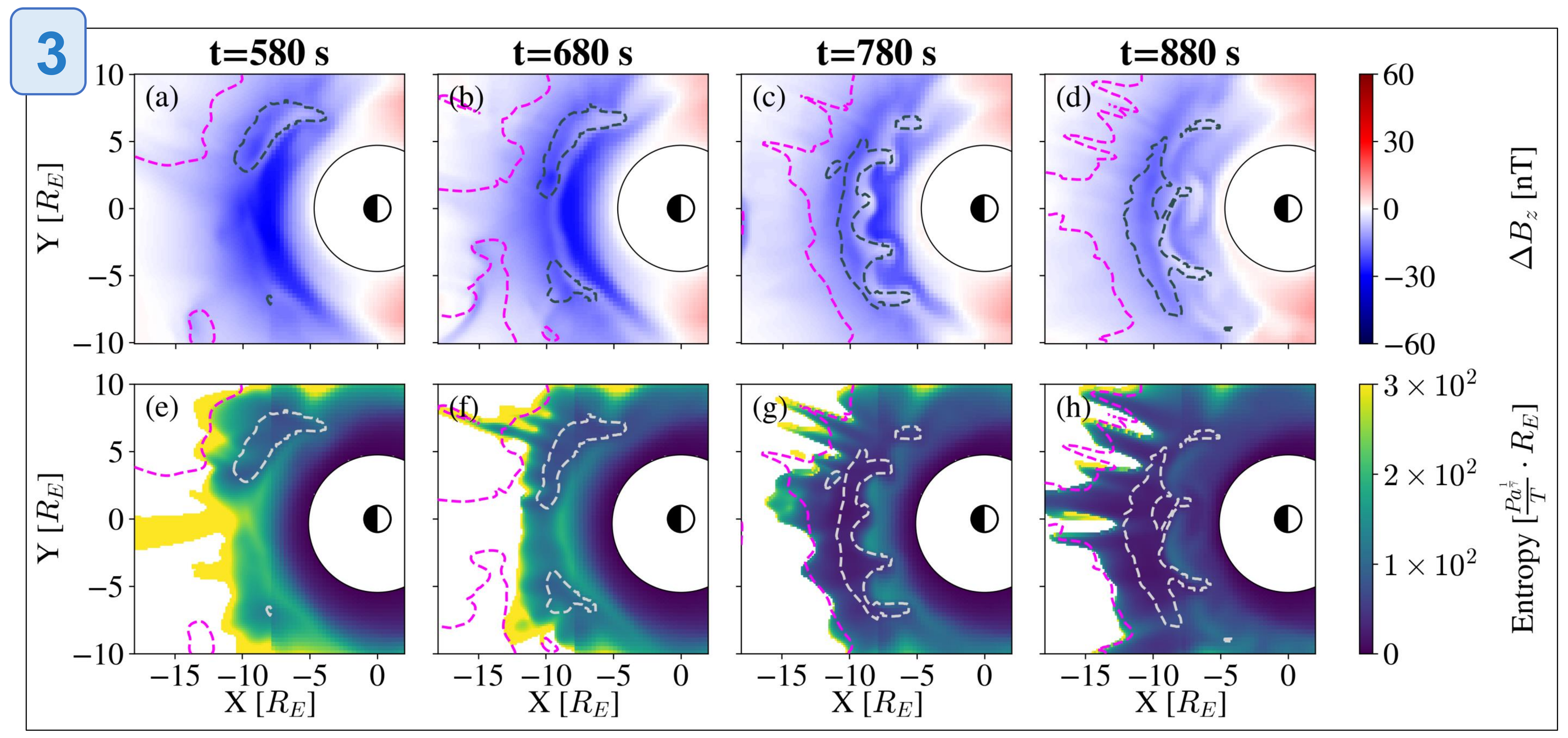

A

$$S = \int p^{1/\gamma} ds/B$$

The flux tube entropy function S, where the integral is taken along closed field lines.

Figure 3: Panels (a-d): Residual B_z , i.e. the magnetic field minus the Earth's dipole field. Panels (e-h) flux tube entropy S. All panels are in the Z=0 plane, with ±400km s−1 velocities marked with grey/pink contours.

FLOW DYNAMICS

- In addition to the instability characteristics, we see that the large-scale flows also play a role as they induce vorticity at the flanks of the flow channels, as shown in Figure 4.
- This vorticity maps onto the ionospheric grid of the simulation, where it can be seen that it coincides with a patchy distribution in the FACs.

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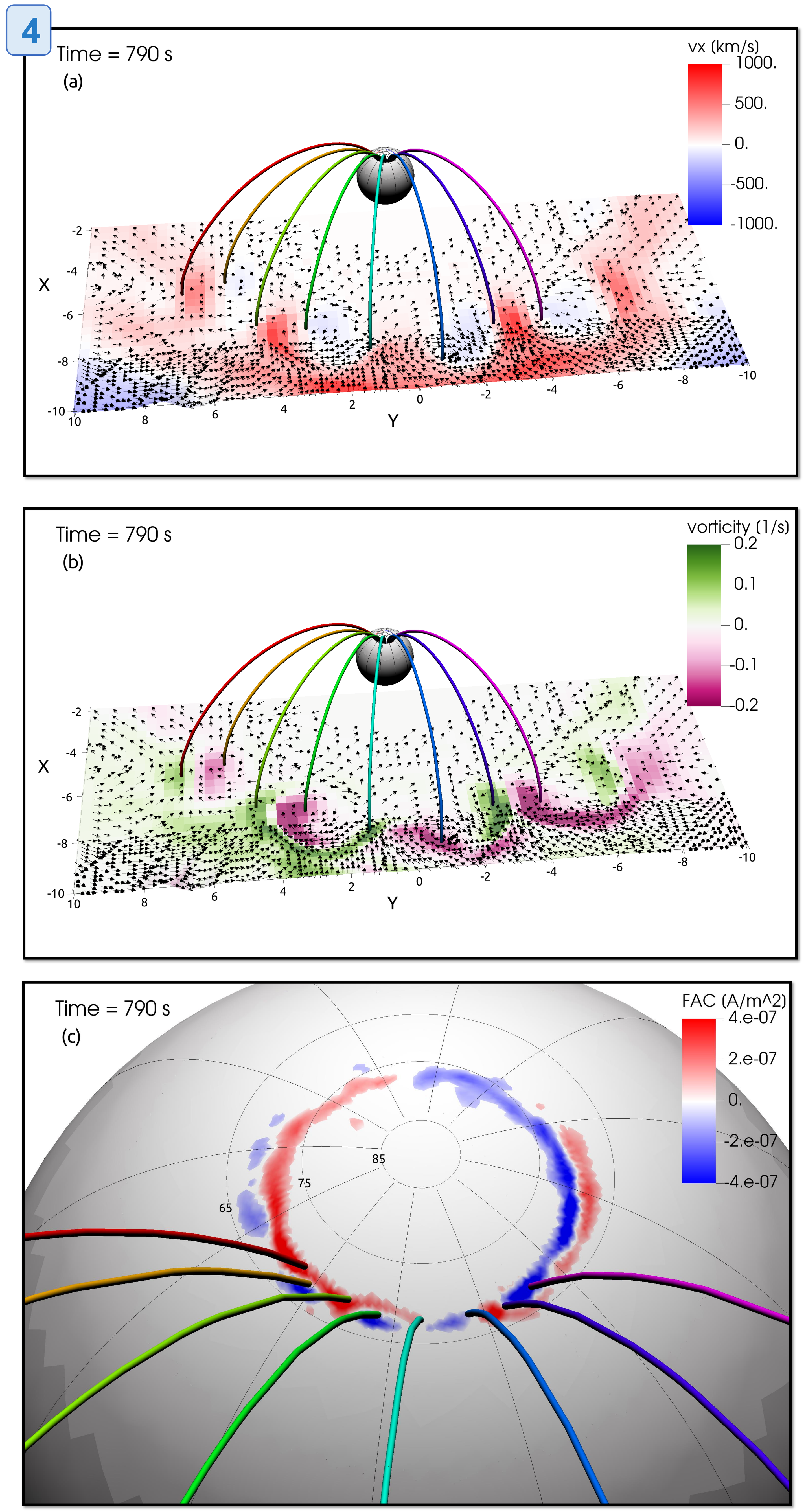

Figure 4: Panel (a): ion v_x, panel (b): the z-component of flow vorticity. Panel (c): Magnetic field lines mapped to the ionosphere, and the FAC strength on the ionospheric grid.