Explanation of global plasmapause characteristics in the frame of interchange instability mechanism

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Introduction

Statistical studies based on CLUSTER, CRRES, and THEMIS satellite data (Verbanac et al., 2015; Bandic et al., 2016, 2017) provided insight into global plasmapause characteristics:
start of erosion between 21-07 MLT and permanent eastward azimuthal propagation.

Recent statistical study (Verbanac et al., 2018) have further showed that the plasmapause behavior derived from experimental data is in agreement with the theory based on the interchange instability mechanism (IIM)
(Lemaire & Kowalkowski,1981; Lemaire & Gringauz, 1998).

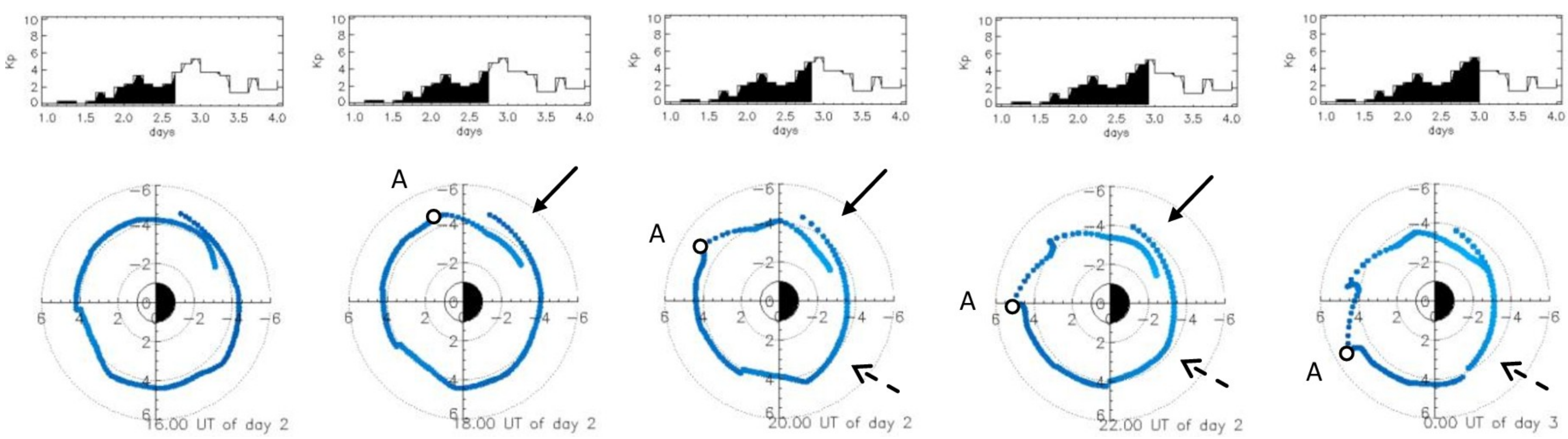
Here we aim to link the observed global plasmapause dynamic with formation and evolution of plasmapause structures.

Plasmapause modeled using IIM

Plasmapause position is calculated assuming the corotation, the Kp-dependent convection electric field model E5D (McIlwain, 1986), associated magnetic field model, and employing geomagnetic index Kp for any chosen date and time and of the preceding day.

A) input: real Kp values

Example of the simulation output: plasmapause in the geomagnetic equatorial plane at five instants of time of 9 August 2008
(Verbanac et.al, 2018)



Dataset - real Kp values

- the simulations are performed for 68 days within 2008-2012
- developed dataset contains 41 000 Lpps
- for each day, at all UT hours, one Lpp within each 1 h MLT bin is randomly extracted
- simulations have perfect UT-MLT coverage
  (1 h space-time resolution: space resolution of 1 h bin MLT, 1 h UT time resolution).

B) input: synthetic Kp changes

What plasmapause characteristics do we expect?

How to produce the dataset which can provide similar plasmapause characteristics as the dataset obtained using real Kp values as input in the simulations?

A lot of synthetic Kp trends could be produced with e.g. Monte Carlo simulations

Questions:

- how much Monte Carlo simulations runs would be needed to obtain the same plasmapause behavior as with real Kp input in IIM?
- how the possible nonphysical Kp trend obtained with Monte Carlo simulations would contribute to nonphysical structures of the plasmapause and distort the generally obtained plasmapause behavior?

So, the question is, not only how many Kp trends do we need, but also if we can at all get an agreement between plasmapause behavior derived for two kind of inputs, real and synthetic Kp !

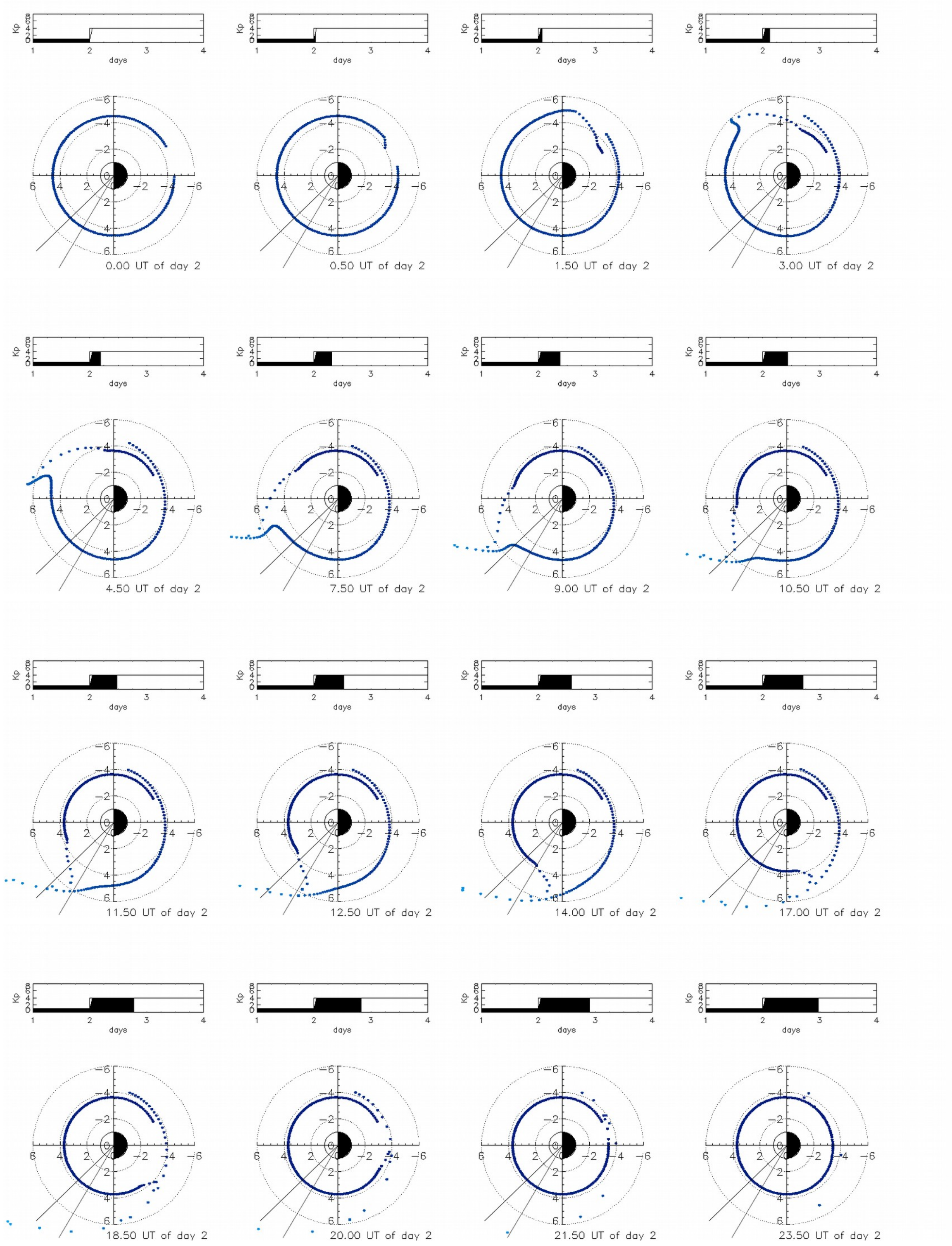
Our approach

Instead of constructing synthetic Kp changes with some kind of simulations (like Monte Carlo), we employed certain types of Kp jumps (certain type of time-dependent changes in the Kp) :

- sharp Kp increase,
- sharp Kp decrease,
- short-time burst enhancement (increase-decrease within 3 hr) in Kp,
- and their combinations to obtain plumes, shoulders, and notches, the structures most often observed in the nature

- <u>developed dataset – the above Kp jumps</u>

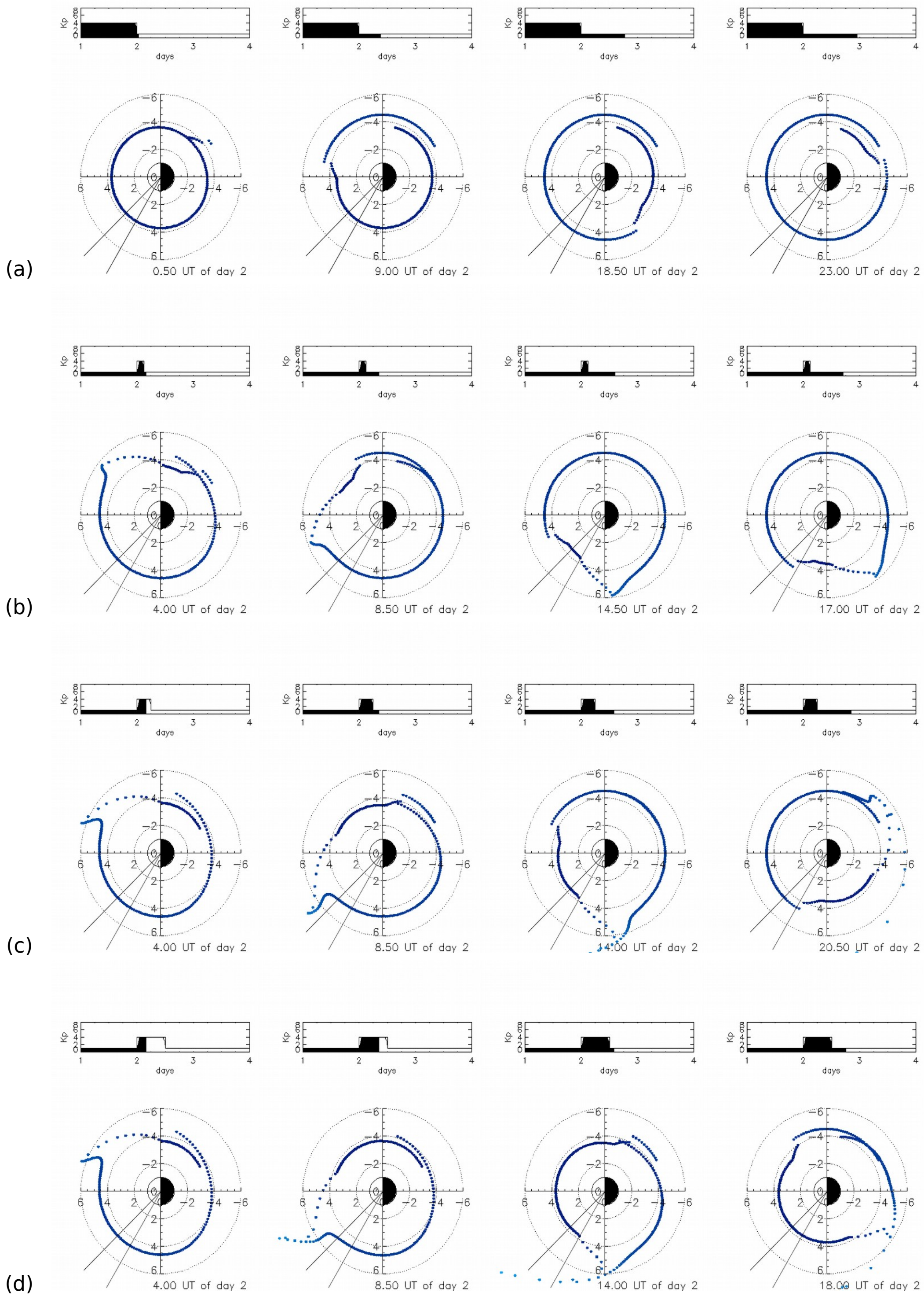
Simulation output at 16 instants of time.
Kp value increases from Kp = 1 to Kp = 4 at UT = 0



Simulation output at four instants of time:

(a) Kp value decreases from Kp = 4 to Kp = 1 at UT = 0

(b)–(d) Kp increases from Kp = 1 to Kp = 4 at UT = 0, retains constant higher value for 3, 6, and 12 hr respectively, and then decreases again to Kp = 1



Method

- by applying the cross-correlation analysis at different 1-hour MLT bins we investigate the relationship between Kp and plasmapause modeled both with real Kp and synthetic Kp changes

- we compare the plasmapause characteristics obtained with synthetic Kp changes with those derived with real Kp changes

Results

- instead of many combinations of Kp changes occurring at different UT times (which would be generated for instance with the mentioned Monte Carlo methods), **only 3 Kp jumps** occurring at one UT time, leads to the same plasmapause characteristics as obtained with simulations using the real Kp values.

- completely unexpected !!!

- three plasmapause structures and their combinations statistically leave the same imprint in the passage through a specific MLT sector as a combination of the plasmapauses created with a large number of the real Kp changes.

- here, we showed that statistically the global plasmapause motions and deformations in time may be simply explained (note that in specific events, plasmapause may show complex and different dynamics)

Conclusion

We have shown that employing only three types of Kp jumps (sharp Kp increase, sharp Kp decrease, short-time burst enhancement in Kp), and the theory based on interchange instability mechanism, the formation and evolution of the main plasmapause can be statistically simply explained (Bandic, et.al, 2020).

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