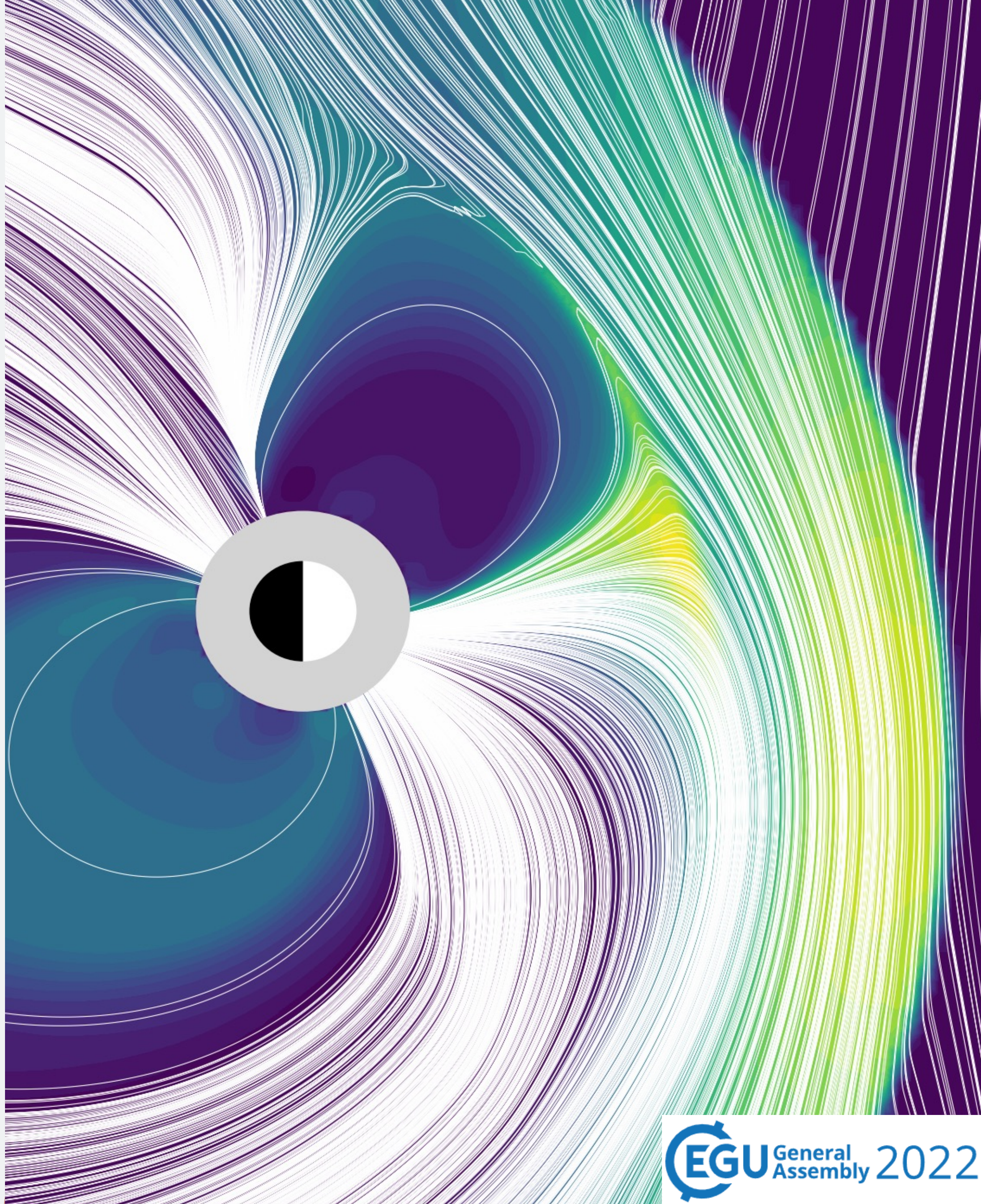
RAPID AURORAL WANDERING DURING THE LASCHAMPS EVENT

AGNIT MUKHOPADHYAY, SANJA PANOVSKA, MICHAEL LIEMOHN, NATALIA GANJUSHKINA, AUSTIN BRENNER, ILYA USOSKIN, MIKHAIL BALIKHIN, DANIEL WELLING, KATIE GARCIA-SAGE, ALEX GLOCER

(CONTACT: AGNIT.MUKHOPADHYAY@NASA.GOV)



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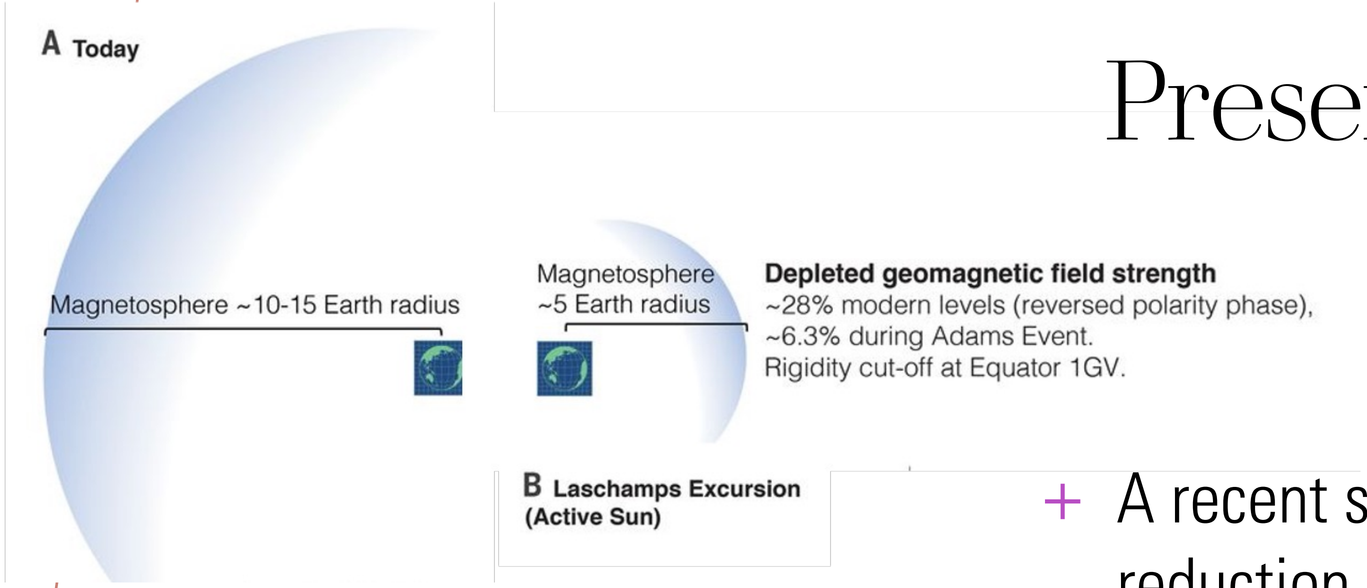
BACKGROUND

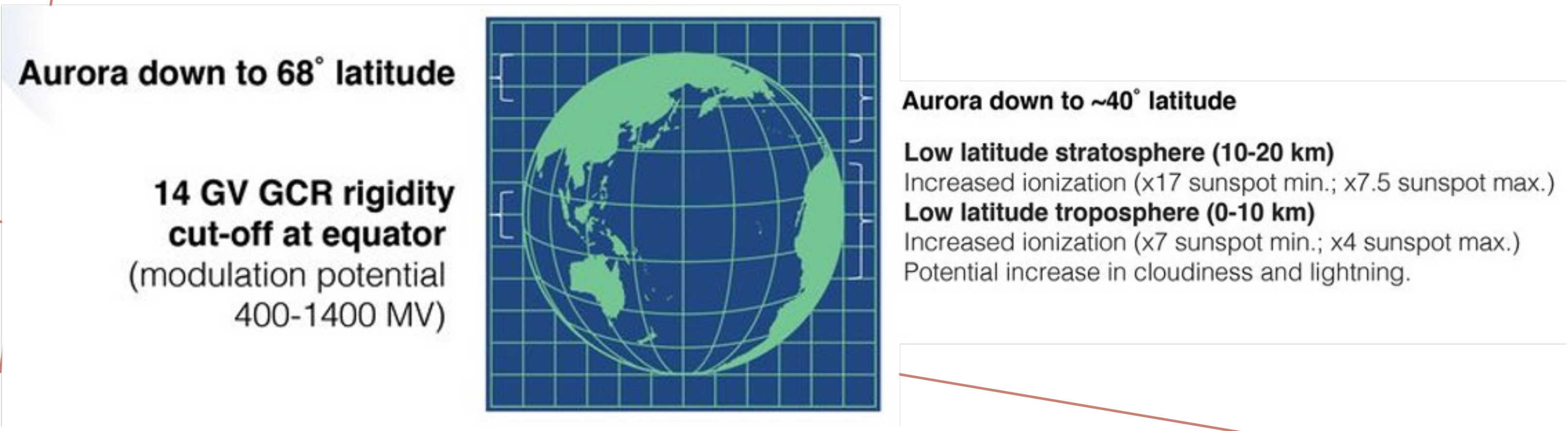
- An *excursion* event is a “short” interval of time when the planetary magnetic field either reduces in strength and/or changes the pole orientation.
- The Laschamp Geomagnetic Excursion occurred between 42k and 39k years, over an approximate span of ~1300 years.
  - Named for Laschamp lava flows in France, where it was first discovered.
  - Studied extensively in academia, most recently using ancient *kauri* trees from New Zealand
- The geomagnetic low was seen during 42,200–41,500 years ago (Adams Event). The geomagnetic dipole strength dropped to ~4% of present values.
- Estimates range from the magnetosphere completely disappearing to diminished dayside. No specific space weather evaluation of this study exists until now.
- Could have had severe consequences on environmental and anthropological factors in paleo-Earth.

Present Guesstimates...



- A recent study estimated that due to the drastic reduction in strength, the magnetosphere would be severely diminished, and the aurora would extend down to 40 degrees latitude.

Cooper et al. (2021), Science

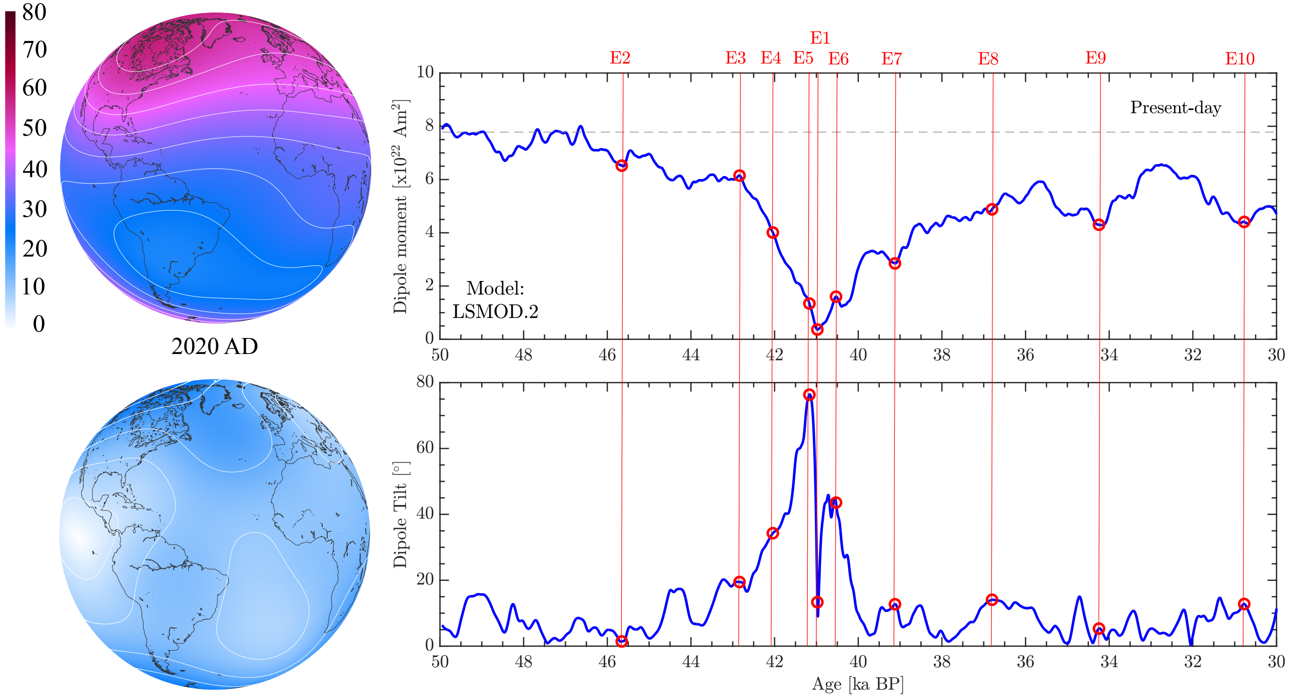


Terrestrial B-Field: LSMOD.2 Paleomagnetic Field Model

+ LSMOD.2 is a terrestrial paleomagnetic field model that predicts the geomagnetic field parameters like IGRF. We have used this model (up till now) for simulations.

+ The model is built on a global data set of paleomagnetic sediment records and volcanic data. The mathematical representation of the model is spherical harmonics in space and B-splines in time.

+ The model also computes the virtual geomagnetic dipole strength and tilt for reference.



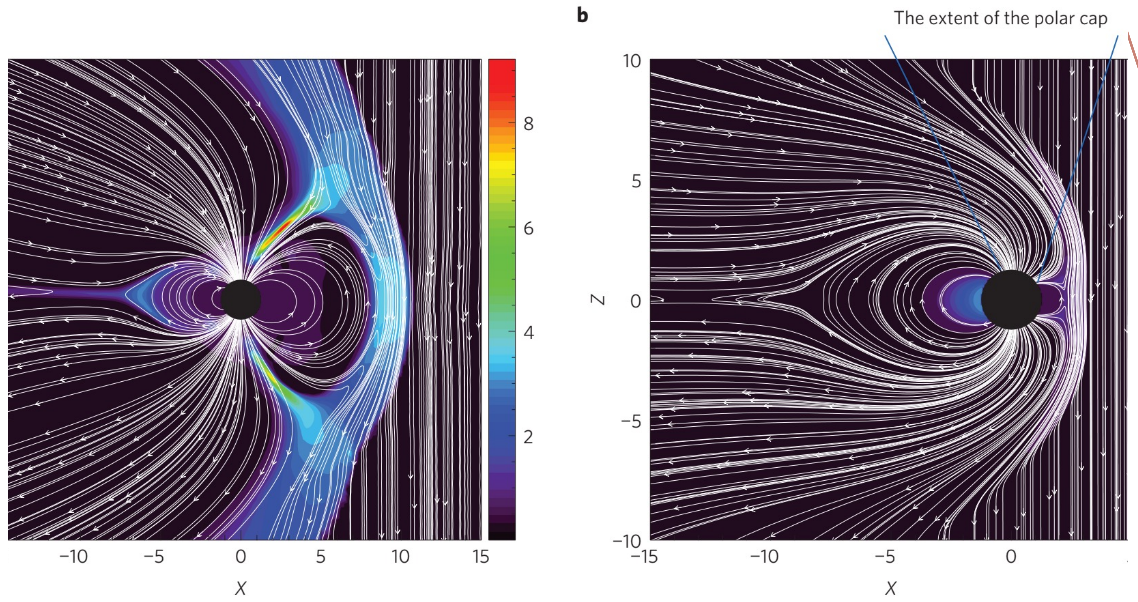
Korte et al. (2019), Frontiers in Earth Sciences
Panovska et al. (2019), Reviews of Geophysics

Global Magnetosphere:
BATS-R-US Global MHD Model

- The global geomagnetic field has been simulated using the Block-Adaptive-Tree-Solar Wind-Roe-Upwind-Scheme magneto-hydrodynamic (MHD) model.

- The geospace version of BATS-R-US solves for the ideal MHD equations for a near-Earth space environment domain spanning 25 R_E to -225 R_E in the x-direction, -128 R_E to 128 R_E in the y and z-directions, and 2.5 R_E from the surface of the Earth.

- BATS-R-US is a dominant component of the Space Weather Modeling Framework, which is used in forecasting space weather in the near-Earth space environment.



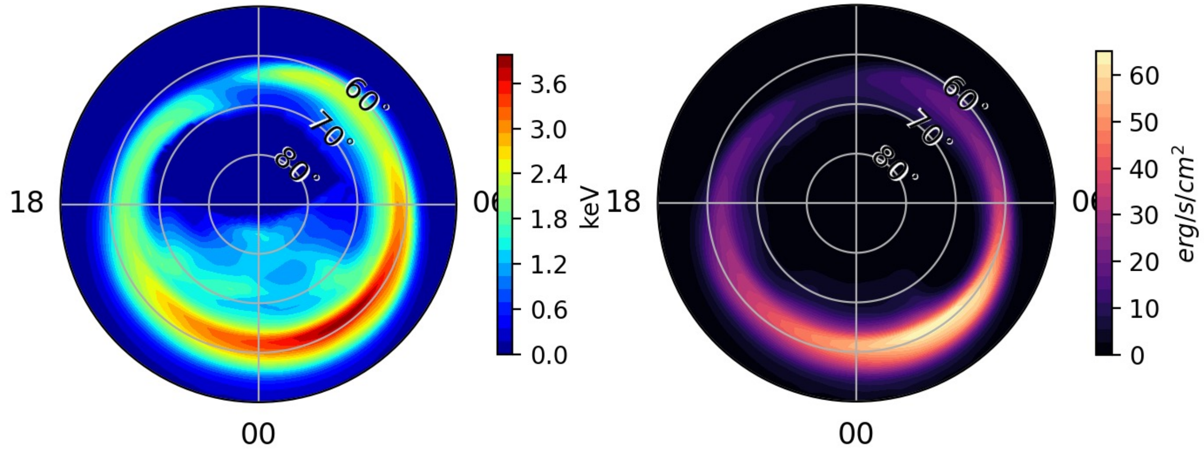
Powell et al. (1999)
Toth et al. (2005)

Auroral Dynamics:
MAGNIT Auroral Precipitation Model

- The MAGNetosphere-Ionosphere-Thermosphere (MAGNIT) Auroral Conductance Model is a physics-based model of the aurora that determines its strength, location and shape for a given magnetospheric configuration.

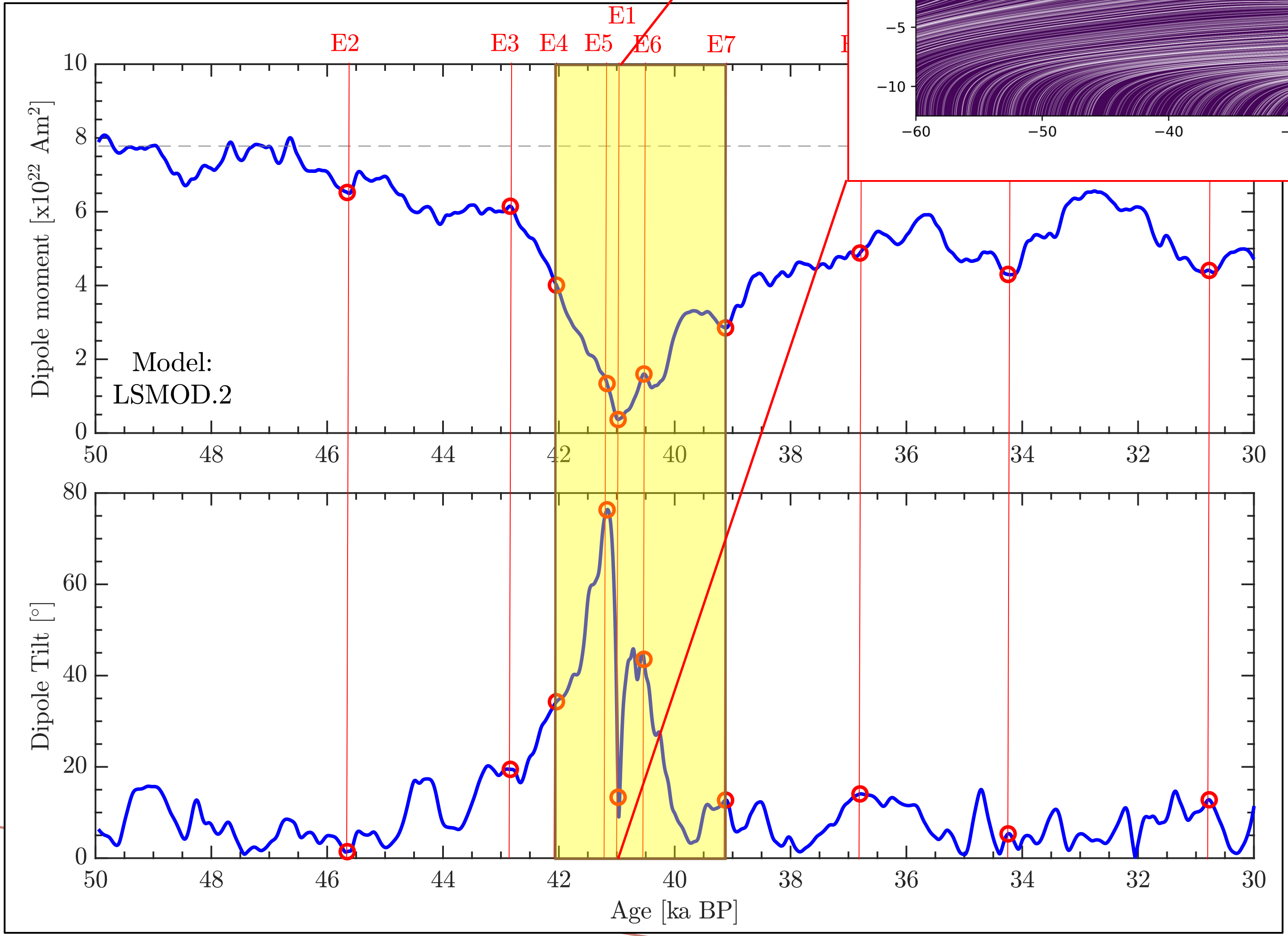
- MAGNIT uses inputs from BATS-R-US quantities like plasma pressure, density, currents to estimate multiple sources of aurora.

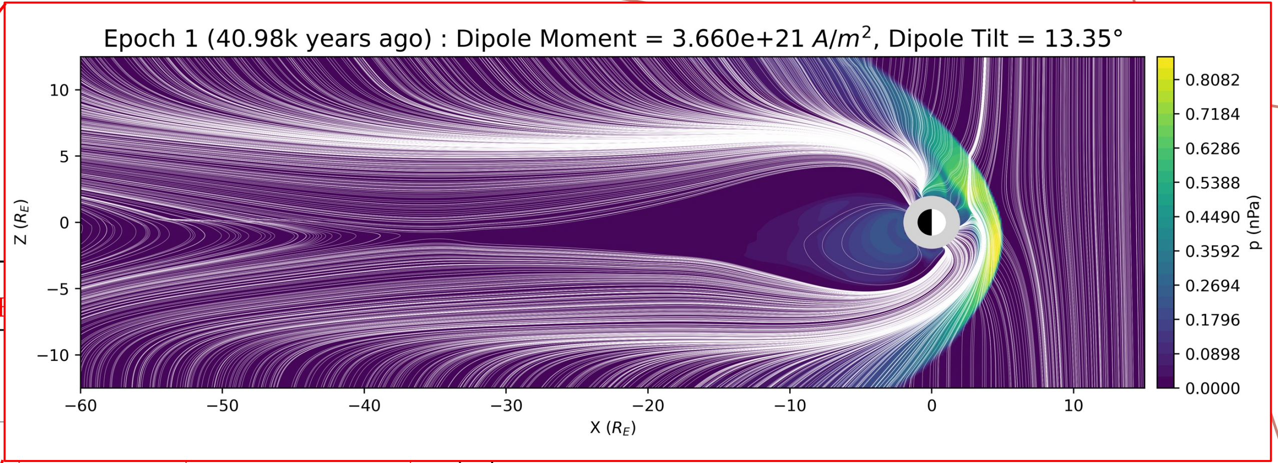
- MAGNIT is a relatively new model. Development was completed in December 2020, and initial simulations of this model with the SWMF show promising results.



Mukhopadhyay et al. (2021), AMS Meeting
Mukhopadhyay et al. (2022), JGR Space Physics (under review)

Results





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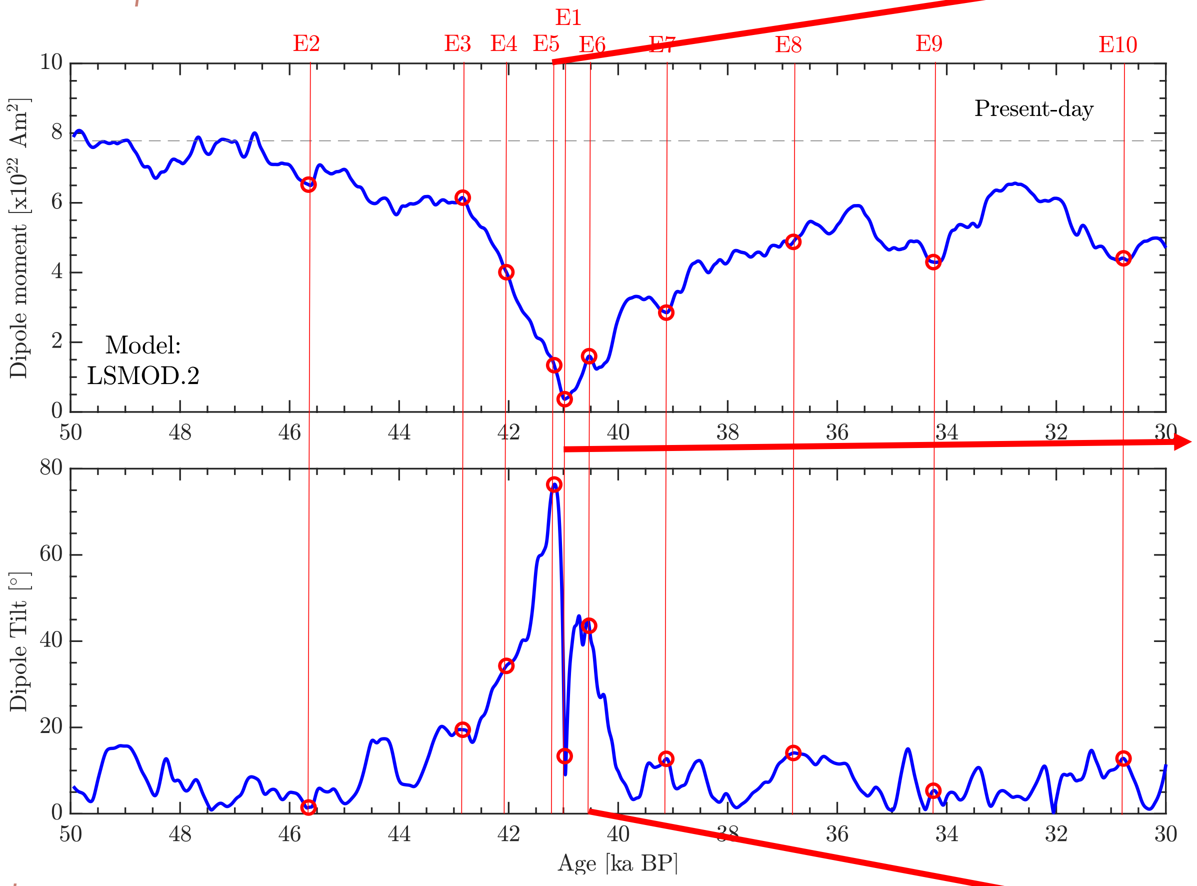
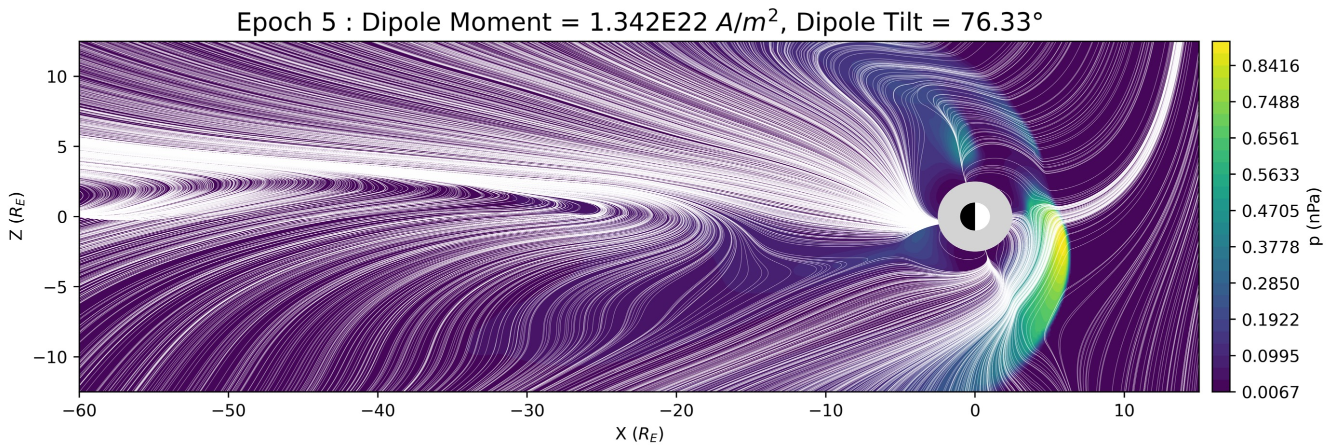
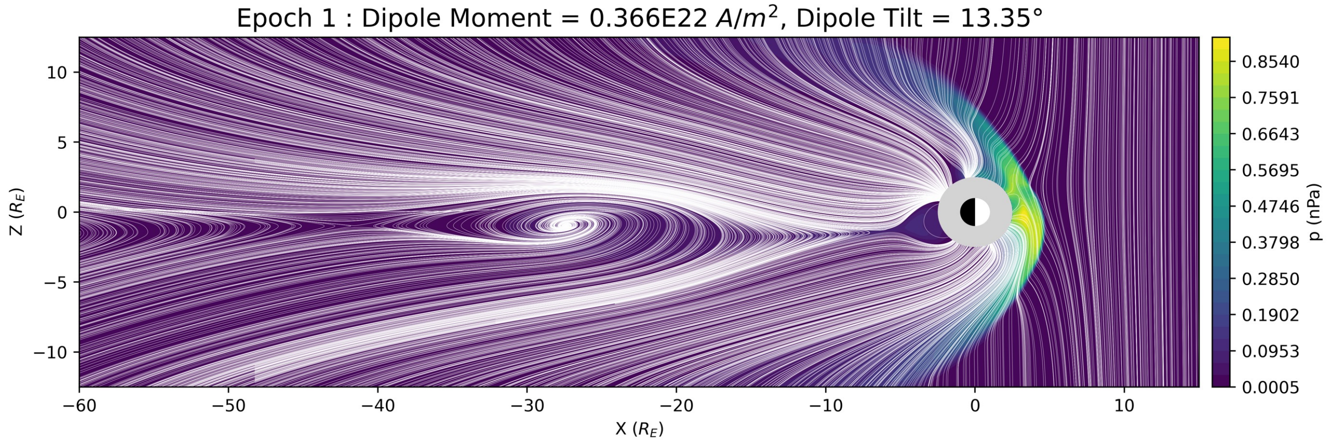
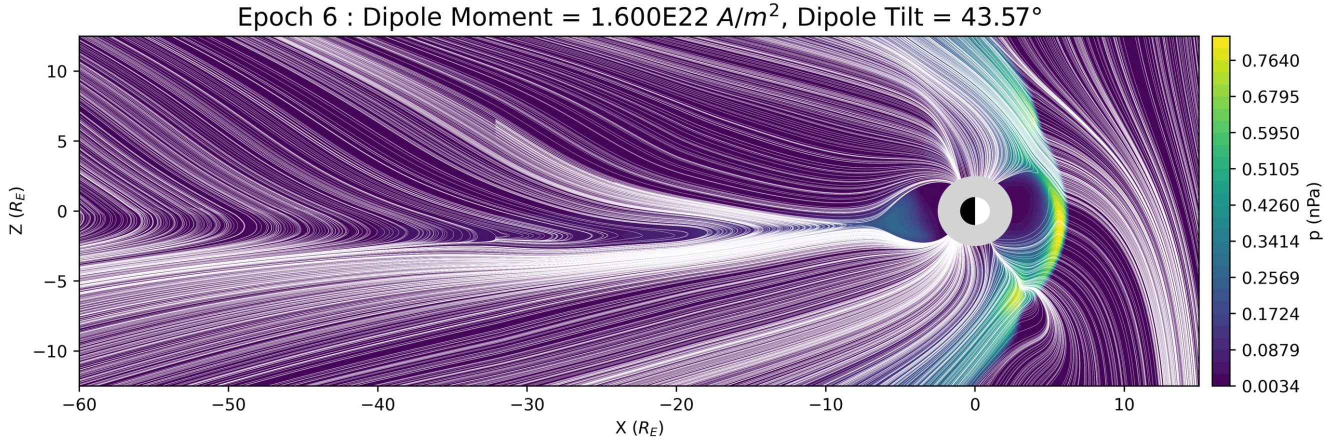
Q1. How realistic are these results?

A. Magnetopause distance reduces to <4 R_E, validating the results found through lit. survey.







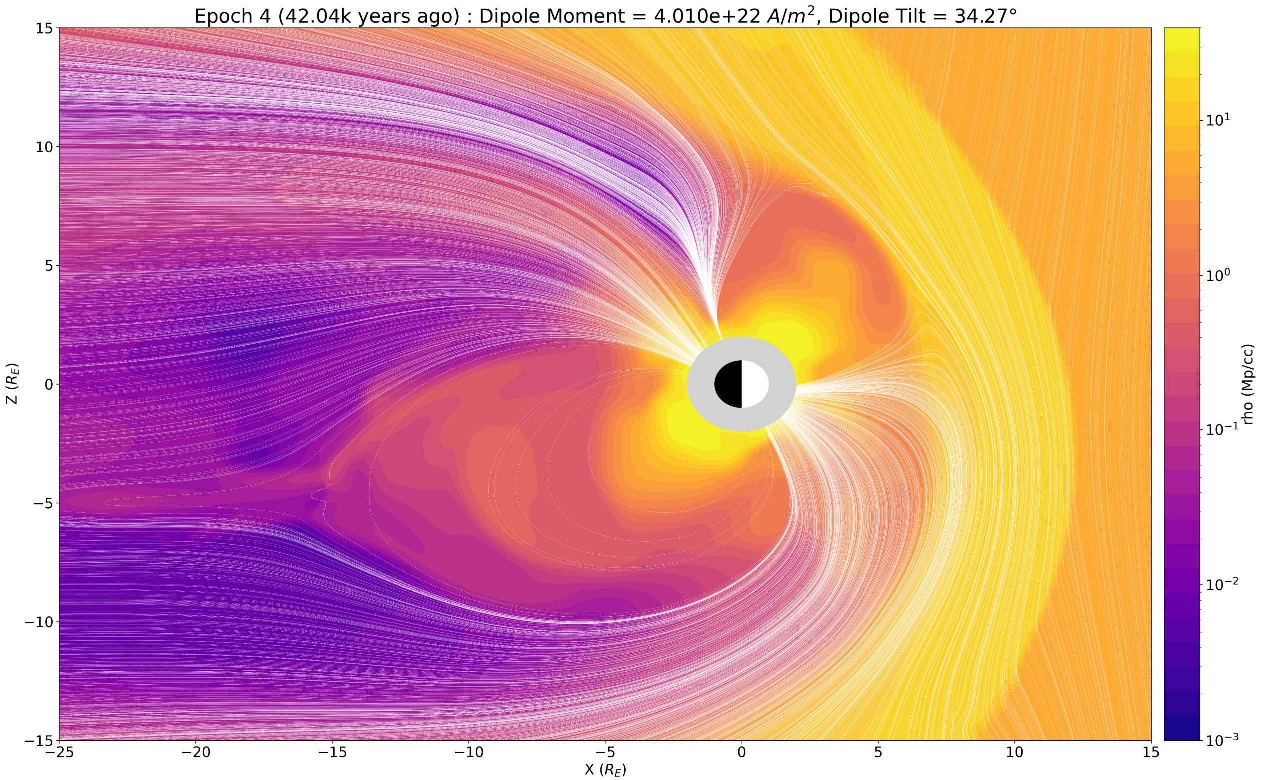


Q2. How significant are these results?

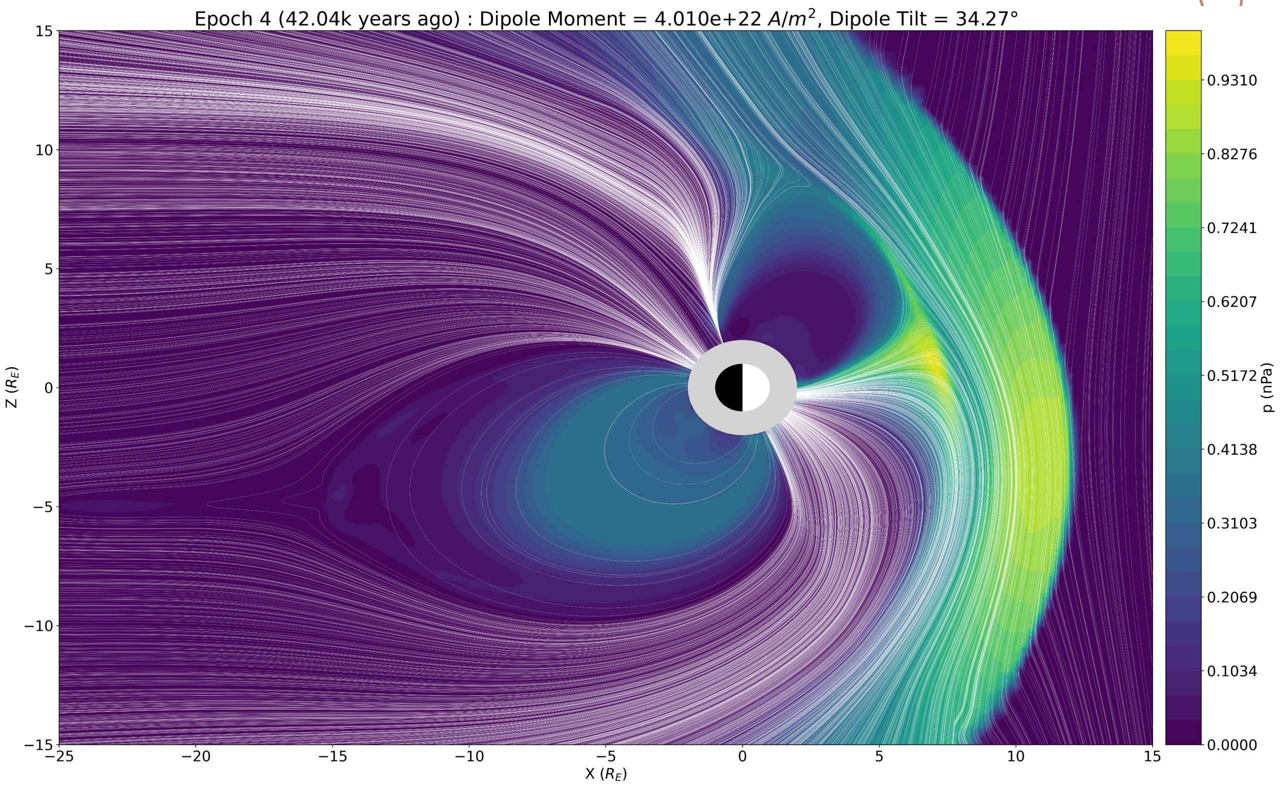
A. We are looking at a detailed study of the change in the magnetosphere over the peak of the event (from 42k to 39k years).

EPOCH 4 (42.04K Years ago)
Dipole moment = 4.010e+22 a/m², Dipole tilt = 34.27°

Log density on the y=0 plane with Bx and Bz field lines

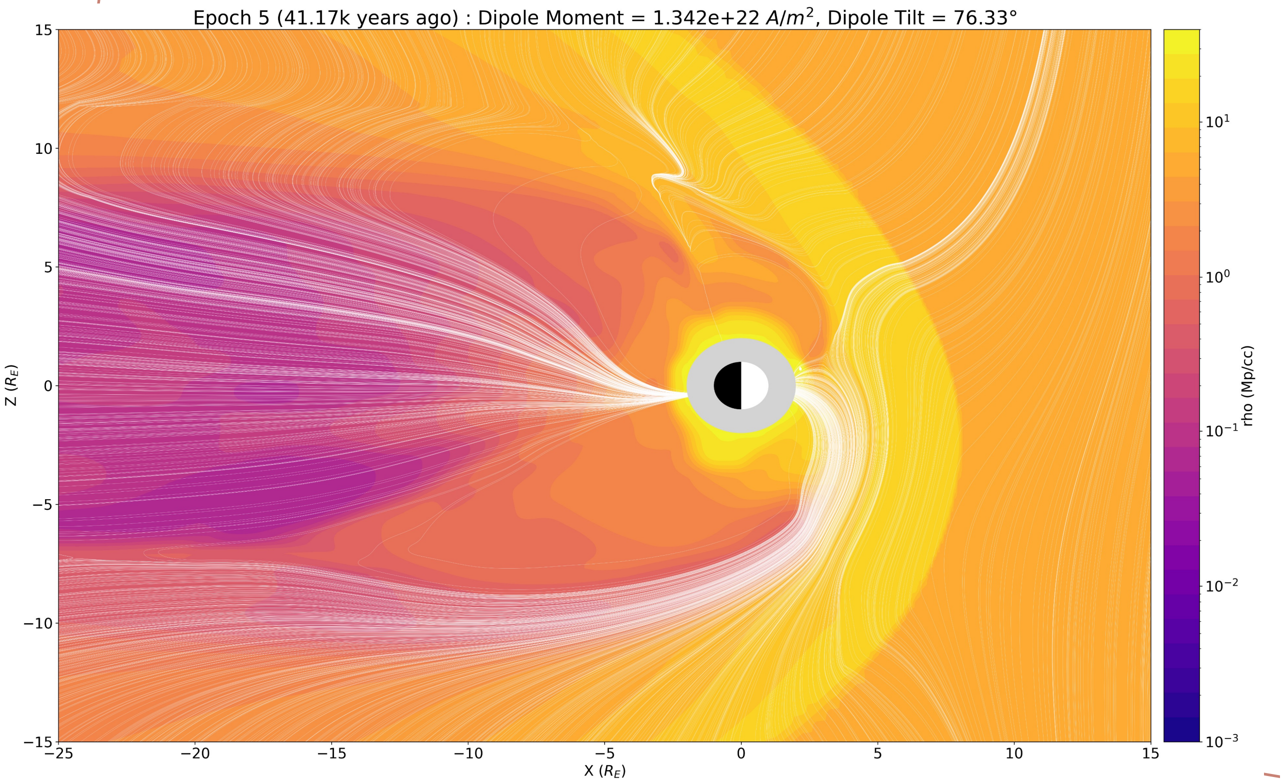


Pressure on the y=0 plane with Bx and Bz field lines

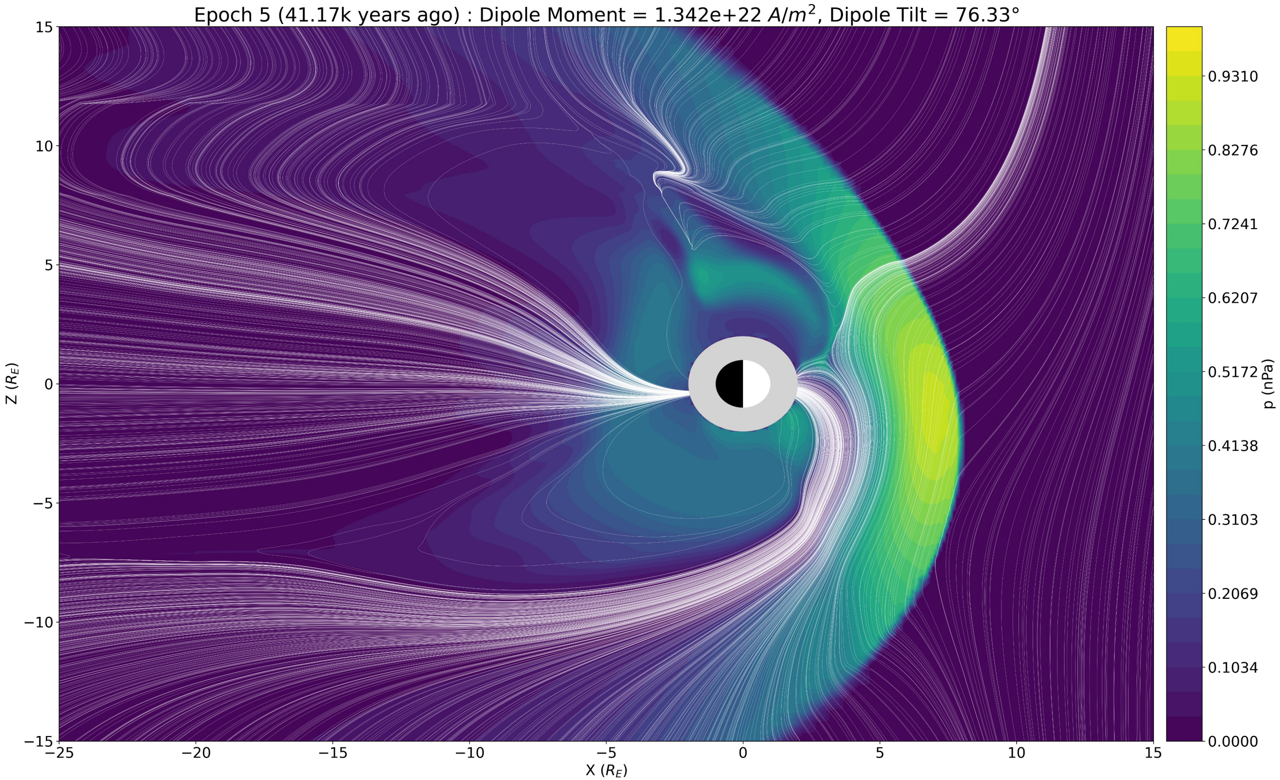


EPOCH 5 (41.17K Years ago)
Dipole moment = 1.342e+22 a/m², Dipole tilt = 76.33°

Log density on the y=0 plane with Bx and Bz field lines

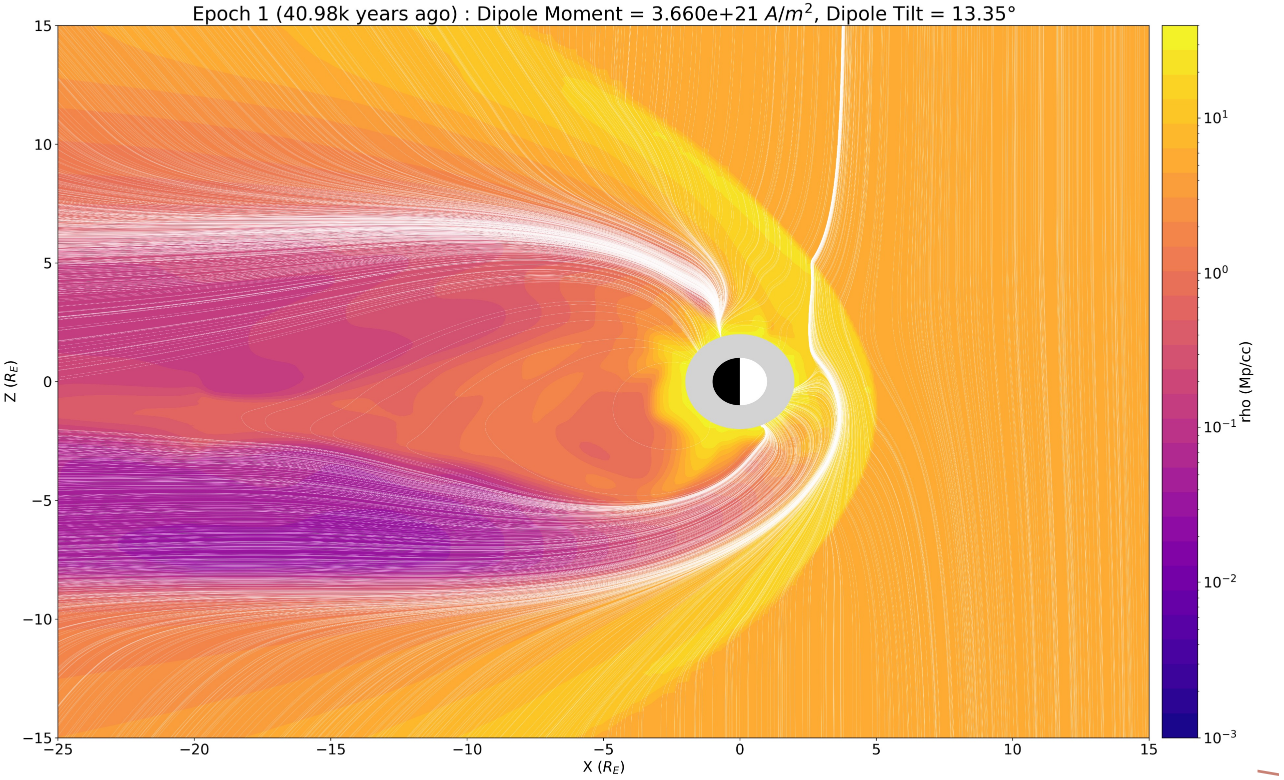


Pressure on the y=0 plane with Bx and Bz field lines

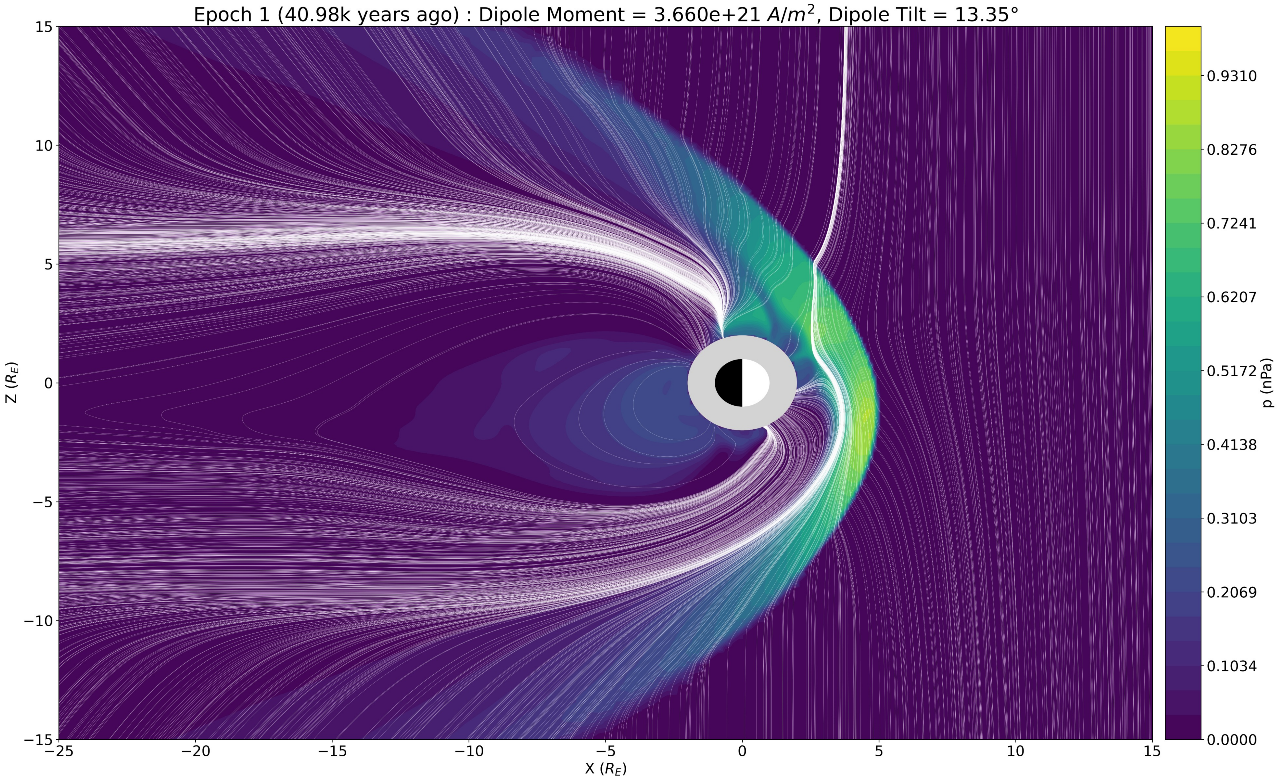


EPOCH 1 (40.98K Years ago)
Dipole moment = 3.660e+21 a/m^2, Dipole tilt = 13.35°

Log density on the y=0 plane with Bx and Bz field lines

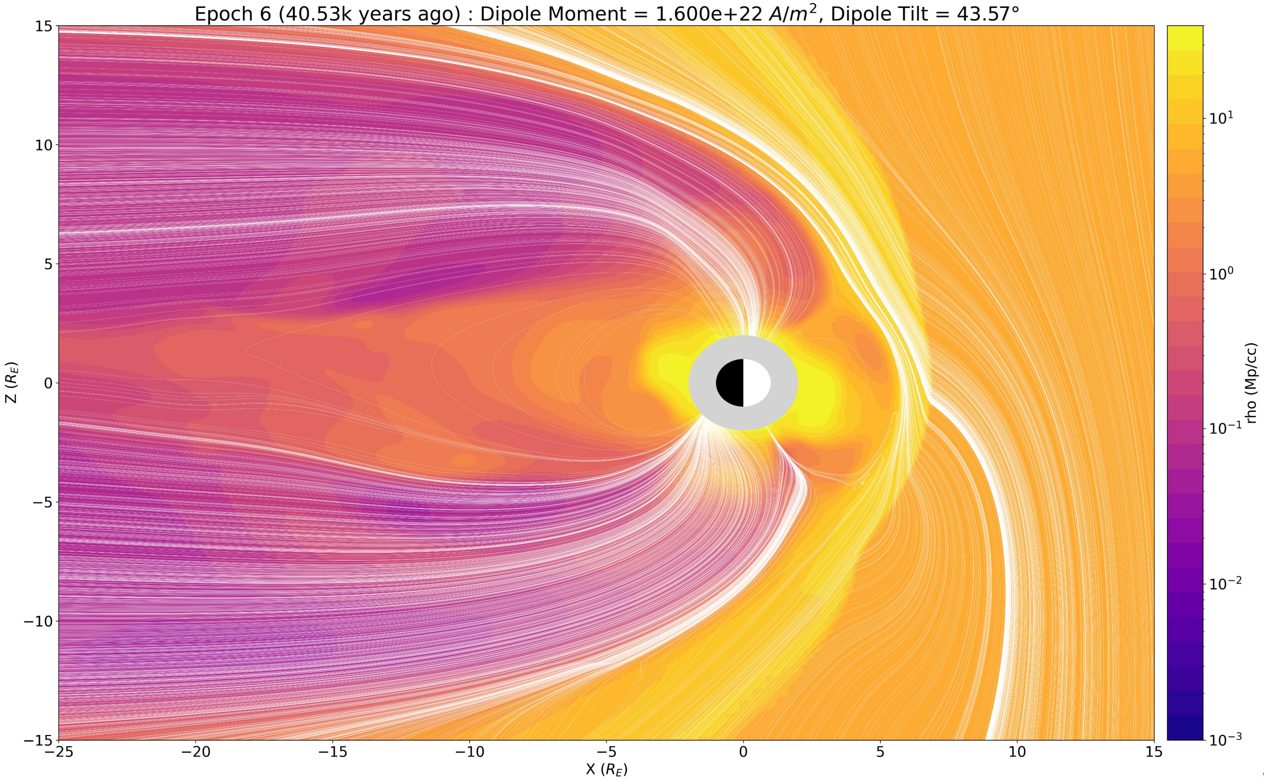


Pressure on the y=0 plane with Bx and Bz field lines

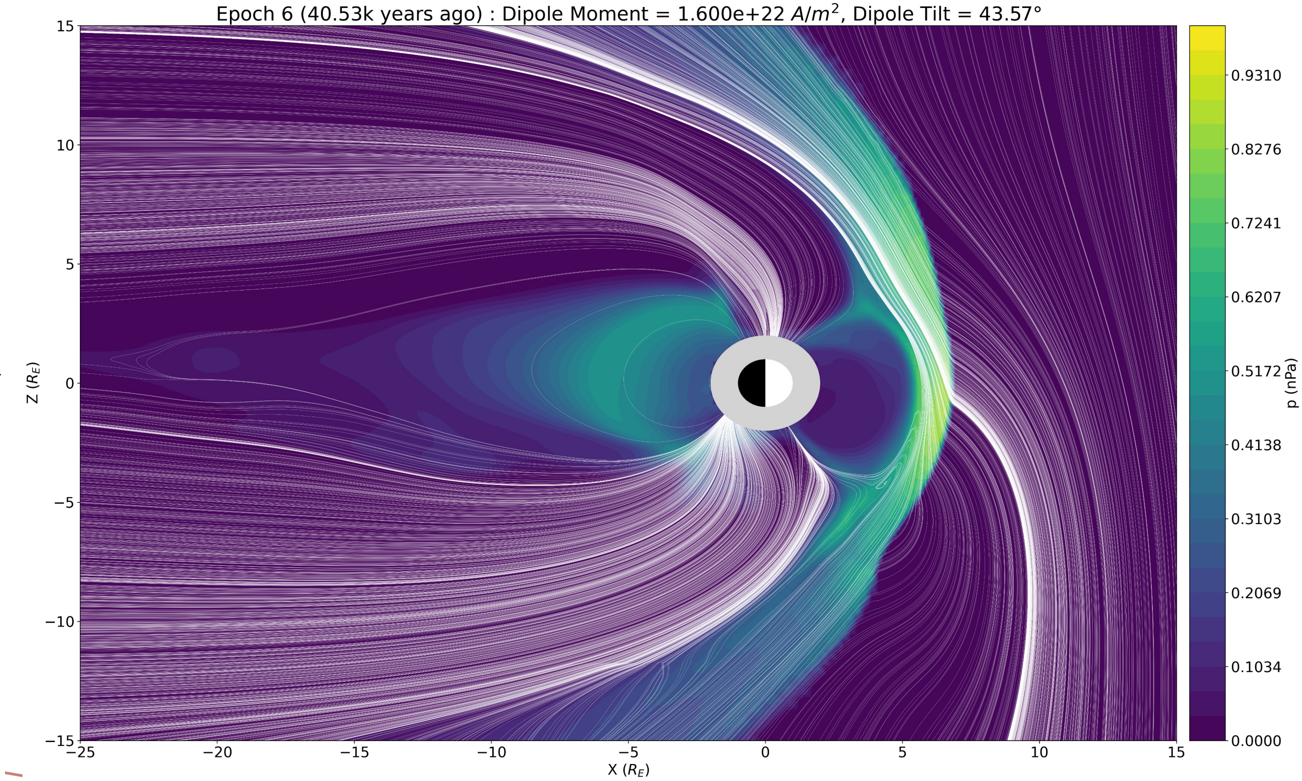


EPOCH 6 (40.53K Years ago)
Dipole moment = 1.600e+22 a/m^2, Dipole tilt = 43.57°

Log density on the y=0 plane with Bx and Bz field lines

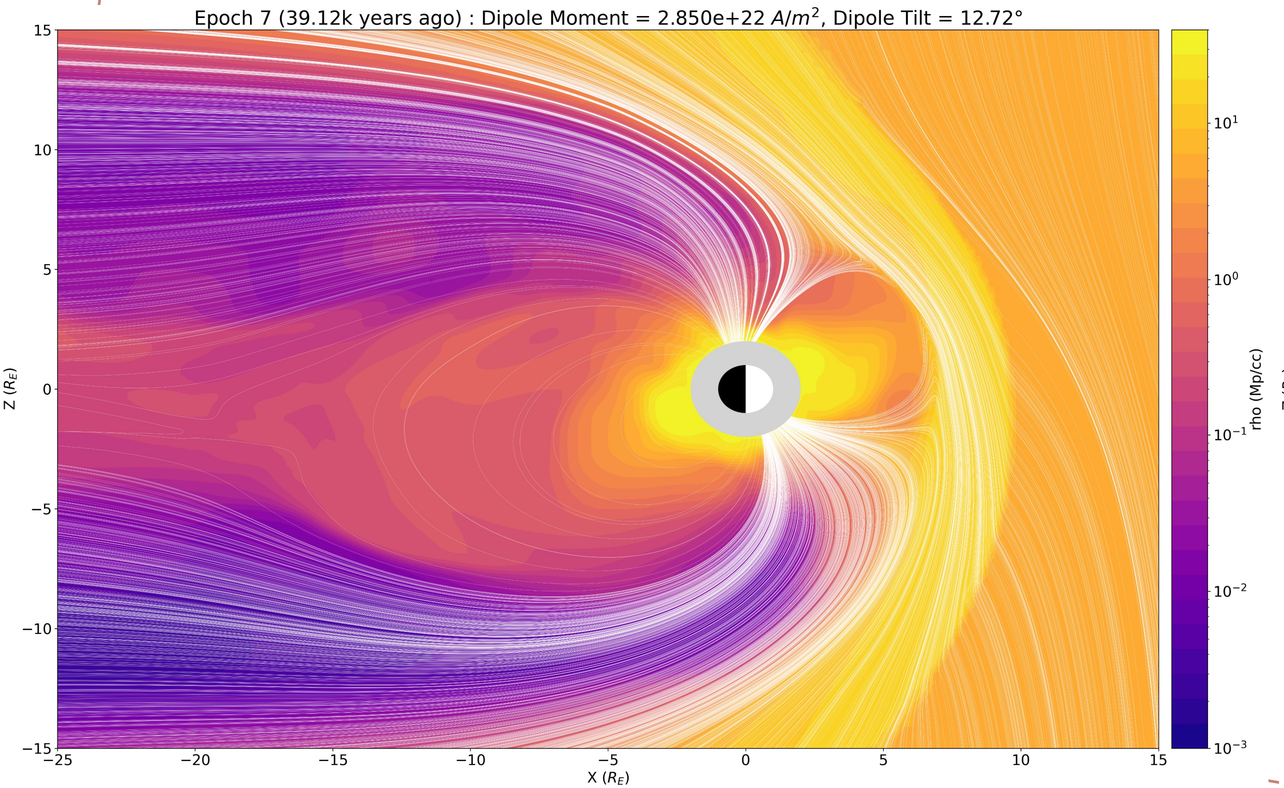


Pressure on the y=0 plane with Bx and Bz field lines

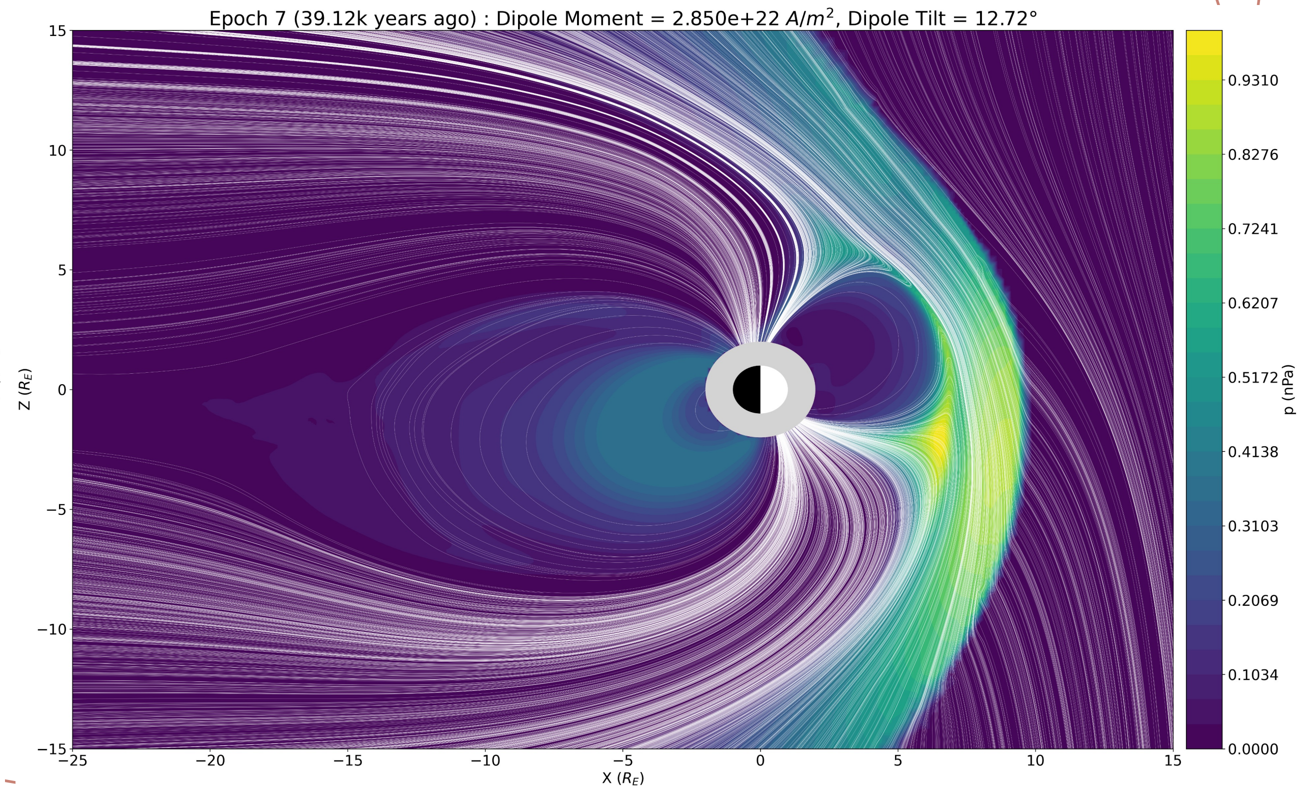


EPOCH 7 (39.12K Years ago)
Dipole moment = 2.850e+22 a/m², Dipole tilt = 12.72°

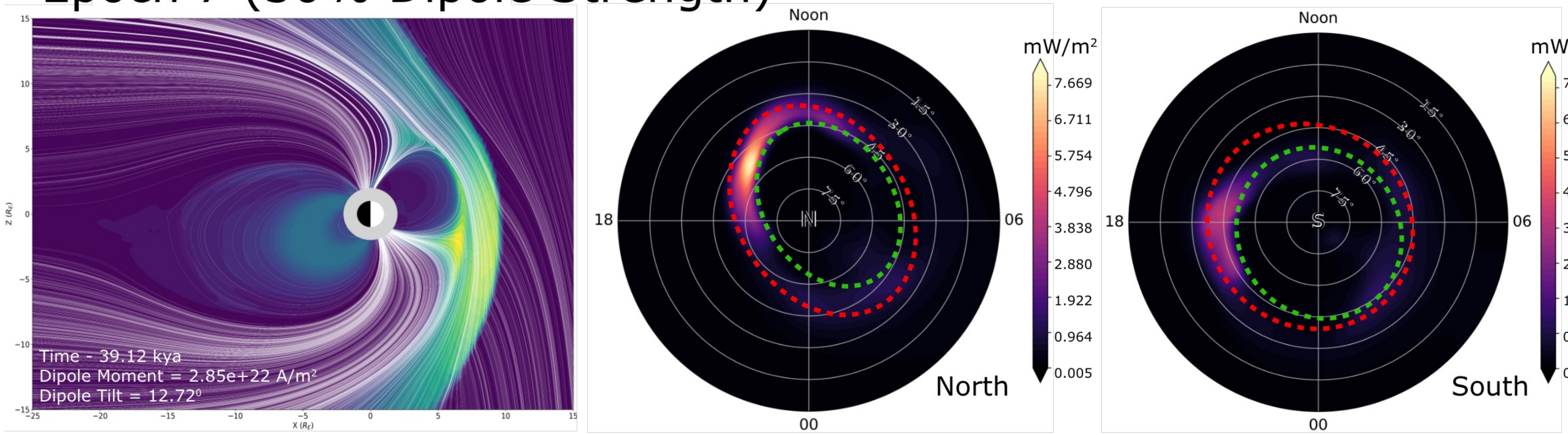
Log density on the y=0 plane with Bx and Bz field lines



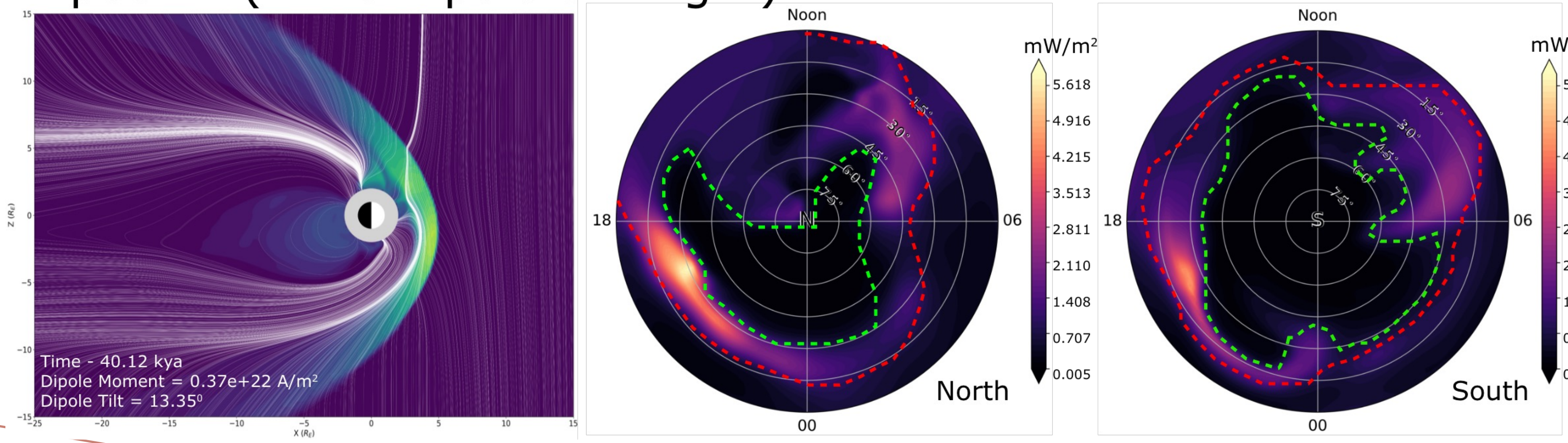
Pressure on the y=0 plane with Bx and Bz field lines



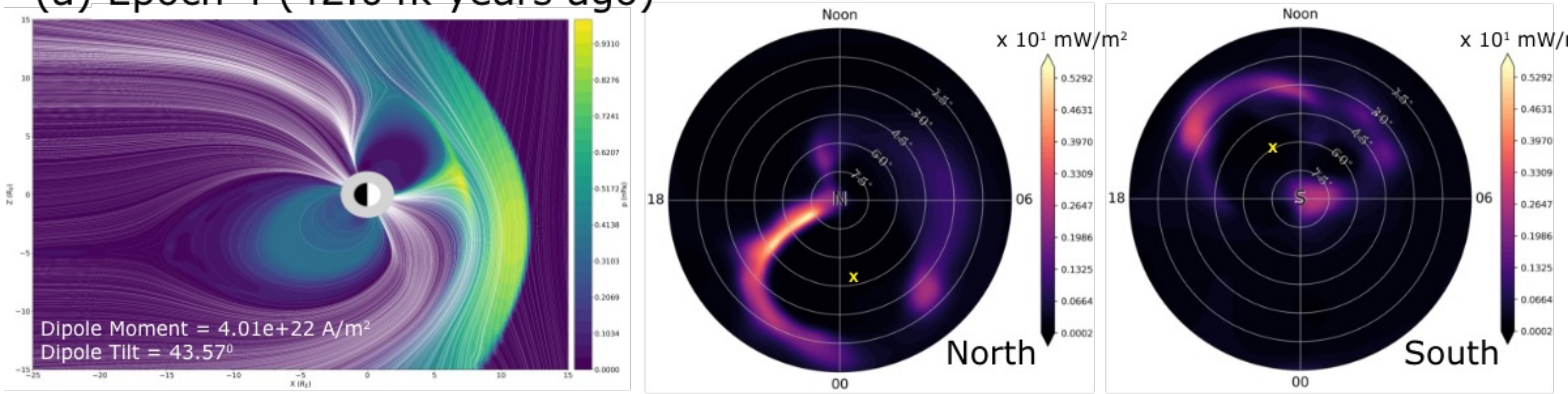
Epoch 7 (30% Dipole Strength)



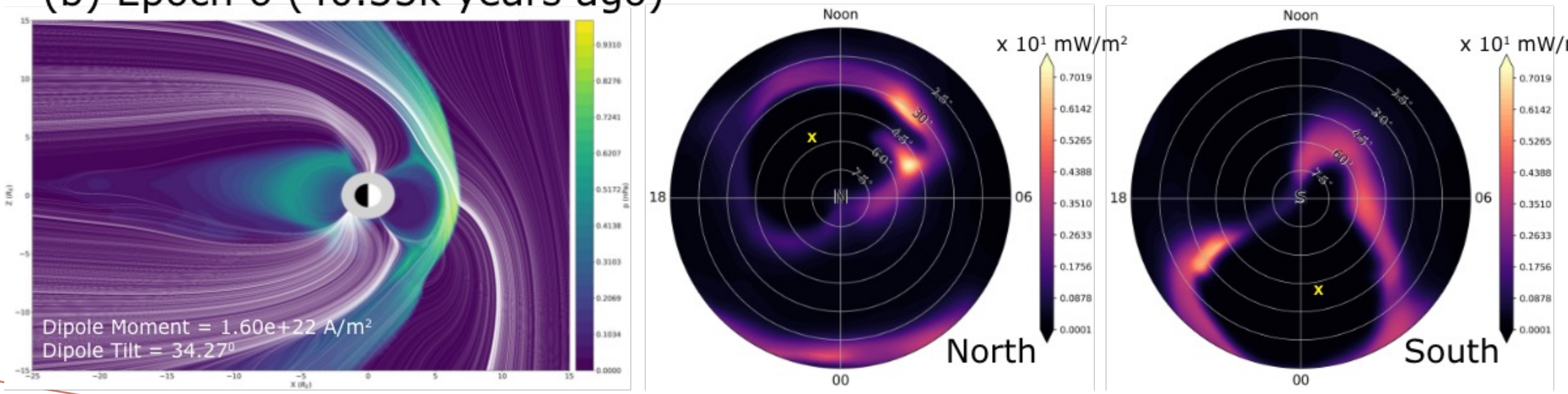
Epoch 1 (~4% Dipole Strength)

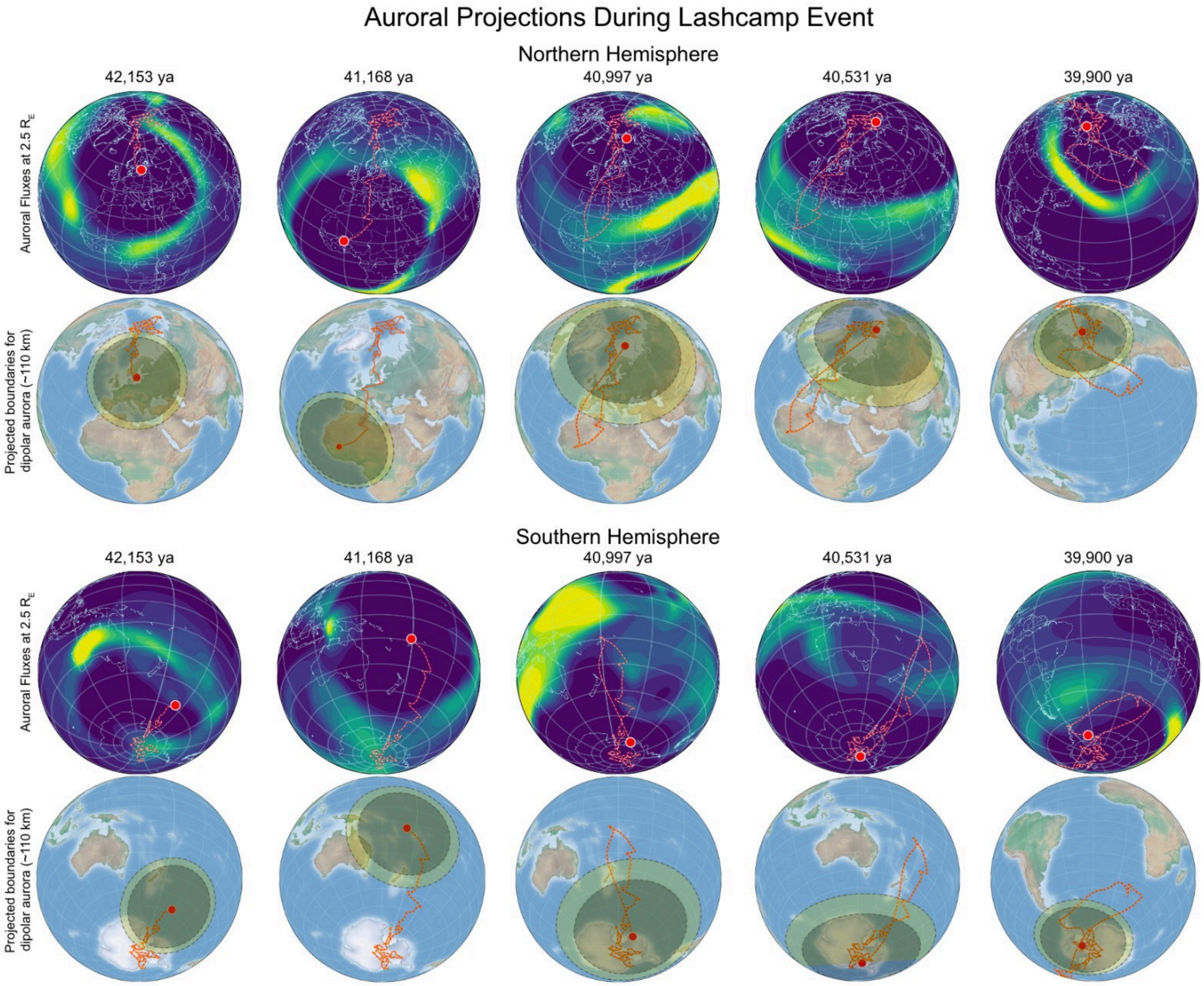


(a) Epoch 4 (42.04k years ago)

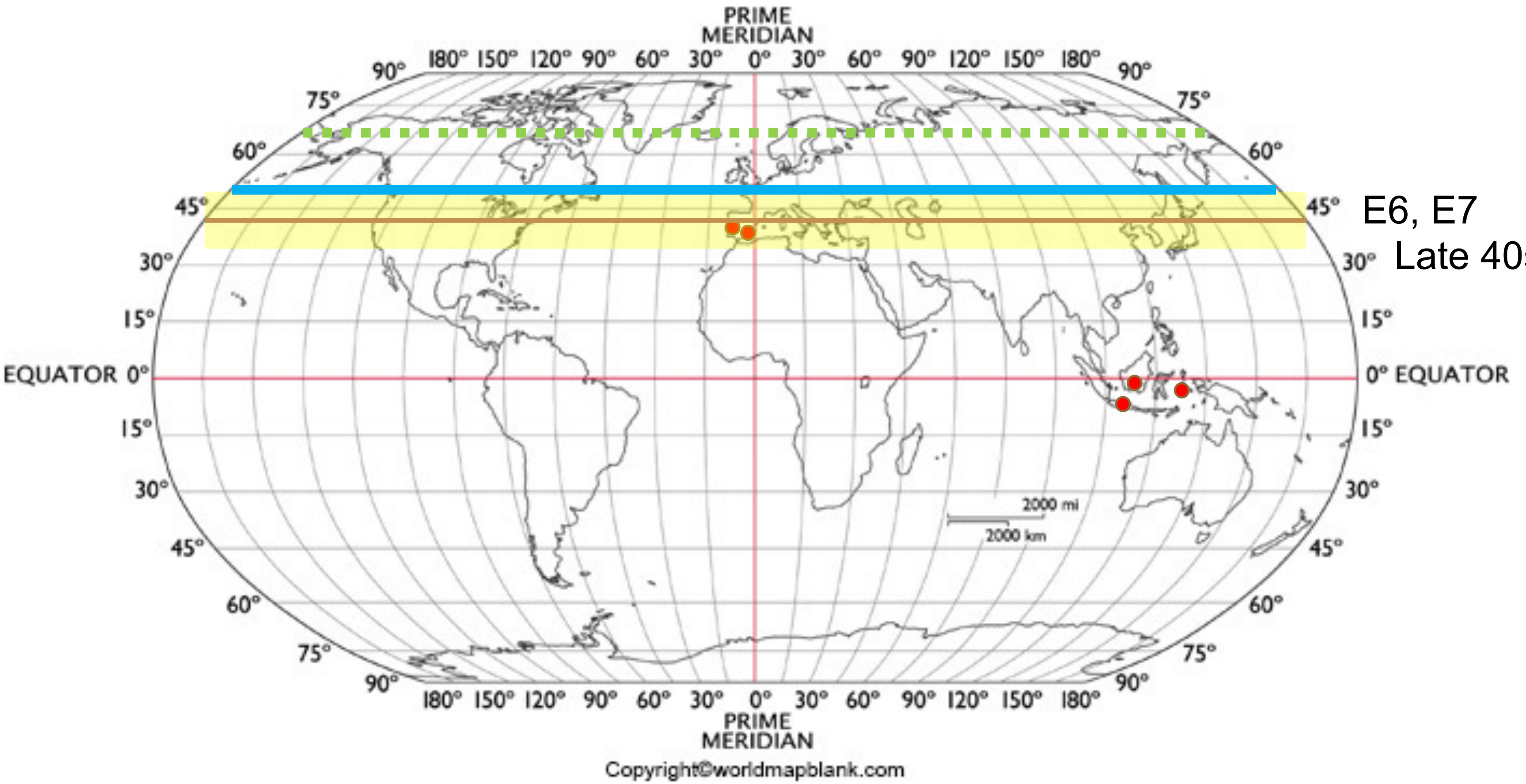


(b) Epoch 6 (40.35k years ago)





Auroral Projections During Lashcamp Event
Northern Hemisphere
42,153 ya
41,168 ya
40,997 ya
40,531 ya
39,900 ya
Auroral Fluxes at 2.5 R_E
Projected boundaries for dipolar aurora (~110 km)
Southern Hemisphere
42,153 ya
41,168 ya
40,997 ya
40,531 ya
39,900 ya
Auroral Fluxes at 2.5 R_E
Projected boundaries for dipolar aurora (~110 km)

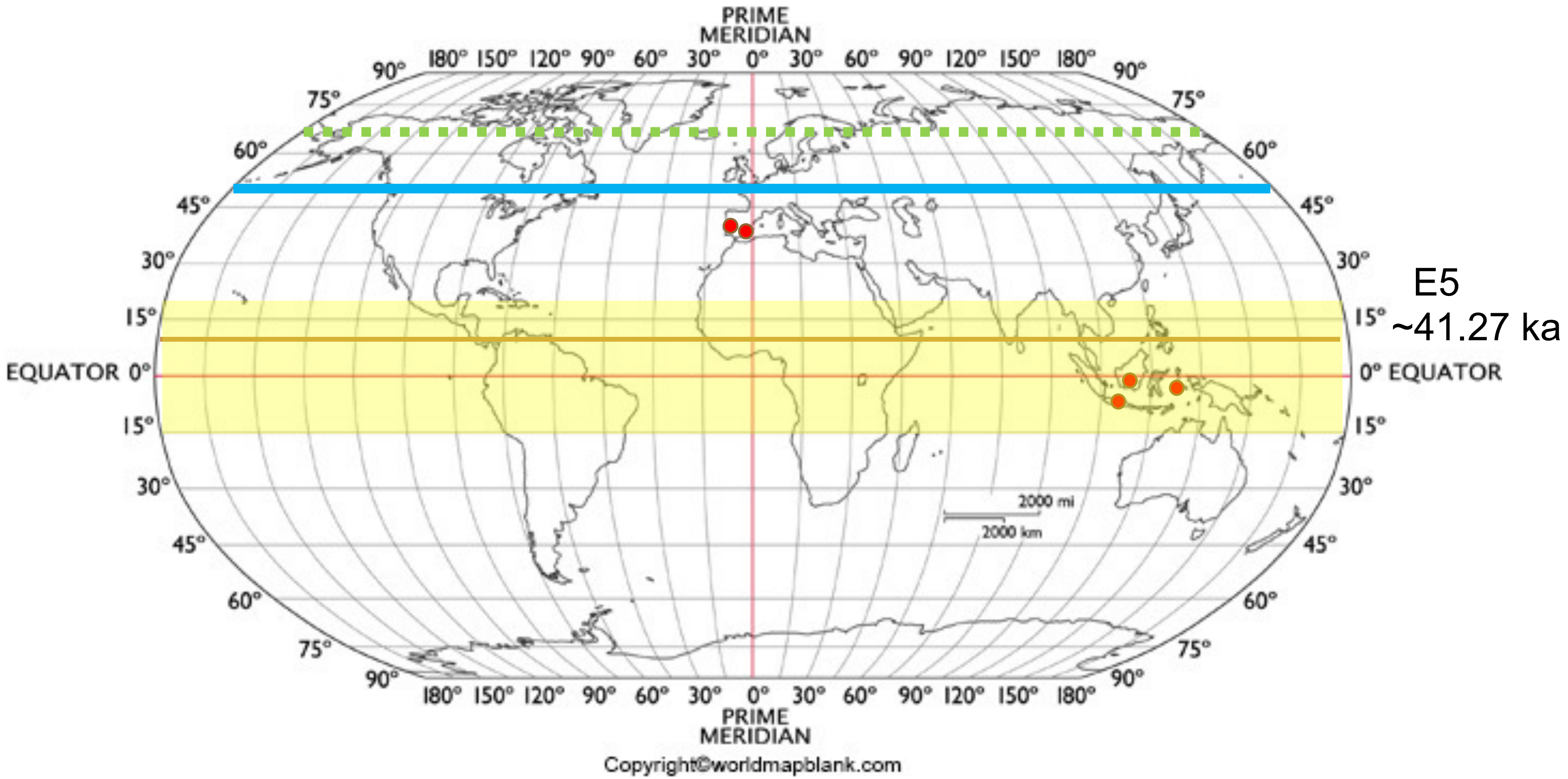


E6, E7
Late 40s ka

Auroral Boundary (Modern Values; Moderate Solar Driving)

Auroral Boundary (as suggested in Cooper+ 2021)

Traces of Human Civilization during the Laschamp Period (Pike et al. 2012; Aubert et al. 2018)



E5
~41.27 ka

Auroral Boundary (Modern Values; Moderate Solar Driving)

Auroral Boundary (as suggested in Cooper+ 2021)

Traces of Human Civilization during the Laschamp Period

CONCLUDING REMARKS

- Using a combination of a paleomagnetic field model, a global MHD model and an auroral precipitation model, we conducted simulations of the geospace variations during the Laschamps Event.
  - Simulations were carried over distinct epochs and varying geomagnetic conditions.
  - Nominal solar wind conditions were used to simulate the study.
- Our estimates show that Earth's magnetosphere underwent a sea change during the excursion peak.
  - Epoch 5 exhibits the largest dipole tilt seen during this excursion. The resulting configuration of the magnetosphere is comparable to Neptune's pole-on magnetospheric configuration.
  - The dipole strength is lowest during Epoch 1, when the dayside magnetosphere is nearly non-existent. Epochs 4, 6 and 7 show reasonable dipole-like features.
- Auroral simulations show both expansion and rapid wandering of the auroral oval, as the dipole tilt changes.
  - The auroral oval expands beyond the estimates suggested in recent studies, and constantly moves between Epoch 4 & 7.
  - The location of the magnetospheric cusp and the auroral oval match with regions of prehistoric anthropogenic activity of the same era found in anthropological surveys, indicating a deeper impact of the geomagnetic changes.