The system earth during geomagnetic polarity transitions
A interdisciplinary co-operation to investigate impacts on geomagnetic field configurations, energetic particle trajectories, and the composition of the neutral atmosphere

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Geomagnetic polarity transitions

- Magnetic field changes polarity every 10-100 years
- Duration of polarity transitions = 5000 years
- Magnetic field strength decreases to less than 25 % of current value
- Position of geomagnetic dipole wanders
- Geomagnetic field can be dominated by higher orders

- During polarity transition, the structure and strength of the magnetic field can be very different from the current situation

Impact on the atmosphere

- Magnetic field determines where and how much energetic particles precipitate into the atmosphere
- Energetic particles ionize the atmosphere
- Ions convert NO, O, O₃ into very reactive species O, NO, N, OH, H
- NO, O, H destroy ozone
- A change of magnetic field configuration can affect middle atmosphere ozone, especially during and after large energetic particle events

Field configurations

Zonal dipole
- currenct setting
- 90° rotated dipole (pole-on configuration)
- B reduced by 70%

Zonal quadrupole

The geomagnetic field

MHD simulations of the paleomagnetic field
International University Bremen

3D magneto-hydrodynamic equations are solved on a grid with algorithm BATS-R-US [Gombosi et al., 1998]

magnetic field B, energetic particle density p, velocity and pressure as a function of the magnetic field geometry and strength, the solar wind direction, and the orientation of the interplanetary magnetic field (IMF).

Zonal dipole, current setting

Magnetic field lines and particle density for a zonal dipole field perpendicular to the solar wind direction, for a northward IMF (left) and a southward IMF (right).

Axysymmetric quadrupole

Magnetic field lines and particle density for an axysymmetric quadrupole-field perpendicular to the solar wind direction, and the IMF perpendicular to the solar wind direction as well.

The middle atmosphere

Atmospheric ionisation
Universität Osnabrück

Both-Block or Monte Carlo simulations of energetic particle energy deposition in the middle and lower atmosphere from ~100 km down to the ground, using observed energetic proton and electron energy spectra

Ionisation of the lower and middle atmosphere as a function of energetic particle fluxes at 100 km altitude.

Proton fluxes for different particle energies, observed by the GOES-7 satellite during a solar proton event in July 2000.

Daily averaged atmospheric ion pair production in the region of the polar caps calculated from the GCMs proton flux measurements for the first three days of the July 2000 solar proton event.

Ion pair production rates calculated from GOES-7 proton flux measurements for the last two solar cycles, for the period 1995-2002.

Composition of the neutral atmosphere

Model simulations of the neutral stratosphere and mesosphere (~15 km to ~100 km) with the two dimensional photolysis, chemistry and transport model TOMCAT [Kinnison, 1996; Chipperfield, 1999] NO, N₂O, and H₂O (H₂O, OH, H₂O)

production rates as a function of atmospheric ionisation are determined with the algorithm used by [Jacchia, et al., 1990].

NO and HO production and subsequent atmospheric ozone loss as a function of atmospheric ionisation during and after large energetic particle events, for different magnetic field scenarios.

Zonal dipole current setting

Modelled excess NO at 76°N (left) and resulting global loss of total column ozone (right) due to atmospheric ionisation for the period 1986-2002.

NO is produced by ionisation mostly above 40 km altitude, and is transported down into the lower stratosphere slowly during polar winter. Ozone destruction by NO is especially effective in the lower stratosphere below 30 km, so significant column ozone loss occurs several months after the large energetic particle event and lasts for several months.

Zonal dipole

Loss of total ozone for the 1986-2002 period calculated for a dipole field with greatly reduced B.

As global NO production is much larger, total ozone loss is much larger than for the current situation, reaching values of more than 25 % after the large events in October 1995, July and November 2000, and April 2002.

90° rotated dipole

Loss of total ozone for the 1986-2002 period, calculated for a 90° rotated dipole field.

The same amount of NO is produced globally as in the current situation, however, the production is now confined to tropical regions instead of polar regions. Ozone loss still confined to polar regions due to the global transport patterns of the middle atmosphere.

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References