PLASMA VORTICES IN ATMOSPHERE AND IONOSPHERE IN NONUNIFORM GEOMAGNETIC FIELD

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Abstract. Plasma vortices are rotating in the crossed electric and geomagnetic fields. Plasma vortices can be generated in atmosphere due to ionized aerosols non uniform distribution and heating. The conservation of plasma vortices in atmosphere and in ionosphere is dependent on geomagnetic field structure. It is shown that at geomagnetic equator plasma vortices can damp that's why both cyclones and anti – cyclones are generated in south and north atmospheric regions separately. Plasma vortices structures cannot cross geomagnetic equator surface as one of geomagnetic field components changes the sign and the coherence of vortices is violated. The principal driver of atmospheric plasma vortices is aerosol. Massive and large particles, aerosols, and their ions are accelerated in pressure gradients fields and can have large impulses and remnant path in collisions with atmospheric atoms and molecules. The free path of atoms and molecules can be comparable with aerosol dimensions so cluster structures can appear in collisions of aerosol with light atmospheric components. Vortices are stochastically excited in the gyrotropic media with non uniform cellular heating and pressure gradients respectively.

Plasma vortices in non uniform geomagnetic field

Vortices structures in gyrotropic media are excited stochastically and modify mass – energy transfer [1-5]. Powerful cyclones and anti – cyclones affect biosphere rather dramatically. Dynamics of atmospheric vortices has some interesting features. For example both cyclones and anti – cyclones are generated in south and north atmospheric regions separately and they do not cross equator.

Variety of dust particles, aerosols, in atmosphere up to 30 km and above is observed. Aerosol dimensions, form and chemical composition depend on the dust sources. Small dust particles with dimensions $r_a < 10^{-5}$cm are usually observed in continental atmosphere, particles with r_a ~ 10^{-5} – 10^{-4}cm and with $r_a > 10^{-4}$ cm are present in see and continental atmosphere [6].

The mean free path of molecules and atoms and their ions in the lower atmosphere is rather small $l \sim (\sigma_n N_n)^{-1} \sim 10^{-3}$ cm, $\sigma_n \sim 10^{-16}$cm^2, $N_n \sim 10^{19}$cm^{-3}. It is much less than vortices dimensions so mass – energy vortices loss is small by the run away of these light particles. Let us mark atoms and molecules and their ions as light particles, light neutrals and light ions respectively. It may be supposed that in the lower atmosphere the light ions can not be effective drivers of plasma vortices. The values of cross sections and masses of light particles are comparable and the effective scattering of ions is probable in a mean time about $\tau \sim 10^{-5}$ s for $\mathrm{v} \sim 10^2$cm/s, $\tau \sim \nu_{in}^{-1}$, ν_{in} is collision frequency of light ions with light neutrals, $\nu_{in} \sim \sigma N \mathrm{v}$, v is particle velocity. It may be presumed that large and massive aerosol particles in comparison with light particles are probable drivers of plasma vortices in atmosphere. Aerosols are accelerated by collisions with light particles alike the ships under the sails as aerosol cross sections are much larger than light particles cross sections. If the velocity of the wind and of the light particles respectively is about $\mathrm{V} \sim 10^3$ cm/s and the mass of one light particle is about $m_n \sim 10^{-23}$g the aerosol particle with $r_a \sim 0.1$ cm and $m_a \sim 10^{-3}$ g appearing in such a wind undergoes collision force $F \sim 1$ g cm s^{-2} for $N \sim 10^{19}$cm^{-3} and is accelerated up to the half velocity of the wind in a time $\tau_1 \sim 1$ s. Aerosol particle with $r_a \sim 10^{-4}$ cm and $m_a \sim 10^{-12}$g appearing in the same wind is accelerated in a time $\tau_2 \sim 10^{-3}$ s up to the half velocity of the wind and in this case the collision force is $F \sim 10^{-6}$ g cm s^{-2}. Large and massive particles and their ions are effectively captured by the fluxes of light particles if some pressure gradients occur due to non uniform heating of atmosphere.

In storm fronts and tornado atmospheric neutral particles are rotating together with aerosol ions in plasma vortices. Ions are driving neutrals by collisions with them, mean free path of neutrals being small in comparison with plasma vortices and large aerosols. However let us estimate the remnant path of aerosol ions in collisions with light neutrals. The aerosol remnant path is easy to estimate in water vapor atmosphere under the supposition of complete water particles condensation on aerosol in its collisions with water vapor molecules. From the impulses conservation law it follows $m_{a0}\mathrm{v}_{a0} = m_c \mathrm{v}_c$, where m_{a0}, m_c are the initial mass of aerosol and of the aerosol – water condensation cluster respectively. If due to the slow down $\mathrm{v}_c \sim 10^{-1}\mathrm{v}_{a0}$, so from the impulses conservation law it turns out to be $m_c \sim 10 m_{a0}$. Let us assume that the cross section of aerosol – water cluster perpendicular to its velocity does not change and is equal to initial aerosol ion cross section $s_c = s_a$, aerosol ion is growing up only parallel to its velocity. The remnant path of aerosol ion is $l_a \sim 9 m_a / (m_n N_n s_a)$. The remnant path of aerosol with $r_a \sim$ 0.1 cm is about $l_a \sim 10^4$ cm under the parameters given above. For the aerosol ion with $r_a \sim 10^{-4}$ cm the remnant path is $l_a \sim$ 10 cm. The aerosol ion remnant path is large in comparison with mean free path of light particles, neutrals and ions. Such a model can be used to estimate the remnant path of aerosol ion in collisions with light particles of different nature. The initial impulse of aerosol ion is distributed between itself and light particles colliding with aerosol ion in its path. From equations

$$\mathbf{v}_c = (m_{a0}\mathbf{v}_a + \sum_n m_n \mathbf{v}_n)/(m_{a0} + \sum_n m_n), \tag{1}$$

$$m_{a0}\mathbf{v}_{a0} = (m_{a0}\mathbf{v}_a + \sum_n m_n \mathbf{v}_n) = (m_{a0} + \sum_n m_n)\mathbf{v}_c, \tag{2}$$

for $\mathbf{v}_c \sim 10^{-1}\mathbf{v}_{a0}$ it follows $m_{a0} + \sum_n m_n = 10 m_{a0}$ and $\sum_n m_n = l_a s_a N_n m_n,\ m_{a0} + l_a s_a N_n m_n = 10 m_{a0}$. So regarding the cluster or group of particles in collisions with aerosol ion the remnant path l_a is not difficult to estimate and it is of the same order as presented above in the case of water vapor. In atmosphere

$N_a / N_n << 1$ is observed. For the case of aerosol ions rotating together in plasma vortices the collisions between them can be neglected. From estimations above it follows that aerosol ions can be good drivers of plasma vortices in atmosphere heated and ionized by the solar photon flux.

At the geomagnetic equator plasma vortices can be disturbed as one of the geomagnetic field components change the sign [7]. The scheme of geomagnetic field at geomagnetic equator is shown in the Figure. Earth rotation vector does not change. Geographic and geomagnetic equators do not coincide. The Coriolis force is important in the atmospheric mass – energy transfer but plasma processes are evident in storm fronts and tornados as powerful lightness is usual in these structures.

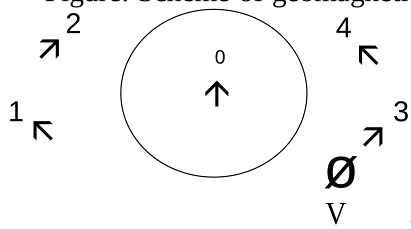

Figure. Scheme of geomagnetic field vectors 1 – 4 in the vicinity of geomagnetic equator. Plasma vortex V cross geomagnetic equator. The change of geomagnetic field disturbs the vortex and it damps. The Earth rotation vector shown by 0 does not change. Cyclones and anti – cyclones do not cross equator. It may be supposed that geomagnetic equator is responsible of such a behavior of these structures.

Plasma vortex electric field is dependent on temperature T and plasma density N gradients

$$\mathbf{E} = \ln(N / N_0)(\nabla T) / e + (T / e)\nabla \ln N, \qquad (3)$$

where e is electron charge. Vortex rotation velocity is linear dependent on geomagnetic field **B**

$$\mathbf{V}_d = [c/(eB^2)]\{\ln(N / N_0)[\nabla T \times \mathbf{B}] + T[\nabla \ln N \times \mathbf{B}]\}.$$

The change of sign of one of geomagnetic field components in the vortex cross through geomagnetic equator affects vortex structure. Vortex structure equations are obtained under supposition that plasma density, temperature and electric field potential correspond to Boltzmann distribution [4, 5].

Electric field energy density W_1 of plasma vortex is

$$W_1 = (8\pi e^2)^{-1}\{\ln(N / N_0)\nabla T + T\nabla \ln N\}^2.$$

Plasma density (concentration of particles) is given by $N = N_0 \exp(e\Phi / T(y))$, T is electron component temperature and N_0 is plasma density for $\Phi = 0$. It is assumed that outside plasma vortex rotating electric field potential is equal to zero. The drifting plasma vortex can capture ions of different mass. Ions can condensate the moisture. Moisture condensation is very important. The vortices self focusing can accelerate due to optic thickness growing up and non uniformity of heating and pressure gradients growing up so the vortex rotation velocity and dimensions are growing up also. It is alike the energy pumping from small and weak vortices to a powerful and large one [1-3].

Plasma vortices in atmosphere are generated in media where collisions between particles are very important. Charged particles are involved in motion across geomagnetic field in pressure gradients and generate electric field. This motion is due to collisions of neutrals with charged particles. Profound vortices are possible as charged particles can propagate across geomagnetic field in collision media. If the mean free path of particles in atmosphere is small in comparison with pressure gradients scales nonlinear processes are possible. In plasma vortices equation nonlinear terms are present such as KdV terms and Jacobian [5]

$$(\Delta\Phi)_t - \frac{e}{T}\Phi_t\Delta\Phi + \frac{e}{M\Omega_{0i}}\Delta\Phi\frac{e}{T}(\Phi\frac{\partial\Phi}{\partial x}\frac{\partial \ln T}{\partial y} - .$$

$$\Phi\frac{\partial\Phi}{\partial y}\frac{\partial \ln T}{\partial x}) + \frac{e}{M\Omega_{0i}}J(\Phi, \ln(\Delta\Phi)) = 0,$$

Φ is electric field potential, M is ion mass, Ω_{0i} is cyclotron frequency, and the Jacobian is

$$J(\Phi, \ln(\Delta\Phi)) = \Phi_x(\ln(\Delta\Phi))_y - \Phi_y(\ln(\Delta\Phi))_x.$$

Conclusion

Plasma vortices of the cyclone kind are rotating in the opposite directions in the south and north geomagnetic hemispheres and it is so with plasma vortices of the anti – cyclone kind. Pressure gradients structure affects vortices generation. Plasma girotropy in geomagnetic field is important. Both cyclones and anti – cyclones do not cross equator. The boundaries of these structures are not abrupt and it may be supposed that geomagnetic equator has to be taken into account to understand these phenomena. It is another evidence of plasma vortices influence on atmospheric mass – energy transfer. The first evidence is clear as lightness is usual phenomenon in tornados and storm fronts. However electric fields in cloudiness can be out of simple observations being less than the fields of discharge.

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