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Plasma mixing and transport across the tail-magnetopause during northward IMF caused by the coupling between the MHD-scale Kelvin-Helmholtz vortex and magnetic reconnection: 2D and Two-fluid simulations

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Our two-dimensional two-fluid simulations including finite electron inertial effects show that the plasma mixing and transport across the low latitude tail-magnetopause during northward IMF conditions are caused by the coupling between the MHD-scale Kelvin-Helmholtz (KH) vortex and magnetic reconnection.

Despite it is highly possible that the development of KH vortices results in the plasma mixing and transport across the magnetopause, there is no conclusive understanding of how KH vortices cause the plasma mixing and transport. This is because most simulations were done by using MHD equations. The MHD approach is not sufficient because plasma mixing cannot take place due to the frozen-in condition. In this study, we use two-fluid equations including electron inertial effects which can break the frozen-in condition. As a result, it is found that two types of magnetic reconnection driven in a KH vortex are crucial factors for determining the structure of the KH vortex itself. One is named 'type-I reconnection', which occurs in the case in which the magnetic field components along the k-vector of the KH instability are anti-parallel across the velocity shear layer (the anti-parallel case). Type-I reconnection assists the KH instability to grow as a rolled-up vortex even when the velocity shear is too weak to produce rolled-up vortices. Another is named 'type-II reconnection', which is driven

in the case in which the velocity shear is strong enough to produce highly rolled-up KH vortices (the strong KHI case). Type-II reconnection destroys the flow pattern of the highly rolled-up vortex. It is also found that type-I reconnection leads directly to plasma mixing across the shear layer and that type-II reconnection forms magnetic islands and plasma contained in these magnetic islands can be transferred from one side to other across the shear layer.

Furthermore, linear analyses on the earth's magnetopause-like cases show that the anti-parallel case is obtained rather commonly and that the strong KHI case cannot appear commonly but there is a sufficient possibility the case appear. These results indicate that type-I and type-II reconnection can explain how the plasma mixing and transport across the magnetopause takes place.