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基于中性原子通量数据的磁暴期间环电流研究

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Study on the Earth ring current during magnetic storms based on energetic neutral atom flux data

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摘要 本文通过分析两次大磁暴期间的中性原子(ENA)通量数据,试图揭示环电流离子通量的变化规律,进一步探讨环电流的形成和损失机制,以及磁暴和亚暴的关系.两次磁暴期间ENA通量的变化呈现出一些重要的特征:(1)通量随能量的增高而快速降低,磁暴主相期间高能端通量所占比重增大;(2)通量比例曲线的起伏远比通量曲线的起伏要平缓;(3)通量的起伏与*AE*指数之间没有简单的对应关系;(4)磁暴恢复相开始前,ENA通量出现短时间的猛烈增长,特别是低能端通量的增长异常迅速;(5)*Dst*/SYM-H指数快速恢复期间,ENA通量的变化表现为两个完全不同的阶段:先降低,后增大.忽略影响ENA通量的其他次要因素,ENA通量的上述特征直接反映了环电流的发展规律.环电流离子通量随能量的增高快速下降,磁暴主相期间可能由于高能O^+的增加使得能谱有所变硬.离子主要受南向行星际磁场(IMF)所引起的对流电场的驱动注入到环电流区域,通量的变化大体上是无色散的.亚暴活动与环电流的增长没有直接的因果关系,但亚暴活动会引起环电流离子通量的短时间尺度波动.恢复相开始前,环电流离子在昏侧区域发生堆积,使得局部离子通量变大.这可能是由于屏蔽电场的形成削弱了内磁层对流电场,造成离子在磁层顶的逃逸损失过程减弱.在*Dst*/SYM-H指数的快速恢复期间,环电流离子通量的衰减速度也可能发生阶段性变化.这说明*Dst*/SYM-H指数并不能准确反映环电流的强度,环电流的衰减过程可能具有比先快后慢更为复杂的阶段性模式.

关键词: 环电流 中性原子成像 磁暴 亚暴 离子

Abstract: By analyzing the energetic neutral atom (ENA) flux data during two major magnetic storms, this study tries to reveal the characteristics of flux variation of the ring current ions. Furthermore, the formation and loss mechanism of the ring current, and the storm-substorm relationship were discussed. During the magnetic storms, ENA flux variation shows some important features: (1) The ENA spectrum shows a rapid decrease as energy increases, and became harder during main phase of the storms. (2) ENA flux fluctuated in a dispersionless mode. (3) There's no straight or clear relation between ENA flux fluctuation and AE index. (4) Before the storms entered recovery phase, or at the end of main phase, ENA flux increased heavily for a short time. (5) During the rapid recovery phase of *Dst*/SYM-H index, ENA flux variation took a two stage recovery mode, first rapid then slow. Ignoring other factors that have less effect on ENA flux, the features of ENA variation can give some implications on ring current dynamics. The spectrum of ring current ions should have a steep minus slope and get harder during main phase of storms possibly due to dramatic increasing of O^+ flux. Ions are injected from the magnetotail to the ring current region in a dispersionless mode mostly by enhanced convective electric field. There's no straight cause and effect relation between sub-storm activities and enhancement of the ring current, although sub-storms may cause short term variations of ion flux. Before recovery phase, ion flux increases rapidly at the dusk side of the Earth. This can be interpreted as a result of piling up of ions due to diminishing of convective electric field on formation of shielding electric field and subsequent weakening of the escaping loss process at the magnetopause. The *Dst*/SYM-H index can't accurately indicate intensity of the ring current and the recovery of the ring current may be more complicated than the rapid and slow mode that *Dst*/SYM-H takes.

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