Substorm Growth Phase, Onset and Dipolarization

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The Earth's magnetosphere and ionosphere during substorms evolve typically from the growth phase to onset to the expansion phase and then recover to quiet time states. During different phases of substorms the magnetosphere and ionosphere exhibit distinguished 3D global and local features. Successful theories or models for understanding substorm dynamics must provide physical understanding of these features. Here, we describe the evolution of 3D global structure of the magnetosphere during the growth phase and ULF (in the Pi 2 frequency range) instabilities of the growth phase magnetosphere that produce the auroral arc that breaks up at and after the substorm onset. The 3D structure of global magnetosphere during growth phase is modeled by quasi-static equilibria solutions obtained from the force-balance equation for given equatorial pressure distributions. The ULF instability that produces the breakup auroral arc is modeled by the Kinetic Ballooning Instability (KBI), which is destabilized by plasma pressure gradient and magnetic field curvature in the high beta region, to explain the substorm observations in both the aurora and near-Earth plasma sheet regions. Our model is based on the theoretical analysis and numerical solutions of the kinetic-MHD mode equations for late growth phase 3D magnetospheric quasi-static equilibria. The results show that the KBI has a real frequency associated with the ion magnetic drift frequency, which is in the Pi2 frequency range, and the most unstable KBI has an azimuthal mode number on the order of 200-300. The theoretical KBI features are consistent with observational features in both the aurora breakup arcs and the near-Earth plasma sheet. During the expansion phase the plasma pressure profile is relaxed due to plasma transport by strong plasma turbulence and it can be shown that the plasma sheet magnetic field becomes depolarized resulting from a small reduction in the plasma pressure. Comparison between our model and substorm observations will be presented.