Foreshock Transient Phenomena and Their Impact on the Magnetosphere and Ionosphere

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Foreshock transient phenomena are frequently observed upstream from the bow shock (such as Hot Flow Anomalies, foreshock cavities, and foreshock bubbles). They play a significant role in the mass, energy and momentum transport from the solar wind into the magnetosphere and impact the global magnetosphere. They are universal phenomena that have been observed at Earth and other planets. The pressure variations associated foreshock transient phenomena perturb the magnetopause, transmit compressional waves into the magnetosphere that can excite resonant ULF waves and cause particles to scatter into the loss cone and precipitate into the ionosphere, generate field-aligned currents in the magnetosphere that drive magnetic impulse events in the high-latitude ionosphere, and trigger transient auroral brightenings. This presentation will discuss the great progress made recently toward answering some specific outstanding questions. Some outstanding questions are listed below. What are the physical differences and relationships between different transient phenomena at the bow shock? What are the formation conditions for the foreshock transients? How do the magnetosphere and ionosphere respond to foreshock transients? Brief answers to these questions are as follows. Some foreshock transients are very similar and could be different stage of the same phenomena. Hybrid simulations show that both tangential discontinuities and rotational discontinuities can generate HFAs by interaction with the bow shock. Hybrid simulations show that rotational discontinuities can drive foreshock bubbles while observations show that tangential discontinuities can also drive foreshock bubbles. The major observational feature to distinguish foreshock bubbles and HFAs is whether the structures have two compressional boundaries (HFAs) or only one shock on the trailing edge (foreshock bubbles). However, sometimes a compressional boundary can also be observed on the leading edge of rotational discontinuity-driven foreshock bubbles and HFAs can also have only one compressional boundary on the trailing edge. Therefore, it is not easy to distinguish HFAs and foreshock bubbles. Hybrid simulations and observations suggest that foreshock cavitons and SHFAs could be different evolution stages of the same phenomena. Statistical studies showed that HFAs prefer to occur under the following conditions: high solar wind speed, radial IMF, Mach number greater than 5, discontinuities with large magnetic shear angles, magnetic field on at least one side of the interplanetary discontinuities has to be connected to the bow shock, the reflected flow from the bow shock is along the discontinuity, current sheets with thickness from 1000 km to about 3162 km. However, HFAs have also been observed under “unreferred” conditions. ULF waves generated by transient phenomena near the bow shock in both Pc 3 and Pc 5 ranges have been reported. There may be considerable variation between ULF waves resulting from different transient features. Both compressional waves and standing Alfvén waves have been observed. The magnetospheric response could be global or localized. The different effects might be caused by the different pressure variation profiles associated with the transients, size of the transients, and the location where the waves were observed in the magnetosphere.