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The bow shock and magnetosheath responses to density depletion structures

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Hot flow anomalies (HFAs) are typical and important foreshock transients characterized by large flow deflection and plasma heating. HFAs can deform the Earth's bow shock by dynamic pressure perturbation resulting in disturbance in the magnetosphere and ionosphere. Traditionally, HFAs are believed to be associated with discontinuities. But recently, HFA-like structures were simulated by an magnetohydrodynamics (MHD) model without the discontinuity prerequisite. In this study, we give three HFA examples to verify this MHD formation mechanism. For the first event, we use multi-points observation from the THEMIS mission to track the formation of the HFA accompanying with a density depletion upstream. For the other two events, we compare observations from the MMS mission and the ARTEMIS mission with the MHD simulation results using density depleted solar wind flux tubes to investigate the physical process of HFA formation. The comparison of simulation and observation shows general agreement particularly in the presence of a core with strong heating and velocity deflection, and two compression regions (shocks) with clear maxima in the ram pressure with a strongly inclined normal boundary at the leading edge and moderately inclined at the trailing edge. Agreement was better when the MHD simulations used a transient change to quasi-parallel solar wind magnetic field during the events. Result suggests that ram pressure may be an excellent diagnostic for HFAs both in the solar wind and in the magnetosheath.