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Multi-spacecraft observations of a foreshock induced magnetopause disturbance exhibiting distinct plasma flows and an intense density compression

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Large-scale magnetopause disturbances can result from several different types of events, including those resulting from phenomena in the foreshock region. Here, we report on multipoint Time History of Events and Macroscale Interactions during Substorms (THEMIS) observations of a magnetopause disturbance along the dawn-side, equatorial flank that exhibits distinct flows in the magnetospheric plasma being displaced around it, evidence of a complex boundary layer and reconnection, and an abnormally strong compression of the plasma density, which peaks at >7 times the density of the near-Earth solar wind. In our presentation, we will discuss the event's features, investigate the plasma distributions associated with the flows, and provide some speculation on the observations and the intense density compression associated with this disturbance.

Four of the five THEMIS spacecraft are used in this study: TH-B, which is in the solar wind along the dawn side near the dawn-dusk meridian just upstream of the bow shock, and TH-A, -D, and -E, which are all in the magnetosphere near the magnetopause around 08:00 MLT at the time of the event. WIND and GOES data are also used to confirm our conclusion as to the cause of the magnetopause disturbance, which is observed by TH-A, -D, and -E. TH-E is the closest to the magnetopause and actually crosses into the sheath during the initial disturbance. After this initial disturbance it observes an overall enhancement followed by a depression in the total field strength and pressure signatures that are evidence of it moving away from then back towards the magnetopause. Associated with these changes in the field, TH-E observes very fast plasma flows, with the strongest component being in the magnetopause normal direction and magnitudes greater than 400 km/s. This is indicative of the sudden and extreme magnetopause motion associated with this event. All three THEMIS spacecraft in the magnetosphere also observe very distinct and fast plasma flows, which are clear evidence of the magnetospheric plasma being diverted around the disturbance. In the solar wind, TH-B observes clear evidence of the foreshock region and a distinct feature that is consistent with a foreshock cavity.

Based on the evidence, we conclude that the magnetopause disturbance is most likely the result of a foreshock cavity being swept along the magnetosphere by a discontinuity in the interplanetary magnetic field. The effects of this foreshock cavity apparently penetrate through the sheath and impinge upon the magnetopause, resulting in its displacement. Interestingly, the magnetospheric plasma flows around the magnetopause disturbance are very similar to those previously reported around flux transfer events. We find that the fastest ion and electron flows are related to two different processes: the ion flows resulting from plasma being displaced around the disturbance and the electron flows related to magnetic reconnection. We present relatively simple schematics of this foreshock cavity and its leading edge compression region that explain many of the observed features and discuss possibilities for the intense density enhancement. Using these simultaneous THEMIS observations from the magnetosphere, magnetosheath, and solar wind, we propose that the most likely scenario is that the abnormal density enhancement was the result of either a combination of compression effects due to the magnetosheath and the cavity's leading-flank compression region or from some complex interaction, like reconnection, near the magnetopause along the event's boundary layer. We finish with a discussion of global hybrid simulations being employed to help understand the underlying nature and unique features of this interesting event.