

**Pi pulsation signatures at substorm onset:
An analysis of the 30 September 2011 substorm event
using induction magnetometer records and all – sky images obtained at the conjugate stations,
Syowa in Antarctica and Husafell, Tjornes in Iceland**

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This work is primarily intended to emphasize the importance of Pi pulsation signatures at substorm onset. The data examined in this work are induction magnetometer records in addition to fluxgate magnetometer records obtained at the conjugate stations, Syowa in Antarctica and Husafell, Tjornes in Iceland for the 30 September, 2011 substorm event. We would like to emphasize usefulness of induction magnetometer records for identification of accurate timings of substorm onset and successive substorm evolutions. The advantage of this work is that we can fortunately make use of simultaneous observations of all – sky images at these three stations, with which auroral signatures at substorm onset, such as, auroral initial brightening, breakups and full poleward expansion are compared in detail. Results obtained in this work are as follows:

1. The substorm observed on 30 September 2011 consisted of three elementary substorm disturbances: the first one was a small (pseudo) – substorm, onset at 23:12:10 UT and lasted about 13 minutes until 23:26 UT, and the second one was a bigger substorm, onset at 23:27 UT and lasted about 9 minutes until 23:36 UT, which was followed by the third substorm, onset at 23:38 UT and lasted about 10 minutes until 23:48 UT. These three substorm disturbances occurred successively, and are examined on the onset signatures compared with all – sky aurora images.
2. Pi pulsation signatures of these substorm onsets are found to be three step evolutions : a first step is Pi 1 (longer period component Pi 1, $T > 20$ sec) and/or Pi 2 pulsation onset, which occurs, as a first precursor, that is the earliest signature informing substorm initiation in the deep magnetosphere, preceding auroral brightening, with about ~one minute. So it can be said that Pi 1 and/or Pi 2 pulsation is the first indicator of physical change of the magnetosphere at substorm initiation onset.
3. Second is small amplitude short period Pi 1 onset ($T < 20$ sec), almost simultaneous with auroral initial brightening.
4. Thirdly, further Pi 1 and 2 enhancements, which begin with auroral activity enhancement, such as a breakup, and successive poleward expansion.
5. From a view of pulsation signatures a substorm disturbance might be constructed with successive appearance of Pi 1 – 2 pulsation activities, i.e., a substorm disturbance is constructed with a train of Pi 1 and Pi 2 pulsation activities.
6. On the other hand, considering conjugate relationships, Pi pulsation activities seem to appear almost similar at both conjugate stations in northern and southern hemisphere throughout substorm phases, particularly in the initial phase. However, non – conjugate signatures appear in the expansion phase, suggesting that in this phase local ionosphere conditions might become more important and exceed effectiveness linking to the magnetic field –line.
7. Finally we would like to remind and recommend usefulness of induction magnetometer observations for identification of accurate timings of substorm onset and successive substorm development features, and further to emphasize much more prevalence of induction magnetometer measurements over the world.