ICE/ISEE Plasma Wave Data Analysis

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INTRODUCTION

The interval reported on here, from January 1992 to September 1993, was one of final processing of ICE plasma wave (pw) data and analysis of late ISEE 3, ICE cometary, and ICE cruise trajectory data, where coronal mass ejections (CMEs) were the first focus of attention. Interest in CMEs inspired an effort to represent our pw data in a condensed spectrogram format that facilitated rapid digestion of interplanetary phenomena on long (> 1 day) time scales. The format serendipitously allowed us to also examine earth-orbiting data from a new perspective, invigorating older areas of investigation in Earth's immediate environment. We therefore continued to examine with great interest the last year of ISEE 3's precomet phase, when it spent considerable time far downwind from Earth, recording for days on end conditions upstream, downstream, and across the very weak, distant flank bow shock. Among other motivations has been the apparent similarity of some shock and post shock structures to the signatures of the bow wave surrounding comet Giacobini-Zinner, whose ICE-phase data we revisited.

Besides our own ongoing and fresh investigations, we have cooperated, within our resources, with studies conducted extramurally by distant colleagues irrespective of the phase of the ISEE 3/ICE mission under scrutiny. The remainder of this report summarizes our processing activities, our investigations, both internal and cooperative, our scientific results, and our publication activity.

DATA PROCESSING

Routine processing of ICE PW data beyond the last Hardcopy multichannel plots through July 1990 was suspended in this interval because of the combination of very low satellite data acquisition rate since then and our disappointing preliminary attempt to find a CME signature in the solar wind. These circumstances dictated that exploitation and analysis of earlier data and experimentation with the new spectrogram format was a far better allocation of closing resources.

Special processing consisting of plotting polarizations, spectra, spectrograms, and sections of high resolution data was resumed in support of TRW's ongoing studies.

We had sought in the preceding contract interval to enable study of CMEs by refining and exploiting a data processing format new to the ISEE 3/ICE pw detector. Instead of processing detector output as 24-hour segments, with all pw channels individually

plotted and stacked one above the next down in frequency, we developed a color spectrogram format appealing to our visual chromatic sense to grasp the changing patterns of pw activity in the ambient plasmas at arbitrary time scales. Since CMEs, with their preceding and following solar wind plasmas, can take more than one day to pass by the spacecraft, a more condensed synoptic view of the pw data was required to identify and assess CME characteristics than has been afforded by the traditional routines. We had addressed this requirement in a major new processing initiative in the preceding two years.

Our new survey format for the pw records consists primarily of color plots of the multichannel data, incorporating frequency smoothing and arbitrary time-averaging. These "channel-based spectrograms" we call "CBS"s are being applied to a study of plasma wave signatures of the patterns of plasma wave occurrence in Earth's magnetosheath and foreshock, including particularly the far downwind regions of both (pursued concurrently with a separate GI program).

THE LAST QUARTER

In the course of high resolution reprocessing of critical 1983 data, it was discovered that the original tapes had so degenerated that the reading heads were accreting tape debris and had to be cleaned at short intervals in order to accomplish any processing at all. Also, fresh data gaps were appearing where there had heretofore been continuity. Processing was immediately halted, and we were fortunate in being able to transfer the affected data to exobyte storage with minimal gaps, even an improvement, in the record, and to continue our processing. We now have backup exabyte records corresponding to old tape numbers DCM 265-268, covering the time 9/4/83 to 10/1/83.

Our concerns regarding loss of data from unique ISEE 3 environments and locations was communicated to NASA, with our recommendation that immediate steps be taken to backup all important sections of the ISEE 3 data base for archiving before they are lost forever. It is our understanding that an effort to find resources to support this vital function is underway as this report is written.

Specialized CBCs and detailed spectra and channel plots were produced in support of the studies described below. Also, the reduction codes were modified to provide cross-plots, i.e. scatter diagrams, of pw intensity against various other parameters from simultaneous measurements, especially magnetic field parameters.

Scientific Results

Magnetosheath variability. We concluded tentatively in the previous quarter that the ISEE 3/ICE pw detector in and behind the shock was picking up real wavemodes not previously noted and that these wavemodes may persist for tens or hundreds of Earth radii downstream, with only moderate damping in the magnetosheath plasma. This characteristic requires explanation by itself. Further scrutiny of the downstream data, however, with the additional help of CBSs representing all frequencies in compressed presentation, disclosed that, persistent or not, the post shock pw record was occasionally punctuated with total, and almost total, dropouts of signals in the ion acoustic range (IAR) of frequencies 300 Hz < f < 10 kHz.

Looking for a geometric magnetic correlation first, we found that rotation of the IMF, as modified in the deep downstream magnetosheath, to an orientation essentially perpendicular to the presumed solar wind flow coincided with these disappearances across all IAR frequencies. Figure 1a compares a CBS with a plot of corresponding IMF orientation represented by Θ_{XB}, the "cone" angle between the X-direction and the ambient field B. The example shows a series of pw drop outs or partial drop outs coinciding with elevations of Θ_{XB} toward 90°. An example of the same behavior, but with the opposite pattern, in Figure 1b, shows an interval in which the pw activity was relatively quiet and Θ_{XB} was predomimantly near 90°, with bursts of signal when Θ_{XB} dropped to values around 30°. This correlation has yet to result in a physical explanation for itself, and is being studied intently as this report is written.

Foreshock mapping. A recent result obtained from Pioneer Venus Orbiter (PVO) magnetometer data in by G. K. Crawford, consisting of a comprehensive mapping of the Venus pw foreshock at two frequencies, 30 and 5.4 kHz, called attention to the lack of a comparable mapping of Earth's pw foreshock. Inspection of ISEE 3's 1983 trajectories suggested that a quite respectable similar mapping of a part of Earth's foreshock uniquely traversed by that satellite can be done with our data. Such a mapping would be less comprehensive than that of PVO spatially but far more complete spectrally because of the full range of channels of the ISEE 3 instrument. Furthermore, the ISEE 3 orbits cover sections of the foreshock that might be critical in defining some pw spectral boundaries within the foreshock that are hinted at in the PVO results and in earlier, very limited results from ISEE 1,2 data. We therefore embarked on a mapping project, using our CBSs, which

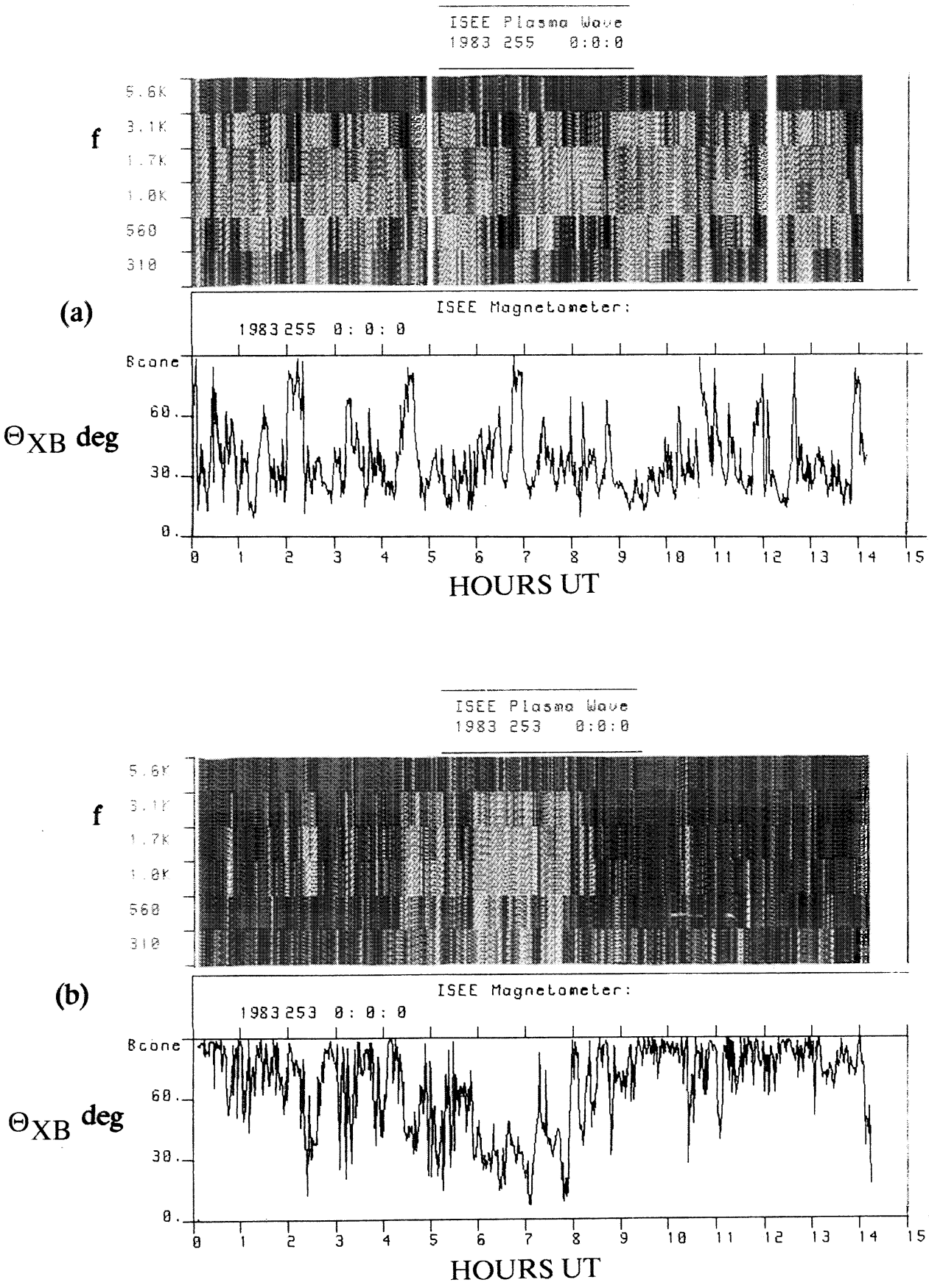

Figure 1. Two contrasting examples of plasma wave disappearance, (1a), and appearance, (1b) (color panels) correlated with high and low values of ambient magnetic field cone angle (B&W line plots).

is in progress with other funding as this report is written, and the subject of a proposal to NASA HQ.

Re-examination of pw measurements at the highest resolution. Attempts to understand apparently impulsive pw signals in the shock and post shock environments of G-Z and the earth led to careful examination of the records at the highest sampling rates and review of the original instrument calibrations. We clarified the seeming unreproducibility of sequential spectra, concluding that hitherto undifferentiated modes are present sporadically in the data, particularly in Earth's bow shock. As this report is prepared, proofs of the paper describing our results (listed second below) have been returned to AGU to await publication in JGR.

The following paper was published during the last quarter:

"The Quasiperpendicular Environment of Large Amplitude Magnetic Pulses in Earth's Quasiparallel Foreshock: ISEE 1 & 2 Observations," by Greenstadt, Moses, Coroniti, Farris, and Russell, [Greenstadt et al., *Geophys. Res. Lett., 20*, 1459, 1993].

The following paper, partially researched and during the last quarter, awaits printing:

"Plasma Waves Downstream of Weak Collisionless Shocks," by Coroniti, Greenstadt, Moses, Smith, and Tsurutani, [Coroniti et al., *J. Geeophys. Res., in press*, 1993.

RESULTS OF THE PROGRAM

The foregoing paragraphs summarize the results of final quarter of this investigation. The overall results of the project have been summarized periodically in preceding quarterly reports and will not be recapitulated here. The most comprehensive, complete, and authoritative roundup of the scientific studies conducted under this contract is contained in the 49 publications by one or more of the program's investigators, to be found in the peer-reviewed space plasma literature. We therefore close this report with an APPENDIX containing copies of the first pages of all the papers authored or coauthored at TRW, using or based on ISEE 3 pw data.

RECENT COOPERATIVE EFFORTS

In addition to the papers with direct TRW contributions, several other reports were published by outside (foreign) inves-

tigators incorporating ISEE 3 pw measurements, with acknowledgement, where coauthorship was not provided or necessary. Recent papers are listed below.

Tsutsui, M., R. J. Strangeway, B. T. Tsurutani, H. Matsumoto, J. L. Phillips, and M. Ashour-Abdalla, Wave mode identification of electrostatic noise observed with ISEE 3 in the deep tail boundary layer, *J. Geophys. Res., 96*, 14,065-14,073, 1991.

Achatz, Droege, Schlickeiser, and Wibberenz, Interplanetary Transport of Solar Cosmic Rays, *Proc. 22nd International Cosmic Ray Conference*, Dublin, Ireland, Vol. 3, 240-243, 1991. (Also *J. Geophys. Res., 98*, 13261, 1993)

Droege, Achatz, Schlickeiser, and Wibberenz, Hochfrequente Fluktuationen elektromagnetischer Felder im Sonnenwind und ihr Einfluss auf die Ausbreitung energetischer solarer Elektronen, presented to the 56th Physikertagung der Deutschen Physikalischen Gesellschaft, Berlin, Germany, March, 1992.

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