PLASMA ELECTRON AND CURRENT EXPERIMENT (PEACE) DATA CONTRIBUTIONS TO THE CLUSTER ACTIVE ARCHIVE (CAA)

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ABSTRACT

The data products provided to the ESA Cluster Active Archive (CAA) by the Plasma Electron And Current Experiment (PEACE) team are presented and explained in this paper. Calibration files and raw data files are made available to the CAA together with data processing software that can be utilised by the CAA team to generate science data files in the CEF2 format used by the CAA. For pitch angle and moments information the PEACE team will use data from supporting Cluster instruments to improve onboard data. Calibration studies will be done to improve accuracy so that the best possible calibrations are used for the Archive. Improvements to the calibrations and moments will be an ongoing process reflecting the 'Active' sense of the Archive.

1. INTRODUCTION

The Cluster quartet [1] were successfully launched in July and August 2000, since which time the mission has been operating well and without any major problems. The data and science returned from the mission has been unprecedented and have led to significant advances in our understanding of the magnetosphere. In response to the ongoing success of the mission, now in its 5th year of science operations, ESA has approved funding with which to create the Cluster Active Archive, which will house all data (raw and processed) from all teams in one convenient and easy to access source. It is expected that this will become the main source of Cluster data and the wider science community will be able to access data from each instrument in a common data format from this single source. The science user will also be able to retrieve calibrated data in scientific units. In response to this initiative from ESA, each of the instrument teams is required to provide the appropriate data to fill the Archive accordingly, under the management of ESA and the CAA.

With regard to the PEACE [2], [3] involvement in this activity, this paper sets out the progress made up until the launch of the CAA at the Cluster 5th Anniversary Symposium in September 2005, and the subsequent planned activities. The data products that are to be included in the CAA will represent a complete suite of data products ranging from Level 1 raw data directly from the instrument, to Level 3 processed data fully calibrated and in scientific units.

A brief outline of the instrumentation is given in the next section, followed by details of the data products that are in the first wave ingested into the Archive. In section 4, a discussion about the generation of moments is given, and finally a summary of the efforts already in place together with what will occur in the coming months.

2. INSTRUMENT DESCRIPTION

The PEACE instrument measures the three dimensional velocity distribution of electrons in a space plasma, for an energy range from a few electron-volts (eV) to about 26 keV, using two sensors per spacecraft; the High Energy Electron Analyser (HEEA) and the Low Energy Electron Analyser (LEEA). Each sensor has a 180 degree instantaneous field of view, subdivided into 12 sectors of 15 degrees. The instrument energy range is subdivided into 88 energy levels. The two sensors will typically operate across overlapping ranges, each of 60 levels, such that the full instrument range is covered by the sensor pair. The sensitivities of the two sensors differ so that the instrument dynamic range is sufficient to cover all plasmas encountered. Typically, the energy range is sampled 32 times during each spin, giving a spin phase angle resolution of 11.25 degrees. The two sensors on each spacecraft are placed on opposite sides viewing radially from the spacecraft so that they cover a complete angular range in ½ rotation (Fig. 1). The radial viewing minimises the access of secondary electrons and photoelectrons produced on the surface of the spacecraft into the aperture of the sensor. A full 3D electron distribution is measured by each sensor during each spin, and is measured for the overlap energy range only during each half spin. Spacecraft data rates do not allow transmission to the Earth of the full 3D data each spin.

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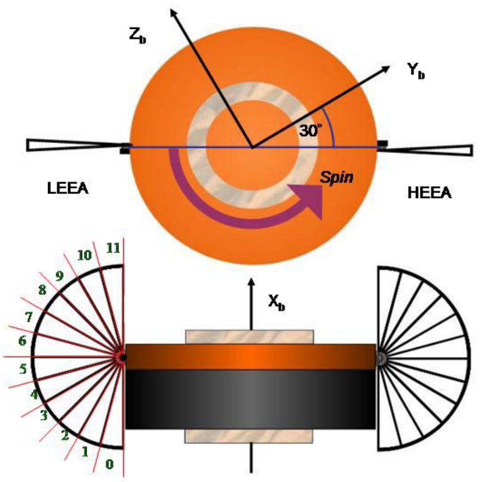

Figure 1. The physical deployment of the sensors on the spacecraft. The spacecraft body coordinate system is shown (X_b, Y_b, Z_b). The sensor numbering with respect to the spin axis is also indicated, e.g. zone 0 looks towards $-X_b$, and sees electrons with velocities roughly along the spin axis direction, $+X_b$. Cluster is orientated with $X_b \sim -Z_{GSE}$ in flight.

The LEEA sensor is designed to specialise in coverage of the very lowest electron energies (< 10 eV) but is also capable of covering the full energy range up to ~26 keV. Apart from precautions to minimise the detection of unwanted low energy photoelectrons, LEEA has a geometric factor appropriate for the higher fluxes usually found at lower energies. The High Energy Electron Analyser (HEEA) has a larger geometric factor which extends the dynamic range of the combination of sensors and can also be operated over the full energy range from 0.6 eV to 26.5 keV. The energy levels are linearly spaced below 10eV and logarithmically spaced above. A full description of the instrumentation is given in [2], [3].

3. PEACE DATA PRODUCTS FOR THE ARCHIVE

The PEACE team have provided the CAA team with full access to the PEACE Database at MSSL and the database export software. The CAA are able to locally generate the calibrated scientific data files from the raw data for inclusion in the Archive. The software used by the CAA to complete this process is produced at MSSL. The software writes CAA compliant CEF2 format files containing the calibrated science data and uses PEACE raw data and calibration files as its input. Details of the data products are given below.

Each of the products listed in the following sections can be returned in 4 different units.

- *Cnts* – Count rate data from the spacecraft
- *PSD* – Phase Space Density
- *DNFlux* – Differential Number Flux
- *DEFlux* – Differential Energy Flux

A separate data product is generated for each sensor (LEEA and HEEA), and for each of the four spacecraft (C1-C4).

3.1 Three Dimensional Data Products

(a) 3DFX – Full High Resolution 3-Dimensional Distribution

This CAA data product amalgamates data from general high resolution data products (3DF, 3DX) produced by PEACE into a single file. 3DFX is the best angle-energy resolution 3D data product available, usually of spin resolution and from one or both sensors (HEEA and LEEA). Typically the data is only available in Burst Mode (BM). A sample of the data available is shown in Figure 2.

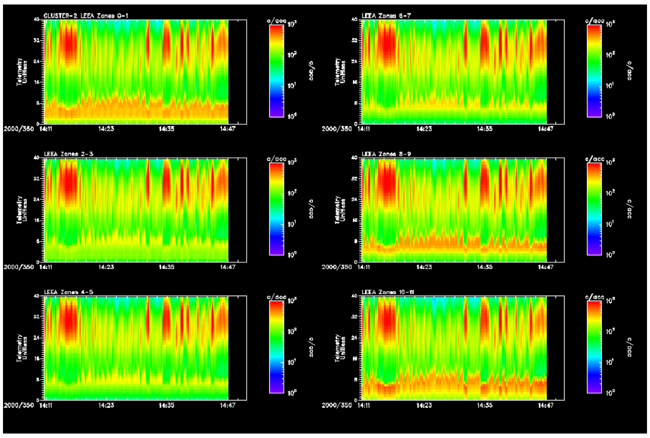

Figure 2. 3DX data from the LEEA sensor

(b) 3DR – Standard Reduced Resolution 3-Dimensional Distribution

Data returned in this format has been reduced by a factor of 8 from the originally measured resolution. The decimation is distributed over energy, polar angle and azimuth. In Normal Mode (NM) spacecraft telemetry 3DR data cannot be returned every spin. On spacecraft 2, telemetry reallocation from CIS has allowed 3DR data to be returned almost every spin, whilst for spacecraft 4 telemetry reallocation from EDI allows the return to be one every 3 spins. On spacecrafts 1 and 3, 3DR distributions are transmitted much less frequently.

(c) LER – Low Energy Reduced Resolution

These data usually only contain information from the LEEA sensor, and in particular the lowest energy levels. This product was designed to show sub 10eV distributions to complement the onboard moments and to monitor the spacecraft potential when ASPOC is running.

3.2 Pitch Angle Data Products

(a) SPINPAD – Pitch Angle Distributions

This product is produced using the data from PAD (see next section) computed onboard the spacecraft but reorganised in a conventional format. No additional processing of the data is performed and no account is taken of any errors that may result from a rapidly changing magnetic field (see PAD description below). A sample data plot of the SPINPAD data is shown in Figure 3. On the ground, once the calibrated magnetic field data are received corrected pitch angles can be produced. CAA files are expected to include ground corrected pitch angle data.

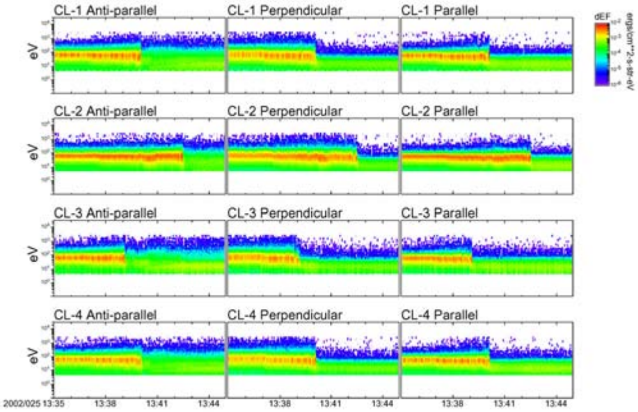

Figure 3. SPINPAD data from C1-C4 in anti-parallel, perpendicular and parallel pitch angle from LEEA and HEEA sensors

(b) PAD – On Board Pitch Angle Data Product

The Inter-Experiment Link (IEL) with FGM provides an estimation of the magnetic field direction onboard the spacecraft. Figure 4 illustrates how the pitch angle data are collected by the instrument. Data are returned from the shaded area in both LEEA and HEEA sensors when the magnetic field lies in the sensor aperture plane which happens once each half spin. The onboard magnetic field direction is not perfectly calibrated and as used by PEACE lags the true field direction by up to one spin. If the field is changing rapidly PEACE may not give a reliable selection of the magnetic field direction. This is not taken into account in the PAD data product (or in SPINPAD above). As with SPINPAD, the corrected pitch angles are included from the calibrated magnetic field directions in the CAA. From Figure 4, it is clear that the pitch angle data can be assembled from each of the sensors, LEEA and HEEA per spin, or half spin in the energy overlap region.

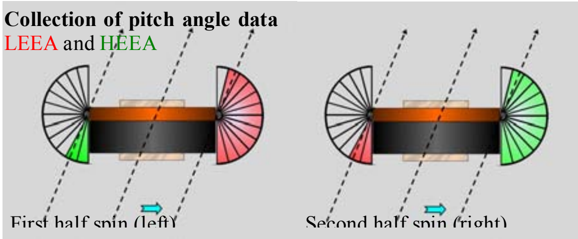

Figure 4. Collection of pitch angle data from the LEEA and HEEA sensors. Dashed lines are magnetic field data in the aperture plane retrieved from FGM the onboard via the Inter-experimental Link.

3.3 NOI

These data are gathered during MCP testing to monitor the MCP performance, and will primarily be used by those wishing to verify PEACE MCP gain estimates and not for mainstream science studies. Both sensors are contained in this data product.

4. DETERMINATION OF MOMENTS

There are several ways to calculate moments from the PEACE data depending on the situation. These are detailed below. Accurate moments can only be achieved when accurate instrument calibration is used and the spacecraft potential related distortions to the measured 3D distribution function are minimal or have been corrected, and spacecraft electrons are excluded from the integration.

4.1 Moments calculated on Ground

On the ground, the moments calculations are fine-tuned to produce the most accurate moments from the 3D distributions. The best available calibrations are used, and photoelectron contamination and perturbations of spacecraft potential are corrected. Figure 5 shows a comparison of the 'best' moments to the PEACE version 3 Prime Parameter (PP) 'improved' onboard moments that reside in the PP database (see next section). It is clear that the ground calculations provide better quality moments as the data have been correctly handled with respect to all other variables. This process cannot be fully automated as there are significant caveats which must be applied depending on the plasma environment spacecraft operation. The production of high quality moments requires an experienced scientist to evaluate individual cases to verify the data and the calculations. For this reason, this process is time consuming and labour-intensive and population of the CAA with such moments has not yet begun.

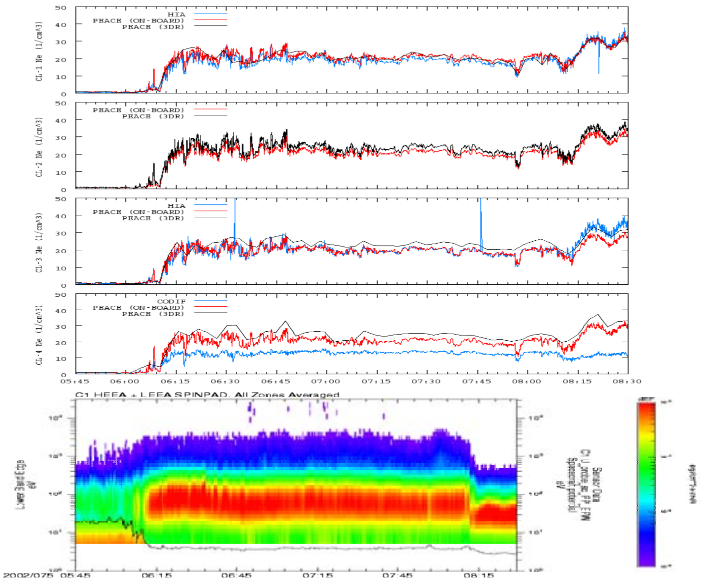

Figure 5. ‘Best moments’ density ground calculations using based on 3DR data, with the most up to date calibrations and potential correction. Compare with PEACE version 3 Prime Parameters ‘improved onboard moments’ and CIS Prime Parameters (not C2).

4.2 CSDS Prime Parameter (PP)

The CSDS PP onboard database is steadily being updated to replace ‘old’ onboard moments with PEACE version 3 PP ‘improved’ onboard moments data. The ‘old’ moments had no correction for photoelectron contamination, and the geometric factor used in the calibration was not always accurate. This led to some of the moments being inaccurate or unreliable. To correct this, ‘improved’ moments have been recalculated taking better account of photoelectrons and also improving the calibration, however corrections for acceleration of electrons by spacecraft potential are not performed. It is important to note that the CSDS PP database contains some ‘old’ moments. The improved PP data are gradually replacing the ‘old’ PP data. The CAA will incorporate the PP data and the user must take care to differentiate between ‘old’ and ‘new’ PEACE PP data.

4.3 Onboard Moments

Onboard calculations of the moments are made for each sensor for a restricted energy range every spin, excluding sub-10eV electrons (this avoids contamination from spacecraft electrons, when ASPOC is active). These data have not been corrected for the variations in spacecraft potential and have minimal correction for photoelectrons at energies >10eV. These are the data on which CSDS PP are based and are included in the Archive for completeness.

The task of calculating accurate onboard moments is a difficult problem to undertake for several reasons. Firstly, onboard calibrations cannot easily be kept accurate and up to date. Secondly, the onboard moments integration uses the measured distribution, 3DR, data product, but makes no correction for spacecraft potential effects. Resulting errors are most notable for low energy electrons close to the spacecraft potential where the electrons can be accelerated significantly. Thirdly, contamination of the measured distributions from spacecraft electrons in not corrected onboard. Having the ASPOC instrument switched on reduces this effect by reducing the spacecraft potential below 10eV, but ASPOC is not on continuously.

5. PROGRESS AND FUTURE

The data products that have been ingested by the CAA so far are the 3DR reduced resolution 3-D distributions, the PAD data measured onboard the spacecraft, the LER low energy distributions and the NOI data. High quality SPINPAD pitch angle data and high quality moments will follow and are being tackled last as they are more challenging, as explained above. There have been significant hurdles to overcome, on file management and producing files compliant to the CEF2 format, which have consumed much of the efforts of the Team thus far. However, now that many of these issues have been resolved, together with the recent appointment of an ESA supported CAA individual, progress should be more forthcoming.

The most significant problems to be addressed are:

- Finish generating the infrastructure to produce data files for SPINPAD and moments.
- Calibration studies to improve calibration knowledge to be applied to the data products and generation of moments.
- Populate the archive with the best possible moments, either from the high resolution 3D distributions, when available or other approaches when 3D data are not available.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

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