SEMEP

Search for ElectroMagnetic Earthquake Precursors

Preparation of COSMOS-900 observational data bank for space and spectral analysis and development the relevant software

Deliverable 4.2

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1 INTRODUCTION

1.1 Purpose

This document provides a description of the activities and results resulting from Task T4.2 of work package 4 of the SEMEP project.

1.2 Aims and Objectives of work package 4

WP4 focuses on the investigation of the particle environment of the ionosphere using data from the COSMOS-900 and DEMETER satellites. The objectives of this analysis are:

1. To determine whether or not the characteristic oscillations observed in ionospheric plasma are related to seismic activity.

2. If the answer to the first question is positive, then to determine the main characteristics of these oscillations, their extension in space and time, and if they are magnetically controlled.

Two types of analysis were planned to be performed:

- statistical analysis
- spectral analysis.

The following set of tasks has been identified:

T4.1. Obtain the DEMETER plasma dataset that contains measurements of the electron/ion densities (Ne, Ni) and electron/ion temperatures (Te, Ti). The quality of these datasets will be assessed to determine their appropriateness for analysis to be performed.

T4.2. Preparation and validation of the set of COSMOS-900 plasma parameters and their formatting into an observational data bank for spatial and spectral analysis and development the relevant software.

T4.3. Development the data processing methods for the analysis of the plasma parameters resulting from tasks 4.1 and 4.2 analysis and their correlation with seismic activity.

T4.3. Interpretation of the results.

2 COSMOS-900 AND EXPERIMENTAL DATA

2.1 Satellite COSMOS-900

Cosmos-900 was launched on April 30, 1977 into circular polar orbit with 523 km apogee, 508 km perigee and inclination 82°. It operated for 2.5 years until September 11, 1979. During this period its height was continuously decreased to around 330 km by the end of the mission.

The ion density *Ni* was measured by a spherical ion trap working in floating mode that complements measurements of *Ni* and ion temperature *T*i by a retarding potential analyzer (RPA) PL-40A. Time resolution of these measurements depends on the mode of onboard memory operation (see below). Measurements of the electron temperature *Te* come from the r.f.-temperature probe DET (a modified Langmuir probe, known as a rectification probe). Its operating cycle provides measurements of *Te* every 4 seconds in all onboard memory modes.

The output voltages for *Ni* and *Te* were fed to analog channels - 5 for *Ni* (increasing the sampling rate) and 1 for *Te* and were stored using the onboard memory. Depending upon the spacecraft operational mode, the onboard memory was capable of storing 5 min in mode ZAP-1, 30 min in ZAP-2, 120 min in ZAP-3 and 1920 min in ZAP-4 with sampling rates of each channel 0.01, 0.08, 0.32 and 5.12 s respectively. After radio link transmission to ground stations the data were

stored on magnetic tapes which were delivered to IKI where they were converted from the format used by the ground station to a more common standard PC tape format. The data for RPA V.A.- curves were transmitted in ZAP-2 and ZAP-3 modes (30 and 120 min). To save the data in early 1980s they were rewritten first to DC2120 mini tapes and then later in 1990s to CD ROM. Unfortunately only the data collected in ZAP-4 mode are available. Thus the COSMOS-900 data sets contain *Ni* with a sampling rate of 5.12/5 (1.024) s and *Te* sampled once (or occasionally twice) in each 5.12 s frame.

2.2 COSMOS-900 data sets

Set of initial raw TM data **K900_ISX**

This set consists of the raw telemetry data stored in ZAP-4 mode obtained from the ground stations and rewritten to CD-ROM. There are 313 data files in this data set, each file containing up to 16 continuous orbits.

Physical parameters data – set of data **OVF**

Of the 313 original data files 298 could be processed, decoding the raw telemetry data into physical parameters forming the set of Cosmos-900 OVF data set. This processing was made using Turbo Pascal program code **K900_CD3.pas** . Since only the ZAP-4 dataset is available, there are no RPA v.a. curves. Three parameters, namely Ni, Te, and the spacecraft potential *Usc* have been recovered from these datasets. Ti is not available because v.a. curves, actually the ion energy spectra, were missing.

These files require "cleaning". This involves the removal of erroneous data points whose value have been corrupted by numerous errors of different types such as satellite hardware effects, transmission, multiple storing, and copying.

Preliminary cleaned data - set of data CD_K900 have been performed in late 1990s.

Preliminary cleaning of the Cosmos-900 data was done in late 1990s to form a "clean data" set CD-K900. At that time, however, this process was not fully completed and not all files were properly cleaned.

	Name of data set	N of files	Size, MB	File format, state
Sept 11, 1979 end of operation Rewritten to CD in early 1980s	K900_ISX	313	139	Ground station format
Early 1990s	OVF	298	35.3	CD-K900Type
Late 1990s	CD-K900	278 + 16 files with errors*	32.4 + 0.5	CD-K900Type, partially cleaned.

2.3 Planning of work for Task 4.2

Although the quantity of Cosmos-900 data is essentially less when compared with DEMETER, similar methodologies were adopted for the validation and reformatting of the two datasets:

1. Work to be done: statistical and spectral analysis of plasma parameters.

This analysis requires data in the form of time series **PARi(Time)** for each plasma parameter.

2. The analysis requires multiple runs over whole data files.

3. In contrast to the DEMETER data sets the Cosmos-900 data contain only plasma parameters. Thus the COSMOS-900 data should be augmented with orbital parameters giving the spacecraft location and parameters indicating geophysical and solar activity.

Therefore a decision has been made to create the "Cosmos-900 experimental data bank" (K900 EDB) constructed using the same principles described in section 2.1 of deliverable 4.1 with the additional requirement that each data point should be accompanied by orbital and solar-geophysical data.

3 OBJECTIVE AND STEPS OF TASK T4.2

In Task T4.2 the following steps were carried out.

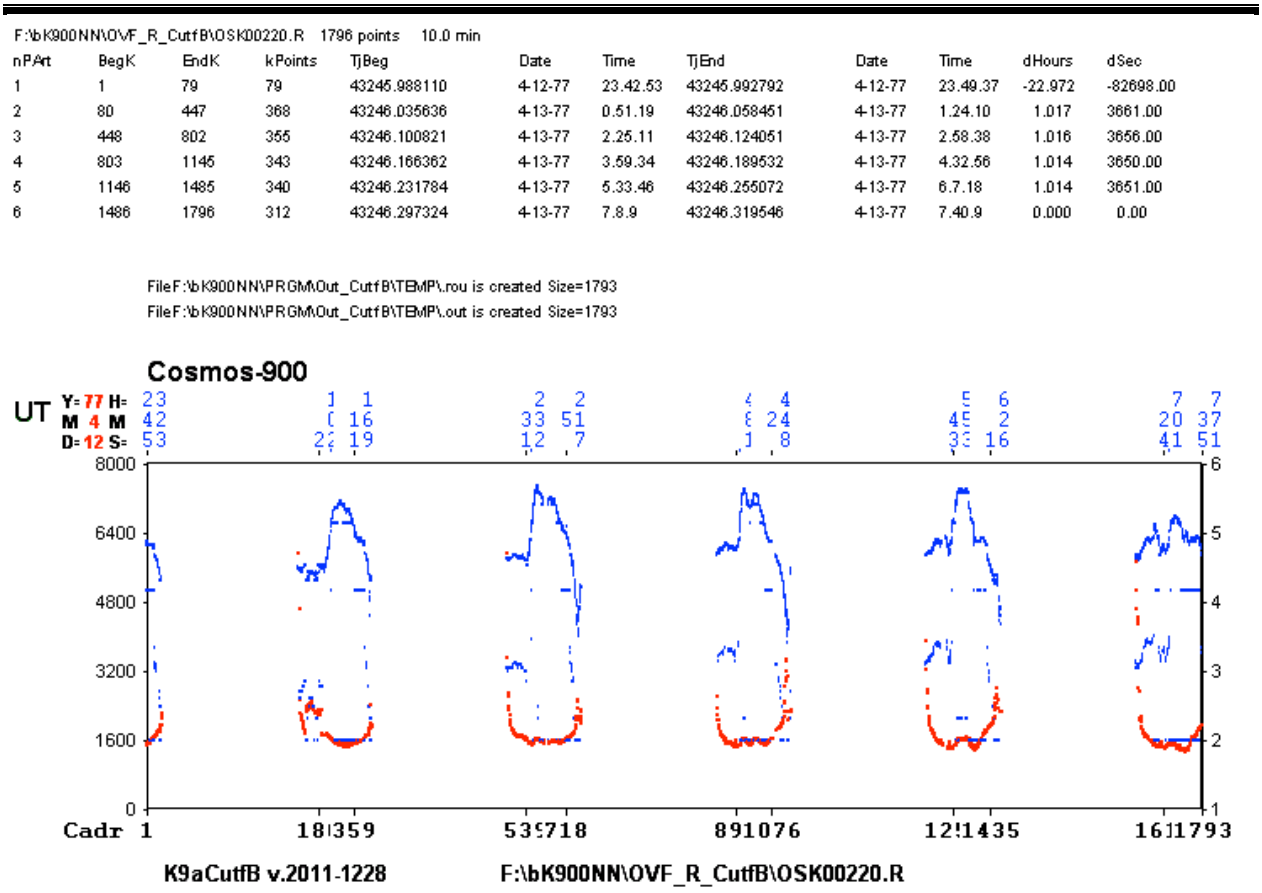
1. Analyze the time continuity of the OVF files and extract sections which possess a continuous, uninterrupted time series – create OVFd (OVF divided) set of files.
2. Clean OVFd files – analyze errors and correct them – create OVFc (OVF cleaned) set of files.
3. Develop a software program for formatting the "Cosmos-900 experimental data bank" K900_EDB such that it contains a series of continuous, sequential time records comprising of the following parameters
   - plasma parameters Ni,Te, Usc,
   - orbital data and geomagnetic parameters (lat, long, alt, L, Invlat, LMT, MLT etc.),
   - solar and geomagnetic activity parameters (Kp, SumKp, DST, F10.7)
4. Create K900_EDB.

4 OUTPUT OF TASK T4.2

4.1 Analyze time continuity of OVF files and create OVFd set of files – OVFd data bank

Program **K9Cutf** was developed to read the OVF files, analyze their time structure and extract sets of continuous time ordered records and write them out as separate files with uninterrupted time.

An example of a file containing a number of continuous sections of data separated by large time gaps is shown in Fig1.



F:\bK900NN\OVF_R_CutfB\OSK00220.R 1796 points 10.0 min

nPArt	BegK	EndK	kPoints	TjBeg	Date	Time	TjEnd	Date	Time	dHours	dSec
1	1	79	79	43245.988110	4-12-77	23.42.53	43245.992792	4-12-77	23.49.37	-22.972	-82698.00
2	80	447	368	43246.035636	4-13-77	0.51.19	43246.058451	4-13-77	1.24.10	1.017	3661.00
3	448	802	355	43246.100821	4-13-77	2.25.11	43246.124051	4-13-77	2.58.38	1.016	3656.00
4	803	1145	343	43246.166362	4-13-77	3.59.34	43246.189532	4-13-77	4.32.56	1.014	3650.00
5	1146	1485	340	43246.231784	4-13-77	5.33.46	43246.255072	4-13-77	6.7.18	1.014	3651.00
6	1486	1796	312	43246.297324	4-13-77	7.8.9	43246.319546	4-13-77	7.40.9	0.000	0.00

FileF:\bK900NN\PRGM\Out_CutfB\TEMP\.rou is created Size=1793
FileF:\bK900NN\PRGM\Out_CutfB\TEMP\.out is created Size=1793

Fig. 1 Example of the output from the program **K9Cutf**. File OSK00220.R consists of 6 continuous data segments separated by about 1 hour gaps – see parameter dHours in the table at the top.

The data in the input file OSK00220.R was rewritten into 6 files OSK00220.v00, OSK00220.v01 … OSK00220.v05.

Fig 2. Shows an example of a file containing data with a few incorrectly time tagged data points (upper panel) and the result of removing these bad points (lower panel).

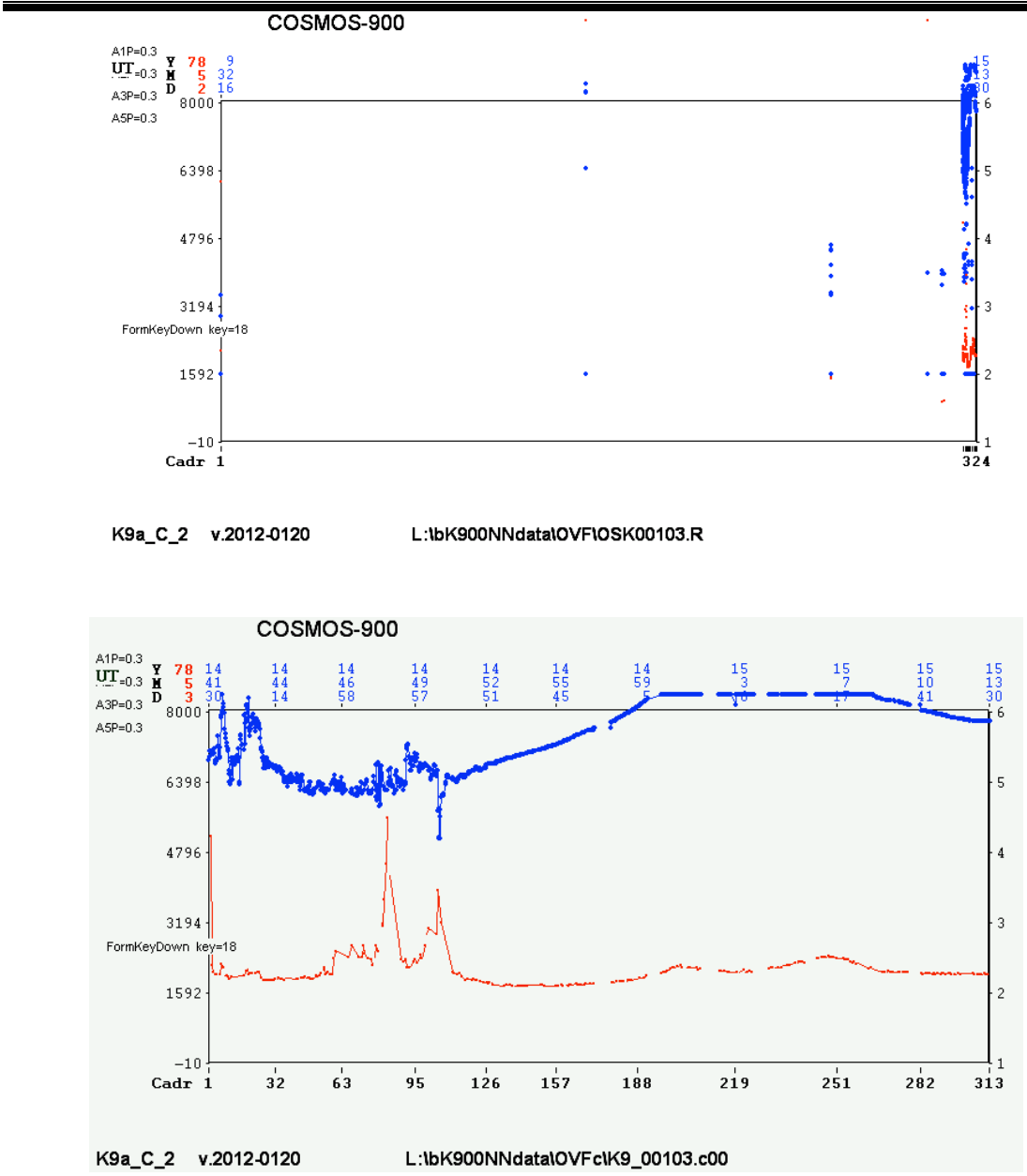


Fig. 2 Upper panel - file OSK0011103.R is drawn as function of time. The first few first points have errors associated with their time tags. Lower panel – the same file after removing these errors.

4.2 Clean OVFd files – analyze errors and correct them – create OVFc (OVF cleaned) set of files.

Program **K9Cutf** corrects only errors in time format. It can not correct "byte errors" - errors in the values of the parameters caused by the onboard storage, downlink, or multiple copying of parameters from the output of the onboard electronic instruments to the OVFd data bank. These errors are visible on plots as outliers as indicated in Fig 3.

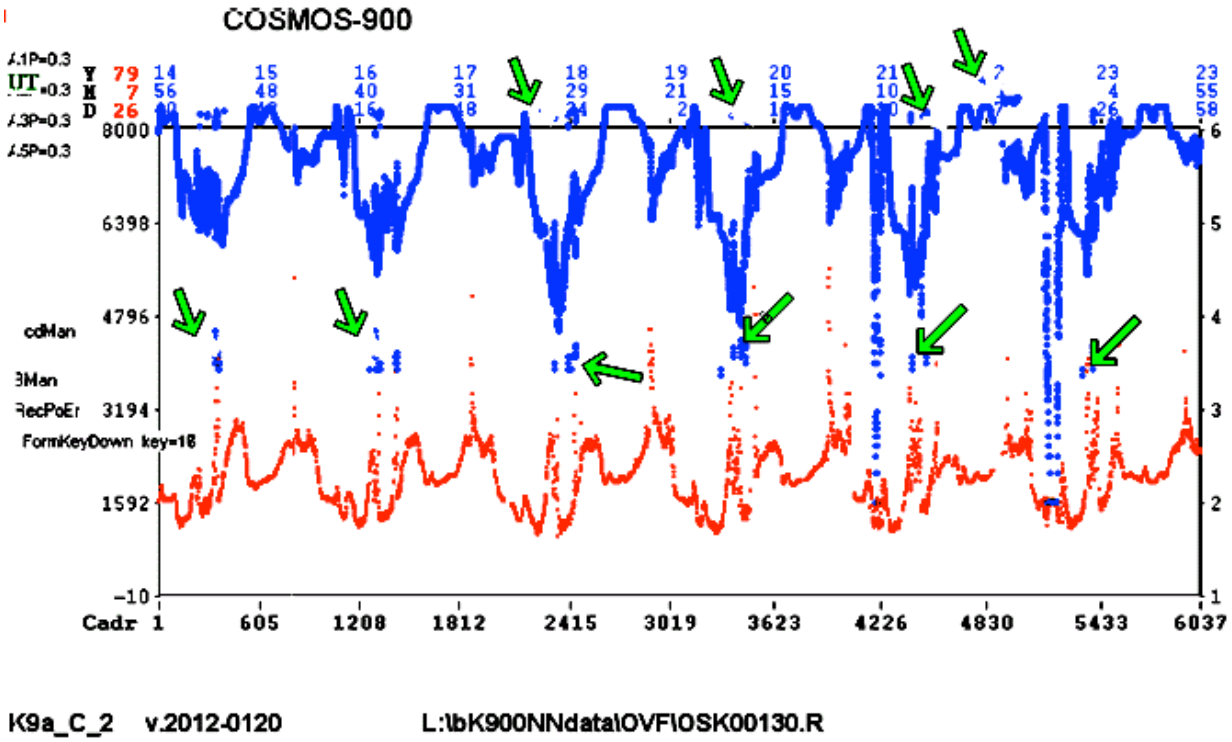
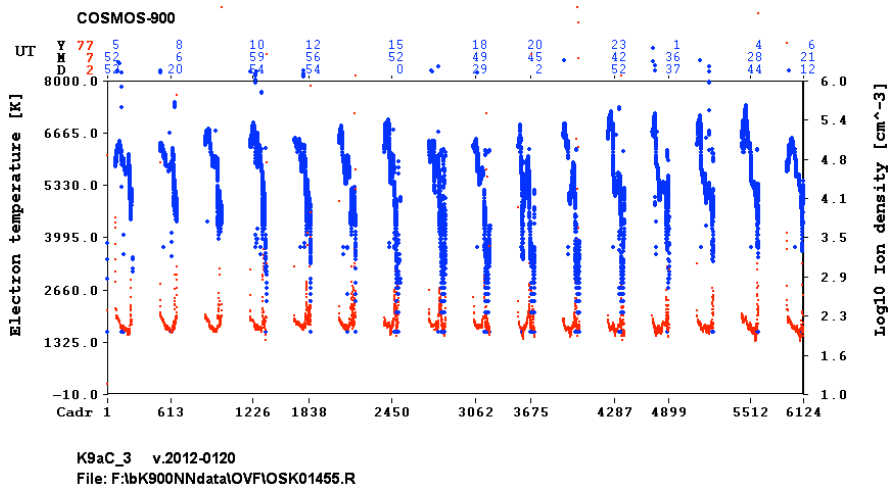


Fig. 3 Example of outliers ("byte errors"). Wrong readings are shown by green arrows (not all errors are indicated).

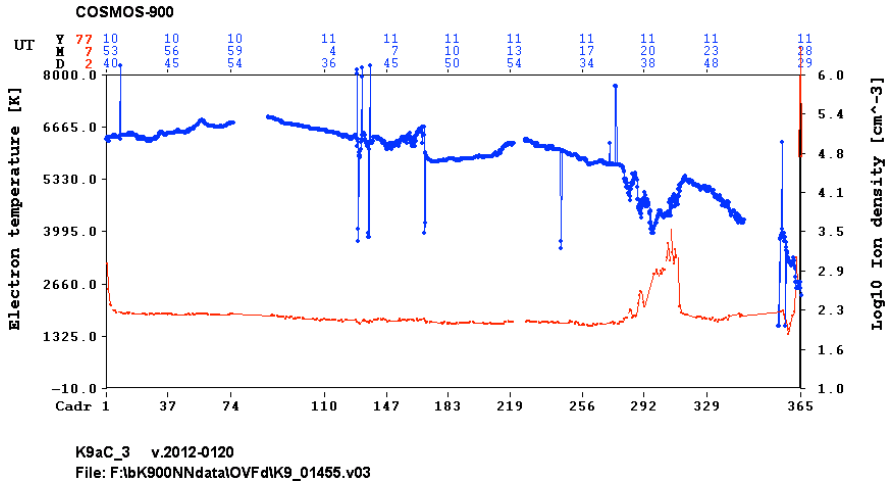
To remove these errors a special interactive program **K9aC** has been developed. It enables an operator to mark bad points, and then visually validate the data set before preparing the output files with the selected bad points removed.

The whole sequence of OVF file processing is shown below.

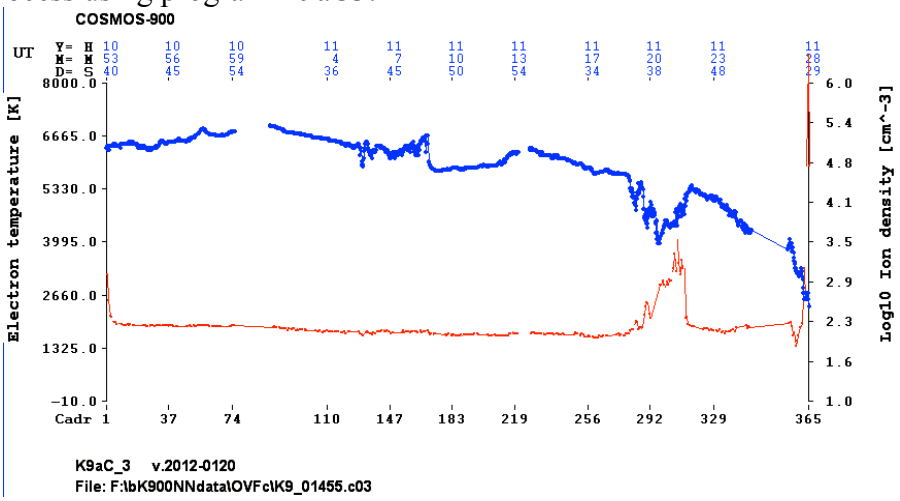
Original OVF file:



After applying **K9Cutf** 15 files are output, an example of one of these files is shown below.



After cleaning process using program K9aC3:



OVFc data bank has been created. Only a few files are not included as they require special treatment. Presently the OVFc data bank includes 1566 files.

4.3 Develop software program for producing "Cosmos-900 experimental data bank" K900_EDB

MBK900m program has been developed. For each of the cleaned data file from the OVFc set, this program prepares corresponding K900_EDB file in which each experimental (measured) point is accompanied by the orbital and solar-geophysical data. The program **MBK900m,** in addition to handling plasma parameters for "measured" point *Ni*, *Te* and *Usc,* contains a special module to calculate the orbital and solar and geomagnetic activity parameters (Kp, SumKp, DST, F10.7). The program:

- reads data "points" from an OVFc file,
- calculates orbital and geophysical parameters by calling orbital module **ORP** for given time Tj (for each "point"),
- calls geomagnetic activity module,
- forms bank-type record (for each "point") and
- writes this record into final output file.

Orbital and geophysical data.

The module **ORP** used to calculate the orbital and geophysical parameters is based on a complex of programs **OR** developed by the author and used during the data processing from many Russian satellites. It calculates about 70 parameters (like well known program CADR by Galperin and Zinin). In contrast to CADR the **OR** programs were specially designed for automated data processing with only one input parameter – time. To get these data the calling routine should contain only one line: "call ORP(Tj), where Tj is MJD time (Modified Julian Date).

This is achieved by the following features of **OR** package.

- the whole OR package uses a continuous time scale Tj ,
- calculation is made for the whole period (1-2 orbital periods) encompassing the requested time Tj,
- calculation is made with adjustable time step to ensure reliable interpolation,
- results of calculation are always present in the memory,

Geomagnetic activity module contains a pre-calculated set of required solar and geomagnetic activity parameters stored in the form of indexed multidimensional array written in the form of external file. This data is read from a file and stored in memory until required, resulting if comparatively fast calculations.

"Cosmos-900 experimental data bank" K900_EDB

Using **MBK900m** program the Cosmos-900 experimental data bank (K900_EDB) has been created in the form of a set of files with continuous time, one file can cover up to 20 satellite orbits. Presently it includes 1565 files.

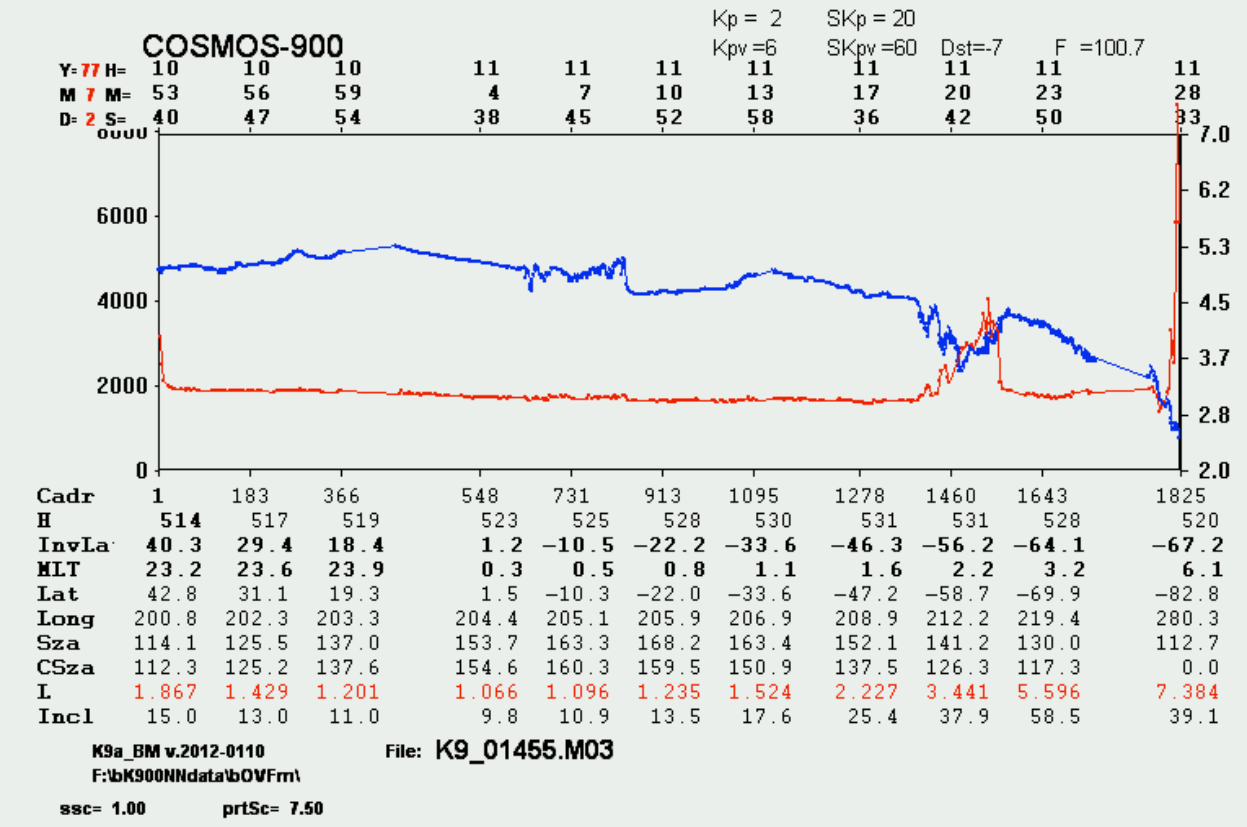
4.4 Develop software program for visualization of K900_EDB files

The program **K9a_BM** has been developed to

- allow selection of any file from the bOVFm bank,
- plot the data parameters and add useful orbital, geomagnetic and solar activity parameters,
- prepares protocol file of drawn part in text mode (creates .TXT file),
- select and data from equatorial latitudes (latitude ≤ 40°),
- writes out equatorial portions of the file in the same format (can be handled in the same way as initial file,
- has built-in "cadr-microscope" ability to select visually any portion of the plot and redraw only selected portion in expanded form.

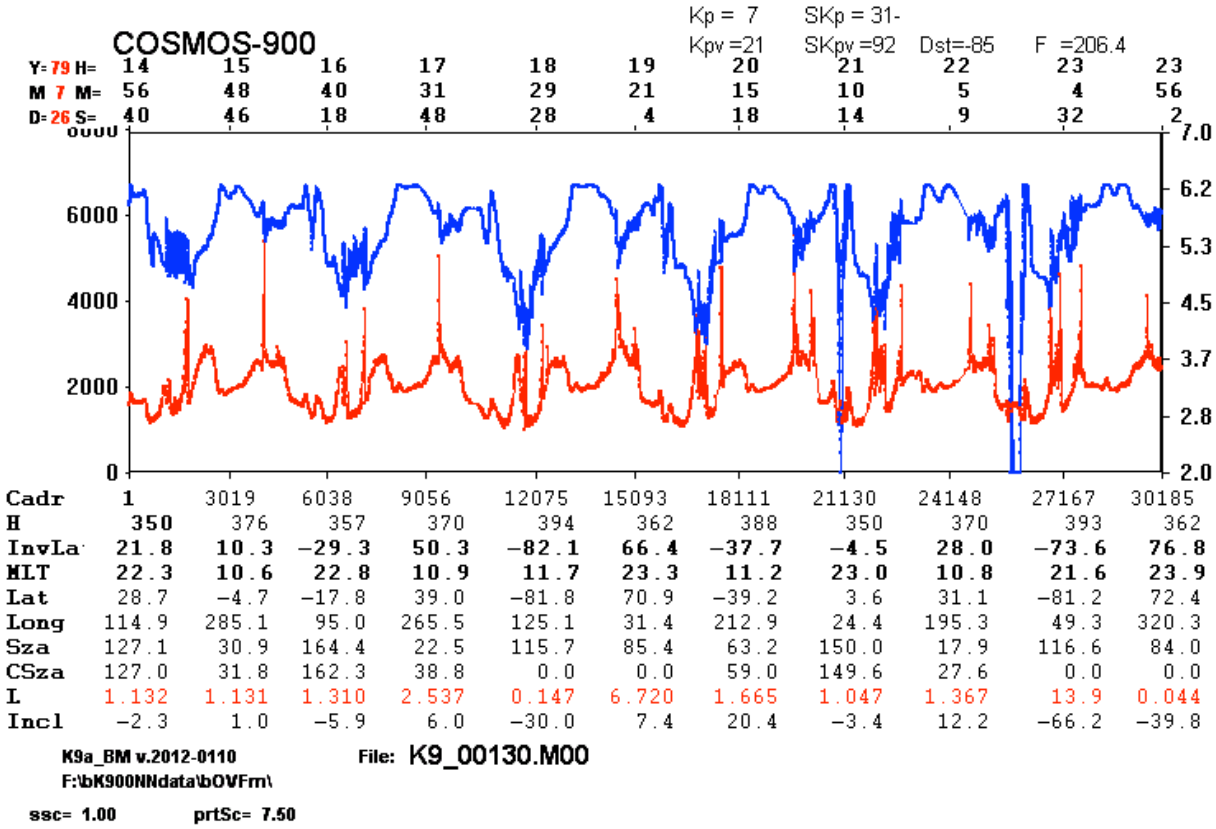
Below are some examples of the output of the program.

Example 1 of K900_EDB file drawn by program **K9aBm** is shown below.

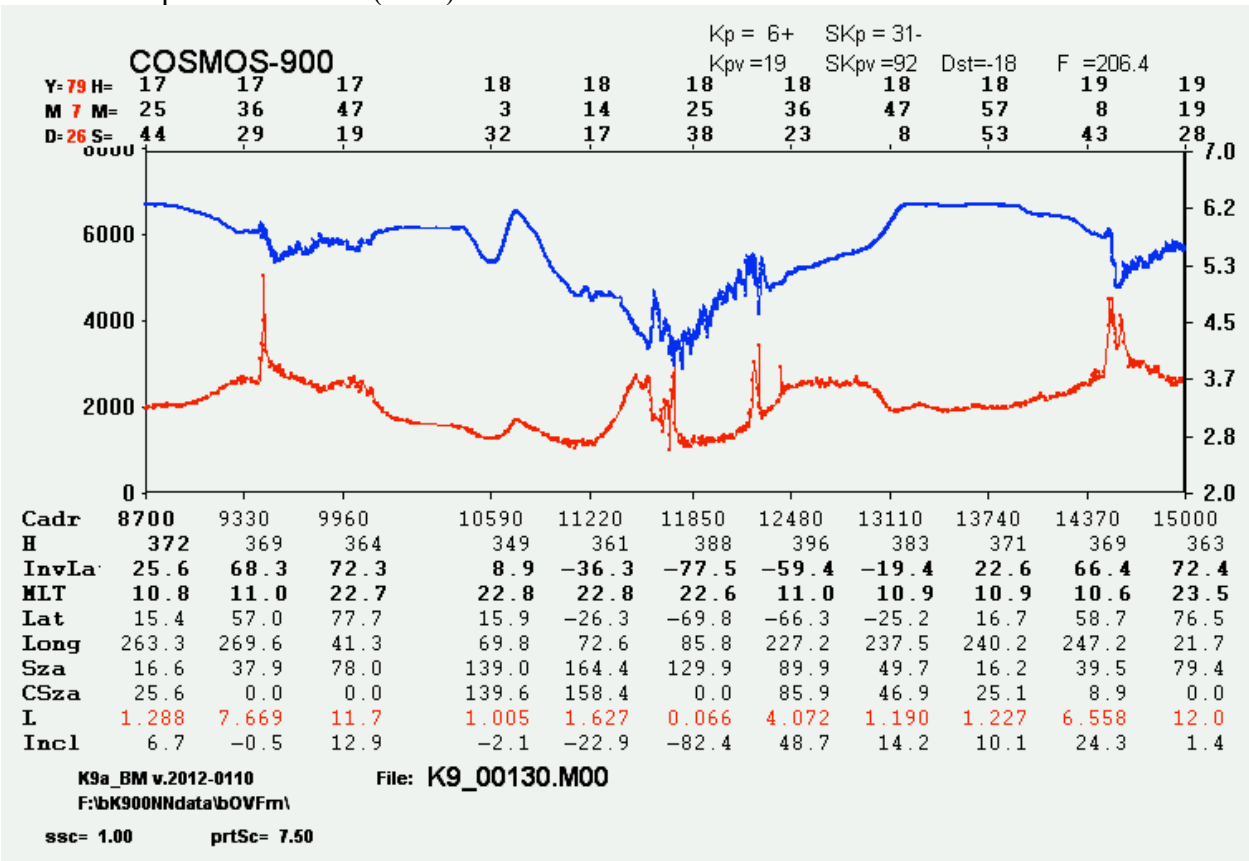


Example 2 of K900_EDB file drawn by program **K9aBm** – illustration 0f "cadr-microscope" feature.

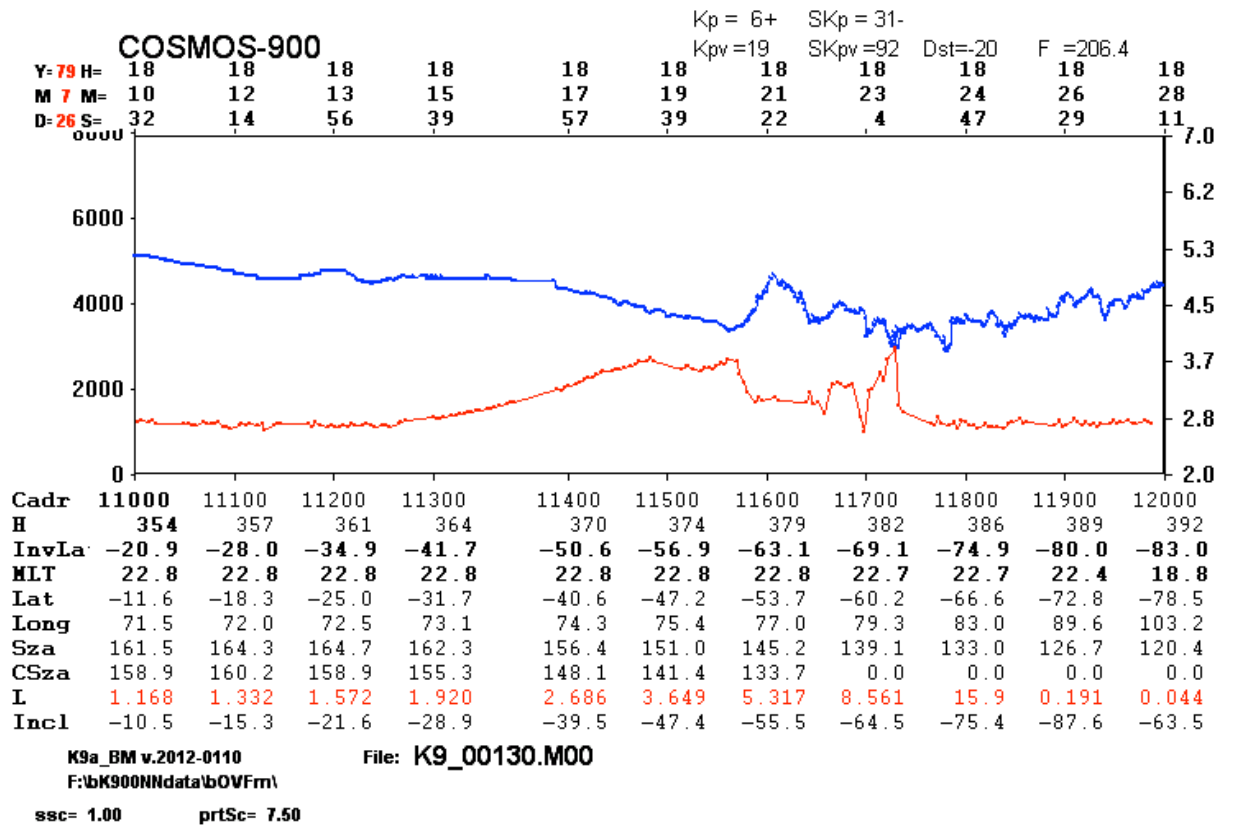
Whole file. Frames (Cadr) 1 – 30185.



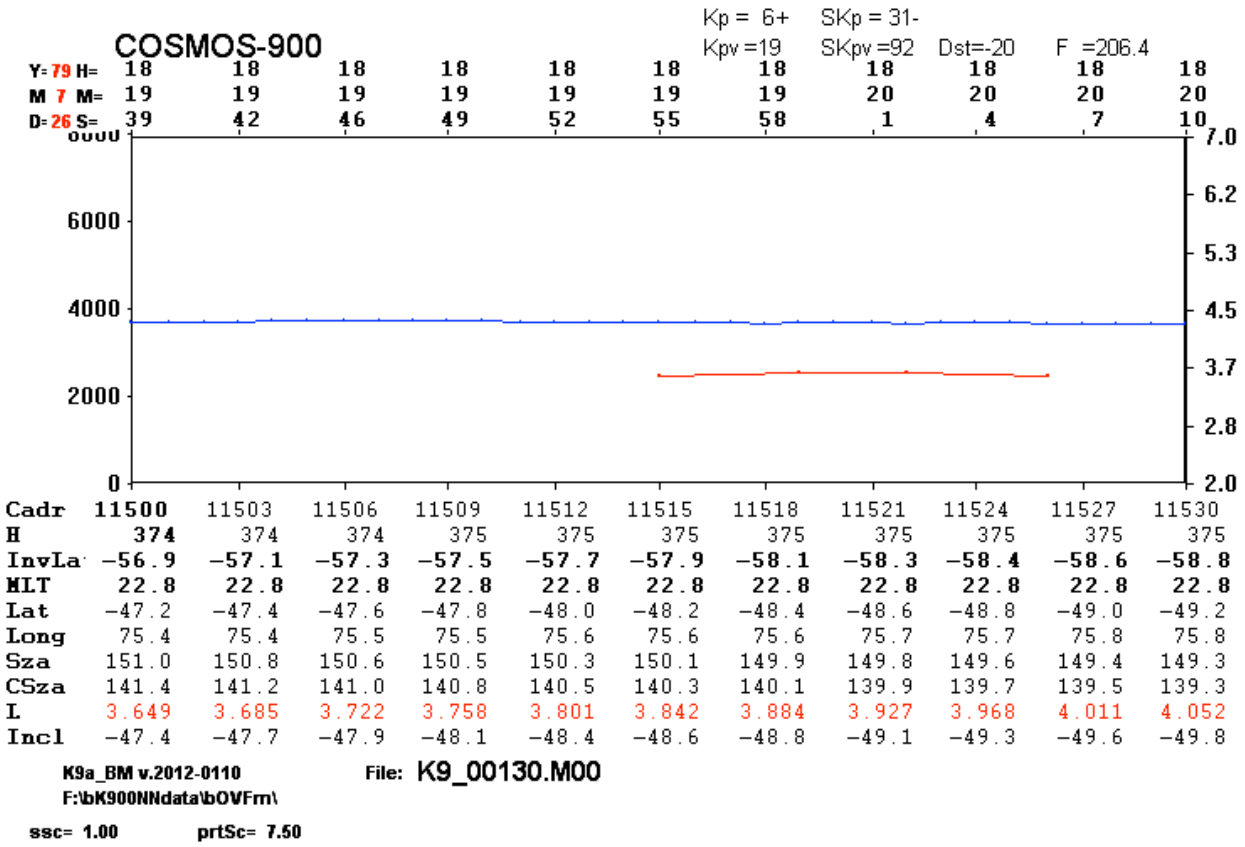
Same file expanded. Frames (Cadr) 7000 – 15000.



Same file expanded in time. Frames (Cadr) 11000 – 12000



The same file expanded further. Frames (Cadr) 11500 – 11530



5 ACCESS TO DATA

1. IKI is not planning to put the Cosmos-900 and DMT data banks obtained in the process of executing the SEMEP project into open public access as this action requires a great amount of extra work and time consuming resources to prepare technical documentation (description, manuals etc.).
2. As next step after completion the SEMEP project a catalogue of the available data files will be prepared. The catalogue will include list of available files with ΔTime, ΔLat and ΔLon intervals covered.
3. The catalogue of the available data files after completion will be available by email request to Dr. Valeriy V. Afonin vvafonin@iki.rssi.ru .
4. Presently any "products" of this work (selections of the data in digital, text or visual form including wavelet spectra) can be obtained by email request to Dr. Valeriy V. Afonin vvafonin@iki.rssi.ru .
5. We plan to develop search_instrument for DEMETER data similar to the described in Delivarable 4.3 search-instrument for COSMOS-900.
6. We are looking into methods for making this data and analysis tools easily available to the science community, probably via a dedicated web site.

6 SUMMARY

During this task, the plasma data from the COSMOS-900 (ZAP-4 mode) have been reprocessed, cleaned by removing spurious data points, validated, and written into the COSMOS-900 Experimental Data Bank. This data set is now suitable for use within the SEMEP project to analyse any plasma anomalies observed in the ionosphere that may be induced by strong seismic activity. Within the consortium, the data are available upon email request to Dr. V. Afonin.