PRediction Of Geospace Radiation Environment and Solar wind parameterS

Work Package 7
Fusion of forecasting tools

Deliverable 7.2
Electron populations in the inner magnetosphere

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Document Change Record

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Contents

Summary

This paragraph provides a summary of the problem and results (an abstract).

It is a well known fact that the fluxes of electrons within the inner magnetosphere, and especially the radiation belts, may vary significantly as a result of changes in the local geospace environment. The forecast of periods of expected high fluxes is vital to the operations of satellites whose orbits lie close to or pass through the radiation belts. Importantly, this includes Geostationary Orbit, which lies on the edge of the outer radiation belt and is home to many of the satellites that provide the infrastructure required for life in todays world.

The occurrence of high fluxes of energetic electrons can cause problems for our satellite infrastructure and the companies that operate them due to internal of surface charging effects. These problems may vary from the rescheduling of manoeuvres and the patching/reprogramming of operations to the temporary or permanent loss of critical operational systems resulting in loss of service or even loss of the satellite itself.

This report outlines the work performed by the PROGRESS team to develop and improve models of the electron environment of the inner magnetosphere and provides details of the methods developed to provide access to the results produced.

1 Introduction

The first paragraph should describe the context of the report, i.e. where it fits in with the other deliverables/work packages.

The aim of Work Package 7 is to collect the results from the various models developed within PROGRESS and presents their results via the project web site. The objective of Task 7.2, is to provide the user with a view of the electron populations within the inner magnetosphere. This data comes from models that have been either developed or significantly improved as a result of activity within the PROGRESS project.

Data regarding the lower (keV) energy electron populations comes from the IMPTAM

model that has undergone substantial revisions and improvements as a result of activities associated with Work Package 5. In particular, this model has been revised to enable it to provide forecasts of the electron populations in the inner magnetosphere where as prior to PROGRESS it was only capable of providing now-cast results. This work, reported in deliverable D5.4, makes use of forecasts of the solar wind parameters generated by the AWSoM/SWIFT model developed in Work Package 2 together with forecasts of the evolution of geomagnetic indices developed within Work Package 3.

Data for the more energetic electron populations comes from the VERB-NARMAX Coupled model (VNC developed within Task T6.3). This model uses the forecasts for the electron fluxes at GEO (energy ranges >800 keV and > 2MeV) resulting from activities performed in Task 6.1 and makes use of the forecasts of the *Kp* geomagnetic index developed in Task T3.4.

This report provides details of the implementation of the results from these models on the PROGRESS web site.

2 IMPTAM

The improvements to the IMPTAM code that have resulted from activities performed within Work Package 5 and have already been reported in the associated deliverables. The IMPTAM code itself runs at FMI. Originally, it was proposed to copy and install the code locally at USFD. However, it has since been decided that it is preferable to download the results from FMI. This development path ensures that the latest version of IMPTAM is always used and that the results are always consistent whether viewed from the FMI web site or PROGRESS. This arrangement also means that the maintenance of IMPTAM is performed by the code developers rather than relying on lower levels of expertise available at USFD.

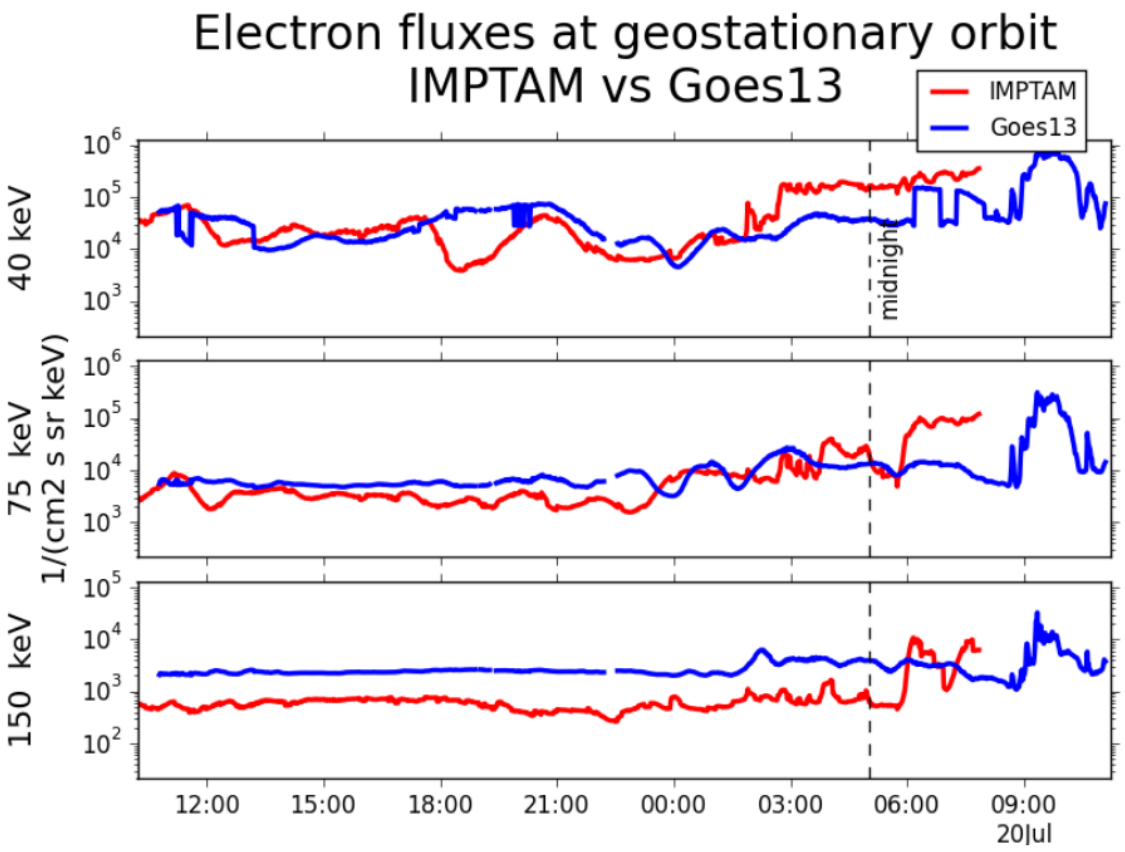

Figure 1: A comparison of the electron fluxes measured by the GOES 13 satellite (blue) and those resulting from the IMPTAM now-cast model (red) for electrons with energies 40 keV (top), 75 keV (middle), and 150 keV (bottom).

2.1 Now-cast results

Currently, plots of the now-cast results from the IMPTAM model are available at both the FMI web site and the project site. To access these plots from the PROGRESS web site the user selects `Electron Flux Forecasts > IMPTAM > IMPTAM vs GOES 13` from the results menu in the left hand column of the PROGRESS home page (https://ssg.group.shef.ac.uk/progress/html/). The user is presented with two sets of plots, shown in Figures 1 and 2.

Figure 1 shows a comparison of the electron fluxes measured by the GOES 13 satellite and those resulting from the IMPTAM now-cast model for electrons with energies 40 keV, 75 keV, and 150 keV for the period 2018-07-19T11:00:00 to 2018-07-20T11:00:00.

It can clearly be seen that the calculations from IMPTAM are consistent with actual measurements from GOES-13 during this geomagnetically quiet (Kp_{max} <3).

Figure 2 shows the IMPTAM electron flux variation of electron flux with radial distance with time calculated by IMPTAM in the midnight meridian plane.

More results are currently being implemented.

2.2 Forecast results

As was mentioned in Section 1, within the framework of PROGRESS IMPTAM has been extended to provide a forecast of the lower energy electron environment of the inner magnetosphere. This application relies on the availability of forecasts of solar wind parameters at L1 provided by the AWSoM/SWIFT model together with forecasts of geomagnetic indices.

The forecast version of IMPTAM runs at U. Michigan. A basic application and web page have been developed to test the download, ingestion, and display of these potential new data sets. This display, shown in Figure 3, is currently only accessible with user intervention on the PROGRESS test web site.

This is currently still under development.

3 VERB

The VERB (Versatile Electron Radiation Belt) model of the electron environment has been developed by Y. Shprits (PROGRESS participant at GFZ) and his collaborators A. Drozdov and A. Kellerman at UCLA. The latest version of this code is run by the team at UCLA to provide a forecast of the evolution of the electron fluxes within the radiation belt region. A plot of the results of these forecasts is available from the VERB web site at UCLA. This plot has also been made available from the PROGRESS web site by selecting `Electron Flux forecasts > VERB > VERB RB forecast` from the results menu on the PROGRESS home page. Figure 4 shows an example forecast plot. The

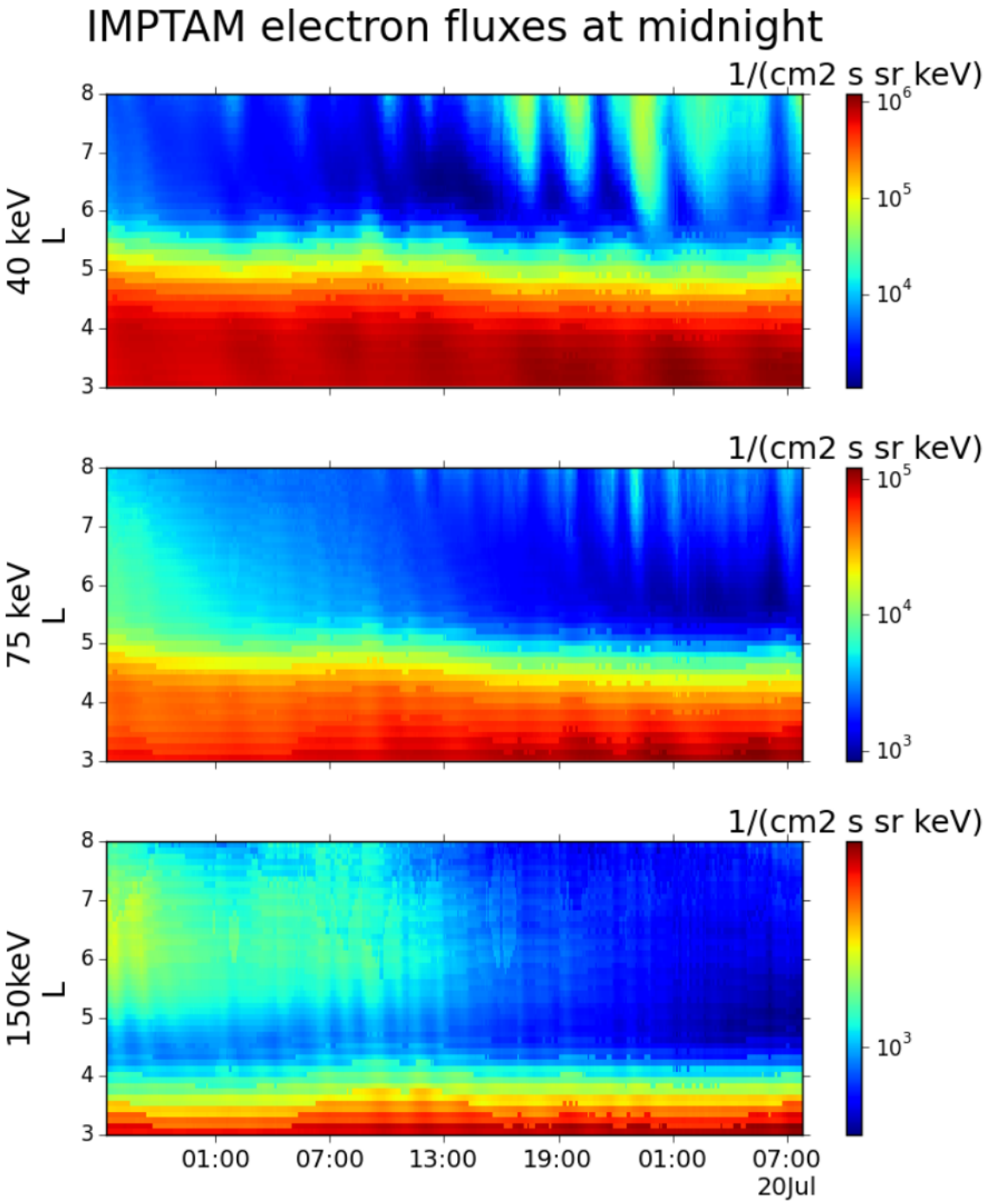

Figure 2: The variation of electron flux with radial distance with time calculated by IMPTAM in the midnight meridian plane of the inner magnetosphere for electrons with energies 40 keV (top), 75 keV (middle), and 150 keV (bottom).

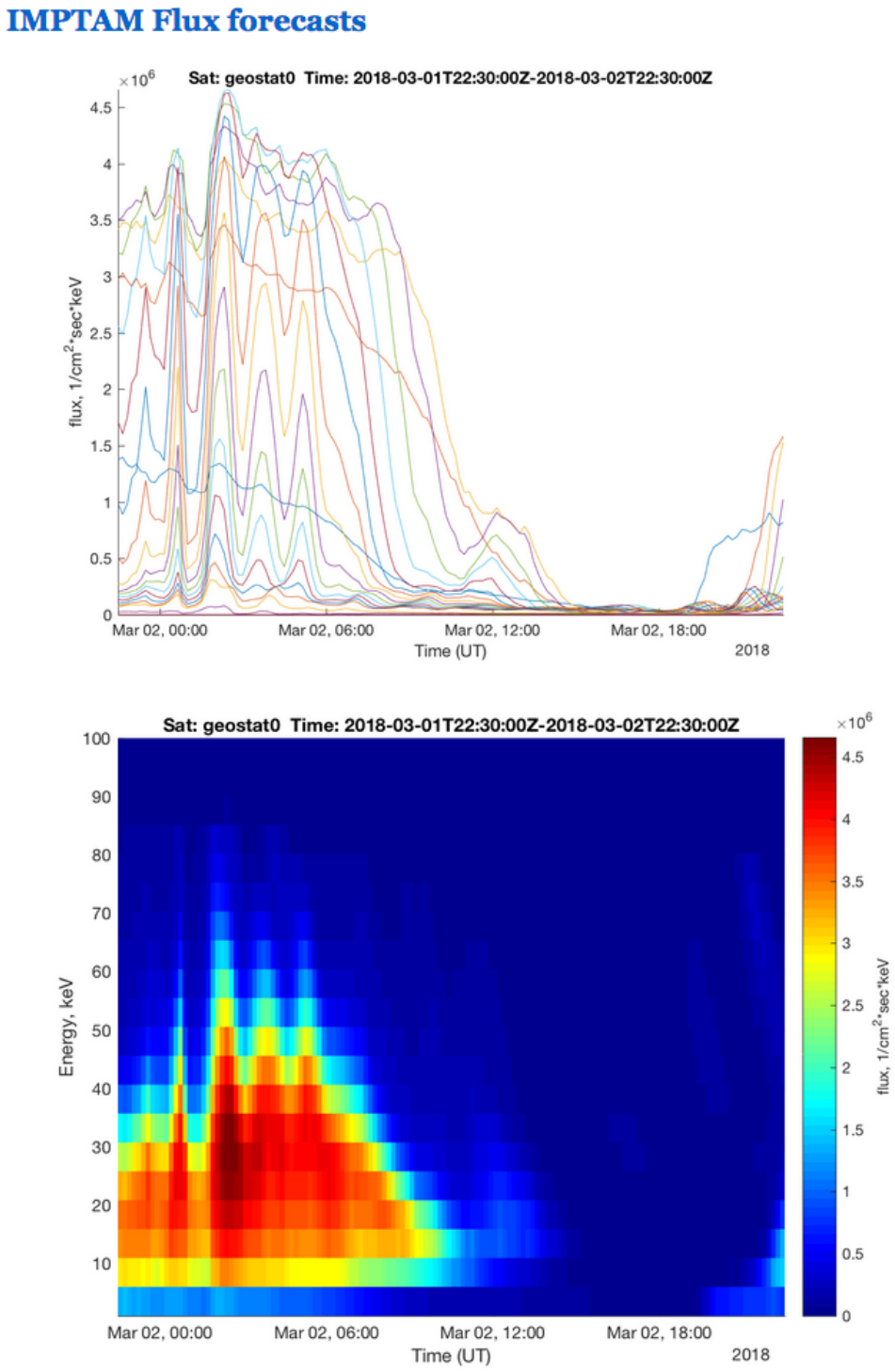

Figure 3: IMPTAM forecasts of the evolution of the electron energy spectra for the period 2018-03-01T22:30:00 to 2018-03-02T22:30:00.

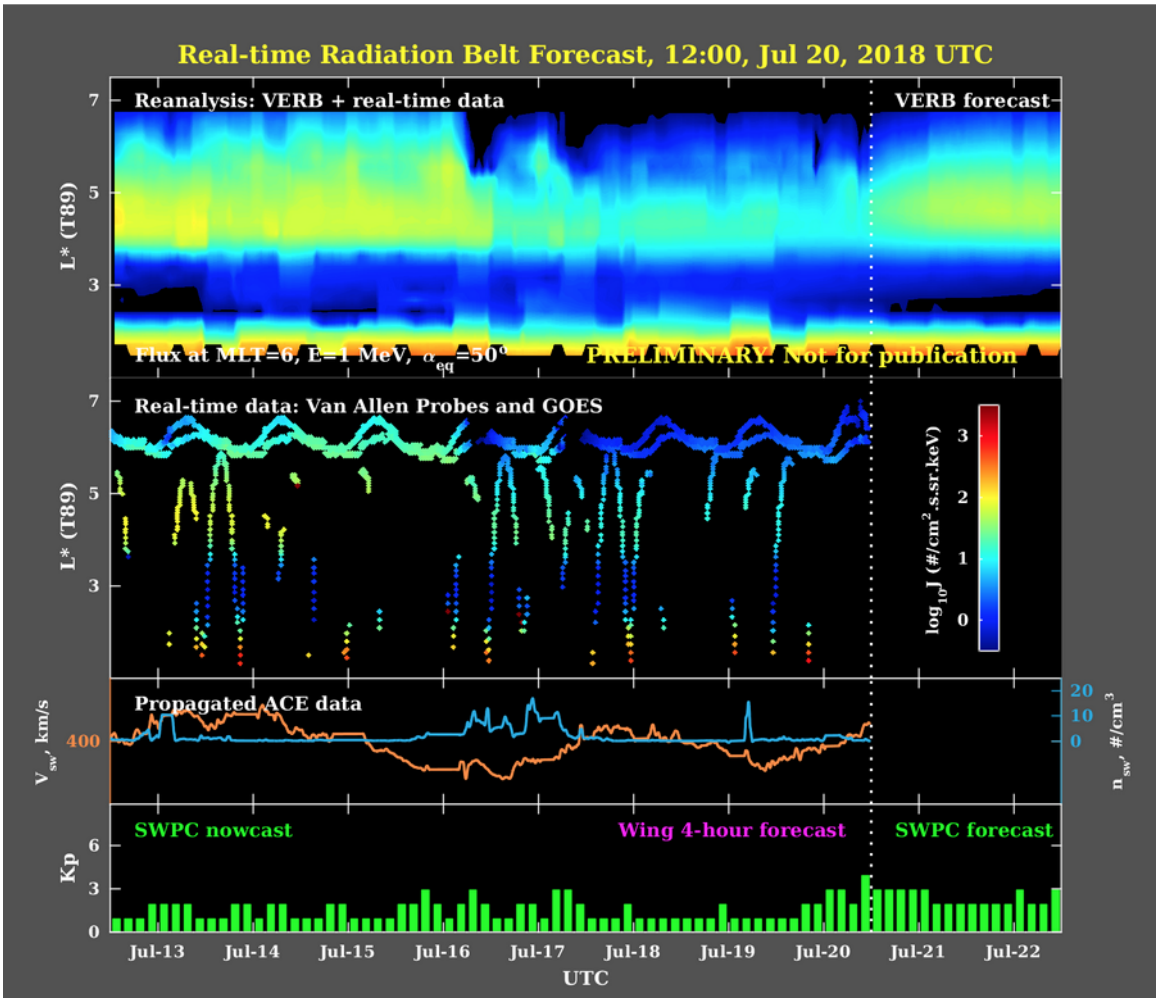

Figure 4: The VERB nowcast and forecast of the radiation belt electron environment.

top panel contains the results of the model run using theVERB code. The results may be compared to actual measurements from the Van Allen Probe and GOES-13 satellite (second panel). The lower two panels show the current solar wind density and velocity and nowcasts/forecasts of the *Kp* index to indicate levels of geomagnetic activity.

4 VNC

The VERB-NARMAX Coupled model for high energy electrons in the inner magnetosphere has been developed within PROGRESS Task 6.3. The objective behind this development was to provide a more realistic set of input parameters to VERB.

VERB may be supplied with two input data series. The first is the *Kp* index which

is used to define the level of geomagnetic activity and select appropriate sets of diffusion coefficients. The second is a quantitative measure of the flux of electrons at the outer boundary of the simulation box. As a result of the activities in Work Packages 3 and 6 PROGRESS is able to provide both accurate forecasts for the evolution of *Kp* and realistic estimates for the electron boundary flux. The development of this model has been discussed in deliverable D6.3. Since this development was performed at USFD, USFD does possess an executable version of the VERB code. This code has a built in expiry date and so should be replaced typically every 6 months, ensuring that it is always current.

The results from this forecast model may be accessed from the PROGRESS web site (`Electron Flux forecasts > VNC > VNC RB forecast` from the result menu). Figure 5 shows an example of the result display. The top panel shows the flux of 0.891 MeV electrons as a function of L* and time. This may be compared with the second panel that shows orbitally average measurements from the Van Allen Probes. The lower panels show the position of the plasmapause (*Lpp*), the variation of *Kp*, and the calculated boundary flux.

The results from the VNC model are also used by the PROGRESS Orbit Tool, developed in Task T7.3 and reported in deliverable D7.3.

5 Conclusions

Summarise the main conclusions of the work associated with the task(s).

This report has shown examples of the data products that may be used to characterise the electron environment of the inner magnetosphere and how to find them on the PROGRESS web site.

6 Future tasks

Specify how these results will be used in future tasks related to the project.

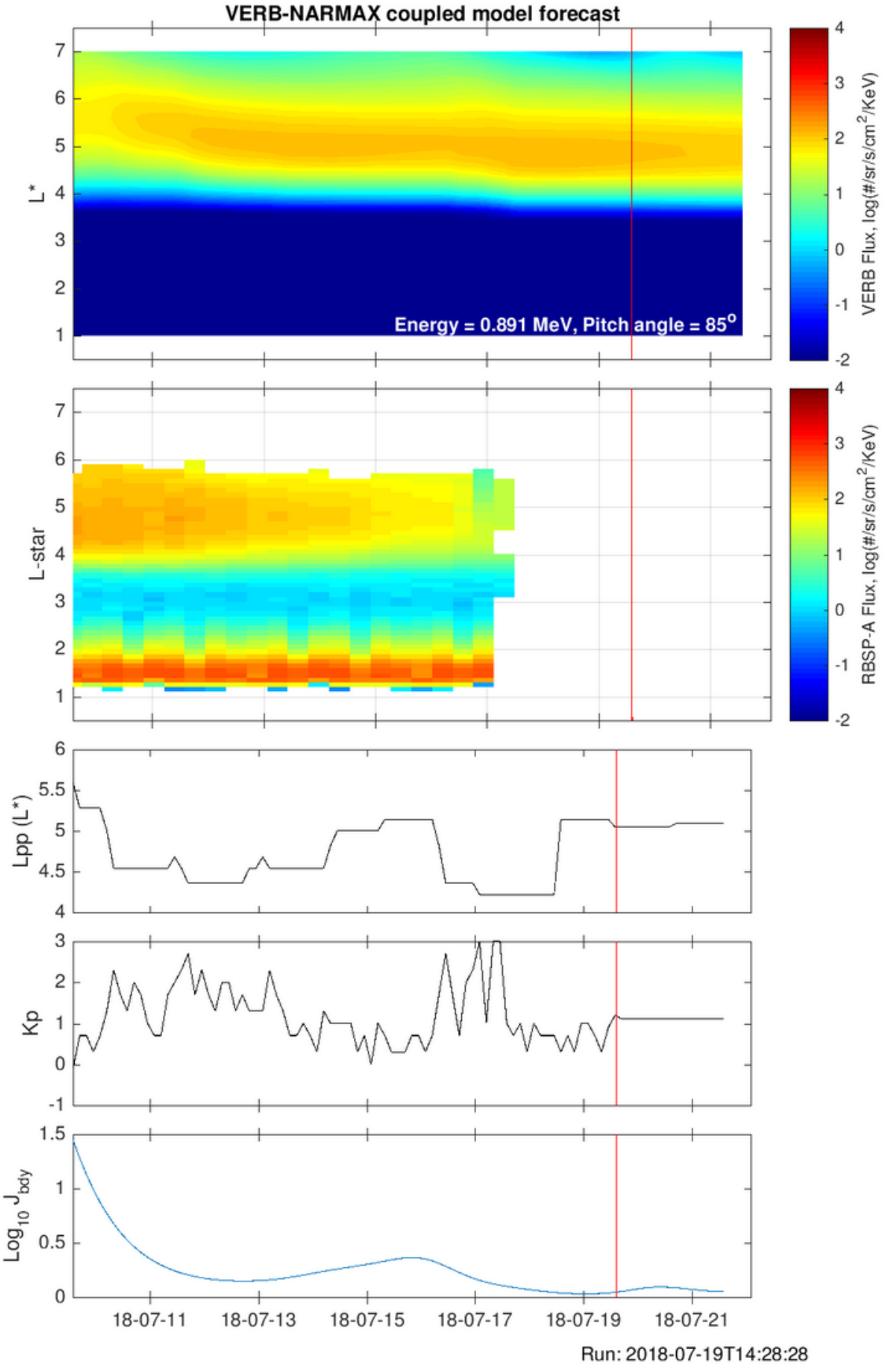

Figure 5: The VNC forecast of electron fluxes within the inner magnetosphere.

The results from the VNC model are used by the PROGRESS Orbit Tool, developed in Task T7.3 and reported in deliverable D7.3. This application shows the electron flux levels that are expected to be encountered along the orbit of a user selected satellite. The use of VNC data should enable instances of potential deep charging events to be identified. This tool could be expanded to use electron flux calculations resulting from IMPTAM. As a result it could also provide information as to the potential occurrence of surface charging effects.

A second offshoot from collaborative developments with the Orbit Tool would be the potential to recreate data sets for past events, enabling the analysis of historical satellite disruption events. These data sets would be calculated as requested and the results mailed to the person requesting the analysis.