Real-time determination and monitoring of the auroral electrojet boundaries

Documentation
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1. General description

The real-time auroral electrojet tracker, which is Deliverable 4.3 in the AFFECTS project, enables the user to monitor the location of the auroral electrojet, and thus the auroral oval, boundaries in the European sector. The tracker uses near real-time data from the Tromsø Geophysical Observatory (TGO) magnetometer network in order to determine the electrojet boundaries, and updates every two minutes, displaying the electrojet boundaries determined from one minute old data.

2. Auroral oval determination by means of geomagnetic measurements – Concept

Large currents flows along the auroral ovals, these are termed the auroral electrojets. In the dusk sector in the northern hemisphere the electrojet flows eastward, and in the dawn sector it flows westward. The electrojets in relation to the auroral oval is illustrated in a simplified manner in **Figure 01**. In the Figure the auroral oval is seen from above, the number 12 in the upper part indicates magnetic local time and, thus, the direction towards the sun. Crosses and dots indicates currents flowing into and out of the ionosphere, solid arrows represetns electrical fields. The dotted lines represents currents induced by the presence of the electrical fields and the vertical geomagnetic field. As is seen, in the dusk sector (left part of the figure), the Eeatward electrojet is indicated within the oval. On the other side, in the dawn sector (right part of the figure), the Westward electrojet is indicated.
The magnetic field disturbances created by the auroral eletrojets are observed on a routine basis from any magnetometer station located at auroral latitudes. Since the electrojets are intimately connected to the auroral oval, and both are aligned in the east-west direction (along the magnetic latitudes), the latitudinal magnetic signature of the electrojet may be used in order to

identify its position, and hence the position of the auroral oval. Furthermore, since the oval width and location is governed by the interaction between the geomagnetic field and the solar wind and therefore will change with time, its dynamic behaviour may be tracked using latitudinally spaced ground-based magnetometers.

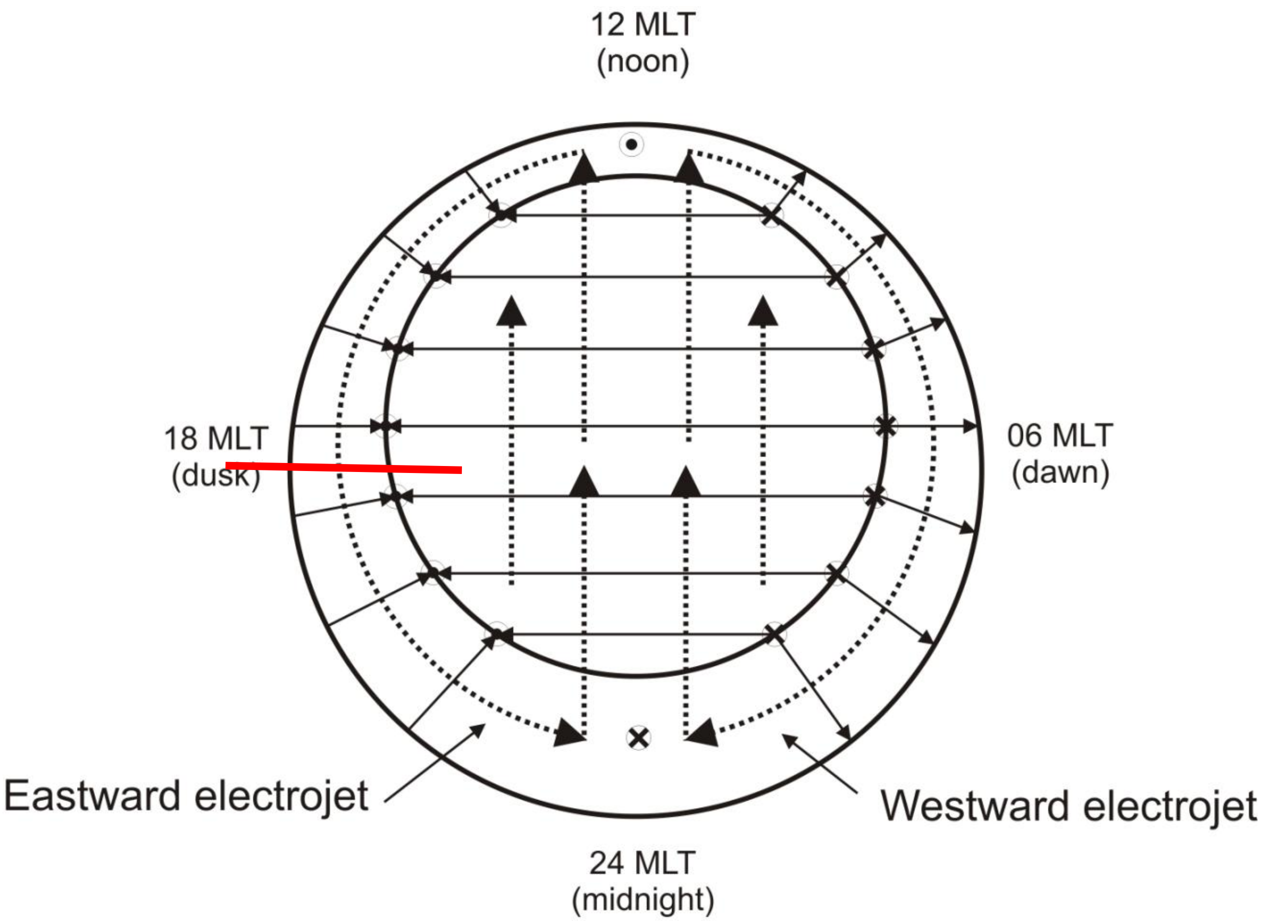

Figure 01: Relationship between auroral oval and electrojets

3. The latitudinal signature of the auroral electrojet

As discussed above, the electrojets flow in the eastward and westward direction of the auroral oval in the dusk and dawn sectors, respectively. Any current will induce its own magnetic field, and it is this field which is observed as a magnetic field variation at stations at auroral latitudes. The latitudinal, magnetic signature of the electrojets may be simulated assuming they are sheet currents flowing 110 km above ground. This is illustrated for a situation in the auroral oval close to the dusk meridian in **Figure 02**, indicated by a red line in Figure 01. The coordinate system used in the simulations is the XYZ system commonly used in geomagnetic observations, the x-axis points northwards, the y-axis points eastwards and the z-axis points downwards. In the bottom panel of Figure 02 the current system as function of latitude is shown. At low latitudes the current is zero, between 65 and 75 degrees the eastward electrojet is flowing, hence the positive sign. North of the electrojet there is a weaker polar cap return current flowing towards the sun/dayside. In the top panel the resulting magnetic field variation owing to the currents in the x-component is shown, the x-component is here the horizontal component. As can be seen the magnetic field increases to a maximum close to the middle of the electrojet, and it decreases below zero further north where the oppositely directed polar cap current is situated. It can also be seen, that the x-component variation is dispersed latitudinally relative to the electrojet and, thus, cannot be used to determine the extent of the oval. However, looking at the middle plot of Figure 02, we clearly see that the z-component (i.e. the vertical component) of the magnetic field variation gets a local maximum and minimum at the equatorward and poleward edge of the electrojet, respectively. This can be used to determine the location of the auroral oval boundaries. In the case of a westward electrojet, the signs of the results in Figure 02 need to be changed, otherwise the result is the same.

Hence, we summarize that in the dusk sector, the equatorward edge of the auroral oval is represented by a maximum in the ground magnetic field variation z-component and the poleward edge is represented by a minimum. In the dawn sector it is opposite, the auroral oval equatorward edge is represented by a minimum in the z-component and the poleward edge by a maximum.

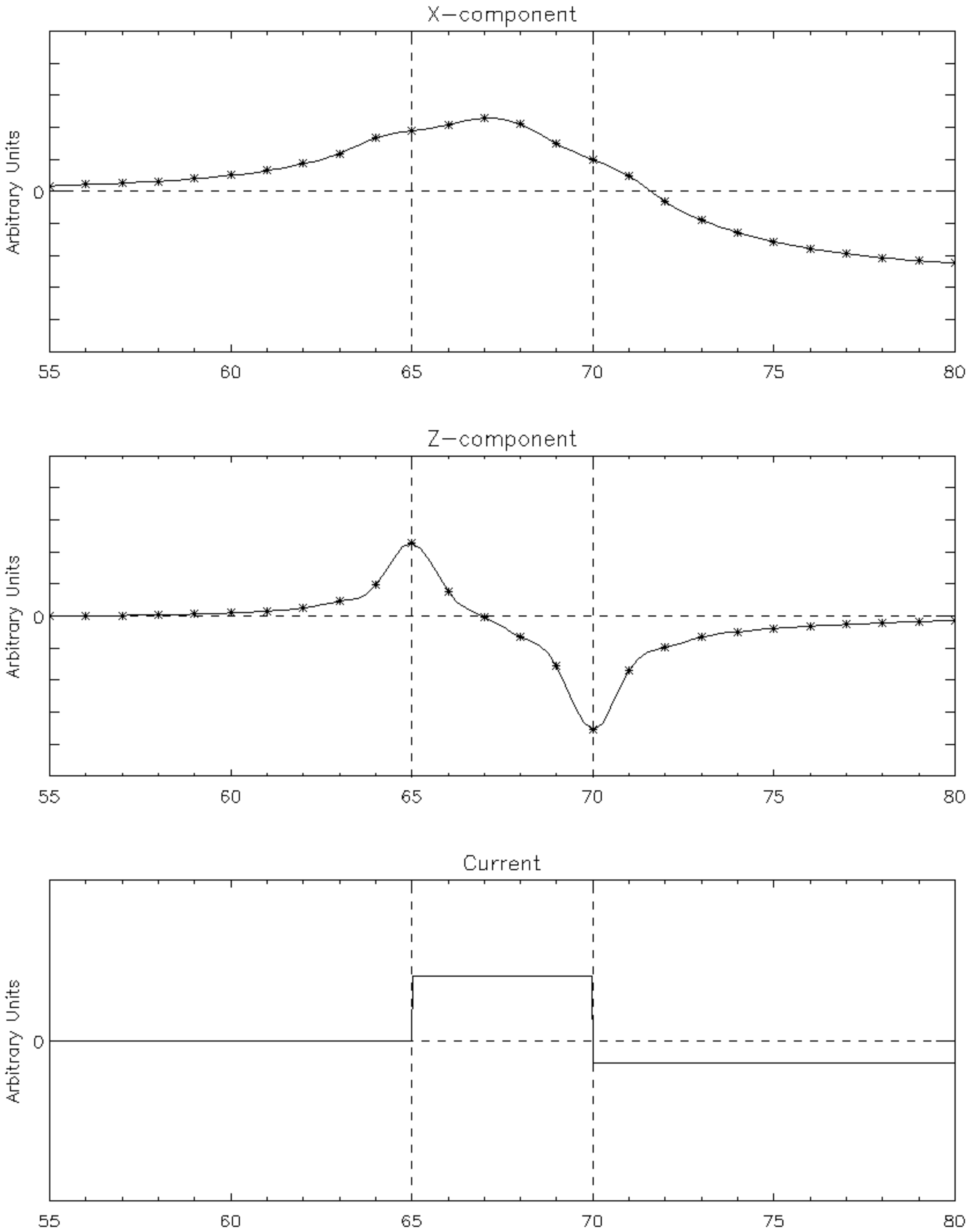

Figure 02: Simulated magnetic field signature of eastward electrojet as function of latitude.

4. Presentation of auroral electrojet tracker

The TGO magnetometer network is evenly spaced in latitude in a north-south manner, which makes its measured data an excellent starting point for a provisional auroral alert and tracking system.

The tracker consists of two graphical parts and one numerical part. The graphical parts are displayed presented together with a short description at the following URL: http://fox.phys.uit.no/AFFECTS/. The first graphical part is a map where the poleward and equatorward edges of the auroral oval, determined from the magnetic field variation z-component, are indicated as green and red dashed lines. In addition plots where the relevant components of the geomagnetic field variations as function of latitude are displayed. The time of the last oval determination is indicated on top of the map, and the corresponding time stamp for the data used is indicated in the bottom right corner. The second graphical part is a graphical representation of the strength and latitude of the maximum in geomagnetic variations in the European sector, it may be referred to as an activity indicator. The activity is indicated by a bar updating in real-time according to the maximum magnetic field variation (x-component) found in the data. The scale chosen to indicate the activity goes from 0 to 10 and is related linearly to the interval 0 – 3000 nT. Values corresponding to quiet, moderate, disturbed and extraordinary conditions are marked. The bar is accompanied with another display indicating the latitude of the maximum disturbance. The third part is an ascii file, which is updated in near real-time, containing numerical values of the poleward and equatorward edges of the auroral oval at present and the previous three hours. The ascii-file can be found on the following URL: http://fox.phys.uit.no/AFFECTS/RT_oval_location.dat

For the tracker data from 9 of TGO's 14 magnetometers have been used in order to get as even latitudinal spacing between them as possible. At each location the local coordinate system has been rotated around the vertical axis in such a way that the observed magnetic field variations are with respect to the local magnetic field dipole meridian rather than the geographic meridian. Natural splines have been fit to the x- and z-components in order to get a latitudinal profile with higher resolution.

Owing to the uncertainties in quiet-time determination of the measured magnetic field, it has proved impossible to get meaningful latitudinal profiles of the magnetic field variations under very quiet conditions. Therefore the auroral electrojet determination is turned off when the maximum in the absolute value of the x-component reaches values of less than a threshold currently set to 40 nT. This is displayed as a message in the graphical display and as NaN (not a number) in the ascii file.

Owing to the greater complexity of the current systems near magnetic noon (cusp) and midnight (Harang discontinuity), the oval determination from the z-component is turned off in the intervals UT 07.00 – 11.00UT and UT 19.00 – 22.00. However, in order to indicate where the oval is located and the degree of activity, the maximum in the x-component and latitude for it, is still found during these intervals (see second graphic display).

In **Figure 03** the obtained auroral oval edges from the magnetic signature of the westward electrojet in the dawn sector, are presented in the same fashion as in the graphical display on the web page of the tracker. Comparing with the simulations in Figure 02 it is seen that the signature of the electrojet as obtained from the TGO magnetometers is very similar. The arrows indicate the strength of the local geomagnetic disturbance (magnetic equivalent convection), and the blue circle shows the field of view of the TGO all-sky camera (http://fox.phys.uit.no/ASC/). In **Figure 04** the activity indicator, which is the second graphical display of the auroral electrojet tracker, is shown for the same event as displayed in Figure 03. As can be seen, for this case, the activity is rather high and situated in northern Fennoscandia.

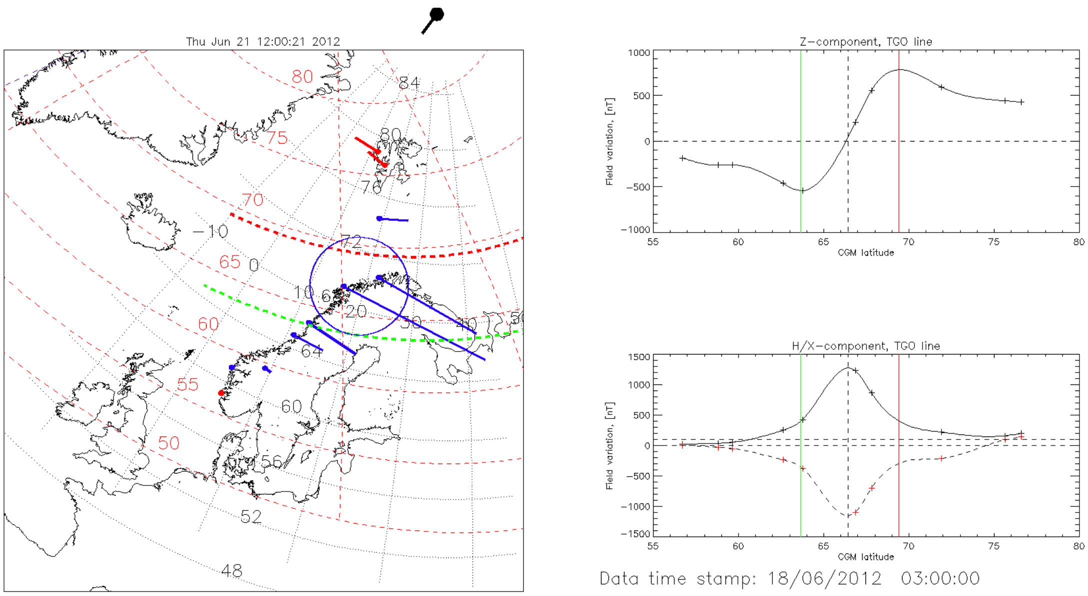

Figure 03: Acquired auroral oval boundaries in dawn sector using the AFFECTS auroral electrojet tracker.

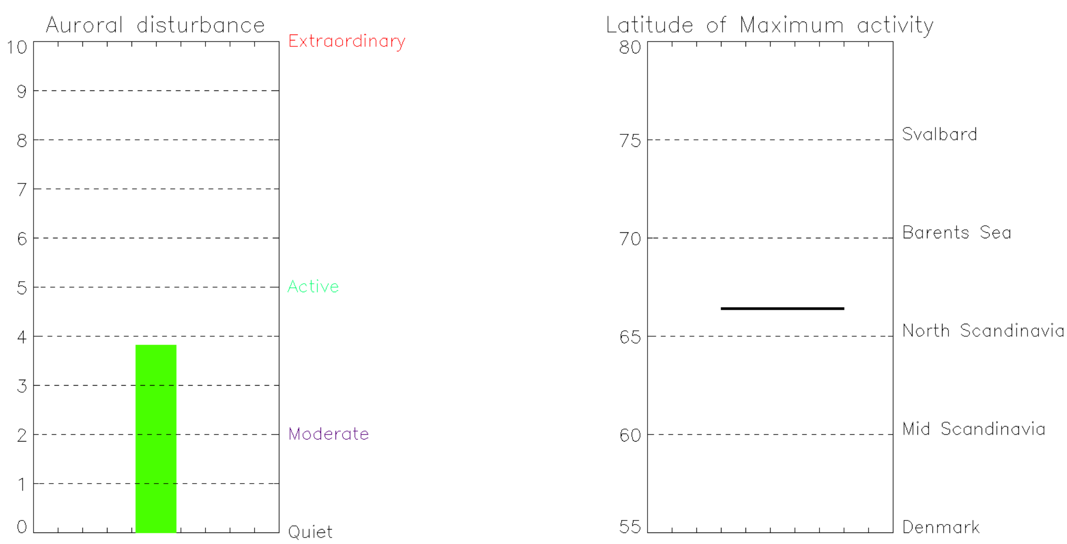

Figure 04: Activity indicator for the same event as presented in Figure 06.

The obtained auroral boundaries are also stored in an ASCII file. The data are presented on the following format:

DD MM YEAR HH MM SS Oval(poleward) Oval(equatorward)

5. Disclaimer

This product was created on best efforts basis and is provided “as is” without warranties of any kind. The forecasts issued by this product are accurate to the best knowledge of the developers; however, the developers cannot be held responsible for any damage, loss of profit and similar charges rising out of the use of this product and its output. In particular, the developers of this product cannot be held responsible for the consequences of any action, or the lack of, based on the forecast provided by this product. Any such consequences shall be at sole responsibility of the respective decision makers.

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