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Local Vector Activity Proxy Indices: using INTERMAGNET observatories to estimate local magnetic field conditions

Sarah J Reay (sjr@bgs.ac.uk) and Alan Thomson
British Geological Survey, West Mains Road, Edinburgh EH9 3LA, UK

ABSTRACT

The INTERMAGNET network of geomagnetic observatories provides high-quality one-minute data from over 100 observatories around the globe. This distribution of ground observatories is potentially a useful resource to determine new activity proxy indices for different scientific and other purposes. As an example we describe how a global proxy index based on AE can be determined for any geomagnetic field component using data from this network of observatories. We also examine whether there is merit in using a local estimate of the external field activity, as opposed to the large-scale indices. Currently standard global indices are used in data selection procedures (to reject geomagnetically active satellite data) when modelling the internal magnetic field. Active periods are regarded as noise for this purpose, as the external field can mask the signal from the internal field. The technique described here may help in such data selection or in weighting datasets. It may also have other applications, for example to help determine the magnetic field variation in areas poorly covered by geomagnetic observatories or where an observatory 3-hour K measure of local variations does not give enough time resolution.

1. Introduction: a global proxy index for AE

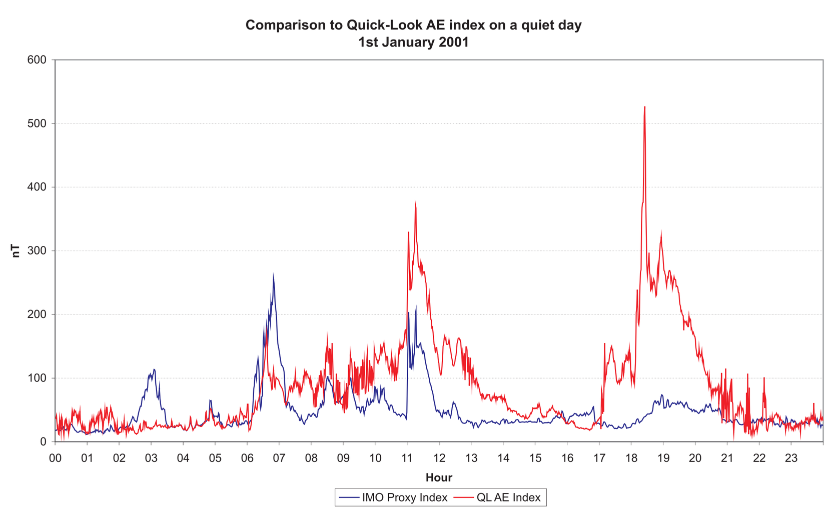
The AE index and the associated AU and AL indices were introduced by Davis and Sugiura [1966] as a measure of global auroral electroject activity. This is derived from a network for geomagnetic observatories covering the auroral region of the Northern Hemisphere close to geomagnetic latitude, λ =70°. The availability of some stations in recent years has been difficult and the resultant derivation of definitive AE index has been delayed. The INTERMAGNET network of observatories provides high-quality one-minute data for over 100 observatories across the globe. Following on from the Thomson and Lesur [2006] derivation of a Vector Magnetic Disturbance (VMD) time series in sub-auroral regions at +50° to – 50° magnetic latitudes, we have investigated whether this resource of observatories could be used to determine a new proxy activity index for mid-to-high latitudes based on the derivation of AE.

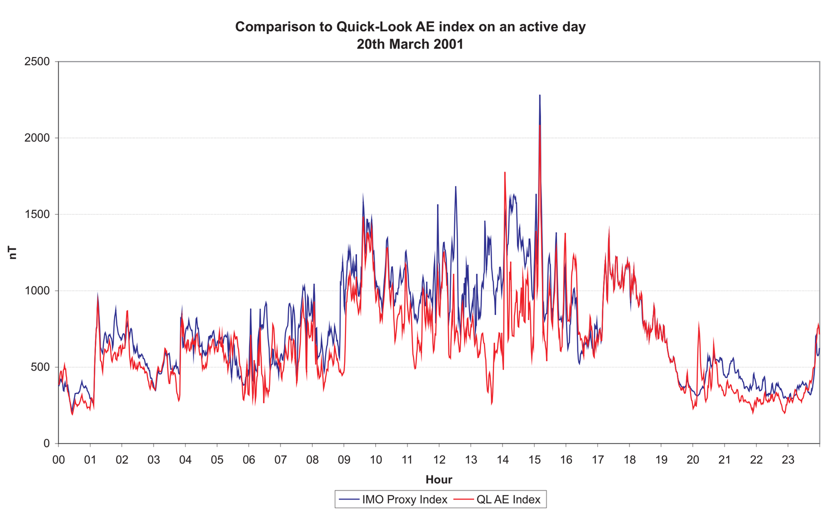
The AE index is derived thus (Mayaund, 1980): A quiet-time level is determined for each station, each month from the average of the Horizontal (H) component during the five internationally quietest days in that month. This quiet-time reference level is then subtracted from each sample in that month's time-series leaving residual values. These residuals are compared against each other, the extreme positive defining the AU and the extreme negative the AL. AE is the difference between these upper and lower envelopes, AU-AL.

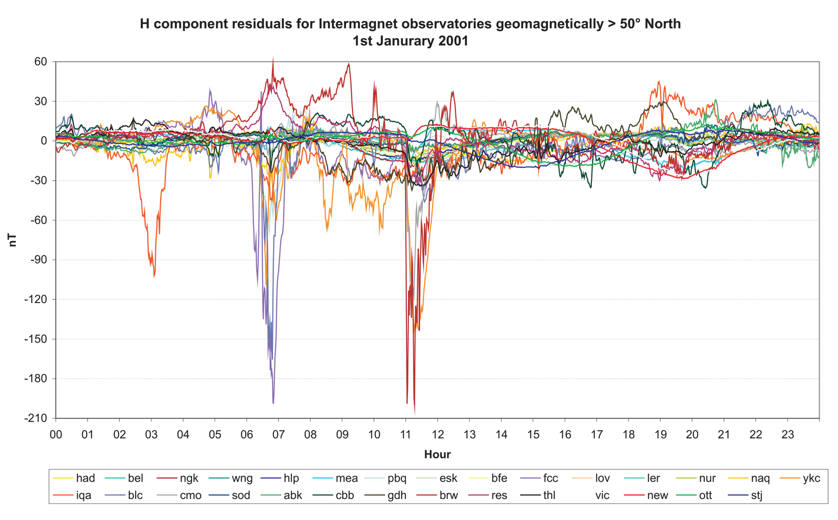
By using data from all INTERMAGNET observatories λ > ±50° and using the same derivation as above it is possible to determine a proxy global index that is similar to AE in the Northern and Southern hemisphere. Although AE is base on H we can repeat the process for any required component of the field.

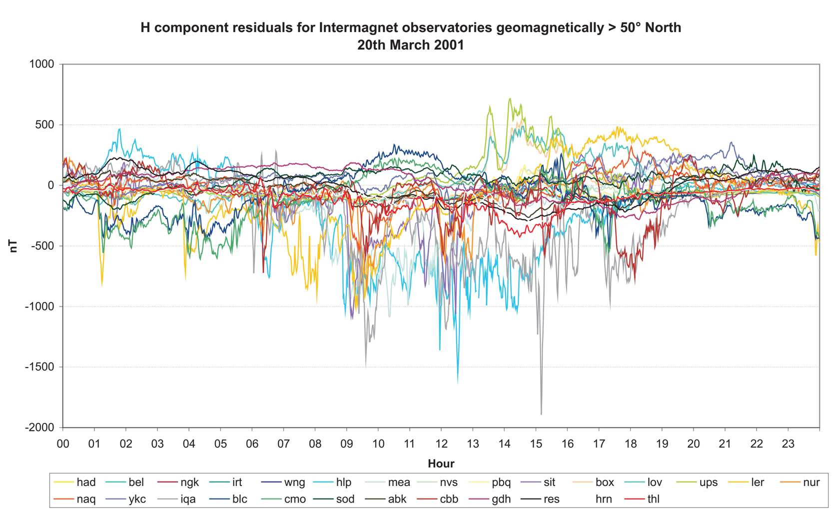
Below are results for example active and quiet days comparing the Quick-Look AE index (derived and available from the World Data Centre for Geomagnetism, Kyoto) to the proxy INTERMAGNET Observatory (IMO) index in the Northern hemisphere for the H component (as used in AE). The associated residuals for each observatory used are plotted below. You can see that during times of global heightened activity the two indices agree favourably. During quiet times both indices are more susceptible to local geomagnetic variations and the two datasets differ due to the different network of observatories used. The lack of coverage over Russia with the proxy IMO index is clear from 17:00 to 21:00 UT on the 1st January 2001 for example.

This proxy IMO index is freely available and may have uses in global field modelling and in other magnetospheric studies that use global geomagnetic indices.







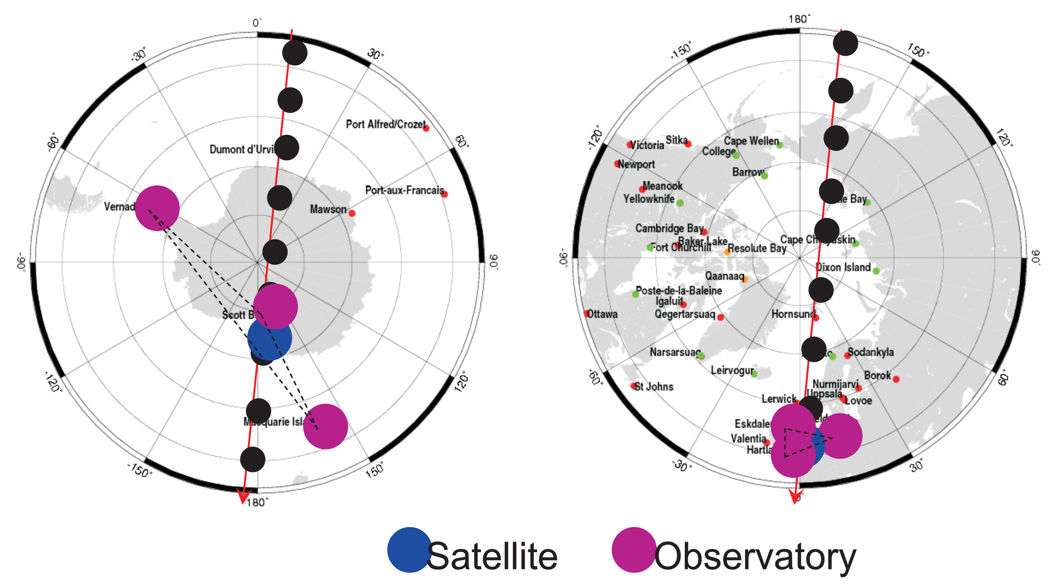


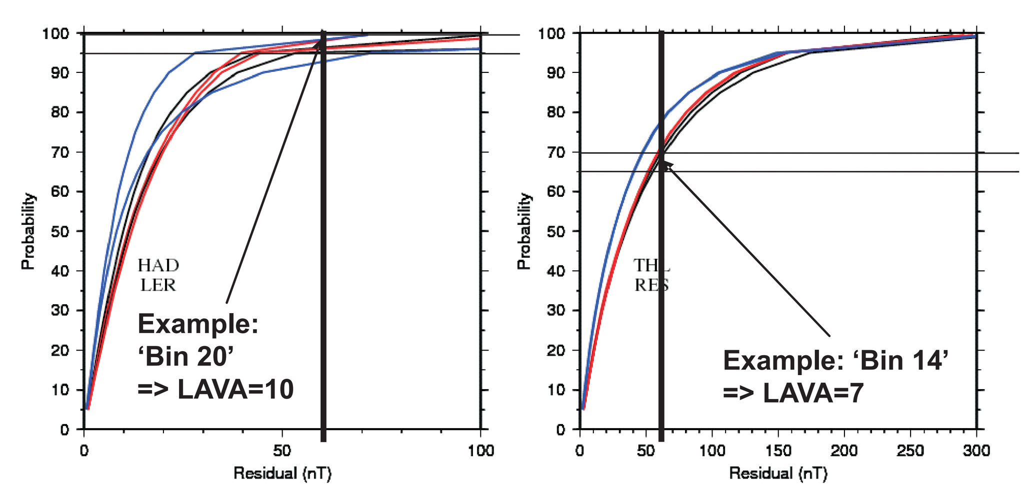
2. Local Vector Proxy Indices

One use of geomagnetic indices is in the selection or weighting of geomagnetically active satellite data when modelling the internal magnetic field. For modellers active periods are regarded as noise, as this can mask the signal from the internal field. Currently global indices are used for this purpose. We have created an alternative technique to assess local activity levels at a given time and place as a satellite passes overhead.

Firstly, we determine the three closest observatories to the satellite position. We apply a technique to give a local area vector activity ('LAVA') proxy index value for these nearby observatories. As with AE calculations, residual values are calculated by subtracting a quiet monthly mean from an average of the five most internationally quiet days. These residuals are then compared against a historical probability distribution (2001-2004 inclusive) of all one-minute data at this observatory. The residual is then binned in 20 steps of 0 – 10 (i.e. ½ units of 'LAVA'). This gives one-minute LAVA proxy index values for each observatory (see example below). These three observatory-LAVA values are then combined, weighted according to their distance from the satellite position.

LAVA values can be derived for any geomagnetic component at any point on the globe. However the distribution of observatories, and particularly INTERMAGNET observatories currently used, is not uniform across the globe. In the example given below for a point over Europe each observatory would be given a fairly equal weight, over Antarctica where observatories are sparse those at a greater distance would be less reliable in giving a local indicator. The decision to use three observatories is arbitrary but is considered to give a good spatial representation. Greater or fewer number of observatories could also be considered when determining a local activity level.





Probability Distributions
Left: Mid-Latitude LAVA X (black), Y (red), Z (blue); Right: High-Latitude LAVA X,Y,Z
2001-2004: All Data (Including Sq) with Quiet Monthly Mean Level Subtracted

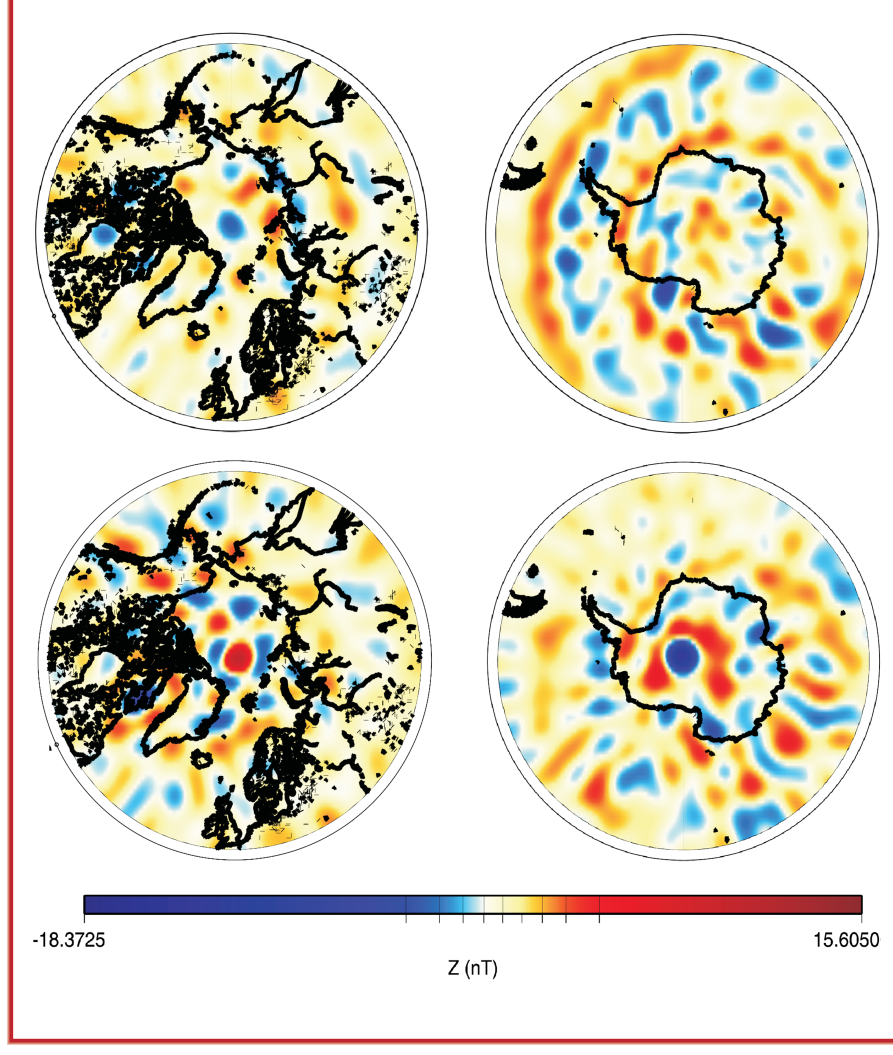
Top Left: *A representation of a satellites path across the South and North poles. The blue dot shows a given satellite position along this path and the three closest observatories to it. Red dots show INTERMAGNET observatories, green show observatories used in AE calculation and orange those in the polar cap.*

Left: *Example of LAVA index determination for mid- and high-latitude observatories showing their residual value probability distribution and associated bin value for a residual of 60nT.*

3. Current applications and future uses

The LAVA proxy index has already been applied to data weighting techniques used in modelling the Earth's internal field. The stereographic plots below show model differences between an independent model, CHAOS (2006), and two BGS models, BGS0706 (without LAVA weighting) and BGS0707 (including LAVA weighting). It can be argued that the addition of this weighting has improved the model over the southern pole removing the 'unnatural' banding seen in the top comparison due to the unavailability of the PC index.

We want to explore further improvements to this LAVA index, examining the use of the 'three nearest' observatories and consider whether producing sector indices similar to Menvielle's aλ longitude sector indices may be beneficial. The lack of high latitude INTERMAGNET observatories over Asia may be a restrictive factor here. We have also studied the LAVA proxy index relation to global indices (3-hour K-index) and we plan to extend this to consider its relationship with other polar/auroral indices.



Differences at North (left) and South (right) poles between models in the vertical (Z) component at 400km altitude, degree 50

Top: *BGS0607 - CHAOS without extra LAVA weighting showing 'unnatural' banding at the South Pole*
Bottom: *BGS0707 - CHAOS with extra LAVA weighing*

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