The Effect of Using an Open-Closed Magnetic Field Line Boundary-Normalised Co-ordinate System on Climatological Maps of Ionospheric Convection

Gareth Chisham[1] and Angeline Burrell[2]

[1]British Antarctic Survey, Cambridge, UK. (gchi@bas.ac.uk)
[2]University of Texas, Dallas, USA. (angeline.burrell@utdallas.edu)

The Saskatoon SuperDARN radar

BACKGROUND

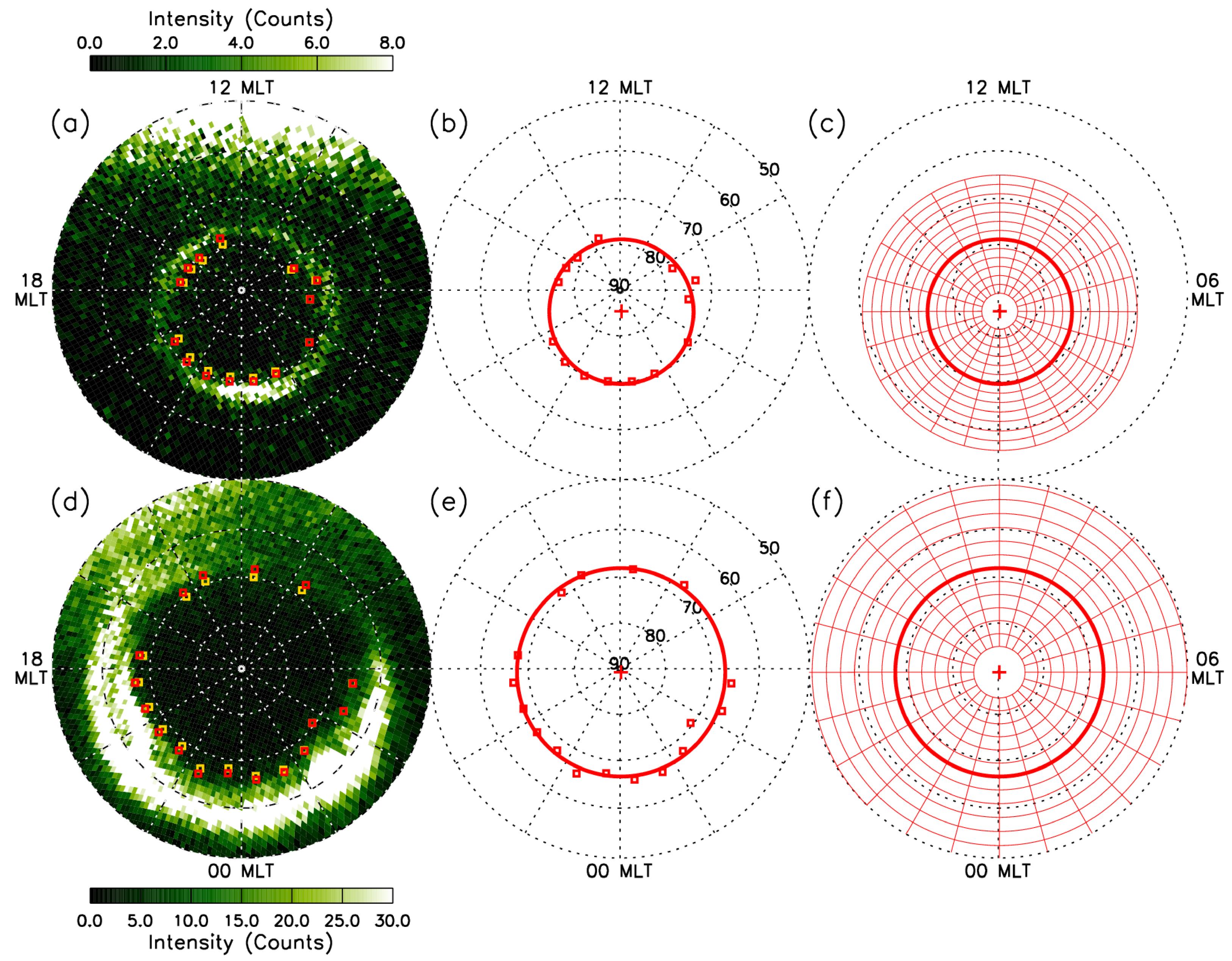
(1) Empirical models and climatologies of polar ionospheric processes, such as ionospheric convection, are a crucially important component of ionospheric space weather applications. Such models allow the tracking of ionospheric plasma density enhancements such as polar patches, which can disrupt and attenuate radio communications through the ionosphere, or allow the estimation of ionospheric Joule heating, which increases the atmospheric drag on low-Earth orbiting satellites.

(2) One common feature of previous empirical models is that measurements have been combined and averaged on fixed co-ordinate grids. This methodology ignores the fact that the polar ionosphere is organised relative to the location of the ionospheric footprint of the boundary between open and closed geomagnetic field lines (OCB). This boundary is in continual motion, and the polar cap that it encloses is continually expanding and contracting in response to changes in the rates of magnetic reconnection at the Earth's magnetopause and magnetotail. As a consequence, models that are developed using fixed co-ordinate grids average together data from the polar cap and auroral region.

(3) Here, we present a new methodology for the development of future models that considers the location of the OCB when gridding data [*Chisham* (2017), JGR, **122**, 932-947]. We present an example of the application of the methodology to northern hemisphere SuperDARN measurements of ionospheric convection.

METHODOLOGY

- Bin data in a co-ordinate grid normalised to the OCB location. This gridding prevents the averaging together of data from the polar cap and auroral region.
- In this example, we use the 2-yr database (2000-2002) of IMAGE FUV auroral images (from Si12, Si13, and WIC imagers).
- Derive corrected OCB latitudes (in 1-hr MLT bins) from imager data using the methodology of *Longden et al.* (2010) [AG,**28**,1659]
- Fit a circle to the observed OCB latitudes measured for every image and scale co-ordinate grid for that time appropriately.

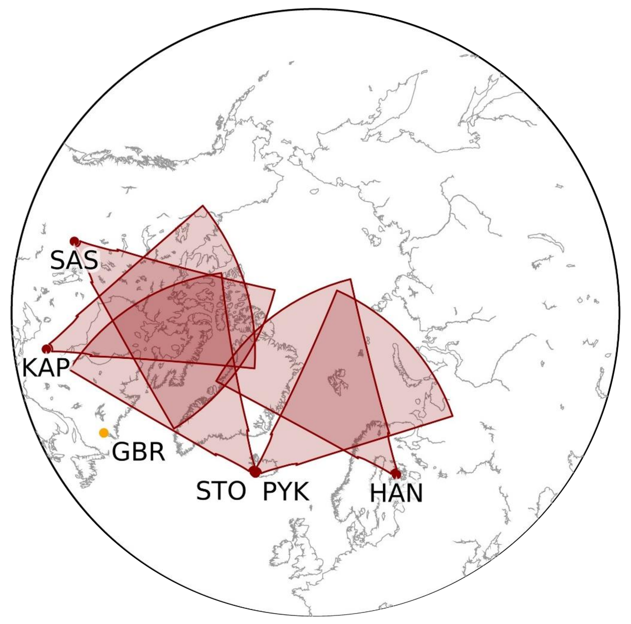


Example IMAGE Si13 images, boundary determinations, and gridding

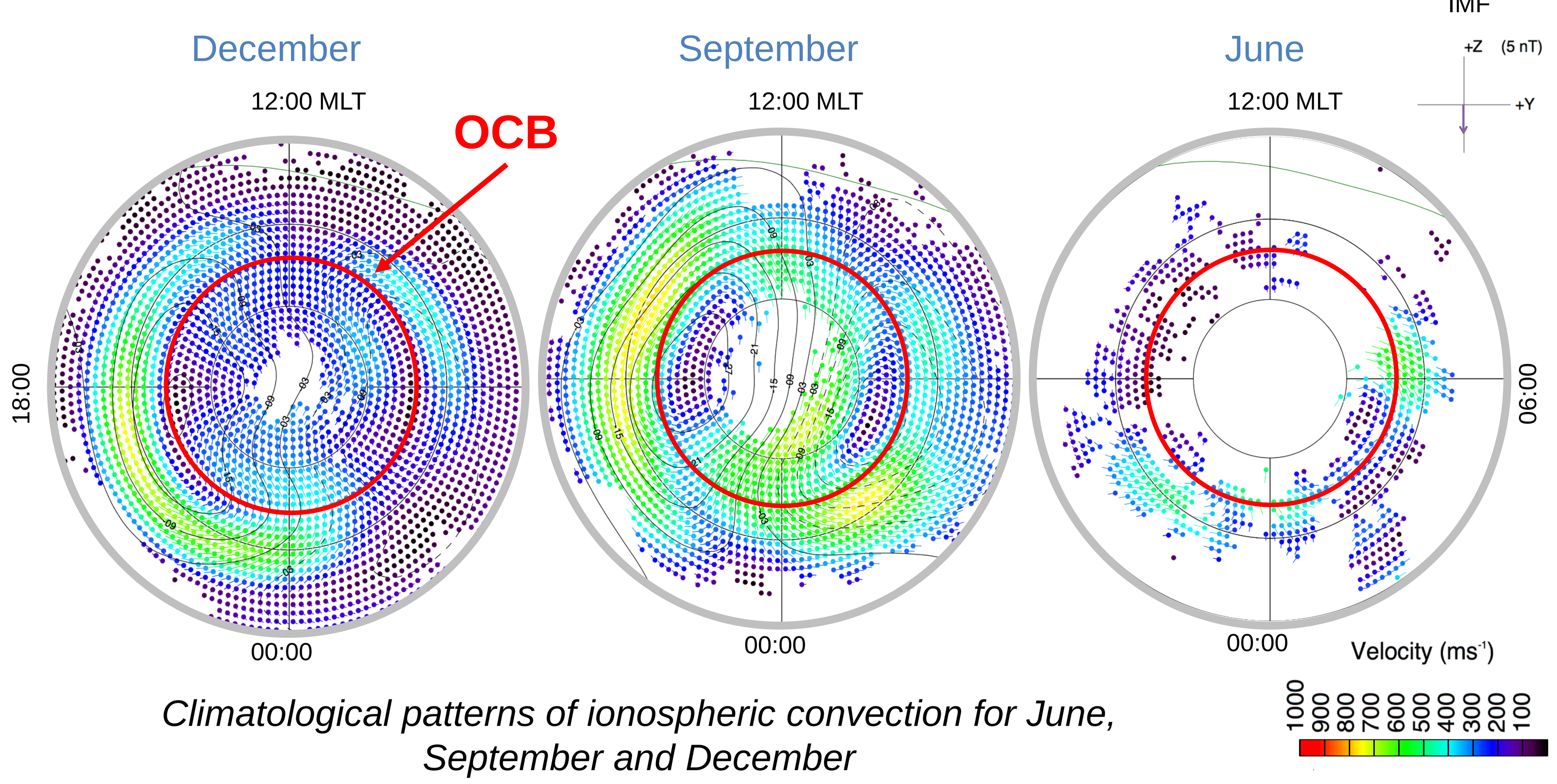
- An open source python module, OCBpy, performs these co-ordinate transformations https://github.com/aburrell/ocbpy
- http://doi.org/10.5281/zenodo.1179231

EXAMPLE DEMONSTRATION – Climatological Maps of Ionospheric Convection

- Resulting patterns compiled from line-of-sight velocity data from 5 northern hemisphere SuperDARN radars (see figure).
- Data analysed from solar cycle 23 maximum (May 2000 – August 2002) (the IMAGE data epoch), and divided by calendar month.
- Data restricted to intervals with IMF B_z between -6 and -2 nT, IMF B_y between -2 and +2 nT, and quiet geomagnetic conditions (A_p < 22).
- SuperDARN data pre-processed using the methodology of *Burrell et al*. (2018) [Radio Sci., **53**, doi:10.1002/2017RS006512].



The SuperDARN radars used to determine the climatological patterns



Climatological patterns of ionospheric convection for June, September and December

- JUNE – Very little backscatter as the higher ionospheric plasma density in the summer months suppresses ionospheric irregularity formation.
- SEPTEMBER and DECEMBER – Both these months show a clear 2-cell convection pattern as expected for negative IMF B_z conditions. In September the plasma convection throat is shifted away from noon to dawn, consistent with an increase in the Hall conductivity on the dayside [*Ridley and Gombosi* (2004), AG, **22**, 567-584]. This also shifts the location of the maximum plasma convection speed in the dusk-cell return flow.

SUMMARY/CONCLUSIONS: (1) We present a methodology for the development of ionospheric climatologies and empirical models that involves binning measurements in a grid that scales with the OCB location. This prevents the averaging together of data from the polar cap and the auroral region. (2) We demonstrate the plausibility of this methodology using ionospheric convection velocity measurements from northern hemisphere SuperDARN radars and OCB measurements from the IMAGE spacecraft FUV auroral imagers. (3) This approach will improve the accuracy and reliability of the next generation of ionospheric space weather models.