**SWIGS annual meeting Cambridge, September 2-4.**

The following are short notes made by Alan Thomson on presentations and discussions at the SWIGS meeting in Cambridge during the 160th anniversary of the Carrington Event. They do not constitute formal minutes of what was, after all, a scientific meeting.

Bold face indicates actions and new research ideas from the meeting. The default is that AT will follow these up and consult with others as needed.

Day 1

Rogers et al.

EVT and 1-minute data. 99.70 percentile. 125 SuperMAG stations. Close association of ULF/Pc5 as a driver, also high latitude lobe reconnection under northward IMF, dayside cusp, substorm onset, SSC. Using 1 min data shows a secondary dB/dt peak in 60-70 degrees. For 1-min data peak is 55-60 deg, as before. dB/dt shows strong directional dependence dependent on MLT, latitude & IMF

Qs.

If eps=o, how does functional form fitting work (since eps appears in denominator)?

* Equation reduces to simple exponential.

Spline fit. How to maximise fit in the 50-60 deg range?

 Various options to sharpen this.

1/2500 years or longer return period

* Error bars are big so very difficult to do!

Stationarity of data

* Concerned for solar cycle dependence

Declustering of data applied and how?

* Threshold applied before declustering
* 2 billion down data: Jan Eichner has ideas about how best to do declustering and thresholding. Follow up off-line.

Livermore et al.

How anomalous is UK for extreme values? Given the different spans of data and differences at same latitude. Can we do better than a spline fit? Are uncertainties in fit independent?

Transdimensional Bayesian Inversion – drawing curves through incomplete data sets. Recovering the distribution from synthetic data with typical fit parameters. Smoothest model consistent with data gives sooth shape parameter with latitude, more complex for scale param. Similar physical mechanism for shape, but scale has more local effects.

Qs

Global scale peak at Esk latitude: BFE plus N American obs. ?

* Yes it appears to be the case that there is a global peak in activity/return level at the latitude of Esk.

Could you subdivide obs into categories, e.g. coastal, high conductance… before applying EVT?

* Might be worth investigating to see if there are subcategories that maximise peak

Freeman et al.

Study of R (dB/dt) in relation to source, eg. DP1, DP2,IMF Bz. What causes damaging R? Substorm, enhanced convection, SC?

Study PDFs and partial PDFs of data distribution and thresholds at 99.97 and 99.0 and 90.0 percentile. Phase of storm defined by SOPHIE model. Extreme R mostly occurs during substorms. And some with enhanced convection. Extreme R increasingly more likely during enhanced convection. Convection electrojets are significant.

Qs

Can SOPHIE have more than 1 source at the same time?

* No. But the convection electrojet do persist through exp+rec phases.

On what basis can you extrapolate to the small sample data points?

* Only from part of the curve where there is far more data.

Rodger et al.

Review of MBIE project in NZ. History of project plus GIC data available from Transpower. Example of 2001, 2015 storms and GIC. Importance of storm commencements in NZ (how does this relate to presentations and results of e.g. by Mervyn, Neil, Phil?). VLF harmonics correlate well with GIC.

Remove lines and transformers when GIC is raised. Seems to be a good mitigation plan.

Extreme events study.

Qs

What level of GIC is dangerous? How long does it need to be high?

* varies greatly between transformers, different age etc

Kavanagh et al

IMAGE and EISCAT data. Height integrated conductivity and vxB. Little structure and correlation between sigma-H and E. Depends on cause of conductance, correlation depends on time and space. Spatial effects may be important in EISCAT data.

Qs.

Change in altitude of conductance with MLT: is that due to precipitation? (Yes) How significant is that is in producing GIC?

* Hard to say yet.

Significance of Rate of change of conductivity

* Promising but early days

Huebert et al

Description of DMM setup, locations etc. Results of MT survey to support E-field models.

Qs

Small scale structure of grid really matters

* Yes, as small scale dominates local measurements and we need to keep up to date with grid changes

How would more than 1 MT unit improve on understanding conductivity?

* Will be touched on in talk tomorrow (Kathy talk)

Beggan et al

Electric fields and current in GRW data from 1800s – need scale factors to get data from published books. Modern data – 100m probe separation. Description of data quality and observation on storms recorded. Thin sheet is ok compared to 3D for ~>50 sec period (Kuvshinov paper). Poor below that. Recommend moving to 3D, particularly for small storms.

Qs

Role of DC interconnectors

* Not believed to be a problem (DC isolated)

Could we use 3D in real-time

* Takes several weeks to run an event, so no. Thin sheet is compromise.

Gaunt et al.

Needs knowledge of science, engineering and societal impact to understand space weather impacts on power systems. Trevor studies transformer response to GIC, and related transformer engineering issues. Lack of consideration of inductance, e.g. in E-field or GIC response to B and network impedances. Power systems have a time constant of minutes. This is not considered in most models, so how can dB/dt be correlated with GIC so well?

Transformer response, Reactive power and voltage collapse risk is only defined for very simple conditions on the grid. Economic models are also simplistic.

Relays in system have time responses of 0.1 seconds or so, making decision making difficult.

Day 2

Clilverd et al

Global mid-lat perturbations and the 2017 storm. Comparing Mag data and GIC measurements. Breaks storm into 3 intervals. Description of how DP1 and DP2 systems, substorms drive specific recorded GIC. Substorm perturbations more important than directly driven solar wind effects. Small scale matters (<100km).

VLF near STA SGT3, which has GIC measurements.

Qs

Suggest a combined data analysis for storm of 5th August and 1st September, as a SWIGS output.

Eastwood et al.

Description of Gorgon code and its history. Resolution is high across the 3D box and not stretched in the tail. Description of M-I coupling and mapping of electrostatic potential. Bx has to be constant.

Comparison of benchmark results for subsolar magnetopause and lobe field strength. Model compares well with others. Next steps are looking at ionospheric response and adding magnetic variation model.

Qs

Using GPUs changes the architecture of Gorgon. Is that a problem?

- Not a quick change to do. Tension between development and management. Need to find a solution that fits student needs for research.

Comet image in solar wind movie.

- Yes – CME strips tail of comet at one point.

Can we generalise to a non-dipole field.

- Yes we can do. And is in the plan.

BATS-RUS model is closest in performance to Gorgon. But what are the main differences?

- Gorgon has uniform grid (BATS is stretched), Other difference is in solving for Div B.

Thomson et al.

See presentation. We can model PSP across the whole GB grid but need to refine pipe parameters with industry help.

Qs

Distorting effects of pipes lines in proximity to rail systems and power transmission system?

- not modelled or understood

Gallagher et al.

Review of data (e.g. SolarMonitor, Flarecast). Instruments at Birr, including several LEMIs. (417M) [www.magie.ie](http://www.magie.ie) – Armagh, Birr, Valentia. No modelling of DC links but think it might be important, given power input from Europe.

Examples of GIC modelling. Reconstruction of E-fields by TF methods. [www.gsi.ie](http://www.gsi.ie) for EM data for Ireland.

Qs

Can you quantify uncertainty in risk e.g. E-field.

- TBD

Discussion Session #1

<review of recent activities>

Smith et al.

Sudden commencements cause large R in the UK (and midlatitudes) – 5 mins duration.

Studied the fraction of R (i.e. dB/dt) attributable to SCs. For >99.975% 6% of large R are due to SCs.

Goes up to >90% of large R are due to 24-72 hours of SCs.

If you can predict SCs (e.g. from L1/L5 monitors) then you can predict the 3-day intervals in which the UK will see largest R.

What are the magneto conditions during large R?; can we predict whether a SC will lead to a storm?; Can we decompose the SC signal to get the dynamic pressure historically?

Qs.

How do your results compare with Mervyn’s work on substorms and exp+rec results?

* Not as significant as the latter.

Clustering in time, do they overlap?

* No we haven’t, so don’t know

Eastwood et al

Impact depends on LT of arrival of CME.

Dipole tilt is +/- 34 deg annually. Location of dayside X-line on dayside varies. Explore how the tilt distorts the current sheet and location of X-line, reconnection rate etc.

Also looked at 10% stronger dipole (cf 1859) but tilt angle is a stronger effect.

Will look to implement a ground magnetic perturbation calculator from the FAC

Qs

Is phase difference (N/S vs tilt) significant.

* Probably not unless >30 deg

Is the tilt vs strength comparison fair? Maybe better to run both historical tilt and strength as it was.

* Yes that makes sense.

Maffei et al.

Forecasting SV and flows – 1859 until today. Some basics on tilt and strength changes. How to model the geodynamo and the problem of realistic parameterisation. Looking at centennial forecasts made by IPGP. How will the tilt and strength change from predicting CHAOS-4, columnar flow, toroidal constant flow? UK Geomag latitude will be 65-75 N in 100 years.

Qs

The decline in intensity isn’t maintained by some flows?

* Yes because we optimised the dipole latitude
* Will the substorm cycle even be possible for very high tilts?

Hapgood et al.

Risk scenarios and benchmarks are how we define worst cases. How should we quantify this?

2012: 5000nT/min (prior to 2012 the figure was 500nT/min)

2018: E could be 20V/km

What records exist to improve the evidence base?; state of art changing internationally?;

Risk for higher HVDC connections? Impact of low carbon generation –alternative technologies and batteries

Qs

E field vs B-field:

- Problem is that E-field is never uniform and that 1 value is never good enough.

Odds and Ends

Juliane & Kathy.

Review of papers from 1970s plus legacy data from Simba and Iapetus projects

Mike.

AGU policy where there is sensitive data, like GIC? Policy is evolving.

Phil.

Location of dip pole in ionosphere might impact neutral wind flow (and vice versa)

David.

Met Office implementing SWMF model (BATS-RUS+Ridley+inner-mag model) in Feb 2020.

Need to spend some time in verification tests.

E-field models (Campanya model) uses BGS obs data.

Day 3.

Quick discussion ahead of start: Date of next meeting - late June or mid September, and to be aware of final meeting the following year (no cost extension makes a difference??) **Doodle Poll required.**

Hapgood et al.

Track circuit issues; low power (10s of Amps) for cables and relays; 2V/km E-field could drive ~70mA which would be sufficient to overcome track circuit control.

South Wales anomaly report: dynamic electrojet during specific events & relation to estimated E-field

**Get track details for the line and model via transmission line theory** (for D Boteler). What is happening re Jim Wild’s plans for measurement in a line?

Rodger et al.

Buy-in by engineers and management in Transpower has made a big difference in engagement on GIC (including at ~ board level).

SW is a hazard amongst many that NZ must deal with. Want data ingestion from Intermagnet for fault analysis.

Want 1:2500 year event. Mitigation case – economic costs and probabilities.

**What is probability of event, what is storm like, how long would it last, what can we do? How will we know it is extreme enough?**

Typical actions: deploy GIC blockers, network reconfiguration plan, more GIC monitors (upper SI and parts of NI), preparation plan ahead of arrival of CME and alternative actions during storm, data portal in control room for GIC, Harmonic data, magnetometer data in real time, routine testing of plan.

Also starting to get PSP data for NI pipeline network. They have UK contacts with data.

How likely is a really big geomagnetic storm? ~25-30% in 50 years (Love, 2012), c.f. 14% of M>7 on Alpine fault in 50 years.

Qs

Length of time needed to respond depends on what you want to achieve. 3-4 days is needed (put everything on the system), very quick to respond if (everything out).

Need to find an answer to the 1:2500 year question.

**Ask Mike Lockwood if it is possible to better quantify a 1:500 (or greater) year event.**

**From Dst peak we can statistically estimate the duration of the storm. But when we can return to normal is still to be quantified and how to quantify this. Checklist of typical markers of the end of a storm, and probability of burst of dB/dt in that tail as a function of time.**

**Ideas brought out in Discussion Session #3 to be followed up:**

* **Multidisciplinary papers at lead author instigation**
	+ **Industry journals? Nature Science summary paper for SWIGS as a whole?**
	+ **Can we fully characterise a storm? Sep 2017?**
* **Follow up on RS summer exhibition (BGS, BAS, RAL, Reading) – need IC and MMSL buy-in, as local hosts**
* **Special journal issue – AGU SW (would likely include external contributions)**
* **Conferences – use SWIGS badging**
* **Industry forum – contact Met Office, GO Science, SEIEG, Mark Prowse to coordinate a round-table in 2021. Maybe tag up with RadSat for impact.**
	+ **How has worst case scenario changed due to SWIGS research?**
	+ **Does space weather preparedness strategy need to be revised?**
* **Doodle to confirm date of next meeting (location?)**
* **‘Researchfish’: record your outputs!**
* **Outreach:**
	+ **Royal Society event**
	+ **New Scientist Live**
	+ **Expensive, how do we get resources? People in London for a week. Interactive displays. Giveaways.**
	+ **What resources do we already have? Some money is in SWIGS budget.**