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Removing local variability from Potential Gradient data – the Carnegie filter

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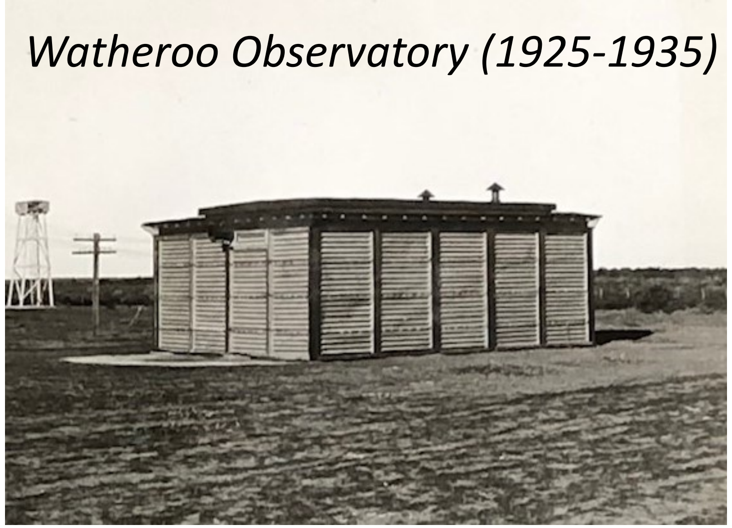
Motivation: How to exploit historical AE data?

Atmospheric Electricity is embedded in the climate system (e.g. Lightning is now recognised as an Essential Climate Variable). Long duration Potential Gradient (PG) measurements exist from many sites, making comparisons possible with other climate parameters.

Lerwick Observatory (1925-1981)

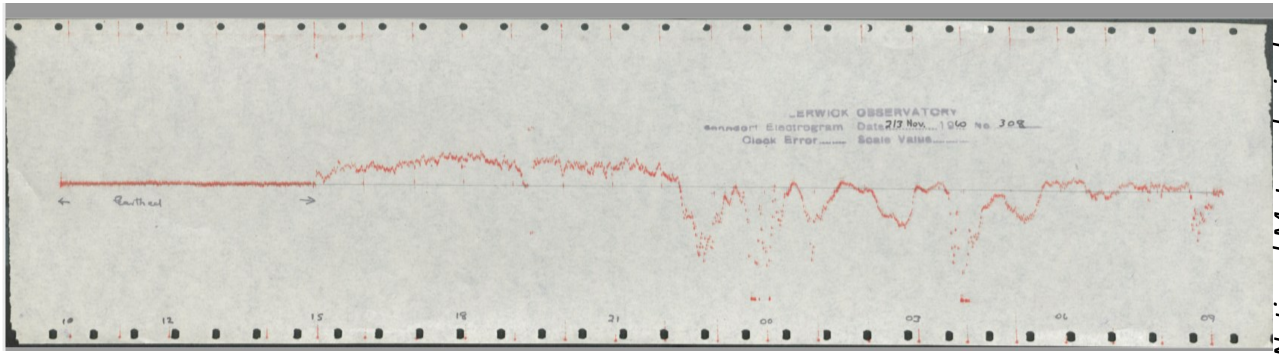


Watheroo Observatory (1925-1935)

DTM Archives, Carnegie Institution for Science

Kakioka Observatory (1929-2021)

Benndorf electrometer



National Meteorological Archive

R.G. Harrison, and J.C. Riddick, HGSS (2022) https://doi.org/10.5194/hgss-13-133-2022,

Data selection methods

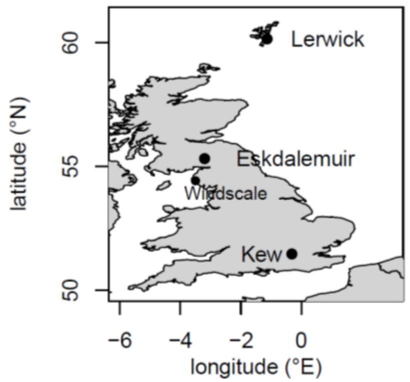
- Atmospheric electrical quantities are useful as they can show **global circuit, climate, and space weather-related effects**.
- However, space weather and global circuit effects can be **masked by local factors**, often weather related.
- Early PG data selection used daily classifications, following geomagnetic practice, but a later, more successful, method is to select data obtained during **fair weather (FW) conditions**
- It is **difficult to apply FW selection retrospectively** to past data, as it requires (1) the original PG data and (2) co-located and simultaneous meteorological data. Not all the data required may have been digitised.
  → New methods are needed to exploit the data.

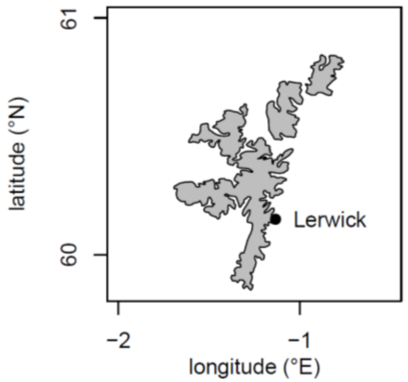
See also: R.G. Harrison and K.A. Nicoll, Fair weather criteria for atmospheric electricity measurements *J Atmos Sol-terr phys* 179, 239-250 (2018) https://doi.org/10.1016/j.jastp.2018.07.008

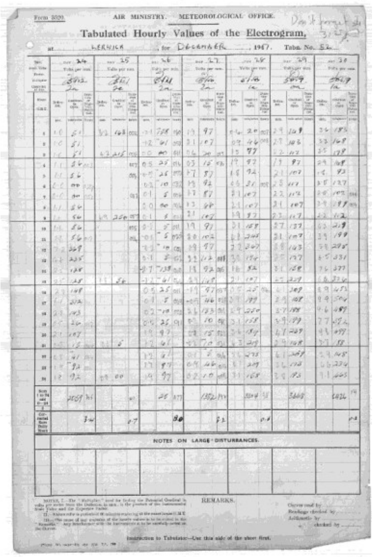
El Niño Southern Oscillation in Lerwick PG, Shetland

Lerwick Observatory operated a radioactive probe PG sensor and electrometer from 1925 to 1984. Good “fair weather” data available from 1968, especially Decembers.

Compare with Pacific ocean temperatures recorded in “Niño 3.4” area (bounded by 5°N-5°S and 120°-170°W), 8000 miles away







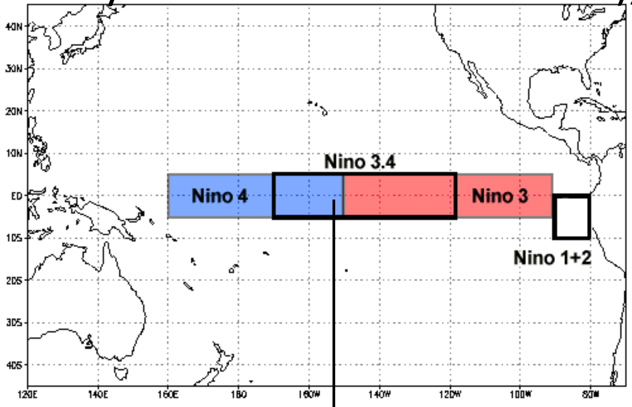
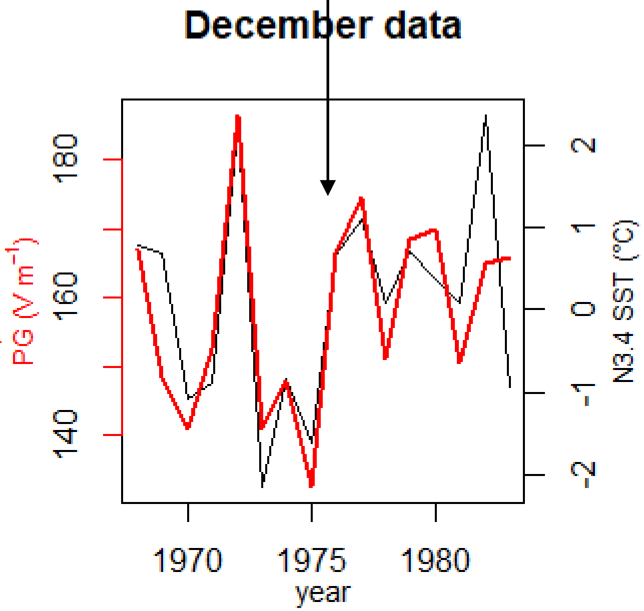


Image from www.ncdc.noaa.gov

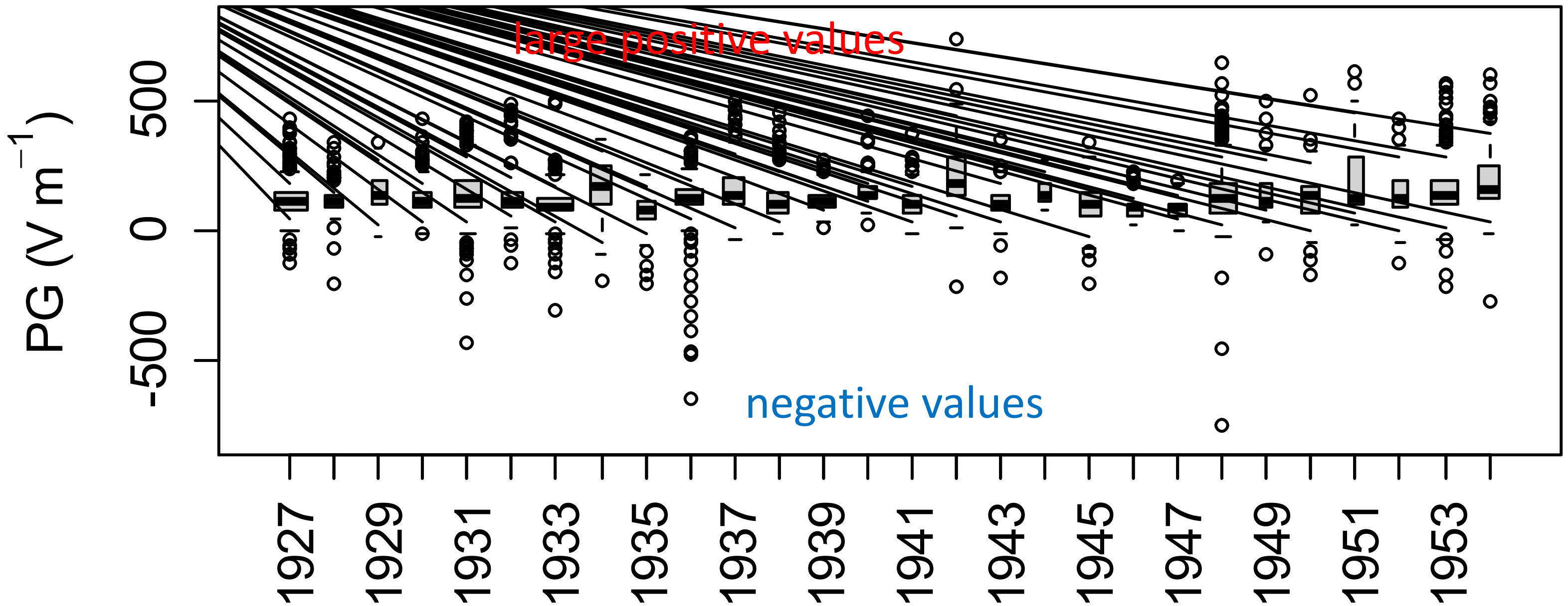


R.G. Harrison, and J.C. Riddick, Atmospheric electricity observations at Lerwick Geophysical Observatory, *Hist. Geo Space. Sci.*, 13, 133–146, https://doi.org/10.5194/hgss-13-133-2022, 2022.

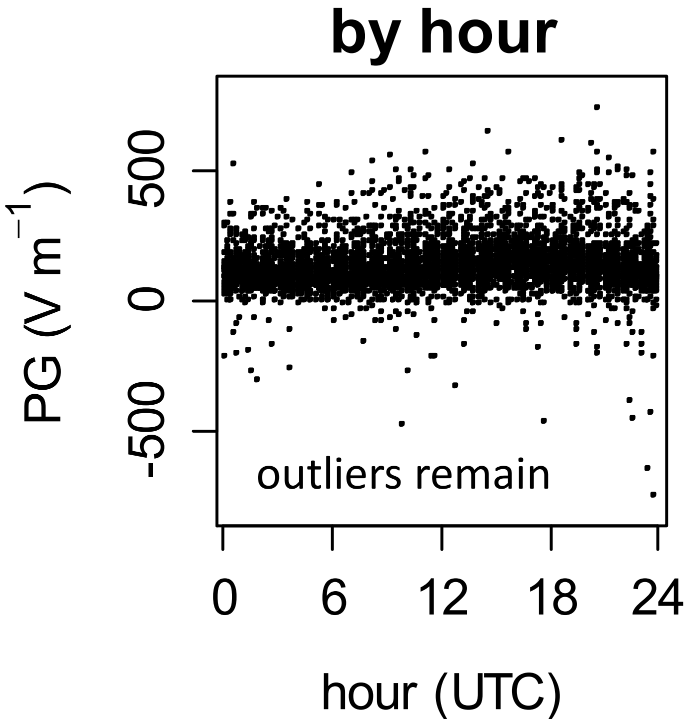
Modelled by Slyunyaev *et al* 2021 *ERL* **16** 044025

What about earlier PG data?

PG data from Lerwick in December, for undisturbed days (classified as 0, 1 or 2) from 1927 to 1954



Organising the **data by hour** suggests a diurnal variation having a maximum later in the day

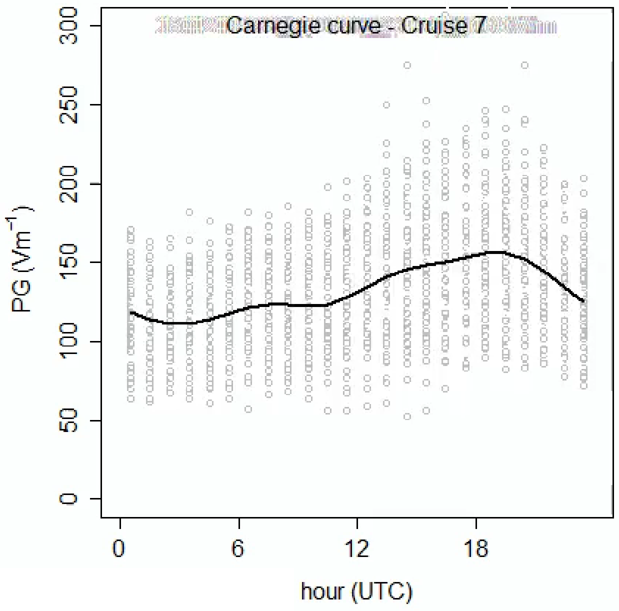


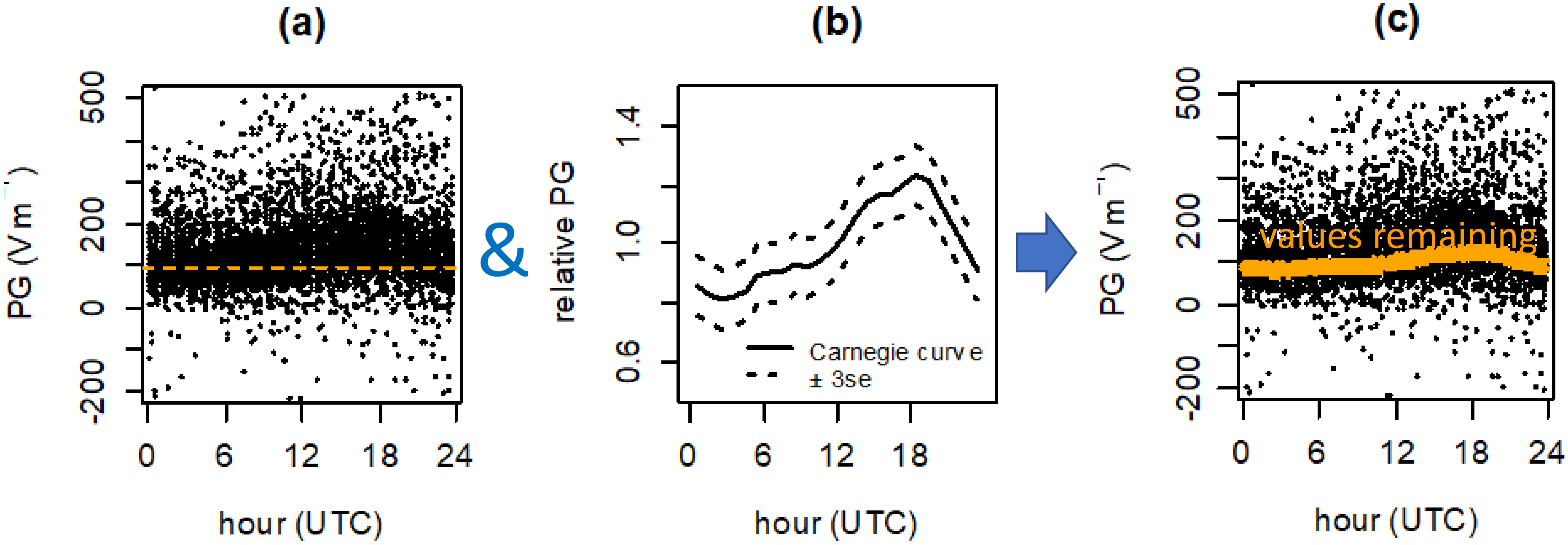
Removing outliers

How much variability is “typical”? During Cruise 7 of the *Carnegie*, 82 undisturbed days were identified, which were averaged to give the **Carnegie curve**.

→ could assume Carnegie variation is **always present and underlying all measurements,** discarding all values which are not “close” to it

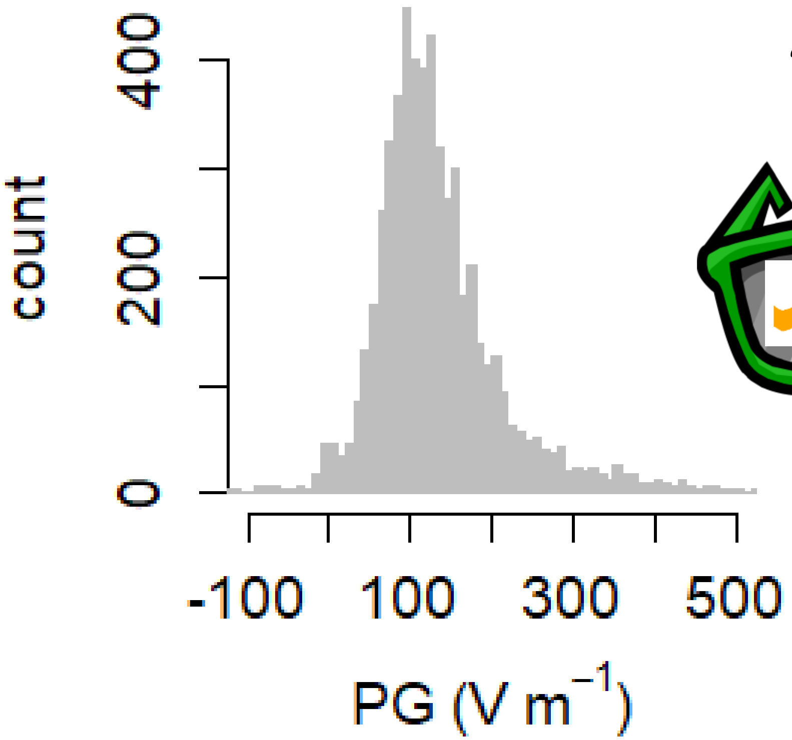
DTM Archives, Carnegie Institution for Science





Effect on distribution of PG values

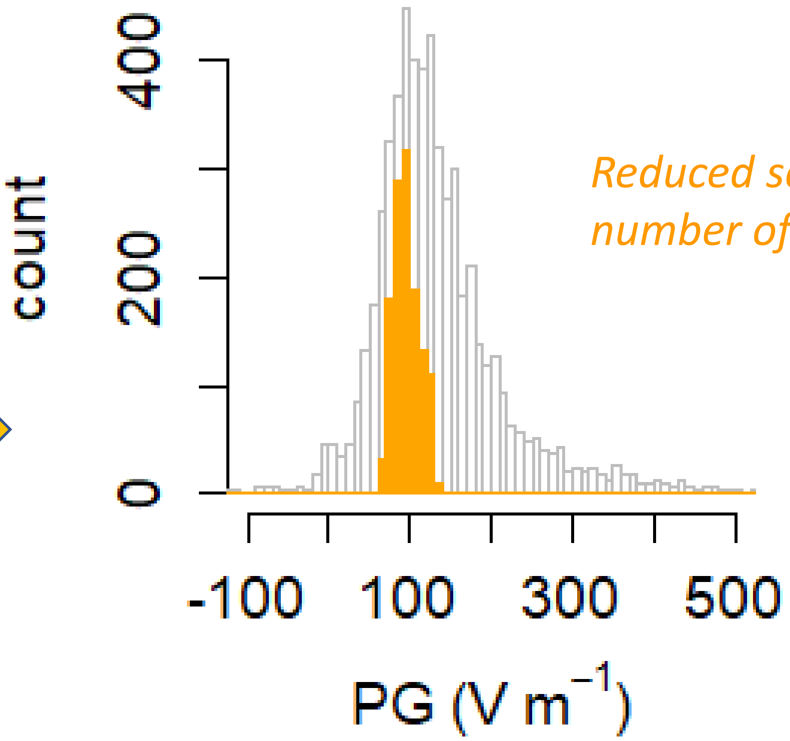
Histogram of hourly values
(Decembers, 1927-1954)



Wide range, including large positive and negative values

“Carnegie filter”

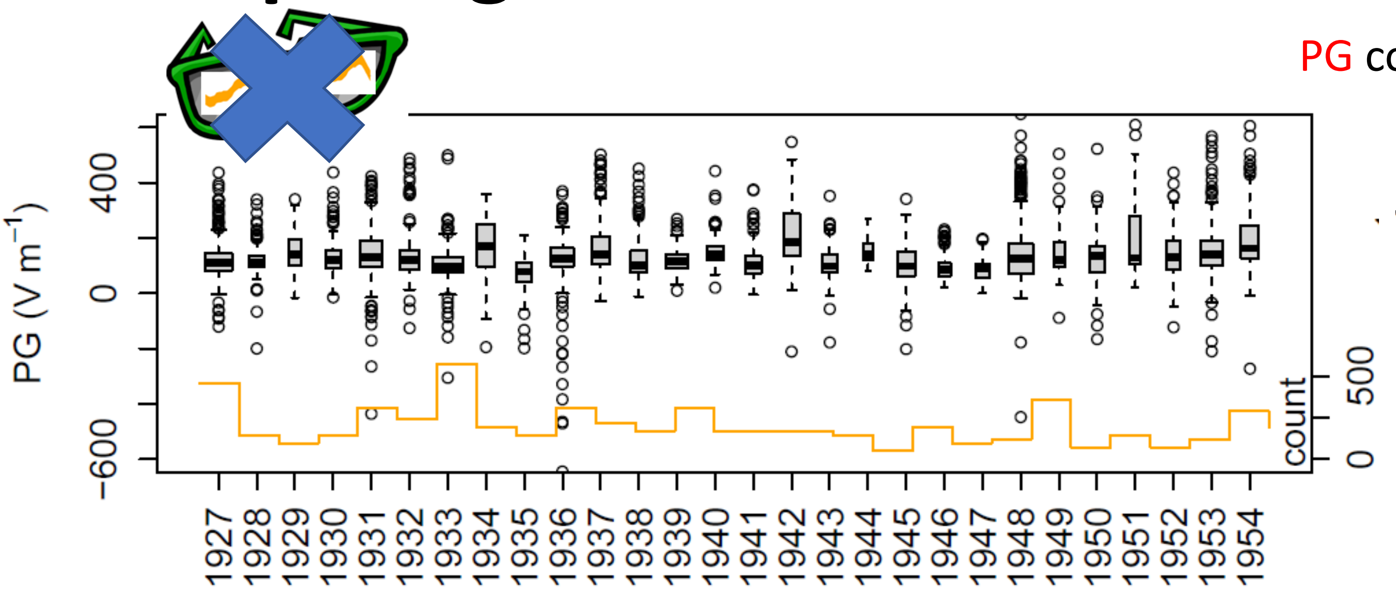
values remaining after
Carnegie filter

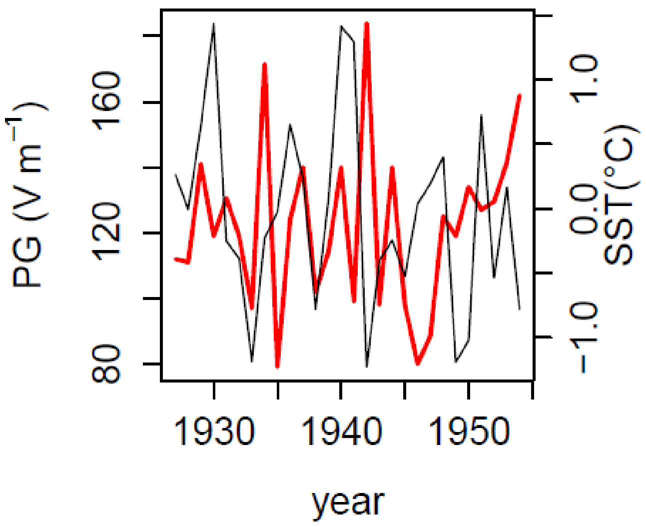


Reduced scatter (and number of points thinned)

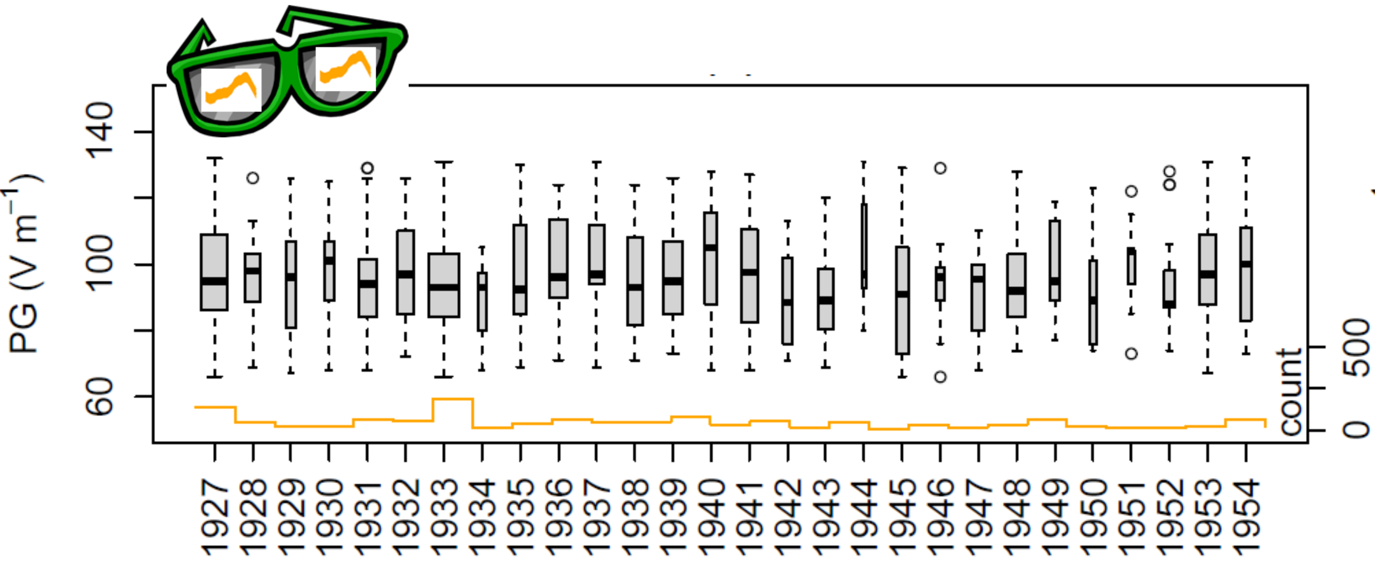
Comparing filtered Lerwick PG with Pacific temperatures

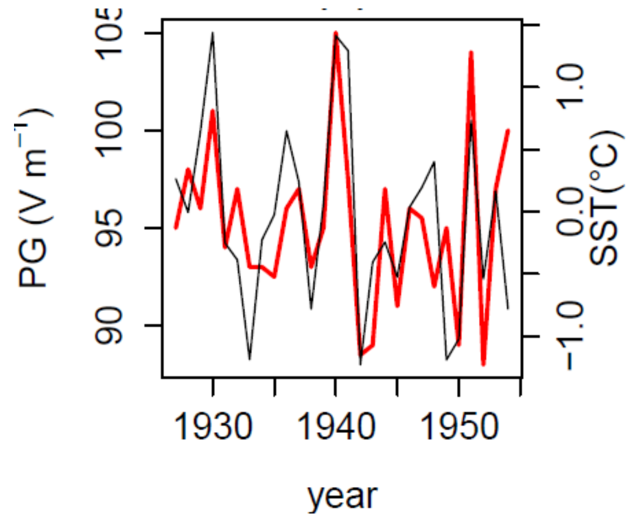
PG compared with Niño 3.4 ocean temperatures





correlation = -0.02

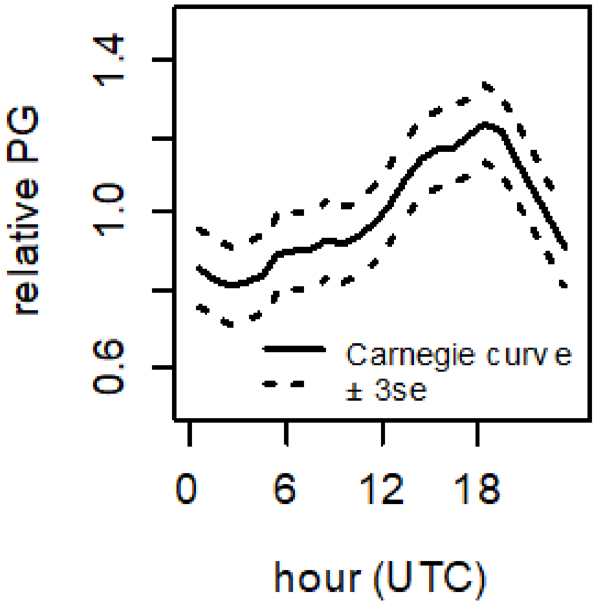




correlation = 0.61
(p<0.005)

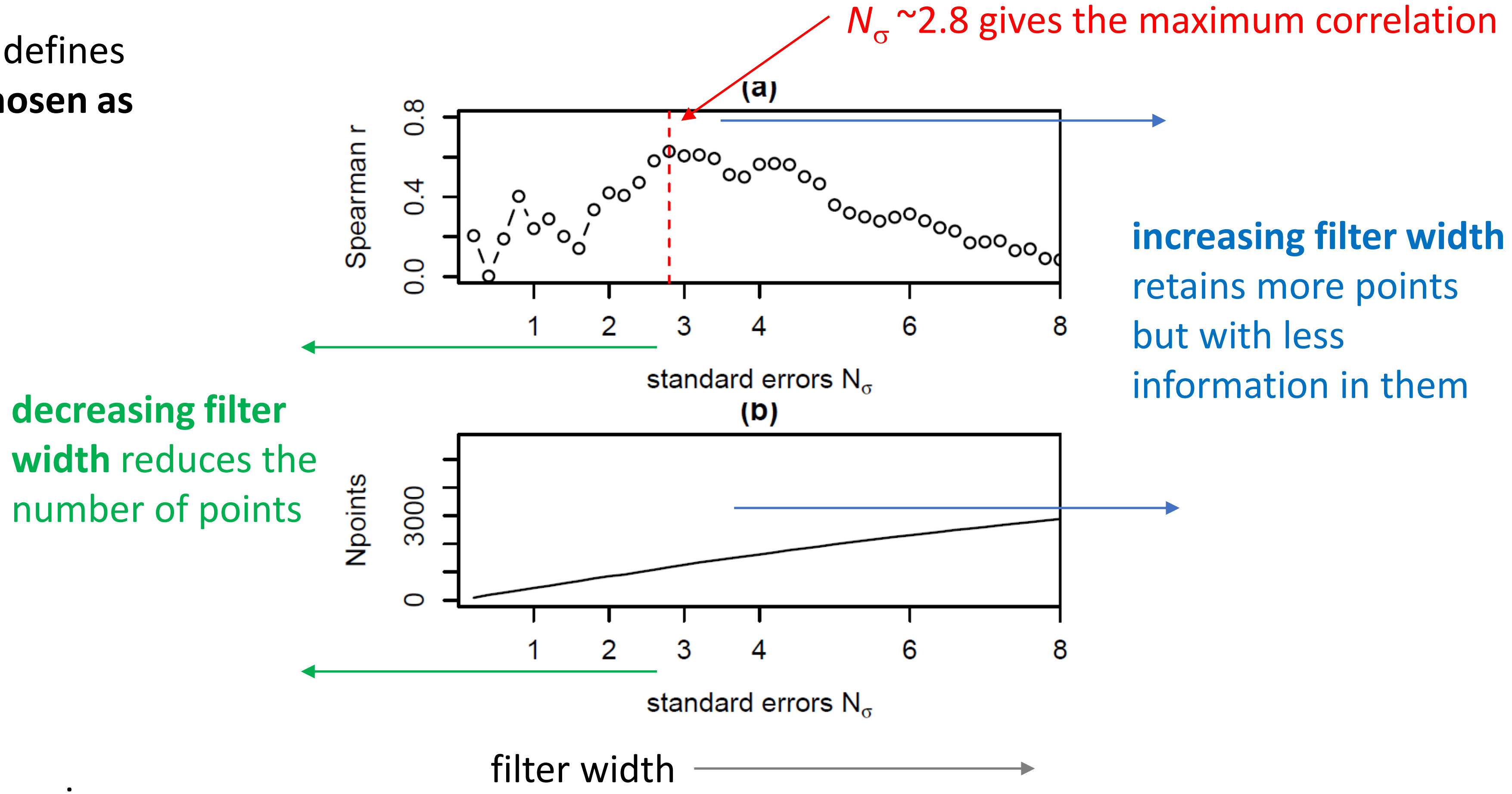
Choice of filter "width"

The "width" of the Carnegie filter defines the points to retain and reject - **chosen as ±3standard errors (N_σ=3)**



→ The **width parameter** (N_σ) determines how many points are retained, and how close they are to the Carnegie curve

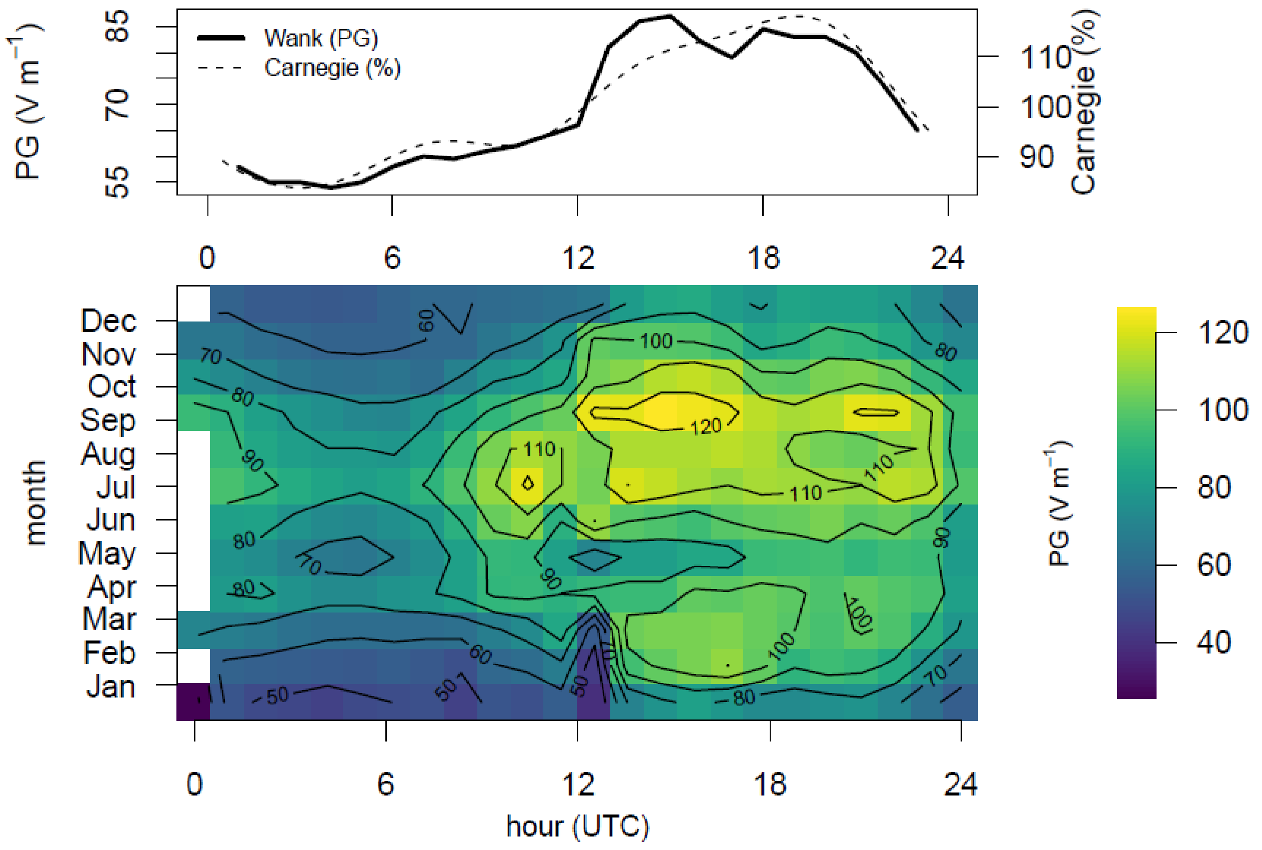
Varying the filter width (N_σ) can be investigated using the resulting PG –SST correlation



Application to Garmisch PG data

- Observations of many parameters were made on Mt Wank in the Bavarian Alps (1780 m, 47° 30' N, 11° 09' E) between 1972 and 1983, by Reinhold Reiter (1920-1998).
- The hourly data have been recovered and digitised (see Harrison and Schlegel, 2023)
- PG values show, on average, a single daily maximum Carnegie-like behaviour

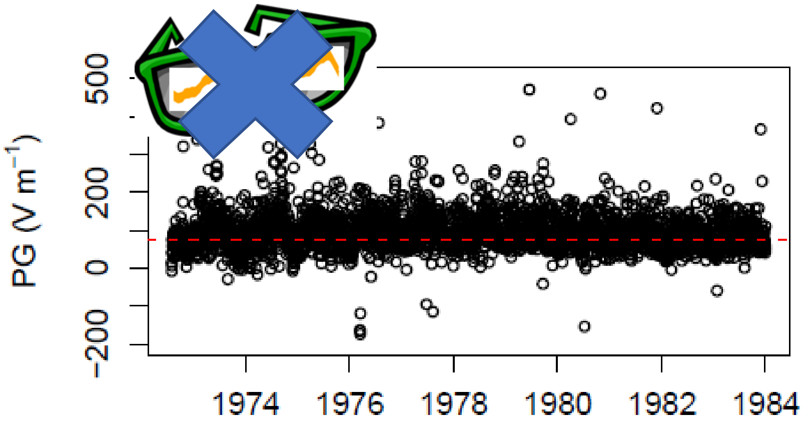
→ Use this dataset to test the Carnegie filter approach

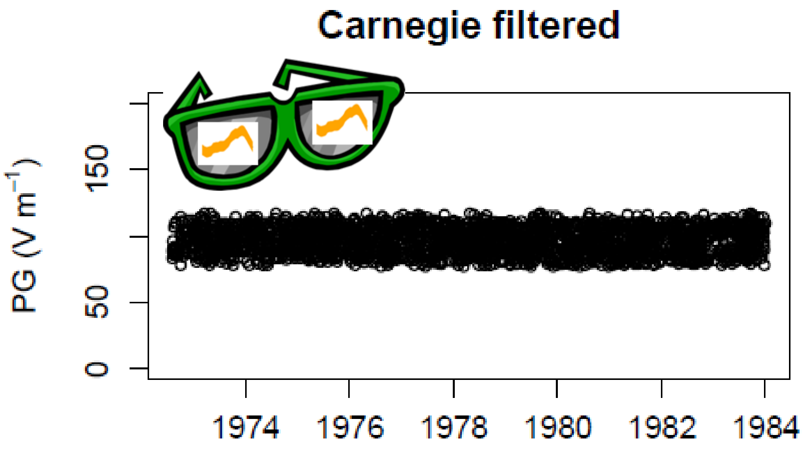


R.G. Harrison and K. Schlegel, Atmospheric electricity observations by Reinhold Reiter around Garmisch-Partenkirchen *Hist. Geo Space. Sci.* https://doi.org/10.5194/hgss-2023-4 (2023)

Carnegie filtering of Garmisch data

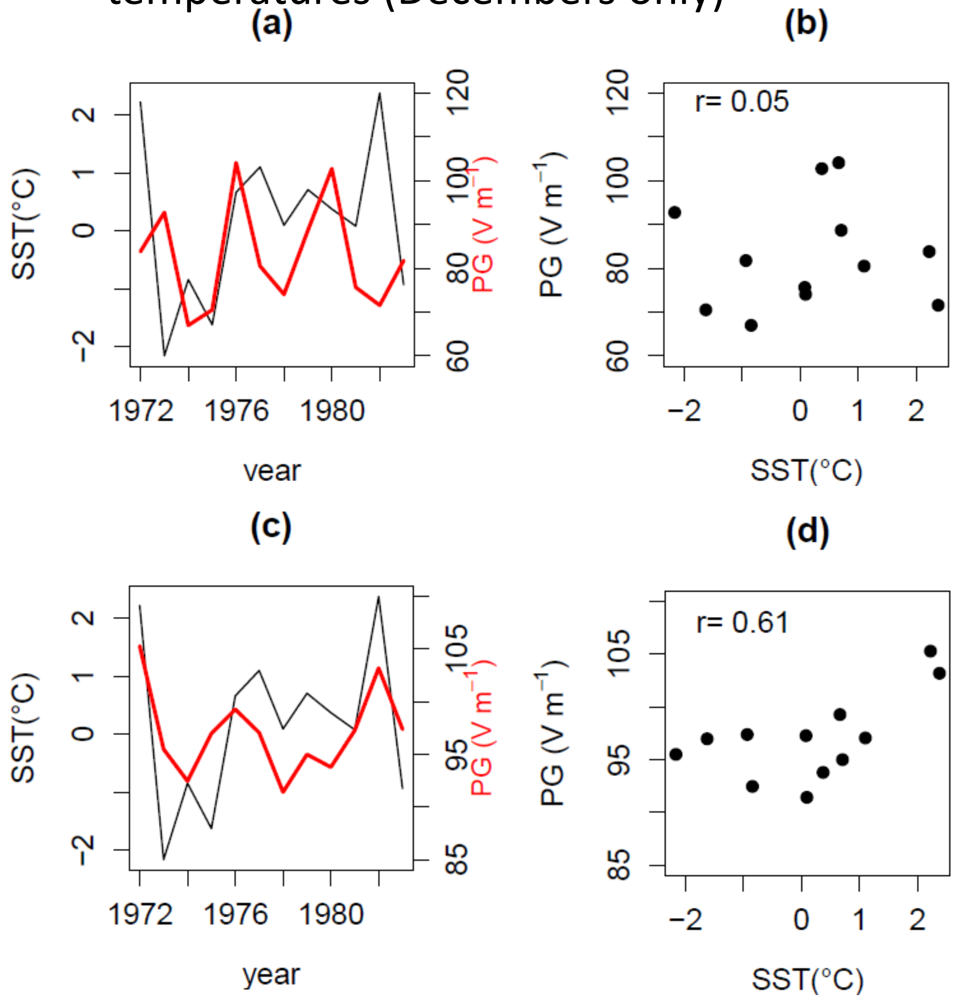
raw hourly PG data





(filter width N_σ =1.4)

PG compared with annual Niño 3.4 ocean temperatures (Decembers only)



→ correlation with SST is improved, despite having fewer points in each yearly average

Conclusions

- The relationship established between El Niño sea surface temperatures in the Pacific and PG, through the global circuit, allows data selection from historical sources to be evaluated

- The "Carnegie filter" removes hourly outlier values, which is rooted in the known behaviour of the global circuit

- Despite thinning the data, Carnegie filtering followed by averaging improves the annual correlation between PG and the SST, implying retention of values more representative of the global circuit i.e. improving signal to noise

See: R.G. Harrison, K.A. Nicoll, M. Joshi, E. Hawkins, Empirical evidence for multidecadal scale Global Atmospheric Electric Circuit modulation by the El Niño-Southern Oscillation *Environ Res Lett* 17, 124048 (2022)

Links to papers:

- R.G. Harrison, K.A. Nicoll, M. Joshi, E. Hawkins: Empirical evidence for multidecadal scale Global Atmospheric Electric Circuit modulation by the El Niño-Southern Oscillation *Environ Res Lett* 17, 124048 (2022) https://iopscience.iop.org/article/10.1088/1748-9326/aca68c
- N.N. Slyunyaev, N.V.I lin, , E.A. Mareev,.G. Price: A new link between El Nino - Southern Oscillation and atmospheric electricity, Environ. Res. Lett., 16, https://doi.org/10.1088/1748-9326/abe908, (2021)
- R.G. Harrison, M. Joshi, K. Pascoe: Inferring convective responses to El Niño with atmospheric electricity measurements at Shetland *Environ Res Lett* 6 (2011) 044028 http://iopscience.iop.org/1748-9326/6/4/044028/
- R.G. Harrison, and J.C. Riddick, Atmospheric electricity observations at Lerwick Geophysical Observatory, *Hist. Geo Space. Sci.*, 13, 133–146, https://doi.org/10.5194/hgss-13-133-2022, 2022
- R.G. Harrison and K. Schlegel**,** Atmospheric electricity observations by Reinhold Reiter around Garmisch-Partenkirchen *Hist. Geo Space. Sci.* https://doi.org/10.5194/hgss-2023-4 (2023)