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An investigation into Geoelectric tides at three sites in the UK

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Introduction

Electric fields are created by the motion of sea water through the geomagnetic field, **E** = **v** x **B**, or by the rapidly magnetic field, ∇x**E**= -∂**B**/∂t (where, **E** is the electric field, **B** is the magnetic field and **v** is the velocity of the conductor). The electric fields created by tidal motion can be expected to 'leak' into the solid earth at the sea-land boundary and be detectable close to the coastline [1].

Continuous geoelectric field monitoring began at the three BGS magnetic observatories, Hartland (HAD), Eskdalemuir (ESK), and Lerwick (LER) (Figs.1,2) in 2012/2013. The observatories are in different settings in relation to the seas surrounding the British Isles and the new data allow investigation of any tidally generated signals.

One of the objectives of this project is to model the motionally induced currents and remove this signal from telluric measurements to reveal space weather effects.

Fig. 1. Locations of geoelectric and geomagnetic observatories (red circle) and the closest tide gauge stations. (blue triangles)

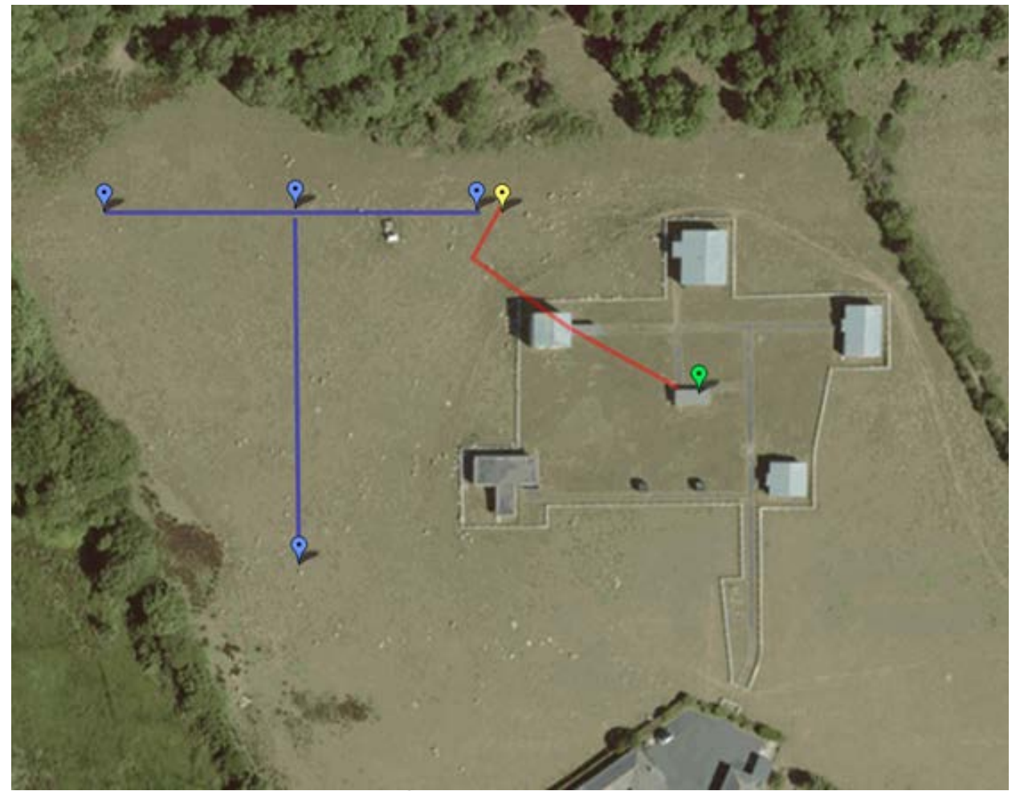
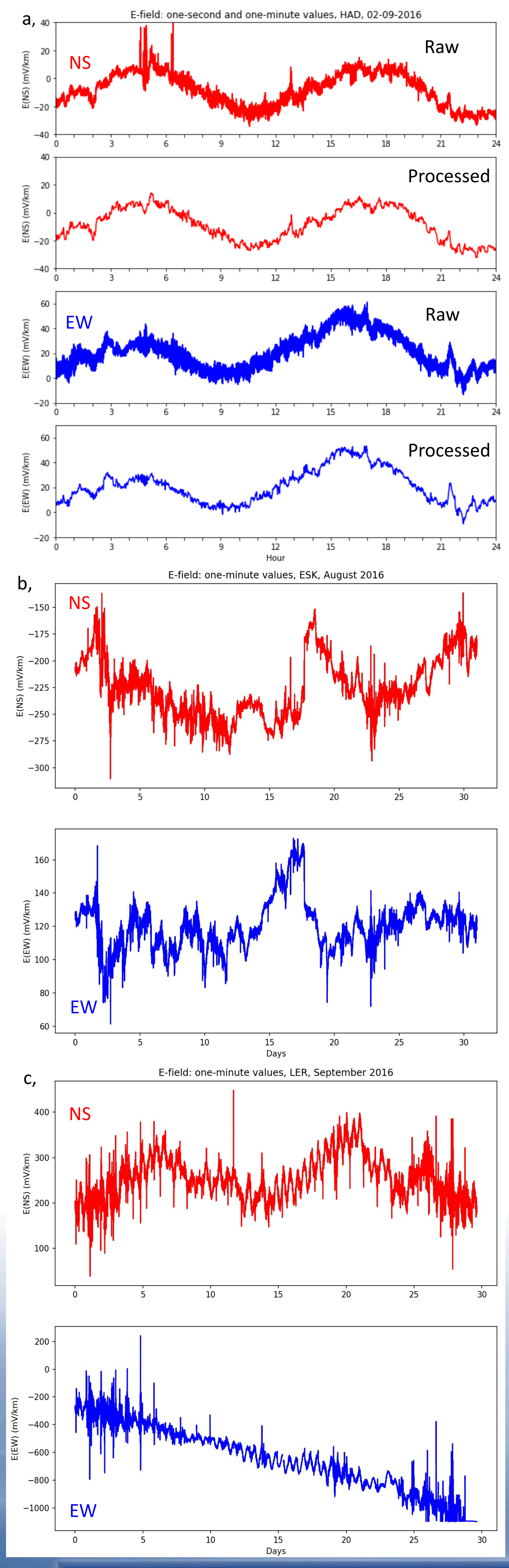


Fig. 2. Hartland E- field recording setup: A pair of electrodes, 100 m apart, oriented in NS-EW direction (blue lines) measure the voltage difference between two points in the ground Non-polarising electrodes are used to minimise self potential. Similar arrangement exists at each site. Red lines show power and communication to the digitiser.

Data and Quality Assurance method



North-South (NS) and East-West (EW) components of the electric field are recorded at 10Hz. The data contain many spikes, steps and gaps of variable duration, and show drift over a period of time.

Data are first 'cleaned' by rejecting obvious outliers and then decimated to derive:

- one-second values by applying a median filter
- one-minute values from the one-second data by first using a Hampel filter where the central value in the data window is replaced with the median if it lies far enough from the median to be deemed an outlier and then by applying a 61-point cosine filter.

The effect of the data processing regime is shown in Fig.3. The current strategy is generally successful in removing spikes and overall noise, however steps still remain in the data. The semi-diurnal tidal signal is most evident at HAD, Fig.3a. This is not surprising since the Bristol Channel has the 2nd highest tidal range in the world. This signal is seen in LER too and even at ESK despite it being furthest away from the coast.

Fig. 3. The effects of various filtering strategies in deriving one-second and one-minute values. a, Daily plot of one-second and one-minute E-field at HAD on 02-Sep-16. Monthly plots of one-minute E-field data from b, ESK Aug-16 and c, LER Sep-16. NS-red, EW-blue.

Which frequencies are present?

We are primarily interested in the signal induced by the gravitationally driven oceanic dynamo. Following previous works on the English Channel and the St George's Channel we try to separate the signals into solar and lunar components using technique called Superposed Epoch Analysis (SEA). [2,3]. Averaging over a lunar day (24 h 50 min) the solar signal cancels out, and averaging over a solar day (24 h) the lunar signal is eliminated (Fig.4).

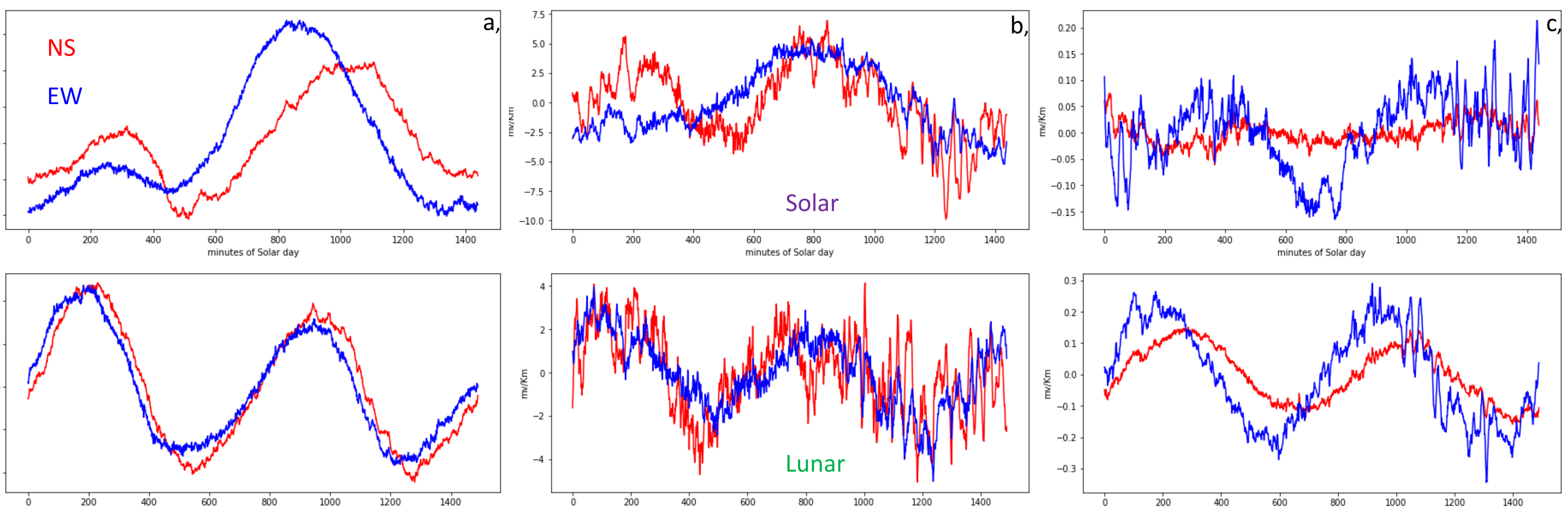


Fig. 4. Superposed Epoch Analysis of E-field components using solar (top) and lunar (below) days for a, HAD Sep-16 b, ESK and c, LER May-16. NS red, EW blue.

A common method of identifying significant signals in a time-series is to carry out a frequency analysis using the fast Fourier transform (FFT). However, our data set has many gaps due to instrument failure, upgrades or simply the data having been removed because of poor quality. As it is unevenly sampled the traditional FFT will not work here. To overcome the problem of non-uniformly sampled time-series we have used the Lomb-Scargle Periodogram (LSP) to find any notable periodic signal (Fig.5). [4]

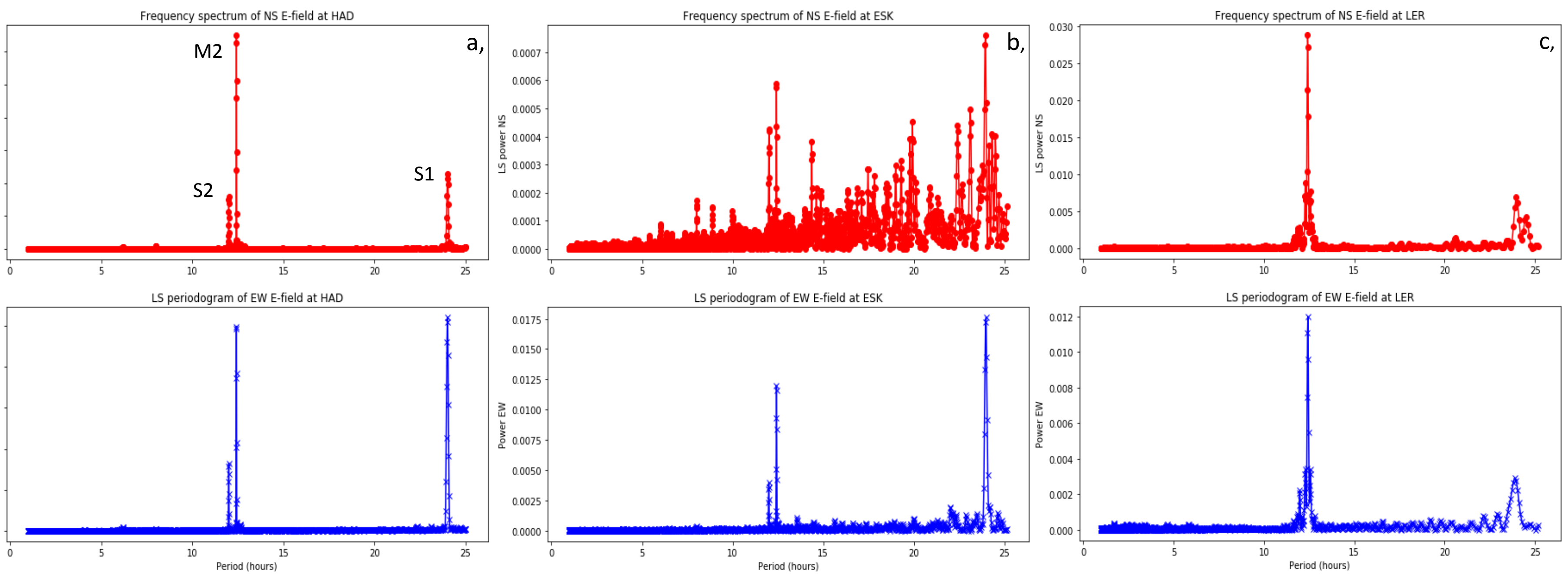


Fig. 5.Lomb-Scargle spectral analysis of E-field components, NS (top) and EW (below) a, HAD May-Dec 16, b ESK Aug-Dec 16 and c, LER Sep-Oct 16. M2 (12.42hrs) is the semi-diurnal lunar tide and S1 (24hr) and S2 (12hr) the solar daily and semi-diurnal tides.

Correlation with tide gauge data

We used the rate of change of the tide height (dh/dt) at Ilfracombe in 2016 to calculate a lag-time for the E-field at Hartland. Maximum correlation is between **E (NS) and dh/dt was at -1 hour** (1 hour lag) for over 80 of the 358 days, and about 50 days for **E (EW) at a lag of -45 min** (Fig.6).

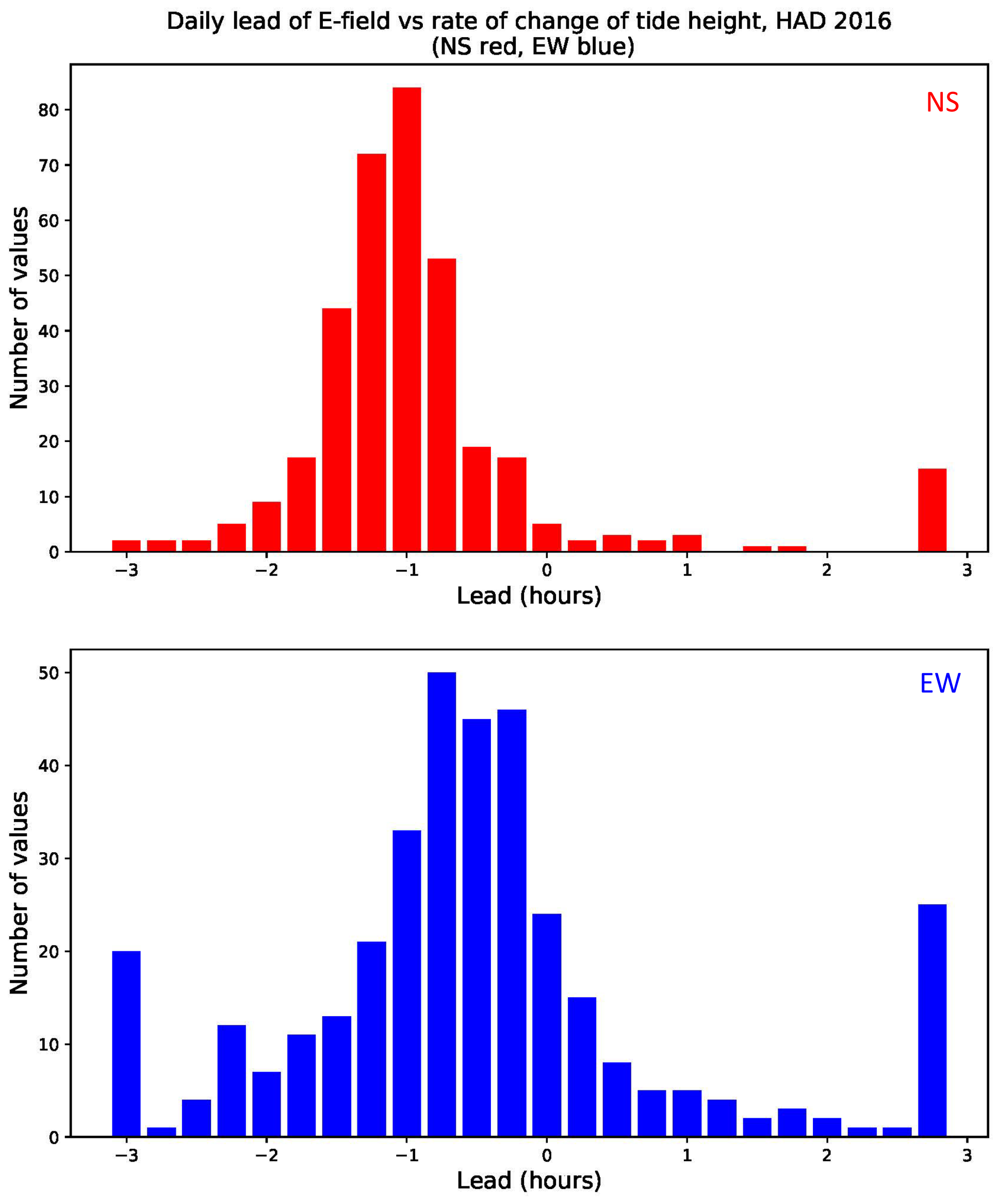


Fig. 6. Correlation between E-field at HAD and dh/dt at ILF during 2016, NS (top), EW below. Negative lead time indicates the E-field lags the tide, as expected.

Summary and further work

The major signal of interest, the lunar semi-diurnal M2 variation, is persistent in the data. The two dominant frequencies at all three stations in both NS-EW components are the M2 (12.42 hr) and the solar-diurnal (24 hr) periods. The solar semi-diurnal, S2, is also present but smaller. In the future we will investigate modelling the tidal signal in E-field data using tidal height or current velocity data. We will also carry out MT analysis to find the impedance tensor at each observatory.

Acknowledgements

BODC and NOC – are thanked for making available tide gauge data from the stations shown in Fig1. I thank BGS for supporting this Master's research project. BGS observatory engineers are thanked for their continued technical support for the geoelectric field measuring equipment and colleagues are thanked for their constructive comments on this project.. The following Python modules were used: Astropy V2.0.2, SciPy.org

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