A Study of Van Allen Belt Signatures of Nuclear Weapon Tests for Future CTBT Technologies

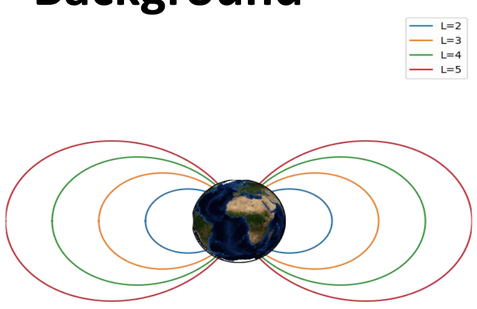
F. Wach, J. Velthuis – *University of Bristol*

C. Steer – *St Mary's University, Twickenham*

Motivation

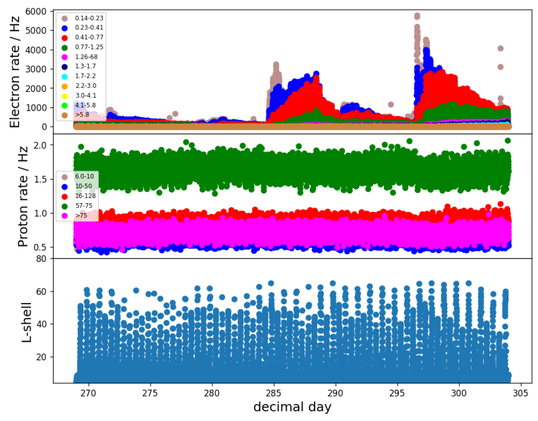
One of the methods of enforcing the Comprehensive Test Ban Treaty (CTBT) involves complementary measurements of seismic signals. Data from low Earth orbit satellites show that seismic events can result in particle bursts which can be detected by sensors on board of satellites. There is strong evidence for precipitation of charged particles in the van Allen belts caused by seismic events. Coincident particle bursts in satellite-borne detectors have been observed with a >5-sigma significance with earthquake activity at the corresponding location in SAMPEX/PET, MARIA/SALYUT-7, GAMMA-1 [1], and DEMETER [2]. The mechanism responsible for particle precipitation can be linked to acoustic gravity wave causing Ultra Low Frequency (ULF) charge oscillation in ionosphere coupling to the magnetosphere through travelling Alfven waves around the Earth's dipolar field [3]. This same mechanism is also expected for underground nuclear tests. The main objective of this project is to study the signatures of nuclear weapon tests performed by North Korea in 2006, 2009 and 2013 and ultimately to discern natural earthquake phenomena from nuclear tests.

Background



L-shell distribution around the Earth

- Data released by Los Alamos National Laboratory from between Jan 2001 to Dec 2016
- 23 high orbit GPS satellites equipped with Burst Detector Dosimeters IIR (BDD-IIR) [4] and Combined X-Ray sensor and Dosimeters (CXD) [5]
- Provides information on rates and fluxes of protons and electrons as well as geographic locations, L-shells and magnetic fields detected by the satellite.
- Data collection interval 240 seconds.



L-shell, electron and proton rates measured by satellite ns53 on 26/09 – 31/10/2010

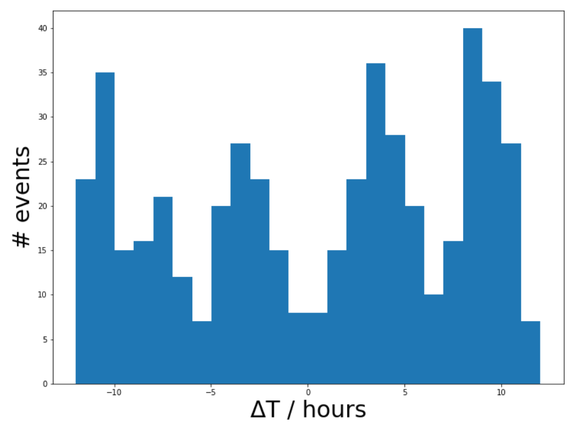
Temporal Correlation Analysis

Method

- As the data available only covers the period of North Korean testing, we use seismic events as a surrogate for this analysis.
- Particle bursts (PB) are defined as occasions where the electron rate measurement exceeding the average by > 4σ
- Earthquakes with M > 4 selected from USGS website and matched with PB within ±12 hours interval.
- L_{EQ} calculated by taking EME coupling altitude = 400 km.
- $\Delta T = T_{EQ} - T_{PB}$ recorded for $\Delta L = L_{EQ} - L_{PB} < 0.07$.

Results

- **Temporal correlation histograms show peaks representing particle burst resulting from earthquakes and their respective time delay.**
- These findings show the same patterns as described in literature.



Temporal correlation histogram for satellite ns54

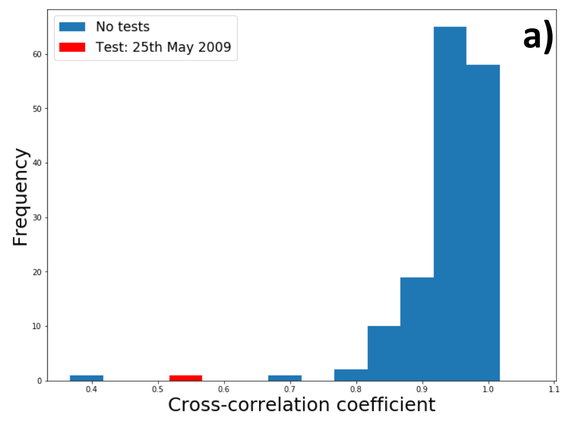
Cross - Correlation Analysis

Method

- Normalised cross – correlation coefficients of 2 week periods between different energy channels calculated for 16 years of data excluding periods of nuclear tests.
- Cross -correlation coefficients calculated for known nuclear tests and the values obtained are compared to overall distribution giving a set of p-vlaues for a given test.

Results

- Particle energies within bursts, in time and spatial coincidence with nuclear tests, are much less correlated than natural sources.
- **Nuclear tests appear as outliers using this detection method.**



b)

Channel	P-value
0	0.49
1	0.72
2	1.00
3	0.01
4	0.01
5	0.04
6	0.04
7	0.07
8	0.05
9	0.03
10	0.03

a) Cross – correlation histogram for channel 2 with channel 4;
b) Table of p-values for DPRK's test from 25th May 2009

Conclusions

- The GPS satellite data show particle bursts coinciding with earthquakes, which has not been observed before at these altitudes.
- Multiple peak structure in the temporal correlation analysis likely to be due to GPS satellite motion in and out of the particle bursts
- **Character of energy correlations within particle bursts associated with nuclear tests are quantitatively different than natural causes of particle bursts.**

Acknowlegements

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