

SHORT TERM SCIENTIFIC MISSION (STSM) SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: CA15211

STSM title: Intercomparing atmospheric electrical potential gradient with GPS derived tropospheric and ionospheric properties

STSM start and end date: 15/11/2019 to 25/11/2019

Grantee name: Attila Buzás

PURPOSE OF THE STSM

The primary objective of the completed STSM was to intercompare different atmospheric electricity and satellite quantities in order to study the coupling mechanisms between the lithosphere, atmosphere, and the ionosphere during a larger earthquake (magnitude: 4.6). To this end, atmospheric electrical potential gradient (PG) and GPS-derived Integrated Water Vapour (IWV) data recorded at the Emilio Serge Observatory, Mount Hermon, Israel (33°18'30"N, 35°47'07"E; HRMN) were analyzed. As one of the most important processes related to earthquakes that can cause an impact on the atmospheric electrical field is the enhanced radon emanation from the soil, radon measurements from HRMN were also included in the research (*Pulinets and Ouzounov, 2011*). Furthermore, to detect possible earthquake-related ionospheric phenomena, we examined variations in the TEC values derived from a global model (UPC-IonSAT; <ftp://cdis.nasa.gov/gnss/products/ionex/>) for the investigated area. Ultimately, water conductivity and water level data measured in a well in Nurit, Israel (32°32'32"N, 35°21'18"E) were added to the research as well.

By constructing a consistent dataset we were able to investigate the lithosphere-atmosphere-ionosphere coupling mechanisms based on several different physical quantities in a case study. We selected a series of larger (maximal magnitude: 4.6), shallow (depth of the largest earthquake: 8 km) earthquakes occurred in the vicinity of the measurement sites (~70 km away from HRMN and ~40 km from Nurit, earthquake preparation area: 95 km, **Fig. 1**).

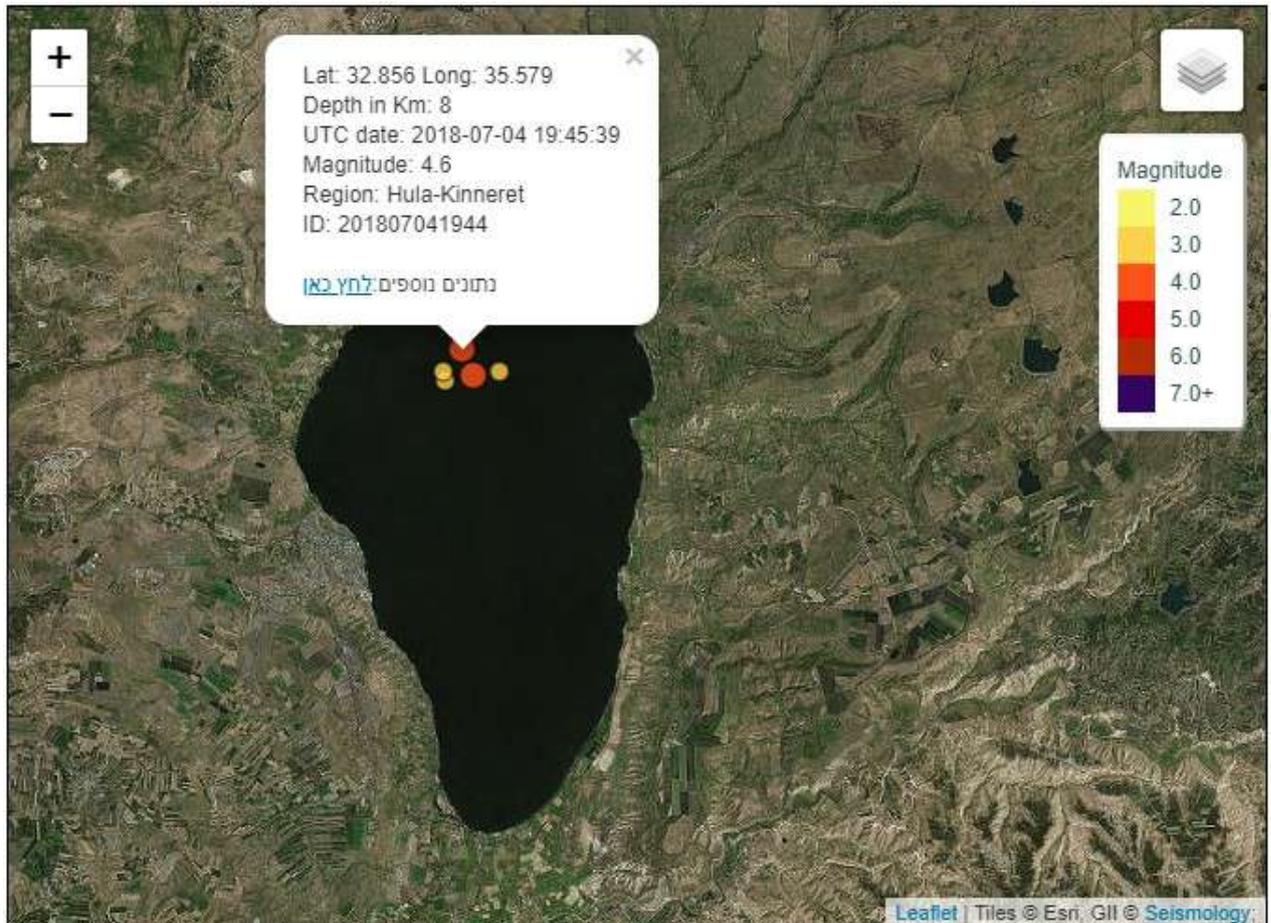


Fig. 1: The investigated earthquakes under the Sea of Galilee, Israel (Geological Survey of Israel).

DESCRIPTION OF THE WORK CARRIED OUT DURING THE STSM

- 15. November 2019: arrival to Tel-Aviv, Israel. Check-in at the hotel.
- 16-17. November 2019: familiarizing with the literature of atmospheric electricity, groundwater, and ionospheric earthquake precursors and the modus operandi of IWV and TEC measurements. Checking data availability and data structure.
- 18. November 2019: visiting Ariel University (the host institute). Discussing the research, i.e. which methods, data to use, selecting the nearest, large earthquake for which data are available (**Fig. 1**) and collecting the appropriate data (i.e. data from HRMN: IWV, radon counts in the air and in the ground, precipitation, PG, TEC and data from Nurit: groundwater conductivity and groundwater level).
- 19-21. November 2019: writing Python scripts to build a coherent, uniform database from all the various data.
- 22-25. November 2019: processing the data and applying statistical and spectral data analysis methods on them, i.e. removing erroneous values, selecting the fair-weather data, calculating spectrograms and periodograms. Looking for possible earthquake-related anomalies in the data and intercomparing them with each other.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

After constructing a consistent database, all the time series 30 days before and after the earthquake occurred (04. July 2018) were plotted (please note that the Nurit groundwater conductivity and level data were only available until 08. July 2018) (**Fig.2a**). However, there were some apparent sharp peaks in the data (denoted by red ellipses on **Fig. 2/a**) which turned out to be erroneous values. These values were removed subsequently (**Fig. 2/b**). There are also some data gaps where the time series were not plotted (**Fig. 2/a and Fig. 2/b**).

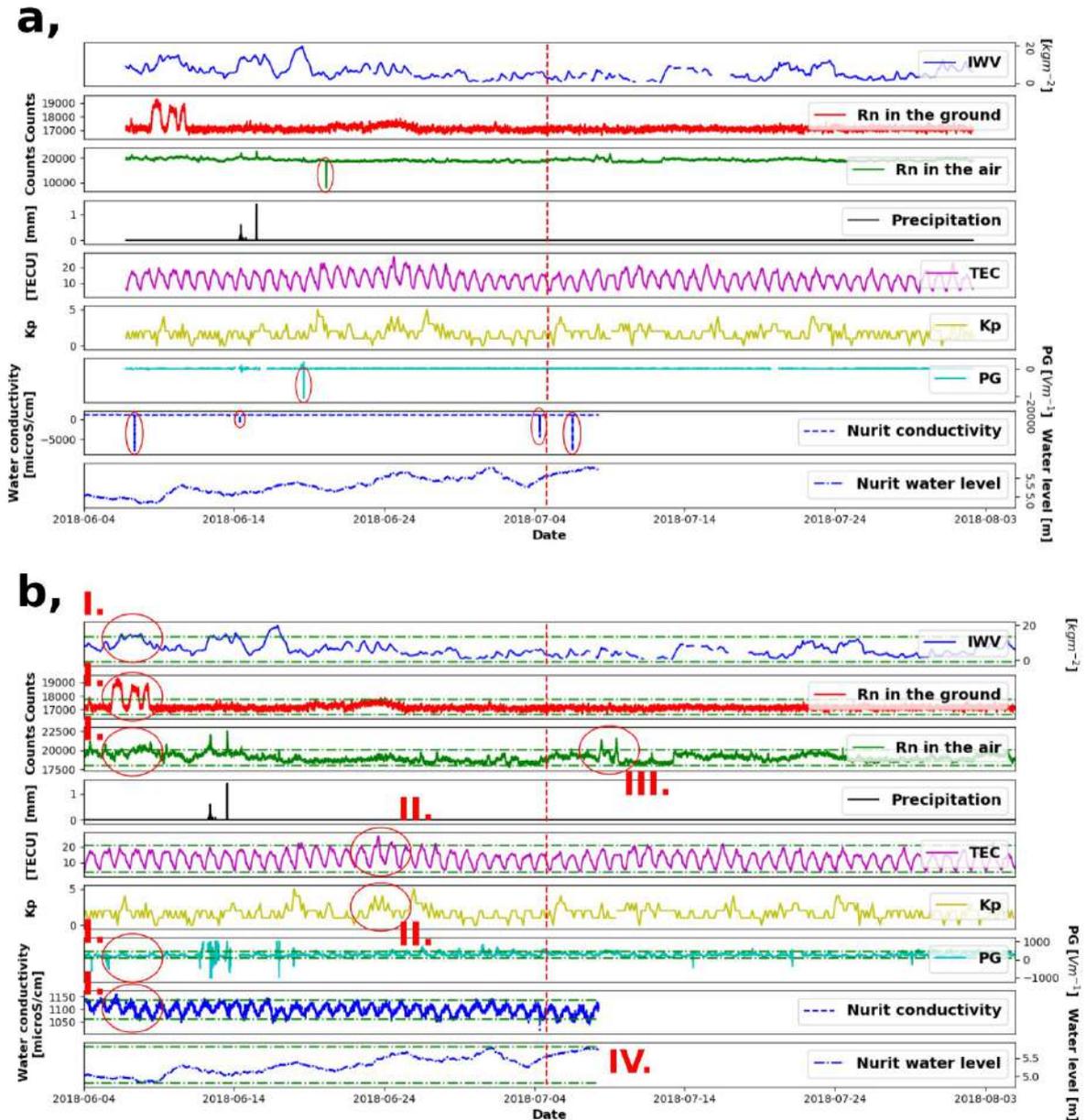


Fig. 2: a, The raw time series. The vertical dashed red line denotes the time of the main earthquake whereas the red ellipses mark erroneous values that were later removed. **b,** The time series after the removal of the erroneous values. The horizontal dashed-dotted green lines represent the data $\pm 2\sigma$ (standard deviation) boundaries, whereas the red circles and Roman numerals denote the investigated anomalies.

When searching for earthquake-related anomalies one has to bear in mind that certain variations might be caused by another physical quantity. For instance, it is important to take into consideration the precipitation as it can affect the PG and, via the wash-out effect, the radon measurements (**Fig. 2/b**). Unfortunately, the proper fair-weather selection of the PG data was not possible owing to the fact that apart from the precipitation data, wind speed, cloud height, and other meteorological data were not available. As for excluding any extraterrestrial effects from the TEC data the Kp index and the X-ray flux measured by the GOES spacecraft were used. After the preprocessing of the data four possible earthquake-related anomalies were chosen to investigate them further:

- i. Between 05. June 2018 and 08. June 2018 (27-30 days before the earthquake) there are some anomalously high (i.e. surpassing the upper 2σ boundary) values in the subsurface radon time series which may be a sign of enhanced pre-earthquake radon emanation (*Pulinets and Ouzounov, 2011*) (**Fig. 2/b and Fig. 3**). However, these high values are not mirrored in the aerial radon and PG measurements, although there is a bay-like depression with a magnitude of $\sim 440 \text{ Vm}^{-1}$ just before the radon enhancement in the PG data (red circle on **Fig. 3**). This negative PG anomaly is in accordance with some other case studies from the literature, however its duration is very short (~ 2 hours) (*Silva et al., 2011*).

Simultaneously with the aforementioned anomalies there are some higher values in the IWV data which behavior was again reported in the literature and was attributed to increased evaporation due to an enhancement of surface latent heat flux before earthquakes (*Dey et al., 2004*) (**Fig. 3**).

Ultimately, a decrease in the water conductivity measured at Nurit station was observed at the same time ($R^2 = 0.25$, **Fig. 3**). This feature has been also reported during other earthquakes (*Zmazek et al., 2002*).

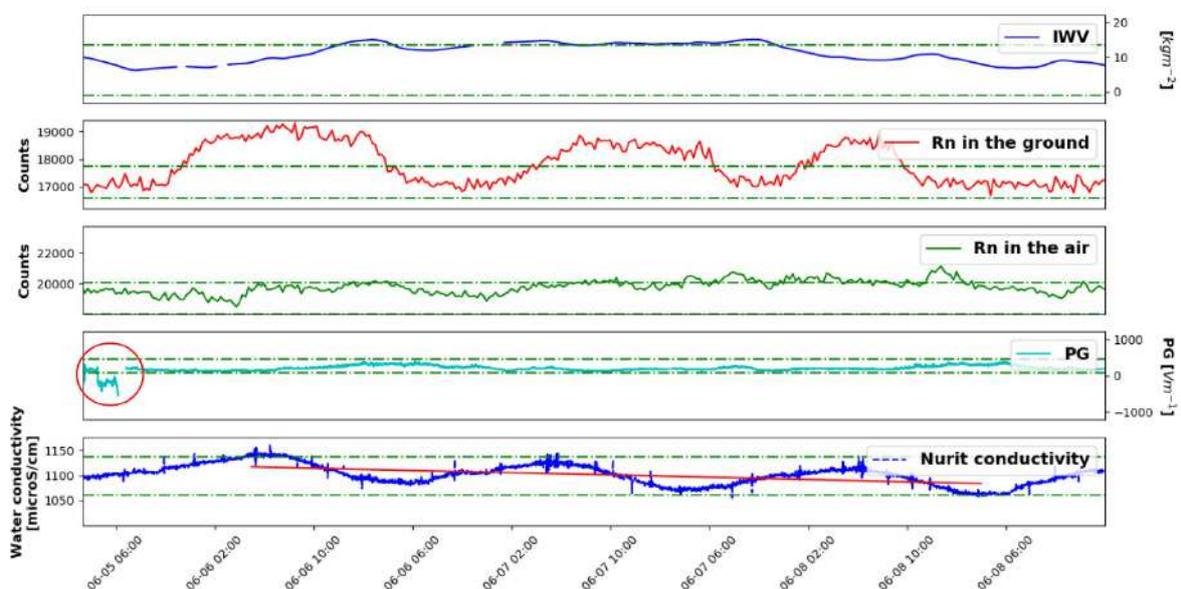


Fig. 3: Time series of IWV, subsurface radon, aerial radon, and water conductivity 27-30 days prior to the earthquake. The red circle denotes a bay-like depression of the PG, whereas the solid red line on the lowest panel represents a line fitted to the water conductivity data.

II. Approximately 11 days prior to the earthquake there is a significant enhancement of the TEC values (**Fig. 2/b**). The increase can be detected as a more pronounced diurnal variation at that time on the spectrogram as well (**Fig. 4/a**). Nonetheless, this might have an extraterrestrial cause as there is a moderate pike in the X-ray flux measured by the GOES satellite in the same time (**Fig. 4/b**) and the Kp index is a bit elevated too (**Fig. 2/b**).

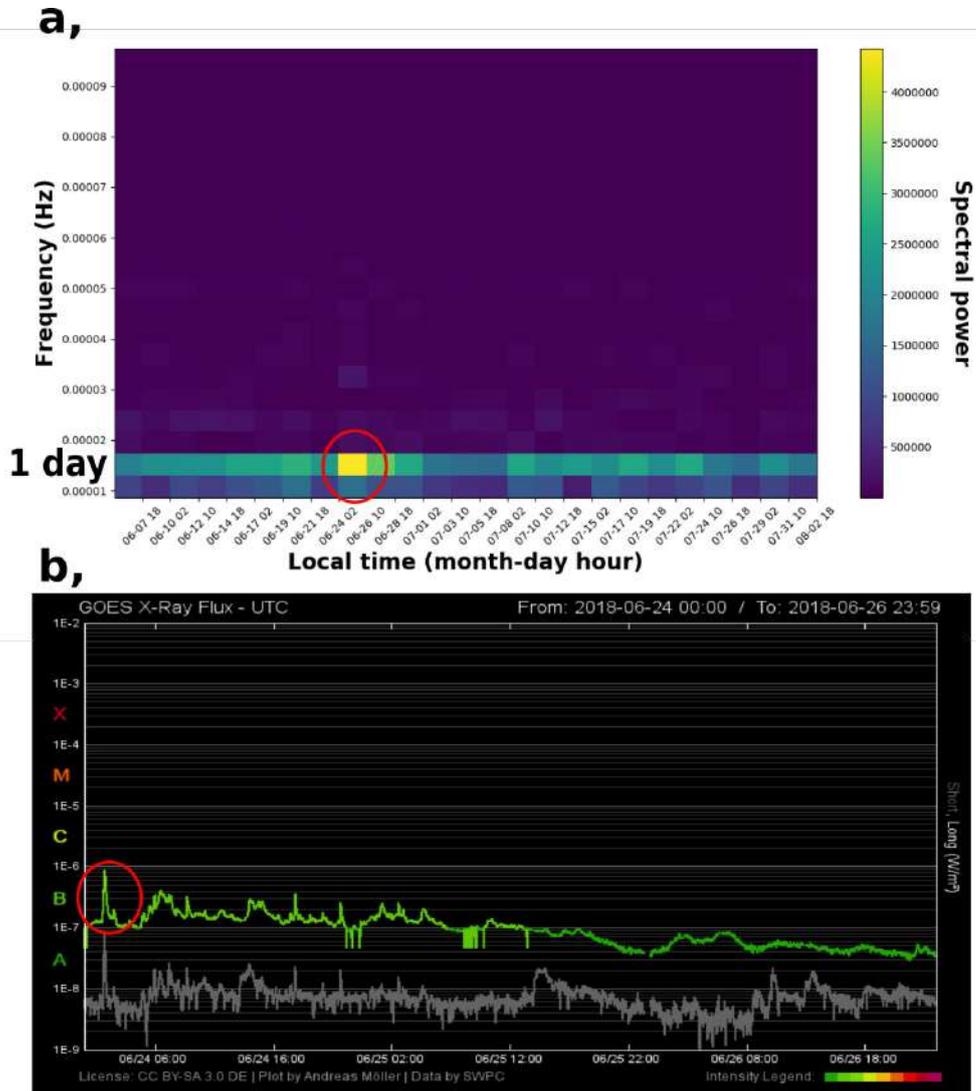


Fig. 4: **a,** Fourier spectrogram of the TEC time series. **b,** X-ray flux measured by the GOES spacecraft (<https://www.polarlicht-vorhersage.de/goes-archive>).

III. 4-5 days after the earthquake there are two significant peaks in the aerial radon time series which is followed by a longer lasting depression (**Fig. 5**). There is not any feature in the other physical quantities that would seem to mirror this behavior (**Fig. 5**).

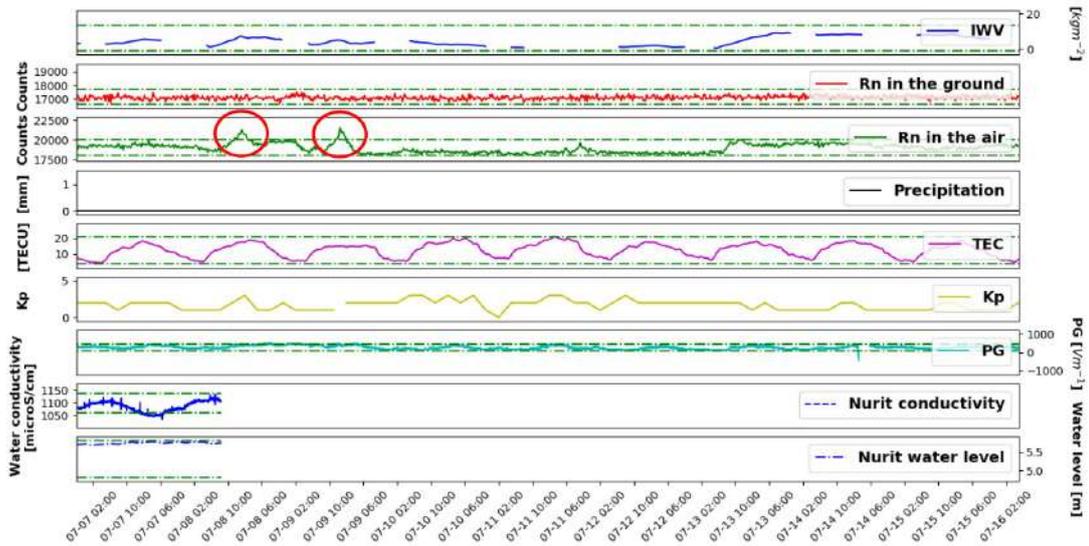


Fig. 5: Significant peaks in the aerial radon flux measurements (denoted by red circles).

IV. There is an apparent increasing trend in the Nurit groundwater data ($R^2 = 0.74$, **Fig. 6**). However, the lack of meteorological data makes its interpretation difficult. Although, there is not a step-like change when the earthquake occurred as reported in the literature (*Chen et al., 2013*), but at the time of the earthquake the slope of the increasing trend changes (denoted by a red ellipse on **Fig. 6**).

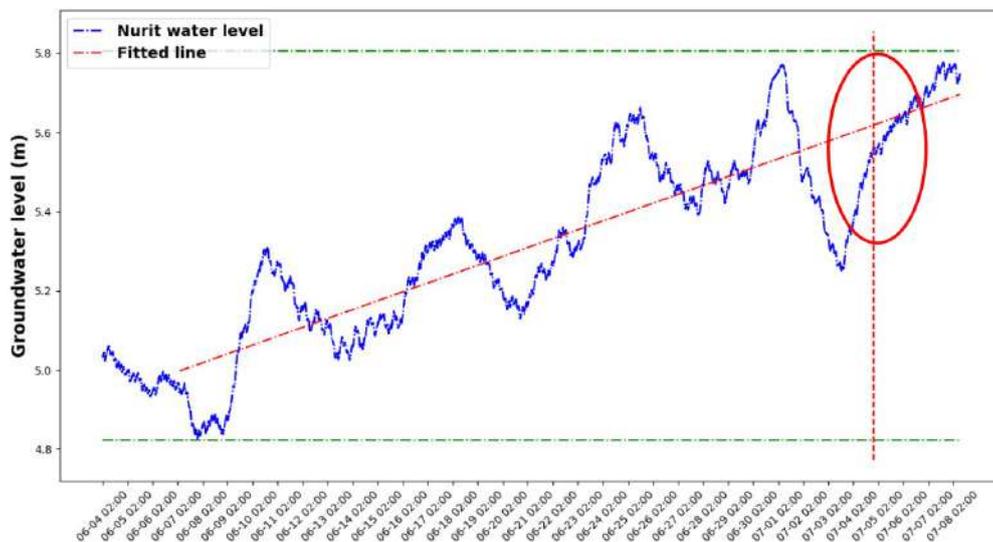


Fig. 6: Nurit groundwater level data.

Ultimately, the grantee found a possible earthquake-related anomaly consistent in multiple time series which is in accordance with the reports from the literature only in one case from the four investigated anomalies (I. Anomaly, **Fig 2/b and Fig. 3**).

References

- Chen, C.-H., Wang, C.-H., Wen, S., Yeh, T.-K., Lin, C.-H., Liu, J.-Y., Yen, H.-Y., Lin, C., Rau, R.-J., and Lin, T.-W. (2013): Anomalous frequency characteristics of groundwater level before major earthquakes in Taiwan. *Hydrol. Earth Syst. Sci.*, **17**, 1693-1703.
- Dey, S., Sarkar, S., and Singh, R. P. (2004): Anomalous changes in column water vapour after Gujarat earthquake. *Advances in Space Research*, **33**, 274-278.
- Pulinet, S. and Ouzounov, D. (2011): Lithosphere-Atmosphere-Ionosphere Coupling (LAIC) – A unified concept for earthquake precursors validation. *J. of Asian Earth Sci.*, **41**, 371-382.
- Silva, H. G., Bezzeghoud, M., Reis, A. H., Rosa, R. N., Tlemçani, M., Araújo, A. A., Serrano, C., Borges, J. F., Caldeira, B., and Biagi, P. F. (2011): Atmospheric electrical field during the $M = 4.1$ Sousel earthquake (Portugal). *Nat. Hazards Earth Syst. Sci.*, **11**, 987-991.
- Zmazek, B., Italiano, F., Živčić, M., Vaupotič, J., Kobal, I., and Martinelli, G. (2002): Geochemical monitoring of thermal waters in Slovenia: relationships to seismic activity. *Applied Radiation and Isotopes*, **57**(6):919-930.

FUTURE COLLABORATIONS

The STSM to Ariel University was highly beneficial to the grantee as he acquired knowledge and know-how on GPS-based and other satellite measurements that will surely aid him in his research regarding atmospheric electricity in the future.

Future collaboration between the grantee and the host institute is planned as the grantee wishes to publish the results of the carried out STSM. One possible way of publication is a poster presentation at the EGU annual meeting 2020 but after elaborating and continuing the research there is the possibility to publish it in a scientific paper as well.

Moreover, the home institute of the grantee and the host institute have similar measurements and are interested in some common research areas. This STSM fostered future collaboration as data and ideas were exchanged and there are topics on which the grantee and the host could definitely work together fruitfully.