The Silence of Canadian Cities: The Seismology Impact of the Covid19 Lockdown

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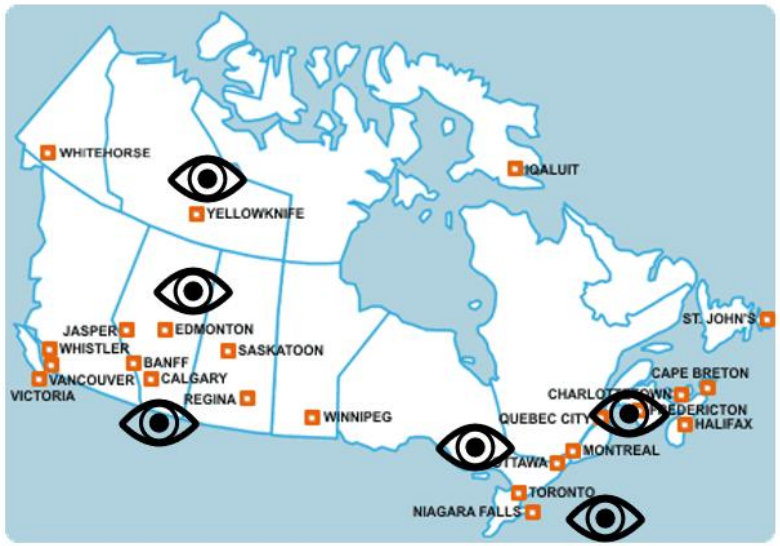
Abstract

On 11 March 2020, the World Health Organization (WHO) declared Coronavirus disease (COVID-19) as a pandemic. The announcement had a cascading effect as countries around the world rushed to declare various states of emergencies. Canada was no exception. All Canadian provinces and territories implemented some health emergency measures to check the spread of COVID-19. This provided an opportunity to study the changes in seismic vibrations registered by the land-based seismic stations before, during, and after the lockdown. I analyzed continuous seismic data for 6 Canadian cities: Calgary (Alberta), Edmonton (Alberta), Montreal (Quebec), Ottawa (Ontario), Toronto (Ontario), and Yellowknife (Northwest Territories). These cities represent the wide geographical spread of Canada. The source of data for the study was seismic stations run by the Canadian National Seismograph Network (CNSN). Data available freely on the Incorporated Research Institutions for Seismology (IRIS) website was used. Python and ObsPy were used to load and convert raw data into Probabilistic Power Spectral Densities (PPSDs). The seismic vibrations in the PPSDs that fell between 0.1 HZ and 20 HZ were extracted and averaged for every two weeks period to determine the trend of seismic vibrations. The lockdown had an impact on seismic vibrations in almost all the cities I analyzed. Except for Ottawa, the seismic vibrations decreased between 14% - 44% with the biggest decrease in Yellowknife in the Northwest Territories. In the 3 densely packed cities of the population over 1 million - Toronto, Montreal, and Calgary, the seismic vibrations dropped by over 30%. In the case of Ottawa, the seismic vibrations increased by 8%. As not all seismic stations were equally close to the cities, they were not equally sensitive to changes in human activities. Furthermore, while lockdown happened in all the cities selected for the study, the strictness enforced and the participation of people in the lockdown varied. Many cities extended the lockdown without any change while others extended the lockdown with a loosening of restrictions. All these differences induced variations in the study. Finally, a comprehensive online training module was created using Jupyter notebooks to allow researchers to analyse lockdown data from other seismic stations.

The Silence of Canadian Cities

The Seismology Impact of the Covid19 Lockdown



S004: Social Seismology: The Effect of COVID-19 Lockdown Measures on Global Seismic Noise I

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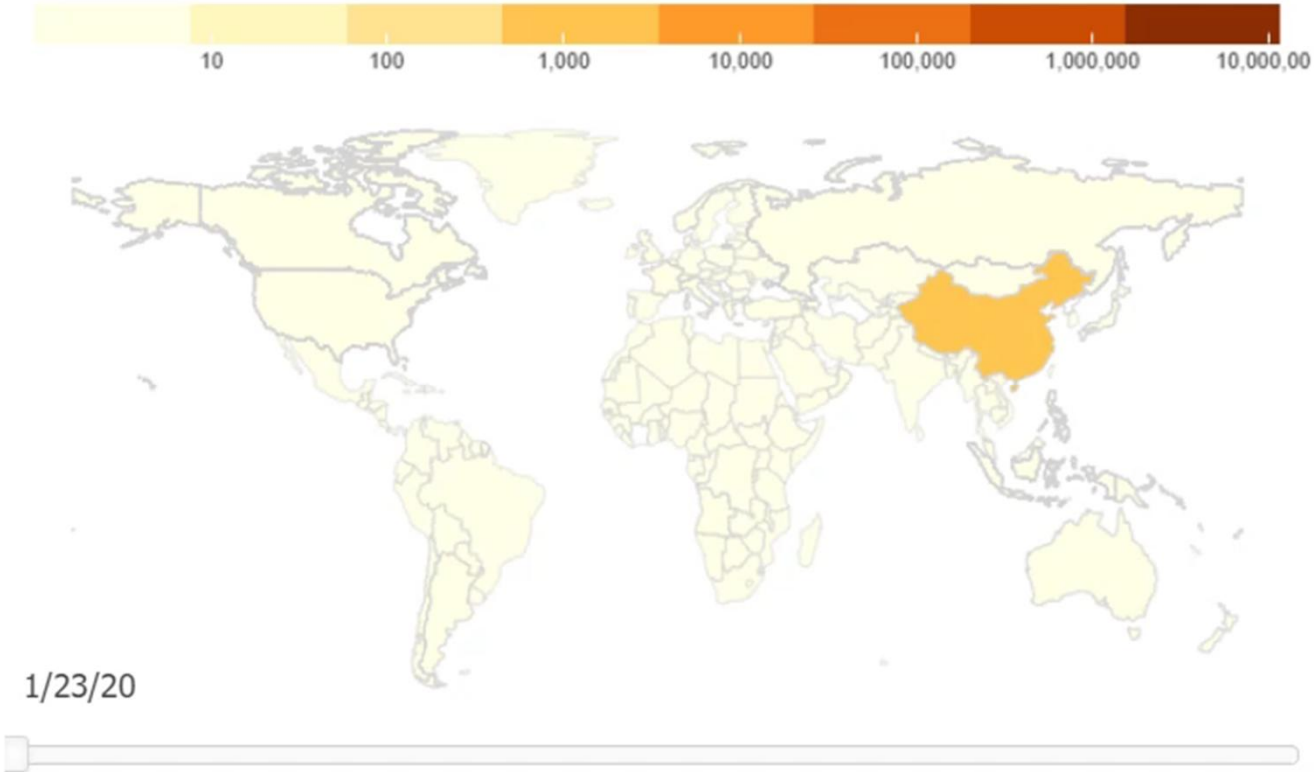
Spread of COVID19 Cases Across the World



First Canadian Case:
25 January 2020

First Community Transmission Case in Canada:
5 March 2020

Canada: COVID 19 Lockdown Timeline

11 March 2020:
WHO declares COVID19 as a pandemic

13 March 2020:
Quebec

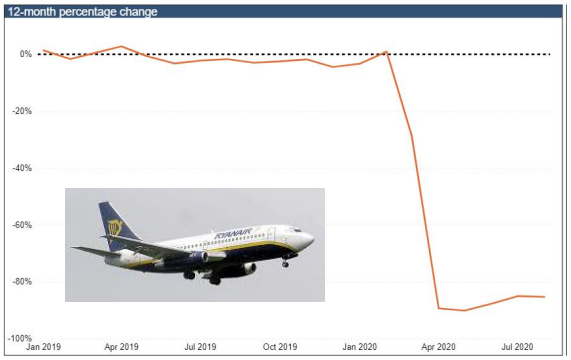
17 March 2020:
Alberta, Ontario, Prince Edward Island, Yukon

18 March 2020:
British Columbia, Saskatchewan, Newfoundland and Labrador, North West Territories, Nunavut

Canada - US border closed

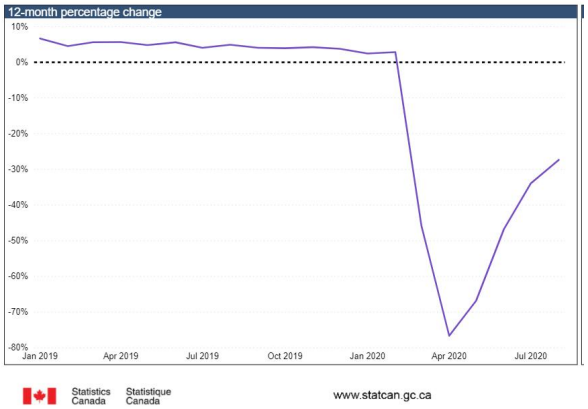
Canada: Socio-Economic Impact of COVID 19

Transportation
Air Travel



Gross Domestic Product

Employment



Entertainment
Restaurants

Source: Statistics Canada. https://www.statcan.gc.ca/

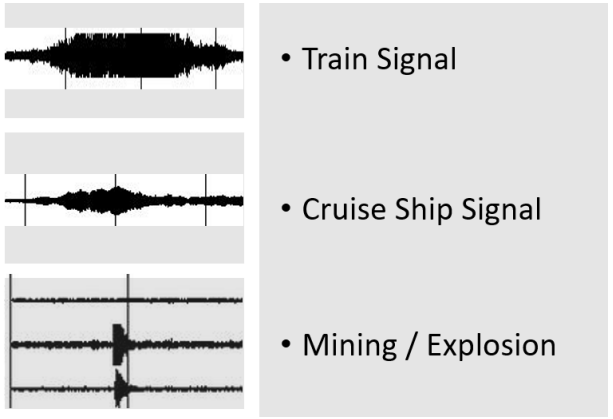
Goal: Measure the Impact of COVID 19 Lockdown on Seismic Vibrations in Canada

Seismic Vibrations Near Cities

- Before Lockdown *(pre 11 March 2020)*
- During Lockdown *(post 11 March 2020)*

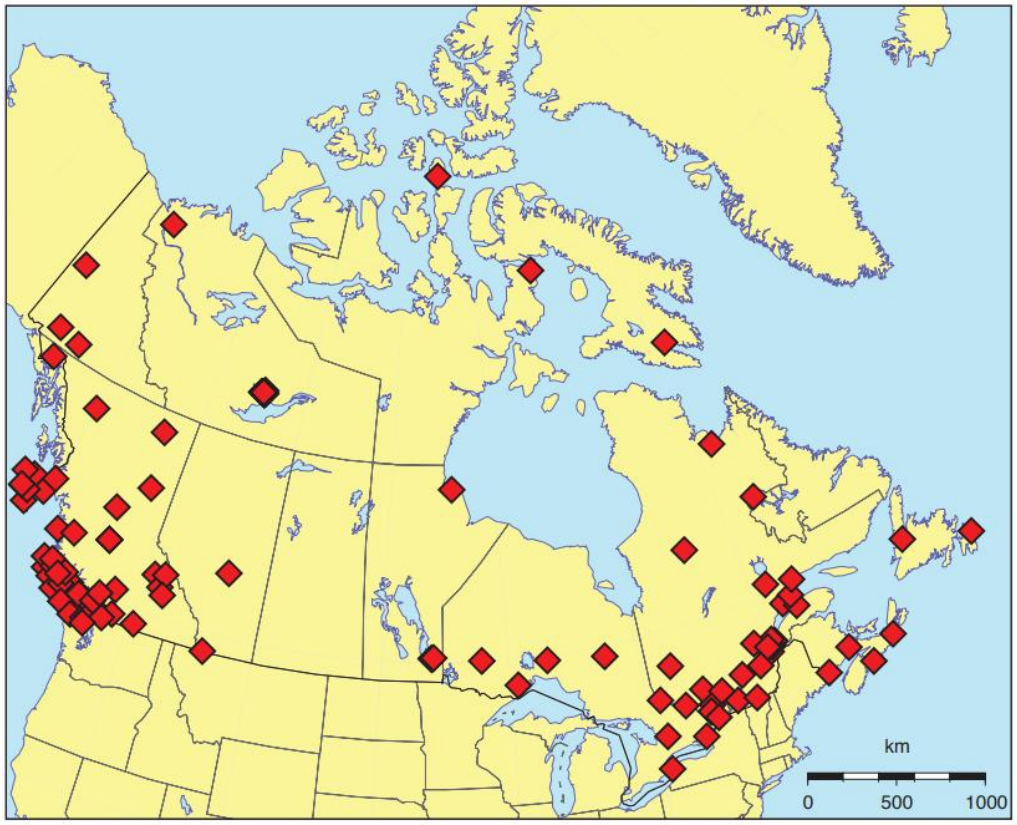
Seismic Vibrations

- Near Cities
- Away from Cities



Canadian National Seismograph Network

- Network of over 200 seismographs
- Operated by the Natural Resources Canada and Universities Network



Seismographs operated by Natural Resources Canada

Source: Natural Resources Canada Website
https://earthquakescanada.nrcan.gc.ca/pprs-pprp/pubs/GF-GI/GEOFACT_SeismographsinCanada.pdf

Selection Criteria for Seismic Stations

1. **Proximity:** be located within 60 kms of a city center to record anthropogenic activities: *construction, transportation, entertainment…*

2. **Operational:** should be active before and during the lockdown period

3. **Open Data:** should be transmitting live data accessible to all

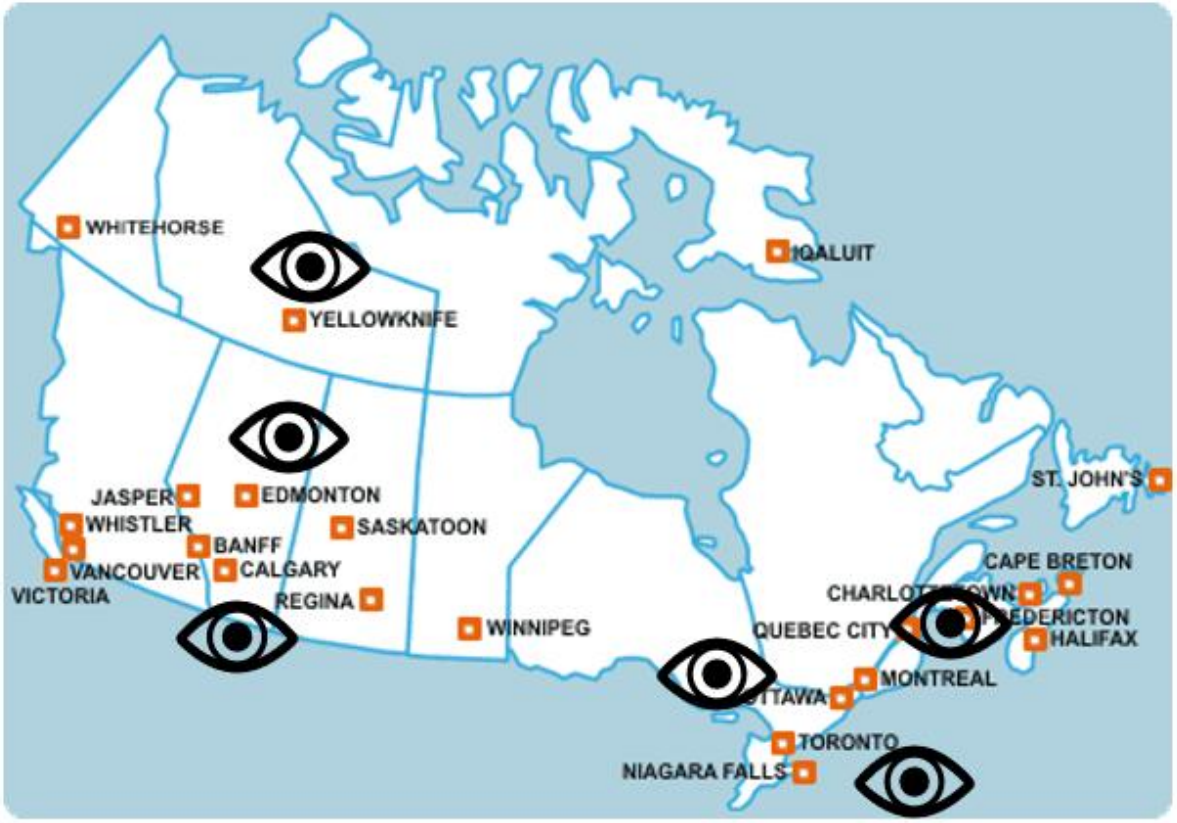
4. **Representation:** locations should be spread over Canada

Six Seismic Stations in 4 Provinces Selected

Period of Study: 15 December 2019 to 13 June 2020 (6 months)

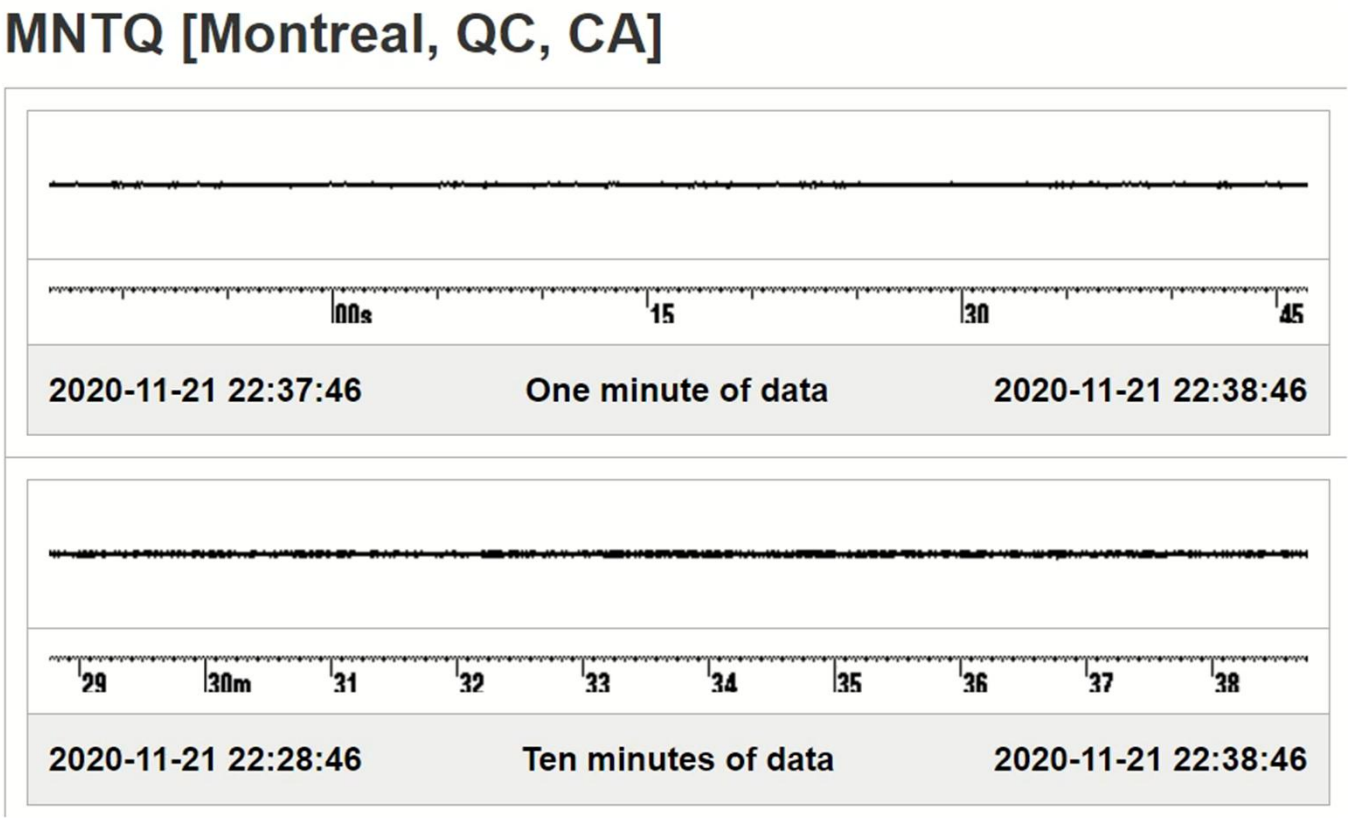
Province	City	City Population	Seismic Station	Distance to City Centre
Alberta	Calgary	1.6 million	TD022	23 kms
	Edmonton	1.5 million	TD002	60 kms
North West Territory	Yellowknife	0.02 million	YKAW1	8 kms
Ontario	Ottawa	1.4 million	OTT	4 kms
	Toronto	6.2 million	TORO	6 kms
Quebec	Montreal	4.2 million	MNTQ	5 kms

Location of Canadian Seismic Stations Monitored for the Study



Seismic Station Monitored

Raw Waveform Data from Seismic Stations



Axis of vibration :
Z-Axis (HHZ)

Sampling Rate :
100 samples / second

Samples per day:
8,640,000

Samples for study period per seismic station:
1.5 billion samples

Data Format, Data Source and Libraries

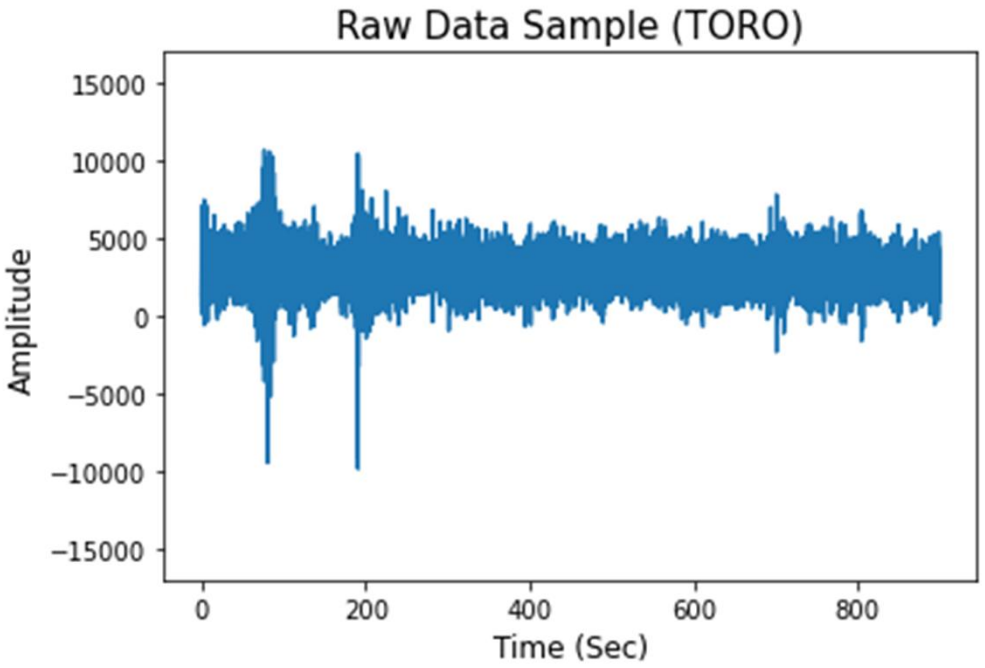
Data Format: MSEED (Mini Standard for the Exchange of Earthquake Data)
contains only waveform data and used for time series data analysis

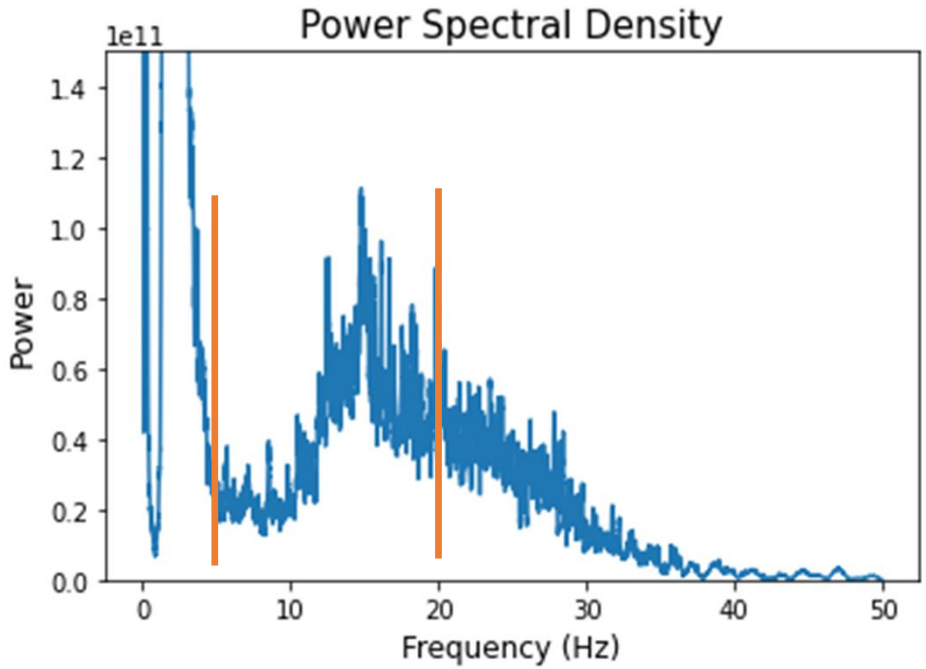
Data Source: Incorporated Research Institutions for Seismology (IRIS)
https://ds.iris.edu/ds/nodes/dmc/data/types/

Python library: ObsPy to download and process MSEED files

Waveform Data to Power Spectral Density

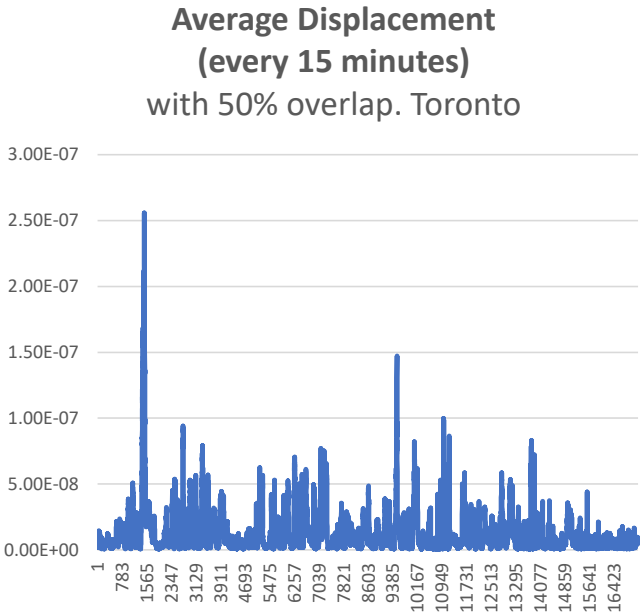
Focus on anthropogenic signals in seismic range (4 to 20 Hz)

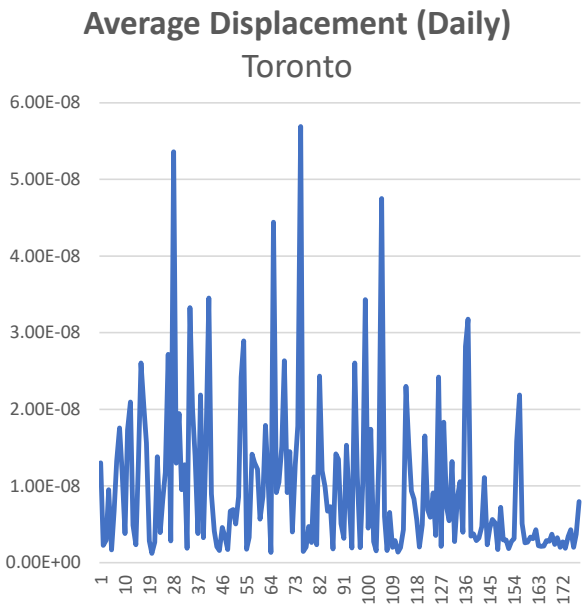


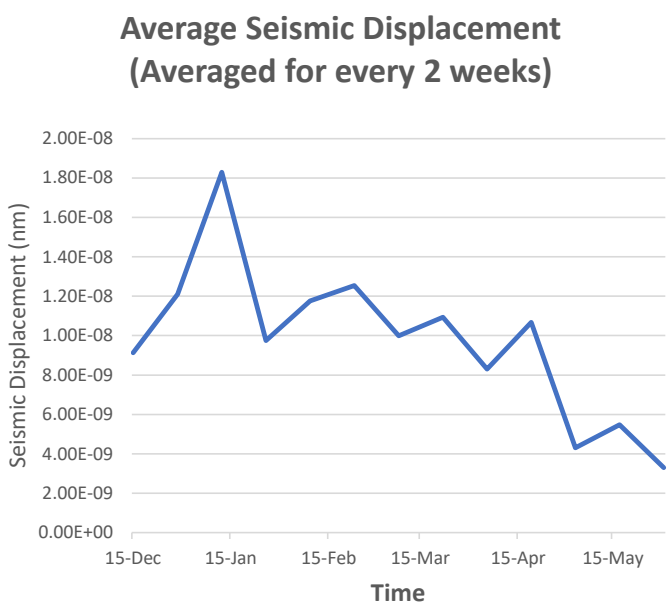


9.5 billion lines of seismic data used for Analysis

PSD Processing – Overlapping and Averaging



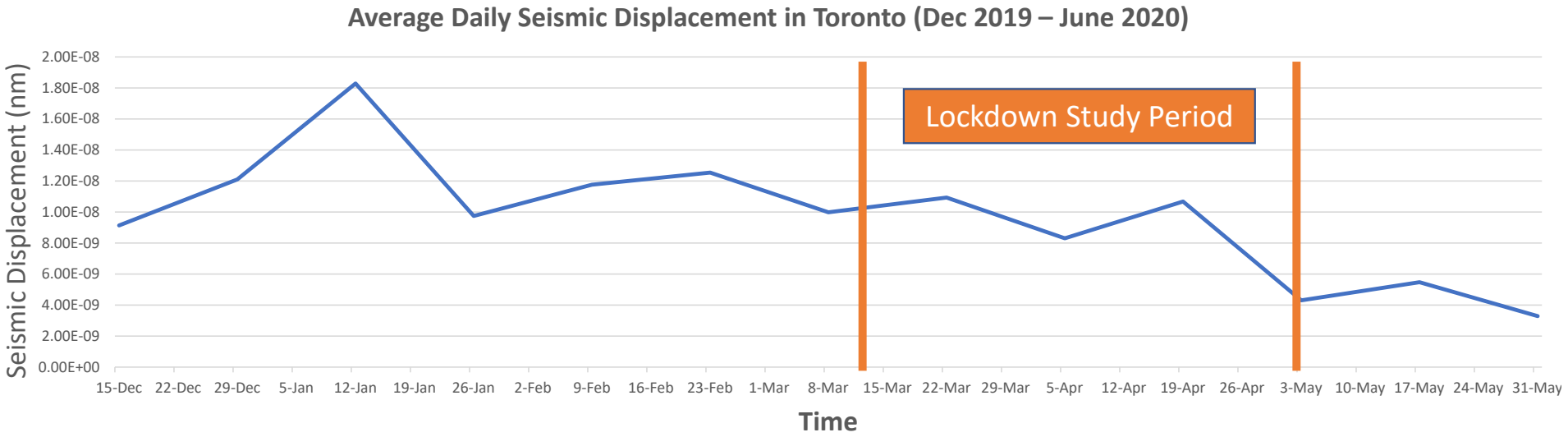




- The RMS (average displacement) was calculated for each 15-minute period inside the main Power Spectral Densities (PSD) files, with an overlap of 50%. The same is done for each 24-hour period in the data
- Tutorial by Thomas Lecocq (github.com/ThomasLecocq/SeismoRMS) was adapted for the trend analysis

Toronto, ON

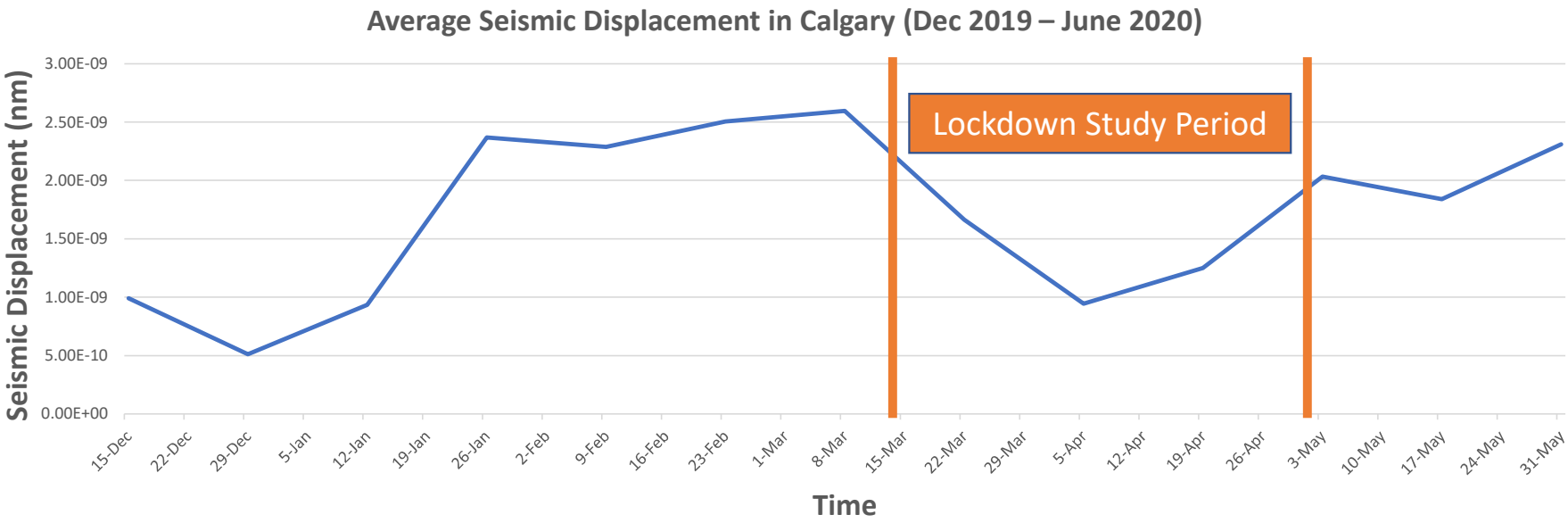
34 % decrease in seismic vibrations during lockdown



Station: TORO
Channel: HHZ

Calgary, AB

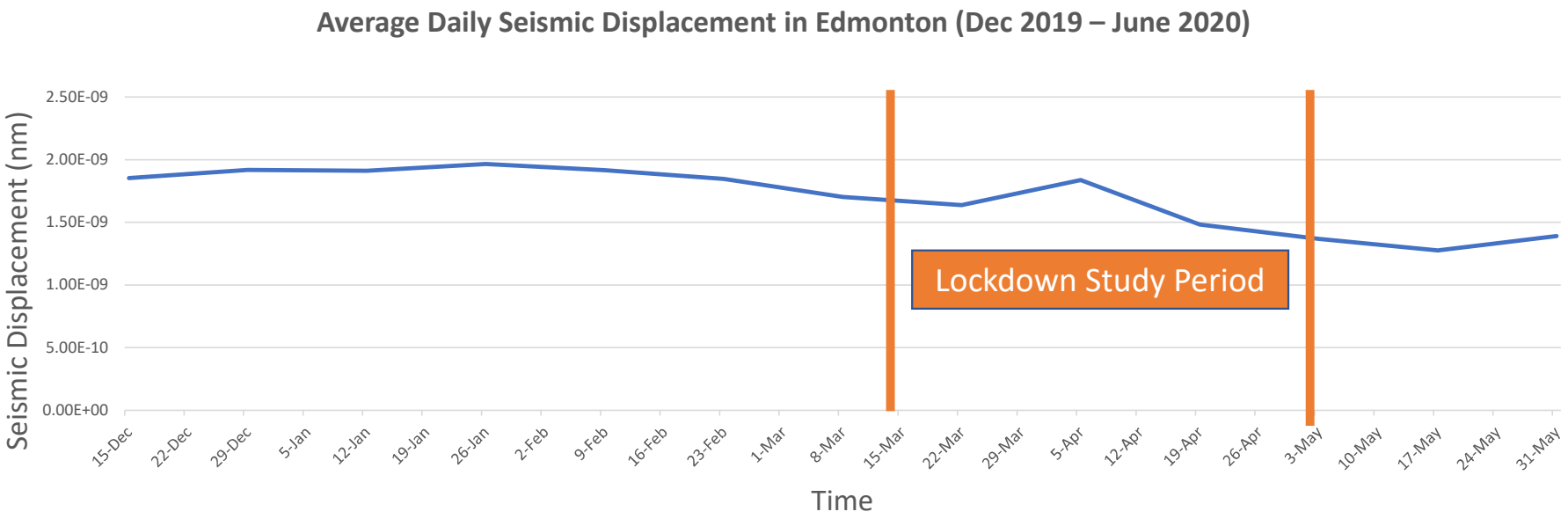
31% decrease in seismic vibrations during lockdown



Station: TD022
Channel: HHZ

Edmonton, AB

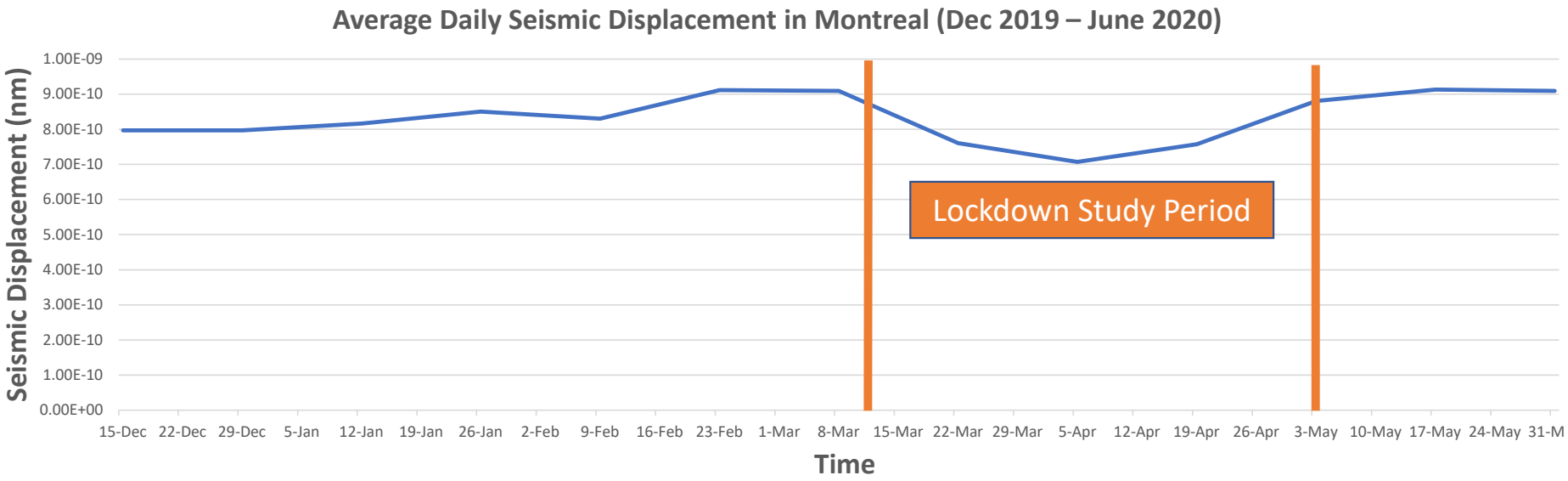
14% decrease in seismic vibrations during lockdown



Station: TD002
Channel: HHZ

Montreal, QC

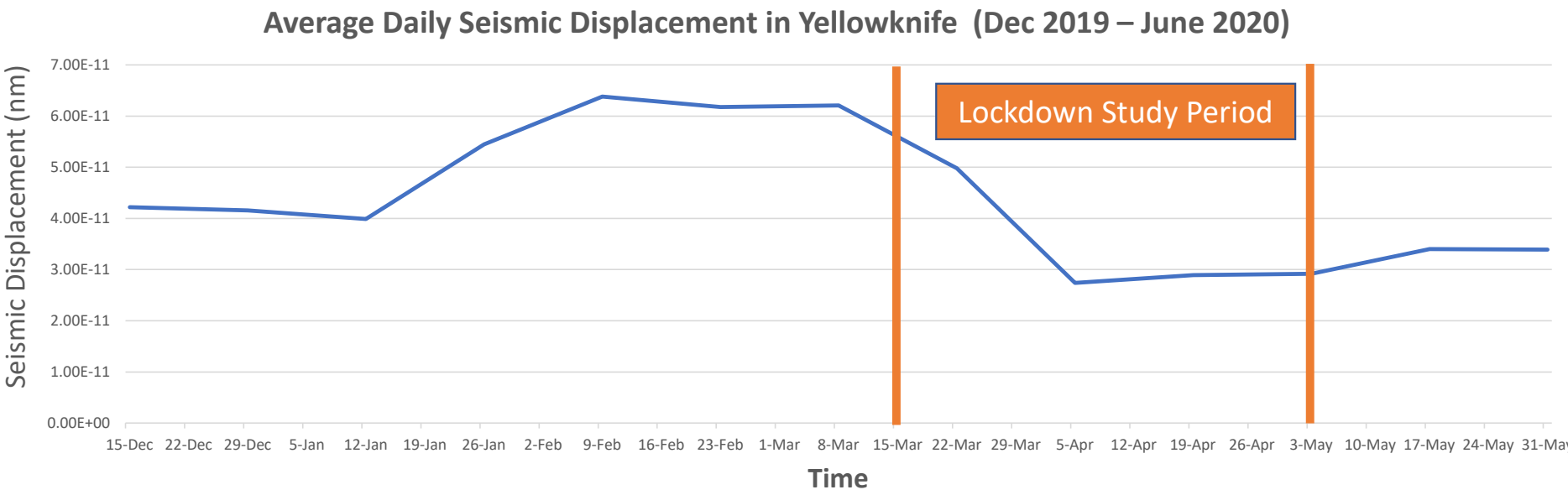
34 % decrease in seismic vibrations during lockdown



Station: MNTQ
Channel: HHZ

Yellowknife, NWT

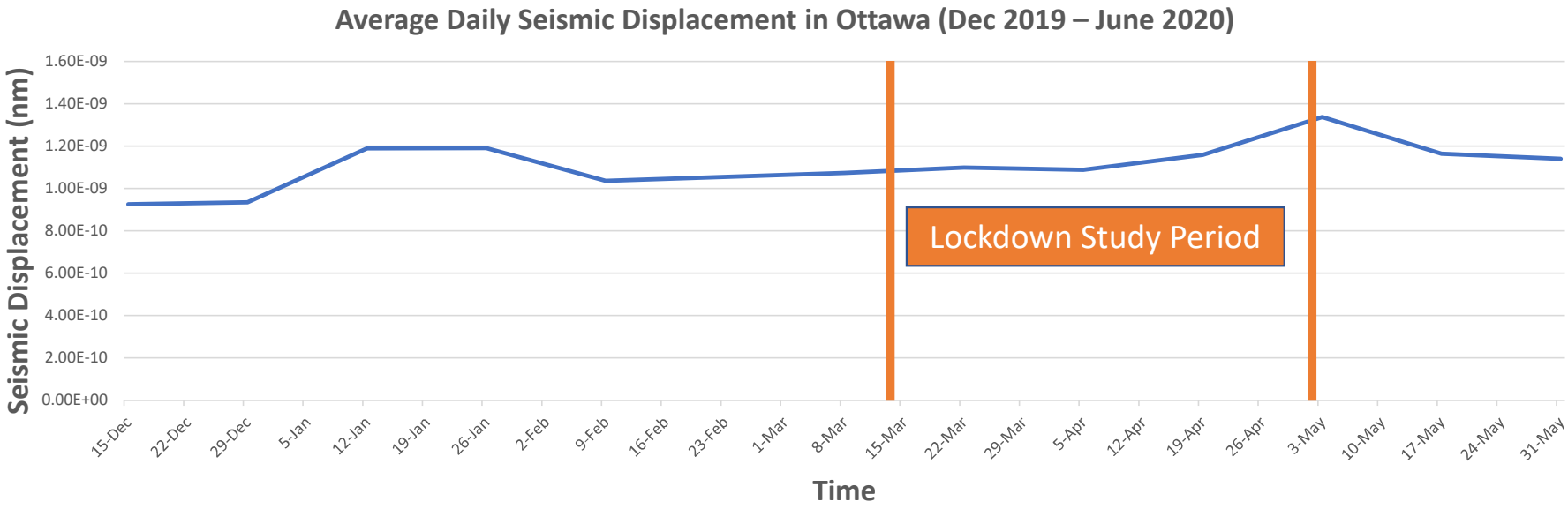
44 % decrease in seismic vibrations during lockdown



Station: YKAW1
Channel: HHZ

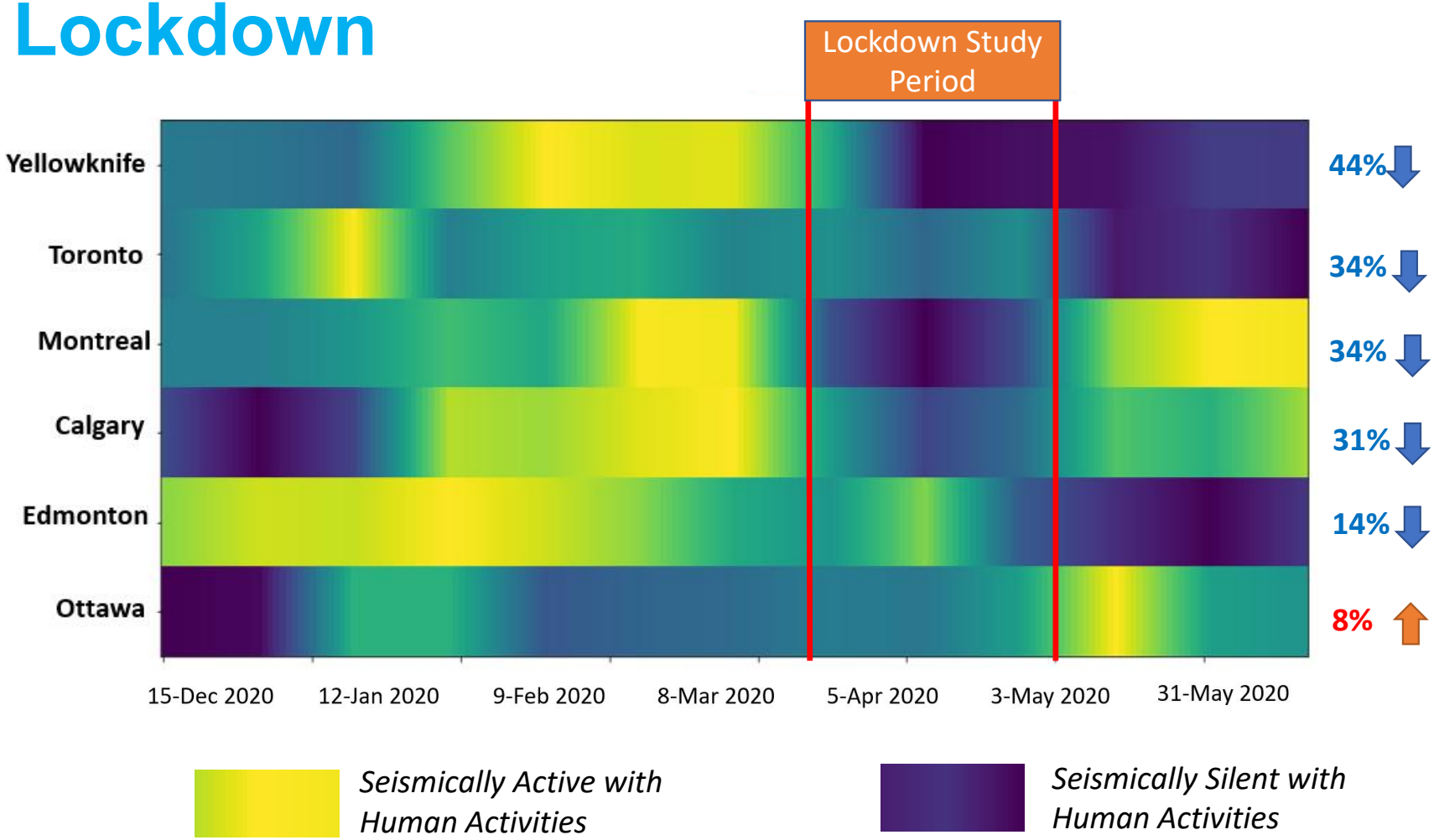
Ottawa, ON

8% increase in seismic vibrations during lockdown



Station: OTT
Channel: HHZ

Seismic Silence of Canadian Cities during Lockdown



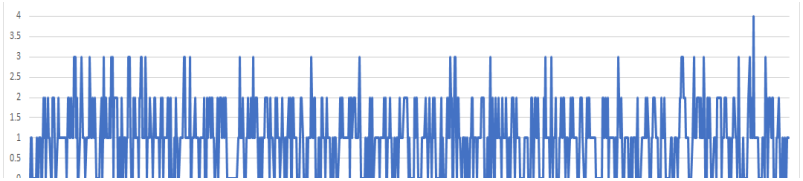
Data Validation from Ground Measurement

Toronto Traffic: 50% decrease during Lockdown

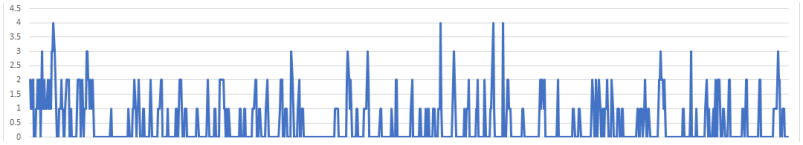
Applying Machine Learning on Live Video Data

TensorFlow

Before Lockdown



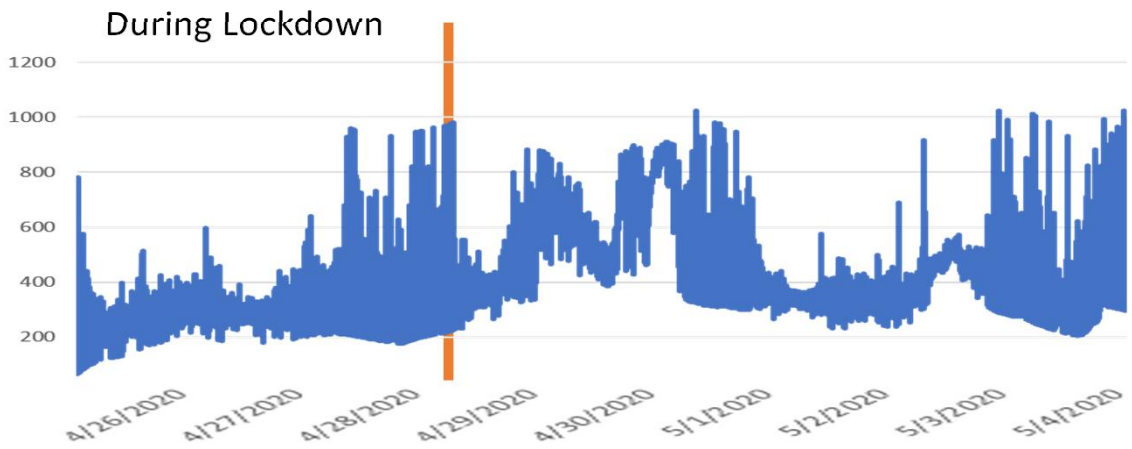
During Lockdown



Live Street Traffic Video Analysis using Convolutional Neural Network Algorithm

Data Validation from Ground Measurement

Toronto Street Sound: 30% decrease during Lockdown



Home-built Sound, Light and Pollution Sensor to gather data during COVID 19 Lockdown

Pandemics and Urban Seismology

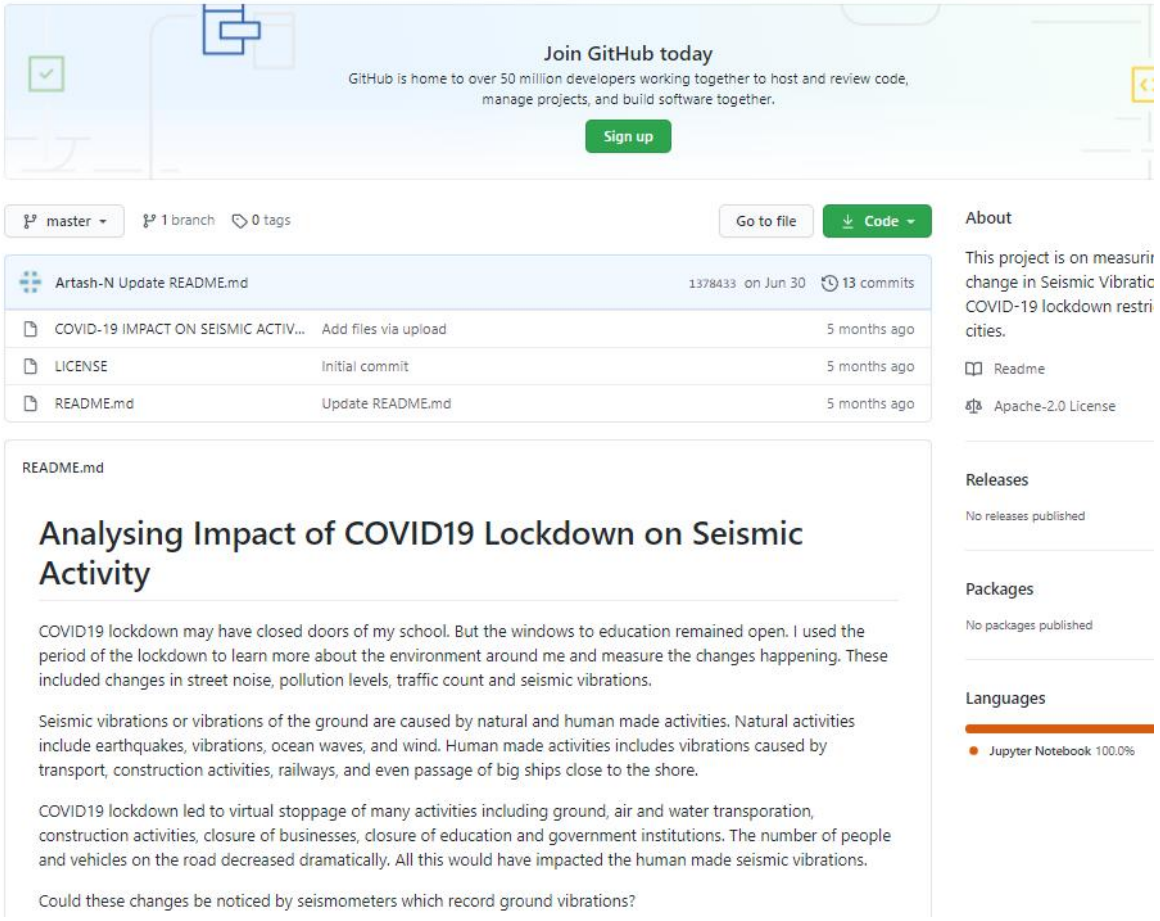
Surgical lockdowns: based on localities, time and actors

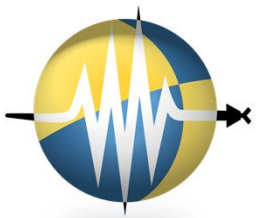
Monitor physical distancing measures

Online Tutorial

To Calculate Changes in Seismic Vibrations for any city

https://github.com/Artash-N/COVID19-Impact-on-Seismic-Activity





ObsPy

A Python Framework for Seismology

pandas

NumPy

PYTHON 3

TensorFlow

Conclusion

- Seismic vibrations decreased in most Canadian cities. Decreased over 30% in 4 cities
- Decrease was due to stoppage in human activity and was validated by ground measurements

Limitations

- Seismic stations located at different distances from the city center
- Types of lockdowns and enforcements differed: by city, by province and health department

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