

# Overview of Ground Motion Characteristics from Potentially Induced Seismic Events in Alberta, Canada



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## Introduction

Several clusters of increased seismic activity in Alberta over the last decade have been identified as potentially-induced seismicity, triggered by oil and gas production, wastewater injection, and hydraulic fracturing (Cui and Atkinson, 2015). Probabilistic seismic hazard analyses (PSHAs) model the probability of exceeding peak ground motion amplitudes in a region at given frequencies of interest.

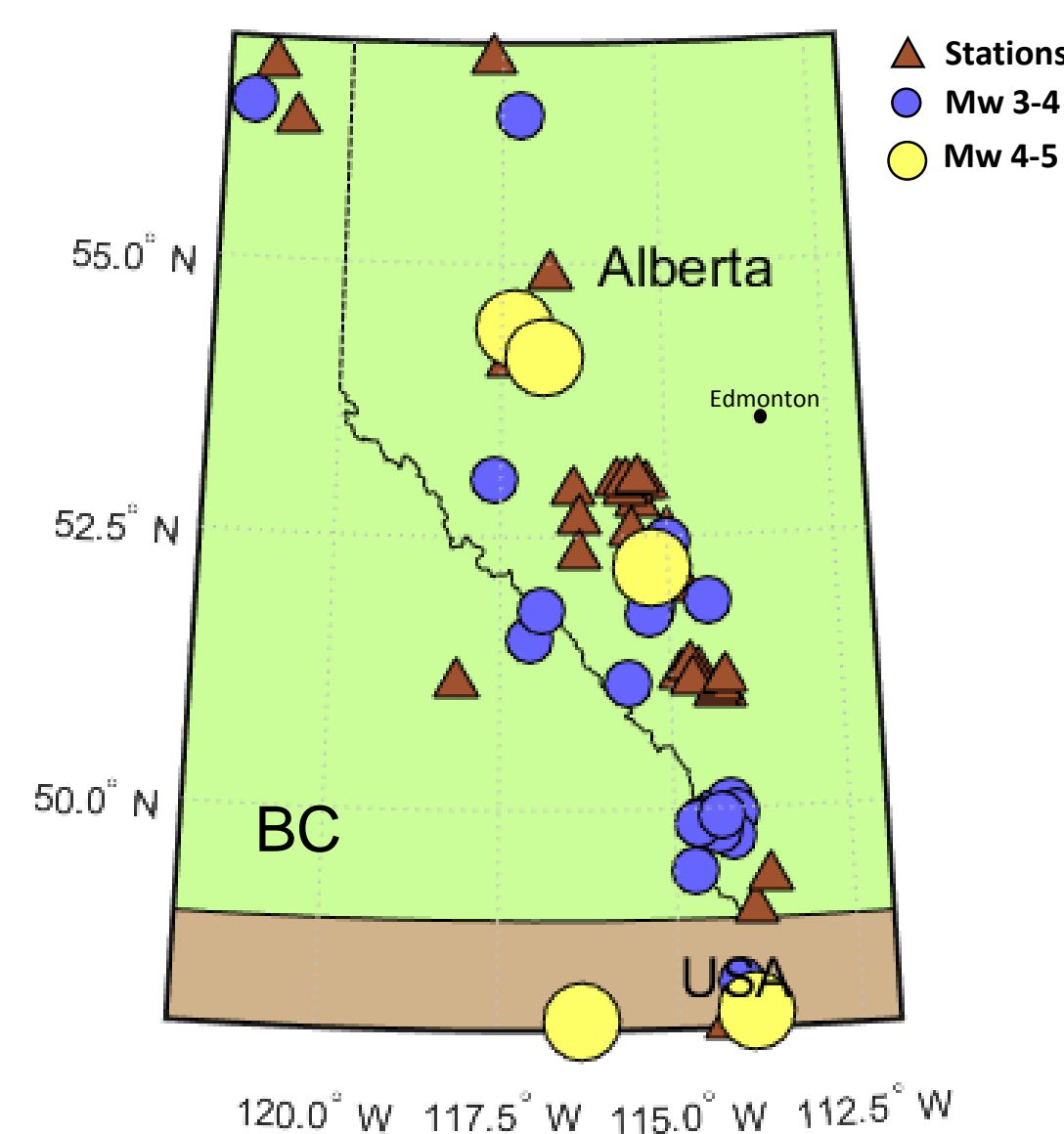
The most imperative component of a PSHA is the predictive framework for ground motion amplitudes given a probable earthquake magnitude and hypocentral distance (GMPEs). This study aims to characterize ground motions from moderate to large ( $M_w > 3$ ), likely induced seismic events, recorded at  $R_{hypo} < 100$  km in Alberta to better incorporate induced event behaviours into our predictive hazard analyses.

In particular, this study focuses on the empirical definition of spectral shapes and amplitudes in Alberta and compares them to those in other regions, such as Oklahoma, USA, and will aim to compare them to those of natural events in the NGA-East and NGA-West2 databases. The project will look to determine how high-frequency ground motions behave, what the controlling factors are, and what the relative significant is of each factor.

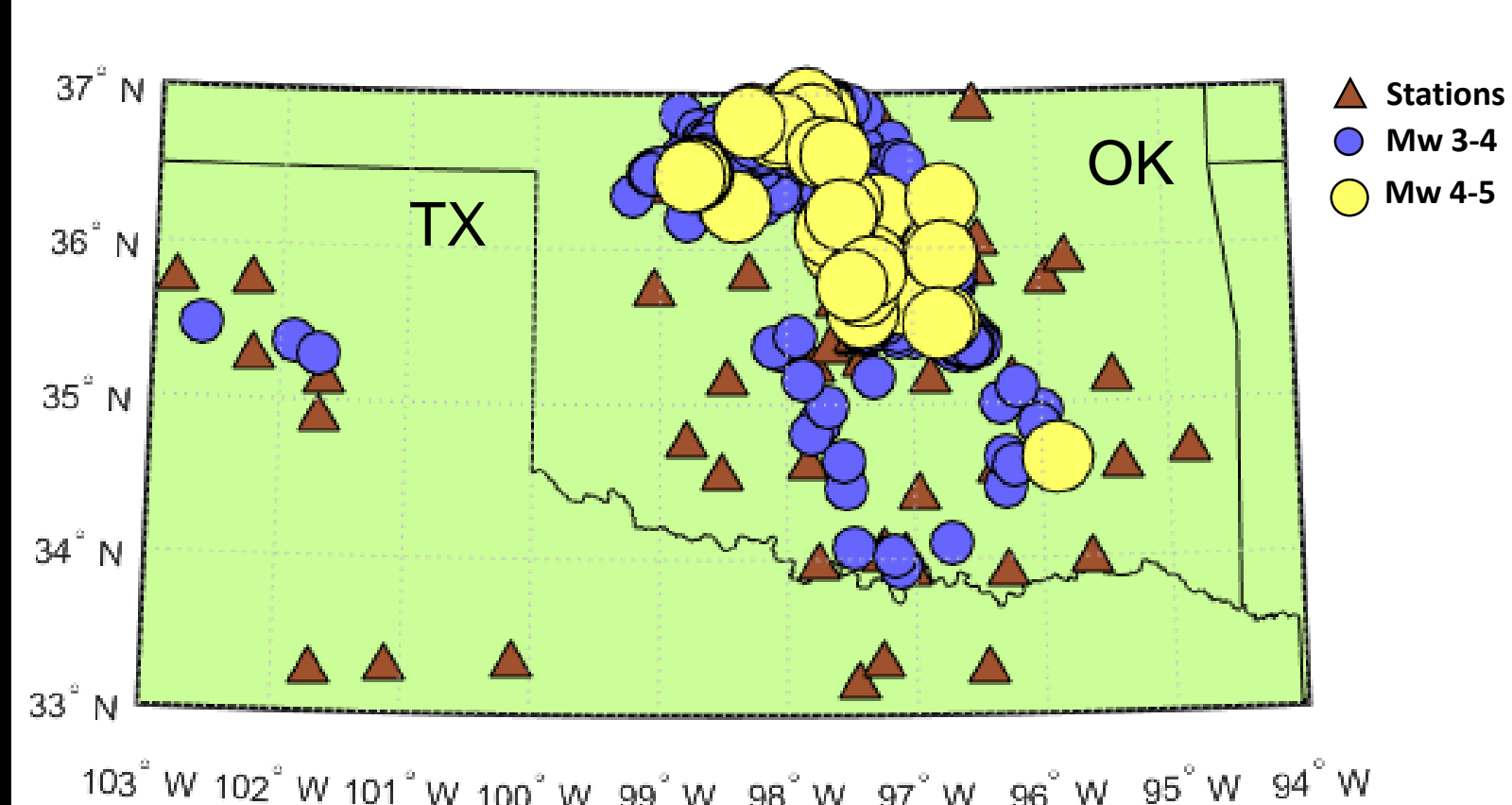
## Overview of Datasets

### Alberta

- Ground motions recorded at ~210 seismic stations in Alberta
- 5% damped PSAs, 0.01 - 50Hz
- Blasts removed based on table from Fereidoni (2016)
- $M_w$  3 - 5M – calculated based on regional attenuation model (Novakovic and Atkinson 2015)
- Recorded within  $R_{hypo} \leq 100$ km



### Oklahoma



- Ground motions recorded ~1300 seismic stations in Oklahoma
- $M_w$  3 - 5M
- Recorded within  $R_{hypo} \leq 100$ km

## Methods/Preliminary Evaluations

- Ground motion PSAs are examined in the spectral domain.
- Horizontal motions are represented by the geometric mean of their horizontal components.
- Comparisons are made across regions, and include both parametric and non-parametric evaluations

### Parametric

- Yenier and Atkinson (2015) developed a regionally adjustable GMPE to predict motions based on the source characteristics, a geometric spreading model, a coefficient of anelastic attenuation, and a effects of site geology:

$$\ln Y = F_E + F_Z + F_Y + F_S + C$$

- Used here to allow for the determination of average stress drop ( $\Delta\sigma$ ) and average frequency-dependent calibration factor ( $C$ ) for each event.

### Non-Parametric

- To compare across regions, events from Oklahoma were binned based on magnitude and hypocentral distance such that:

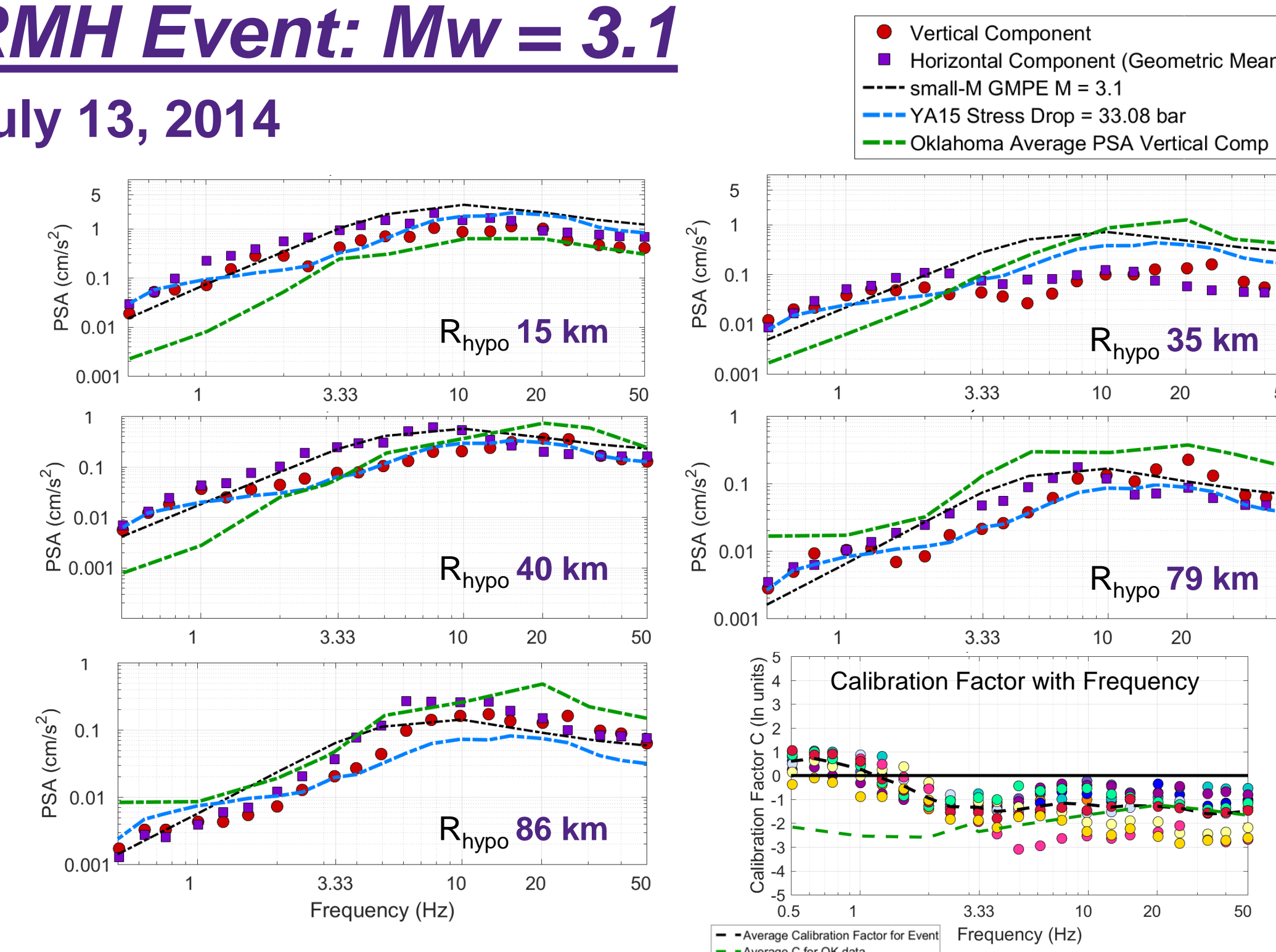
$$M_{wOK} = M_{wAB} \pm 0.15 M$$

$$R_{hypoOK} = R_{hypoAB} \pm 2.0 \text{ km}$$

- PSA spectra were then log-averaged for each  $M_w$ ,  $R$  slice to demonstrate the average behaviour of those events in Oklahoma

### RMH Event: $M_w = 3.1$

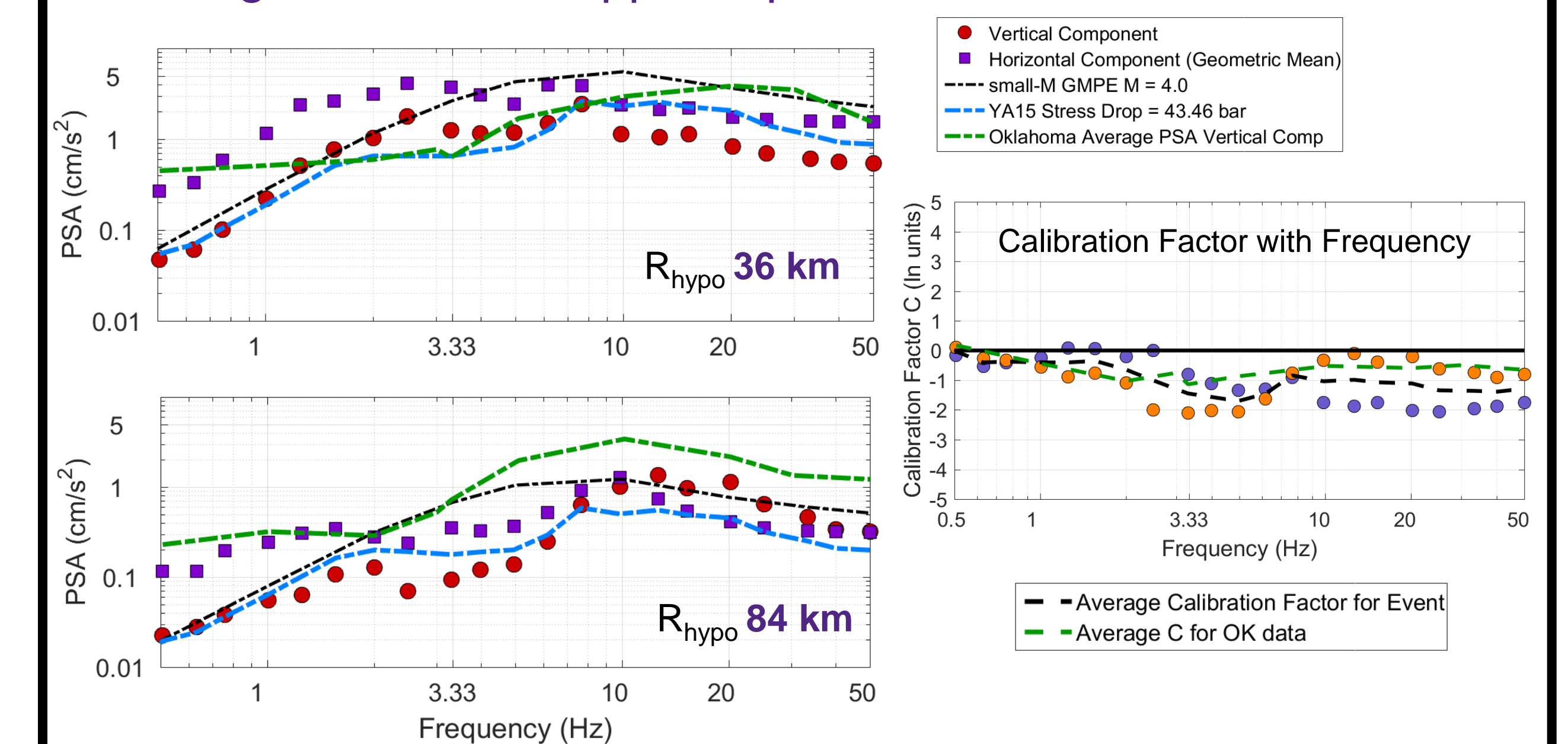
July 13, 2014



### Fox Creek Event: $M_w = 4.0$

June 13, 2015

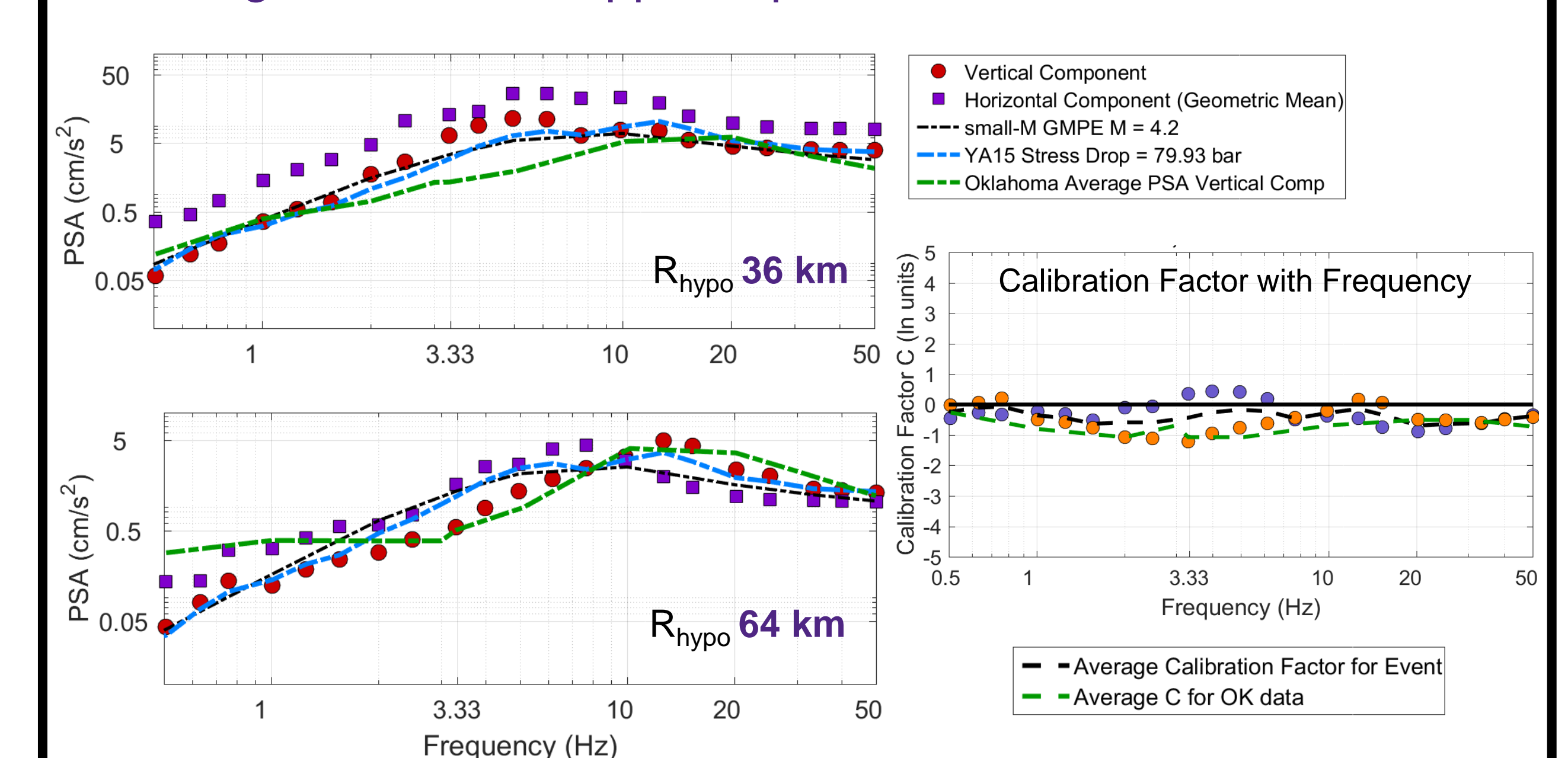
“Red Light” Event – Stopped Operations



### Fox Creek Event: $M_w = 4.2$

January 12, 2016

“Red Light” Event – Stopped Operations



## Next Steps

- Quantify regional comparisons and use descriptive statistics to describe spectral behaviour
- Compare induced events in AB and OK to natural events and identify factors for disparities between the two (i.e. stress drop, attenuation behaviour, etc.)
- Eventually incorporate induced event characteristics into PSHAs for a more complete analysis of seismic hazard in Canada

## References:

- Atkinson, G., 2015. Ground-motion prediction equation for small-to-moderate events at short hypocentral distances, with application to induced seismicity hazards. *Bull. Seism. Soc. Am.*, 105.
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- Novakovic, M., Atkinson, G., 2015. Preliminary evaluation of ground motions from earthquakes in Alberta. *Seism. Res. L.*, 86.
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