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M. Kolaj

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ABSTRACT

The two magnitude 6 earthquakes on May 1, 2017 were felt in the regions of Haines Junction and Whitehorse, YT and minor damage was reported. Five-percent damped spectral accelerations calculated from a seismograph situated near Haines Junction suggest that the first event had stronger ground motions than the second, even though the second had the larger magnitude. In Haines Junction, spectral accelerations reached approximately 1 % to 7.5 % of the 2015 seismic hazard design values (e.g. 3 % at 0.2 s). While the seismograph in Whitehorse was not operational at the time, the predicted motions from the event reached 5 % to 22 % of the design values (e.g. 12 % at 0.2 s for the first event). The higher percentages are largely due to the lower seismic hazard design values for Whitehorse. The results in this work are given for firm ground conditions (site class C), and varying local conditions could amplify or reduce these values.

INTRODUCTION

Southwestern Yukon, and adjacent Alaska and British Columbia, is an area of significant seismic activity related to the collision and ongoing accretion of the Yakutat block with the North American plate and several large strike-slip faults (Figure 1, Hyndman et al., 2005). For example, the 2002 Mw 7.9 Denali Fault earthquake resulted in 340 km of combined surface rupture that terminated near the Yukon-Alaska border and triggered thousands of landslides (Eberhart-Phillips et al., 2003). It is thus not unusual that the Denali fault system is a significant contributor to seismic hazard for several Canadian cities.

At 12:31:53 UT (5:31 PDT) May 1, 2017, a Mw 6.2 earthquake occurred roughly 130 km WSW of Whitehorse, YT. Roughly two hours later, at 14:18:15 UT (7:18 PDT), a second Mw 6.3 earthquake occurred 5 km south of the first event (Figure 2A). Both events were widely felt, and light to strong ground motions were reported in the surrounding regions (Figure 2B). Reports of minor damage (e.g. power outages, surficial cracking in plaster, items falling of shelves) were reported in several Canadian cities, namely in Haines Junction and Whitehorse, YT. The earthquakes were followed by numerous aftershocks (23 with magnitudes greater than 4 as of July 2017; Figure 2A), the ground motions of which were too slight to be of engineering interest. Two major trends are seen in the aftershock sequence. One is roughly aligned with the strike of the Denali fault while the other is oblique to it (approximately northeast-southwest) which may represent conjugate structures (e.g. Riedel shears). The majority of the earthquakes had calculated depths of less than approximately 5 km. As the two large events caused minor damage in Haines Junction and Whitehorse, YT, this study focused on a comparison of the recorded and predicted ground motions and how close they came to the seismic hazard design levels of the 2015 National Building Code of Canada (NBCC 2015).

METHOD

Seismic hazard values as included in the NBCC 2015 were obtained from the online earthquake hazard calculator (Earthquakes Canada, 2016).

Predicted ground motions were calculated from the tabulated values for the western crustal ground motion prediction equations (GMPEs) as used in NBCC 2015 (Halchuk et al., 2015; GSC Open File 7576). Three representative GMPEs are presented (central, lower, upper) whereby each is an estimate of the median GMPE and the range between them is used to show the epistemic uncertainty around the predicted ground motion (Atkinson and Adams, 2013). These three GMPEs are the same crustal GMPEs that were used in Western Canada to derive the seismic hazard values found in the NBCC 2015. Since the tabulated GMPEs are variably tabulated in magnitude and distance, logarithmic interpolation was used to calculate the predictions for specific magnitudes and distances.

Recorded ground motions were processed to give 5% damped spectral accelerations. This involved correcting for instrument response, differentiating to obtain acceleration and computing spectral accelerations using the Nigam and Jennings (1969) method, as implemented within the

GMPE Strong Motion Modeller's Toolkit (Python and OpenQuake-based tool, Pagani et al., 2014; Weatherill, 2014).

All results are presented for a NBCC site class C (firm ground, average shear wave velocity to a depth of 30 m of 450 m/s). Where the site conditions were different, the values were converted to site class C by interpolating (in period) the site class conversion factors used in the 2015 seismic hazard model. A uniform site class of C was used to ensure that the values were directly comparable with each other and to the hazard values in NBCC 2015.

RESULTS AND DISCUSSION

Haines Junction, YT

A seismograph in Haines Junction, YT (station code HYT) located 116 to 119 km NNW from the two epicentres recorded both events (Figure 3). The spectral accelerations for the north-south and east-west component, the NBCC 2015 seismic hazard values, and the predicted ground motions from the GMPEs for the two events can be seen in Figure 4 and Figure 5. Since the site is located on bedrock, the calculated spectral accelerations were corrected, from an assumed site class A (hard rock), to simulate the response on a NBCC 2015 site class C (firm ground).

The NBCC 2015 spectral acceleration hazard values for Haines Junction are nearly 1 g at 0.2 s which can be attributed to the region's high level of historical seismicity and its proximity to the Denali fault. The recorded spectral accelerations ranged from approximately 1 % to 7.5 % of design values for the Mw 6.2 event and 0.5 % to 3 % for the Mw 6.3 event. The spectral accelerations for the Mw 6.2 are similar to the central predicted motions for $T \geq 0.7$ s, but much lower for $T < 0.7$ s. The spectral accelerations for the Mw 6.3 are lower than even the lower GMPE estimate for all periods.

It is interesting to note that the larger Mw 6.3 event produced weaker ground motions in Haines Junction, as is clearly visible in Figure 3. This is likely due to variations between the events in focal mechanisms, hypocenter depths, radiation patterns, and directivity (i.e. rupture towards or away from a site); the dominant reason is not yet determined. To emphasise the difference, Figure 6 shows the ratio of the Mw 6.2 to the Mw 6.3 event for the two horizontal components at HYT. A ratio between the spectral accelerations will remove the common path and site effects and will highlight the differences between the two events. The ratio ranges from 1 to 4 and is, on average, larger for the north-south component (mean and standard deviation of 1.8 ± 0.7). The ratio also has strong peaks around 0.3 s and 1 s which are due to relatively large spectral accelerations at those periods for the Mw 6.2 as opposed to the subsequent Mw 6.3 earthquake.

Whitehorse, YT

The seismograph located in Whitehorse, YT (station code WHY) was not operational during the time of the two earthquakes, therefore no CNSN ground motion recordings are available from that area. The calculated spectral accelerations (site class C), predicted ground motions from the GMPEs and the NBCC 2015 seismic hazard values can be seen in Figure 7 and Figure 8. The NBCC 2015 spectral accelerations for Whitehorse are lower than for Haines Junction (e.g. 0.34 g at 0.2 s; nearly 3 times smaller). The predicted ground motions suggest that the motions ranged from approximately 5 % to 22 % of the design values (e.g. 12 % at 0.2 s for the central GMPE of the Mw 6.2 event). While the recorded motions were, in general, below the predicted GMPEs at Haines Junction, caution should be taken to infer a similar result for Whitehorse as the two locations are at different azimuths from the events (Figure 2). Similarly, while the GMPEs will suggest stronger grounder motions for the larger Mw 6.3 event it is possible that the spectral accelerations may have been in-fact smaller.

CONCLUSION

The reported shaking and incidences of only minor damage in Haines Junction and Whitehorse, YT from the two M 6 events on May 1, 2017 are consistent with the conclusions of this study which found that the ground motions were well below the 2015 seismic hazard design values. In Haines Junction, 5% damped spectral accelerations reached approximately 1 % to 7.5 % of the 2015 seismic hazard design values (e.g. 3 % at 0.2 s). While the seismograph in Whitehorse was not operational at the time, the predicted motions from the event are 5 % to 22 % of the design values (e.g. 12 % at 0.2 s for the central estimate of the first event). The higher percentages are largely due to the lower seismic hazard design values for Whitehorse.

ACKNOWLEDGEMENTS

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FIGURES

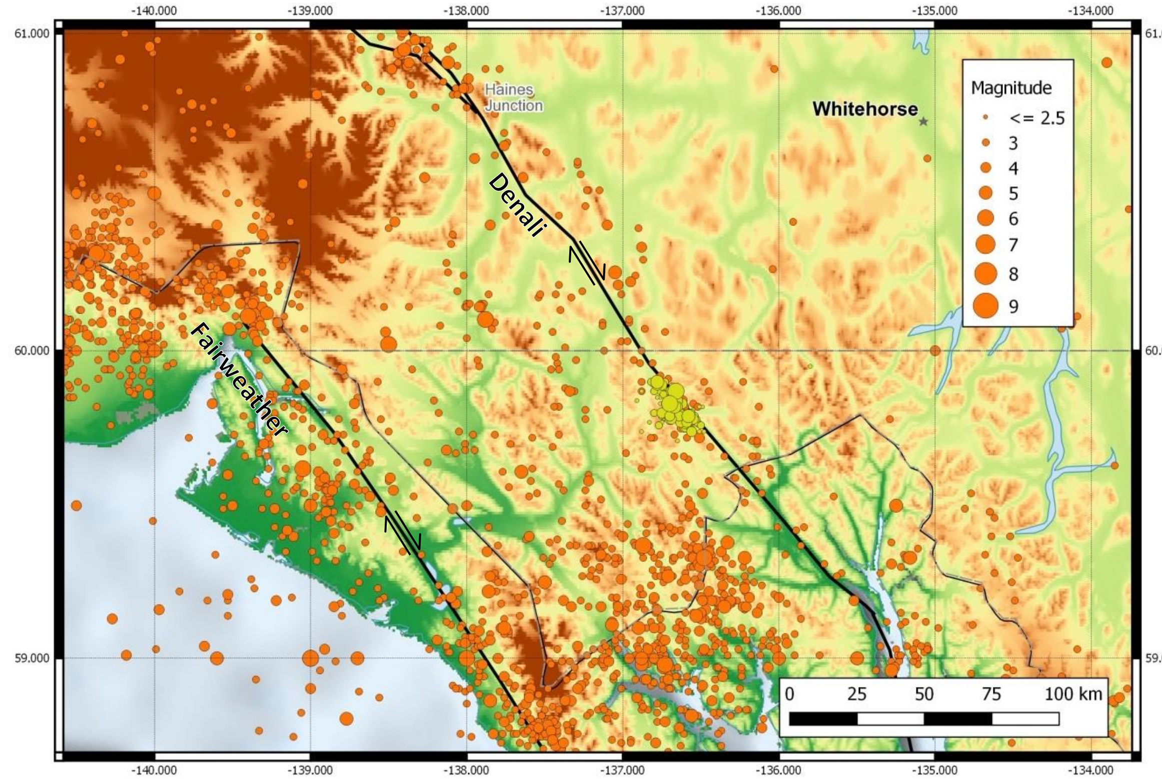

Figure 1. Seismicity within Southwestern Yukon (M >= 2.5) as extracted from the complete Canadian National Earthquake Database on July 2017. Yellow circles represent the Tatshenshini-Alsek Park earthquake sequence. Major faults and relative movement as included in the 2015 seismic hazard model shown. Background relief map adopted from GTOPO30 (made available through the U.S. Geological Survey).

A.

B.

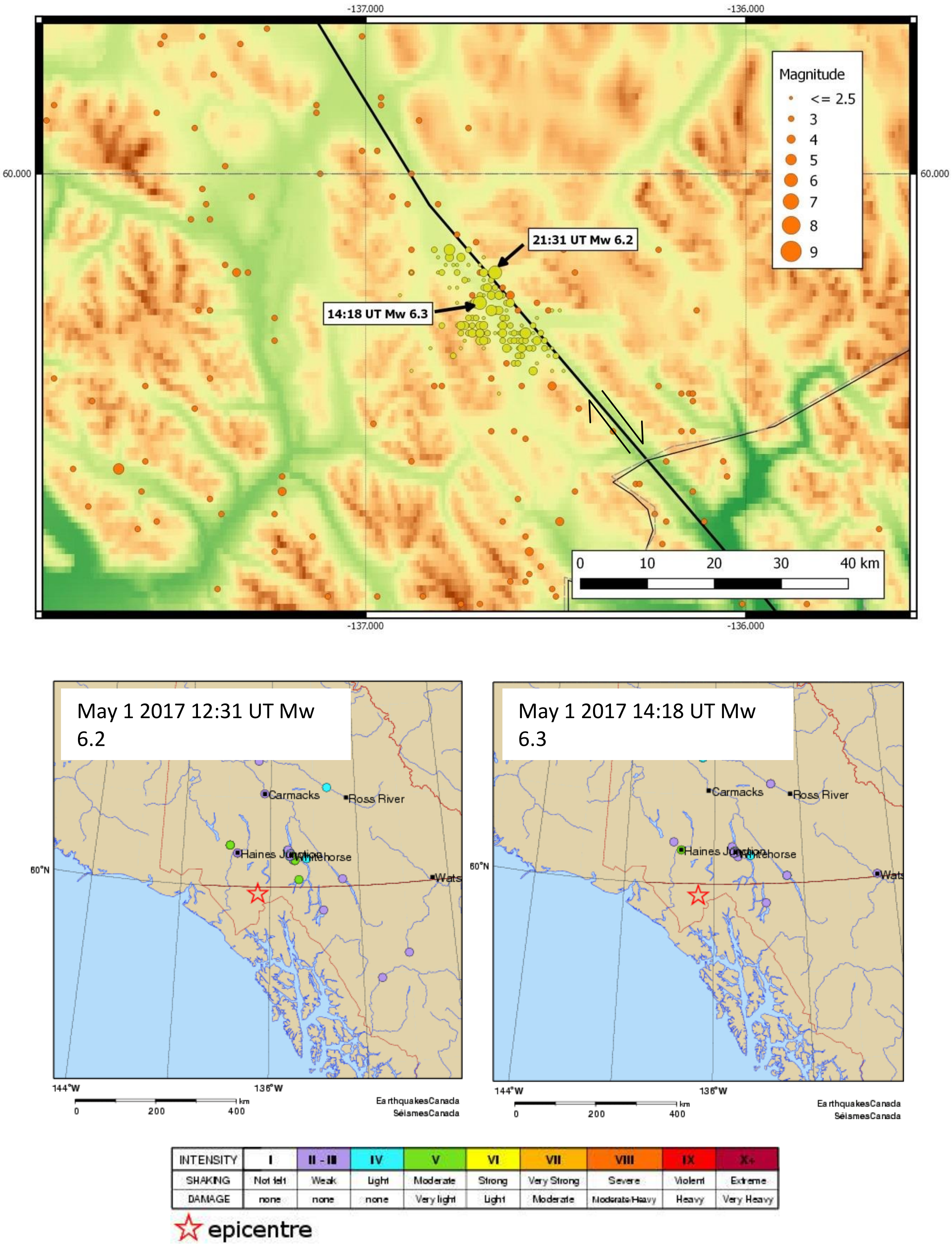

Figure 2. A. Close-up of the Tatshenshini-Alsek Park earthquake sequence shown in Figure 1. **B.** Community internet intensity maps generated from user submitted felt reports for the two M 6 events.

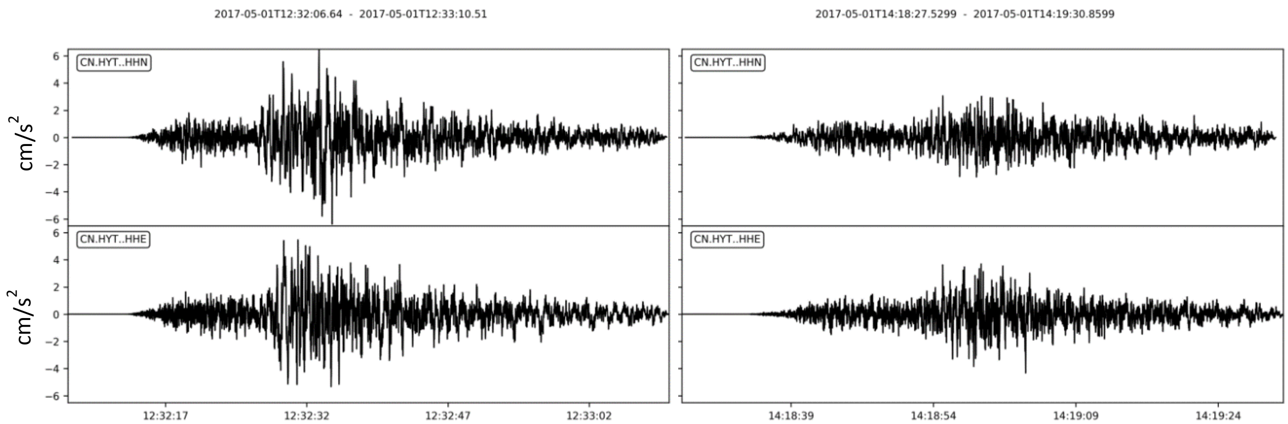

Figure 3. Horizontal (top: north-south; bottom: east-west) acceleration (cm/s^2) time series for the Mw 6.2 (12:31 UT, left column) and Mw 6.3 (14:18 UT, right column) earthquakes of May 1, 2017. Constant Y-axis scale is used for all traces.

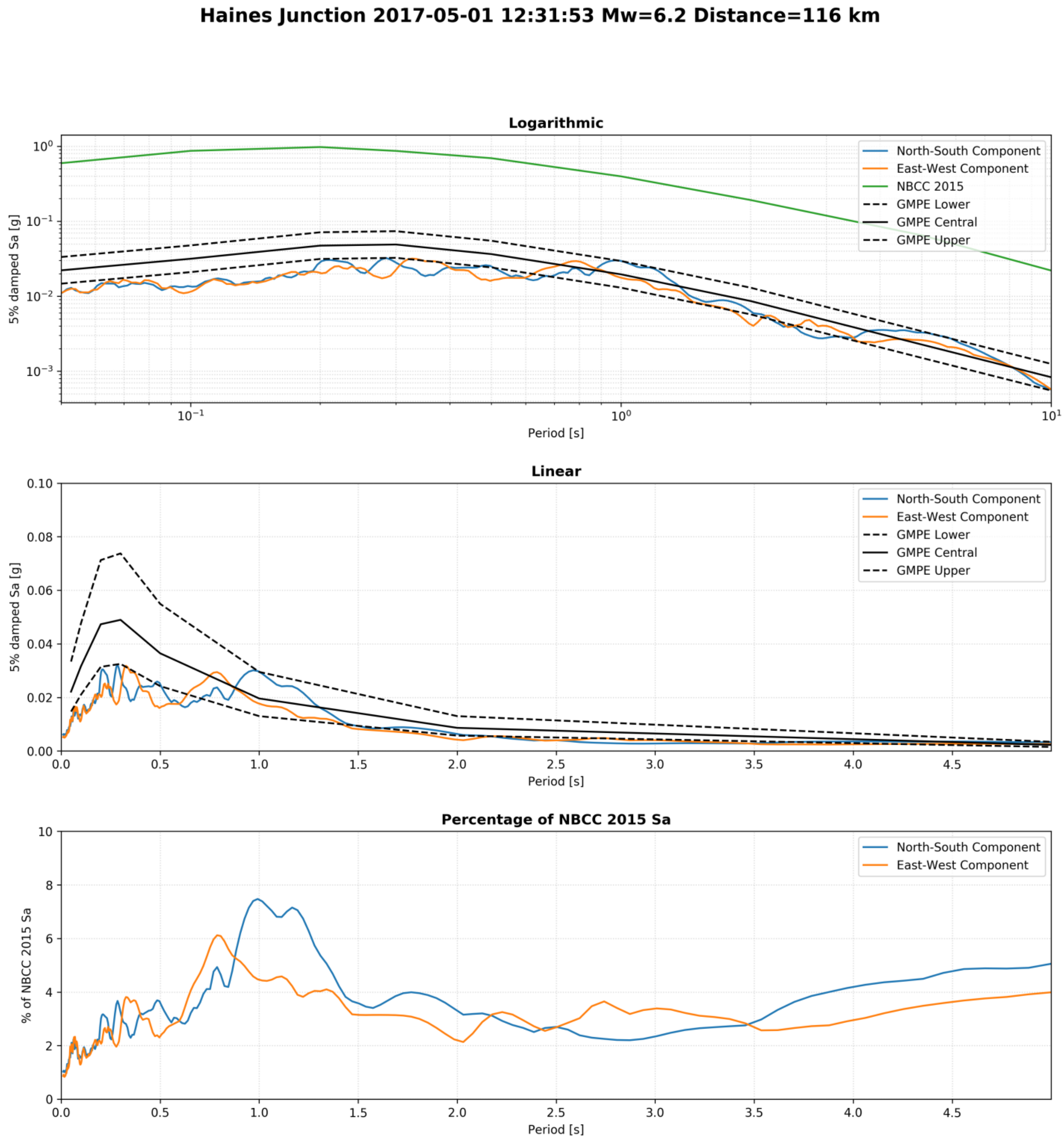

Figure 4. Top panel: 5 % damped spectral acceleration (Sa) for the north-south and east-west components of the recorded Mw 6.2 event at Haines Junction, the NBCC 2015 seismic hazard values for Haines Junction and the predicted Sa from the GMPEs on a logarithmic scale. Middle panel: Same as top panel but on a linear scale (NBCC 2015 values too large to display). Bottom panel: Recorded Sa as a percentage of the NBCC 2015 seismic hazard values. All values presented for NBCC site class C.

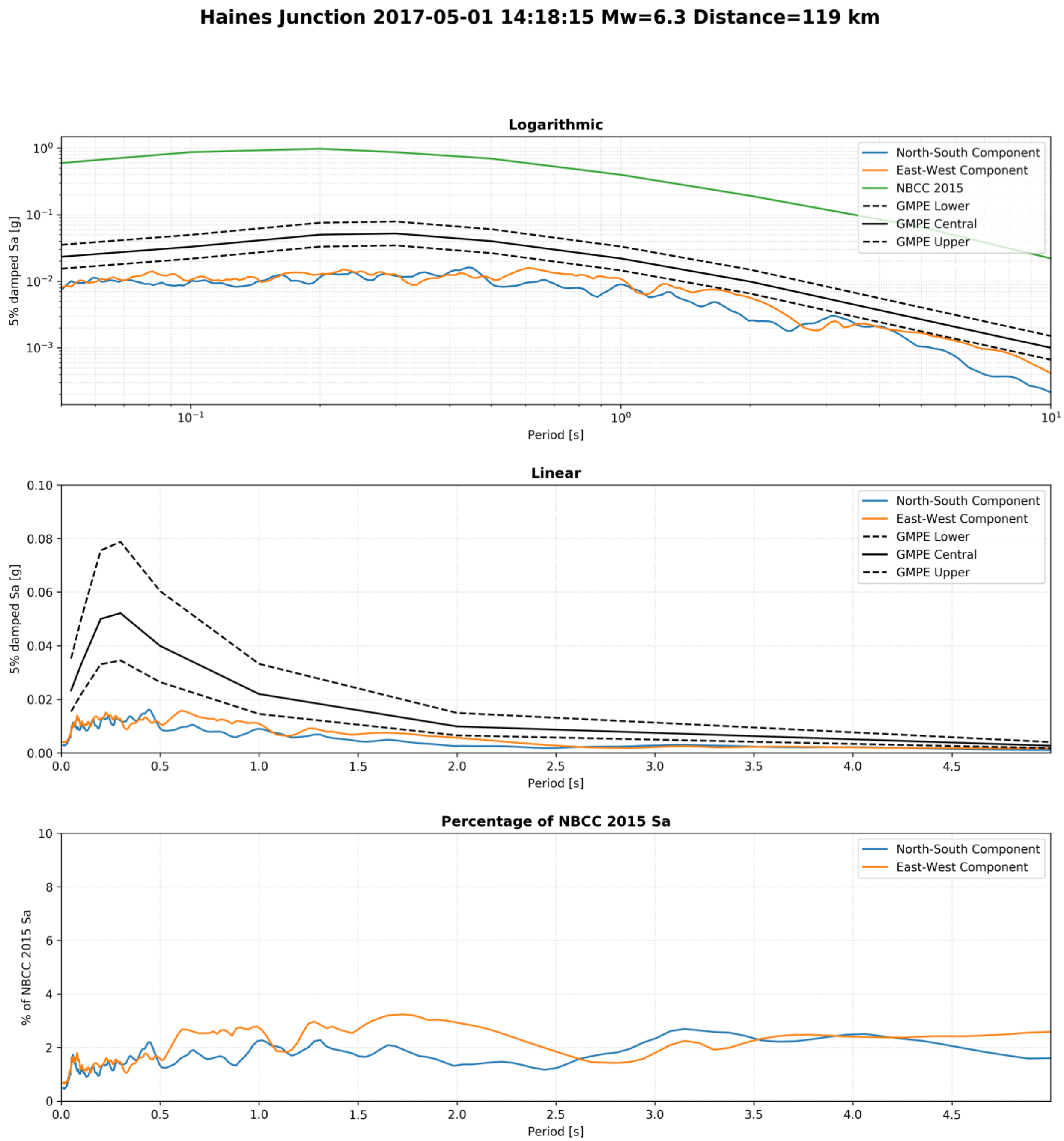

Figure 5. Top panel: 5 % damped spectral acceleration (Sa) for the north-south and east-west components of the recorded Mw 6.3 event at Haines Junction, the NBCC 2015 seismic hazard values for Haines Junction and the predicted Sa from the GMPEs on a logarithmic scale. Middle panel: Same as top panel but on a linear scale (NBCC 2015 values too large to display). Bottom panel: Recorded Sa as a percentage of the NBCC 2015 seismic hazard values. All values presented for NBCC site class C.

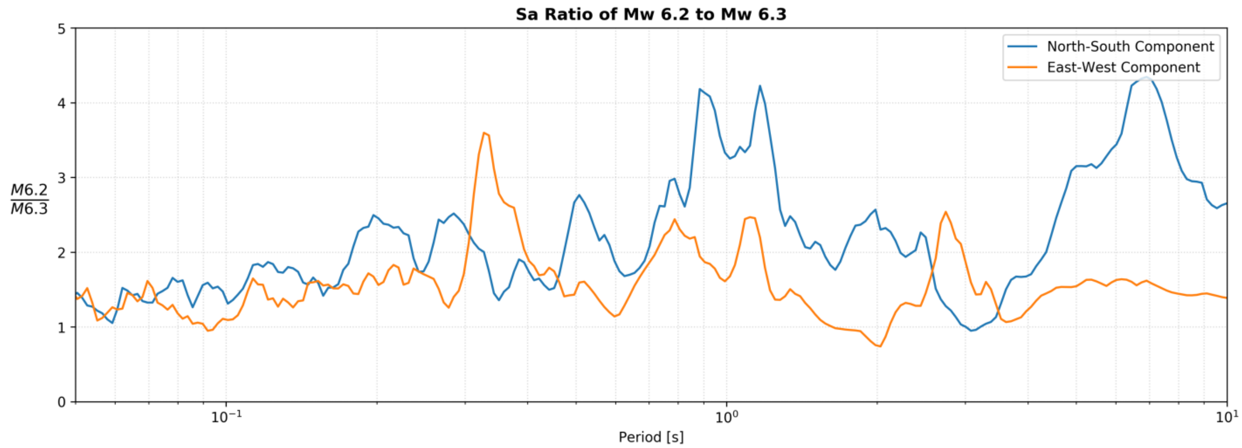

Figure 6. Ratio between the spectral acceleration (Sa) of the Mw 6.2 to the Mw 6.3 event for both horizontal components at HYT.

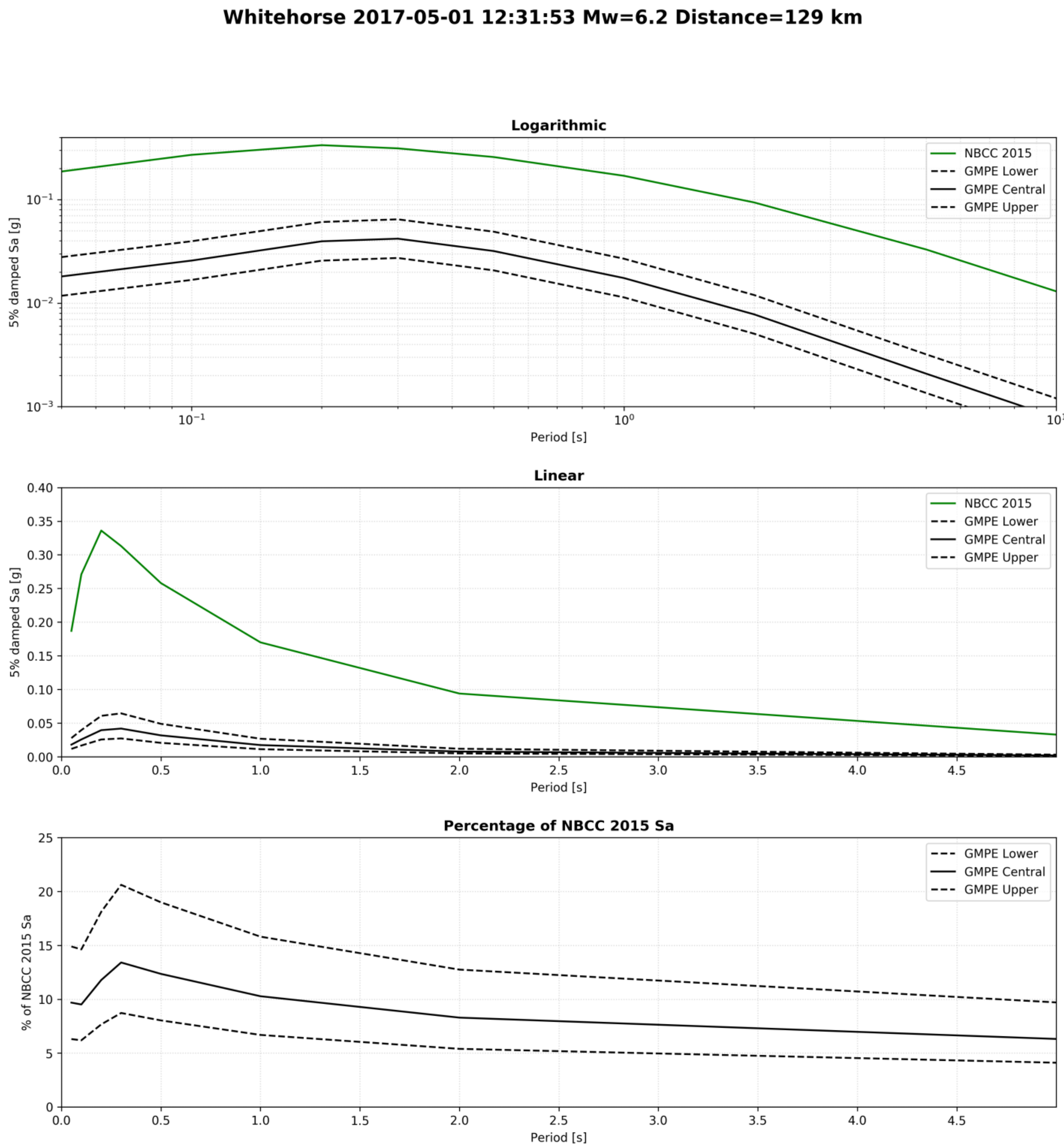

Figure 7. Top panel: Predicted 5 % damped spectral acceleration (Sa) calculated from GMPEs for the Mw 6.2 event and the NBCC 2015 seismic hazard values at Whitehorse (logarithmic scale). Middle panel: Same as top panel but on a linear scale. Bottom panel: Predicted GMPEs as a percentage of the NBCC 2015 seismic hazard values. All values presented for NBCC site class C.

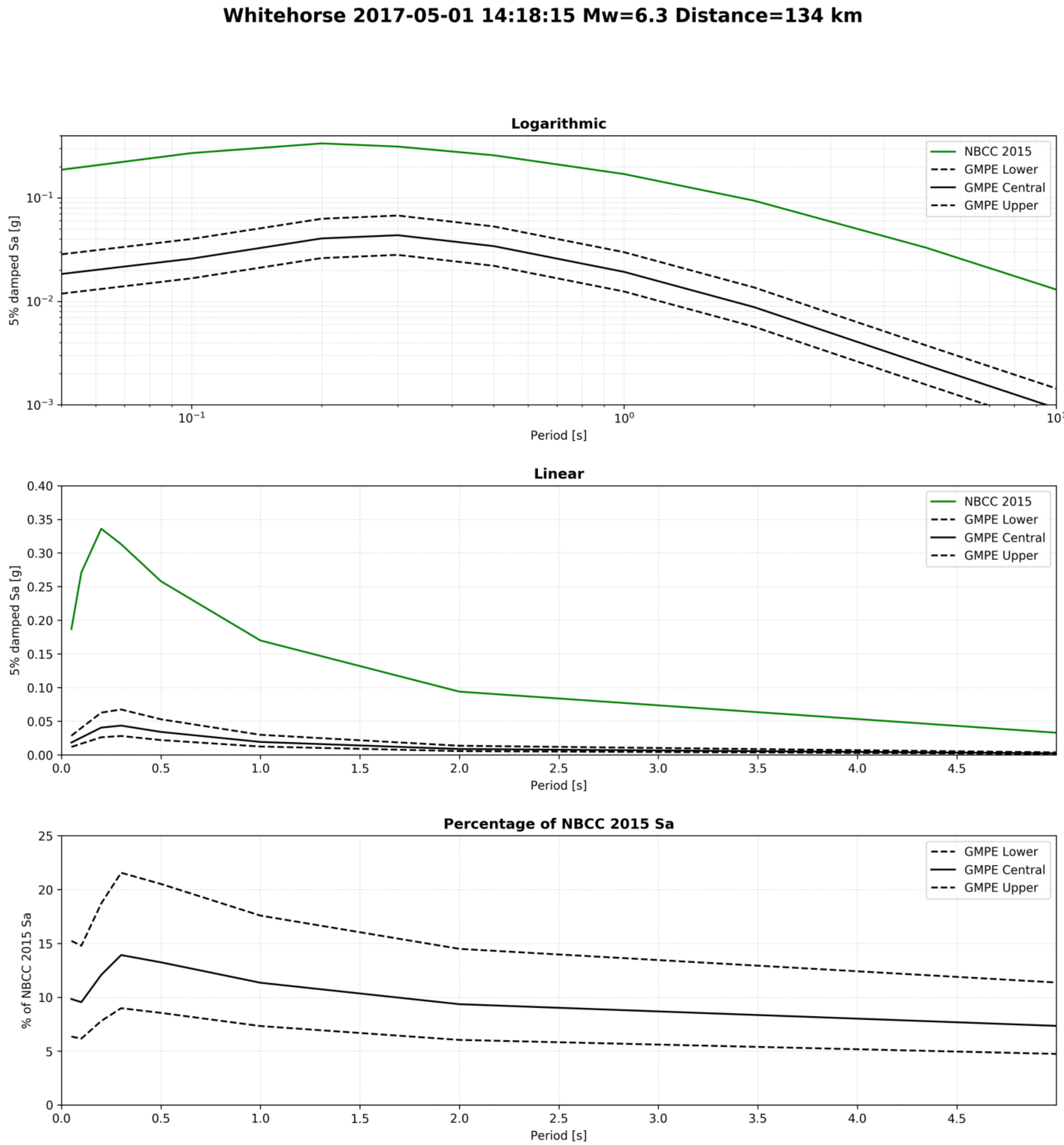

Figure 8. Top panel: Predicted 5 % damped spectral acceleration (Sa) calculated from GMPEs for the Mw 6.3 event and the NBCC 2015 seismic hazard values at Whitehorse (logarithmic scale). Middle panel: Same as top panel but on a linear scale. Bottom panel: Predicted GMPEs as a percentage of the NBCC 2015 seismic hazard values. All values presented for NBCC site class C.