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Improvement of Regional Seismograph Networks in Northeast BC and Western AB: Impact on Regulations of Unconventional Hydrocarbon Development

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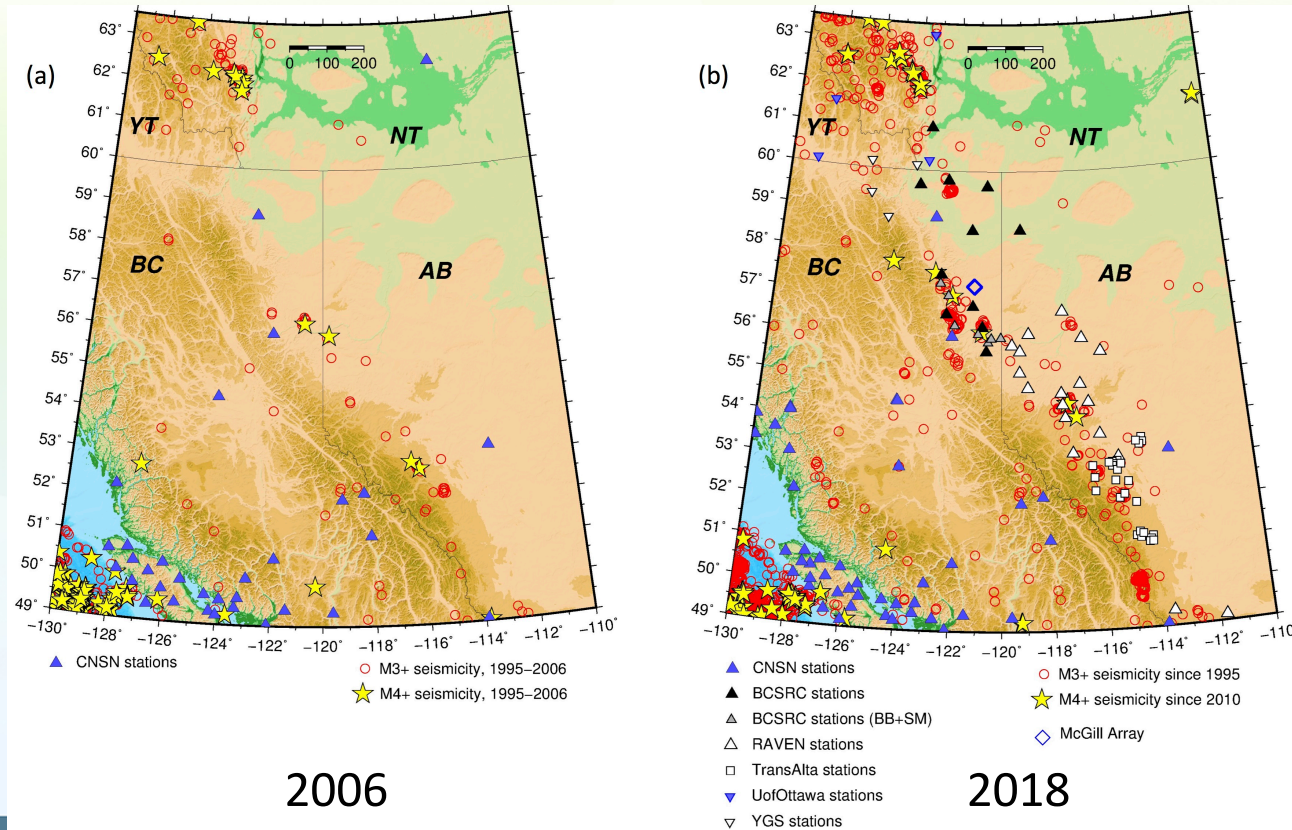
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Outline

- Densification of Regional Seismograph Networks
- Development of Collaborations
- Impact on Regulatory Performances
 - Traffic light protocols for induced seismicity
 - Induced seismicity monitoring requirements
 - Effective mitigation of seismic hazards from induced seismicity



Regional Seismicity and Seismograph Networks in Western Canada

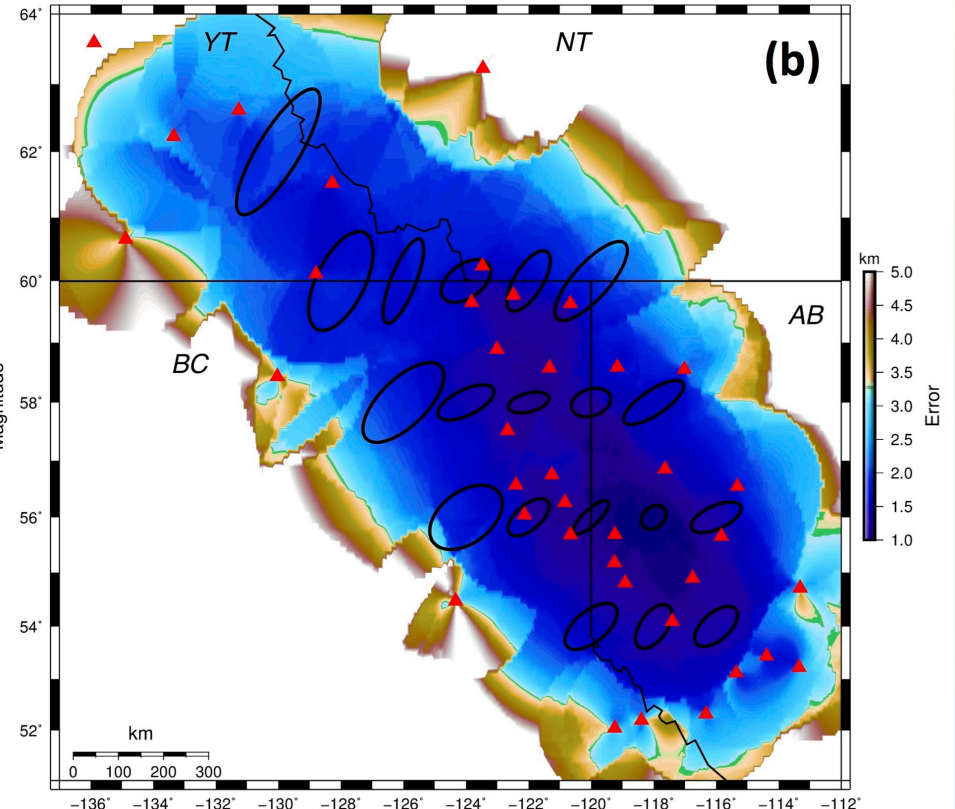
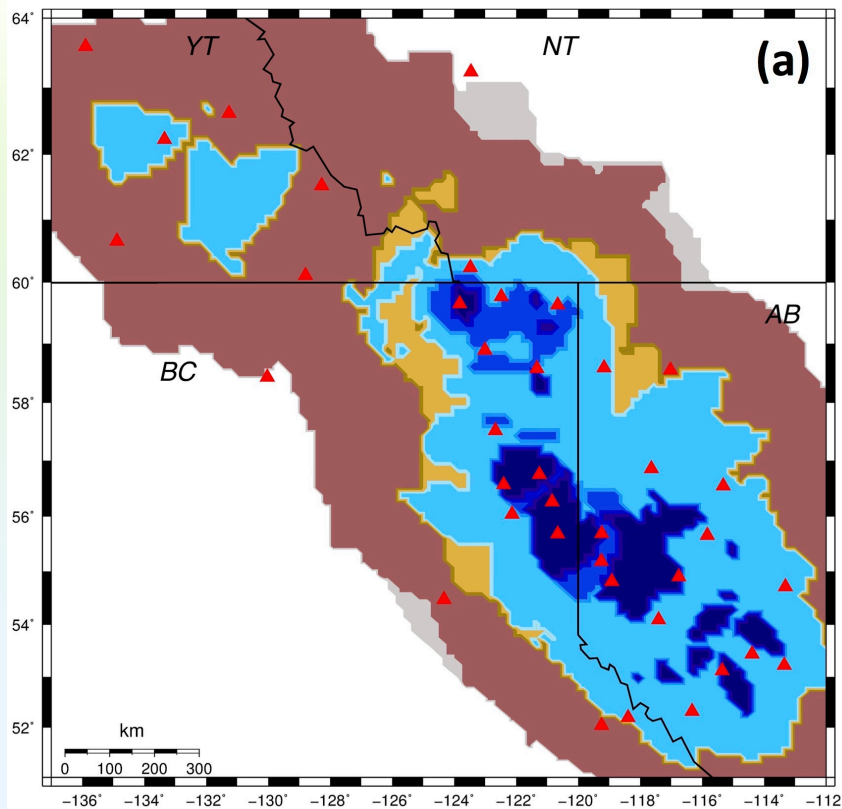


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Improvement in Earthquake Monitoring



Babaie Mahani et al. (2016, *SRL*), Kao et al. (2018, *GRL*)

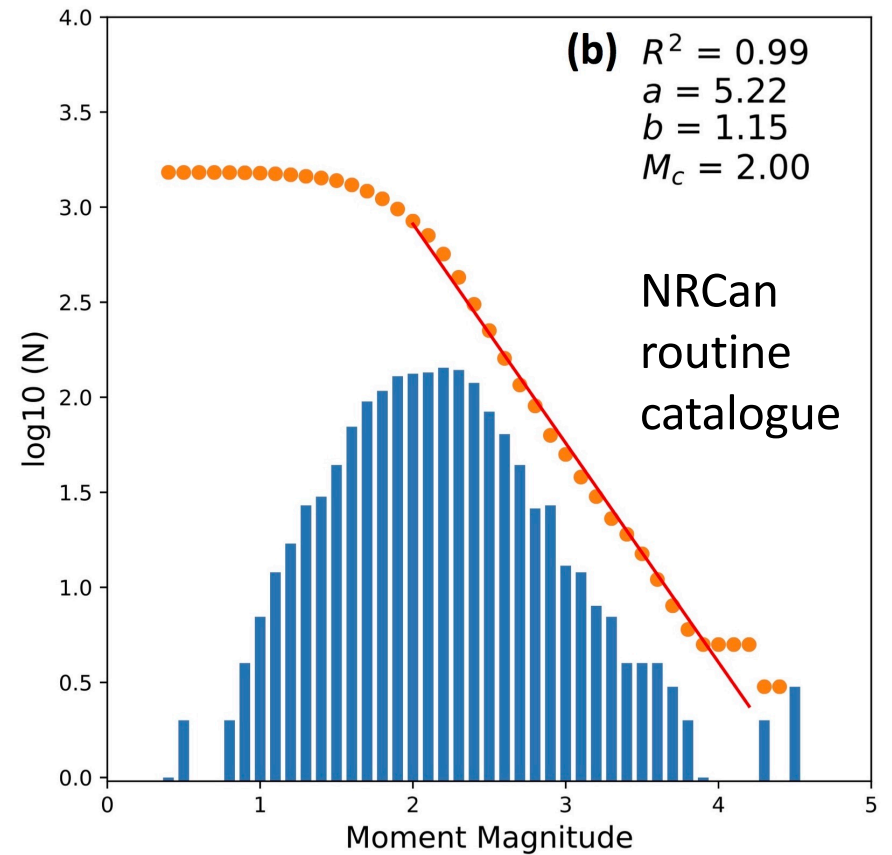
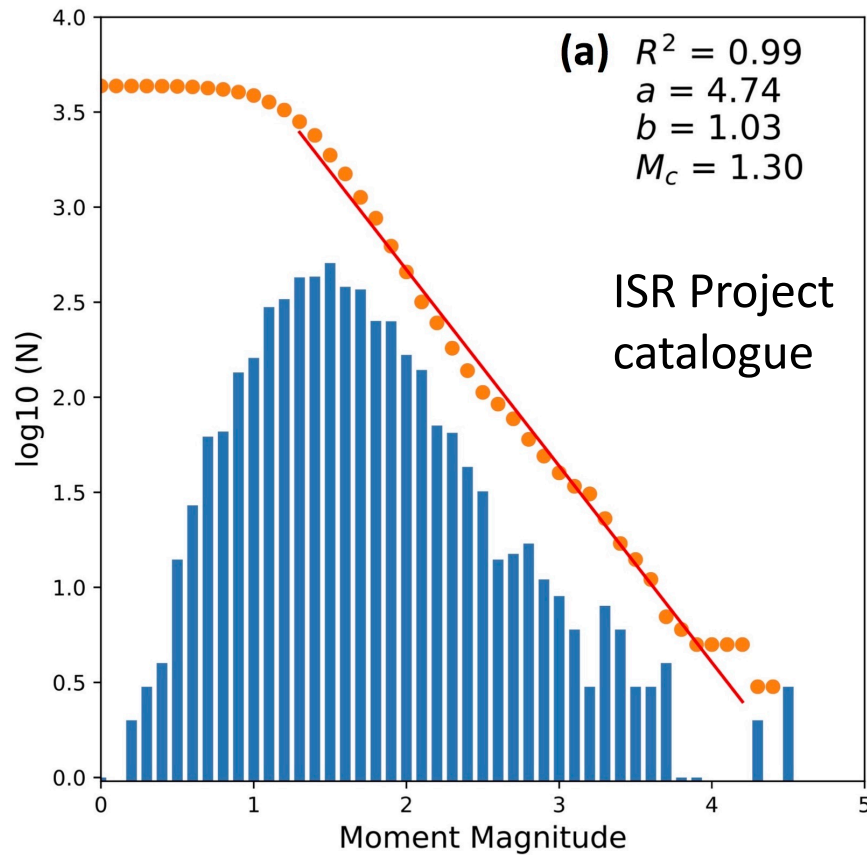


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Improvement in Earthquake Monitoring



Visser et al. (2017, *GSC open file*)



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Development of Collaborations

- Microseismic Industry Consortium
 - Established in 2010
 - Led by Prof. D. Eaton (Univ. of Calgary, NSERC/Chevron Industrial Research Chair) and Prof. M. van der Baan (Univ. of Alberta)
 - Sponsored by a large number of industrial partners
 - Take a multidisciplinary approach to conduct research related to data acquisition, processing and interpretation
 - Specific research goals and objectives have been developed in close consultation with industry sponsors
- <https://www.microseismic-research.ca/>



Development of Collaborations

- BC Seismic Research Consortium
 - Established in 2012
 - Consisted of 4 original members: GSC/NRCan, BCOGC, Geoscience BC, and CAPP
 - Yukon Geological Survey joined in 2016
 - To form a framework for research co-operation to study induced seismicity in NE BC
 - Densify the regional seismic network in the unconventional hydrocarbon production areas
 - Promote research of induced seismicity related to the development of unconventional hydrocarbons
 - Facilitate data sharing and information exchange



Development of Collaborations

- Canadian Induced Seismicity Collaboration
 - Established in 2014
 - Based on an Industrial Research Chair funded by NSERC and two industrial partners (TransAlta and Nanometrics) and a NSERC Collaborative Research and Development (CRD) grant to Western University (Prof. G. Atkinson)
 - Partners include Univ. of Calgary, AGS/AER, GSC/NRCan, Univ. of Alberta, and McGill Univ.
 - Coordinate research efforts focusing on understanding the mechanisms and seismic hazards associated with industry-related induced seismicity
 - Expansion of the seismic network in Alberta
 - Promote research collaborations on hazards from induced seismicity and induced seismicity processes
- <http://www.inducedseismicity.ca/>



Development of Collaborations

- NSERC Strategic Partnership for Induced Earthquake Research
 - Funded by a NSERC Strategic Research grant to McGill Univ. (Prof. Y. Liu and Prof. R. Harrington) from 2016 to 2020
 - Partnered with GSC/NRCan and BCOGC
 - Multidisciplinary studies of induced seismicity in BC
 - A dense seismic array in the Dawson Creek area
 - Geodetic monitoring (InSAR and GPS)
 - Groundwater chemistry monitoring



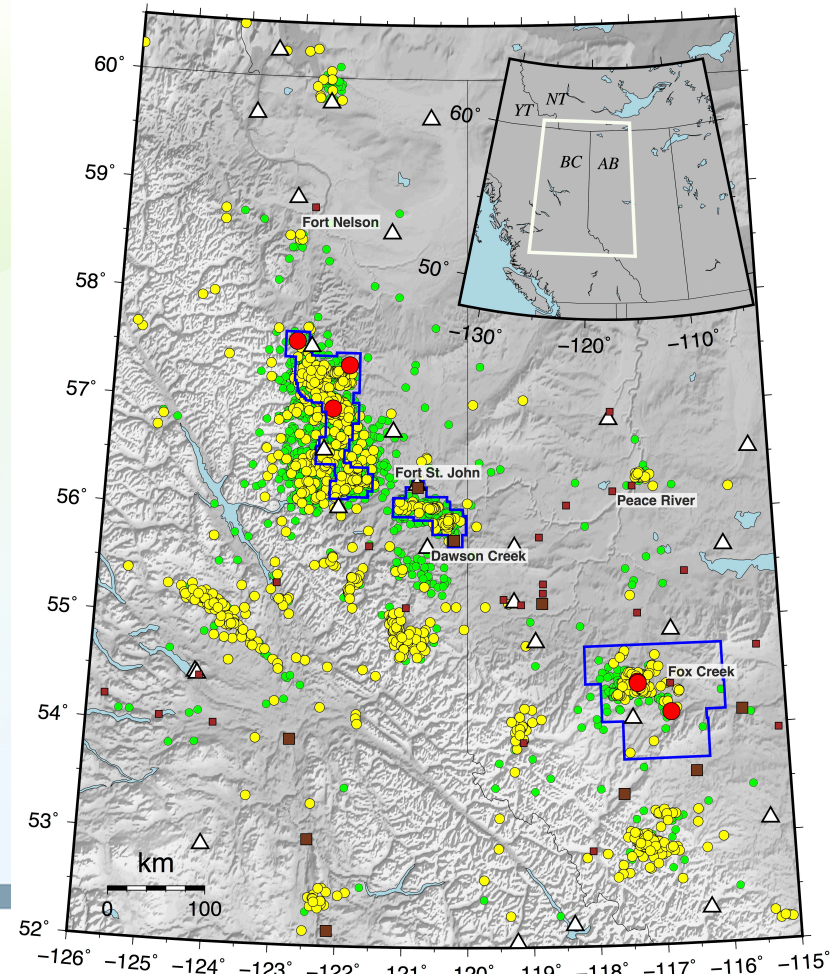
Development of Collaborations

- Comprehensive Ground Motion Monitoring Network in NE BC
 - Funded by BCOGC and GSC/NRCan with in-kind support from the industry
 - 9 new stations equipped with both broadband seismometer and accelerometer at strategic locations
 - Real-time communication via cell modems to provide ground shaking monitoring (PGV and PGA distributions) of induced events
 - 7 stations completed in Oct 2018, 2 more in early 2019



Impact on Regulatory Performances

1. Identify and define “sweet spots” of injection-induced earthquakes.
2. Strengthen earthquake monitoring requirements for specific sites.
3. Rapidly respond to media and public inquiries about possible felt induced events.
4. Understand the full impact/consequence of ground shaking caused by individual induced events.



New Regulations

- Induced Seismicity Traffic Light Protocol (IS-TLP)
 - AER Subsurface Order No. 2 (issued on 19 February 2015)
 - Require all operators in the Fox Creek area to establish seismic monitoring arrays capable of detecting M_L 2+ events within 5 km of a HF well.
 - Yellow light = M_L between 2 and 4, implement predefined mitigation strategies in an attempt to limit the escalation of magnitudes.
 - Red light = $M_L \geq 4$, immediate suspension of injection operations.
 - Similar regulations were implemented by BCOGC (Section 21.1 “Induced seismicity”, Drilling and Production Regulation, Oil and Gas Activities Act) in June 2015 (suspension if $M_L \geq 4$ within 3 km).
 - Workshop on IS-TLP: Summary and Recommendations (Kao et al., 2016, GSC open file)
 - Details on Canadian IS-TLP and performance analysis (Kao et al., 2018b, TLE)



Timeline of Regulatory Changes in BC

- **2014**, new permit conditions for drilling and production operations in the Horn River Basin to address the issue of induced seismicity.
- **2015**, new regulation on induced seismicity (Section 21.1 “Induced seismicity”, Drilling and Production Regulation, Oil and Gas Activities Act).
- **2016**, new permit conditions requiring ground motion monitoring within certain oil and gas development areas (BCOGC Industry Bulletin 2016-19).
- **2017**, amendments to the Drilling and Production Regulation on induced seismicity associated with both fracturing and disposal operations (BC OGC Industry Bulletin 2017-10).
- **2018**, new order on monitoring, mitigation and reporting requirements for permit holders in the Kiskatinaw Seismic Monitoring and Mitigation Area (aka, the Farmington area, BC OGC Special Project Order 18-19-001).



Conclusions

- Significant efforts have been made by governments, academia, and industry to improve the monitoring capability of regional seismograph networks in western Canada.
- Detection threshold of regional seismicity has been improved by one magnitude unit from $M_L \sim 2.5$ to 1.5, which is deemed appropriate for regulatory purposes.
- Multidisciplinary research collaborations were proactively promoted to address critical knowledge gaps identified by regulators, industry, and the research community.
- As a result, regulatory performances are constantly improved with a balanced approach between economic benefit of unconventional resource development and the protection of public safety and environments.

THANK YOU!



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