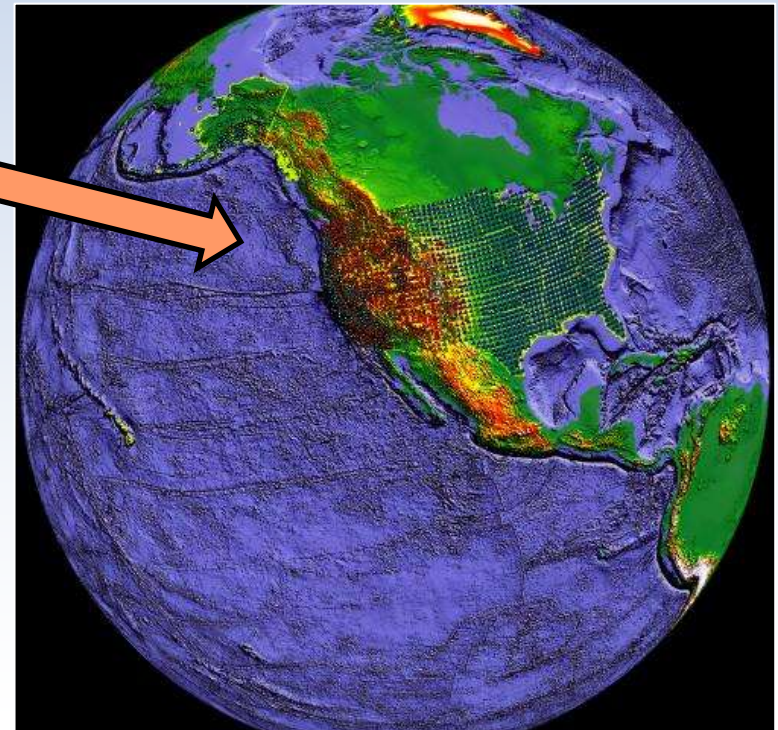
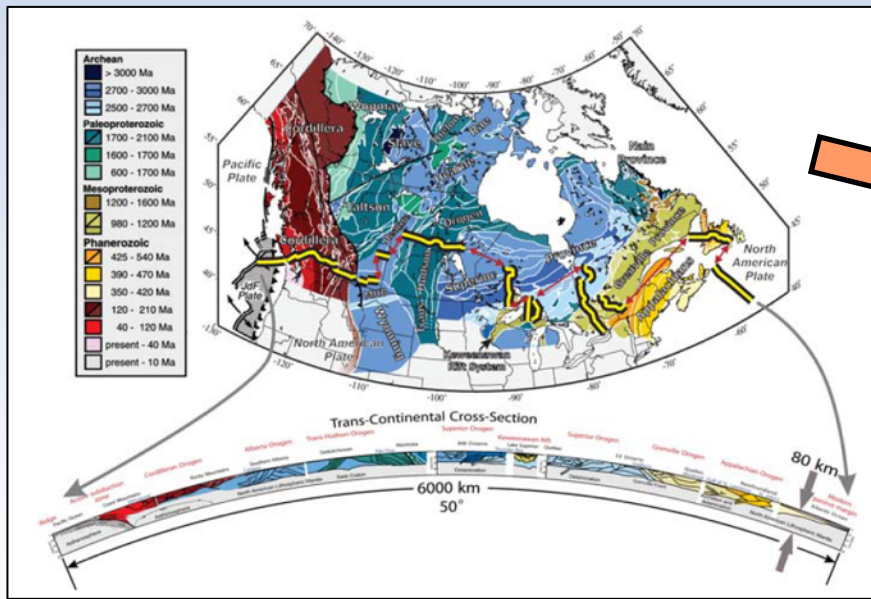


The CCArray: Towards an EarthScope-like program for Canada

“Geoscience without Borders”

James, T. (GSC/UVic), Boggs, K. (MRU), Eaton, D. (UofC),
 Hyndman, R. (GSC/UVic), Audet, P. (UofO), Schmidt, M. (UofC),
 Aster, R. (CSU), Schutt, D. (CSU), Rowe, C. (McGill),
 Morell, K. (UVic), Leonard, L. (UVic), and many others



2-D to 3-D

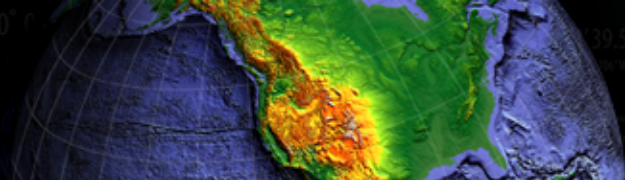


Passion & Excitement

Dream It.
Believe It.
Achieve It.

- Cort Christie

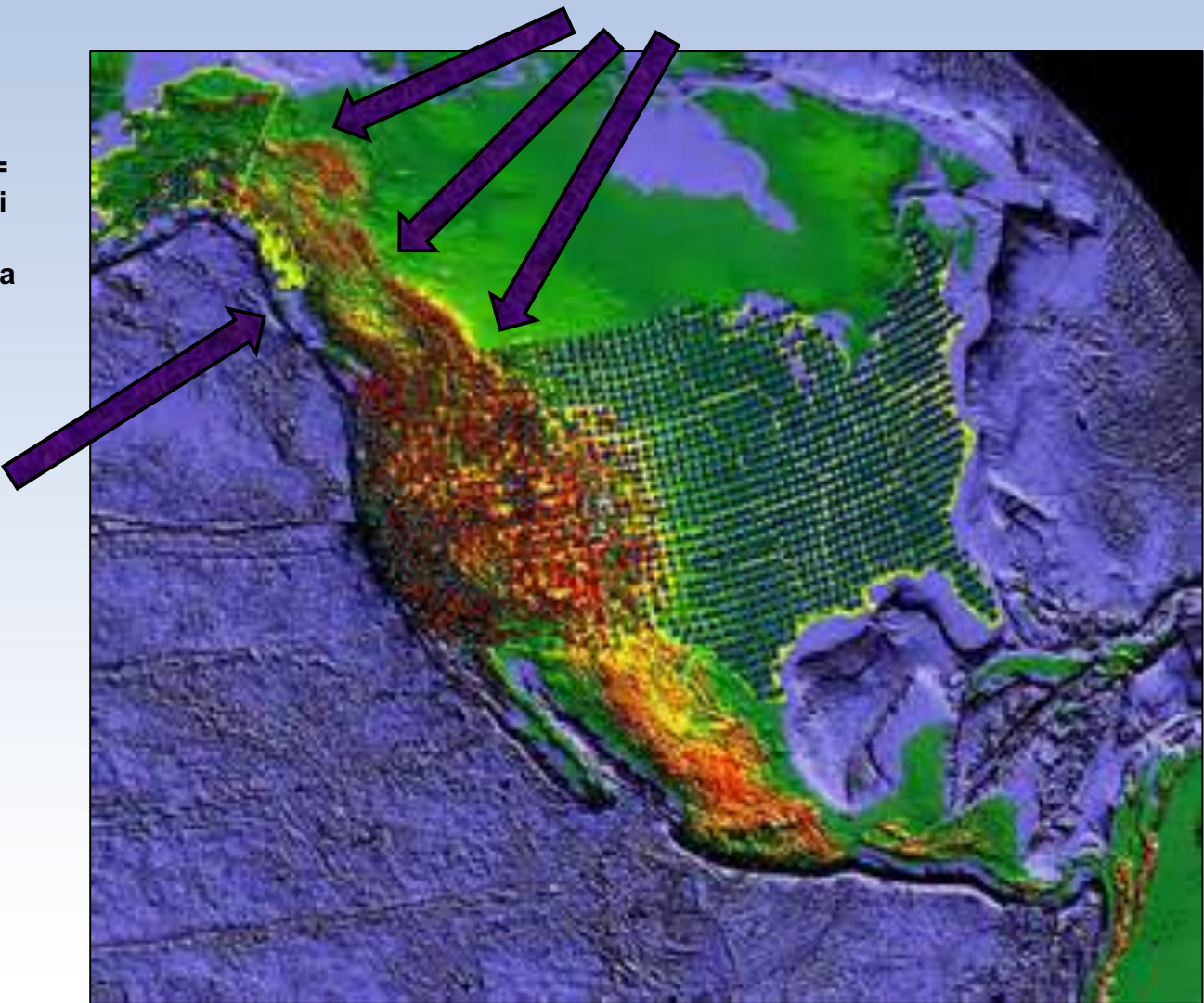




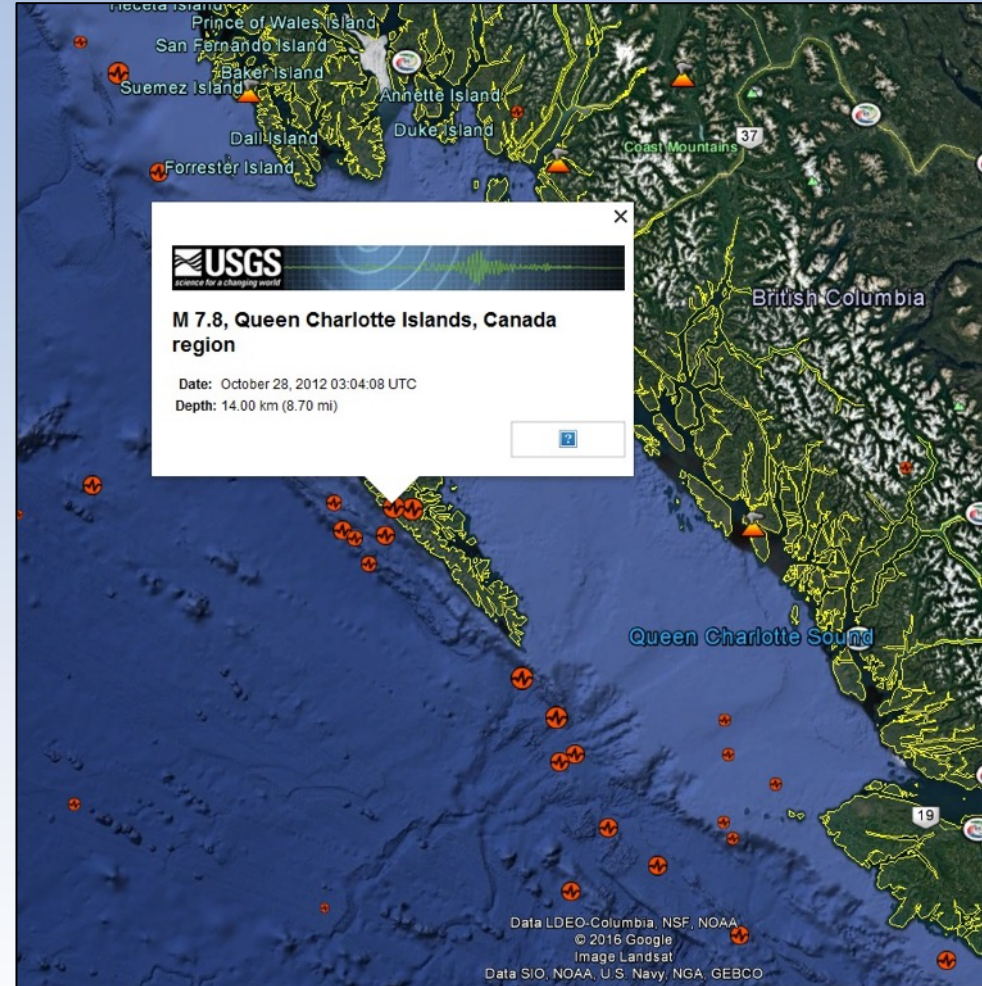
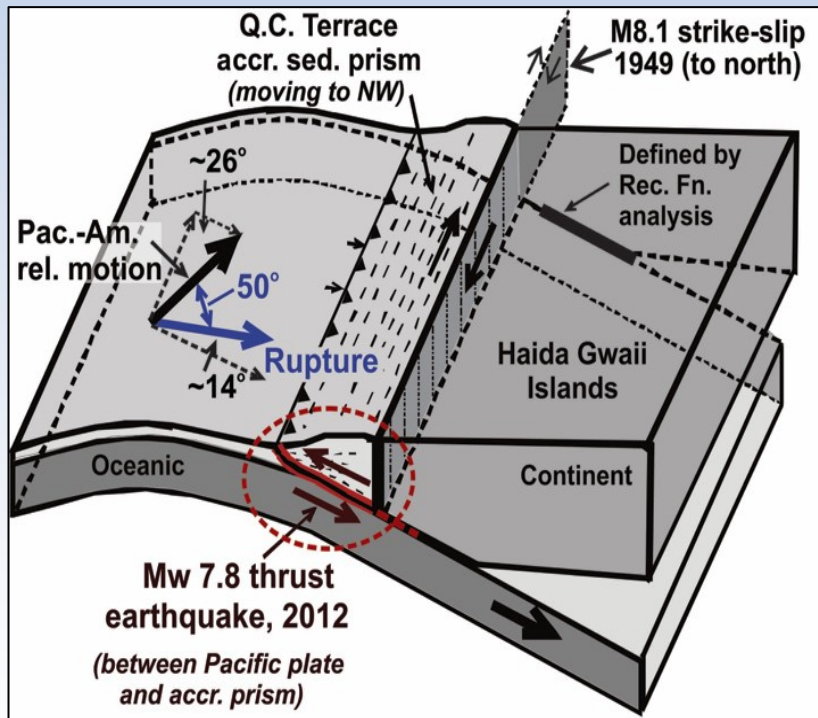
Complete the “structure & evolution of the North American continent”

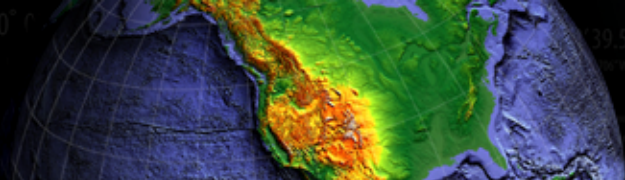
Case One:
Oct. 2012 Eq =
Large tsunami
not directly
witnessed by a
person.

Detected by
a tide gauge
in Hawaii.



Haida Gwaii Margin
 -partition of oblique
 convergence into strike slip
 -thrust Earthquake
 (Hyndman et al 2014)



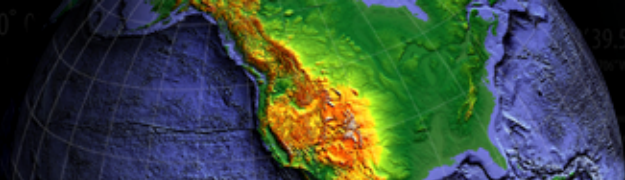


Part 1: Katherine – Overview

- "EarthsCAN" – CCArray – CC-NET
- Scientific goals; structure

Part 2: Tom – GNSS Workshop

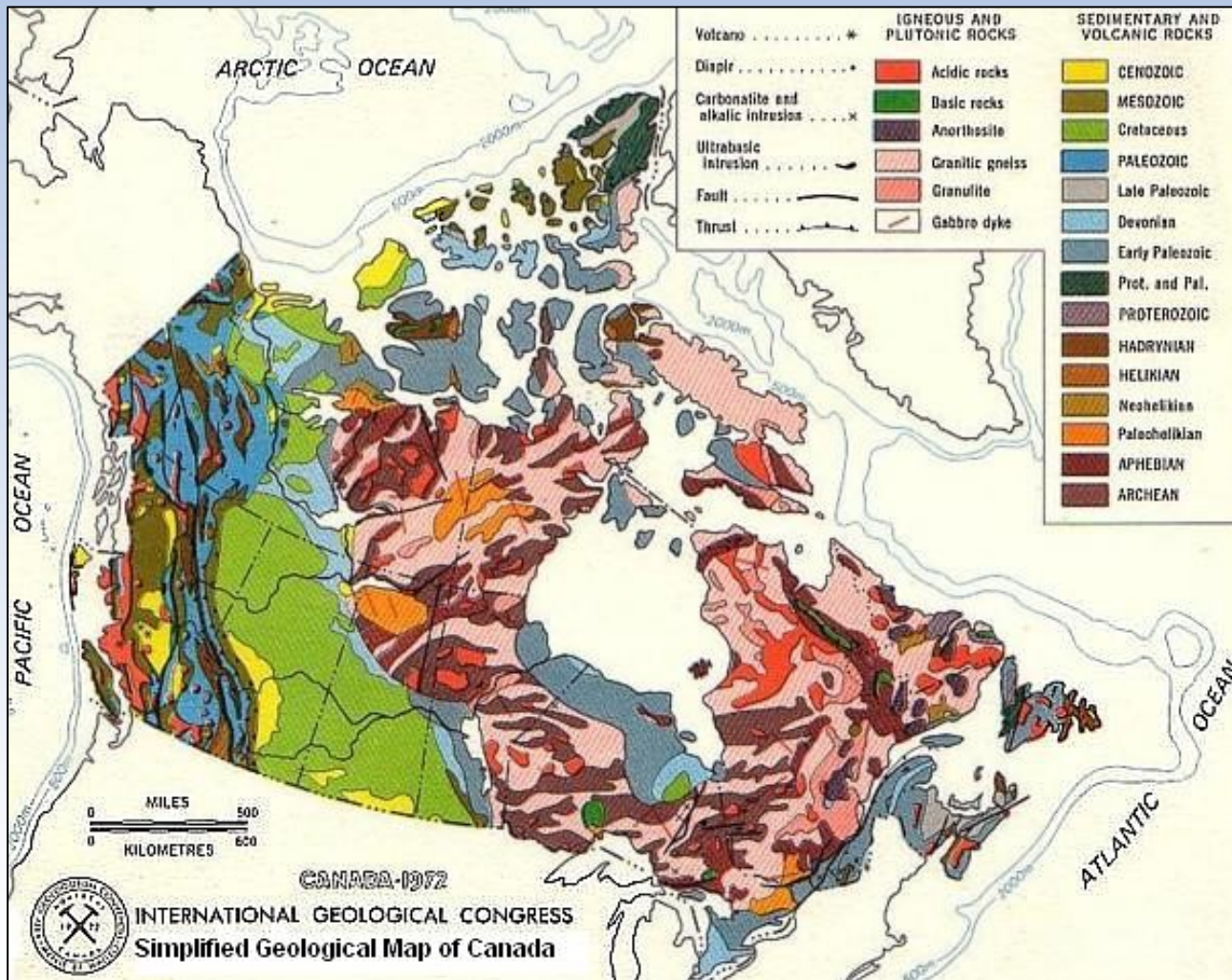
- Scientific goals continued



1. Introduce CCArray
2. Advice, lessons learned or suggestions are appreciated!
3. We look forward to collaborations; please talk to us

“EarthsCAN” – pan-Canada

“Magnetosphere through crust to core”



“EarthsCAN” – Motivation:

Maintain North American Large Geoscience Research Program Momentum



LITHOPROBE
“Other Supporting Geosciences”
1000 geoscientists
& 1500 scientific pubs
(1984 to 2004)

(Hammer et al 2011; GSA Today)

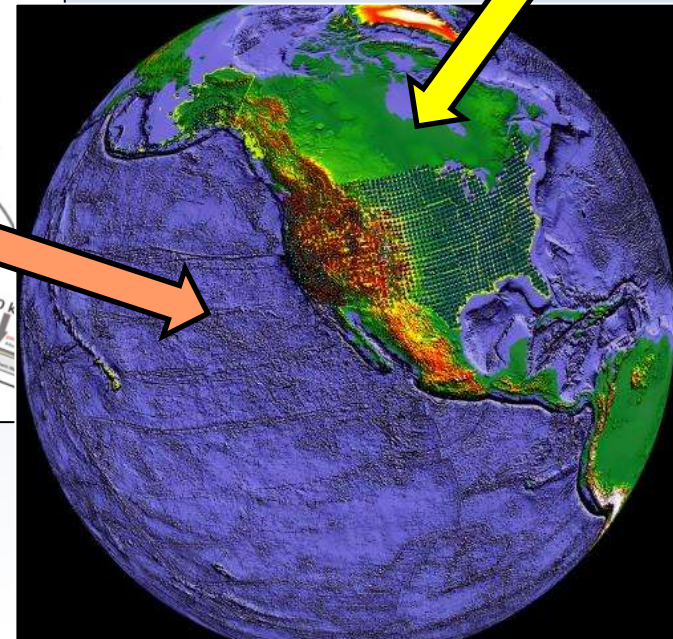
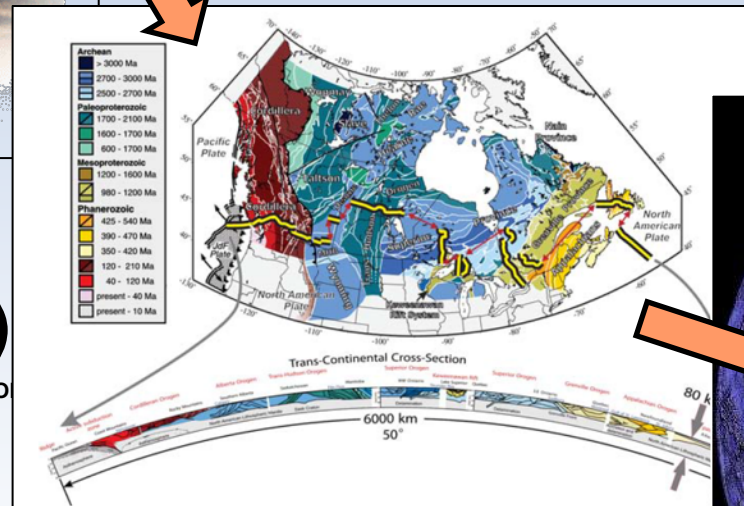
EarthScope (IRIS)
TA – 2226 sites
>290 scientific pubs 2009 to 2013
(2004 to ~2018)

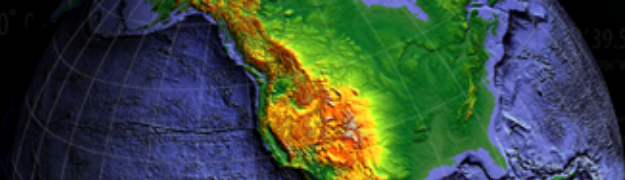
<http://www.earthscope.org>

“EarthsCAN?”
~2017 to ???

**Consortium for Continental
Reflection Profiling**
11,000km - 30 US states
(~1980 to 1997)

<http://www.geo.cornell.edu/geology/cocorp/COCO>



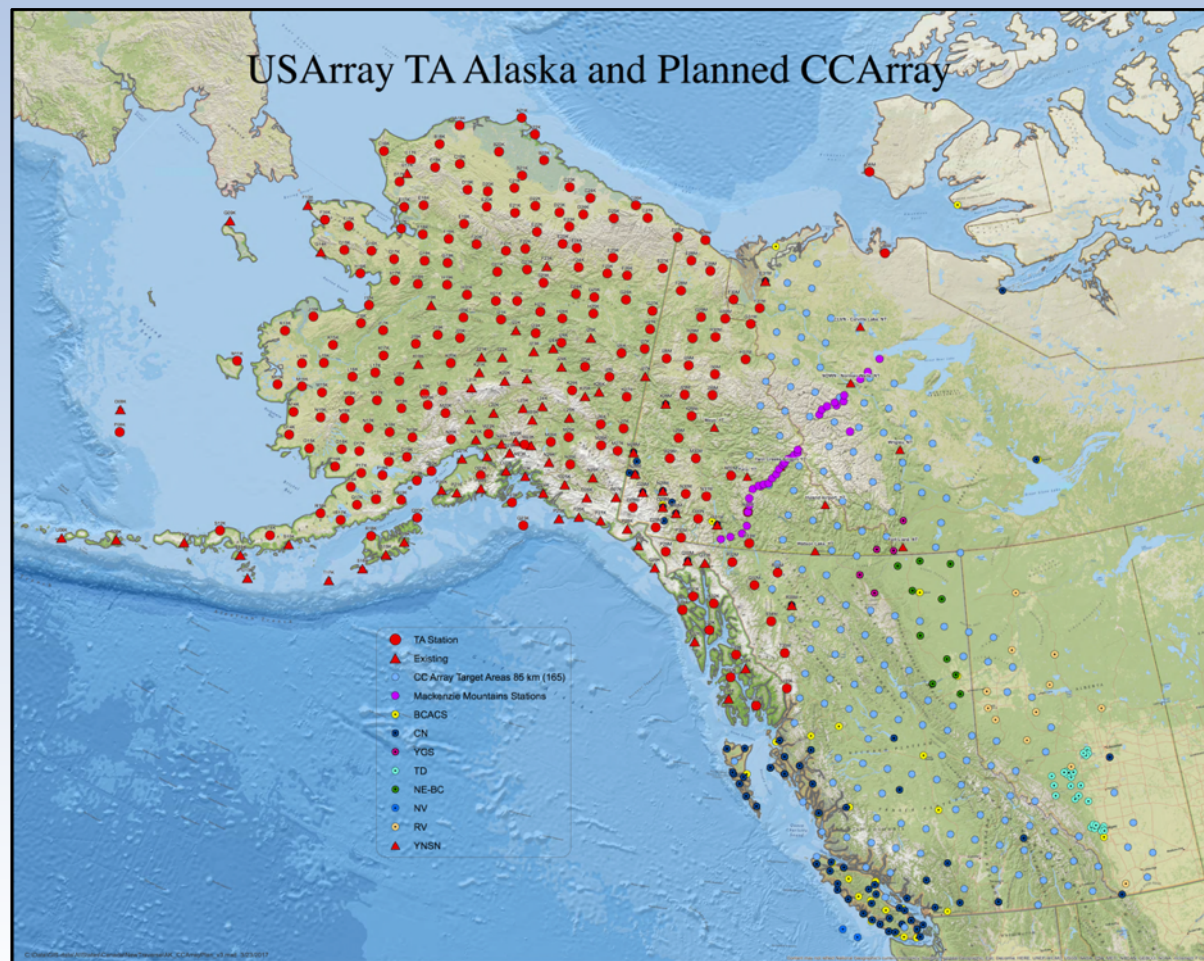


Why timing is critical: EarthScope – 2004 to ~2018

**Instruments now in
Alaska and nw
Canada**

**Instruments could be
removed as early as
2019**

**CCArray separated
from EarthsCAN**

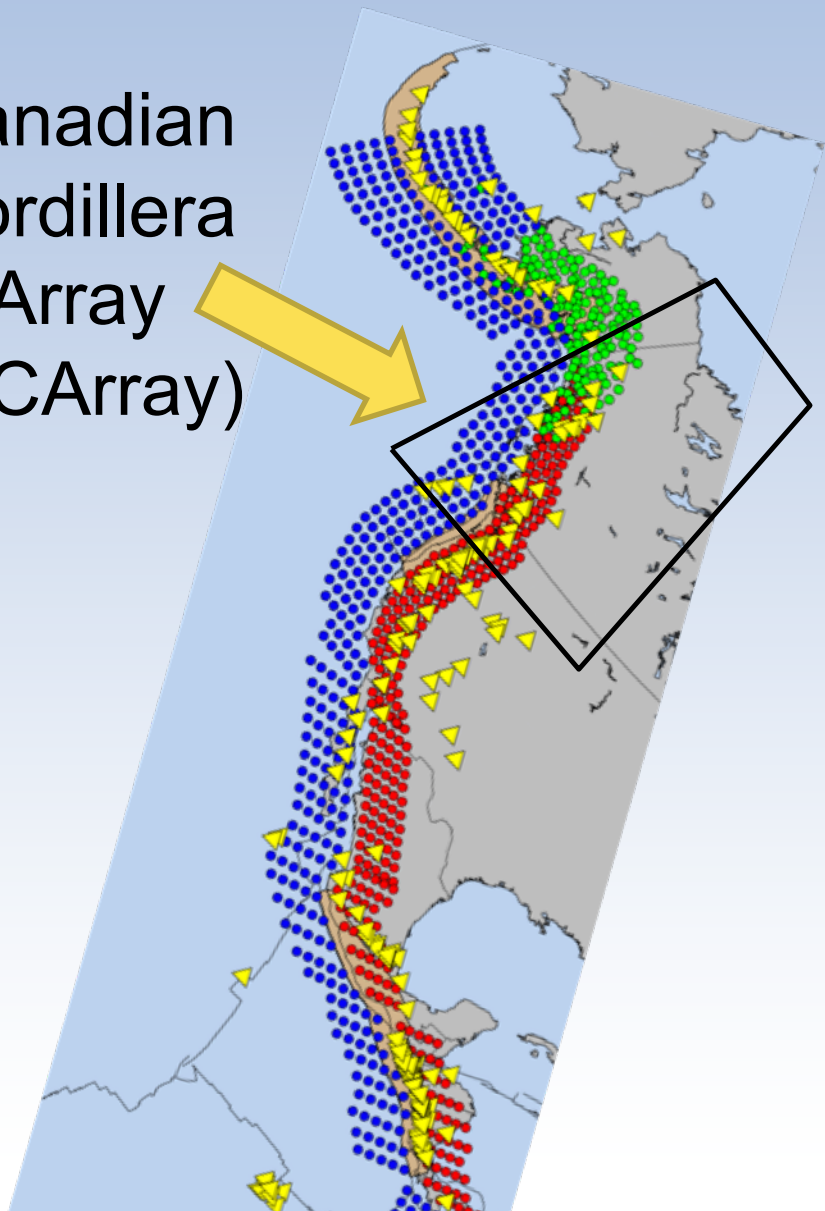


Map courtesy S. Azevedo and R. Busby.

Subduction Zone Observatory

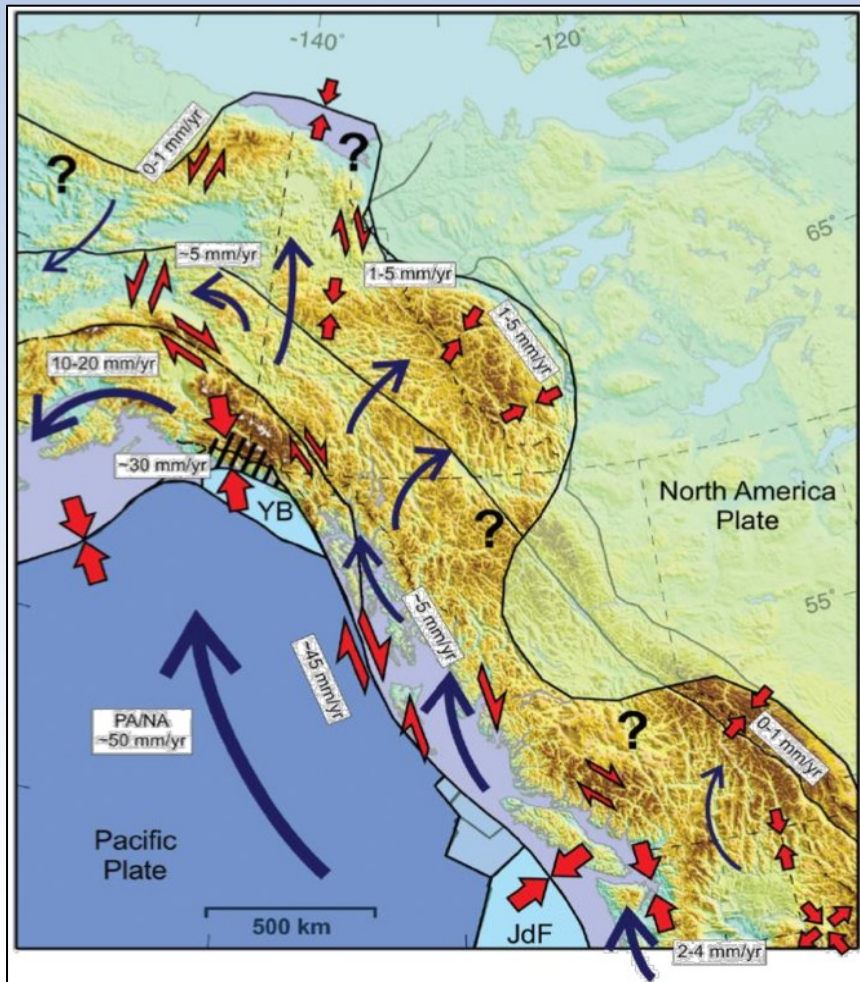


Canadian
Cordillera
Array
(CCArray)



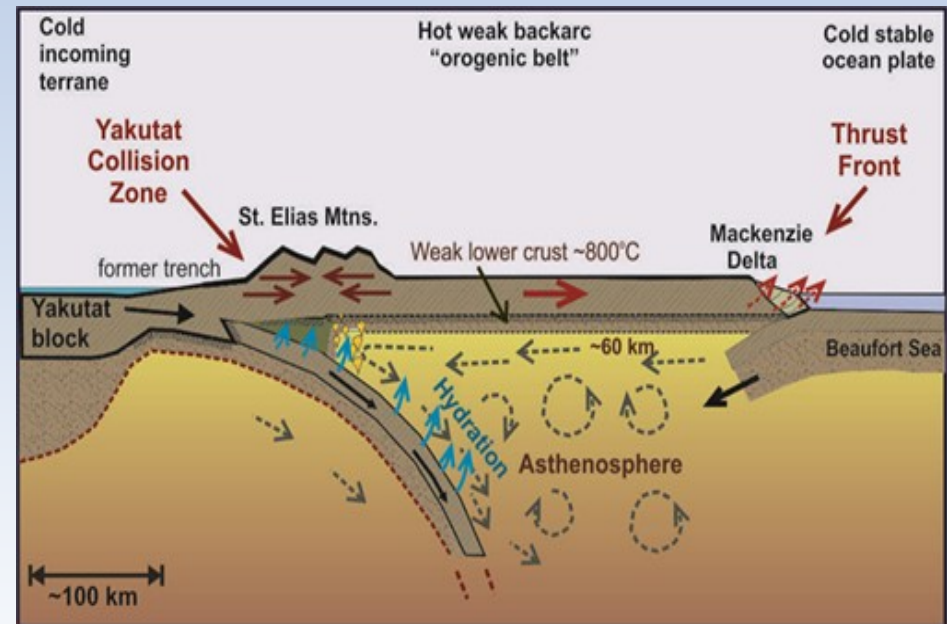
(From IRIS Workshop June 2016;
EarthsCAN brainstorming workshops
Calgary/Ottawa Aug. 2016;
SZO Workshop Sept. 2016)

“Mini Himalayas” Yakutat Block



(Mazzotti et al 2008)

Orogenic Float Model

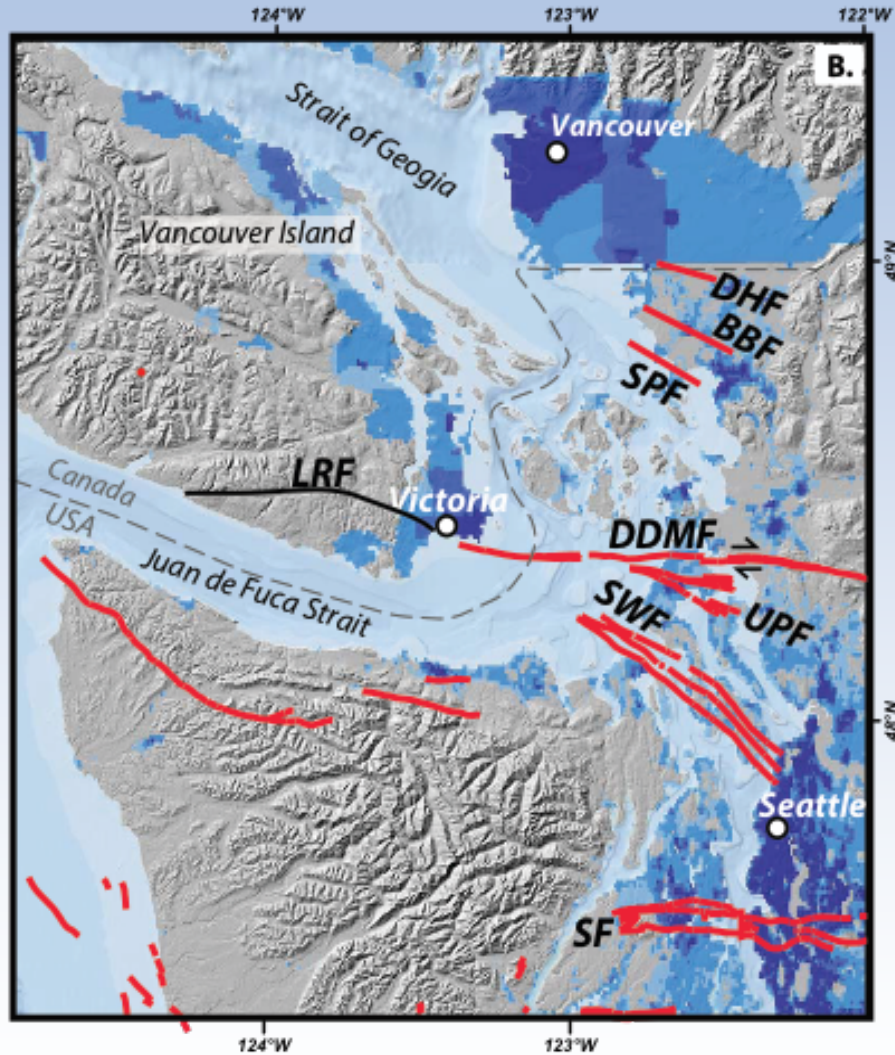


(Hyndman & Mazzotti 2002)

Missing Active Faults??

First White Paper – Cascadia Forearc active fault

(Amos (WWU), Harrington (McGill), Kirkpatrick (McGill), Leonard (UVic), Levson (UVic), Liu (McGill), Morrell (UVic), Regalla (Boston U) , Rowe (McGill); Morrell et al GSA Today 2016)



Red – active crustal faults

No previous active faults proven in Canada

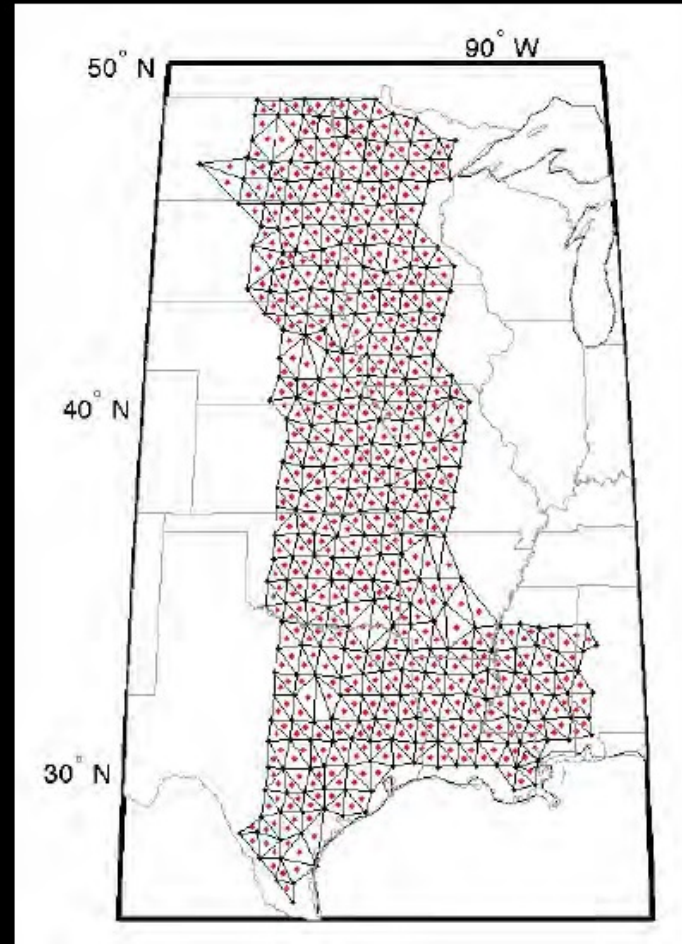
Recent lidar, field work, & paleoseismic trenching
→ large (M6-7) late Quaternary Eq on Leech River Fault

Proposed:
Expand lidar, seismic, GPS
→ fieldwork, trenching
→ ID other active crustal faults in western (and NW) Canada

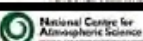
Consider the TA as a massive collection of arrays

Use Delauney triangulation
to define 580 triads

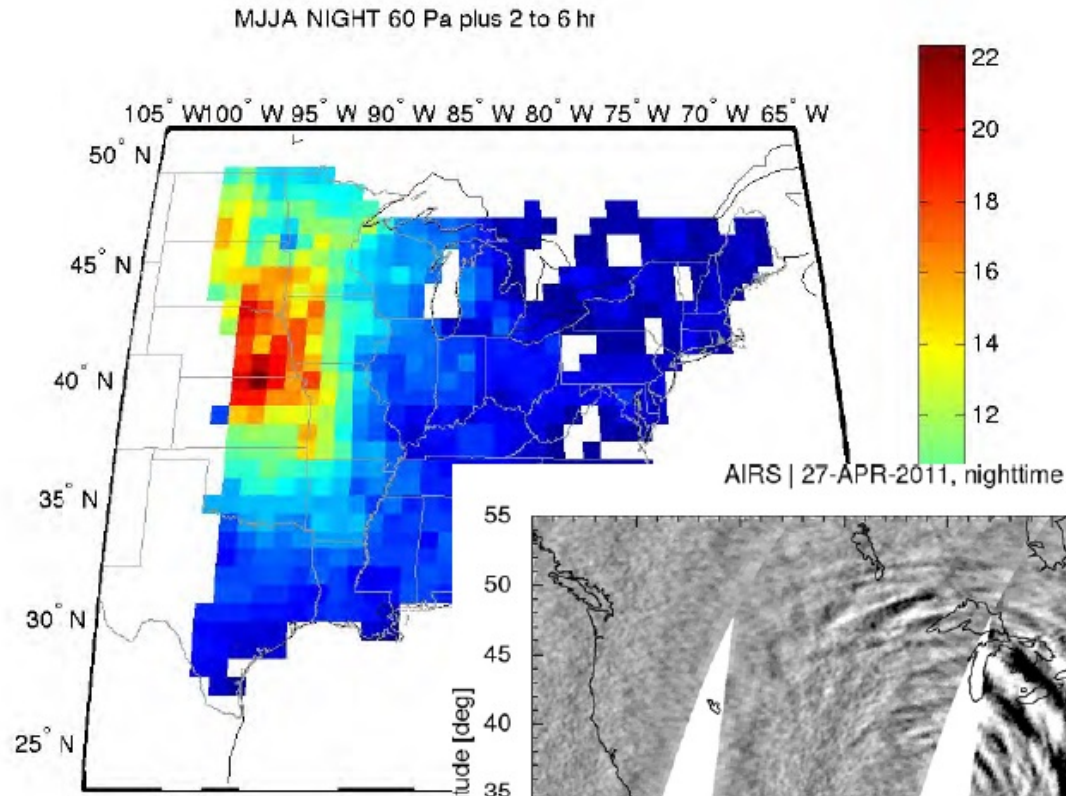
Modelling atmospheric
gravity waves
(see de Groot-Hedlin &
Hedlin posters)



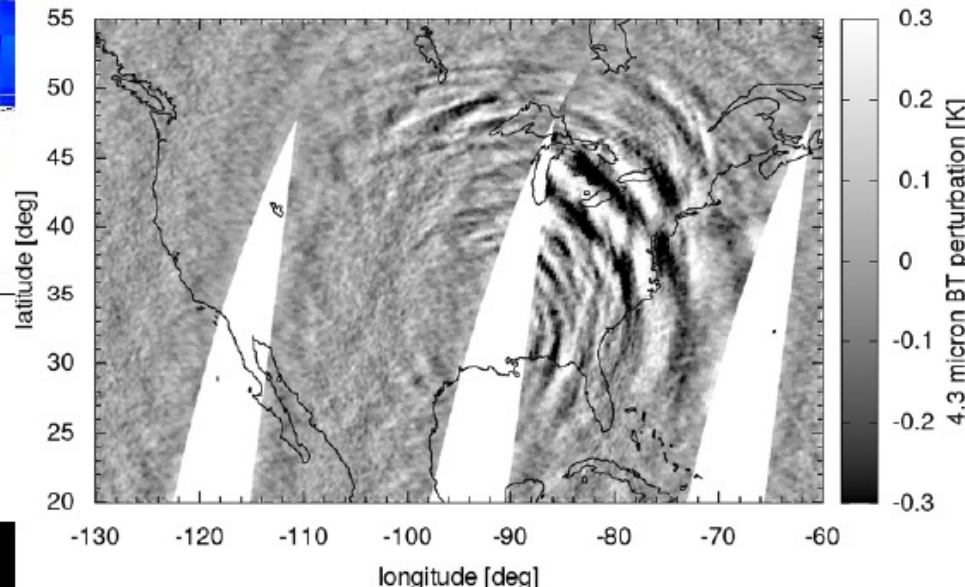
de Groot-Hedlin, Hedlin and Walker, 2013



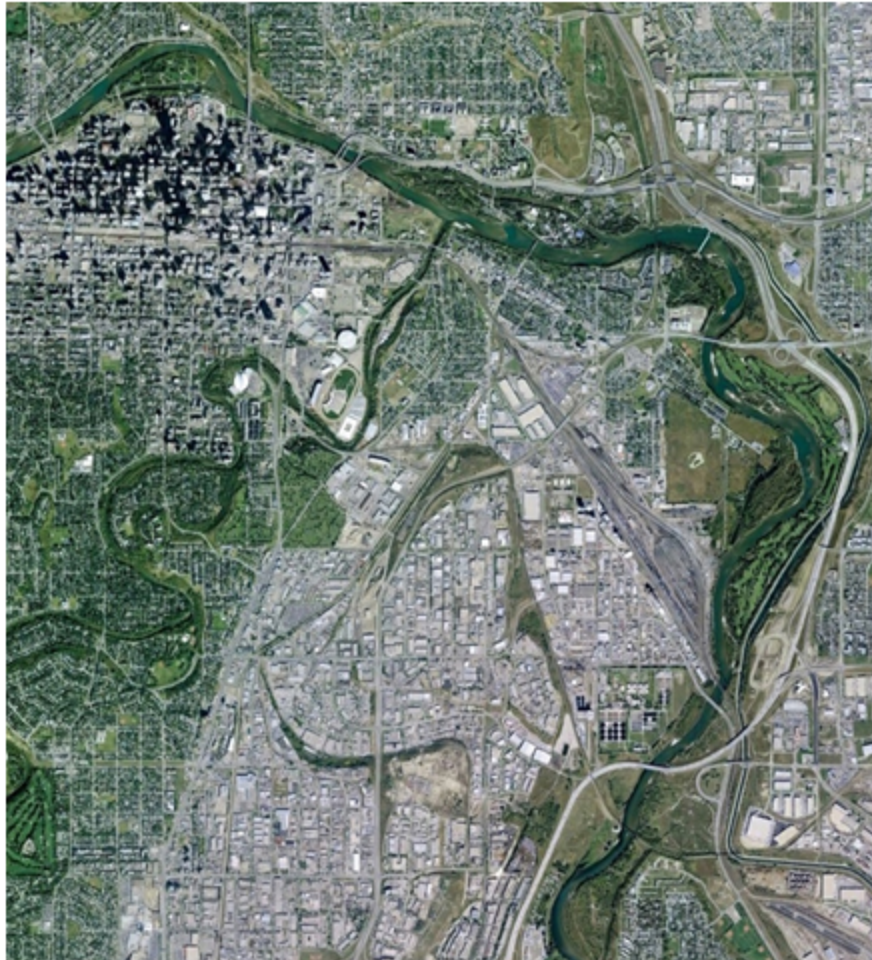
May-August: 2010-2014



**Next stage for improving predictive
Component of Numerical Weather Modelling**



Calgary Pre-Flood/Post-Flood Comparison



Before flood: Google Earth Image
September 2008



After flood: NASA/ISERV Image
June 22, 2013

This image was taken by ISERV-- a new NASA-developed testbed camera onboard the International Space Station.



CC-Net (Pilot for CCArray)

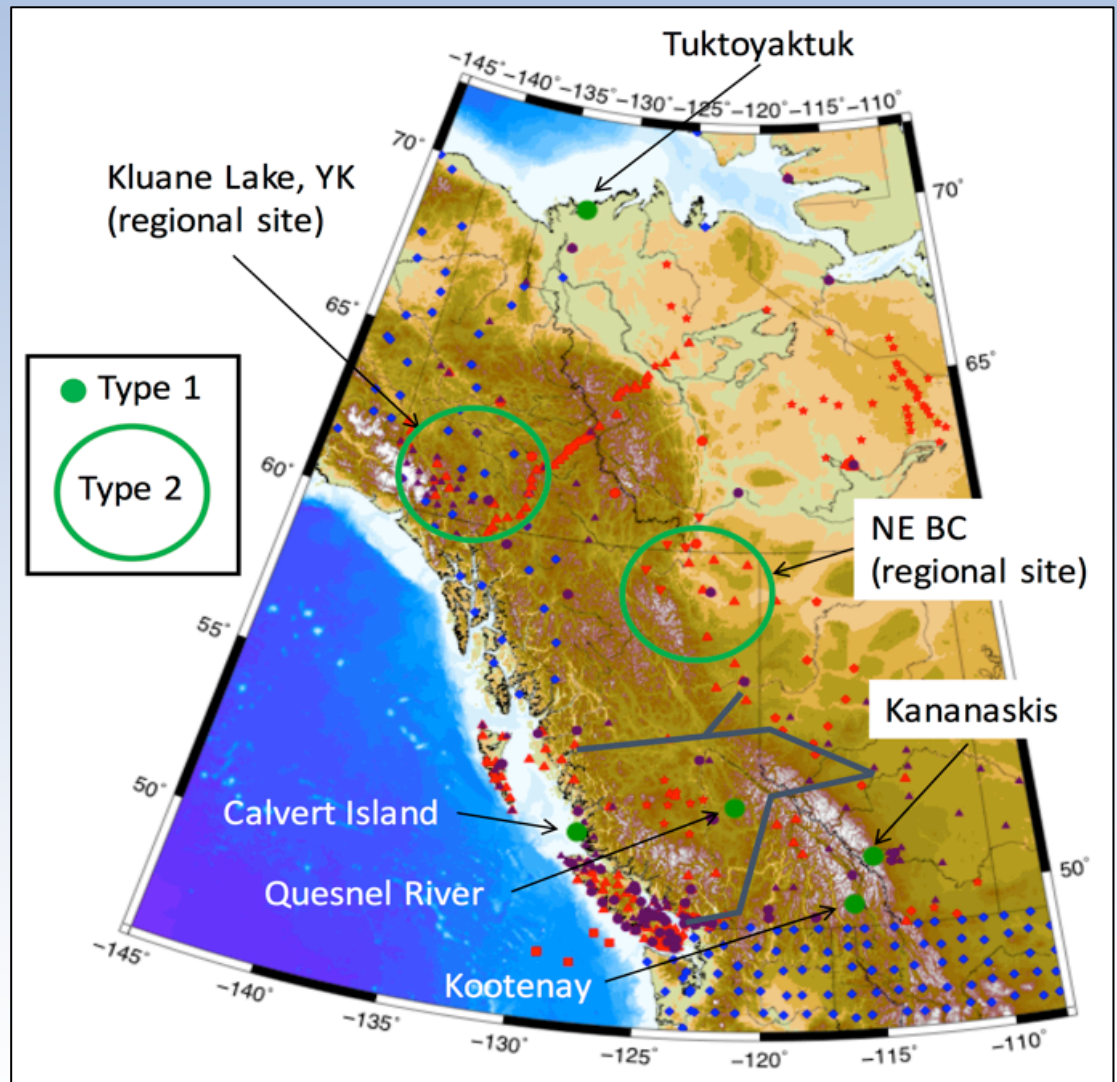
CC-NET (pilot phase):

NSERC – LOI Submitted

- Create a new national research network, with Canadian and international partners
- Establish a set of pilot sites
- Commence collaborative research within 4 themes that are linked to the NSERC strategic target areas
- Create a scalable management structure

Represents a start to build upon for future larger funding

Develop protocols needed for stations to support multiple sensors



Summer 2017 – Calvert Island



1st Type I site – Calvert Island

-Hakai Institute

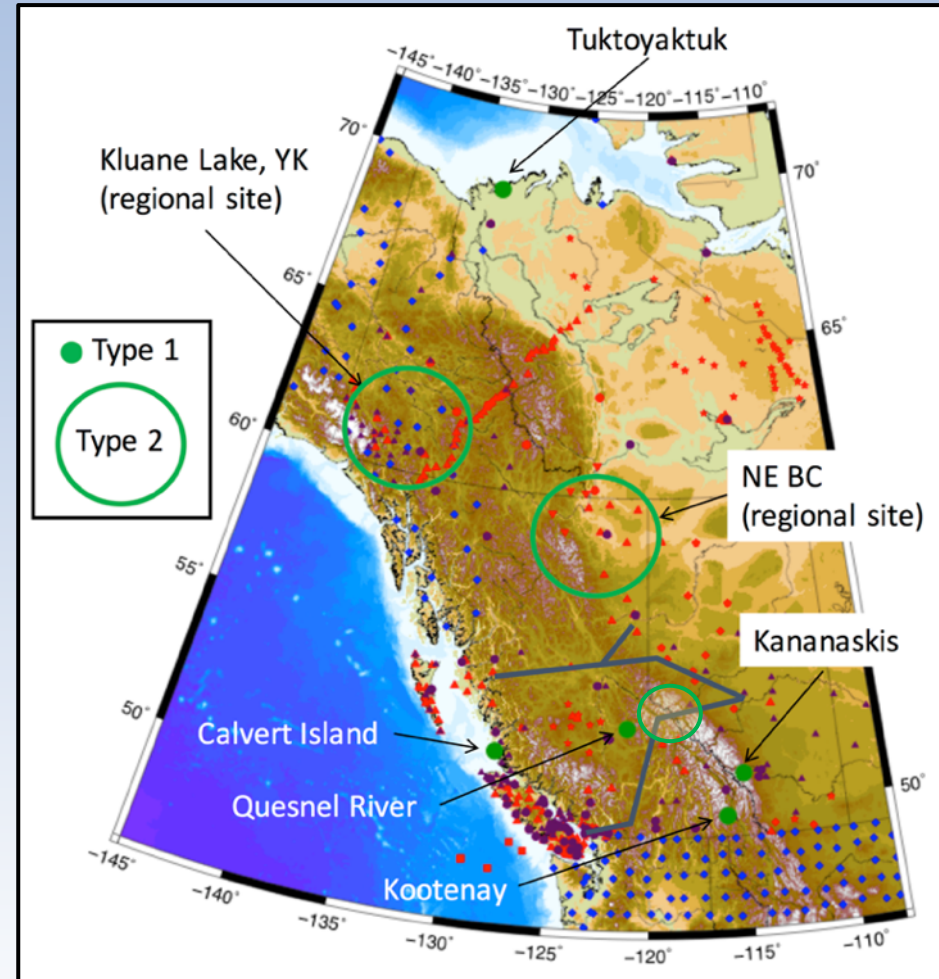
-seed funds from UofC

1st Type II site (?) – Valemount

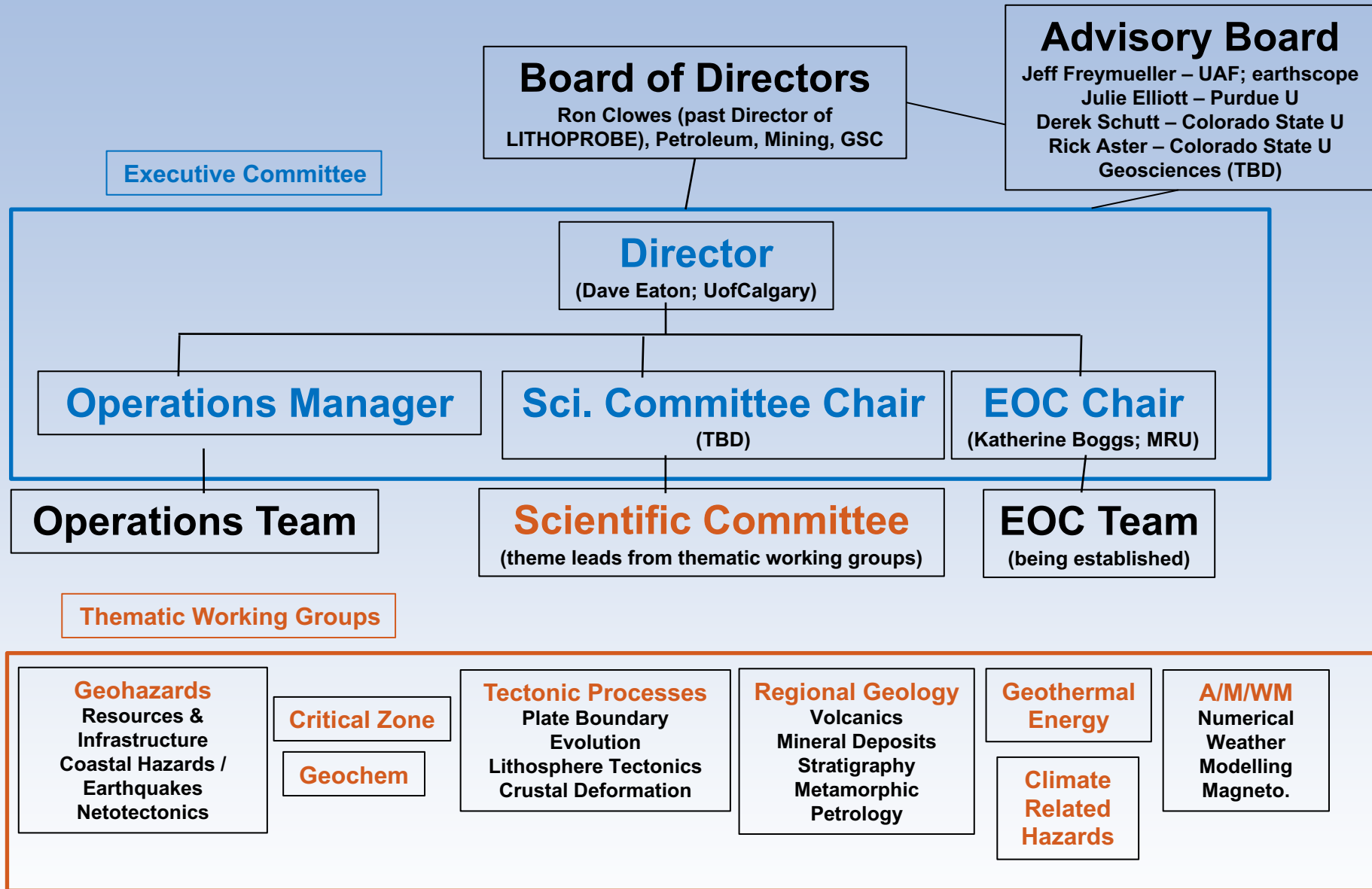
-linked to geothermal E

Other Type II sites – AINA Kluane Lake, NE BC

Sponsorship – Borealis Geopower, Geoscience BC, BC Hydro



CCArray Proposed Organizational Structure



Recent Progress

- 1st townhall April 2017
- website launched last Friday
- strategic plan in progress



The screenshot shows the website for the Canadian Cordillera Array (CCArray). The header features a large image of a snowy mountain range with the text "Canadian Cordillera Array" and "CCARRAY" below it. A dark navigation bar contains the following links: Home, About, Scientific Themes (with a dropdown arrow), Education, Outreach & Communication, News, Related Projects (with a dropdown arrow), Resources, and Links.

CCArray Virtual Townhall Meeting

by reism 📅 May 5, 2017 ⌚ 10:04 am 💬 Leave a comment 🏷️ Uncategorized

On April 26, 2017 the CCArray scientific community held a virtual townhall meeting to review the current status of the project. Notes from the meeting are available here: [CCArray_Townhall_April2017](#)



NATURAL RESOURCES CANADA - INVENTIVE BY NATURE

Global Navigation Satellite System (GNSS) workshop for Canadian Cordillera Array (CCArray)

March 20 & 21, 2017
Pacific Geoscience Centre



Natural Resources
Canada

Ressources naturelles
Canada

Canada

Goal of workshop

- Define high-level scientific targets and geographical regions for a densified GNSS network in western Canada as part of the Canadian Cordillera Array (CCArray) initiative, capitalizing on anticipated domestic and international opportunities for instrumentation, operations, and funding.
- About 40 participants
- One day of talks, ½ day of discussion and breakout groups
- Main output is map of proposed densified GNSS network, accompanying science rationale.



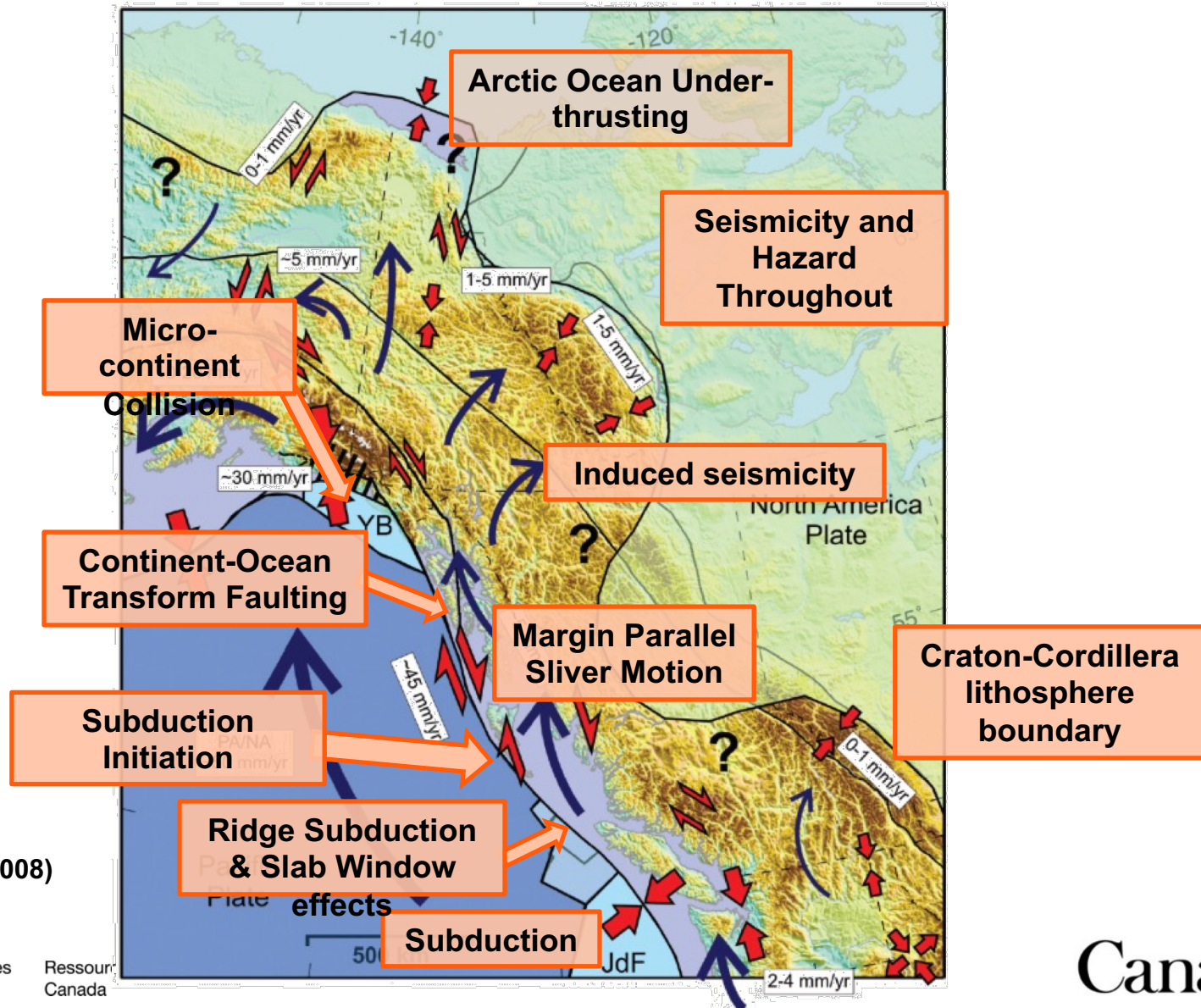
Outline

- (Some) science goals
- Present GNSS network
- Workshop outcomes
 - suggested network densification
 - additional science community engagement
 - Programmatic considerations, looking forward



Plate Interactions, Tectonics, and Earthquakes

Crustal Motion Measured by GNSS



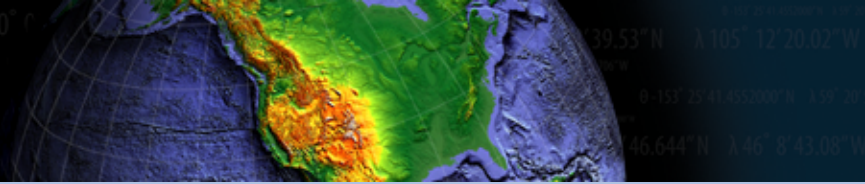
(Mazzotti et al., 2008)



Natural Resources
Canada

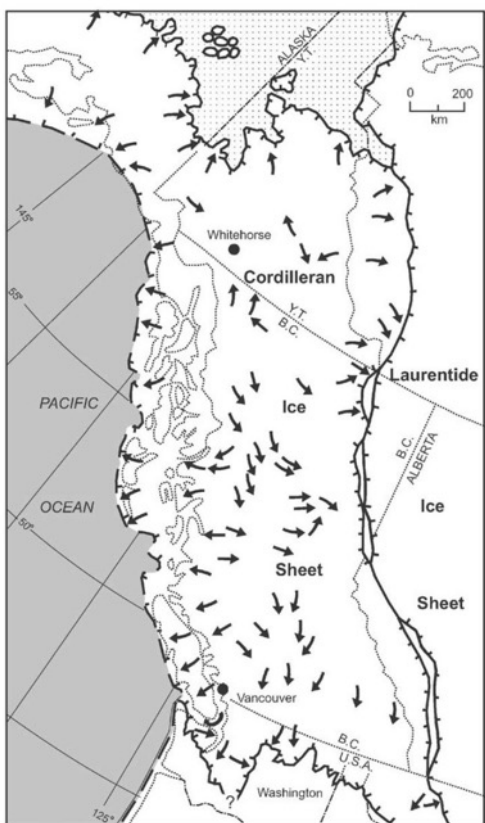
Ressour
Canada

Canada



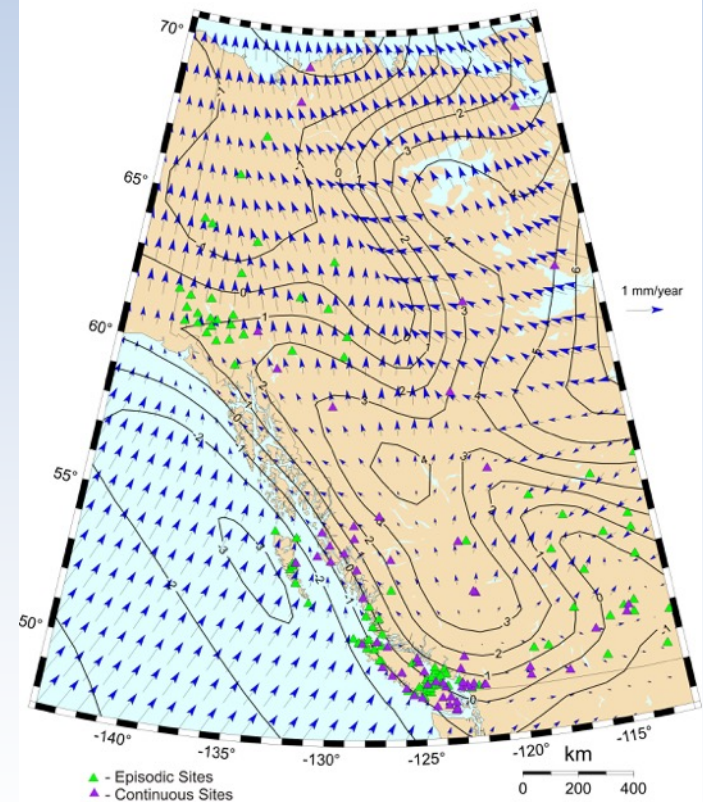
Postglacial Rebound – aka Glacial Isostatic Adjustment

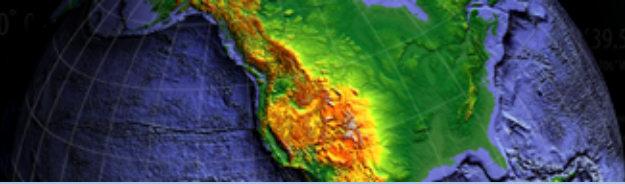
Cordilleran Ice Sheet



Uplift rates generally
measured in mm/yr,
horizontal motions
~1 mm/yr

ICE-6G

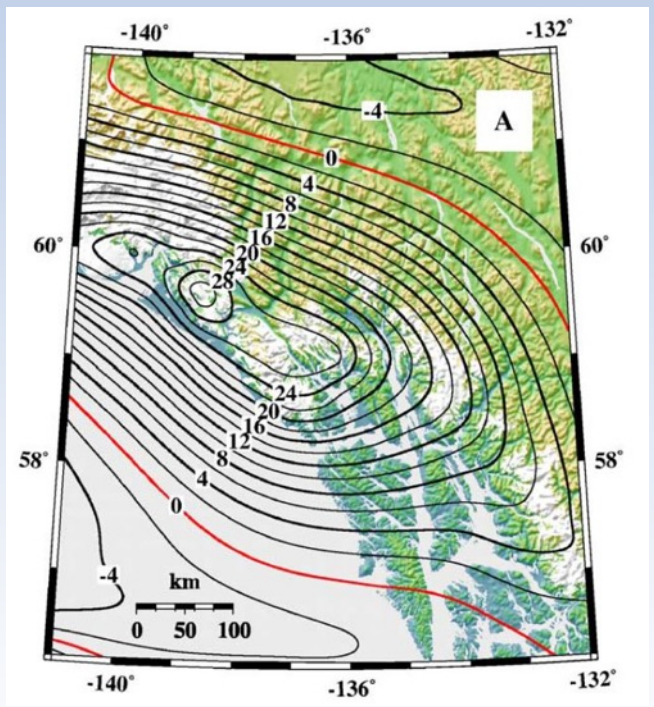




59.53°N 105° 12' 20.02" W
 6.157 25.41 65.50000 1.00 20.000000
 46.644°N 146° 0' 43.08" W

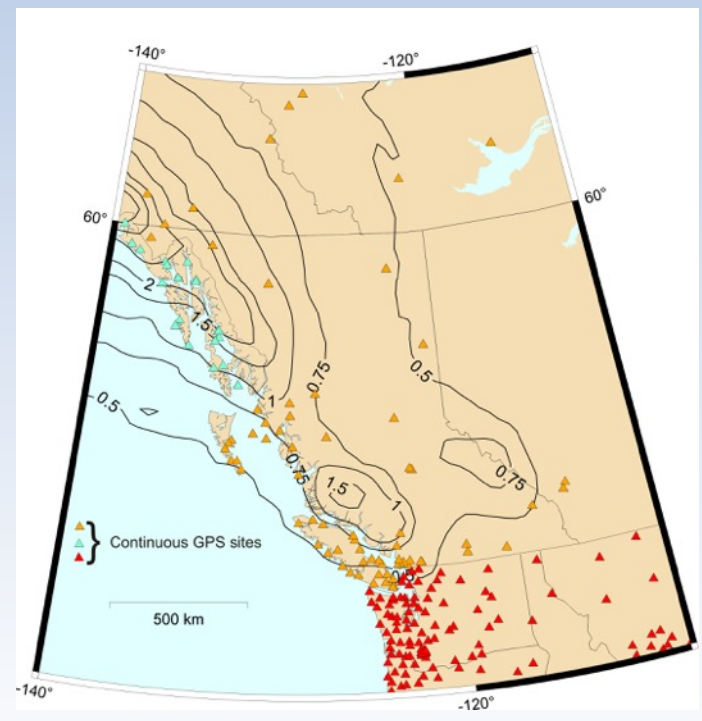
Postglacial Rebound – aka Glacial Isostatic Adjustment

Alaska, response to Neoglacial fluctuations



Larsen et al., 2005

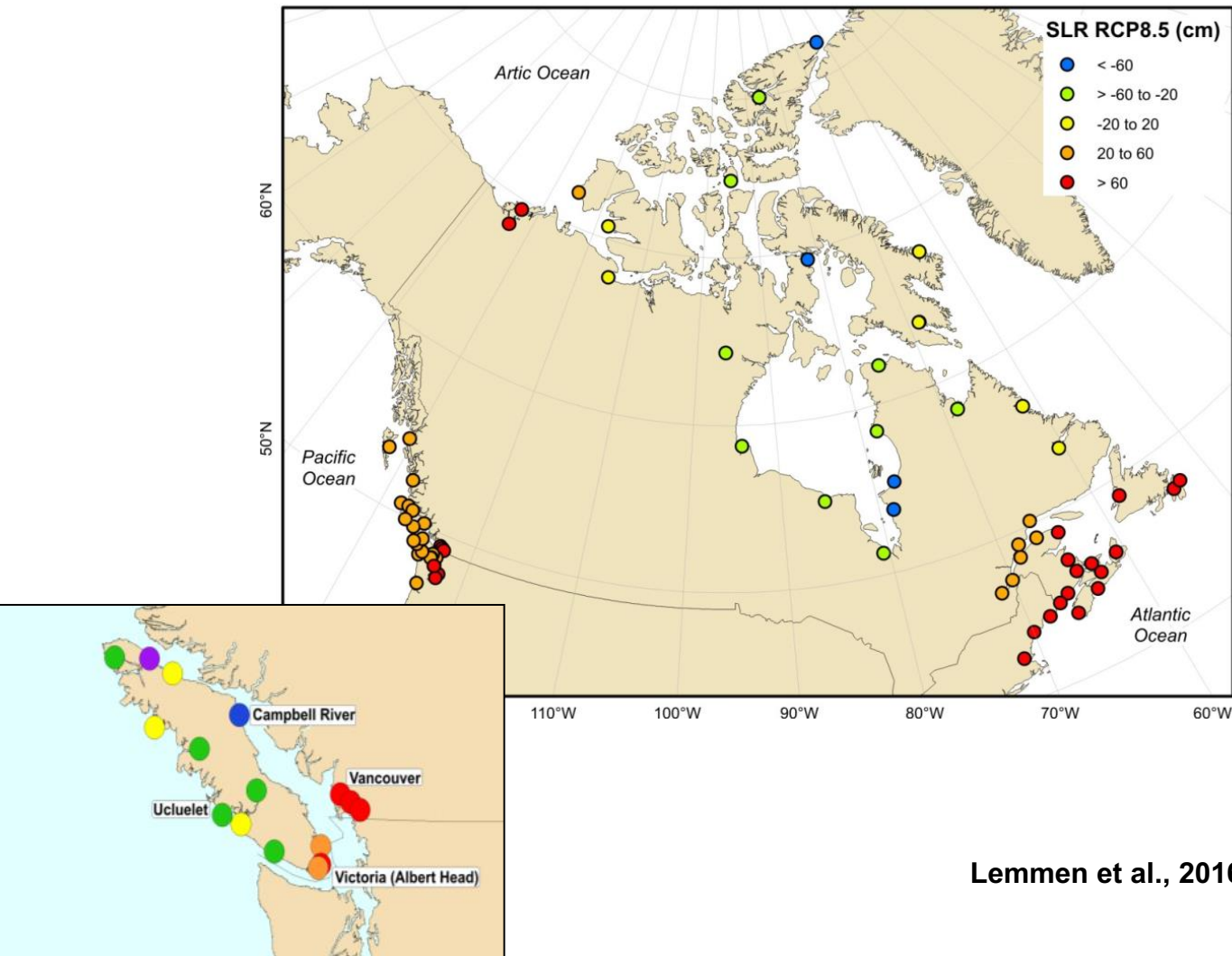
BC and Alaska, elastic response to present-day ice mass change



T James, based on G. Cogley's compilation.

Models require ice load history and assumed Earth structure and rheology

Sea-level projection for high-emissions scenario at 2100



Vertical crustal motion exerts a dominant control on relative sea-level projections

Shows all sites for which projections are provided.

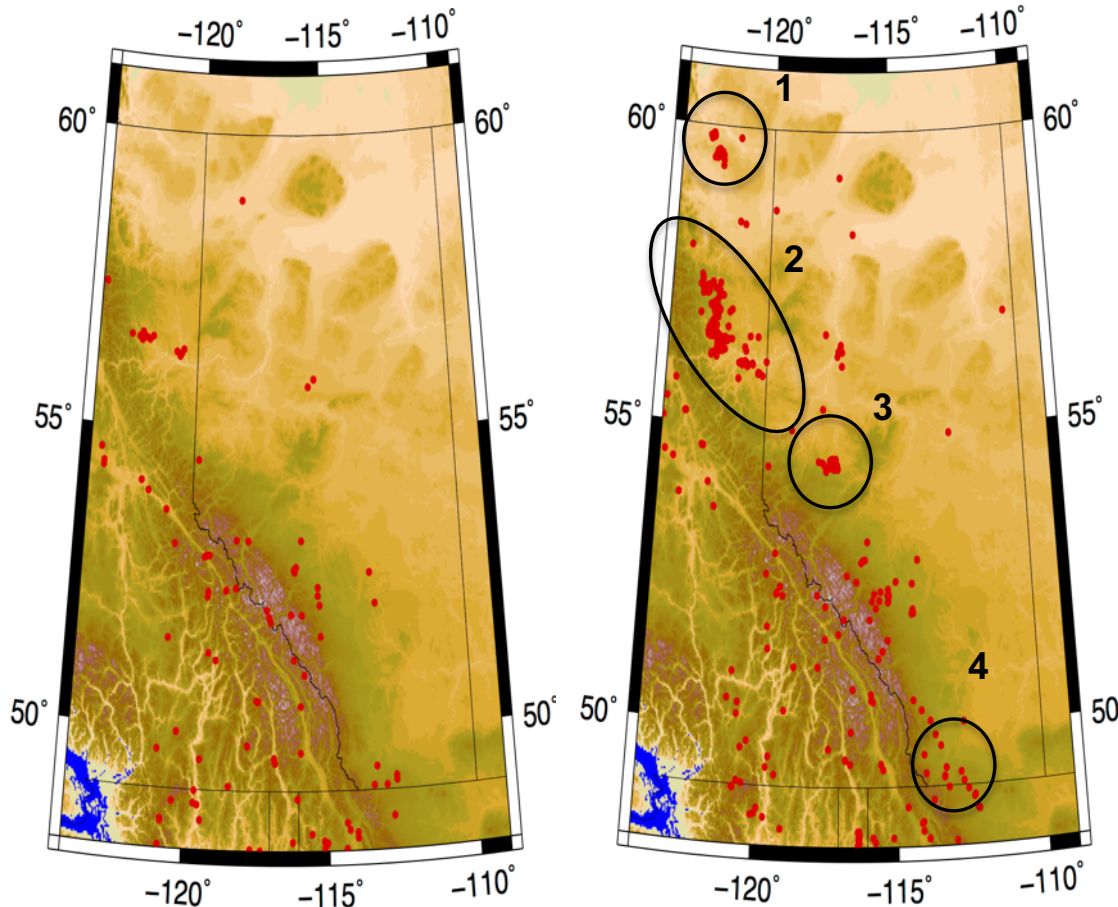
James et al., 2014; 2015
Lemmen et al., 2016 “Canada’s Marine Coasts in A Changing Climate”



Western Canada interior - seismicity

2001-2008 ($N = 97$)

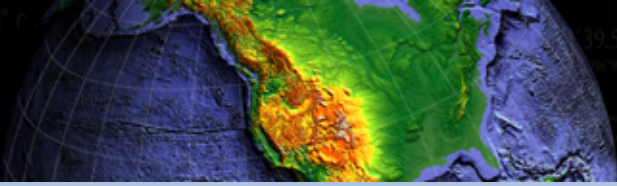
2009-2016 ($N = 429$) *Inferred link to hydraulic fracturing*



1. Horn River basin (BC Oil and Gas Commission, 2012)
2. Montney (BC Oil and Gas Commission, 2013)
3. Duvernay (Schultz et al., GRL, 2015)
4. Alberta Bakken (Schultz et al., BSSA, 2014)

Slide courtesy D. Eaton, U. Calgary

Source: inducedseismicity.ca/catalogues/ $M_L \geq 2.5$ (probable quarry blasts removed)



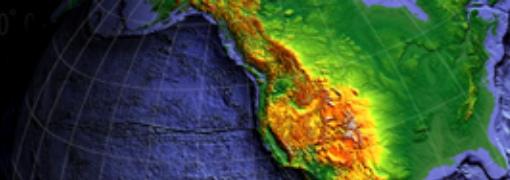
Other Potential Topics

- Ionospheric, tropospheric studies
- Hydrological loading
- Snow, water levels, vegetation, soil moisture monitoring (PBO H2O web site)

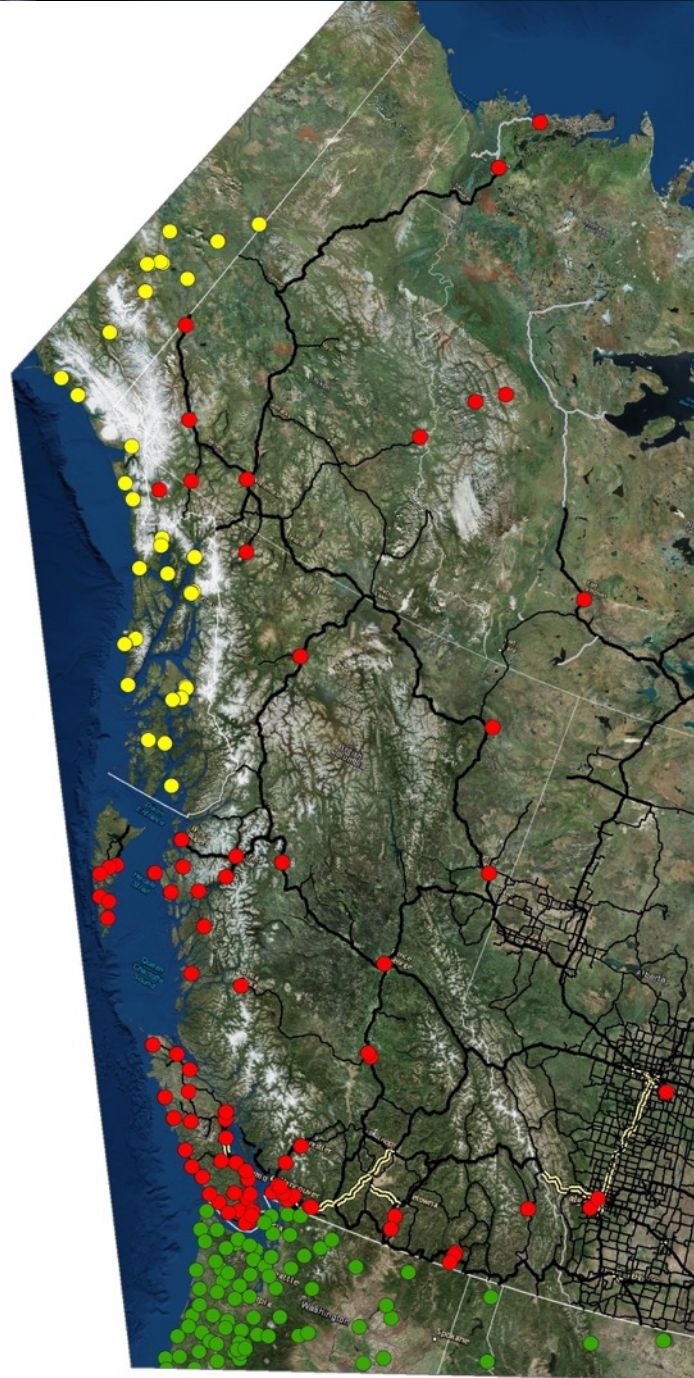
Outline

- (Some) science goals
- **Present GNSS network**
- Workshop outcomes
 - suggested network densification
 - additional science community engagement
 - Programmatic considerations, looking forward





Western Canada and Adjacent US continuous GNSS Stations



- Canada Continuous
- Alaska Continuous
- Continental US Continuous

Earthquake Early Warning Augmentation of Network

Ocean Networks Canada – Province of BC (EMBC) – Natural Resources Canada

- **Network:** Installation by March 31, 2019
- Development of Earthquake Early Warning system targeting Cascadia Subduction Zone events;
- Installation of strong-motion and GNSS instruments, offshore component focussing on seismic instrumentation;

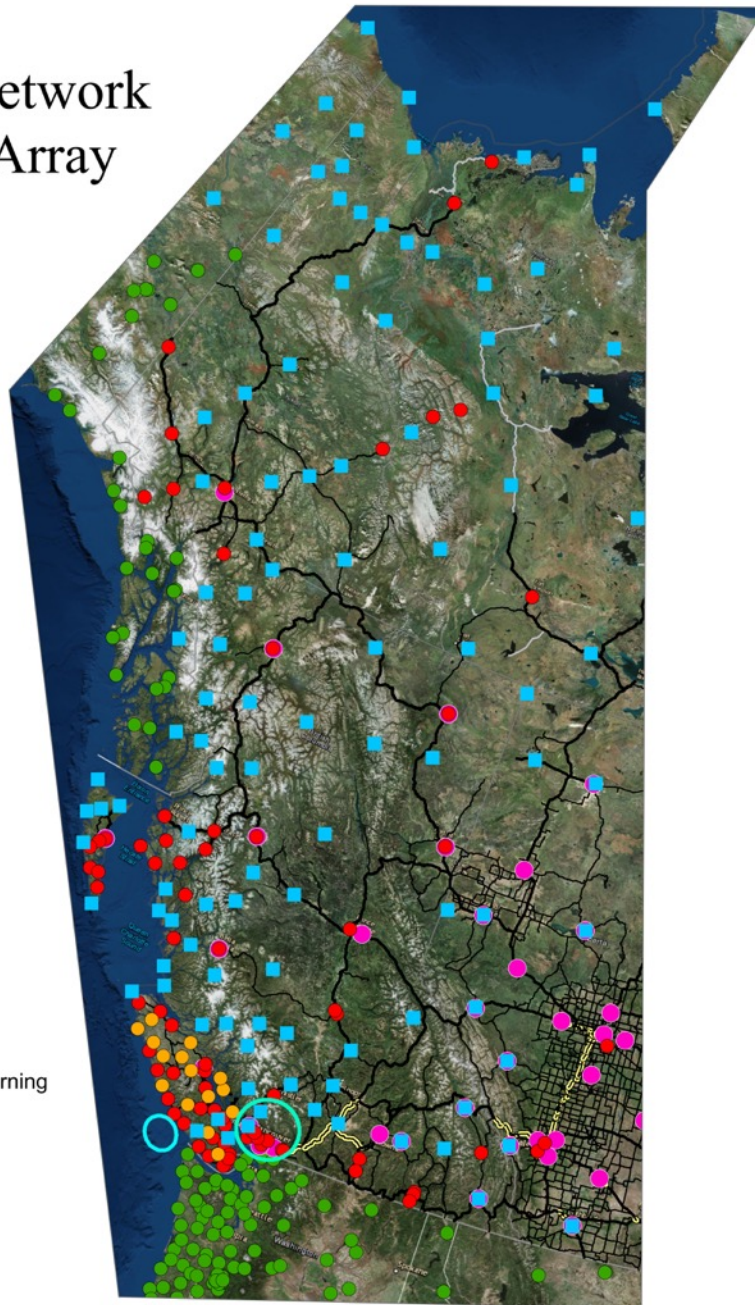


Outline

- (Some) science goals
- Present GNSS network
- **Workshop outcomes**
 - suggested network densification
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GNSS Network for CCArray



Legend

- New
- Earthquake Early Warning
- Canada Continuous
- CBN
- US Continuous

0 95 190 380 570 760 950
Kilometers

Key Elements

- Substantial interest (at workshop) in active tectonics and earthquake hazard
- Fill in gaps in interior for distributed strain
- Sites to detect present-day (and past) mountain glacier change
- Regional strain field to better understand induced seismicity
- Opportunities offered by technological developments – e.g., acoustic (sub-sea) GPS
- About 100 new sites + circles

Key elements (continued)

- GNSS distribution is ‘pure’ – generated solely based on the requirements to answer questions (mainly kinematic), but how does it relate to provisional seismic instrument distribution?
 - Co-locate sites, where feasible, price out costs
- With regard to GNSS, need to more fully engage with various communities:
 - Meteorology – numerical weather modelling
 - Glaciology
 - Volcanology
 - Mt. Meager, Garibaldi volcanic belt, Anahim VB
 - Induced seismicity
 - Regional/local targets (and INSAR/repeat LIDAR)



Key Elements (continued)

- Need to consider supporting geoscience to answer questions, e.g.,
 - INSAR/LiDAR for local/regional ground deformation;
 - surface exposure dating for glaciological history for GIA modeling;
 - glacier monitoring;

Programmatic

- Devote substantial resources to outreach and education (15-30%?)
- Be aware of data management (esp. meta-data) requirements

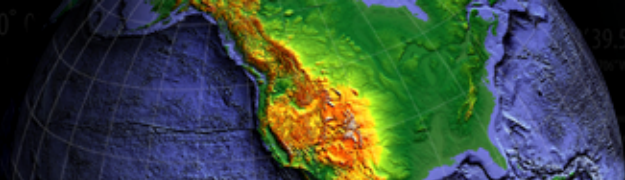
- Workshop report is pending



Next Steps for CCArray

- Monthly teleconferences; regular updates
- June – 2017 GSA Rocky Mtn Section Mtg in Calgary at MRU
- August – First Annual CCArray Meeting – Compose complete submission for NSERC – SPGN grant
- August – install instruments on Calvert Island
- Fall 2017 – write CFI proposal for instrumentation to co-install with seismometers
- December – AGU session
- Spring 2018 – start installing CC-NET instruments

1. Introduce CCArray
2. Advice, lessons learned or suggestions are appreciated!
3. We look forward to collaborations; please talk to us



Thank you!

Questions?