

Glacial Isostatic Adjustment Modelling of the Coast Mountains of British Columbia and Southeastern Alaska



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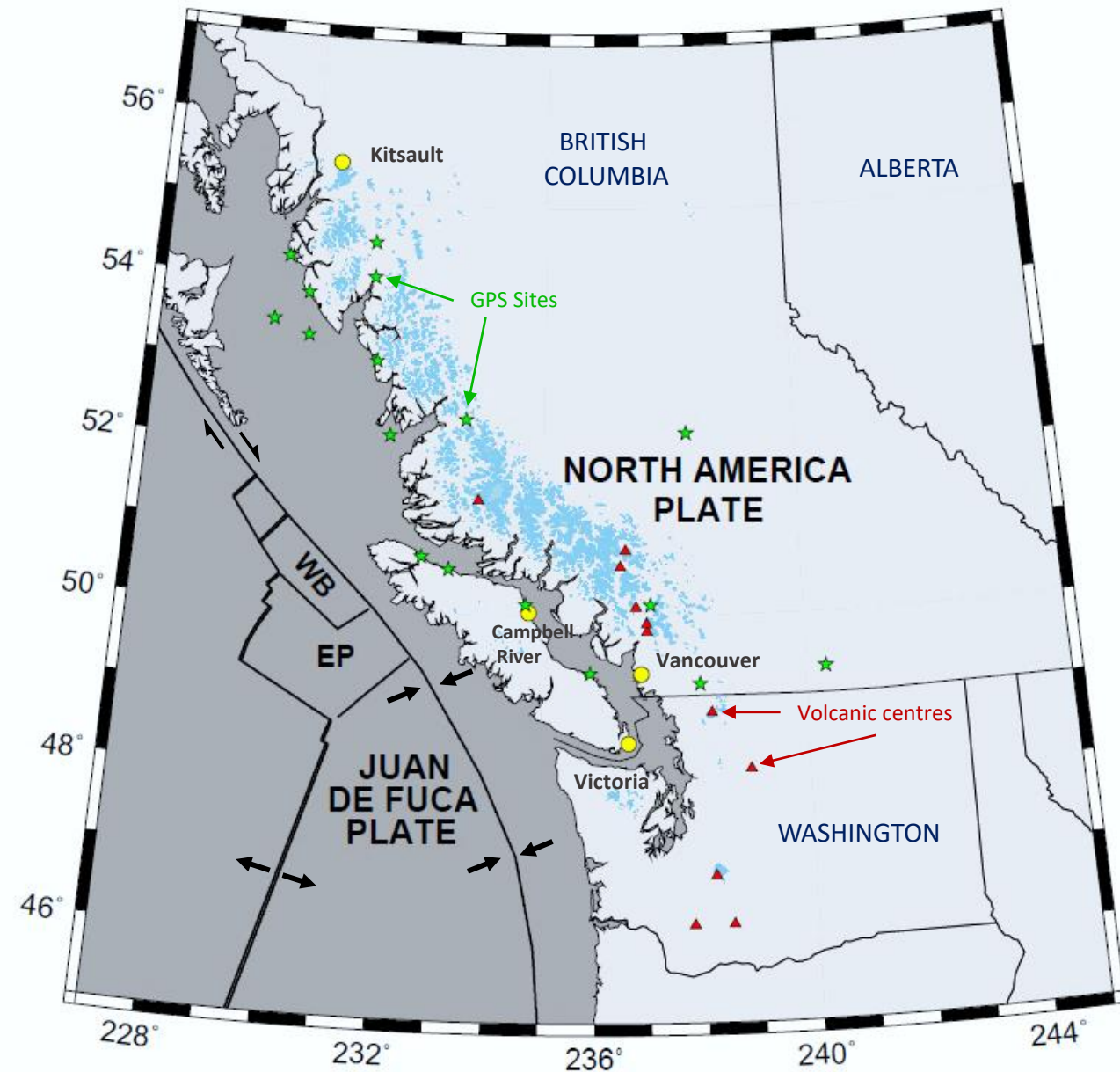


Overview

- Purpose of this study is to find optimal GIA models for recent ice history of the southern Coast Mountains
- Estimate the glacier load history for the central and southern Coast Mountain region, dating back to the Little Ice Age (LIA)
- Compute GIA model results for a range of 2 main model parameters for the load history:
 - Effective elastic lithosphere (EEL) thickness
 - Asthenospheric viscosity
- Compare results to observable uplift rates to determine most likely pair of above parameters
- These results will improve understanding of Earth structure and mantle rheology
- Results will be used to:
 - Improve relative sea level (RSL) models for the coast of BC
 - Separate GIA and tectonic components

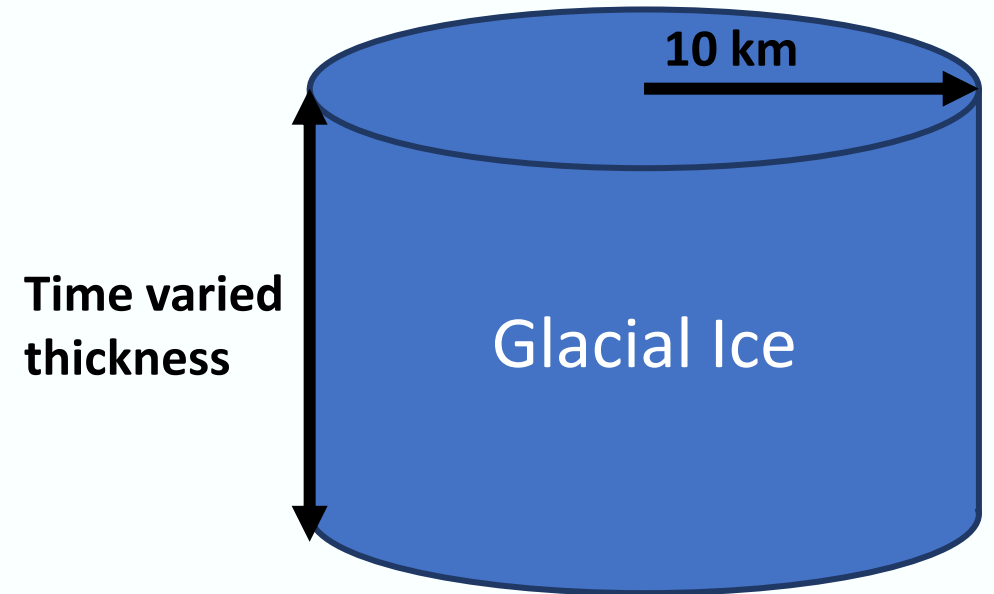
Study Area

- Preliminary model focuses on southern and central portions
- Current ice extent in the Southern and Central Coast Mountains study area, $\sim 10,938 \text{ km}^2$ (Menounos *et al.* 2019, Schiefer *et al.* 2007)
- The area has experienced recent ice mass changes since the Little Ice Age
- Tectonically active region (subduction zone in the south, and a major transform fault adjacent to the northern portion)



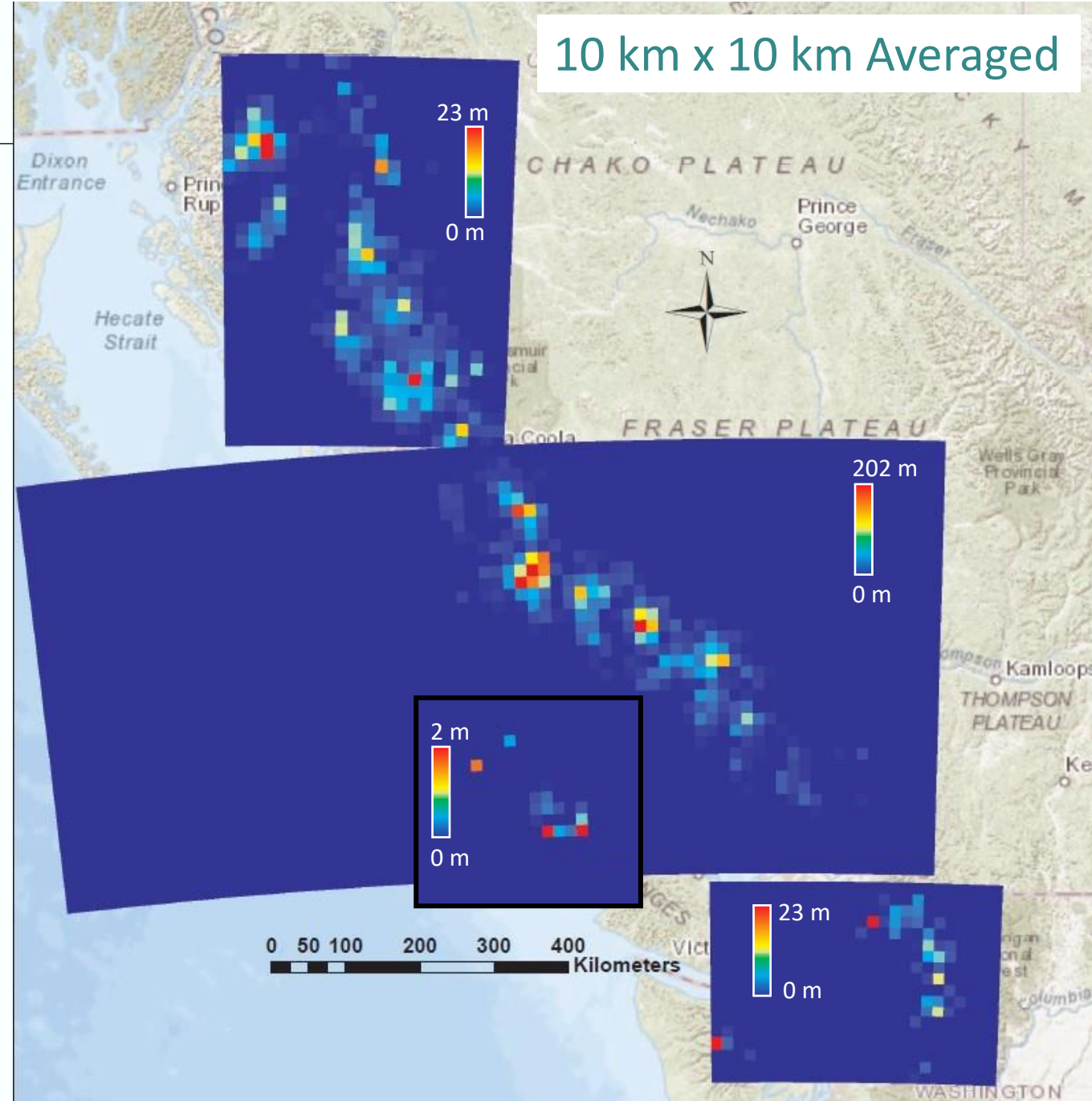
Model Setup

- The GIA model is based on two inputs:
 - The ice loading history spatially distributed as 10 km diameter discs of ice that change in thickness over time
 - Preliminary Reference Earth Model (PREM) where the upper two layers (EEL and asthenosphere) are varied



Ice Thickness

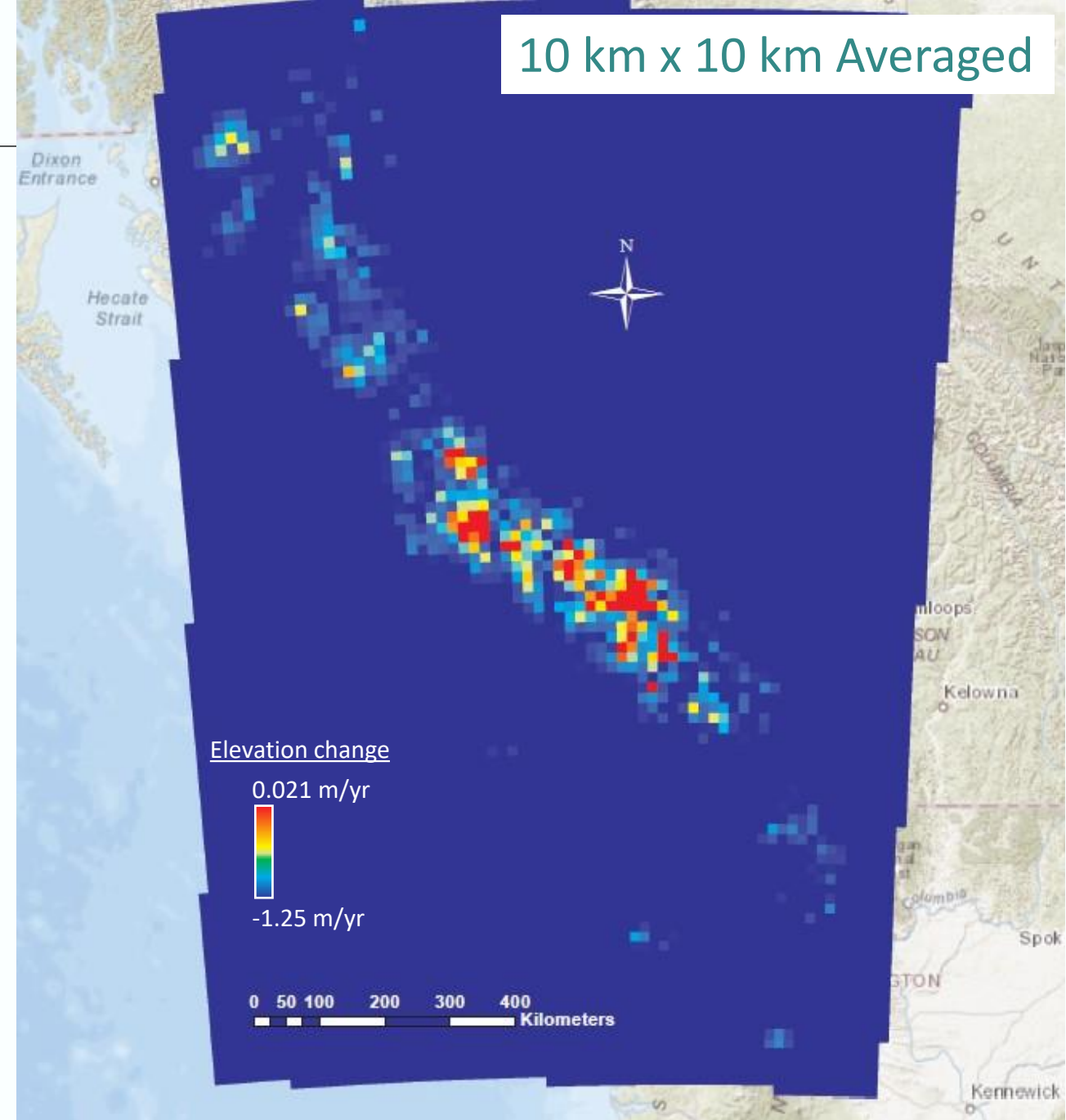
- Present ice thickness map from Glacier Thickness Database (Supplement to Farinotti *et al.* 2019)
- Averaged over a 10 km x 10 km grid



Melt Rates

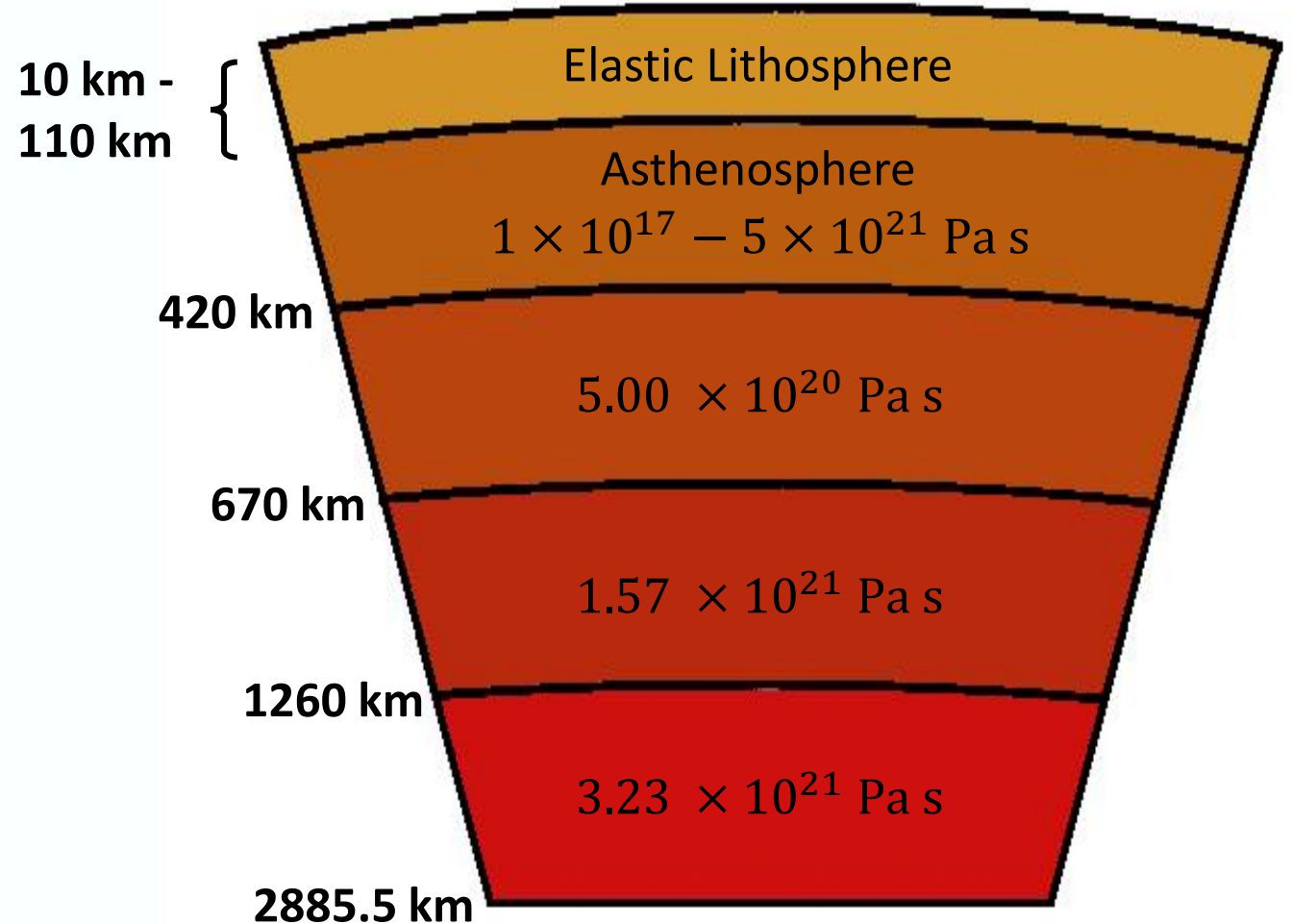
ASTER melt rate data taken from 2000-2019 (Menounos *et al.* 2019)

- Averaged glacier melt rates from 2000-2019 over a 10 km grid
- Average melt rate extrapolated back to LIA (around 300 years before present, Koch *et al.* 2009)



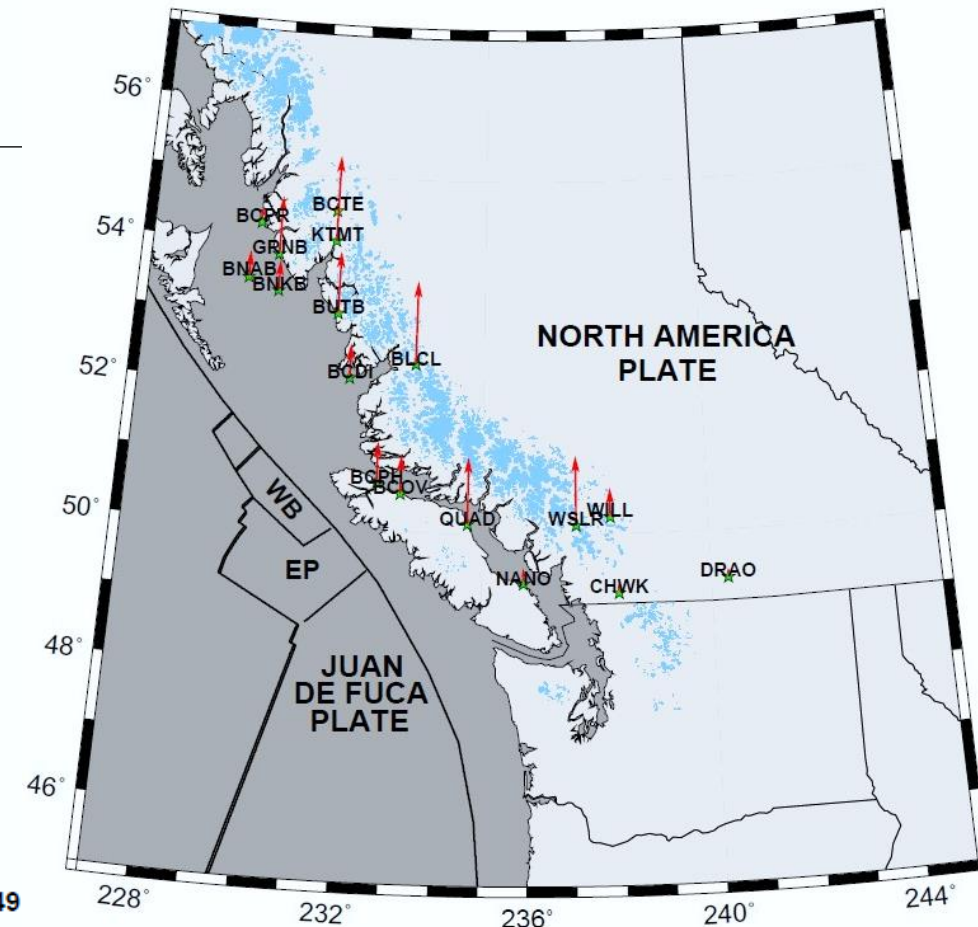
Earth Model

- Preliminary Reference Earth Model (PREM, Dziewonski and Anderson 1981) and VM5a viscosity structure (Peltier *et al.* 2015) below 420 km
- Varied Parameters:
 - EEL thickness from 10 km to 110 km thick
 - Asthenosphere viscosity from 1×10^{17} Pa s to 5×10^{21} Pa s

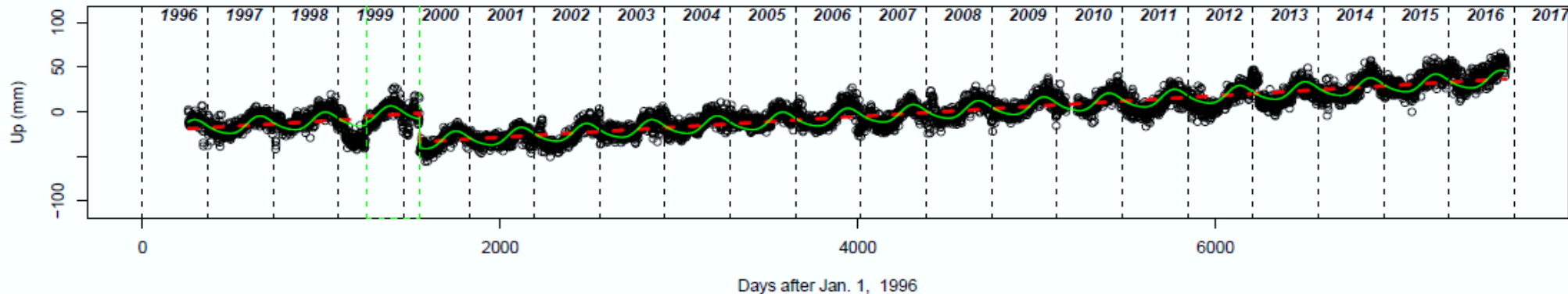


GPS Uplift Rates

- GPS station map and names, used to compare model results for each parameter pair
- Example: Whistler uplift rate (with station maintenance offsets applied 1999 and 2000)

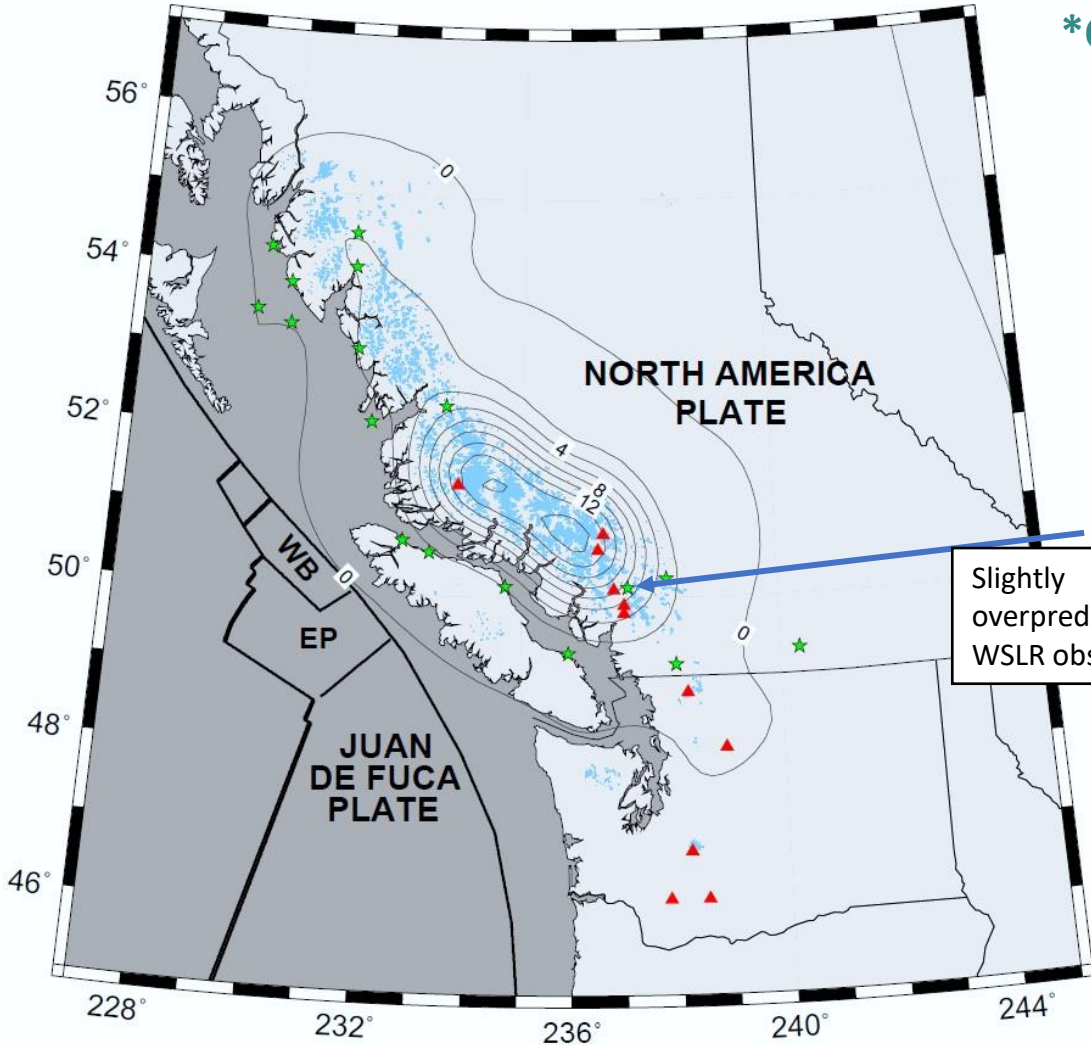


WSLR Up rate: 4.25 ± 0.02 mm/yr, col. error (-0.6): 0.11 ; RMS scatter: 7.49



Results: Varying EEL Thickness

20 km and 1×10^{19} Pa s

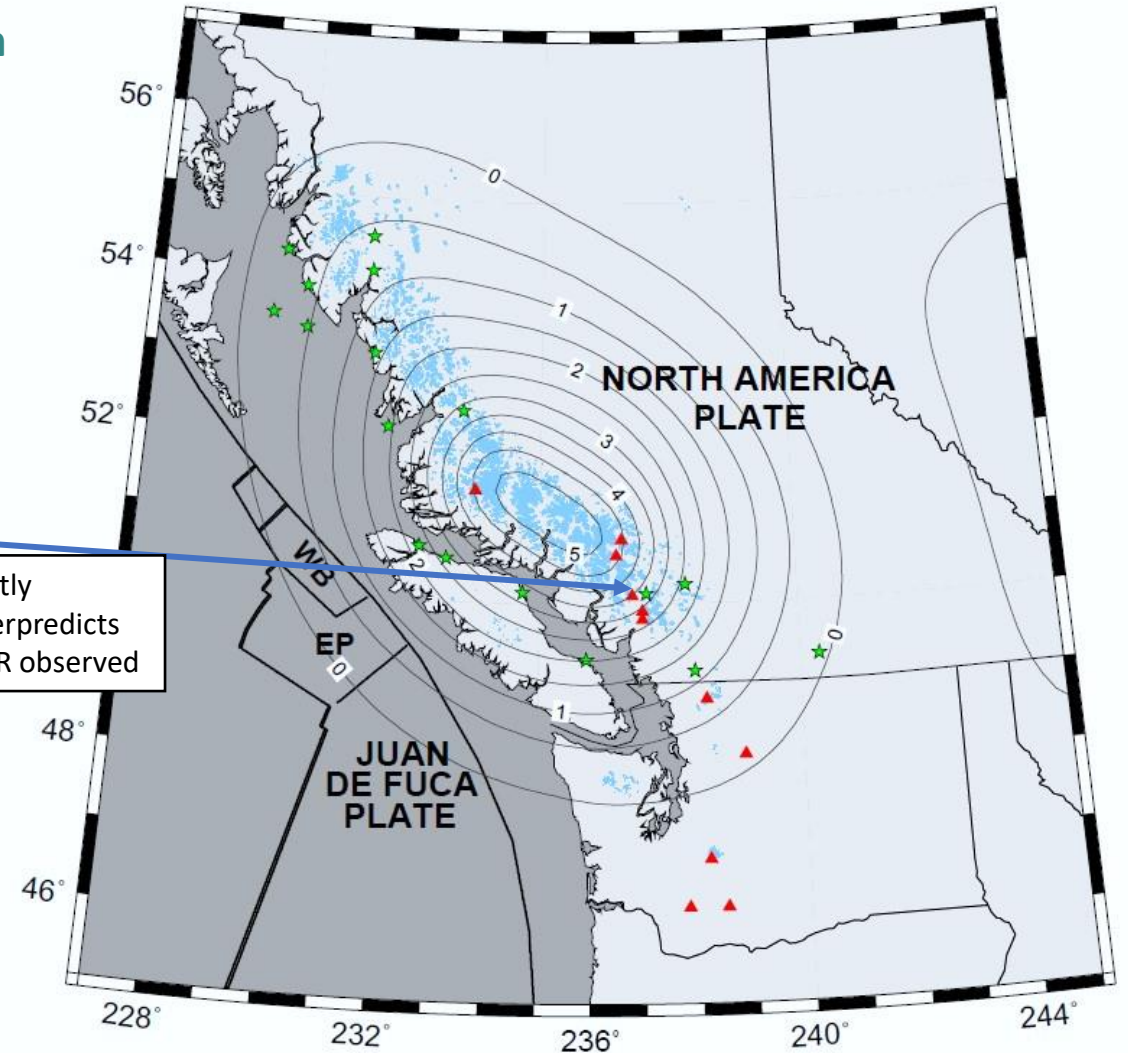


*Contours in
mm/yr

WSLR

Slightly
overpredicts
WSLR observed

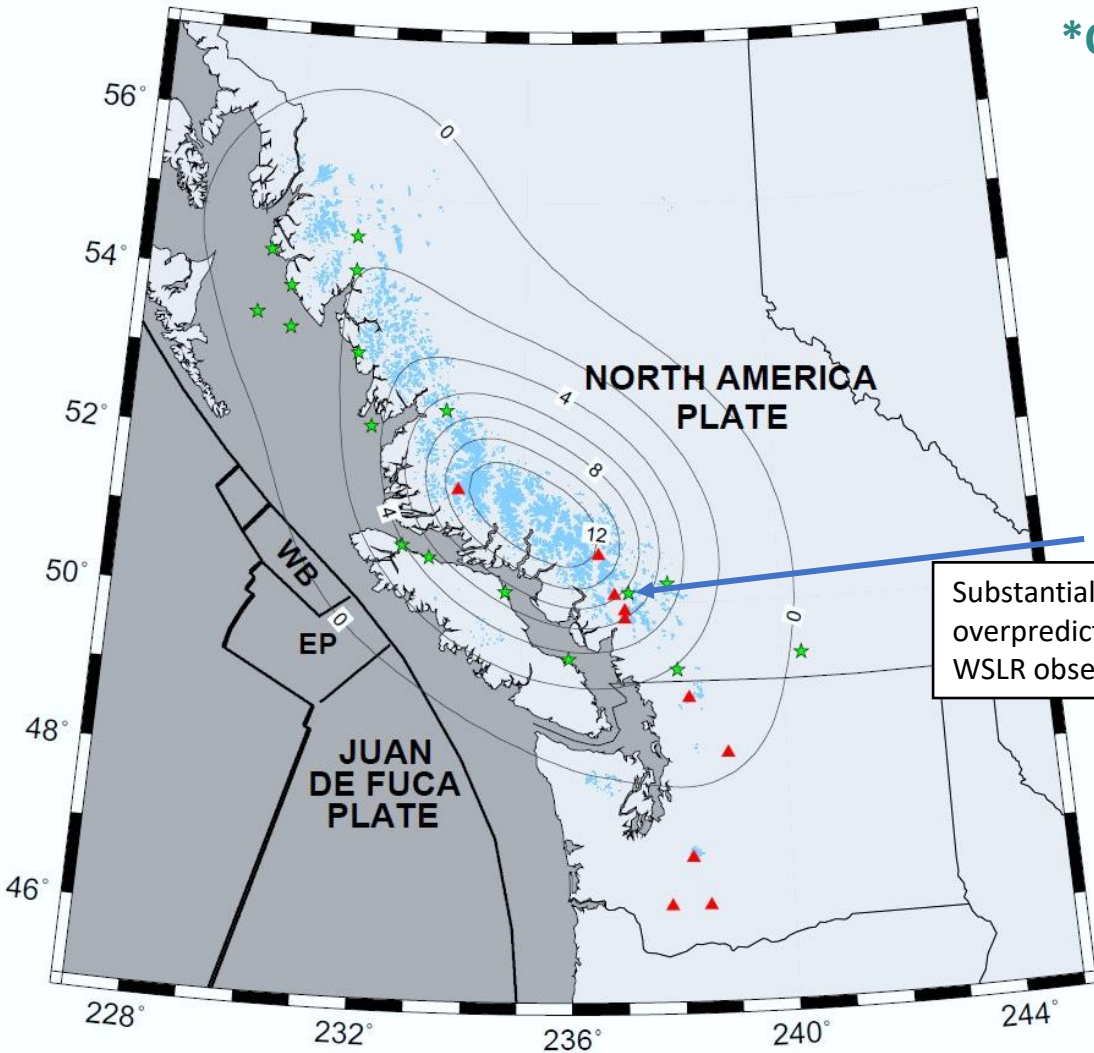
100 km and 1×10^{19} Pa s



Slightly
underpredicts
WSLR observed

Results: Varying Asthenosphere Viscosity

50 km and 1×10^{18} Pa s

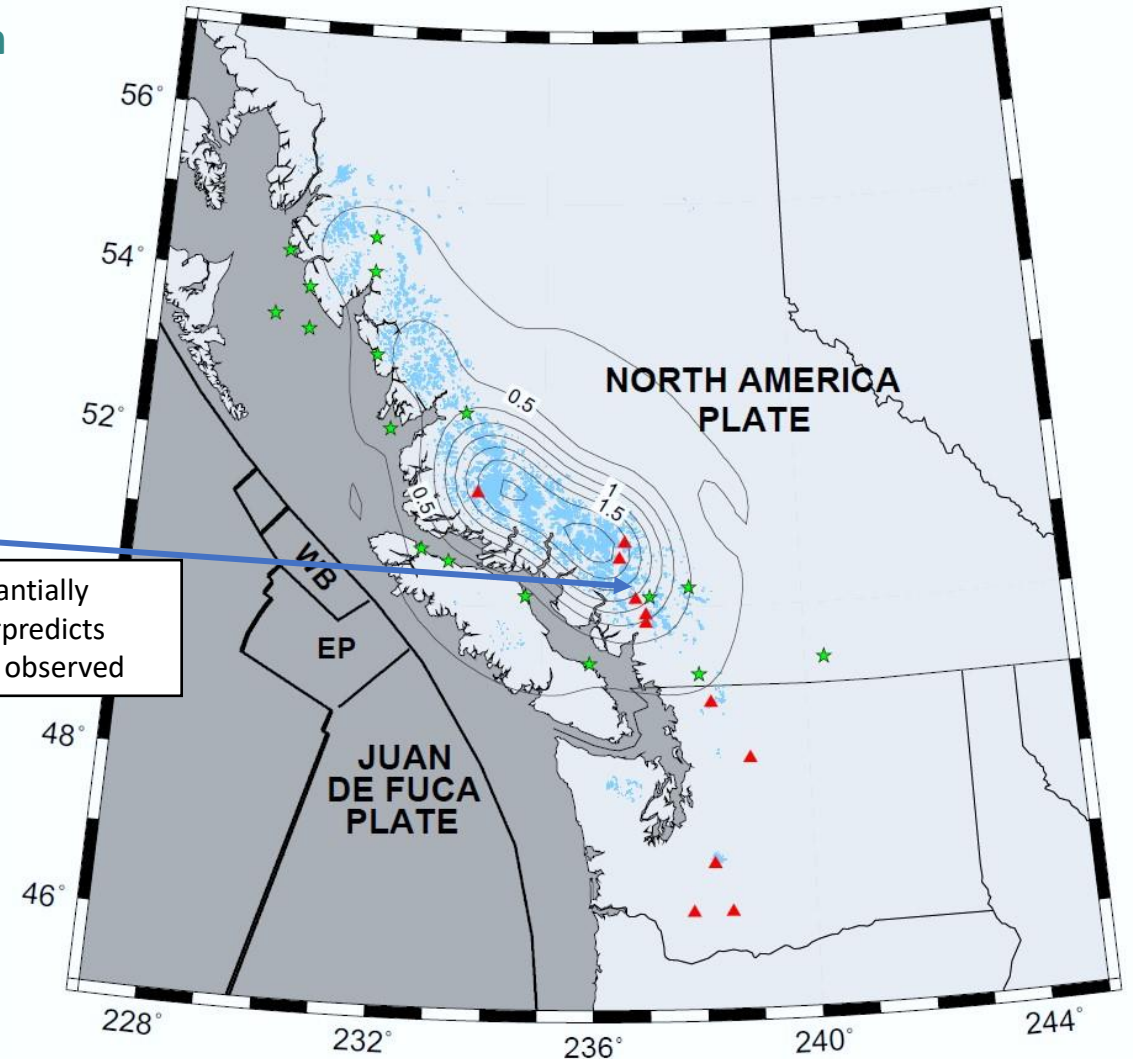


*Contours in mm/yr

WSLR

Substantially overpredicts WSLR observed

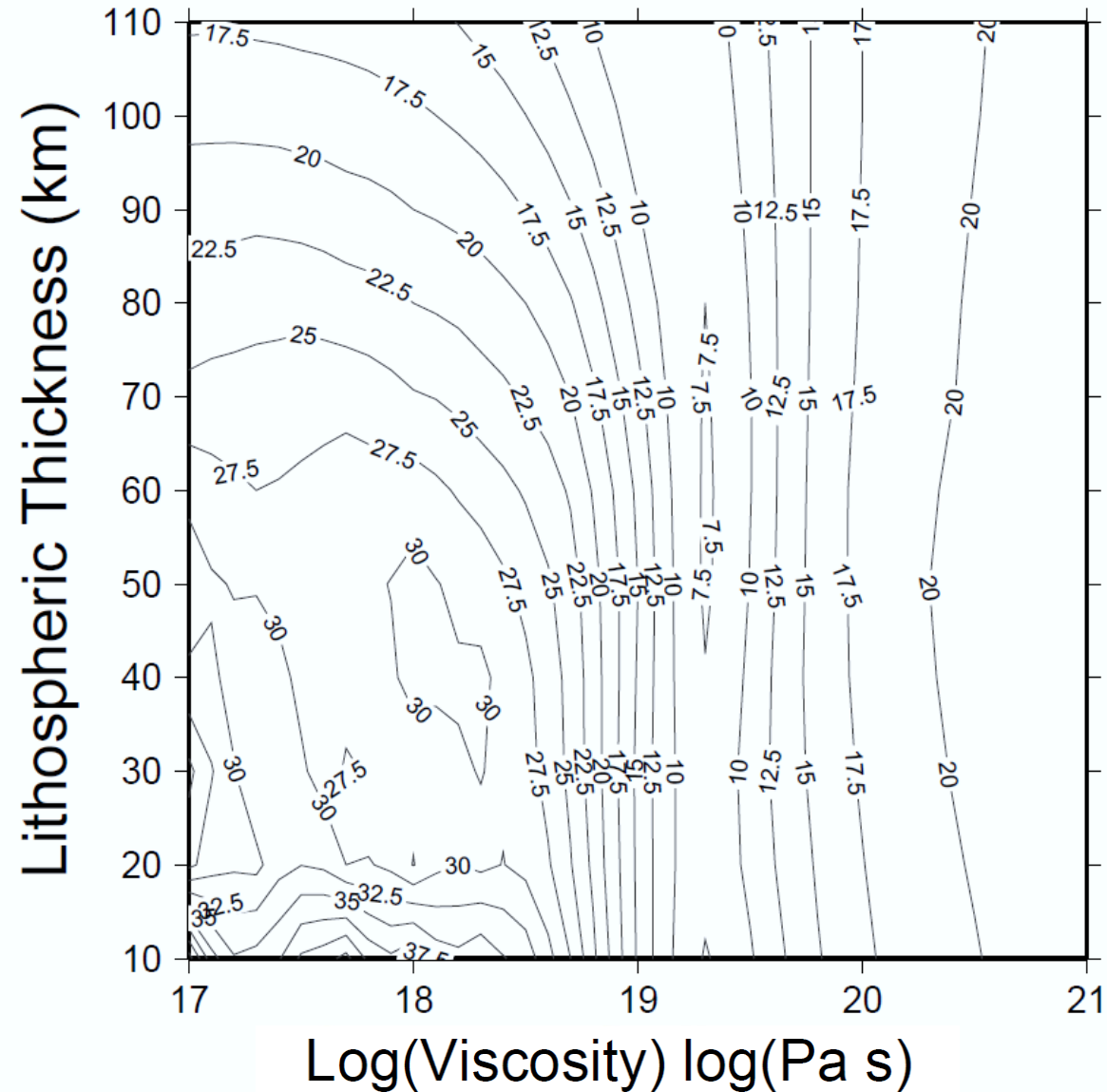
50 km and 1×10^{20} Pa s



Substantially underpredicts WSLR observed

Results: Fit to Observations

- Goodness of fit test (chi square) to observed GPS vertical
 - Smaller values imply better fit to measurements
 - Contoured values for varying EEL thickness and asthenospheric viscosity
- Current best fit around 50-80 km EEL thickness and 2×10^{19} Pa s asthenospheric viscosity



Results: Maps of Best Fit Parameters

50 km and 2×10^{19} Pa s

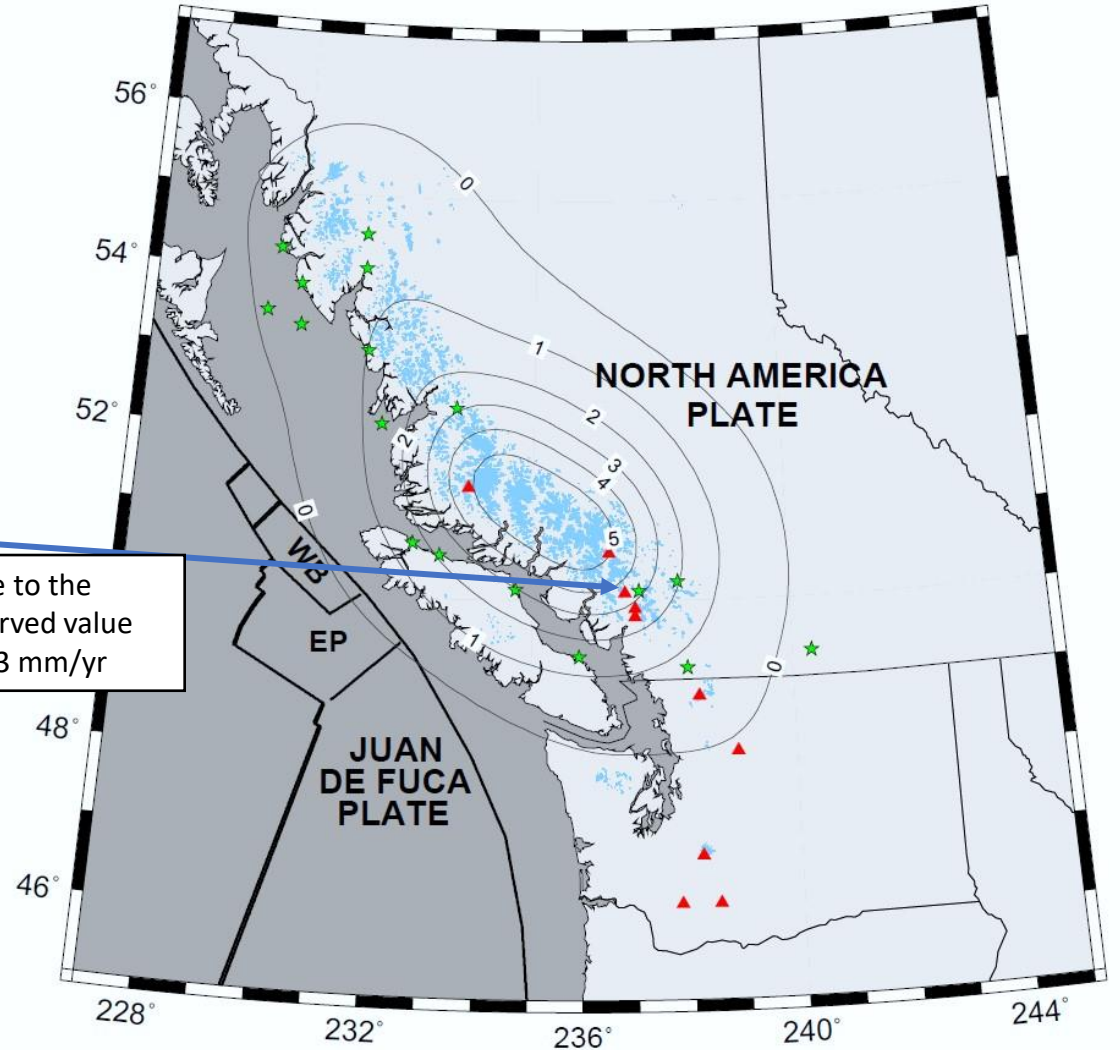
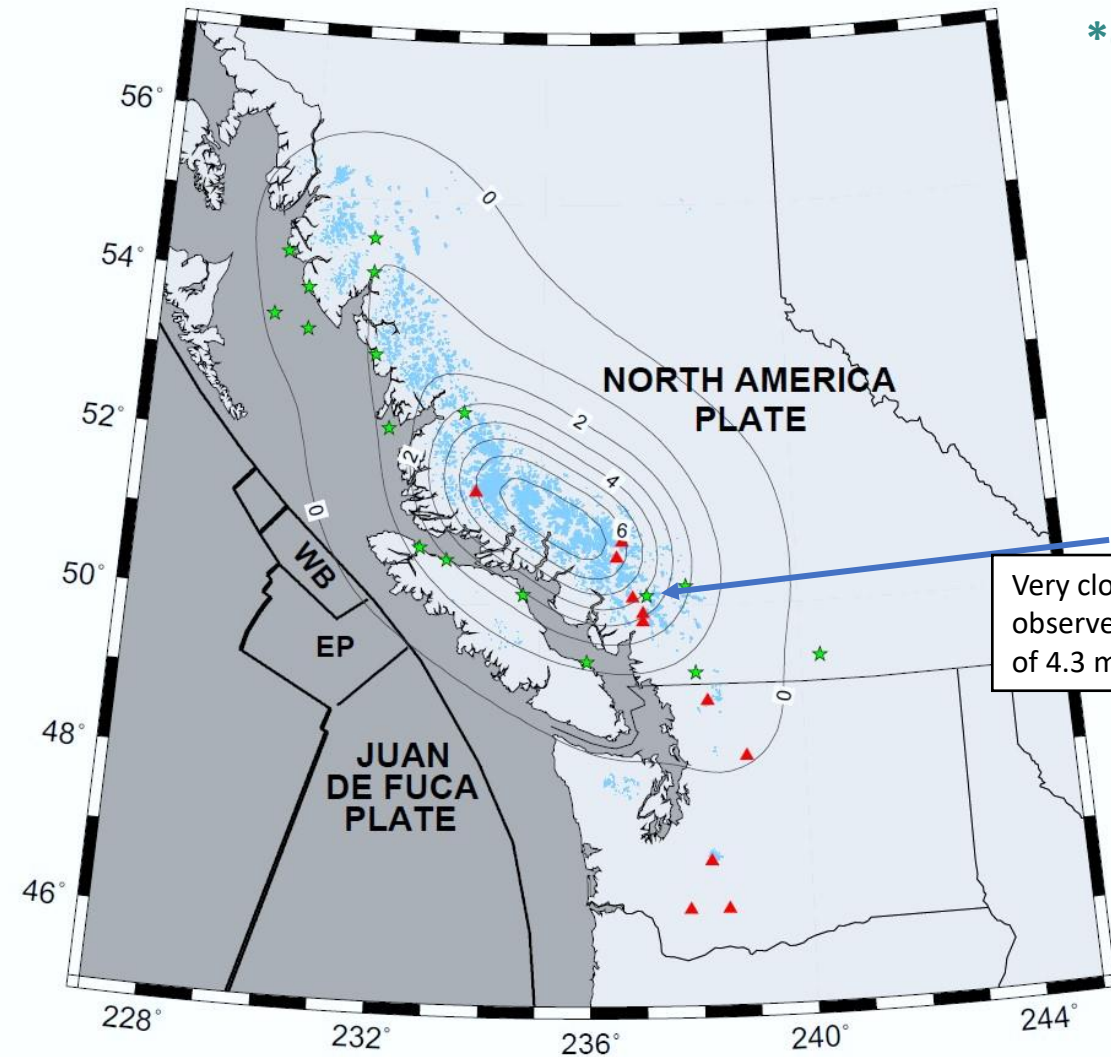
70 km and 2×10^{19} Pa s

*Contours in
mm/yr

WSLR

Very close to the
observed value
of 4.3 mm/yr

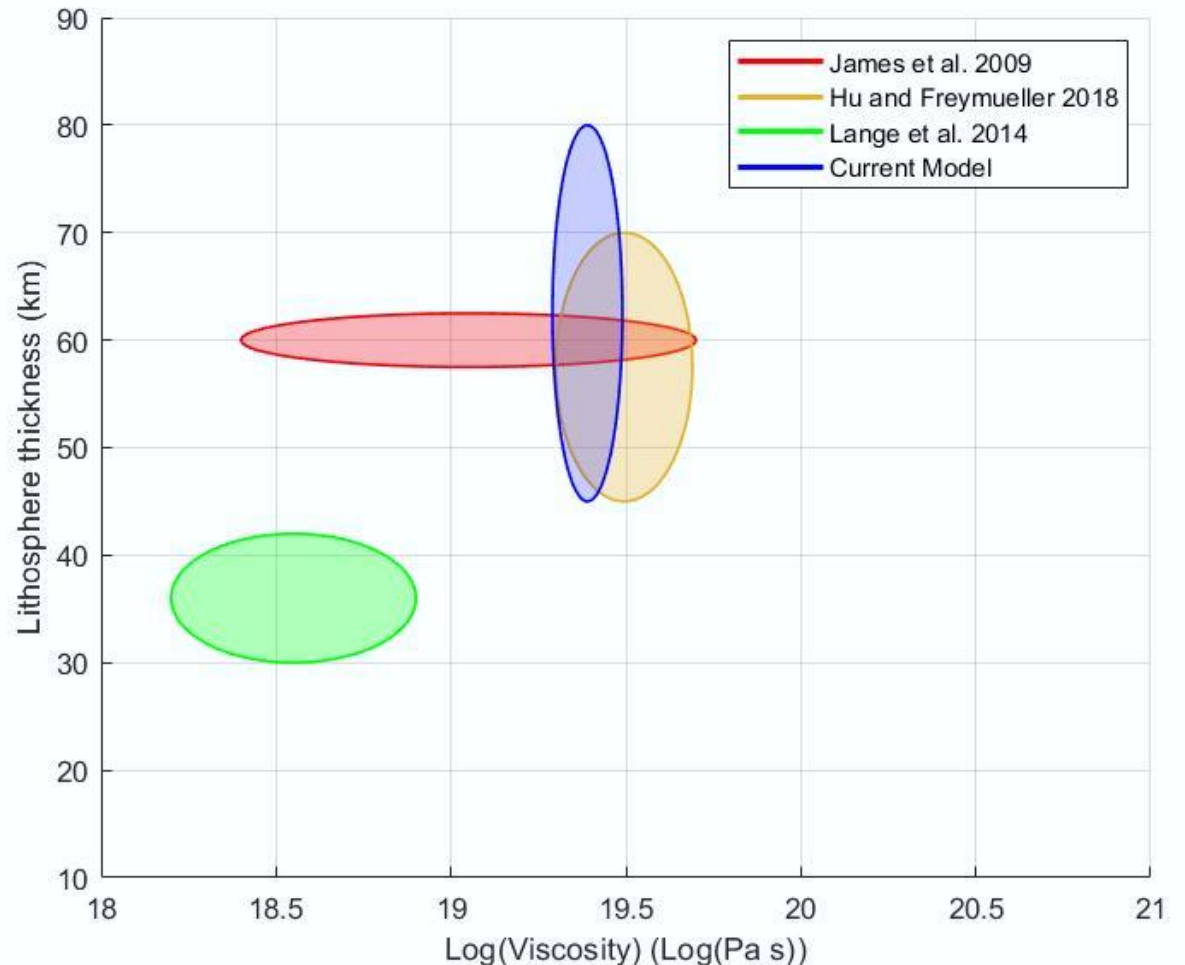
Close to the
observed value
of 4.3 mm/yr



Discussion: Comparisons to Previous Studies

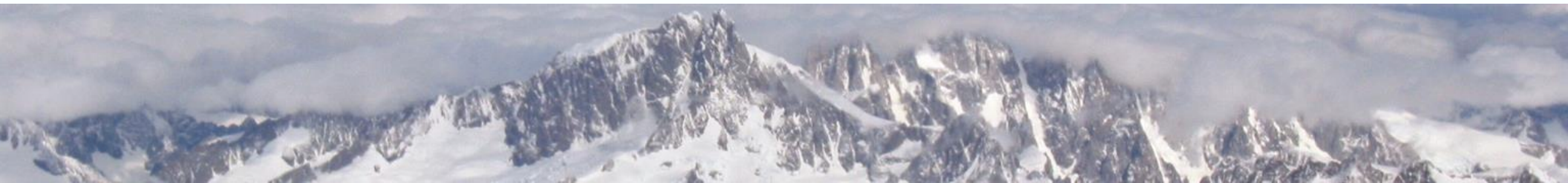
- Previous GIA modelling found similar parameters:
 - James *et al.* 2009 modeled GIA response in Southwestern BC, focused on the Cascadia Subduction Zone
 - Hu and Freymueller 2018 modeled GIA in Southeastern Alaska and Northwestern BC for ice change since LIA
 - Lange *et al.* 2014 modeled LIA derived GIA in Patagonia, which has similar proximity to active tectonic margins with alpine glaciers

Comparison of Previous Parameters to Current Model Results



Conclusions

- Preliminary model results are in close or partial agreement with previous studies in tectonically active regions
- Currently best fitting parameters are EEL thickness between 50 and 80 km and asthenospheric viscosity of 2×10^{19} Pa s
- Next steps for model improvement:
 - Analyze local multi-epoch levelling line data to improve and increase observational data
 - Utilize more detailed ice load history based on literature from moraine and dendrochronological histories in the area
 - Include Northern Coast Mountains glaciers as they have significant ice mass and could affect the northernmost GPS sites shown previously
 - Implement Open Global Glacier Model (Maussion *et al.* 2019) to simulate glacier evolution leading up to, and subsequent to, the Little Ice Age



References

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