Addendum to: Inter-seismic, co-seismic and post-seismic rates of vertical land movement in the Christchurch district and implications for future changes in sea level

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Addendum to: GNS Science Consultancy Report 2023/81
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Context and purpose of this addendum

In 2023, an update to the vertical land movement (VLM) across the Christchurch district was undertaken to include effects of the co- and post-seismic deformation following the 2010/11 Canterbury earthquakes, the 2016 Valentine's Day earthquake and 2016 Kaikōura earthquake. Updated post-seismic VLM rates were estimated from Sentinel-1 SAR data and followed the resampling approach of Hamling et al. (2022) to extract the predicted VLM rates along the same 2-km grid as produced through the NZ SeaRise programme. After consultation with Christchurch City Council and Environment Canterbury staff, it was decided that a modified sampling approach was required to capture the higher spatial variability in VLM that was being lost when applying the original spatial averaging approach. This addendum lays out the new approach and updates the VLM estimates based on this change.

Original sampling approach

In the national-scale VLM derivation (NZ SeaRise), at each of the 2-km coastal locations, Hamling et al. (2022) selected a search radius around each point that was optimised based on the number of InSAR/GNSS observations available and the radial distance used to bin the observations (Figure 1). A preferred search radius was selected which maximised the number of observations while aiming to keep the search radius as small as possible. However, due to the more limited data distribution away from urban areas in the original dataset, the starting search radii was set at 2.5 km. Applying the same approach to the Christchurch district, there is a significant reduction in the spatial heterogeneity visible in the post-seismic datasets. As a result, in some locations the VLM is biased because of the large search radius being applied. For example, in the Moncks Bay and Sumner regions, where locally VLM rates are ~ -2 mm/yr, applying a search radius of 2.5 km includes points across the estuary mouth on New Brighton spit, leading to a downward bias in the VLM of ~4 mm/yr (Figure 1).

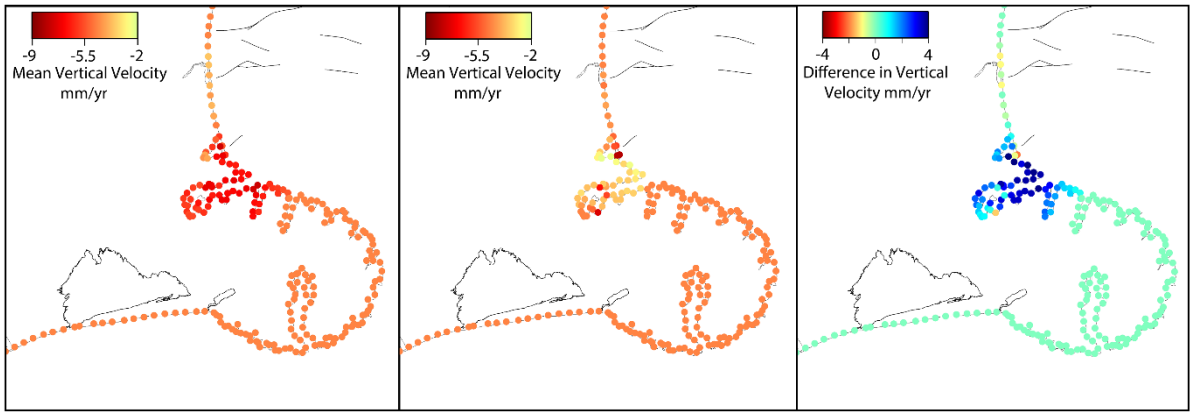

Figure 1. Comparison between VLM estimates based on the original (left) and modified (centre) sampling approaches and the difference (right). Negative values indicate lower rates when using the modified approach.

Revised sampling approach

To limit the effect of the search radius, here we use a modified selection criteria to optimise point selection but with a reduced search radius from 250 m to a maximum of 5 km. As a result, sampling in areas with dense InSAR coverage (built-up areas) tends to sample over shorter distances with the larger search values only used where the InSAR data distribution drops. Additionally, because of the potential of a subsidence bias in points in agricultural or vegetated areas, we increase the weight of InSAR datapoints located on urban or bare-rock ground-cover classes by a factor of 10.

The most significant changes are in locations around Sumner, the southern end of New Brighton spit and around Lyttleton Harbour and Port Levy. By limiting the search radius, the influence of the higher rates of subsidence on the spit, previously affecting the VLM around Sumner, leads to a reduction in VLM rates of ~3-4 mm/yr (Figure 1). Conversely, the lower rates of subsidence in Sumner previously subdued the subsidence rates on the spit. Rates around Lyttleton also reduce by 1 to 2 mm/yr. However, it is worth noting that the coverage of this Sentinel-1 InSAR dataset area was limited in Lyttelton Harbour and Port Levy, meaning points required larger search radii, so there is larger uncertainty in these estimates. As a result of this revised sampling approach, data points located close to the VLM 2-km coastal locations are given more weight and provide a more accurate estimate of the local VLM in these locations.

Vertical land movement and relative sea level

While the effect on the future RSL projections is largely unchanged for most areas, points where there has been a decrease in VLM have had a reduction to the total RSL by ~0.5 m, under the scenario where increased VLM occurs out to 2150. Under the scenarios where VLM returns to their inter-seismic rates in 2030, 2050 and 2100, there is a more modest drop of 0.05 to 0.1 m (Figures 2,3). In the original report, we used the adjusted VLM rates to estimate the change in timeframe to reach the projected RSL in 2050. As a result of the decreased rates of subsidence (and co-seismic uplift), areas around Lyttleton and on the south side of the Avon Heathcote estuary have pushed out the timing to the 2050 RSL by ~10 years or more (Figure 4).

Final remarks

This addendum highlights the importance of a user-guided approach when generating estimates of future VLM. By incorporating input from local end-users, a VLM sampling design can be created to maximise the usefulness of the data and help address their specific needs.

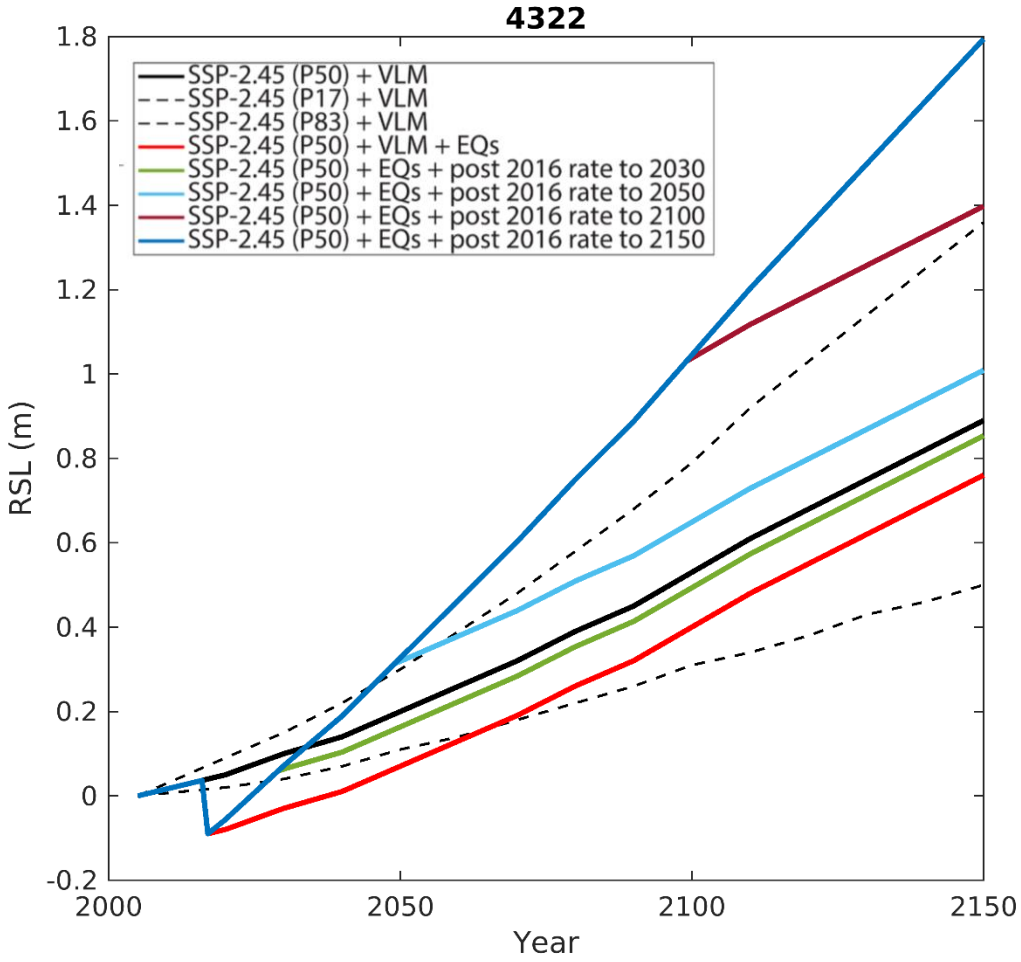

Figure 2. Re-projected vertical land movement estimates at Moncks Bay (4322) from original report for the different scenarios.

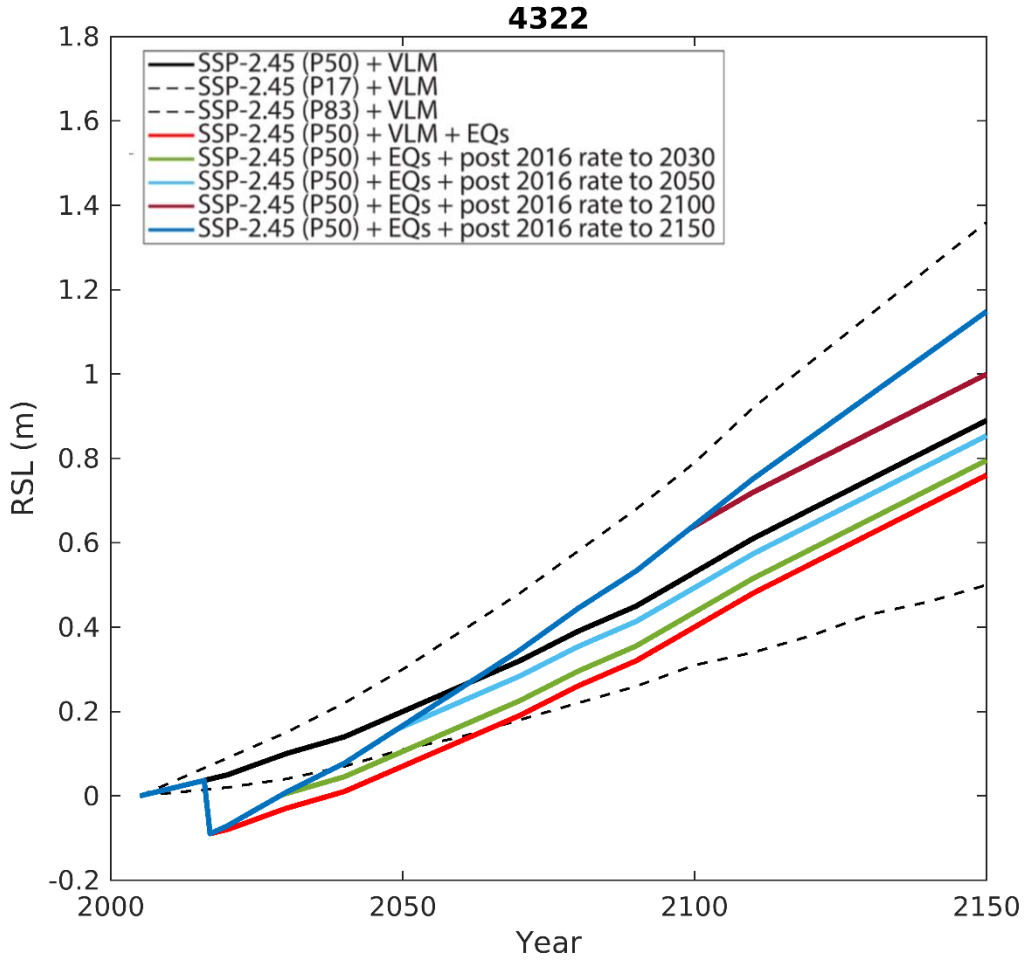

Figure 3. Re-projected vertical land movement estimates at Moncks Bay (4322) using modified VLM for the different scenarios.

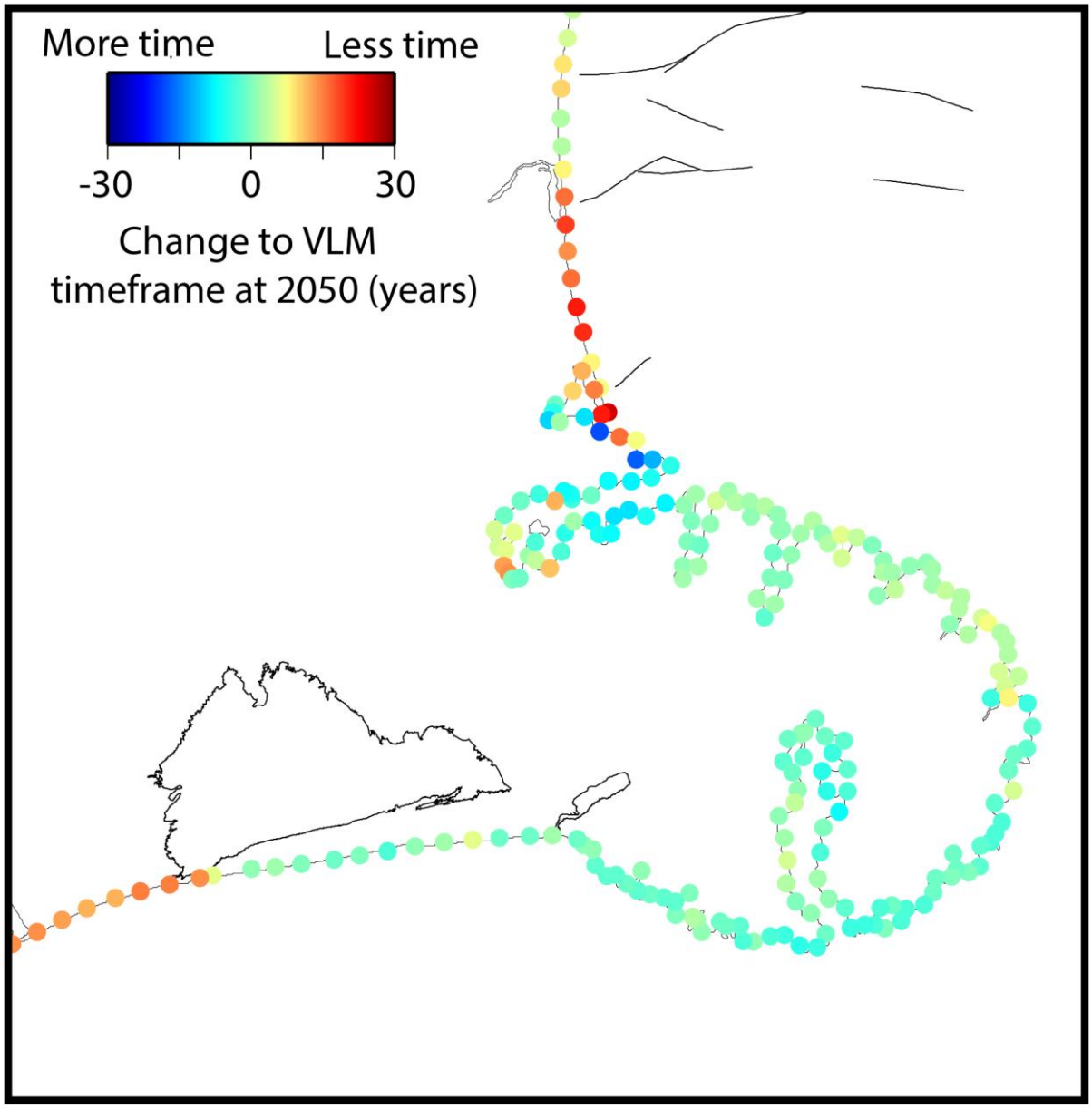

Figure 4. Change in timeframe of relative sea level (RSL) in 2050 based on re-projected rates and co-seismic displacements. Negative times indicate that RSL has been pushed back in time.

Appendix

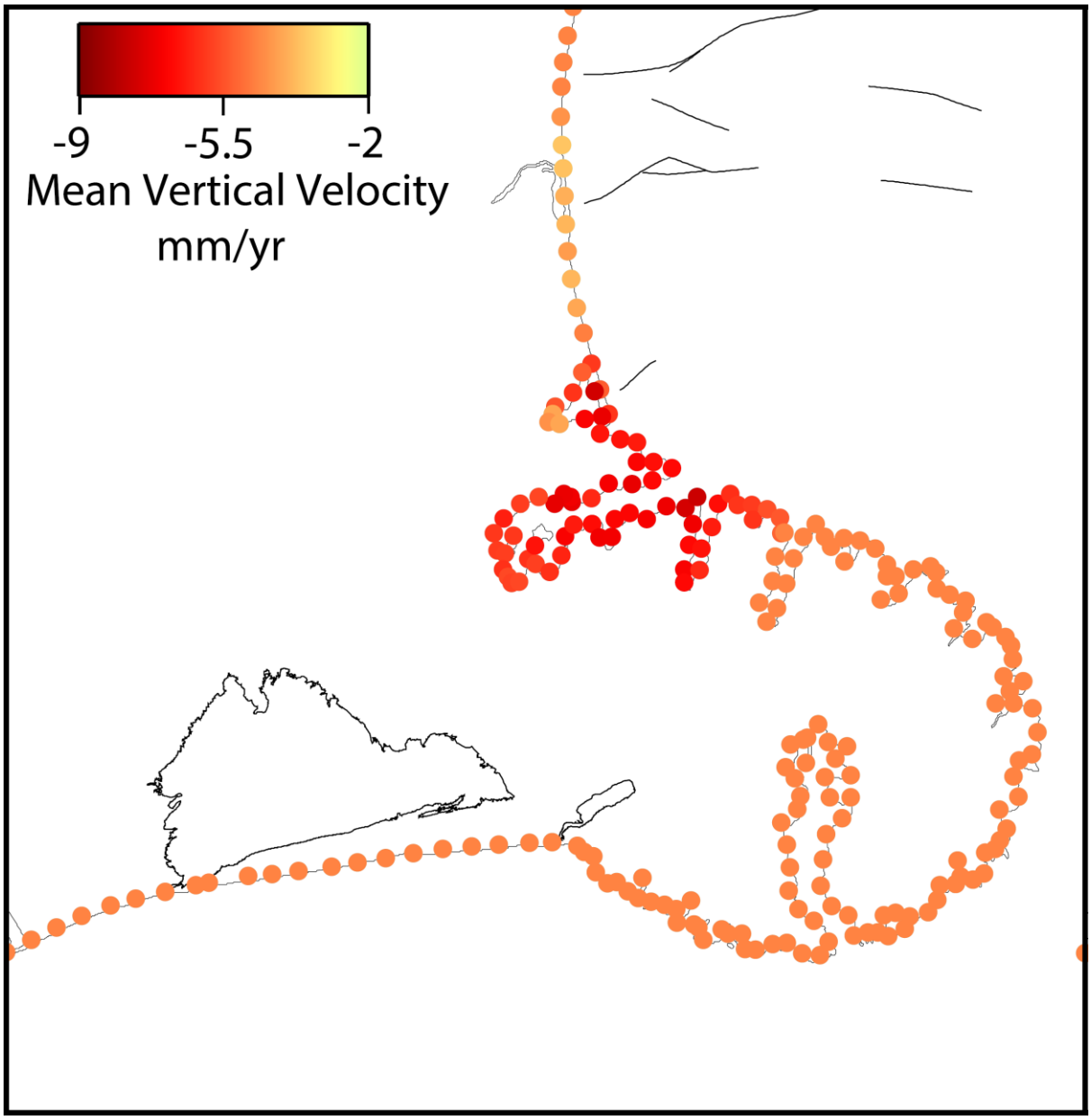

Figure A1. VLM estimates from original report.

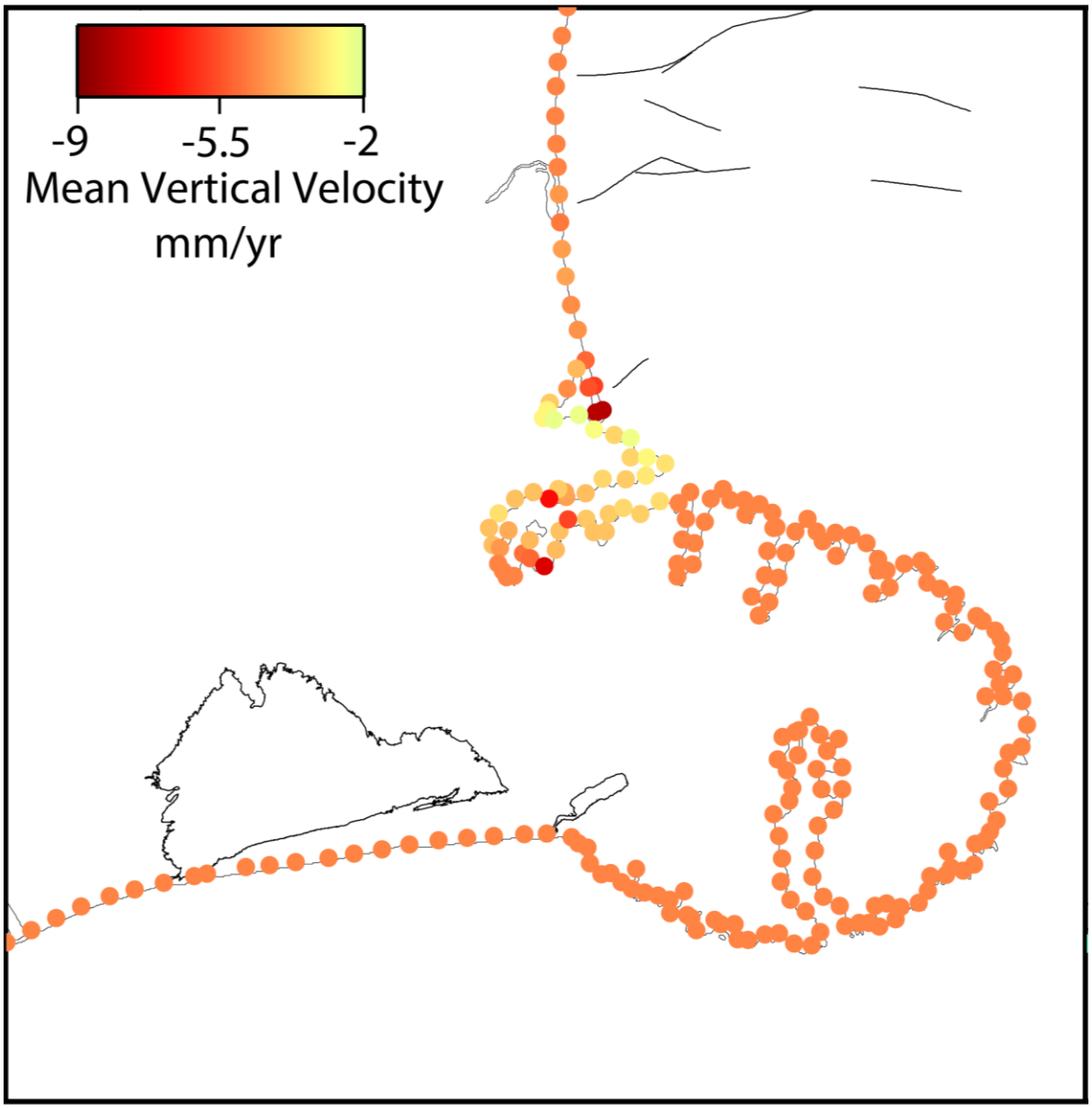

Figure A2. Updated VLM using modified search radius.

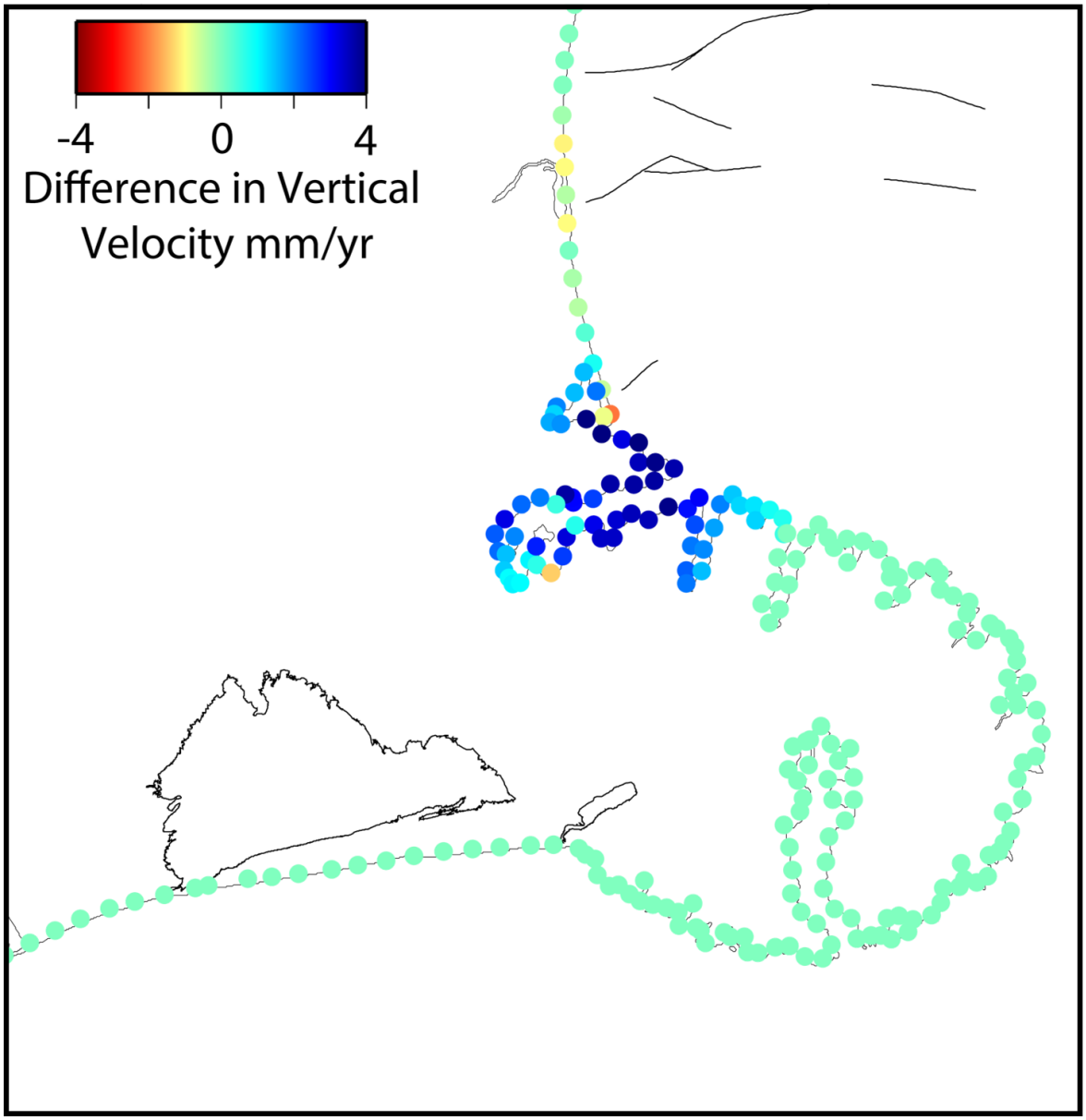

Figure A3. Difference in VLM using modified approach. Negative values indicate lower rates when using the modified approach.