UAV-derived change detection without ground control points, an example from the cliff coast of Rügen

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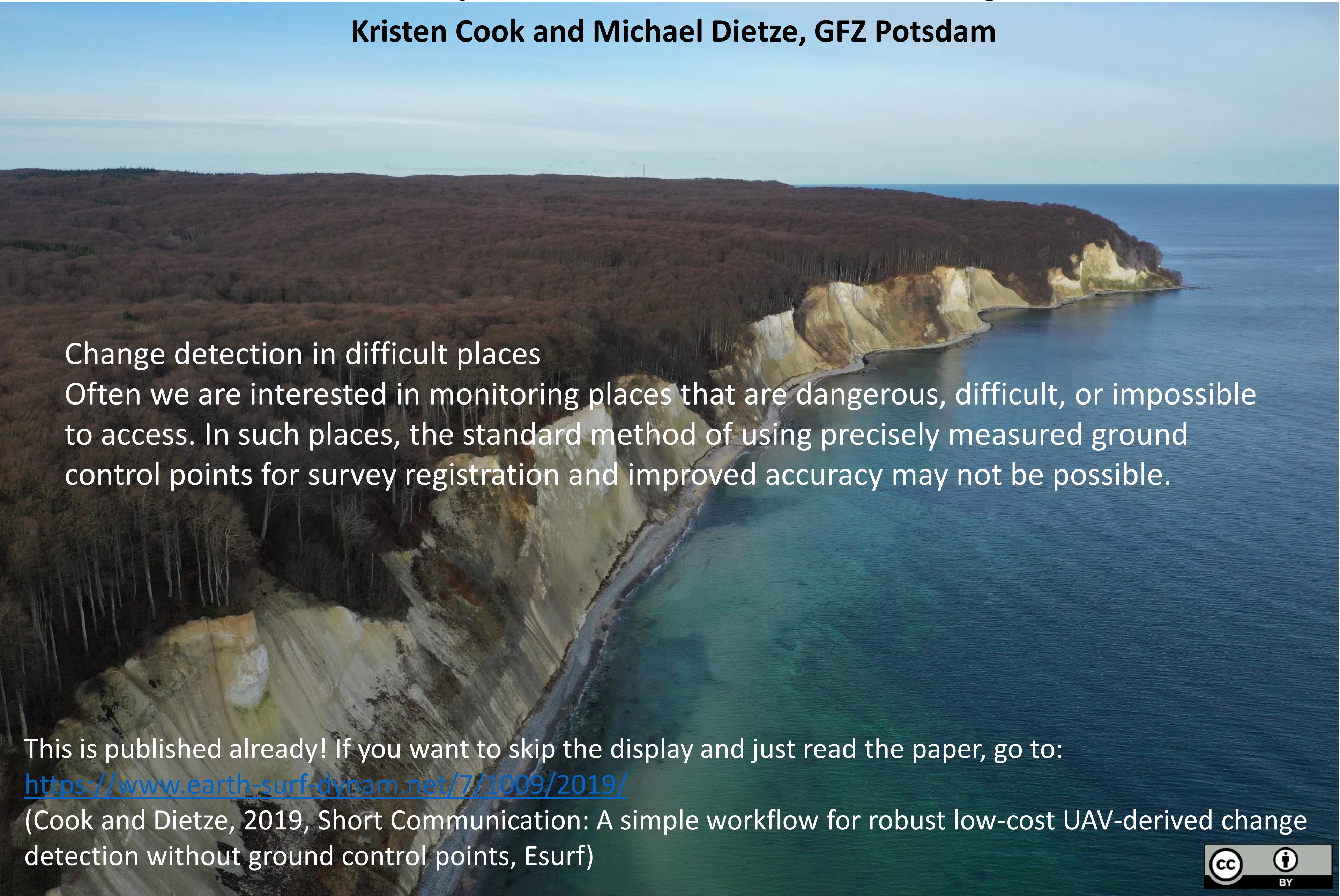
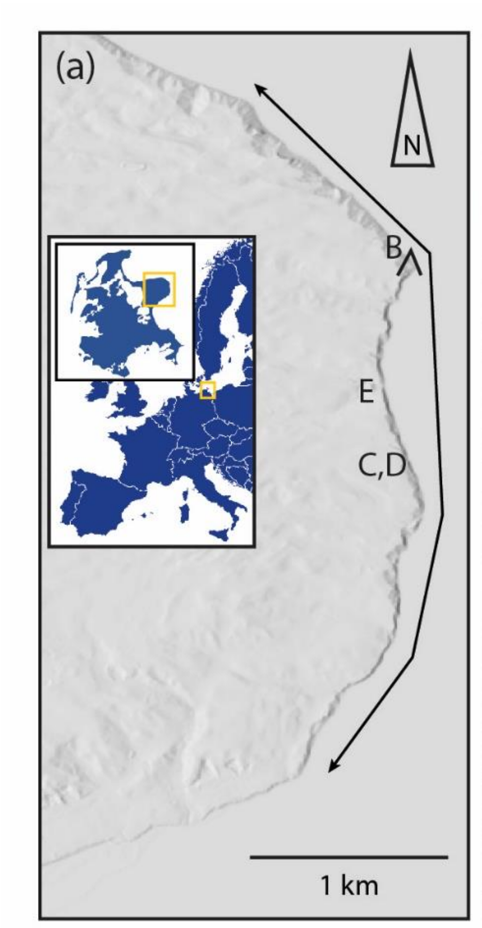


Change detection in difficult places

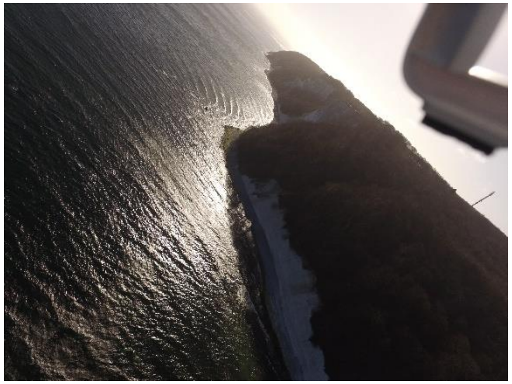
Often we are interested in monitoring places that are dangerous, difficult, or impossible to access. In such places, the standard method of using precisely measured ground control points for survey registration and improved accuracy may not be possible.

This is published already! If you want to skip the display and just read the paper, go to:
https://www.earth-surf-dynam.net/7/1009/2019/
(Cook and Dietze, 2019, Short Communication: A simple workflow for robust low-cost UAV-derived change detection without ground control points, Esurf)

One such difficult place is the cliff coast in Jasmund National Park, on the island of Rügen, on the Baltic coast of Germany. The chalk cliffs here experience frequent mass wasting events, which are a hazard to park visitors and play an important role in the geomorphic evolution of the coast.

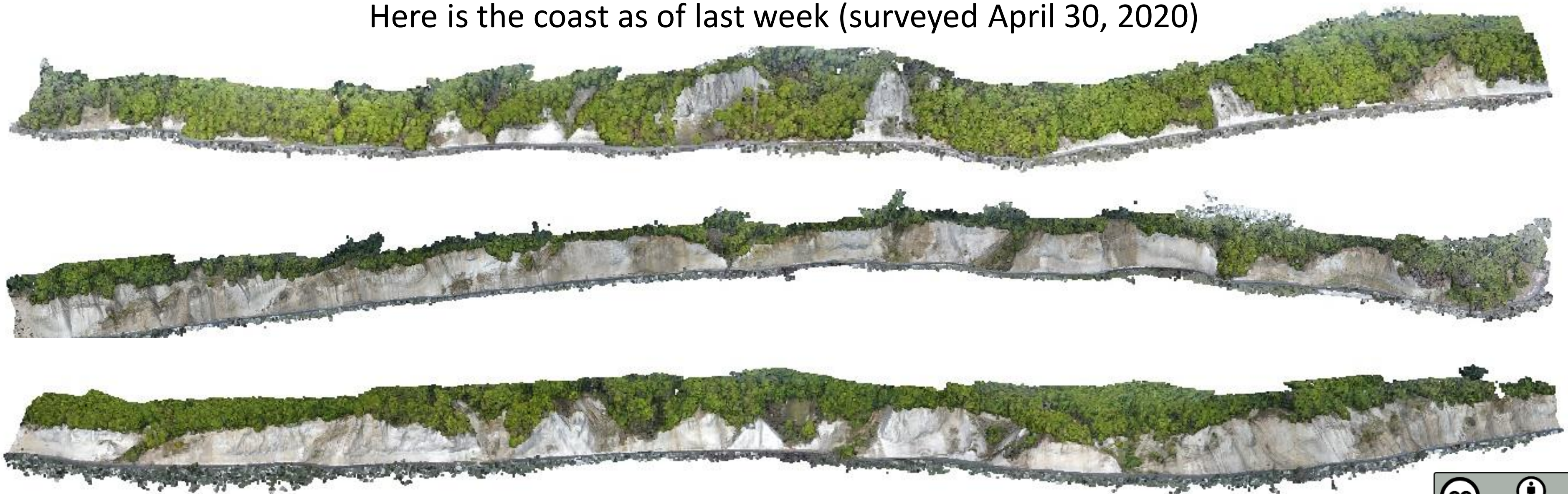


But this area is not easy to survey: 7 km of coastline to cover, steep to overhanging cliffs up to 118 m high, access to the beach not allowed, frequent bad weather (it’s always so windy!), so many trees, short winter days (when most activity happens)…



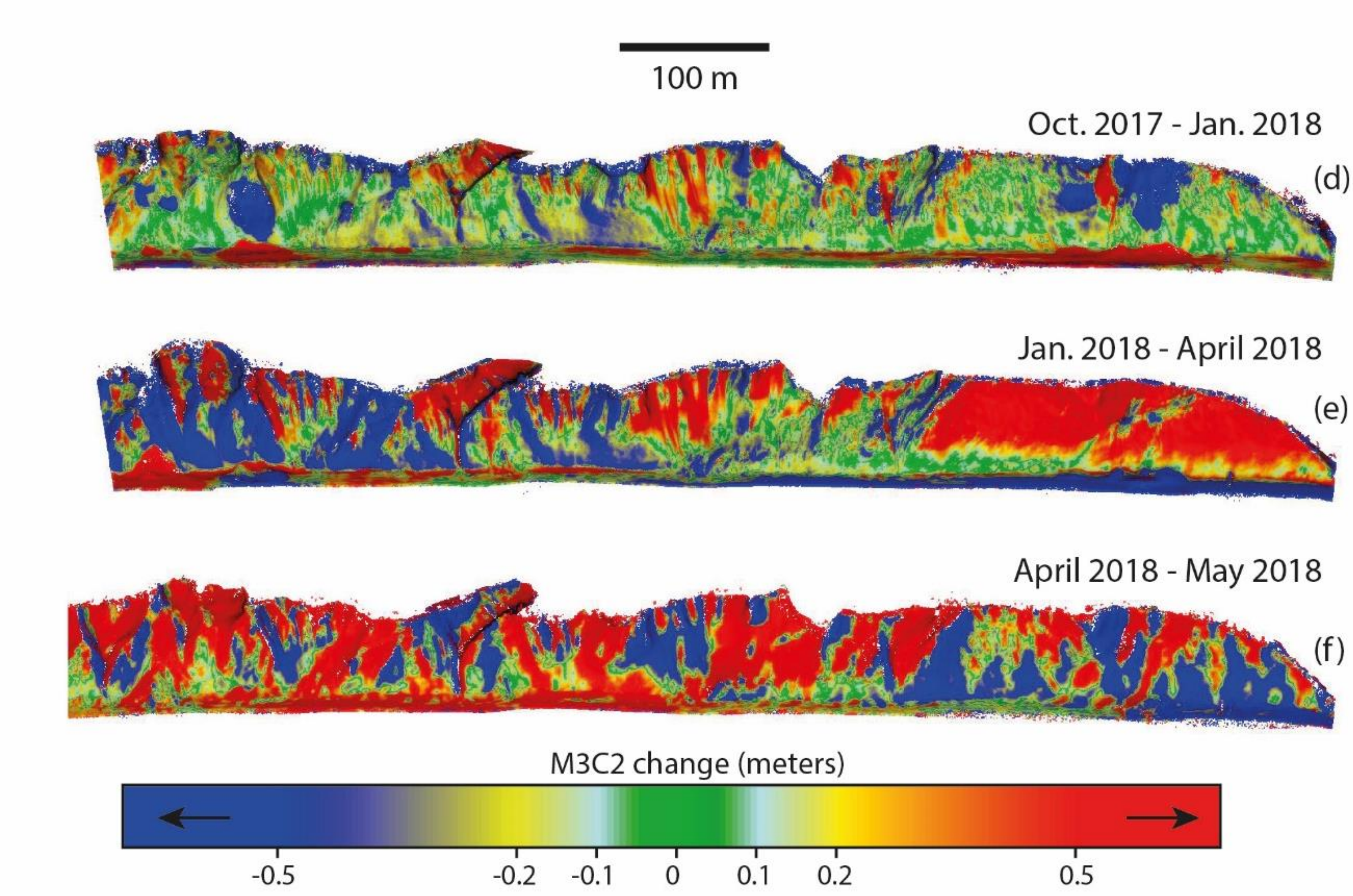
But with some careful manual UAV flying we can photograph all 7 km of coast in a few hours and then use Agisoft Photoscan/Metashape to produce nice point clouds

Here is the coast as of last week (surveyed April 30, 2020)



However, with no ground control points, a standard DJI UAV (Phantom 3, Mavic Pro, or Mavic 2 Pro), and the usual processing in Agisoft Photoscan/Metashape, when we compare different point clouds, we get change maps that look like this (calculated using M3C2 in CloudCompare).

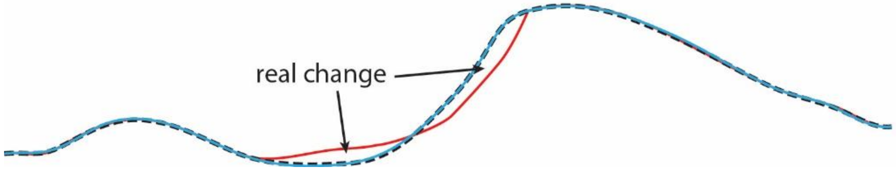
These are completely useless to detect anything but the largest cliff failures!



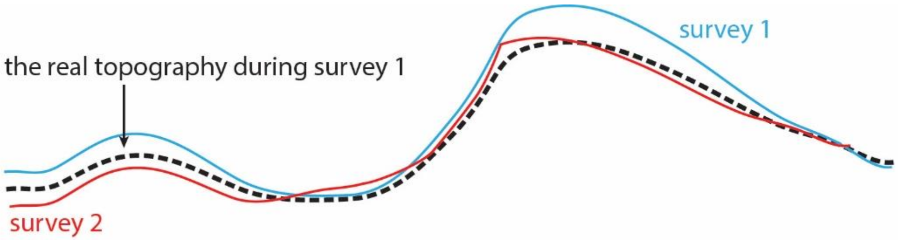
A quick aside: some notes on survey accuracy

We can distinguish three types of survey accuracy:
absolute accuracy: accuracy of the scaling and georeferencing of the model
relative accuracy: internal accuracy (distortion) of the model
comparative accuracy: accuracy of the difference between model pairs, or to what degree the models are consistent with each other
These can occur in some different combinations:

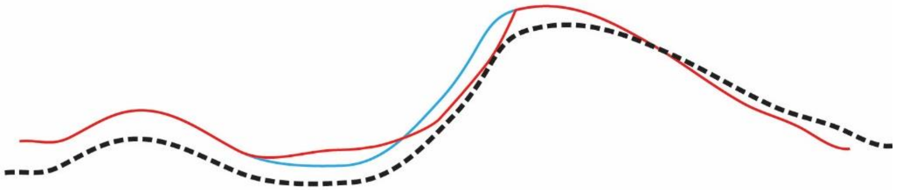
- high absolute accuracy, high relative accuracy, and therefore high comparative accuracy
- real change can be distinguished from error, and dimensions of change are highly accurate
- typically requires ground control or RTK/PPK drone
- best case result



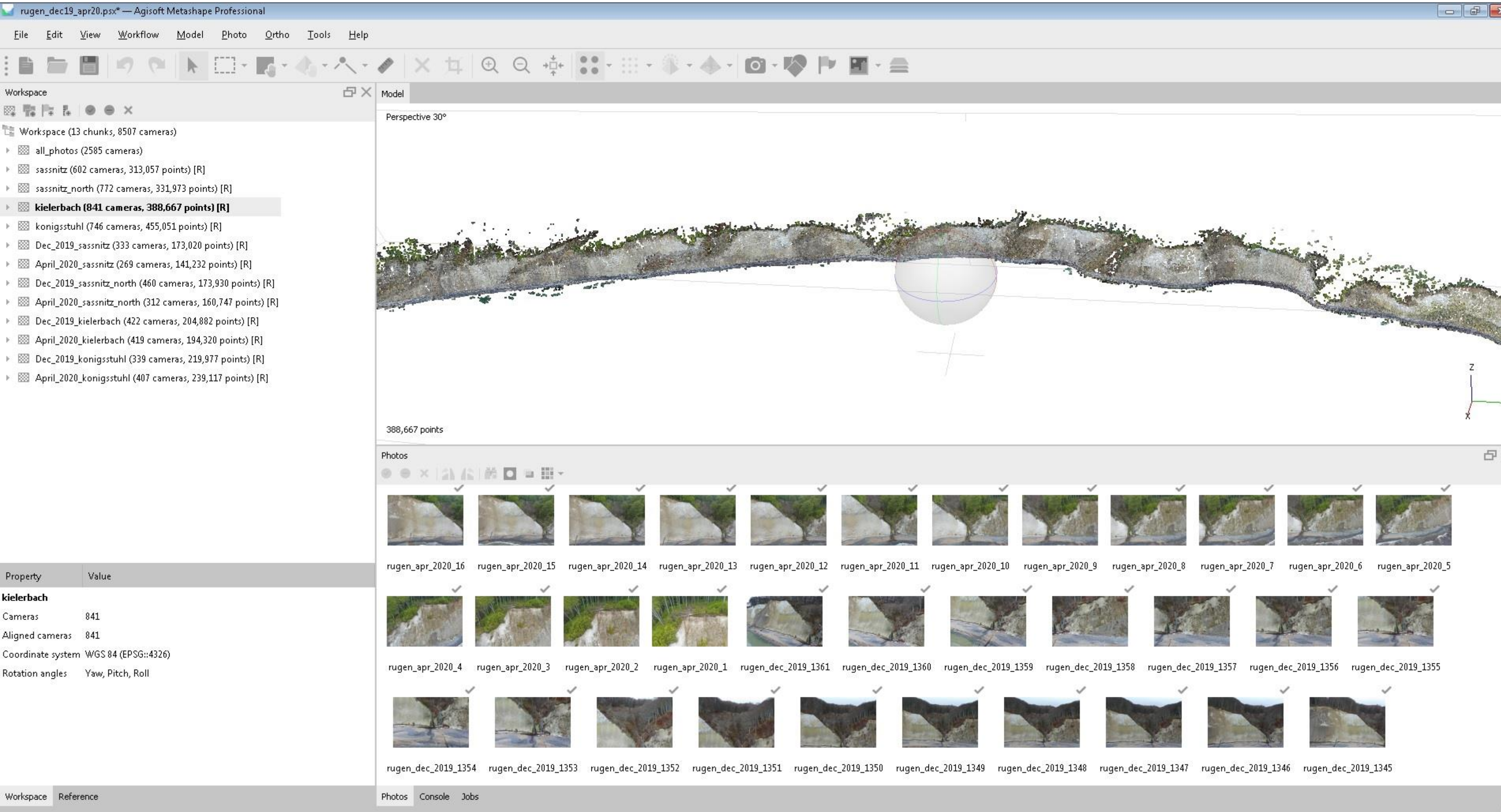
- low absolute accuracy, low relative accuracy, low comparative accuracy
- real change can't be distinguished from error
- typical result for surveys without ground control or RTK/PPK drone
- worst case result



- low absolute accuracy, low relative accuracy, high comparative accuracy
- real change can be distinguished from error, but dimensions of change may be less accurate
- the result that we aim for with no ground control or RTK/PPK
- acceptable result for many change detection purposes



So, what to do? We found that, with one simple trick during SfM processing, we can get significantly improved comparative accuracy. This involves combining the photos from multiple surveys into one chunk for the point detection and matching, initial bundle adjustment, and optimization steps. We call this the co-alignment workflow.



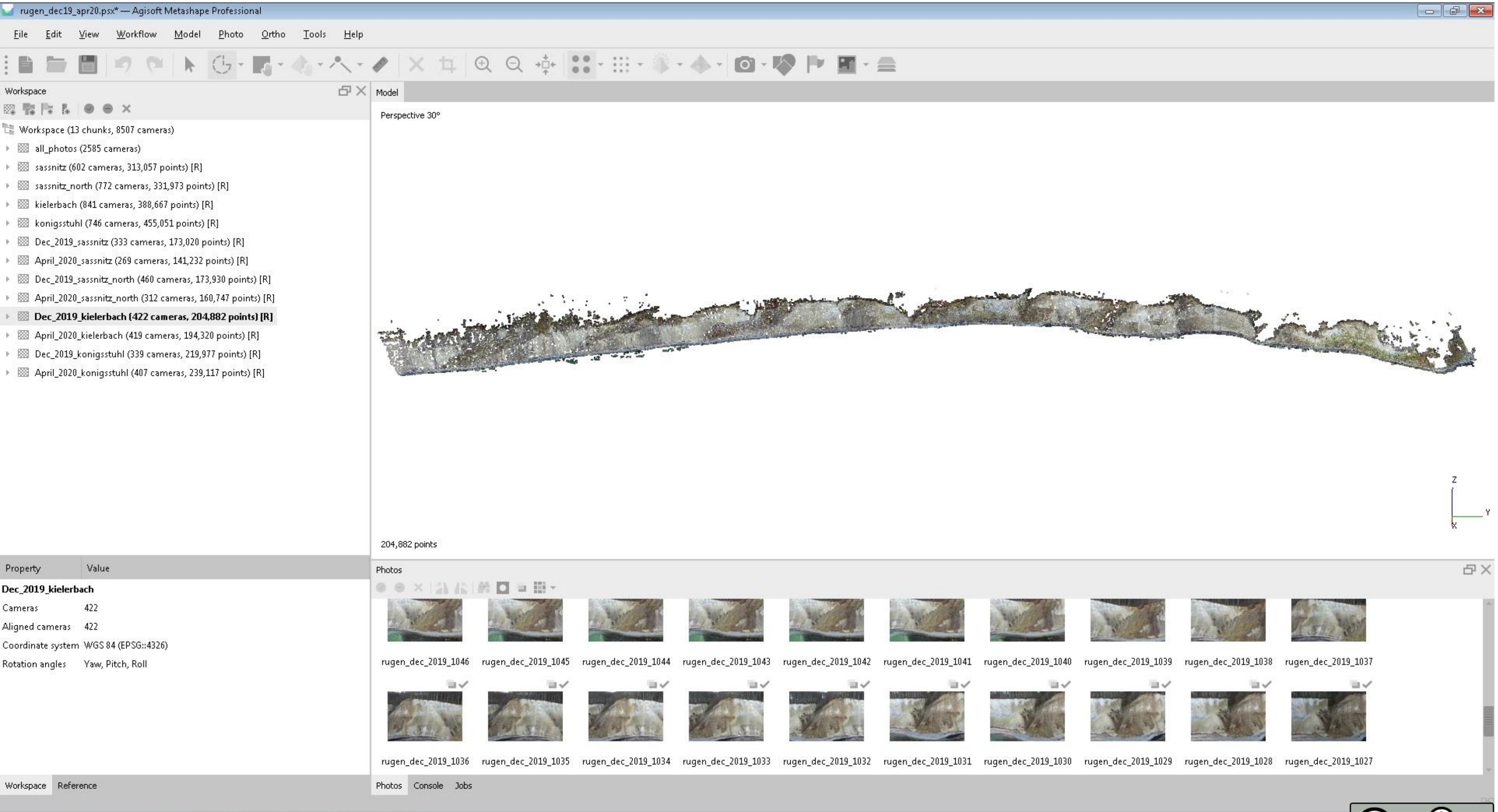
Hopefully, points will be matched between photos from the two different surveys.
Here is an example showing 25 valid matches detected between a Dec. 2019 photo and an April 2020 photo.
Tie points like these enforce a common geometry between the two surveys.

Matches

rugen_apr_2020_897

Photo	Total	Valid	Invalid
rugen_apr_2020_681	234	178	56
rugen_apr_2020_887	213	157	56
rugen_apr_2020_679	207	151	56
rugen_apr_2020_680	192	143	49
rugen_apr_2020_678	173	128	45
rugen_dec_2019_380	79	25	54
rugen_dec_2019_381	72	25	47
rugen_dec_2019_339	72	24	48
rugen_dec_2019_379	71	25	46
rugen_dec_2019_333	71	25	46
rugen_dec_2019_382	70	24	46
rugen_dec_2019_341	70	22	48
rugen_dec_2019_342	69	23	46
rugen_dec_2019_383	68	26	42
rugen_dec_2019_378	68	25	43
rugen_dec_2019_336	68	25	43
rugen_dec_2019_384	67	25	42
rugen_dec_2019_377	67	26	41
rugen_dec_2019_376	67	23	44
rugen_dec_2019_338	67	22	45
rugen_dec_2019_375	66	25	41

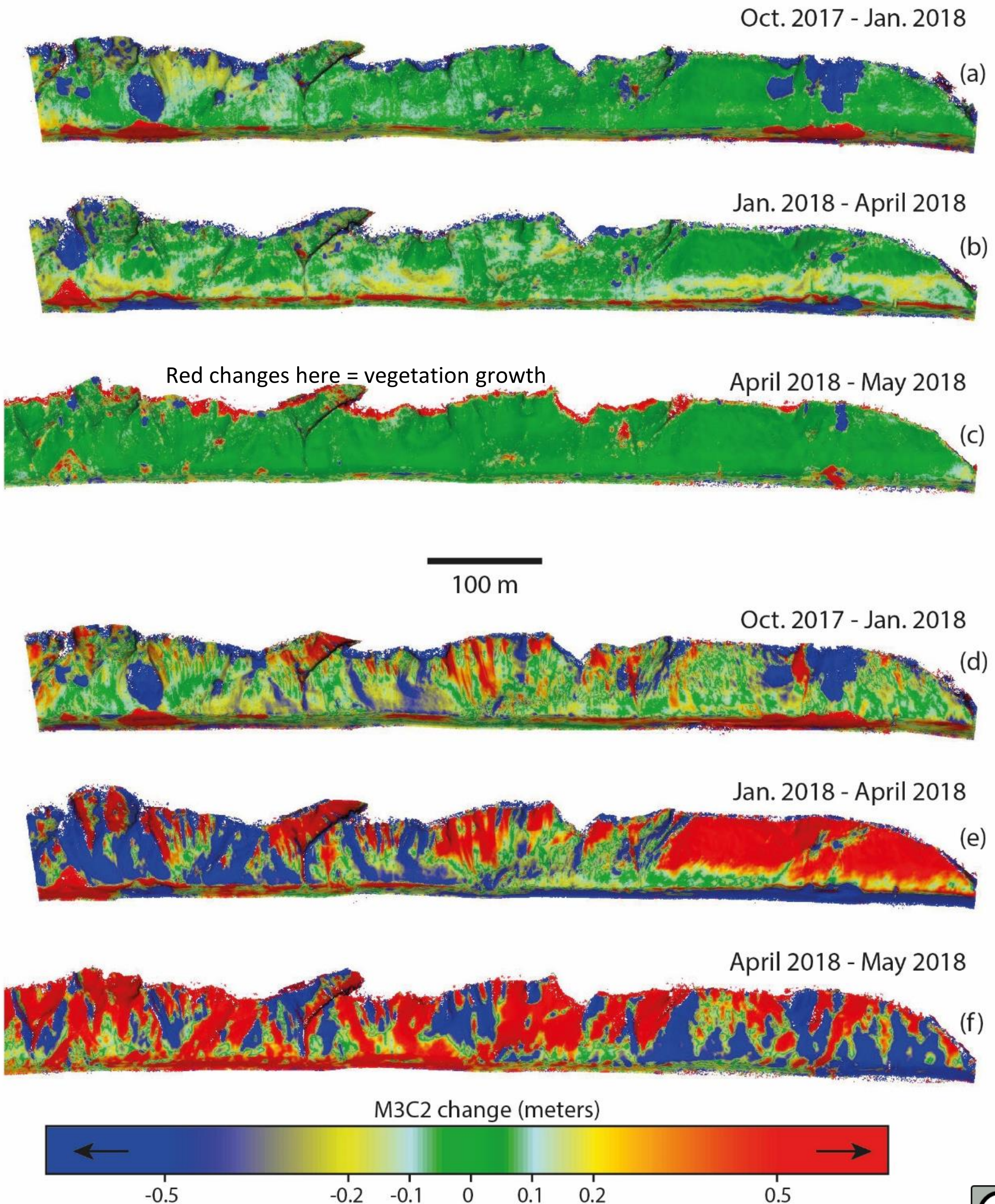
When we are ready for the dense cloud construction, we take our co-aligned chunk, duplicate it a few times, remove photos as needed to create chunks for each survey, and then calculate dense clouds for each survey. (here we have also divided the coast into 4 segments, creating a lot of chunks to keep track of!)



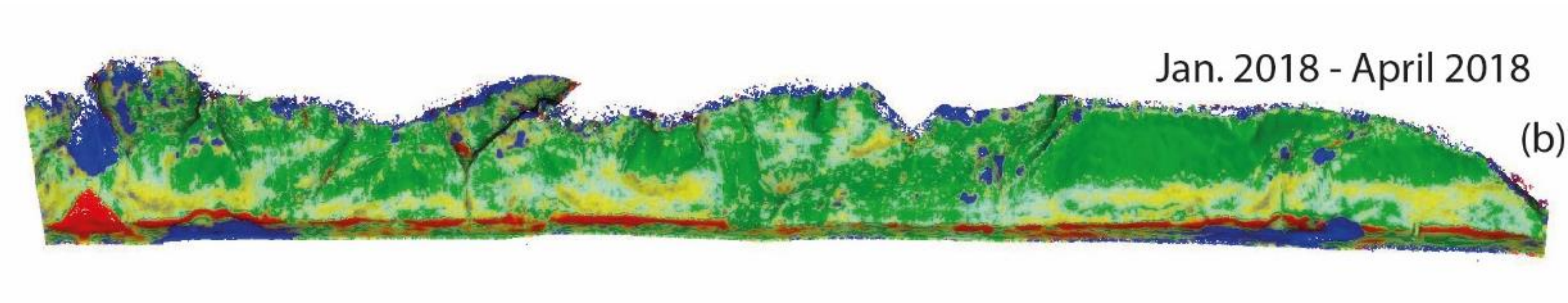
The same data, but processed using the co-alignment workflow

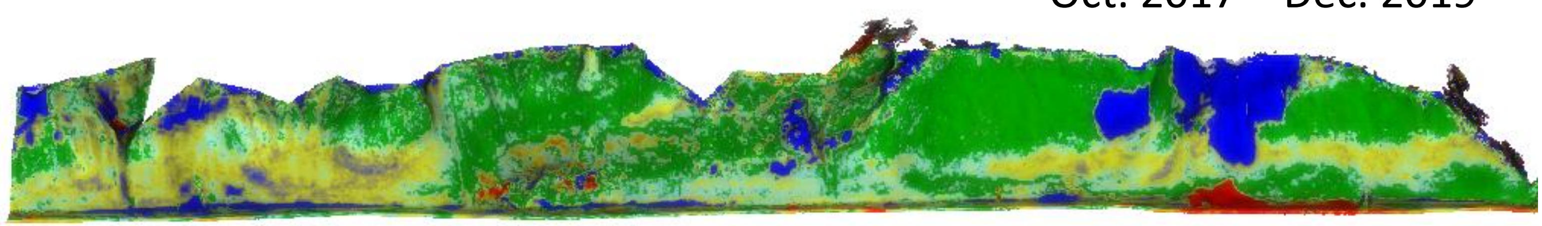
This is much more useful! Even small failures can be reliably detected.

For comparison: the useless results that we saw earlier

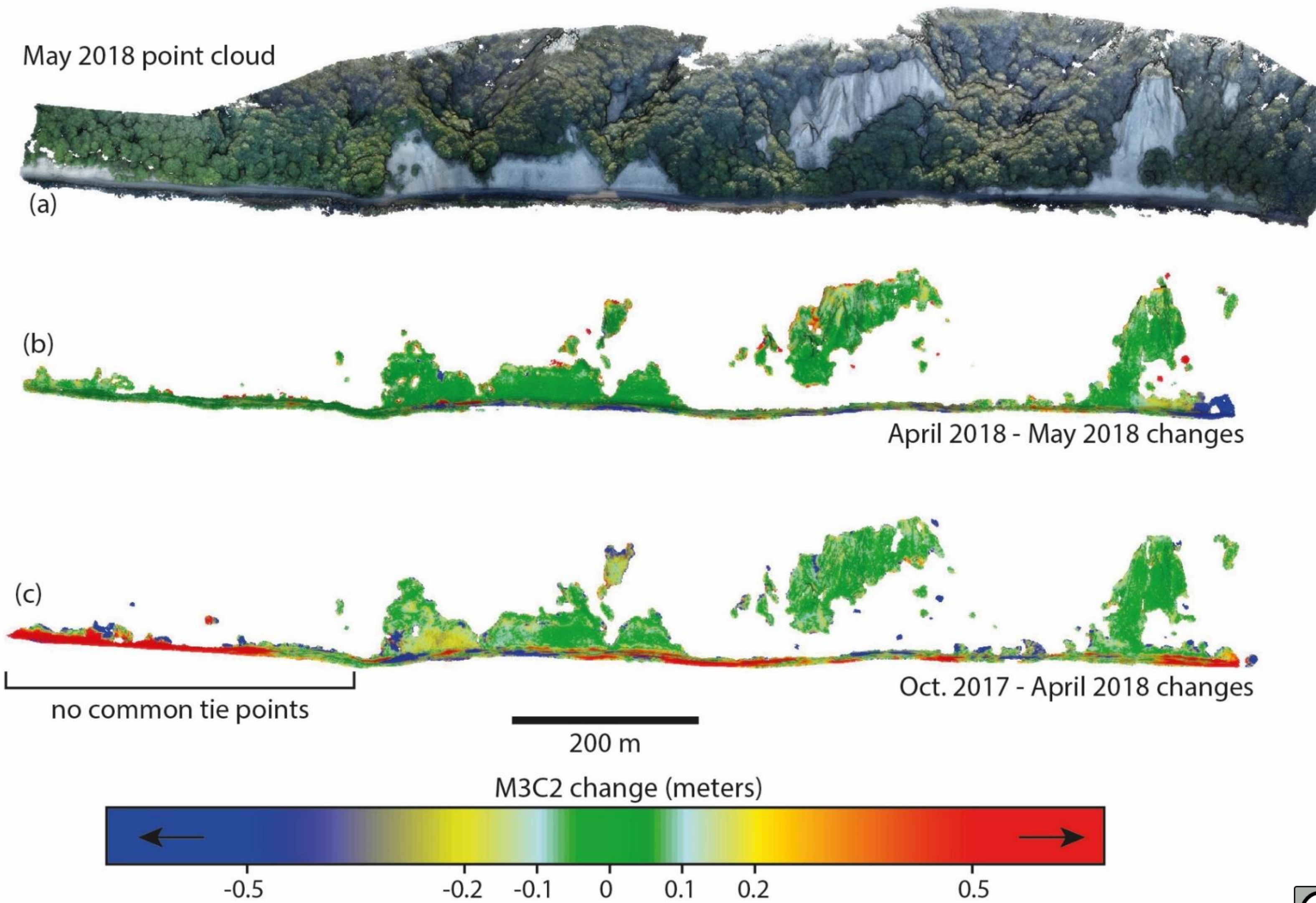


If we look more closely, we can detect more than just failures. The bands of yellow change seen on this map look like they could be error, but they show up consistently between all survey pairs that bracket early 2018, suggesting that these are real changes of ~10-20 cm. This appears to be more diffuse erosion of the chalk cliffs, matched by the narrow band of red deposition at the base of the cliff in the Jan 2018 – April 2018 pair.

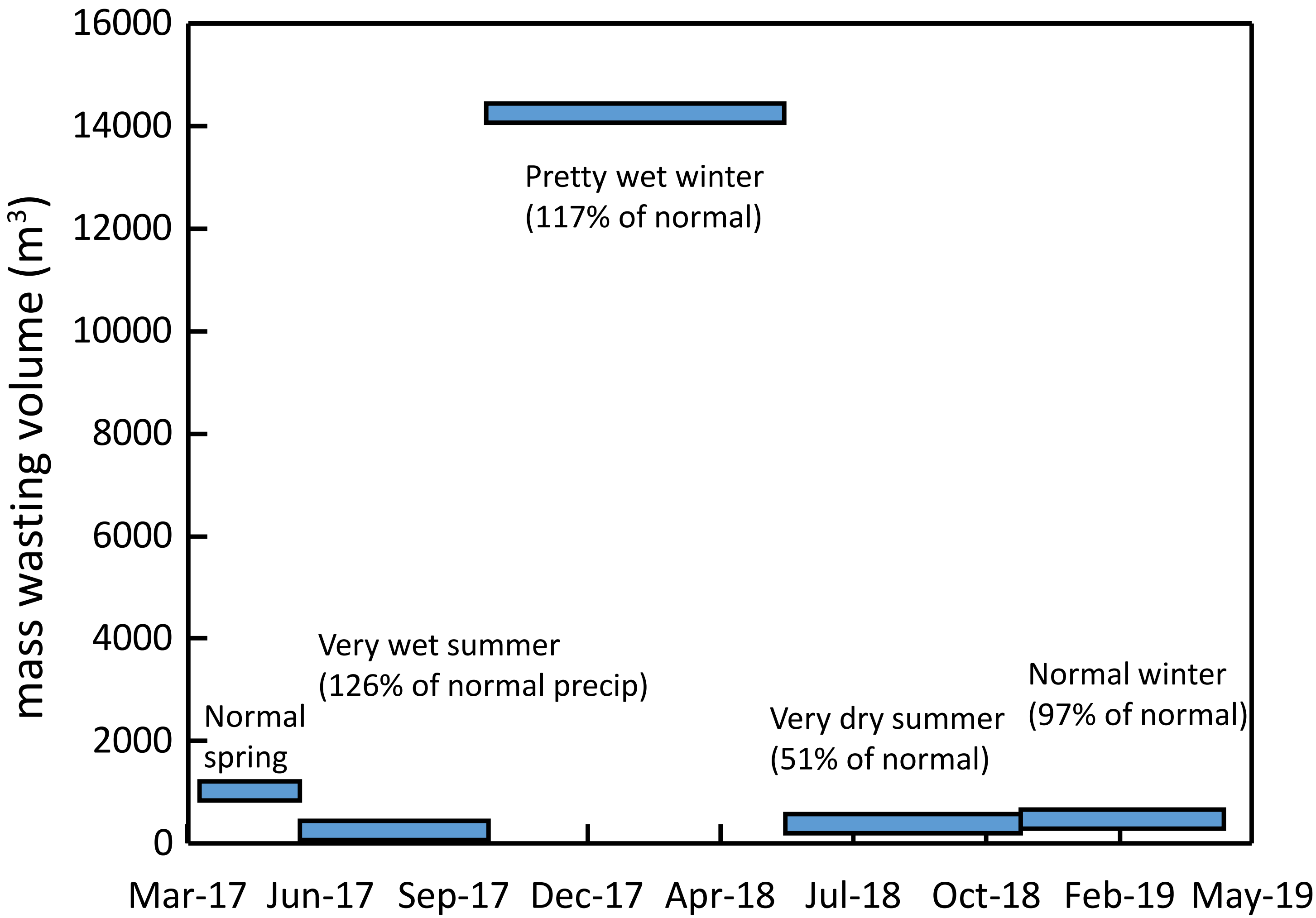




It doesn't always work – if no common tie points are detected over a portion of the area, that area may be poorly aligned. Here, the left side of the region has only a narrow sliver of tree-less area, making point matching difficult. (note that the tree-covered areas have been trimmed from the change maps) So care should be taken when evaluated the measured changes.



With our new reliable change detection capabilities, we can calculate mass wasting along the entire cliff from 2017 through 2019 (summer 2019 and winter 2019-2020 still in progress). We can start to see the role of precipitation and season in driving collapses. Collapses occur primarily in the winter (when trees are not taking up water), and the amount of rain in the summer may affect the amount of collapses in the following winter. The diffuse erosion also took place almost entirely during the winter 2017-2018, when everything was wet.



Another example of the effectiveness of the co-alignment workflow, from a completely different setting: a river gorge in Taiwan (you can find all the details about this site in Cook, 2017, An evaluation of the effectiveness of low-cost UAVs and structure from motion for geomorphic change detection, Geomorphology)

Here we can see how co-alignment compares to processing using ground control points.

Comparing the two change maps, we can see that they are almost identical, as are the distributions of the changes (the distributions are so similar that you can't even see the blue GCPs line behind the orange co-alignment line!)

This is pretty encouraging!