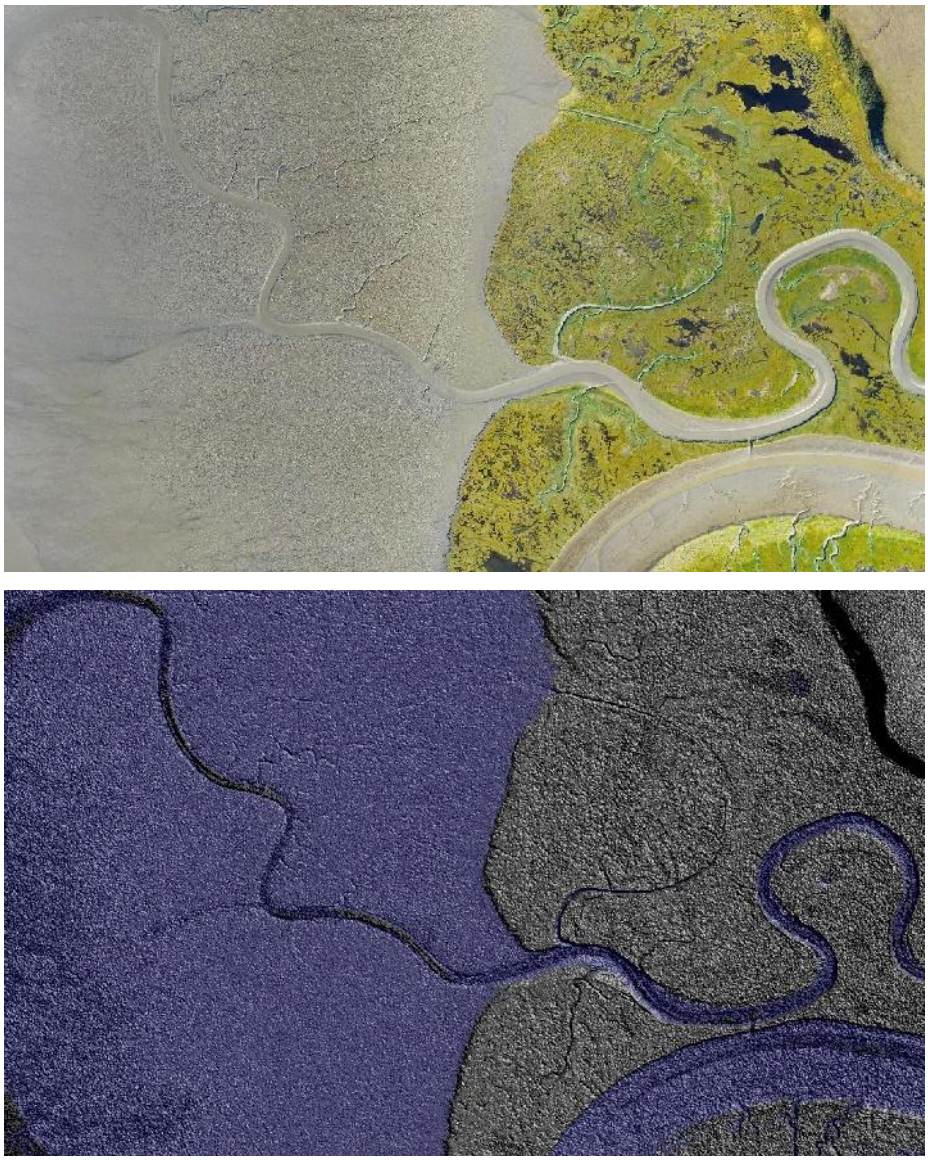
Contract 10-15-053

Final Report

28 July 2016

Submitted to

Alaska Department of Natural Resources



Orthoimage and DSM of mudflats and coast near Toksook Bay

Submitted by

Fairbanks Fodar

www.fairbanksfodar.com

Summary

This report describes the delivery of coastal data per terms of contract AK DNR Contract 10-15-053. 'Coastal' data in this context distinguishes this report and delivery from 'village' data collected in 2015 and delivered in January 2016. The delivered coastal data consists primarily of a DSM and orthomosaic at 20 cm posting covering roughly a 1500-2500 m swath of coastline extending roughly 1500 miles from Wales to Platinum at 9-17 cm ground sample distance acquired in 2015 and 2016 using fodar, a survey-grade SfM photogrammetric technique. Also included here are 3 of 7 villages (Goodnews Bay, Quinhagak, and Eek) added as an amendment to the contract in April 2016; the remaining 2016 village data will be delivered later along with an appendix to this report. The data delivered with this report meet or substantially exceed all specifications, including the vertical accuracy specification of +/- 39 cm, horizontal accuracy specification of +/- 49 cm, and AOI width of 1500 m (and occasionally more), with only a few exceptions as described in this report which in total amount to much less than our 5% cloud cover allowance.

1. A summary report of all completed field work with a description of each deliverable.

Field work in 2015 commenced on 30 July 2015, about a week after signing the contract, and ended on 12 September 2015. Flights totaled 14,262 miles, acquiring roughly 118,000 photos over about 94% of the intended coastline and about 85% of the overall project. As agreed, blog posts were made from the field on or shortly after each day of flying that detailed each flight, the weather, and the accomplishments that day with text and photos; most of this information will not be repeated here but links are given below and flight tracks can be found in the figures. All village data were processed and delivered beginning October 16 and in final form on 12 Jan 2016 along with a final report for those data; most of this information will not be repeated here. In spring 2016, we provided low resolution orthoimages for the entire 2015 dataset to validate coverage and discuss the 2016 AOI; the contract was subsequently amended to revise the 2015 AOI to complete the Hazen Bay coast, add a new section of coast from Bethel to Platinum, and add 7 villages. Field work in 2016 commenced on 30 April 16 and ended 8 May 18, acquiring roughly 25,000 photos to finish the coastal and inland areas, as well as 5 out of 7 villages added in the contract amendment; the remaining two villages (Bethel and Shaktoolik) will be acquired after this report is submitted and the data delivered with an appendix to this report, describing only deviations from the methods and formats described here, as well as any new ground control assessments.

Table 1. Dates of field acquisitions with links to blogs describing each flight. Our overnight bases were Unalakleet (Unk), Bethel, Nome, and St Mary's and unless otherwise indicated each flight began and ended at the same location.

30-Jul-15	Unalakleet	http://fairbanksfodar.com/success-in-unalakleet-again
5-Aug-15	Unk to Elim	http://fairbanksfodar.com/a-big-day-in-norton-sound
6-Aug-15	Unk to Stebbins	http://fairbanksfodar.com/coast-of-eastern-norton-sound-complete
10-Aug-15	Unk to Bethel	
11-Aug-15	Bethel to Kipnuk	
12-Aug-15	Bethel to Kong	http://fairbanksfodar.com/a-bit-better-weather-in-bethel
13-Aug-15	Bethel to Chevak	http://fairbanksfodar.com/a-happy-day-in-hooper-bay
14-Aug-15	Bethel to Nunam	http://fairbanksfodar.com/mapping-the-dash
19-Aug-15	Bethel to Kipnuk	http://fairbanksfodar.com/tiptoeing-over-tuntutuliak
21-Aug-15	Bethel to Toksook	http://fairbanksfodar.com/two-one-charlie-vs-the-toxic-avenger
22-Aug-15	Bethel to Unk	
23-Aug-15	Unk to Nome	http://fairbanksfodar.com/theres-no-place-like-nome
26-Aug-15	Nome to Cape Rodney	
27-Aug-15	Nome to Wales	http://fairbanksfodar.com/wales-russians-and-snow-oh-my
28-Aug-15	Nome to Wales	http://fairbanksfodar.com/saving-the-wales
29-Aug-15	Nome to St Marys	http://fairbanksfodar.com/the-bombs-of-st-marys
31-Aug	St Marys to Yukon Delta	
1-Sep-15	St Marys to Toksook	http://fairbanksfodar.com/mapping-the-golden-pixel
6-Sep-15	St Marys to Bethel	http://fairbanksfodar.com/west-coast-villages-complete
7-Sep-15	Bethel to Baird Inlet	
9-Sep-15	Bethel to Nightmute	http://fairbanksfodar.com/a-mile-wide-and-a-micron-deep-mapping-the-coastline-from-wales-to-bethel
1-May-16	Bethel to Eek, Kong, Kwig	http://fairbanksfodar.com/eek
4-May-16	Bethel to Platinum	http://fairbanksfodar.com/goodnews-sort-of
5-May-16	Bethel to Goodnews	http://fairbanksfodar.com/more-goodnews
6-May-16	Bethel to Hazen Bay	
7-May-16	Bethel to East Nelson Is.	http://fairbanksfodar.com/not-goodnews-great-news

Deliverables described by this report include:

- Digital Surface Models. These DSMs are described in more detail later in this report and in the figures, but consist of the entire 2015-2016 coastal area acquired at 9-17 cm GSD and posted at a uniform 20 cm for the entire area. We believe their geolocational accuracy to be well within the contract spec from ASPRS 2014 guidance based on our validation efforts here and in the past. No GCPs were used in DSM creation, only validation. Only one photogrammetric block required a shift to meet specs, described later, though below we give recommendations for additional shifts to achieve optimal alignment at the 10-20 cm level (that is, sub-specifications optimization). The DSM are provided as geotiffs, tiled as described later. Point clouds in .las format were also delivered as a courtesy using a similar tiling scheme and are not described further in this report.

- Orthomosaics. The individual photos were orthorectified using the delivered DSM and resulting mosaics output as geotiffs, tiled according to a similar naming convention as the DSMs. We believe their geolocational accuracy to be well within the contract specs based on our validation assessments.
- Tile Index. A tile index for the DSM and orthomosaics is provided in KML format.
- Flight lines. Flight lines for each mission day are provided in KML format, organized by flight date.
- Metadata. Metadata is embedded within each deliverable file suitable for use in any common GIS software. Our understanding is that the State will create FGDC metadata for this delivery based on the file metadata as well as our reports and blogs, as it did for our village delivery in January 2016; we are happy to assist with further information as needed.
- Raw data. Raw data provided includes the GPS files from the Trimble 5700 used in the airplane and all raw images acquired.

2. Overview of data delivery formats and file naming schemes

Both the DSMs and orthomosaics are delivered in geotiff format as described previously, just like the village data delivery in January. The vertical datum is NAVD88 Geoid12B and projected onto NAD83(2011) UTM 3, except for eastern Norton Sound which was processed in UTM 4. The region from Bethel to Platinum crosses the UTM 3/4 boundary several times and was processed only in UTM 3.

The coastal project (that is, not including the village data delivered in January) was broken into 11 blocks and each block given descriptive names based on location, listed below. Each of these segments was treated as a single photogrammetric block for alignment and bundle adjustment to ensure optimal alignment over the largest practical area. After this, some of these blocks were further divided into sub-blocks for DSM and ortho creation on multiple computers; note again that this occurred after the alignment and bundle adjustment, so these sub-blocks are perfectly aligned with each other. For example, the Wales2Nome block was broken into eastern and western sub-blocks. These sub-blocks were further broken down into processing chunks and output tiles, both with a row-column structure appended to the file name with a resulting format of {Block}_{subblock}_{Chunk}_{Type}_{Tile}.tif where {subblock} was optional. For example, file "Kotlik2Stebbins_Chunk_1-2_dem_20cm_0-1.tif" is a DSM from the Kotlik2Stebbins block, Chunk 1-2 (out of six chunks labelled 1-2 to 6-2), and tile 0-1 of Chunk 1-2. The orthomosaics have a similar structure, appended with "_ortho_20cm", using the same block and chunk labels, but different tiles due to data structure and layout. This structure was output from Photoscan and permits easy identification of the Photoscan Project each tile came from, in case reprocessing is necessary. Note that in some of the tables below and in various notes the block names are abbreviated, eg Chevak2Nunam is C2N. Chunks were processed and output with 1-3% overlap, but tiles within them have no overlap.

The exception to the block-subblock protocol described above occurred at Goodnews Bay. This block was the last processed and we were going to reprocess it to improve some issues with alignment that were in spec but could be improved. However, the State was eager to have all data in hand ahead of the deadline so rather than re-align the entire block we re-aligned only the northern half to save time. Without the mountains of the southern-half providing scale, the nearly flat northern half processed about 75 cm lower vertically, though spatially alignment was fine. Because different input data were used for the southern and northern sub-blocks, there are spatially-correlated noise differences on the order of 10-20 cm between them. Thus these two sub-blocks are not perfectly aligned as the others are, but are still well within spec, as shown in the figures. Reprocessing these fully as a single block would restore them to perfect alignment.

So the exceptions to this tiling nomenclature rule are the Hazen Bay and northern Goodnews Bay DSMs, which were raised in elevation and re-output from Global Mapper in a row-column format denoted by letters and number (eg, B-5). Each tile has an associated tile extent boundary in the provided KML file.

3. Details of executed data collection and data processing steps, explanation of any deviations from original Project Execution Plan, all processing steps including software and equipment used.

To our knowledge, no deviations occurred from the Project Execution Plan. All data were collected at a tide lower than MHW. Details of our data collection are provided in great detail in the blogs referenced above, which as agreed serve as a reference for this work. The equipment used in processing has been fully described in our quote, our Project Execution Plan, prior reports and in this paper (Nolan, Matt, Chris Larsen, and Matthew Sturm. "Mapping snow depth from manned aircraft on landscape scales at centimeter resolution using structure-from-motion photogrammetry." *The Cryosphere* 9, no. 4 (2015): 1445-1463), but in short consists of a Nikon D800E and a Trimble 5700 attached together to ultimately to provide photo centers accurate to within about 10 cm, flown in a Cessna 170B at a planned height of 2700' AGL but often as low as 1000' depending on weather. Flight lines were planned at 500 m spacing, but moved closer to accommodate lower flying heights in bad weather, and 4-6 lines were planned or flown over the entire coast. The processing workflow is also described fully in that paper, but in short includes using Agisoft Photoscan as the primary photogrammetric tool. Relevant settings in Photoscan include Aligning images at High, Optimizing, Building a Dense Point Cloud at High with Moderate Filtering, Building a Mesh at High, Building a DEM using the Mesh at 20 cm, and Building an Orthomosaic using the DEM at 20 cm. Once the data were all created, the blocks were compared to each other and to GCPs for both overall validation and network continuity. We found that all data were in spec and no further processing or shifting of the data occurred, except for the 2016 Hazen Bay block which we raised 35 cm and the northern section of Goodnews Bay block which we raised 75 cm.

4. Summary of field operations, including flight lines and data collection times.

Dates of field collections are given in Table 1 and each of the raw photos provided is stamped with EXIF data which includes time accurate to within a few seconds. All of the flight lines are provided in KML format.

Field operations are described in great detail within the blogs referenced in Table 1, but in short they consisted of a daily schedule of checking the weather in the early morning, making a decision as to which mission had the greatest likelihood of success given the weather, and either executing a mission or not. Every phase of all operations were conducted solely by Dr Matt Nolan, including mission planning, weather checking, flying and acquiring data, post-flight data validation, and subsequent data processing.

5. Coordinates of all ground control points that were used in the production of the final deliverables.

No GCPs were used in the production of the data delivered here and no new GCPs were collected by us. We did use the GCPs provided by the State to validate the data.

6. Full accuracy assessment for each delivered product consistent with the quality control laid out in the Project Execution Plan.

We assessed accuracy in three ways: 1) comparison to GCPs, 2) comparisons to previously delivered village data, and 3) comparisons at block overlaps. We assessed DSM misfit at every GCP provided in the coastal areas, but not necessarily every village GCP. Given that the bulk of the GCPs were located in villages and that the village data had already been reduced to those GCPs, we used villages DSM and orthos as pseudo-GCPs to get better statistics than actual GCPs alone could do; we chose only 1-2 villages, as noted, for each block for convenience. Similarly, we created raster difference DSMs at every block overlap to make assessments where no GCPs existed. At the end of each block we included one or more flight lines to extend into the adjacent block to help ensure continuity and provide better comparisons but without duplicating too much processing. We did not trim these data to provide the State with maximum of information. While the extended overlap regions are largely all within spec, some care needs to be taken when interpreting overlap misfits because often there are fewer flight lines utilized in these regions (sometimes only 1 flight line) and if the State uses these data in a WMS server as a single mosaic rather than blocks some care should be taken to trim the blocks where their widest swaths meet. The table below gives an overview of our results and is supported by numerous figures included at the end of this report. The 46 GCPs used in validation had a mean vertical misfit of 14 cm with a standard deviation of 22 cm. Only two GCPs were found outside of spec. Sinuk, was found outside spec (by 2 cm) and we assume given the misfit of the other 7 assessments in this block, including block overlaps, were all less than 25 cm that this point was an anomaly. Similarly, the Bald Head misfit was found to be 65 cm, and given that it was placed in a rock cairn and the other 7 assessments in this block, including block overlaps, were found to be < 25 cm, we again assume this point was an anomaly.

Data quality was also assessed by inspecting each tile visually. Overall, data quality is superb within the AOI and there should be no issues for using these data for their intended purpose and much more. Minor corduroy ripples can be found throughout at the 1-5 cm level; this is the level of random noise. There were perhaps half a dozen small gaps in coverage amounting to less than 1% of total area. There are three instances of processing artifacts in the form of a gap 3-5 pixels wide extending across several kilometers; most of these occurred outside the AOI and where it intersected the AOI it amounts to less than 0.01% of the total area. The origin of these artifacts is still unclear, but delivered as is in the interest of time. Spatially correlated errors are minor, caused by slight misalignment of one or more photos, and we found no instances where these exceeded 20 cm height error or about 5 pixels spatial error, amount to much less than 5% of the total area. Our experience has shown that such errors can really only be quantified by creating difference DEMs using a second acquisition. These results and prior experience have shown that the internal precision of the data is in the 10-20 cm range, such that spatially correlated errors can cause apparent differences of 20-40 cm in difference DEMs. However, even in the extreme cases, because these spatially-correlated errors stand out visually in a difference DEM, signals on the order of several centimeters change can still be detected through careful analysis in combination with the orthomosaics. On steep hillsides, careful examination of shaded reliefs can reveal seam lines between chunks, as the chunks overlap by 1-3% and their edges are constrained differently in mesh creation, but the offsets are only several centimeters at most.

Comparison with the delivered 2015 village data generally revealed minor misfits, all within spec. The coastal data used a mixture of both village and coastal data so it is not expected that they should be identical. Village data were typically acquired on a single day whereas each block of coastal data used data acquired on 2-6 days. Thus with coastal data, GPS from different days are used in the bundle adjustment, which attempts to make the best sense of any systematic errors in GPS data acquired on different days, and this is likely the biggest source of misfit. Further, village data were vertically fit to the GCPs, which likely led to some of them being overfit. Thus some care must be taken when using the 2015 village data for comparisons as any observed misfits may be due to the village data, which in many senses is the weaker photogrammetric solution due to its smaller area and lack of mountains. In one case, the Stebbins & St Michaels combined villages, there were no photo identifiable GCPs and it appears this already-accepted village suffers from the notorious WGS84-NAD83 offset.

The raster were not trimmed to the AOI boundary and thus we have substantially over-delivered inland of what was contracted. We did not rigorously assess the amount of bonus data, but it is likely on the order of 25%. Here various artifacts are larger and gaps more numerous, due to the decrease in sidelap on this inland edge. No significant variations in extent occurred in this delivery compared to the low resolution orthoimage we provided in February. The main reason for not cropping the AOI besides it being potentially useful was due to a shoreline vector not yet being made from these data, but additionally because we tried to start our lines at the water's edge to capture as much mudflat as possible, as discussed in our planning meetings. Thus our measurements of whether full width extents were delivered are in general based on a starting point ocean-ward of the actual MHW mark. There were only a few locations where full width extent was not achieved, notably in the mountainous area near Wales and Goodnews Bay, the southeast side of Nelson Island, and a 30 mile stretch on the south side of Toksook Bay where bad weather forced us to fly our lines lower repeatedly, amounting to under 3% of total area. As agreed, mountainous areas were not a priority and as far as we could determine (given how diffuse the MHW is in some locations), there are no gaps in MHW coverage throughout the entire AOI and an excellent vector of MHW location can be measured by a savvy and patient expert.

Other than the several small gaps and minor artifacts noted above and in the figures, we found no significant errors within the data and that all specs are exceeded. Given the generally poor weather, essentially every gap, minor artifact, and thin swath can be considered a cloud cover issue and out of the 5% allowance we believe these to amount to under 0.5% in total, though we did not calculate this rigorously and on balance this is dwarfed by the approximately 25% overdelivery in inland extent. The primary effect of our QA/QC was to catch blunders in processing. None of the blunders discovered caused the data to be out of spec, but we felt compelled to provide the best data possible. These took the form of outputting at the wrong resolution (always too high), missing some imagery as input, projection errors in GPS or photogrammetric processing, and the like, which were all solved by investigation and reprocessing. Thus though we did not use the GCP for the processing itself, they were useful in catching these blunders and we therefore believe that some form of ground control will always be useful, especially in large projects like these with ample opportunities for blunders.

Though the data were delivered several weeks before the contractual deadline, production speed could be significantly improved through lessons learned. By far the biggest delay in delivering these data was delivering the village data six months ahead of the contractual deadline to accommodate the State by providing the most publicly useful data first. That effort processed roughly 1/3 of the total photos and took 3.5 months, though a significant portion of that time was post-delivery effort. Because processing the coastal data incorporated the bulk of the village photos, the village delivery caused a duplication of effort of several months. Power outages due to winter storms and summer lightening probably caused another month of pure delay. These outages not only cause 4-5 days of processing to be repeated on several computers, but often they caused corruptions to earlier steps of processing already saved, and this corruption was only discoverable at the end of the second attempt of 4-5 days processing. This means reprocessing the earlier step a second time and the interrupted for a third time. Standard UPS have proven insufficient to prevent these interruptions reliably, as they do not have the power storage to power these large server computers long enough to hibernate depending on task and memory usage. Hardware failures and flaky hard disks also caused notable delays in troubleshooting and reprocessing. And of course the various blunders and improvement tweaks caused reprocessing efforts that suffer from all of the above. Despite these delays, processing still only took 5 months from start to delivery, which is a significant accomplishment in its own right for such a data set of such unprecedented magnitude and quality, though in the future an expedited delivery could likely be made within 3 month's time.

Table 2. Summary of validation assessments. See Figures for more details on these assessments. Negative vertical misfit mean that the DSM was higher than GCPs. Horizontal misfit of < 20 cm means that the GCP is as good as can be measured by eye (within a pixel). Many GCPs have no photoidentifiable targets in the orthomosaic, but all of those were found to be in the correct area based on the GCP field photos.

Block #	Block Name	GCPs, Overlap, or Village	Vertical Misfit	Horizontal Misfit
1	**Wales2Nome**	Lost River	-0.12	< 20 cm
		KTS2	0.08	coastal is ~40 cm south
		KTS3	0.25	coastal is ~20 cm south
		KTS7	-0.02	coastal is ~30 cm south
		Sinuk	0.51	< 20 cm
		Wales Village	0.15	< 40 cm
		Brevig Village	0.05	coastal is ~30 cm south
		N2E Overlap	< .2	"+/- 20 cm
2	**Nome2Elim**	ELI5	-0.1	< 20 cm
		Rocky Point	0.3	Not photoidentifiable (but looks right)

		Darby	0.2	< 20cm
		Bluff	0.1	Not photoidentifiable (but looks right)
		Soloman	0.09	Not photoidentifiable (but looks right)
		Elim	0	<20cm
		OME1	0.25	< 20 cm
		OME7	-0.16	coastal is ~20 cm south
		OME8	0.1	coastal is ~ 40 cm south
		Eli5	-0.1	< 20 cm
		Nome village	0	< 20 cm
		Elim village	0	< 20 cm
		W2N overlap	< .2	"+/- 20 cm
		Norton overlap	0	< 20 cm
3	**Norton UTM4**	Bald Head	0.658	not photoidentifiable (but looks good)
		Egavik	0.127	not photoidentifiable (but looks good)
		Oliver	0.277	not photoidentifiable (but looks good)
		Reindeer		
		Tolstoi	0.244	not photoidentifiable (but looks good)
		Ungalik	0.021	not photoidentifiable (but looks good)
		k2S overlap	0	< 20 cm
		N2E overlap	0	< 20 cm
4	**Kotlik2Stebbins**	Romanof	0.14	not photoidentifiable (but looks good)
		Kotlik village	0.1	< 20 cm
		Stebbins village	NA	Stebbins is 1.4 m off due to projection
		Norton overlap	0	< 20 cm
		Yukon overlap	-0.3	yukon is ~35 cm west of kotlik
5	**Yukon Delta**	Alakanuk	0.19	<20cm
		Emmonak	0.3	not photoidentifiable
		Emmonak Village	0.25	< 40 cm
		Kotlik village	0.25	
		K2S Overlap	0.3	yukon is ~35 cm west of kotlik
		C2N Overlap		N/A no overlap
6	**Chevak2Nunam**	Black	0.13	not photoidentifiable (but looks right)
		Melatolik	-0.05	not photoidentifiable
		Scammon	0.17	< 20 cm
		Towak	0.32	not photoidentifiable (and poor vertical gcp)
		Kokechik	0.19	not photoidentifiable

		Nunam	0.27	not photoidentifiable
		Hooper Bay	-0.14	< 20 cm
		Cheevak	0.01	< 20 cm
		Nunam Village	0.1	<20cm
		Hooper Village	0.1	< 20cm
		Yukon overlap	N/A	
		Hazen Bay overlap	-0.35	< 20 cm
7	**Hazen Bay**	Kashanuk	0.16	<20 cm
		Opagyarak	0.28	< 20 cm
		Manokinak	0.32	< 20 cm
		Naskonat	0	not photoidentifiable (but looks right)
		Newtok	0.1	< 20 cm
		Metarvik	0	not photoidentifiable (but looks right)
		Newtok village	0.1	< 20 cm
		C2N overlap	0	< 20 cm
		East Nelson overlap	-0.35	< 20cm
8	**East Nelson**	Metarvik	0.197	not photoidentifiable (but looks right)
		Chakchak	0.48	< 20 cm
		Hazen overlap	0	< 20 cm
		B2T overlap	NA	ramp in single pass
		Toksook overlap	0	< 20 cm
9	**Toksook**	Erhchakrtuk	0.26	not photoidentifiable (but looks right)
		Toksook	0.2	< 20 cm
		Tununak	-0.37	not photoidentifiable (but looks right)
		Toksook village	0.02	< 20cm
		Tununak	0.02	< 20 cm
		Hazen overlap	NA	no overlap
		B2T overlap	-0.2	
10	**Bethel2Toxic**	Koskovak	0.38	
		Kong	-0.04	< 20 cm
		Kwig	0.27	< 20 cm
		Loon	0.34	< 20 cm
		Nightmute	0.06	< 20 cm
		Kong village	-0.05	< 20 cm
		Toksook overlap	0.2	< 40 cm
		East nelson overlap	NA	ramp in single track

11	**Goodnews**	0609_001	-0.095	< 20 cm
		0609_003	-0.208	< 20 cm
		0609_0011	0.016	20 cm (but loose sheet metal)
		0609_0013	-0.137	< 20 cm
		0609_0014	-0.211	< 20 cm

Table 3. Suggested vertical and horizontal shifts for optimal sub-spec alignment.

	Block	Move North	Move East	Move Up
1	Wales2Nome	-0.25	0	0.15
2	Elim2Nome	-0.1	0	0.1
3	Norton_UTM4	0	0	0.1
4	Kotlik2Stebbins	0	0.2	0
5	YukonDelta	0	0.25	0.25
6	Chevak2Nunam	0	0	0.1
7	HazenBay	0	0	0
8	EastNelson	0	0	0.2
9	Toksook	0	0	0
10	Bethel2toxic	0	0	0.15
11	Goodnews	0	0	-0.1

7. All field notes, as well as all original raw data.

Our field notes consist solely of the blogs referenced in Table 1. The original data provided includes the Trimble 5700 data and the raw image files collected from the air. The Trimble data are all in a single directory using the original file names and the photos are organized in folders by acquisition date, separated further with folders by data card (eg, “CF1” or “SD3”) if applicable.

Figures

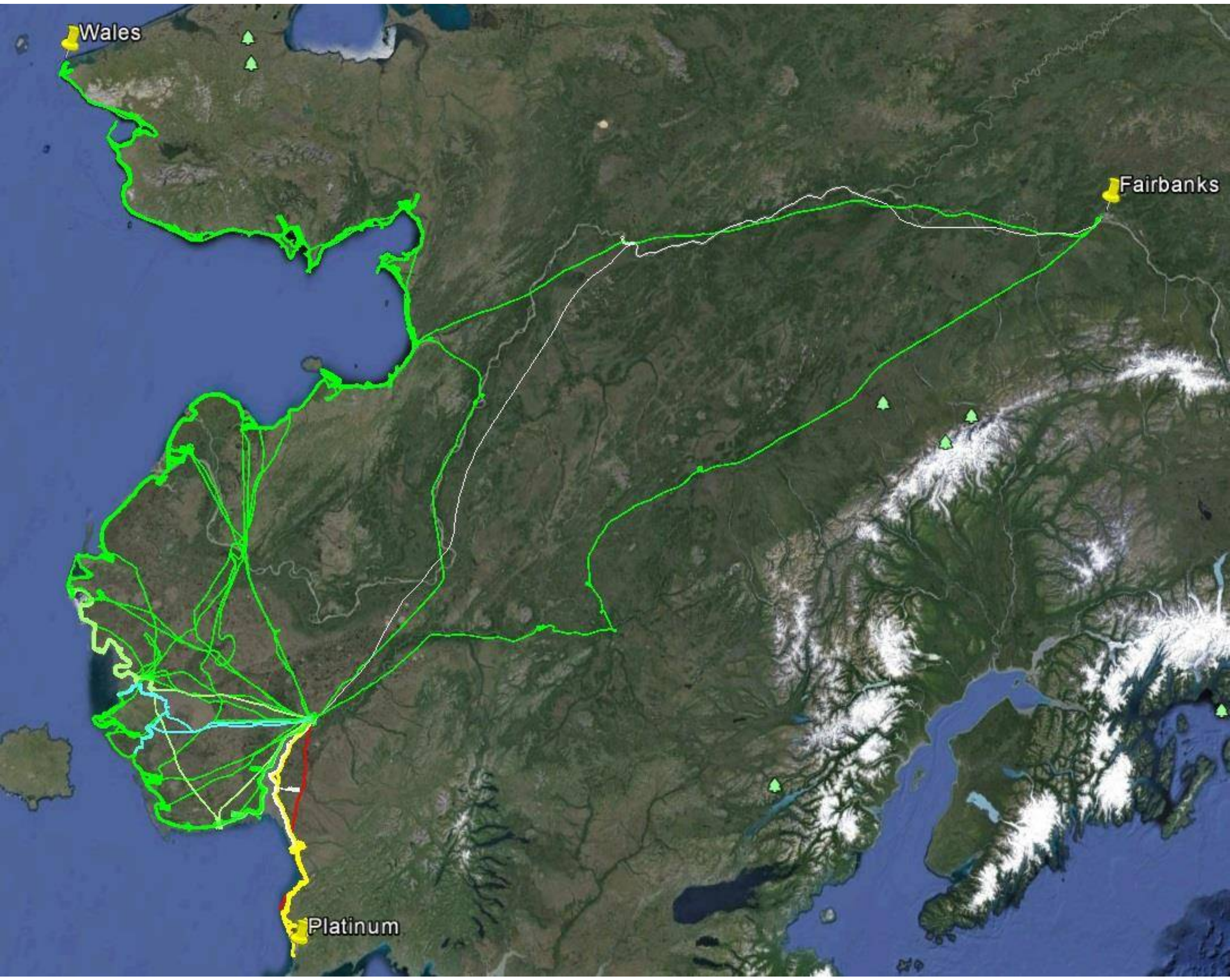
These figures are arranged by photogrammetric block from north to south.

Each section begins with a selection of GCP, village, and block overlap comparisons, though not every comparison used in validation has a figure here. In all cases where a colormap was used for difference DEMs, the range is +40 cm to – 40 cm.

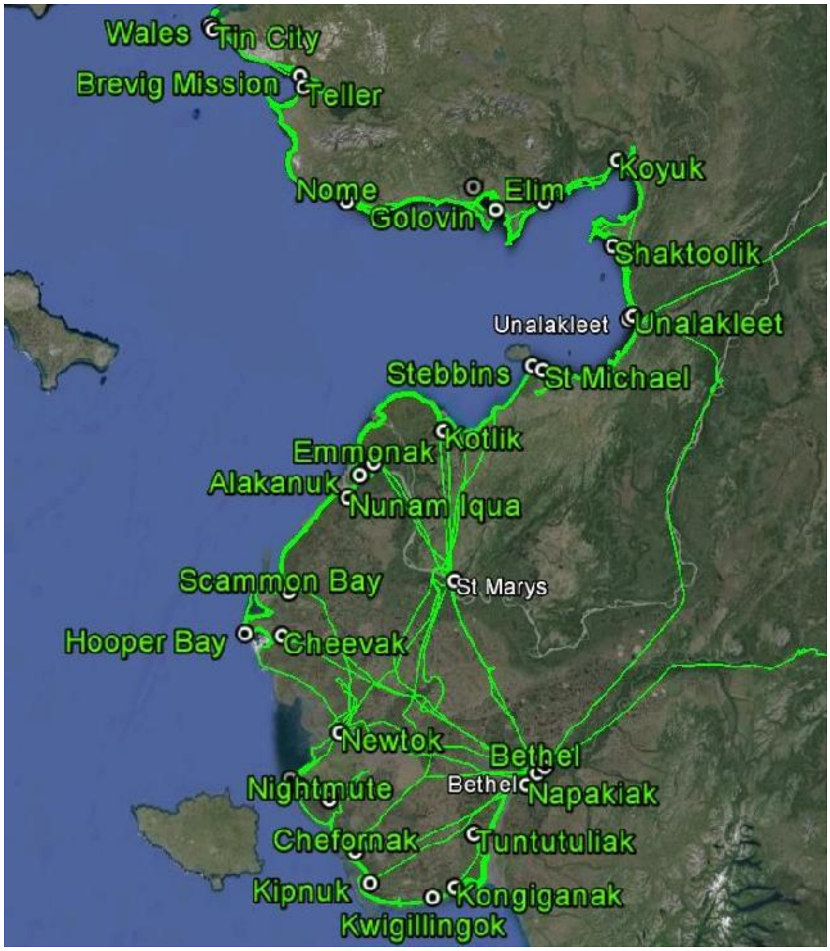
Then any anomalies found within the data are presented, or a representative selection of them.

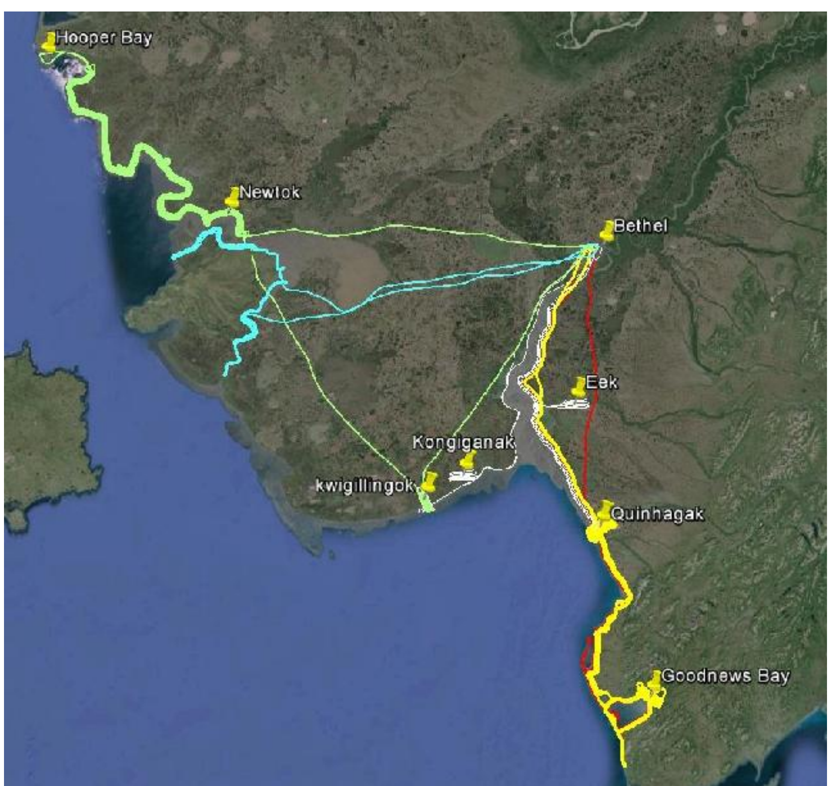
Lastly, a selection of image pairs showing data quality and scientific features of interest are presented. The DEM and ortho images for each location are presented on separate pages, such that the reader can flicker back and forth between them to see how they correspond. The blue shading in the DEMs indicates simulated sea level in the 1.5 m – 2.5 m range for graphic effect and is not meant to be used scientifically.

While image quality is compressed a bit here, don’t forget you can zoom to see further detail.



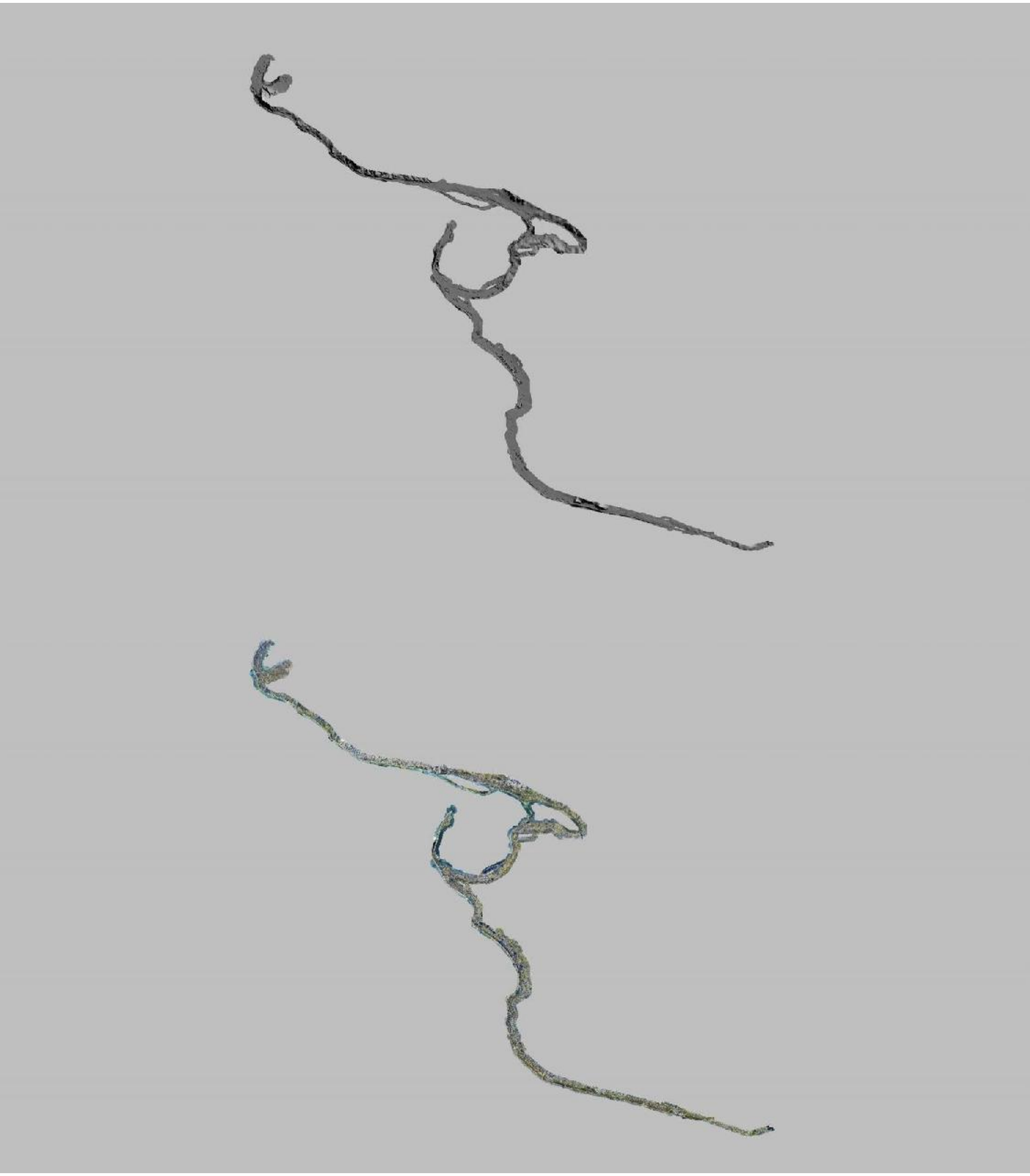
Flight tracks from 2015 and 2016.



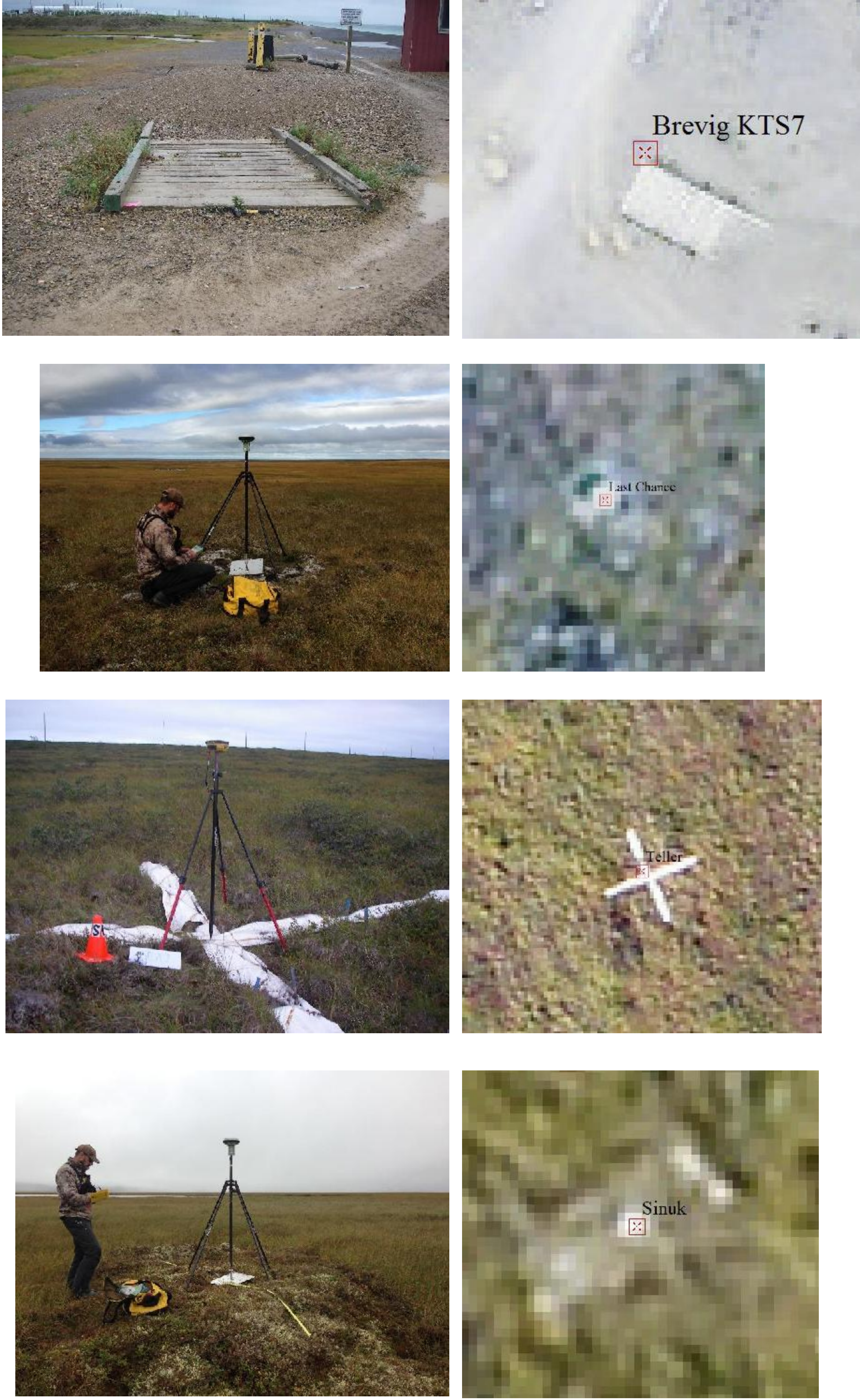


Flight track detail from 2015 (top) and 2016 (bottom).

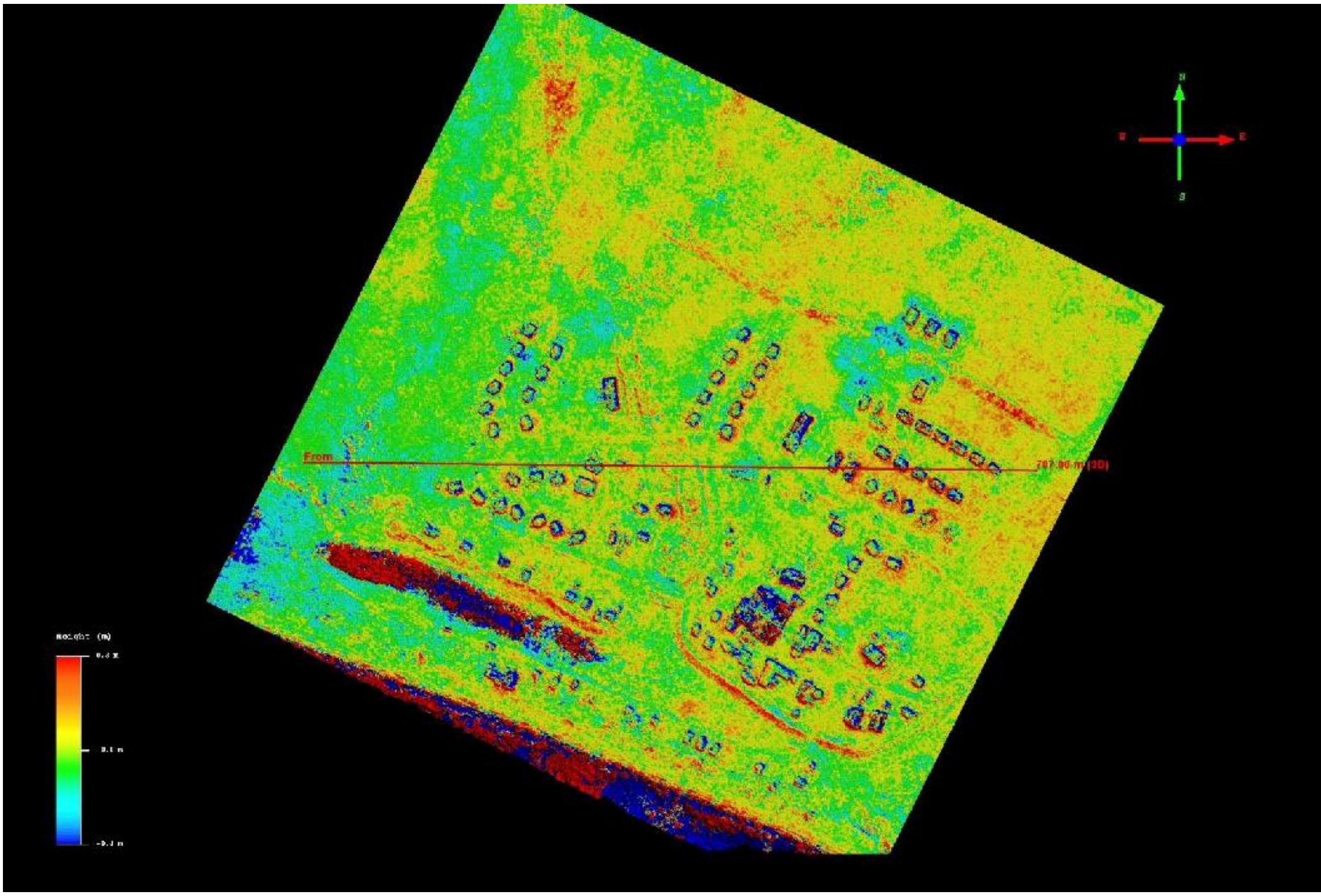
Wales to Nome Block

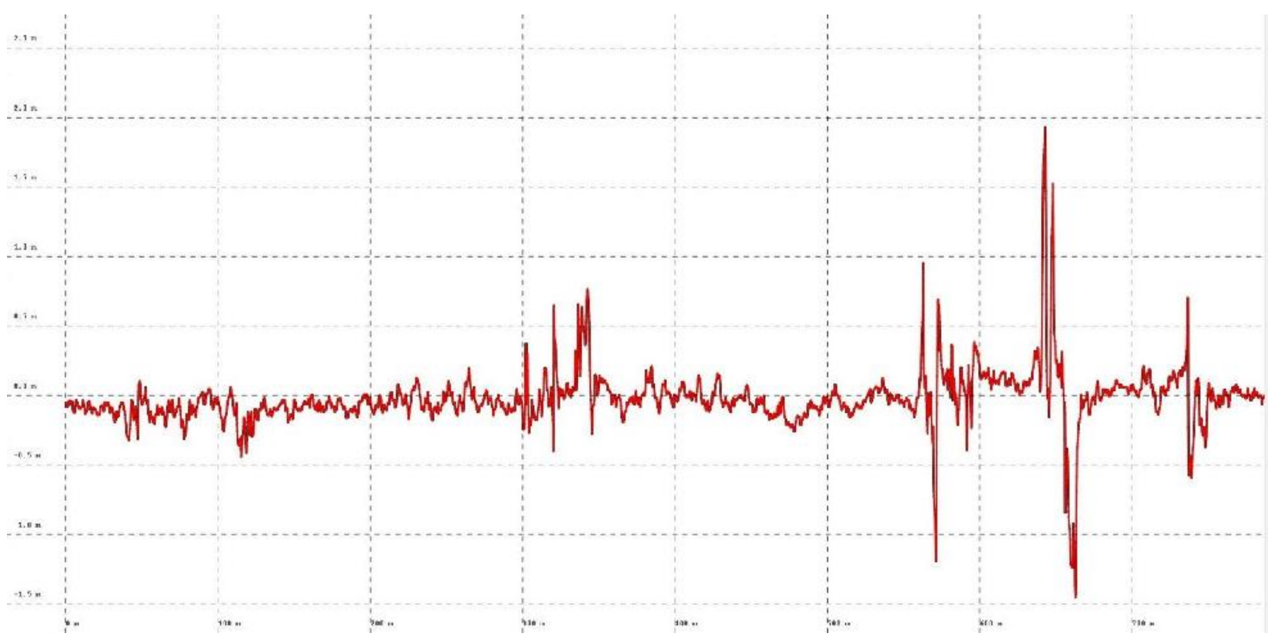


Overview of DEM and orthomosaic

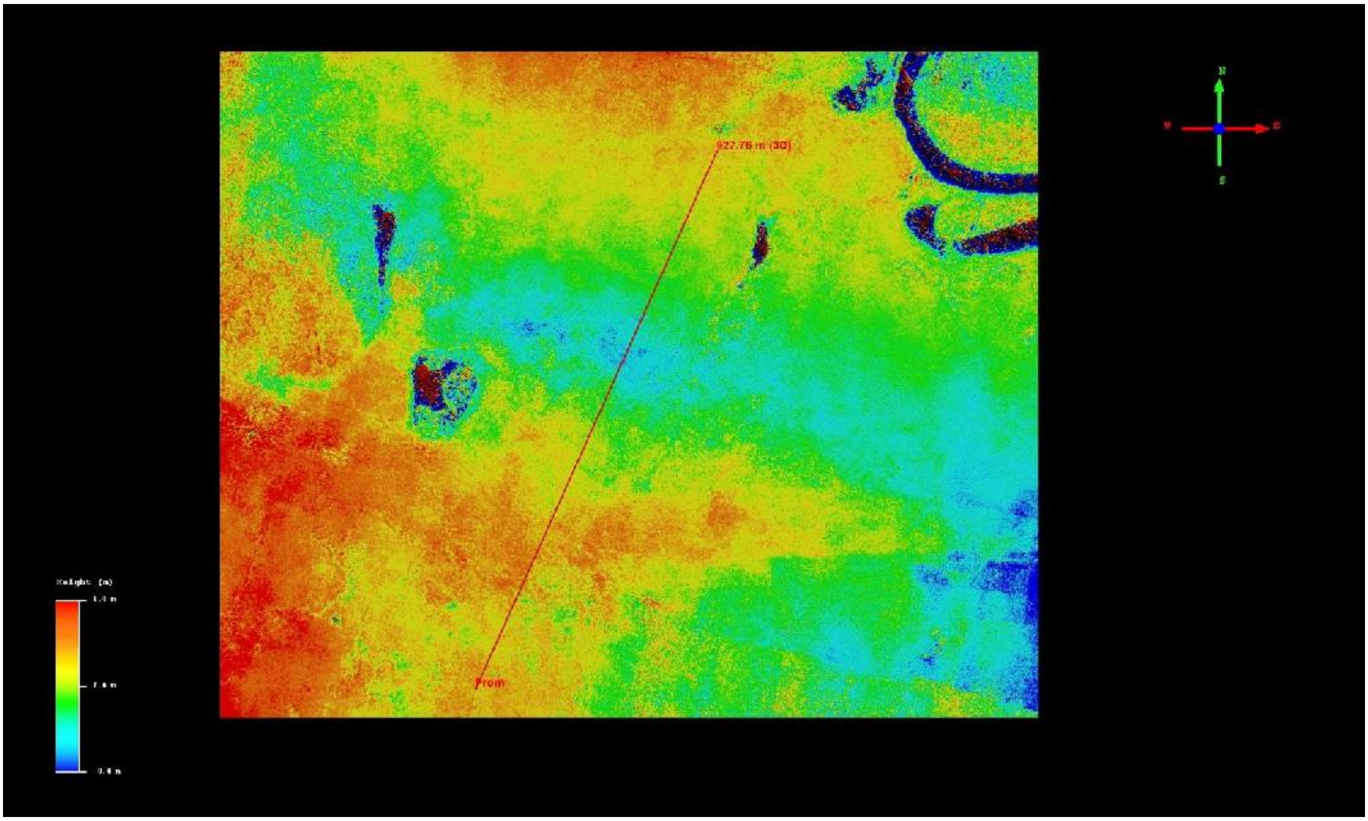


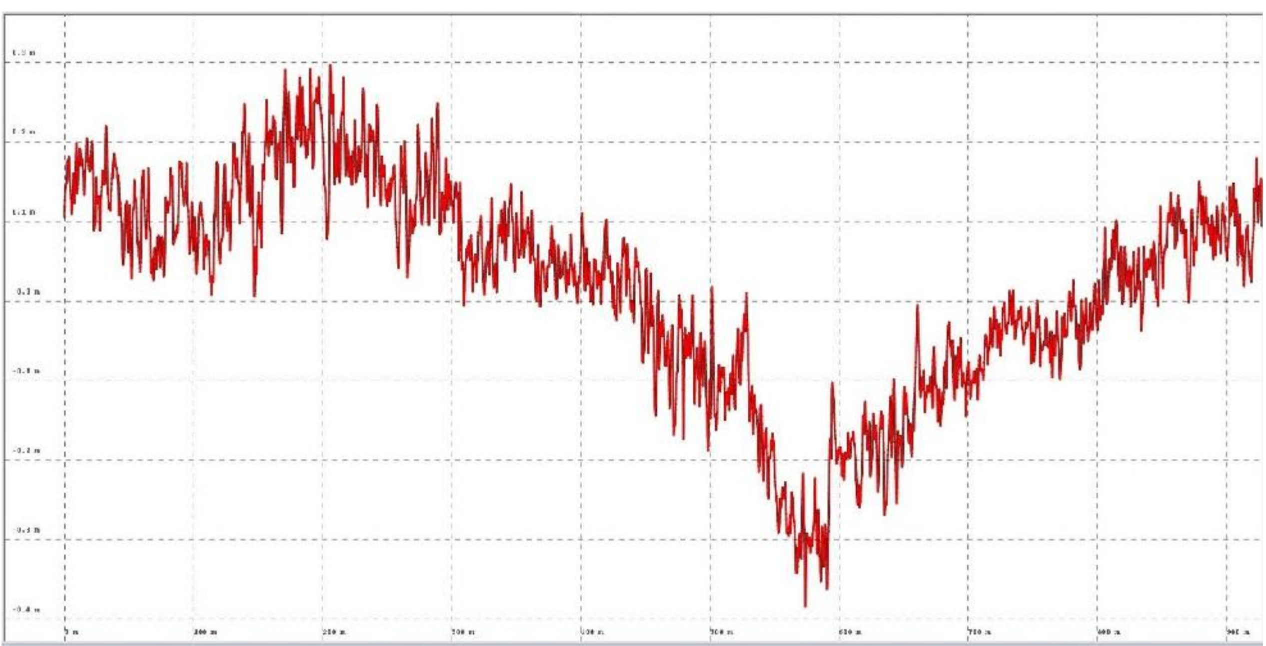
GCPs



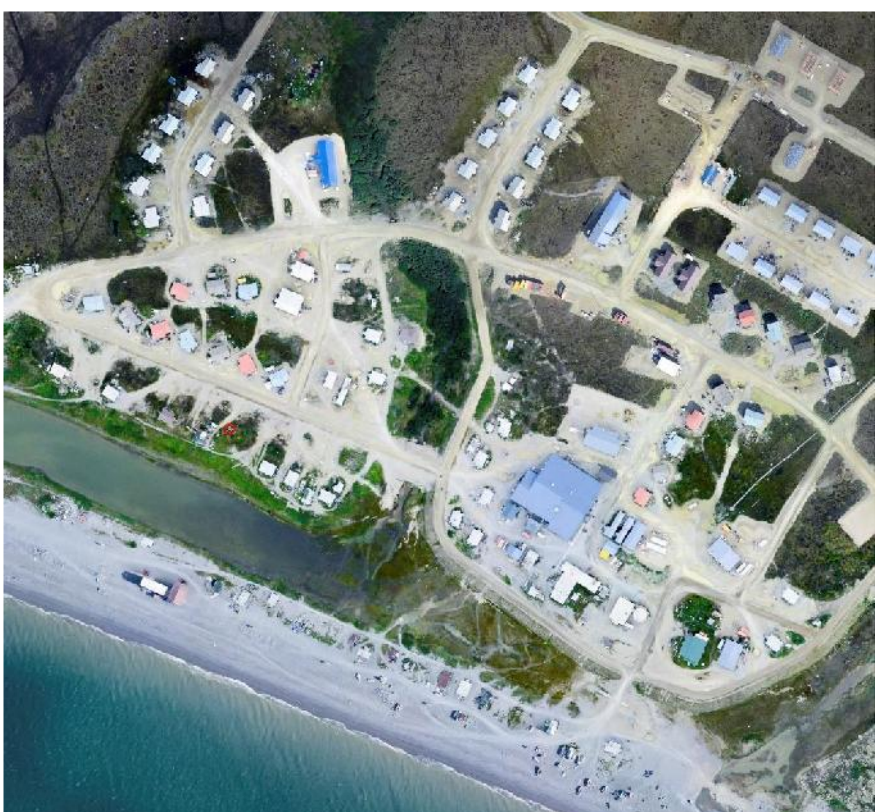


Difference image of Brevig Mission village to coastal data. Elevation differences are less than 20 cm, except at building edges and water bodies. The coastal data appears to be about 30 cm south of the village data.



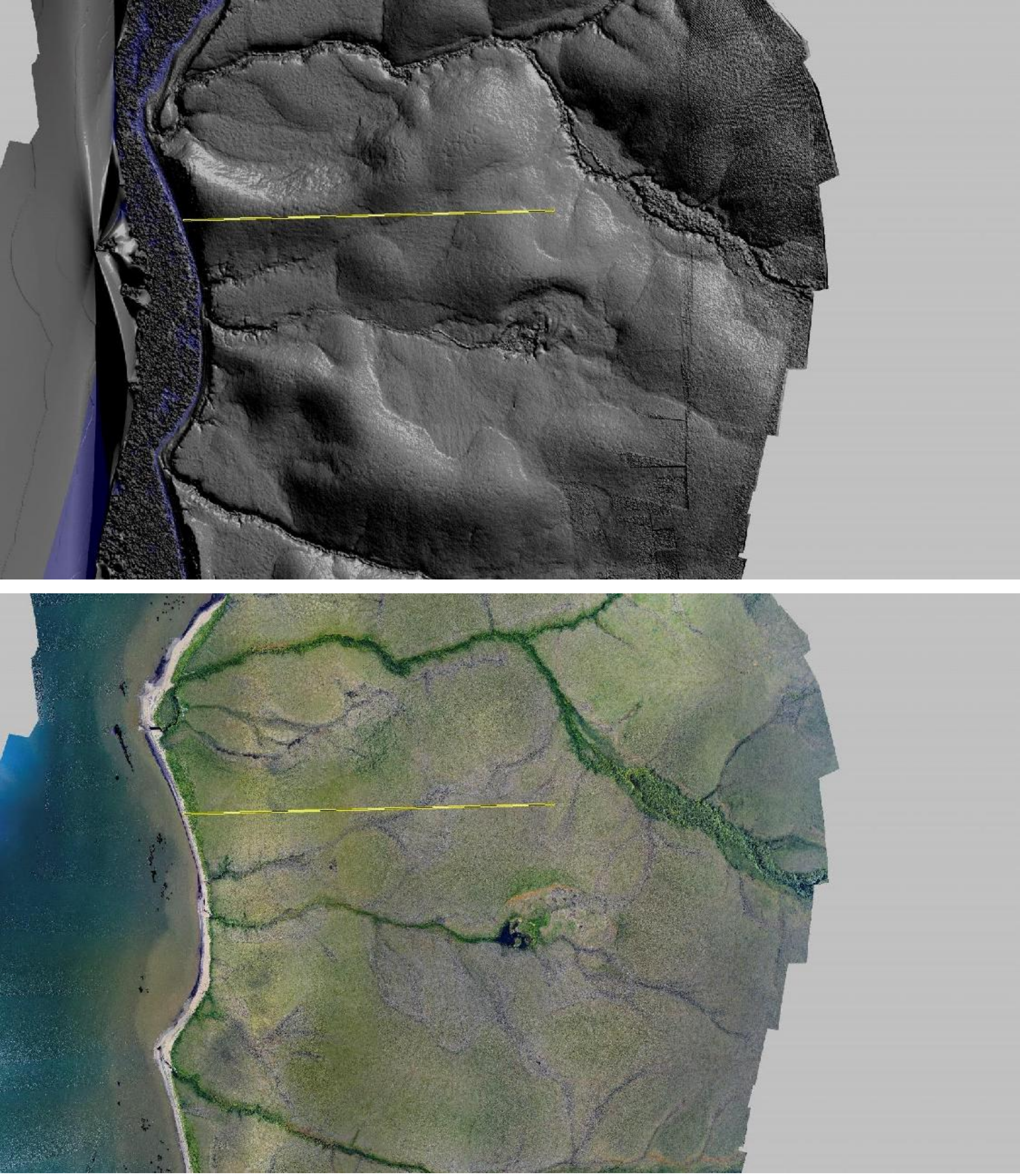


Difference image of overlap with Nome2Elim block. Elevation differences have a random noise of about +/- 5 cm and a spatially correlated noise of about 25 cm. This is average for the entire data set.

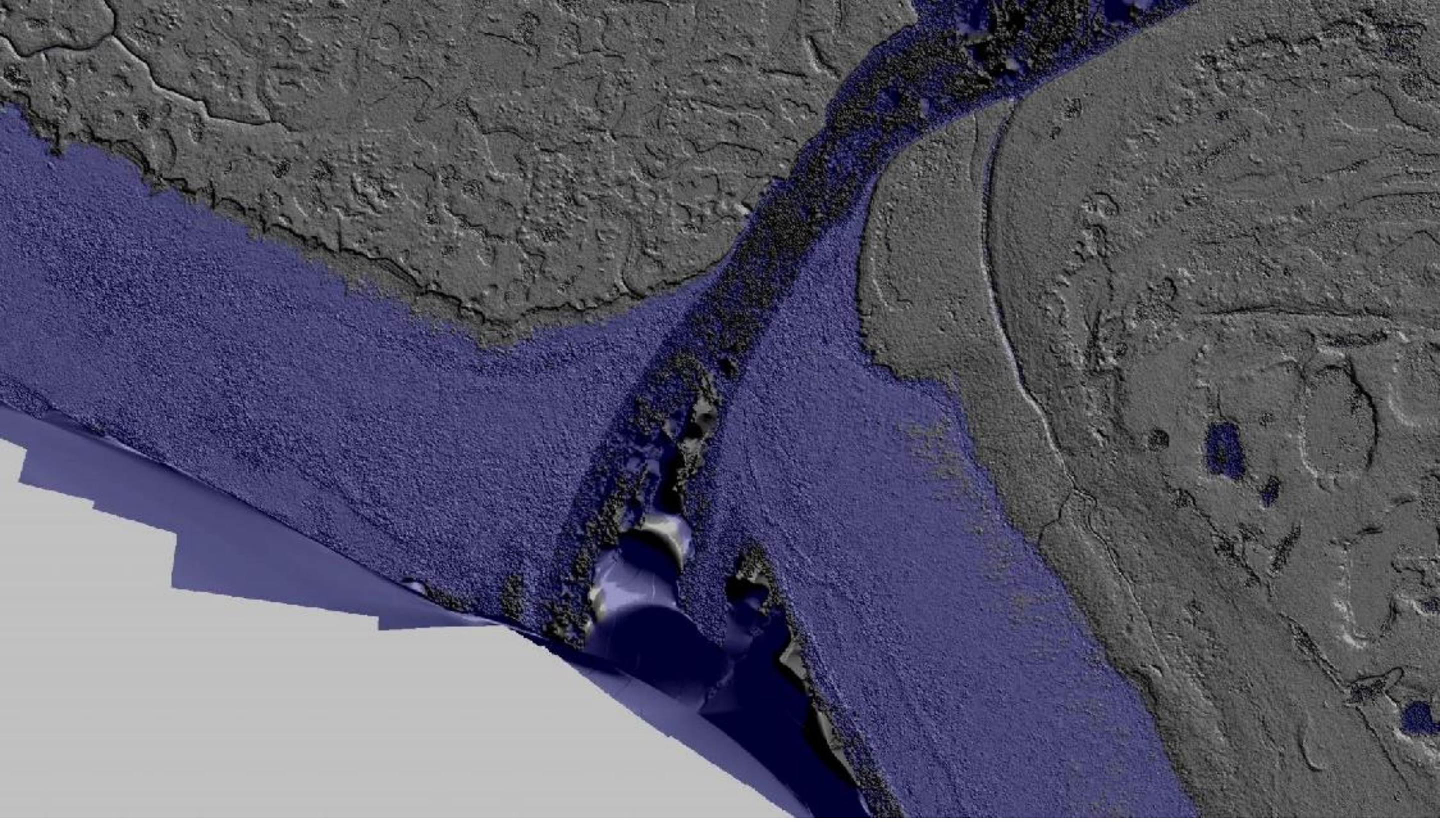


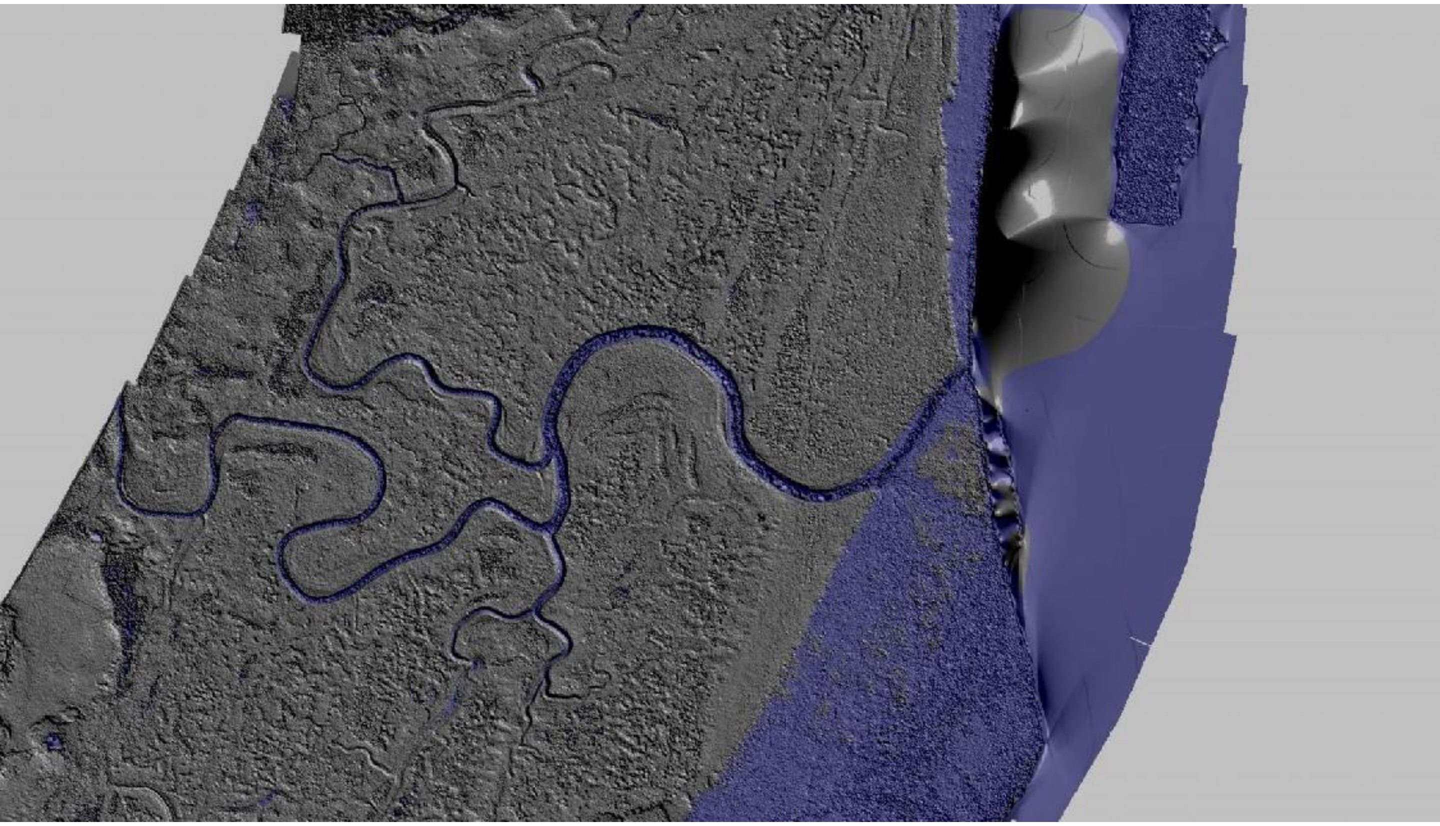
Examples of horizontal misfit assessment using village data, Brevig in this case. These images are from the village data. Flicker with the next page to see the coastal delivery.

Examples of horizontal misfit assessment using village data, Brevig in this case. These images are from the coastal delivery. Flicker with the next page to see the village delivery. A 1-2 pixel offset was common.

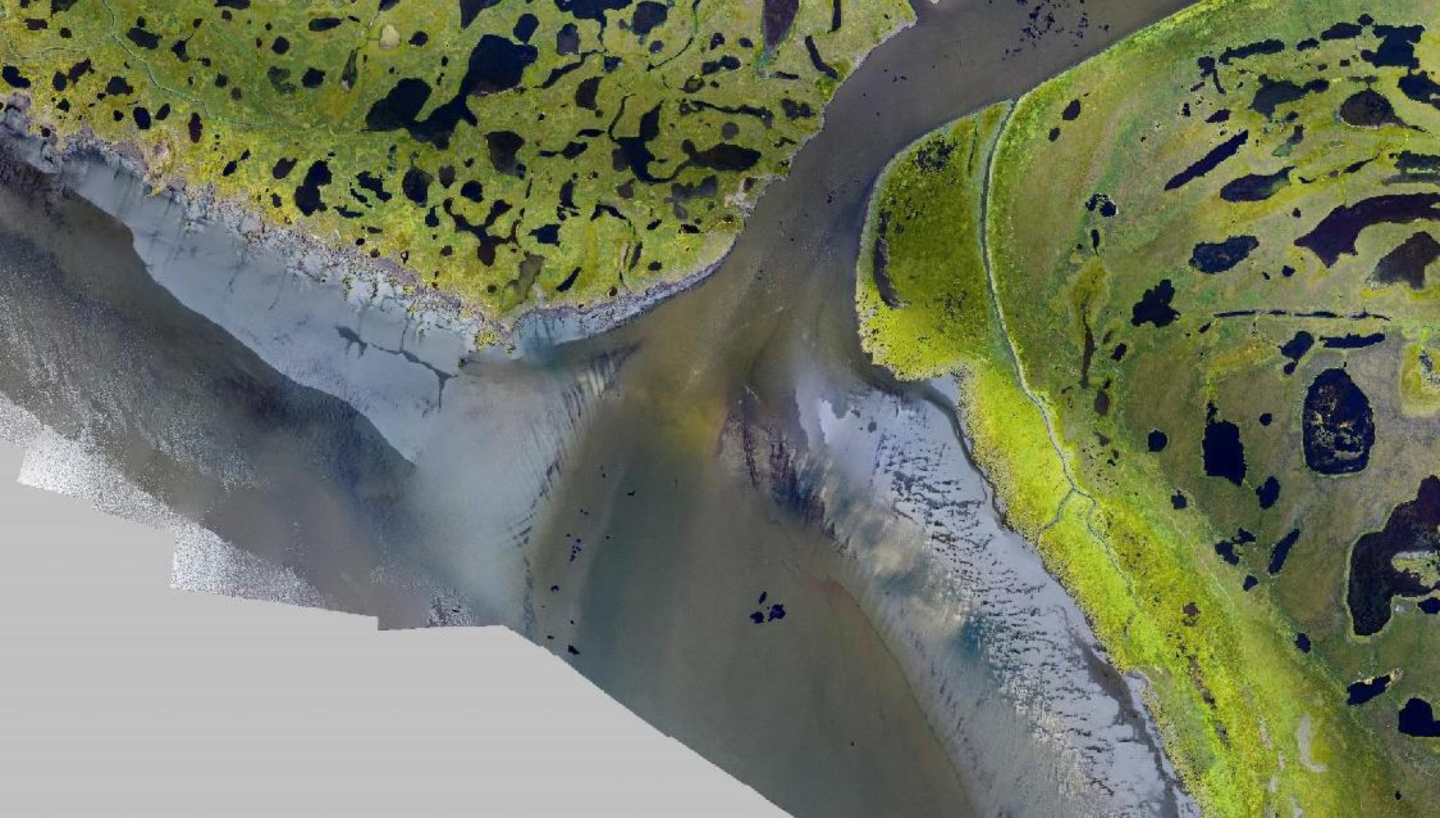


Yellow line indicate 1500 m, the AOI spec. Notice that outside this area are examples of spatially correlated noise due to low overlap causing 10-80 cm deep rectangular. The orthoimage is essentially unaffected by this. These pits are not uncommon outside the AOI in the 10 – 40 cm range, but we only found two cases of it exceeding the vertical accuracy spec within the AOI – one east of Nome and another in southeastern Norton Sound, both caused by low overlap due to flying low to avoid clouds, and both small in area.

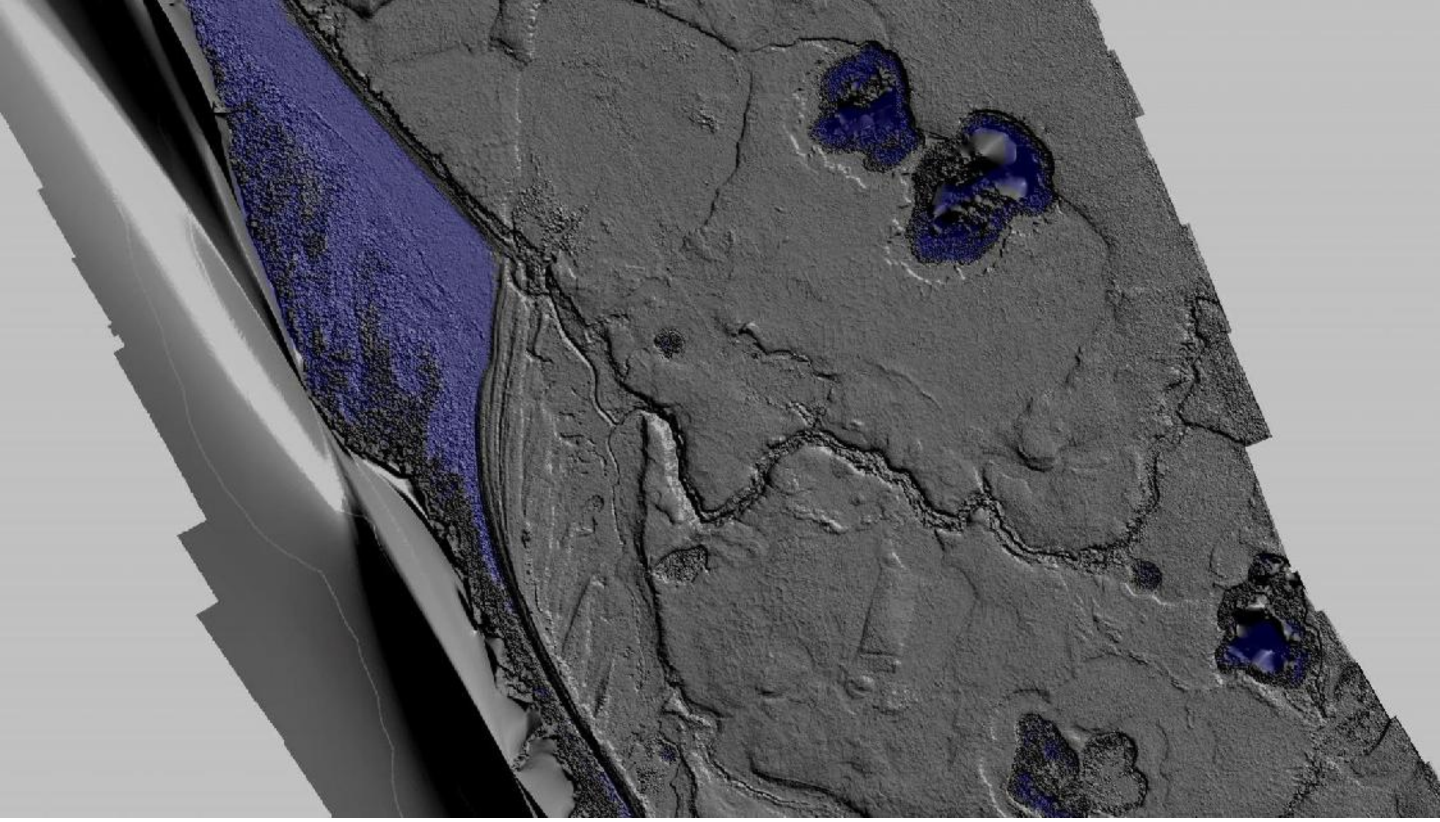


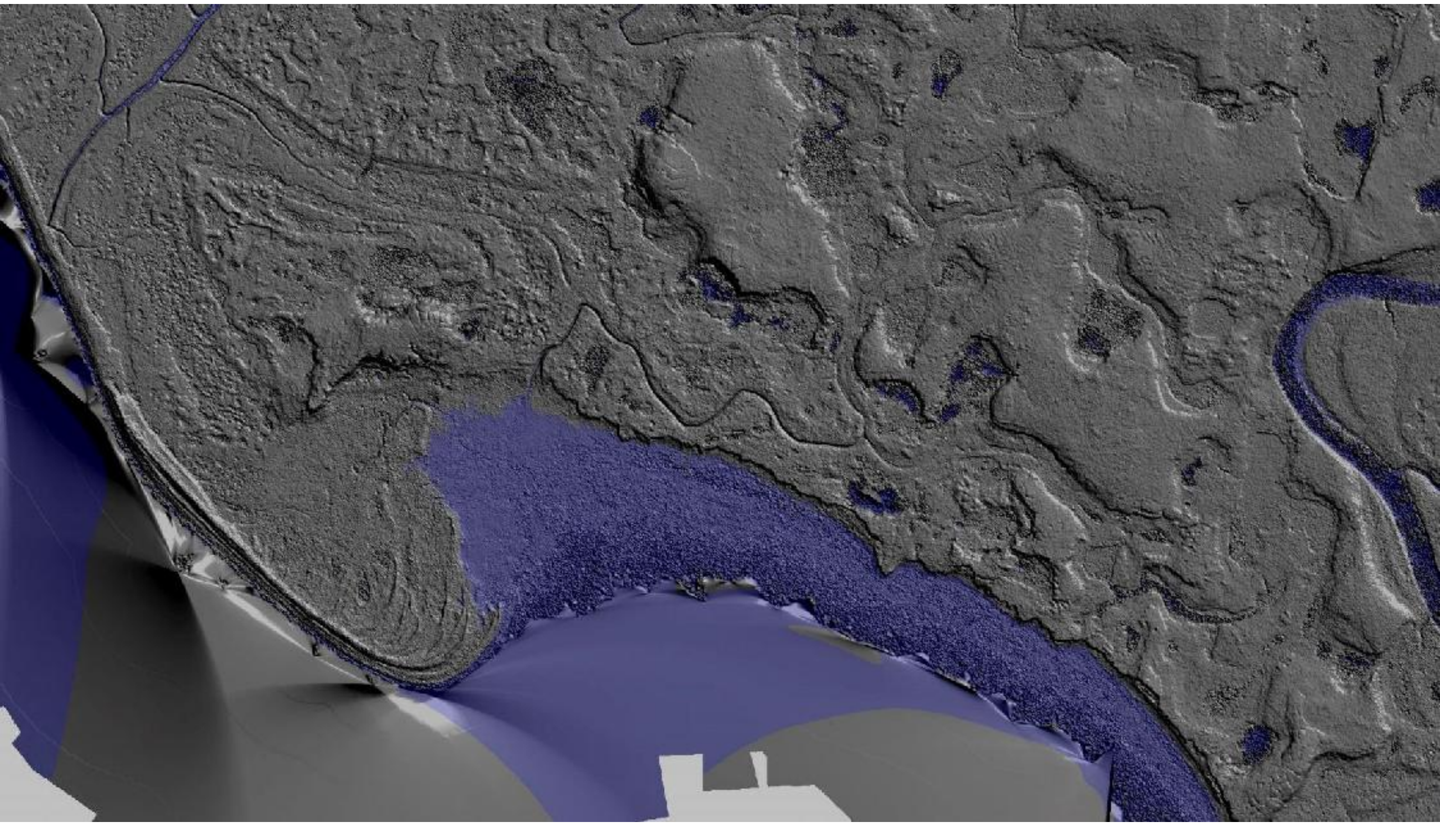


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

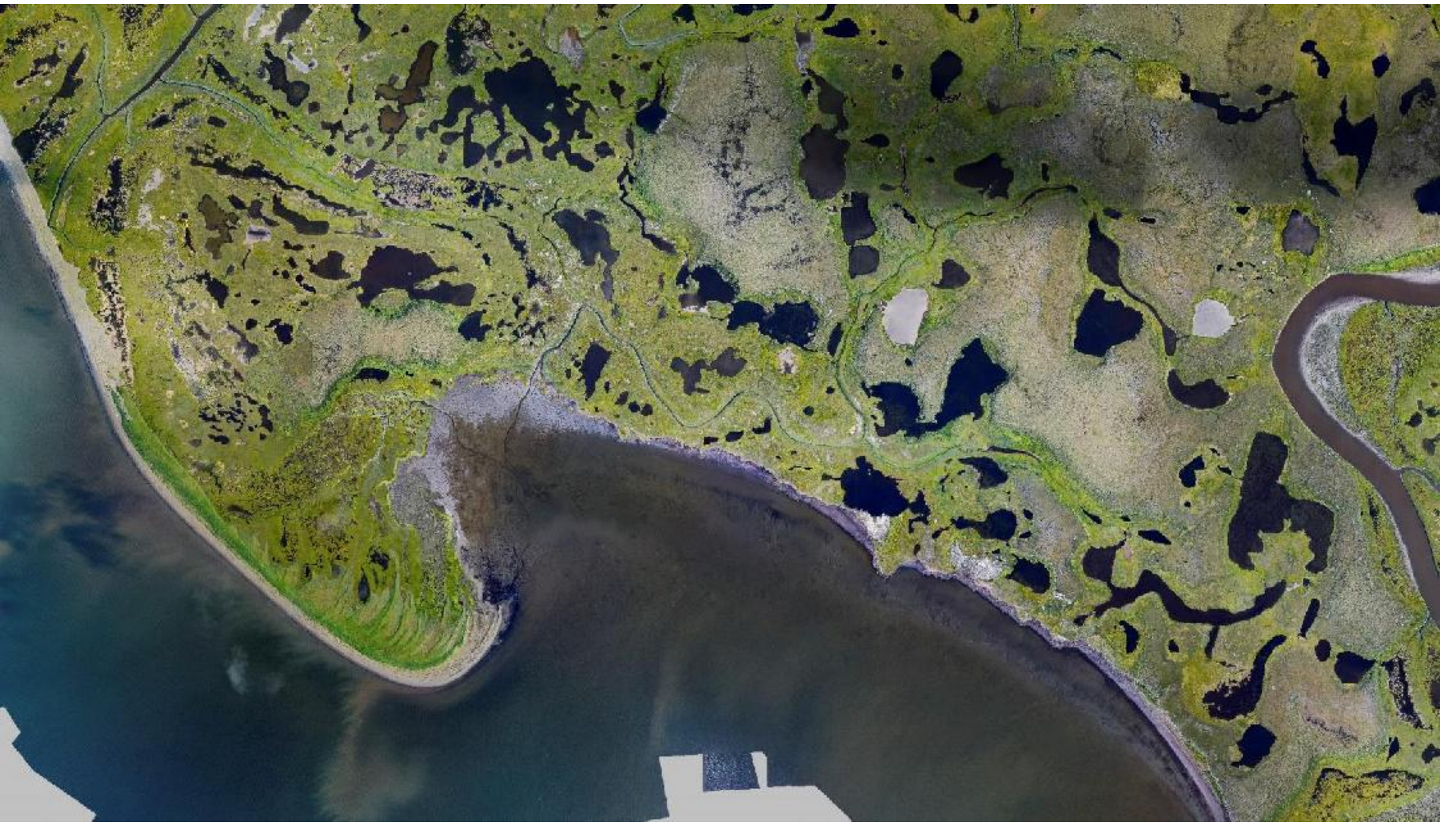


Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

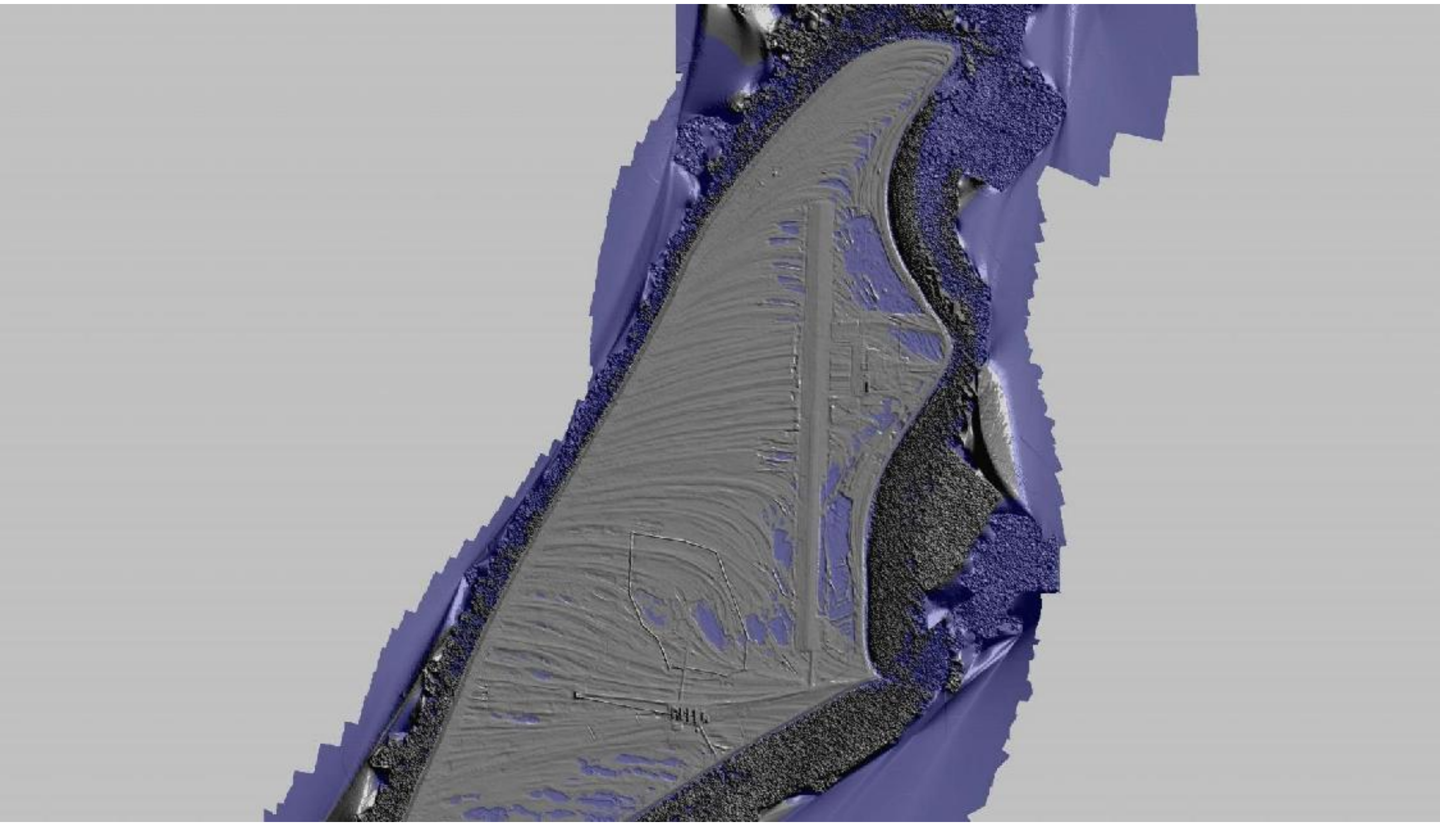




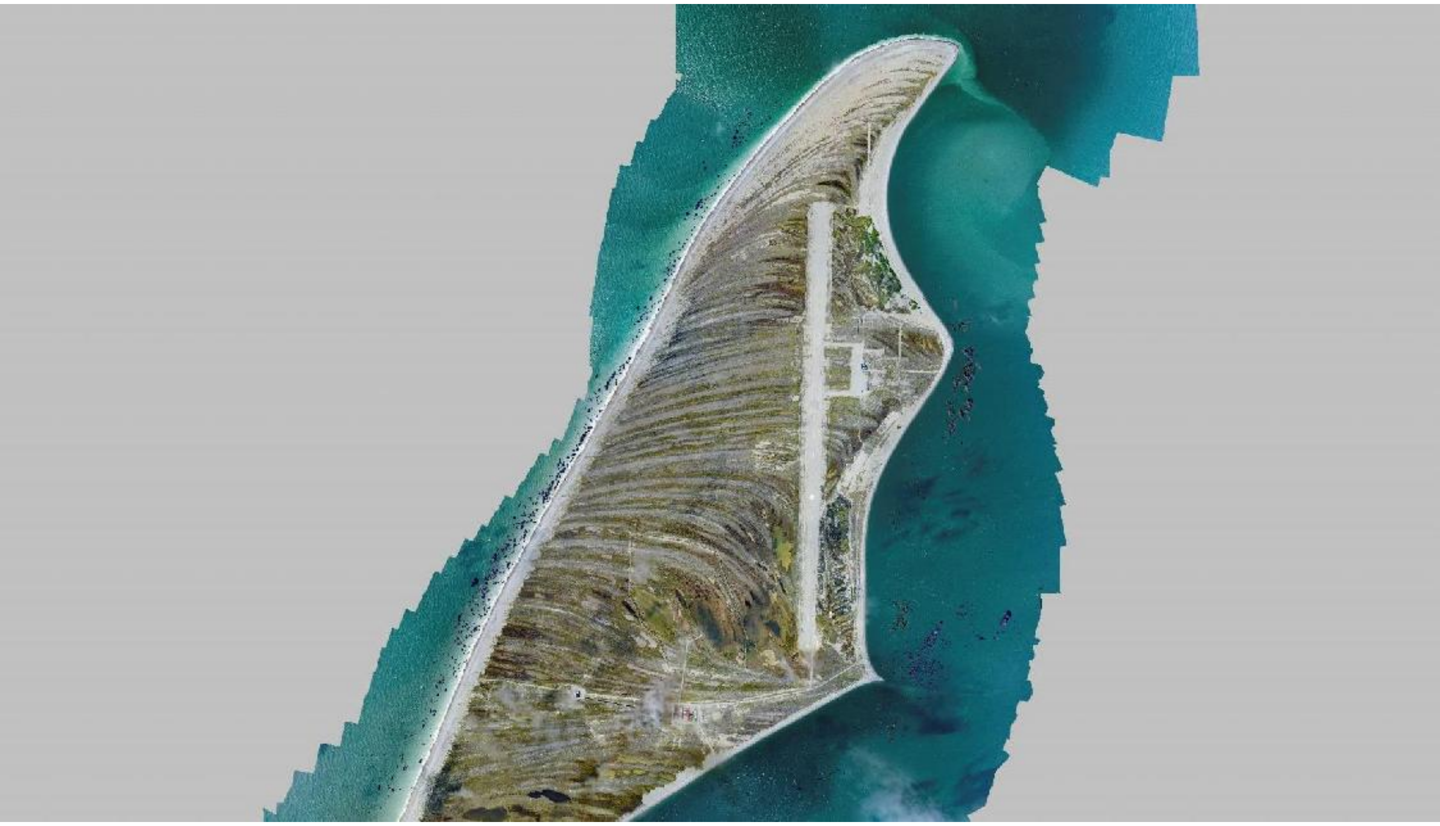
Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.



Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

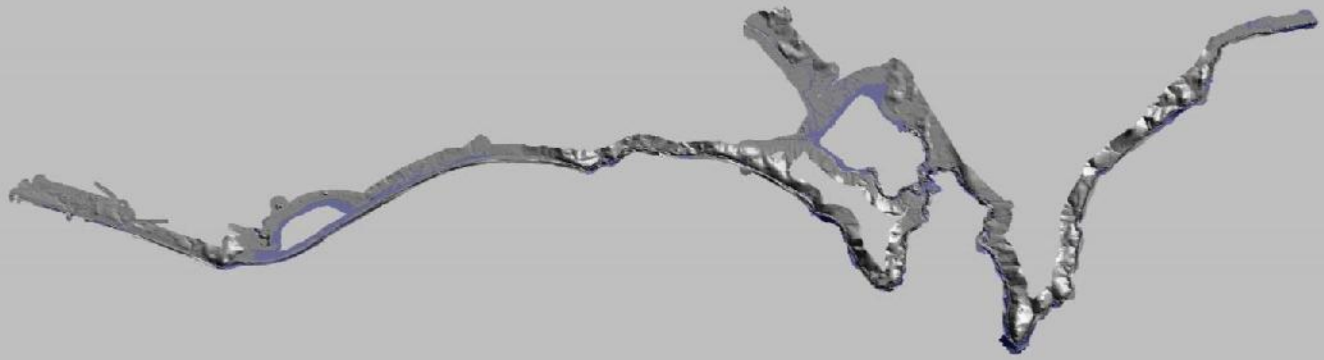


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

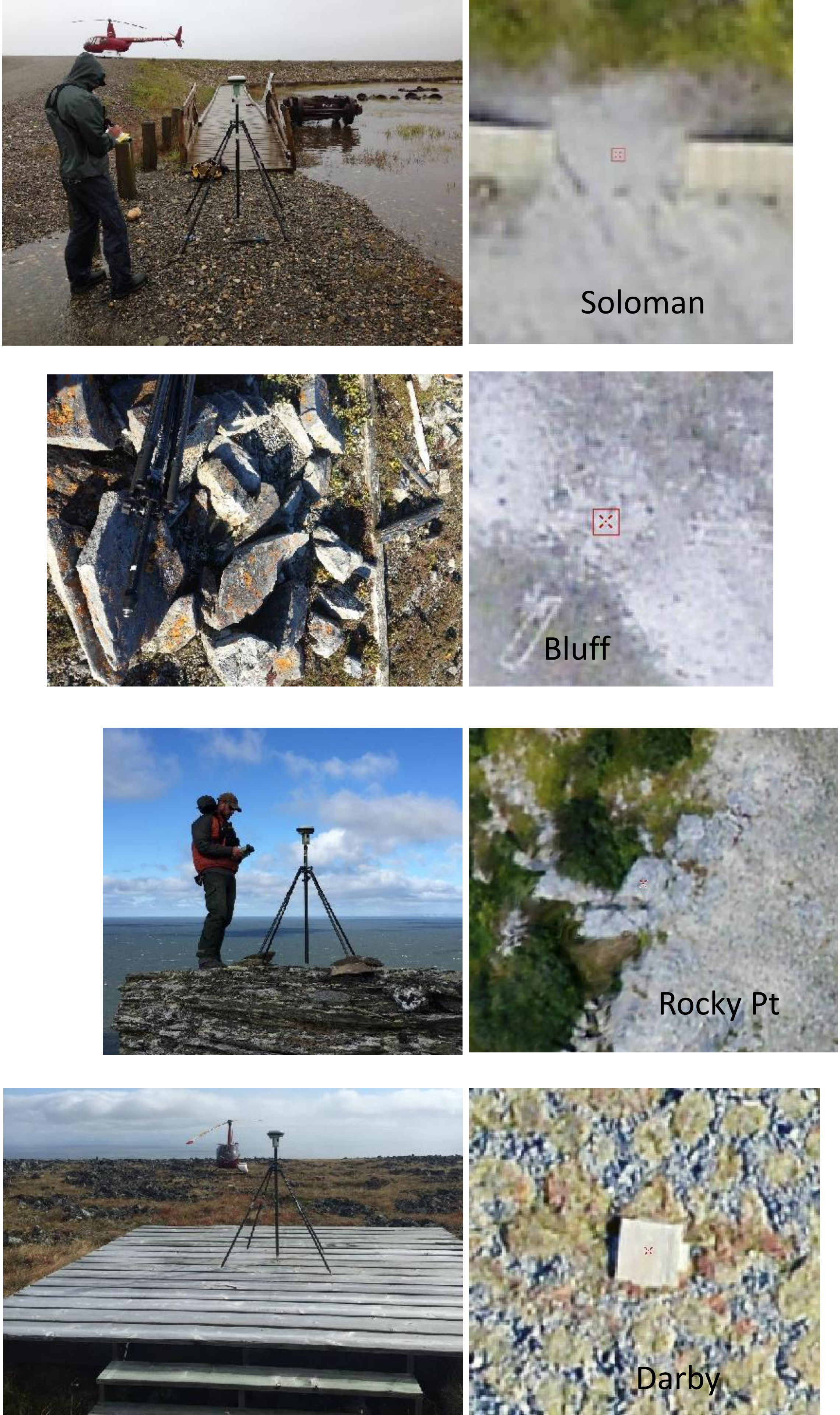


Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

Nome to Elim Block

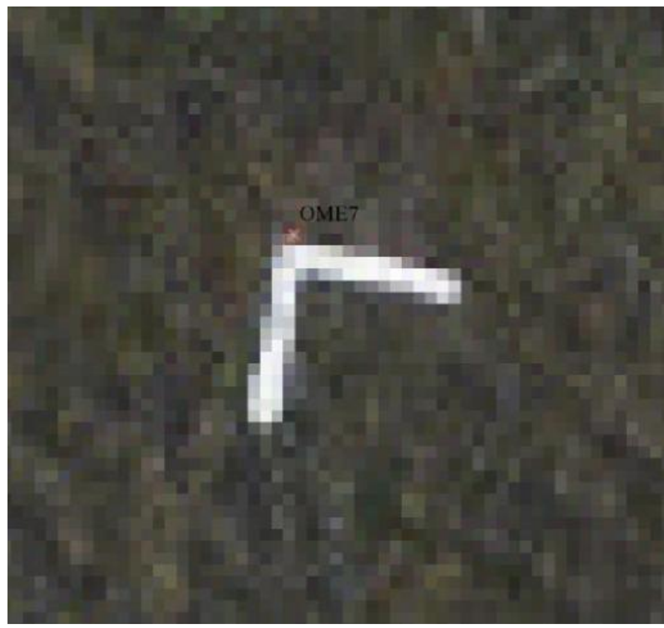


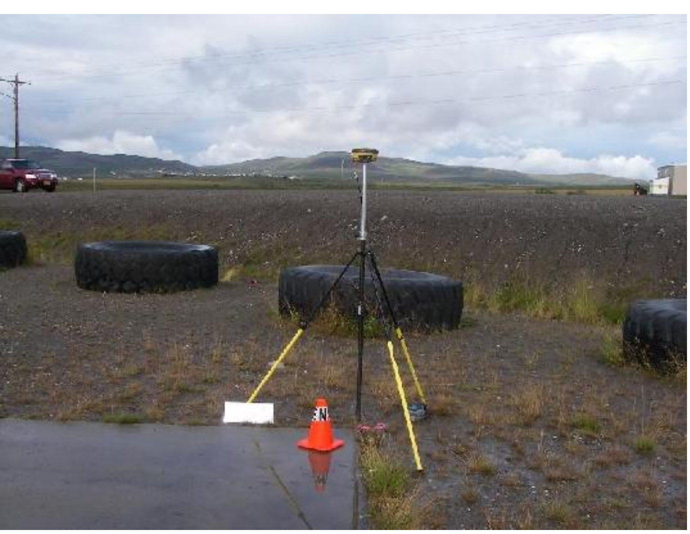
Overview of DEM and orthomosaic

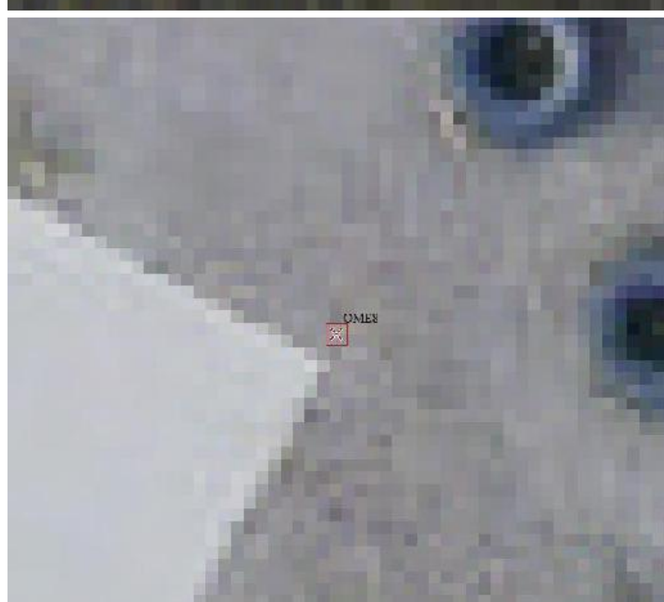


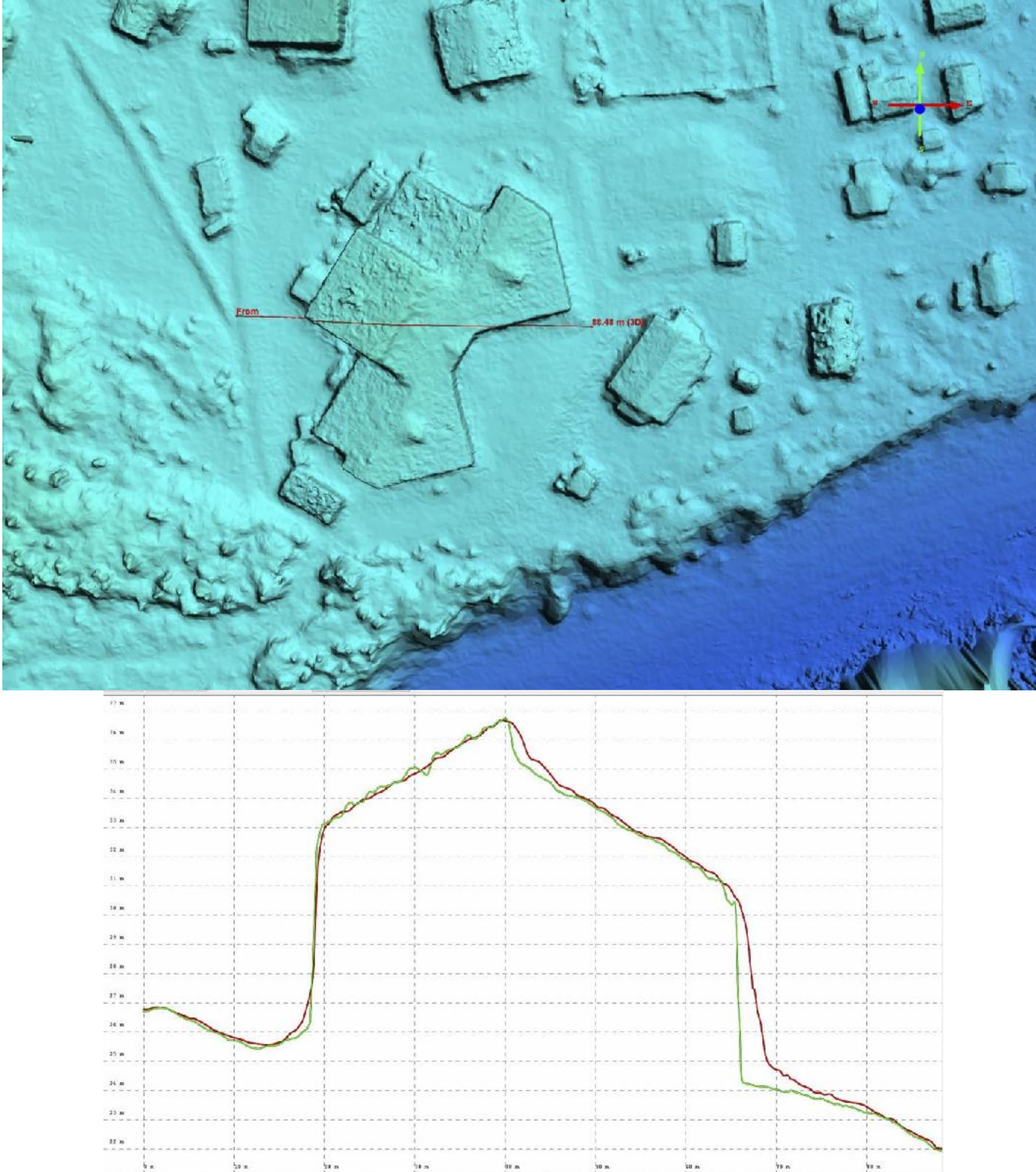
GCPs


OME1

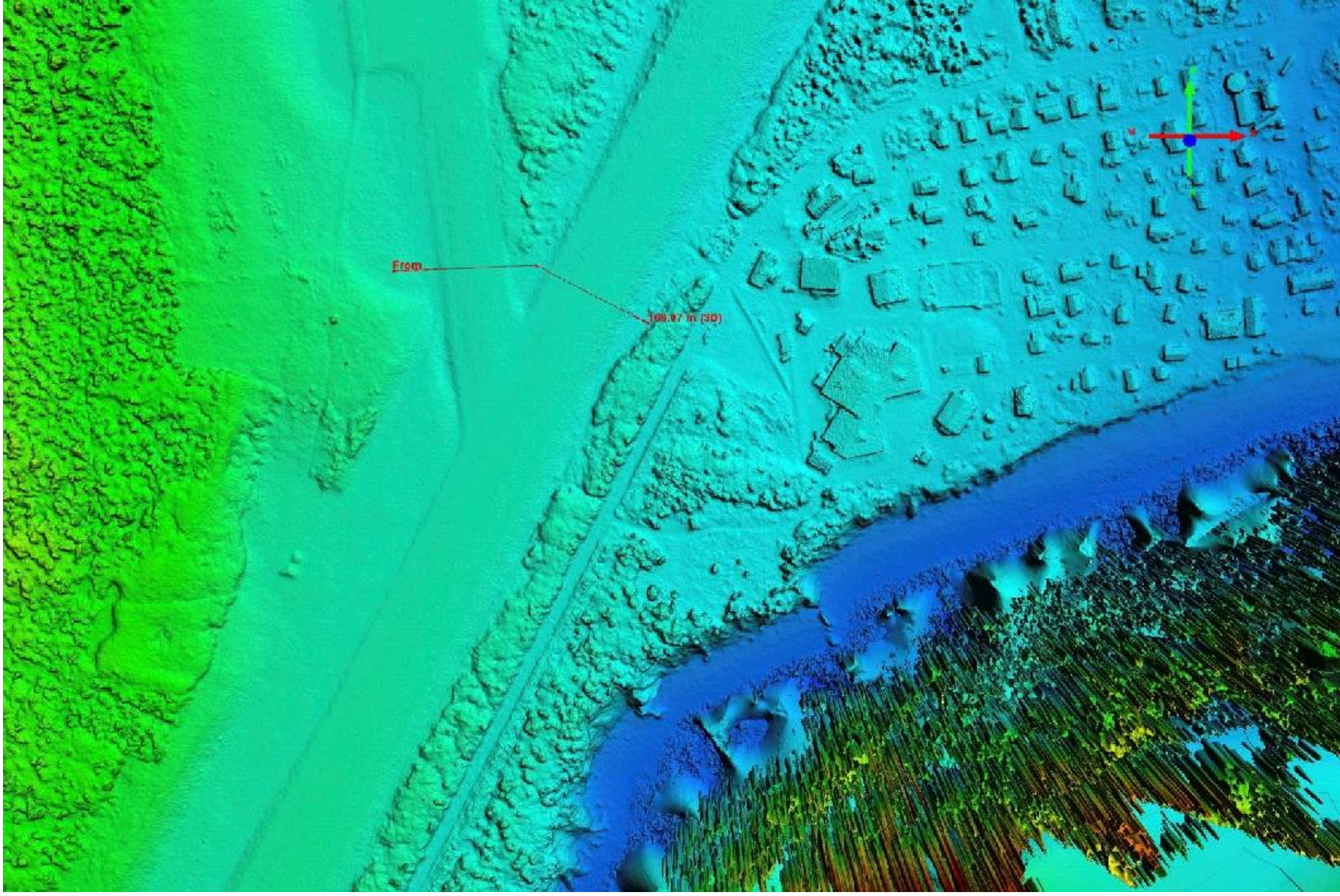

OME7



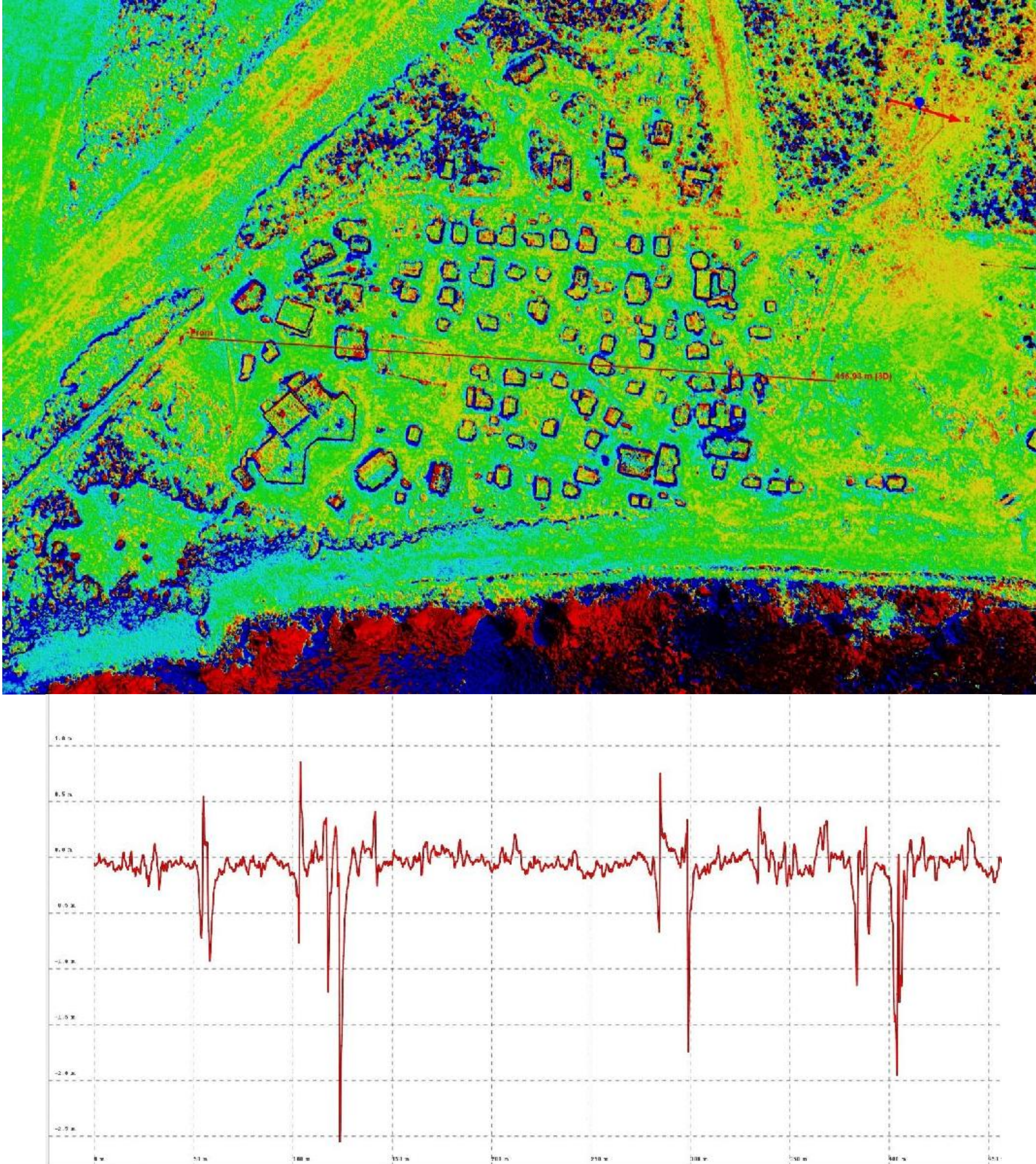

OME8



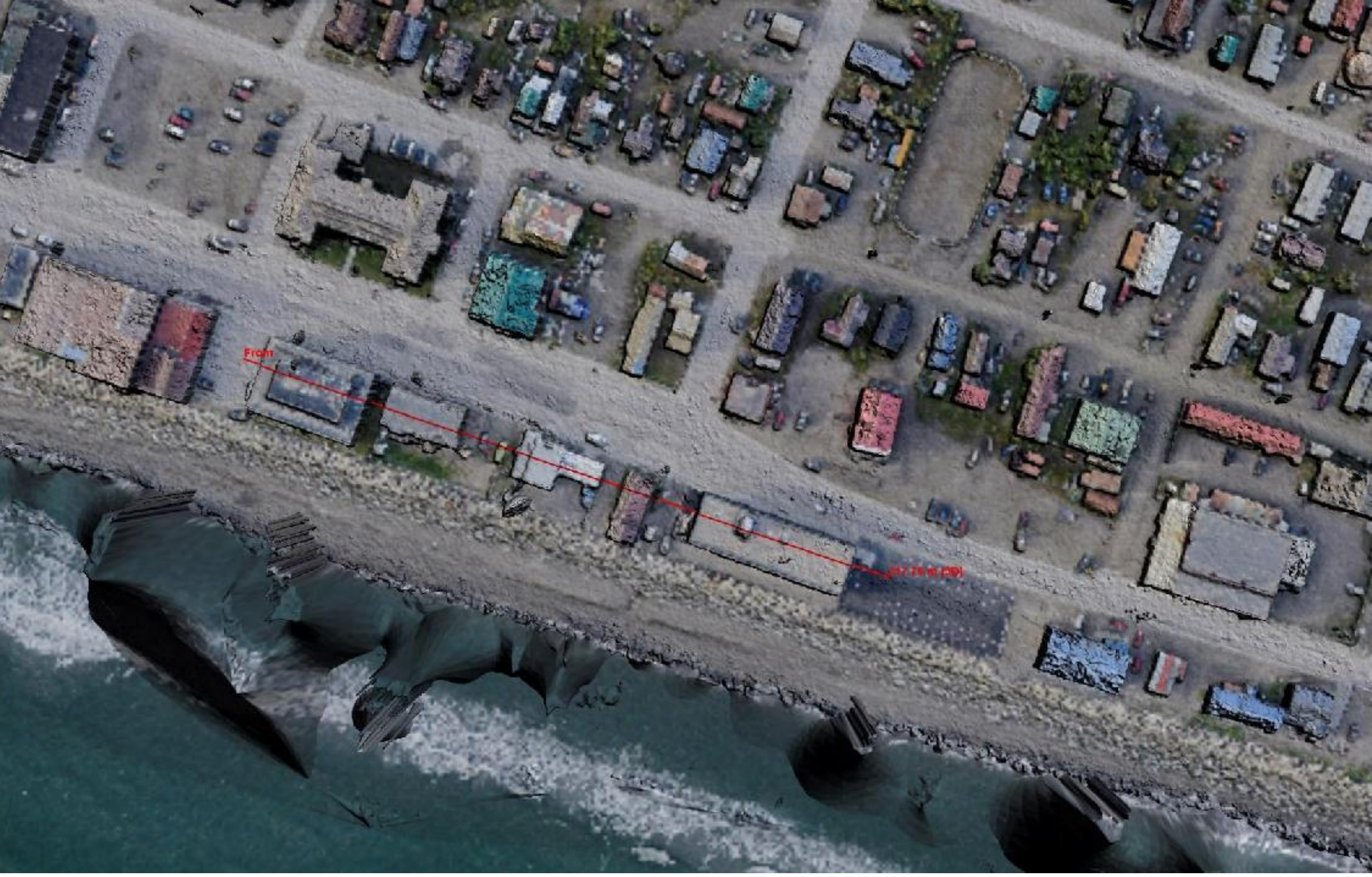
Comparison of Elim village DEM to coastal. The alignment is essentially perfect, with minor differences due to the lower resolution of the coastal data (red).

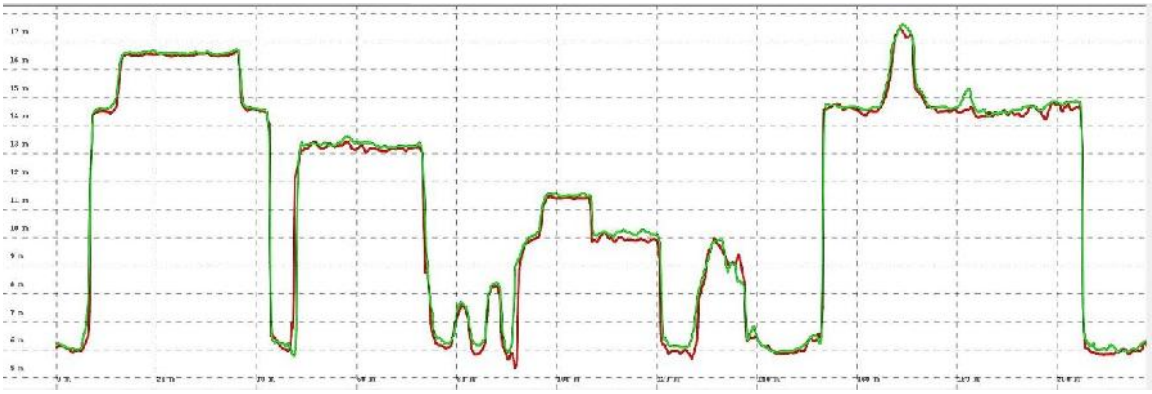


Comparison of Elim village DEM to coastal. The alignment is essentially perfect, with minor differences due to the lower resolution of the coastal data (red). This is the runway and ramp at Elim.

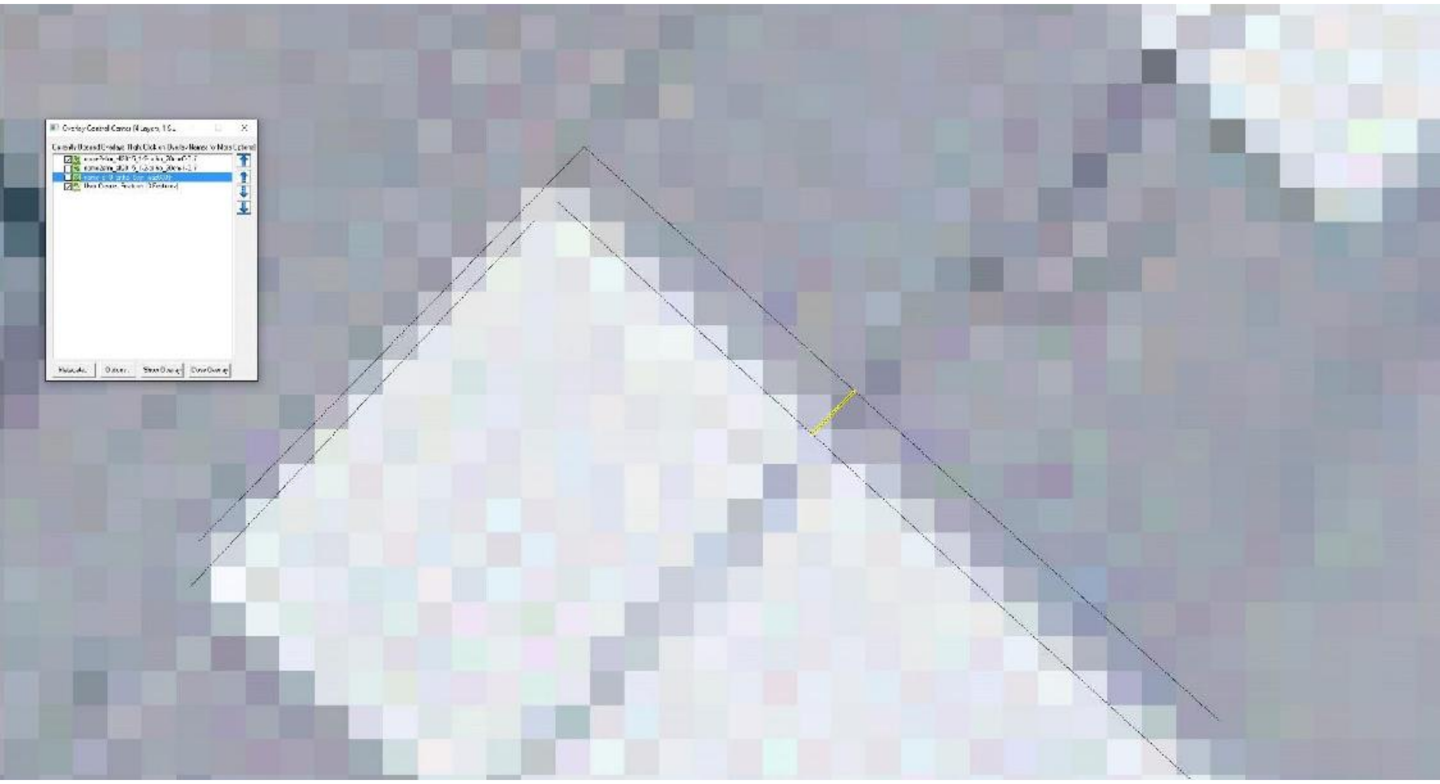


Comparison of Elim village DEM to coastal. The alignment is essentially perfect, with minor differences due to the lower resolution of the coastal data (red). The bulk of the data is within +/- 7 cm, with excursions due to building edges.

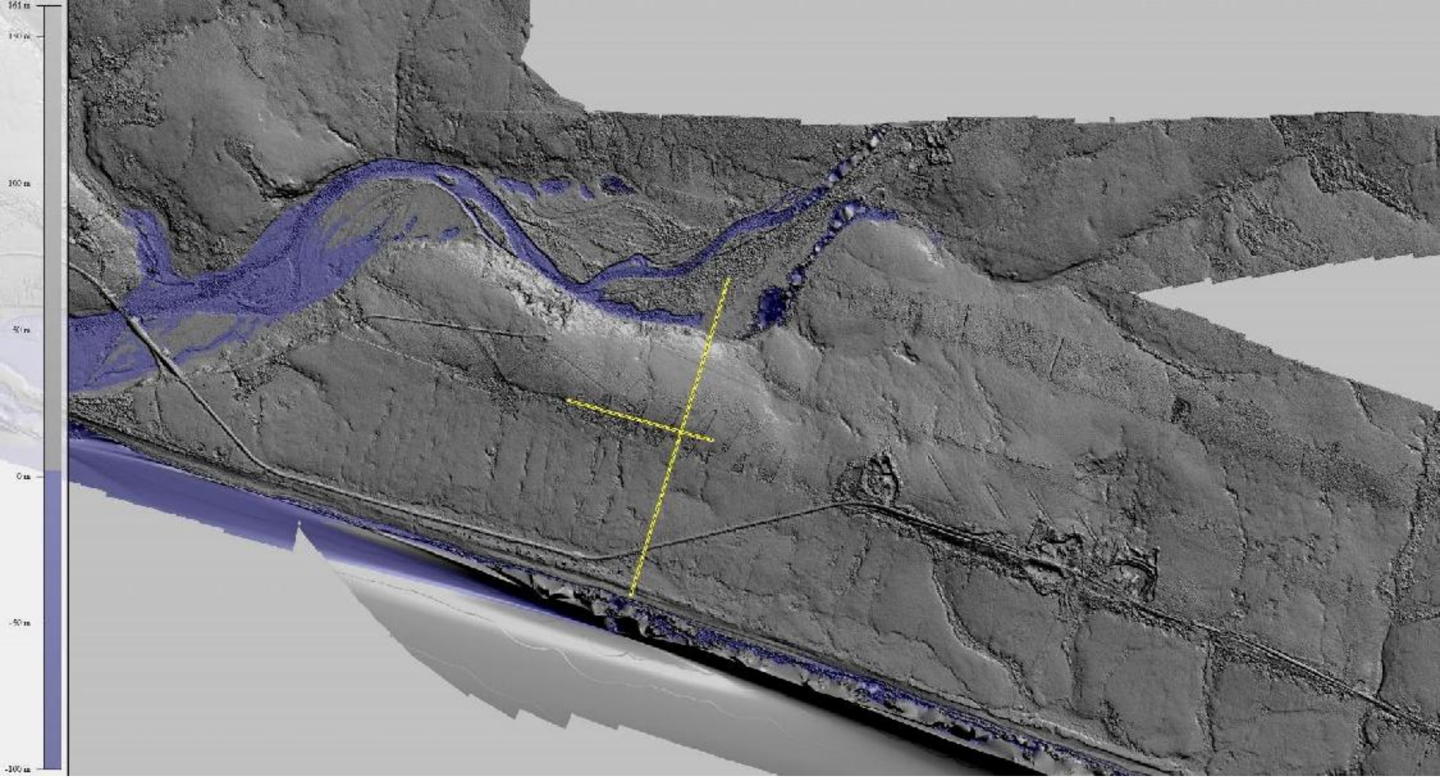


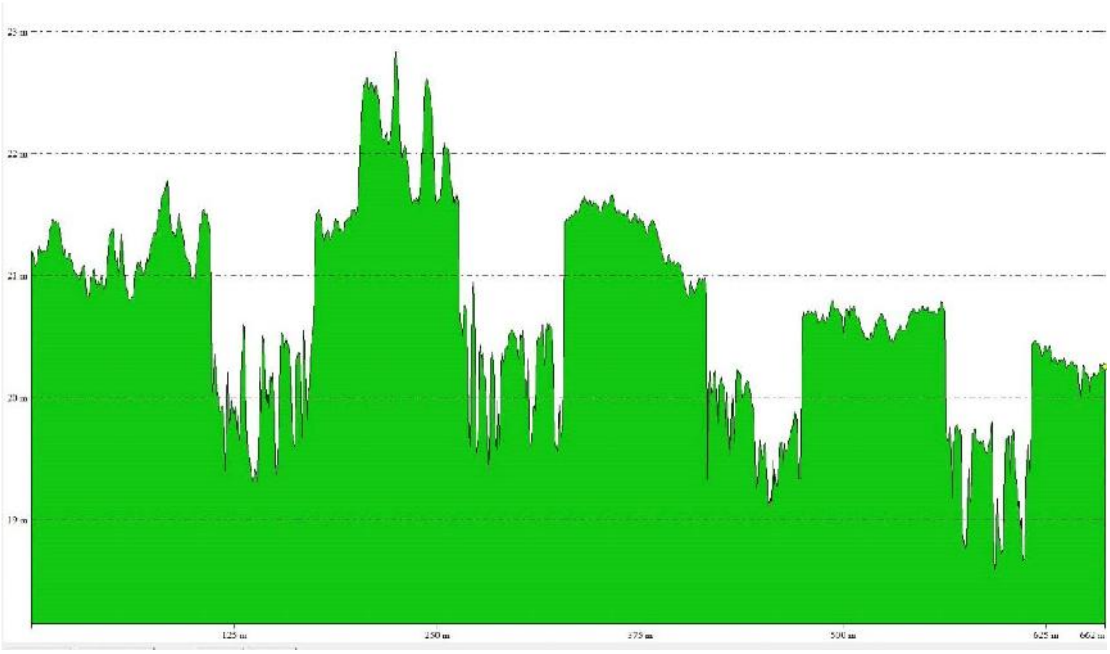


Comparison of Nome village DEM to coastal. The alignment is essentially perfect, with minor differences due to the lower resolution of the coastal data (red).

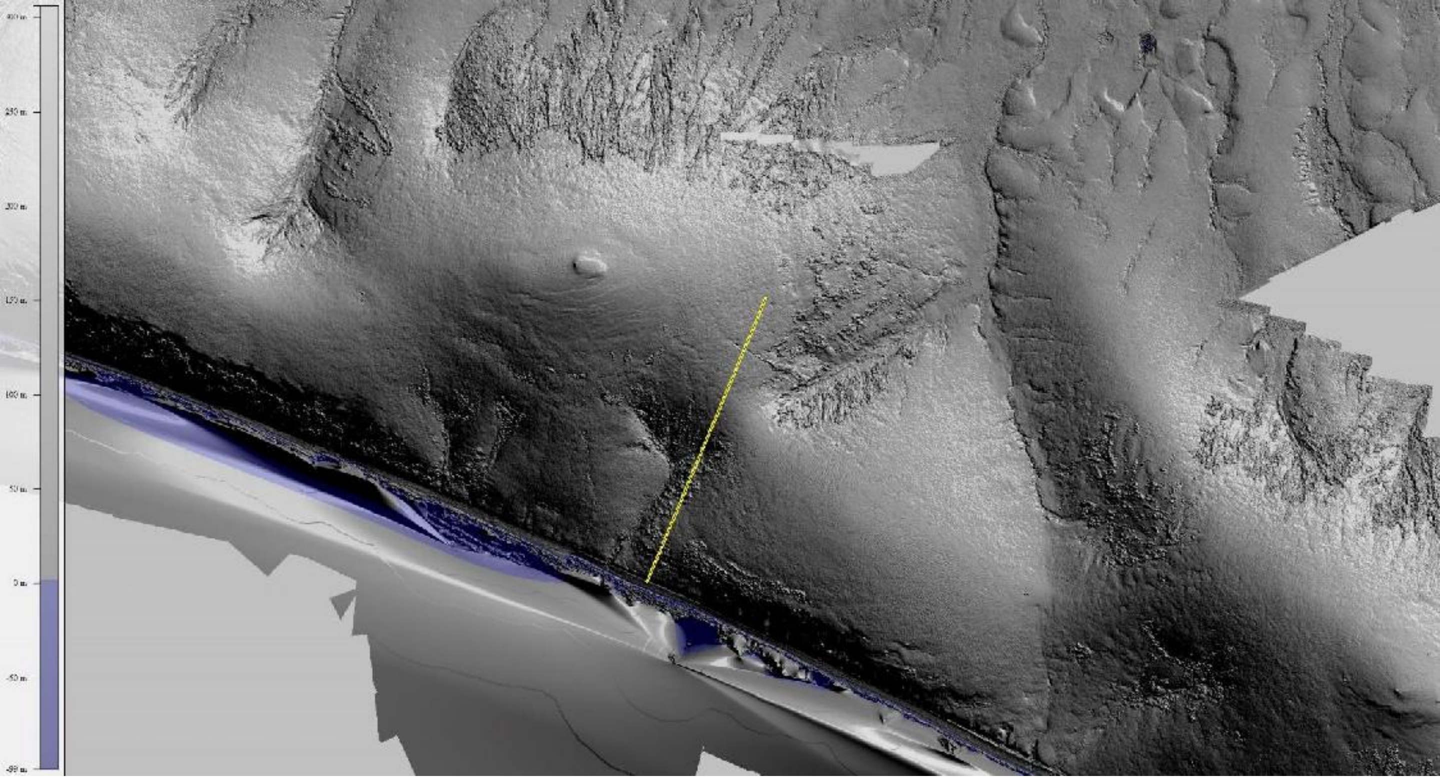


Comparison of Nome village DEM to coastal DEM (bottom). This is a runway stripe. Differences of only 1-2 pixels are typical of the entire data set.

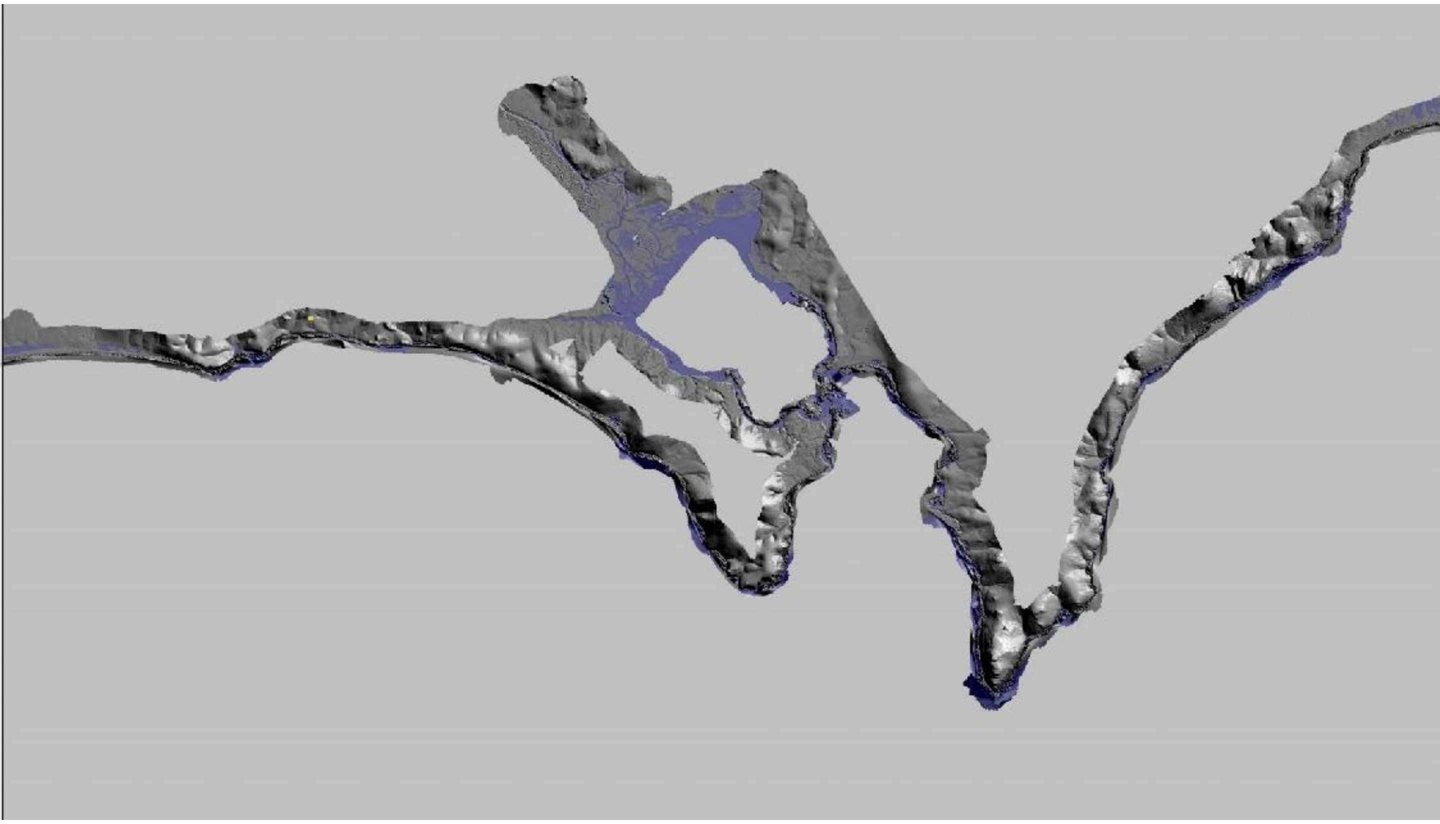




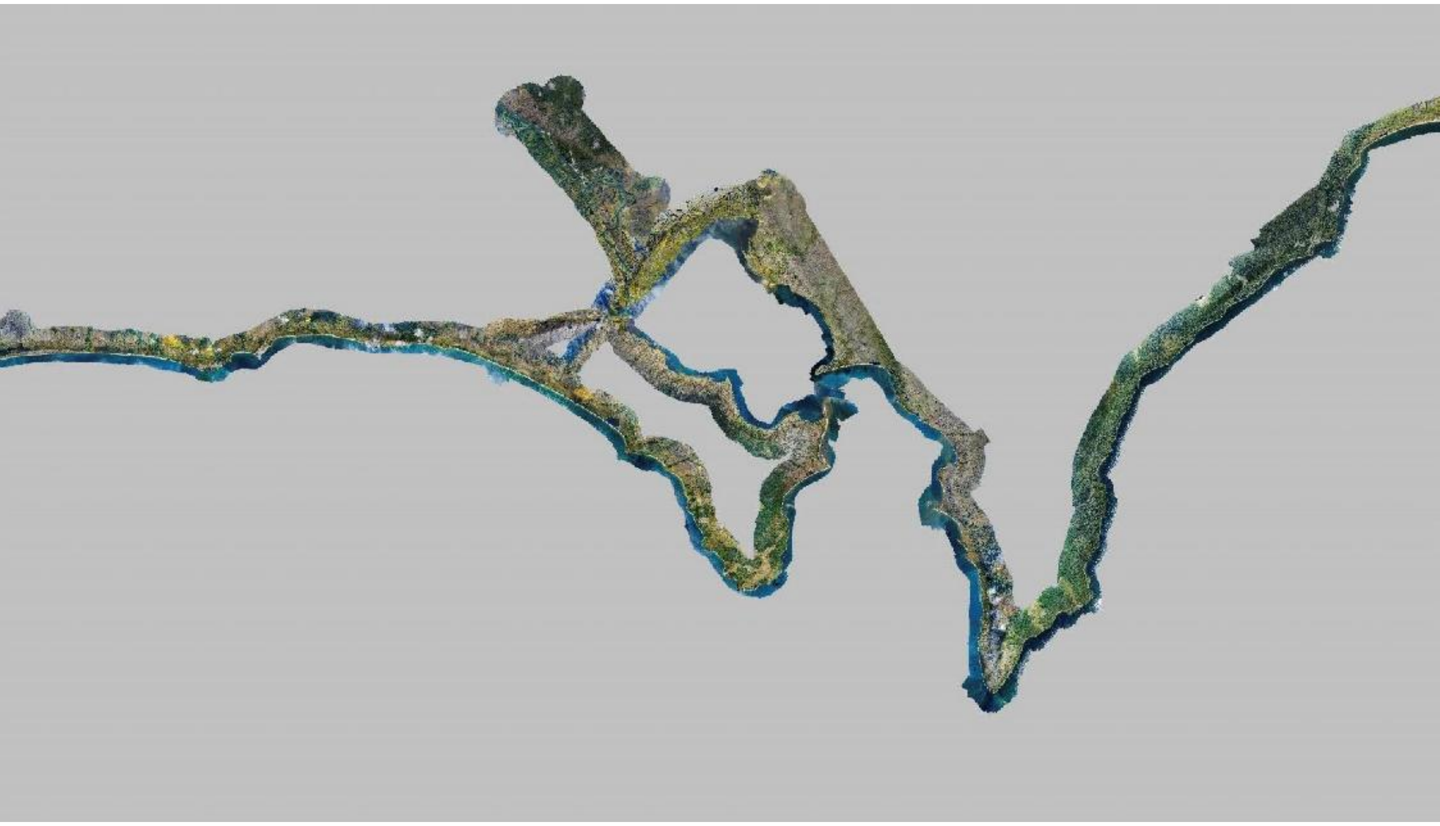
Beneath the short yellow line is one of only two cases within the data that we found of spatially coherent noise that exceeds specs within the AOI of the entire dataset. Here insufficient overlap caused by flying low to avoid clouds without increasing the acquisition rate sufficient caused pits up to a meter deep. The long yellow line indicates the 1500 m spec of the AOI. This area is just east of Nome. Similar noise can be found outside the AOI in many locations.



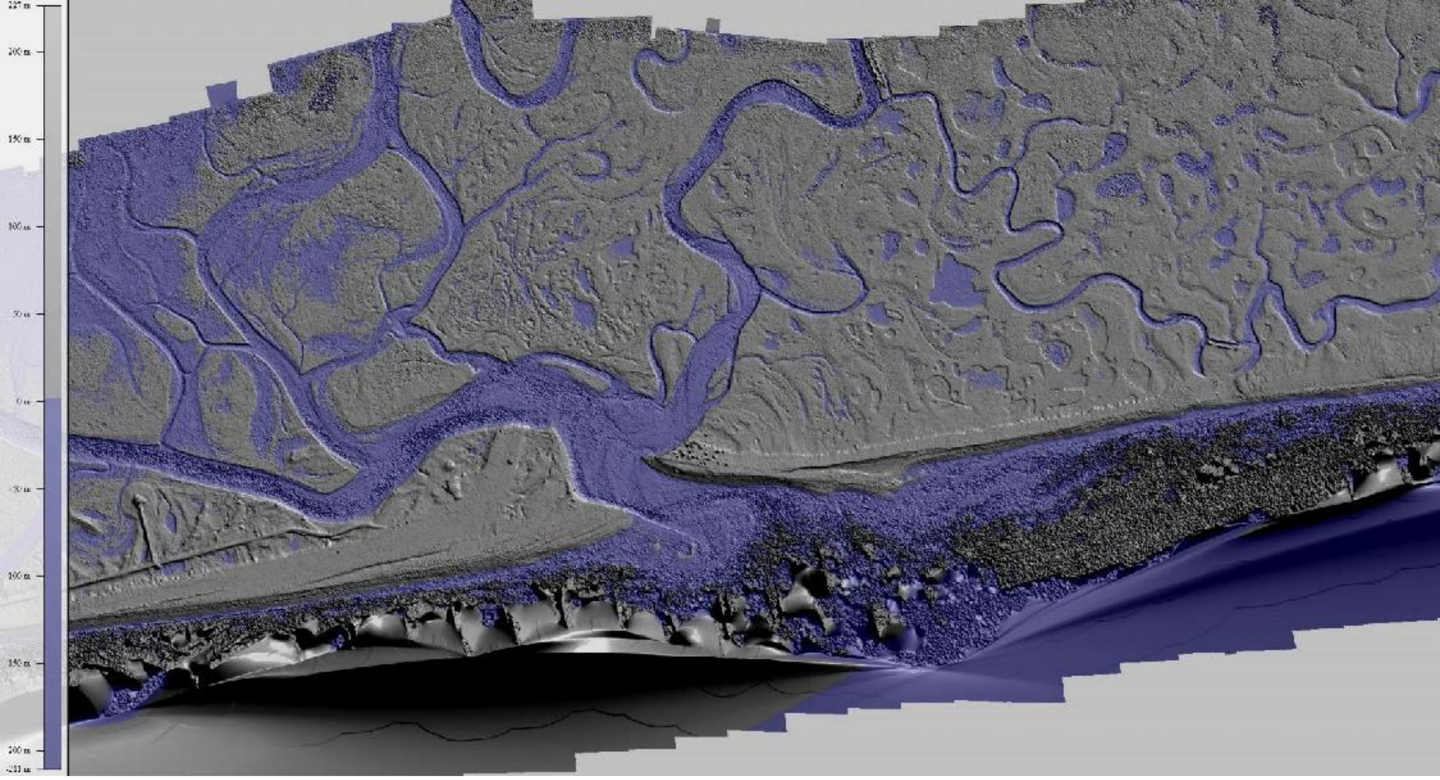
Here is a small gap, which is common in the hills outside of the AOI, indicated by the 1500 m long yellow line.

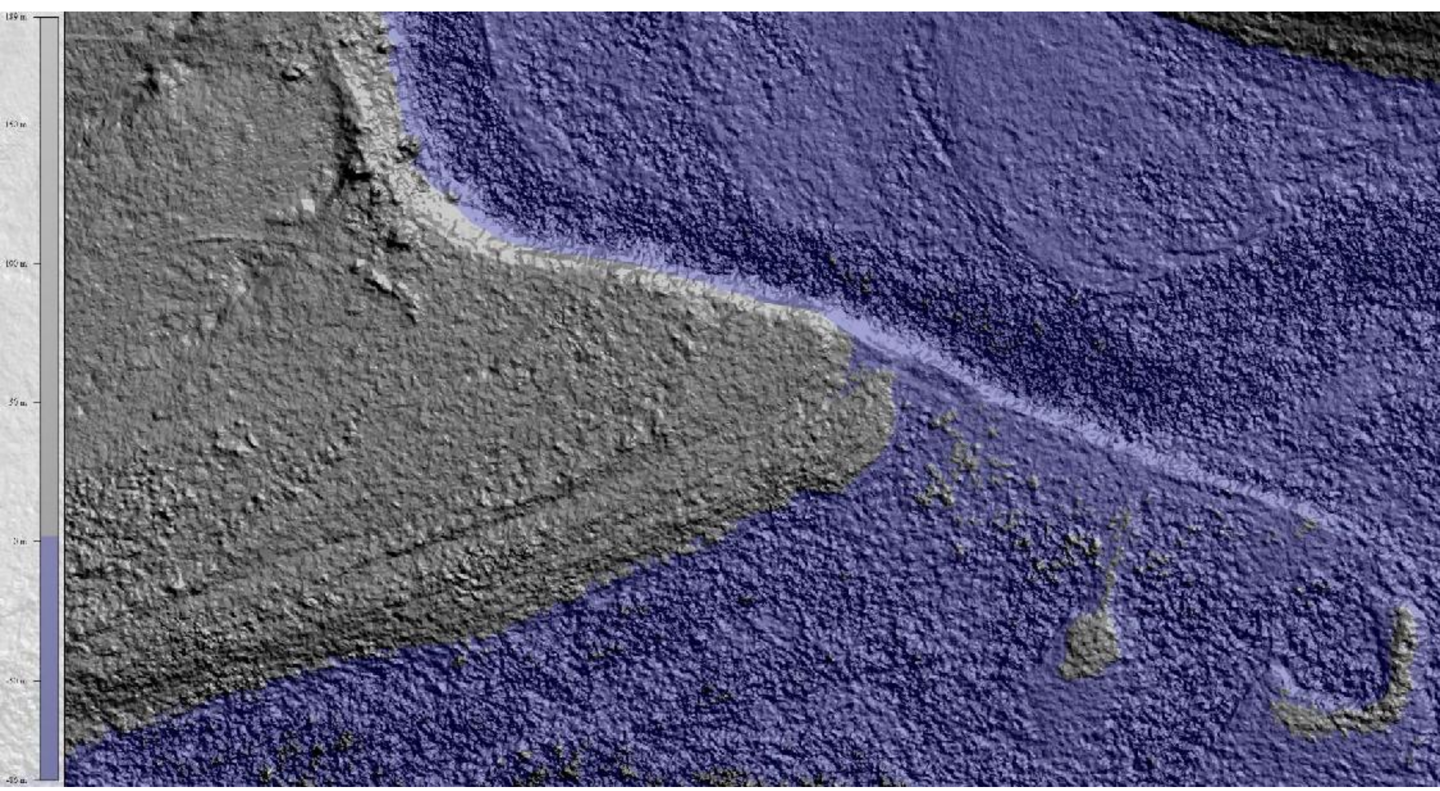


Closeup of Golovin Bay DEM and orthomosaic.



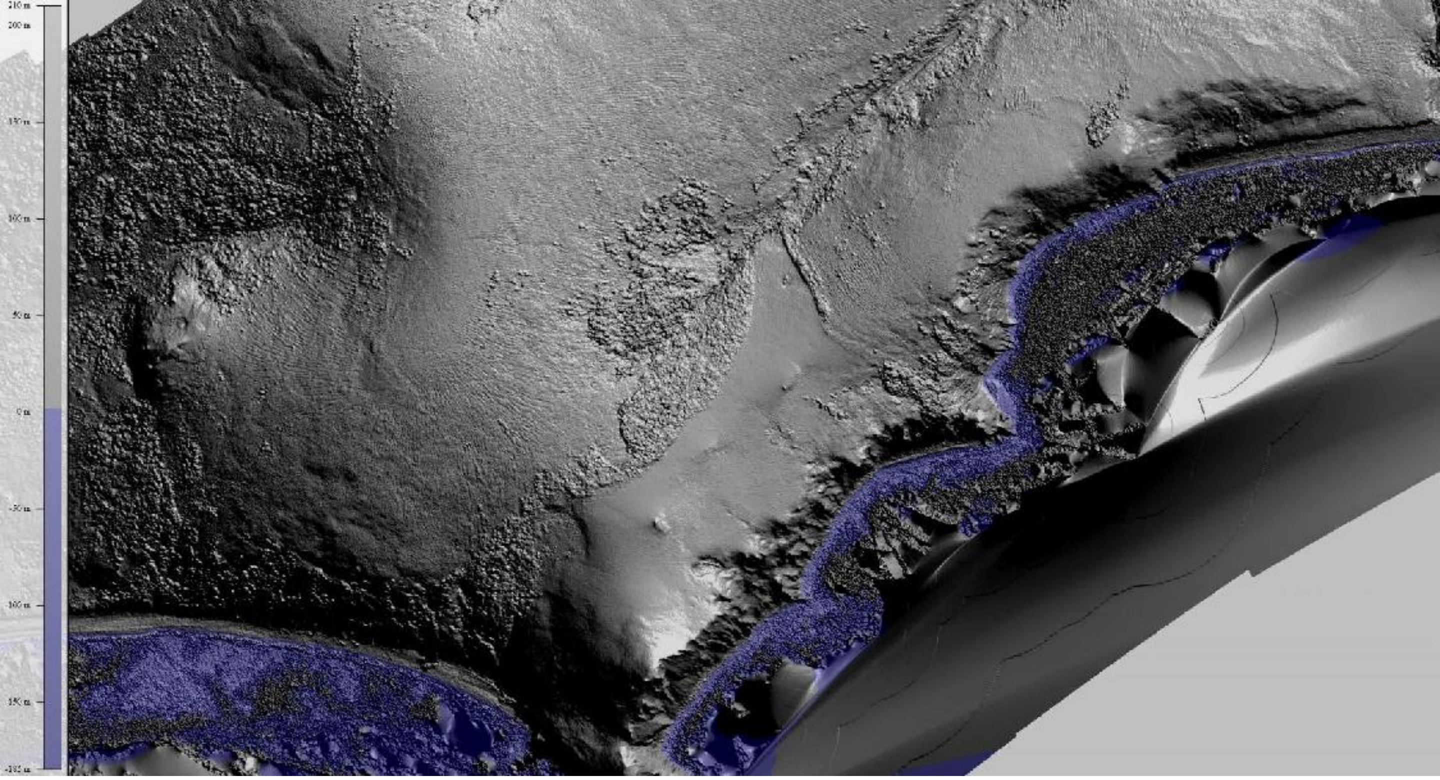
Closeup of Golovin Bay DEM and orthomosaic.

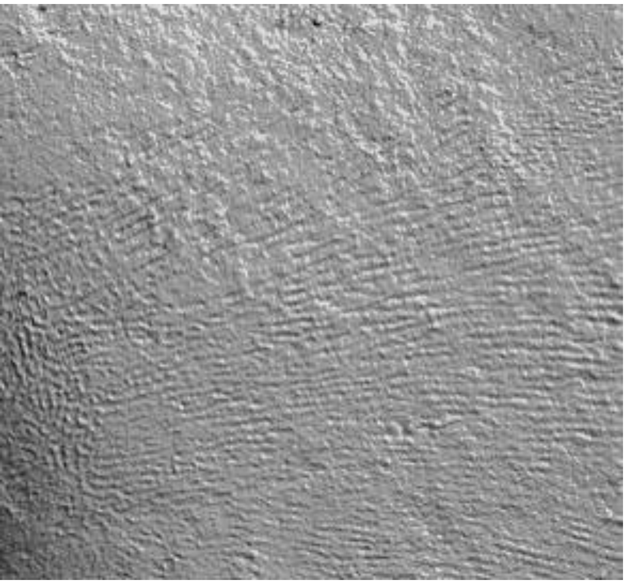


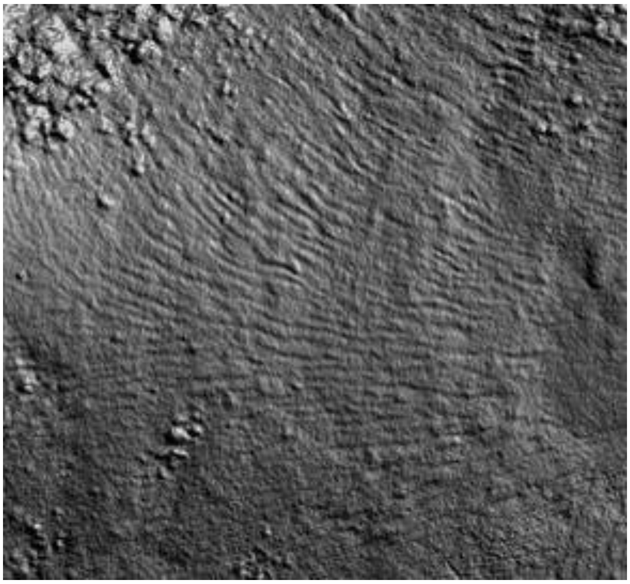


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

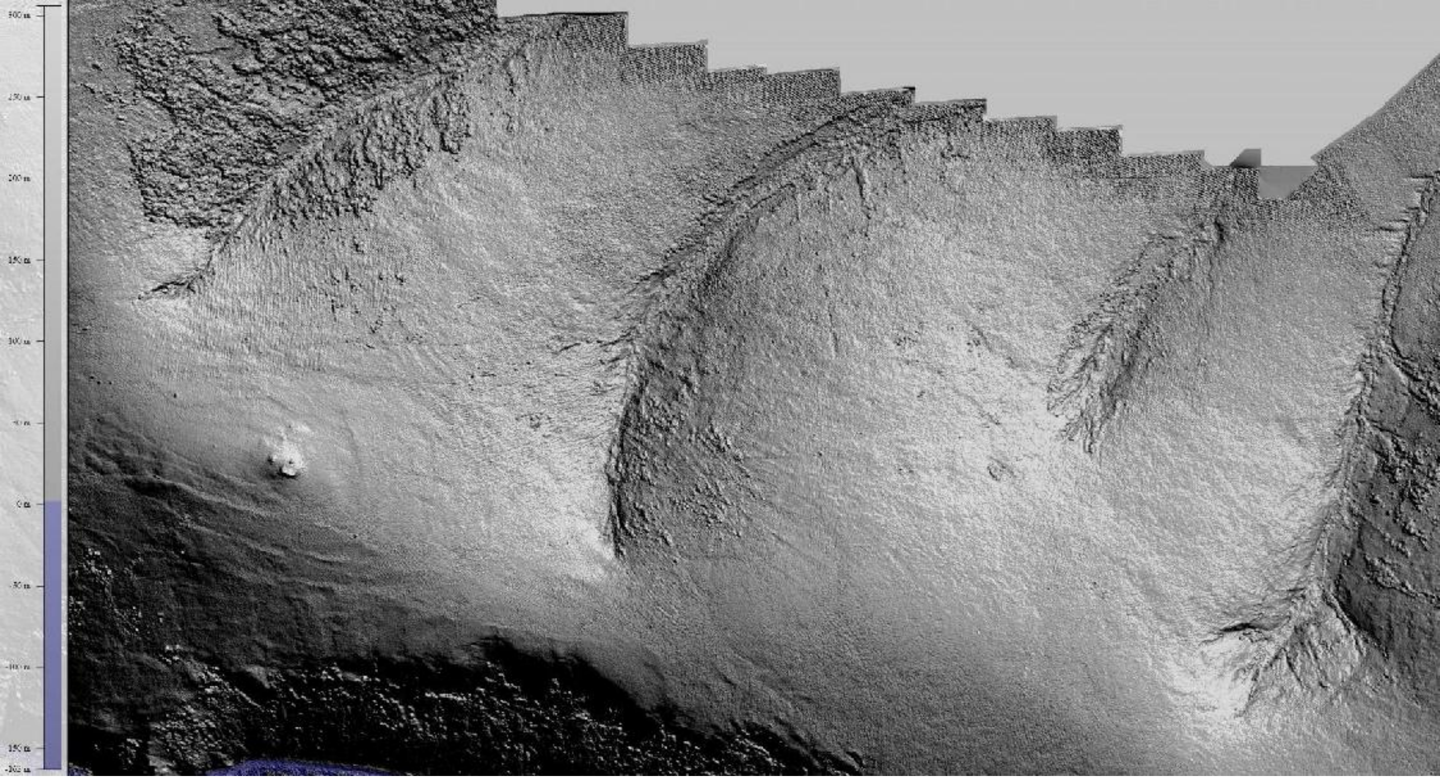


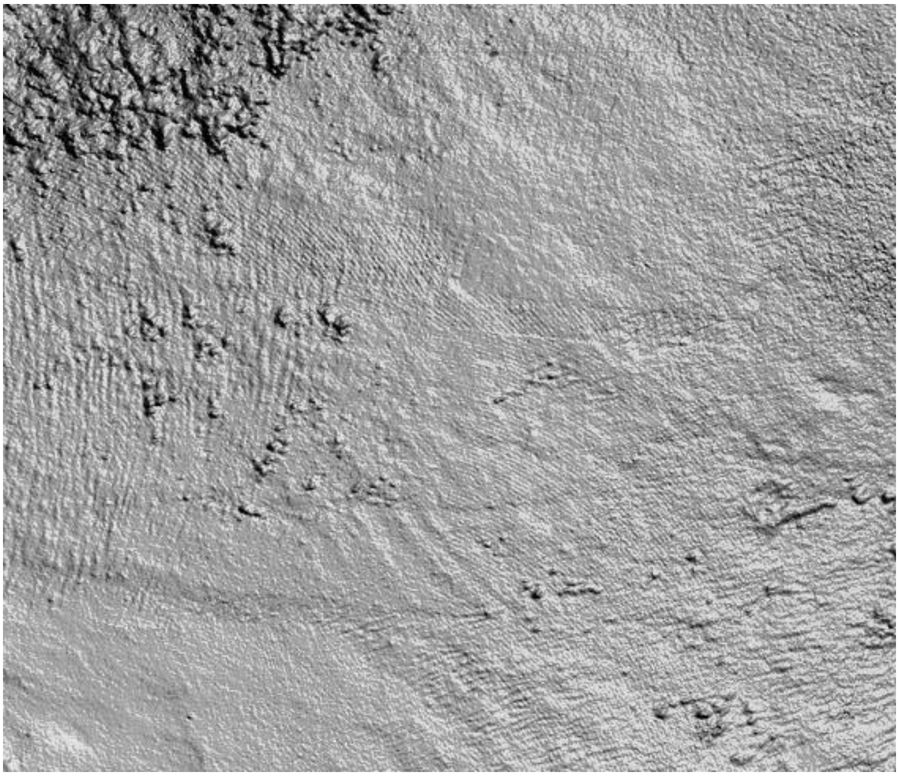




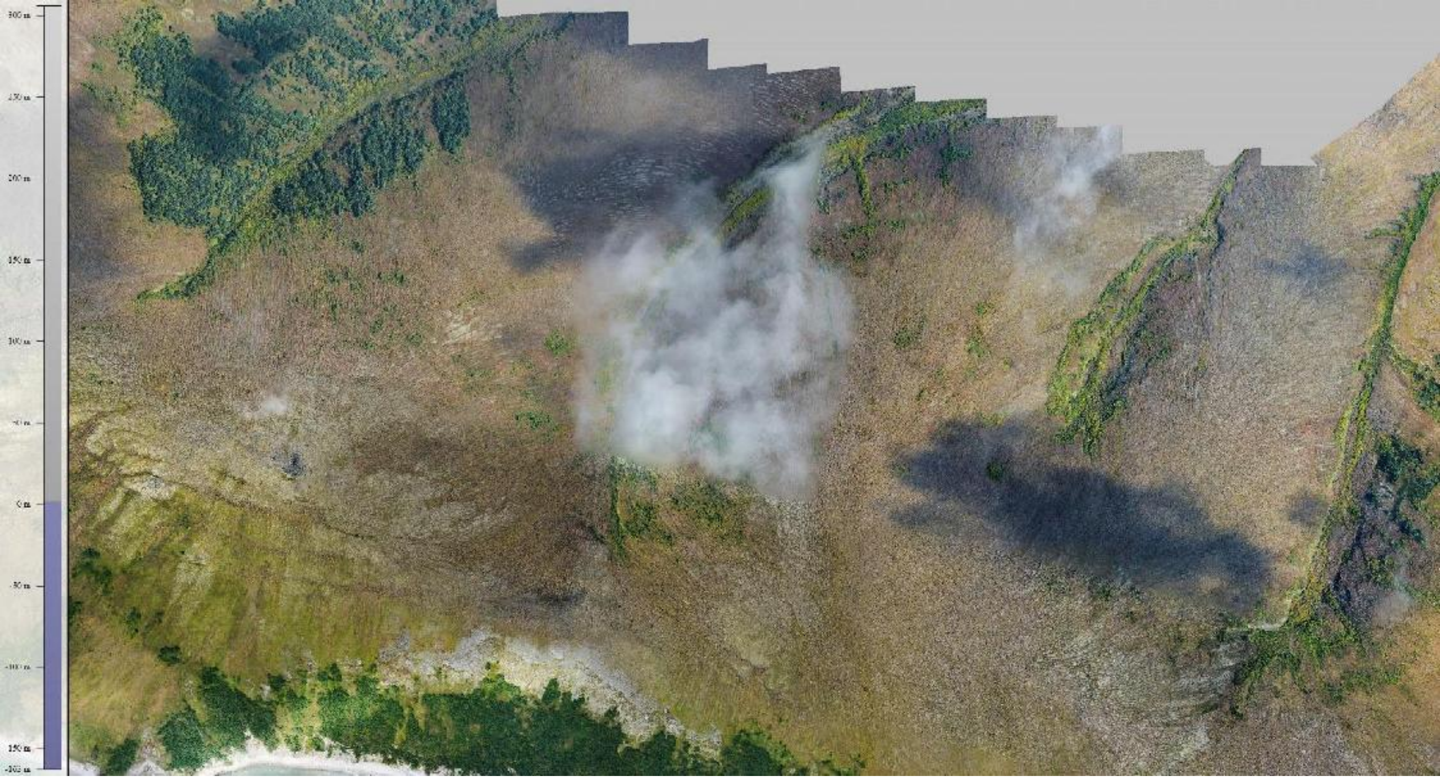
Examples of data quality and scientific features. Note what appears to be corduroy noise in this DEM are actually watertracks, as revealed in the orthoimages on the next slide. The two lower images are close-ups from the upper one.

Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail, noting how the subtle watertracks are revealed in topography and could easily be mistaken for noise without the orthomosaic.

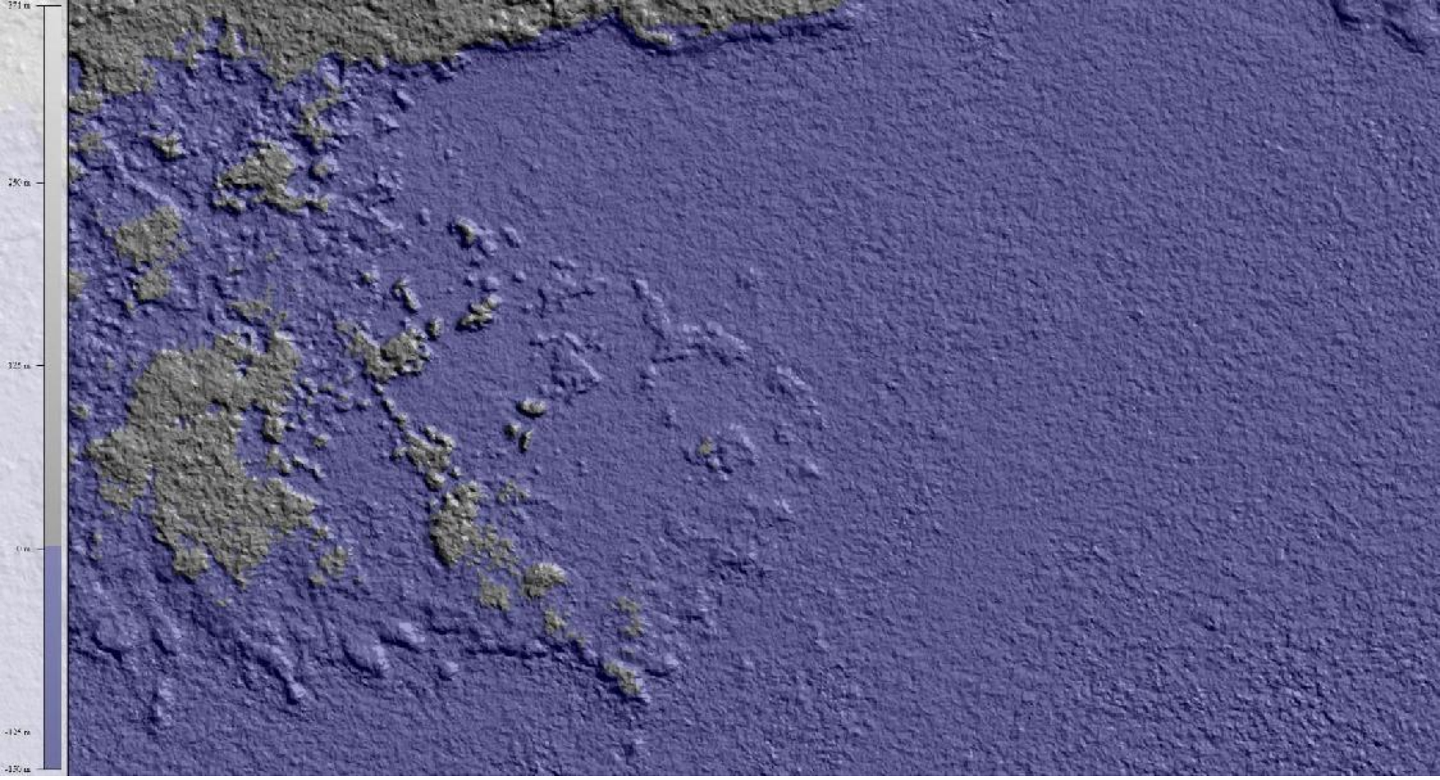


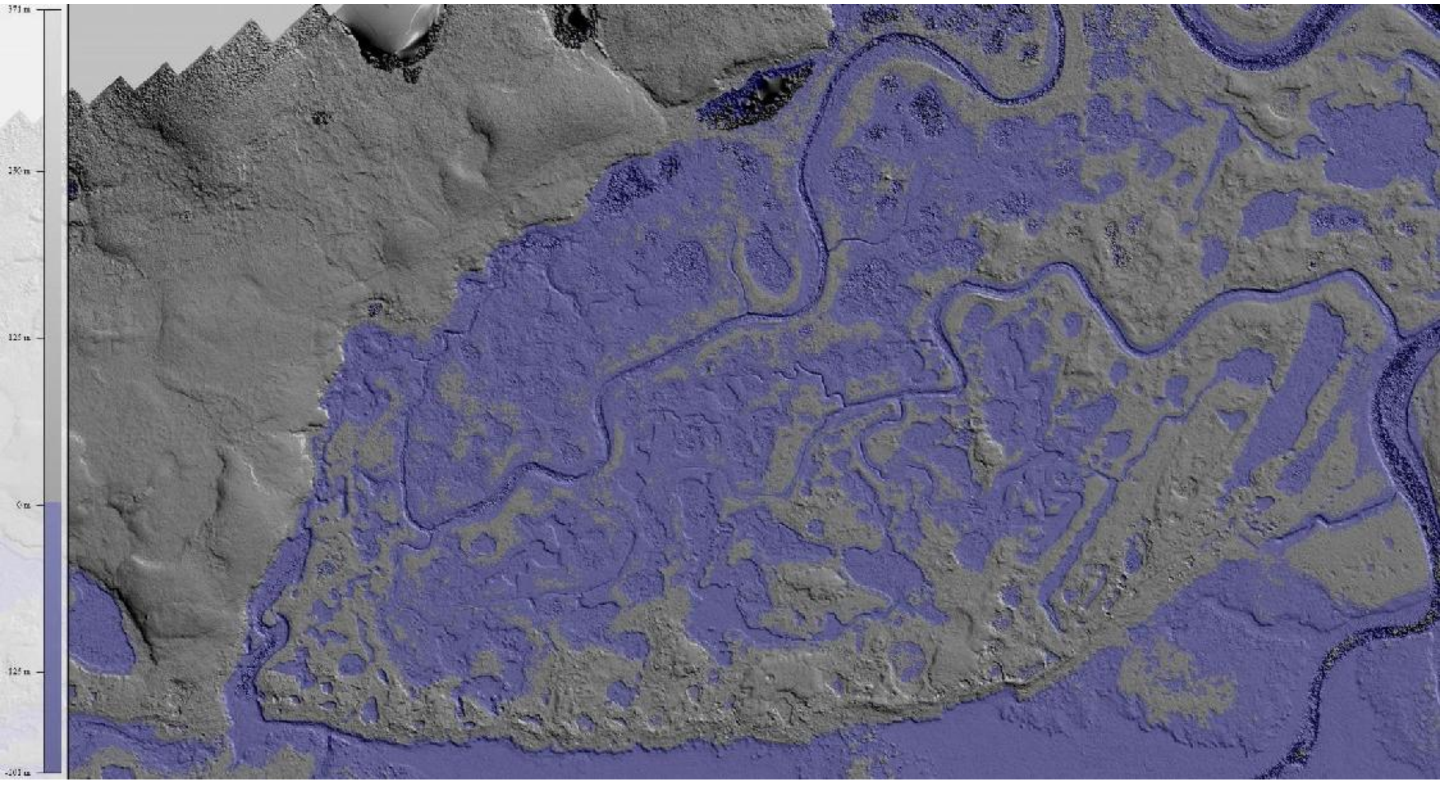


Examples of data quality and scientific features. Note that most of what appears to be corduroy noise in this DEM is actually watertracks, as revealed in the orthoimages on the next slide, but some of it is real noise (rectangle near center of lower image). The two lower images are close-ups from the upper one.

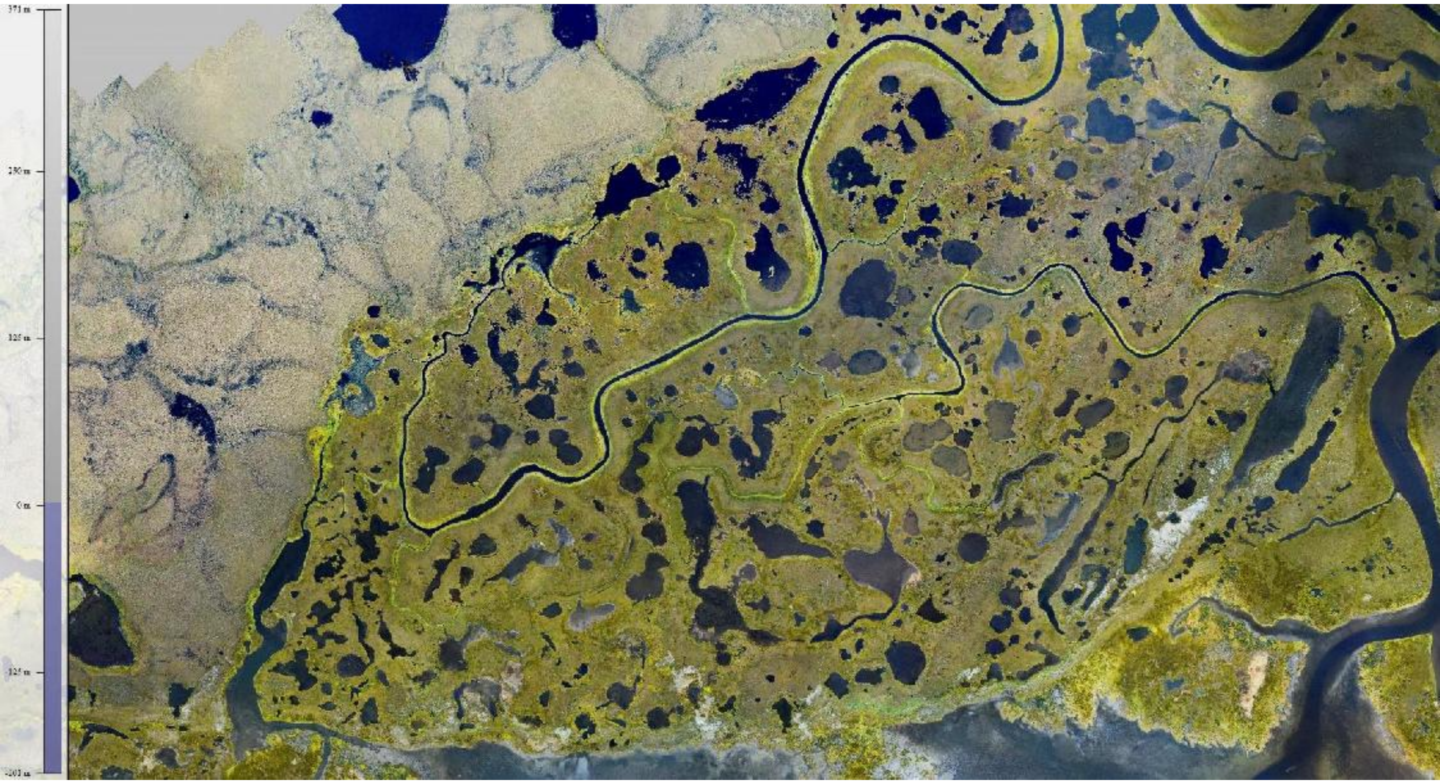


Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail, noting how the subtle watertracks are revealed in topography and could easily be mistaken for noise without the orthomosaic. The corduroy noise seen in the DEMs is less than 10 cm in amplitude, caused by low overlap due to clouds. Note that the cloud seen in this image did not affect the DEM due to multiple passes as the cloud moved.

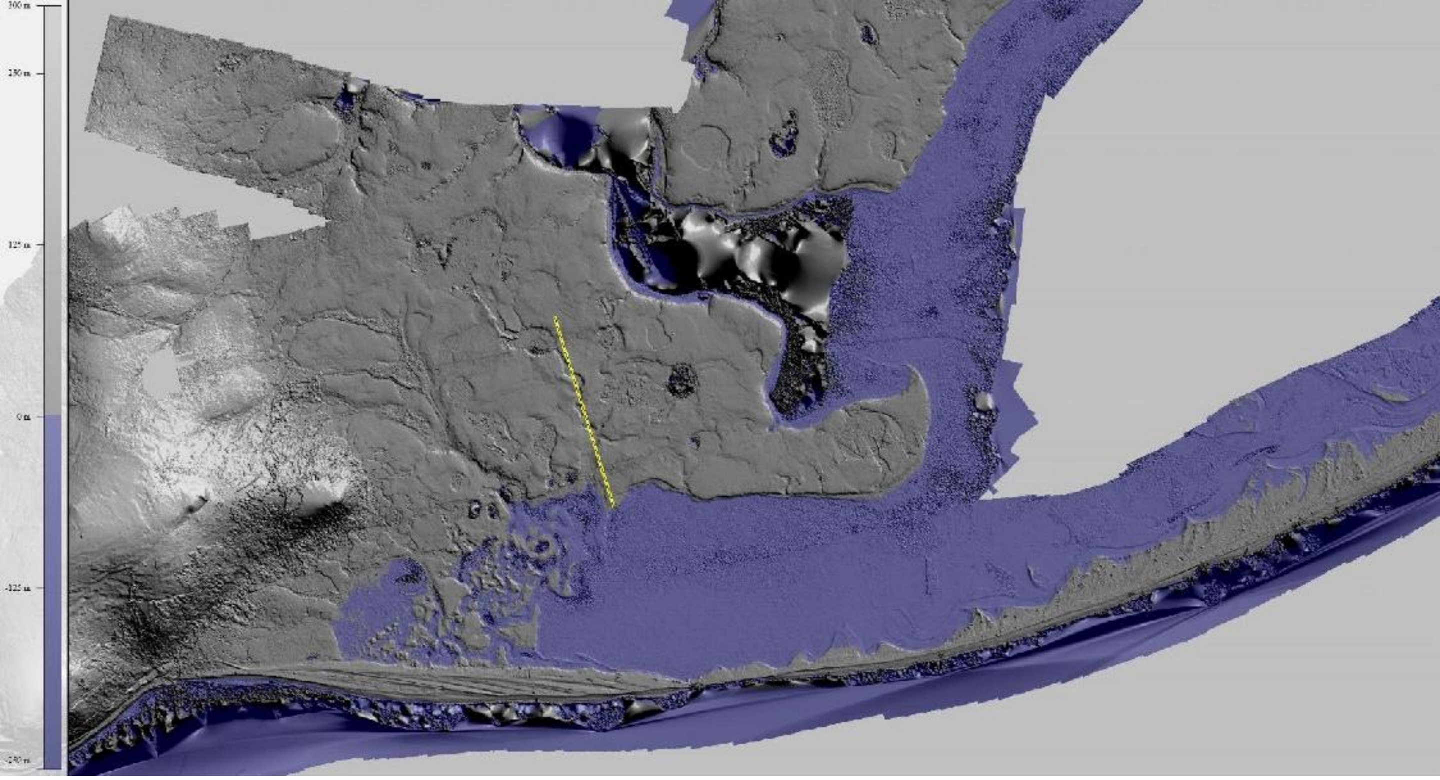


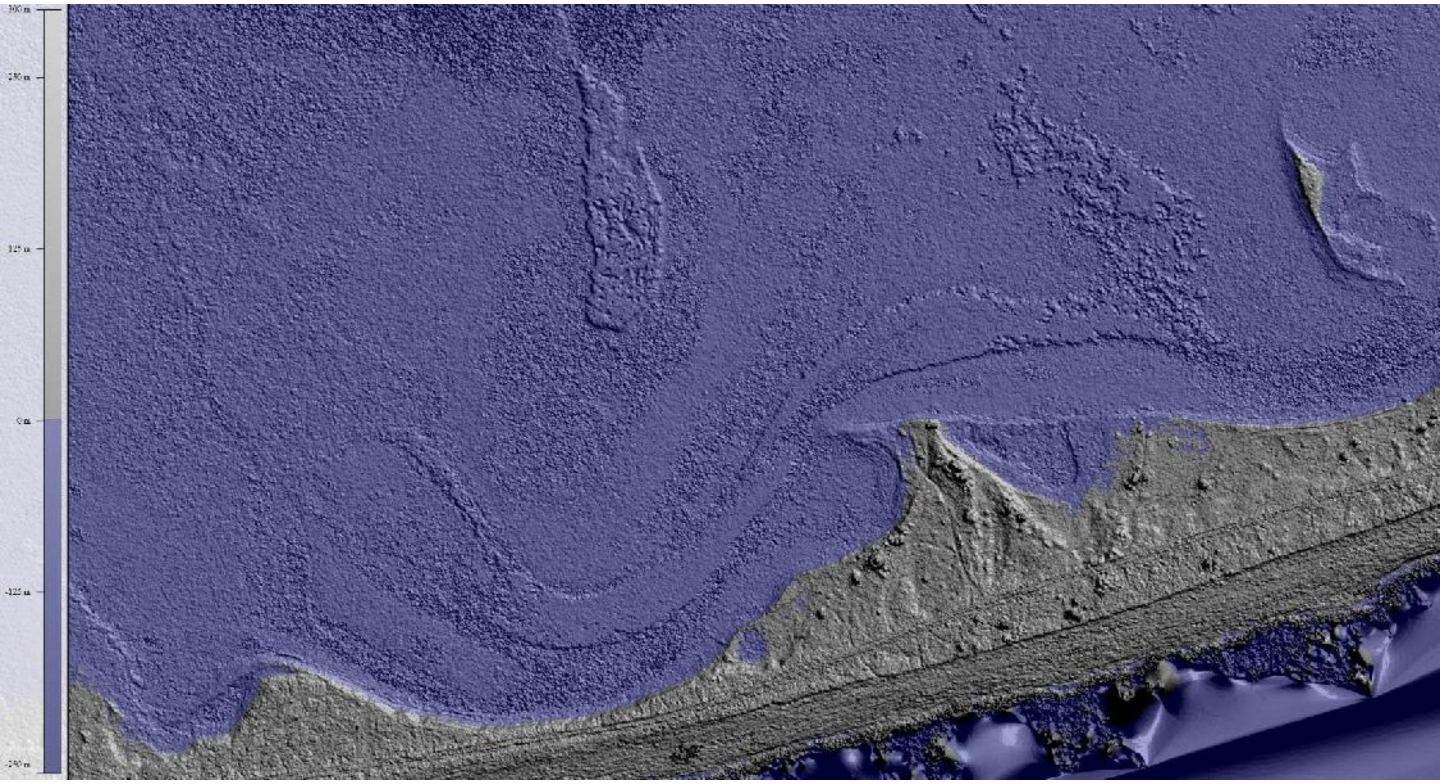


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.



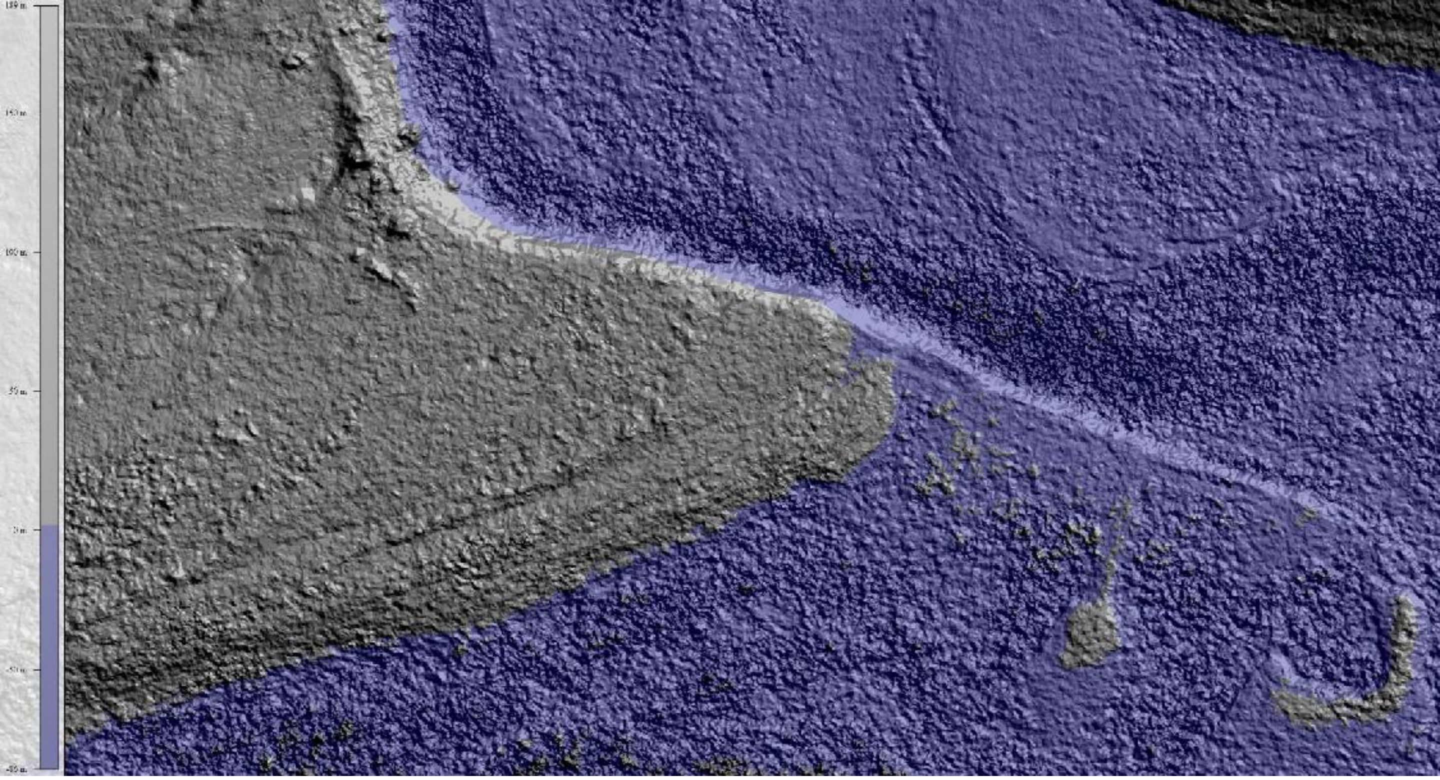
Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.





Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

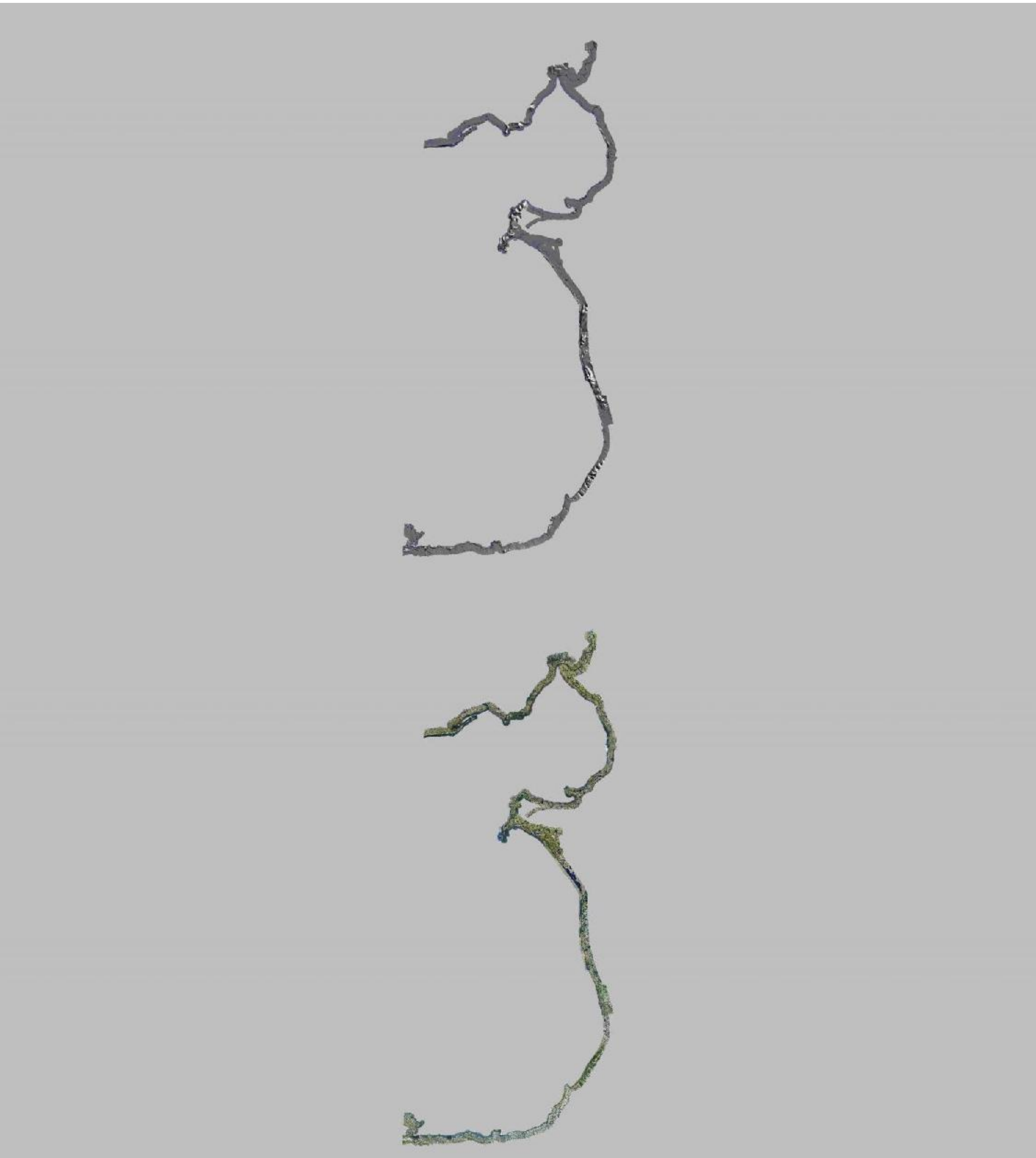
Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.



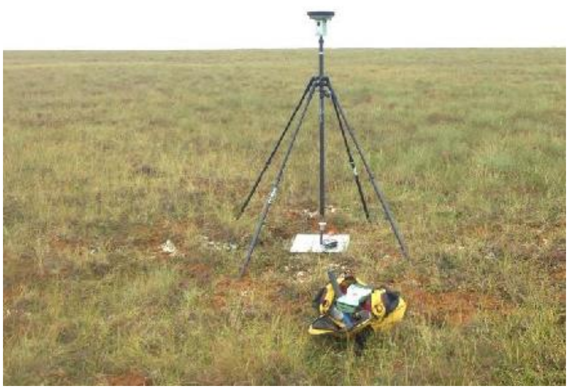
Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

Norton Block

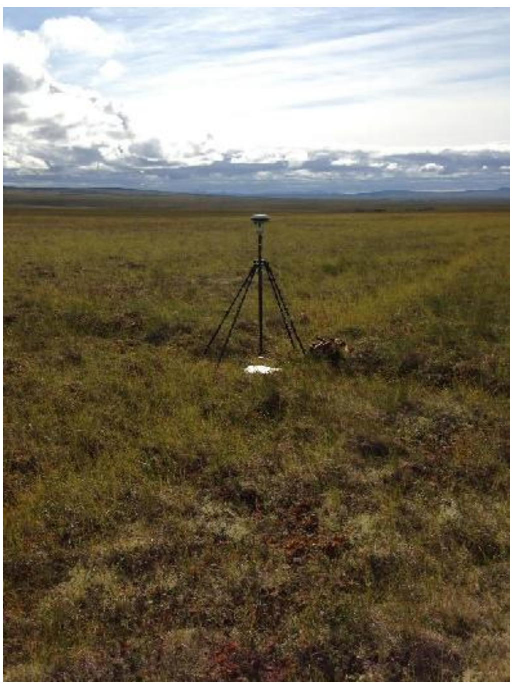



Bald Head




Ungalik


Egavik

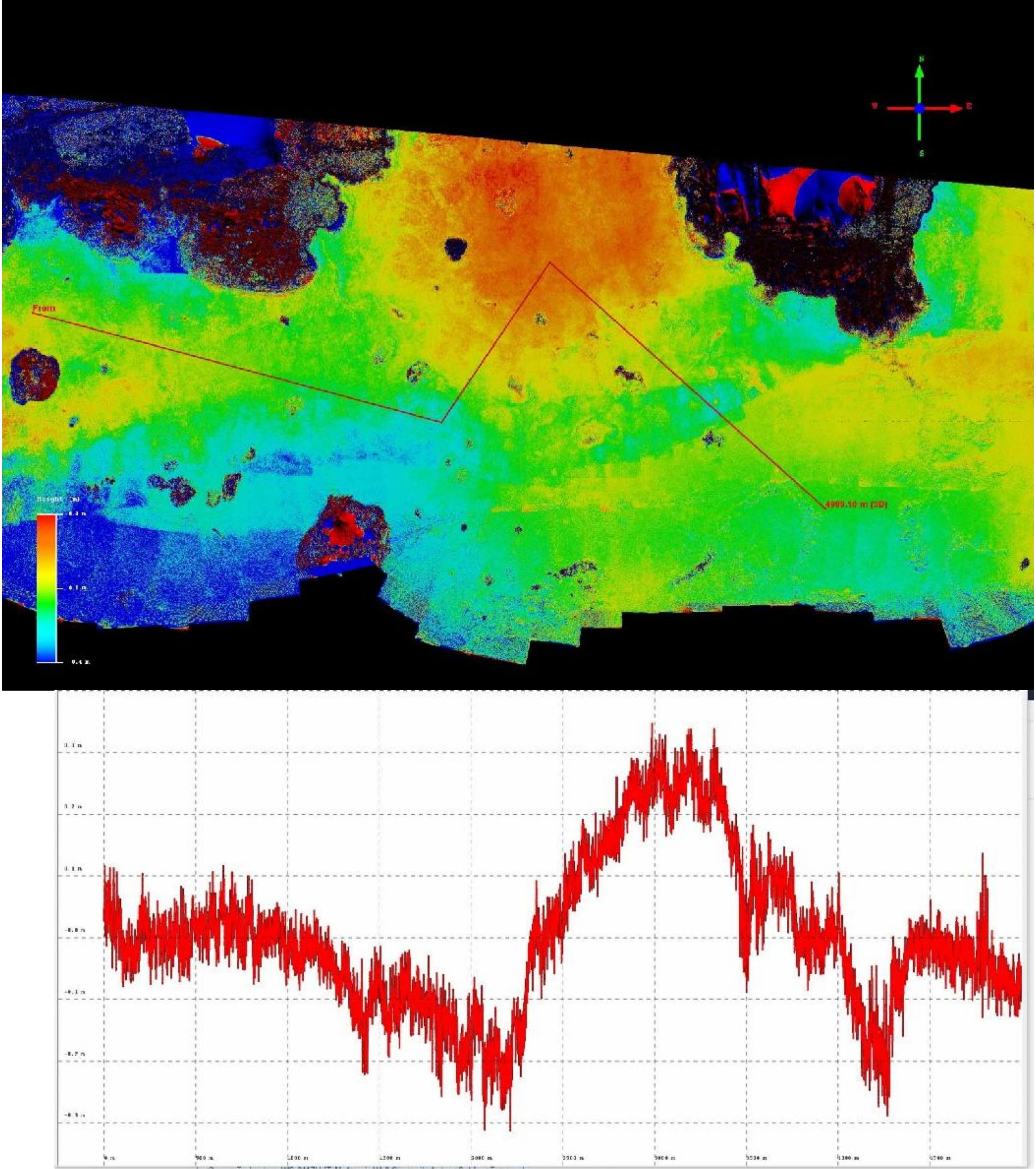



Tolstoi

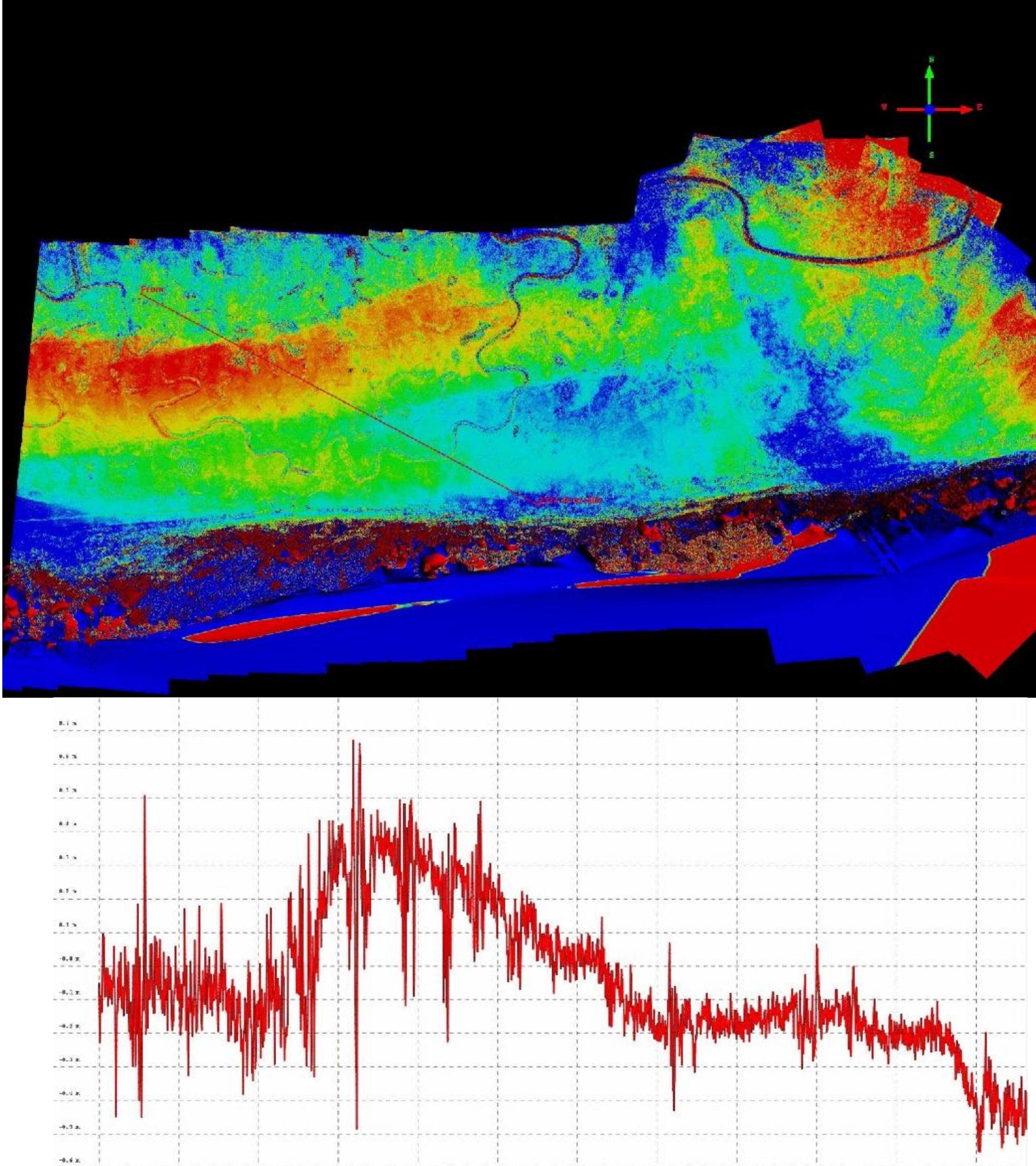

Oliver

Comparisons of overlap with Kotlik to Stebbins block (top) and Nome to Elim block (bottom), here showing the Norton block othoimage. Flicker with the next figure to see the other blocks' orthoimage. Offsets of 1-2 pixels are common here, which is excellent, especially considering they are across a UTM zone boundary at high latitudes.

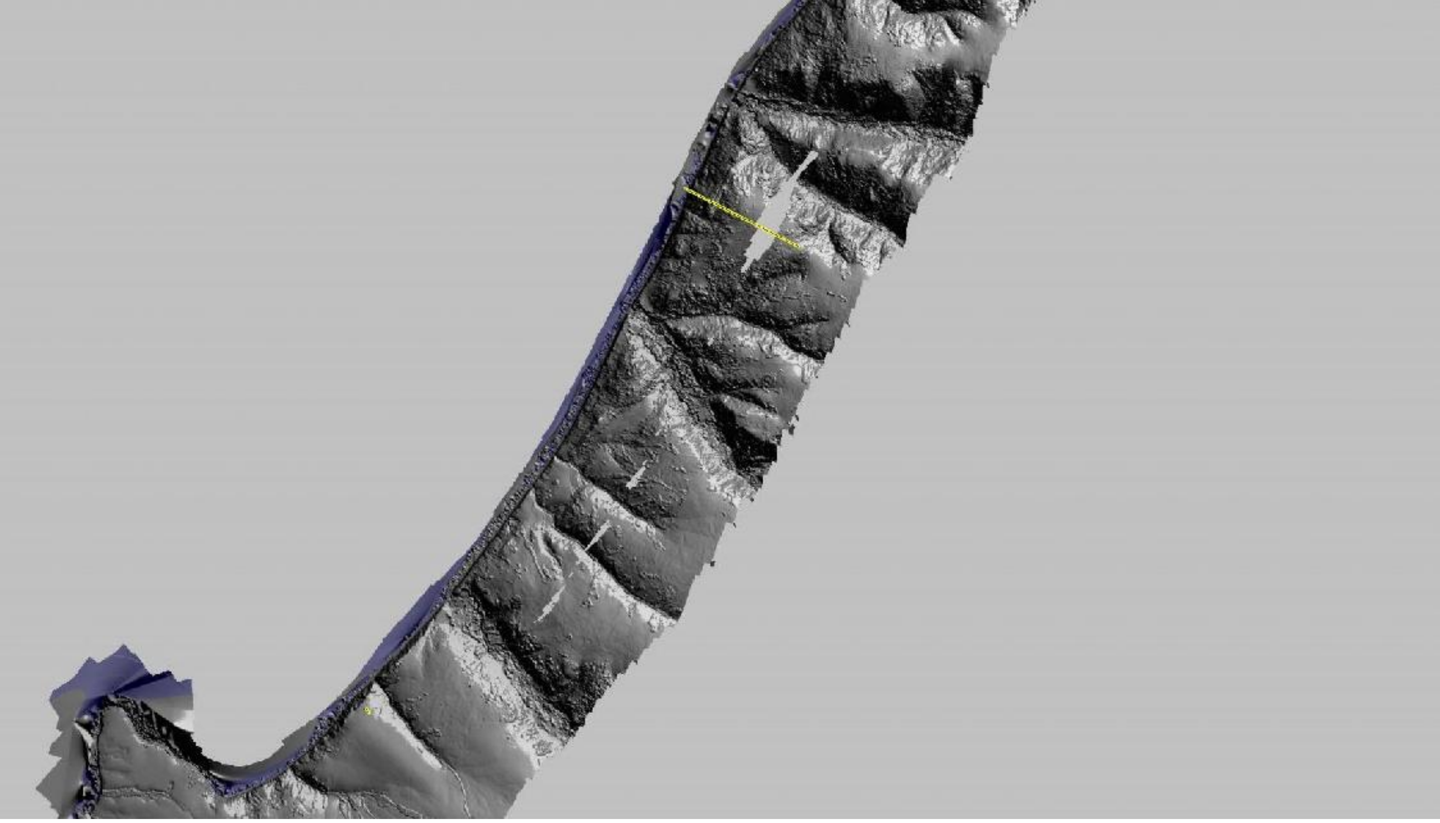
Comparisons of overlap with Kotlik to Stebbins block (top) and Nome to Elim block (bottom), here showing the Norton block othoimage. Flicker with the next figure to see the other blocks' orthoimage. Offsets of 1-2 pixels are common here, which is excellent, especially considering they are across a UTM zone boundary at high latitudes.

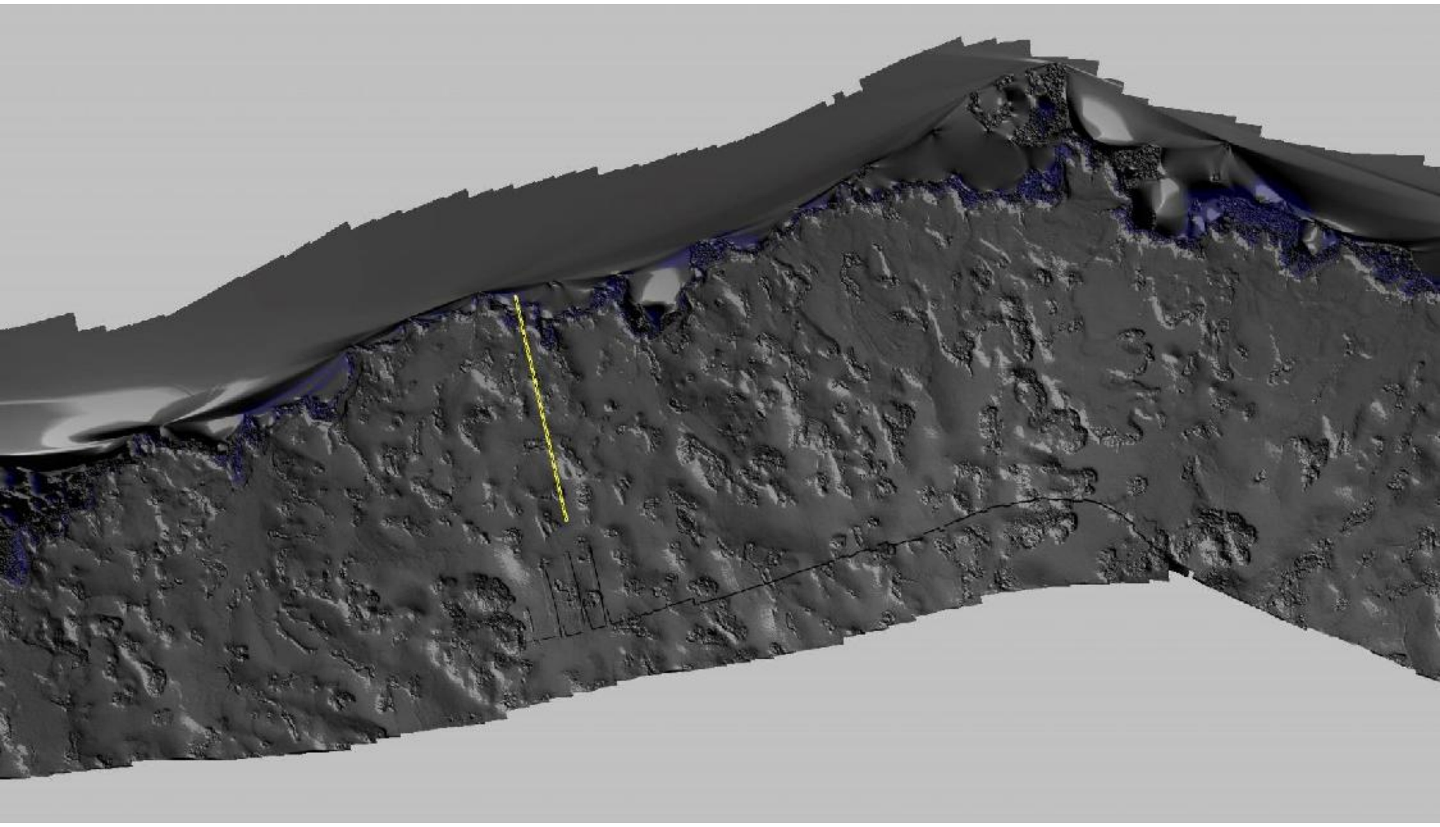


Comparison of overlap with the Kotlik to Stebbins block reveals random noise on the +/- 5 cm level and spatially correlated noise on the +/- 20 cm level.

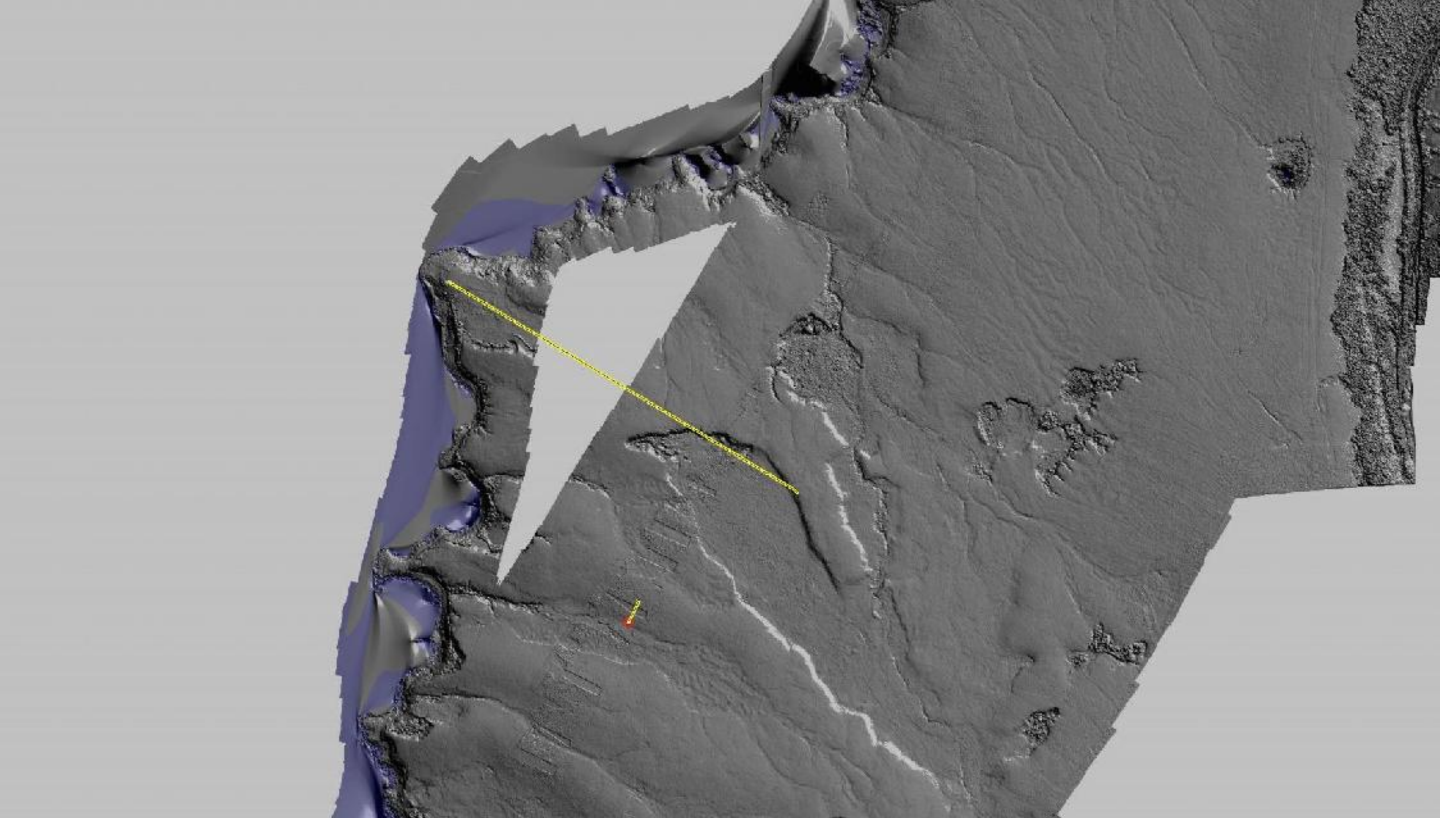


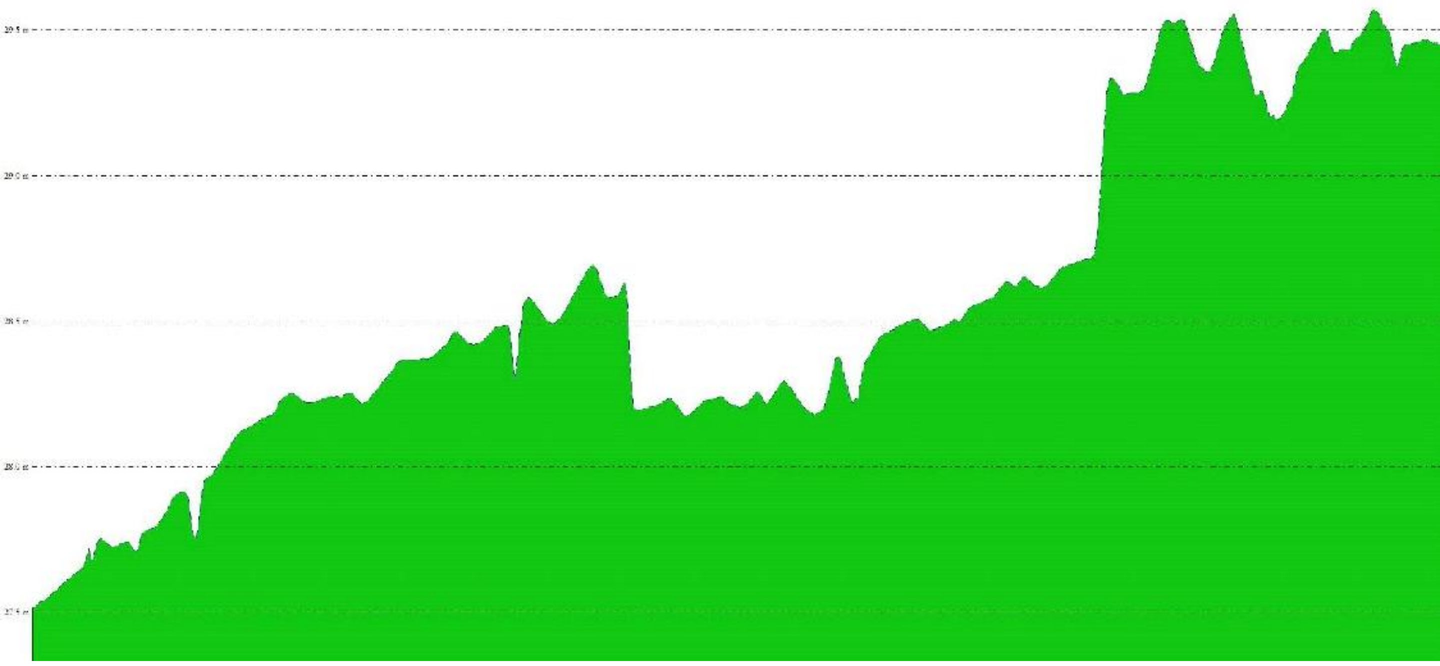
Comparison of overlap with the Nome to Elim block reveals random noise on the +/- 5 cm level and spatially correlated noise on the +/- 25 cm level.



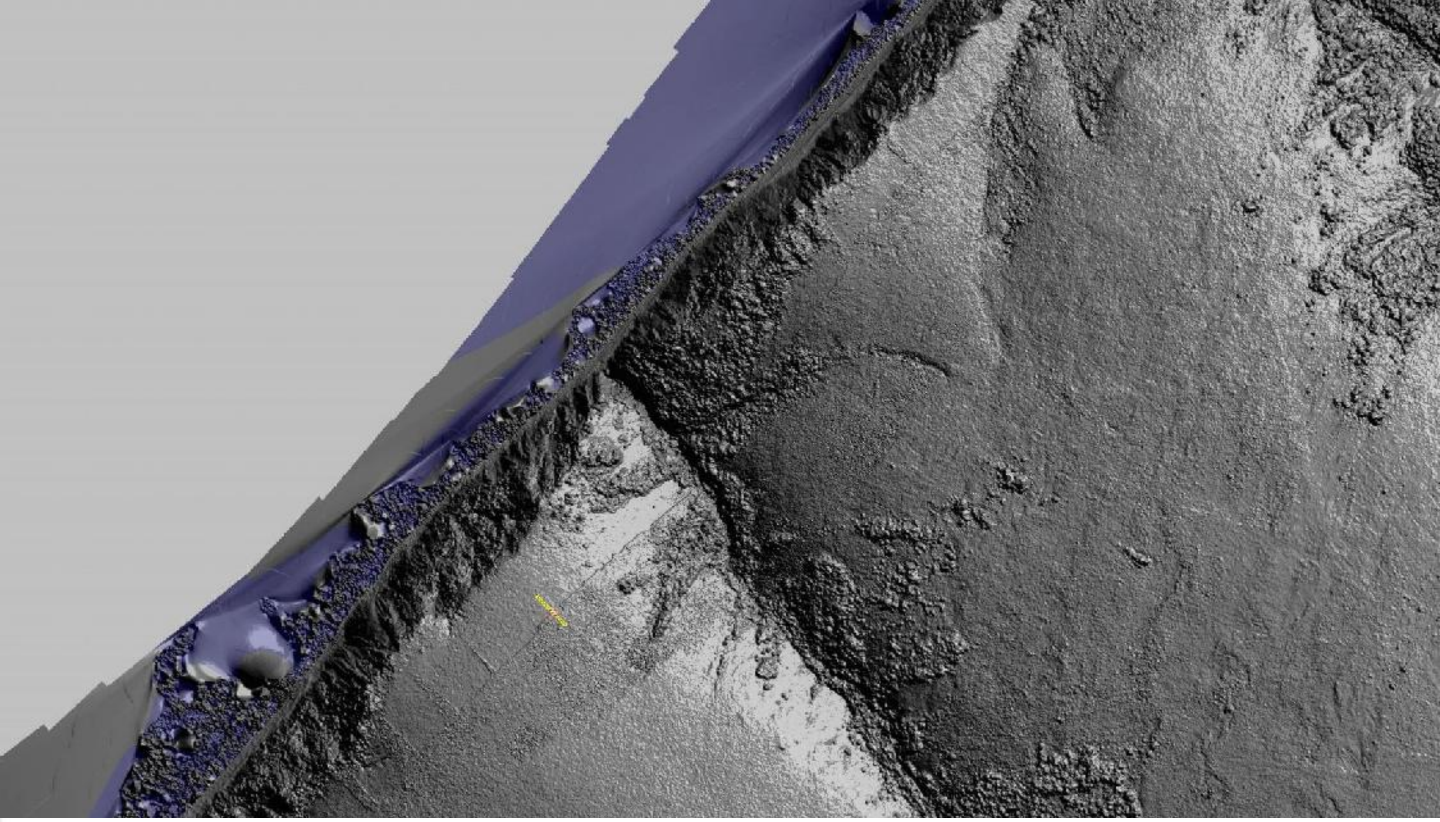


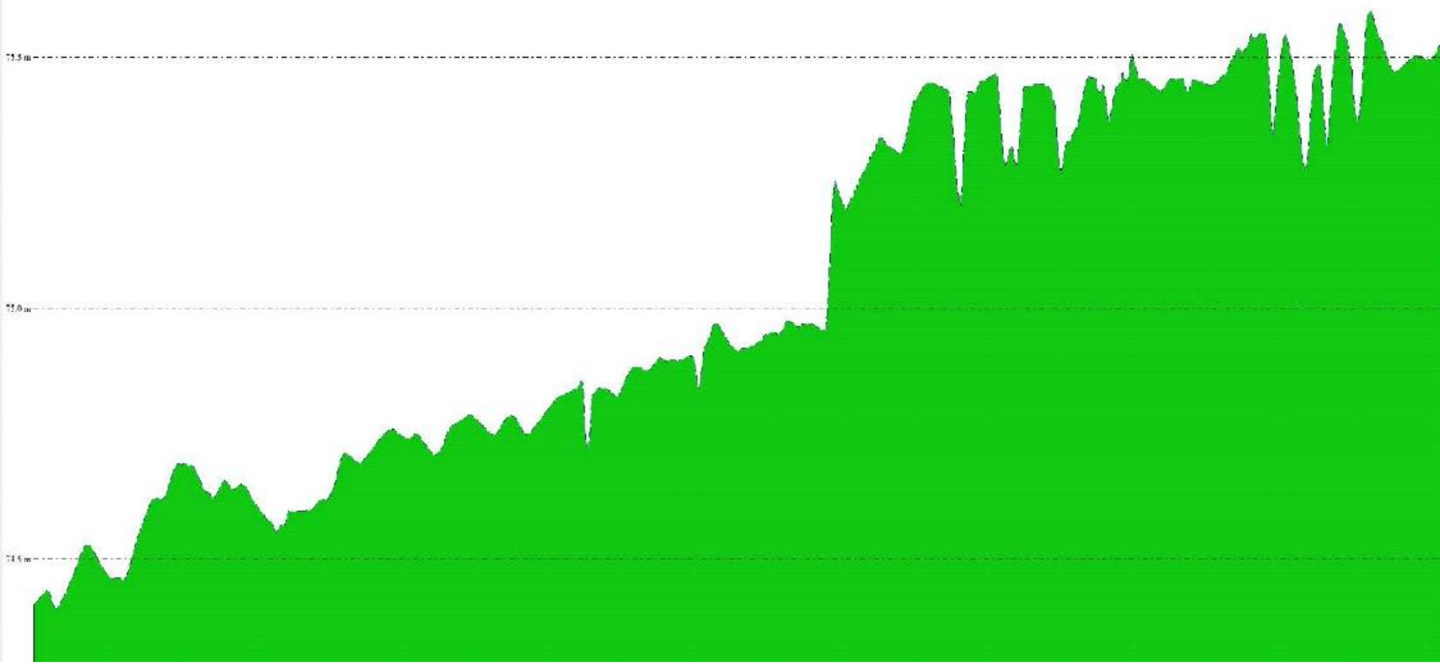
The southeastern corner of Norton Sound suffered the worst gaps of the project due to persisted bad weather. At top, low clouds over the mountains forced lower flying altitudes and small gaps, but these amount to only about 0.2% of the project area. At bottom, some pits exist, but are outside the AOI.



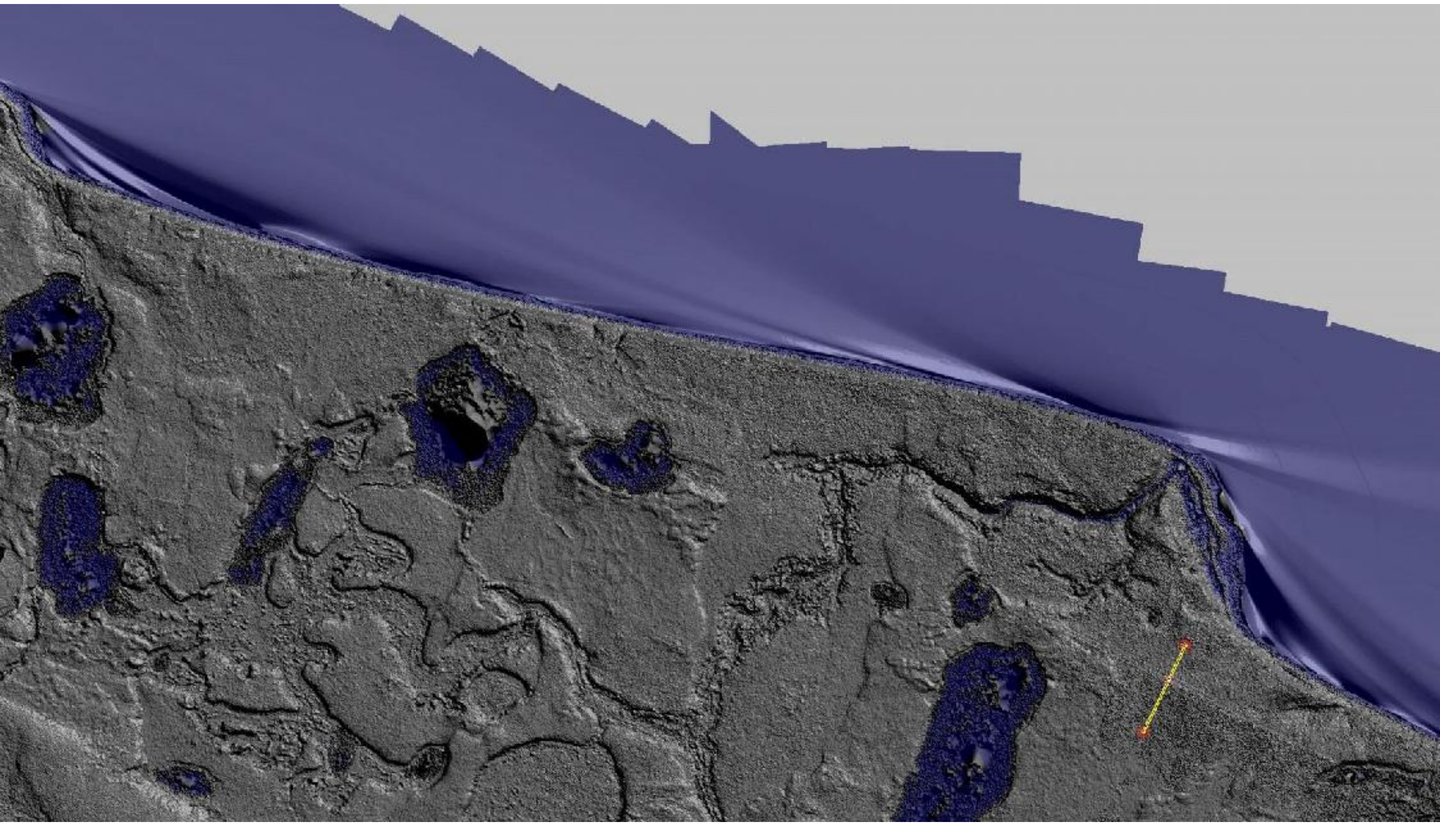


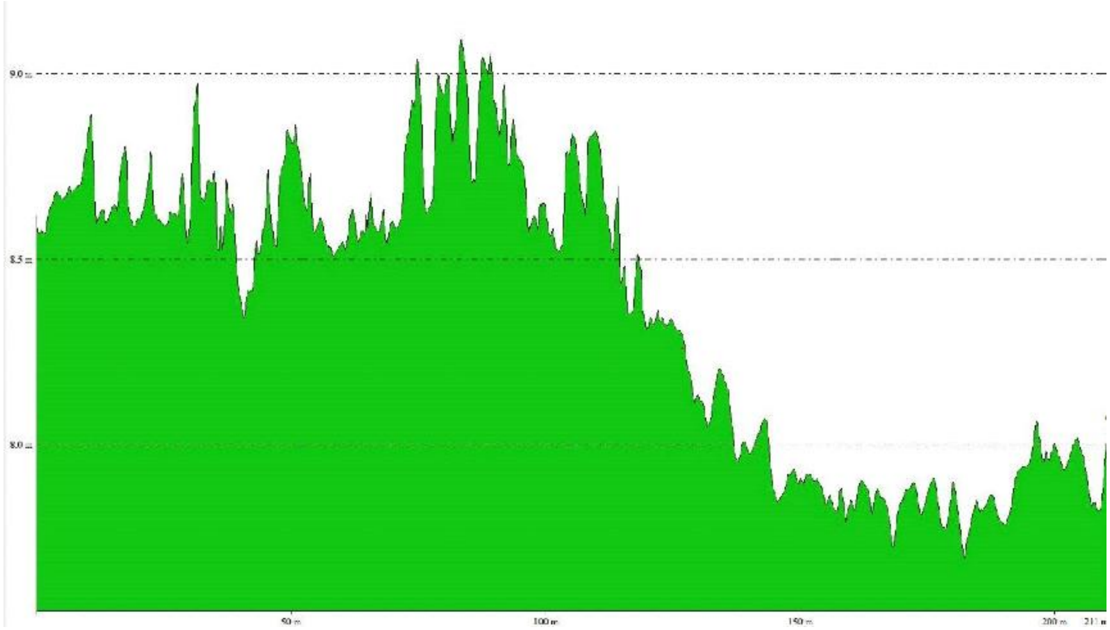
Another small gap near the coast due to low clouds in the same area as previous figure, only about 0.4 sq km. The GSD on the coast is twice spec and the inland area also twice spec in coverage (yellow line is 1500 m). Some small rectangular pits exist here caused by low altitude flying, with the worst amplitude at about 80 cm.



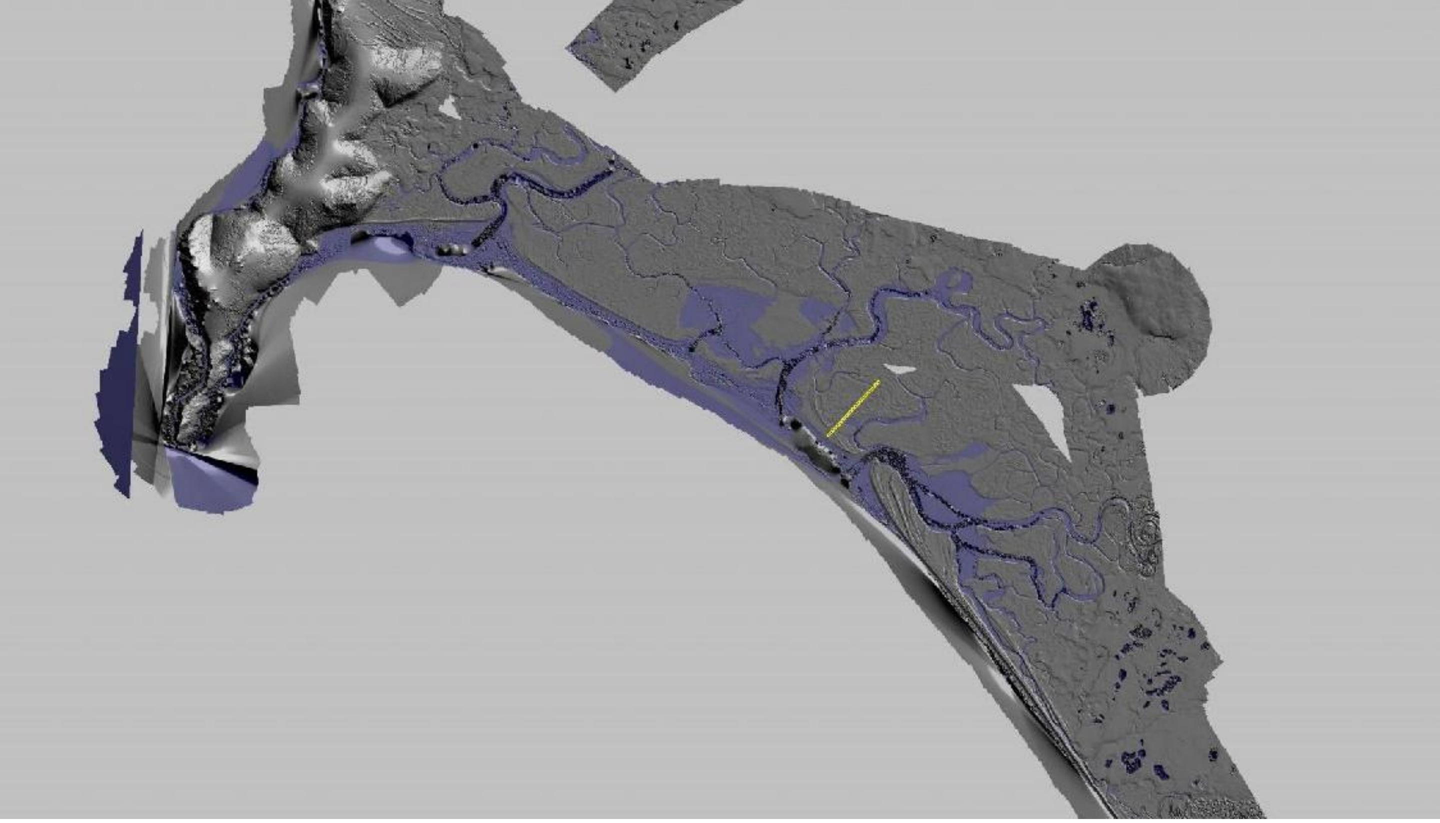


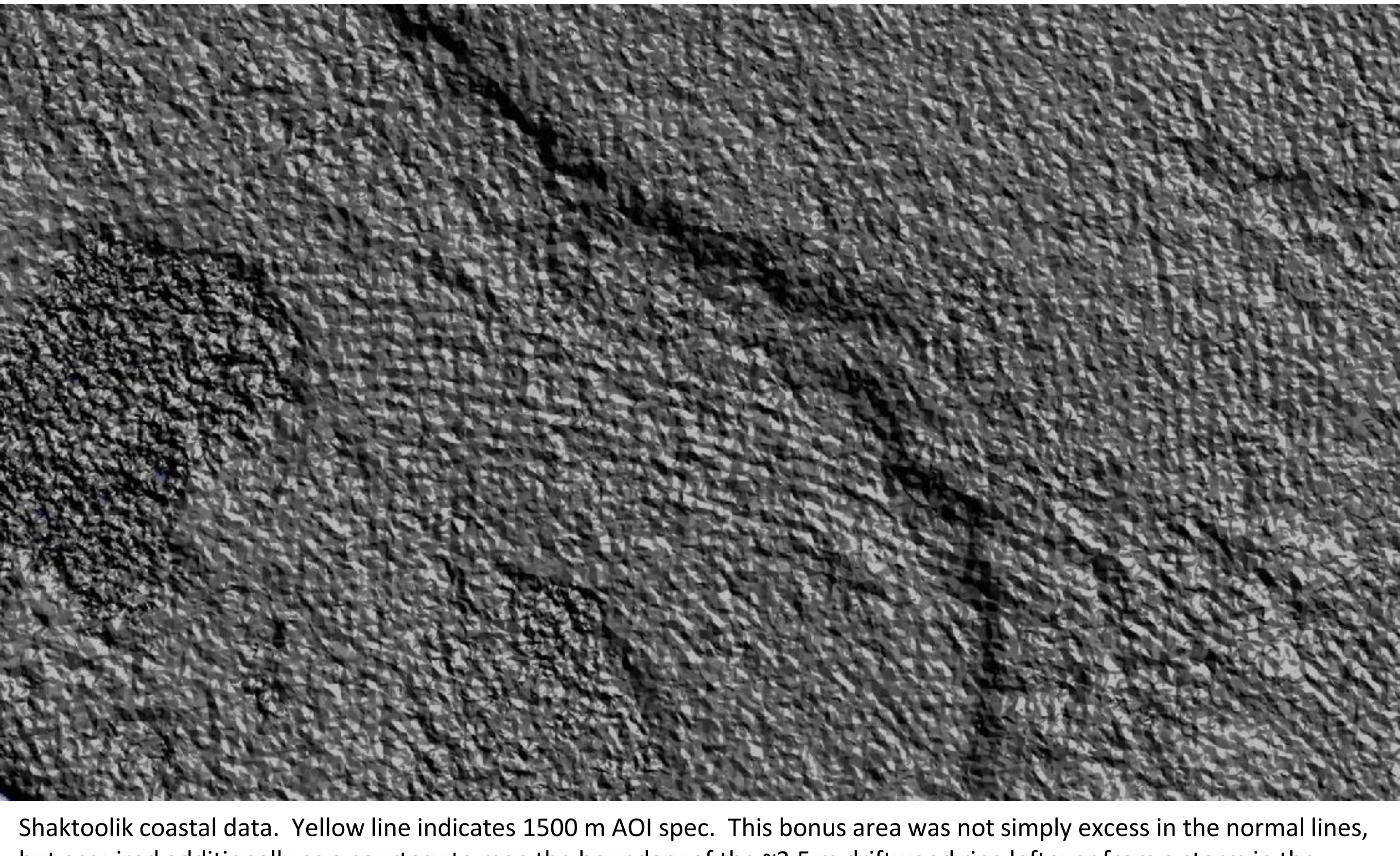
More pits in the same area as previous figure, with an amplitude of about 25 cm, within spec. These past three slides show the extent of the largest artifacts within the dataset.





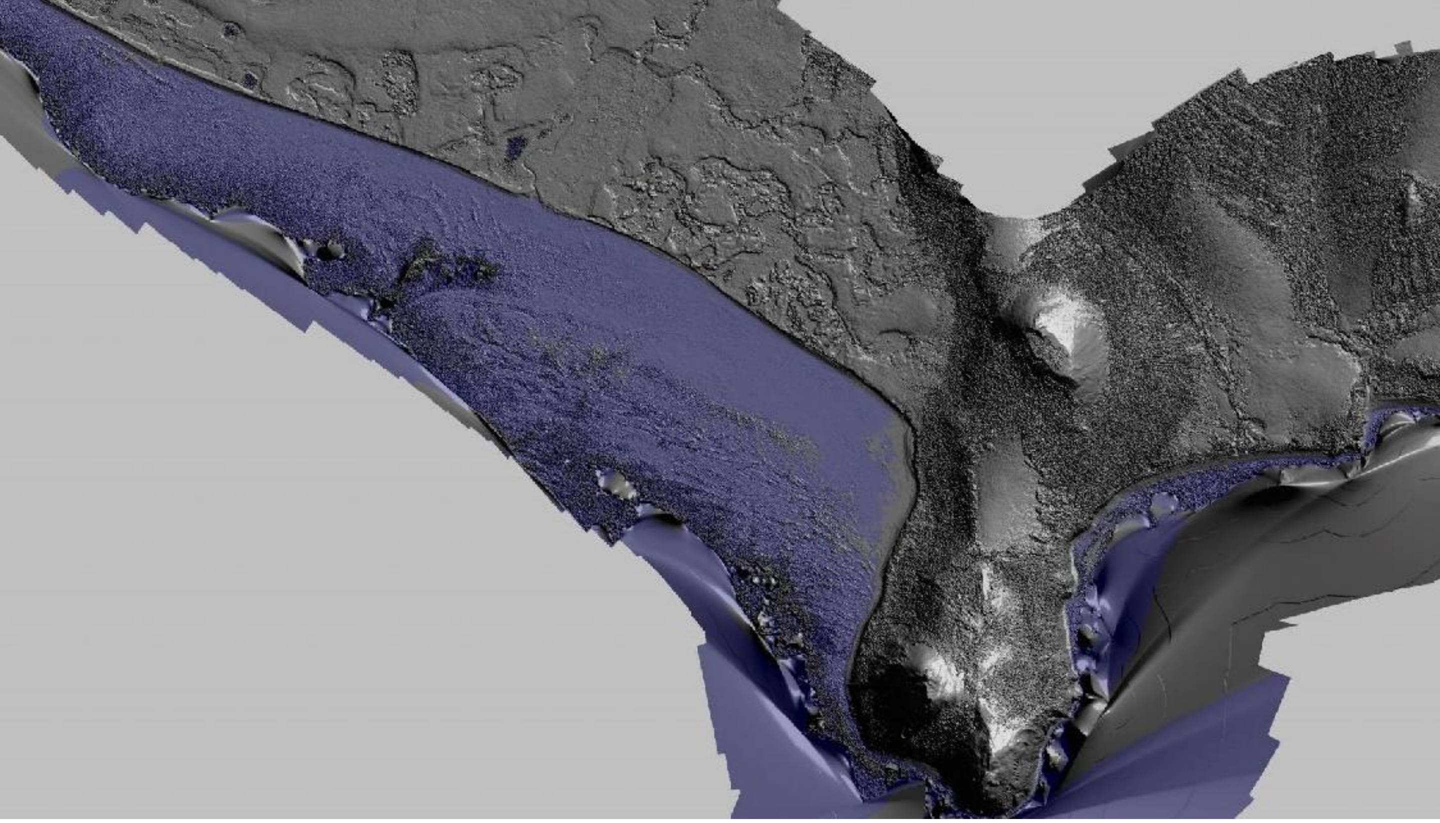
A similar feature as in previous figure, visible in the shaded relief which highlights edge detail, but barely visible in the actual transect. The orthomosaic is essentially unaffected by any artifacts other than gaps.

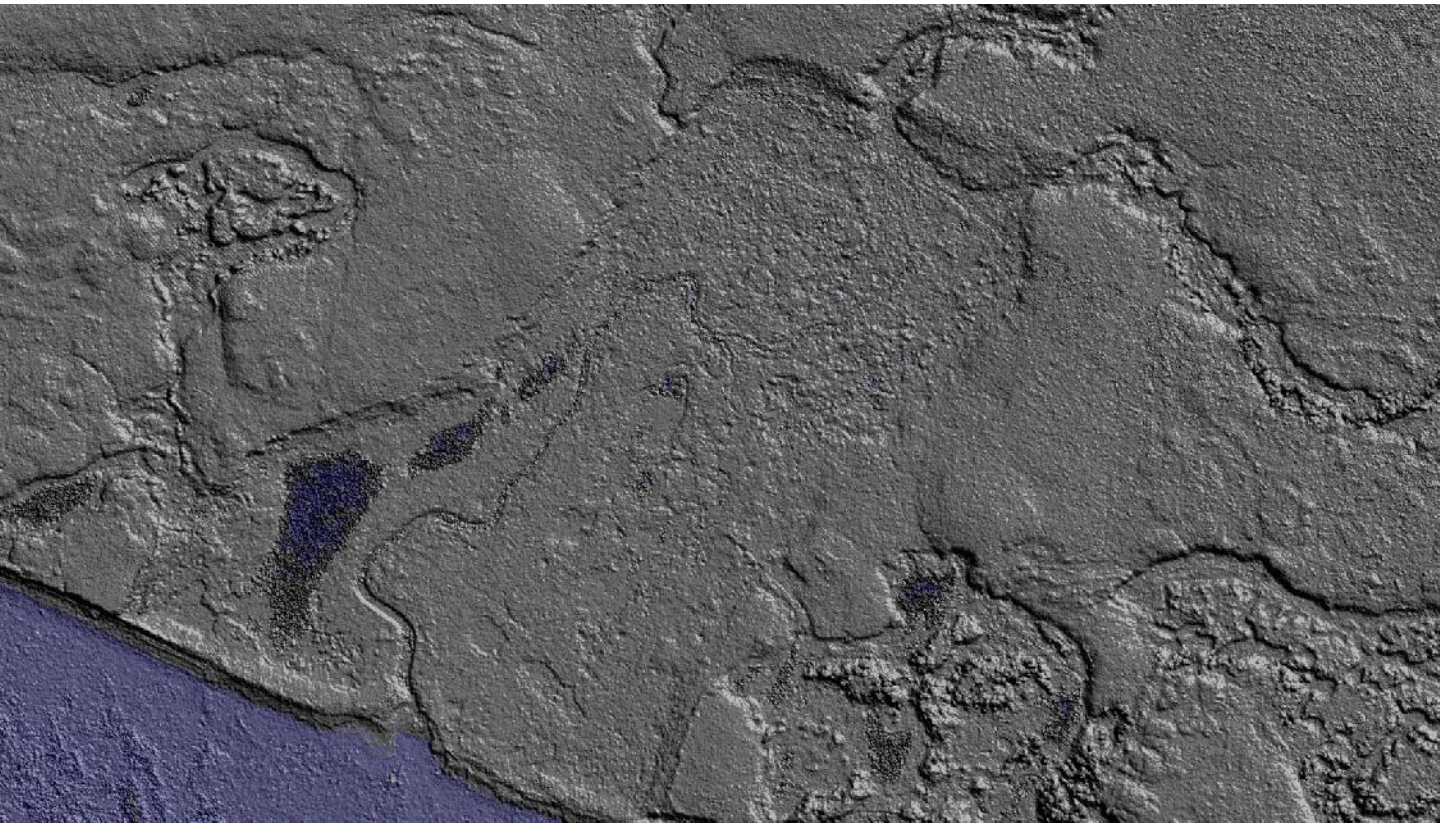




Shaktoolik coastal data. Yellow line indicates 1500 m AOI spec. This bonus area was not simply excess in the normal lines, but acquired additionally as a courtesy to map the boundary of the ~2.5 m driftwood ring leftover from a storm in the 1970s. Flicker with next figure to see the logs. The corduroy seen here has an amplitude of about +/- 10 cm, not bad for edge data.

Shaktoolik coastal data. Yellow line indicates 1500 m AOI spec. This bonus area was not simply excess in the normal lines, but acquired additionally as a courtesy to map the boundary of the ~2.5 m driftwood ring leftover from a storm in the 1970s. Flicker with previous figure to see the DEM.

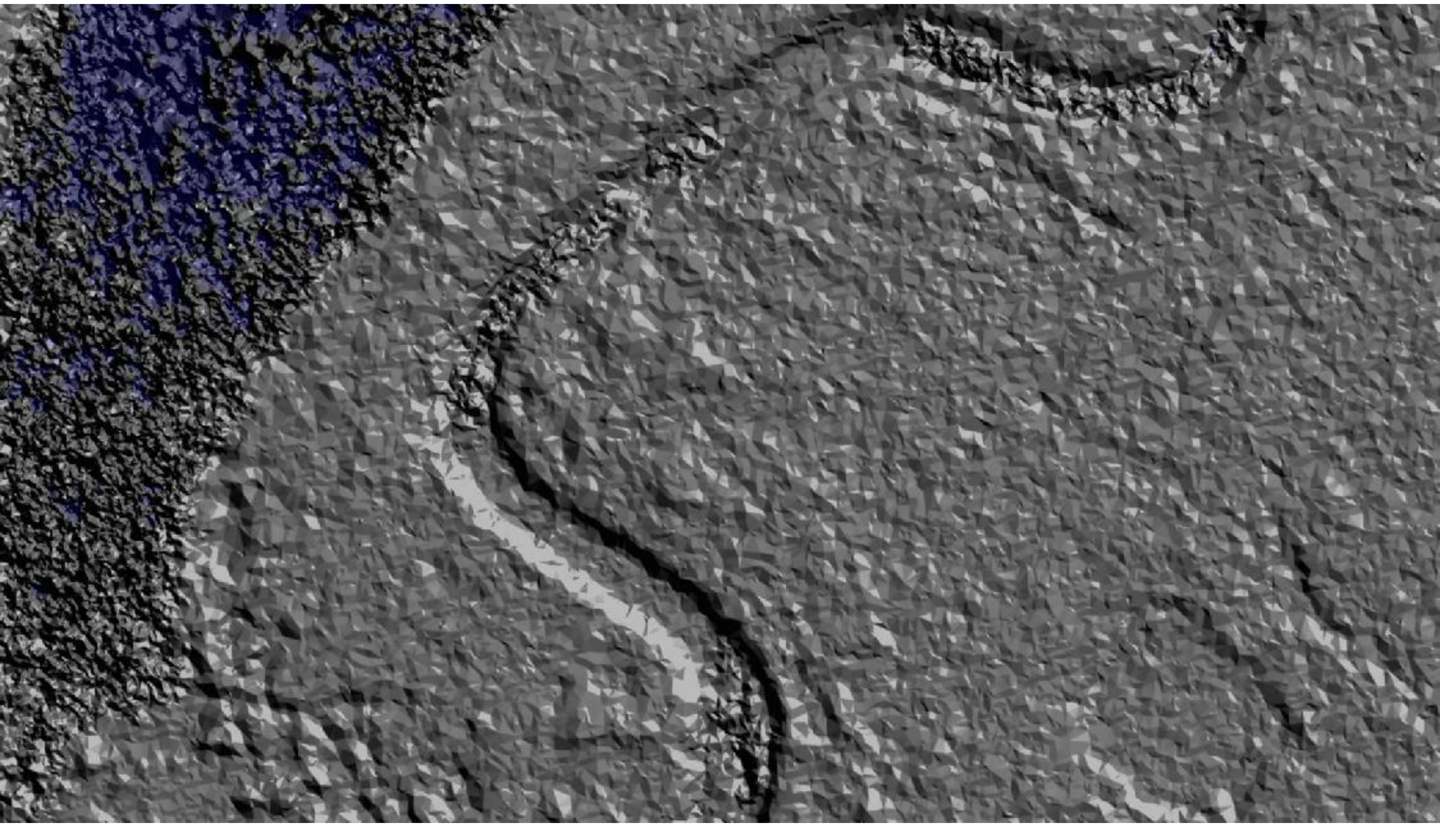




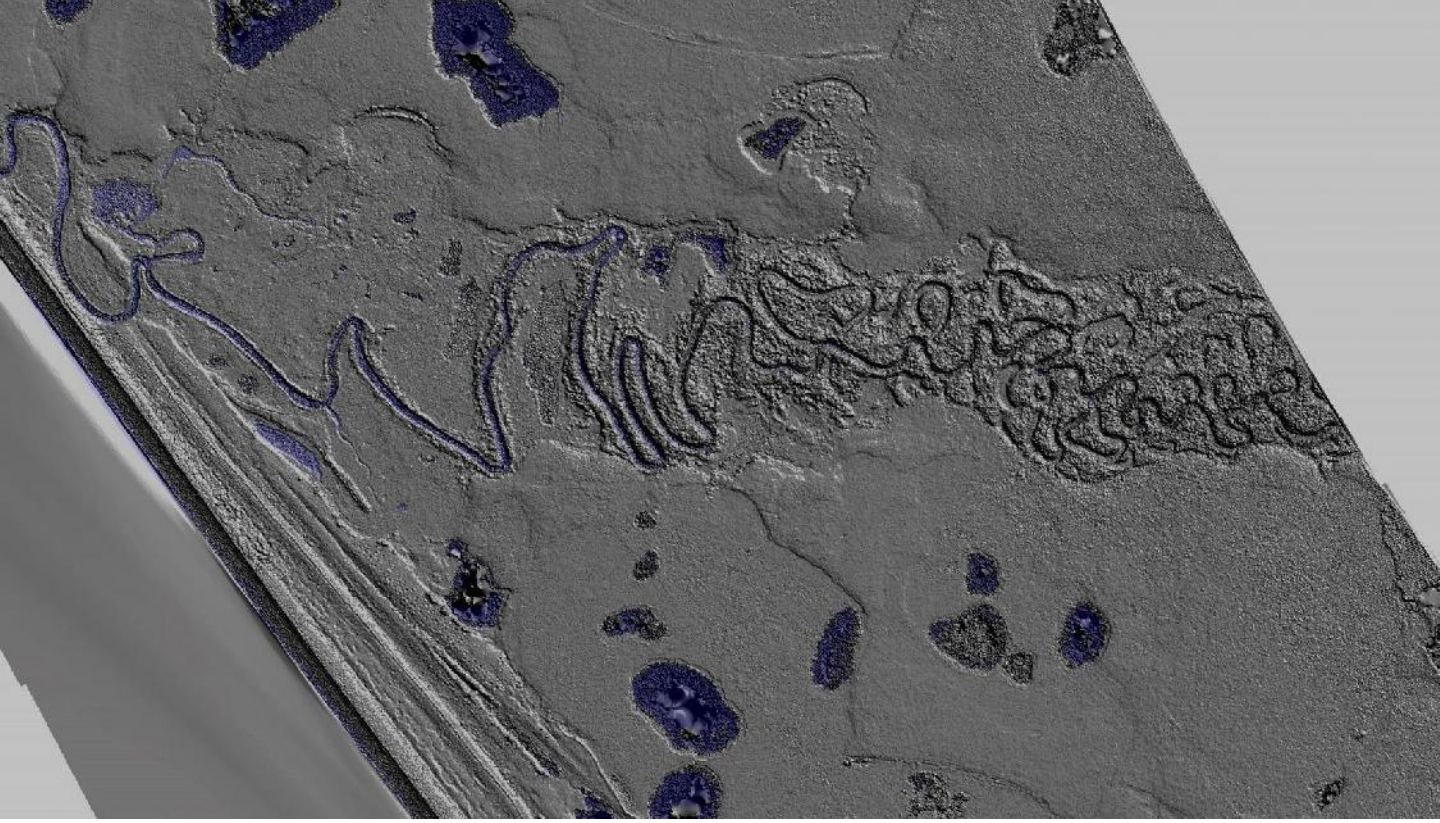
Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

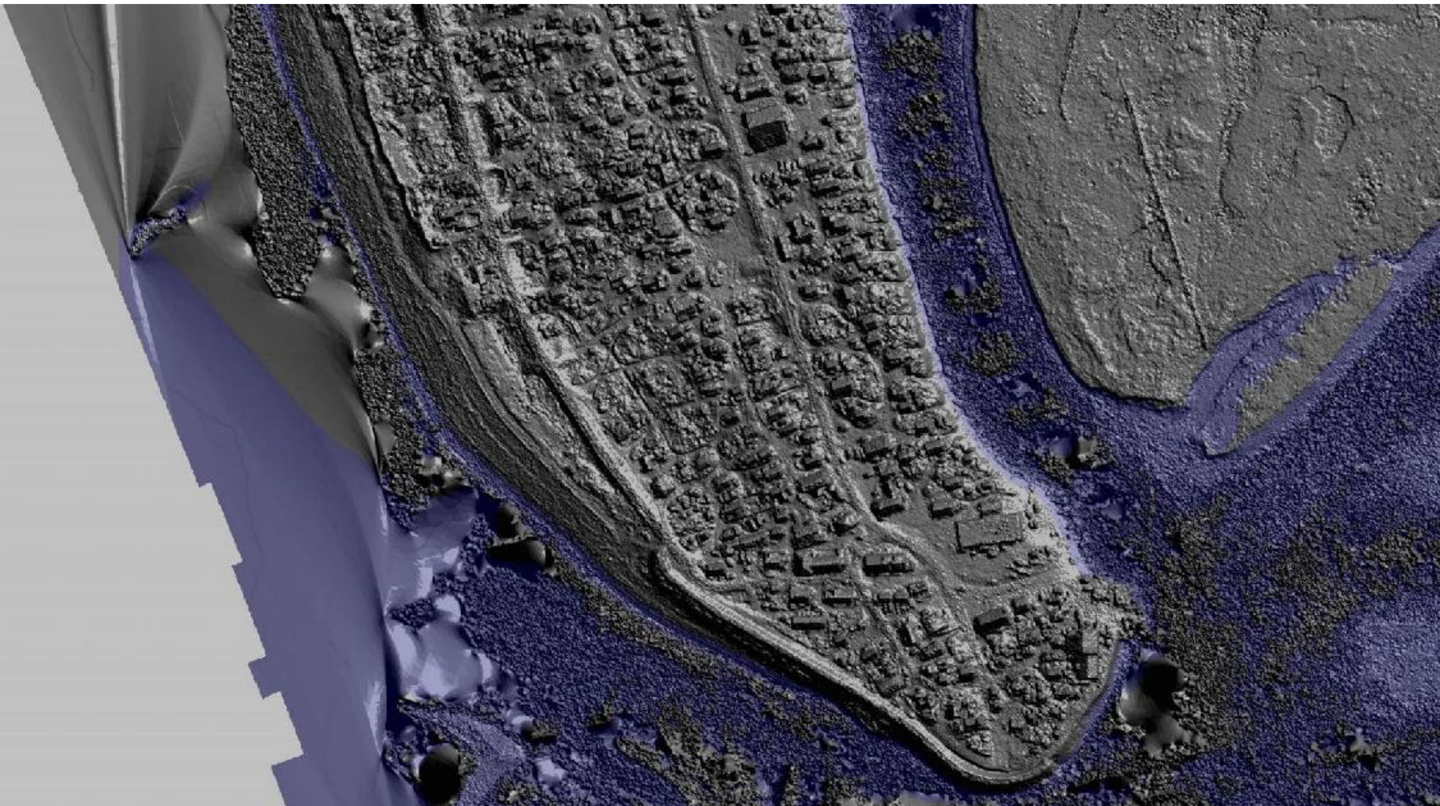
Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail. The white areas are driftwood logs.

Examples of data quality and scientific features. This in an orthomosaics corresponding with the DEMs on the next page. Flicker between them to study detail. Here in particular you can see the log jam has moved during acquisition by flickering with the DEM in the next figure.

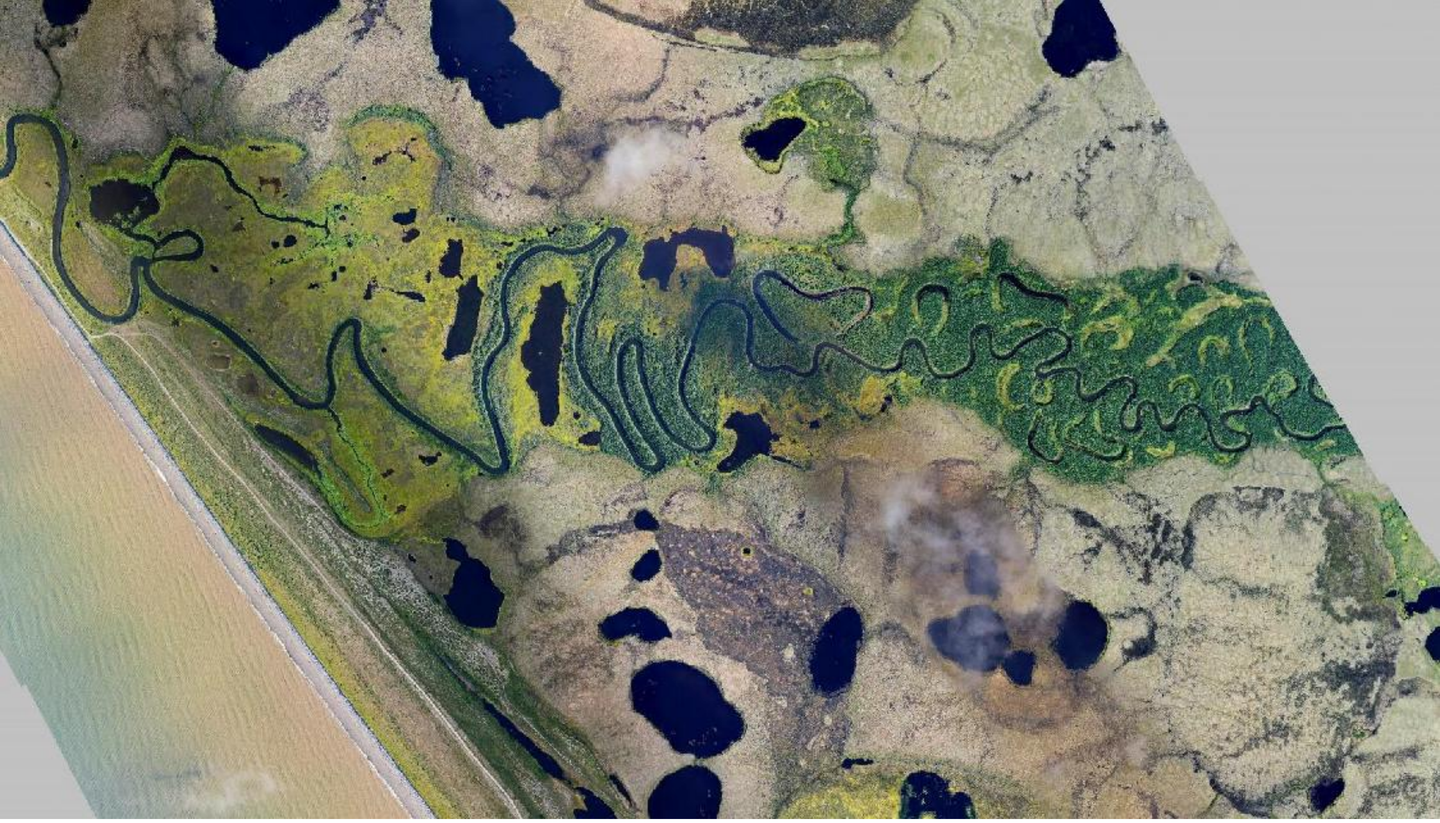


Examples of data quality and scientific features. This is a DEM shown in shaded relief with blue indicating approximately MHW. Flicker with the previous page to see the corresponding orthomosaic.

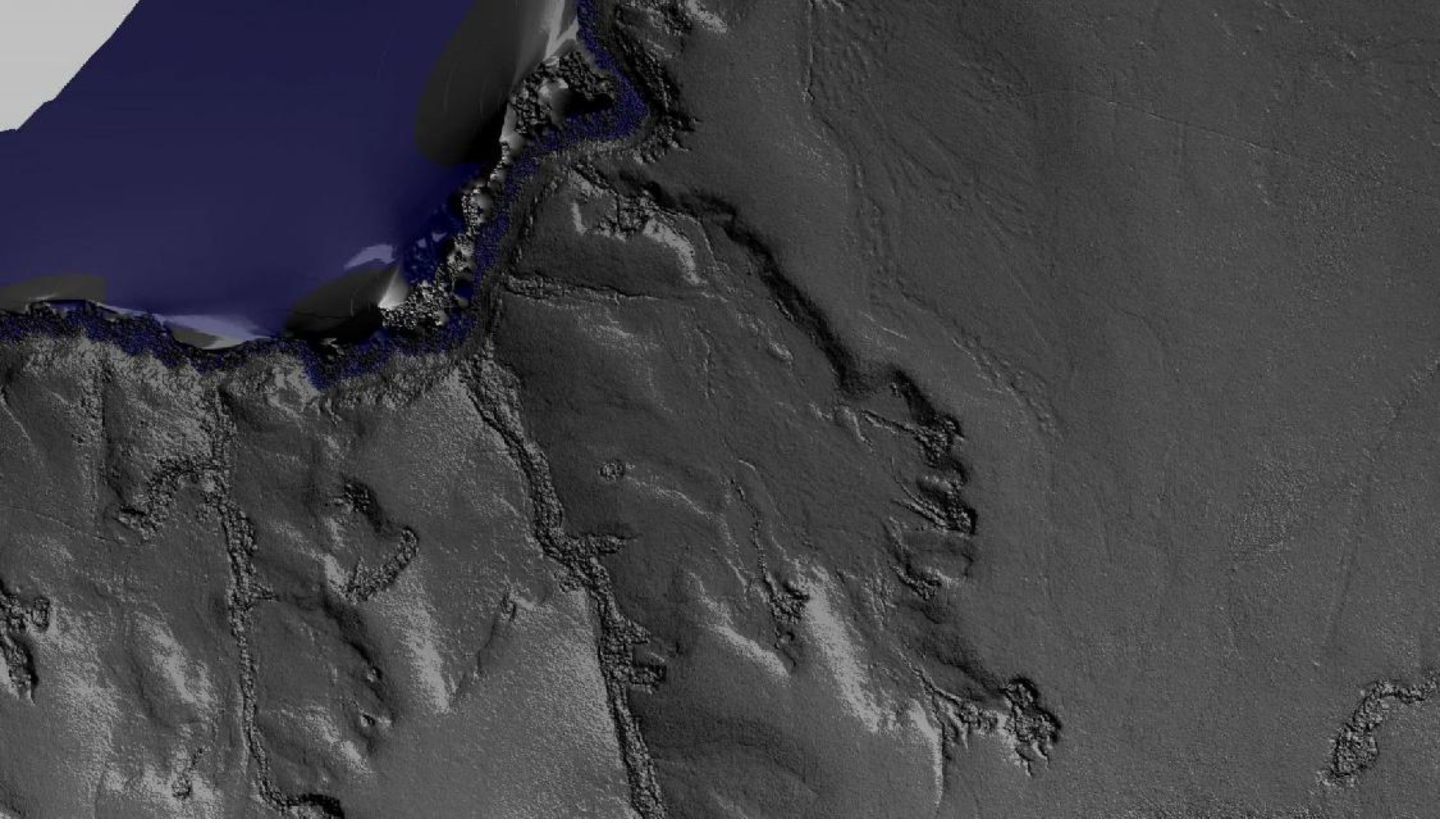


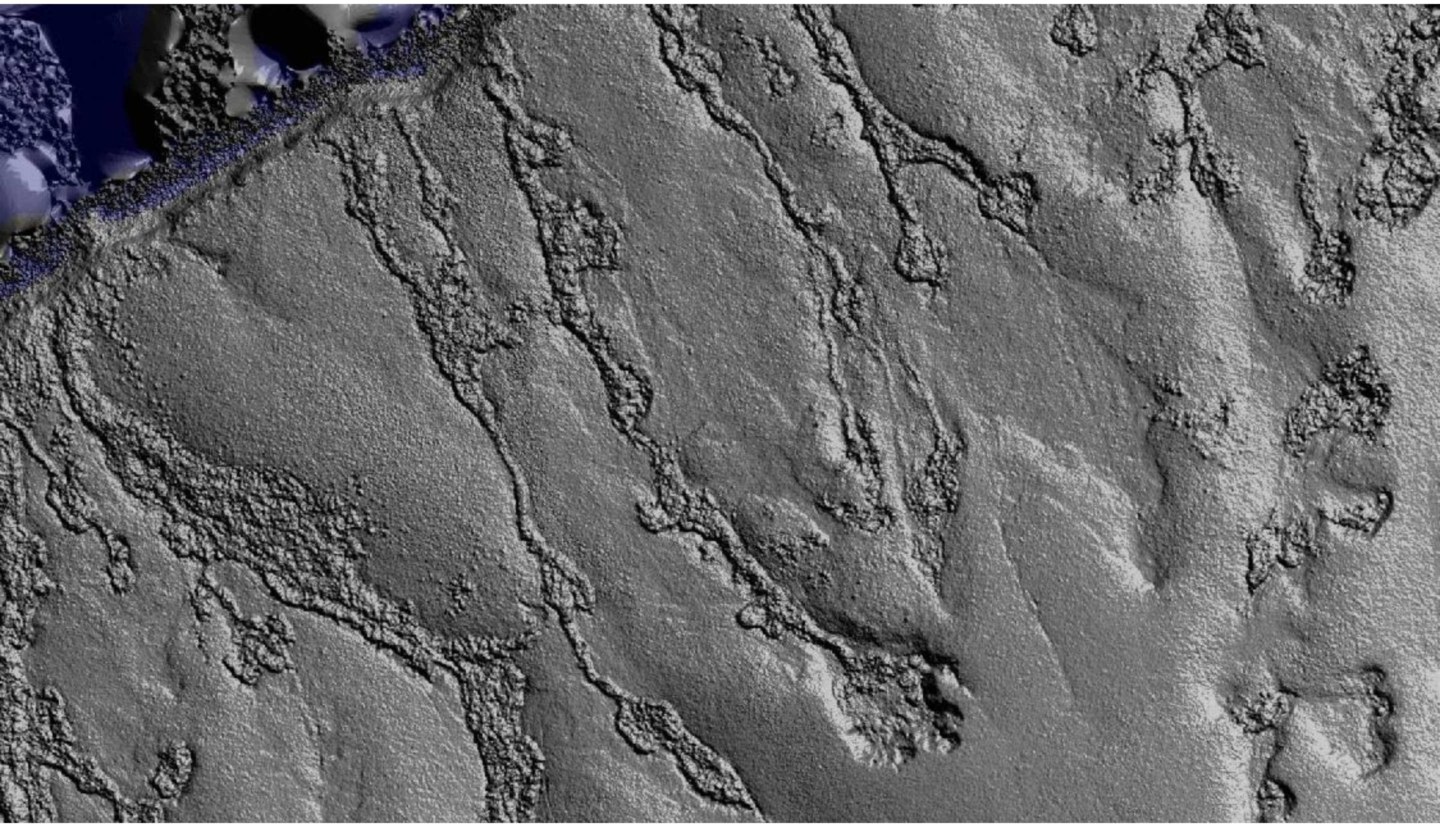


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.



Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

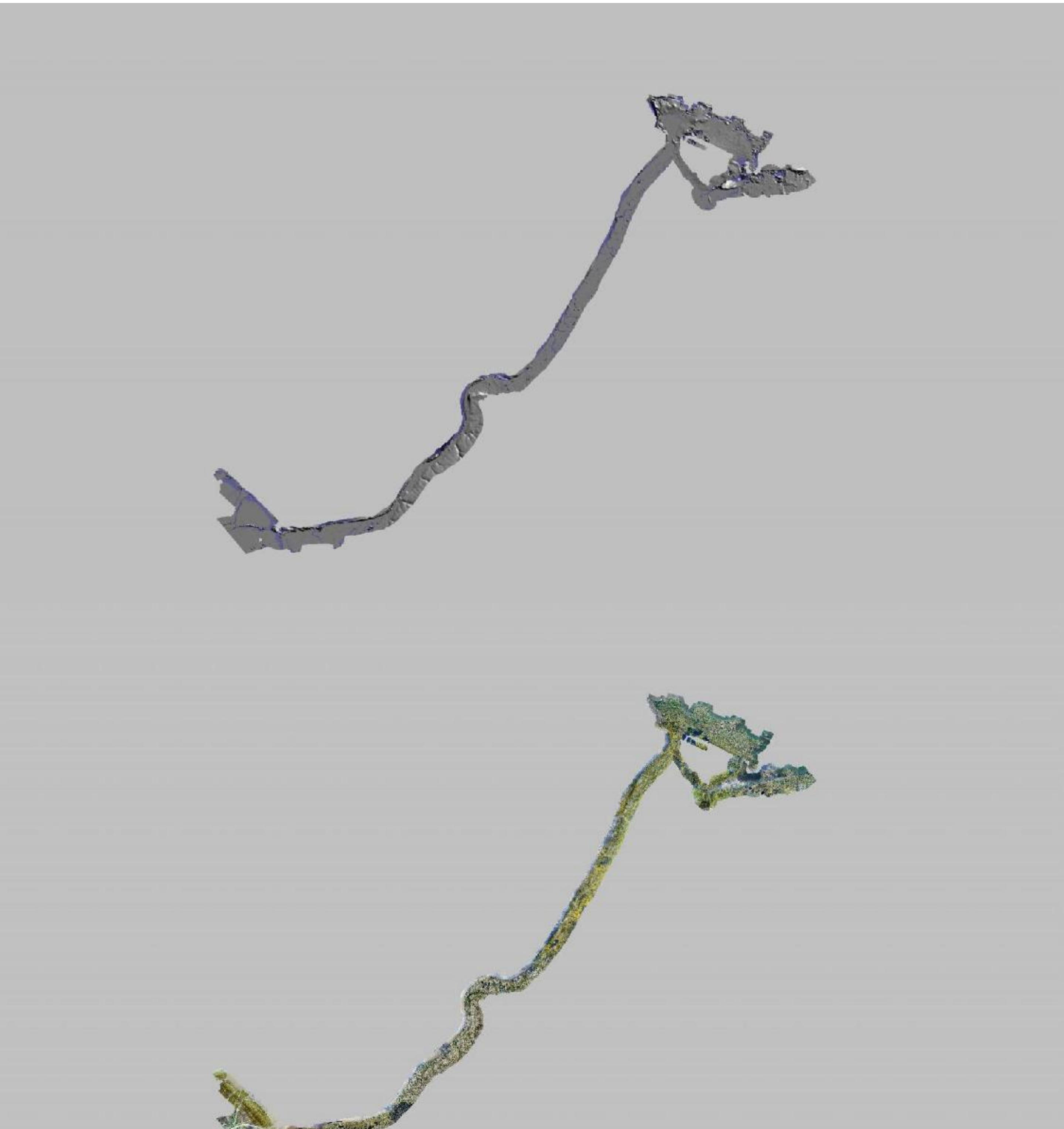




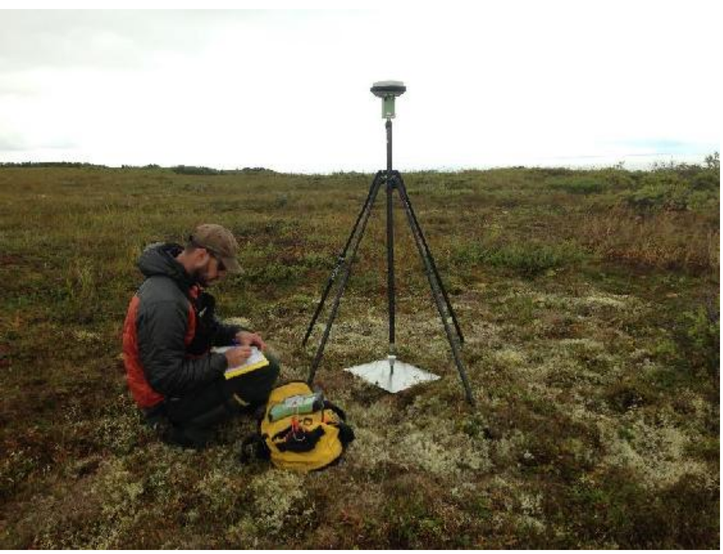
Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail. Here would be a great study on the interactions between permafrost thaw, shrub growth, and snow depth.

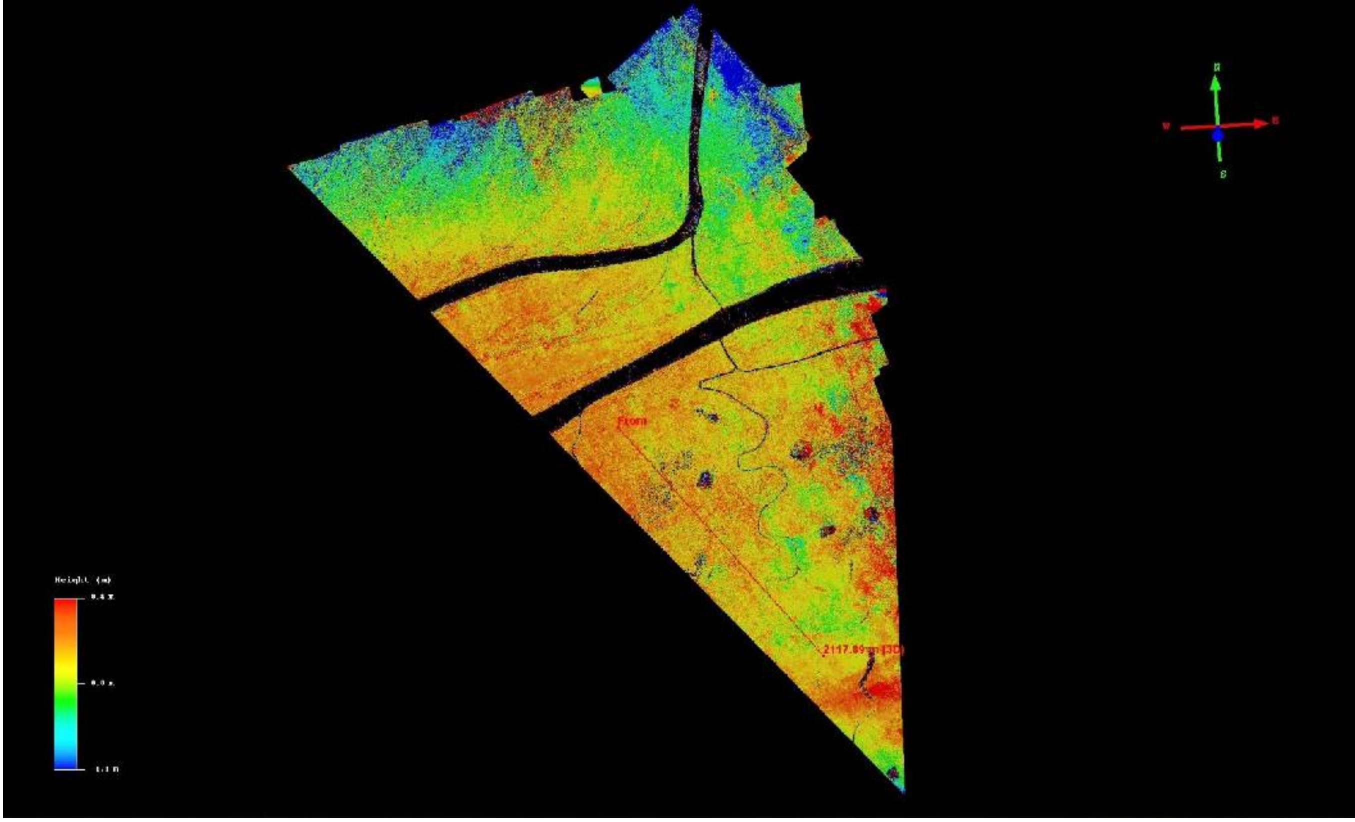
Kotlik to Stebbins Block

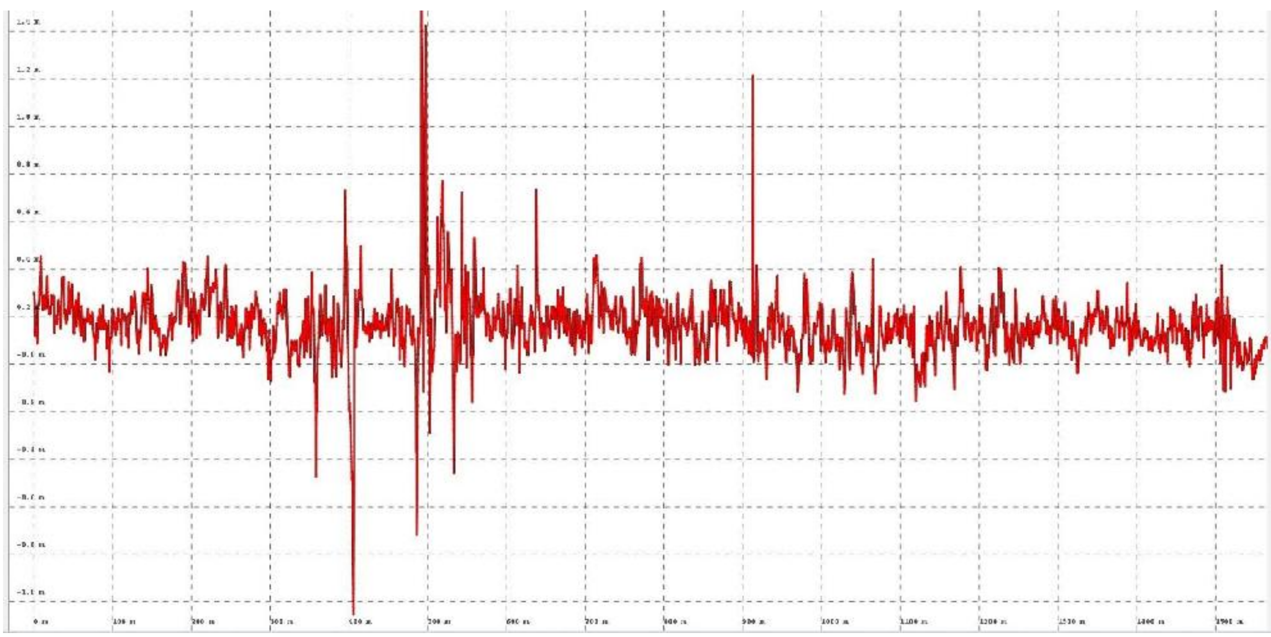


Overview of DEM and orthomosaic

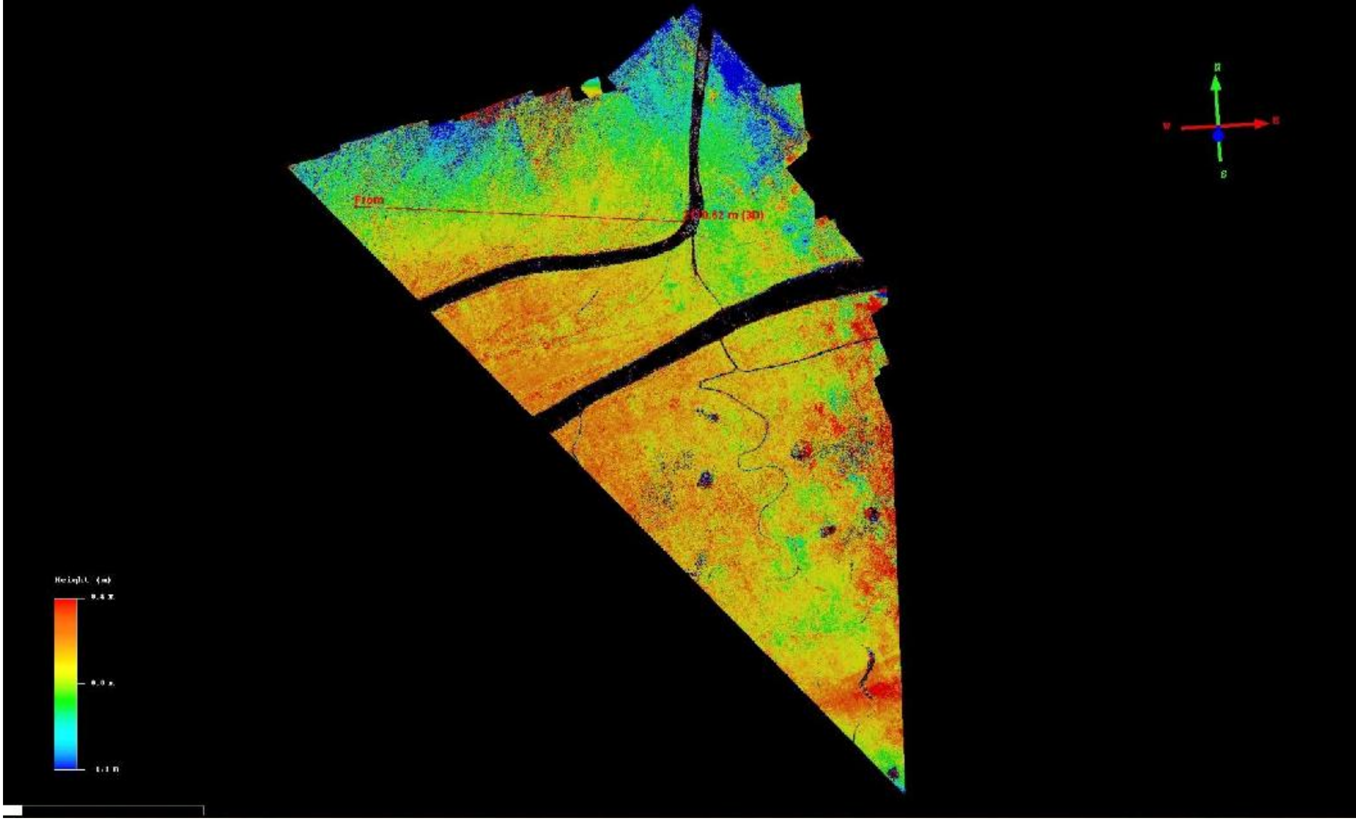


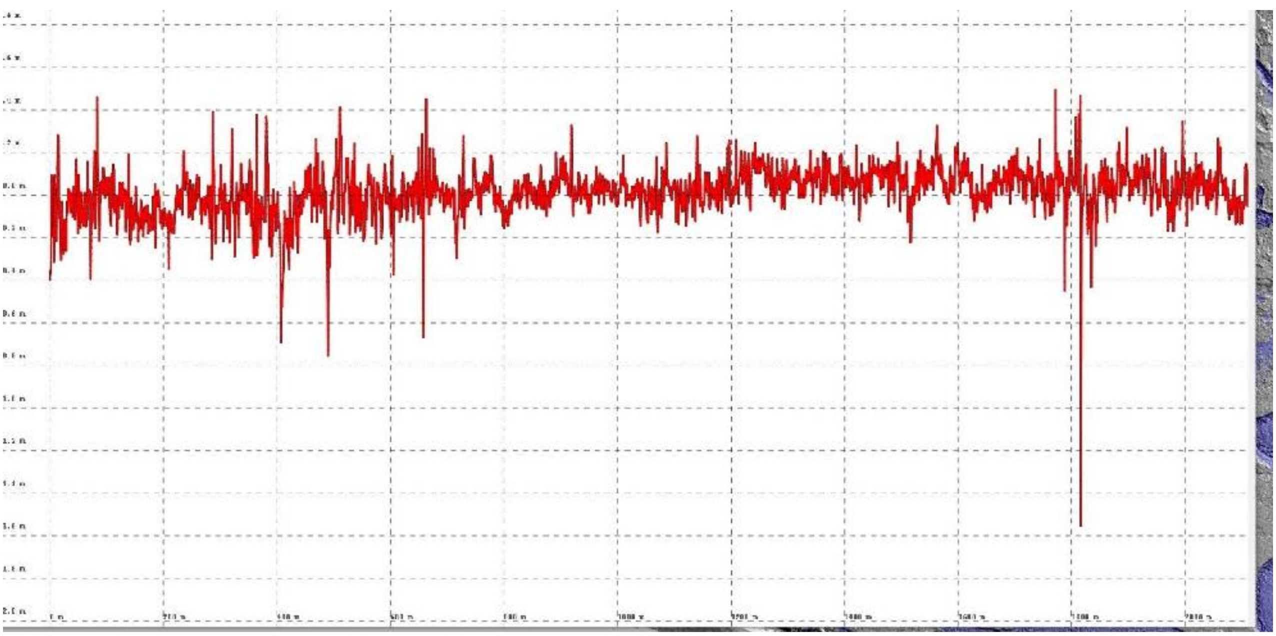
GCPs





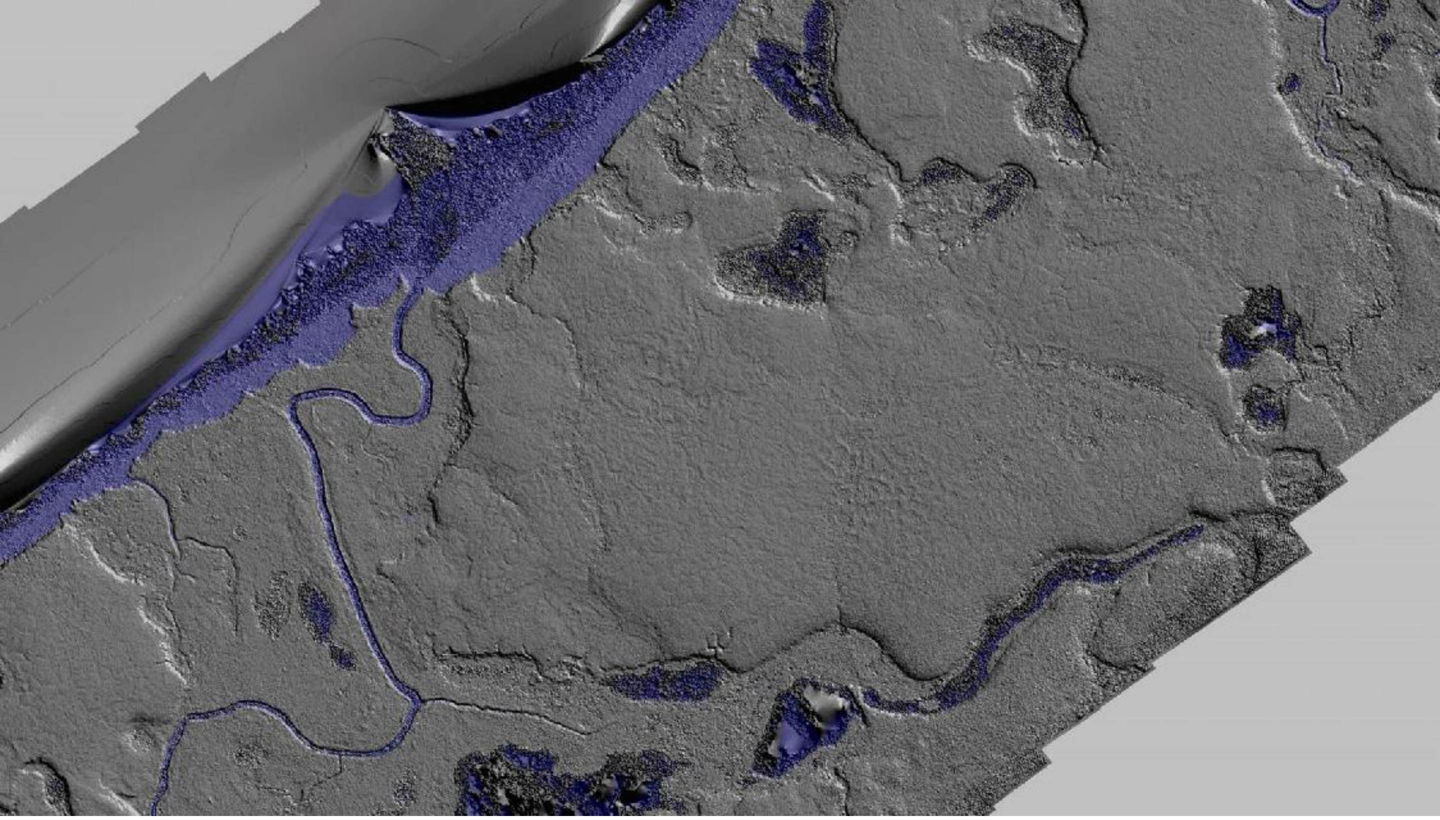
Difference image of overlap comparison to Kotlik village data. The bulk of the data is +/- 8 cm, offset by the coastal data being about 15 cm lower, with larger excursions due to water bodies.

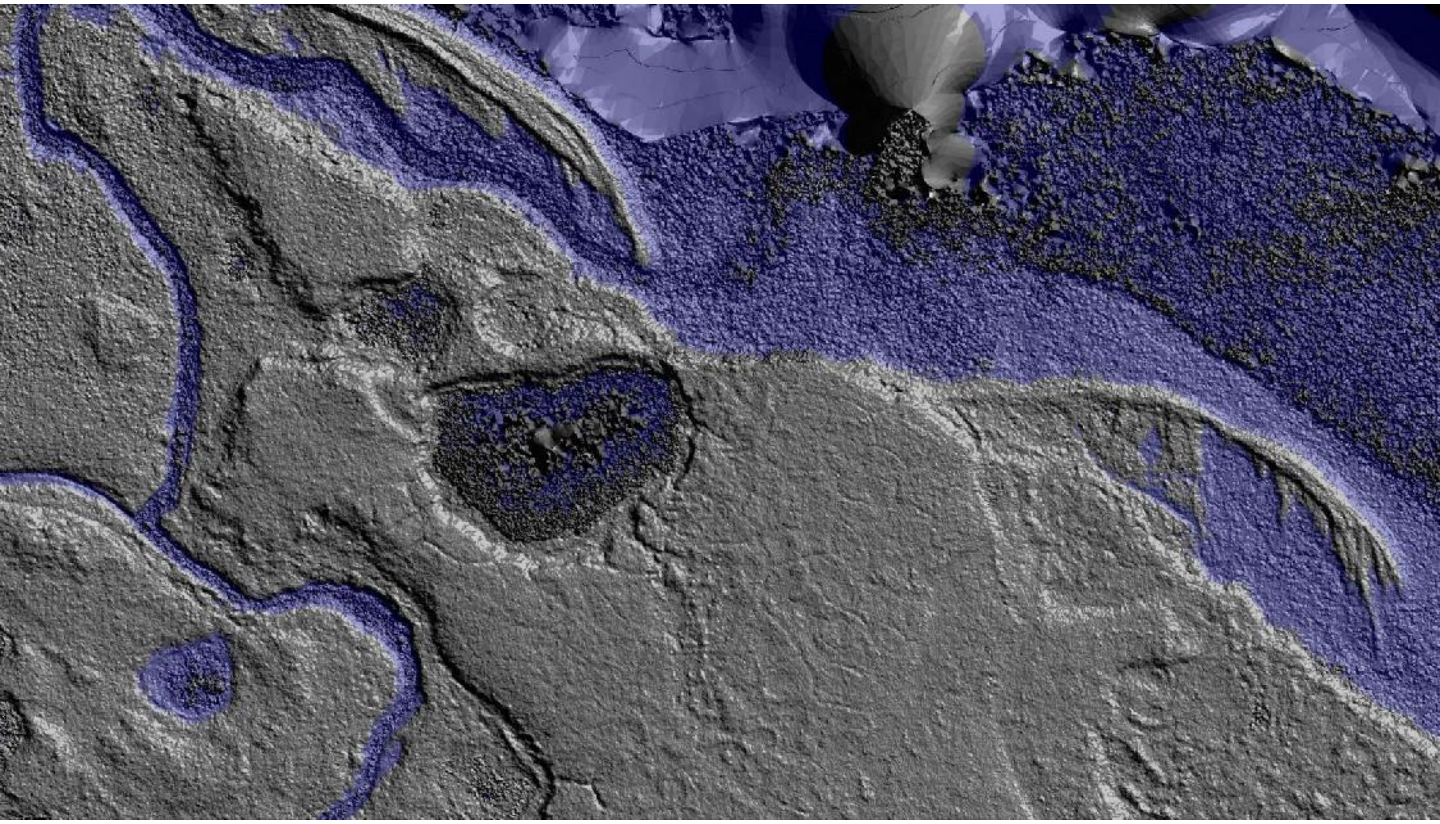




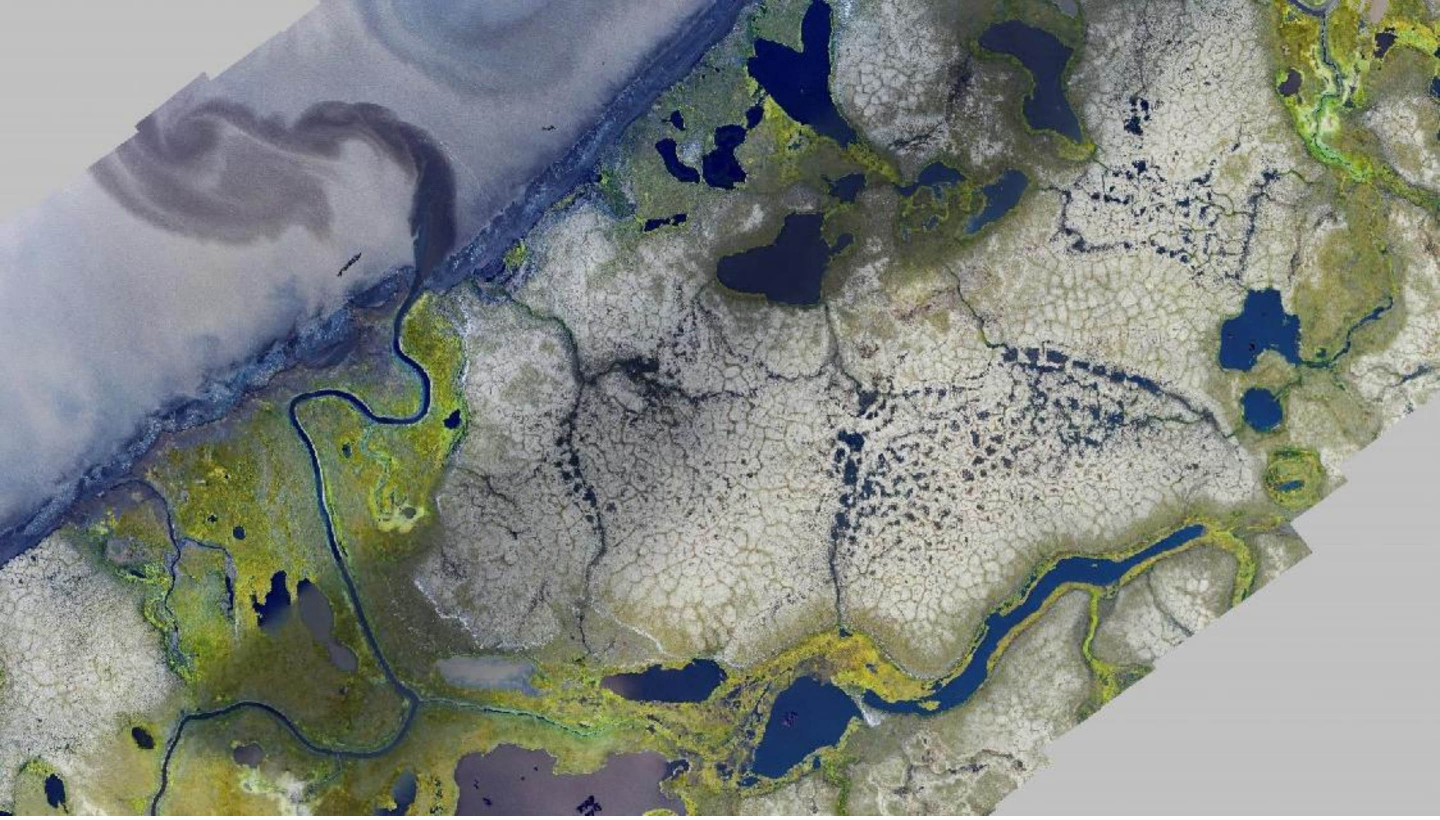
Difference image of overlap comparison to Kotlik village data. The bulk of the data is +/- 8 cm, with about a zero mean difference, with larger excursions due to water bodies. Spatially coherent noise on the 10-20 cm level accounts for the differences in offset, such as in the previous figure.

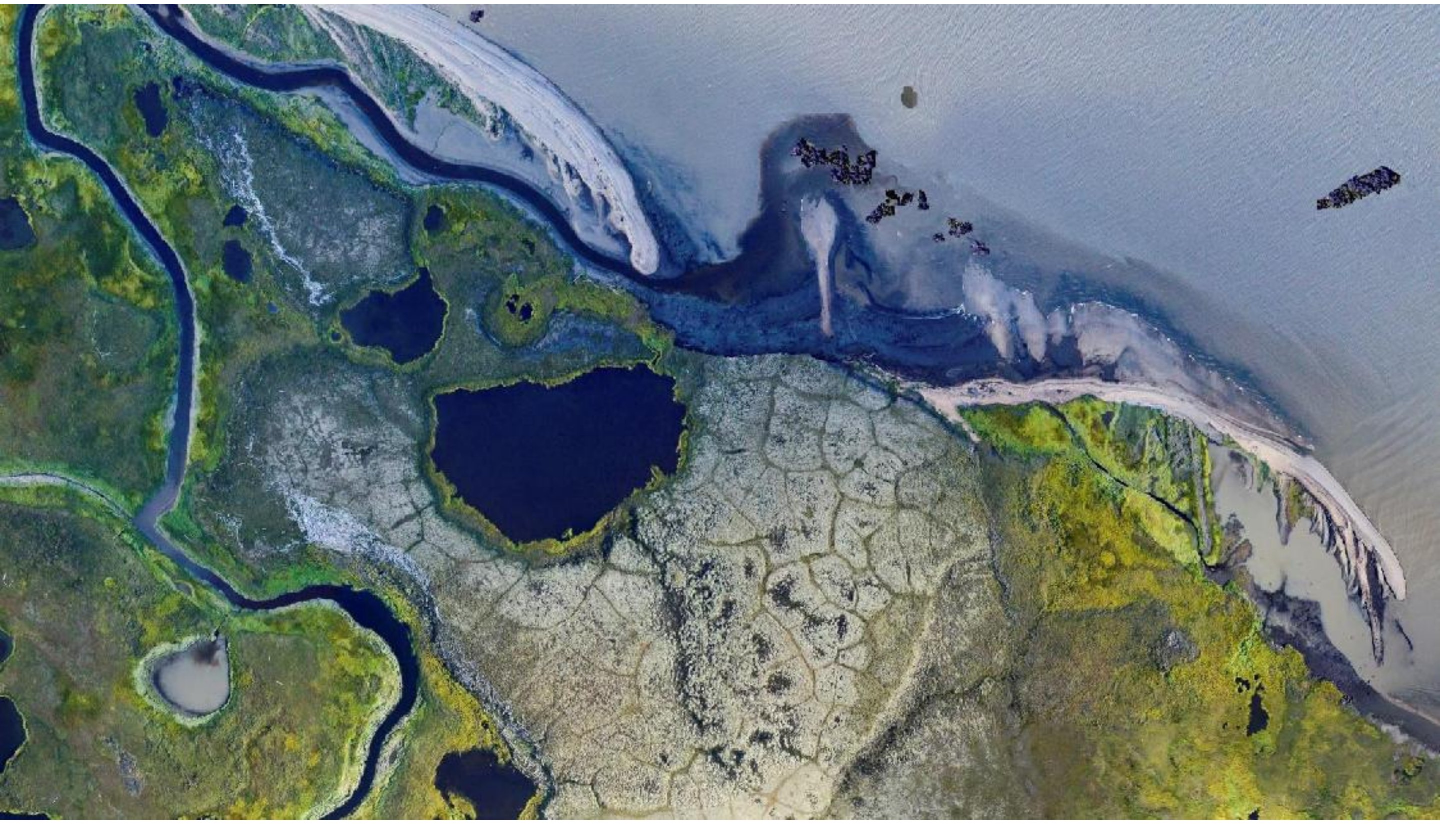
Comparison with the Stebbins village data. Note the roughly 1.4 m difference in position, caused by a projection error in the village data (top).



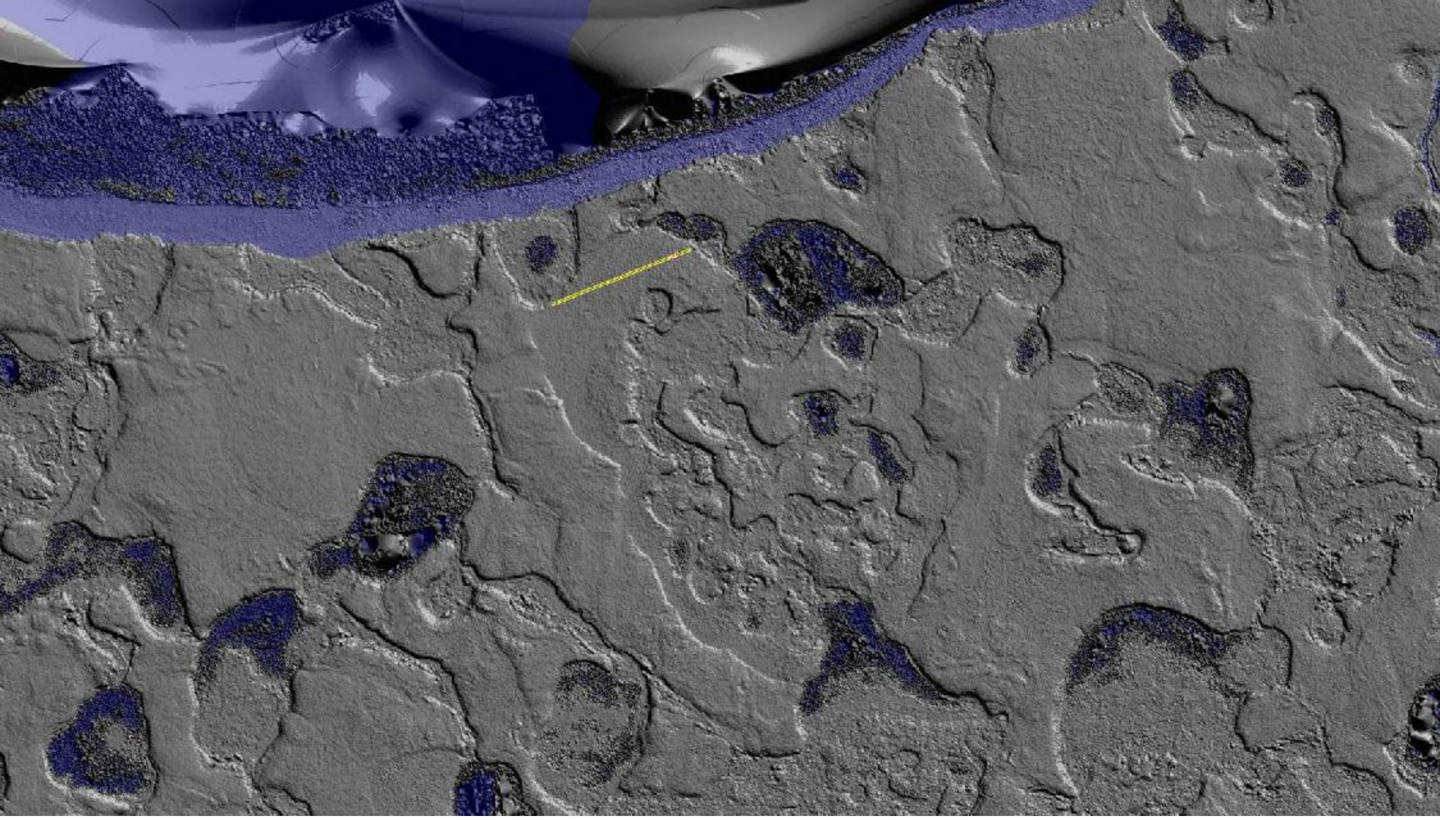


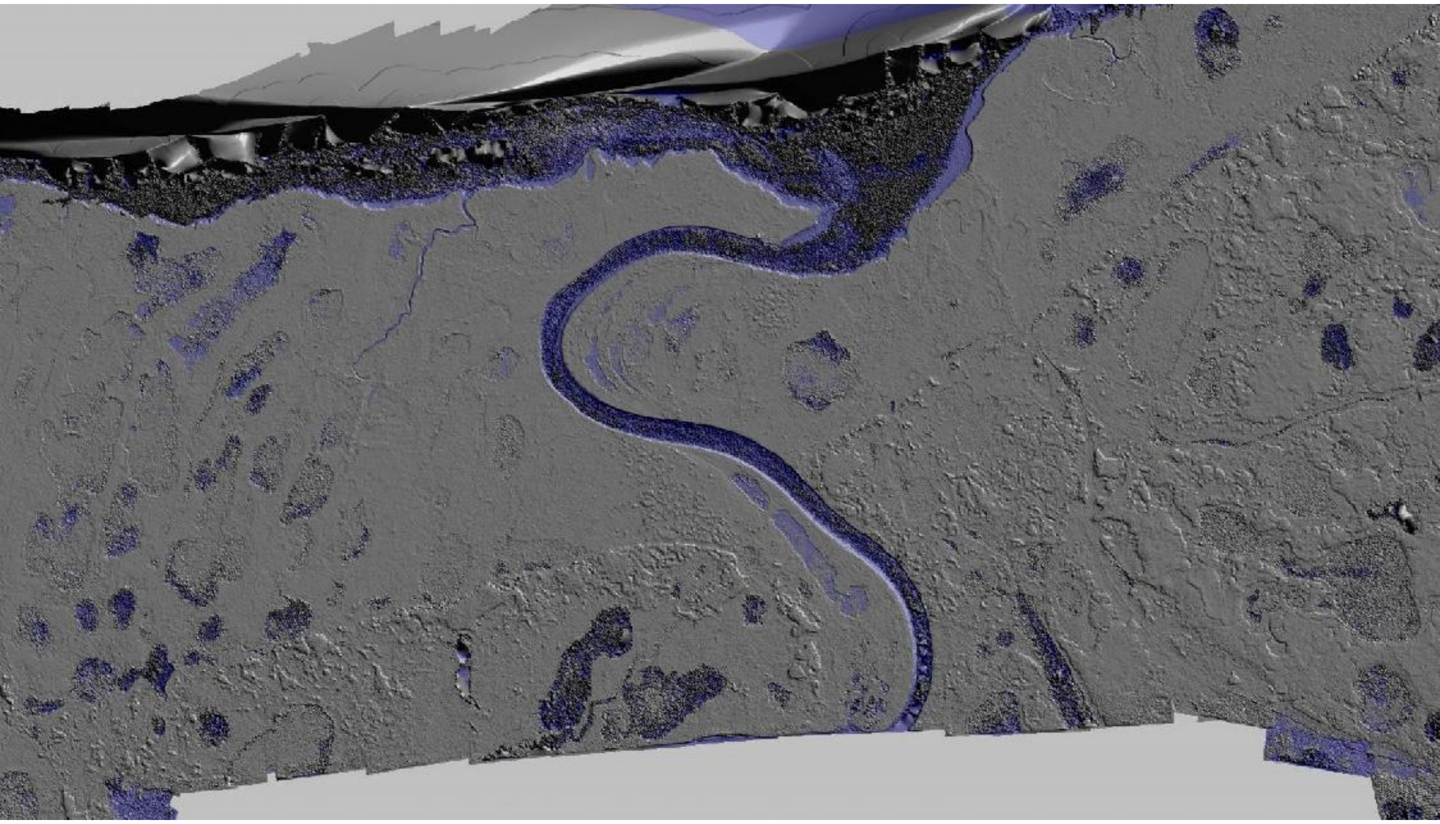
Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.



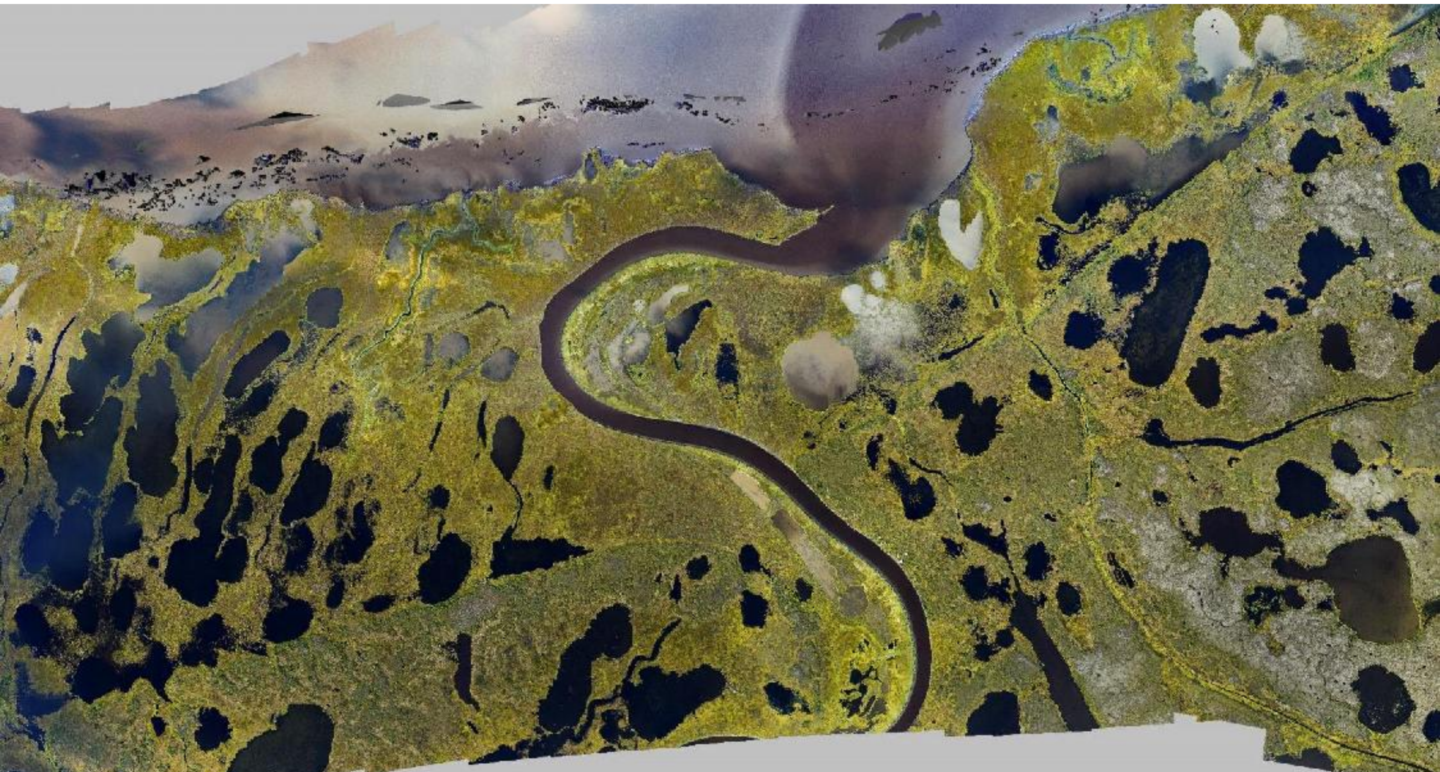


Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.





Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

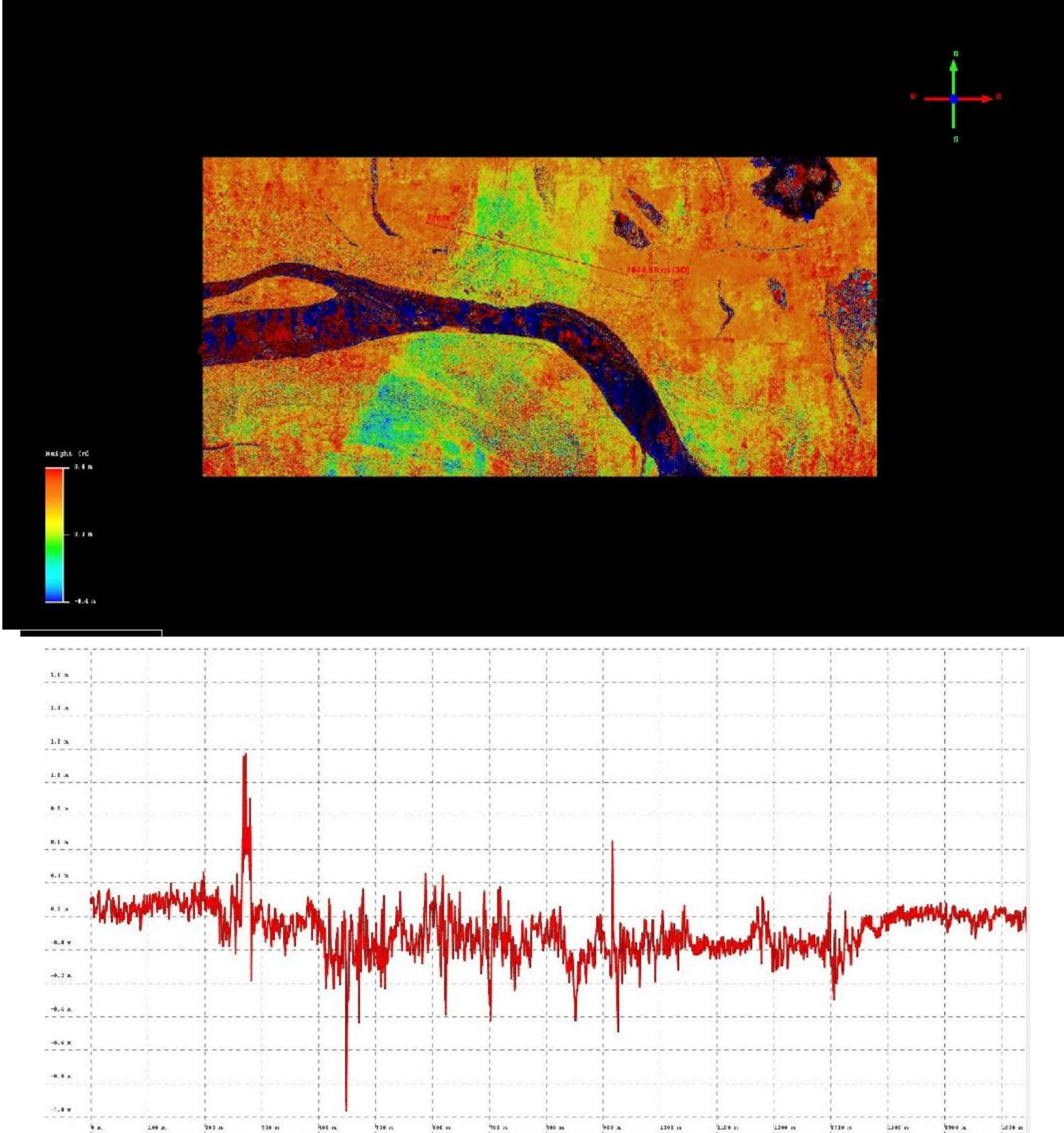


Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

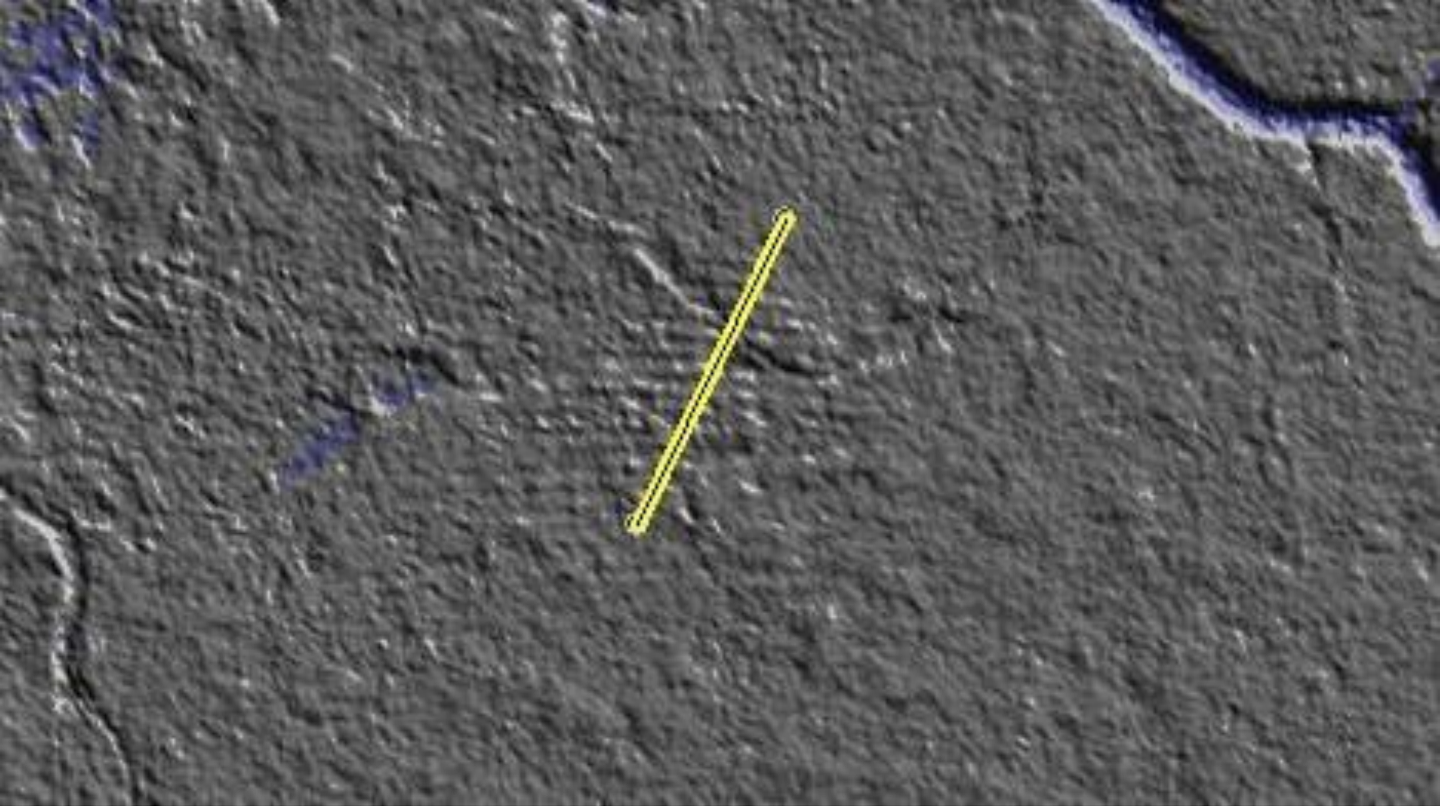
Yukon Delta Block

Overview of DEM and orthomosaic

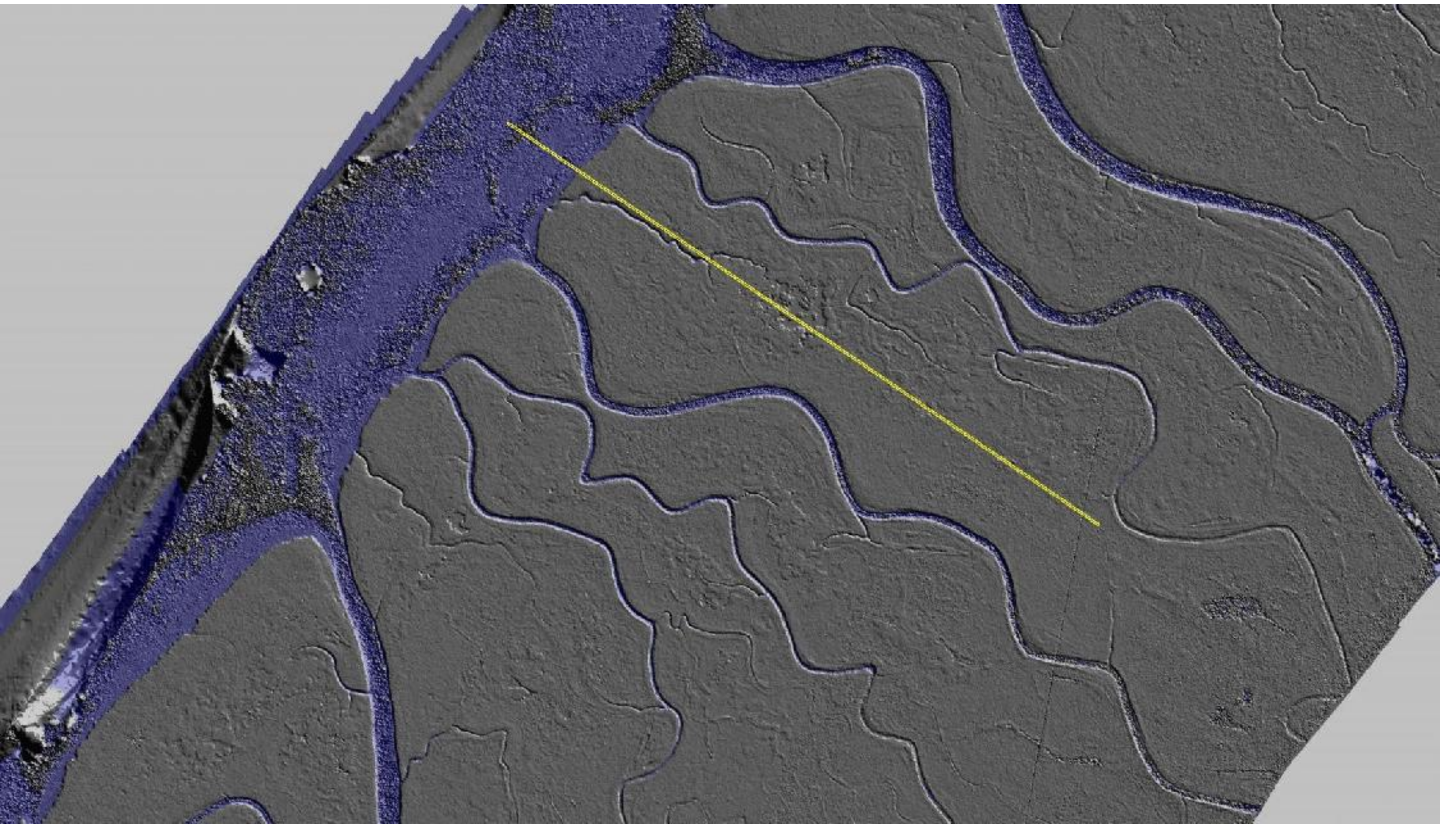
GCPs



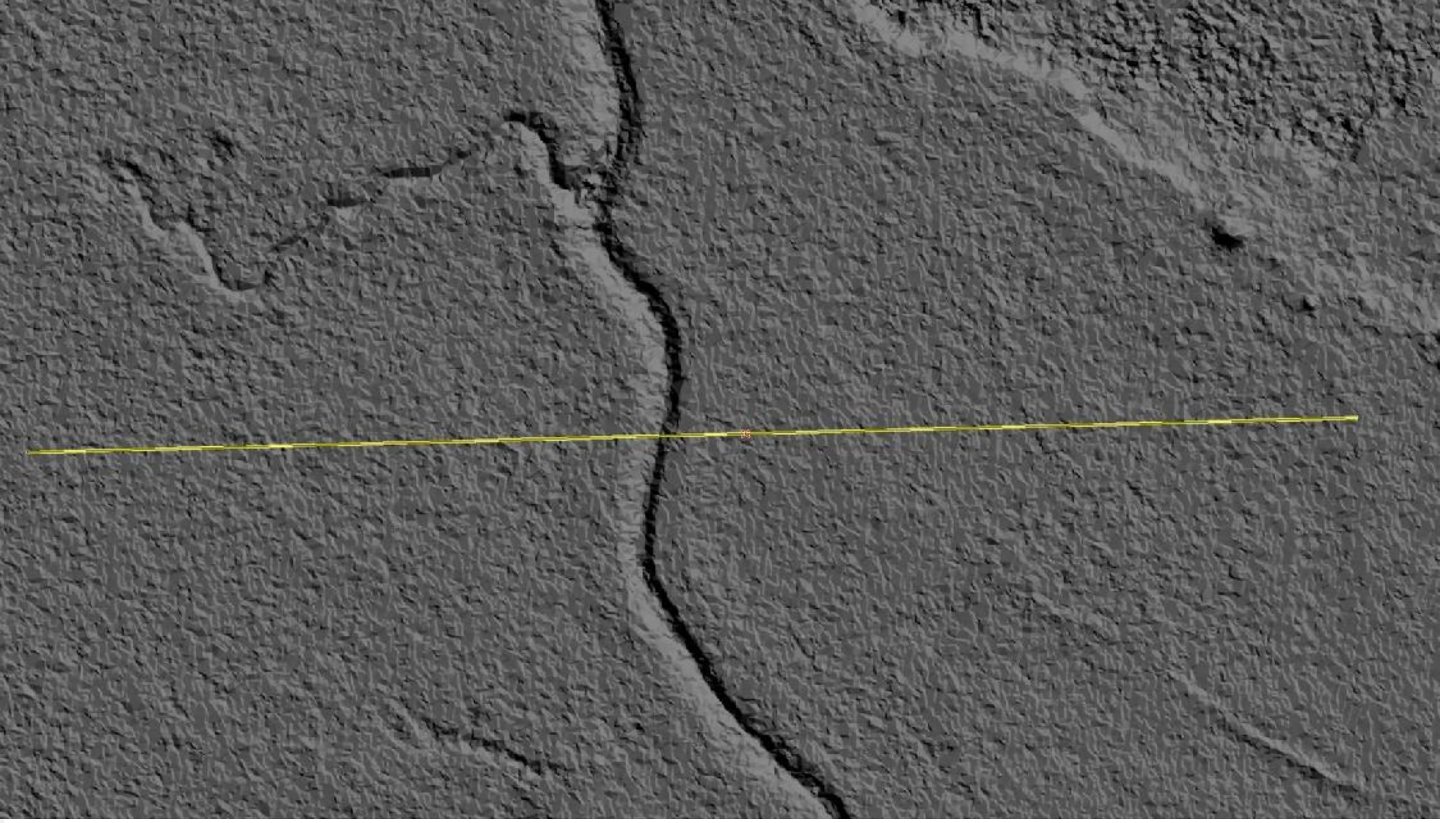
Comparison with Emmonak village data. Note the spatially correlated noise caused by one flight line, seen in green. Despite the garish look caused by the color stretch, the noise itself is less than 20 cm as revealed by the transect, and signals much less than 20 cm can still be revealed with careful analysis.

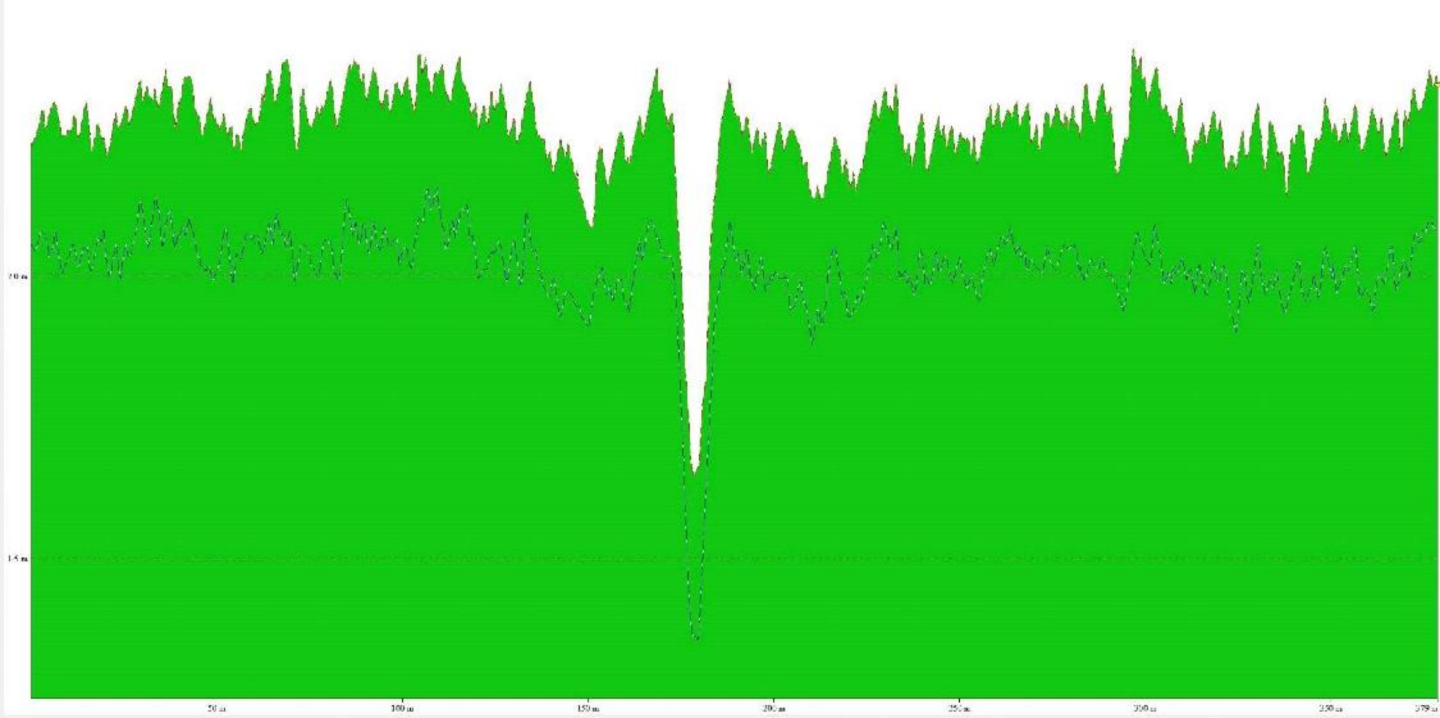


Some corduroy artifacts seen in shaded relief. The plot reveals these to be about +/- 8 cm, a bit higher than the random noise level of about +/- 3 cm. Small patches like these can be found throughout the dataset.

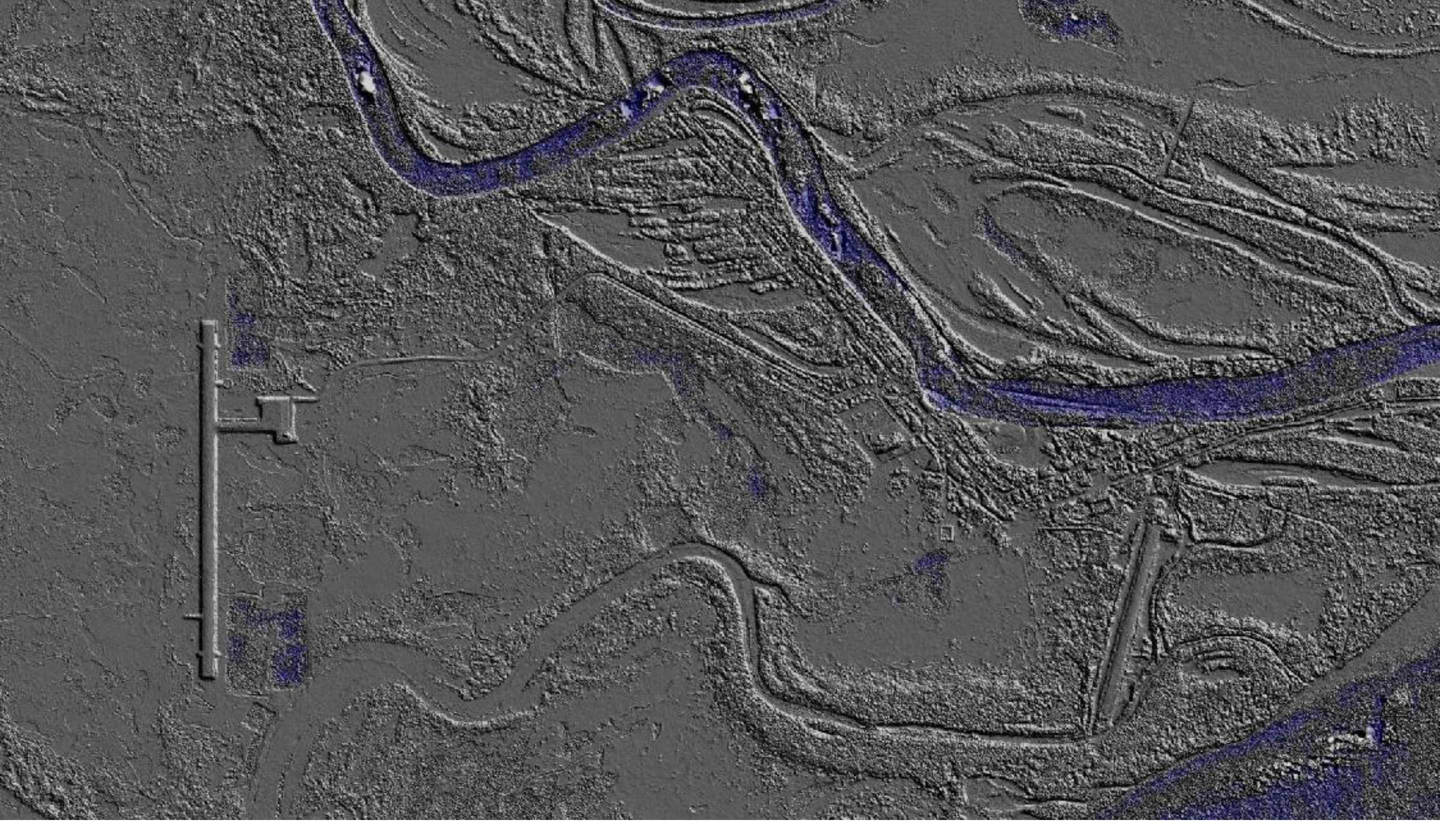


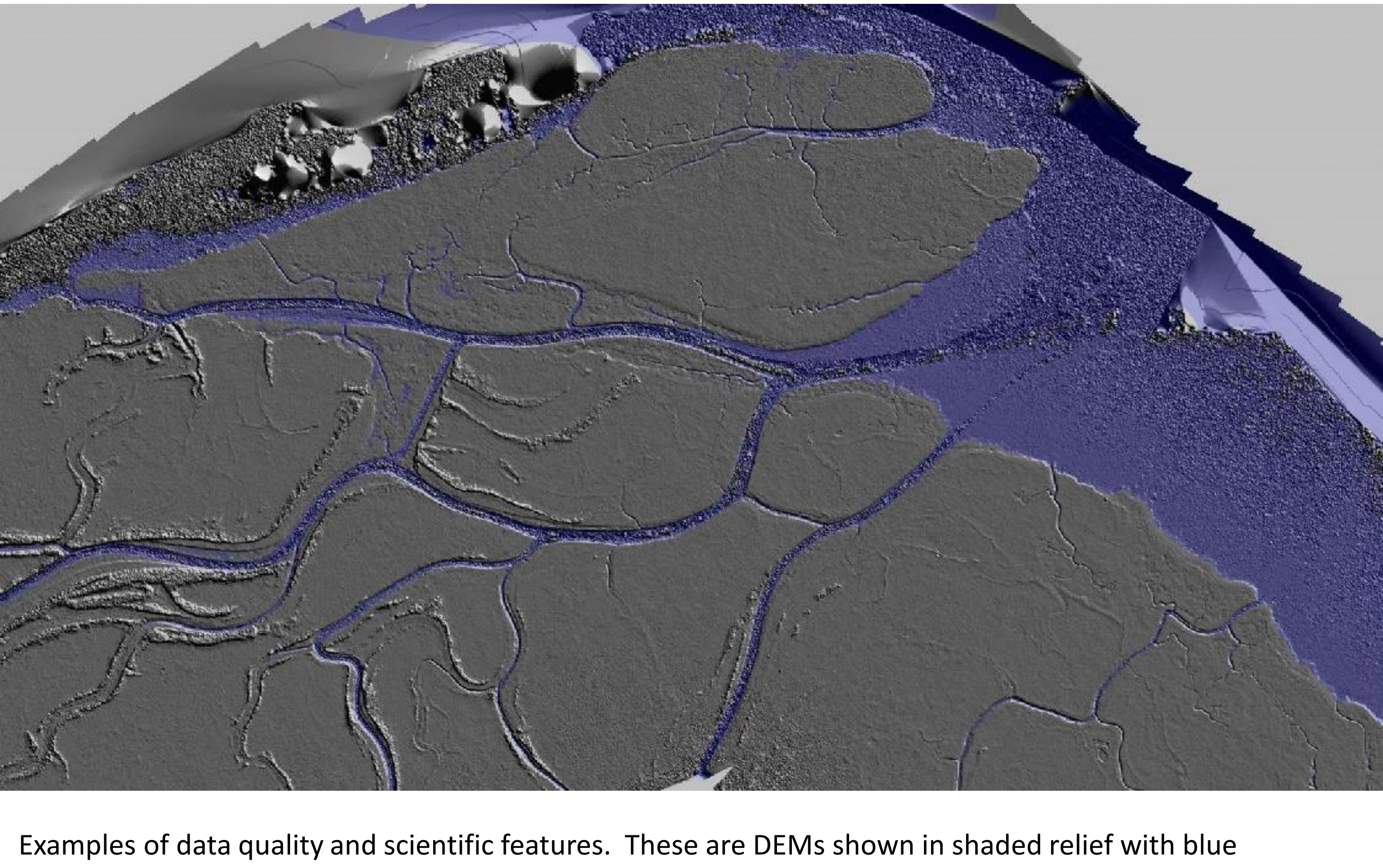
The Yukon block AOI is 2000 m, shown by the yellow line.





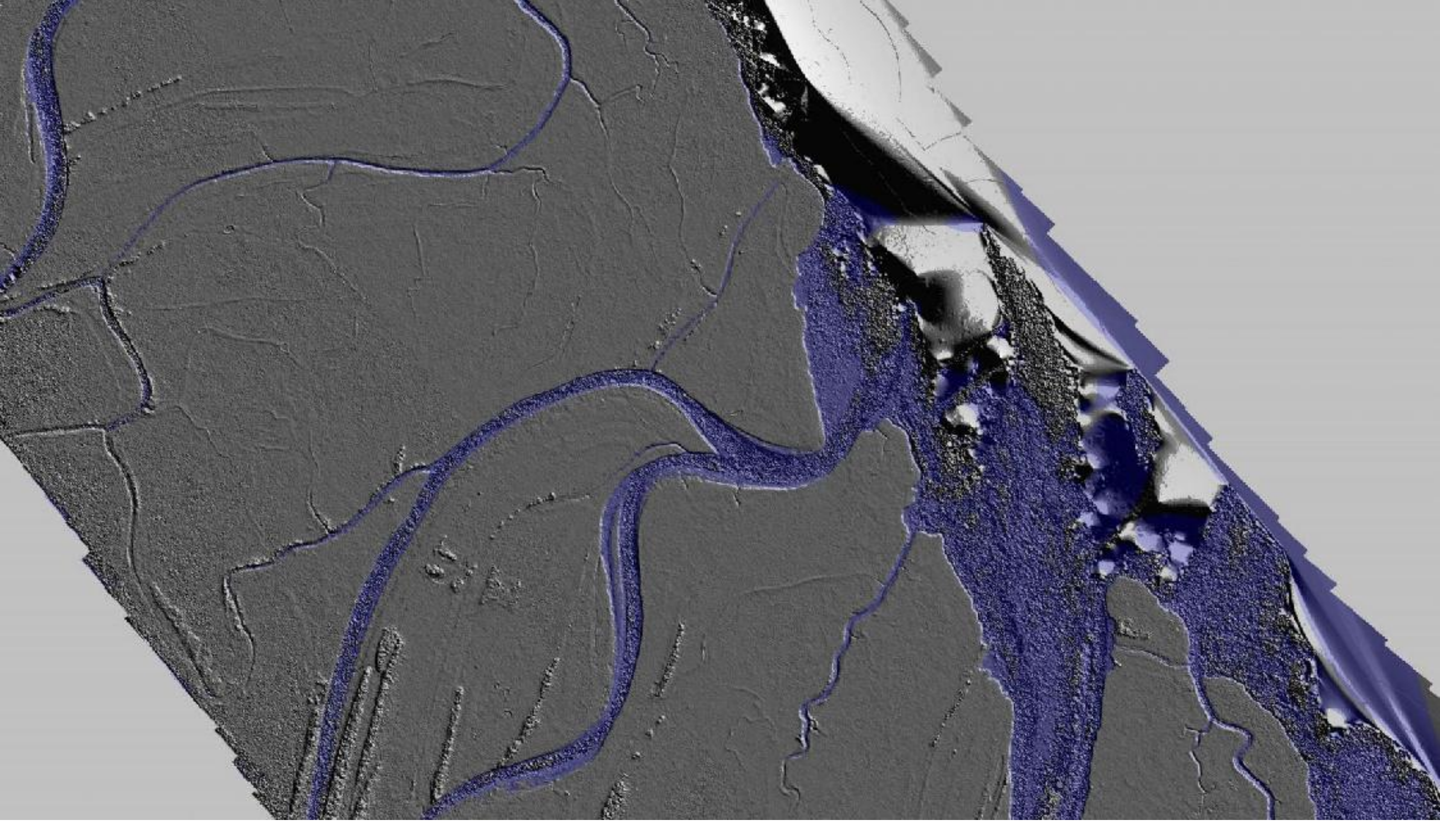
Comparison of overlap with the Kotlik to Stebbins block. The Yukon block is about 30 cm lower than the Kotlik block.

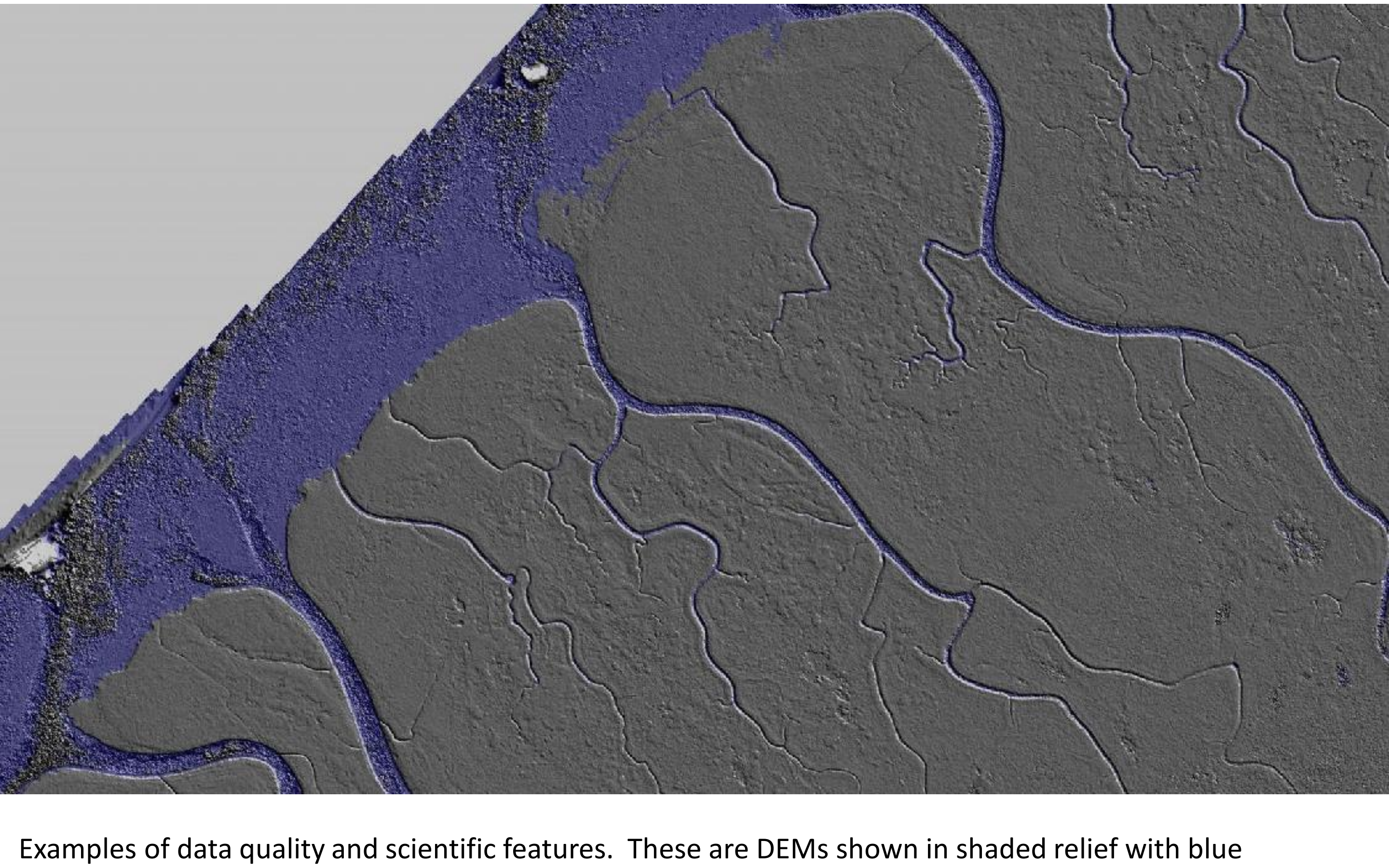




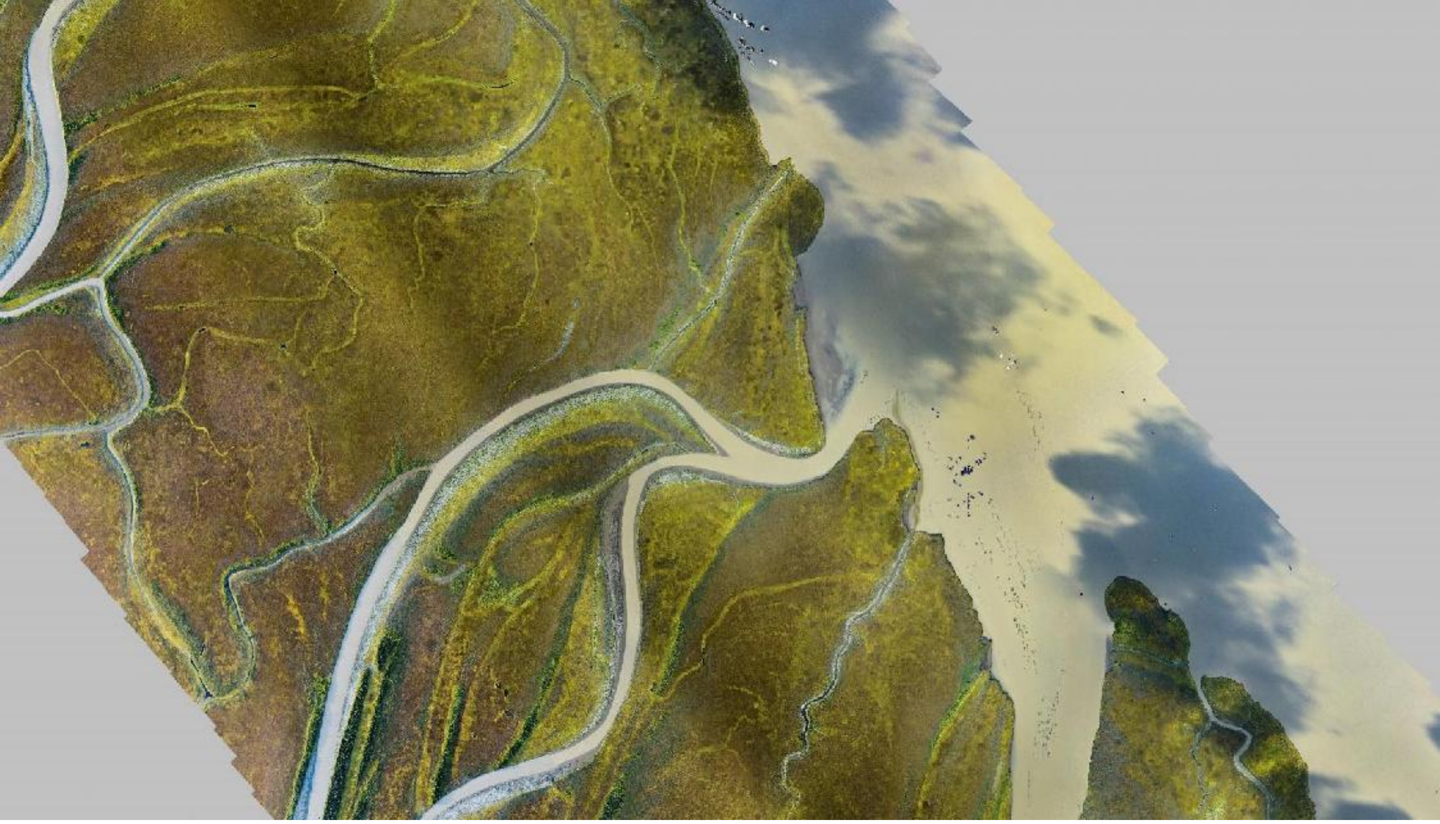
Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

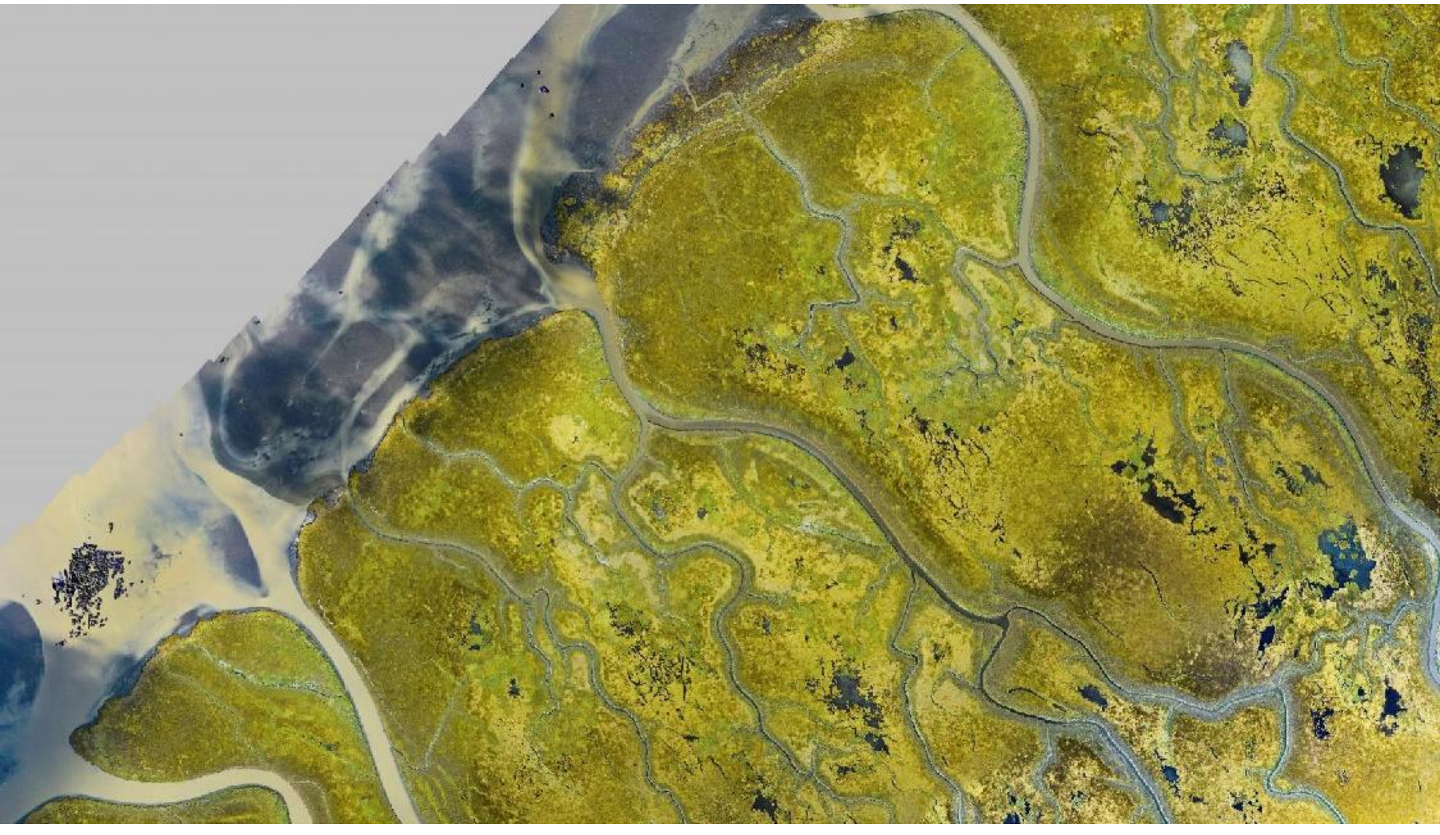
Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.



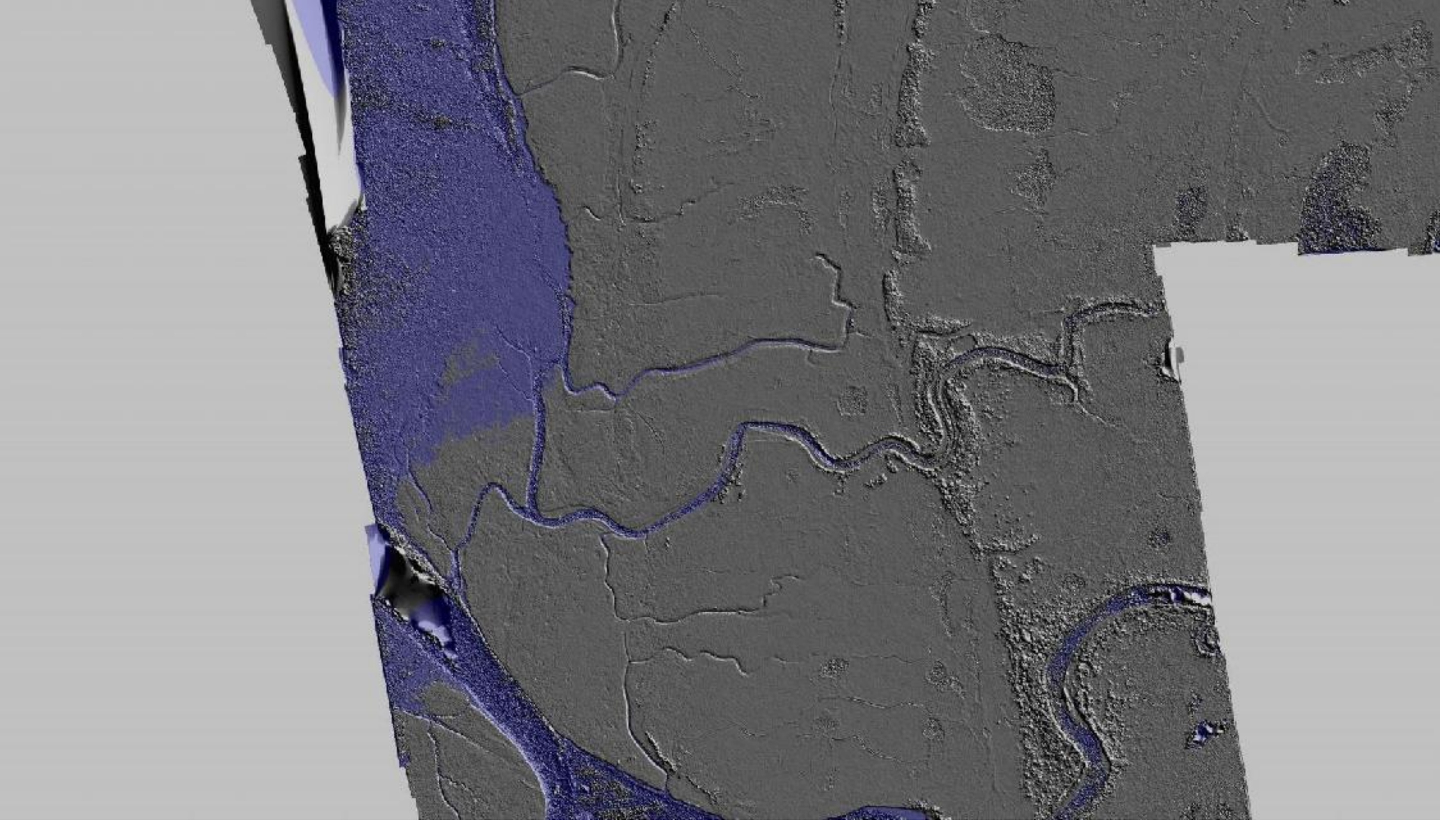


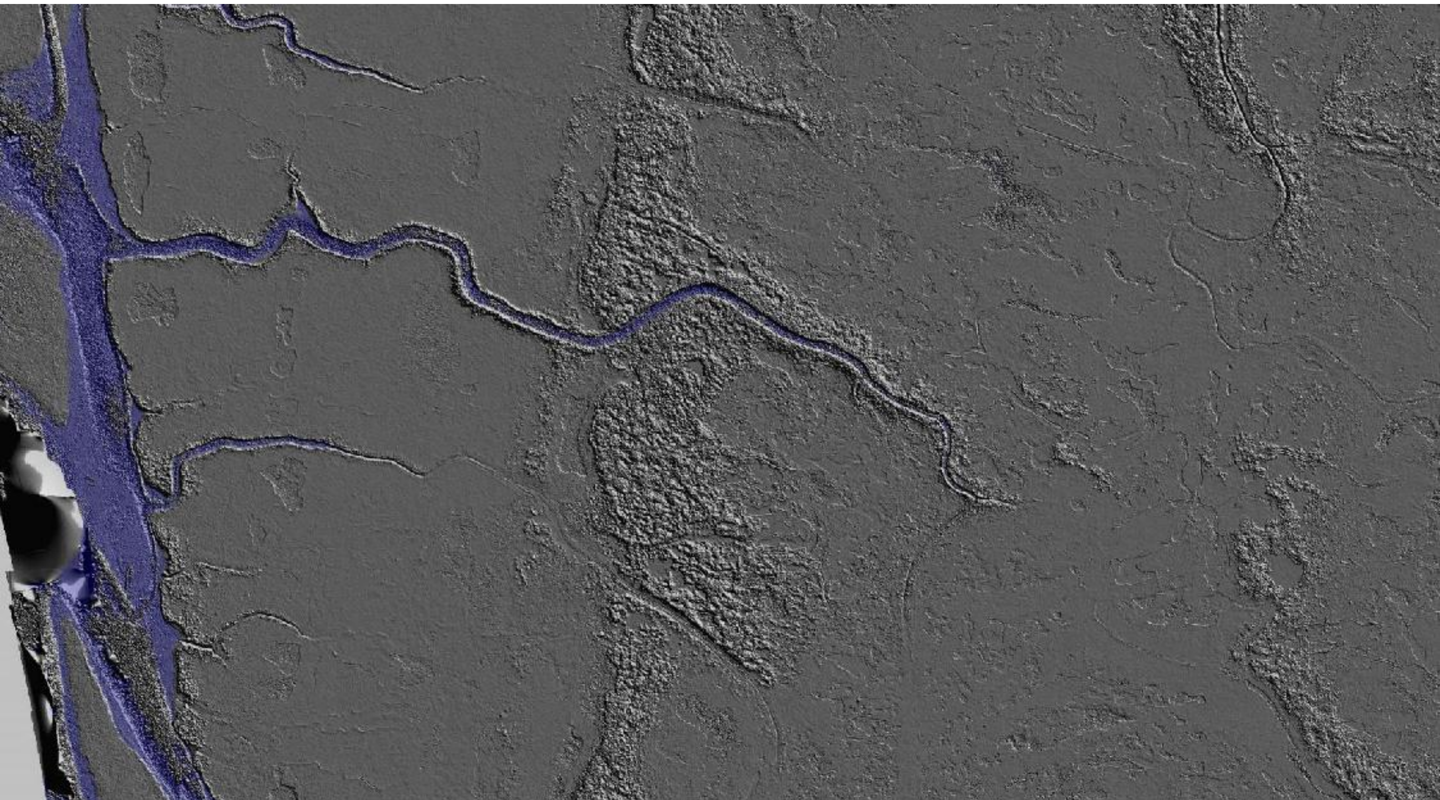
Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.





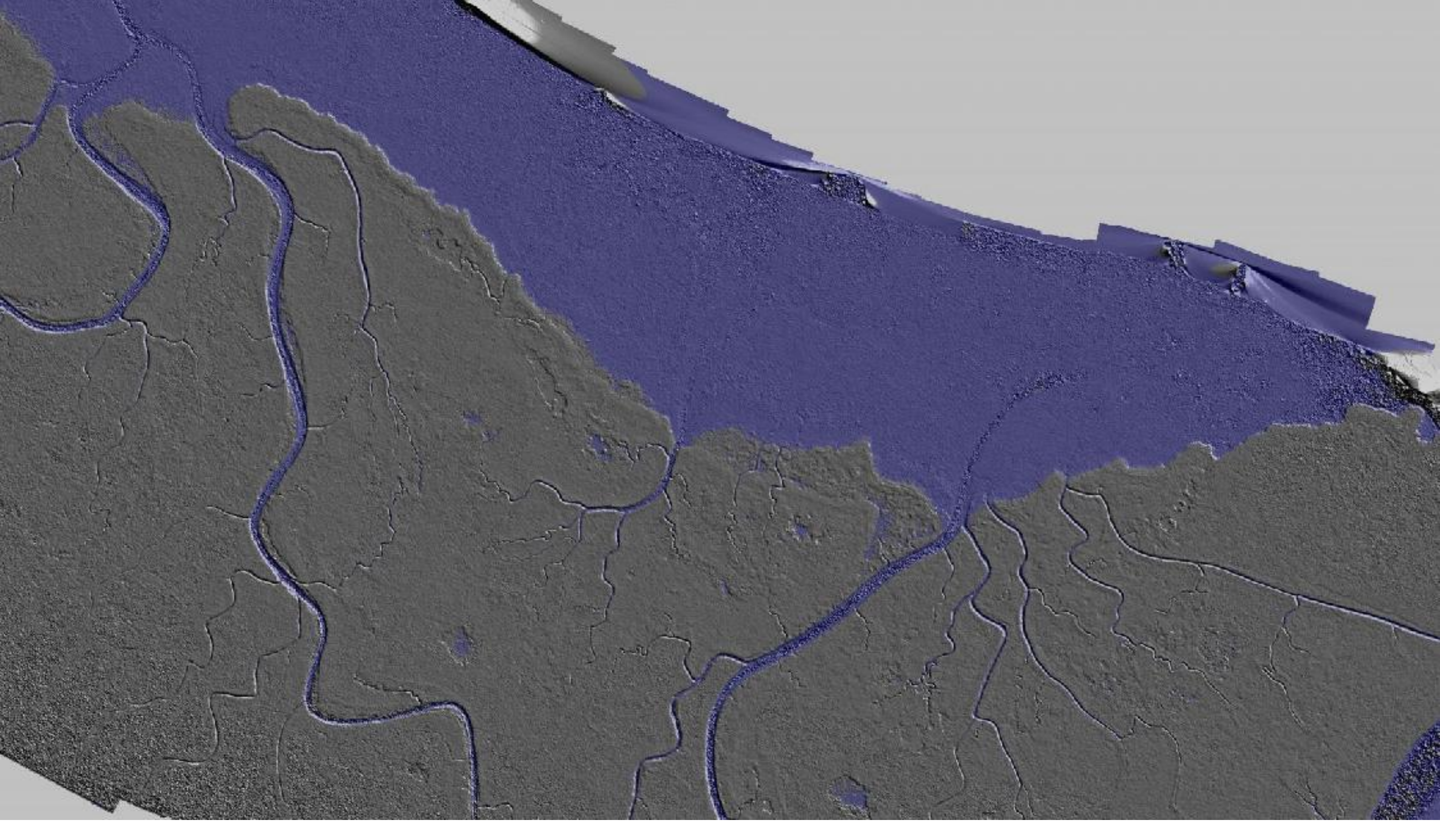
Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

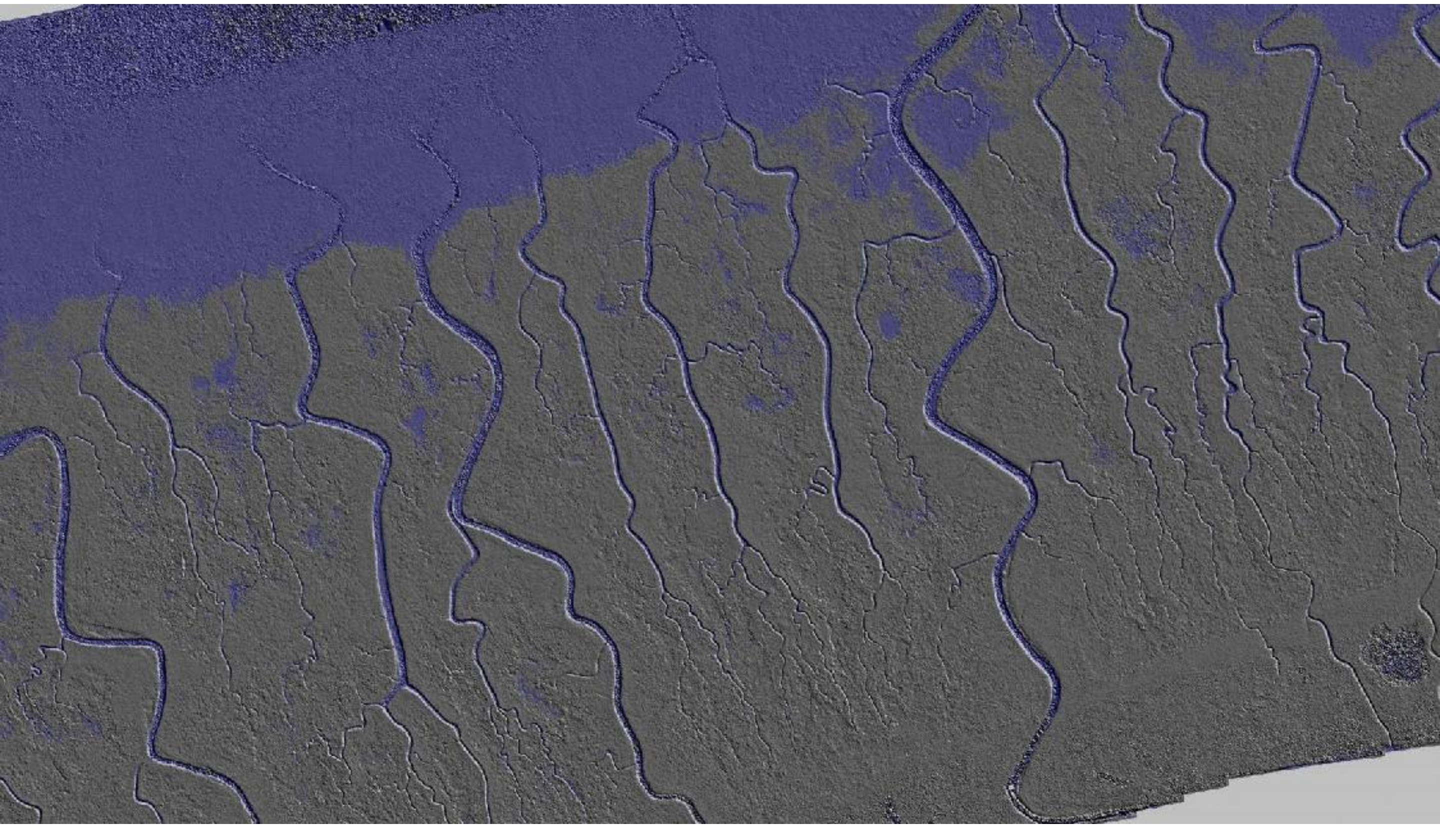




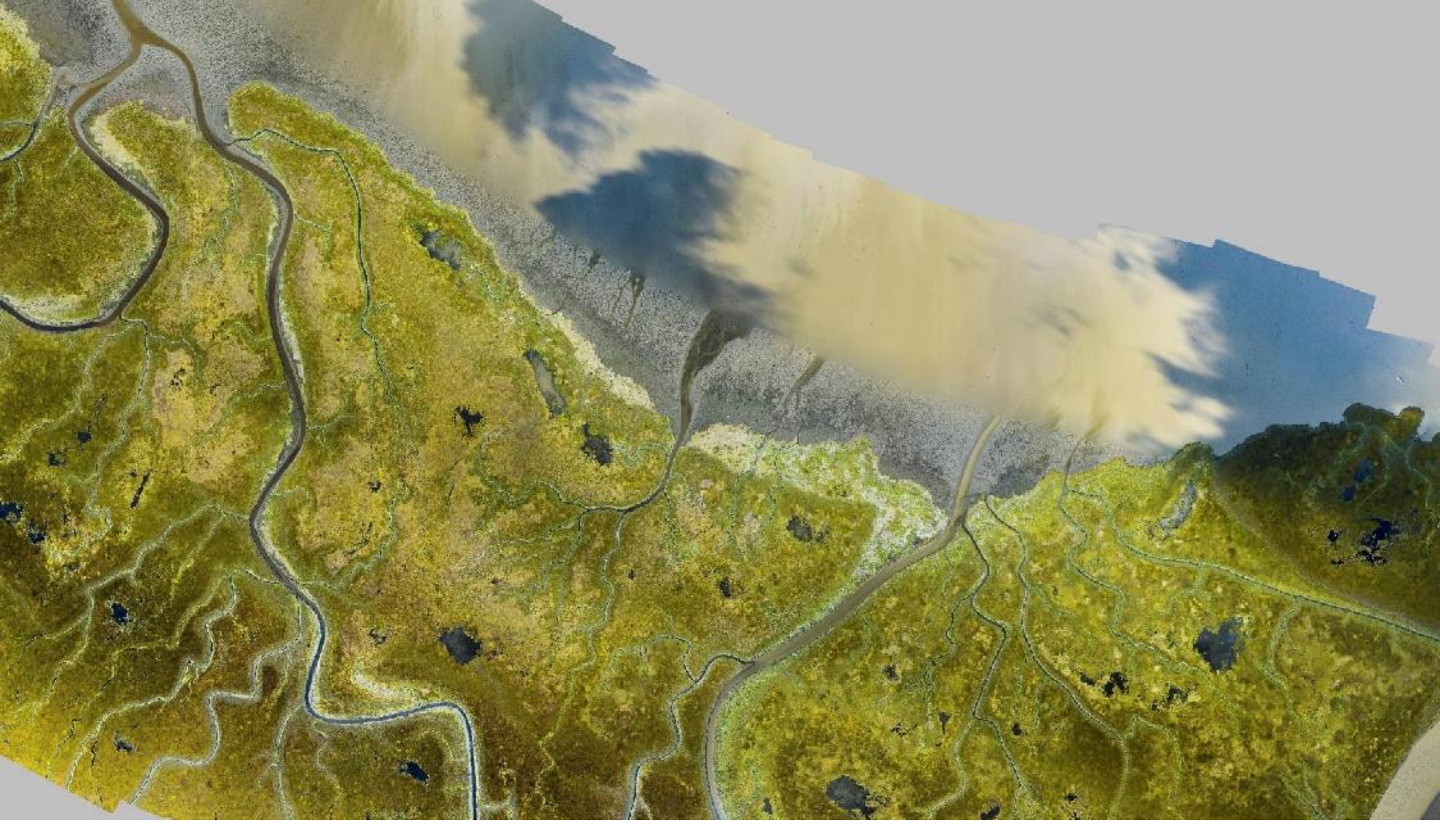
Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

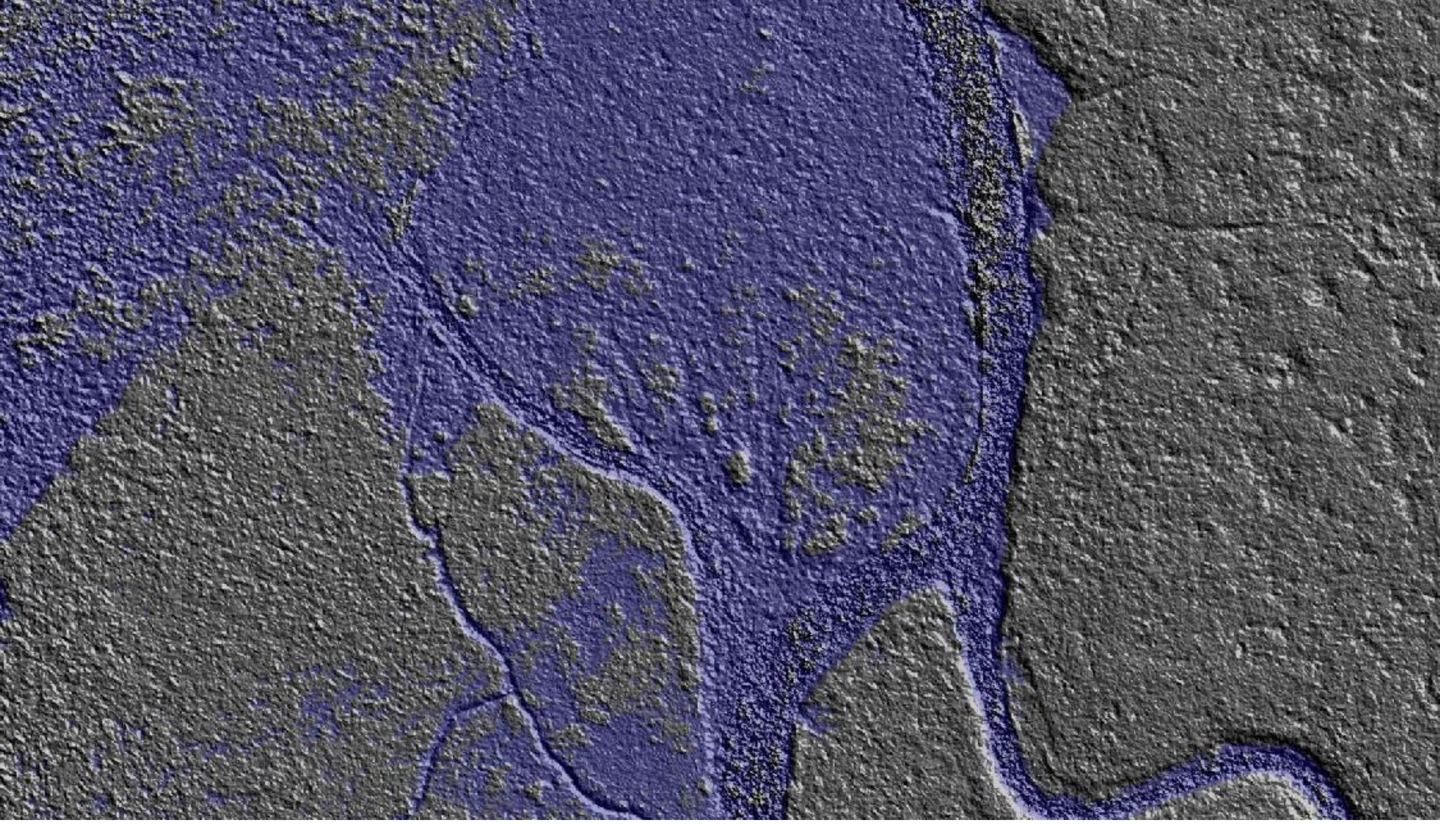


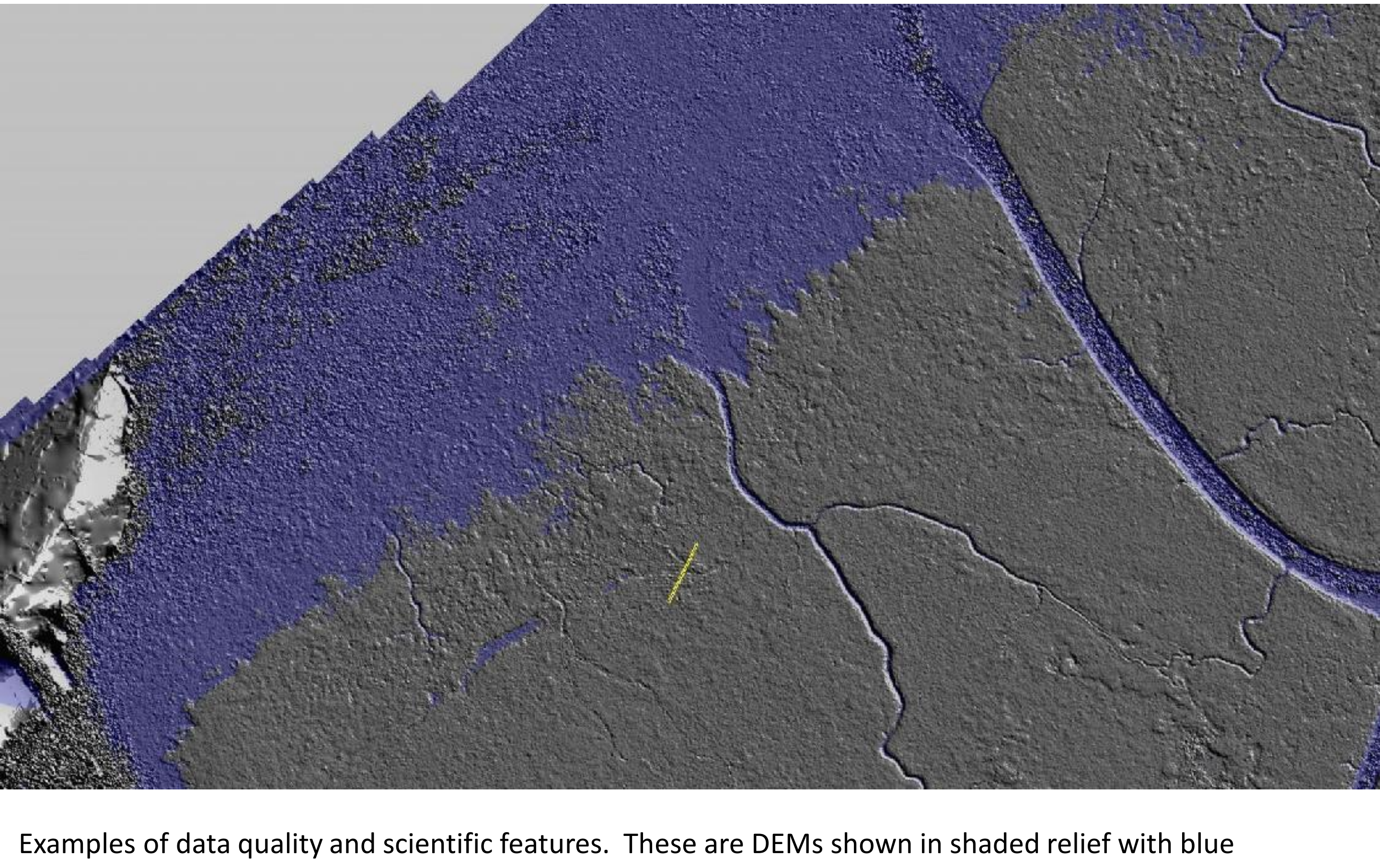


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

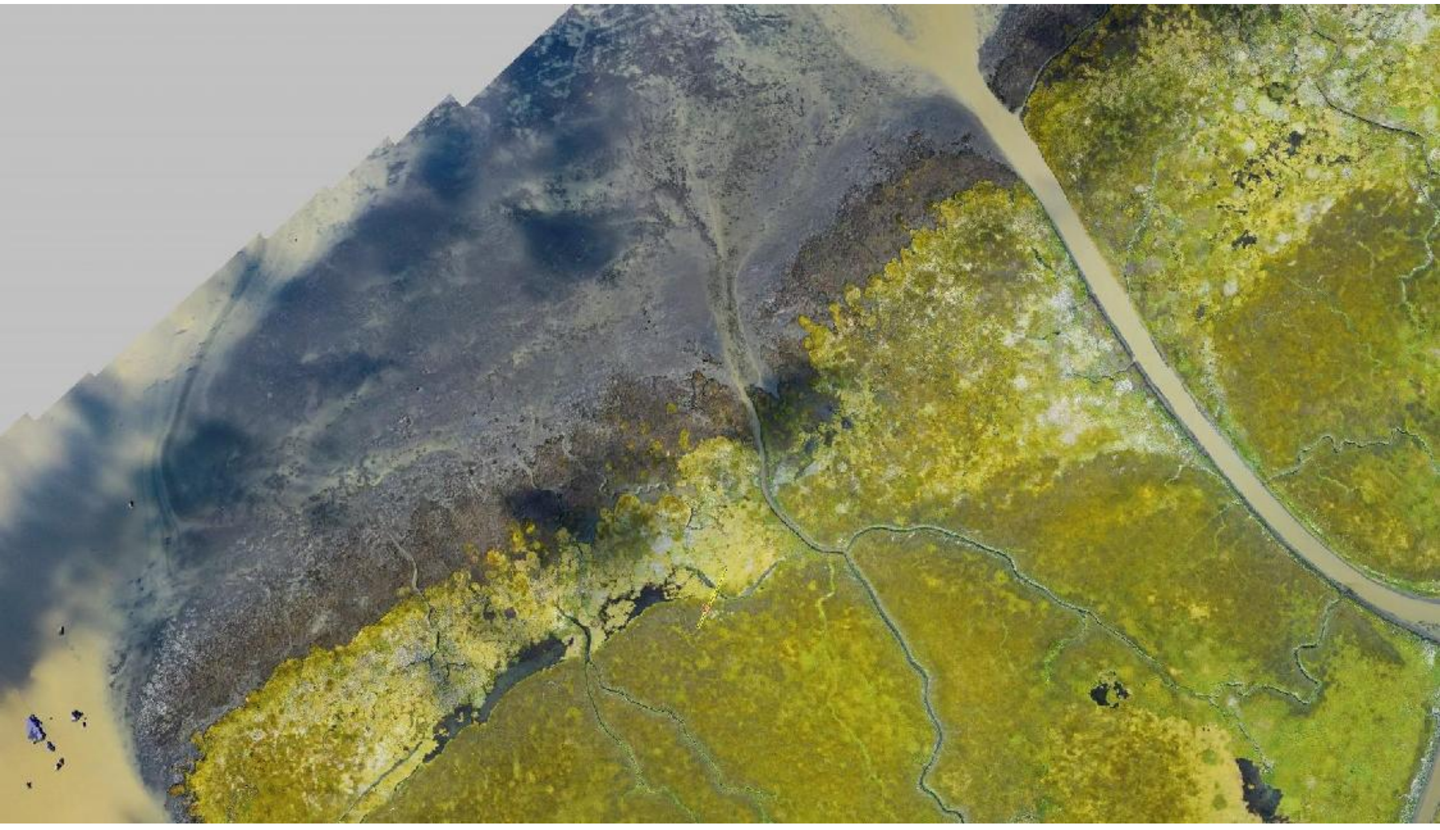


Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.



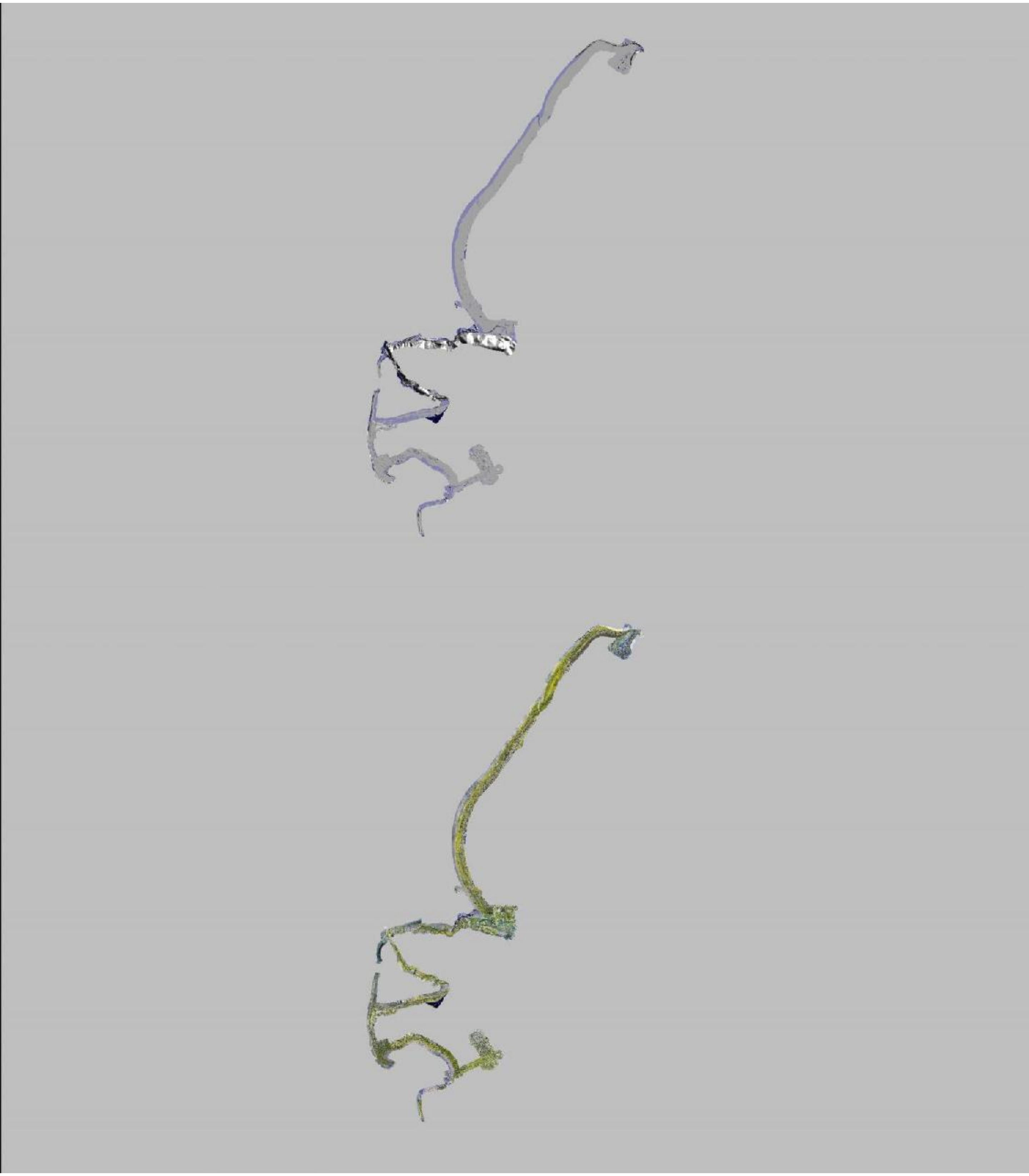


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

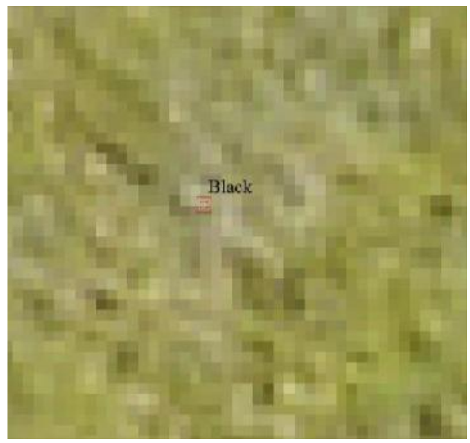


Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

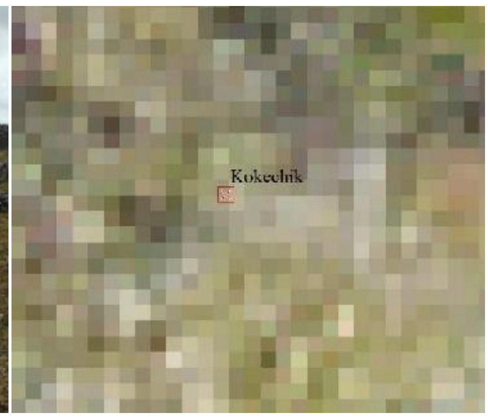
Chevak to Nunam Block



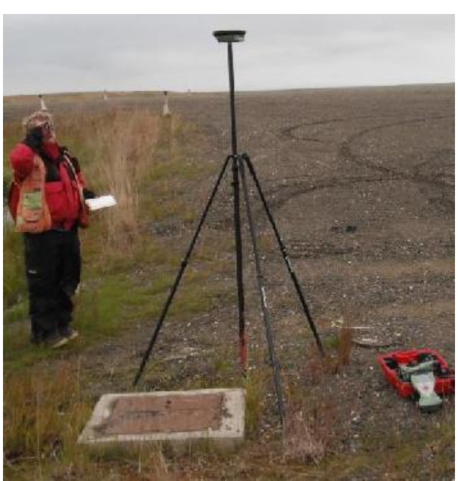
Overview of DEM and orthomosaic

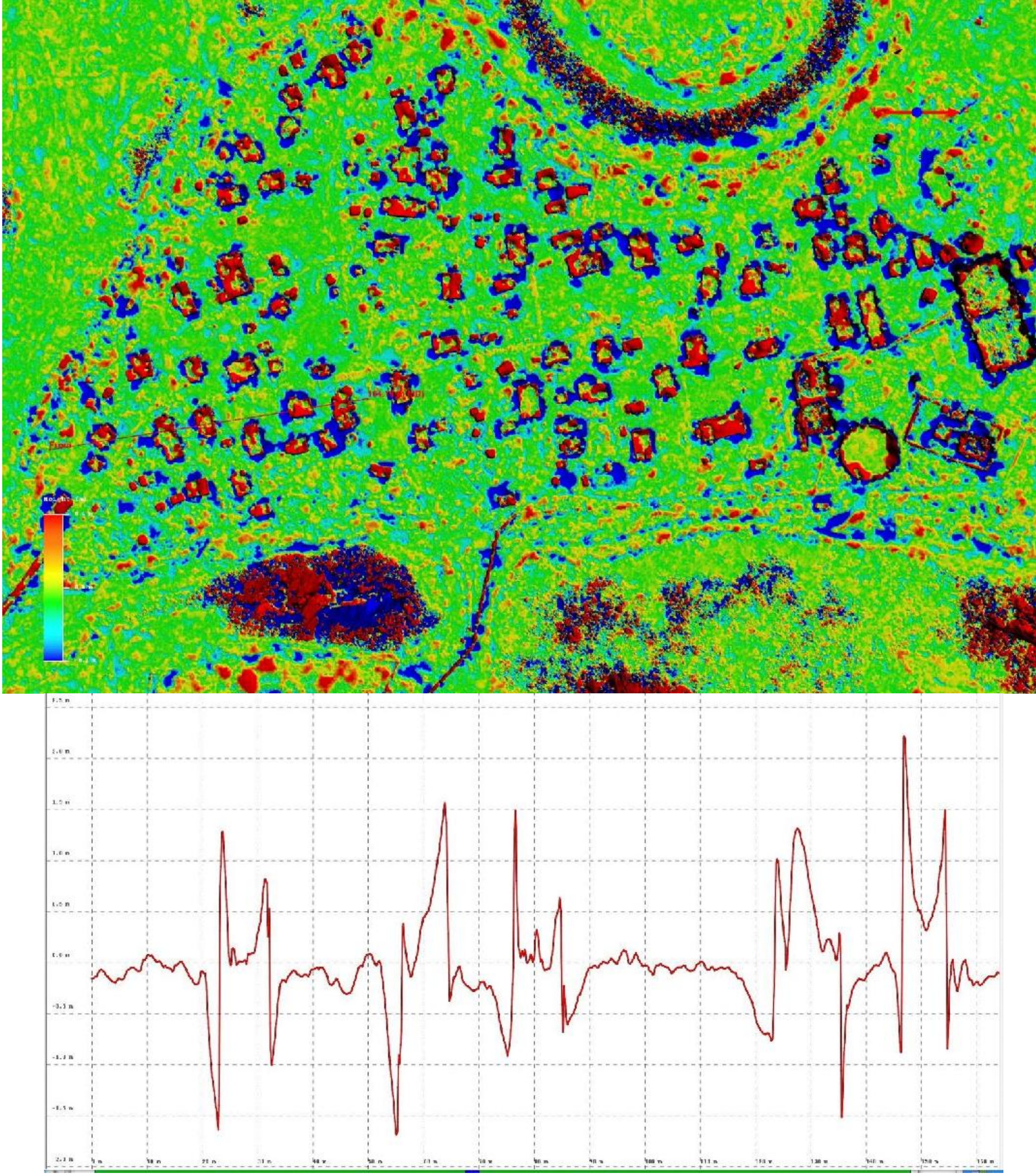


GCPs

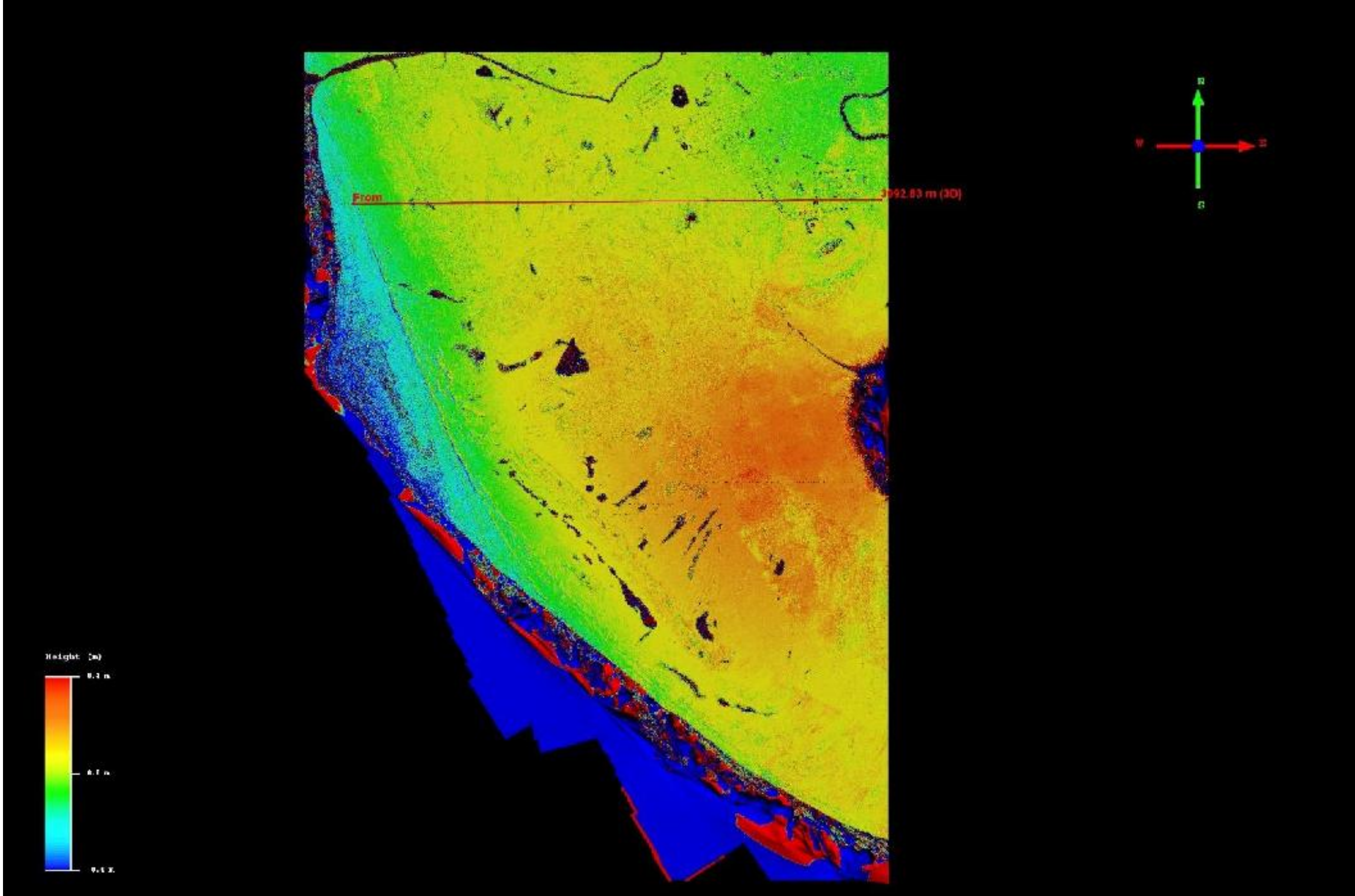


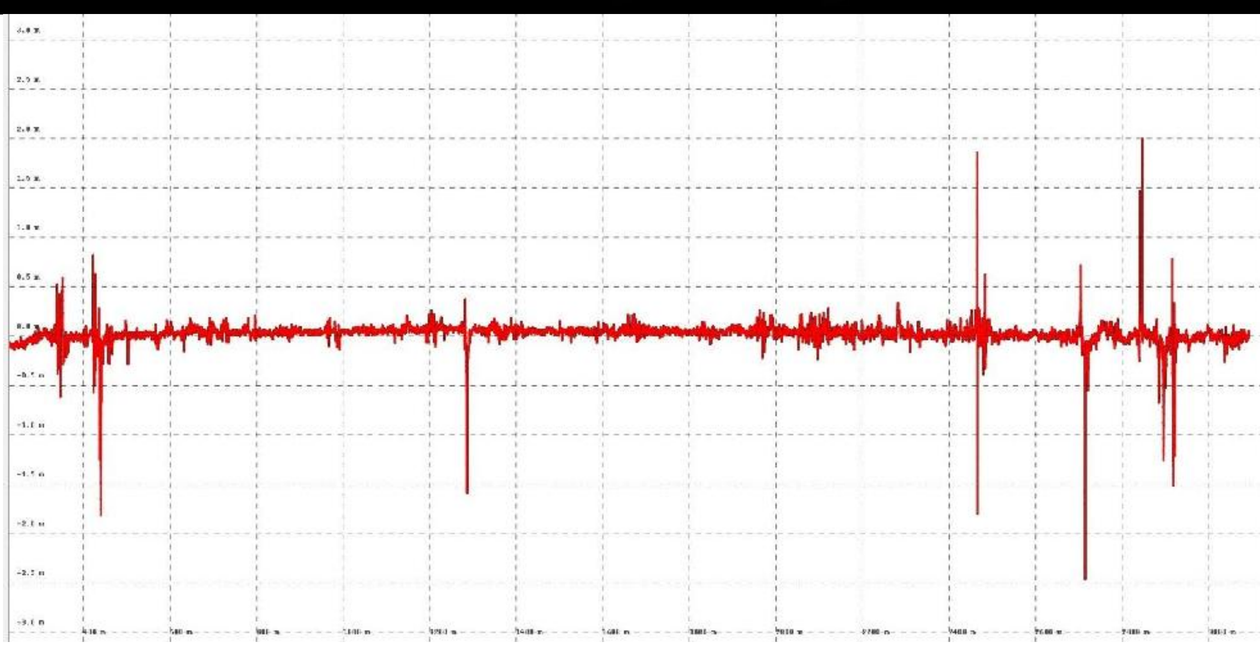
GCPs



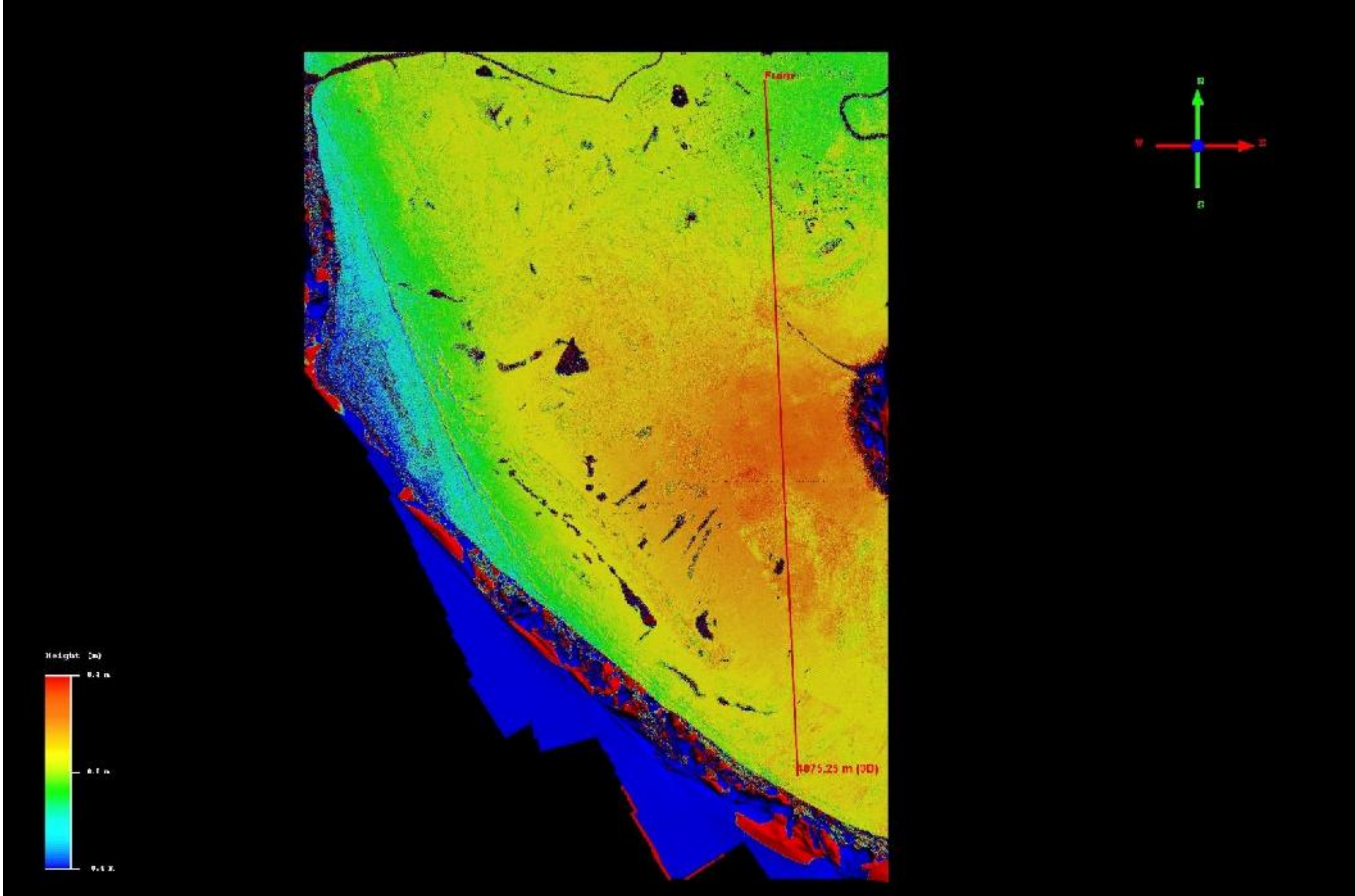


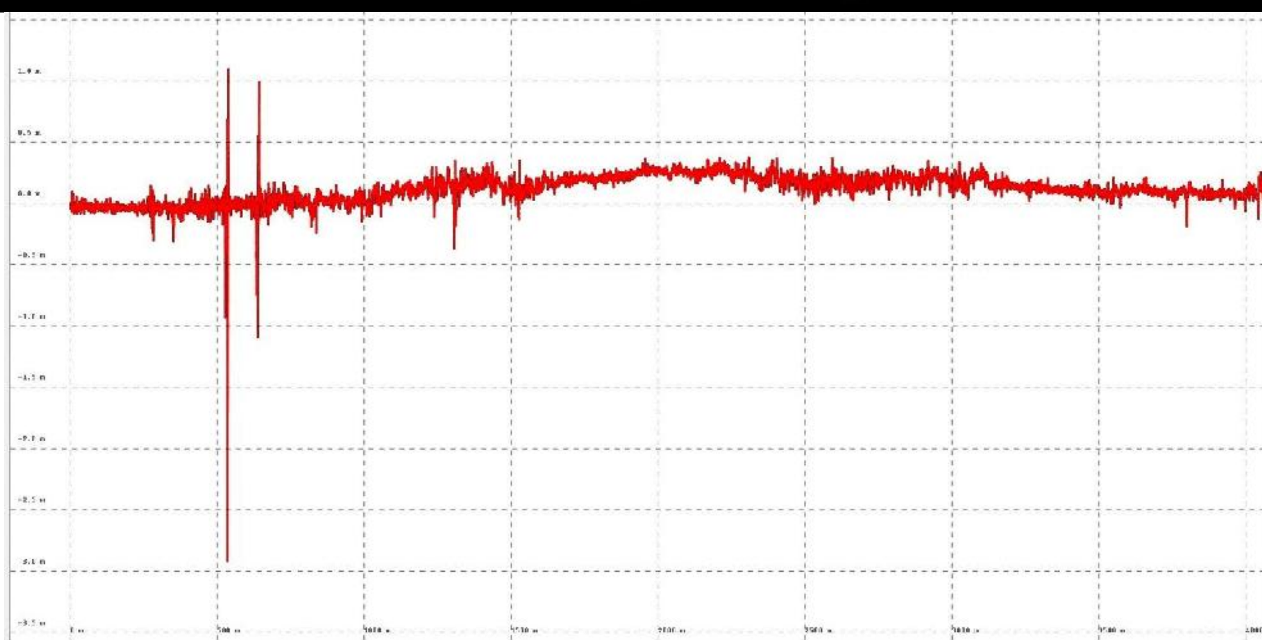
Comparison to Hooper Bay village. Alignment is excellent, with random noise at the +/- 8 cm level, with excursions caused by spatial biasing at building edges caused by differences in resolution.



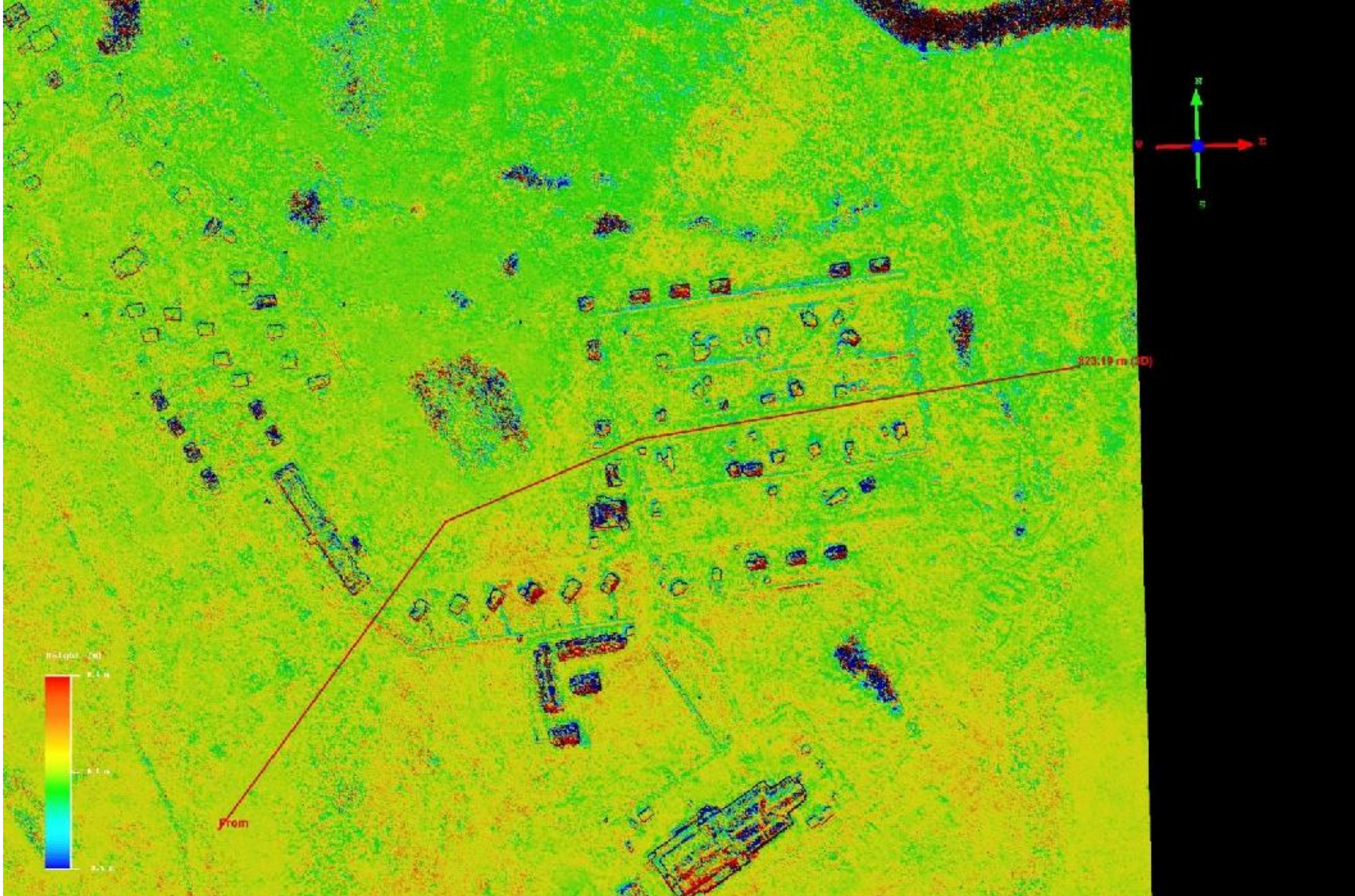


Comparison to Hooper Bay village. Alignment is excellent, with random noise at the +/- 8 cm level, with excursions here caused mainly by water bodies.

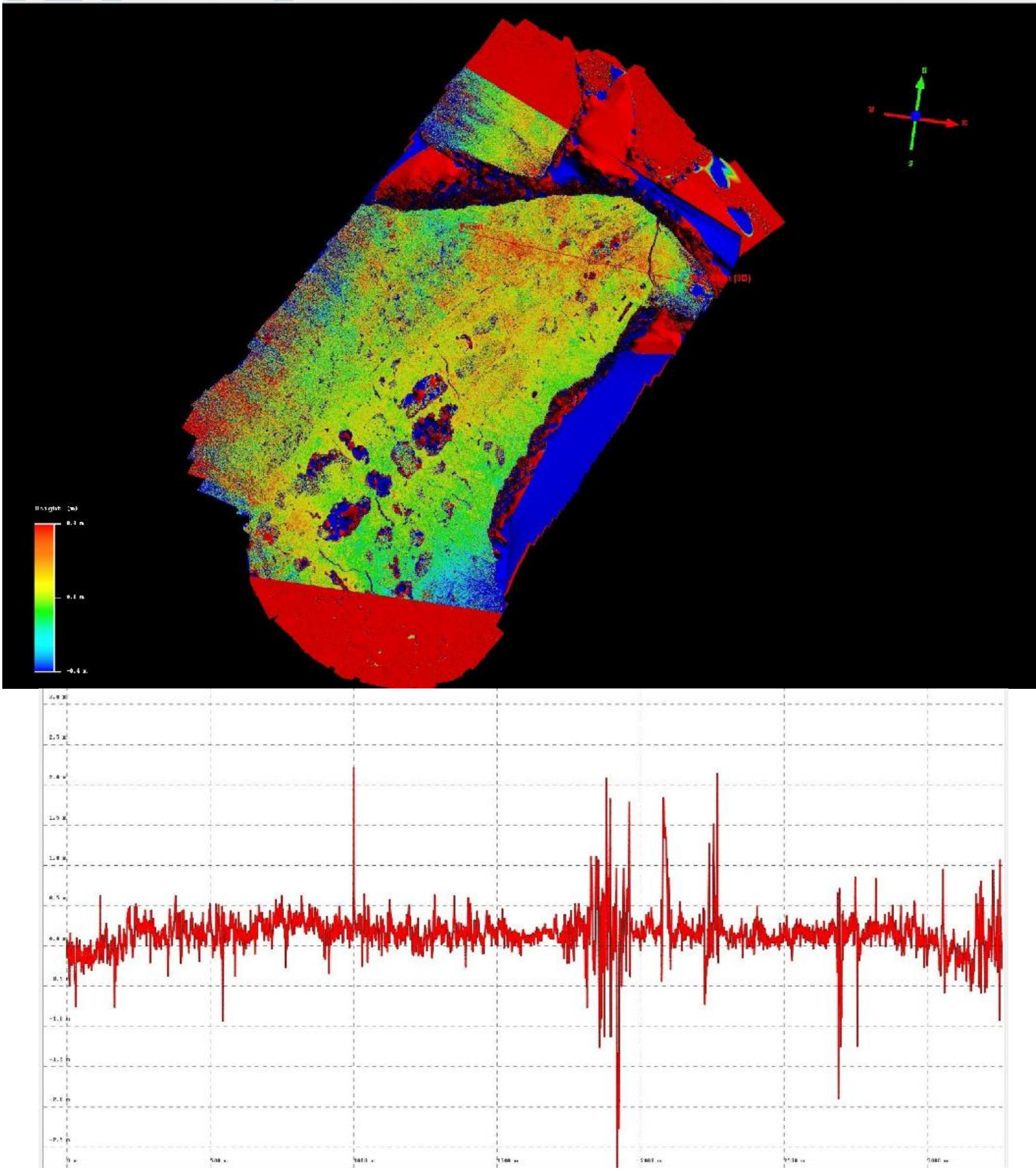




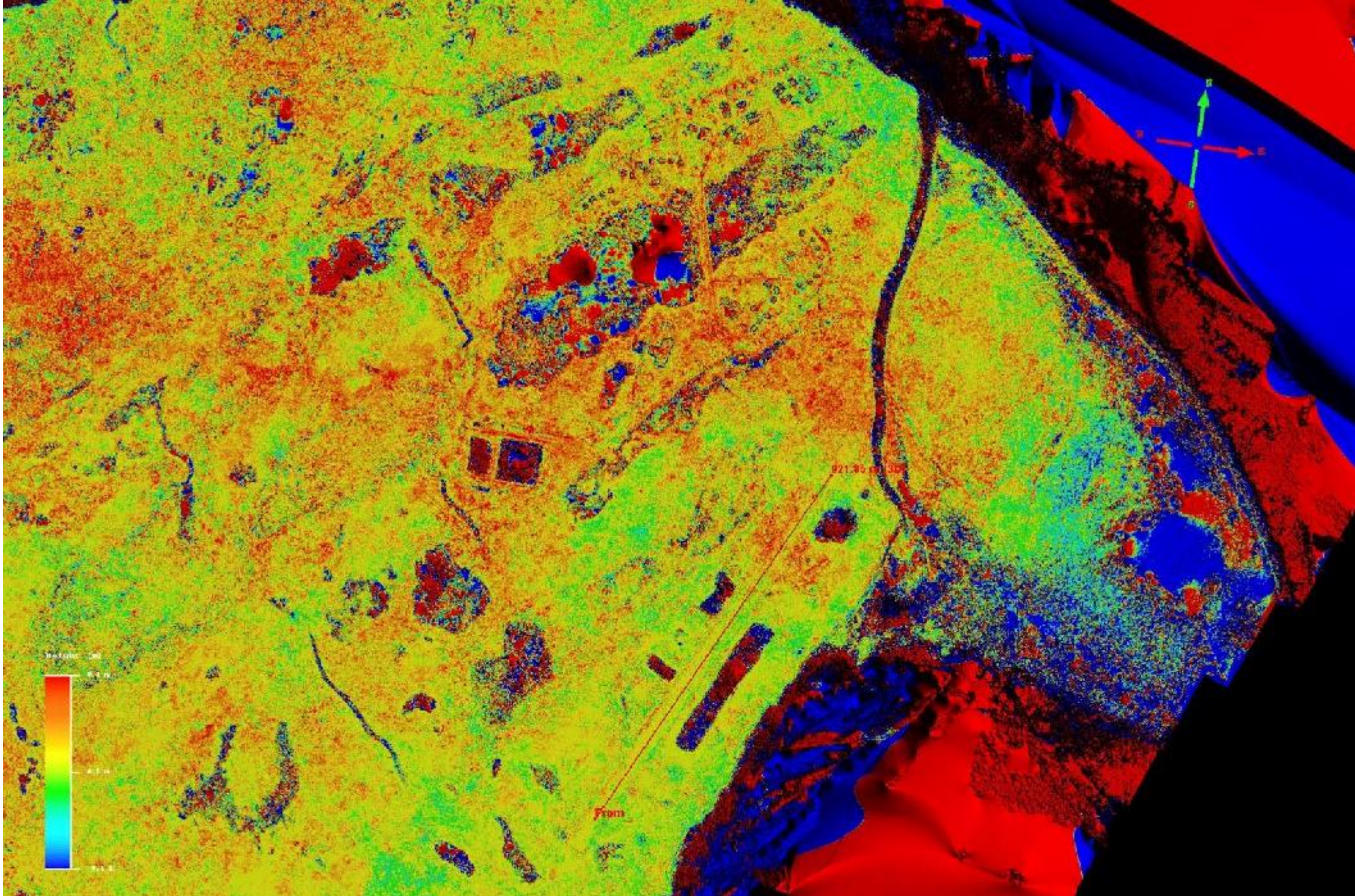
Comparison to Hooper Bay village. Alignment is excellent, with random noise at the +/- 8 cm level, with excursions here caused by spatially coherent noise at the 25 cm level.



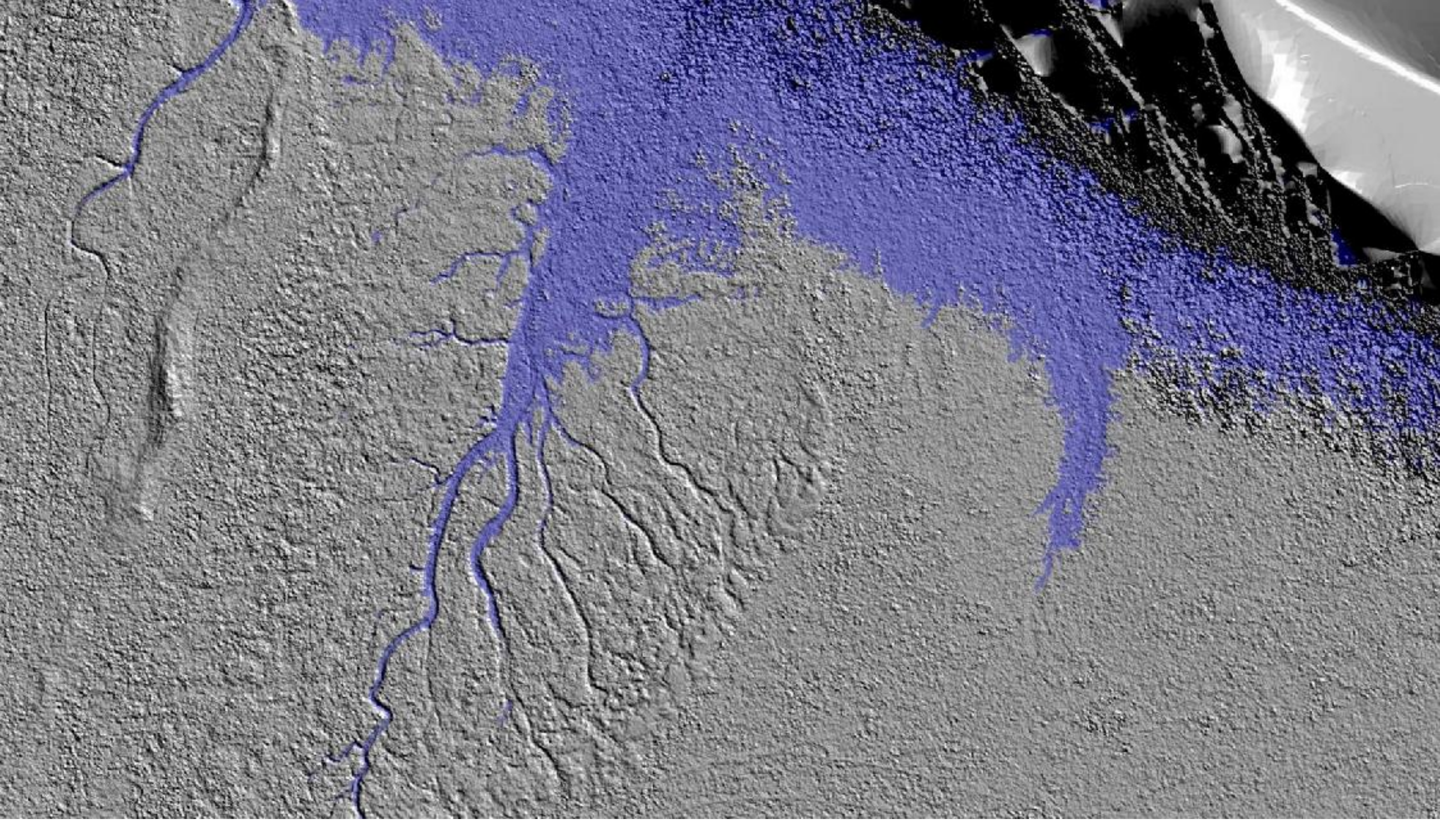
Comparison to Hooper Bay village. Alignment is excellent, with random noise at the +/- 8 cm level or better.

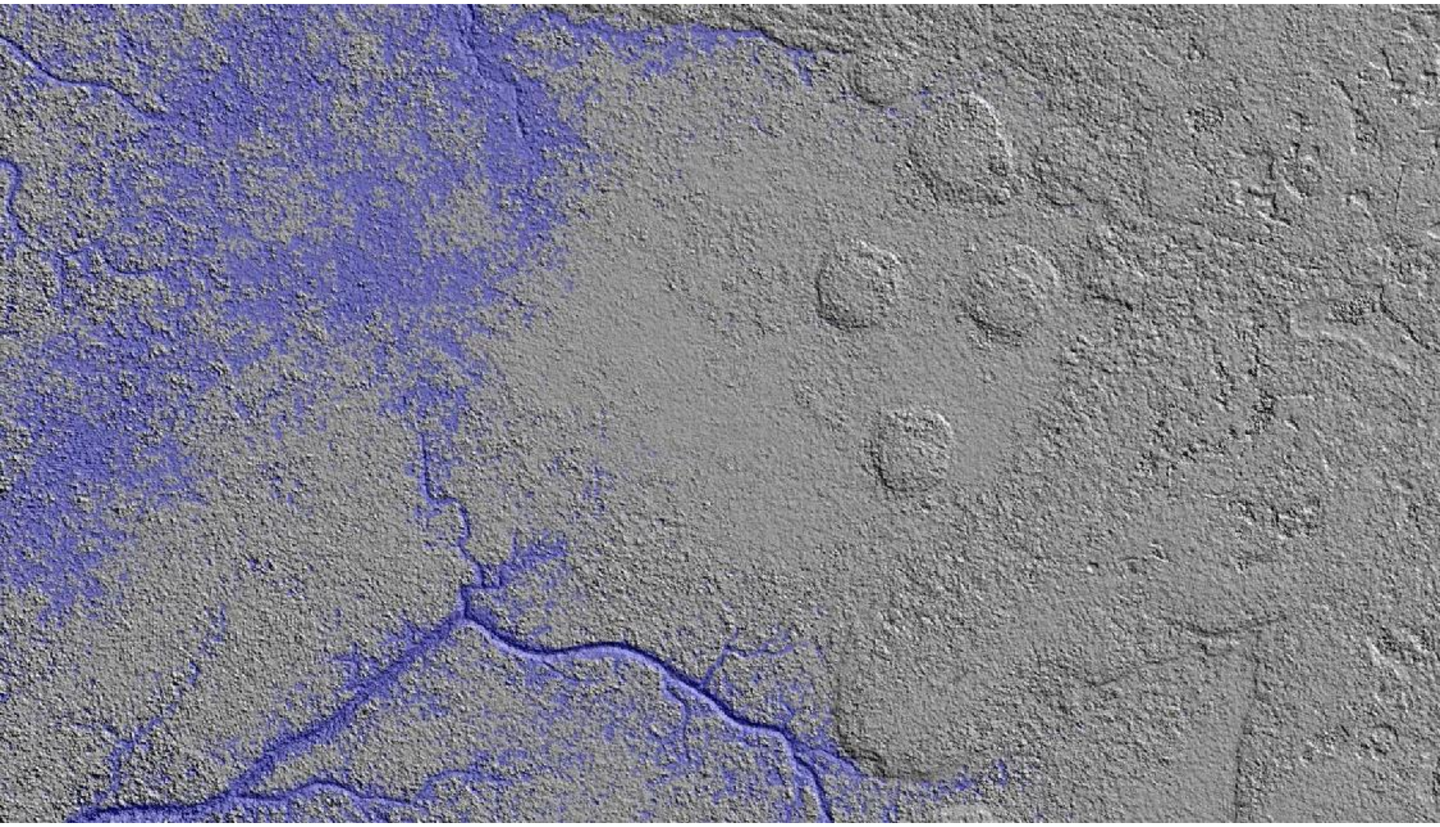


Comparison to Nunam Iqua village. Alignment is excellent, with random noise at the +/- 8 cm level, with excursions caused by spatial biasing at building edges and water bodies, with 10-20 cm of spatially coherent noise.

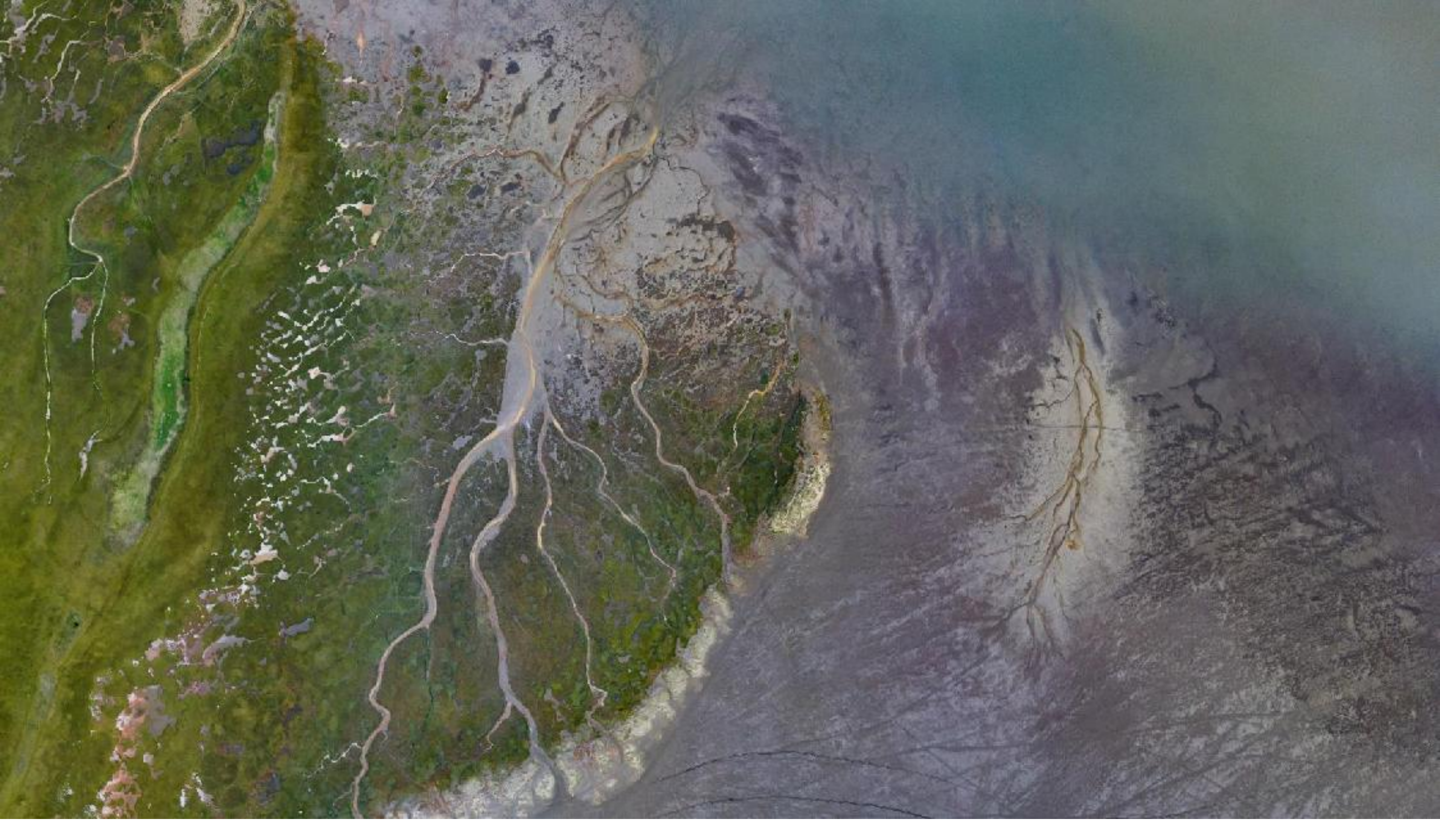


Comparison to Nunam Iqua village, along the runway. The bulk of the runway shows random noise at the +/- 5 cm level, suggesting that some of the increase in difference on the north end of the runway may be real. Careful inspection using the orthomosaic would help further distinguish signal from noise.

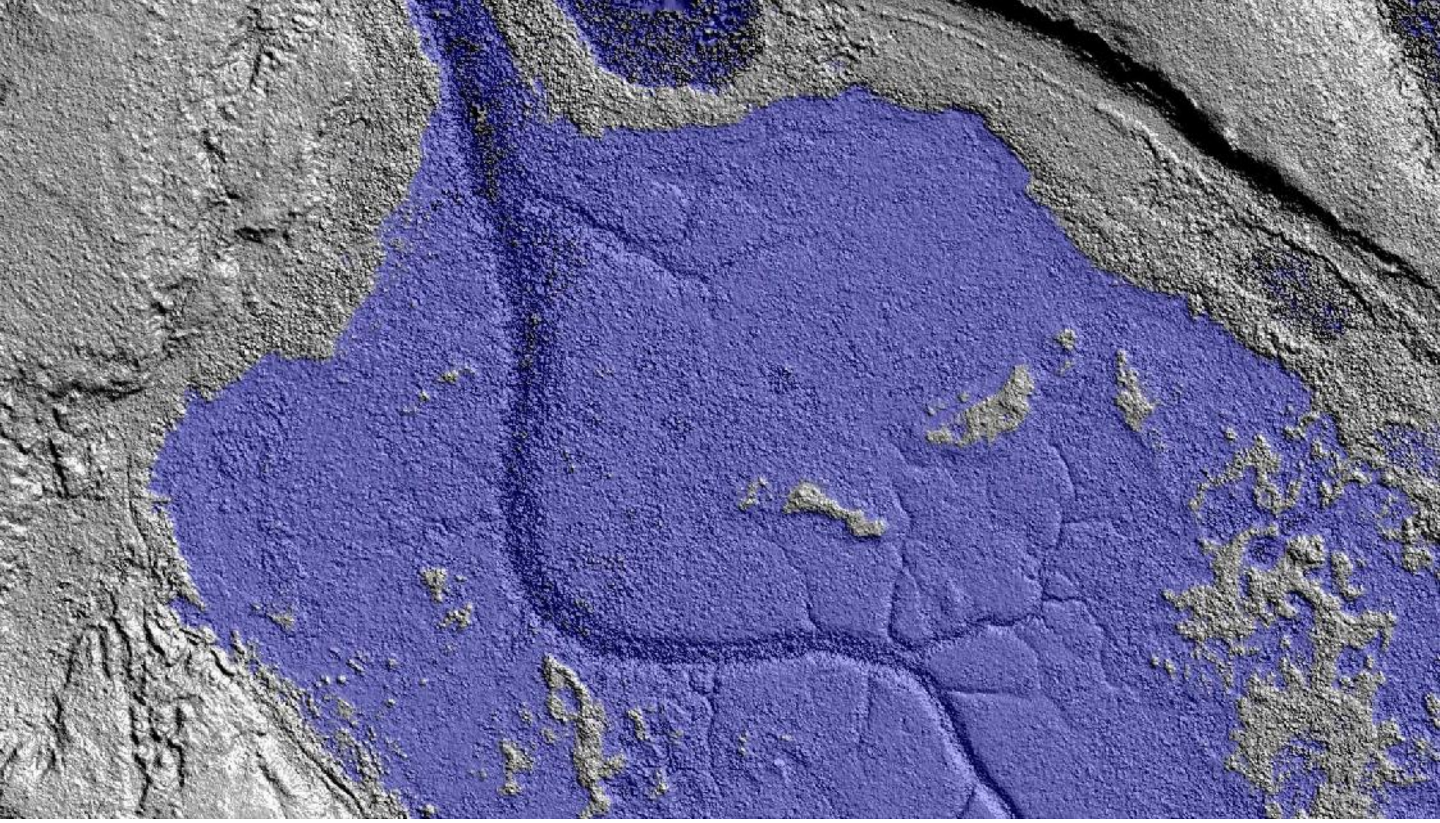


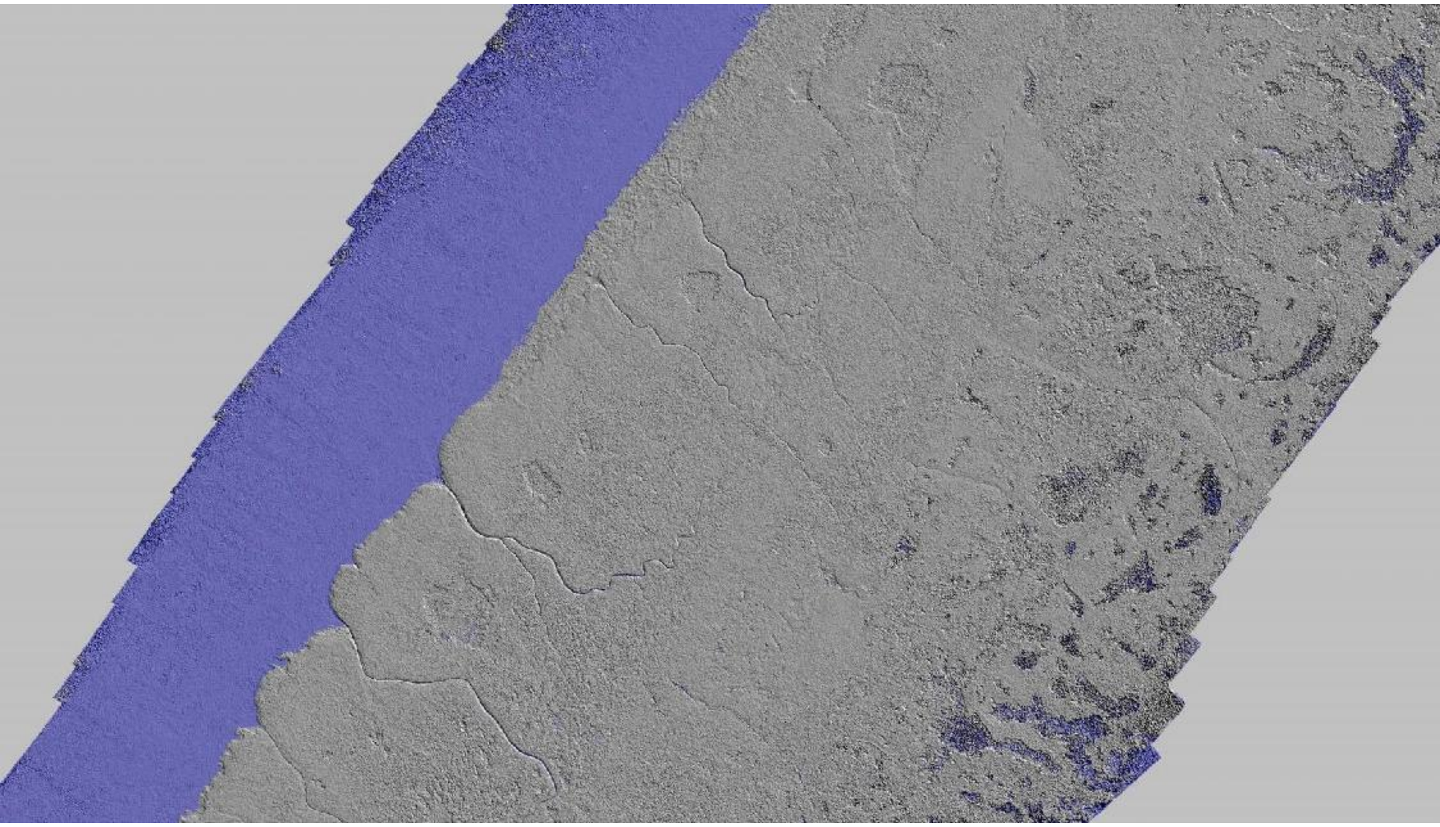


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

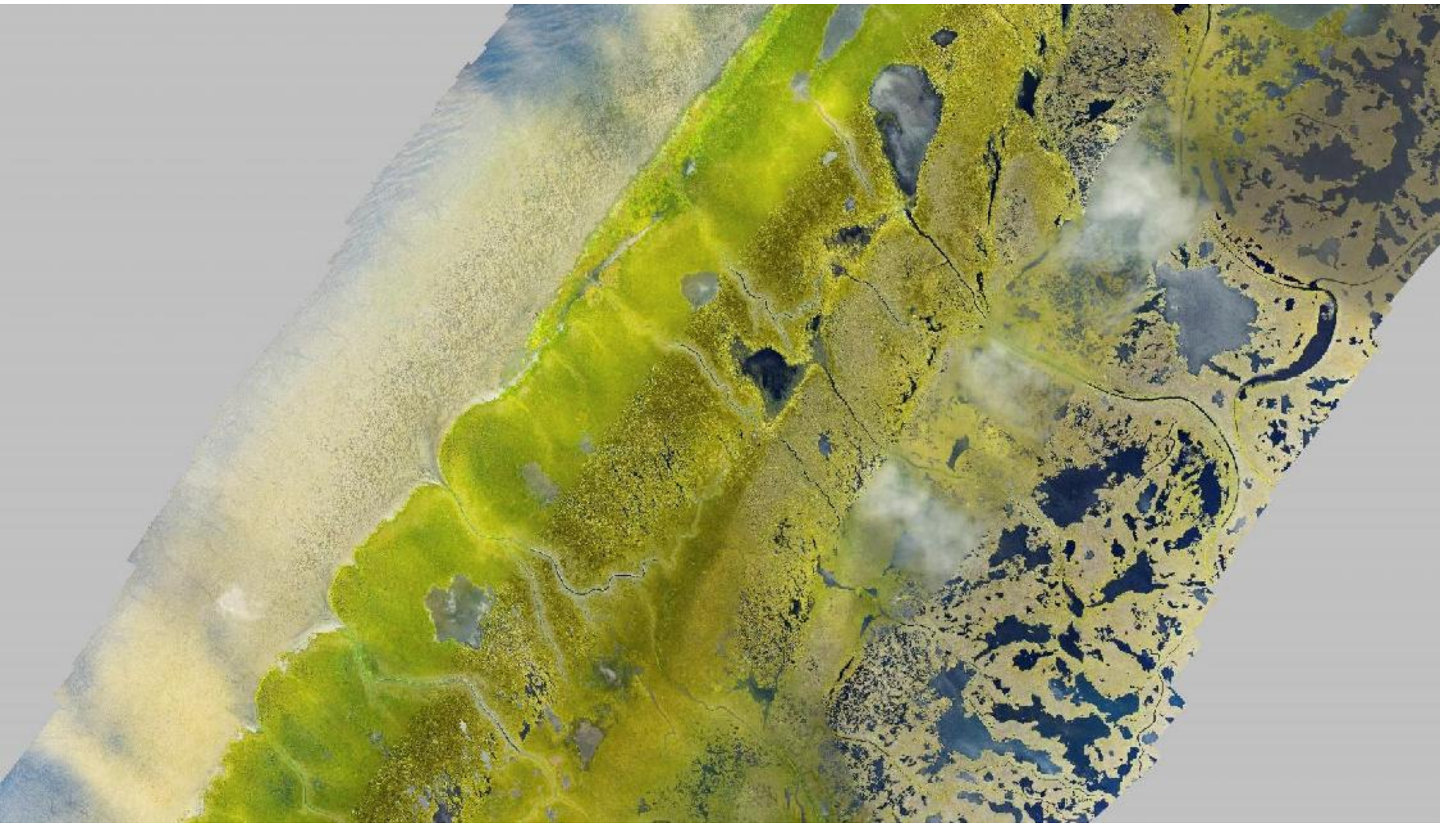


Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

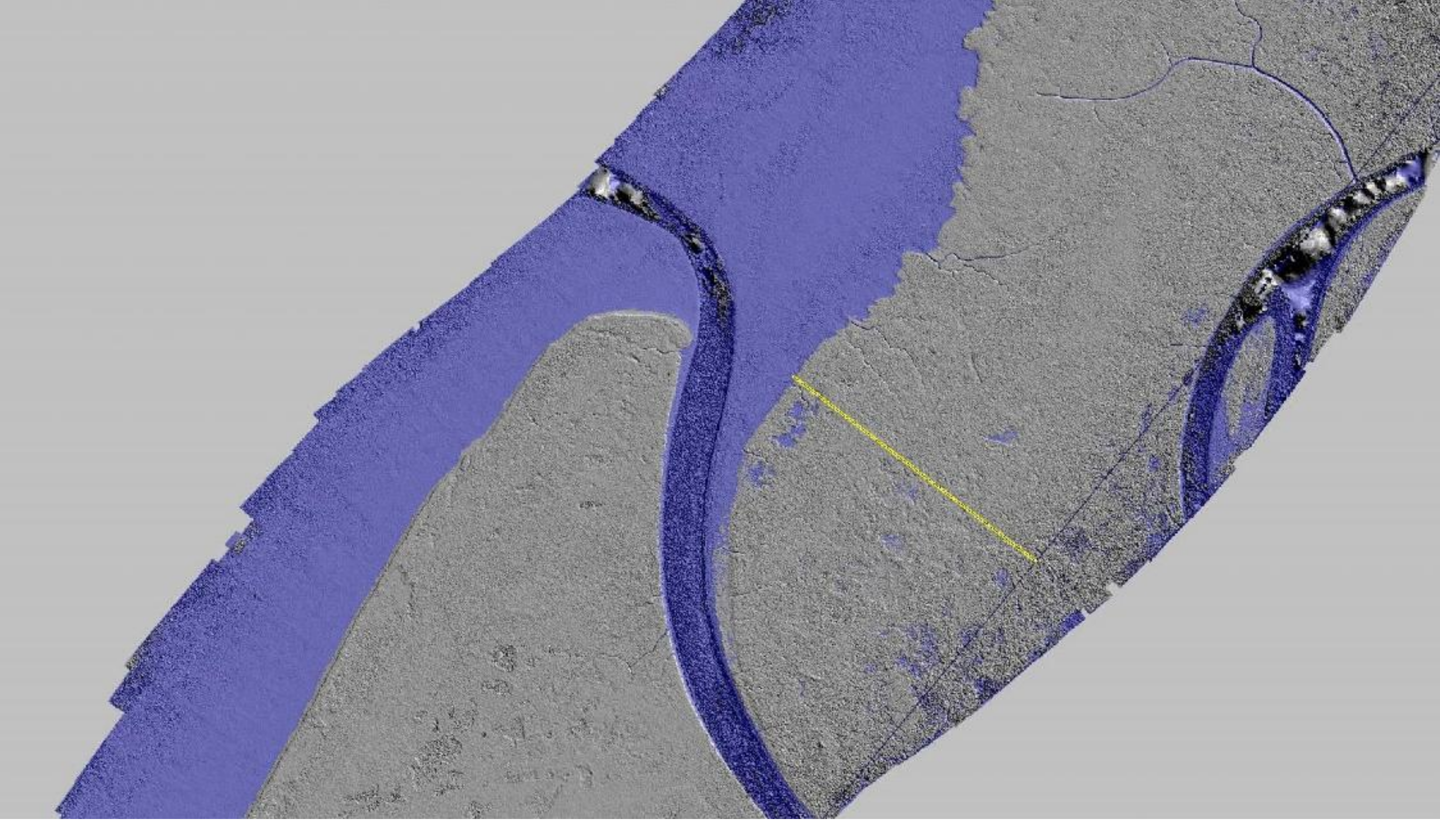


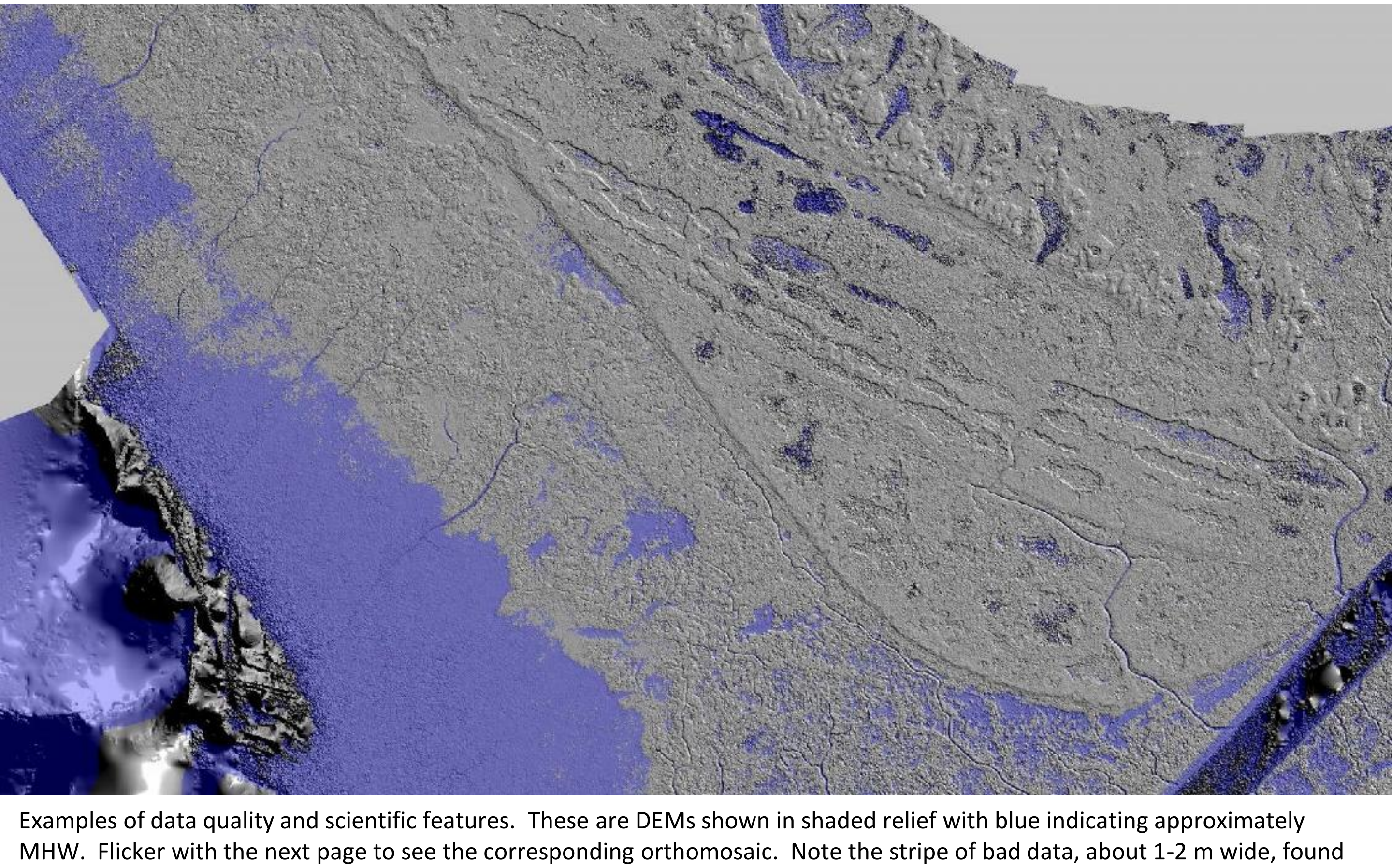


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

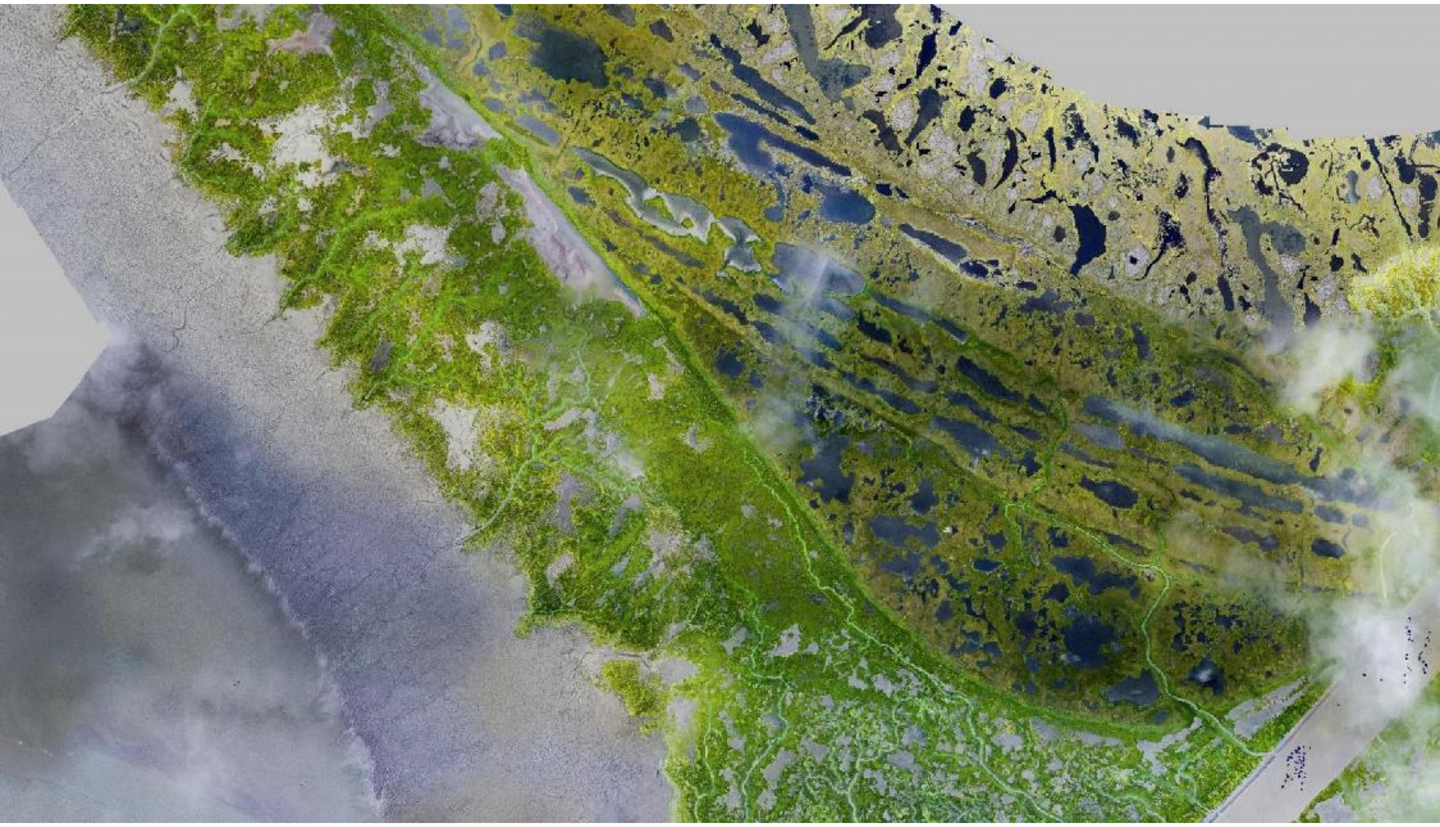


Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.



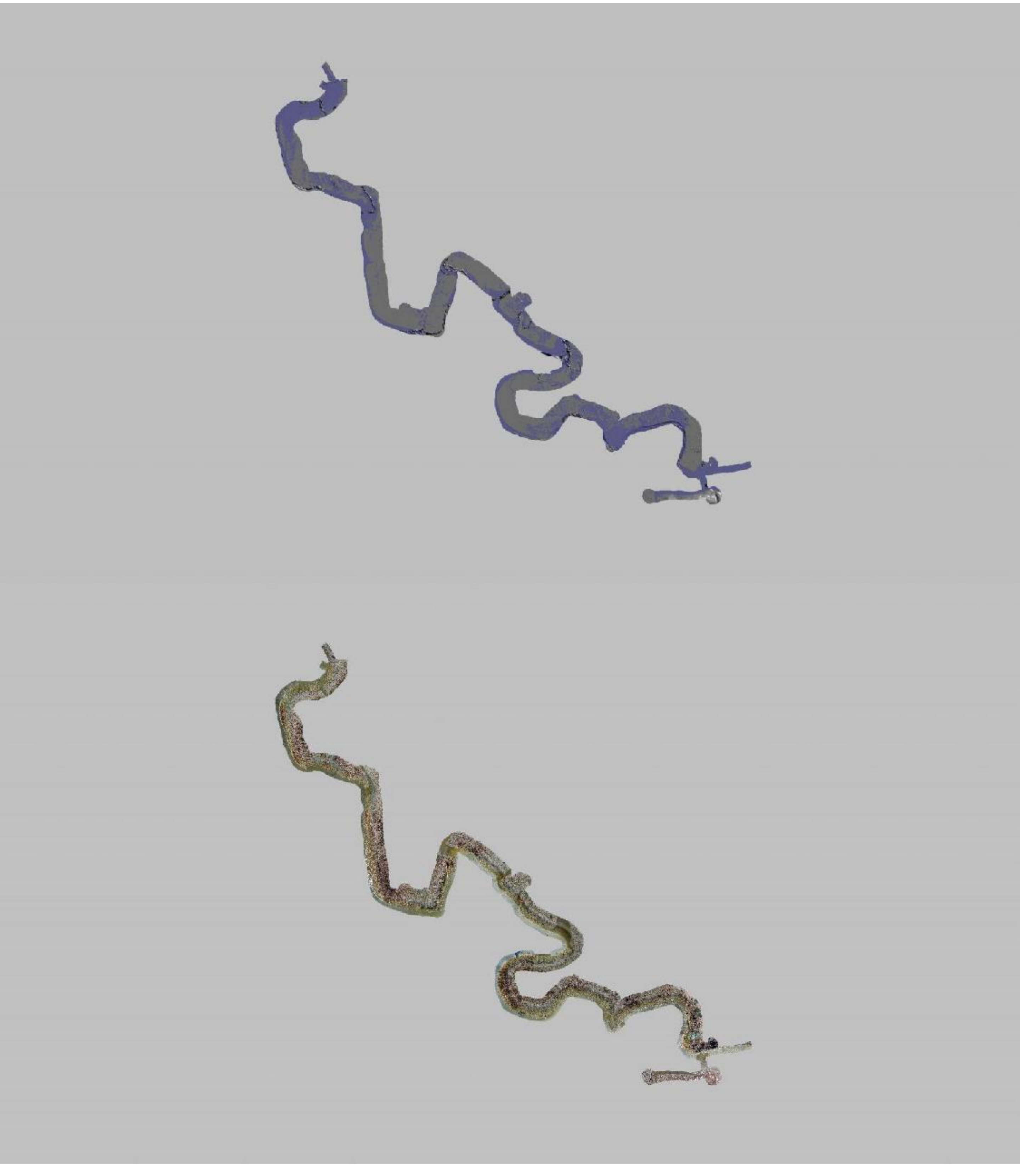


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic. Note the stripe of bad data, about 1-2 m wide, found move than 1500 m (yellow line) from the MHW make and even further from the water's edge. Several such artifacts are found in the data set, only one of which is in the AOI. The othomosaic is unaffected.



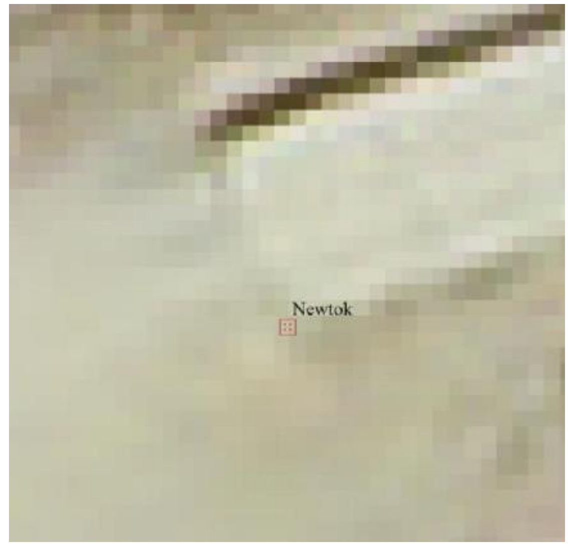
Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

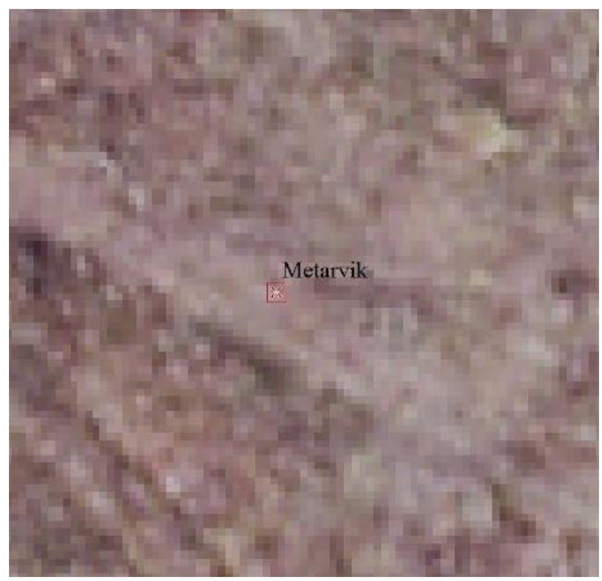
Hazen Bay Block



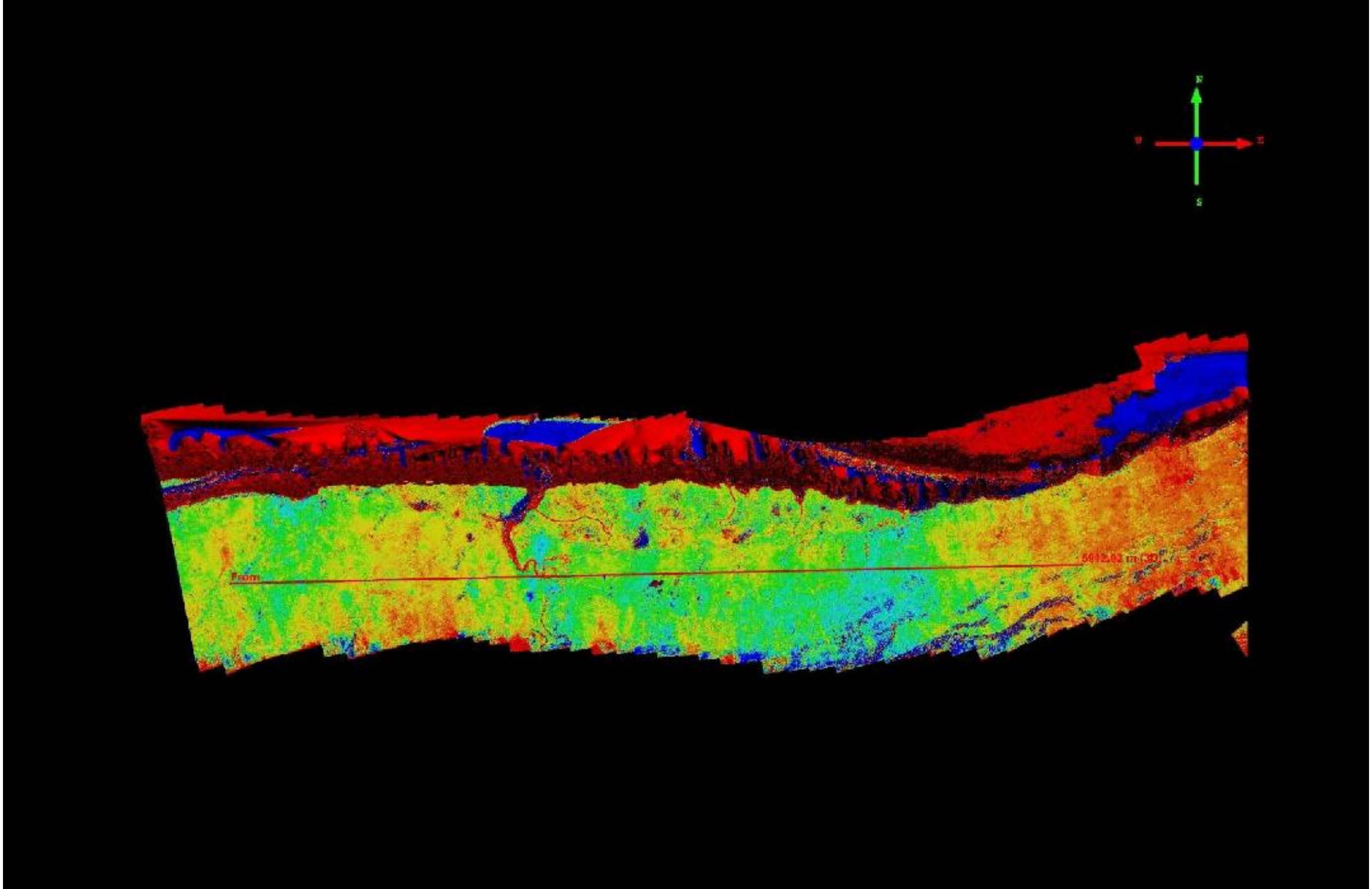
Overview of DEM and orthomosaic

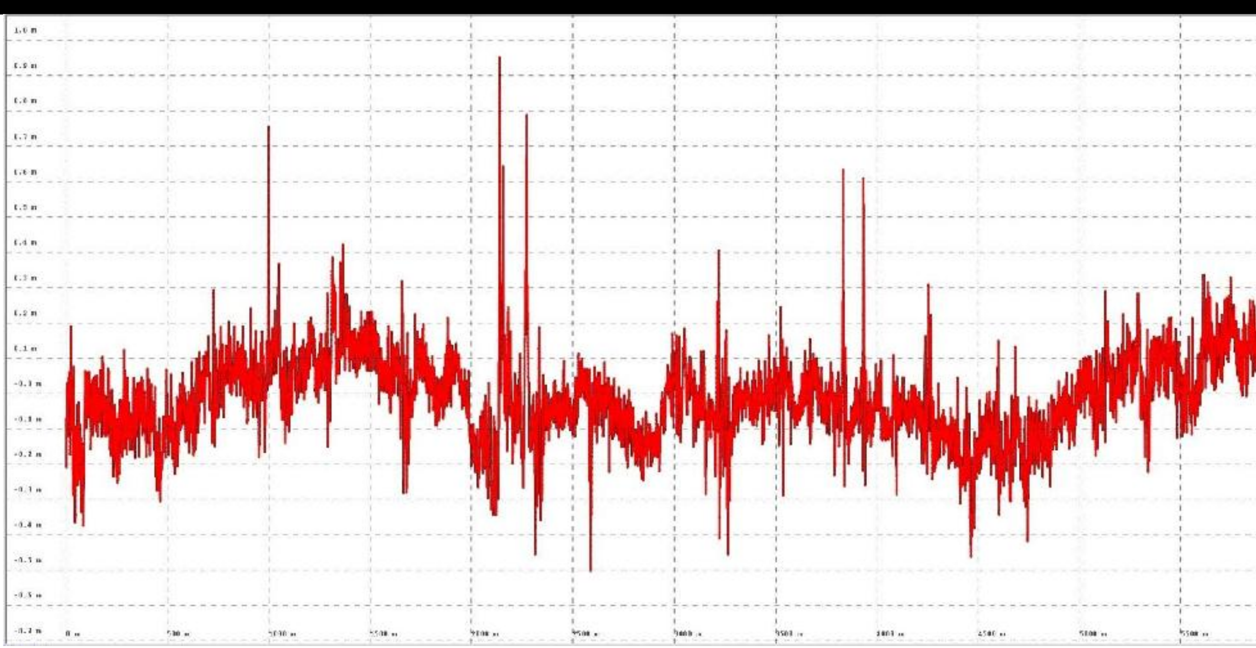
GCPs



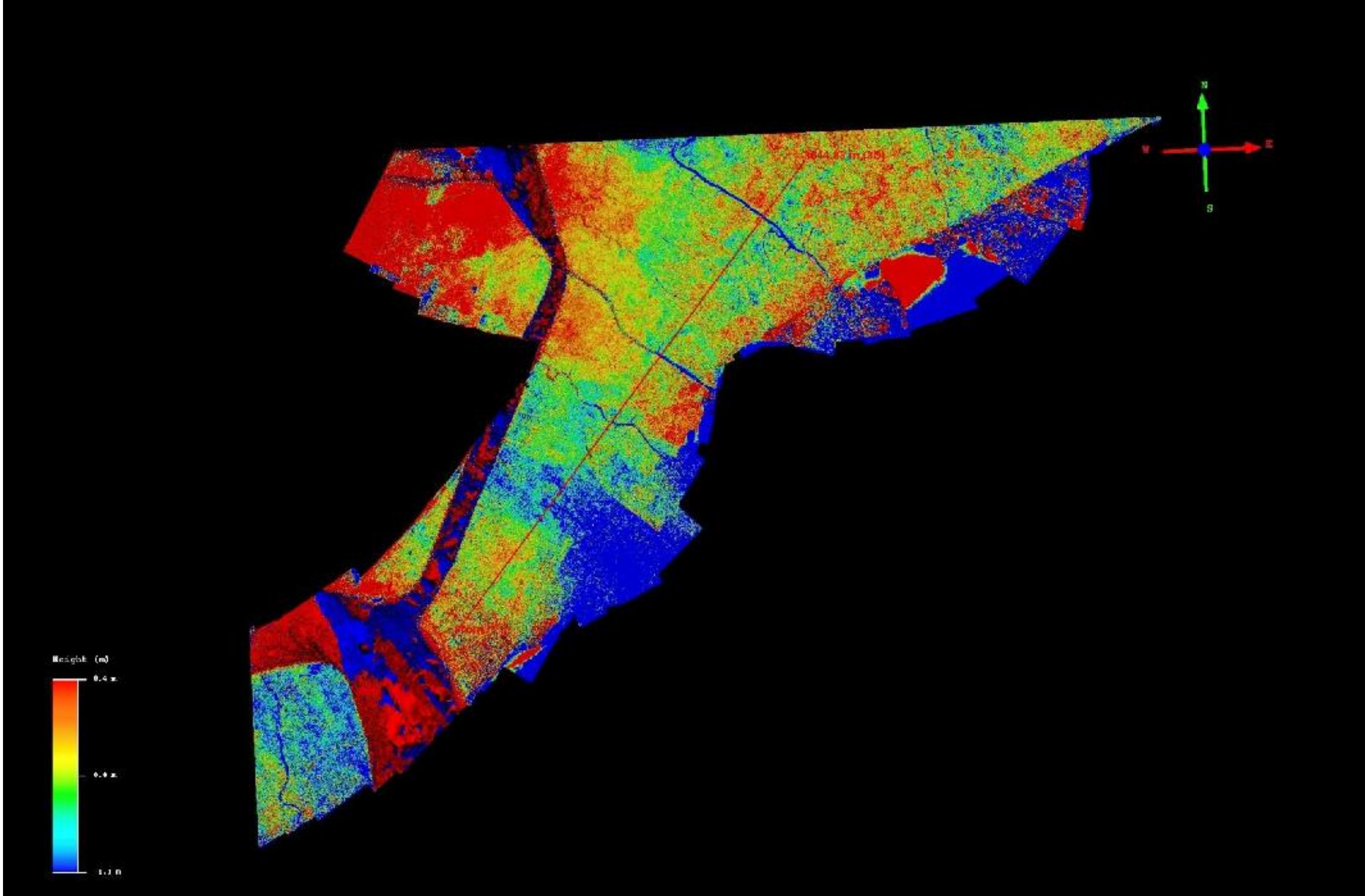


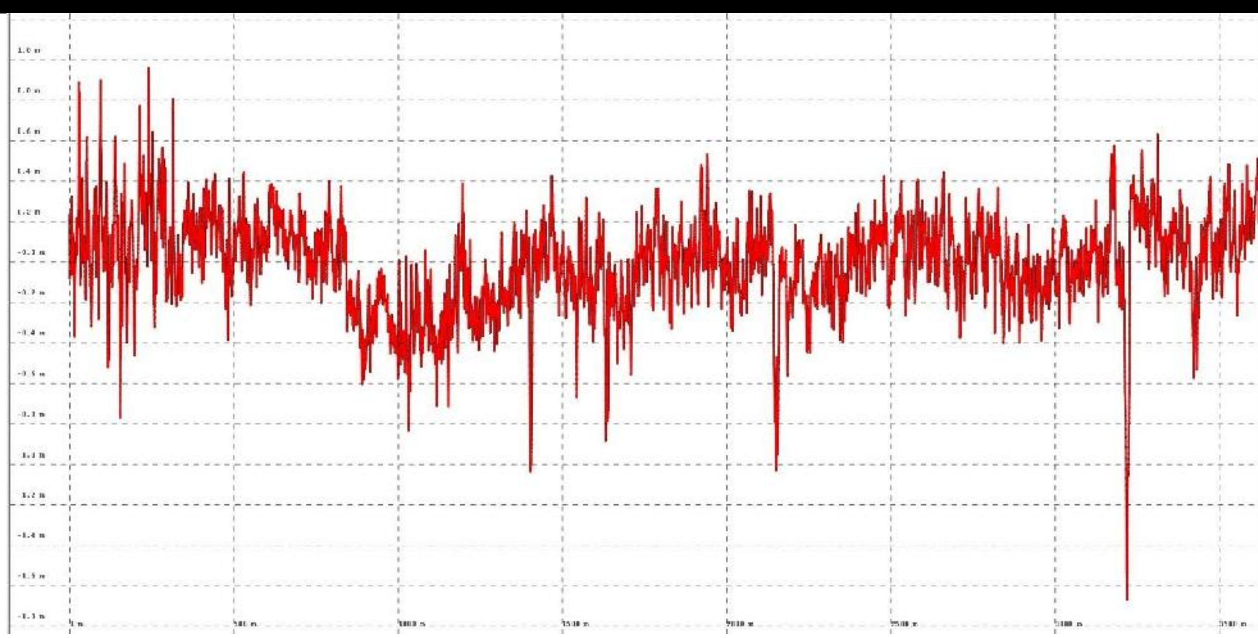
GCPs



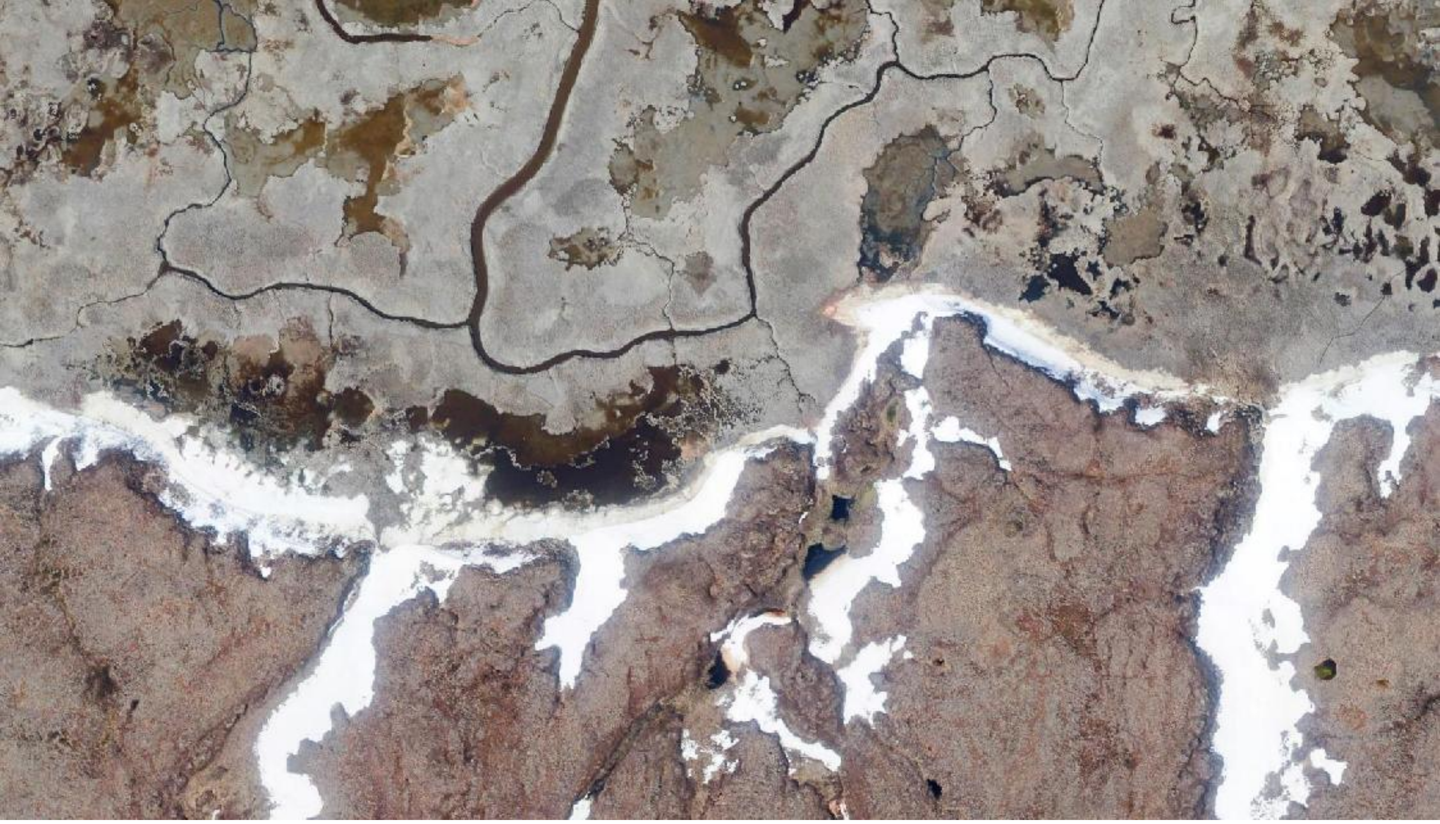


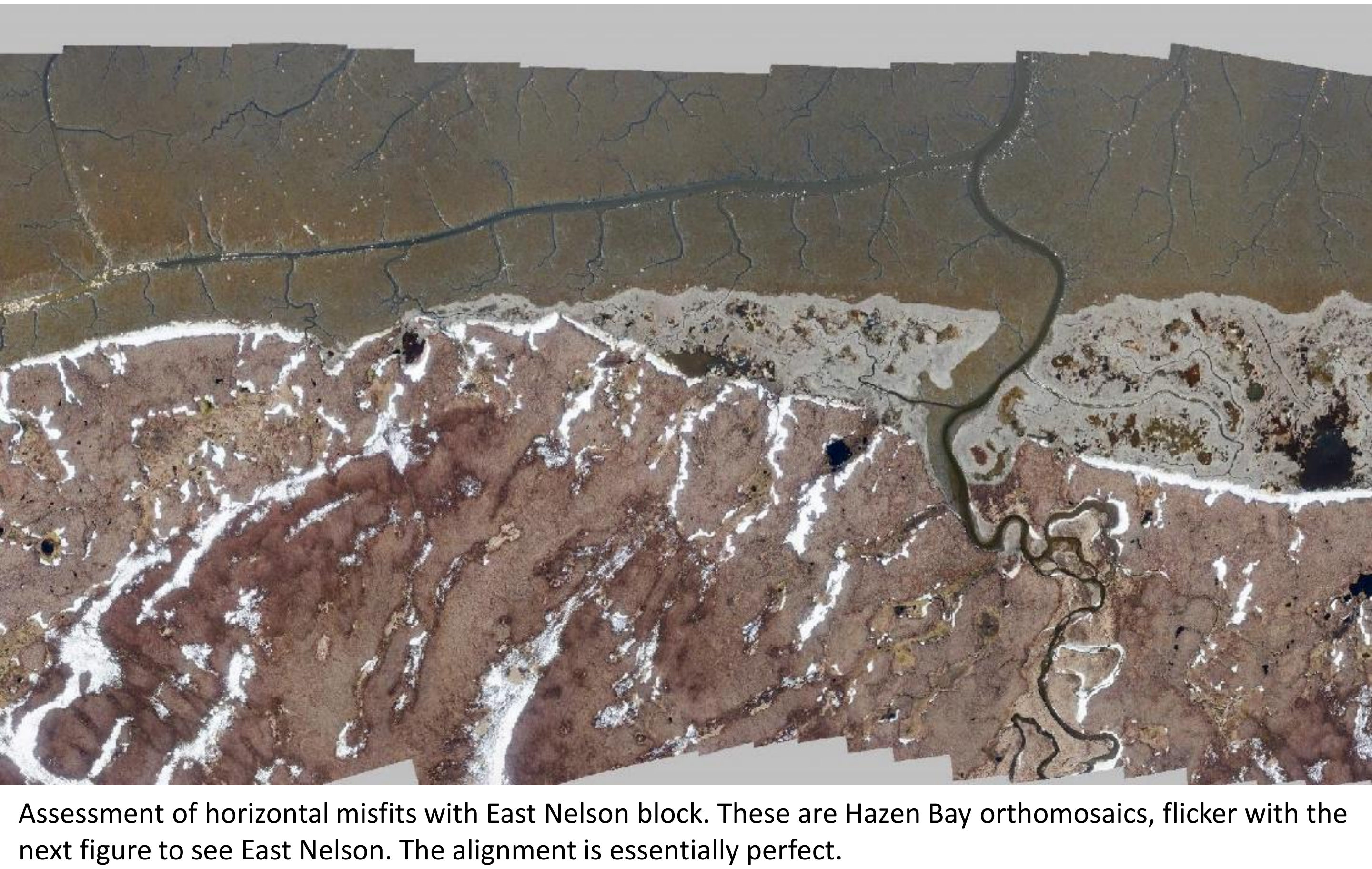
Comparison of overlap with East Nelson block. Random noise is roughly +/- 8 cm and spatially coherent noise roughly 20 cm.



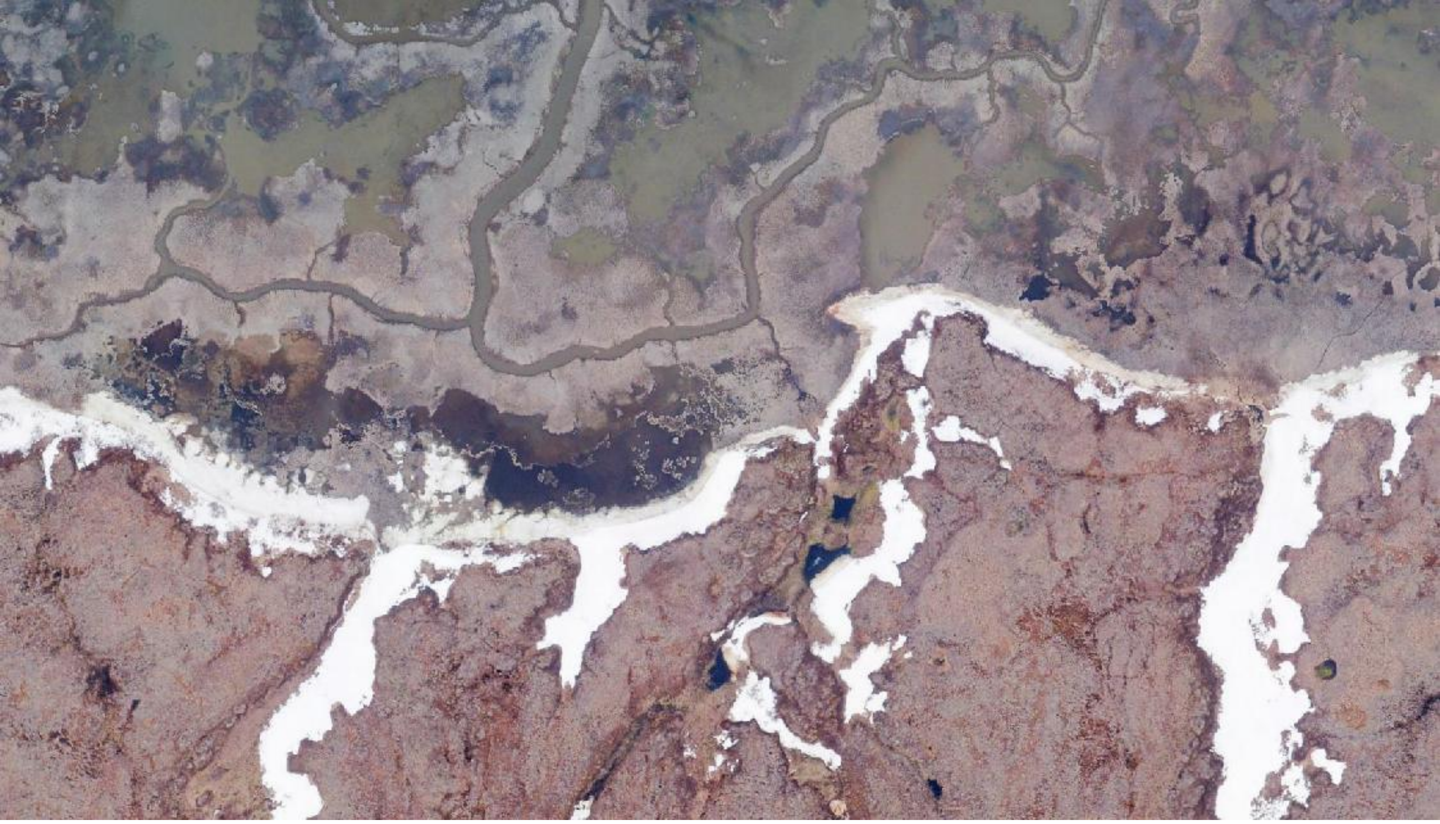


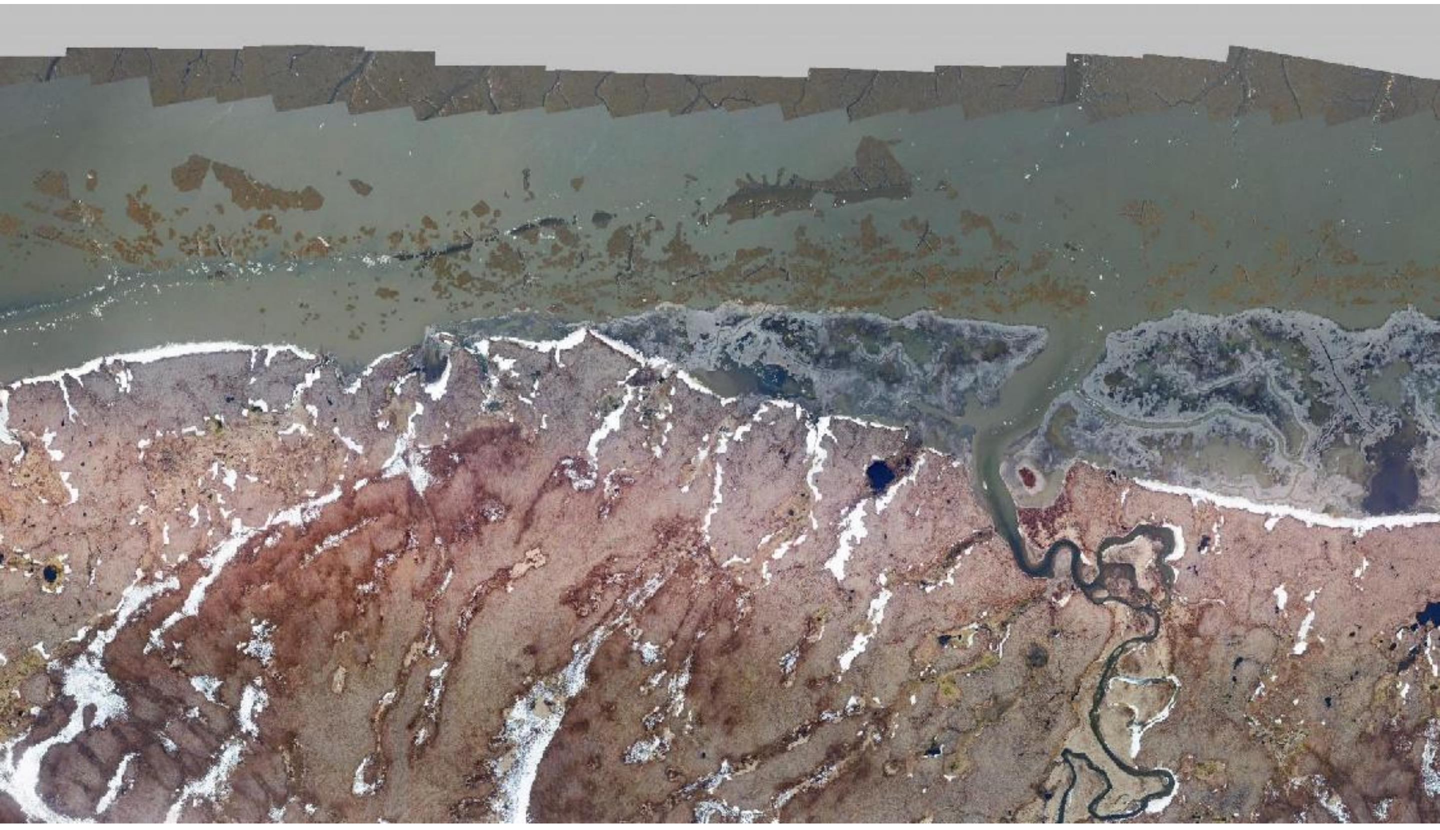
Comparison of overlap with Bethel2Toxic block. Random noise is roughly +/- 8 cm and spatially coherent noise roughly 25 cm.





Assessment of horizontal misfits with East Nelson block. These are Hazen Bay orthomosaics, flicker with the next figure to see East Nelson. The alignment is essentially perfect.

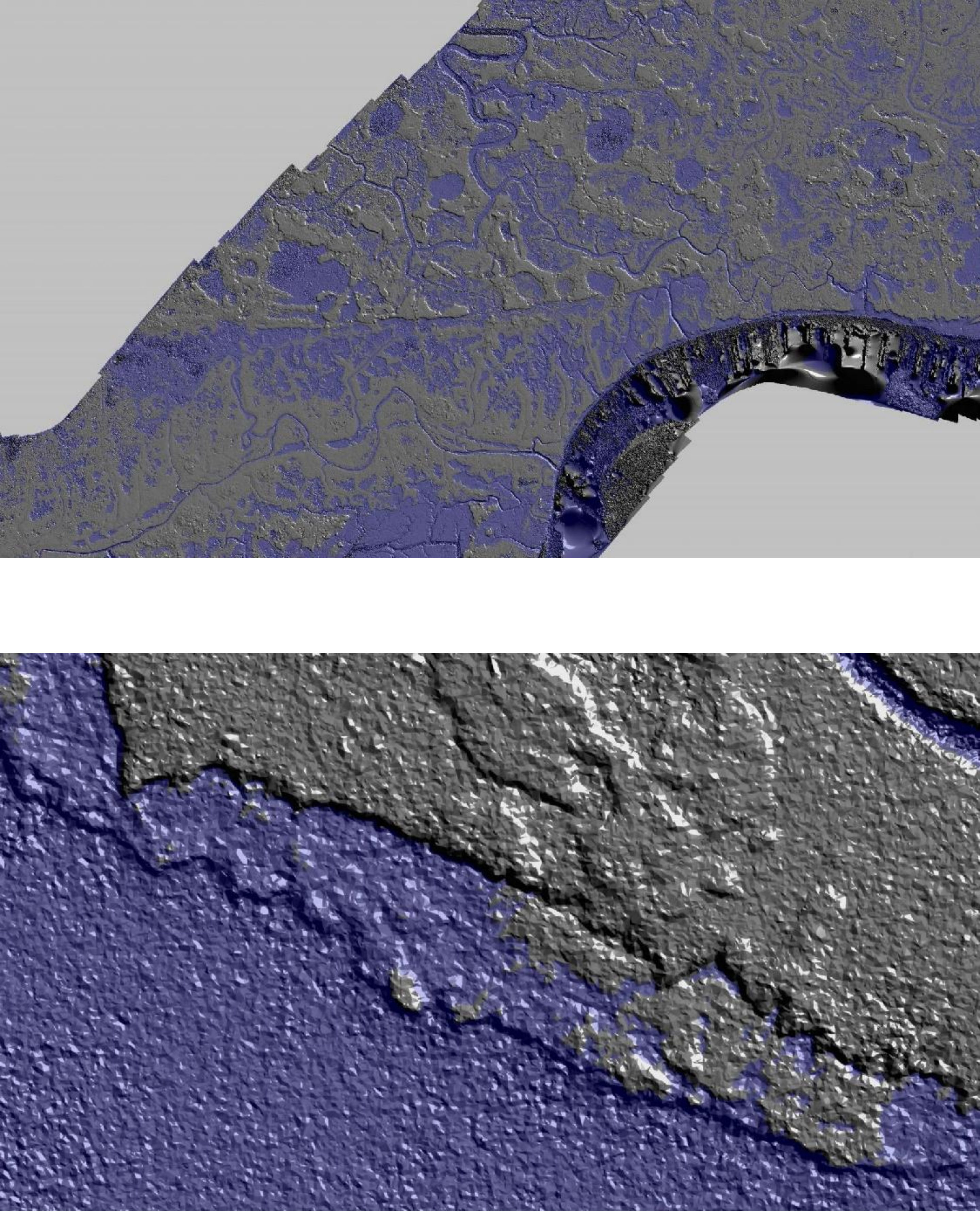




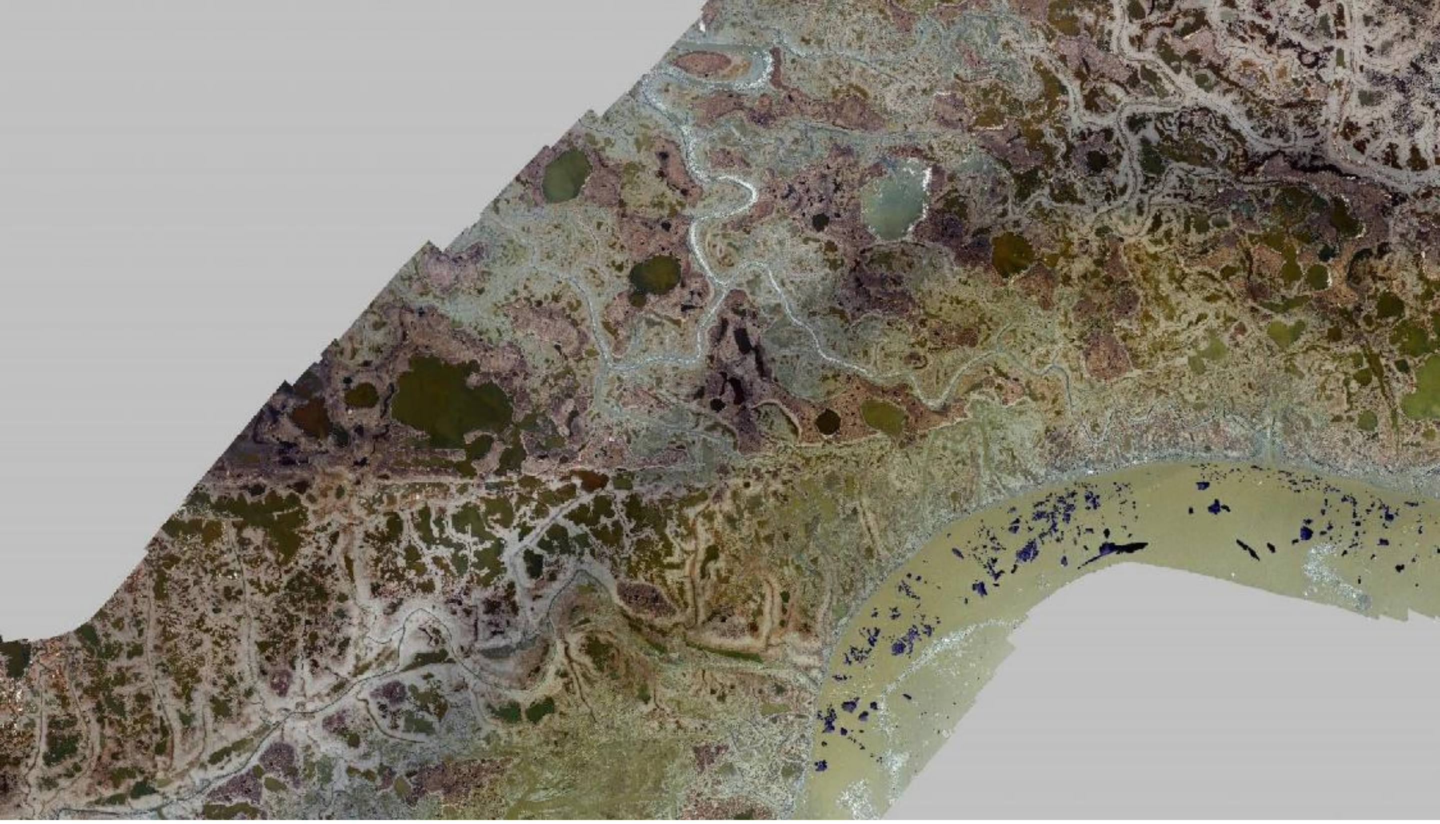
Assessment of horizontal misfits with East Nelson block. These are Hazen Bay orthomosaics, flicker with the next figure to see East Nelson. The alignment is essentially perfect. These blocks were acquired on subsequent days, notice the difference in tide levels. With repeat fodar maps like these, we can actually measure tide heights by drawing an outline of water extent of the higher tide and extracting elevations from the low tide DEM.

Assessment of horizontal misfits with Chevak2Nunam block. These are Hazen Bay orthomosaics, flicker with the next figure to see Chevak2Nunam. The alignment is essentially perfect.

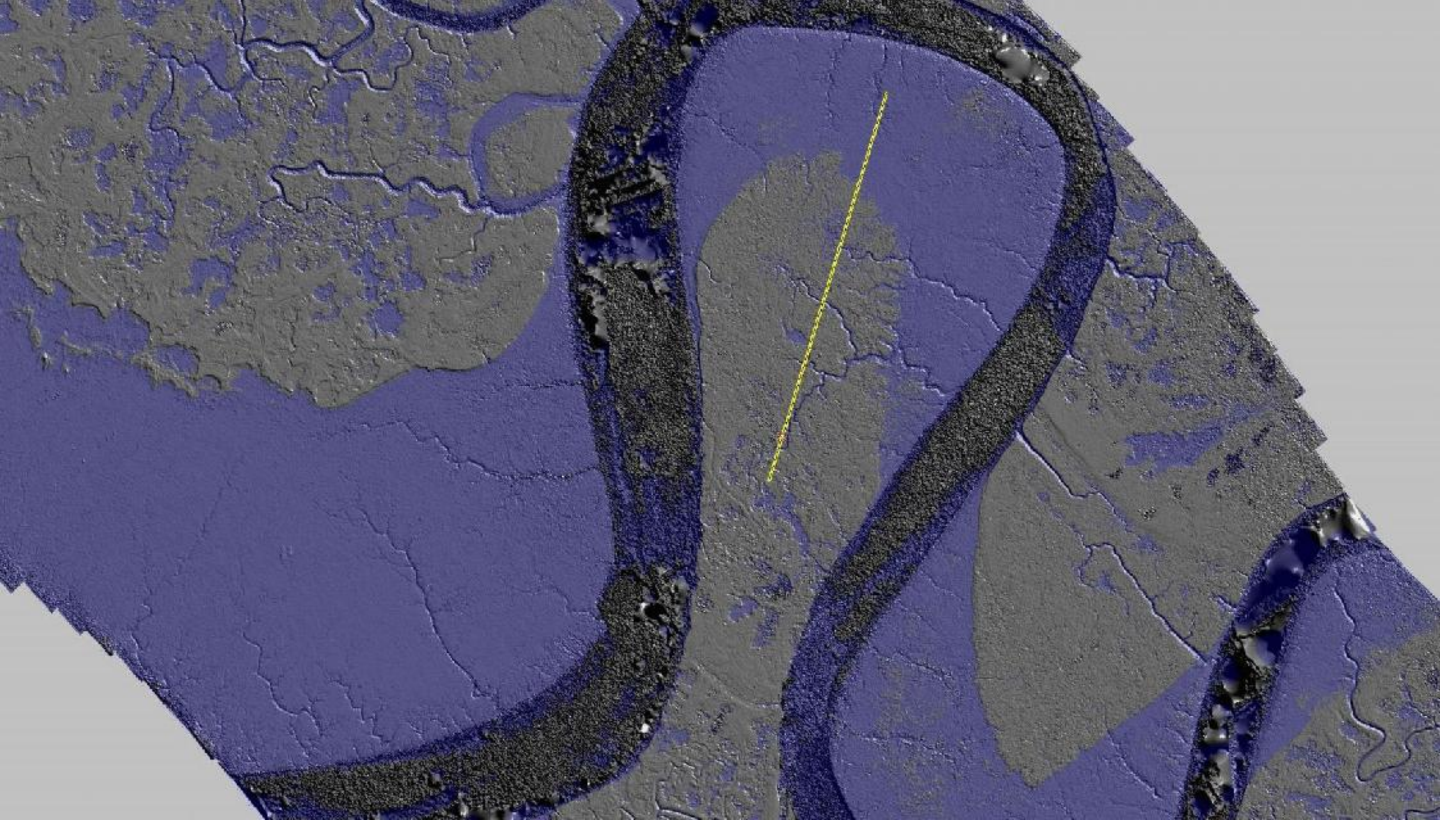
Assessment of horizontal misfits with Chevak2Nunam block. These are Chevak2Nunam orthomosaics, flicker with the next figure to see Hazen Bay. The alignment is essentially perfect. These blocks were acquired in different seasons.

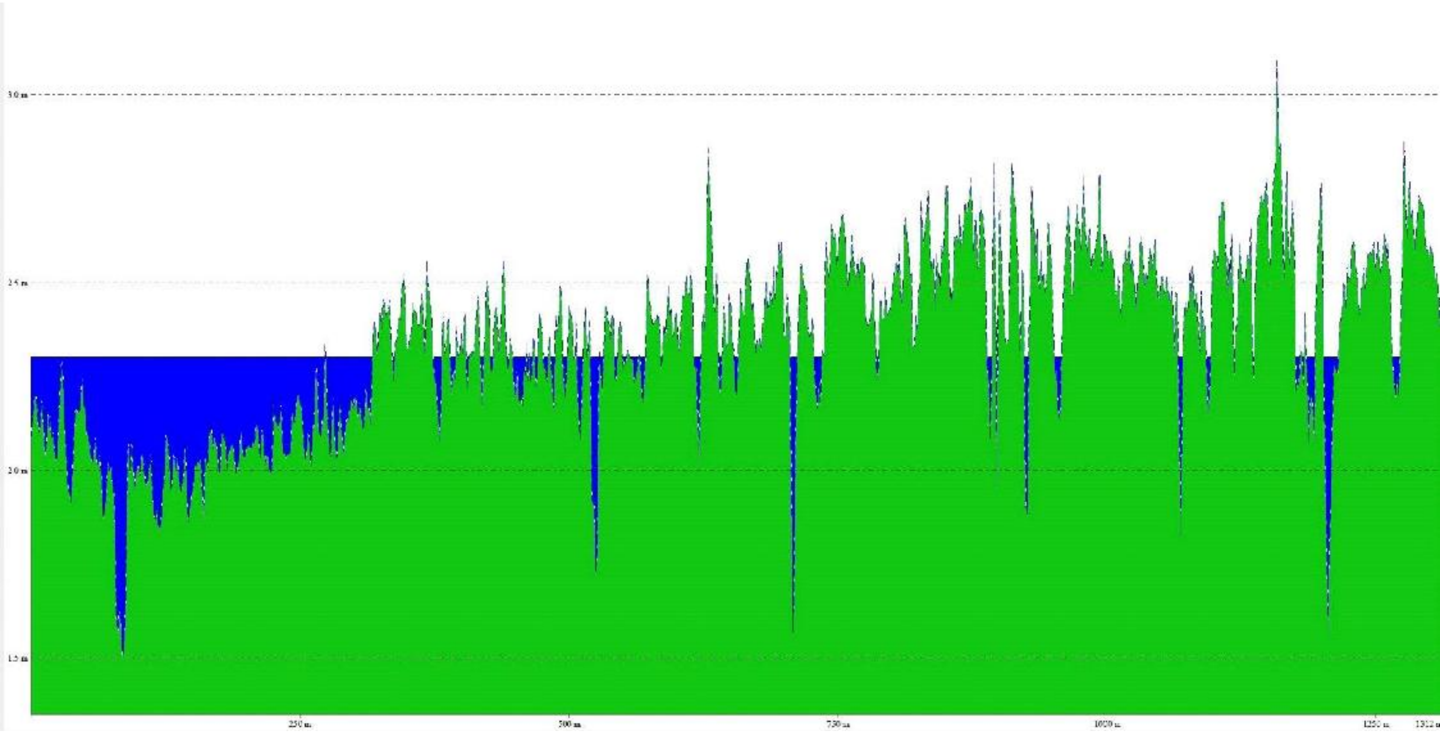


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

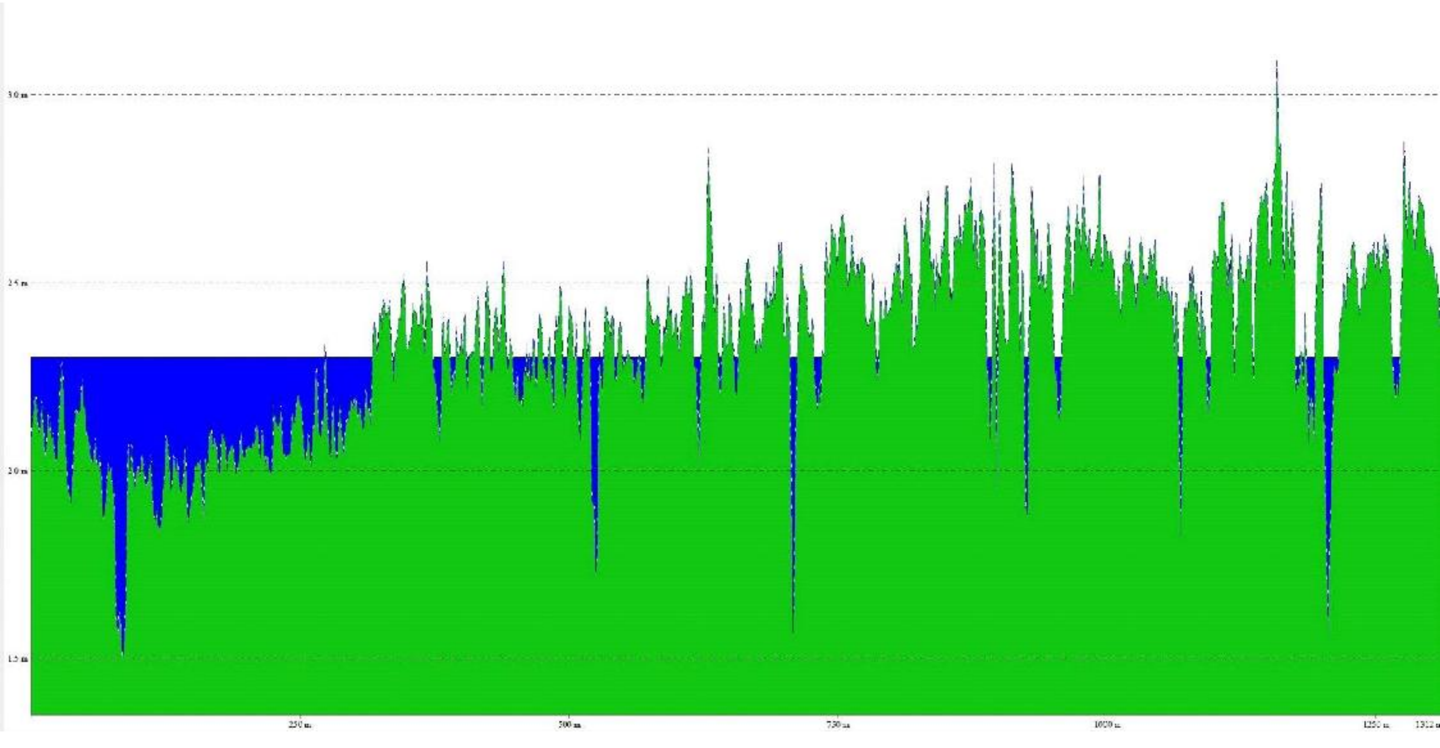


Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail. Note the erosion patterns in the lower image.

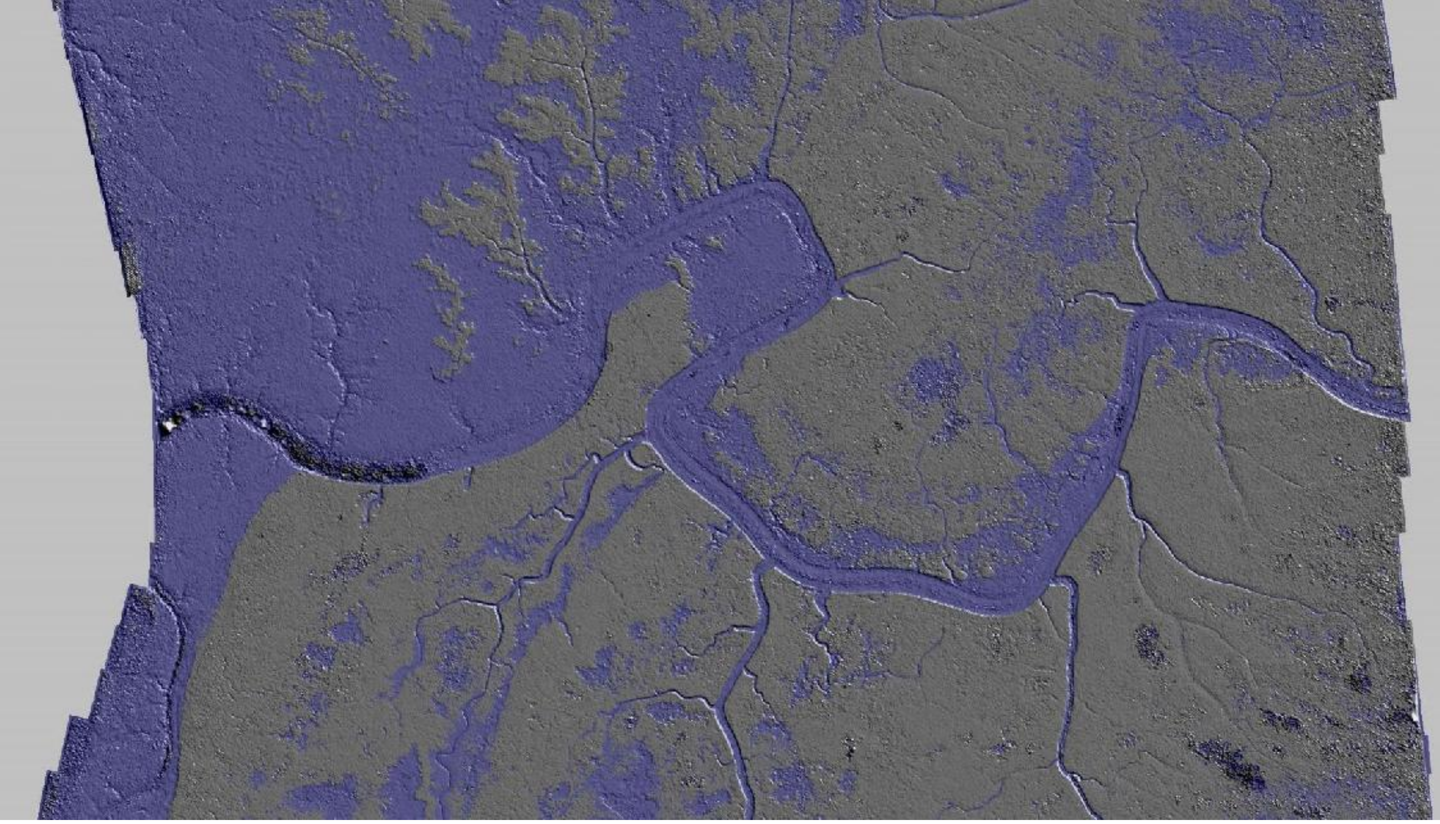


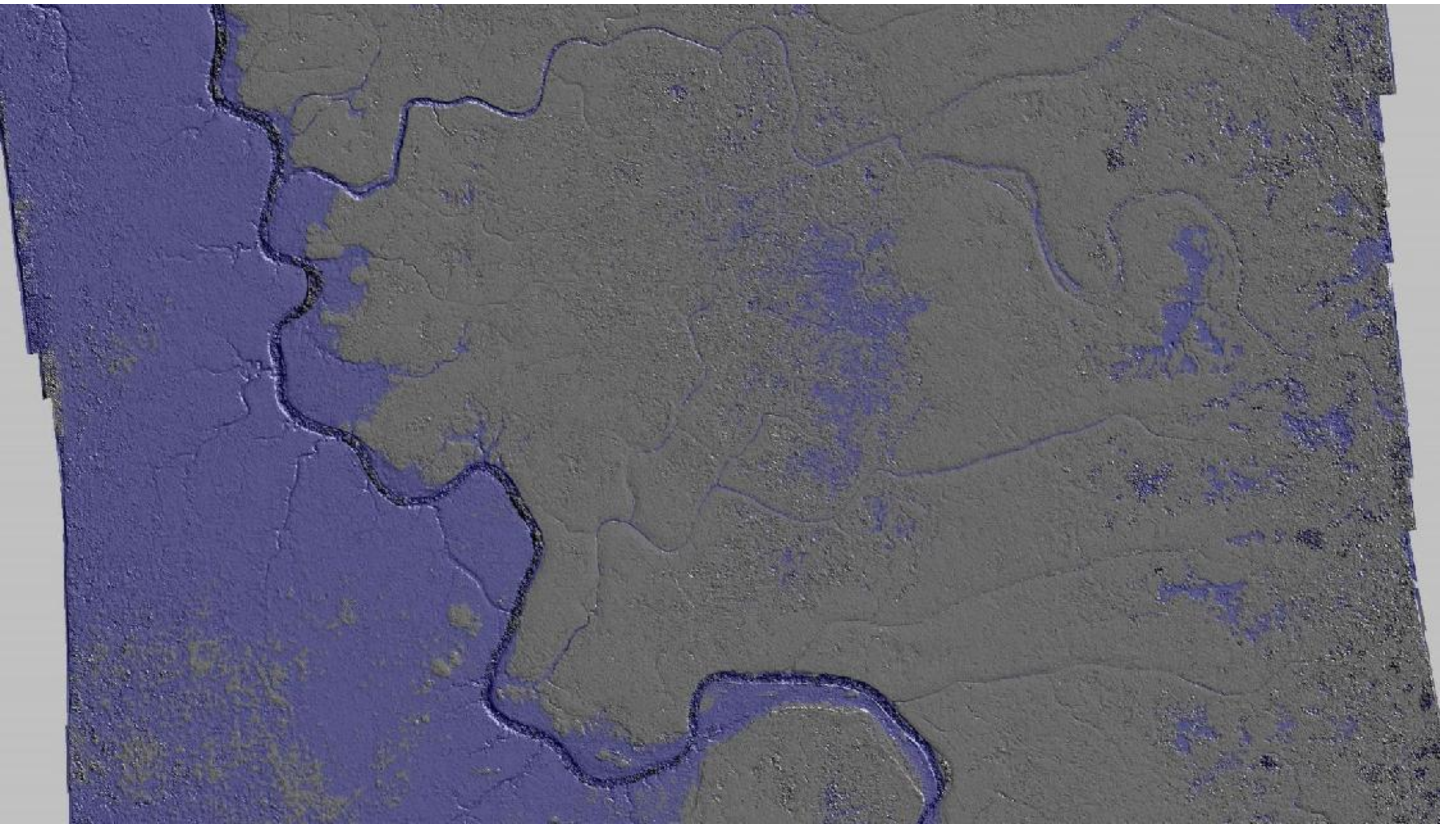


Example transect showing centimeter-level measurement capabilities with these data.



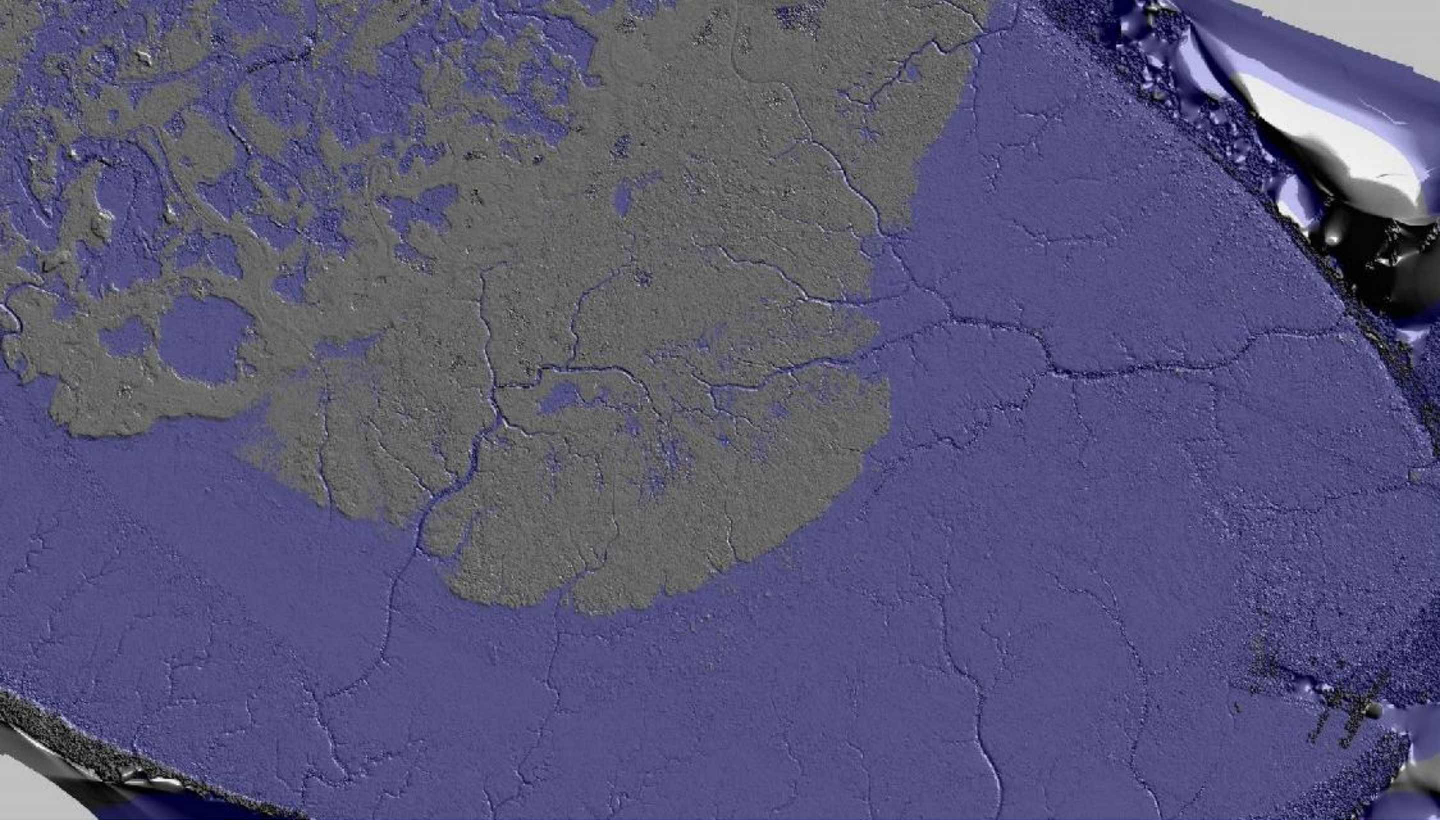
Example transect showing centimeter-level measurement capabilities with these data.

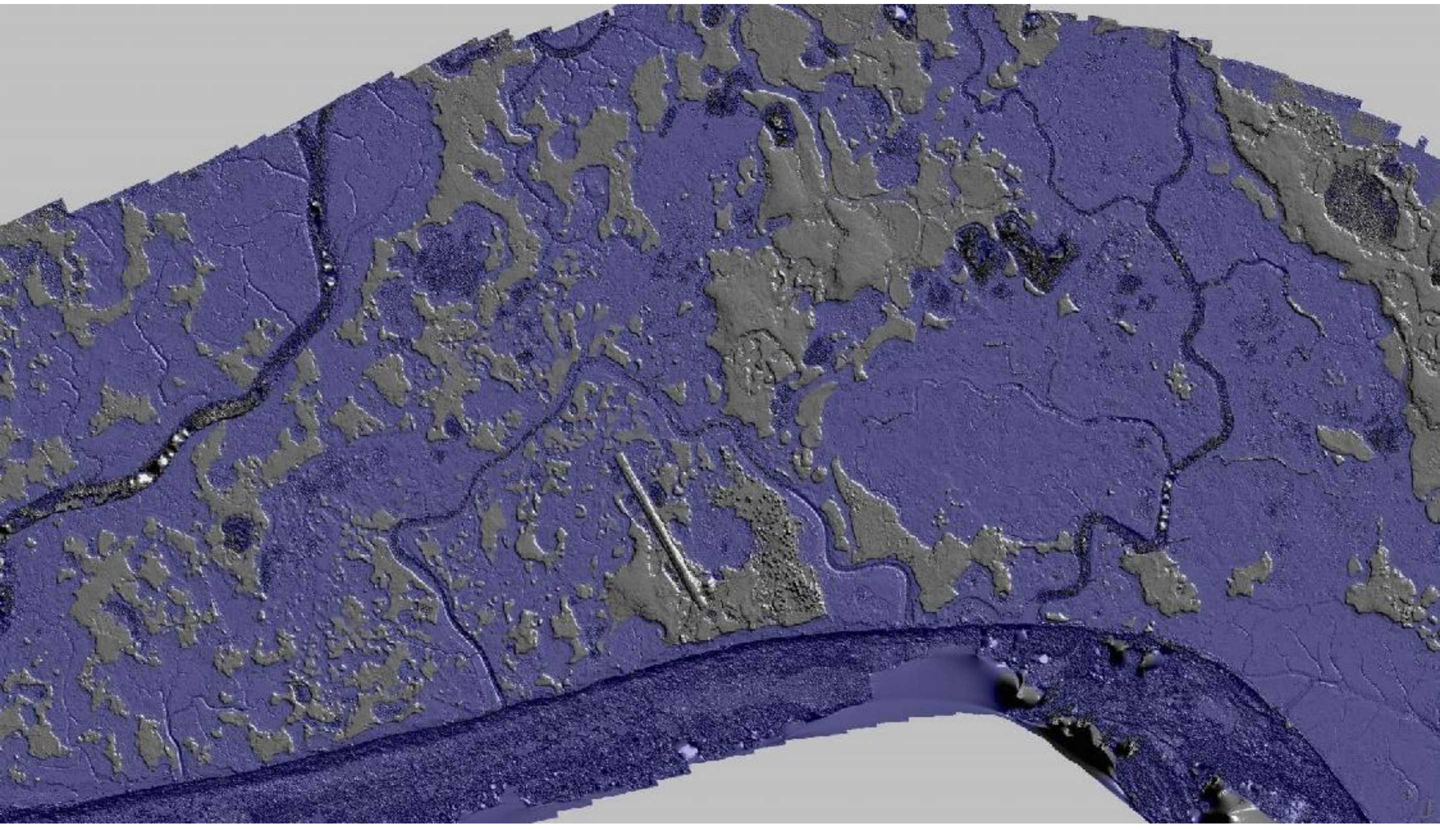




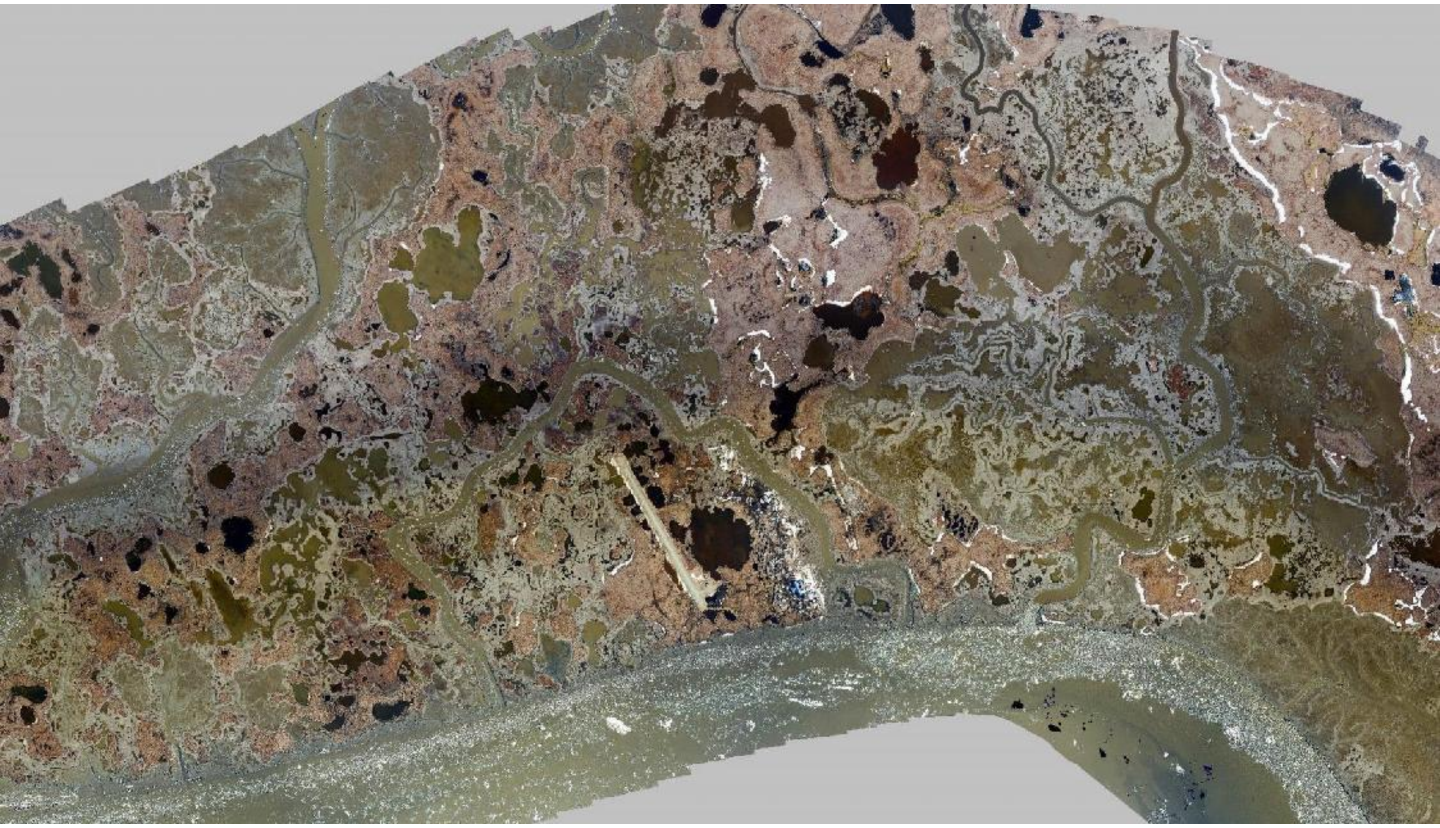
Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.



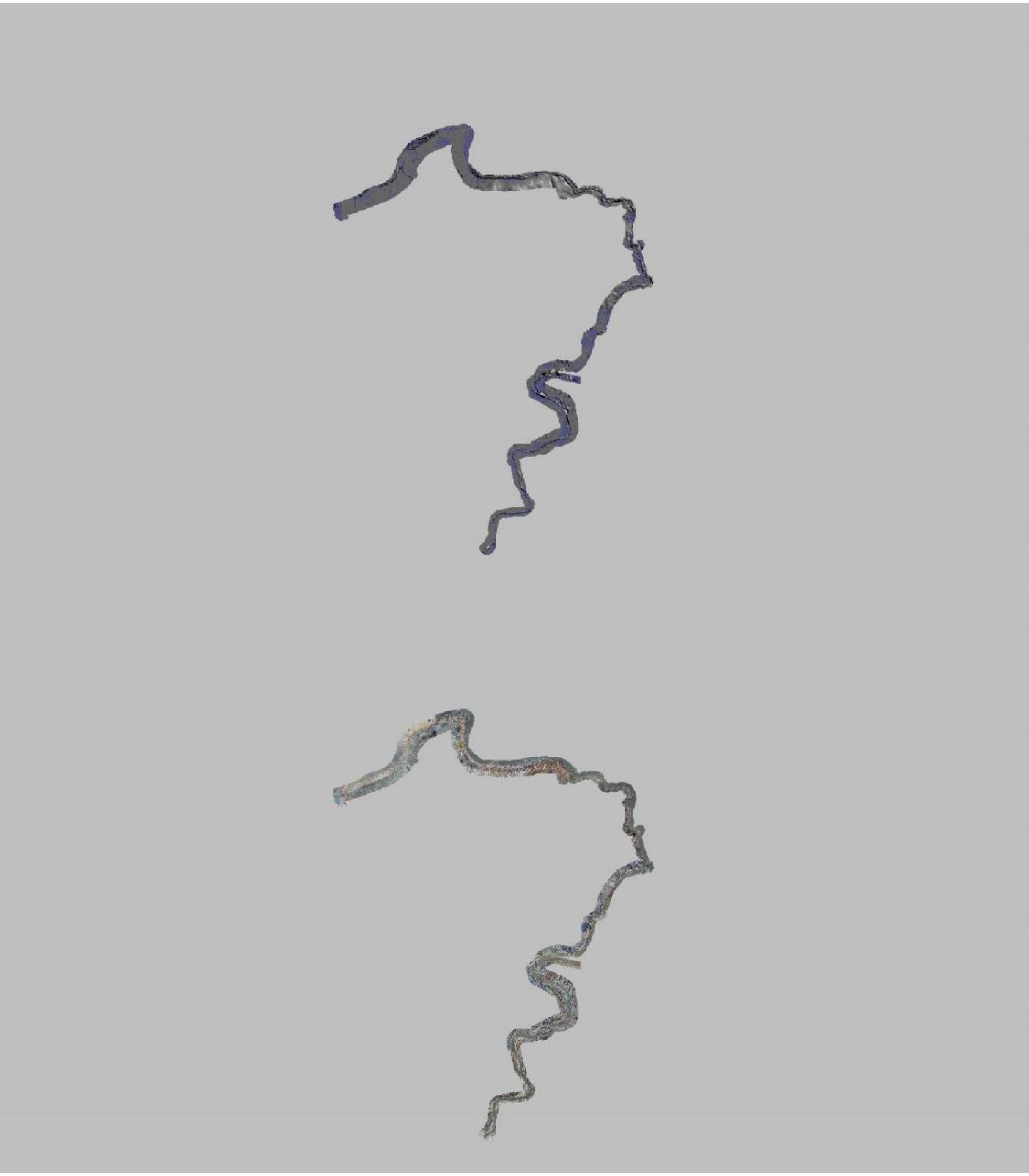


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic. The lower image is Newtok with its airport standing out, which essentially an island.

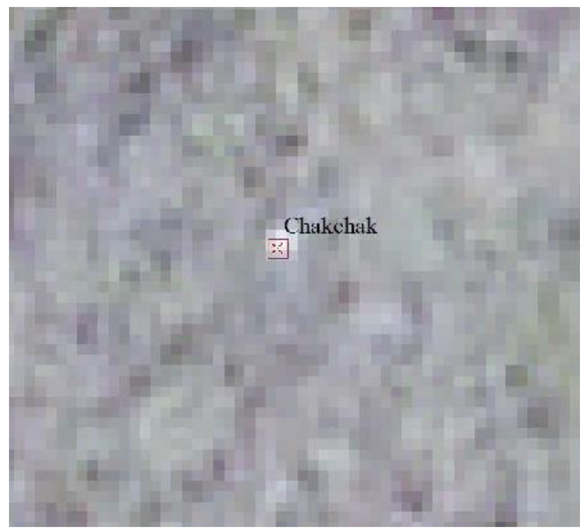


Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

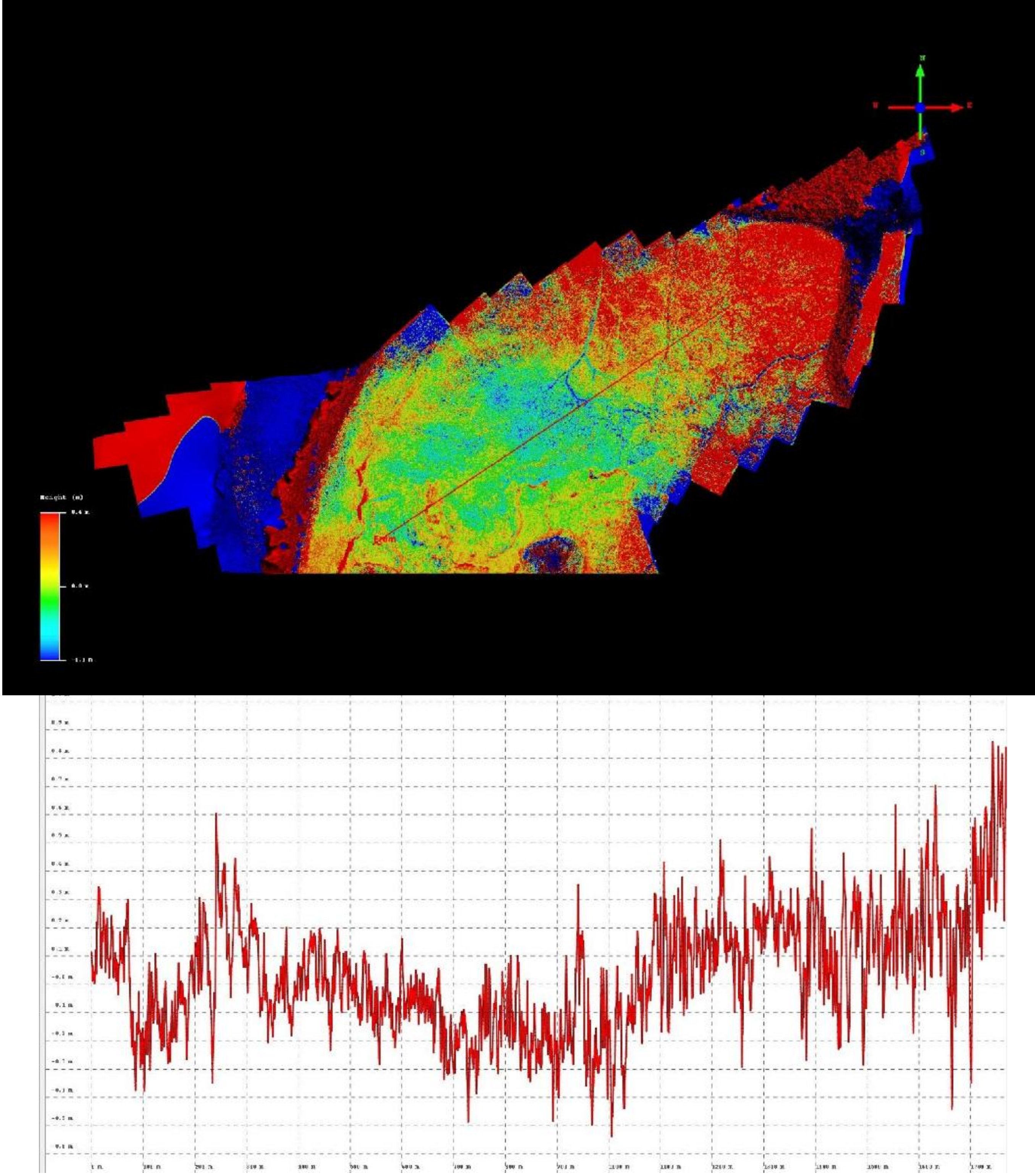
East Nelson Block



Overview of DEM and orthomosaic

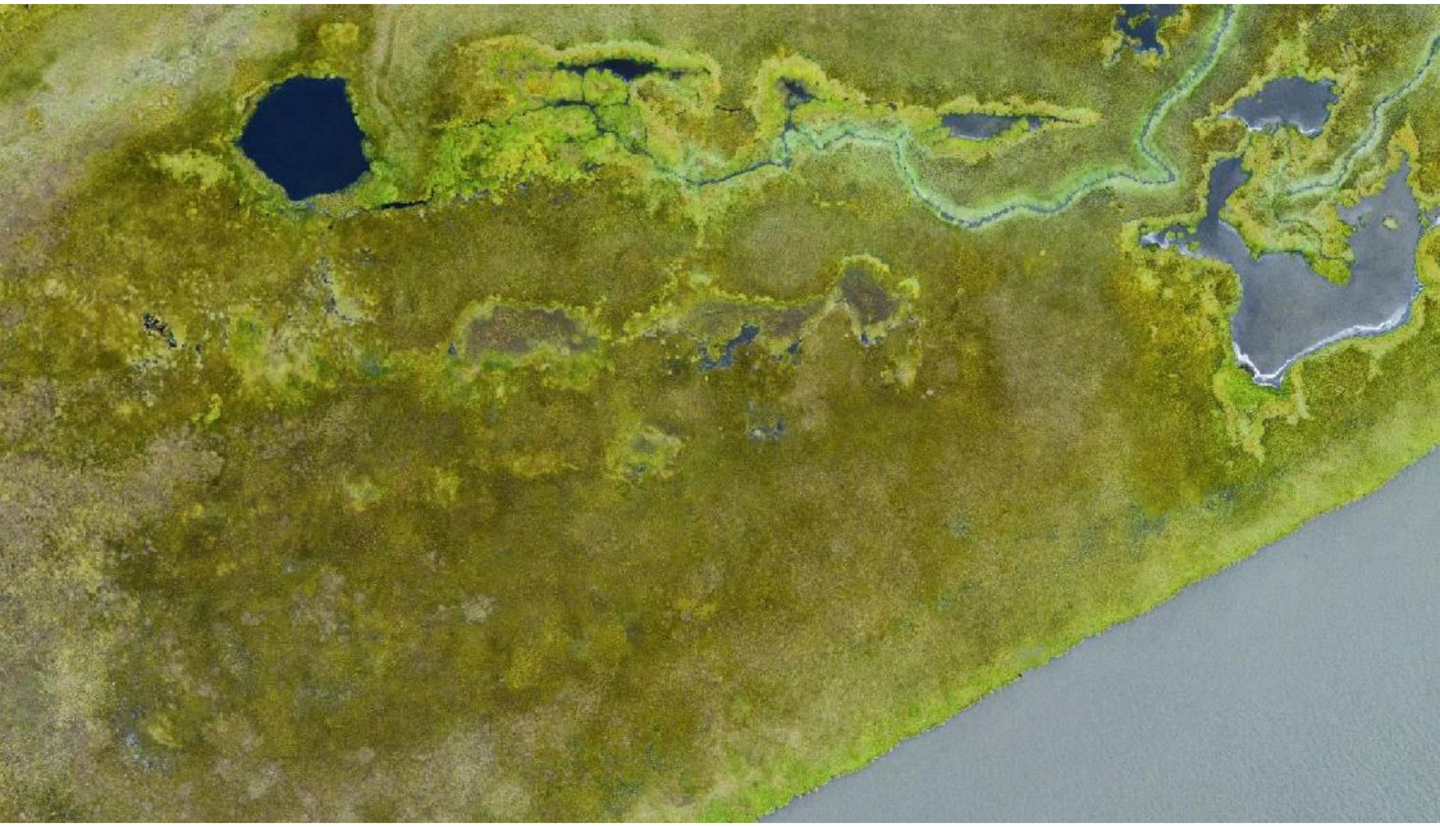


GCPs

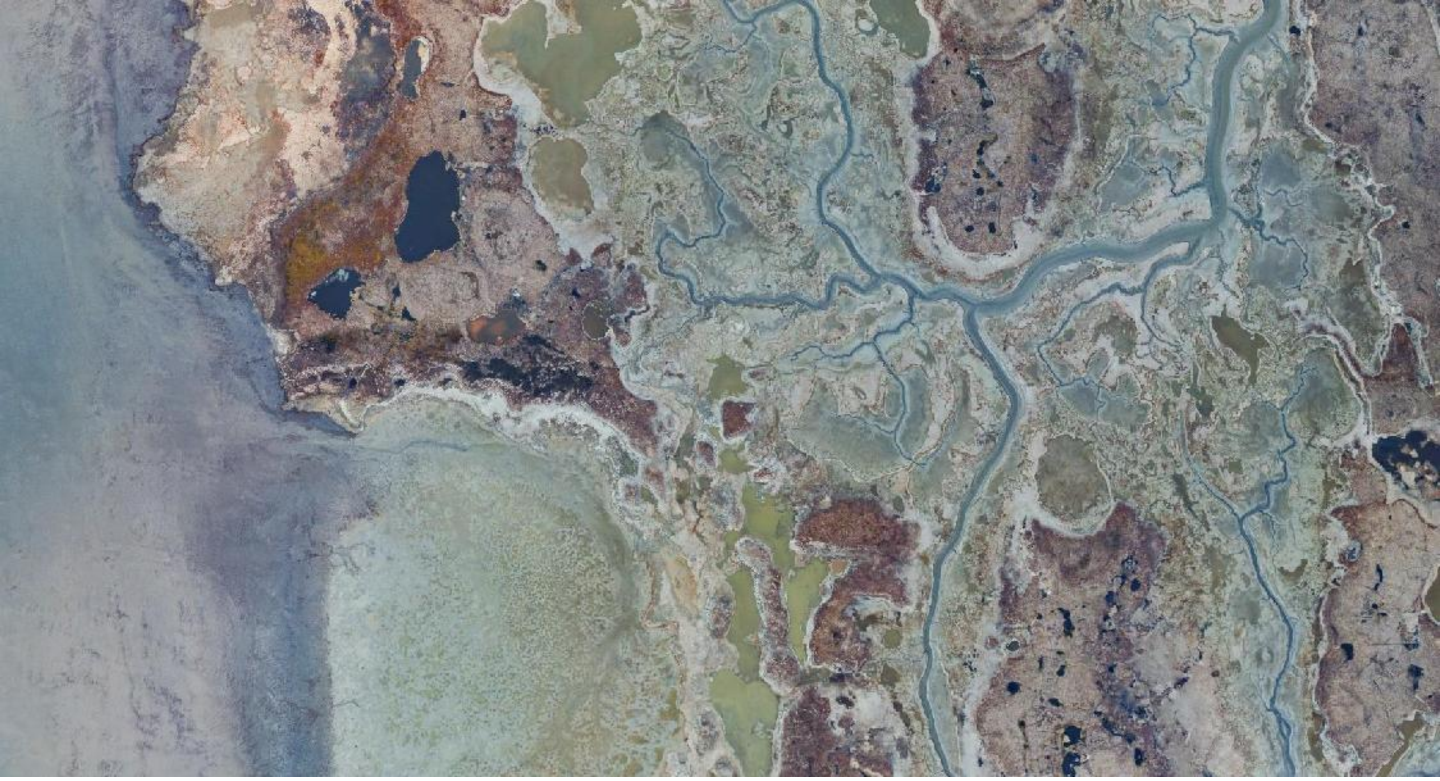


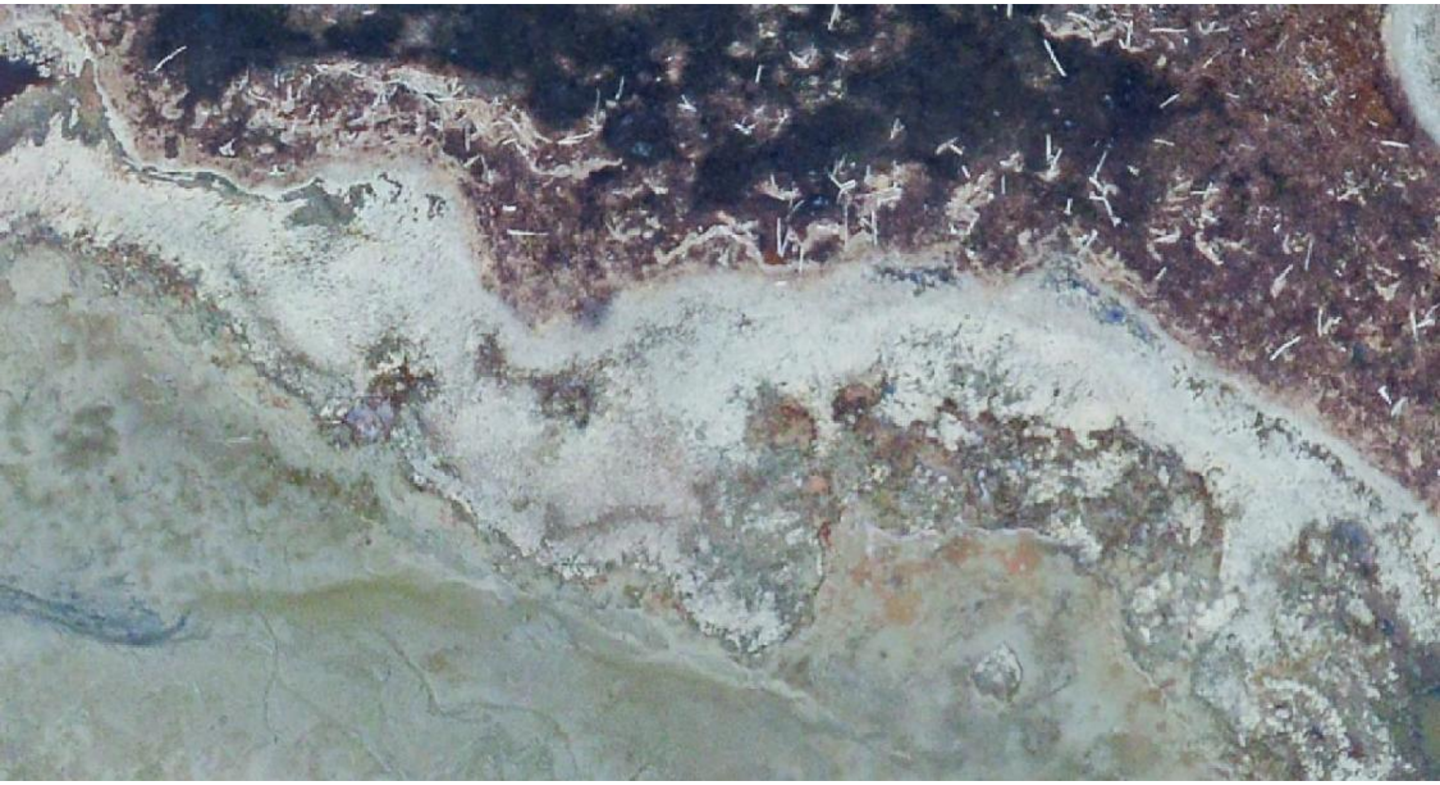
Comparison with Toksook block. Random noise is about +/- 10 cm, with spatially correlated noise at about 25 cm.

Comparison of overlap with Bethel2Toxic block. Here are East Nelson orthomosaics. Flicker with the next figure to see Bethel2Toxic orthomosaics.

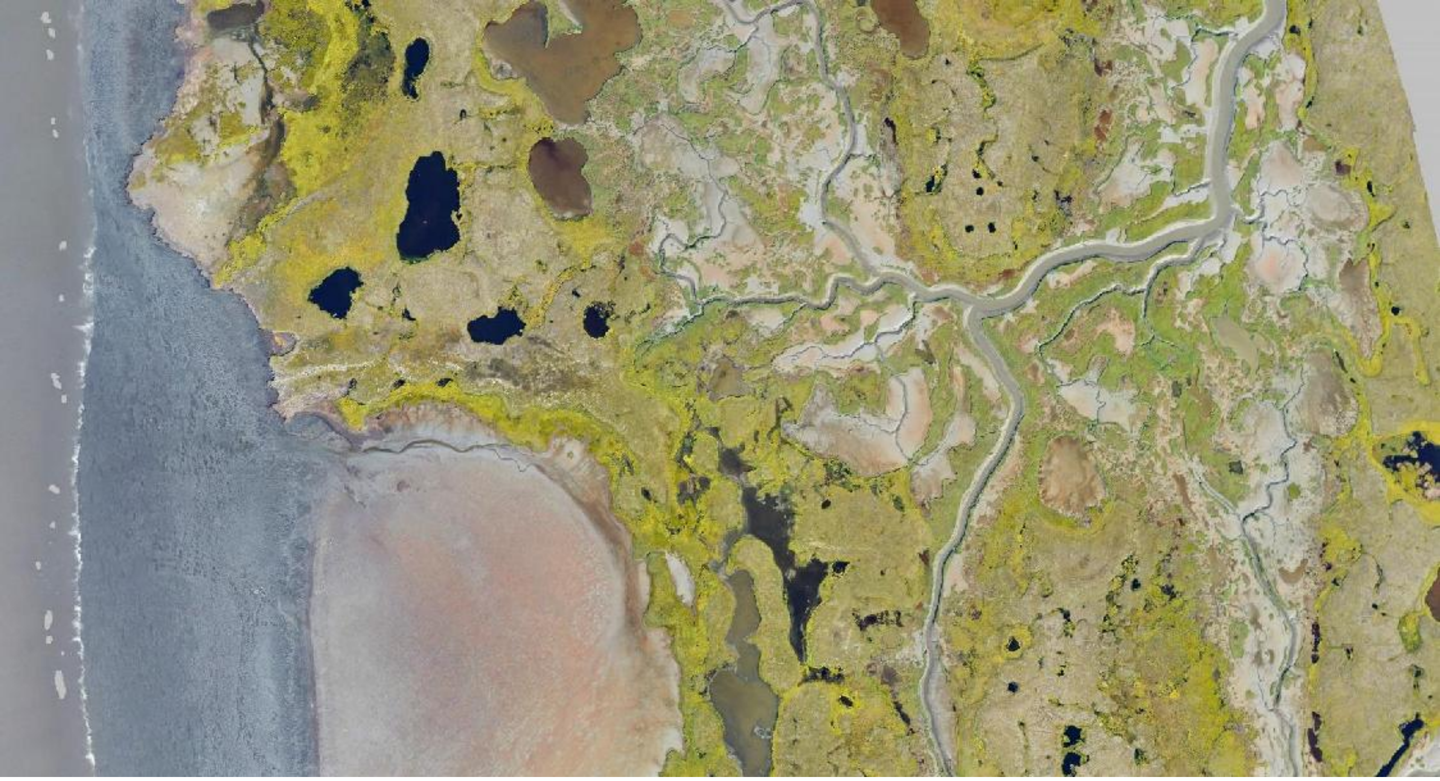


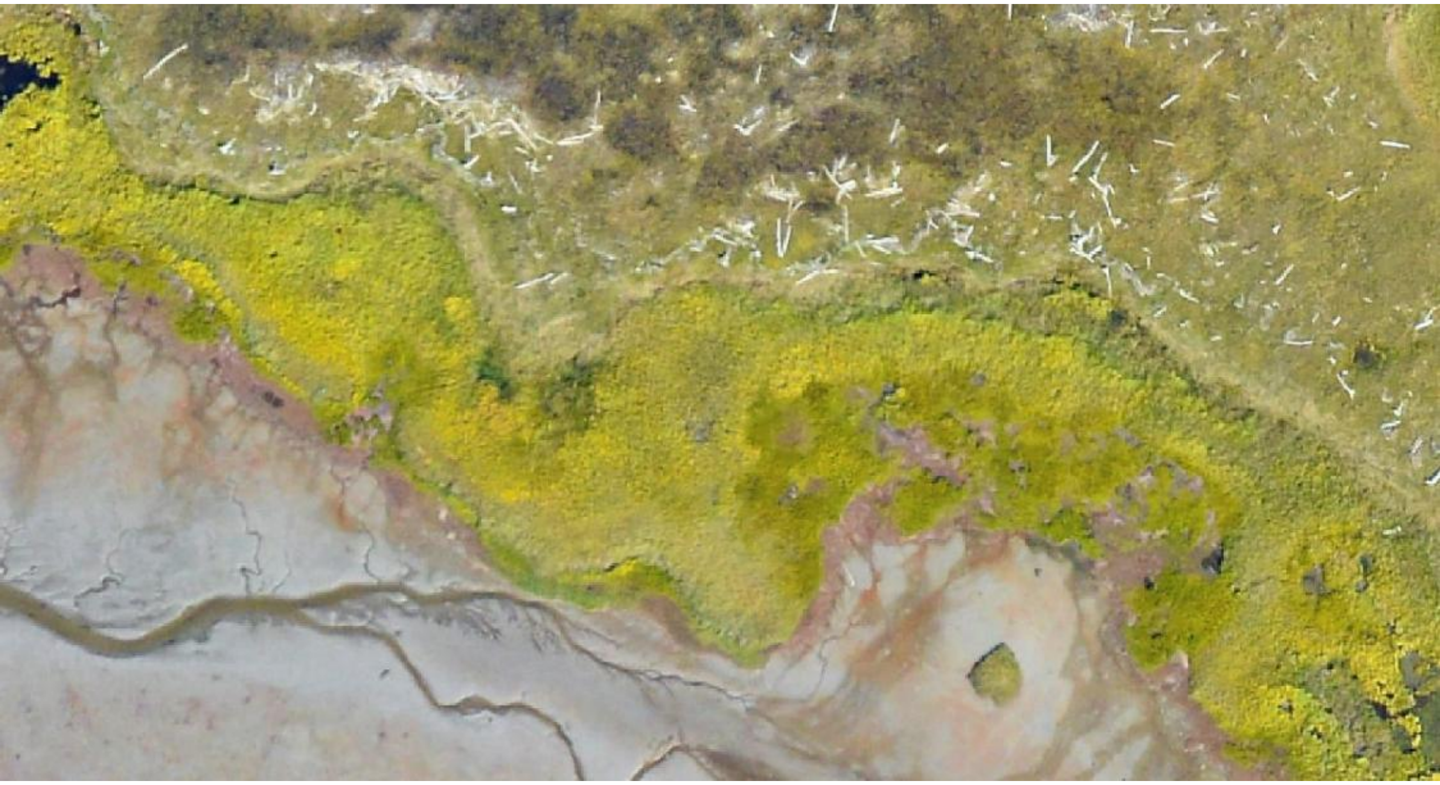
Comparison of overlap with Bethel2Toxic block. Here are Bethel2Toxic orthomosaics. Flicker with the previous figure to see East Nelson orthomosaics. Spatial offsets are on the 1-2 pixel level. More interestingly, note the seasonal changes between August 2015 and May 2016. The scientific possibilities of repeat mapping with fodar are essentially unlimited.





Comparison of overlap with Toksook block. Here are East Nelson orthomosaics. Flicker with the next figure to see Toksook orthomosaics.

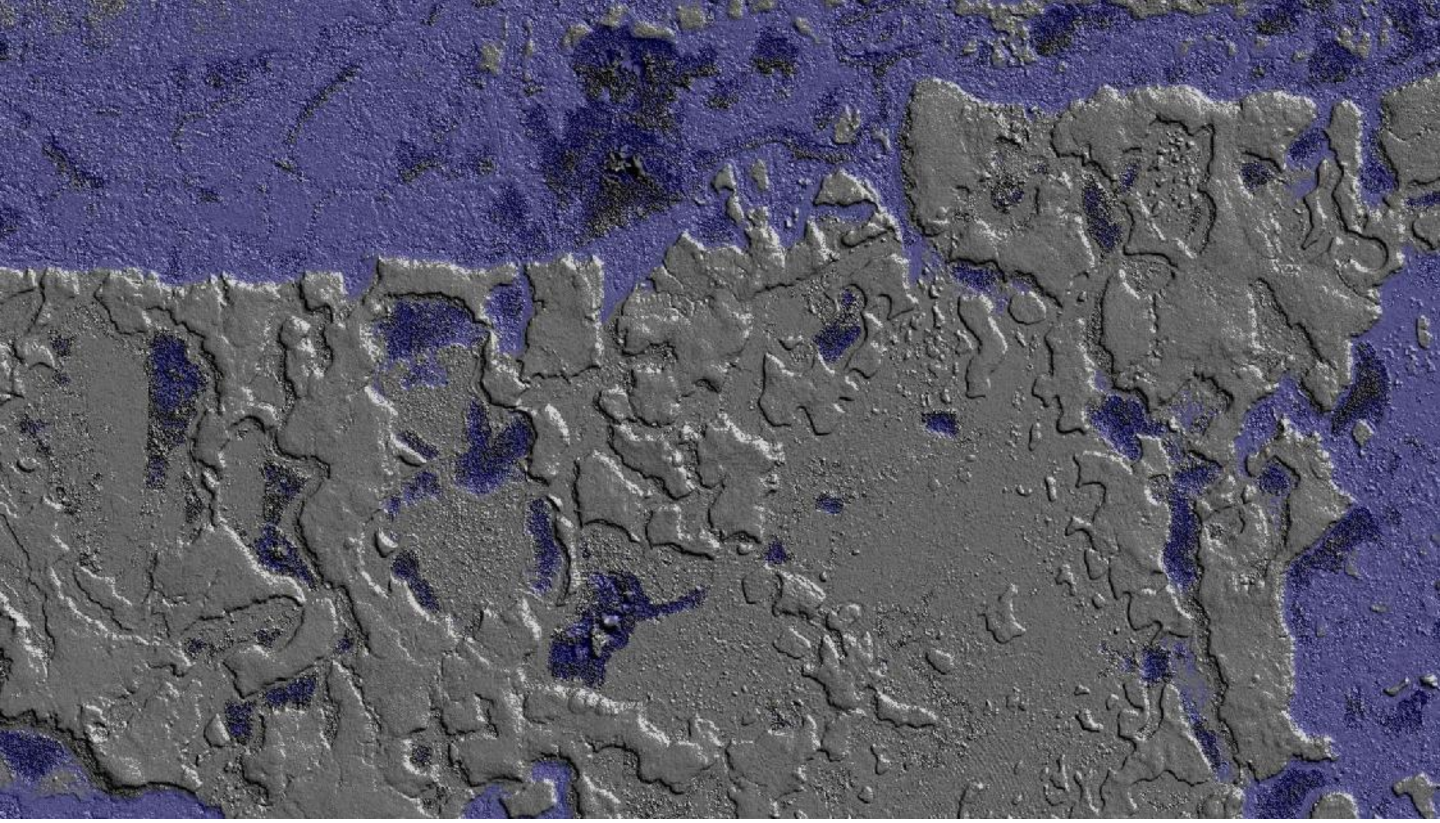


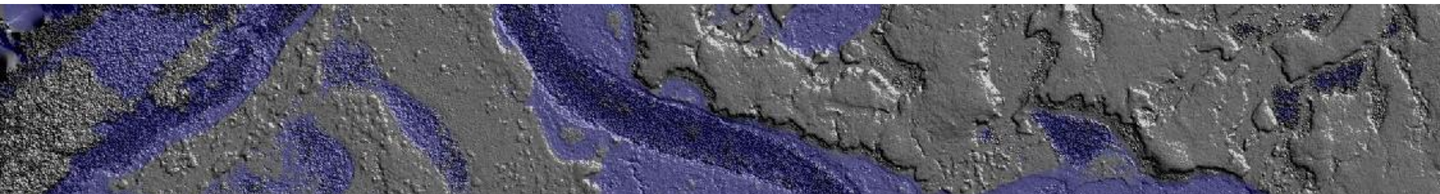


Comparison of overlap with Toksook block. Here are Toksook orthomosaics. Flicker with the previous figure to see East Nelson orthomosaics. Spatial offsets are on the 1-2 pixel level. More interestingly, note the seasonal changes between August 2015 and May 2016. If you look close, you can see that some of the driftwood has moved.

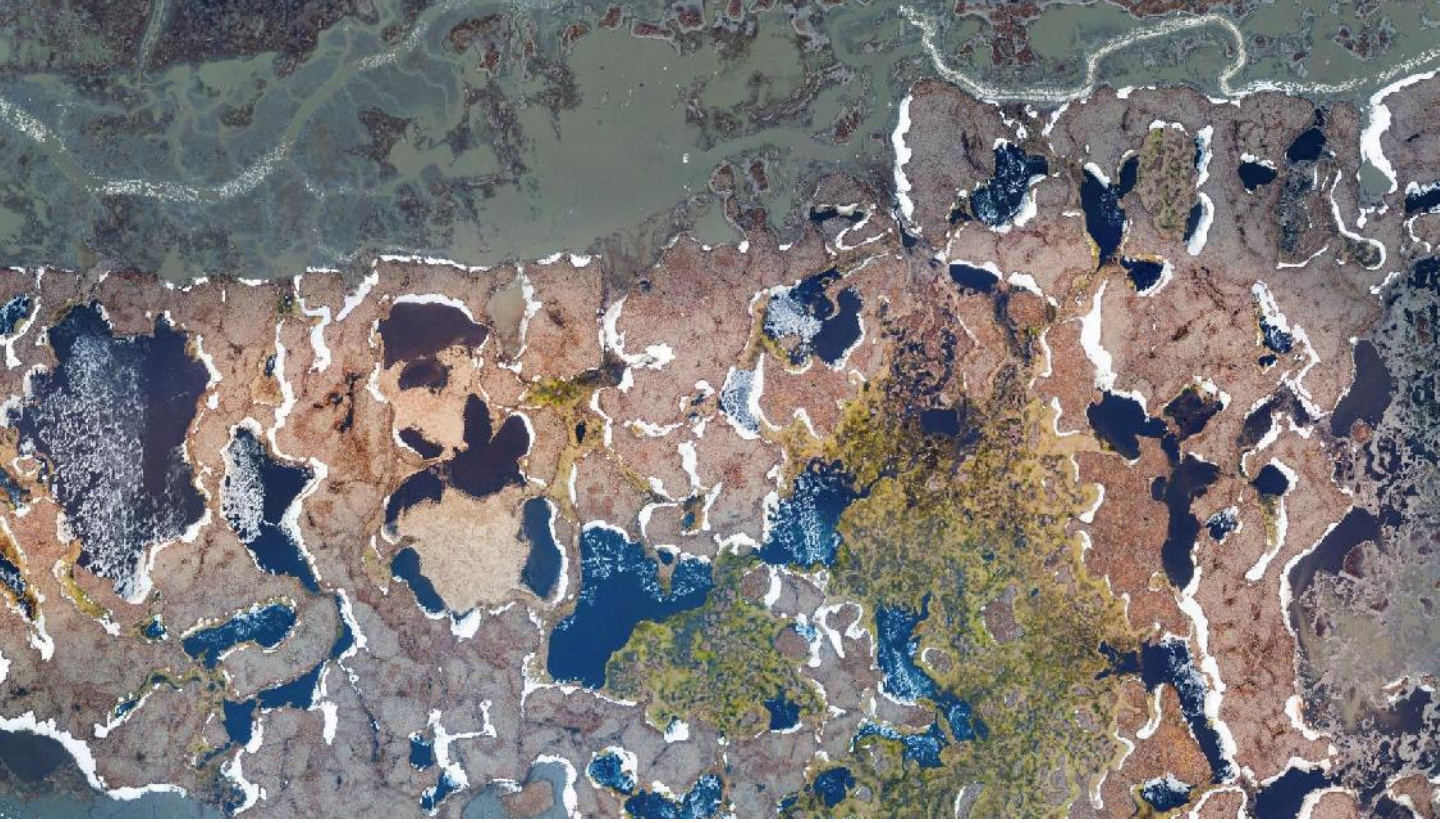
Comparison of overlap with Hazen Bay block. Here are East Nelson orthomosaics. Flicker with the next figure to see Hazen Bay orthomosaics.

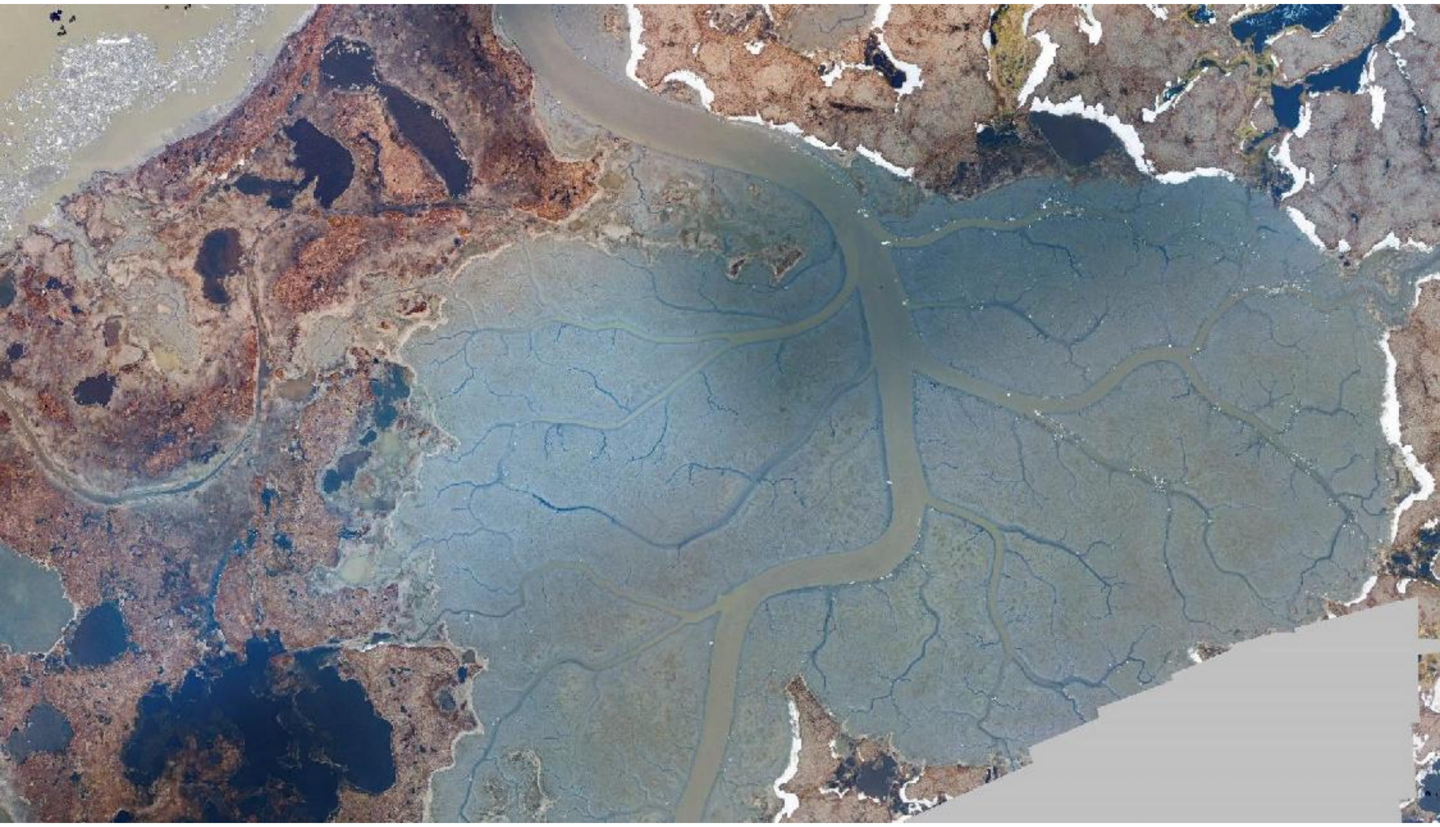
Comparison of overlap with Hazen Bay block. Here are Hazen Bay orthomosaics. Flicker with the previous figure to see East Nelson orthomosaics. Spatial offsets are on the 1-2 pixel level. The mosaics were made with imagery acquired on subsequent days.



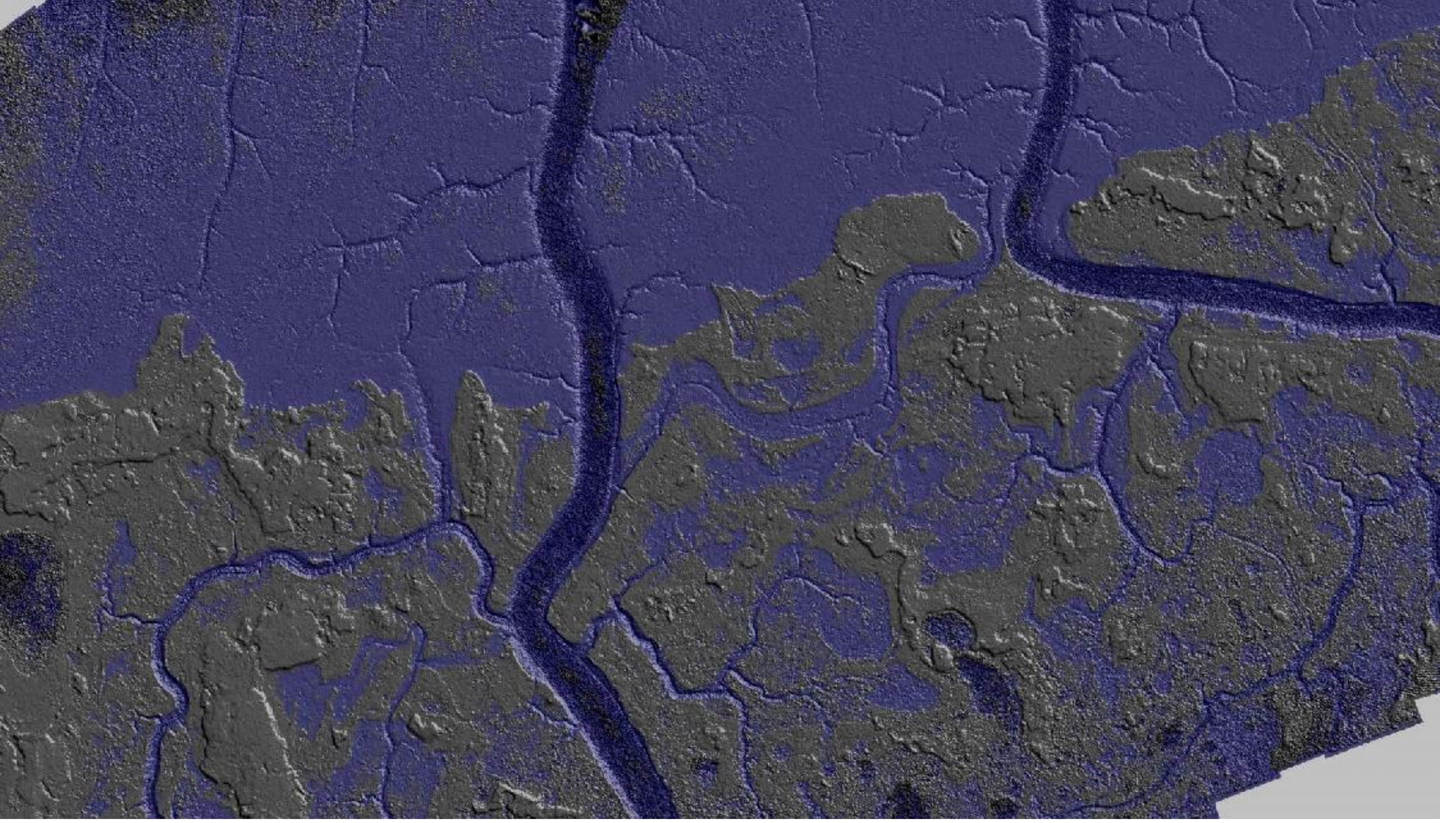


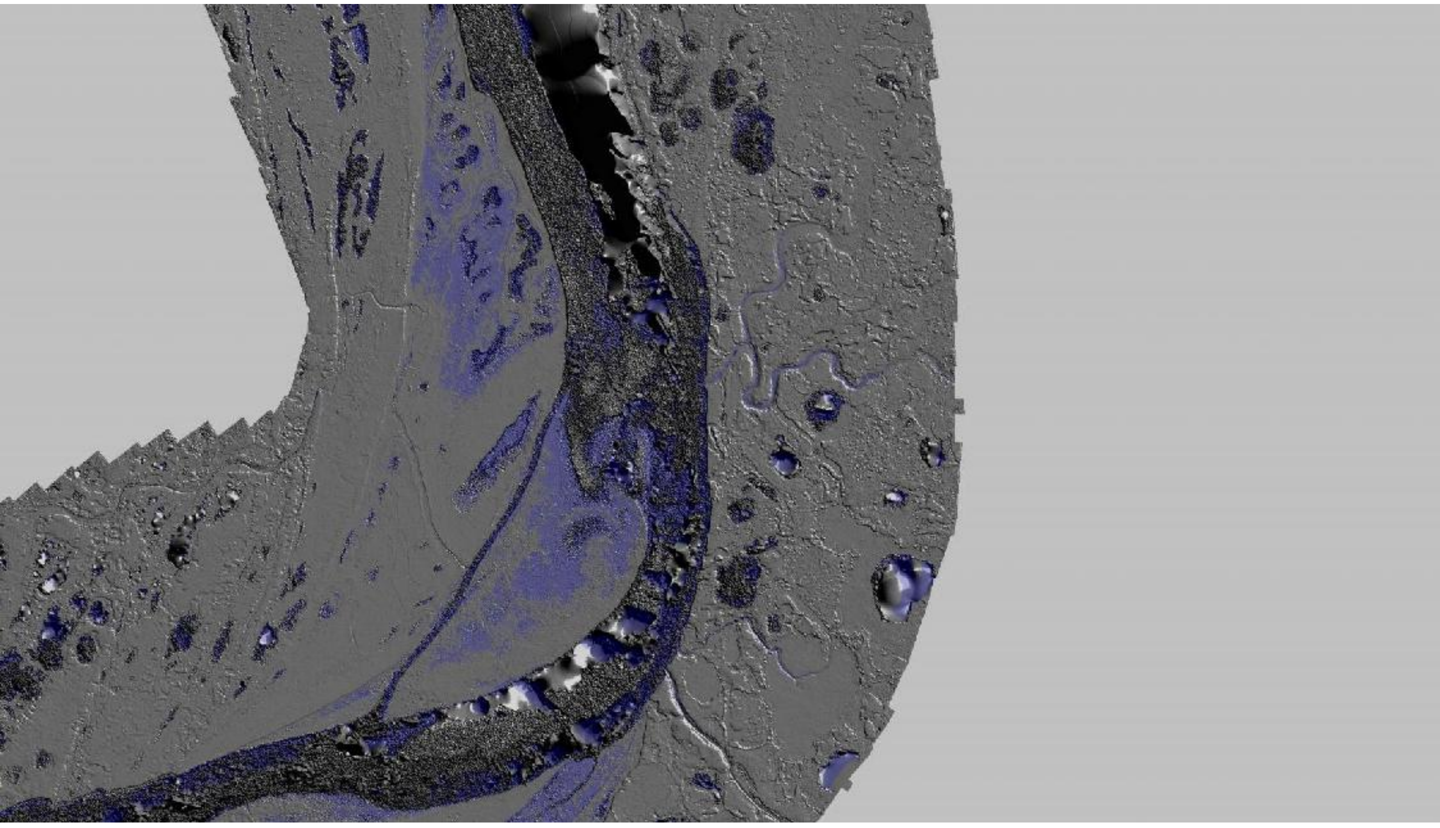
Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.



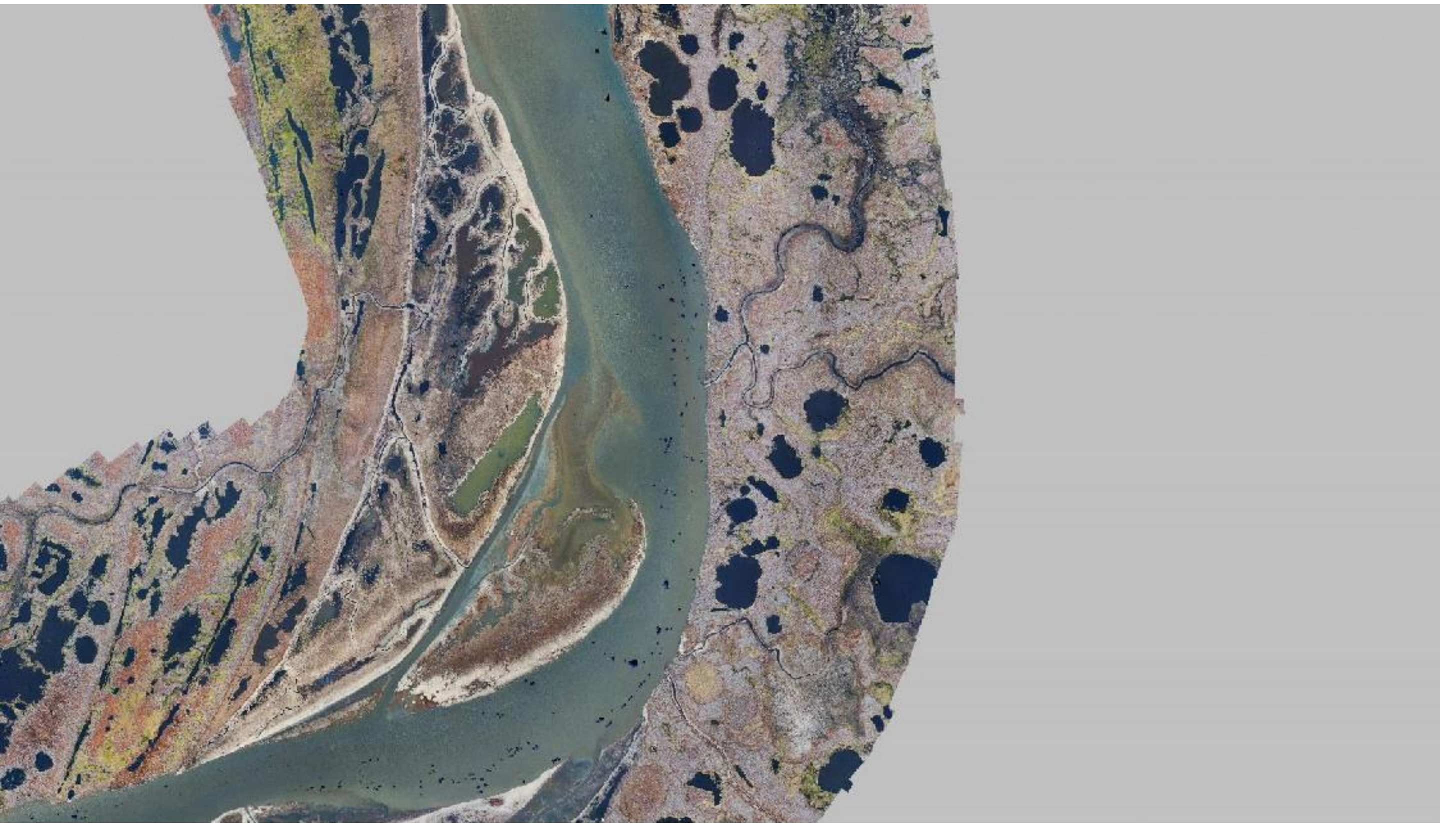


Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.



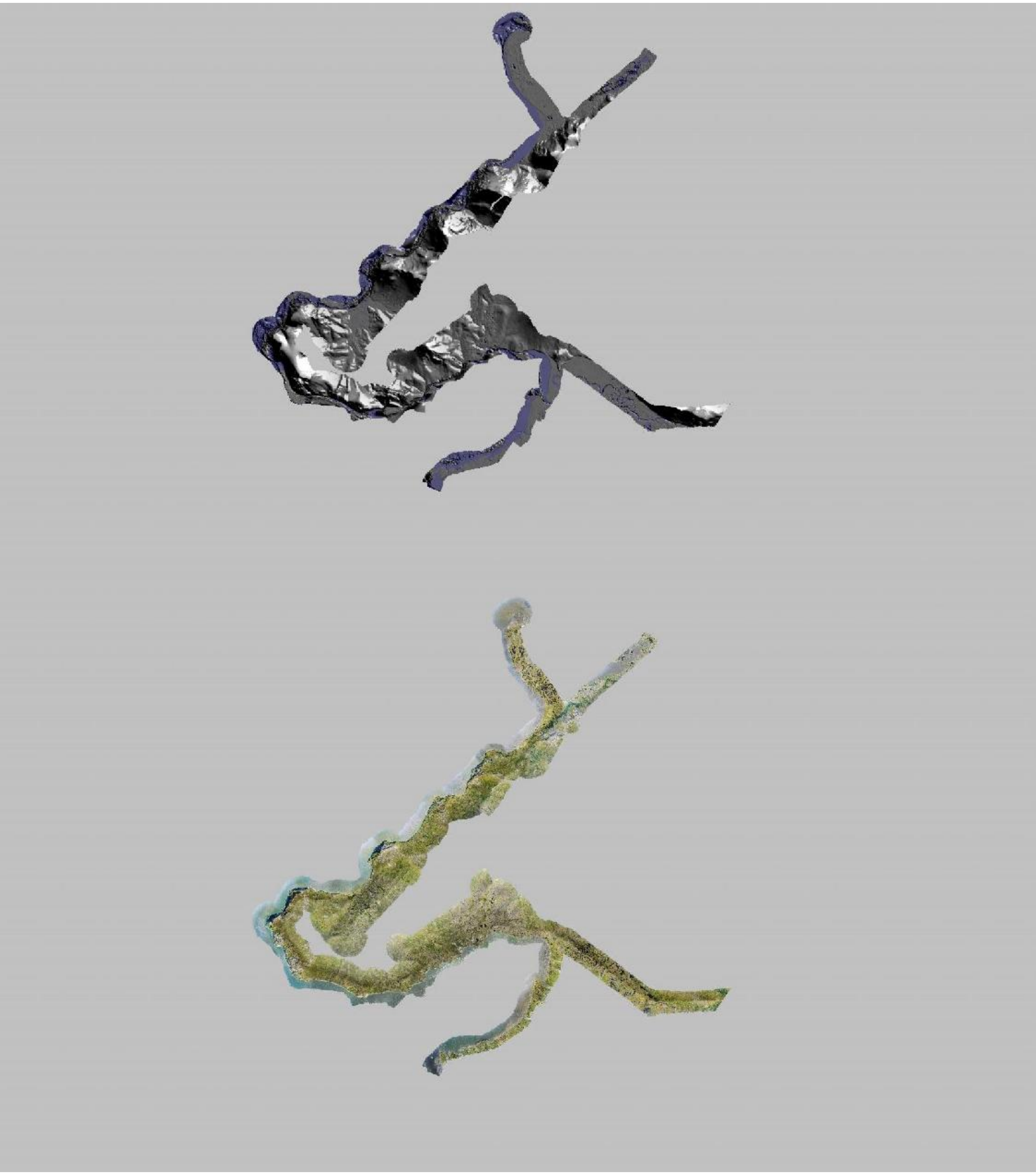


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

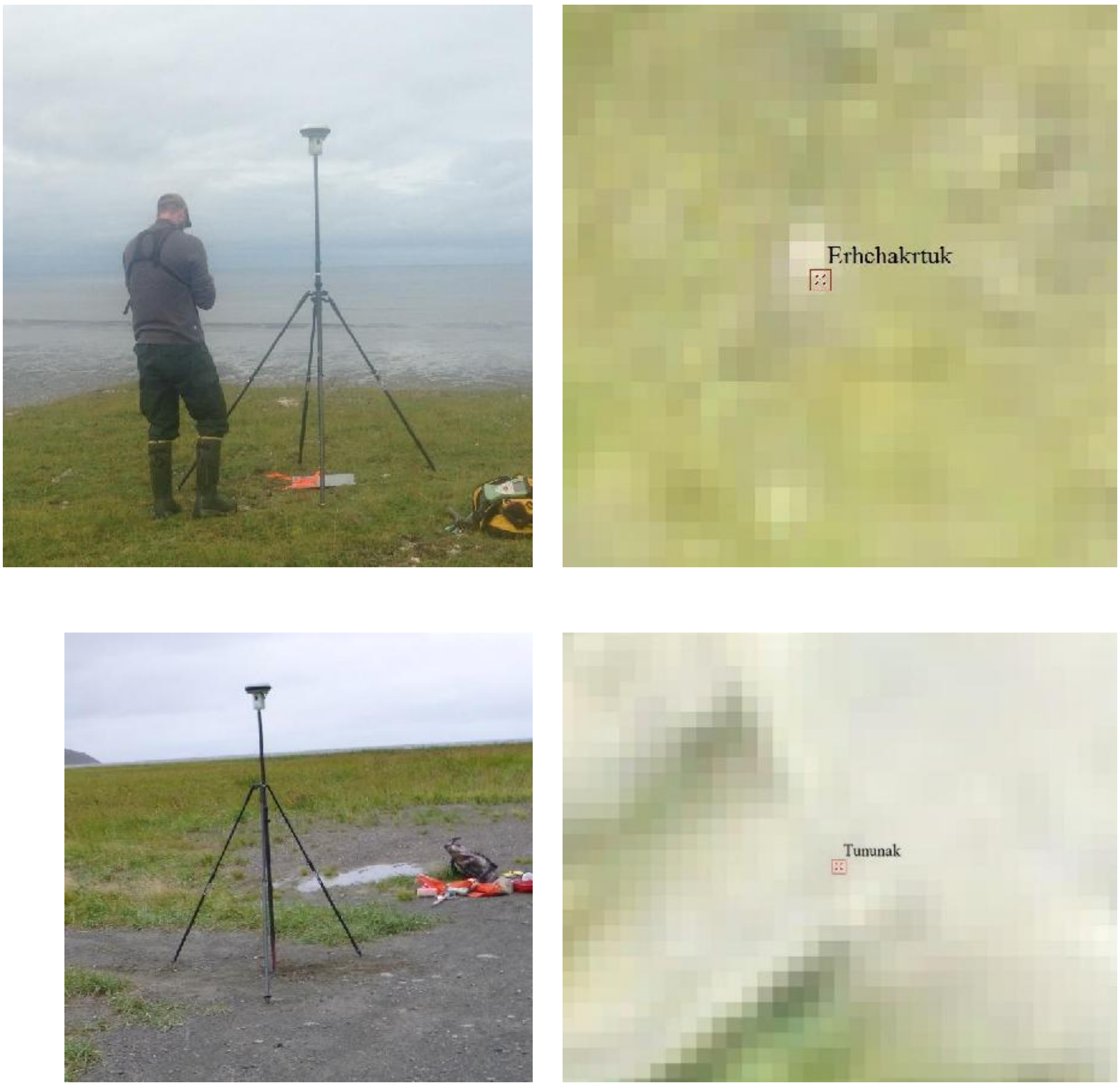


Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

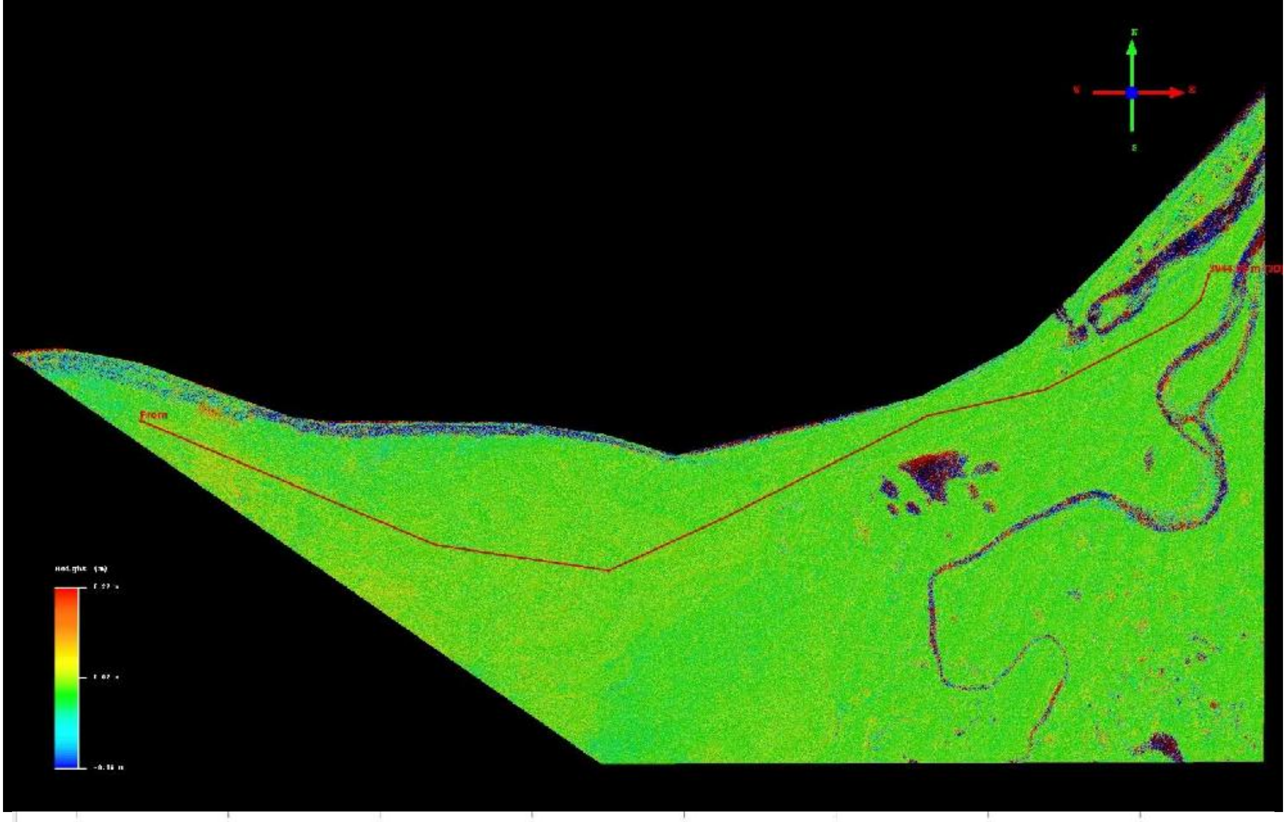
Toksook Block

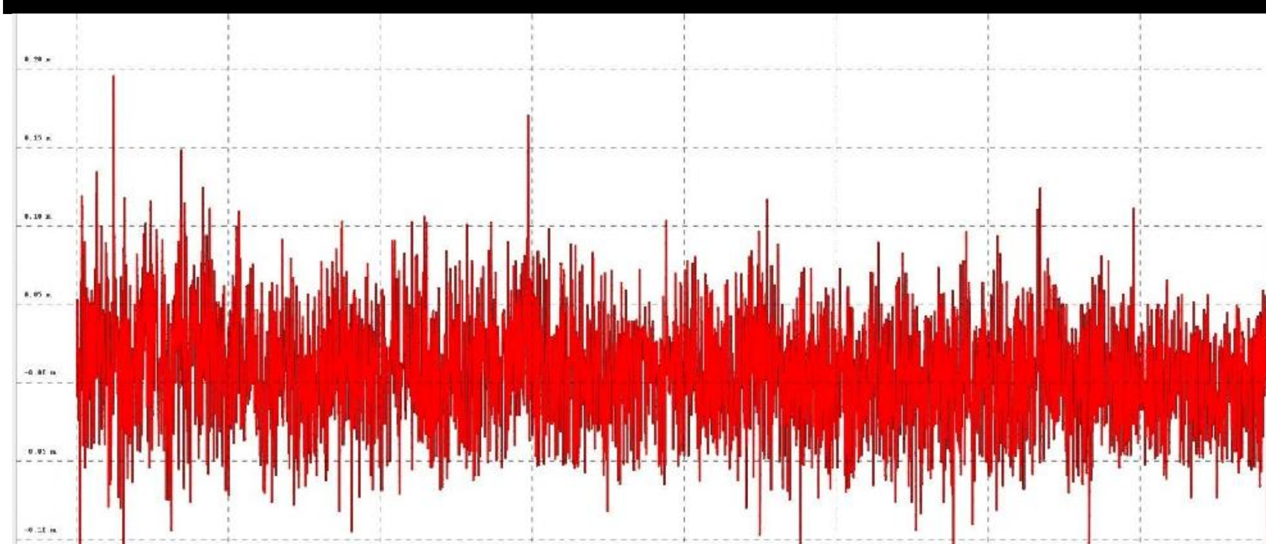


Overview of DEM and orthomosaic



GCPs

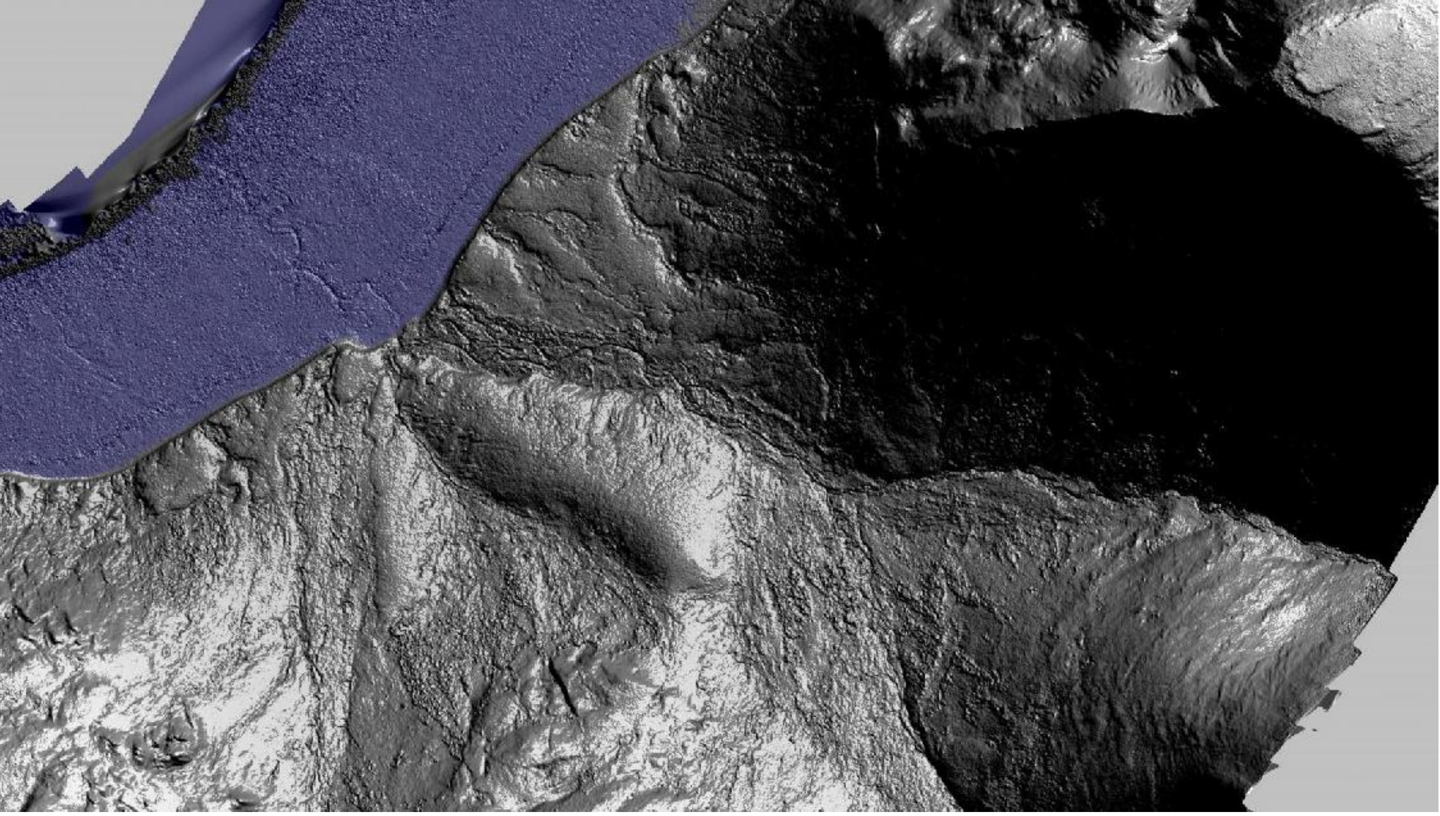


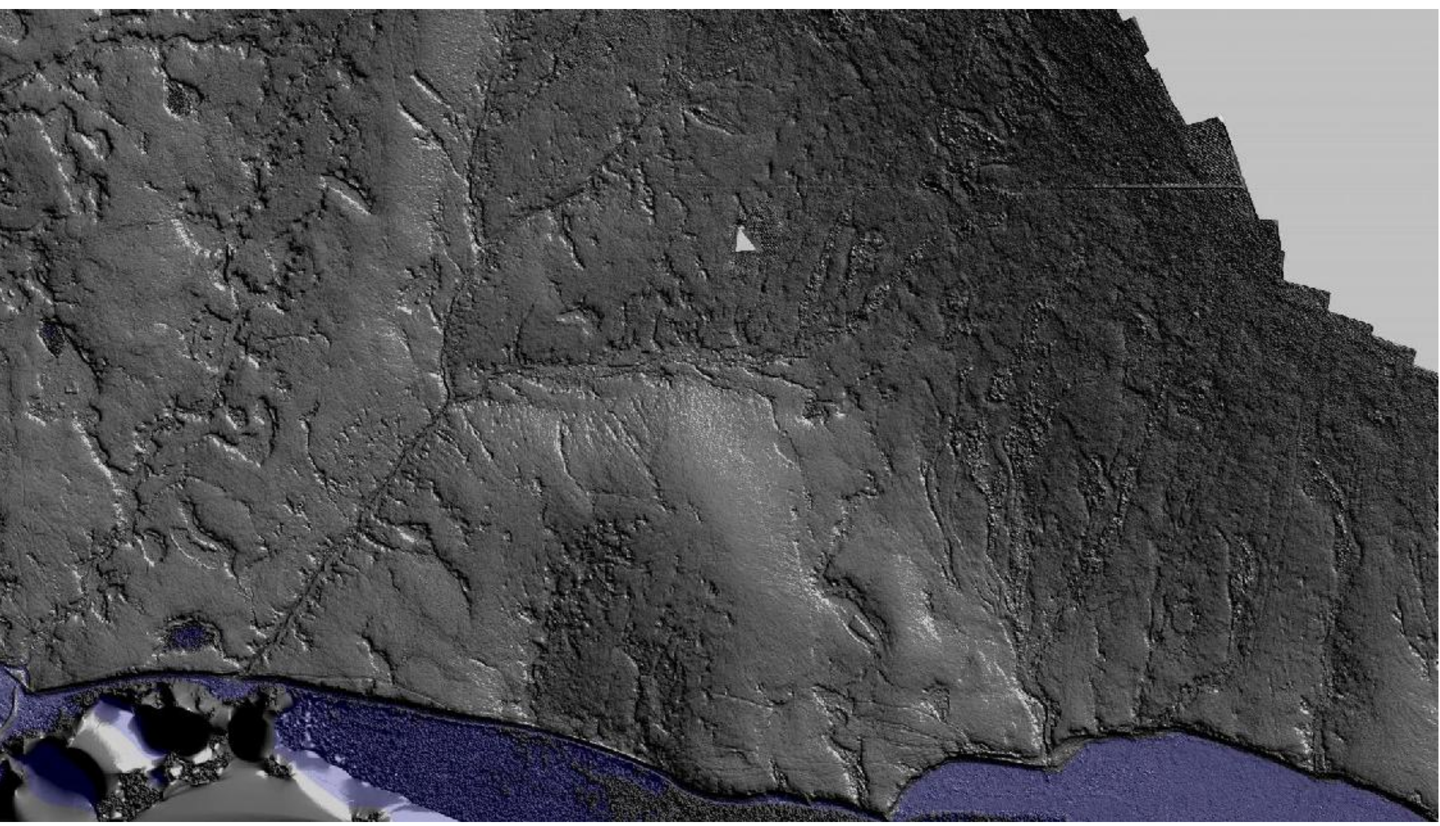


Comparison with Tunanuk village data. Random noise is roughly +/- 8 cm.

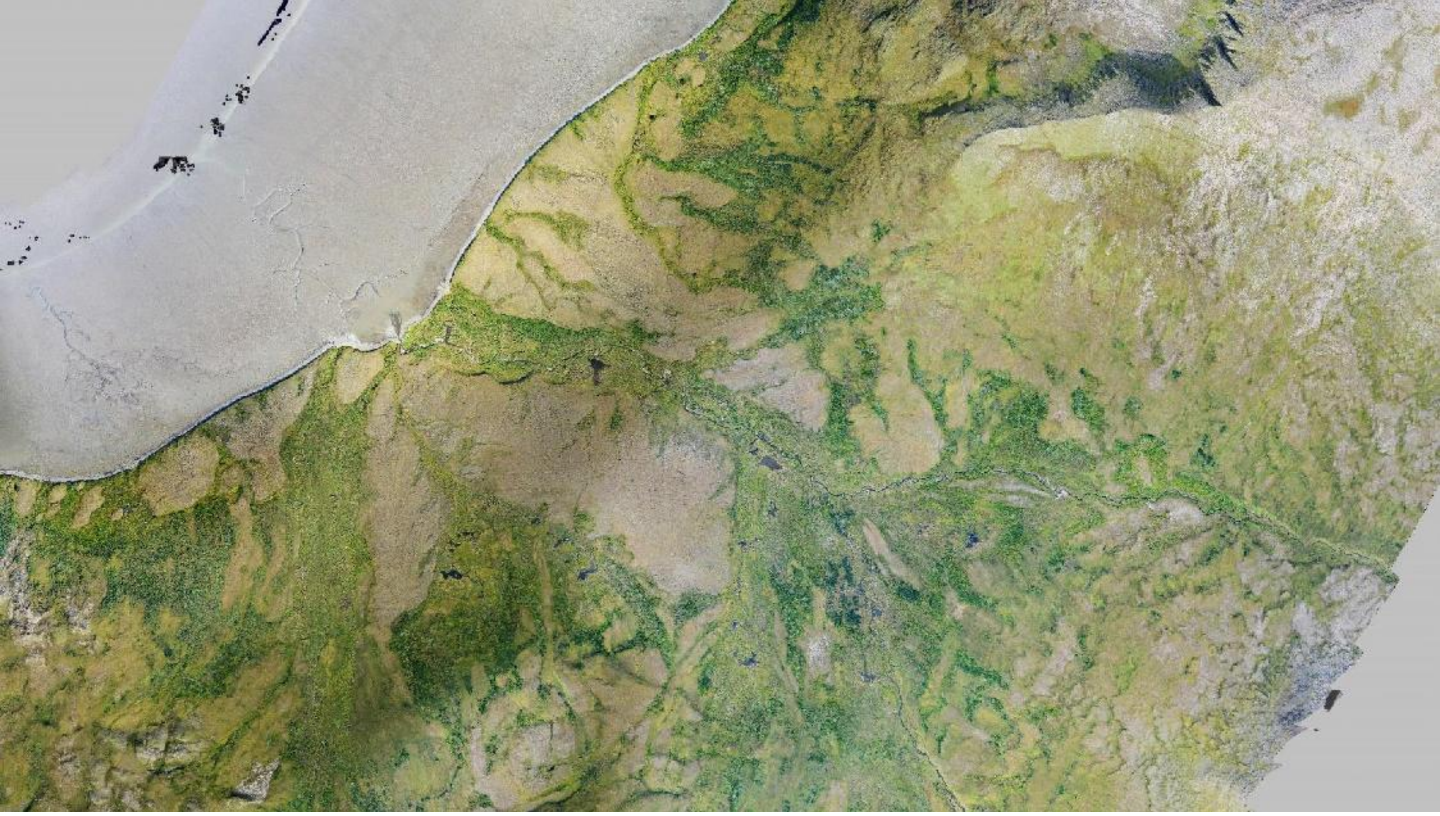
Assessment of horizontal misfit between coastal and village data at Toksook. This is the coastal data, flicker with the next figure to see village orthomosaic. The alignment is essentially perfect.

Assessment of horizontal misfit. This is the village data. The alignment is essentially perfect.

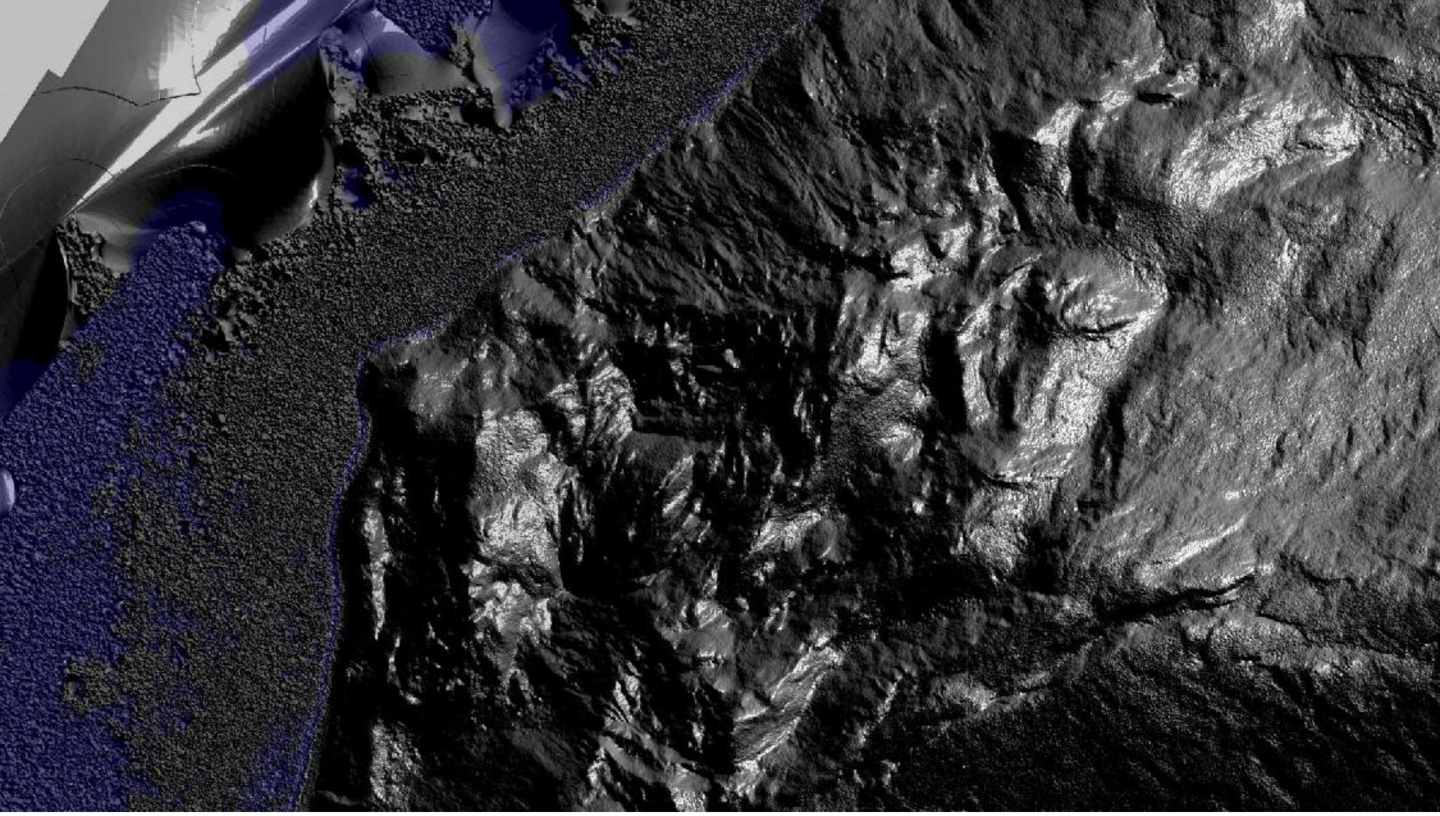


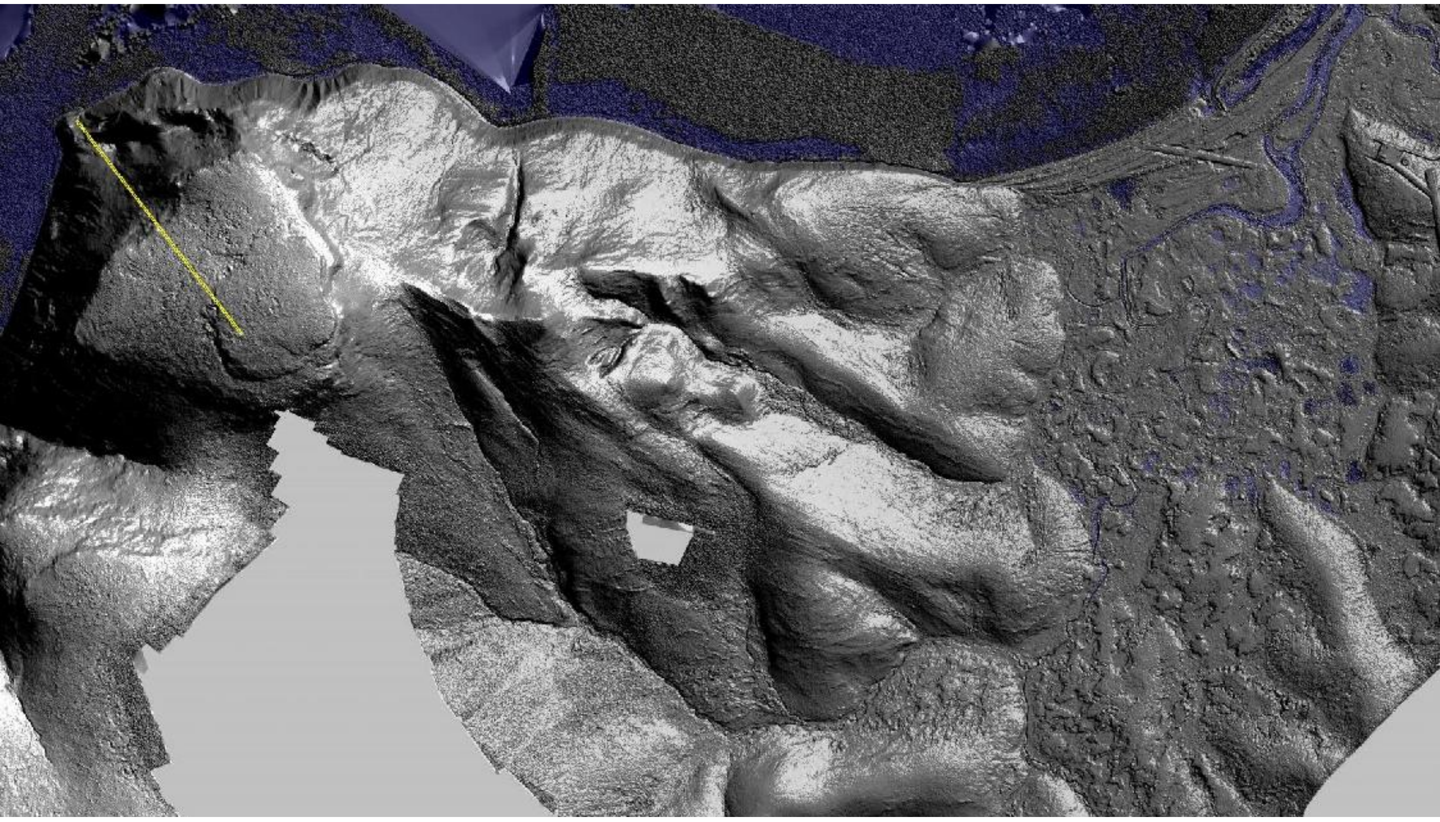


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

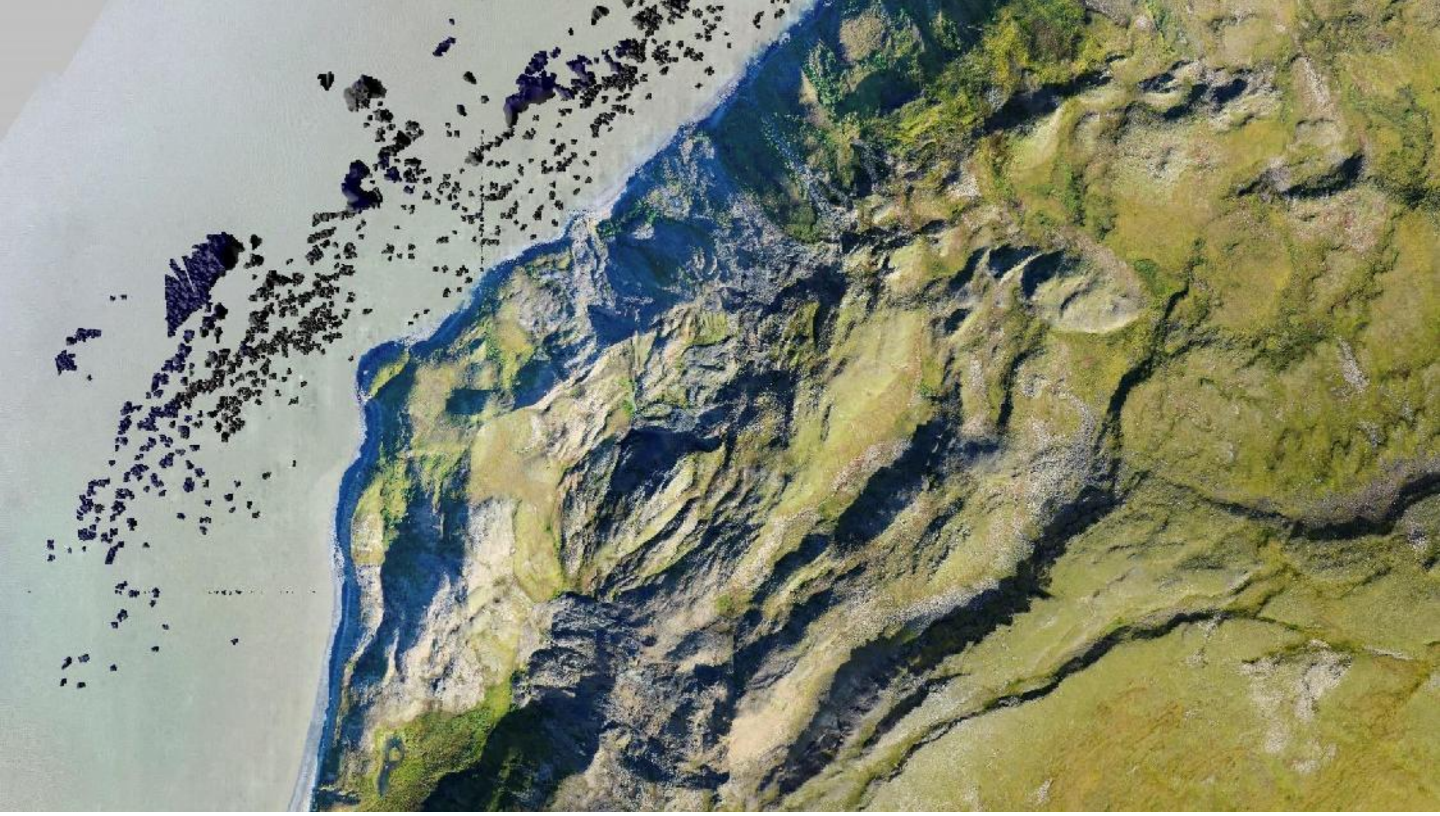


Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

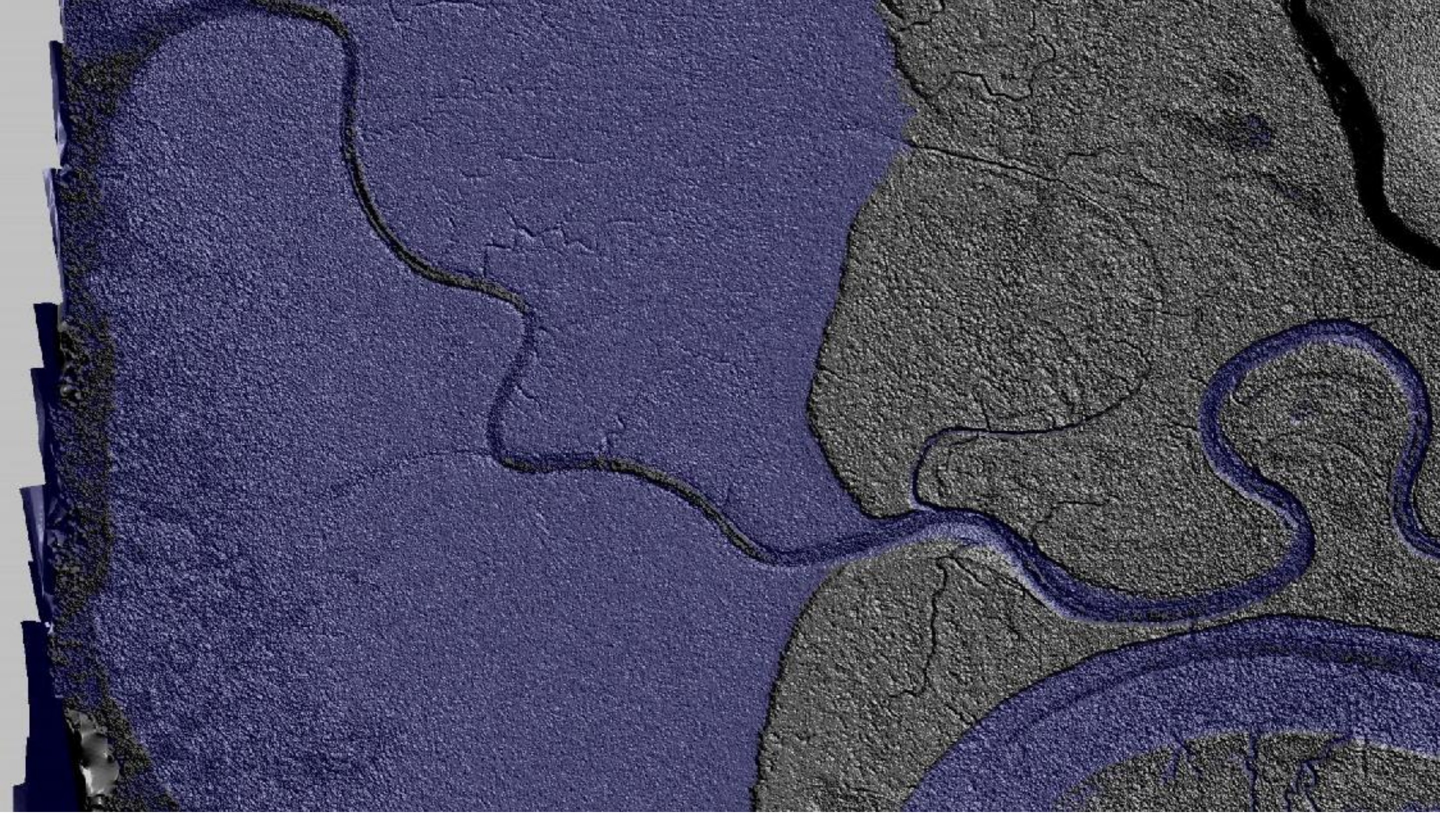




Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.



Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

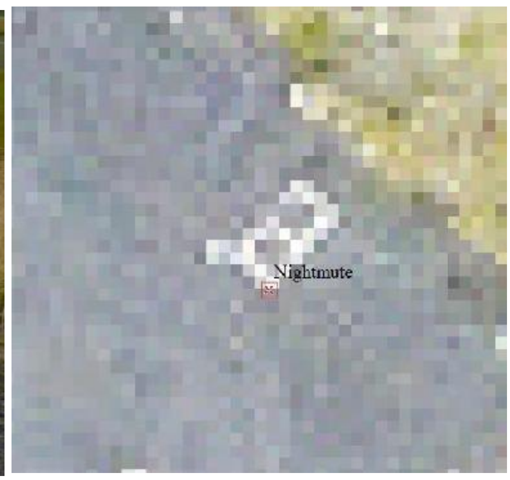


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

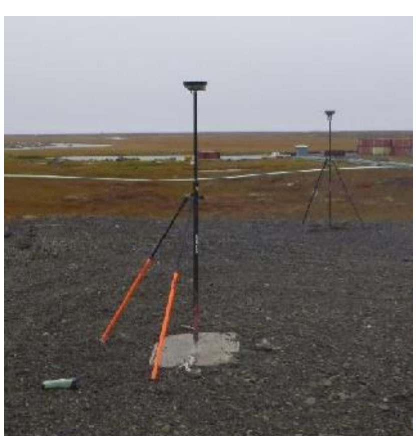
Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

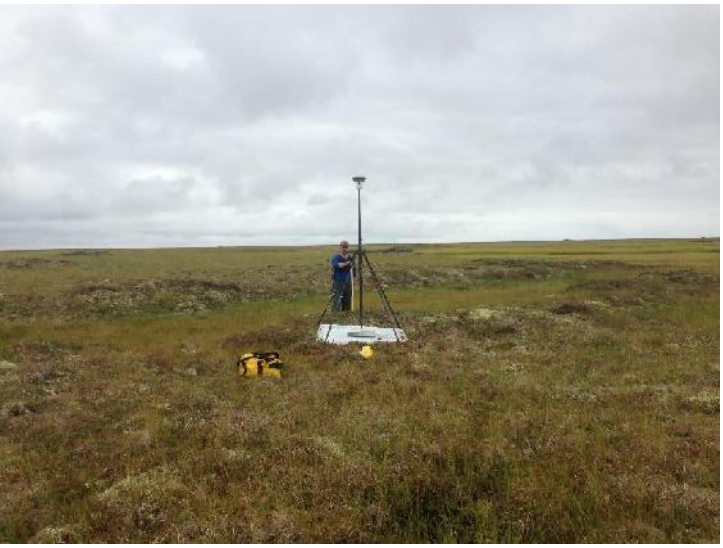
Bethel to Toksook Block

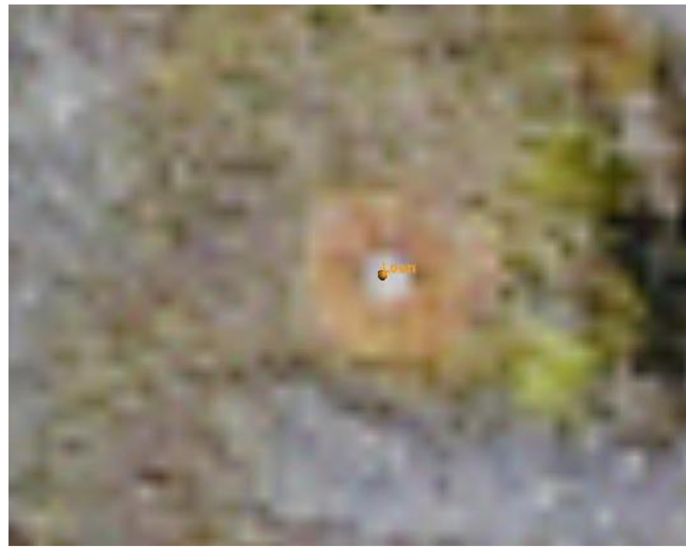
Overview of DEM and orthomosaic



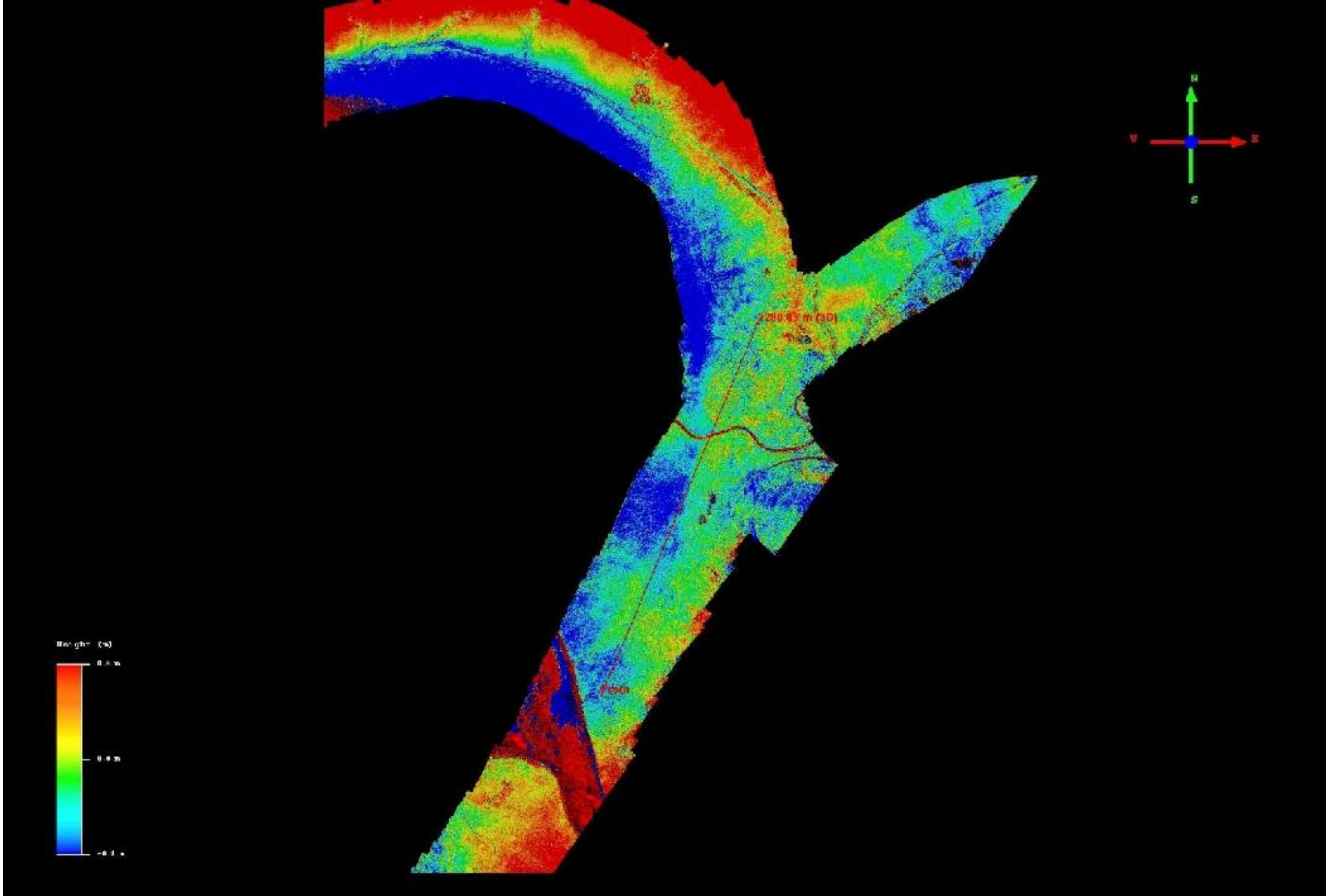
GCPs

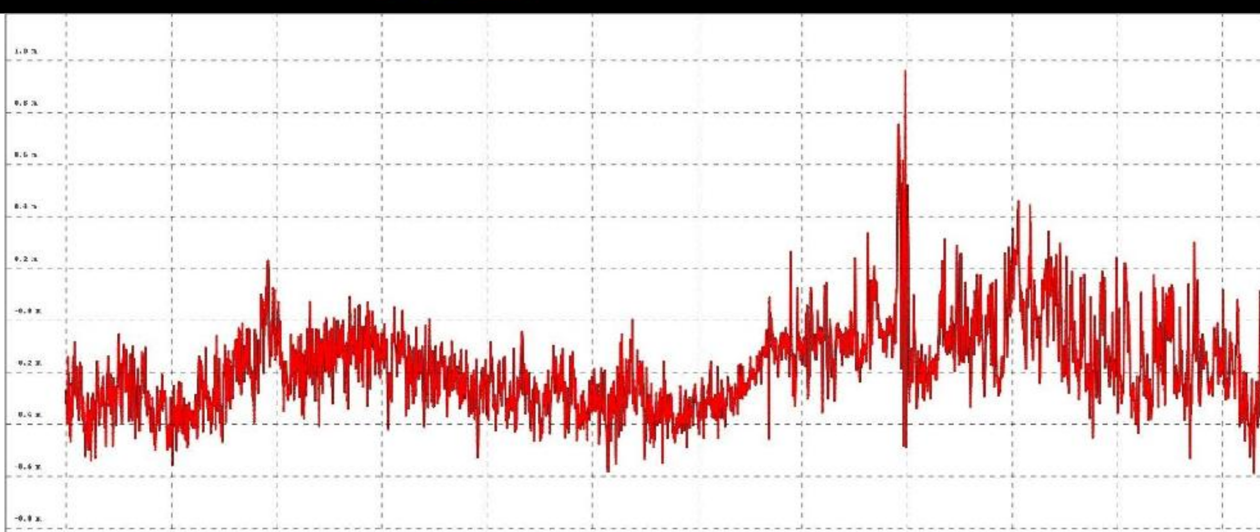




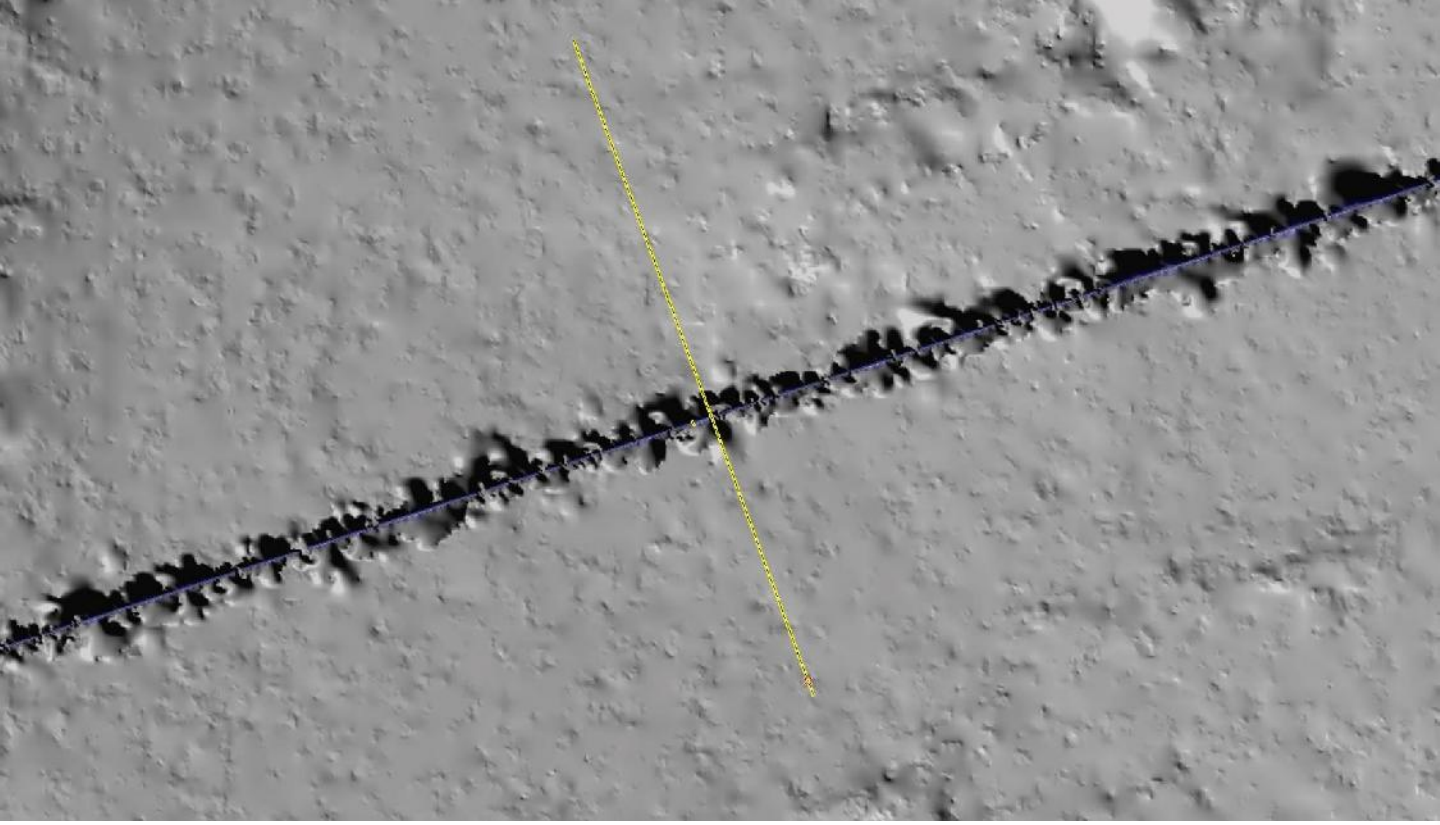


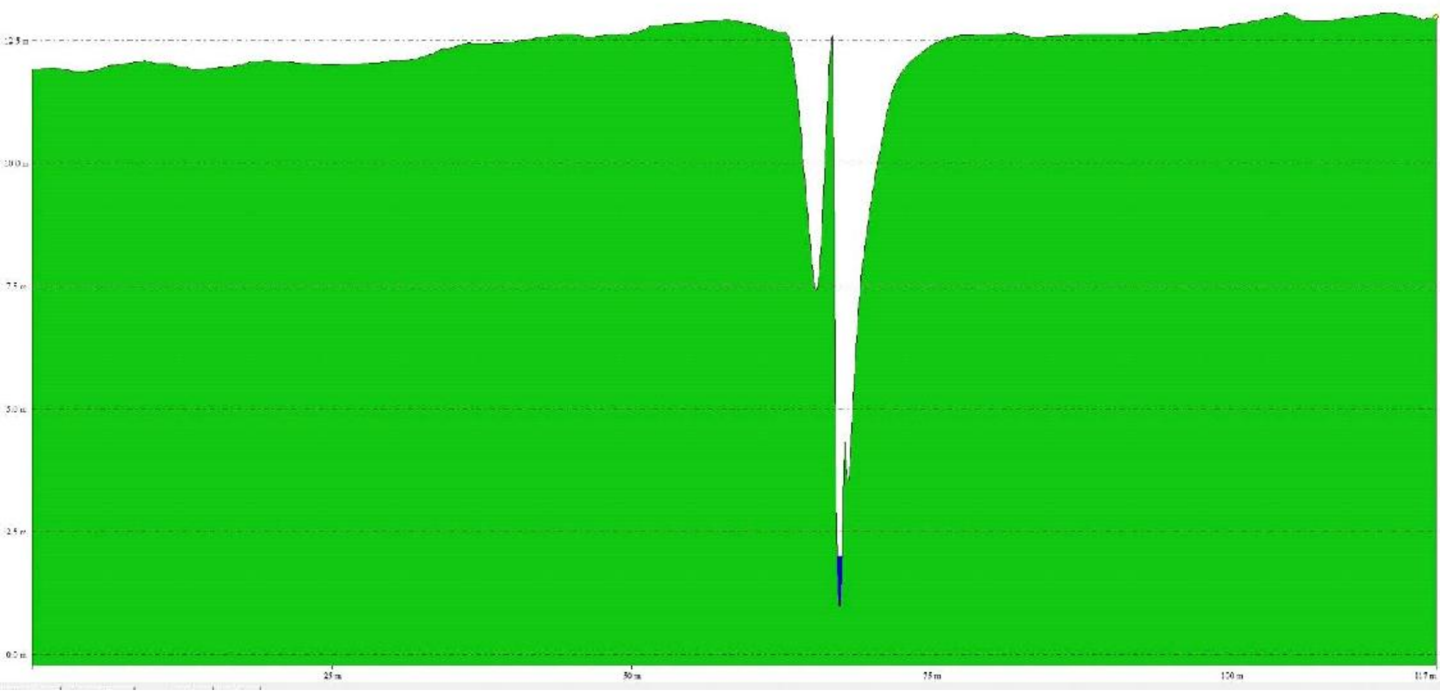
GCPs



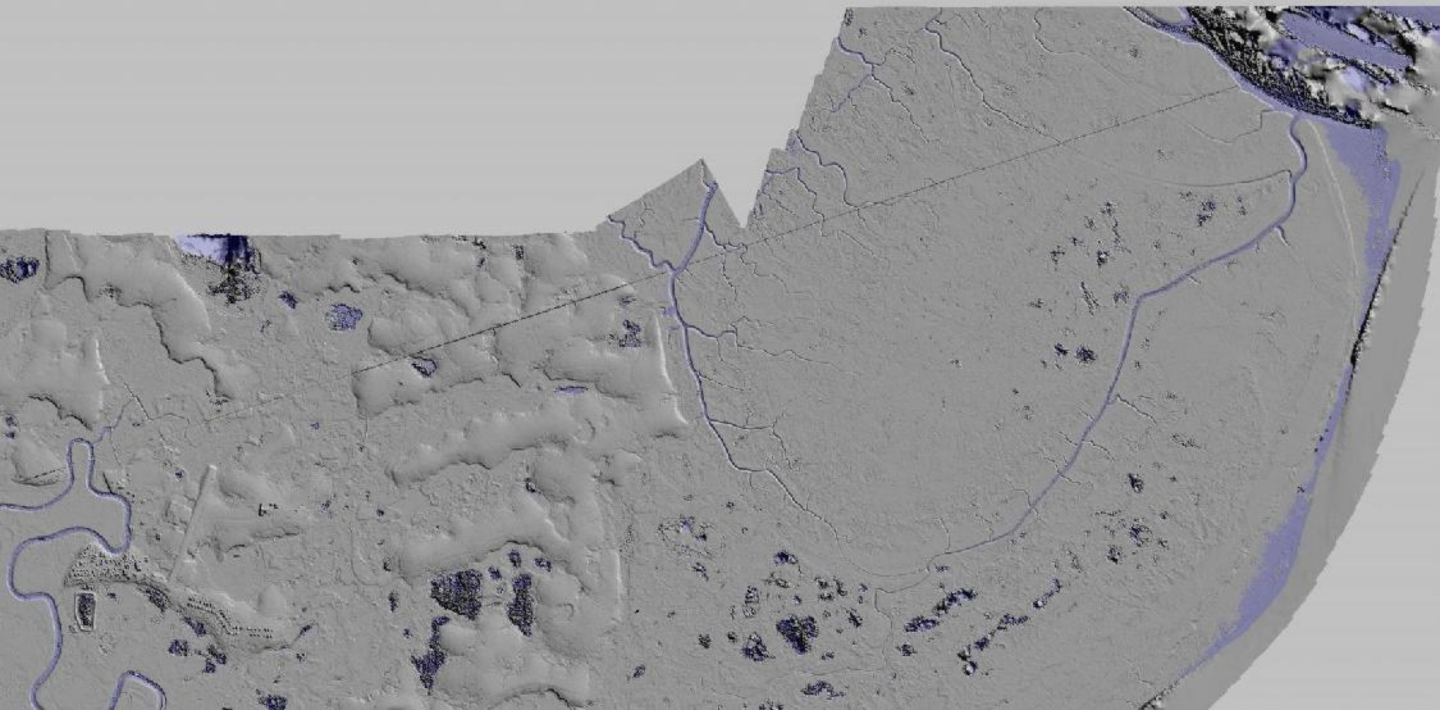


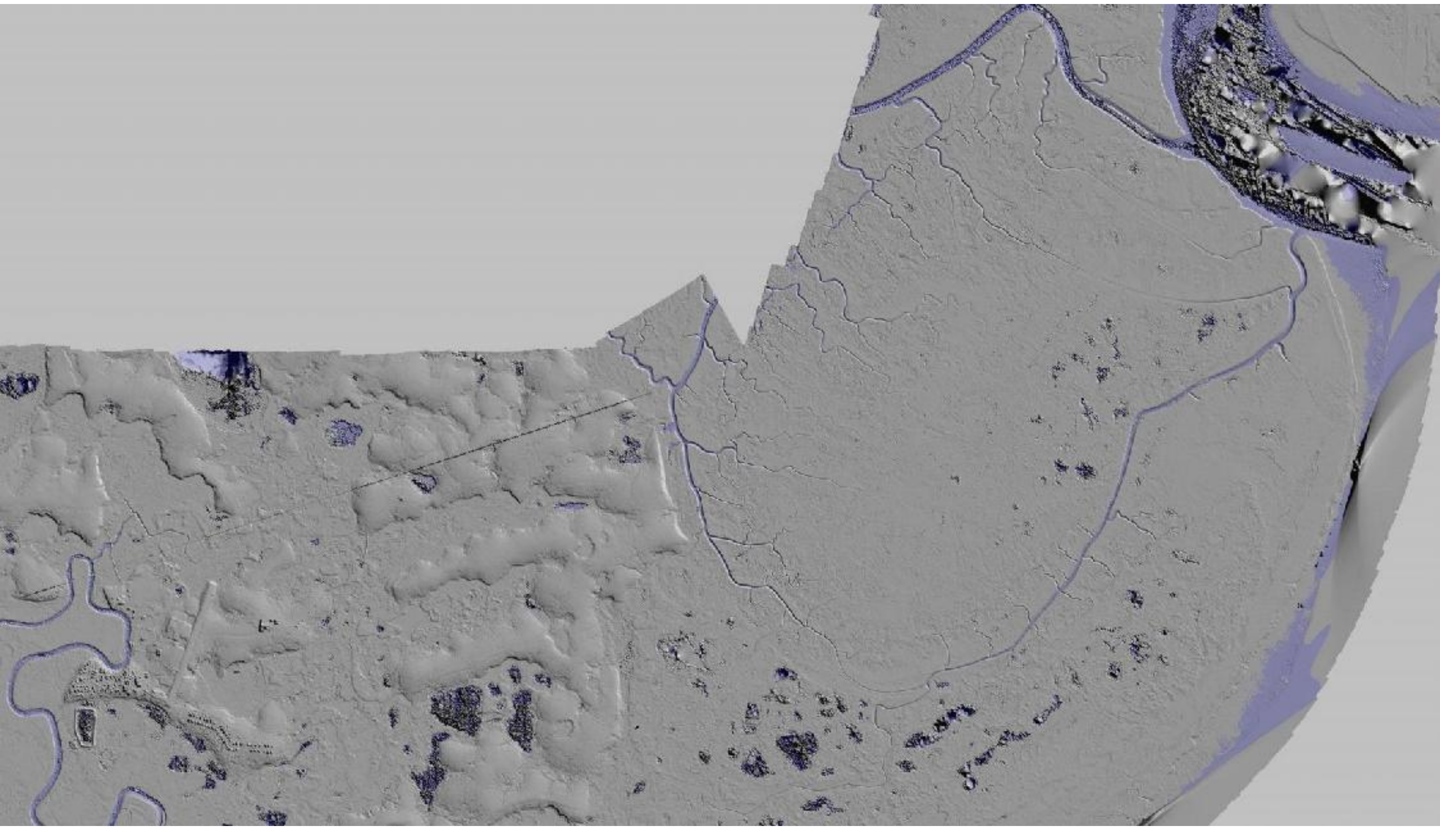
Comparison of overlap with Toksook block. Random noise is roughly +/- 8cm, spatially coherent noise ~20 cm, and Bethel2Toxic block about 20 cm lower than Toksook.



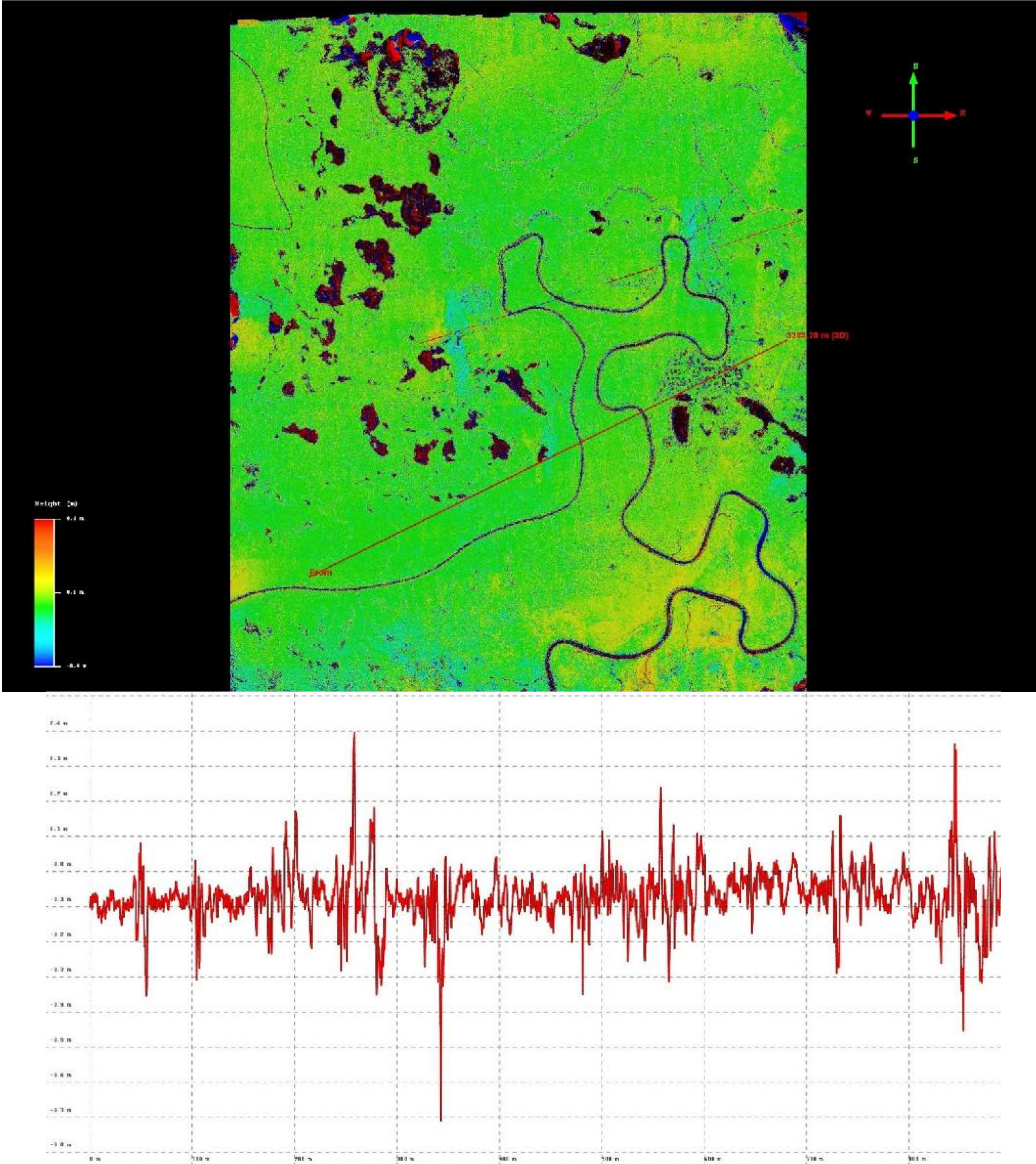


Example detail of a stripe artifact. This is the only such artifact within the AOI. It varies up to several meters wide.

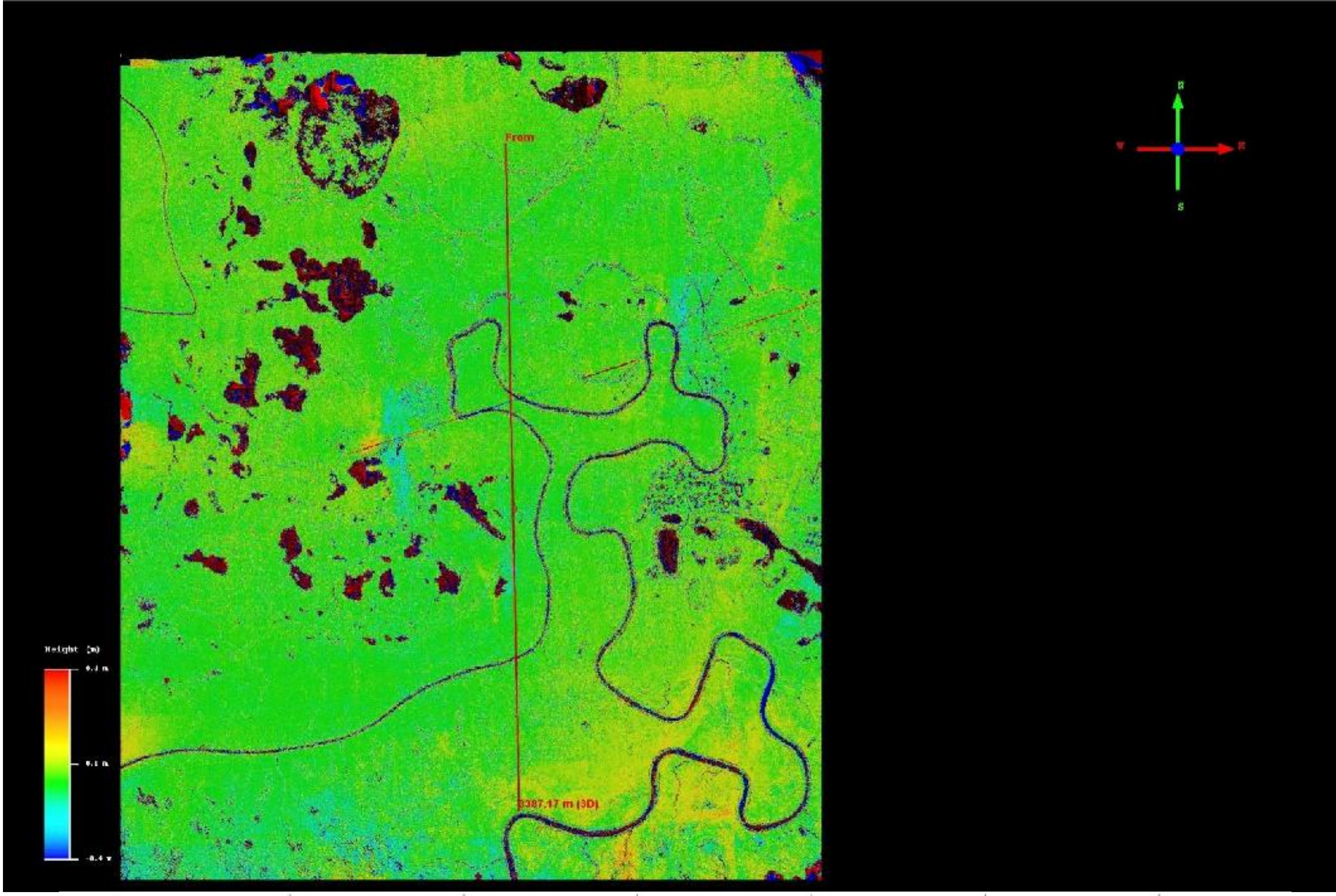


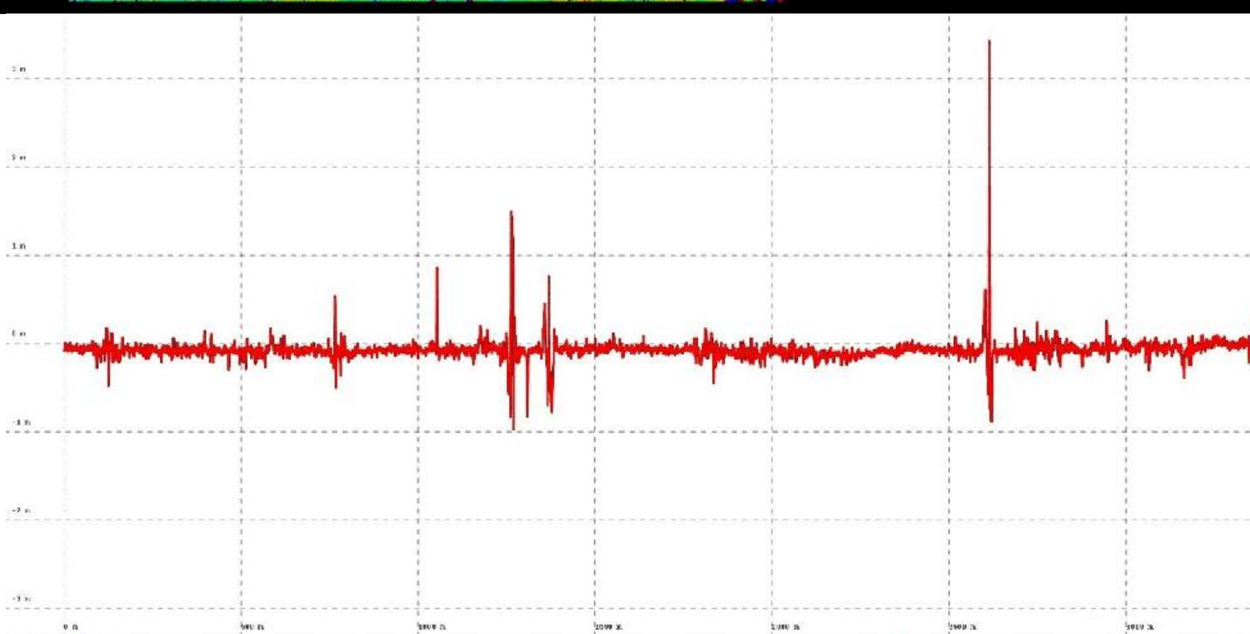


Overview of the stripe artifact. It happened to fall within the overlap between two processing chunks, with seam between them just to the left of center. Notice it does not appear in the chunk at right, suggesting it is a processing artifact. It does not exist in the point cloud, suggesting it is an artifact of the mesh or DEM creation stages. Reprocessing will likely eliminate it, but in the meantime it is less than 0.0001% of the total AOI.

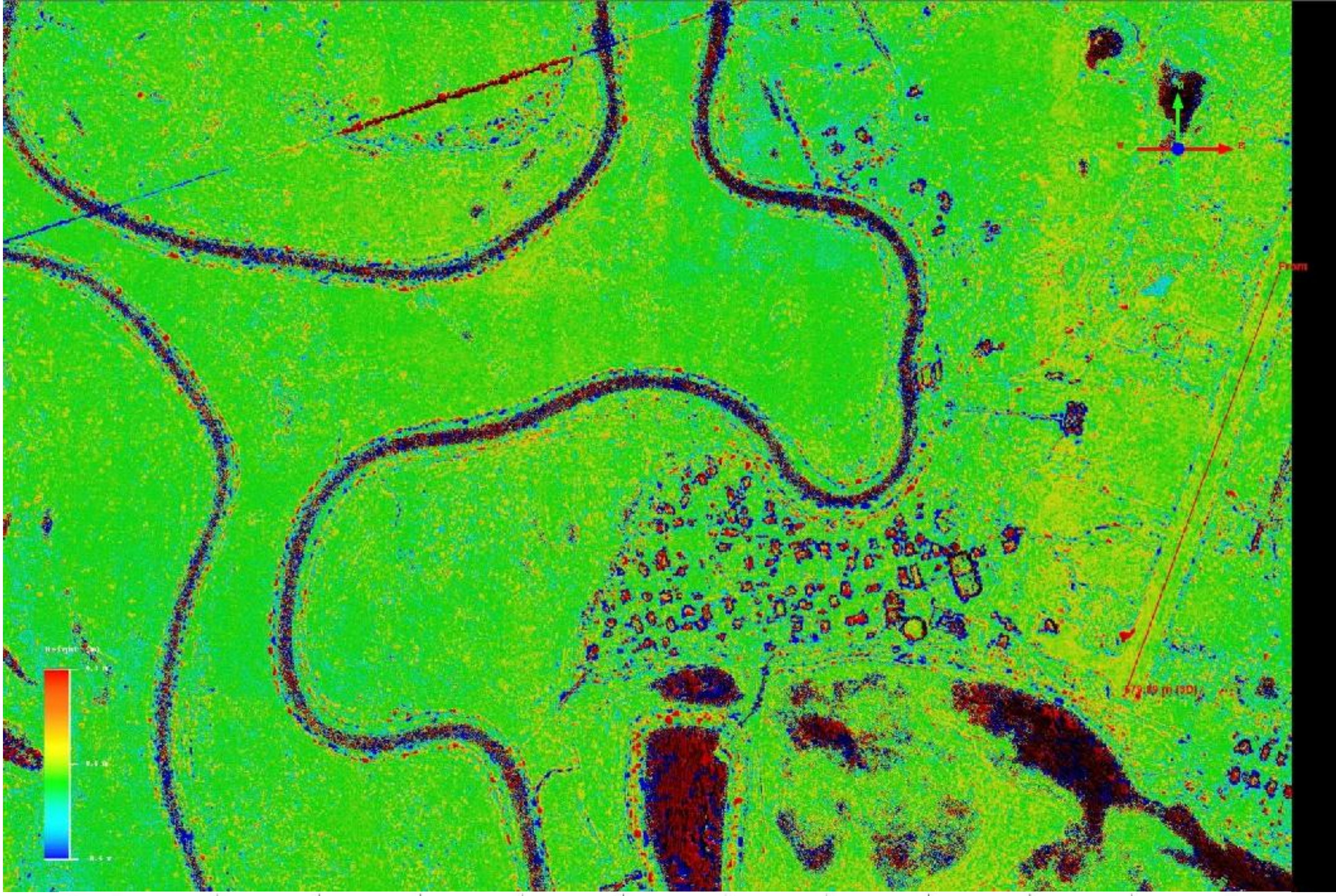


Comparison to Kongiginak village data. The random noise level is roughly +/- 8 cm, with about a 8 cm offset.

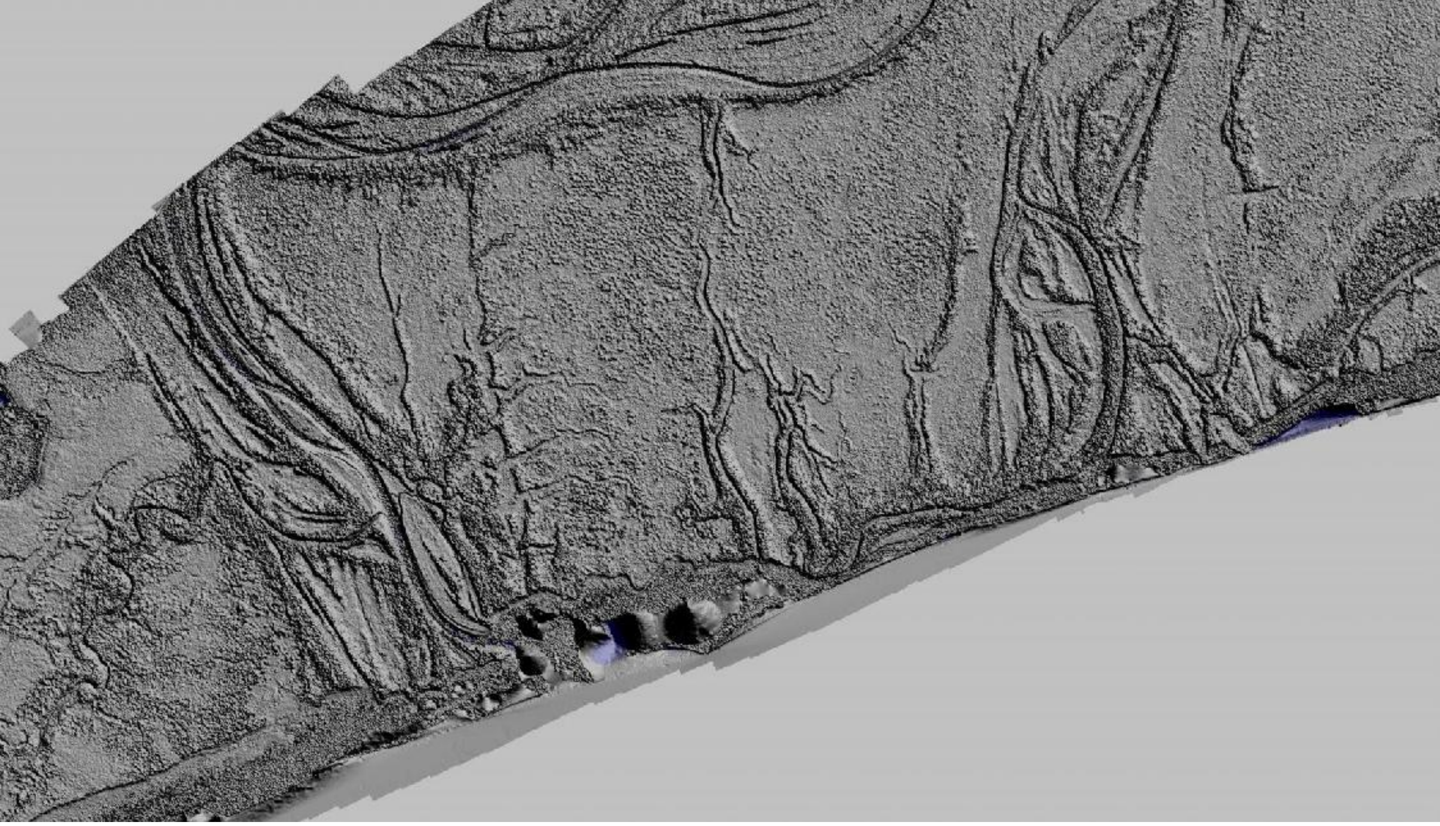


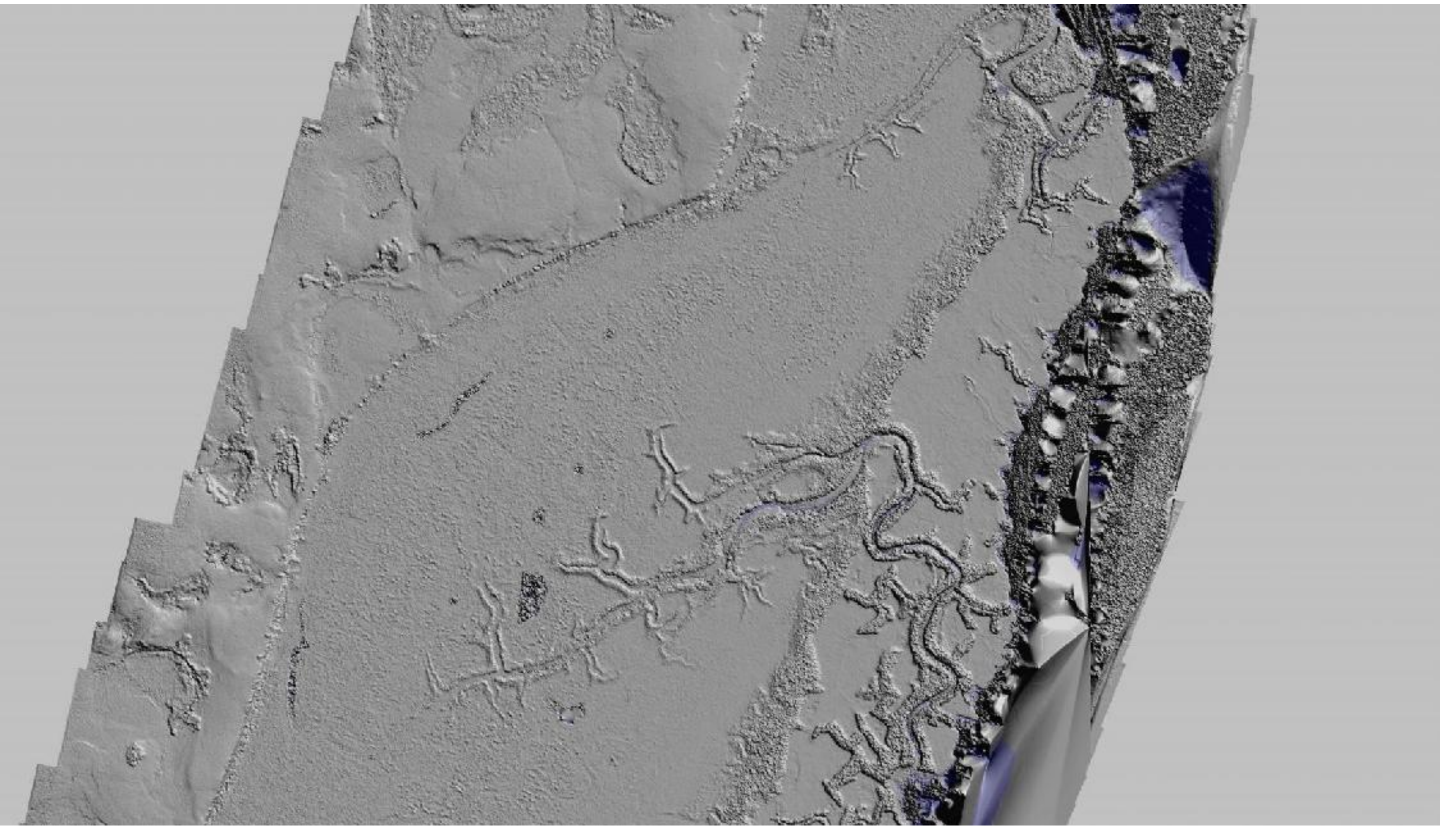


Comparison to Kongiginak village data. The random noise level is roughly +/- 8 cm, with about a 8 cm offset and no spatially coherent noise apparent.

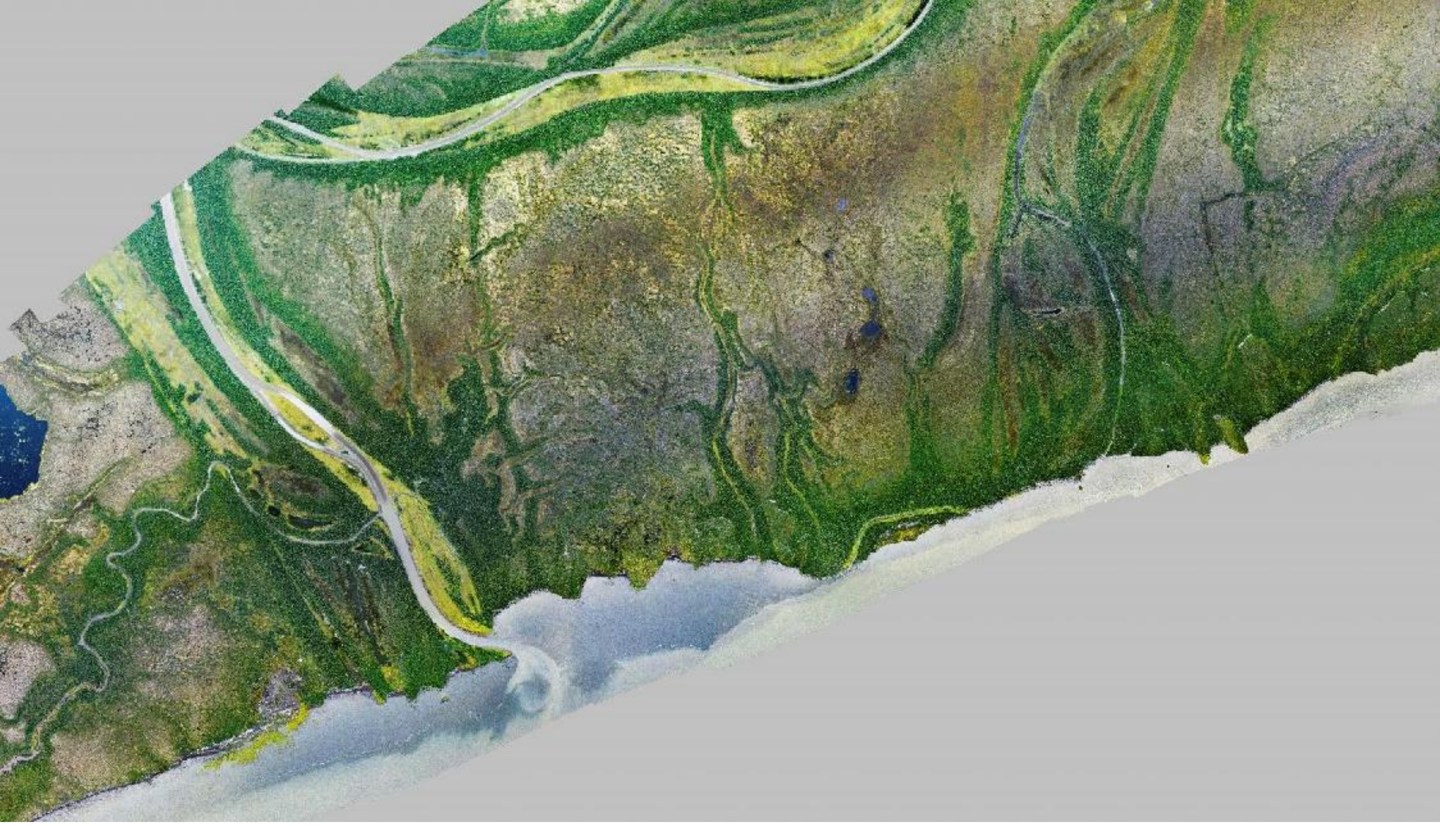


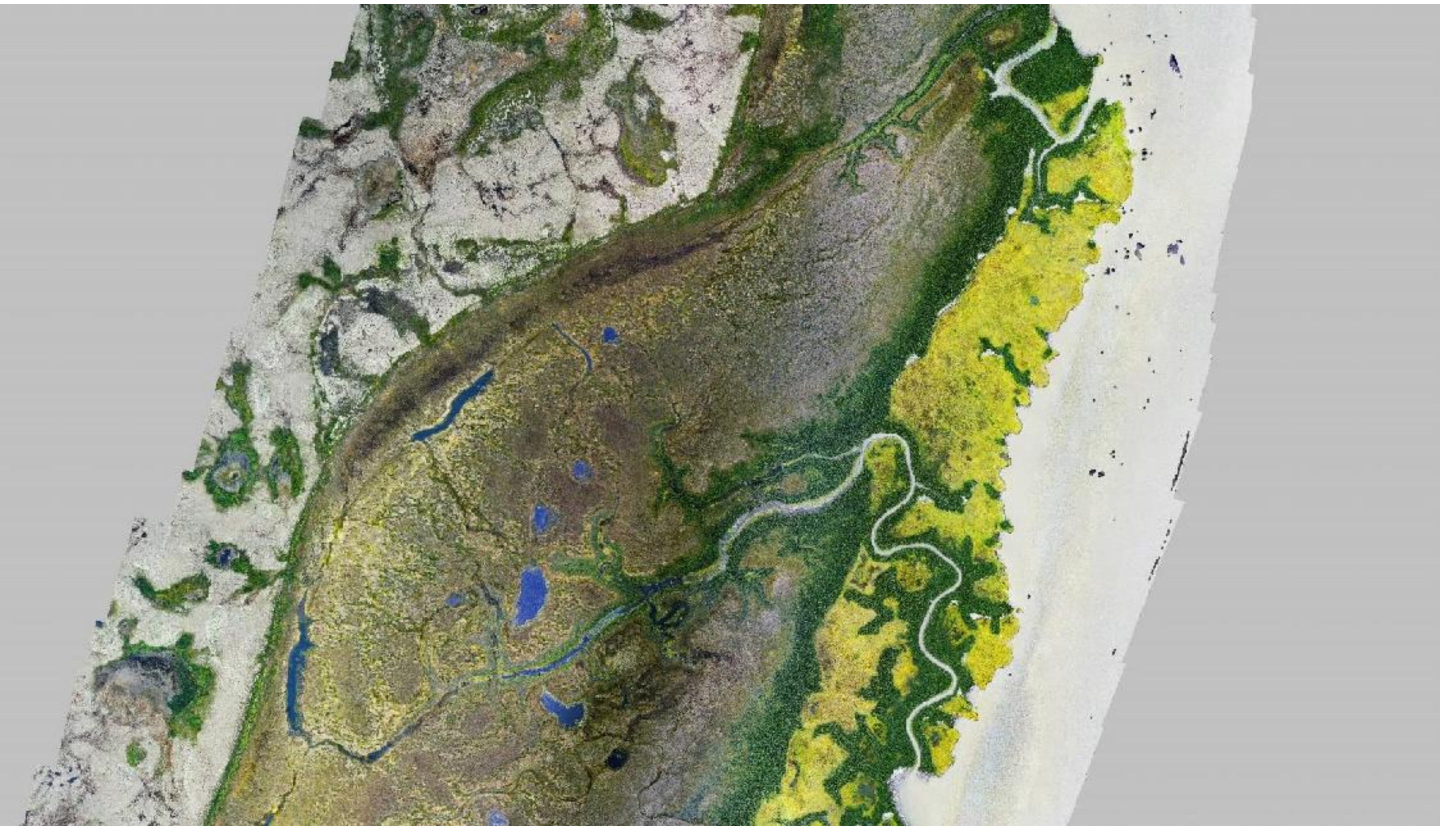
Comparison to Kongiginak village data on the runway. The total range of variation is about 12 cm, indicating that we can measure change to infrastructure like this on the centimeter level.



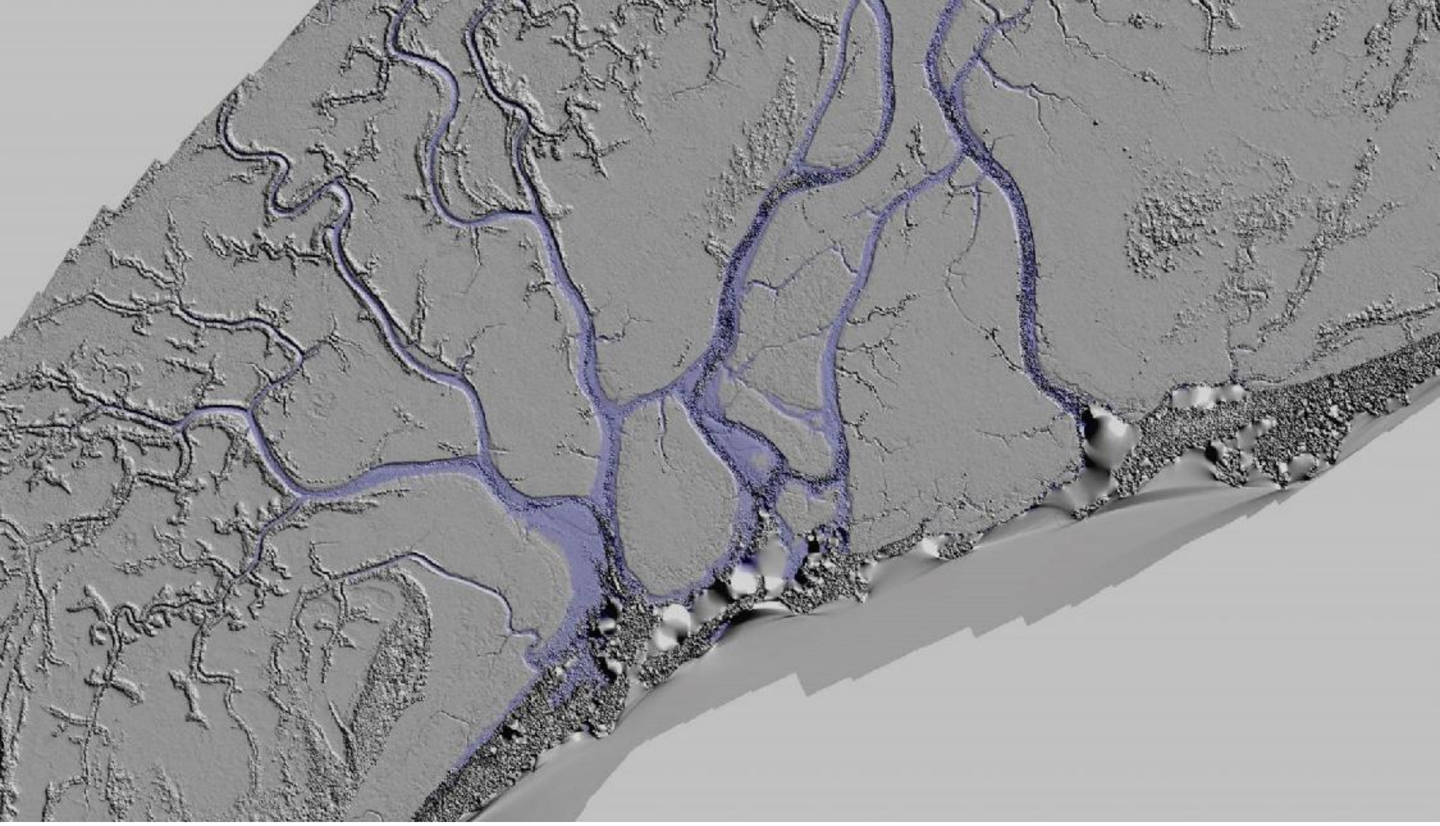


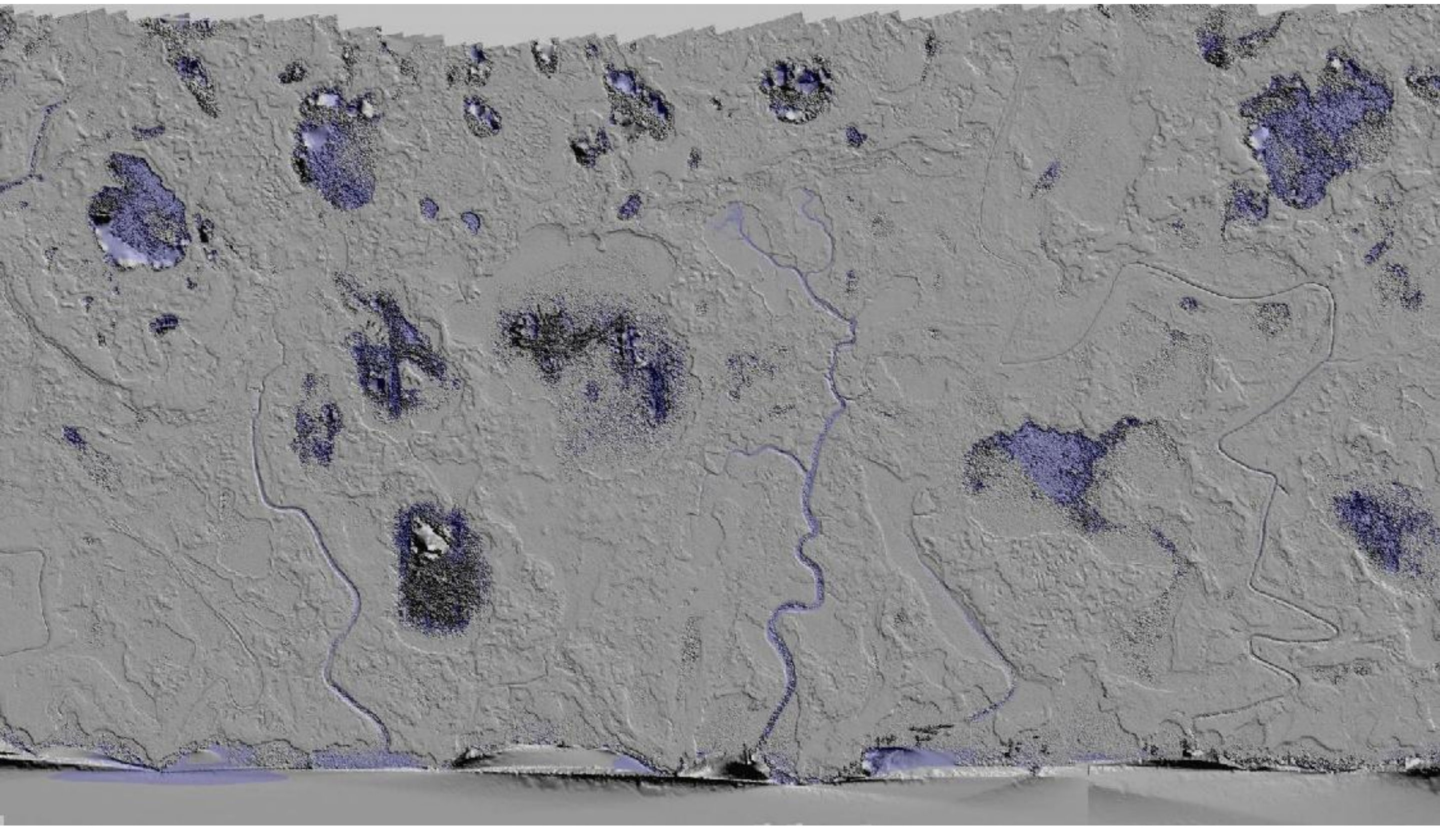
Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.



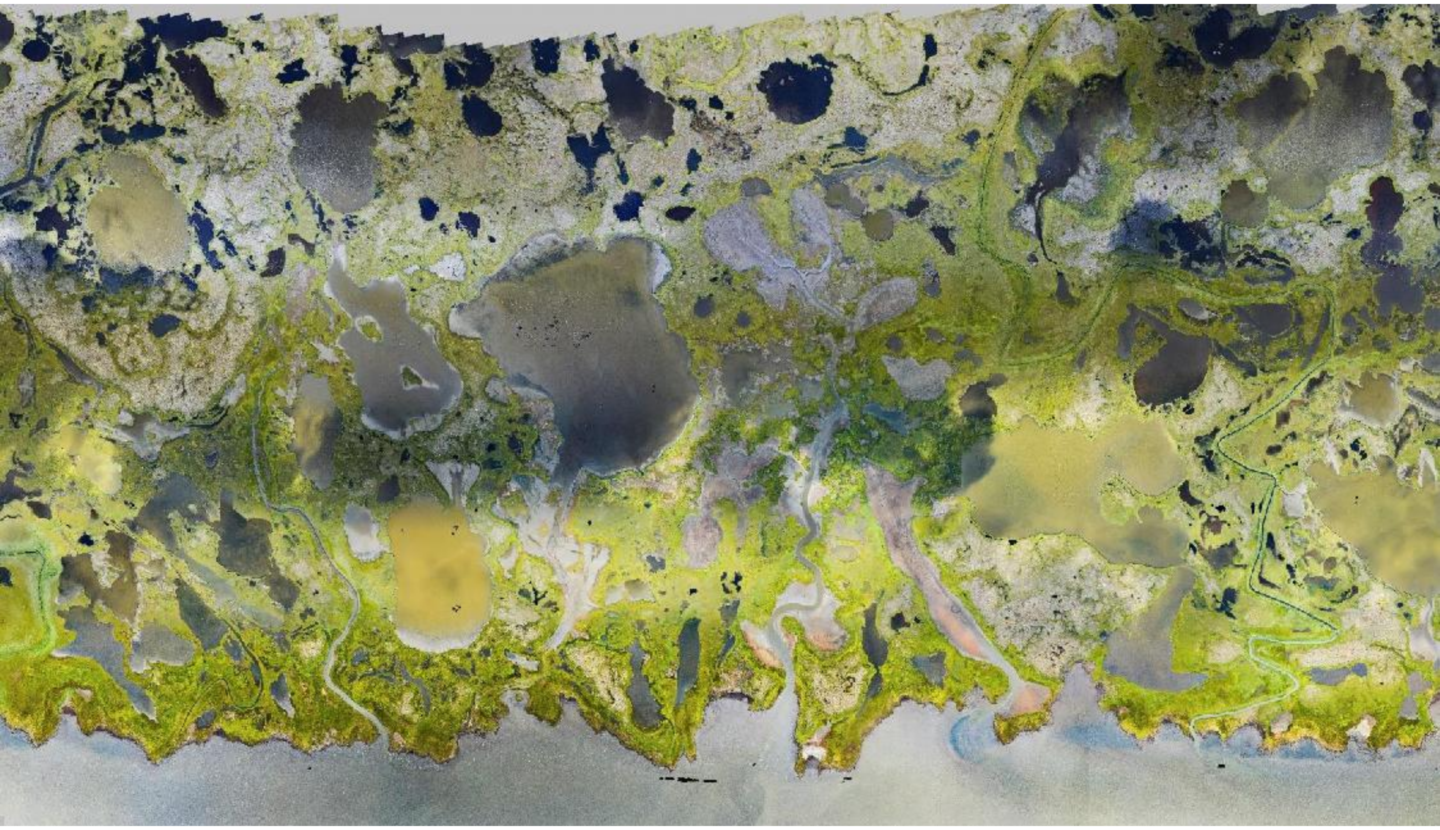


Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

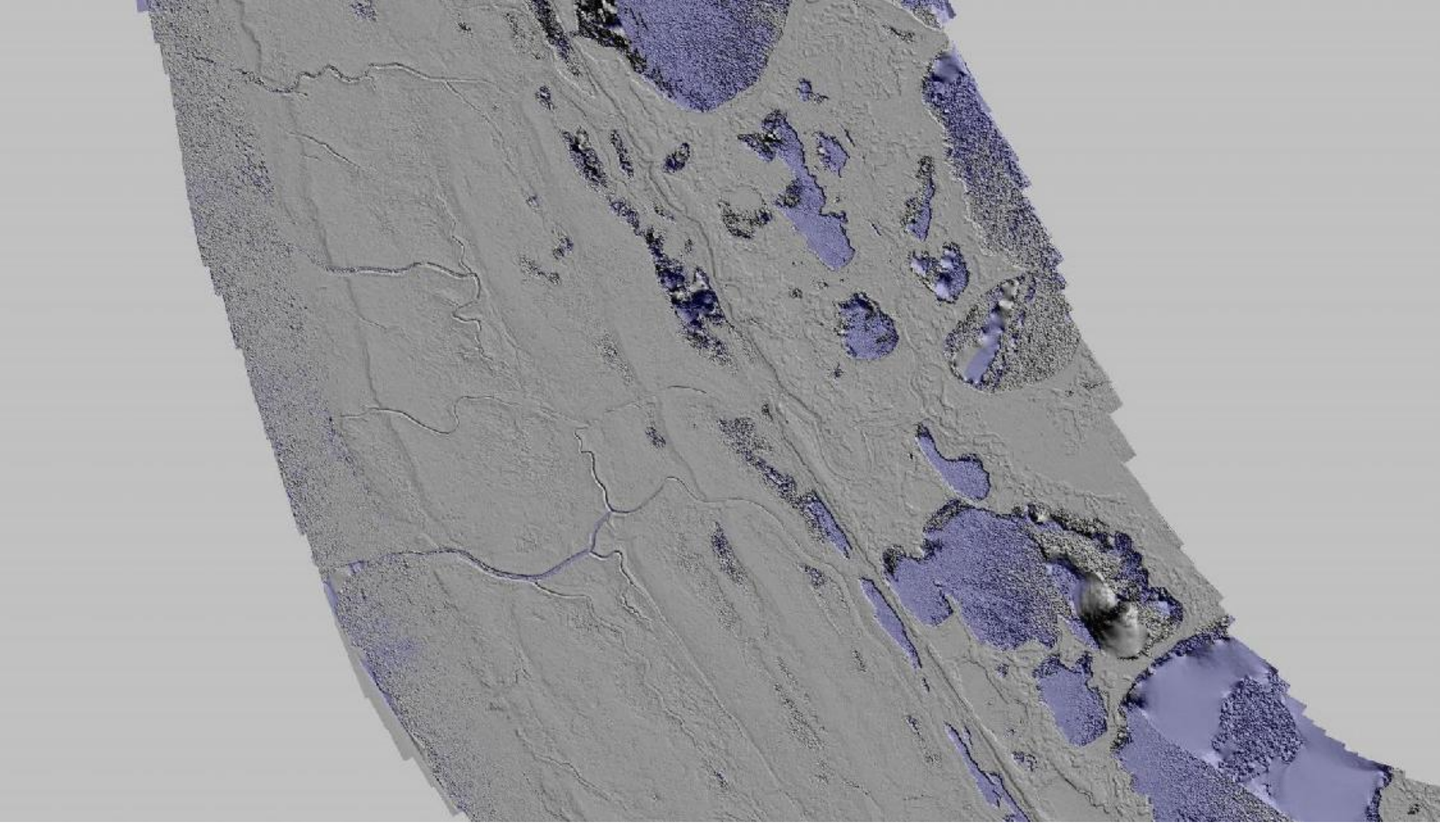


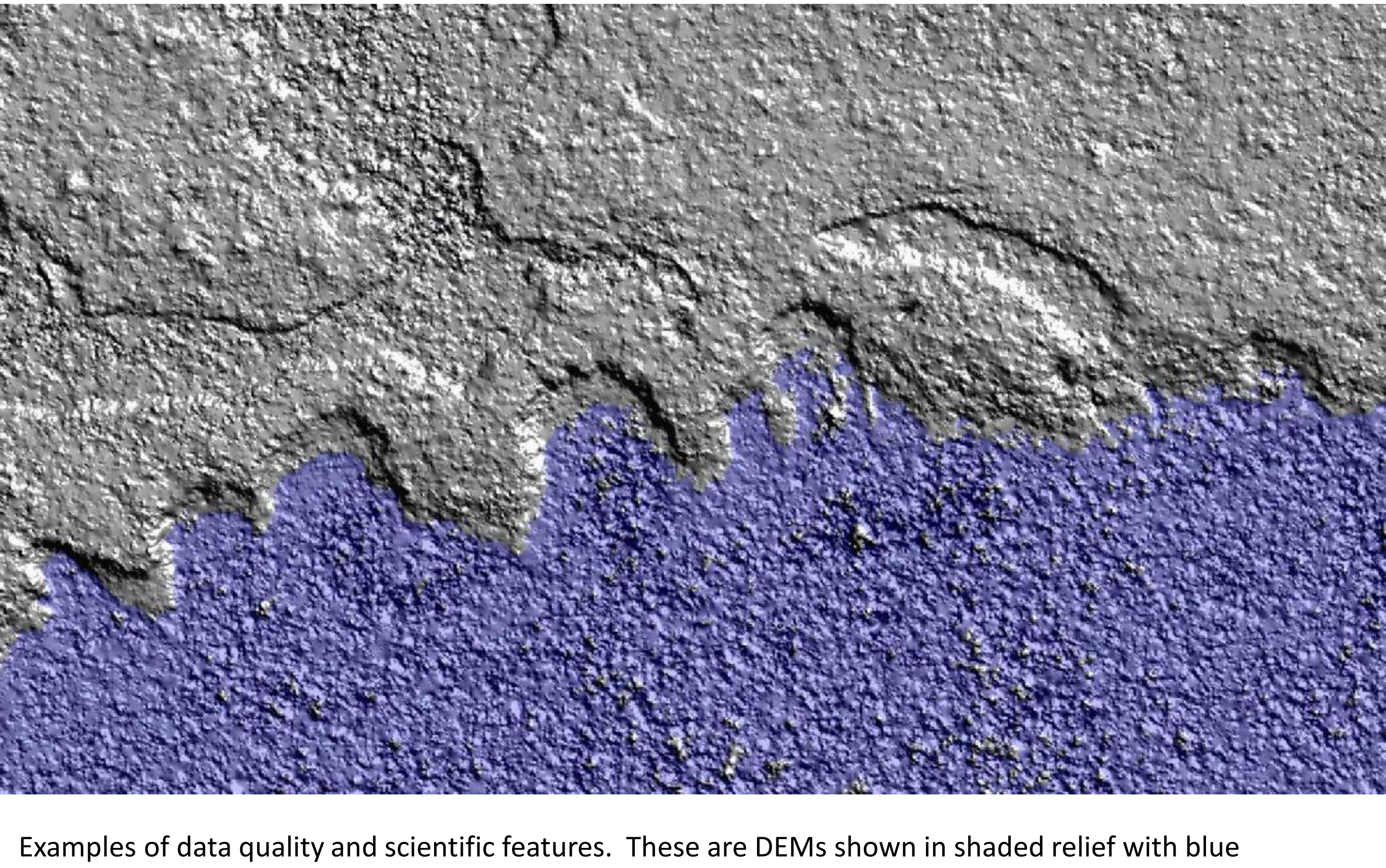


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

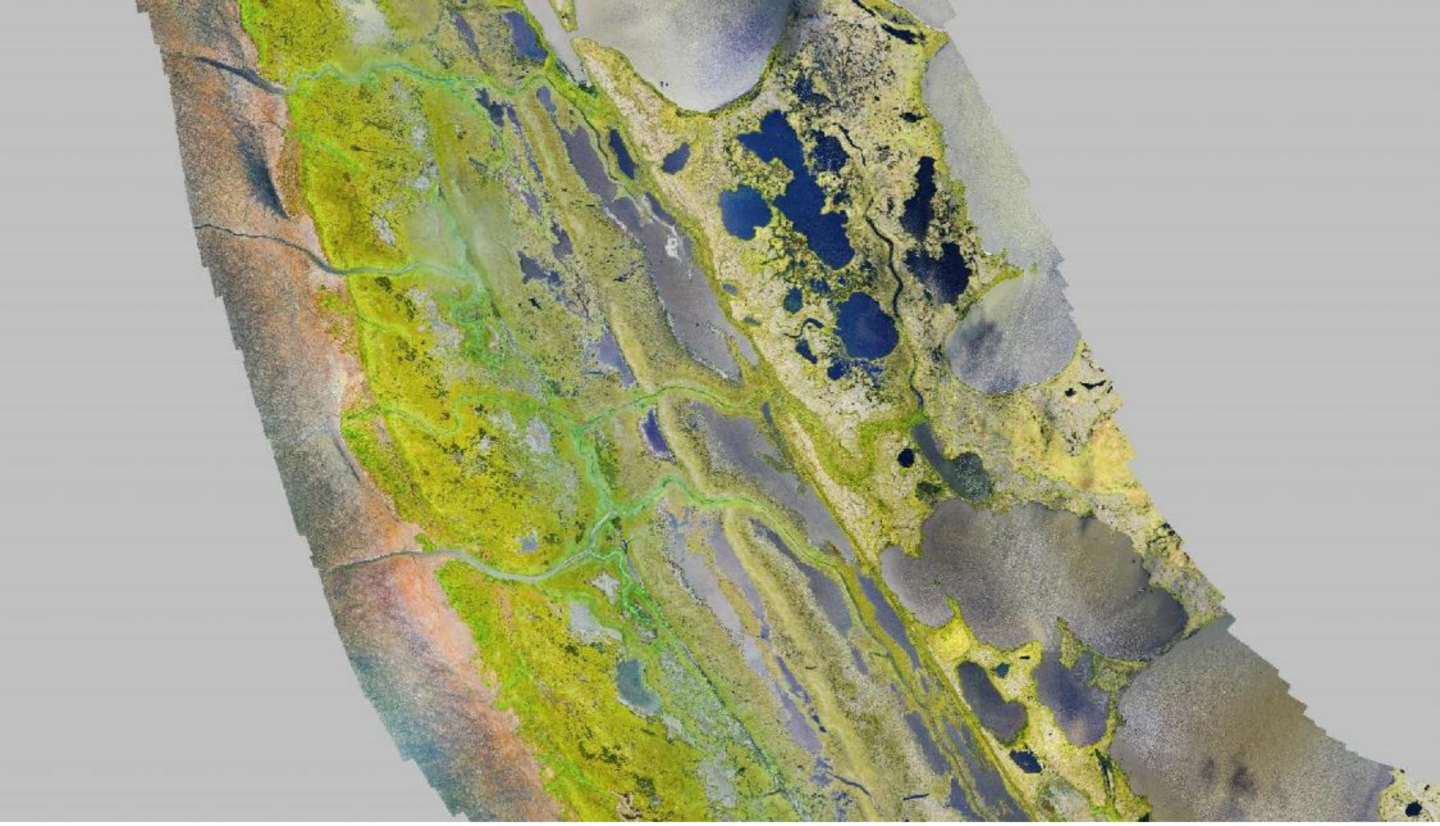


Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

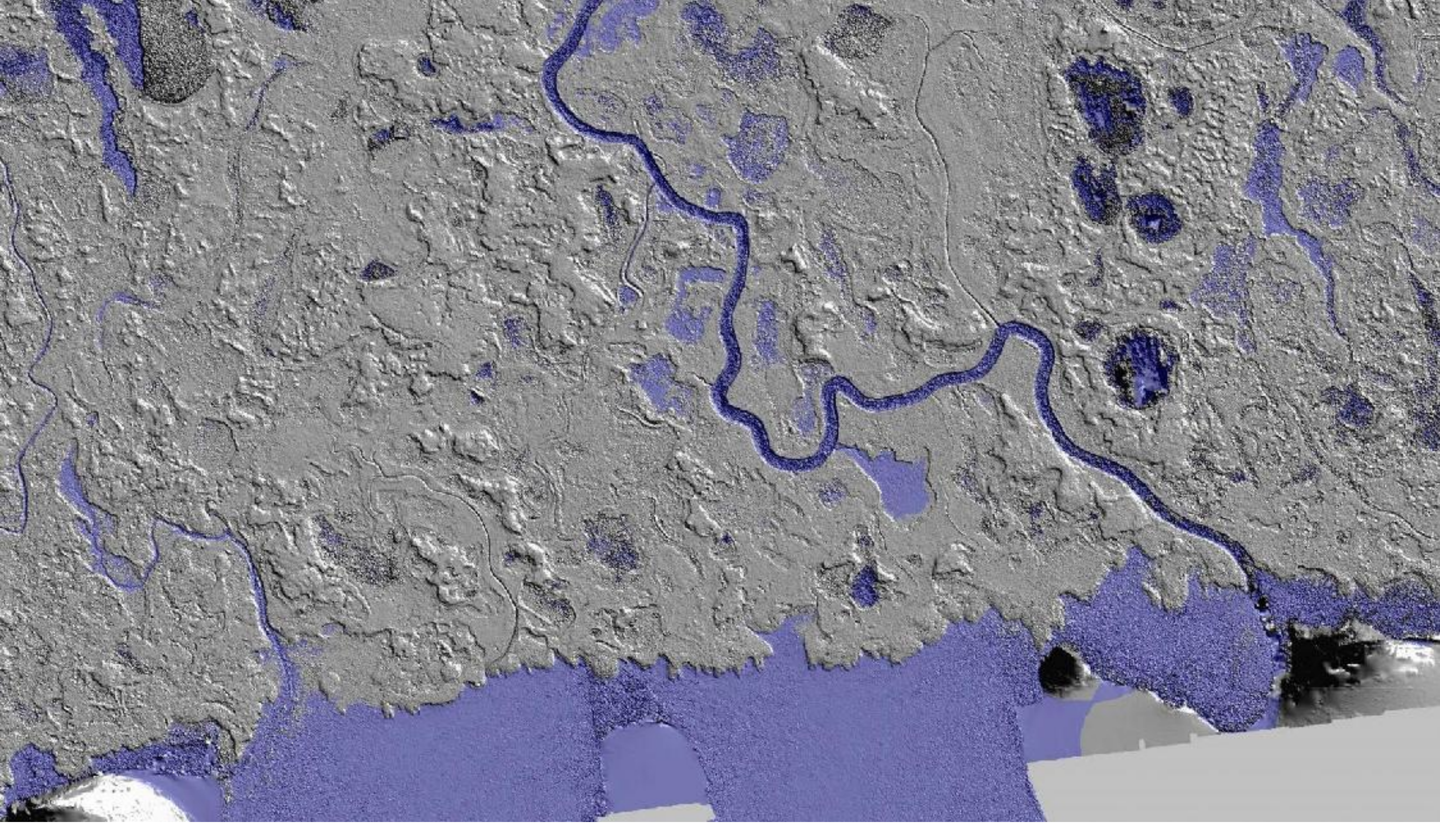


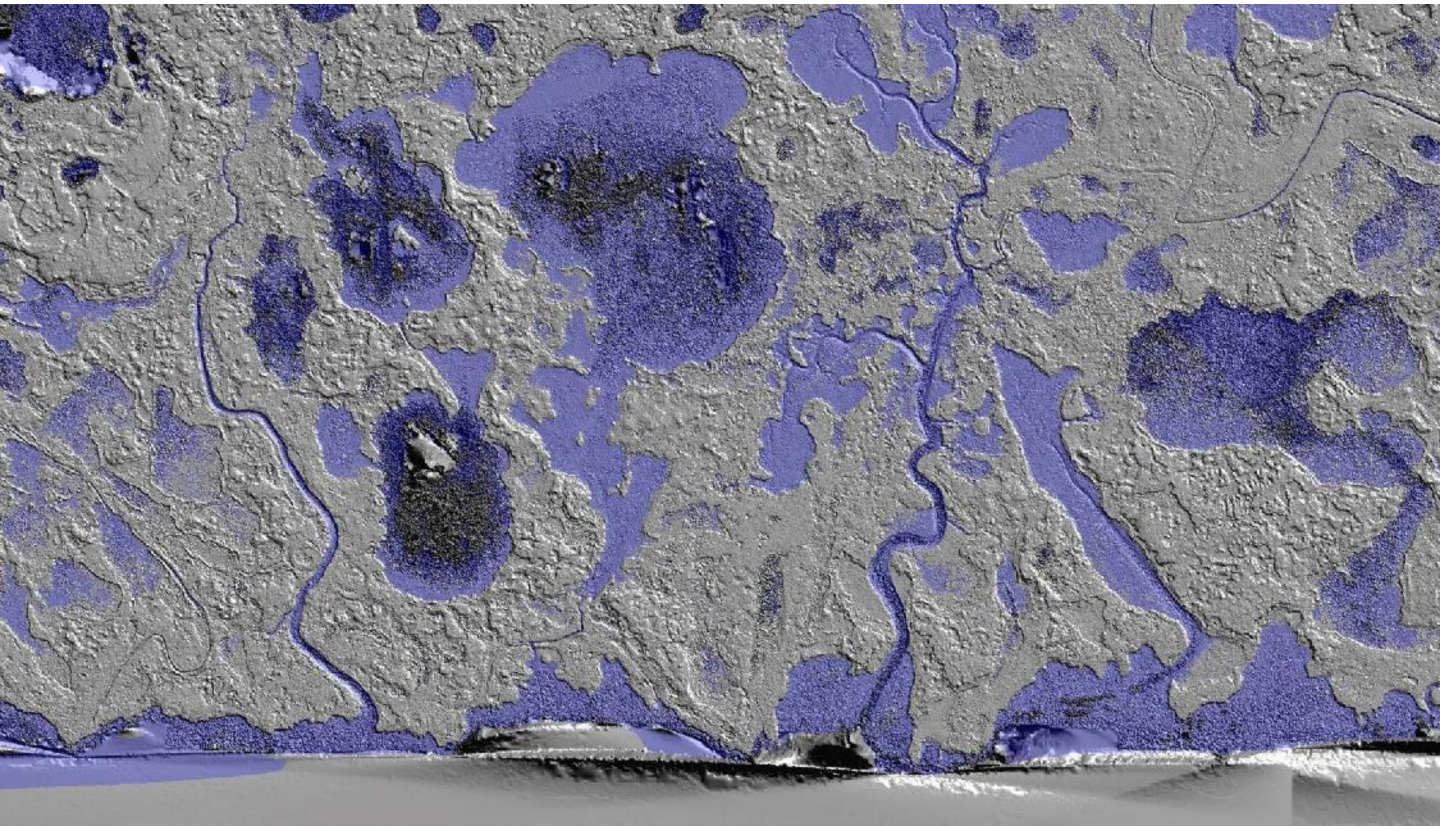


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

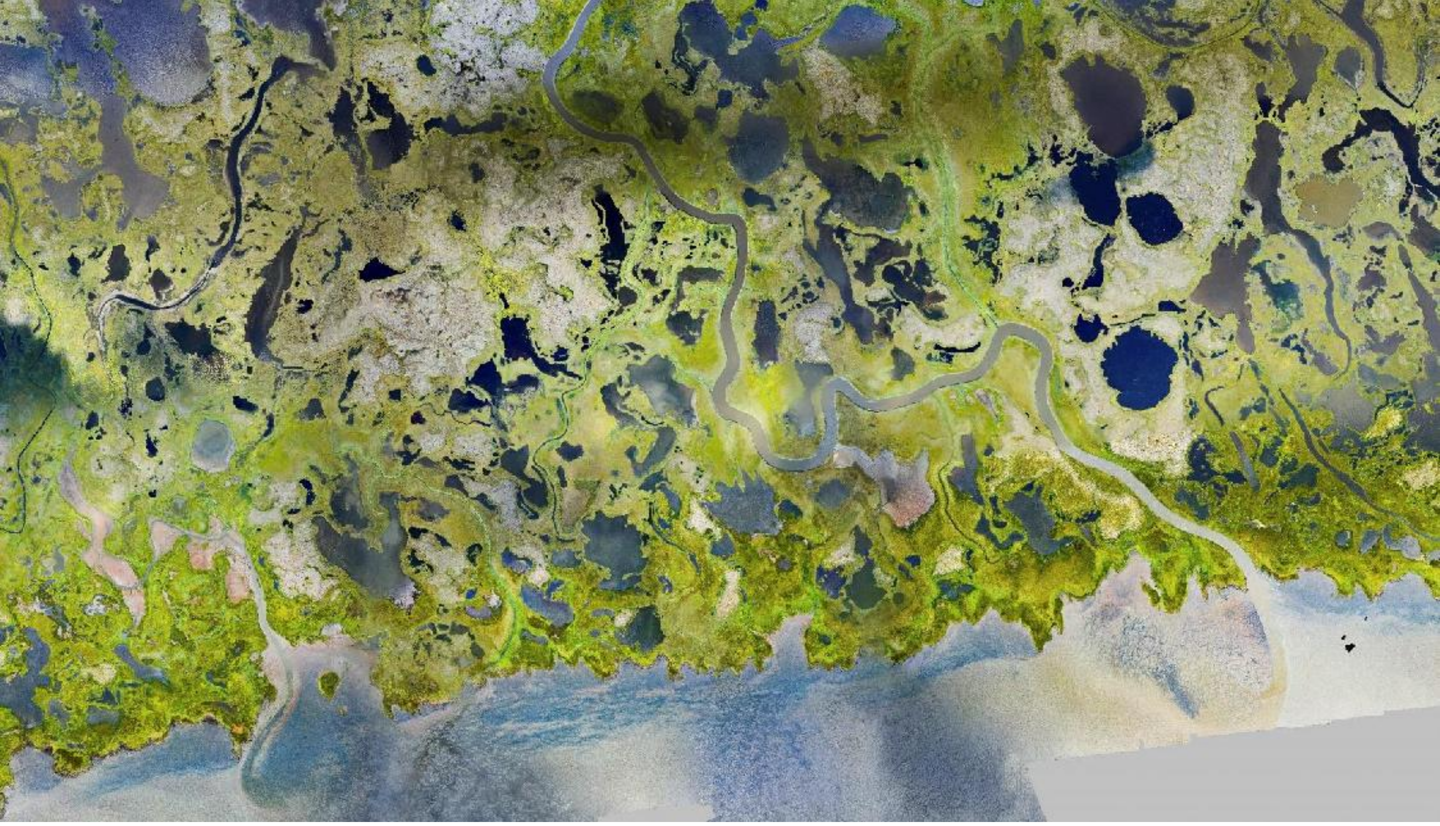


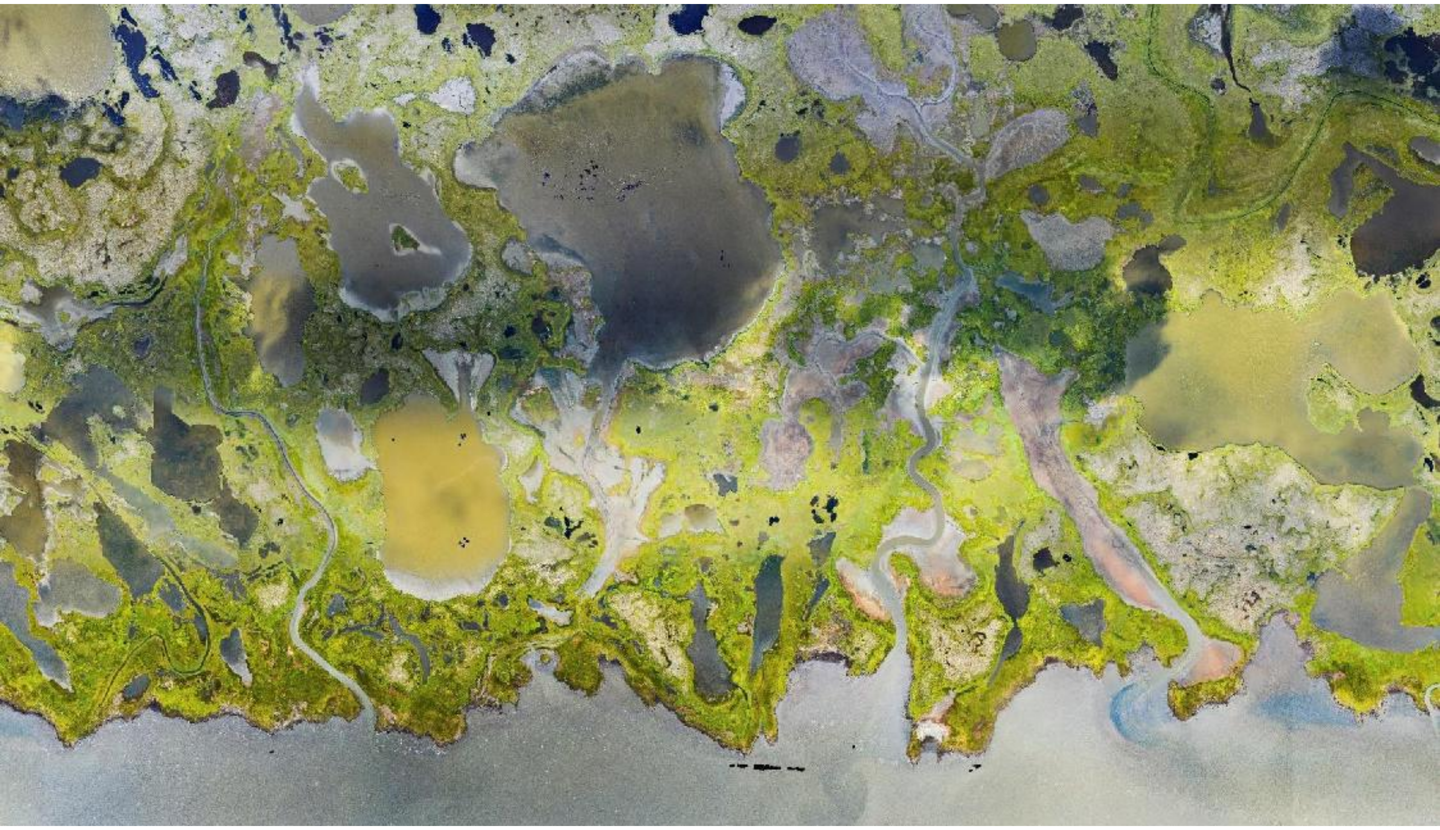
Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.



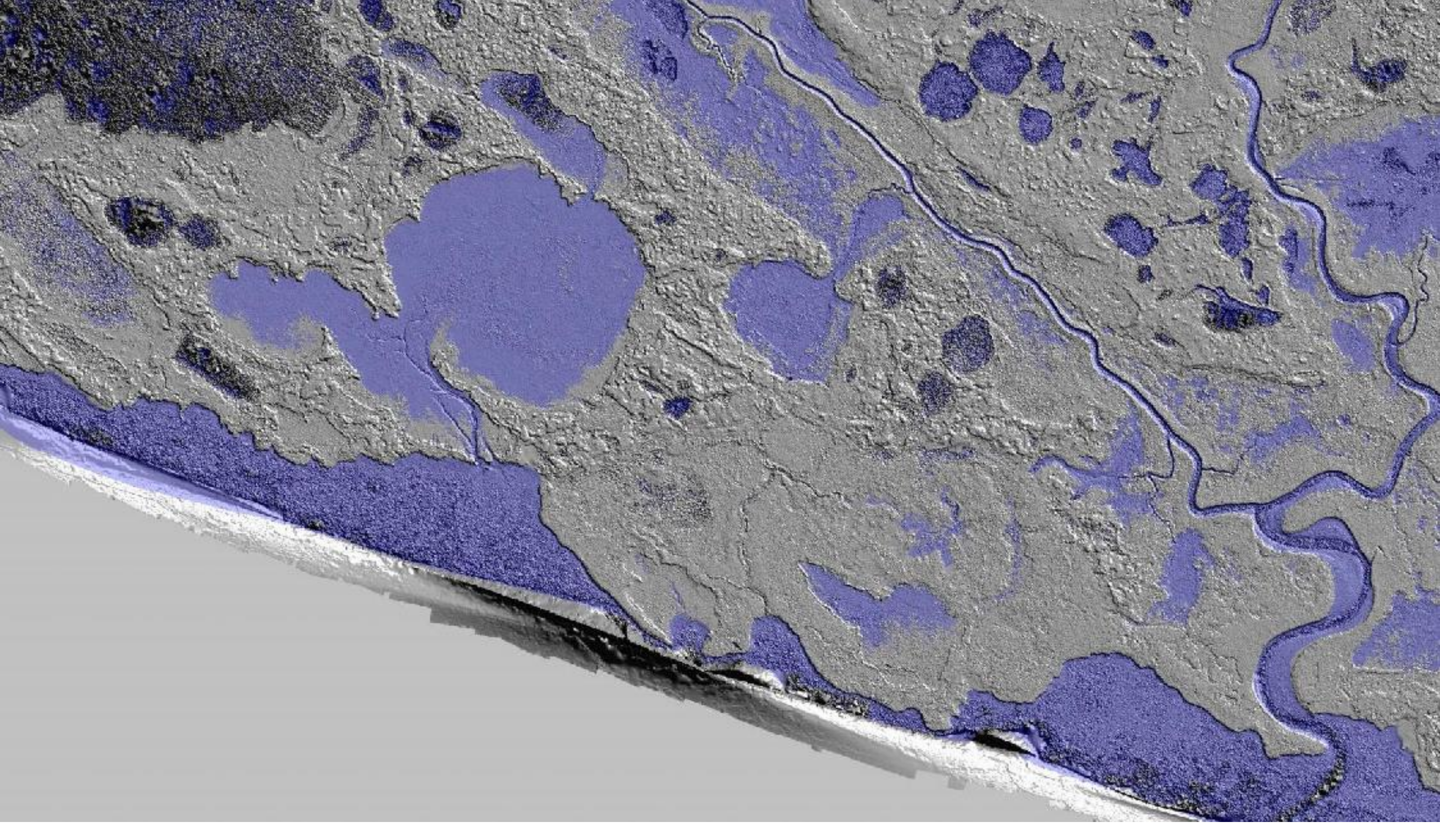


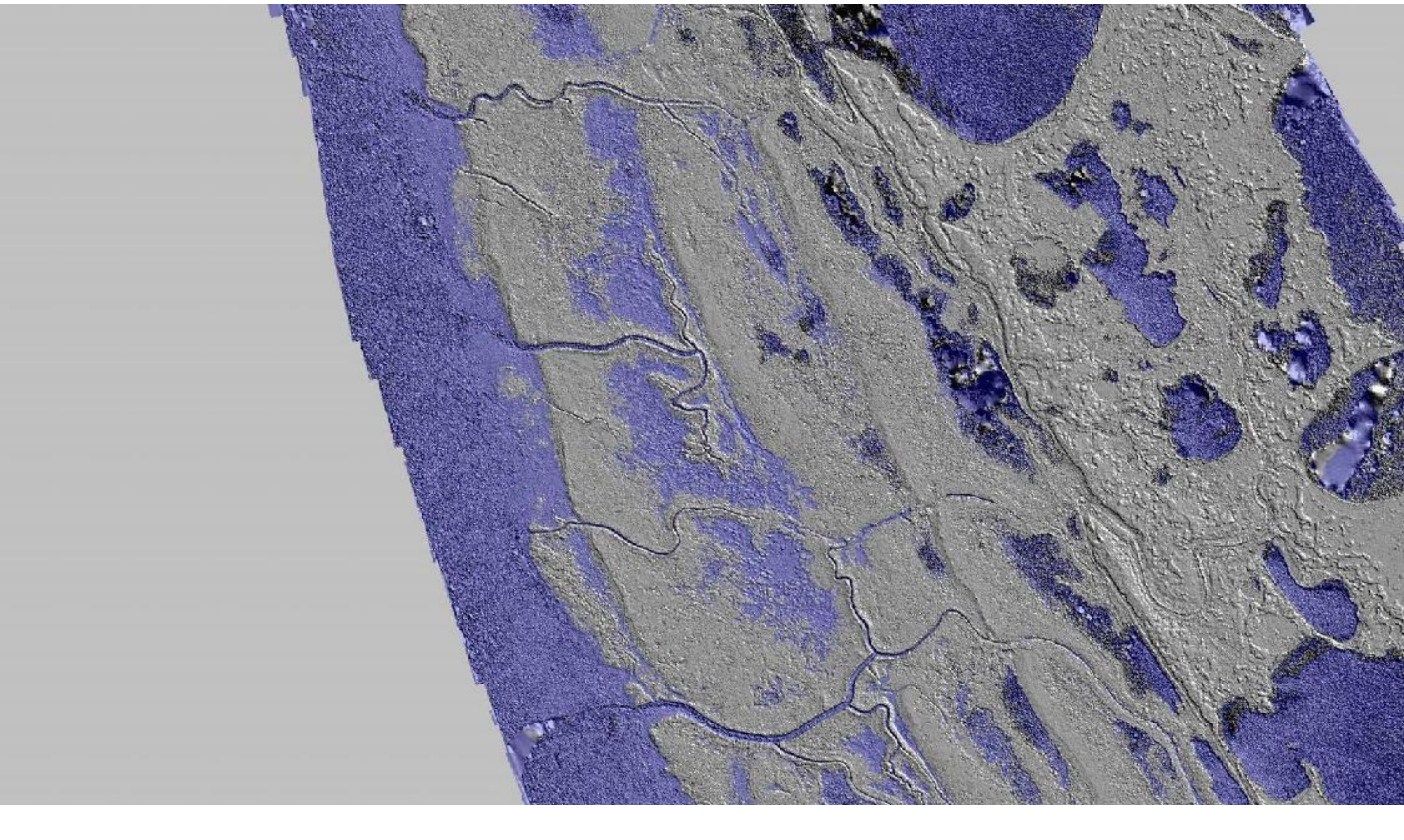
Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.



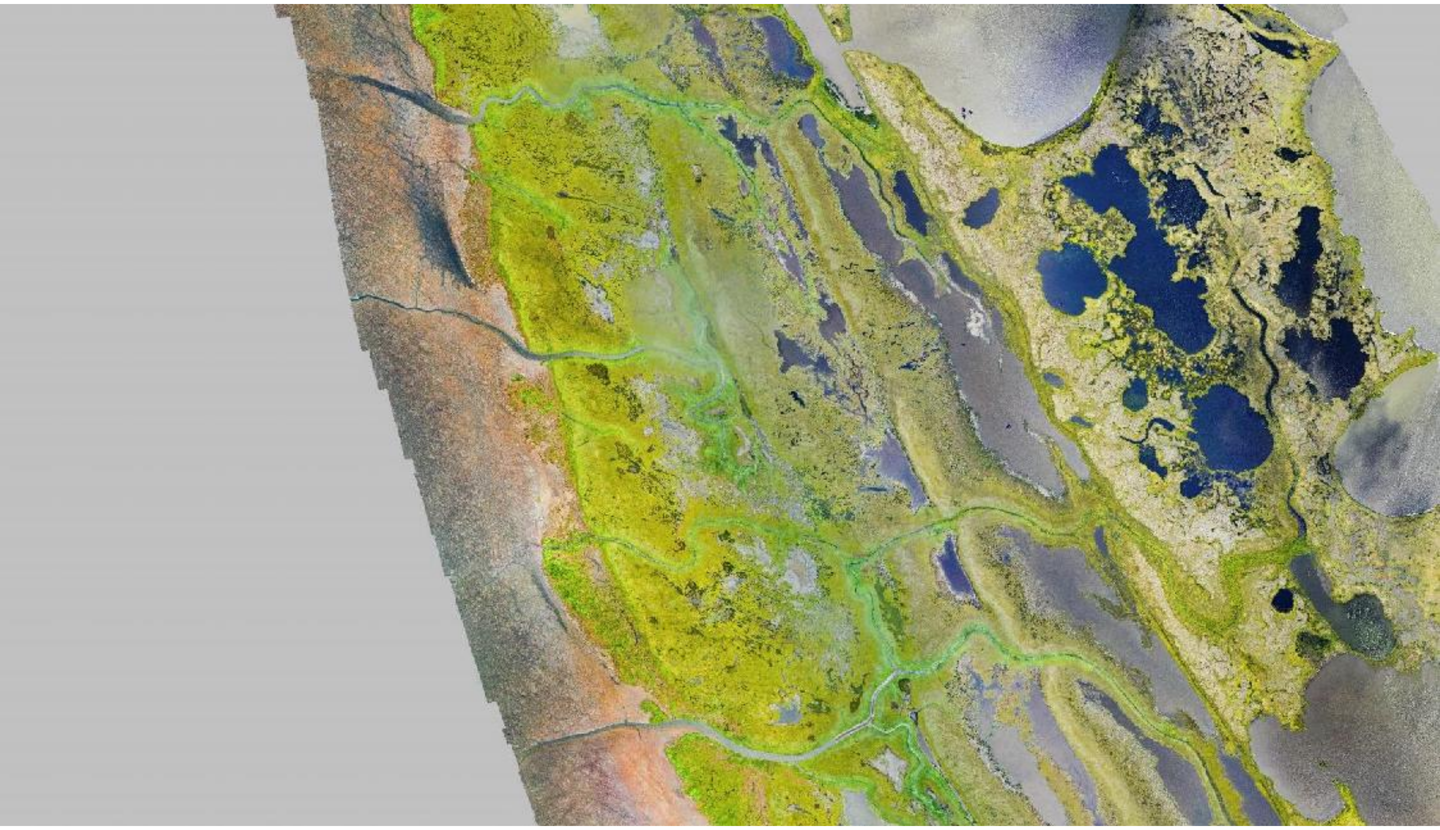


Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

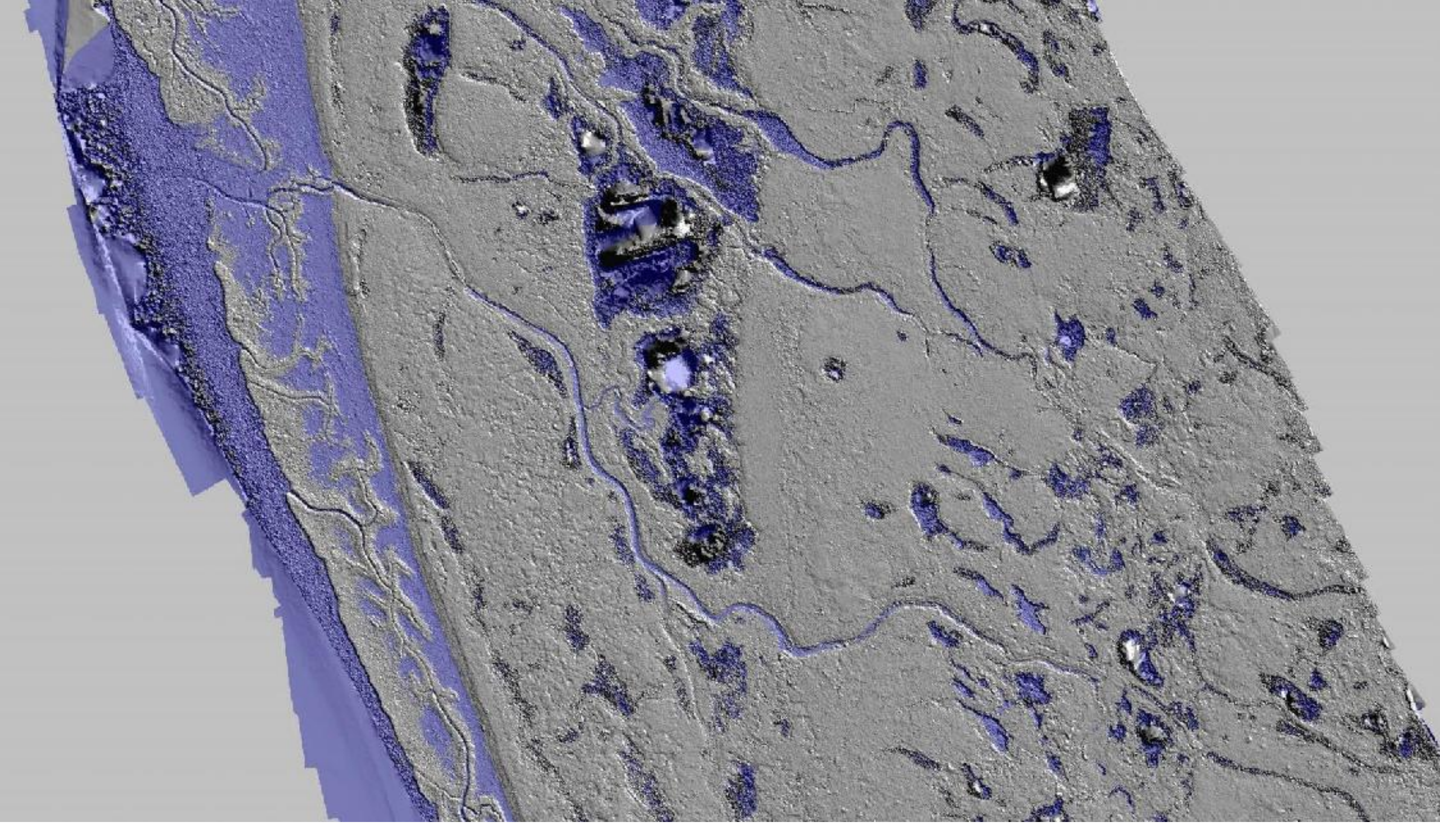


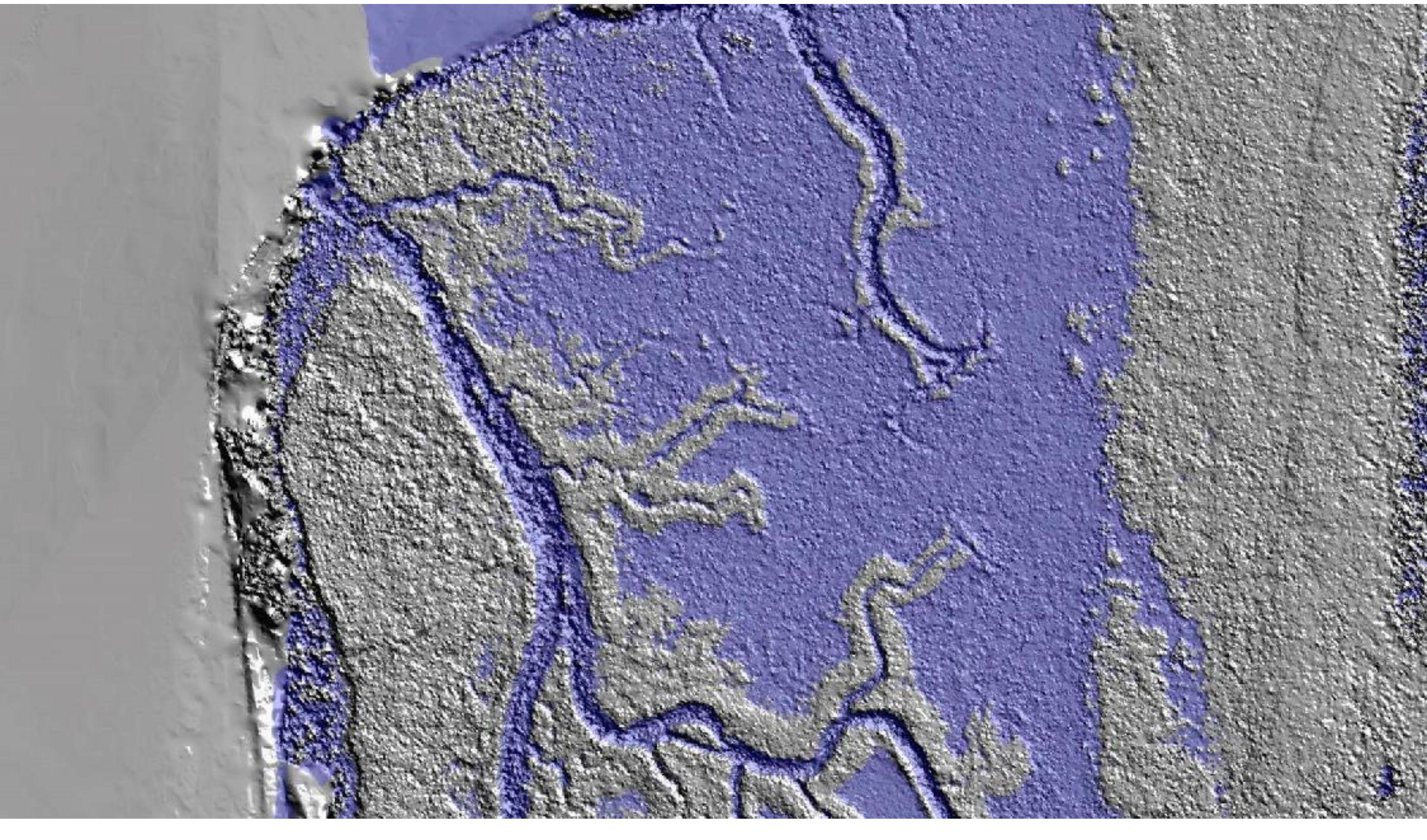


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.



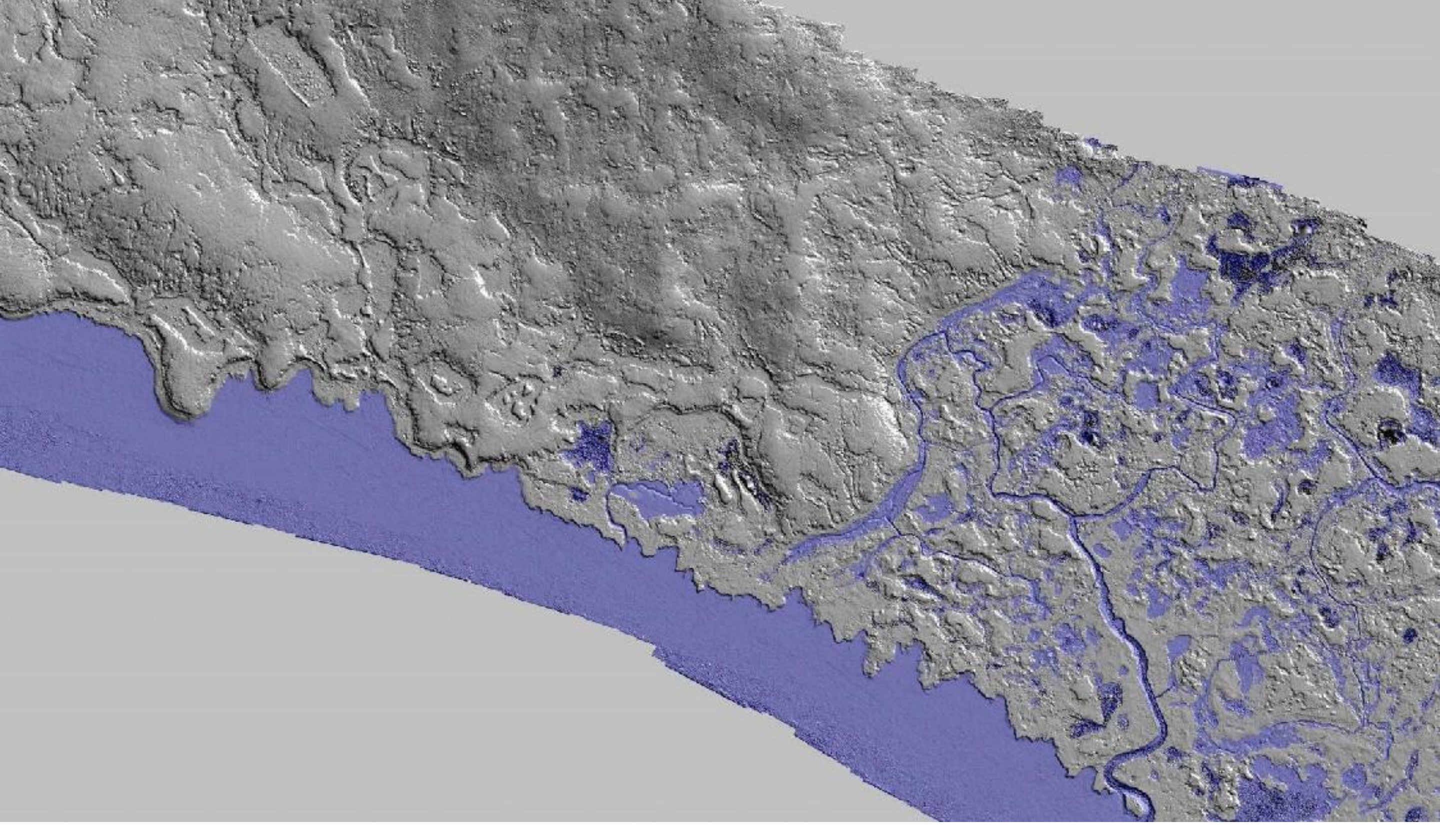
Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

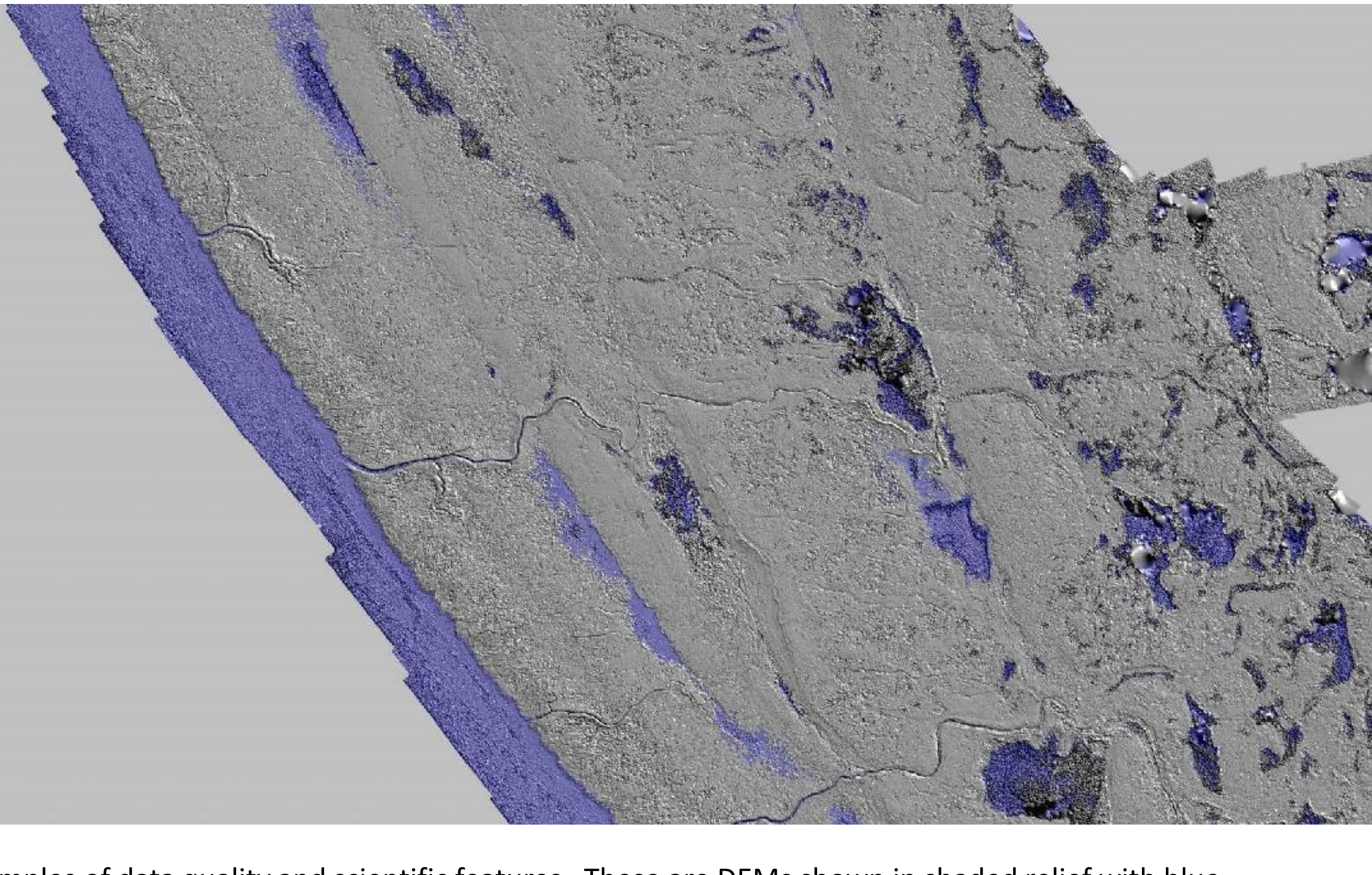




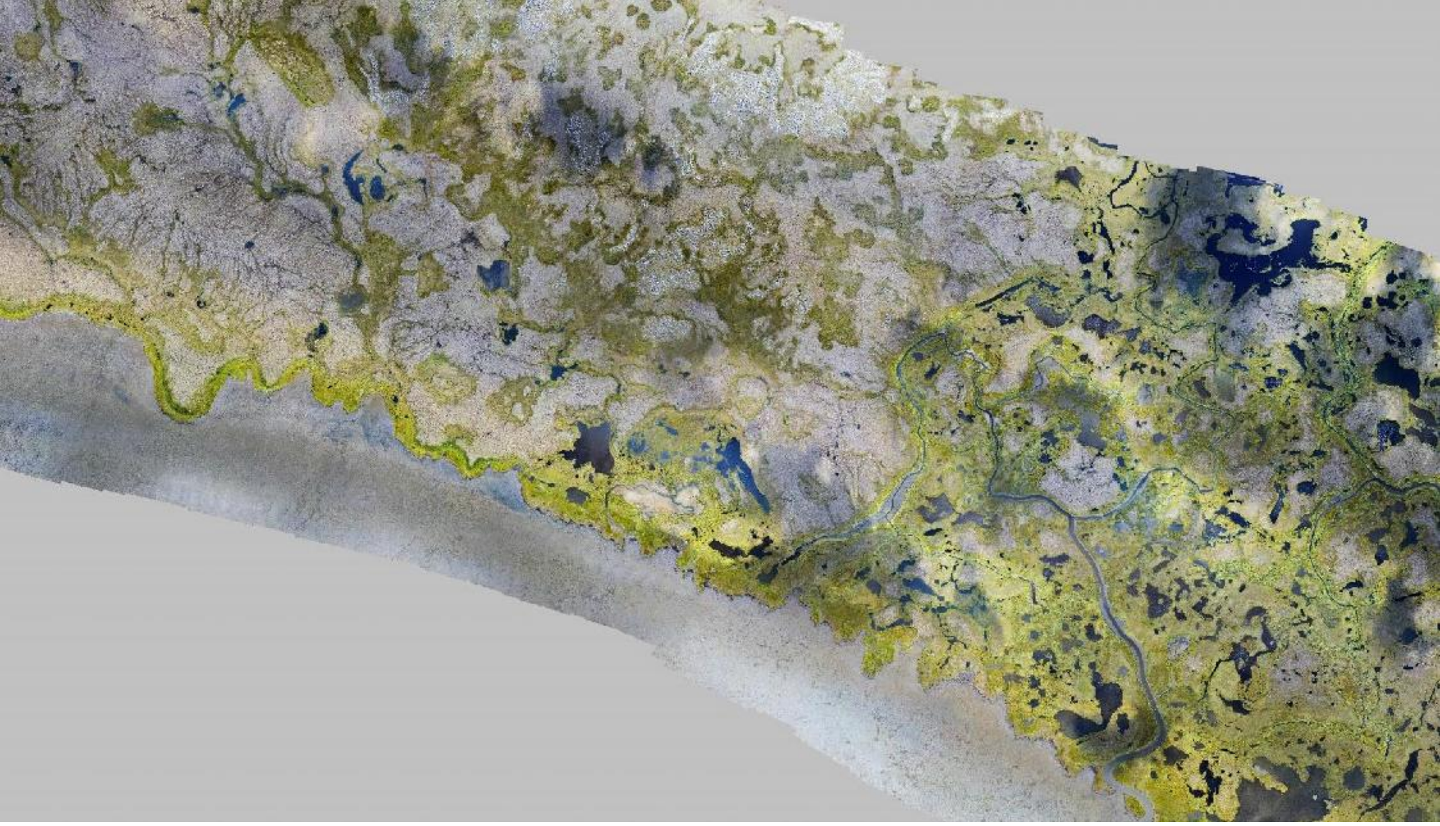
Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

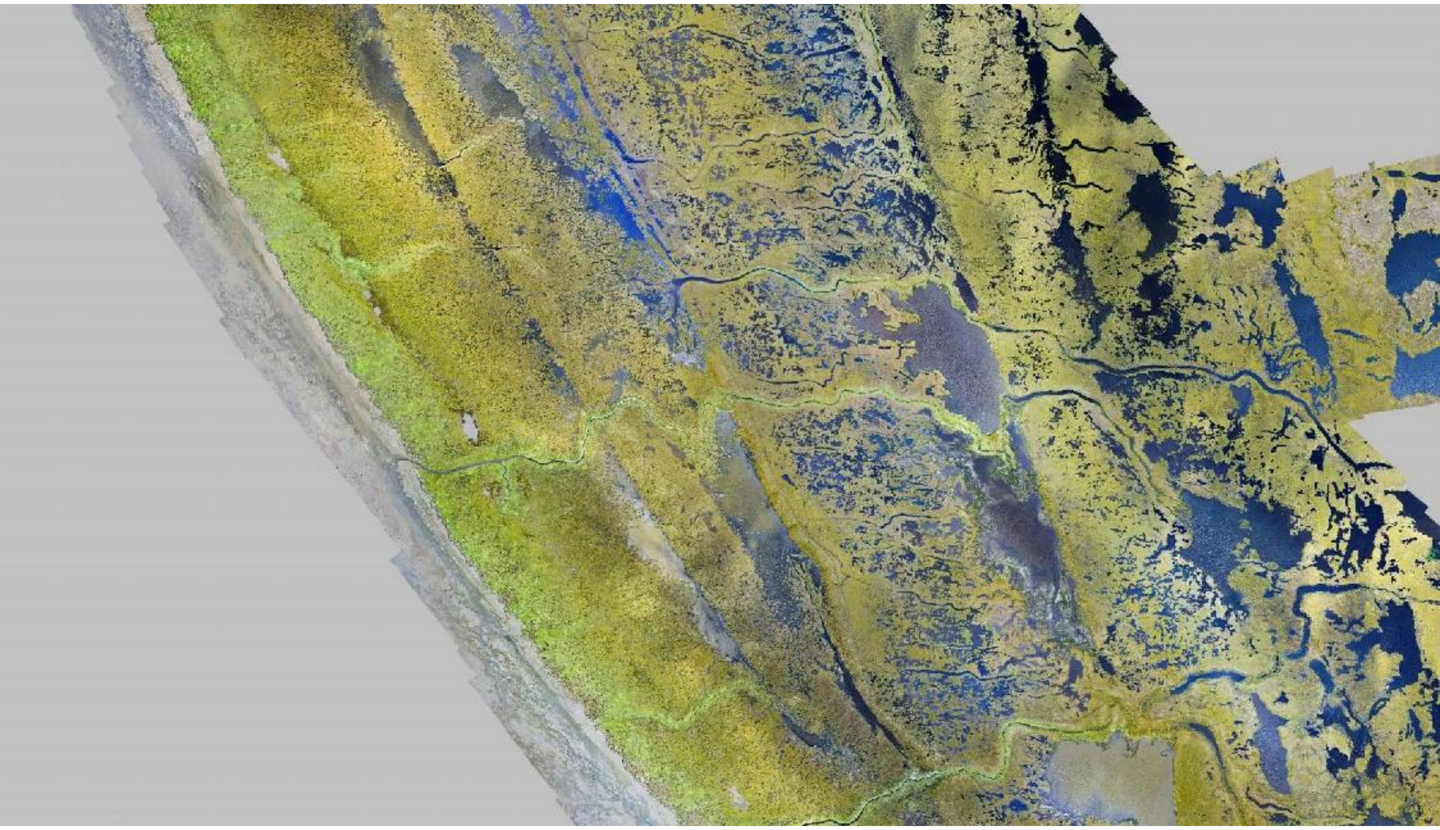
Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.



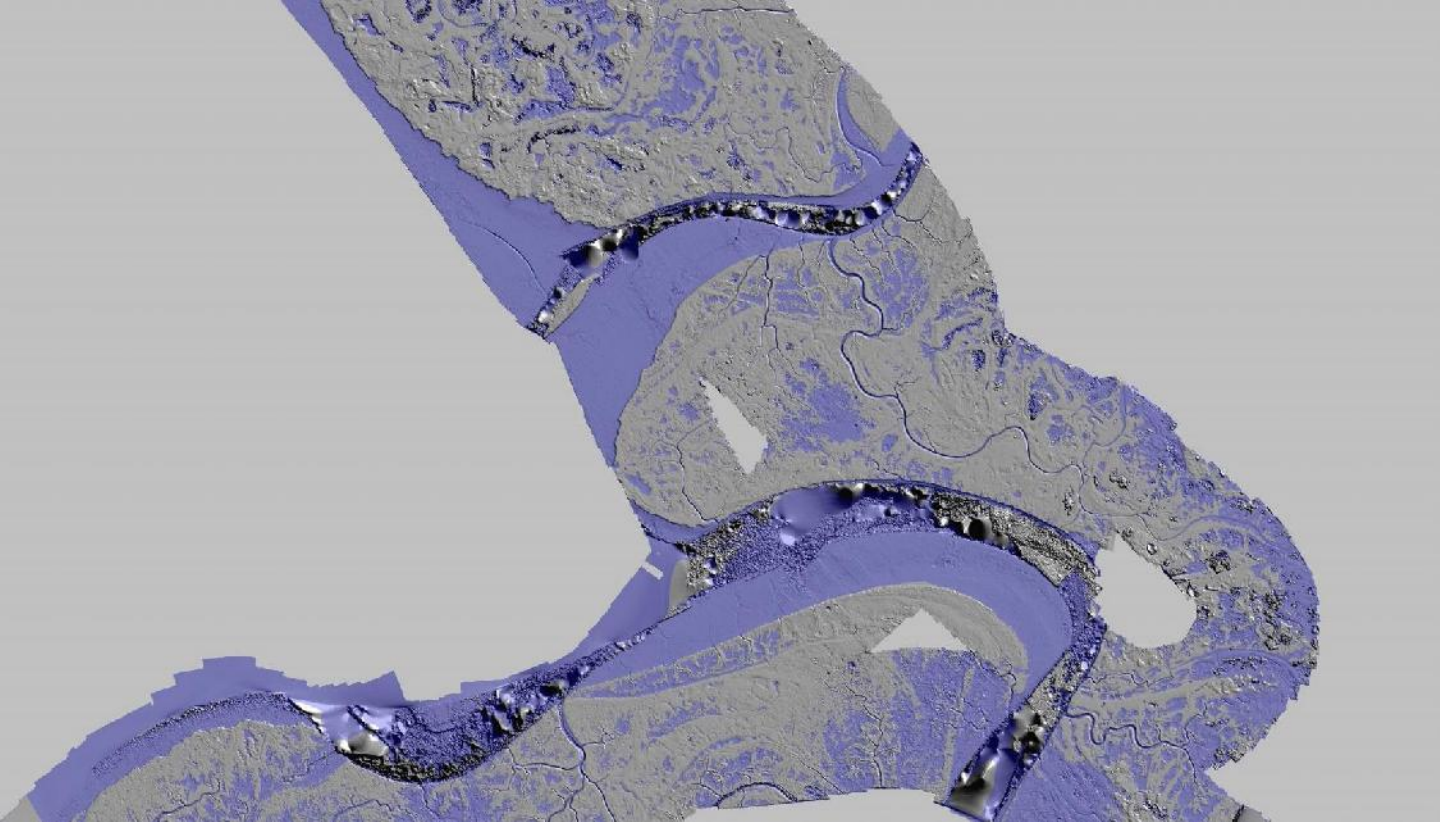


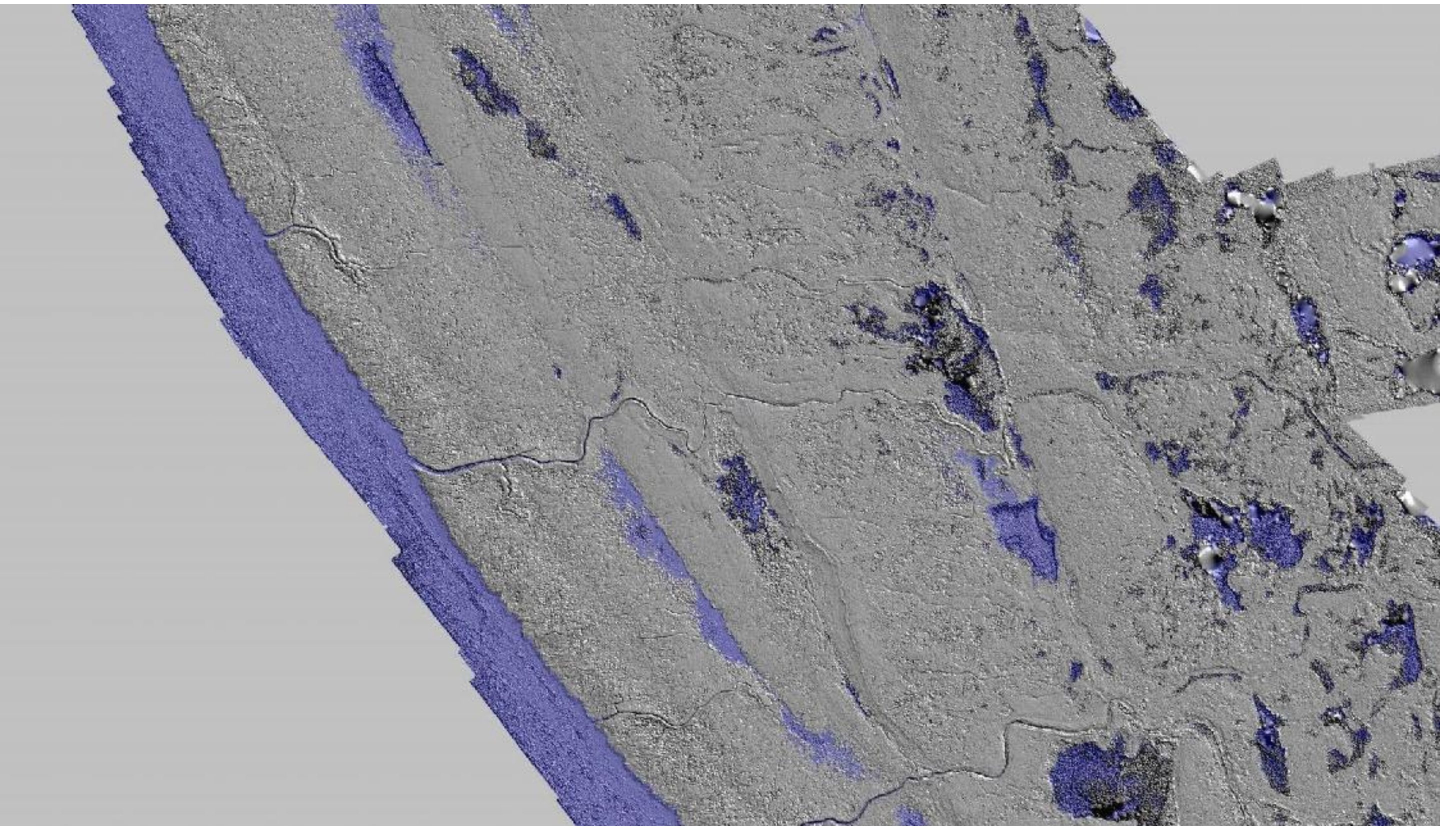
Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.



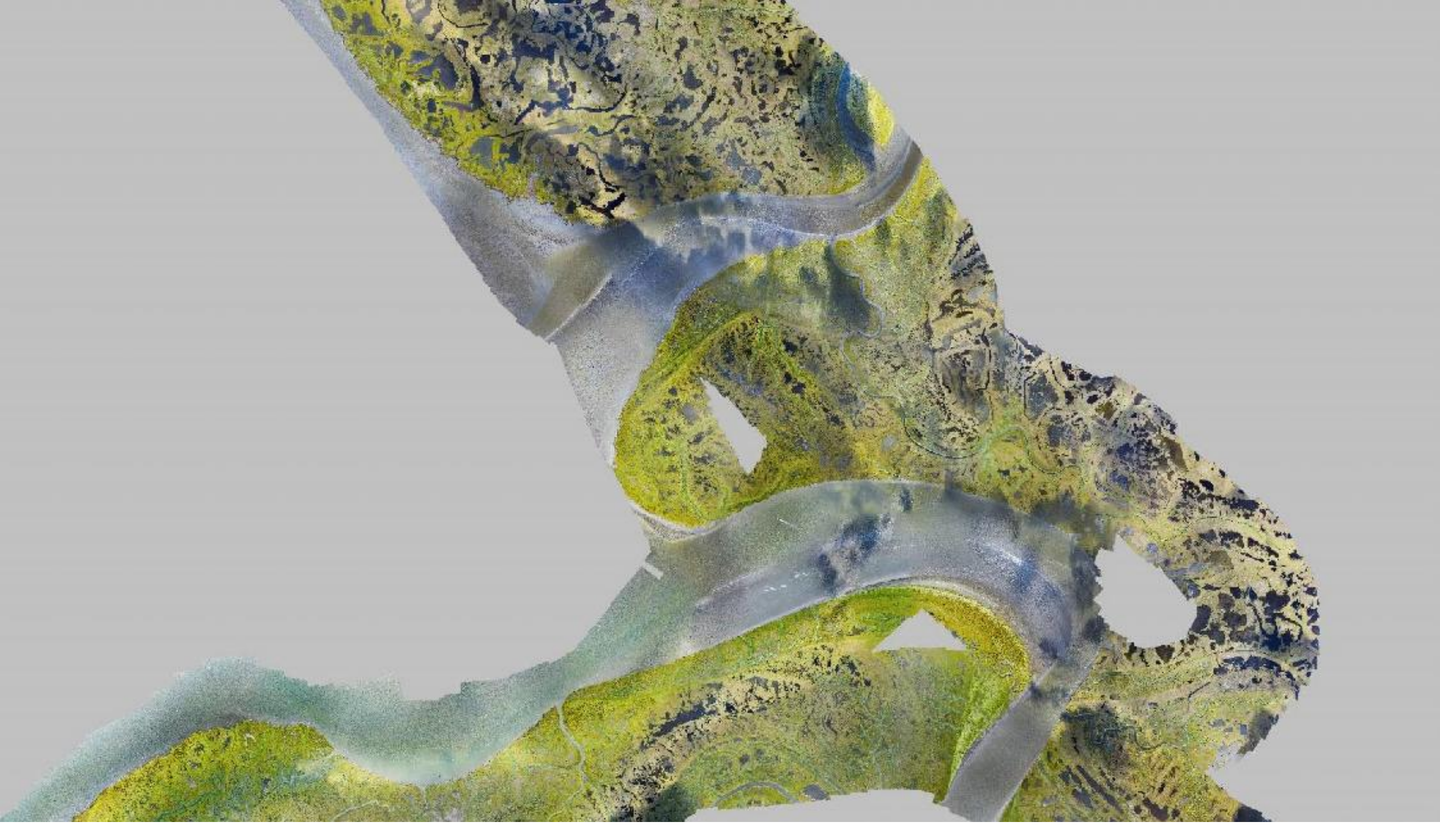


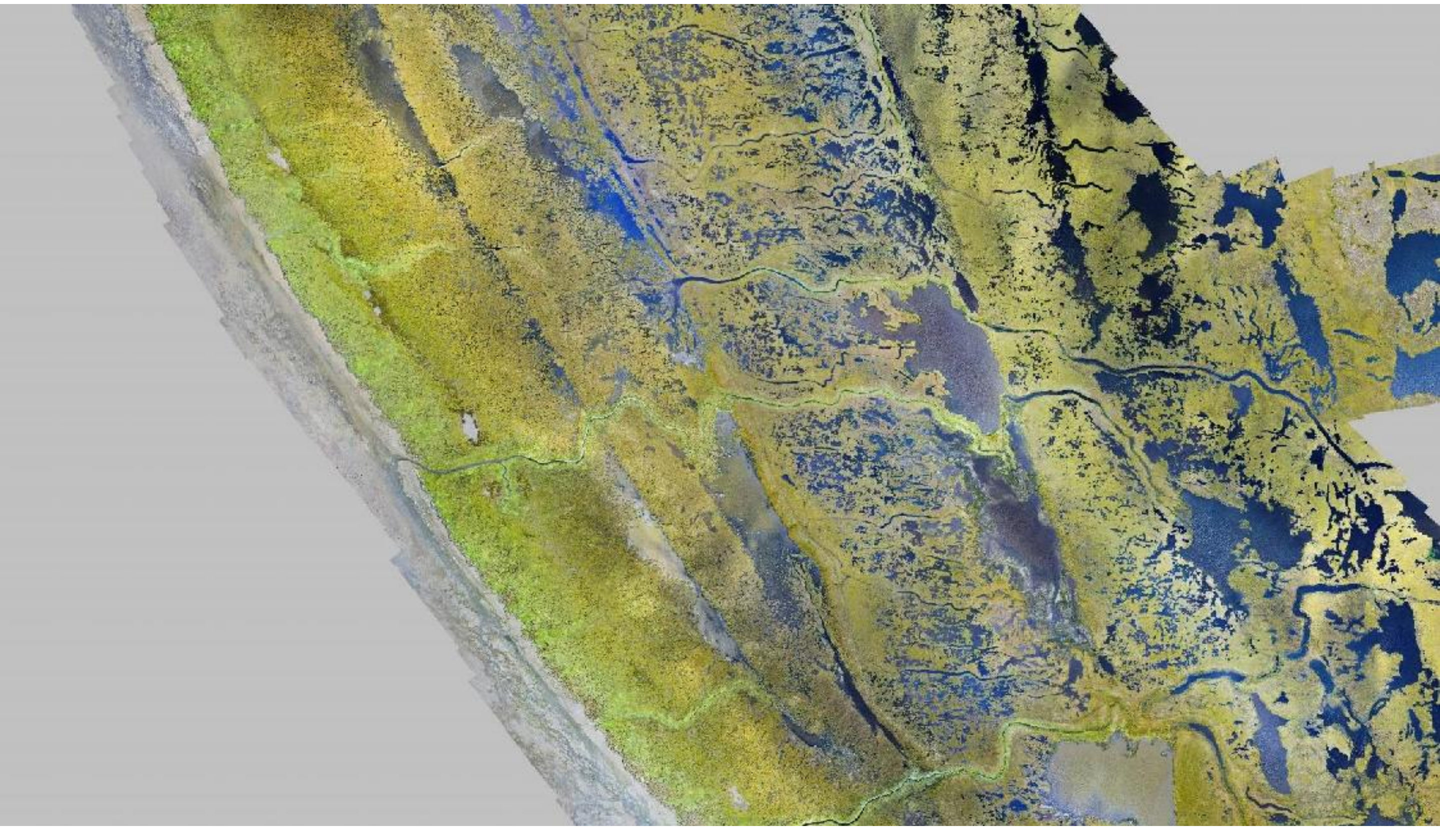
Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.





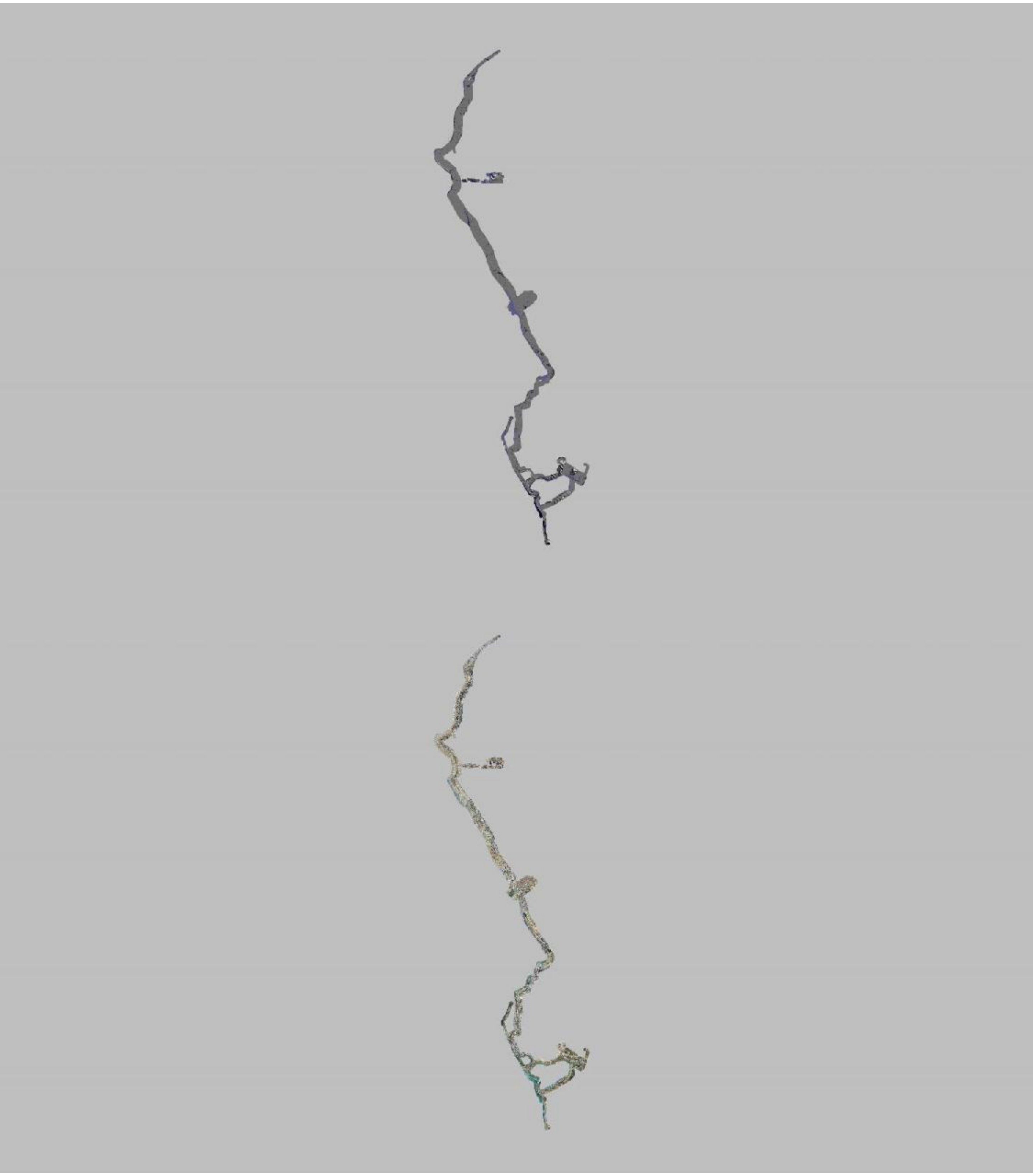
Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.





Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

Goodnews Block

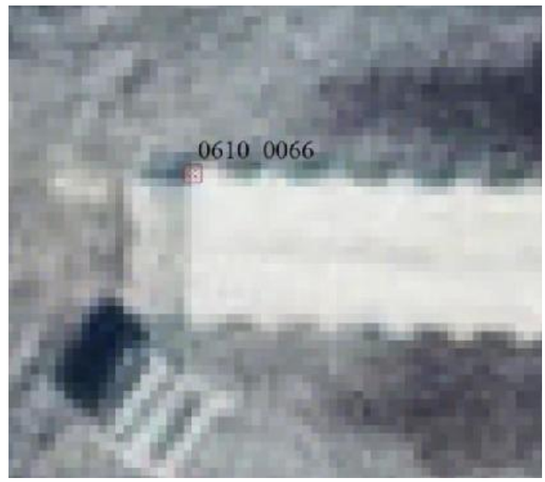


GCPs


0610 0061


0610-0065


0610-0062


0610 0066

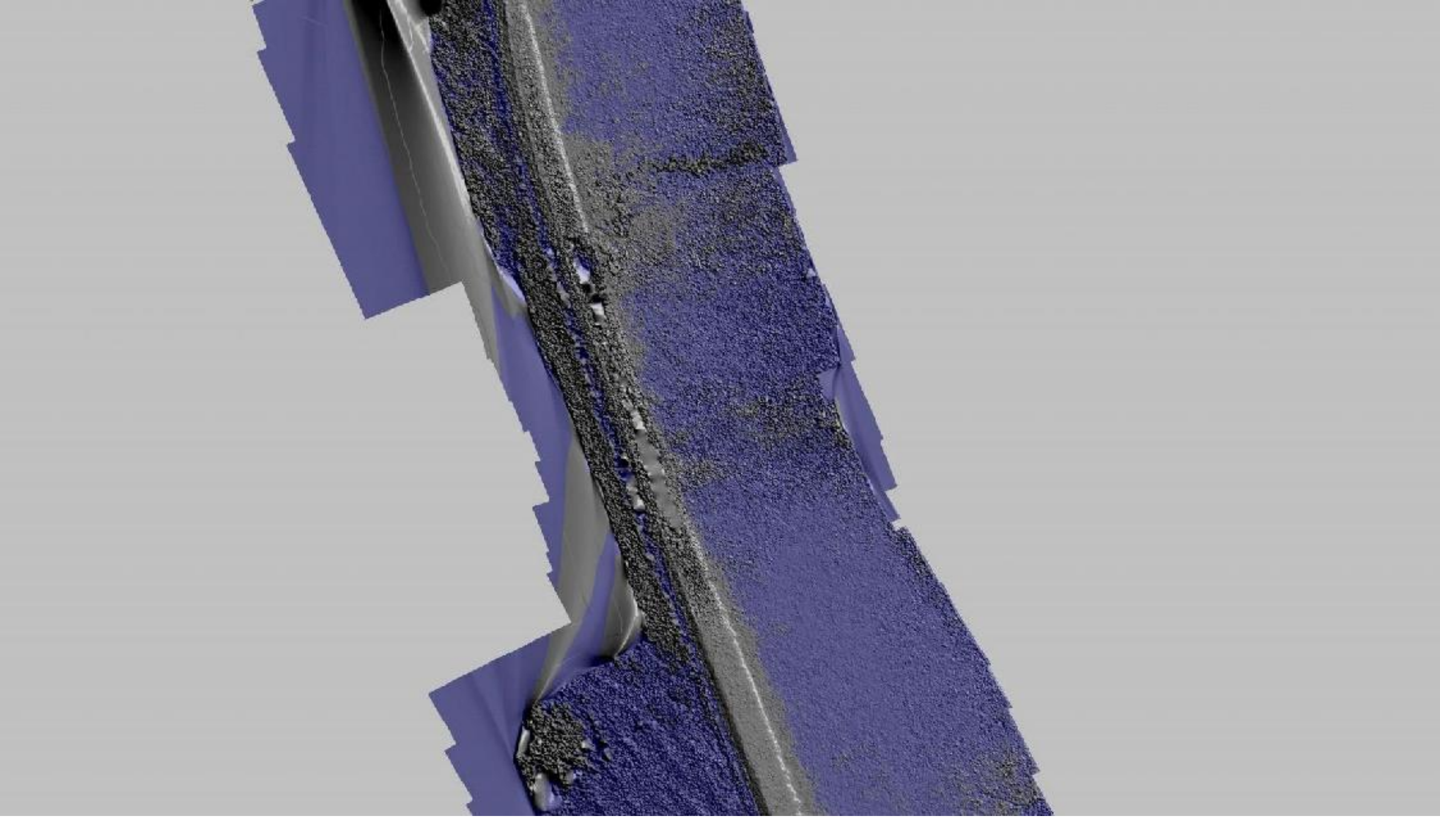

0609_003

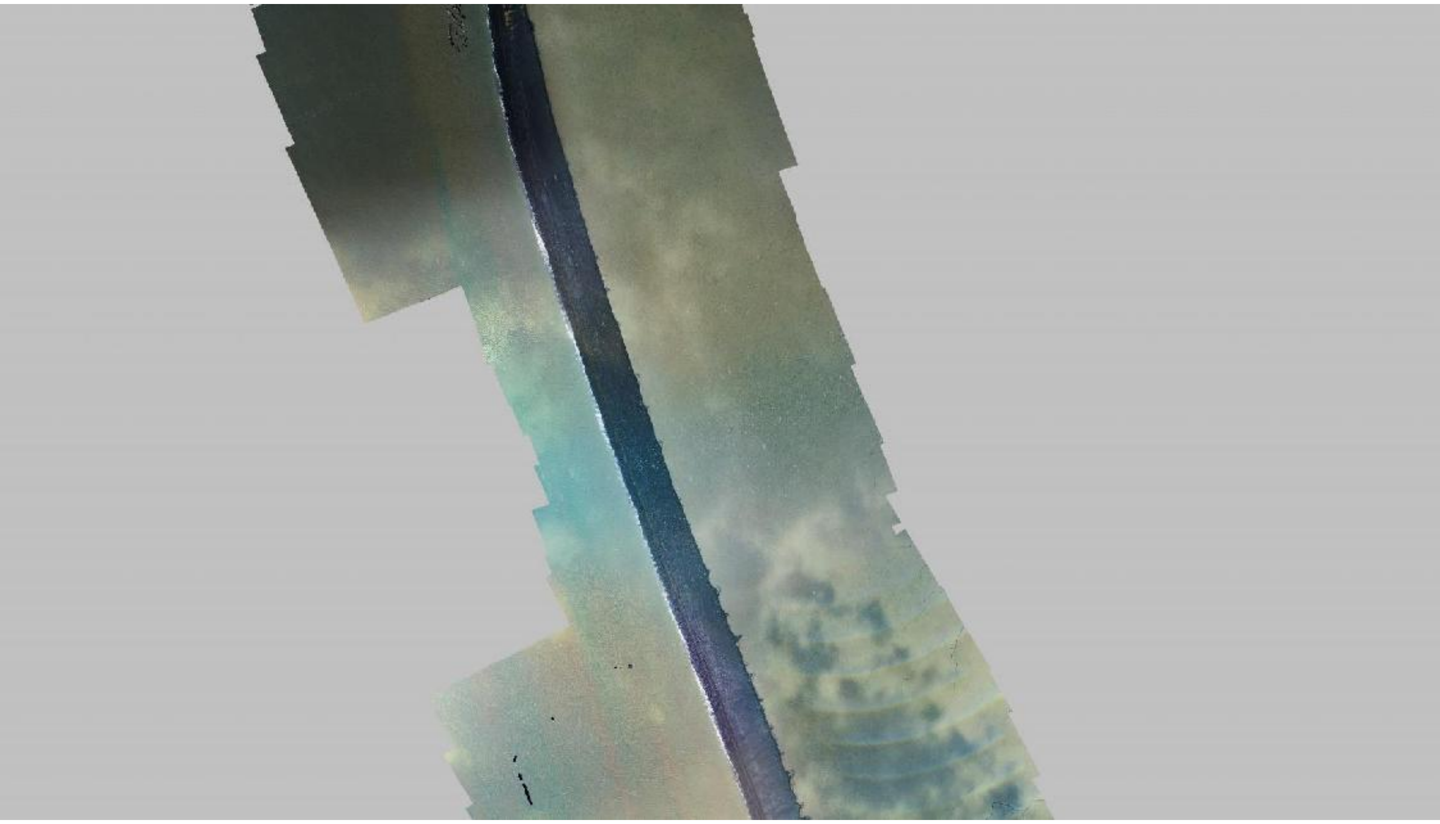

0609_001


0610 0057

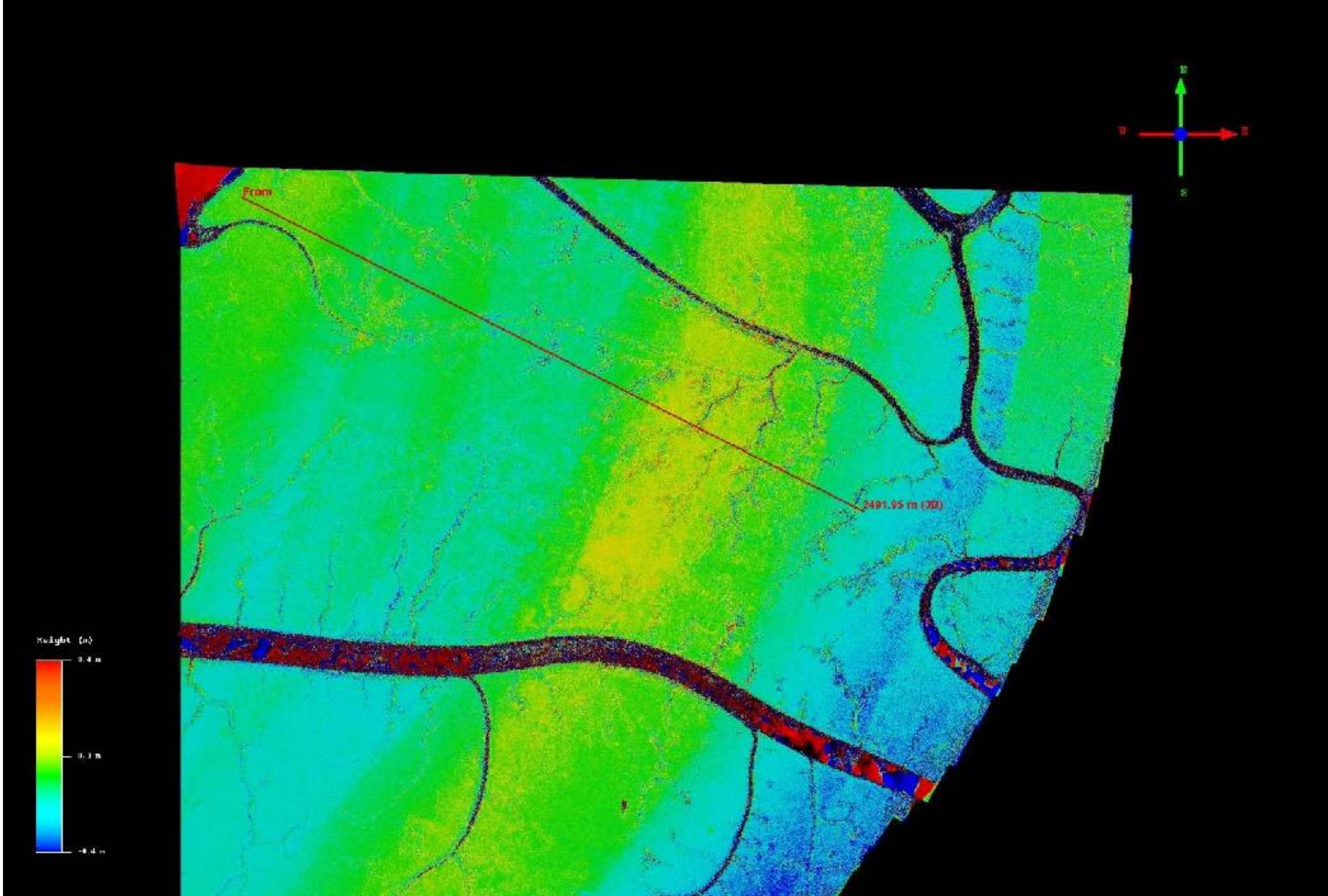

0609_0014

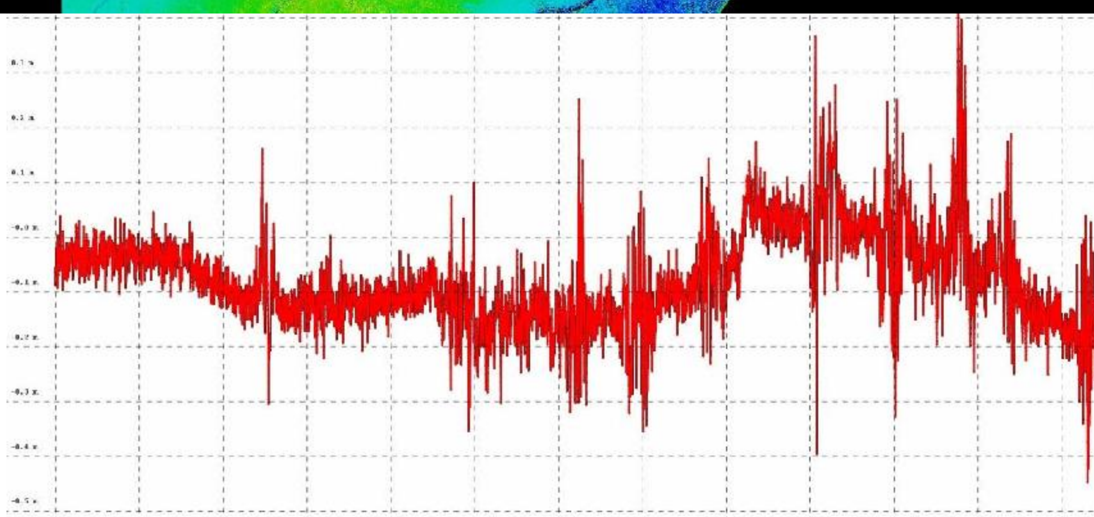

0610_0063



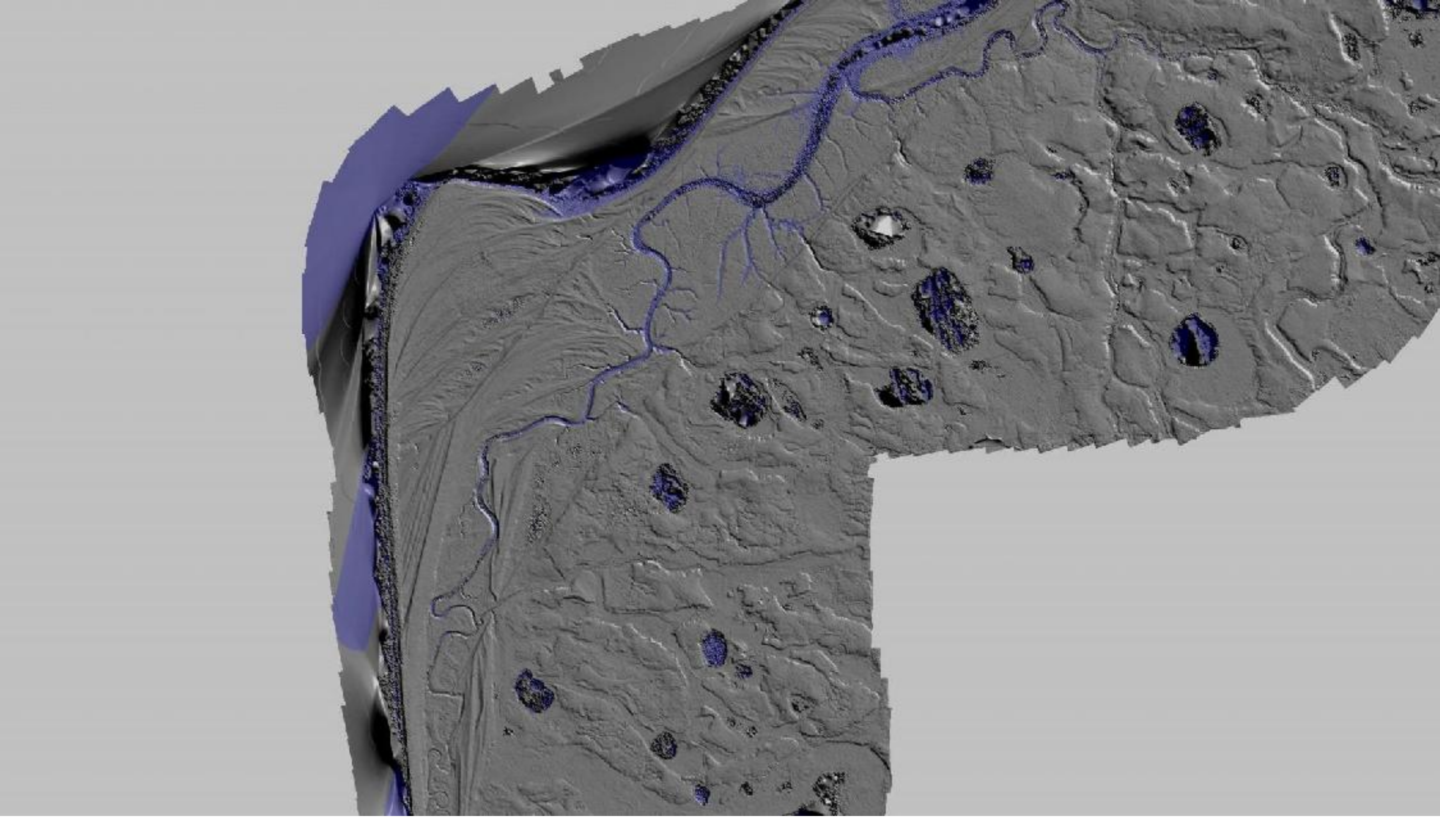


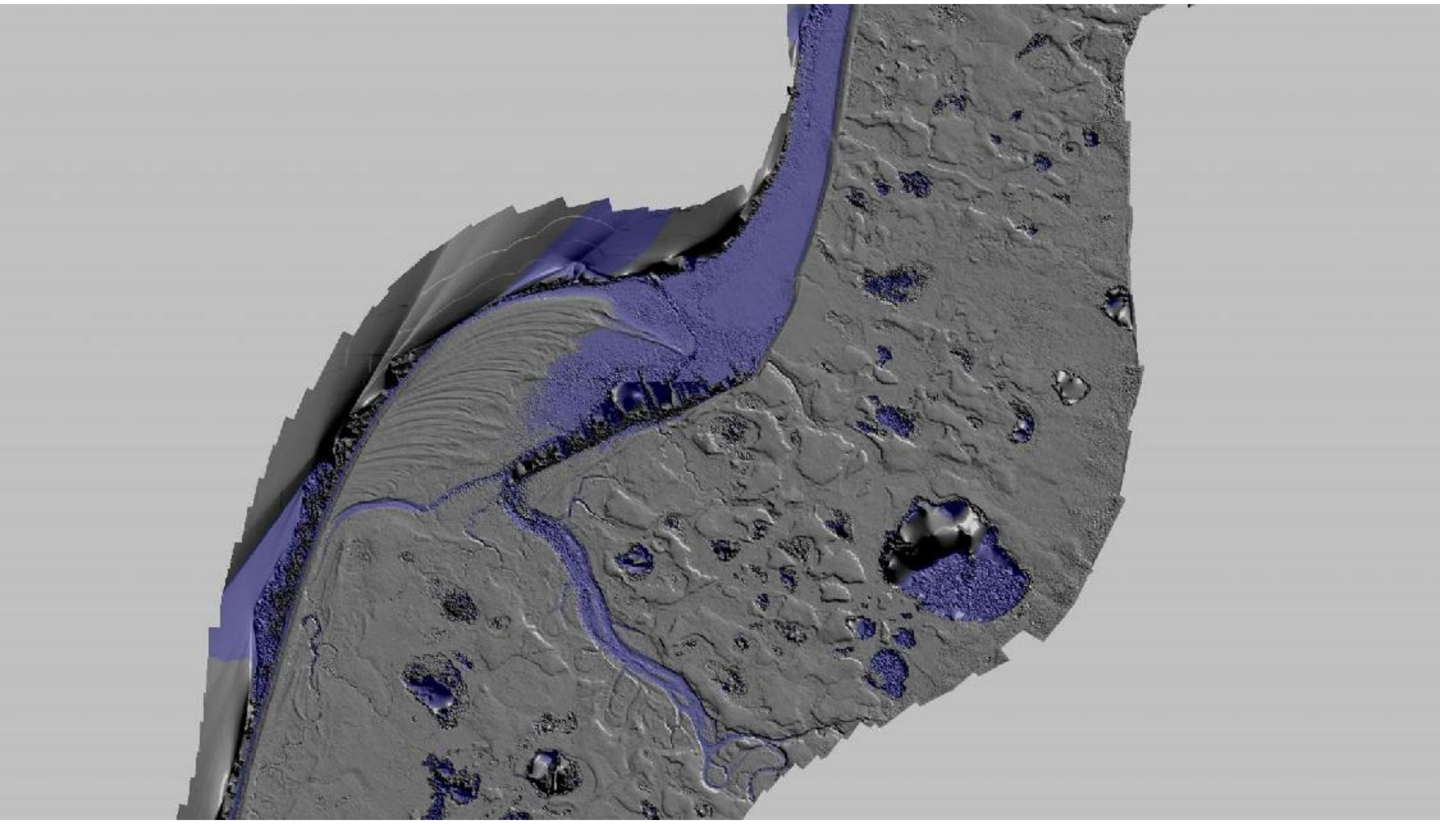
The biggest artifacts in this block is along this spit – there was a snow squall beneath a dark cloud in this stretch. You can actually see the snow in the orthomosaic, which remains unaffected by the problems with the DEM.



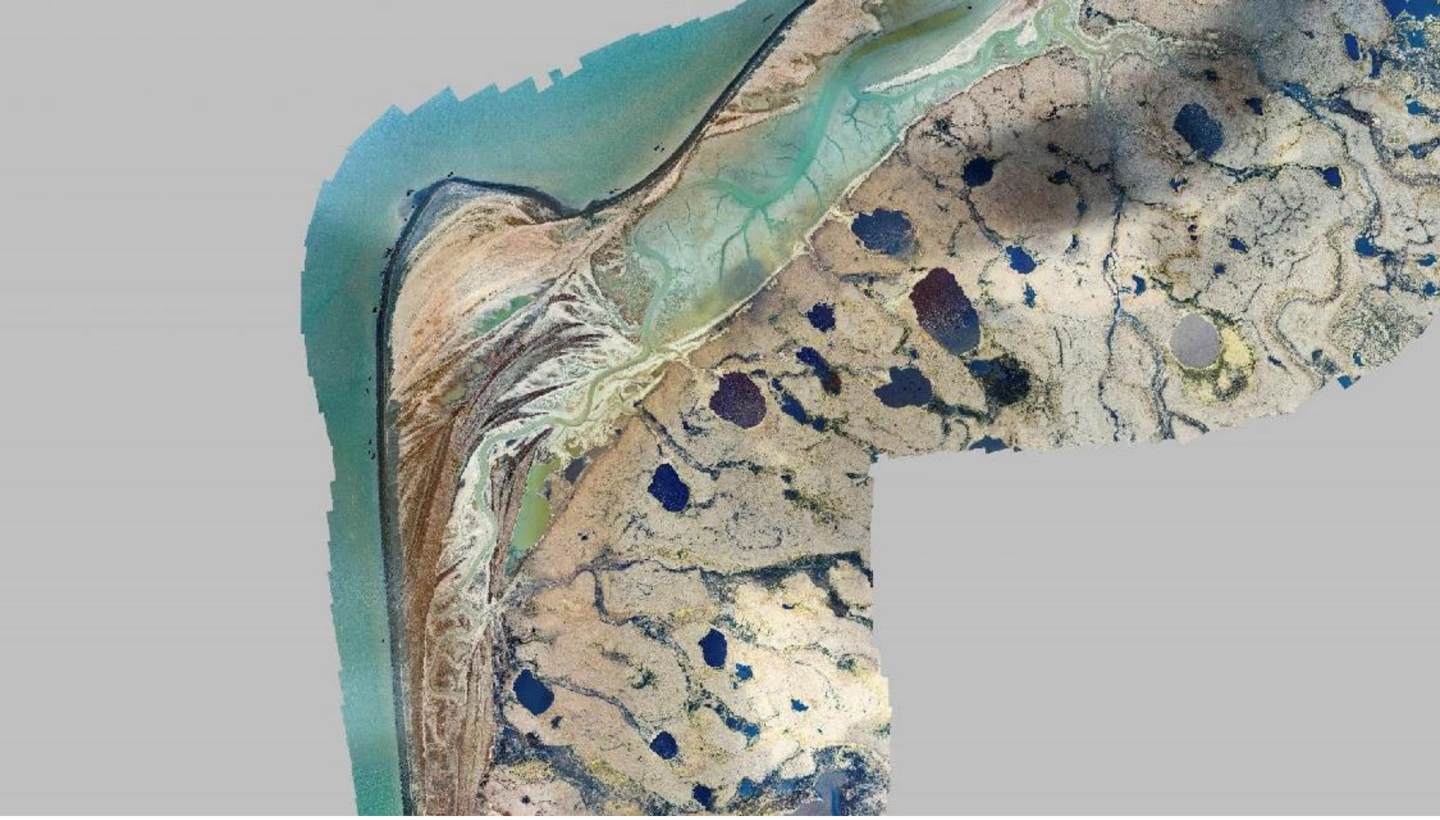


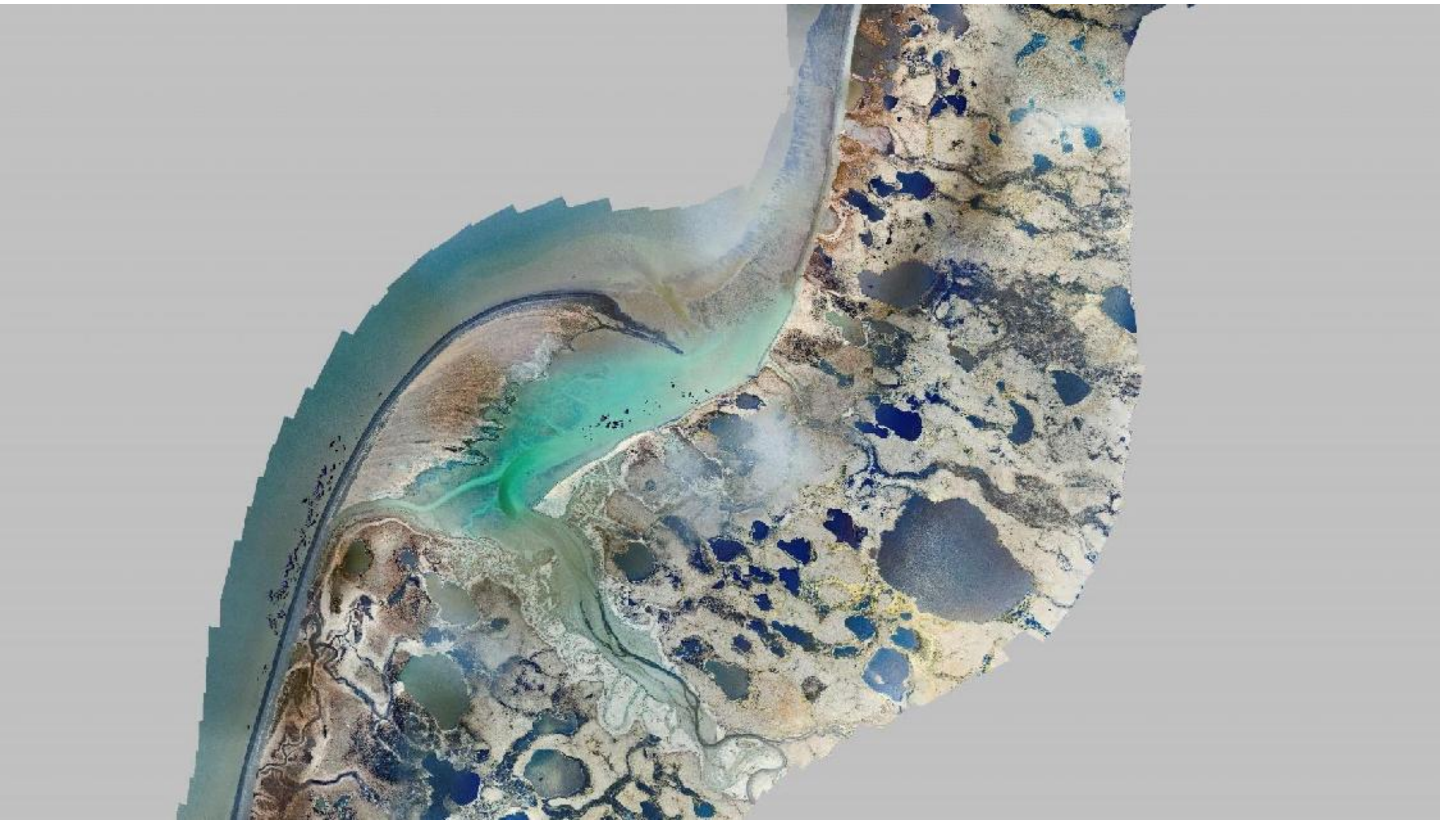
The northern half of the Goodnews Bay block was re-aligned using additional photos, technically making it a separate block, to save time compared to re-aligning the entire block. Here is the overlap between the northern and southern block. The northern block has already been shifted upwards by 75 cm, to minimize misfit here and with the GCPs. Some of the misfit seen here is spatially correlated with flight lines, though only on the order of 10-20 cm. Reprocessing both Goodnews blocks as a single unit would both eliminate this noise and need for vertical shift of the northern block.



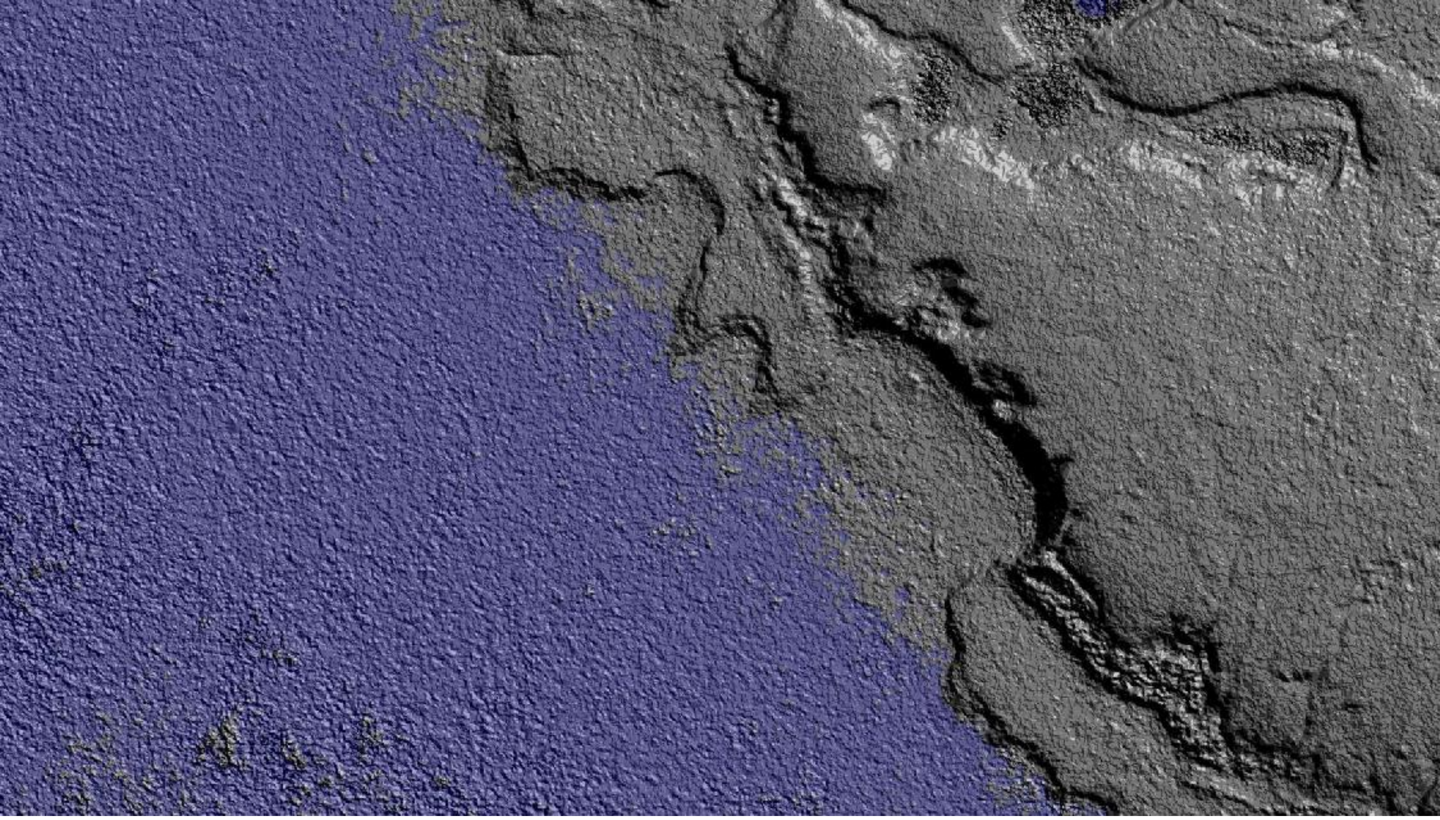


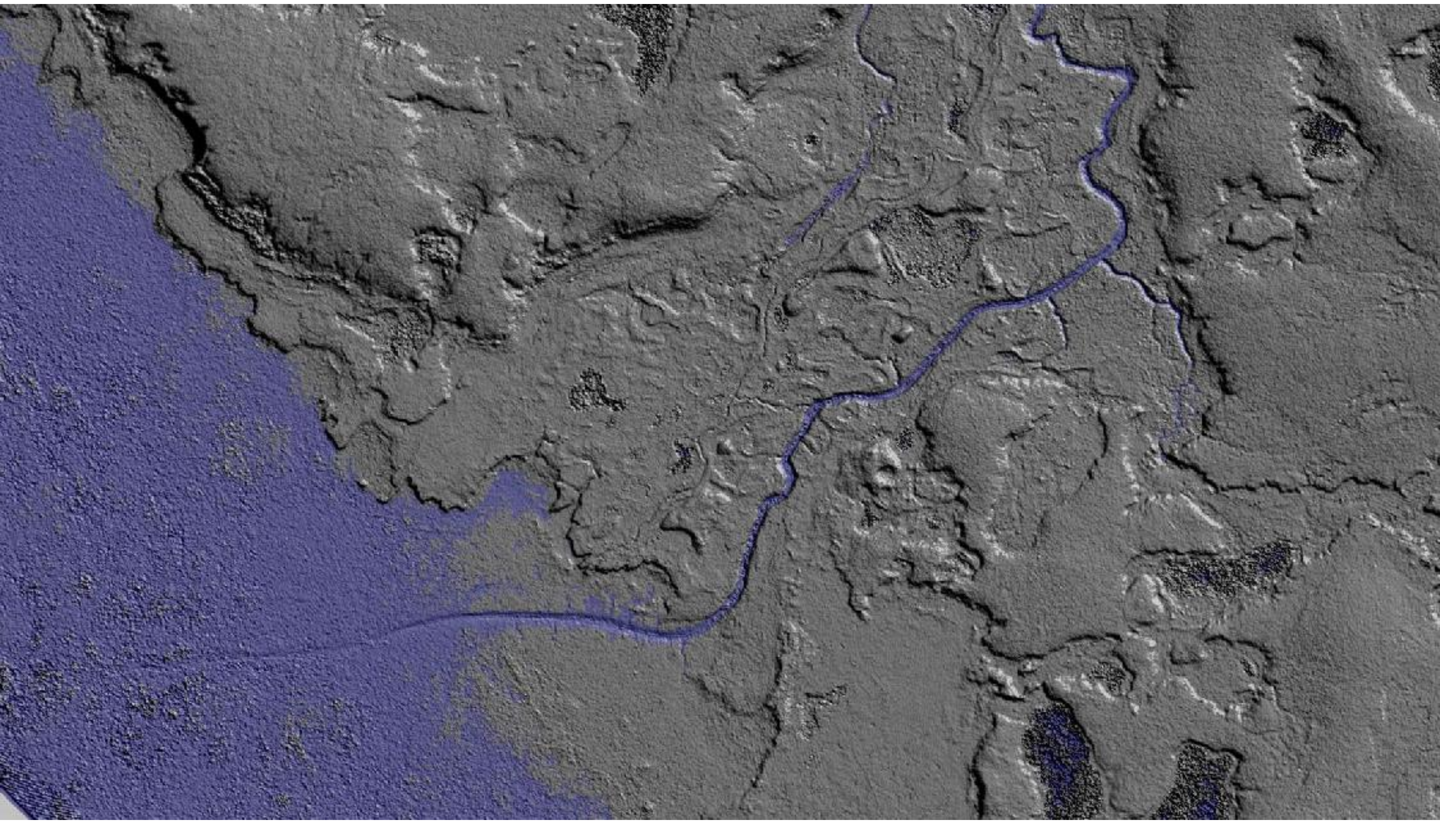
Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.



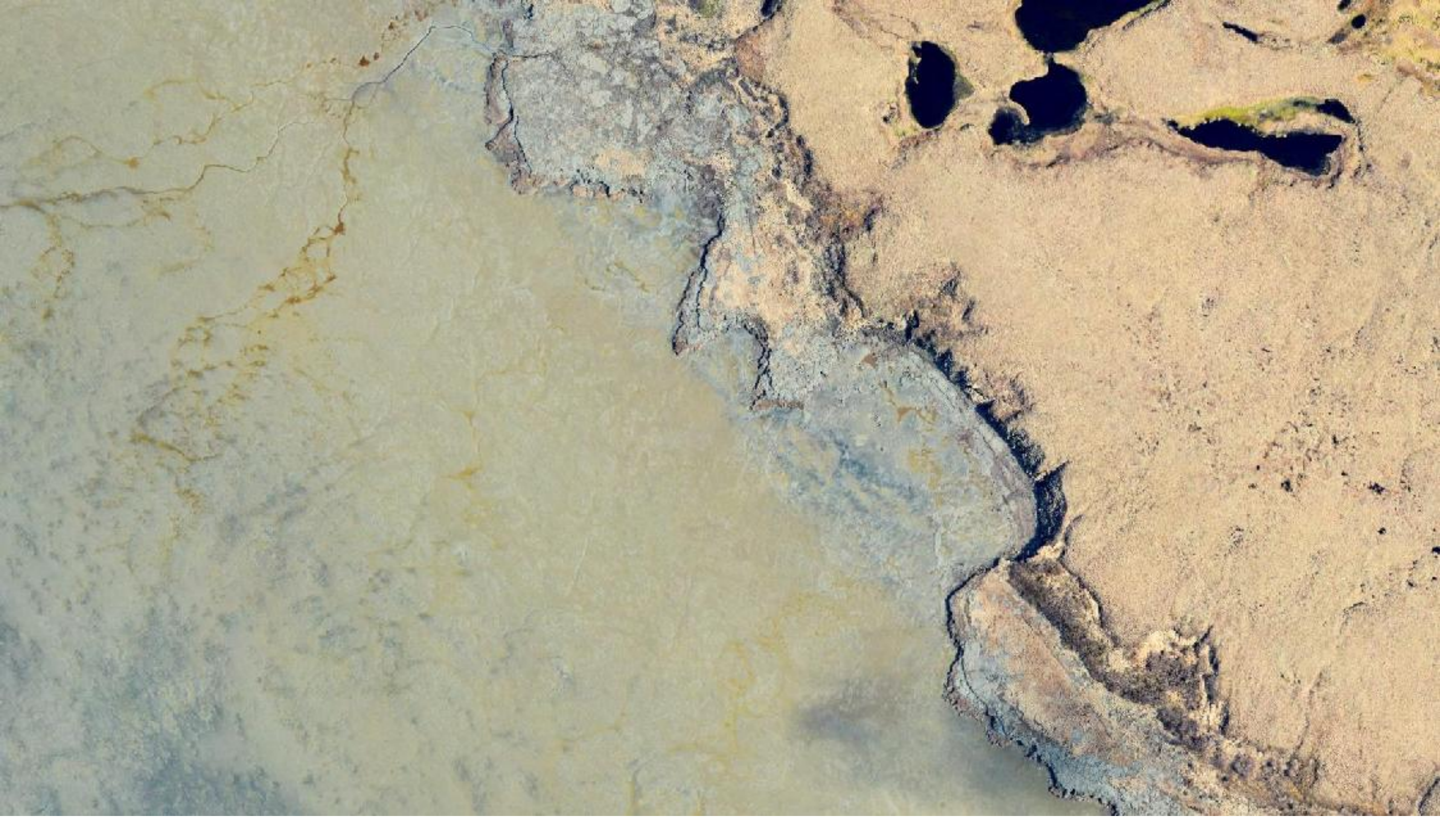


Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

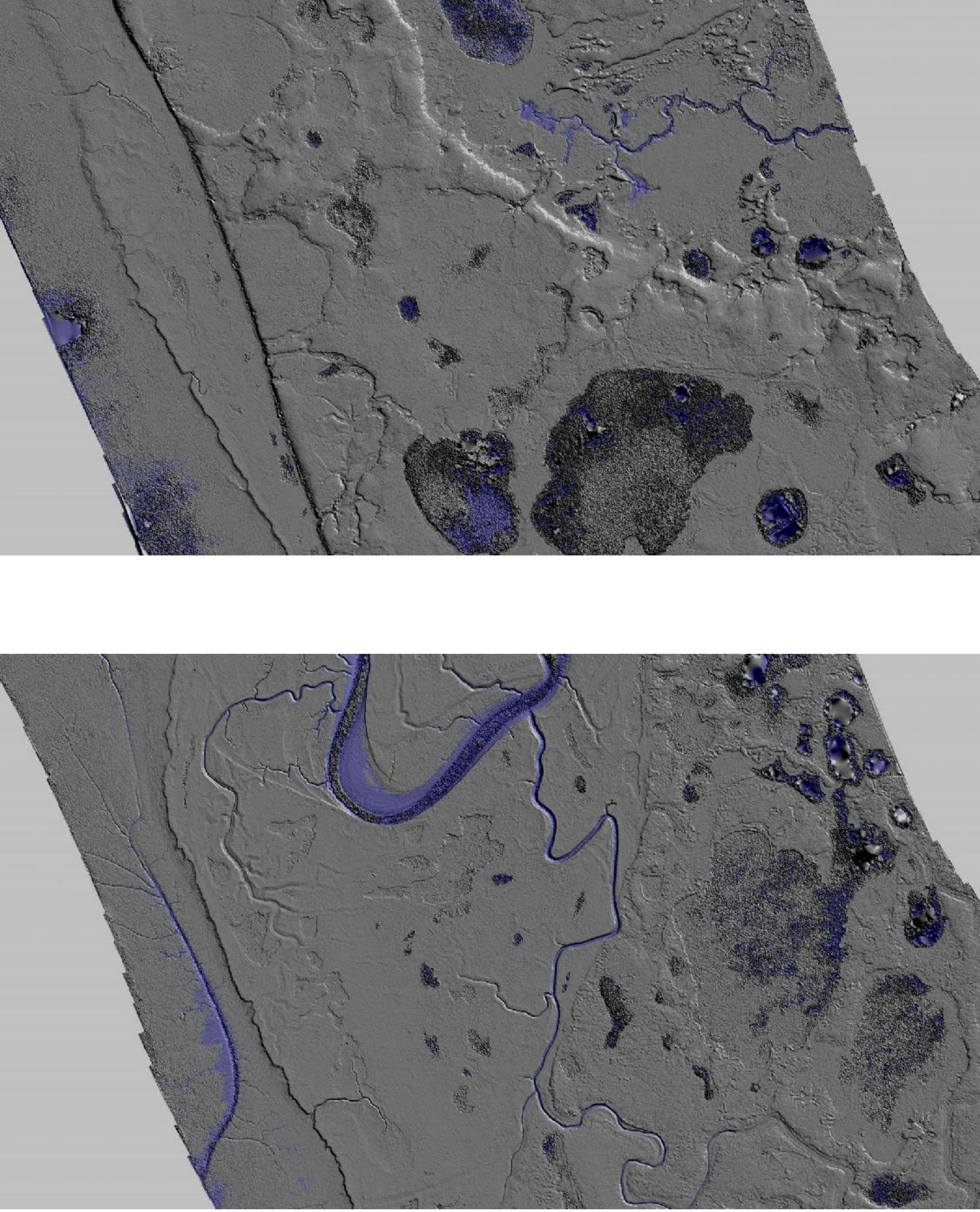




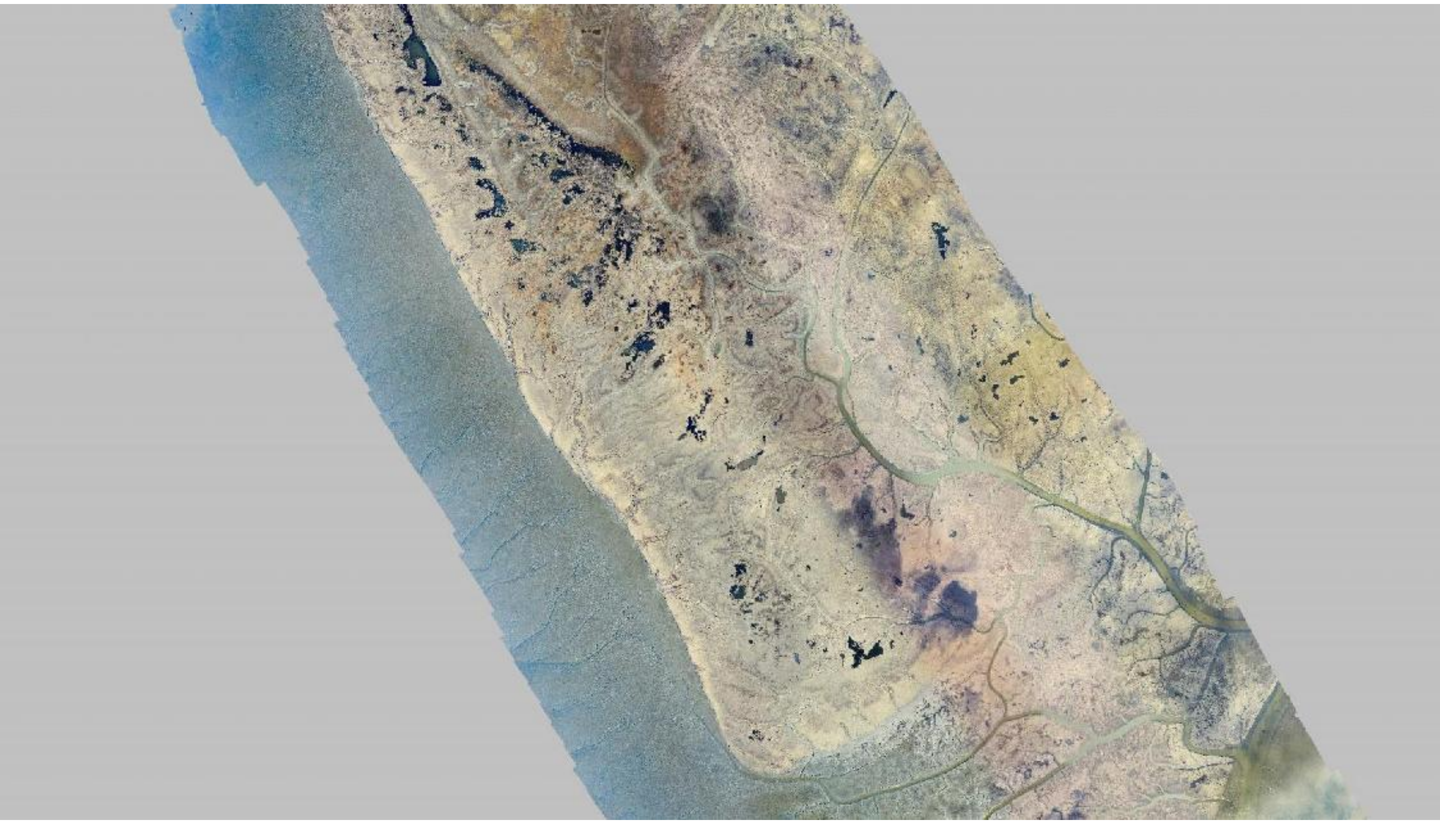
Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.



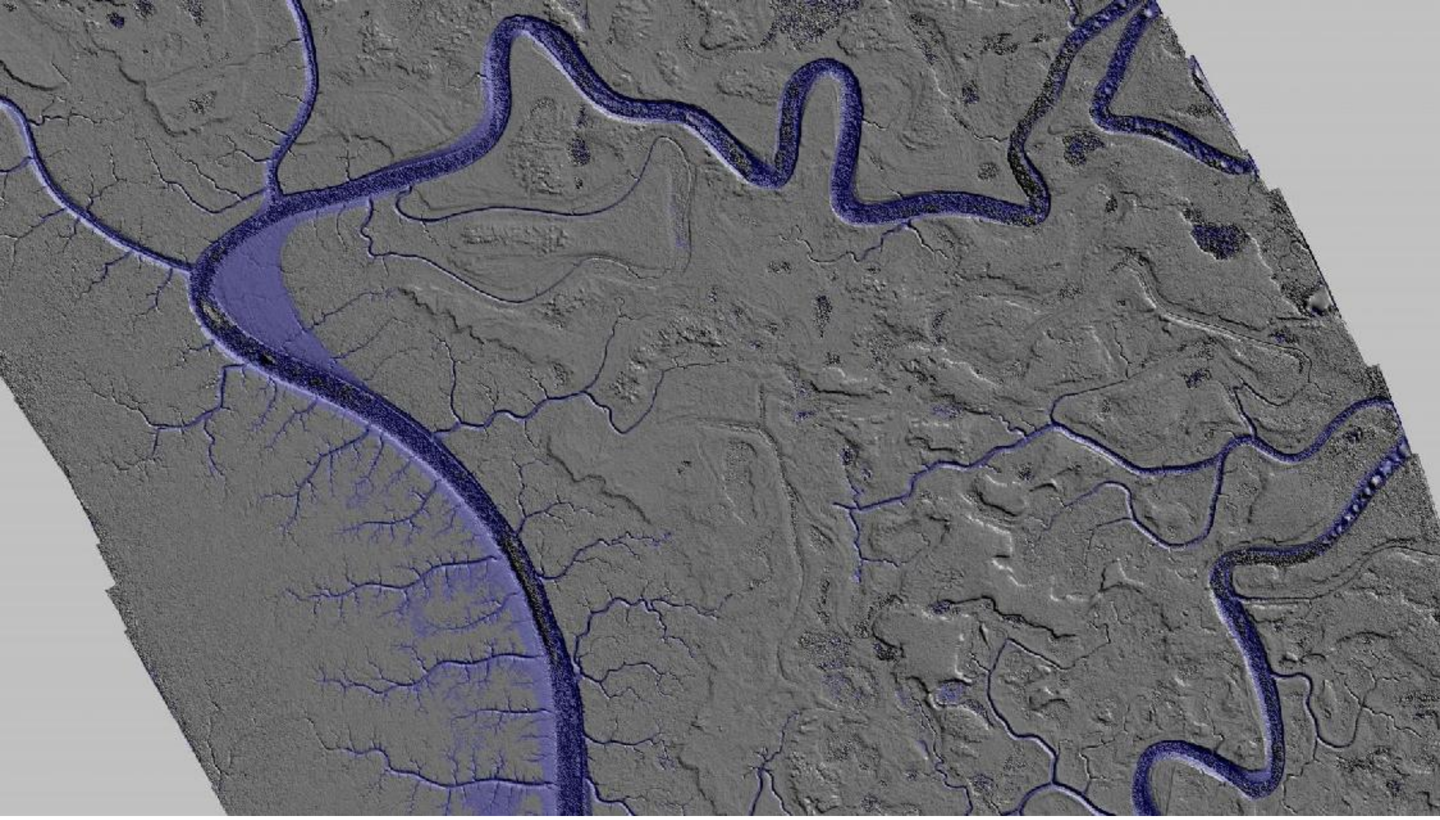
Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

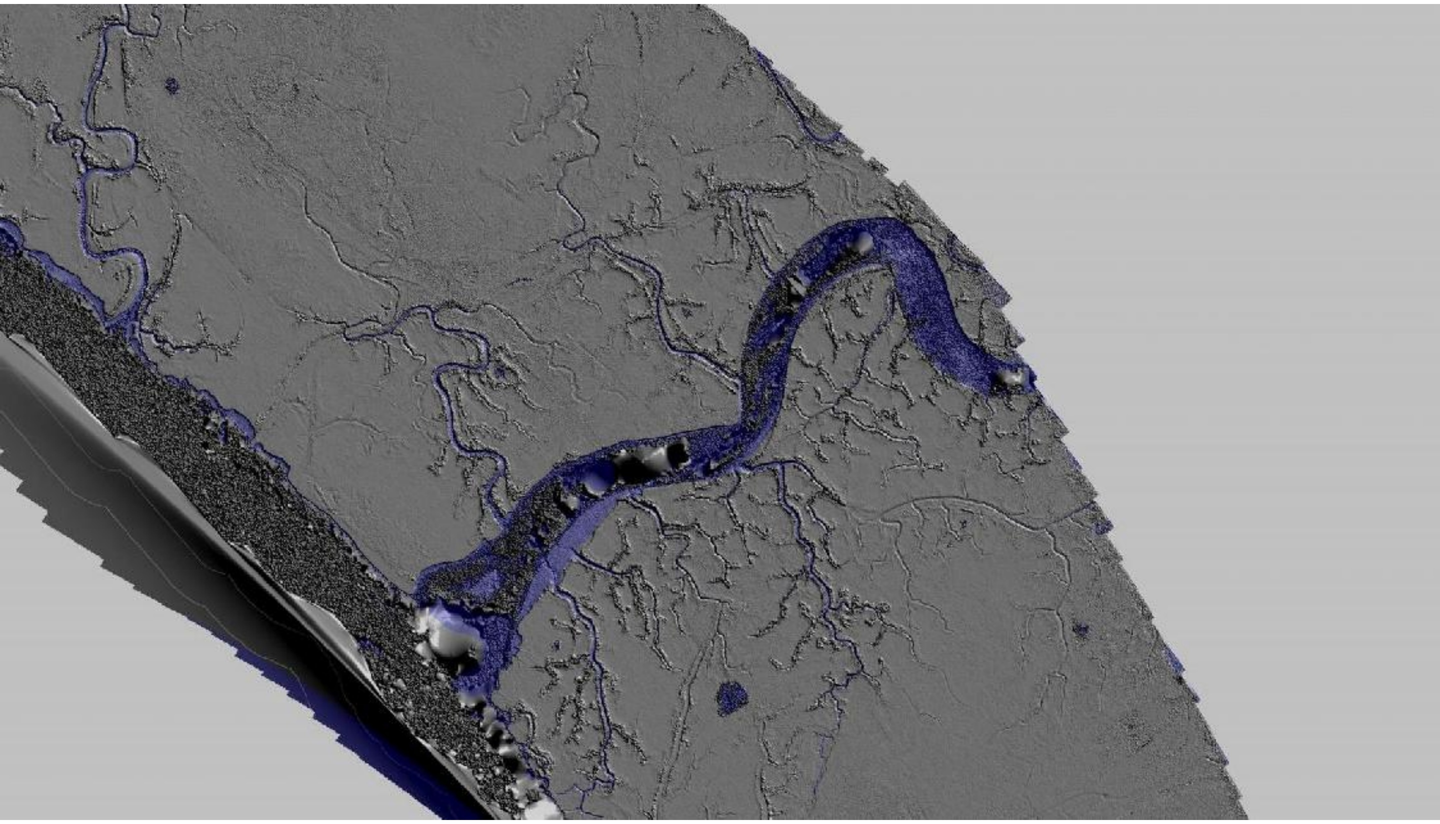


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

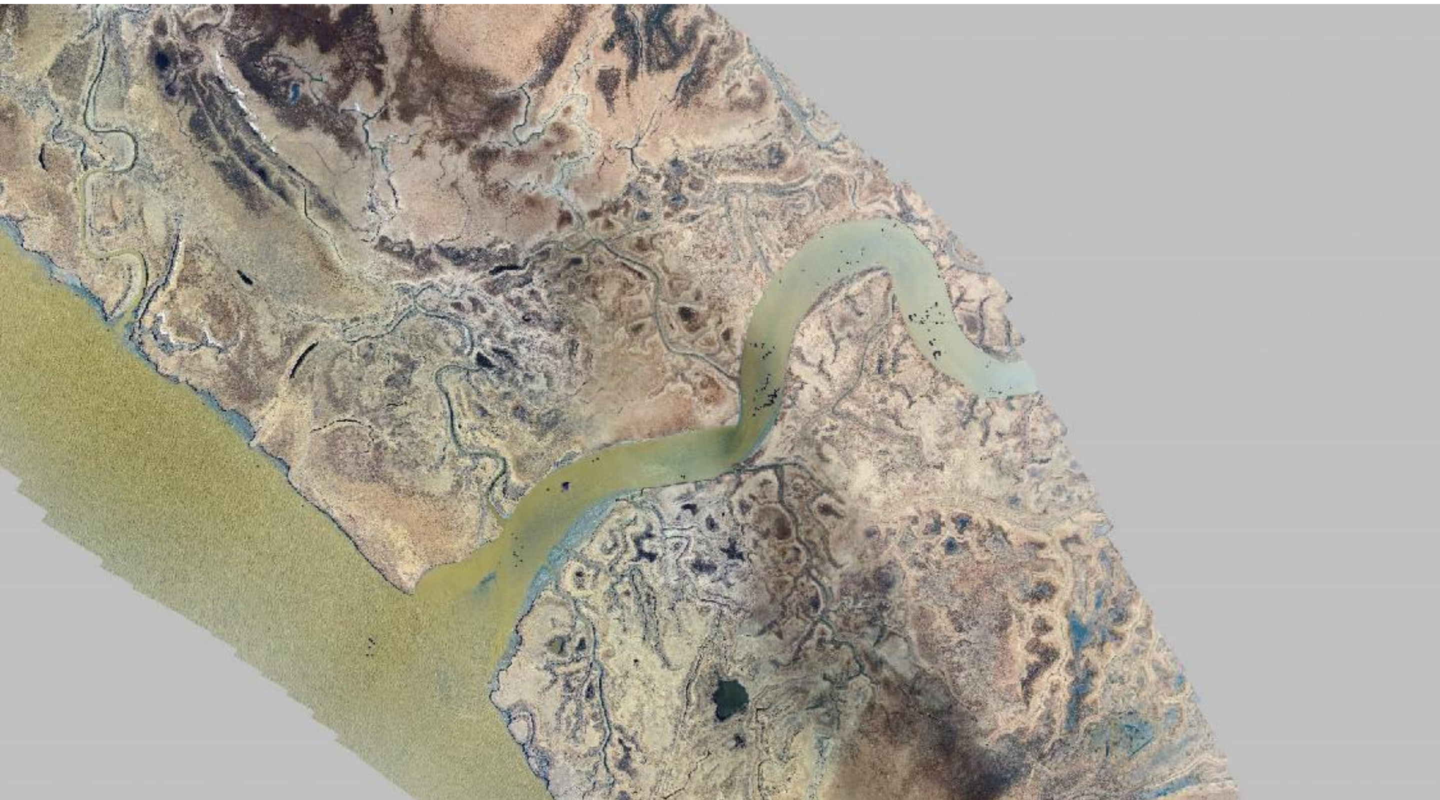


Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

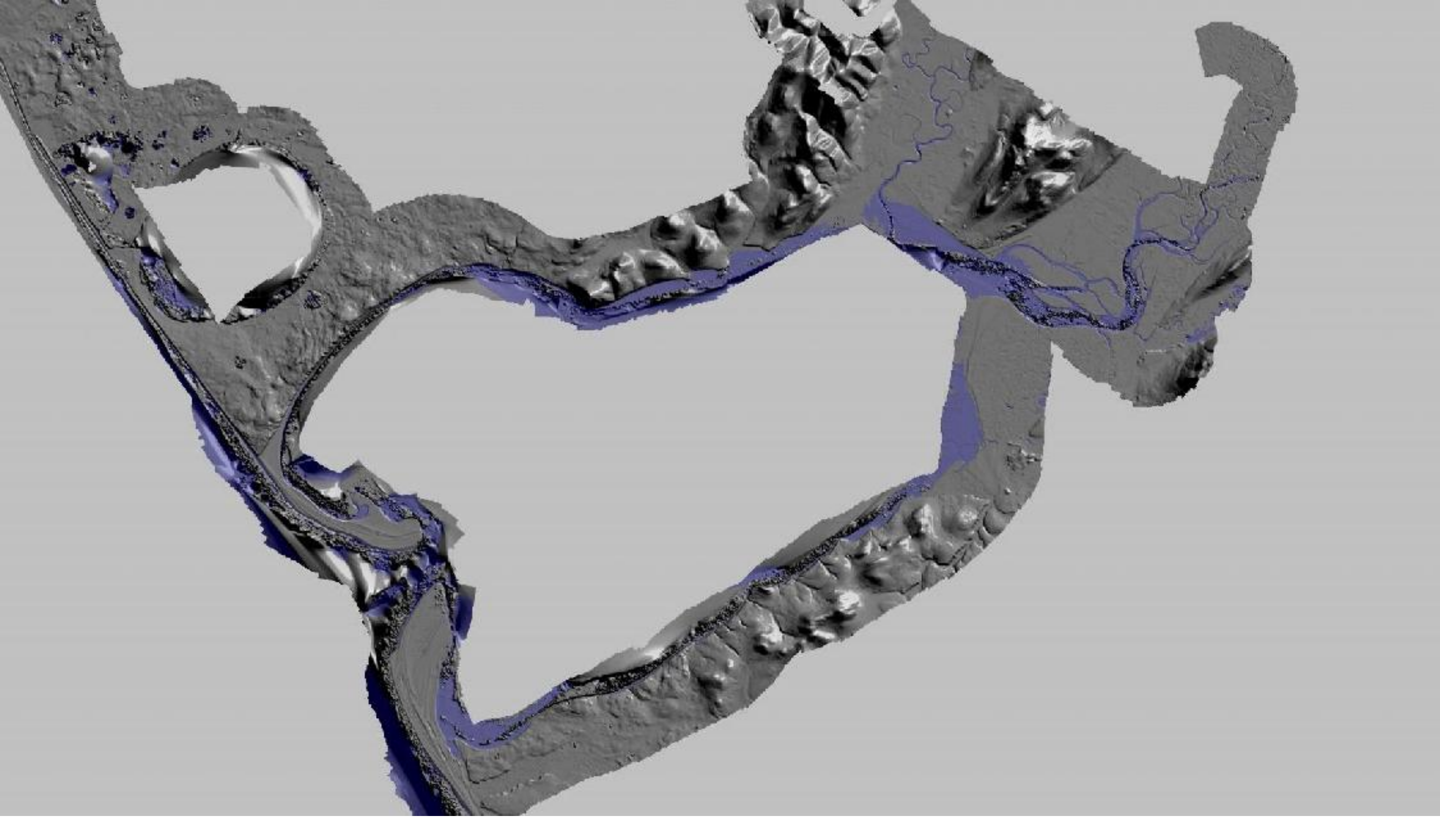


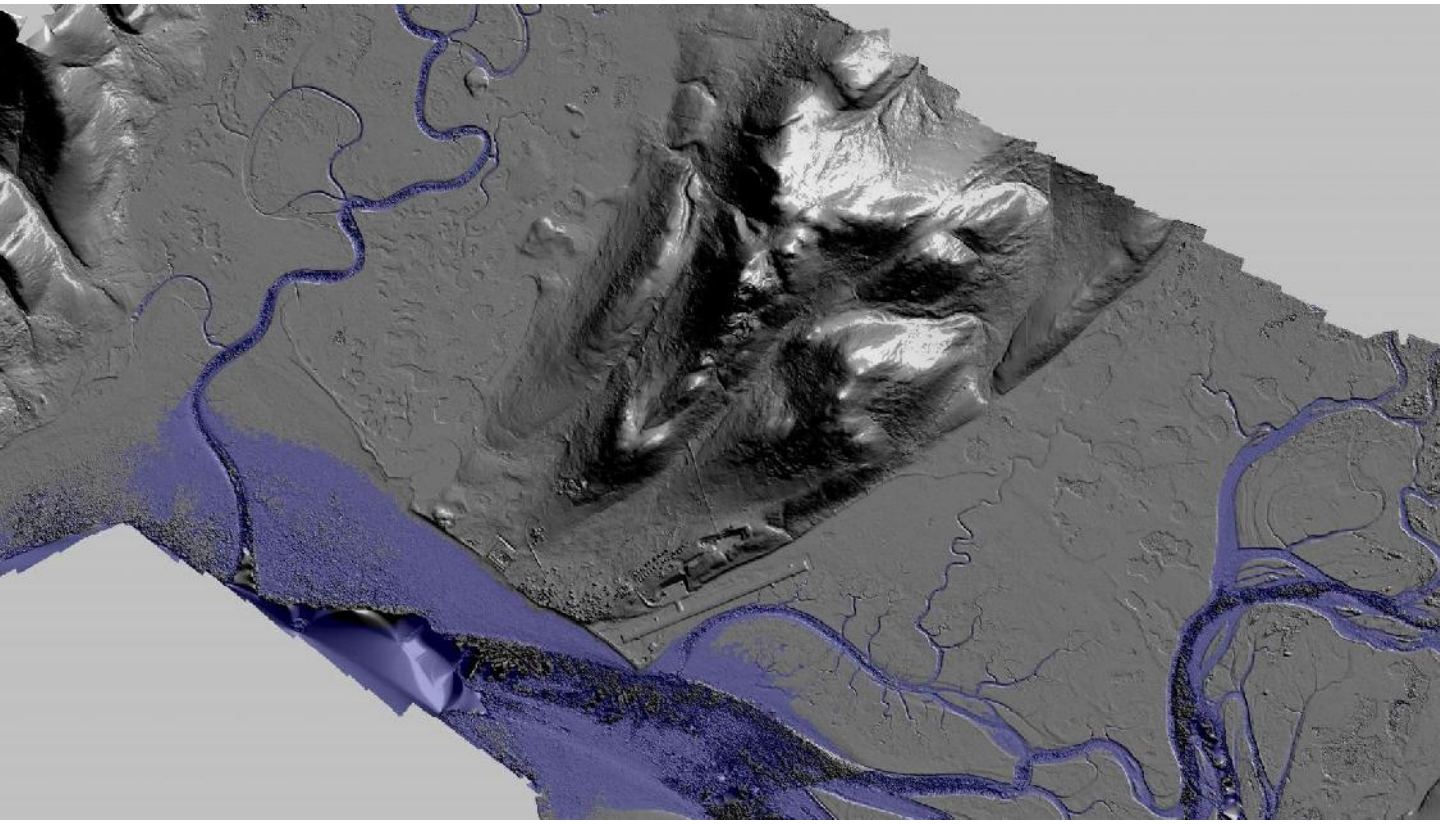


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

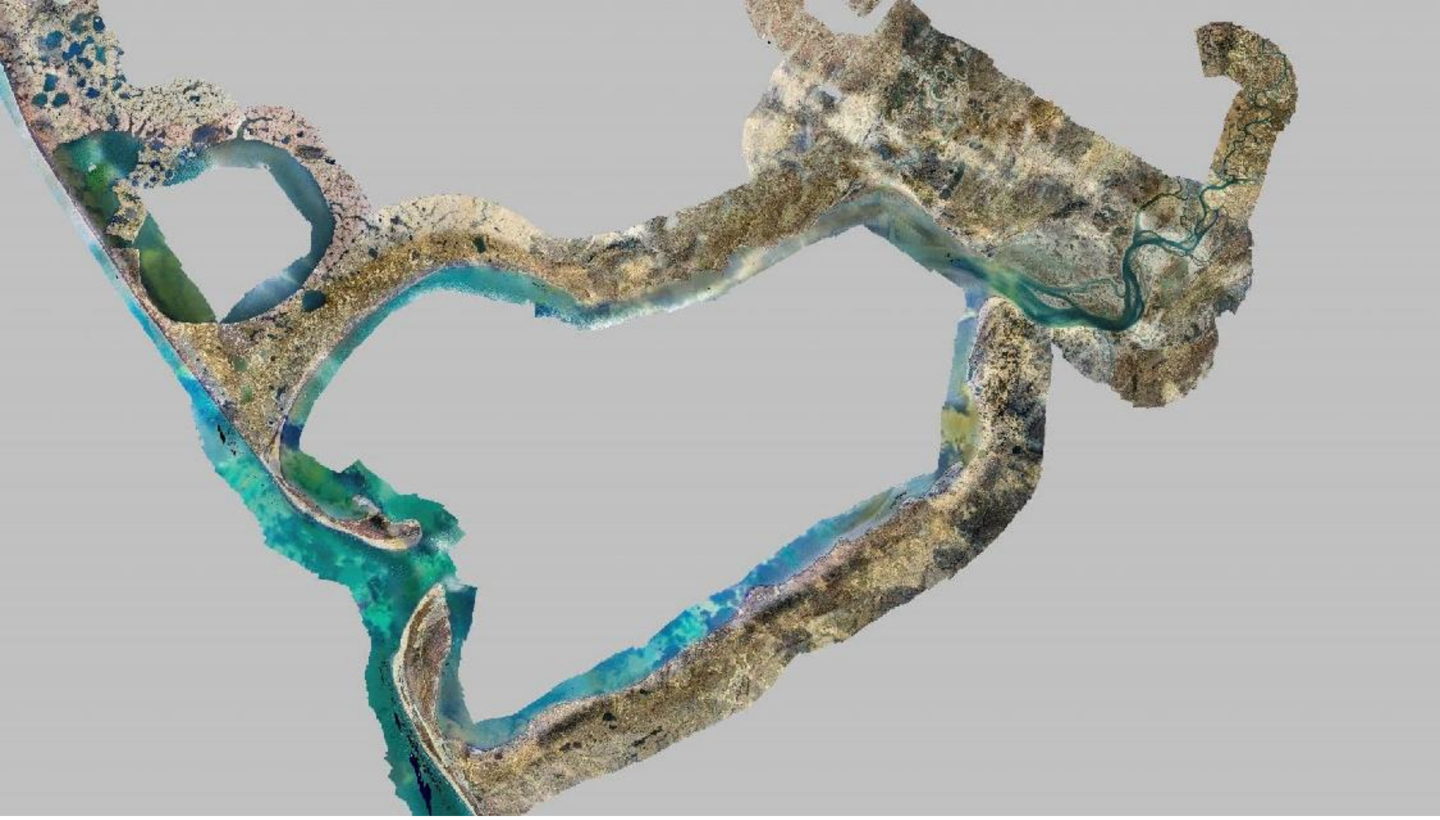


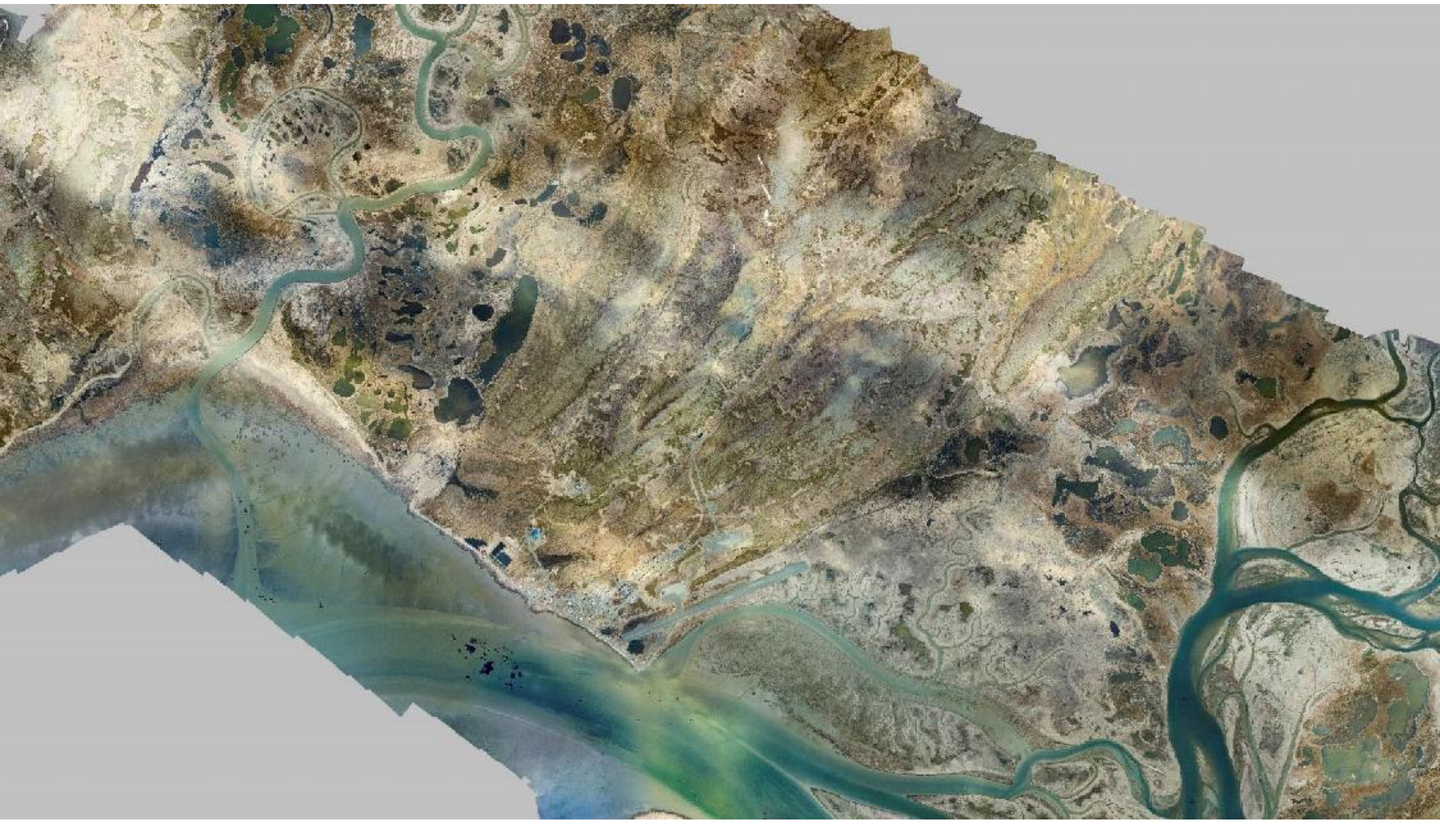
Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.



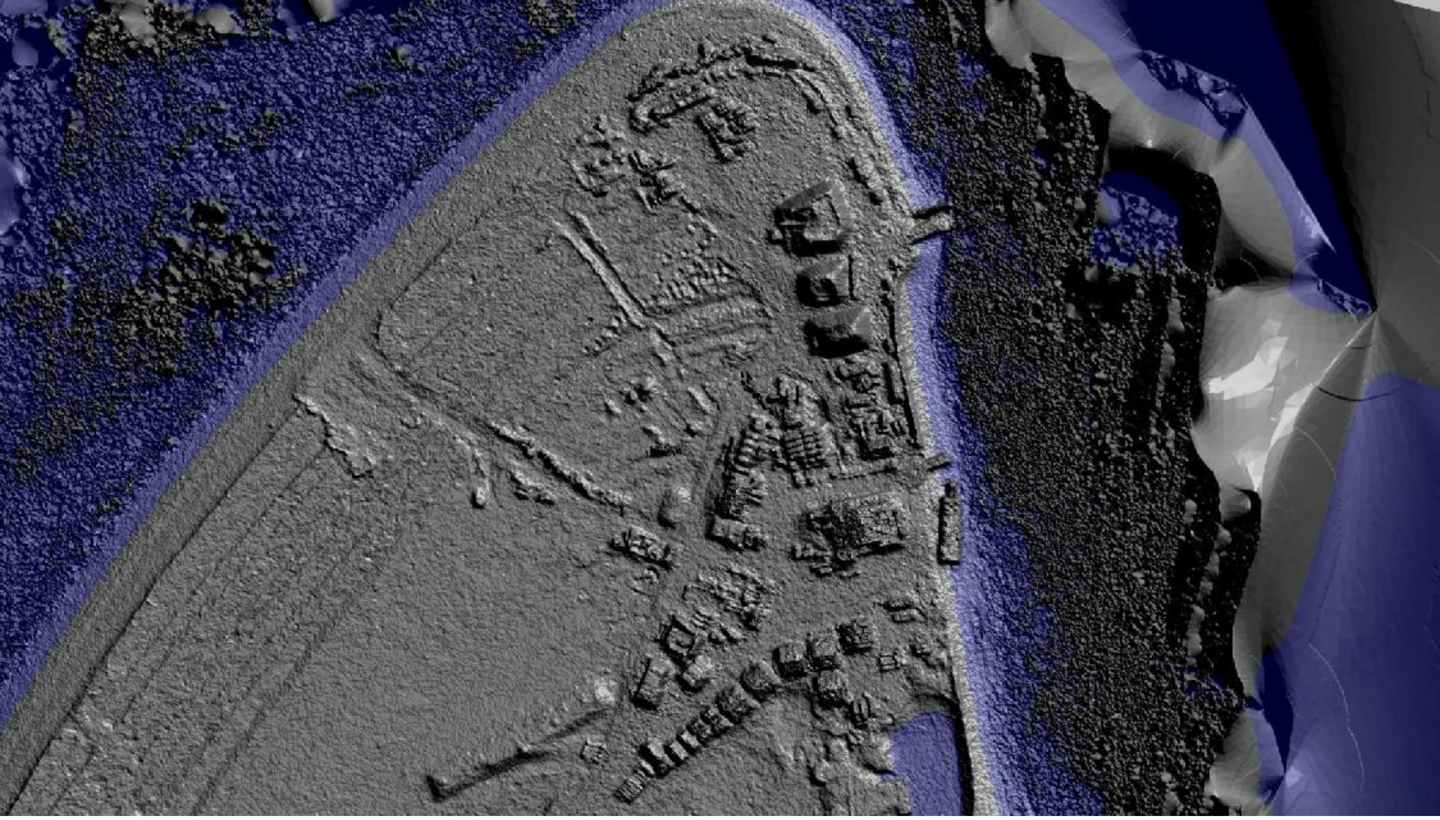


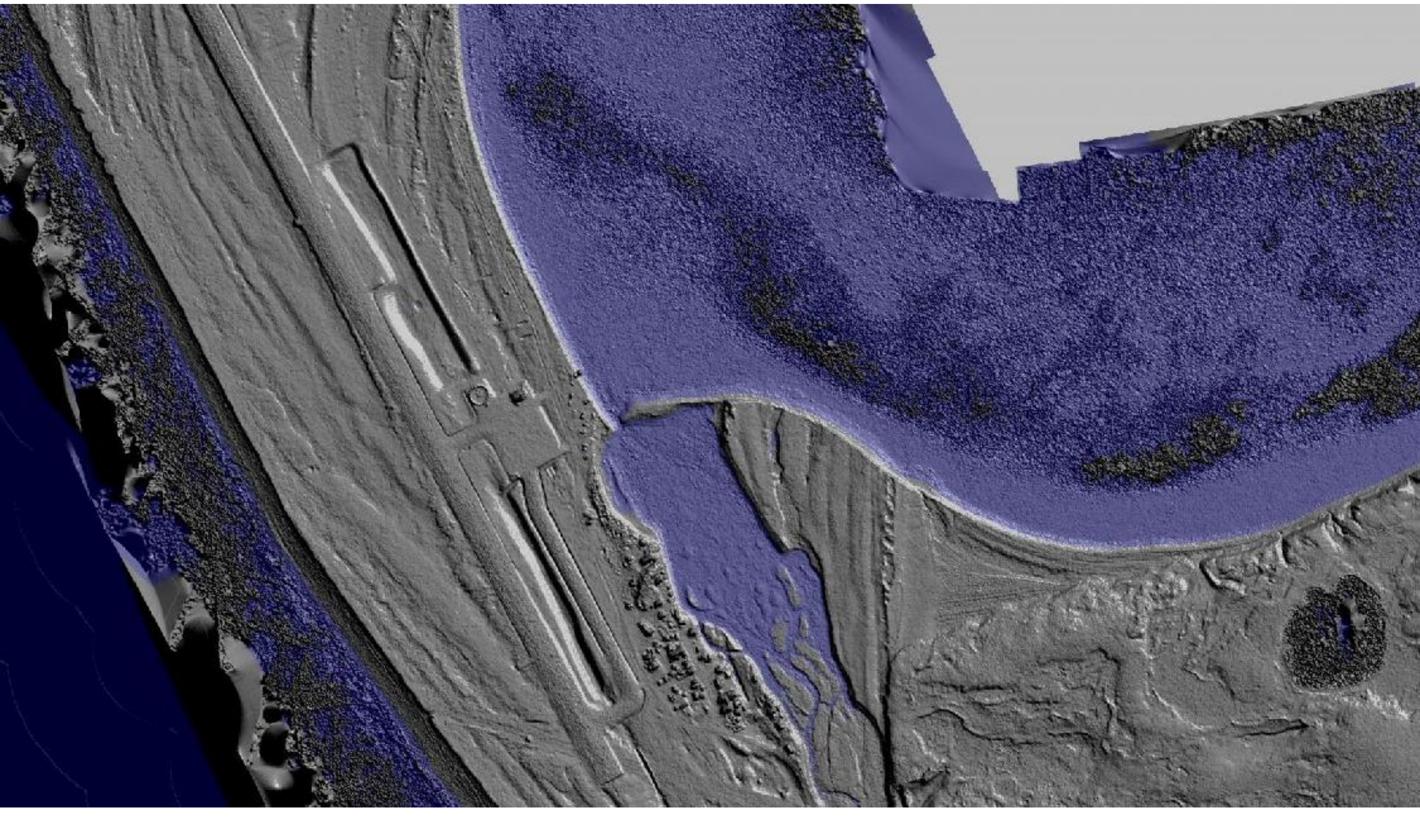
Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.





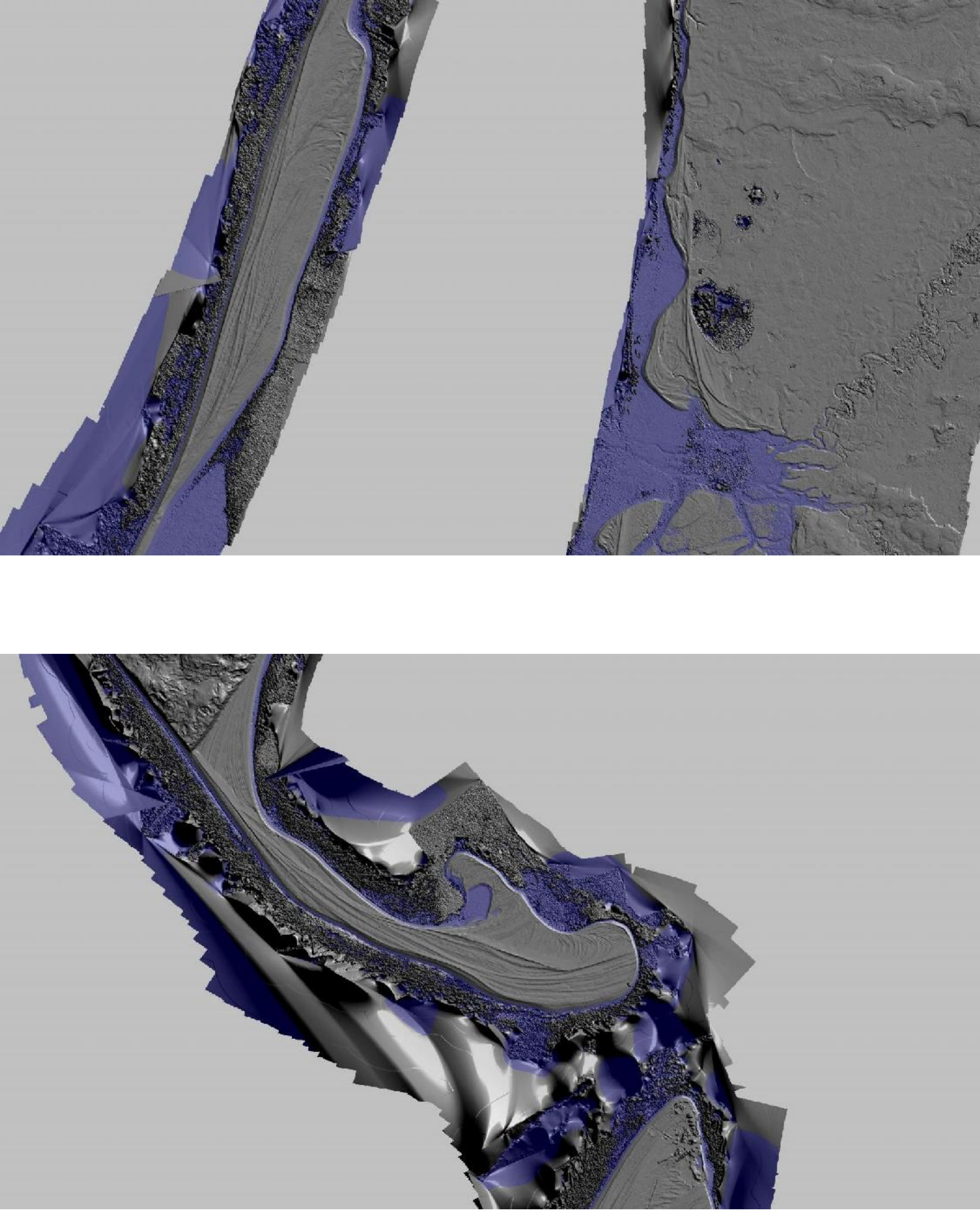
Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.



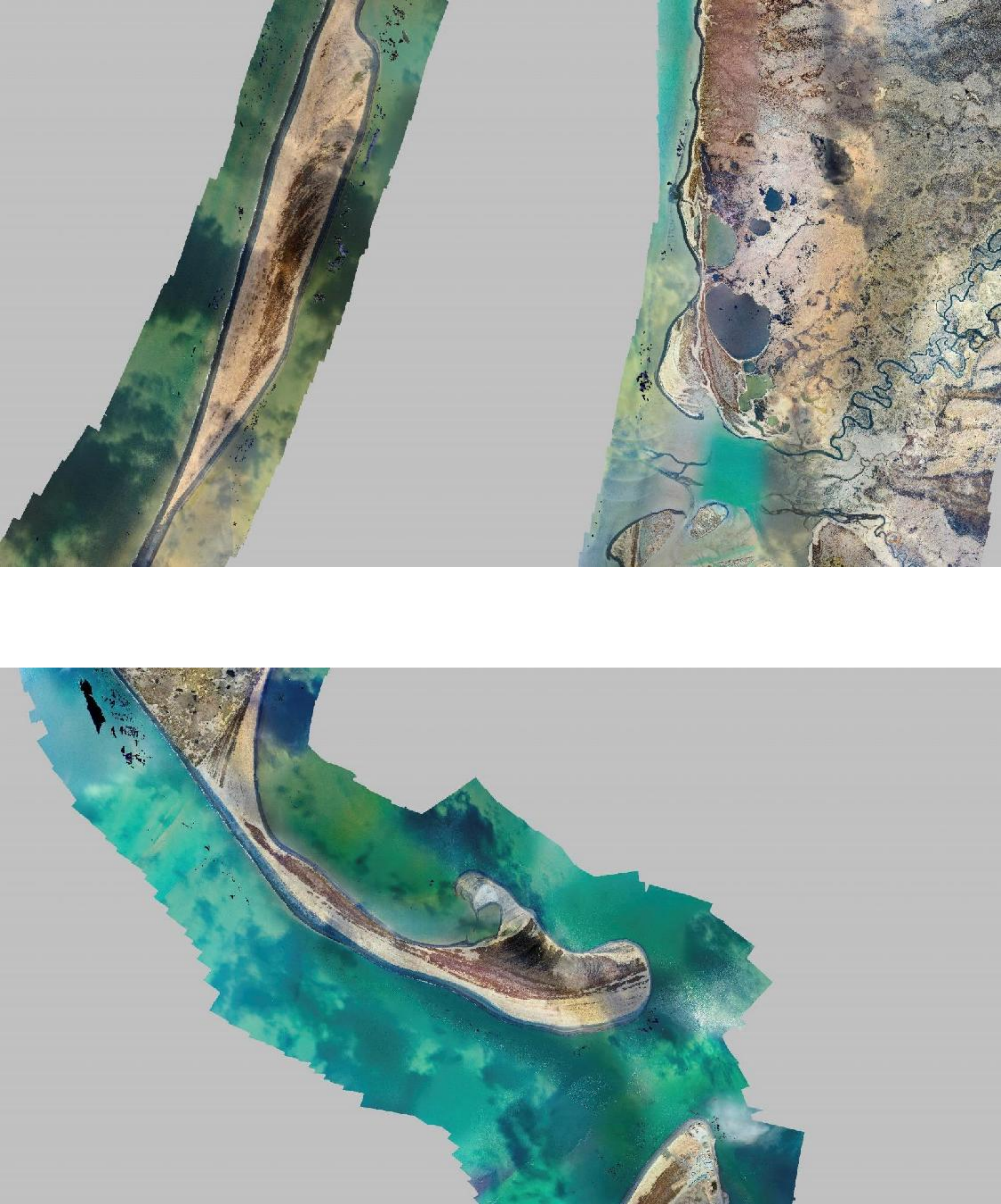


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

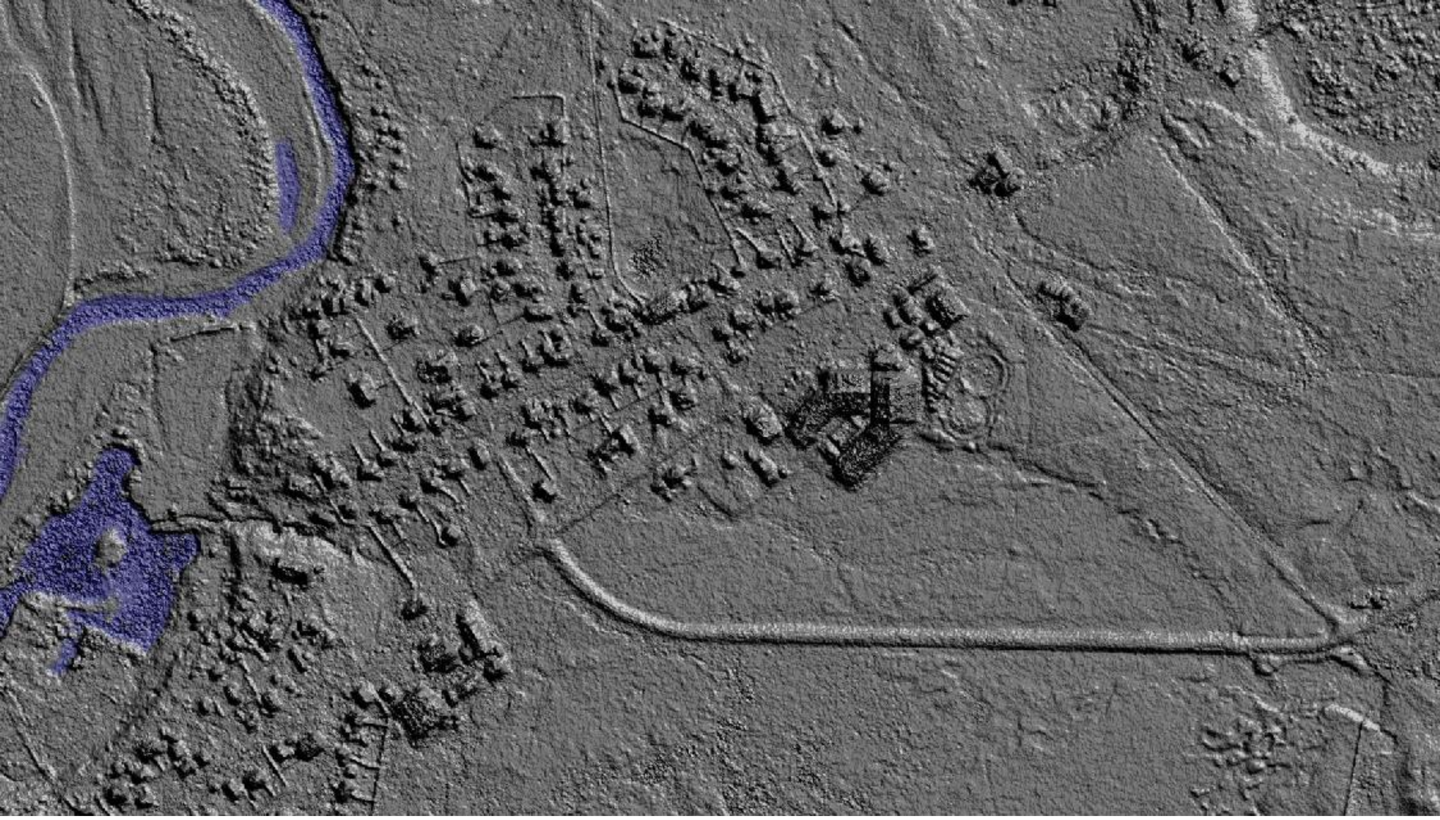
Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.

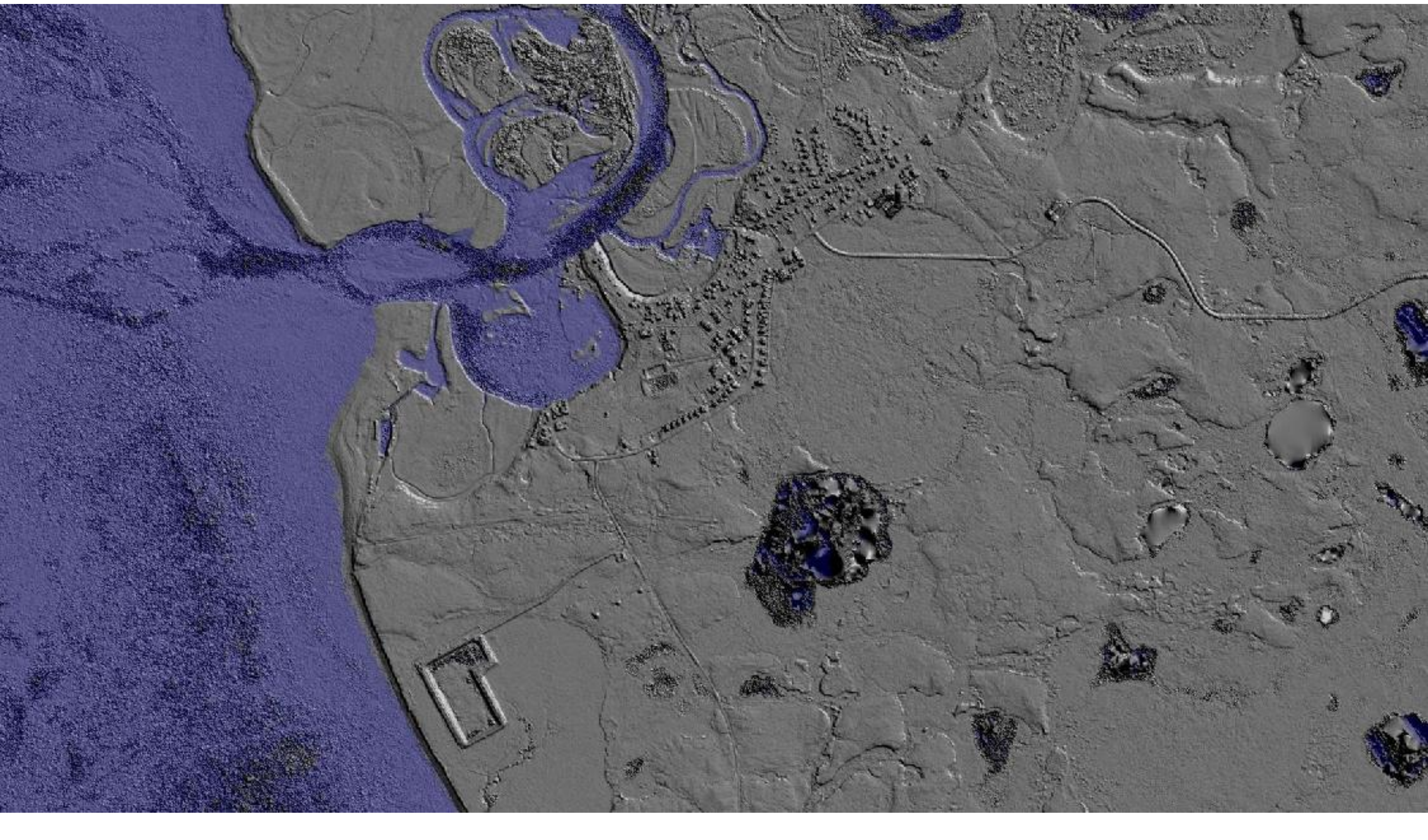


Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.



Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.





Examples of data quality and scientific features. These are DEMs shown in shaded relief with blue indicating approximately MHW. Flicker with the next page to see the corresponding orthomosaic.

Examples of data quality and scientific features. These are orthomosaics corresponding with the DEMs on the previous page. Flicker between them to study detail.