These are configured screening categories. They are not an independent geomorphic inventory.

Table S1: AOI categories used by the classification script.

| Category | AOIs |
|---|---|
| Inland lake plain | Anabar Lowland; Anderson Plain; Old Crow Flats; Selawik Lowlands; Seward Peninsula; Taimyr Lowland; Yukon Flats |
| Coastal lake plain | Barrow Coastal Plain; Bykovsky; Gyda; Prudhoe Bay; Teshekpuk; Tuktoyaktuk Peninsula; Yamal; Yamal South |
| Deltaic or channelized lowland | Indigirka Lowland; Kolyma Lowland; Lena Delta East; Lena Delta West; Mackenzie Delta; Pechora Lowland; Yana Indigirka East |
| Other permafrost lowland | Kurungnakh |

Index and reflectance thresholds are dimensionless. Area thresholds are in pixels. All three elongation thresholds must be met for that rejection rule.

Table S2: Initial water-mask settings.

| Configuration | NDWI | MNDWI | NIR/SWIR | Min. | Max. | Elong. area | Ratio/Ecc. |
|---|---|---|---|---|---|---|---|
| anabar_lowland_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| anderson_plain_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| barrow_coastal_plain_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| bykovsky_2023_v11_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| bykovsky_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| gyda_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| indigirka_lowland_2023_v11_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| indigirka_lowland_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| kolyma_lowland_2023_v11_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| kolyma_lowland_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| kurungnakh_2023_v11_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| kurungnakh_2023_v4_global_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| lena_delta_east_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| lena_delta_west_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| mackenzie_delta_2023_v11_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| mackenzie_delta_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| old_crow_flats_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| pechora_lowland_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| prudhoe_bay_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| selawik_lowlands_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| seward_peninsula_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| taimyr_lowland_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| teshekpuk_2023_v11_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| teshekpuk_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| tuktoyaktuk_peninsula_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| yamal_2023_v11_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| yamal_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| yamal_south_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| yana_indigirka_east_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |
| yukon_flats_2023_v1_256 | 0.05 | 0.05 | 0.15/0.15 | 10 | 50000 | 10000 | 5.0/0.98 |

These settings describe the original standard and geographic runs. The newly buffered Mackenzie experiment uses the separate settings in the main text.

Table S3: Configuration of the original U-Net baseline runs.

| Setting | Value |
|---|---|
| Network | Three-level U-Net; five input bands; initial channel width 32. |
| Convolution blocks | Two convolutions with batch normalization and ReLU activations. |
| Upsampling and output | Transposed convolutions; one output logit per pixel. |
| Reflectance preparation | Clip values to [0, 0.4], then divide by 0.4. |
| Loss | BCEWithLogitsLoss with positive-class weight 10, plus soft Dice loss. |
| Optimizer | AdamW; learning rate 0.001; weight decay 0.0001. |
| Batch size | 16 for the standard split; 8 for geographic holdouts. |
| Duration and seed | 10 epochs; random seed 42. |
| Image augmentation | Random horizontal and vertical flips; random 0/90/180/270 degree rotations. |
| Checkpoint selection | Highest validation IoU. |
| Water decision | Probability threshold 0.5. |
| Software and hardware | PyTorch 2.3.1 with CUDA; NVIDIA RTX 4080 workstation. |

Each released image matched the corresponding five-band window in its original AOI composite. The stored initial mask and pilot probabilities were then passed through the documented combination, object-screening and final cleaning steps. All three recalculated QA layers also matched the release exactly. The intermediate counts below describe these automatic processing steps.

Table S4: Replay of automatic mask production for the illustrated samples.

| Example | Initial | Candidate | Screened | Automatic final | Released final | Different |
|---|---|---|---|---|---|---|
| Seward Peninsula | 1744 | 1706 | 1706 | 1706 | 1706 | 0 |
| Yukon Flats | 705 | 2070 | 2070 | 2070 | 2070 | 0 |
| Yana Indigirka East | 5807 | 6555 | 6555 | 6555 | 6555 | 0 |

Counts are water pixels, except the last column, which counts differing pixels between the automatic final mask and released mask. Tile identifiers are shown in the corresponding enlarged comparisons (Figs. S24–S26).

The original split assignments shown in Figs. S1–S23 are evaluated for spatial overlap in Sect. 4.8 of the main text.

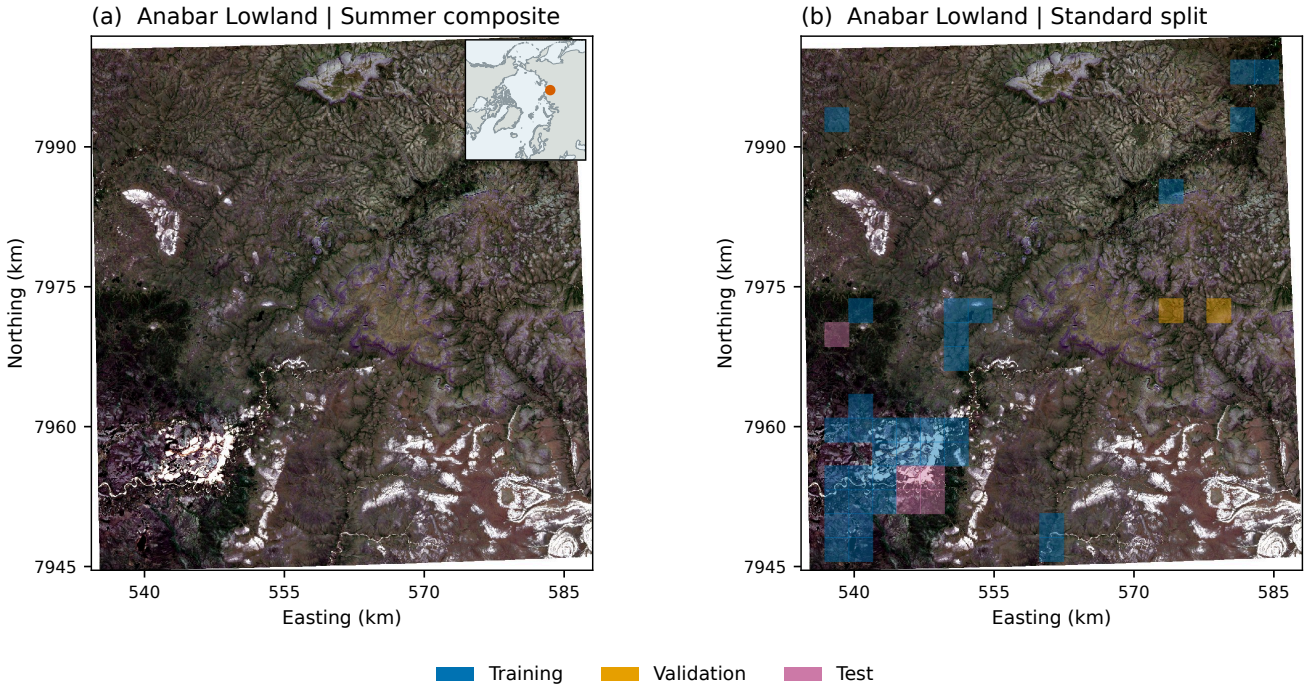



Figure S1: Anabar Lowland. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32649. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

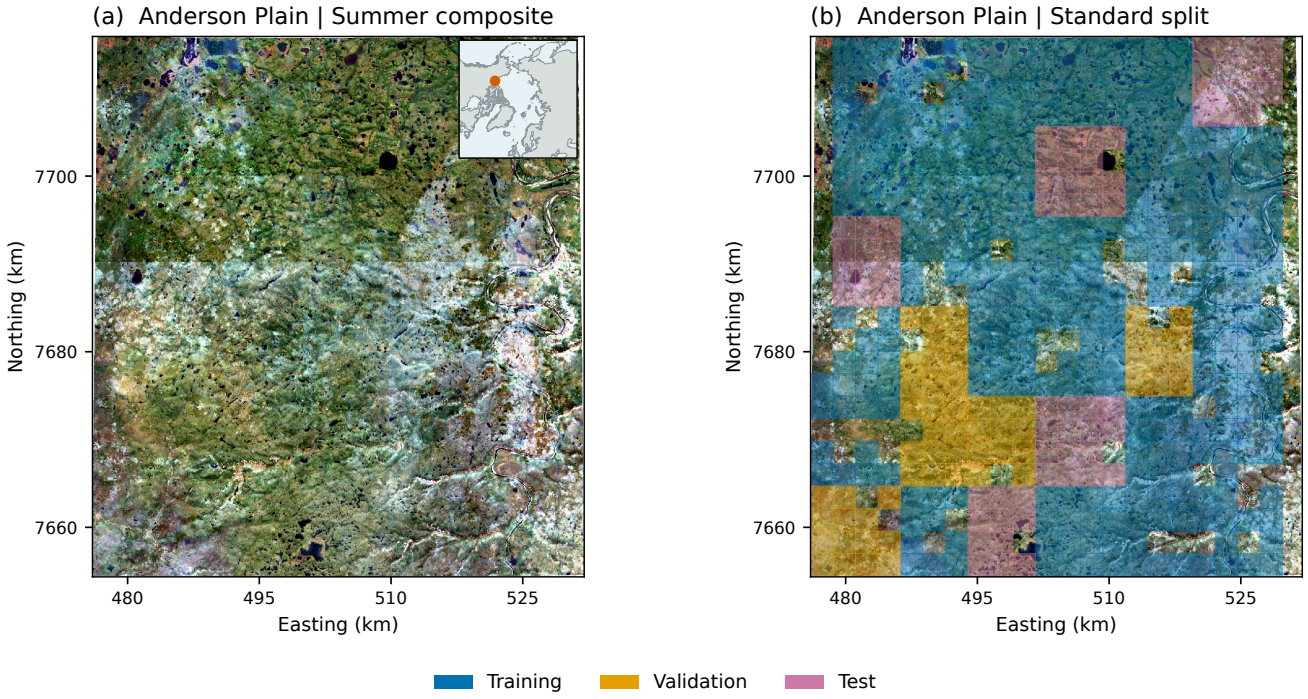



Figure S2: Anderson Plain. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32609. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

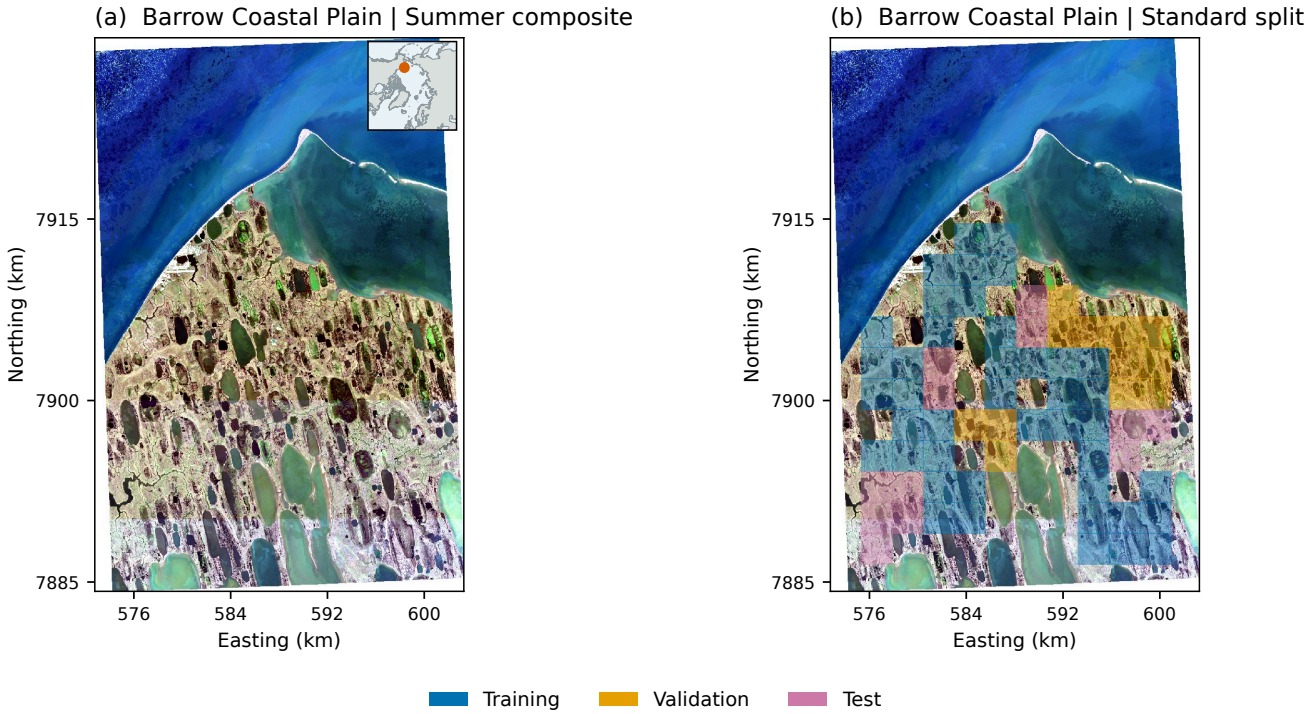



Figure S3: Barrow Coastal Plain. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32604. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

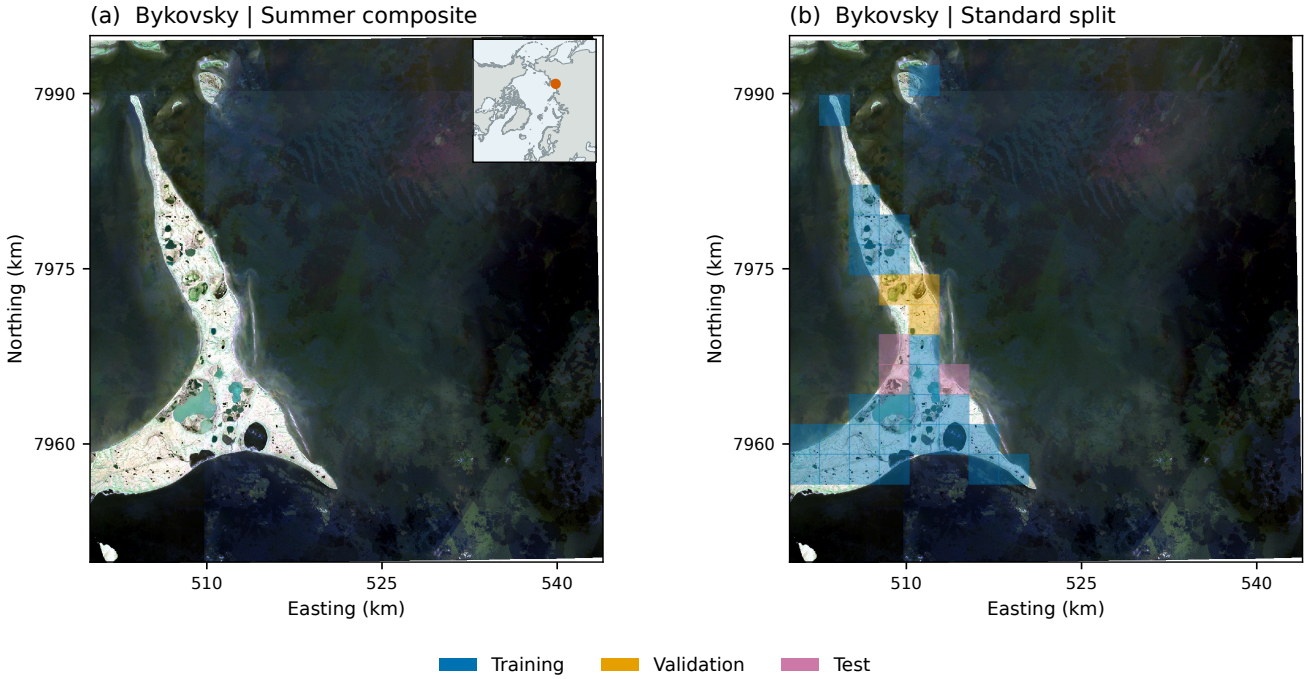



Figure S4: Bykovsky. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32652. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

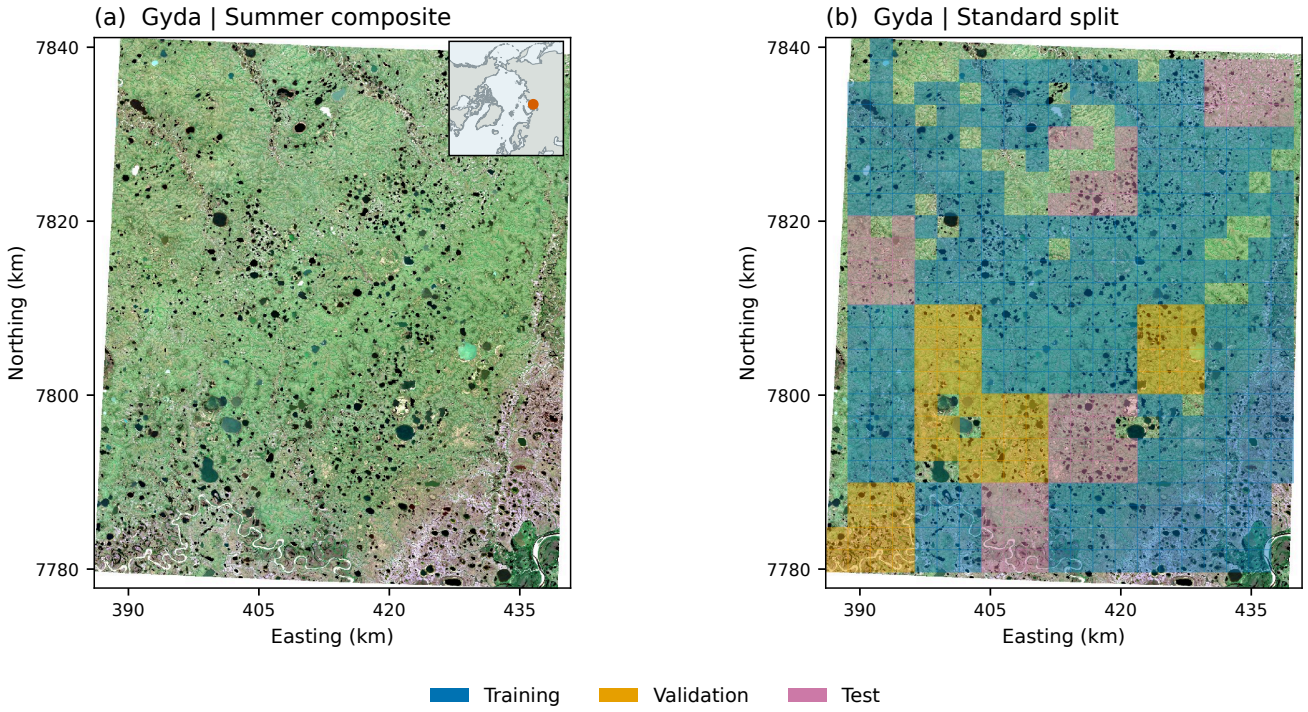



Figure S5: Gyda. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32644. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

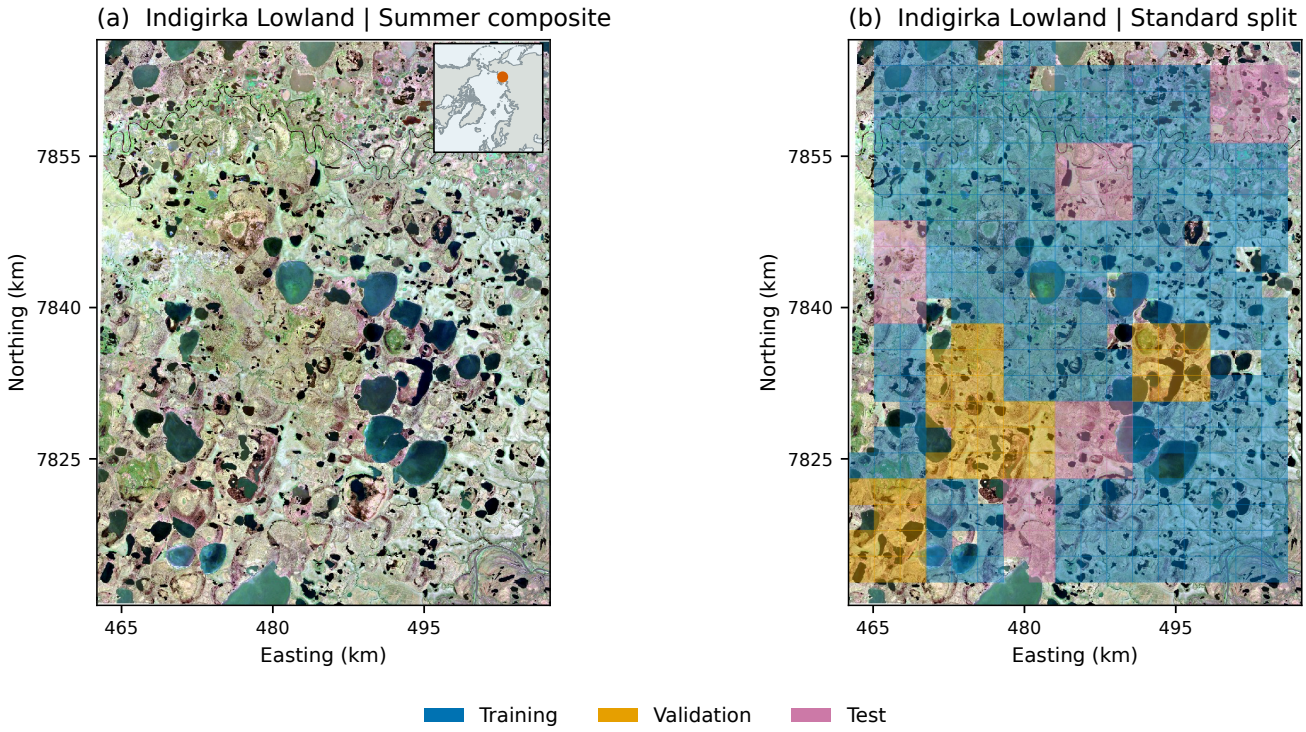



Figure S6: Indigirka Lowland. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32655. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

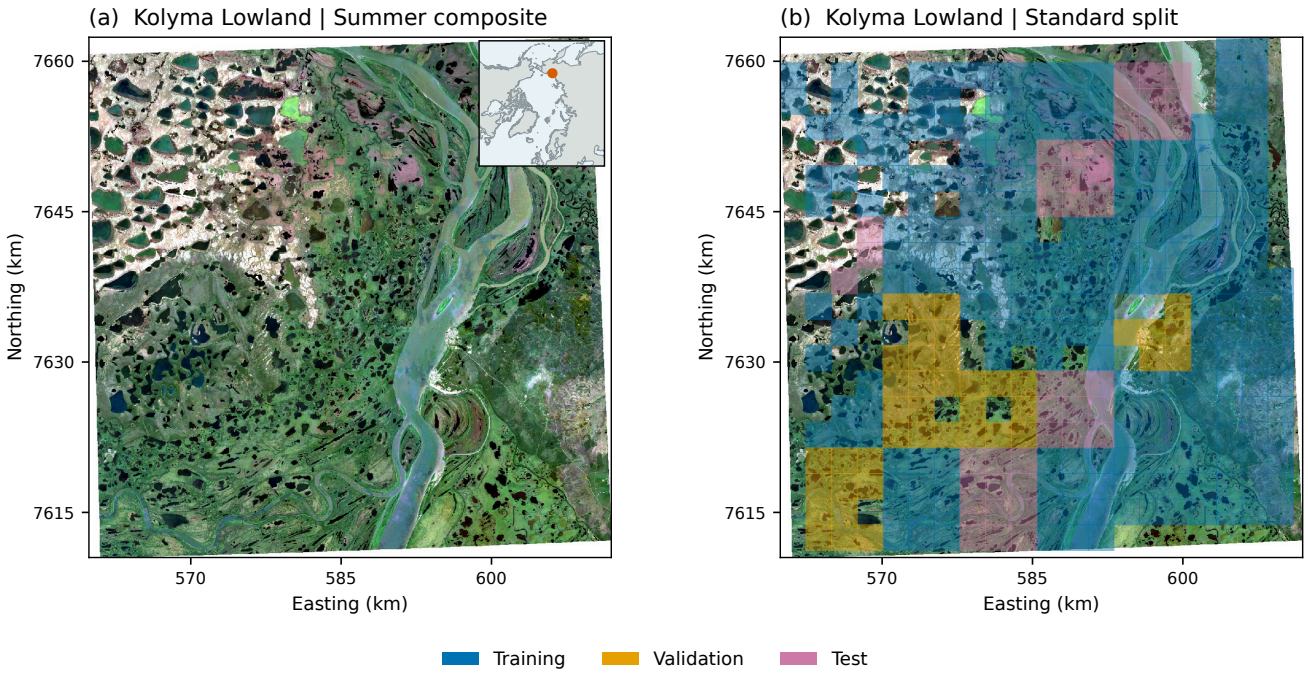



Figure S7: Kolyma Lowland. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32657. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

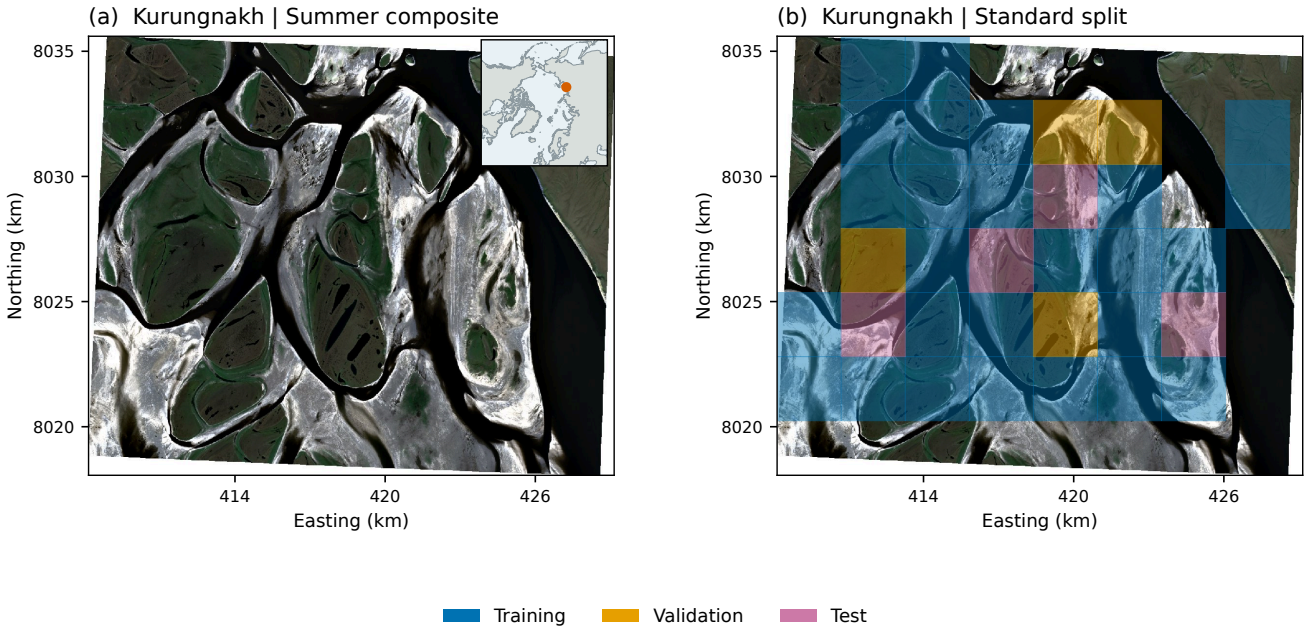



Figure S8: Kurungnakh. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32652. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

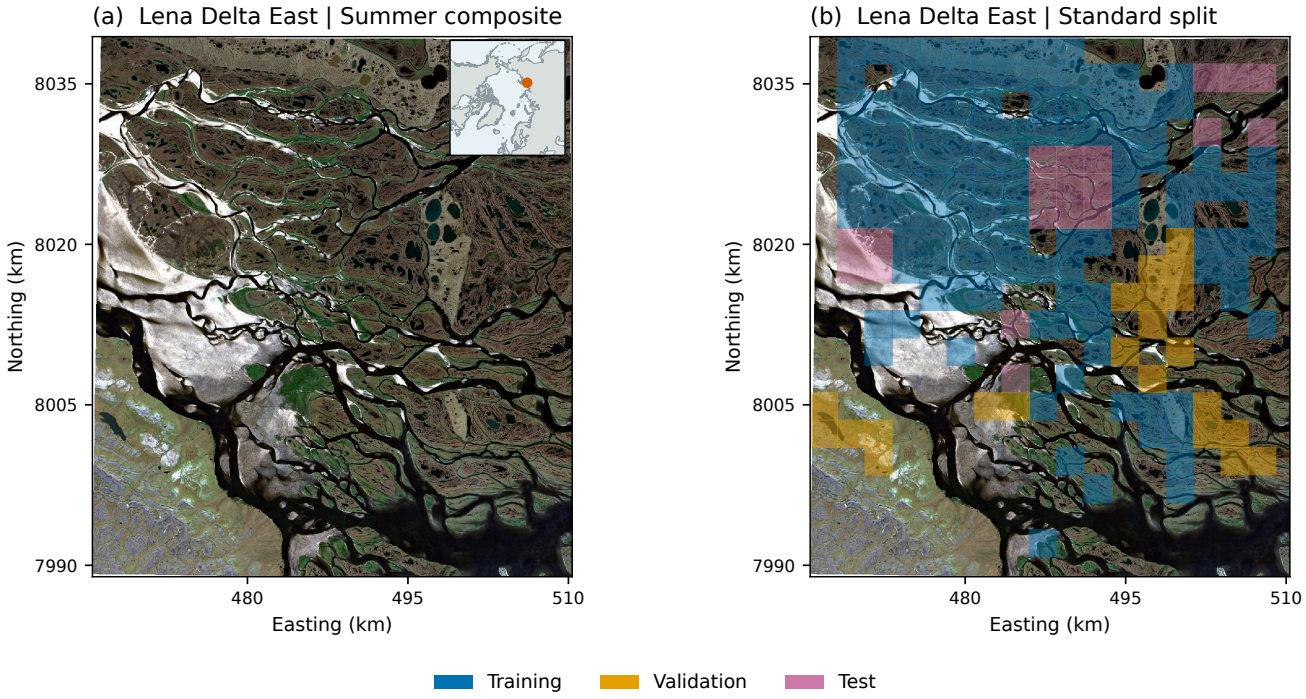



Figure S9: Lena Delta East. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32652. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

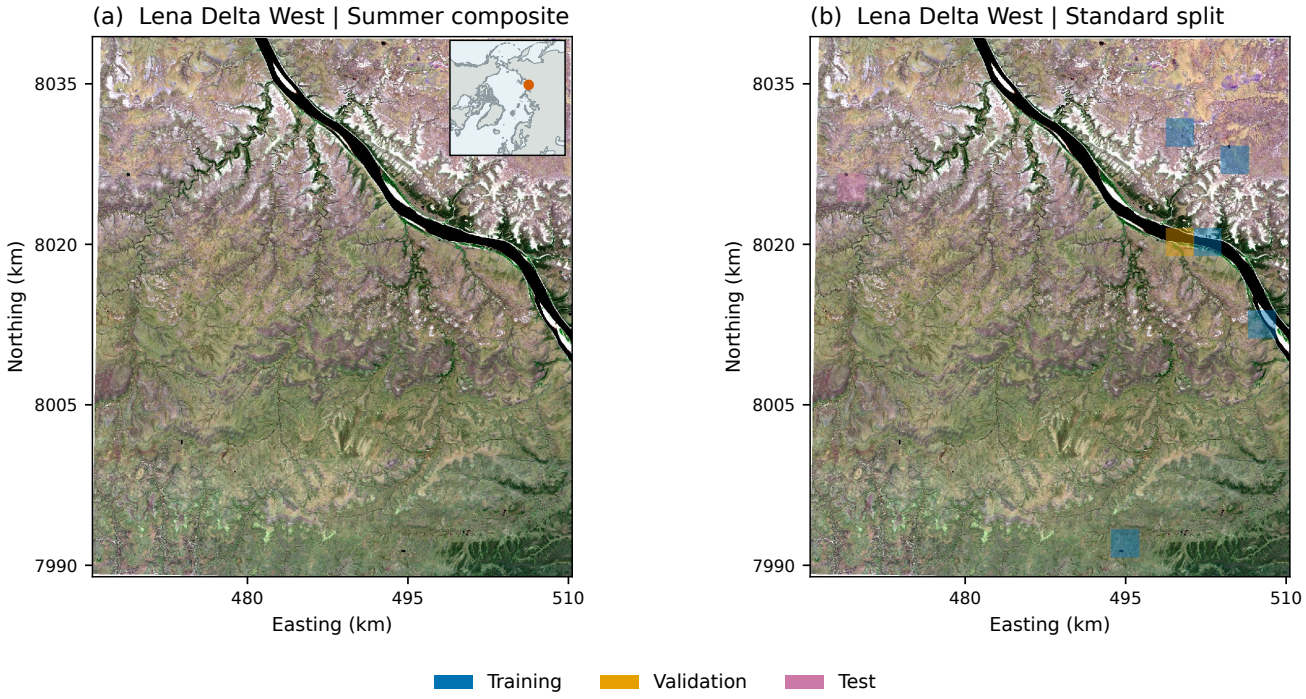



Figure S10: Lena Delta West. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32651. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

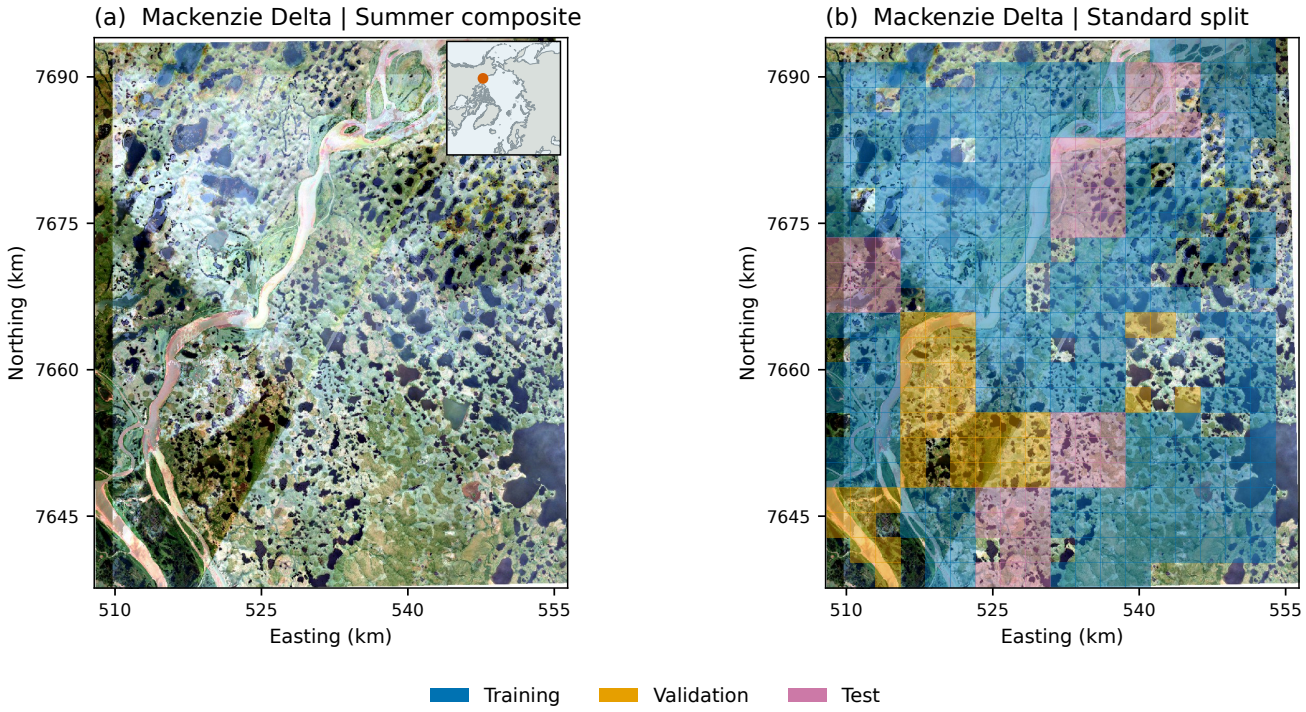



Figure S11: Mackenzie Delta. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32608. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

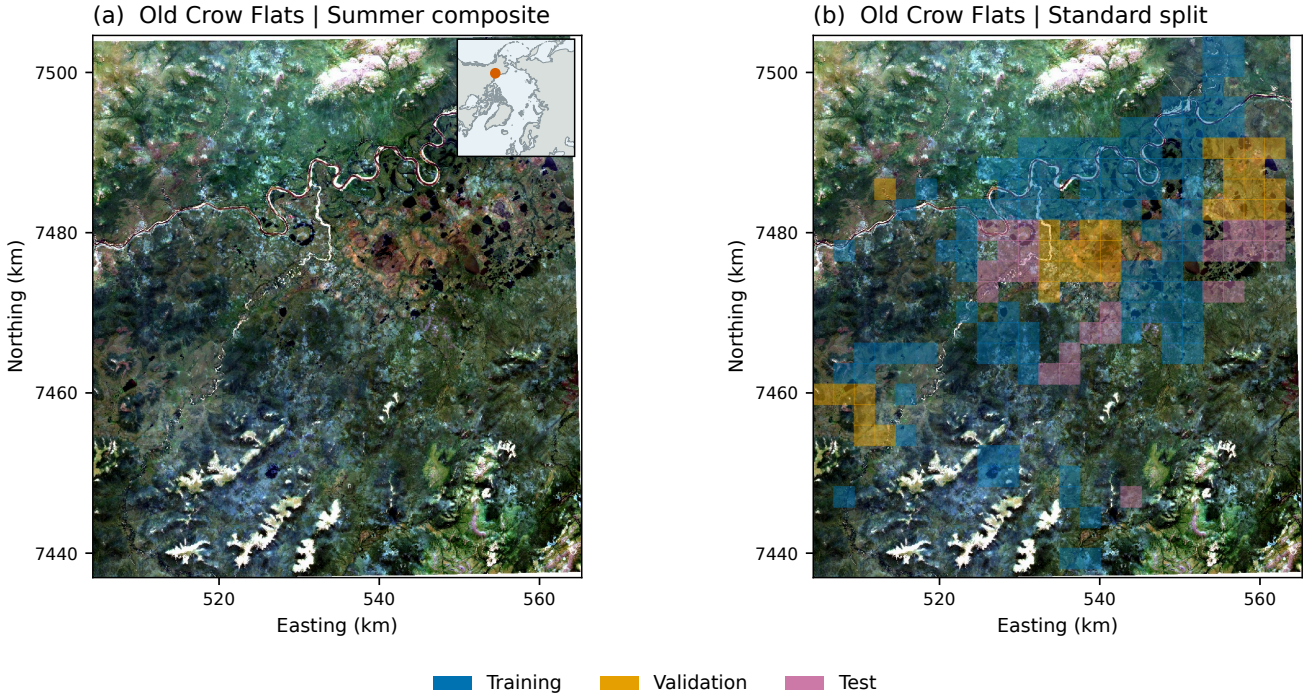



Figure S12: Old Crow Flats. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32607. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

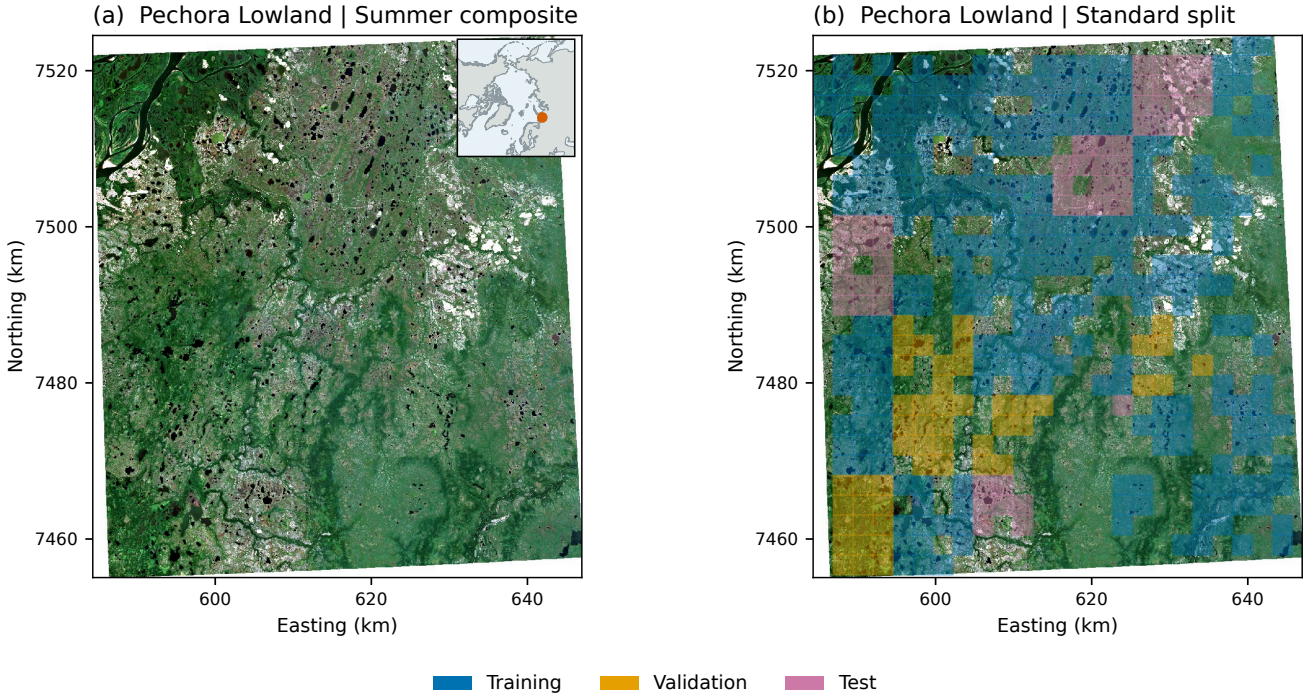



Figure S13: Pechora Lowland. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32639. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

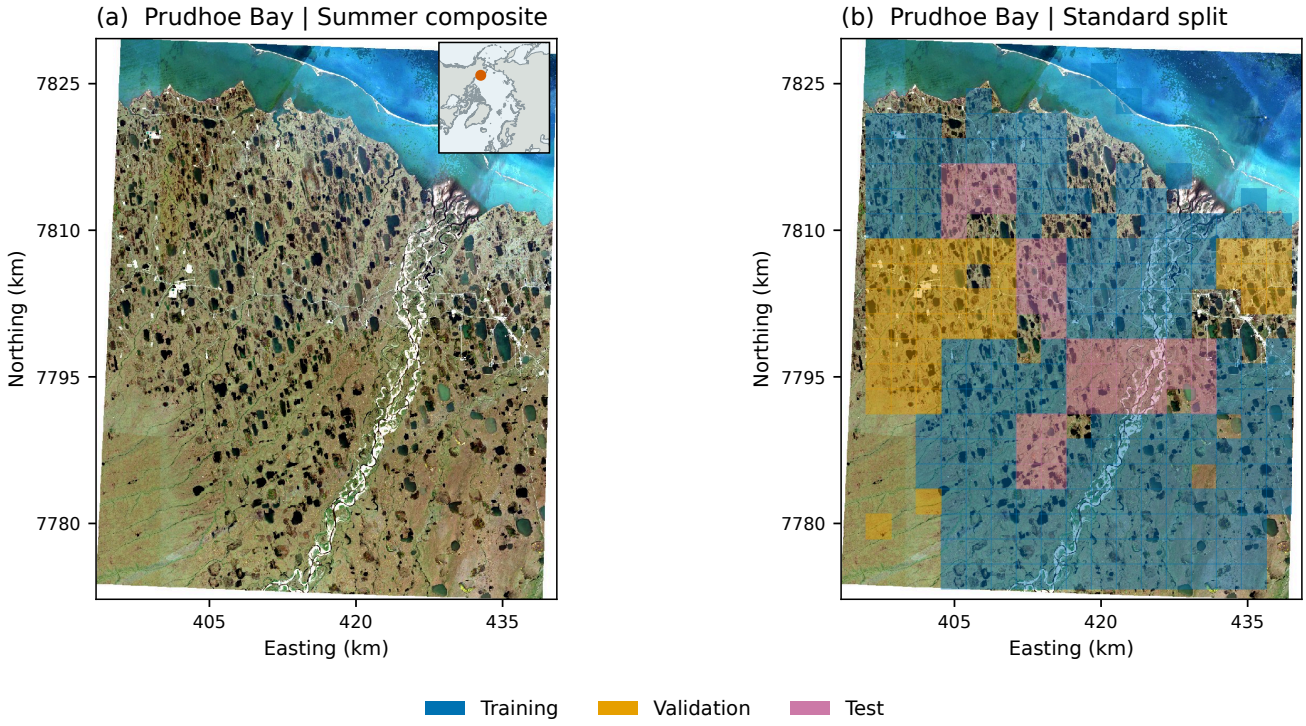



Figure S14: Prudhoe Bay. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32606. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

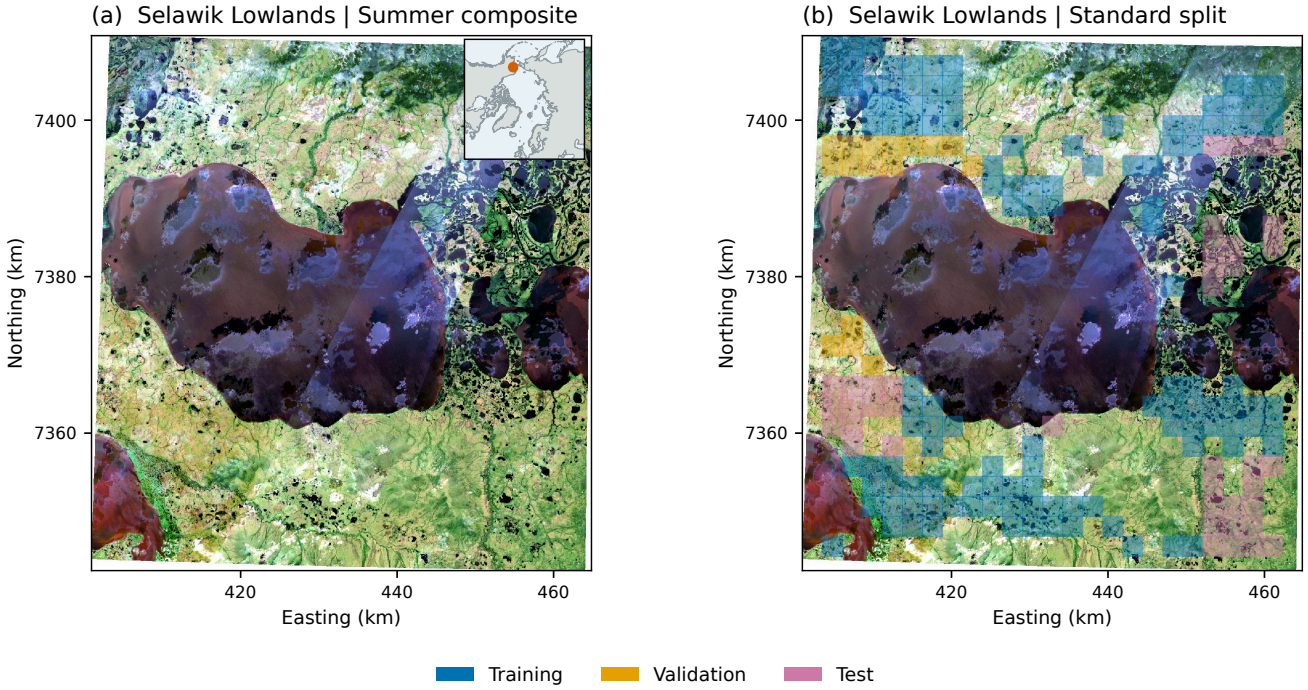



Figure S15: Selawik Lowlands. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32604. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

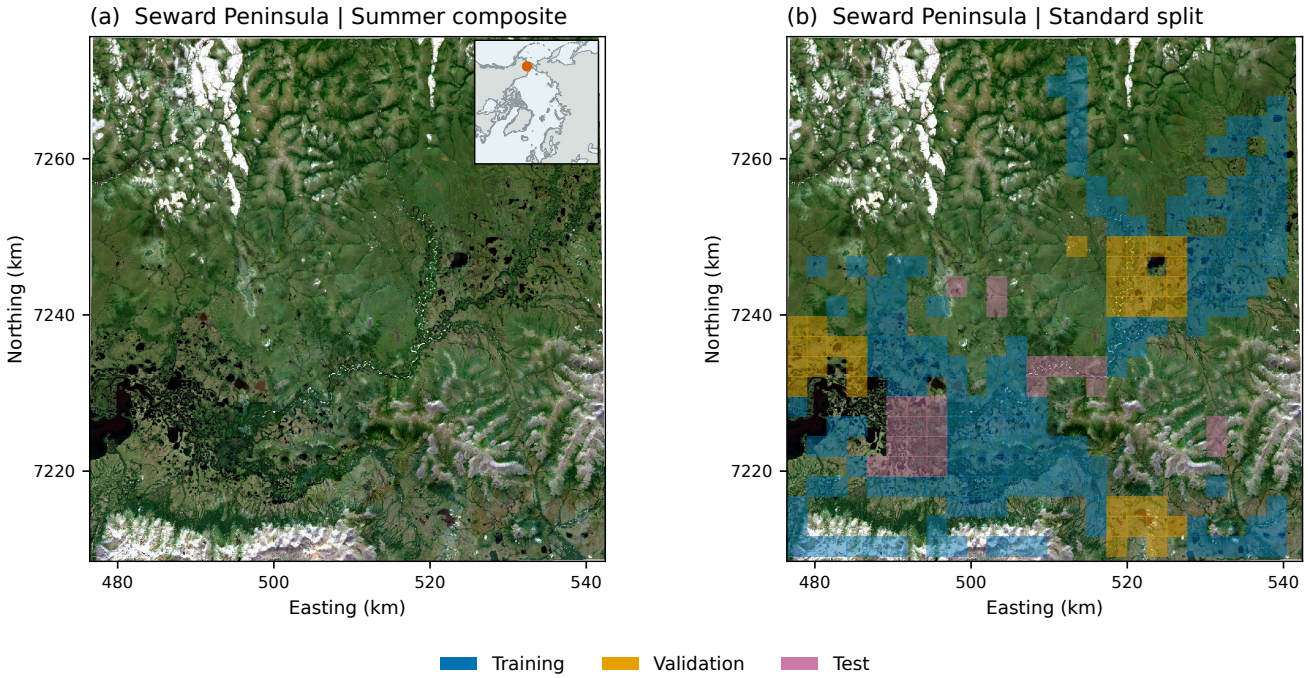



Figure S16: Seward Peninsula. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32603. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

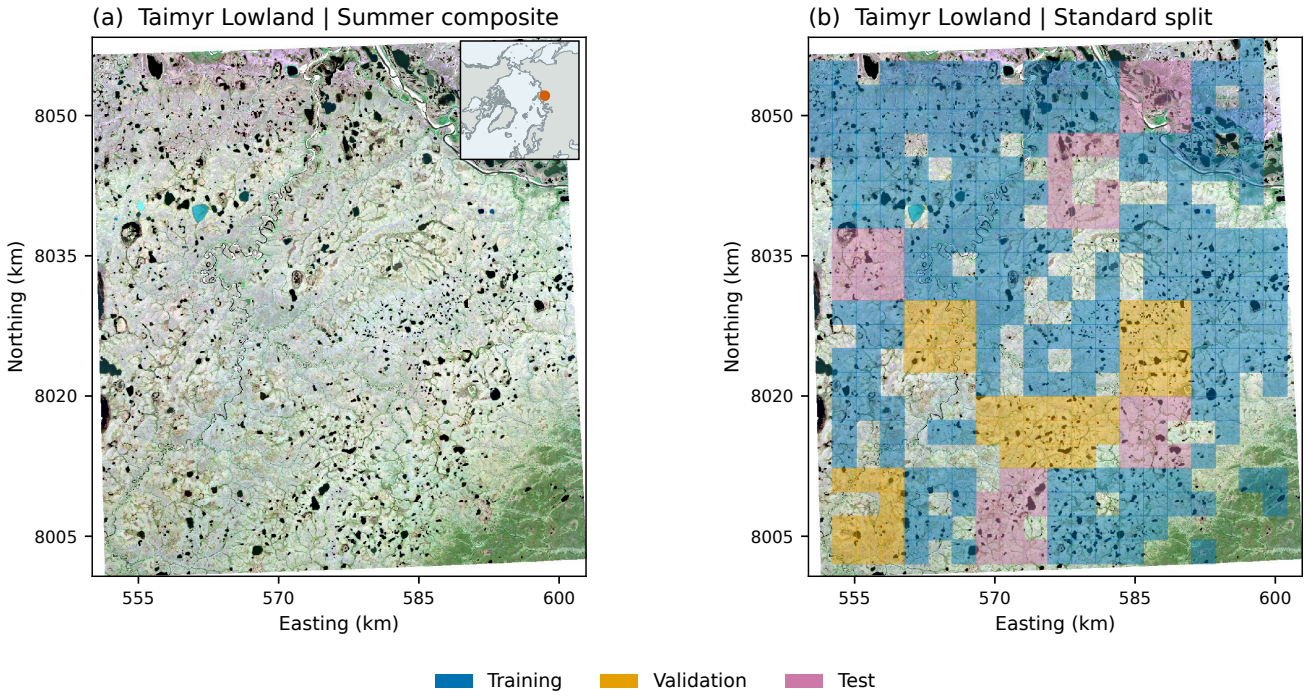



Figure S17: Taimyr Lowland. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32647. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

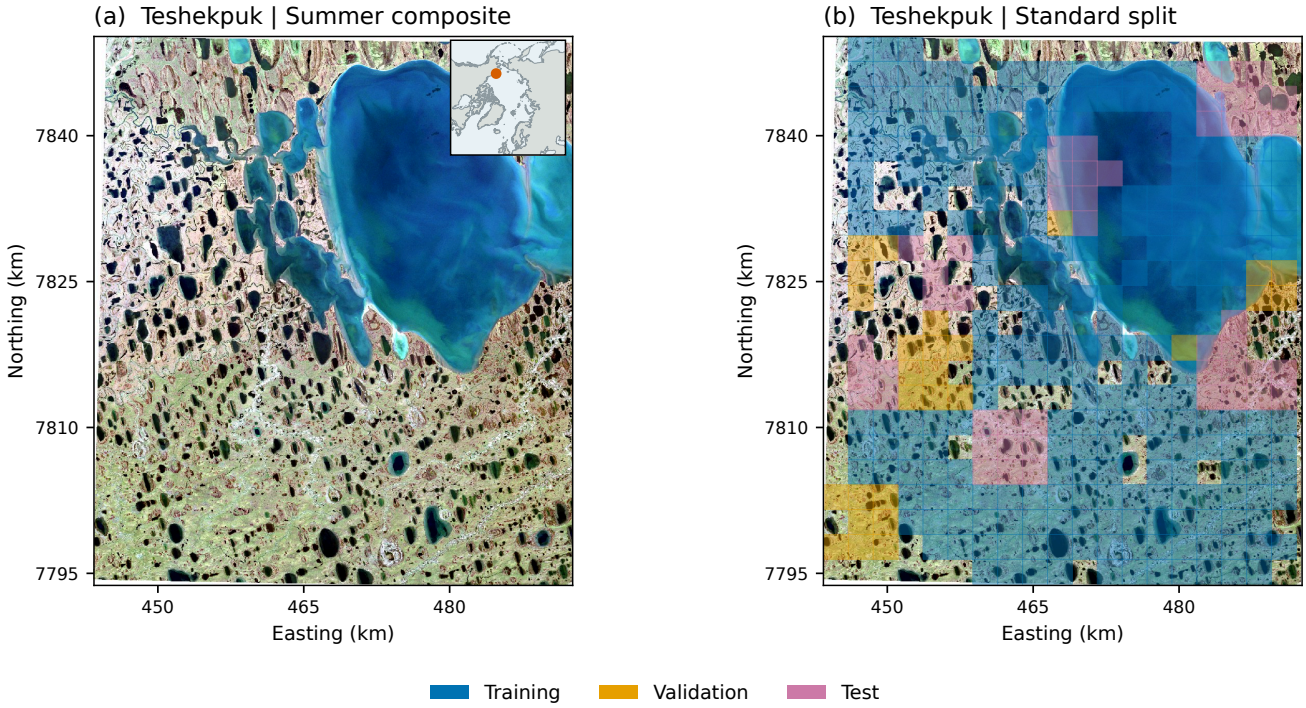



Figure S18: Teshekpuk. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32605. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

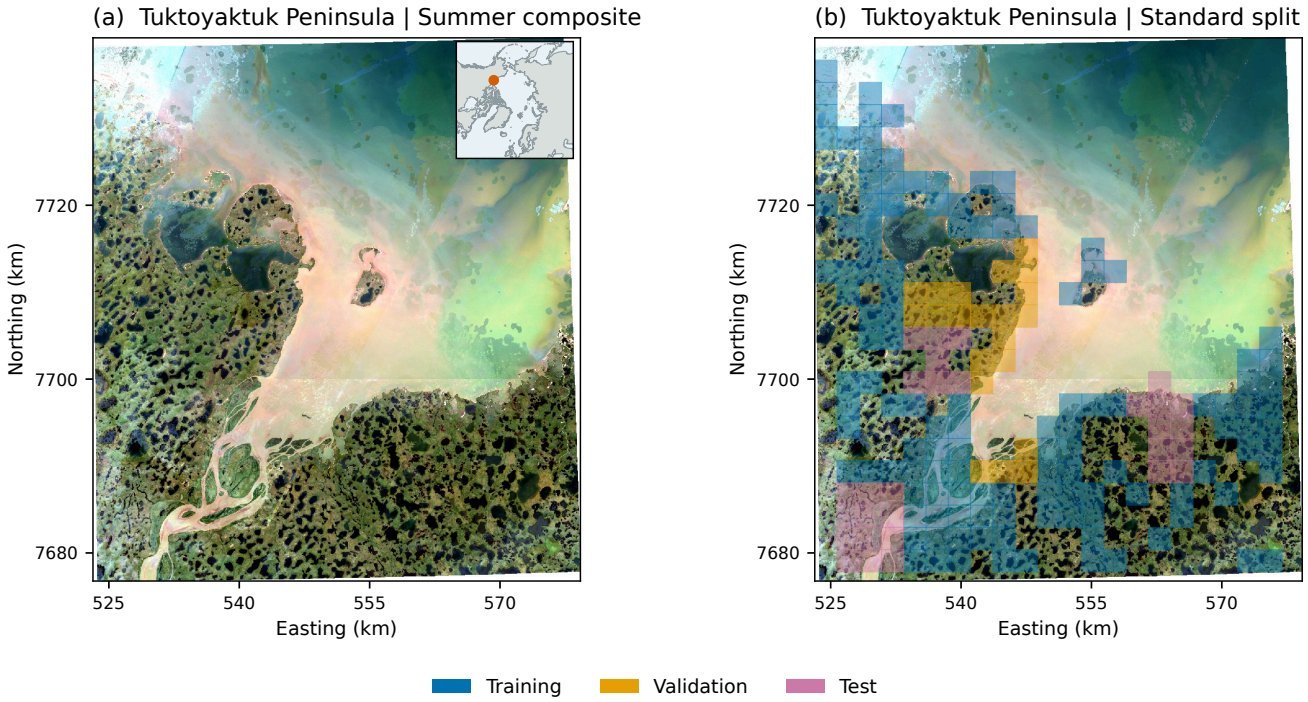



Figure S19: Tuktoyaktuk Peninsula. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32608. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

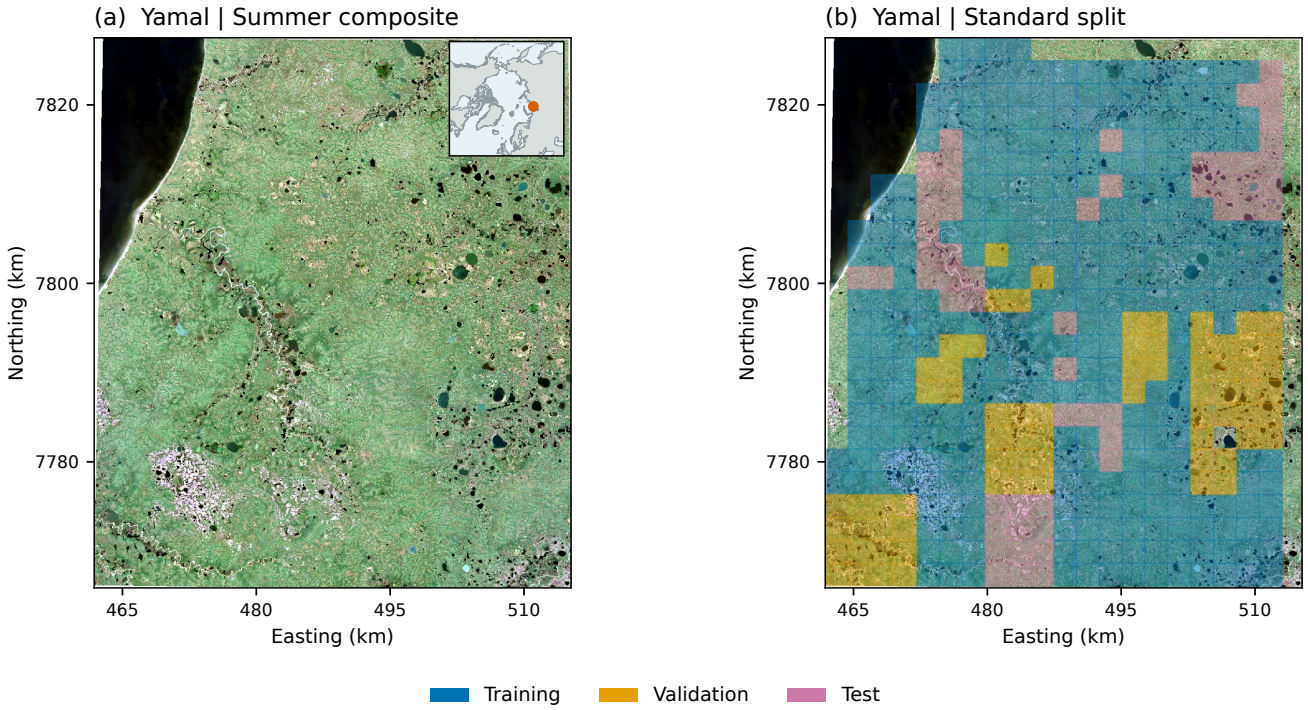



Figure S20: Yamal. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32643. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

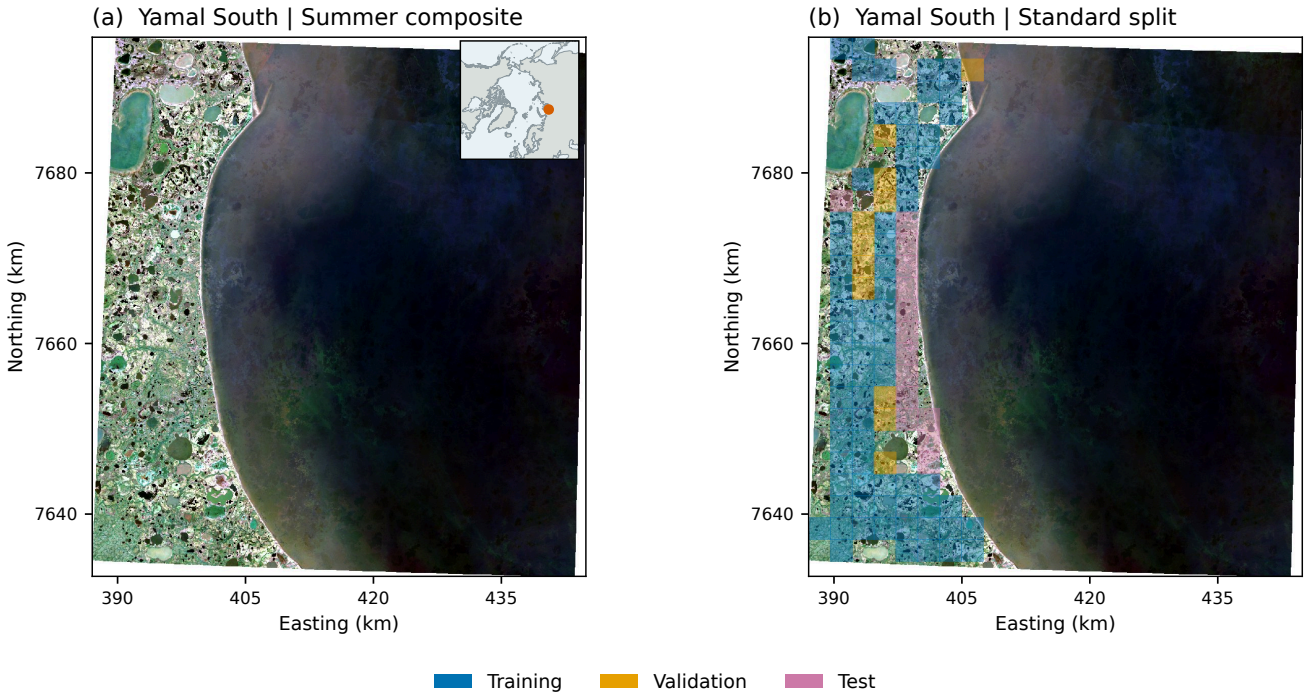



Figure S21: Yamal South. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32643. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

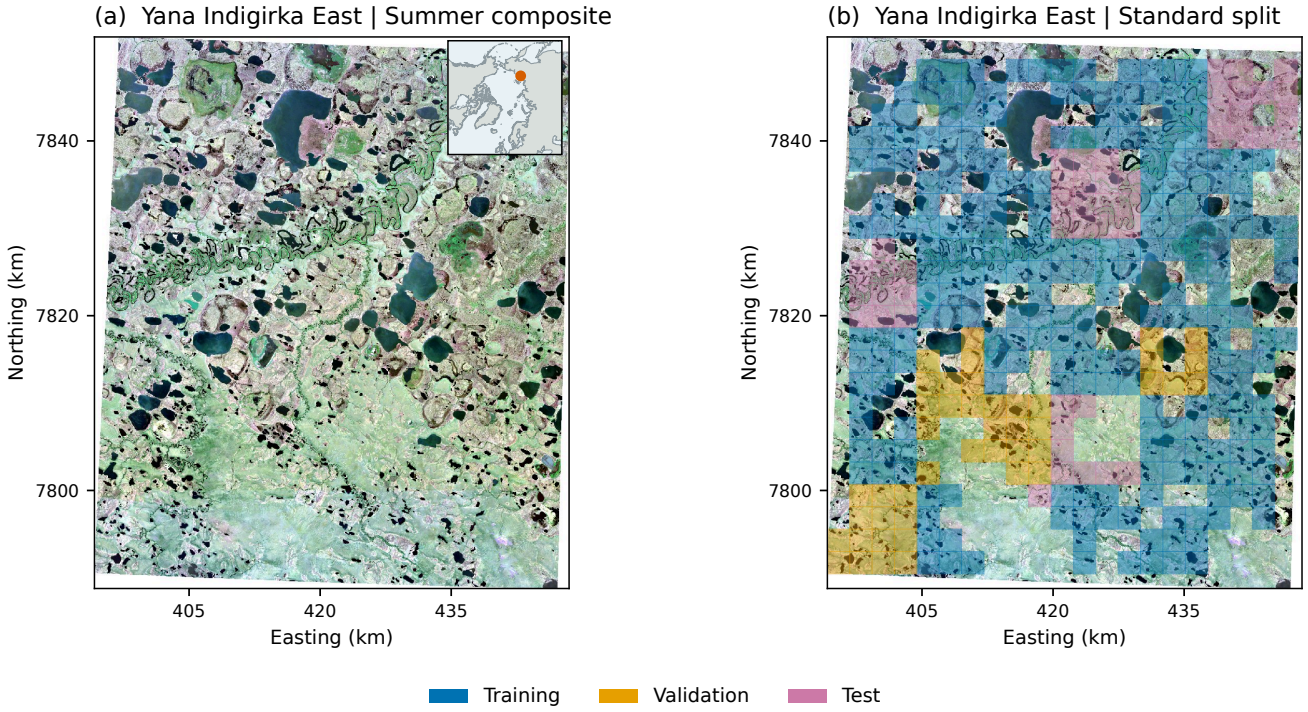



Figure S22: Yana Indigirka East. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32655. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

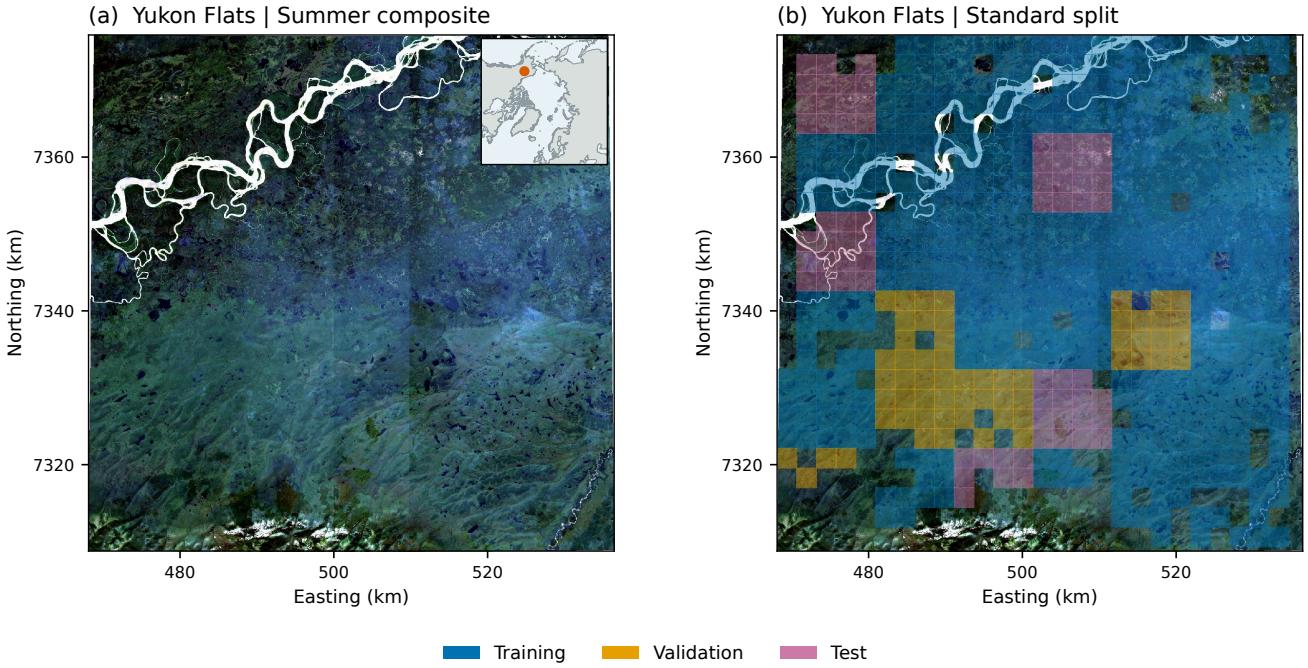



Figure S23: Yukon Flats. Summer Sentinel-2 composite (left) and released sample footprints coloured by the original training, validation and test assignments (right). Insets locate each AOI in the Arctic. Coordinates are in kilometres in EPSG:32606. Contains modified Copernicus Sentinel data (2023); locator land outlines: Natural Earth.

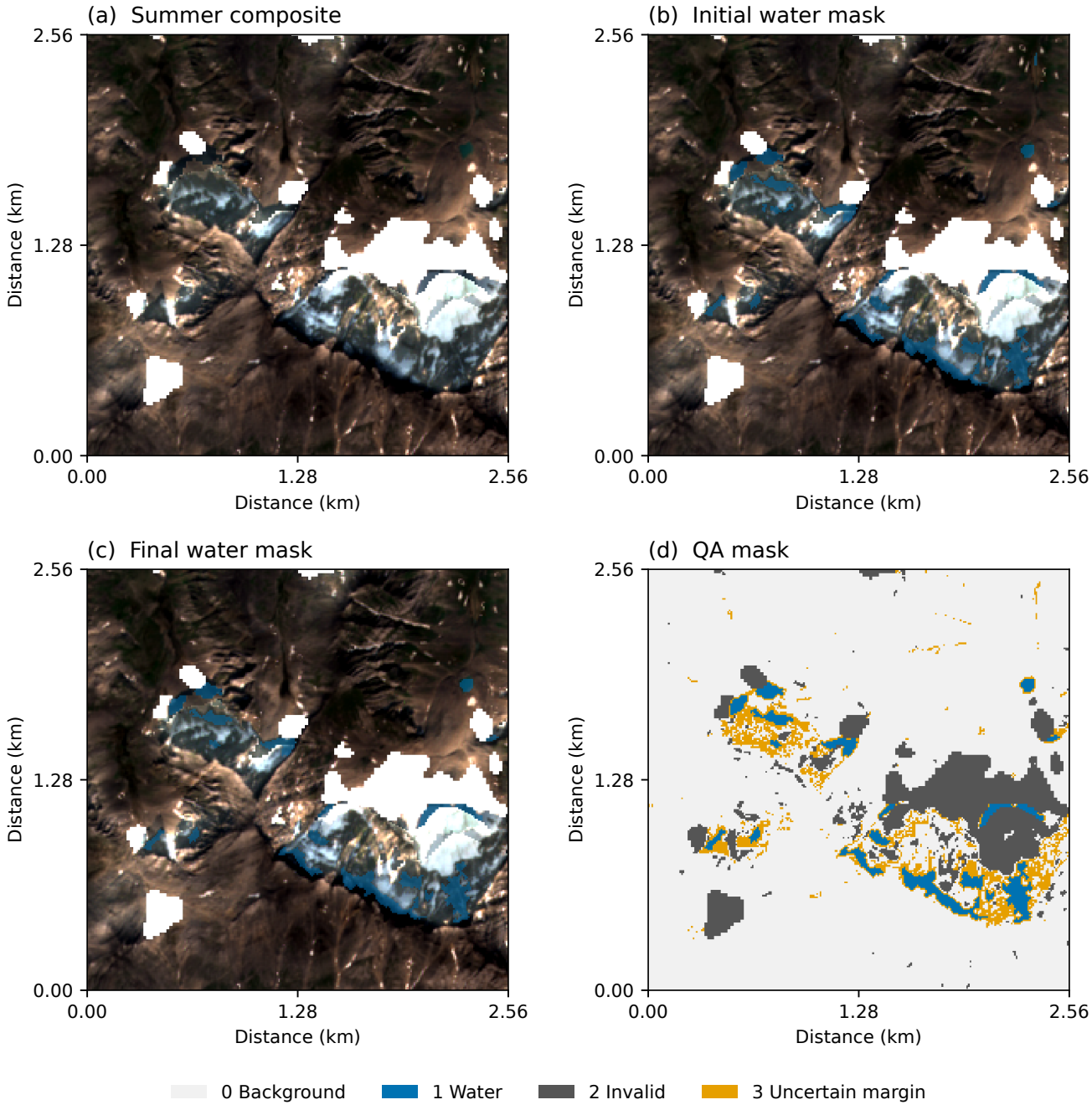



Figure S24: Enlarged processing comparison for `seward_peninsula_2023_r006400_c000512`. All panels use the same released image grid. Water pixels are blue in the two overlays; the QA legend identifies all four codes. Relative to the archived initial mask, the final mask adds 0 pixels and removes 38 pixels. QA recalculation matched the released QA layer exactly. These are processing comparisons rather than independent shoreline references. Contains modified Copernicus Sentinel data (2023).

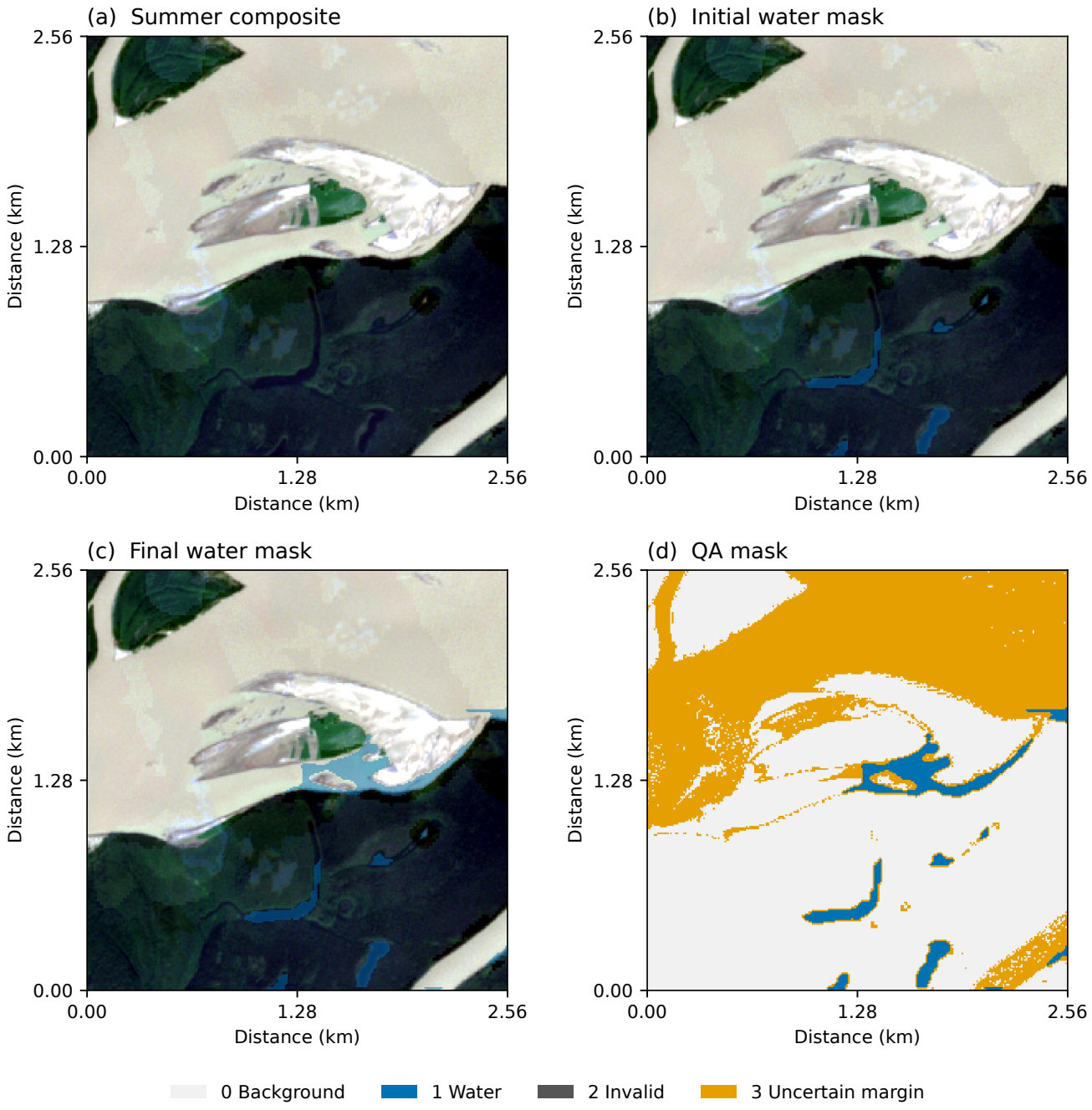



Figure S25: Enlarged processing comparison for `yukon_flats_2023_r000512_c003584`. All panels use the same released image grid. Water pixels are blue in the two overlays; the QA legend identifies all four codes. Relative to the archived initial mask, the final mask adds 1366 pixels and removes 1 pixels. QA recalculation matched the released QA layer exactly. These are processing comparisons rather than independent shoreline references. Contains modified Copernicus Sentinel data (2023).

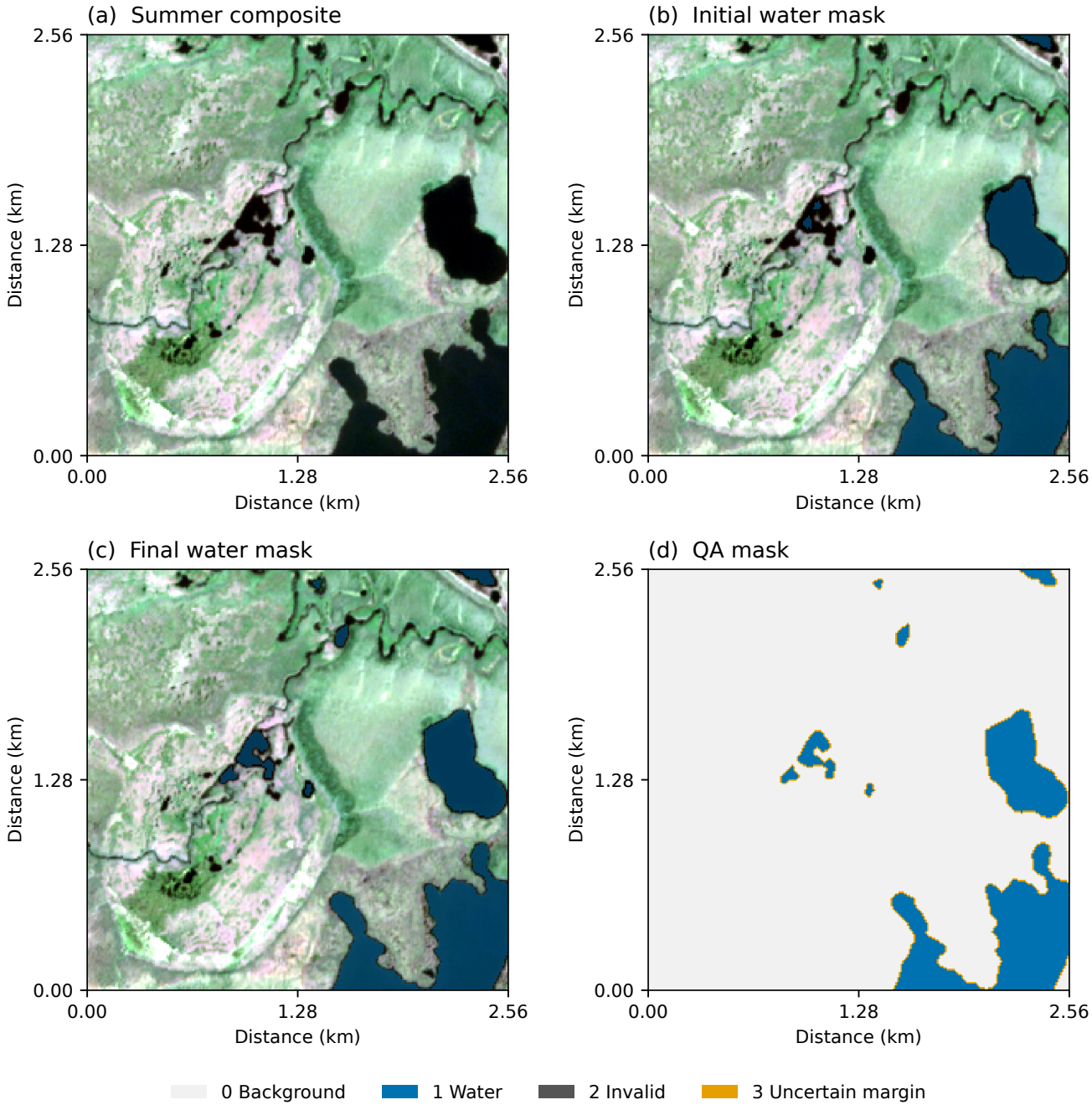



Figure S26: Enlarged processing comparison for `yana_indigirka_east_2023_r004608_c000512`. All panels use the same released image grid. Water pixels are blue in the two overlays; the QA legend identifies all four codes. Relative to the archived initial mask, the final mask adds 748 pixels and removes 0 pixels. QA recalculation matched the released QA layer exactly. These are processing comparisons rather than independent shoreline references. Contains modified Copernicus Sentinel data (2023).