Synthesis study: Water for waterbirds

Applying remote sensing data to understand how spatiotemporal variation in development of open water influences waterfowl arrival and breeding habitat preference

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Motivation

- Timing of migratory waterfowl arrival at northern breeding sites is partly determined by environmental conditions at the breeding sites and on the landscapes along migration routes.
- Presumably, the development of open (liquid) water on the breeding landscape is particularly important to waterfowl arrival timing, as well as breeding habitat preference.
- However, the scale of Arctic landscapes and the challenges of employing remote sensing at high latitudes complicate the detection of open water at ecologically relevant temporal and spatial scales.

Approach

- We compiled estimates of first springtime open-water dates for the years 2019–2023 for locations in Alaska, Yukon, and Northwest Territories at which data from acoustic recording units (ARUs) allow automated identification of waterfowl arrival timing and breeding habitat preference (Fig 1).
- For ARUs with high waterfowl vocal activity, we developed first-open-water date estimates using datasets derived from:
  - Sentinel-2 imagery, including both human image evaluation and Dynamic World[1] automated image classification
  - A water detection algorithm[2] employing synthetic aperture radar (SAR) from Sentinel-1
  - Soil Moisture Active Passive (SMAP) first seasonal soil moisture detections
- We were interested in:
  - Relationships among estimated open water dates derived from different sources,
  - Relationships between remotely derived estimates of open water dates and the arrival dates of migratory waterfowl (arrival was defined as the date when vocal activity reached half its annual max).
  - Identifying spatial scales at which summertime cover of open water best relates to waterfowl activity during that time (i.e. breeding season)

[1] Brown, C.F., Brumby, S.P., Guzder-Williams, B. et al. 2022. Dynamic World, Near real-time global 10 m land use land cover mapping. Sci Data 9, 251.
[2] Battaglia, M.J., Banks, S., Behnamian, A., et al. 2021. Multi-Source EO for Dynamic Wetland Mapping and Monitoring in the Great Lakes Basin. Remote Sensing 13: 599

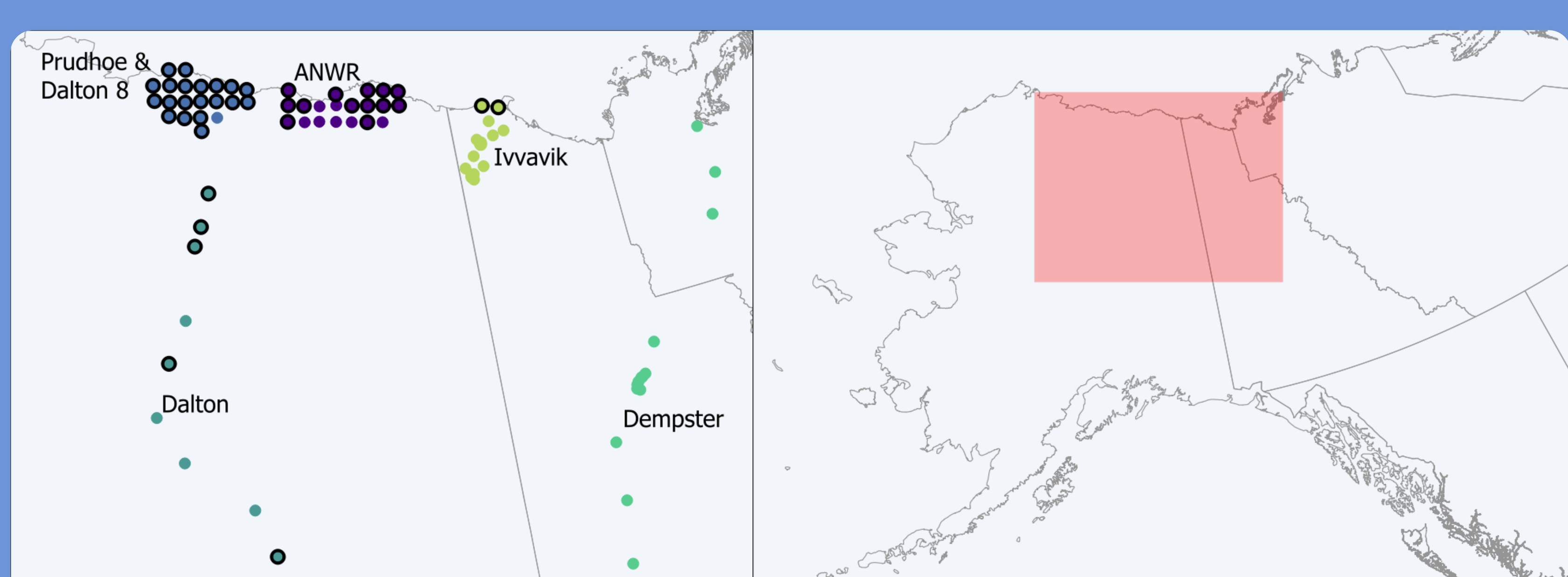

Fig 1. Left: Locations of acoustic recording units (ARUs) situated in the area highlighted in the map at right. ARU locations circled in black have particularly high vocal activity detected for waterfowl during the spring arrival period. Regions labeled in map at left are referenced in Figs 2-5.

Precise remote detection of annual first open water requires frequent satellite overpass and high sensor spatial resolution

- First-water dates derived from Dynamic World (DW) landcover classifications were most closely related to human estimates of first water dates based on visual inspection of Sentinel-2 data, although DW water classifications were subject to noise often related to cloud and snow artifacts.
- SMAP L3 and SAR both tended to miss early (especially April) water, potentially because these southern early-melting sites tended to be smaller isolated waterbodies. Such waterbodies are likely too small to be detected by the coarse resolution of SMAP, and may not present enough surface area for detection by the SAR classification algorithm.
- The current SAR water detection algorithm may need additional parameterization to account for the variance in scattering signatures observed in arctic lake ice and to distinguish the difference between ice and wind roughened water.
- Sentinel-2, which is the source for DW classifications, benefits from good spatial resolution and high temporal resolution in northern latitudes, but frequent cloudiness still presents challenges to both human and algorithmic classifiers.

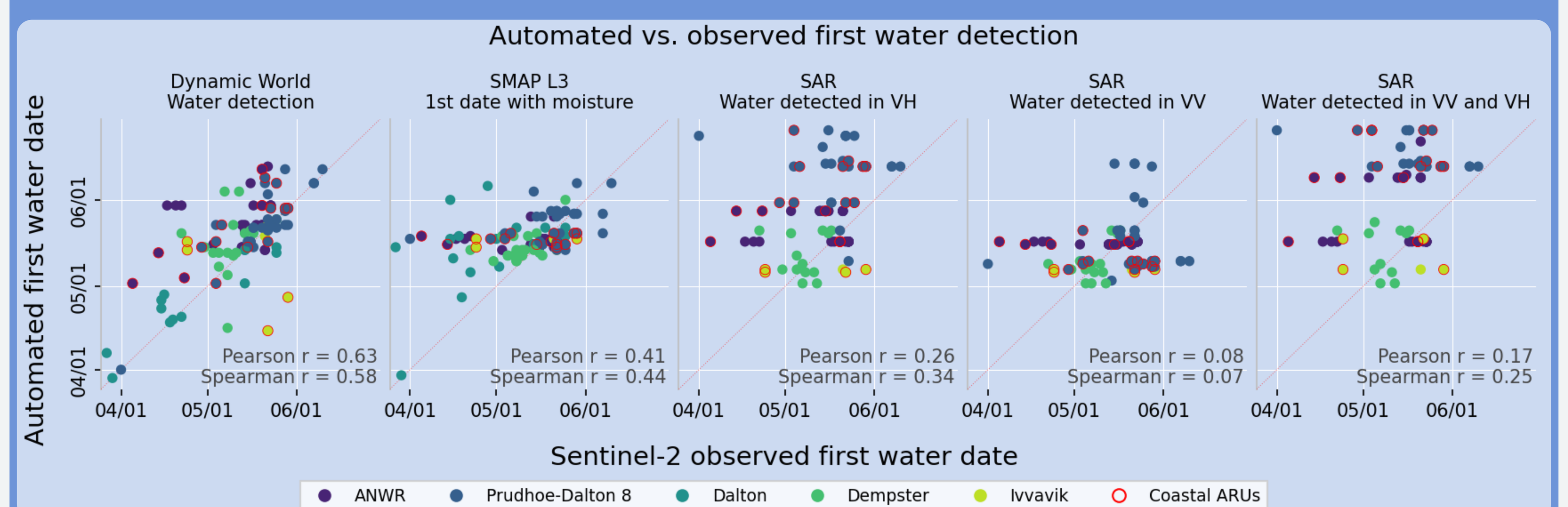

Fig 2. Comparison of first water dates derived from automated classification algorithms against first date water was detected by a human evaluating time series of true- and false-color Sentinel-2 MSI images. All datasets were clipped to a 5000 m buffer surrounding acoustic recording units (Fig 1). For SAR data (Sentinel-1), 'Water detected in VH' is the first date with water detected using VH polarization; 'Water detected in VV' is the same for VV polarization; and 'Water detected in VV and VH' shows the first date with areas predicted as water by both VV and VH.

Waterfowl arrival timing correlates best with date of first open still water

- Of remotely sensed first-water dates we tested, waterfowl arrival dates correlated best with first open still water (i.e., lakes and ponds) identified by a human observer from Sentinel-2 true- and false-color imagery (Pearson r=0.64; Spearman r=0.53).
- Correlations between waterfowl arrival and water from any source (i.e., running or still) were poorer (Pearson r=0.46; Spearman r=0.40).
- This suggests it is important to distinguish still water from running water when considering habitat availability, although automated water detection algorithms generally do not do this.

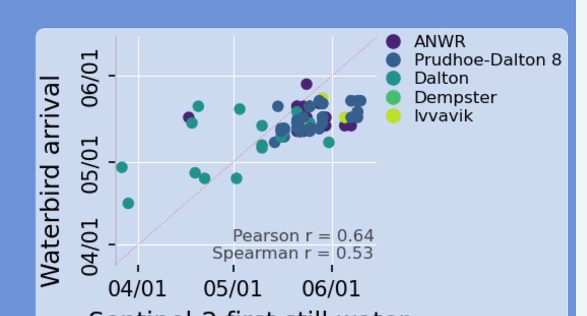

Fig 3. Waterbird arrival date vs first Sentinel-2 still water within 5 km

Choosing neighborhood over backyard:

When choosing breeding territory, summer water cover of the wider landscape matters more than local water cover

- We sampled median percent cover of water within a range of distances around each acoustic recording unit (ARU) during July and August of the acoustic sampling years (2019 – 2023)
- Mean daily frequency of waterfowl vocal activity (vocal activity index, VAI) at the ARUs was best correlated with percent summer water cover at 5 km, which was the largest radius we sampled.
- ARUs with the highest VAIs (>0.10) had summer water cover of at least 30% at all radii sampled.
- ARUs that had low water cover at a distance of 5 km tended to have low waterfowl VAIs, even if there was comparatively high water cover within 500 – 1000 m of the ARU.
- Similarly, ARUs with low nearby water cover but relatively high water cover at greater distances often had moderately high waterfowl VAI.

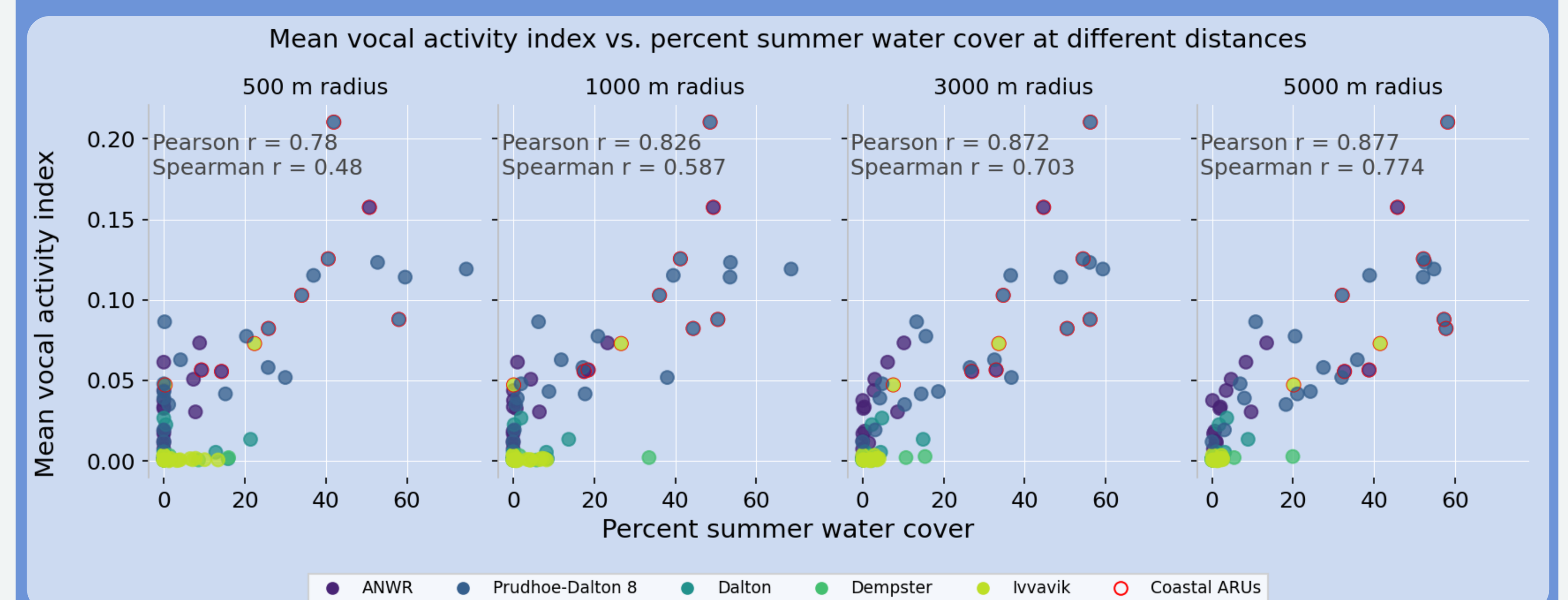

Fig 4. Relationship between mean vocal activity index and the percent cover of water within increasing radii of the acoustic recording unit (ARU). Coastal ARUs are those within 5 km of the northern coastline. Mean vocal activity index is the daily fraction of 10-second acoustic samples that contain waterbird vocalizations. Percent cover of water was calculated as the median Dynamic World July-August percent water cover. Waterbody type was not considered in this analysis.

Interannual variation in arrival and first still water co-vary

- At Prudhoe ARUs in 2021, both mean arrival and first still water date were significantly delayed relative to 2019: waterbird arrival was 5.6 days later on average than in 2019, and first still water appeared 10.6 days later than in 2019.
- In contrast, in ANWR in 2021, mean waterbird arrival was only 2.2 days later on average than in 2019, and first still water appeared only 4 days later on average than in 2019.

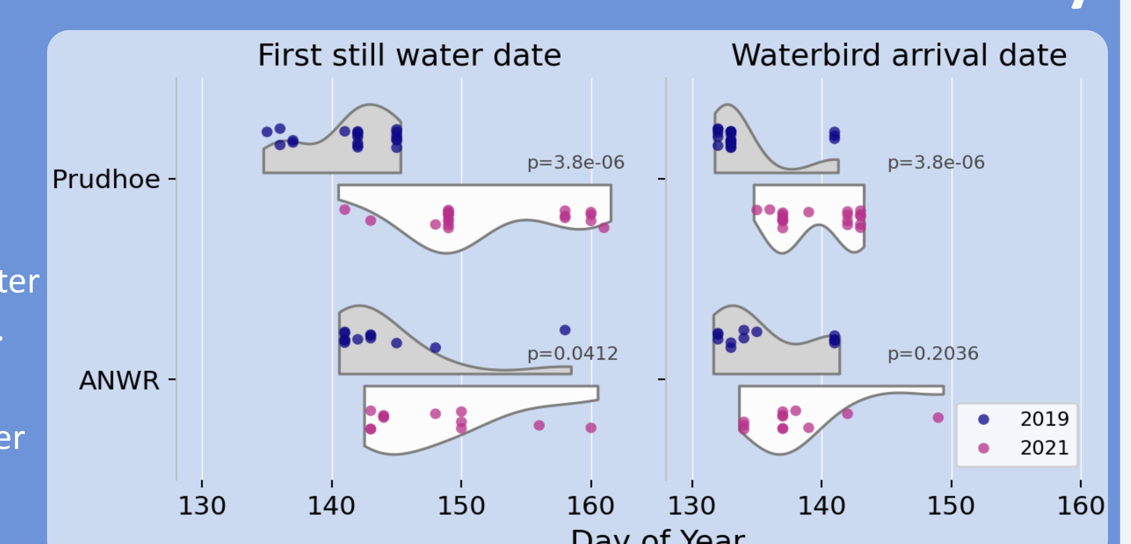

Fig 5. Interannual differences in timing of first still water and waterfowl arrival. P-values are from two-sided Wilcoxon signed-rank tests.

Acknowledgements

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