Using High Resolution Satellite Imagery to Examine Melt Ponds on Arctic Sea Ice

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Introduction

- As melting begins to occur on Arctic sea ice in the late spring and early summer, meltwater from snow and ice begins to form "melt ponds" in areas of low local topography (Polashenski et al., 2012)
- Melt ponds are small (meter scale) and numerous(>30% coverage of an ice flow) (Perovich, 2002)
- Melt ponds increase light transmission to the water column, resulting in warming, thermal expansion, and early phytoplankton blooms (Arrigo et al., 2014; Assmy et al., 2017, Hill et al., 2018; Perovich et al., 2008)
- Consistent, pan-arctic shipboard and ice camp observations are unrealistic
- Public imagery lacks spatial resolution (MODIS=1 km, VIIRS=0.75km)
- Worldview satellites, owned and operated by Digital Globe, have sub-meter scale spatial resolution

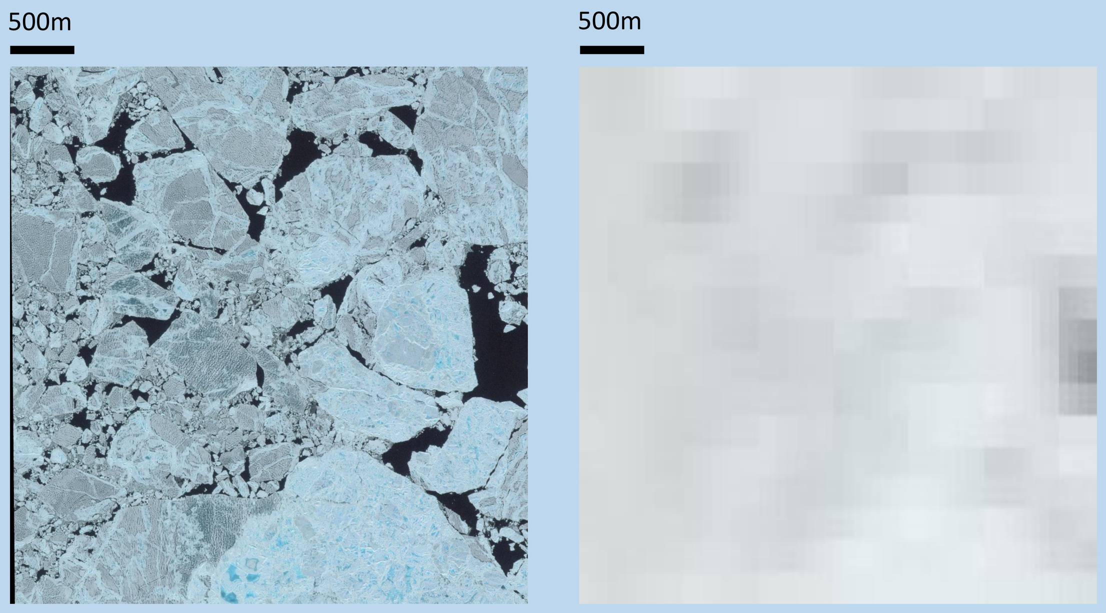
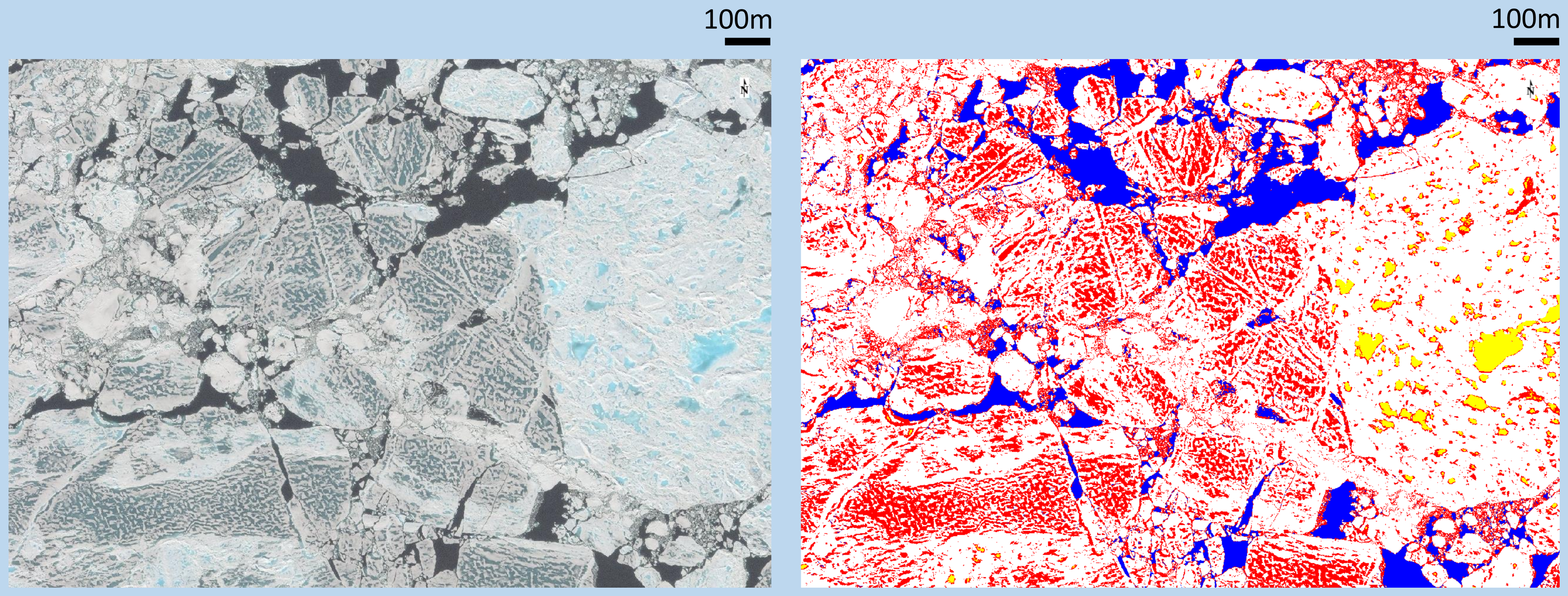


Figure 1- Comparison of Worldview 2 image (left, ~0.5m pixel width) to a corresponding MODIS image (right, 250m pixel width). Images taken from June 27, 2018. Upper left extent: 72° 50'37" N, 166° 8'15" W. Bottom right extent: 72° 48'25" N, 166° 1'5" W (Northern Chukchi Sea).

Methods

- Supervised classifications are performed in ENVI, using the Maximum Likelihood Classification module
- 4 user defined classes used for training- water, light melt pond (LMP), dark melt pond (DMP), and un-ponded sea ice (ice)



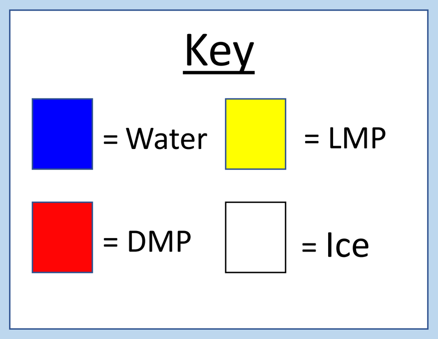


Figure 2- Original Worldview 2 image from June 28, 2018 (left), and corresponding classified image (right). 4 classes include water, light melt pond (LMP), dark melt pond (DMP), and ice. Classified image accurately defines patches of open water. Melt ponds within the ice pack are identified, while still preserving the ice ridges in between.

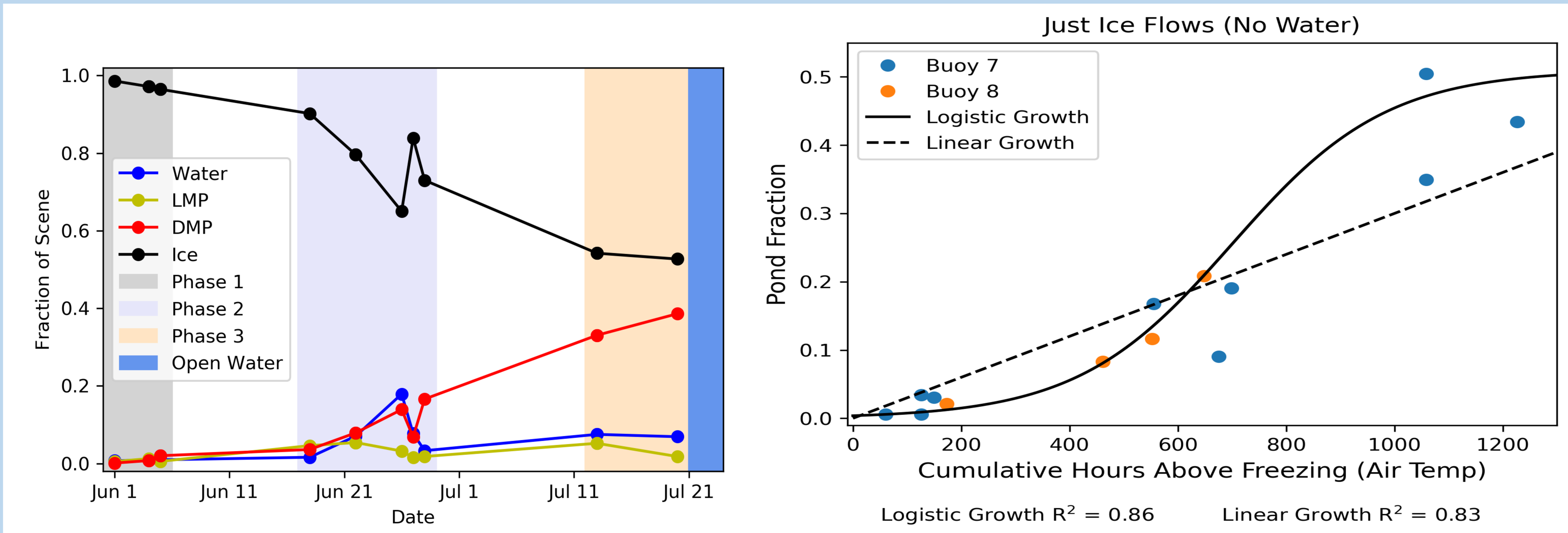


Figure 3- Class distribution data from Worldview imagery (left). "Phases" simply refer to temporally segregated groups of available images. Suggested pond growth model (mid) (R^2=0.86) was based on qualitative (Fig 4) and quantitative (Table 1, right) observations, and plotted as a function of cumulative hours above freezing (air temperature from two buoys in the region). This dependent variable allows for a relationship that can be applied to historical or future temperature data.

$$y = \frac{a}{1+e^{-k(x-b)}}$$
(Eq. 1)

Variable Name	Mathematical Description	Qualitative Description	Value
a	Upper Limit of Curve	Maximum Pond Fraction Observed	0.51
b	Midpoint of Curve	Point in which Pond Formation Rate Begins to Decline (hr)	650
k	Logistic Growth Rate (Slope)	Solved for Using Known x and y (hr^{-1})	0.008

Table 1- Descriptors of variables used to plot the Logistic Growth Curve shown in Figure 3.

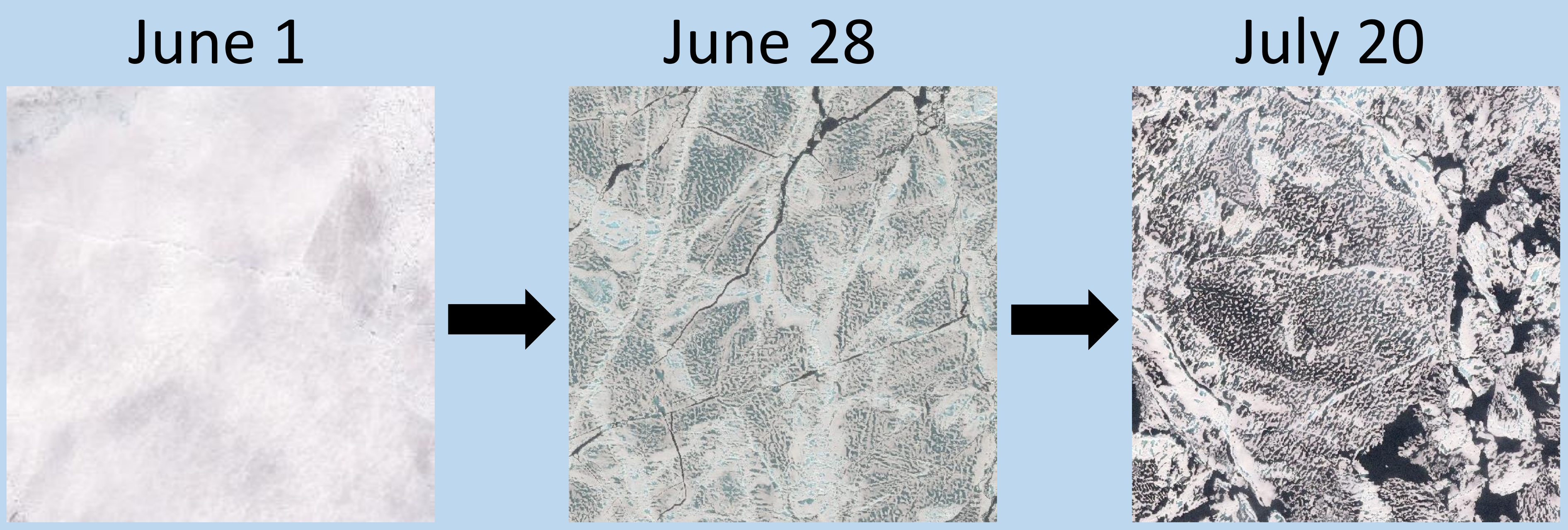


Figure 4- Qualitative progression of melt pond development. Pond abundance increases rapidly during the month of June, before development slows as the ice becomes saturated with ponds and begins to break apart in July. All images are 1 km².

Results

- Satellite scenes from 14 scenes during the spring/summer melt season of Arctic sea ice in the Northern Chukchi Sea were processed and classified
- Relationship between melt pond abundance (fraction of scene) and cumulative hours above freezing established (Fig 3, Table 1)
- Limitations to these data include only fair temporal resolution, including a large gap in imagery during the first two weeks of July (product of Worldview satellites being task-based)

Discussion

The goal of this ongoing work is to develop a robust data product that effectively describes melt pond coverage on First Year Ice in the Arctic Ocean as a function of time during the melting season. Though more testing and analysis is required, the results presented in Figure 3 and Table 1 provide a starting point for accomplishing this task. A relationship between pond coverage and cumulative hours above freezing allows for theoretical reconstruction of melt pond coverage data from historical climate records or future climate predictions. The biogeochemical applications of this model are numerous, potentially improving predictions ranging from primary production to heat budget.

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