The Writing's on the Snow: Determining Snowmelt Onset and Early Snowmelt Events in High Latitude Drainage Basins Using Passive Microwave Remote Sensing

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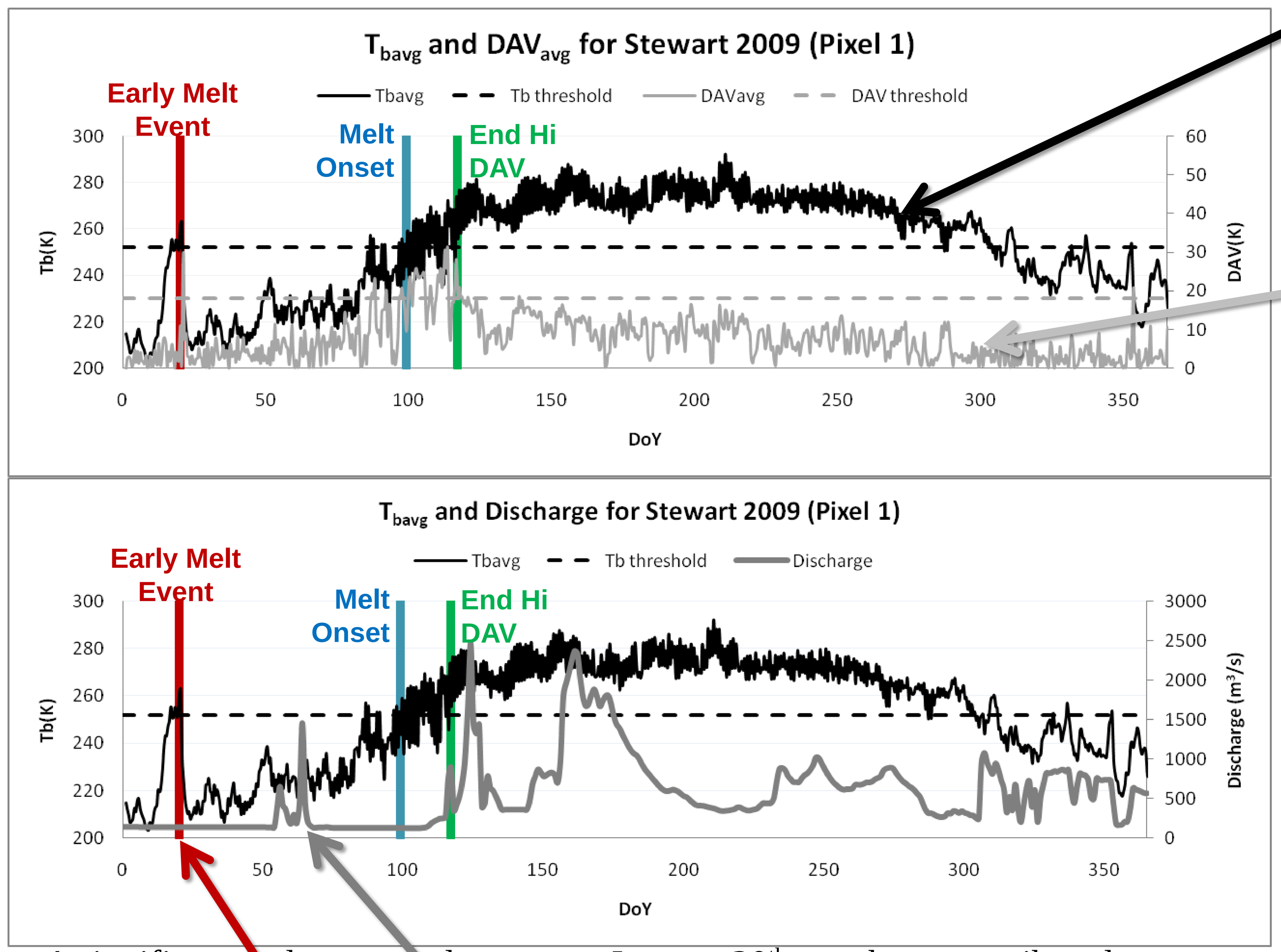
Melt Onset and Early Snowmelt Events

Melt Onset: Start of sustained snowmelt in the spring

Early Snowmelt Events: Short-term periods of melt occurring before full melt onset



T_b is the product of emissivity and physical temperature. Frozen snow has low emissivity compared to wet snow.

DAV represents the dynamism of the snowpack – when high the snowpack is melting during day and refreezing at night.

When Tb>252K & DAV>18K the snowpack is melting.

- When sustained for several days it is **melt onset.**
- All melt before melt onset are **early melt events**.
- When thresholds no longer met (**end high DAV**) snowpack is fully melting (not refreezing)

A significant early snowmelt event on January 20th may have contributed to the small peak in discharge on ~day 60.

Figure 1. Brightness temperatures (T_b) and **diurnal amplitude variation** (DAV) (from AMSR-E data) for 2009 for pixel near the mouth of the Stewart River.

How do you detect melt?

Passive microwave AMSR-E brightness temperature (T_b) data detect melt in the snowpack as the emissivity of wet snow versus dry snow is distinguishable. Using thresholds for T_b and diurnal DAV (Ramage *et al*. 2006; Apgar *et al*. 2007) melt onset and end melt-refreeze period can be determined. A similar, modified algorithm detects early melt.

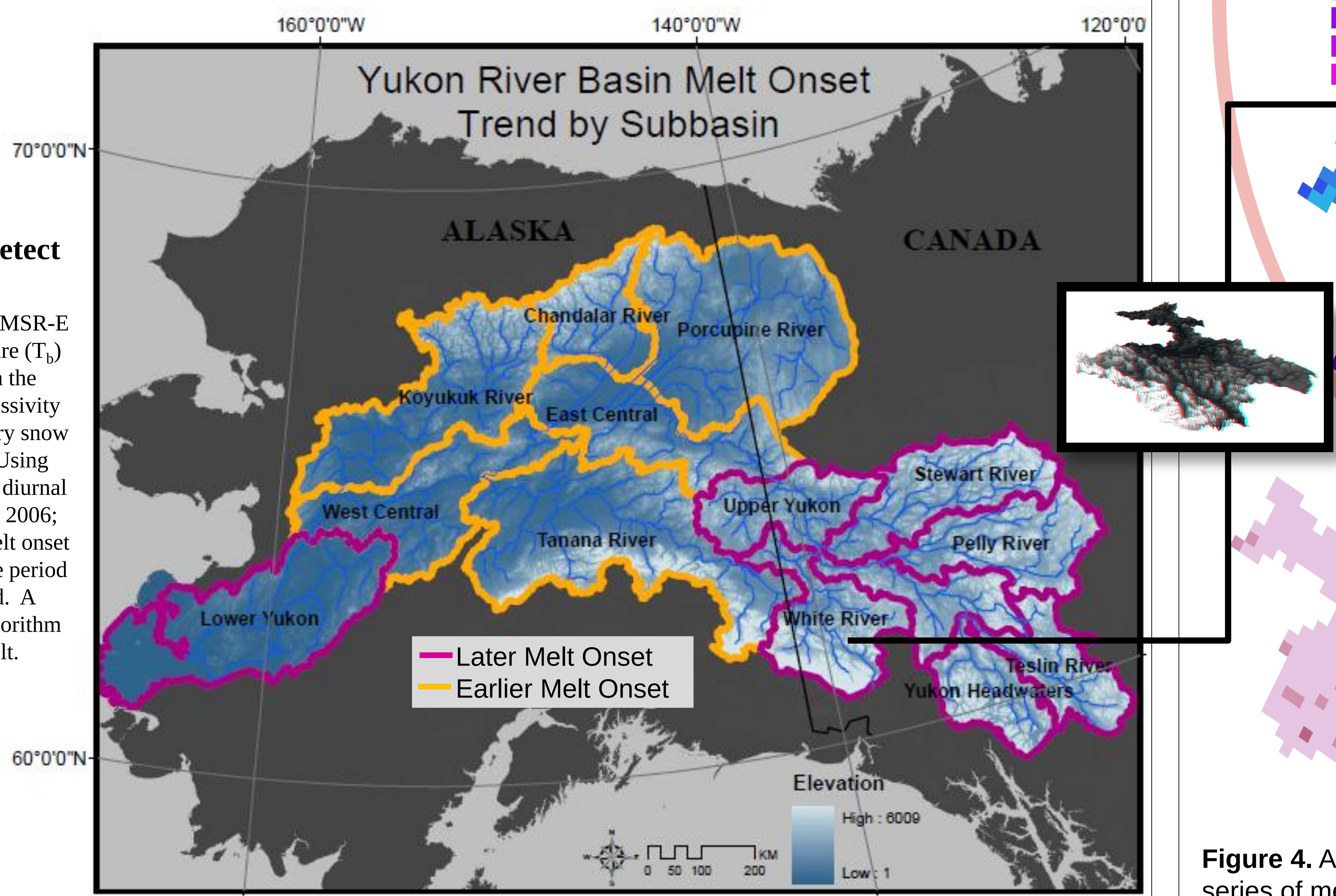


Figure 2. DEM of the Yukon River Basin(YRB) with sub-basins color-coded to depict trend in melt onset for 2003-2010. Orange basins have a earlier melt onset trend while magenta basins have a later melt onset trend. Trends are linear best fits to the average melt onset date for each basin.

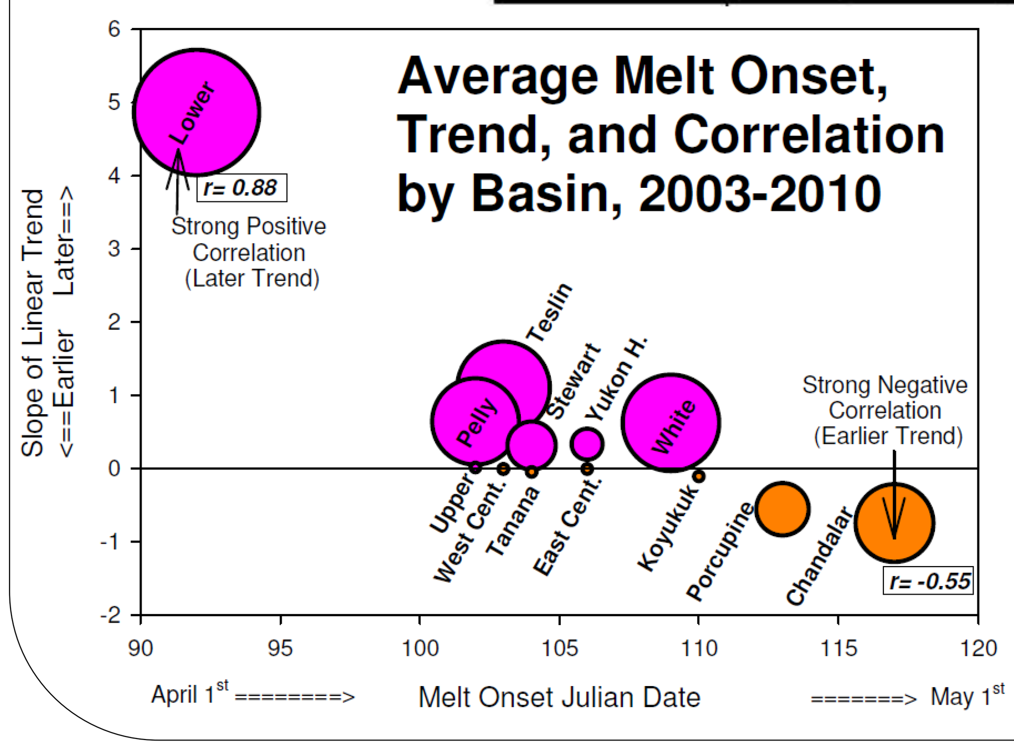


Figure 3. Average melt onset (2003-2010) for each basin (x axis) and linear trend slope (y axis). Bubble size corresponds to size of correlation coefficient with end members denoted (Lower and Chandalar). Note strong later melt onset trends for lower latitude headwater basins.

Annual Variation of Melt Onset and Early Snowmelt Events

Hypothesis: melt events alter snowpack characteristics, affecting melt duration and peak discharge. Trends in melt onset timing and occurrence of melt events may be indicators of climate change in high latitude drainage basins.

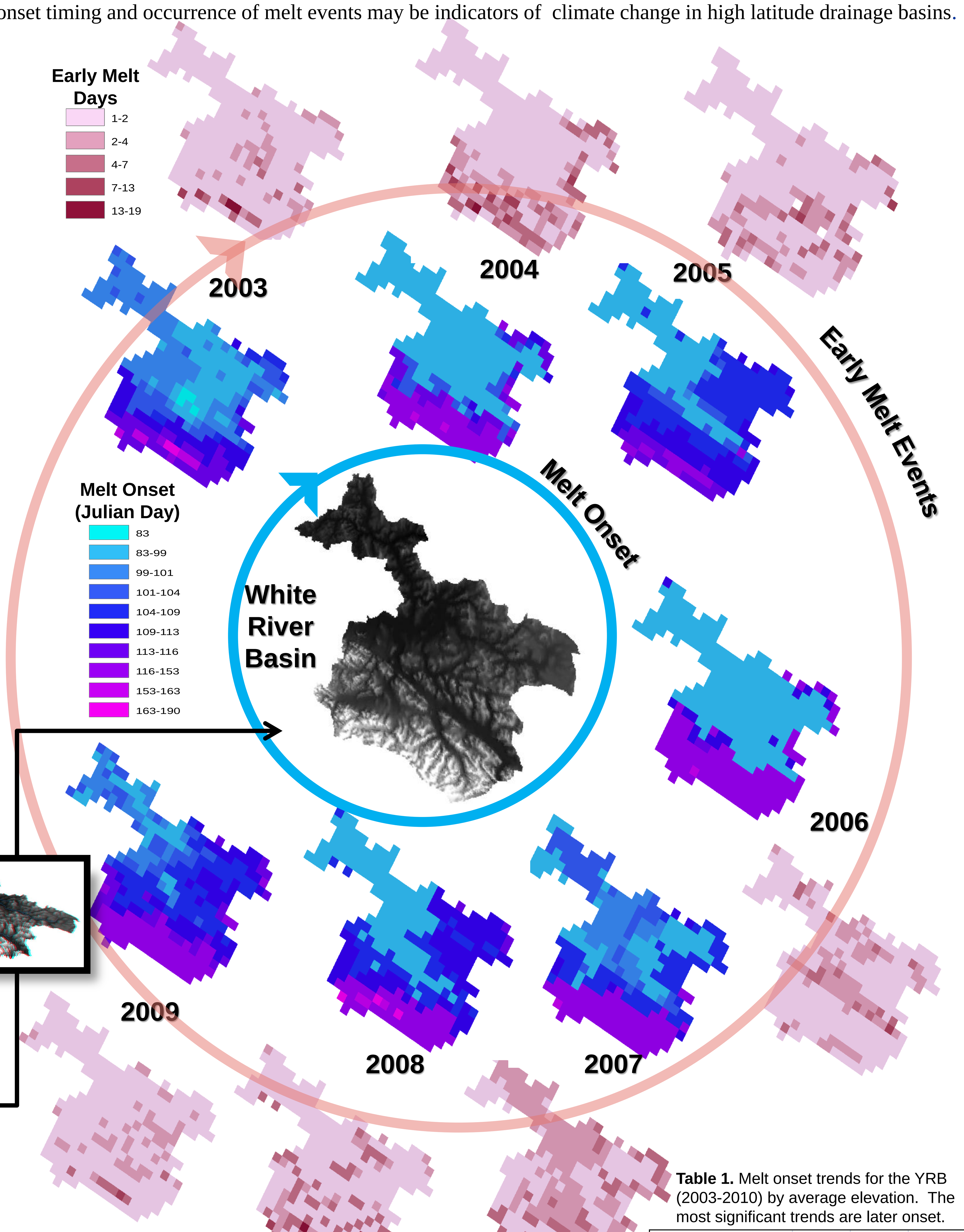


Table 1. Melt onset trends for the YRB (2003-2010) by average elevation. The most significant trends are later onset.

Average Elevation (m)				
Earlier	**Later**	**slope**	**R^2**	**r**
	0-500	1.18	0.29	0.54
500-1000		-0.02	0.00	-0.02
	1000-1500	0.30	0.10	0.31
1500-2000		-0.02	0.00	-0.01
	2000-2500	1.12	0.13	0.36
	2500-3000	1.27	0.22	0.47
	3000-3500	0.84	0.07	0.26
	3500-4000	0.83	0.05	0.21

Figure 4. Annual spatial time series of melt onset in Julian day of the year (blue inner circle) and number of early snowmelt events (light red outer circle) for the White River sub-basin of the YRB. The White basin has some of the highest elevations in the YRB and has glaciers in the headwaters. White has a significant later melt onset trend, which is also reflected in the elevation average melt onset trends (Table 1).

Future Objectives

1) Occurrence of early melt events will be corroborated with field data.
2) Longer time series using SSM/I T_b data from 1988 to 2010 for trend analysis.
3) Correlation and sensitivity analyses to determine the influence of melt events on:
   - Other snowmelt timing parameters (melt onset and melt refreeze period)
   - Streamflow as modeled with SWEHydro (Yan *et al.* 2009) and verified with gauge data.

References

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Ramage J, McKenney R,Thorson B, Maltais P, Kopczynski S, (2006), Relationship between Passive Microwave-Derived Snowmelt & Surface-Measured Discharge, Wheaton R., Yukon, *Hydrol. Proc.* ***20***, 689-704.

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