

# Development of Integrated Terrestrial Surface Water State Indicators for Climate Assessment

Principal Investigator:

Kyle McDonald

Environmental Crossroads Initiative and  
CUNY CREST Institute

Department of Earth and Atmospheric Sciences

The City College of New York

Phone: 212-650-8218

[kmcdonald2@ccny.cuny.edu](mailto:kmcdonald2@ccny.cuny.edu)

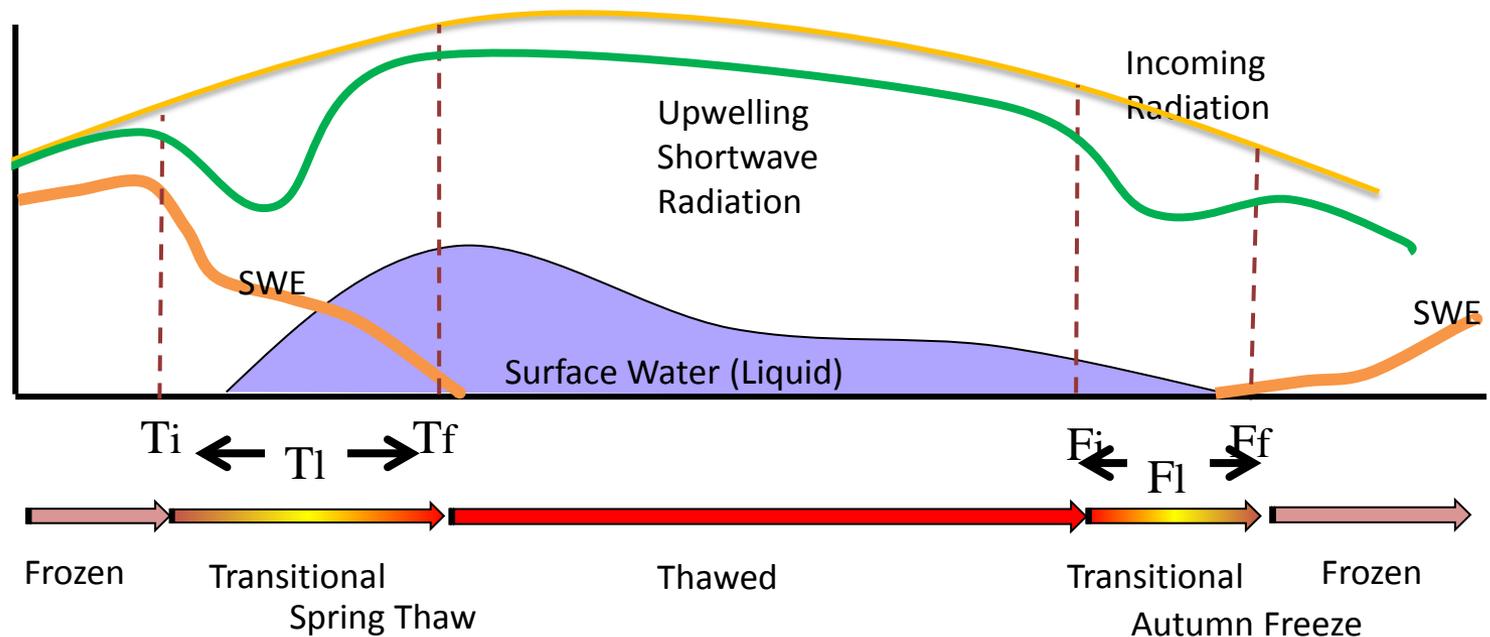
Co-Investigators:

Charles Vörösmarty

Balazs Fekete

The City College of New York

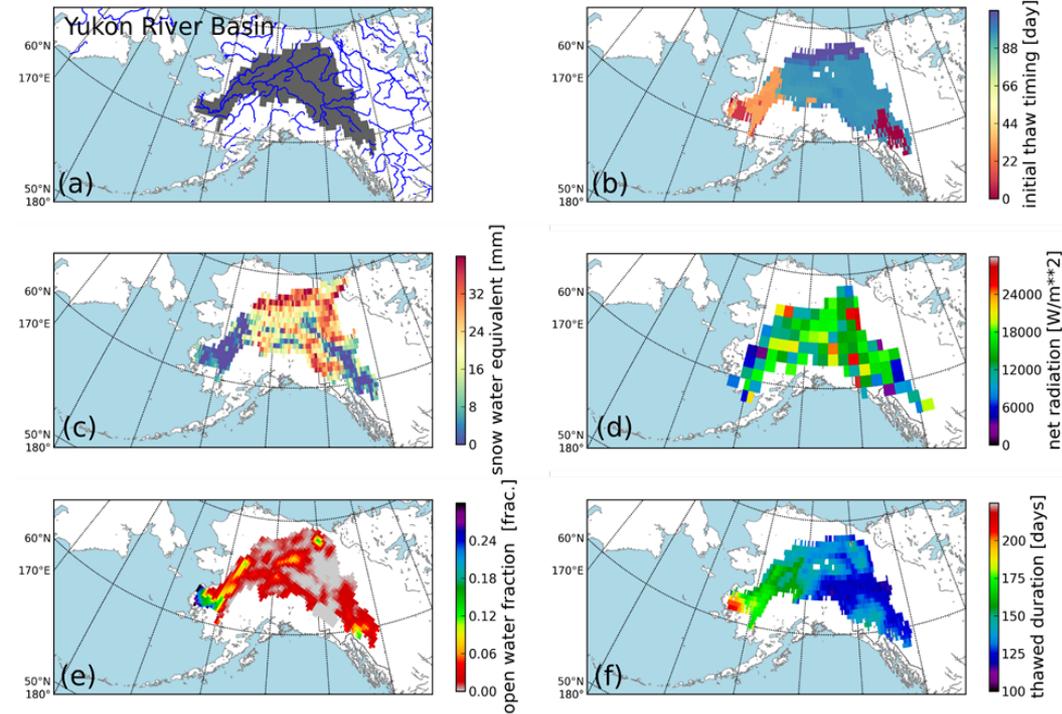
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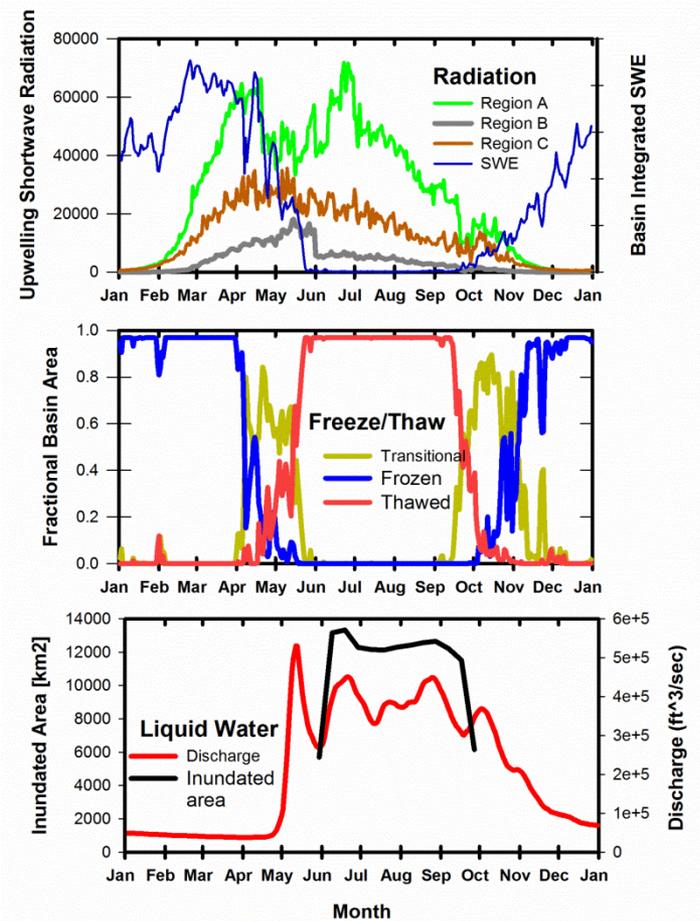
Indicator	Inputs	Key derivatives (with units)
Freeze/thaw: Growing season length; Frozen / non-frozen season	Landscape freeze/thaw state	Day of thaw start ( $T_i$ ) & end ( $T_f$ ) (day of year) Duration of thaw transition ( $T_I = T_f - T_i$ ) (days) Day of freeze start ( $F_i$ ) & end ( $F_f$ ) (day of year) Duration of freeze transition ( $F_I = F_f - F_i$ ) (days) Annual max & min thawed and frozen areas ( $\text{km}^2$ ) Potential growing season (days)
Land Surface Inundation	Inundated area fraction ( $F_w$ ) $F_w$ on days of thaw completion and freeze initiation	Days of max. and min. inundation (day of year) Annual max. and min. inundation area ( $\text{km}^2$ ) Annual integrated inundated area days (days * $\text{km}^2$ )
Snow melt duration and melt rate	Freeze/thaw state SWE at time of initial thaw	$SWE(T_i)/\text{transition length} = SWE/(T_f - T_i)$ (mm/day)
Hydrology - Radiation Balance	Radiative flux; Freeze/thaw state; SWE	Integrated long and short wave radiative flux (upwelling and downwelling) over key seasonal periods (frozen seasons, thawed seasonal, and transition periods) reported by grid cell and by hydrologic basin.

## Integrated Terrestrial Surface Water State Indicators

Integrated System Indicator		
Integrated basin-scale indicator	Integrated surface energy balance (long and short wave), FT, SWE, Surface temperature and albedo, river discharge	Integrated fluxes over key seasonal periods (frozen seasons, thawed seasonal, and transition periods) correlated with river discharge and temperature.

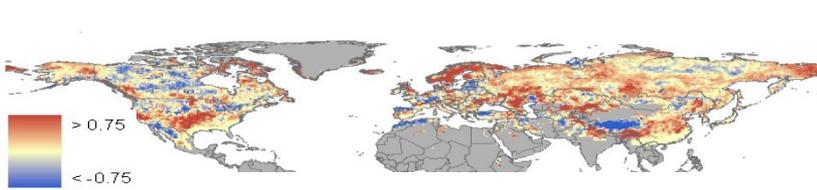


Example of key inputs and indicators for the Yukon river Basin region, shown for 2007. Examples are for surface water state changes during 2007, (b) basin area subset of day of initial thaw, (c) SWE at time of initial thaw, (d) total net accumulated radiation during the snow-melt period, (e) the seasonal maximum surface water fraction, and (e) and total thawed duration (corresponds to the length of the thaw transition period).

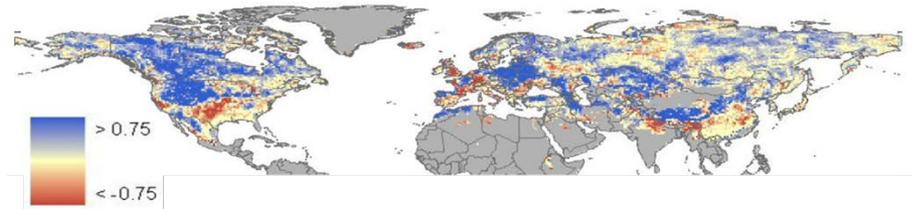


Yukon River Basin for 2007. Upwelling shortwave radiation (shown at top along with basin-integrated SWE) is shown separately for three regions of the basin. SW radiation decreases with the timing of freeze/thaw transition (during both the spring thaw and the autumn freeze). The inundated area increases with snowmelt, as does river discharge (bottom graph).

# Combined SSM/I + SMMR 30-year Record

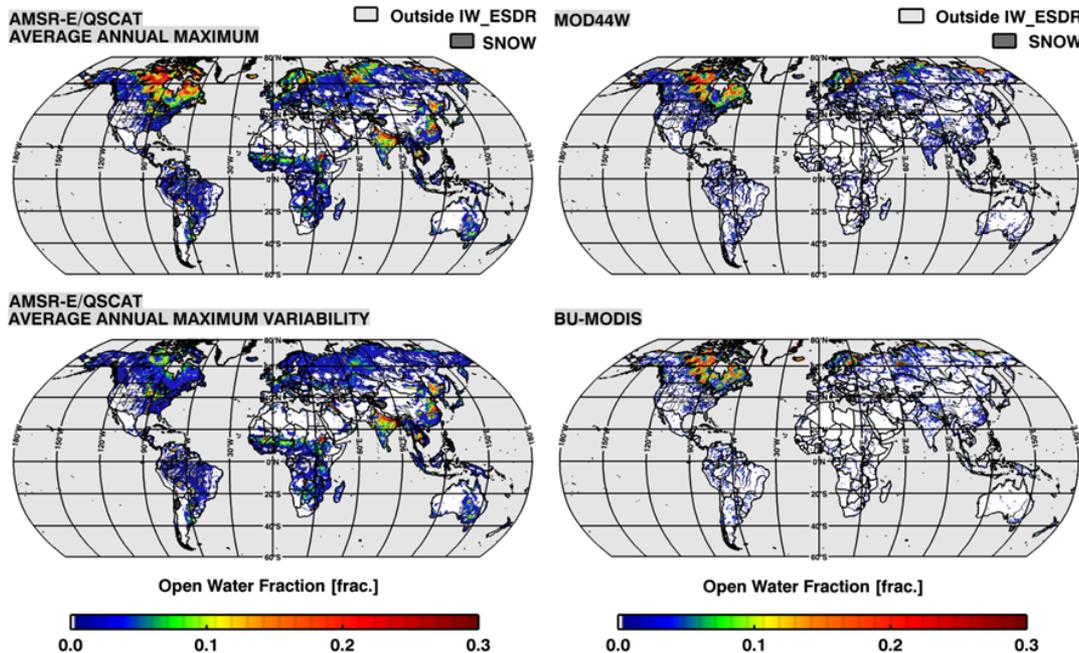


Non-Frozen Period Trend (Days yr-1)



Transition Period Trend (Days yr-1)

Regional trend patterns (days yr-1) derived from Kendall's tau test over the 30-year FT record (1979-2008) for non-frozen period and transitional period parameters. Trends are derived using Kendall's tau. Land areas in grey represent outliers and areas outside of the Northern Hemisphere FT domain that were masked from the analysis.



Average annual maximum extent (top left) and average annual maximum variability (bottom left) as obtained from 7+ years of the Fw dataset. For comparison, the static high-resolution 250 m land-water mask from MODIS-SRTM (MOD44W) (top right) and the Boston University MOD12Q1 V004 (BU-MODIS) permanent open water and wetland distribution map (bottom right) are shown (Schroeder et al. 2013)