An Integrated Multi-Scale Approach to the Study of Evapotranspiration on the Alaskan North Slope: Preliminary Characterization of Fluxes and Turbulence in the Imnavait Creek

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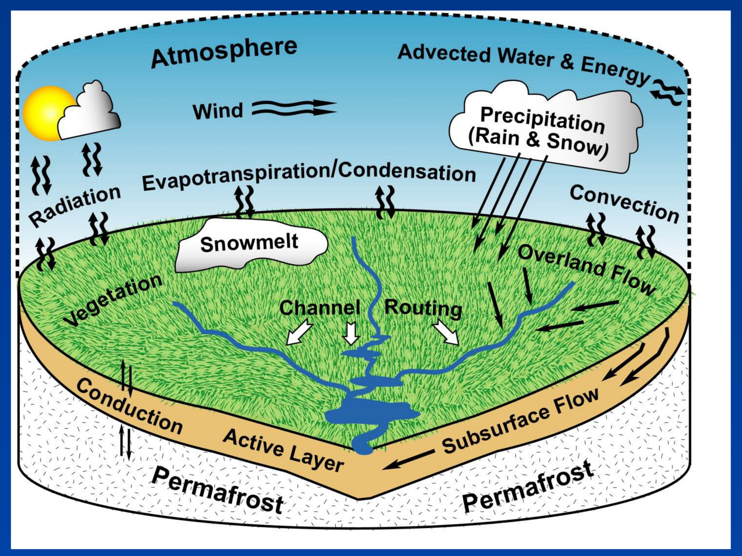
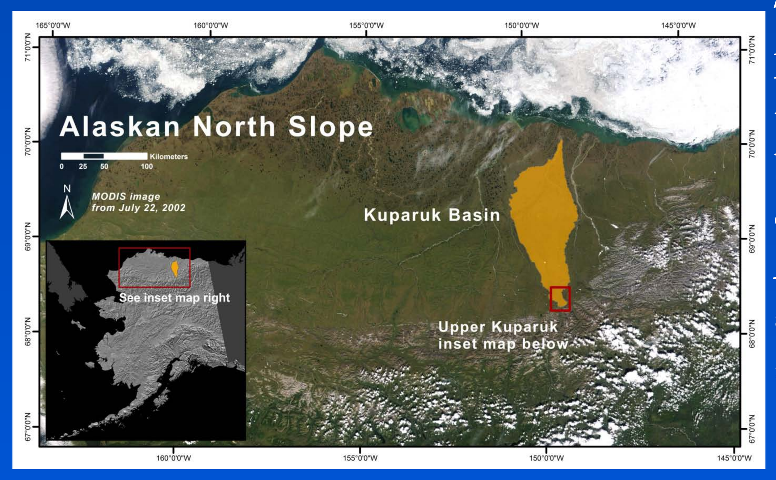
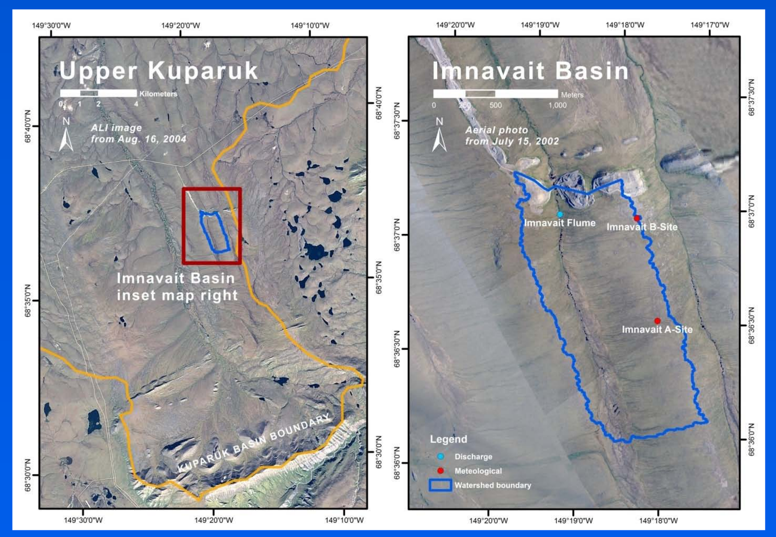
Introduction



Evapotranspiration (ET) plays a significant role in the hydrologic cycle of Arctic basins. Surface-atmosphere exchanges due to ET in the Imnavait Creek Basin are estimated from water balance computations to be about 74% of summer precipitation or 50% of annual precipitation. Even though ET is a significant component of the hydrologic cycle in this region, the bulk estimates don't accurately account for spatial and temporal variability due to vegetation type, topography, etc. (Kane and Yang, 2004). A preliminary experiment was carried out in the summer of 2009 to characterize the turbulent fluxes (i.e. buoyancy fluxes) at two levels of 1 and 3 m AGL and the heat fluxes in an integrated horizontal path covering about 80% of the basin. We present a preliminary analysis and characterization of the turbulent fluxes in the basin and we discuss the design of a multi-scale experimental and modeling approach to the study of ET that integrates point, spatial and volumetric in situ measurements, up to satellite scale observations. The ultimate focus of this exercise is to develop a consistent satellite-based ET retrieval approach.

Imnavait Creek Topography, Experimental Layout & Instruments





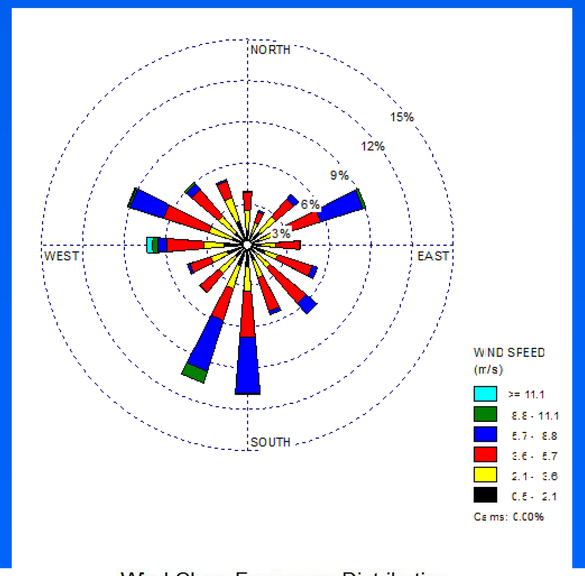
The Imnavait Creek Basin is a small headwater basin of approximately 2 km^2, located in the foothills of the Brooks Range (68 30'N, 149 15'W), 250 km south of the Arctic Ocean. The Imnavait Creek flows parallel to the Kuparuk River for 12 km before it joins the Kuparuk River that drains into the Arctic Ocean. The topographic elevation in this area ranges from 880 m at the outlet to 960 m (Trochim, 2009)

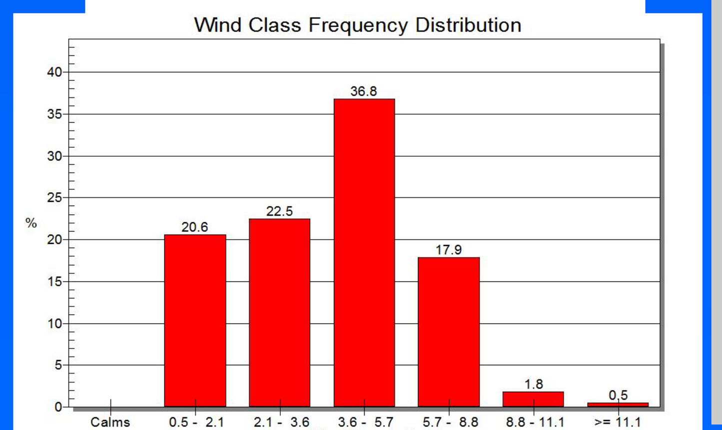
A preliminary experiment was carried out to characterize turbulent fluxes during the summer period from July to September 2009 including hydrological, meteorological and turbulent instruments.

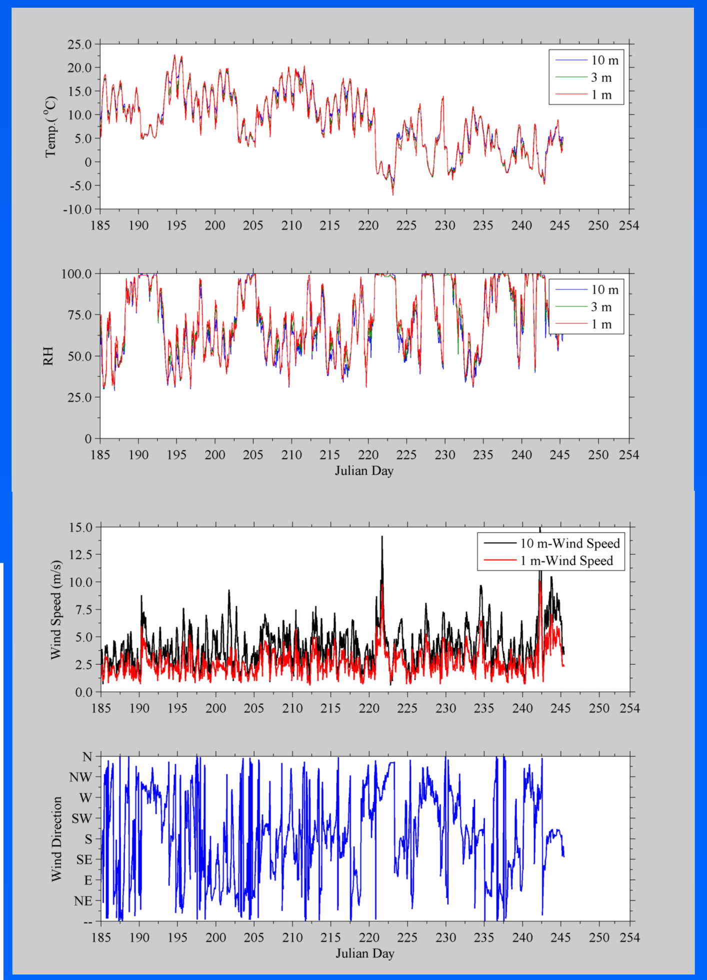
Meteorological, Hydrological (left panel) and Turbulent Measurements in the Boundary Layer including sonic anemometers (middle panel) and scintillometer (right panel)

Upper panel (Kuparuk Basin, Alaskan North Slope)
Lower panel (Imnavait Creek Basin
Experimental site and location of hydrological, meteorological and turbulent instruments)

Synoptic Flow Statistics & Meteorological Scales

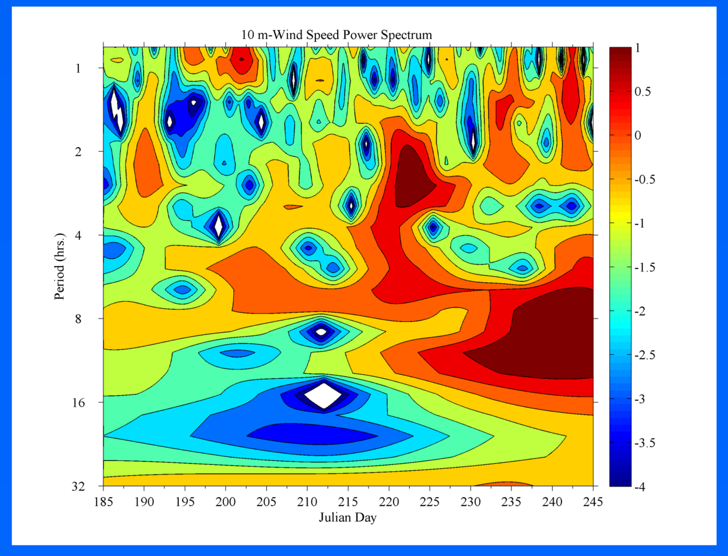






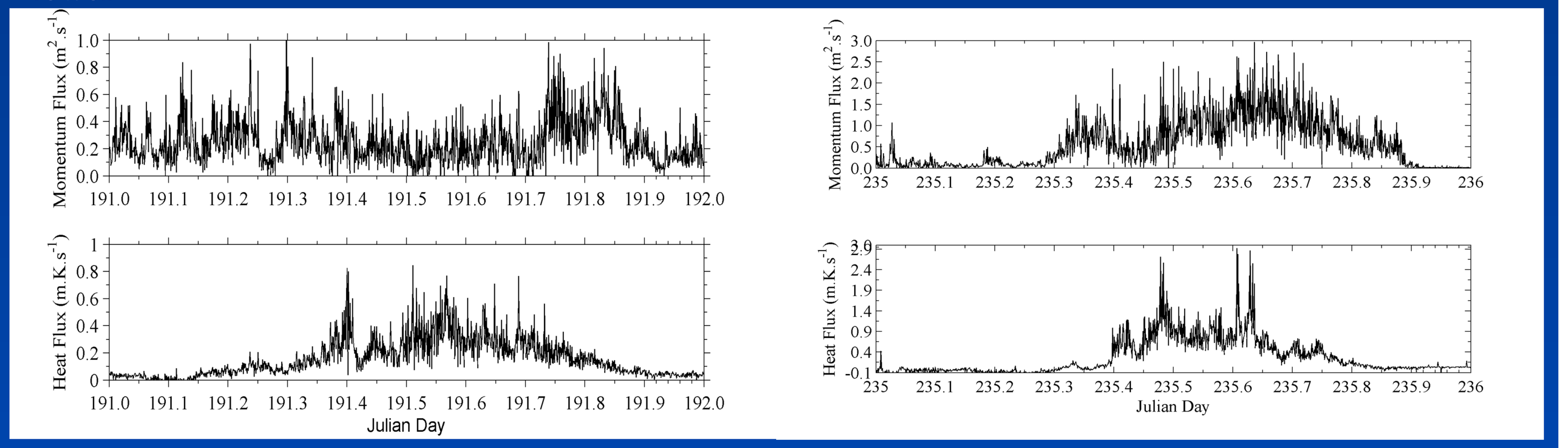
Synoptic air mass in the Imnavait Basin is dominated by Southern flows with two secondary statistical modes WNW and ENE due to the basin orientation.

Morlet wavelet power spectrum demonstrate the occurrence of these two modes after the summer maxima when near-surface temperature approaches the freezing point.

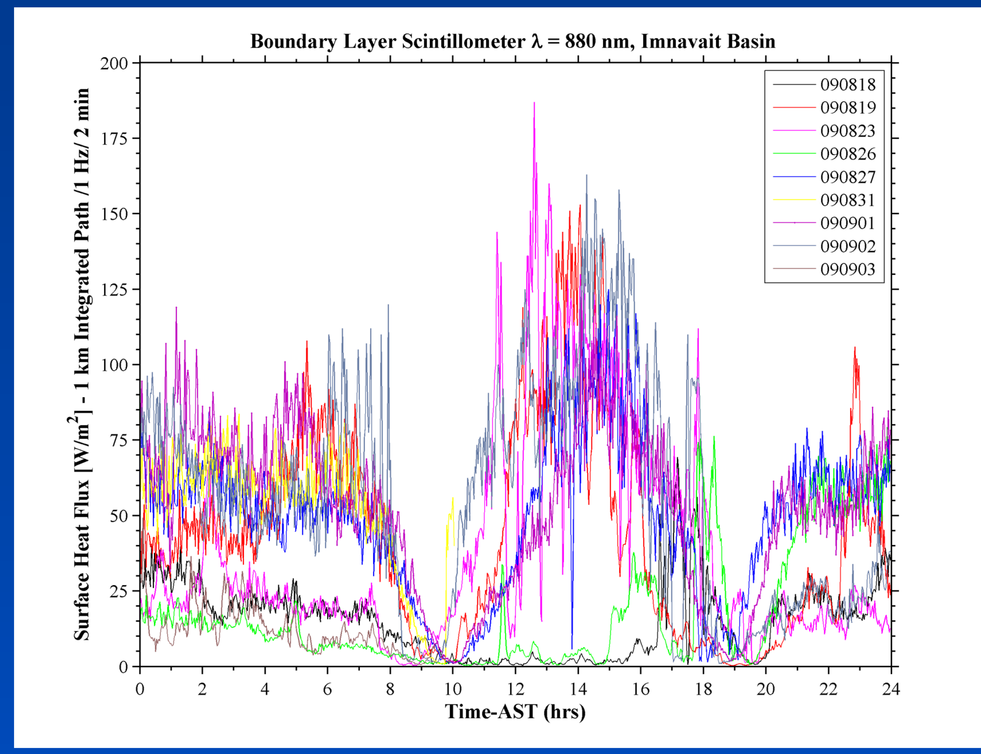


Turbulent fluxes punctual and horizontal path integrated

➢Surface Heat ($w'.\theta'$) and Momentum fluxes ($u'.w'$) derived by Eddy-Covariance from 3m – sonic anemometers tower-



➢Sensible heat flux derived from Boundary Layer Scintillometer 1 km path integration



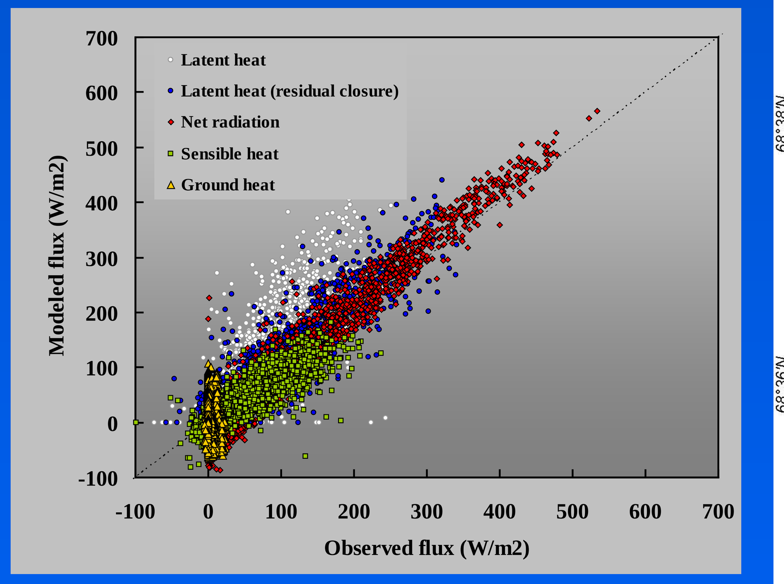
Satellite Remote Sensing Retrieval of Evapotranspiration- Two Source Energy Balance (TSEB) model

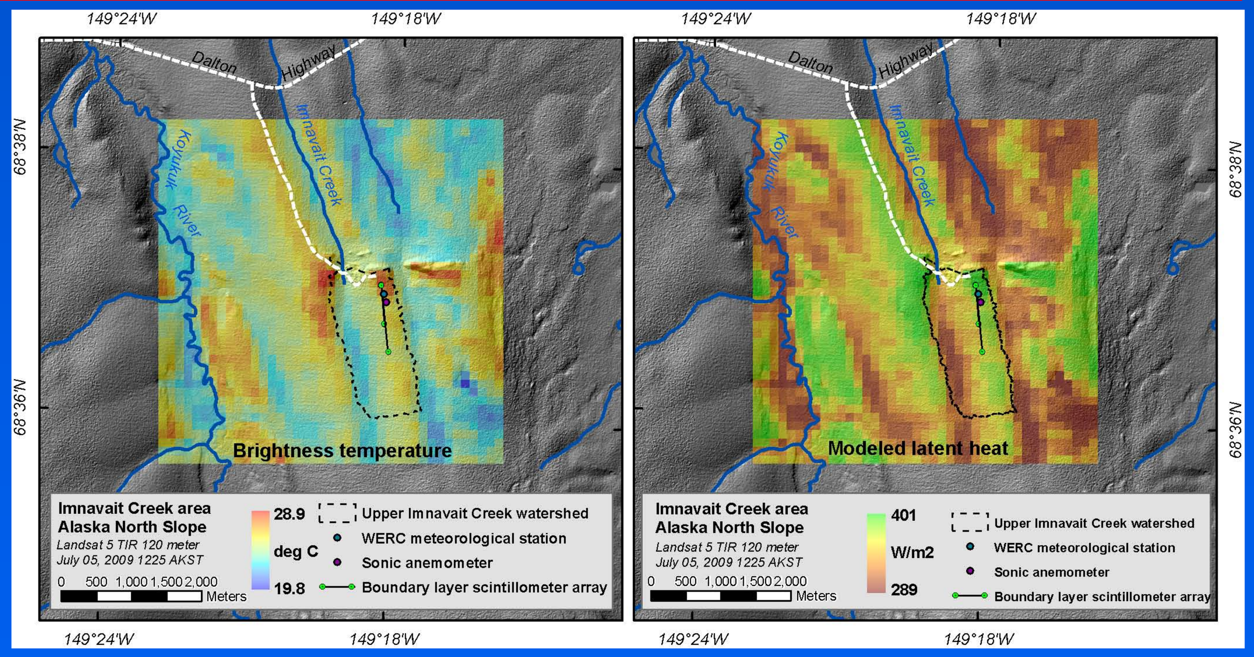
Model variables and parameters (Anderson et al., 2008)

TSEB_PT model

Symbol	Units	Description
α	-	Reflectivity of soil-canopy system
α_c	-	Priestley-Taylor coefficient for canopy transpiration
α_g	-	Soil heat flux coefficient
Δ	kPa K^{-1}	Slope of saturation vapor pressure vs. temperature curve
F	-	Leaf area index
$f(\theta)$	-	Fractional vegetation cover at view angle θ
f_g	-	Fraction of green vegetation
G	W m^{-2}	Soil heat flux
γ_p	kPa K^{-1}	Psychrometer constant
H	W m^{-2}	System sensible heat flux
H_C	W m^{-2}	Canopy sensible heat flux
H_S	W m^{-2}	Soil sensible heat flux
λ	J kg^{-1}	Latent heat of vaporization
λE	W m^{-2}	System latent heat flux
λE_C	W m^{-2}	Canopy transpiration
λE_S	W m^{-2}	Soil evaporation
θ	deg	TIR sensor view angle from nadir
R_A	s m^{-1}	Aerodynamic resistance for momentum
R_x	s m^{-2}	Bulk two-sided leaf boundary layer resistance
R_S	s m^{-3}	Soil boundary layer resistance
RN	W m^{-2}	Net radiation above canopy
RN_C	W m^{-2}	Net radiation divergence within canopy
RN_S	W m^{-2}	Net radiation above soil surface
ρc_p	J K^{-1} m^{-3}	Volumetric heat capacity of air
T_{AC}	K	Aerodynamic temperature
T_C	K	Canopy temperature
T_S	K	Soil surface temperature
$T_{RAD}(\theta)$	K	Surface radiometric temperature at view angle θ

Preliminary results of recent efforts to model mass and energy fluxes in this arctic watershed using the USDA TSEB model (Anderson et al., 2008), which has been successfully applied at lower latitudes. The agreement between the modeled and observed fluxes may improve as we adjust the input vegetation parameters (leaf area index, green fraction, etc.) to values appropriate for the arctic, and as we identify arctic-specific modifications to the model that may better describe the energy flux in the very cold soils. Point-mode model results are used to tune the input parameters by comparison to the Arctic Observatory Network Imnavait Ridge station flux and met tower data (lower panel left), and these are then combined with satellite brightness temperature data to model the flux over an area that includes the station (lower panel right).





Summary

Local scale temporal and spatial variability of fluxes is induced by surface heterogeneity (water tracks), small scale local flows (downslope flows) and thermodynamic (late summer fog) processes in the Imnavait Basin.

Satellite retrieval reveals signatures according to basic thermodynamic processes in the basin.

This preliminary experiment demonstrates the need for a multi-scale flux observing system with volume control to fully capture the variability of fluxes. Single-point, horizontal path and volume-integrated measurements are necessary to account for space-time variability of evapotranspiration fluxes.

Consistent satellite retrieval rely on a realistic ground-truth calibration accounting for the physical properties of the basin.

Acknowledgements

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