Profusions of Evaporation Pan Observations on the Alaskan North Slope

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I. Abstract

Evapotranspiration (ET) plays a significant role in the hydrologic cycle of all basins, yet is only occasionally measured in the Arctic. One simple index method to evaluate ET is the evaporation pan. The energy environment surrounding the simple evaporation pan varies considerably from that of the natural environment. Yet, an evaporation pan is a sound way to estimate the potential ET and also determine an ET pan coefficient (assuming there is also a complementary estimate of actual ET). The few existing ET estimates in the Arctic are based on water balance, energy balance and methods like the Priestley-Taylor method that require less input data.

An Evaporation pan was initially installed in 1986 on the North Slope of Alaska with the intention of collecting data for only 3 years; but in reality, pan evaporation data has been collected for 22 years. The summer maximum, average, minimum and standard deviation of pan evaporation are 420 mm, 324 mm, 280 mm and 40 mm, respectively from 1986 to 2008 (1989 missing). Both the seasonal water balance and the Priestley-Taylor method of the 2.2 km2 Imnavait Creek catchment were used to produce seasonal estimates of actual ET. When used in conjunction with the pan evaporation measurements, a pan coefficient of 0.57 was found in both cases; typically the pan coefficient in temperate regions is 0.5. The pan evaporation results can also be correlated with other measured variables (such as air temperature, wind direction and speed, summer precipitation, Net Radiation, Shortwave Radiation, etc.). For example, we see a very strong correlation (r2 > 0.94 for each of the 22 summer seasons) between pan evaporation amount and thawing degree days (TDD). A Best-fit equation for TDD is used to estimate potential ET through measurements of TDD, and tested against past summer estimates of Pan Evaporation. This should not be too surprising as TDD is an indicator of the thermal regime side of the equation, but it does not account for the amount and timing of summer precipitation that has ranged from a seasonal low of 53 mm to a high of 342 mm at this site.

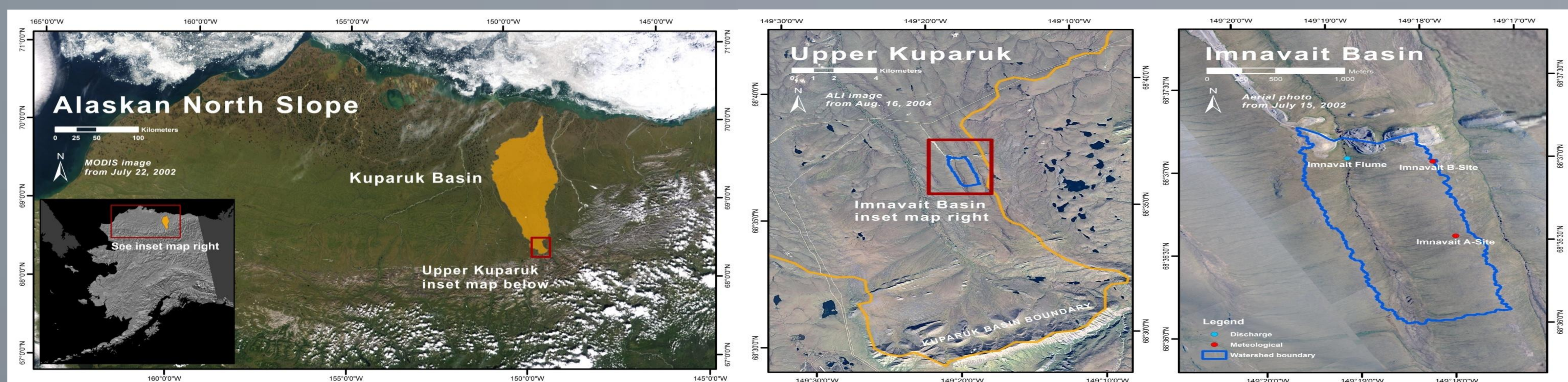

Figure 1A- Kuparuk River Basin, North Slope of Alaska (Trochim, 2009). Figure 1B- Imnavait Creek Basin located in the Kuparuk Basin. (Trochim, 2009). Figure 1C - The Experimental site watershed (Trochim, 2009).

II. Evaporation Pan and Project Background

- Evaporation (E) is the change of state of water between liquid to vapor. Evapotranspiration is the combination of evaporation and transpiration (water vapor emitting from plants) of water back to the atmosphere and is a key component of the hydrologic cycle.
- This project looks into relationships between the potential E and variables of the environment, and also comparing it with estimates of ET to come up with an Evaporation Pan Coefficient.
- The Evaporation Pan was located on the eastern ridge of the Imnavait Creek Basin (Figure 1C) on the North Slope of Alaska (Figure 1A and 1B)(Kane et al., 1990).
- Potential E is the estimate of evaporation rate if there was a constant supply of water (simulates open water evaporation such as a pond with a modified energy balance).
- Evaporation Pan must be used in areas where there is a clear fetch or an area that is flat and has no objects above the level of the pan (Figure 2).

III. Methods

- Evaporation Pan measured hourly for 22 years during the summer months (warm season) at Imnavait Creek Basin (Figure 1B,C and Figure 2) in concert with a precipitation gauge.
- The standard American Class A pan was used (25.4 cm deep, 120.65 cm in diameter; Kane and Yang, 2004).
- Meteorological variables (precipitation, air temperature, wind speed and direction, vapor pressure deficit, net radiation, etc.) measured at the meteorological station located near the Evaporation Pan in Imnavait Creek Basin (Figure 3).
- The Priestley-Taylor was used to estimate the ET within the watershed. This method uses a coefficient to correct for surface moisture, temperature and vegetation conditions $ET=\alpha(\Delta/(\Delta+\gamma))E_R$ (Kane and Yang, 2004) . Δ is the slope of the temperature-saturated vapour pressure curve in $Pa°C^{-1}$, γ is the psychometric constant in Pa°C, E_R is the energy balance component, and α is a "constant."
- The coefficient is usually 1.26 in the subArctic but it has been found to vary in the Arctic. It was determined that surface control factors for several different kinds of tundra and woodland surfaces in the Canadian Subarctic produced a lower coefficient of α=0.95 (Rouse et al., 1976).

Figure 2-Evaporation Pan (standard Class A pan) located at the B site of Imnavait Creek Basin, North Slope of Alaska.

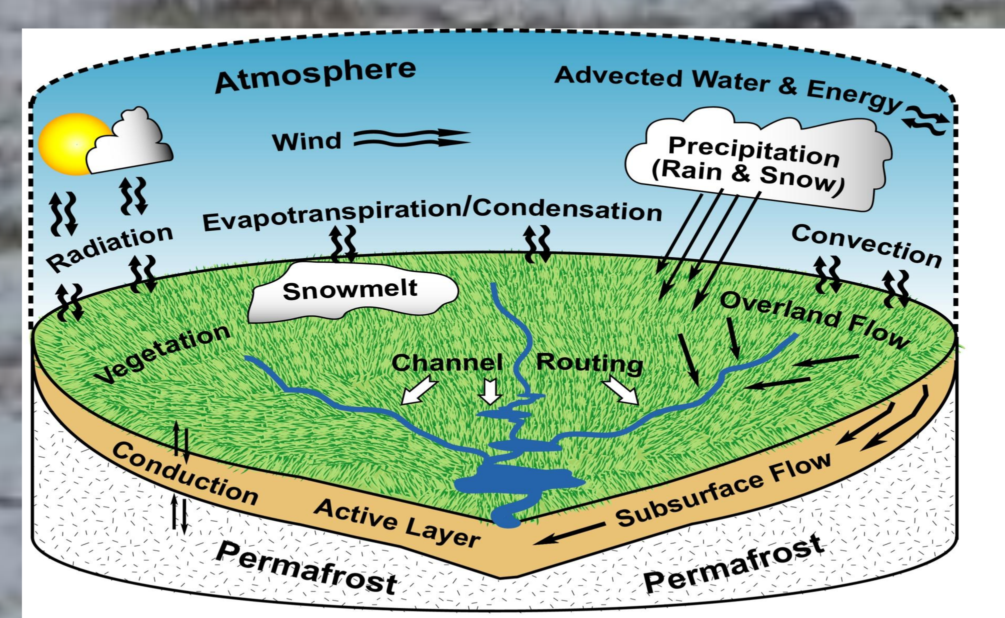

Figure 3- Hydrologic cycle, (Kane and Yang, 2004)

IV. Evaporation Pan Results and Variable Correlation

- June and July had the highest amounts of monthly Evaporation (E). It varied over the 22 years which specific month had more E, but overall June had the highest (Figure 4).
- The summer maximum, average, minimum and standard deviation of E are 420 mm, 324 mm, 280 mm and 40 mm, respectively from 1986 to 2008 (1989 missing).
- Evaporation also has slightly increased over the last 22 years with an increasing trend (Figure 6).
- The correlation between Thawing Degree Days (TDD) (the amount of degrees per day above 0ºC) and Evaporation is extremely high with all 22 years summer total correlations being $r^2 > 0.94$ (Figure 7 and 8).
- The Best fit equation between TDD and Pan Evaporation is y= 0.0363x + 2.7968 (Figure 9).
- The correlation between Net Radiation (Rnet) (the difference between incoming and outgoing radiation) and Evaporation is extremely high with all 22 years summer total correlations being $r^2 > 0.975$.
- The Best fit equation between the Rnet and Pan Evaporation is y= 0.00015x + 0.1501 (Figure 10).
- Vapor Pressure Deficit (VPD) (Saturated Vapor Pressure – Air Vapor Pressure) (difference between how much moisture is in the air to how much moisture the air can hold) and Pan Evaporation have a strong relationship only a few years have full summer measurements of VPD but for 2007 and 2008 the correlation is $r^2 > 0.93$ (Figure 11).

V. Pan Evaporation Coefficient

- The Evaporation Coefficient is calculated (actual Evapotranspiration/potential Evaporation) by dividing the estimated Priestley-Taylor ET estimate (or some other estimate or measurement of ET) by the measured Pan Evaporation.
- The Priestley-Taylor, being actual estimate of ET over the summer, always has a lower summer total than the measured potential Evaporation from the Pan (Figure 5 and 6).
- The average pan coefficients for the months of June, July, and August for the 22 years are 0.6, 0.59, 0.52 respectively (Table 1).
- The Monthly average ends up being 0.57, this is the same as the total average over the 22 years.
- The total average in 2003 was 0.55 (Kane and Yang, 2004), but since then has increased slightly.

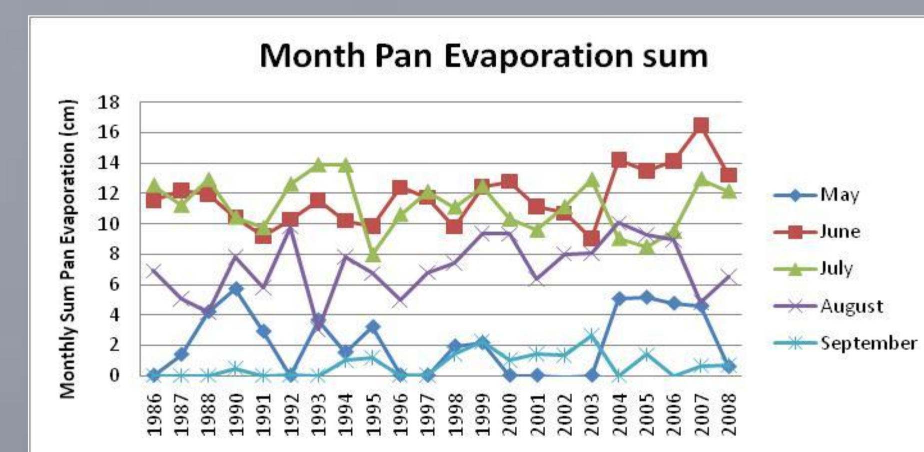

Figure 4- Monthly Pan Evaporation summation (cm).

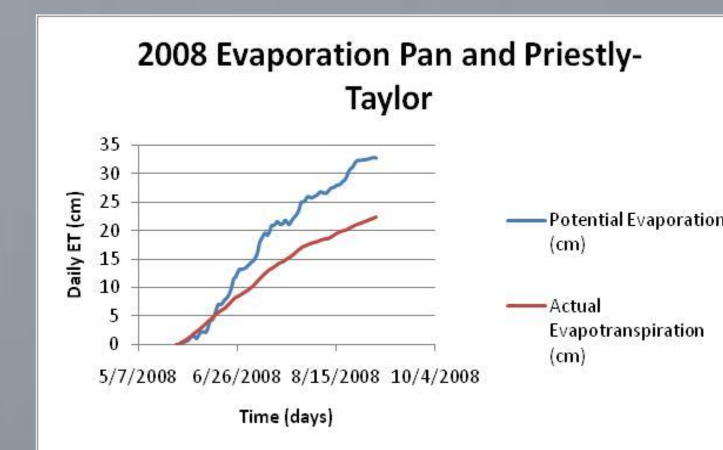

Figure 5- "Warm season" 2008 Evaporation Pan and Priestley-Taylor comparisons with time.

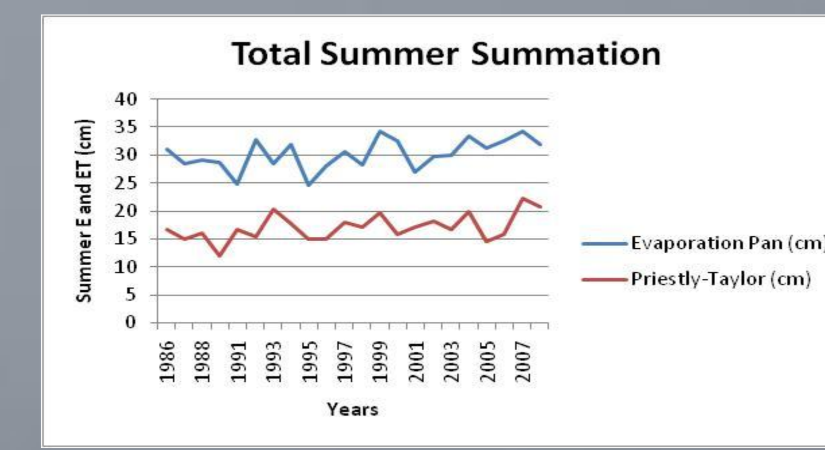

Figure 6- Total Summer summation of Evaporation Pan and Priestley-Taylor estimates.

June Average Coefficient	0.60
July Average Coefficient	0.59
August Average Coefficient	0.52
3-Month Average Coefficient	0.57
Total Summer Average Coefficient	0.57

Table 1- Summer Monthly, 3-month and total summer average Evaporation Pan Coefficients.

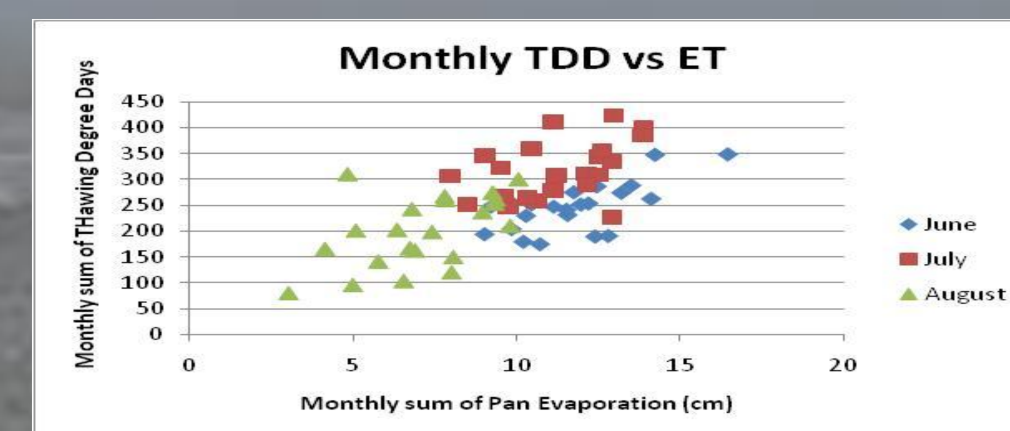

Figure 7- Monthly Thawing Degree Days vs Pan Evaporation (cm) for June, July, and August.

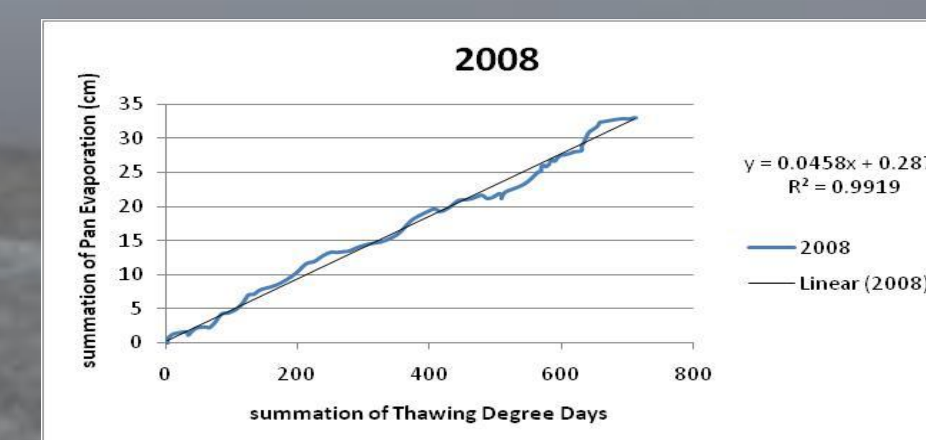

Figure 8- 2008 summer correlation between Evaporation and Thawing Degree Days.

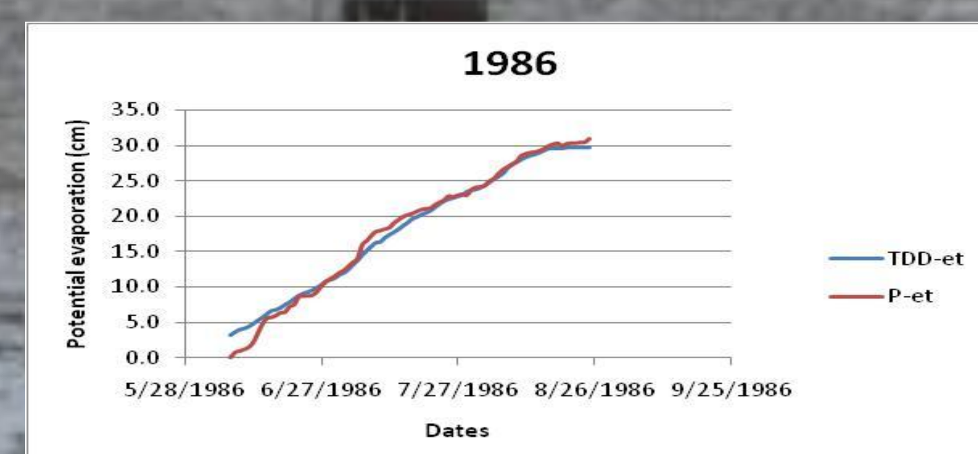

Figure 9- 1986 evaporation Pan measurements and estimated Potential evaporation from TDD.

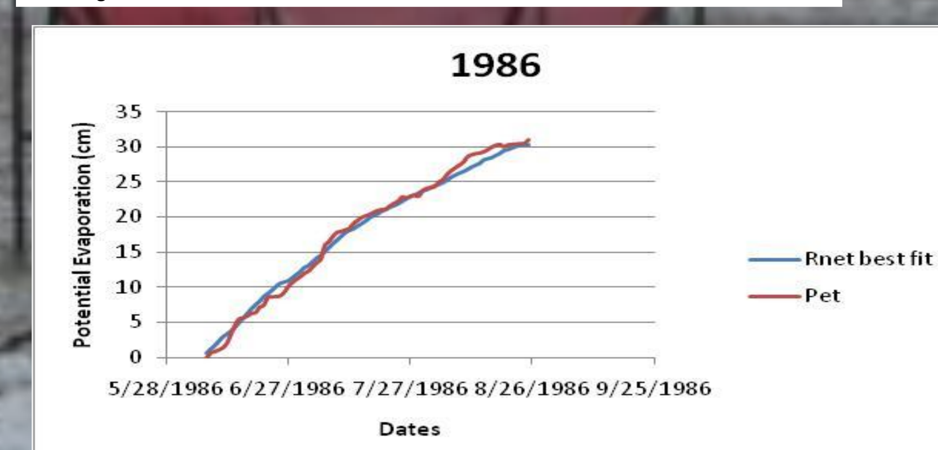

Figure 10- 1986 Pan evaporation measurements And estimated Potential evaporation from Rnet.

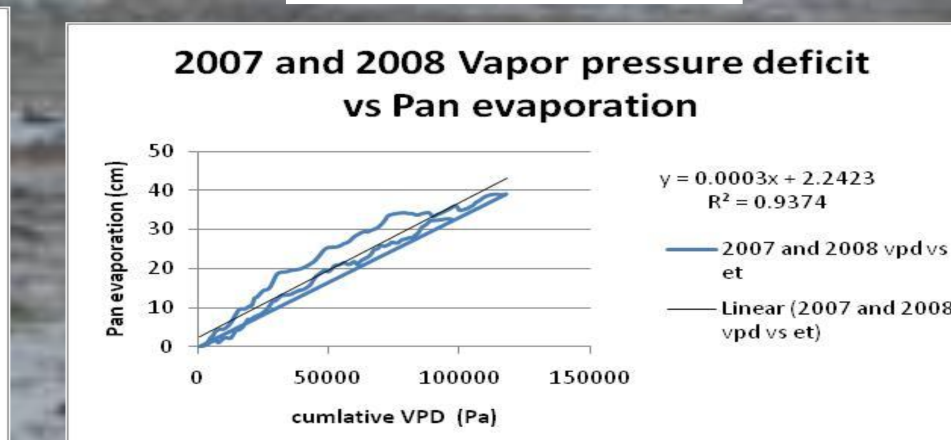

Figure 11- 2007 and 2008 relationship between Vapor Pressure Deficit and Pan evaporation

VI. Conclusions and future ideas

- The Pan E has a strong linear relationship with TDD, Rnet, and VPD.
- TDD and Rnet are a good proxy for the surface energy balance (the warmer the atmosphere the more energy available for latent energy fluxes) and therefore highly correlated with pan evaporation. Both had Best fit equations that can use measured TDD and Rnet to estimate Potential ET that were very successful.
- VPD is a good proxy for the water balance and the ability for ET to occur (if the atmosphere can't hold any more moisture ET will not occur) and the higher the VPD the more ET will occur.
- The summer coefficient for the North Slope in a foothill tundra environment is 0.57, this is slightly higher than the 2003 coefficient of 0.55 found by Kane and Yang (2004). This is partially due to 2007 and 2008 experiencing high pan coefficients.
- In the future, we plan to take the data and correlate it against other methods such as the Penman-Montieth and also further explore the relationship between TPD and pan Evaporation.

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