Examining the Spatial Variability of Actual Evaporation under Clear Skies

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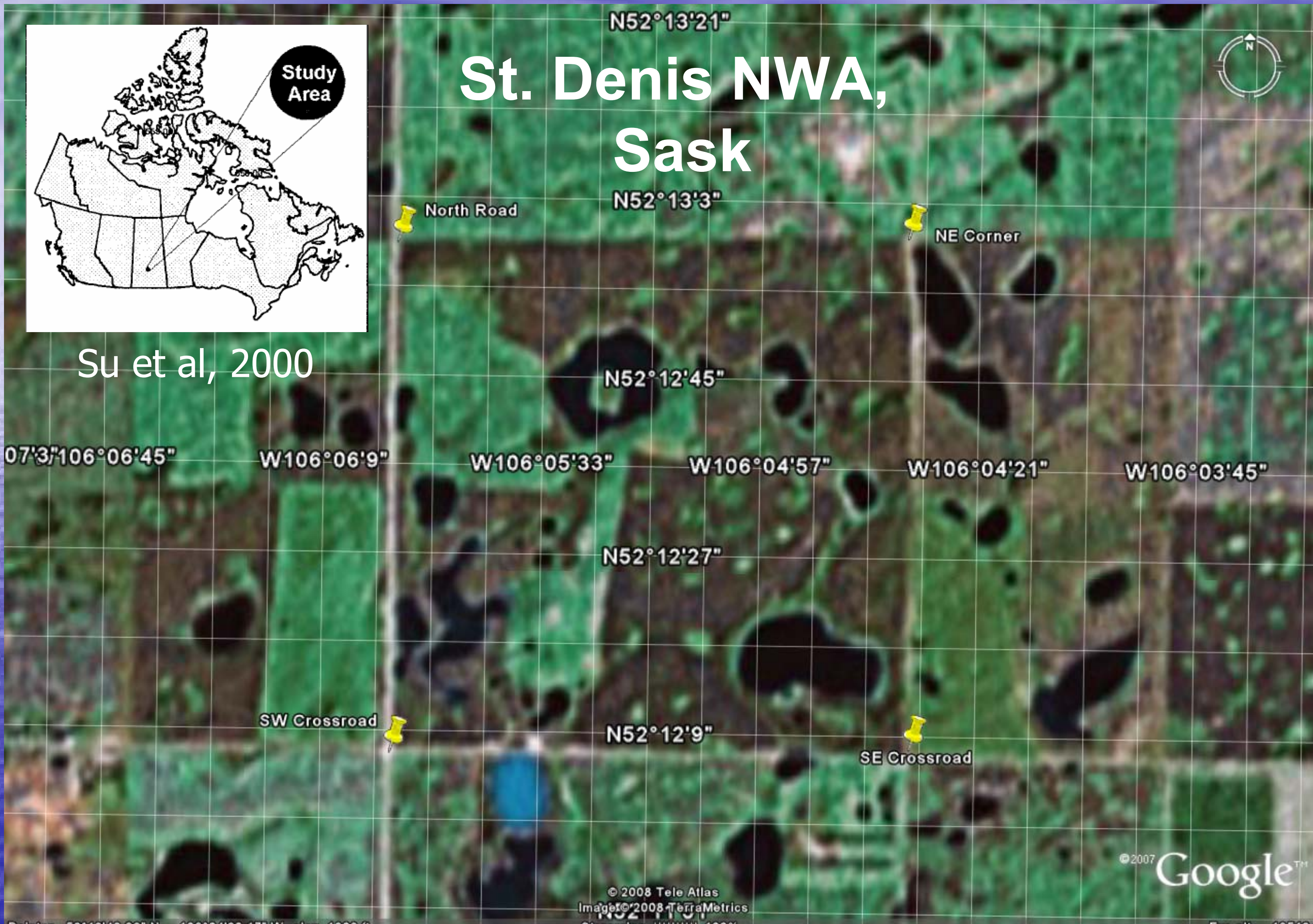
Spatial Variability Problem



Su et al, 2000

Examining the Spatial Variability Problem "Evaporation Ratio"

- Ratio of instantaneous evaporation to an instantaneous reference evaporation;

$$E_R = E_i / E_{iref}$$

- Obtained by distributing evaporation estimates over space at midday

- Allows for sensitivity analysis of midday evaporation relative to derived analytical ratios

Estimating Evaporation

- Granger – Gray (1989) method
  - Introduced relative evaporation, G (ratio of actual to potential); function of the relative drying power, D
  - Obs. drive model; Q* (S↓, L↓, remote sensing), T, RH, u, z_o
  - Does not require soil moisture; offset by radiation balance

Estimates actual rate of evaporation
from a non-saturated land surface

$$E = \frac{\Delta G \frac{(Q^* - Q_g)}{\lambda} + \gamma G E_A}{\Delta G + \gamma}$$

E_A "Drying power of the air"

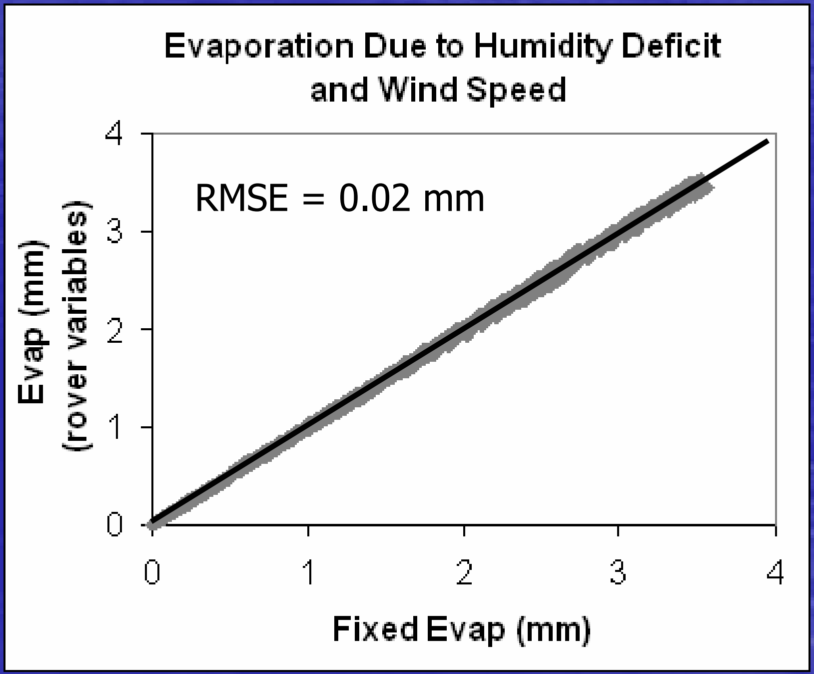
- Product of Wind function and Humidity Deficit

$$E_A = f(u)(e^*_a - e_a)$$

$$f(u) = 8.19 + (0.22 \times \mathrm{z_o}) + (1.16 + 0.08 \times \mathrm{z_o}) \times \mathrm{u}$$

  - function of surface roughness and daily wind speed

$$e^*_a = 0.611^{\left(\frac{17.27 * \mathrm{T_{air}}}{\mathrm{T_{air}} + 237.3}\right)}$$



Midday Analytical Ratios

- Ratio of instantaneous value to an instantaneous reference value

Albedo ratio; $\alpha_R = \alpha_i / \alpha_{iref}$ (terrestrial image)

Longwave ratio; $L_R = L\uparrow_i / L\uparrow_{iref}$ (thermal image)

Radiation ratio; $R_R = f(\alpha_R, L_R)$

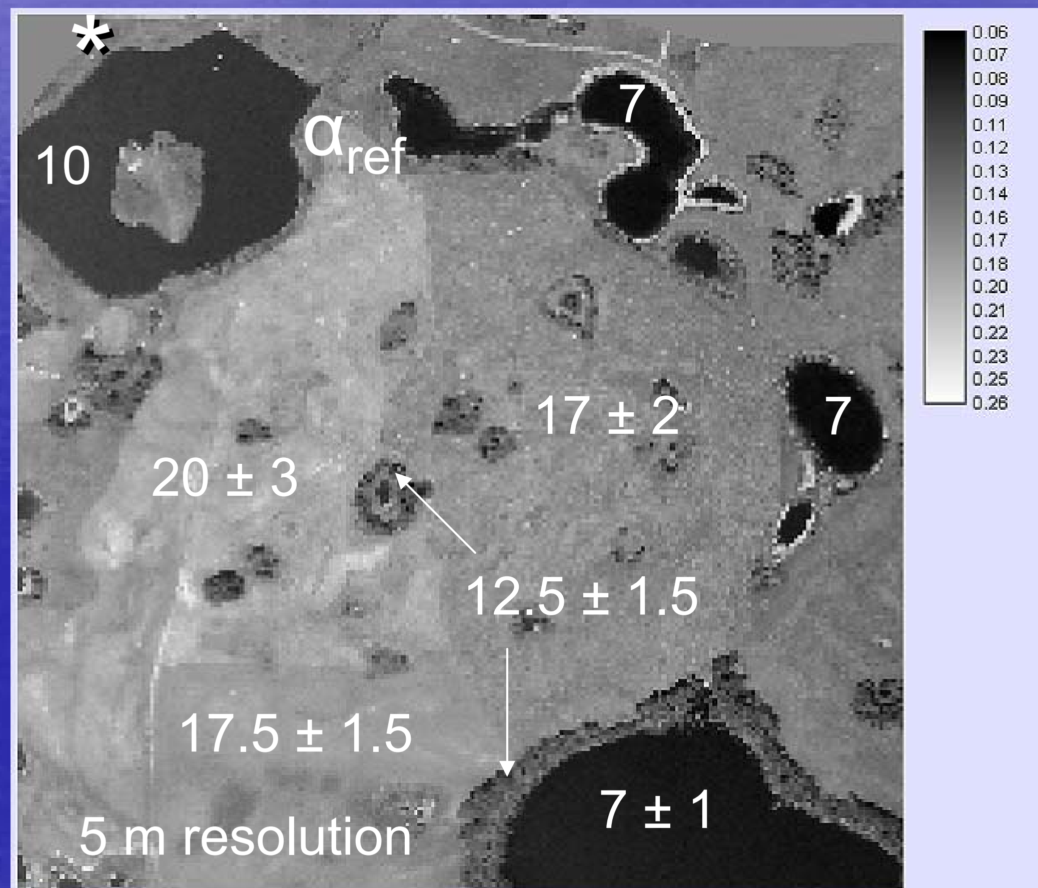
Roughness ratio; $z_{oR} = z_{oi} / z_{oiref}$ (terrestrial image)

Evaporation ratio; $E_R = f(R_R, z_{oR})$

Spatial Variability of Albedo for S↑

- Simplified Corripio (2004); tested it for growing season
  - *measured albedo (≈ 17 %); α_{pixel} (16+ %); $\Delta S\uparrow \approx 8$ W m^{-2}

$$\alpha_{pixel} = \alpha_{ref} \frac{DN_{pixel}}{DN_{ref}}$$



Spatial Variability of L↑ from Thermal Image

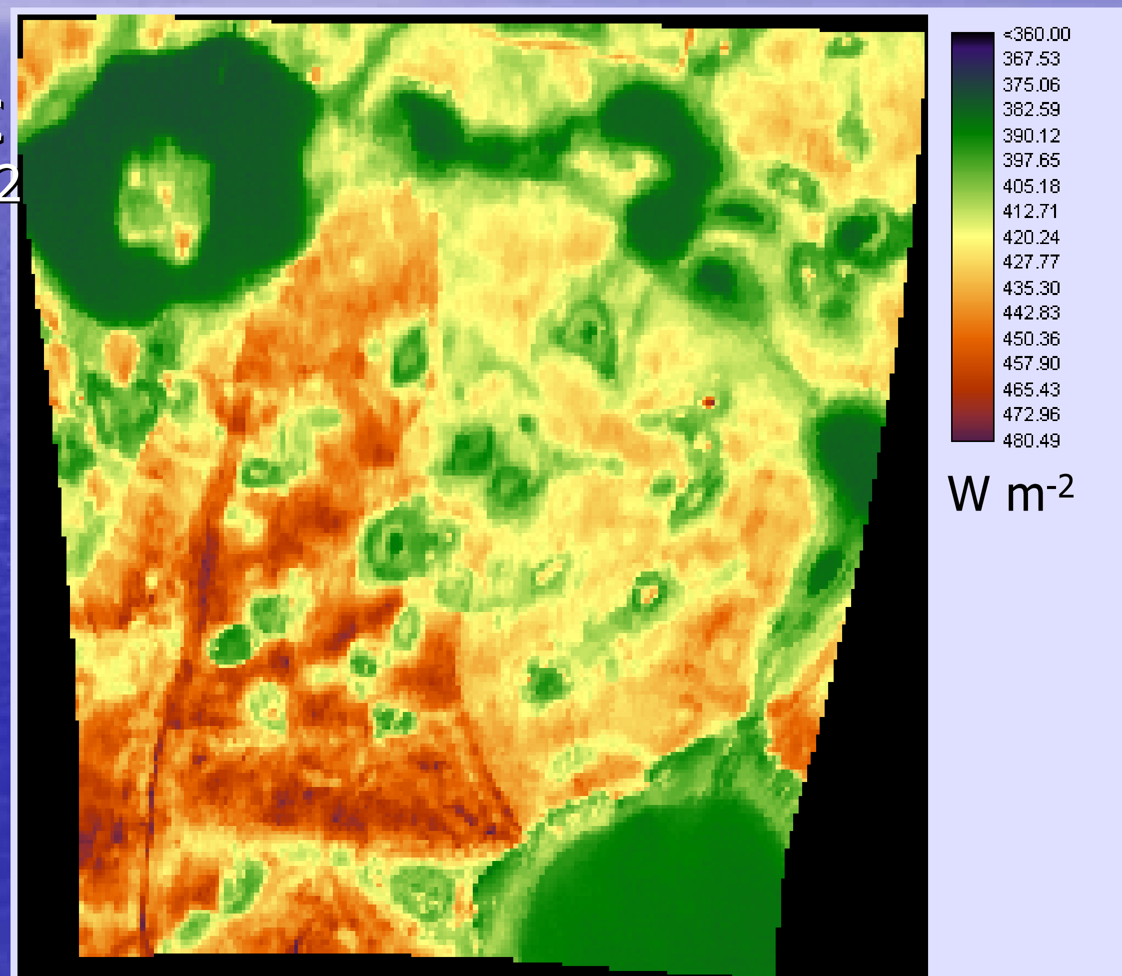
- Thermal image; FLIR Camera (7.5 - 13 µm)

$$L\uparrow = \varepsilon\sigma(Ts+273.15)^4 \ ; \ \varepsilon = 0.98 \ ; \ \sigma = 5.67 \times 10^{-8}$$

- -2 °C versus IRTC obs; ≈ 11 W m^{-2}

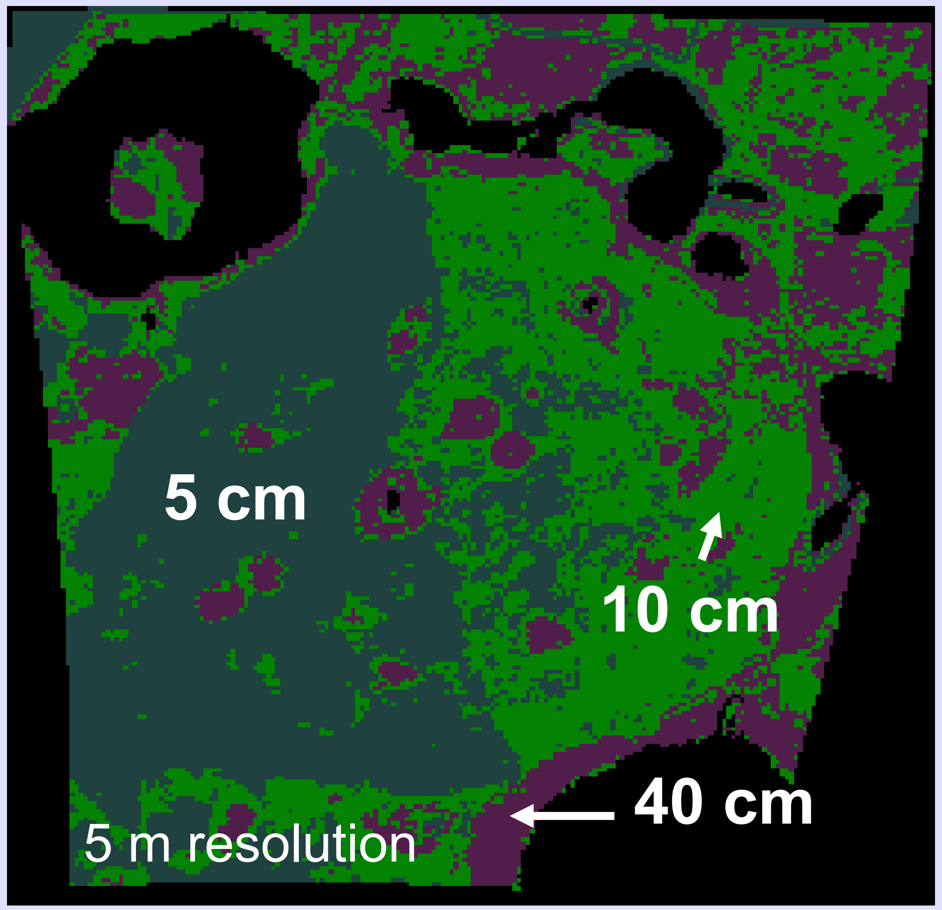
Aug 5,2007

5 m resolution



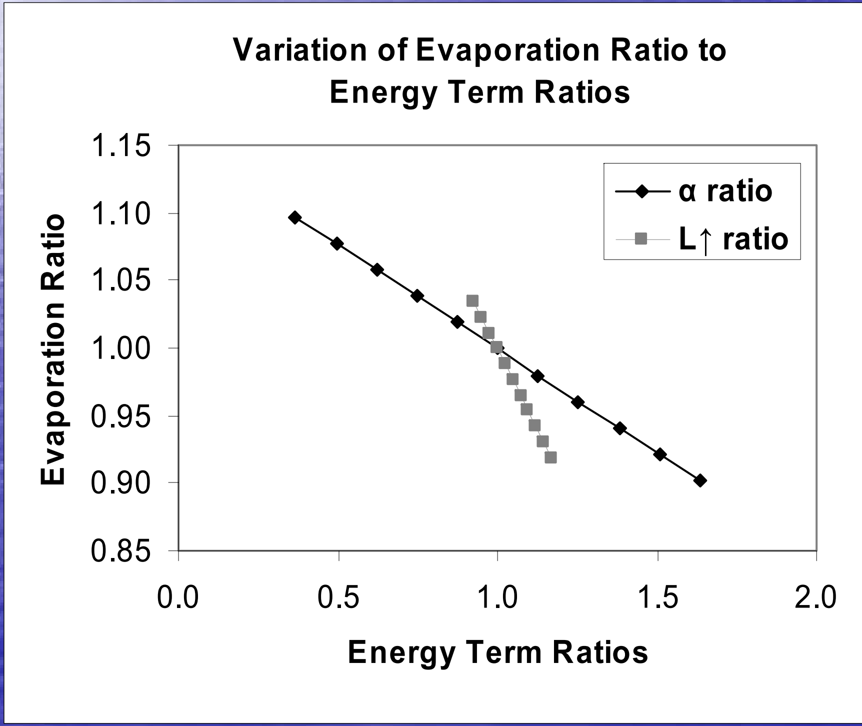
Spatial Variability of Roughness Height

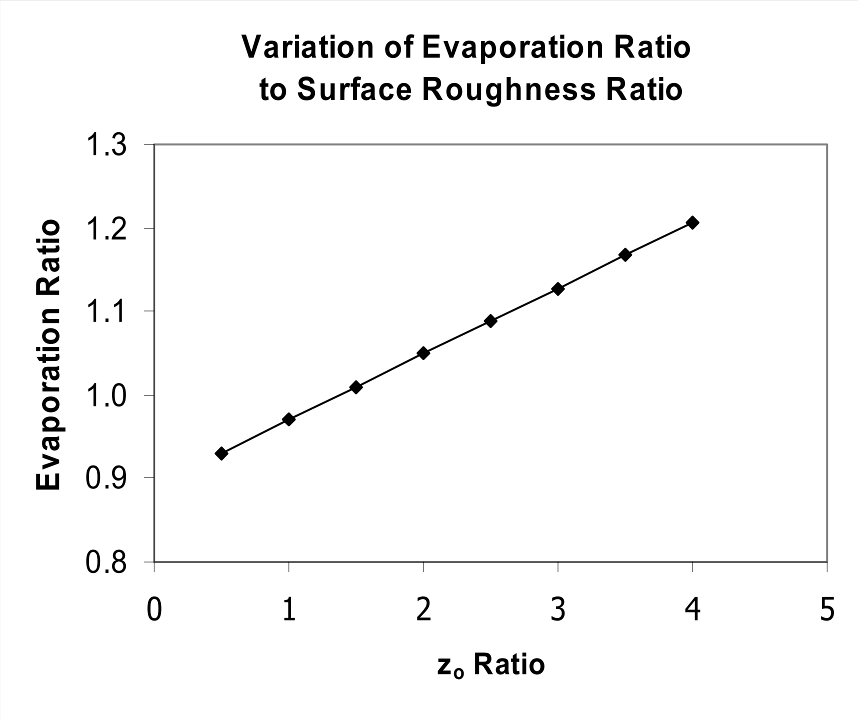
- Z_o (cm) influences turbulent transfer
  - Segmented terrestrial image into several classes (Std. Dev. filter); reclassified into similar roughness - applied typical Z_o values (cm)



Sensitivity of Instantaneous Evaporation to Midday Analytical Ratios

- Evaporation relatively more sensitive to increases in L↑
  - 17% increase in L↑ results in ≈ 10% reduction in evaporation; similar reduction requires 50% increase in albedo
  - Evaporation increases by 10% for ≈ 300% increase in roughness





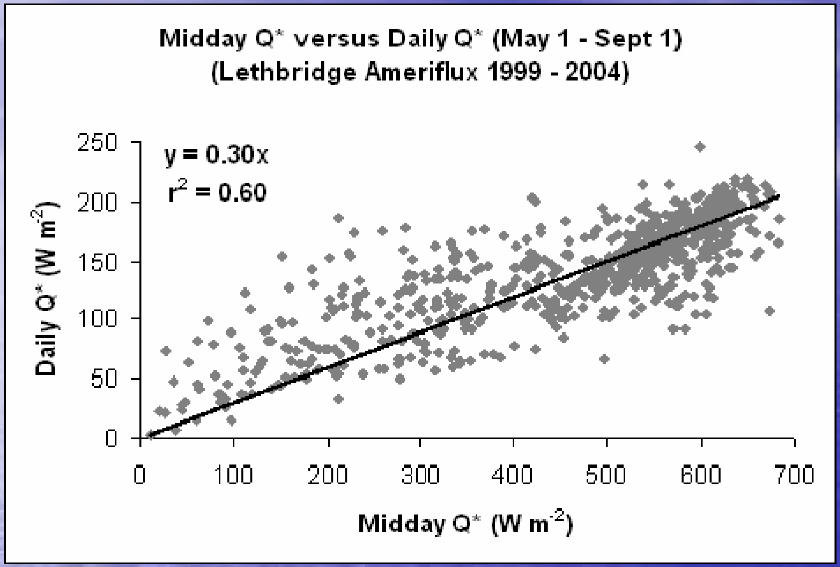
Distributing Daily Evaporation Estimates "Temporal Transfer Function"

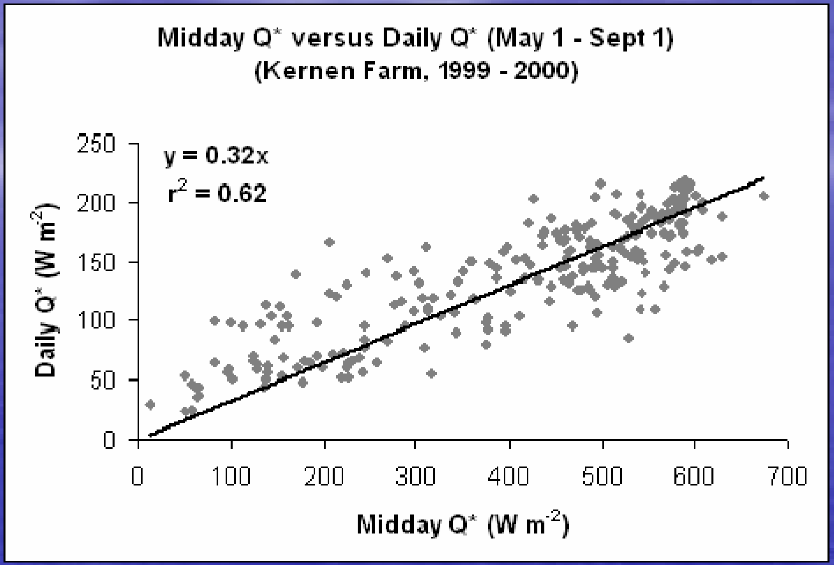
- To convert instantaneous net radiation to daily net radiation. Tested using reference values.

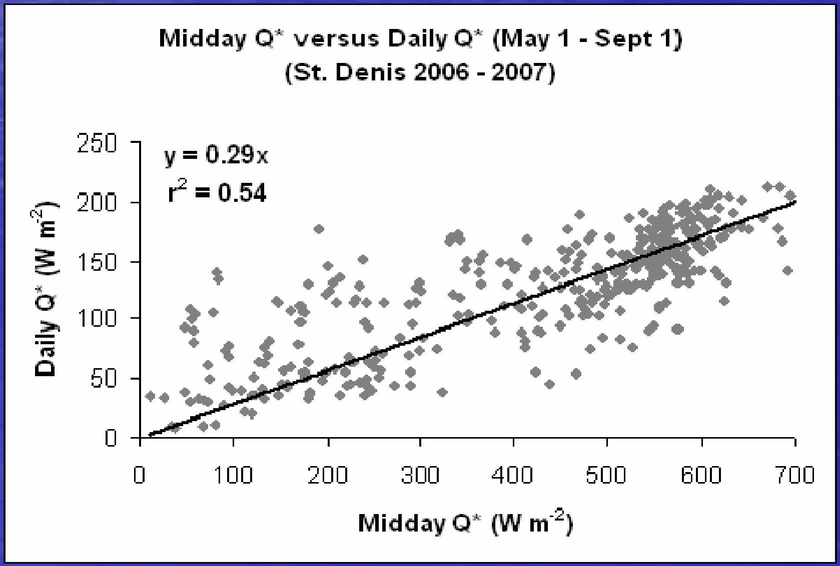
$$R_R = Q^*_i / Q^*_{iref}$$

  - Assumes a linear relationship between Q^*_i and Q^*_d with zero intercept
  - Permits estimation of daily, Q^*_d distributed over space from a reference Q^*_d value and the radiation ratio

Daily Q* versus Midday Q*







Distributed Daily Radiation Map

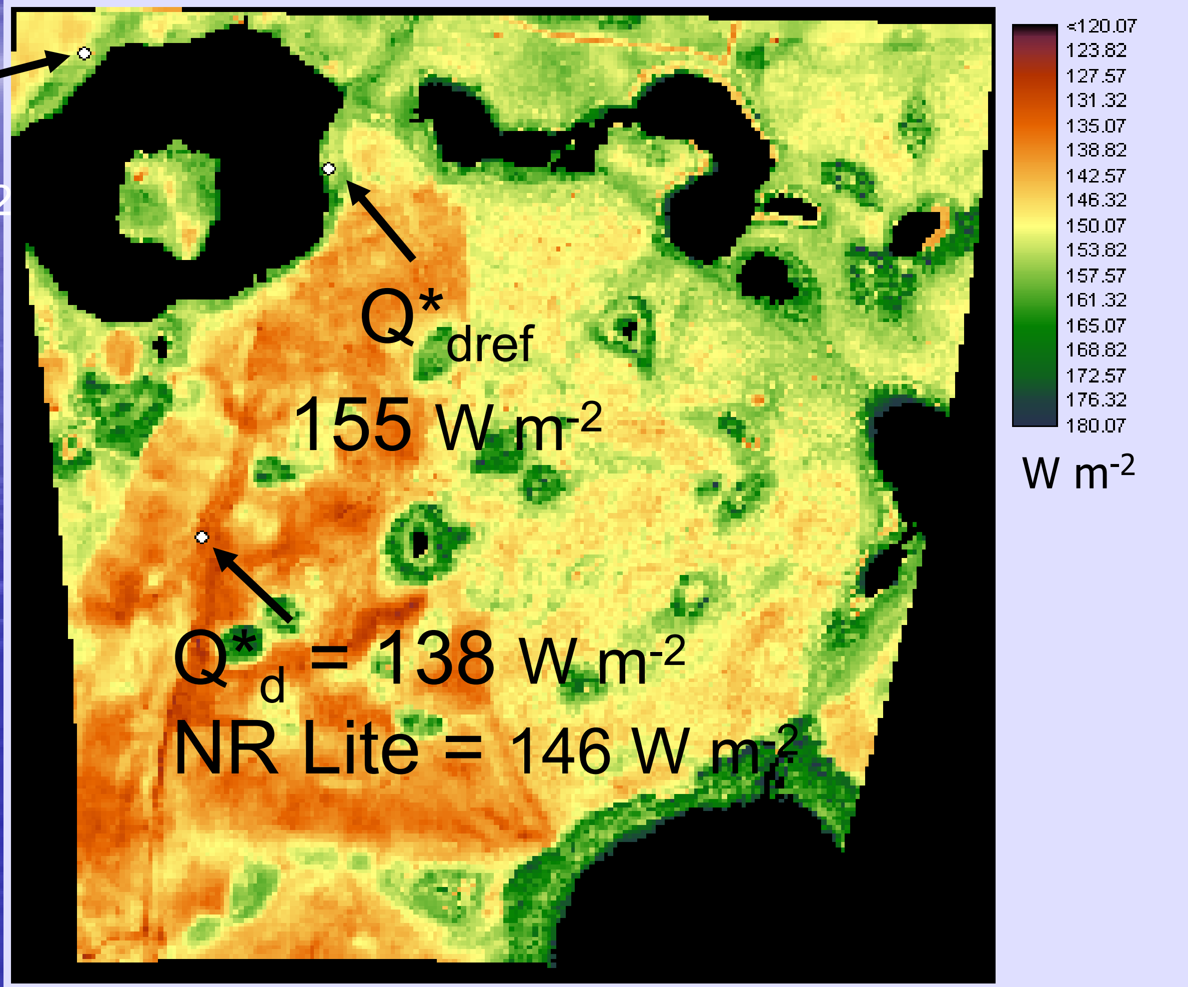
- Q^*_d is a function of the radiation ratio, R_R and reference value $Q^*_{d\_ref}$

Q^*_d = 152 W m^{-2}
CNR1 = 144 W m^{-2}

Q^*_d estimated

$$Q_d^* = R_R \cdot Q_{dref}^*$$

~ 5 % error



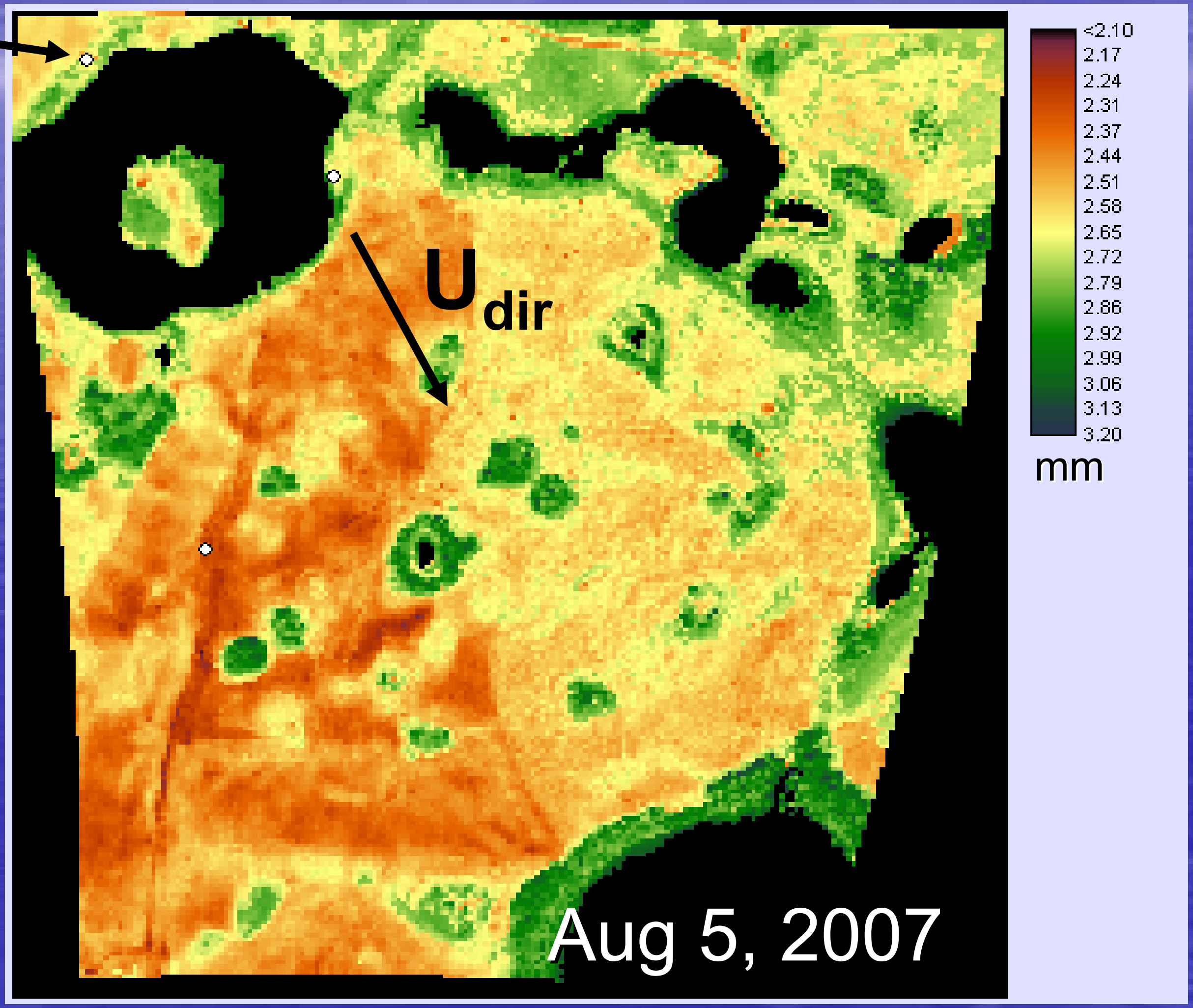
Distributed Daily Evaporation Map

- G-D model (same as in Cold Regions Hydrological Model)

Validation site

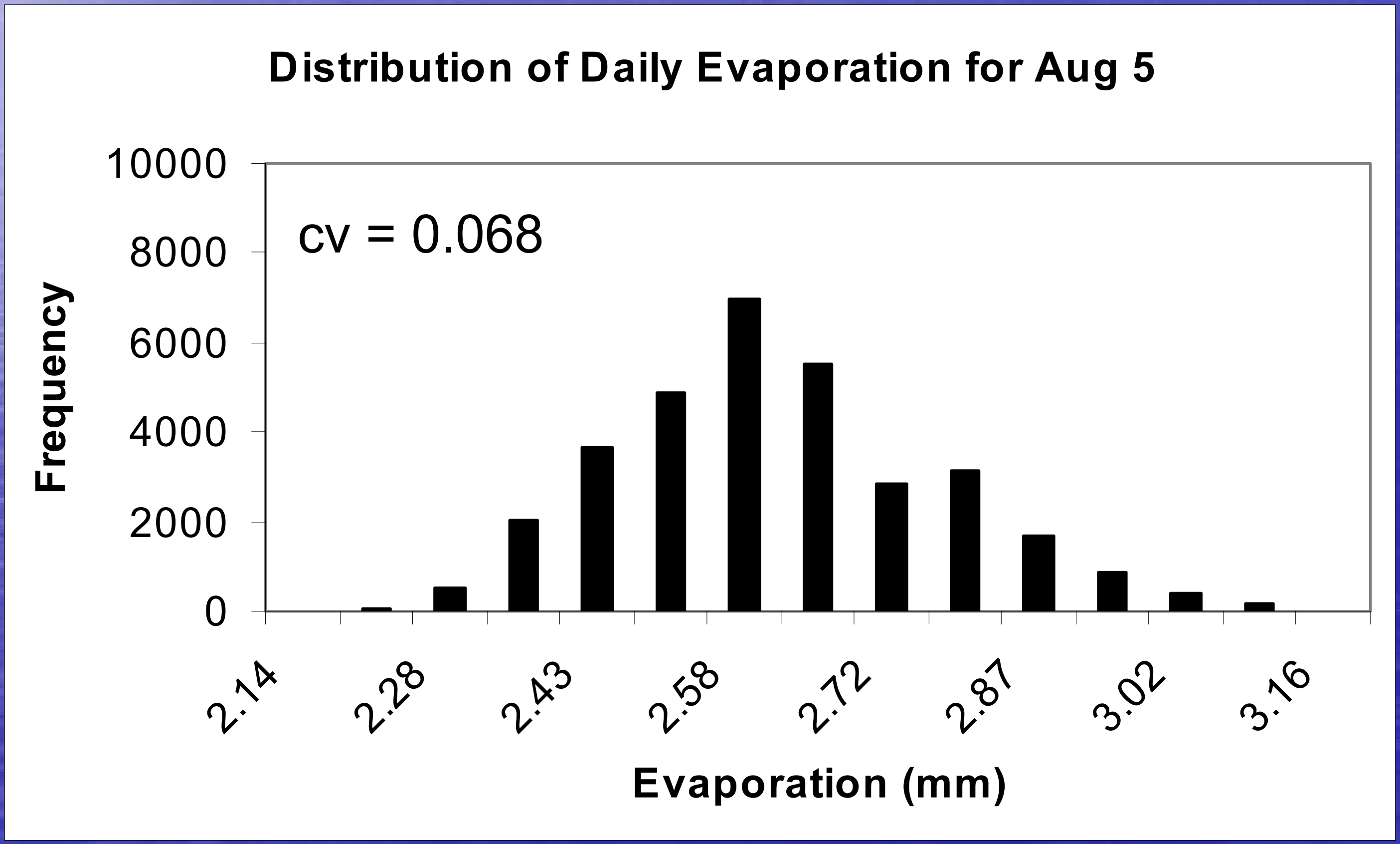
Eddy Cov
E = 2.2 mm

Granger-Gray
E ≈ 2.6 mm



Distribution of Daily Evaporation

- Mean for all land surface grid cells = 2.6 mm
  - Evaporation from means for all input values = 2.57 mm



Summary and Conclusions

- Distributed daily evaporation estimates may be obtained for large areas using an evaporation ratio approach
  - Demonstrated for a relatively complex Prairie landscape
  - Possible to distribute daily evaporation from known values at a reference location and a radiation ratio
  - Estimated daily net radiation within 5% of measured values at two validation sites
  - G-D daily evaporation estimate 0.4 mm higher than measured value (Eddy Covariance)

Summary and Conclusions

- Remotely sensed imagery provides key variables for modelling applications
  - Directly calculate surface emitted longwave, reflected shortwave, aerodynamic function; key variables for calculating evaporation
  - Potential for improving estimates of regional scale evaporation using remote sensing