Observations of Turbulent Energy Fluxes Over an Open Prairie Snow Field

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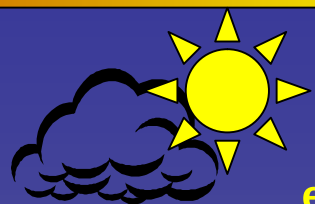
Background

- It is often commented that sublimation of surface snow accounts for significant snow loss in the prairie
  - Few *direct* measurements have been made
  - Is this and example of hydro-mythology?
- Regardless, turbulent fluxes are important energy balance terms
  - Estimation is required for modeling snowmelt and land-surface interactions

Purpose

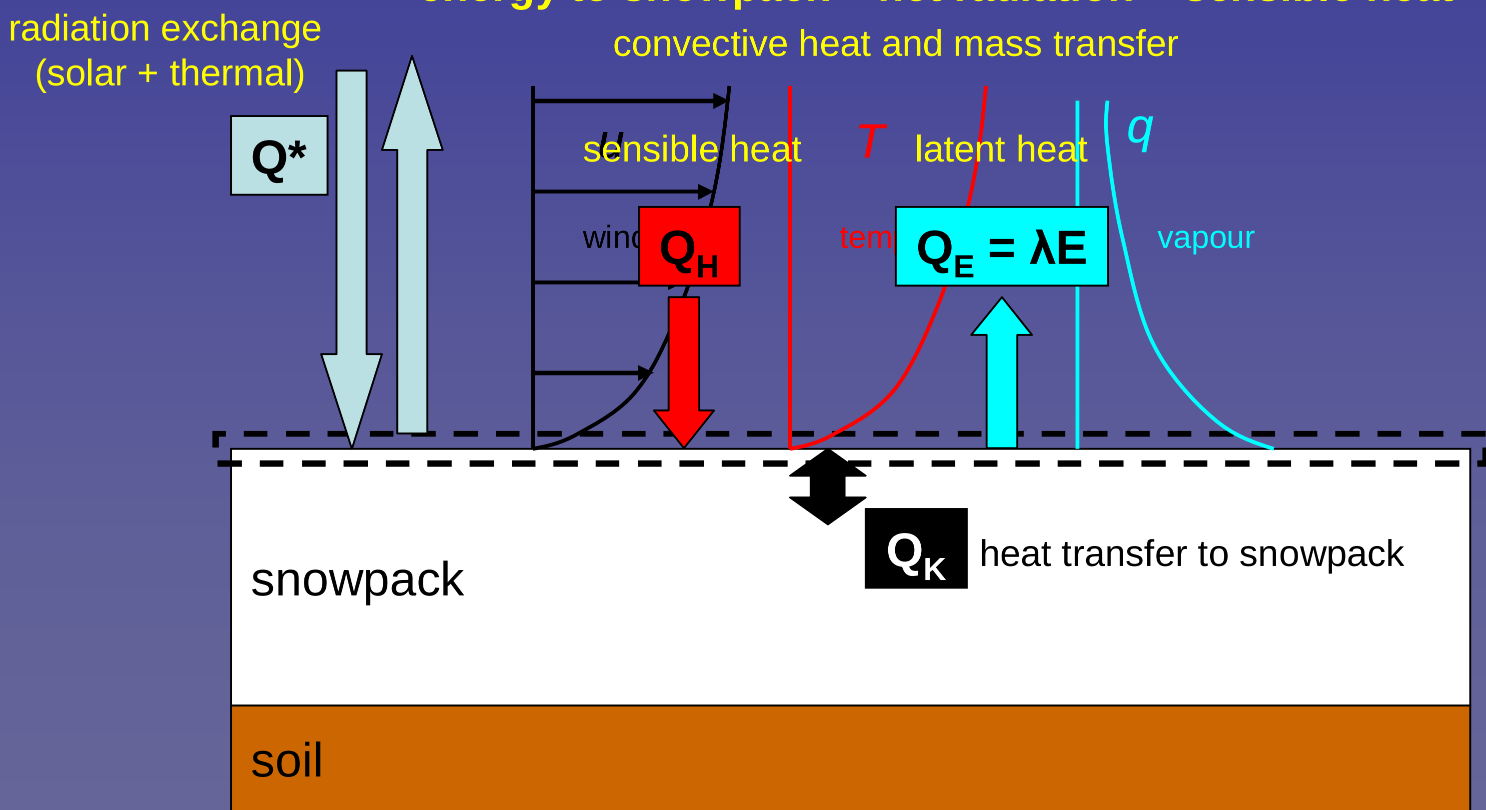
1. What is the significance of sublimation from snow surfaces in a prairie environment?
2. What is the role of latent heat flux within the energy balance?
3. How applicable are flux-gradient (bulk transfer) estimation techniques in a snow-covered prairie environment?

Snow surface energy balance



$$Q_K = Q^* + Q_H + Q_E$$

energy to snowpack = net radiation + sensible heat + latent heat

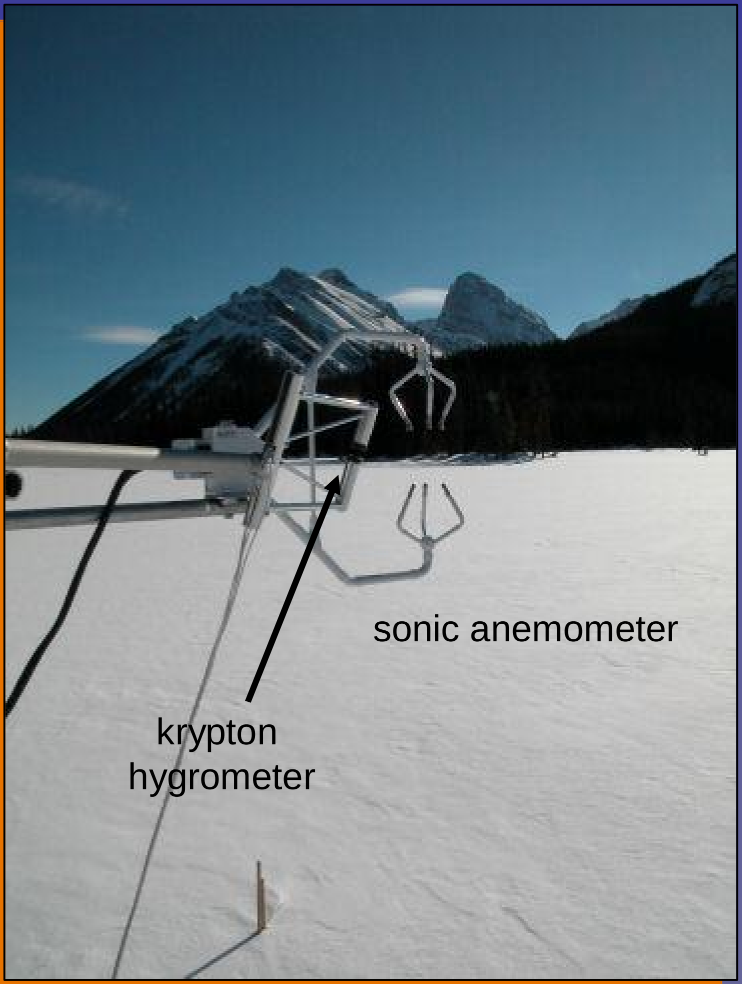


Measurement

Eddy Covariance Technique

- 20 hz. measurements
  u, v, w, T_s, q
- 30 min. covariances

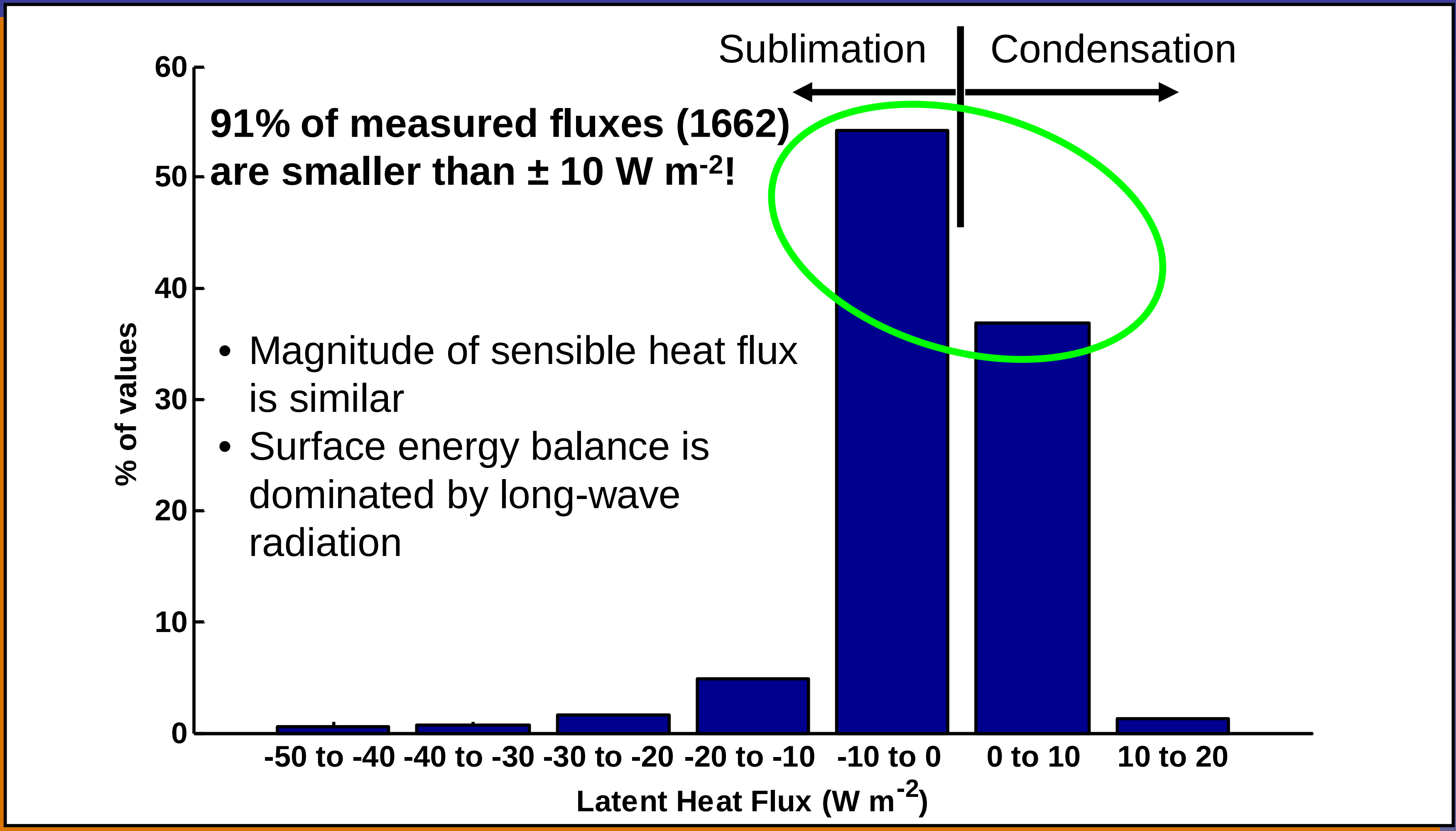
sensible heat flux	$Q_H = r c_p \overline{w'T'}$
latent heat flux	$Q_E = l_{sub} r \overline{w'q'}$
momentum flux	$t = r \overline{u'w'}$
friction velocity	$u* = \sqrt{\overline{u'w'}}$



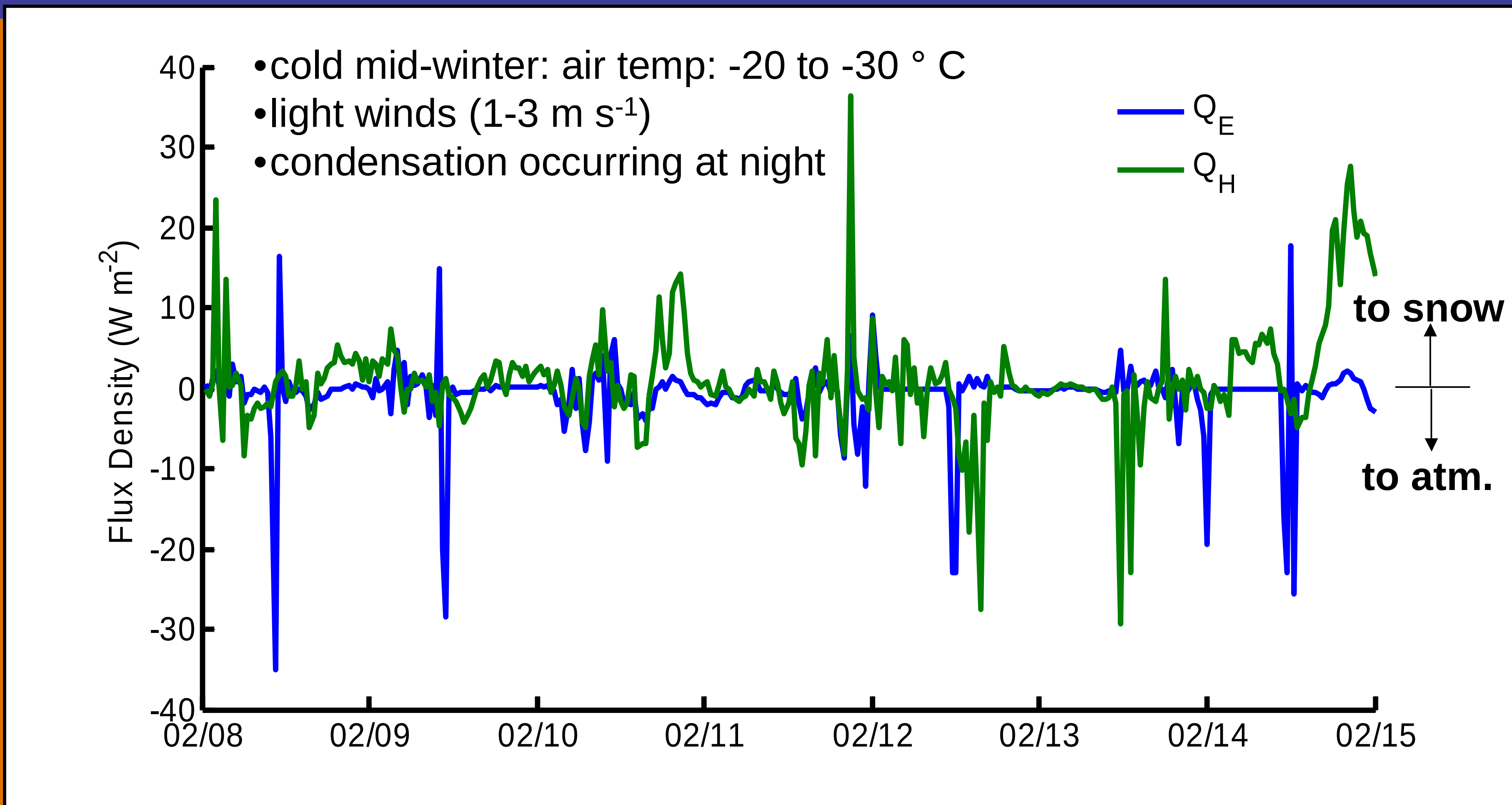
Study site: Kernen Farm, SK

- Kernen Farm:
  - 5 km E. of Saskatoon
  - open fetch ~ km(s)
  - Jan - Mar, 2007
  - snow depth: 30 cm
- Instrumentation
  - 2-level eddy covariance
  - Full instrument suite (radiation, air temp., RH ground heat flux, snow temps, blowing snow, etc.)

Latent heat fluxes are very small



Typical Long Stable Periods

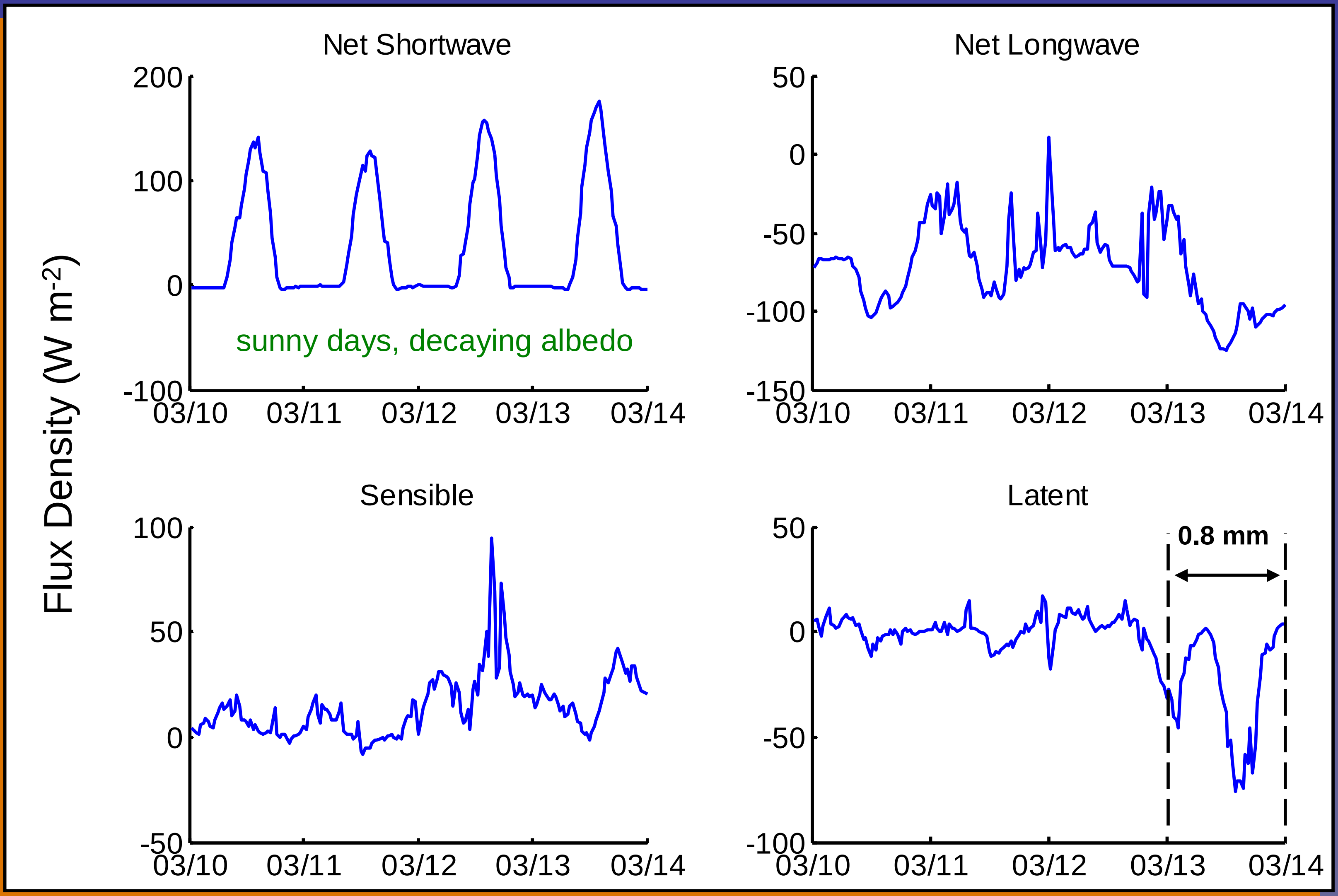


Characterization

- Small heat and vapour fluxes (0-10 W m^{-2})
  - stable atmosphere (thermal stratification)
  - laminar flow (U_{2m} < 3 m s^{-1}) - intermittent turbulence
  - fluxes become indistinguishable from measurement noise
  - condensation forms on instruments

Melt Period Energy Balance

** positive fluxes contribute to melt **



Characteristics

- Larger heat and vapour fluxes (10-50 W m^{-2})
  - occur with higher wind speeds brought on by changing weather patterns
  - often occurs at same time as falling snow and blowing snow... introduces measurement problems
  - higher wind speeds result in near neutral atmospheric conditions

Summary

- Sublimation from surface snow represents a negligible water loss from this prairie site
- Latent heat flux is still important in the energy balance... during certain meteorological conditions
- Overall, mid-winter turbulent heat fluxes are quite small

Modeling Background

Flux gradient theory:

Sensible heat flux $$Q_H = r c_p K_H \frac{dT}{dz}$$

Latent heat flux $$Q_E = r\, l_{sub} K_V \frac{dq}{dz}$$

Momentum flux $$t = r K_m \frac{dU}{dz}$$

Conditions:

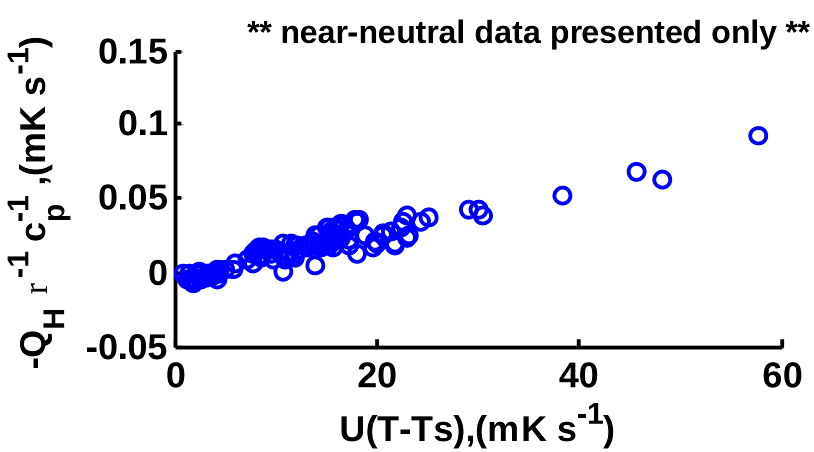
1. Fluxes are proportional to a gradient
2. Eddy diffusivities can be adequately parameterized for the local environment
   - Ø Monin-Obukhov similarity theory applies
3. Homogeneous, 2-d boundary layer, constant fluxes with height

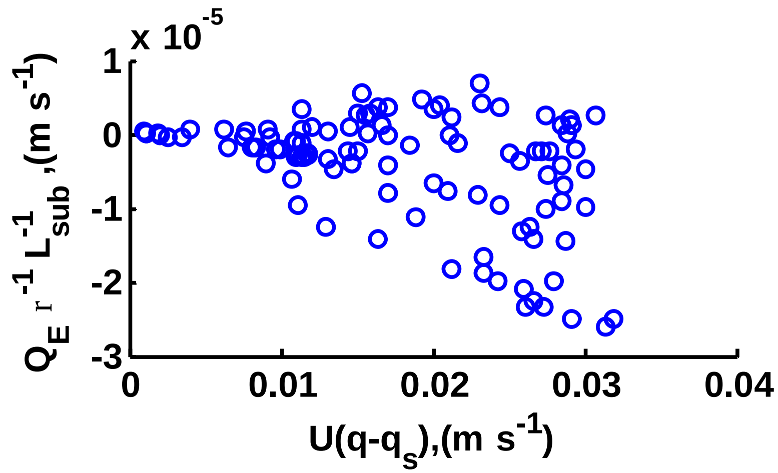
State of the Science:

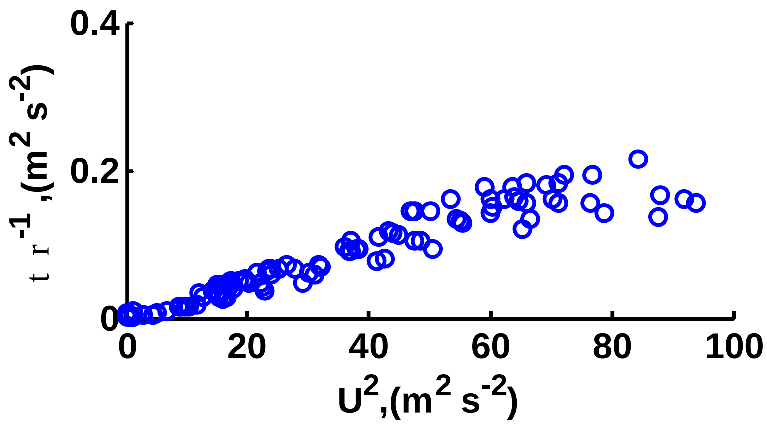
- Flux-gradient approach was developed for flat homogeneous terrain

"It soon became clear that the flatness and uniformity of the Kansas site could not be matched anywhere else in the continental United States. The closest we could come was the Red River valley in northwestern Minnesota"
(Kaimal and Wyngaard, 1990)

Applicability of flux-gradients?



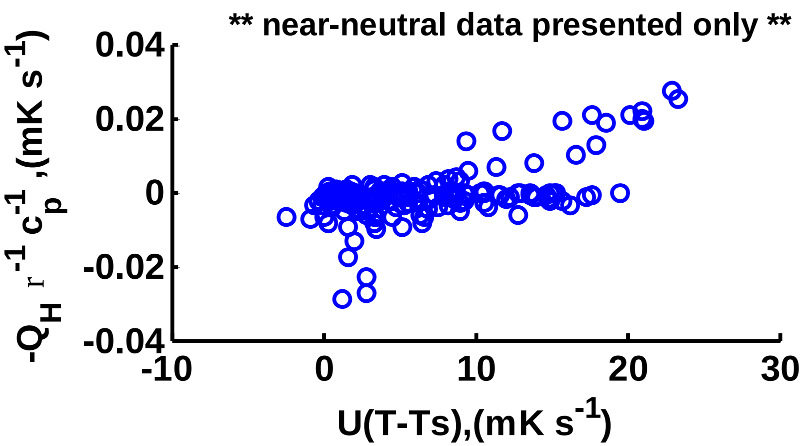


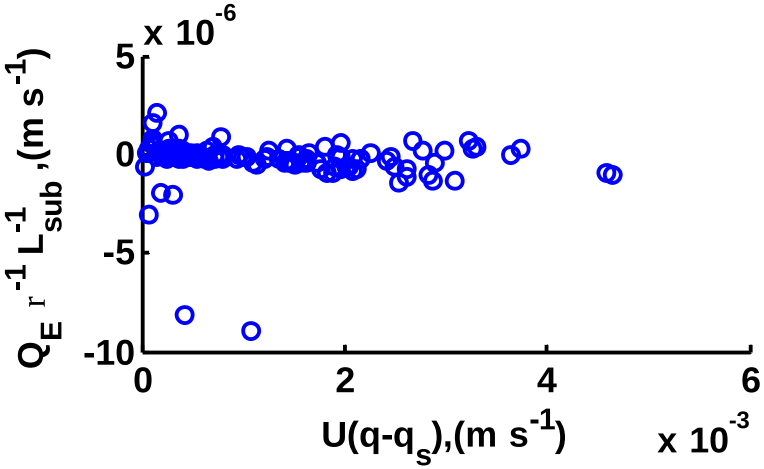


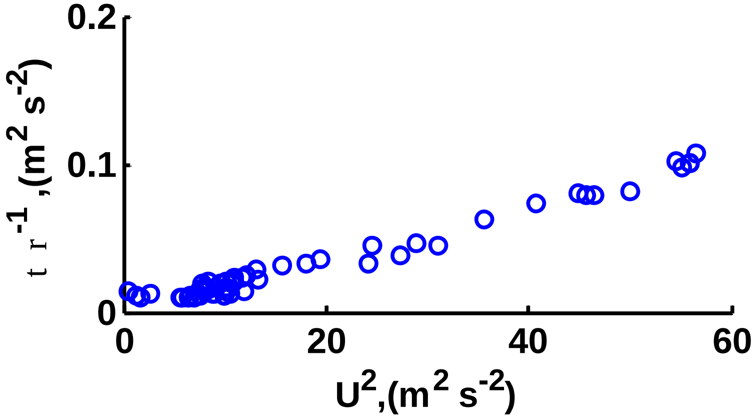
Melt period, larger fluxes

- sensible heat and momentum fluxes are proportional to gradients, but latent heat is not
- these conditions represent < 10% of dataset
- constant flux criteria is met

Applicability of flux-gradients?







Mid-winter period, small fluxes

- momentum flux is proportional to gradients, but sensible and latent heat are not
- these conditions represent ~ 90% of dataset
- constant flux criteria is met

Summary

- Flux gradient estimation techniques work best under strong turbulence and large heat fluxes (these conditions rarely observed at this site)
- For the majority of the data periods, the relationship between fluxes and gradients is not known
  - require an improved understanding of turbulent transfer processes in cold stable environments

Questions?