Parameterization of Heat Roughness Length using Fluxnet

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Introduction

- Bulk method to produce surface heat flux:
  - resistance for heat
  - the difference between the potential temperature at a reference height and the air temperature at the roughness height for heat

$$H = \frac{\rho c_p (T_S^R - T_a)}{r_h},$$

Introduction

- Two types of temperatures:
  - aerodynamic temperature

  - radiative surface temperature

Introduction

- Air temperature at the roughness height: cannot be directly measured (only be inferred by extrapolation)

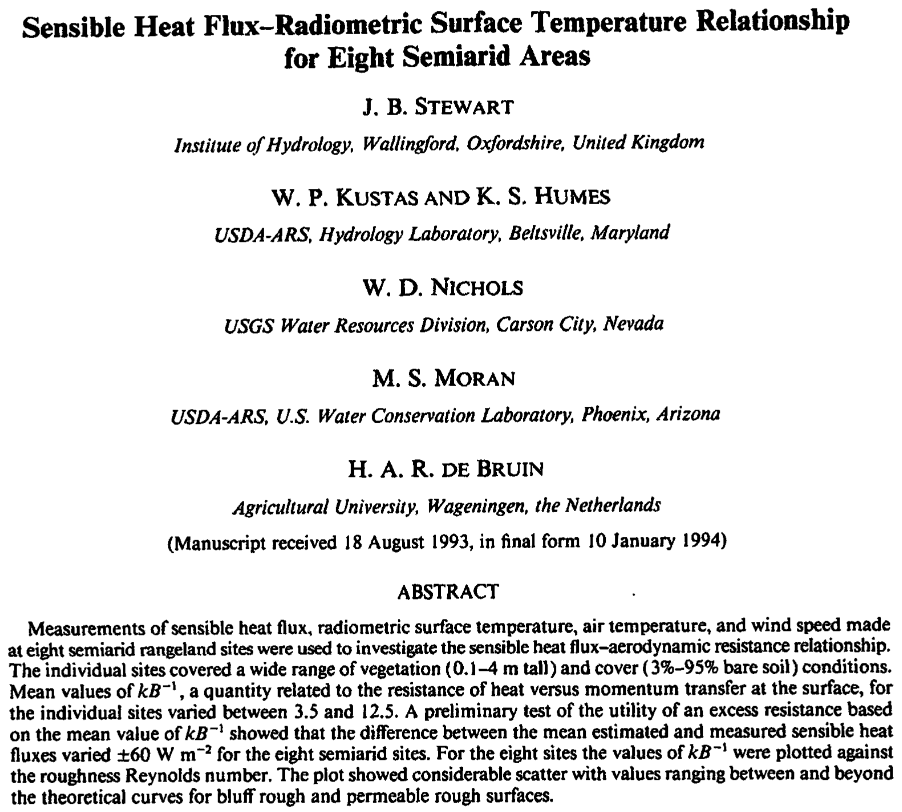
- Radiative surface temperature:
  - replace the air temperature
  - more easily measured or obtained from model
  - may be significantly different from aerodynamic temperature (2-6C higher under unstable condtn. lower under stable condtn.(Holtslag,1991; Hall, 1992))

Introduction

- Idea:
  - In order to produce accurate surface heat fluxes in bulk method using radiative surface temperature, a “radiative” heat roughness length is necessary
  - Aim: “radiative” heat roughness length parameterization (independent from SH)

Introduction

- Previous efforts:



Sensible Heat Flux–Radiometric Surface Temperature Relationship for Eight Semiarid Areas

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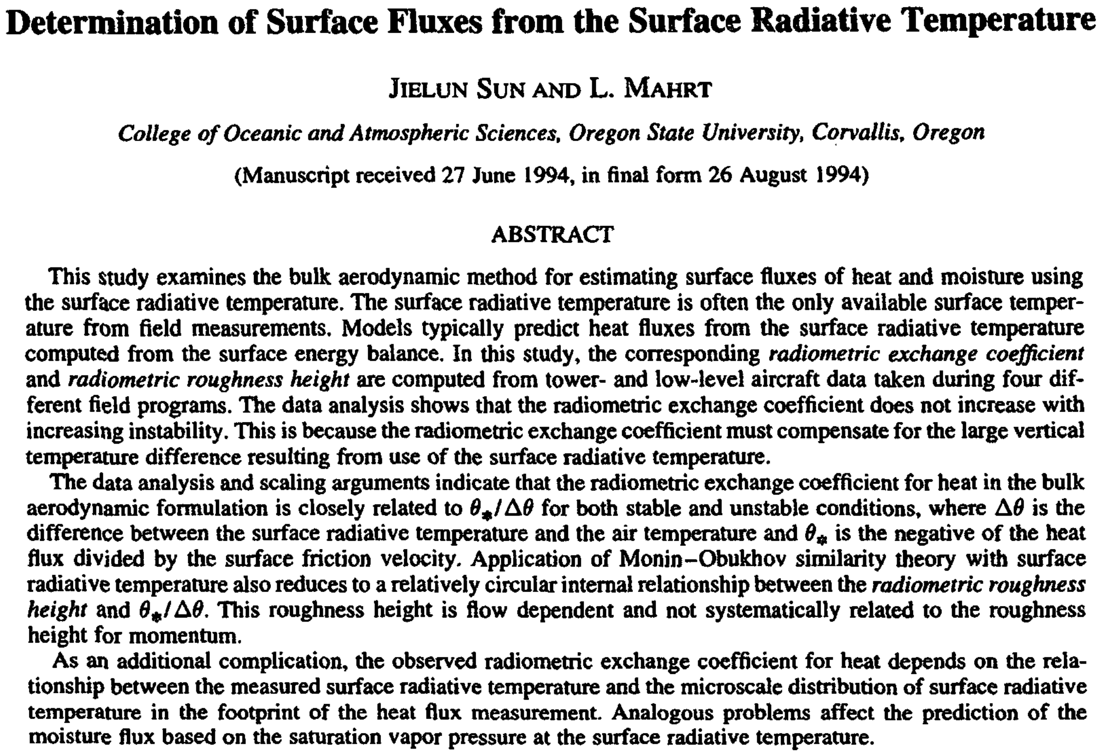
ABSTRACT

Measurements of sensible heat flux, radiometric surface temperature, air temperature, and wind speed made at eight semiarid rangeland sites were used to investigate the sensible heat flux–aerodynamic resistance relationship. The individual sites covered a wide range of vegetation (0.1–4 m tall) and cover (3%–95% bare soil) conditions. Mean values of kB^{-1}, a quantity related to the resistance of heat versus momentum transfer at the surface, for the individual sites varied between 3.5 and 12.5. A preliminary test of the utility of an excess resistance based on the mean value of kB^{-1} showed that the difference between the mean estimated and measured sensible heat fluxes varied ±60 W m^{-2} for the eight semiarid sites. For the eight sites the values of kB^{-1} were plotted against the roughness Reynolds number. The plot showed considerable scatter with values ranging between and beyond the theoretical curves for bluff rough and permeable rough surfaces.

Introduction

- Previous efforts:



Determination of Surface Fluxes from the Surface Radiative Temperature

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ABSTRACT

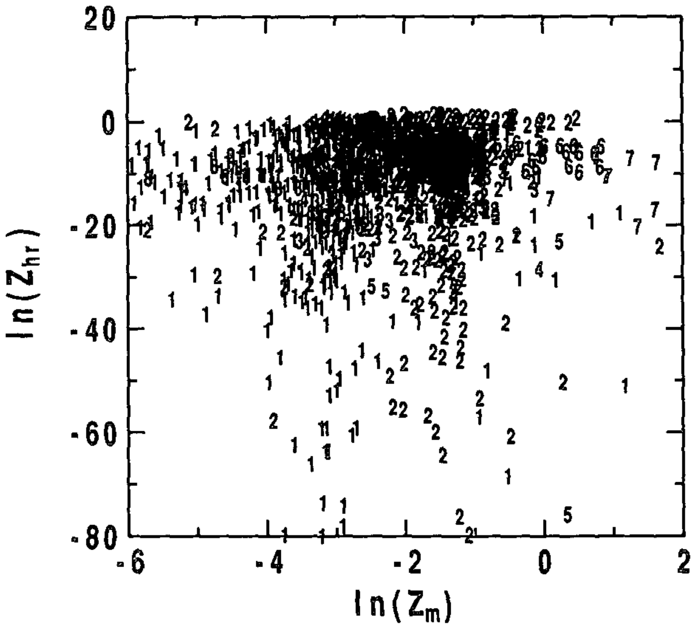
This study examines the bulk aerodynamic method for estimating surface fluxes of heat and moisture using the surface radiative temperature. The surface radiative temperature is often the only available surface temperature from field measurements. Models typically predict heat fluxes from the surface radiative temperature computed from the surface energy balance. In this study, the corresponding *radiometric exchange coefficient* and *radiometric roughness height* are computed from tower- and low-level aircraft data taken during four different field programs. The data analysis shows that the radiometric exchange coefficient does not increase with increasing instability. This is because the radiometric exchange coefficient must compensate for the large vertical temperature difference resulting from use of the surface radiative temperature.

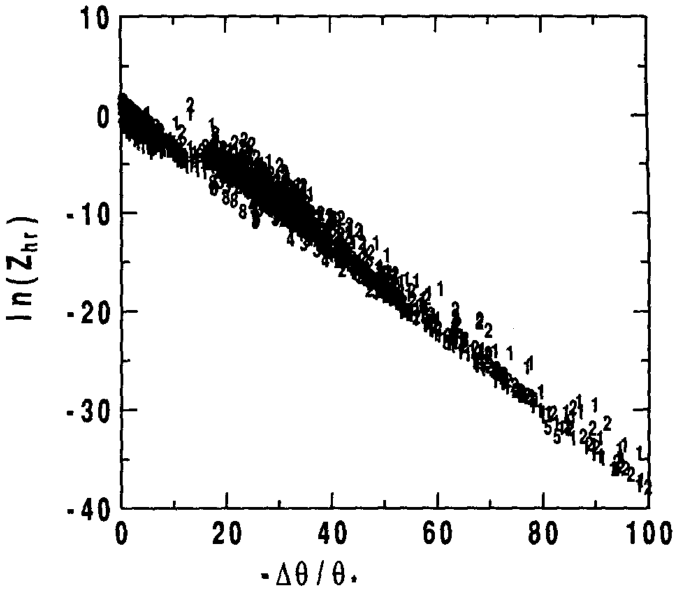
The data analysis and scaling arguments indicate that the radiometric exchange coefficient for heat in the bulk aerodynamic formulation is closely related to $\theta_* / \Delta\theta$ for both stable and unstable conditions, where $\Delta\theta$ is the difference between the surface radiative temperature and the air temperature and θ_* is the negative of the heat flux divided by the surface friction velocity. Application of Monin–Obukhov similarity theory with surface radiative temperature also reduces to a relatively circular internal relationship between the *radiometric roughness height* and $\theta_* / \Delta\theta$. This roughness height is flow dependent and not systematically related to the roughness height for momentum.

As an additional complication, the observed radiometric exchange coefficient for heat depends on the relationship between the measured surface radiative temperature and the microscale distribution of surface radiative temperature in the footprint of the heat flux measurement. Analogous problems affect the prediction of the moisture flux based on the saturation vapor pressure at the surface radiative temperature.

Introduction

- Previous efforts:





$$\ln(z_{hr}) = \ln(z) + k\Delta\theta/\theta_* - \Psi_h(z/L).$$

Dataset

- Fluxnet Canada: Tower sites in Saskatchewan
  - OA; OBS; OJP; HJP (different ages); Grassland

- One winter month and one summer month

- Span a large range of momentum roughness

Methodology

- Radiative surface temperature is backed out from radiation measurement
- All other quantities come from the Tower measurements
- Span a large range of momentum roughness

Methodology

$$H = \frac{\rho c_p (T_S^R - T_a)}{r_h},$$

$$C_h = 1/(r_h{}^{*}U)$$

$$C_h = \frac{k^2}{[\ln(z/z_m) - \Psi_m(z/L)][\ln(z/z_h) - \Psi_h(z/L)]},$$

- Measurements: *H*, *Ta*, *U*,
- Calculated: *L*, *Zm*, ρ

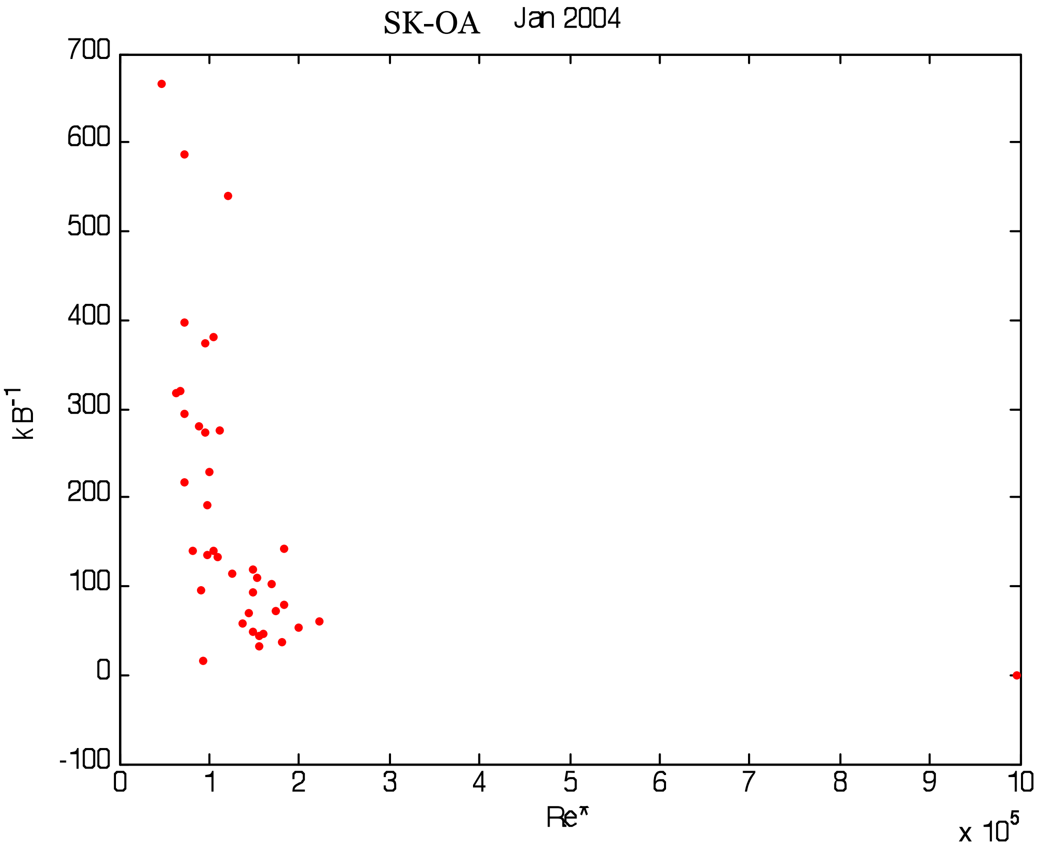
Methodology

- Determine z_m in both ways:
  - $z_m=0.1*h$
  - $u=(u^*/k)\ln((z-d)/z_m)$ under near neutral stability where $d=0.7h$
- At this stage, our calculation only involves near neutral condition

Analysis

On z_m and z_T in terms of $Re*$

Preliminary Results



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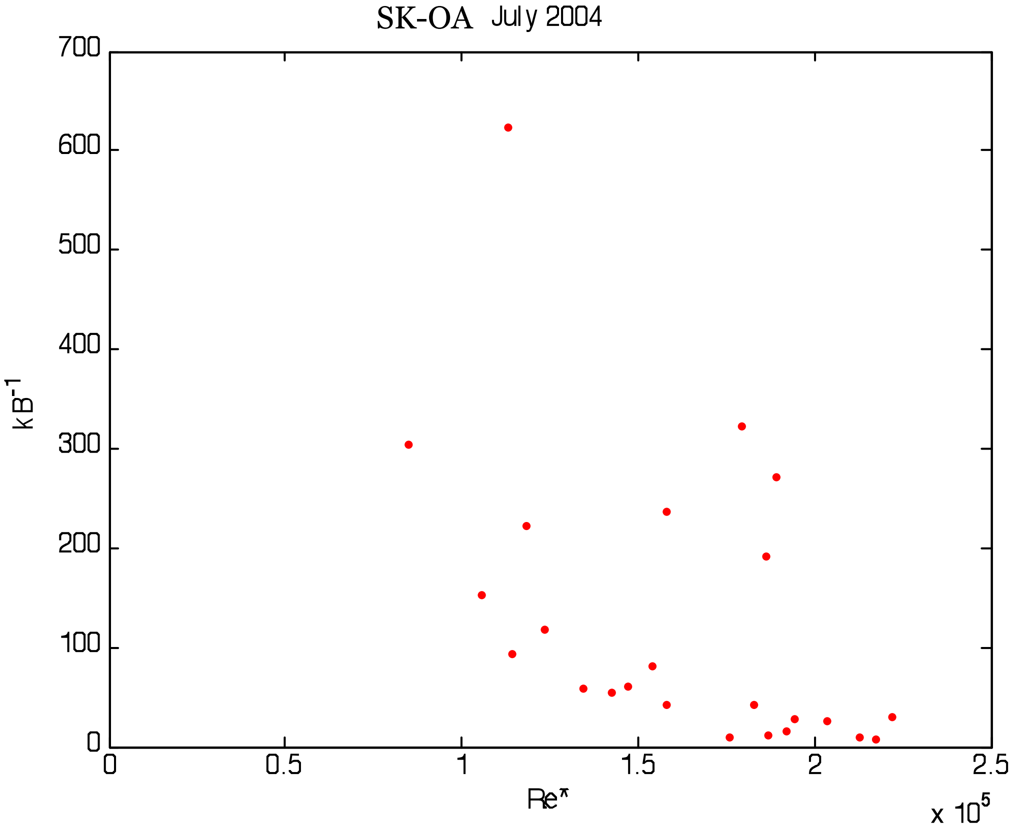

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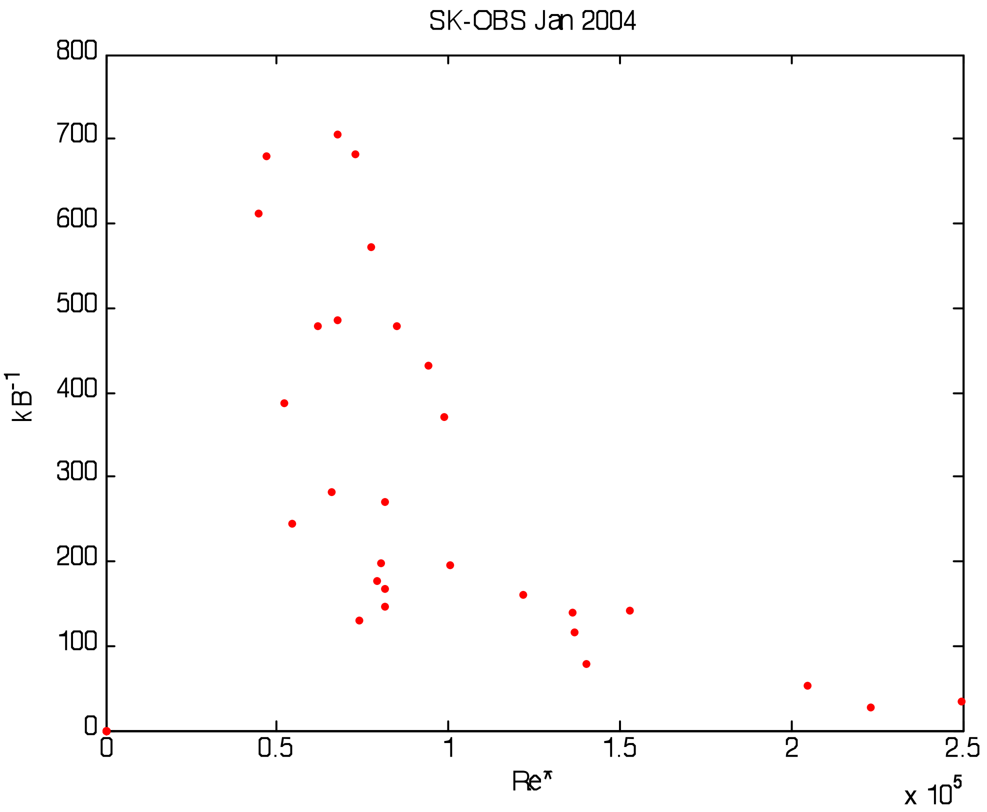

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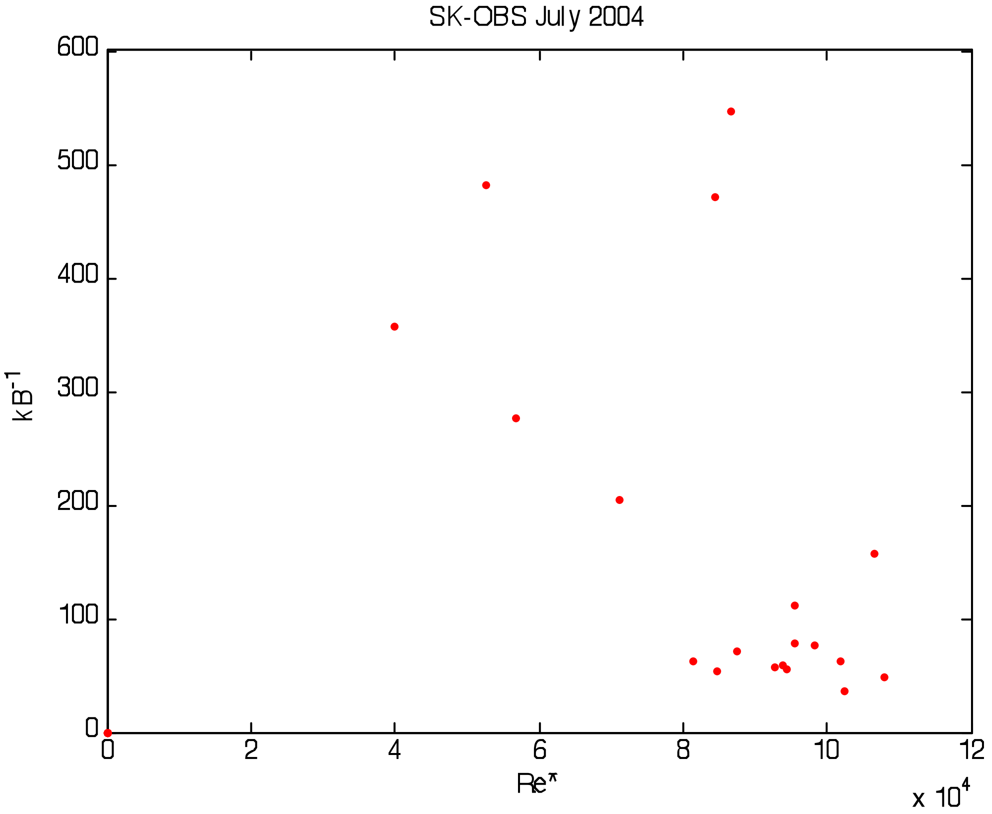

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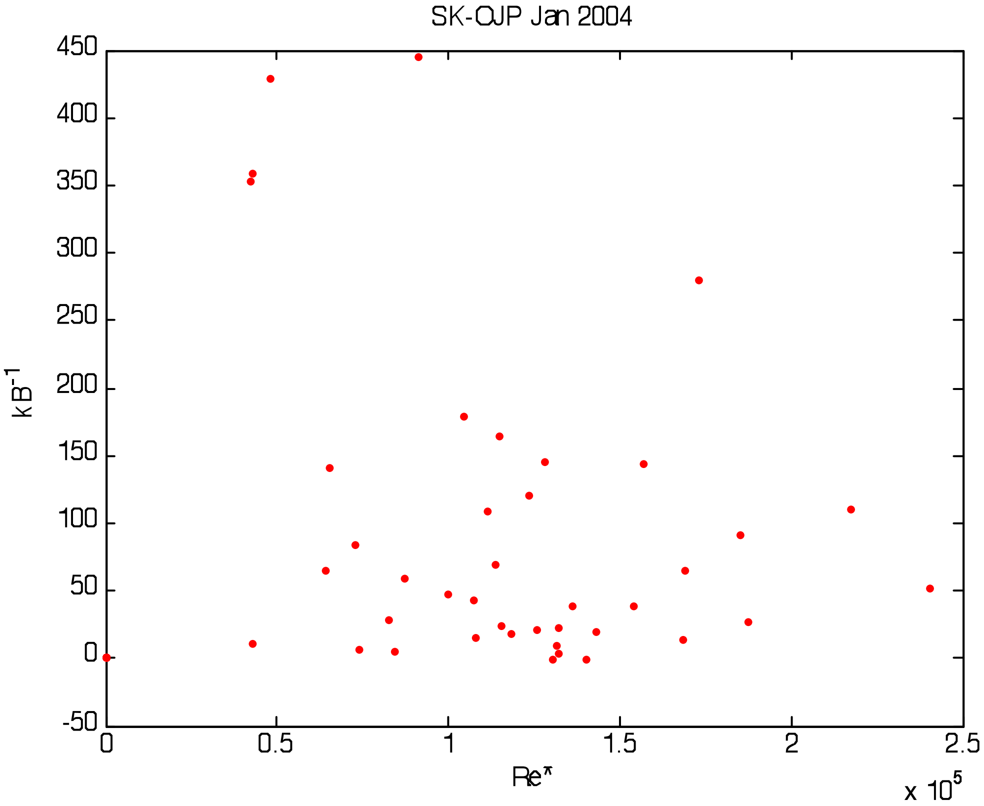

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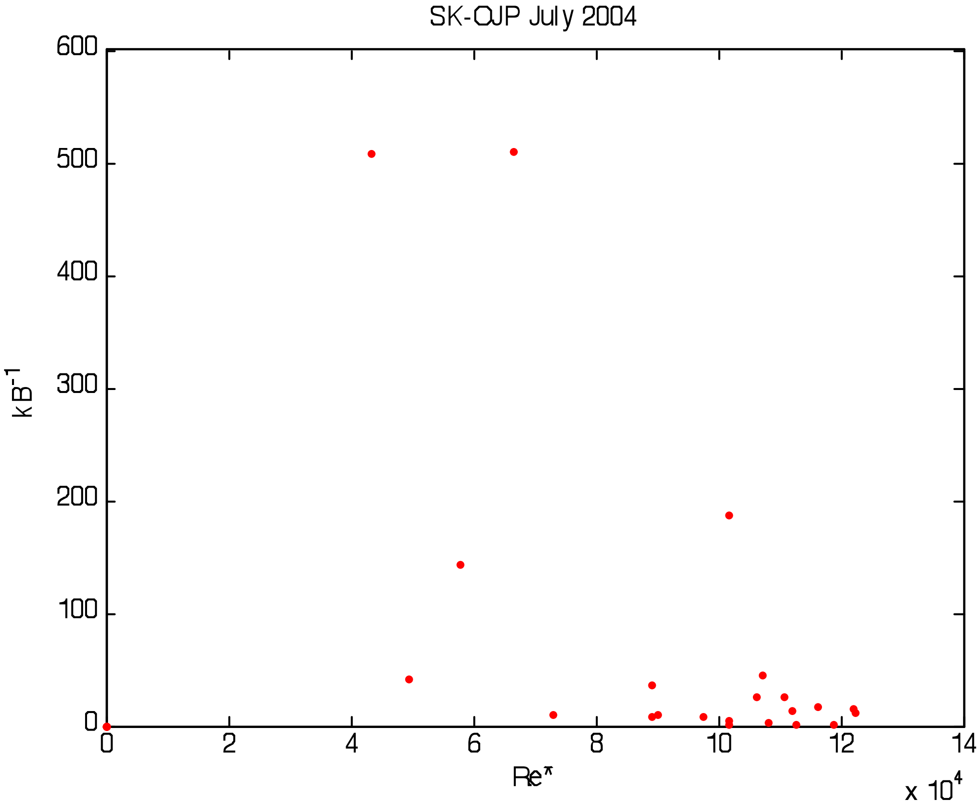

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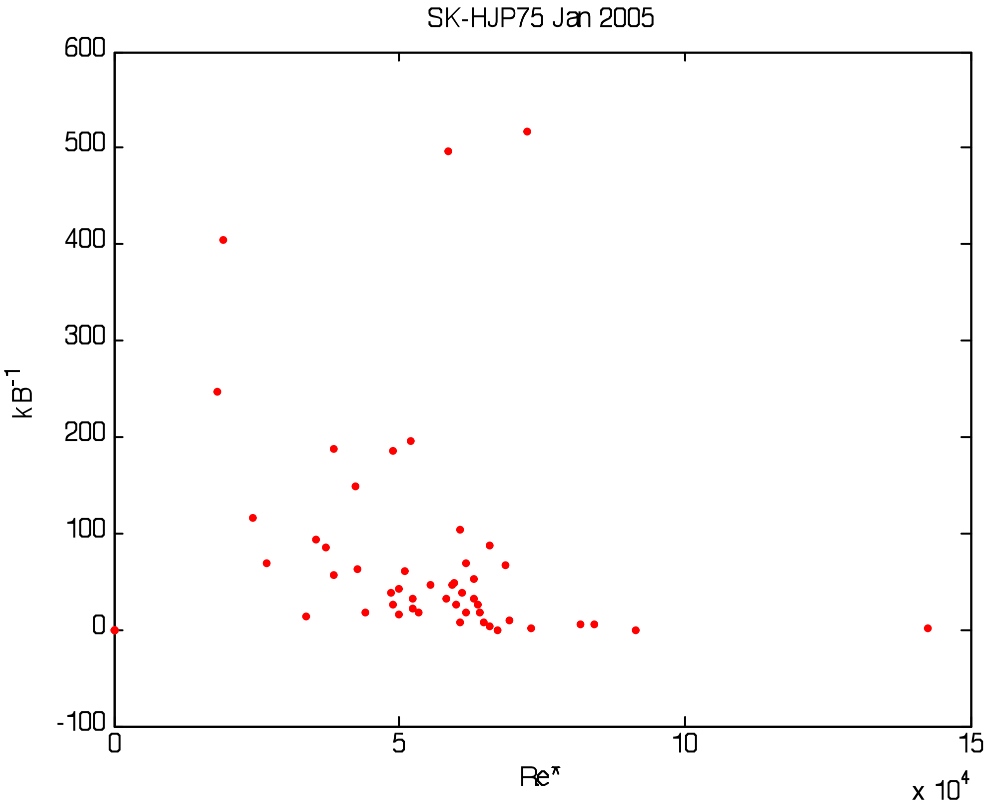

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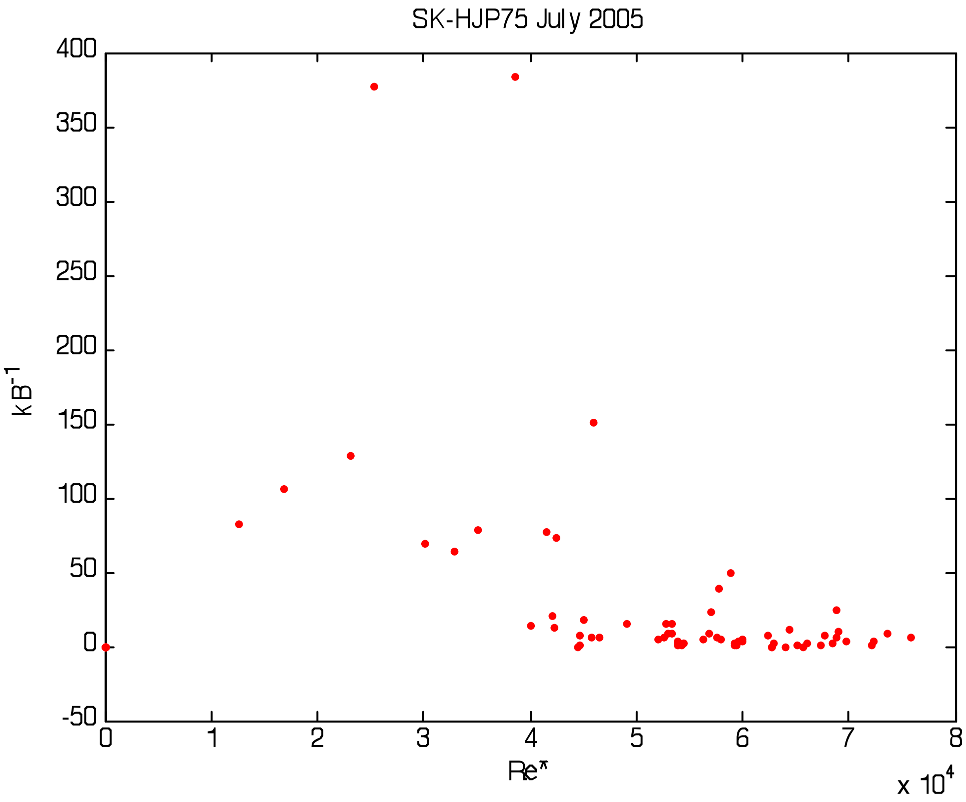

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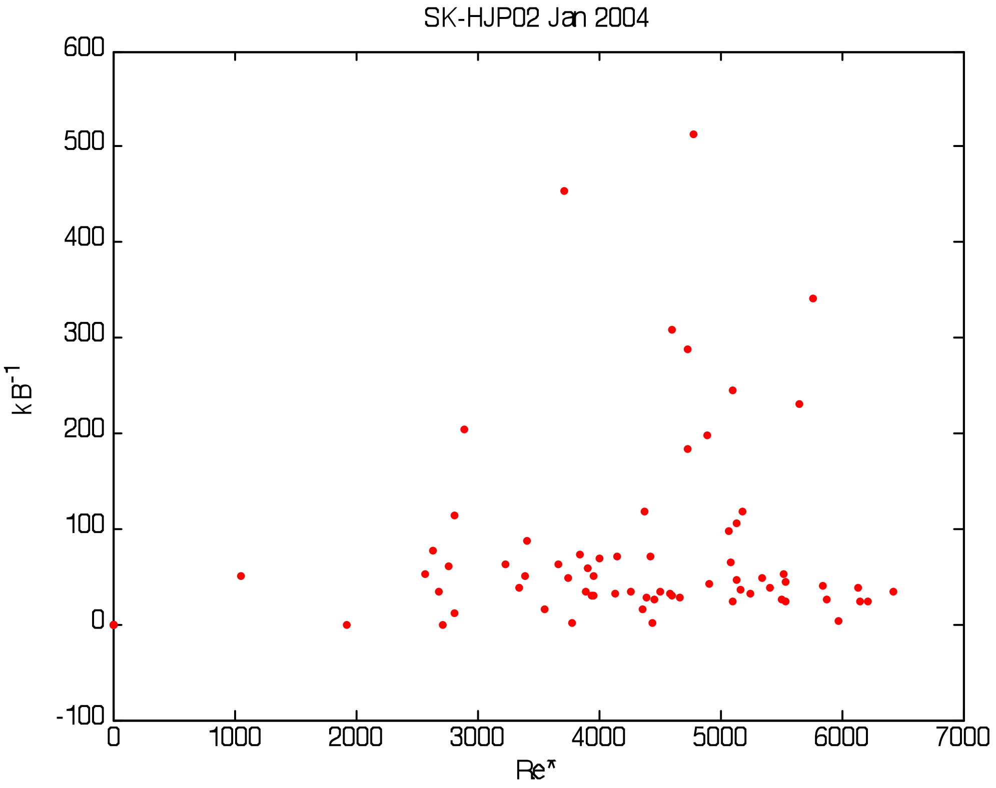

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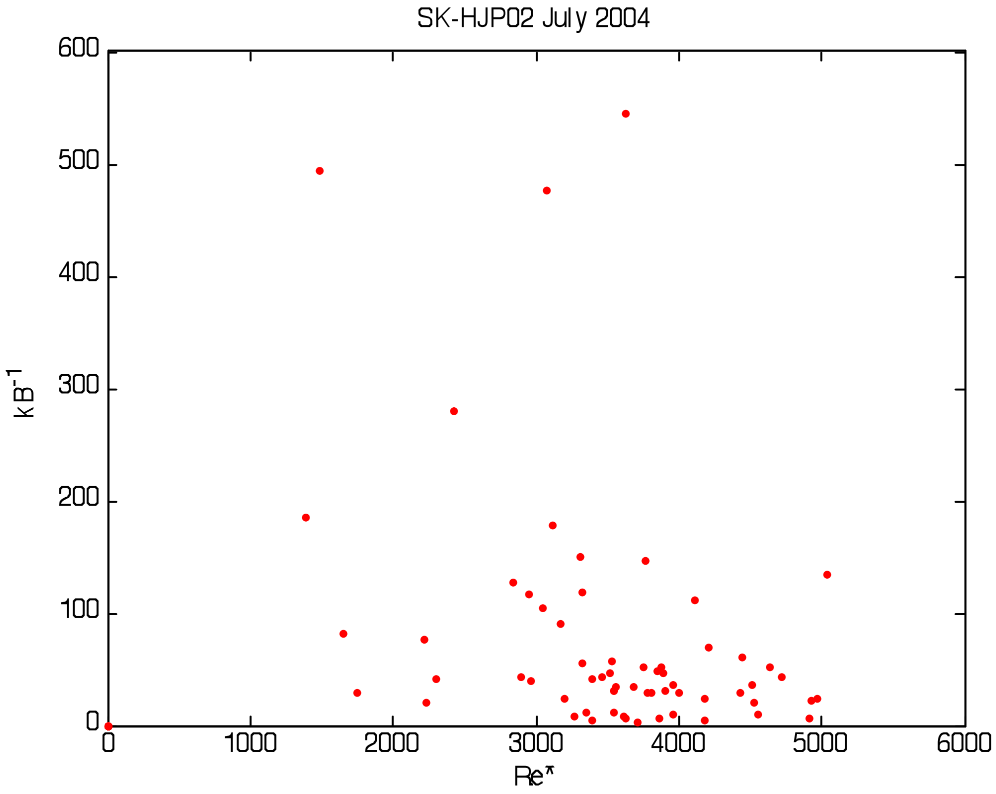

Uncertainties

- Emissivity – default value
- Z_m – empirical parameterized
- Winter time: snow depth
- All uncertainties from the measurements

Next Stage

- Find a good way to determine the actual emissivity
- Enlarge to grassland
- Enlarge to unstable and stable conditions
- Enlarge to different years
- Try to derive the mathematical underpinning for the relation obtained

Thank you &
Happy Chinese New Year!