On Improving Sensible Heat Flux Estimate from Radiative Surface Temperature

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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 surface temperatures:
  - aerodynamic temperature
  - radiative surface temperature

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- Rad
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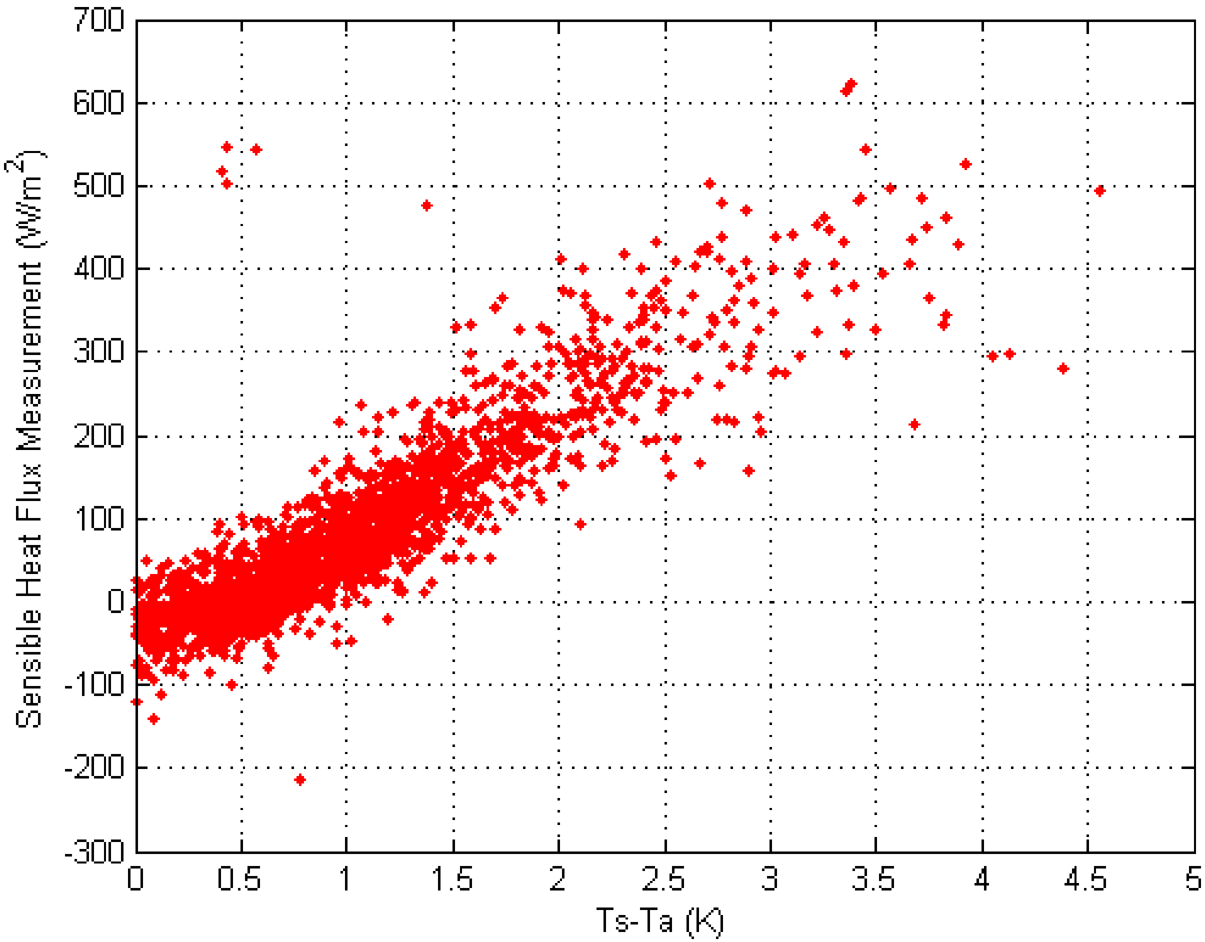

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Overestimate the sensible heat flux

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
...rface radiative temperature.
...that the radiometric exchange coefficient for heat in the bulk
...$\Delta\theta$ for both stable and unstable conditions, where $\Delta\theta$ is the
...re and the air temperature and θ_* is the negative of the heat
...lication of Monin–Obukhov similarity theory with surface
...cular internal relationship between the *radiometric roughness*
...dependent and not systematically related to the roughness

...diometric exchange coefficient for heat depends on the rela-
...mperature and the microscale distribution of surface radiative
...surement. Analogous problems affect the prediction of the
...re at the surface radiative temperature.

Approach 1: Determine a new stability function for the radiometric exchange coefficient that predicts the correct heat flux when the surface radiative temperature is used (Brutsaert 1992).

Approach 2: Replace the roughness height with the "radiometric roughness height" defined to be the roughness height adjusted so that use of the surface radiative temperature in the usual similarity formulation correctly predicts the heat flux (Kustas et al. 1989; Sugita and Brutsaert 1990; Kohsiek et al. 1993).

Approach 3: Formulate an empirical formula between the surface aerodynamic temperature and the surface radiative temperature (Zilitinkevich 1970; Garratt and Francey 1978; Brutsaert 1982). Such a relationship can be posed in terms of the roughness height for heat. This roughness height can be inferred from either an assumed relationship between roughness heights for momentum and heat or from the assumed relationship between vegetation height and roughness height for heat (Choudhury et al. 1986; Brutsaert 1982).

Approach 4: Retain the traditional roughness height for heat and introduce an extra resistance term due to the difference between the temperature at roughness height and surface radiative temperature. Lhomme et al. (1988) found that replacing the aerodynamic tem-

Introduction

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

- Idea:
  - In order to produce accurate surface heat fluxes in bulk method using radiative surface temperature, a “different” resistance is required to offset the difference between two is necessary
  - Aim:
    - find a way to parameterize the “different” resistance itself
    - find a way to parameterize the radiative heat roughness length

Dataset

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

  Ameriflux

  Flux China
- winter months and summer months

- 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

Methodology

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

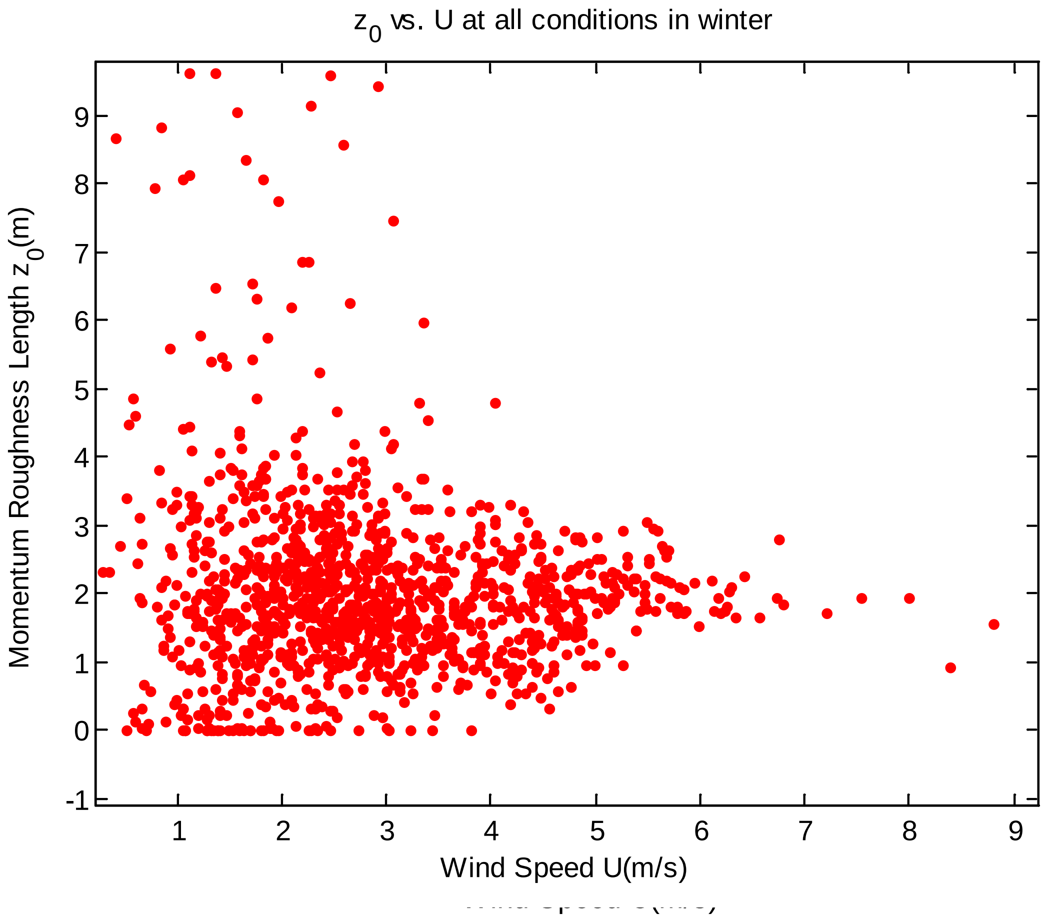
$$C_h = 1/(r_h * U)$$

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

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

Analysis

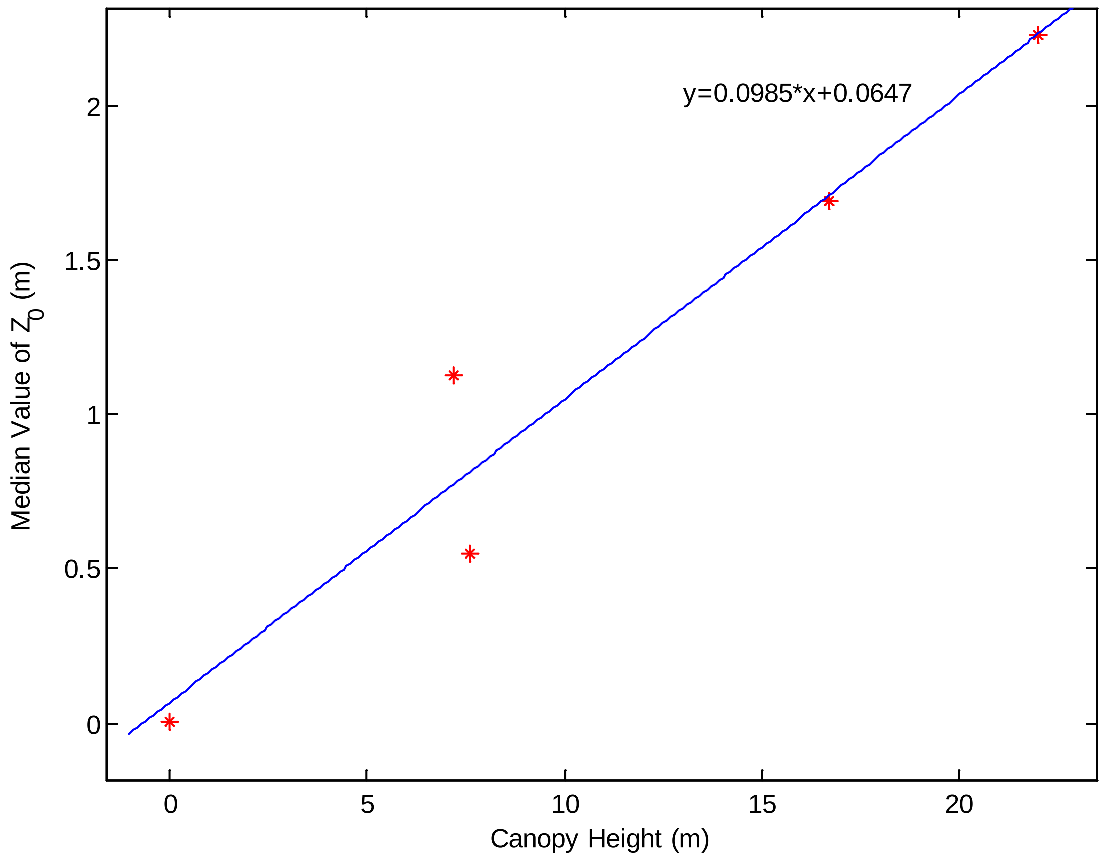
- Dat
  - U
  - St
  - W



Analysis

On z_m and z_T in terms of $Re*$

Analysis



y=0.0985*x+0.0647
Median Value of Z0 (m)
0
0.5
1
1.5
2
0
5
10
15
20
Canopy Height (m)

Analysis

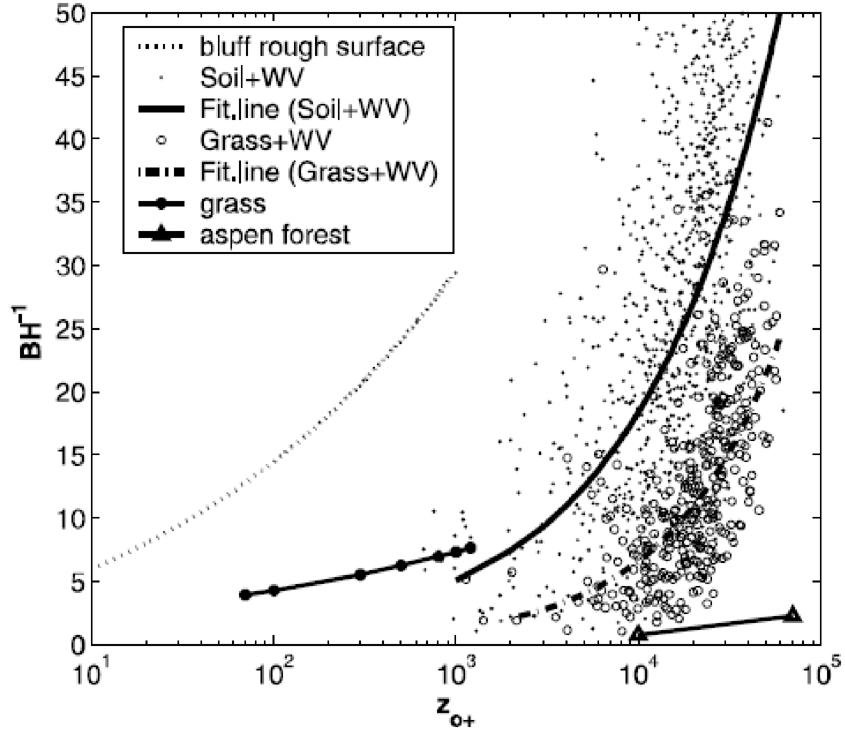
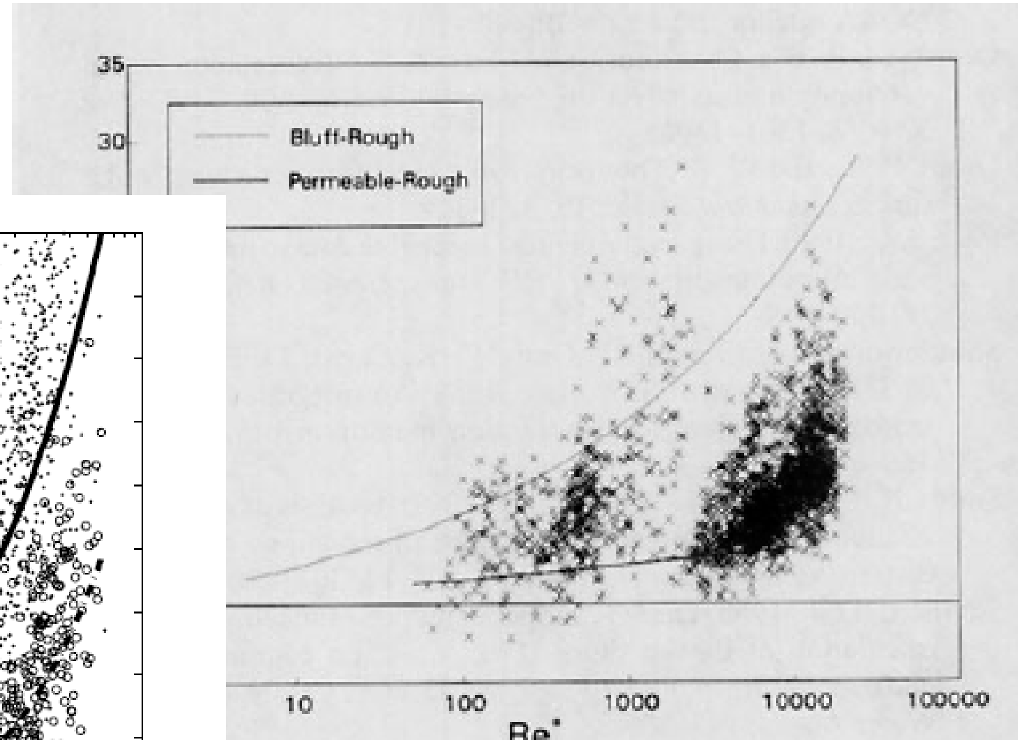
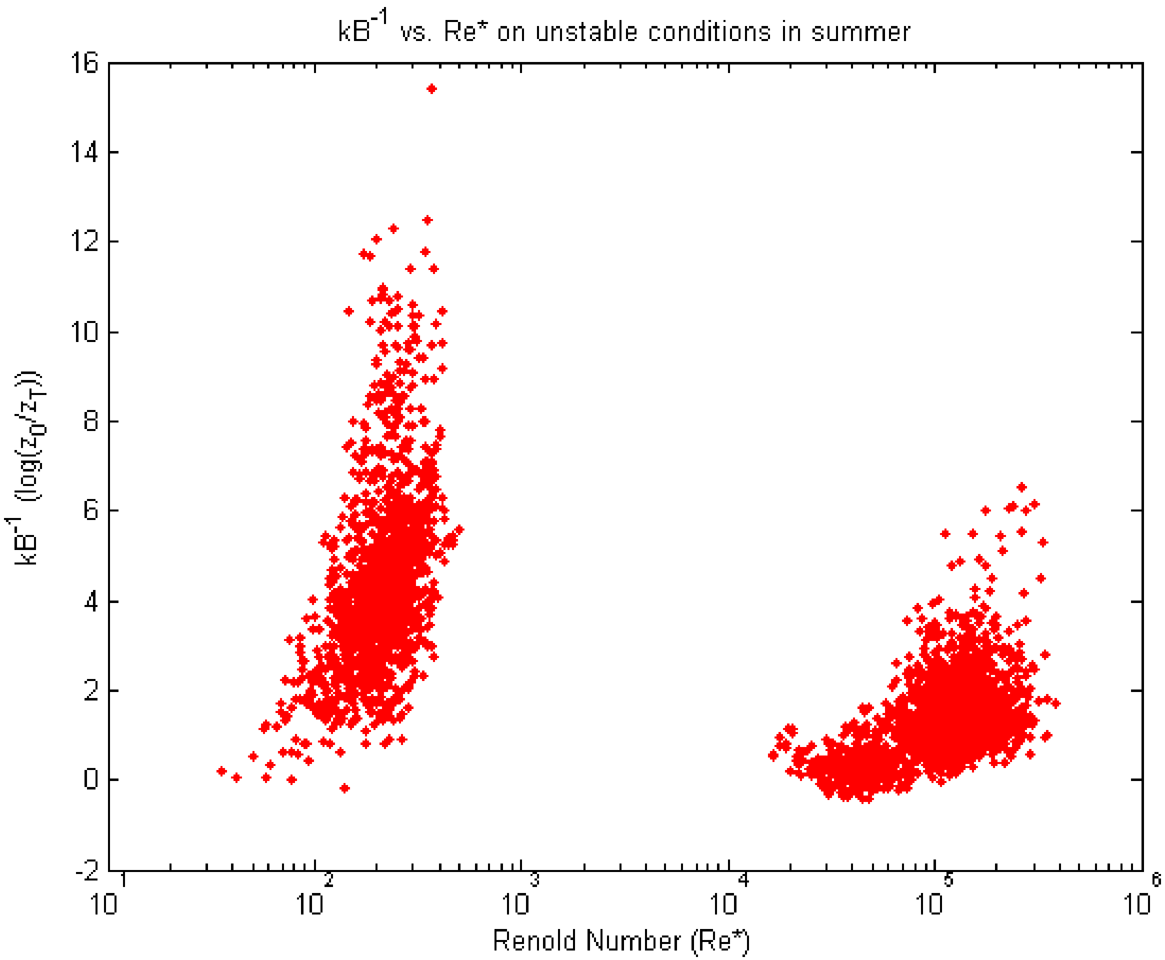


Figure 6. B_H^{-1} values estimated from observed data using (12) versus z_{o+} for the composite soil-WV and grass-WV surfaces. For reference, published B_H^{-1} values for bluff rough surface, grass, and an aspen forest are reported.



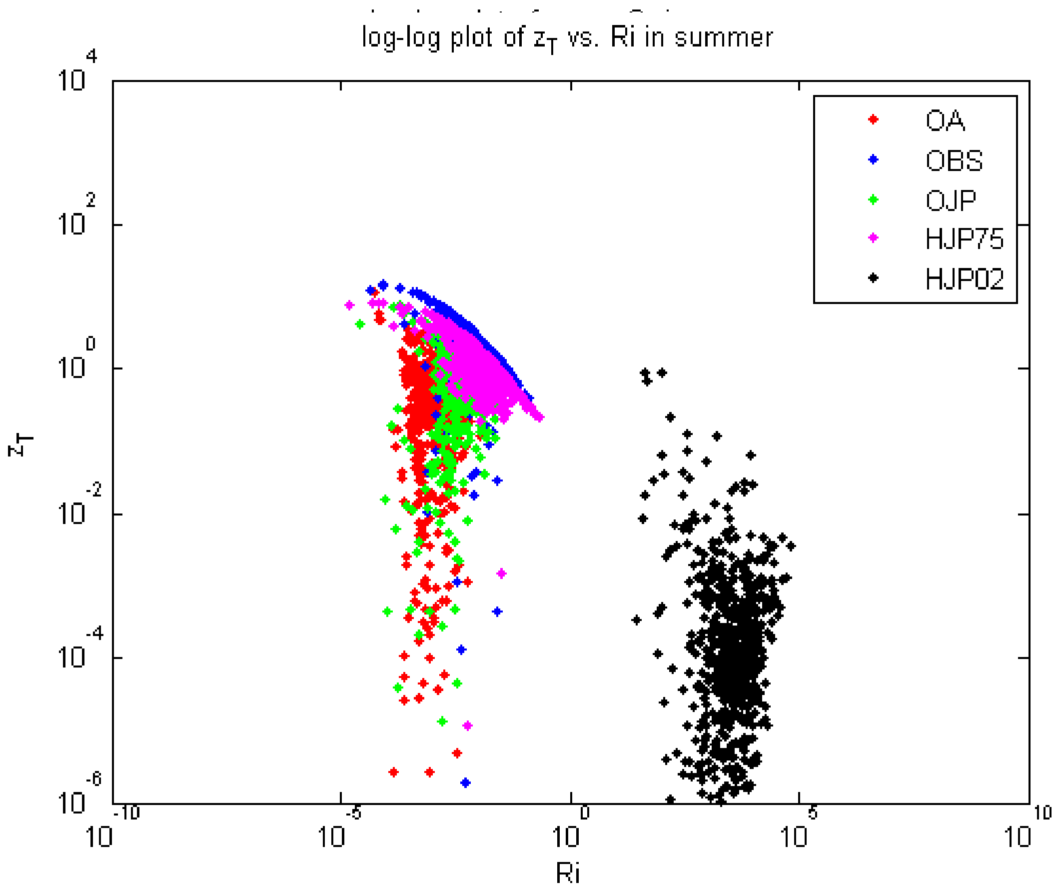
. The relationship between kB^{-1} and the roughness Reynolds Re* ($=z_{0m}u_*/\nu$, where ν is the kinematic viscosity of air) ght semiarid sites. The values were computed from the hourly : two curves from Brutsaert (1982) represent the behavior 'or bluff rough and permeable rough elements.

Analysis



kB^{-1} vs. Re* on unstable conditions in summer
16
14
12
10
8
6
4
2
0
-2
kB^{-1} (log(z$_0$/z$_T$))
10^1
10^2
10^3
10^4
10^5
10^6
Renold Number (Re*)

Analysis



log-log plot of z_T vs. Ri in summer
10^4
10^2
10^0
10^{-2}
10^{-4}
10^{-6}
z_T
10^{-10}
10^{-5}
10^0
10^5
10^{10}
Ri
OA
OBS
OJP
HJP75
HJP02

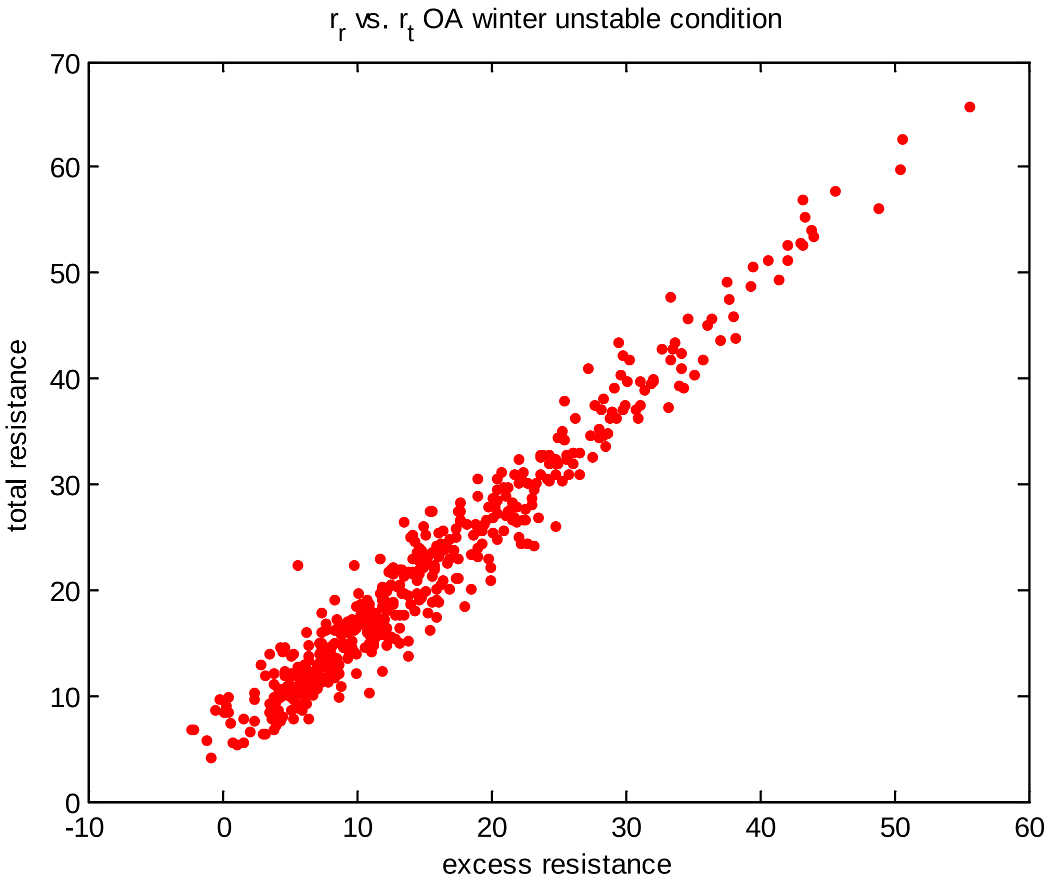
Analysis

Another way --- parameterize resistance itself

- separate the resistance into two parts:
  - $r_t = r_a + r_e$
- two different assumptions in calculating aerodynamic resistance:
  - $\log(z_0/z_T)=0$
  - $\log(z_0/z_T)=2$

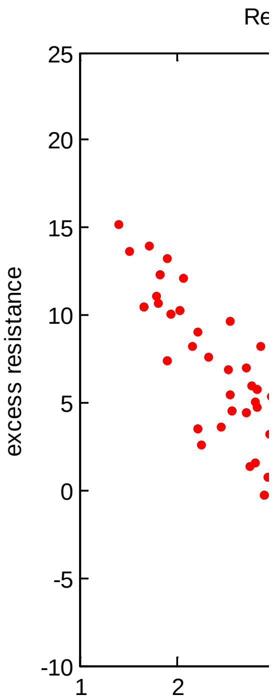
Different physical meanings for r_e

Analysis

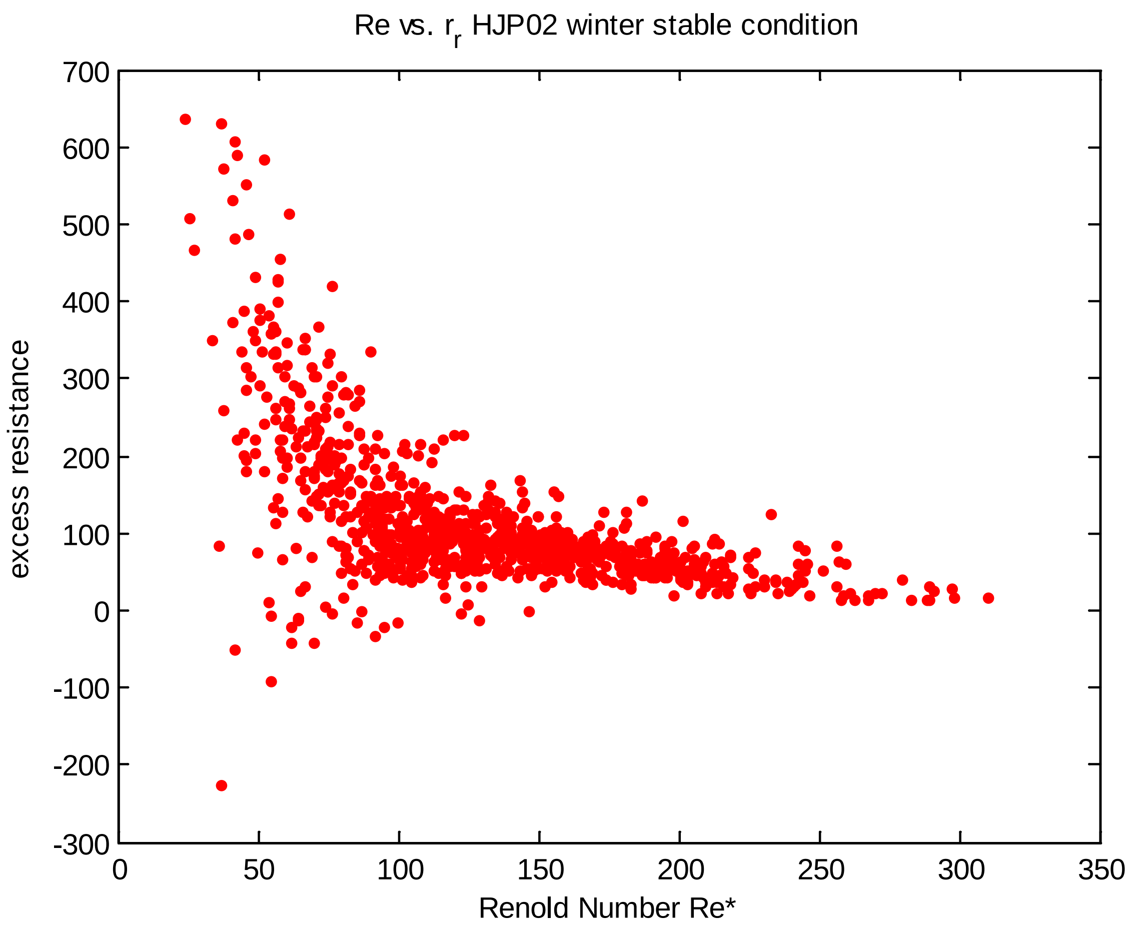


r_r vs. r_t OA winter unstable condition
total resistance
excess resistance
0
10
20
30
40
50
60
70
-10
0
10
20
30
40
50
60

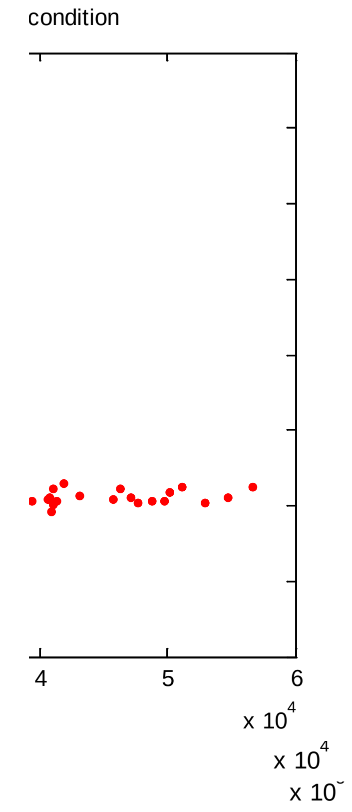
Anal



Re
excess resistance
25
20
15
10
5
0
-5
-10
1
2

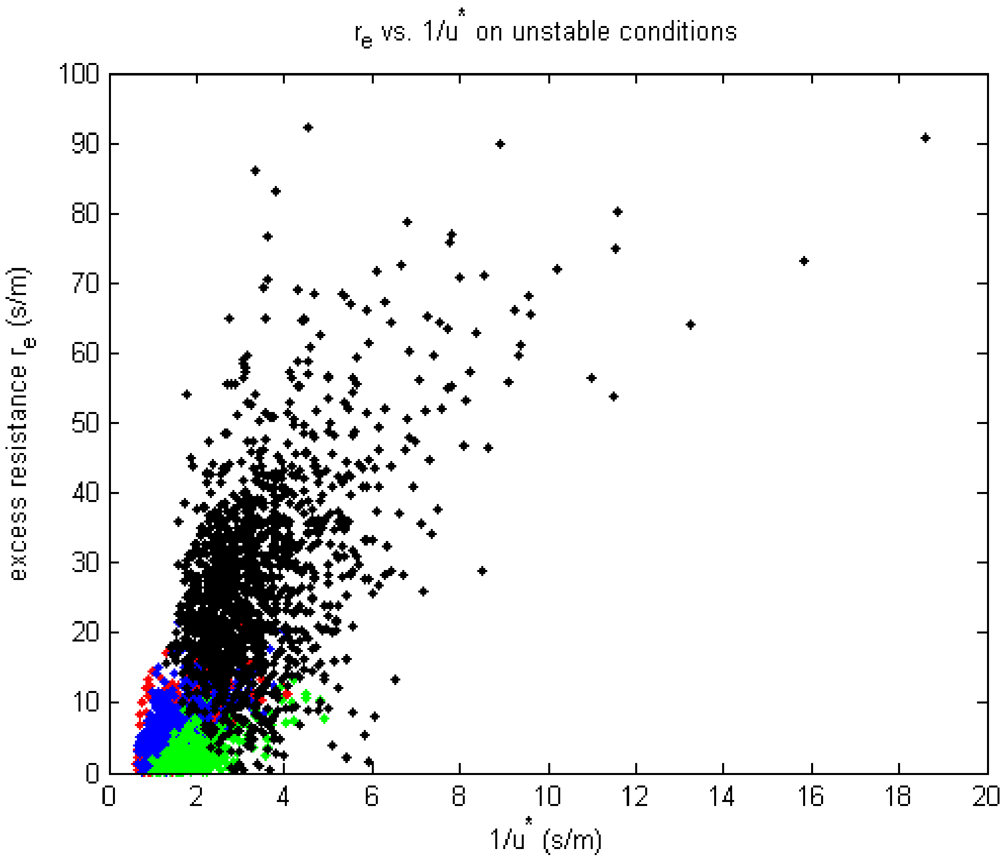


Re vs. r_r HJP02 winter stable condition
excess resistance
700
600
500
400
300
200
100
0
-100
-200
-300
0
50
100
150
200
250
300
350
Renold Number Re*



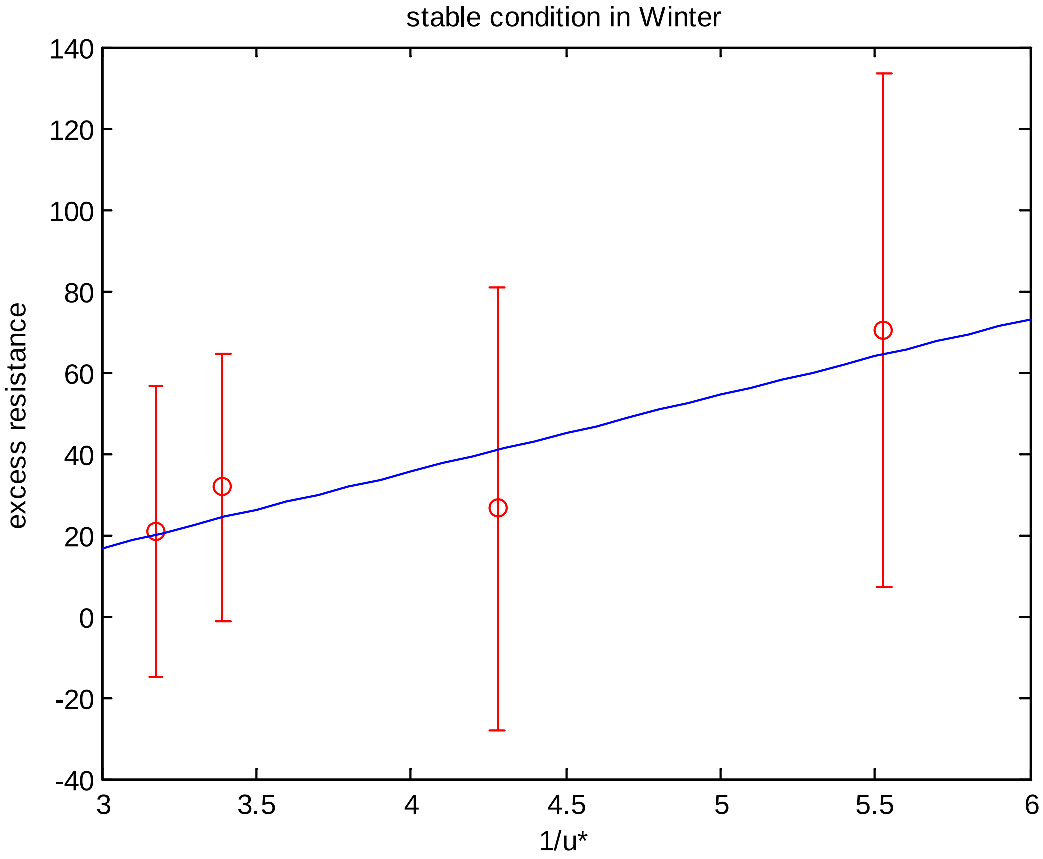
condition
4
5
6
x 10^4
x 10^4

Analysis



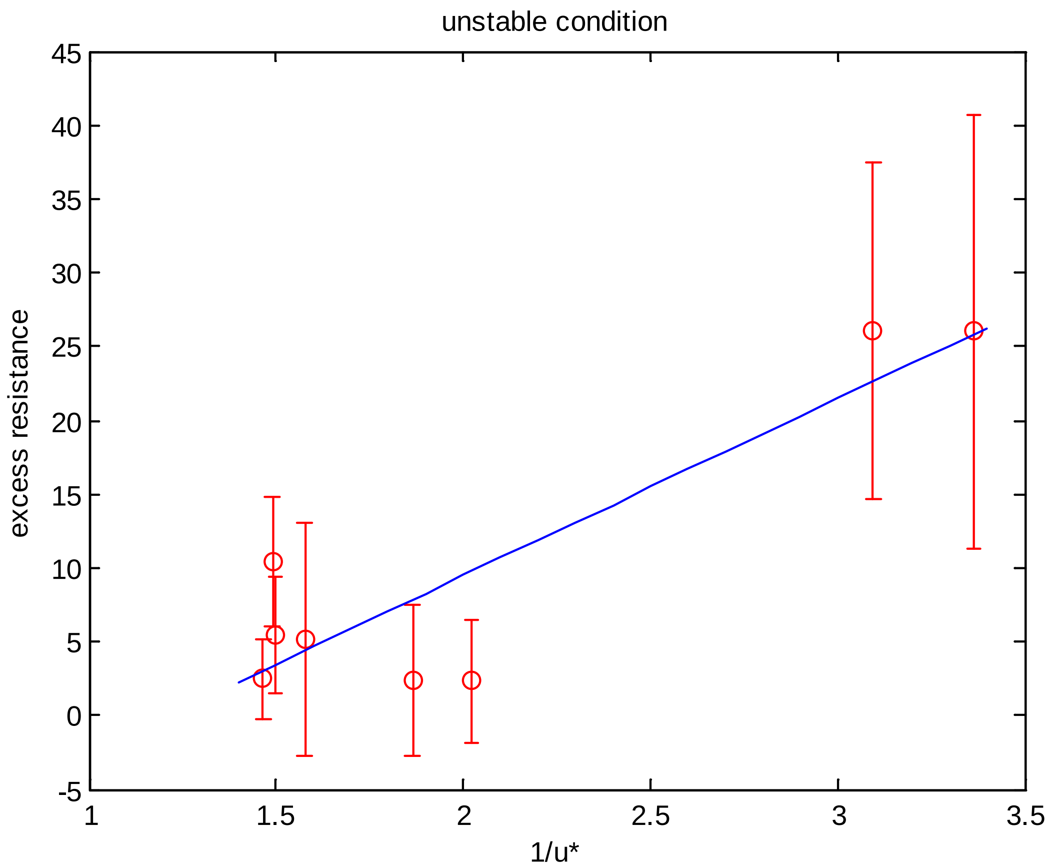
r_e vs. 1/u* on unstable conditions
excess resistance r_e (s/m)
1/u* (s/m)
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18
20

Analysis



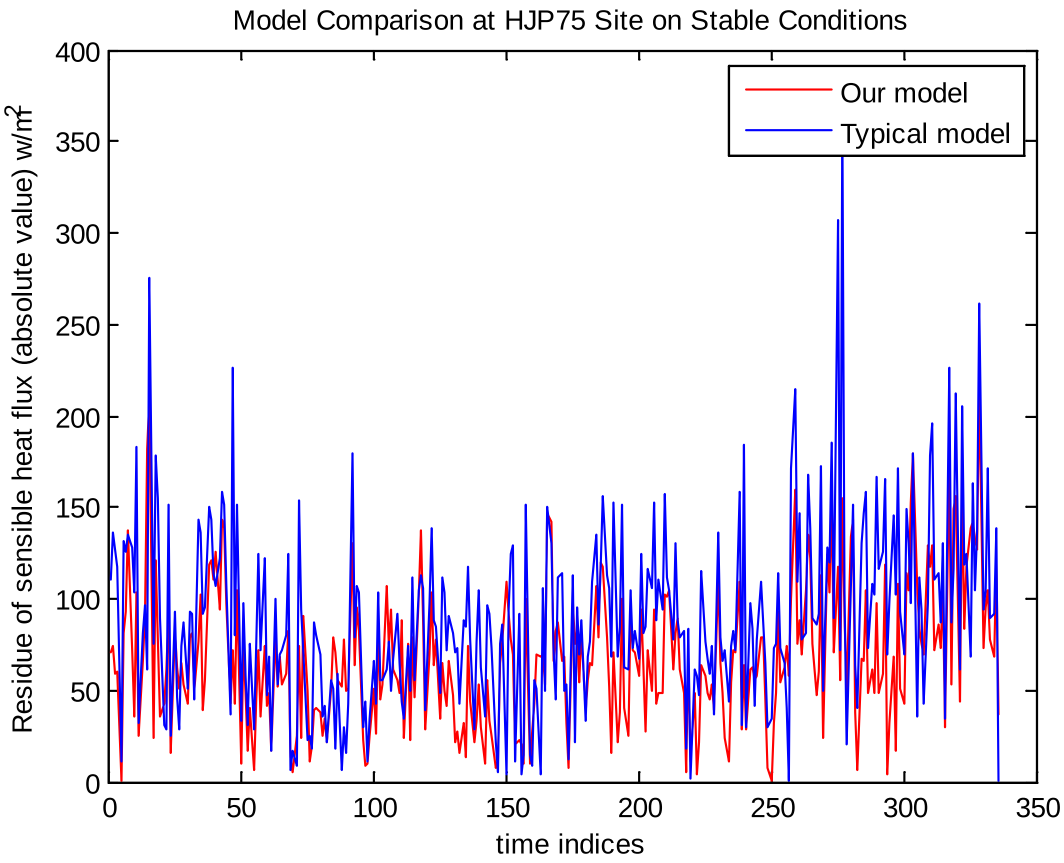
stable condition in Winter
140
120
100
80
60
40
20
0
-20
-40
excess resistance
3
3.5
4
4.5
5
5.5
6
1/u*

Analysis



unstable condition
excess resistance
1/u*
45
40
35
30
25
20
15
10
5
0
-5
1
1.5
2
2.5
3
3.5

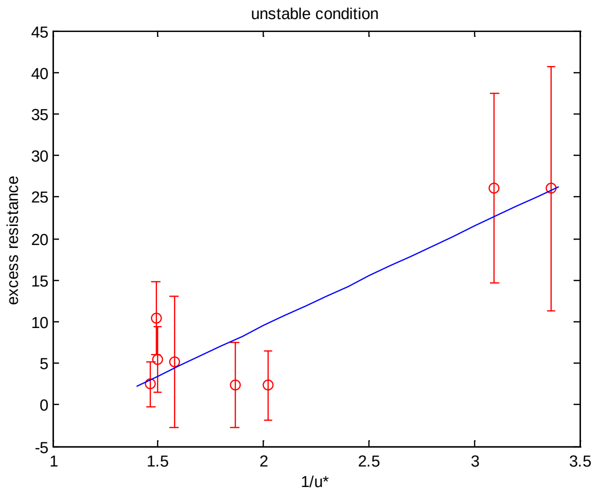
Examples of the parameterization



Current and future work

- Physical base derivation:
  - $r_a \sim \delta/\kappa \quad \delta \sim Re^a$

- Introduce more sites with medium canopy heights



Thank you