Differences of Rainfall-Interception (RI) Characteristics btw Urban and Forest Canopies

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Content

- Background -urban water balance-
- Experimental description
- Characteristics of urban RI, focusing on the difference from forest RI
- Cause for RI differences btw urban and forest canopy

Background

Rain = Runoff + Infiltration + Rainfall Interception

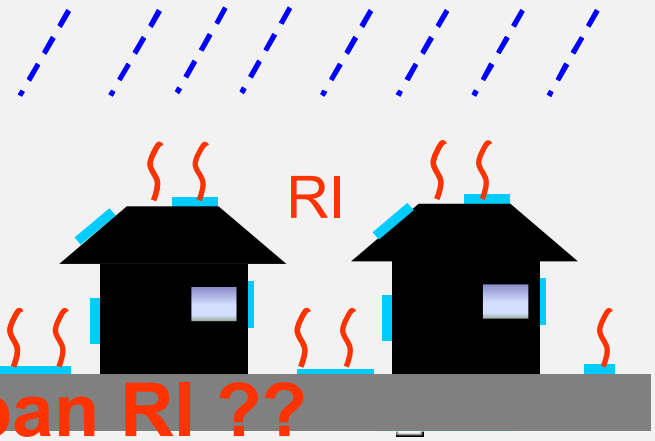
Sewage water ?

Ground water ?

?

?

RI: evaporation from the wetted surface during & after rainfall



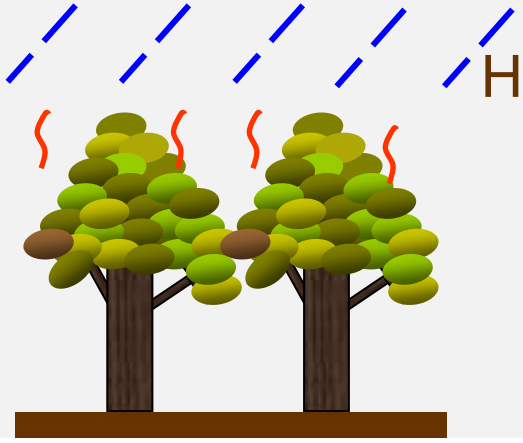
Urban RI ??

Difficult to estimate

Forest RI:

10-50% of gross rainfall

Hormann et al,1996



Methodology

Comprehensive Outdoor Scale MOdel (COSMO)

1.5 m concrete cubes

Flow & thermal inertia similarity with real cities

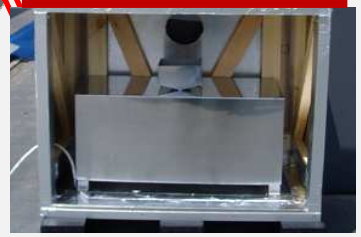
Rain gauge

TR-525M, Texas Electronics, Inc.

RI catchment

Impervious area
(6m×6m)

Flow meter



UIZ-TB1000, UIZIN, Ltd.

✓**Simplified water balance equation**

RI = Rain - Runoff

RI during rainfall + Water storage capacity (St)

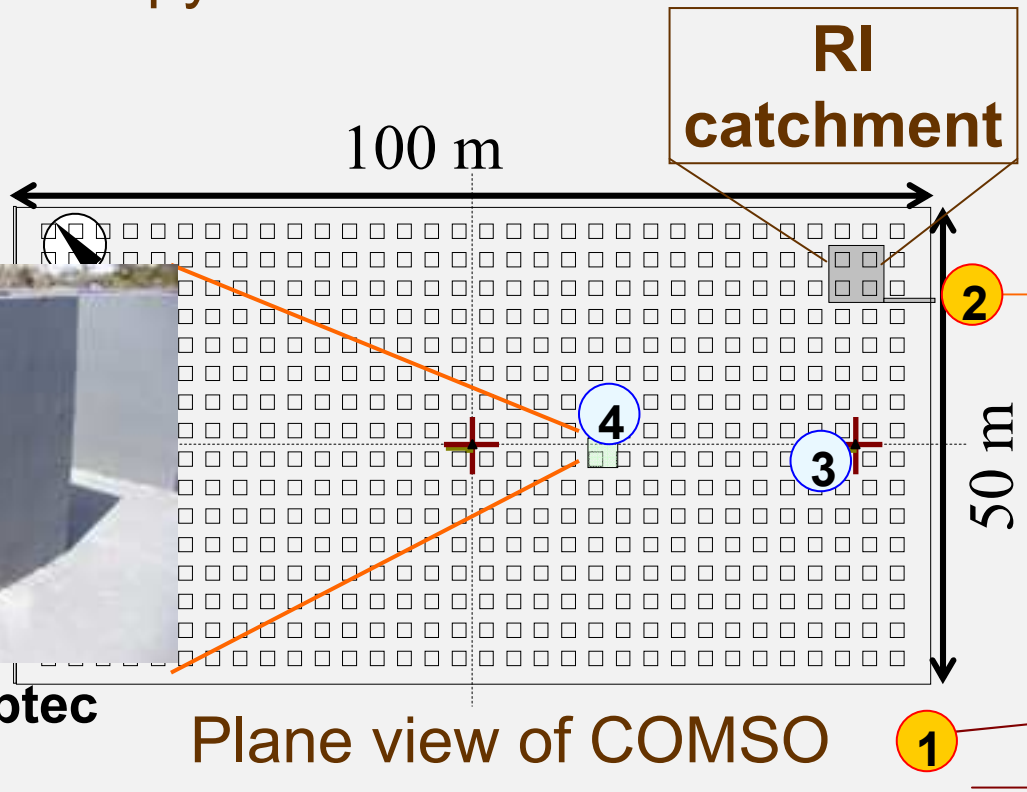
St :
0.25mm

✓**Quite small time lag btw rain & runoff**

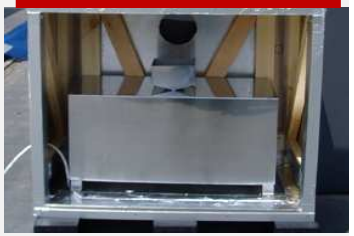
Measurement items

1. Rainfall
2. Runoff
3. Wind velocity, T_{air}, Relative Humidity (RH) at 3 m above the pavement
4. $T_{surface}$, Canopy heat flux

HF-300T, Captec



Flow meter



Rain gauge

Results Period：2006/9/1-2007/1/31

Number of Rainfall event：32

Gross rainfall：0.2 - 134.5 mm

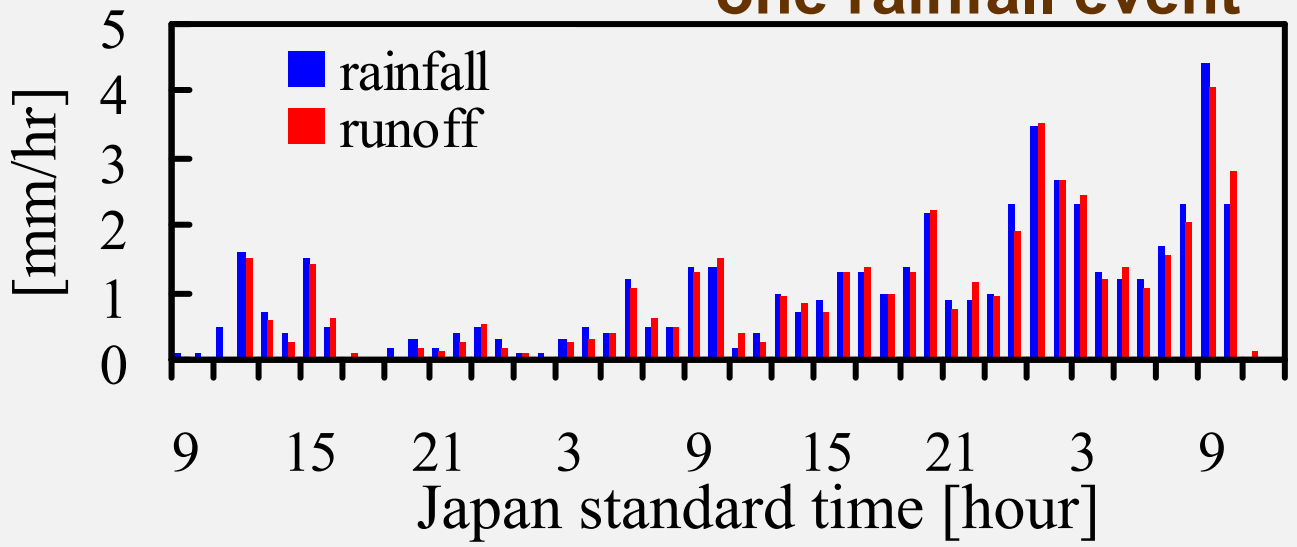
Hourly rainfall: 0.1 - 10.5 mm/h

one rainfall event

Rain: 52.1 mm

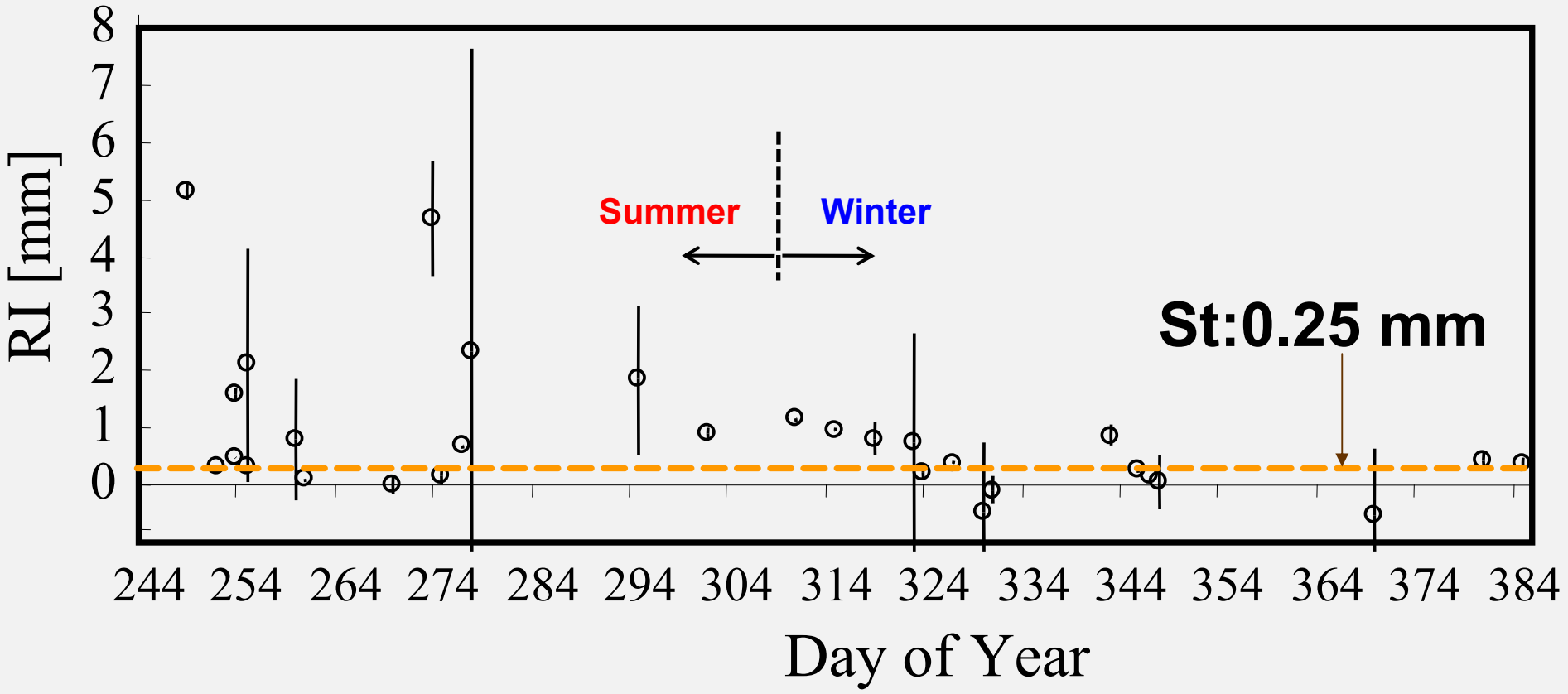
Runoff: 50.0 mm

RI: 2.1 mm



- ✓ Seasonal trend of RI
- ✓ Temporal change of RI
- ✓ Heat balance of RI

Results ~seasonal trend



RI / gross rainfall: 6% **<<** (**Forest**:10-50%) **e.g., Hörmann et al. (1996)**

Results ~Temporal trend~

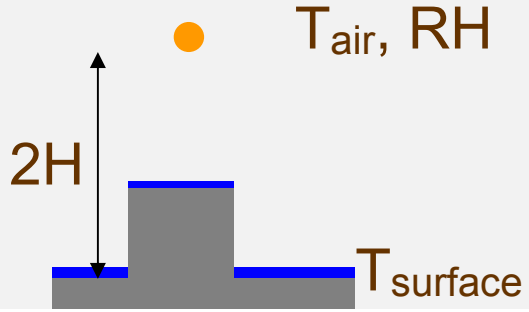
Decrease with time

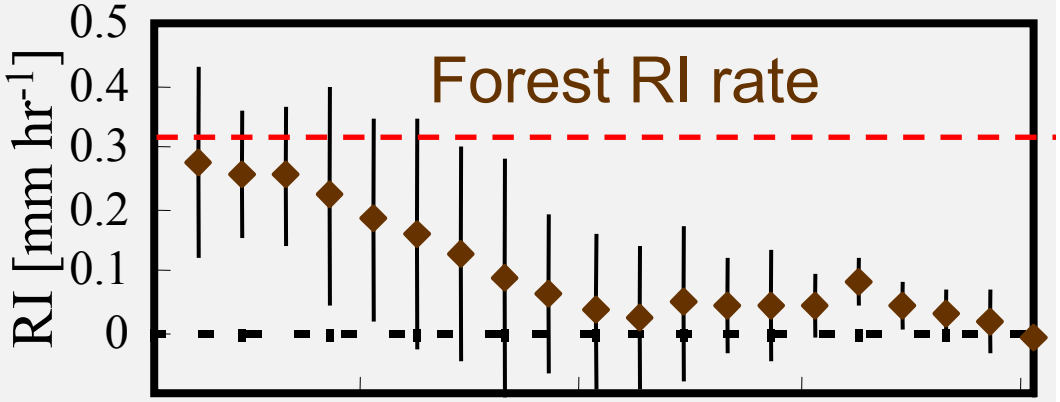
cf. constant RI rate for Forest canopy (0.3 mm/h)

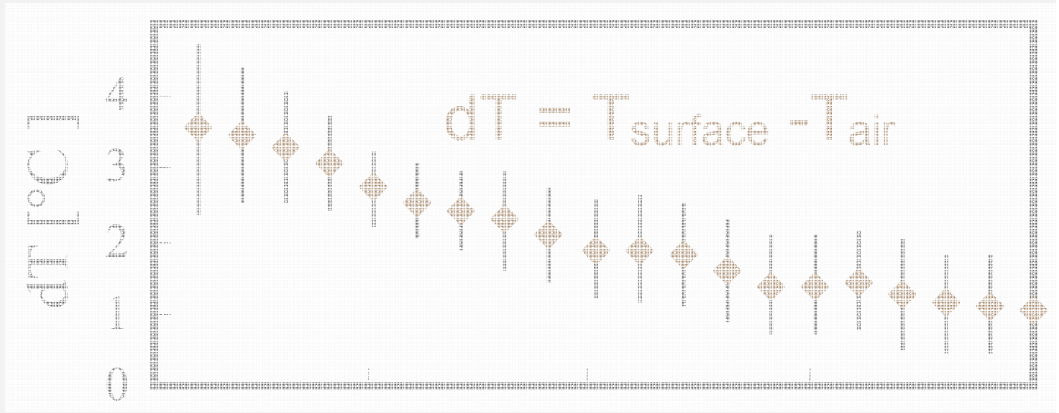
e.g.,Gash et al 2008

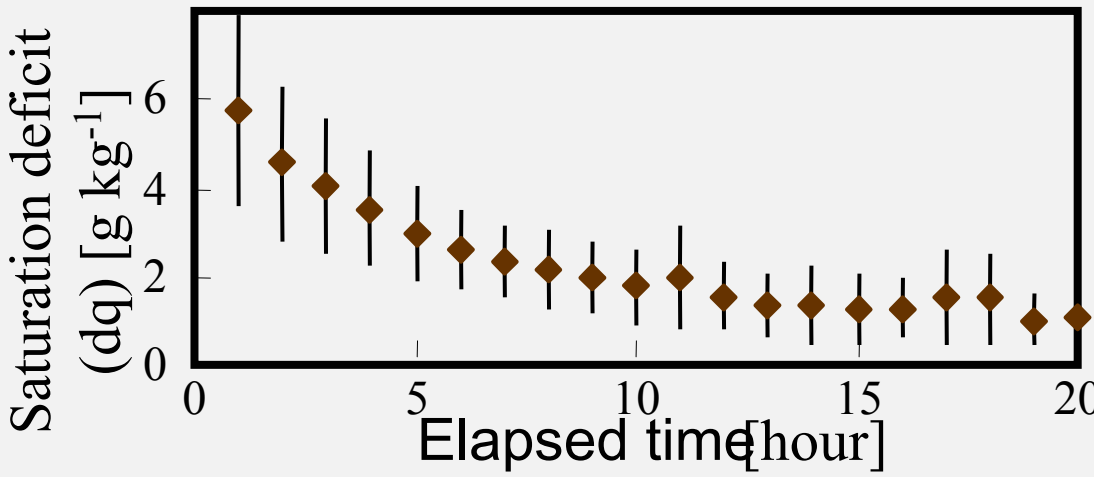
$T_{surface}$: averaged surface temp.

dT>0 (large heat capacity)

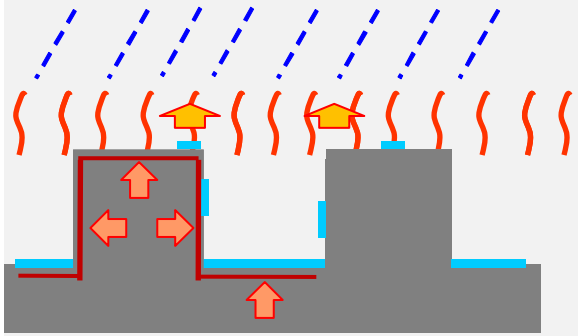


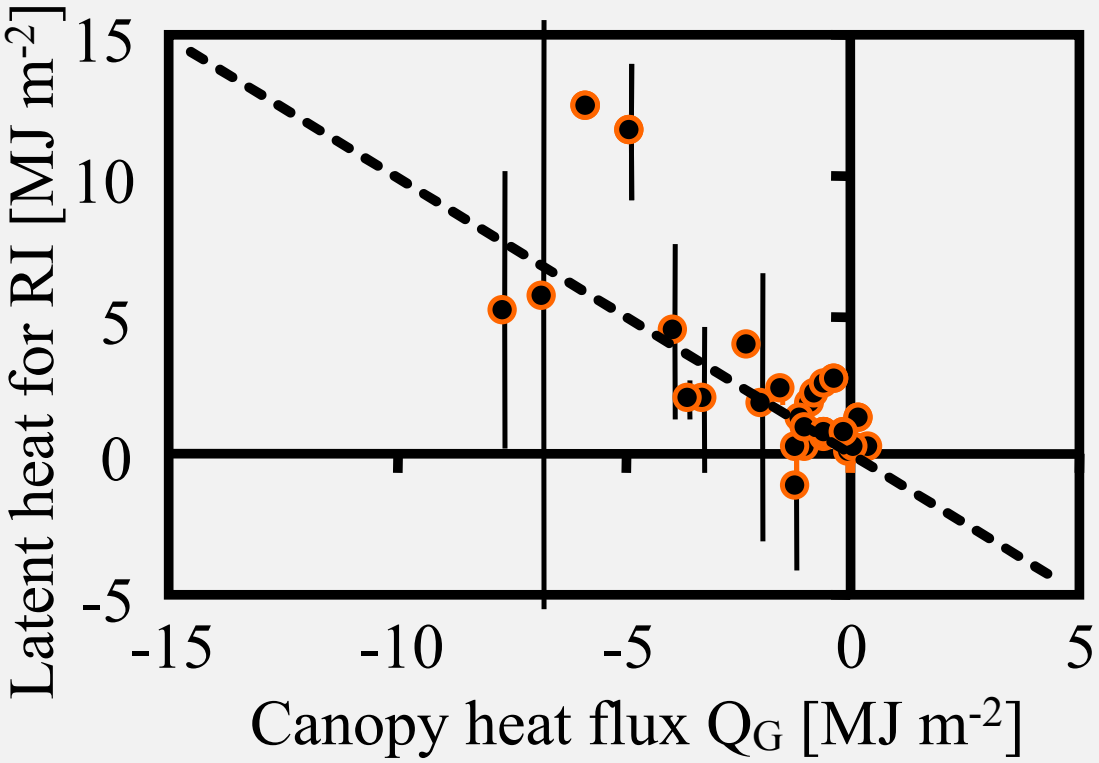






Results ~Heat balance of RI~



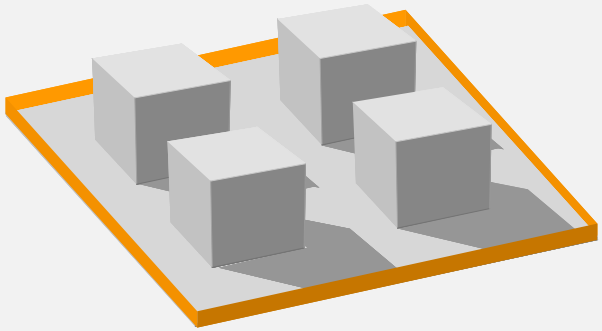


Latent heat for RI was almost balanced by Q_G

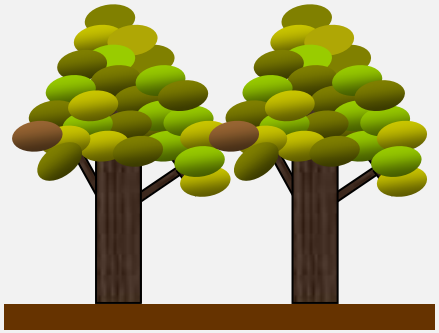
c.f., net radiation (Q*) & sensible heat (Q_H) for forest RI

e.g., Stewart, 1977

RI characteristics in U.C and F.C



Urban canopy (U.C.)



Forest canopy (F.C.)

	Urban canopy (U.C.)	Forest canopy (F.C.)
RI / gross rain	6%	10 ~ 50%
Temporal RI rate	Decrease with time	Almost constant
Heat supply for RI	Q_G	Q^* & Q_H

Cause for RI difference btw U.C & F.C

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Canopy Structure

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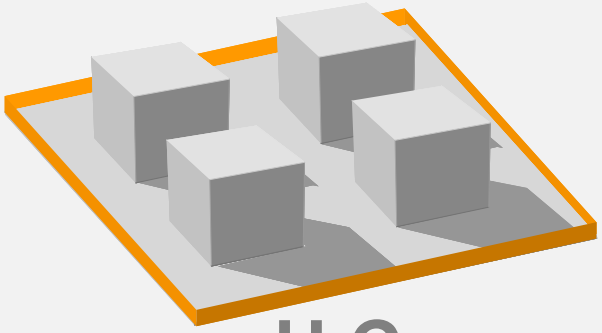
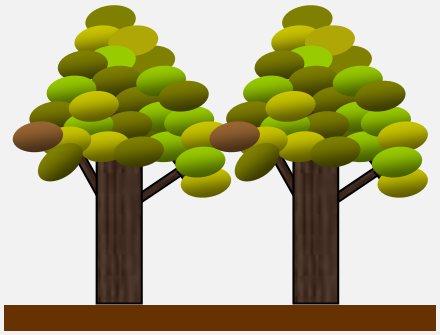


U.C.



F.C.

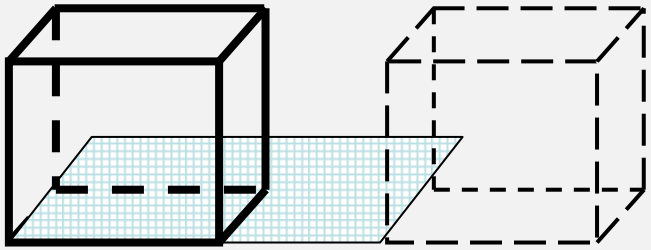
- Surface Area Index (SAI)
- Scalar roughness parameter kB^{-1}
- Canopy heat capacity

Surface Area Index (SAI)

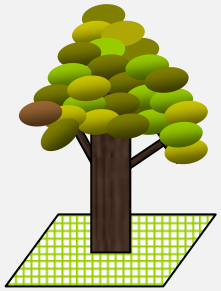
RI magnitude

$$SAI = \frac{\text{Total S.A.}}{\text{Horizontally projected ground S.A.}}$$

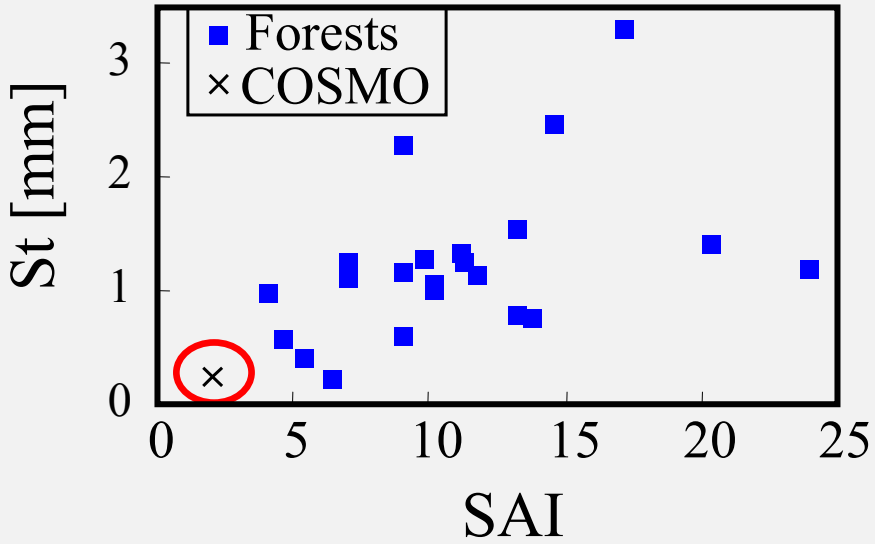
Measure of wettable Area

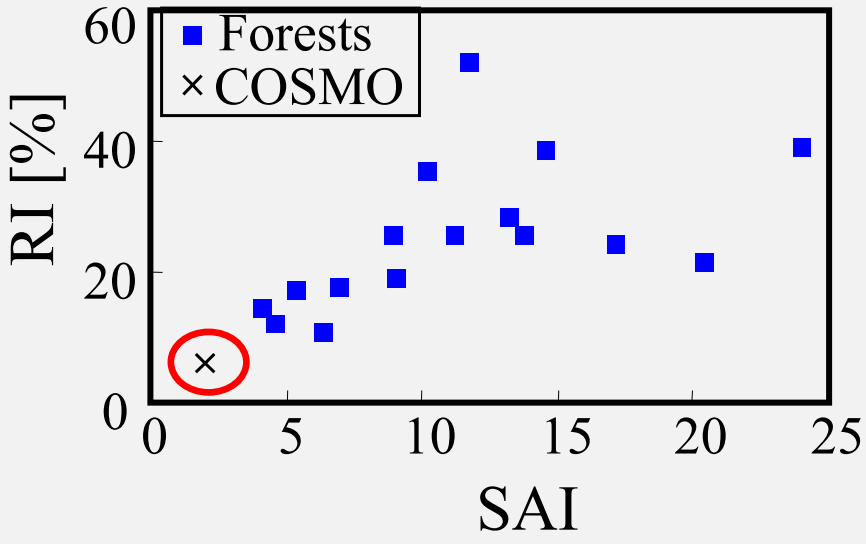


SAI=2



SAI~5-25 (2 x LAI)





kB^{-1} RI magnitude

$$kB^{-1}=\ln(Z_0/Z_T)$$

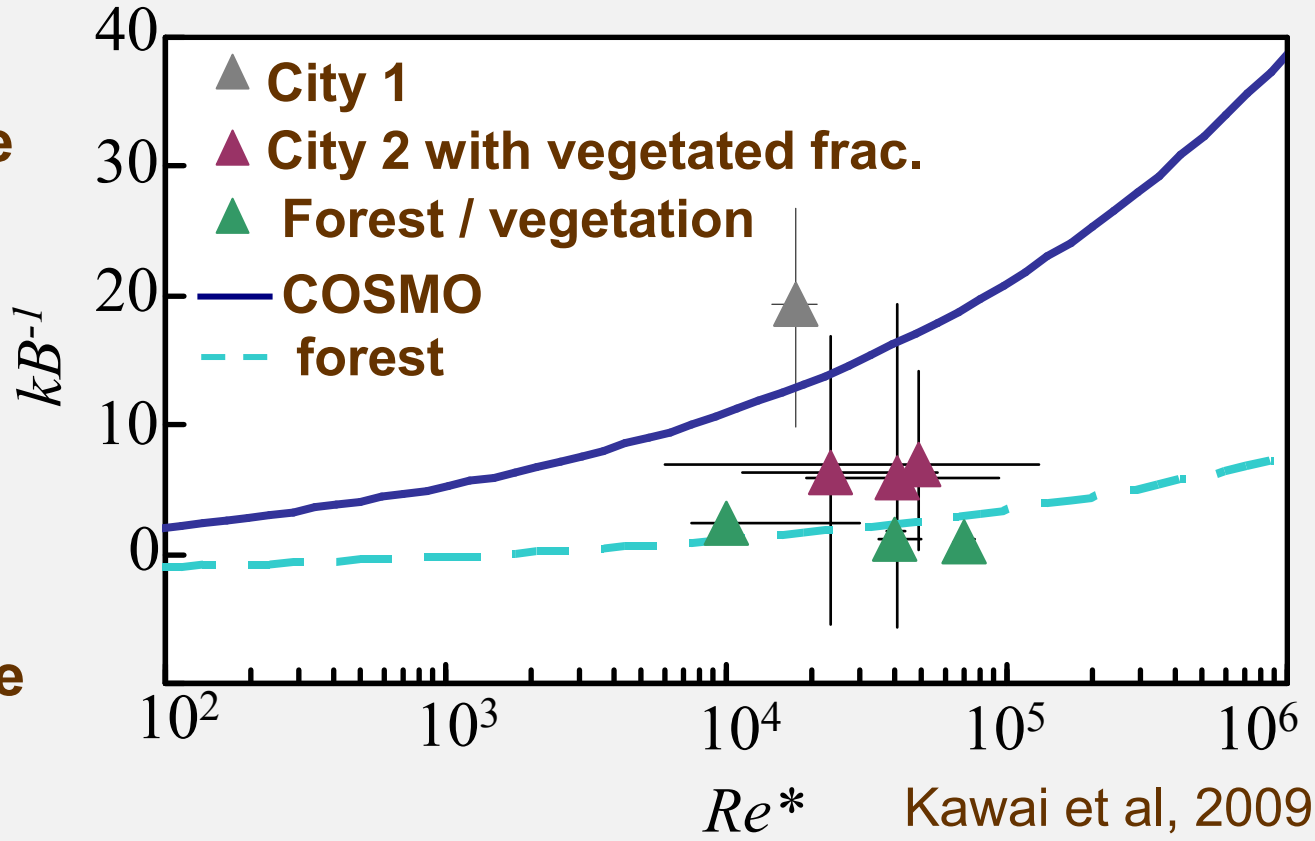
Z_0 : roughness momentum

Z_T : roughness heat

Measure of heat transfer resistance

high resistance

low resistance



Kawai et al, 2009

U.C.: high resistance for heat transfer

Small RI in COSMO is a reasonable result

U.C.: high resistance for scalar transfer

Difference of kB^{-1} btw U.C. and F.C.

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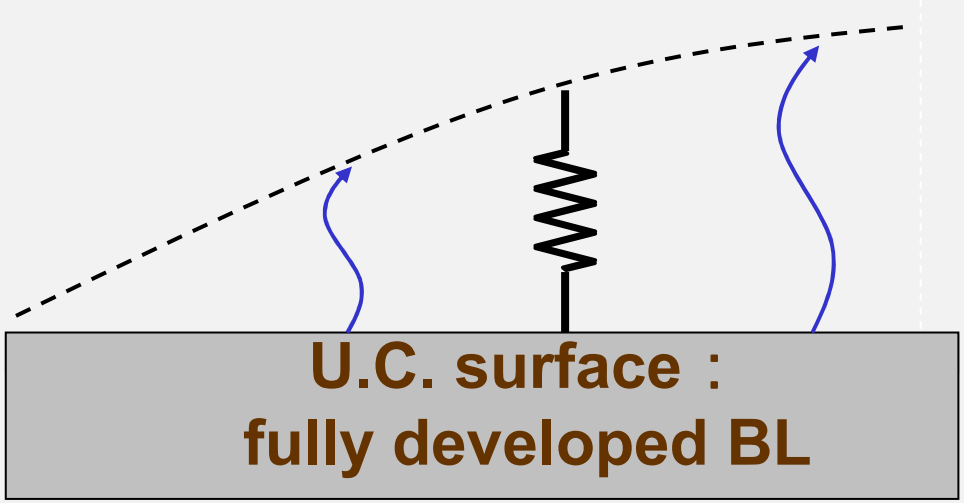
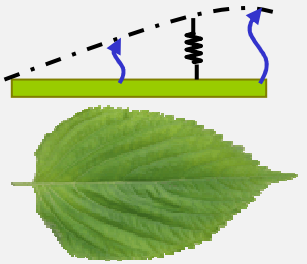
Difference in size of individual roughness element



High resistance of scalar transfer



Leaf surface：
BL hard to develop

Low resistance

F.C.: aggregation of small leaves

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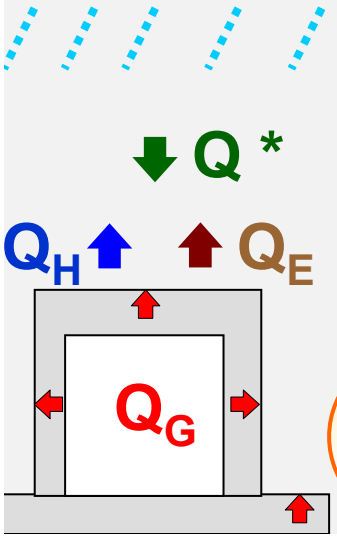
kB-1 in F.C. expected to be small

Canopy heat capacity

heat supply for RI & temporal RI rate

Urban Canopy	Forest canopy
Large heat capacity	Small heat capacity
can sustain RI	cannot sustain RI
$T_{air} < T_{surface}$	$T_{air} > T_{surface}$
Q_H : Upward	Q_H : Downward

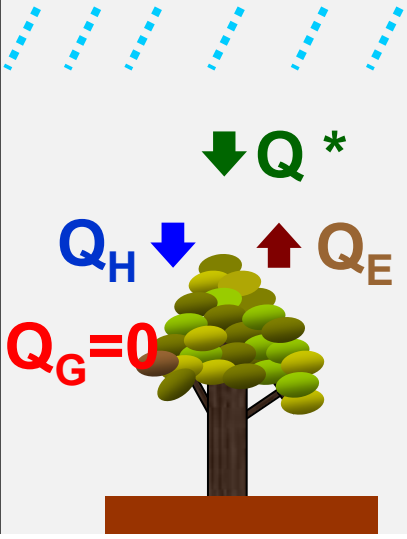
Q^*: net radiation Q_G: canopy heat Q_H: sensible heat Q_E: latent heat



$Q_E \fallingdotseq Q_G$

Exhaustible heat supply

Temporal RI: decrease with time



$Q_E = Q^* + Q_H$

Continuous heat supply

Temporal RI: constant

Cause for RI difference btw U.C & F.C

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Canopy Structure

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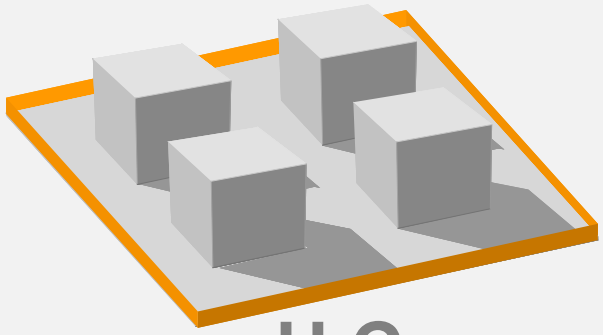
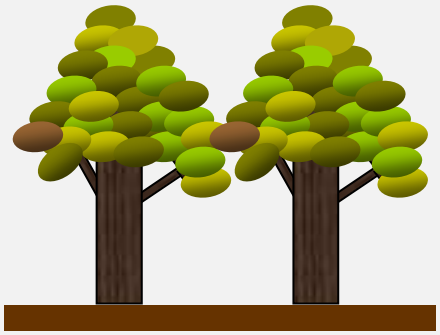


U.C.



F.C.

Surface Area Index (SAI)

difference of **RI magnitude**

Scalar roughness parameter kB^{-1}

difference of **RI magnitude**

Canopy heat capacity

difference of **heat supply for RI** & **temporal RI rate**

Thank you for your attention

Nakayoshi et al,
Experimental study on rainfall interception over an outdoor urban-scale model
Water Resource Res., 2009
doi:10.1029/2008WR007069

RI in COSMO	RI in Ragab et al. 2003
6 %	30 %
Bulk RI on entire canopy	**Local RI** on roof surface

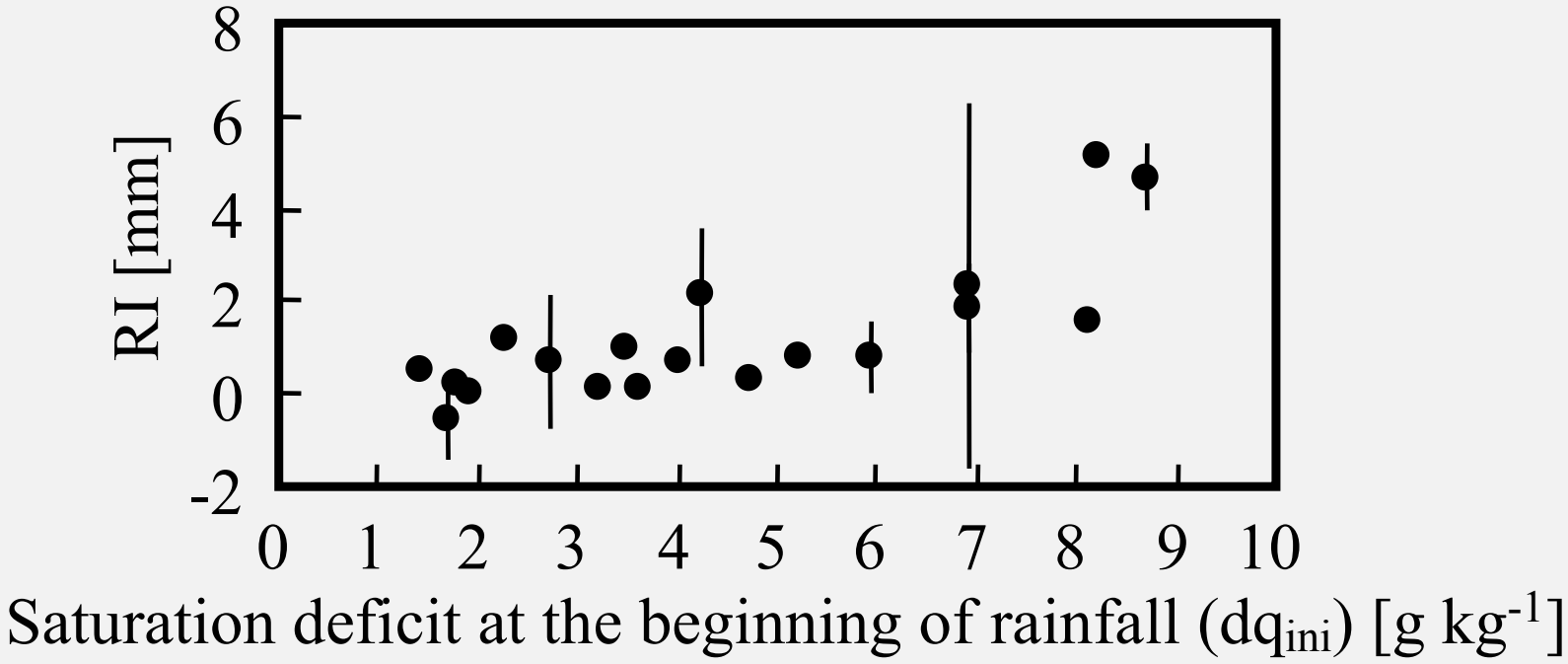
Local RI on roof can be larger than bulk RI

1. Local scalar transfer rate on roofs is larger than on other surfaces (e.g., Narita, 2007)

2. Roofs are better located to receive solar radiation than other surfaces: more available radiative energy

3. Splash loss of raindrops can increase with time & rainfall intensity in Ragab et al, because catchment in Ragab was not enclosed by water proof fencing.

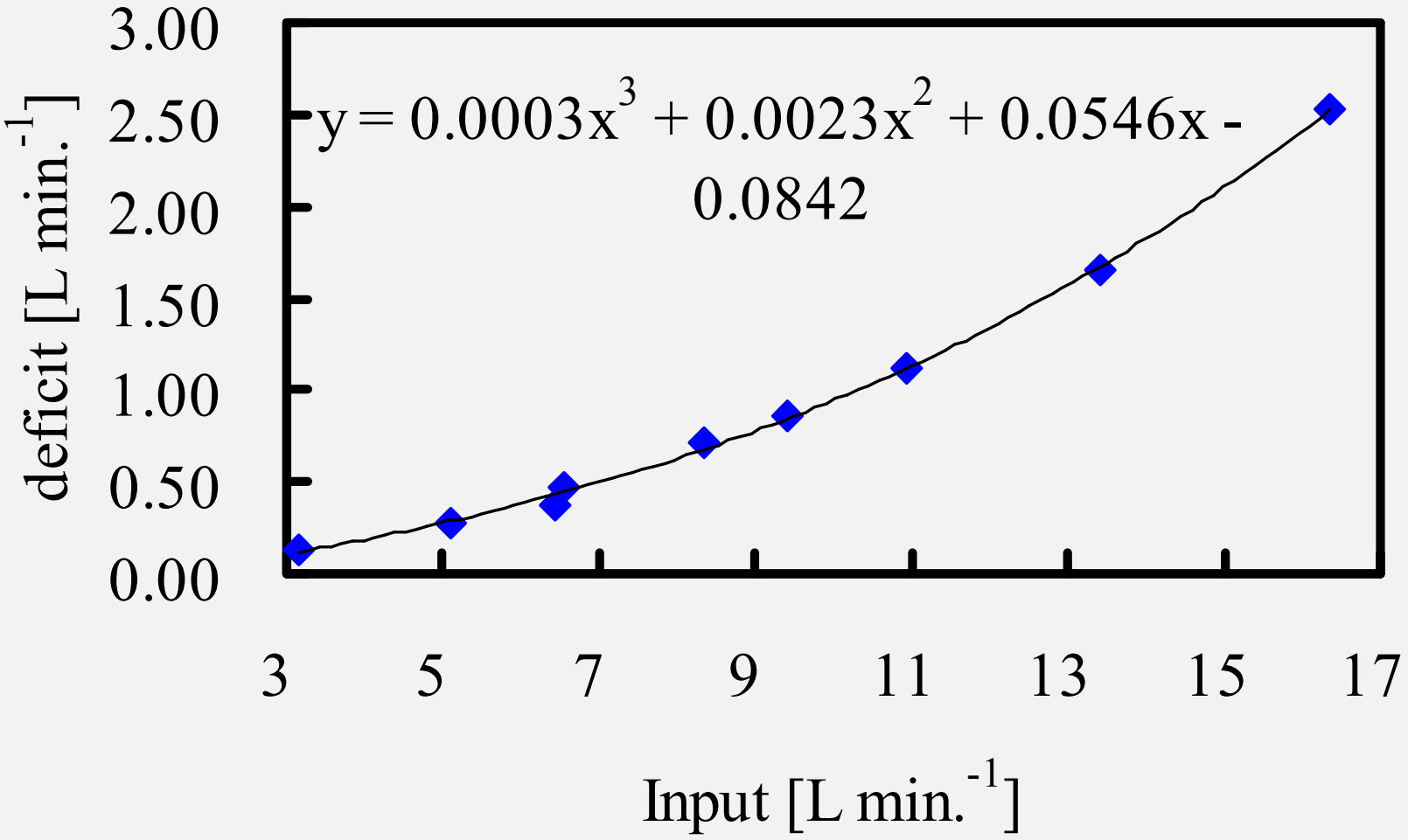
Results ~Governing parameter~



RI was well-correlated with dq_{ini}

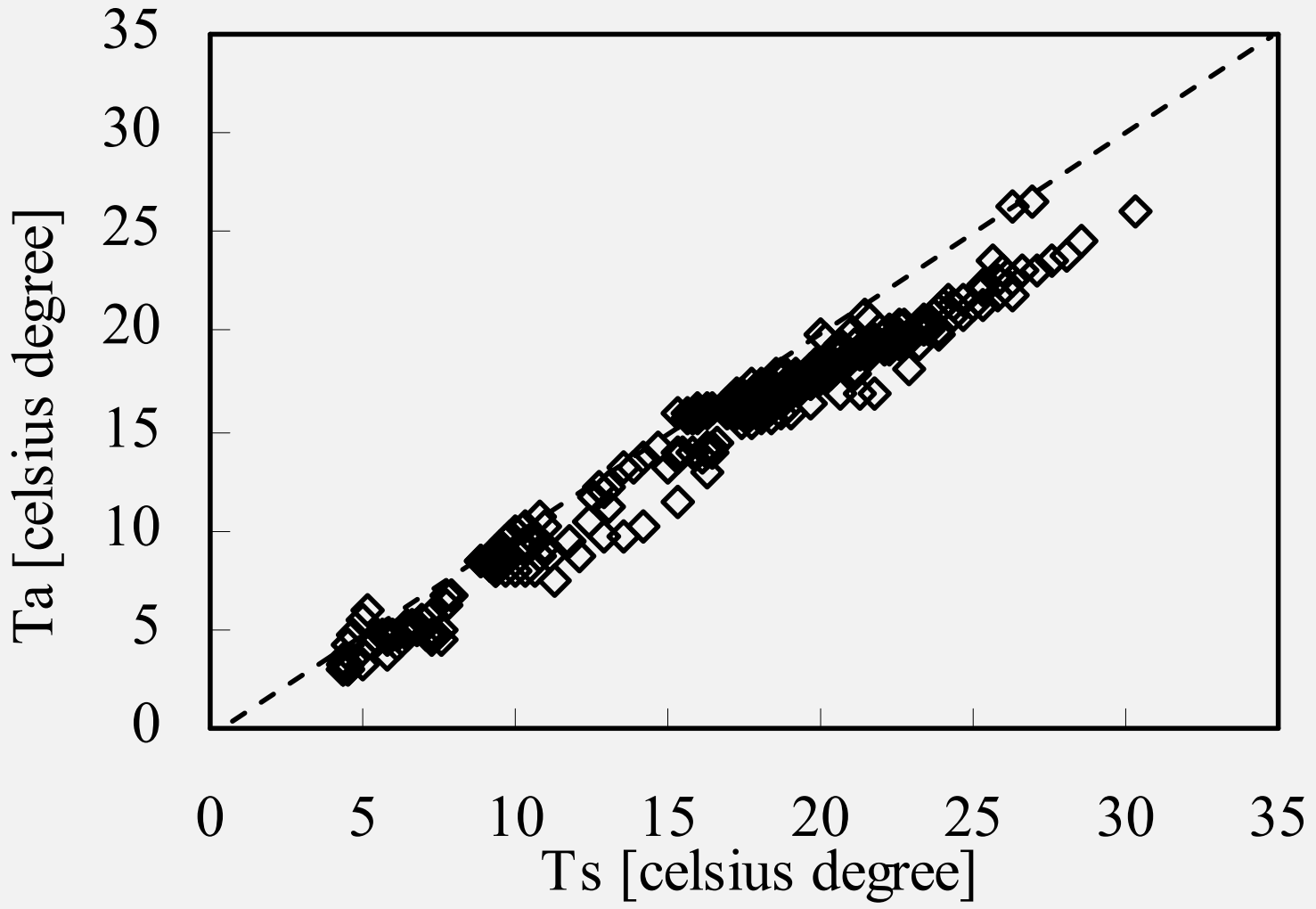
c.f. rainfall intensity & duration
for forest RI

Flow meter ~input vs deficit~



Infiltration check

pictures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