Sensitivity analysis and optimization of an urban energy balance parameterization at a tropical suburban site

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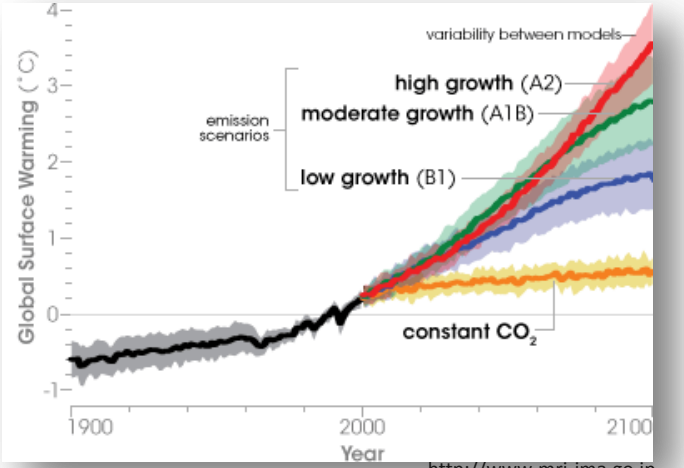
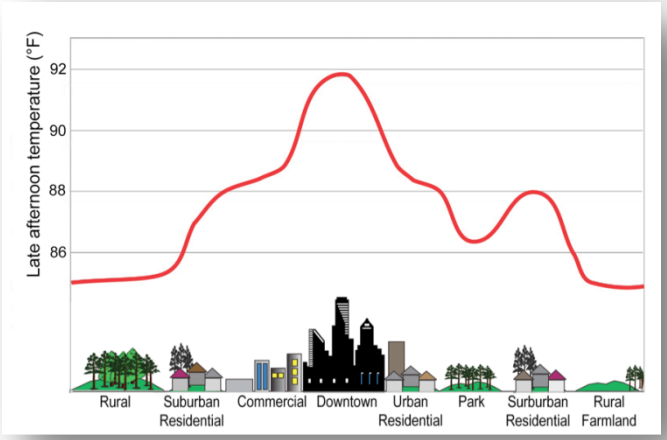
Why need for urban canopy parametrizations?

- Higher frequency of extreme weather events (IPCC 2013)
- Cities take up only small fraction of earth's surface, but half of the human populations now live in cities, and this is expected to increase in the coming decades
- Combined effects of heat wave and UHI, have large socio-economic impacts, e.g. France 2003, excess of mortality (Masson 2006)
- Current CPU capabilities made it possible to run operational models in 1 Km resolutions, thus cities can be represented.
- Thus useful for mitigation, adaptation and planning



http://www.mri-jma.go.jp



http://www.uta.edu

Motivation

- Most of the parametrizations were incorporated in to Meso-scale models without proper validation and more studies are needed
- Generally few urban climate studies from tropics (Roth 2006)
- Urban morphometric, radiative and thermal parameters are difficult to obtain
- Large number of input parameters make sensitivity analysis and optimization challenging but this is an urgent task
- Only few studies have been reported (Loridan et al. 2011, Wang et al. 2011)
- Implication for model development, design of field experiments, urban planning etc.

Method

Sobol' GSA
Morris SA

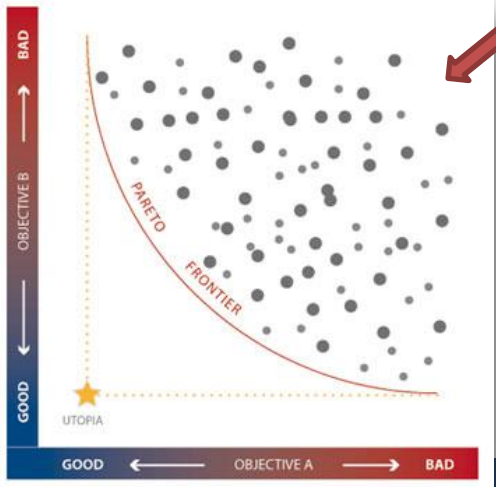
Dry (Mar)
Wet (Dec)
Mixed (Aug)

Most influential Ranking

SURFEX LSM

Validation
18/05/13 to 17/04/14

RMSE (Q_H, Q_E, Q^*)



Borg MOEA

Dry (Mar)
Wet (Dec)
Mixed (Aug)
Reduced Parameters

Pareto-optimal solutions

Run SURFEX on 3 solutions (Full period)

Min. of Euclidian distance

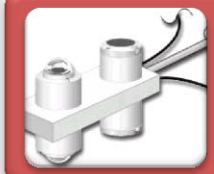
www.enginsoft.com

Study Area

Telok Kurau

Forcing variables from measurements in the ISL

- T, P, q, Precip, wind speed



Radiation Components

- Long and shortwave radiation

Turbulent fluxes

- Q_H, Q_E, ΔQ_S

Surface Temperature

SURFEX V7.3

TEB + ISBA

68 input Parameter and ranges

Derived from local site (Velasco et al. 2013) and literature

Moigne 2012

Sobol' GSA

Variance Based

First order , higher and total interaction

Quantitative and accurate

Computationally demanding

n (k+2) ,translates to >200,000

Saltelli et al. 2004

Morris SA

OAT yet global

Average effect, non-linear

Less FE

r (k+1), translates to >30,000

Campolongo et al. (2008)

Borg MOEA

Multi-modal, non-linear

Elitism, Diversity

Multi operator

Multi-objective , large parameter, fast

Superior to other popular MOEAs (e.g AMALGM)

200,000 FE

Hadaka & Reed 2013

Results– Sensitivity Analysis

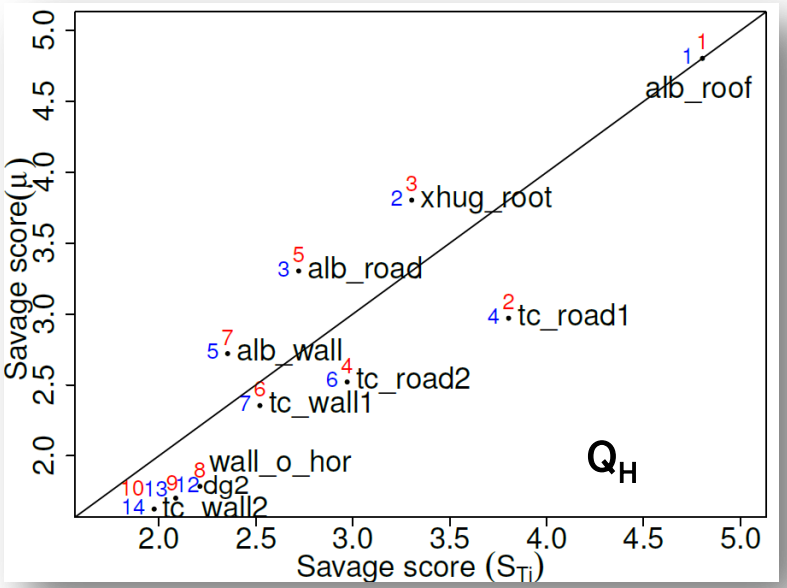
$S_i \geq \%5$

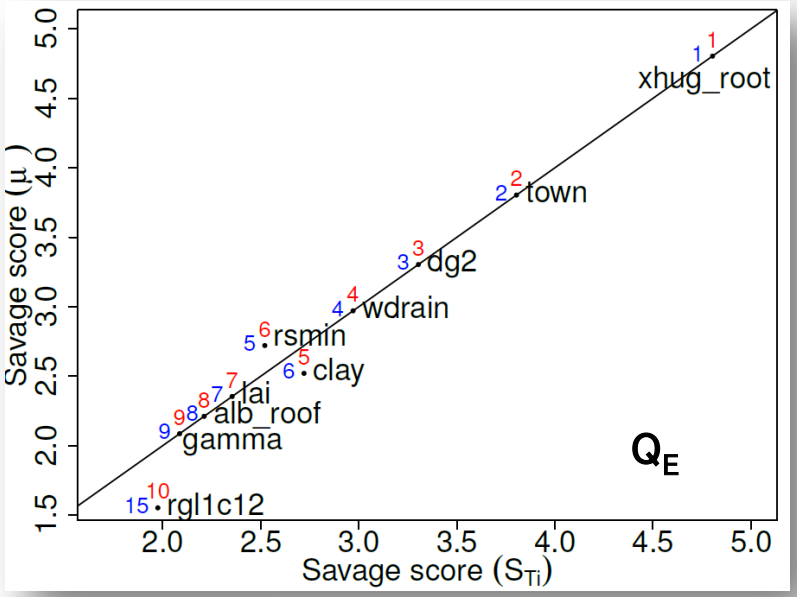
Parameters	$Q_H(Dry)$	$Q_H(Wet)$	$Q_H(Mixed)$	$Q_E(Dry)$	$Q_E(Wet)$	$Q_E(Mixed)$	$Q*(Dry)$	$Q*(Wet)$	$Q*(Mixed)$
ALB_ROAD		0.05	0.06				0.11	0.11	0.12
ALB_ROOF	0.12	0.21	0.22		0.15		0.42	0.43	0.45
ALB_WALL							0.07	0.09	0.07
CLAY				0.07					
DG2				0.08		0.11			
TC_ROAD1	0.10	0.09	0.11						
TC_ROAD2	0.06								
TOWN		0.07		0.21	0.46	0.21			
WALL_O_HOR					0.06		0.24	0.20	0.22
WDRAIN						0.05			
XHUG_ROOT			0.08	0.41		0.36			

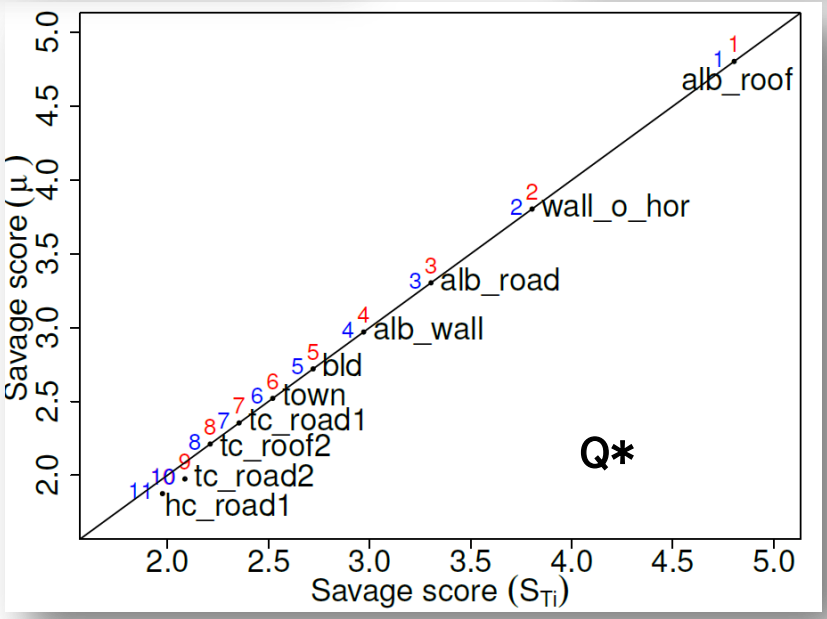
$S_{Ti} \geq \%5$

Parameters	$Q_H(Dry)$	$Q_H(Wet)$	$Q_H(Mixed)$	$Q_E(Dry)$	$Q_E(Wet)$	$Q_E(Mixed)$	$Q*(Dry)$	$Q*(Wet)$	$Q*(Mixed)$
ALB_ROAD	0.09	0.06	0.07				0.13	0.11	0.12
ALB_ROOF	0.30	0.26	0.28		0.18		0.46	0.45	0.46
ALB_WALL			0.05				0.08	0.09	0.08
CLAY		0.05		0.11	0.06	0.08			
DG2				0.14		0.16			
HC_ROAD1	0.07								
RSMIN				0.08		0.07			
TC_ROAD1	0.22	0.15	0.15						
TC_ROAD2	0.14	0.08	0.08						
TC_ROOF2	0.05								
TC_WALL1	0.12	0.08	0.06						
TC_WALL2	0.06								
TOWN	0.05	0.11		0.26	0.50	0.27			
WALL_O_HOR	0.06				0.07		0.27	0.22	0.23
WDRAIN				0.08		0.11			
XHUG_ROOT	0.11		0.11	0.50		0.46			

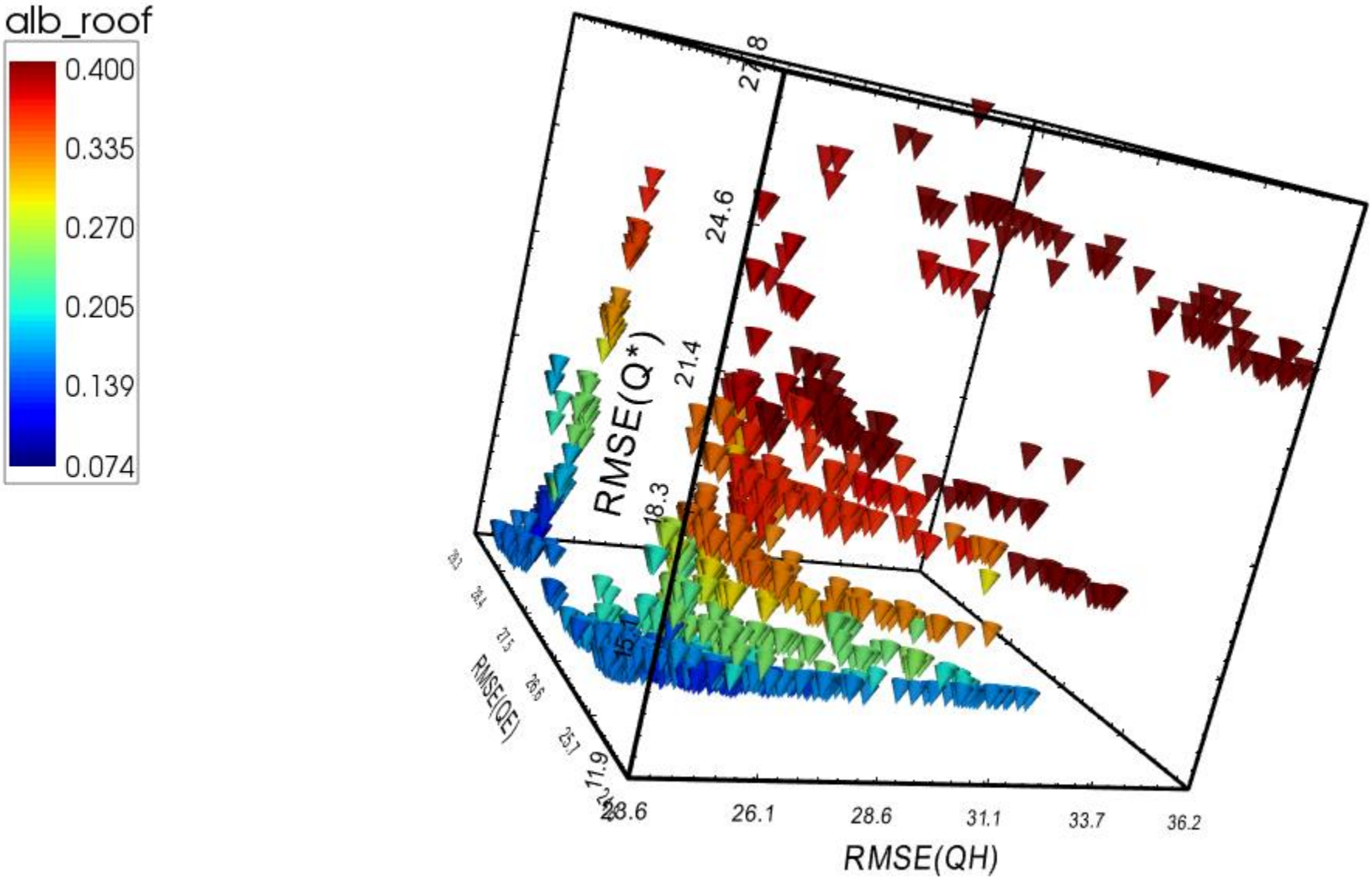
Sobol' vs. Morris

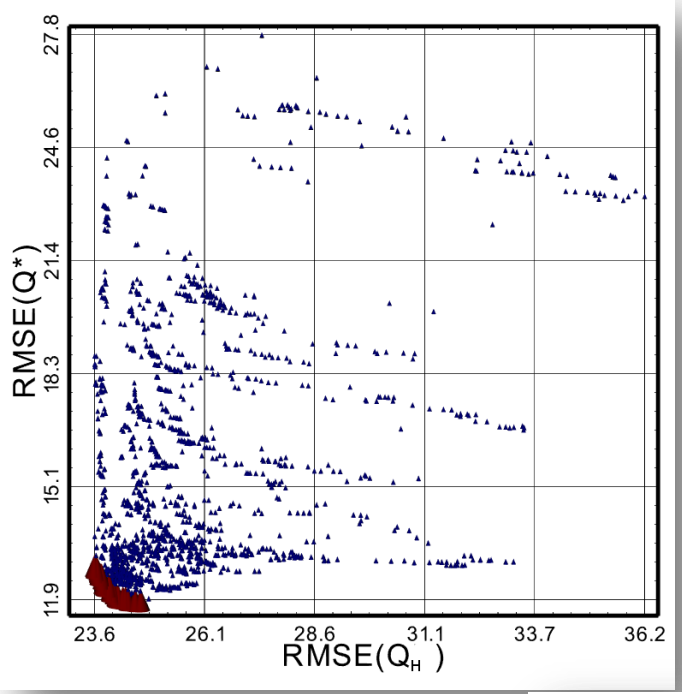


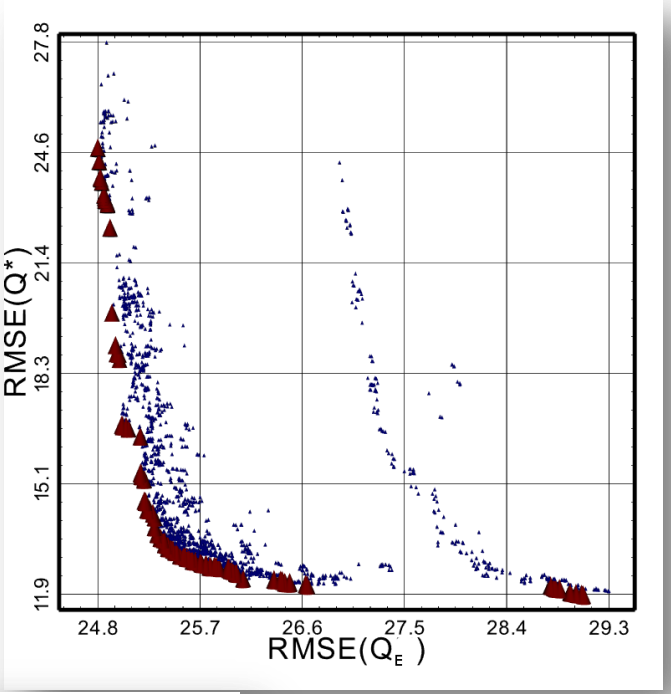


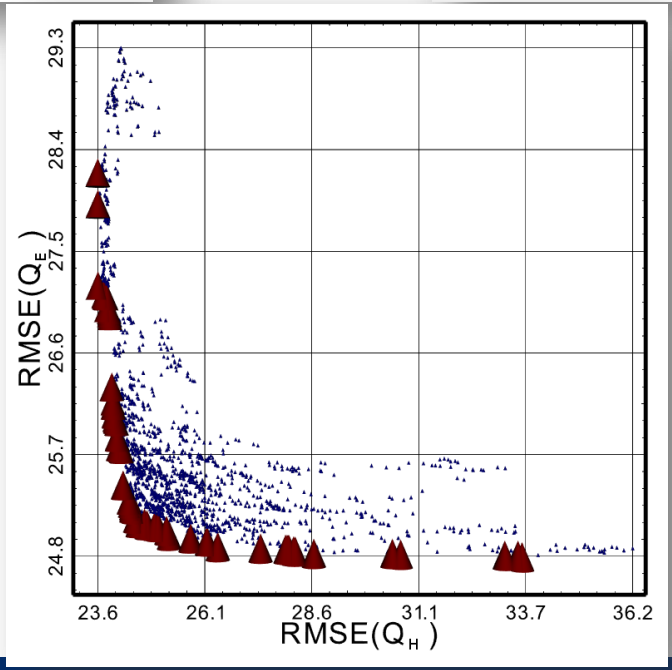


Results– Optimization




RMSE(Q*)
27.8
24.6
21.4
18.3
15.1
11.9
23.6
26.1
28.6
31.1
33.7
36.2
RMSE(Q_H)

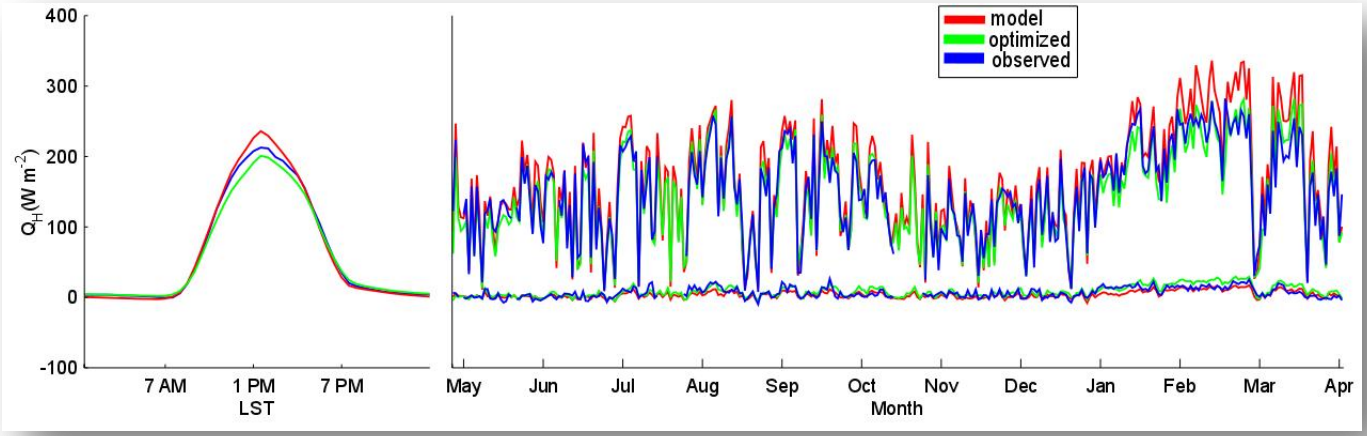

RMSE(Q*)
27.8
24.6
21.4
18.3
15.1
11.9
24.8
25.7
26.6
27.5
28.4
29.3
RMSE(Q_E)


RMSE(Q_E)
29.3
28.4
27.5
26.6
25.7
24.8
23.6
26.1
28.6
31.1
33.7
36.2
RMSE(Q_H)

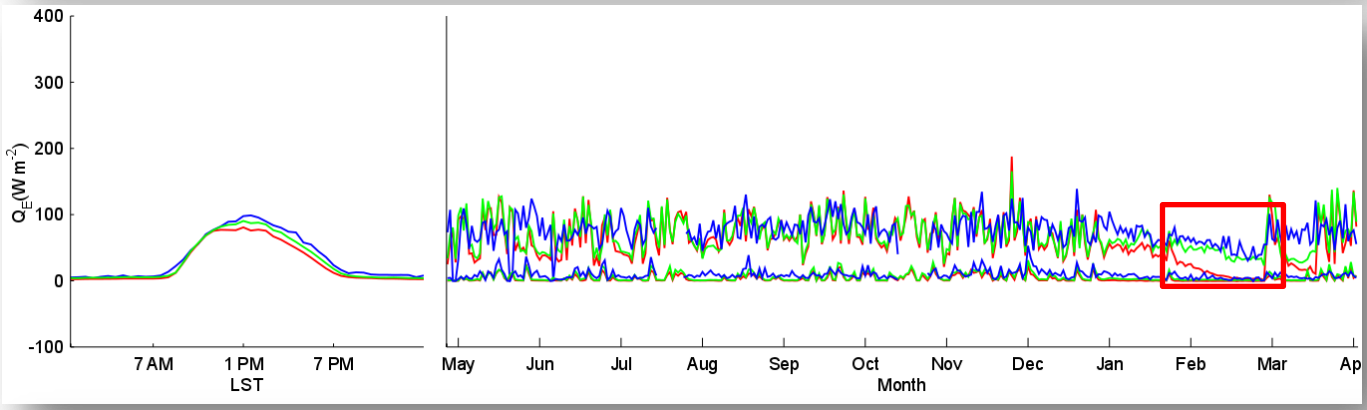
	Default RMSE	Optimized RMSE
$Q_H(Wm^{-2})$	27.89	22.43
$Q_E(Wm^{-2})$	44.33	39.52
$Q*(Wm^{-2})$	27.58	12.98
$\Delta Q_S(Wm^{-2})$	53.74	46.87
$K\uparrow(Wm^{-2})$	17.00	20.92
$L\uparrow(Wm^{-2})$	33.34	16.60
$T_{surf}(^0C)$	3.70	1.60

	Default	Min	Max	Median	Optimized
ALB_ROAD	0.08	0.06	0.25	0.20	0.25
ALB_ROOF	0.20	0.08	0.16	0.11	0.09
ALB_WALL	0.50	0.05	0.09	0.07	0.09
CLAY	0.47	0.34	0.77	0.67	0.70
DG2	1.50	1.68	3.74	3.67	3.66
TC_ROAD1	1.64	1.56	2.10	2.08	2.10
TC_ROAD2	2.10	1.36	2.10	2.09	2.10
TOWN	0.85	0.75	0.77	0.75	0.75
WALL_O_HOR	0.66	0.95	1.10	1.10	1.10
WDRAIN	0.00	0.00	0.05	0.00	0.01

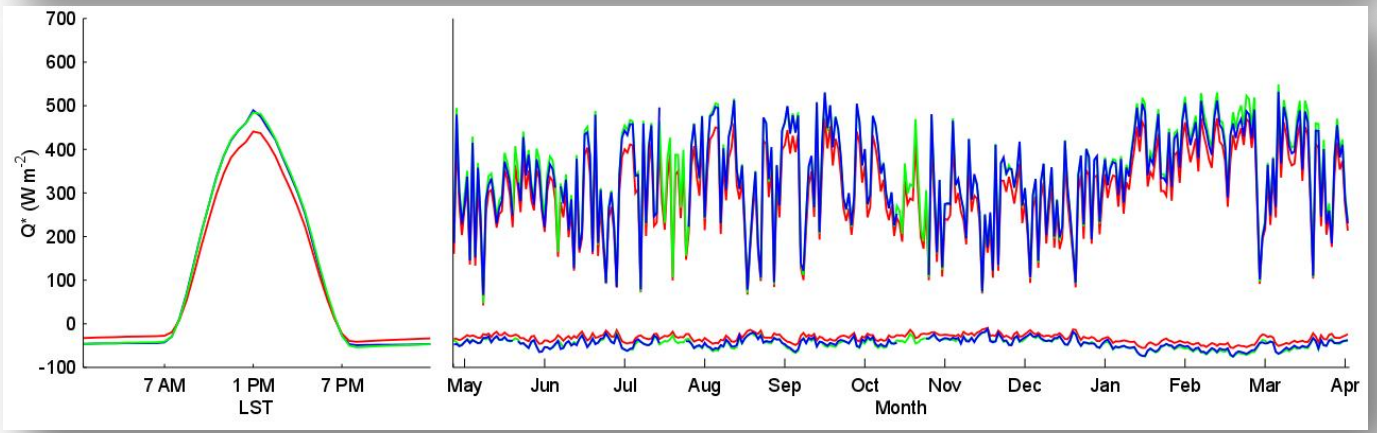
Q_H


model
optimized
observed
Q_H (W m^{-2})
400
300
200
100
0
-100
7 AM
1 PM
7 PM
LST
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
Month

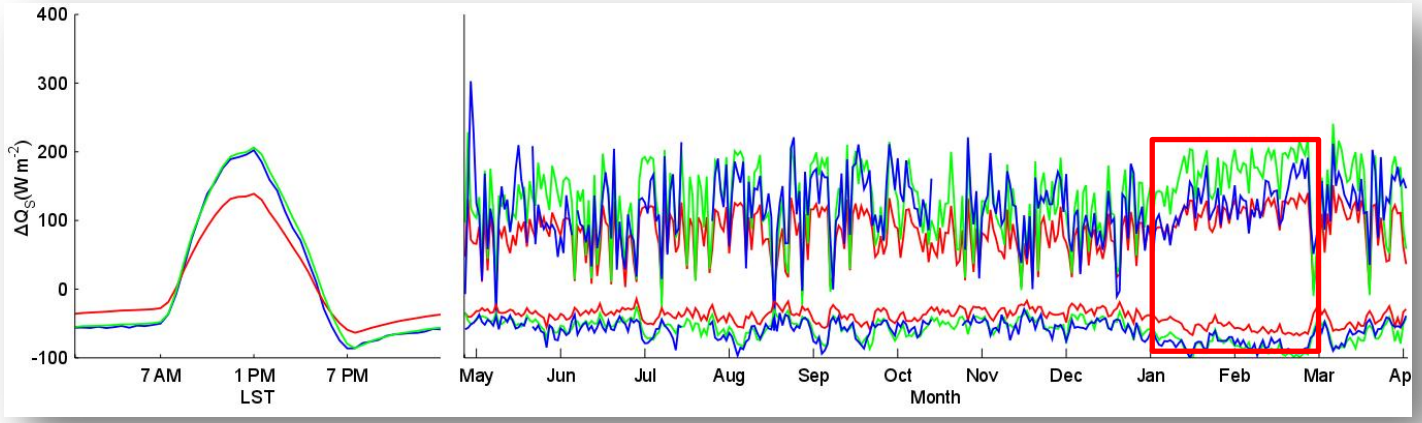
Q_E


Q_E (W m^{-2})
400
300
200
100
0
-100
7 AM
1 PM
7 PM
LST
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Ap
Month

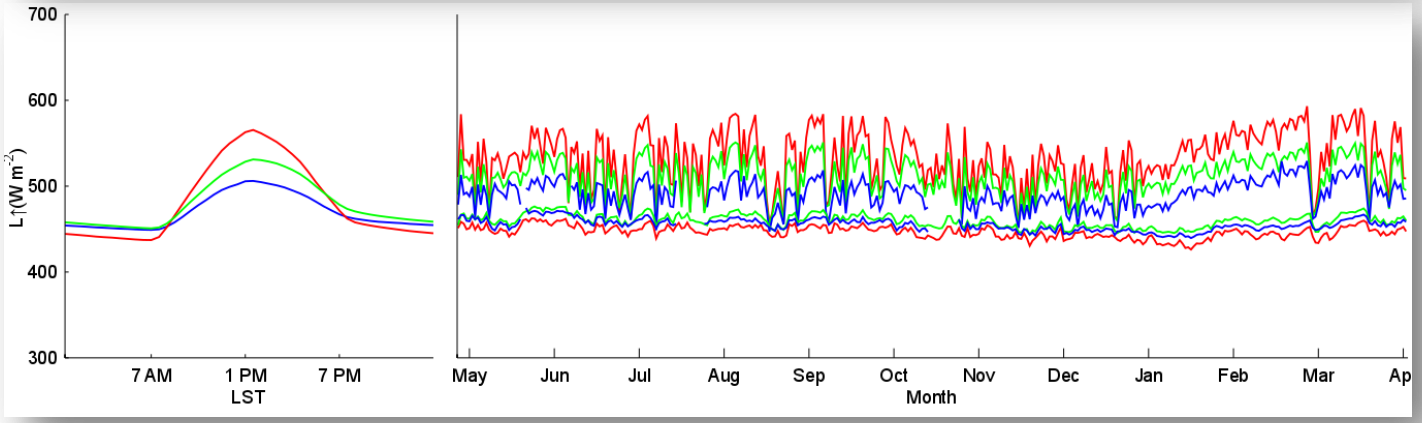
Q^*


Q^* (W m^{-2})
700
600
500
400
300
200
100
0
-100
7 AM
1 PM
7 PM
LST
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
Month

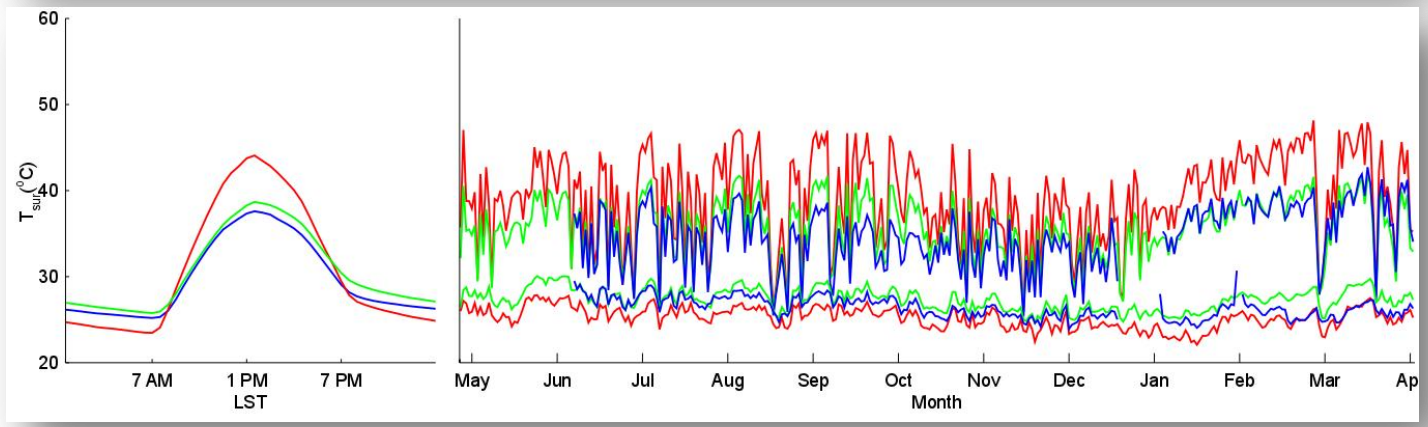
ΔQ_S



L_{up}



T_{surf}



Conclusions

- Only 16 parameters showed greater than 5 % variance and
- Sum of first order indices are lesser than sum of the total order indices (interaction)
- Q* is easier to model with less parameter interaction
- Larger number of parameters showed influence in Q_H
- Morris methods may be trustable alternative to Sobol' GSA
- Accurate soil moisture initialization is crucial
- Albedo, town fraction were in general, the most dominant
- Seasonal dependency of parameter sensitivity and convergence indicates some inadequacies of the parametrization
- Q_H, Q_E and Q* pairs show trade-off
- Optimization experiment showed some skill in reducing model errors, however often parameters converges to non-feasible values

Questions ?