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Mean radiant temperature modeling outdoors:
A comparison of three approaches

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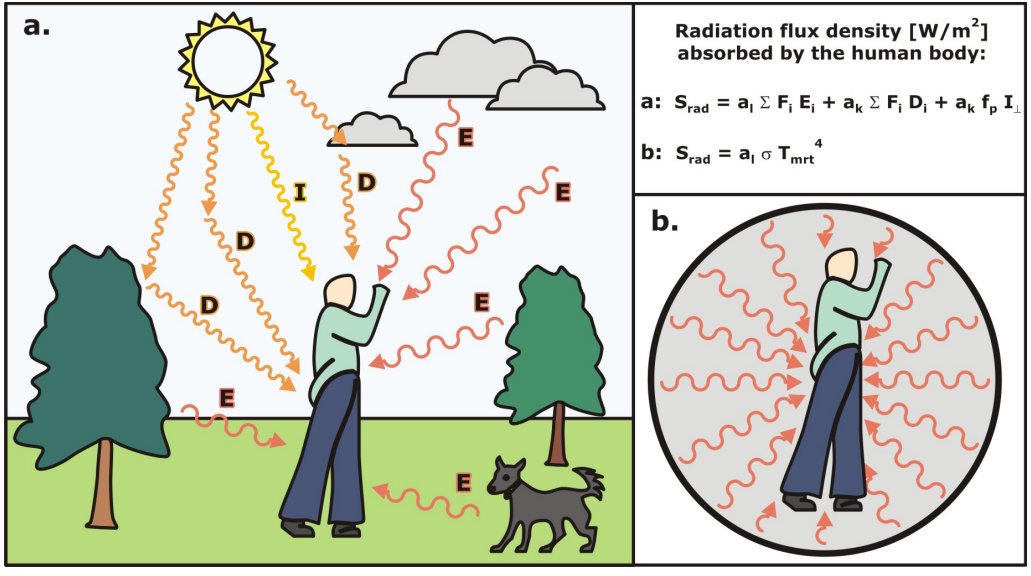
DALARNA UNIVERSITY

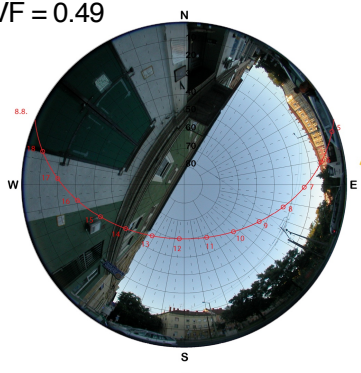
Mean radiant temperature (T_{mrt})



T_{mrt} expresses the short- and longwave radiation exchange of a standard human body in Celsius degrees. Celsius degree refers to the uniform temperature of an imaginary enclosure that results in an equivalent radiant heat exchange as the actual, non-uniform enclosure.

Bartók Square, Szeged (Hungary)

SVF = 0.49



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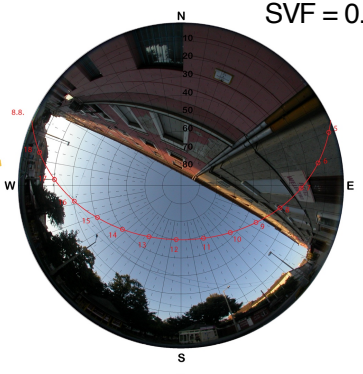

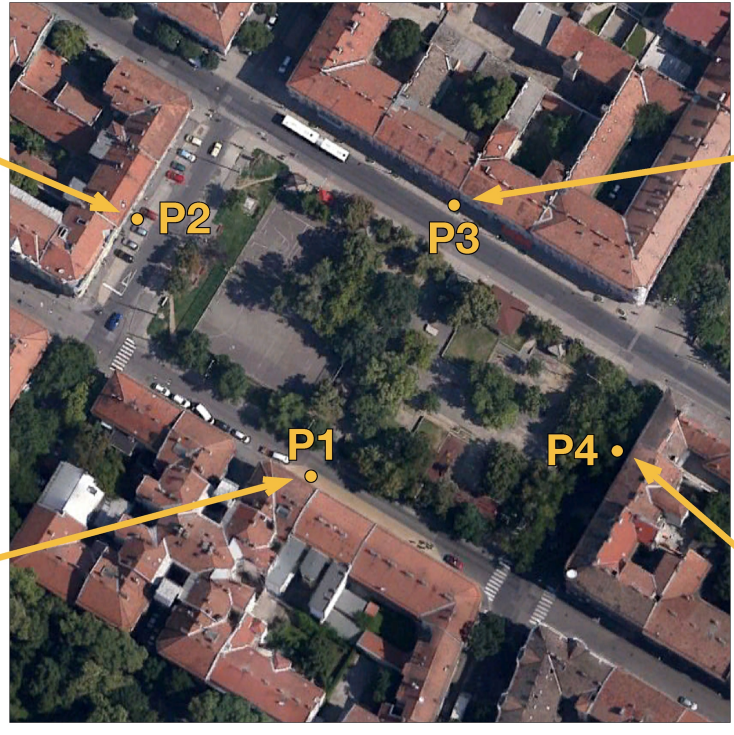

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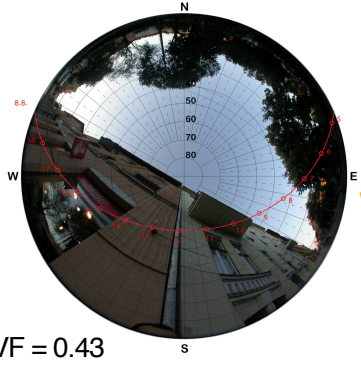
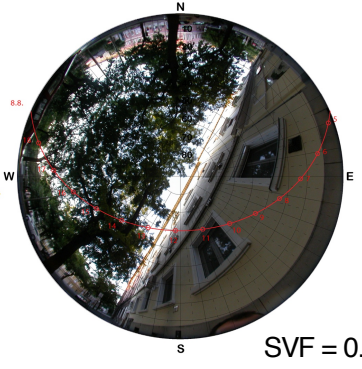
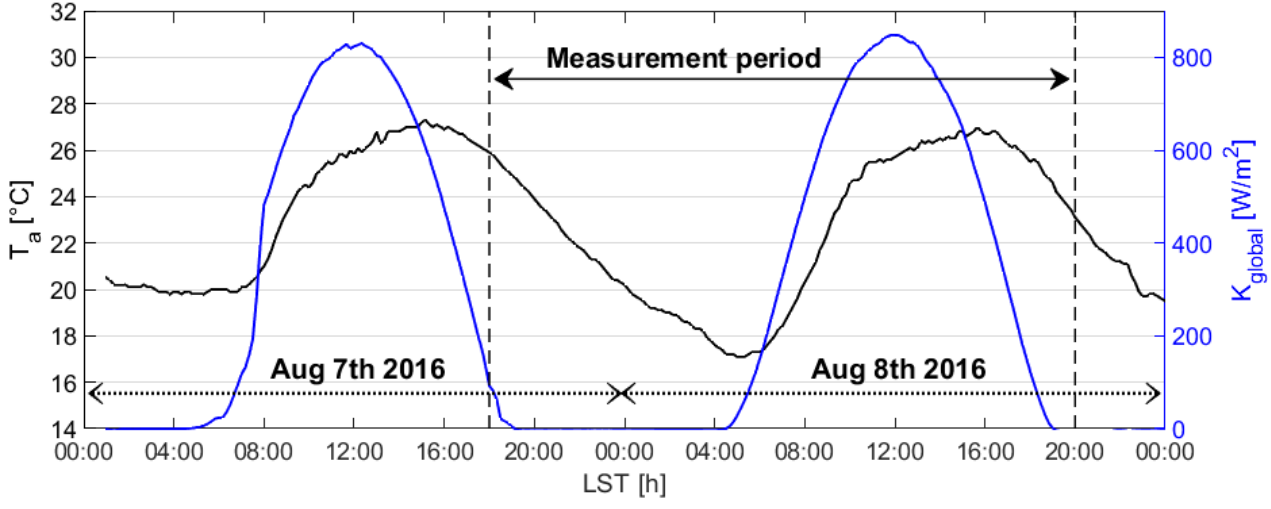


SVF = 0.08



Air temperature and global radiation



Numerical models

ENVI-met v4.4.2 (Bruse 1999)

CDF model :: surface-plant-air interaction

T_{mrt} :: German VDI standards

projected area factor (f_p) :: Underwood & Ward (1966)

elliptical cylinder with major axis facing the sun

Indexed View Sphere (IVS) algorithm

retains view factor – element connection

Grasshopper, Microclimate Map Analysis (Mackey 2010)

T_{mrt} :: effective radiant field ERF approach (Arens et al. 2014)

T_{mrt} = ERF + base T_{mrt}

f_p :: Fanger (1972), seated

VTUF-3D v2 (Nice 2016)

urban energy balance model :: vegetation-radiation interaction

extension of TUF-3D (Krayenhoff & Voogt 2007)

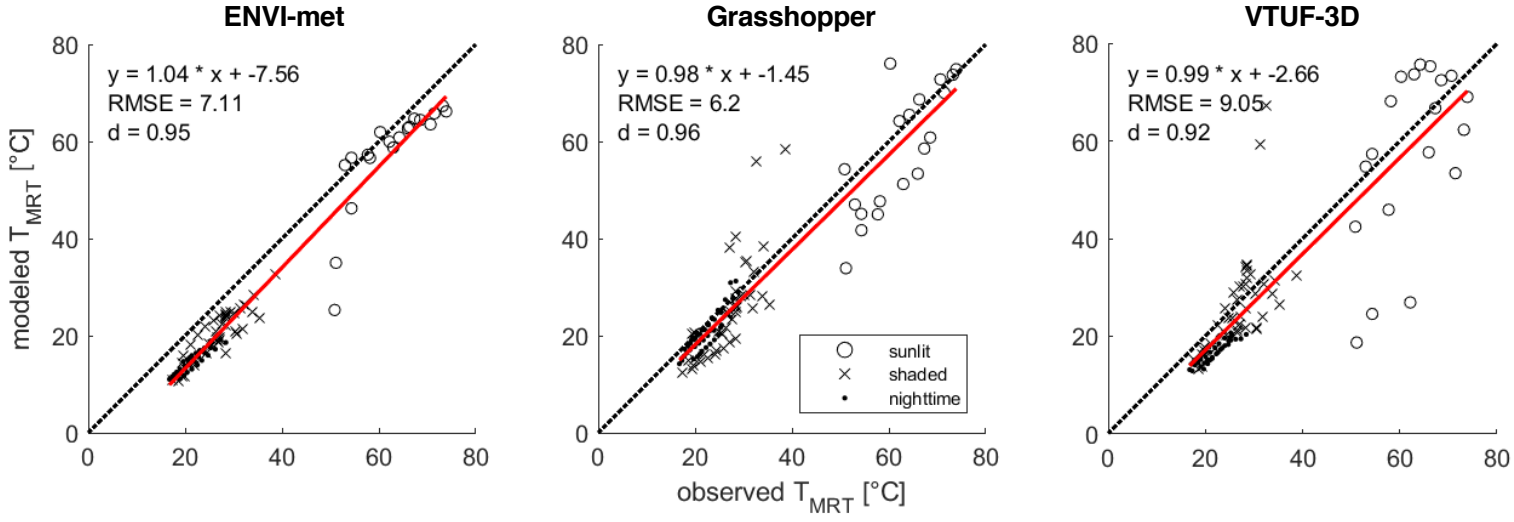
T_{mrt} :: modeled T_g

Human parameters / Numerical models	*SW rad. absorptivity*	*LW rad. absorptivity*	*Posture*
ENVI-met	0.70	0.97	standing
Grasshopper	0.70	0.95	seated
VTUF-3D	T_g	T_g	~squatting

Domain / Numerical models	*Grid size*
ENVI-met	3 x 3 m
Grasshopper	6 m x 6 m (LW) 3 m x 3 m (SW)
VTUF-3D	5 m x 5 m

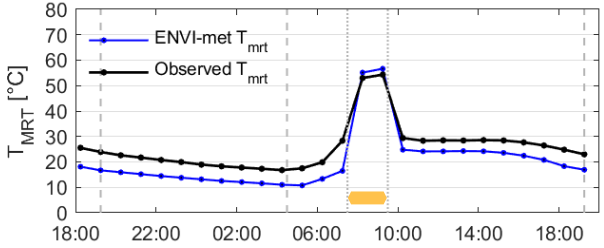
Surface and obstacle parameters	*Albedo*	*Emissivity*	*Transmissivity*
Ground	0.18	0.95	-
Wall	0.20	0.90	-
Tree	0.20	0.95-0.96	0.07

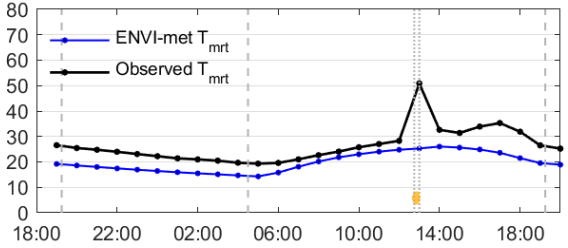
Scatterplot of observed-modeled T_{mrt}



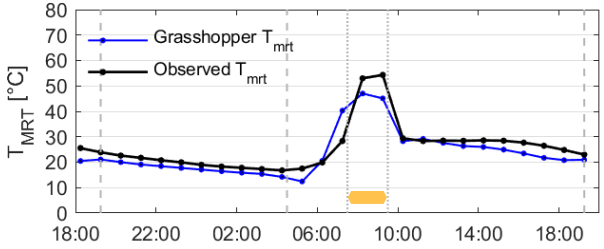
	ME	*RMSE*	*RMSEs*	*RMSEu*	*d*
ENVI-met	-6.32	7.11	6.35	3.21	0.95
Grasshopper	-2.13	6.20	2.16	5.82	0.96
VTUF-3D	-3.05	9.05	3.06	8.51	0.92

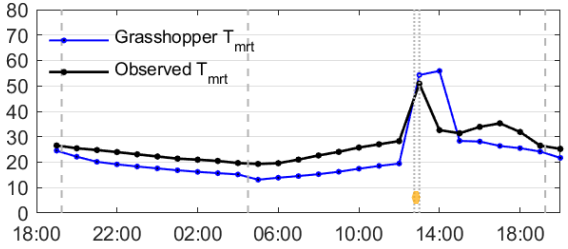
P1


ENVI-met T_{mrt}
Observed T_{mrt}
T_{MRT} [°C]
0 10 20 30 40 50 60 70 80
18:00 22:00 02:00 06:00 10:00 14:00 18:00


ENVI-met T_{mrt}
Observed T_{mrt}
0 10 20 30 40 50 60 70 80
18:00 22:00 02:00 06:00 10:00 14:00 18:00

P4


Grasshopper T_{mrt}
Observed T_{mrt}
T_{MRT} [°C]
0 10 20 30 40 50 60 70 80
18:00 22:00 02:00 06:00 10:00 14:00 18:00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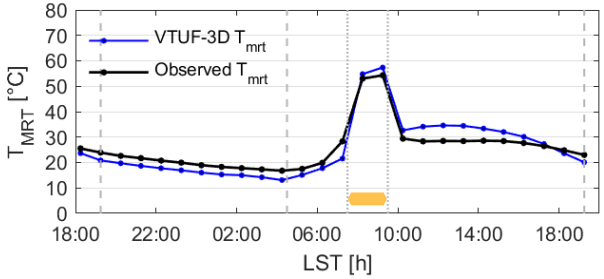
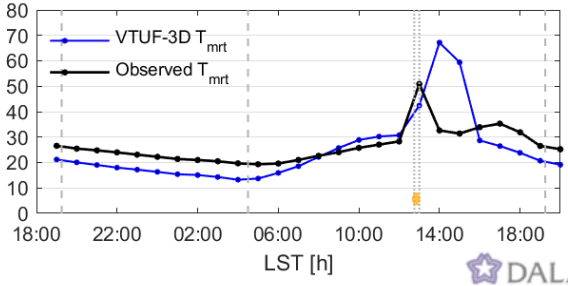

VTUF-3D T_{mrt}
Observed T_{mrt}
T_{MRT} [°C]
0 10 20 30 40 50 60 70 80
18:00 22:00 02:00 06:00 10:00 14:00 18:00
LST [h]


VTUF-3D T_{mrt}
Observed T_{mrt}
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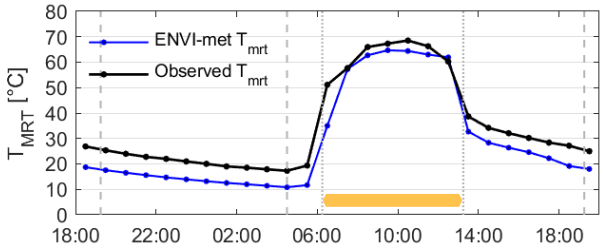
LST [h]

P2


ENVI-met T_{mrt}
Observed T_{mrt}
T_{MRT} [°C]
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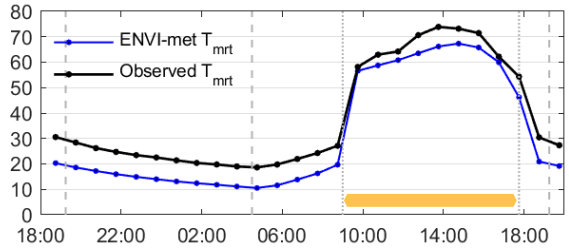
18:00 22:00 02:00 06:00 10:00 14:00 18:00


ENVI-met T_{mrt}
Observed T_{mrt}
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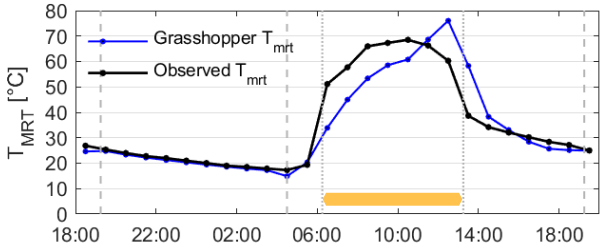
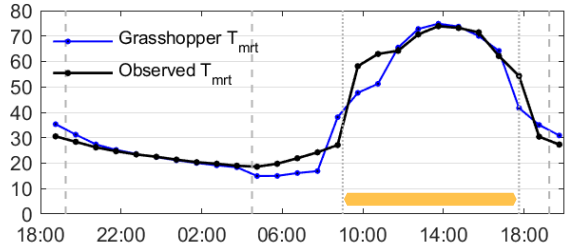
18:00 22:00 02:00 06:00 10:00 14:00 18:00

P3


Grasshopper T_{mrt}
Observed T_{mrt}
T_{MRT} [°C]
0 10 20 30 40 50 60 70 80
18:00 22:00 02:00 06:00 10:00 14:00 18:00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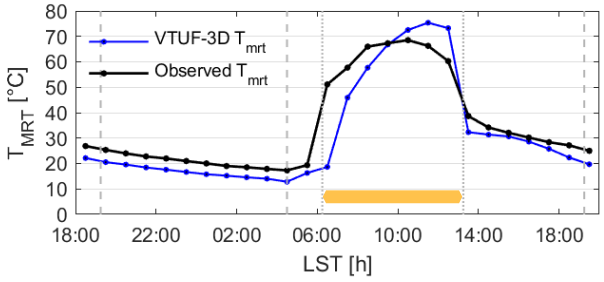
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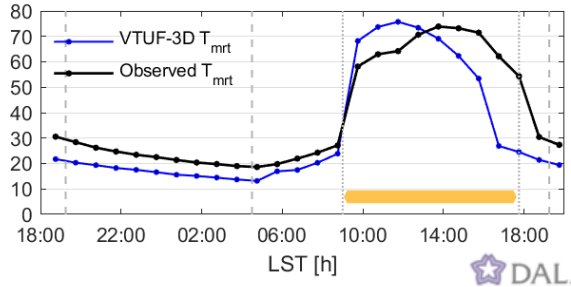
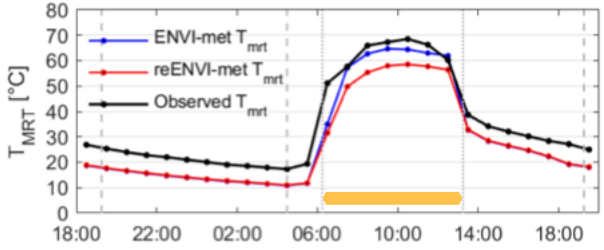
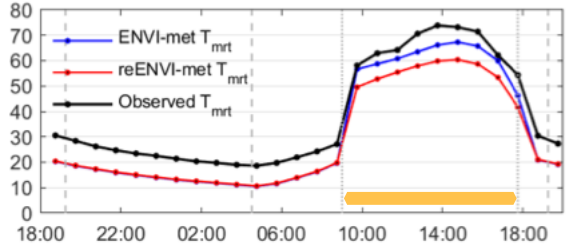

VTUF-3D T_{mrt}
Observed T_{mrt}
0 10 20 30 40 50 60 70 80
18:00 22:00 02:00 06:00 10:00 14:00 18:00
LST [h]

P2


ENVI-met T_{mrt}
reENVI-met T_{mrt}
Observed T_{mrt}
T_{MRT} [°C]
18:00 22:00 02:00 06:00 10:00 14:00 18:00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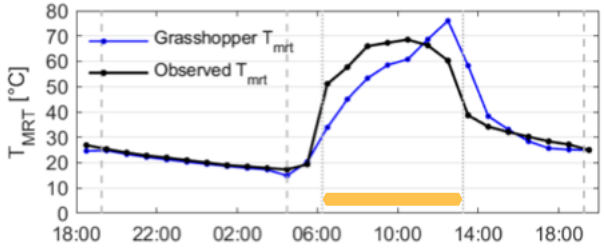
reENVI-met T_{mrt}
Observed T_{mrt}
18:00 22:00 02:00 06:00 10:00 14:00 18:00

P3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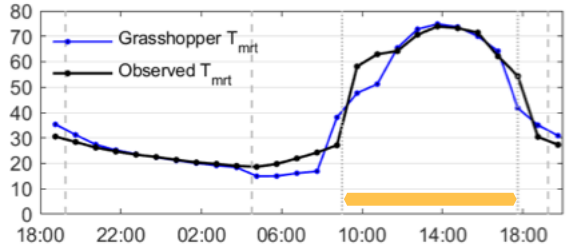
Observed T_{mrt}
T_{MRT} [°C]
18:00 22:00 02:00 06:00 10:00 14:00 18:00


Grasshopper T_{mrt}
Observed T_{mrt}
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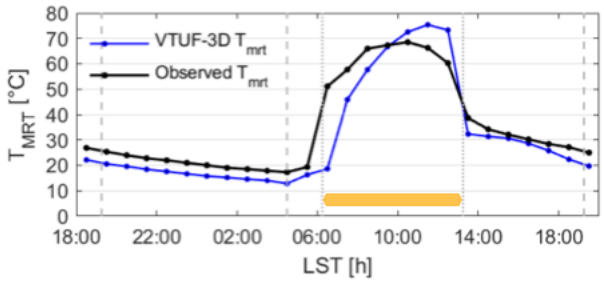
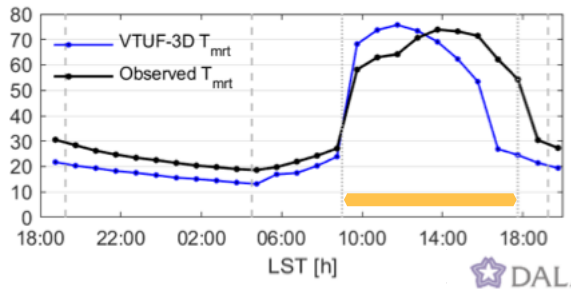
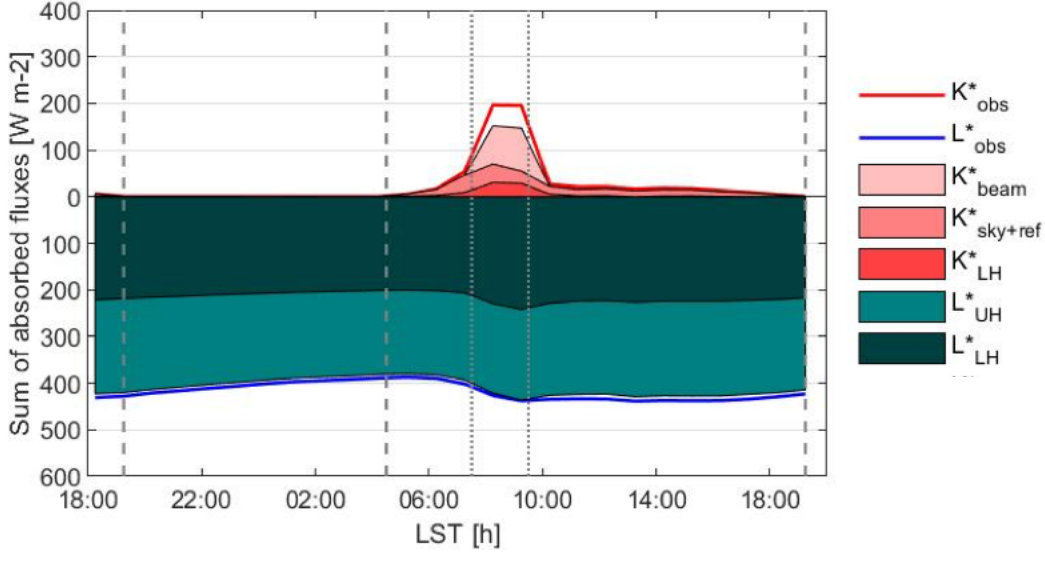
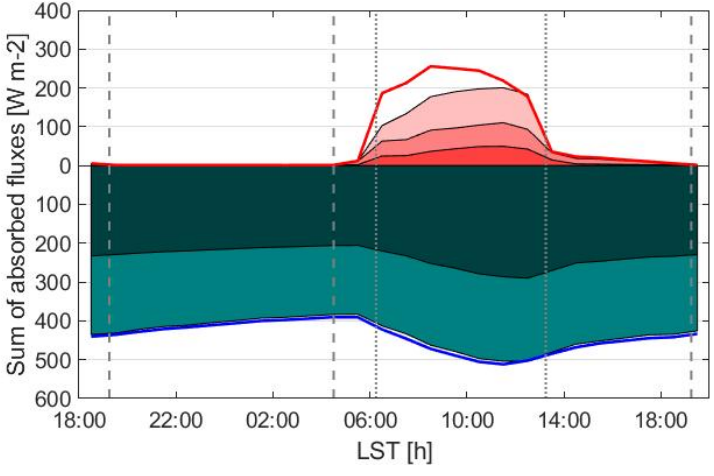

VTUF-3D T_{mrt}
Observed T_{mrt}
T_{MRT} [°C]
18:00 22:00 02:00 06:00 10:00 14:00 18:00
LST [h]

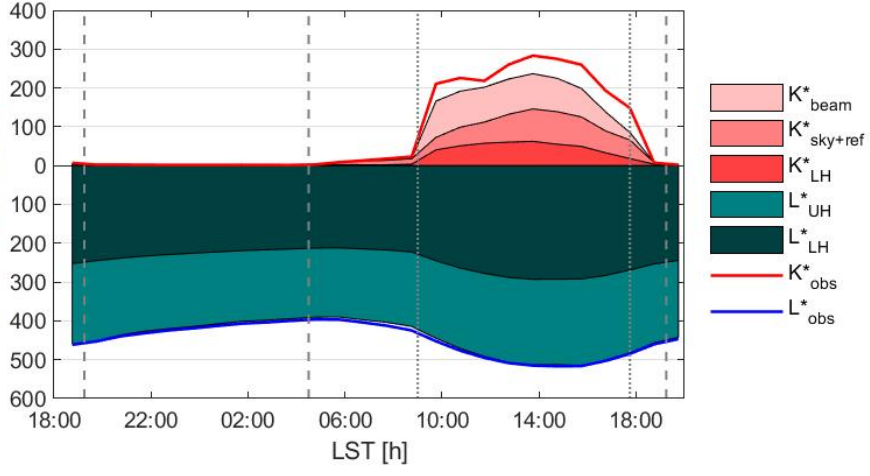

VTUF-3D T_{mrt}
Observed T_{mrt}
18:00 22:00 02:00 06:00 10:00 14:00 18:00
LST [h]

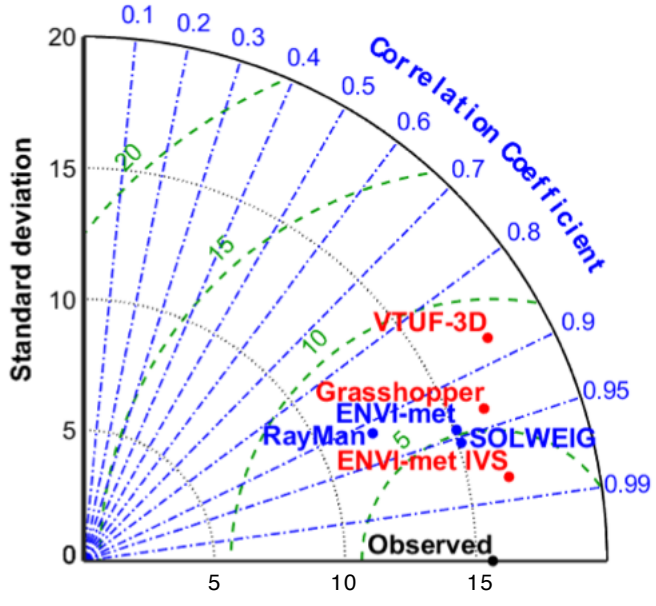

Sum of absorbed fluxes [W m-2]
400
300
200
100
0
100
200
300
400
500
600
18:00
22:00
02:00
06:00
10:00
14:00
18:00
LST [h]
K*obs
L*obs
K*beam
K*sky+ref
K*LH
L*UH
L*LH

P2


Sum of absorbed fluxes [W m-2]
400
300
200
100
0
100
200
300
400
500
600
18:00
22:00
02:00
06:00
10:00
14:00
18:00
LST [h]

P3


400
300
200
100
0
100
200
300
400
500
600
18:00
22:00
02:00
06:00
10:00
14:00
18:00
LST [h]
K*beam
K*sky+ref
K*LH
L*UH
L*LH
K*obs
L*obs



- ENVI-met is the most precise model, followed by the Grasshopper component and VTUF-3D.
- ENVI-met tend to underestimate nighttime T_{mrt}, while Grasshopper and VTUF-3D are able to reproduce them more accurately.
- When sunlit, estimated the T_{mrt} is influenced by:
  1. the assumed posture of the body (f_p),
  2. T_{mrt} calculation method.
- The shape of the body should also be considered in absorbed diffuse radiation calculations.


Thank you!