Letecká hyperspektrální termální data - senzor TASI

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Obsah

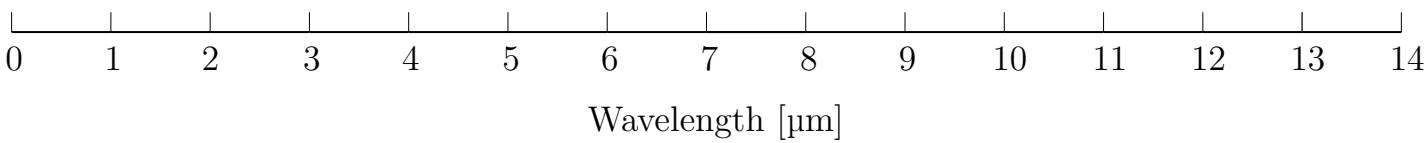
1. Letecké laboratórium (FLIS)

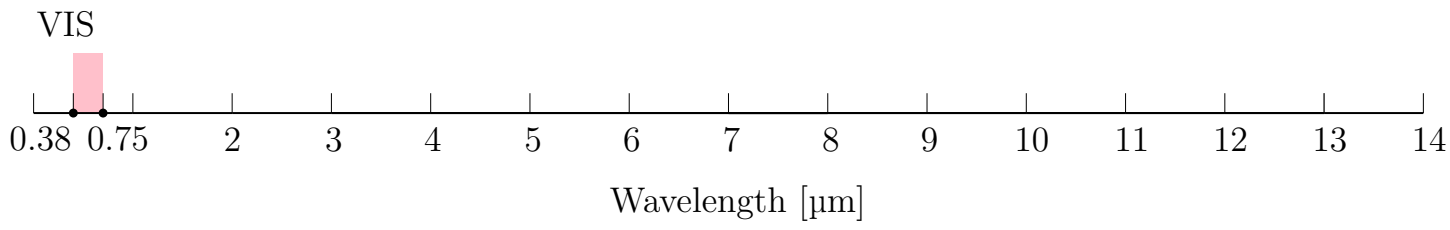

OK-CZG

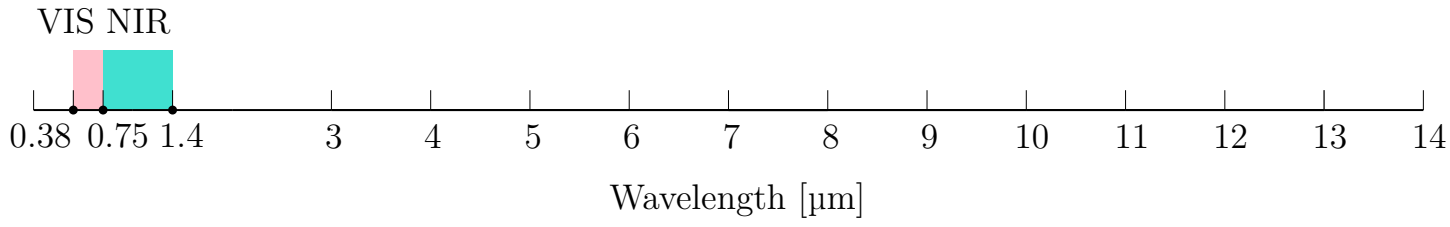


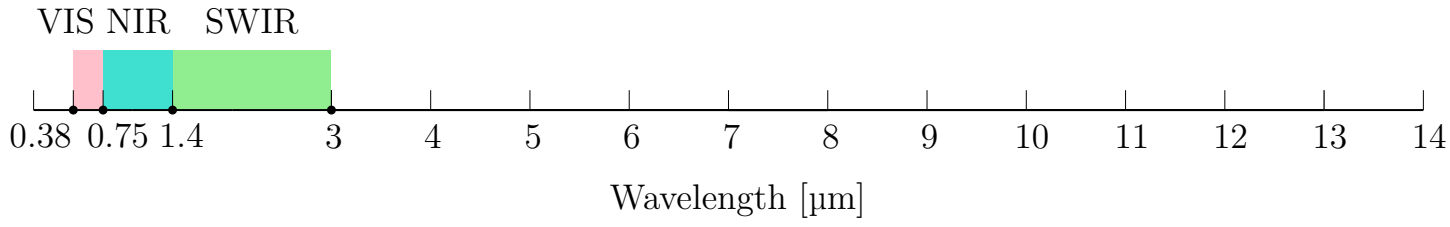
Senzor	CASI	SASI	TASI
Spektralna oblasť	VNIR	SWIR	LWIR
Spektrálny rozsah [nm]	380 – 1050	950 – 2450	8 000 – 11 500
Počet priestorových pixelov	1500	600	600
Max. spektrálne rozlišenie [nm]	3.2	15	110
Zorný uhol [°]	40	40	40

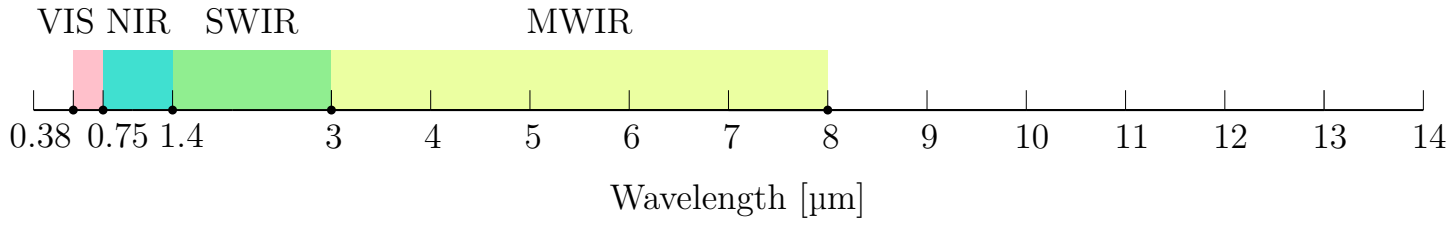
2. Teoretický základ

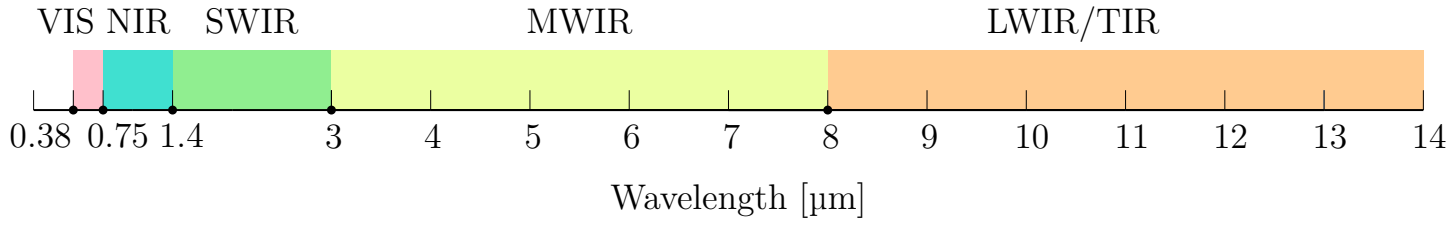

0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Wavelength [µm]

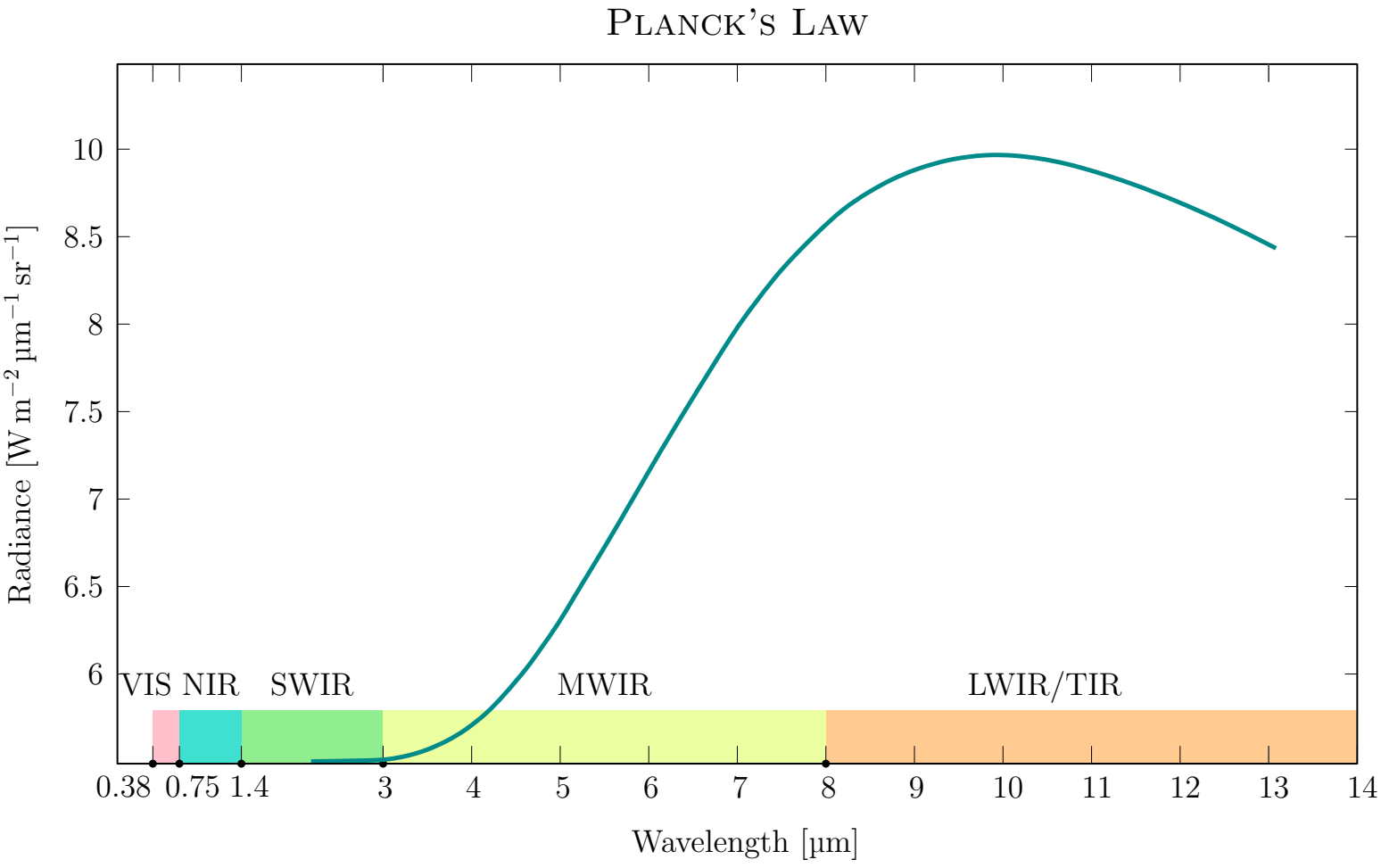

VIS
0.38
0.75
2
3
4
5
6
7
8
9
10
11
12
13
14
Wavelength [µm]

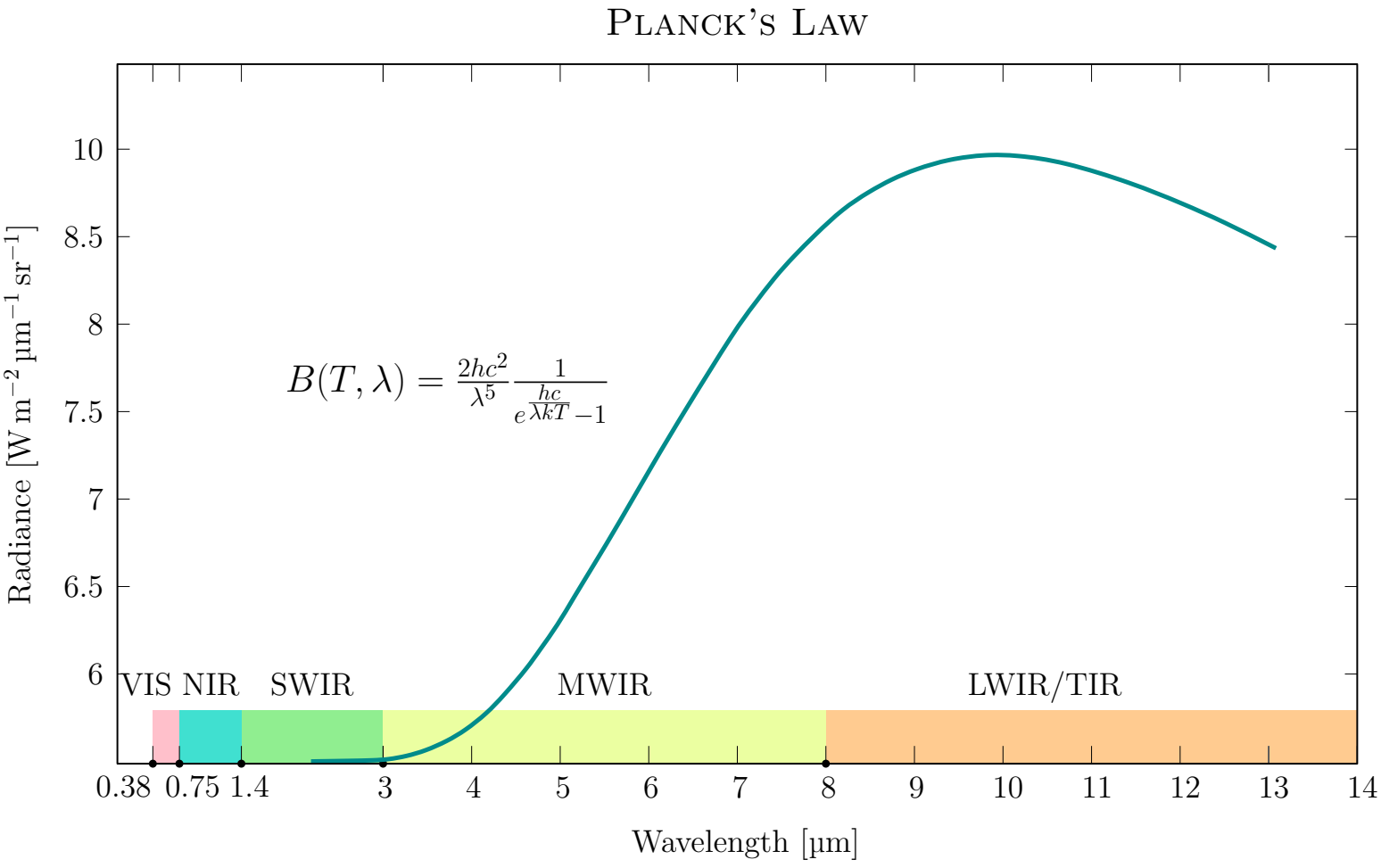

VIS NIR
0.38
0.75
1.4
3
4
5
6
7
8
9
10
11
12
13
14
Wavelength [µm]

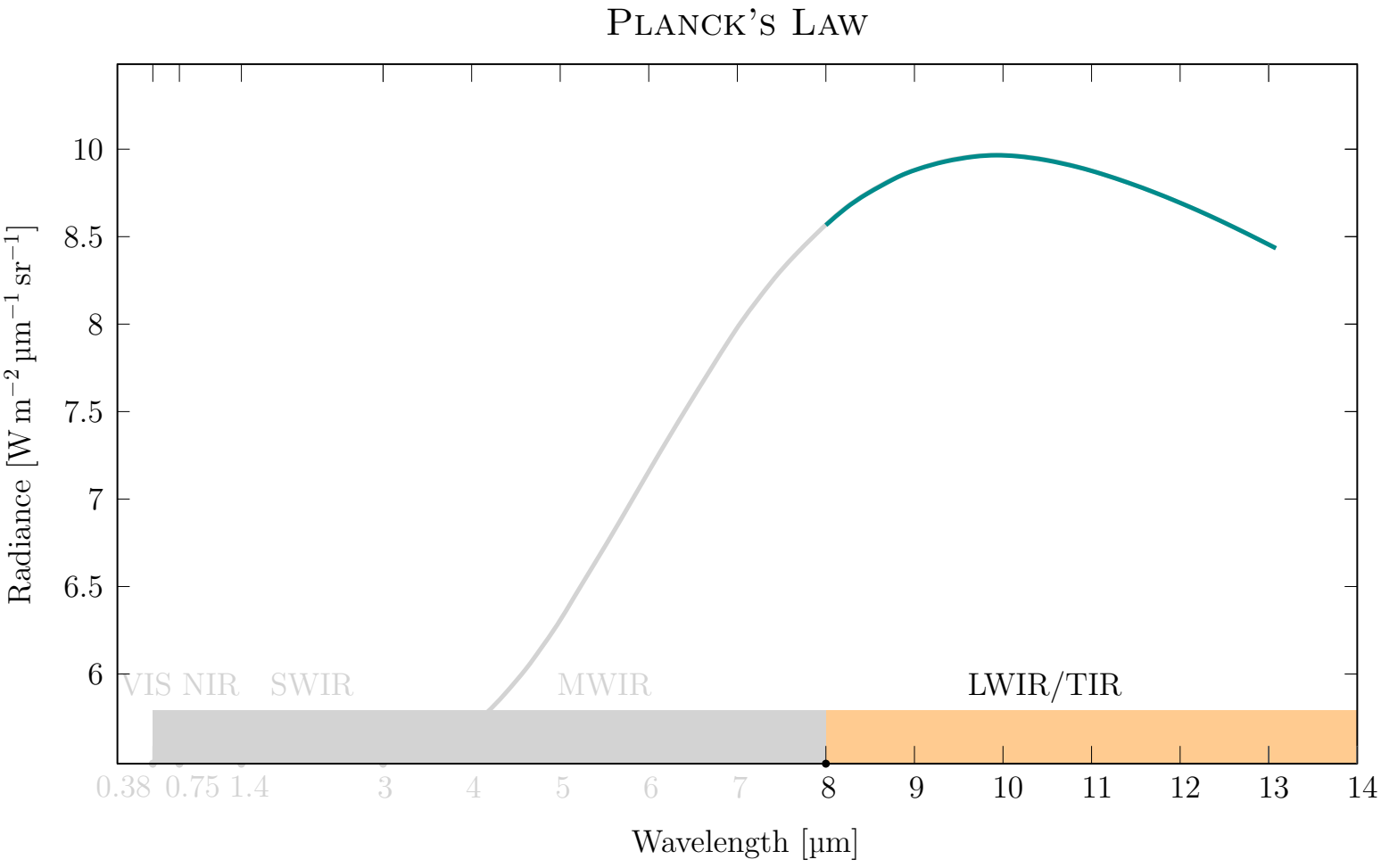

VIS
NIR
SWIR
0.38
0.75
1.4
3
4
5
6
7
8
9
10
11
12
13
14
Wavelength [µm]

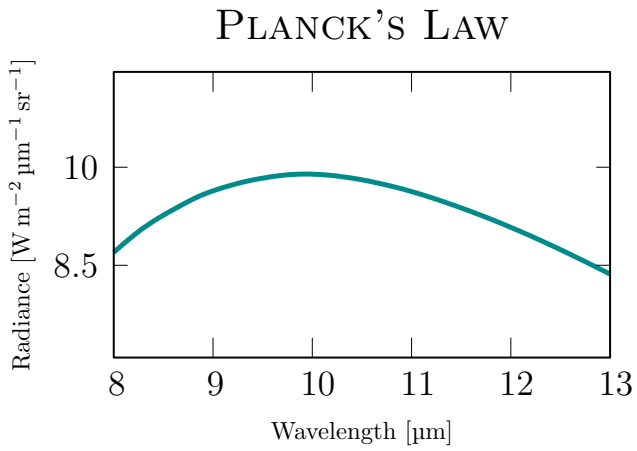

VIS
NIR
SWIR
MWIR
0.38
0.75
1.4
3
4
5
6
7
8
9
10
11
12
13
14
Wavelength [µm]


VIS
NIR
SWIR
MWIR
LWIR/TIR
0.38
0.75
1.4
3
4
5
6
7
8
9
10
11
12
13
14
Wavelength [µm]

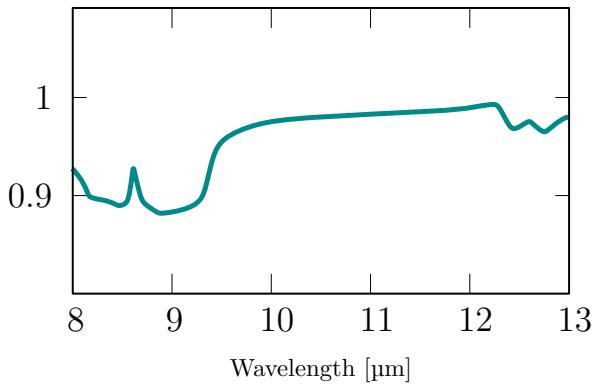

Planck's Law
Radiance [W m^{-2} µm^{-1} sr^{-1}]
10
8.5
8
7.5
7
6.5
6
VIS
NIR
SWIR
MWIR
LWIR/TIR
0.38
0.75
1.4
3
4
5
6
7
8
9
10
11
12
13
14
Wavelength [µm]


Planck's Law
$B(T,\lambda) = \frac{2hc^2}{\lambda^5}\frac{1}{e^{\frac{hc}{\lambda kT}}-1}$
Radiance [W m^{-2} µm^{-1} sr^{-1}]
10
8.5
8
7.5
7
6.5
6
VIS
NIR
SWIR
MWIR
LWIR/TIR
0.38
0.75
1.4
3
4
5
6
7
8
9
10
11
12
13
14
Wavelength [µm]

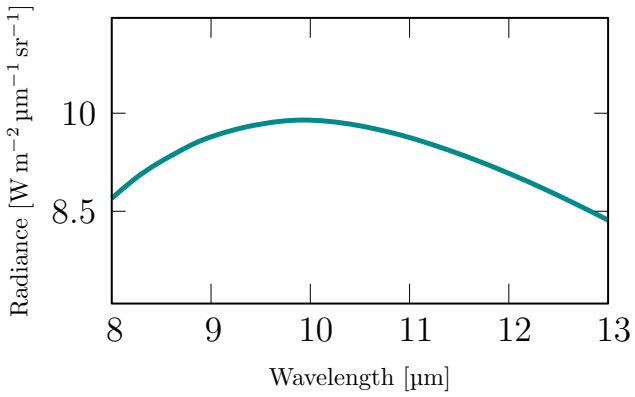

Planck's Law
Radiance [W m^{-2} µm^{-1} sr^{-1}]
10
8.5
8
7.5
7
6.5
6
VIS NIR
SWIR
MWIR
LWIR/TIR
0.38 0.75 1.4
3
4
5
6
7
8
9
10
11
12
13
14
Wavelength [µm]

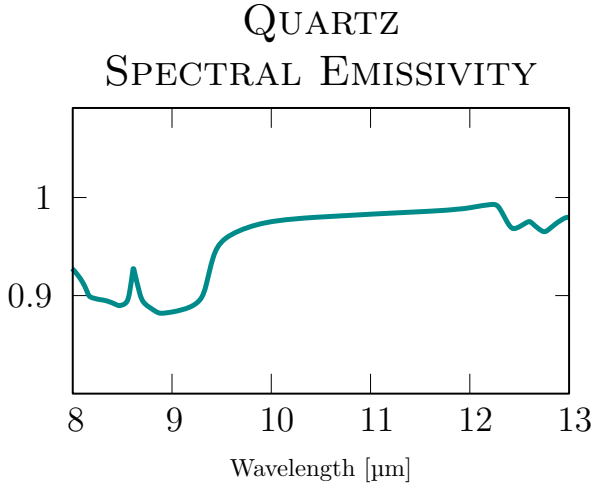

Planck's Law
Radiance [W m^{-2} µm^{-1} sr^{-1}]
10
8.5
8
9
10
11
12
13
Wavelength [µm]

Quartz Spectral Emissivity

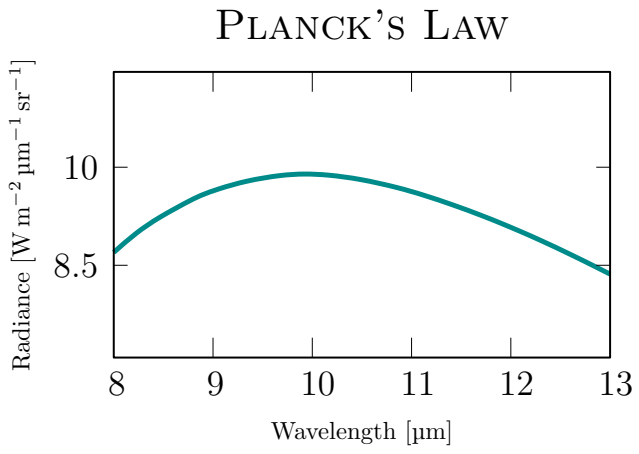


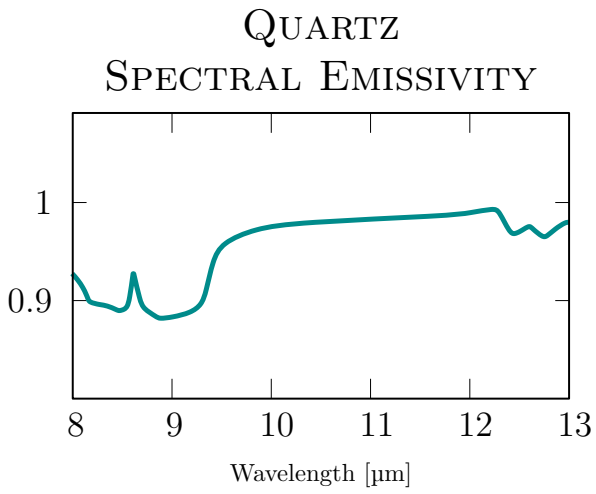
Planck's Law



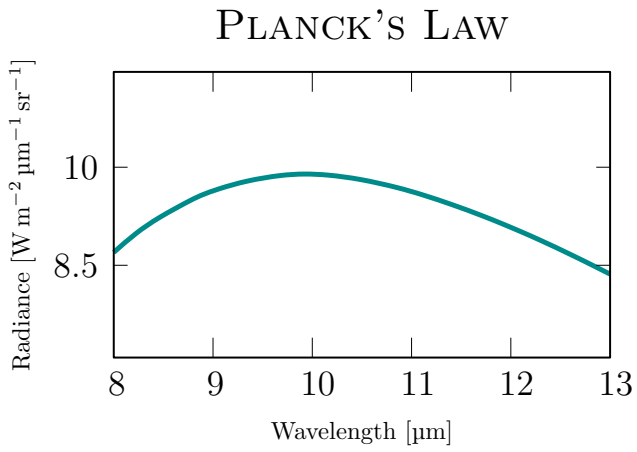

Quartz
Spectral Emissivity
1
0.9
8
9
10
11
12
13
Wavelength [µm]

×


Planck's Law
Radiance [W m^{-2} µm^{-1} sr^{-1}]
10
8.5
8
9
10
11
12
13
Wavelength [µm]

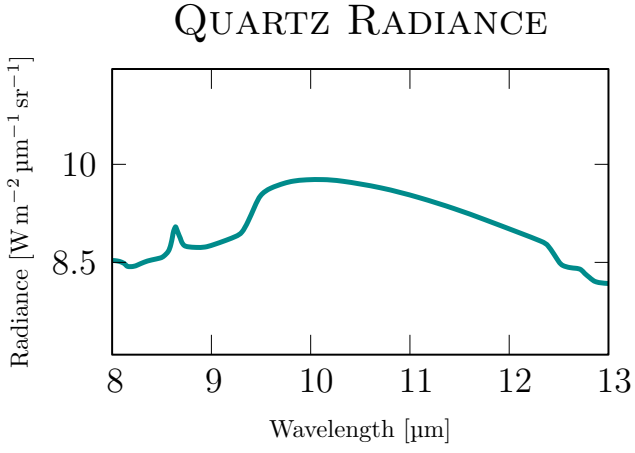

Quartz
Spectral Emissivity
1
0.9
8
9
10
11
12
13
Wavelength [µm]

×

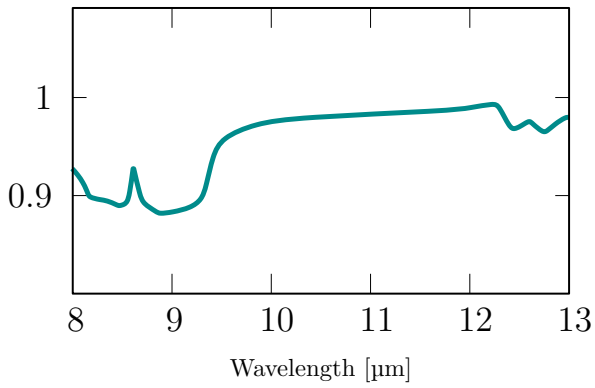

Planck's Law
Radiance [W m^{-2} µm^{-1} sr^{-1}]
10
8.5
8
9
10
11
12
13
Wavelength [µm]

=

=

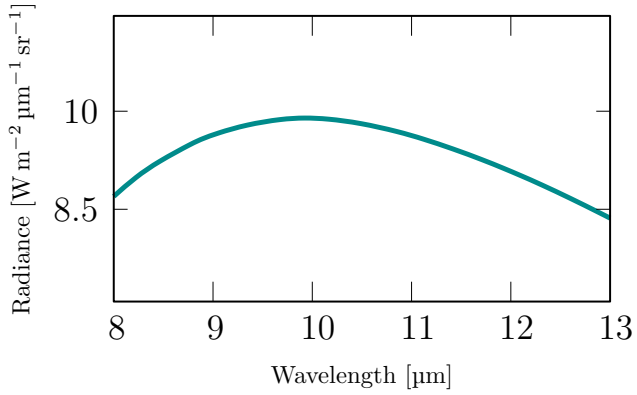

Quartz Radiance
Radiance [W m^{-2} µm^{-1} sr^{-1}]
10
8.5
8
9
10
11
12
13
Wavelength [µm]

Quartz Spectral Emissivity



×

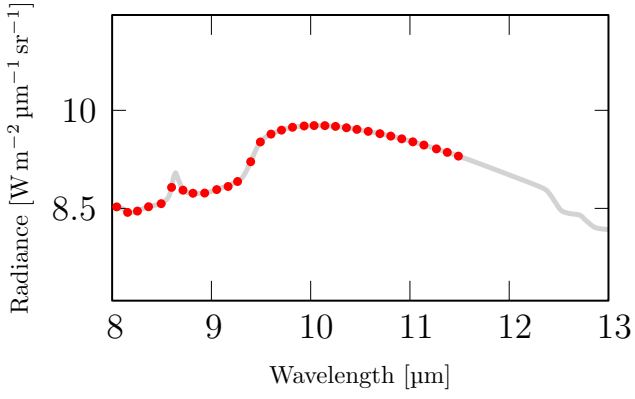
Planck's Law



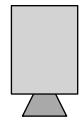
=

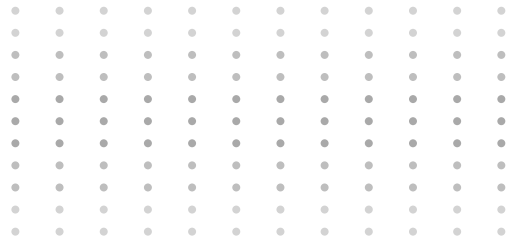
=

Quartz Radiance by TASI

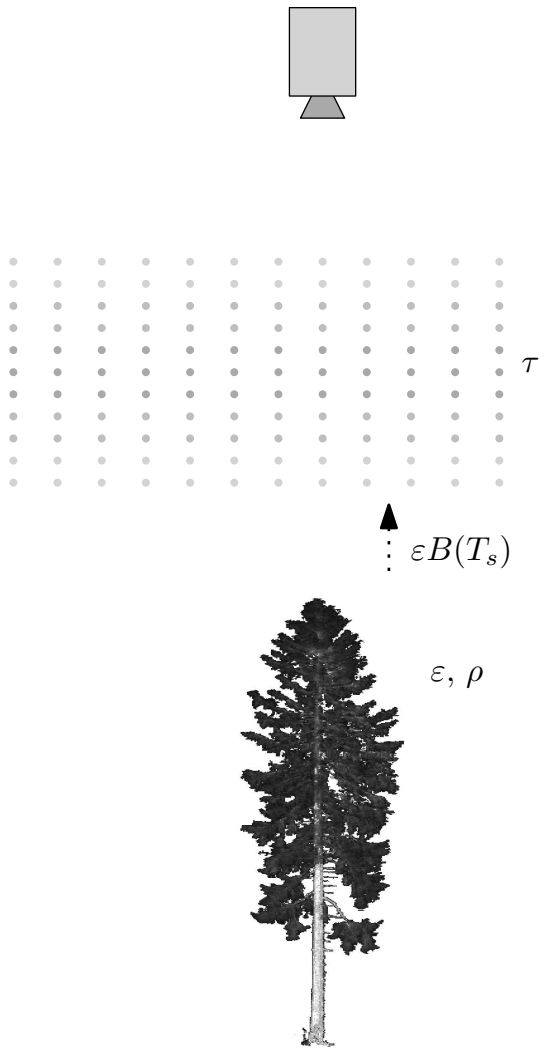


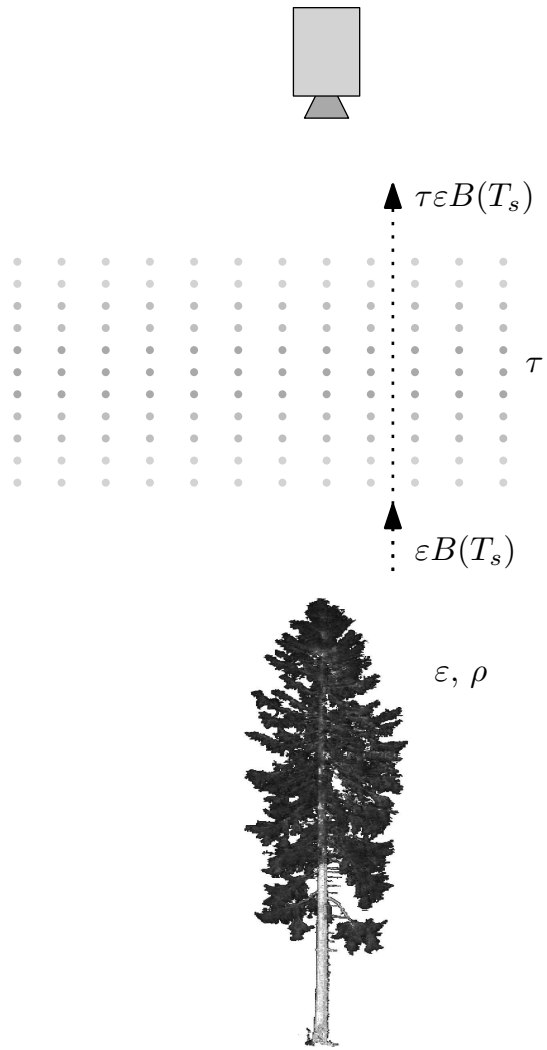
3.
Rovnica radiačného prenosu

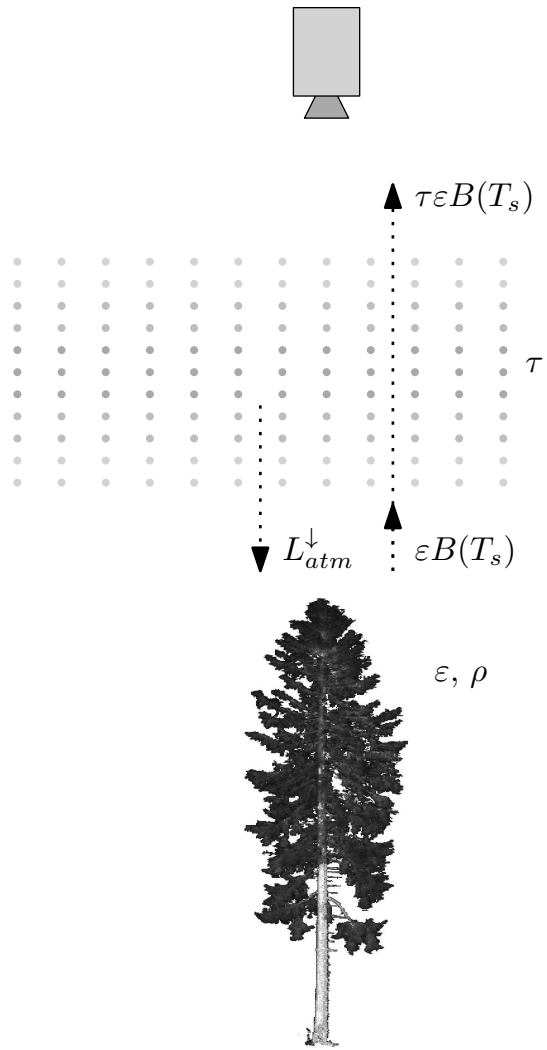


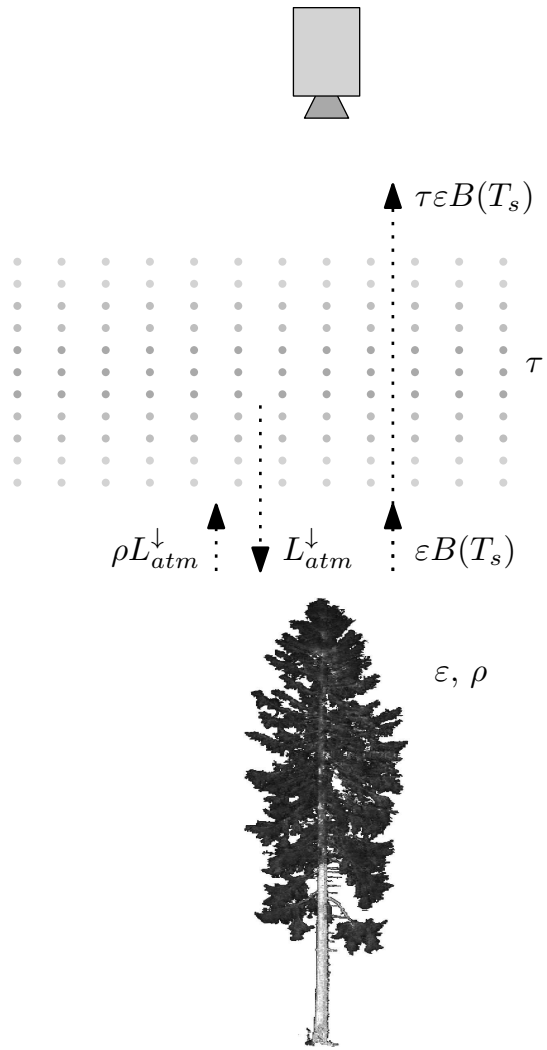

τ

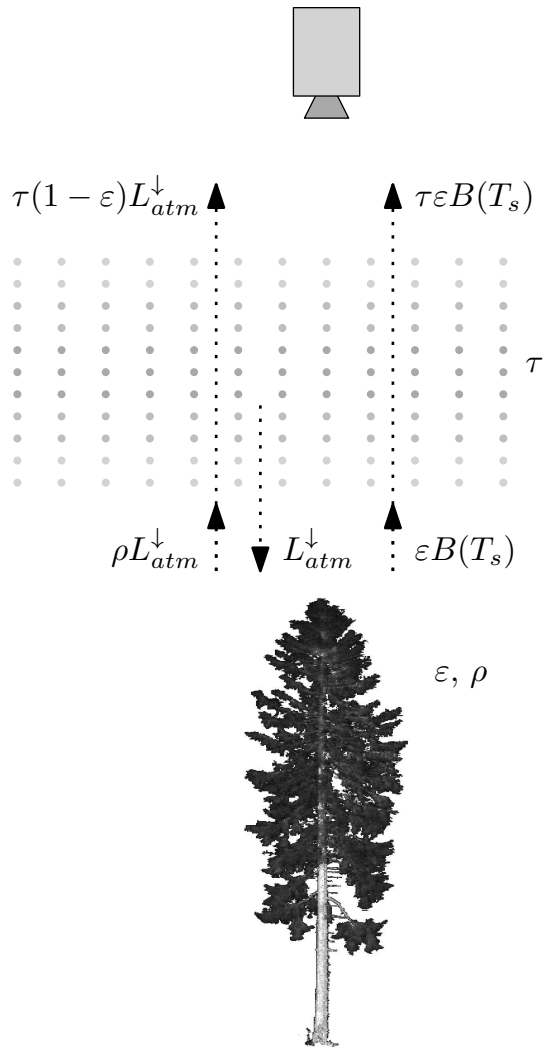

$\varepsilon,\ \rho$

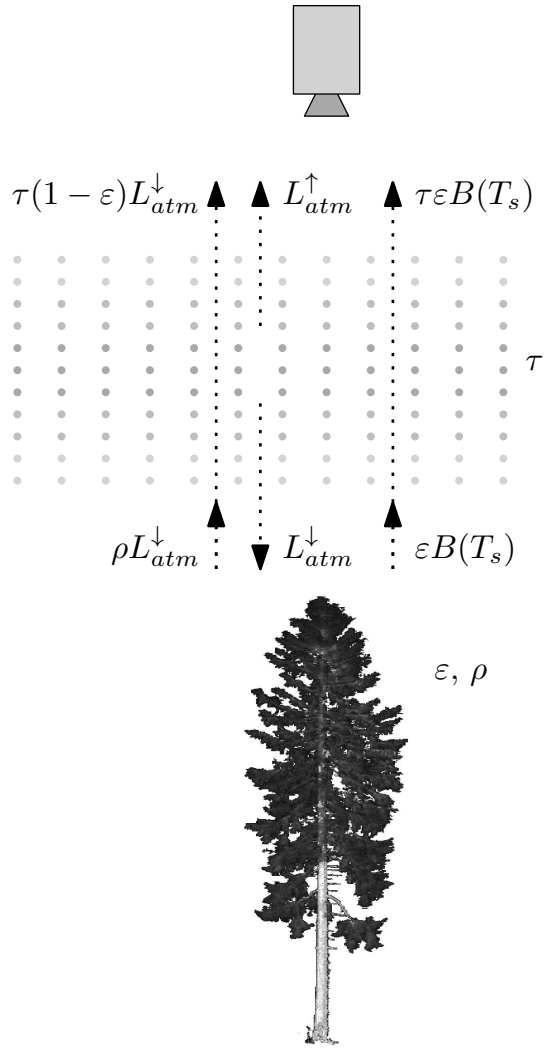

τ
εB(T_s)
ε, ρ


$\tau\varepsilon B(T_s)$
τ
$\varepsilon B(T_s)$
$\varepsilon,\ \rho$

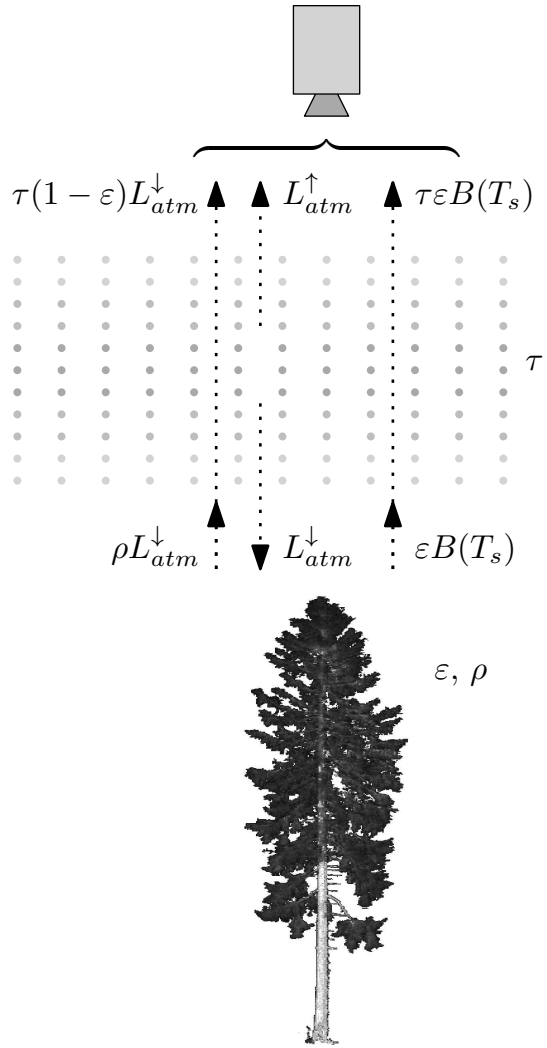

$\tau\varepsilon B(T_s)$
τ
$L^{\downarrow}_{atm}$
$\varepsilon B(T_s)$
$\varepsilon,\ \rho$


$\tau\varepsilon B(T_s)$
τ
$\rho L^{\downarrow}_{atm}$
$L^{\downarrow}_{atm}$
$\varepsilon B(T_s)$
$\varepsilon,\ \rho$


$\tau(1-\varepsilon)L^{\downarrow}_{atm}$
$\tau\varepsilon B(T_s)$
τ
$\rho L^{\downarrow}_{atm}$
$L^{\downarrow}_{atm}$
$\varepsilon B(T_s)$
$\varepsilon,\ \rho$


$\tau(1-\varepsilon)L^{\downarrow}_{atm}$
$L^{\uparrow}_{atm}$
$\tau\varepsilon B(T_s)$
τ
$\rho L^{\downarrow}_{atm}$
$L^{\downarrow}_{atm}$
$\varepsilon B(T_s)$
$\varepsilon,\ \rho$

$$L_m = \tau\varepsilon B(T_s) + \tau(1-\varepsilon)L^{\downarrow}_{atm} + L^{\uparrow}_{atm}$$



$$L_m = \tau\varepsilon B(T_s) + \tau(1-\varepsilon)L_{atm}^{\downarrow} + L_{atm}^{\uparrow}$$

$$\begin{aligned}
\lambda_1 : \quad & L_m(\lambda_1) = \tau(\lambda_1)\varepsilon(\lambda_1)B(T_s,\lambda_1) + \tau(\lambda_1)(1-\varepsilon(\lambda_1))L_{atm}^{\downarrow}(\lambda_1) + L_{atm}^{\uparrow}(\lambda_1) \\
\lambda_2 : \quad & L_m(\lambda_2) = \tau(\lambda_2)\varepsilon(\lambda_2)B(T_s,\lambda_2) + \tau(\lambda_2)(1-\varepsilon(\lambda_2))L_{atm}^{\downarrow}(\lambda_2) + L_{atm}^{\uparrow}(\lambda_2) \\
\vdots \qquad & \qquad\qquad \vdots \\
\lambda_{32} : \quad & L_m(\lambda_{32}) = \tau(\lambda_{32})\varepsilon(\lambda_{32})B(T_s,\lambda_{32}) + \tau(\lambda_{32})(1-\varepsilon(\lambda_{32}))L_{atm}^{\downarrow}(\lambda_{32}) + L_{atm}^{\uparrow}(\lambda_{32})
\end{aligned}$$

$$L_m = \tau\varepsilon B(T_s) + \tau(1-\varepsilon)L^{\downarrow}_{atm} + L^{\uparrow}_{atm}$$

$$\begin{aligned}
\lambda_1 : \quad & L_m(\lambda_1) = \tau(\lambda_1)\varepsilon(\lambda_1)B(T_s,\lambda_1) + \tau(\lambda_1)(1-\varepsilon(\lambda_1)\ L^{\downarrow}_{atm}(\lambda_1) + L^{\uparrow}_{atm}(\lambda_1) \\
\lambda_2 : \quad & L_m(\lambda_2) = \tau(\lambda_2)\varepsilon(\lambda_2)B(T_s,\lambda_2) + \tau(\lambda_2)(1-\varepsilon(\lambda_2)\ L^{\downarrow}_{atm}(\lambda_2) + L^{\uparrow}_{atm}(\lambda_2) \\
\vdots \quad & \qquad\qquad \vdots \\
\lambda_{32} : \quad & L_m(\lambda_{32}) = \tau(\lambda_{32})\varepsilon(\lambda_{32})B(T_s,\lambda_{32}) + \tau(\lambda_{32})(1-\varepsilon(\lambda_{32})\ L^{\downarrow}_{atm}(\lambda_{32}) + L^{\uparrow}_{atm}(\lambda_{32})
\end{aligned}$$

$$L_m = \tau\varepsilon B(T_s) + \tau(1-\varepsilon)L^{\downarrow}_{atm} + L^{\uparrow}_{atm}$$

$$\begin{aligned}
\lambda_1: &\quad L_m(\lambda_1) = \tau(\lambda_1)\varepsilon(\lambda_1)B(T_s,\lambda_1) + \tau(\lambda_1)(1-\varepsilon(\lambda_1)\ L^{\downarrow}_{atm}(\lambda_1) + L^{\uparrow}_{atm}(\lambda_1)\\
\lambda_2: &\quad L_m(\lambda_2) = \tau(\lambda_2)\varepsilon(\lambda_2)B(T_s,\lambda_2) + \tau(\lambda_2)(1-\varepsilon(\lambda_2)\ L^{\downarrow}_{atm}(\lambda_2) + L^{\uparrow}_{atm}(\lambda_2)\\
\vdots &\quad\quad\quad\quad \vdots\\
\lambda_{32}: &\quad L_m(\lambda_{32}) = \tau(\lambda_{32})\varepsilon(\lambda_{32})B(T_s,\lambda_{32}) + \tau(\lambda_{32})(1-\varepsilon(\lambda_{32})\ L^{\downarrow}_{atm}(\lambda_{32}) + L^{\uparrow}_{atm}(\lambda_{32})
\end{aligned}$$

$\Rightarrow$ Nedourčená sústava rovníc

$$L_m = \tau\varepsilon B(T_s) + \tau(1-\varepsilon)L^{\downarrow}_{atm} + L^{\uparrow}_{atm}$$

$$\begin{aligned}
\lambda_1: &\quad L_m(\lambda_1) = \tau(\lambda_1)\varepsilon(\lambda_1)B(T_s,\lambda_1) + \tau(\lambda_1)(1-\varepsilon(\lambda_1)\ L^{\downarrow}_{atm}(\lambda_1) + L^{\uparrow}_{atm}(\lambda_1)\\
\lambda_2: &\quad L_m(\lambda_2) = \tau(\lambda_2)\varepsilon(\lambda_2)B(T_s,\lambda_2) + \tau(\lambda_2)(1-\varepsilon(\lambda_2)\ L^{\downarrow}_{atm}(\lambda_2) + L^{\uparrow}_{atm}(\lambda_2)\\
\vdots &\quad\quad\quad\quad \vdots\\
\lambda_{32}: &\quad L_m(\lambda_{32}) = \tau(\lambda_{32})\varepsilon(\lambda_{32})B(T_s,\lambda_{32}) + \tau(\lambda_{32})(1-\varepsilon(\lambda_{32})\ L^{\downarrow}_{atm}(\lambda_{32}) + L^{\uparrow}_{atm}(\lambda_{32})
\end{aligned}$$

$\Rightarrow$ Nedourčená sústava rovníc

Odchádzajúca radiancia $\qquad L_{LL} = \varepsilon B(T_s) + (1-\varepsilon)L^{\downarrow}_{atm}$

$$L_m = \tau\varepsilon B(T_s) + \tau(1-\varepsilon)L^{\downarrow}_{atm} + L^{\uparrow}_{atm}$$

$$\begin{aligned}
\lambda_1: &\quad L_m(\lambda_1) = \tau(\lambda_1)\varepsilon(\lambda_1)B(T_s,\lambda_1) + \tau(\lambda_1)(1-\varepsilon(\lambda_1)\ L^{\downarrow}_{atm}(\lambda_1) + L^{\uparrow}_{atm}(\lambda_1)\\
\lambda_2: &\quad L_m(\lambda_2) = \tau(\lambda_2)\varepsilon(\lambda_2)B(T_s,\lambda_2) + \tau(\lambda_2)(1-\varepsilon(\lambda_2)\ L^{\downarrow}_{atm}(\lambda_2) + L^{\uparrow}_{atm}(\lambda_2)\\
\vdots &\quad\quad\quad\quad \vdots\\
\lambda_{32}: &\quad L_m(\lambda_{32}) = \tau(\lambda_{32})\varepsilon(\lambda_{32})B(T_s,\lambda_{32}) + \tau(\lambda_{32})(1-\varepsilon(\lambda_{32})\ L^{\downarrow}_{atm}(\lambda_{32}) + L^{\uparrow}_{atm}(\lambda_{32})
\end{aligned}$$

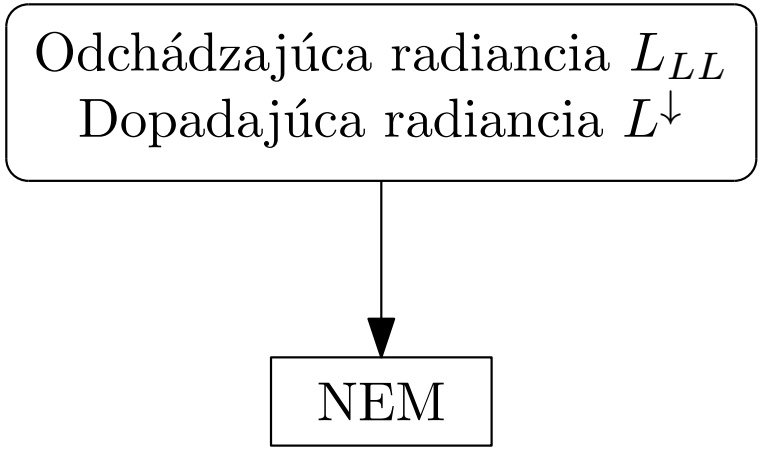
$\Rightarrow$ Nedourčená sústava rovníc

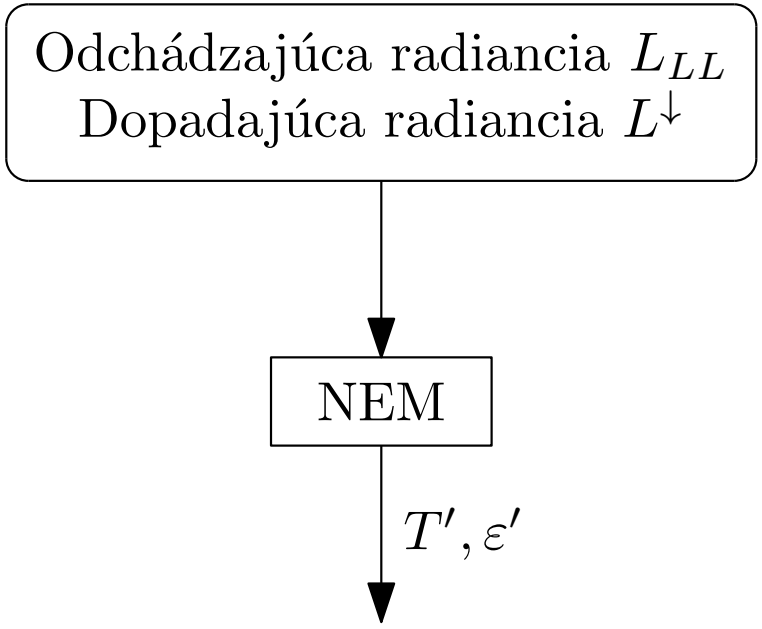
Odchádzajúca radiancia	$L_{LL} = \varepsilon B(T_s) + (1-\varepsilon)L^{\downarrow}_{atm}$
Jasová teplota	$B^{-1}(L_{LL},\lambda)$

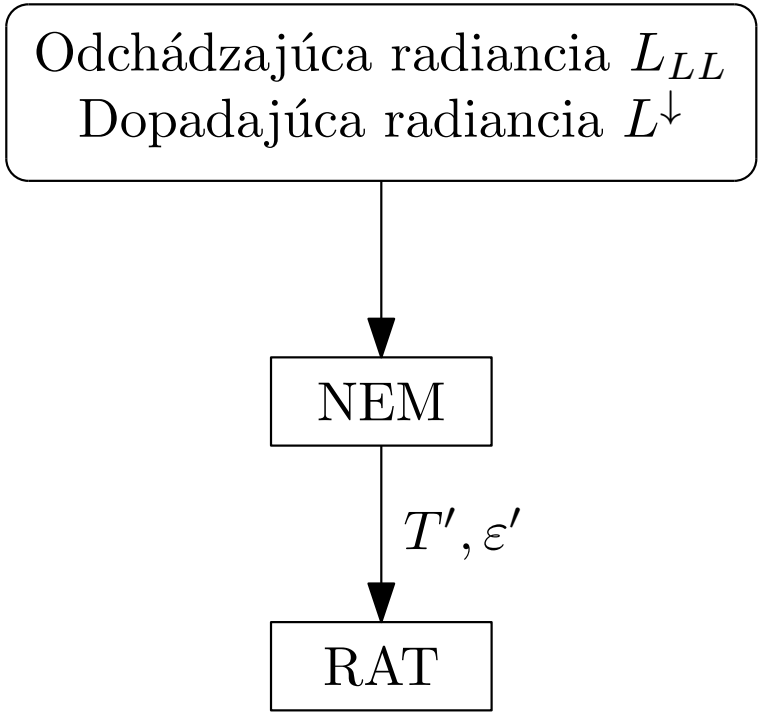
4.

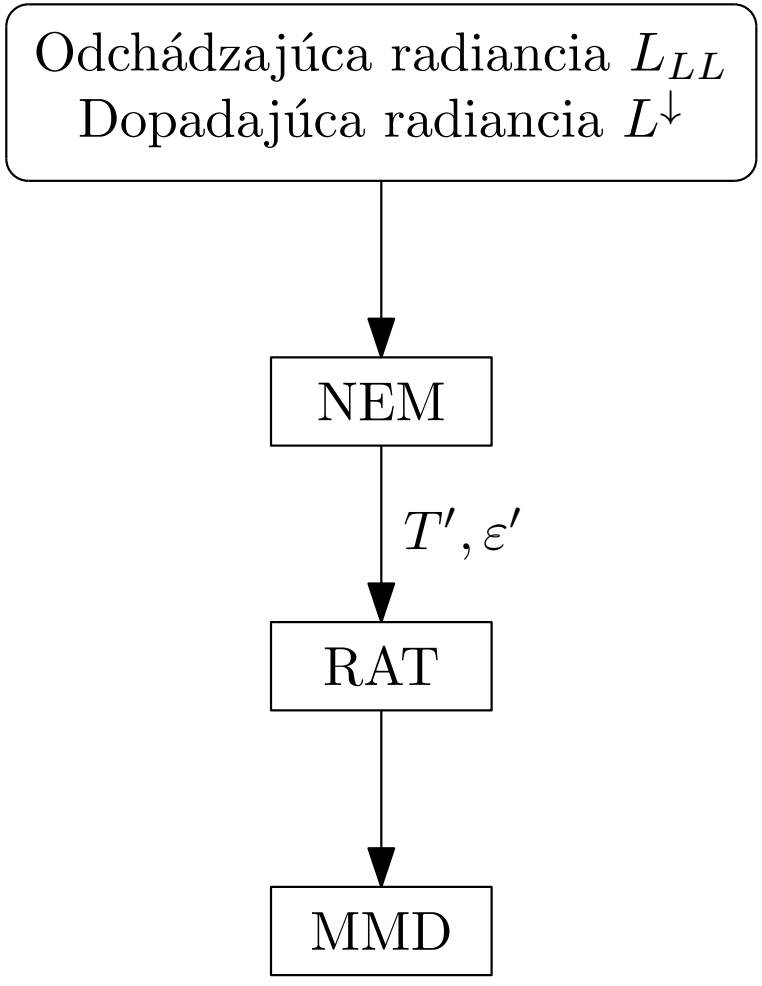
Separácia teploty a emisivity

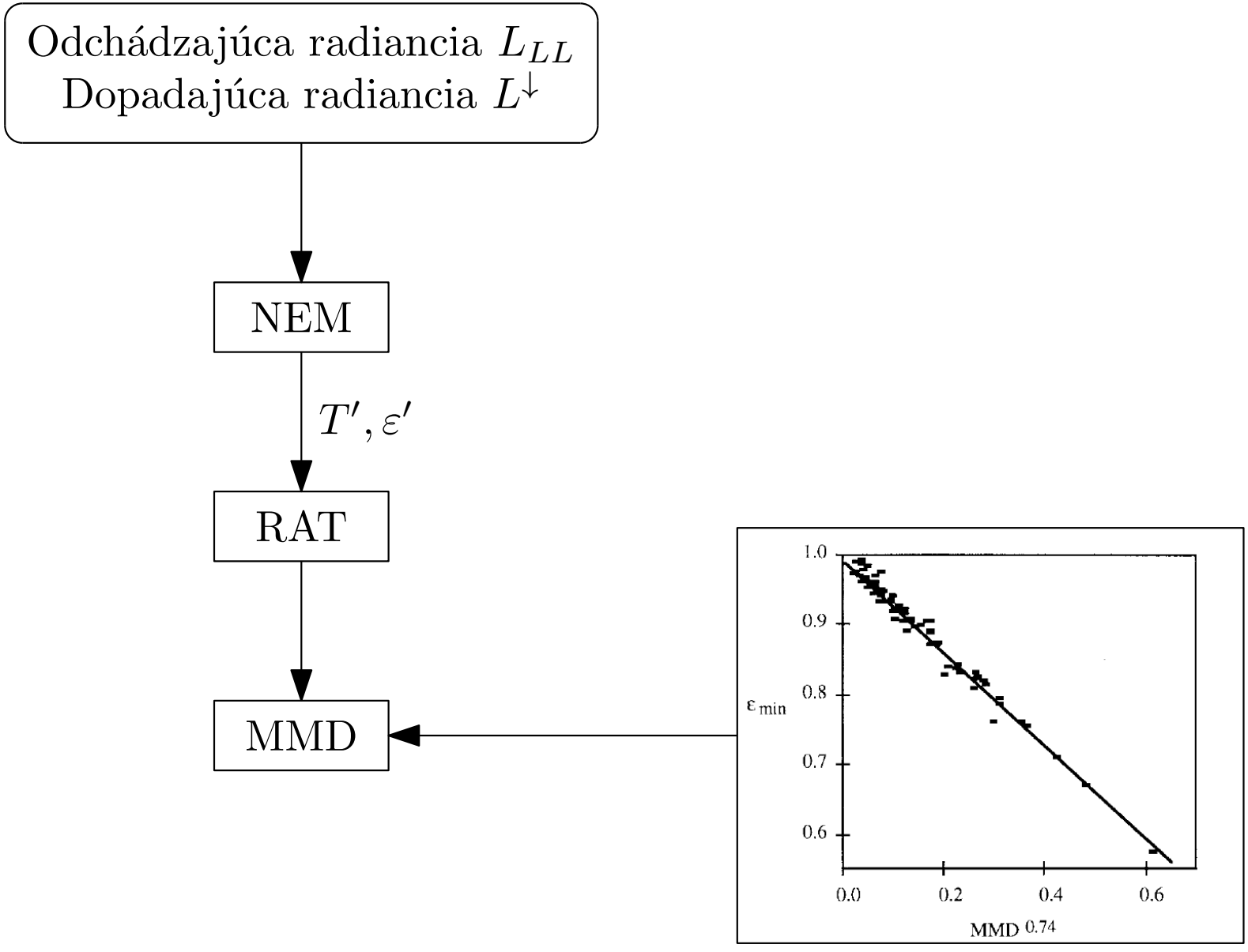
Odchádzajúca radiancia L_{LL}
Dopadajúca radiancia $L^{\downarrow}$

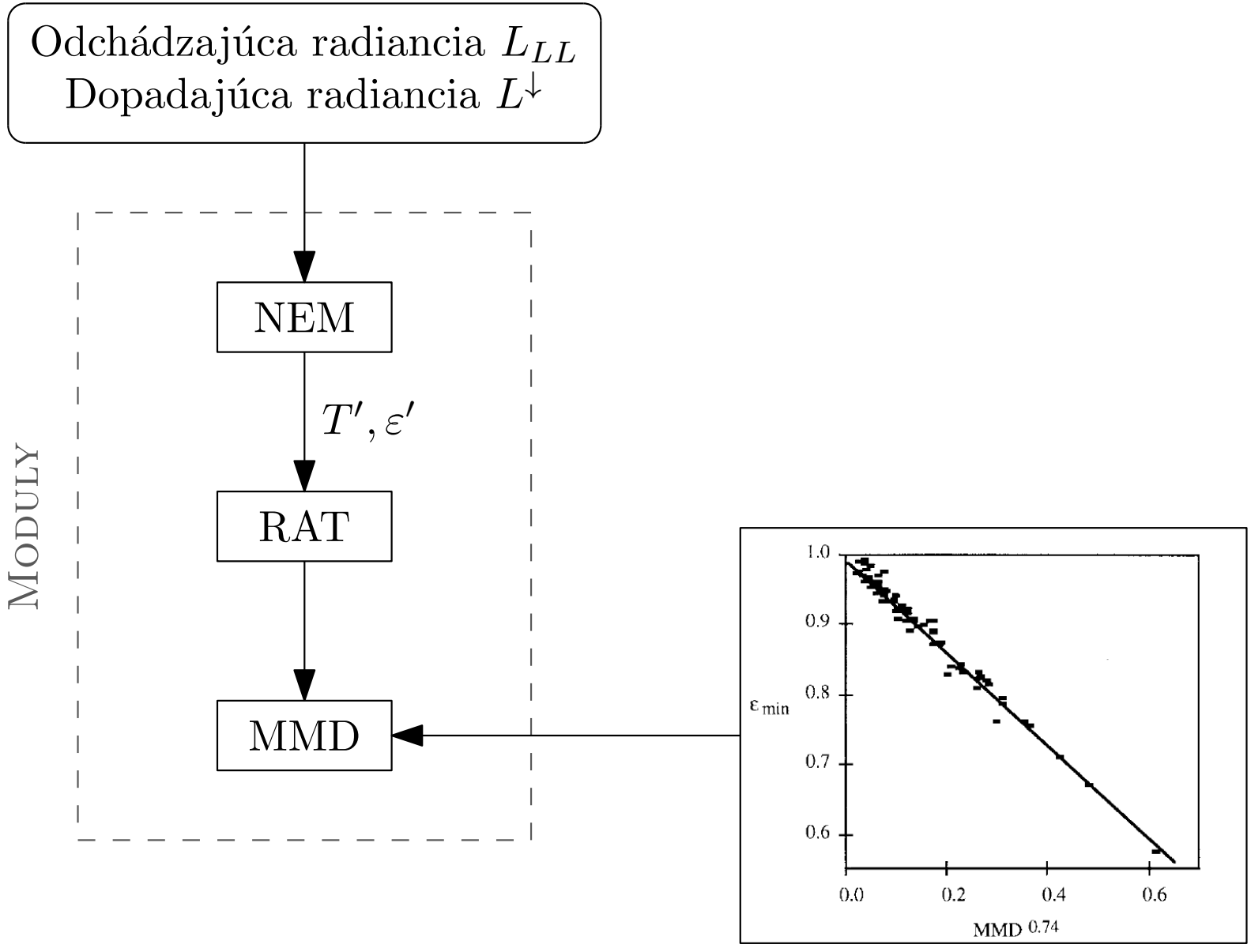

Odchádzajúca radiancia L_{LL}
Dopadajúca radiancia $L^{\downarrow}$
NEM

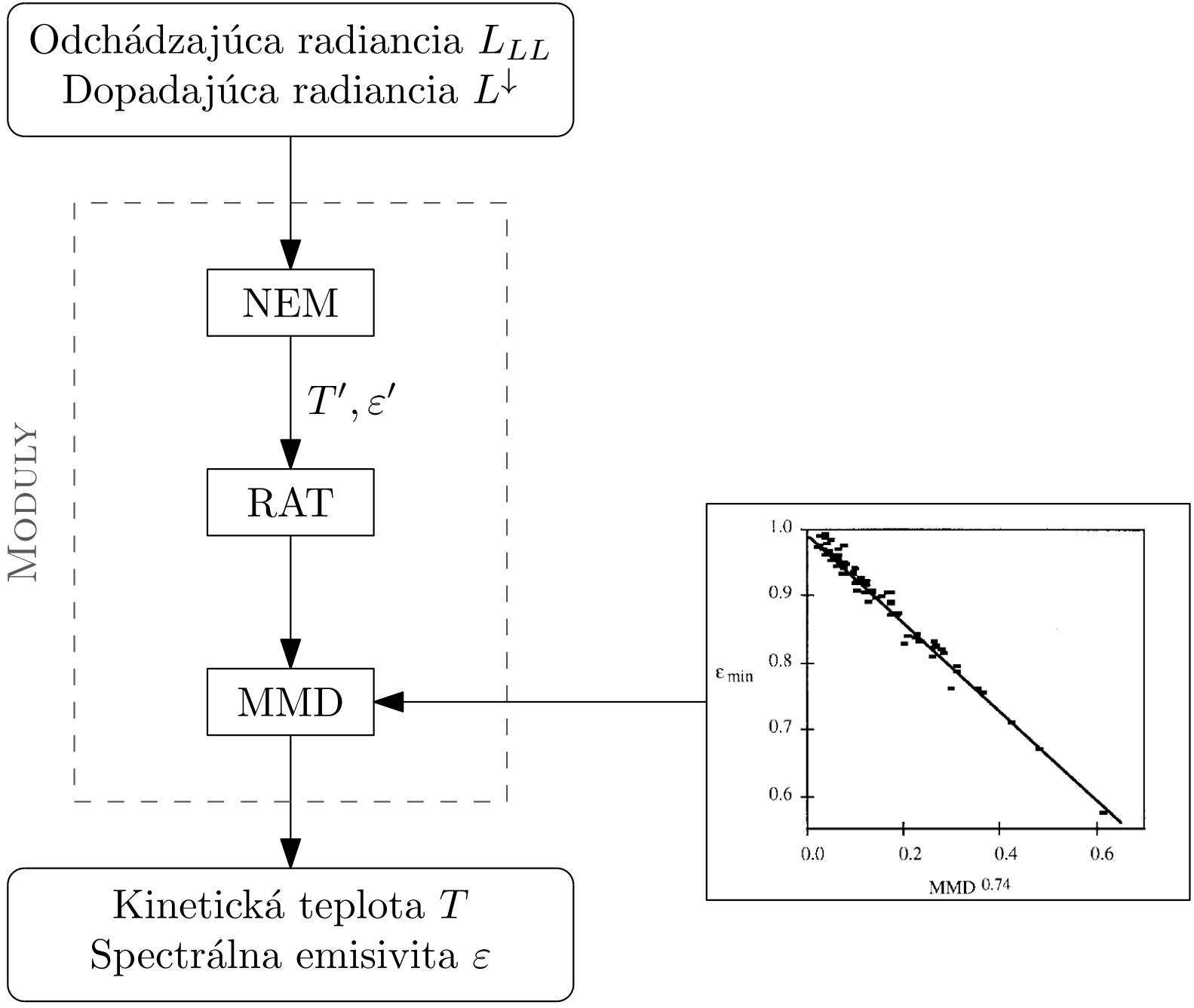

Odchádzajúca radiancia L_{LL}
Dopadajúca radiancia $L^{\downarrow}$
NEM
T', ε'


Odchádzajúca radiancia L_{LL}
Dopadajúca radiancia $L^{\downarrow}$
NEM
T', ε'
RAT

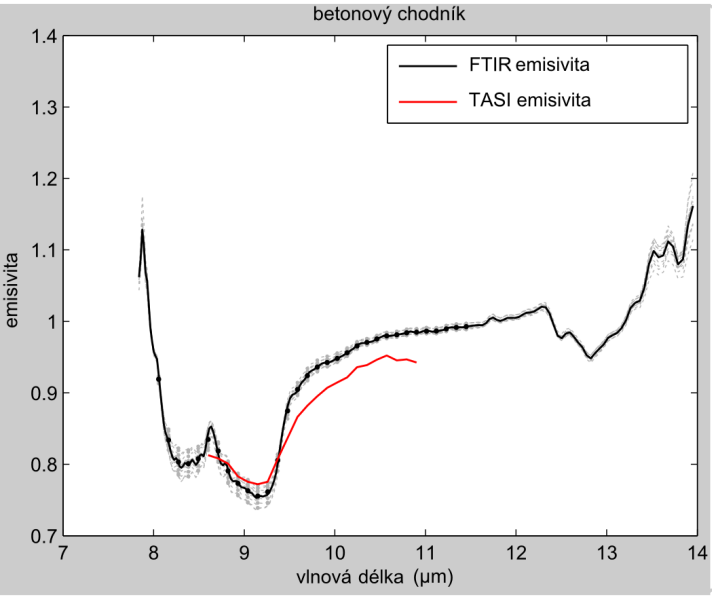

Odchádzajúca radiancia L_{LL}
Dopadajúca radiancia $L^{\downarrow}$
NEM
T', ε'
RAT
MMD

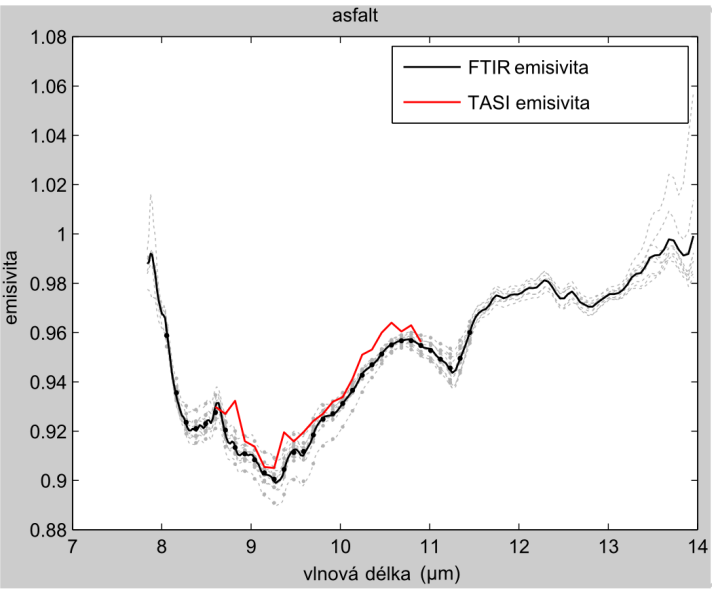

Odchádzajúca radiancia L_{LL}
Dopadajúca radiancia $L^{\downarrow}$
NEM
T', ε'
RAT
MMD
1.0
0.9
0.8
0.7
0.6
ε_{min}
0.0
0.2
0.4
0.6
MMD 0.74

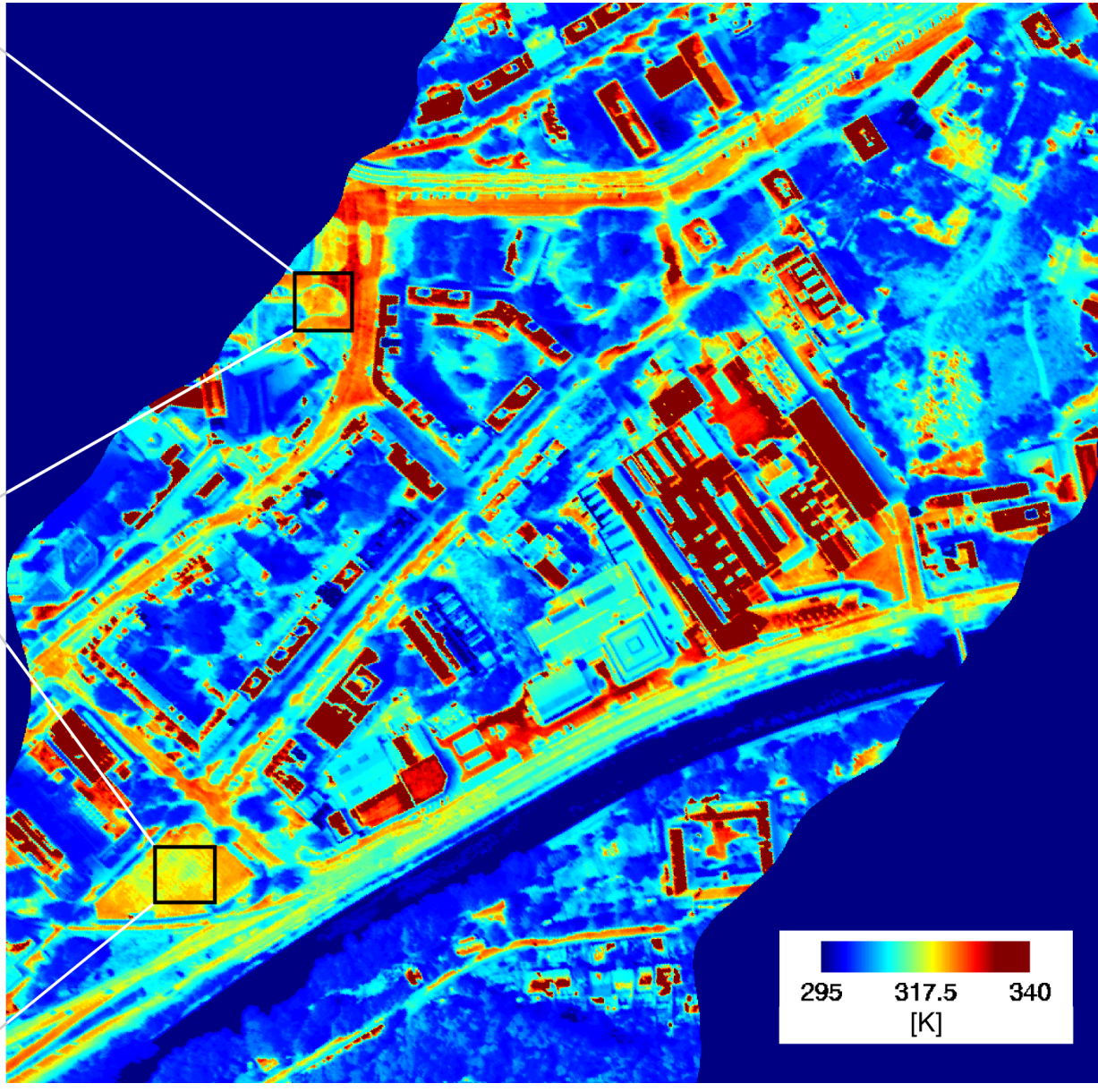

Odchádzajúca radiancia L_{LL}
Dopadajúca radiancia $L^{\downarrow}$
NEM
T', ε'
RAT
MMD
Moduly
1.0
0.9
0.8
0.7
0.6
ε_{min}
0.0
0.2
0.4
0.6
MMD 0.74

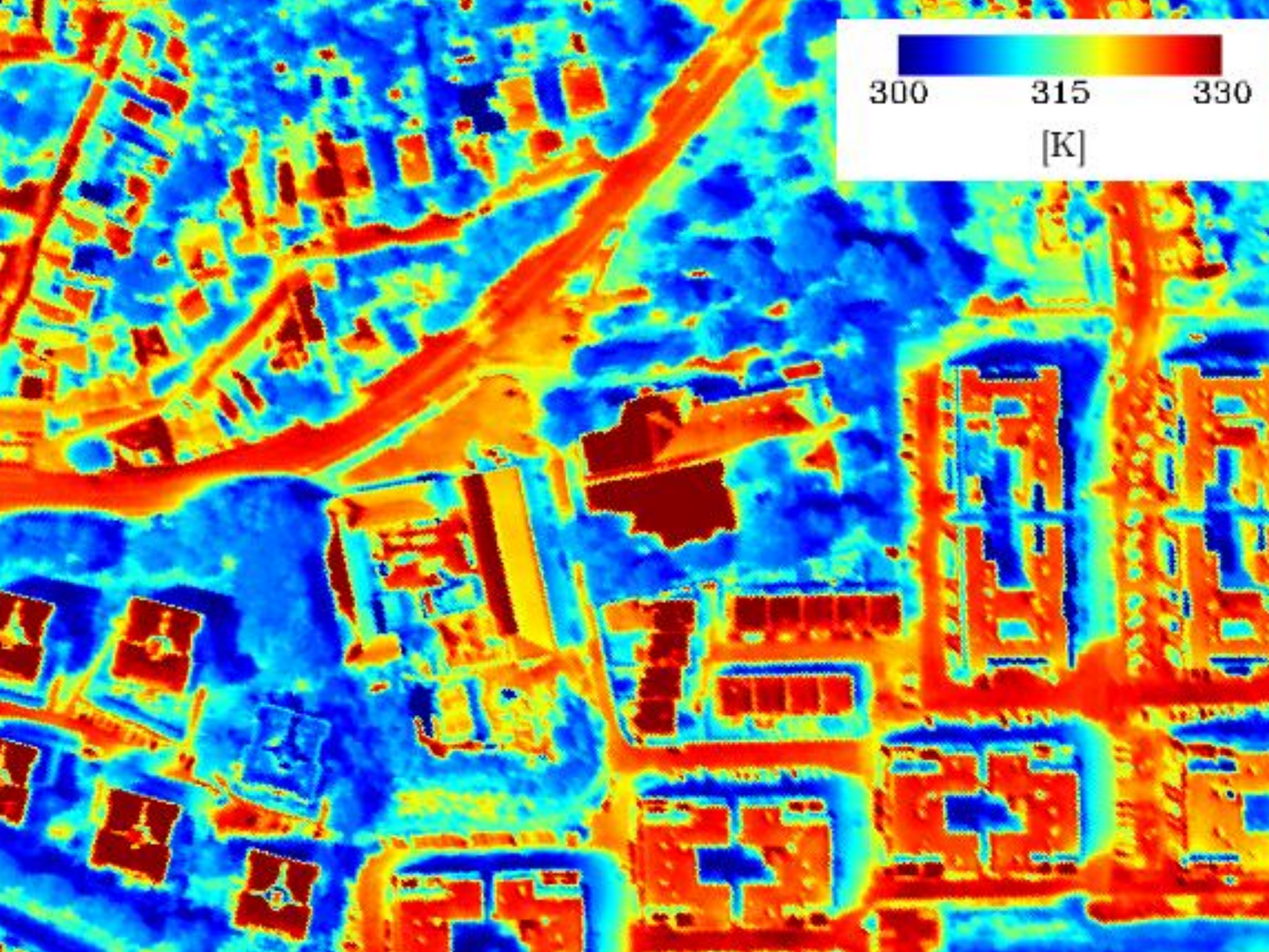

Odchádzajúca radiancia L_{LL}
Dopadajúca radiancia $L^{\downarrow}$
NEM
T', ε'
RAT
MMD
Moduly
Kinetická teplota T
Spectrálna emisivita ε
1.0
0.9
0.8
0.7
0.6
ε_{min}
0.0
0.2
0.4
0.6
MMD 0.74

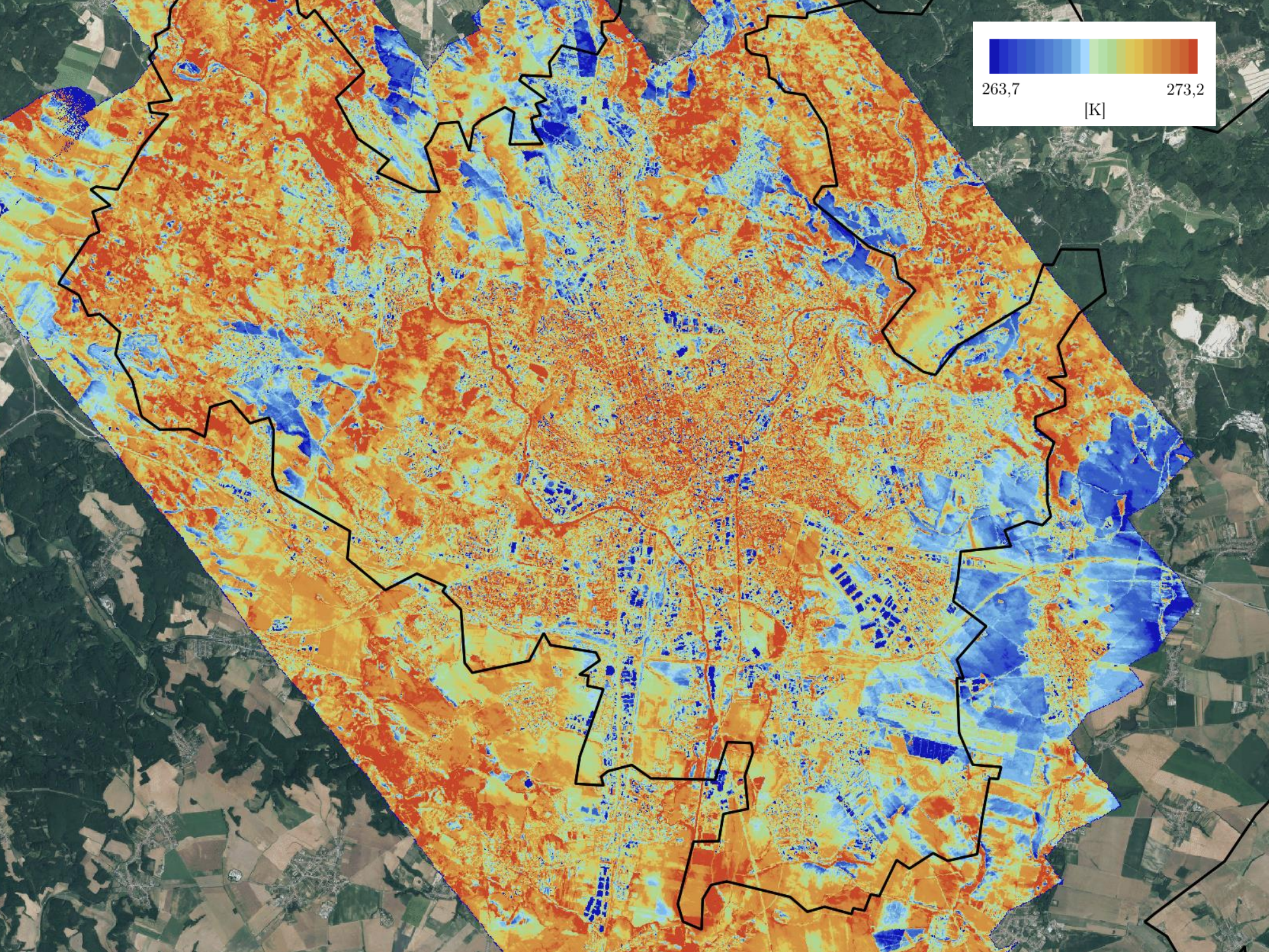
5.
Výsledky


betonový chodník
FTIR emisivita
TASI emisivita
emisivita
vlnová délka (μm)
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
7
8
9
10
11
12
13
14


asfalt
FTIR emisivita
TASI emisivita
emisivita
vlnová délka (μm)
1.08
1.06
1.04
1.02
1
0.98
0.96
0.94
0.92
0.9
0.88
7
8
9
10
11
12
13
14


295
317.5
340
[K]


300
315
330
[K]


263,7
273,2
[K]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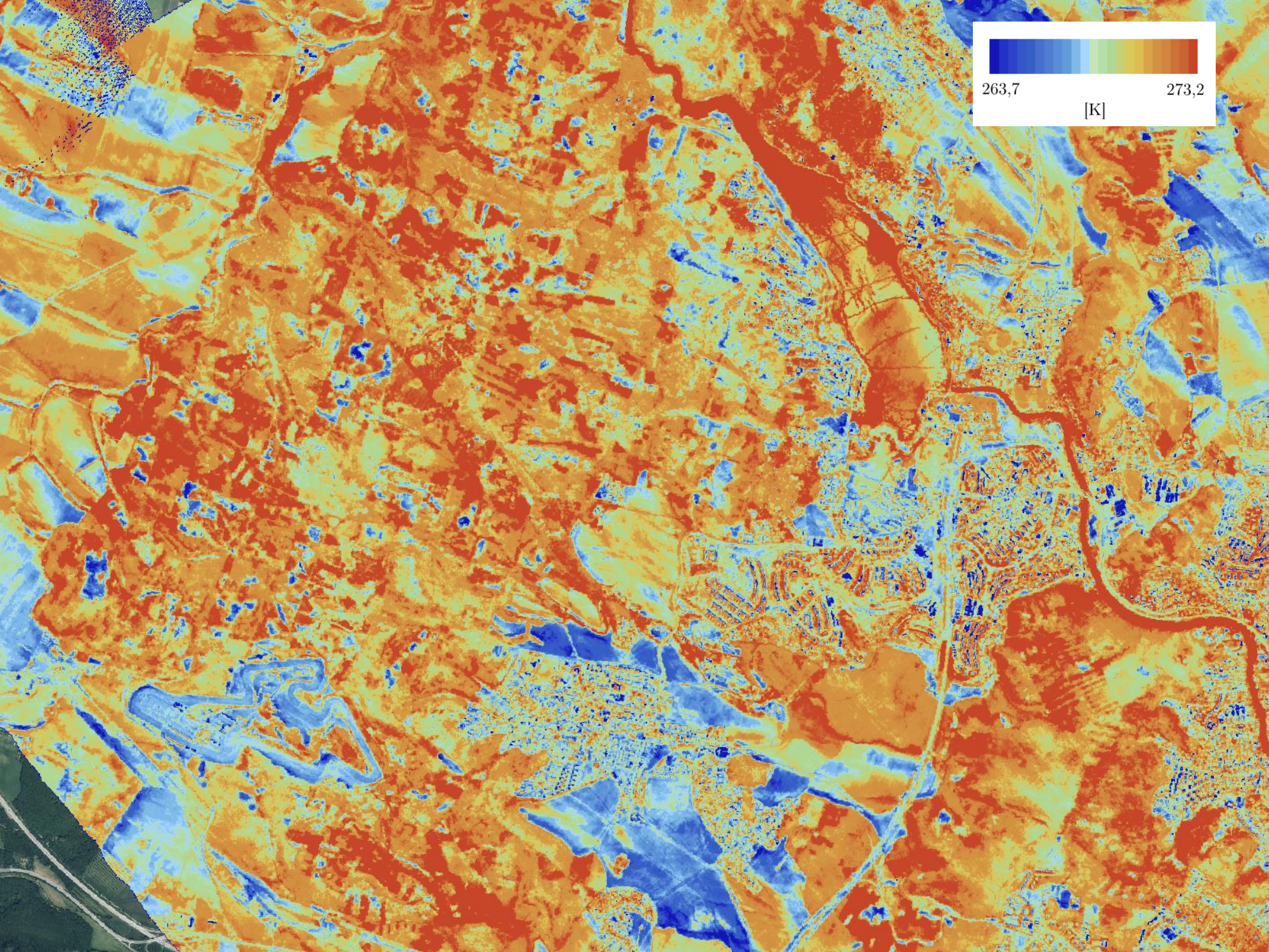
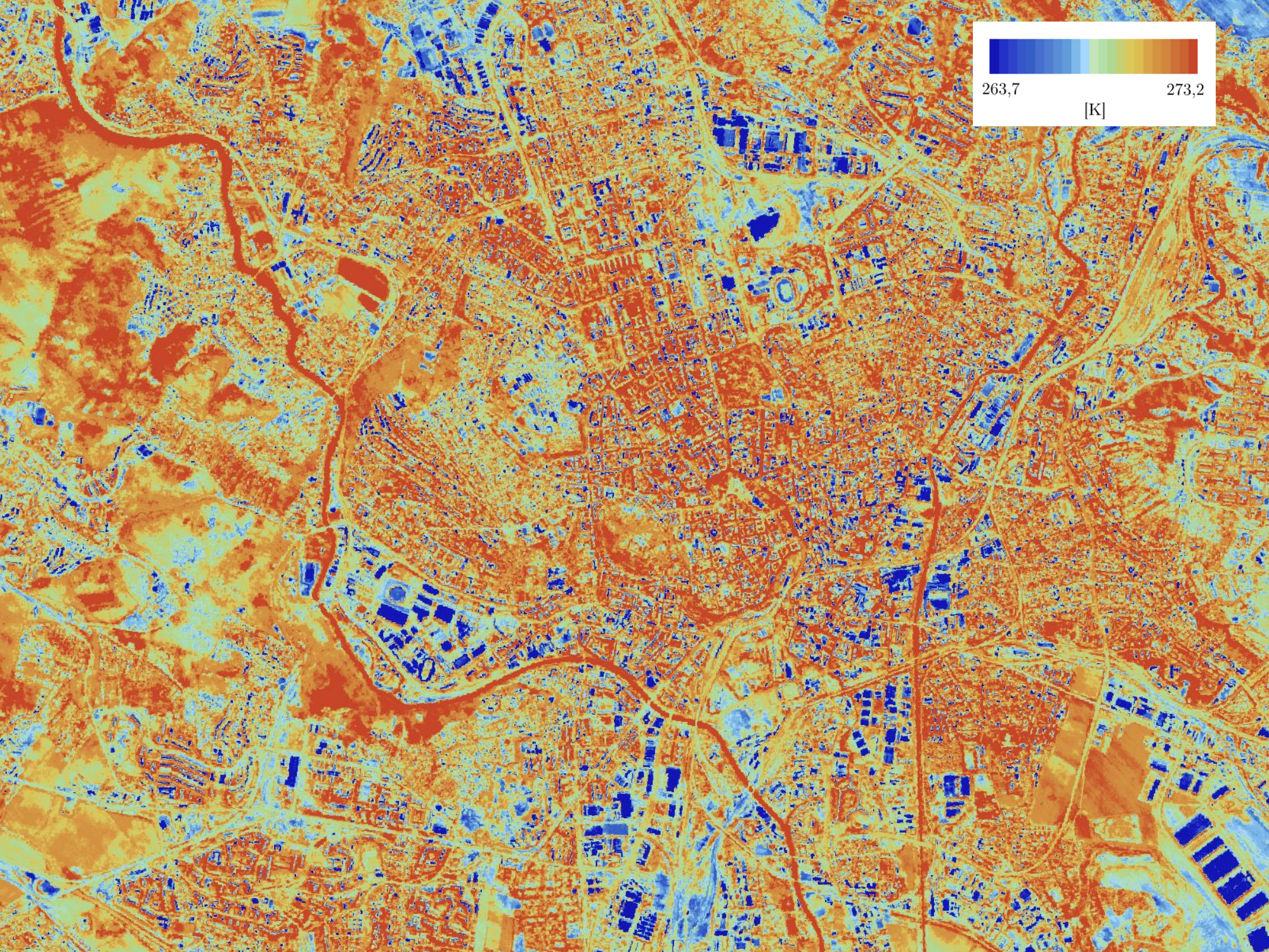
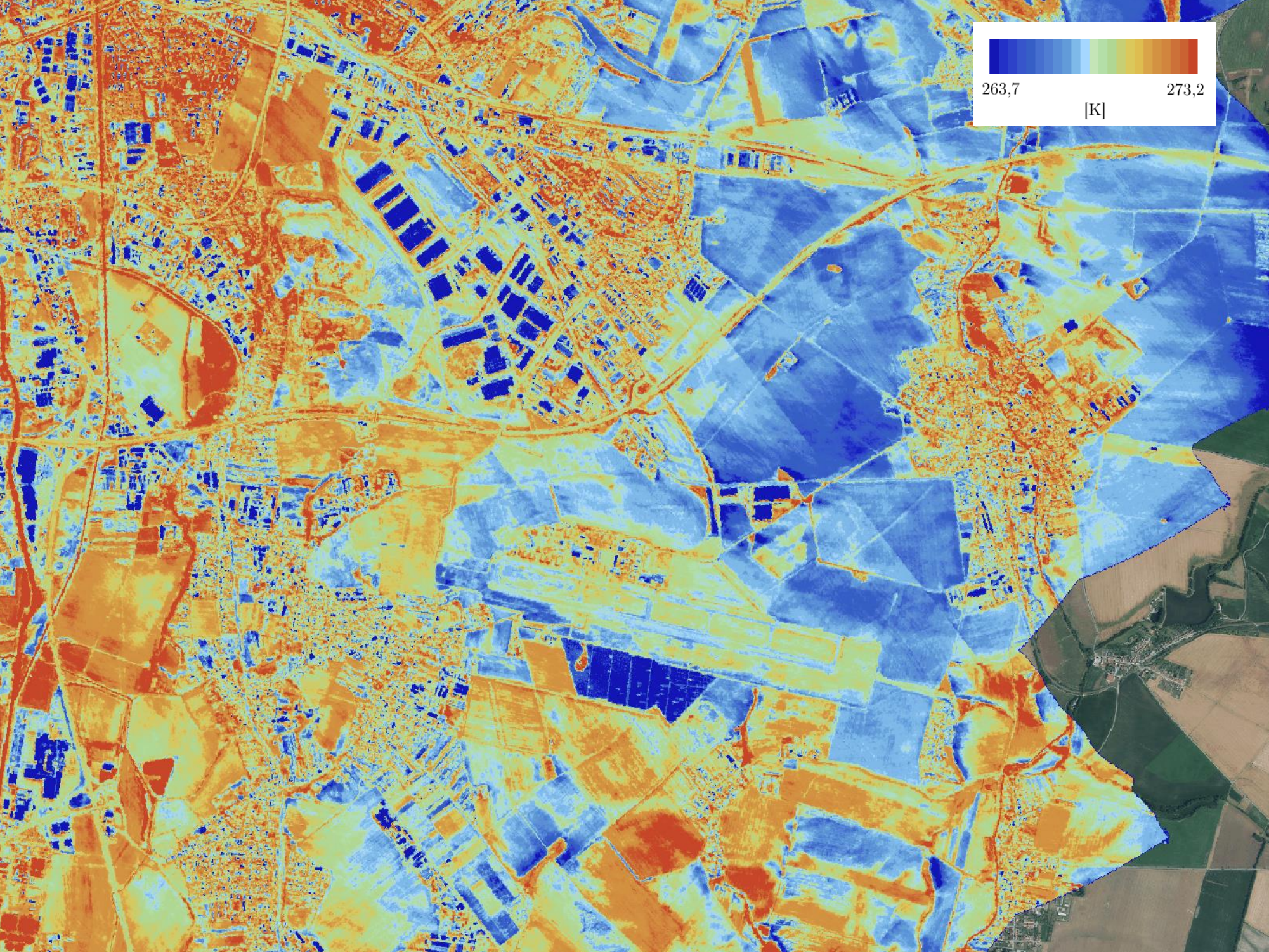

263,7
273,2
[K]


263,7
273,2
[K]


263,7
273,2
[K]

Ďakujem za pozornosť

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