Uncertainty indices of high spatial resolution Land Surface Temperature over urban areas

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Outline

- Land Surface Temperature (LST) and uncertainties
- High resolution LST methodology briefing
- Uncertainty estimation method
- Results on a test site
- Conclusions

Why Land Surface Temperature

Land Surface Temperature (LST) is a ***key variable*** for studying ***land surface processes*** and ***interactions with the atmosphere***.

Detailed, ***frequent*** and ***accurate*** satellite-derived ***LST products*** may support various urban applications, related to ***urban microclimate***, like the monitoring urban heat island.

For the derived products to be used as effectively as possible, it is important to ***provide uncertainty estimates***.

Uncertainties in LST retrieval

Freitas, S.C., Trigo, I.F., Bioucas-Dias, J.M., Göttsche, F. (2010). Quantifying the Uncertainty of Land Surface Temperature 525 Retrievals from **SEVIRI/Meteosat**, *IEEE Trans. Geosci. Remote Sens*. 48, 523-534.

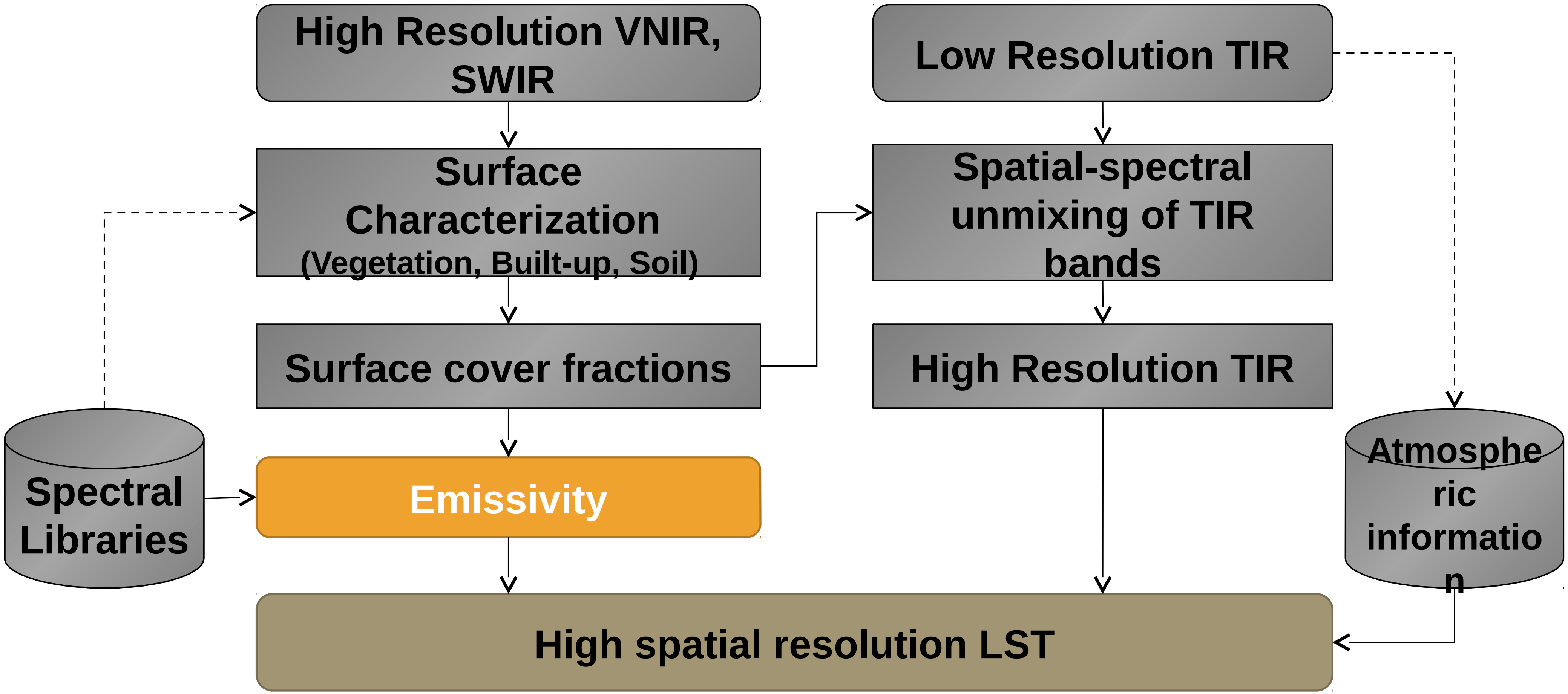
Hulley, G.C., Hughes, C.G., Hook, S.J. (2012). Quantifying uncertainties in land surface temperature and emissivity retrievals from **ASTER** and **MODIS** thermal infrared data. *J. Geophys. Res.* 117(D23), D23113.

Ghent, D., Remedios, J. (2013). Developing first time-series of land surface temperature from **AATSR** with uncertainty estimates. EGU General Assembly, Vienna (AUT), 7-12 April.

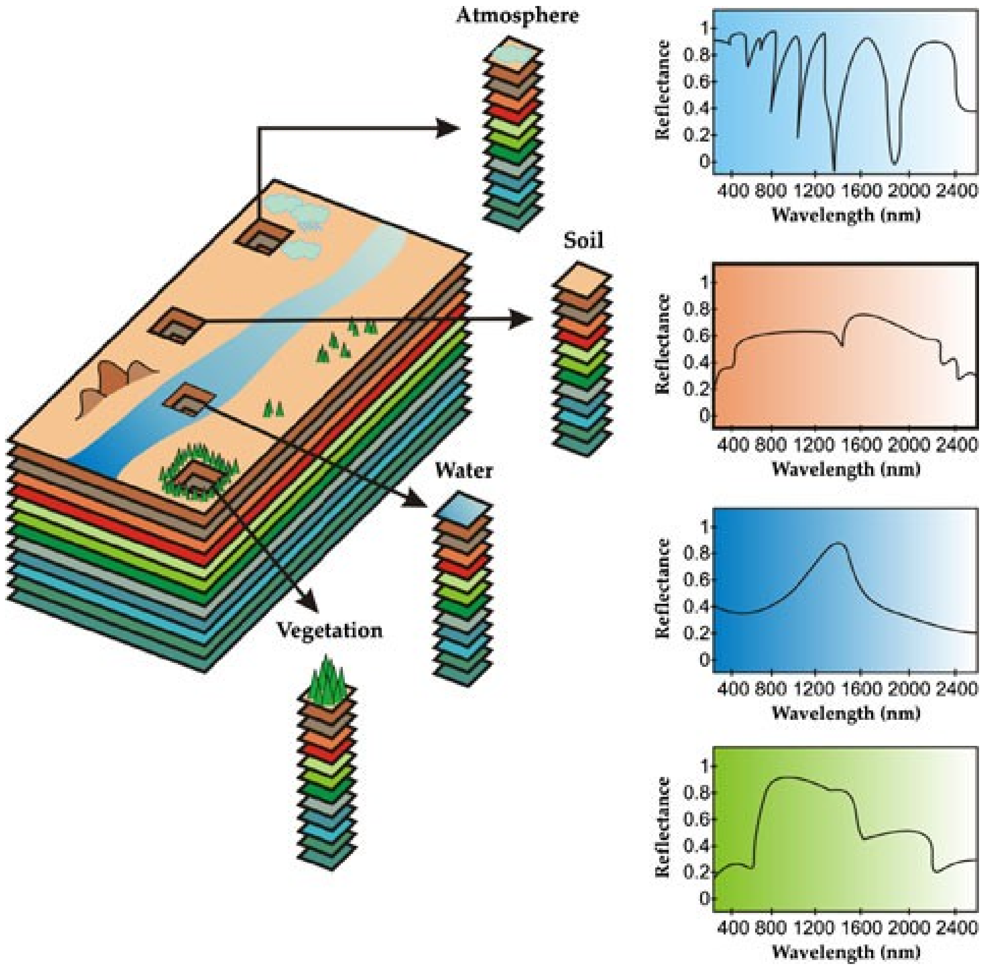
Uncertainty sources in LST retrieval:

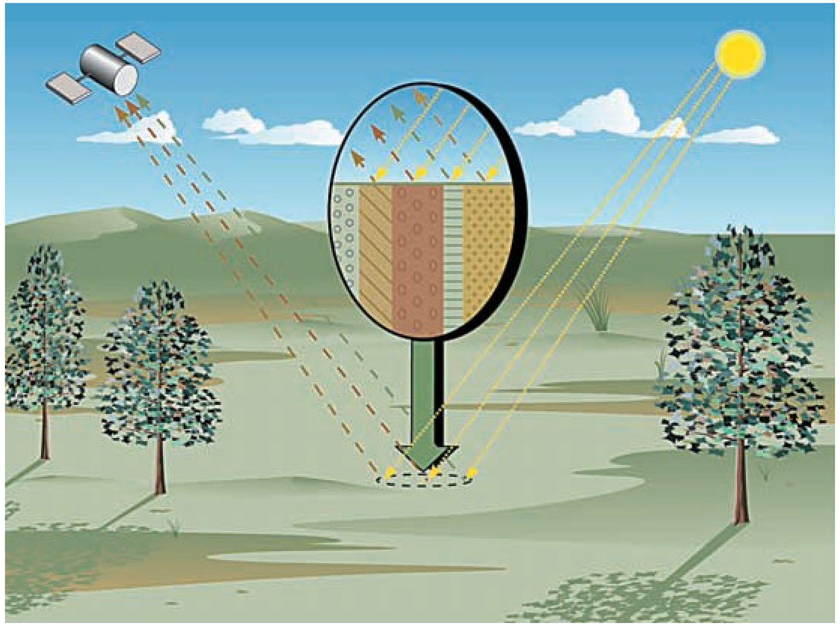
radiometric noise, surface emissivity, atmospheric contribution (water vapor), sensor view angle and the model

High resolution LST methodology



Surface Cover Fractions





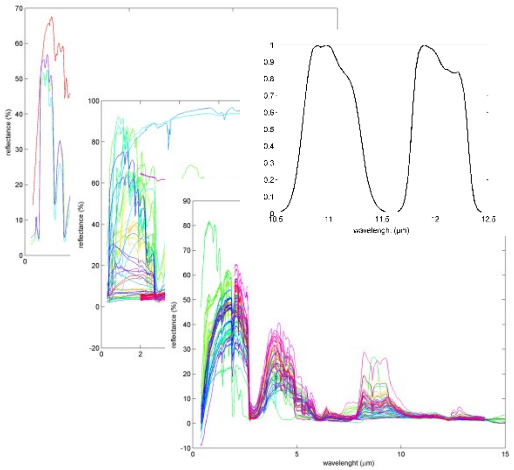
$$R_i = \sum_{k=1}^{n} a_k\, R_{ik} + ER_i$$

$$\sum_{k=1}^{n} a_k = 1, a_k \geq 0\ \forall k$$

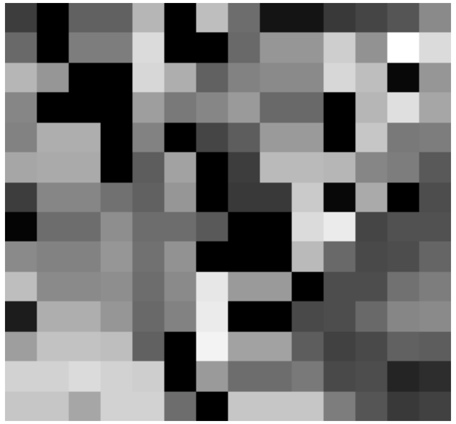
Emissivity

Fractions (a_k) derived from high resolution image

image



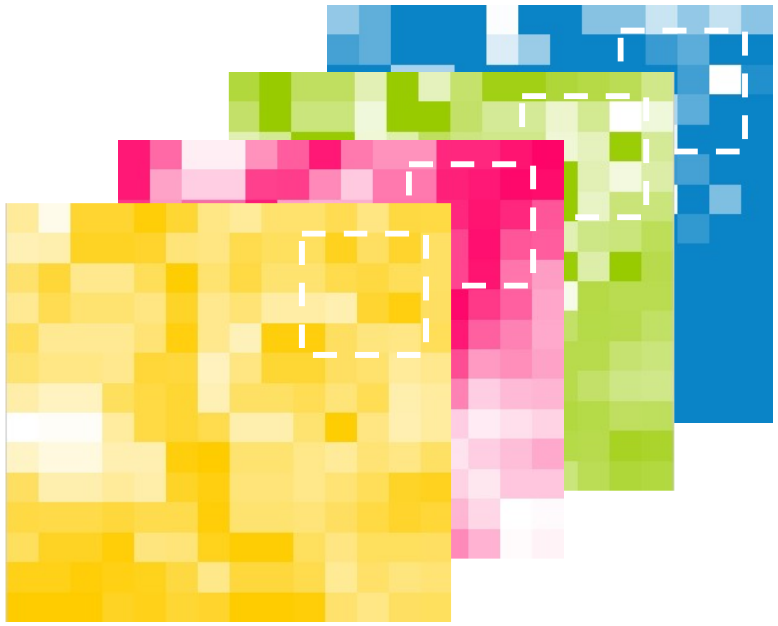
Emissivity (ε_k) information
from spectral libraries
adjusted to the sensor



High resolution

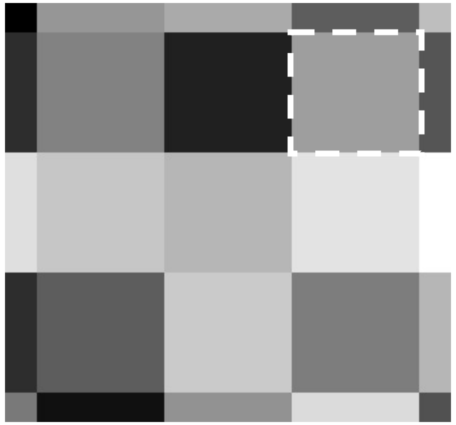
$$\varepsilon_i = \sum_{k=1}^{n} \varepsilon_k \cdot a_k$$

High Resolution TIR Band

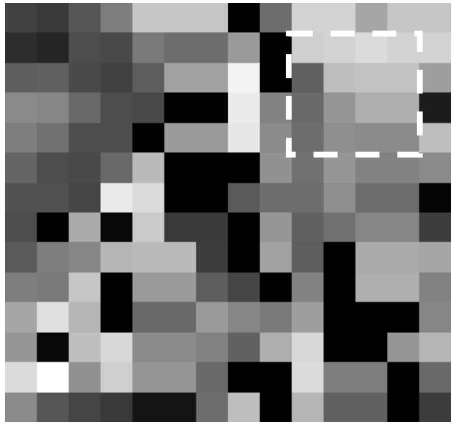


Fractions $(\mathbf{A}^{(H)})$ derived from high resolution imag

image



Low resolution thermal band $(\mathbf{S}^{(L)})$



High resolution thermal band $(\mathbf{S}^{(H)})$

$$\mathbf{E}^{(L)} = \min_{\mathbf{E}} \left\| \mathbf{S}^{(L)} - \mathbf{A}^{(L)} \cdot \mathbf{E}^{(L)} + a\frac{w^2}{n}\left(\mathbf{E}^{(L)} - \bar{\mathbf{S}}'^{(L)}\right) \right\|_2^2$$

$$\mathbf{S}^{(H)} = \mathbf{A}^{(H)} \cdot \mathbf{E}^{(L)}$$

LST

from a split-window algorithm

$$LST = T_i + c_1(T_i - T_j) + c_2(T_i - T_j)^2 + c_0 + (c_3 + c_4 wv)(1 - \varepsilon) + (c_5 + c_6 WV)\Delta\varepsilon$$

where T_i, T_j are the brightness temperatures for bands i and j

$\varepsilon = (\varepsilon_i + \varepsilon_j)/2$ is the mean emissivity of bands i and j

$\Delta\varepsilon = \varepsilon_i - \varepsilon_j$

wv is the atmospheric water vapor content

c_0 to c_6 are coefficients (Jiménez-Muñoz et al., 2008)

Uncertainty Propagation

Monte Carlo

an experimental probabilistic method to solve difficult deterministic problems by ***simulating a large number of experimental trials***

Advantages

- ***closer to the underlying physics*** of actual measurement processes
- can handle both ***small and large uncertainties***
- do ***not*** require ***complex*** partial differentiations
- ***accounts for*** input covariances or ***dependencies***

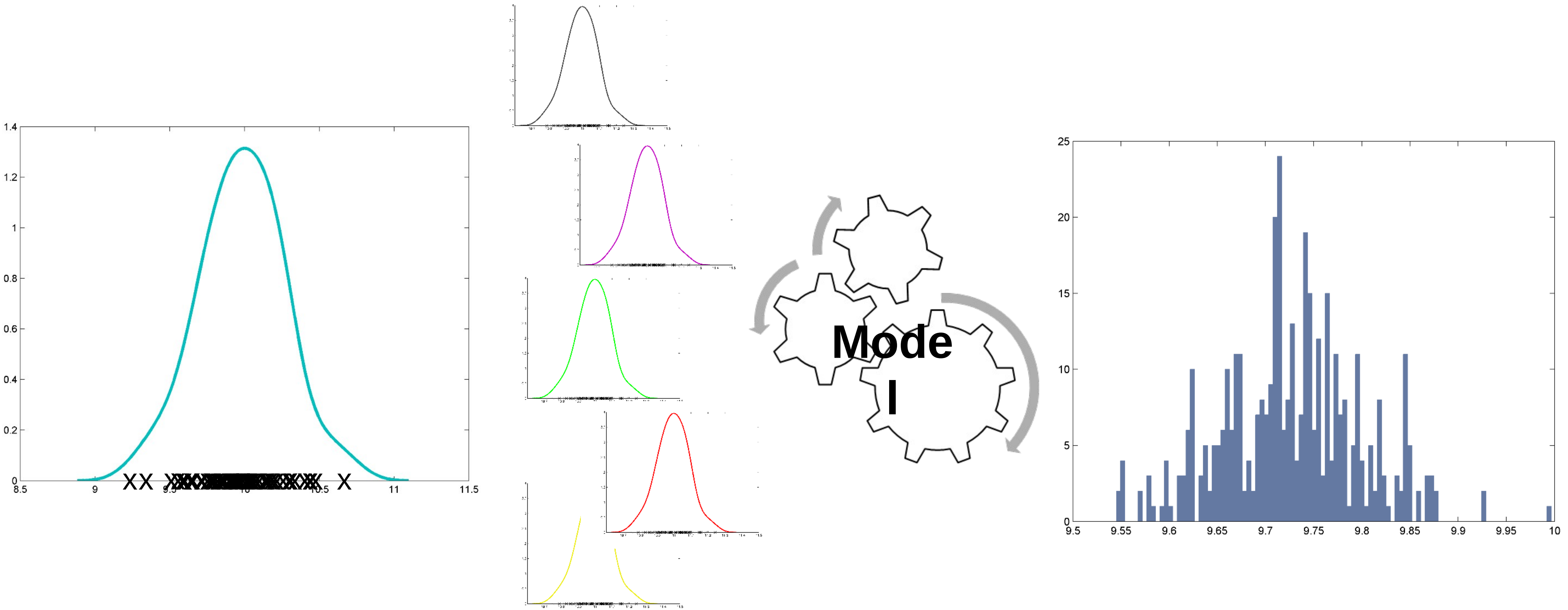
Disadvantage

- ***computationally expensive*** especially for EO data → hundreds of simulation for each pixel

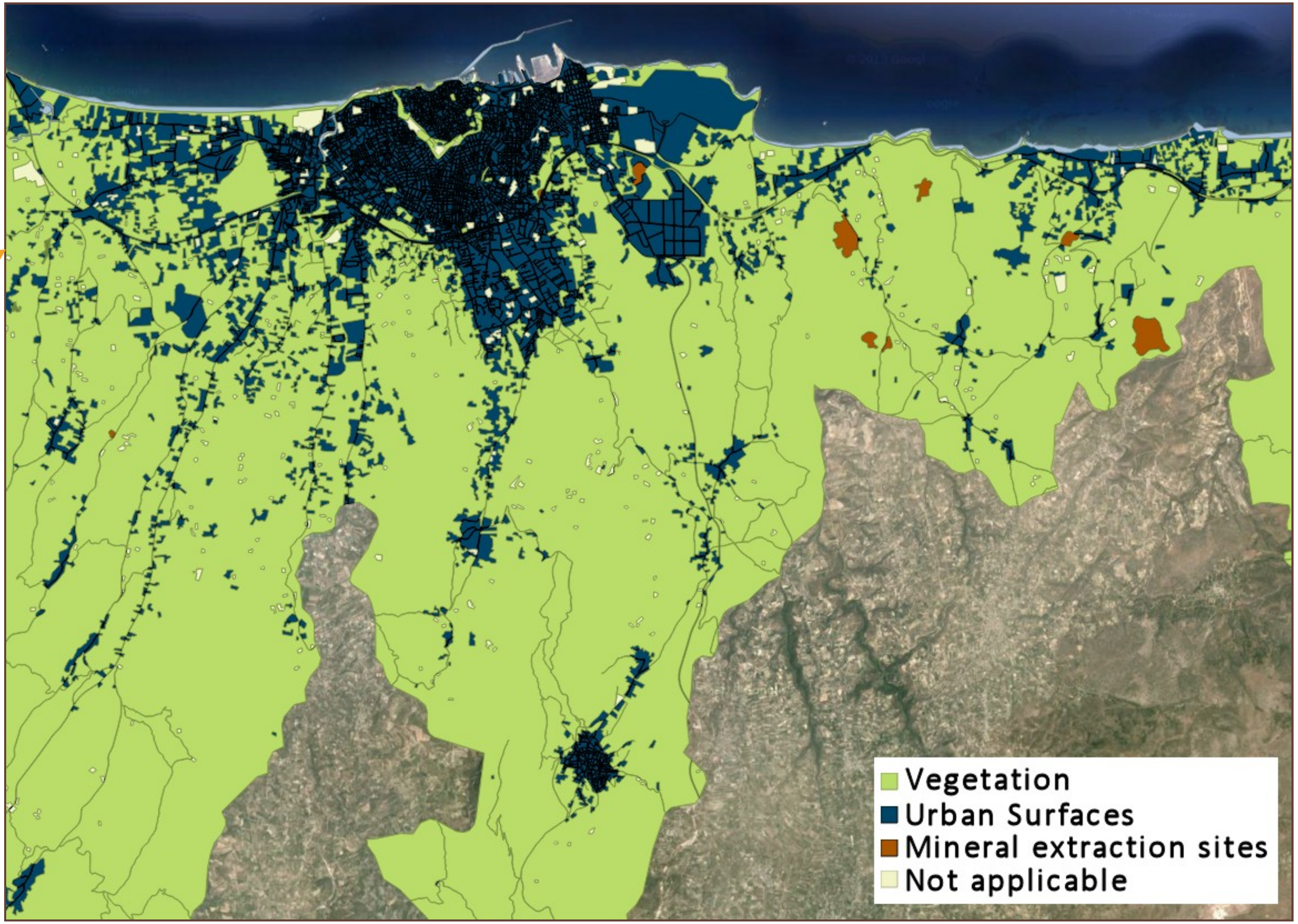
Bootstrap

repeatedly **resample** from the given sample (Monte Carlo simulation results) and estimate the confidence intervals for each new sample

Uncertainty Propagation



Test site and data



<u>Study site:</u>
Heraklion, Greece
Urban and rural area ~315 km2

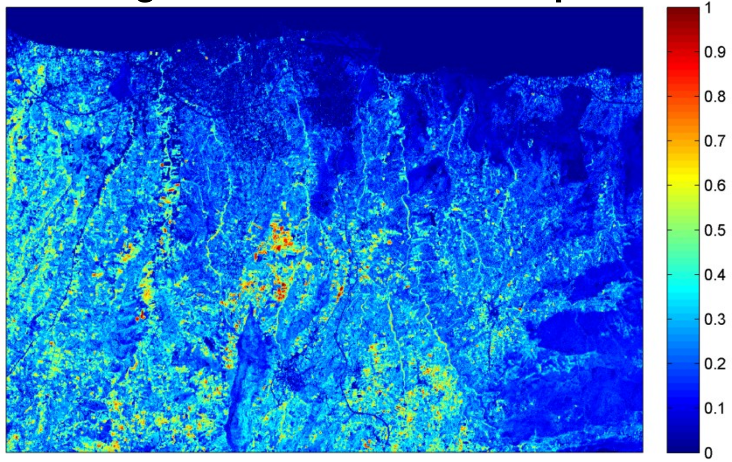
<u>Data:</u>

MODIS Level 1 (MOD021KM), Water Vapor Product (MOD05)
1 km spatial resolution

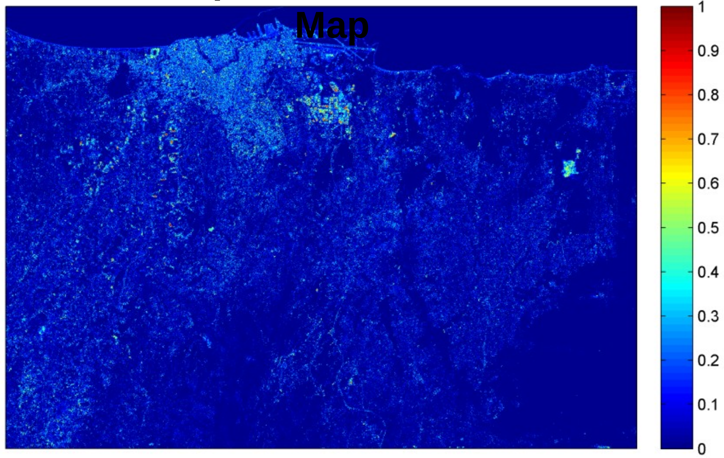
ASTER Level 1b (AST_L1b)
30 m spatial resolution

Surface Cover Fractions

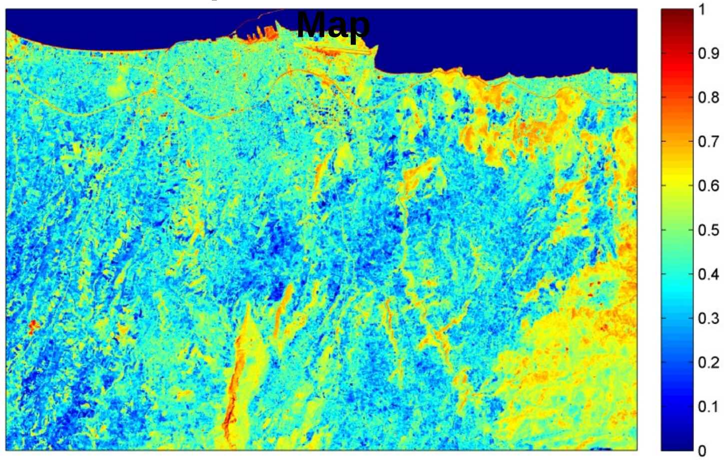
Vegetation Abundance Map



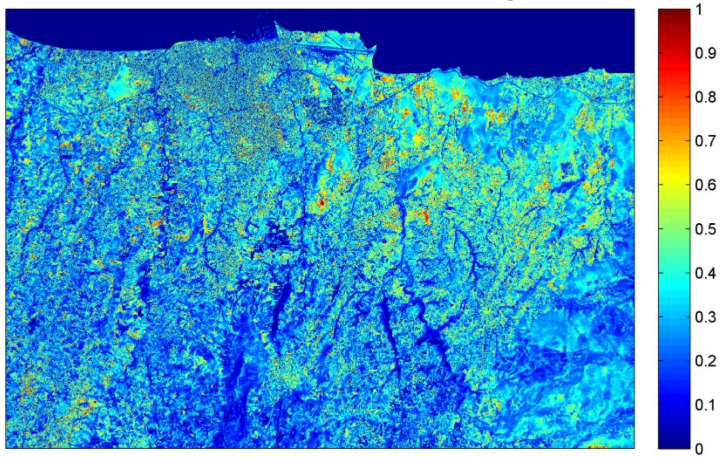
High-Albedo Impervious Surface Abundance Map



Low-Albedo Impervious Surface Abundance Map

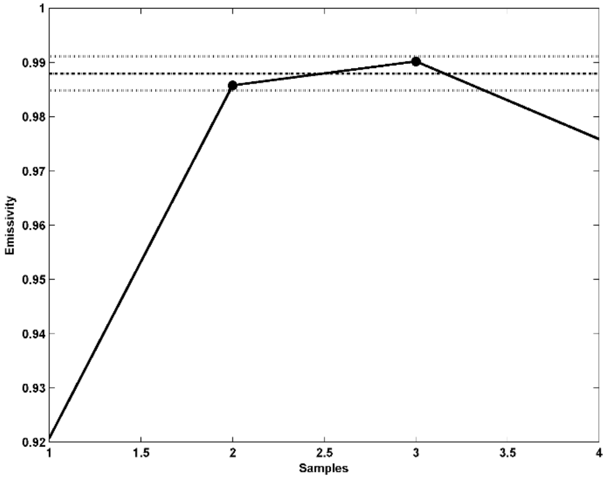


Soil Abundance Map

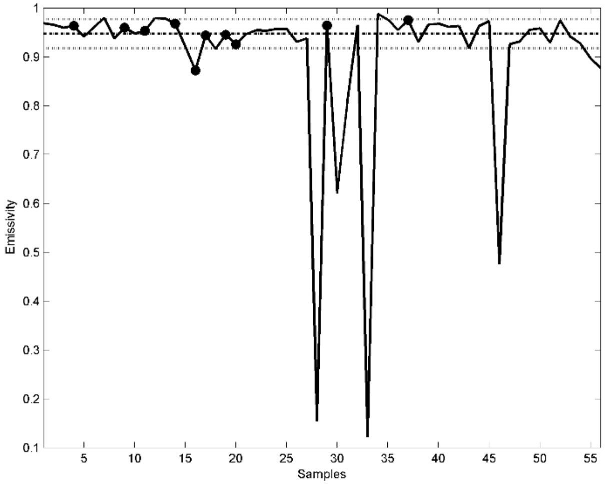


Emissivity

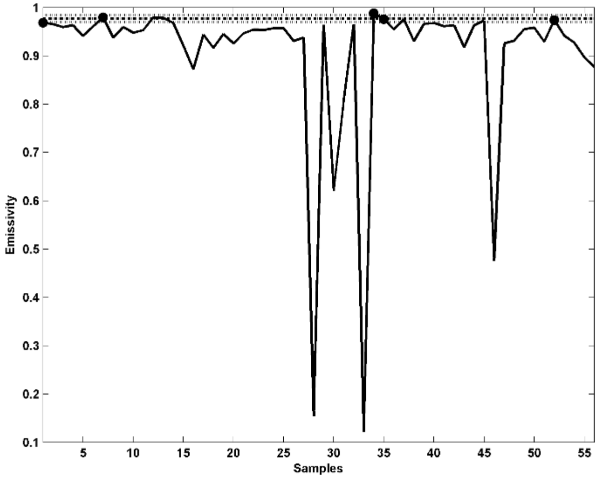
Vegetation



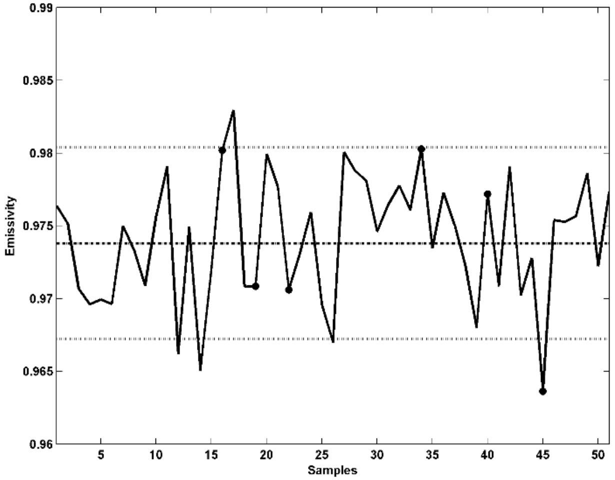
High Albedo Manmade



Low Albedo Manmade

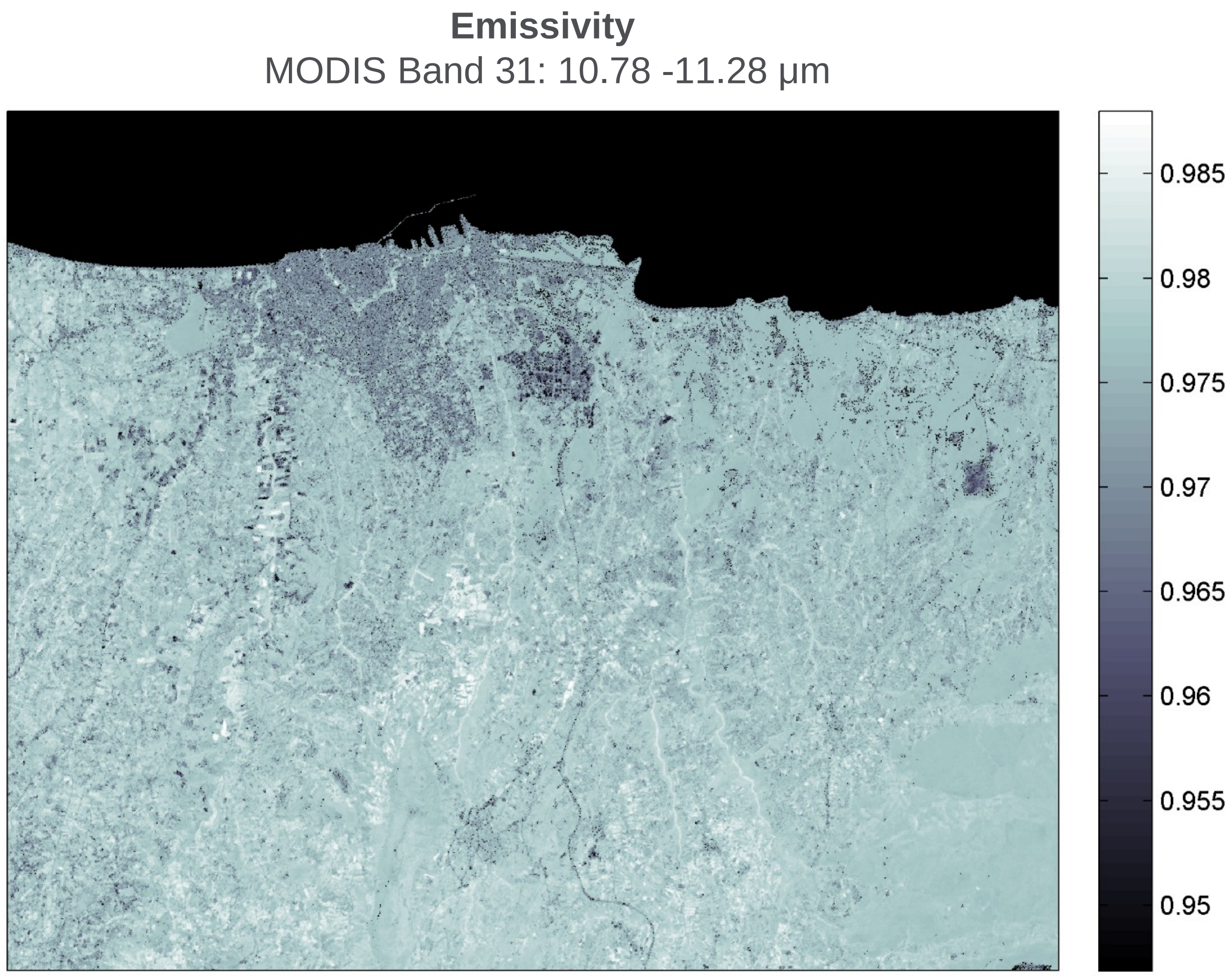


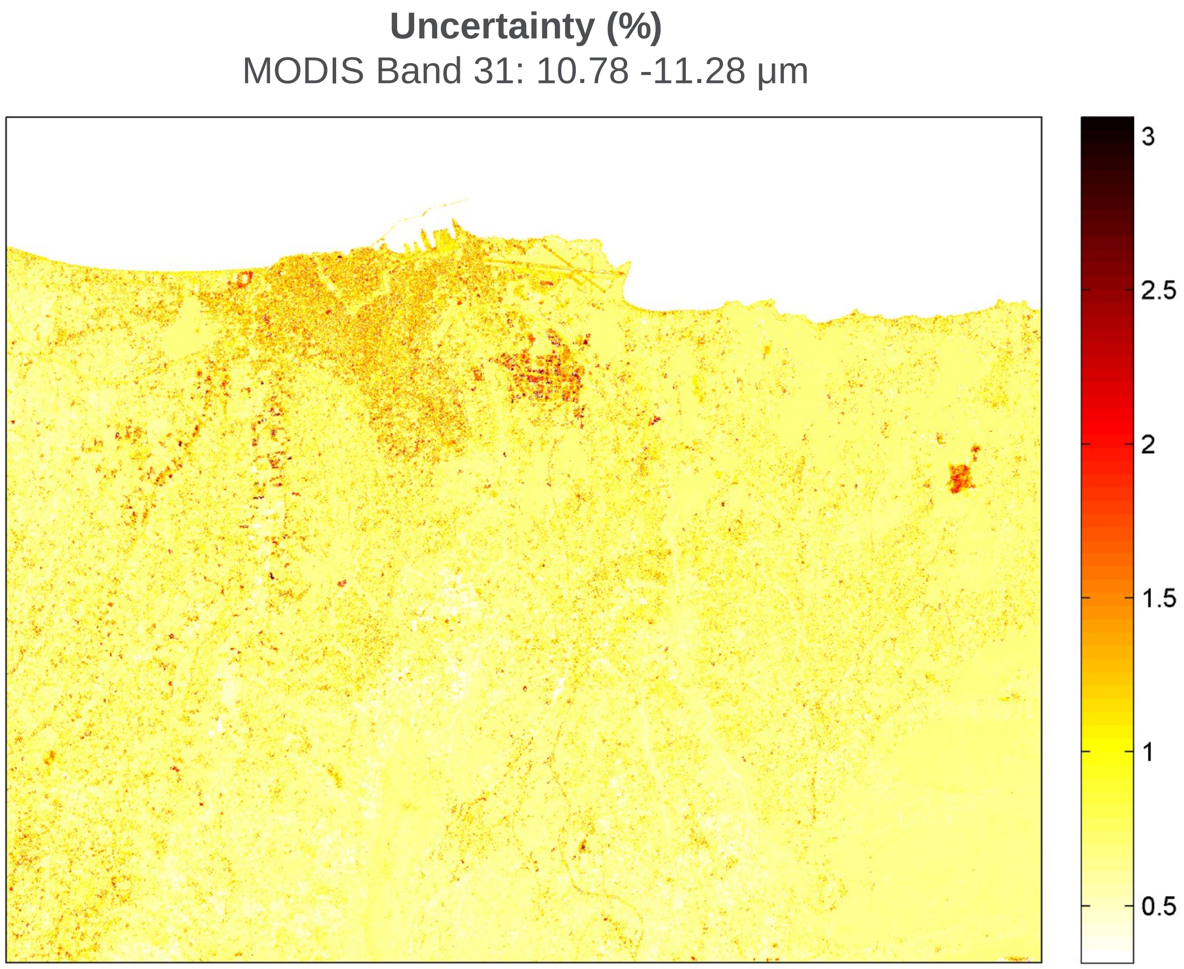
Soils



Surface Cover Type	Emissivity MODIS Band 31 10.78 -11.28 µm	Emissivity MODIS Band 32 11.770-12.270 µm
Vegetation	0.988 ± 0.003	0.991 ± 0.001
High Albedo Manmade	0.95 ± 0.02	0.96 ± 0.02
Low Albedo Manmade	0.977 ± 0.007	0.978 ± 0.003
Soil	0.973 ± 0.07	0.981 ± 0.003

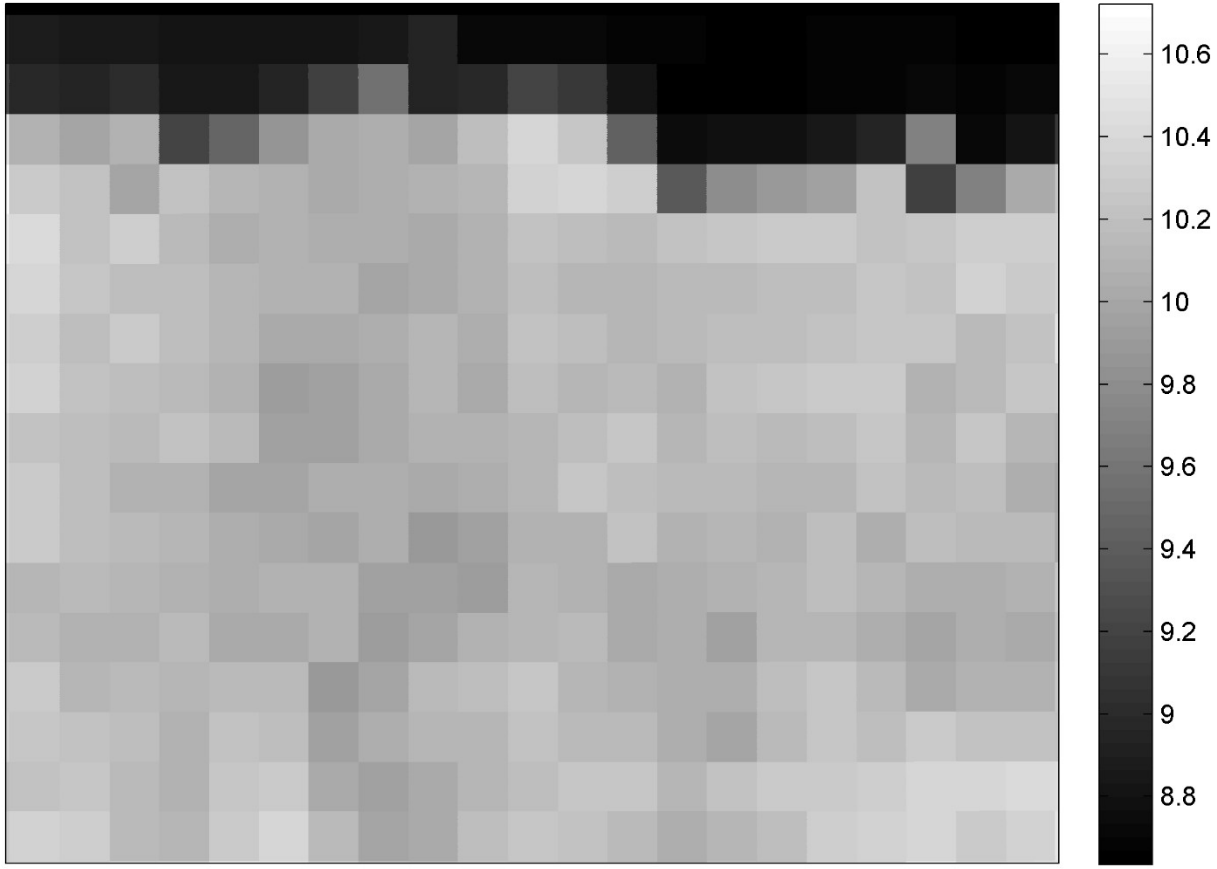
Emissivity


Emissivity
MODIS Band 31: 10.78 -11.28 µm
0.985
0.98
0.975
0.97
0.965
0.96
0.955
0.95

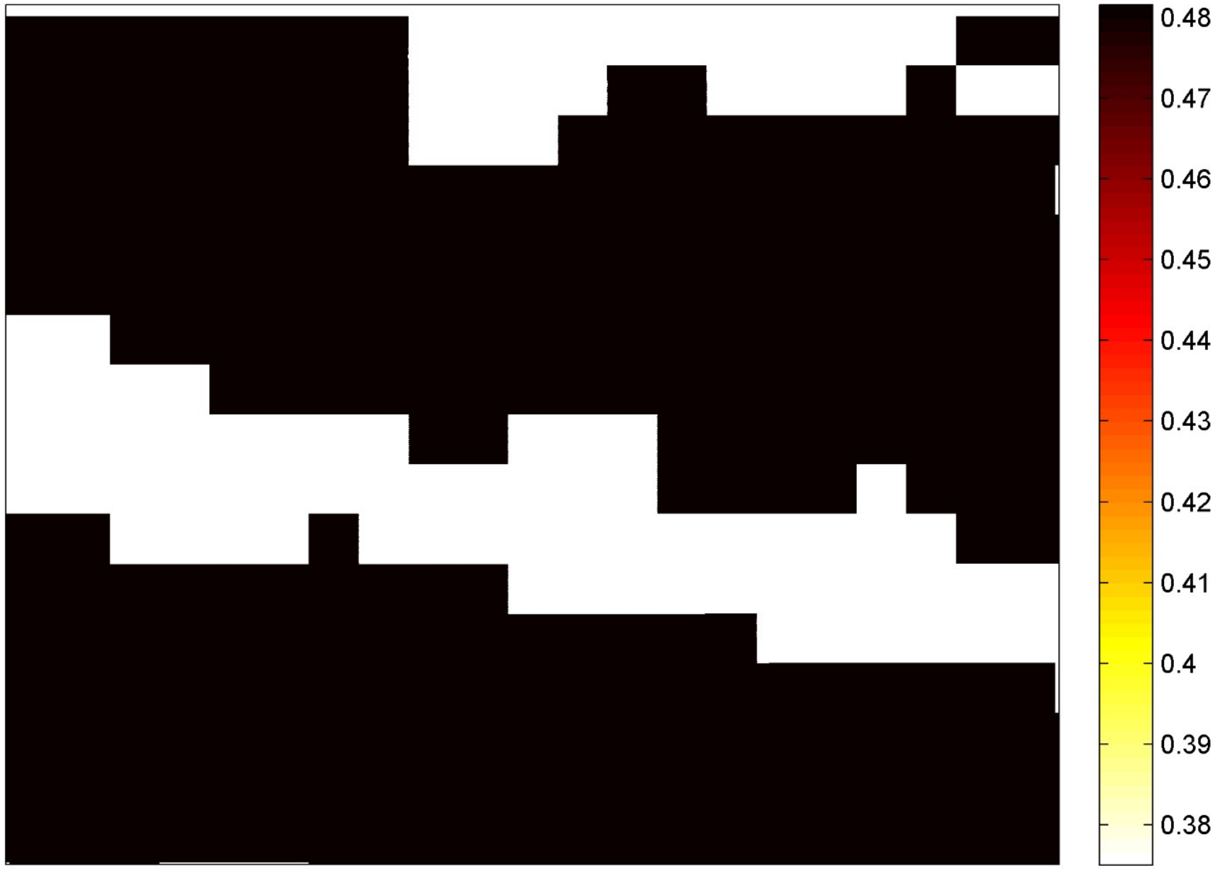

Uncertainty (%)
MODIS Band 31: 10.78 -11.28 µm
3
2.5
2
1.5
1
0.5

Low Resolution TIR Band

Radiance
MODIS Band 31: 10.78 -11.28 μm



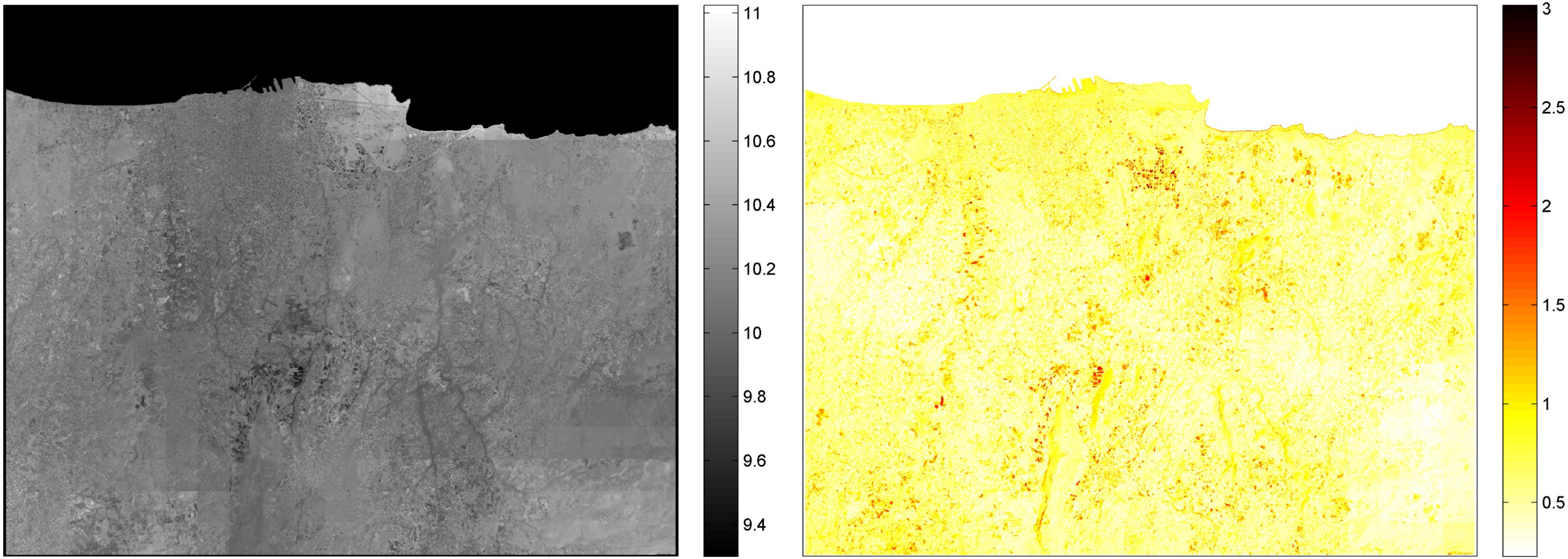
Uncertainty (%)
MODIS Band 31: 10.78 -11.28 μm



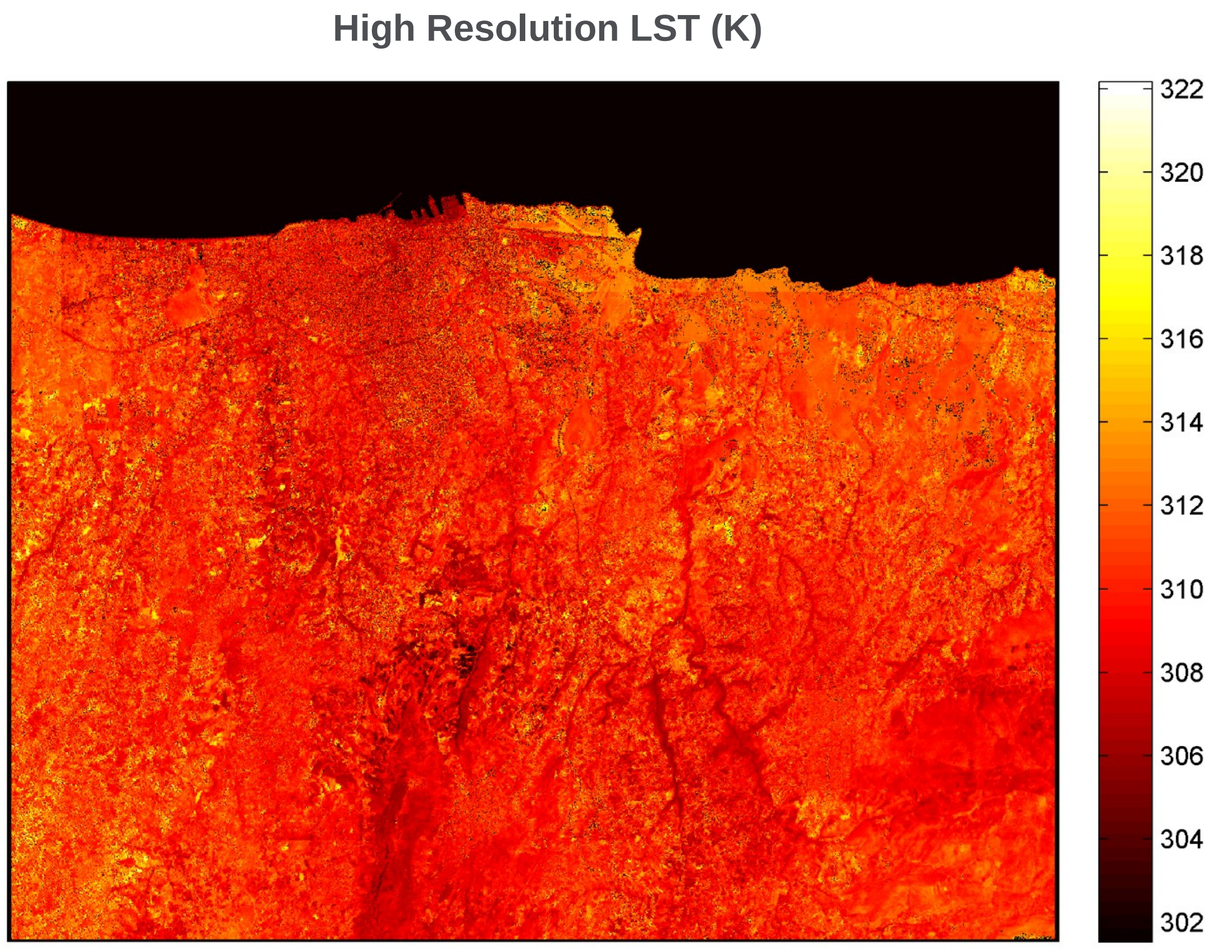
High Resolution TIR band

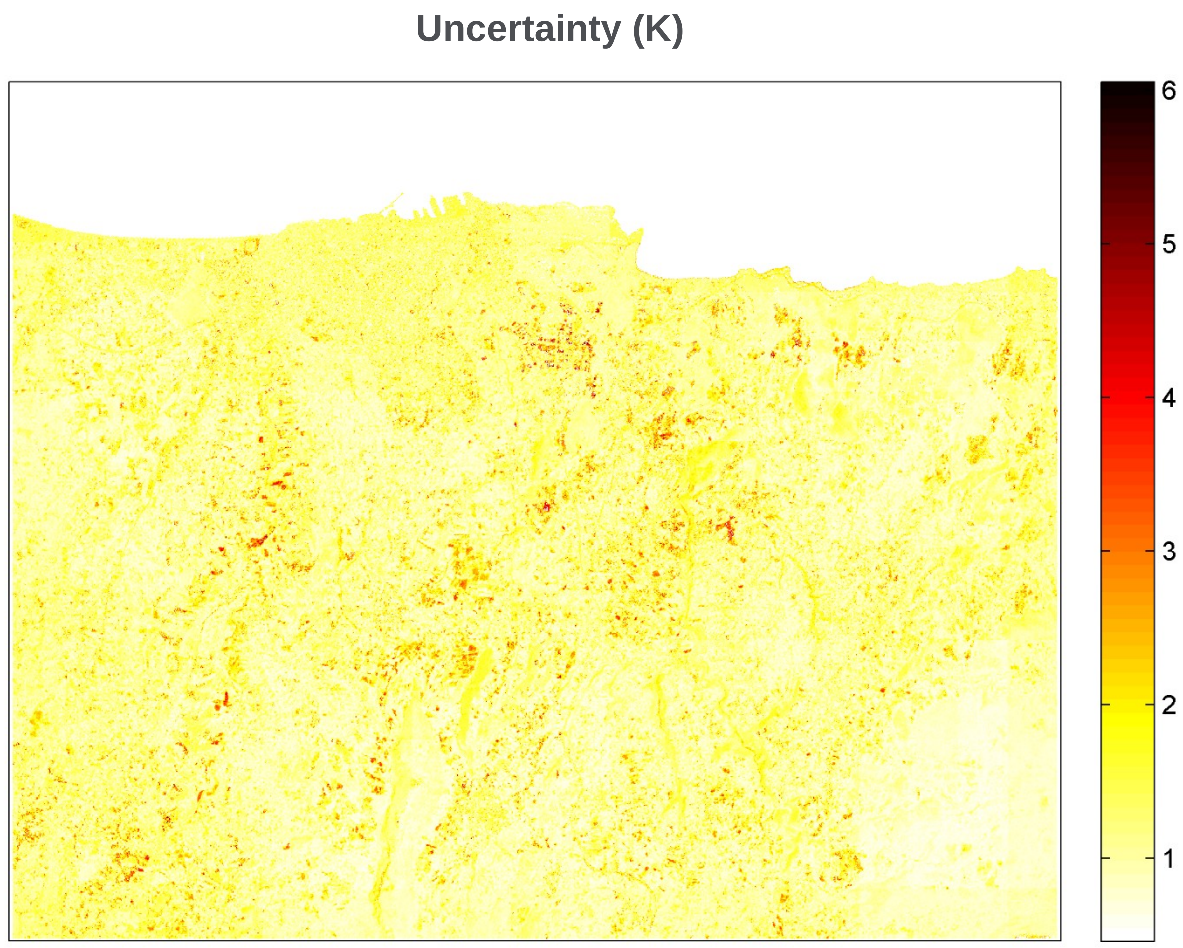
Radiance
MODIS Band 31: 10.78 -11.28 μm

Uncertainty (%)
MODIS Band 31: 10.78 -11.28 μm

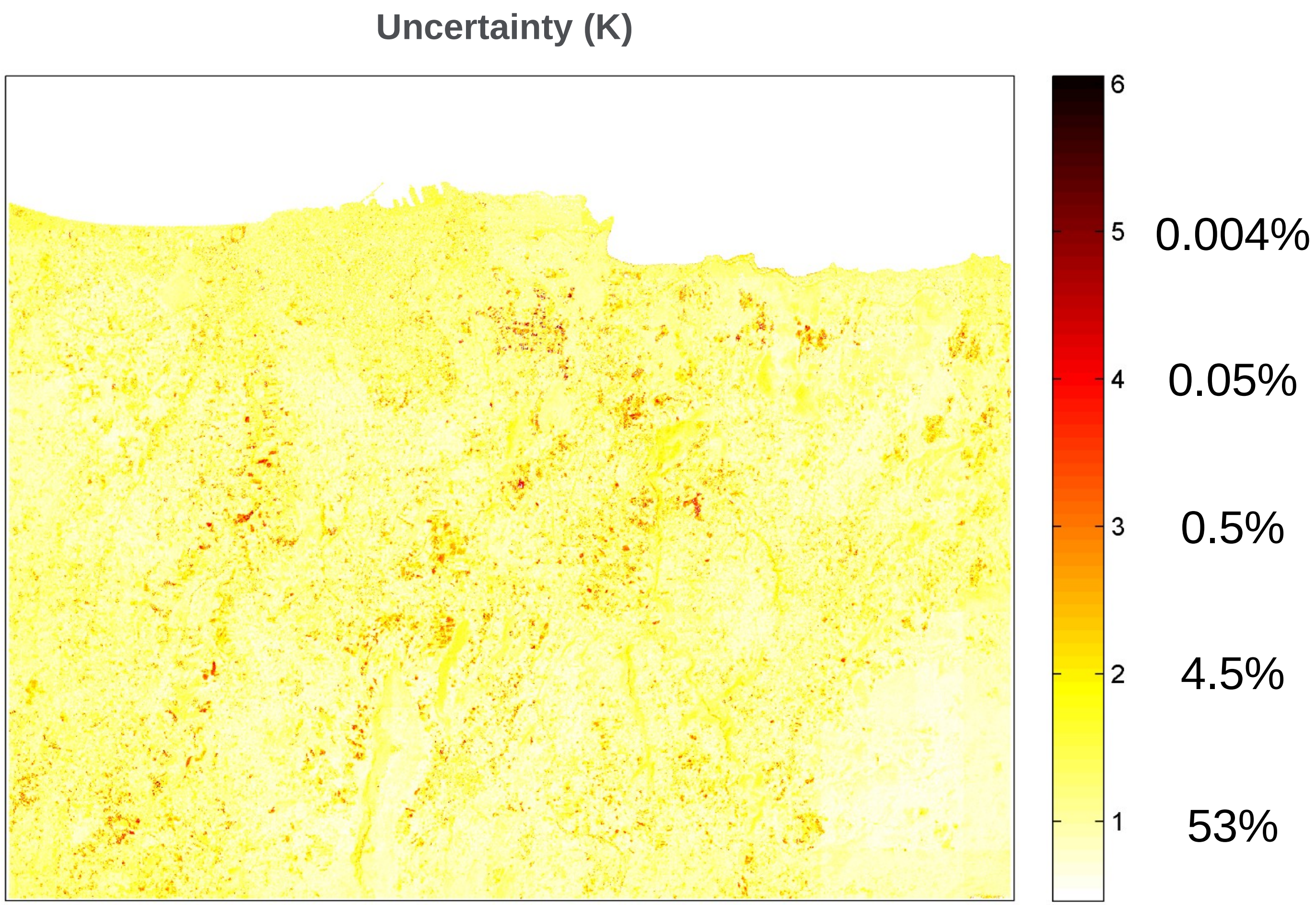


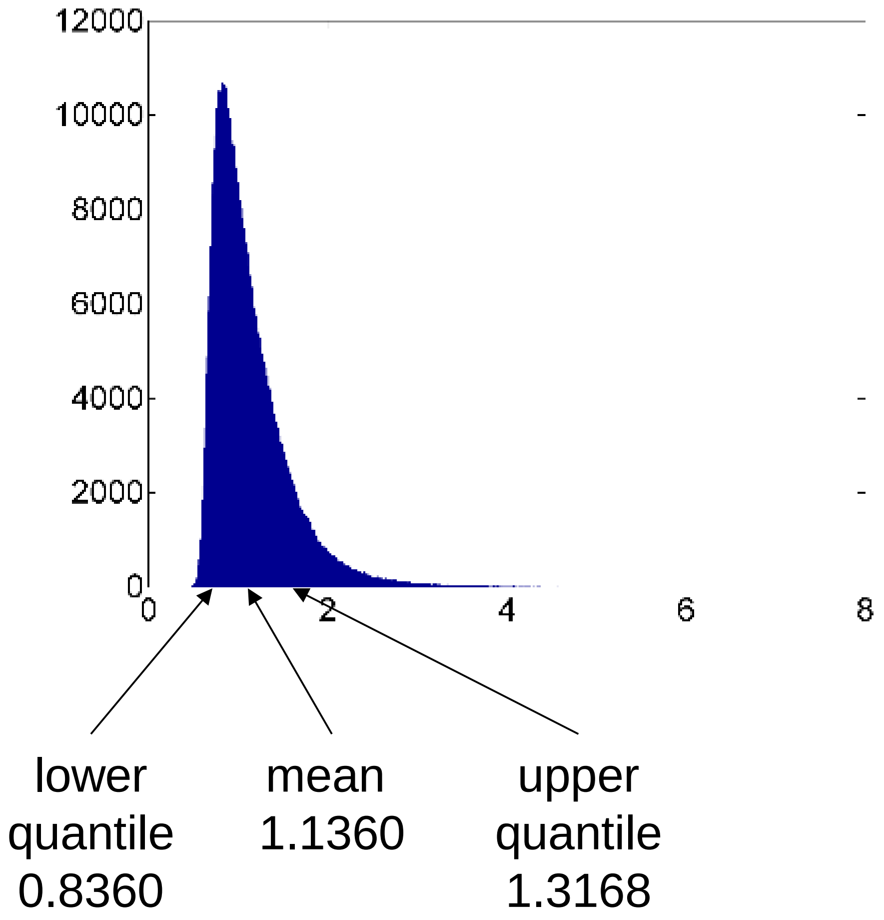
LST


High Resolution LST (K)
322
320
318
316
314
312
310
308
306
304
302


Uncertainty (K)
6
5
4
3
2
1

LST


Uncertainty (K)
6
5
4
3
2
1
0.004%
0.05%
0.5%
4.5%
53%


12000
10000
8000
6000
4000
2000
0
0
2
4
6
8
lower quantile 0.8360
mean 1.1360
upper quantile 1.3168

Conclusions – Further Research

- ***Users require uncertainty estimates*** for EO-based LST products
- Uncertainty estimates of LST products provide ***insights for both the data and the algorithms***, thus they provide valuable source of information for the EO community for data quality and models sensitivity analysis
- ***Statistical methods based on simulations*** can be proven valuable for the estimation of uncertainty in satellite-derived products
- Those methods are ***computationally demanding***, but ***solutions*** to overcome this limitation, may arise in assumptions for the ***behavior of the remote sensors*** as well as for the ***algorithms***
- Assessment of the ***efficiency of different uncertainty propagation methods on EO data*** and algorithms and intercomparison
- Other techniques (i.e. jackknife method) and ***combinations of uncertainty methods*** can be tested

Thank you for your attention…