In-situ LST uncertainty analysis of the new Copernicus LAW stations

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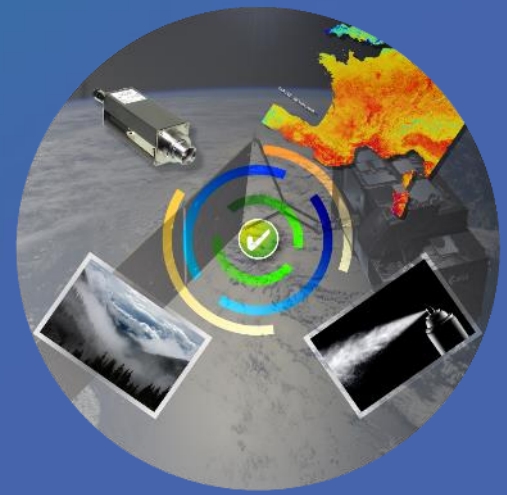
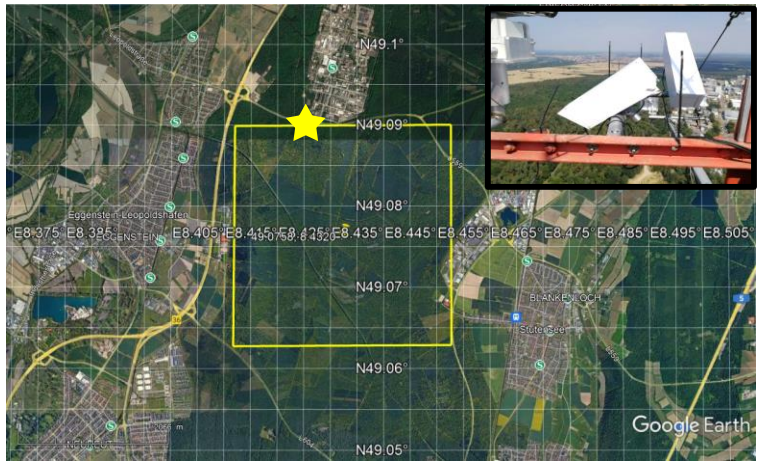


“Copernicus Space Component Validation for Land Surface Temperature, Aerosol Optical Depth and Water Vapor Sentinel-3 Products (LAW)” Project

- Copernicus LAW started in January 2021.
- Main objective: validate operational Sentinel-3 products for Integrated Water Vapour (IWV), Aerosol Optical Depth (AOD) and Land Surface Temperature (LST).
- Project details and some LST validation results:
  - https://law.acri-st.fr/
  - ESA LPS 2022: Posters 64013 (Project overview), 63004 (Sentinel-3 LST validation)
- Five new LST validation stations over previously unrepresented biomes:
  - KIT Forest – Germany: closed broadleaved deciduous forest.
  - Svartberget – Sweden: open needle leaved deciduous or evergreen forest.
  - Hyytiälä – Finland: closed to open mixed broadleaved and needle leaved forest.
  - Robson Creek – Australia: closed to open broadleaved evergreen and/or semi-deciduous forest.
  - Puéchabon – France: holm oak forest.

Copernicus LAW sites

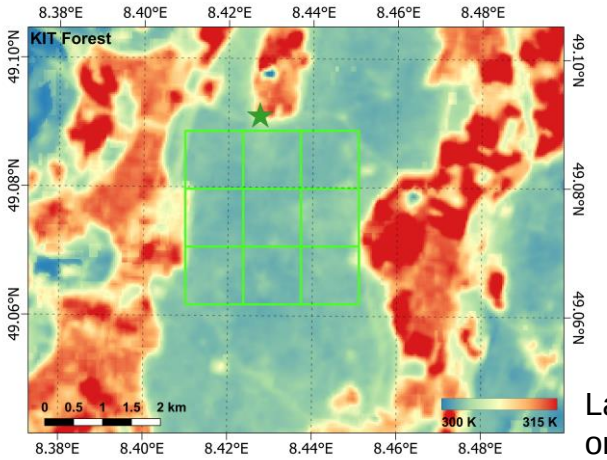
KIT Forest - GERMANY



Latitude, Longitude
49.091°N, 8.425°E

Deployment
August, 2020

Land cover class
Closed broadleaved deciduous forest



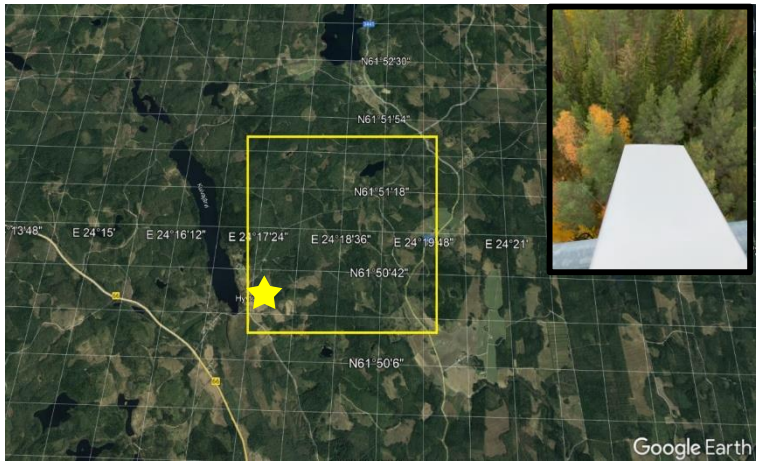
Thermal homogeneity

Estimated as SD of pixels in

- 1 x 1 km^2: 0.3 K
- 1.5 x 1.5 km^2: 0.3 K
- 3 x 3 km^2: 0.5 K

Landsat 8 – TIRS LST scene acquired on 14th of August, 2021

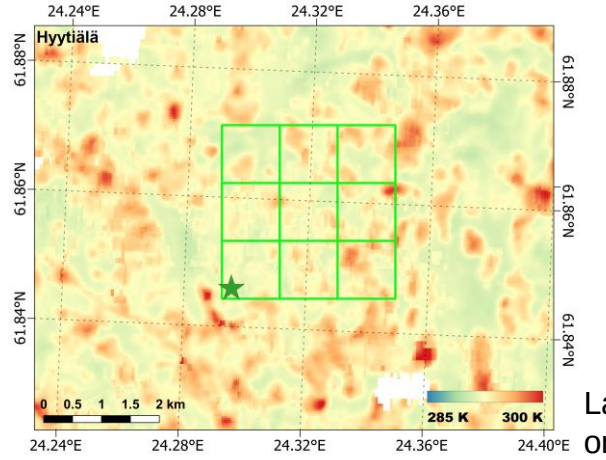
HYYTIÄLÄ - FINLAND



Latitude, Longitude
61.846°N, 24.296°E

Deployment
October, 2021

Land cover class
Closed to open mixed broadleaved and needle leaved forest



Thermal homogeneity

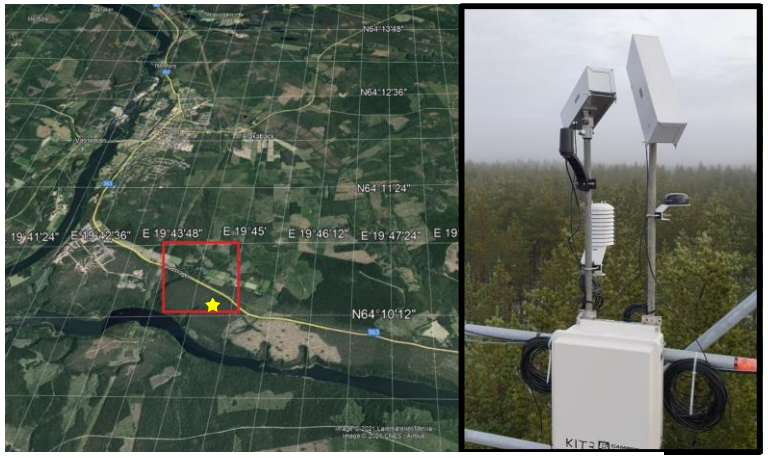
Estimated as SD of pixels in

- 1 x 1 km^2: 0.5 K
- 1.5 x 1.5 km^2: 0.9 K
- 3 x 3 km^2: 1.2 K

Landsat 8 – TIRS LST scene acquired on 28th of June, 2019

Copernicus LAW sites

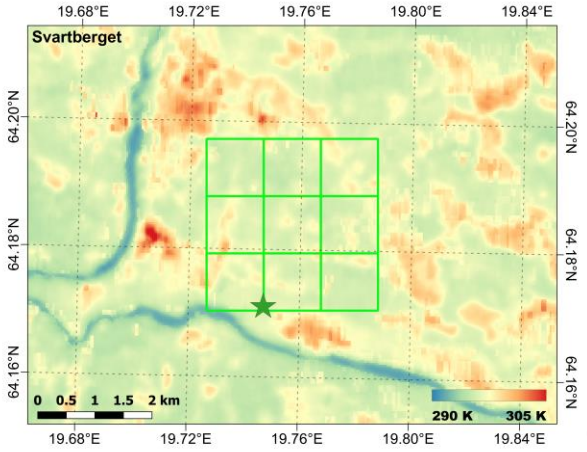
SVARTBERGET - SWEDEN



Latitude, Longitude
64.171°N, 19.747°E

Deployment
October, 2021

Land cover class
Open needle leaved deciduous or evergreen forest



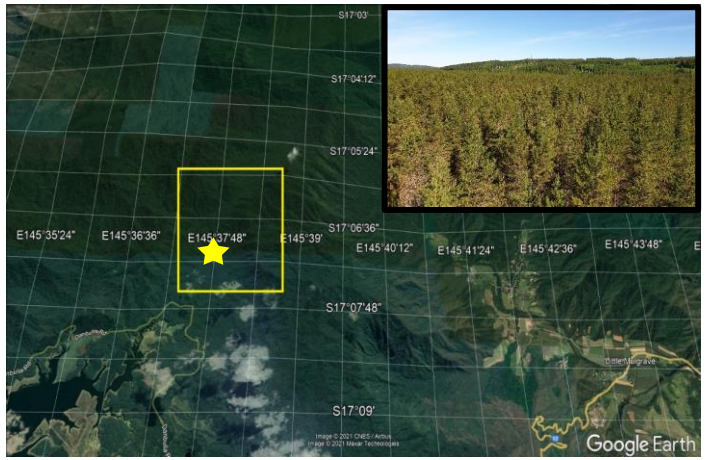
Thermal homogeneity

Estimated as SD of pixels in

- 1 x 1 km^2: 0.5 K
- 1.5 x 1.5 km^2: 0.6 K
- 3 x 3 km^2: 1.1 K

Landsat 8 – TIRS LST scene acquired on 27th of August, 2019

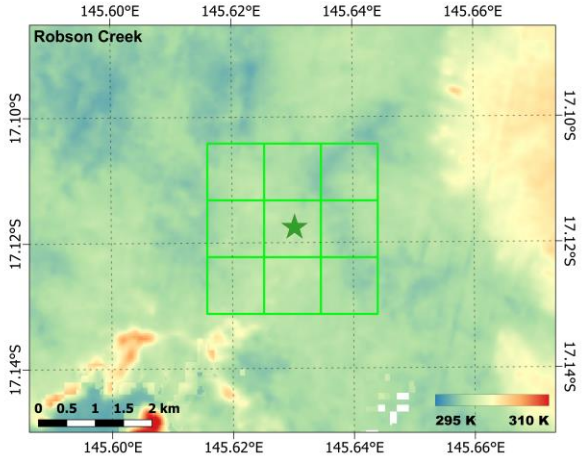
ROBSON CREEK - AUSTRALIA



Latitude, Longitude
-17.118°N, 145.630°E

Deployment
October, 2021

Land cover class
Broadleaved evergreen and/or semideciduous forest (tropical rainforest)



Thermal homogeneity

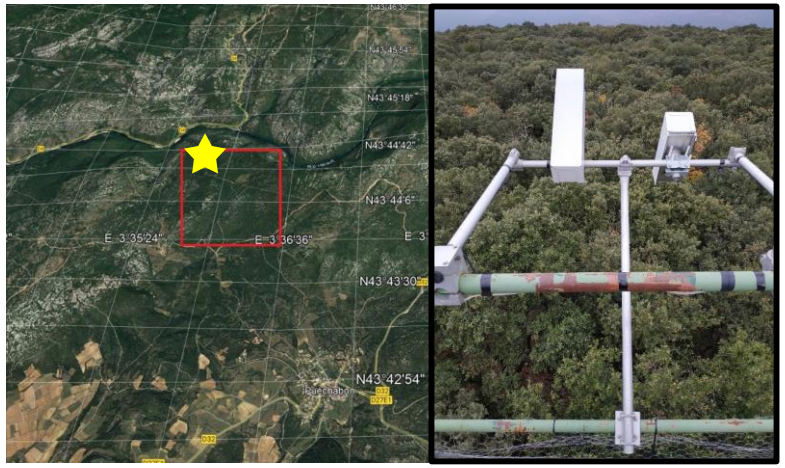
Estimated as SD of pixels in

- 1 x 1 km^2: 0.3 K
- 1.5 x 1.5 km^2: 0.4 K
- 3 x 3 km^2: 0.5 K

Landsat 8 – TIRS LST scene acquired on 12th of October, 2021

Copernicus LAW sites

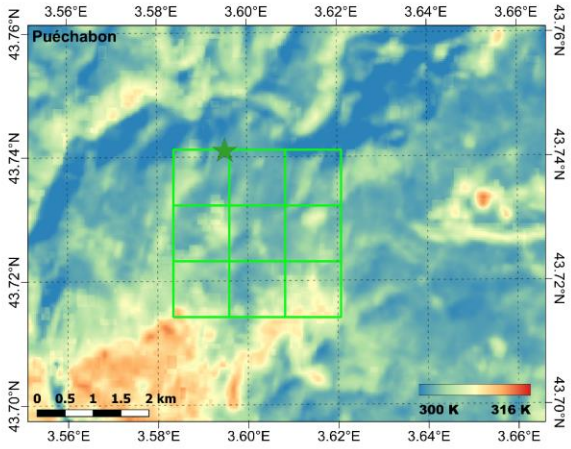
PUECHABON - FRANCE



Latitude, Longitude
43.741°N, 3.596°E

Deployment
October, 2021

Land cover class
Holm oak forest
(Sparse vegetation in ALB2 classification)

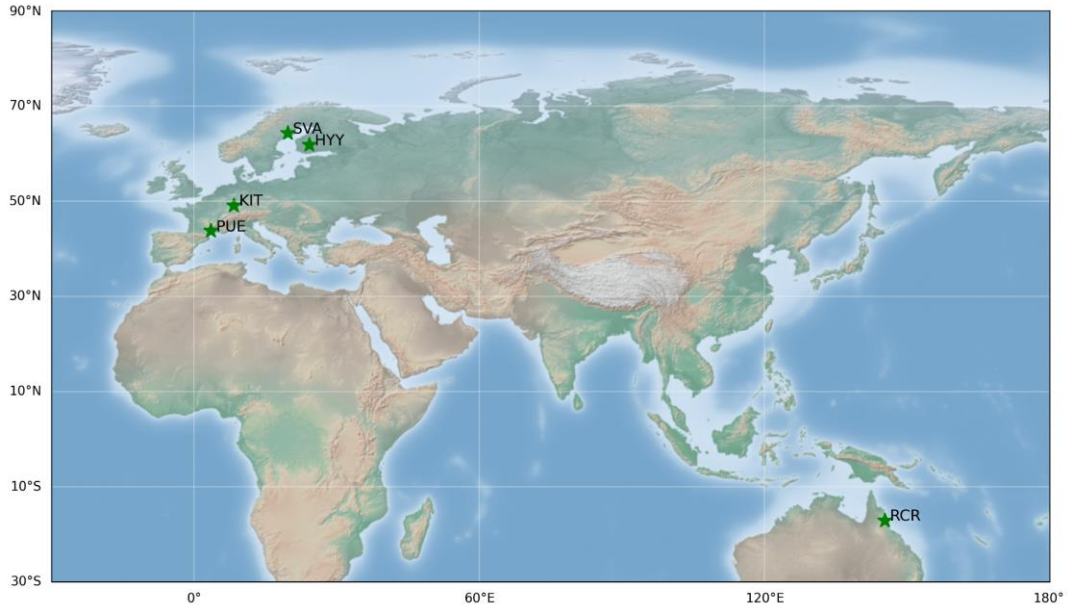


Thermal homogeneity

Estimated as SD of pixels in

- 1 x 1 km^2: 0.5 K
- 1.5 x 1.5 km^2: 0.9 K
- 3 x 3 km^2: 1.5 K

Landsat 8 – TIRS LST scene acquired on the 28th of August, 2021



Site	Deployment	Latitude (°)	Longitude (°)
KIT CN	30/7/2020	49.091	8.425
Hyytiälä	1/10/2021	61.846	24.296
Puechabon	5/10/2021	43.741	3.596
Robson Creek	15/10/2021	-17.118	145.630
Svartberget	27/10/2021	64.171	19.747

https://law.acri-st.fr/sites

Measuring instruments

All Copernicus LAW stations are equipped with:

- Two thermal infrared Heitronics KT15.85 IIP radiometers:
  - Spectral range: 9.6 – 11.5 µm
  - Field of view of 8.5°
  - Uncertainty of ±0.3 K
  - High temporal stability

- Air temperature & humidity sensor (HygroVUE10)
  - Relative humidity uncertainty: ±2 %
  - Air temperature uncertainy: ±0.2 °C

- Remote access & GPS receiver (stable timing)

Heitronics KT15.85 IIP

Source: https://www.heitronics.com

HygroVUE10

Source: https://www.campbellsci.com/hygrovue10

In-situ LST and uncertainty retrieval

1) Ground brightness Temperature (BT_L) and sky temperature (BT_S) are converted to radiance (L_g and L_S, respectively) via the Planck function.

2) The sky measurements must be corrected for the rain and dust protective window contribution (nominal transmissivity (τ_w) of 0.895).

3) The corrected sky radiance and surface emissivity (ε) are then used to correct measured ground radiance for atmospheric and emissivity effects:

$$\boldsymbol{B(LST)} = \frac{\boldsymbol{L_g} - (1 - \boldsymbol{\varepsilon})\boldsymbol{L_S}}{\boldsymbol{\varepsilon}}$$

4) LST uncertainty is obtained via error propagation (equation below) using the estimated uncertainties of the involved variables (table to the right).

$$\boldsymbol{\delta(y)} = \sqrt{\sum_{\boldsymbol{i}} \left[\frac{\partial(\boldsymbol{y})}{\partial(\boldsymbol{x_i})}\boldsymbol{\delta(x_i)}\right]^2}$$

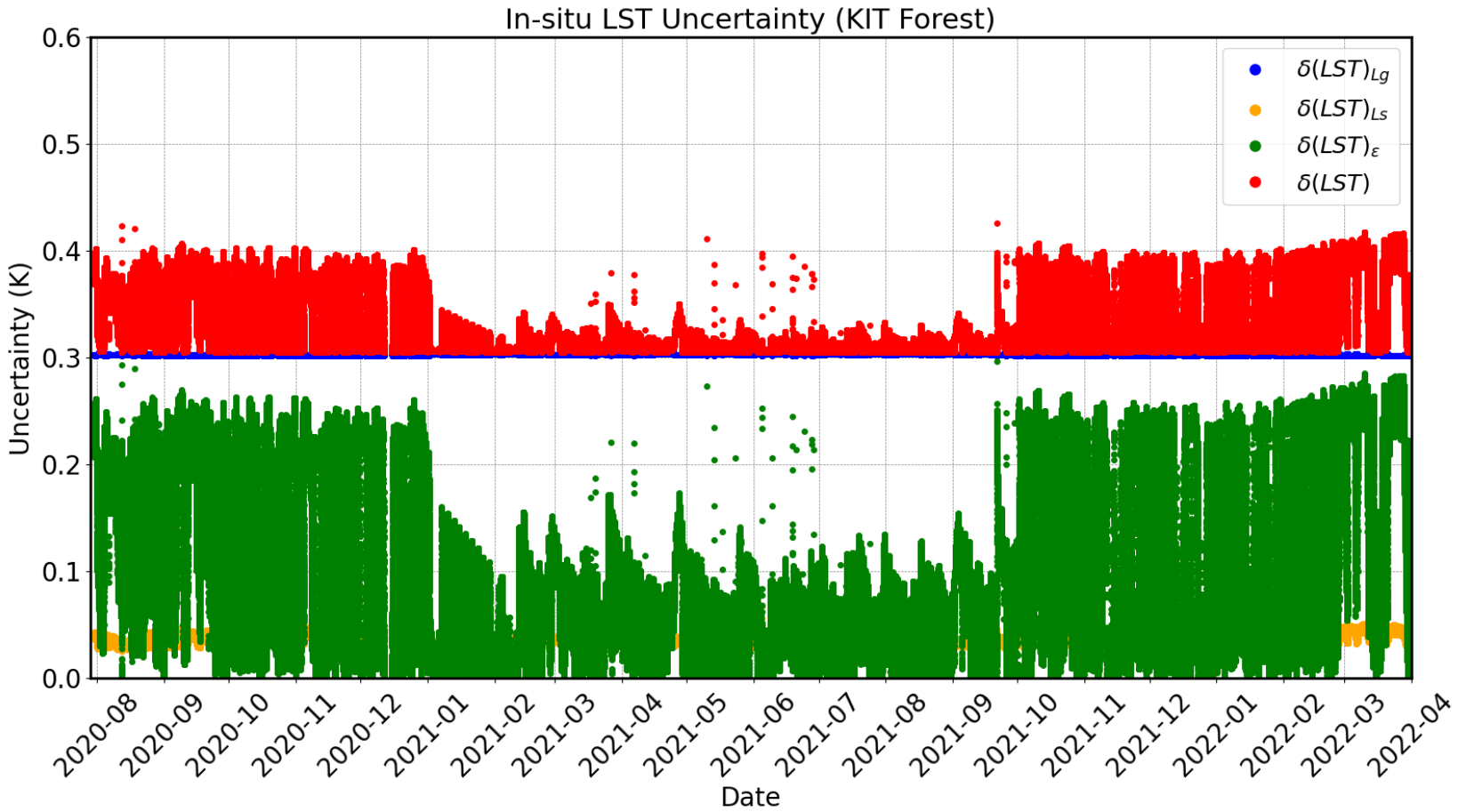
Effective KT15.85 emissivity for each site

Site	ε (10.8 µm)
KIT CN	0.988 ± 0.005
Hyytiälä	0.991 ± 0.006
Puechabon	0.991 ± 0.006
Robson Creek	0.991 ± 0.006
Svartberget	0.989 ± 0.005

Uncertainties of the variables involved in LST retrieval

Variable	Uncertainty
BT	±0.03 K
τ_w	-0.045
ε (KIT Forest, Puechabon)	±0.005
ε (Hyytiälä, Svartberget, Robson Creek)	±0.006

In-situ LST uncertainty



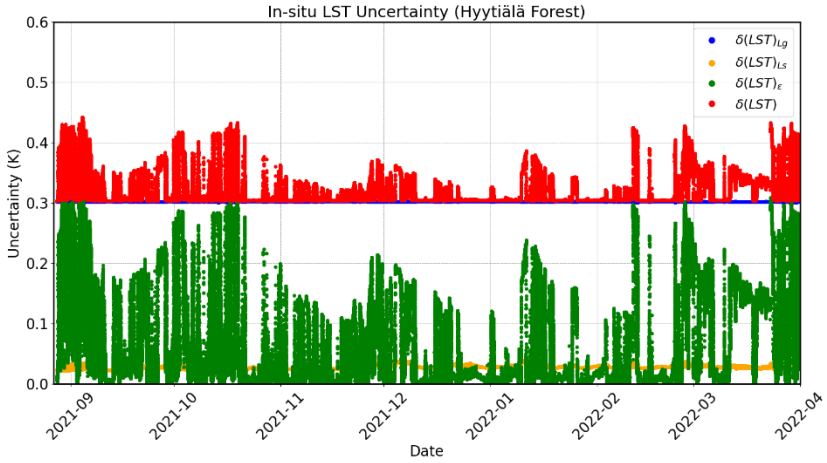
Uncertainty of in-situ LST, δ(LST)

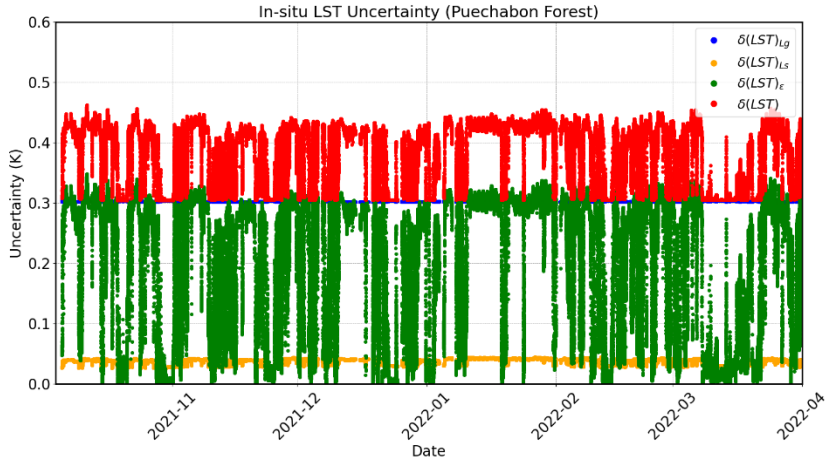
Contribution to δ(LST) of the variables:

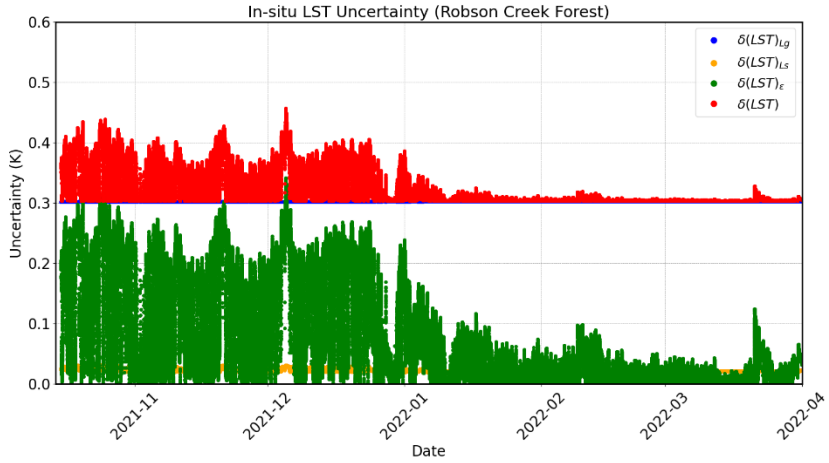
- Ground radiance, $\delta(LST)_{Lg}$
- Sky radiance, $\delta(LST)_{Ls}$
- Emissivity, $\delta(LST)_{\varepsilon}$

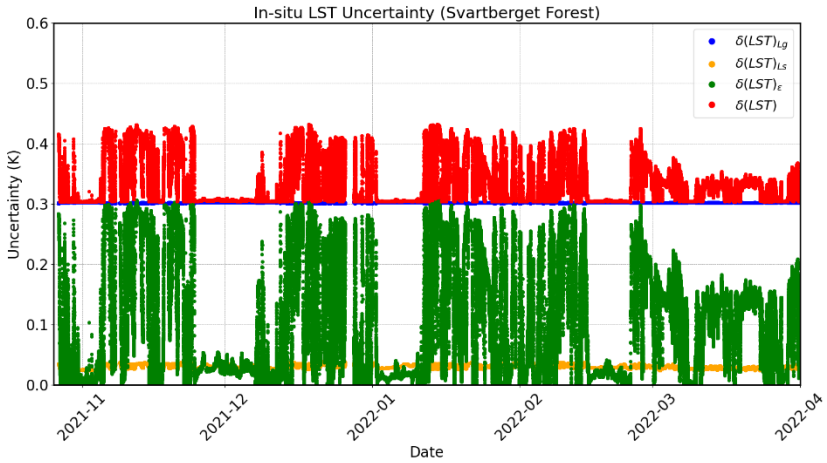
Uncertainty	Mean (K)	SD (K)	Max (K)
δ(LST)	0.327	0.030	0.425
$\delta(LST)_{Lg}$	0.3030	0.0006	0.305
$\delta(LST)_{Ls}$	0.035	0.005	0.072
$\delta(LST)_{\varepsilon}$	0.090	0.081	0.297

In-situ LST uncertainty









Mean, SD and maximum of the in-situ LST uncertainty, δ(LST), at the five LAW sites

Site	Mean (K)	SD (K)	Maximum (K)
KIT Forest	0.33	0.03	0.43
Hyytiälä	0.32	0.03	0.44
Puéchabon	0.38	0.05	0.46
Robson Creek	0.32	0.03	0.46
Svartberget	0.33	0.04	0.43

Summary & Conclusions

- Copernicus LAW deployed five new LST validation stations (previously unrepresented biomes).
- All sites are thermally homogeneous at the Sentinel-3 SLSTR pixel scale, i.e. 1 x 1 km^2
  - KIT Forest and Robson Creek are thermally homogeneous up to 3 x 3 km^2
- For all sites similar LST uncertainties were determined:
  - Mean LST uncertainties are between 0.3 and 0.4 K
  - Maximum LST uncertainties are below 0.5 K
- The largest uncertainty contribution is associated with emissivity under clear sky conditions, i.e. when the difference between sky radiance and ground radiance is large.
- For conservative validation results, the determined maximum value of ~0.5 K should be taken as in-situ LST uncertainty.