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Validation of Sentinel-3 Land Surface Temperature datasets against ground-based measurements

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1. Introduction

- **Land Surface Temperature (LST) data is integral to our understanding of the Earth's surface energy budget and challenges including urban heat, and agricultural stress and yield.**
- The **Sea and Land Surface Temperature Radiometer (SLSTR) aboard Sentinel-3A/B** provides LST data at **unprecedented spatial resolutions (1 km)**. LST measured by these instruments must have an **accuracy of < 1.0 K** (Sentinel-3 Mission Requirements Document, 2007), and a **precision of < 1.0 K** (GCOS Implementation Plan, 2016)
- Started in 2020 for a two-year period, the *Copernicus Space Component Validation for Land Surface Temperature, Aerosol Optical Depth and Water Vapor Sentinel-3 Products Project* (LAW) aims to perform an **extensive and systematic validation of Sentinel-3 LST data via comparison with in-situ measurements.** The SL_2_LST retrieval algorithm is **biome-specific**, so in-situ data must come from a variety of biomes.
- The Gap Analysis (2020) revealed that **existing LST in-situ networks lacked adequate coverage of specific biomes**. To remedy this, LAW established **five new in-situ stations**:

Site Name	Country	Biome (ALB2 class)	Valid Data From
Svartberget	Sweden	Open (15–40%) needleleaved deciduous or evergreen forest (>5 m) (9)	26/10/2021
Hyytiälä	Finland	Closed to open (>15%) mixed broadleaved and needleleaved forest (>5 m) (10)	01/10/2021
KIT forest site	Germany	Closed (>40%) broadleaved deciduous forest (>5 m) (6)	30/07/2020
Robson Creek	Australia	Closed to open (>15%) broadleaved evergreen and/or semideciduous forest (>5 m) (5)	18/11/2021
Puéchabon	France	Sparse (>15%) vegetation (woody vegetation, shrubs, and grassland) (15)	05/10/2021

Table 1: LAW in-situ LST validation station locations, ALB2 biome classification, and data availability

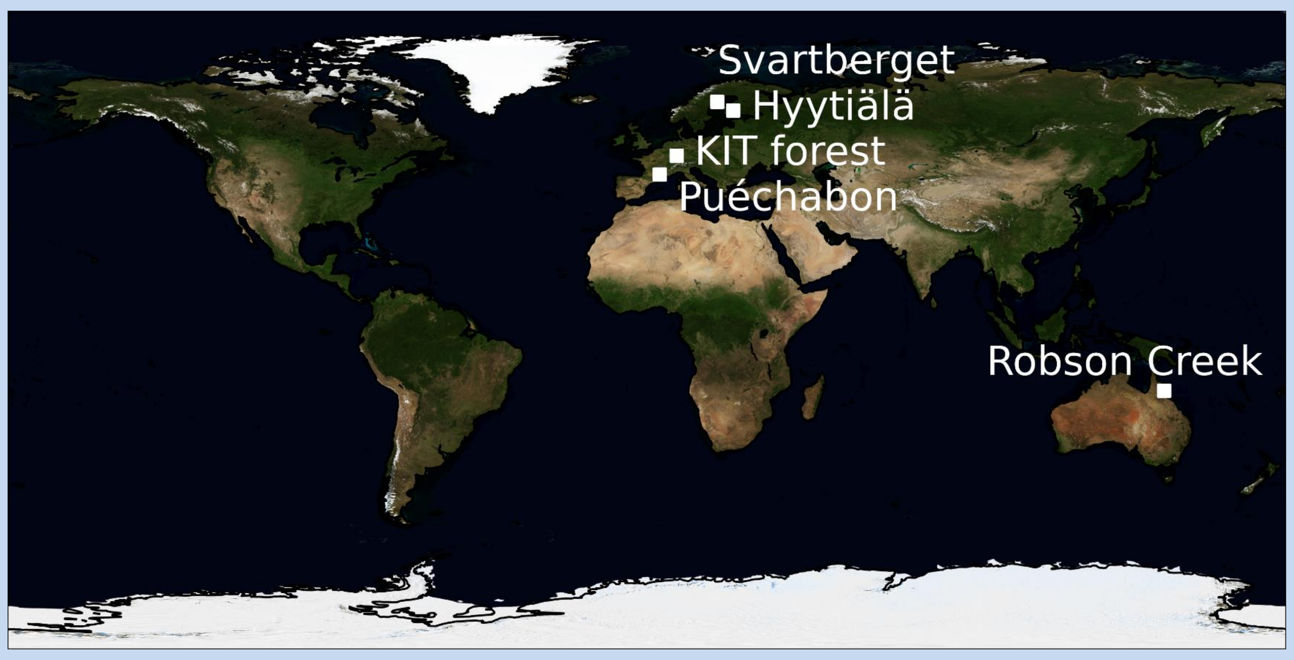

Figure 1: LAW in-situ LST validation station locations

2. LST Validation

- Sentinel-3A/B LST **data up to February 2022** were compared against in-situ measurements.
- Due to **scene inhomogeneity** around the stations, **Svartberget, KIT, and Hyytiälä** data were compared against **spatially offset ground pixels** thought to be more representative of the site biome. The area around **Robson Creek and Puéchabon** is **spatially homogeneous**, so **ground pixels overstriking these sites** were used in this analysis.
- In-situ data recorded to the **nearest minute of the satellite overpass** was selected.
- Additional **cloud clearing** was performed a **2σ Hampel filter** applied to the Sentinel-3 LST data (Göttsche et al, 2013)
- The following metrics were calculated for **day/night** matched observations for both Sentinel-3A and 3B:
  - **Accuracy:** Median bias between Sentinel-3 and in-situ LST data
  - **Precision:** Robust standard deviation of the bias between Sentinel-3 and in-situ LST

Site name	Sentinel-3A						Sentinel-3B					
	Day			Night			Day			Night		
	N	Acc	Prec	N	Acc	Prec	N	Acc	Prec	N	Acc	Prec
Svartberget	60	-0.875	1.542	63	-0.774	1.496	63	-0.970	1.344	61	-1.342	1.020
Hyytiälä	49	-0.904	0.484	48	-1.052	0.662	50	-0.690	0.569	51	-1.022	0.724
KIT forest	110	0.223	0.653	142	-0.432	0.477	107	-0.036	0.612	148	-0.432	0.509
Robson Creek	10	-0.683	0.321	35	0.550	0.702	12	0.826	0.785	37	0.628	0.532
Puéchabon	48	0.763	1.124	51	-0.134	0.814	47	0.402	0.592	64	-0.235	0.600

Table 2: Validation statistics of the comparisons between Sentinel-3 and in-situ LST. N = number of cloud-free overpasses, Acc = accuracy, Prec = precision [K]

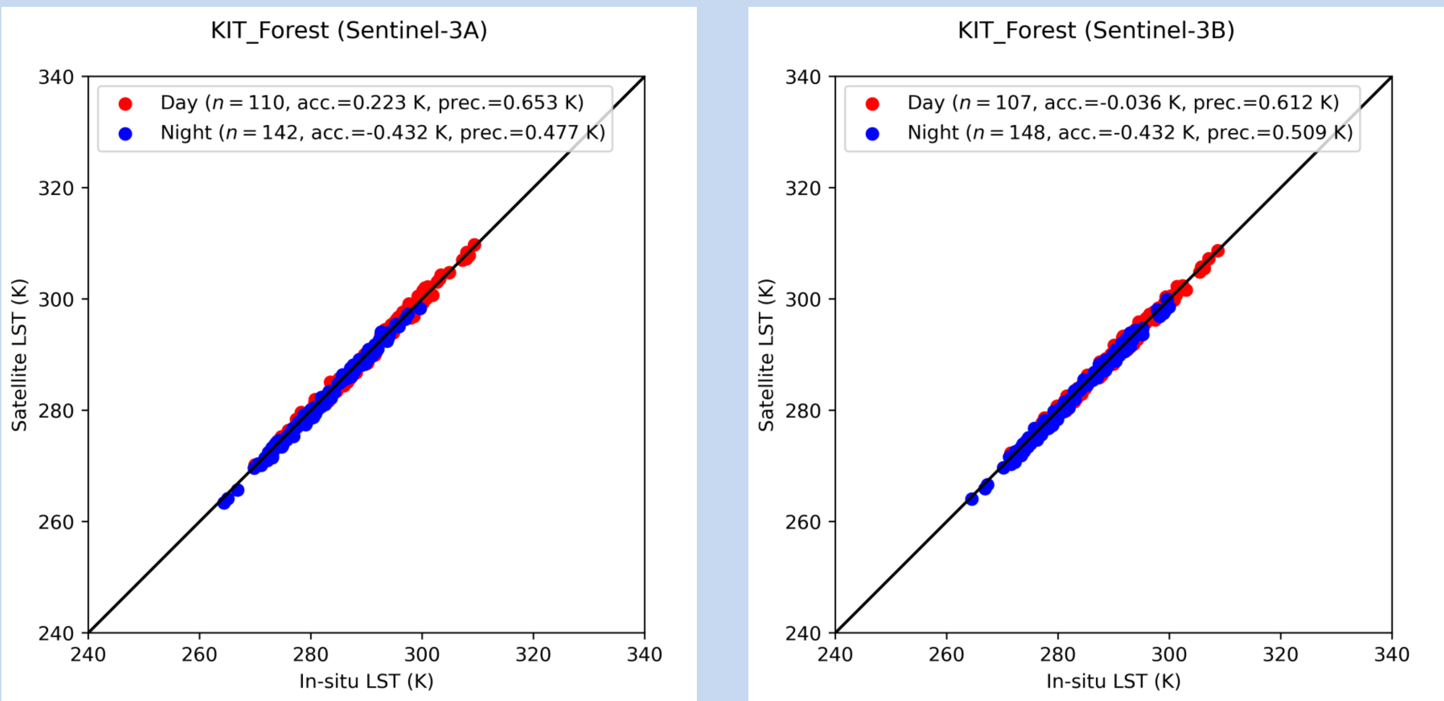

Figure 2: Validation of the Sentinel-3 LST against observations from the KIT forest LAW site

3. LST Uncertainty Validation

- The **uncertainty associated with the Sentinel-3 LST** was also validated using the approach discussed in Ghent et al (2019). The **standard deviation of the satellite – in-situ bias** was compared against **total satellite product matchup uncertainty** for each associated matchup ($\boldsymbol{\sigma_{total}}$). This is calculated from the Sentinel-3 LST uncertainty ($\boldsymbol{\sigma_{sat}}$), in-situ LST uncertainty ($\boldsymbol{\sigma_{IS}}$, 0.5 K), and the spatial matching uncertainty ($\boldsymbol{\sigma_{space}}$, standard deviation of the surrounding 5 × 5 ground pixel LSTs), using:

$$\sigma_{total} = \sqrt{\sigma_{sat}{}^2 + \sigma_{IS}{}^2 + \sigma_{space}{}^2}$$

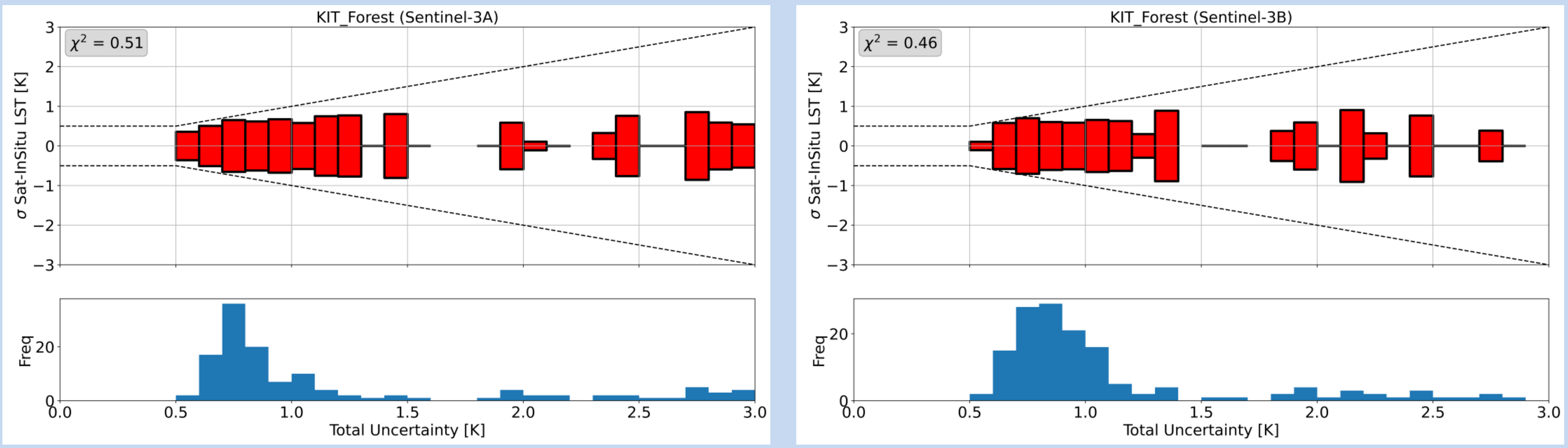

Figure 3: Validation of the satellite LST uncertainty estimated for Sentinel-3 against LST observations from the KIT forest site. The standard deviation of the satellite – in-situ LST bias is plotted against bands of the total Sentinel-3 matchup uncertainty, σ_{total}. The bounding cone is distorted for near-zero total uncertainties because of the inherent calibration uncertainty of the in-situ instruments (0.5 K). The reduced chi-squared goodness-of-fit statistic is also given for both satellites.

4. Conclusions

- **Sentinel-3A/B appear to meet the accuracy criterion for all LAW sites**, with comparable results to those reported by operational validation (S3MPC)
- Most sites also report the **similar numbers of day and night-time observations**, suggesting that **no diurnal coverage biases exist** – consistent with the S3MPC Cyclic Reports. However, a night-time coverage bias may exist for Hyytiälä, Robson Creek, and Puéchabon (Sentinel-3B only)
- **Mixed performance over some biomes** (e.g. negative biases over Hyytiälä for both satellites). Such biases can be addressed by updating the SL_2_LST retrieval algorithm biome-specific coefficients
- **Robson Creek is an outlier**. **Despite the homogeneous land cover, the results show very large spread before Hampel filtering**. Further analysis required to determine if this is due to excess cloud contamination, retrieval parameters, or issues with in-situ data
- **Validation of total uncertainty shows good agreement between $\boldsymbol{\sigma_{total}}$ and observed bias at KIT forest site**. However, a minority of matchups where $\boldsymbol{\sigma_{total}}$ **> 1.1 K greatly overestimate the observed bias** – these observations may be the result of incomplete cloud flagging. **Other sites had insufficient cloud-free data to analyse**

5. References

- Drinkwater, M. et al (2007): Sentinel-3 Mission Requirements Document, EOP-SMO/1151/MD-md
- WMO (2016): GCOS 2016 Implementation Plan, GCOS 200
- Göttsche, F. M. et al (2013): "Validation of land surface temperature derived from MSG/SEVIRI with in situ measurements at Gobabeb, Namibia," Int. J. Remote Sens.
- Ghent, D. et al (2019): "A New Approach to Defining Uncertainties for MODIS Land Surface Temperature," Remote Sensing

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