Application of a Land Surface Temperature Validation Protocol to AATSR data

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LST Validation Protocol

Land surface temperature validation protocol:

No existing protocol for LST validation

To establish several categories classifying the primary approaches to validation of satellite-based LST

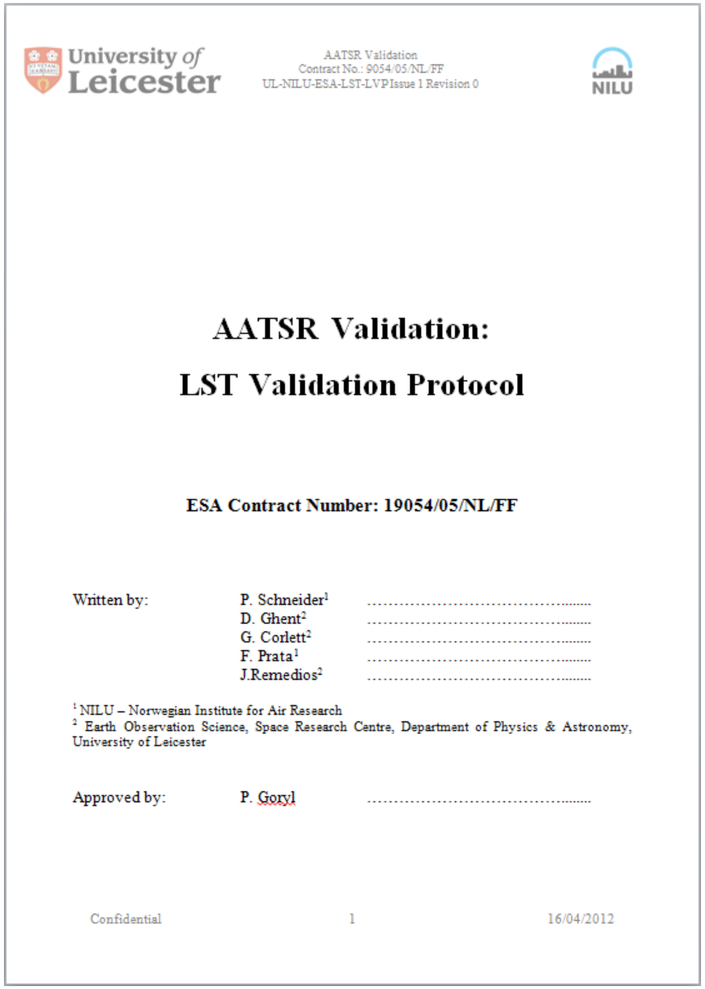
To establish several quality levels for each validation category

To describe a recommended LST validation methodology for each category and level

To satisfy the community requirements for a set of guidelines for validating LST

To be sensor independent

To present a standard and consistent nomenclature


University of Leicester

AATSR Validation
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NILU

AATSR Validation:

LST Validation Protocol

ESA Contract Number: 19054/05/NL/FF

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Document open to community for feedback

Category A: Comparison of satellite LST with in situ measurements

This is the traditional and most straightforward approach to validating LST. It involves a direct comparison of satellite-derived LST with collocated and simultaneously acquired LST from ground-based radiometers.

Category B: Radiance-based validation

This technique uses top-of-atmosphere (TOA) brightness temperatures (BTs) in conjunction with a radiative transfer model to simulate ground LST using data of surface emissivity and a atmospheric profiles of air temperature and water vapour content.

Category C: Inter-comparison with similar LST products

A wide variety of airborne and spaceborne instruments collects thermal infrared data and many provide operational LST products. An inter-comparison of LST products from different satellite instruments can be very valuable for determining LST.

Category D: Time series analysis

Analysing time series of satellite data over a temporally stable target site allows for the identification of potential calibration drift or other issues of the instrument that manifest themselves over time. Furthermore, problems associated with cloud contamination for example may be identified from artefacts evident in the time series. Care must be taken in distinguishing between instrument-related issues such as calibration drift and real geophysical changes of the target site or the atmosphere.

LST Validation Protocol

	Category			
	A	**B**	**C**	**D**
	In situ	**Radiance-based**	**Inter-comparison**	**Time series**
Highest accuracy	A1	B1	C1	D1
	A2			D2
Accuracy Class	A3	B2	C2	
	A4			D3
	A5			
Lowest accuracy	A6	B3	C3	D4

Schematic overview of LST validation categories

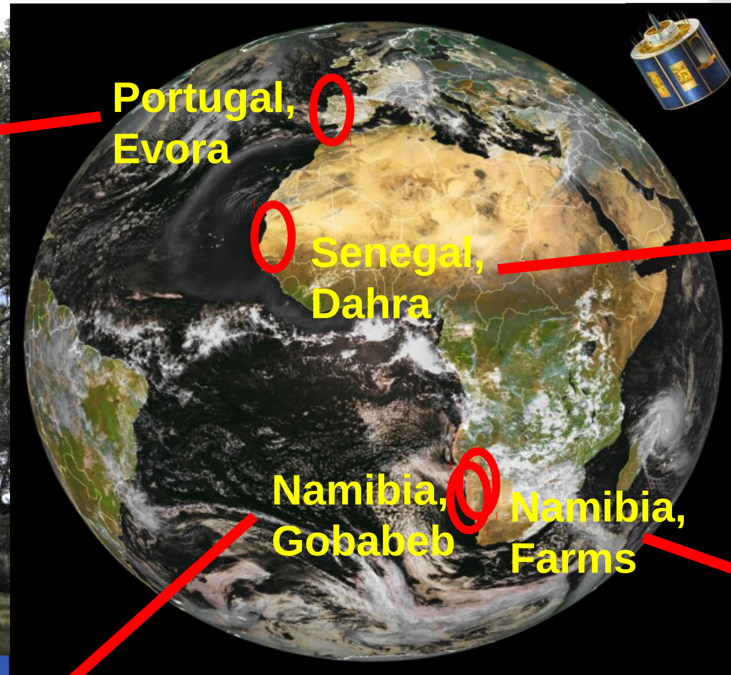
Each of the four validation categories are subdivided into classes based on the complexity of the methodology and the expected accuracy of the validation

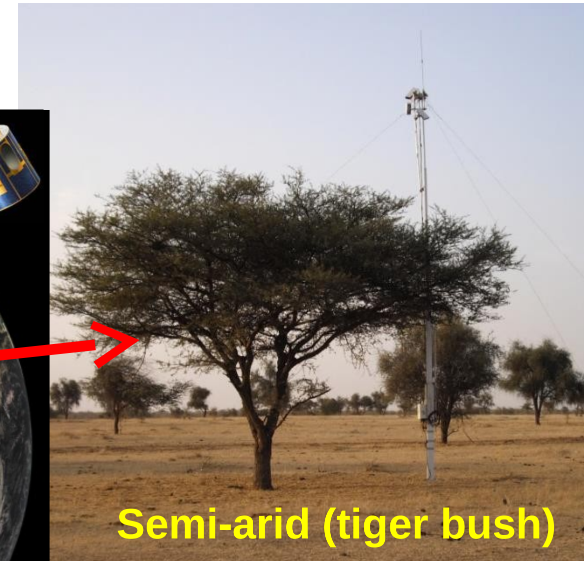
Requirements for Category A validaton

In-situ LST based on the following components:

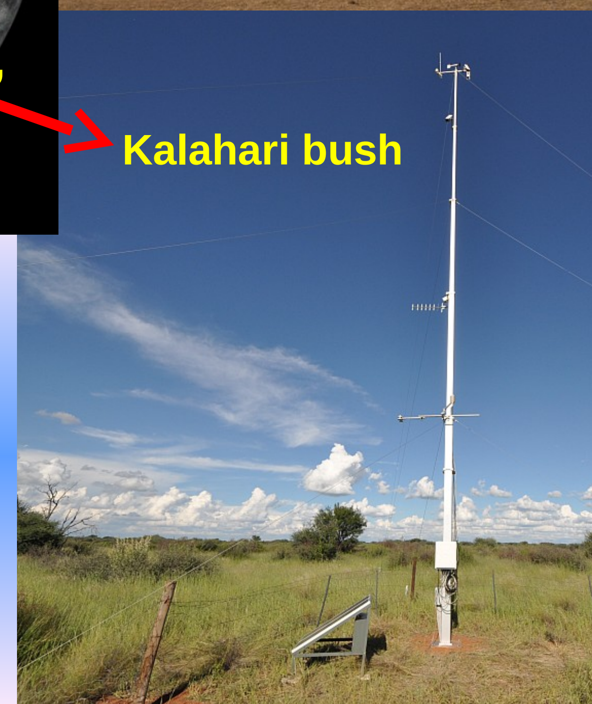
- Upwelling radiance from relevant surface covers, i.e. the ’end members’
- **Land surface emissivities (LSE)** of end members
- Downwelling radiance in spectral range of in-situ radiometer
- **Directional** distribution of surface leaving radiance
- **Composition** of end members over validation area

KIT Validation Stations

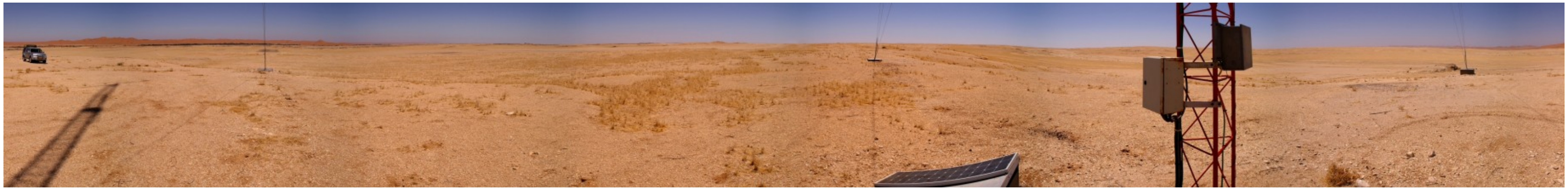




- Large, **homogeneous** sites
- Well **characterised**
- Different climates & biomes
- **Dedicated** to LST validation



Gobabeb, Namibia: Desert



Main end-members:
gravel (75%) and dry grass (25%)

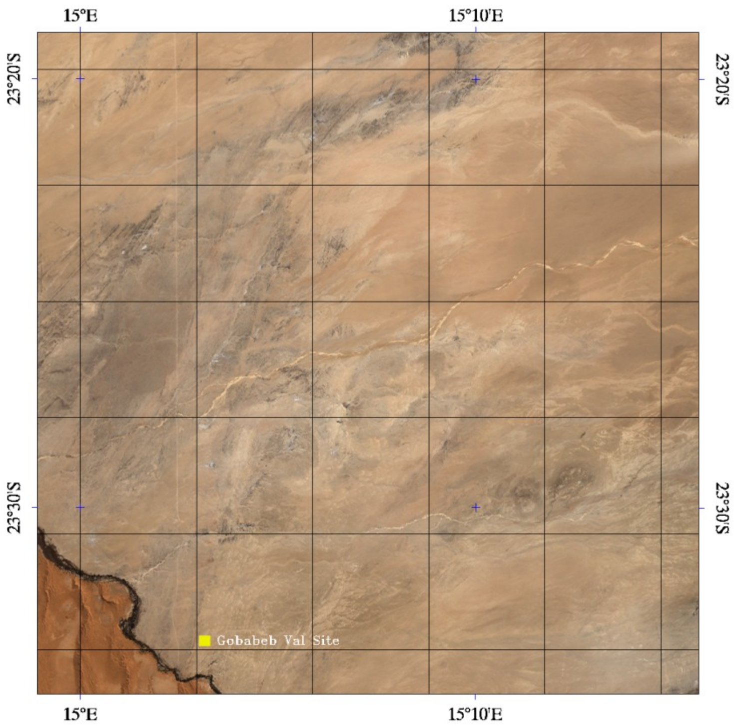
Rain every few years

Some “rivier” (wadis) and rock outcrops

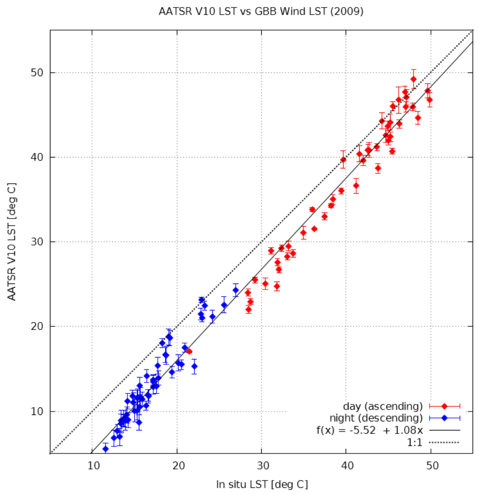
Desert climate (~23° South)

460 m asl

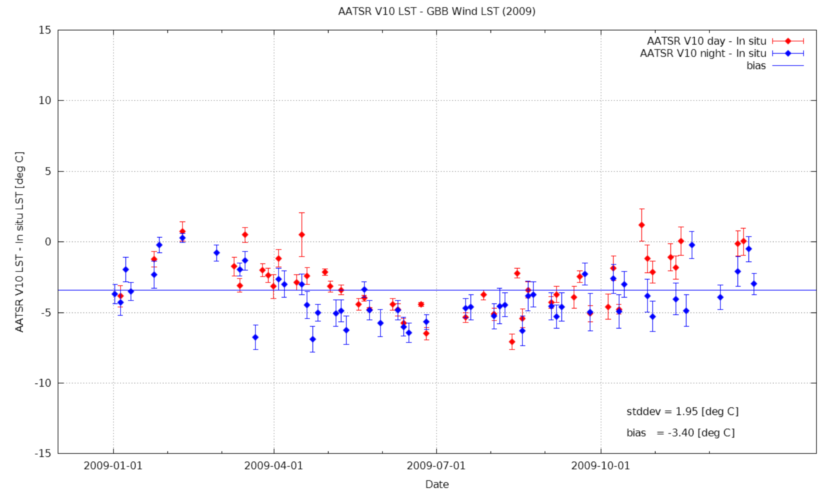
Landsat ETM+, 06.04.2000, True Colour

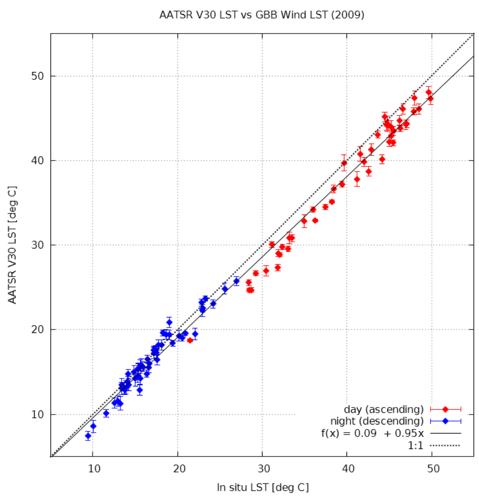


T-Based AATSR Example: Gobabeb 2009

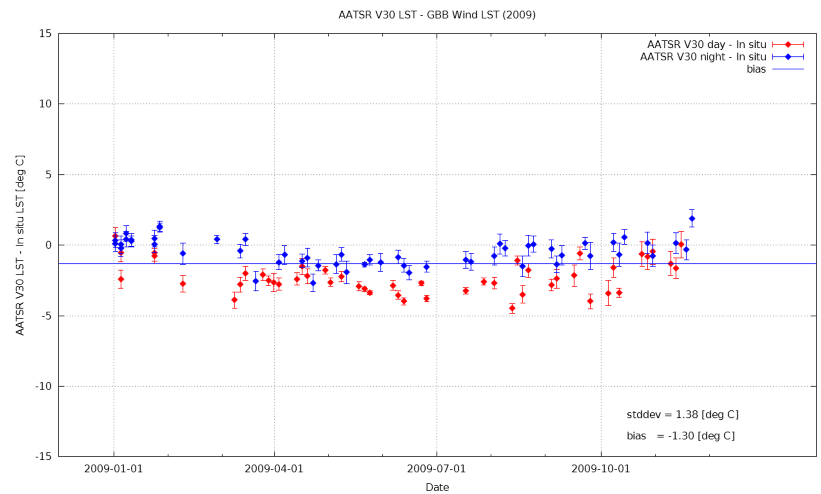


ESA_V2





UOL_LST



R-Based Methodology

The radiance-based (R-based) approach does not require ground-based LST measurements

An opportunity to validate satellite LST retrievals over a wide range of biomes, under different surface and atmospheric regimes

Radiative transfer is used to simulate at-sensor BTs from atmospheric profiles and surface data

Iteratively perturb the surface temperature until the simulated BTs bracket the observed BT - the input surface temperature being the satellite-retrieved LST – the R-based temperature (LSTR) is determined by interpolation

The difference, δLST, between the satellite-retrieved LST and LSTR is the LST uncertainty

Key criteria are the homogeneity of the surface in terms of emissivity and accurate representation of the atmosphere

To assess whether the atmospheric profiles represent the true atmospheric conditions observed during satellite retrievals the discrepancy δ(T11 – T12) between the observed BT difference (T11 – T12)obs and the simulated BT difference (T11 – T12)sim is assessed. A sensitivity analysis is used to determine the correct threshold for this quality test

R-based example: AATSR validation

Biome #	Day						Night					
	ESA_V2			UOL_LST			ESA_V2			UOL_LST		
	μ (K)	σ (K)	RMSE (K)	μ (K)	σ (K)	RMSE (K)	μ (K)	σ (K)	RMSE (K)	μ (K)	σ (K)	RMSE (K)
1	-0.27	1.65	1.67	0.23	0.55	0.59	-0.57	1.55	1.65	0.32	0.55	0.64
2	1.83	2.90	3.43	1.28	0.70	1.45	-0.38	0.70	0.79	-0.02	1.00	1.00
3	-0.68	1.85	1.97	-0.17	0.80	0.82	-0.17	1.90	1.91	0.58	0.30	0.65
4	0.38	1.80	1.84	0.98	0.60	1.14	0.18	2.25	2.26	1.78	1.95	2.64
5	3.08	4.33	5.31	-0.02	0.60	0.60	2.82	4.58	5.37	0.68	0.85	1.09
6	4.77	5.85	7.55	0.83	0.65	1.05	4.02	5.10	6.50	0.63	0.50	0.80
7	1.58	3.50	3.84	0.98	0.70	1.20	-0.82	1.60	1.80	0.63	0.55	0.83
8	0.68	2.30	2.40	0.38	0.55	0.67	0.22	1.95	1.96	0.38	0.55	0.67
9	-0.32	1.55	1.58	-0.02	0.70	0.70	-2.48	1.95	3.15	-0.13	0.80	0.81
10	1.68	2.75	3.22	-0.18	0.85	0.87	0.63	1.80	1.91	-0.13	0.70	0.71
11	1.77	2.65	3.19	-0.77	1.15	1.39	-0.38	1.45	1.50	-0.63	1.20	1.35
12	0.03	2.15	2.15	0.63	0.80	1.02	0.27	1.90	1.92	1.18	1.00	1.54
13	0.73	1.25	1.45	1.18	0.70	1.37	-0.22	2.30	2.31	1.18	0.80	1.42
14	0.03	1.75	1.75	1.02	0.45	1.12	-0.13	1.65	1.65	0.92	0.65	1.13
15	-0.17	1.60	1.61	0.18	0.60	0.63	-1.58	1.55	2.21	-0.43	1.05	1.13
16	2.52	1.70	3.04	-0.52	1.10	1.22	-0.98	0.95	1.36	-0.72	1.35	1.53
17	3.18	5.10	6.01	-0.47	1.05	1.15	2.77	3.65	4.59	-0.52	1.00	1.13
18	-0.03	1.80	1.80	-0.07	0.75	0.75	-0.58	1.55	1.65	-0.33	1.00	1.05
19	-0.82	1.60	1.80	0.58	0.60	0.83	-1.27	2.05	2.41	-0.12	0.70	0.71
20	-1.23	1.45	1.90	-0.37	0.75	0.84	-1.73	1.70	2.42	0.78	0.20	0.80
21	-2.72	2.10	3.44	1.38	0.90	1.64	-3.83	3.15	4.96	0.83	0.50	0.96
22	-1.47	1.45	2.07	0.82	0.60	1.02	-3.02	2.15	3.71	0.58	0.60	0.83
23	-1.98	1.70	2.61	0.77	0.55	0.95	-3.33	2.55	4.19	0.57	0.50	0.76
24	-2.88	2.00	3.50	0.53	0.55	0.76	-3.13	2.25	3.85	0.43	0.60	0.74
25	-1.37	1.55	2.07	-0.58	1.15	1.29	-1.68	1.65	2.35	-0.63	1.10	1.27
26	-0.38	1.55	1.59	-0.32	0.85	0.91	-0.97	1.45	1.75	-1.53	1.95	2.48
27	1.52	2.70	3.10	1.28	0.90	1.56	0.43	2.10	2.14	1.08	0.65	1.26

Intercomparison

Only the highest quality cloud-free pixels are considered. LST data that do not meet the highest quality control are discarded.

Spatial variability in the IFOV for each the satellite is handled through spatial re-gridding onto a common grid (in this example 0.05º x 0.05º) by way of averaging all geo-referenced, cloud free pixels of the highest quality weighted by the proportion of each individual pixel within the grid-cell.

Temporal variability between the LST datasets for a matchup is minimised by time interpolation between adjacent GEO measurements for example to correspond to the coincident overpass time of LEO.

Daytime and night-time monthly composites of the differences between datasets are derived from the individual comparisons carried out over the course of the month.

Intercomparison: AATSR vs. SEVIRI

January | April | July | October

Day

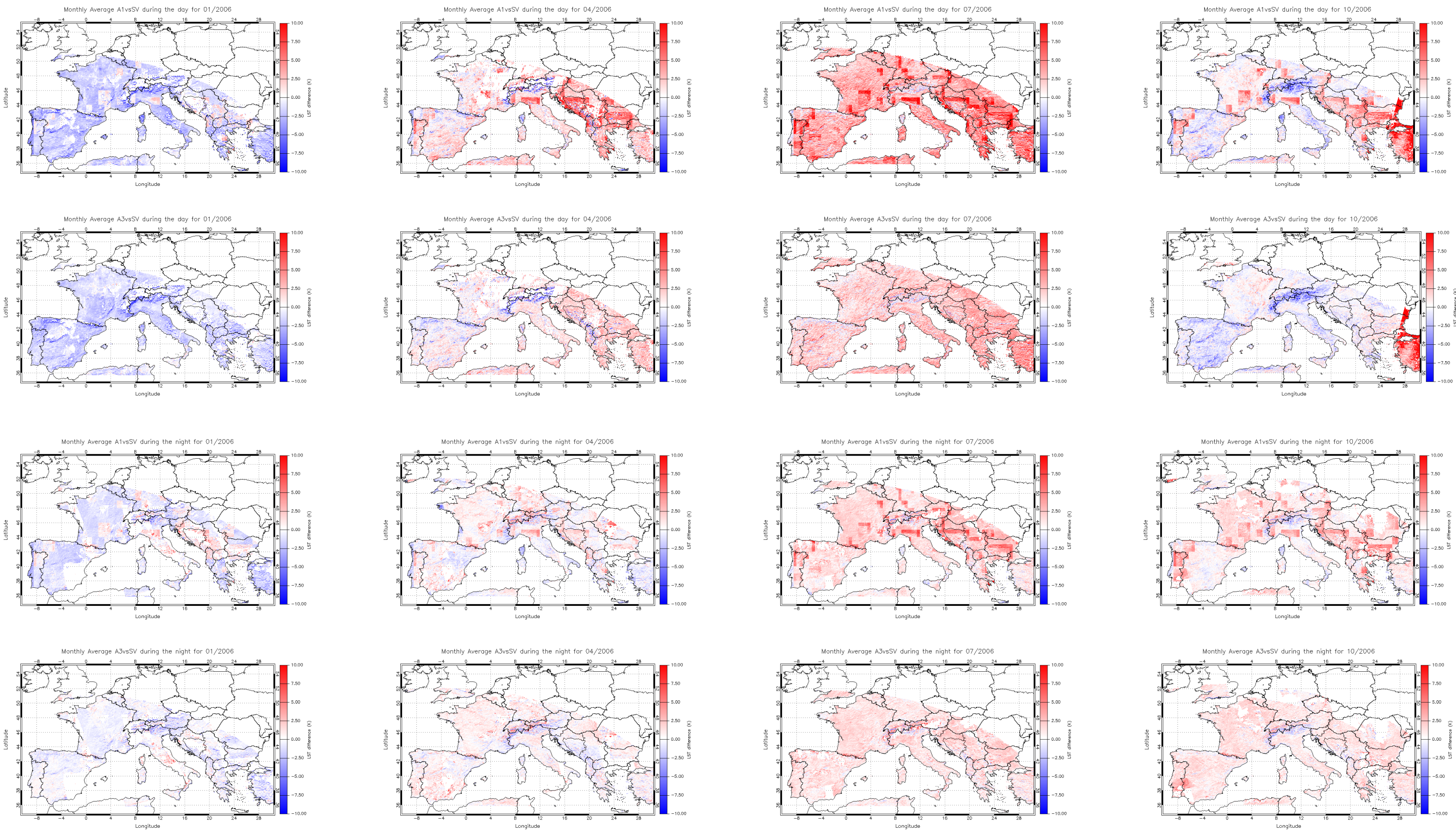
ESA_V2

UOL_LST

Nigh t

ESA_V2

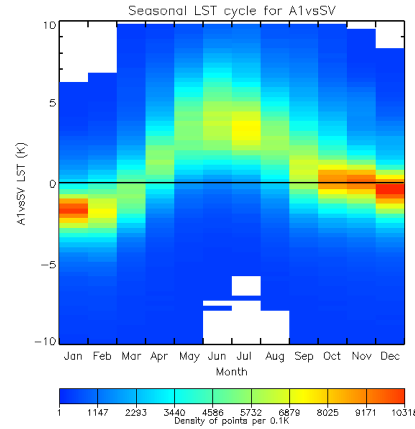
UOL_LST

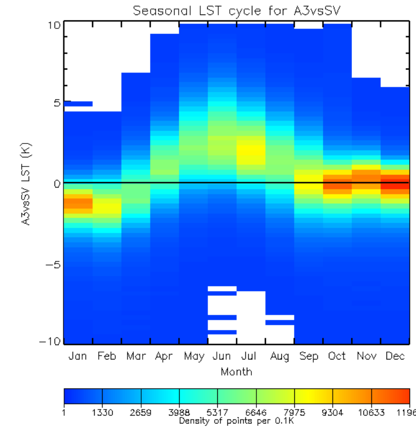


Intercomparison: AATSR vs. SEVIRI

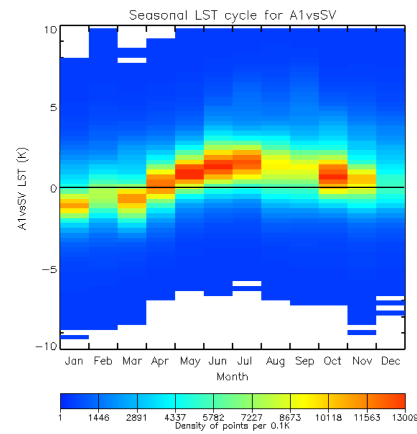
Month	LST product	Day μ (K)	Day σ (K)	Day RMSE (K)	Night μ (K)	Night σ (K)	Night RMSE (K)
Jan	ESA_V2	-1.75	1.87	2.56	-0.65	1.68	1.80
	UOL_V3	-1.63	1.54	2.24	-0.35	1.29	1.34
Feb	ESA_V2	-1.73	2.21	2.81	-0.19	1.91	1.92
	UOL_V3	-1.78	1.83	2.55	-0.03	1.57	1.57
Mar	ESA_V2	-0.29	2.74	2.75	-0.31	1.74	1.76
	UOL_V3	-0.76	2.15	2.28	-0.12	1.32	1.33
Apr	ESA_V2	1.73	2.96	3.43	0.38	1.61	1.65
	UOL_V3	0.80	2.35	2.48	0.45	1.34	1.41
May	ESA_V2	3.41	2.77	4.39	1.09	1.57	1.91
	UOL_V3	2.24	2.36	3.25	1.02	1.31	1.66
Jun	ESA_V2	4.04	2.71	4.86	1.59	1.62	2.27
	UOL_V3	2.75	2.24	3.55	1.39	1.30	1.91
Jul	ESA_V2	3.78	2.82	4.72	1.79	1.75	2.50
	UOL_V3	2.13	2.05	2.96	1.27	1.20	1.74
Aug	ESA_V2	2.81	3.01	4.12	1.51	1.96	2.48
	UOL_V3	1.29	2.21	2.55	1.11	1.34	1.74
Sep	ESA_V2	1.72	3.06	3.51	1.65	2.10	2.68
	UOL_V3	0.24	2.11	2.13	1.04	1.38	1.73
	ESA_V2	0.93	2.99	3.13	1.22	1.72	2.11

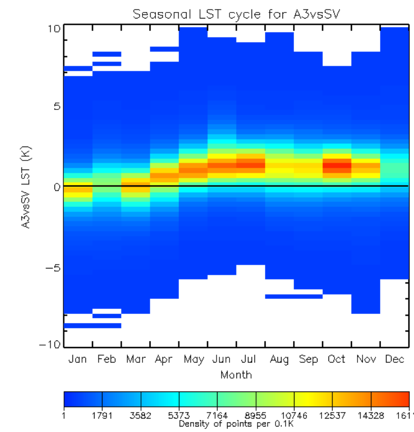
Day



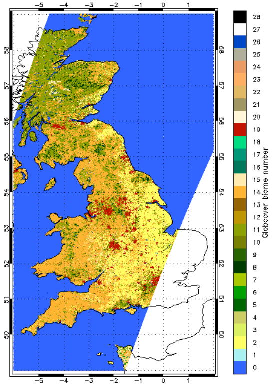


Night

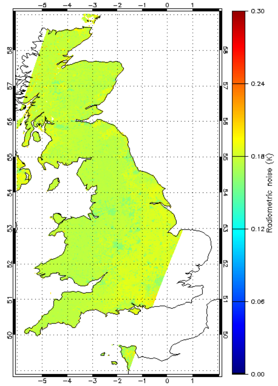




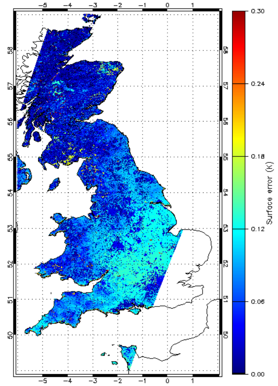
Validation of uncertainties



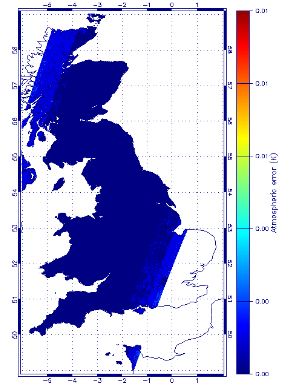
Biome map



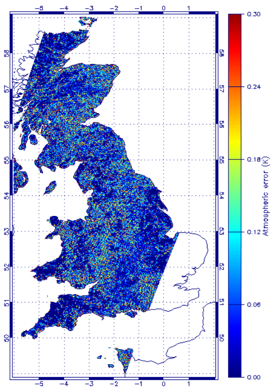
Radiometric noise



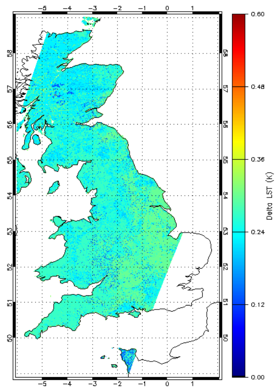
Surface component



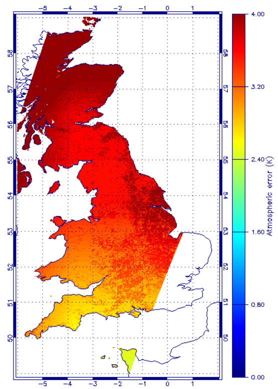
Atmosphere component



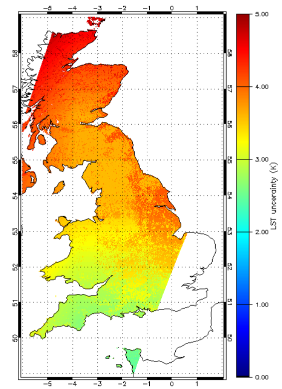
Geolocation



Model fitting

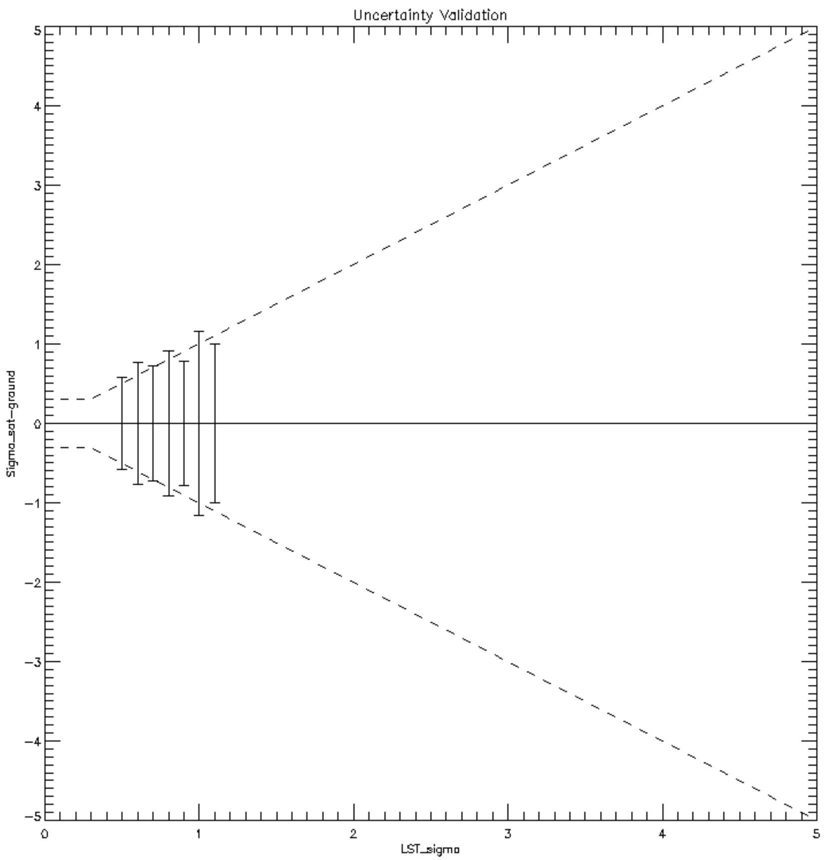


Cloud detection

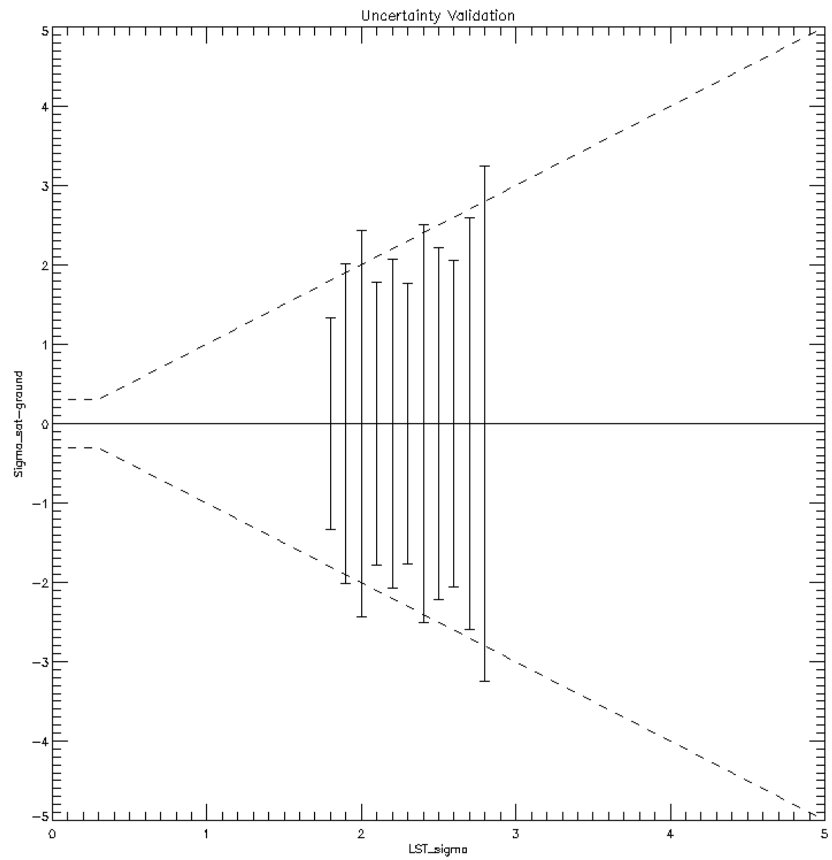


Total

Validation of uncertainties



Without cloud uncertainty



With cloud uncertainty

Matchup database (GT_MDB)

1. **Definition of validation and intercomparison protocol and plan**
   - **Create a list of suitable sources of ground-based validation data, e.g. KIT's stations, SURFRAD sites (see Yu et al.), Lake Tahoe, Salton Sea, BSRN, Atmospheric Radiation Measurement (ARM) sites …**

2. **Data preparation**
   - **Collect sample sets of ground-based validation data**
   - **Construction of an in situ matchup database**
   - **Development of tools for extracting matchups**
   - **Extraction of satellite vs. in-situ LST matchups**
   - **Populations of in situ matchup databases for all instruments at selected sites**
   - **Construction of an intercomparison matchup database**

3. **Maintain the in-situ matchup database populating with new matchups as satellite and in situ datasets are updated**
   - **LST from matchup sources – in situ, satellite**
   - **Uncertainties from matchup sources – in situ, satellite**
   - **Time of matchup (Julian Date)**
   - **Satellite Quality Flags including cloud cover**
   - **Solar zenith angle**
   - **Satellite zenith angle**
   - **Emissivity**
   - **Land cover type**
   - **Met. fields – LSAT, up- and downwelling radiation (if available)**
   - **Additional info, e.g. location (area), sensor, producer, version, etc.**

LST Validation Protocol: Summary

- A standard and consistent nomenclature
- Sensor independent approach for LST / IST / LSWT validation
- Set of guidelines open to the community
- Successfully applied to AATSR validation – chosen methodology for GlobTemperature
- A suggested baseline for a LPV best practices guide fro LST