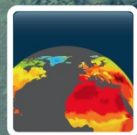


climate change initiative

→ LAND SURFACE TEMPERATURE

Validation of LST_cci products

Olimpia Bruno, Frank Götsche



land surface
temperature
cci



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Introduction: Why is validation important?



- **Assessment of LST product quality (understanding the data and its limitations)**
- **Validation by KIT: independent from data producers**
 - All in-situ datasets are produced by KIT
 - One year of data for each sensor and site is shared with data producers
 - KIT provides feedback from validation to data producers
- **All data processing in LST_cci harmonized format**
- **Validation follows community established protocols, e.g.:**
 - LST Validation Protocol (Schneider et al., 2012)
 - CEOS LPV Best Practices (Guillevic et al., 2018; i.e., robust standard deviation (RSTD))



Introduction: How is validation performed?



Satellite – In-Situ validation

Globally distributed stations
(scarce)



Broad range of land covers,
elevations and climates

Satellite – Satellite intercomparison

monthly & seasonal data
(continental scale)



Time series, different satellite
angles, land covers, elevations



In-situ validation: Sites



- Validation period: 1995 to 2023
- A total of 20 in-situ stations



KIT: set up for LST validation, large homogeneous and well characterized areas, since 2009

SURFRAD: long-term availability since 1995 / 1998, broadband measurements

ARM: Narrowband measurements, since 2003

HEIHE: China, broadband measurements, from 2013 to 2015

Copernicus LAW: set up for LST validation, five different forest biomes, since 2020



In-situ validation: Matchups

- **Spatial matching:**

- LEO-IR: All pixels with the same land cover in a $0.05^\circ \times 0.05^\circ$ grid around the station are averaged.
- GEO-IR & LEO-MW: The pixel over the in-situ station is used.

- **Temporal matching:**

- At KIT, SURFRAD, ARM, and Copernicus LAW sites, the two closest times to the satellite overpass are linearly interpolated.
 - Temporal differences are smaller than 1 minute.
- At HEIHE stations (temporal resolution of 30 min) the closest time to satellite overpass is used.
 - Temporal differences are limited to 10 minutes.

- **24 LST CCI data sets were validated:**

- 14 LEO data sets:
 - 9 IR products: Aqua/Terra-MODIS (MODISA/MODIST), ATSR-2 (ATSR_2), AATSR (ATSR_3), AVHRR3/MetopA (AVHRMA) and SLSTRA/B (SLSTRA/SLSTRB), Suomi-NPP VIIRS (VIIRS0), NOAA20 VIIRS (VIIRS1)
 - 5 MW products: Aqua AMSR_E (AMSR_E), GCOM-W1 AMSR2 (AMSR_2), SSMI-13, SSMI-17, SSMI-18 (SSMI_13/17/18)
- 10 GEO data sets:
 - GOES12/13/16, SEVIRI (SEVIR1/2/3/4), MTSAT-2 (MTSAT2), HIMAWARI 8 (HMWR_8), HIMAWARI 9 (HMWR_9).

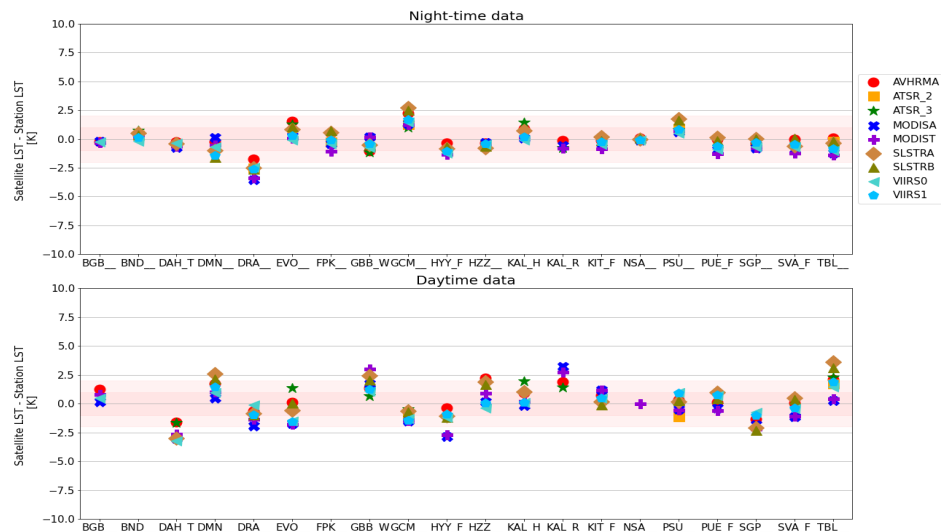


In-situ validation: LEO-IR datasets

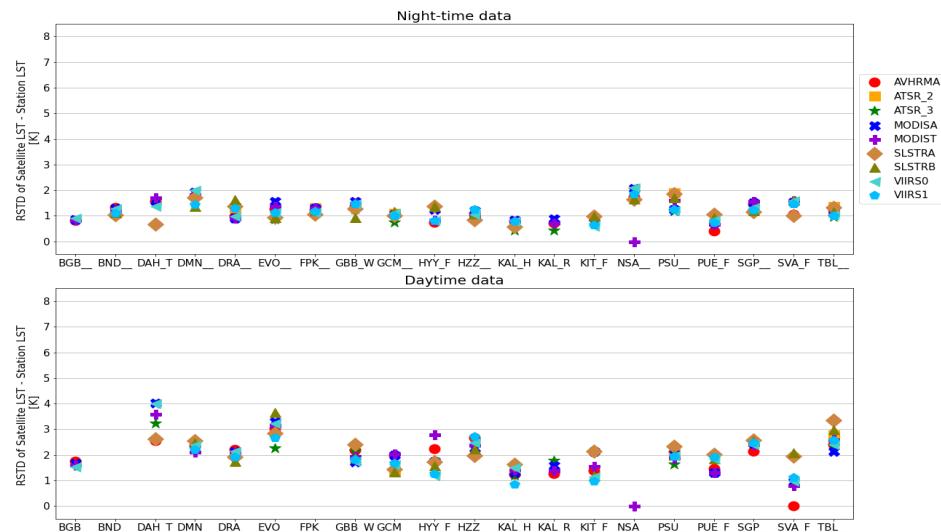


Average nighttime (daytime) bias of 0.8 K (1.2 K) and average nighttime (daytime) RSTD of 1.1 K (2.0 K)

Bias



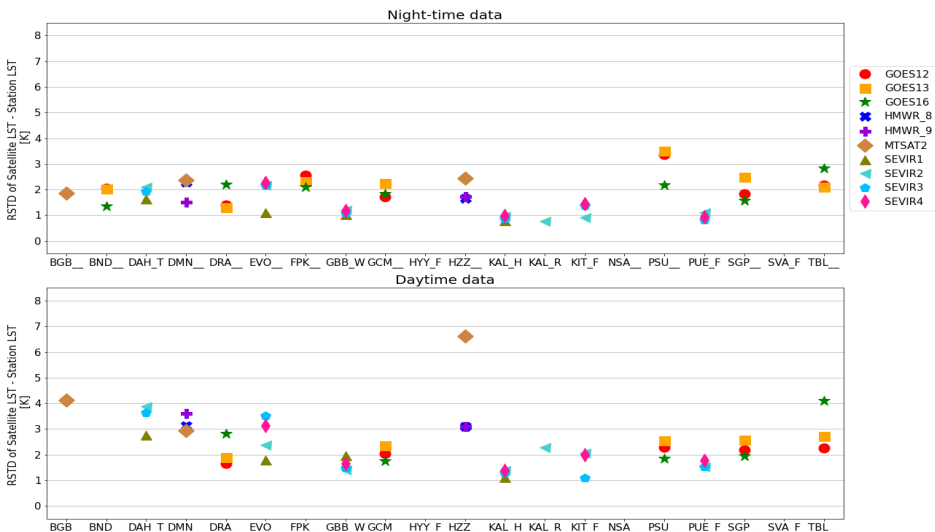
RSTD





K (2.4 K)

RSTD



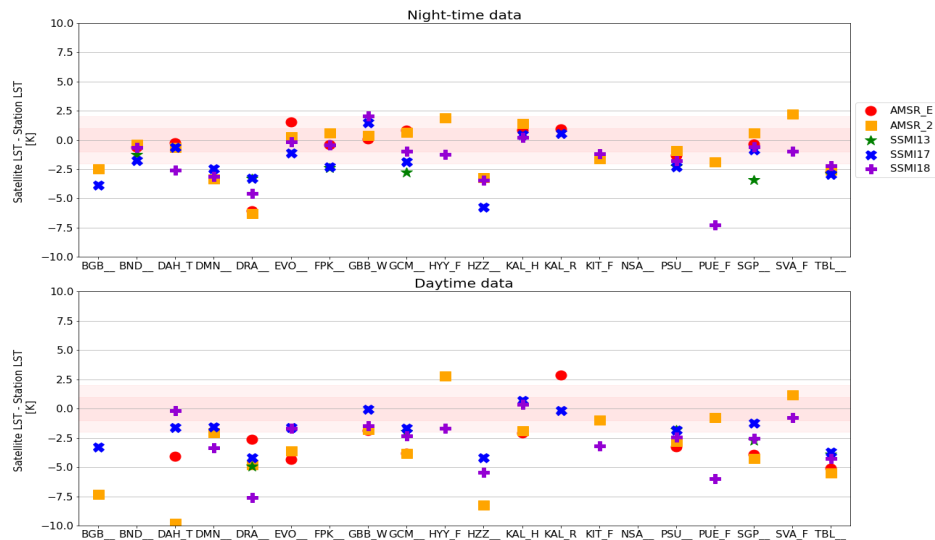


In-situ validation: LEO-MW datasets

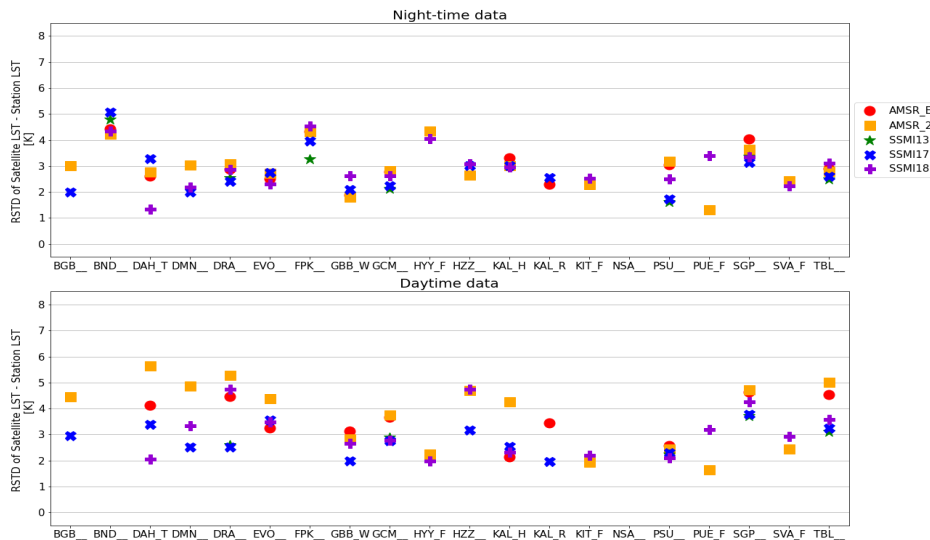


Average nighttime (daytime) bias of 1.9 K (3.0 K) and average nighttime (daytime) RSTD of 2.9 K (3.3 K)

Bias



RSTD





Bias

- **Nighttime biases are smaller than daytime biases**
- **LEO-MW data sets show larger biases due to their larger spatial resolution**
- **GEO-IR: Most biases are within ± 2.0 K at most in-situ stations**
- **IR: biases are within ± 1.0 K at most in-situ stations**

RSTD

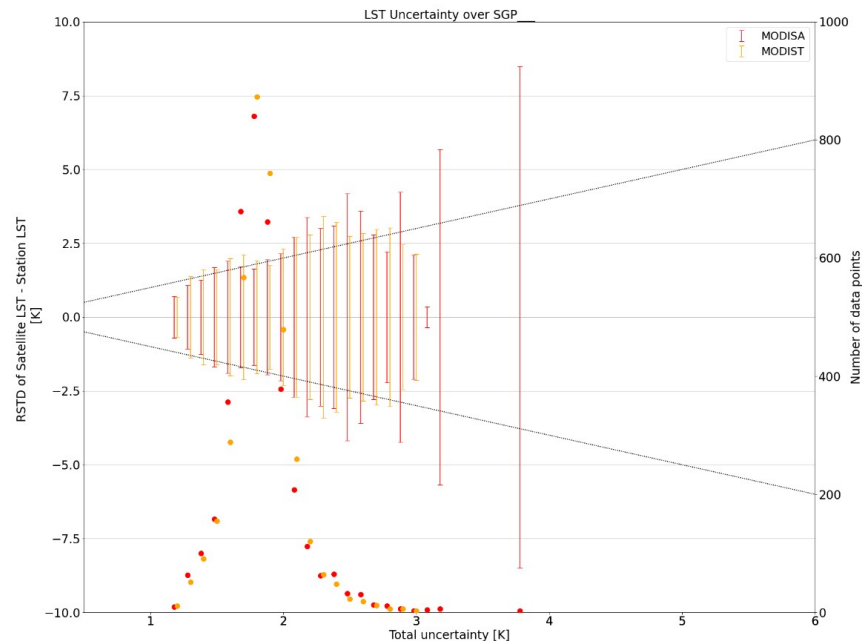
- **Most data sets show RSTDs within ± 2.5 K in nighttime**
- **Larger RSTDs are observed in daytime**
- **Causes of large RSTDs:**
 - Heterogeneities around in-situ stations.
 - Undetected clouds.
 - Overpass time close to sunrise/sunset for SSMI sensors.



In-situ validation uncertainty



- To assess the in-situ validation uncertainty, the total matchup uncertainty is compared against the RSTD of satellite and in-situ differences.
- The total matchup uncertainty considers:
 - Satellite LST uncertainty
 - In situ LST uncertainty
 - Spatial mismatch uncertainty
 - Temporal mismatch uncertainty





Satellites intercomparison: Satellite pairs



- The intercomparison covered the periods between 2008 – 2010 and 2018-2020 (SEVIR4)
- Eleven satellite pairs were intercompared:
 - 8 LEO – GEO pairs: Over Africa and Europe (SEVIRI disk)
 - 3 LEO – LEO pairs: Over all continents.

LEO – GEO	LEO – LEO
MOD11A – SEVIR2	ATSR_3 – MOD11T
MODISA – SEVIR2	ATSR_3 – MODIST
ATSOP – SEVIR2	MODIST – ATSOP
ATSR_3 – SEVIR2	
MOD11T – SEVIR2	
MODIST – SEVIR2	
SLSTRA – SEVIR4	
SLSTRB – SEVIR4	

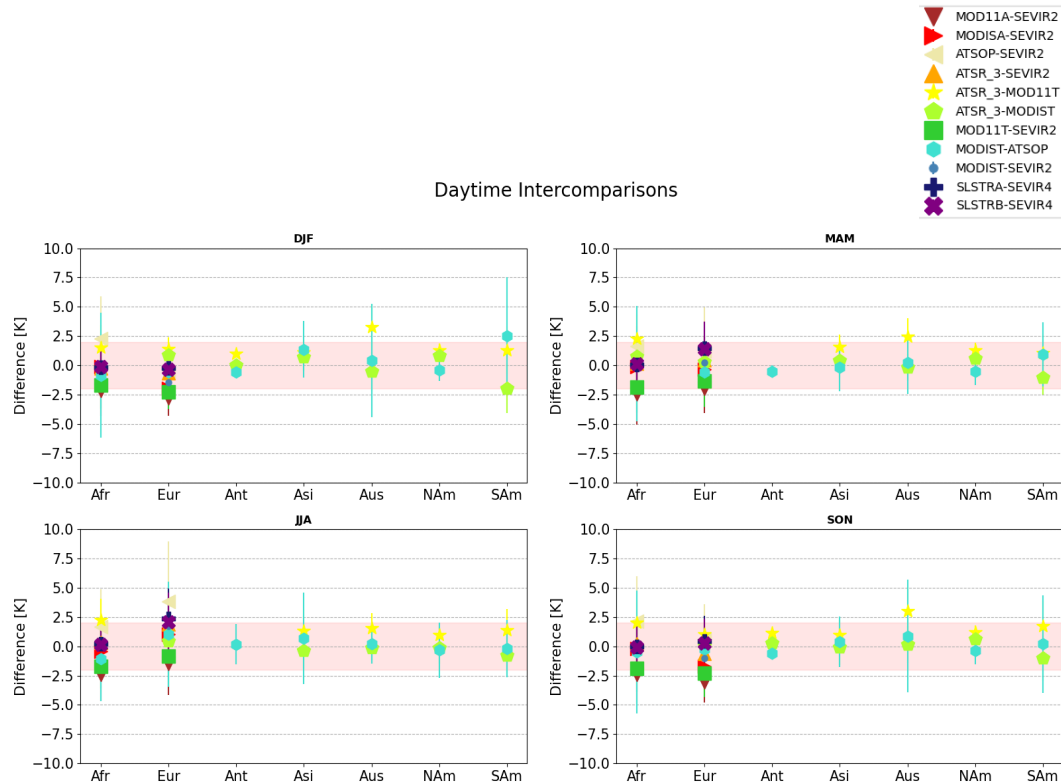


Satellites intercomparison: Bias daytime



- MOD11A and MOD11T show more negative differences than the other data pairs.
- ATSR_3-MOD11T show the largest differences between LEO-LEO pairs.
- All LST_cci data pairs show a good agreement (bias within ± 1.5 K).
- RSTD (error bars) are within ± 2 K, except for MODIS and ATSOP.

Daytime Intercomparisons

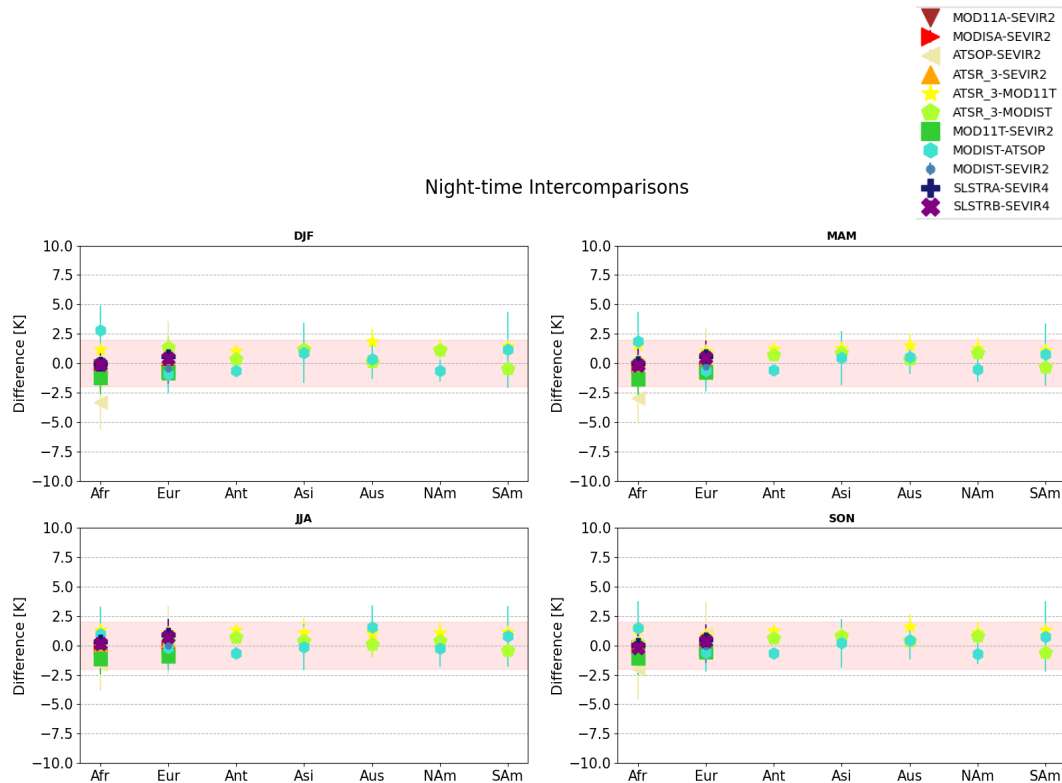




Satellites intercomparison: Bias nighttime



- **Smaller differences and RSTDs, except for Africa.**
- **The largest differences are observed for ATSOP (MODIST-ATSOP and ATSOP-SEVIR2).**
- **For most comparisons, biases and RSTDs are slightly smaller than for daytime ($<\pm 1.5$ and $<\pm 2.0$ K respectively).**





- **Satellite – In-Situ Validation:**

- 20 LST validation stations were used to validate 24 LST_cci products
- Most LST_cci products show a bias smaller than ± 2.5 K over most stations
- IR products mostly show a bias smaller than ± 1 K
- Most stations show RSTD within ± 2.5 K
- Biases and RSTDs are smaller during nighttime than daytime
- The in-situ validation uncertainty depends on the site (e.g., KIT_F, GBB_W smaller uncertainties).

- **Satellite – Satellite intercomparison:**

- Differences between LST_cci data set pairs were generally within ± 1.0 K.
- Larger differences were observed with Operational MODIS and AATSR LST products.

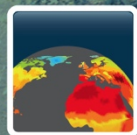
- **More details in the Product Validation and Intercomparison Report (PVIR v4.1).**

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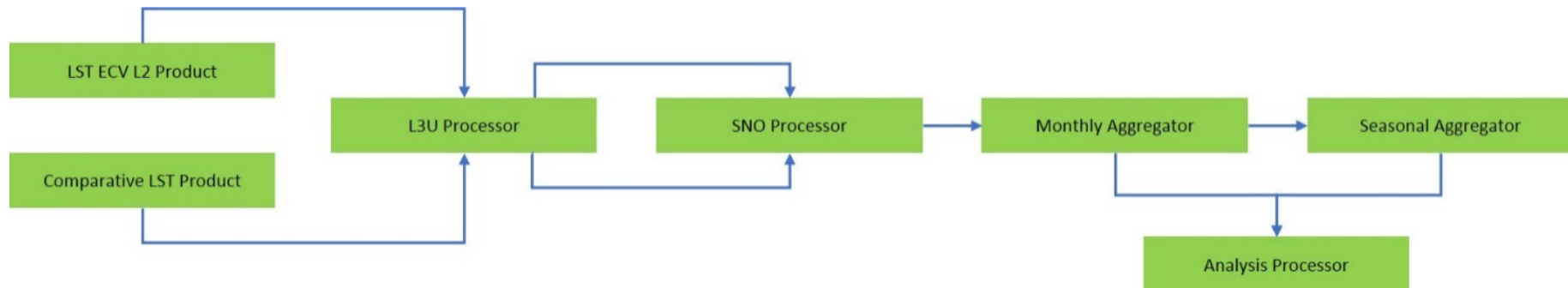
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Satellites intercomparison: Approach



- **Conversion of original Level-2 data to harmonised L3U data**
- **Determination of simultaneous overpasses (± 5 min) of the LEO within the reference GEO disk or LEO orbit**
- **Creation of monthly median fields in same L3U format to derive monthly statistics**
- **Aggregation of monthly L3U data to seasonal statistics**
- **Generate results and visualizations**





In-situ validation: LEO datasets data points

Number of averaged data points over all validated LEO satellite LST data sets and stations

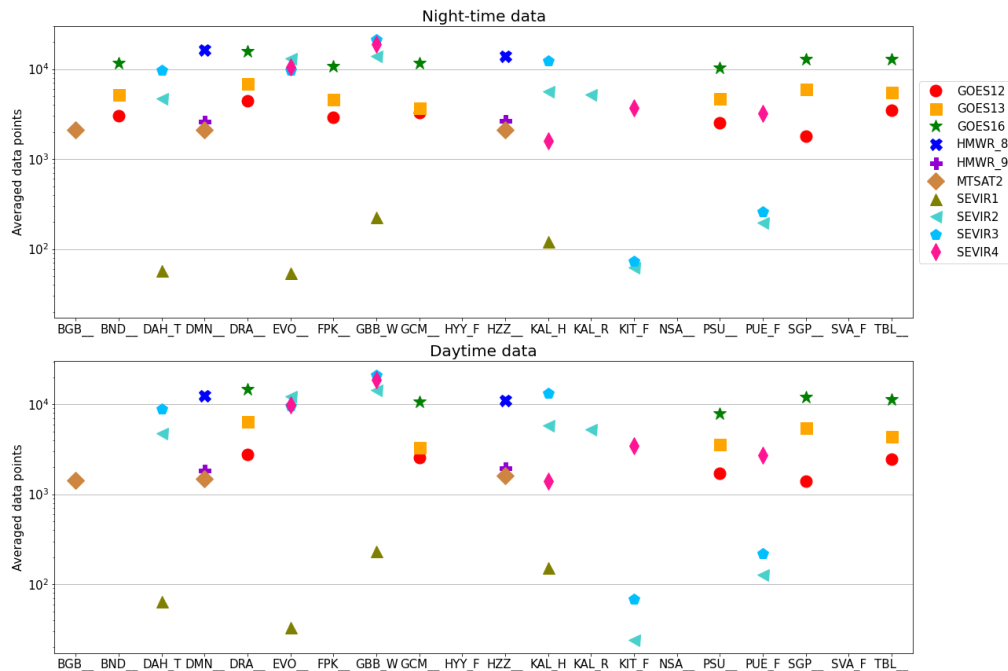




In-situ validation: GEO datasets data points



Number of averaged data points over all validated GEO satellite LST data sets and stations





In-situ validation: MW datasets data points

Number of averaged data points over all validated MW satellite LST data sets and stations

