Spatial evaluation of CAMS Radiation service using dense pyranometric networks

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CAMS-Rad (CRS) is a CAMS operational service providing solar radiation data

- CRS is based on atmospheric content from **CAMS** and cloud optical properties from **Apollo-NG**
- An important aspect of CRS is the **regular evaluation** against reference in-situ measurements

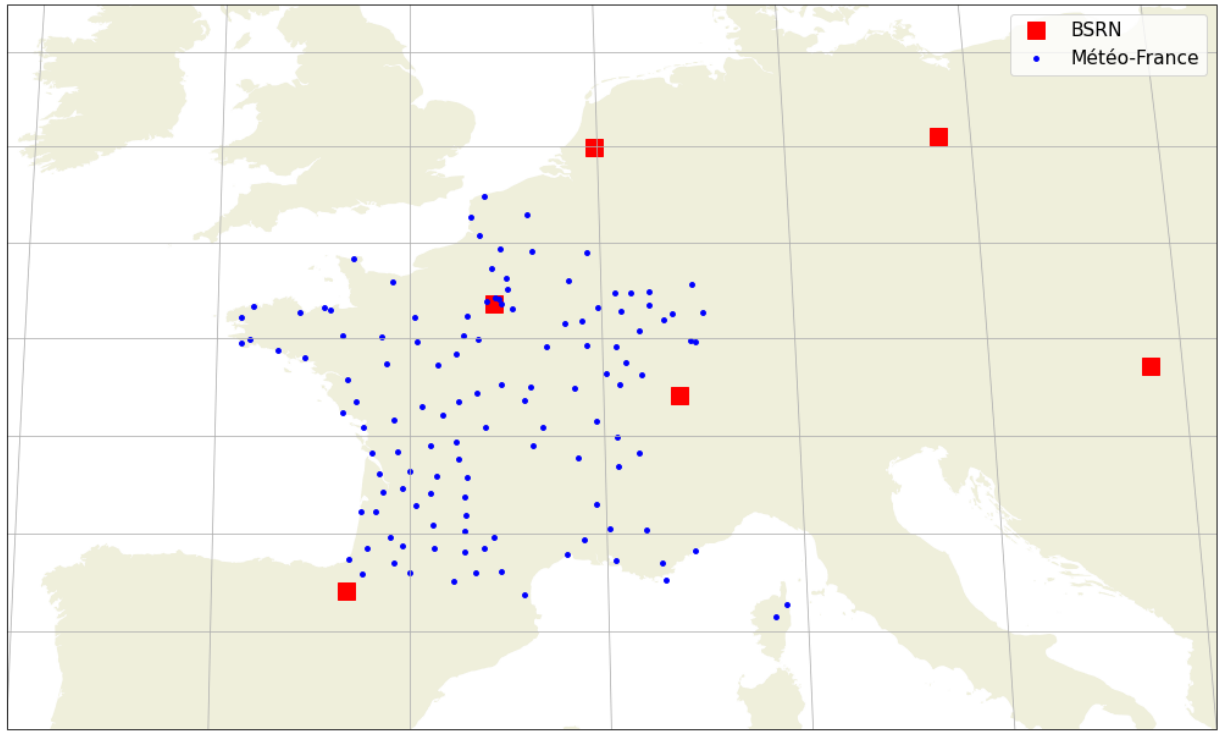
Quarterly CRS evaluation is performed using high quality radiation measurement stations

- The **spatial distribution** of the reference measurements is **sparse**
- Regular EQC doesn't allow to understand the spatial evolution of CRS performance and **predict uncertainty in "unseen locations"**

Potential added value of dense network of pyranometers

- High-density network of pyranometers can address the limitation of scarce networks
- However, the availability of a **single component** and the **less frequent maintenance** question their suitability for evaluation purpose.

Considering the operational characteristics of a meteorological network, such as the pyranometric network of Météo-France, can it be used for a reliable evaluation?



Overview of the network used in this analysis

- BSRN network
  - + 1-min measurement since the 1990s
  - + GHI, DIF and DNI
  - + 10 stations in Europe
  - + 1 station currently in operation in France (PAL)
- Météo-France solar radiation network
  - + 1-min measurement between 2015 and 2023
  - + Only GHI
  - + 270 stations in France

Data collection and preparation

BSRN station in Palaiseau (*https://sirta.ipsl.fr/*)

Quality control of measurements from BSRN stations

- The standard BSRN quality control can be applied:
  - + Physical possible (PPL) and extremely rare limit (ERL) tests for GHI, DIF and DNI
  - + Upper limit for the ratio K=DIF/GHI
  - + Closure test verifying that GHI=DIF+μ*DNI
- High confidence on quality-controlled data
  - + BSRN tests are recognized in the scientific community
  - + The closure test is particularly efficient for flagging faulty measurements

Data collection and preparation

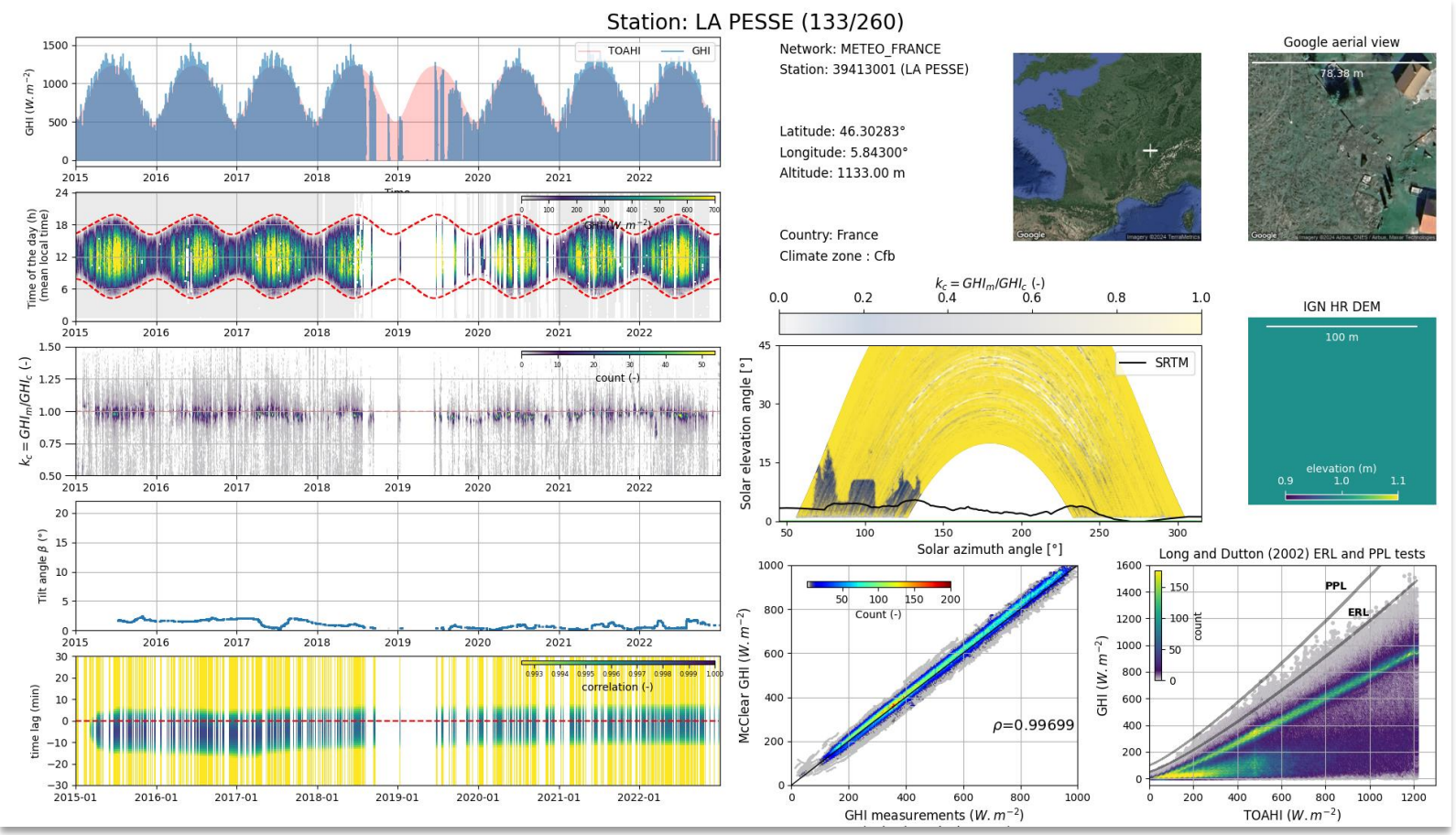
Meteo-France station Nice Airport (fiche_06088001.pdf) (*https://donneespubliques.meteofrance.fr*)

Quality control of measurements from Météo-France stations

- Only GHI is available
- Among BSRN tests, only PPL and ERL tests for GHI can be applied
- Cleaning and maintenance operations are less frequent than for BSRN stations

–> Need for additional inspection of the data

Data collection and preparation



A visual support has been developed to verify:

- The temporal reference of the data
- The calibration coefficient of the instrument
- Shading
- Pyranometer levelling

Suspicious data have been manually flagged

- Manual flagging is a delicate and subjective task
- All measurements faults cannot be detected

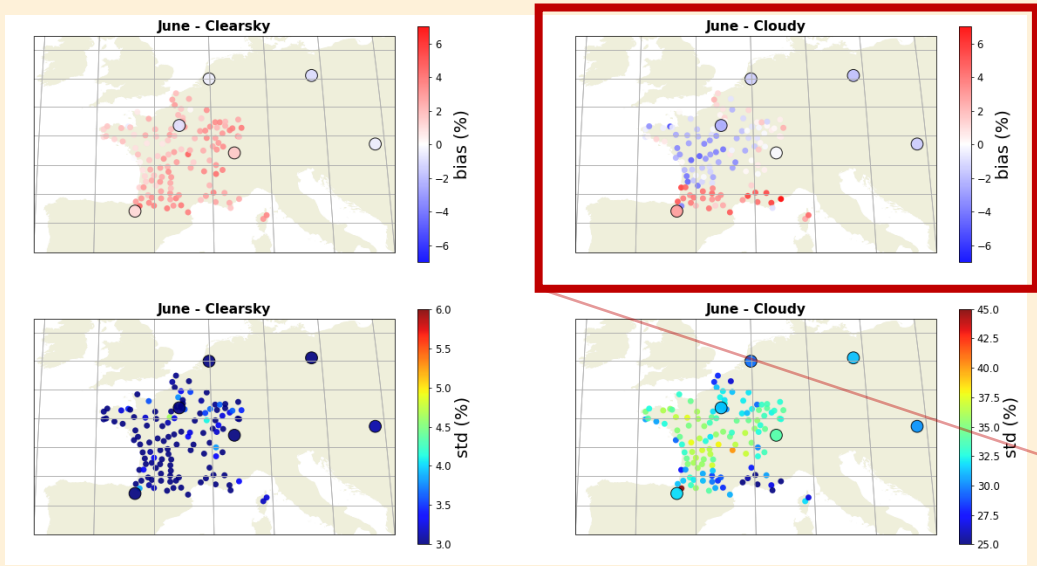
-> Level of confidence lower than for BSRN stations

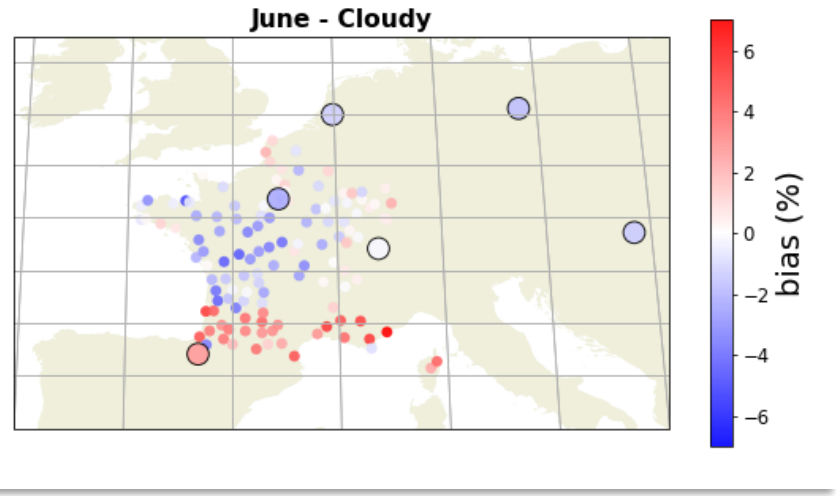
Evaluation methodology

- We compare quality-controlled data from **Météo-France** and **BSRN** stations with CAMS-Radiation data
- Only instants with a **solar elevation greater than 15°** and an **elevation less than 500 m** were used
- 1-min measurements are aggregated over a **15-min period** for the evaluation
- The performance of CAMS Radiation is assessed by assessing the **relative bias** and **standard deviation** (bias and standard deviation divided by the average irradiance)
- The evaluation is conducted for **two classes of weather conditions**:
  + Clear sky conditions: only clearsky instants detected with the Hansen and Reno (2016) algorithm are used
  + Overcast conditions: only values corresponding to a clearsky index less than 0,5 are used
- The analysis has been conducted for **each month of the year**

First results

June

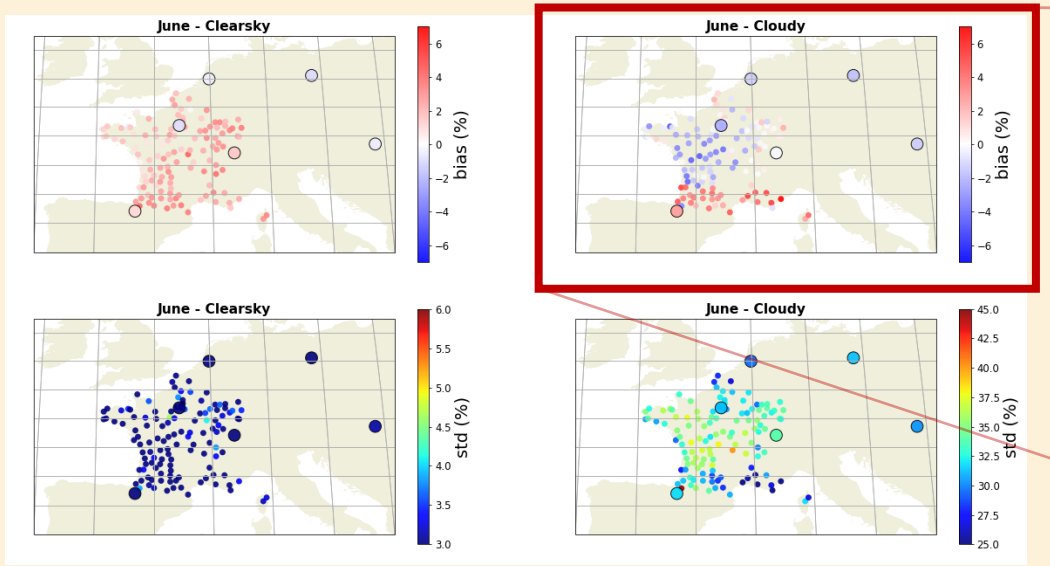


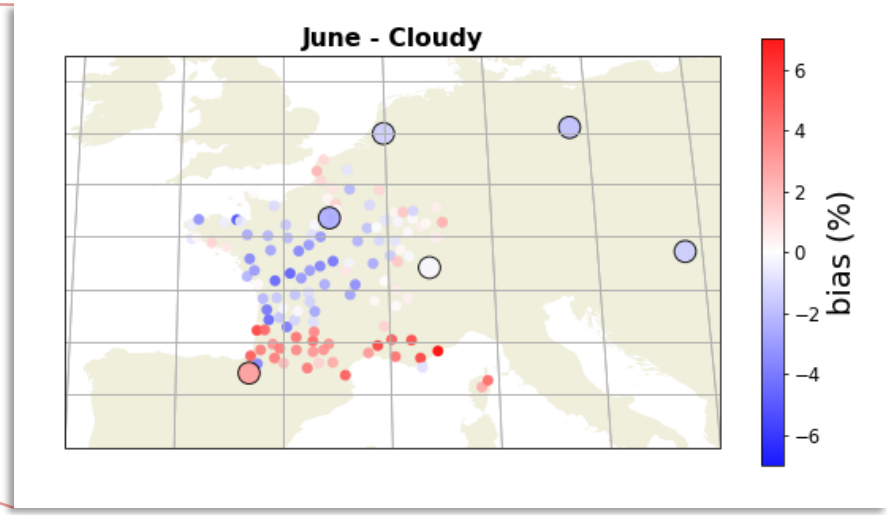


=> Consistency between Météo-France and BSRN

First results

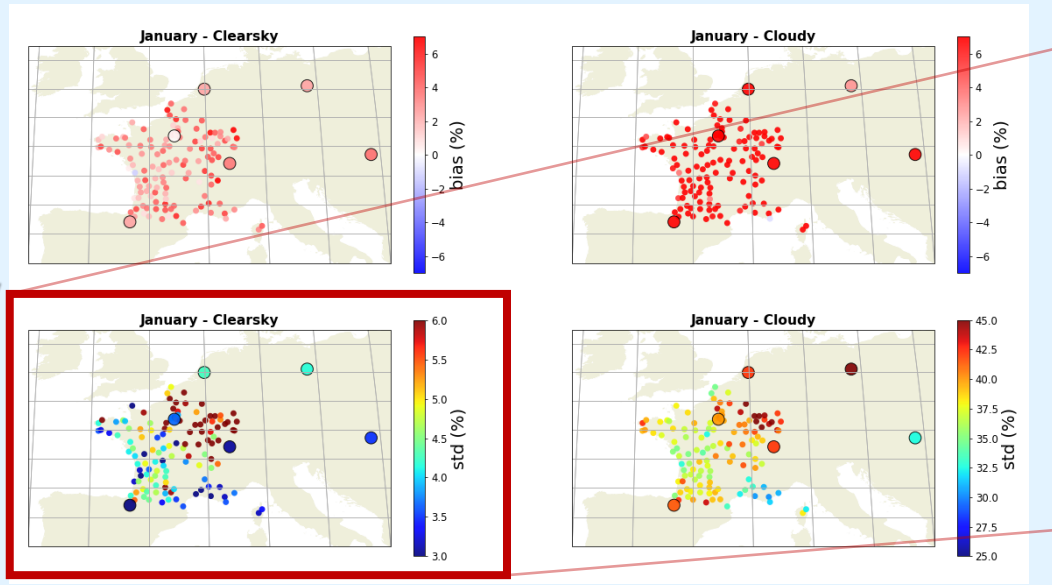
June

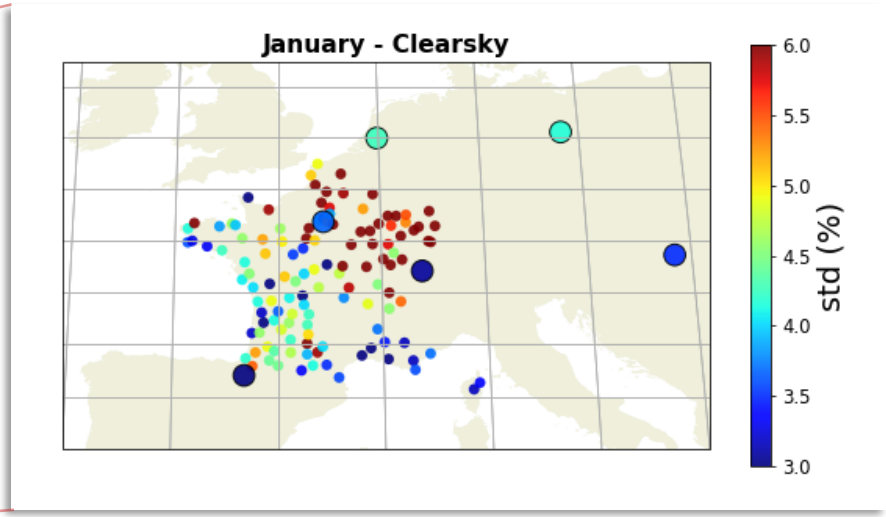




=> Consistency between Météo-France and BSRN

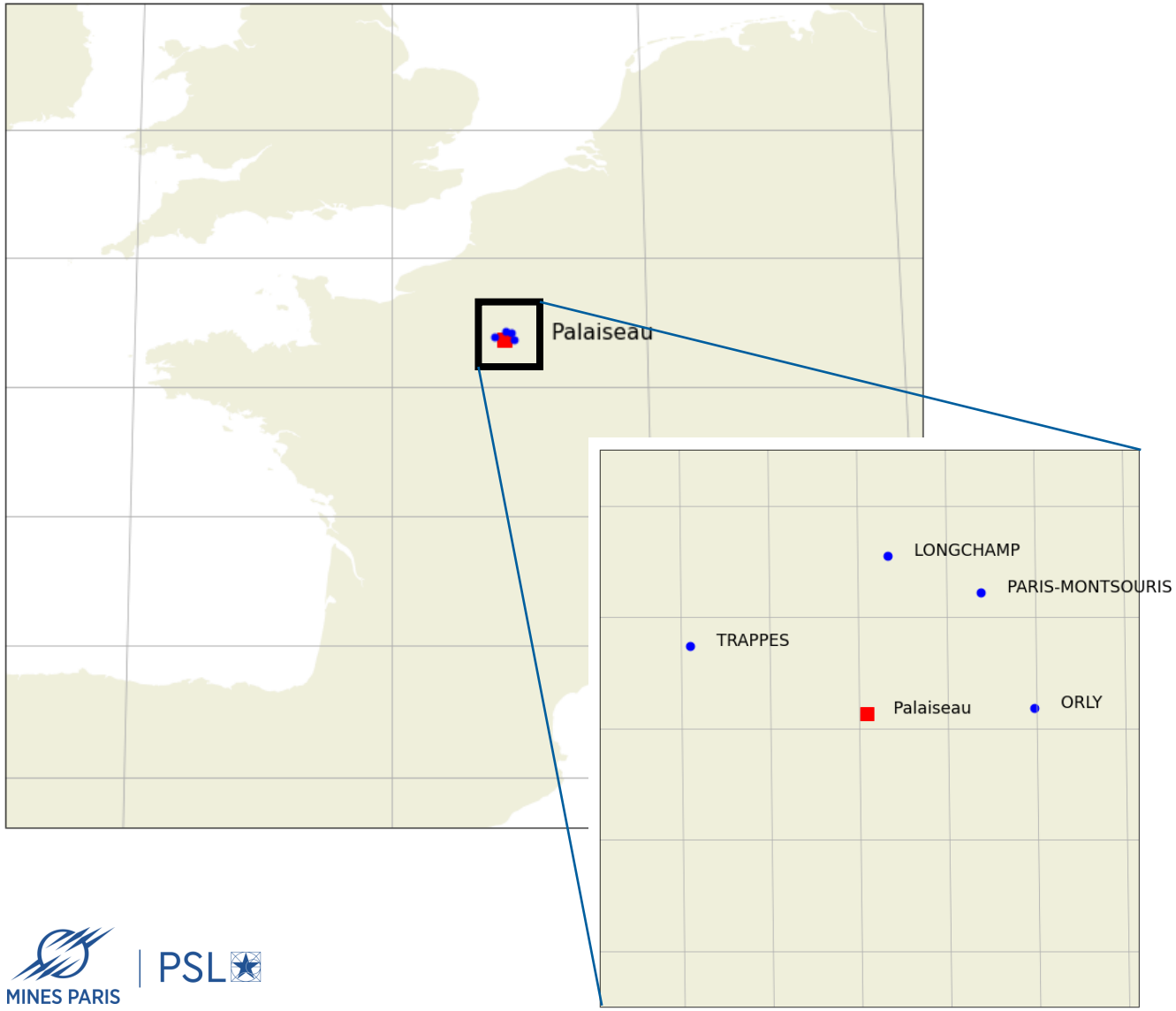
January





=> Lack of consistency between Météo-France and BSRN

Analysis of the consistency between Météo-France and BSRN around Palaiseau



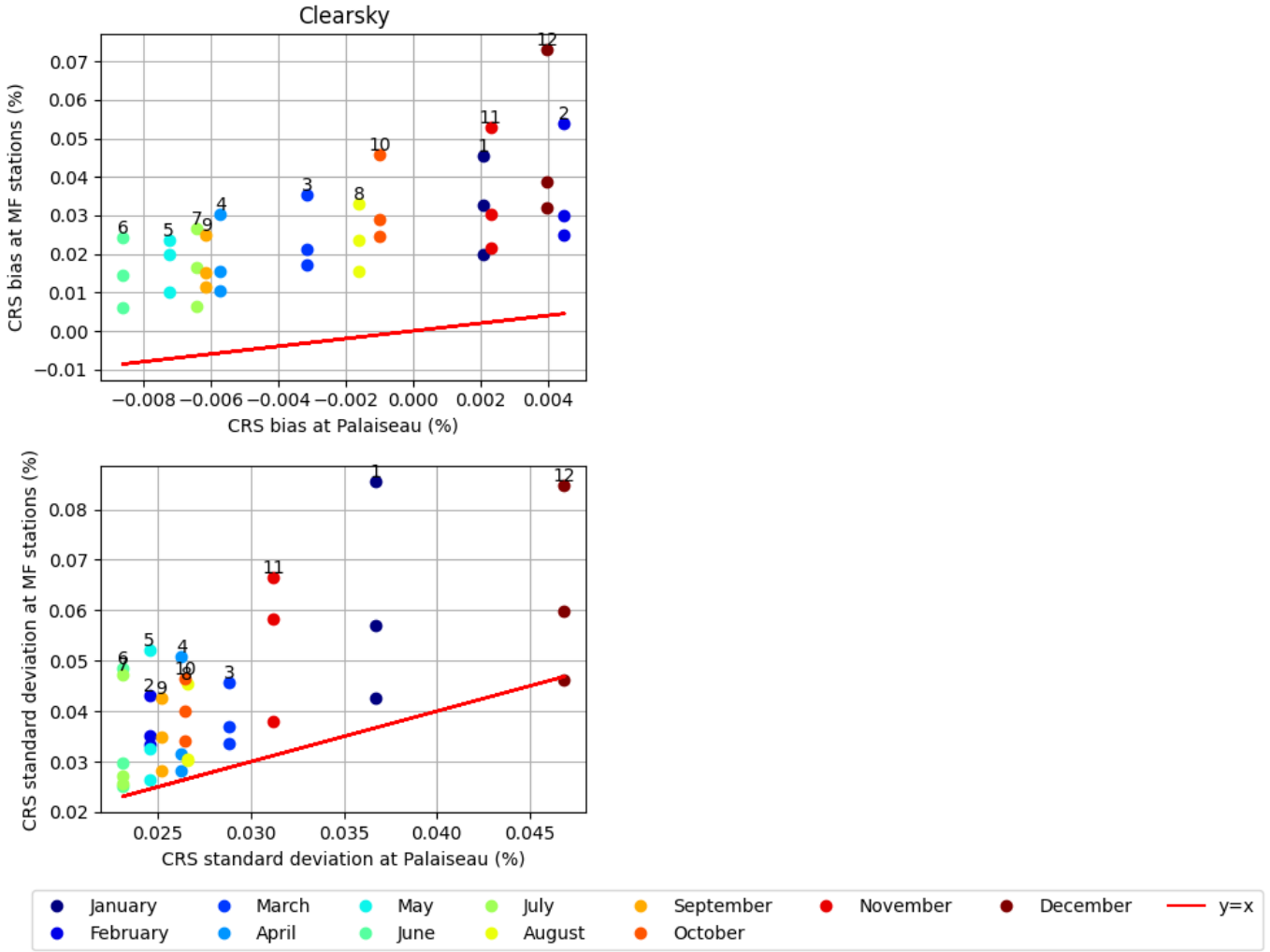
To assess the consistency between results obtained with BSRN and Météo-France :

- We focus on the BSRN station Palaiseau
- We select neighbouring MF stations at less than 30 km from Palaiseau: 4 MF stations

We expect that - at a monthly scale - the CRS analyses made with the two data sources give comparable results

- Deviations may however occur due to a sampling error resulting from possible difference in data availability

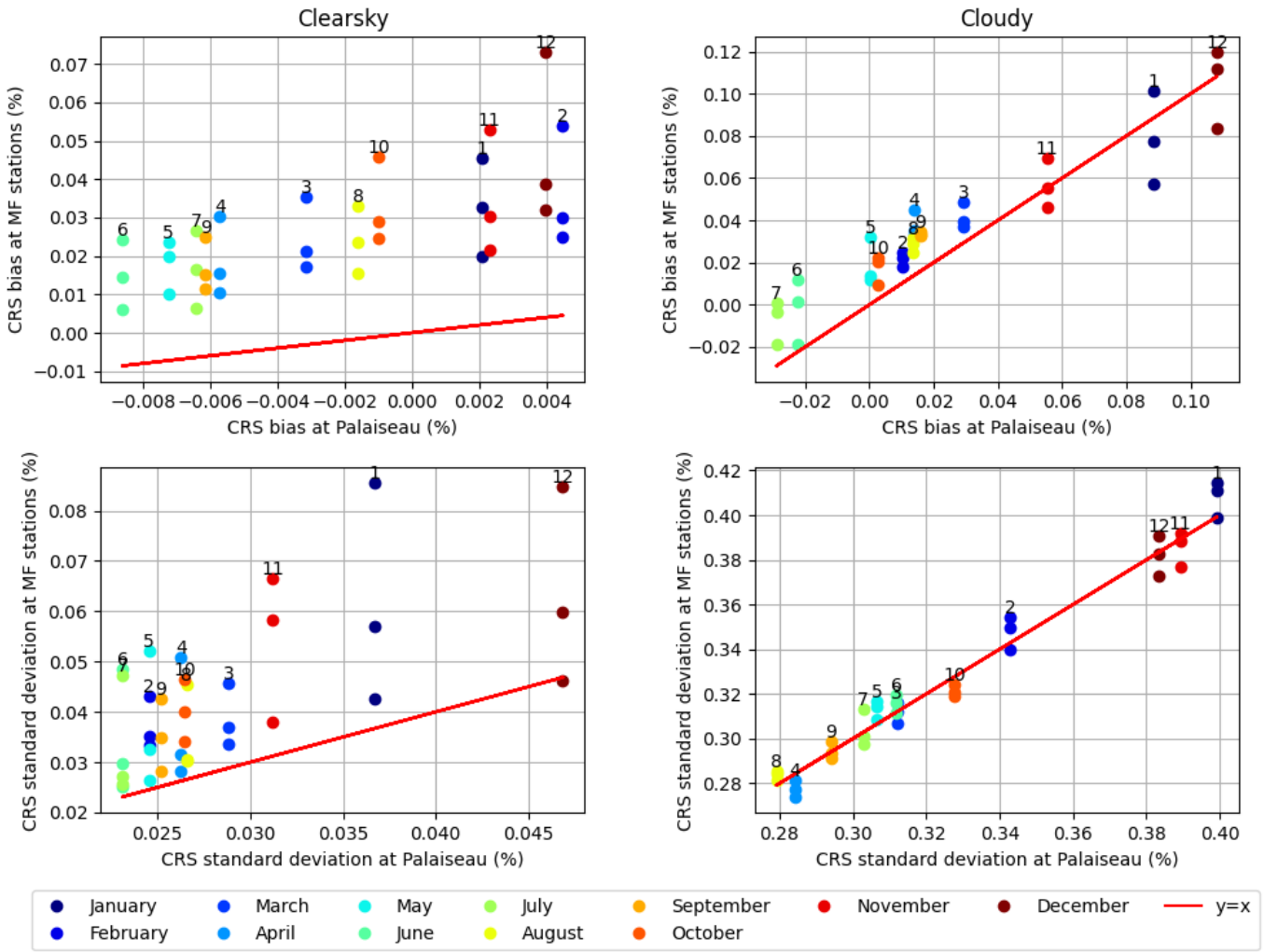
Analysis of the consistency between Météo-France and BSRN around Palaiseau



Results for clear-sky conditions:

- The bias evaluated with MF stations is greater than the ones found at the BSRN station
- The bias and standard deviation evaluated with MF and BSRN stations are weakly correlated

Analysis of the consistency between Météo-France and BSRN around Palaiseau



Results for clear-sky conditions:

- The bias evaluated with MF stations is greater than the ones found at the BSRN station
- The bias and standard deviation evaluated with MF and BSRN stations are weakly correlated

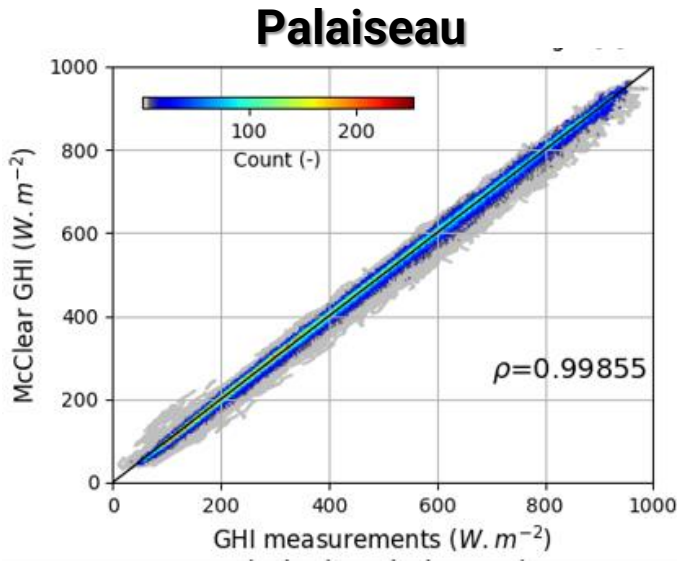
Results for cloudy conditions:

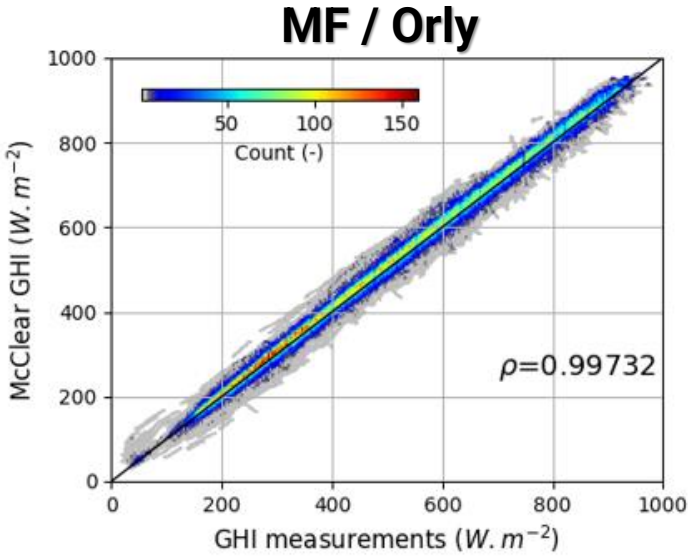
- A clear correlation is observed between the bias and bias and standard deviation evaluated with MF and BSRN stations

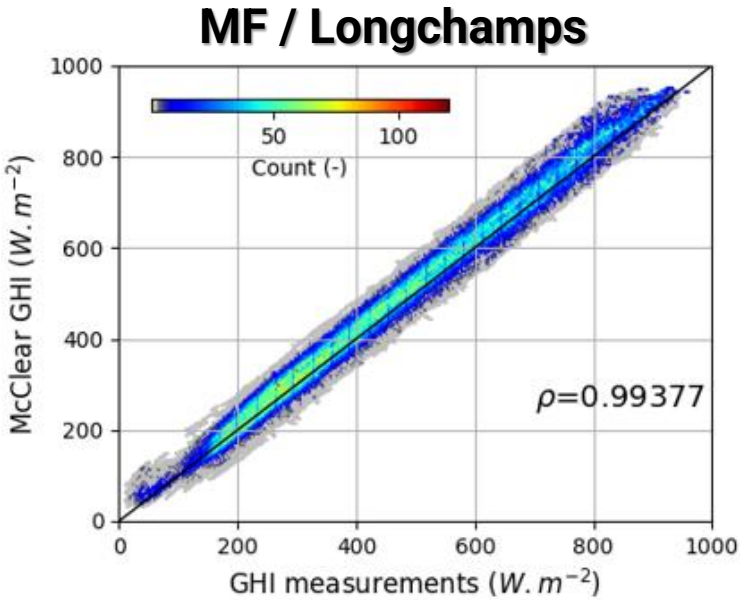
Analysis of the consistency between Météo-France and BSRN around Palaiseau

BSRN station

Météo-France station







Comparison with scatter plot:

- Previous results are confirmed by scatter plots of CRS vs. reference measurements in clear sky conditions.

Possible origin of the difference in clear sky:

- Pyranometer soiling ?
- Pyranometer levelling ?
- Pyranometer calibration ?

Conclusion:

The performances of CRS assessed on BSRN and Météo-France stations have been compared

Based on a detailed analysis around Palaiseau, we found that the consistency between the two performances depends on the weather class

- Results are consistent in cloudy situations:
  - The high density of the MF network can be used to improve our understanding of the performance of CRS
- Noticeable differences were found in clear sky conditions
  - The difference is likely resulting from a calibration, soiling or levelling issue (?)
  - The MF measurements should be use with caution (cf. data driven approach)

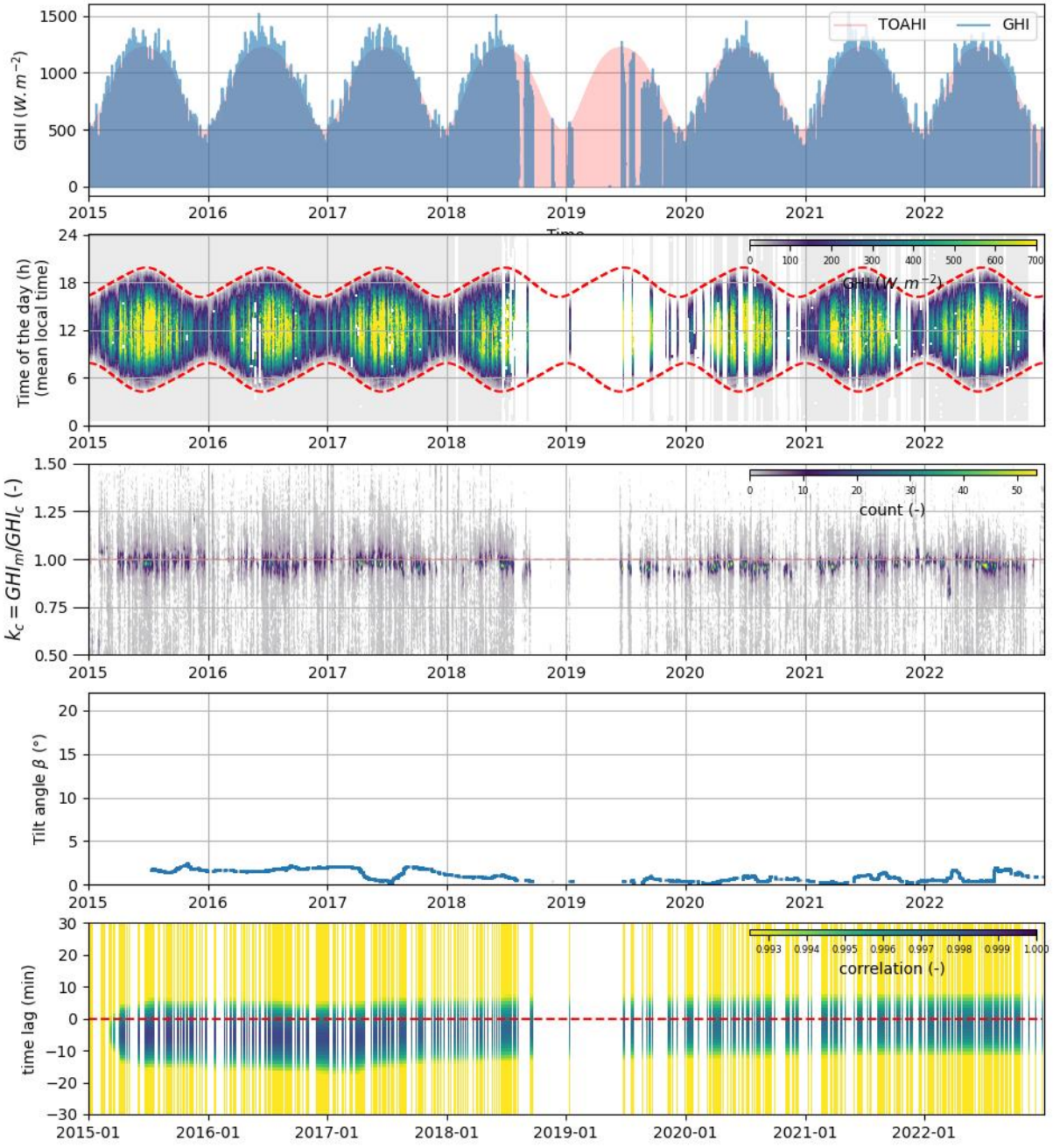
Some open questions:

- How do the results obtained at Palaiseau generalize to other stations?
- What is the effect of the sampling error due to the different QC and availability of the data?

Backup slides

1. example of visual quality control

Station: LA PESSE (133/260)

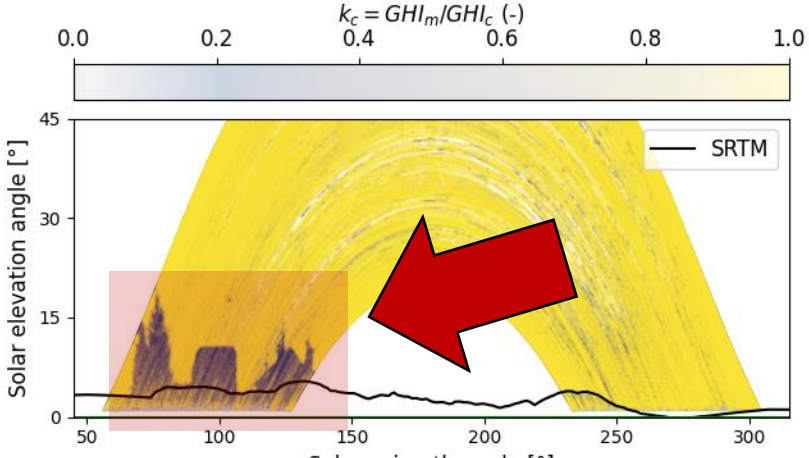


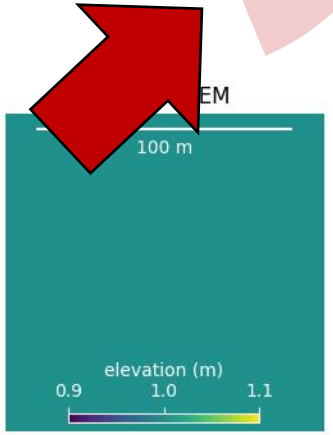
Network: METEO_FRANCE
Station: 39413001 (LA PESSE)

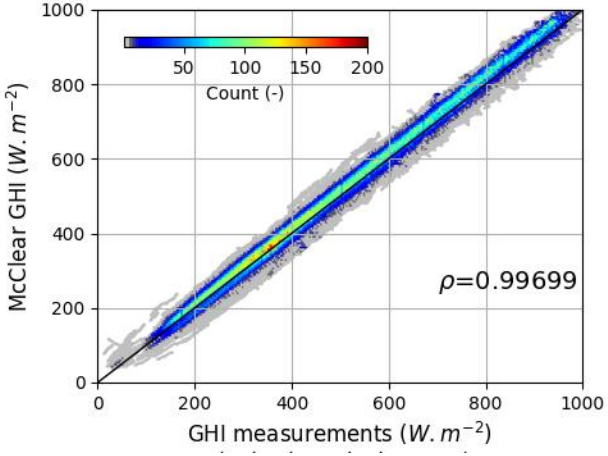
Latitude: 46.30283°
Longitude: 5.84300°
Altitude: 1133.00 m

Country: France
Climate zone : Cfb

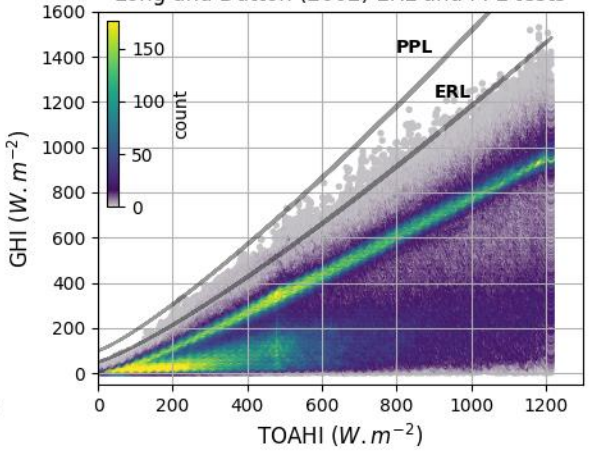
Google aerial view



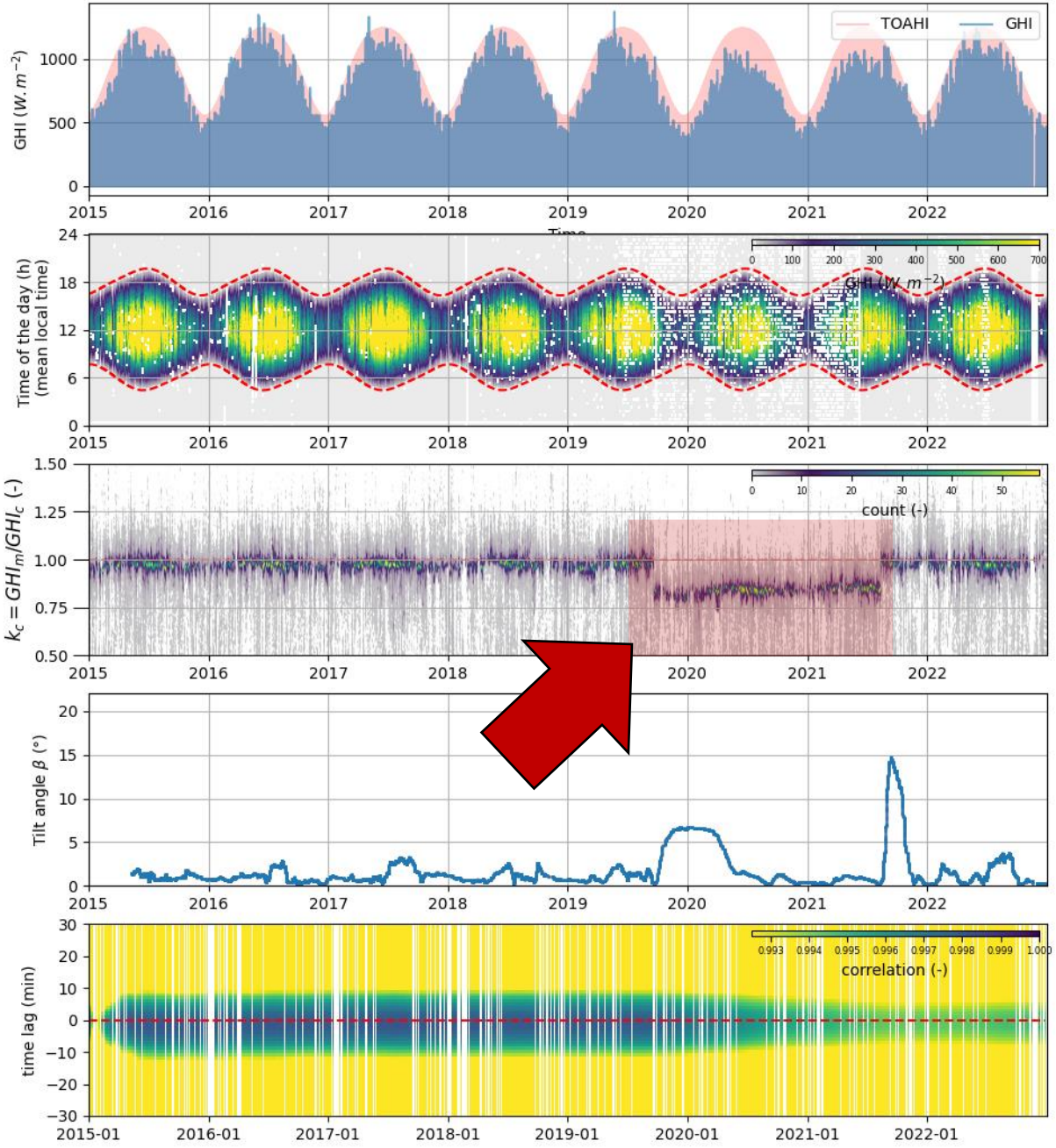




Long and Dutton (2002) ERL and PPL tests



Station: NICE (74/260)

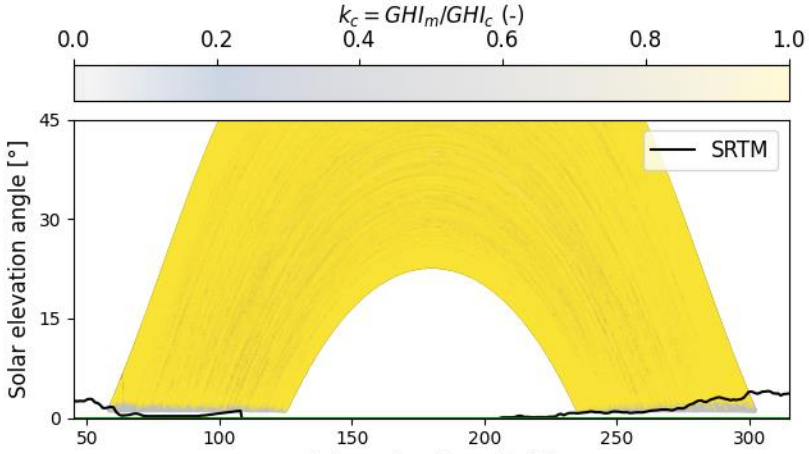


Network: METEO_FRANCE
Station: 6088001 (NICE)

Latitude: 43.64883°
Longitude: 7.20900°
Altitude: 2.00 m

Country: France
Climate zone :

Google aerial view



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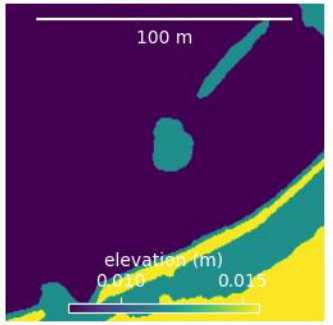

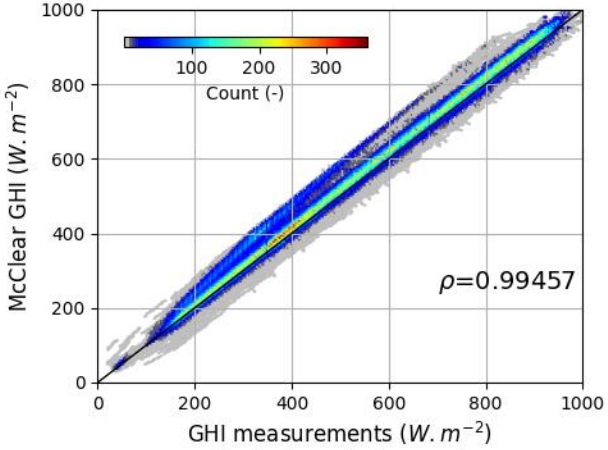

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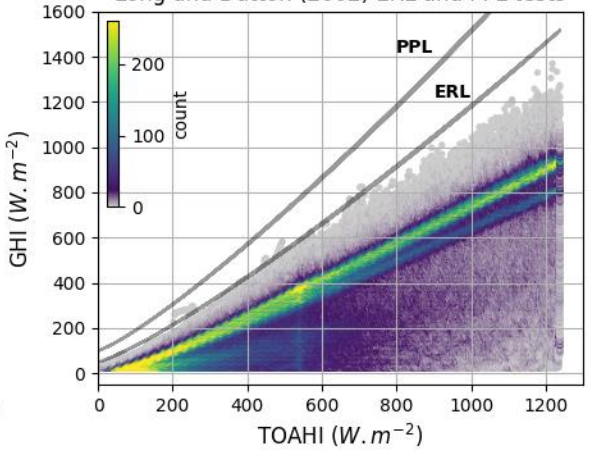


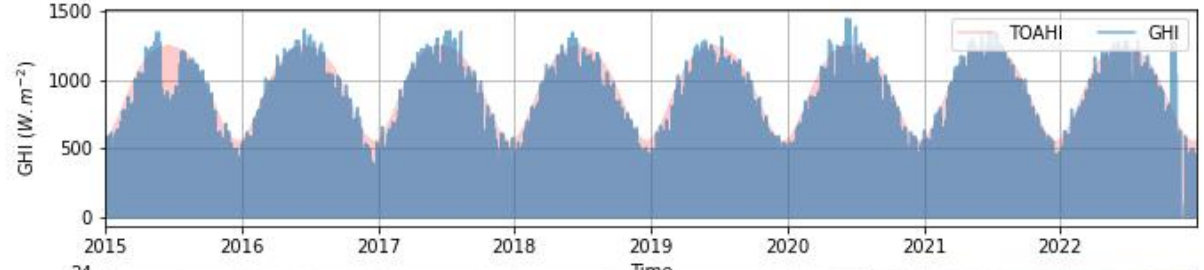
Station: DAX (10/260)

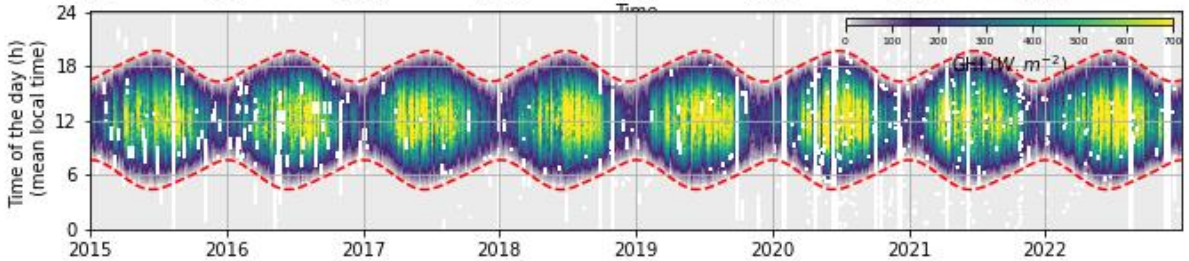
Network: METEO_FRANCE
Station: 40088001 (DAX)

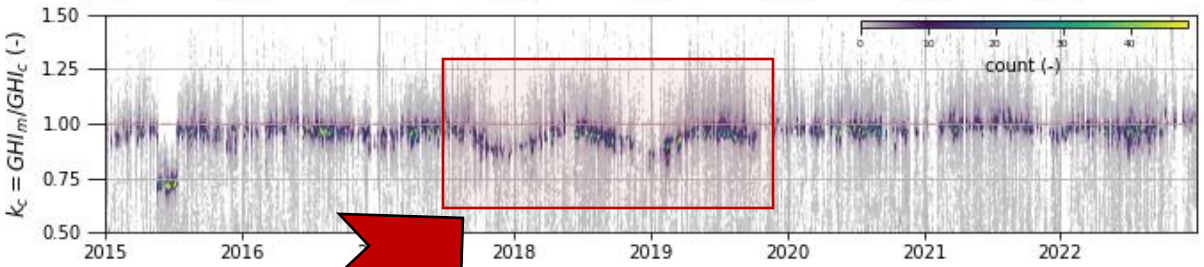
Latitude: 43.68983°
Longitude: -1.07000°
Altitude: 31.00 m

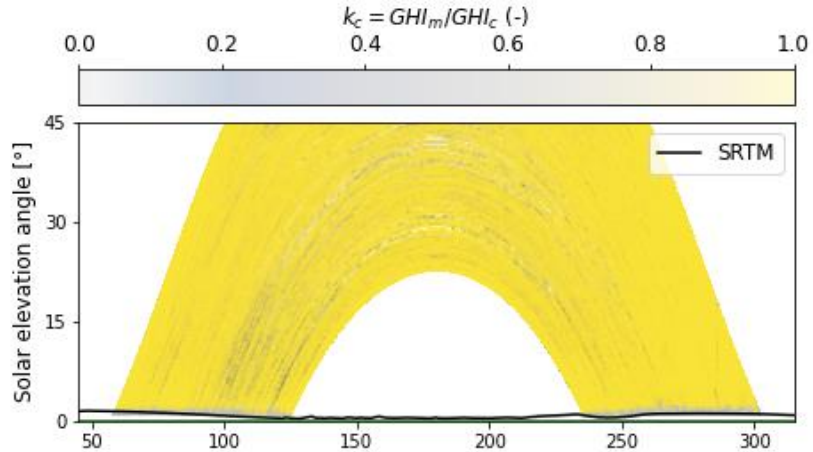
Country: France
Climate zone : Cfb

Google aerial view









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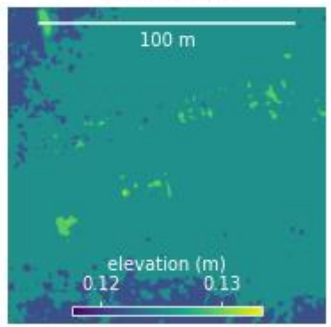

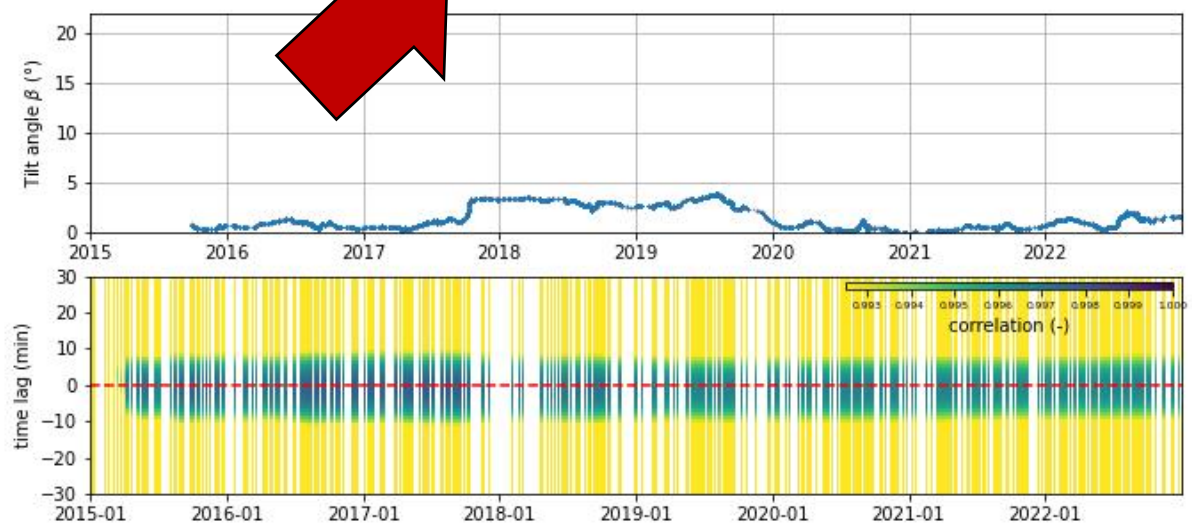

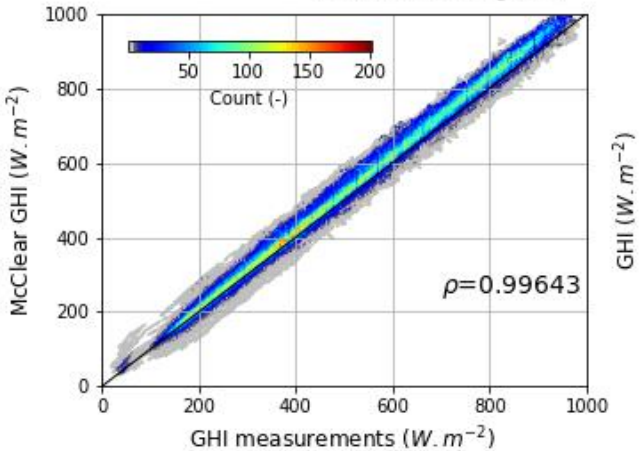

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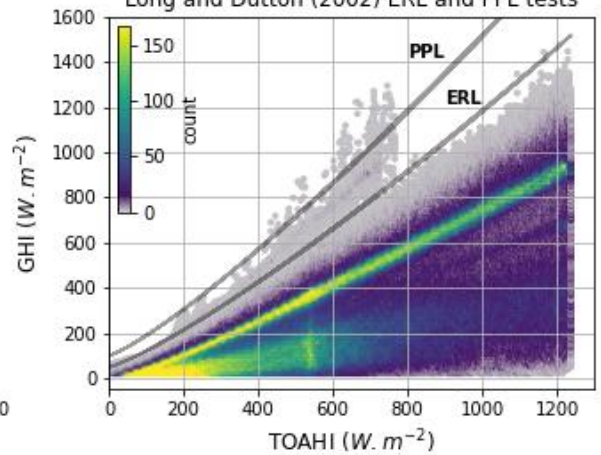
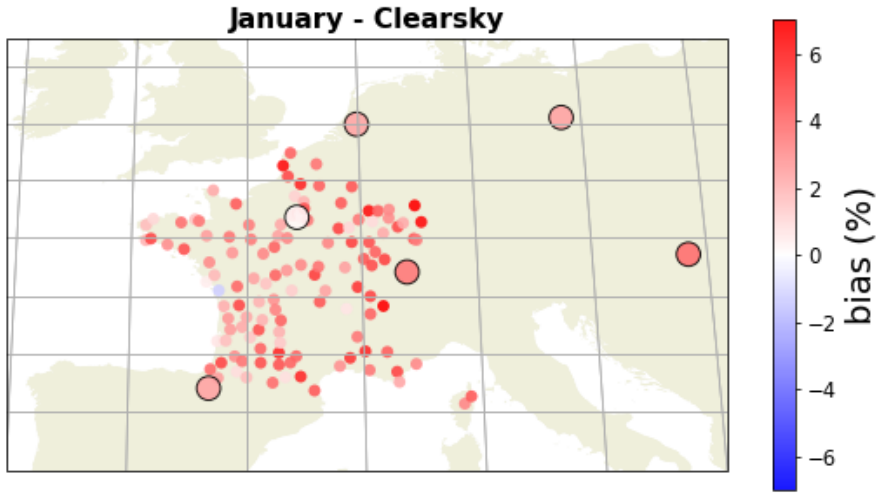
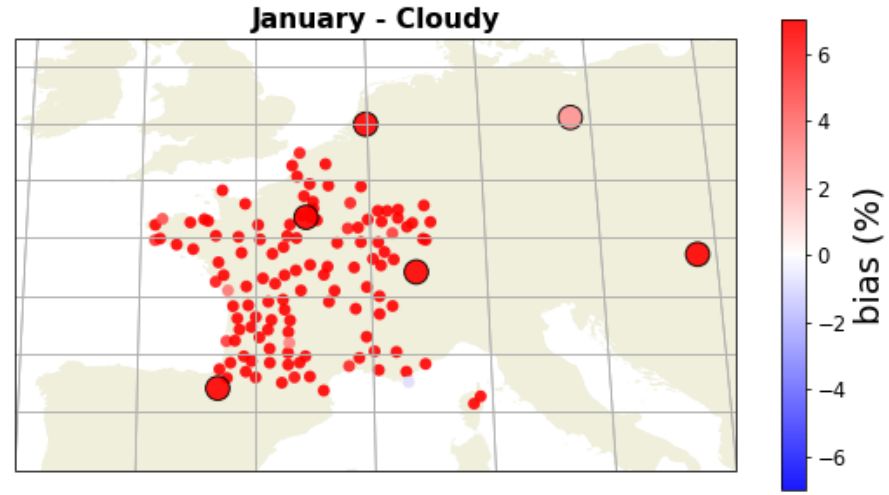
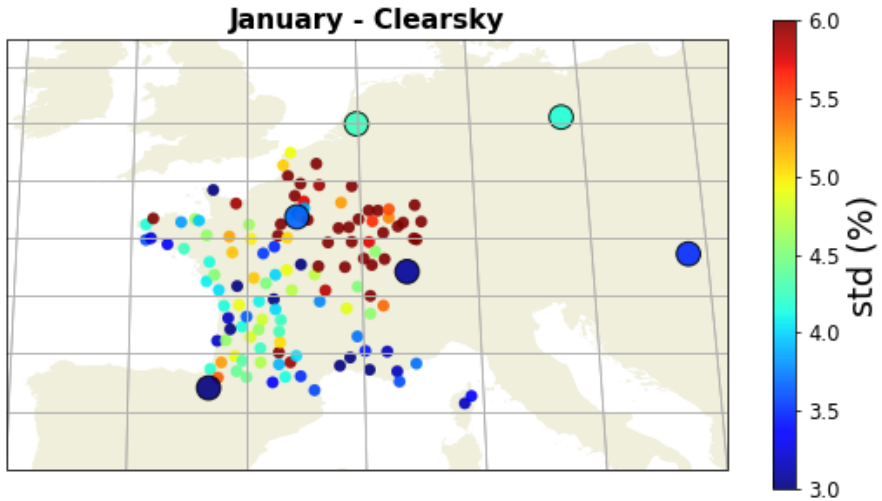


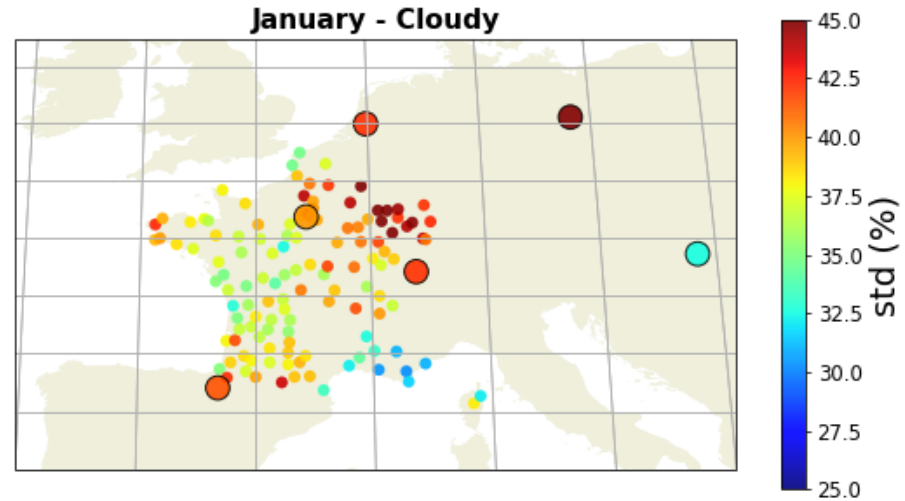
Backup slides

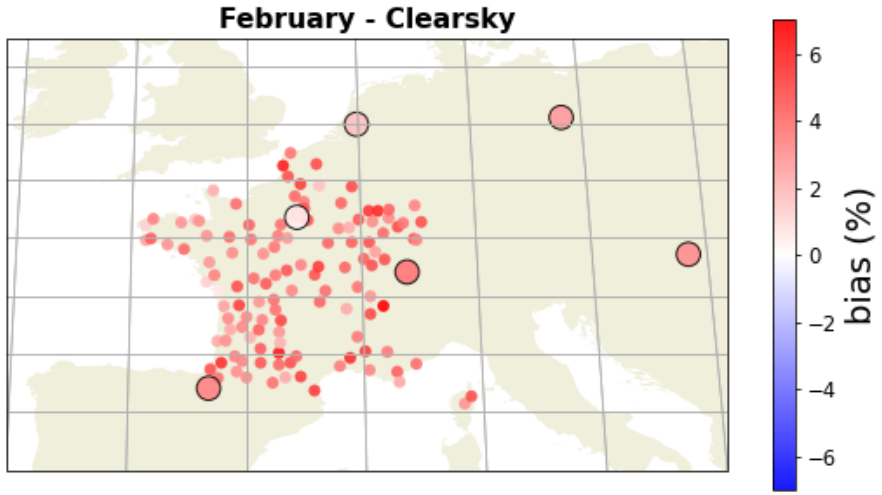
2. Evaluation results for each month


January - Clearsky
6
4
2
0
−2
−4
−6
bias (%)

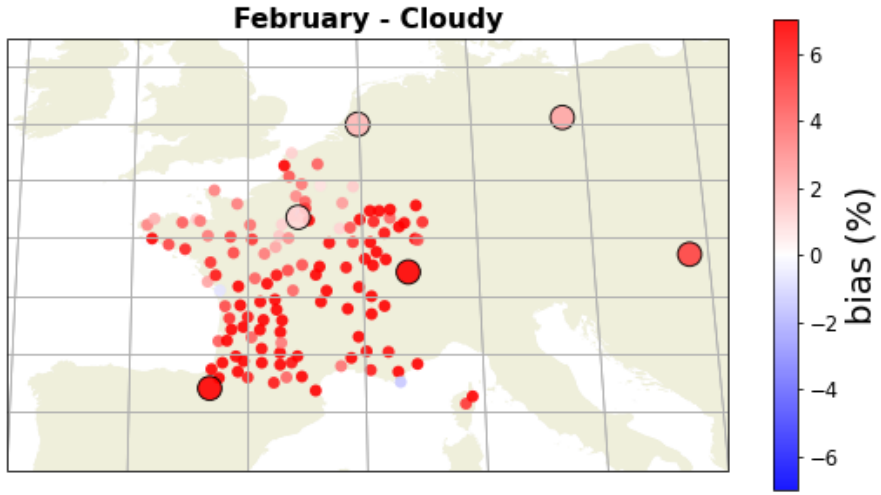

January - Cloudy
6
4
2
0
−2
−4
−6
bias (%)


January - Clearsky
6.0
5.5
5.0
4.5
4.0
3.5
3.0
std (%)

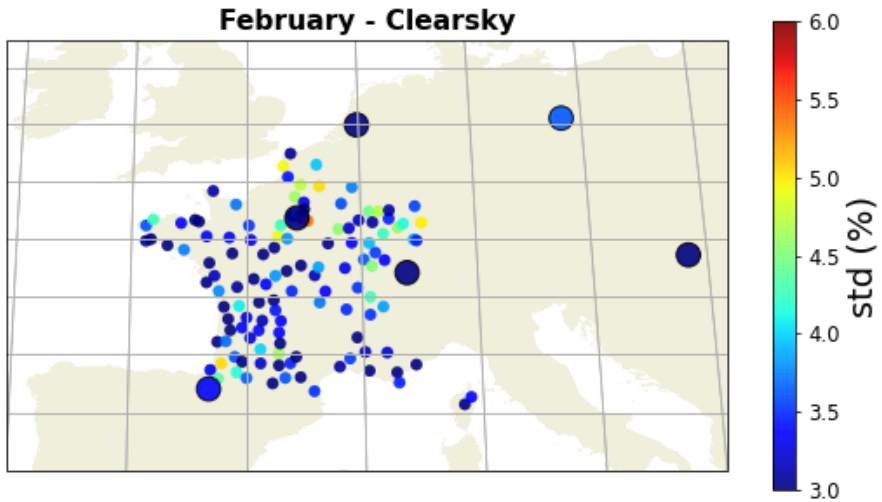

January - Cloudy
45.0
42.5
40.0
37.5
35.0
32.5
30.0
27.5
25.0
std (%)


February - Clearsky

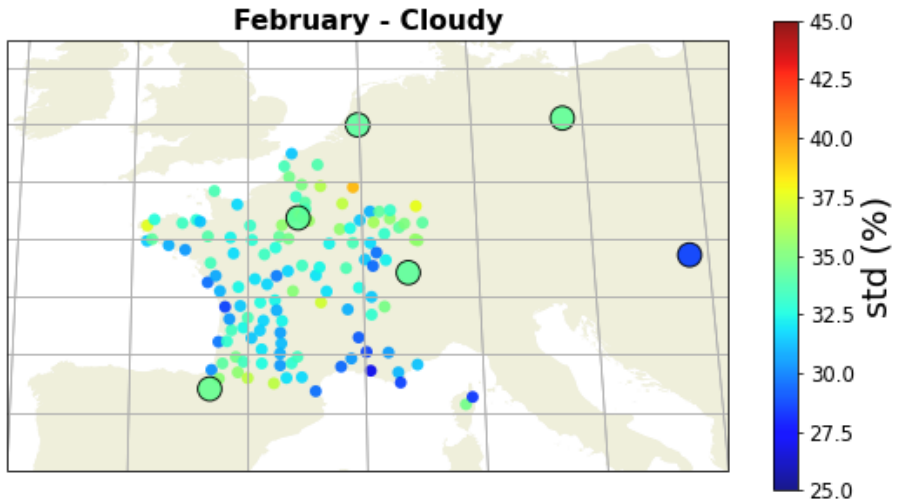
6
4
2
0
−2
−4
−6
bias (%)


February - Cloudy

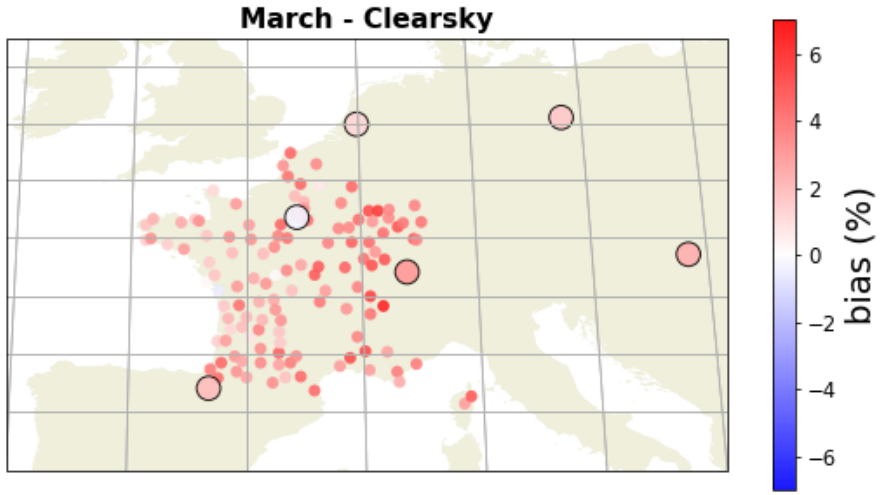
6
4
2
0
−2
−4
−6
bias (%)

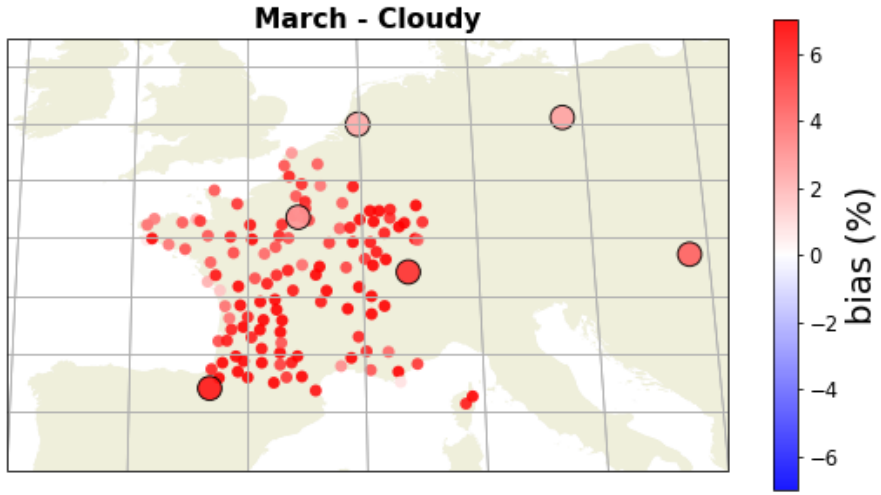

February - Clearsky

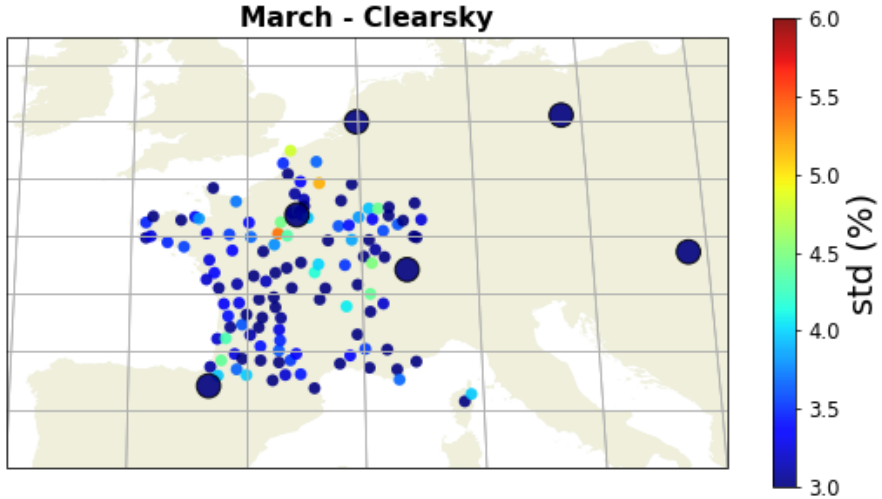
6.0
5.5
5.0
4.5
4.0
3.5
3.0
std (%)

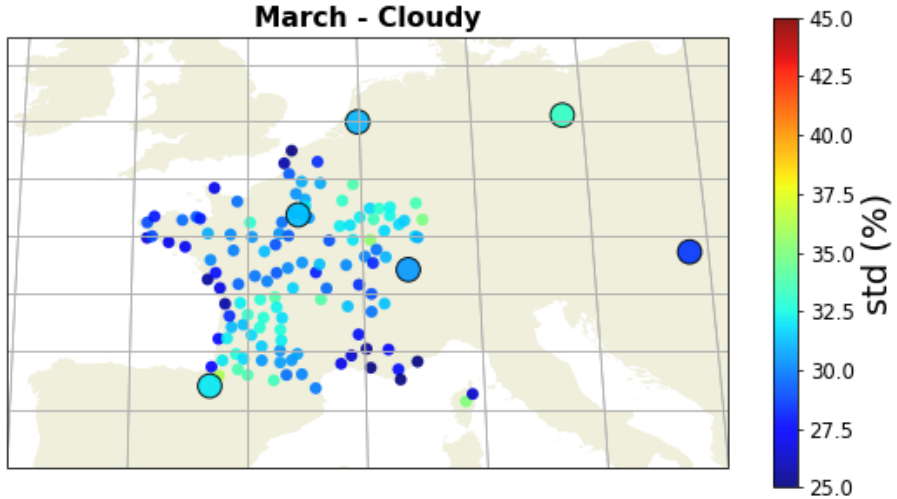

February - Cloudy

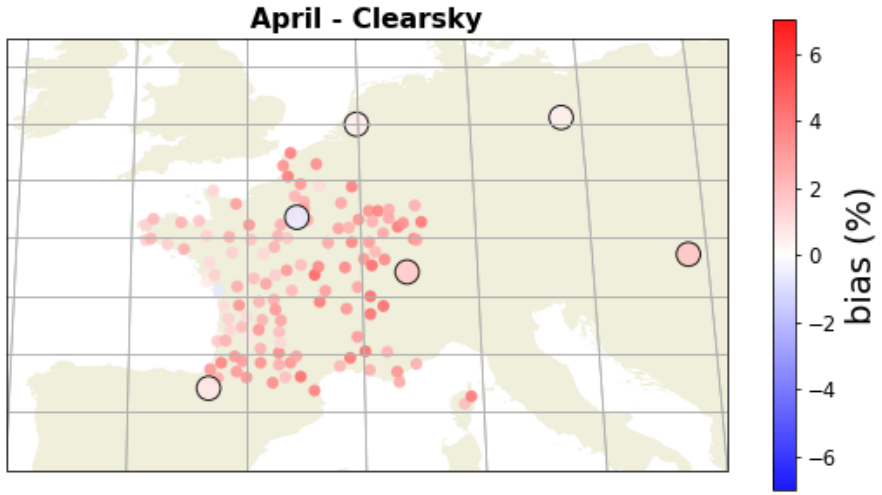
45.0
42.5
40.0
37.5
35.0
32.5
30.0
27.5
25.0
std (%)


March - Clearsky
6
4
2
0
−2
−4
−6
bias (%)

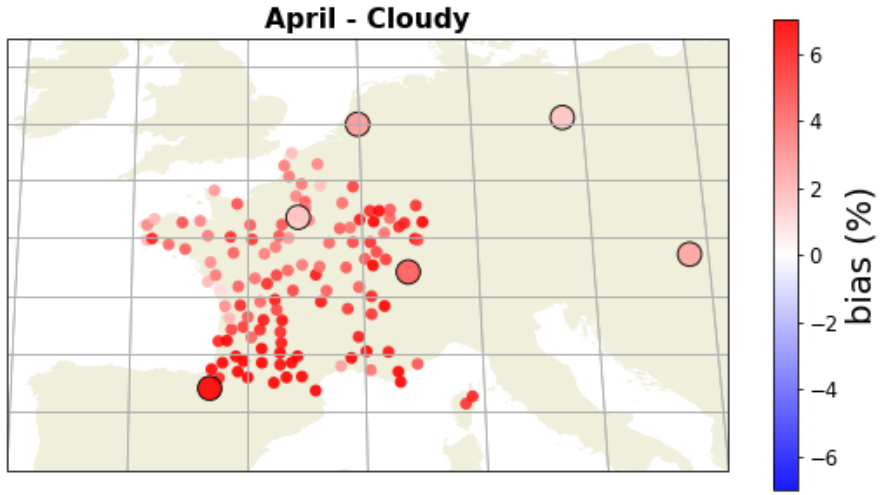

March - Cloudy
6
4
2
0
−2
−4
−6
bias (%)


March - Clearsky
6.0
5.5
5.0
4.5
4.0
3.5
3.0
std (%)

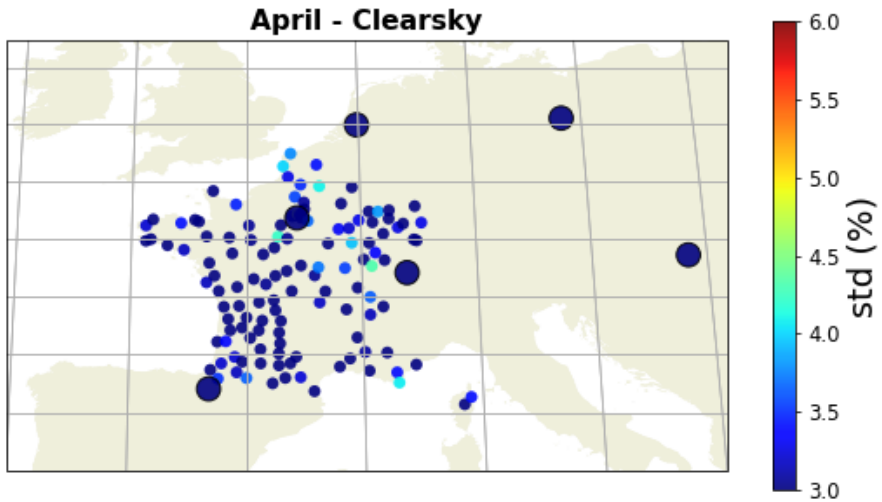

March - Cloudy
45.0
42.5
40.0
37.5
35.0
32.5
30.0
27.5
25.0
std (%)


April - Clearsky

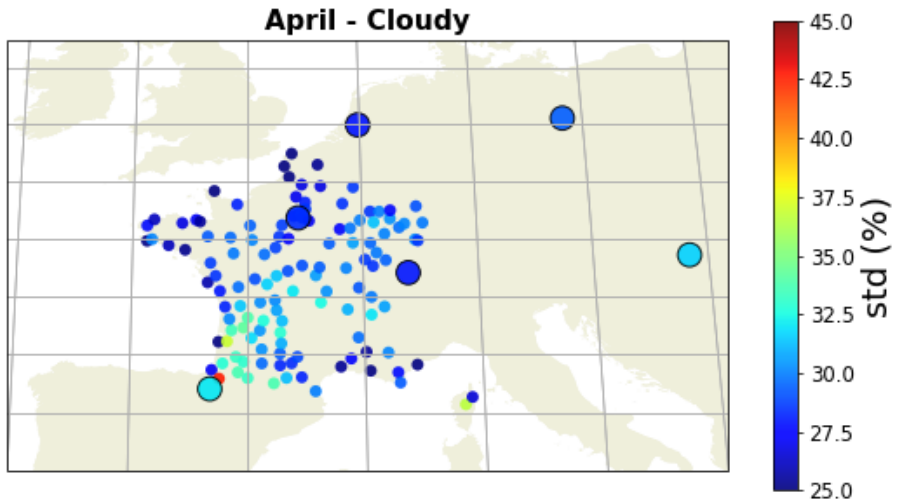
6
4
2
0
−2
−4
−6
bias (%)


April - Cloudy

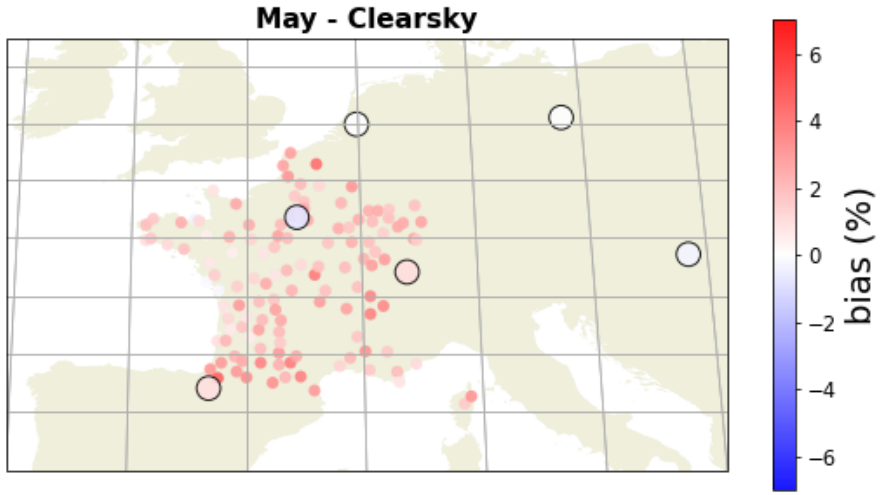
6
4
2
0
−2
−4
−6
bias (%)

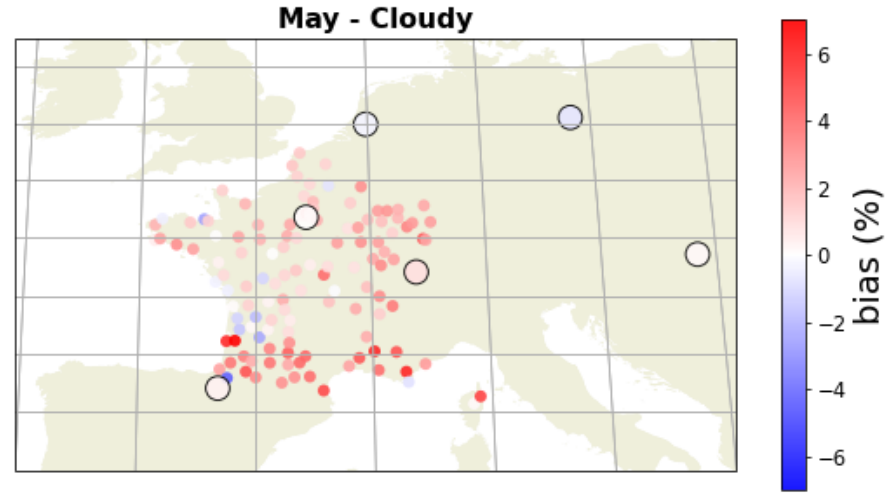

April - Clearsky

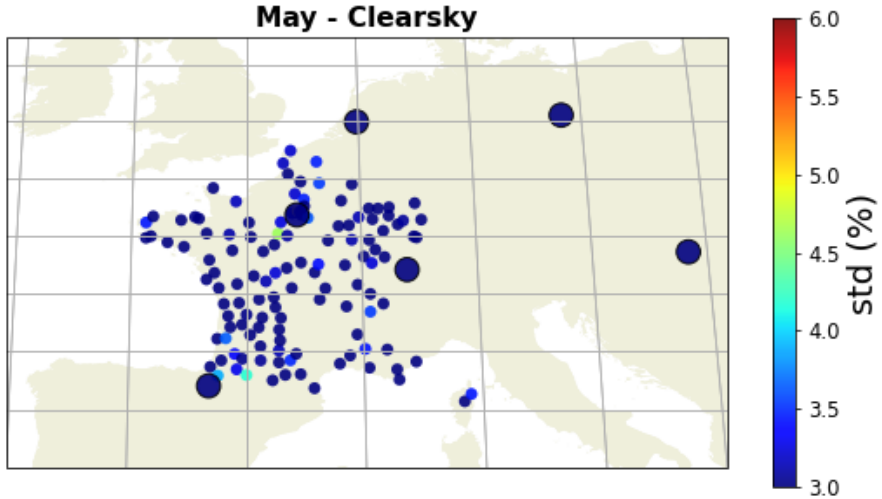
6.0
5.5
5.0
4.5
4.0
3.5
3.0
std (%)

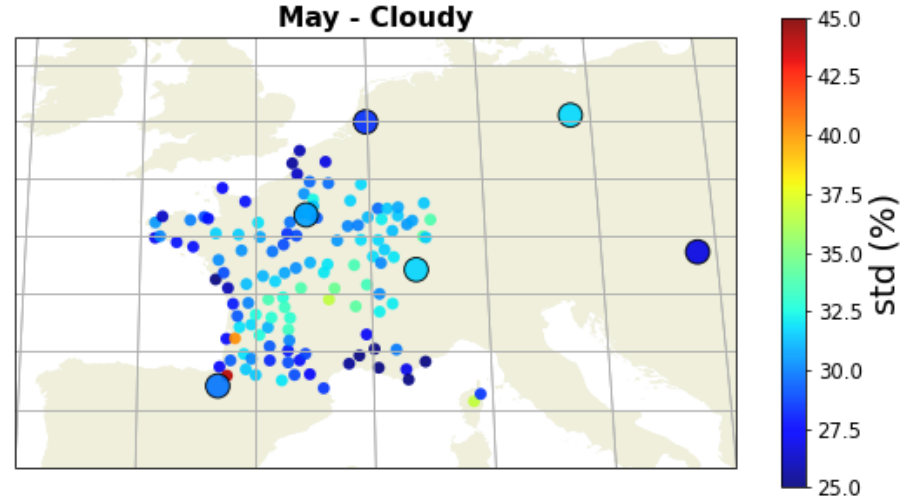

April - Cloudy

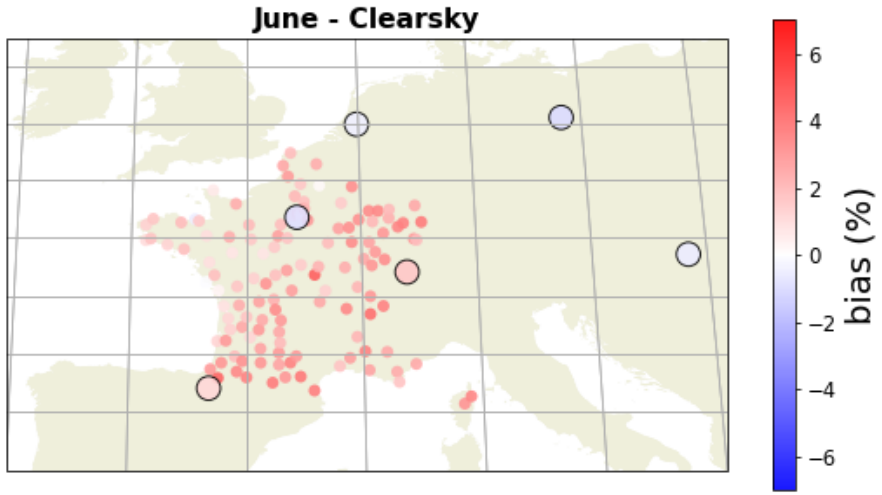
45.0
42.5
40.0
37.5
35.0
32.5
30.0
27.5
25.0
std (%)

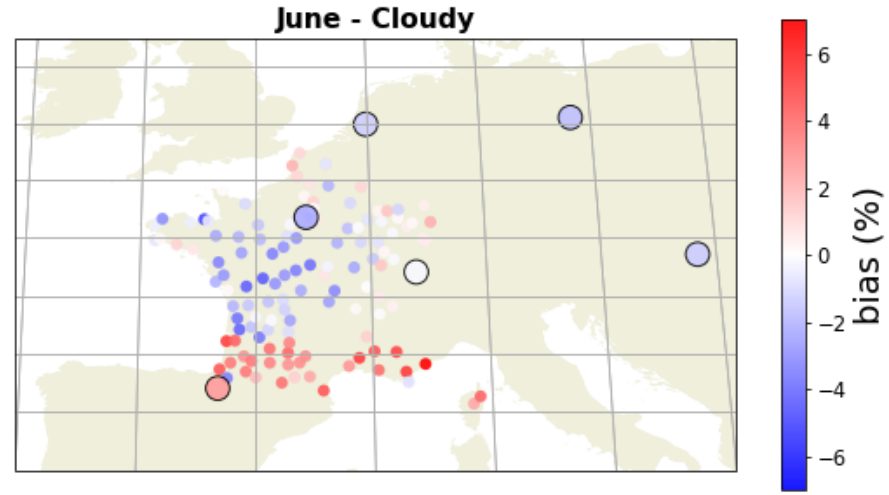

May - Clearsky
6
4
2
0
−2
−4
−6
bias (%)

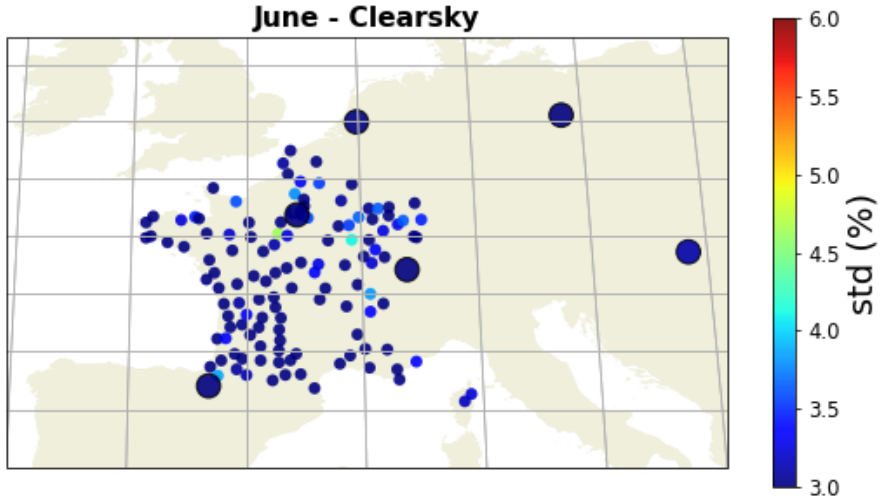

May - Cloudy
6
4
2
0
−2
−4
−6
bias (%)

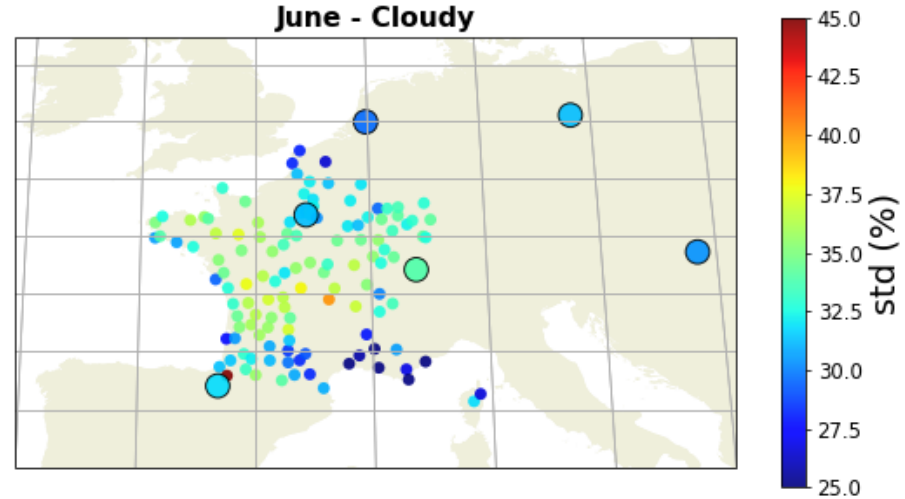

May - Clearsky
6.0
5.5
5.0
4.5
4.0
3.5
3.0
std (%)

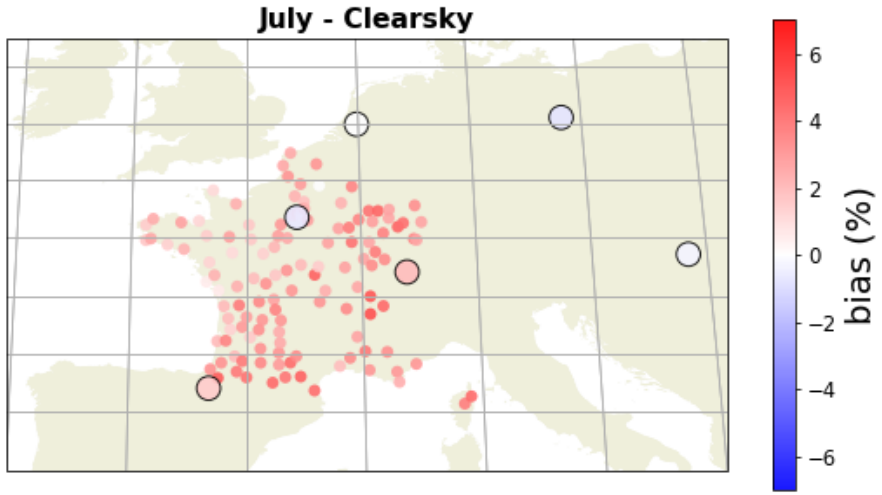

May - Cloudy
45.0
42.5
40.0
37.5
35.0
32.5
30.0
27.5
25.0
std (%)


June - Clearsky
6
4
2
0
−2
−4
−6
bias (%)

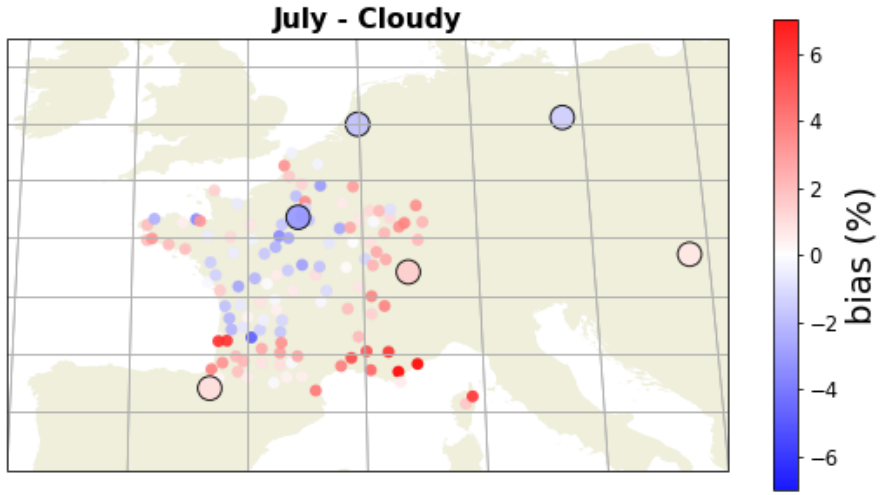

June - Cloudy
6
4
2
0
−2
−4
−6
bias (%)


June - Clearsky
6.0
5.5
5.0
4.5
4.0
3.5
3.0
std (%)

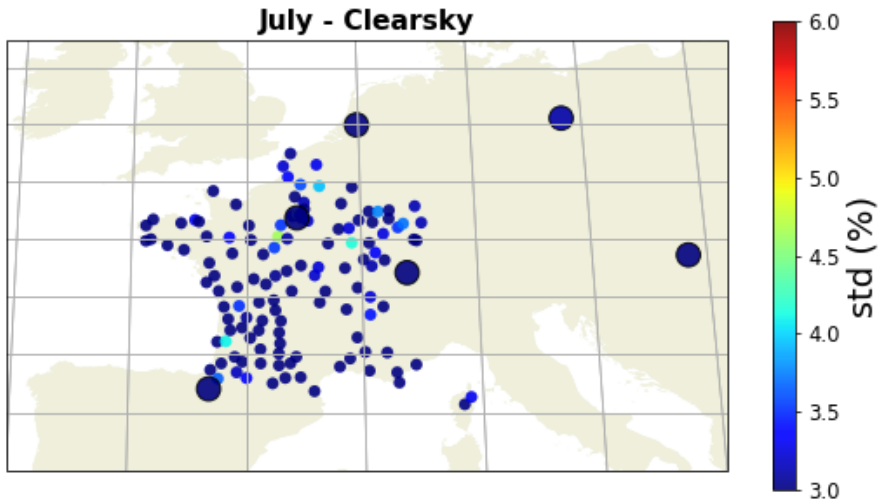

June - Cloudy
45.0
42.5
40.0
37.5
35.0
32.5
30.0
27.5
25.0
std (%)


July - Clearsky

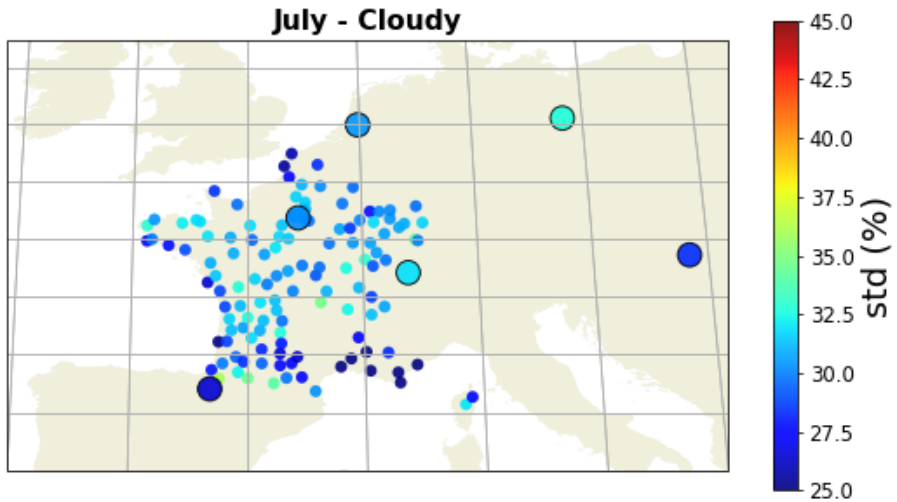
6
4
2
0
−2
−4
−6
bias (%)


July - Cloudy

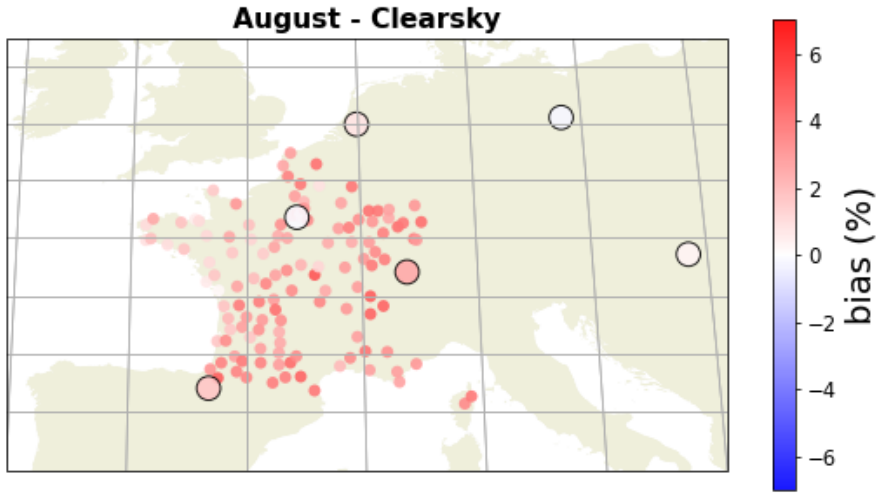
6
4
2
0
−2
−4
−6
bias (%)

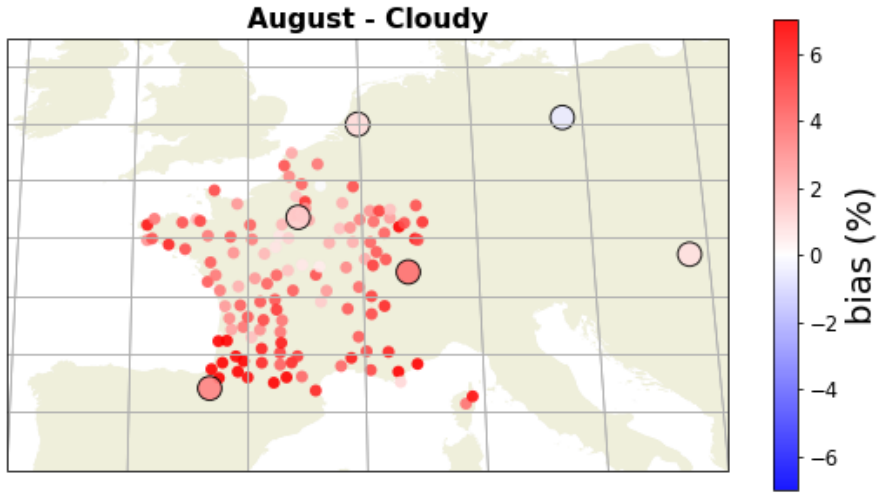

July - Clearsky

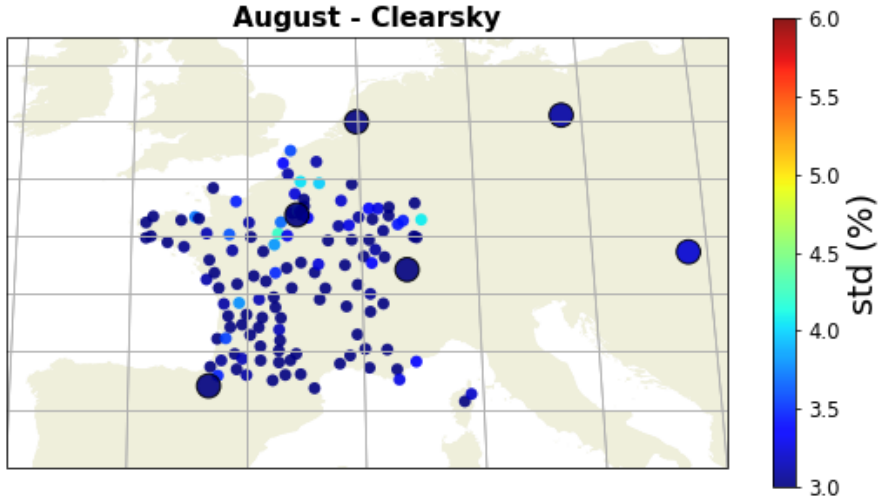
6.0
5.5
5.0
4.5
4.0
3.5
3.0
std (%)

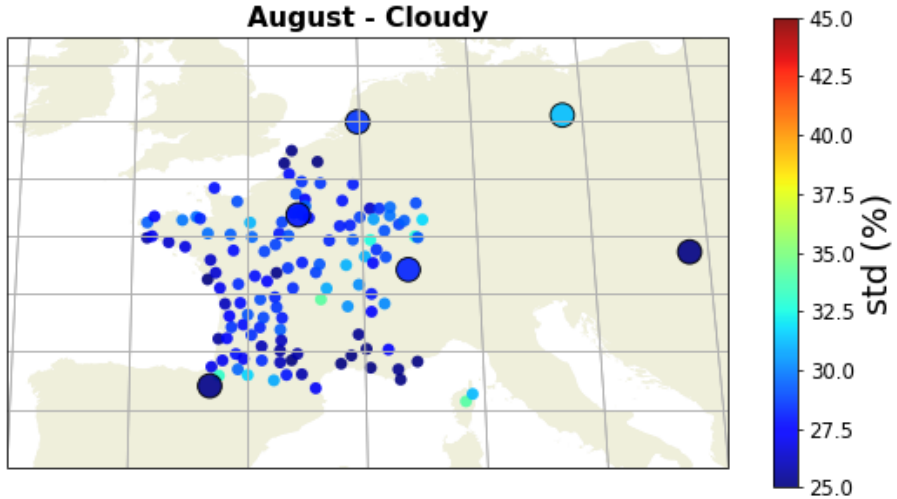

July - Cloudy

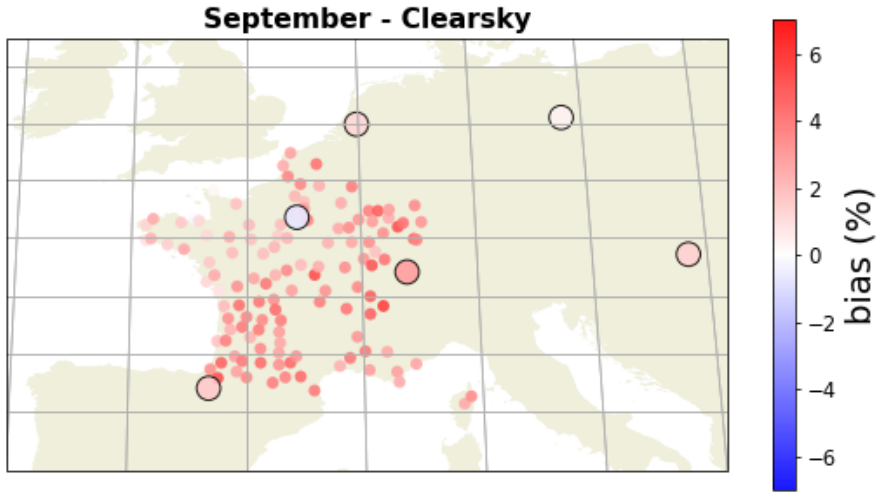
45.0
42.5
40.0
37.5
35.0
32.5
30.0
27.5
25.0
std (%)

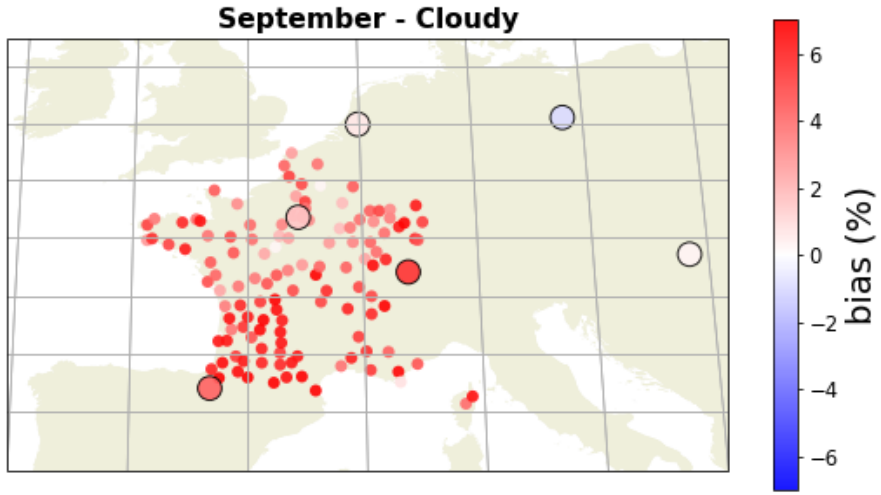

August - Clearsky
6
4
2
0
−2
−4
−6
bias (%)

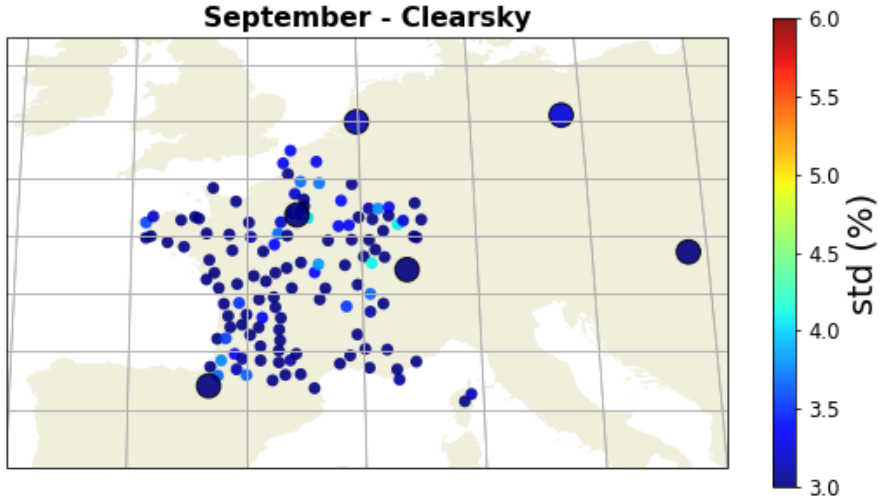

August - Cloudy
6
4
2
0
−2
−4
−6
bias (%)

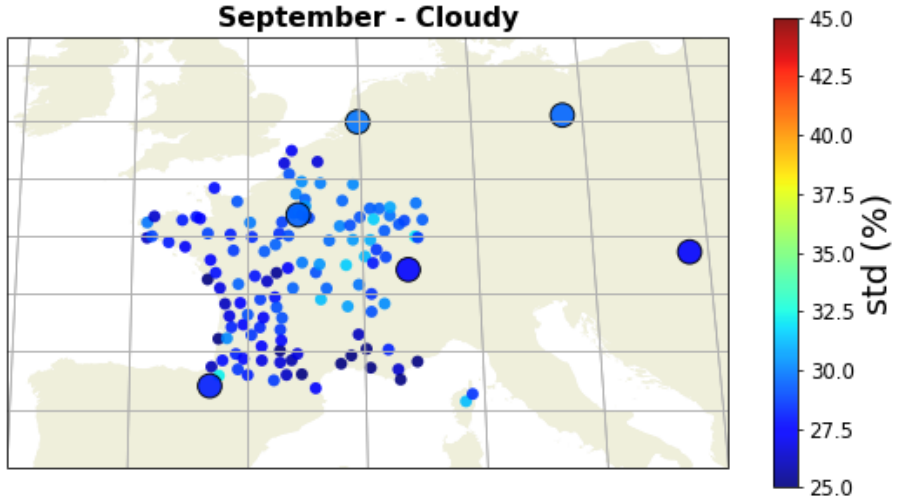

August - Clearsky
6.0
5.5
5.0
4.5
4.0
3.5
3.0
std (%)

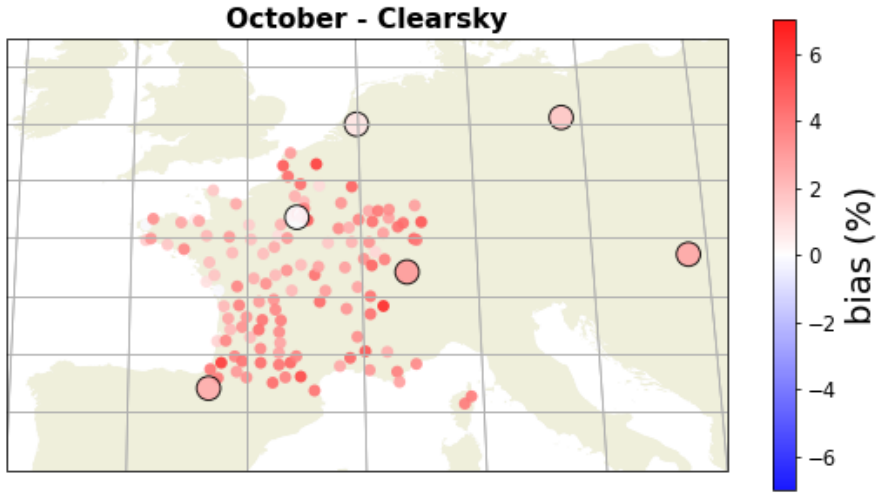

August - Cloudy
45.0
42.5
40.0
37.5
35.0
32.5
30.0
27.5
25.0
std (%)

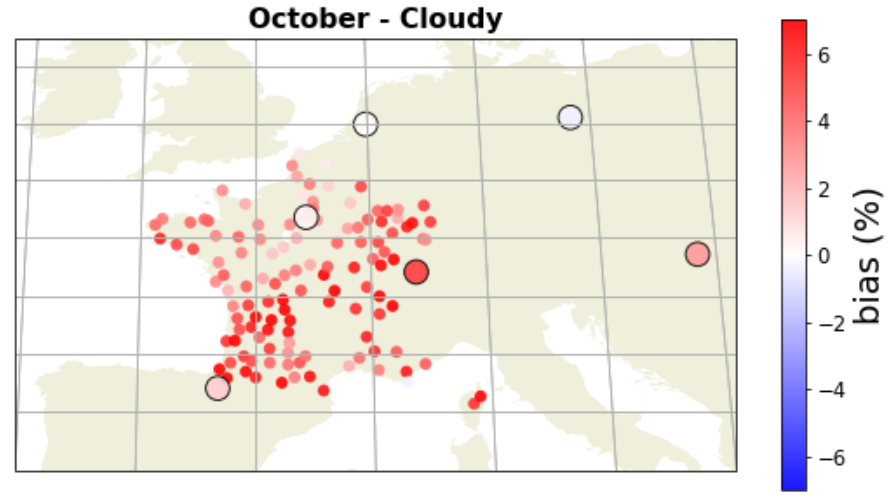

September - Clearsky
6
4
2
0
−2
−4
−6
bias (%)

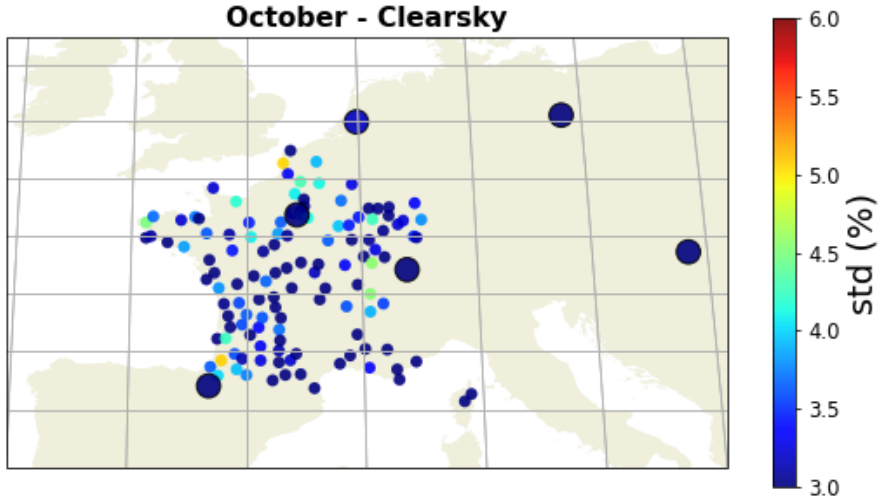

September - Cloudy
6
4
2
0
−2
−4
−6
bias (%)

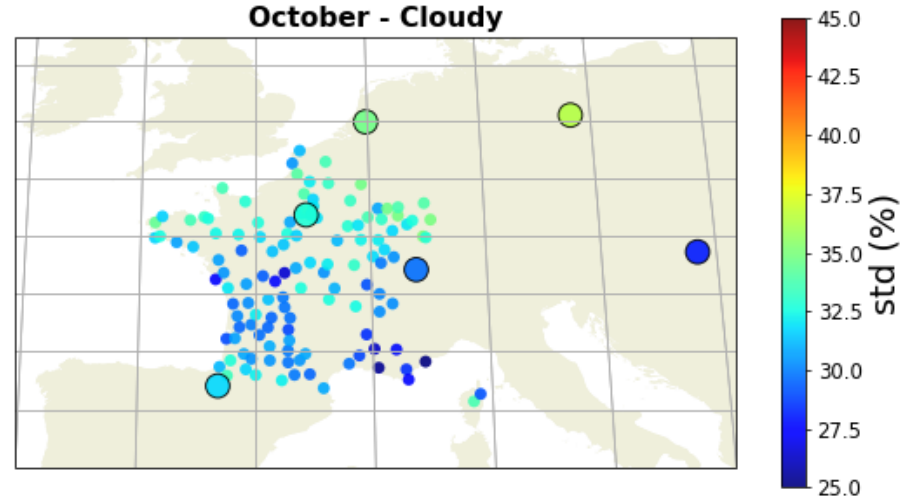

September - Clearsky
6.0
5.5
5.0
4.5
4.0
3.5
3.0
std (%)


September - Cloudy
45.0
42.5
40.0
37.5
35.0
32.5
30.0
27.5
25.0
std (%)


October - Clearsky
6
4
2
0
−2
−4
−6
bias (%)


October - Cloudy
6
4
2
0
−2
−4
−6
bias (%)


October - Clearsky
6.0
5.5
5.0
4.5
4.0
3.5
3.0
std (%)


October - Cloudy
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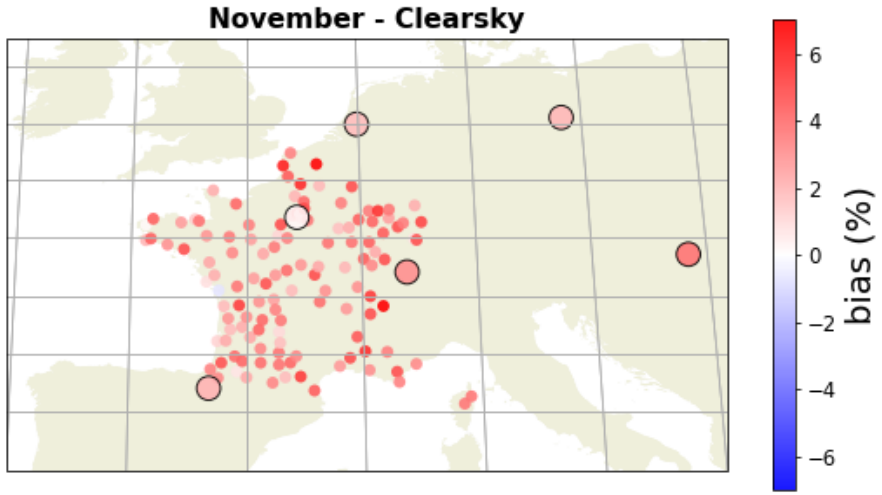
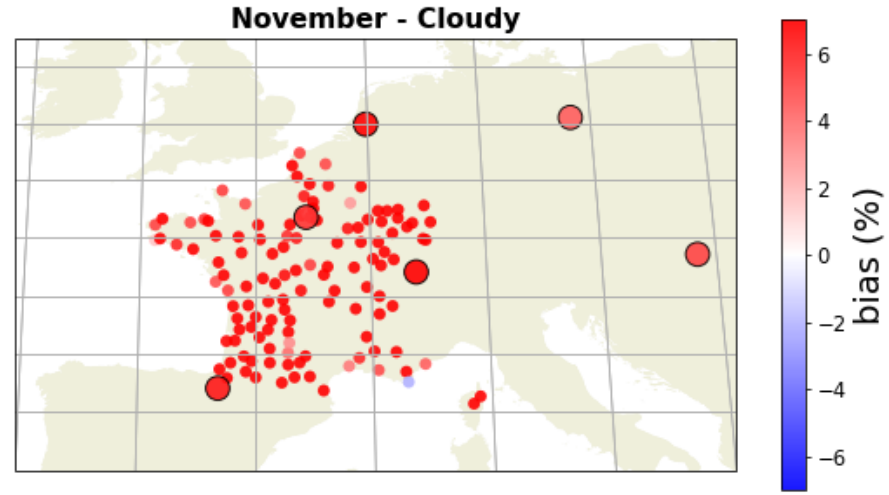
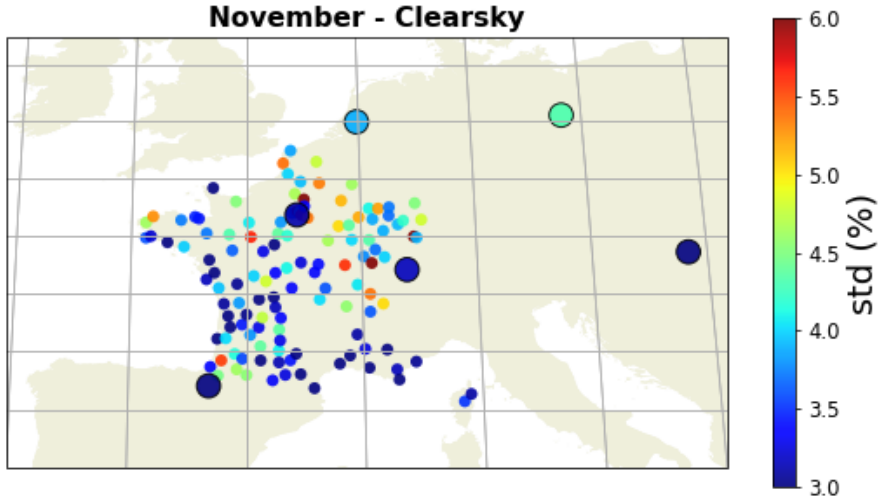
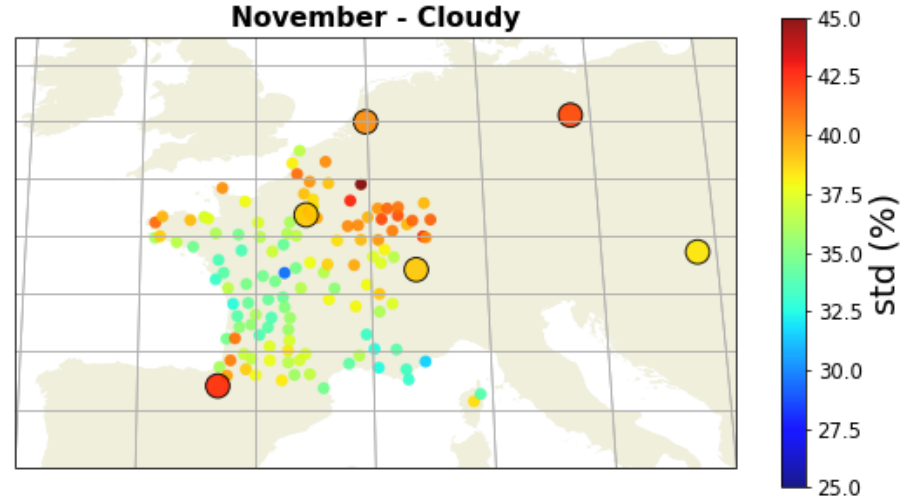
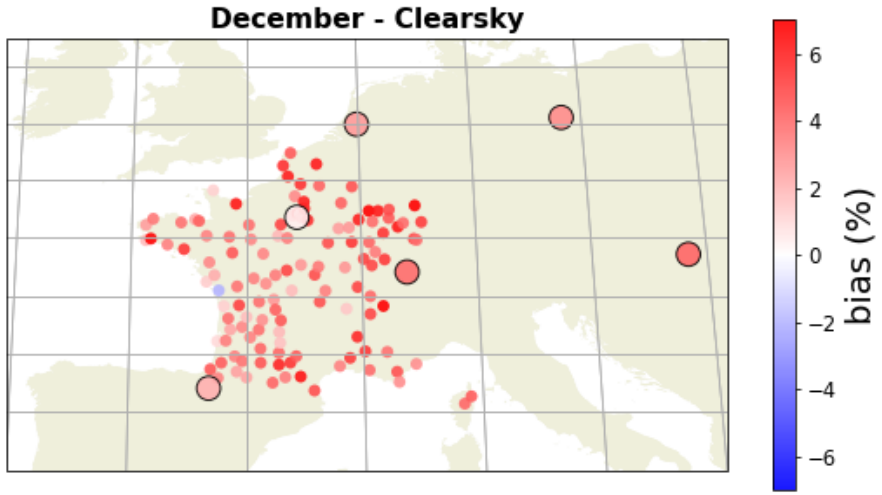
42.5
40.0
37.5
35.0
32.5
30.0
27.5
25.0
std (%)

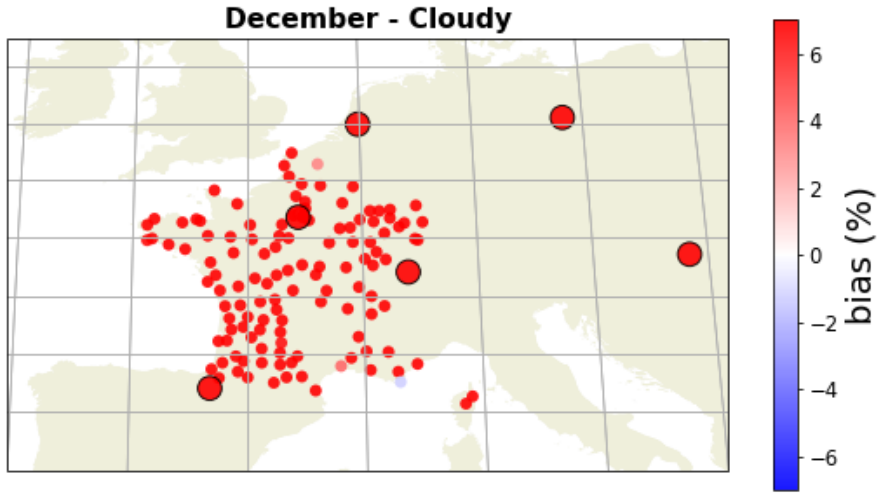

November - Clearsky
6
4
2
0
−2
−4
−6
bias (%)

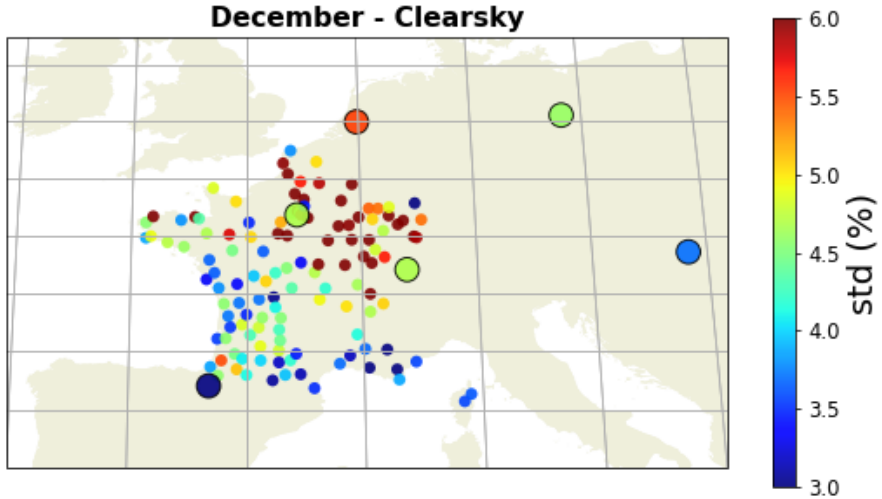

November - Cloudy
6
4
2
0
−2
−4
−6
bias (%)

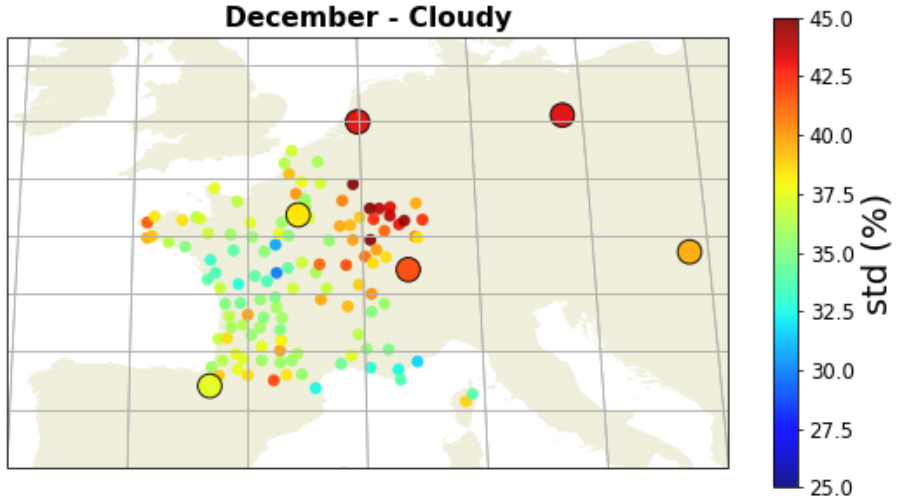

November - Clearsky
6.0
5.5
5.0
4.5
4.0
3.5
3.0
std (%)


November - Cloudy
45.0
42.5
40.0
37.5
35.0
32.5
30.0
27.5
25.0
std (%)


December - Clearsky
6
4
2
0
−2
−4
−6
bias (%)


December - Cloudy
6
4
2
0
−2
−4
−6
bias (%)


December - Clearsky
6.0
5.5
5.0
4.5
4.0
3.5
3.0
std (%)


December - Cloudy
45.0
42.5
40.0
37.5
35.0
32.5
30.0
27.5
25.0
std (%)