Comparison of three methods used for radar reflectivity calibration

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Introduction - Radar reflectivity calibration

- The Marshall-Palmer Z-R relationship is applied for operational rain estimation at Météo-France as

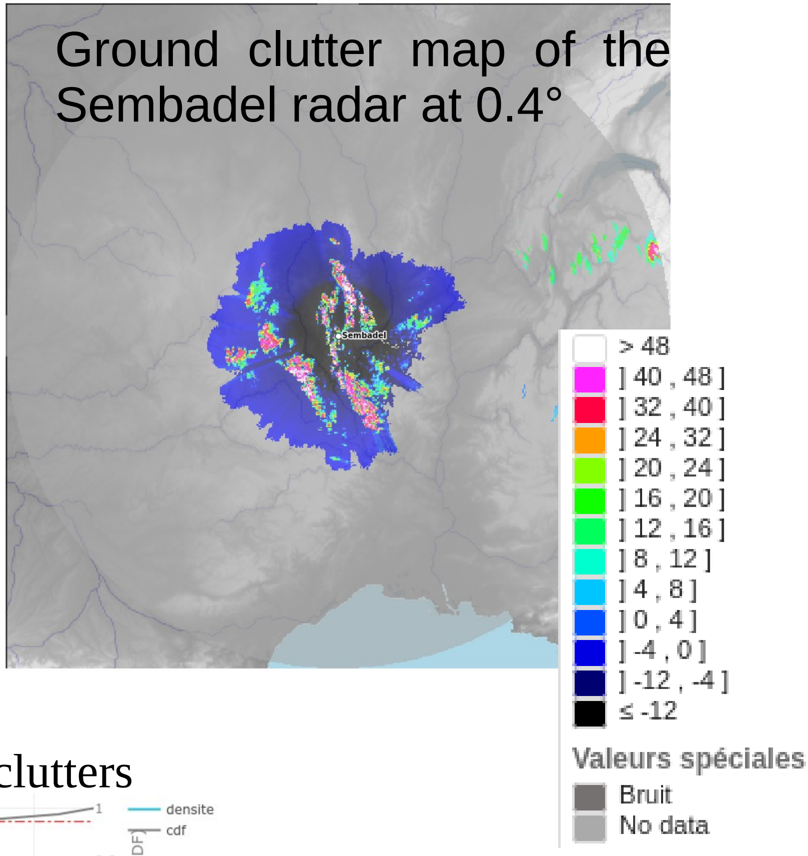
$$Z = 200\,R^{1.6}$$

- The objective of our calibration is to reduce the uncertainty in Z measurement to <= 1 dB (dBZ_m-dBZ_t <= 1dB). Hence the rain estimation error due to Z calibration is less than 15%

$$\frac{R_m}{R_t} = 10^{\frac{dBZ_m - dBZ_t}{16}}$$

- Three methods of Z calibration are applied for two C-band radars (Treillieres and Sembadel) in this study:
  - Ground clutter monitoring
  - Self-consistency among dual-pol variables
  - **Comparison with rain gauges (oper.)**

Method 1 - Ground clutter monitoring *Louf et al. (2019)*

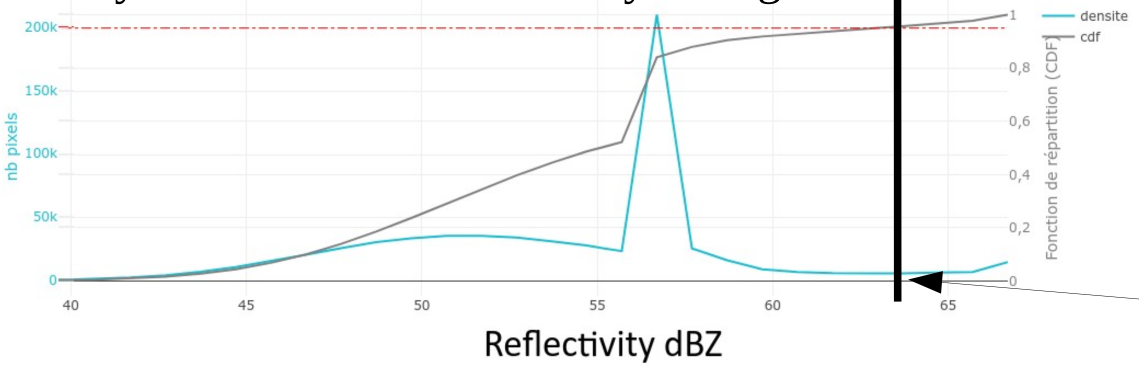

Ground clutter map of the Sembadel radar at 0.4°

- Step 1 : Identification of the non-meteorological echoes at the lowest elevation scan during dry days (dry days = 10 % of the most drys days during 3 months)

- Step 2 : Localization of ground clutters with Z > 50 dBZ.

- Step 3 : Each day, we monitor these ground clutters and a distribution of their reflectivities is calculated. The 95th percentile reflectivity is used to represent the ground clutter reflectivity level.

Daily distribution of reflectivity over ground clutters

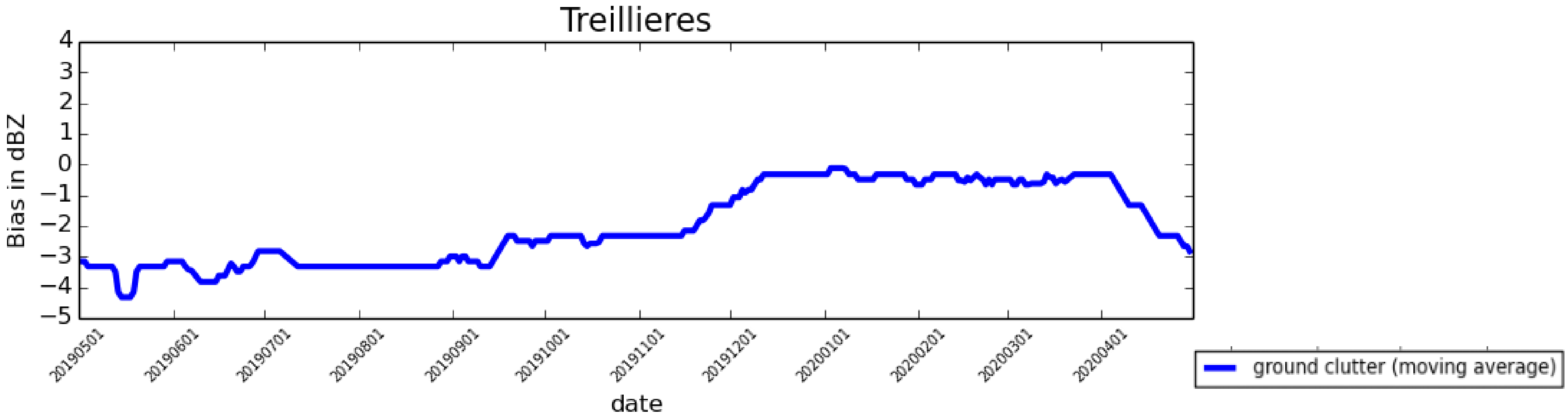


95th percentile Z

= 63.7 dBZ

Step 4 : a time series of ground clutter monitoring can be obtained.

Method 1 - Ground clutter monitoring *Louf et al. (2019)*



12-month ground clutter monitoring (Treillieres radar)

- Ground clutter monitoring is a robust method with less uncertainty related to the method itself.
- The variability of ground clutter monitoring is less than 1 dB after a 6-day moving average filter. But this variability varies from one radar to another and it is difficult to understand if this variability is due to reflectivity measurement error or other errors.
- Other errors : antenna position errors in azimuth and elevation; radar beam propagation conditions, ground clutter stability etc …
- This ground clutter doesn't allow an absolute calibration

Method 2 - Self-consistency among dual-pol variables

- The self-consistency method is based on the auto-consistency relationship among Kdp, Z and Zdr for liquid rain drops. If Kdp and Zdr are known, the Z can be derived from

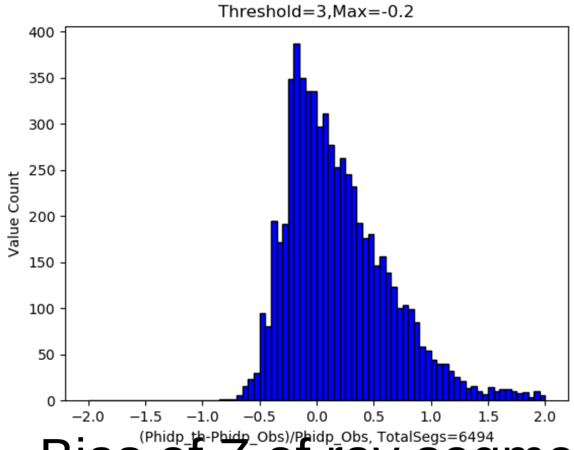
$$\frac{Kdp}{Z^{0.95}} = 1.82\times10^{-4}\times Zdr^{-1.28}$$

Kdp one-way in (°/km) Z in (mm^6m^{-3}) Zdr (no unit)

At C band ; Gorgucci et al. (1992)

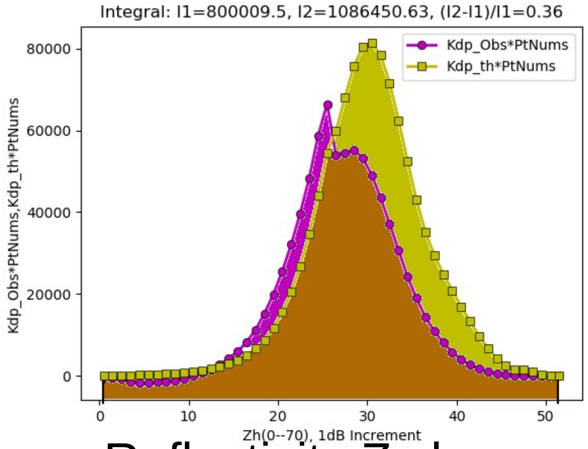
To overcome the uncertainty in Kdp determination

- The method of Gourley et al. (2009) works on ray segment with Phidp. Each segment yields a bias of Z. The radar bias is determined by the mode of the distribution of all ray segments observed within one day



Bias of Z of ray segment

- The method of Ryzhkov et al. (2005) is based on the averaged values of <KDP>, <Zdr> and <Z>. The integration of *observed <Kdp>* and *estimated Kdp* from <Zdr> and <Z> from Z = 0 dBZ to Z =50 dBZ allows a radar calibration



Reflectivity Z classes

- Radar can be absolutely calibrated by these methods.

Method 2.1 - Self-consistency Gourley et al. (2009)

Shortcomings of the method of Gourley et al. (2009)

- We need enough rain (enough Phidp shift over a rain segment) to perform the calibration.

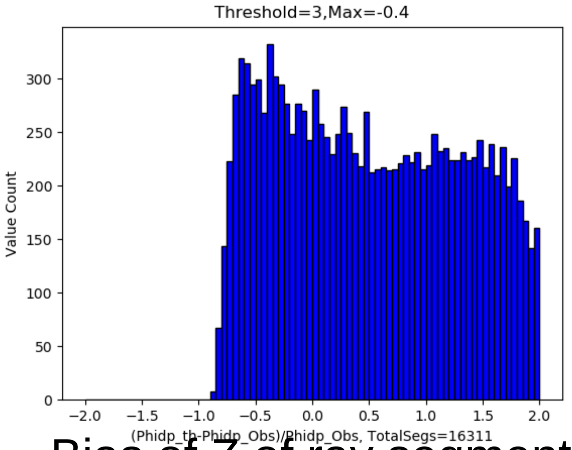
$$\frac{Kdp}{Z^{0.95}} = 1.82 \times 10^{-4} \times Zdr^{-1.28}$$

At C band. Gorgucci et al. (1992)

- The self-consistency relationship is not always constant. It depends on the temperature, shape of drops, and drop size distribution etc. Based on the DSD simulations, the self-consistency relationship is significantly variable when Zdr is less than 1 dB.

- The calibration result depends on rain/non-rain identification over the segment.

- The calibration result depends on Zdr calibration, Zdr attenuation correction and Z attenuation correction.



Bias of Z of ray segment

A spread distribution of Z bias. It is difficult to determine a reliable bias.

Z classes

Method 2.2 - Self-consistency Ryzhkov et al. (2005)

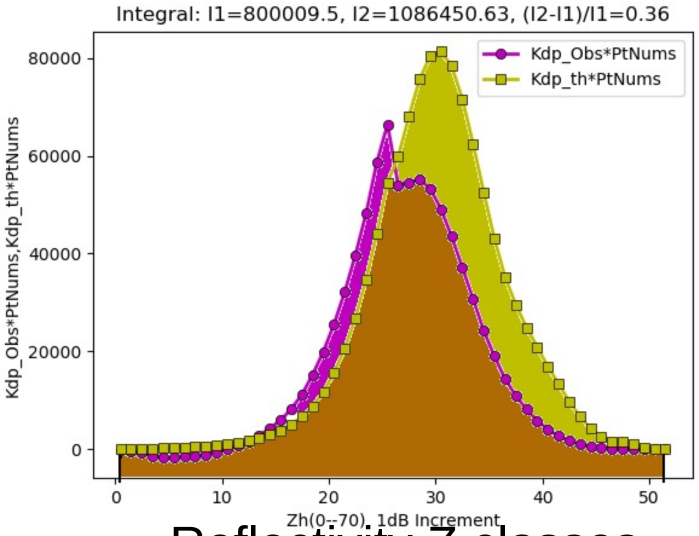
The shortcomings of this method are similar to those of Gourley et al. (2009), except that

- It is less sensitive to the rain/non-rain identification error.
- It has usually large sample size in the analysis. The sample size in the calibration analysis is equal to the rain pixel number.
- However, because we use the average of <Kdp> in the analysis, the calibration result depends on the Kdp regression techniques.

The estimated Kdp is often > the observed Kdp for Z>30 dBZ;
The estimated Kdp is often < the observed Kdp for Z<30 dBZ.

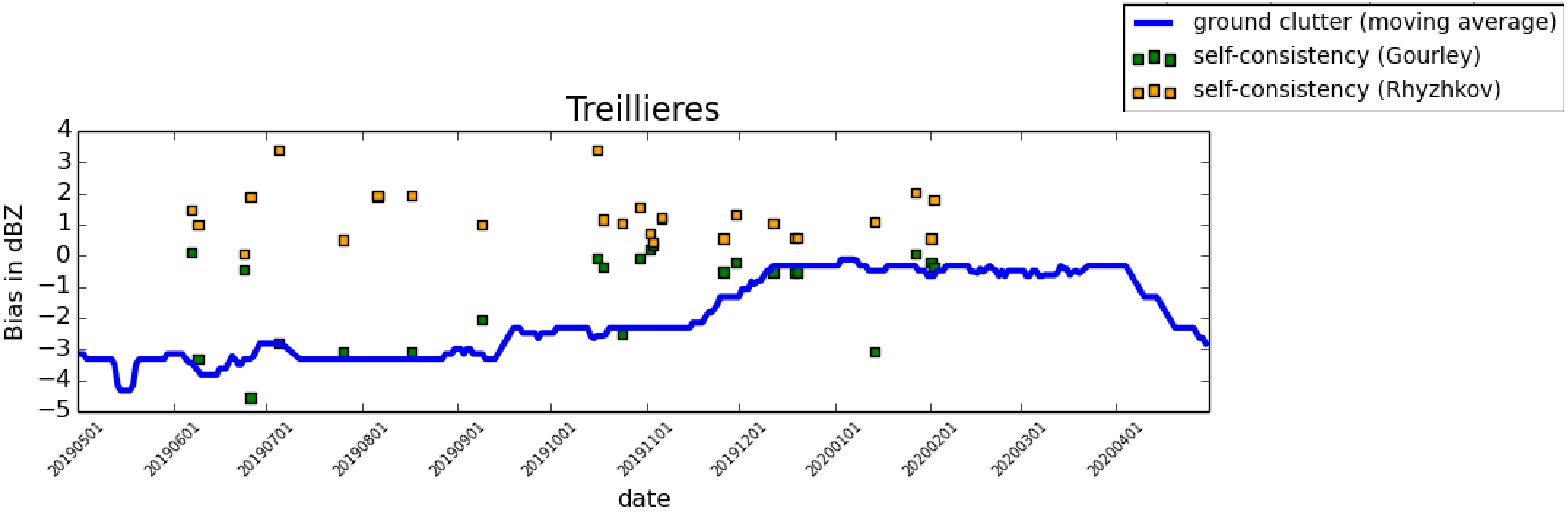
And it well known that the observed Kdp is under-estimated for heavy rain, and over-estimated for light rain due to regression.

Hence the result of calibration depends also on rain intensity. (Yu et al. 2019)



Reflectivity Z classes

Method 2 - Self-consistency : two methods



The calibration from the ground clutter, the self-consistency (Gourley) and the self-consistency (Ryzhkov)

- From the ground clutter monitoring, we observe an increase of 3dB between 2019 and 2020
- The method of Gourley has a similar trend but with a large variability.
- No trend is observed in the method of Ryzhkov.
- Hence we believe that the method of Gourley is a better choice for radar calibration.

Method 3 – Radar reflectivity adjustment with raingauge

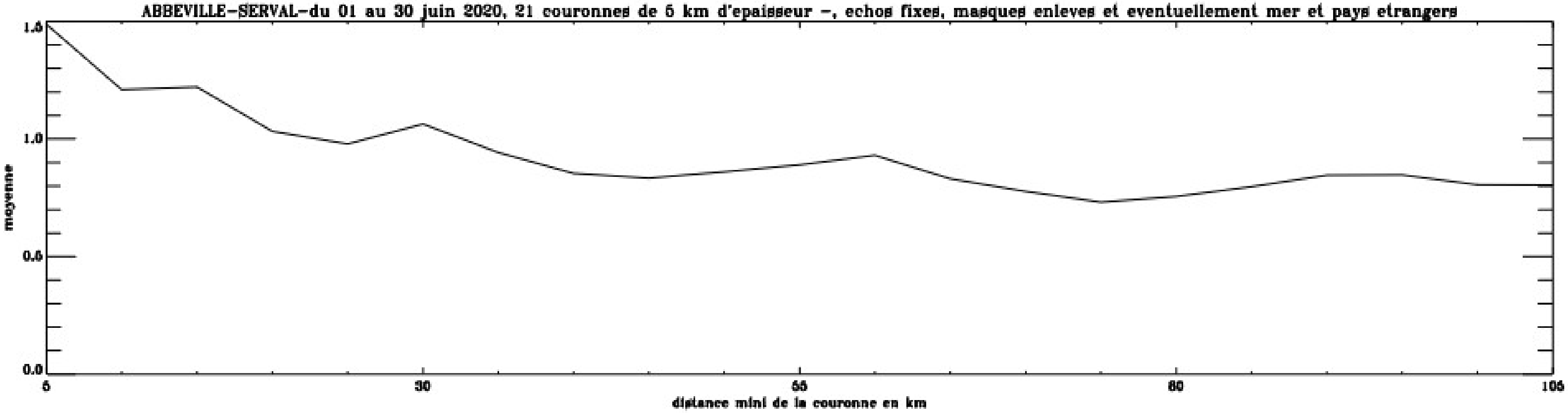
Method historically used at Meteo-France

A ratio (called HYDRAM) was calculated between spatialized raingauge and QPE radar (at distances from the radar where the ratio is the most stable, generally between 30 and 80 km).

Until circa 2007 this ratio was applied to QPE and converted in dB before being added to the reflectivity.

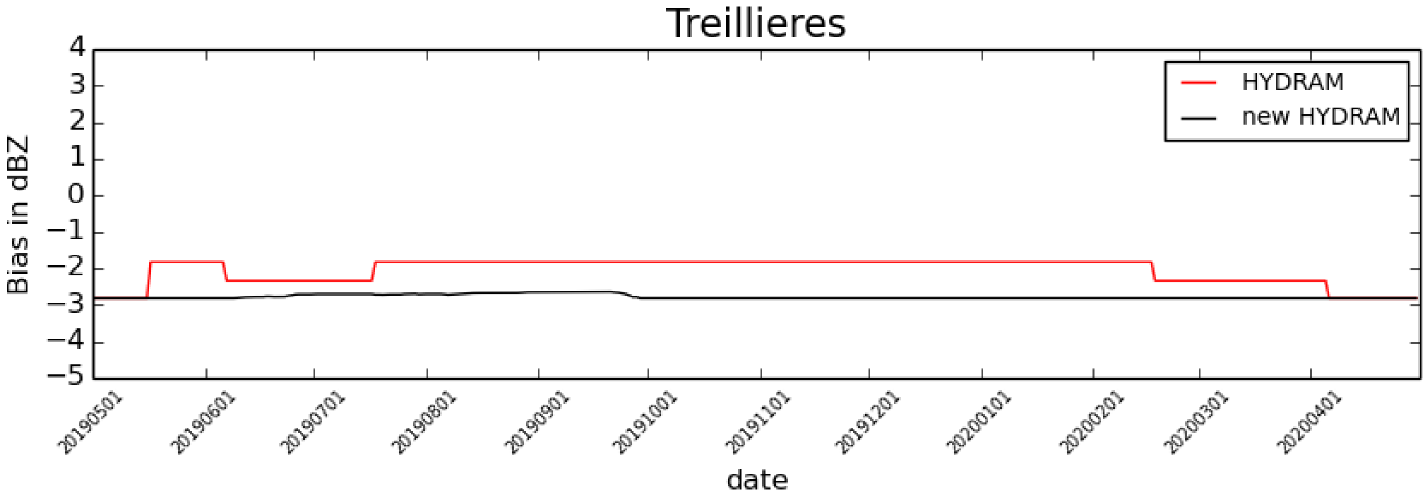
Since circa 2007, Meteo-France adjusts the QPE with an hourly factor (in which the HYDRAM factor comes as a callback term)

Since 2021 a new HYDRAM factor is used (which is a moving averaging window of hourly factors)

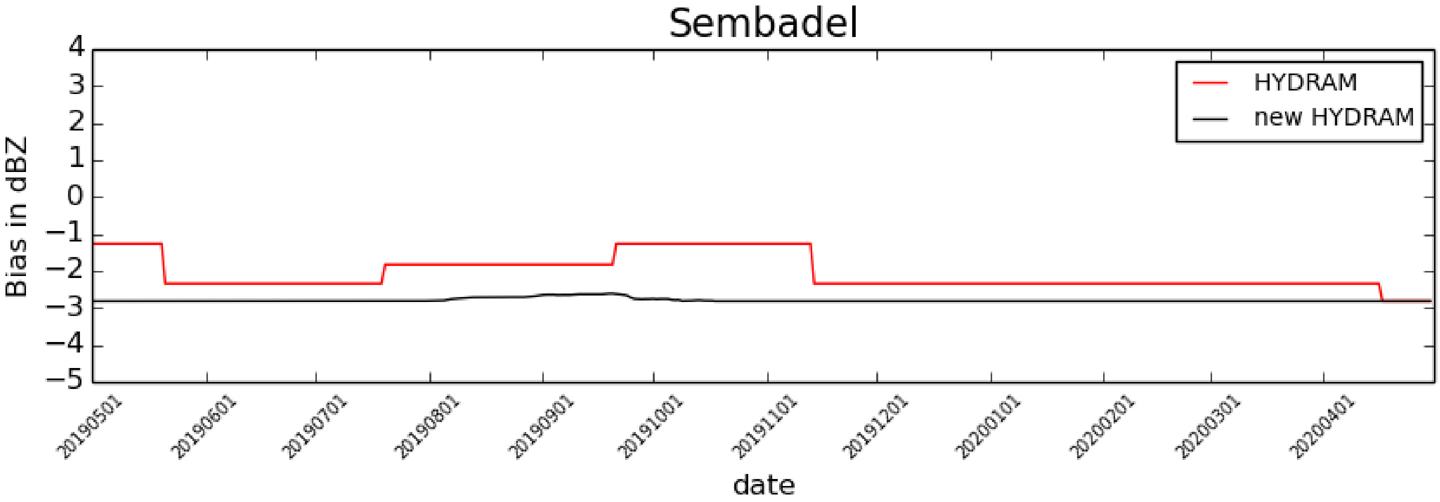


ABBEVILLE-SERVAL-du 01 au 30 juin 2020, 21 couronnes de 5 km d'epaisseur -, echos fixes, masques enleves et eventuellement mer et pays etrangers

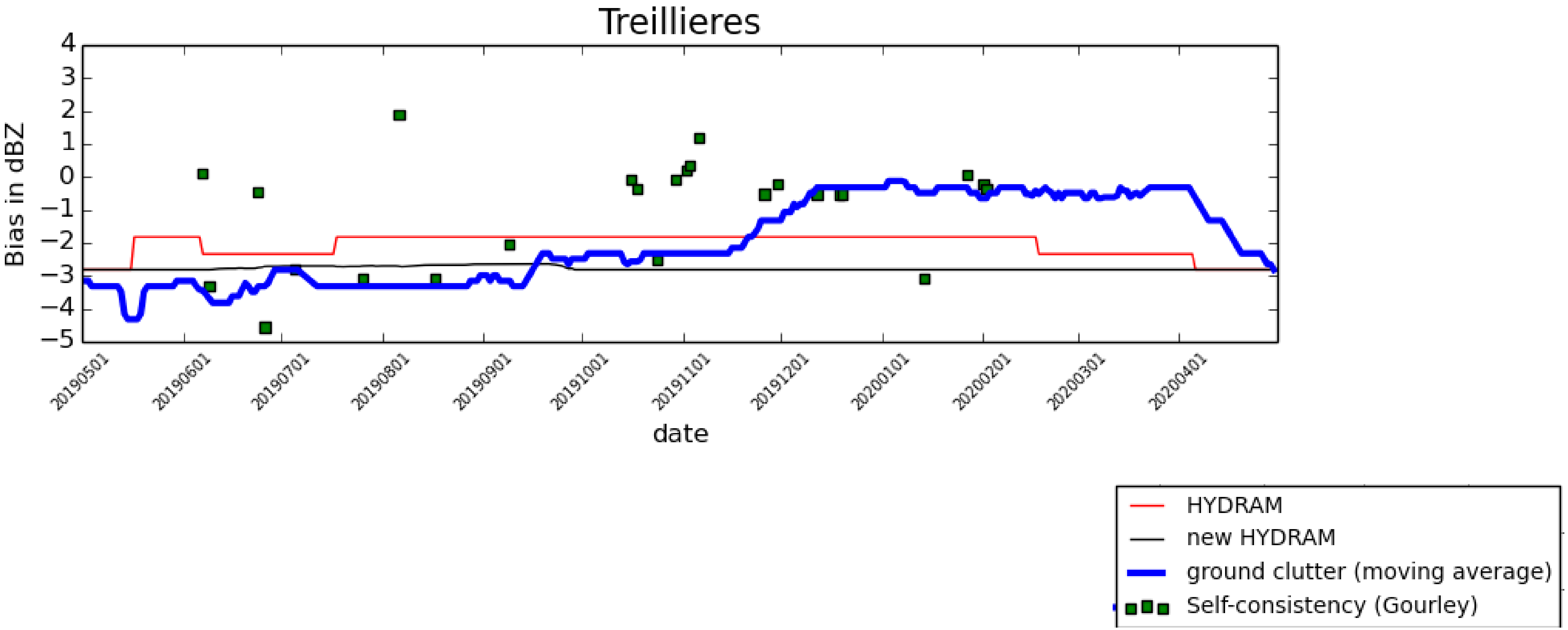
Method 3 – Radar reflectivity adjustment with raingauge



For most of the radar studied, HYDRAM and new HYDRAM values are generally high (between 1,5 and 2,7 dB), new HYDRAM reinforces this tendency



Results of comparison - Treillières

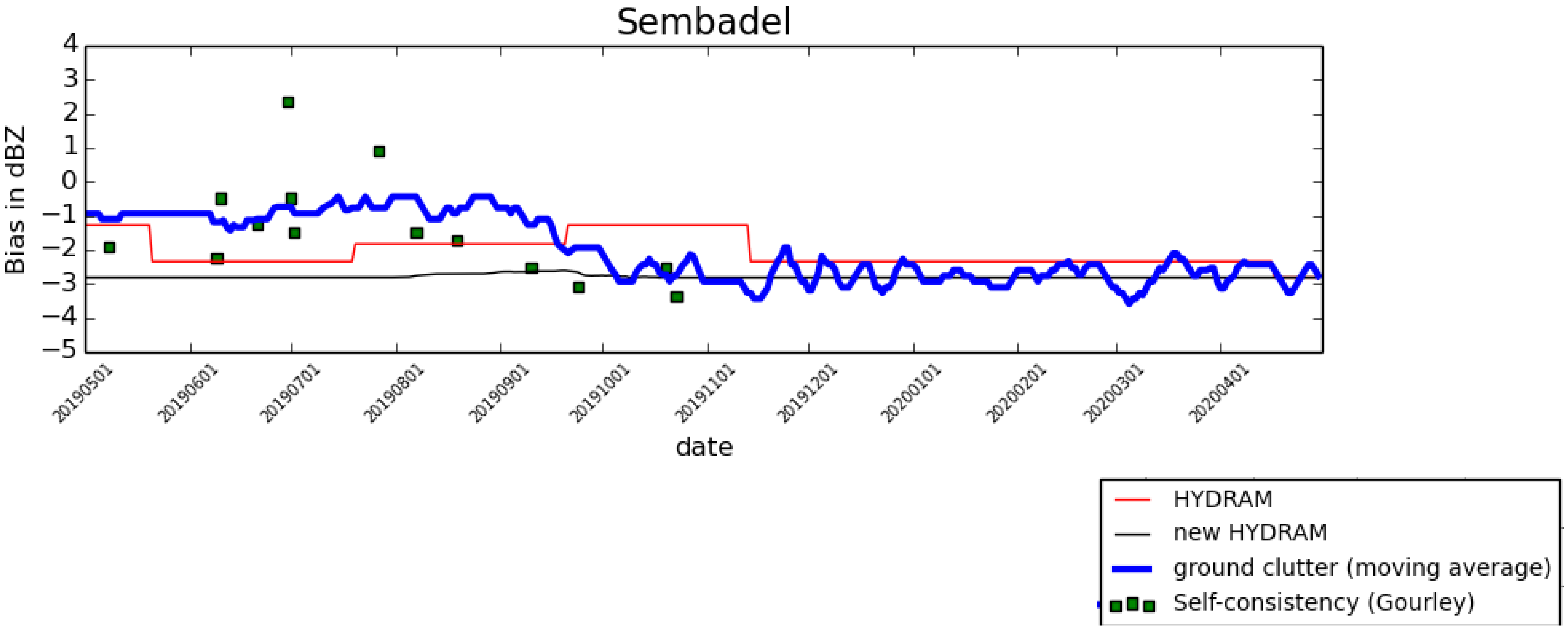


In December 2019, the ground clutter bias had a 3dB change.

This trend is also present in the results of the self-consistency (Gourley) but less visible.

Biases of HYDRAM and new HYDRAM do not follow this trend and are very stable.

Results of comparison - Sembadel



In September 2019, the ground clutter bias changed by 2 dB and the same trend is visible in the results of the self-consistency method (Gourley).

Again, the HYDRAM and new HYDRAM factors do not follow the same trend and are very stable.

Results of comparison

For the two radar studied, we have relatively good correlations between ground clutter and self-consistency results (Gourley).

But no correlation between HYDRAM (or HYDRAM new) factors and the ground clutter monitoring trends.

Most of time, it is probable that the calibration used at Meteo-France to correct the QPE product does not reflect a real instrumental variability, but compensates for non instrumental residuals errors (VPR correction, vegetation beam blockages, type of precipitation,...) in particular because tree or even forests are presents close to the 2 radars.

Conclusions and perspectives

The ground clutter monitoring follows the variability of the intensities received (uncertainties are related to the antenna position or ground clutter identification) therefore this monitoring can provide a relative calibration with an offset.

The self-consistency method developped by Gourley provides an absolute calibration and the changes observed in the calibration follow the trends obtained from the ground clutter method. However this method only works when it rains.

The HYDRAM calibration (current operational method) does not reflect the changes in the instrumental calibration.

In future, we plan to monitor the calibration of the French weather radars using the ground clutter monitoring (but first check thoroughly the stability of the ground clutter used) and the self-consistency method by Gourley will be used an occasional basis to provide an absolute calibration.