STSM Report

Radar Calibration in Spain: Comparison of Ornithological and Weather During the Autumn 2014 Bird Migration Season

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1. INTRODUCTION

This is a report for a Short Term Scientific Mission (STSM) in the COST Action ES1305 (European Network for the Radar surveillance of Animal Movement, ENRAM), under working group 2: Improvement of Weather Radar Data Quality and Validation of Biological-classification Algorithms;
Host institution: Department of Biology (University of Cádiz, Spain) hosted by Dr Gonzalo Muñoz;
Date: 06/07/2015 - 20/07/2015;
Purpose: In order to validate the outputs of biological-detection algorithms applied to two Spain weather radars we (i) compiled, processed and analysed bird data from weather radars located close to the Strait of Gibraltar (Malaga and Seville); we (ii) compared weather radar data to local meteorological stations; we (iii) investigated bird data from a Merlin System and we set up filters for increasing data quality.

2. MATERIALS & METHODS

2.1. The Spanish weather radars

Two weather radars have been identified close to the ornithological radar: the Seville weather radar (S_WR, Cañada Alta, Castillo de las Guardas) and the Malaga weather radar (M_WR, Pico Mijas, Alhaurín el Grande) and they are away from the ornithological radar 180 km and 90 km respectively. The application of the bird - detecting algorithm developed by Adriaan Dokter (Dokter et al 2010) allowed to discriminate data such as bird reflectivity (which is a measure of density), bird velocity (as ground speed), flight heights (S_WR from 700 to 5900 m and M_ WR from 1300 to 5900 m), probability of rain, wind directions and speed from 1st August to 31th October 2014. All the weather radar information data have been provided by the National Agency of Meteorology (AEMET). Weather radar data consisted in daily files (92 files per weather radar) in .txt format. Firstly we unified all the days in a unique file (one for Malaga and one for Seville weather radar, respectively). Afterwards we imported in a database (Microsoft Access 2013) and we ran queries needed for analysis. On advice from Adriaan Dokter and Hidde Lijense, we used radial velocity

standard deviation as a filter to separate birds from insects/rain (below 2 m/s=insect/rain; above 2 m/s=bird). Instead we did not used a ground clutter filter to remove noise due to the scattering on the ground, because both weather radars are located over hills (lowest value of altitude for S_WR is 700 m and ca 1.300 m for M_WR).
For a better understanding of bird migration pattern we divided the 24 hour period into day time (6:00 - 18:00) and night time (18:00 - 6:00): Adriaan Dokter suggested this step because the weather radar's performance of tracking birds increases during night (see Dokter et al 2010).
The addition of seven local meteorological stations and in particular three around Seville area (Cazalla de la Sierra, Guadalcanal, Seville airport) and four around Malaga (Fuengirola, Coìn, Malaga airport and Torremolìno) allowed to exclude possible risk of rain contamination (> 0.2 mm) into weather radars.

2.2 The Ornithological Radar: the Merlin System

The ornithological radar is based on a Merlin System and it is permanently located in los Barrios (Cádiz). It collected horizontal and vertical data from 1st August to 31th October 2014 in a 24 hour period. A engineer of De tect (formerly he was the responsible of the los Barrios Merlin System) reported that the Merlin is recording data almost without any automatic filtering method and, as a consequence, we are obtaining something similar to very row data.
Daily databases (ca. 200-300 megabytes each) automatically produced by the Merlin System consisted in a complex of thirteen tables (mainly metadata or system data not useful for this study) and each of them contained seventy different parameters. Firstly we extracted tables with information that we needed and secondly, we created monthly databases. Because of space – limit problems in Microsoft Access database (a singular database in MS access cannot exceed 2 gigabytes) it has not be possible to merge all the months in one and in particular, for a preliminary analysis, we reduced the number of columns to essential parameters (i.e. date, track id, number of echoes, flight altitude, flight direction and ground speed).
In this part of this STSM we investigated on some parameters and we focussed on which thresholds (i.e. flight altitude, ground speed, number of echoes into a track) could be selected for future analysis to increase data quality.
Because of time limit of this STSM we focussed analysis on the vertical radar.

2.3 Analysis

We created weather and bird radar database in MS Access 2013 and we ran all the statistical analysis using R 3.1.2 (R Core Team 2014).

3. RESULTS & DISCUSSION

3.1 Comparison between Malaga and Seville weather radar

Figures 3.1a and 3.1b represent "theoretical" bird migration split by night and day detected by weather radar from Malaga (blue) and from Seville (red). Data are plotted without standard deviation radial velocity filter and therefore insects and rain could be present. Correlations between M_WR and S_WR are very week during night (r=0.3) and day (r=0.02).

When filtering by standard deviation radial velocity over 2.0 m/s, correlations between M_WR and S_WR data are still very weak (night: r=0.3; day: r=0.22).

As first impression this result could suggested that the 2.0 m/s threshold, previously used in another STSM to separate birds from insects/rain in the UK dataset, it is not working for Spanish radars and probably because i) there are no insects or rain precipitations to remove from the data and ii) it is necessary a different threshold.

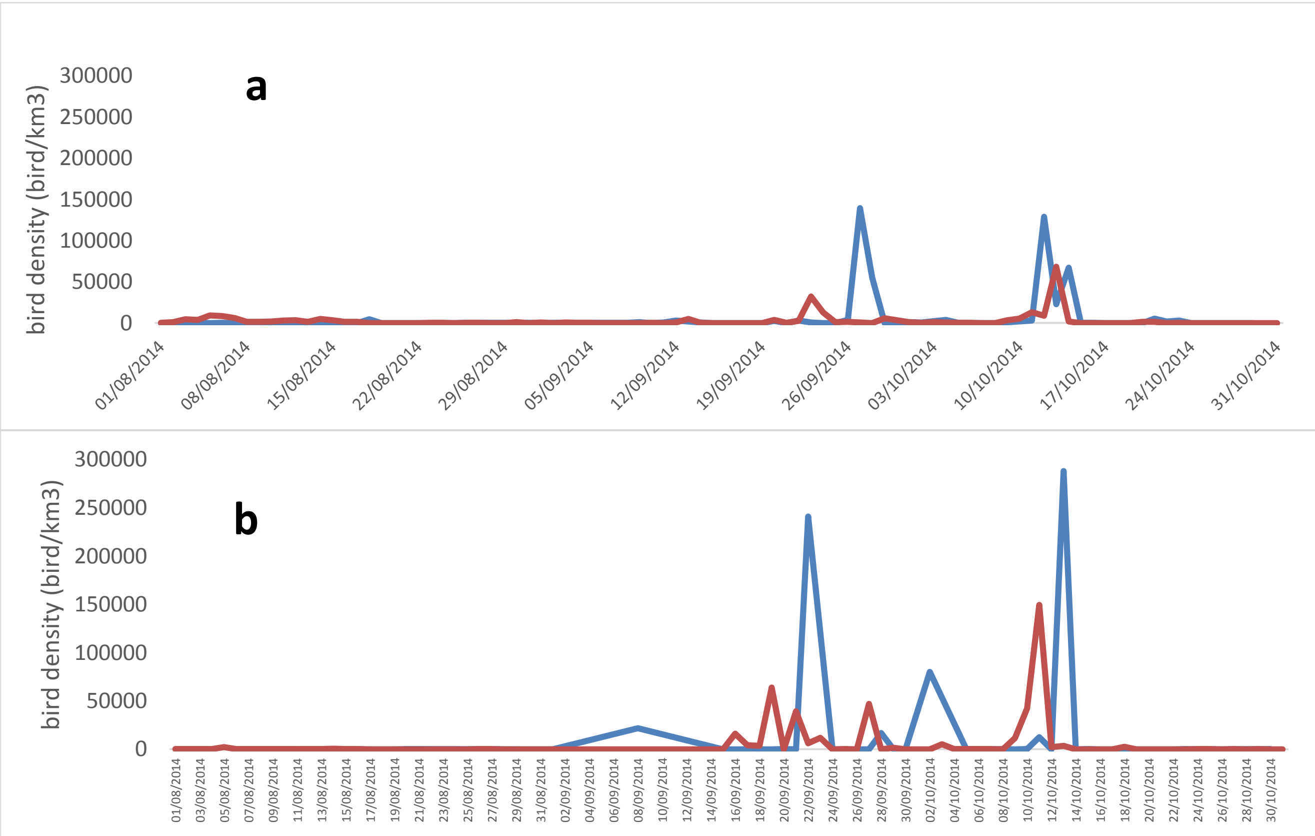

Fig. 3.1 - "Theoretical" bird migration during night and day time expressed in bird/Km^3 and represented as a daily sum. During night (fig. 3.1a) intense and anomalous peaks appear on the 27th of September and on the 12th of October in Malaga (ca. 139.000 and 128.000 bird density respectively). At day time (fig. 3.1b), two another big peaks recorded in Malaga (22/09 and 13/10) and one in Seville on the 11th of October 2014.

To test the first hypothesis, we compared rain recorded by local meteorological stations to our weather radar data. We used the parameter “total reflectivity” from weather radar data, which is a measure of density including bird, rain and insects echoes. Rain precipitation and radar reflectivity (fig. 3.2a and 3.2b) are correlated in Seville (r=0.55) and strongly correlated in Malaga (r=0.81). In particular: correlation between S_WR and meteorological data are good with both Seville airport (r=0.63) and very good with Guadalcanal (r=0.87) meteorological stations; correlation obtained between Malaga and meteorological data are significant for four meteorological stations (Fuengirola, r=0.78; Coin, r=0.71; Malaga airport, r=0.84; Torremolinos, r=0.88). These results proved that data in both weather radars are contaminated by rain and as a consequence the bird – detection algorithm is not working to remove rain in the case of Spanish weather radars. An empirical demonstration of the rain effect detected by the Merlin System in Los Barrios has been showed in figure 3.3.

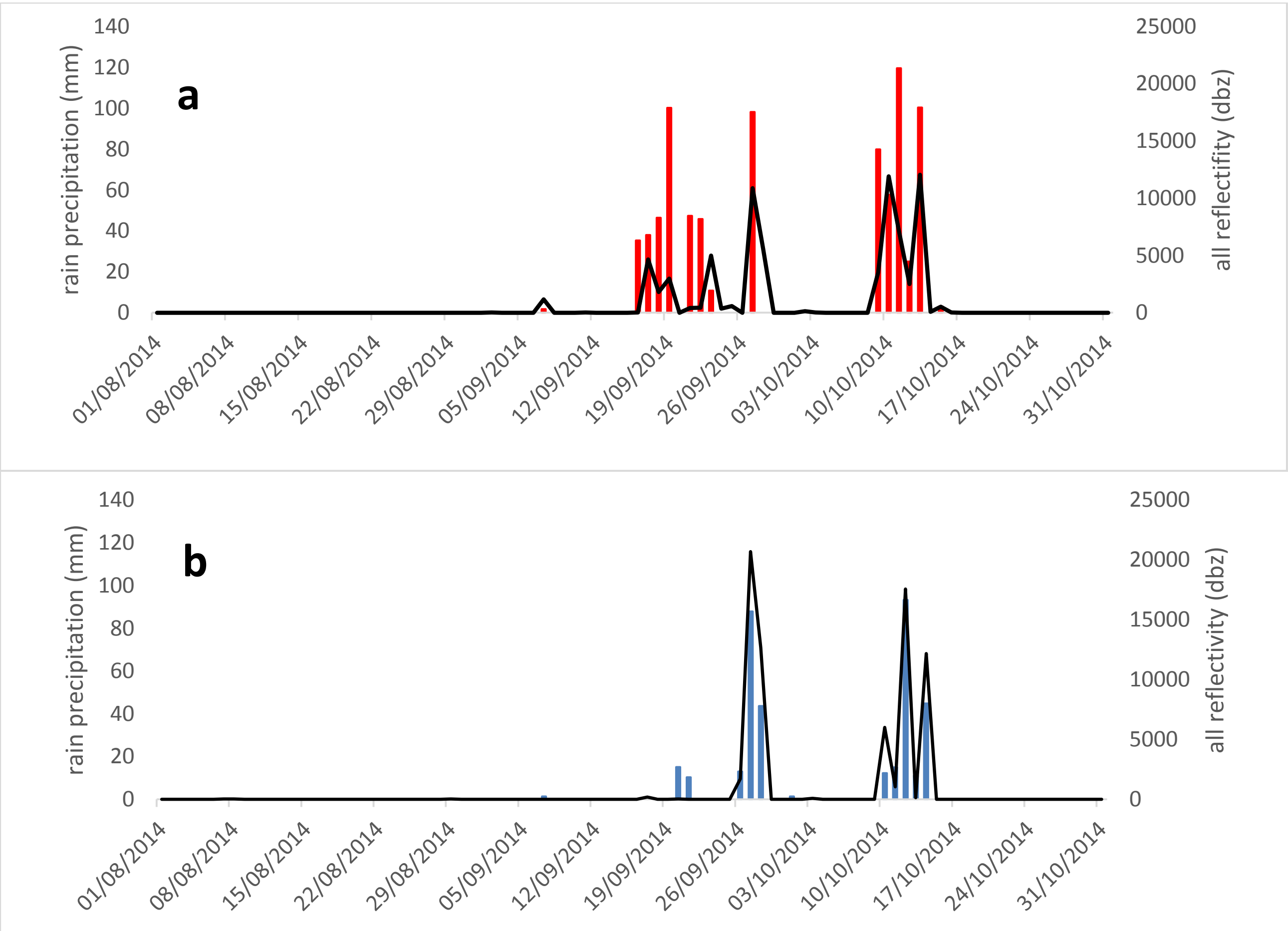

Fig 3.2 – Weather radar reflectivity and rain. In 3.2a: similar pattern in S_WR reflectivity (red) and rain precipitation (black). In 3.2b M_WR reflectivity in blue and rain in black: highest rain precipitation days correspond to intense “bird migration” days.

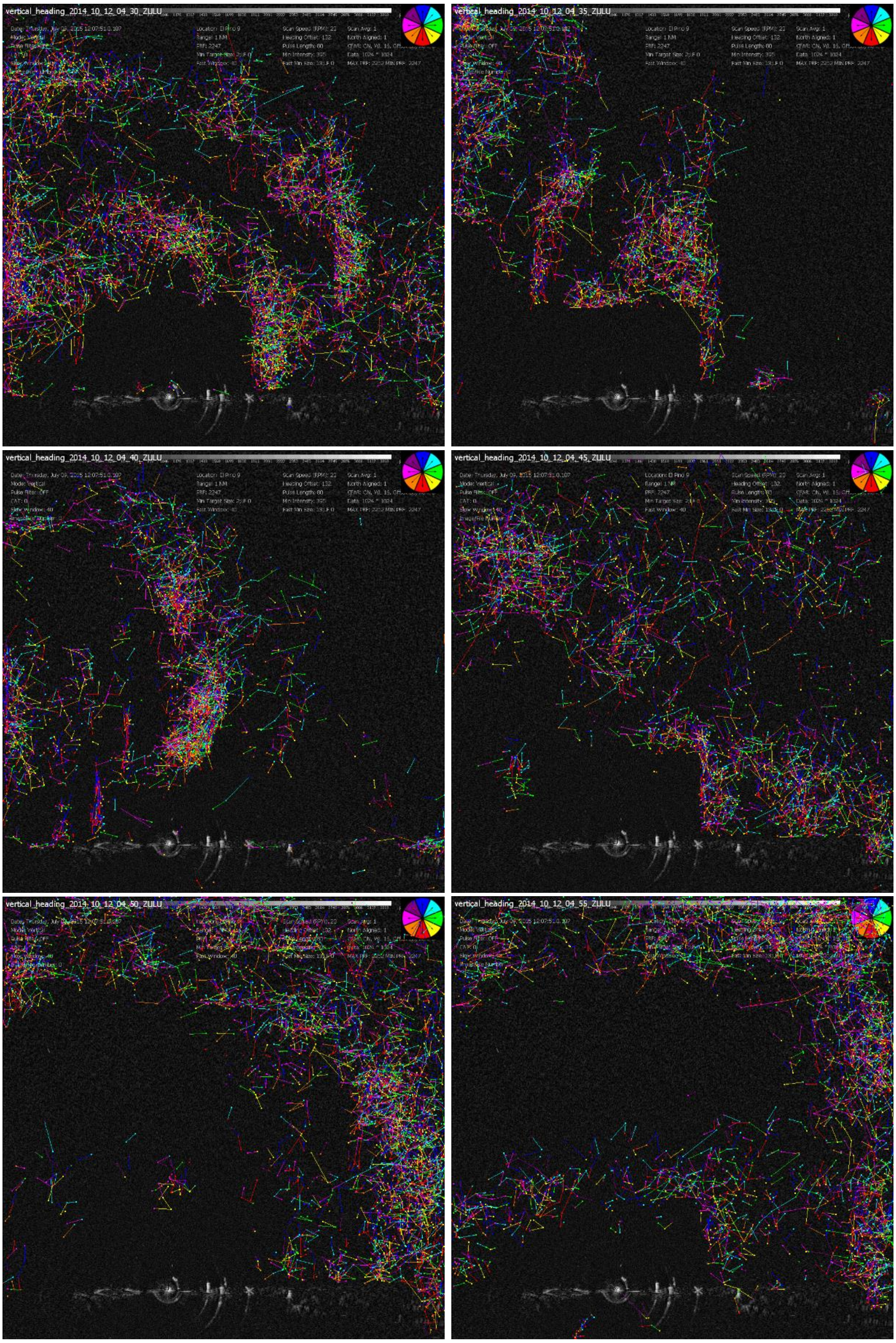

Fig 3.3 – Images of Merlin Bird Radar (vertical heading) of el Pino from 12th October (04:30 – 04:55 am) showing the passage of a rain front.

To completely remove rain from our weather radar dataset, we chose 0.2 millimetres as a threshold and we manually eliminated rain hours from both weather radars.

Results (fig 3.4 and 3.5) showed that removing rain strongly reduce high and anomalous rain peaks, but correlations between M_WR and S_WR remain no relevant (night time: r=0.23; day time: r=0.26).

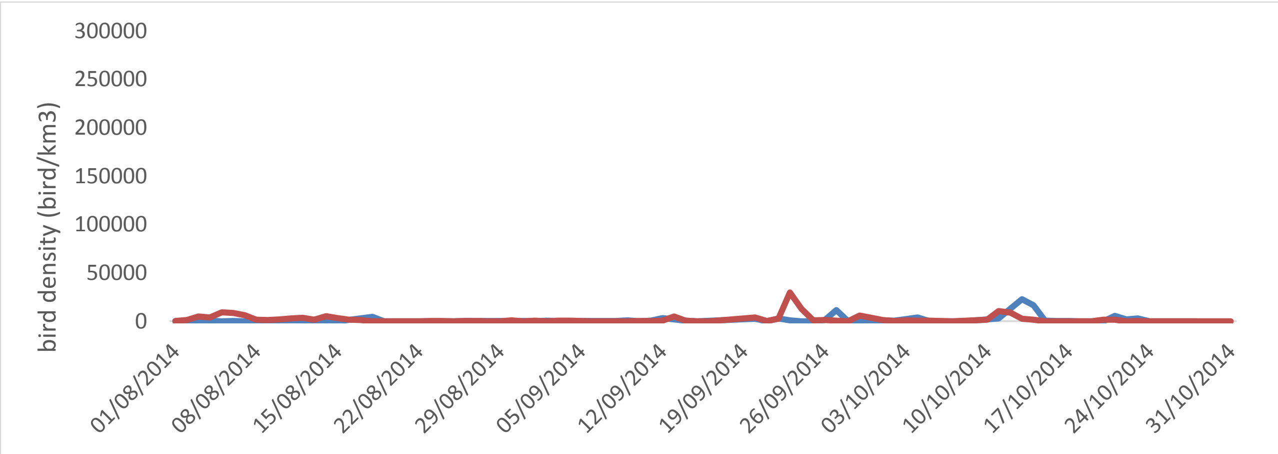

Fig. 3.4 Bird migration at night time (18:00 - 6:00) after filtering rain precipitation. Blue and red colours represent Malaga and Seville weather radars respectively. Despite there is no correlation (r=0.23), intense and anomalous rain peaks are now disappeared.

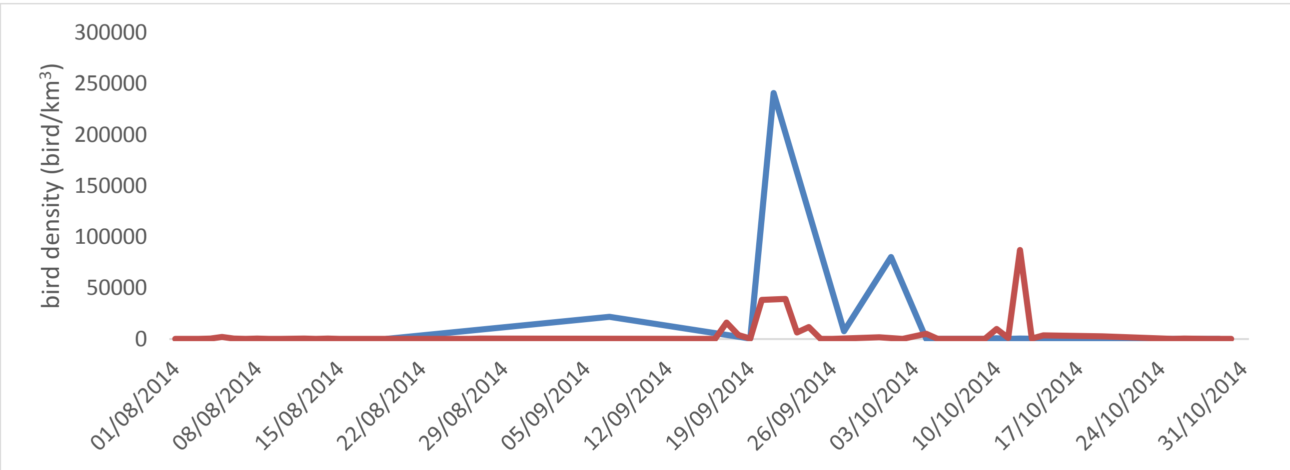

Fig. 3.5 - Bird migration at day time (6:00-18:00) after filtering rain precipitation. Blue and red colours represent Malaga and Seville weather radars respectively. Bird migration pattern appears very flat during August and the first two weeks in September.

We also tested the standard deviation radar velocity hypothesis: we correlated bird migration from S_WR and M_WR (both filtered from rain hours) filtering all values over 2.5 m/s. We did not find any correlation (r=0.11).

We also presented the two bird migration pattern during the 24 hours (fig. 3.6) and we found interestingly a clear peak of density at sunset in M_WR. We did not find any peak at sunrise in both radars.

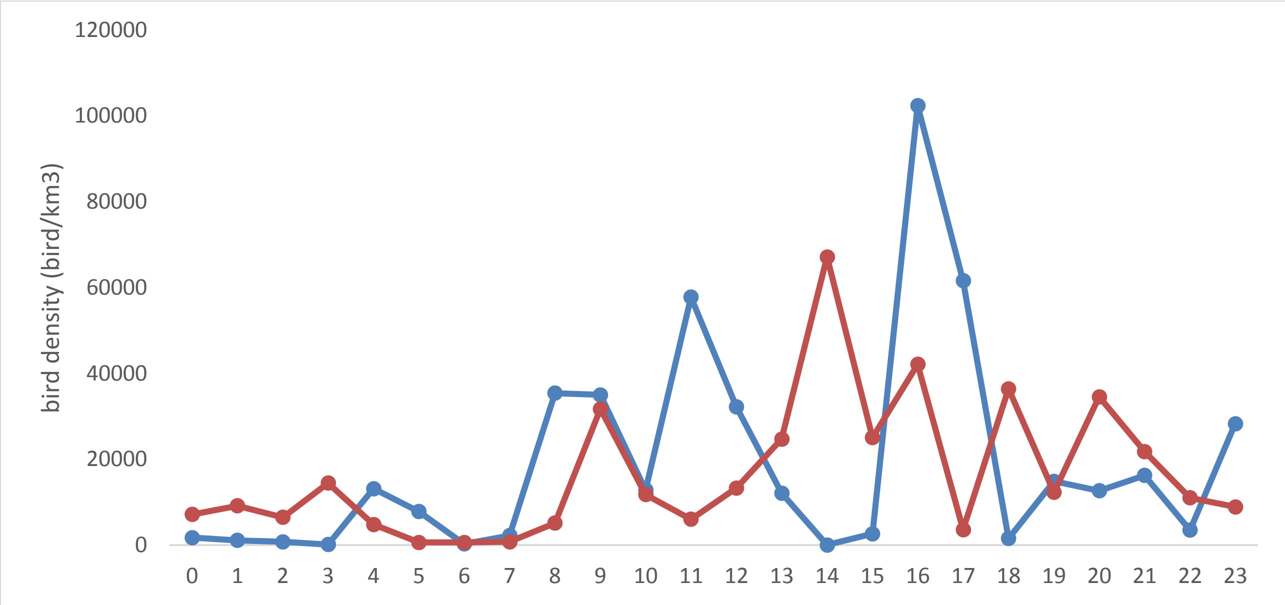

Fig 3.6 – Bird migration (filtered from rain and standard deviation >2 m/s) represented during the 24 hour period. The bird density is represented as a sum by hour (Malaga=blue; Seville=red).

3.3 The ornithological radar

Bird data from the Merlin radar needs to be analyse in a better database software. In fact, MS Access does not allow to import large quantity of data and even when filtering, 700-800 megabytes are still uncomfortable for this software.

From Merlin radar screenshots (fig 3.7) and also during the analysis process, we noticed a moderate quantity of non-bird tracks (i.e. different type of errors, rain).

In a sub-samples of 300.000 tracks detected in August 2014 (fig. 3.8), we found out that many non-bird tracks are formed by 1-5 consecutive echoes (in particular one echo). In a sample of 460.000 tracks (fig. 3.9), many altitude values were negative and many of them below 150 metres. Also ground speed values indicated some non-bird tracks (fig 3.10).

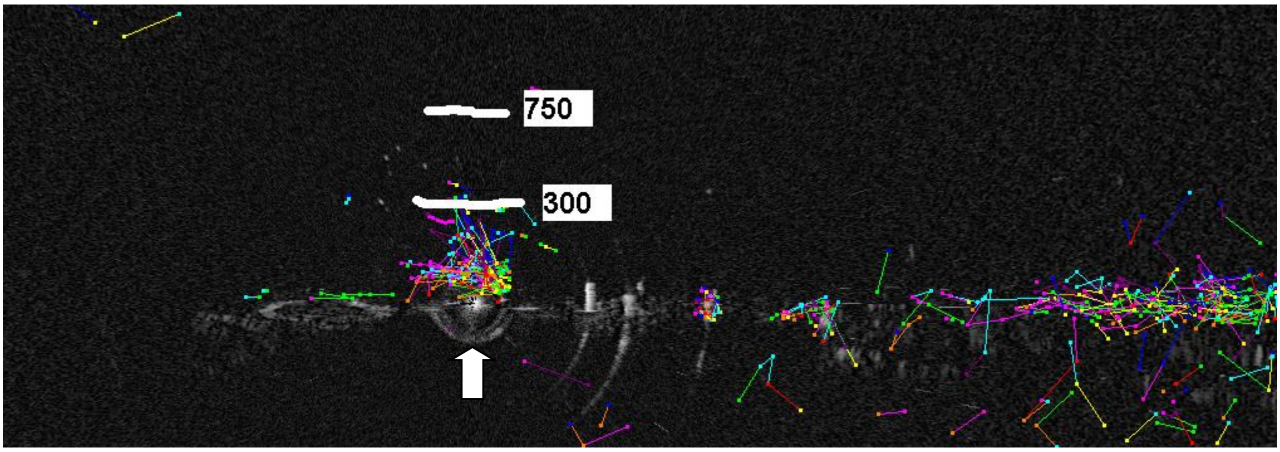

Fig 3.7 – Merlin Radar, vertical data. Screenshot from August 2014. White arrow indicates the radar centre. Tracks below ground level and very short one need to be remove. White plots (300 and 750) indicate approximately altitude from the radar.

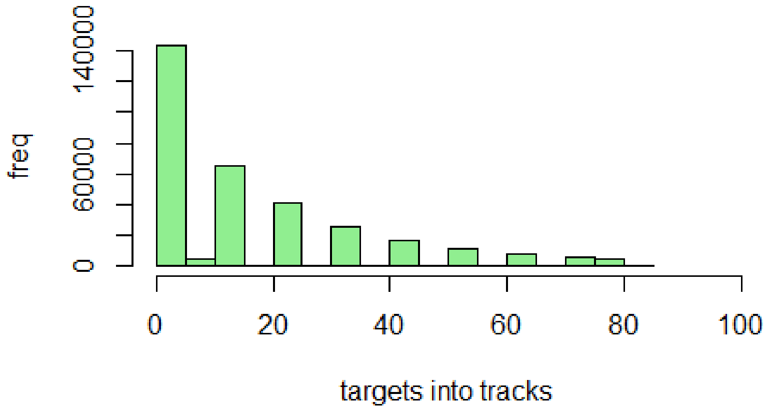

Fig 3.8 – Frequency distribution of the number of echoes present into tracks. Points or tracks formed less than 5 echoes should be excluded from the data.

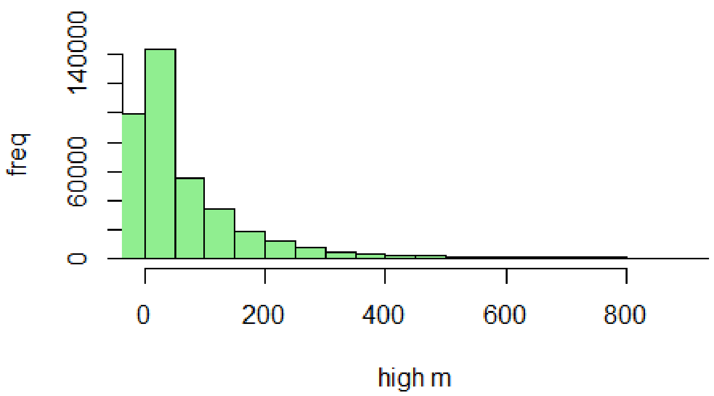

Fig 3.9 – Frequency altitudes distribution. Lots values are negative and need to be remove. The range 0-50 metres is the most frequent but it could include several non-bird tracks.

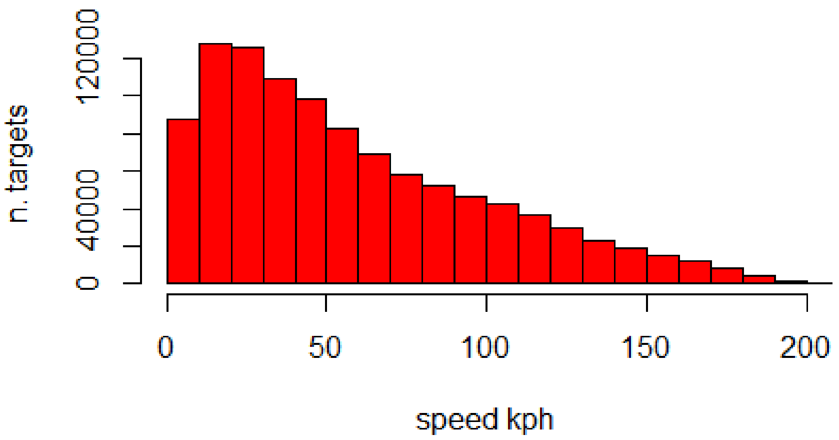

Fig 3.10 – Frequency speed distribution. In a sample of 300.000 tracks a good range for identify bird tracks could be 30-80 km/h.

4. CONCLUSIONS

In order to improve and validate the biological – detection algorithm produced by working group 1, this STSM has strongly contributed to understanding some unknown aspects of two Spanish weather radars:

1) The biological – detection algorithm applied to Spanish weather radars is not good enough at the moment to discriminate birds from rain/insects: we found out rain into the weather radar dataset;
2) The patterns of echoes density obtained from the two weather radars (Malaga and Seville) are not correlated. This can be expectable since they are located quite distant from each other, and consequently they shouldn't reflect necessarily the same front of migration;
3) When filtering out manually precipitations from dataset, a possible pattern of nocturnal bird migration seems to appear. No clear patterns of diurnal movements were observed;
4) The Merlin Radar System located in los Barrios (Cadiz) could be considered as a possible good tool to identified bird migration, but more effort and further technical requirements are necessary to asses it; in any case, it would require future adjustments and filtering systems to improve data quality.

5. AKNOWLEDGMENTS

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I am grateful to Gonzalo Muñoz, Antonio Román Muñoz and Adriaan Dokter for helping me in data analysis.

6. REFERENCES

- Dokter, M. A., Liechti, F., Stark, H., Delobbe, L., Tabary, P. and Holleman, I. 2010 Bird migration flight altitudes studied by a network of operational weather radars. *J Roy Soc Interface*. doi:10.1098/rsif.2010.0116.
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