STSM Report

GIS analysis of radar tracks during fall migration in Southern Sweden

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1. INTRODUCTION

This is the report due at the completion of the Short Term Scientific Mission (STSM) which I carried out within 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: University of Lund (Sweden) - Department of Biology.
Supervised by Dr. Johan Bäckman and Dr. Cecilia Nilsson.

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Purpose: My STSM was carried out during the cross-calibration campaign in the Kullaberg peninsula (Sweden, autumn 2015). During the campaign, four different radar systems and one weather radar were operated simultaneously and in the same area. The aim of the campaign was to analyse data obtained with these five different systems and search for common patterns to quantify and compare the aerial traffic of animals.
Specifically, my STSM was intended to contribute to the main campaign objective, by collecting data with a X-band marine radar and analyzing some quantitative and descriptive aspects of the bird movement, to make them available for comparative analyses with the other systems.
In particular, I analyzed the flight direction of the tracks detected by our radar in relation to: flight speed, altitudinal distribution and hourly distribution (time of the day).
The analyses I performed for this STSM are a complement of the ones carried out by Marco Cianchetti on the same dataset, within his STSM.

2. MATERIALS AND METHODS

The cross calibration campaign took place from the beginning of July to the end of November 2015, in the Kullaberg peninsula (Sweden).

Five radar systems were operated simultaneously detecting birds and insects flying over the same area during fall migration:

1. The Weather Radar located in Angelholm (22-24 km northern from Kullaberg)
2. and the tracking radar both from Lund University (Sweden);
3. the Vertical-looking Entomological Radar (VLR) from the Insect Migration Group at Rothamsted (Harpenden, UK);
4. the X-band fixed-beam radar from the Swiss Bird Institute (Sempach, Switzerland);
5. the X-band marine radar from our group (*Ornis italica* Association, Rome, Italy).

All radars, except the weather radar, were set up on the same location (Björkeröd, around 2 Km from Mölle) and were positioned at short distance (~5-20 m) between each other.
Our radar system was set up on the 5th of October and was oriented vertically with the rotation plan along North-South, the main flight direction for migrating birds. The radar collected data continuously over a 24h period at 1.2 Km scale from October 5 to 17.

Data were recorded as screen shots (1 Hz) and cumulated and edited in separate 3-hours video clips (.avi format) by using a screen capture software (NCH).

Then I processed these videos by using *RadR* (Taylor *et al.*, 2010), a plugin of the statistical software *R* (R Core Team, 2014).
This plugin allowed to reconstruct bird tracks from radar's echoes recorded in video files. The echoes can be filtered according to a variety of settings, for instance echoes size, maximum speed, minimum number of echoes and maximum time interval between subsequent echoes to build a track.
These filters are required to select and track birds of interest as accurately as possible (in the specific case, passerines were our target birds).

The *RadR* output is a text file where each point is described by the track id it belongs to, the timestamp and the X and Y coordinates: the X value represents the horizontal distance from the radar's centre, while the Y one is the vertical distance from the radar's centre (which from hereon will be referred to as quote or altitude). Both the coordinate values are expressed in metres, according to the chosen scale.

Then, I used *QuantumGIS* (QGIS Development Team, 2015) to connect the points (echoes) with tracks by using the *PointToPath* plugin.
In addition, for each track I calculated: length, time interval, speed and the clockwise bearing calculated from the Y axis.

All these information allowed me to analyze the tracks in terms of direction, speed, altitudinal distribution and hourly distribution.

In particular, since data were analyzed in two dimensions (altitude and horizontal distance from the radar's centre), it was not possible to calculate the real direction of a track crossing the radar's beam, so that tracks' speed and bearing couldn't be measured accurately.
Therefore, I could appreciate only the relative value of these information, in order to compare them among different tracks.

The analyses were performed with *R 3.2.1* (by using the package "*circular*") and *OriginPro 8.5*.

3. RESULTS AND DISCUSSION

I analyzed the direction of the nocturnal tracks, grouping them into three daily periods: (*i*) sunset: from 6 pm to 7 pm; (*ii*) night: from 7 pm to 9 am; (*iii*) sunrise: from 9 am to 10 am.

The rose diagrams in *Fig.3.1* show main movement directions, where the ray length depends to the number of tracks.
The common pattern of these three diagrams has a strong South component, as expected during fall migration.
But we can also notice a considerable amount of tracks going up at the sunset (*Fig. 3.1.a*) and going down in the morning (*Fig. 3.1.c*). We might read these tracks as departing and landing birds.
In the central hours of the night the most evident component is the N-S one (*Fig. 3.1.b*).
In all these graphs is also evident a smaller North component, that we could interpret as reverse flight.

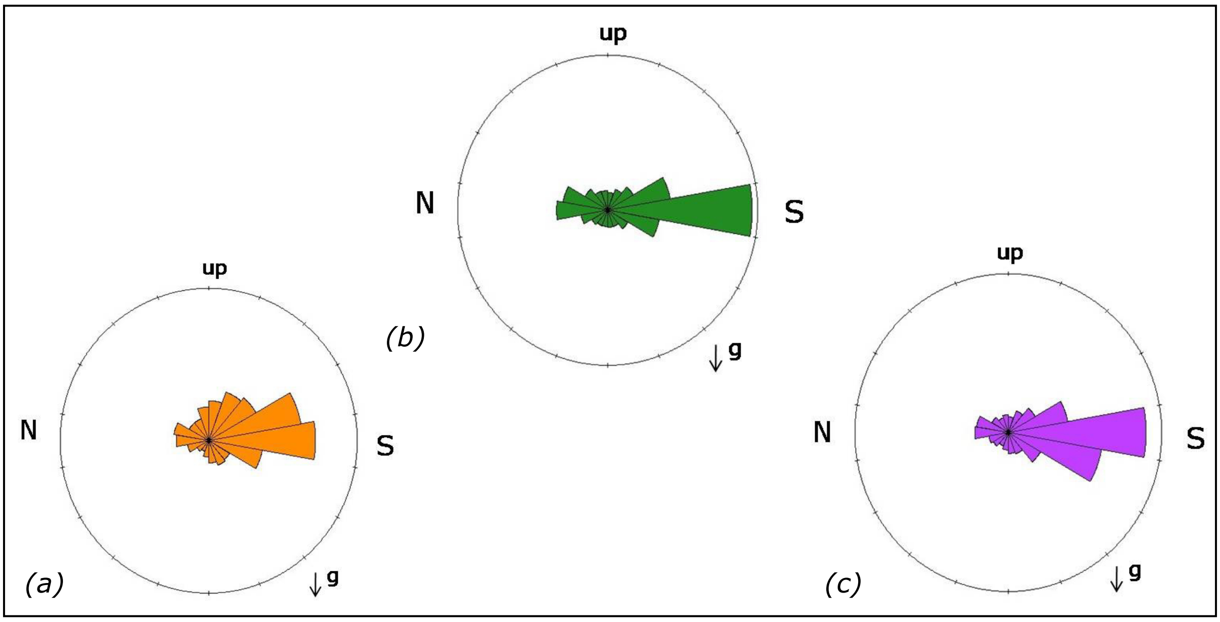

Fig. 3.1.: Main movement directions of nocturnal tracks: *(a)* from 6 pm to 7 pm; *(b)* from 7 pm to 9 am; *(c)* from 9 am to 10 am.

Given these results I wanted to quantify the presence of reverse movements among the recorded tracks.

I considered only nocturnal tracks between 9 pm and 6 am, in order to exclude those tracks read as departing or landing birds.
I classified the tracks by defining: as *forward tracks* those with a bearing between 60 and 120 degrees; as *reverse tracks* those with a bearing between 240 and 300 degrees.
By using this criterion, I found 33023 tracks belonging to the *forward* category and 7787 tracks belonging to the *reverse* one, with reverse tracks representing 19% of the total number of tracks.

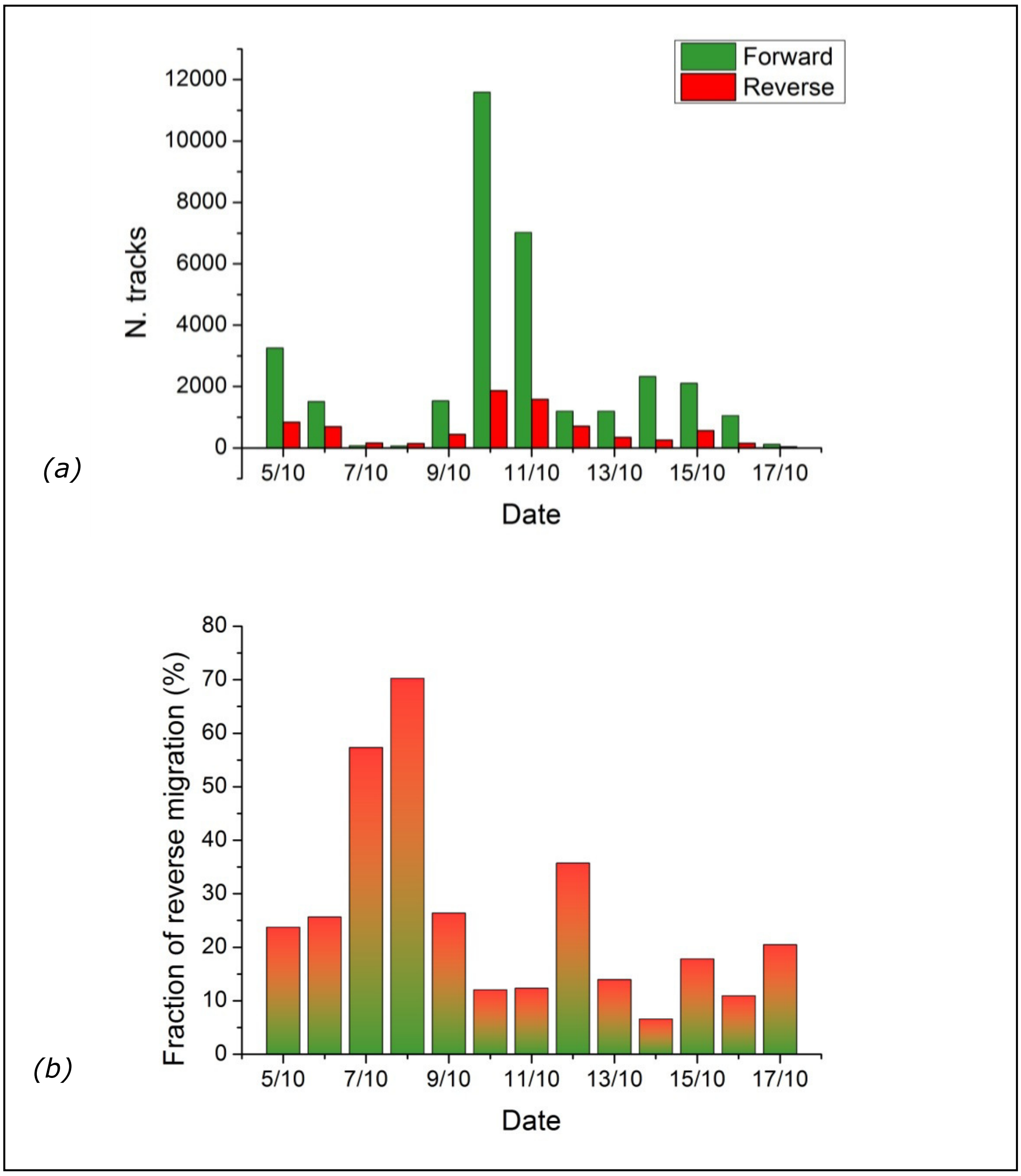

Fig. 3.2.: *(a)* Daily distribution of the number of forward and reverse tracks; *(b)* fraction of reverse tracks over the total amount of tracks per day.

The barplot in *Fig. 3.2.a* shows the daily distribution of the number of forward and reverse tracks, while *Fig. 3.2.b* shows the fraction of reverse tracks over the total amount of tracks per day.
These graphs outline quite different results, mainly in day with bad weather conditions (for instance on the 7th and 8th of October). At this level of analysis we didn't take into account any external factors (such as cloud cover, wind direction or weather variables), but the difference between the daily going of these two graphs suggests that different factors affect reverse and forward migration, as previous studies outlined (Åkesson *et al.*, 2001; Schmaljohann and Naef-Daenzer, 2011).

I also compared the flight speed between forward and reverse migrants (*Fig. 3.3*).
Reverse migrants seem to fly slower than forward migrants, with an average speed of 7.41±0.016 m/s against 9.14±0.006 m/s, consistently with what previous studies found out (Bruderer and Liechti, 1998; Nilsson and Sjöberg, 2015).

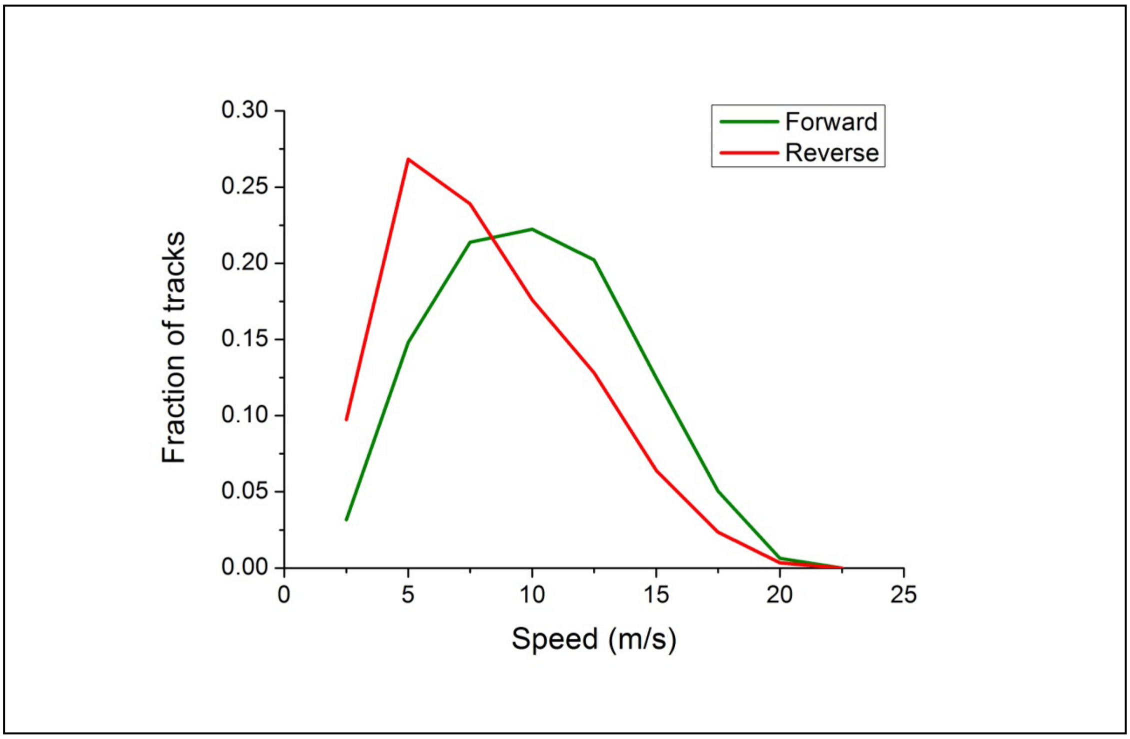

Fig. 3.3: Comparison between flight speed of forward and reverse migrants.

Finally, I compared hourly and altitudinal distribution of reverse and forward tracks by using three contour plot graphs (*Fig. 3.4*).
Fig. 3.4.b, if compared with *Fig. 3.4.a*, indicates that reverse migrants fly at lower altitudes and later in the night.

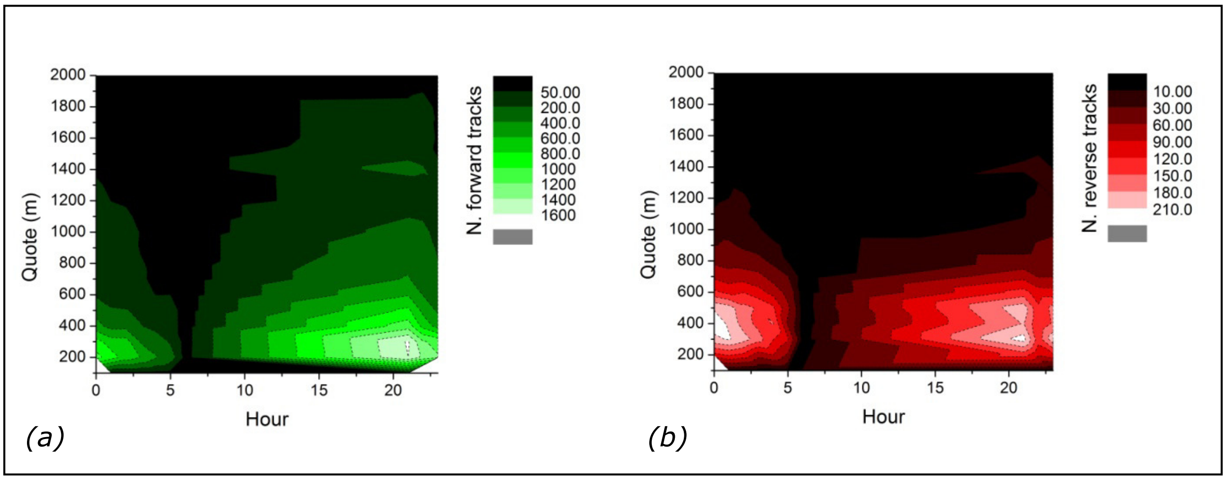

Fig. 3.4: Hourly and altitudinal distribution of: *(a)* forward tracks; *(b)* reverse tracks.

Concluding, with the data collected during this campaign from our radar apparatus, it was possible to: (*i*) find out the relative flight direction of the recorded tracks; (*ii*) classify and count the number of forward and reverse migrants; (*iii*) compare their: flight speed, hourly distribution and altitudinal distribution.

Our results show that reverse migrants tend to fly slower, at lower altitudes and later in the night, consistently with other results in literature (Bruderer and Liechti, 1998; Nilsson and Sjöberg, 2015).

4. CONCLUSIONS

From our point of view, the validation campaign and then the comparison between different radars' outputs is an occasion to improve our filter settings during raw data processing, for instance to discriminate birds from insects by using size or speed filters.

The comparison of flight speed recorded from different apparatuses would allow us to better understand the limitation of our system in measuring this parameter.
Moreover, comparing the number of birds detected from different radar systems in bad weather conditions will help us to evaluate the reliability of our data in those circumstances.

5. AKNOWLEDGMENTS

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