# Analysis of wind profiler data in the context of bird migration

## STSM-2015 Cost Action ES1305-European Network for the Radar surveillance of Animal Movement (ENRAM)

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[This STSM was proposed to complement the analysis of wind profiler data, which is part of the PhD project of Nadja Weisshaupt at Aranzadi - Society of Sciences. The PhD was initiated in September 2013 and will last three years. It is a joint project of biologists from Aranzadi - Society of Sciences and engineers from Euskalmet – Basque agency for meteorology/University of the Basque Country. It aims at characterizing the migration phenology of birds passing the Bay of Biscay on their journey between Central/Northern Europe and the Iberian Peninsula and to complement information from existing ringing data. The assessment of the significance of the Bay of Biscay as a geographical barrier for migrating landbirds is important from an ecological and evolutionary point of view and regarding the conservation of Basque coastal ecosystems as stopover sites.]

# Methodology

## Pre-STSM data collection

The data analysed in this STSM was collected at the wind profiler site in Punta Galea, Spain in March 2015. Radar data was obtained from the local L-band wind profiler. Simultaneous recordings were collected by a thermal-imaging camera, which was set up vertically on the south side of the radar and as close to the radar as possible. The southern side was chosen because birds in spring migration were anticipated to cross the radar beam in about this direction on their journey northwards, provided they fly through the main lobe. This should increase the probability of recording the same birds as the radar.

Thermal-imaging data was then videotaped for four hours from sunset at the radar site on overall 10 nights in March 2015. The purpose of these simultaneous recordings was to establish a reference and potential support for interpreting the quantitative and temporal patterns in the radar data of 2015.

The recordings yielded a variety of bird counts. In an exploratory campaign in spring 2014 counts between 0-1100 birds were recorded. In 2015, numbers were lower, ranging from 1 to 502 birds. For the STSM, based on these two field seasons, bird counts between 0-100 birds were classified as “weak migration”, 100-400 birds as “moderate migration”, 400-700 birds as “strong migration” and above 700 birds as “very strong migration”. Thus in 2015, the camera database included weak to strong migration events. Examples of snapshots are included in the Appendix.

All bird targets passing the screen were time-stamped and classified as to first, second, third, fourth hour of recording to facilitate posterior comparison of migration intensity with radar data. Further comments as to flock size, other/unidentified targets etc. were added, if applicable. In the presence of clouds, it was possible to see the wind direction based on cloud movement.

Nadja Weisshaupt’s role was to provide the camera database and her ornithological background to complement/support the interpretation of the radar data analysis, which was performed as follows.

## STSM

## Time series

The analysis and interpretation of the time series data and is a complex task because it is based on raw data and many scatterers could be mixed together.

For this reason it is very important to identify the least complex signals, the strongest signals and individual signals in the data. A certain leeway in data interpretation has been taken into account in the results. Only signals where uncertainty about the interpretation was considered low were taken into account in the study.

The signal depicts the radial velocity of the scatterers relative to the beam position. This means the projection of the movement of the scatterer in the direction of the beam. When the antenna is pointing vertically, radial velocity is the vertical movement of the scatterer. For this reason the vertical beam is chosen to discard information related to the horizontal movement and to associate the signals with vertical movement of the birds (we assume that the selected scatterers are bird). The first assumption is that the only vertical movement of the bird is the wing beat. Therefore the return echoes give us information of the wingbeat patterns of the birds.

For the present STSM we selected the vertical beam of the low mode. The advantage of this mode is that with its range of 2 km it covers approximately the same range as the camera, which reaches up to 3 km. In some cases, the high mode is used as a verification tool.

## Bird targets

It is well known that bird echoes are stronger than atmospheric signals. Therefore the following assumptions were made:

1. The bird could be detected in the side lobes before crossing the main lobe or only by the side lobes if it doesn't pass over the main lobe. The path of the bird modifies the signal.

2. The strong echo of the bird or other echoes of equal or stronger intensity have an impact on the range-weighting function (RWF). The range-weighting function determines how individual scatterer's contributions are weighted as a function of range in a resolution volume.

3. The receiver could be saturated because of strong echoes and while it is recovering, the echo return signals are modified (the receiver cannot work under specifications, the amplification of the return signal could be incorrect).

4. The time series plots are normalized plots. The features of each gate are represented independently and the amplitudes cannot be compared visually between gates to evaluate the strength/presence or absence of an echo.

## Biological information

One of the most important points of this STSM is that the interpretation of the signals requires biological knowledge. Therefore thermal imaging data was crucial and was considered in this study together with knowledge about biological behaviour of birds.

## Input data

1. Wind profiler data at the moment level was reviewed in order to identify the days of bird migration for March 2015 and compared with the database of the camera campaign.

2. Time series analysis. It is important to be familiar with this data, to know the characteristics of an atmospheric versus a non-atmospheric signal.

3. As it is difficult to analyse frequencies in the time series data, spectrograms were created during the STSM to better understand the frequencies of the echoes. The patterns are easier to identify in the spectrograms although a combination of both time series and spectrograms is best.

4. The video recordings were used to verify single birds, groups of birds or other targets and to confirm clear air conditions, visibility conditions and in case of low clouds, wind direction/strength.

## Data analysis

The following steps describe the approach for data analysis.

1. Wind profiler data was analysed at the moment level of all beams and in both modes. Then the vertical beam of the low mode was selected for the study.

2. Features of the moment data taken into account for analysis: intensity of bird contamination during the sampled days (number of profiles and gates that could be related to bird contamination), manual (visual) identification of the layers of bird contamination, time after sunset when data started to show signs of bird contamination.

3. By using the information of the camera the days were classified in four groups based on bird counts as described previously:

    a. Low contamination.

    b. Moderate contamination.

    c. High contamination.

    d. Very high contamination

   The features associated with each bird detected by the camera were previously described in a separate analysis (not ENRAM-related).

4. The analysis of the time series started with a day of moderate migration according to the camera. The aim was to identify a pattern of a single bird in the time series.

5. Combining the time series data and the spectrogram plots to identify the frequencies associated with vertical movements in single scatterers and strongest signals. The spectrogram shows the frequencies in each gate.
6. Information extracted from time series and spectrograms was collected in Word and Excel sheets: time (to find time-stamped targets in the simultaneous camera recordings), gates in which the targets were located, any kind of comments on particular repetitive patterns, screen shots of special/extraordinary patterns, doubts to be clarified with our host Volker Lehmann etc.
7. The study is repeated for each intensity group. The spectral data is used to verify the results of a previous assessment at spectral level.

## *Results*

### At the moment level.

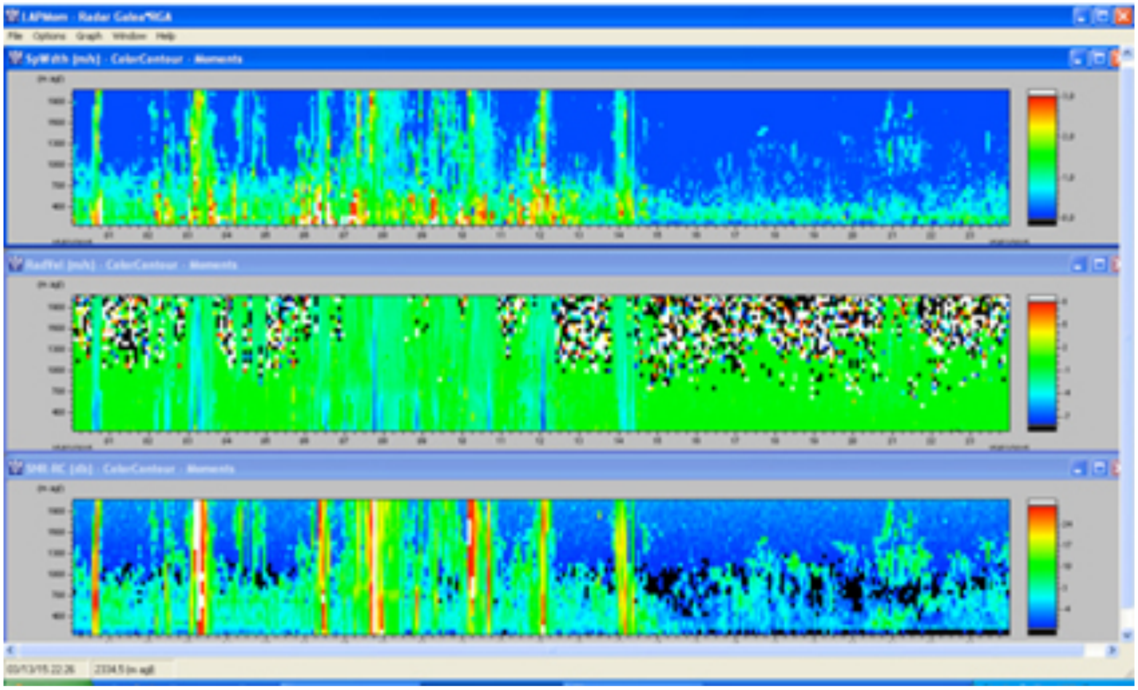
The moment plots display the three moments radial velocity, spectral width and signal-to-noise ratio (SNR) in a contour plot. The X-axis represents the time and the Y-axis represents the height.

The main observations at the moment level are:

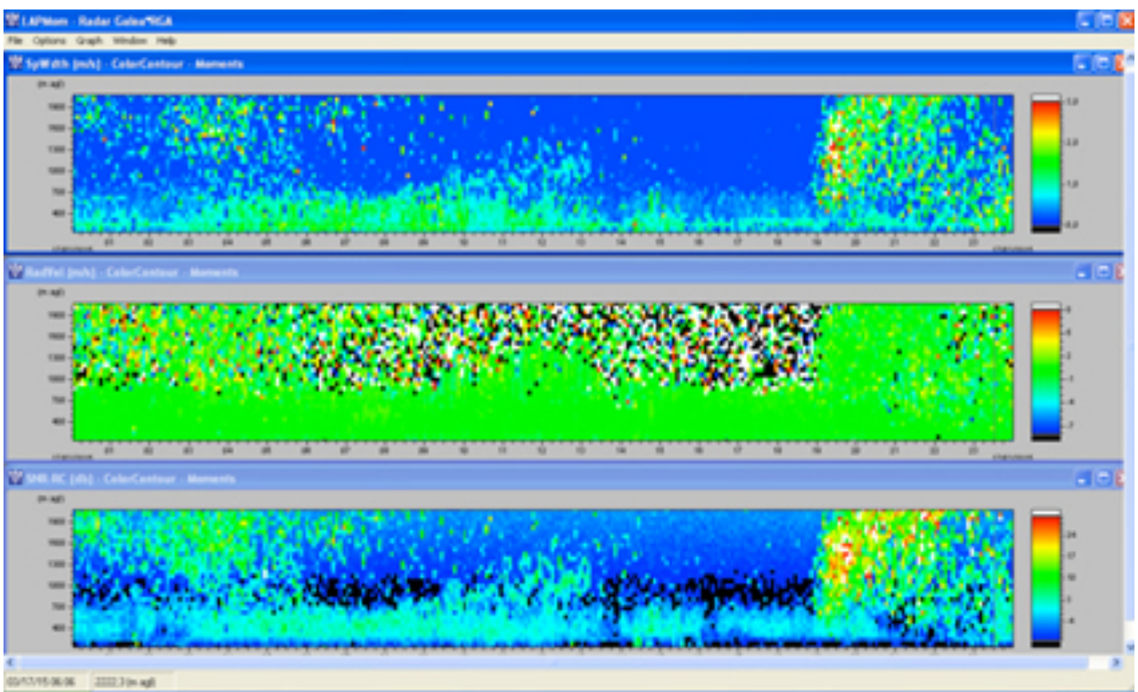
1. There are slight differences between the beams at the moment level. The low mode shows more details of the bird patterns in the course of time and across the gates. The low mode matches the sampling height of the camera.
2. Further work is needed to investigate differences between the beams.
3. March 2015, is a month in which there are clear conditions from 5 to 10, from 16 to 18 and at the end of the month. Higher values of SNR and spectral width, and a strong variability of radial velocity and spectral width are associated with bird contamination.
4. The bird contamination is linked to the area associated to bird features in the contour plots at the moment level. This area might be correlated to bird density. The moment level shows the efficiency of the signal processing technique to identify atmospheric signals, not bird signals.

## Bird characteristics

Low contamination- 15 March 2015 (starting at about 19:00)



High contamination - 17 March 2015 (starting at about 19:00)

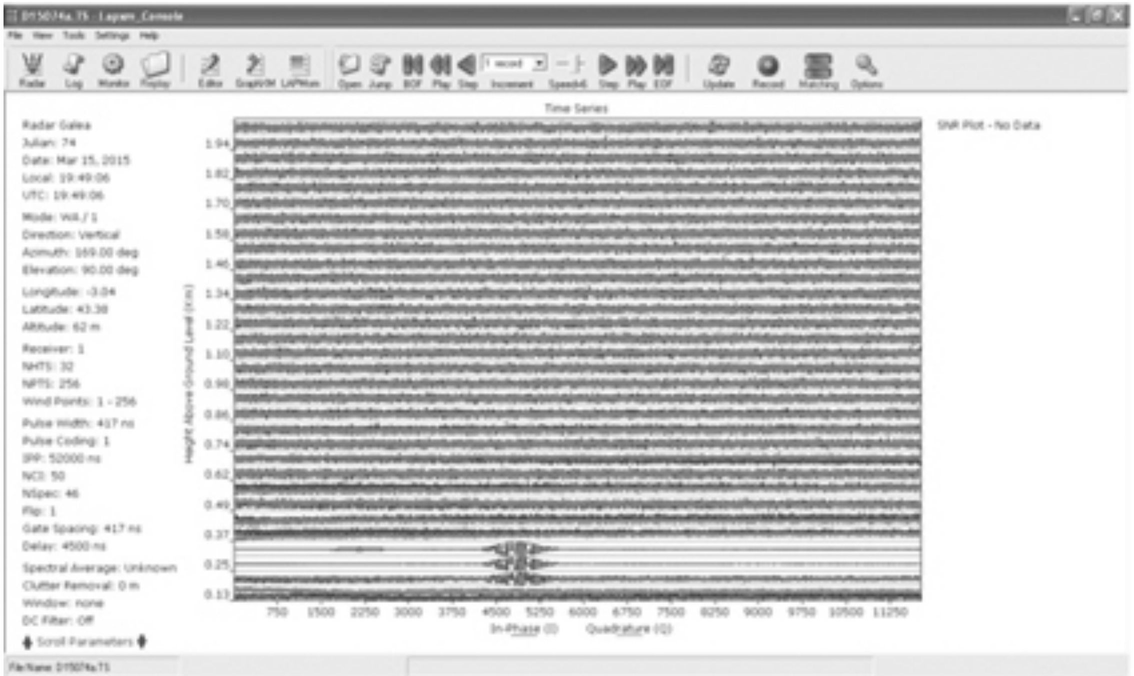


After sunset there is strong discontinuity in the three moments.

## At the time series level

The time series plots show the time series of the I-Q signals for each gate (Y-Axis) plotted against time (X-Axis).

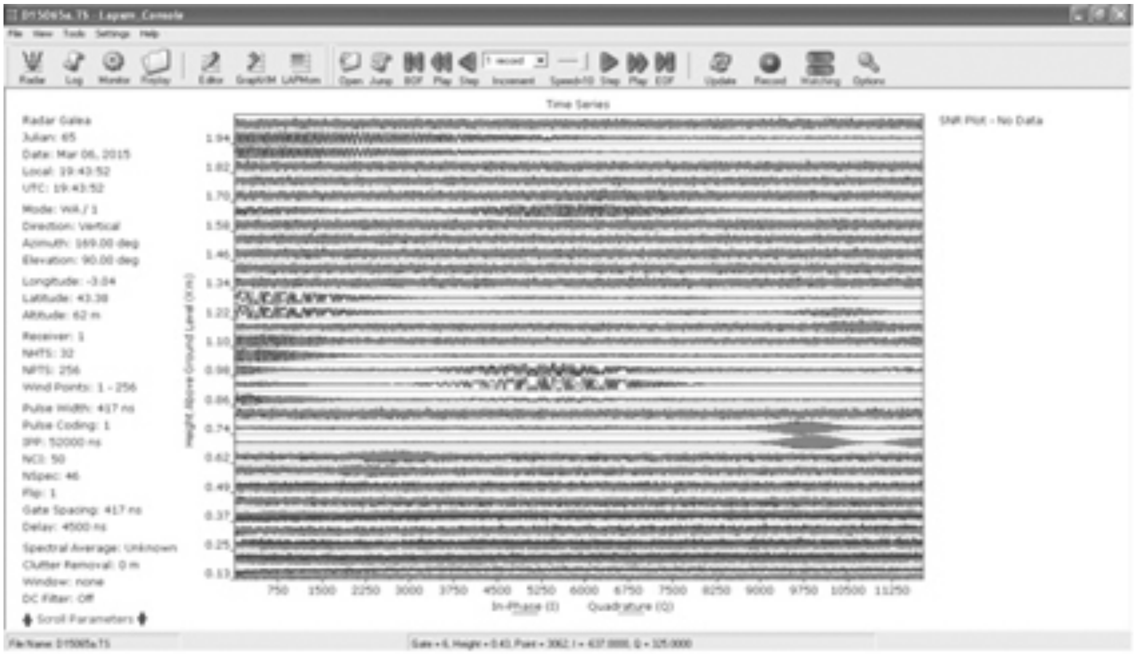
<u>Low contamination:</u>




Generally bird echoes have an elliptical shape. The strong signal and the weighting function applied in the signal processing cause the multiplication of the patterns into several gates. In the above example, three gates are contaminated by one bird. It is identified as one bird based on the codification of the ellipse (i.e. the pattern shaping the ellipse). The bird is located in the “strongest” gate, i.e. the gate where the bird signal exhibits the greatest signal-to-noise ratio (difference to surrounding noise).

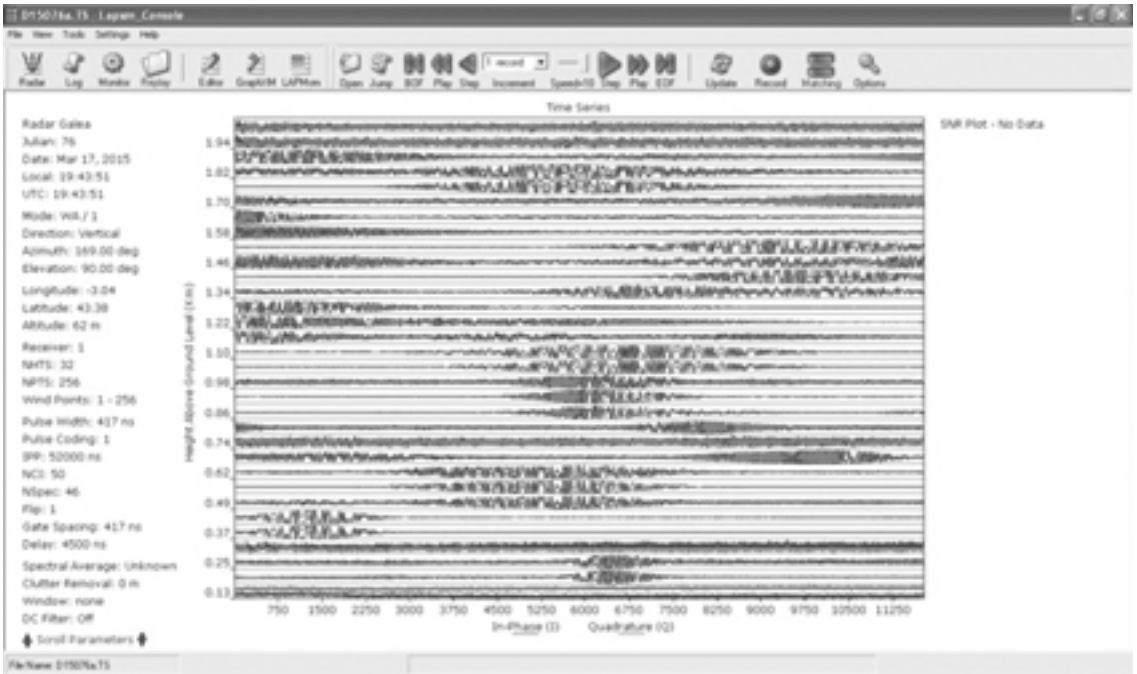
The ellipse appears to contain information on wing beat patterns (e.g. continuous or pause-flapping-pause-flapping etc.), however, this aspect needs further investigation.

<u>Moderate contamination:</u>



The density of the ellipses has increased across height and time. The analysis is potentially more difficult because birds could mutually mask each other in the same gate. Neighbouring gates cannot be compared visually because of normalization (see introduction).

High contamination:



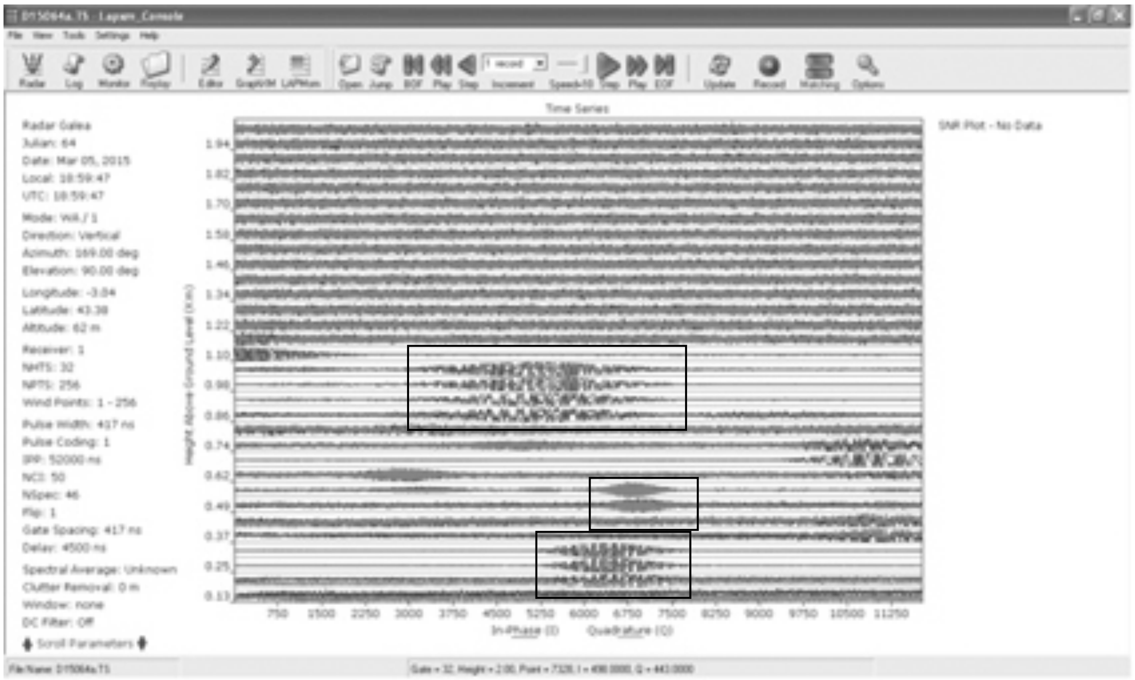

With increasing density the risk for mixed ellipses containing several birds augments, i.e. bird signals can be concatenated to form long ellipses. A high degree of expertise and familiarity with this kind of data is required. In many cases it is difficult to separate or distinguish between the data from the main lobe and the side lobes although the data from the main lobe contains information on the movement of the bird - if it passes perpendicularly to the beam, the frequency is zero.

As the analysis of the frequencies is very complex based on the sinusoidal curve in the I-Q data, spectrograms were created for the sampled dates. The combination of both plot types facilitates the analysis and reveals many features of the data very useful not only for ornithologist studies but also for meteorology.

## Spectrograms vs. time series - different patterns and some explanations

The differences between the time series plots and spectrograms are illustrated on the basis of 5 March 2015.

Below a time series plot of 5 March with the frame indicating the signals, which are further detailed in the spectrograms.



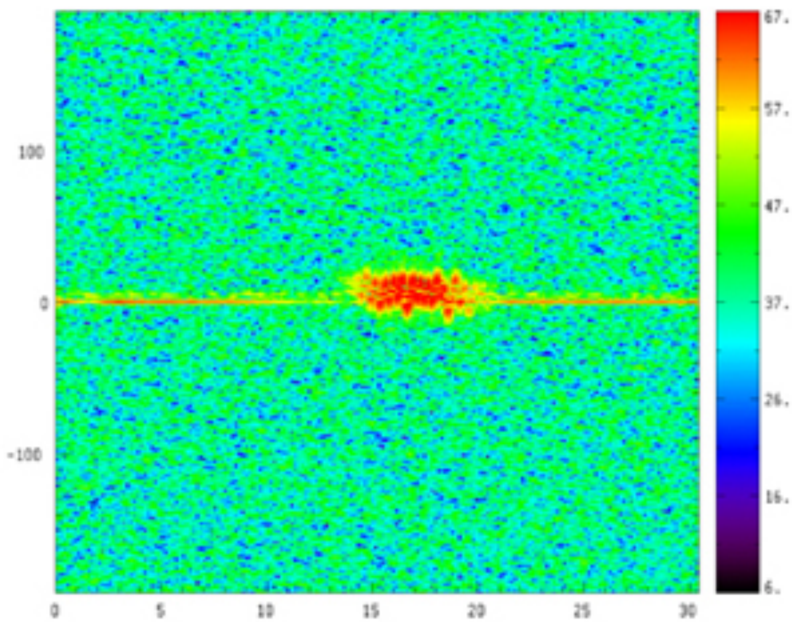
Spectrograms

The spectrogram is a contour plot representing the signal strength along the frequencies (Y-axis) against time (X-axis) for each gate.

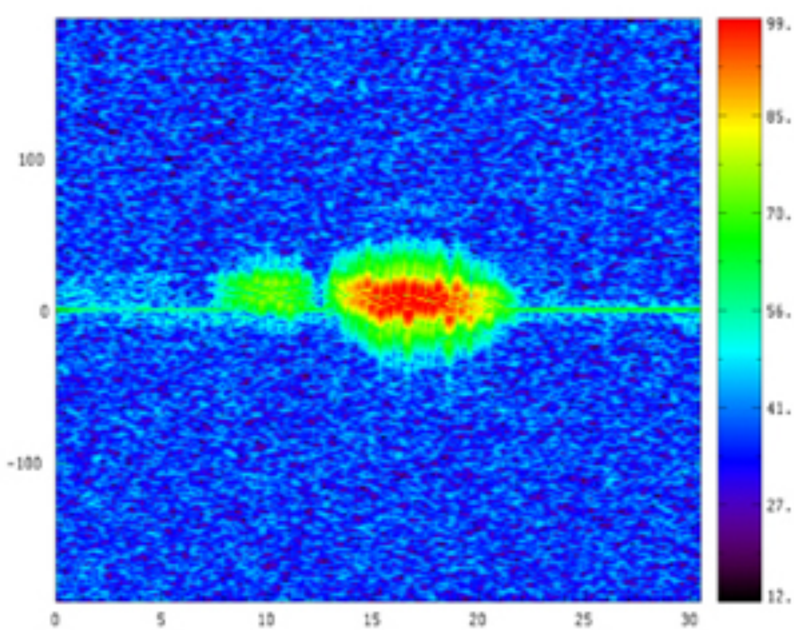
Example 1

Starting at the bottom, a bird is identified in the time series in the gates 2-3-4, the ellipse and the codification of the ellipse is identical so it is assumed that it is one single bird. The spectrogram analysis reveals the vertical frequencies and the height in which the bird is flying. It is possible to determine the flight altitude in time series but it is easier based on the maximum signal-to-noise value of the spectrogram.

Gate 2

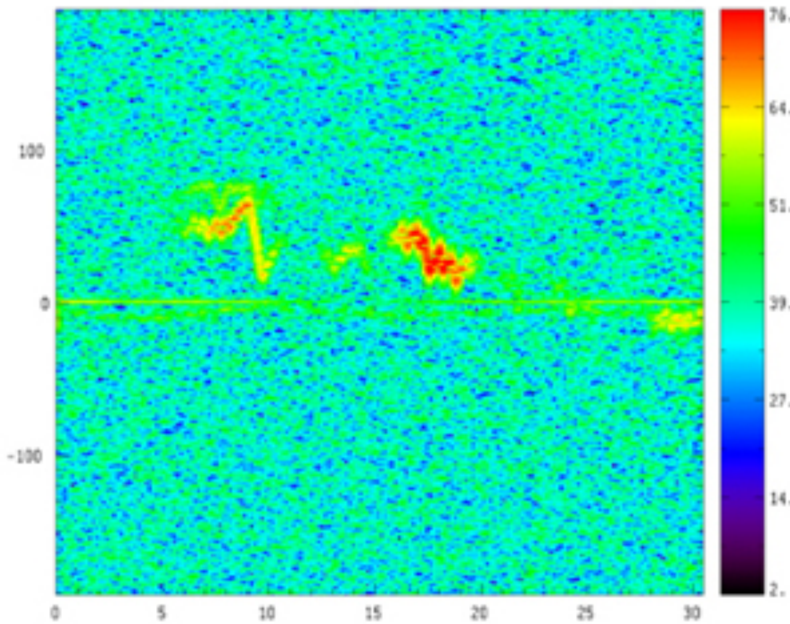



Gate 3




Gate 3 contains the strongest signal and thus defines the flight altitude of the bird. The frequencies indicate an oscillating zigzag. These oscillations are being further explored at this moment, but they are probably associated with wing beat patterns when the bird crosses the beam.

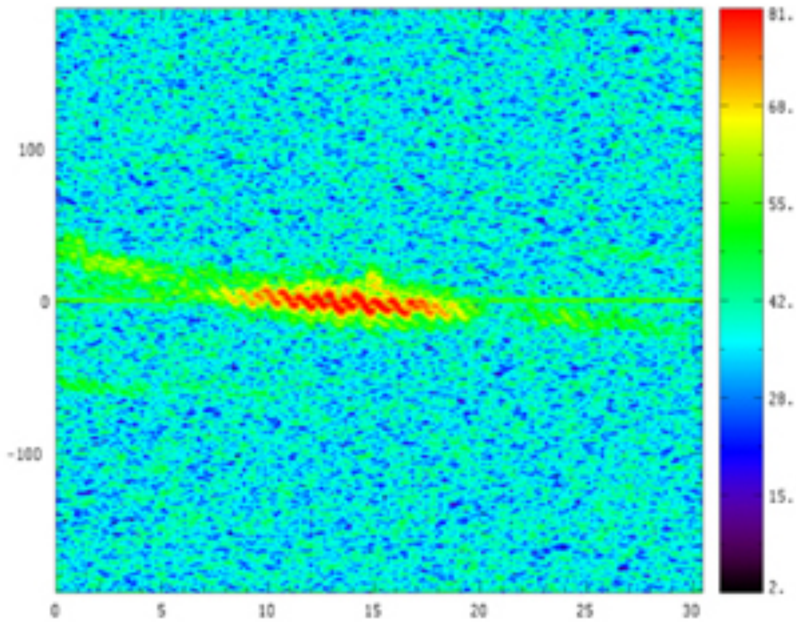
Example 2. Sometimes birds do not cross the main lobe and thus exhibit frequencies other than 0 (no perpendicular movement relative to radar).Gate 8




Example 3

In the following spectrograms, the bird is flying at an altitude of 0.86 km, longer ellipses are observed and the target needs more time to cross the beam at this height.

Gate 14




These are some of the main features related to the spectrogram. The powerful information resulting from combining time series and spectrogram has helped us understand the movements of the birds when they cross the beams. The codifications of the ellipses are being studied in more detail at the moment and more research is needed to complete the work.

## Verification with the spectral information

In days with high bird densities, the spectral data was analysed in combination with the time series. The main result of this study was that if the signal of a bird is very clear in a gate, the bird is removed by signal processing. The problem lies in the adjacent gates containing a fuzzy or noisy copy of the bird signal which is not removed. Therefore, it was concluded that spectral information provides an erroneous picture on migration parameters (e.g. flight altitude).

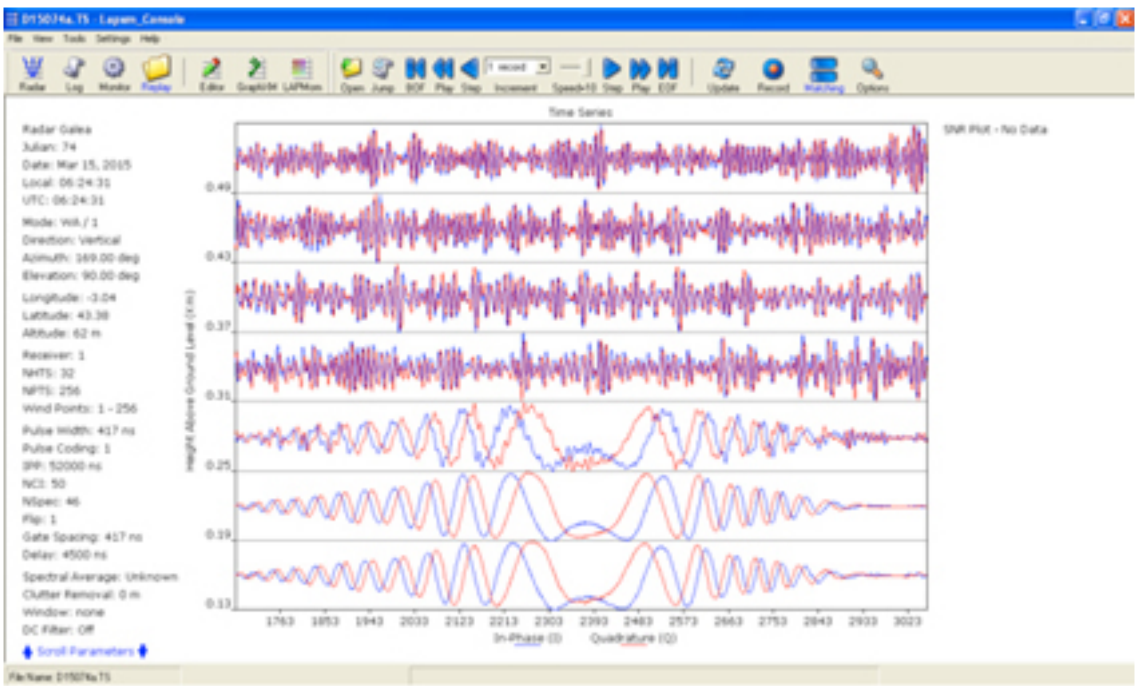
Additionally, in days of weak migration with only single birds, the signal processing worked reliably and clean radar data effectively. Thus only the time series contained accurate information on birds.

## Verification by camera

The camera recordings provided data on overall migration intensity and target identification (occurrence of single migrants vs. groups, other objects) which will be further analysed in combination with time series and spectrograms. However, so far it is not quite clear to what extent and how reliably the amera data on small single targets (passerines) actually coincides with single targets observed in time series, i.e. if one bird passing over the camera is exactly the same bird which will be seen and depicted in the time series as the sampling volume is different. Currently, this issue seems of less importance in case of larger objects (airplanes) or larger flocks of birds. Further analysis will probably shed more light on this aspect.

## Other targets vs. birds

On 15 March, birds were detected during precipitation events. Bird signals are completely different from precipitation signals (see below).



The lower three gates show one single bird (located in the second gate at 0.19 km) and the upper gates show precipitation (gates 0.31-0.49 km).

# *Conclusions & outlooks*

The STSM enabled the researchers to perform pioneer work in the analysis of time series data. It was possible to evaluate the reliability and the information content of the different data levels (moments vs. spectra vs. time series) and to identify characteristics of different targets. The results shown are preliminary and represent a selection of the variety found in wind profiler data. Data analysis is on-going. Future work will focus on a more detailed analysis of target identification (e.g. birds vs. other objects, classification of birds) and to extract and analyse further bird migration parameters that were not reliably accessible based on moments, spectra and consensus data. These parameters include the determination and refined analysis of flight altitude and migration intensity (in combination with thermal-imaging data) as well as the evaluation of a potential impact of weather conditions on migration dynamics. Further parameters will be extracted if possible.

The results will be published in collaboration with the host of this STSM.