Verification of insect presence in raw data of radar wind profilers

STSM- April 2017 Cost Action ES1305- European Network for the Radar surveillance of Animal Movement (ENRAM)

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The present STSM builds on the previous STSMs by Mercedes Maruri and Nadja Weisshaupt (Maruri 2015, Weisshaupt 2015, see www.enram.eu/stsm) which established a methodology for bird target identification in wind profiler time series. During this previous study, line targets were identified which could not reasonably be attributed to birds (lack of wing beats). A possible explanation for these line targets could be insects or any other (non-) biological target or alternatively any transient meteorological phenomenon, which has not been taken into account previously.

This STSM was proposed along with the STSM by Mercedes Maruri at the same site and in the same period to maximize the benefit of the expected outcomes by combining knowledge from meteorology and biology.

The current STSM was hosted by Dr. Volker Lehmann from the Meteorological Observatory in Lindenberg (Deutscher Wetterdienst), Germany. Volker Lehmann is an expert in radar wind profilers (RWP) and also highly knowledgeable in other remote-sensing systems.

Objectives

The objective was the verification and identification of non-bird targets (both atmospheric and biological) by using wind profilers in conjunction with other remote-sensing systems (such as cloud radar) available at the host site to compare data of these different systems. Special attention was paid to potential presence of insects.

A further topic related to advanced target identification was to define the first steps to extend the frequency analysis of bird echoes in Gabor spectrograms, which could potentially contribute to refine the bird echo analysis (e.g. bird composition by frequency).
Both of these aspects were studied on time series level (raw data).

1. Advanced signal interpretation

Input data

Data was obtained from two UHF-band radar wind profilers (Lindenberg and Bayreuth, Germany) and a Ka-band cloud radar at the Meteorological Observatory Lindenberg. In addition, spring data from the L-band RWP at Punta Galea, Spain, was consulted as a reference to compare the signal characteristics. The specifications of the different systems are given below.

	Boundary Layer RWP	Tropospheric RWP Lindenberg / Bayreuth	Cloud radar
Operational frequency	1290 MHz (23 cm)	Both 482 MHz (62 cm)	35.5 GHz (8 mm)
Vertical resolution	417 ns (60m) 0.133-2.001 km	1000 ns (gate spacing 650 ns) (94m) 0.45-9.38 km / 1675 ns (gate spacing 1000ns) (140m) 0.55-10.52 km	30 m (sample range: 0.25-12 km)
Number of gates	32	96 / 70	
Sampled season/Location	Spring/Punta Galea-SPAIN	Summer, Autumn/Lindenberg, GERMANY	Summer, Autumn/Lindenberg, GERMANY

Cloud radars have been known to register insect presence (Drake and Reynolds 2012). Therefore this type of radar was considered a suitable secondary device in combination with the RWP systems.

Methodology

As birds are strong scatterers in RWP data and could potentially mask insects, if both were mixed in the same sample volume, the aim was to start with as simple conditions as possible, i.e. outside the main passerine migration hours. Experience from weather radars showed insect presence to be more easily visible during the day than at night. Similarly, local cloud radar data showed diurnal (and nocturnal) aeroplankton presence. So, in a first approach, the late afternoon hours (16:00-18:00 UTC) of the Lindenberg and the Bayreuth RWP were assessed on a clear day (4 Oct 2016) regarding presence of any potential biological (non-bird) targets, e.g. any kind of shift in patterns around sunset, different echo signatures during day hours compared to bird echoes etc.

In a second step, in order to increase the probability of detecting insect echoes and to decrease the probability of bird echoes in the data, a summer day without precipitation was selected, i.e. 15 July 2015 (Fig. 1). This day presented an interesting case of an aeroplankton layer up to 2 km and a pronounced chaff layer at about 2-5 km, which might have been an alternative cause for the transient line echoes in RWP spectrograms.

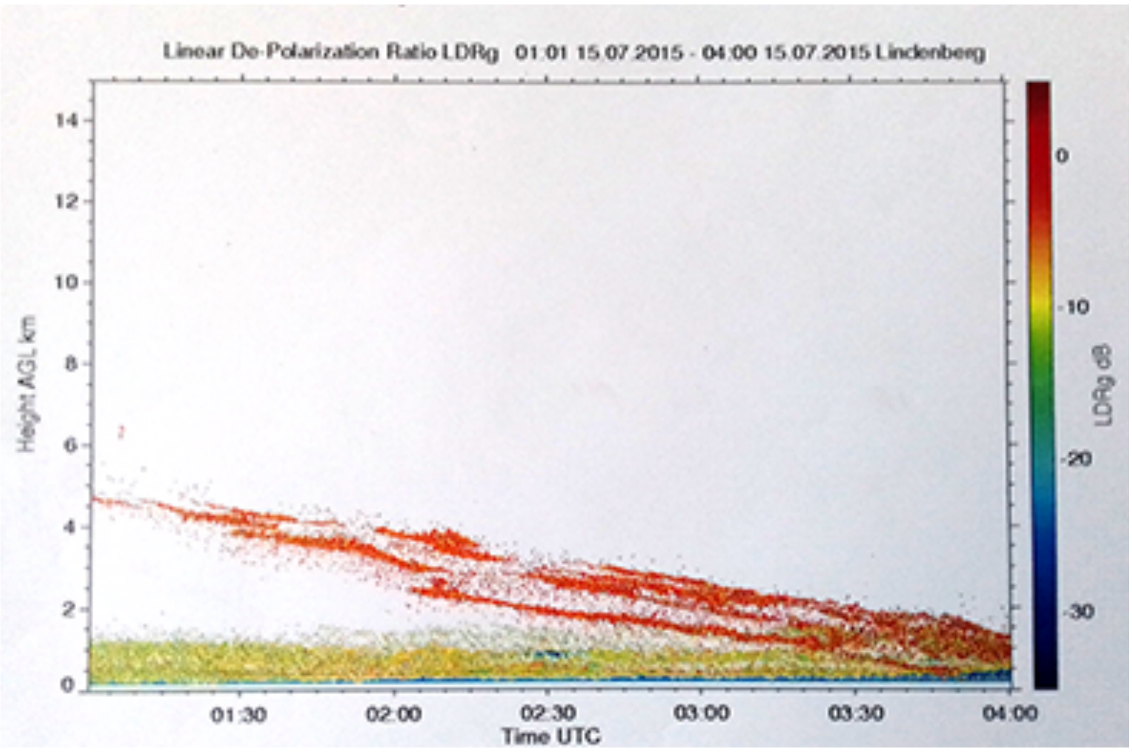

Fig. 1 Cloud radar at Lindenberg showing chaff layer (red) and aeroplankton (yellow) on 15 July 2015.

For the analysis, spectrograms were created for the RWP system, and plots of SNR, radial velocity and spectral width were obtained from the cloud radar for a limited night period (00:00-04:30 UTC). To clarify the capacity of the RWP to detect chaff, the SNR-values were extracted and plotted for the RWP height profile up to 6 km to detect any kind of fluctuations or irregularities matching the pattern in the cloud radar.

Results

Pre- vs. post-sunset analysis

The pre-sunset analysis showed line echoes as the predominant features in the Bayreuth radar (see Fig. 2) in contrast to post-sunset spectrograms where typical bird echoes (Fig. 3) took over. The Lindenberg RWP showed overall fewer lines, both before and after sunset. The presence/absence of lines could easily be an artefact of the stronger bird echoes which could mask the lines. Still, there are many cases where these line patterns persist despite simultaneous bird echoes (Fig. 4) and exhibit SNR values of >100 dB. Additionally, in most cases the time series patterns of line echoes clearly differ from bird ellipses through their irregular and ragged shape (Fig. 5, 6)

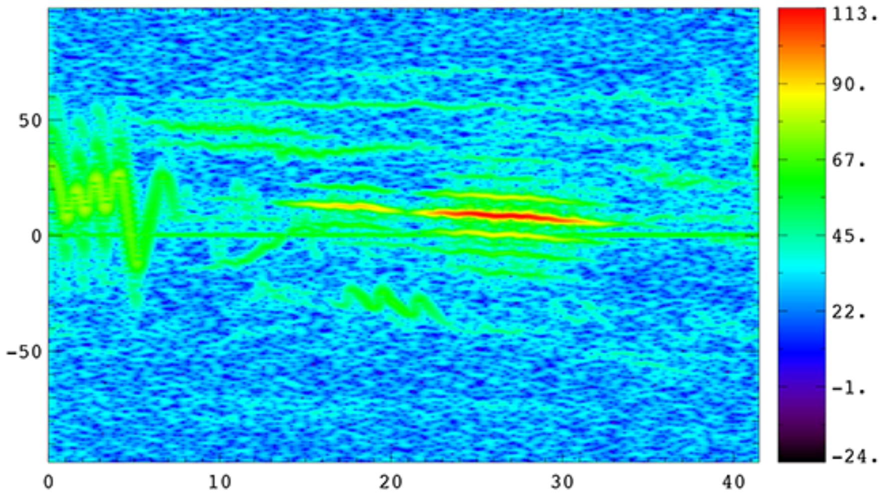

Fig. 2 Line pattern in Bayreuth RWP spectrogram in Gate 15 in northern beam on 4 Oct 2016 at 18:12:36 UTC.

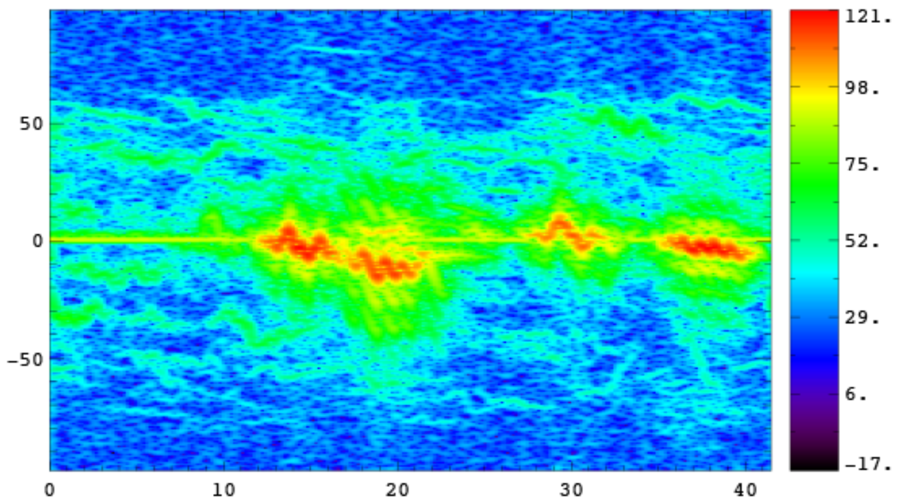

Fig. 3 Typical zigzag patterns of bird echoes in Bayreuth RWP spectrogram in Gate 7 in southern beam on 4 Oct 2016 at 18:43:22 UTC.

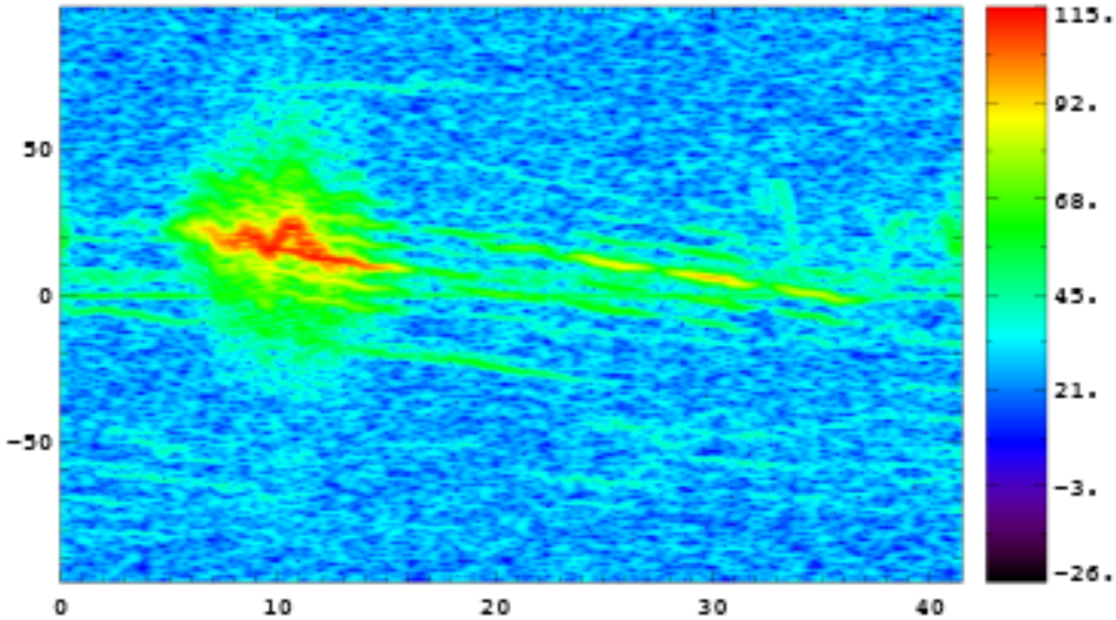

Fig. 4 Spectrogram showing bird echo mixed with a line in Bayreuth RWP in the northern beam in Gate 13 at 18:01:34 UTC on 4 Oct 2016.

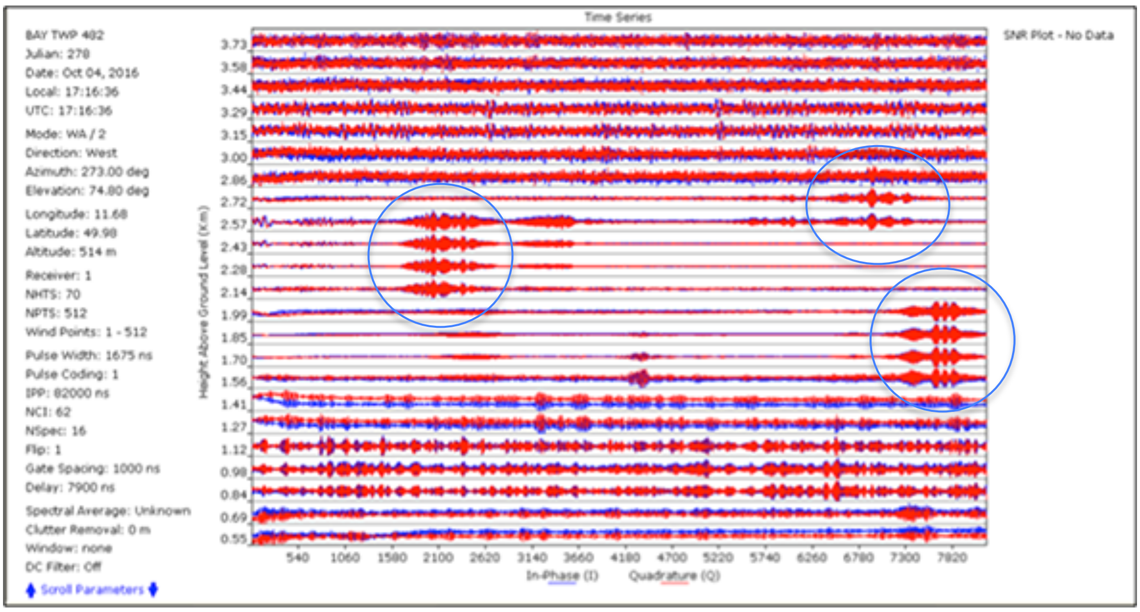

Fig. 5 Time series echoes of lines (in blue circles) from the Bayreuth RWP on 4 Oct 2016 at 17:16:36 UTC.

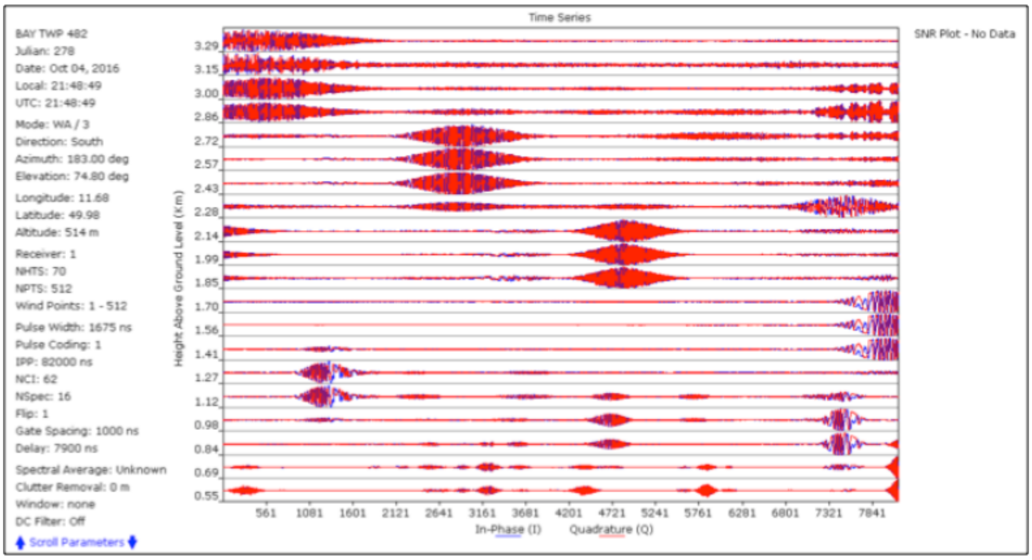

Fig. 6 Time series showing bird echoes from the Bayreuth RWP on 4 Oct 2016 at 21:48:49 UTC (except non-bird echo at the end of gate 17).

Cloud radar analysis

Chaff was successfully identified in RWP spectrograms through elevated SNR values, which is, by the way, a previously unknown finding. The altitudinal distribution of the higher SNR matched very well with the cloud radar data (see also Appendix Fig. 1). Apart from that, chaff did, however, not exhibit any particular point target feature in the RWP time series or spectrograms, so the line patterns are not due to chaff.

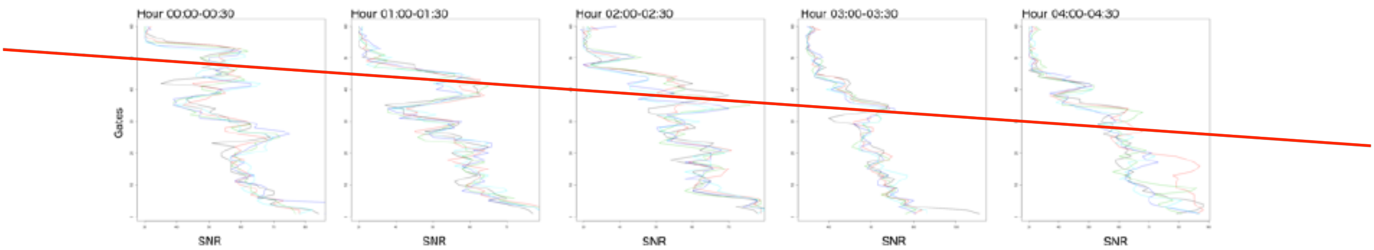

Fig. 7 Height profile of SNR ratios for chaff extracted from RWP spectrograms as observed in Lindenberg on 15 July 2015, covering the first 6 km (gate 1-60) of the sample height. Chaff can be observed as a peak in SNR decreasing in altitude (red line as a help).

When checking the plankton layer in the cloud radar data, a suspicious increase in radial velocity was observed in some areas. A comparison with the RWP time series and spectrograms did, however, not reveal any marked shift in signal characteristics, i.e. there was no sudden appearance of lines at the time when the higher radial velocity indicated potential biological movement in the sampled period.

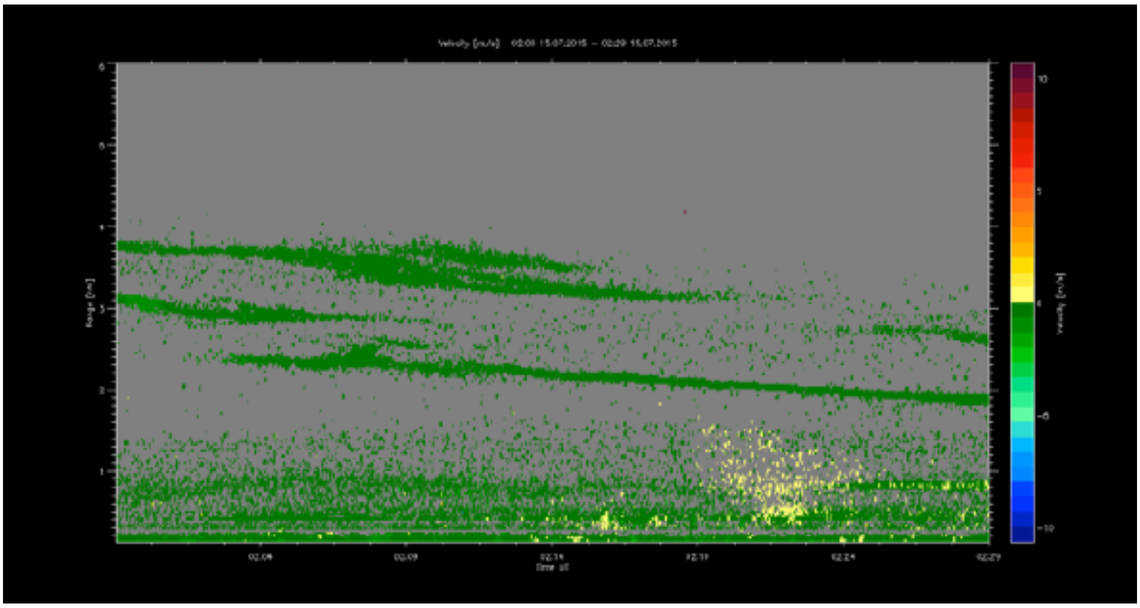

Fig. 8 Radial velocity patterns of the Lindenberg cloud radar from 02:00-02:30 UTC on 15 July 2015, showing the chaff layer (above) and the plankton layer (bottom) with interspersed sprinkles of elevated radial velocities of about 1-2 m/s.

2. Extended bird composition analysis

On Monday 3 March a meeting was arranged with Prof. Dr. Gerd Teschke from the University of Neubrandenburg, who is a renown expert in Applied Mathematics and had been involved in the development of the Gabor filter and related computational methods (e.g. Lehmann and Teschke 2008). The objective was to talk about a mathematical/model-based approach to extract information on bird composition in radar wind profiler data. In the previous work related to RWP signal analysis, the need for a more automated and computer-based analysis, classification and processing of the different signals for (biological) research purposes has become more and more obvious. The aim was thus to check the potential for developing an objective way to classify targets according to their spectrogram features and eventually extract wing beat frequencies, among other. The first steps needed to check the feasibility of this undertaking were discussed. In a trial a first visualisation and remodelling of the bird signal was produced (see Fig. 9 below).

This project requires the combination of the expertise of mathematicians, meteorologists and ornithologists, as well as the respective tools, which could be addressed and developed in a future STSM.

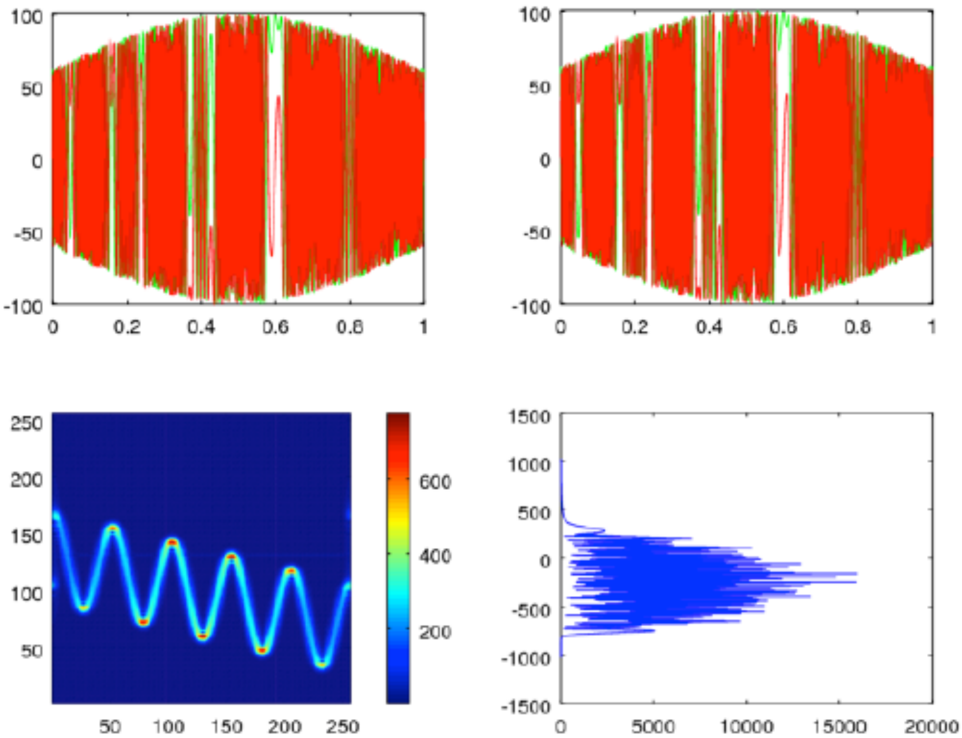

Fig. 9 Sample output of bird echo in time series (top row) and spectrogram reproduction (left bottom)

An automated target processing could potentially help deal with the great amount of target echoes found during bird migration (or other periods, depending on the research interest) in order to identify and isolate bird echoes and to apply the methodology previously developed by Weisshaupt et al. (2017). It could furthermore shed light on so far non-clarified atmospheric and biological targets to help understand the different features in the time series signal pool when going back and forth between time series and spectrogram features.

Such an automated method would not only be beneficial to the ornithological community, but also generally in regard to qualitative aspects related to radar wind profilers or similar devices.

Conclusions

The STSM allowed extending the echo analysis on time series level and paving the way for new approaches to advance with the bird signal interpretation. The combined cloud radar-RWP analysis allowed identifying chaff for the first time in RWP data and at the same time excluding it as the source of the line echoes. Unfortunately the origin of the line targets could not be unequivocally solved. The temporally and spatially reduced occurrence of the lines indicate a biological source, however, more verification, probably in combination with actual field work, would be needed to draw any final conclusions. It is important to emphasize that more work is necessary to fully process and make use of these new findings.

Acknowledgements

I would like to thank Dr. Volker Lehmann for hosting me during this second STSM at the institution and for sharing his expertise on remote-sensing systems. Furthermore I thank Prof. Dr. Gerd Teschke who explicitly visited to check the possibilities for a mathematical approach in advanced bird echo identification. Dr. Uli Görsdorf was very supportive with the cloud radar data. And finally, thanks go to the other staff at the Meteorological Observatory of Lindenberg, who was very welcoming and helpful.

Literature

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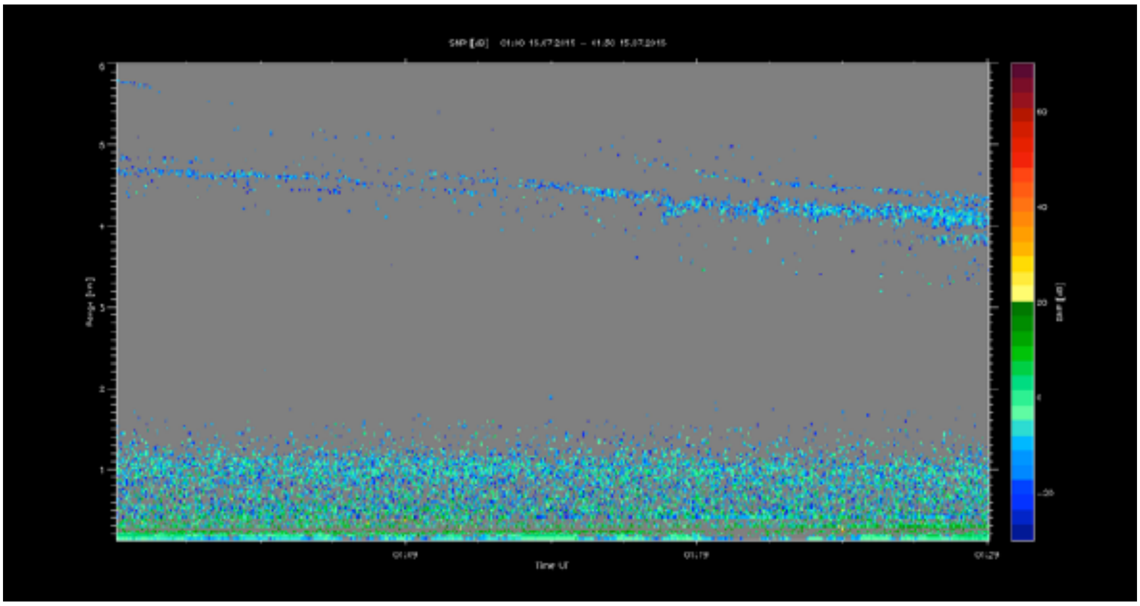
Lehmann, V. and Teschke, G. (2008) Advanced Intermittent Clutter Filtering for Radar Wind Profiler: Signal Separation through a Gabor Frame Expansion and its Statistics. Ann. Geophys., 26, 759–783.

Weisshaupt, N., Lehmann, V., Arizaga J. and Maruri, M. (2017) Radar wind profilers and avian migration - a qualitative and quantitative assessment verified by thermal imaging and moon watching. Methods in Ecology and Evolution. DOI: 10.1111/2041-210X.12763.

Appendix

Fig. 1 Chaff as seen by cloud radar descending in altitude from (a) 5 km at 01:00-01:30 to (b) 3-4 km at 02:00-02:30 on 15 July 2015.

(a)



(b)