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METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

UNIVERSITY OF HELSINKI

TOBB
UNIVERSITY OF
ECONOMICS AND TECHNOLOGY

BIOLOGICAL ECHO CLASSIFICATION IN DUAL-POL WEATHER RADAR DATA

SHORT TERM SCIENTIFIC MISSION REPORT

Host Scientist / Institution:

- Jarmo Koistinen, Finnish Meteorological Institute, Helsinki, Finland
- Matti Leskinen, University of Helsinki, Helsinki, Finland

Visiting Scientist / Institution:

- Sevgi Zübeyde Gürbüz, TOBB University of Economics and Technology, Ankara, Turkey

Research Visit Period: 3 April – 9 April 2016

Introduction

The main goal of this joint work is to classification algoritms for dual-pol weather radar data, especially the discrimination of insects, birds, clutter, and hydrometeor returns. An important aspect of these algorithms is also the degree to which they may be generalized for radars located in drastically different climates and geographies. Thus, our goal was to examine dual-pol weather radar data from Finland, Turkey, and eventually the UK as part of this STSM and follow-on collaboration.

In preparation for this STSM, the timing of bird migrations through İstanbul and on down to Hatay was investigation through consultation with a Turkish biologist, Mr. Tansu Tuncalı. Based upon his recommendations, weather radar data was requested from the Turkish Meteorological Service for the days of March 22, March 26-28, March 30, and April 1-5, 2015. These dates were chose as times when bird migration was expected but no significant precitipation was recorded. Data was obtained for both a single-pol radar located at Çatalca (Figure 1) on the European side of İstanbul as well as a dual-pol radar in Hatay, southern Turkey (Figure 2). These locations were viewed as critical because of the migrations that are know to occur over the Bosphorus Straits and later down through Hatay moving south over Israel.

(a)

(b)

(c)

Figure 1. Geographic location of İstanbul / Çatalca Radar (41°20'28"N 28°21'24"E).

Figure 2. Geographic location of Hatay Radar (36.3180 N and 35.7881 E).

As can be seen from these maps, the Hatay radar is especially in a challenging location, facing potential sea clutter to the west and mountains to the east. Thus, one of the key objectives of the STSM was to assess whether or nor the Hatay radar could be used for any algorithm validation studies of dual-pol algorithms.

If bird migration could be at least visually observed through manual examination of the data, then this could be used to compare and validate algorithms. In particular, Adriaan Dokter's bird algorithm could be tested on the data and results compared with that of pixel based naive Bayesian and fuzzy logic classification algorithms. Potentially algorithms could also be tested on radar data obtained from the UK via collaboration with Phil Stephanian.

Further biological work could also be potentially accomplished by comparisons with the results given by dual-pol radars in Israel, with potential collaboration envisioned with Nir Sapir in this regard.

Work Description

DAY 1 – 4 APRIL 2016

- Met with FMI team; Jarmo, Matti, Seppo, and Jani
- Seppo initiated process of converting and plotting single and dual-pol data to HDF5
- Discussed data quality issues with Jarmo and Seppo
- Attended seminar given by Jarmo and Terhi (Makinen) on dual-pol classification algorithm and on the mathematics behind FMI's newly developed algorithm OPT

DAY 2 – 5 APRIL 2016

- Began examination of converted and plotted single and dual-pol data taken on 27 March 2015 with Jarmo, Matti, and Eren
- Discussed possibility of getting support and collaboration with Nir Sapir to see how Hatay radar results would correlate with Israel radar results
- Email conversation initiated with Nir Sapir on the subject of collaborations
- Data conversion process completed
- Plotting process on-going (Python)
- Jani initiated running naive Bayesian algorithm on converted HDF5 Hatay data

DAY 3 – 6 APRIL 2016

- Eren began to analyze HDF5 data in MATLAB, as well as coding a MATLAB version of plotting software
- Python plotting process completed
- Jarmo examined weather reports to determine independently tentative periods where it could be expected to observe birds

DAY 4 – 7 APRIL 2016

- Jarmo's observations about Hatay data discussed
- Some issues noted with PPI plots – Seppo's code in Python and Eren's code in MATLAB tested and found to yield correct plots, thus, plotting process re-initiated and completed
- Jarmo, Matti, Sevgi and Eren continued to examine and visually detect birds and insects in single-pol and dual-pol Turkish radar data
- Visit with Matti to meet Dmitri of University of Helsinki Physics Department and see Kumpula Radar

DAY 5 – 8 APRIL 2016

- Discussed primary outcomes and conclusions of STSM
- Planned future work, Malta presentations, and suggestions for upcoming WG1 meeting
- Discussed possible journal publications and ERAD abstract submission
- Completed visual inspection of dual-pol weather radar data from Hatay
- Continued to inspect single-pol weather data from İstanbul/Çatalca

Conversion of Turkish Weather Radar Data to HDF5

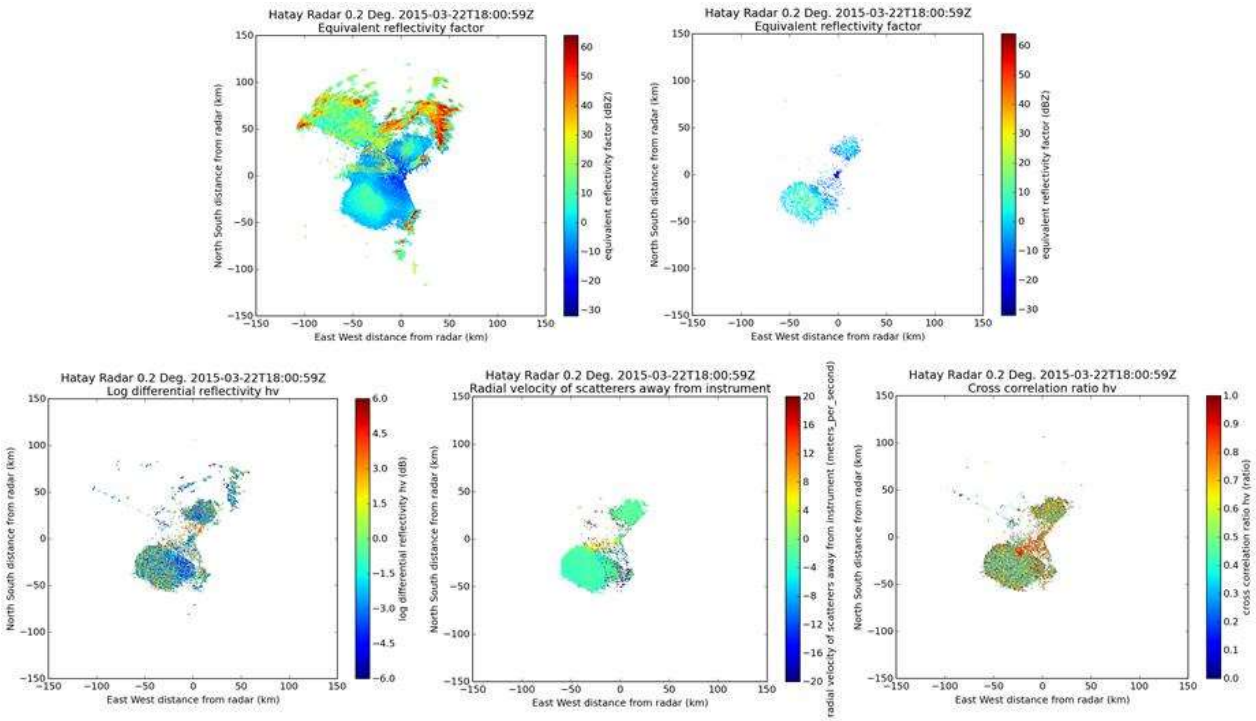
The data provided by the Turkish Meteorological Service was in IRIS format that contained multiple elevations. As a result existing Python conversion code that had been shared prior to the STSM had not been successful in converting the data format. On Day 1, Seppo from FMI wrote a modification to the Python conversion code that was successful in converting the data to the HDF5 format.

During the course of the STSM all single-pol and dual-pol data was successfully converted. However, it was noticed that the single-pol data appeared to have some "holes" in a few of the data. Due to the mountains, the dual-pol Hatay data omitted a southeast slice so that only about 270 degrees of coverage is given by the radar. Initially it was thought that these sectors were intentionally not acquired; later, since very small returns were seen close to the radar, it was thought that the returns were suppressed because of the strong clutter returns expected from the mountains.

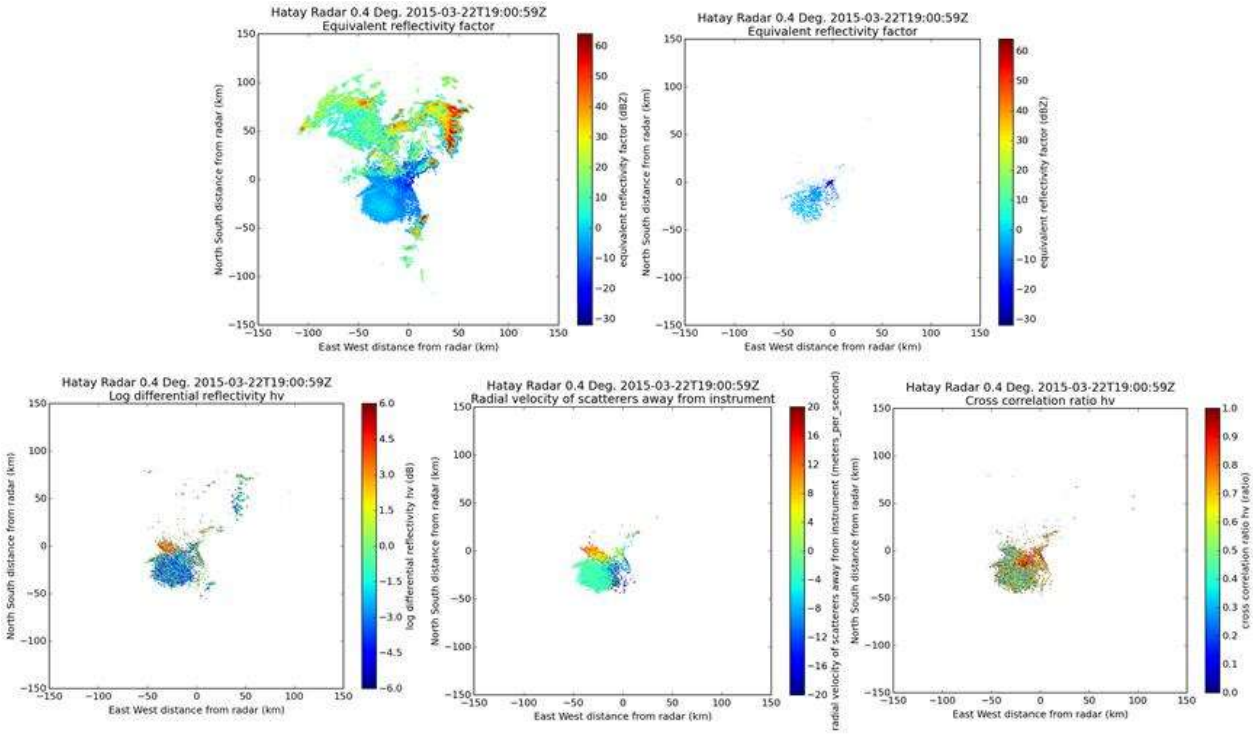
Plots and Observations of Dual-Pol Hatay Radar Data

22 March 2015 @ 18:00:59

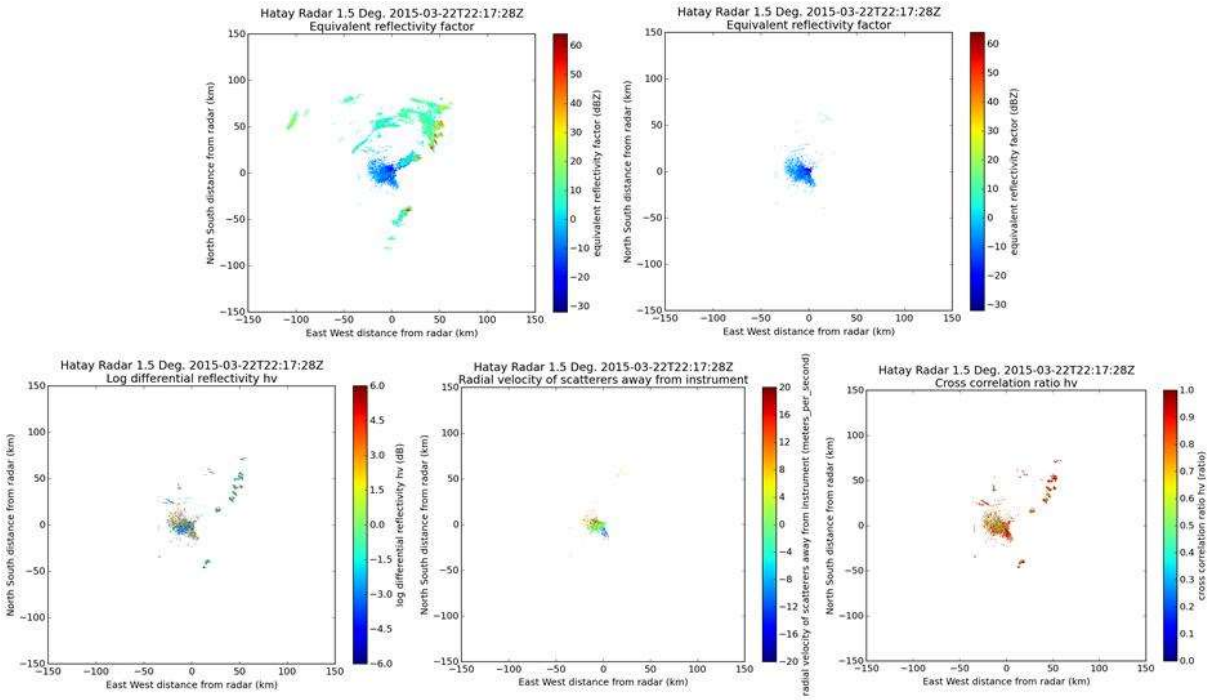
- Nocturnal migration, some insects close to radar



@ 19:00:57

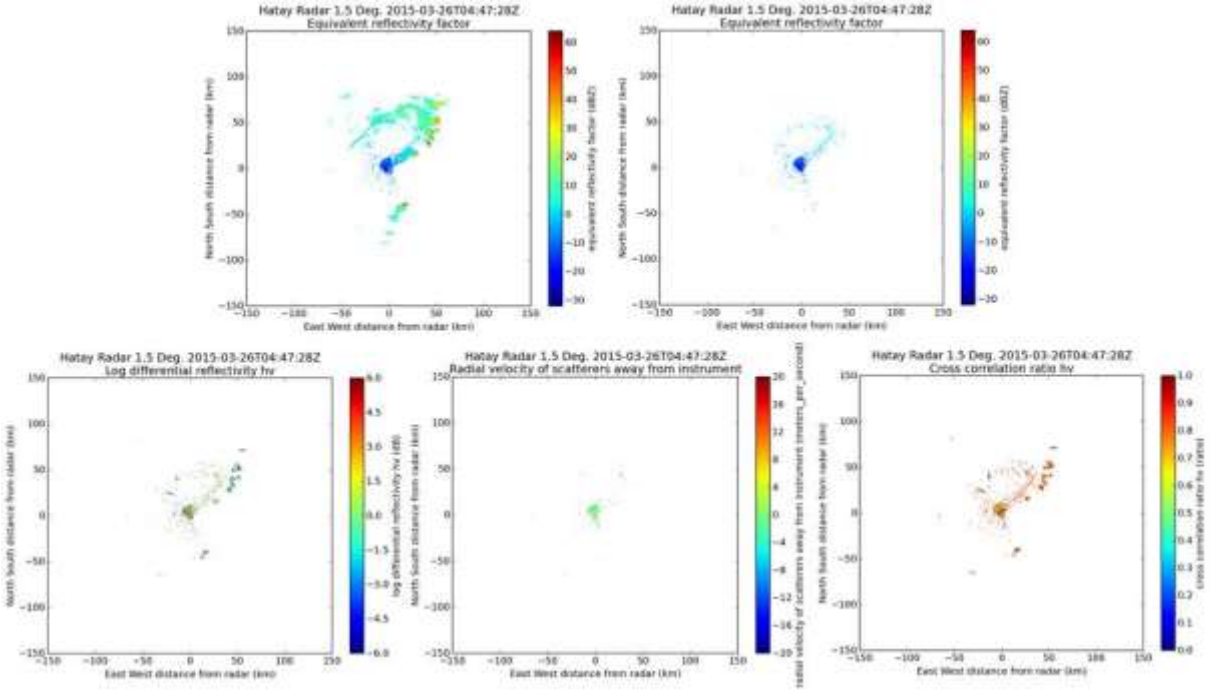


@ 22:17:27



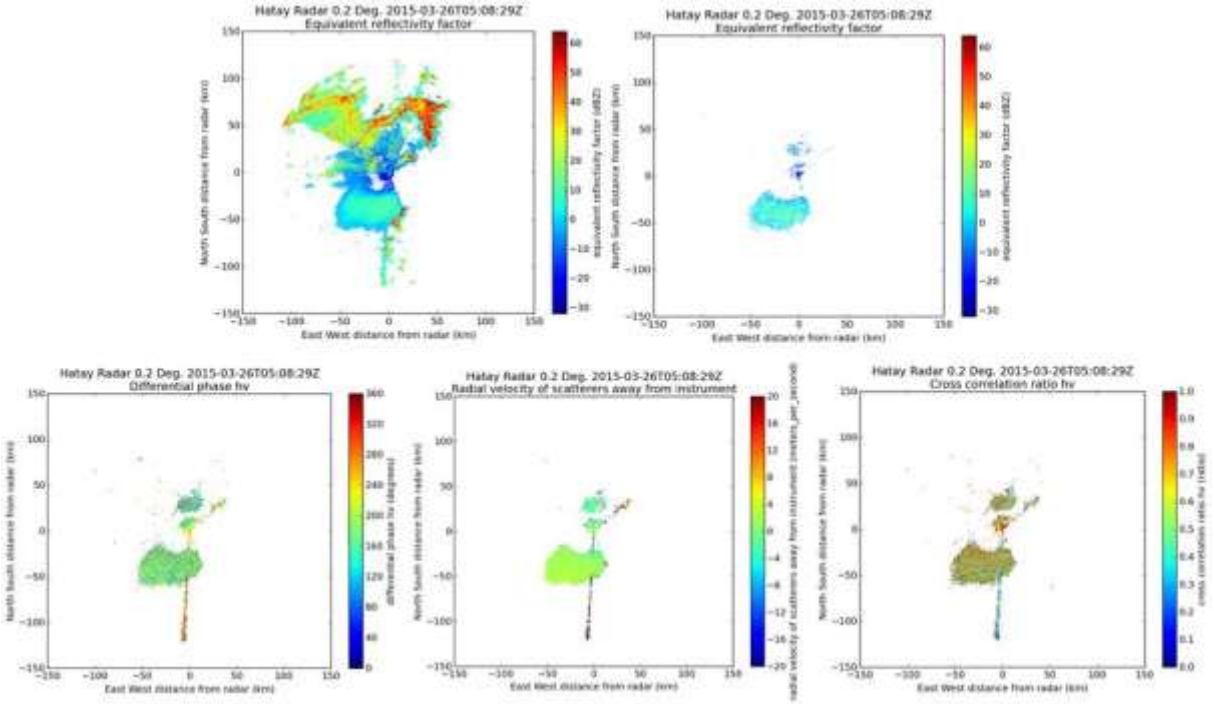
26 March 2015 @ 04:47:28

- Weak bird migration



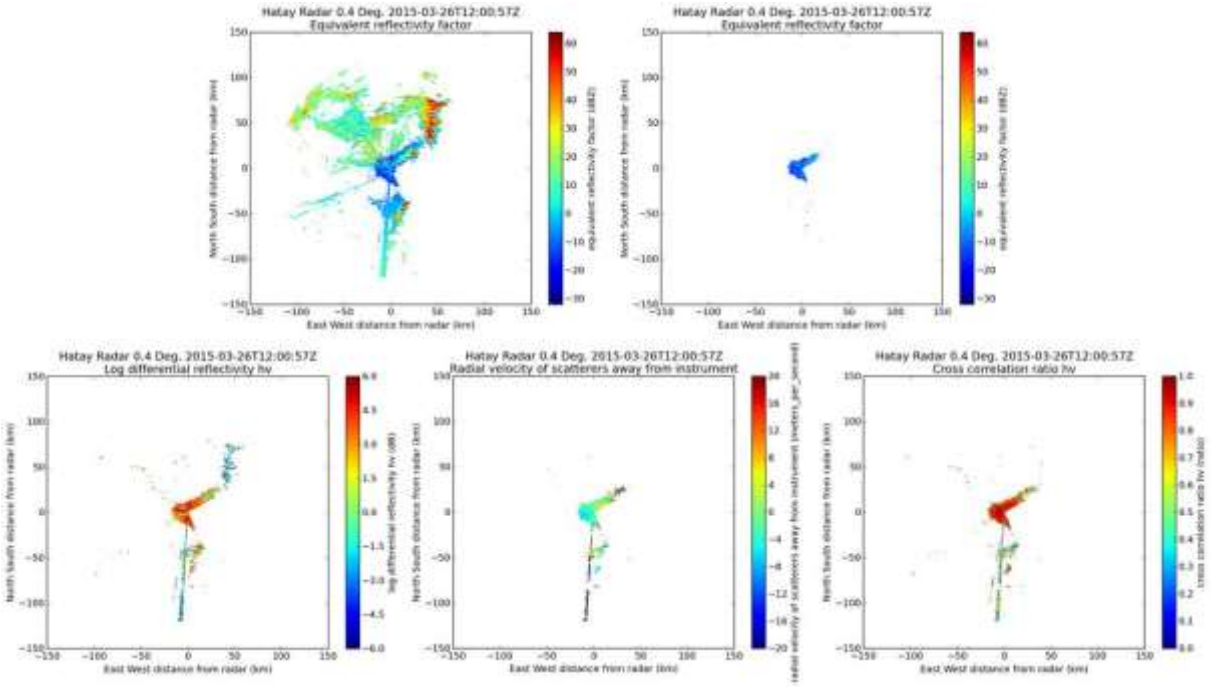
@ 05:08:29

- Weak bird migration; clutter; sun



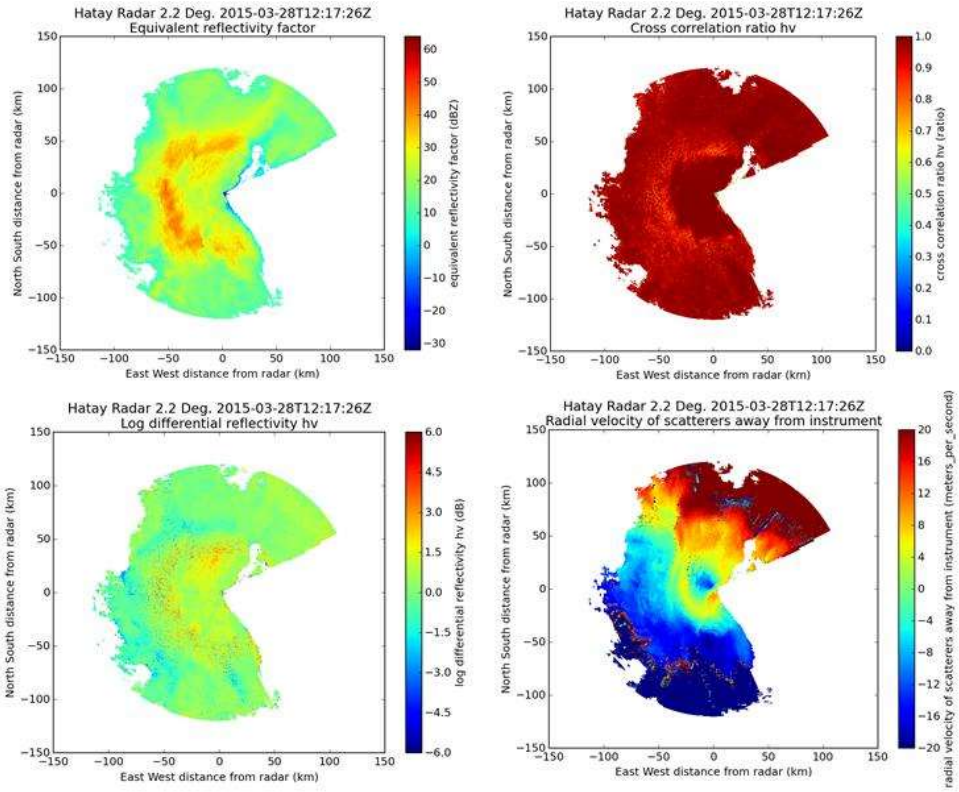
@ 12:00:57

- Insects



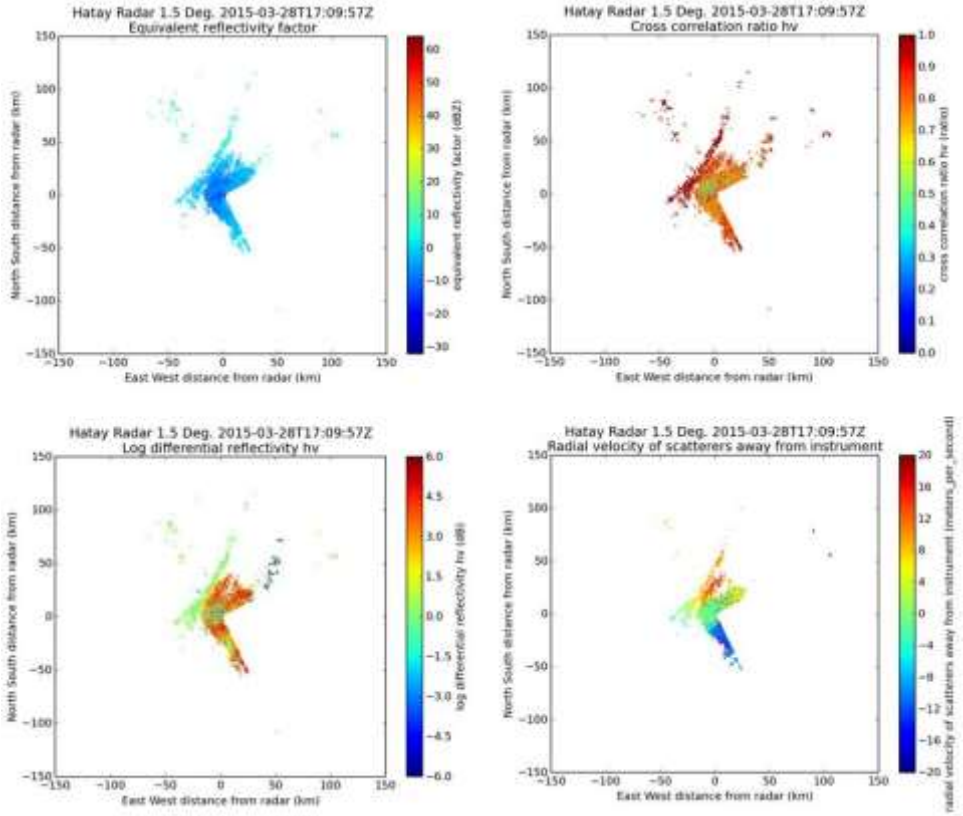
28 March 2015 @ 12:17:62

- Precipitation



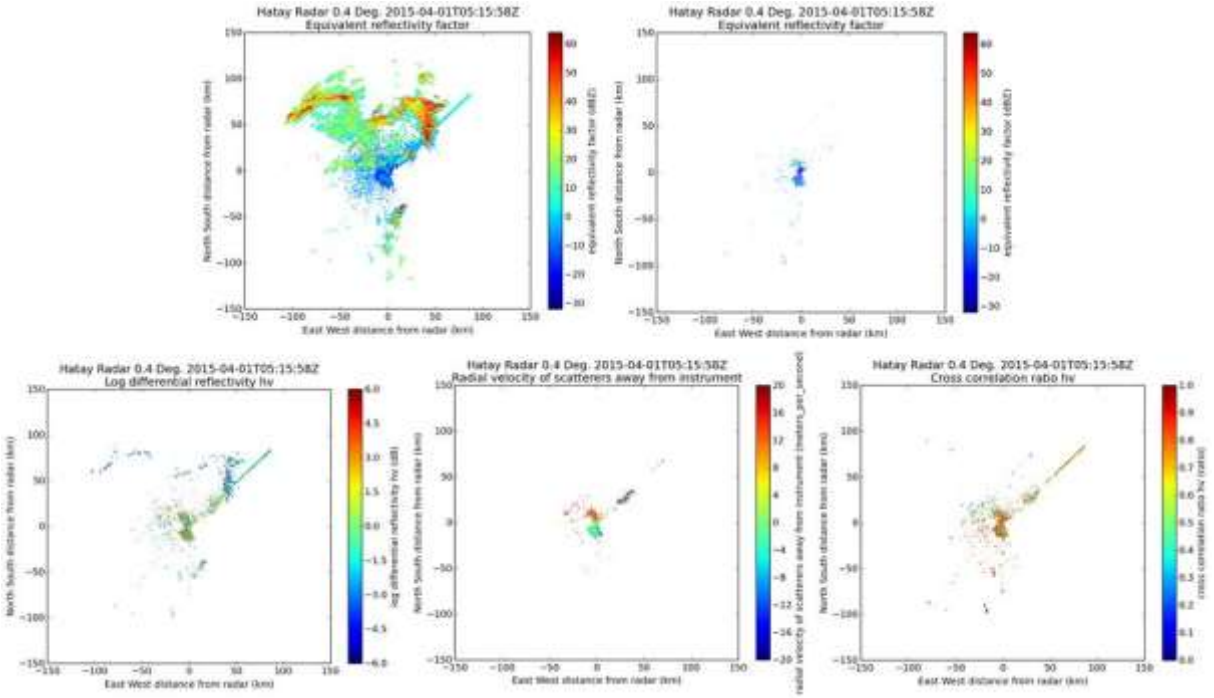
@ 17:09:57

- Precipitation and insects



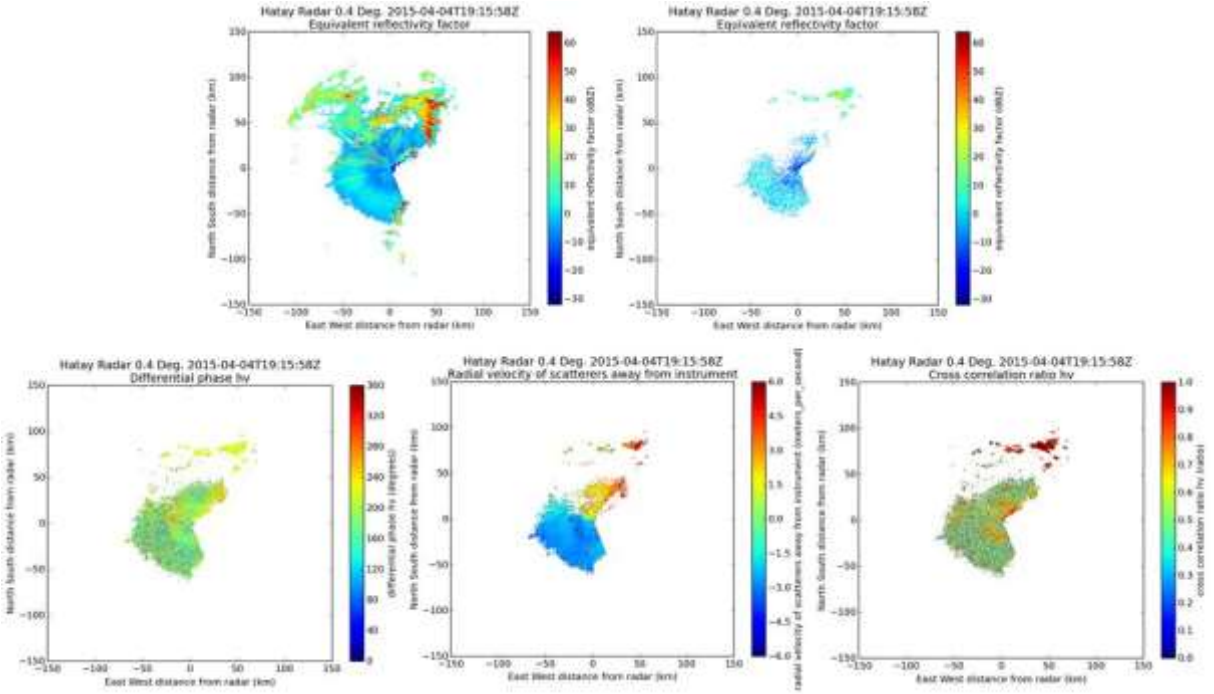
1 April 2015 @ 05:15:58

- Good morning flight of sea birds
- Flock leaving cape towards gulf shows as a plume moving northwest



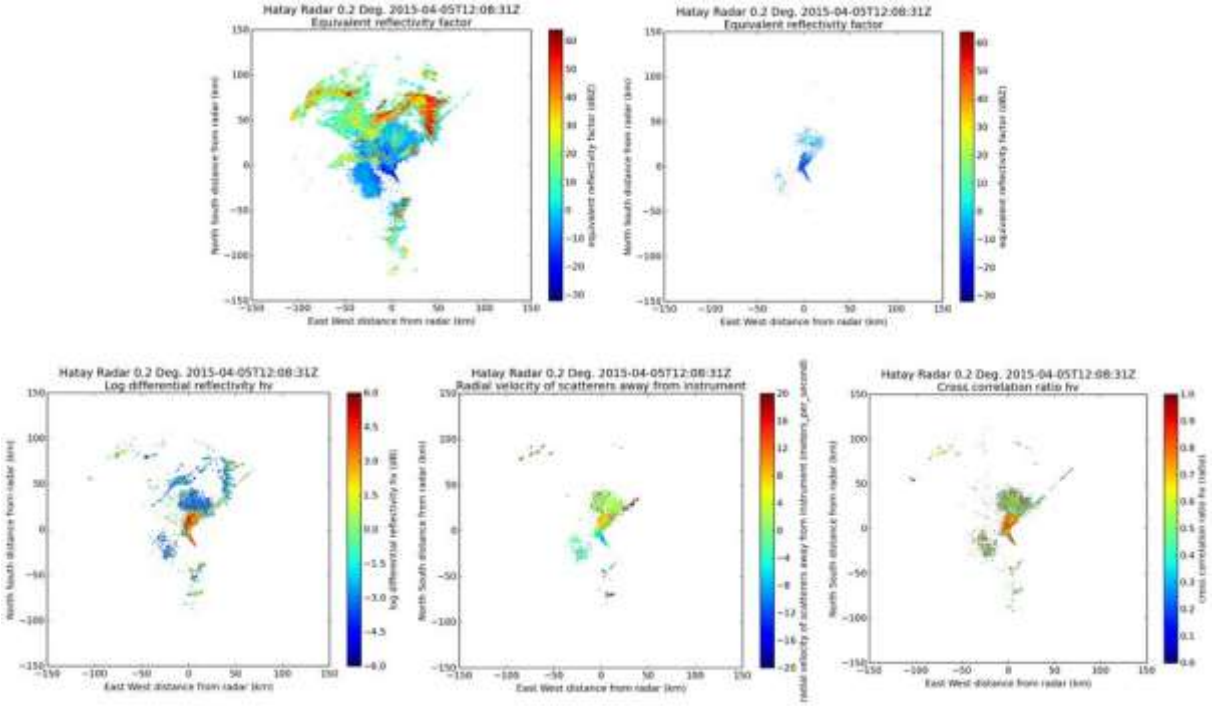
4 April 2015 @ 19:15:58

- Insect emission; scattered birds; sea clutter



5 April 2015 @ 12:08:31

- Insects; some birds



Summary and Conclusions from Observations

Content of the radar images viewed was estimated by two independent methods:

1. Examination of local weather conditions as seen from synoptic weather maps and satellite images;
2. Visual inspection of radar data.

Table 1 summarizes the classification findings of this investigation.

Table 1. Suggested good migration periods at Hatay.

Date in 2015	Approx. clock time (UTC)	Phenomenon	Radar data inspection
22 March	18-24	Nocturnal migration	18 utc: birds at relatively low altitudes, insects very close to radar (a little) 19 utc: birds closer to coast, flying NW (leaving Domuz Burnu or Akinci Burnu) 22 utc: number of birds much less, more to NW from the radar, more insects but still only a very shallow layer
23 March	05	Morning migration	no data
25 March	18	Nocturnal migration	no data
26 March	05	Morning migration	Weak migration after 5 utc (possibly some large flocks sparsely), moderate before 5 utc sea clutter, ground clutter, the sun
26 March	12	Insect migration, soaring migration	Rather good case of insects
28 March	12-18	Rainfall	1200 Precipitation 1700 Sea clutter; insects; and a narrow band of precipitation
31 March	05	Morning migration	no data
1 April	05	Morning migration	Good morning flight of sea birds and plume of land birds from cape towards the gulf
4 April	18-24	Nocturnal migration	19 utc: insect emission from the cape to NNE, scattered birds blended with uniform sea clutter
5 April	05	Morning migration	Plume of birds and frontal departure from the coast
5 April	12	Insect migration, soaring migration	Insects northwards along the coast and over the bay; band of insects (?) over the sea; some birds

Furthermore, several important comments and observations were made relating to the data:

- It seems that second trip weather echoes are coherent, thereby indicating that the radar is a klystron system – this suspicion needs to be confirmed. An important consequence is that the naïve Bayesian classification rules of magnetron systems should be checked and adjusted, if needed, for the Klystron systems. Probably such an adjustment is needed only for the class ‘second trip echo’.

- The images display only the first Nyquist interval of the unambiguous range of Doppler velocity (V) that is ± 6 m/s if the PYART software is used (a bug). The higher order intervals should be recovered from the data and de-aliased before the Vertical Profile of Birds (VPB) algorithm (Dokter et al., 2011) can be used.

    - It was later found that this affect was due to the plotting software, not the data. Code was updated in both Python and MATLAB.

- The lowest elevation angles of 0.0-0.7 (and even higher) degrees contain regularly significant areas of sea clutter or ground clutter as well as second trip echoes (of precipitation and ground clutter) that establish a challenging environment for the testing of bird and insect algorithms. The implication is that angles of 1-1.5 degrees and higher seem to be better.

- The radar scans at the lowest angles contain a 90-degrees wide complete beam blockage sector towards ESE. This may reduce the skill of the VPB algorithm in cases of less intensive migration.

- Why the Hatay RHOHV with insects is so high, higher than in Finland – roundish insects? Implication: Hydroclass may fail in separating precipitation and non-meteorological echoes. On the other hand high RHOHV together with high ZDR may help in diagnosing insects.

Overall comments:

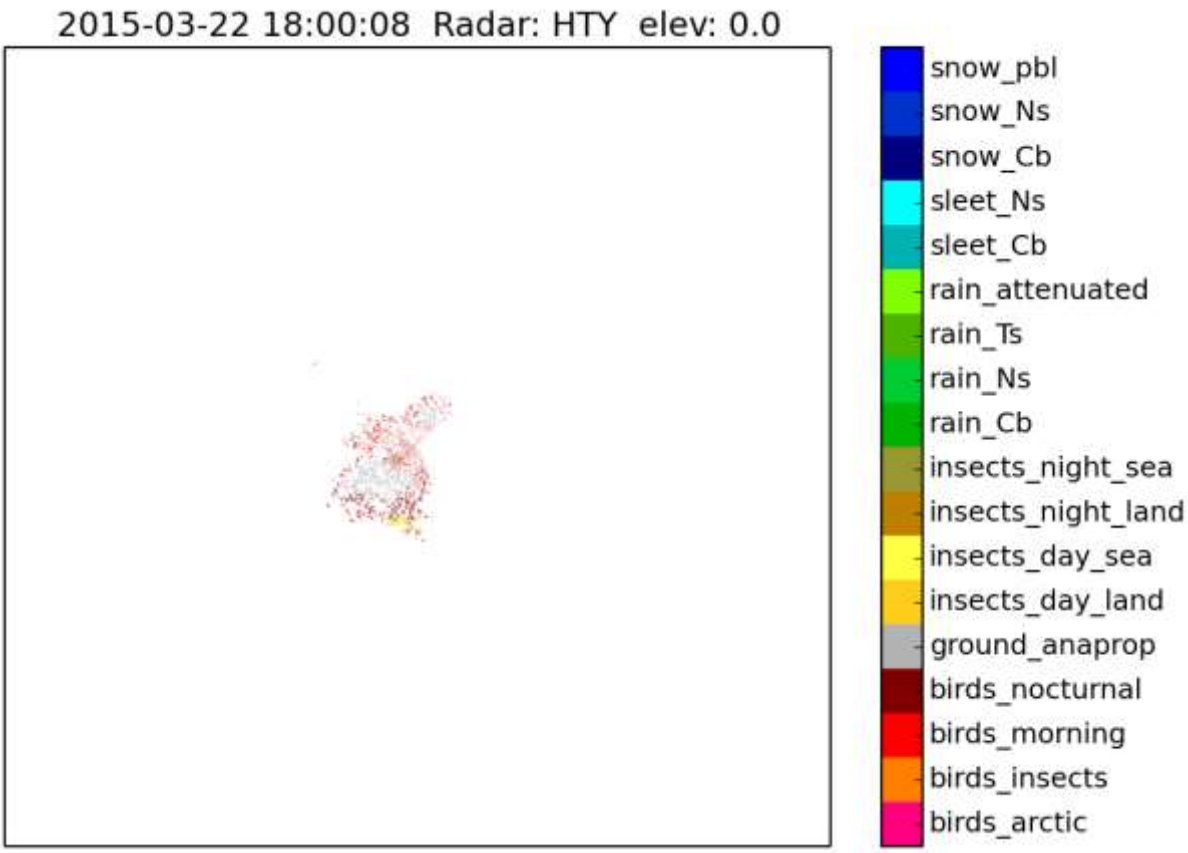
- Çatalca seems to fit better for the testing of VPB as sea and ground clutter is much less present than at Hatay.

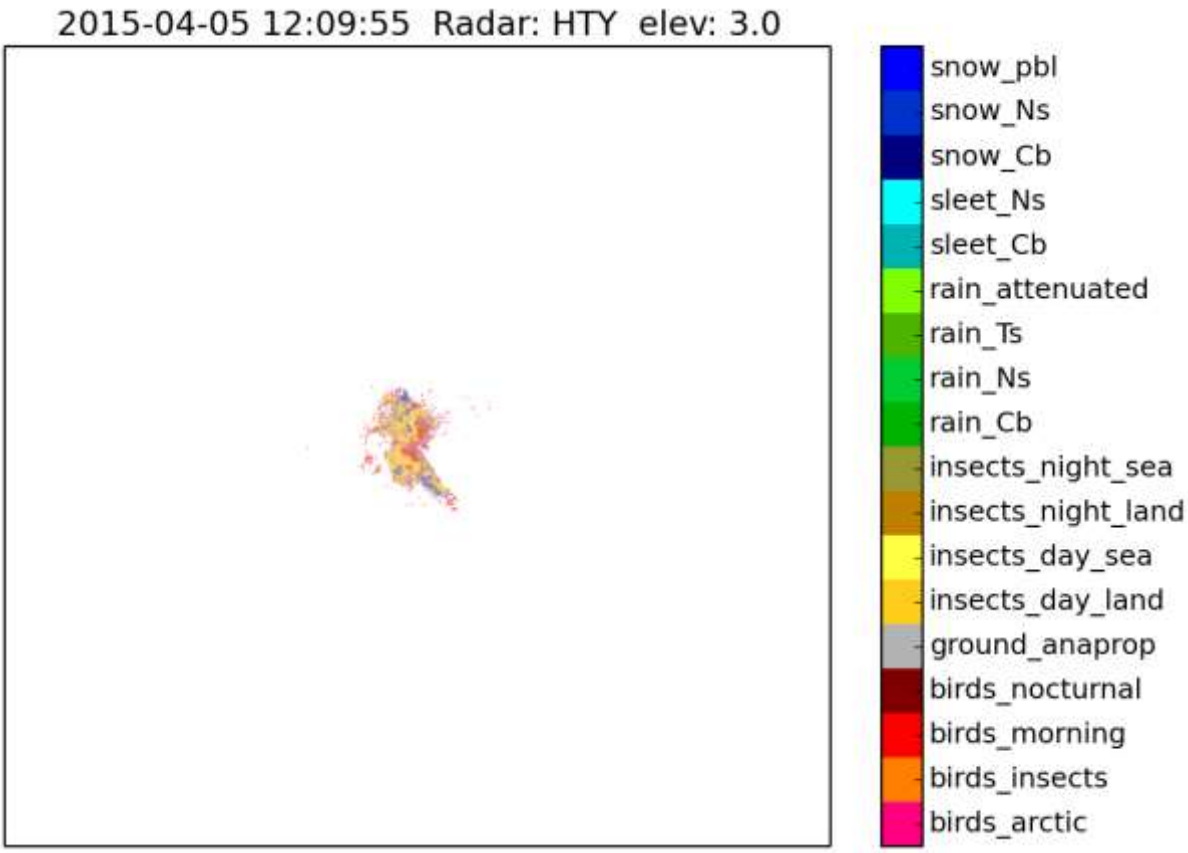
- It should be asked from the biological community (Tansu, Nir etc.) which time periods are the best at both radars for detecting nocturnal passerine migration and soaring migration of birds as well as insect migration.

Preliminary Implementation of Finnish Naive Bayesian Classifier

During the STSM the rough version of the Finnish Naive Bayesian classifier was tested on the Hatay Dual-Pol data. Note that the classes as well as rules were devised according to Finnish data; but we were curious about what we would get with no tweaking when applied on a different data set, such as the Turkish data.

Example results are shown in the figures below. Happily the results primarily did show presence of birds and insects, but in a few cases the algorithm incorrectly thought that there was snow, something that would not be expected at that time of year in Hatay. So clearly some adjustments are needed.


2015-03-22 18:00:08 Radar: HTY elev: 0.0
snow_pbl
snow_Ns
snow_Cb
sleet_Ns
sleet_Cb
rain_attenuated
rain_Ts
rain_Ns
rain_Cb
insects_night_sea
insects_night_land
insects_day_sea
insects_day_land
ground_anaprop
birds_nocturnal
birds_morning
birds_insects
birds_arctic


2015-04-05 12:09:55 Radar: HTY elev: 3.0
snow_pbl
snow_Ns
snow_Cb
sleet_Ns
sleet_Cb
rain_attenuated
rain_Ts
rain_Ns
rain_Cb
insects_night_sea
insects_night_land
insects_day_sea
insects_day_land
ground_anaprop
birds_nocturnal
birds_morning
birds_insects
birds_arctic

Future Plans

Resolution of Issues Involving Data:

- Investigation of why RhoHV for insects seems to be so high (0.8-0.9) in Hatay data.
    - Typically to get high RhoHV with insects the shape should be roughly spherical. But since most bugs are elongated, even a slight shift in direction would case for misalignments resulting in a lower RhoHV, such as 0.6 to 0.7.
    - Because RhoHV in the data is so high, the Finnish naive Bayesian algoritm has some confusion in classes. High RhoHV is more characteristic of precipitation; if ZDR is also high, this could cause confusion with ice crystals
    - One possible solution could be finding the melting layer, and if ZDR is high but location is below melting layer then it is not cold and more likely insects
    - May need to use temperature as a guide of what is possible, even for hydrometeor classification
    - Another possibility is to look at SNR, but this would required discussion with Kurtuluş Özturk of the Turkish Meteorological Service about the radar settings
    - Also need to check if high RhoHV occurs consistently in just Hatay data, or if this affect is noticable in other Turkish dual-pol radars, such as the Bursa radar

Guidance for Requesting New Data:

- Bursa dual-pol radar data:
    - to be used for both RhoHV investigation and viewing migration across İstanbul to Hatay
- Hatay dual-pol radar data:
    - Observations of data show that good bird migrations can be seen in the data, especially of nocturnal bird migration. However, the current data set may not necessarily reflect the optimal time frame.
    - Would be beneficial to coordinate with Nir and learn of best observation dates based on İsraeli weather radar measurements and request new data accordingly
    - Not very active morning migration, so nocturnal and soaring migration would be focused upon

Algorithm Development:

- Finding proper texture filters
    - Terhi, Sevgi and Jarmo will discuss over email
    - Eren will try to code some filters seen in literature

- Finnish Naive Bayesian Classifier – FMI / University of Helsinki
    - Algorithm currently based upon observations in Finnish radar data; should be tweaked to give better results in Turkish data
    - Classes need to be modified and reduced. Two possibilities
        - 14 Classes
            - aircraft + ships
            - birds_arctic + birds_morning + birds_nocturnal
            - buildings + ground_anaprop

- chaff
- drizzle + snow_pbl
- emitter + sun
- insects_day_land + insects_day_sea + insects_night_land + insects_night_sea
- noise
- rain_attenuated
- rain_cb + rain_ns + rain_ts + snow_ns + snow_cb
- reflection
- sea_sausage + sea_sector
- second_preci
- sleet_cb + sleet_ns

  - Hierarchial Structure:
    - 1st separate precipitation vs. not precipitation
    - 2nd classify birds / insects / clutter / other

- Fuzz Logic Classifier – TOBB University
  - For comparison a fuzzy logic classifier will be coded by Sevgi and Eren

- Adriaan's Bird Algorithm
  - Results to be compared against results of dual-pol classification algorithms
  - Must make sure plots of the radial velocity do not contain any folding / aliasing

- Goal is to develop algorithm that does not require any external information, such as time of day or air temperature (for more information, see ENRAM discussion document "Insect Algorithm Considerations")

Dissemination Plans

- Present findings of bird and insect activity in Turkish single-pol and dual-pol radar data to the team of Kurtuluş Öztürk at the Turkish Meteorological Service

- Publication Goals:
  - ERAD Abstract:
    - Qualitative observations comparing Naive Bayesian on Finnish versus Turkish dual-pol data
  - Journal papers:
    - Algorithm paper comparing dual-pol classification results (naive Bayesian and fuzzy logic) to Adriaan's algorithm on both Finnish and Turkish data (potentially other dual-pol radars could also be added)
    - Biological paper that combines observations along the Eastern Flyway from Israel up to Finland with contributions from as many radars as possible along the route. Recruit involvement of ENRAM members in general with the goal of submission before the end of ENRAM Nir, Tansu, maybe more of ENRAM members; tracking the bird

- Idea for having WG1 meeting in Helsinki in September 2016

Acknowledgements

We would like to acknowledge the contributions and assistance of all the wonderful scientists at FMI and University of Helsinki, especially Jarmo Koistinen, Matti Leskinen, Seppo Pulkkinen, Jani Tyynelä, Terhi Mäkinen, Harri Hohti, and Dmitri Moisseev .