Update on OPERA data quality evaluation for biological studies by ENRAM in 2016-2017

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ENRAM, the European Network for Radar surveillance of Animal Movement, has evaluated the data quality of OPERA data for biological retrievals for the period 19 Sep – 9 Oct 2016. This first continental-scale radar study in Europe aims to demonstrate the potential of OPERA for providing harmonized European-wide bird movement information.

The signing of the ENRAM-OPERA data license has allowed us to recently test biological (bird migration) retrievals from 14 OPERA countries, see Figure 1 below. A major milestone is that we succeeded in extracting bird migration profiles for 58 OPERA radars in 10 countries (see Fig. 1 & 2), a major milestone relative to 6 radars tested before the start of the license.

Based on our evaluation of the data quality of these radars, we have compiled a list of main recommendations for data quality improvements, which we hope to be of use in upcoming OPERA discussions.

Main recommendations

1) Our community was informed that OPERA has recommended its delegates to start sending data as clean as possible, e.g. by applying dual-polarization filtering to reflectivity and radial velocity data. We are greatly concerned that this practice will make OPERA data useless for our user group, as such filtering will also remove all biological echoes. If delegates decide to send cleaned data, we strongly recommend (1) to **also send both the TH/TV and CCORH/CCORV fields**. (2) to not remove biological scattering from the VRADH/VRADV fields. Without these provisions OPERA data will become useless to communities interested in biological signals. We note that sending only uncorrected reflectivity (TH) has been shown to be problematic for biological studies, because biological echoes are then contaminated by ground clutter, leading to severe speed and density biases.
2) We strongly recommend each country to **send scans with both reflectivity and radial velocity data**. Biological extractions are mainly based on high-quality velocity scans, for which we also need the associated reflectivity. We found Belgium, Poland, Norway, and UK do not send simultaneously measured DBZ and VRAD , which makes these data not useable for our purposes. So if VRAD is sent, please include reflectivity data for the same scan.
3) We found ongoing issues with countries that **apply too strong meteorological filtering** that removes all or most of the biological signals, in particular Denmark, Spain, Hungary, UK, and Sweden. We require data to be **Doppler-filtered** by the radar signal processor, in order to separate non-aerial ground clutter contaminations from aerial scatters. If other filtering steps such as thresholding and post-processing are carried out on the data before international distribution to OPERA, we

recommend that **both TH/TV and CCORH/CCORV fields are sent** as well, and that biological echoes are always retained in VRADH/VRADV.

4) We found that for many countries critical **metadata was missing**. We would like to request the following metadata to become mandatory:
    1. To have **a single unique radar identifier** included in /what/source. We suggest NOD, since it includes both country and radar
    2. **Wavelength**: /how/wavelength
    3. **Nyquist velocity**: /how/NI
    4. Information on the **scan ordering in polar volumes**: /how/scan_index and /how/scan_count
    5. Information about sensitivity radar itself: /how/NEZH, /how/NEZV, and /how/LOG
    6. More clearly defined information about Doppler and clutter filter settings
5) We recommend radial velocity data to have an **unambiguous velocity interval** of $\pm$ 35 m/s or more (to cover the travelling speeds of migrating animals), with a **low occurrence of aliasing errors, also in the weak reflectivity regime of biological scatters** (i.e. -30 to 5 dBZ range at C-band). We have good experiences with unambiguous velocities extended by dual-PRF techniques. The quality of radial velocity data however is highly variable between countries. For example, the French radial velocity data, which are collected using a triple-PRT scheme, contains frequent aliasing errors in the case of biological echoes. **Extending the unambiguous velocity at the level of the radar processor is preferred over dealiasing post-processing methods**, as we have found dealiasing algorithms to often produce poor results in the inherently noisy radial velocity data of biological signals (which in the case of birds are caused by real variability in speeds and directions of individuals).
6) If any dual-pol data is exchanged, **we strongly prefer RHOHV**, because this quantity has proven extremely reliable in separating biological from meteorological signals.
7) In general we would like to encourage OPERA to continue improving the **harmonization of the data quality**, in particular algorithms used for **velocity ambiguity removal**, the **Doppler and clutter filter settings**, and the **absolute calibration** of DBZ (and future polarimetric quantities)
8) We would like to **invite more countries to sign the license agreement** between OPERA and ENRAM, which permits data exchange for scientific purposes only: Bulgaria, Cyprus (2x), Estonia, Greece, Hungary, Iceland, Ireland, Latvia, Malta, Moldova, Romania, Serbia.
9) We would like to suggest to OPERA to consider making the volume data from the European radar network available through web services that support cloud computing. Volume data from the United States' NEXRAD network is currently available on both Amazon Web Services (https://aws.amazon.com/public-datasets/nexrad/) and the Google Cloud (cloud.google.com/storage/docs/public-datasets/nexrad). Cloud computing and online data access has increased tremendously the speed and spatial and temporal scales at which data analyses are possible (see Figure 3), and in the US cloud infrastructure has greatly enhanced and increased the use of radar data in meteorology and ecology alike. Making radar data available on cloud infrastructure has benefits for many research fields, as it fuels research into improving the quality of weather radar products, and into the understanding of continental-scale weather systems. NEXRAD data is currently

hosted by large internet companies at no cost for the data provider (NOAA), and we encourage OPERA to seek the interest of such internet companies to host OPERA data as well. The following recent publication discusses the details on NOAA's Big Data Partnership: Ansari, S., S. Del Greco, E. Kearns, O. Brown, S. Wilkins, M. Ramamurthy, J. Weber, R. May, J. Sundwall, J. Layton, A. Gold, A. Pasch, and V. Lakshmanan, 0: Unlocking the potential of NEXRAD data through NOAA's Big Data Partnership. *Bull. Amer. Meteor. Soc.,* **0**, https://doi.org/10.1175/BAMS-D-16-0021.1

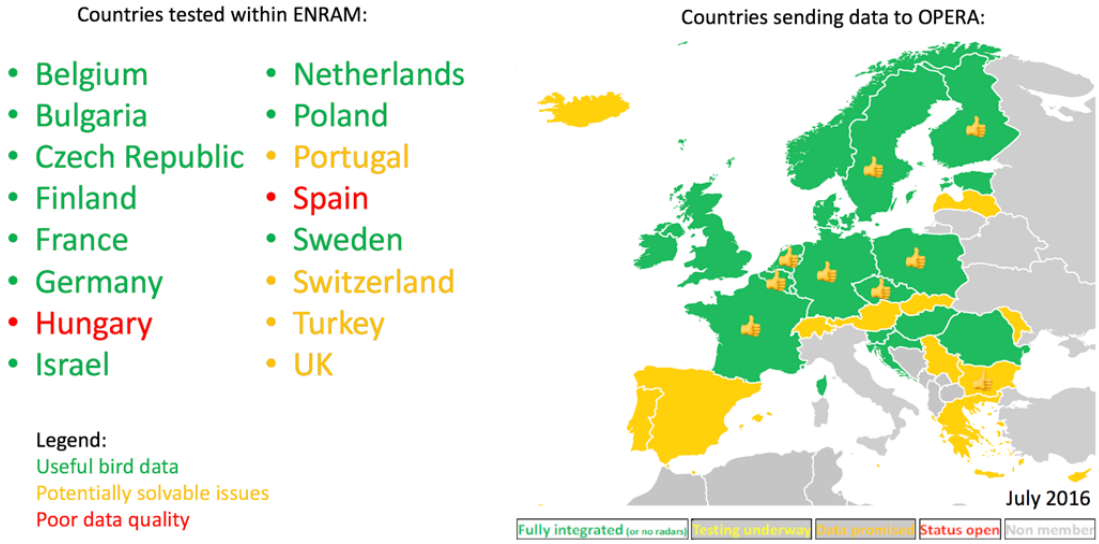

Figure 1: Countries for which useful biological information was extracted after signing the ENRAM-OPERA data exchange license. Green countries on the map send both DBZ and VRAD data. Israel and Turkey are not OPERA members, but were tested within ENRAM.

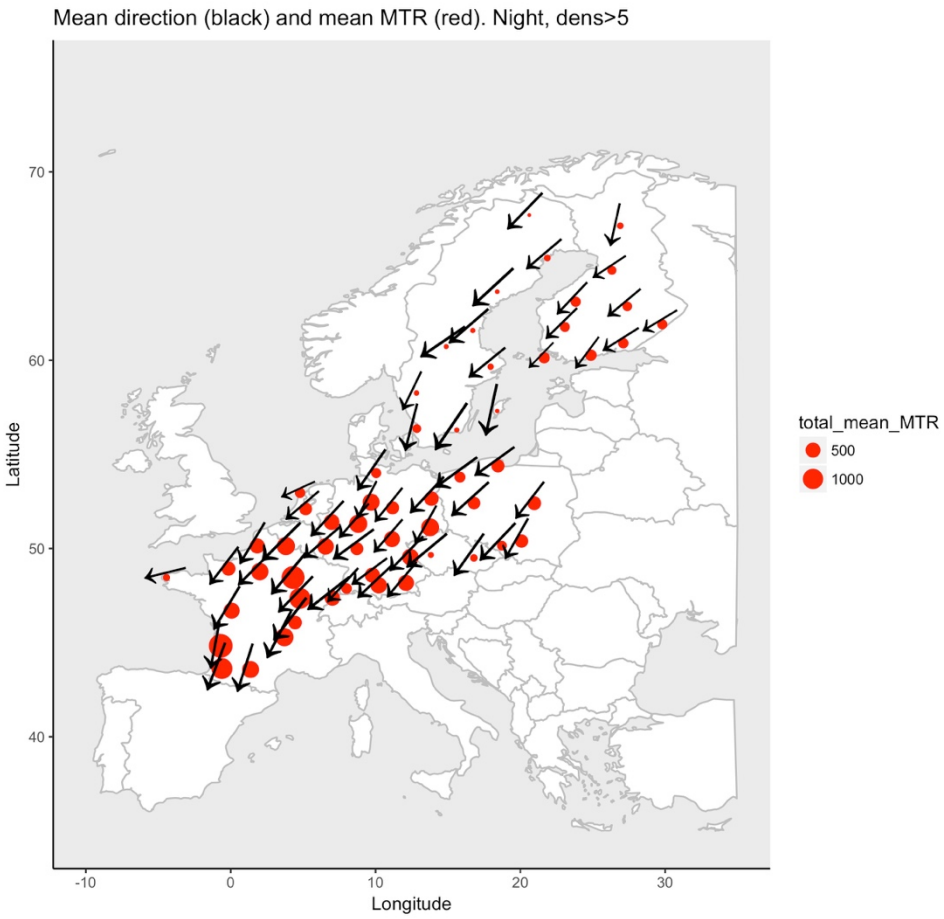

Figure 2: Mean migration direction (black arrows) and mean migration traffic rate (size of red dots, in birds/km/h) at all the available OPERA sites for the period 19 Sep – 9 Oct 2016.

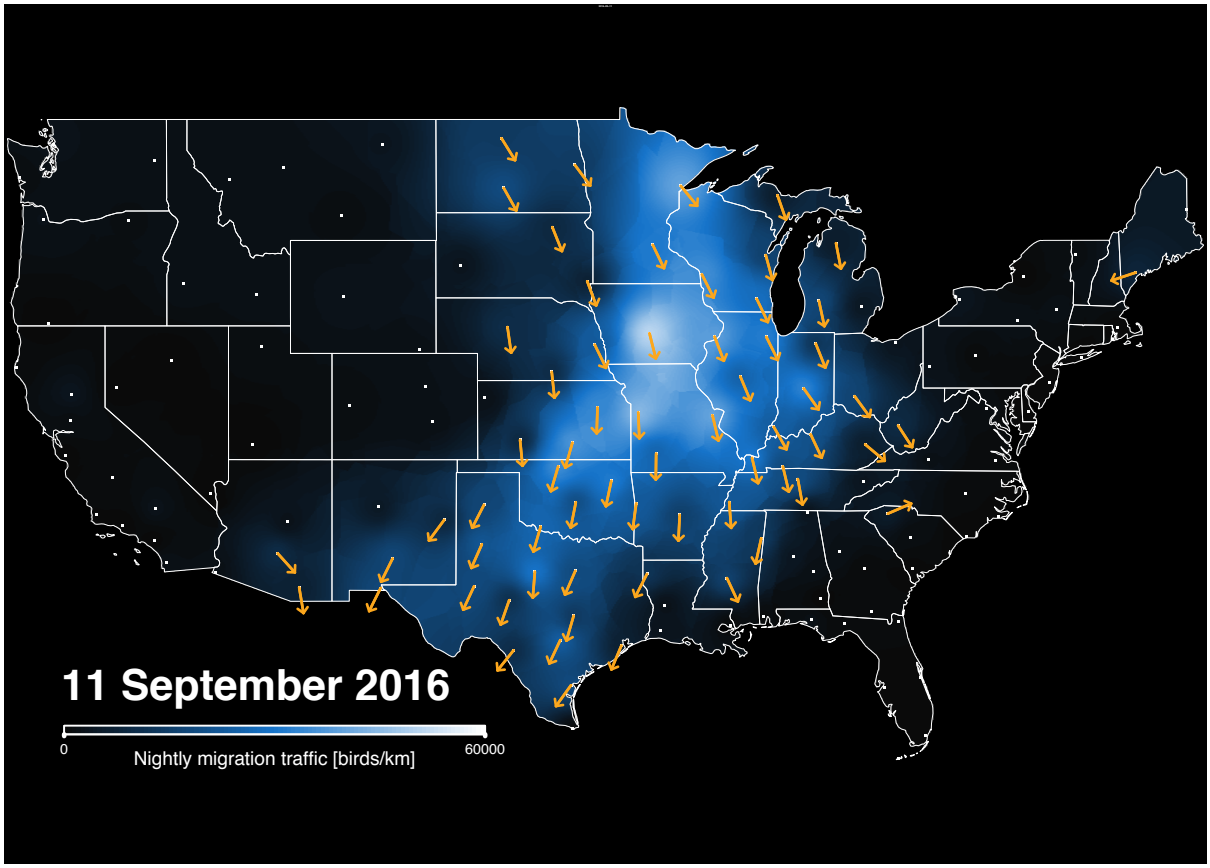

Figure 3: Using cloud computing on AWS, continental-scale migration could be extracted for the full NEXRAD network for multiple years. This figure shows a snapshot for a single night (11 Sep 2016), showing migration traffic (blue) and mean migration direction (arrows) (image courtesy: Cornell Lab of Ornithology).