Elena Saltikoff and FMI team, 30 September 2016.

Cost benefit of dualpol exchange

Executive summary

Members have acquired dual polarization radars mainly to improve the quality of the rainfall estimates. The new product which would have most appeal to end users would be a European-wide hail map. Making full use of the new methods on European level, especially in a network where only part of the radars are dual polarization, requires research and development.

If we want to perform the quality control centrally, sending all raw data to Odyssey requires 320% of the present bandwidth (after planned radar upgrades by members by 2020). The data delivered to NWP by OIFS will increase to approximately 150% of present level.

1. Introduction

In OPERA ITT, the task OD14 was

*"Extending the exchange of volume data to additional parameters such as **dual polarization parameters**. These parameters may have use in the production of the composites, but the main goal is their collection and redistribution to other members using the data centre. "*
OPERA expert team Et2015b decided that this is premature, and replaced the task with a small cost-benefits study.

2. Potential data for exchange

2.1 Measured dual-polarisation parameters

- ZDR- Differential Reflectivity
- RhoHV – Correlation Coefficient
- PhiDP – Differential Phase
- KdP Specific Differential Phase
- LDR – Linear Depolarisation Ratio
- CDR - Circular Depolarisation Ratio, suggested by A. Ryzchov's group. At the moment not used operationally anywhere in Europe.

In addition to these, DWD is collecting 53 different parameters,

2.2. New products and algorithms based on dual-polarisation measurements

- **Hydrometeor classification.** Snow/rain/wet snow/graupel/hail
- **Hail recognition.** One type of hydrometeors.
- **Attenuation correction.** Improving Z-based rainfall estimates.
- **Weather/non-meteo classification**. Polarimetric Meteorology Index PMI. The PMI describes the consistency of the data with the hypothesis of precipitation (the default preference). The estimate is obtained from the ratio of the rule strengths of the HydroClass pre-classifier class "Meteo" to the maximum rule strengths of the alternative hypotheses "Bio Scatter" and "Ground Clutter / AnomalousPropagation".

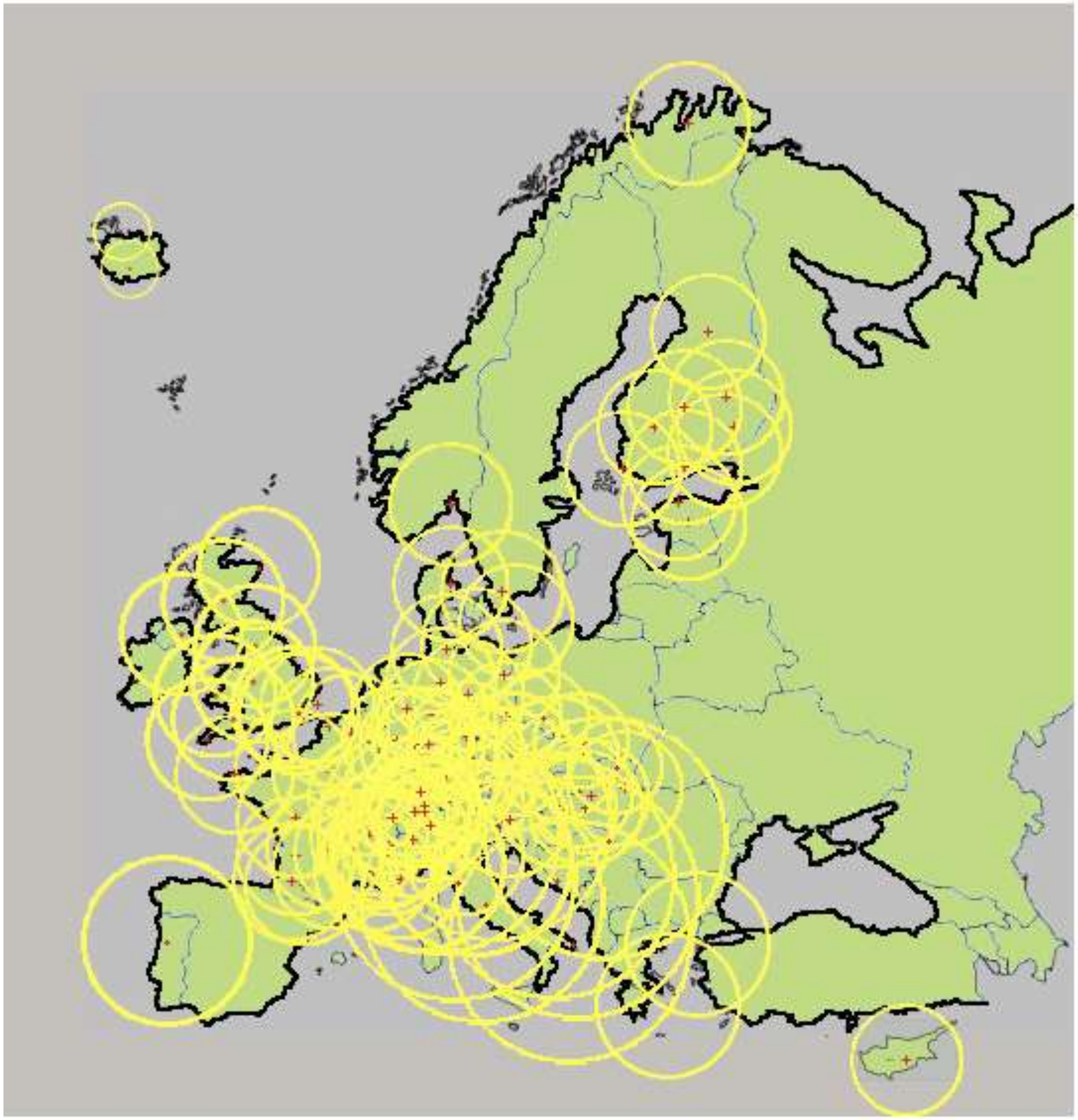
2.3 Radars and countries

At the time of writing, OPERA members have 203 radars, 106 of which are dual-polarization radars. Members have announced their plans to buy 42 more dualpol radars by 2020, either by upgrades or by new installments. This means in 2020 we would have 148 dualpol radars of the present members. The number may grow by new members joining OPERA, especially Italy which has 24 radars; however their dualpol status or plans are not known. Note that also 9 of the present members have not reported their plans.

Country	Radars	DP now	More by 2020	Notes
Austria	5	5	0	
Belgium	3	1	2	By 2020, one new dual-pol and one upgraded. Expected status in 2020 : 1 single-pol and 3 dual-pol, all C-band
Croatia	4	1	5	C-band, project for EU funding
Czech rep	2	2	0	
Cyprus	1	1	0	
Denmark	5	2	3	At the end 2017 planned to have all 5 of our radars with DP capabilities.
Estonia	2	2	0	
Finland	10	9	1	
France	30	25	5	6 X band radars not yet used for Odyssey
Germany	20	19	0	
Greece	8	2		
Hungary	4	4	1	
Iceland	4	2		
Ireland	2	0	0	Post 2020 plans to upgrade network
Latvia	1	0		
Malta	1	0		
Moldova	1	1	0	
Netherlands	2	0	2	Both radars planned to be installed in 2016
Norway	10	3	3	New radar at Hafjell is planned to be installed in 2016
Poland	8	3	1/2	New radars at "Góra Świętej Anny" and/or "Użranki"
Portugal	3	1	4	Upgrade of 2 radars in mainland and 2 new ones, one in Madeira and another one in Azores
Serbia	15	1		
Slovakia	4	4	0	
Slovenia	2	1	0	Upgrade of the old Lisca radar to dual-pol around 2024
Spain	15	0		
Sweden	12	2	10	
Switzerland	5	5	0	
UK	15	11	5	
Jersey	1	0		
Romania	8	0		

Bulgaria	2	0		
Total	**203**	**106**	**42***	Plans of 9 countries not known

Map of dualpol coverage according to database March 2016:)



3. Potential applications for exchanged data

3.1. Applications in the data centre

European hail composite. This could be either be based on national hail products or by running a hail recognition algorithm centrally. In neither cases the quality would be homogenious throughout Europe, due to differences in hardware, software and measurement practices. Some algorithms exist also for single pol radars (e.g.Valdvogel, Holleman) . They require full vertical resolution. An additional challenge for hail composite would be the timeliness: convective events develop rapidly.

End users for such product could be found among aviation and civil protection.

Attenuation correction. Task O9 in Opera4 is collecting experiences of the dualpol-base correction for attenuation by intervening precipitation, and preliminary results indicate that even though this is one of the big marketing arguments of the manufacturers, the experiences are not completely positive:

> Out of 22 members with dualpol radars, five members are using a dual-polarization based attenuation correction schema, three of them developed their own (France, Germany and Denmark), two are using one provided by the manufacturer. In addition, six members are testing a schema. Four are not using it, and seven members who have dual-polarisation radars have not reported their status..

Rainfall products (QPE). Already now some members calculate their national QPE products based on combination of dualpol and traditional ZR methods. A composite could be either based on these, or a central algorithm. It is likely to produce some seams at borders, but may be worth qualitative estimation.

Quality control of reflectivity (and velocity) data. The existing applications are applied on signal processor level and can not be executed centrally. For members who apply this already at the radars, re-application brings no added value. For radars where this is not applied, the input data does not always exist.

3.2. Applications for redistributed data

Assimilation to NWP. Even though forward operators have been published in research literature (Li and Mecikalski 2012; there are no known operational applications in Europe yet. MF some attempts of assimilating Zdr and Kdp (in AROME) have successed (unlike tests using RhoHV and Phidp observations too far away from the counterpart simulated model values). This work has been mainly done by Clotilde Augros, a PhD student. Of course even for Kdp and Zdr some problems can occur because of limited one-moment microphysic scheme but comparisons between model and observations are consistent.

Although the preliminary study by Li and Mecicalski (2012) was encouraging, they raised the question how much additional information can be retrieved from the dual-polarization observations and to what extent it can improve the NWP model forecast. It is certainly an area requiring more studies. While the strengths of dual-polarization radar observations have been conclusively shown for rain and hail hydrometeors, it is less clear how much information is provided in mixed-phase and ice-only regions. The results highlight the need for a thorough exploration of forward model sensitivities prior to performing radar data assimilation. (Posselt et al, 2015).

Note that even assimilation of dBZ and velocity data benefits of more detailed clutter cancellation, e.g. possibility to identify and remove bird echoes.

Verification of NWP. The dualpol parameters can be used to verification of NWP, especially for comparison of cloud physic schemas (Min et al, 2015)

Regional hail composites Even though the radar network of all Europe is rather heterogenious, there are areas where neighbours could benefit of each other's data. OPERA could also study the usefulness of severe weather maps using different radar-based hail detection methods and the 3D composites created in SESAR as input.

3D Snow/rain analysis As the hydrometeor classification determines for each measured pixel in 3D data whether it is snow, rain or melting snow, it is possible to determine the location of melting layer within the data. Note that this does not easily correspond to the precipitation type observed at the surface, because snow can melt below the lowest radar measurement.

3. Potential end-users

Product/User	Aviation	NWP assimilation	Verification	Nowcasting	Civil protection
Hail	YES	No known use	principally	YES	YES
Graupel	Icing ?	No known use	principally	no	Lightning ?
Improved rainfall rate*	Limited use	ECMWF, COSMO	YES	YES	YES (flooding)
3D Snow/rain**	Limited use	no	Why not	Winter weather nowcasting (?)	Perhaps for traffic
ZDR, KdP	No	Research in France	principally	No	No
RhoHV, PhiDP	No	No	no	No	No
LDR, CDR	No	no	no	no	No

*"Improved rainfall rate" summarizes the effects of dualpol-based improvements such as clutter removal, attenuation correction and potential to use KdP-based rainfall schemas for heavy rain events.

**Note that this is not telling you directly whether it snows on ground level

4. Costs associated with exchange

Bandwidth

Dual pol parameters add filesizes. A simple calculation says that between the radar and NMS central site, 4-5 times more data will be moved. How much to ODC and to OIFS, depends on applications.

Calculation is based on single pol radars sending 4 parameters (dBT, dBZ,V,W,SQI) and dual pol radar adding (ZDR,rhoHV,phiDP, KDP, HC, dBTV, dBZV) so that amount of variables is , at least, doubled. Often to benefit from RhoHV the data is changed from 8-bit to 16-bit, and then because of increase in resolution the amount of data is doubled.

In case we would send all this data to ODC now, the datastream would be 250% of the present bandwidth. Adding the planned radars as upgrades would demand 320% of the present bandwidth. We may want all this data in the ODC of we want to perform quality control centrally.

In case we want to add a hail composite in ODC, then number of products would go from 6 to 8, assuming we provide it in HDF5 and BUFR.

For OIFS, the number of parameters would go from 3 to 5 (adding ZDR and KDP), so at the moment bandwidth needs would be roughly 135% of present level, and in 2020 after planned upgrades 150% of present level

Development

Many of the dualpol algorithms applied nationally are propriertary of the software manufacturer, and can not be integrated to a 3rd party system such as ODC. Commercially the price of such software is in order of xxx.

If we apply the dualpol algorithms nationally and utilize the results centrally, new composition algorithms and new versions of the ODIM data format are needed.

5. Conclusions and recommendations

- Apply the quality improvement algorithms (attenuation, PME clutter cancellation) nationally to improve the reflectivity data. Create tags in ODIM to indicate where these have been applied.
- Include the DP parameters and results of hydrometeor class in next ODIM.
- Create 2D and 3D hail fields for ODIM.
- Develop an independent hail composite product. Discuss with end users, whether this should include all hail at any height or only the hail falling to ground. Share this product to any members who want to run it nationally or regionally. Encourage members for bilateral exchange.
- Make case studies for days of active convection to see the difference of "ZR rainrates" vs, "Dp rainrates" and the hail composites.

6. Literature references

The articles with (*) will be uploaded to OPERA wiki and EUMETNET portal.

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* Li, Xuanli and John R. Mecikalski, 2012: Impact of the Dual-Polarization Doppler Radar Data on Two Convective Storms with a Warm-Rain Radar Forward Operator. *Monthly Weather Review* 140:7, 2147-2167

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*Posselt, Derek J., Xuanli Li, Samantha A. Tushaus, John R. Mecikalski. (2015) Assimilation of Dual-Polarization Radar Observations in Mixed- and Ice-Phase Regions of Convective Storms: Information Content and Forward Model Errors. *Monthly Weather Review* 143:7, 2611-2636.

*Sun Juanzhen, Hongli Wang. (2013) WRF-ARW Variational Storm-Scale Data Assimilation: Current Capabilities and Future Developments. *Advances in Meteorology* 2013, 1-13.

*Waldvogel A. et al. (1979): Criteria for the Detection of Hail Cells. **Journal of Applied Meteorology** 18, 1521 - 1525.