11th European Conference on Severe Storms
8 to 12 May 2023

Statistical comparisons between observed and simulated Z_{DR} columns using AROME model with different microphysics schemes


Credit : Sean Ramsey

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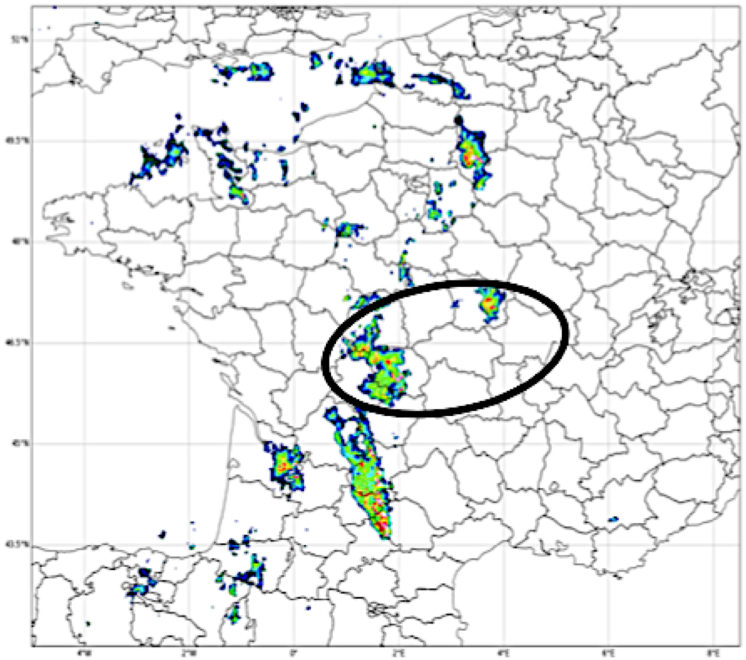
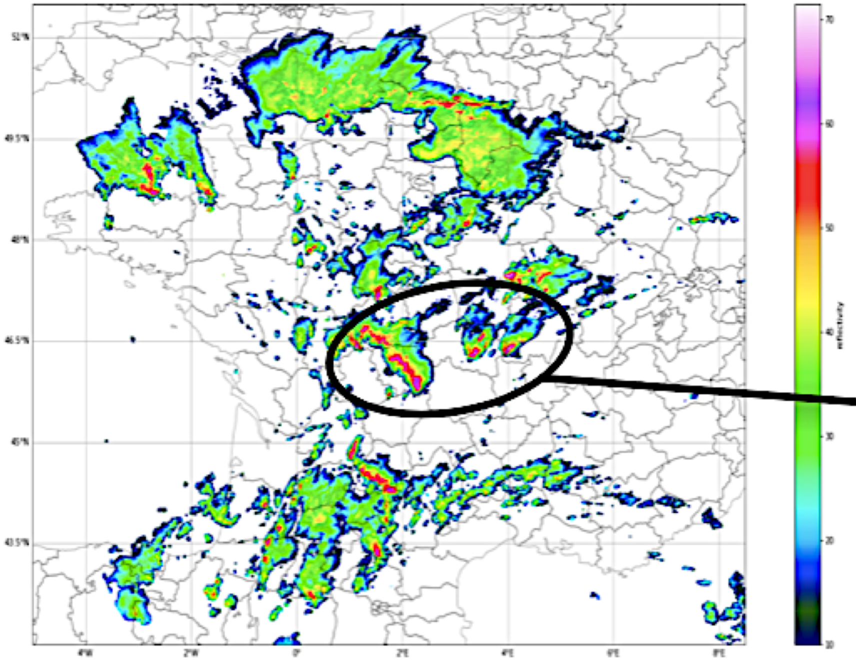
Context – PhD thesis

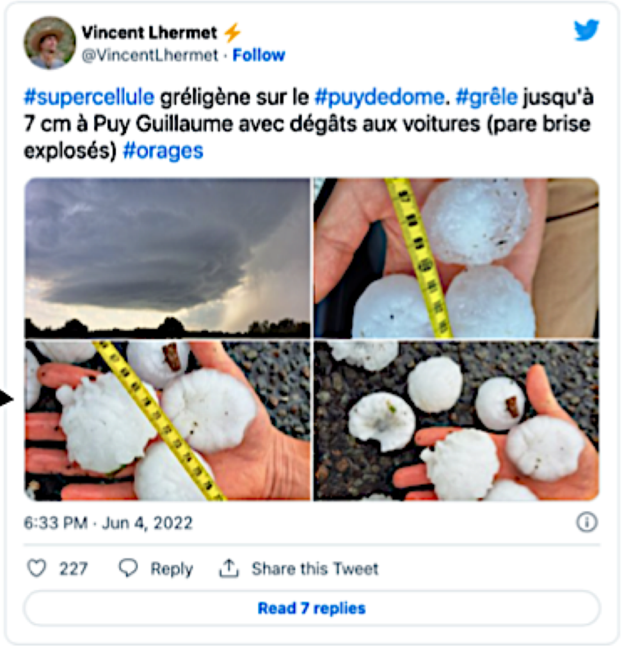
run AROME 00Z of the 04/06/2022 23 UTC



radar reflectivity observed at 23:00 UTC



June 4, 2022 tweet



Context – PhD thesis

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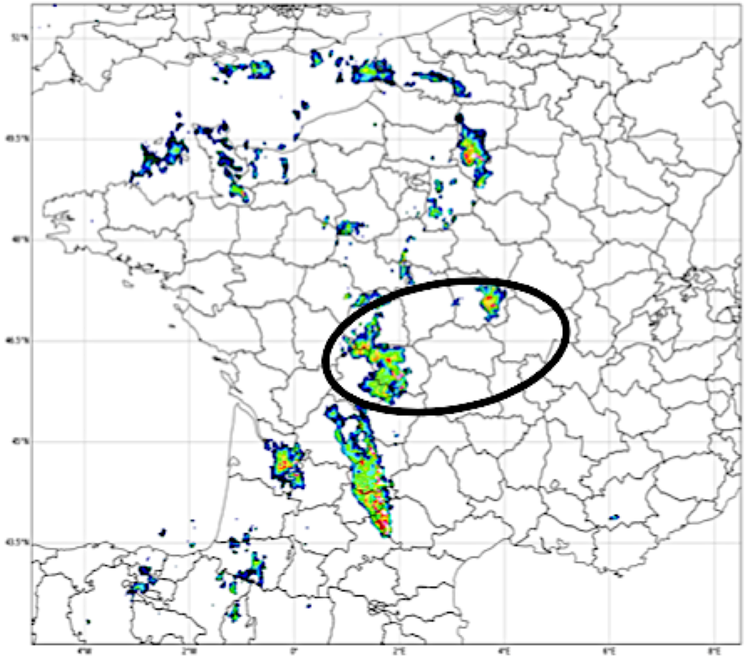

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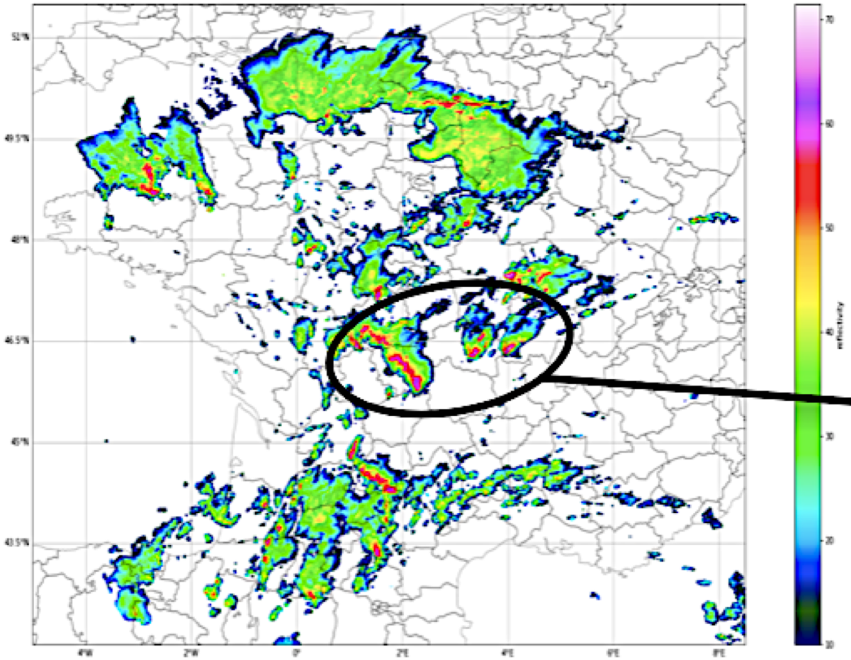
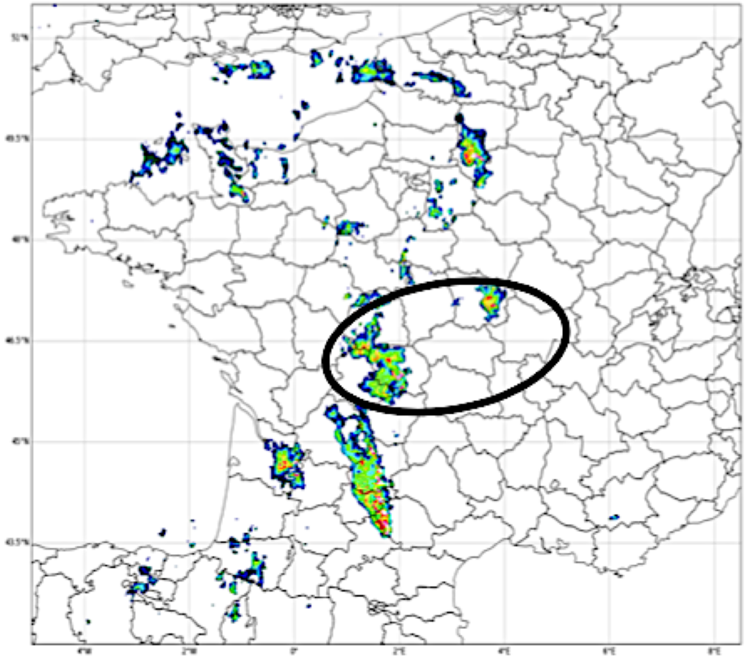


June 4, 2022 tweet

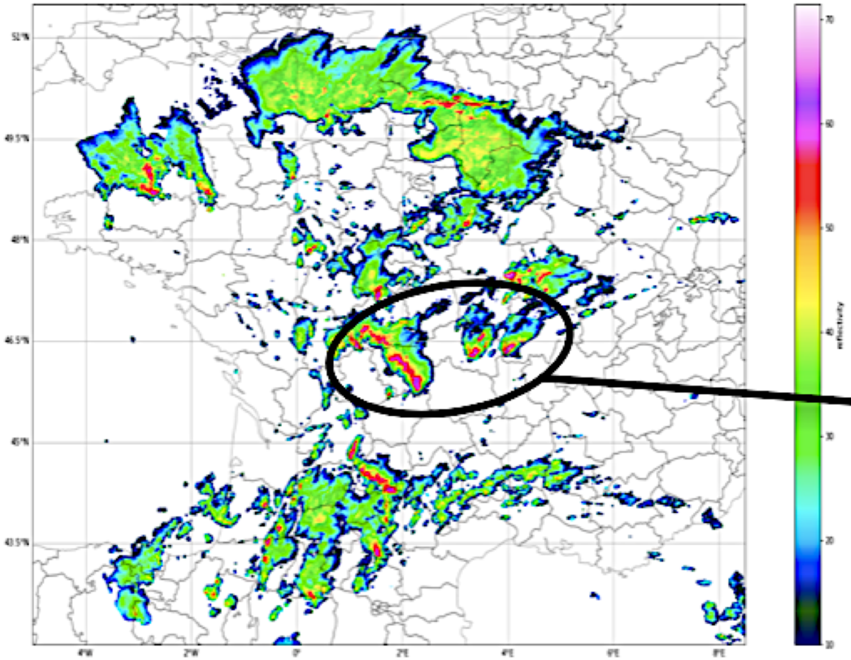
- What can we do to improve thunderstorm forecast ?
  - increase model resolution
  - use more complex microphysics schemes
  - assimilate new observations

Context – PhD thesis

AROME French operational convective scale model forecast



radar reflectivity observed at 23:00 UTC



June 4, 2022 tweet

- What can we do to improve thunderstorm forecast ?
    - increase model resolution
    - use more complex microphysics schemes
    - assimilate new observations

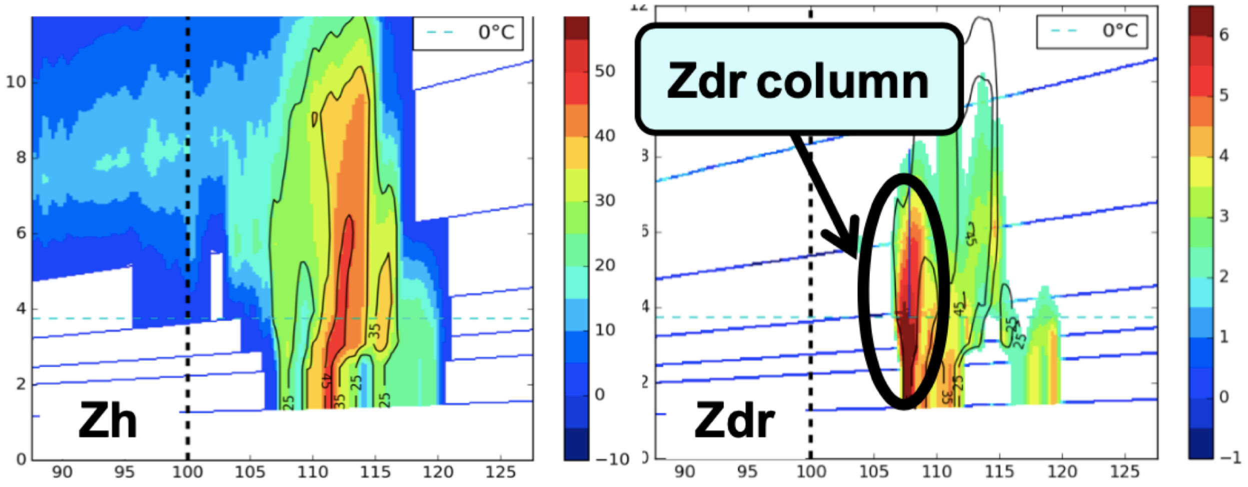
} PHD → "Preparing the assimilation of polarimetric observations to enhance thunderstorm forecasting with LIMA microphysics scheme"

Context – Polarimetric signatures and Z_{DR} columns

- Polarimetric radar observations provide very useful information about storms microphysics (*Ryzhkov et al., 2020*)

- Specific polarimetric signatures are observed in severe thunderstorms (*Kumjian and Ryzhkov, 2008; Kumjian et al., 2014; Johnson et al., 2016; Snyder et al., 2017a, b*)

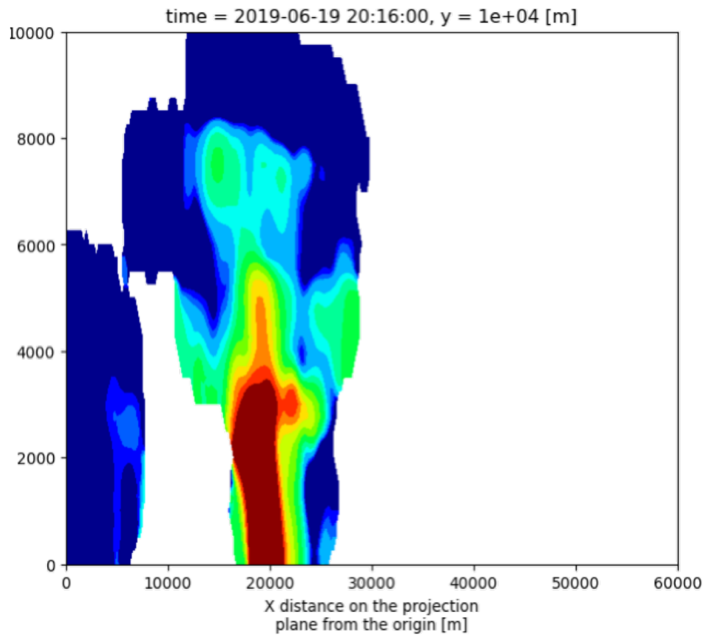
- Z_{DR} columns :
  - columns of enhanced differential reflectivity (Z_{DR} > 2 dB) above the iso 0°C
  - typical horizontal extension of 4 – 8 km
  - proxy of storm's updrafts (Snyder et al., 2015)
  - linked to storms severity (hail, strong winds) (*Kuster et al., 2019; Wilson et al., 2022)*



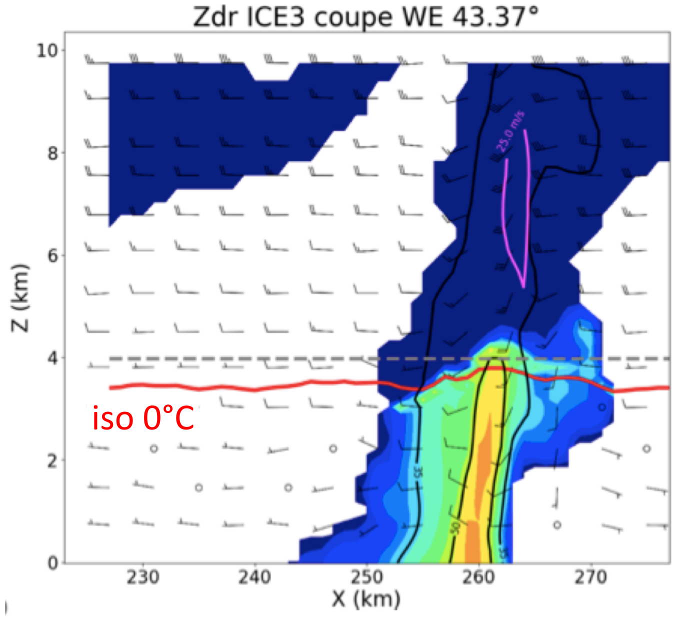
- Pre-requisite before assimilating these observations : needs good polarimetric signatures reproduction

Context – Preliminary results

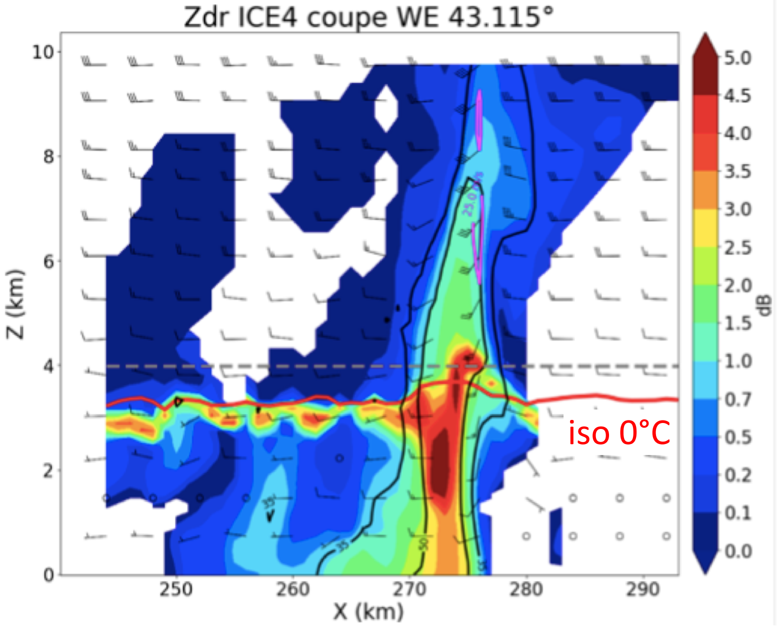
(see ERAD 2022 presentation : https://www.erad2022.ch + paper in prep.)



radar observations



Meso-NH* simulation with **ICE3**



Meso-NH* simulation with **ICE4**

ICE3 microphysics (1 moment) :

rain, snow, ice crystals, graupel

ICE4 microphysics (1 moment) :

rain, snow, ice crystals, graupel + hail

* **Meso-NH** = research model (same physic as convective fine scale model AROME)

Plan

Objectives :

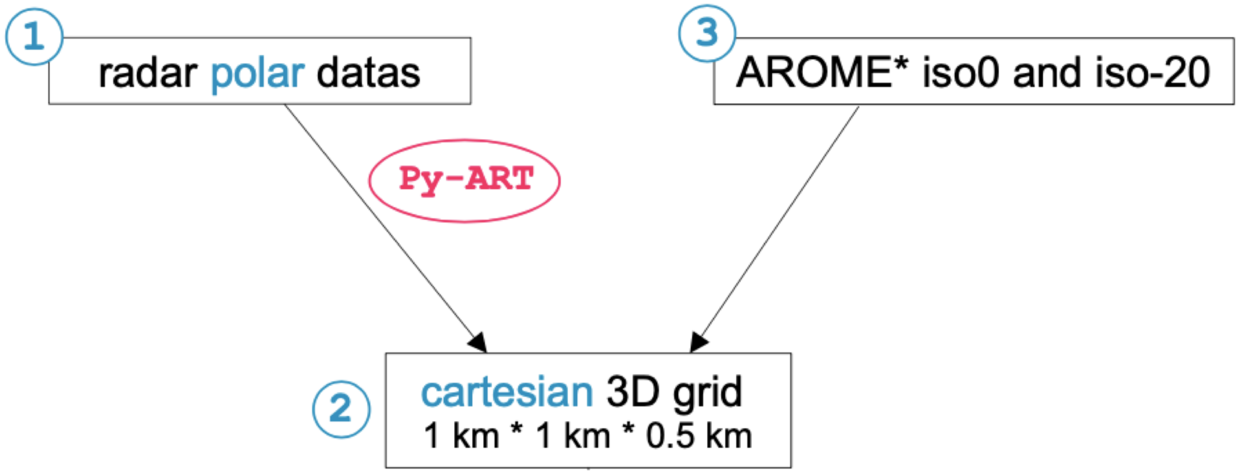
- Automated detection of Z_{DR} columns following *Snyder et al. (2015)* and *Starzec et al. (2017)*
- AROME simulations with different microphysics options + application of *Augros et al. (2016)* polarimetric radar forward operator
- Comparisons of observed and simulated columns characteristics (height, area)

In this presentation :

- ✓ Z_{DR} column depth computation method
- ✓ Qualitative comparisons
- ✓ First statistics on column height and area

Method – Z_{DR} columns depth computation

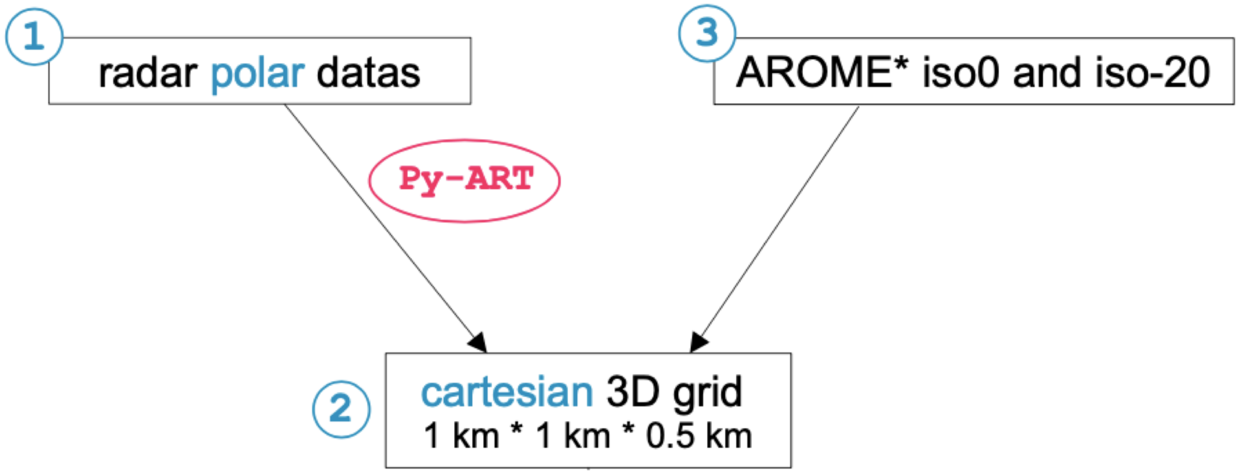
radar observations	models



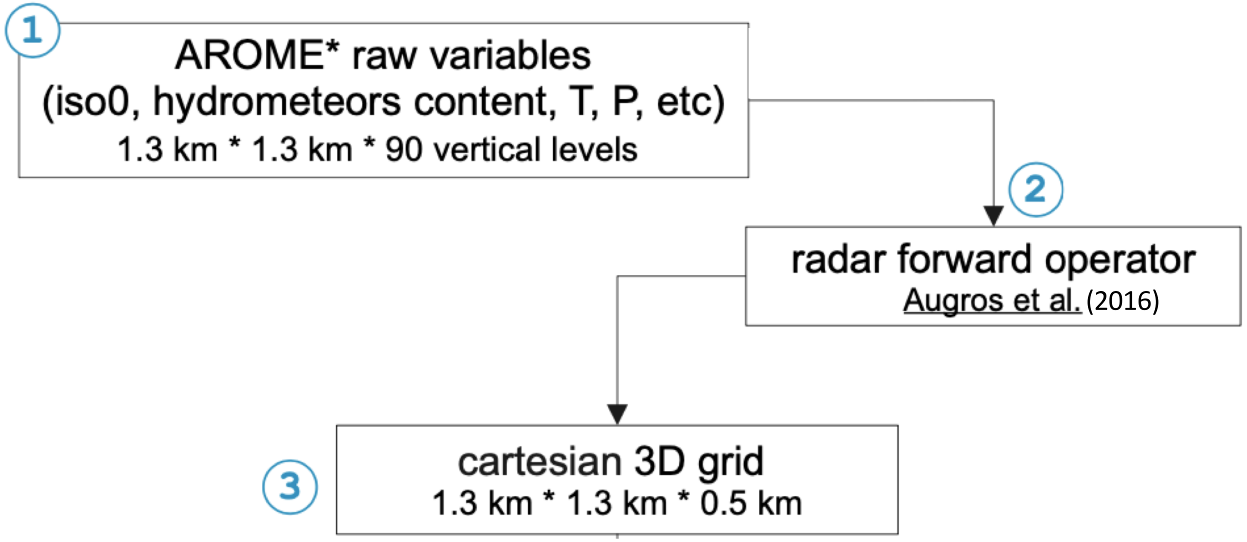
*French convective scale model

Method – Z_{DR} columns depth computation

radar observations



models



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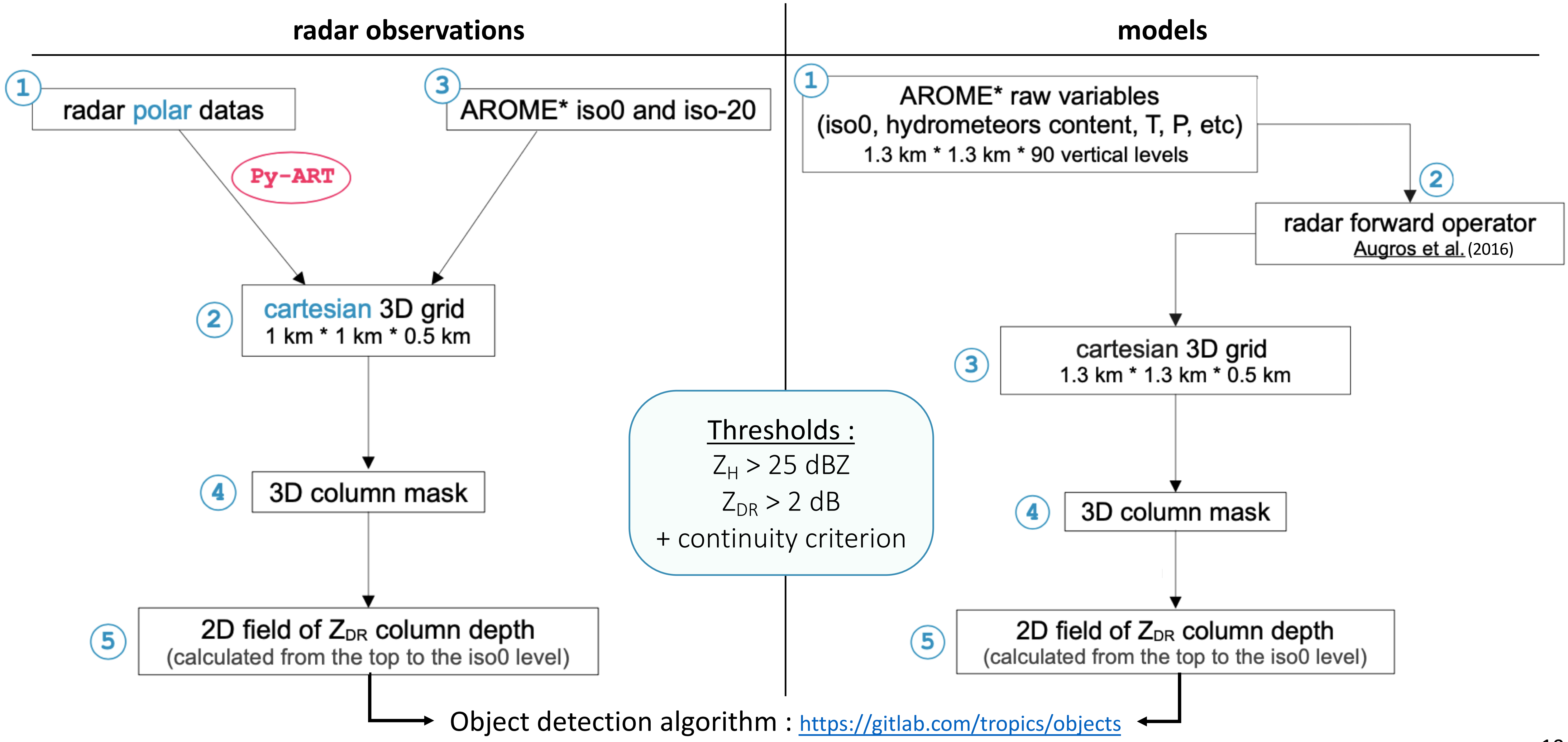
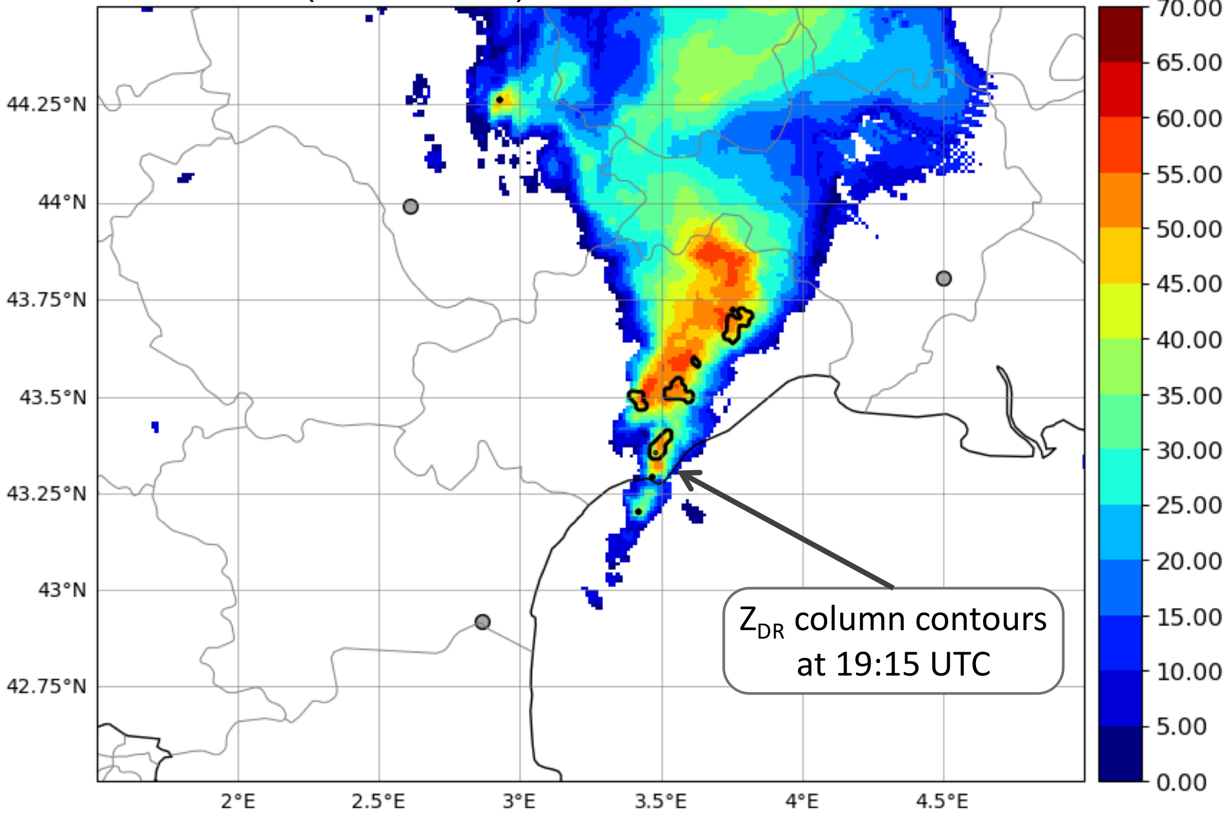
Method – Z_{DR} columns depth computation



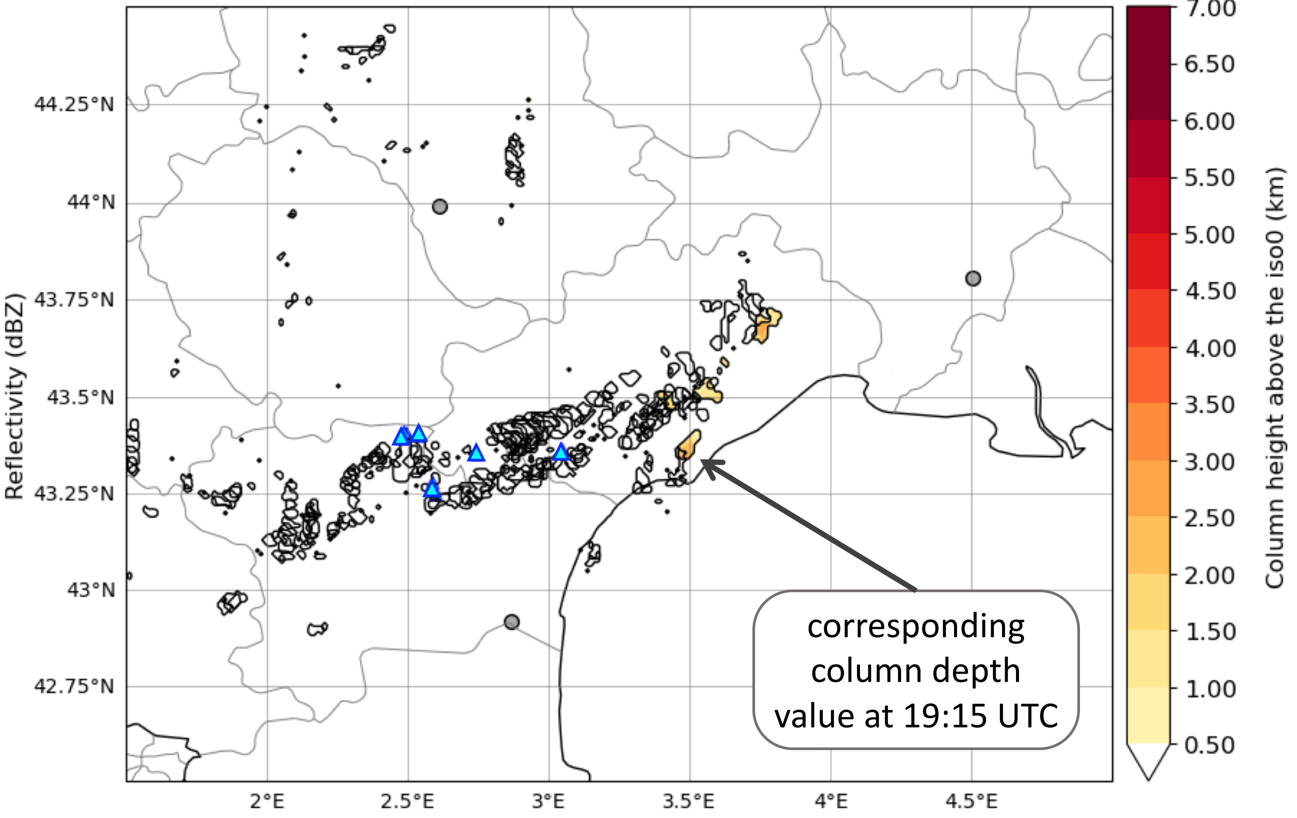
*French convective scale model

Z_{DR} columns tracks in observations

Observed horizontal reflectivity + 500 m column contours (solid black) at 19:15 UTC – 16-08-2022



Accumulated 500 m column contours (solid black) from 14:00 to 19:15 UTC + column depth value at 19:15 UTC



Legend :

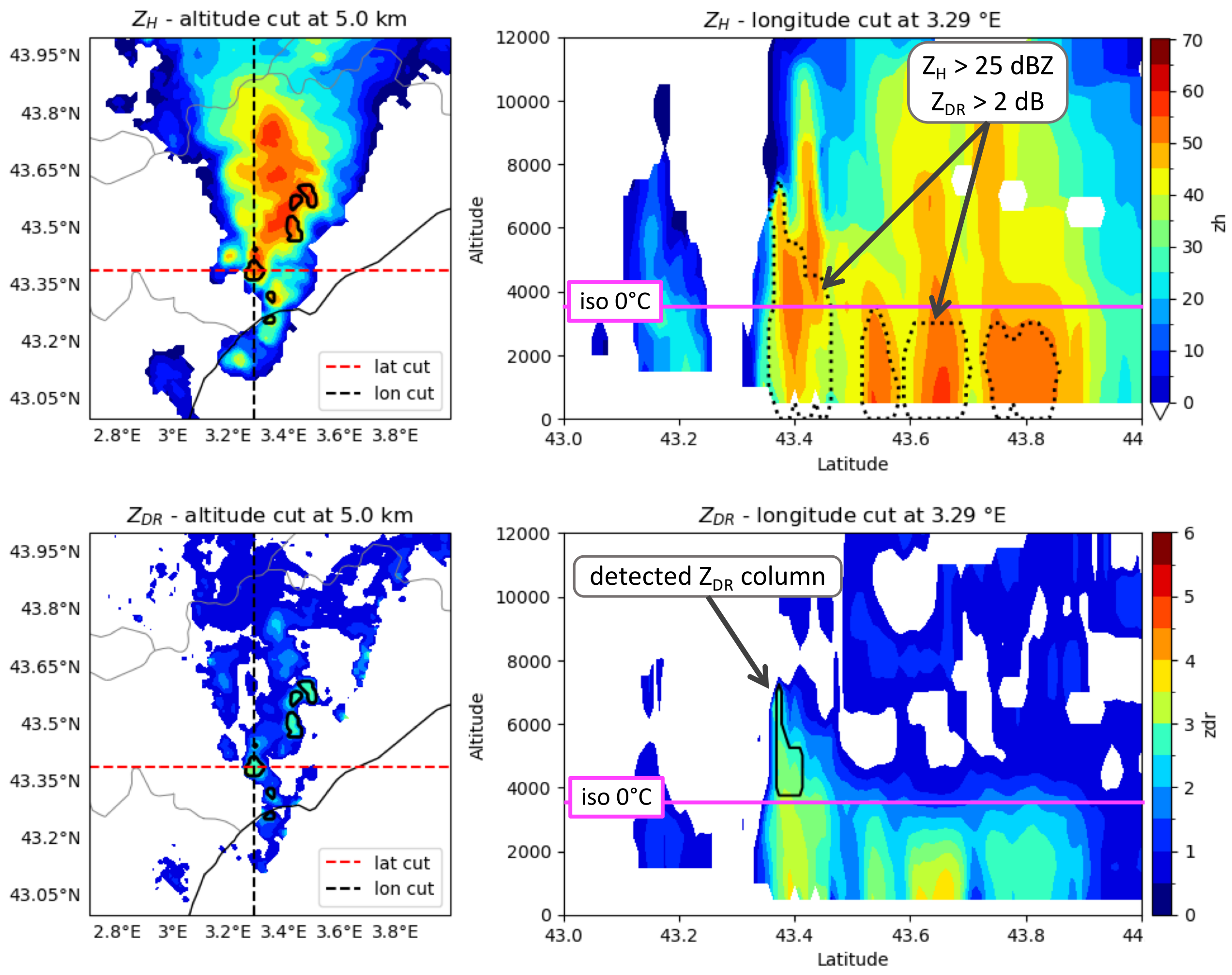
Hail locations from ESWD website : https://eswd.eu

Column contour at the corresponding timestep if filled

2022-08-16 18:40

Signature reproductibility

Interpolated radar observations



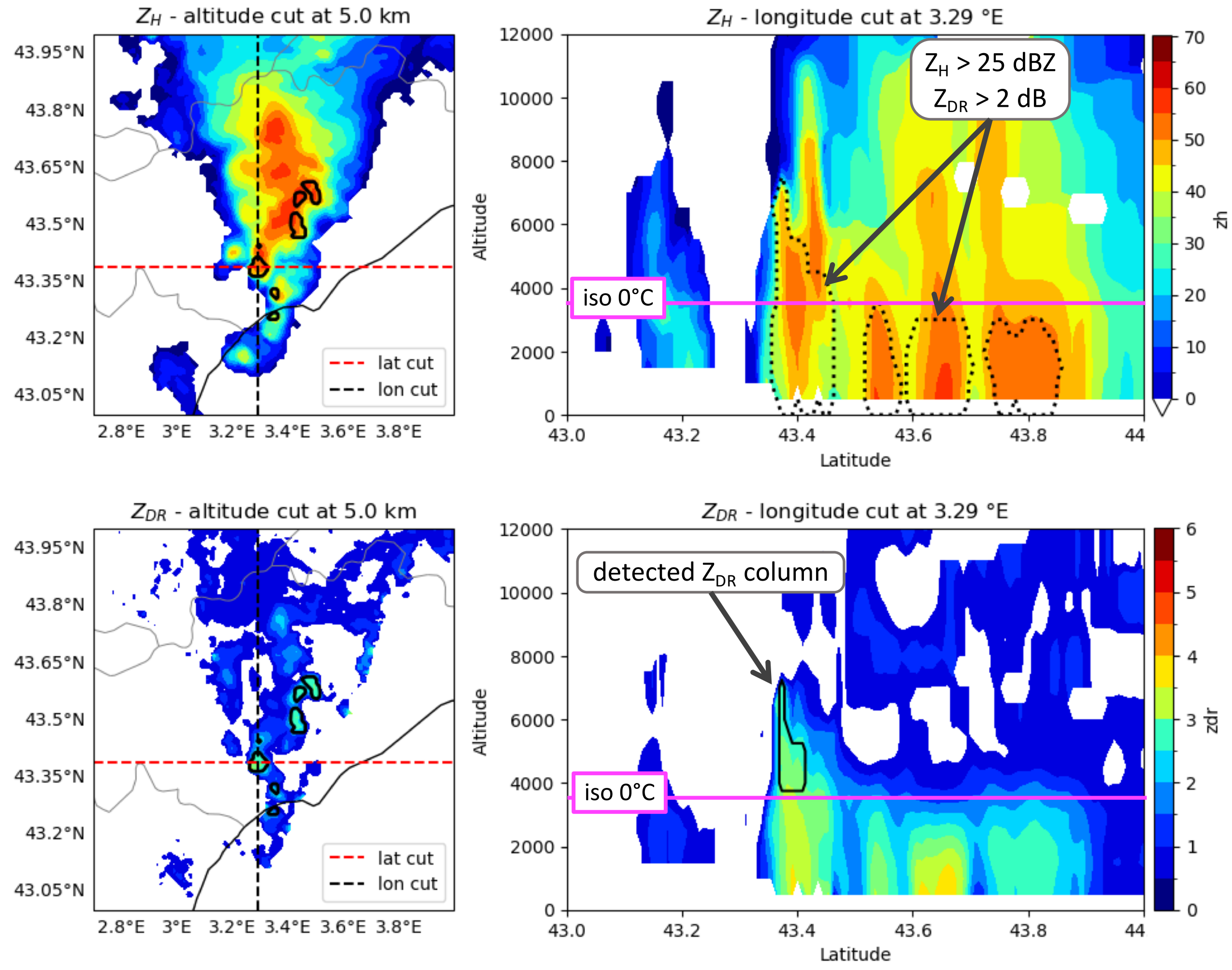
Legend :

Z_H > 25 dBZ + Z_{DR} > 2 dB — column contours

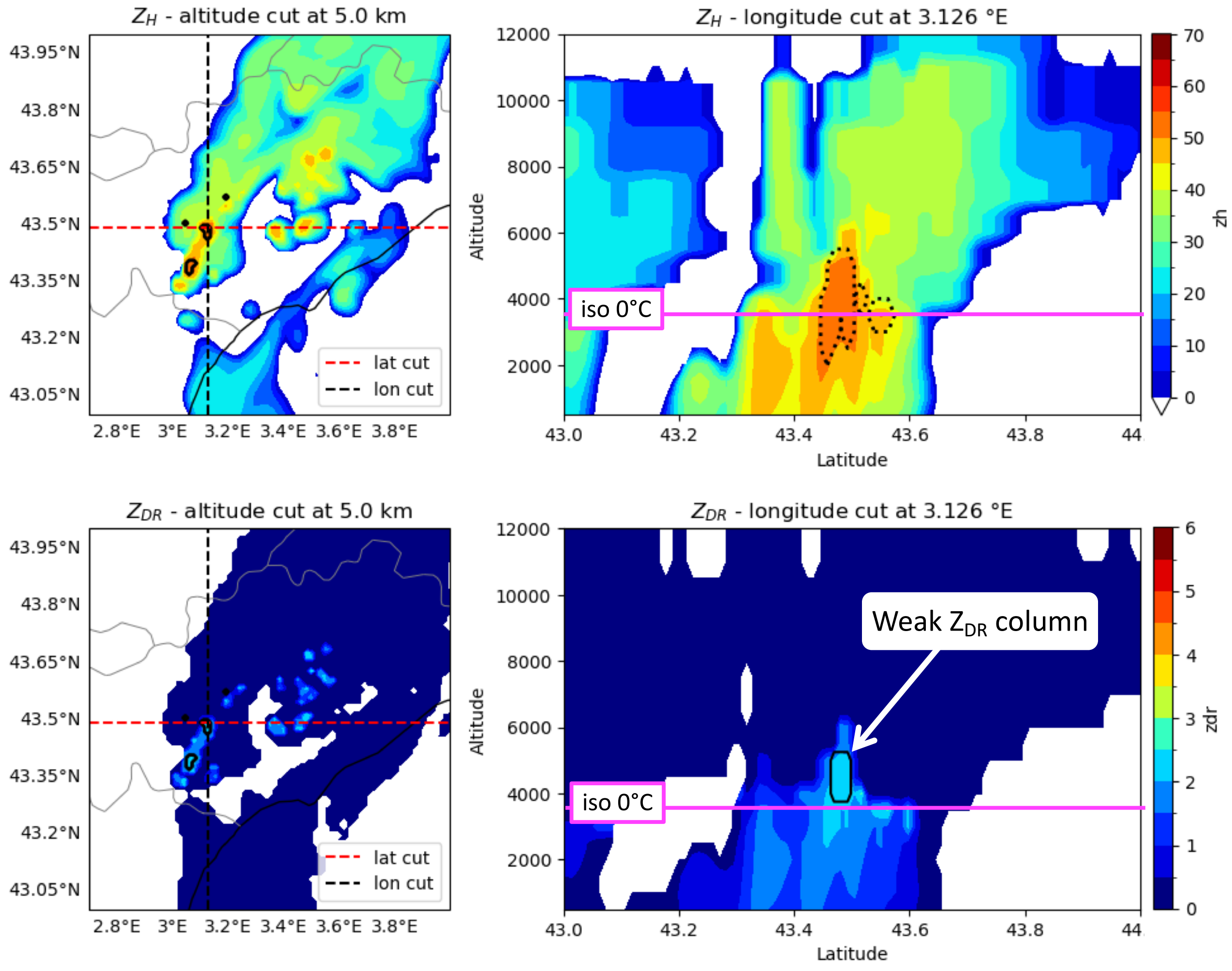
2022-08-16 18:40

Signature reproductibility

Interpolated radar observations



Simulated polarimetric variables with ICE3 microphysics



Legend :

- - - Z_H > 25 dBZ + Z_{DR} > 2 dB ——— column contours

ICE3 microphysics (1 moment) :

rain, snow, ice crystals, graupel

2022-08-16 18:40

Signature reproductibility

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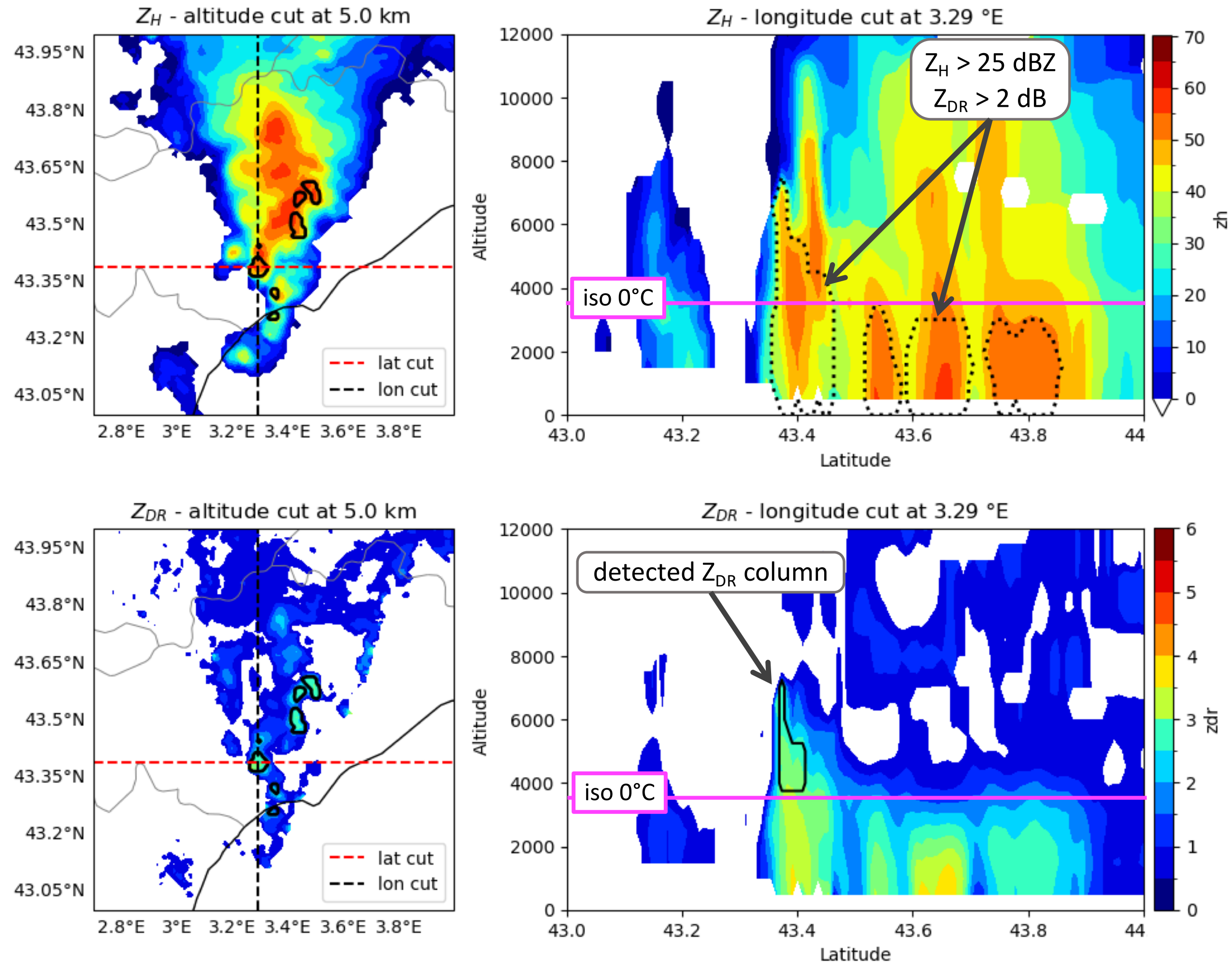
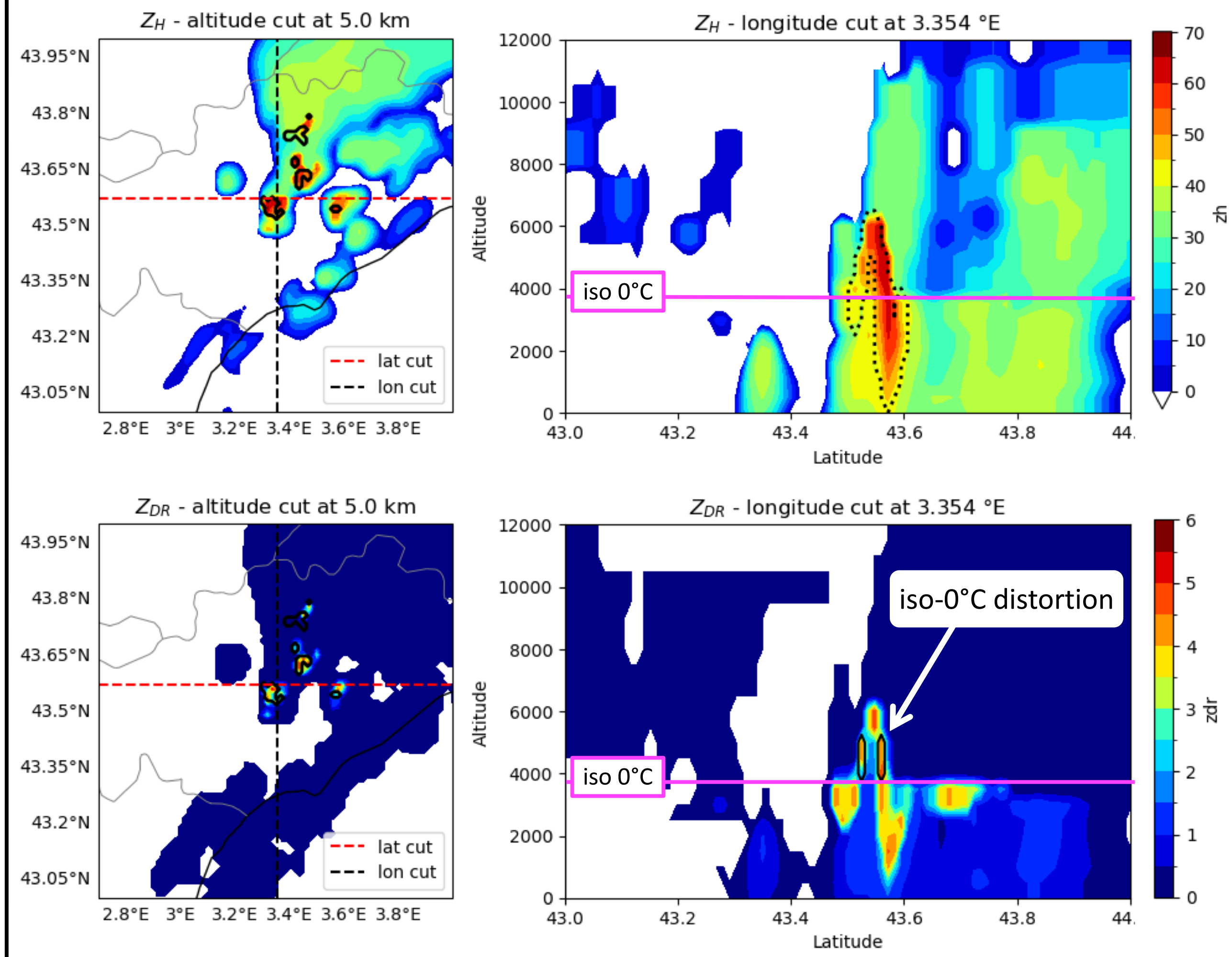


Simulated polarimetric variables with ICE4 microphysics



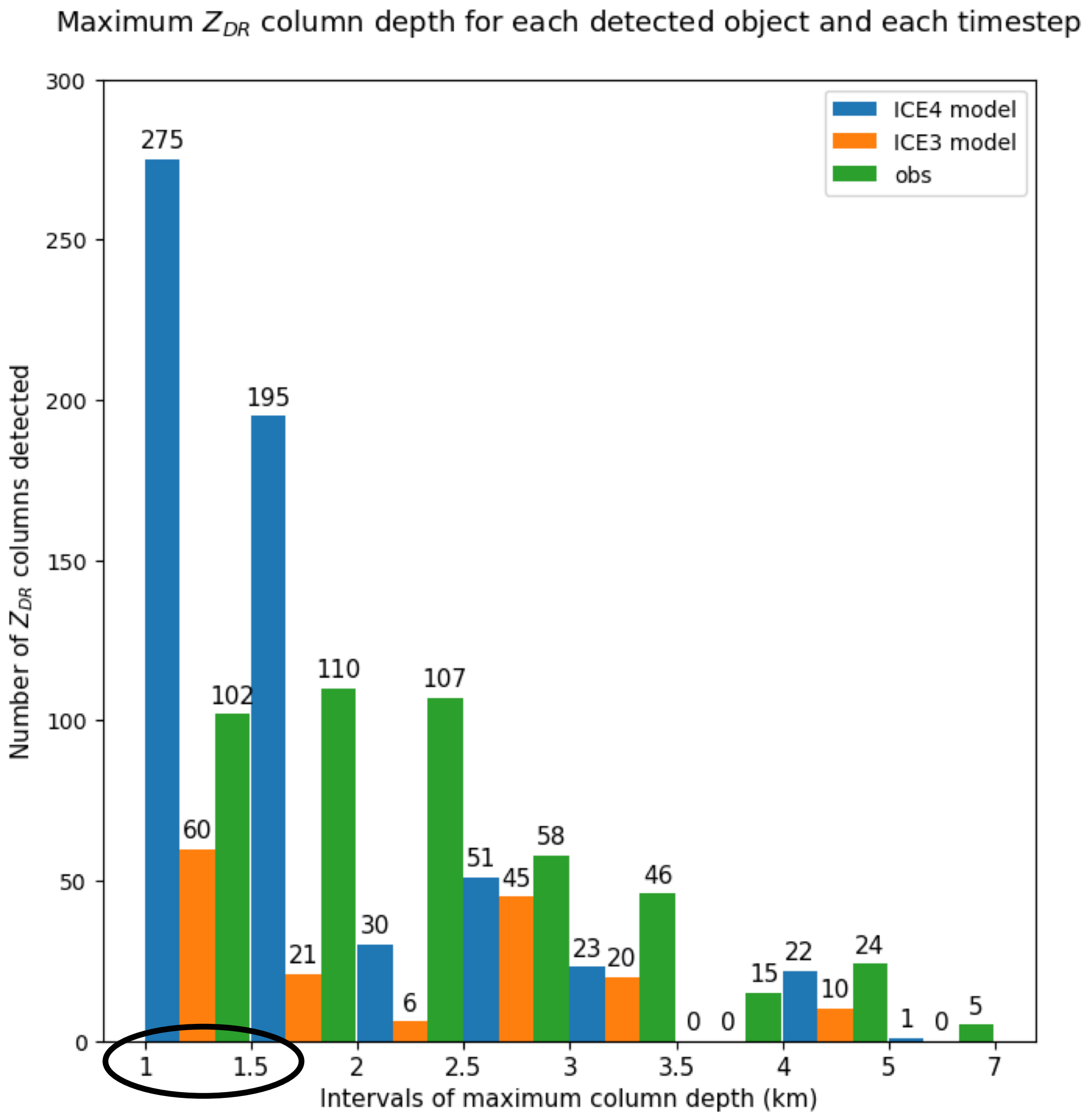
Legend :

- - - Z_H > 25 dBZ + Z_{DR} > 2 dB ——— column contours

ICE4 microphysics (1 moment) :

rain, snow, ice crystals, graupel + hail

First statistics – area and column depth

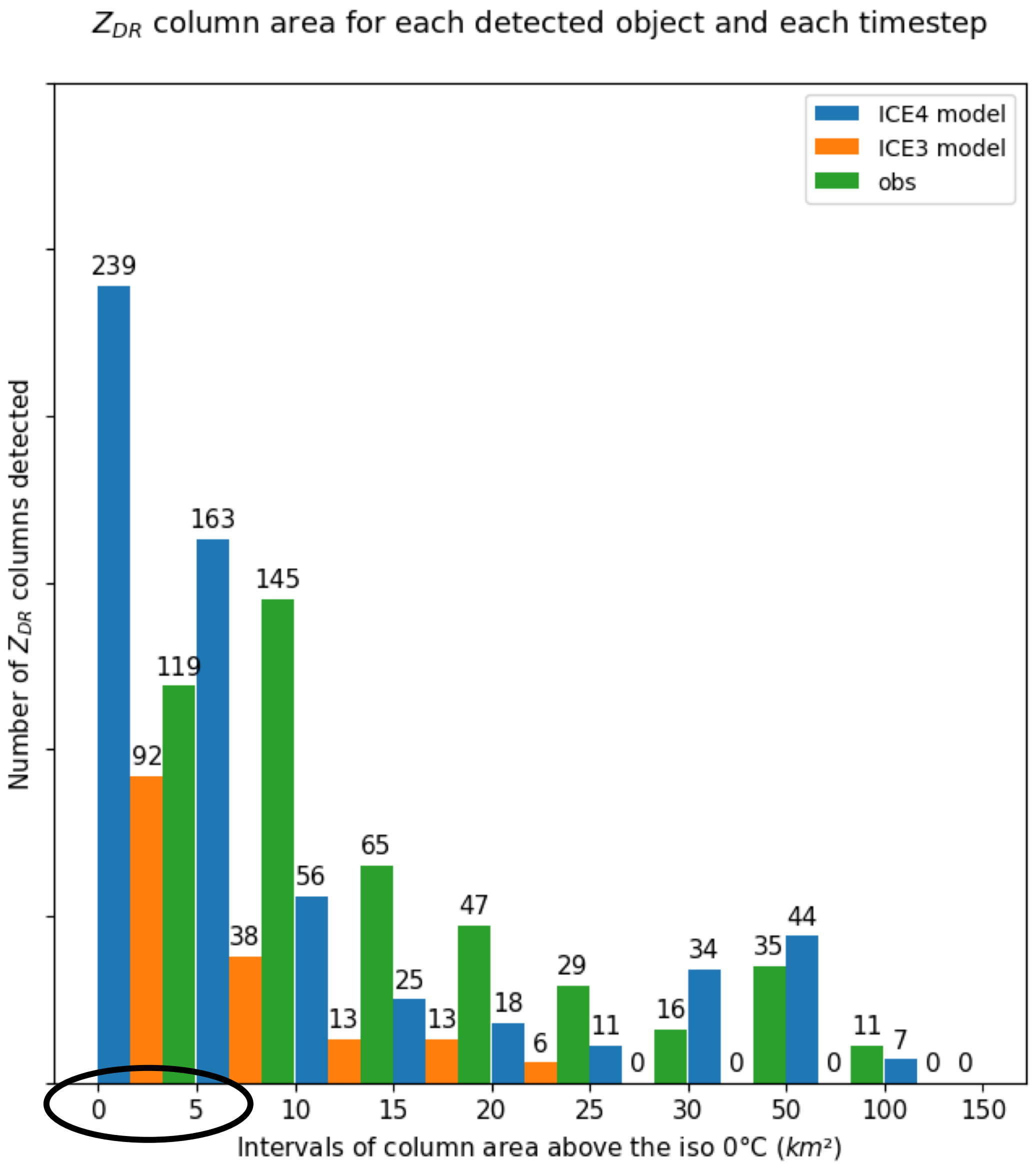


Total

ICE4 : 597

ICE3 : 162

obs : 467



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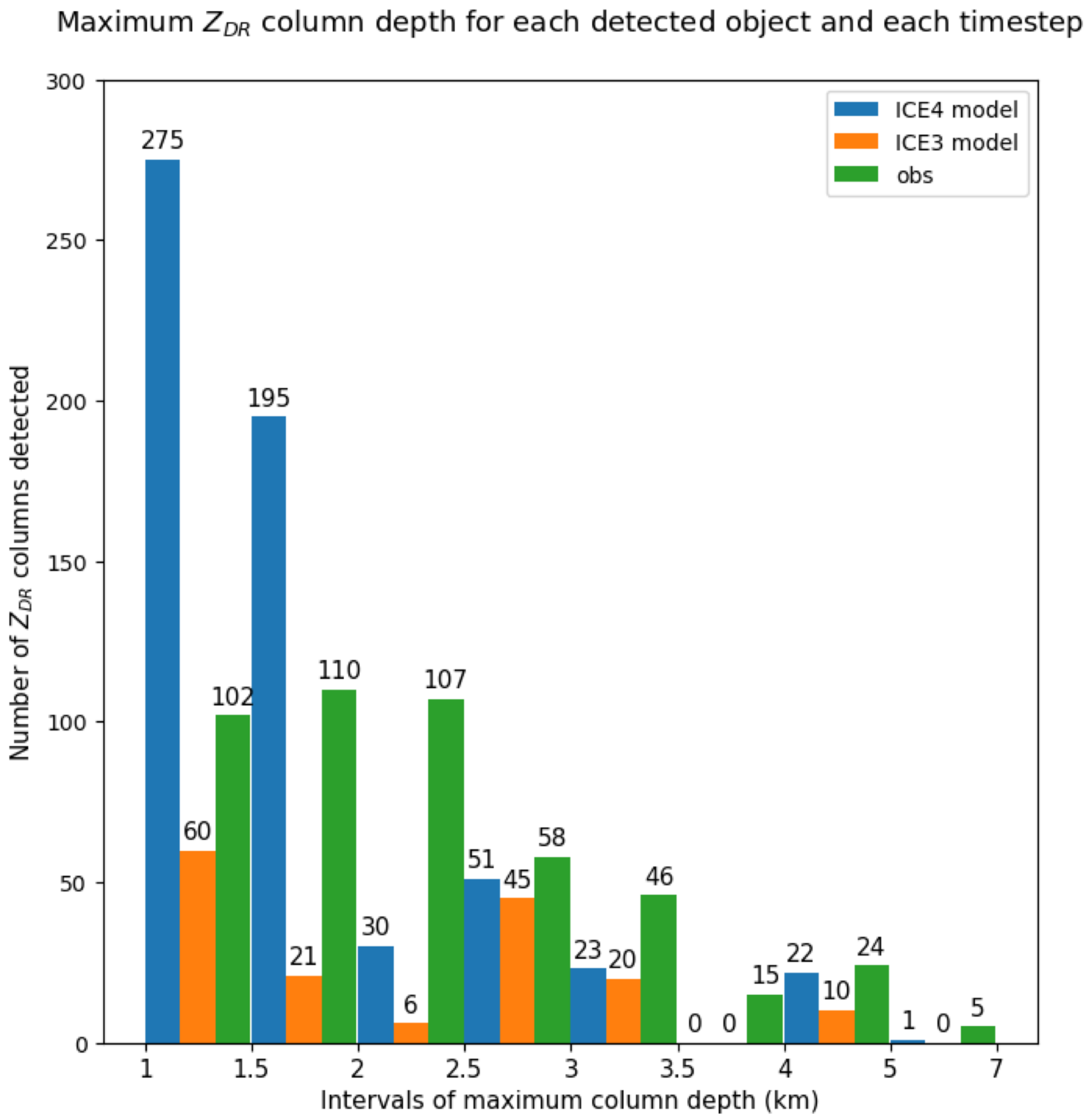

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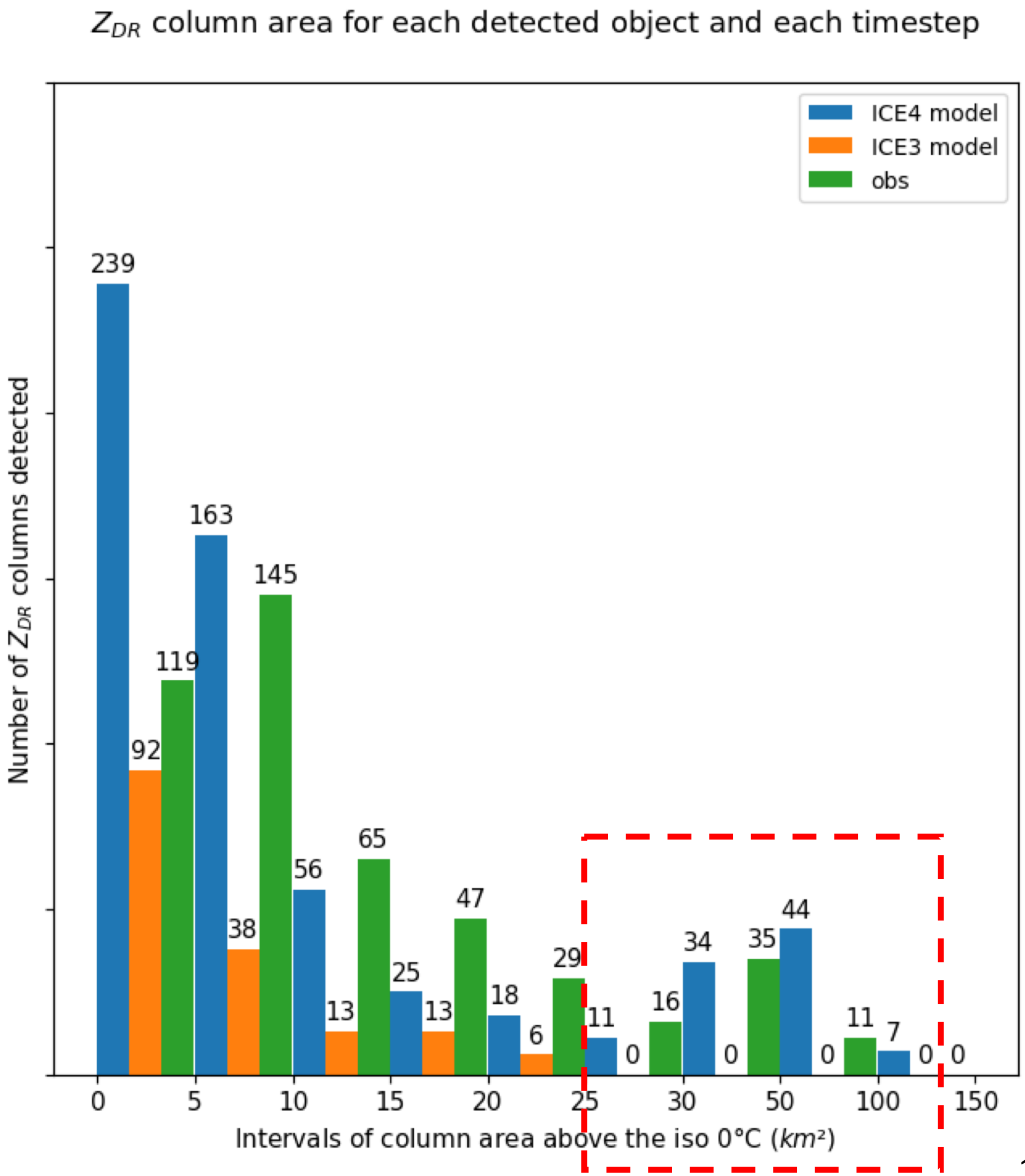

Conclusion and perspectives

Conclusion

- Z_{DR} column tracks are consistent with hail locations
- AROME operational model succeed in representing polarimetric signatures (especially Z_{DR} columns)
- ICE4 (1 moment scheme with hail) is better at representing large Z_{DR} columns **but** a lot of (too) small objects → need to adjust the radar forward operator

Perspectives

- Improve object detection algorithm criteria for a better time tracking
- Go deeper into the radar forward operator’s settings
- Further investigations with our 2-moment microphysics scheme LIMA (Vié et al., 2016) and the role of hail as a distinct category of hydrometeor
- Application over more cases

Thanks for your attention

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METEO FRANCE

ECSS European Conference on Severe Storms

cnrs dépasser les frontières

CNRM

Picture credit : Sean Ramsey

References

Ryzhkov, A.V.; Snyder, J.; Carlin, J.T.; Khain, A.; Pinsky, M. What Polarimetric Weather Radars Offer to Cloud Modelers: Forward Radar Operators and Microphysical/Thermodynamic Retrievals. *Atmosphere* (**2020**), *11*, 362. https://doi.org/10.3390/atmos11040362

Kumjian, Matthew R., and Alexander V. Ryzhkov. "Polarimetric Signatures in Supercell Thunderstorms". *Journal of Applied Meteorology and Climatology* 47.7 (**2008**): 1940-1961. https://doi.org/10.1175/2007JAMC1874.1

Kumjian, Matthew R., Alexander P. Khain, Nir Benmoshe, Eyal Ilotoviz, Alexander V. Ryzhkov, and Vaughan T. J. Phillips. "The Anatomy and Physics of ZDR Columns: Investigating a Polarimetric Radar Signature with a Spectral Bin Microphysical Model". *Journal of Applied Meteorology and Climatology* 53.7 (**2014**): 1820-1843. https://doi.org/10.1175/JAMC-D-13-0354.1

Johnson, Marcus, Youngsun Jung, Daniel T. Dawson, II, and Ming Xue. "Comparison of Simulated Polarimetric Signatures in Idealized Supercell Storms Using Two-Moment Bulk Microphysics Schemes in WRF". *Monthly Weather Review*144.3 (**2016**): 971-996. https://doi.org/10.1175/MWR-D-15-0233.1

Snyder, Jeffrey C., Howard B. Bluestein, Daniel T. Dawson II, and Youngsun Jung. "Simulations of Polarimetric, X-Band Radar Signatures in Supercells. Part II: ZDR Columns and Rings and KDP Columns". *Journal of Applied Meteorology and Climatology* 56.7 (**2017**): 2001-2026.

Snyder, Jeffrey C., Alexander V. Ryzhkov, Matthew R. Kumjian, Alexander P. Khain, and Joseph Picca. "A ZDR Column Detection Algorithm to Examine Convective Storm Updrafts". *Weather and Forecasting* 30.6 (**2015**): 1819-1844. https://doi.org/10.1175/WAF-D-15-0068.1

Augros, C., **David C.**, Caumont O., Vié B., Natalia Parisotto Sinhori, Didier Ricard, “Use of dual-polarization signatures in supercell storms for the evaluation of Méso-NH ICE3 and LIMA microphysics schemes“. ERAD 2022 https://www.erad2022.ch/bookofabstracts2022

Augros, C., **David C.**, Caumont O., Vié B., Natalia Parisotto Sinhori, Didier Ricard. "Polarimetric signatures of an idealized supercell simulated with Meso-NH using ICE3 and LIMA microphysics schemes" ; Atmospheric Chemistry and Physics, in preparation

Lac, C., Chaboureau, J.-P., Masson, V., Pinty, J.-P., Tulet, P., Escobar, J., Leriche, M., Barthe, C., Aouizerats, B., Augros, C., Aumond, P., Auguste, F., Bechtold, P., Berthet, S., Bielli, S., Bosseur, F., Caumont, O., Cohard, J.-M., Colin, J., Couvreux, F., Cuxart, J., Delautier, G., Dauhut, T., Ducrocq, V., Filippi, J.-B., Gazen, D., Geoffroy, O., Gheusi, F., Honnert, R., Lafore, J.-P., Lebeaupin Brossier, C., Libois, Q., Lunet, T., Mari, C., Maric, T., Mascart, P., Mogé, M., Molinié, G., Nuissier, O., Pantillon, F., Peyrillé, P., Pergaud, J., Perraud, E., Pianezze, J., Redelsperger, J.-L., Ricard, D., Richard, E., Riette, S., Rodier, Q., Schoetter, R., Seyfried, L., Stein, J., Suhre, K., Taufour, M., Thouron, O., Turner, S., Verrelle, A., Vié, B., Visentin, F., Vionnet, V., and Wautelet, P. Overview of the Meso-NH model version 5.4 and its applications. Geosci. Model Dev. (**2018**) 11, 1929–1969. https://doi.org/10.5194/gmd-11-1929-2018

Pinty J.P., Jabouille P., **1998** : *A mixed-phase cloud parametrization for use in a mesoscale non- hydrostatic model : simulations of a squall line and of orographic precipitation*

Augros, C., Caumont, O., Ducrocq, V., Gaussiat, N. and Tabary, P. (**2016**), Comparisons between S-, C- and X-band polarimetric radar observations and convective-scale simulations of the HyMeX first special observing period. Q.J.R. Meteorol. Soc., 142: 347-362. https://doi.org/10.1002/qj.2572

Helmus, J.J. & Collis, S.M., (**2016**). The Python ARM Radar Toolkit (Py-ART), a Library for Working with Weather Radar Data in the Python Programming Language. Journal of Open Research Software. 4(1), p.e25. DOI: http://doi.org/10.5334/jors.119

Carlin, Jacob T., Jidong Gao, Jeffrey C. Snyder, and Alexander V. Ryzhkov. "Assimilation of ZDR Columns for Improving the Spinup and Forecast of Convective Storms in Storm-Scale Models: Proof-of-Concept Experiments". *Monthly Weather Review* 145.12 (**2017**): 5033-5057. https://doi.org/10.1175/MWR-D-17-0103.1