



Leveraging FAIR principles for efficient management of meteorological radar data

Argonne
NATIONAL LABORATORY



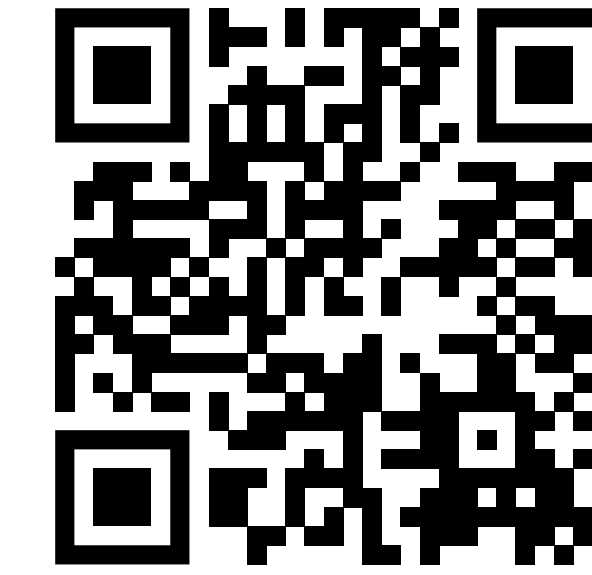
UNIVERSITÄT BONN

Alfonso Ladino¹, Max Grover², Stephen Nesbitt¹, Kai Mühlbauer³,

¹Department of Climate, Meteorology and Atmospheric Sciences, University of Illinois at Urbana-Champaign, Urbana, IL, USA

²Argonne National Laboratory, Lemont, IL, USA

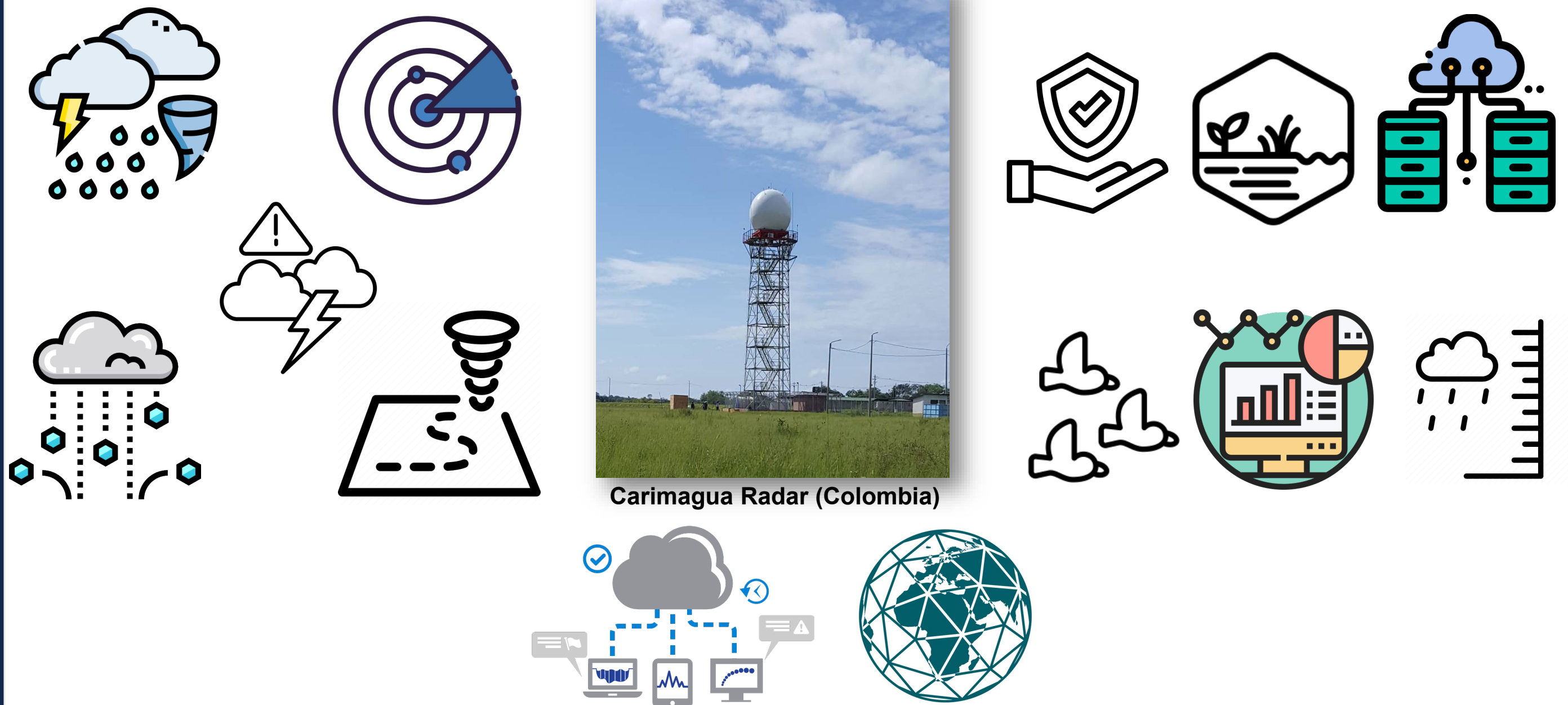
³University of Bonn, Bonn, Germany



INTRODUCTION

Near Real Time

Offline



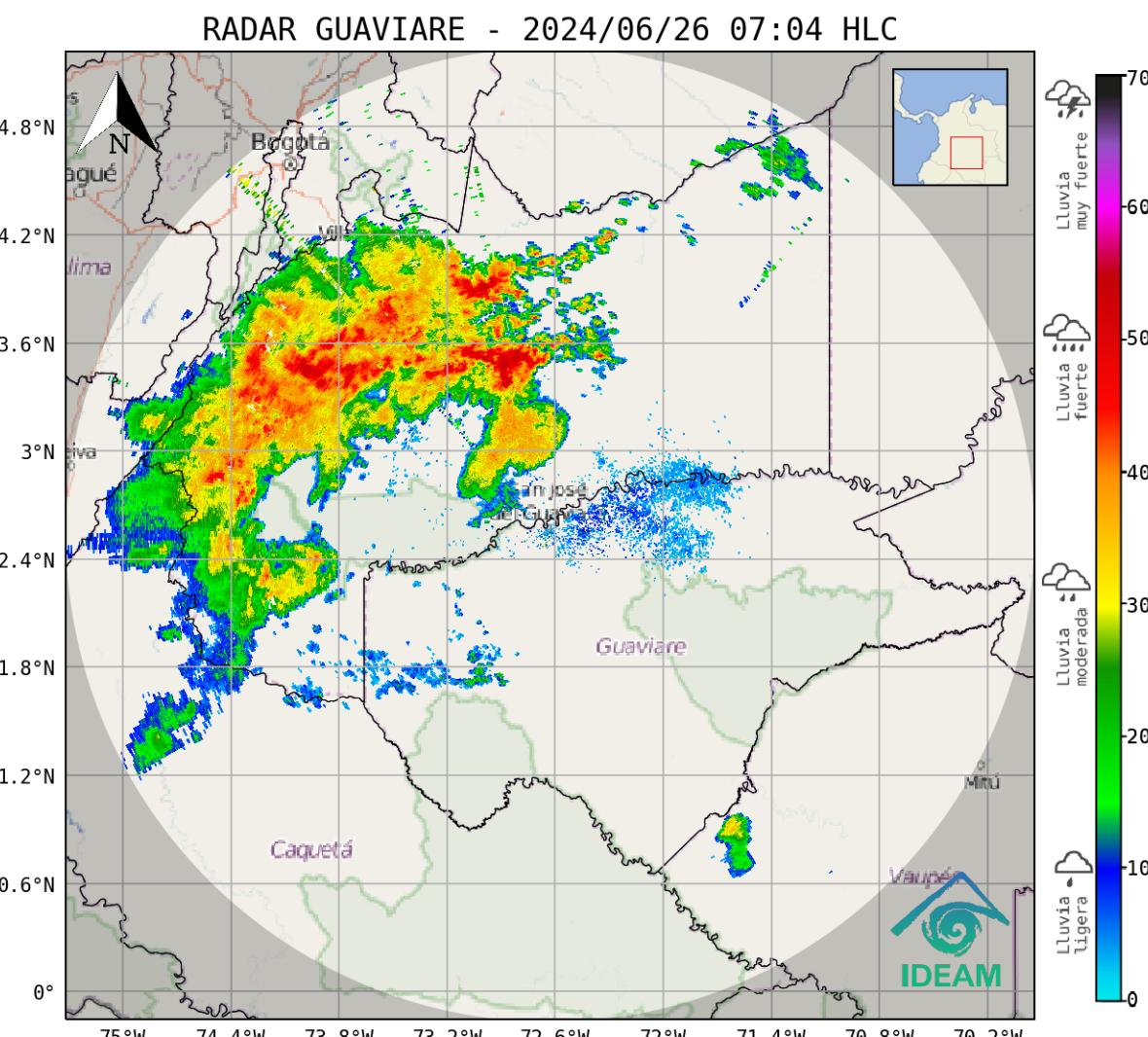
Offline radar products demand extensive input-output (I/O) operations over data stored in proprietary (binary) formats



MOTIVATION

- Time-series data model to **arrange**, **manage**, and **store** radar data in cloud-storage buckets efficiently using **Analysis-Ready Cloud-Optimized (ARCO)** format [1].
- Use a **hierarchical tree** structure based on the Climate and Forecast (CF) format-based FM301 (World Meteorological Organization) [2].
- Align with the **open data** paradigm, emphasizing the **FAIR** principles (**F**indable, **A**ccessible, **I**nteroperable, **R**eusable)

DATA

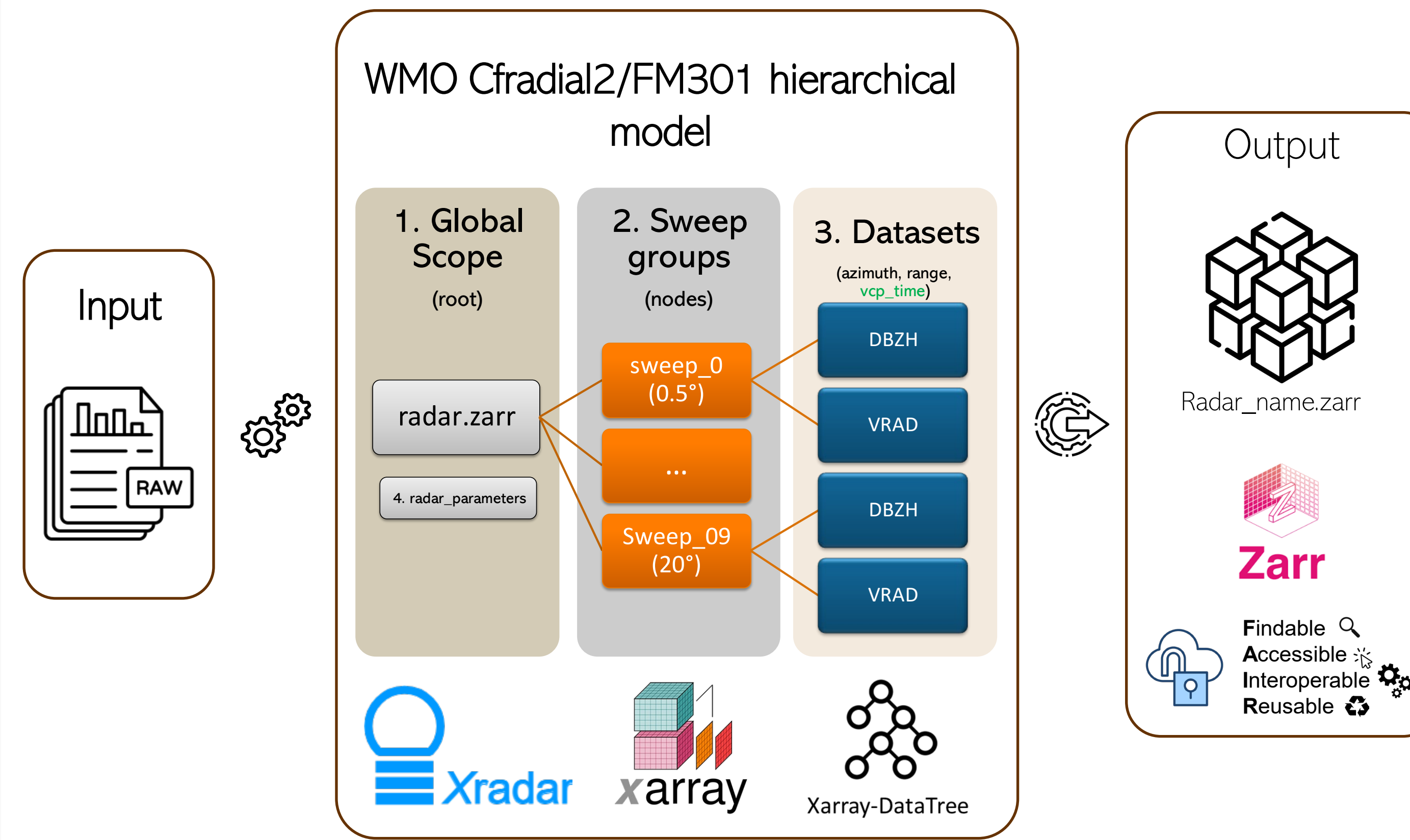


Guaviare Radar (Colombia)

- 10 elevations (0.5 to 20 degrees)
- 1 moth of consecutive data (from 08/01/2022 to 08/31/2022)
- Sigmet files (Binary format)
- 5-min VCP
- Data currently available at: <https://registry.opendata.aws/id-eam-radares/>

METHODS

1. Hierarchical tree-like radar data model (time series)



<https://github.com/aladinor/raw2zarr>



2. Testing on radar products

a. Quasi-Vertical Profile (QVP) [3]

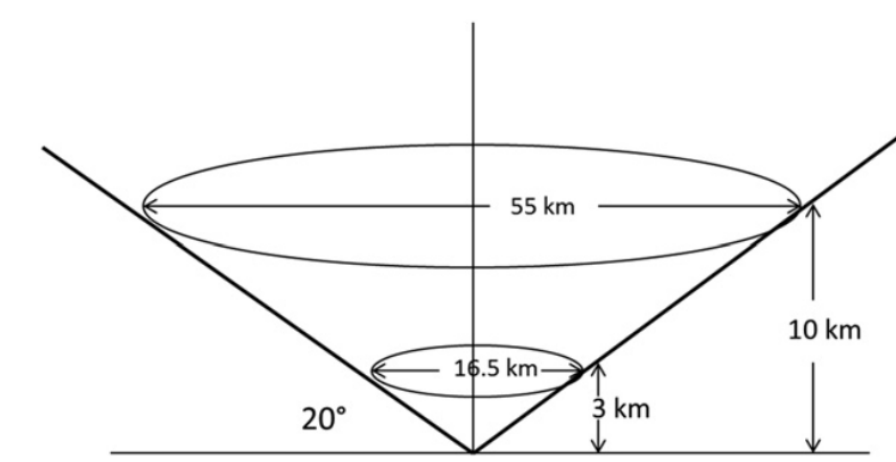


FIG. 2. Conical volume representing azimuthally averaged quasi-vertical profiles of radar variables.

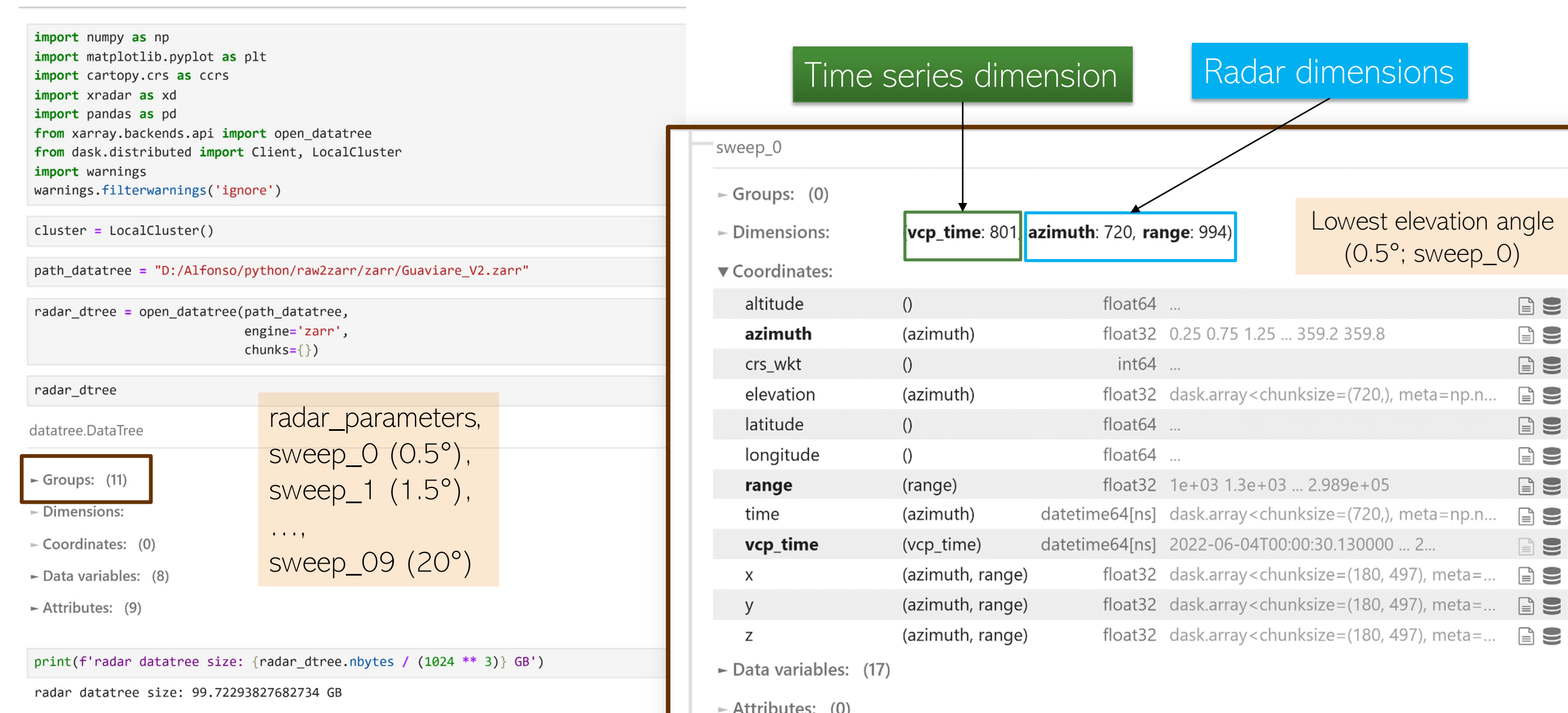
b. Radar Quantitative Precipitation Estimation (QPE)

$$Z = 200R^{1.6} \text{ Marshall \& Palmer (1948) [4]}$$

$$R[\text{mm/hr}] = \left[\frac{Z[\text{mm}^6\text{m}^{-3}]}{200} \right]^{\frac{1}{1.6}}$$

RESULTS

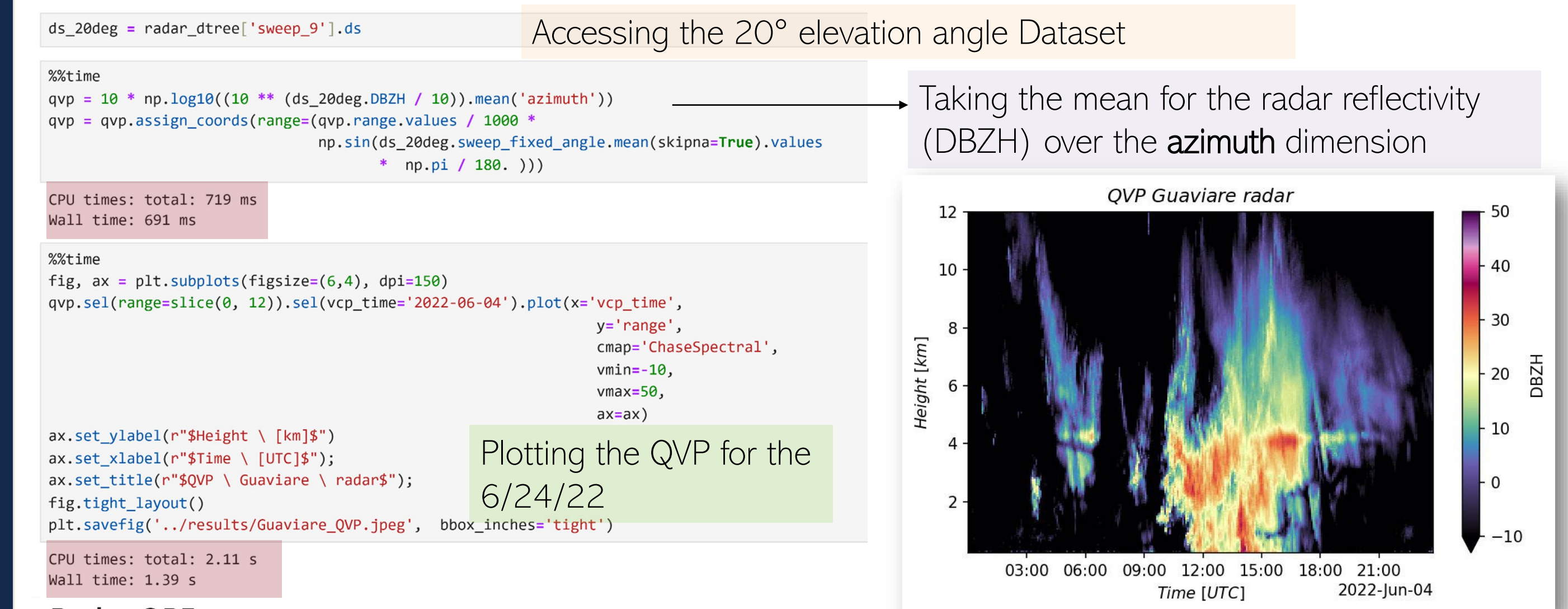
Pythonic representation of the WMO Cfradial2/FM301 standard data model



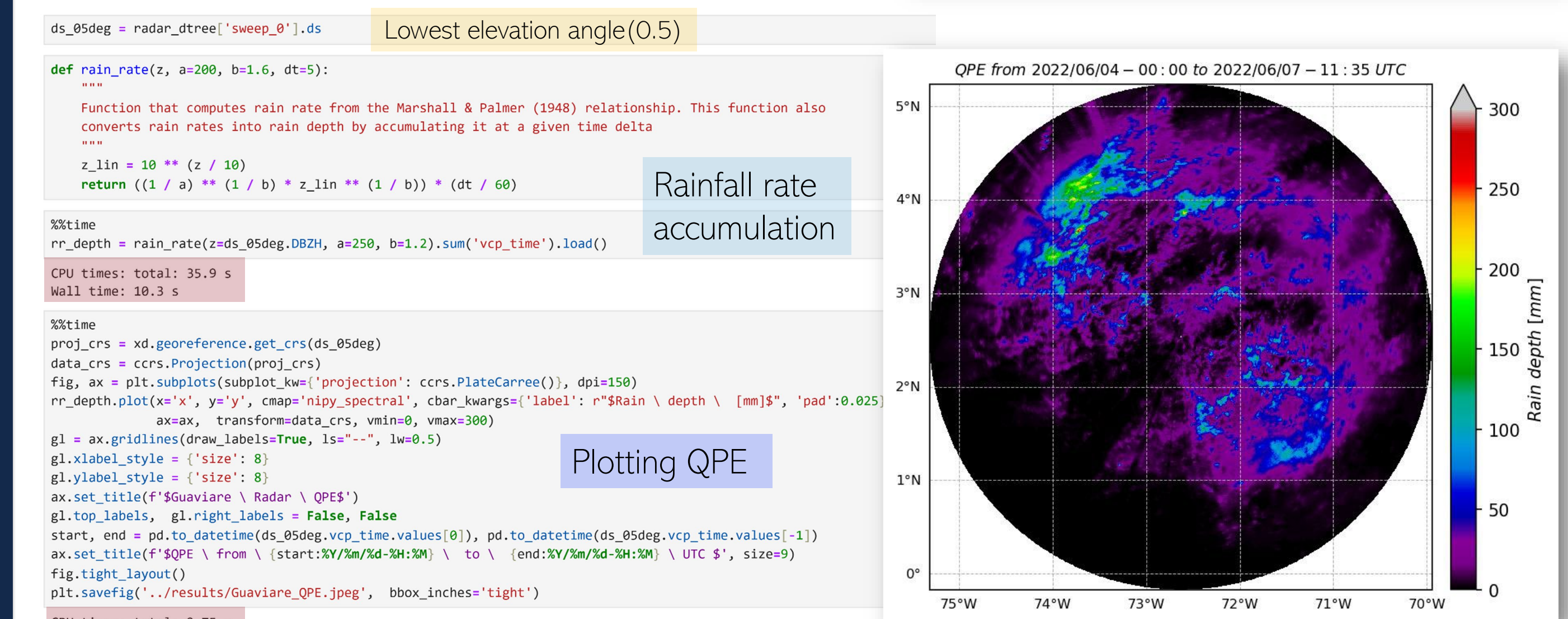
The tree-like data model encompasses **all sweeps** set up within the radar operation and the "radar_parameters" group. Each 'sweep_xx' includes a **dataset** with 'azimuth' and 'range' as **radar dimensions** and **coordinates**. The additional 'vcp_time' dimension enables the dataset to represent a **time series**.

RESULTS (Cont.)

Quasi-Vertical Profile (QVP)



Radar QPE



Radar data stored in ARCO format allow us to perform operations on the entire dataset with just a few lines of code, and the results will be ready in a few seconds, as shown in the **red squares**.

CONCLUSIONS

- The hierarchical radar data model, based on the WMO Cfradial2/FM301 standard, provides an effective solution for storing historical radar data. Adhering to FAIR principles and optimized for cloud storage.
- The time series at each node enables efficient analysis of historical datasets, climatology computation, and offline product generation without extensive computing resources and within reasonable times.
- The sequential translation from RAW to ARCO formats preserves the chronological order of radar scans, which is required for this data model despite its time-consuming.

REFERENCES

- [1] Abernathy, R. P., Augspurger, T., Banihirwe, A., Blackmon-Luca, C. C., Crone, T. J., Gentemann, C. L., Hamman, J. J., Henderson, N., Lepore, C., McCaie, T. A., Robinson, N. H., & Signell, R. P. (2021). Cloud-Native Repositories for Big Scientific Data. *Computing in Science & Engineering*, 23(2), 26–35. <https://doi.org/10.1109/MCSE.2021.3059437>
- [2] Dixon, M. J., Curtis, M., Michelson, D., Hardin, J., Kehoe, K., & Haimov, S. (2019). CFRadial2 data file format: CF2 NetCDF format for RADAR and LIDAR data in radial coordinates - v2.0. doi:10.5065/fy2k-x587
- [3] Ryzhkov, A., Zhang, P., Reeves, H., Kumjian, M., Tschallener, T., Trömel, S., & Simmer, C. (2016). Quasi-Vertical Profiles—A New Way to Look at Polarimetric Radar Data. *Journal of Atmospheric and Oceanic Technology*, 33(3), 551–562. <https://doi.org/10.1175/JTECH-D-15-0020.1>
- [4] Marshall, J. S., & Palmer, W. M. K. (1948). THE DISTRIBUTION OF RAINDROPS WITH SIZE. *Journal of the Atmospheric Sciences*, 5(4), 165–166. [https://doi.org/10.1175/1520-0469\(1948\)005<0165:TDORWS>2.0.CO;2](https://doi.org/10.1175/1520-0469(1948)005<0165:TDORWS>2.0.CO;2)