NCAR RADAR TECHNOLOGY WORKSHOP, 2026

LINKING DATA PROCESSING, MANAGEMENT, AND PRODUCTS THROUGH SOFTWARE

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With many contributors!

U.S. DEPARTMENT of ENERGY

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ARM

Argonne NATIONAL LABORATORY

SOFTWARE

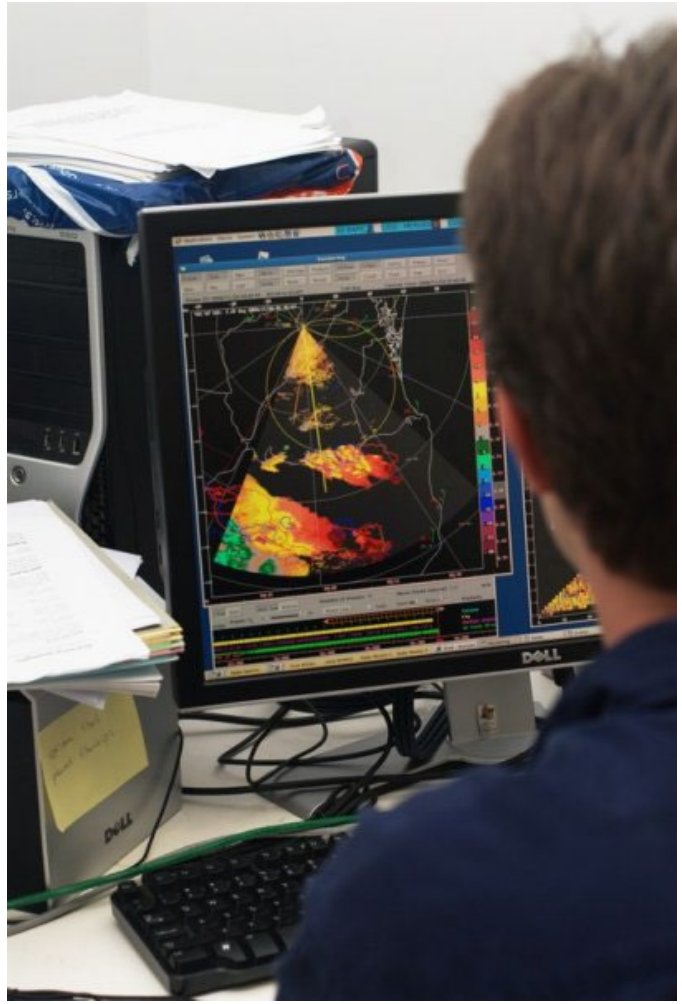
Who here does not use software?

- Very few papers or other research output are produced without software.
- Software is critical research infrastructure.
- Much of the software used by the community started as a side hustle.

OPEN VERSUS PROPRIETARY

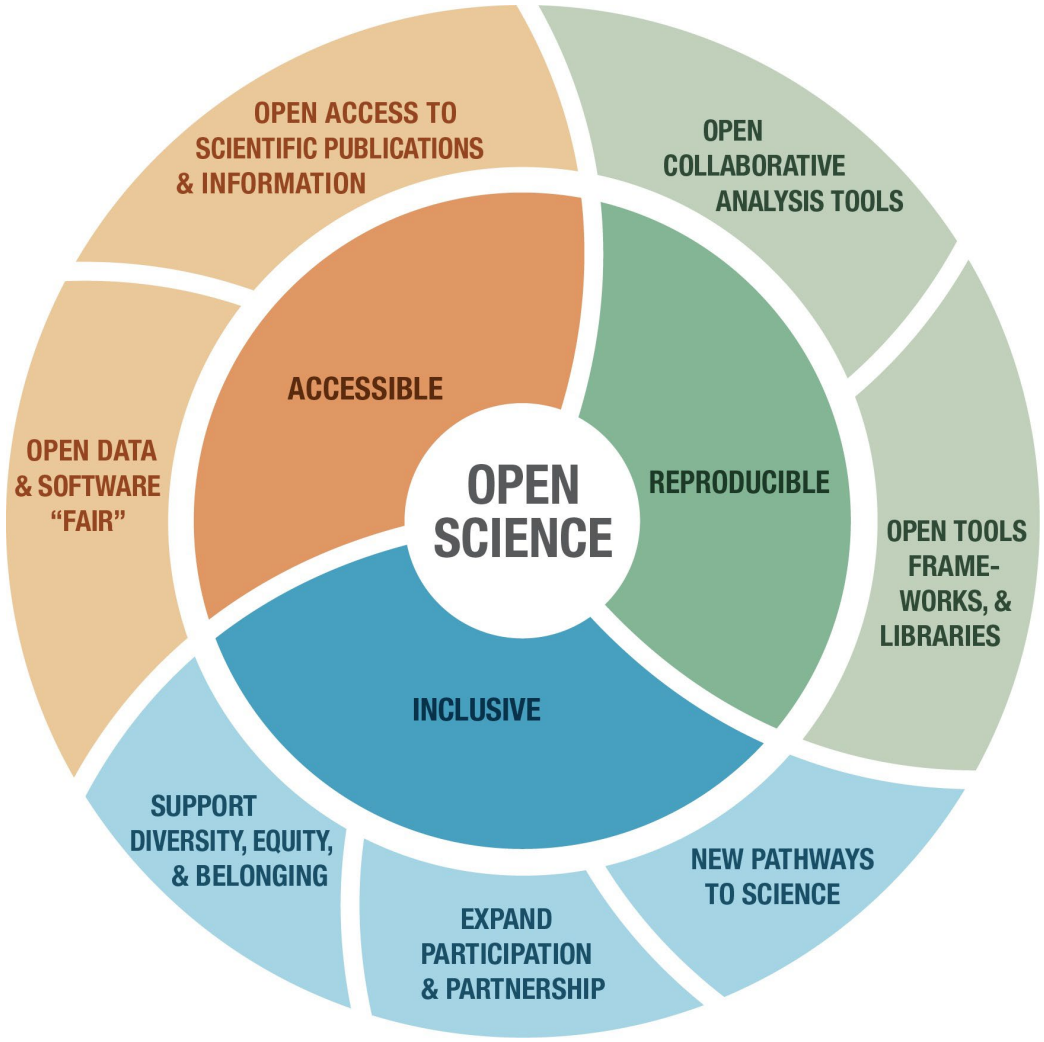
This presentation will deal mainly with open software

- There is a place for both closed and open source software in our ecosystem.
- What is important is that software is well engineered, robust and tested. For example, good APIs.
- There can be a healthy exchange between the two. Right tool for the job!
- In general, the further you get from the transmitter, the more open options exist.

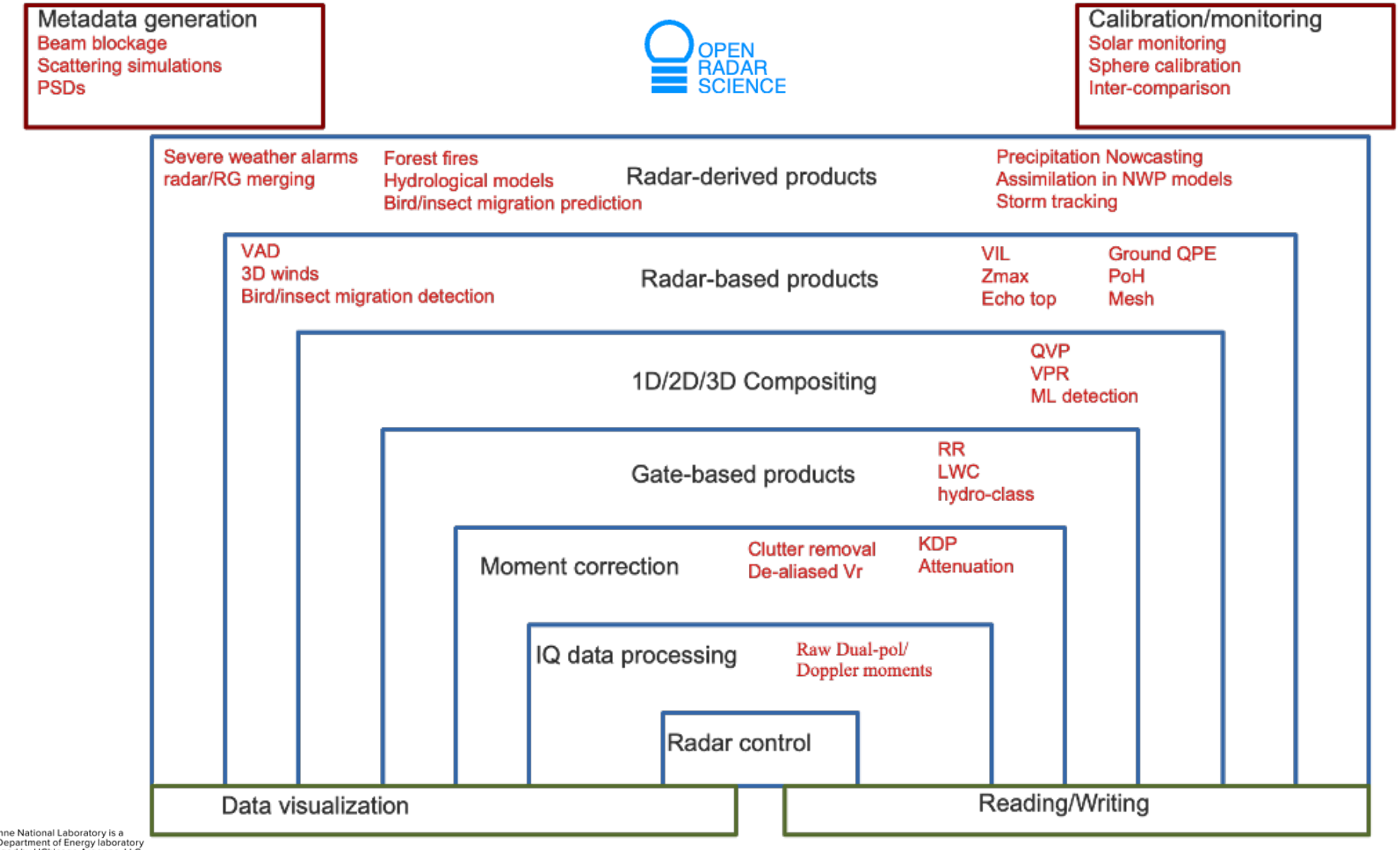


OPEN SCIENCE

- Open source software is part of the wider ecosystem of open science.
- The combination of open source software, open educational materials and open data creates a cycle of reproducibility and reusability.



TYPICAL DATA CHAIN



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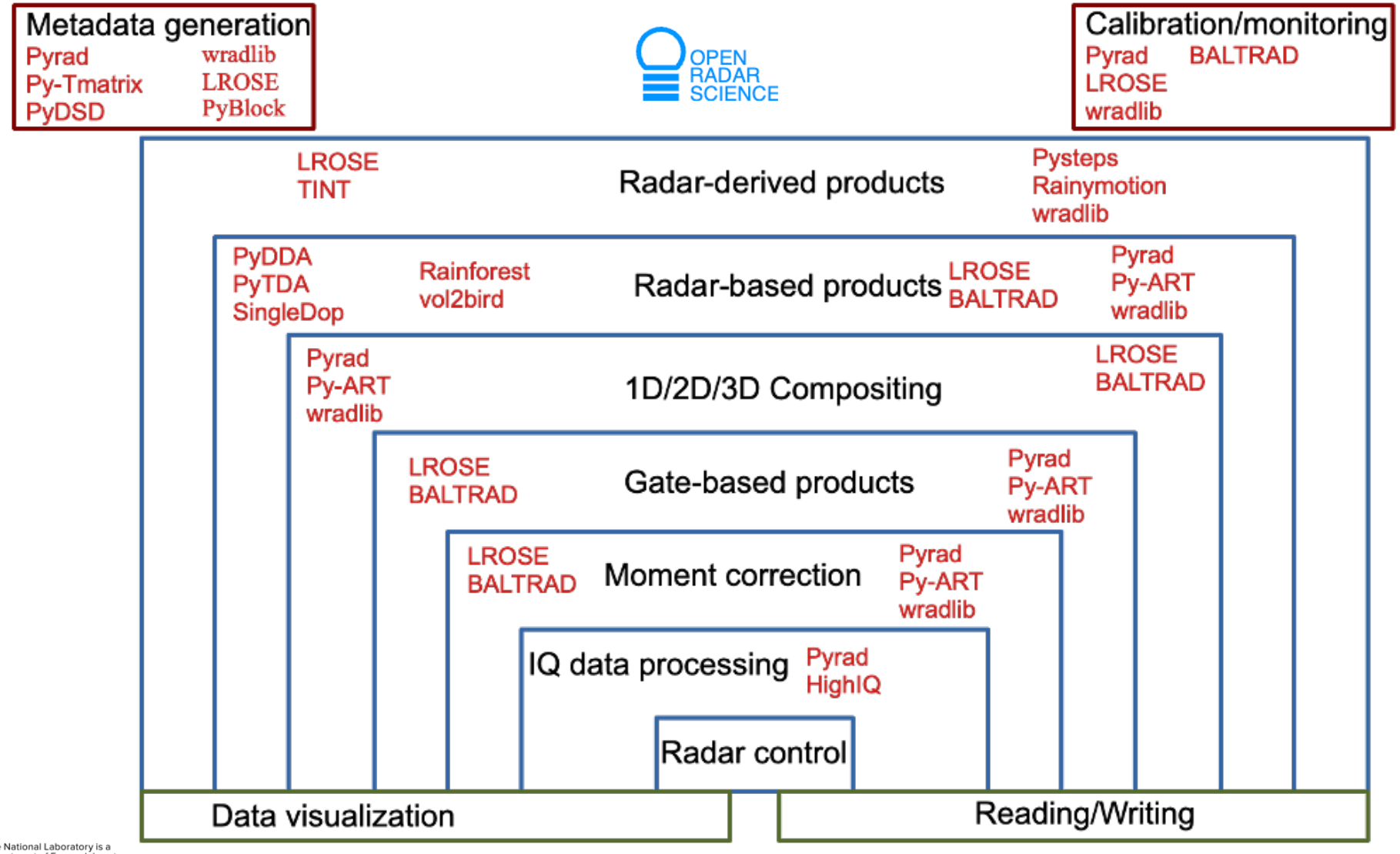
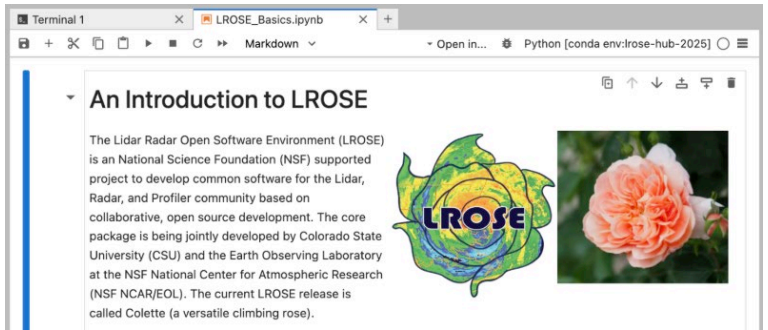
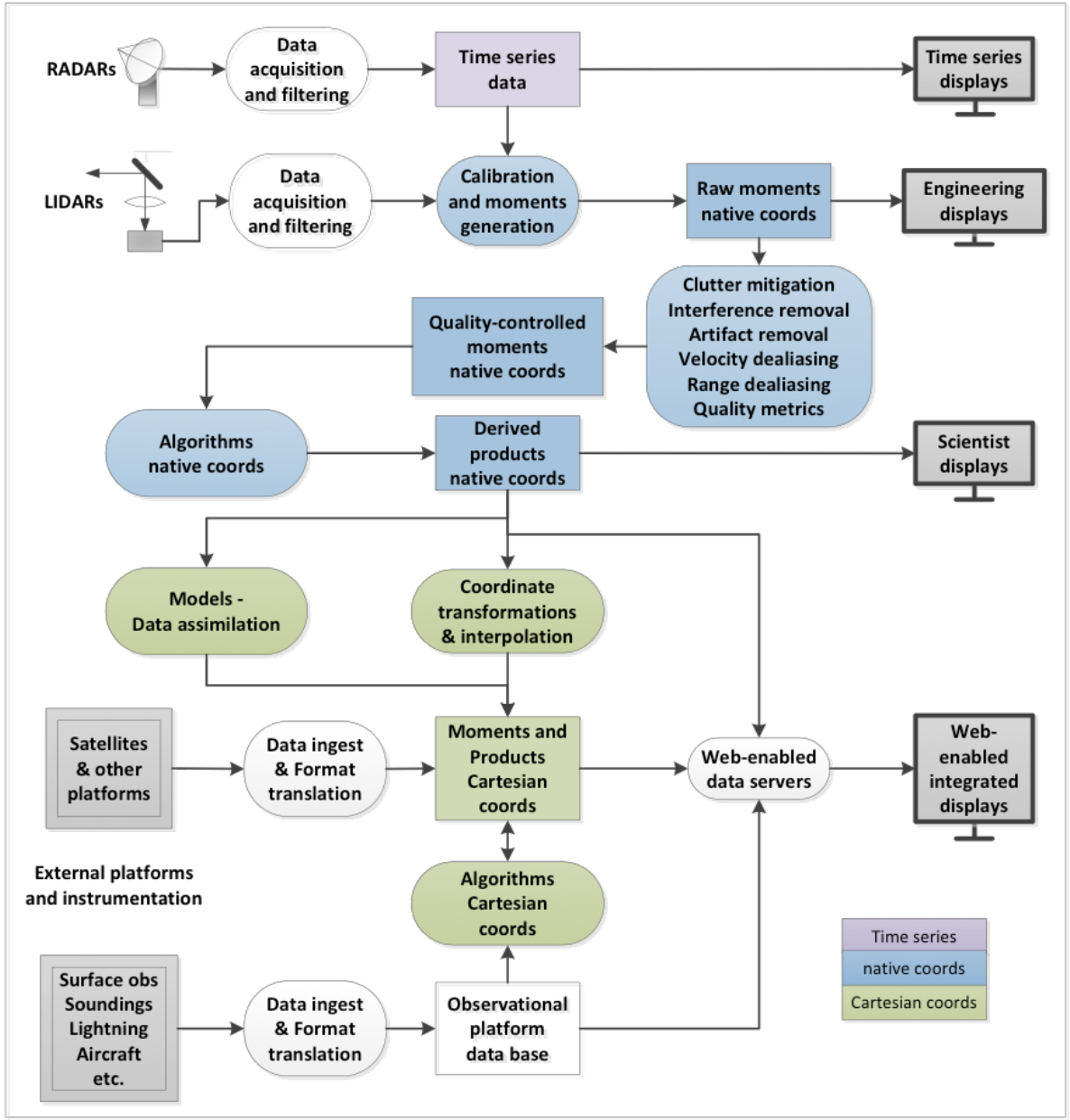


LROSE

High quality building blocks for complex workflows

- http://lrose.net/
- Based on legacy of NCAR and CSU tools
- Mostly C++
- Linux/Mac/partially Windows
- Many stand-alone tools
- LROSE Science Gateway



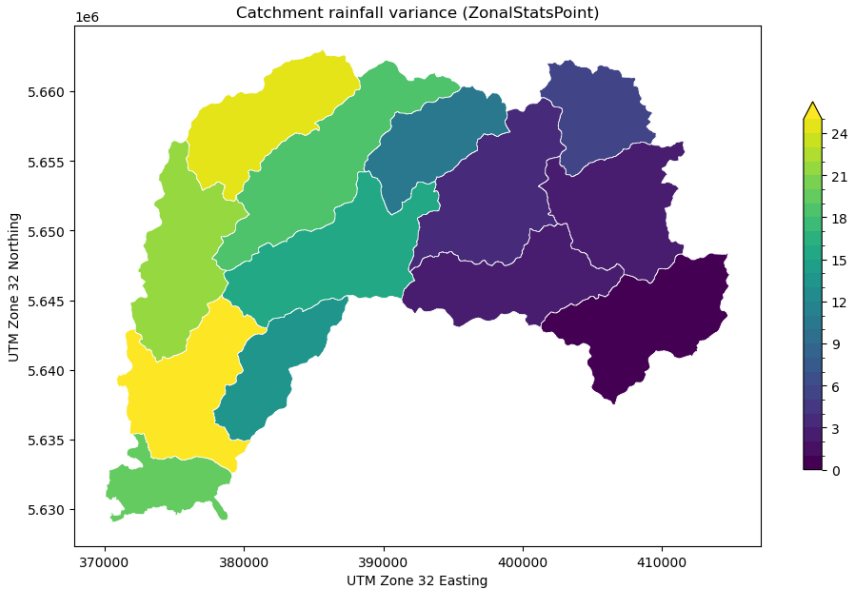


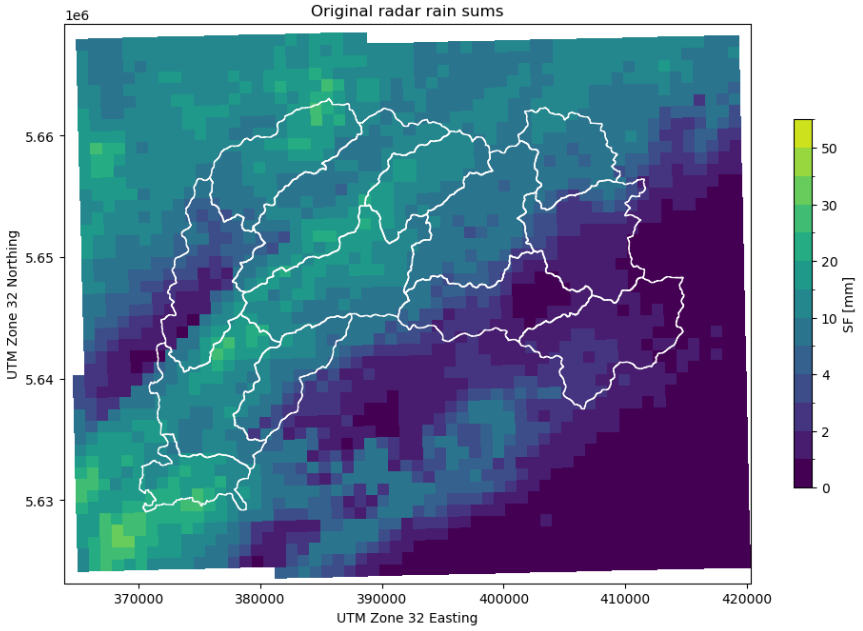
Thank you Jenn DeHart!

WRADLIB

Keep the magic to the minimum (let the user decide)

- One of the oldest python radar packages.
- Flat data model that allows maximum flexibility to interact with the data.
- Nice interactions with geographic elements, eg catchment shapefiles.

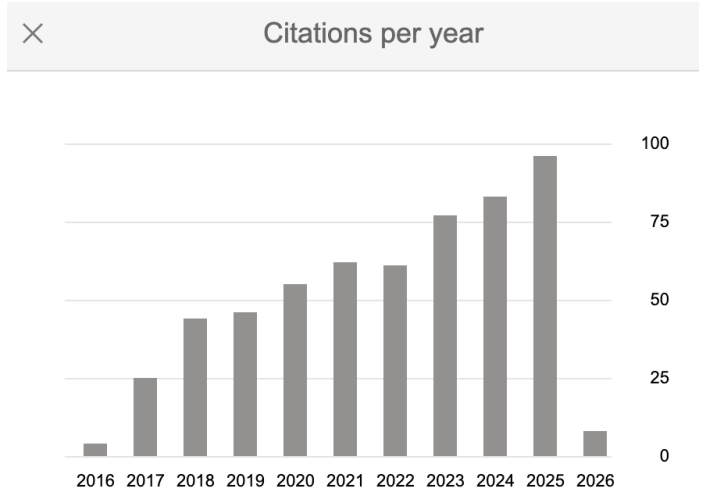


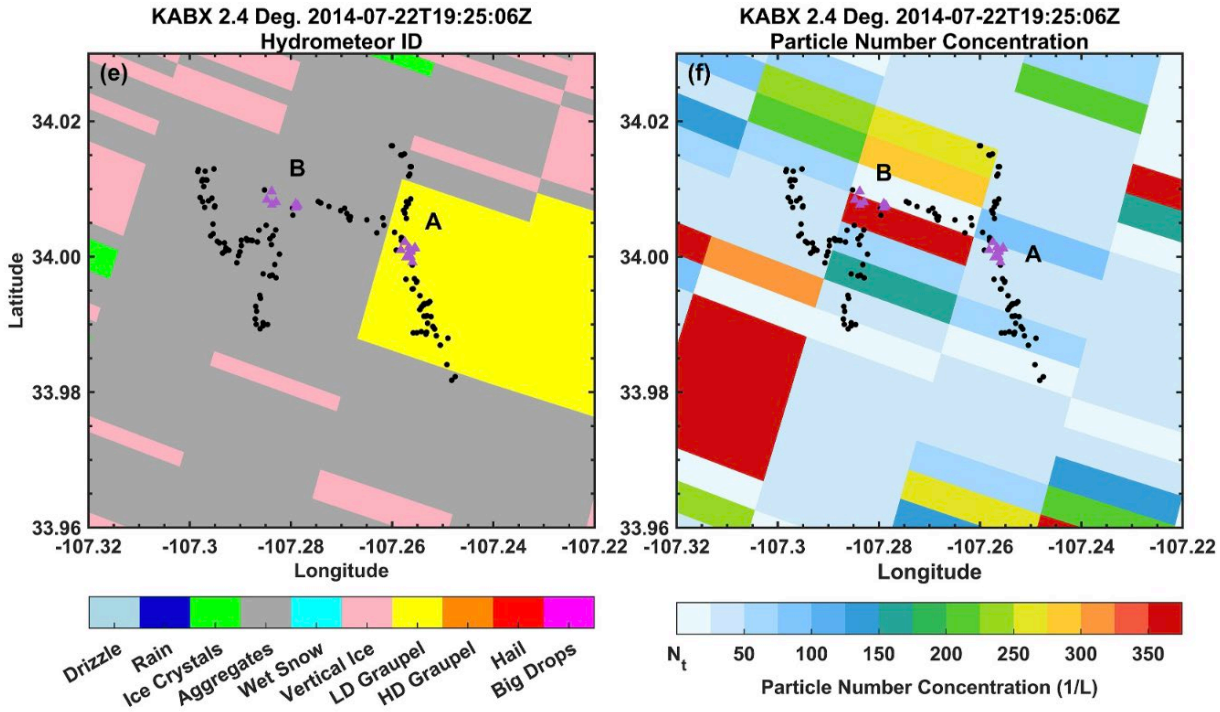


PY-ART

It's all about the data model

- The Python ARM Radar Toolkit. Supported by the ARM User Facility with a network of contributors.
- Rich ecosystem of packages: ART-VIEW, PyTDA, PyDDA, CSU-Radar tools, Pyrad.
- Guided by a five year roadmap, our third roadmap will be out soon!





Li, Y., Zhang, Y., Zhang, Y., Xu, L., &Krehbiel, P. R. (2026). The Microphysicalstructure of thunderstorms in the horizontal development of lightning. JGR: Atmospheres, 131. https://doi.org/10.1029/2025JD045109 Mix of Py-ART and CSU Radar Tools

WHY PYTHON?

- The Python programming language has a rich scientific ecosystem thanks to Numpy and Scipy.
- Python is the language of machine learning.
- Through projects like Pangeo there is a growing ecosystem to address knowledge discovery from massive datasets.

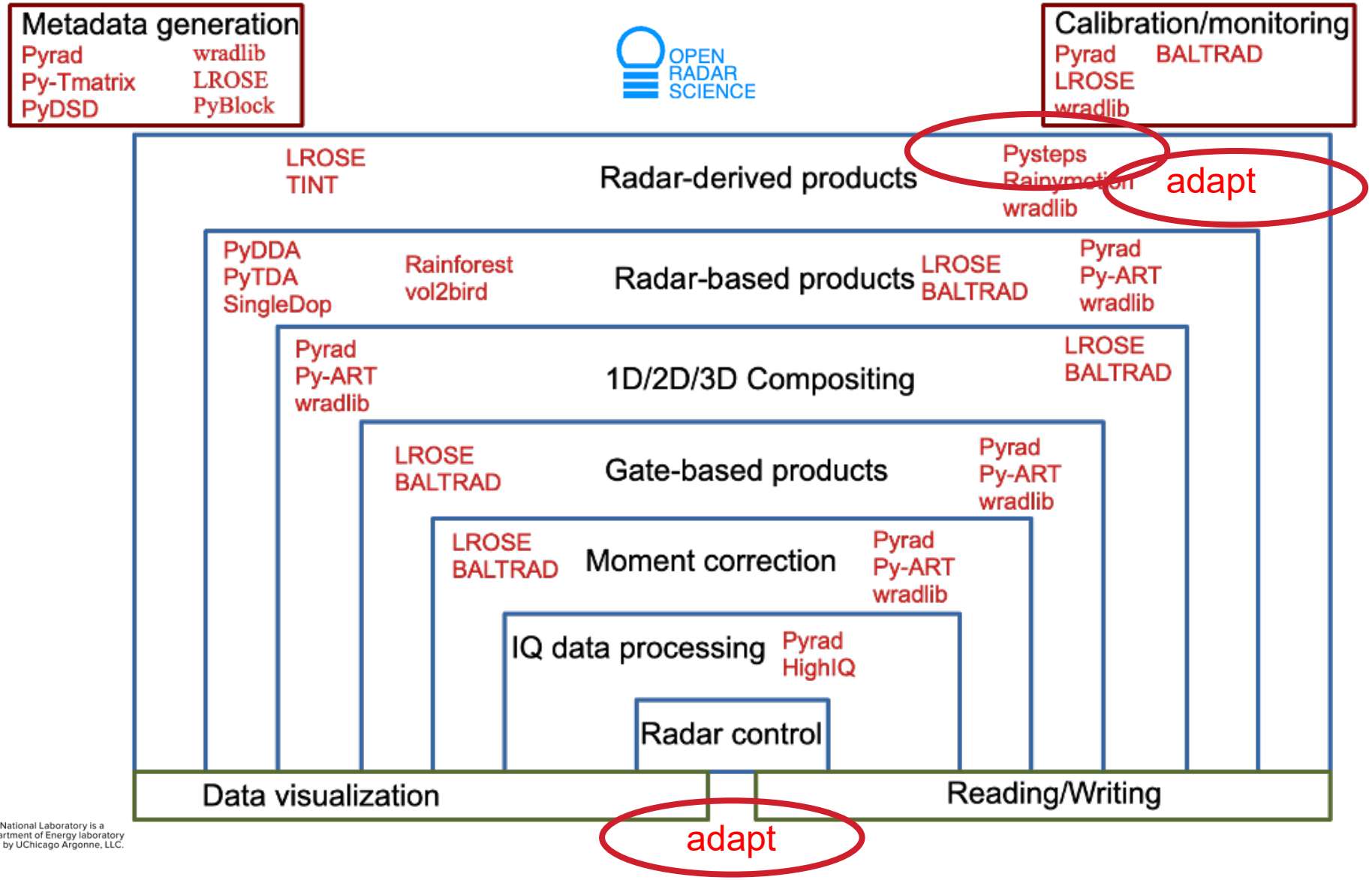
Gentemann, C. L., Holdgraf, C., Abernathey, R., Crichton, D., Colliander, J., Kearns, E. J., et al. (2021). Science storms the cloud. *AGU Advances*, 2, e2020AV000354. **https://doi.org/10.1029/2020AV000354**

XRADAR

An international collaboration on data model driven IO - FM301

- Hatched at ERAD 2022 the leads of the base open radar codes decided to invest in a common IO layer. Linked to FM301 cf-radial.
- This links the radar data models to the, now, robust and powerful xarray data model.
- As our next speaker will show, this unlocks very powerful cloud operations.

TYPICAL DATA CHAIN

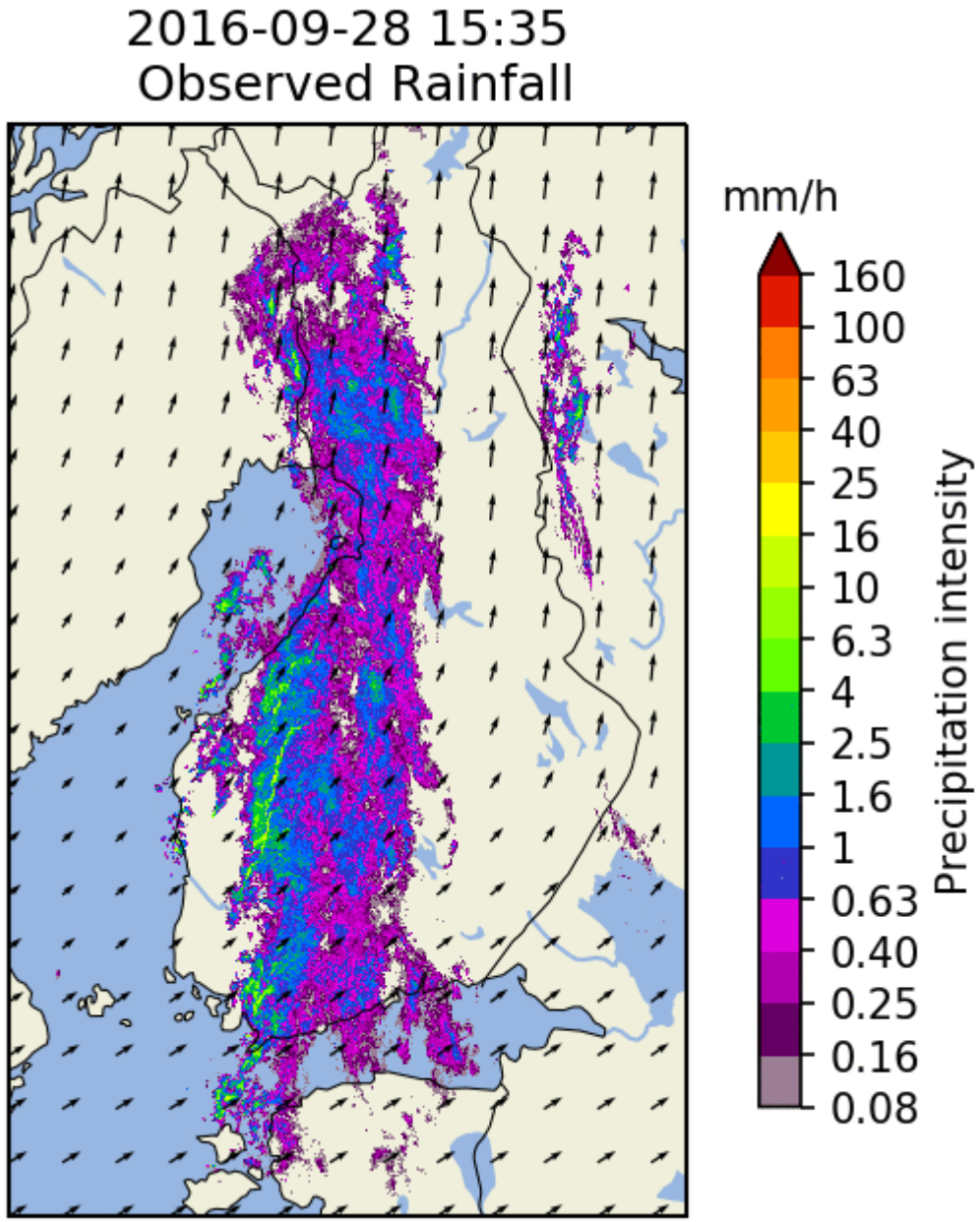


PY-STEPS

Precipitation nowcasting

- Part of a wider open source nowcasting initiative.
- Probabilistic nowcasting of “image like” data through Lagrangian projection and the addition of stochastic perturbations.

Library	Language	Website	Availability	Reference
Com-SWIRLS	Python, C++	https://com-swirls.org (last access: 23 September 2019)	Open source*	Wong et al. (2016)
IMPROVER	Python, Shell	https://improver.readthedocs.io (last access: 23 September 2019)	Open source	Flowerdew (2018)
INCA	C, Fortran, Shell	https://www.zamg.ac.at (last access: 23 September 2019)	Free license	Haiden et al. (2011)
pysteps	Python	https://pysteps.github.io (last access: 23 September 2019)	Open source	This study
rainymotion	Python	https://github.com/hydrogo/rainymotion (last access: 23 September 2019)	Open source	Ayzel et al. (2019)
STEPS	C, C++	https://www.bom.gov.au (last access: 23 September 2019)	Free license	Bowler et al. (2006), Seed et al. (2013)



Pulkkinen, S., Nerini, D., Pérez Hortal, A. A., Velasco-Forero, C., Seed, A., Germann, U., and Foresti, L.: Pysteps: an open-source Python library for probabilistic precipitation nowcasting (v1.0), Geosci. Model Dev., 12, 4185–4219, https://doi.org/10.5194/gmd-12-4185-2019, 2019.

ADAPT

Building a standardized open adaptive scanning system

- Designed for informed real-time adaptive scanning in ARM field campaigns.
- Configurable, predefined pipelines: Acquisition, Detection, Analysis, Projection, and Tracking.
- Built on **Py-ART and Xarray** with modular, replaceable components for gridding, segmentation, and polarimetric variable handling.

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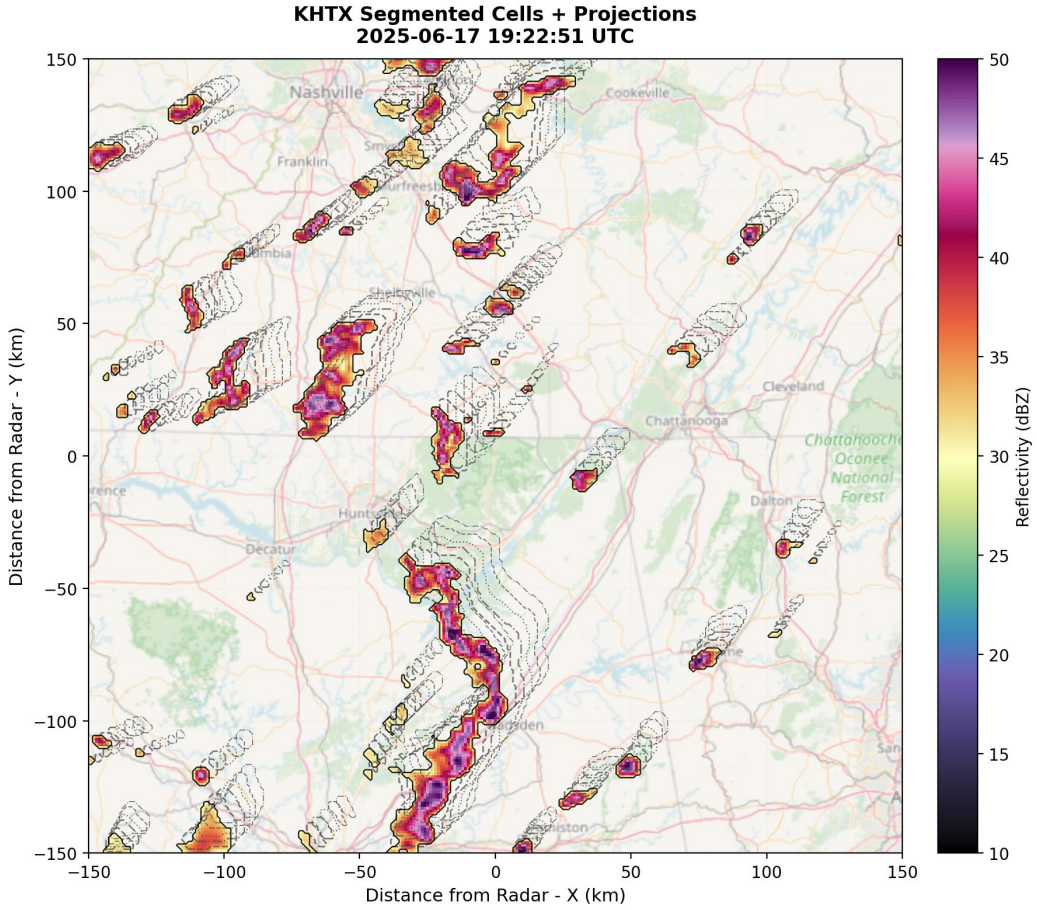


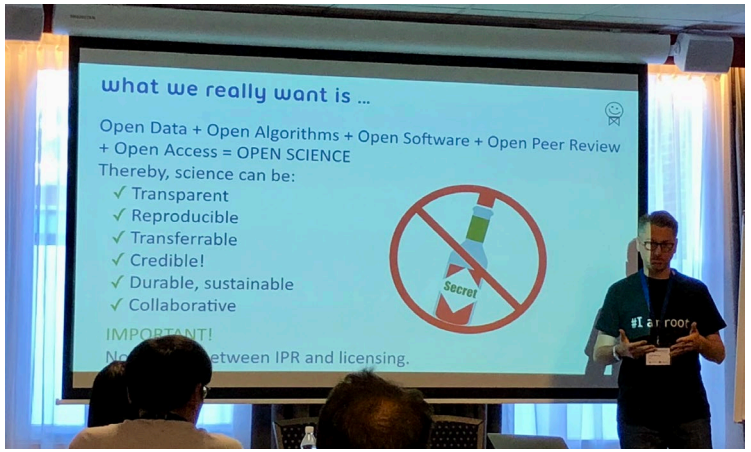
OVER A DECADE OF OPEN RADAR COURSES

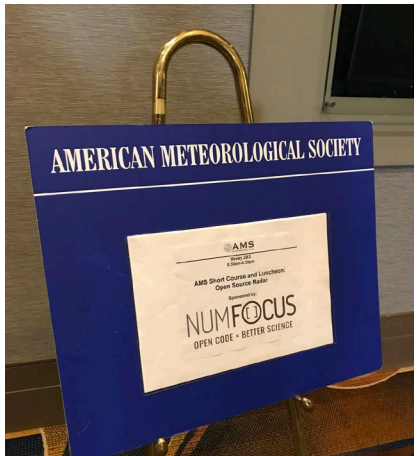
https://openradarscience.org

ERAD and AMS since 2013

- Toronto 2025, Rome, 2024 Minneapolis 2023, Locarno 2021, Nara 2019, Utrecht 2018, Chicago 2017, Antalya 2016, Norman 2015, Garmisch 2014.
- All open. Developing the workforce of the future. Each course focusing on interoperability.

https://openradar.discourse.group/





DATA FORMATS AND EXCHANGE

Super simple: FM301

- No proprietary formats please!
- FM301/CF Radial 2.0 is **the way to store and disseminate radar data.**
- Zarr allows distributed radar data. This allows for Cloud Optimized Analysis Ready (ARCO) data. The next speaker will say a lot more!
- Maintaining Data archives and software is like doing the dishes: Unless you never plan to use it again you will always be doing it!
- Always add DOIs always cite data!

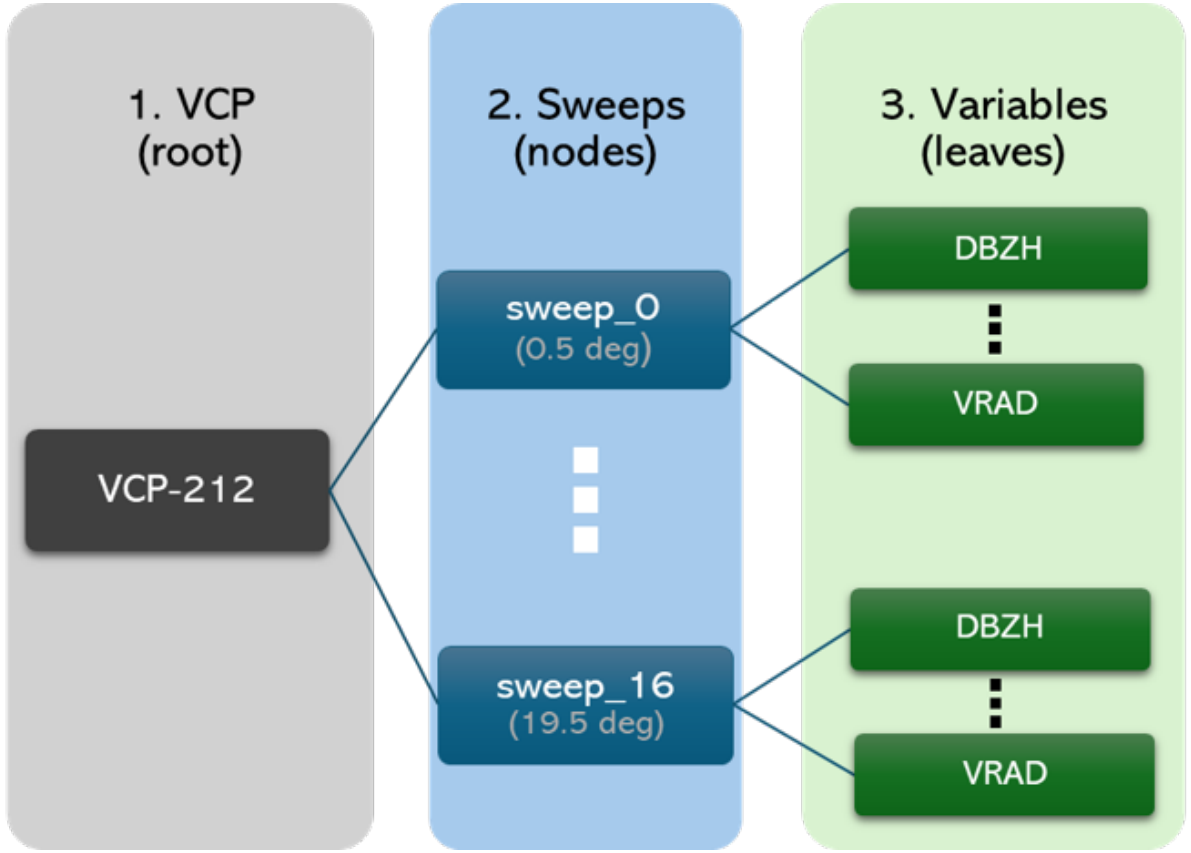
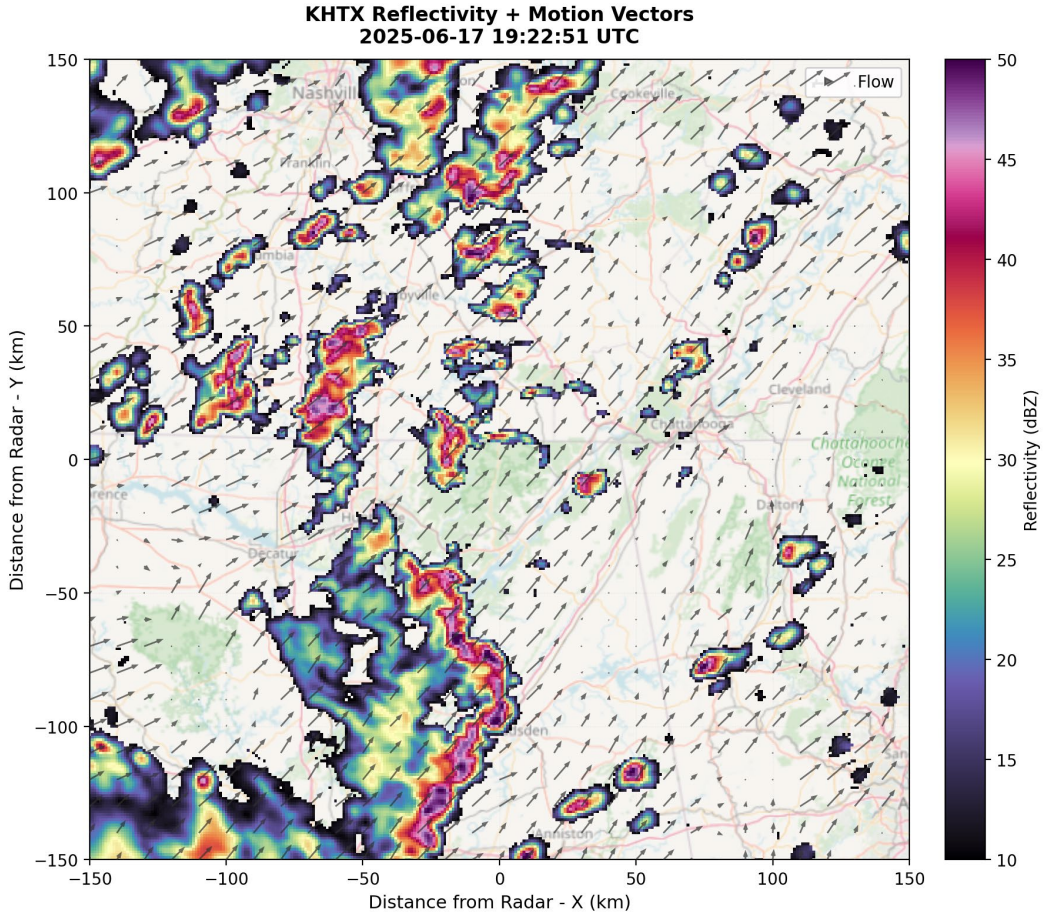


Image courtesy Alfonso Ladino-Rincon

COMMUNITY SOFTWARE IS A NATURAL R2O CONDUIT

Well engineered software is how we can share science to operations

- Good software is tested and can be deployed on a variety of systems.
- By implementing algorithms on a community software base layer and sharing code these algorithms can be used in testbed etc..
- Community software and data also enables O2R! Think of how much science is done with NEXRAD.



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https://www.linkedin.com/in/scott-collis-open/