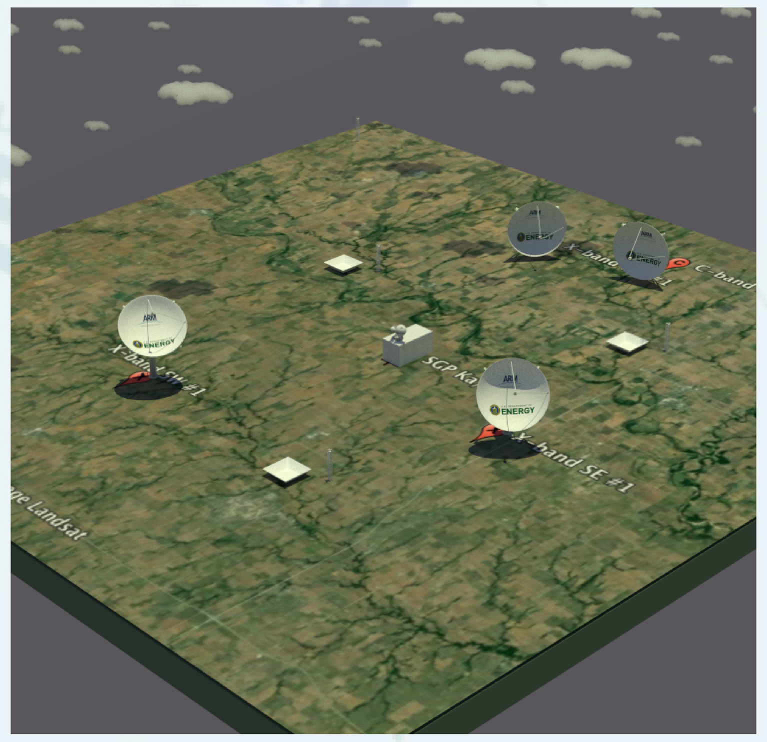
Architectures for Rainfall Property Estimation From Polarimetric Radar

Scott Collis[1] scollis@anl.gov, Scott Giangrande[2], Jonathan Helmus[1] and Silke Troemel[3]

1: Argonne National Laboratory Argonne, IL United States
2: Brookhaven National Laboratory, Upton, NY United States
3: Meteorologisches Institut der Universität Bonn, Bonn, Germany

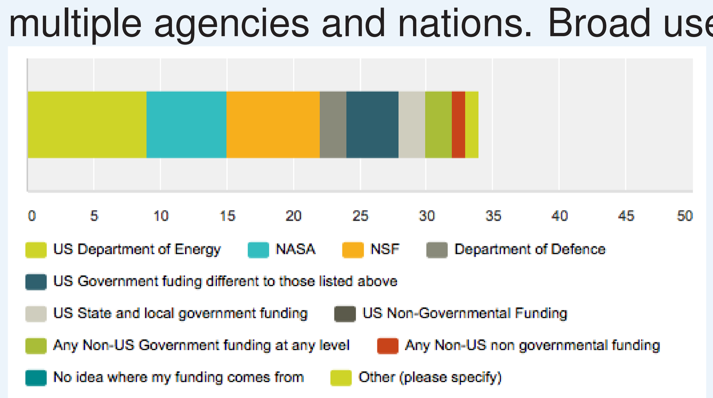
Introducton

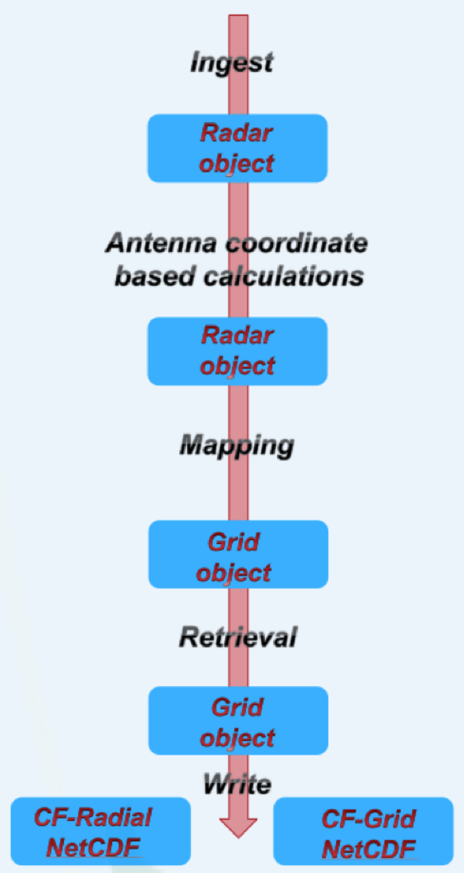
- Numerical simulations of decadal climate are done at resolutions far courser than the natural scale of precipitation. To even have a chance of understanding future precipitation extremes we must reconcile the relation between the statistics of broad-scale precipitation and high resolution observations.
- To this end The Department of Energy's ARM Climate Research Facility operates a network of 5 and 3 cm scanning radar systems.
- Fixed sites are at the Azores, Barrow on the North Slope of Alaska and a multi-scale heterogeneous network on the Southern Great Plains of Oklahoma.



Achieving insight with the community: The Python ARM Radar Toolkit

- Weather radars are not a new invention, first academic mention in Bent et al. (1943).
- Massive advances in computing and radar software has not kept up.
- They Python ARM Radar Toolkit, Py-ART is a data model driven architecture for interactively and offline processing of active remote sensing data. Open source and, using GitHub, community based.
- Part of a larger growing international community of codes, see Heistermann et al. (2014)
- Twenty four forks, eight active contributors from multiple agencies and nations. Broad user base.





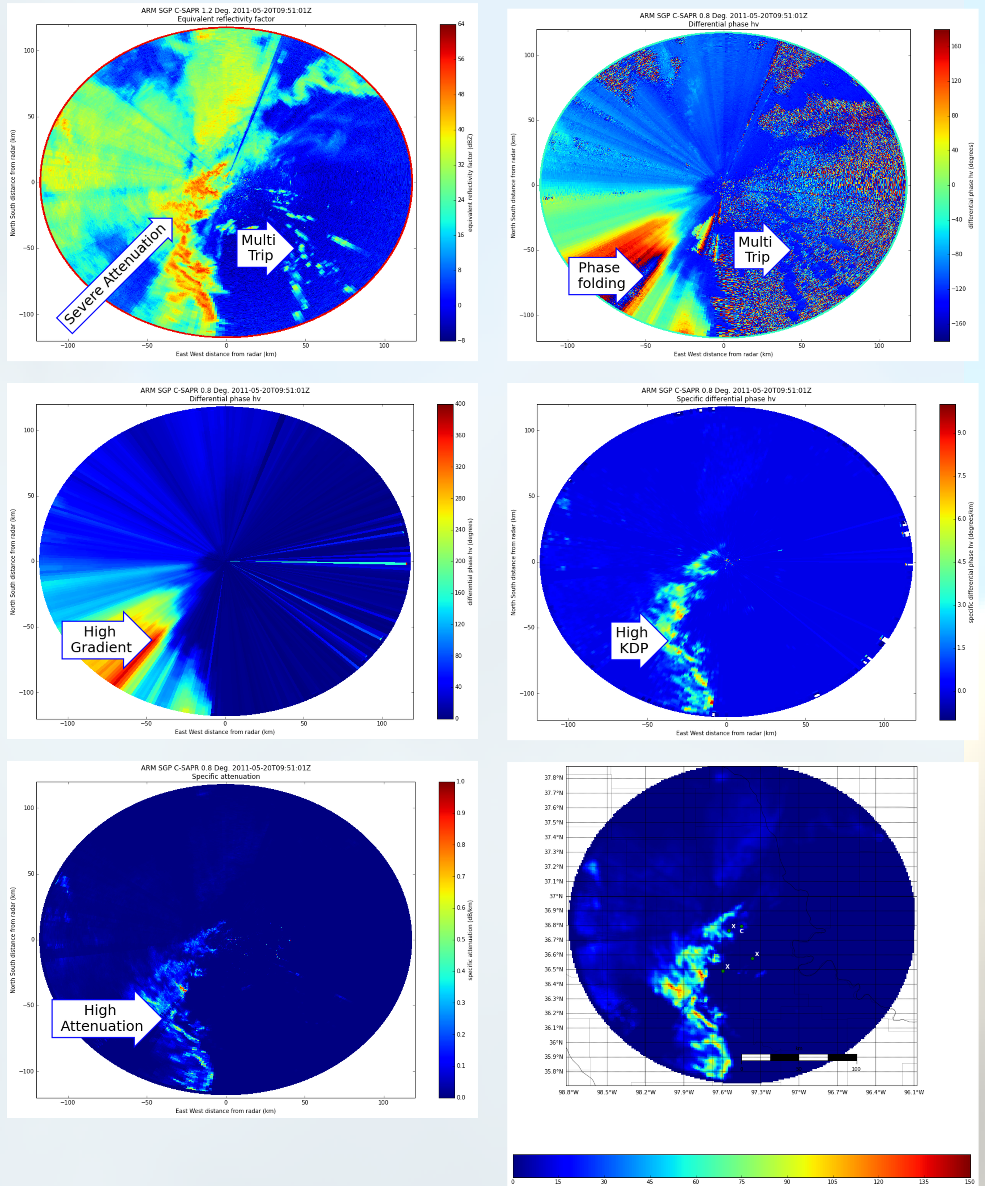
Links

The Python ARM Radar Toolkit : http://arm-doe.github.io/pyart/

This is an open source poster, for notebooks, code and tex: http://github.com/scollis/AGU 2014

Raw data to Quantitative Precipitation Estimates

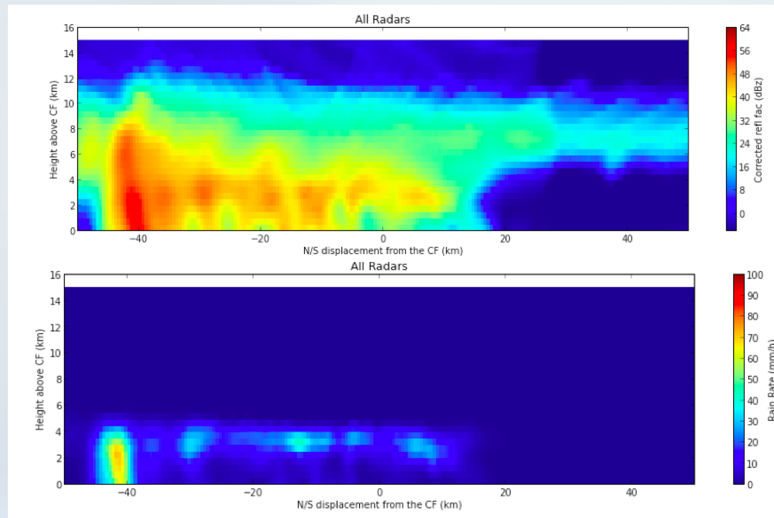
- Raw collected radar data in engineering units is unsuitable for comparison with model data.
- Shorter wavelength radar have a higher attenuation cross section. However Signal to noise in phase information much higher and calibration insensitive.
- Measured phase is a mix of propagation phase, phase shift on backscatter and artifacts: $\phi_{dp}^{signal}(r) = \phi_{dp}^{prop}(r) + \delta(r) + E(r)$.
- When calculating Specific Differential Phase, K_{dp} only the propagation component should be considered, $K_{dp} = \frac{d\phi_{dp}^{prop}(r)}{dr}$.
- Method of Giangrande et al. (2013) used to extract ϕ_{dp}^{prop} and a 20 point sobel filter $K_{dp} = \phi_{dp}^{prop} * f_{20} = \sum_{M=0}^{19} \phi_{dp}(r-M)f(M)$ where $f(M)$ is a linear ramp through zero.



- Specific attenuation is calculated using K_{dp} and Z_e using a method after Gu et al. (2011) and is used as a an estimator for rainfall using a method after Ryzhkov et al. (2014).

Mapping: Objective analysis

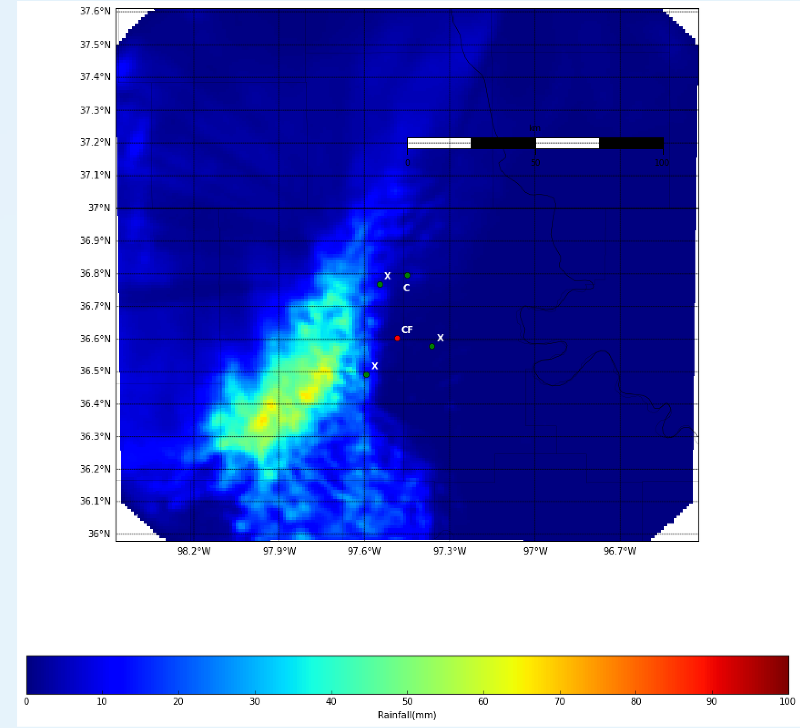
- Radar data is on , θ and ϕ coordinates, there is a need to estimate on different coordinates systems (Cartesian, Sigma, pressure).
- Py-ART tags each gate with an estimate of its central coordinate and inserts these into a cloud.
- For propagation insensitive variables (not radial velocity or ϕ_{dp}), gates can be drawn from mulitple radars to be estimated onto a single grid.



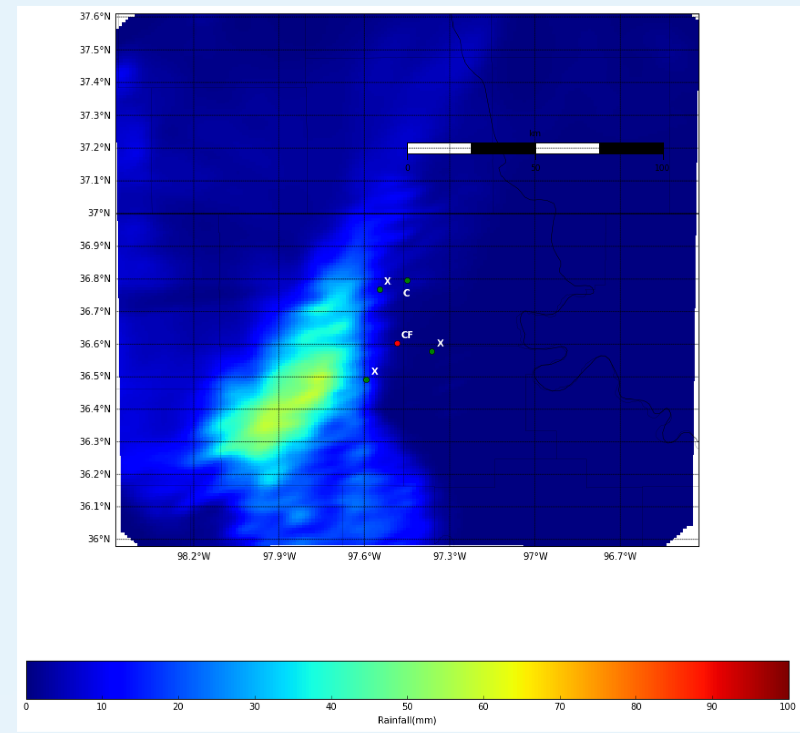
- In Py-ART the act of gridding takes in a *n-tuple* of radar objects and returns a grid object which can be saved to a CF-Radial complaint file.

```
mesh_mapped_x = pyart.map.grid_from_radars((xnw_radar,xsw_radar,xse_radar),
                                           grid_shape=(35, 401, 401),
                                           grid_limits=((0, 17000), (-50000, 40000), (-60000, 40000)),
                                           grid_origin = (36.57861, -97.363611),
                                           fields=['corrected_reflectivity', 'rain_rate_A', 'reflectivity'],
                                           refl_field='corrected_reflectivity',
                                           max_refl=100.)
```

Advective interpolation



- Simply accumulating precipitation retrievals by integrating can create a "chain of pearls effect" due to the lack of spatial coherency between successive radar scans.



References

Bent, A. E., Massachusetts Institute of Technology., and Radiation Laboratory., 1943: *Radar echoes from atmospheric phenomena*. Radiation Laboratory, Massachusetts Institute of Technology, [Cambridge, Mass.].

Giangrande, S. E., R. McGraw, and L. Lei, 2013: An application of linear programming to polarimetric radar differential phase processing. *Journal of Atmospheric and Oceanic Technology*, **30**, 1716–1729, doi:10.1175/JTECH-D-12-00147.1.
URL http://journals.ametsoc.org/doi/abs/10.1175/JTECH-D-12-00147.1

Gu, J.-Y., A. Ryzhkov, P. Zhang, P. Neilley, M. Knight, B. Wolf, and D.-I. Lee, 2011: Polarimetric attenuation correction in heavy rain at c band. *J. Appl. Meteor. Climatol.*, **50**, 39–58, doi:10.1175/2010JAMC2258.1.
URL http://journals.ametsoc.org/doi/abs/10.1175/2010JAMC2258.1

Heistermann, M., S. Collis, M. J. Dixon, S. Giangrande, J. J. Helmus, B. Kelley, J. Koistinen, D. B. Michelson, M. Peura, T. Pfaff, and D. B. Wolff, 2014: The emergence of open source software for the weather radar community. *Bull. Amer. Meteor. Soc.*, doi:10.1175/BAMS-D-13-00240.1.
URL http://journals.ametsoc.org/doi/abs/10.1175/BAMS-D-13-00240.1

Ryzhkov, A., M. Diederich, P. Zhang, and C. Simmer, 2014: Potential utilization of specific attenuation for rainfall estimation, mitigation of partial beam blockage, and radar networking. *J. Atmos. Oceanic Technol.*, **31**, 599–619, doi:10.1175/JTECH-D-13-00038.1.
URL http://journals.ametsoc.org/doi/abs/10.1175/JTECH-D-13-00038.1

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