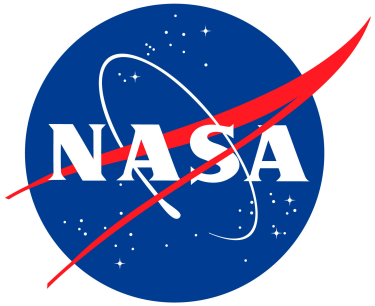
python

Marshall Space Flight Center and the open-source radar software revolution

Timothy J. Lang



Brenda Dolan, Brody Fuchs, Paul Hein, Elizabeth Thompson

Colorado State University

Scott Collis, Jonathan Helmus

Argonne NATIONAL LABORATORY

Nick Guy

Acknowledgments

Jason Burks, Steve Nesbitt, George Priftis, Brent Roberts

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Background

My radar software history …

Graduate School – RDSS, Reorder, SPRINT, Fortran, and pltgks

Research Scientist – IDL, solo, Reorder, SPRINT

NASA Civil Servant (2012) – Stick with IDL or go Python?

NASA Marshall's Lightning Group is mostly an IDL shop

But folks are receptive to Python and some want to learn!

I made the switch in early 2014

MSFC Science Goals

1. Understand lightning production in extreme weather events – *GLM, ISS-LIS*

2. Validate precipitation estimates from space – *GPM*

3. Study how well scatterometers characterize convective variability – *RapidScat, CYGNSS*

Open-source radar software, powered by Python, plays a prominent role in all of these tasks!

Marshall MRMS Mosaic Python Toolkit (MMM-Py)

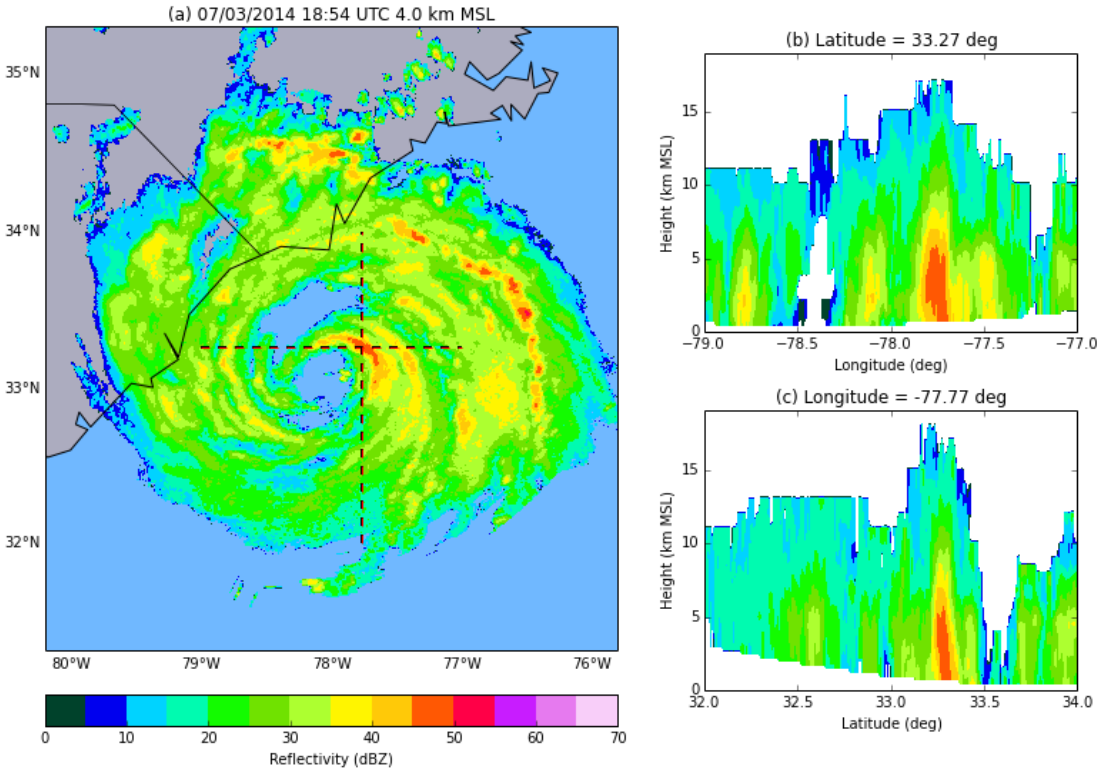
https://github.com/nasa/MMM-Py

Goal

Simplify the ingest, analysis, and display of NOAA MRMS 3D radar reflectivity mosaics in a Python environment

Features

- Can read any format MRMS, from 2009 onward
- Easy tile merging and domain subsetting
- Customizable plotting methods
- Save custom mosaics to file
- Demonstration Jupyter notebooks available



Python Turbulence Detection Algorithm (PyTDA)

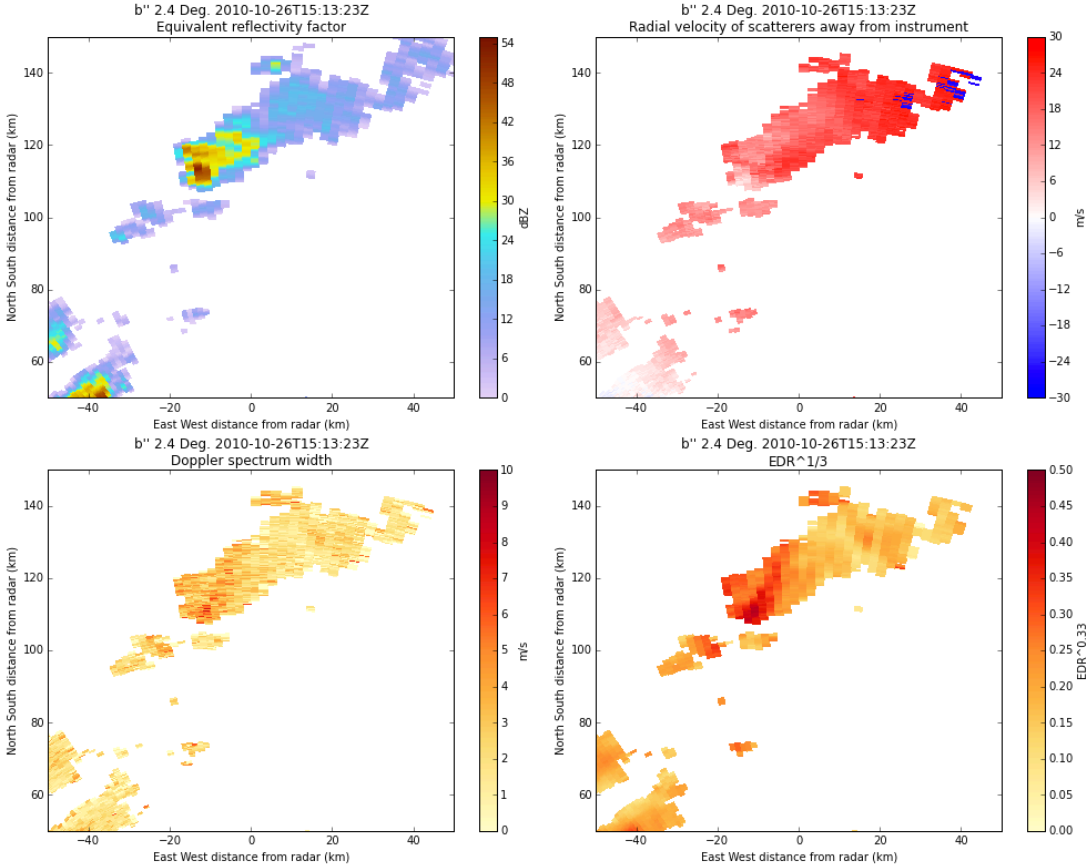
https://github.com/nasa/PyTDA

Goal

Estimate eddy dissipation rate (EDR) from arbitrary Doppler radar sweep or volume

Features

- Module contains independent functions for processing
- Works seamlessly with Py-ART Radar object
- NTDA-like filtering and quality control of data if desired
- Uses sklearn trees, NumPy function broadcasting, and some Cython to allow near real-time use on a laptop



Single Doppler Retrieval Toolkit (SingleDop)

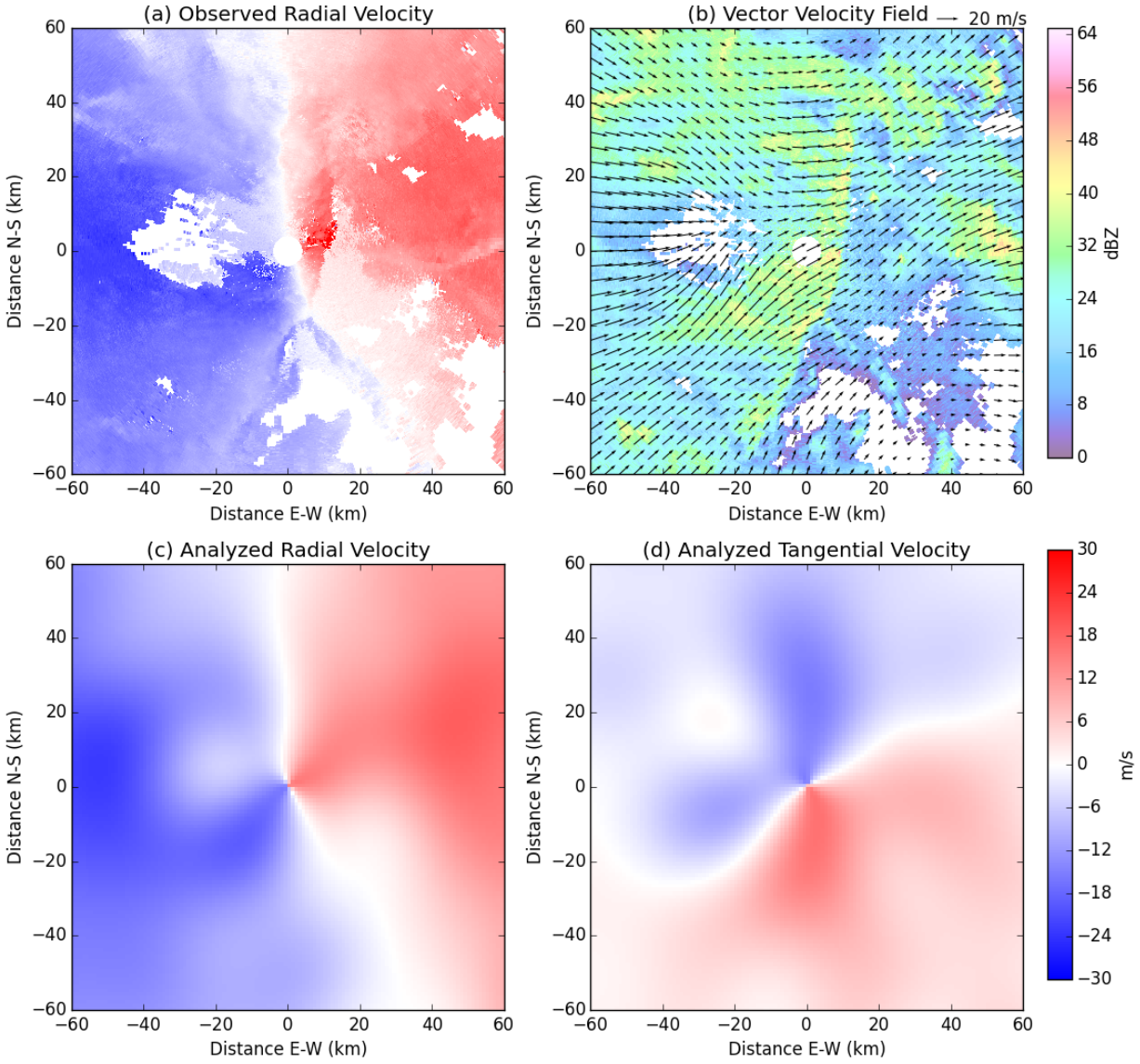
https://github.com/nasa/SingleDop

Goal

Estimate low-level 2D winds from single Doppler radar

Features

- Xu et al. (2006) method
- Works with real or simulated radar data
- Background field can be specified or determined via VAD
- Uses Py-ART for data input and display
- Output gridded analyses to Python-readable binary (pickle) or netCDF (xray)
- Contour, vector, and mixed multi-panel plots supported



Colorado State University Radar Tools (CSU_RadarTools)

https://github.com/CSU-Radarmet/CSU_RadarTools

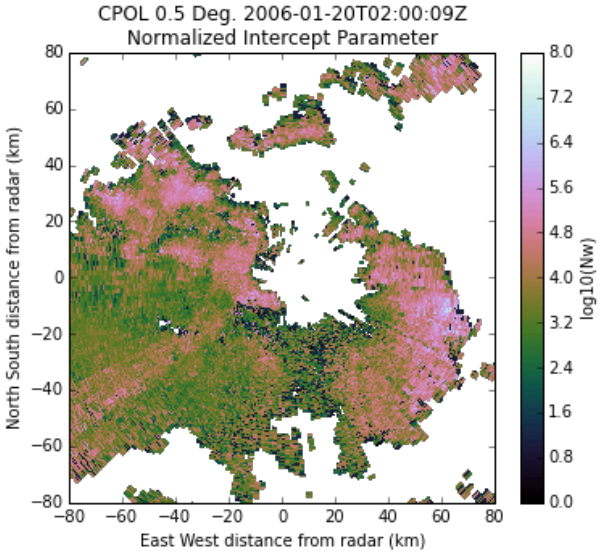
Colorado State University

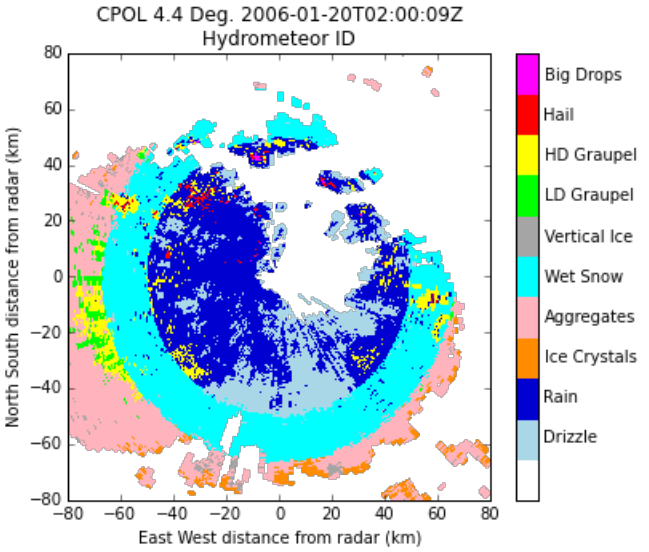
Goal

Provide routine polarimetric radar analysis and QC tools originally developed/used at CSU

Features

- Independent of any other software framework
- Works with ndarrays or scalars
- CSU Fuzzy-Logic Hydrometeor ID (X, C, S-band)
- CSU Blended Rainfall Calculations
- CSU Ice and Liquid Water Mass calculations
- CSU Drop-Size Distribution calculations
- CSU KDP calculations (FIR based)
- Miscellaneous QC (insect filter, despeckling, etc.)
- Each works as importable sub-module
- Thorough demo notebook available, shows how to use with SkewT and Py-ART.





Python Interface to Dual-Pol Radar Algorithms (DualPol)

https://github.com/nasa/DualPol

Goal

Simple workflow for merging CSU_RadarTools with Py-ART

Features

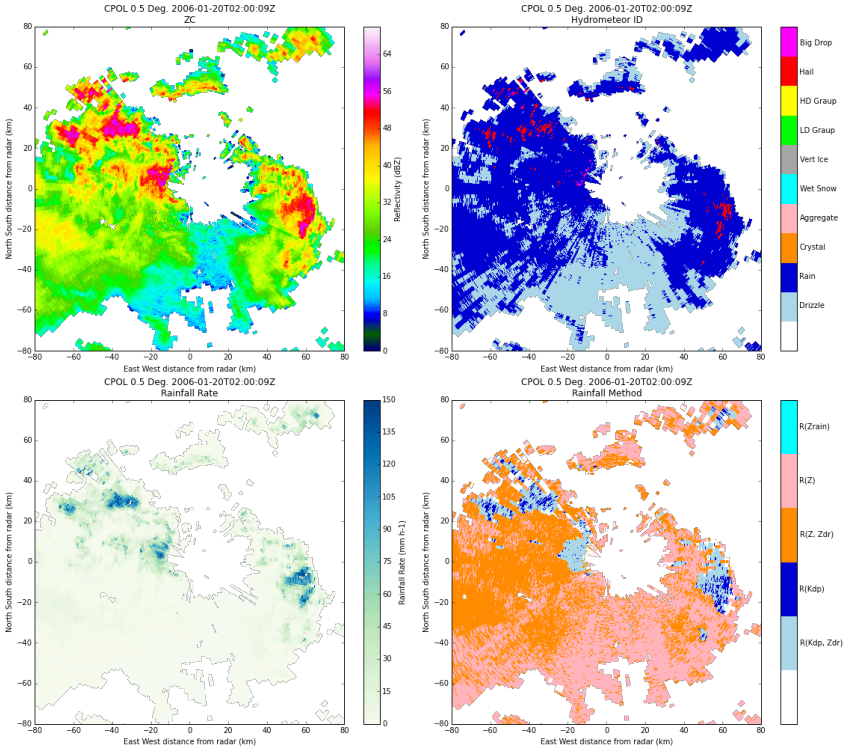
- One-line implementation for dual-pol retrievals and integrating them within Py-ART radar object
- Class that simplifies display of HID & rain method colorbars

In [4]:
```
sndfile = '/Users/tjlang/Documents/OVWST/CPOL/soundings/snd_Darwin.txt'
retrieve = dualpol.DualPolRetrieval(files[0], dz='ZC', dr='ZD', kd='KD', rh='RH',
                                    use_temp=True, band='C', fhc_method='hybrid',
                                    sounding=sndfile, fhc_T_factor=2,
                                    ice_flag=True, rain_method='hidro')
```

In [5]:
```
print retrieve.radar.fields.keys()
```

```
[u'DC', u'DZ', 'FH', u'FL', u'HD', u'PF', u'PH', u'RH', 'method', 'NW', u'AD', u'ZD', u'AH',
'rain', u'ZC', u'VR', u'KD', u'SR', 'MI', 'MU', 'MW', 'D0']
```

In [11]:
```
display = pyart.graph.RadarDisplay(retrieve.radar)
swp = 0
lim = [-80, 80]
fig = plt.figure(figsize=(16, 14))
ax1 = fig.add_subplot(221)
display.plot_ppi('ZC', swp, vmin=0, vmax=70, cmap='gist_ncar')
display.cbs[0].ax.set_ylabel('Reflectivity (dBZ)')
display.set_limits(xlim=lim, ylim=lim)
ax2 = fig.add_subplot(222)
hidcolor = dualpol.HidColors()
display.plot_ppi('FH', swp, vmin=0, vmax=10, cmap=hidcolor.cmaphid)
display.cbs[1] = hidcolor.adjust_fhc_colorbar_for_pyart(display.cbs[1])
display.set_limits(xlim=lim, ylim=lim)
ax3 = fig.add_subplot(223)
display.plot_ppi('rain', swp, vmin=0, vmax=150, cmap='GnBu')
display.set_limits(xlim=lim, ylim=lim)
ax4 = fig.add_subplot(224)
display.plot_ppi('method', swp, vmin=0, vmax=5, cmap=hidcolor.cmapmeth)
display.cbs[3] = hidcolor.adjust_meth_colorbar_for_pyart(display.cbs[3])
display.set_limits(xlim=lim, ylim=lim)
plt.tight_layout()
```



Python Polarimetric Radar Beam Blockage Calculation (PyBlock)

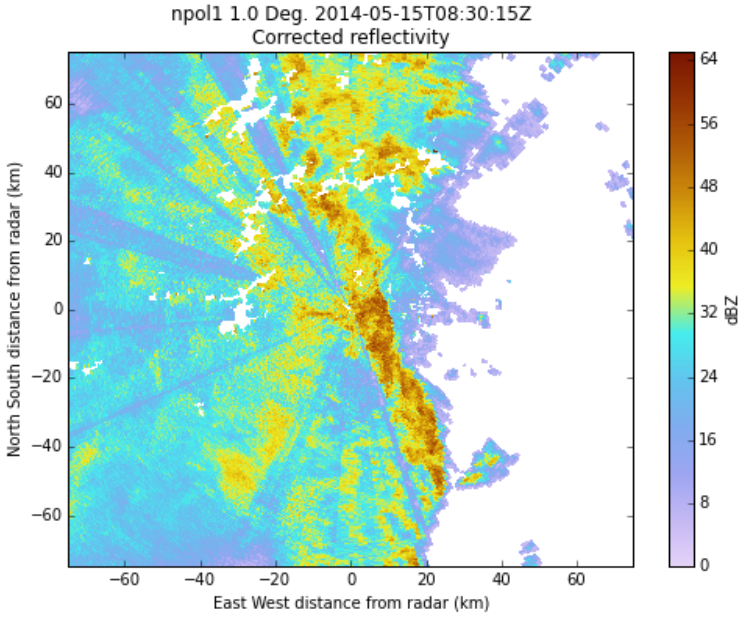
https://github.com/nasa/PyBlock

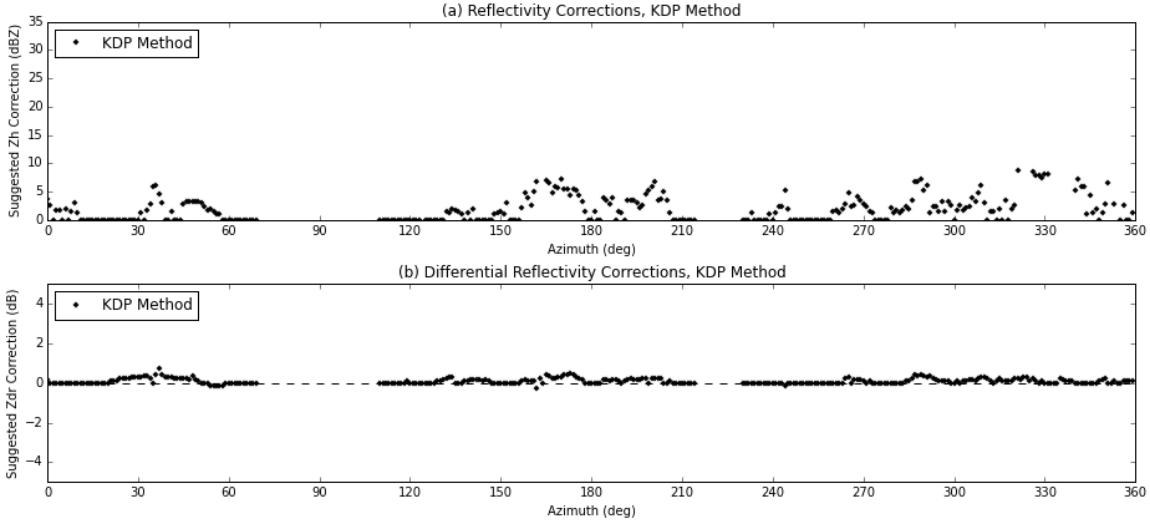
Goal

Calculate beam blockage and estimate corrections needed for polarimetric radar data

Features

- KDP Method from Lang et al. (2009)
- Fully Self-Consistent Method from Giangrande and Ryzhkov (2005)
- Interfaces w/ DualPol, Py-ART, CSU_RadarTools
- Process one volume or an entire field campaign's worth of radar volumes
- Output results to image or file
- Demonstration notebook





Collaborations

Py-ART Contributions

- Color blindness friendlier rainbow color table
- NOXP radar data reader
- Automated dealiasing testing (Poster session #3 today)

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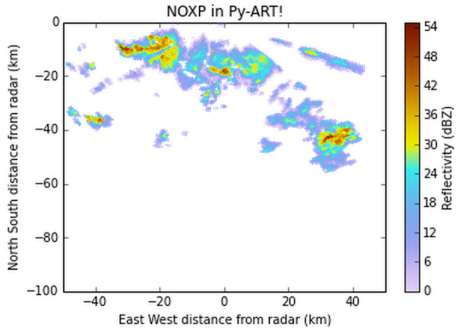
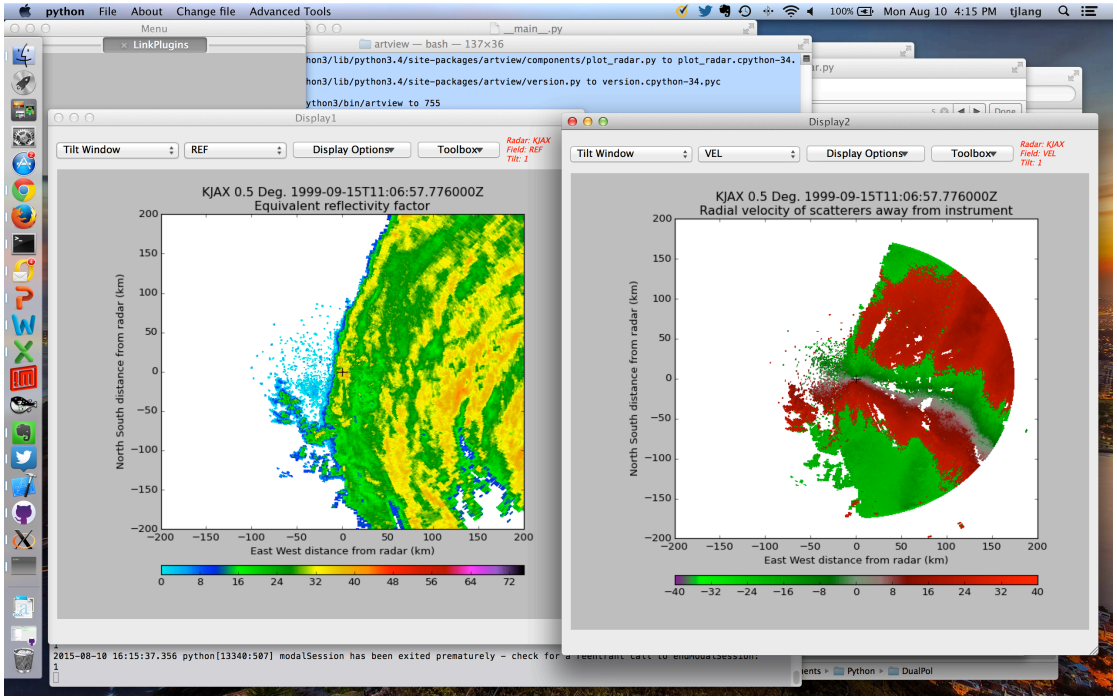
ARTview Contributions

- Minor feature additions
- Code cleanup/bug fixes
- Testing and evaluation

University of Wyoming

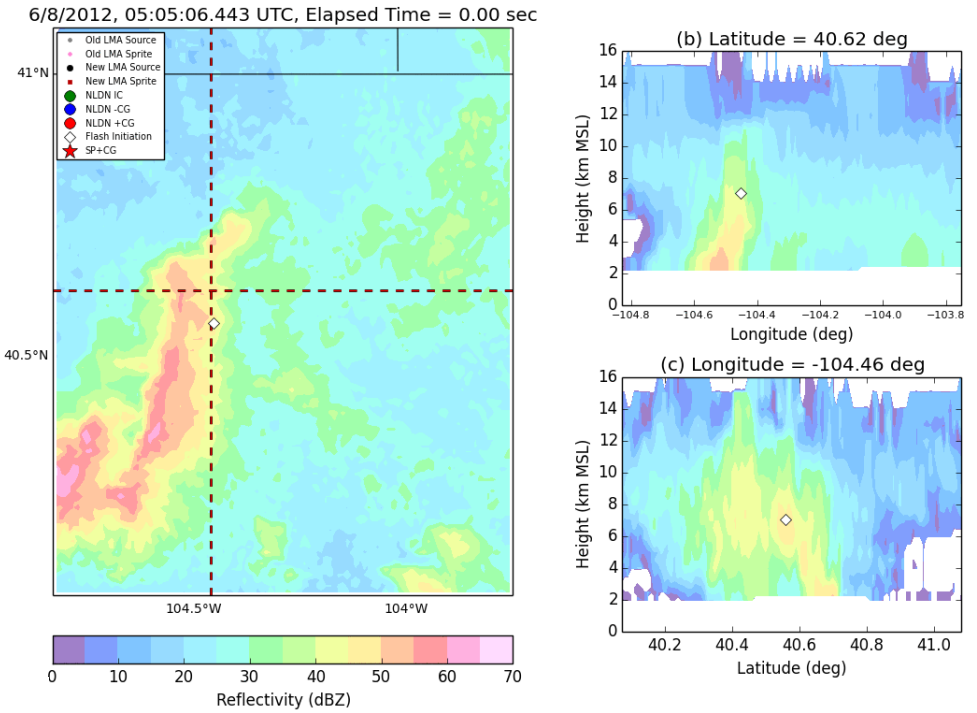
```
In [11]: radar = pyart.aux_io.read_noxp_iphex_nc(files[55], exclude_fields=['m1', 'm2'])
         display = pyart.graph.RadarDisplay(radar)
         display.plot('reflectivity', vmin=0, vmax=55, cmap='pyart_LangRainbow12',
                      title='NOXP in Py-ART!', colorbar_label='Reflectivity (dBZ)')
         lim = [-50, 50]
         display.set_limits(xlim=lim, ylim=[-100, 0])
```

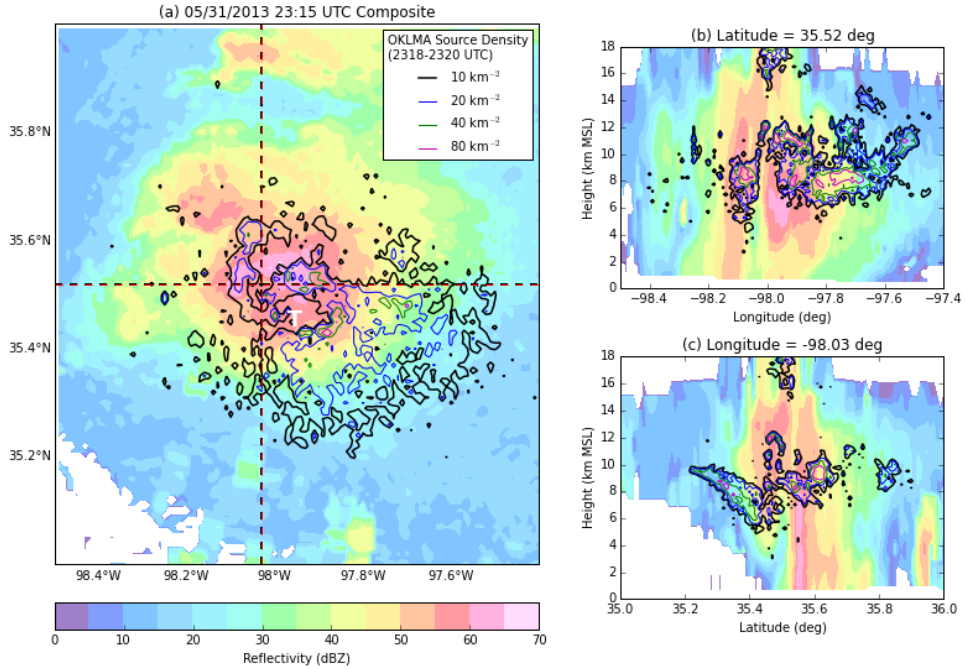




Putting it all together …

MMM-Py combined with in-house Python modules that merge MRMS and Lightning Mapping Array (LMA) data to study storms that produce large charge moment change lightning and/or sprites





- Colorado sprite-producing storm (2012)
- MRMS w/ animated Colorado LMA sources

- El Reno storm (2013)
- Tornadic Stage
- MRMS w/ Oklahoma LMA source densities

Putting it all together …

IPHEx Field Campaign Data Fusion in support of GPM GV

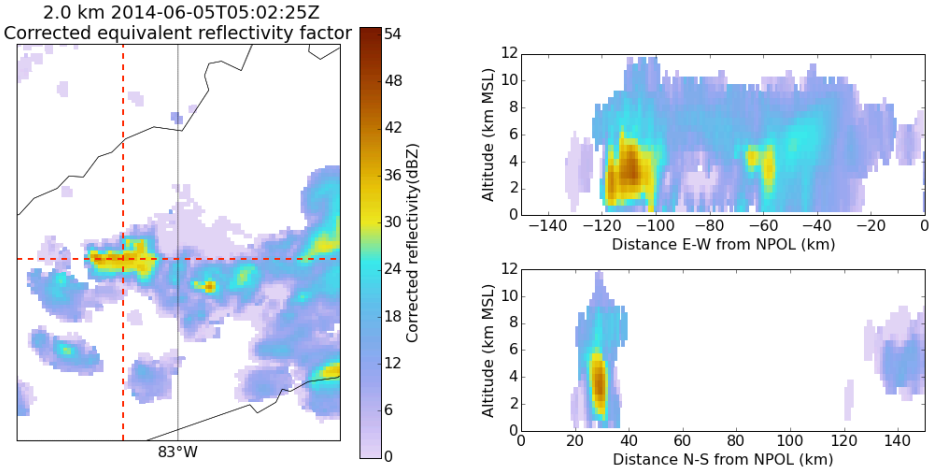
<u>Radars</u>

Mixture of research and ops: NPOL, NOXP, KCAE, KGSP, KHTX, KMRX, KRAX, KFFC

<u>Tasks</u>

- Py-ART to ingest and merge radar volumes onto common grid
- DualPol to compute rainfall and DSD parameters
- CSU_RadarTools to mask insect echoes & high differential phase texture, and despeckle remainder

Z



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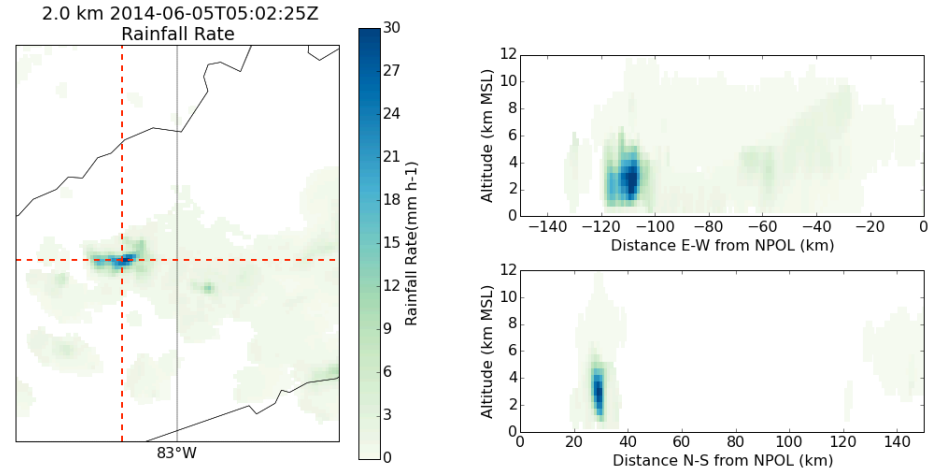

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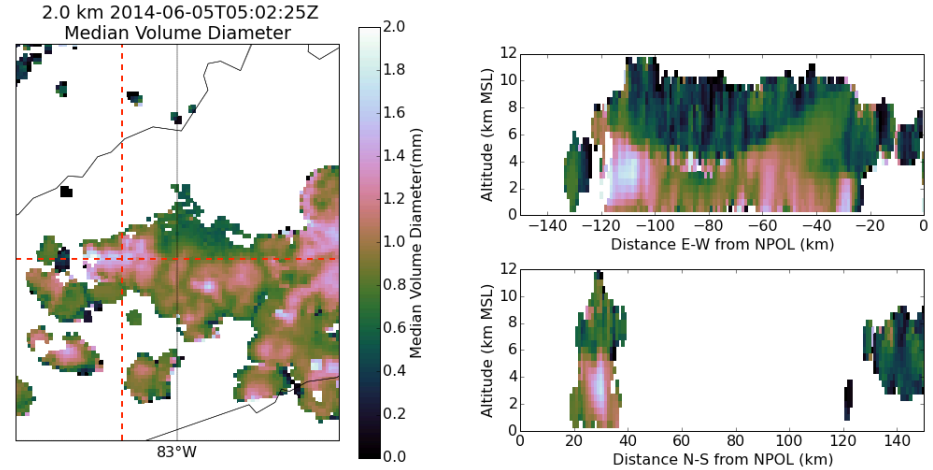
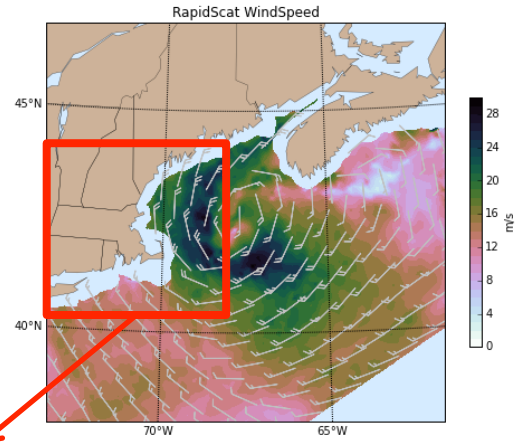
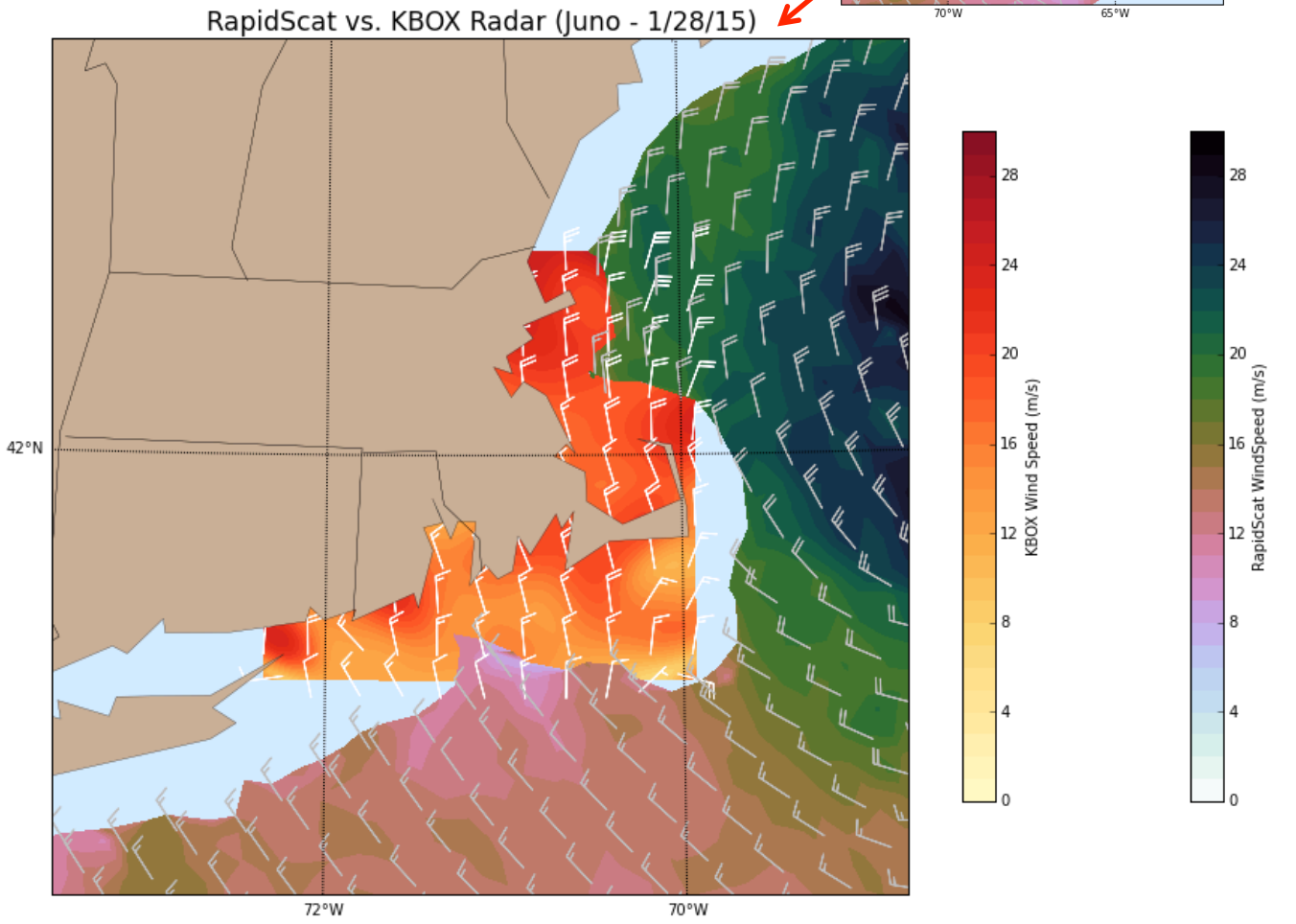


Putting it all together …

Exploring the best ways to compare scatterometers to ground-based Doppler radars





Tasks

- Pydap to ingest RapidScat data via OPeNDAP
- Py-ART to ingest radar data and dealias velocity
- SingleDop to perform 2D low-level wind retrievals
- Also: DualPol, CSU_RadarTools

Summary

Six Radar Modules

1. MMM-Py
2. PyTDA
3. SingleDop
4. CSU_RadarTools
5. DualPol
6. PyBlock

Open source, play nice with Py-ART, support Python 3, & are available on GitHub right now (nasa & CSU-Radarmet)

Contact Info:
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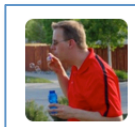
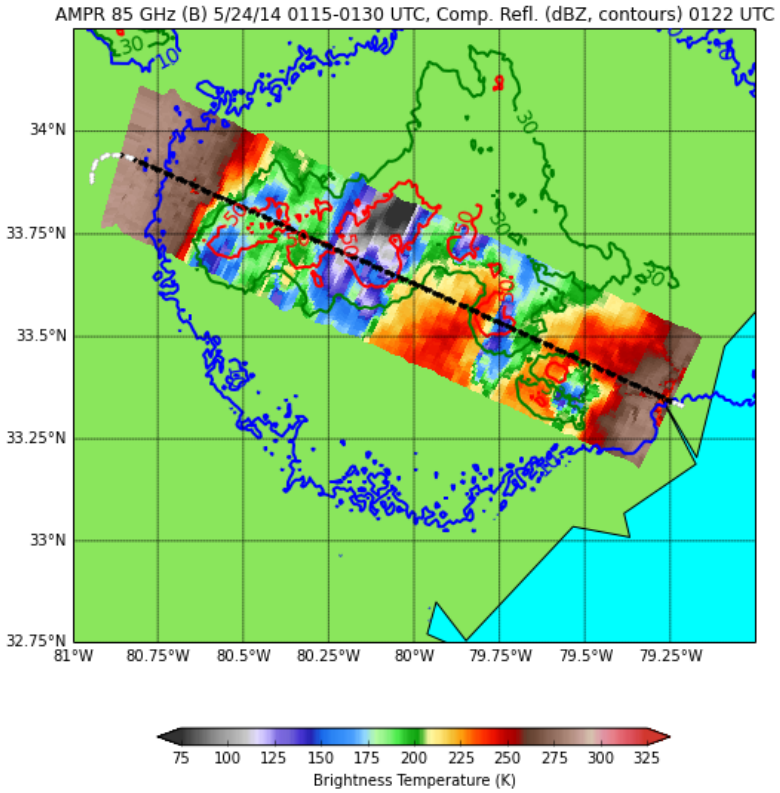


Timothy Lang
@tjlang

Just completed a preliminary case study using Python 3 @Py_ART, ARTview (zenodo.org/record/27358#….), and SingleDop (github.com/nasa/SingleDop)

8/11/15, 10:53 AM

+ PyAMPR!



The Future

Major coding done for now, but some possible ideas for directions to go:

- Merge into MSFC_RadarTools?
- Integration of components within Py-ART or wradlib?
- Make part of some future scikits-radar?
- NASA airborne radar module or interface?

But for now … http://code.nasa.gov takeover!