Data Informatics and Geophysical Retrievals (DIGR)

Argonne NATIONAL LABORATORY

# EVALUATION OF MULTIPLE DOPPLER RETRIEVALS OF CONVECTION IN DARWIN


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10th European Conference on Radar in Meteorology and Hydrology
Ede, Netherlands, 2018


This project is funded by the Climate Model Development and Validation Activity, sponsored by:

ASR Atmospheric System Research

ARM CLIMATE RESEARCH FACILITY

E3SM Energy Exascale Earth System Model


[1] Image source: Wikipedia (Hector)

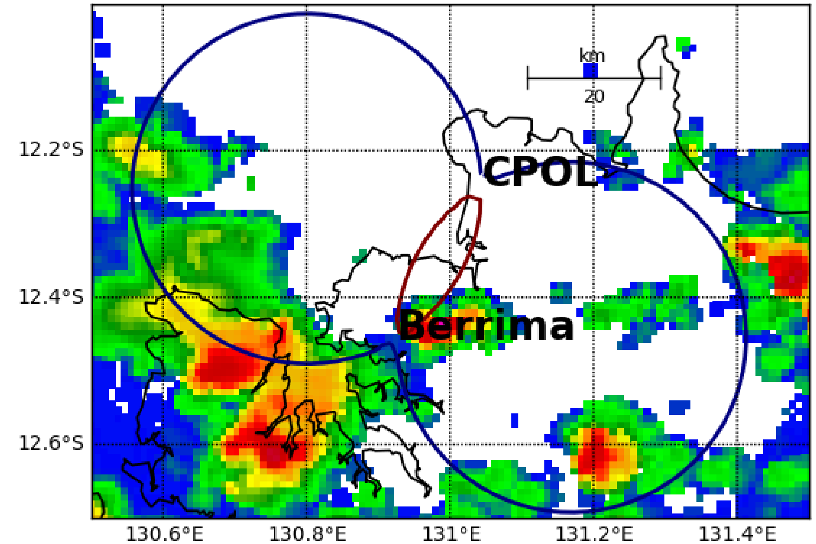
# Motivation

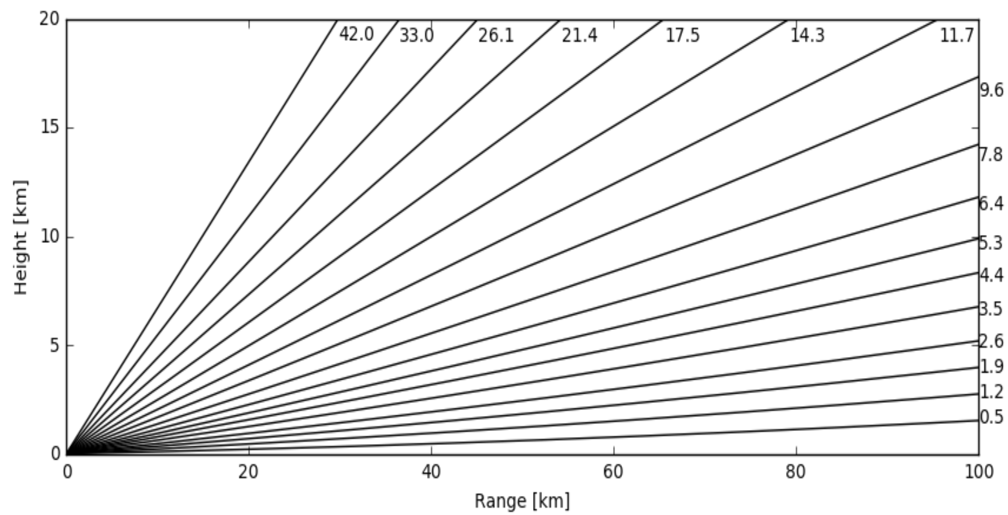
## Climate Model Development and Validation

- DOE’s E3SM model being developed with goal of an increased resolution of 13 km → assumptions made in convective parameterizations may not apply
- Need long term dataset with quantifiable large scale forcings to evaluate performance of convective parameterizations
- Vertical velocities are critical for calculating mass fluxes but are poorly represented in GCMs
- Dual Doppler techniques can retrieve vertical velocities, but uncertainties can be high due to sampling, mass continuity assumptions, fall speed assumptions, boundary conditions
- Can use high-resolution model simulated radar variables to assess impacts of such uncertainties

# Darwin

- The C-band POLarization Radar (CPOL) collected 17 wet seasons of full volume scans from 1998-2017 (excluding 2007/8, 2008/9 wet seasons).
- We like Darwin as a testbed because of quantifiable large scale forcing! (See: “CONVECTIVE CLOUD TOP HEIGHTS IN NORTHERN AUSTRALIA IN DIFFERING WET SEASON REGIMES” @ Tuesday, 3 July, 11:00-11:15)
- In addition, there is an operational radar located at Berrimah in addition to CPOL at Gunn Pt.
- CPOL/Berrimah made synchronized PPI scans every 10 minutes at 15 elevations:



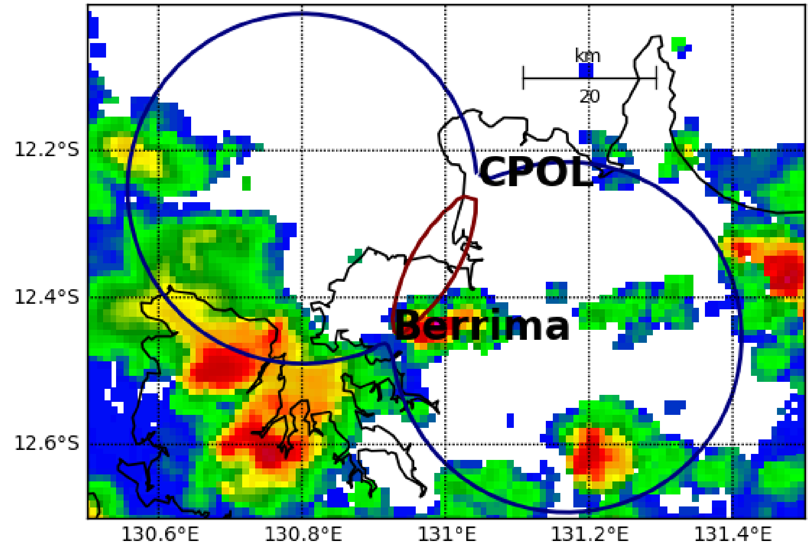
# 3D Variational Technique (3DVAR)

The 3D Variational technique retrieves the winds u, v, w by minimizing a cost function J:

$$J = c_o J_o + c_m J_m + c_o J_s + c_v J_v$$

Where:

- $J_o$ = MSE between radar radial velocity and retrieved winds
- $J_m$ = Proportional to $\nabla \cdot \vec{V}$ (mass continuity)
- $J_s$ = Smoothness $(\nabla^2 \vec{V})$
- $J_v$ = Deviation from vertical vorticity equation




Each $J_x$ has a constant $c_x$ which determines weight.

# Existing toolkits for multiple Doppler wind retrieval

**CEDRIC (C**ustom **E**diting and **D**isplay of **R**educed **I**nformation in **C**artesian space)

- u, v are explicitly retrieved from radial velocities
- w is retrieved by integrating the anelastic mass continuity equation
- REORDER used to grid, then (long) scripts used as inputs for CEDRIC.
- Not very easy to use.

**Multidop**

- Python wrapper around DDA package (3DVAR)
- Py-ART used to make grids
- Based off of 3D variational technique of Shapiro et al. (2012) and Potvin et al. (2009) for 2 or 3 radars
- Does not run on Windows, requires DDA to be compiled.
- Input dictionary still rather long.

Available at:
https://github.com/nasa/MultiDop

# PyART/PyDDA

**PyART**

- Package for analysis and visualization of radar data written in Python. For more information, see Sherman et al. talk on Monday at 13:00.

**PyDDA**

- New package developed at ANL using faster optimization and written entirely in Python.
- Built on Py-ART
- Based off of 3D variational technique of Shapiro et al. (2012) and Potvin et al. (2009)
- Support for n radars, custom initialization fields.
- Easier to scale to thousands of radar files
- Runs on Windows!

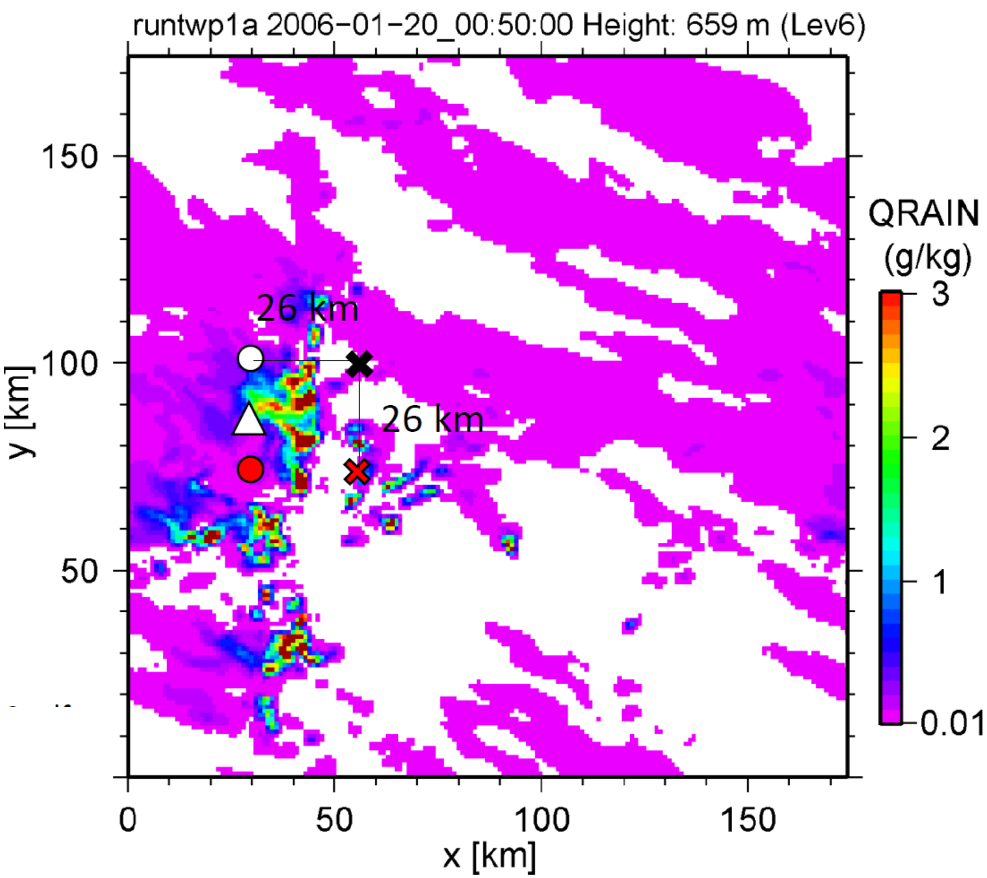
http://www.github.com/rcjackson/PyDDA

**Want to make into universal data assimilation framework! We are looking for collaborators!**

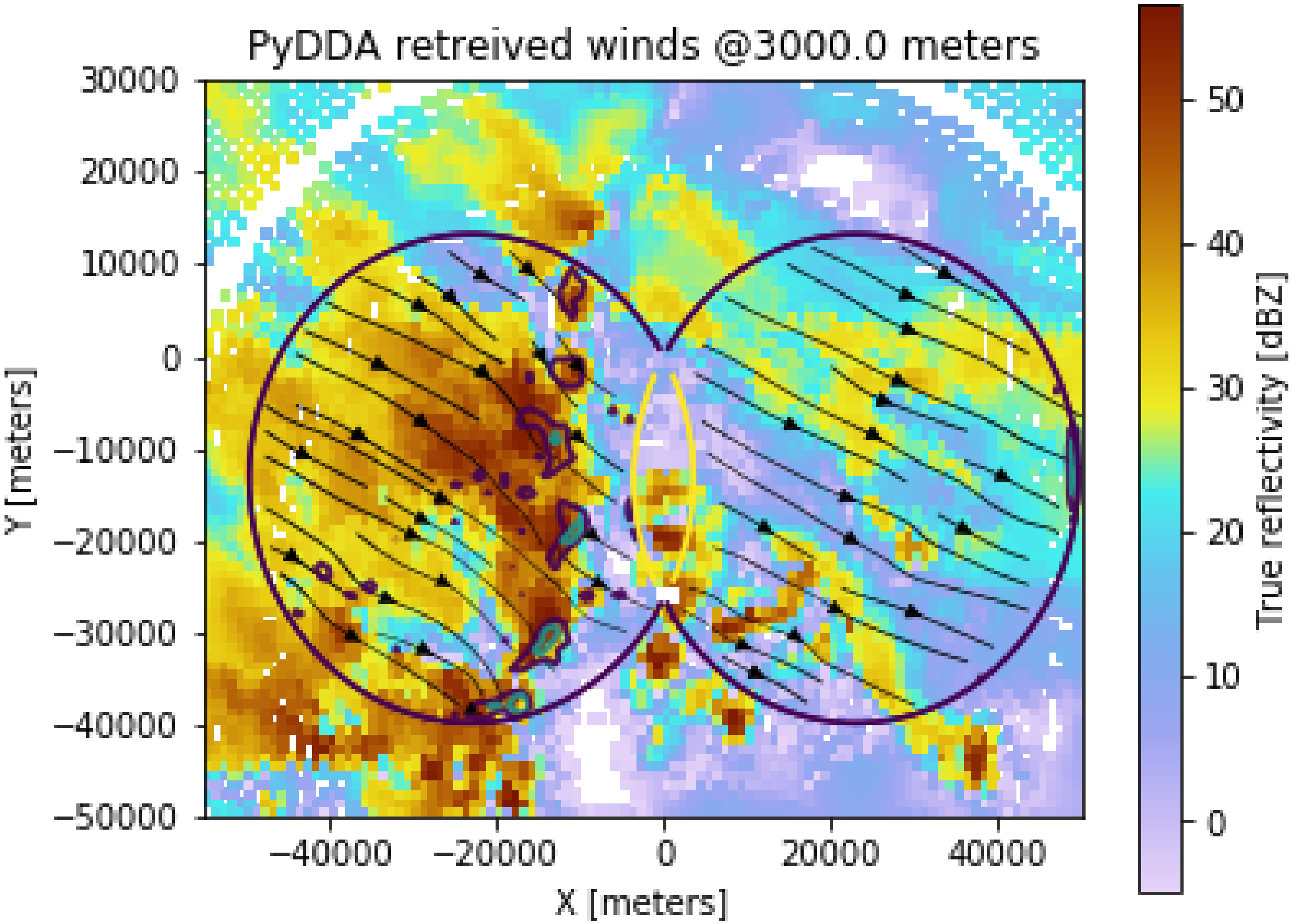
```python
import pyart
import pydda
from matplotlib import pyplot as plt
import numpy as np


berr_grid = pyart.io.read_grid("/home/rjackson/data/berr_Darwin_hires.nc")
cpol_grid = pyart.io.read_grid("/home/rjackson/data/cpol_Darwin_hires.nc")

sounding = pyart.io.read_arm_sonde(
    "/home/rjackson/data/soundings/twpsondewnpnC3.b1.20060119.231600.custom.cdf")


# Load sounding data and insert as an intialization
u_init, v_init, w_init = pydda.initialization.make_wind_field_from_profile(
        cpol_grid, sounding, vel_field='VT')

# Start the wind retrieval. This example only uses the mass continuity
# and data weighting constraints.
Grids = pydda.retrieval.get_dd_wind_field([berr_grid, cpol_grid], u_init,
                                          v_init, w_init, Co=10.0, Cm=1500.0,
                                          Cz=0, vel_name='VT', refl_field='DT',
                                          frz=5000.0, filt_iterations=2,
                                          mask_outside_opt=True, upper_bc=1)
```

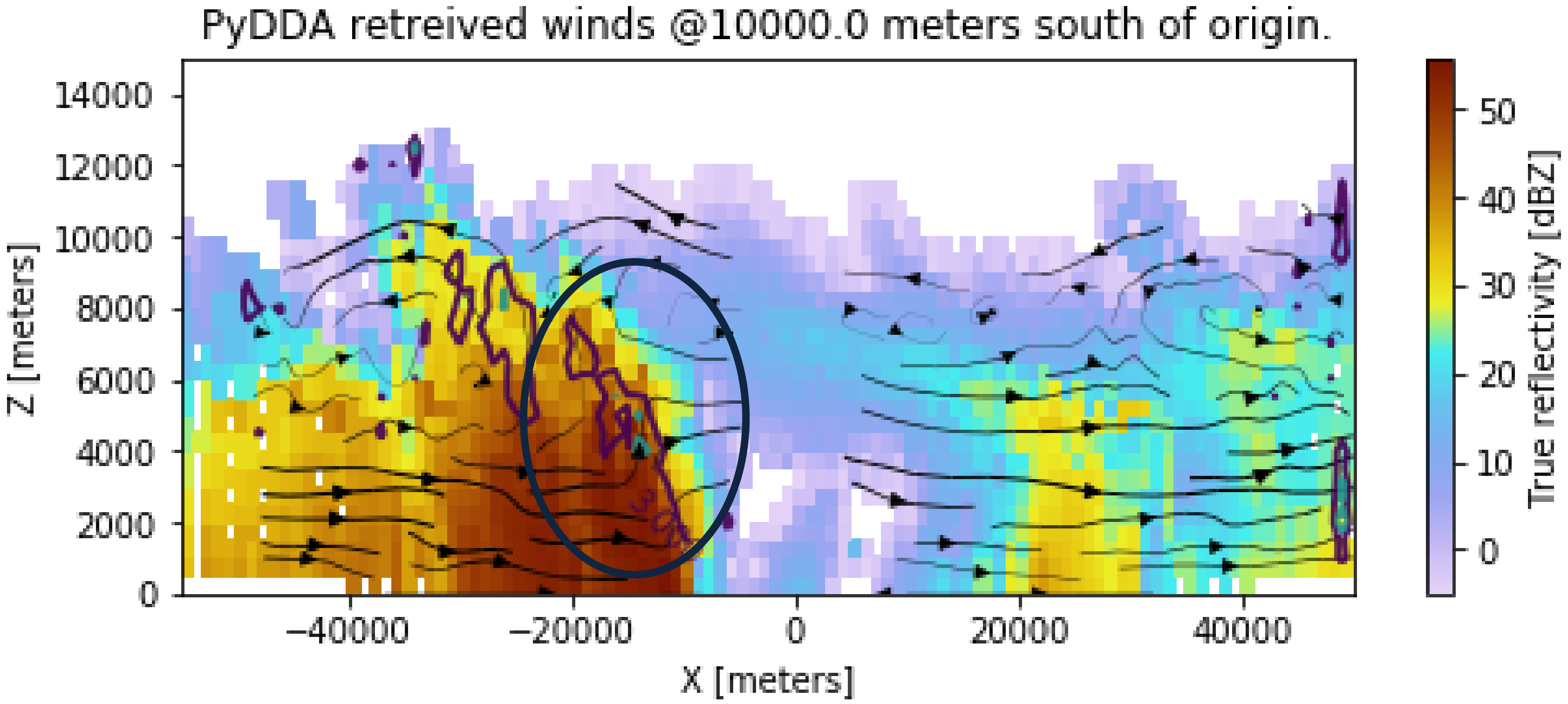
# Simulated radar data and retrieval constraints

- WRF run at 1 km resolution to simulate active monsoon period of TWP-ICE: 19-23 Jan 2006
- CRSIM used to simulate radar moments at 15 and 60 elevations at 5 different radar locations.
- Grid simulated variables to 1 km by 1 km by 0.5 km resolution using Py-ART
- Multidop and PyDDA both executed on various configurations of 2, 3, 4, and 5 radars
- Impermeability condition (w=0 at top, bottom).
- Mass continuity constant = 1500.0. Data weighting constraint = 2.0 for 2 radars, 0.05 for > 2 radars.

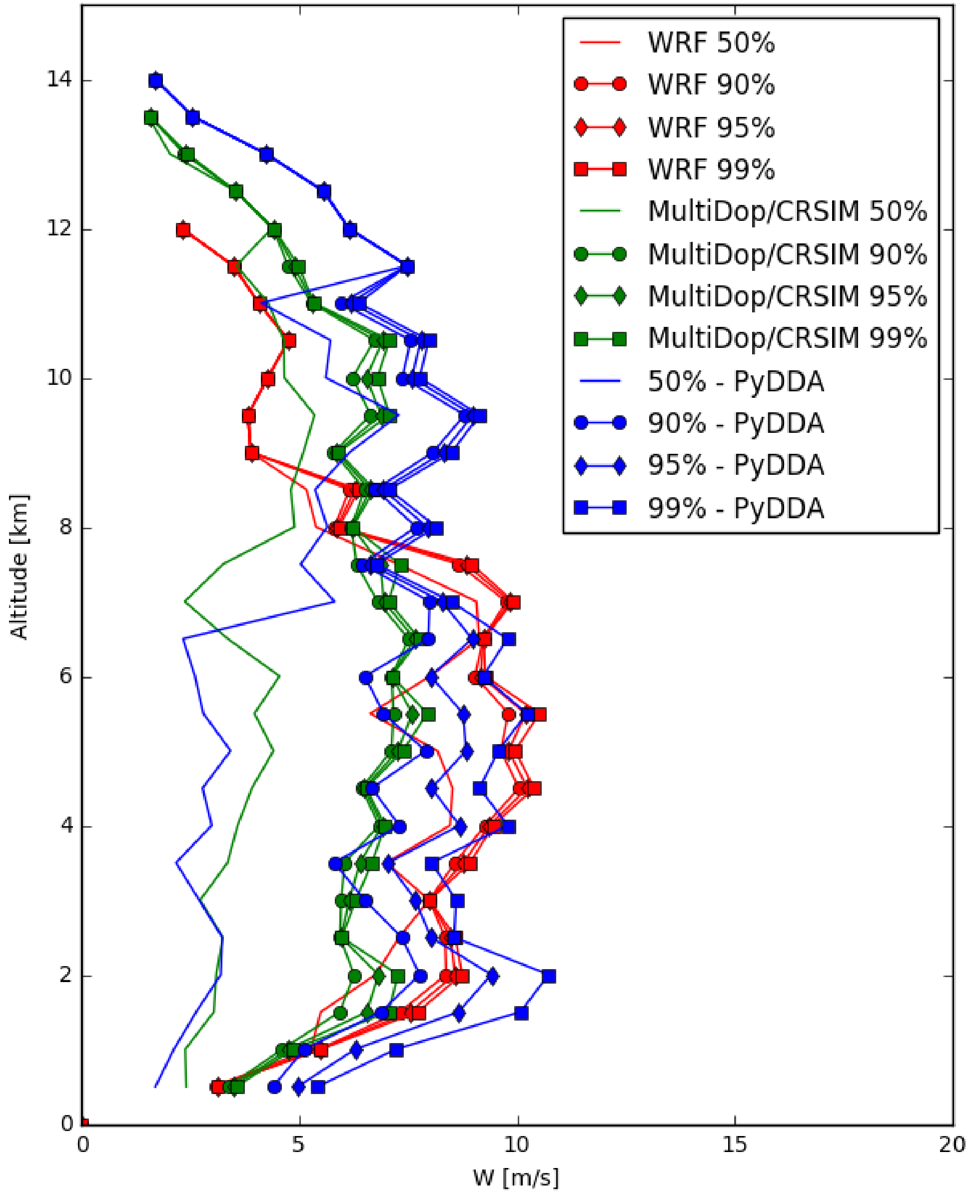


# Retrieved wind fields….

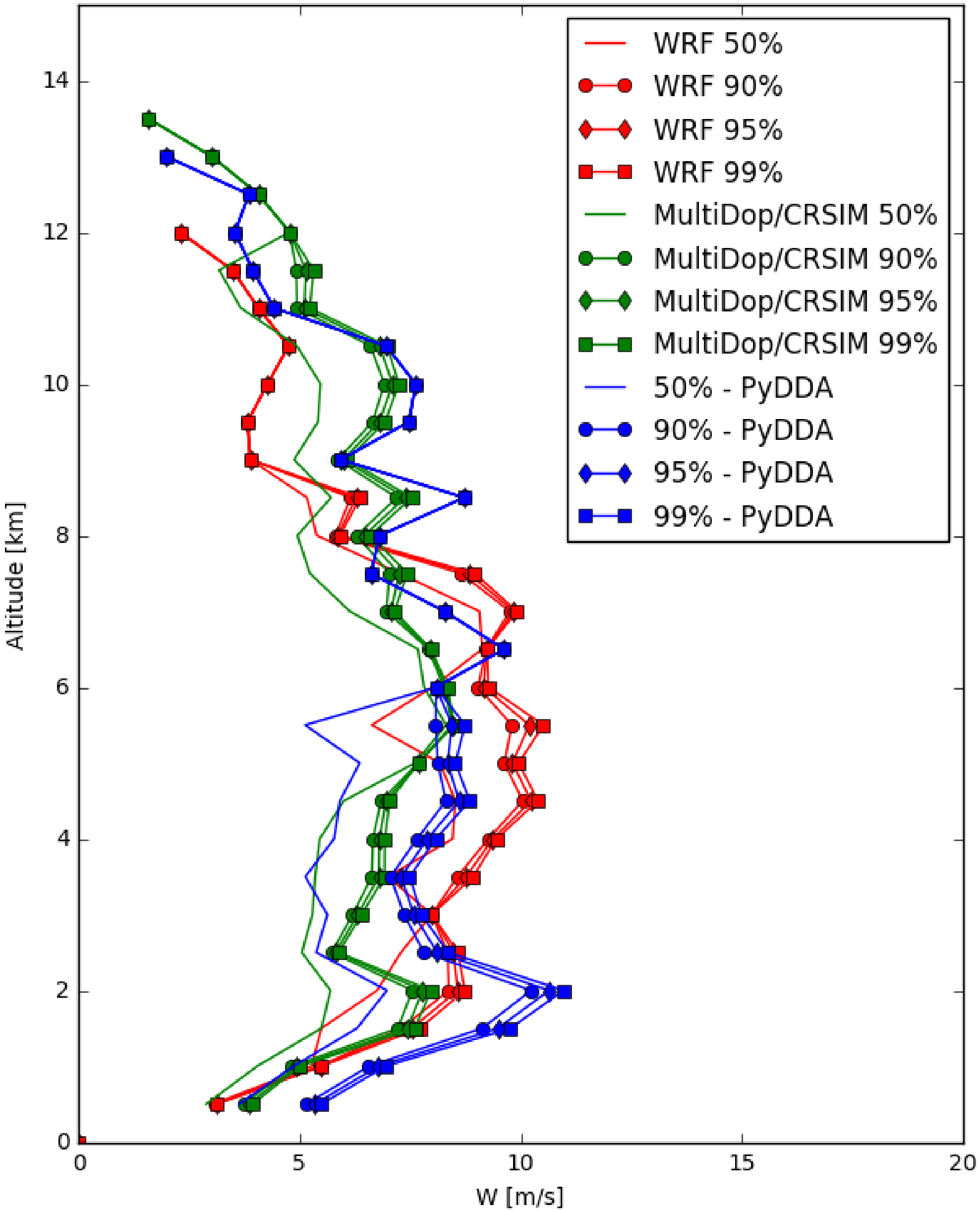



PyDDA retreived winds @10000.0 meters south of origin.
Z [meters]
X [meters]
True reflectivity [dBZ]
14000
12000
10000
8000
6000
4000
2000
0
−40000
−20000
0
20000
40000
50
40
30
20
10
0

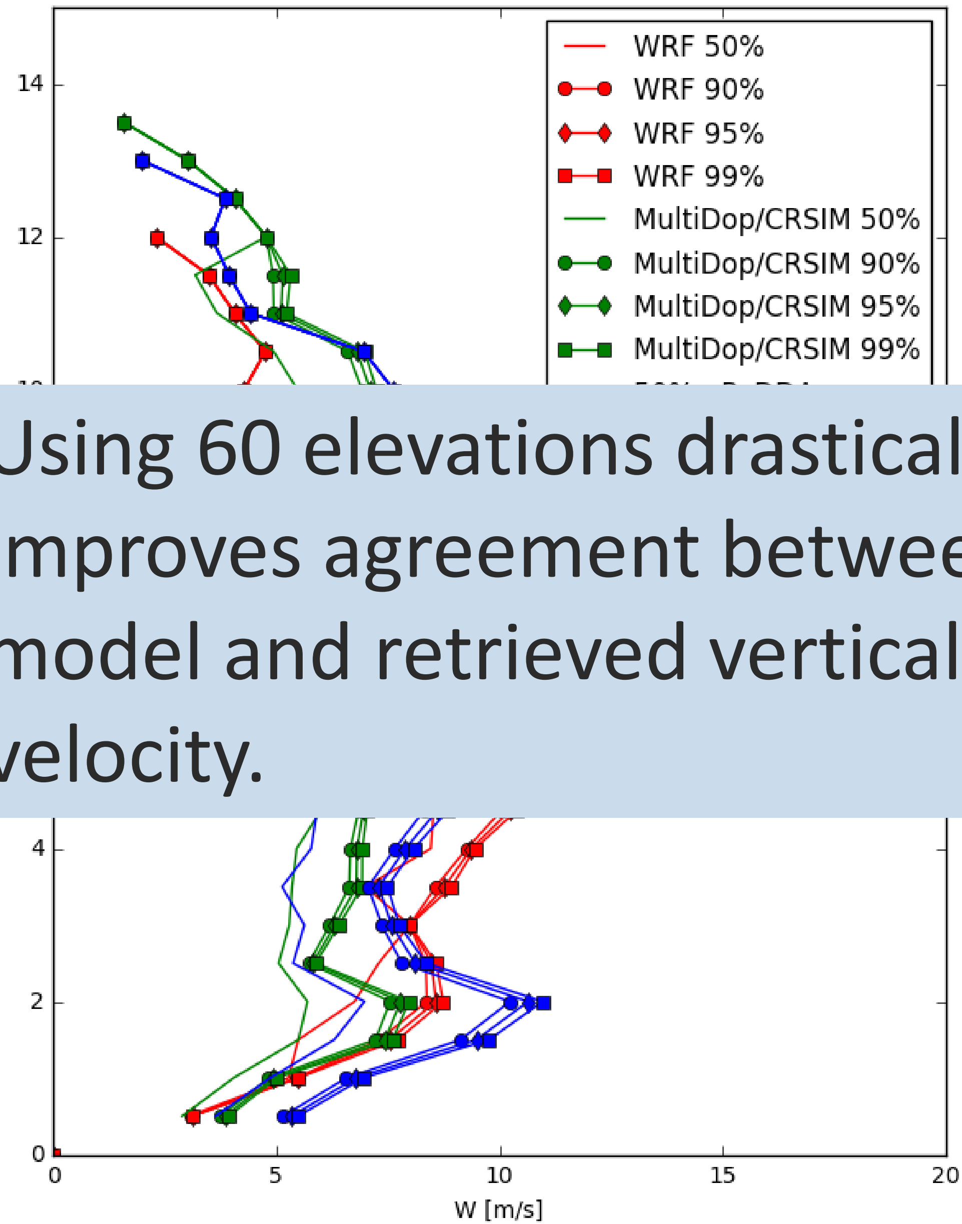
# 2 radars – 15 elevations



# 2 radars – 60 elevations

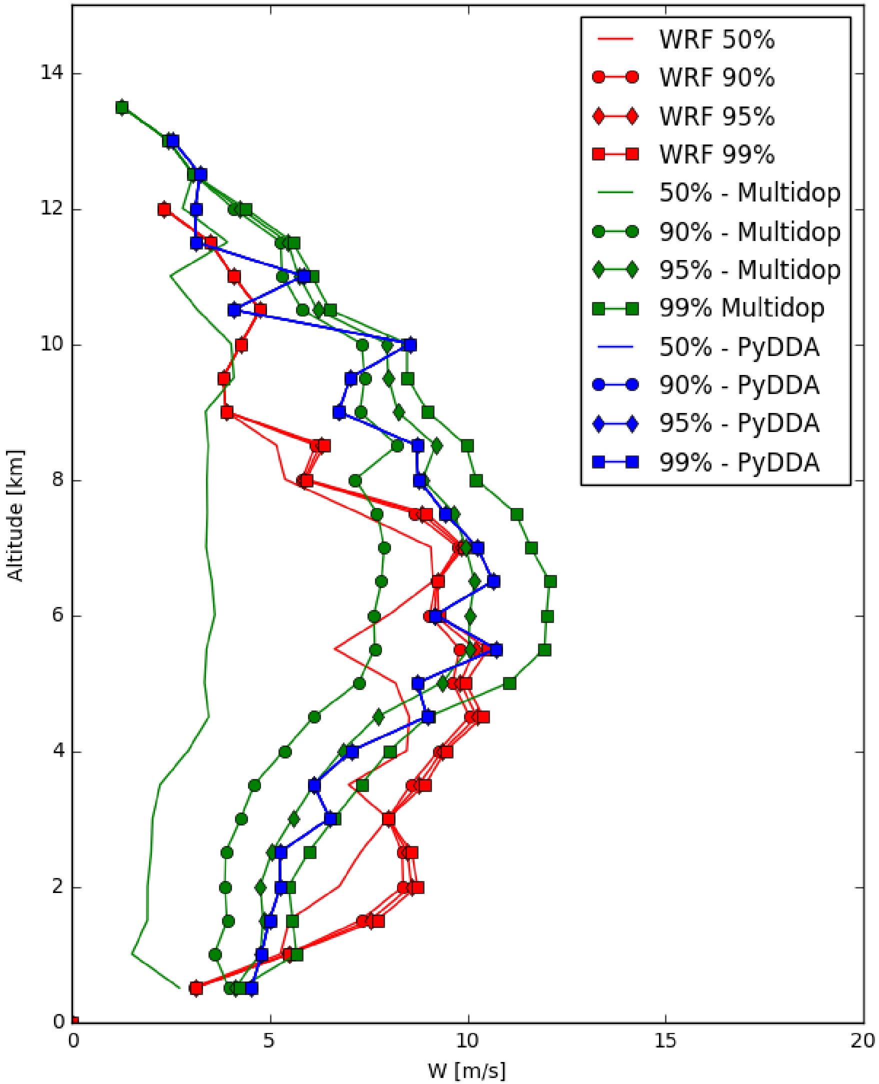


## 2 radars – 60 elevations

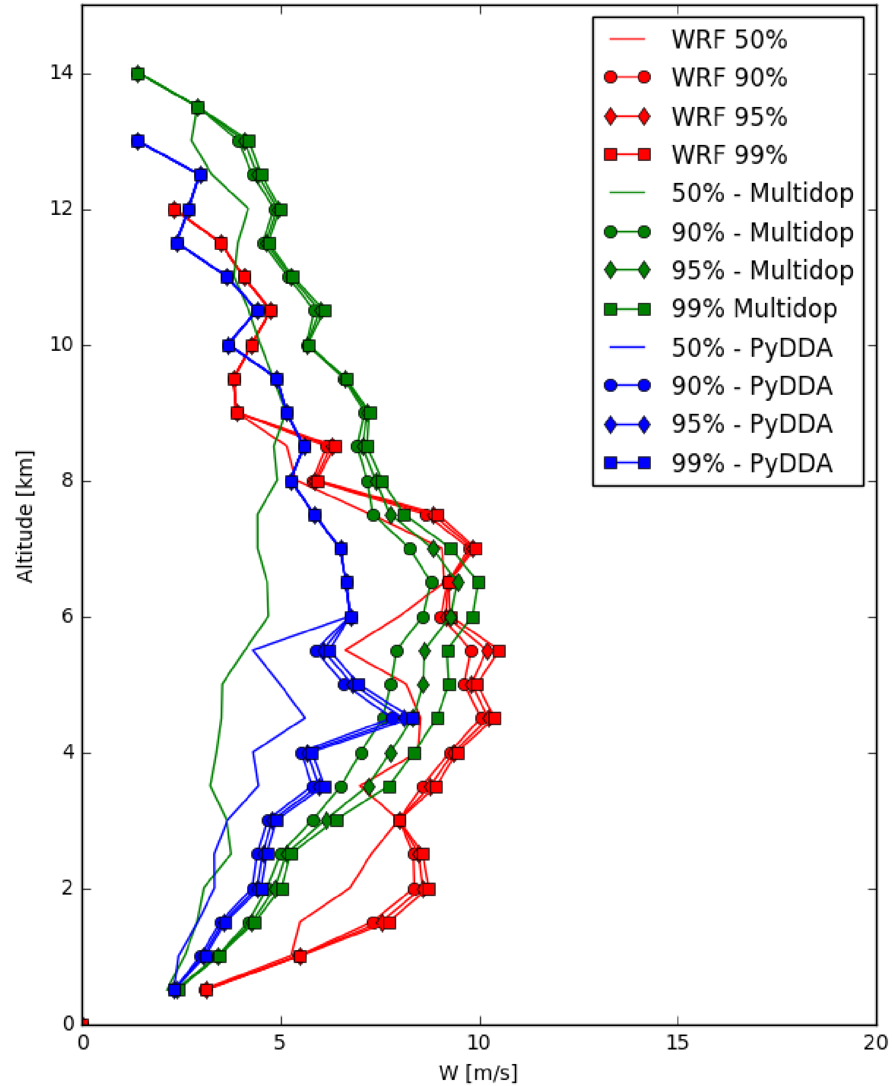



Using 60 elevations drastically improves agreement between model and retrieved vertical velocity.

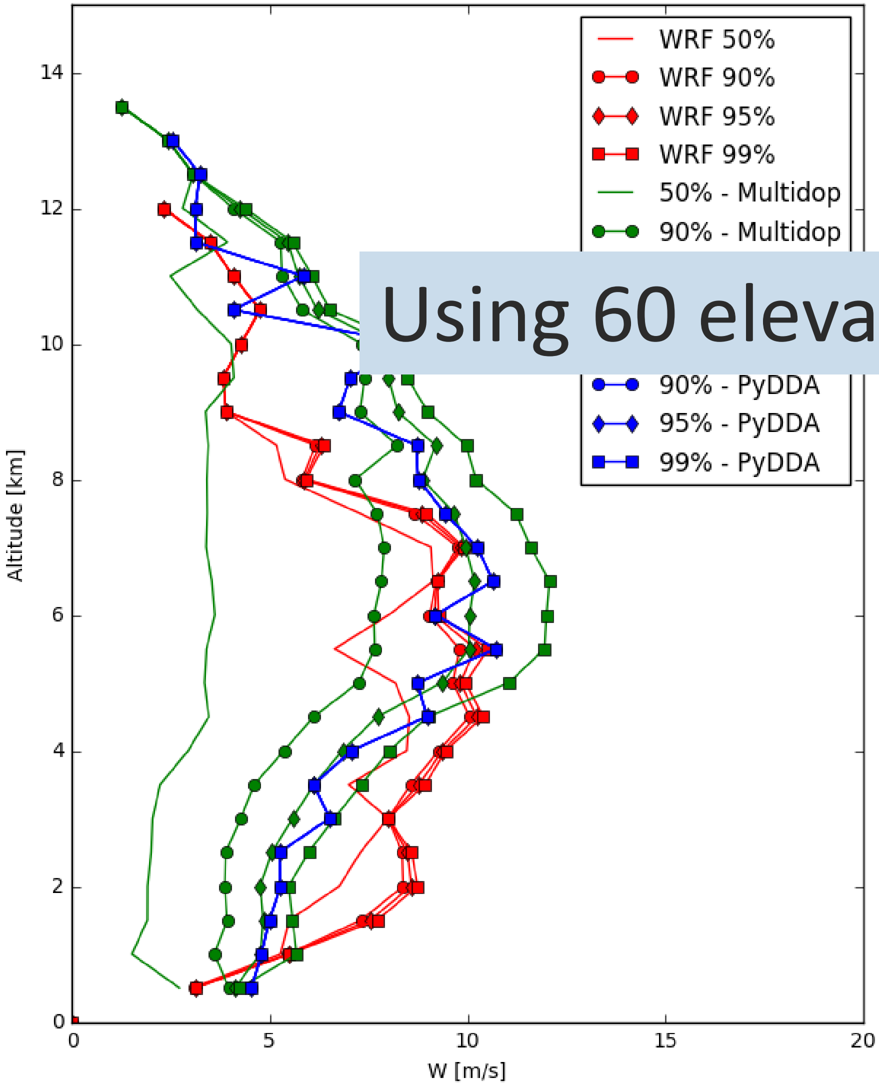
3 radars – 15 elevations



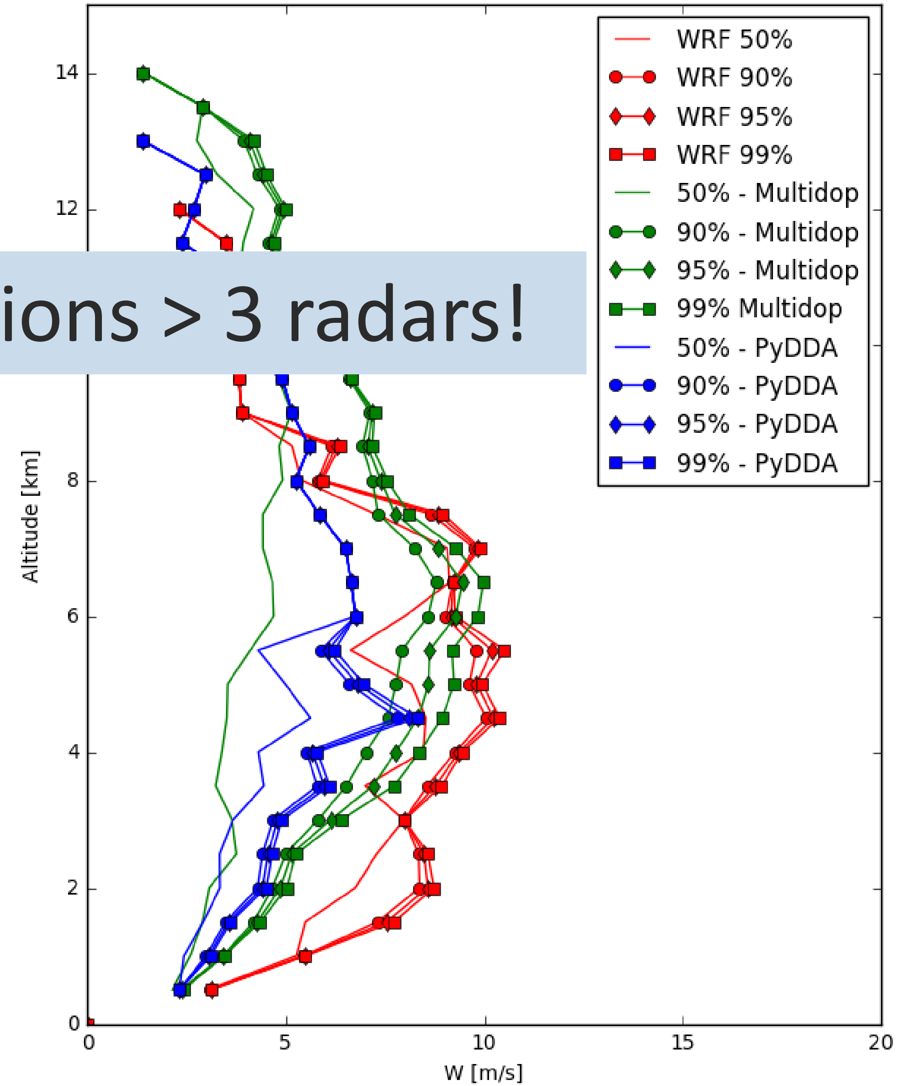

3 radars – 60 elevations



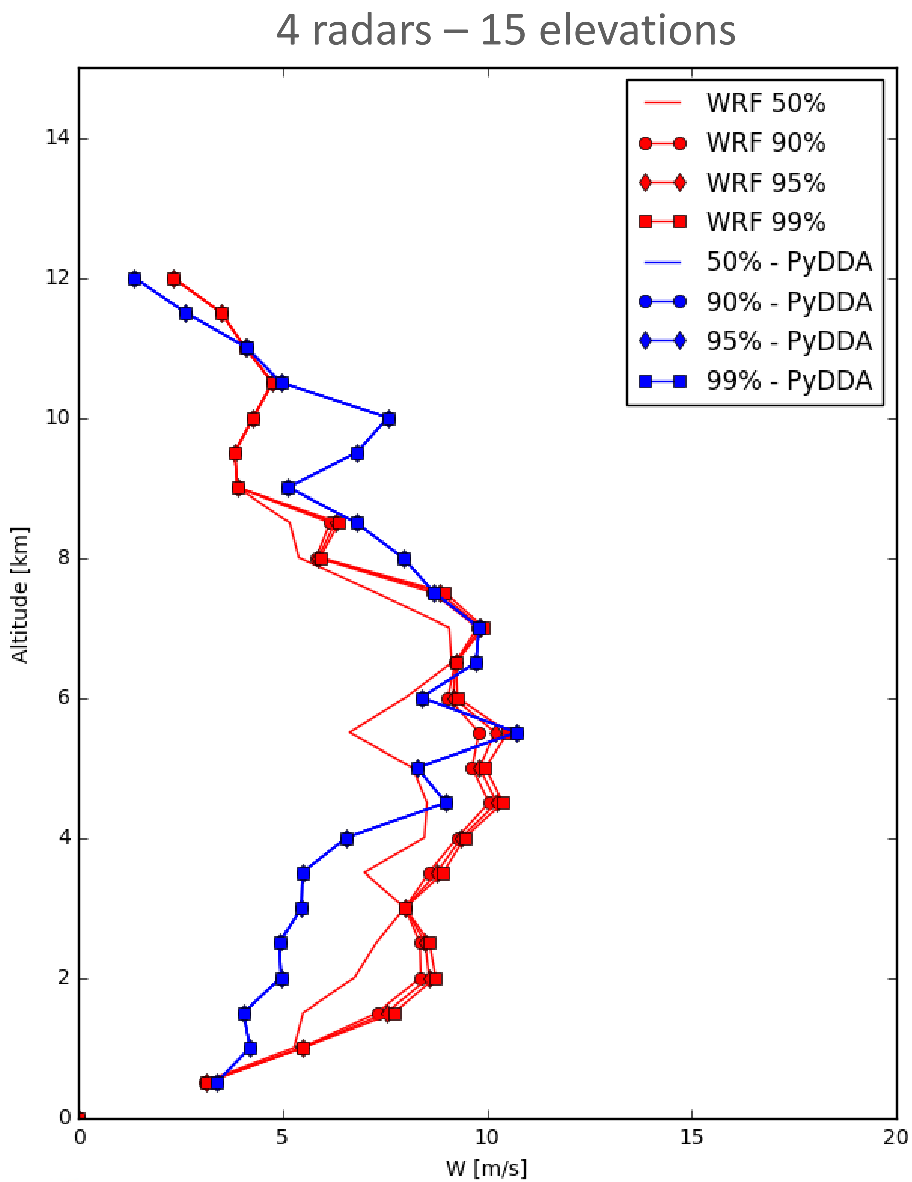
## 3 radars – 15 elevations

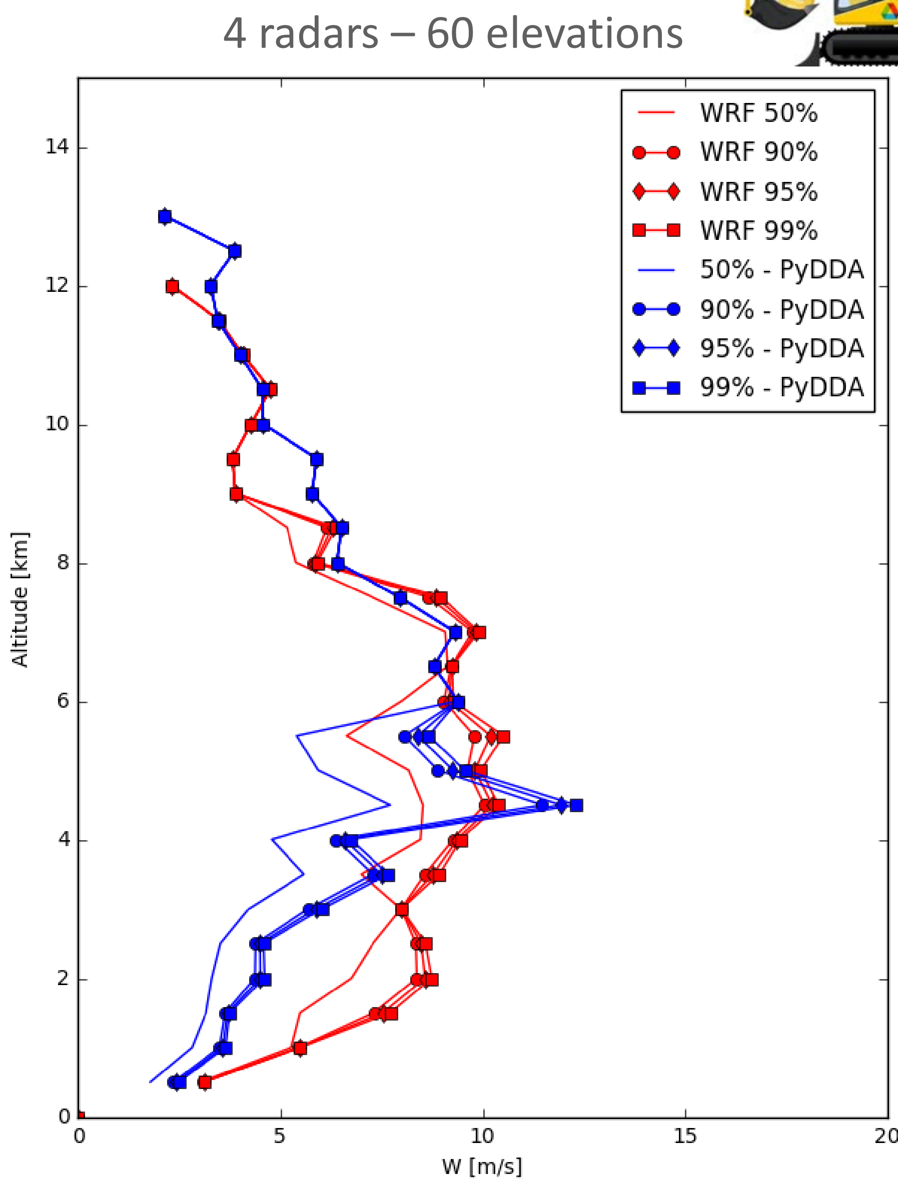



## 3 radars – 60 elevations

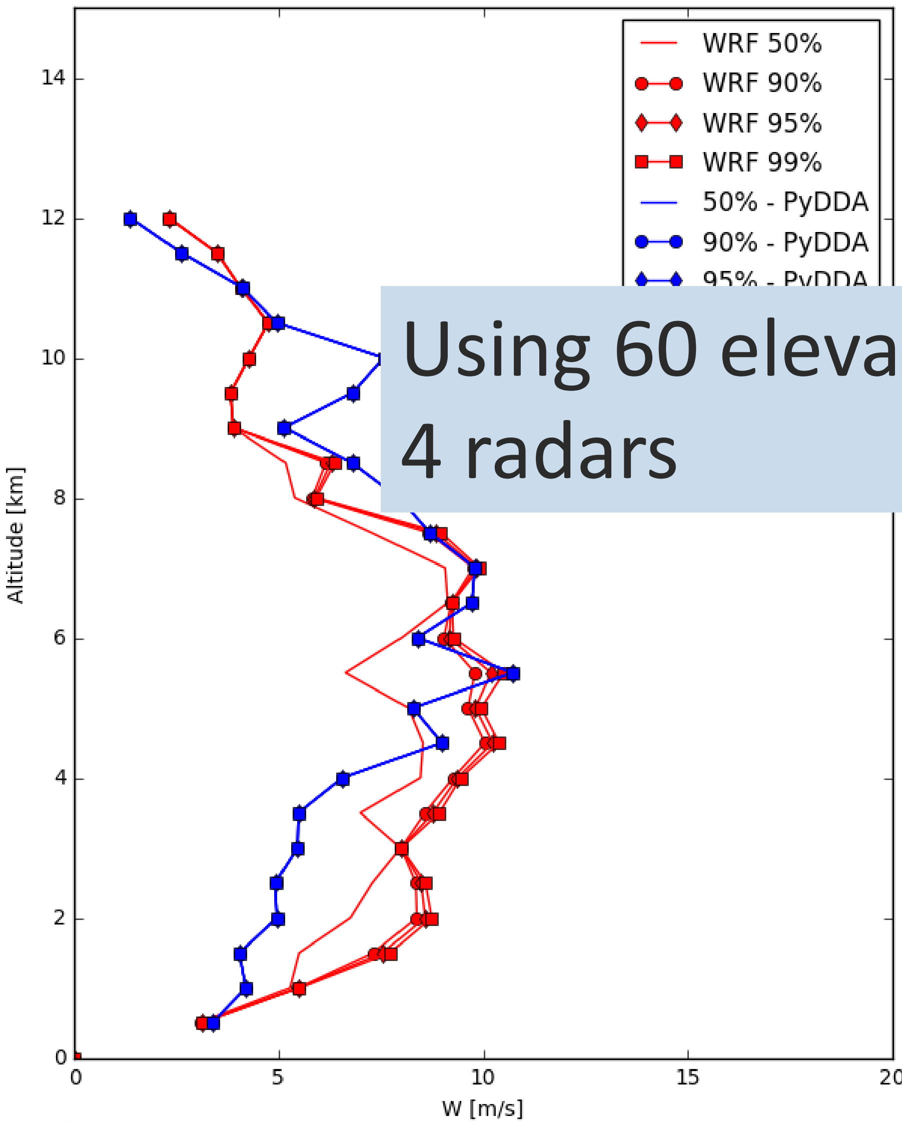



# Using 60 elevations > 3 radars!

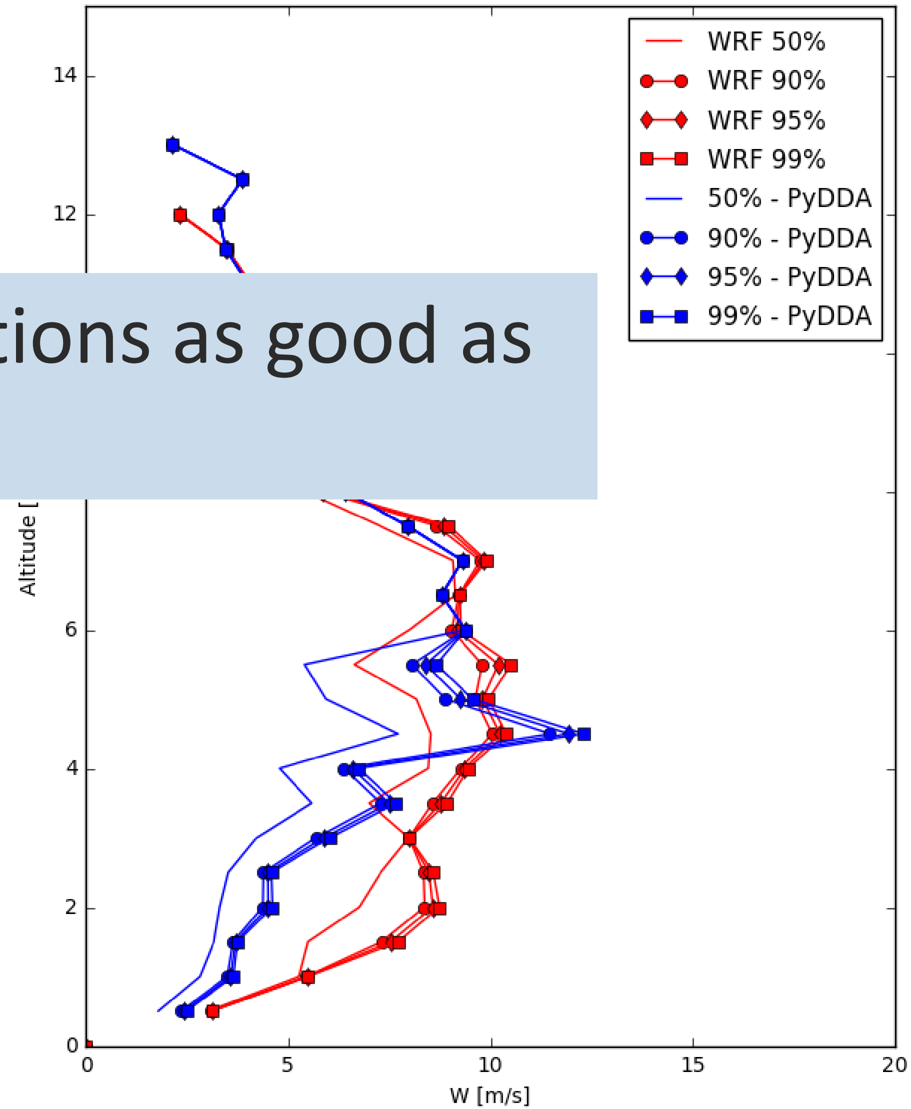

4 radars – 15 elevations
WRF 50%
WRF 90%
WRF 95%
WRF 99%
50% - PyDDA
90% - PyDDA
95% - PyDDA
99% - PyDDA
Altitude [km]
W [m/s]
0
2
4
6
8
10
12
14
0
5
10
15
20


4 radars – 60 elevations
WRF 50%
WRF 90%
WRF 95%
WRF 99%
50% - PyDDA
90% - PyDDA
95% - PyDDA
99% - PyDDA
Altitude [km]
W [m/s]
0
2
4
6
8
10
12
14
0
5
10
15
20

4 radars – 15 elevations



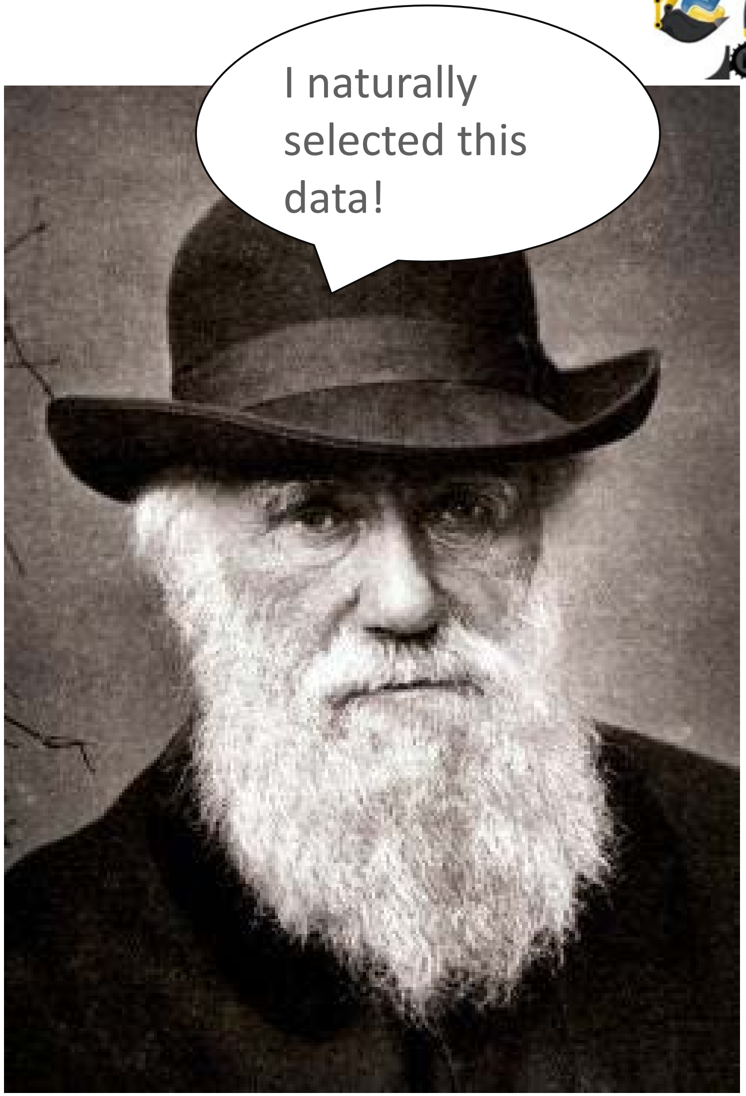

4 radars – 60 elevations




Using 60 elevations as good as 4 radars

# Key conclusions...

- New software package called PyDDA developed that makes multiple Doppler retrievals easier
- w in DCCs can be retrieved within 6 m/s using the default configuration of CPOL and Berrimah radars.
- Using either 60 elevations or 4-5 radars vastly improves the agreement between model and retrieved w
- Recommend we use at least 4 radars for retrieving dynamics in convection in Darwin
- **Future work:** We aim to find out what is needed to adequately resolve vertical motions in multiple Doppler retrievals over Darwin.



Questions???

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