

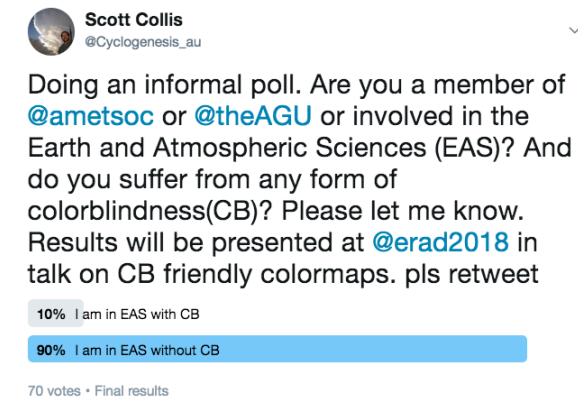
IT'S TIME FOR COLOR VISION DEFICIENCY FRIENDLY COLOR MAPS IN THE RADAR COMMUNITY

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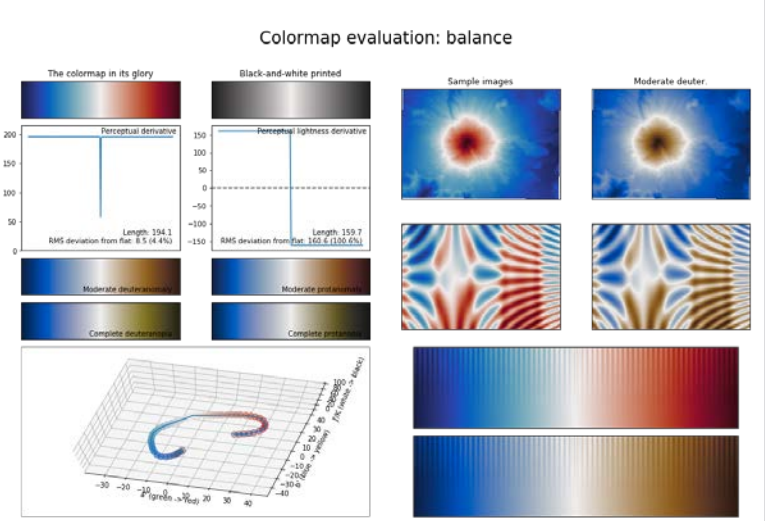
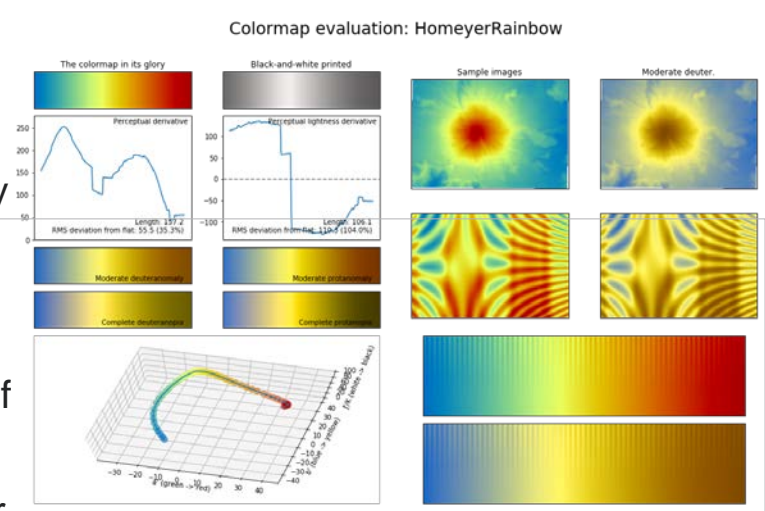
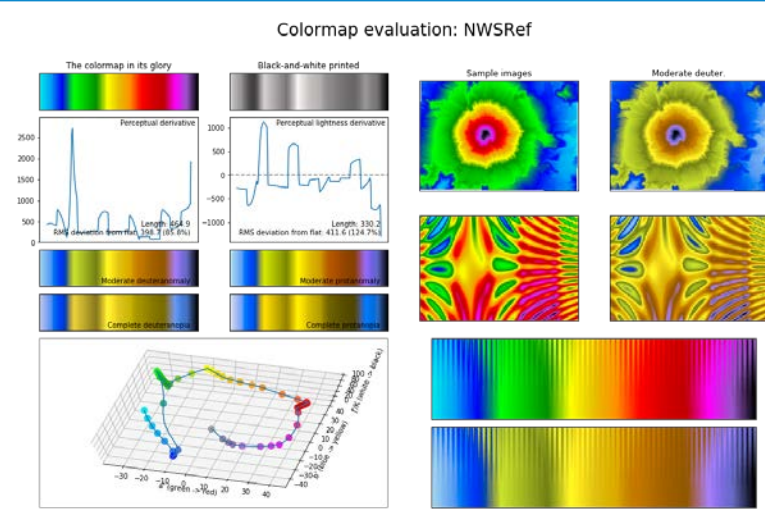
INTRODUCTION

- Color Vision Deficiency (CVD) is a decreased ability to discern between particular colors.
- 8% of men and 0.4% of women have some form of CVD. An informal poll of AGU and AMS twitter followers yielded 10% of 70 respondents self identifying as having CVD.
- When presenting data on a two-dimensional plane it is common to use colors to represent values, the mapping between values and colors is known as a colormap.
- Colormap choice is personal and is influenced by:
 - Ability to highlight scientifically interesting data.
 - Institutional choices (supervisor insists on a certain colormap).
 - Domain dominance of a particular colormap (common in the radar community).
- Colormap choice **should** be influenced by:
 - Ability to highlight scientifically interesting data.
 - Perceptual uniformity (thus not creating artificial structure).
 - Approachability by those with visual impairments (CVD).
 - Ideally, but not always achievable, reproducibility in greyscale.



METHODOLOGY

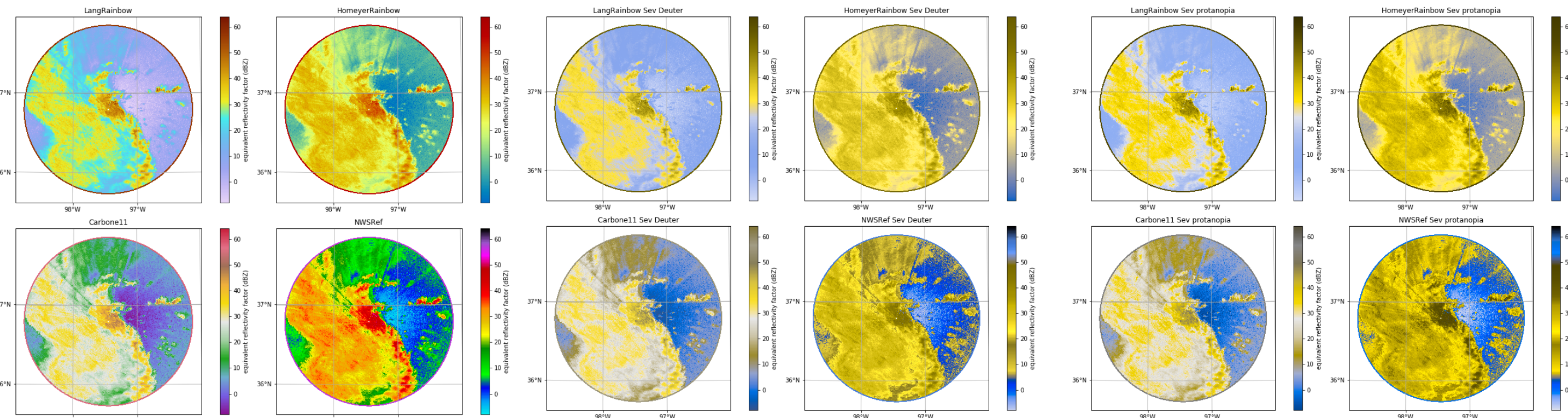
- The aim is to create a set of CVD friendly colormaps which will be implemented in `pyart.graph.cm_colorblind` [1].
- A repository for this work was created at: <http://bit.ly/cvd-cm>
- A set of criteria for different radar variables was created here: <http://bit.ly/cm-req>



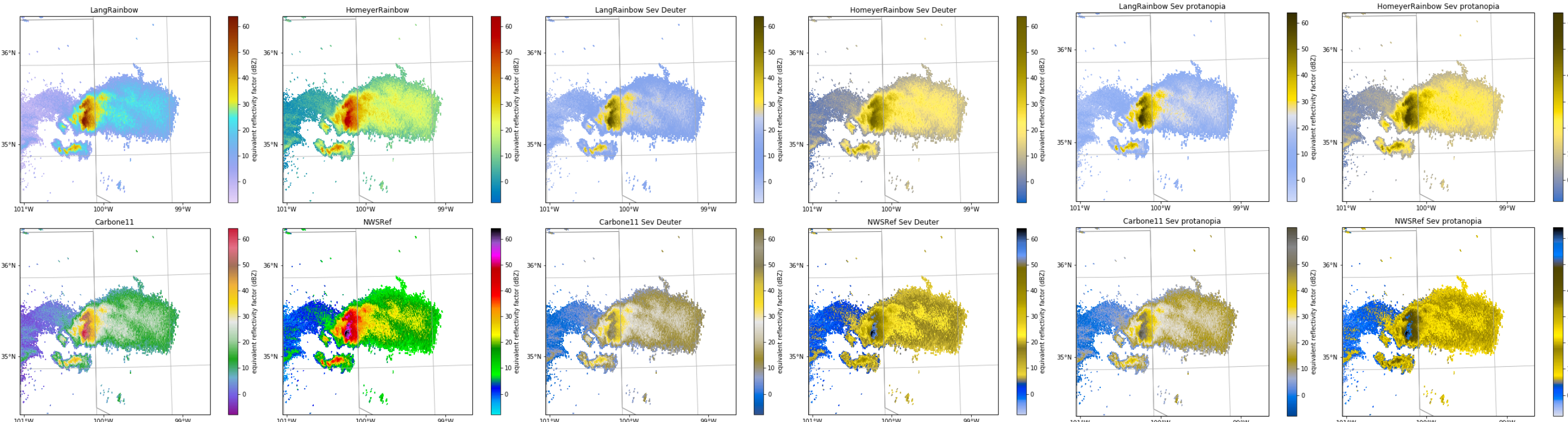
- Each colormap was modified for severe deuteranomaly (5% of men) and protanomaly (1% of men) using the Python `colormap` [2] package.
- The python `viscm` [3] provides a comprehensive assessment of the "quality" of the colormap.
- The figures to the right show viscm output for the NWS Reflectivity, HomeyRainbow and cmcean balance colormaps. The NWS colormap is an example of a **bad** colormap while the Homey and balance colormaps are considered good.
- Two cases were chosen: A large scale squall line in Oklahoma observed by the ARM C-Band radar during MC3E [4] and a Pyro-Cumulonimbus storm in Mallard, Co [5].

RADAR REFLECTIVITY FACTOR

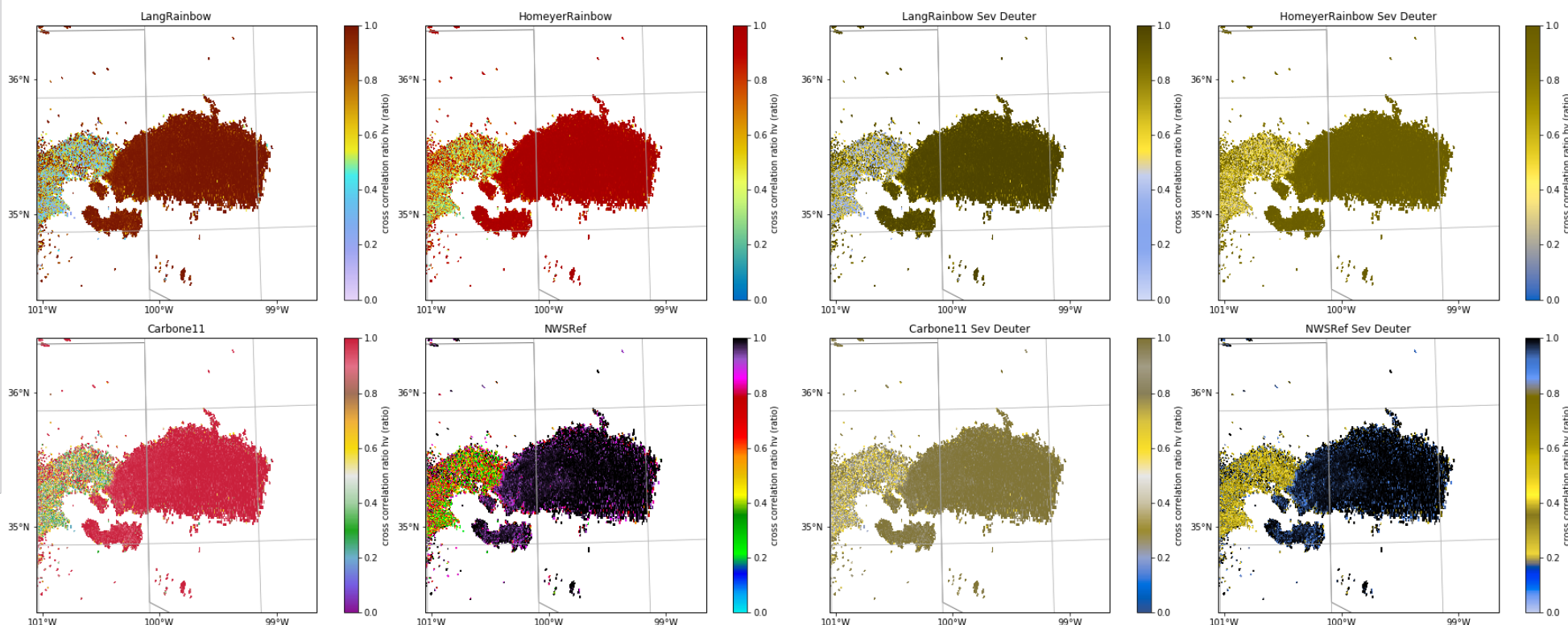
MCS from ARM C-SAPR During MC3E



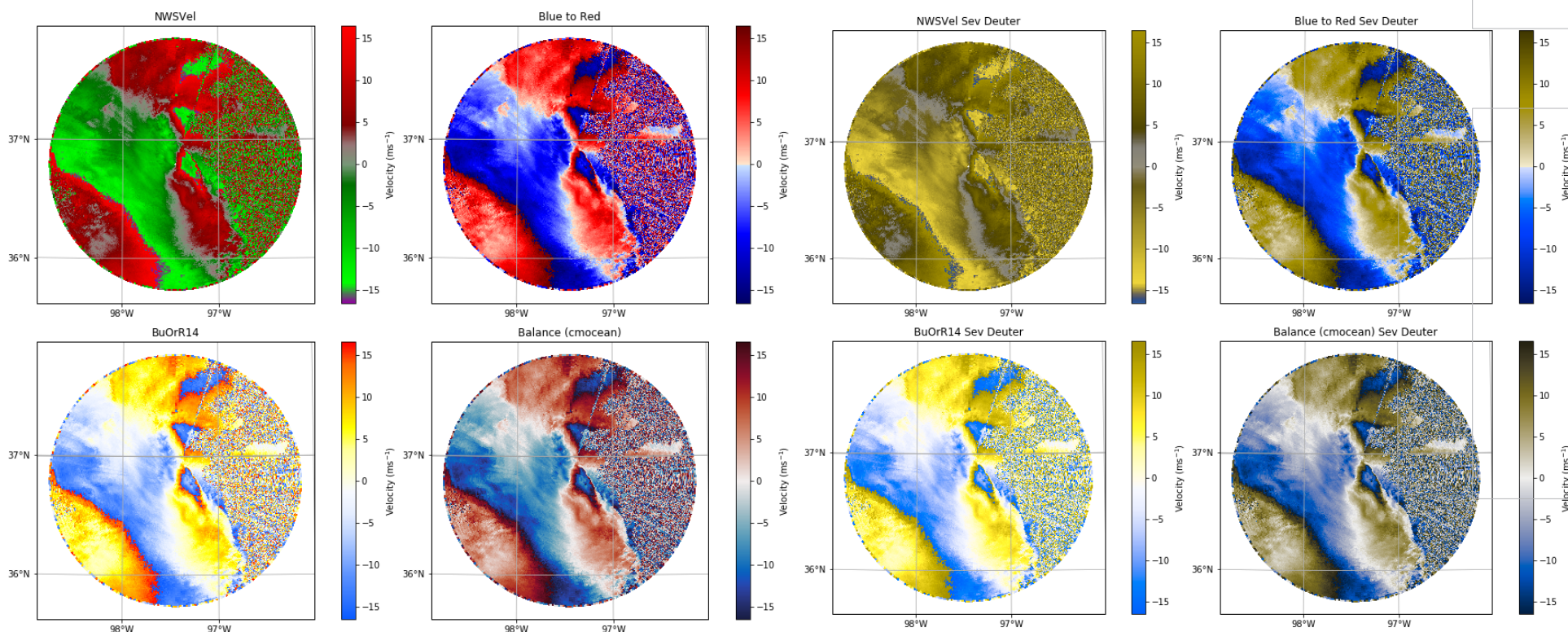
Mallard Fire Pyro-Cumulonimbus



CORRELATION COEFFICIENT



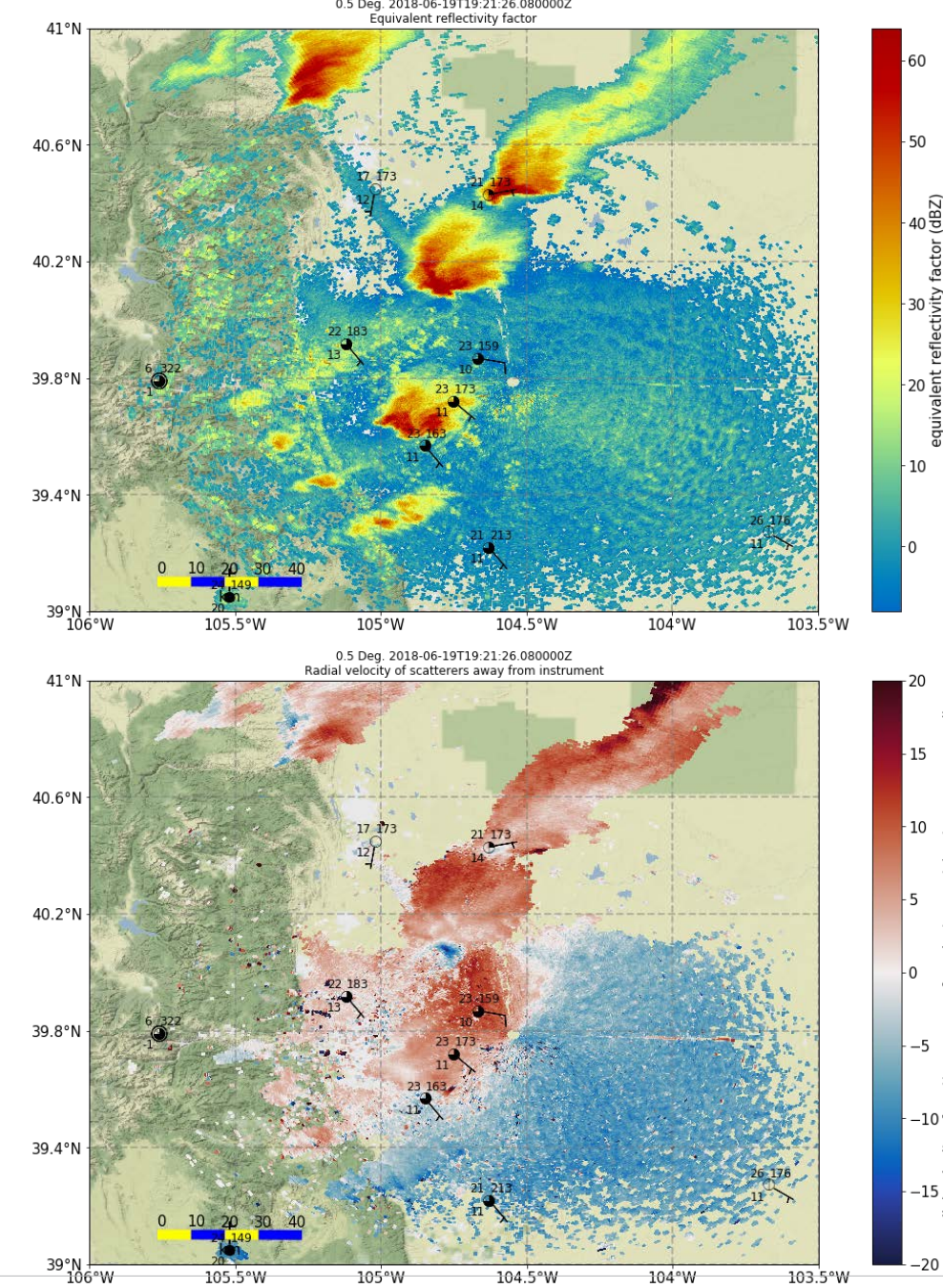
RADIAL VELOCITY



CONCLUSIONS AND RECOMMENDATIONS

- Reflectivity and Correlation:** The existing Lang Rainbow colormap is a reasonable option and we will be optimizing this in the future. The recently added Homey Rainbow colormap is **very good** at showing detail and currently provides the best mapping to CVD color spaces and currently stands as the **recommended** colormap for accessibility. However both Lang and Homey are **far better than the terrible NWS colormap**.
- Velocity:** There were two visual targets for radial velocity, (1) highlight zero isodop (2) make sure there is a good perception jump across Nyquist. The BuOrR14 map performs well but is very poor in perceptual uniformity and has poor definition of the zero isodop. Blue to red is better in perceptual uniformity but is poor at highlighting the Nyquist jump. Balance is near perfect in perceptual uniformity and projects well into Deuteranomaly space. The NWS velocity colormap is bad in both perceptual uniformity and in its projection into CVD spaces. On balance (pun intended) **we recommend Balance for radial velocity**.

By using these colormaps you get visually pleasing accurate plots that do not exclude > 5% of the community



NEXT STEPS

- While the Homey and Lang colormaps work well for Correlation and other moments like differential reflectivity, KDP etc.. We will explore if there are better colormaps.. For example it would be good to have a colormap to highlight regions around zero ZDR for calibration reasons.
- We will be submitting a BAMS article with our recommendations for optimized radar colormaps for CVD.
- We will work with the American Meteorological Society's committee on Radar Meteorology to craft a recommendation for colormaps suitable for those who have CVD.

REFERENCES AND ACKNOWLEDGEMENTS

- [1] Helms, J., Collis, S., 2016. The Python ARM Radar Toolkit (Py-ART), a Library for Working with Weather Radar Data in the Python Programming Language. Journal of Open Research Software 4. <https://doi.org/10.5334/jors.119>
- [2] Nathaniel J. Smith, Richard Futrell, Stefan van der Walt, Thomas Mansencal, TFIe, Edward Betts, ... Brien Dieterle. (2018, April 8). nsmith/colormap v1.1.2 (Version v1.1.2). Zenodo. <http://doi.org/10.5281/zenodo.1214904>
- [3] <https://github.com/matplotlib/viscm>
- [4] Jensen, M.P., Petersen, W.A., Bansemmer, A., Bharadwaj, N., Carey, L.D., Cecil, D.J., Collis, S.M., Del Genio, A.D., Dolan, B., Gerlach, J., Giangrande, S.E., Heymsfield, A., Heymsfield, G., Kollias, P., Lang, T.J., Nesbitt, S.W., Neumann, A., Poellot, M., Rutledge, S.A., Schwaller, M., Tokay, A., Williams, C.R., Wolff, D.B., Xie, S., Zipser, E.J., 2015. The Midlatitude Continental Convective Clouds Experiment (MC3E). Bull. Amer. Meteor. Soc. <https://doi.org/10.1175/BAMS-D-14-00228.1>
- [5] LaRoche, K. T. and T. J. Lang, 2017: Observations of Ash, Ice, and Lightning within Pyrocumululus Clouds Using Polarimetric NEXRAD Radars and the National Lightning Detection Network. Mon. Wea. Rev., 145, 4899–4910, <https://doi.org/10.1175/MWR-D-17-0253.1>

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