# P2.11 New Features of the VCPExplorer: Simulated Precipitation

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## 1. INTRODUCTION

The VCPExplorer was designed for the Warning Decision Training Branch (WDTB) to aid National Weather Service (NWS) forecasters with a *qualitative* understanding of radar beam path propagation as well as sampling issues associated with local terrain and scanning strategies (Manross, et al. 2005). Figure 1 shows the layout of the user interface. WDTB has already incorporated the VCPExplorer in its training exercises (LaDue, et al. 2006), with perhaps the greatest impact coming from displaying the effects of volume coverage pattern (VCP) on radar-based algorithms - particularly those from the Hail Detection Algorithm (Witt, et al. 1998).

It cannot be understated that, at this point, the VCPExplorer is intended to provide *qualitative* results. This is due to the sometimes subtle changes in the index of refraction of the troposphere and its influence on the propagation of the radar beam path. Nonetheless, if a "standard atmosphere" is assumed, the output of the VCPExplorer provides realistic results which effectively illustrate the related concepts to the user.

## 2. RADAR PRECIPITATION ESTIMATION

A great deal of attention has been devoted to estimating rainfall at the Earth's surface by using radar. Part of the reason for the multitude of papers written on this topic is due to the variety of sources of error involved in radar rainfall estimates. Although far from exhaustive, this list includes:

- Terrain/ground-clutter contamination (Joss and Lee 1995)
- Range from radar
- Drop-size distribution and its effect on reflectivity (I.e., "Z-R Relationship") (Marshall and Palmer 1948)
- Freezing level, or "bright-banding" effects (Smith 1986)
- Sub-cloud evaporation (Brandes, et al. 1998)
- Beam widths
- Scanning strategy

Meteorologists and Hydrologists, alike, could benefit from better understanding of the limitations of radar when estimating rainfall amounts. The VCPExplorer is designed to aid in that understanding by providing the user with the ability to explore various scenarios involving radar settings as well as local environmental effects.

## 3. ADDITIONS TO THE VCPEXPLORER

The recent upgrades to the VCPExplorer center on the errors in radar precipitation estimation, particularly those mentioned in the previous section. This section describes how the upgrade of the VCPExplorer addresses these situations. The first thing the use must do is to set a vertical profile of reflectivity (VPR) using a graphical user interface (Figure 2).

### *a. Terrain Effects and Ground Clutter*

Estimation of rainfall amounts by radar are scored by correlating the radar algorithm output to surface rain gauges. The VCPExplorer incorporates terrain data at 30 arc-second resolution, which is roughly a grid point, with associated terrain elevation, at roughly 1 km for the entire radar domain. The user sets a VPR (above the lowest altitude in the radar domain) and this is deemed the "true" reflectivity profile. Then, at every grid point, the VCPExplorer calculates the surface rainfall rate, from the VPR with a user defined Z-R relationship. This is considered the ground

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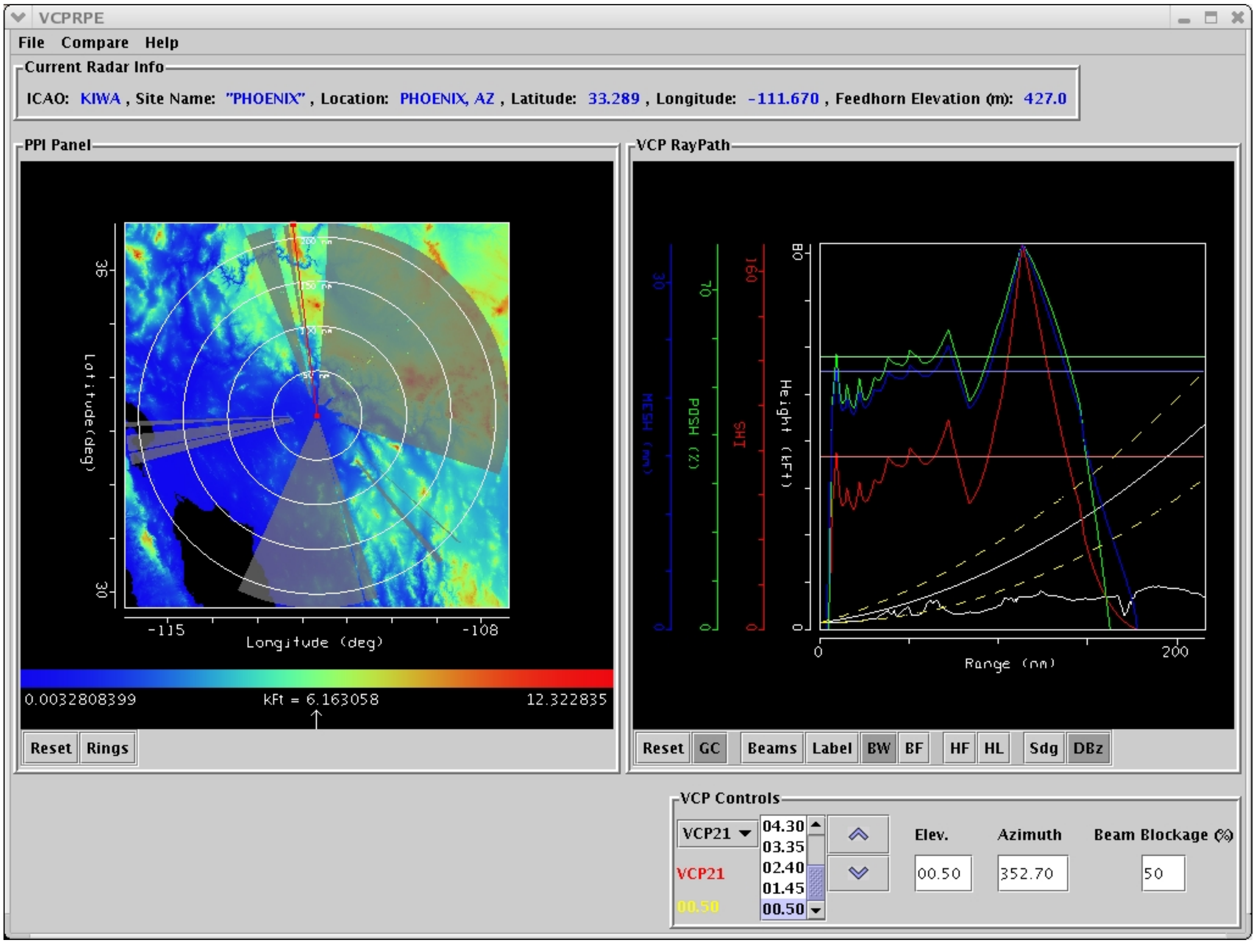


**Figure 1. The VCPExplorer.**
**For more information, please visit: http://www.cimms.ou.edu/~kmanross/VCPRPE/**

truth, and is plotted as an overlay on the plan projection image (PPI). In essence, it is assumed that the Z-R provides a true rainfall rate estimate at the surface, and we compare it to the discrete vertical sampling of the VPR by the VCP

Now that the ground truth is established, the VCPExplorer will calculate the radar-observed precipitation at the lowest elevation angle. This elevation angle is determined using the terrain-based hybrid scan algorithm currently used by the Weather Surveillance Radar – 1988 Doppler (WSR-88D). Figure 3 illustrates how the lowest elevation scan is determined and the read is referred to O'Bannon (1997) for a description on this technique. After calculating the "observed" precipitation, another overlay is produced for the PPI and the user can toggle between the true and observed surface rainfall rates.

*b. Range from Radar*

Due to Earth's curvature, the distance between the Earth's surface and the radar beam height increases with increasing range from the radar. This causes the beam to sample the VPR at higher altitudes as range increases and therefore causes discrepancies in precipitation estimates. For precipitation algorithms that rely on VCP, the VCPExplorer shows the user the effects of range and VCP on those algorithms similar to the way it displays the HDA algorithms (see Section 3.2 and Figures 3a-d of Manross, et al. 2005)

*c. Z-R Relationship*

As mentioned earlier, the user has the ability to define any Z-R relationship. The user can see the differing results that various Z-R settings will have on rainfall estimates. This is even illustrated with the “true” PPI overlay described in Section 3a. The Z-R properties will likely be emphasized as the beam samples higher reflectivity values throughout the VPR.

*d. Bright-banding and Evaporative Effects*

Radar-reflectivity contamination due to melting of precipitation causes considerable estimation errors on rainfall estimation. The VCPExplorer user will be able to toggle and modify a simulated bright-band associated with the defined VPR. Likewise, the user can investigate the influence that sub-cloud evaporation might have on precipitation estimates

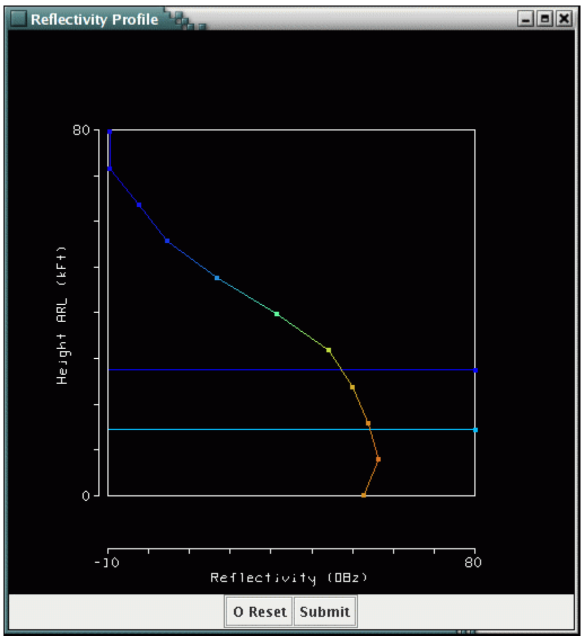


**Figure 2. The Vertical Profile of Reflectivity (VPR) defined by the user. Horizontal lines indicate the height of the freezing (light blue) and --20°C (dark blue) isotherms.**

*e. Beam Width and VCP*

The user has control over the width of the radar beam. This allows him/her to see what effects this might have on rainfall estimation. Likewise, the user can select several available VCPs to determine which one produces the best or desired result. The user can also develop any VCP and test it.

## 4. CONCLUSIONS

The VCPExplorer was designed for qualitative instruction of the effects of radar and environmental influences on the remote sensing of the atmosphere. It has already been used in WDTB training materials. The VCPExplorer has recently been upgraded to allow investigation of precipitation estimation and the potential sources of error associated with radar algorithms that provide these estimates.

## 5. ACKNOWLEDGEMENTS

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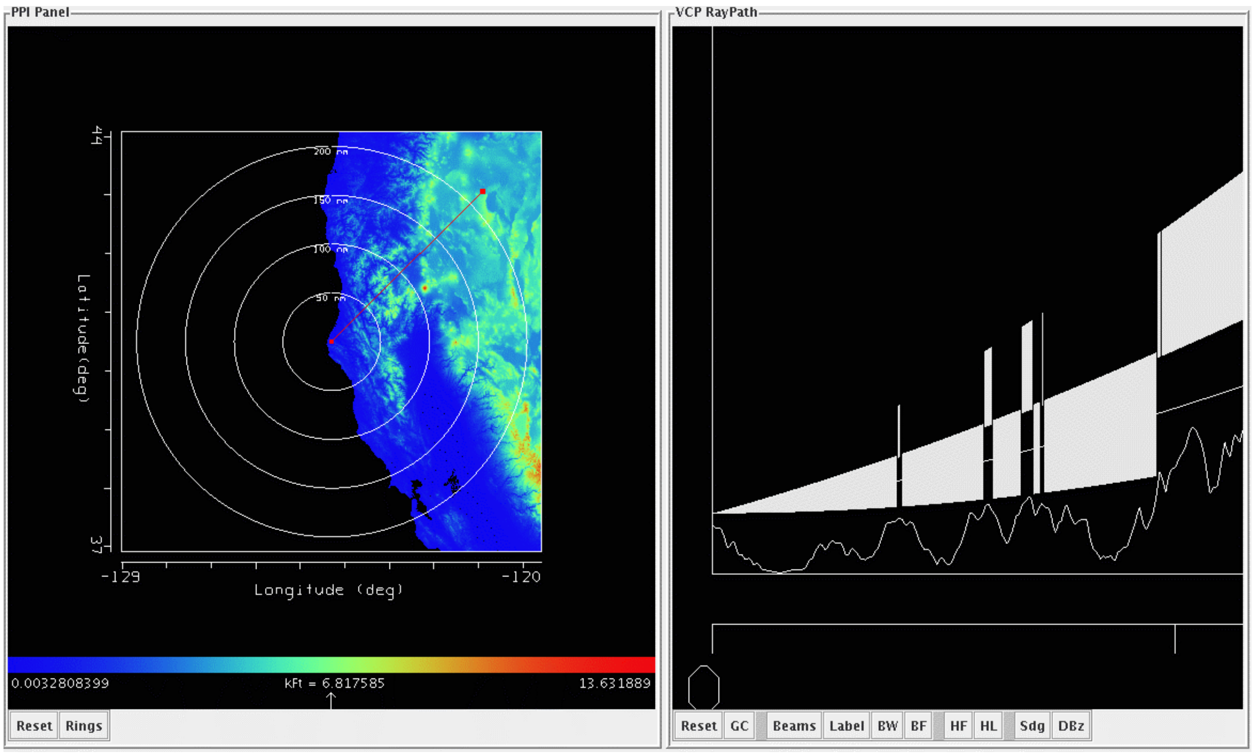


**Figure 3. PPI image (left) displaying terrain along California coast with radar radial (red) oriented along 45° azimuth. RHI image (right – zoomed in) showing terrain (jagged line) and resulting "Terrain Based Hybrid Scan" after O'Bannon (1997).**