4.4 Weather and Radar Processor (WARP) Products for en-route controller displays

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1. INTRODUCTION

Air traffic controllers at the FAA's Air Route Traffic Control Centers (ARTCC) have been using NEXRAD mosaics on their situation displays for five years now. These NEXRAD displays are different from those used by meteorologists and the general public. That's because controllers don't have time to study and analyze the product. They are too busy directing traffic. Thus their NEXRAD products must be instantly understandable and remain in the background, behind the more important aircraft information. Because of these unique requirements, the FAA developed a special color scheme for the NEXRAD products on the ARTCC controller displays. Table 1 shows this color scheme.

Table 1
NEXRAD Color Scheme for Controllers Display

Reflectivity	Color	Phraseology
< 30 dBZ	Blank	N/A
30-40 dBZ	Royal Blue	Moderate precipitation
40-50 dBZ	Checkered Cyan	Heavy precipitation
>50 dBZ	Cyan	Extreme precipitation

Note: Only echoes 30 dBZ and above are displayed on en-route controller displays.

In addition, the controllers have four layered products to choose from (Table 2). Recently however, controllers have been instructed not to use the low layer product and to use the 0-60,000 ft product instead. There are three primary reasons for this:

(1) The 0-60,000 ft CR is generated using the WARP optimal mosaic (see below) while the 0-24,000 ft CR is not. Thus the low layer product is typically much noisier.
(2) The range of the individual 0-60,000 ft CR products used in the WARP mosaic is 248 nm. The range of the 0-24,000 ft NEXRAD CR product is only 124 nm. This limits the amount of coverage for the WARP low layer mosaic, particularly off-shore and in data sparse areas.
(3) The maximum reflectivity value from radars in the clear air mode is capped at 30 dBZ for the 0-60,000 CR while the maximum in the 0-24,000 ft CR is not capped. Thus the 0-60,000 ft CR mosaic will typically be less noisy when contributing radars are in the clear air mode.

Table 2
NEXRAD Layers Available on Controller Displays

Mosaic Name	Layer (ft)
Composite Reflectivity	0-60,000
CR Low	0-24,000
CR High	24,000-33,000
CR Super High	33,000-60,000

2. Areas for Improvement

While the WARP NEXRAD mosaics provide a much improved weather picture for en-route controllers, there is still room for improvement. Data latency, coverage, and noise are the three

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main areas cited by controllers as still needing improvement.

Data latency is a problem because even in the best of coverage areas (eastern 2/3 of the US) there is typically a 3 to 5 minute lag between the time a given radar sees a feature and that feature shows up on the controller display. In areas like the Mountain West where there is mostly single coverage, the update rate is even worse. See fig 1 below.

The factors that go into this typical 3-5 minute latency include:

- Controller display update rate – 25 sec
- WARP processing (mosaic generation) – 5 sec
- NEXRAD product generation – 10 sec
- Communications between NEXRAD and ARTCC WARP – 10 to 20 sec
- Volume Coverage Pattern (VCP) and radar overlap – 2 to 5 min

This last number depends on many factors such as, how many radars can see the feature, the feature's altitude, and which tilts from which radars detected it.

In regions where there is considerable overlap, like the Kansas City ARTCC shown in Fig 2, the controller's display will give a more timely depiction of the leading edge of a storm than the trailing edge. That's because as the storm clears an area the WARP mosaic typically keeps that feature until the last radar sends an update showing the area is now clear. So the update rate on the leading edge of the storm may be 3-5 minutes but the clearing of the storm on the trailing edge may be somewhat slower. In a sense the storm is depicted like a comet with a tail, the tail being an artifact of the mosaic process.

As we have already seen, latency and coverage are inter-related. The better the coverage the more frequent the updates and thus the lower the latency. As Figs 1 and 2 show, coverage varies widely over the CONUS. Coverage gaps are most pronounced out West. Yet even in the East, there are coverage gaps offshore. These offshore coverage gaps are much worse for the NEXRAD layer products than they are for the 0-60,000 ft CR. That's because like the 0-24,000 ft CR, the 24,000-33,000 CR and the 33,000-60,000 ft CR only have a range of 124 nm. Fig 3 shows an example of how a controller working an off-shore sector could miss many storms if he/she chose to use the layer products. For this reason, controllers working offshore sectors have been instructed to always use the 0-60,000 ft CR, regardless of their sector altitude.

The last area for improvement, and perhaps the one where perhaps the greatest improvements have already been made, is noise. Noise, for the purpose of this discussion is any weather information that incorrectly indicates an aviation hazard. We include ground clutter, anomalous propagation, and bright band contamination on this list. Clutter and AP have been greatly reduced by:

- removing all precipitation below 30 dBZ
- introducing an interference detection and editing program to remove power spikes and maintenance bulls-eyes
- implementing an optimal mosaic algorithm that evaluates which radars have the best view of the storm and using their data to remove clutter and AP

Bright band contamination is not usually removed by any of the current WARP quality enhancements. In this regard, one might ask, "Why not switch from CR to VIL?" The reason we have chosen not to do so is in cases of rapid storm development, the CR will be the first to identify the storm as dangerous. The VIL will have to wait until the storm matures further and has a deeper vertical extent.

3. Improvement Efforts

The most recent improvement to the WARP NEXRAD mosaics for controllers came in May 2007. That's when FAA implemented the optimal mosaic on the 0-60,000 ft CR mosaic. The optimal mosaic is described in detail in Lang, 2003. The optimal mosaic typically removes 80% of the AP and clutter that remain after the interference editor has done its work and all echoes below 30 dBZ have been removed. The result is that except for areas in the Mountain West and Alaska where there is little or no radar coverage overlap, the vast majority of AP and clutter have now been removed.

The only remaining noise problem where there is still significant room for improvement is bright band contamination. The most promising tool for mitigating bright band contamination is the selectable layers tool described later in this paper. This tool however, is still being evaluated and will not likely be implemented before 2010.

The most likely next step in improving the weather depiction on the controllers' displays will be the addition of lightning data from the National Lightning Detection Network (NLDN). This promises to greatly improve coverage in data sparse areas like the Mountain West and will reduce thunderstorm data latency to about 30 minutes.

WARP has already developed the software to send the lightning data to the controller displays. Unfortunately, additions to the controller displays have been halted until fielding of the En-route Automation Modernization (ERAM). In addition, the human factors for modifying the controller display still need to be worked out. The target date for putting lightning on the controller displays now appears to be early 2009.

While these enhancements are undergoing development and test, the WARP program is moving forward to incorporate some of the newer NEXRAD products into the meteorologist workstation and the briefing terminals that support traffic managers and area supervisors. The most noteworthy new products will be local and national mosaics of the NEXRAD enhanced echo tops (EET) and the digital VIL (DVL). The VIL mosaics will likely replace the CR and base reflectivity mosaics on the BTs primarily because it is much cleaner and noise free. As stated earlier however, CR will likely remain the product of choice for controllers who are working traffic in real-time.

The addition of the EET mosaics provides an opportunity to replace the controllers' layer products with a "selectable layers" capability. With this capability a controller could set the floor of his/her NEXRAD presentation to an altitude that matches the floor of his/her sector. Sectors in today's National Airspace System (NAS) do not necessarily match the NEXRAD layer products.

This selectable layers system would use the EET product to filter the 0-60,000 ft CR. For example, if the controller selected 16,000 ft for his data floor the algorithm would overlay a data mask where all pixels with echo tops below 16,000 ft would be black and all those above 16,000 ft would be white. This mask would be overlaid on the 0-60,000 ft CR and wherever the mask is black, the final product would be black and wherever the mask is white the final product would be the reflectivity from in the 0-60,000 ft CR.

This is not exactly like the current layer products that depict the maximum reflectivity value within the layer itself. This scheme would depict the maximum reflectivity for the entire column for any storms with echo tops at or above the selected floor. Considering the inherent latency of the NEXRAD mosaics and the speed at which thunderstorms change in the vertical, it may actually be preferable, at least from an aviation safety standpoint, to show the maximum reflectivity within the entire column.

What makes this capability particularly attractive from the controllers' stand point, is it allows those controllers working high level sectors to remove echoes that are below their traffic. Under the current FAA rules, many controllers must use the 0-60,000 ft CR for their sector, even when the floor of their sector is 24,000 ft or higher. Also, they must "call the weather" to all aircraft. The net result is many weather false alarms, particularly during the winter months when low-level stratiform precipitation is prevalent. With the selectable layers algorithm, the high level controller could remove much of this "noise," which often includes bright band contamination.

This past fall the WARP test group at the FAA's William J. Hughes Technical Center developed a real-time prototype of the selectable layers algorithm. Fig 4 contains some snapshots taken from this program during a stratiform event over the Northeast.

4. Conclusion

Air traffic controllers have different requirements than traffic managers and meteorologist. These requirements have led the FAA to provide a unique set of NEXRAD products for en-route controller displays. These products continue to be improved, particularly in the areas of data latency, coverage, and noise. Incorporating lightning data onto the controllers' displays, hopefully within the next two years, will greatly improve coverage and latency. A selectable layers algorithm also shows promise for reducing false alarms caused by low level stratiform precipitation, particularly when there is bright band contamination.

5. REFERENCES

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Doppler weather radar coverage of CONUS at 4,000, 6,000, and 10,000 feet above radar ground elevation from the nationwide network of WSR-88Ds (Next Generation Weather Radars). (Courtesy of SRI International)

Fig 1 NEXRAD coverage map (source: NOAA NEXRAD Radar Operations Center)

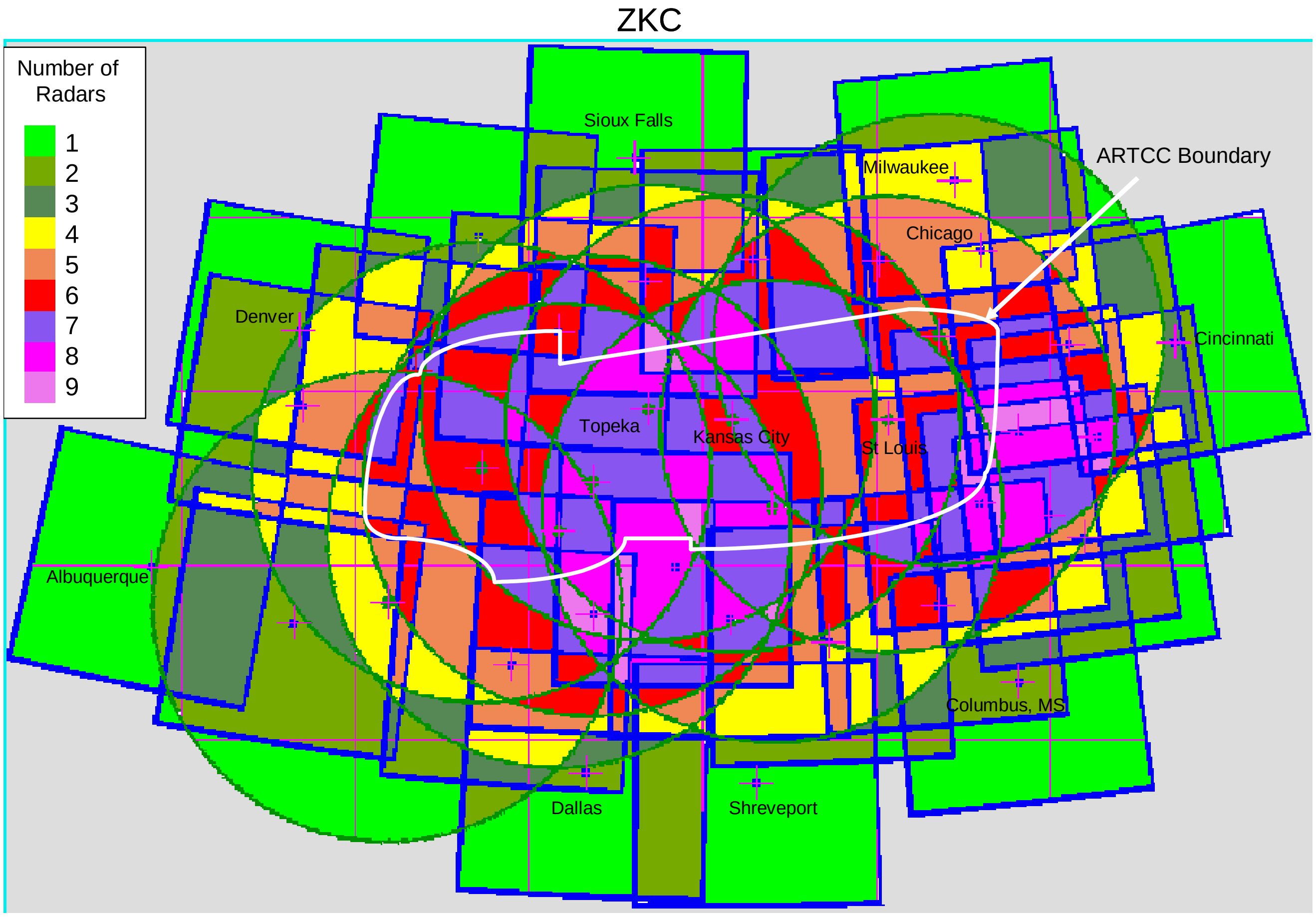


Fig 2 This figure shows the overlapping NEXRAD coverage for the Kansas City ARTCC airspace. The ARTCC boundary is depicted in white. The number of radars that can see a given area is color coded as shown. Notice that the radars on the outer edges of this mosaic only contribute data out to a range of a 124 nm square. The radars within the ARTCC boundary contribute their complete 248 nm circle range. This mix of ranges is done to minimize computational time while still providing ample coverage overlap within the ARTCC boundary.

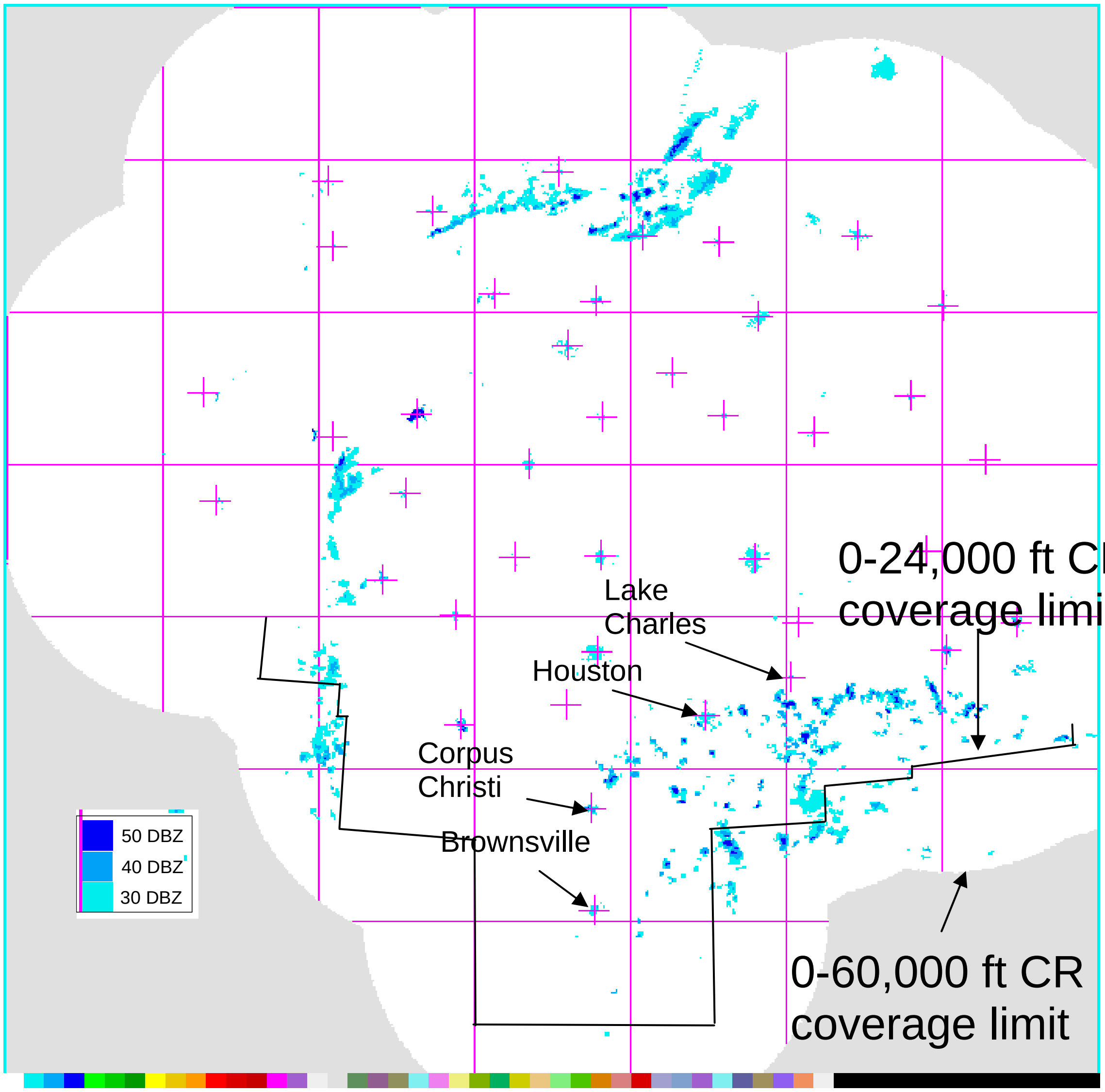
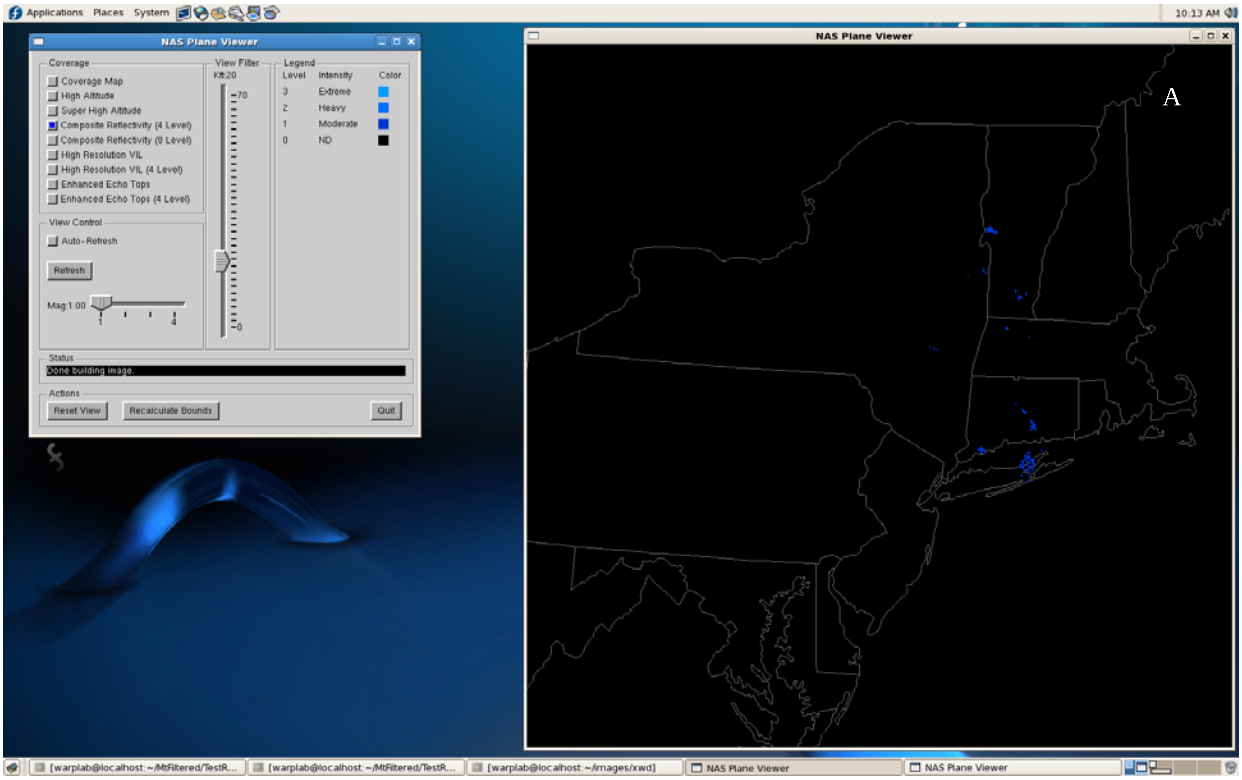


Fig 3 This figure shows the difference in coverage over the Texas Gulf Coast for the 0-60,000 ft CR and the other three layer products. In this case, many heavy and extreme precipitation areas would be missed if a controller selected the 0-24,000 ft CR instead of the 0-60,000 ft CR.


A
NAS Plane Viewer
Coverage
Coverage Map
High Altitude
Super High Altitude
Composite Reflectivity (4 Level)
Composite Reflectivity (8 Level)
High Resolution VIL
High Resolution VIL (4 Level)
Enhanced Echo Tops
Enhanced Echo Tops (4 Level)
View Control
Auto-Refresh
Refresh
Mag:1.00
View Filter
Kft:20
Legend
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3 Extreme
2 Heavy
1 Moderate
0 ND
Status
Done building image.
Actions
Reset View
Recalculate Bounds
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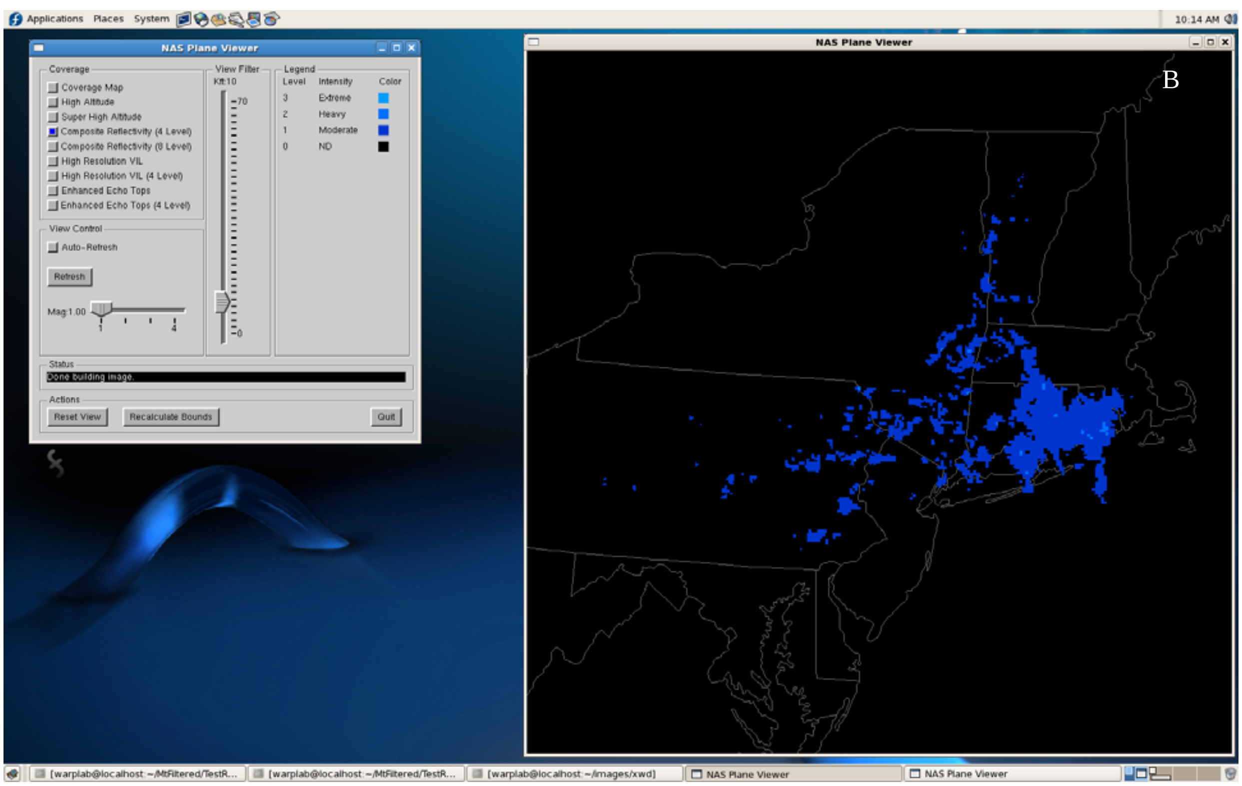
B
NAS Plane Viewer
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Composite Reflectivity (4 Level)
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High Resolution VIL (4 Level)
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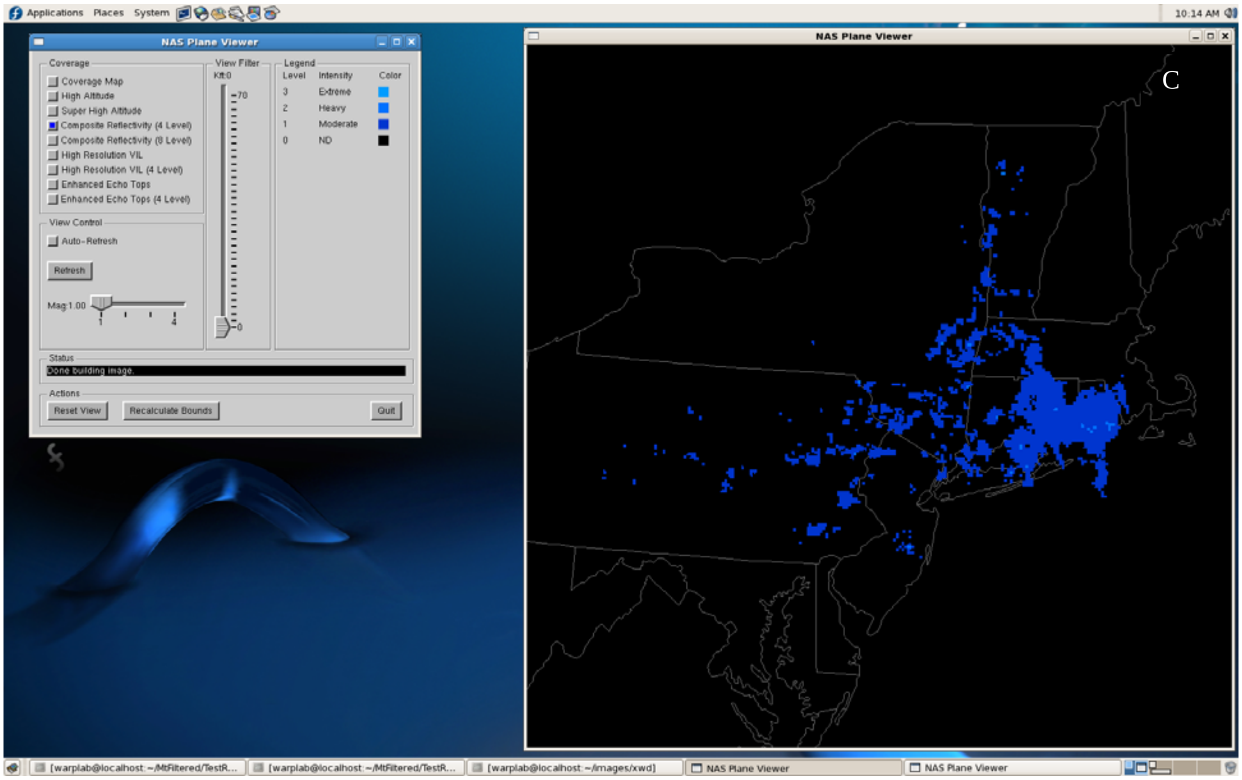

Fig 4 Snapshots from prototype selectable layers algorithm. The top image (A) has the data floor set to 20,000 ft, the middle image (B) to 10,000 ft and the bottom image (C) to 0 ft. Notice that almost all the precipitation is below 20,000 ft.