# AN EXTENDED WINTER FOG EVENT IN ARIZONA'S LITTLE COLORADO RIVER VALLEY

**Robert Bohlin, WFO Flagstaff, AZ**

## INTRODUCTION

Extended dense fog events of three continuous days or more are rare in Northern Arizona and typically occur in the Little Colorado River Valley (LCR). Based on Winslow airport surface observations from NCDC, extended fog events with ¼ mile visibility or lower have occurred at least 11 times in the LCR from 1952 to present. During this same time period the month of December recorded 7 of these 11 events, more than any other month. The purpose of this WES case was to help forecasters anticipate the onset, duration and dissipation of these extended LCR fog events.

This study examines one event which started on December 9th 2004 and ended on December 15th 2004. Prior to the fog event, a winter storm moved into northern Arizona covering the entire LCR with 3 to 9 inches of snow. After the snowfall, a significant warm up in temperatures caused the snowfall to melt rapidly. The available moisture was trapped in the LCR valley by a strong subsidence cap which prevented both vertical mixing and horizontal advection of the moist airmass under the cap. This fog event produced a significant visibility hazard (Fig. 1) for six days as an extensive area of fog eventually blanketed much of northeastern Arizona.

Fig 1. Photos of Wupatki National Monument following the snowstorm and subsequent fog event. Courtesy of the National Park Rangers at Wupatki NM.

**TOPOGRAPHY OF THE LITTLE COLORADO RIVER VALLEY AND NORTHERN ARIZONA.**

The Little Colorado River Valley basin (Fig. 2) in Northern Arizona is bounded by the Mogollon Rim to the south and west and Black Mesa/ Defiance Plateau to the north and east. The basin slopes downward toward the northwest and drains into the Grand Canyon covering an area of approximately 70,000 km².

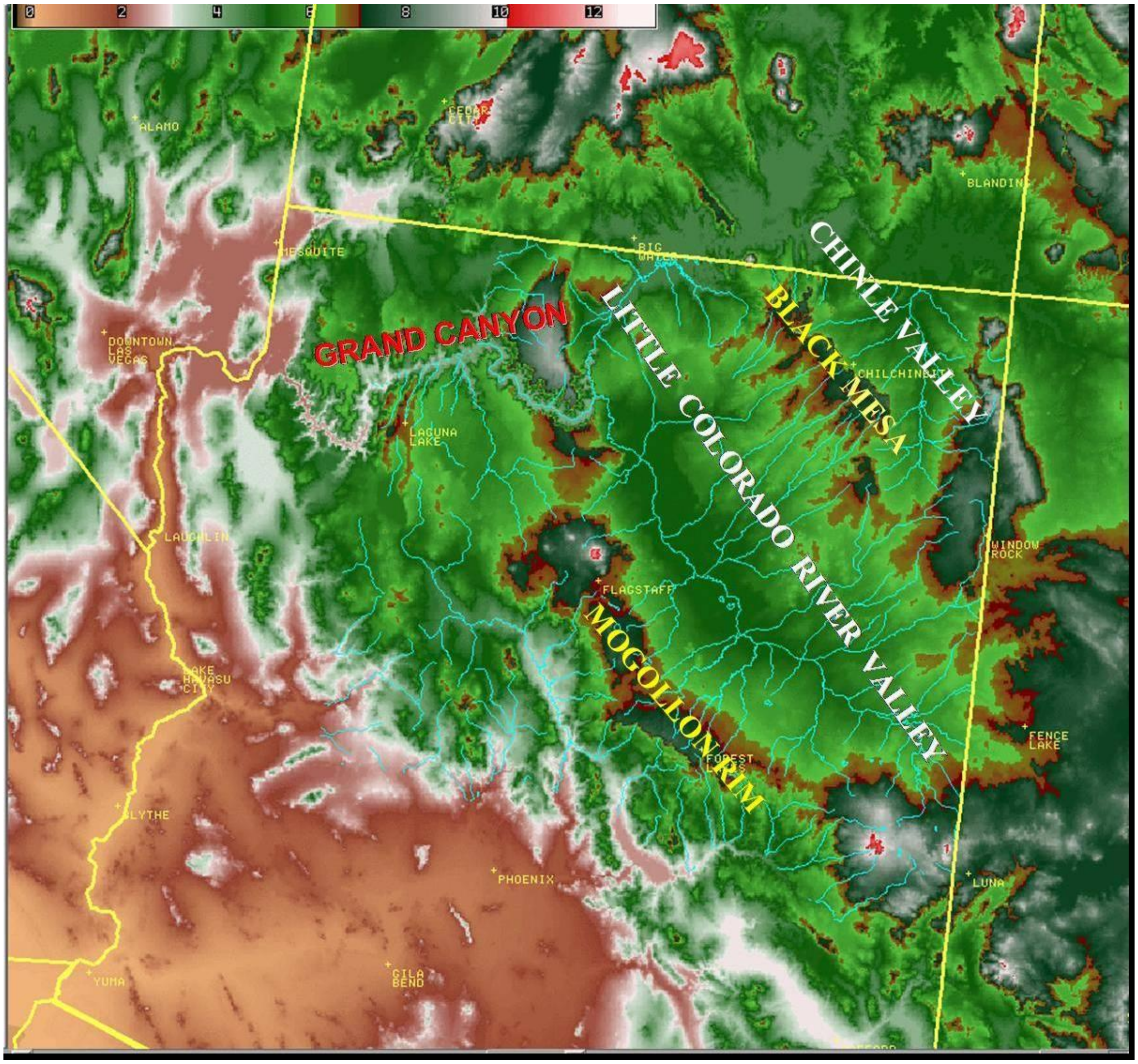


Fig. 2. Map of the Little Colorado River Valley and surrounding terrain features. Surface elevation (kft) shaded according to scale at upper left.

**SNOWSTORM EVENT**

On December 4th through 6th a cold front moved through the LCR lowering snow levels to below 5000 feet. The temperature observations below (Fig. 3) are three day averages which will be used to contrast the maximum temperature during the snowfall event with the warm up period. The precipitation observations represent three day total accumulations reported from available cooperative observing sites. Snowfall amounts with this system were observed between 3 and 9 inches in and around the LCR. Maximum temperatures for the snowfall event ranged from lower 30's near Flagstaff (elevation 7003 ft) to lower 40's in Winslow (elevation 4886 feet).

Unfortunately the observations are sparse in this area with Winslow ASOS being the only reliable source for hourly data and although the official snow observation at Wupatki National Monument was missing it should be noted that there were significant snow accumulations during the event (as shown in picture on Fig 1).

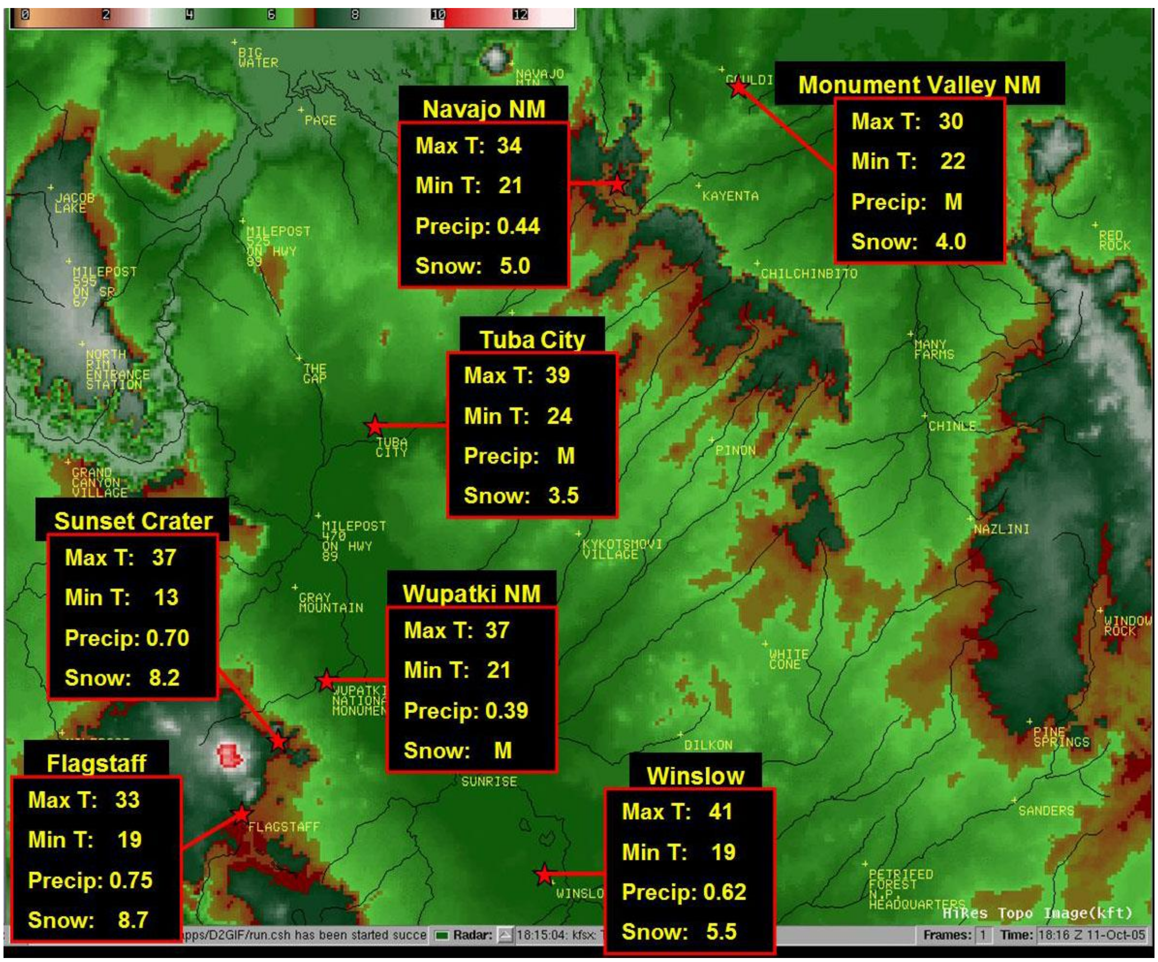


Fig. 3. Map of Little Colorado River Valley with COOP & ASOS observation sites in and around the LCR. Temperatures (º F) are three day averages (December 4th, 5th & 6th) and precipitation and snowfall reports are three day accumulation totals.

## THE UPPER LEVEL RIDGE BUILDS IN OVER NORTHERN ARIZONA

Following the snow event an upper level ridge built in rapidly over northern Arizona (Fig. 4a and 4b) producing large scale subsidence and adiabatic warming. This warming trend triggered rapid snow melt in the LCR basin and provided abundant moisture, light winds, and a strong subsidence cap, which are all primary ingredients for fog formation. Depicted in these figure are 500 mb geopotential height (dm) shown in green, 700 mb wind barbs (knots) shown in white and 700 mb isotherms (degrees C) shown in red.

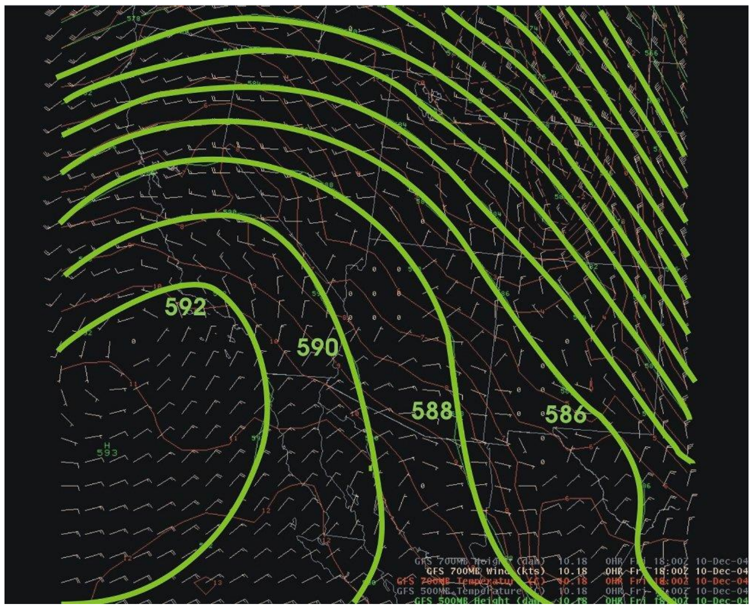


Fig. 4a. GFS 00HR analysis for December 10th 1800 UTC.

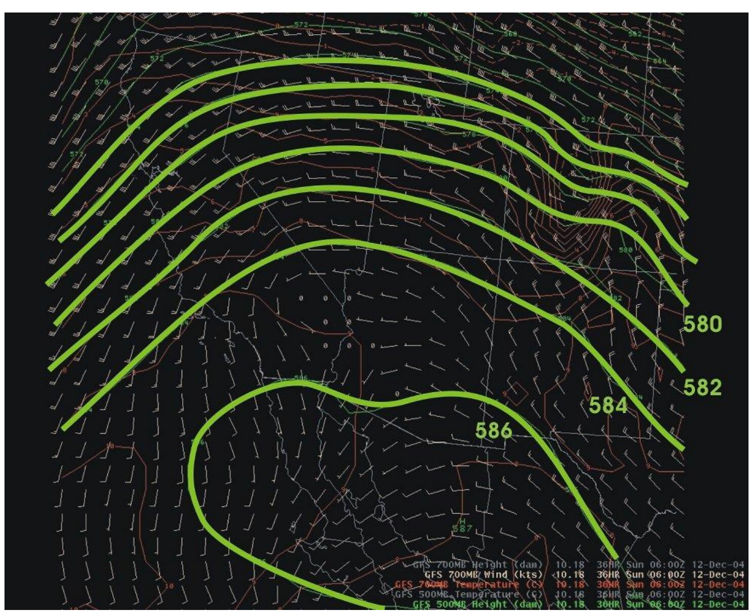

Fig. 4b. GFS 36HR forecast for December 12th 0600 UTC.

By December 9th the maximum temperature for most sites in the LCR increased by approximately 10° F as compared to the average maximum temperatures recorded on December 4th through the 6th. Notice that brief fog events were reported for the two highest elevation stations of Flagstaff and Navajo National Monument. These fog observations and the 50 degree maximum temperatures are clear signs that the snow melt was well underway.

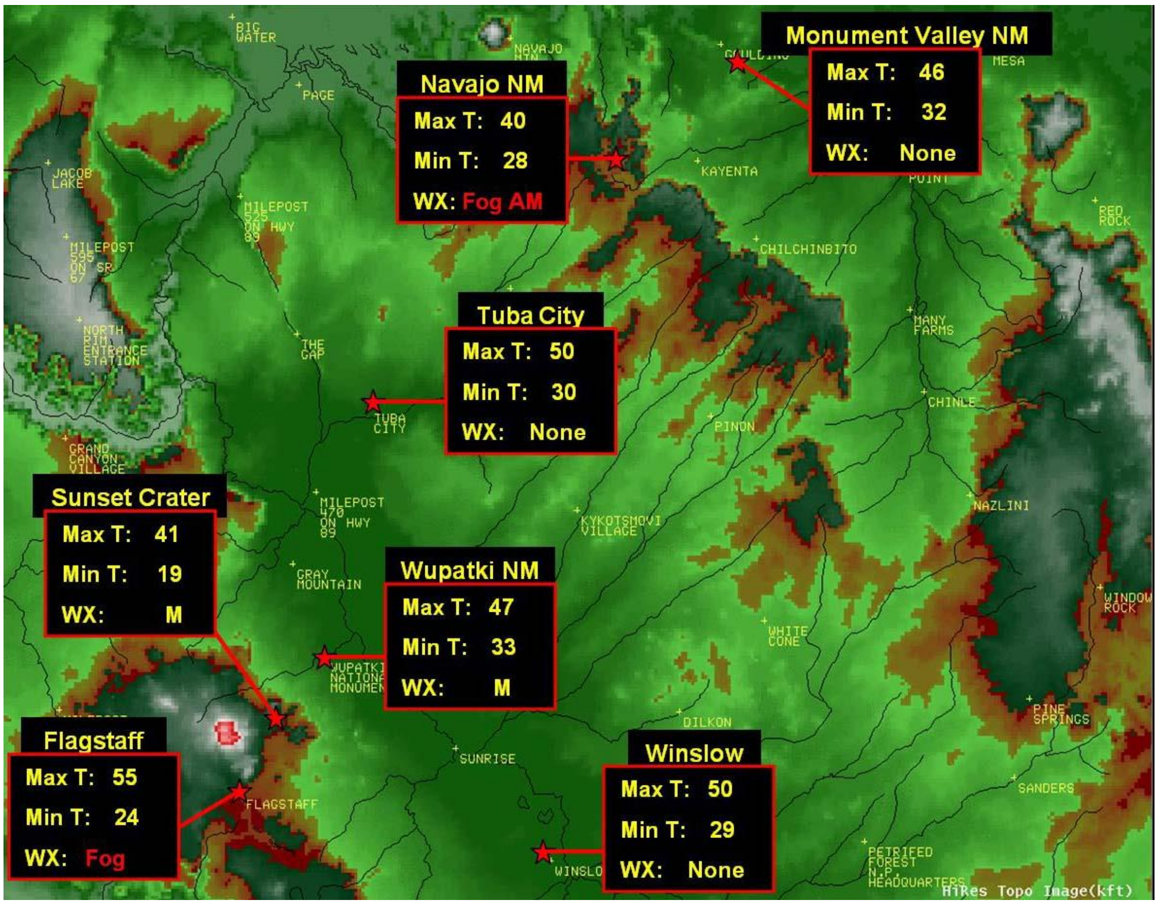


Fig. 5. Map of Little Colorado River Valley with COOP & ASOS observation sites.
Temperature and weather reports are from December 9th .

## FOG FORMATION

Early in the morning of December 10th, based on fog channel IR imagery (Fig. 6), an extensive fog bank set up in the LCR. There were several interesting features that appeared on the satellite data in the early stages of the event. The first feature of note is the valley fog in the Northern LCR which appears to be responding to the snowmelt on Black Mesa. Another interesting feature was the fog bank formation in the southern LCR with a dry cloud free region located near Winslow which extends along the base of the valley towards Snowflake. This was possibly caused by insufficient cooling at the lowest elevations which prevented the moist boundary layer in the base of the valley to reach saturation. The initial formation of the fog bank appears to be along the higher slopes of the LCR.

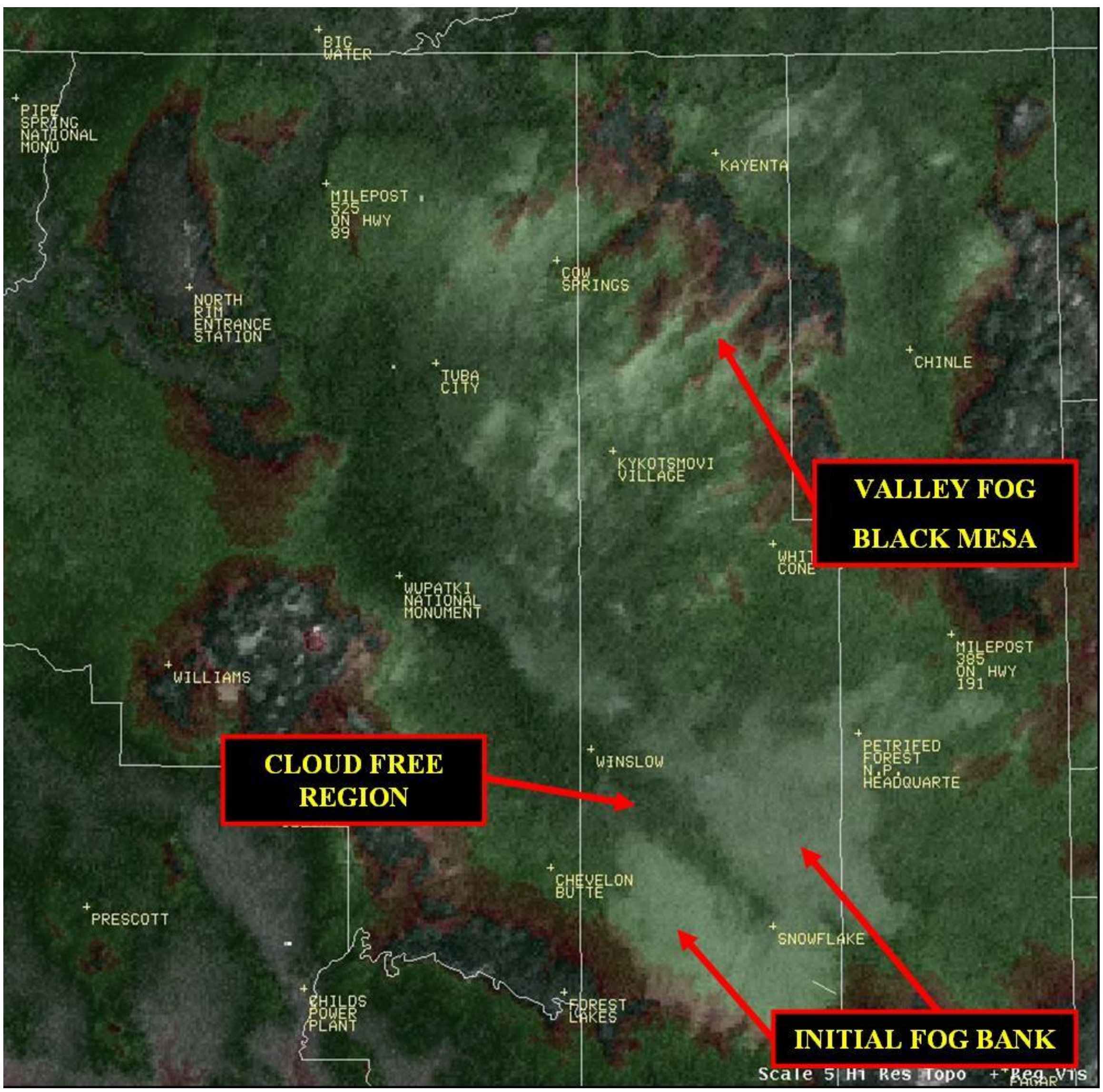


Fig. 6 GOES VIS satellite image of the Little Colorado River Valley for December 10th 1530 UTC. This visible satellite image is combined with a topography layer to provide elevation detail.

On the second day of the event, December 11th, GOES satellite imagery (Fig. 7) showed the fog bank had spread to cover most of the LCR valley floor as far north as the Grand Canyon. The animated satellite imagery (not shown) indicated that the fog bank was confined throughout the day to the lowest elevation areas in the LCR. Observations at Winslow ASOS (KINW) showed visibility dropping to ¼ mile in fog. This pattern continued through the third day of the event with a slight increase in the spatial extent of the fog bank. Another feature of note is the clouds forming between Kayenta and Mexican Hat which is another low elevation area.

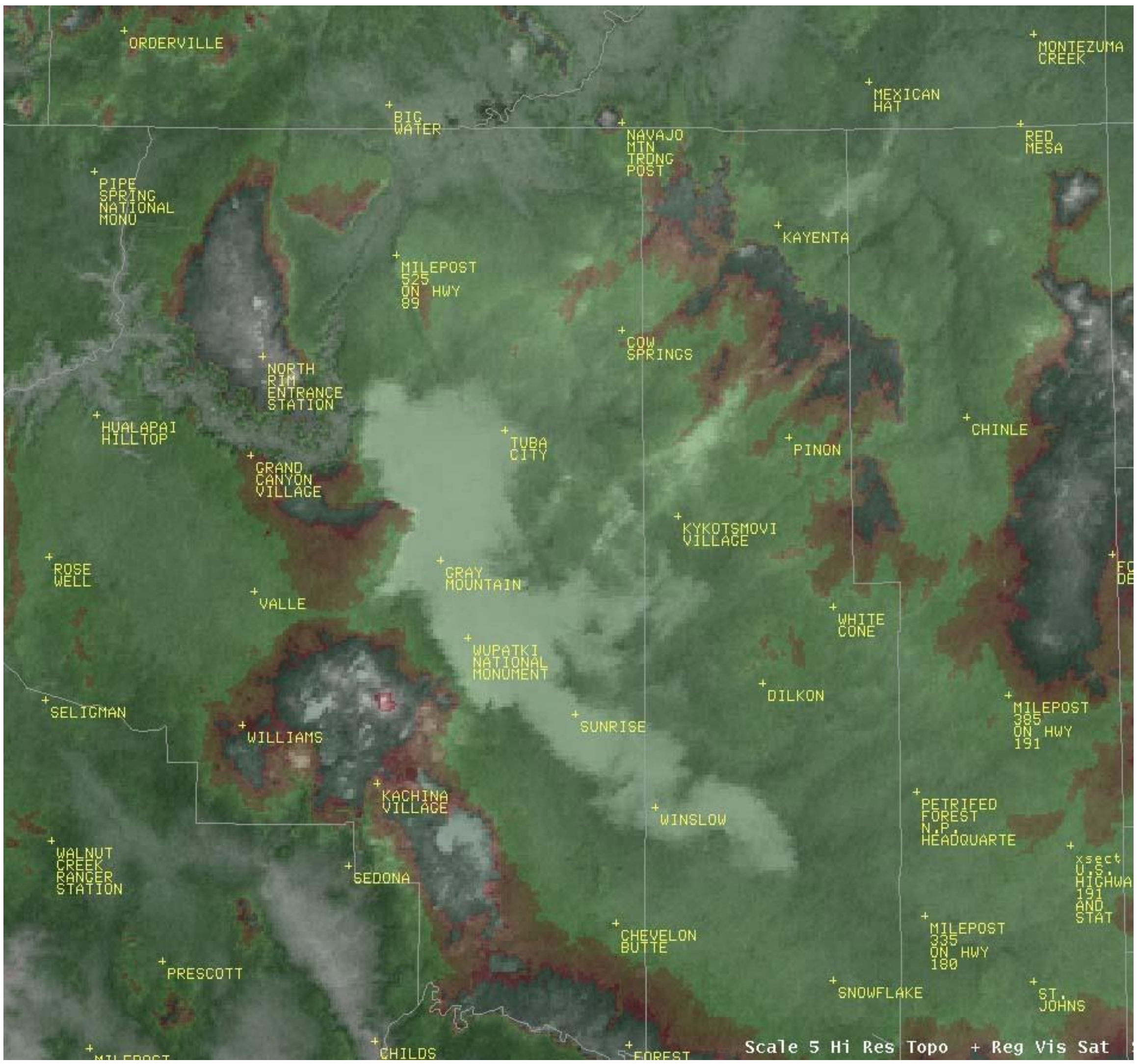


Fig. 7 GOES VIS satellite image for December 11th 2004 1900 UTC. This image is combined with color enhanced terrain data.

By the fourth day, December 13th, GOES satellite imagery (Fig. 8) showed a massive expansion in the fog bank was noted and it covered the majority of the Little Colorado River Valley. It appears at this point the height of the subsidence inversion was the main controller on how wide the fog spread. At this time there were additional reports of visibility dropping below ¼ mile along Interstate 40 (southern LCR near Winslow). Notice in the upper left portion of the image there is another area of extensive fog (Chinle Valley). The satellite imagery for December 14th (Not Shown), was slightly more extensive in coverage as compared to December 13th.

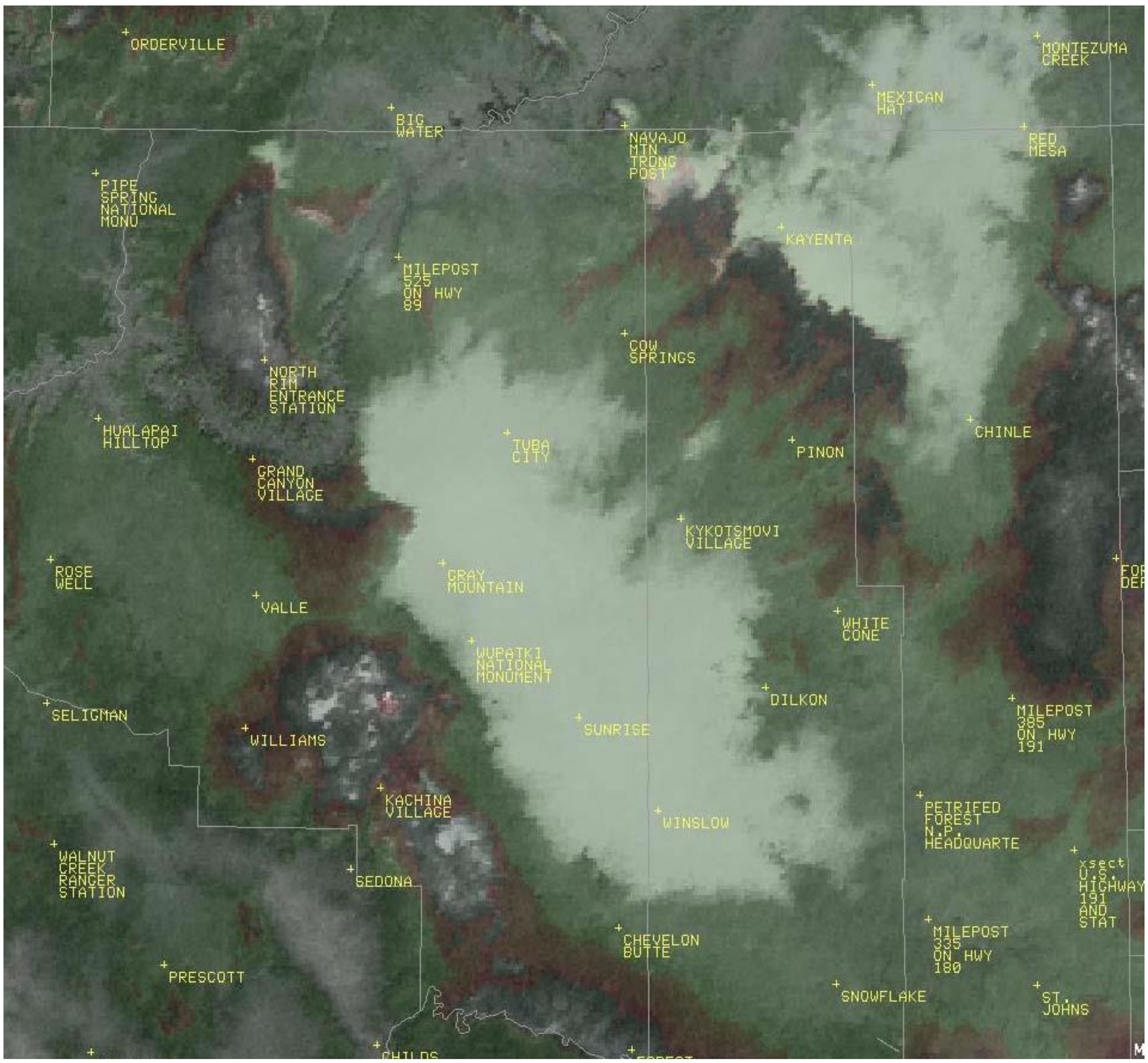


Fig. 8. GOES VIS satellite image for December 13th 2004 1830 UTC. This image is combined with color enhanced terrain data.

On December 15th, the entire LCR valley was covered in dense fog. The fog was so extensive it was actually spilling over into the Grand Canyon. The visible satellite image below (Fig. 9) represents the last day of the LCR fog event and it clearly shows that these rare events can significantly impact customers in Northern Arizona.

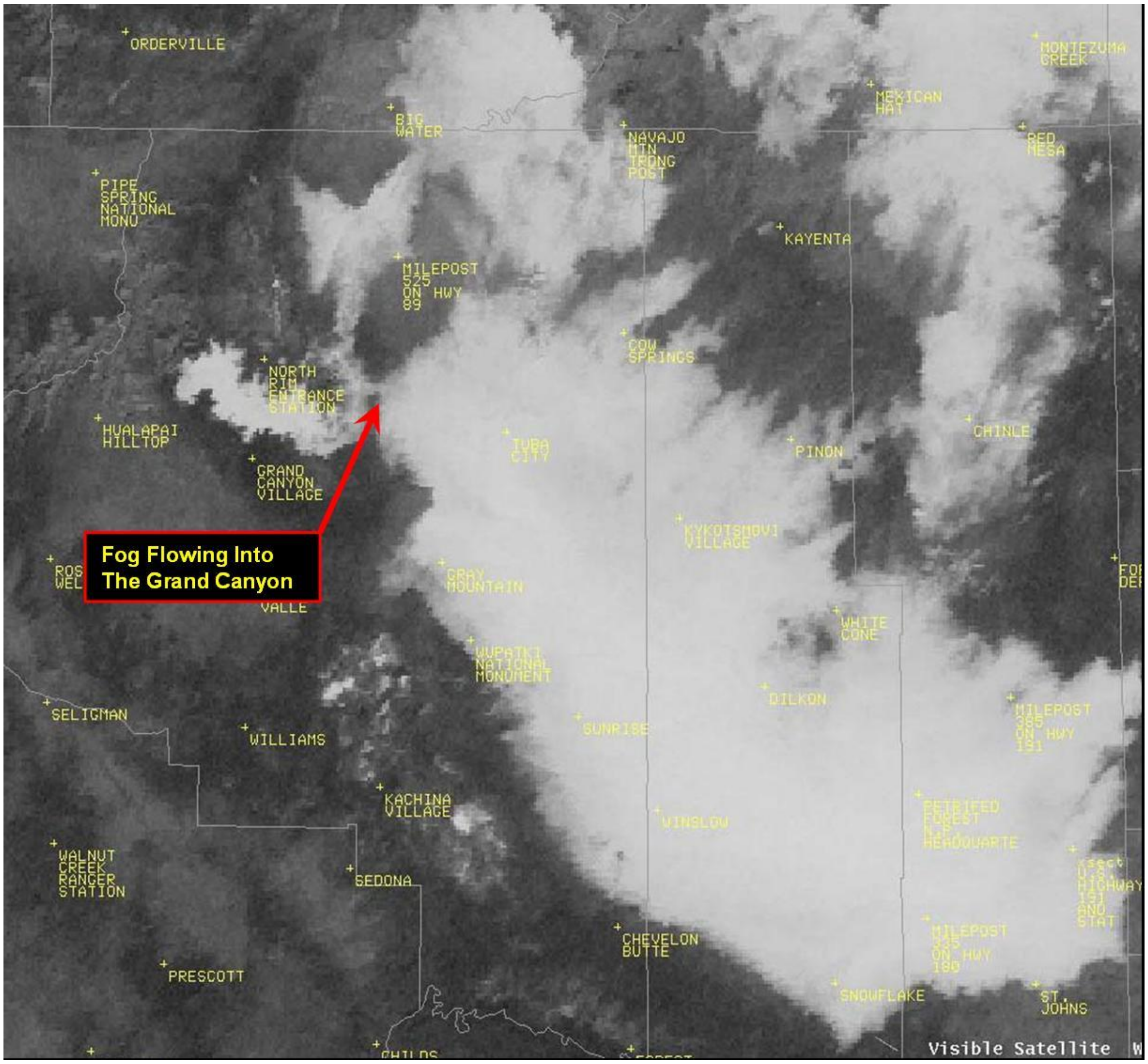


Fig. 9 GOES VIS satellite image for December 15th 2004 1830 UTC.

On December 16th, a frontal system moved into the area from the north lifting the subsidence cap and scouring out the moisture from the LCR. This system brought an end to the weeklong LCR fog event which dissipated as rapidly as it formed.

## CONCLUSIONS

This case demonstrated how one weather event (snowfall) can rapidly evolve into a second significant event (1/4 mile fog). While fog is rare in the LCR, this study shows how these types of events can significantly impact our customers on a broad scale by creating a considerable long term hazard for travel on local roadways and interstates. Accurately forecasting these fog events even 24 hours out can provide substantial benefits for travelers in northern Arizona.

The main lesson learned from this WES case is to anticipate the potential for dense fog to form after a widespread snowfall event in the Little Colorado River Valley. Under these conditions rapid warming in maximum temperatures coupled with a strong capping inversion increasing the likelihood of dense fog formation. The indicators for this event were similar for any valley fog event (light winds, subsidence cap and available moisture) with no real surprises. The challenge is in anticipating and forecasting these events due to their climatological rarity. Since these events are so climatologically rare with roughly one event every three years, it is difficult for both numerical models and forecasters to anticipate such rapid changes to occur under a high pressure ridge pattern.

## REFERENCES

NCDC, cited 2006: Local Climatological Data, Edited [Available online at http://www7.ncdc.noaa.gov/IPS/LCDPubs?action=getstate&LCD=hardcode]

Glorice Pavey / US National Park Service, cited 2004: Photo's of Wupatki National Monument

NCDC, cited 2006: Unedited Surface Weather Observations (SWO) [Available online at http://www5.ncdc.noaa.gov/cgi-bin/script/webcat.pl?action=ALL]