Advanced Warning Operations Course

Simulation Guide: *Dec. 22-23, 2004 Event*

Presented by the
Warning Decision Training Branch

Acknowledgments

Special thanks to John Kwiatkowski and the IND NWS office and Ted Funk and the LMK offices for providing data and assisting with development of the simulation guide.

Photo from the Scott County, IN genealogy and history website: http://www.scottinhistory.com/countypictures.html

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Document History

The document history is provided to track updates and changes to the simulation guide. The version number, seen at the bottom of every page will be updated as each significant change is made to the simulation guide.

Version	Date	Description
1.0		
2.0	Fall of 2008	We are now at WES8.3 Changes have been made to reflect new winter warning policies discussed in IC2.1
3.0	Fall of 2009	We are now at WES9.0

Note: the date of modification is listed on the cover page.

To provide feedback, comments or ideas related to this document, please visit our web site at: http://www.wdtb.noaa.gov

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1: How to Use This Document

I. Introduction

Welcome to the ***Dec. 22-23, 2004*** Simulation Guide! The purpose of this guide is to provide the trainer at a forecast office with case-specific materials needed to prepare and deliver effective simulations for the winter track of the Advanced Warning Operations Course (AWOC). The general approach for using simulations in the winter track of AWOC is the same as with the simulations associated with the core and severe tracks of AWOC. You may choose to use these materials and the case provided for your simulations, or you may use these to help design simulations using a different case. For general guidance on preparing and delivering simulations for AWOC please consult section 1 from the AWOC Simulations Master Document from the 2005 AWOC.

Since this document outlines the "answers" to the challenges of the event, it is specifically meant for the use of the trainer only.

In order to create effective simulations with this case you will need to familiarize yourself with the details of this event. We recommend installing the case first, followed by reading each short section in order. It will help to have the data available for static review while reading the document. See Table 1-1 for a description of the layout of this document.

Table 1-1: Simulation Guide Layout

1: How to Use This Document	
I. Introduction	The introduction describes contents of the simulation guide and how to use this document.
2: The Dec. 22-23, 2004 Event Overview	
Overview	The event overview provides a summary of the key components of this event.
3: Background Information	
Background Information	Read this section to become familiar with the data characteristics of this case, information on WESSL, as well as notes from the forecast office.
	4: Simulation Suggestions

Table 1-1: Simulation Guide Layout

Simulation Suggestions	A sample of potential simulations are provided along with performance objectives and evaluation criteria to illustrate how to create simulations for AWOC using this case.
Supporting Data	
Appendix A: Storm Reports	Appendix A: Storm Reports contains a text list of Storm Data valid for the simulations.
Appendix B: Support Materials	Appendix B: Support Materials contain a master list of all evaluation criteria and performance objectives for potential use with the simulation. Two CWA maps of IND and LMK are also provided.

After reviewing the simulation guide and becoming familiar with the details of this event, the trainer will be ready to begin creating simulations for the trainees. The trainer will need to understand the AWOC performance objectives and review the trainee's performance on all the AWOC ICs taken to determine the emphasis of the simulation. A simulation should be organized to reemphasize important AWOC fundamentals in a way that allows the student to apply the concepts learned and in a way the trainer can easily evaluate.

Nearly all of the AWOC lessons contained performance objectives that can be used to help focus a simulation. Some of these are more suited for simulations than others. For example, performance objectives 2 and 3 of the following example below are good ones to focus on in a simulation:

<u>Performance Objectives</u>

1. Identify what is needed to create a climatology
2. Determine if the anomaly is significant and its potential impact on the winter weather expected
3. Understand the strengths and limits of climatic anomalies.

To help narrow the focus of the simulation and provide proper instruction for the trainee, we suggest defining evaluation criteria. An example of this is shown below for the above performance objectives 2 and 3:

<u>Evaluation Criteria</u>

1. Identify any significant anomalies in the ensemble forecasts that are relevant to the forecasts for Indiana and Kentucky using picflip (250mb, 500mb, 850mb, 2m, and MSLP).

2. Document the importance of the anomalies.
3. Document how the anomalies relate to classic winter storms.

The evaluation criteria are explicitly stated to the trainee in the simulation to help them focus on the objectives of the simulation, and there are specific answers that can be used to evaluate the performance of the simulation. In Appendix B we have provided examples of evaluation criteria that are relevant for this case to illustrate how to tailor performance objectives to this case to develop focused simulations.

We have also provided four simulation examples for this case complete with answer keys in the Simulation Suggestions section for you to consider using as is, or for you to use as a starting point to design your own simulations. The simulations feature one watch period simulation and one warning/nowcast period simulation for the IND and LMK CWAs. Each simulation contains about 5-7 evaluation criteria with the workload arranged to support the performance objectives.

Training research indicates that one-on-one training, where ***trainer and trainee participate together for the optimum learning experience***, is the most effective way to run a simulation. While time consuming, this can insure that:

1. trainee remains focused on the objectives of the simulation,

2. the trainee receives essential feedback on performance, and

3. the facilitator develops a solid understanding of how well the trainee comprehends the training and how well the trainee transfers the training to application.

In order to manage a simulation session, the trainer must be able to run a simulation as documented with the WES install and testing instructions included with the WES software. The simulations will be much more relevant if local AWIPS customizations (e.g. procedures, color tables, etc.) are ported to the WES machine as outlined in the WES installation instructions. For more information on the WES, visit http://www.wdtb.noaa.gov/tools/wes/index.htm

2: The *Dec. 22-23, 2004* Event Overview

Over the span of ~36 hours on 22 and 23 December, 2004, a potent winter storm paralyzed much of the Ohio Valley as it moved from northeast Arkansas northeast to Lake Erie. Hardest hit were the Indianapolis, IN (IND), Paducah, KY (PAH), Louisville, KY (LMK), Wilmington, OH (ILN), and Cleveland, OH (CLE) County Warning Areas (CWAs). These simulations focus on LMK and IND. Over 30 inches of snow fell across parts of south-central Indiana, and

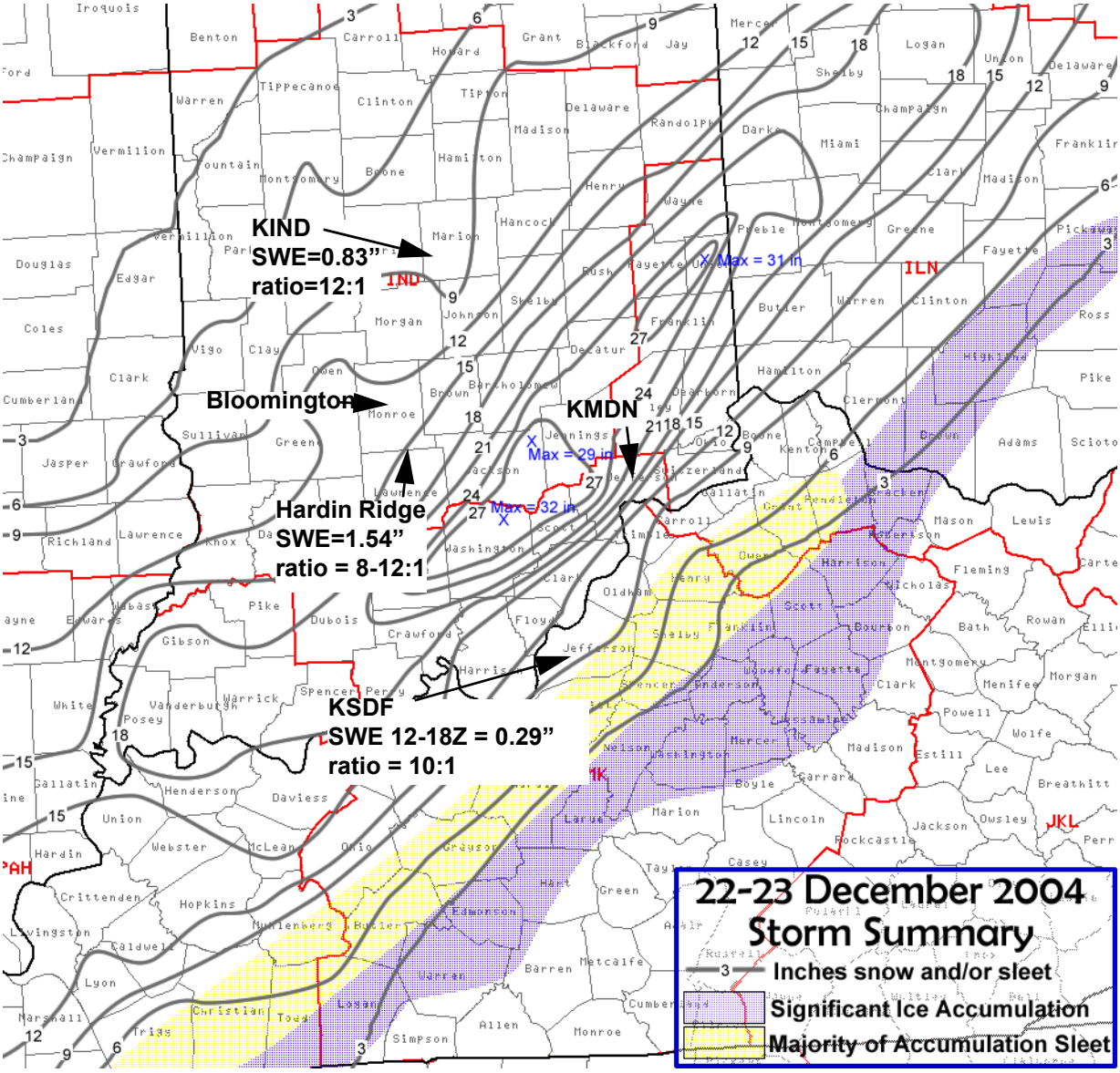

Figure 2-1. Storm total accumulation for the Ohio Valley region from 22-23 December, 2004. Grey contours are snow/sleet totals, while shaded regions are where significant sleet (yellow) or ice accumulation (blue) occurred. Specific place names are referred to in the text.

widespread amounts of 1-2 feet with drifts over 3 feet were common over a large area of the Ohio Valley (Fig. 2-1). In LMK, Grayson and Butler Counties, KY received 6 inches of sleet, and many counties to the south and east saw up to an inch of ice accumulation. Thunder snow and sleet were reported for several hours across the areas receiving the heaviest precipitation. Ground transportation across southern Indiana, southwest Ohio, northern Kentucky, and southern Illinois was crippled as every major interstate highway was shut down in the region, including I-64, I-65, I-74, and I-70. Air travel was also severely

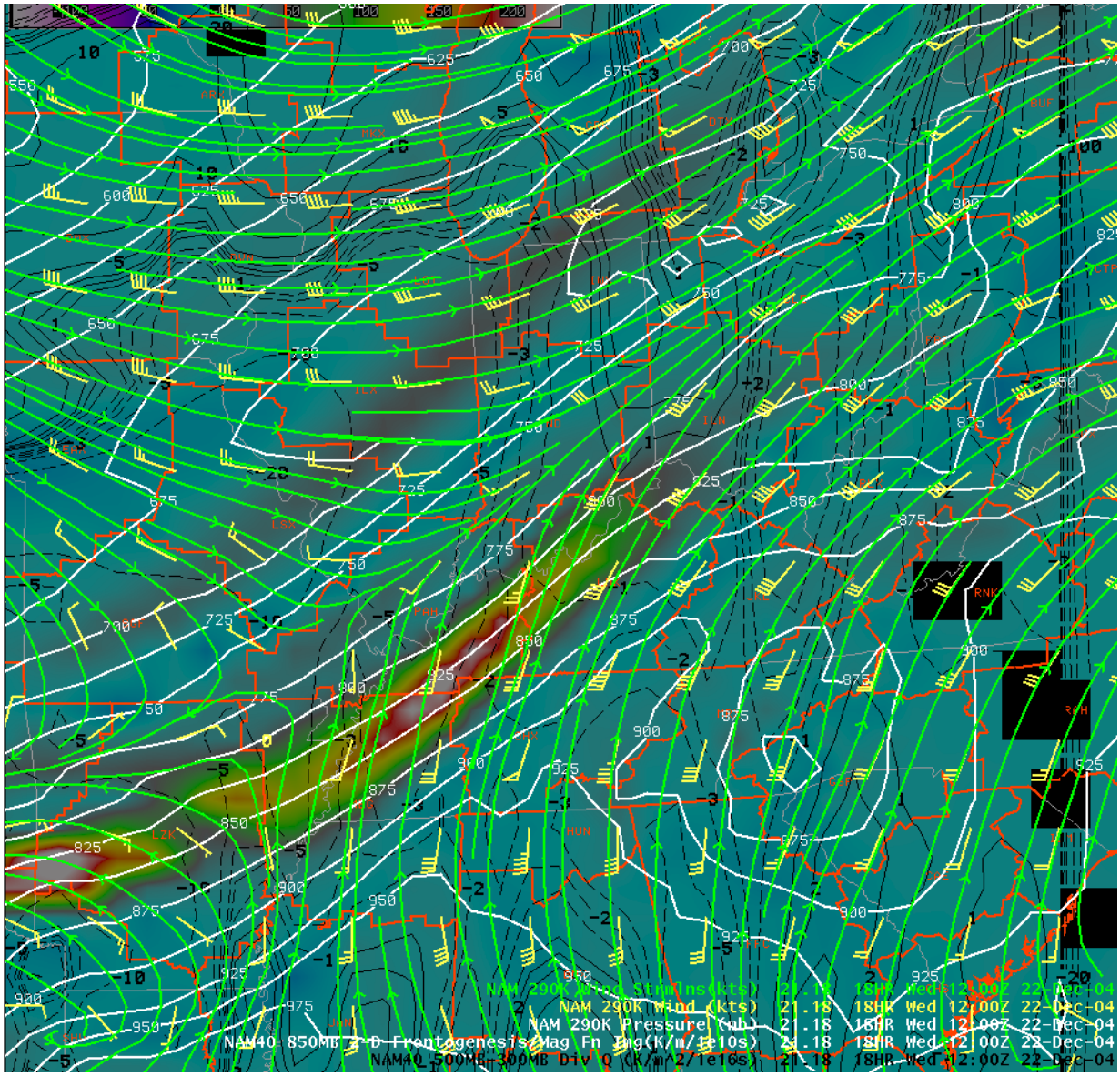

Figure 2-2. ETA (NAM) 18 hr forecast from the 18 UTC 21 December 2004 initialization, valid at **12 UTC 22 December 2004**. CWA boundaries outlined in solid red, 290 K isentropic surface pressure (mb) are solid white, 290 K isentropic surface wind barbs (streamlines) are yellow (green contours), black contours are 500-300 mb Q vector divergence fields (dashed=convergence), and shading is 850 mb 2-D frontogenesis.

hampered for several days. The Louisville airport had vastly reduced departing flights on 22 December, and no flights were allowed at all throughout 23 December. Because Louisville is a hub for UPS, and this was right before Christmas, the financial impacts of no flights getting out were enormous. Historically, this storm ranked near or at the top of the lists in terms of snowfall totals and economic losses in many parts of the region.

The event was the result of two rounds of heavy precipitation, each with different forcing mechanisms. The overview of these two rounds of precipitation are

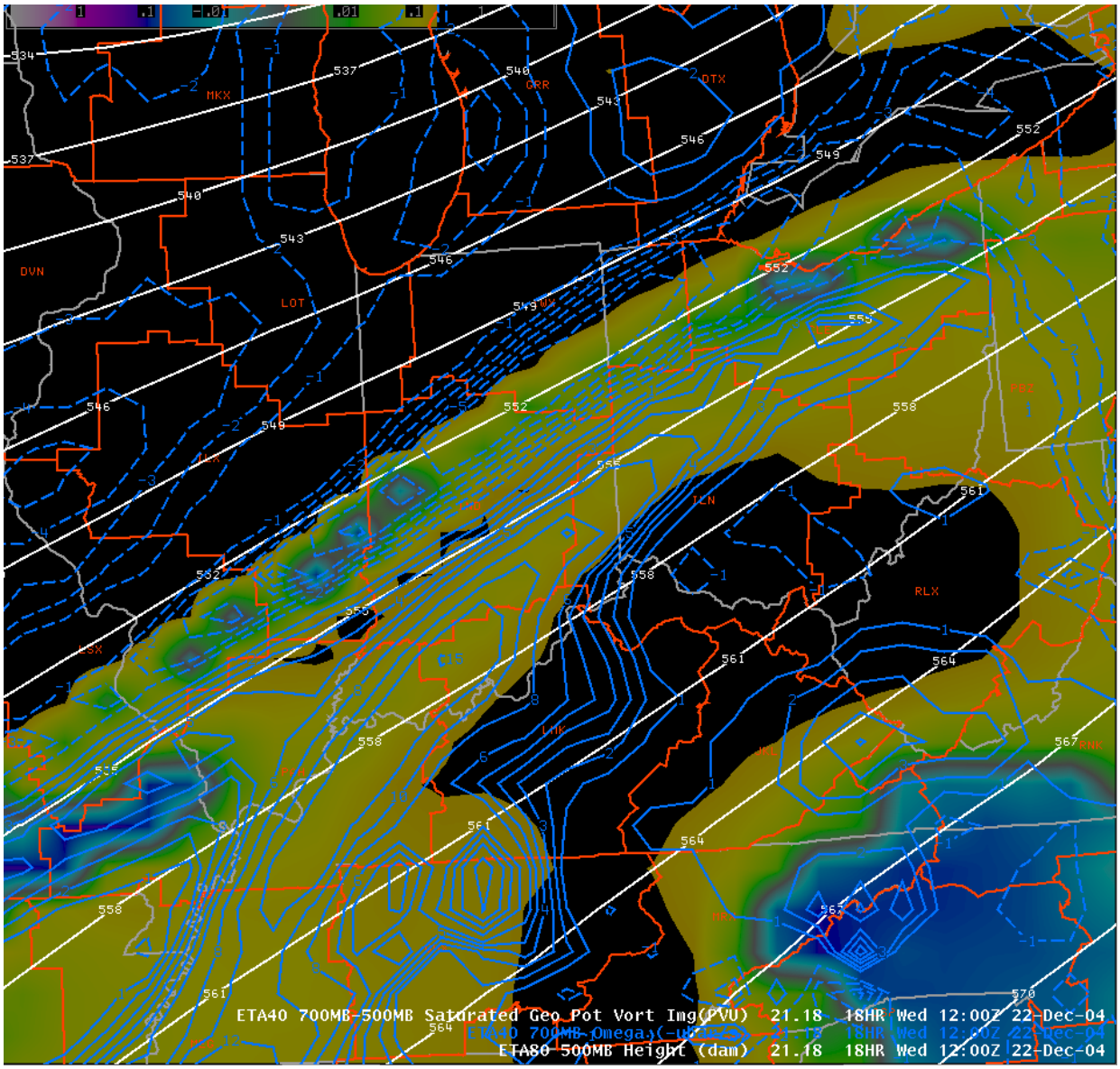

Figure 2-3. ETA (NAM) 18 hr forecast from the 18 UTC 21 December 2004 initialization, valid at **12 UTC 22 December 2004**. CWA boundaries outlined in solid red, 500 mb heights are solid white, 700-500 mb Saturated EPVg is shaded, and 700 mb omega are blue contours.

contained in the following sections I and II, and discussion of the snow water equivalent and top-down approach issues are contained in section III.

I. ROUND ONE (22 December 0200 - 1800 UTC)

The first round of heavy precipitation began around 0200 UTC on 22 December 2004 and was largely due to low-level frontogenesis. Temps ranged from the mid 20's across central and northern Indiana to the upper 40's along the Ohio River. Precipitation began as rain across the Ohio River but the colder near-sur-

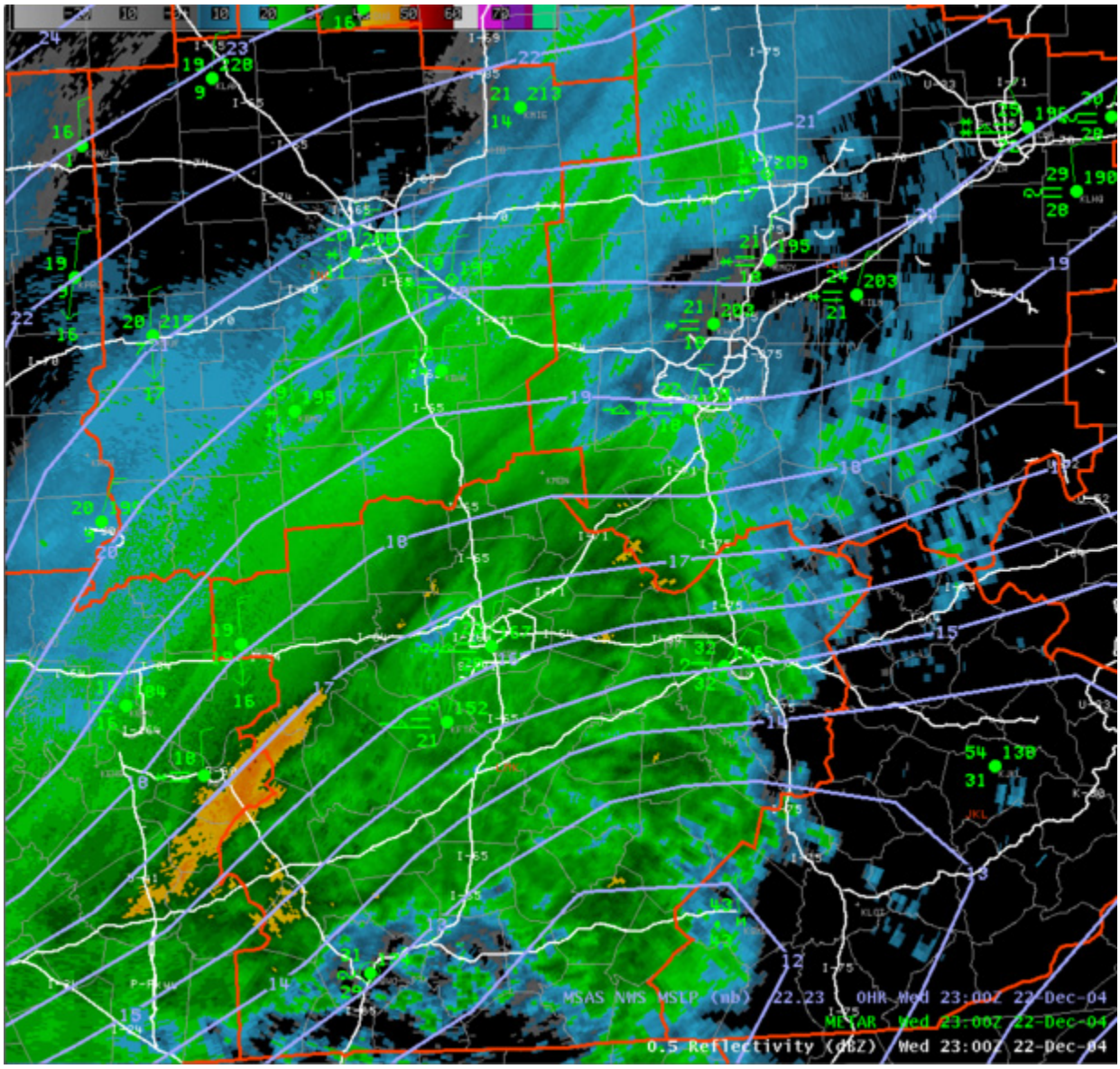

Figure 2-4. 23 UTC 22 December 2004 0.5 degree reflectivity mosaic across the IND and LMK CWAs. CWA boundaries are thick red, interstate highways are white, MSLP contours are blue, and plotted METARS are green.

face air deepened to the north of the frontal boundary (aided by frontogenesis) such that it was all snow across southern Indiana and northern Kentucky by ~7 UTC. This first round of precipitation was aided by being in the right entrance region of a 125 knot jet streak. Strong frontogenesis at 850 mb was present throughout this first shot of snow, and 40-50 knots southwest winds on the 290 K isentropic surface brought moist air northeast, producing an isentropic upglide set-up centered on the Ohio River Valley in southern IN and northern KY (Figure 2-2 on page 2).

Examining Q-vector patterns at upper-levels, it was clear that short wave trough dynamics had very little effect on the precipitation forcing for this first shot of precipitation, as the primary trough was still west of the CWA. At 06 UTC on 22 December the primary short wave trough centered over northern Minnesota was strongly baroclinic. A southern stream short wave trough existed over west Texas at 06 UTC that would eventually provide significant upper-level forcing across the Ohio Valley with the second round of precipitation.

Instability was also a factor throughout the first round of precipitation. Figure 2-3 on page 3 shows at least the presence of CSI above the surface front across the Ohio Valley, and the 700 mb vertical motion appears to be tied to the frontogenetical circulation. The area of 850 mb frontogenesis shown in Figure 2-2 remained quasi-stationary for several hours along the IN/KY border. As the jet streak moved northeast around the base of the long wave Hudson Bay trough, and the cold front slid slightly southeast into central Kentucky, the heaviest precipitation was focused into northern and western Kentucky. By 14 UTC a narrow band of heavy sleet developed just behind the surface cold front in northern Kentucky and the heaviest snow shifted to extreme southeast Indiana by 18 UTC on 22 December.

II. ROUND TWO (22 December 1800 UTC - 23 December 12 UTC)

From 18 UTC on 22 December through 12 UTC on 23 December, along and just south of the Ohio River in Kentucky, a persistent band of sleet and freezing rain led to 6 hr precipitation totals of 0.1 to 0.40 inches and set the stage for even worse road conditions as the next round of precipitation developed from the southwest. At 20 UTC the second round of snow developed across the Ohio Valley in extreme western Kentucky, expanding northeast and intensifying with

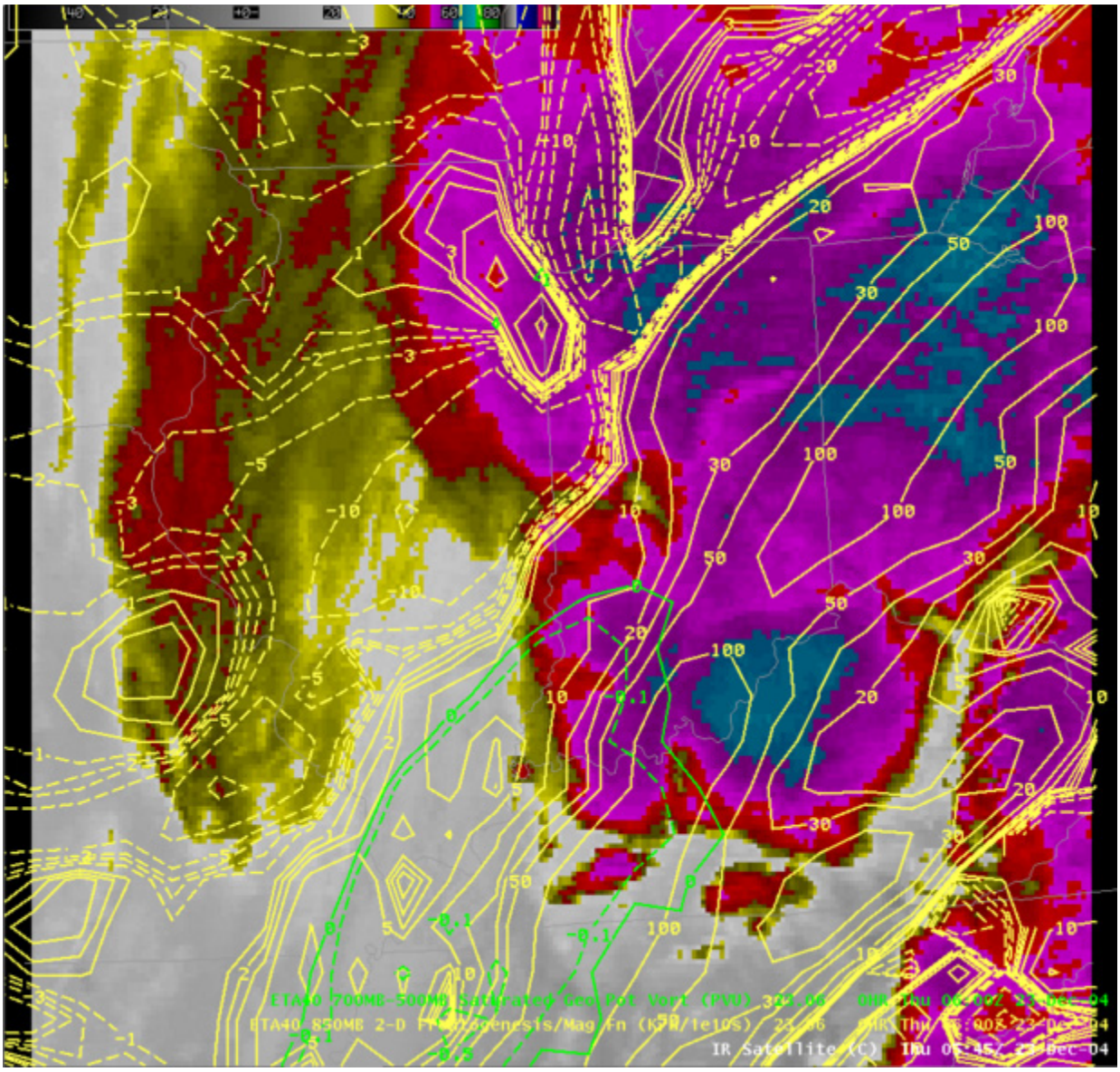

Figure 2-5. Forecasts analysis at **06 UTC 23 December 2004**. IR satellite from 05:45 UTC shaded, 40 km ETA 850 mb 2-D frontogenesis are yellow contours, and 40 km ETA 700-500 mb saturated geostropic equivalent potential vorticity are green contours (negative dashed).

time. Figure 2-4 on page 4 shows the location of the heaviest precipitation at 23 UTC, and it was essentially in the same region as the first round of snow.

At 00 UTC, raobs (not shown) indicated strong 500 mb southwest flow over the IN/KY region as the vorticity maximum approached from the west. 500 mb temps were -20 C across the Ohio Valley and certain to get colder with 500 mb temps at Topeka and Aberdeen of -31 C and -39 C respectively. The two short wave troughs at 500 mb early on the 22nd had phased into a very broad trough by 00 UTC on the 23rd, with the trough axis from northern Minnesota SSW into

Central Texas and strong southwest flow across IN/KY (Fig. 2-6 on page 7). Just after 00 UTC, a classic coupled jet streak pattern existed across southern Indiana and northern Kentucky, and the backed 850 mb flow contributed to intense frontogenesis along the quasi-stationary front.

The 850 mb low at 00 UTC was roughly centered over Memphis, TN and the low-level jet east of the 850 mb low intensified to over 50 knots across northern Tennessee and eastern Kentucky. At the surface, a 1032 mb high was located over western Iowa, and a 1006 mb surface low (a reflection of the southern

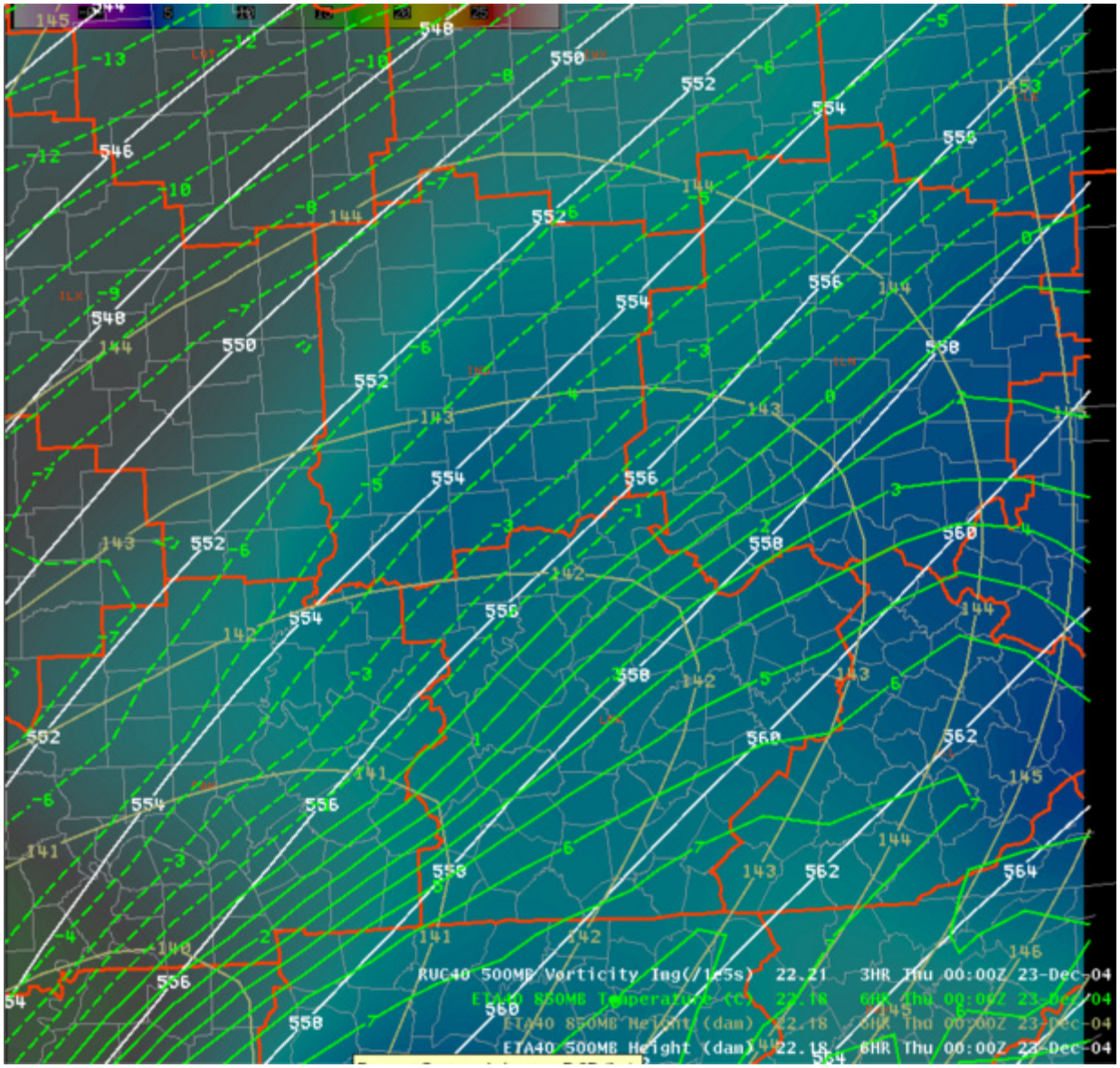

Figure 2-6. Forecasts valid **00 UTC 23 December 2004**. CWA boundaries are red, 500 mb 40 km ETA heights are white, 850 mb 40 km ETA heights are light brown, 850 mb 40 km ETA temperatures are in green (dashed below 0C), and 500 mb 40 km RUC absolute vorticity is shaded.

stream vorticity maximum) was located across eastern Mississippi at 00 UTC (See Fig. 2-4. for the 23 UTC MSLP in blue). An inverted surface trough extended northeast of the surface low from northern Alabama to western Pennsylvania, and the surface low tracked along the surface trough. On the mesoscale, strong low-level frontogenesis with neutral slantwise instability above the frontal surface continued to indicate strong banded ascent at 00 UTC on 23 December across northern Kentucky and south-central Indiana.

Moderate to heavy precipitation continued across the southern half of Indiana into all of western and northern Kentucky for the better part of 12 hours, through about 12 UTC on the 23rd. Snow was the dominant type along and north of the Ohio River, while freezing rain and sleet dominated further south into Kentucky. A quasi-stationary narrow band of 2-3 inch per hour snowfall rates occurred from 00 UTC through nearly 06 UTC along and just north of the Ohio River which led to some extreme snowfall totals. This band was forced on the mesoscale by a frontogenetical circulation from the 900-750 mb layer, enhanced by negative saturated equivalent geostrophic potential vorticity (EPVg) just above the frontogenesis (Fig. 2-5), and aided by upper-level divergence from classic coupled jet streaks. During the second part of the warning time period, upward forcing from an upper-level shortwave trough phased with the lower level frontogenetical forcing allowing more widespread precipitation while preserving 2 - 3 inch per hour snowfall rates in the quasi-stationary band.

III. Snow Water Equivalent and Top-Down Approach

One the key features of this historic snowfall event is the relationship between storm total snowfall and Snow Water Equivalent (SWE). Since there are only limited observations a careful analysis is required. Our best estimates of snow ratios are between 8:1 and 13:1 throughout the IND and LMK CWAs. The discussion that follows is a more detailed examination of ground truth snow ratios:

- KIND (see Fig. 2-1) reported a storm total snowfall of 10.1” with a SWE of 0.83”. The snow ratio of 12.1:1 is 1” higher than climatology. However, there is some question about whether the SWE is accurate. The data were extracted from the F6 reports. The time trace of the Caribou snow ratio technique viewed in BUFKIT (i.e. “Zone Omega”) shows that the highest ratios of 23:1 occurred during the periods of the greatest forecast precipitation rates. The fraction of the vertically integrated ascent in the dendrite production zone is the highest of all the sites, and that is why the

snow ratios were forecast to be so high. The Caribou technique overestimates the observed ratio for several possible reasons. These could include:

- Drifting and settling of snow on the ground reduced the ratios.
- Observed omega within the dendrite production zone could have been higher. The model under forecast the second phase of the snow storm.
- Incorrect snow ratio vs. temperature graph.

- For the KMDN profile (see Fig. 2-1 to locate KMDN), in the LMK and IND simulations, there are no reports to verify the snowfall ratio technique. However, there is a RAWS site called Hardin Ridge in southern Monroe county that recorded 1.54” of SWE in a heated tipping bucket gauge. While this site does not record snow depth, a nearby cooperative observer in Bloomington, IN reported 13” of snow. Hardin Ridge likely received more precipitation than Bloomington, and so we created an upper and lower bound of likely snow ratios based on the snow depth analysis from all the snow depth reports. On the lower bound, we divided the Bloomington snow fall with the Hardin SWE of 1.54” to get a ratio of 8.4:1 figuring that Hardin at least had this much snow fall. On the upper bound, we divided an 18” snow depth by the same SWE to get a ratio of 11.7:1. It is possible that the SWE could be underestimated, as is often the case with evaporation from heated gauges or poor quality shielding, but that only serves to decrease the snow ratio. A composite forecast ratio between the KMDN and the KIND sites suggests that the Caribou technique likely overestimated the ratios at the Hardin Ridge site and Bloomington.
- For the KSDF observation (see Fig. 2-1 to locate KSDF), snow ratios would be difficult to ascertain given the mixed phased precipitation that occurred up to 1240 UTC. However, 3” of snow was reported by 18 UTC corresponding to a 12-18 UTC SWE of 0.29”. About 40 minutes of that SWE occurred as freezing rain corresponding to almost .06” of SWE. Thus, 0.23” of SWE corresponded to 3” of snow for a ratio near 13:1. The snow ratio was likely anywhere from 10 to 13:1 assuming the SWE is accurate. However, this is an ASOS site gauge, exposed to 10 mph north winds and therefore, the SWE is likely underestimated. The snow ratio was likely smaller.

Another key feature of this historic snowfall event, especially across the LMK CWA, was the variation of precipitation type. A few important details of the top down approach versus ground truth follows:

- KSDF is in a transition as the cold front passed. At 15 UTC on the 22nd, it is all snow. During 11 - 12 UTC, precipitation vacillated between freezing rain and snow twice. The 27 hr ETA forecast indicates a +1.9 C warm nose at 801 mb. The top down approach suggests ice pellets transitioning to snow, assuming ice is introduced in the upper reaches of the clouds.
- The KMDN site is forecast by the top down approach to be all snow at 12 UTC, but not by the ETA P-type algorithm. The warm nose temperature decreases in time falling below 0 C by 12 UTC on 22 December. After 12 UTC KMDN is all snow.
- The KIND site is more than cold enough for the top down approach to indicate all snow throughout the entire event.

3: Background Information

I. Loading the Case

There is one install DVD and three companion case DVDs for the 22-23 Dec. 2004 case. The DVDs were shipped to each AWOC facilitator. The case occupies ~ 51GB of disk space. For details on how to load the case, see the README on the install DVD.

II. Data Characteristics

The original data set came from the IND office archives, so the regionally clipped data sets are centered around IND. The details of the data sets are included below:

Model Data:

The following model data exists from the IND office: Eta12, Eta40, Eta80, GFS80, gfsLR, DGEX, RUC40, RUC80, NGM, LAPS (IND).

BUFR Profiles and Bufkit Data:

Bufkit BUFR profiles are available for both the watch and warning phase (06 UTC and 12 UTC model runs on the 21st). The data are stored along with a new release of Bufkit featuring the Caribou technique in Bufkit_AWWT_Simulations.zip on the install DVD disk #4. BUFR profiles are also available in AWIPS.

GFE Data:

You will need to update the default grids using the WES “Create GFE Dataset” tool for the IND and LMK CWAs for the 06z and 15z 21 Dec. simulations. These are selectable in the WES simulation entry window. Macros with the GFE data settings are installed with the cases. To access these just click on the “Load Saved Settings” button in the WES Simulation Entry window, and select the appropriate macro (IND-0601-21Dec2004, IND-1501-21Dec2004, LMK-0601-21Dec2004, LMK-1501-21Dec2004).

Radar Data:

Eight-bit data exists for kind and klvx. Other radars with low-level base data include: kvwx, kiwx, kiln, kilx, klot, khpx, kpah, klsx, and kjkl. The radar snow algorithm files are included with the data, but the data isn't viewable with OB6. The data were created with the default ZS algorithm for Indianapolis ($Z=180S^{2.0}$) We have included gif images of the snow data in the picflip tool in wessl to allow viewing of the data in the simulation. Once OB7 is released, and it is incorporated into WES, you will be able to view the snow data in D2D with the rest of the case.

III. Localizations:

OB6 localizations for IND and LMK are included with the case which will need to be updated to OB9.0. We encourage you to customize your WES from your AWIPS, so you can create your own to allow forecasters to "train as they fight". For information on customizing WES, please see the WES users guide available with the WES release.

IV. WES

The original version of the AWOC winter IC 8 WES case was released during WES6.0. The AWOC winter 2009/2010 case needs to be upgraded to the following in order to be up to date:

1. WES9.0

Follow these instructions if you have not loaded the case already.

1. Install WES 9.0 if you haven't done so already.
2. Install the four case DVDs (see README on Install Disk #4). Note: the case was broken up into the Dec. 21st data (in 2004Dec21, for simulations) and the Dec. 22nd and Dec. 23rd data (in 2004Dec22, for static review) for performance reasons. If you would like to combine all the data into one large and slower performing case, you may copy the 2004Dec22 case into the 2004Dec21 case after you install all four DVDs and before you convert to DRT format.
3. Install the OB9.0 localization update DVD.
4. Convert 2004Dec21 case to DRT format after you have done #4.

5. Run the WES create GFE Dataset tool for whichever simulation you choose. Remember to choose one of the following start times for whatever c
   - IND: 2004 December 21 - 0601 UTC
   - IND: 2004 December 21 - 1501 UTC
   - LMK: 2004 December 21 - 0601 UTC
   - LMK: 2004 December 21 - 1501 UTC
6. Select one of the macros from the “Load Saved Settings” button in the WES Simulation Entry window (IND-0601-21Dec2004, IND-1501-21Dec2004, LMK-0601-21Dec2004, LMK-1501-21Dec2004).
7. Run start_GFE and start_awips to start D2D and GFE.

We recommend each WWAWOC facilitator run through the WES9.0 installation pdf (INSTALL_WES90.pdf) to become familiar with how to use GFE in WES. A short introduction to WES9.0 articulate will be placed in the LMS for AWOC facilitators, and an announcement will be posted on the awocfac email list.

If you want to use a different time than in the Simulation Suggestions section, you may need to create a new set of default GFE grids if the 0601 and 1501 UTC Dec. 21, 2004 grids won’t work for you. You can create GFE grids for your own local cases as well using the “Create GFE Dataset” button under the “Tools” section of start_simulator. For more information on the details of WES9.0 and running GFE please consult the INSTALL_WES90.pdf from http://www.wdtb.noaa.gov/tools/wes/docs/INSTALL_WES90.pdf.

V. WESSL:

Four WESSL files are included in the 2004Dec21/wessl directory with this case, ind_0601.wessl, ind_1501.wessl, lmk_0601.wessl, and lmk_1501.wessl. These files launch HPC graphics, SREF ensemble/anomaly graphics, snowfall algorithm graphics, the WWAWOC articulate and pdf navigation web page, and numerous response boxes. Note for the articulates to play in a browser on Linux you will need to have installed the flash plugin as documented in the WES9.0 installation (see INSTALL_WES90.pdf in /awips/fxa or on the WES9.0 release CD). Also note the response boxes can be used to document answers and save them. WESSL now stores the response box entries in one easy to read file with a date/time stamp in the <your_case>/wessl directory. To become familiar with

the content of the wessl files, open each wessl file in /data/awips/2004Dec21/wessl using /awips/fxa/DRT/wessl/wessl/builder.tcl, and step through each popup by clicking on the run button in the upper right part of the interface.

VI. Notes From the Offices

IND Office

One of the big challenges of the event for the Indianapolis metro area was the accumulations and timing of the heavy snow. The significant snow arrived in Indianapolis later than the models predicted, and there was a strong gradient in snowfall across Indiana. Accumulations were noticeably higher across the south side of the metro compared to the north side of the metro. While the overall forecast ended up working out, the delay in snowfall onset created a unique state of anticipation and uncertainty about the event outcome.

LMK Office

The historic winter storm of 22-23 December 2004 brought 24-30 inches of snow and 4-5 foot drifts to parts of south central Indiana, up to 6 inches of sleet in north central Kentucky (including parts of the Louisville area), and devastating ice accumulation (around one inch) in parts of central Kentucky. The storm closed Interstates 64 and 65 for up to 3 days in southern Indiana, and caused severe travel problems, widespread power outages, roof damage, tree damage, and airline flight cancellations as well. Some local businesses lost up to 80 percent of expected sales during and just after the storm.

Dedicated WFO Louisville (LMK) employees provided near continuous information before, during, and after the storm. They collaborated well with NCEP/HPC and neighboring WFOs. LMK's average winter storm watch (warning) lead time was 49 (19) hours. These lead times along with winter storm outlooks initially issued on 17 December (5 days before the storm) allowed emergency managers, road crews, state and local planners, and the public ample time for preparatory and storm mitigation actions. WFO Louisville also issued frequent hazardous weather outlooks, local storm reports, special weather statements, short term/NDFD forecast updates, area forecast discussions, and public information statements, and communicated with media, emergency managers, and

other officials concerning storm trends and impact. WFO Louisville's home page "news" section was updated often as well to maximize public awareness and proper response. Such proactive actions helped to mitigate the negative effects the winter storm. Indeed, there was zero loss of life and very few if any injuries.

Heavy snow, sleet, and ice on roadways endangered the safety of WFO employees traveling to and from the office during and after the storm. Nevertheless, employees put service above self to ensure the office provided frequent, proactive information to the public. For example, one forecaster traveled over 30 miles from home, risking injury and property damage, and dodging downed large tree limbs to get to work. Travel was very treacherous for other employees as well. Another employee remained on station nearly 24 hours, while others worked tirelessly to ensure consistent service. The NWS parking lot also was very difficult to navigate, requiring a group effort to try to push cars in and out of the lot. In areas where snow and unusually large amounts of sleet fell, the snow/sleet pack was so hard that an adult could walk on top of the pack without making a dent. This made shoveling the snow and sleet extremely difficult and tiring.

Historic, record events, such as the 22-23 December 2004 winter storm, often create long-term memories for those who experienced them. How the NWS performed during such an event can create a lasting impression and perception as well. As a result of NWS proactive, quality service associated with this storm, positive perceptions and enhanced partnerships likely resulted, which should serve the NWS well in the long-term.

4: Simulation Suggestions

I. Introduction

Four simulation examples are included in the Simulation Suggestions section to illustrate focused simulations using the Dec. 22-23, 2004 case. Simulation 1 focuses on the watch phase of the IND CWA, and it is the predecessor to simulation 2. Simulation 2 focuses on the warning/nowcasting phase of the IND CWA, and it contains a review of what happened. Simulations 3 and 4 are structured just like simulations 1 and 2 only they are centered on the LMK CWA. The IND CWA primarily experiences heavy snow, while the LMK CWA experiences heavy snow, sleet, freezing rain, and rain.

The simulation examples are provided for illustration of the process, and the facilitator is encouraged to modify these or create new ones. Each 2.5 hour simulation provides for a short startup and introduction, the primary application of skills to winter weather forecasting, and a short debrief with feedback by the evaluator. Feedback can be provided to the trainee throughout the simulation as evaluation criteria are completed and also at the conclusion of the simulation. WES macro files are available for each simulation that have all the settings saved for running a simulation. The times of the simulations in the macro extend beyond the 2.5 hours of the simulation in case a simulation goes long, and the trainee needs more time.

A Wessl file is provided to help pace the simulation and provide extra data sets. The Wessl file response boxes can also be used to document information that can be accessed after the simulation is over. Feel free to modify the Wessl files provided as you tailor the simulation to your needs.

II. Simulations

Simulation 1 (21 Dec. 0601 UTC - 0831 UTC) IND Winter Weather Watch Phase

WES Macro: IND-0601-21Dec2004

IC Focus: IC2 Lesson1, IC2 Lesson 2, IC4 Lesson 2, IC6 Lesson 3, IC6 Lesson 4

Summary:

This simulation focuses on the challenge of recognizing the scope of the winter weather potential in the IND CWA for a major winter weather snow event that was focused around two closely timed rounds of precipitation. The simulation 1 start time is 0601 UTC Dec. 21, 2004, at which time the 06 UTC models are beginning to come into more agreement on a significant winter weather event for the first round of precipitation, and a stronger second round of precipitation. There is considerable uncertainty in the forecasts with significant differences between the GFS and NAM. The recently released internal HPC QPF graphics have just come out, and significantly cut back the amounts from the previous forecasts of significant snow in the CWA (from 18” to 4”).

The simulation is 30 hours before the onset of the first precipitation around 09 UTC on the 22st. ***Simulation 1 is designed to be used with and taken before simulation 2, therefore you are advised to not discuss what happened with the event at the conclusion of simulation 1.*** Simulation 2 covers the 12 UTC morning model run of the 21st as well as the nowcasting elements and an overview of what happened. The schedule for the trainee, evaluation criteria, and answer keys are included below. Note the evaluation criteria are listed at the end of each line in the schedule (e.g. EC2 for Evaluation Criteria 2).

Schedule for trainee:

- 0600-0610 (10 min): Shift change and HPC product review.
- 0610-0615 (5 min: **EC1**): Collaboration strategy after shift briefing.
- 0615-0635 (20 min): Familiarization with basic analysis and forecast.
- 0635-0645 (10 min: **EC2**): Climatic anomalies.
- 0645-0700 (15 min: **EC3**): SREF ensembles analysis.
- 0700-0745 (45 min: **EC4**): Ingredients Method analysis.
- 0745-0750 (5 min: **EC1**): Document collaboration strategy after analysis.
- 0750-0815 (25 min: **EC5**): Use GFE to issue winter weather products.
- 0815-0830 (15 min): Discussion of performance with facilitator.

Evaluation Criteria 1 (IC2 Lesson2). Document a generic strategy for effective collaboration when prompted at the beginning of the simulation and after analyzing data. Include details about when you should collaborate and how.

Answer Key 1. The trainee should exhibit an attempt to address 2 key issues in their strategy: 1. Determine if their WFO is in line with adjacent impacted WFOs on the synoptic scale pattern evolution within the time scale of the event. 2. Determine the greatest impact to the public within their CWA.

The trainee should demonstrate the above by a) stating an intent to collaborate with adjacent WFOs and HPC WWD b) stating the greatest potential impact of the event to the public c) demonstrating how they would determine areas in need of collaboration. It is critical the trainee either demonstrate or indicate these are completed *prior* to editing ISC grids.

After looking at the data, the trainee should discuss that precipitation type and amounts are key points to focus collaboration on.

Evaluation Criteria 2 (IC4 Lesson2).

1. Identify any significant anomalies in the ensemble forecasts that are relevant to the forecasts for Indiana and Kentucky using picflip (250mb UV, 500mb H, 850mb UV and TA, 2m T, and MSLP).
2. Document the importance of the anomalies.
3. Document how the anomalies relate to classic winter storms.

Answer Key 2. The trainee should document the anomalous U components in the upper level jet and the low-level jet as being significant for this CWA. They are important because they relate to the upper-level jet dynamics and the transport of low-level moisture into the cold air. Lack of other anomalies at many levels suggests this event is not a prototypical major winter storm.

Evaluation Criteria 3 (IC6 Lesson3).

1. Use the SREF data in the picflip viewer to identify:
   - areas of high certainty and uncertainty in forecast variables
   - areas of higher likelihood of rain, freezing rain, sleet, and ice, and
   - areas of higher likelihood of significant amounts

Answer Key 3. The trainee should document significant uncertainty in 500mb heights, mslp, and low-level freezing temperatures, particularly with the second round of precip. The high likelihood of significant precipitation amounts > 0.5” with greatest snow likelihood in southern Indiana, and sleet and freezing rain in southern Indiana and northern Kentucky.

Evaluation Criteria 4 (IC6 Lesson4).

1. Apply the ingredients method to identify:
   - areas of synoptic forcing using Q vectors and tropopause maps
   - levels of maximum Frontogenesis
   - where the front interacts with the upper level wave
   - low-level Frontogenesis and stability

as they relate to the two rounds of precipitation over the IND CWA.

Answer Key 4.

1. Synoptic forcing using QG theory: The shortwave upper level trough axis does not pass over the IND CWA until 12 UTC on the 23rd, which in theory should shut off any precipitation. Through 06 UTC on the 22nd, Q-vector convergence is weak but present across the IND CWA at all levels/layers from 700-300 mb. As the shortwave trough approaches from the southwest between 00-06 UTC on the 22nd, Q-vector convergence strengthens at all levels, with the maximum over the IND CWA occurring in the 500-300 mb layer and remaining intact through about 06 UTC on the 23rd.
2. Levels of maximum frontogenesis: In the lowest levels (925-850 mb) the frontogenesis remains just south of the IND CWA for the next 48 hours, but it is very strong starting at 06 UTC on the 22nd. For the IND CWA, 850 mb is a good height to examine the maximum in frontogenesis starting especially at 06 UTC on the 22nd. It is very strong and the maximum enters the southern Indiana counties, remaining strong through 06 UTC on the 23rd. At 700 mb frontogenesis is weak across southern IND CWA, but really picks up at 06 UTC on the 22nd, although further northwest and not as strong as the 850 mb frontogenesis.
3. Front interacts with the upper-level short wave trough: The thermal gradient across northern Kentucky and southern Indiana becomes coupled with the short wave trough in mid and upper levels starting at 06 UTC on the 22nd. Exceptionally strong deformation acting frontogenetically is evident from 12

UTC on the 22nd through 06 UTC on the 23rd across extreme southern IND CWA, and shifts south from 06-12 UTC on the 23rd.

4. Low-level frontogensis and stability: Using 850 mb 2-D frontogenesis with 800-700 mb saturated EPVg and 700-600 mb saturated EPVg overlaid, it is evident that instability exists just above the frontogenesis in a manner consistent with the mesoscale banding training, favorable for strong upward vertical motion. The instability is not exceptionally strong, but for a short period of time it is well coupled with the frontogenesis across the southern part of IND CWA, with best coupling occurring around 15 UTC on the 22nd.

Evaluation Criteria 5 (IC2 Lesson1): Create winter weather products using GFE that effectively discriminates between different winter weather events.

Answer Key 5: A winter weather watch should be considered for southern Indiana. A could also be considered at this time, given the need for advanced lead time during the holiday travels. However, uncertainty in evolution should limit confidence in precip type and amounts.

Simulation 1 Debrief

At the end of the simulation, 15 minutes is provided to discuss trainee performance and to provide feedback. Some of the issues to consider discussing include:

1. recognizing uncertainty and communicating that appropriately in products

2. blending ensemble analysis with the ingredients method approach

3. collaborating effectively in situations of uncertainty

4. challenges to transferring learning and application in the course/simulations to operations

The ensembles can be a useful tool to help gauge the level of uncertainty in some of the important forecast variables, which can affect your decision of what products to issue (e.g. watch/warning) and when. However, a more complete understanding of the dynamics of the weather event results from a more detailed analysis of individual model runs using the ingredients method. In this event the ensembles showed significant uncertainty with the development of the

second round of precipitation, while the ingredients method clearly showed a quasi-stationary region of strong frontogenesis throughout both rounds of precipitation, coupled with elevated instability during the second round of precipitation. Thus, there is an optimal blend of using both techniques in forecasting that varies with the amount of uncertainty in the event, the skills of the forecaster, and the time available for analysis among many other things.

With increasing uncertainty in the model forecasts, there is greater potential for interpretation differences in the forecast process, which increases the need for effective collaboration and communication. Although addressing collaboration issues effectively in a simulation is challenging without human feedback and more context, having a strategy for collaboration is something that can be focused on in a meaningful way in the simulation that can increase the likelihood of transfer to operations. The training of the simulations and of the course in general can be greatly improved if the challenge of transferring AWOC learning to operations can be addressed at the completion of the simulation and linked with local operations improvement plan.

Simulation 2 (21 Dec. 1501 UTC - 1731 UTC) IND Winter Weather Warning/Nowcasting Phase

WES Macro: IND-1501-21Dec2004

IC Focus: IC2 Lesson1, IC3 Lesson 1, IC6 Lesson 1, IC6 Lesson 3, IC6 Lesson 4, IC6 Lesson 5, IC7 Lesson 2

Summary:

This simulation focuses on the challenge of recognizing the scope of the winter weather potential in the IND CWA for a major winter weather snow event that was focused around two closely timed rounds of precipitation. This is the follow-on simulation to simulation number 1. The simulation 2 start time is 1501 UTC Dec. 21, 2004, which is about 18 hours before the onset of the first precipitation around 09 UTC on the 22st. Since this is closer to the warning time scale with more certainty in the forecasts, more emphasis is placed on forecasting snow totals. Also, the latter part of the simulation involves reviewing what happened and looking at the new snowfall algorithm products.

The latest trend in expectations at HPC has been to reduce the amounts in the snowfall probabilities in the early morning forecast, consistent with the QPF graphic discussed in the first simulation. The general forecast trend at 12z is for more agreement between the NAM and GFS, with 1-1.5” of QPF predicted. Although there are clear signals supporting a winter storm in the model forecasts, the magnitude of the snow, sleet, and ice amounts are challenging to anticipate.

Schedule for trainee:

- 1500-1510 (10 min): Shift change and HPC product review.
- 1510-1525 (15 min): Familiarization with basic analysis and forecast.
- 1525-1535 (10 min: **EC1**): SREF ensembles analysis.
- 1535-1610 (35 min: **EC2**): Ingredients method analysis.
- 1610-1625 (15 min: **EC3**): Top down analysis.
- 1625-1640 (15 min: **EC4**): Forecast snow ratios.
- 1640-1645 (5 min: **EC5**): Document potential significant impacts to users.
- 1645-1705 (20 min: **EC6**): Use GFE to issue winter weather products.
- 1705-1720 (15 min: **EC7**): Precip estimation and radar snow algorithm.
- 1720-1735 (15 min): Discussion of performance and wrap-up with facilitator.

Evaluation Criteria 1 (IC6 Lesson3).

1. Use the SREF data in the picflip viewer to identify:
   - areas of high certainty and uncertainty in forecast variables
   - areas of higher likelihood of rain, freezing rain, sleet, and ice, and
   - areas of higher likelihood of significant amounts

Answer Key 1. The trainee should recognize the increased certainty in the 500mb H, the continued certainty in freezing temperatures and significant QPF across the IND CWA, and the continued uncertainty in the surface pressure pattern (on the 22nd).

Evaluation Criteria 2 (IC6 Lesson4).

1. Apply the ingredients method to identify:
   - areas of synoptic forcing using Q vectors and tropopause maps
   - levels of maximum Frontogenesis
   - where the front interacts with the upper level wave
   - low-level Frontogenesis and stability

as they relate to the two rounds of precipitation over the IND CWA.

Answer Key 2. The only new data available to the trainee are the 80 km model runs of the NAM and GFS from 12 UTC. Both the NAM and GFS runs contain about 0.5” more QPF with a stronger system in general. The synoptic QG-induced forcing is weak until 18 UTC on the 22nd across the IND CWA. However, the upper level system passes directly through the CWA, leading to strong synoptic forcing from 18 UTC on the 22nd through 12 UTC on the 23rd. Q-vector convergence is much stronger with the 12 UTC model runs, and mid-level frontogenesis is stronger at the beginning of the first round of precipitation, while low-level frontogenesis is stronger during the second round of precipitation. Both the 80 km GFS and NAM have the upper low passing through central Indiana, with the GFS stronger than the NAM.

Evaluation Criteria 3 (IC6 Lesson1). Apply the Top Down Approach to the NAM BUFR vertical profiles at Indianapolis (KIND...in the CWA) and Jefferson Proving Ground (KMDN...next to the border with LMK). You may use the BUFR profiles in AWIPS or BUFKIT if your facilitator has installed the BUFKIT data on a separate PC.

For KIND and KMDN profiles at 12z on the 22nd, document what precipitation type you would expect and why base on:

1. cloud top temperature
2. maximum temperatures in the warm layer
3. surface effects

Answer Key 3. At KIND, the sounding supports snow with cloud top temperatures (-60C) supporting ice, warm nose too cold to melt ice (-2.4 C), and surface temperatures not favorable for melting snow (-6C). At KMDN, the sounding supports snow with cloud top temperatures (-50C) supporting ice, warm nose too

cold to melt ice (-0.1 C), and surface temperatures not favorable for melting snow (-2.6C).

Evaluation Criteria 4 (IC6 Lesson5). Estimate the snow ratios for the central part of the CWA using the KIND profile and the southern part of the CWA using the KMDN profile, and document your reasoning.

Answer Key 4. Climatology is about 11:1 for the lower half of the CWA. Qualitative examination of the KIND profile shows surface winds 10-15 kts and temperatures colder than -10 C above 950mb, supportive of average to light snow ratios. Across the central portion of the CWA, there is some vertical motion in the dendritic growth zone supportive of light snow ratios (20:1). Snow ratios 15-20:1 are reasonable.

Qualitative aspects of the KMDN sounding support average snow ratios but heavier than KIND due to the warmer temperatures in an isothermal layer between 950 and 750 mb. The correlation of vertical velocities in the dendritic growth zone is slightly lower compared to the northern and central parts of the CWA. Thus, snow ratios between 12:1 and 18:1 are reasonable. Given that precipitation is not expected to begin until 18 hours from this model run, changes in vertical motion forecasts and precipitation type can have significant effect on the actual snow ratios observed.

Evaluation Criteria 5 (IC3 lesson 2). Document the potential significant impacts to road conditions in the IND CWA using your forecast and the map provided. Will roads start out icy or wet at the onset of precipitation on I65 and I74? What is the likelihood that major roads will become snow covered?

Answer Key 5. The trainee should mention the impact to holiday travel could be significant, including traffic along interstates (e.g. I65 and I74). Visibilities can be reduced to less than 1/4 mi and significant road accumulations are particular factors for the IND CWA. Assuming the winter weather watches went out, then maintenance crews should have plenty of time to pre-treat these highways and the initial precipitation may land and melt, however snowfall rates are expected to increase and turn roads snow covered..

Evaluation Criteria 6 (IC2 Lesson1): Create winter weather products using GFE that effectively discriminates between different winter weather events.

Answer Key 6. A winter storm warning should be considered for the IND CWA given the large area forecast of deep snow accumulations. If multiple weather types are anticipated in the southern part of the CWA, then the winter storm warning content would include these possibilities.

Evaluation Criteria 7 (IC7 Lesson2). Review the KIND snowfall algorithm data with picflip, and diagnose any sources of error in the radar estimates over your CWA at 12z on the 22nd and 12z on the 23rd.

Answer Key 7. At 12z on the 22nd, trainee should recognize significant overestimation of snow accumulation in western parts of the CWA due to evaporation (note 11F T-Td spread on metar). At 12z on the 23rd trainee should recognize that bright banding may be increasing amounts in some areas.

Simulation 2 Debrief

At the end of the simulation, 15 minutes is provided to discuss trainee performance and to provide feedback. Some of the issues to consider discussing include:

1. challenges of forecasting snowfall amounts

2. increases in certainty and more detailed analysis to provide more specificity in forecasts

3. challenges to transferring learning and application in the course/simulations to operations

As certainty grows in the model forecasts when approaching the winter weather event, this allows for more detailed analysis to provide more specificity in forecasts. More time can be spent on addressing the highest impact elements of the forecast, which in this case was the precipitation type, amounts, and timing. In this case the ensembles showed a significant decrease in uncertainty in some forecast variables and the ingredients method continued to show strong quasi-stationary frontogenesis along the Ohio River valley from 06 UTC on the 22nd through 06 UTC on the 23rd, and an increase in the QG forcing during the second round of precipitation relative to previous model runs.

Careful application of the top down approach can significantly improve snowfall forecasts relative to model guidance. In this event the models incorrectly forecast precipitation types and thus snowfall amounts while a top-down approach strongly suggested all snow for the entire IND CWA. Additionally, the models shifted higher QPF amounts too far south across the CWA and incorrectly forecast the snowfall to be in the first period (6-18 UTC on the 22nd), whereas the snowfall occurred in the second period (18-06 UTC on the 23rd) across the northern 2/3 of the CWA.

The link between QPF and winter weather precipitation amounts is challenging to understand, much less forecast, given our current snowfall and liquid water equivalent observations. The Zone Omega technique in BUFKIT overestimated ratios across the IND CWA, but because model QPF was too low, the technique produced reasonable amounts. The radar snow accumulation algorithm significantly overestimated amounts due to evaporation and bright banding at times, but final accumulations after both rounds of snowfall were reasonable over large parts of the CWA. While new tools such as the radar snowfall algorithm and the snow ratio techniques in BUFKIT can aid in improving estimates of precipitation in some situations, the complexity of the process still requires significant analysis by the forecaster to use properly.

The training of the simulations and of the course in general can be greatly improved if the challenge of transferring AWOC learning to operations can be addressed at the completion of the simulation and linked with local operations improvement plan.

Simulation 3 (21 Dec. 0601 UTC - 0831 UTC) LMK Winter Weather Watch Phase

WES Macro: LMK-0601-21Dec2004

IC Focus: IC2 Lesson1, IC2 Lesson 2, IC4 Lesson 2, IC6 Lesson 3, IC6 Lesson 4

Summary:

This simulation focuses on the challenge of recognizing the scope of the winter weather potential in the LMK CWA for a major winter weather snow/ice/freezing

rain event that was focused around two closely timed rounds of precipitation. The simulation 3 start time is 0601 UTC Dec. 21, 2004, at which time the 06 UTC models are beginning to come into more agreement on a significant winter weather event for the first round of precipitation, and a stronger second round of precipitation (Note the 0 UTC NAM forecast severely underplays the potential). There is considerable uncertainty in the forecasts with significant differences between the GFS and NAM. The recently released internal HPC QPF graphics have just come out, and they significantly cut back the expected amounts from the previous forecasts of significant snow and ice in the CWA (from 18” to 4” of snow and from > 0.5” ice to < 0.25” of ice).

The simulation is 30 hours before the onset of the first precipitation around 09 UTC on the 22st. ***Simulation 3 is designed to be used with and taken before simulation 4, therefore you are advised to not discuss what happened with the event at the conclusion of simulation 3.*** Simulation 4 covers the 12 UTC morning model run of the 21st as well as the nowcasting elements and an overview of what happened. The schedule for the trainee, evaluation criteria, and answer keys are included below. Note the evaluation criteria are listed at the end of each line in the schedule (e.g. EC1 for Evaluation Criteria 1).

Schedule for trainee:

- 0600-0610 (10 min): Shift change and HPC product review.
- 0610-0615 (5 min: **EC1**): Collaboration strategy after shift briefing.
- 0615-0635 (20 min): Familiarization with basic analysis and forecast.
- 0635-0645 (10 min: **EC2**): Climatic anomalies.
- 0645-0700 (15 min: **EC3**): SREF ensembles analysis.
- 0700-0745 (45 min: **EC4**): Ingredients Method analysis.
- 0745-0750 (5 min: **EC1**): Document collaboration strategy after analysis.
- 0750-0815 (25 min: **EC5**): Use GFE to issue winter weather products.
- 0815-0830 (15 min): Discussion of performance with facilitator.

Evaluation Criteria 1 (IC2 Lesson2). Document a strategy for effective collaboration when prompted at the beginning of the simulation and after analyzing data.

Answer Key 1. The trainee should exhibit an attempt to address 2 key issues in their strategy: 1. Determine if their WFO is in line with adjacent impacted WFOs on the synoptic scale pattern evolution within the time scale of the event. 2. Determine the greatest impact to the public within their CWA.

The trainee should demonstrate the above by a) stating an intent to collaborate with adjacent WFOs and HPC WWD b) stating the greatest potential impact of the event to the public c) demonstrating how they would determine areas in need of collaboration. It is critical the trainee either demonstrate or indicate these are completed *prior* to editing ISC grids.

After looking at the data, the trainee should discuss that precipitation type and amounts are key points to focus collaboration on.

Evaluation Criteria 2 (IC4 Lesson2).

1. Identify any significant anomalies in the ensemble forecasts that are relevant to the forecasts for Indiana and Kentucky using picflip (250mb UV, 500mb H, 850mb UV and TA, 2m T, and MSLP).
2. Document the importance of the anomalies.
3. Document how the anomalies are similar and different to classic winter storms.

Answer Key 2. The trainee should document the anomalous U components in the upper level jet and the low-level jet as being significant for this CWA. They are important because they relate to the upper-level jet dynamics and the transport of low-level moisture into the cold air. Lack of other anomalies at many levels suggests this event is not a prototypical major winter storm.

Evaluation Criteria 3 (IC6 Lesson3).

1. Using SREF data in the picflip viewer identify:
   - areas of high certainty and uncertainty in forecast variables
   - areas of higher likelihood of rain, freezing rain, sleet, and ice
   - areas of higher likelihood of significant amounts

Answer Key 3. The trainee should document significant uncertainty in 500mb heights, mslp, and low-level freezing temperatures, particularly with the second round of precip. The high likelihood of significant precipitation amounts > 0.5”

with greatest snow likelihood in southern Indiana, and sleet and freezing rain in southern Indiana and northern Kentucky.

Evaluation Criteria 4 (IC6 Lesson4).

1. Apply the ingredients method to identify:
   - areas of synoptic forcing using Q vectors and tropopause maps
   - levels of maximum Frontogenesis
   - where the front interacts with the upper level wave
   - low-level Frontogenesis and stability.

as they relate to the two rounds of precipitation over the LMK CWA.

Answer Key 4.

1. Synoptic forcing using QG theory: Synoptic forcing is weak to non-existent for the first 24 hours. Weak Q-vector convergence shows up at 3 UTC on the 22nd, but this is confined to below 500 mb. From 3 UTC through 6 UTC on the 23rd, Q vector convergence is deep (up to tropopause) but never much stronger than -10 $K/m^2/1e^{16}s$. The strongest Q-vector convergence throughout the 22nd into early on the 23rd occurs at 21 UTC over the northern part of the CWA, from 700-400 mb.
2. Levels of maximum frontogenesis: The frontogenesis is sloped upward from southeast to northwest across the LMK CWA, and strongest from 06 UTC on the 22nd through 06 UTC on the 23rd. The 925 mb frontogenesis enters the CWA as early as 00 UTC on the 22nd, and intensifies and expands northeast through 15 UTC on the 22nd. By 00 UTC on the 23rd, it shifts southeast of the CWA. At 850 mb frontogenesis is weak until 03 UTC on the 22nd when strong frontogenesis enters the west central part of the CWA. Through 06 UTC on the 23rd the strongest frontogenesis at 850 mb is across the north and western half of the CWA. At 700 mb, frontogensis is much weaker and only affects the extreme north and northwest counties of the CWA, from 18 UTC on the 22nd through 06 UTC on the 23rd.
3. Front interacts with the upper-level short wave trough: The surface low passes just southeast of the CWA at 03 UTC on the 23rd, but an inverted surface trough exists for about 24 hours prior to the passage of the surface cylone. The inverted surface trough aided in a strong zone of deformation favorable for frontogenesis that remained essentially quasi-stationary from 06 on the 22nd through 06 UTC on the 23rd. In the mid- and upper-levels the

Q-vector convergence and frontogenesis are not strongly coupled, mainly because the Q-vector convergence is weak. However, throughout the 22nd and early on the 23rd weak Q-vector convergence exists above the maximum in frontogenesis.

4. Low-level frontogensis and stability: Trainee should examining the saturated EPVg 100 mb above the maximum in frontogenesis. Weak but potential instability exists in a deep layer from 12 on the 22nd through 12 UTC on the 23rd across the entire CWA. The strongest instability existed in the southern half of the CWA, southeast of the maximum in frontogenesis.

Evaluation Criteria 5 (IC2 Lesson1): Create winter weather products using GFE that effectively discriminates between different winter weather events.

Answer Key 5: A winter weather watch should be considered for southern Indiana. A heavy snow warning could also be considered at this time, given the need for advanced lead time during the holiday travels. However, uncertainty in evolution should limit confidence in precip type and amounts.

Simulation 3 Debrief

At the end of the simulation, 15 minutes is provided to discuss trainee performance and to provide feedback. Some of the issues to consider discussing include:

1. recognizing uncertainty and communicating that appropriately in products

2. blending ensemble analysis with the ingredients method approach

3. collaborating effectively in situations of uncertainty

4. challenges to transferring learning and application in the course/simulations to operations

The ensembles can be a useful tool to help gauge the level of uncertainty in some of the important forecast variables, which can affect your decision of what products to issue (e.g. watch/warning) and when. However, a more complete understanding of the dynamics of the weather event results from a more detailed analysis of individual model runs using the ingredients method. In this

event the ensembles showed significant uncertainty with the development of the second round of precipitation, while the ingredients method clearly showed a quasi-stationary region of strong frontogenesis coupled with elevated instability during both rounds of precipitation. Thus, there is an optimal blend of using both techniques in forecasting that varies with the amount of uncertainty in the event, the skills of the forecaster, and the time available for analysis among many other things.

With increasing uncertainty in the model forecasts, there is greater potential for interpretation differences in the forecast process, which increases the need for effective collaboration and communication. Although addressing collaboration issues effectively in a simulation is challenging without human feedback and more context, having a strategy for collaboration is something that can be focused on in a meaningful way in the simulation that can increase the likelihood of transfer to operations. The training of the simulations and of the course in general can be greatly improved if the challenge of transferring AWOC learning to operations can be addressed at the completion of the simulation and linked with local operations improvement plan.

Simulation 4 (21 Dec. 1501 UTC - 1731 UTC) LMK Winter Weather Warning/Nowcasting Phase

WES Macro: LMK-1501-21Dec2004

IC Focus: IC2 Lesson1, IC3, IC6 Lesson 1, IC6 Lesson 3, IC6 Lesson 4, IC6 Lesson 5, IC7 Lesson 2

Summary:

This simulation focuses on the challenge of recognizing the scope of the winter weather potential in the LMK CWA for a major winter weather event that was focused around two closely timed rounds of all types of winter precipitation. This is the follow on simulation to simulation number 3. The simulation 4 start time is 1501 UTC Dec. 21, 2004 which is about 18 hours before the onset of the first precipitation around 09 UTC on the 22nd. Since this is closer to the warning time scale with more certainty in the forecasts, more emphasis is placed on forecasting precipitation type and amounts.

The latest trend in expectations at HPC has been to reduce the amounts in the snowfall probabilities in the early morning forecast, consistent with the QPF graphic discussed in the first simulation. The general forecast trend at 12z is for more agreement between the NAM and GFS, with 1-1.5” of QPF predicted. Although there are clear signals supporting a winter storm in the model forecasts, the location of the snow/sleet/freezing rain across the CWA and the precipitation amounts are challenging to anticipate.

Schedule for trainee:

- 1500-1510 (10 min): Shift change and HPC product review.
- 1510-1525 (15 min): Familiarization with basic analysis and forecast.
- 1525-1535 (10 min: **EC1**): SREF ensembles analysis.
- 1535-1610 (35 min: **EC2**): Ingredients method analysis.
- 1610-1625 (15 min: **EC3**): Top down analysis.
- 1625-1640 (15 min: **EC4**): Forecast snow ratios.
- 1640-1645 (5 min: **EC5**): Document potential significant impacts to users.
- 1645-1705 (20 min: **EC6**): Use GFE to issue winter weather products.
- 1705-1720 (15 min: **EC7**): Precip estimation and radar snow algorithm.
- 1720-1735 (15 min): Discussion of performance and wrap-up with facilitator.

Evaluation Criteria 1 (IC6 Lesson3).

1. Use the SREF data in the picflip viewer to identify:
   - areas of high certainty and uncertainty in forecast variables
   - areas of higher likelihood of rain, freezing rain, sleet, and ice, and
   - areas of higher likelihood of significant amounts

Answer Key 1. The trainee should recognize the increased certainty in the 500mb H, the continued certainty in freezing temperatures and significant QPF across the northern 2/3 of the LMK CWA, and the continued uncertainty in the surface pressure pattern (on the 22nd).

Evaluation Criteria 2 (IC6 Lesson4).

1. Apply the ingredients method to identify:
   - areas of synoptic forcing using Q vectors and tropopause maps
   - levels of maximum Frontogenesis
   - where the front interacts with the upper level wave
   - low-level Frontogenesis and stability

as they relate to the two rounds of precipitation over the LMK CWA.

Answer Key 2. The only new data available to the trainee are the 80 km model runs of the NAM and GFS from 12 UTC. Both the NAM and GFS runs contain about 0.5” more QPF with a stronger system in general. The synoptic forcing is weak until 18 UTC on the 22nd across the LMK CWA. Only the northern third of the CWA is significantly impacted by synoptic forcing throughout the forecast time periods. Q-vector convergence is much stronger with the 12 UTC model runs, and mid-level frontogenesis is stronger at the beginning of the first round of precipitation, while low-level frontogenesis is stronger during the second round of precipitation. Both the 80 km GFS and NAM have the upper low passing through central Indiana, with the GFS stronger than the NAM.

Evaluation Criteria 3 (IC6 Lesson1). Apply the Top Down Approach to the NAM BUFR vertical profiles at Louisville (KSDF) and Jefferson Proving Ground (KMDN...next to the border with IND). You may use the BUFR profiles in AWIPS or BUFKIT if your facilitator has installed the BUFKIT data on a separate PC.

For the KMDN profile at 12z and KSDF at 15z on the 22nd, document what precipitation type you would expect and why based on:

1. cloud top temperature
2. maximum temperatures in the warm layer
3. surface effects

Answer Key 3. At KSDF, the sounding supports snow and ice pellets with cloud top temperatures (-60C) supporting ice, warm nose cold enough to partially melt some ice (+1.8 C), and surface temperatures not favorable for melting snow (-0.6C). At KMDN, the sounding supports snow with cloud top temperatures (-50C) supporting ice, warm nose too cold to melt ice (-0.1 C), and surface temperatures not favorable for melting snow (-2.6C).

Evaluation Criteria 4 (IC6 Lesson5). Estimate the snow ratios for the central part of the CWA using the KSDF profile and the northern part of the CWA using the KMDN profile, and document your reasoning.

Answer Key 4. Climatology is about 11:1 for LMK. On the KSDF profile, changeover to snow should occur around 16-18 UTC on the 22nd. The qualitative aspects of the sounding support average snow ratios due to a deep isothermal layer from 950-750 mb centered around 0C, and surface winds in the 10-15 kt range. The zone omega technique suggests average to light ratios (10:1 to 20:1) are possible at times depending on whether the vertical velocity is below or within the dendritic growth zone. Thus a range of snow ratios between 10-15: 1 are reasonable. Given that precipitation is not expected to begin until 18 hours from this model run, changes in vertical motion forecast and precipitation type can have significant effect on the actual snow ratios observed.

Qualitative aspects of the KMDN sounding support average snow ratios but lighter than KSDF due to the colder temperatures in the isothermal layer. The correlation of vertical velocities between the dendritic growth zone and warmer layers is better compared to the southern and central parts of the CWA (15 or 20:1), especially during the greatest vertical velocities. The location of the vertical velocities relative to the dendritic growth zone varies widely during the period of snowfall. Thus, snow ratios of 12-18:1 are reasonable across the northern part of the CWA.

Evaluation Criteria 5 (IC3). Document the potential significant impacts to roads in the IND CWA using your forecast and the map provided. Where would de-icing operations on overpasses be hampered by the expected weather (recall IC3, lesson2, part 4)? What content would you put in your warning products describing expected road conditions?

Answer Key 5. The trainee should mention the impact to holiday travel could be significant, including traffic along interstates (e.g. I65, I64, I71). The myriad of precipitation types combined with lowered visibilities during expected periods of intense precipitation rates are particular factors for the LMK CWA. In some areas, the precipitation may be expected to start as rain. The trainee should recognize that overpasses may not be able to be de-iced in these areas and some other less effective strategy may need to be done.

Evaluation Criteria 6 (IC2 Lesson1): Create winter weather products using GFE that effectively discriminates between different winter weather events.

Answer Key 6. A heavy snow warning should be considered for the counties north of the Ohio River and in the western half of the LMK CWA given the large area forecast of mostly snow. South of the Ohio River, a winter storm warning could be valid there with significant sleet/snow in the northern Kentucky counties, and sleet and freezing rain in the central Kentucky counties. Trainee should recognize the southwest to northeast orientation of the low-level thermal gradient and thus produce warning products that take that into account. The southeastern counties probably shouldn't have any winter weather warnings.

Evaluation Criteria 7 (IC7 Lesson2). Review the KLVX snowfall algorithm data with picflip, and diagnose any sources of error in the radar estimates over your CWA at 12z on the 22nd and 12z on the 23rd.

Answer Key 7. At 12z on the 22nd, trainee should recognize significant overestimation of snow accumulation throughout the CWA due to melting of snow to rain (southwest part of CWA) and bright banding (northern and western CWA). At 12z on the 23rd trainee should recognize that bright banding caused huge overestimations throughout the CWA.

Simulation 4 Debrief

At the end of the simulation, 15 minutes is provided to discuss trainee performance and to provide feedback. Some of the issues to consider discussing include:

1. challenges of forecasting mixed phase precip and amounts

2. increases in certainty and more detailed analysis to provide more specificity in forecasts

3. challenges to transferring learning and application in the course/simulations to operations

As certainty grows in the model forecasts approaching the winter weather event, this allows for more detailed analysis to provide more specificity in forecasts.

More time can be spent on addressing the highest impact elements of the forecast, which in this case was the precipitation type, amounts, and timing. In this case the ensembles showed a significant decrease in uncertainty in some forecast variables and the ingredients method continued to show strong quasi-stationary frontogenesis along the Ohio River valley from 06 UTC on the 22nd through 06 UTC on the 23rd, and an increase in the QG forcing during the second round of precipitation relative to previous model runs.

Careful application of the top down approach can significantly improve precipitation type and snowfall forecasts relative to model guidance. In this event the models incorrectly forecast precipitation types in the northern part of the CWA in Indiana and thus model forecasted snowfall amounts were grossly low in that region.

The link between QPF and winter weather precipitation amounts is challenging to understand, much less forecast, given our current snowfall and liquid water equivalent observations. The Zone Omega technique in BUFKIT overestimated ratios across the LMK CWA. The radar snow accumulation algorithm significantly overestimated amounts due to a precipitation type of rain and some evaporation towards the beginning of the event, and significant bright banding throughout the event. While new tools such as the radar snowfall algorithm and the snow ratio techniques in BUFKIT can aid in improving estimates of precipitation in some situations, the complexity of the process still requires significant analysis by the forecaster to use properly.

The training of the simulations and of the course in general can be greatly improved if the challenge of transferring AWOC learning to operations can be addressed at the completion of the simulation and linked with local operations improvement plan.

Appendix A: Storm Reports

I. IND CWA Storm Data entries

INDIANA, Central: Counties	Time (UTC)	Storm Characteristic
Howard, Montgomery, Boone, Tipton, Hamilton, Madison, Delaware, Randolph, Putnam, Hendricks, Marion, Hancock, Henry, Vigo, Clay, Owen, Morgan, Johnson, Shelby, Rush, Sullivan, Greene, Monroe, Brown, Bartholomew, Decatur, Knox, Daviess, Martin, Lawrence, Jackson, Jennings	22 December 0600 UTC-23 December 2100 UTC	Heavy Snow

Description

A winter storm of historic proportions affected central Indiana on 22-23 December 2004. Unusual in that the first round of heavy snow was not directly associated with the passage of a surface cyclone, but rather an area of strong forcing well ahead of the main area of low pressure, the storm nonetheless produced snow totals rivaling and exceeding those of the legendary Blizzard of January 1978 in some areas, crippling much of mainly southern portions of central Indiana, in some cases, for several days. Fortunately for those affected, however, blizzard conditions were not produced thanks to winds much weaker than those accompanying the 1978 storm.

The snow storm began during the very early morning hours of the 22nd, and continued through the day in south central Indiana. By the evening heavy snow of 4 to nearly 10 inches had fallen, generally south of Interstate 70. The greatest totals were in southern Indiana where approximately 10 inches had fallen.

There was a sharp cutoff for this heavy snow. Much of the state north of I-70 did not see any snow. In the Indianapolis area, the Carmel and Brownsburg areas received no snow while the Greenwood area measured 4 inches.

During the evening of the 22nd, the second band of snow moved in as the surface low passed to the southeast of the state, blanketing all of central and southern Indiana. Thundersnow was reported in several areas across central Indiana. Snow of 4 to more than 18 inches fell from this next storm system. Once again

the heaviest snow fell in southern Indiana. This brought the accumulation in much of southern Indiana to more than 20 inches with some spots reporting more than 30 inches of total snow by the afternoon of the 23rd. Such snowfall amounts are historic not only in southern Indiana but for the entire state.

Snowfall in northwestern portions of central Indiana was heavy at times, approaching 3 to 5 inches in Warren, Tippecanoe, Carroll, Clinton, Fountain, Vermillion, and Parke Counties.

This epic snow storm closed I-64, I-65, I-743, and crippled I-70 in Indiana. This stranded hundreds of motorists in their vehicles for hours and some for a few days. A train derailment and collision also occurred in southern Indiana as a result of the snow. One hundred National Guardsmen were called out in some areas, especially in those areas where motorists were stranded. Two blackhawk helicopters and 47 humvees were used in searching for stranded motorists. Statewide, 200 property damage auto accidents were reported, along with 1,000 slide-offs, according to the Indianapolis Star. Several rescues were necessary. Snow drifts of up to 4 feet occurred in much of southern Indiana. Damage estimates were found in local newspaper reports.

II. LMK Storm Data entries

KENTUCKY, Central: Counties	Time (UTC)	Storm Characteristic
Hancock, Breckenridge, Meade, Trimble	22 December 1140 UTC - 23 December 1215 UTC	Heavy Snow

Description

A winter storm dropped 10 to 20 inches of snow over the area. Drifts of two to five feet were reported. Most area roads were dangerous or impassible.

KENTUCKY, Central: Counties	Time (UTC)	Storm Characteristic
Ohio, Bullitt, Jefferson, Oldham, Henry, Shelby, Spencer	22 December 1445 UTC - 23 December 1215 UTC	Winter Storm

Description

A winter storm began with freezing rain and sleet. It soon turned over to snow, and dropped five to ten inches of snow over the area. Many roads were dangerous or impassable, but the major highways and interstates remained open. Many flights out of Louisville International Airport were delayed or cancelled.

KENTUCKY, Central: Counties	Time (UTC)	Storm Characteristic
Grayson, Butler	22 December 2100 UTC - 23 December 1215 UTC	Winter Storm

Description

A winter storm dropped about three to six inches of sleet and snow over the area. Some structural damage was reported, mainly to outbuildings adn service

station canopies. About 3300 residents were without power for some period of time.

KENTUCKY, Central: Counties	Time (UTC)	Storm Characteristic
Franklin, Scott, Harrison, Anderson, Woodford, Fayette, Bourbon, Nicholas, Washington, Mercer, Jessamine, Clark, Larue, Marion, Boyle, Garrard, Madison, Edmonson, Hart, Logan, Warren, Barren	23 December 0229 UTC - 23 December 1215 UTC	Ice Storm

Description

A winter storm began with freezing rain, then changed over to sleet and snow over parts of south central and east central Kentucky. Ice accumulations up to one half inch were reported, with up to an inch of snow or sleet on top. Some structural failures were reported, mainly in outbuildings and awnings covering service stations. A few flights were cancelled out of Bluegrass Field in Lexington. Many residents were without power for an extended time period, mainly in Franklin, Harrison, and Scott Counties. Trees and limbs brought down by the weight of the ice blocked many area streets and roads.

KENTUCKY, Central: Counties	Time (UTC)	Storm Characteristic
Hardin, Nelson	23 December 0300 UTC - 23 December 1215 UTC	Ice Storm

Description

A winter storm began with freezing rain. This left a layer of ice about one inch thick on surfaces. Two to four inches of snow and sleet fell on top of this. A hangar collapsed at the airport in Elizabethtown, destroying a few airplanes. A few structures failed, mainly service station canopies or outbuildings. Some businesses reported ceiling or other minor building damage, but no major structural damage was reported at businesses or residences. Numerous residents were without power for an extended period of time. The weight of ice brought down many trees and large limbs in the area. Roads were dangerous or impassable

due to the ice, sleet, and snow cover. Other driving problems resulted because of fallen trees or limbs blocking roads.

INDIANA, South Central: Counties	Time (UTC)	Storm Characteristic
Orange, Washington, Scott, Jefferson, Dubois, Crawford, Perry, Harrison	**22 December 1020 UTC - 23 December 1215 UTC**	**Heavy Snow**

Description

A winter storm brought heavy snow to south central Indiana. Storm total amounts of 20 to 30 inches were reported over the area. High winds developed later in the day on the 23rd, creating drifts of snow up to four or five feet. Most roadways were dangerous or impassable, and sections of Interstate 64 were closed for a time due to accidents. The roofs on several business warehouses and storage buildings collapsed due to the weight of the snow in Jasper (Dubois County) and Paoli (Orange County). At least 11 turkey houses in Dubois county collapsed due to the snow. Hundreds of birds were killed or injured. Outbuildings and carports collapsed in Tell City in Perry County. Homes in Crawford and Orange Counties were damaged when roofs collapsed due to the weight of snow. A warehouse collapsed in Madison in Jefferson County, and some boats stored nearby were damaged.

INDIANA, South Central: Counties	Time (UTC)	Storm Characteristic
Floyd, Clark	**22 December 1140 UTC - 23 December 1215 UTC**	**Heavy Snow**

Description

A winter storm dropped 10 to 20 inches of snow over the area. Many roads were dangerous or impassable.

Appendix B: Support Materials

This Appendix includes:

I. A list of evaluation criteria examples for this case to illustrate how to tailor the performance objectives to this case to make focused simulations with clear instruction. These are based on the performance objectives from the Winter Weather AWOC training modules. Some of the evaluation criteria come from the Simulation Suggestions section of the simulation, and these have answers. The following lessons are not included in this list due to applicability, redundancy, or unavailability of data: IC1 lesson1, IC4 lesson 1 parts 1-4, IC4 lesson 2 part 2, IC4 lesson 3, IC7 lesson3.

II. A map of the Indianapolis, IN CWA (See Fig. B-1 on page 10.)
III. A map of the Louisville, KY CWA (See Fig. B-2 on page 11.)

I. Master List of Evaluation Criteria and Performance Objectives

IC2 Lesson 1 Why Certain Products Are Issued

Performance Objectives
1. None

Evaluation Criteria
1. Create winter weather products using GFE that effectively discriminates between different winter weather events.

IC2 Lesson 2 Forecast and Product Collaboration

Performance Objectives
1. Execute an effective collaboration process within the forecast process
2. Identify and demonstrate effective and appropriate use of collaboration tools
3. Demonstrate knowledge of collaboration triggers
4. Effectively integrate opportunities for collaboration as part of HPC's Winter Weather Desk and SPC's Winter Mesoscale Discussions

Evaluation Criteria

1. Document a generic strategy for effective collaboration when prompted at the beginning of the simulation and after analyzing data. Include details about when you should collaborate and how.

IC3 Lesson 2 Weather Impacts & Surface Transportation Management Strategies

Objectives
1. Describe the techniques currently available for maintenance crews can use to treat roadways and mitigate the impact of a significant weather event.
2. Describe the parameters that impact road surface temperatures and when those parameters are most important.
3. Identify the aspects of "sub-advisory" winter weather that can result in a significant event.

Evaluation Criteria
1. Discuss the expected road conditions based on expected preciptitation, temperature, wind, and allowable road surface treatment strategies. Consider factors into determining initial road conditions as precipitation begins and also road conditions at the height of the expected winter storm.
2. Based on your forecast, discuss the most significant impacts for road maintenance in this event (e.g. road temps, precip type, wind speed, and intensities).

IC3 Lesson 4

Performance Objectives
1. Identify ways NWS products & services may help transportation operators meet their mission
2. Describe how NWS forecasters can better partner with the transportation community to help meet the NWS mission based upon the discussion items in this lesson.

Evaluation Criteria
1. Based on your forecast, develop a strategy to mitigate the events for many users (include tools for enhanced communication internet/media, how, when, and what to interact with the media, how and when to interact with EMs, information for road maintenance (road temps, precip type, wind speed, and

intensities), school closing), recent event experience (this was the first significant winter storm of the season)).

IC3 Lesson 5 Comparing Timelines of NWS Products and Ground Transportation Mitigation Strategy Implementation

Objectives

1. Identify how weather information and surface transportation management strategies fit into the basic concept of operations presented
2. Describe, in general terms, how NWS products and services fit into the event timeline of each of the conceptual events presented.

Evaluation Criteria

1. Discuss the best timing for winter weather products considering the behavior of motorists with respect to the time of day/week, the media, and road crew needs.

IC4 Lesson 2 Climatological Degree of Rarity of Hazardous Winter Weather- Building a Climatology

Performance Objectives

1. Identify what is needed to create a climatology
2. Determine if the anomaly is significant and its potential impact on the winter weather expected
3. Understand the strengths and limits of climatic anomalies.

Evaluation Criteria

1. Identify any significant anomalies in the ensemble forecasts that are relevant to the forecasts for Indiana and Kentucky using picflip (250mb, 500mb, 850mb, 2m, and MSLP).
2. Document the importance of the anomalies.
3. Document how the anomalies relate to classic winter storms.

IC5 Lesson 1 Potential Vorticity and Its Applications in Operations

Performance Objectives

1. Be able to use tropopause maps to identify the location of troughs, ridges and jet streaks.

2. Be able to develop forecast techniques that allow the display of both upper-level (PV) forcing and low-level (frontal) forcing for the development of intense precipitation

Evaluation Criteria

1. Document the location of all short-wave troughs using tropopause maps, and to estimate their vertical extent.
2. Using a tropopause map in the procedures provided, document the signatures of jets, troughs, and ridges. For these features, relate the temperature or pressure advection to movement and strengthening.
3. Locate those areas where upper-level forcing, and low-level forcing coincide.
4. Using a tropopause map in the procedure provided, relate pressure advection to layer vertical motion to describe areas of upper level forcing and the potential impact on low level wind fields.

IC5 Lesson 2 Diagnosing Mesoscale Internal Forcing: Frontogenesis

Performance Objectives

1. Determine which form of the frontogenesis equation available in AWIPS is most appropriate for diagnosing frontal bands.
2. Use satellite to help identify areas where differences in diabatic heating could enhance frontogenesis.
3. Apply the concept of coupling between upper-level waves and lower-level fronts to determine where the ascent associated with a frontal circulation may be strongest.

Evaluation Criteria

1. Document the strongest regions and layers/heights (either is fine) of 2-D frontogenesis. Explain where an ageostrophic vertical circulation will develop and how it will affect horizontal and vertical motions in the region of the frontogenesis.
2. Examine the low-level temperature gradient and axis of dilatation to determine whether the configuration is frontogenetic or not.
3. Using IR satellite and surface observations, document regions where frontogenesis might be enhanced due to diabatic effects.

IC5 Lesson 3 The Effect of Stability on the Response to Internal Forcing in the Atmosphere

Performance Objectives
1. Determine the proper layer to examine EPVg
2. Determine the impact that stability can have on the snowfall rate and the width of a snowband

Evaluation Criteria
1. Document regions where saturated EPVg exists and discuss how it relates to the frontogenesis and the nature of the resulting vertical motion.
2. Using cross sectional analyses, diagnose the potential for slantwise or upright convection.

IC5 Lesson 4 Examples of Frontal Precipitation Bands

Performance Objectives
1. Apply the diagnostics shown in this lesson to snowfall forecasts during events featuring major cyclogenesis
2. Apply the diagnostics shown in this lesson to snowfall forecasts during more subtle events

Evaluation Criteria
1. Using a 32-frame loop of hourly radar data (load sfc obs then radar data), identify a major frontal precipitation band.
2. Document the features that explain the forcing for this band using saturated EPVg, RH, and frontogenesis.

IC5 Lesson 5 Precipitation Forcing Mechanisms and Conceptual Models: Structure of TROWALS

Performance Objectives
1. Once training has been completed, students will be able to:
   A. Identify the TROWAL using several analysis methods
   B. Analyze data and model output to identify trowel location
   C. Analyze data and model output to predict continued trowel evolution

Evaluation Criteria
1. Using an isentropic map with winds and pressure plotted, discuss the presence or absence of a TROWAL.

IC6 Lesson 1 Introduction to the Top-Down Methodology

Performance Objectives

1. Be able to utilize the top-down approach in an operational setting including:
   A. Assess potential for heterogeneous nucleation
   B. Assess impact of warm layer
   C. Interrogate near surface layer (i.e. wet-bulb effects)

Evaluation Criteria

Apply the Top Down Approach to the NAM BUFR vertical profiles at Indianapolis (KIND...in the CWA) and Jefferson Proving Ground (KMDN...next to the border with LMK). You may use the BUFR profiles in AWIPS or BUFKIT if your facilitator has installed the BUFKIT data on a separate PC.

For KIND and KMDN profiles at 12z on the 22nd, document what precipitation type you would expect and why base on:

1. cloud top temperature
2. maximum temperatures in the warm layer
3. surface effects

IC6 Lesson 2 Strengths and Weaknesses of P-type Algorithms

Performance Objectives

1. From this instruction, you should be able to:
   A. Assess the validity of various algorithms in different forecast situations
   B. Anticipate potential algorithm failures in an operational setting
   C. Compare algorithm output with an understanding of each algorithm's strengths and weaknesses

Evaluation Criteria

1. Utilize the BUFKIT data provided to determine which P-Type Algorithm is most appropriate for this event and CWA.

IC6 Lesson 3 Using Ensembles in Winter Weather Forecasting

Performance Objectives

1. Demonstrate why you should use ensemble forecast information during winter storms in the outlook, watch, and warning phases.
2. Identify the strengths and limitations of EPS products such as mean, spaghetti, spread, plume charts, and probability of exceedance.

3. Demonstrate how to recognize uncertainty /high probability outcomes in EPS data.
4. Demonstrate how probabilistic forecasting duties in winter weather are related to ensemble forecasting.

Evaluation Criteria

1. Use the SREF data in the picflip viewer to identify:
   - areas of high certainty and uncertainty in forecast variables
   - areas of higher likelihood of rain, freezing rain, sleet, and ice, and
   - areas of higher likelihood of significant amounts

IC6 Lesson 4 The Ingredients-Based Method for Forecasting Heavy Precipitation

Performance Objectives

1. Use the AWIPS procedures provided in IC 8 (WES case) to display and use the ingredients approach for an actual winter weather precipitation event

Evaluation Criteria

1. Apply the ingredients method to identify:
   - areas of synoptic forcing using Q vectors and tropopause maps
   - levels of maximum Frontogenesis
   - where the front interacts with the upper level wave
   - low-level Frontogenesis and stability

as they relate to the two rounds of precipitation over the CWA.

IC6 Lesson 5 Snowfall Forecasting

Performance Objectives

1. Improve estimates of snow density by
   A. Diagnosing the snow ratio category (light, average, heavy) by inspection of NWP profiles of temperature, dewpoint, and vertical motion
   B. Modifying snowfall accumulation rates based on sub-cloud and surface conditions
   C. Convert NWP forecasts of equivalent liquid precipitation to snowfall
2. Be able to apply two diagnostic tools to assess snow ratio and snowfall

Evaluation Criteria

Estimate the snow ratios for the central part of the CWA using the KIND profile and the southern part of the CWA using the KMDN profile, and document your reasoning.

IC7 Lesson 1 Monitoring Model Accuracy

Performance Objectives

1. Identify strategies where observations can be used to assess model accuracy, and therefore clues as to how to modify model forecasts.

Evaluation Criteria

1. Evaluate trough/ridge location and movements vs. models, surface low pressure strength, movement, and location and explain how this may affect your forecast.
2. Examine radar data to see if the model depiction of frontogenesis is accurate and if the models had a good handle on mesoscale banded precipitation.
3. Using 700-500 mb RH with Water Vapor to track the arrival and position of the dry slot, then explain what the dry slot means for the nature of the precipitation.

IC7 Lesson 2 Accuracy of radar-derived precipitation rates)

Performance Objectives

1. Determine where the radar is overestimating precipitation due to overshooting.

Evaluation Criteria

Review the KIND and KLVX snowfall algorithm data with picflip, and diagnose any sources of error in the radar estimates over your CWA at 12z on the 22nd and 12z on the 23rd.

IC7 Lesson 4 Diagnosing Unexpected Areas of Precipitation

Performance Objectives

1. Identify a methodology to efficiently diagnose and assess future behavior of unexpected precipitation areas.

Evaluation Criteria

1. Use the 5 step process (monitor conditions, recognize forecast departure, diagnose cause for forecast departure, forecast persistence, and update forecast) to determine the cause of the heavy precipitation in the counties just north of the Ohio River in Indiana, and update the forecast accordingly.

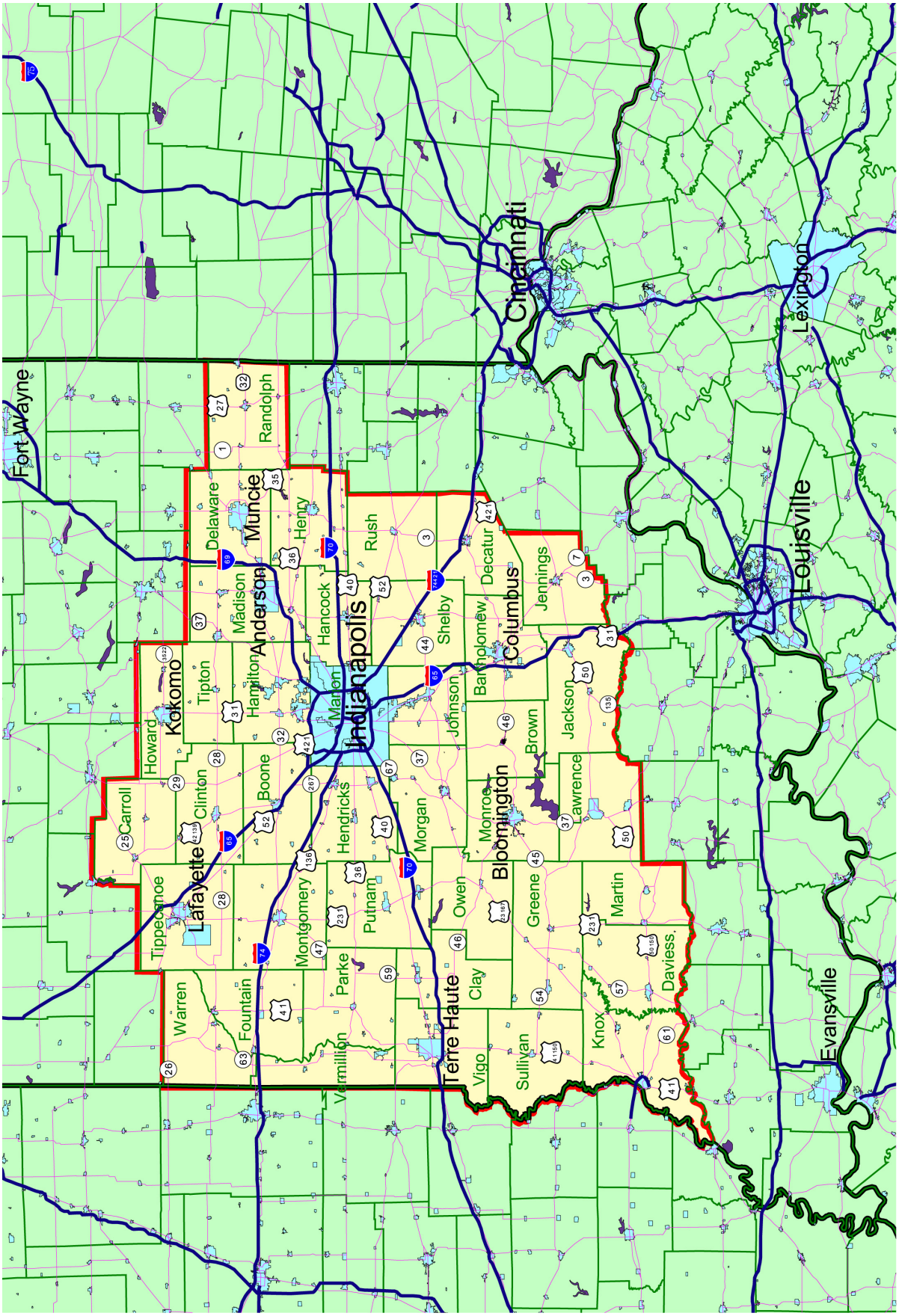

Figure B-1. A map of the Indianapolis, IN (IND) CWA

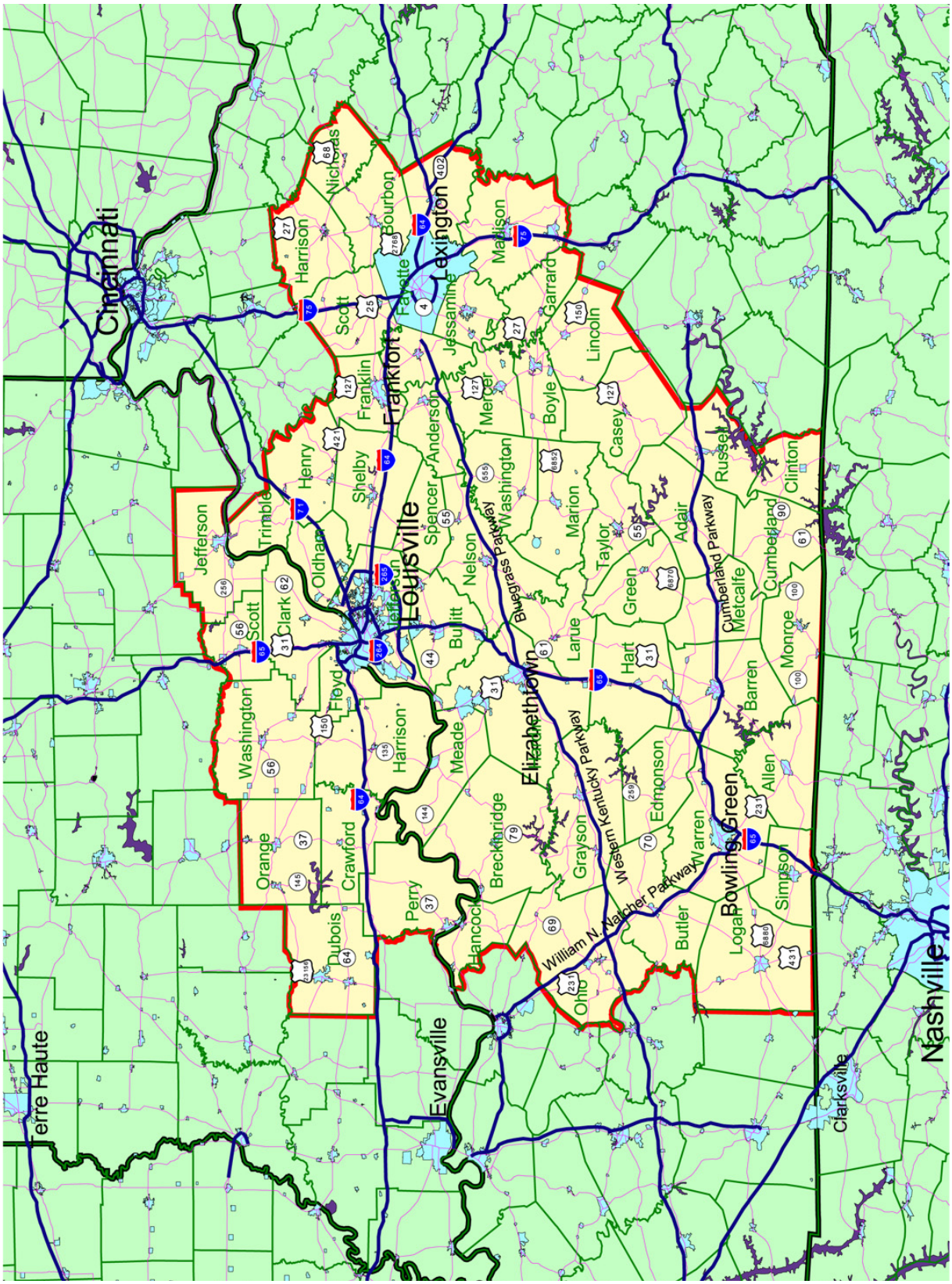

Figure B-2. A map of the Louisville, KY (LMK) CWA