USE OF GOES SOUNDER DATA TO FORECAST A WINTER CONVECTIVE HEAVY RAIN / FLASH FLOOD EVENT IN THE MISSISSIPPI VALLEY

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Abstract

Since 1996, the Satellite Analysis Branch (SAB) of NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) has been evaluating and using GOES Sounder data operationally to enhance satellite precipitation analyses for: briefings to the NOAA/NWS Hydrometeorological Prediction Center (HPC) of the National Centers for Environmental Prediction (NCEP); and composing satellite precipitation estimate messages for dissemination to the NWS Weather Forecast Offices (WFOs) and River Forecast Centers (RFCs). The heavy rain, flash flood and severe weather outbreak of 21-22 January 1999 over the lower Mississippi Valley (centered over Arkansas) was an extraordinary case. GOES Sounder data, indicating well above normal Precipitable Water (PW) values and very unstable Lifted Index (LI) values, was invaluable in helping the operational forecaster anticipate the event at least 9 hours before it occurred. In conjunction with other satellite and conventional data, the GOES Sounder data was instrumental in helping the satellite analysts in SAB anticipate both the location and intensity of the convective outbreak, thus providing plenty of lead time to brief NCEP/HPC and disseminate satellite precipitation estimate messages preceding and during the event. A satellite perspective of the event involving GOES Sounder data, model forecasts, observations, and how SAB and HPC (which comprise the National Precipitation Prediction Unit) handled the event will be discussed in this technical note.

1. Introduction

Hourly GOES-8 Sounder data (Menzel et al. 1998) was highly useful to NESDIS/Satellite Analysis Branch (SAB) meteorologists prior to and during the lower Mississippi Valley flash flood/severe weather event of 21-22 January 1999. The timely and reliable GOES Sounder Precipitable Water (PW) and Lifted Index (LI) data available throughout the day on 21 January helped SAB precipitation meteorologists anticipate and effectively monitor this major event as it unfolded. During the 24-hour period ending 1200 UTC 22 January, three to six inches of rain fell over parts of the area from Louisiana to southern Illinois resulting in flash flooding. At the same time, multiple tornadoes had touched down in Arkansas and Mississippi resulting in six deaths and dozens of injuries.

This paper will show how the GOES Sounder data was used to enable operational meteorologists of SAB and the Hydrometeorological Prediction Center (HPC) of the NWS/National Centers for Environmental Prediction (NCEP) to: better anticipate the development, location, and magnitude of the convection; improve upon the models' precipitation forecasts; and provide better ongoing guidance as the event unfolded.

2. Surface, Upper-Air, and GOES Sounder Data (circa 1200 UTC 21 January 1999)

During the morning of 21 January 1999, a 500-mb trough was located over the central and southern Plains (Fig.1), while a southerly surface flow was advecting unusually moist air (dewpoints in the 60's F) for this time of year across the lower Mississippi Valley. A frontal system extended across Oklahoma and Missouri to the Appalachians, while a dryline extended from central Oklahoma to southwest Texas (Fig. 2). GOES Sounder data (Hayden et al. 1996; Menzel et al. 1998) at 1215 UTC indicated Precipitable Water (PW) values ranging up to an inch or more (Fig. 3a) and Lifted Index (LI) values as low as -6 (Fig. 4a) over the lower Mississippi Valley.

3. SAB Briefings to HPC

SAB provides briefings to HPC several times per day, focusing on satellite features/data that have a direct bearing on precipitation. The mid-morning briefing is usually provided by 1330 UTC. SAB utilizes GOES Infrared (IR) and Water Vapor (WV) imagery and Sounder data, along with polar-orbiting composite data from the Defense Meteorological Satellite Program's (DMSP) Special Sensor Microwave Imager (SSM/I) (Ferraro et al. 1998). Using the GOES Sounder data, the satellite meteorologist is able to overlay digital values of PW and LI on corresponding Derived Product Imagery (DPI). DPI provides an image composite of GOES Sounder parameters, such as PW

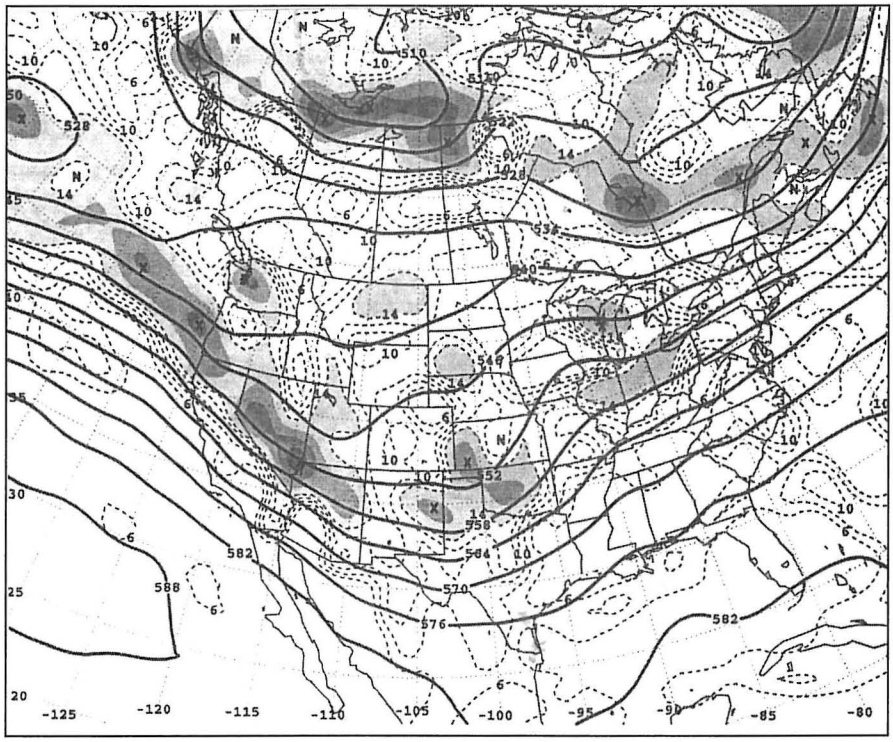


Fig. 1. Eta model 500-mb height and absolute vorticity 0-h forecast chart valid 1200 UTC 21 January 1999.

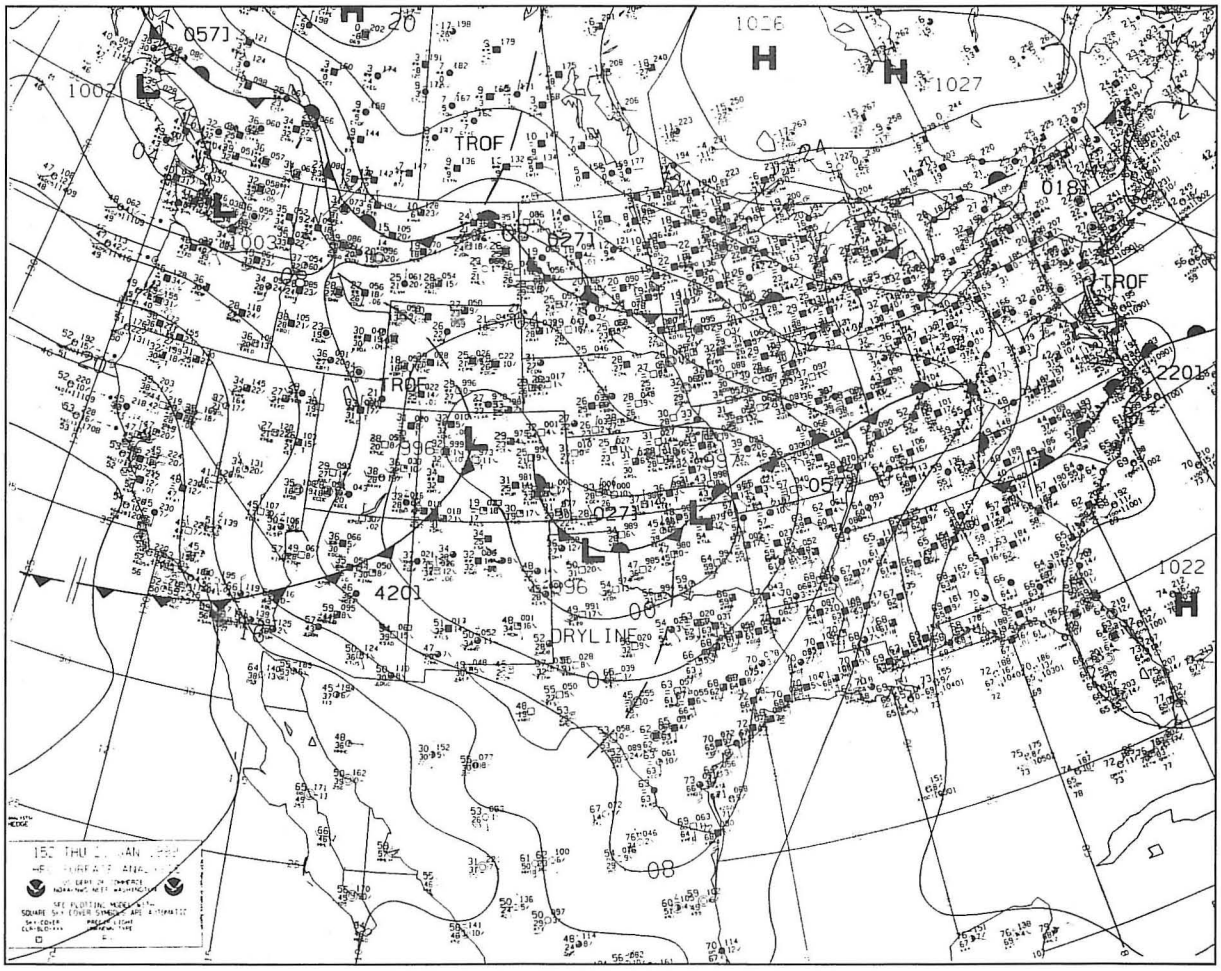


Fig. 2. NWS/NCEP/HPC surface analysis valid 1500 UTC 21 January 1999.

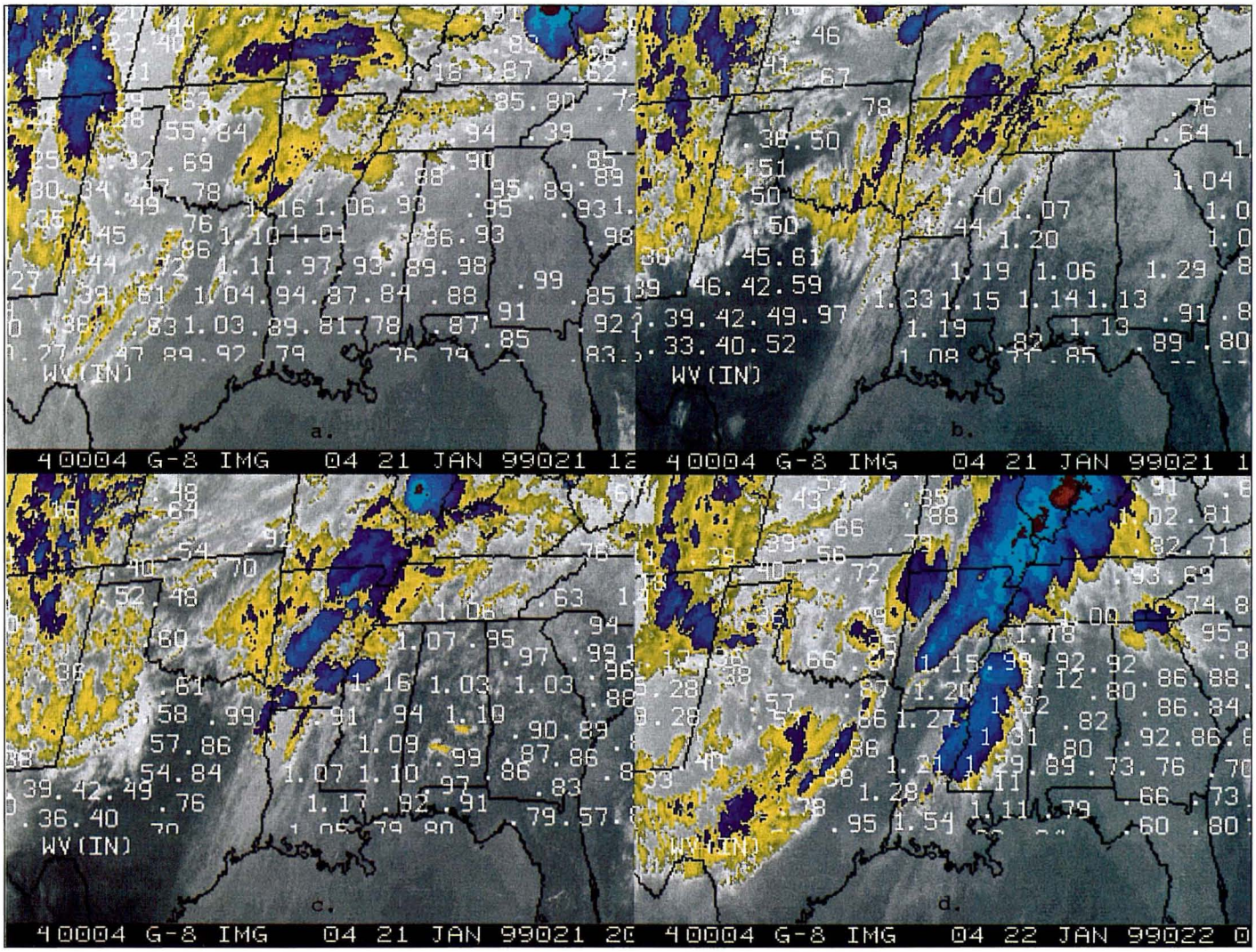


Fig. 3. GOES-8 IR color-enhanced imagery with Precipitable Water values (inches) overlaid on each image. Image times are: a) 1215 UTC 21 January 1999; b) 1815 UTC 21 January 1999; c) 2045 UTC 21 January 1999; and d) 0215 UTC 22 January 1999.

(Fig. 5) and LI, in which shades or colors are calibrated to correspond to digital values (Menzel et al. 1998). By looking at a DPI loop the meteorologist is able to see a visual composite of trends over a period of time.

The 1246 UTC 21 January DPI PW imagery showed very high PW values (up to 1.1 inches; near 200% of normal) over the lower Mississippi Valley, with the highest over Arkansas (Fig. 5). The most negative/unstable LI values (Fig. 4a) were over northeast Texas and Arkansas. PW and LI satellite loops indicated that both moisture and instability had steadily increased during the night. These significant observations and trends were pointed out to HPC during the morning satellite briefing. The satellite data along with factors such as the very moist surface flow, and positive vorticity advection as per 500-mb height/vorticity analysis and forecast (Figs. 1 and 6), indicated the likelihood of heavy precipitation developing over Arkansas during the afternoon. (Note: In Fig. 6, the 24-hour forecast from the 0000 UTC model run was used due to the fact that HPC generally issues its early morning products before new 1200 UTC model run data is available). According to Scofield et al. (1998), "High values of PW and instability are often collocated and become antecedent conditions prior to the development of heavy rainfall and flash floods...and when a lifting mechanism is present (e.g., trough/positive vorticity advection) heavy precipitation often occurs."

Incorporating the information from SAB's satellite briefing into their forecast process, HPC meteorologists included part of Arkansas and Louisiana in their Excessive Rainfall Potential Outlook issued at 1405 UTC (Fig. 7). Additionally, HPC meteorologists forecasted precipitation maxima for parts of the area from northern Louisiana to southeast Missouri (especially Arkansas) in their 6-hour forecast periods ending 0000 UTC and 0600 UTC 22 January (Fig. 8). Note that this was farther west and higher in magnitude than the precipitation forecasts from the 0000 UTC 21 January run of the AVN and Eta models (Fig. 9). The models predicted the highest rainfall amounts mainly across

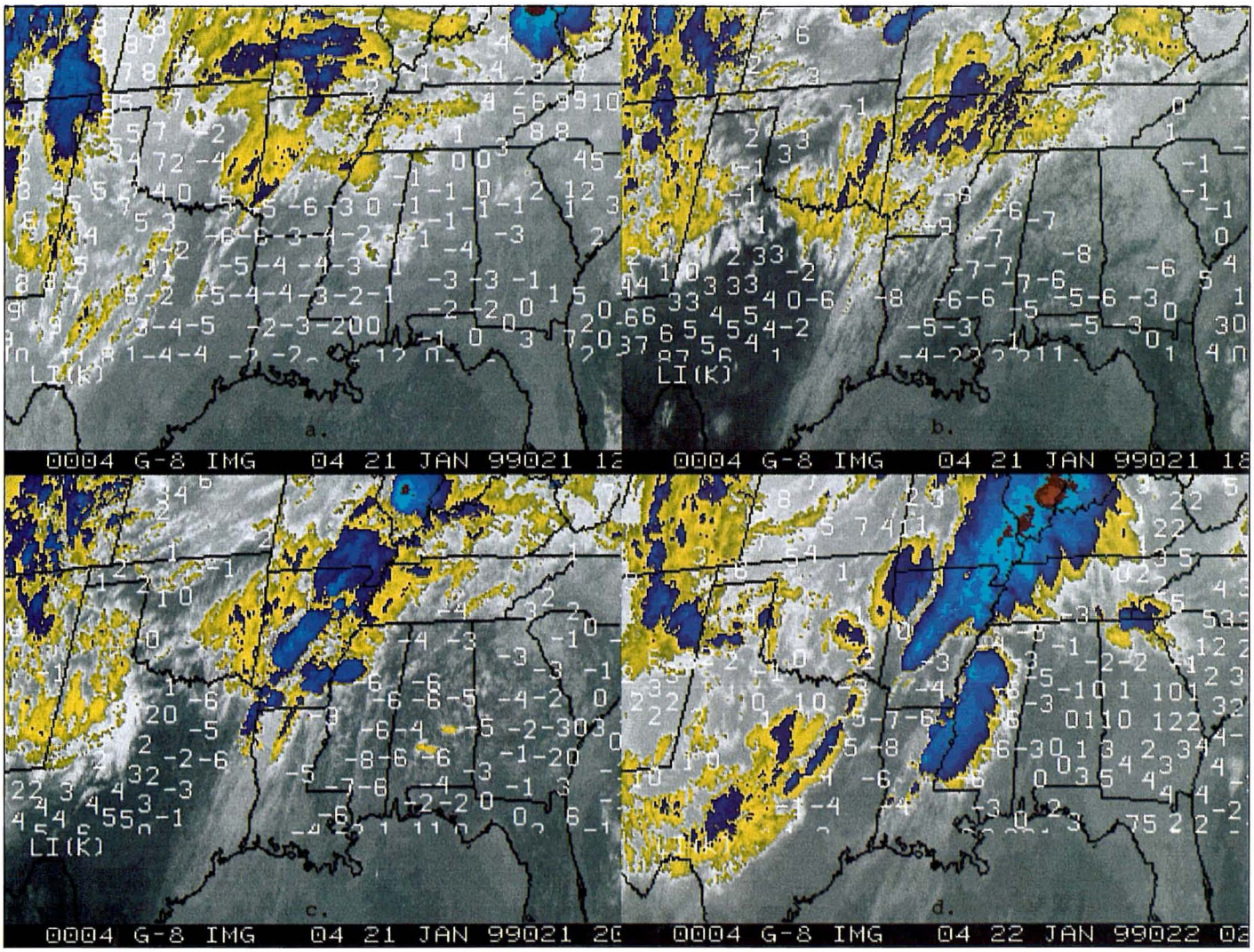


Fig. 4. GOES-8 IR color-enhanced imagery with Lifted Index values (degrees C) overlaid on each image. Image times are: a) 1215 UTC 21 January 1999; b) 1815 UTC 21 January 1999; c) 2045 UTC 21 January 1999; and d) 0215 UTC 22 January 1999.

the area from western Tennessee to Ohio for the combined 12-hour periods ending 0000 UTC 22 January and 1200 UTC 22 January.

4. SAB Support to National Weather Service Weather Forecast Offices

The NESDIS/SAB employs a monitoring and estimating plan in their satellite precipitation estimate support to the NWS Weather Forecast Offices (WFOs) and River Forecast Centers (RFCs) across the country. SAB closely monitors areas where heavy precipitation is expected to develop. Satellite rainfall estimates are derived and then disseminated via satellite precipitation estimate messages (SPENES) when rainfall amounts are expected to approach or exceed flash flood guidance criteria.

Following the early morning briefing to HPC on 21 January, SAB continuously monitored weather changes over the Mississippi Valley using satellite and conventional data, and began estimating rainfall around 1815 UTC. Based on the data, especially from the GOES Sounder, which indicated high PW values of 1.4+ inches (well above normal for this time of year) and very unstable LI values of -9, the SAB meteorologist alerted NWS WFOs and RFCs to impending heavy precipitation/flash flood potential. A SPENES message (Fig. 10) was issued at 2040 UTC emphasizing: 1) the trend of the GOES Sounder PW and LI data (Figs. 3 and 4), highlighting the unusual values for the time of year; 2) the current convective developments on satellite data; and 3) the later concerns for heavy precipitation/flash flooding as moisture and the 500-mb short wave trigger continued to come together.

As satellite estimates began to approach and for some localities exceed flash flood guidance, a second SPENES (Fig. 11) was sent at 0215 UTC 22 January. Satellite rainfall estimates were provided for counties in Arkansas, southeast Missouri, southern Illinois and southern Indiana. Remarks included GOES Sounder DPI trends and applications of the PW data to increased rainfall efficiency, factors that increased

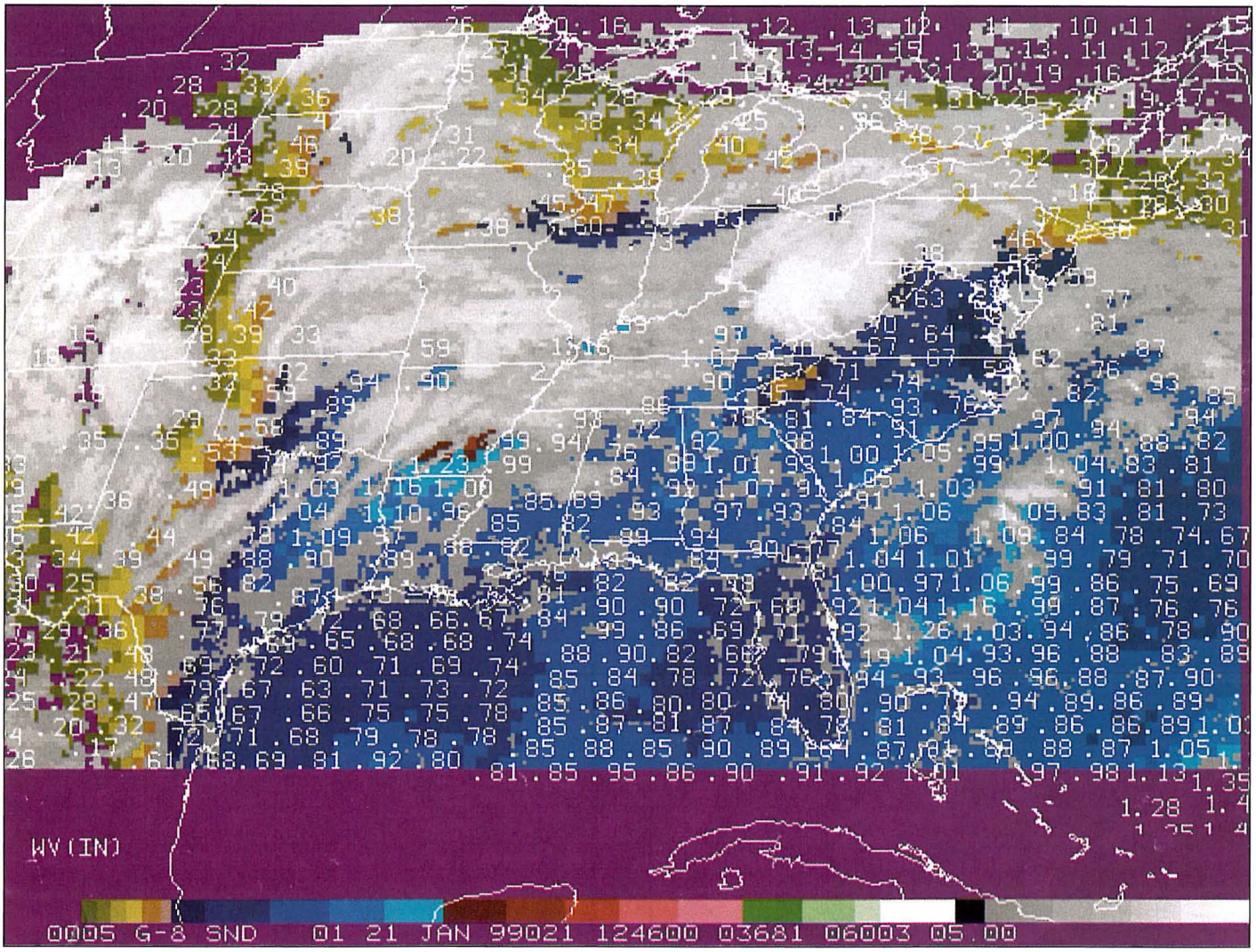


Fig. 5. GOES-8 Precipitable Water DPI from 1246 UTC 21 January 1999 with digital values (inches) overlaid on the image. The highest PW is over southern Arkansas, as indicated by the red color enhancement.

confidence that more widespread flooding could occur. Five additional SPENES messages were sent during the remainder of the night.

5. Reports and Observations

As of 1200 UTC 22 January, the observed 24-hour rainfall (Fig. 12) included maximum reports of 5.2 in. over northeast Arkansas, 6.2 in. along the Missouri/Illinois border, 4.9 in. over western Mississippi, and 3.2 in. over Louisiana. The NWS Flood Summary (Fig. 13) reported widespread flooding occurred over the lower Mississippi Valley. Additionally, it reported that multiple tornadoes had touched down in Arkansas and Mississippi, resulting in six deaths and dozens of injuries.

6. Summary and Conclusions

This case has not only demonstrated the utility of real-time GOES Sounder data in anticipating the development and trends of a major convective event, but also in updating/improving upon numerical model forecasts. The GOES Sounder Derived Product Imagery (DPI) enabled SAB and HPC meteorologists to observe the real-time evolution (magnitude and trend) of two major atmospheric forecasting parameters: Precipitable Water (PW) and Lifted Index (LI). The DPI showed increasingly high PW and increasingly negative LI values over the lower Mississippi Valley. This in conjunction with other satellite imagery and surface/upper-air analyses alerted SAB and HPC meteorologists to the likelihood of heavy/excessive rainfall over the region, further west than the models were indicating. This was reflected in HPC's forecast products, issued well in advance of the event. Then as the event unfolded, GOES Sounder data were continuously used by SAB in providing guidance to NWS Forecast Offices via Satellite Precipitation Estimate messages and to HPC in ongoing briefings.

In this case and in others (Heil 2000), GOES Sounder data have proven to be an invaluable analy-

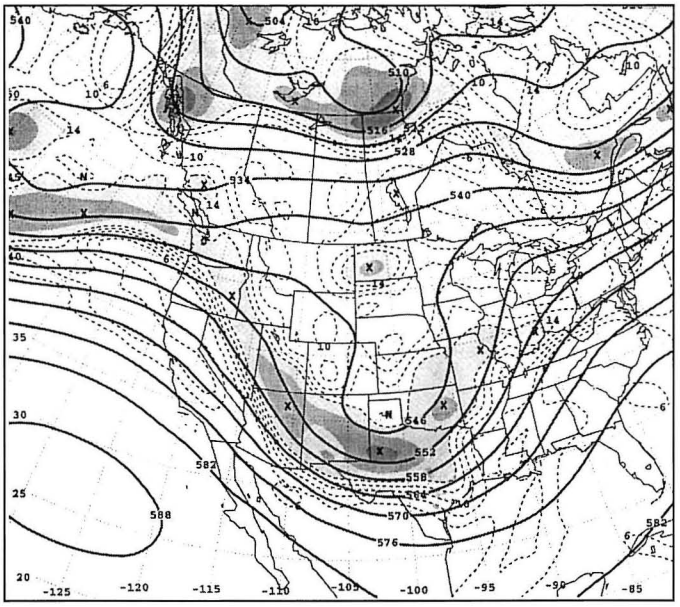


Fig. 6. Eta model 500-mb height and absolute vorticity 24-h forecast chart valid 0000 UTC 22 January 1999

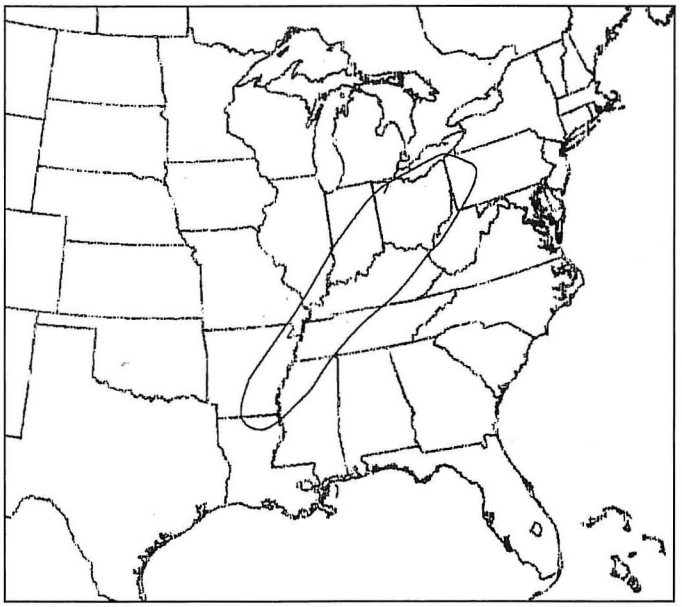
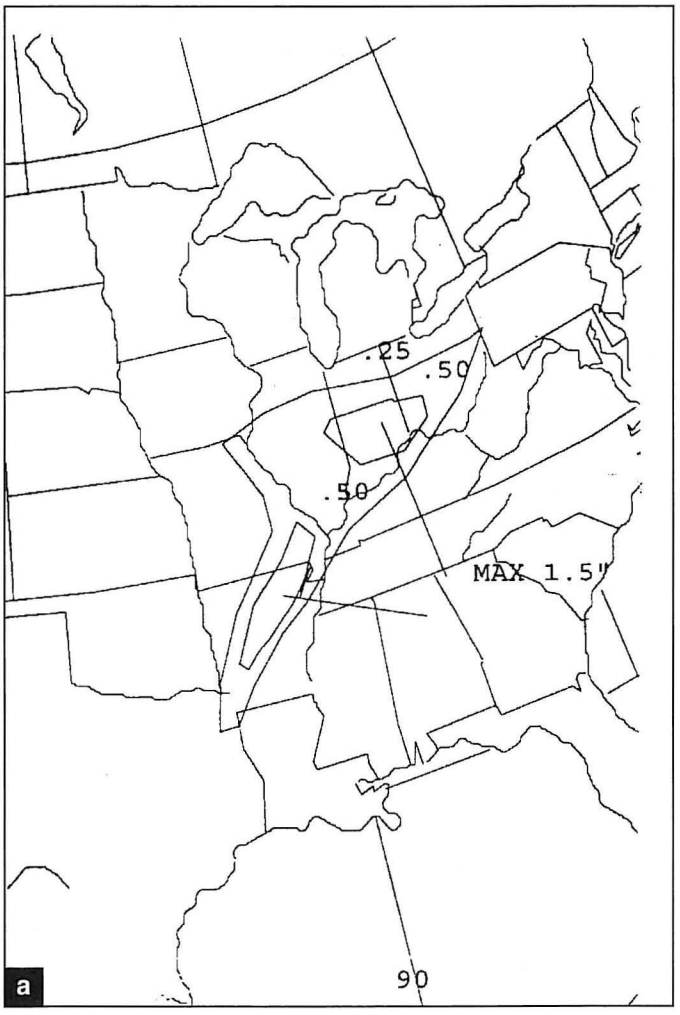


Fig. 7. NWS/NCEP/HPC Excessive Rainfall Potential Outlook issued 0905 EST (1405 UTC) 21 January valid 1500 UTC 21 January thru 1200 UTC 22 January 1999.



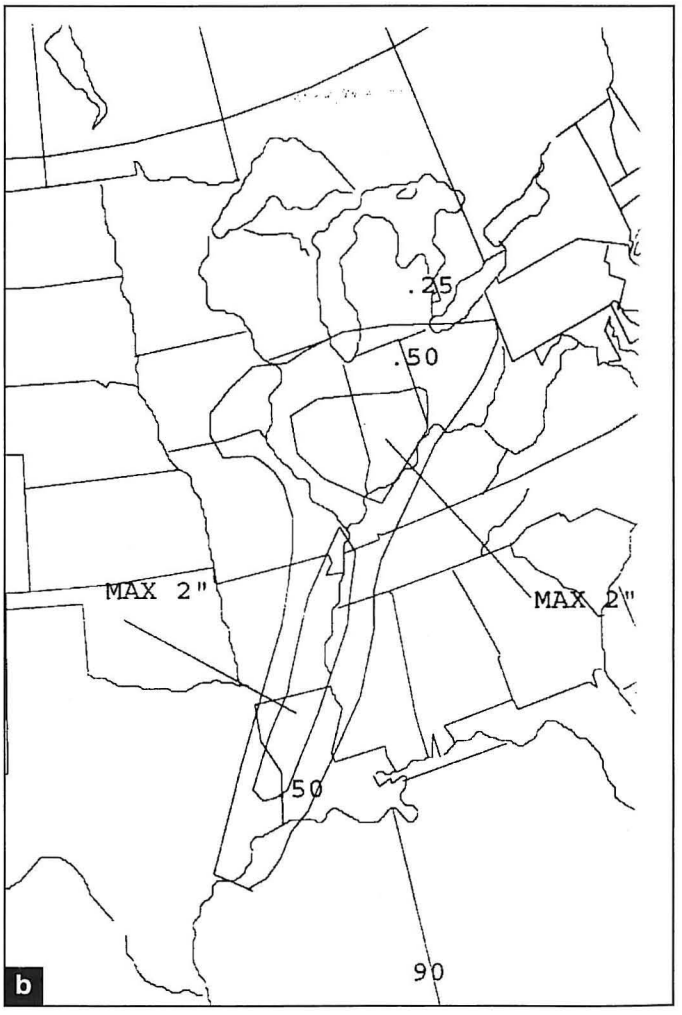


Fig. 8. NWS/NCEP/HPC 6-h Quantitative Precipitation Forecasts (QPFs) issued 0950 EST (1450 UTC) 21 January 1999 valid: a) 1800 UTC 21 January thru 0000 UTC 22 January, and b) 0000 UTC 22 January thru 0600 UTC 22 January 1999.

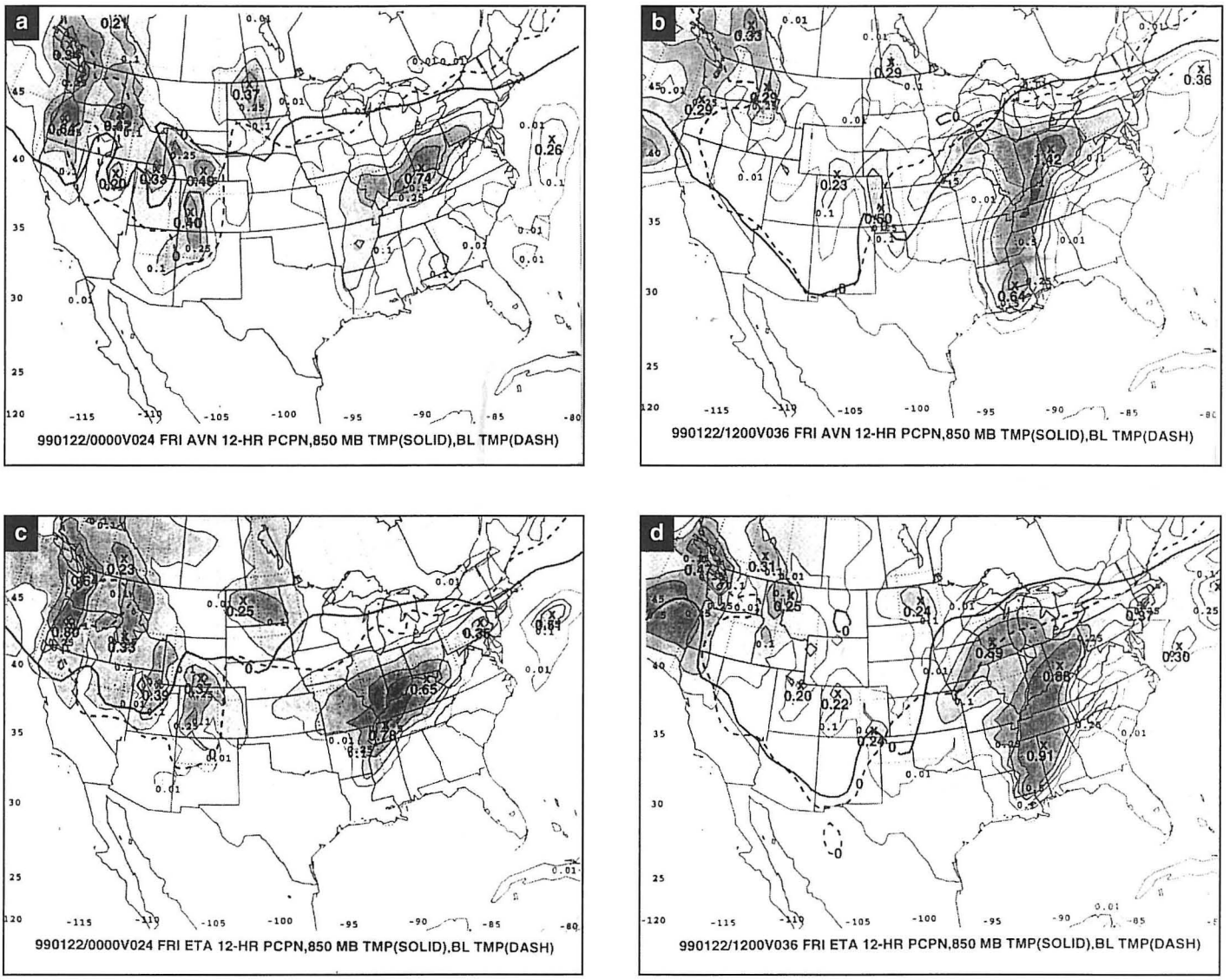


Fig. 9. AVN and Eta model forecasts of 12-h precipitation amounts (inches), 850-mb freezing line (solid), and boundary-layer freezing line (dashed): a) AVN 24-h forecast valid 0000 UTC 22 January, b) AVN 36-h forecast valid 1200 UTC 22 January, c) Eta 24-h forecast valid 0000 UTC 22 January, and d) Eta 36-h forecast valid 1200 UTC 22 January 1999.

sis and forecasting tool to NESDIS and NWS meteorologists, instilling greater confidence in forecasting the development and progress of convective events. Additionally, for SAB, it has been instrumental in improving satellite precipitation (estimate and guidance) support to the NWS WFOs, RFCs, and the HPC.

Acknowledgments

The authors thank: Mike Eckert, Pete Manousos, and Wes Junker of NWS/NCEP/HPC; Dr. Rod Scofield of NESDIS Office of Research and Applications (ORA); John Paquette of NESDIS/SAB; Dr. Kevin Schrab of NWS/Western Region Scientific Services Division; and Dr. Dan Bikos of CIRA/RAMMT for reviewing this paper and providing helpful comments and suggestions. The authors also thank Dr. Brett McDonald of NCEP/HPC for providing the figure for 24-hour precipitation.

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Sheldon J. Kusselson has been a meteorologist with the Satellite Analysis Branch (SAB) of the National Environmental Satellite, Data and Information Service since 1979. Since 1983, he has been a member of the SAB Precipitation Team, specializing in operational satellite precipitation estimates and satellite applications for the analysis and short term forecast-

ZCZC NFDSPENES ALL DDHHMM;350,0930 350,0900 340,0900 340,0940;
TTAA00 KNFD DDHHMM

SATELLITE PRECIPITATION ESTIMATES..DATE/TIME 1/21/99 2040Z
THE SATELLITE ANALYSIS BRANCH/NESDIS---NPPU--- TEL.301-763-8678
VALUES ARE MAX OR SGFNT EST. NO OROGRAPHIC CORRECTION UNLESS NOTED.
...EST'S FM: /GOES8-CNTRL AND E. U.S. / GOES10 - W. U.S...
LATEST DATA USED: G8 2015Z

LOCATION...AR...
NO ESTIMATES AT THIS TIME...MONITORING...SEE REMARKS...

REMARKS...BEEN WATCHING GOES SOUNDER LI/PRECIP WATER VALUES GET PROGRESSIVELY UNSTABLE/MOIST PAST 6HRS CNTRD ON N LA/S AR AND INTO MS. LATEST SOUNDER LIs/PWs AN IMPRESSIVE -8 TO -9/1.25" OVER SE AR AND CONSISTENTLY -5 OR LOWER/1"+ PAST FEW HRS OVER C/N LA. AS A RESULT BEST CONVECTION FIRING SW TO C AR ON BACK EDGE OF FAVORED PRECIP WATER GRADIENT. INITALLY NOT TOO CONCERNED ABOUT FF THREAT...BUT THINGS AT LEAST HAVE THE POTENTIAL TO CHANGE RAPIDLY NXT FEW HRS AS SHT WAVE SWINGS INTO AREA...MOISTURE CONTINUES TO GET DRAWN NORTHWARD THRU LOWER MS VALLEY AND DISORGANIZED CONVECTION SE AR AND LTL BETTER ORGANIZATION TX-LA-AR BDR AREA TRIES TO FILL INTO THE AREA CNTRD ON AR. WILL CONTINUE TO MONITOR...

NO GRAPHICS CURRENTLY AVAILABLE ON THE INTERNET FOR THIS EVENT.

SEE HPC QPF GRAPHICS AND DISCUSSIONS FOR FCST...

http://www.ssd.noaa.gov/SSD/ML/pcpn-ndx.html
[ONLINE SSD PRECIPITATION PRODUCT INDEX]

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Fig. 10. Satellite Precipitation Estimate Message issued 2040 UTC 21 January 1999.

ZCZC NFDSPENES ALL DDHHMM;330,0940 330,0900 390,0860 390,0890;
TTAA00 KNFD DDHHMM

SATELLITE PRECIPITATION ESTIMATES..DATE/TIME 1/22/99 0215Z
THE SATELLITE ANALYSIS BRANCH/NESDIS---NPPU--- TEL.301-763-8678
VALUES ARE MAX OR SGFNT EST. NO OROGRAPHIC CORRECTION UNLESS NOTED.
...EST'S FM: /GOES8-CNTRL AND E. U.S. / GOES10 - W. U.S...
LATEST DATA USED: G8 0145Z

LOCATION...AR TO SE MO TO S IL/EXT W KY TO S IN AR...	TOTALS	TIME
GARLAND	2.2"	1815-0145Z
SALINE	2.3"	"
FAULKNER-PULASKI BDR	1.9"	"
WHITE	1.8"	"
CRAIGHEAD	1.3"	"
GREENE	1.6"	"
SE MO...		
DUNKLIN	1.4"	"
NEW MADRID	1.2"	"
S IL...WAYNE-RICHLAND BDR AREA	1.2"	"
S IN...LAWRENCE TO KNOX/DA VIESS	1.0"	"

REMARKS...GOES SOUNDER SHOWING PRECIP WATER VALUES CONTINUE INCRG LA INTO SOUTHERN ARKANSAS...85H WINDS INCRG TO 50KTS AS PER RAOB...MAKING FOR INCRG MOISTURE ADVECTION AND RAINFALL EFFICIENCY ACROSS C/E AR THRU SE MO/NW TN...PROBABLY TRANSLATING NEWD INTO S INDIANA. WHOLE AREA WILL BE VERY VULNERABLE FOR LOCALIZED FLOODING JUST BECAUSE FF GUIDANCE VALUES AREA LOW...BUT WILL MONITORING FOR INCRG WIDESPREAD FOOD POTENTIAL AS BEST MOISTURE CONTINUES TO SPREAD FURTHER N/NEWD INTO WESTERN OHIO VALLEY DURING THE NIGHT. WILL CONTINUE TO MONITOR...

GRAPHIC OF SATELLITE ESTIMATES FOR THE PERIOD 1815-0145Z CURRENTLY AVAILABLE ON THE INTERNET AT THE ADDRESS BELOW....

SEE HPC QPF GRAPHICS AND DISCUSSIONS FOR FCST...

http://www.ssd.noaa.gov/SSD/ML/pcpn-ndx.html
[ONLINE SSD PRECIPITATION PRODUCT INDEX]

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Fig. 11. Satellite Precipitation Estimate Message issued 0215 UTC 22 January 1999.

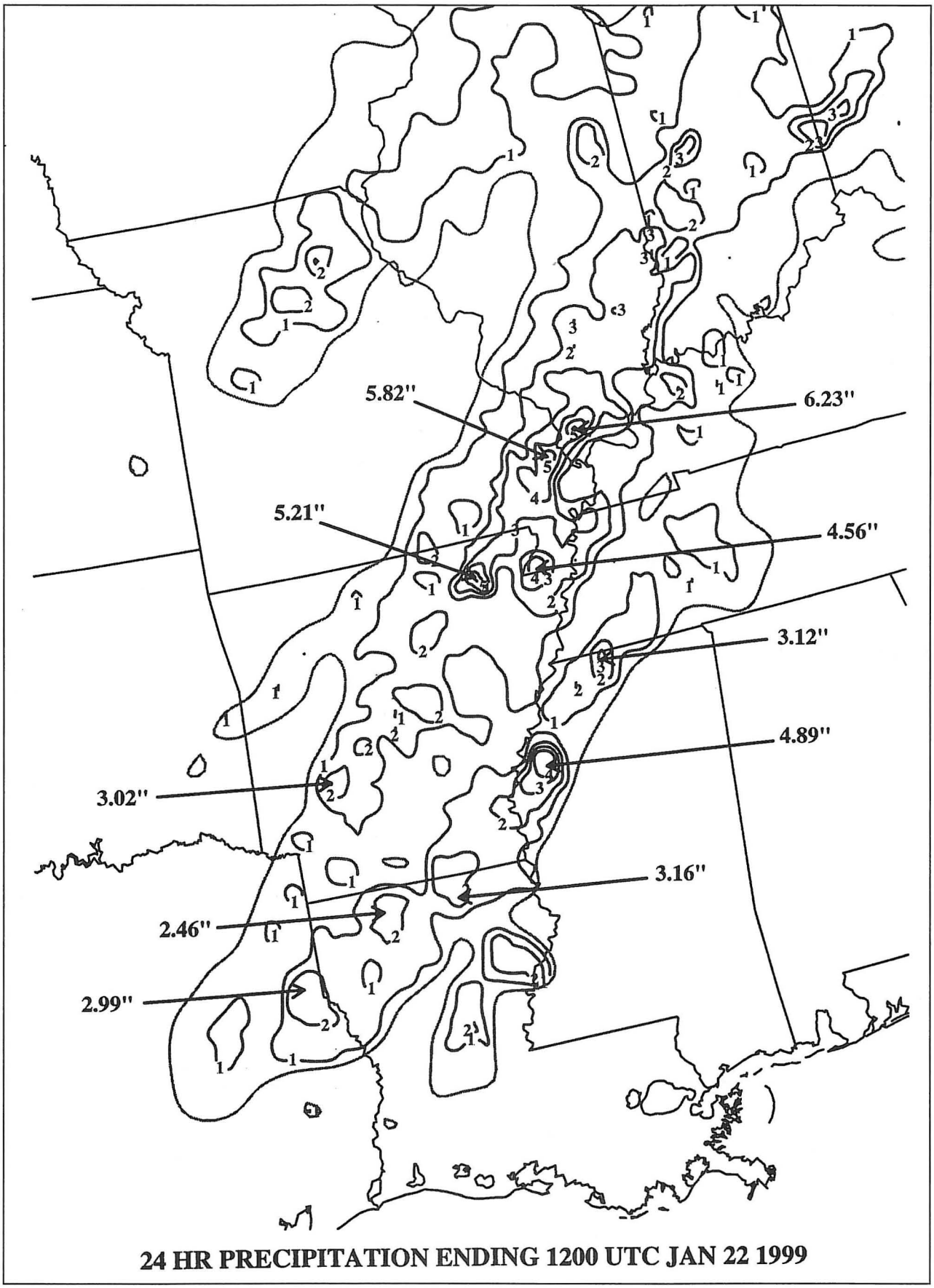

Fig. 12. Analysis of 24-h observed precipitation for period ending 1200 UTC 22 January 1999.

National Flood Summary

Hydrologic Information Center

9:25 a.m., EST, Friday, January 22, 1999

Flood Summary

Stormy Weather in the Midwest and Southeast

Severe weather covered a broad area from northeastern Texas, northeastward to western Pennsylvania. Multiple tornadoes touched down in Arkansas and parts of Mississippi. Preliminary indications are there were six deaths in Arkansas with dozens injured. In addition, widespread flooding materialized over Arkansas, Missouri, Illinois, Indiana, Ohio and West Virginia, as well as in Louisiana and Mississippi late yesterday. Isolated evacuations were necessary in the Reedy, West Virginia area as well as Darke and Preble Counties, Ohio. In the northern areas, rain combined with snowmelt and frozen ground to bring lowland flooding. Runoff has resulted in numerous rivers rising above flood stage. Some residual flooding continues in western Washington and Oregon.

Currently, Flood Watches are in effect for Louisiana, Mississippi, Missouri, Iowa, Illinois, Indiana, Ohio and Michigan. As the storm system responsible for this severe weather and flooding moves east, it will bring significant rain to the eastern U.S. through the weekend

FLASH FLOODING:

Flood/Flash Flood Warnings and/or Urban and Small Stream Flood Advisories were issued over the past 24 hours for the following locations *(in alphabetical order, by state)*:

- Arkansas: Clark, Clay, Cleburne, Craighead, Cross, Dunklin, Faulkner, Garland, Greene, Hot Spring, Independence, Lawrence, Lonoke, Pemiscot, Poinsett, Pulaski, Randolph, Saline, St. Francis and White Counties
- Illinois: Alexander, Champaign, Clay, Fayette, Franklin, Hamilton, Jackson, Jefferson, Lee, Marion, Ogle, Piatt, Union, Washington, Wayne, Williamson and Winnebago Counties
- Indiana: Rush, Vanderburgh and Wayne Counties
- Missouri: Alexander, Bollinger, Butler, Cape Girardeau, Chariton, Cooper, Perry, Pettis, Ripley, Saline, Scott, Stoddard and Wayne Counties
- Ohio: Darke, Miami, Monroe, Preble and Shelby Counties
- West Virginia: Barbour, Calhoun, Gilmer, Lewis, Roane, Upshur and Wirt Counties

Fig. 13. Excerpt of NWS National Flood Summary issued 0925 EST (1425 UTC) 22 January 1999.

ing of heavy precipitation. Mr. Kusselson received a B.S. degree in Meteorology from The Pennsylvania State University in 1975.

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