CRH SSD
MAY 1989

CENTRAL REGION TECHNICAL ATTACHMENT 89-15

THE MIDDLESBORO, KENTUCKY TORNADO OF 1988

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1. Introduction

On the morning of May 9, 1988, a strong short wave trough was moving east through the Upper Mississippi Valley. A surface low was centered over Wisconsin at 15Z with a cold front extending south into Arkansas. Abundant low level moisture lay ahead of the front in an unstable air mass. At 00Z May 10, 1988, the cold front was pushing slowly east through central Kentucky. The 00Z sounding at Nashville, Tennessee had a lifted index of -7 indicating the air mass ahead of the cold front was unstable. Also, relatively strong vertical shear existed at Nashville. All of these elements combined to create a favorable severe weather environment.

At approximately 10:20 p.m. on May 9th, a tornado struck Middlesboro, Kentucky. The tornado damaged much of downtown Middlesboro and it resulted in one fatality. Approximately 30 minutes before the Middlesboro tornado, an unconfirmed tornado occurred near Williamsburg, Kentucky, some 25 miles northwest of Middlesboro. No damage was reported with this tornado.

The purpose of this paper is to show how Vertically Integrated Liquid (VIL) can be used as a quick way to identify the stronger thunderstorms within an area or line of thunderstorms.

2. Vertically Integrated Liquid

The RAdar DAta Processor (RADAP II) is a digital radar processing system which preformats information about reflectivity, echo tops, VIL and an experimental Severe Weather Probability (SWP). In particular, VIL has been found to be a very useful product in predicting severe weather and is most suited for predicting hail occurrences. It has less utility in identifying tornadoes and damaging wind events (Devore, 1983; McGovern et al., 1984; and Beasley, 1986). Put very simply, VIL measures the relative magnitude and distribution of liquid water in a cloud using certain assumptions regarding the in-cloud drop-size distribution. VIL is given in kilograms of water per square meter of surface area.

Values of VIL associated with severe weather vary at any given location and from season to season. Several papers have been done relating VIL to severe

weather and some NWS offices use VIL as a severe weather forecasting tool. For example, Davis and Drake (1987) used a VIL of 45 kg-m^{-2} as one basis for issuing severe thunderstorm warnings.

3. The Case Study

This case study was done on the Middlesboro tornado using RADAP II data from WSO Jackson, Kentucky. Four different times were used in this case study. Each time had a .5 reflectivity radar overlay and a corresponding VIL overlay. All of the overlays were prepared using archived RADAP II data. Unfortunately, the vertical structures of these storms was unknown since that data was unavailable. No assumptions can be made about the storm structures using the prepared overlays since the resolution of the RADAP II data is not good enough to make such a detailed analysis.

At 0120Z on May 10, 1988 (see Figs. 1 and 2), several strong cells can be seen in the reflectivity overlay. The cells in Whitley County, Kentucky appear to be the strongest. However, at first glance the cells in Clay and Harlan Counties also appear to be strong. When the VIL overlay is compared to the reflectivity overlay, the strongest cells are immediately revealed. A VIL maximum of 40 kg-m^{-2} corresponds to the cell in northern Whitley County and a VIL maximum of 35 kg-m^{-2} in the southern Whitley County cell. Notice how low the VIL was with the other seemingly strong cells. Ten minutes later, at 0130Z (see Figs. 3 and 4), the overlays further reveal the strong cells in Whitley County. The cells in Whitley County apparently produced a tornado near Williamsburg, Kentucky sometime between 0130Z and 0200Z.

By 0210Z (see Figs. 5 and 6), the .5^{o} reflectivity overlay showed a line of thunderstorms along the Tennessee-Kentucky border. Several strong cells were embedded in the line. Once again the VIL overlay revealed where the strongest cells were. The strongest cell was located in Bell County, Kentucky with a VIL of 40 kg-m^{-2} and another strong cell was in Harlan County, Kentucky.

Finally, the 0220Z (see Figs. 7 and 8) reflectivity overlay continued to show a line of thunderstorms with several VIP 5 cores. The VIL overlay showed a single strong cell over southern Bell County. This cell produced the tornado which moved through Middlesboro.

4. Conclusions

This case study showed how VIL can possibly point out the stronger thunderstorms within an area or line of thunderstorms. The VIL values presented here are not very high in comparison to other severe events but the maximum VIL values presented here did point out where the severe weather did occur.

To the forecaster or the meteorological technician who has VIL available, this case study showed how VIL possibly could be used to locate the stronger thunderstorms. This can be done by looking at a VIL map and comparing it to the .5 reflectivity map. Then he or she could concentrate on the stronger cells which are more likely to become severe.

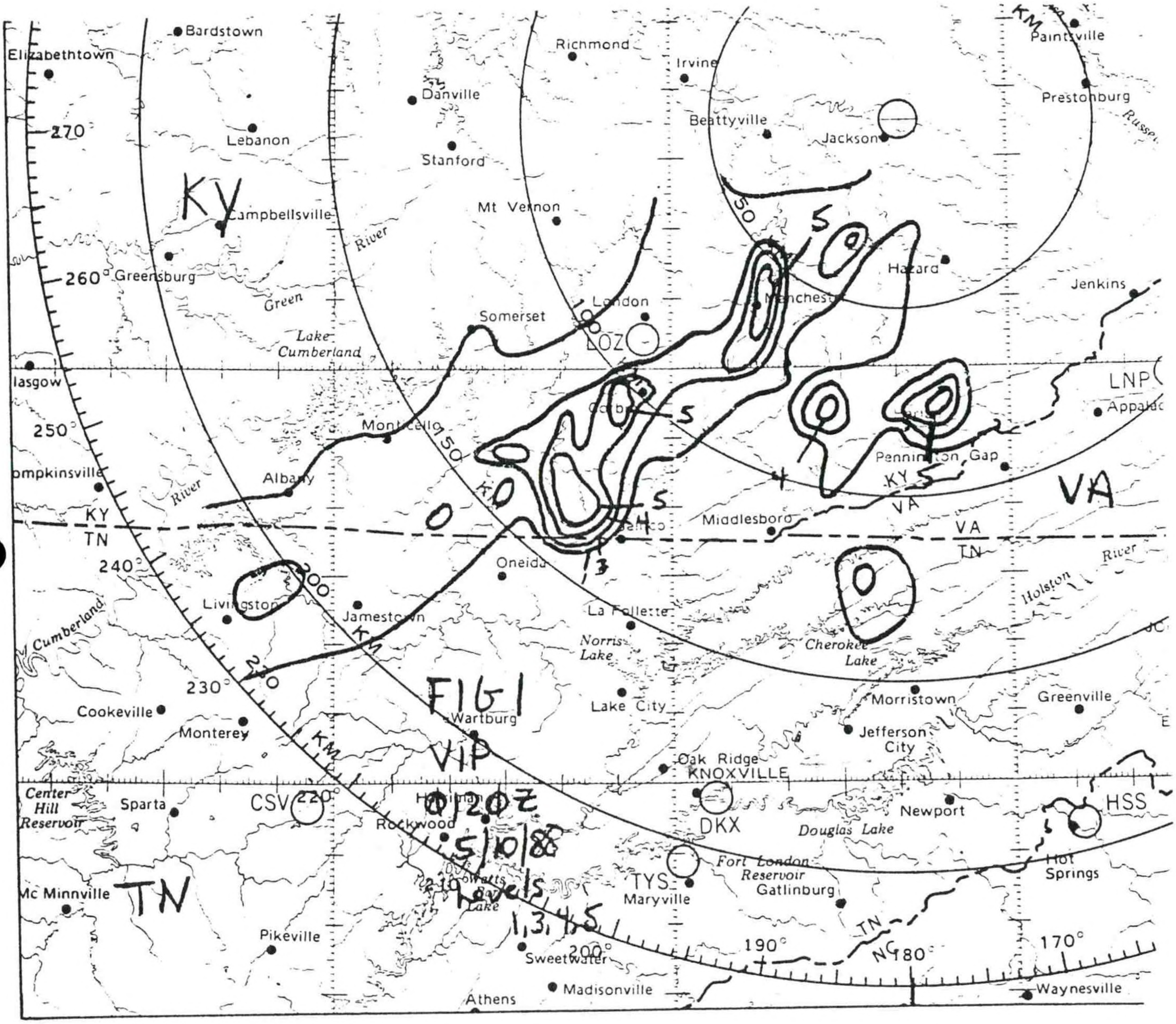
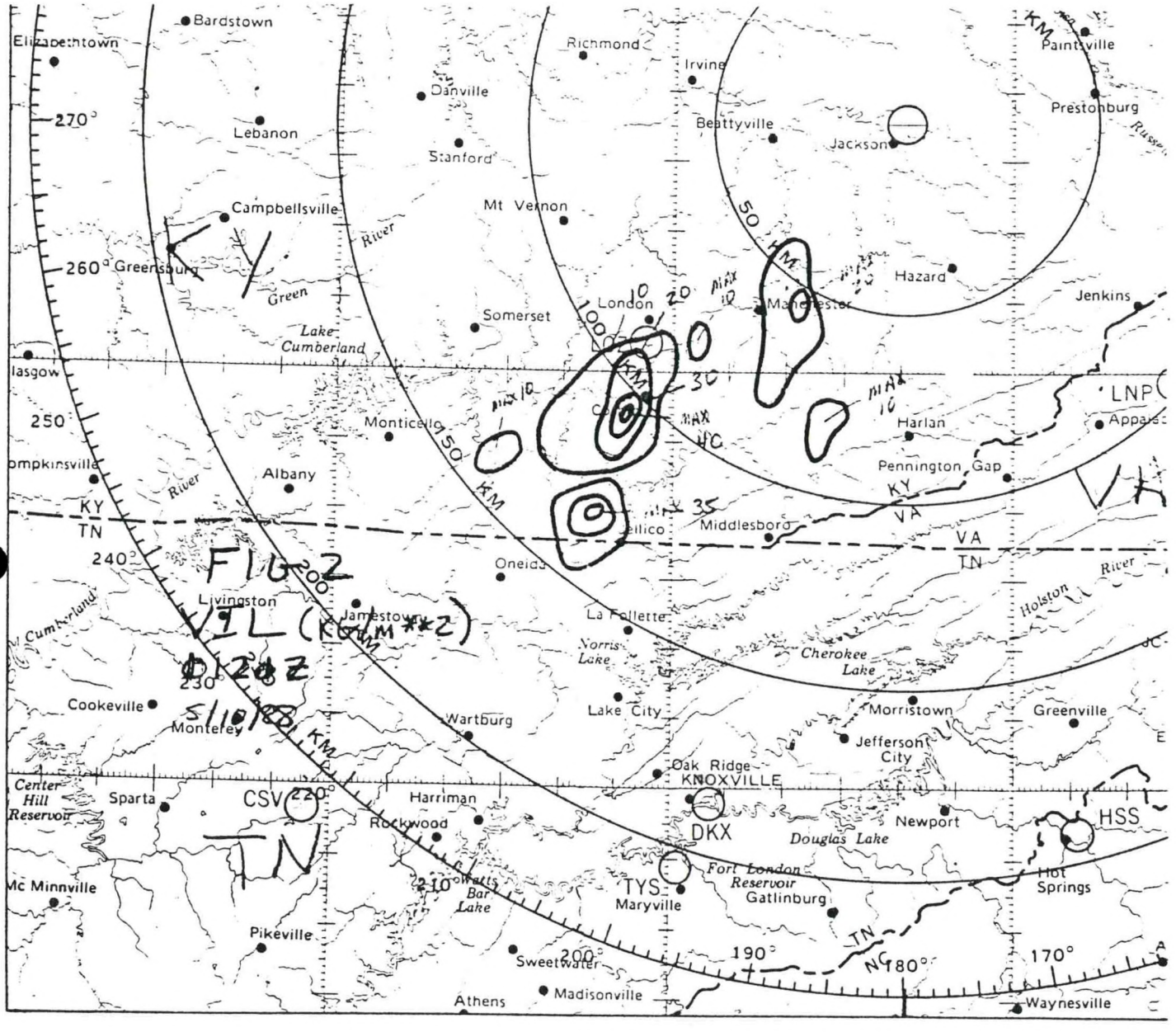


FIG 1
VIP
0120Z
5/10/88
Levels
1,3,4,5
KY
TN
VA
Bardstown
Elizabethtown
Richmond
Irvine
Paintsville
Danville
Prestonburg
Lebanon
Beattyville
Jackson
Stanford
Campbellsville
Mt Vernon
Hazard
Greensburg
Jenkins
London
Somerset
Lake Cumberland
LOZ
LNP
Monticello
Albany
Pennington Gap
Middlesboro
Oneida
La Follette
Livingston
Jamestown
Norris Lake
Cherokee Lake
Cookeville
Monterey
Wartburg
Lake City
Morristown
Greenville
Jefferson City
Oak Ridge
KNOXVILLE
Center Hill Reservoir
Sparta
CSV
Rockwood
DKX
Newport
HSS
Douglas Lake
Fort London Reservoir
Hot Springs
TYS
Maryville
Gatlinburg
Mc Minnville
Pikeville
Sweetwater
Madisonville
Athens
Waynesville
Holston River
Cumberland
Green River
270°
260°
250°
240°
230°
220°
210°
200°
190°
180°
170°
50 KM
100
150 KM
200 KM
230 KM


Bardstown
Elizabethtown
Richmond
Irvine
Paintsville
Danville
Prestonburg
270°
Lebanon
Beattyville
Jackson
Stanford
Campbellsville
Mt Vernon
50 KM
260°
Greensburg
Green River
Hazard
Jenkins
London
Somerset
Manchester
Lake Cumberland
LNP
250°
Monticello
Harlan
Albany
Pennington Gap
KY
TN
VA
240°
Middlesboro
Oneida
Livingston
Jamestown
La Follette
Cumberland River
Norris Lake
Cherokee Lake
Holston River
Cookeville
Monterey
Wartburg
Lake City
Morristown
Greenville
Jefferson City
Oak Ridge
KNOXVILLE
Center Hill Reservoir
Sparta
CSV
220°
Harriman
Rockwood
DKX
Newport
Douglas Lake
HSS
Mc Minnville
Watts Bar Lake
TYS
Maryville
Fort London Reservoir
Gatlinburg
Hot Springs
210°
Pikeville
Sweetwater
200
190°
180°
170°
Athens
Madisonville
Waynesville
FIG 2
VIL (KGM**2)
5/10/88

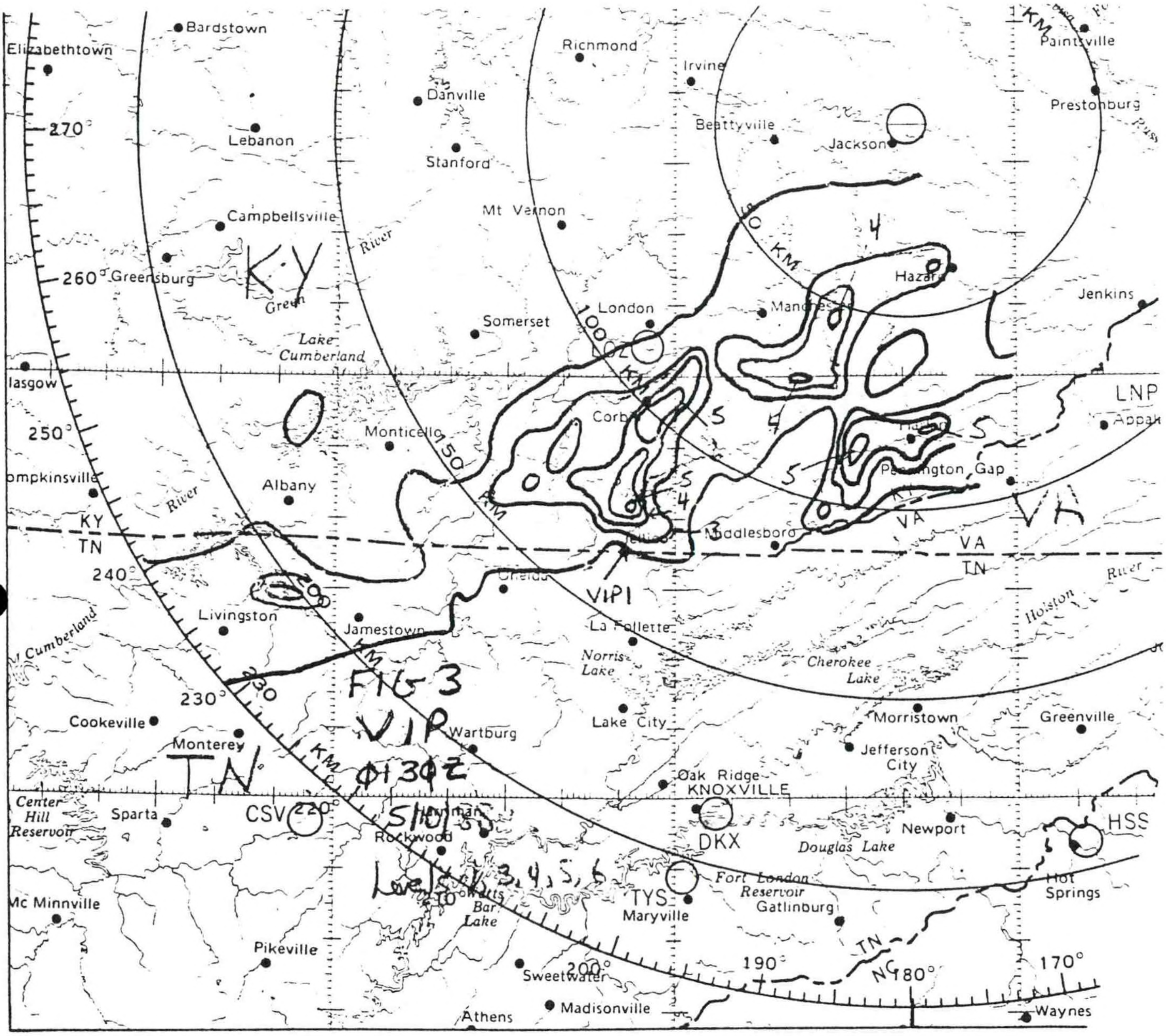


FIG 3
VIP
Φ130Z
5/10/88
Levels 3, 4, 5, 6
KY
TN
VA
VIP1
Bardstown
Elizabethtown
Richmond
Irvine
Paintsville
Danville
Prestonburg
Lebanon
Beattyville
Jackson
Stanford
Mt Vernon
Campbellsville
Greensburg
Hazard
Jenkins
London
Manchester
Somerset
Lake Cumberland
Monticello
Corbin
Albany
Pennington Gap
Middlesboro
Livingston
Jamestown
La Follette
Norris Lake
Cherokee Lake
Cookeville
Monterey
Wartburg
Lake City
Morristown
Greenville
Jefferson City
Oak Ridge
KNOXVILLE
Center Hill Reservoir
Sparta
CSV
Rockwood
DKX
Douglas Lake
Newport
HSS
Hot Springs
TYS
Fort London Reservoir
Maryville
Gatlinburg
Mc Minnville
Pikeville
Sweetwater
Madisonville
Athens
Waynes
LNP
100 KM
150 KM
230 KM
270°
260°
250°
240°
230°
220°
200°
190°
180°
170°

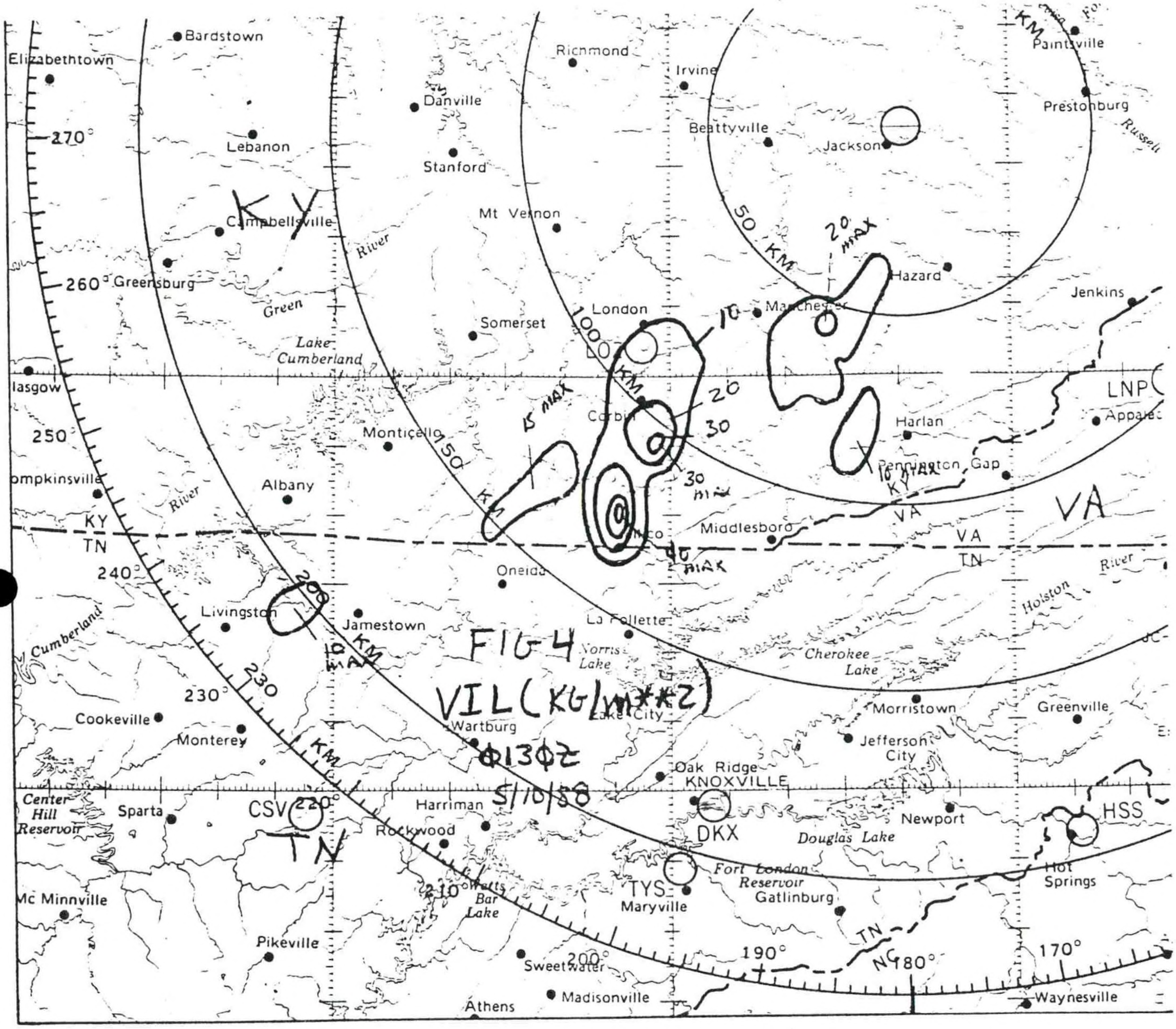
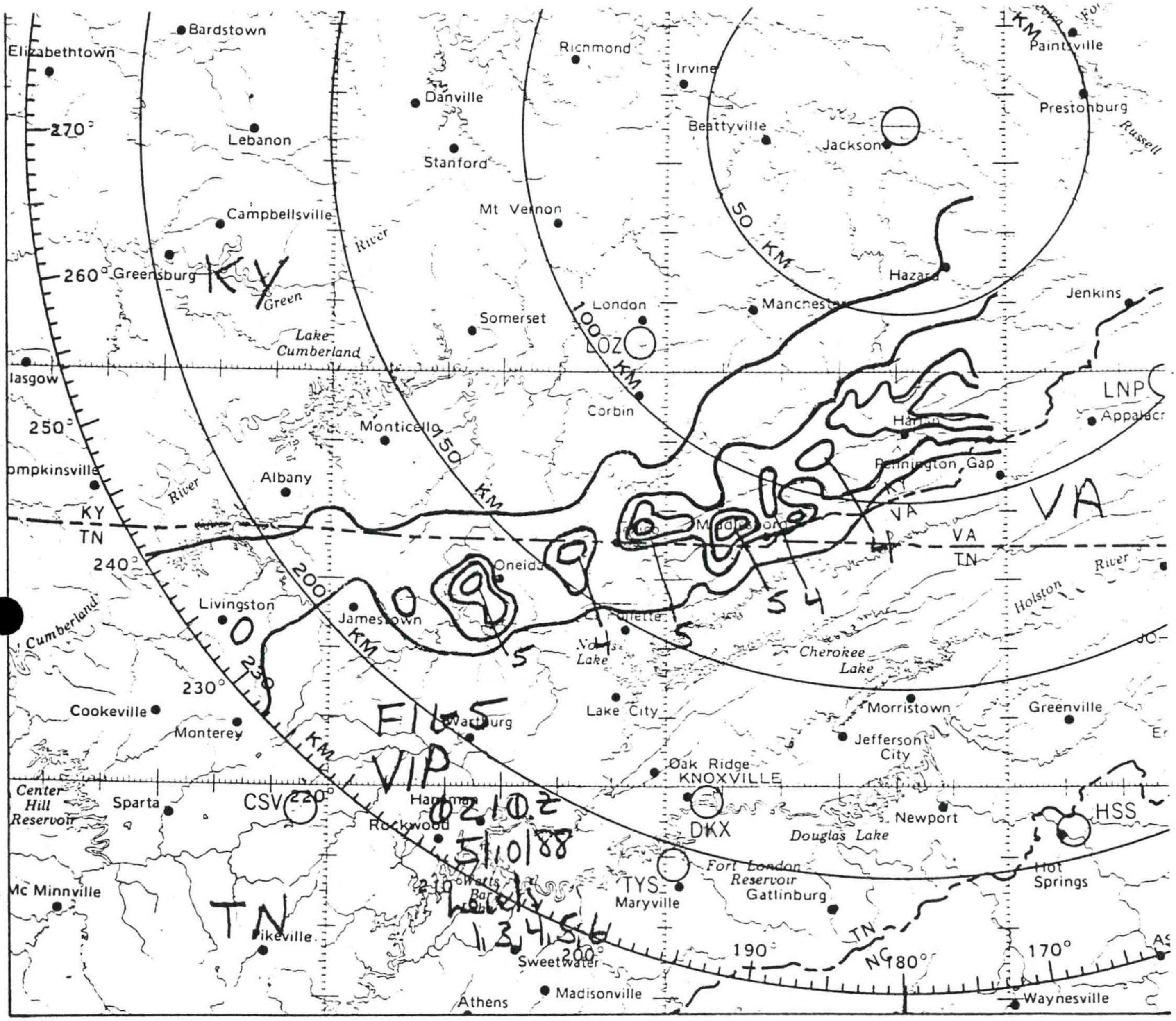
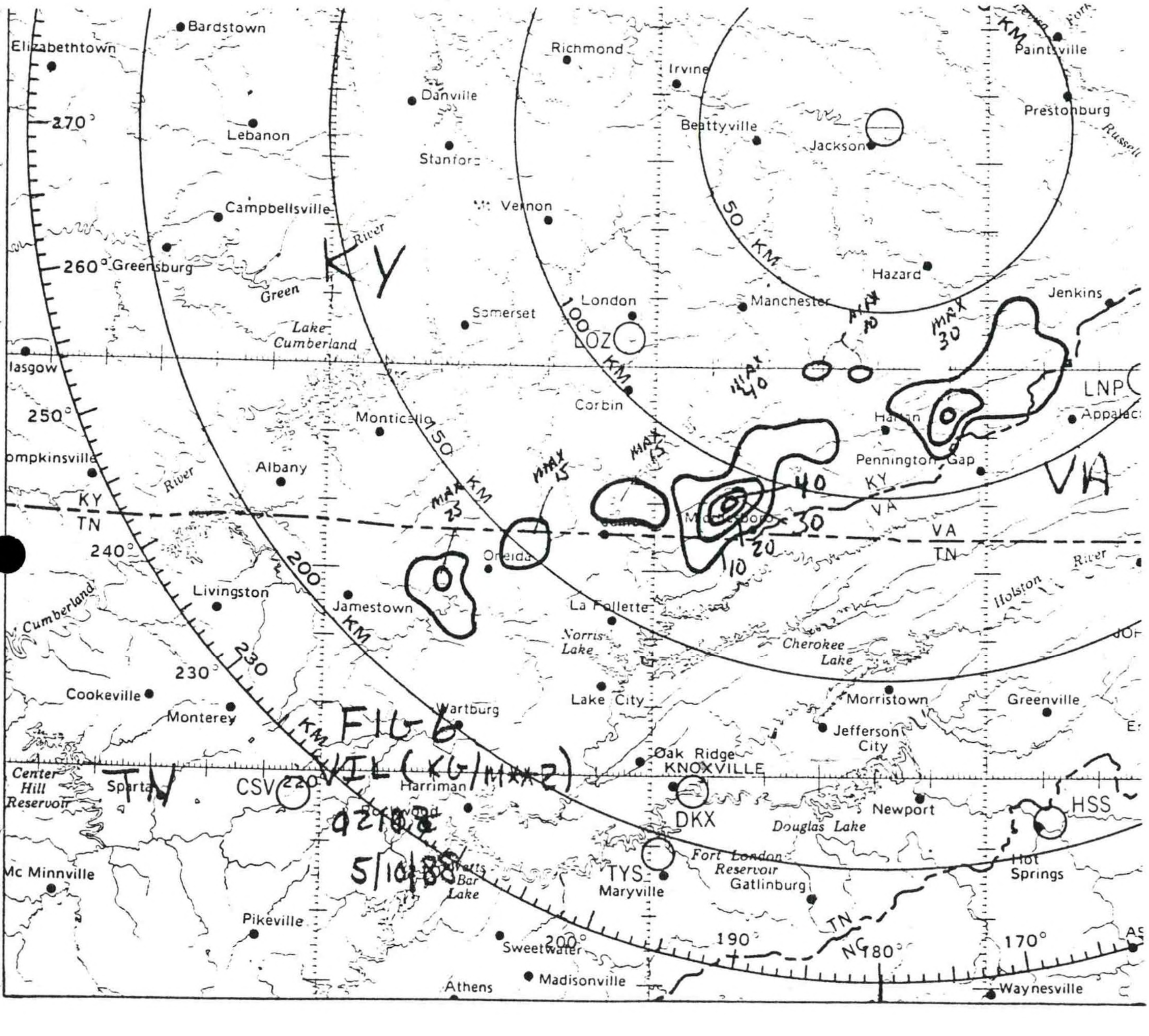
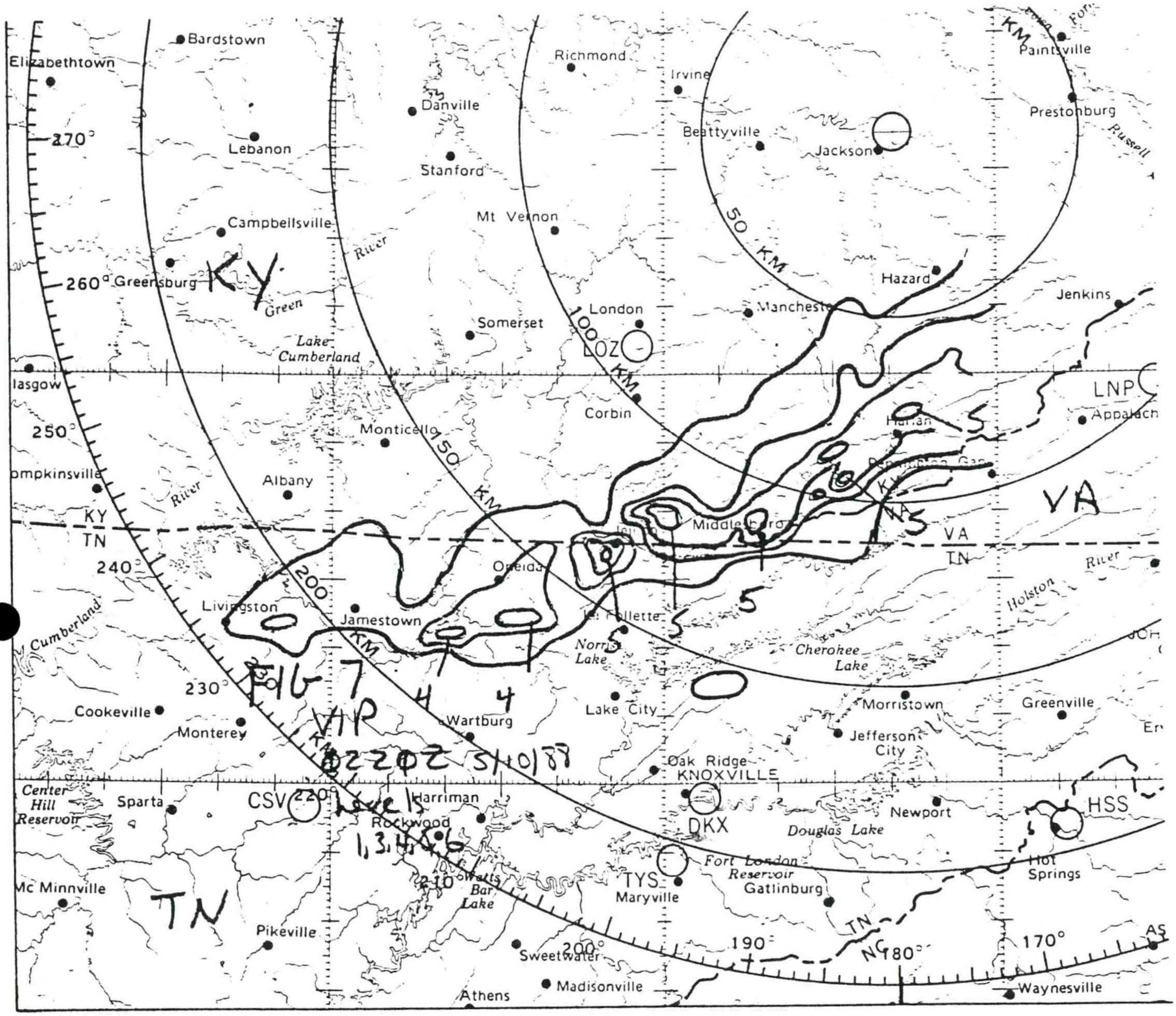


FIG 4
VIL (KG/M**2)
Ø13ØZ
5/10/88
KY
TN
VA
Bardstown
Elizabethtown
Richmond
Irvine
Danville
Paintsville
Prestonburg
Russell
Beattyville
Jackson
Lebanon
Stanford
Mt Vernon
Campbellsville
Greensburg
Green
River
Hazard
Jenkins
London
Manchester
Somerset
Lake Cumberland
Glasgow
LNP
Appalac
Corbin
Harlan
Monticello
Pennington Gap
Tompkinsville
Albany
Middlesboro
Oneida
Livingston
Jamestown
La Follette
Holston
Cherokee Lake
Norris Lake
Cumberland
Cookeville
Monterey
Lake City
Wartburg
Morristown
Greenville
Jefferson City
Oak Ridge
KNOXVILLE
Center Hill Reservoir
Sparta
CSV
Harriman
Rockwood
DKX
Douglas Lake
Newport
HSS
Hot Springs
Watts Bar Lake
TYS
Maryville
Fort Loudon Reservoir
Gatlinburg
Mc Minnville
Pikeville
Sweetwater
Madisonville
Athens
Waynesville
NC
270°
260°
250°
240°
230°
220°
210°
200°
190°
180°
170°
50 KM
100 KM
150 KM
200 KM
230 KM
10
20
30
10 MAX
15 MAX
20 MAX
30 MAX
40 MAX


Bardstown
Elizabethtown
Richmond
Irvine
Paintsville
Danville
Prestonburg
Lebanon
Stanford
Beattyville
Jackson
Campbellsville
Mt Vernon
Greensburg
KY
Hazard
Jenkins
London
Somerset
Manchester
Lake Cumberland
LOZ
Glasgow
LNP
Corbin
Harlan
Monticello
Pennington Gap
Tompkinsville
Albany
VA
KY
TN
Oneida
Livingston
Jamestown
La Follette
Cherokee Lake
Lake City
Morristown
Greenville
Cookeville
Monterey
Wartburg
Jefferson City
Oak Ridge
KNOXVILLE
Center Hill Reservoir
Sparta
CSV
Harriman
Rockwood
DKX
Newport
HSS
Douglas Lake
Fort Loudon Reservoir
TYS
Maryville
Gatlinburg
Hot Springs
Mc Minnville
TN
Pikeville
Sweetwater
Madisonville
Athens
Waynesville
NC
50 KM
100 KM
150 KM
200 KM
230 KM
FIG 5
VIP
0210Z
5/10/88
Levels
1,3,4,5,6


Bardstown
Elizabethtown
Richmond
Irvine
Paintsville
Danville
Prestonburg
270°
Lebanon
Beattyville
Jackson
Stanford
Mt Vernon
Campbellsville
50 KM
KY
260°
Greensburg
Hazard
Green River
London
Manchester
Jenkins
Somerset
Lake Cumberland
100 KM
LOZ
MAX 10
MAX 30
MAX 40
Glasgow
Corbin
LNP
250°
Monticello
150 KM
Harlan
Tompkinsville
Albany
Pennington Gap
MAX 15
VA
MAX 25
40
KY
VA
KY
TN
30
240°
Oneida
20
VA
TN
10
Livingston
Jamestown
La Follette
Holston River
Cumberland
200 KM
Norris Lake
Cherokee Lake
230
230°
Cookeville
Wartburg
Lake City
Morristown
Greenville
Monterey
FIG 6
VIL (KG/M**2)
Oak Ridge
KNOXVILLE
Jefferson City
Center Hill Reservoir
Sparta
TN
CSV
220°
Harriman
HSS
0210Z
DKX
Newport
Douglas Lake
5/10/88
Fort London Reservoir
Hot Springs
Mc Minnville
TYS
Maryville
Gatlinburg
Pikeville
200°
190°
TN
NC
180°
170°
Sweetwater
Madisonville
Athens
Waynesville


Bardstown
Elizabethtown
Richmond
Irvine
Paintsville
Danville
Prestonburg
Lebanon
Beattyville
Jackson
Stanford
Mt Vernon
Campbellsville
50 KM
Greensburg
KY
Hazard
Jenkins
London
Manchester
Somerset
100 KM
LOZ
Lake Cumberland
LNP
Corbin
Monticello
150 KM
Albany
VA
KY
TN
Oneida
Middlesboro
200 KM
Livingston
Jamestown
Norris Lake
Cherokee Lake
Holston
FIG 7
VIP
2220Z 5/10/88
Cookeville
Monterey
Wartburg
Lake City
Morristown
Greenville
Jefferson City
Oak Ridge
KNOXVILLE
Center Hill Reservoir
Sparta
CSV
Harriman
Rockwood
Newport
HSS
DKX
Douglas Lake
Levels 1,3,4,5,6
Fort Loudon Reservoir
Hot Springs
Mc Minnville
TYS
Maryville
Gatlinburg
Watts Bar Lake
TN
Pikeville
Sweetwater
NC
Madisonville
Athens
Waynesville
270°
260°
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210°
200°
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180°
170°

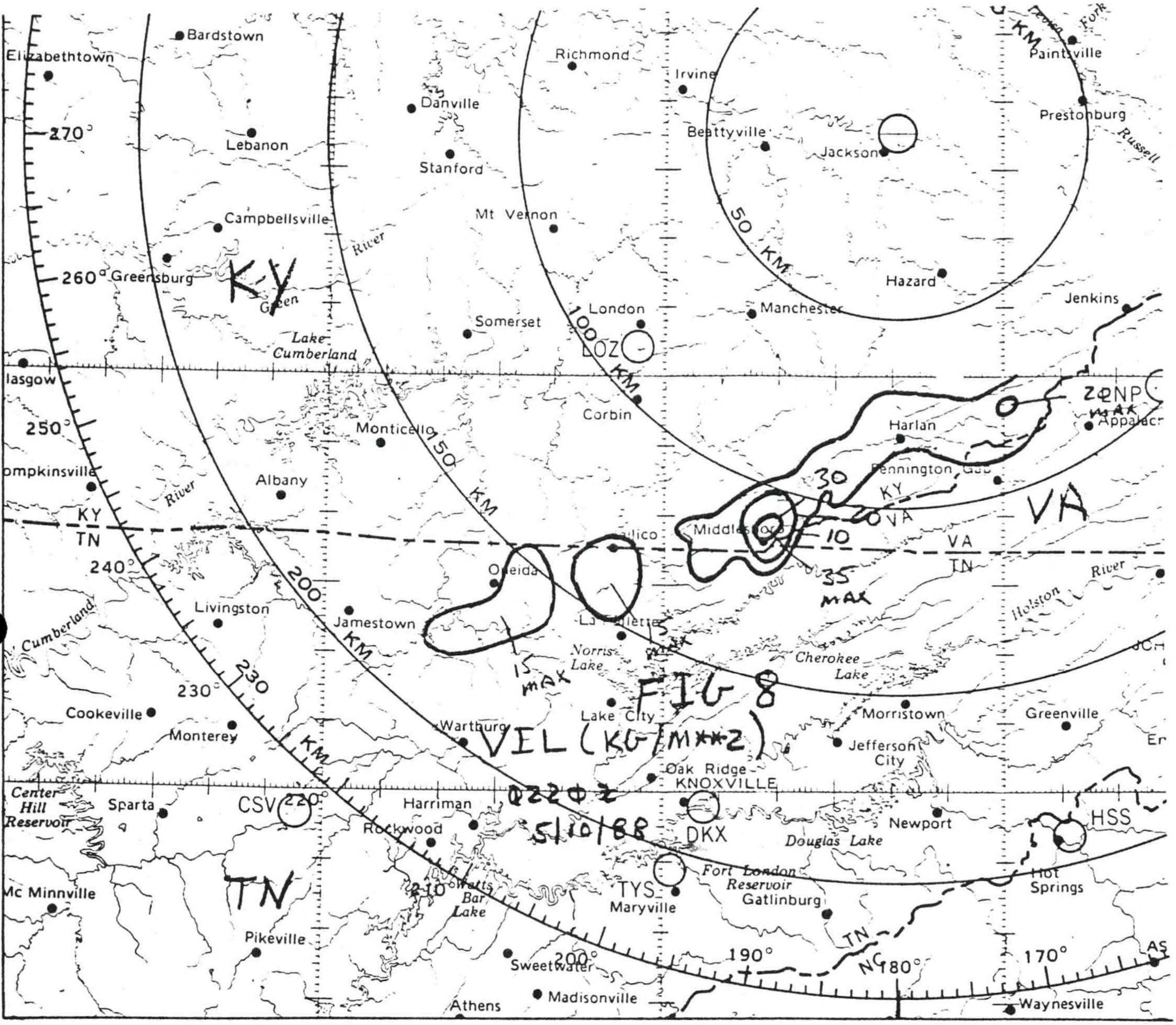
FIG 8
VEL (KG/M**2)
Ø22Ø Z
5/10/88
KY
TN
VA
Bardstown
Elizabethtown
Richmond
Irvine
Danville
Lebanon
Stanford
Beattyville
Jackson
Paintsville
Prestonburg
Campbellsville
Mt Vernon
Greensburg
Somerset
London
Manchester
Hazard
Jenkins
Lake Cumberland
Monticello
Corbin
Harlan
Albany
Pennington Gap
Middlesboro
Oneida
Jamestown
Livingston
Cookeville
Monterey
Wartburg
Lake City
Norris Lake
Cherokee Lake
Morristown
Greenville
Jefferson City
Oak Ridge
KNOXVILLE
Harriman
Rockwood
Sparta
Center Hill Reservoir
Newport
Douglas Lake
Hot Springs
Mc Minnville
Pikeville
Maryville
Gatlinburg
Fort London Reservoir
Watts Bar Lake
Sweetwater
Madisonville
Athens
Waynesville
LOZ
CSV
DKX
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HSS
50 KM
100 KM
150 KM
200 KM
230 KM
270°
260°
250°
240°
230°
220°
210°
200°
190°
180°
170°
15 MAX
20 MAX
30
10
35 MAX
Cumberland
Holston River
Green River

5. References

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