TURBULENCE ACCIDENT RECONSTRUCTION

Michael L. Kaplan, Yuh-Lang Lin, Allen J. Riordan,

Allan W. Huffman and Kevin M. Lux

Department of Marine, Earth, and Atmospheric Sciences North Carolina State University

Raleigh, North Carolina

1st Aviation Safety Program (AvSP) Weather Accident Prevention (WxAP)

Annual Project Review

Hampton, Virginia

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PRESENTATION OVERVIEW

- MESO-ALPHA SCALE 44 CASE STUDY DIAGNOSTIC ANALYSES
- METHODOLOGY
- MAIN RESULTS AND CONCLUSIONS
- MASS SIMULATIONS OF THE MESO-BETA SCALE STRUCTURE OF THE CAPE GIRARDEAU (NON-CONVECTIVE) FDR CASE STUDY
- BASIC MODEL EXPERIMENT
- KEY FEATURES OF THE SIMULATION
- VERTICAL SOUNDING STRUCTURE AT THE ACCIDENT LOCATION
- TASS MESO-GAMMA SCALE SIMULATIONS OF CAPE GIRARDEAU
- BASIC MODEL EXPERIMENT
- WAVE DYNAMICS AT THE MESO-GAMMA SCALE
- IMPLICATIONS FOR TURBULENCE
- SUMMARY AND CONCLUSIONS
- FUTURE WORK

NTSBNUMBER	DATE	LOCATION	TIME	HT(MSL)	TYPE	(#)
BFO90LA043	5/11/90	WASHINGTON, DC	1700Z	2800M	CAT	1
MIA90LA152	7/14/90	MIAMI, FLA	1949Z	4100M	TRW	2
MIA90LA155	7/18/90	FORT MYERS, FLA	2048Z	10100M	CAT	3
FTW90LA156	8/9/90	CORPUS CHRISTIE, TX	1315Z	11000M	CAT	4
CHI91LA115	3/23/91	BUFFALO, NY	2315Z	10300M	CAT	5
ATL91LA091	5/4/91	TULSA, OK	2240Z	14300M	TRW	6
SEA91LA126	6/5/91	ELKO, NEVADA	0100Z	CRUISE	CAT	7
BFO91LA055	6/16/91	PHILADELPHIA, PA	1900Z	6700M	TRW	8
NYO91LA164	7/1/91	NEWARK, NJ	0047Z	11700M	TRW	9
ATL91LA123	7/4/91	ALMA, GA	1607Z	12300M	TRW	10
FTW92LA001	10/5/91	LITTLEROCK, AR	0730Z	11700M	TRW	11
FTW92LA142	5/14/92	PALACIOS, TX	0150Z	4300M	CLD	12
CHI92LA206	7/2/92	JANESVILLE, WI	0550Z	8700M	TRW	13
FTW92LA200	8/3/92	SPRINGFIELD, MO	1915Z	6500M	TRW	14
BFO93LA048	3/5/93	PHILADELPHIA, PA	2140Z	FINALA	CLD	15
MIA93LA090	3/23/93	JACKSONVILLE, FLA	2352Z	770M	TRW	16
DCA93MA033	3/31/93	ANCHORAGE, AK	2034Z	670M	MTN	17
CHI93LA192	6/4/93	CHICAGO, IL	2340Z	CLIMB	CAT	18
CHI93LA224	6/24/93	BARABOO, WI	1729Z	9700M	CLD	19
MIA93LA151	7/16/93	CARRIBEAN SEA (N OF VENEZUELA)	0815Z	11700M	CLD	20
ATL93LA159	9/15/93	ATLANTA, GA	0145Z	4500M	TRW	21
MIA94LA010	10/22/93	ATLANTIC OCEAN (450NM SE OF MIAM	0730Z	11700M	CAT	22
LAX94LA141	2/12/94	PACIFIC OCEAN (10SLAT 157ELON)	1345Z	11700M	TRW	23
NYC94LA111	6/29/94	EAST HAMPTON, NY	1745Z	8000M	TRW	24
MIA94LA173	7/5/94	VALDOSTA, GA	1210Z	6000M	CAT	25
FTW94LA229	7/7/94	SOUTH BEND,IN	2159Z	6700M	CLD	26
MIA94LA214	9/19/94	WEST PALM, FL	2239Z	DESCENT	CLD	27
MIA95LA055	1/6/95	MONROE, LA	1520Z	3062M	CAT	28
ATL95LA062	3/16/95	ALMA, GEORGIA	1935Z	12300M	CAT	29
FTW95LA176	4/19/95	UTOPIA, TX	0314Z	8300M	CAT	30
CHI95LA188	6/20/95	CHAMPAGNE, IL	2310Z	13000M	TRW	31
CHI95LA271	8/4/95	GRAND RAPIDS, MI	0248Z	9000M	TRW	32
LAX96LA013	10/17/95	PACIFIC OCEAN (40NLAT 152ELON)	0944Z	11000M	CAT	33
MIA96LA019	11/7/95	PENSACOLA, FLA	2056Z	6000M	CAT	34
SEA96LA026	11/25/95	PORTLAND, OR	2323Z	6700M	CAT	35
LAX96LA090	12/30/95	HONOLULU, HI	1943Z	2300M	TRW	36
MIA96FA064	1/17/96	CAT ISLAND, BA	1938Z	11700M	TRW	37
FTW96LA107	1/28/96	BERNAL, NM (AGL)	2200Z	333M	MTN	38
FTW96LA157	3/23/96	TAOS, NM	1620Z	11000M	CAT	39
IAD96LA058	4/7/96	SW OF BERMUDA (300NM SW)	0000Z	10300M	CAT	40
FTW96LA271	6/22/96	GRANITE, CO	2145Z	8000M	CAT	41
MIA96LA220	8/29/96	CHATTANOOGA, TN	1953Z	11700M	CAT	42
LAX97LA051	11/19/96	BISHOP, CA	0150Z	9700M	CAT	43
FTW97LA070	12/20/96	DENVER, CO	0050Z	4700M	MTN	44

44 Case Study Turbulence Categories

CAT	19	-3	16*
TRW	16	-2*	-0*
CLD	6	-2*	4*
MTN	3	-0*	3*
TRW*	0		13*

44 Case Study Location Distribution

WARM OCEAN	7
NORTHWEST	5
SOUTHWEST	3
NORTH CENTRAL	6
SOUTH CENTRAL	7
NORTHEAST	6
SOUTHEAST	10

44 Case Study Monthly Distribution

JANUARY	3
FEBRUARY	1
MARCH	6
APRIL	2
MAY	3
JUNE	7
JULY	8
AUGUST	4
SEPTEMBER	2
OCTOBER	3
NOVEMBER	3
DECEMBER	2

44 Case Study Diurnal Distribution

01-04Z	8
05-08Z	4
09-12Z	2
13-16Z	5
17-20Z	10
21-00Z	15

44 Case Study Altitude Distribution

1-3000M	5
3001-6000M	5
6001-9000M	10
9001-12000M	16
12001-15000M	4
>15000M	0

SPECIFIC METEOROLOGICAL FIELDS USED TO DERIVE PREDICTORS

- TEMPERATURE
- HEIGHT
- TOTAL WINDS
- GEOSTROPHIC WINDS
- AGEOSTROPHIC WINDS
- OMEGA
- ABSOLUTE VORTICITY
- RELATIVE VORTICITY
- VELOCITY DIVERGENCE
- VERTICAL TOTAL WIND SHEAR
- ISENTROPIC POTENTIAL VORTICITY
- EQUIVALENT POTENTIAL VORTICITY
- POTENTIAL TEMPERATURE
- EQUIVALENT POTENTIAL TEMPERATURE
- RICHARDSON NUMBER
- THERMAL WIND
- RELATIVE HUMIDITY
- LAPSE RATE

CROSS SECTIONS FROM THE SURFACE TO 100 MB (~16 KM) CENTERED ON ACCIDENT LOCATION

- JET NORMAL AND TANGENTIAL TOTAL WINDS
- JET NORMAL AND TANGENTIAL POTENTIAL TEMPERATURE
- JET NORMAL AND TANGENTIAL EQUIVALENT POTENTIAL TEMPERATURE
- ORIGINATION-DESTINATION TOTAL WINDS
- ORIGINATION-DESTINATION POTENTIAL TEMPERATURE
- ORIGINATION-DESTINATION EQUIVALENT POTENTIAL TEMPERATURE
- ORIGINATION-DESTINATION ISENTROPIC POTENTIAL VORTICITY
- ORIGINATION-DESTINATION EQUIVALENT POTENTIAL VORTICITY
- ORIGINATION-DESTINATION RICHARDSON NUMBER
- ORIGINATION-DESTINATION RELATIVE VORTICITY
- ORIGINATION-DESTINATION RELATIVE HUMIDITY
- ORIGINATION-DESTINATION TOTAL VERTICAL WIND SHEAR

VERTICAL SOUNDINGS AT THE ACCIDENT LOCATION

- SKEW-T/LOG-P
- RICHARDSON NUMBER
- BRUNT-VAISALA FREQUENCY
- VERTICAL TOTAL WIND SHEAR

ACTUAL PREDICTOR FIELDS (Part 1)

- IMMEDIATE UPSTREAM CURVATURE
- ENTRANCE/EXIT REGION OF THE JET STREAM
- SIGN OF OMEGA
- LAPSE RATE >= MOIST ADIABATIC
- DIRECTION OF THE AGEOSTROPHIC WIND VECTOR
- SIGN OF THE HORIZONTAL TEMPERATURE ADVECTION
- SIGN OF THE HORIZONTAL ADVECTION OF THE TOTAL WIND VELOCITY SHEAR
- VERTICAL VARIATION OF THE BRUNT-VAISALA FREQUENCY > THRESHOLD VALUE
- FLIGHT LEVEL ABSOLUTE VORTICITY <= 10^{-4} s^{-1}
- ABSOLUTE VORTICITY AVERAGED OVER TWO LEVELS <= 10^{-4} s^{-1}
- FLIGHT LEVEL RELATIVE VORTICITY <= 0 s^{-1}
- RELATIVE MAGNITUDE OF ISOBARIC PV TERMS
- VERTICAL TOTAL WIND SHEAR > THRESHOLD VALUE

ACTUAL PREDICTOR FIELDS (Part 2)

- RELATIVE HUMIDITY >= 50%
- SIGN OF HORIZONTAL ADVECTION OF VERTICAL LAPSE RATE
- AGEOSTROPHIC WIND VELOCITY >= THRESHOLD VALUE
- VERTICAL VARIATION OF THE RICHARDSON NUMBER >= THRESHOLD VALUE
- VERTICAL VARIATION OF THE TOTAL WIND VELOCITY SHEAR >= THRESHOLD VALUE
- RICHARDSON NUMBER <= THRESHOLD VALUE
- CONVECTIVE CLOUDS (ALL BASES) ON SATELLITE IMAGERY < 100 KM FROM ACCIDENT LOCATION
- CONVECTIVE CLOUDS (ALL BASES) ON SATELLITE IMAGERY < 30 KM FROM THE ACCIDENT LOCATION
- ELLROD INDEX VALUES (ELLROD AND KNAPP 1992)
- NCSU MODIFICATION OF THE ELLROD INDEX (ELLROD INDEX / IPV)

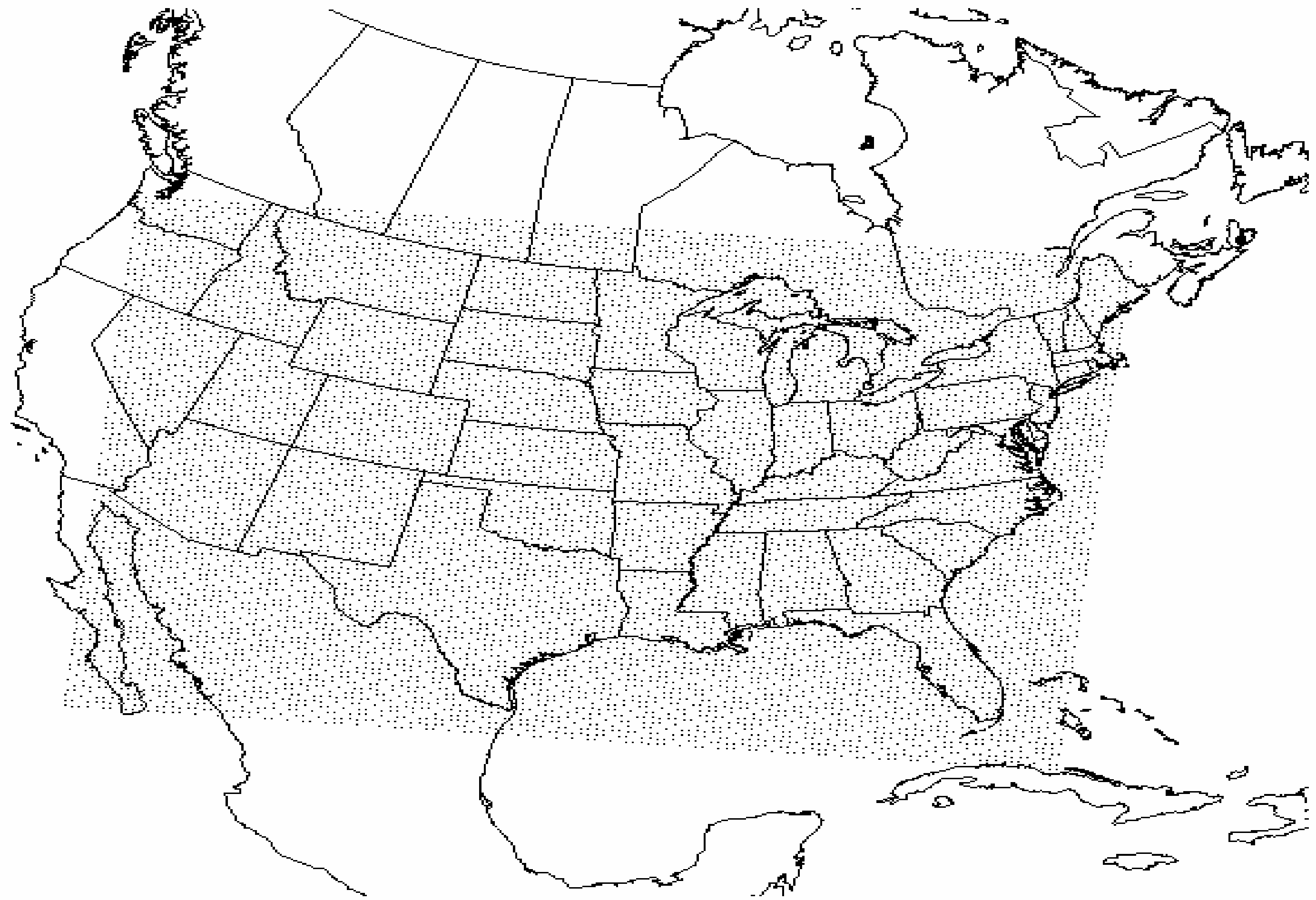
BEST PREDICTORS FOR ALL 44 CASE STUDIES

- IMMEDIATE UPSTREAM CURVATURE (98%)
- CONVECTIVE CLOUDS (ALL BASES) < 100 KM AWAY (86%)
- UPWARD VERTICAL MOTION (82%)
- LAYER AVERAGED ABSOLUTE VORTICITY <= 10^{-4} S^{-1} (80%)
- JET ENTRANCE REGION (77%)
- HIGHER VERTICAL SHEAR ADVECTION (77%)
- LAPSE RATE >= MOIST ADIABATIC (77%)
- ABSOLUTE VORTICITY AT FLIGHT LEVEL <= 10^{-4} S^{-1} (75%)
- CONVECTIVE CLOUDS (ALL BASES) < 30 KM AWAY (74%)
- HORIZONTAL COLD ADVECTION (73%)
- FLIGHT LEVEL RELATIVE VORTICITY <= 0 S^{-1} (68%)
- LEFTWARD-DIRECTED $V_{AGEOSTROPHIC}$ FLOW (64%)

MASS SIMULATIONS OF THE MESO-BETA SCALE STRUCTURE OF THE CAPE GIRARDEAU CASE STUDY - BASIC MODEL EXPERIMENT

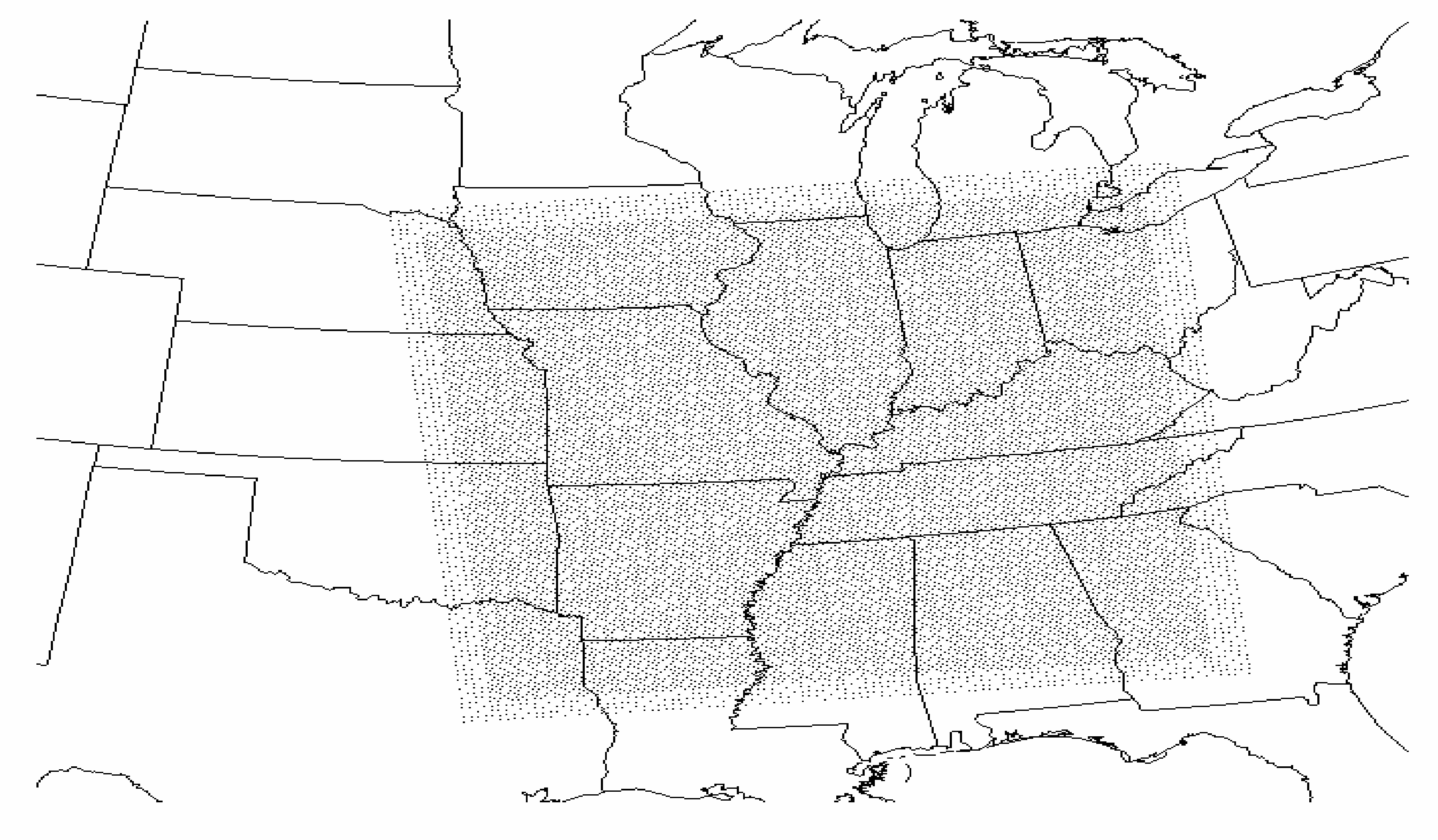
- INITIAL CONDITIONS FROM THE NWS ETA MODEL ANALYSES
- MASS VERSION 5.13
- 30 KM COARSE RESOLUTION 18 HOUR SIMULATION (35 VERTICAL LEVELS)
- 12 KM NESTED-GRID 12 HOUR SIMULATION (45 VERTICAL LEVELS)
- 6 KM NESTED-GRID 8 HOUR SIMULATION (60 VERTICAL LEVELS)

30KM MASS MODEL DOMAIN

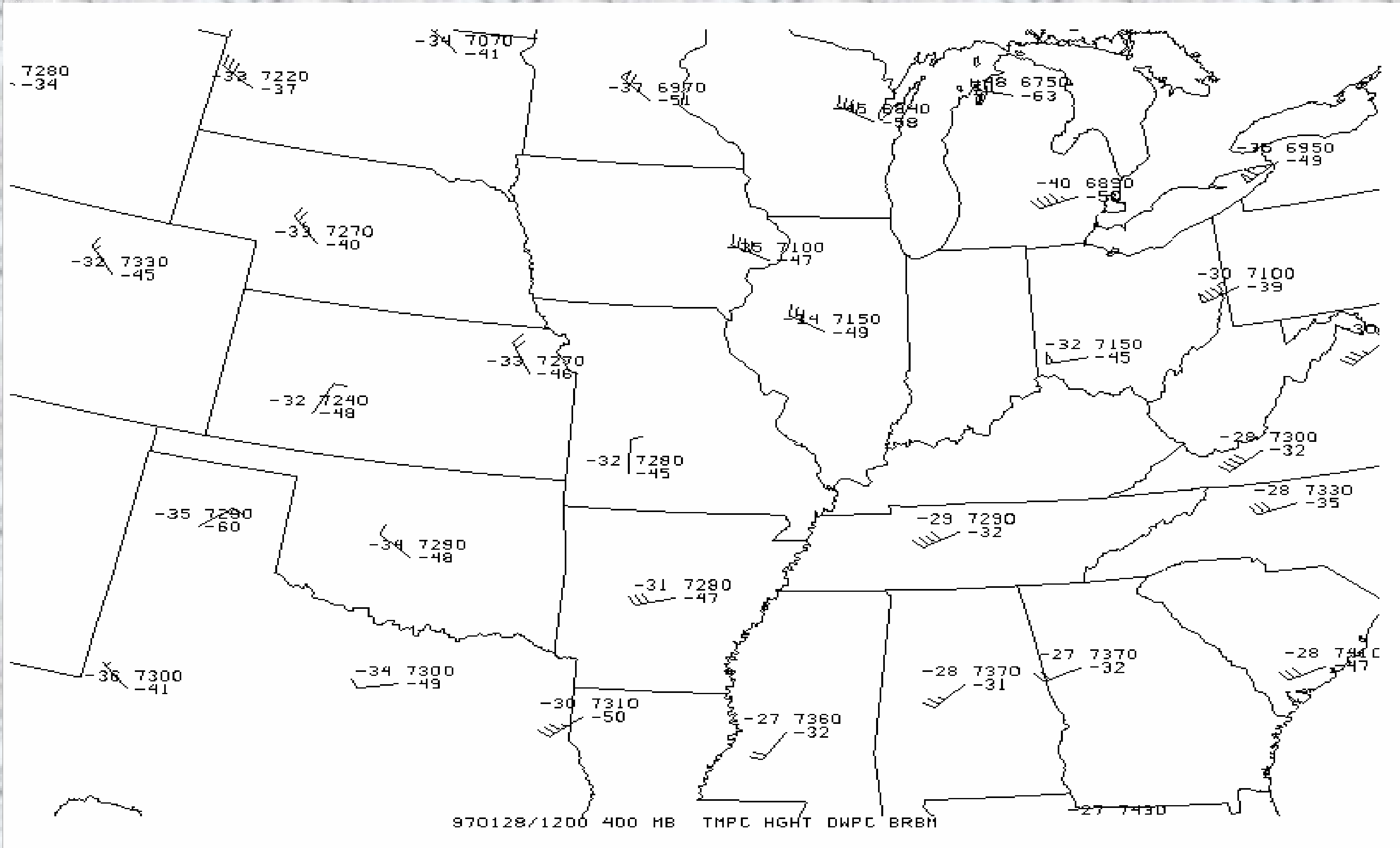


30km Model Domain

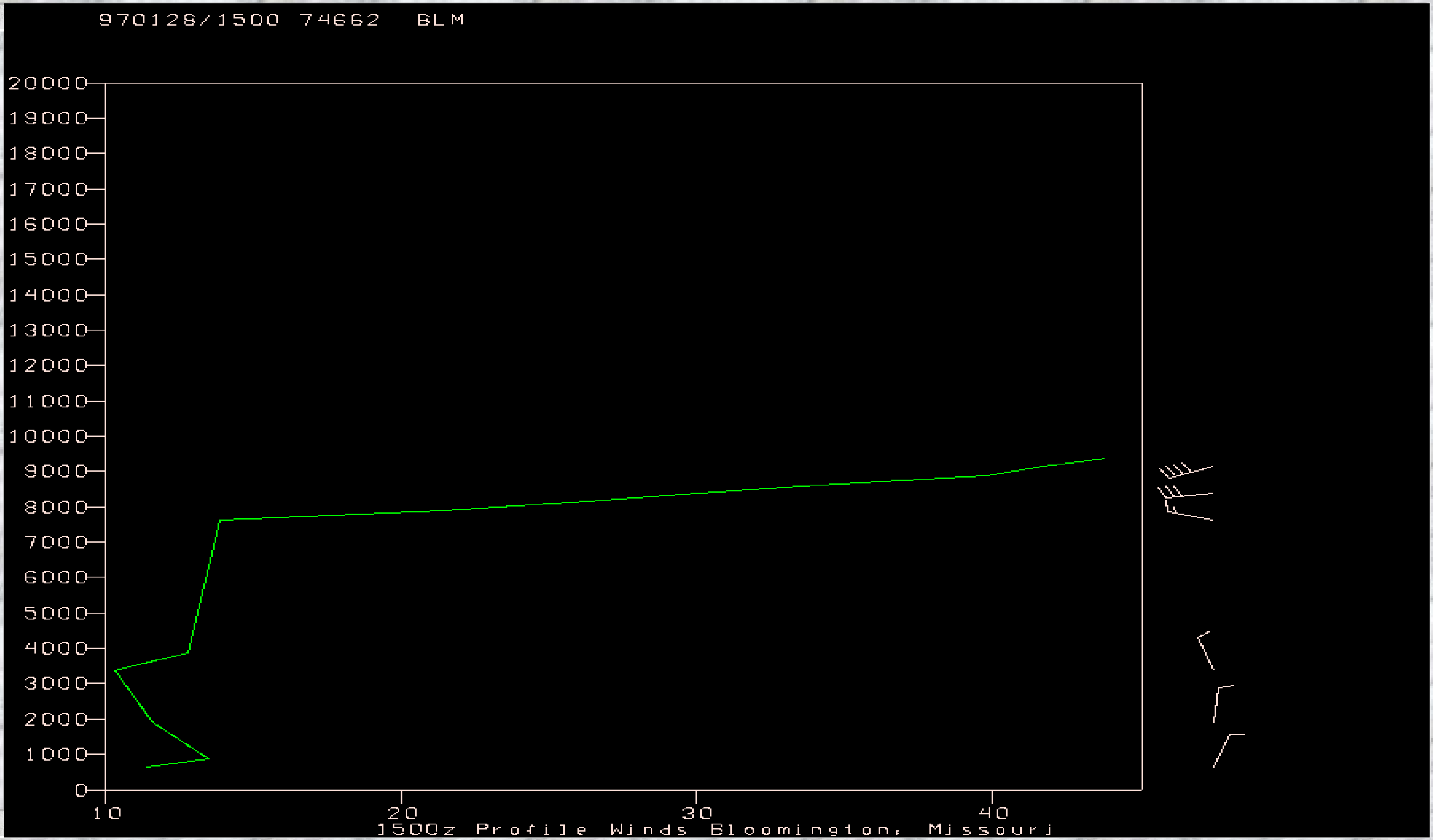
12KM AND 6KM MASS MODEL DOMAINS



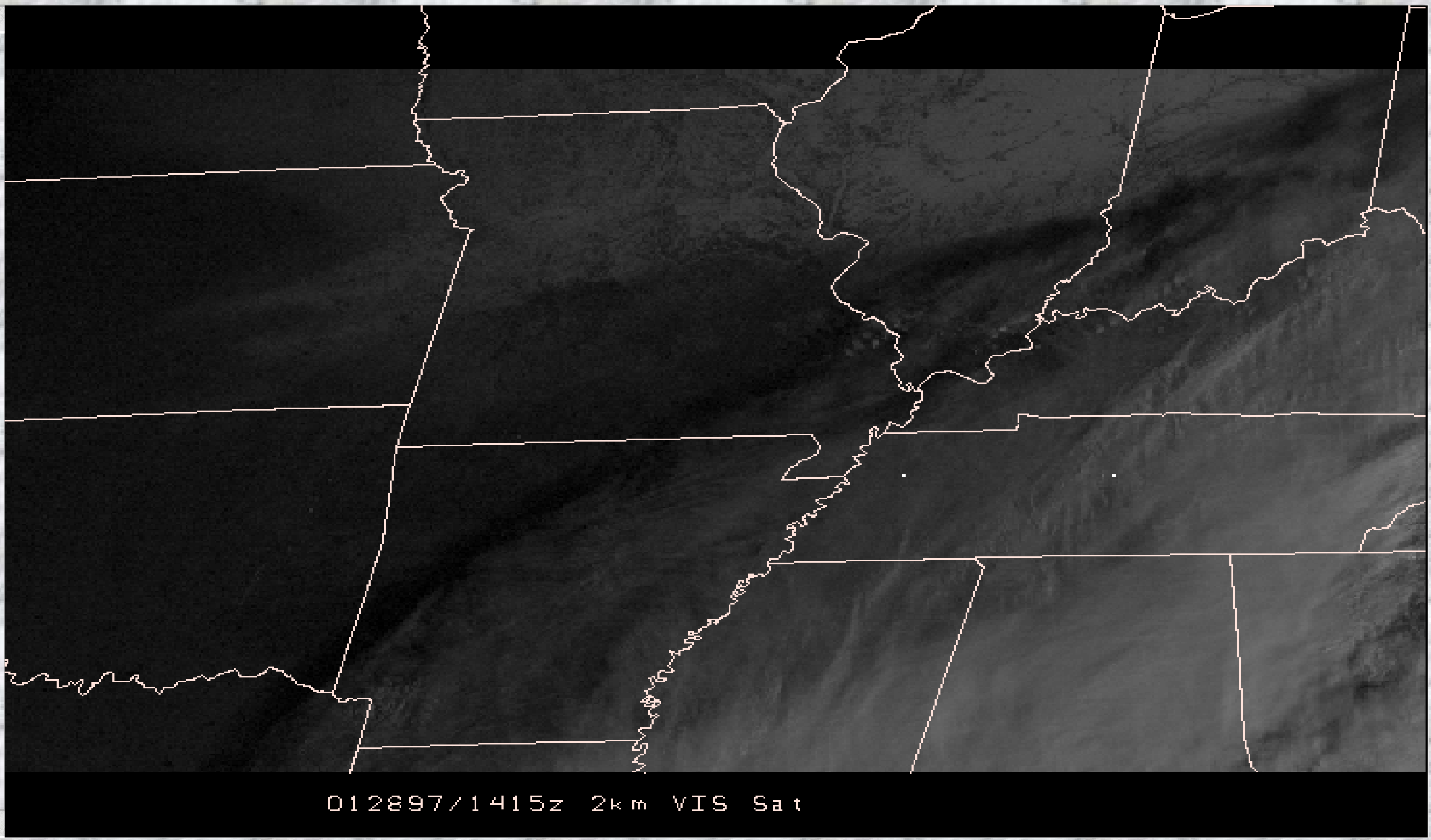
12Z UPPER AIR OBSERVATIONS



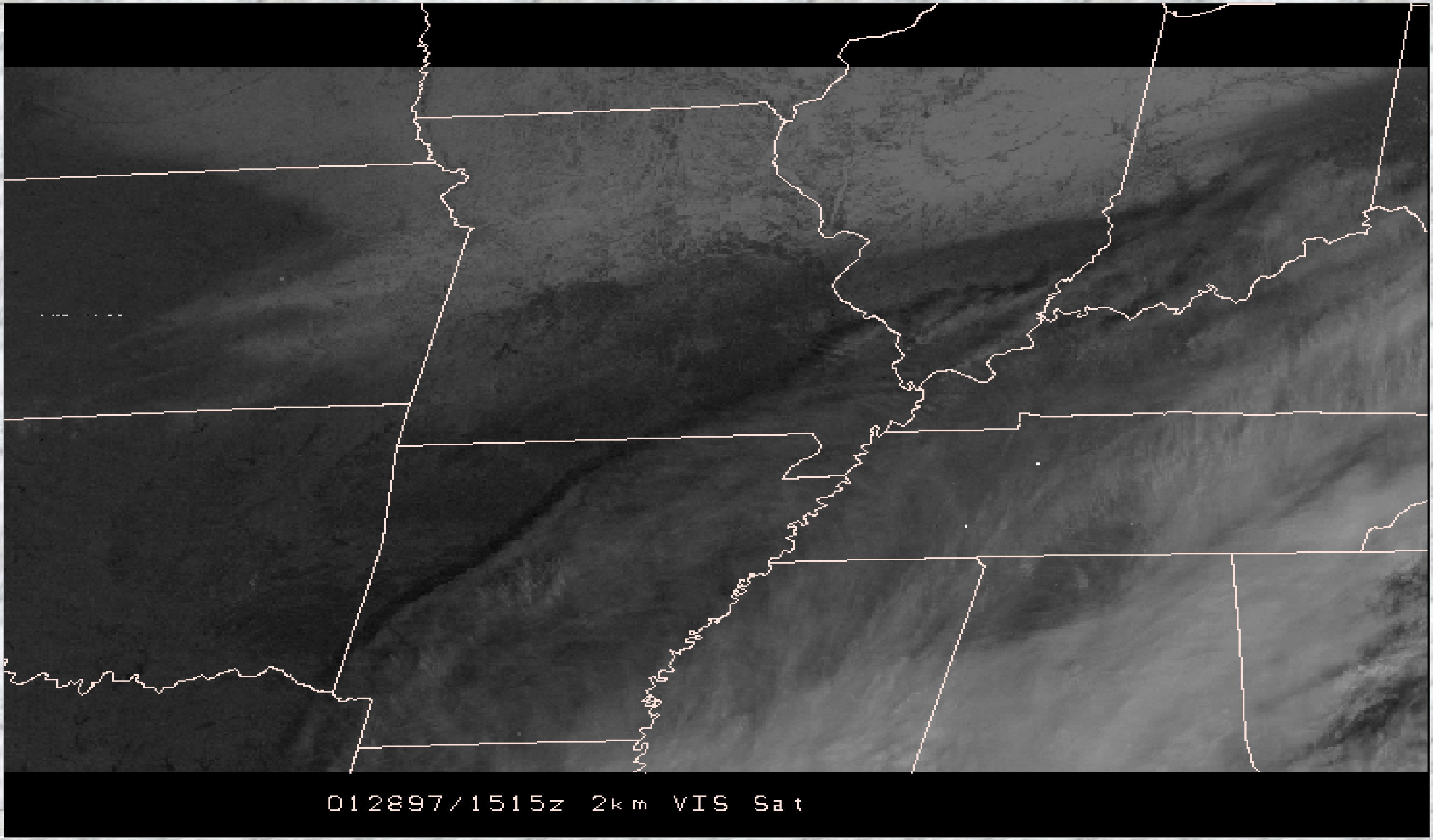
BLOOMFIELD, MO PROFILER - 15Z



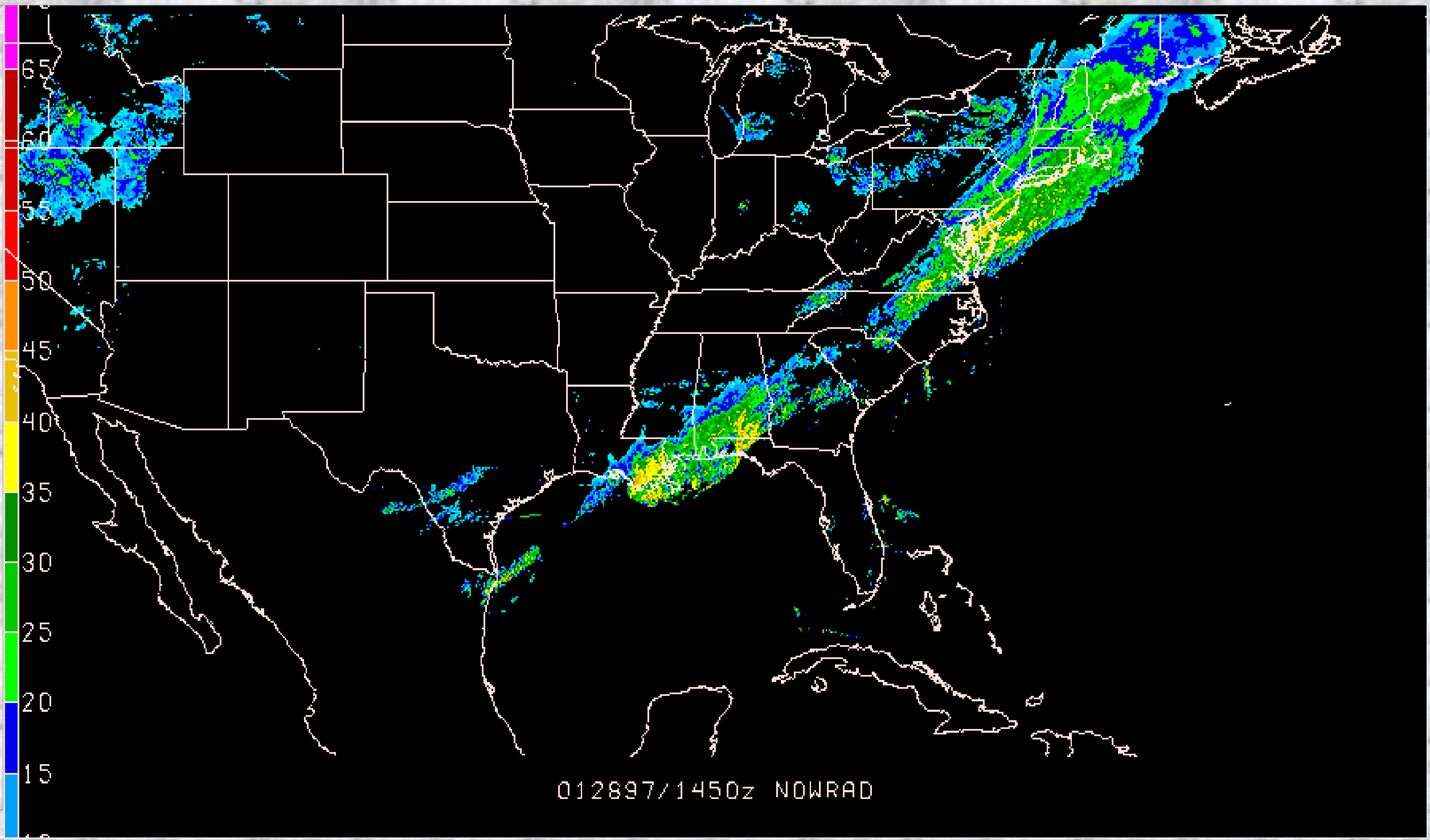
1415Z VISIBLE SATELLITE



1515Z VISIBLE SATELLITE

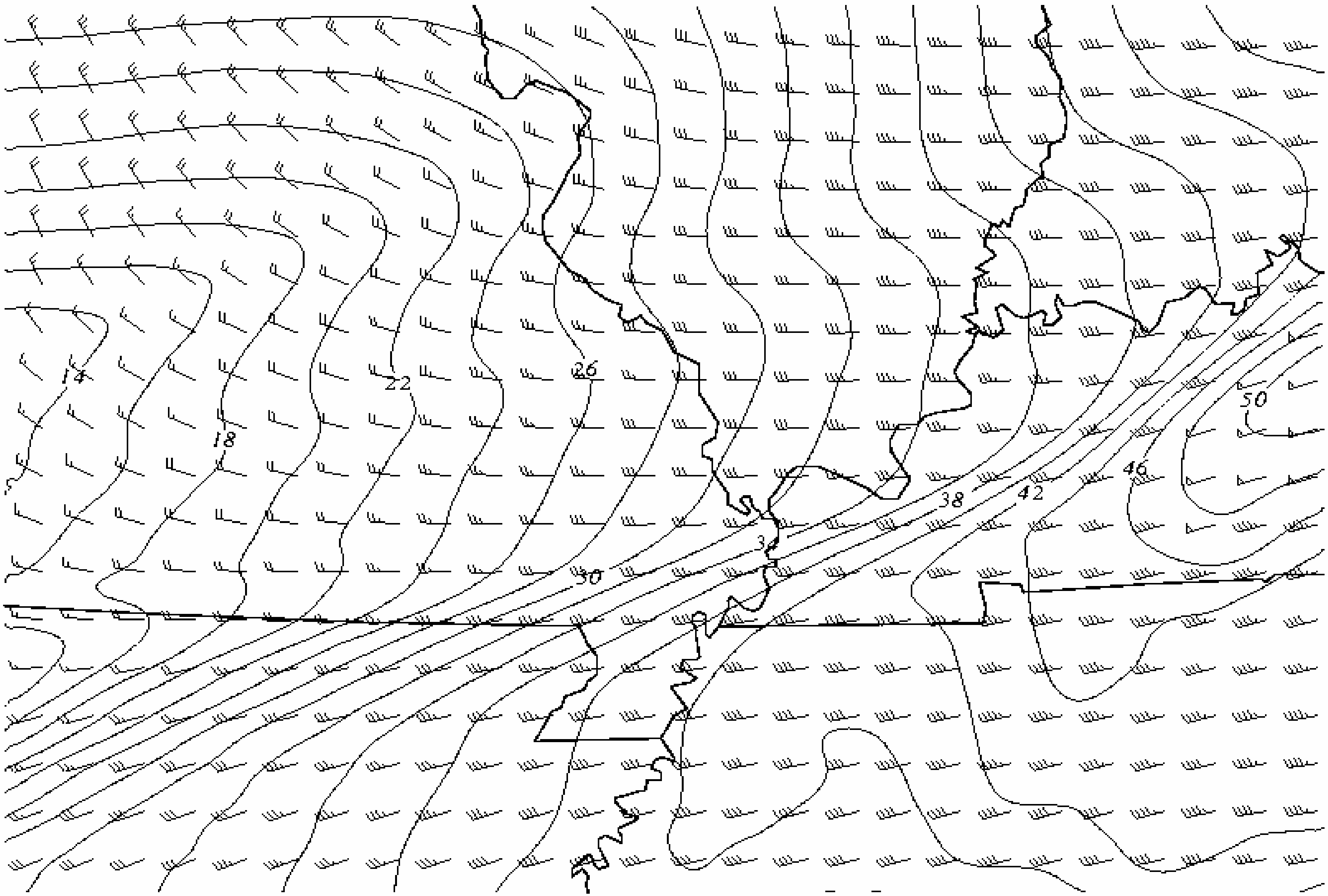


1450Z NOWRAD IMAGE

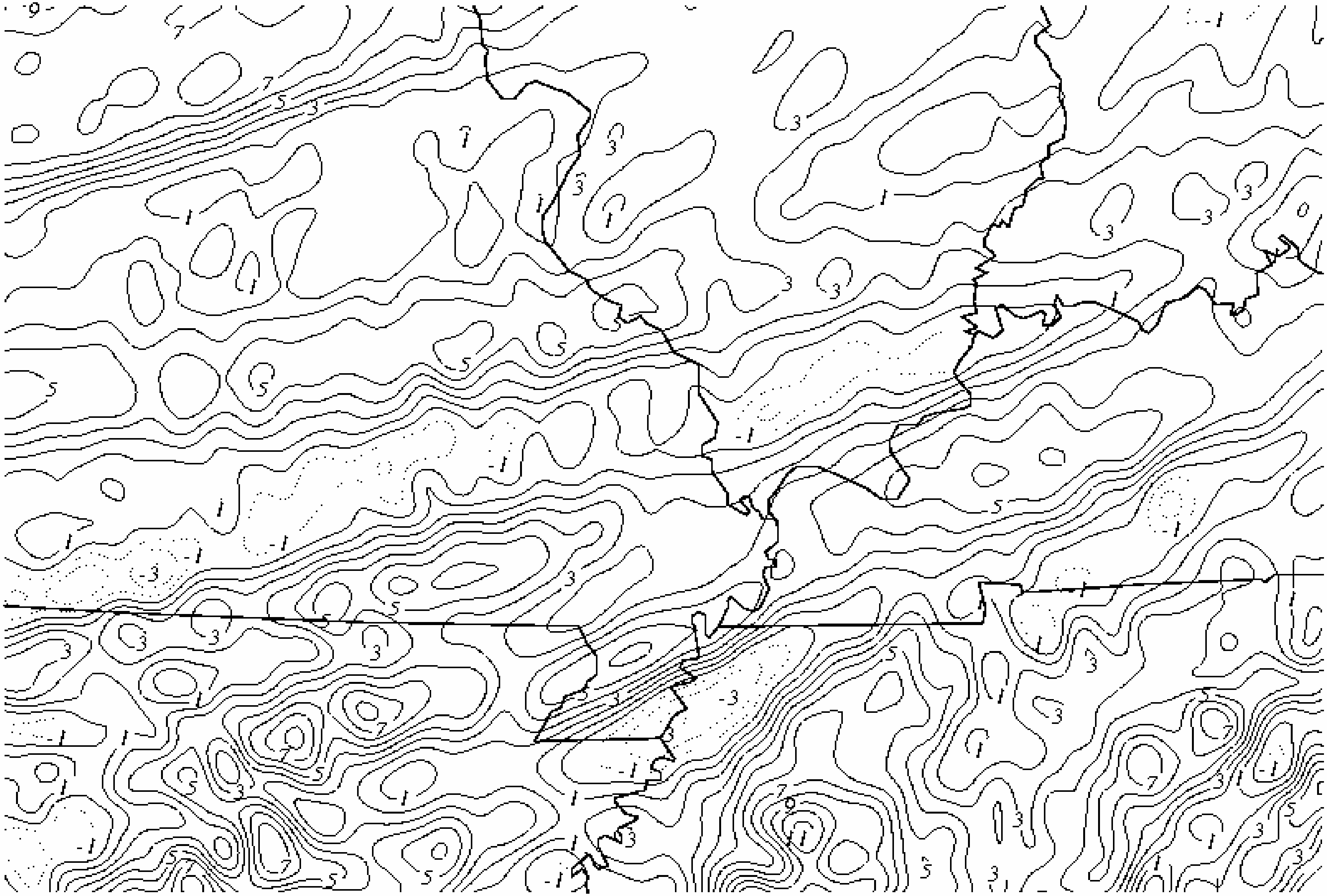


KEY FEATURES OF THE CAPE GIRARDEAU SIMULATION

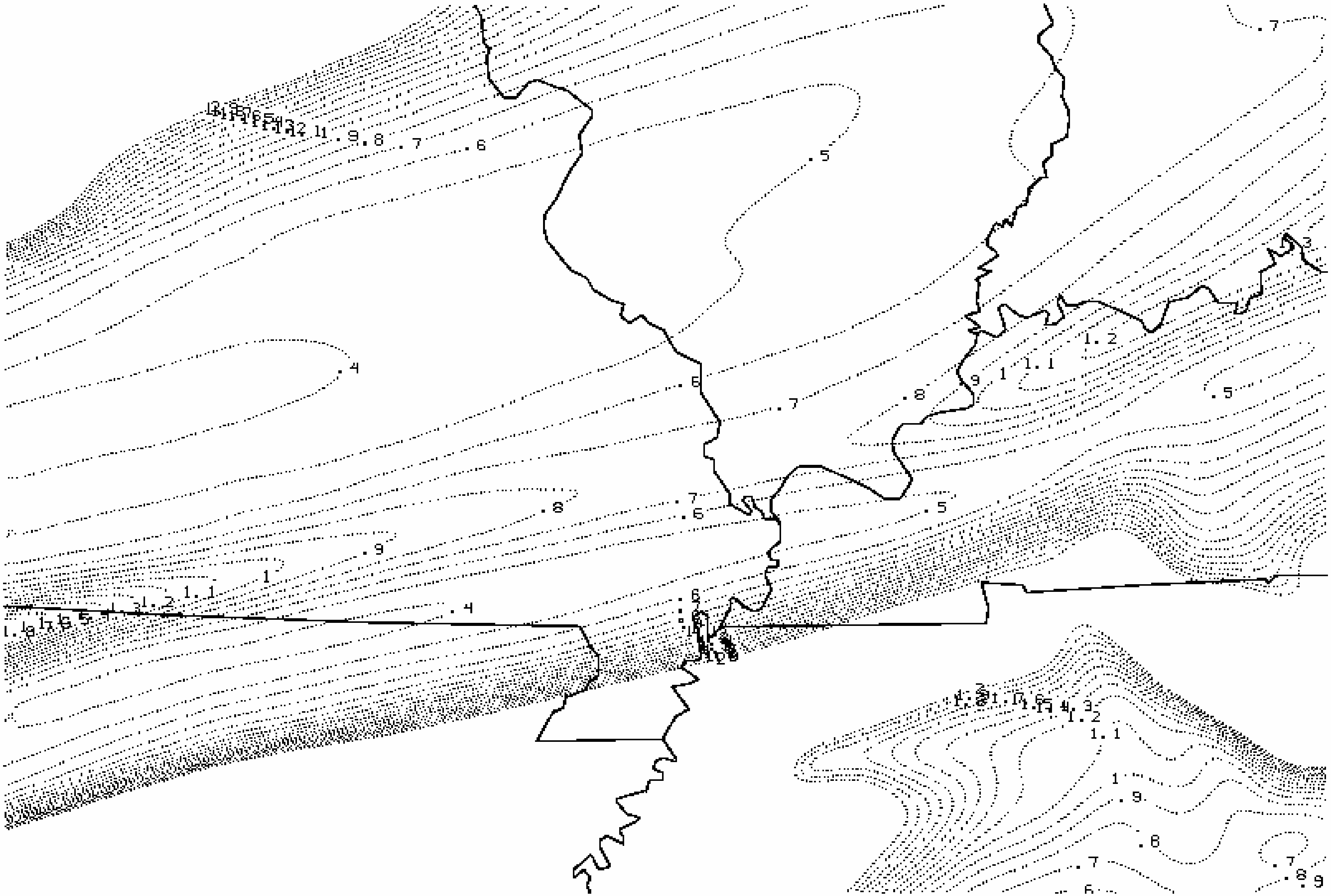
- STRONG CURVATURE JUST UPSTREAM
- JET ENTRANCE REGION LOCATION
- DOUBLE JET (PJ AND STJ) STRUCTURE
- COLD DRY AIR ADVECTION IN THE MIDDLE TROPOSPHERE
- ACCIDENT OCCURS WHERE COLD DRY AIR ADVECTION WITH PJ UNDERCUTS NORTHWESTERN FRINGE OF STJ



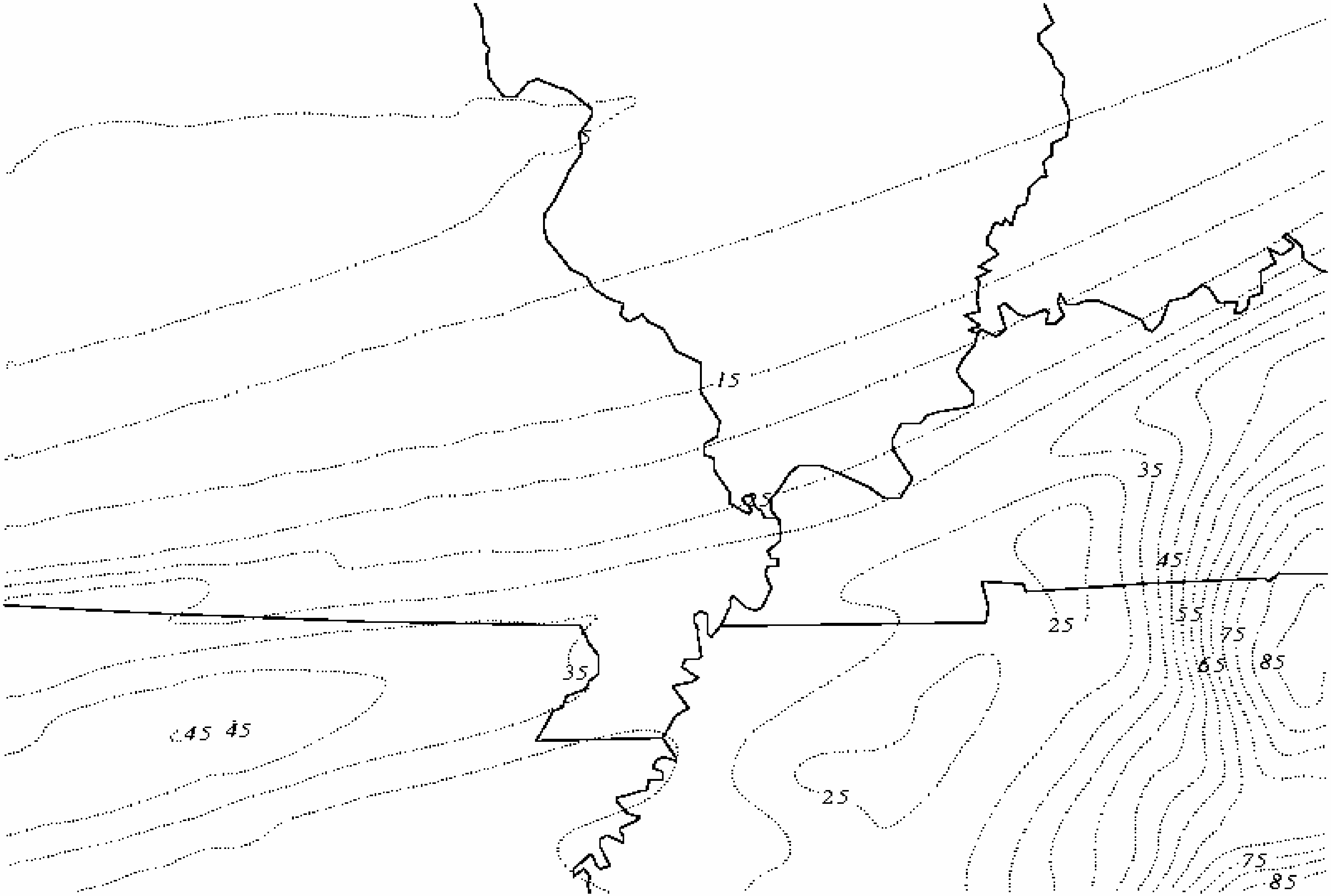
970128/1000F00230 314K wind



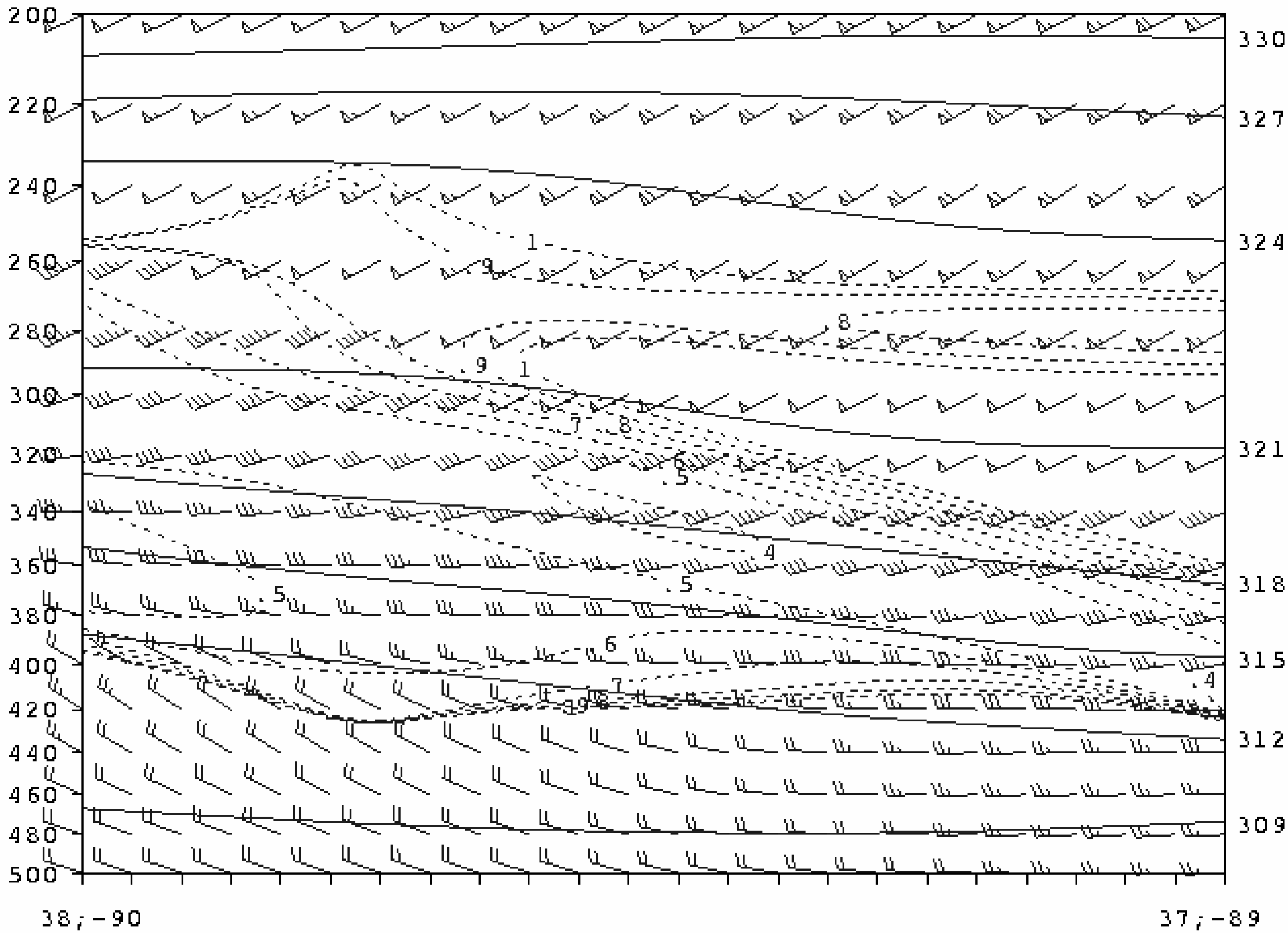
970128/1000F00230 314 K omega



970128/1000F00230 313:315K Richardson number



970128/1000F00230 314K humidity


200
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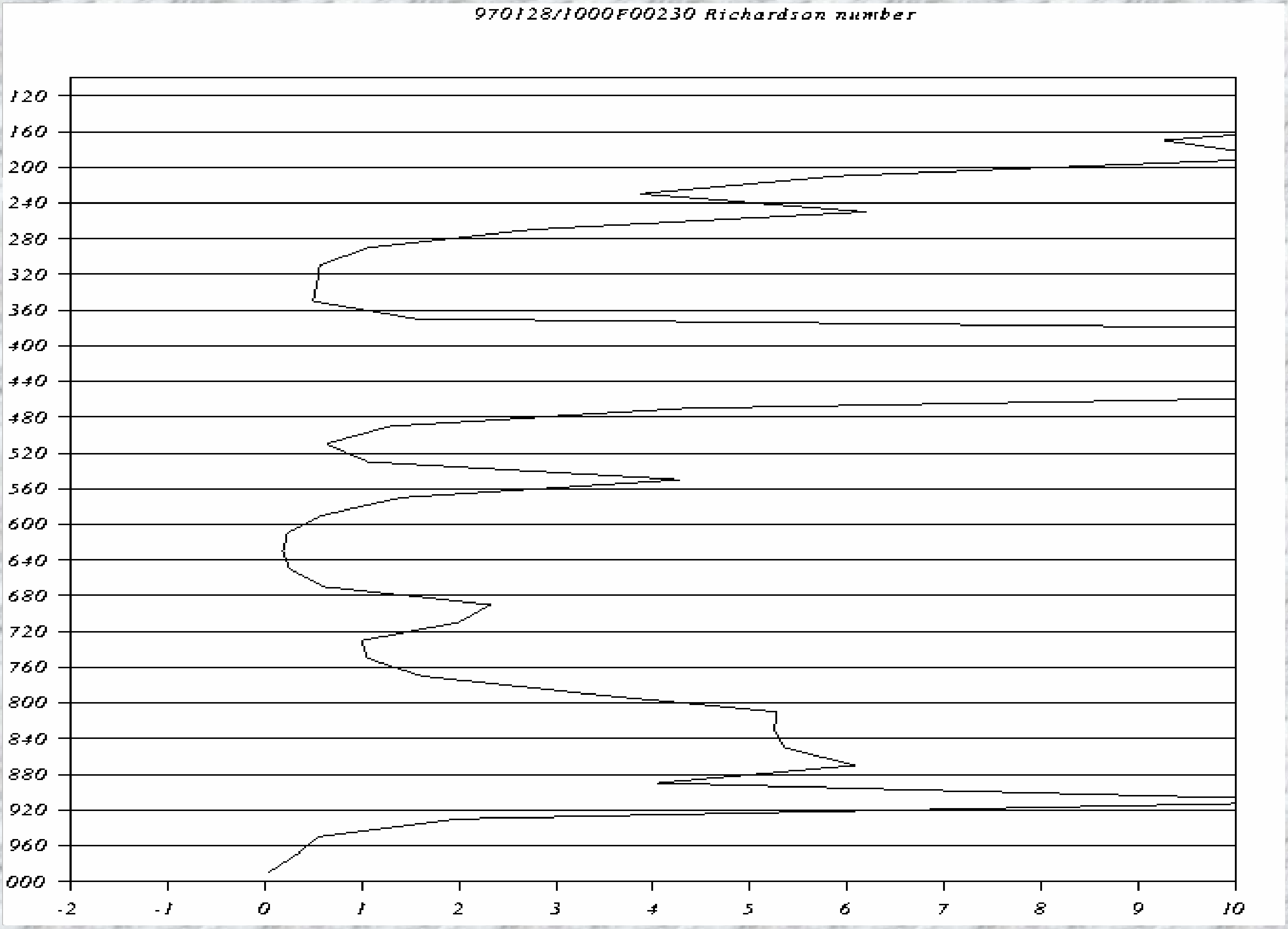
324
321
318
315
312
309
38;-90
37;-89

VERTICAL SOUNDING STRUCTURE AT THE ACCIDENT LOCATION

- BUOYANT MIDDLE LAYER (LOW BRUNT-VAISALA FREQUENCY)
- STRONG VERTICAL WIND SHEAR ABOVE BUOYANT LAYER
- RICHARDSON NUMBER MINIMUM AT INTERFACE BETWEEN LAYERS
- POOR WAVE DUCT AT INTERFACE BETWEEN LAYERS
- LOW WIND VELOCITY IN BUOYANT LAYER = WAVE CRITICAL LAYER


970128/1000F00230 Richardson number
120
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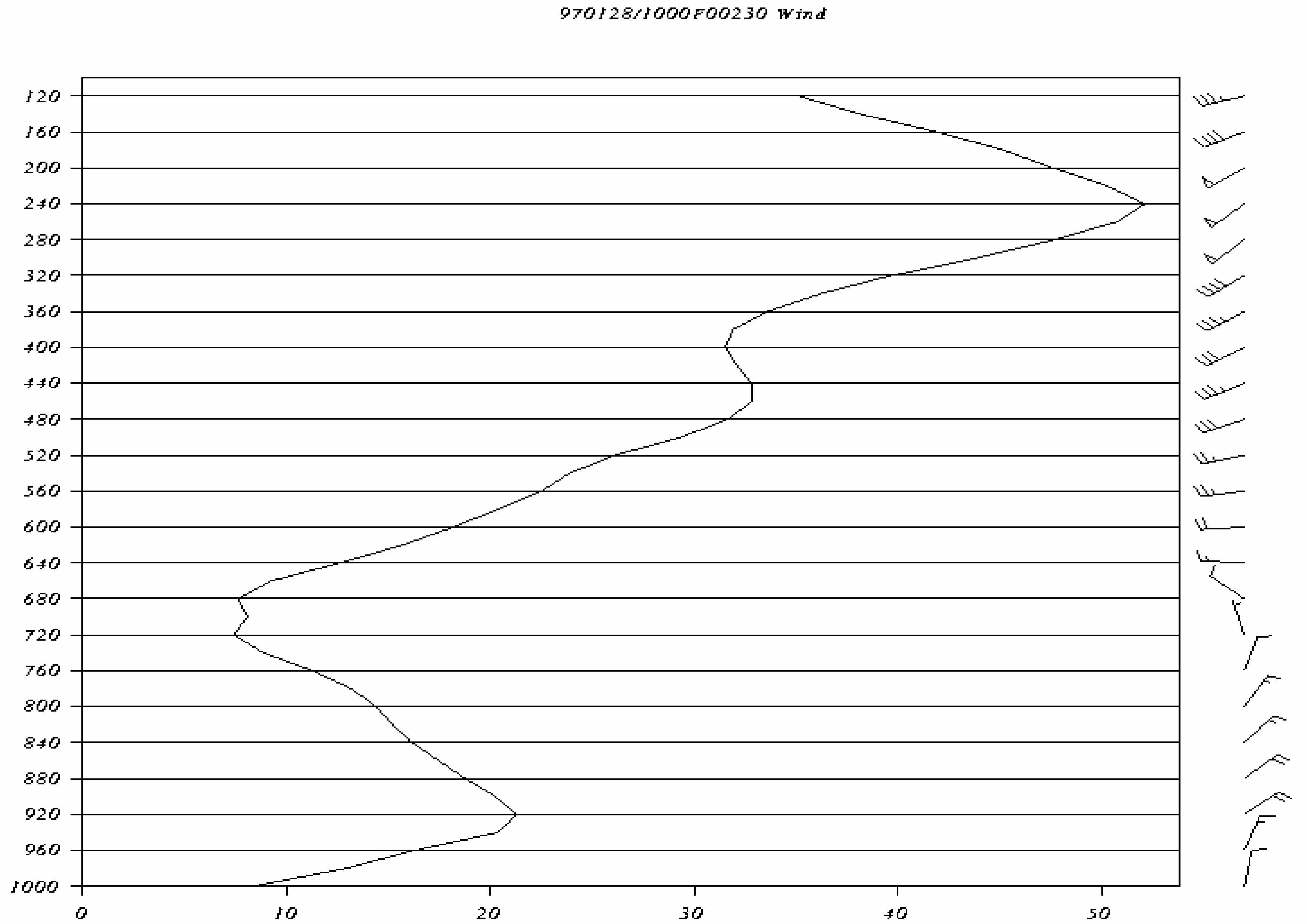
970128/1000F00230 Wind
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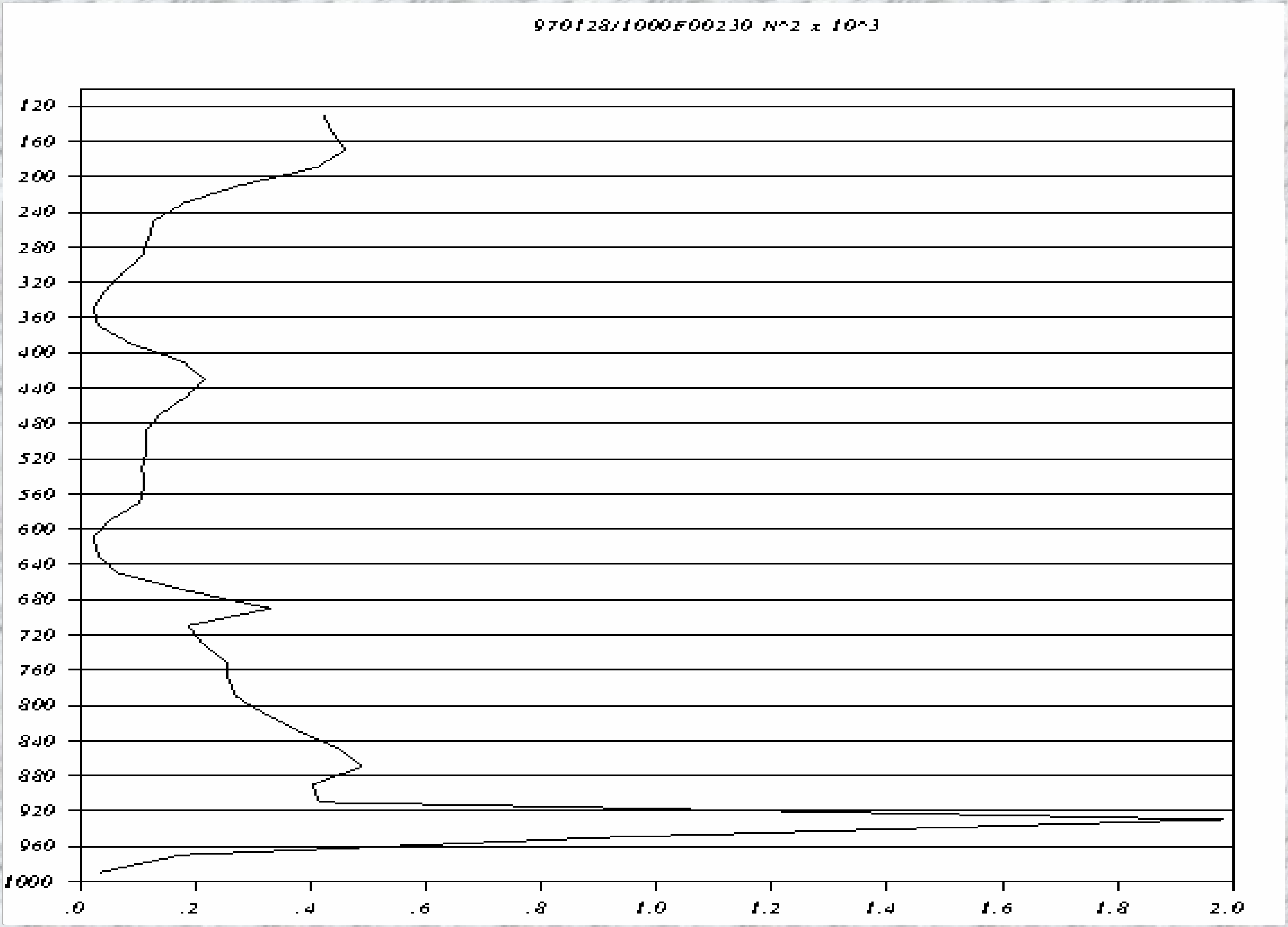
970128/1000F00230 N^2 x 10^3
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.6
.8
1.0
1.2
1.4
1.6
1.8
2.0

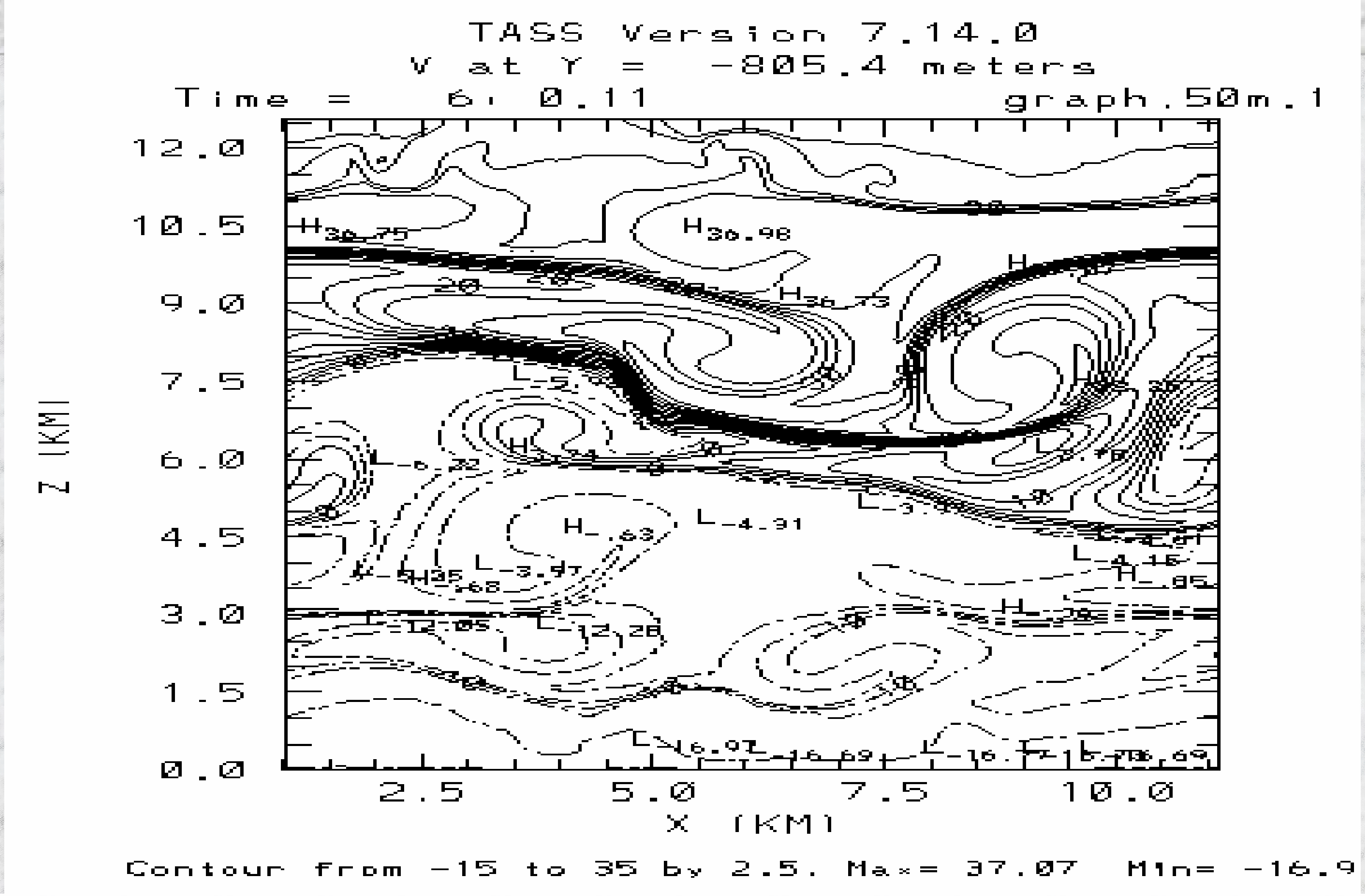
TASS MESO-GAMMA SCALE SIMULATIONS AT CAPE GIRARDEAU - BASIC MODEL EXPERIMENT

- INITIALIZE WITH MASS 6 KM CGI SOUNDING AT 1230 UTC
- 3-D MODEL SIMULATION WITH 50 M HORIZONTAL RESOLUTION
- 100 VERTICAL LAYERS

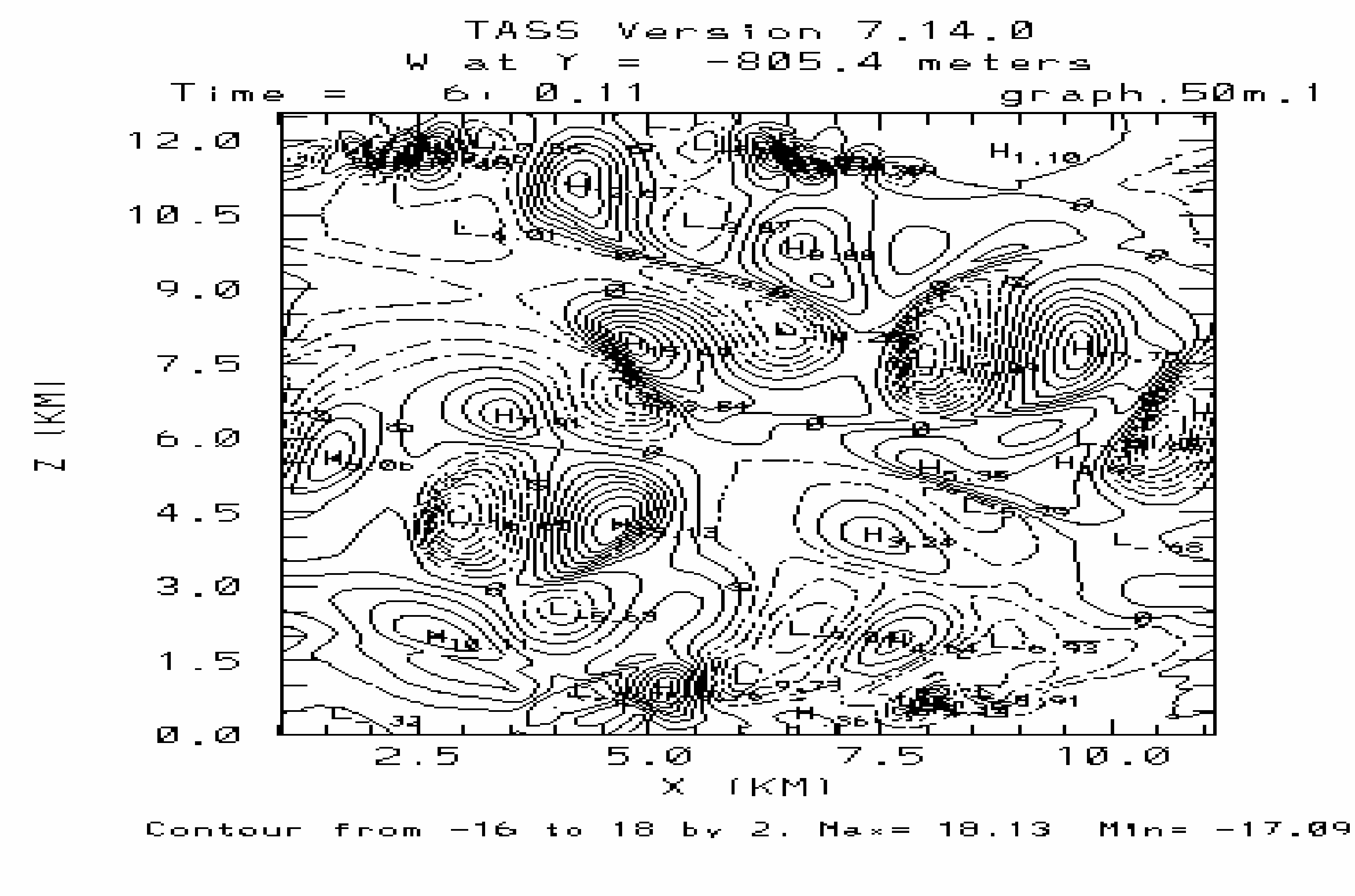
WAVE DYNAMICS AT THE MESO-GAMMA SCALE

- ~2 KM INTERNAL GRAVITY WAVE
- ~1 KM UPDRAFT/DOWNDRAFT COUPLET WITH ~30 M/S MAX DOWNDRAFT CENTERED JUST BELOW ACCIDENT ALTITUDE
- IMPLIES STRONG BUOYANT PLUME AND VERTICAL MOMENTUM FLUX ALONG AIRCRAFT FLIGHT PATH

TASS 50M SIMULATED V-WIND



TASS 50M SIMULATED VERTICAL VELOCITY



IMMEDIATE FUTURE WORK:

- MASS AND TASS SIMULATIONS AND ANALYSES FOR CROSS CITY, GRANITE, AND CHATTANOOGA FDR CASE STUDIES (ALL CONVECTIVE)
- DEVELOP FORECASTING ALGORITHM BASED ON 4 FDR CASE STUDIES
- REAL-TIME SUPPORT OF TURBULENCE EXPERIMENT WITH MASS AND NEW FORECASTING ALGORITHM
- PUBLISH DIAGNOSTIC AND PROGNOSTIC FINDINGS IN NASA TECH MEMOS AND REFEREED JOURNAL ARTICLES