Nowcasting Flash Floods and Heavy Precipitation --- A Satellite Perspective

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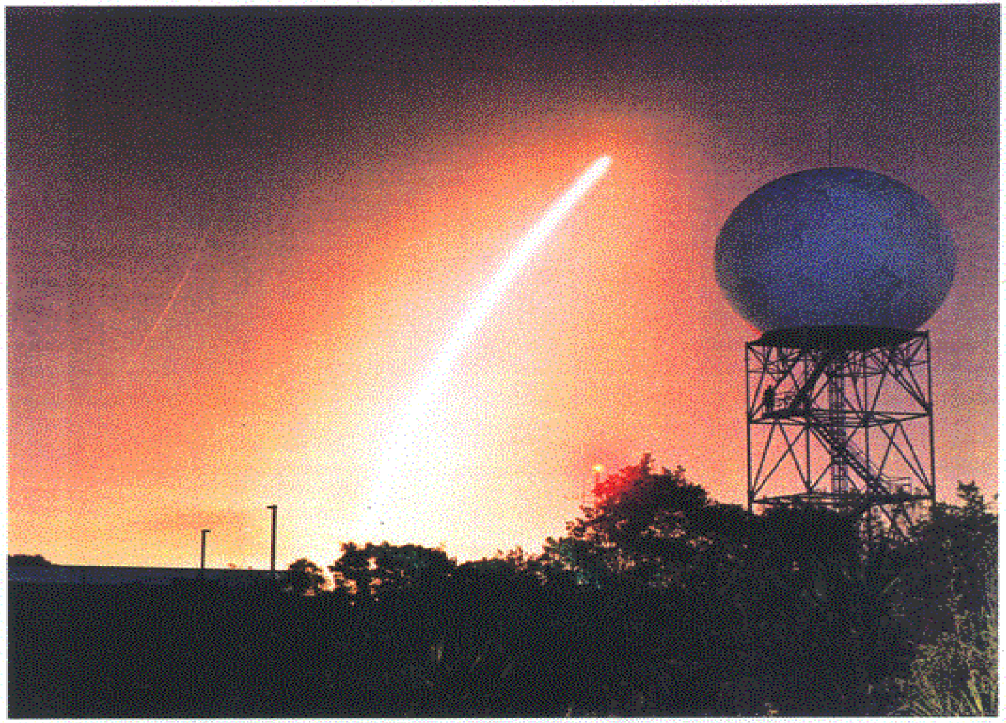
THE LAUNCH OF GOES-I (APRIL 13, 1994)
and
THE RADOME OF MELBOURNE, FLORIDA'S
WSR-88D

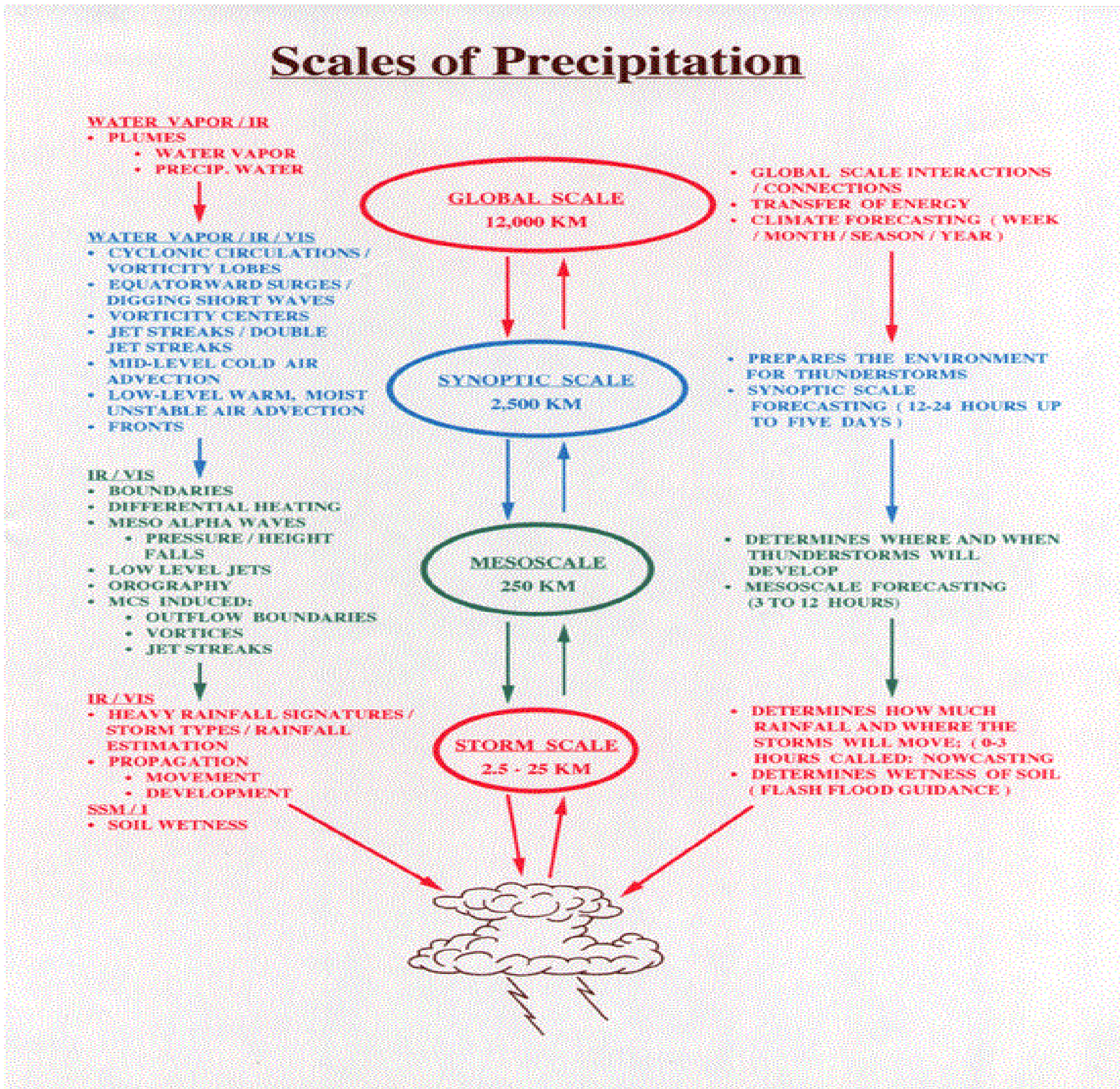


Satellite Pictures

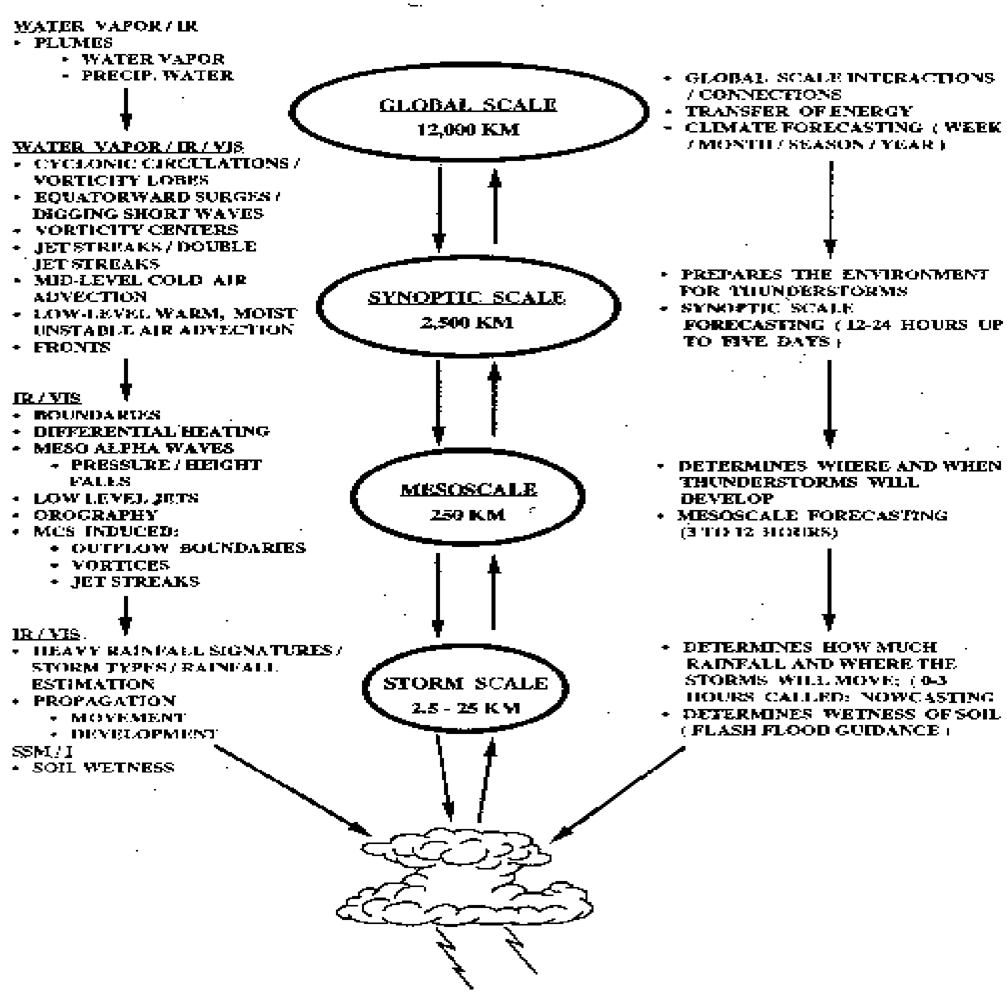
- **GOES Water Vapor (6.7 μm) day and night): detects moisture and weather systems between 700 - 300 mb**
- **GOES Infrared (10.5 - 12.6 μm) day and night): detects cloud top temperature and surface temperature**
- **GOES Visible (0.55 - 0.75 μm) (day only): what you can see: clouds, water, land**

Satellite Pictures

- **Polar Microwave (SSM/I and AMSU): detects precipitation, moisture, snow cover, ocean surface winds, surface wetness**

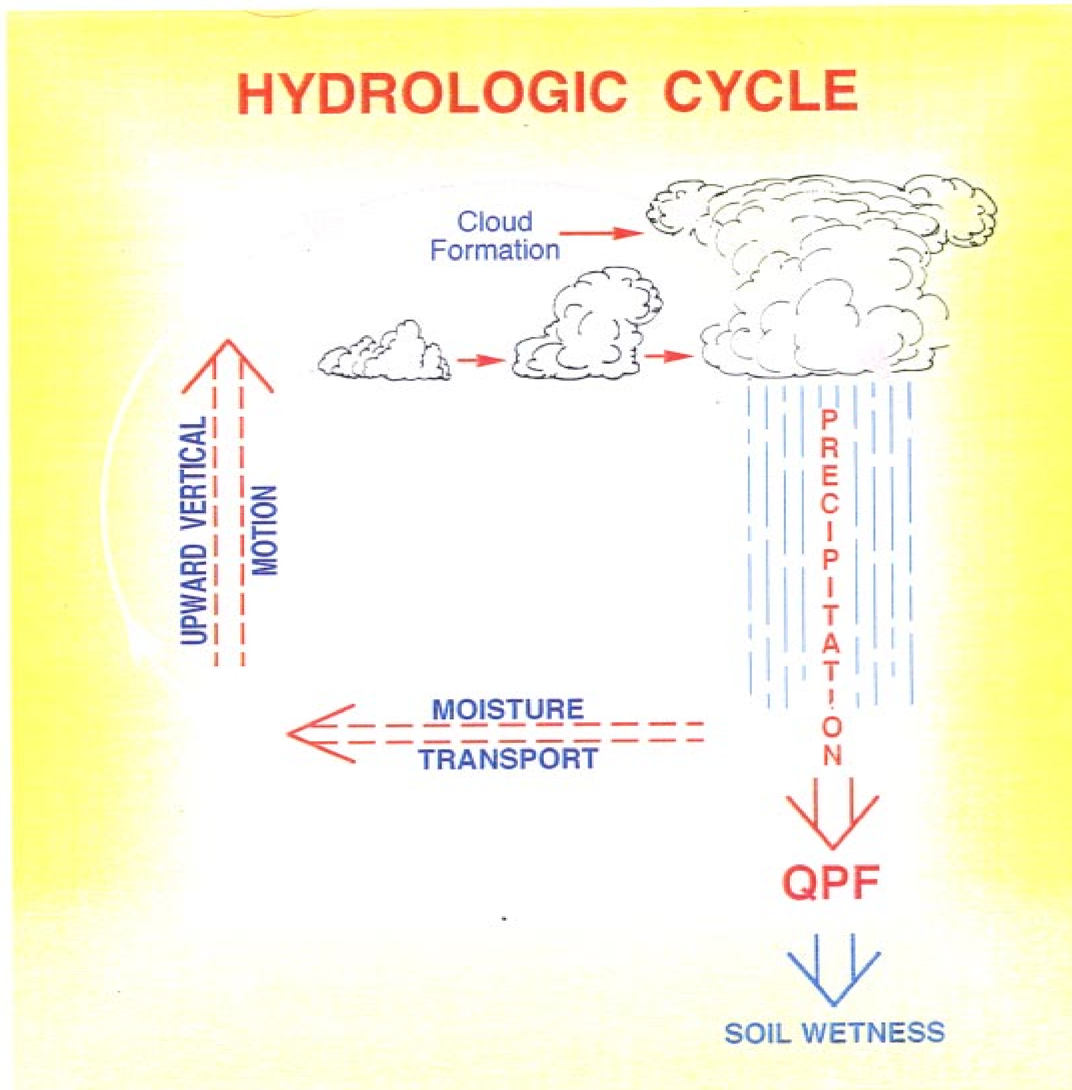

Scales of Precipitation
WATER VAPOR / IR
• PLUMES
• WATER VAPOR
• PRECIP. WATER
GLOBAL SCALE
12,000 KM
• GLOBAL SCALE INTERACTIONS / CONNECTIONS
• TRANSFER OF ENERGY
• CLIMATE FORECASTING (WEEK / MONTH / SEASON / YEAR)
WATER VAPOR / IR / VIS
• CYCLONIC CIRCULATIONS / VORTICITY LOBES
• EQUATORWARD SURGES / DIGGING SHORT WAVES
• VORTICITY CENTERS
• JET STREAKS / DOUBLE JET STREAKS
• MID-LEVEL COLD AIR ADVECTION
• LOW-LEVEL WARM, MOIST UNSTABLE AIR ADVECTION
• FRONTS
SYNOPTIC SCALE
2,500 KM
• PREPARES THE ENVIRONMENT FOR THUNDERSTORMS
• SYNOPTIC SCALE FORECASTING (12-24 HOURS UP TO FIVE DAYS)
IR / VIS
• BOUNDARIES
• DIFFERENTIAL HEATING
• MESO ALPHA WAVES
• PRESSURE / HEIGHT FALLS
• LOW LEVEL JETS
• OROGRAPHY
• MCS INDUCED:
• OUTFLOW BOUNDARIES
• VORTICES
• JET STREAKS
MESOSCALE
250 KM
• DETERMINES WHERE AND WHEN THUNDERSTORMS WILL DEVELOP
• MESOSCALE FORECASTING (3 TO 12 HOURS)
IR / VIS
• HEAVY RAINFALL SIGNATURES / STORM TYPES / RAINFALL ESTIMATION
• PROPAGATION
• MOVEMENT
• DEVELOPMENT
SSM / I
• SOIL WETNESS
STORM SCALE
2.5 - 25 KM
• DETERMINES HOW MUCH RAINFALL AND WHERE THE STORMS WILL MOVE: (0-3 HOURS CALLED: NOWCASTING
• DETERMINES WETNESS OF SOIL (FLASH FLOOD GUIDANCE)

Scales of Precipitation



Hydrologic Cycle

- **The change of state, and the vertical and horizontal transport of water substance between earth, the atmosphere, and the sea**

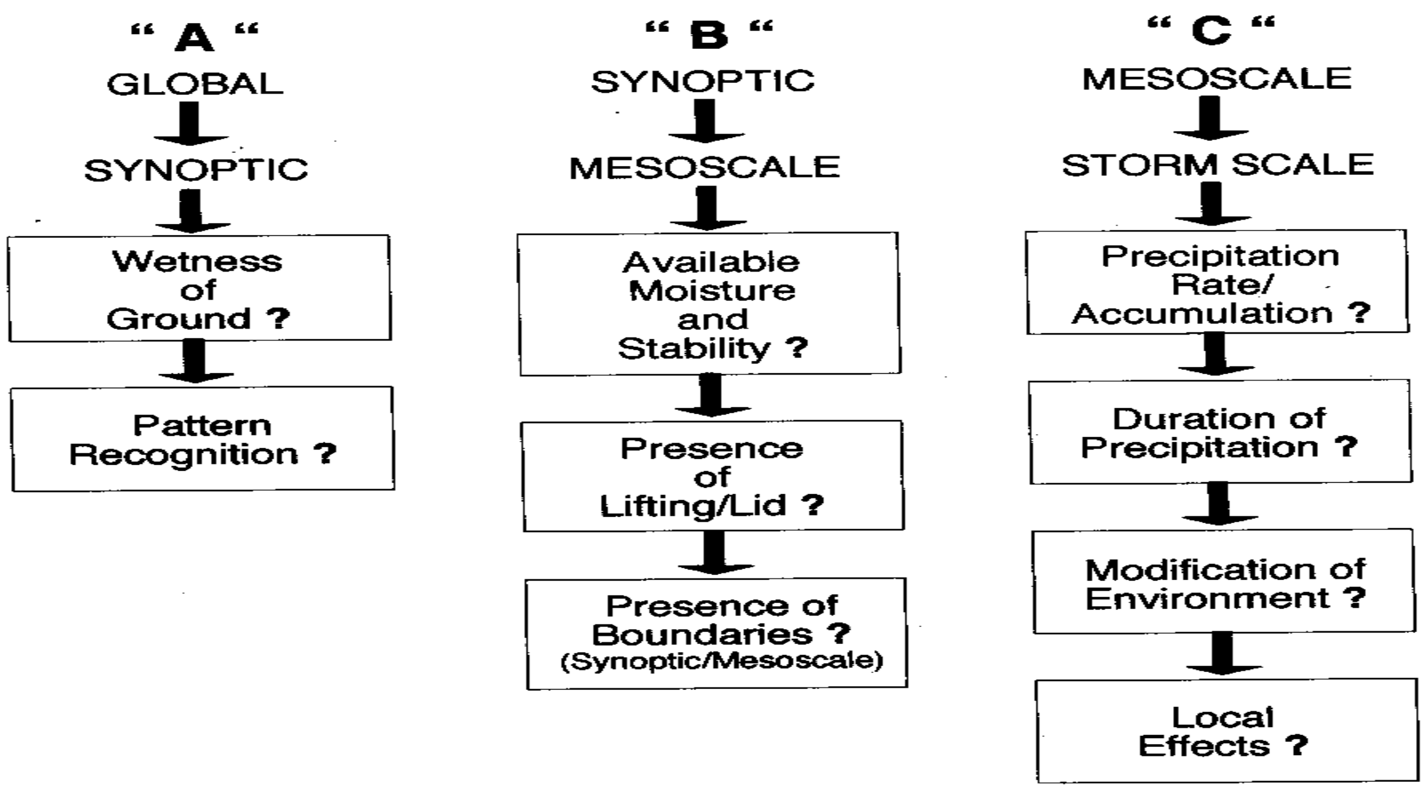

HYDROLOGIC CYCLE
Cloud Formation
UPWARD VERTICAL MOTION
PRECIPITATION
MOISTURE TRANSPORT
QPF
SOIL WETNESS

Quantitative Precipitation Forecasts (QPF)

- **The prediction of how much precipitation (e.g., 1/2 inch, 1 inch, 2 inches, etc) will fall during a specified period of time (e.g., 3 hours, 6 hours, 12 hours, 24 hours, etc)**

Questions to ask when preparing QPF

- Satellite Interpretations/Signatures
- Satellite Conceptual Models
- Satellite Products

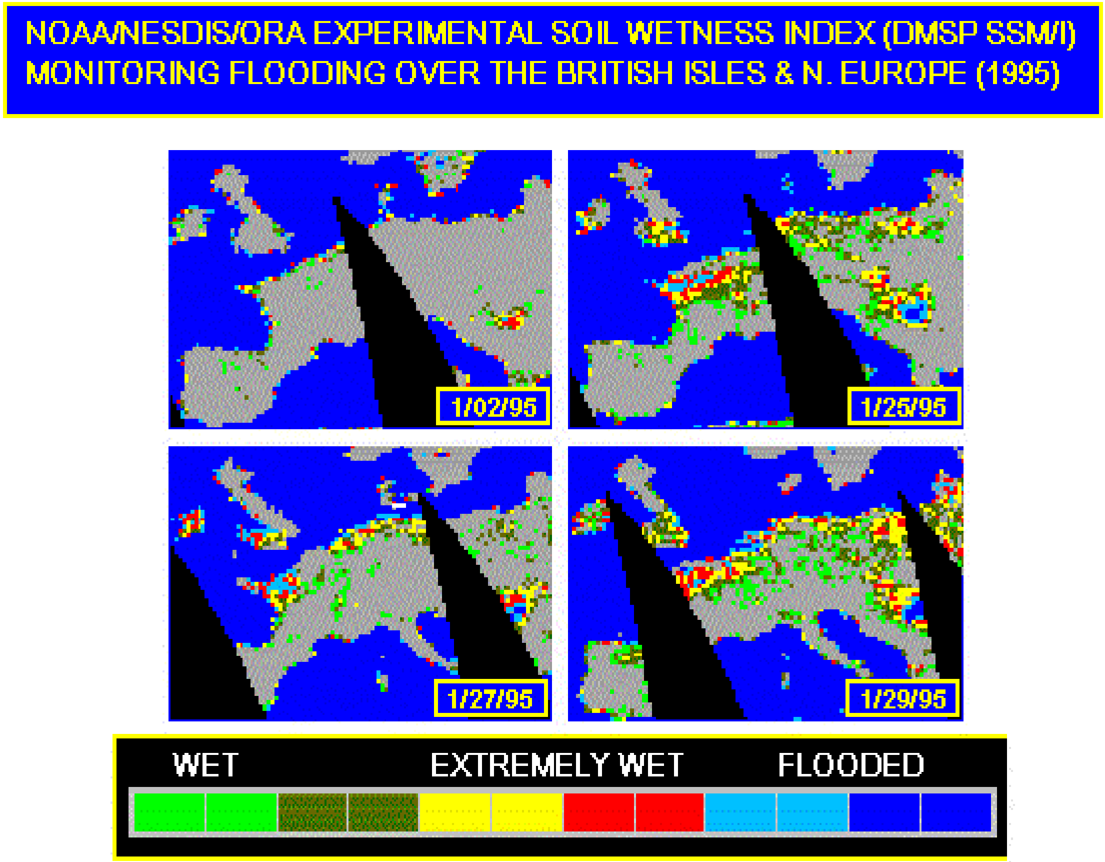


Questions to ask when preparing Nowcasts and QPF "this involves"

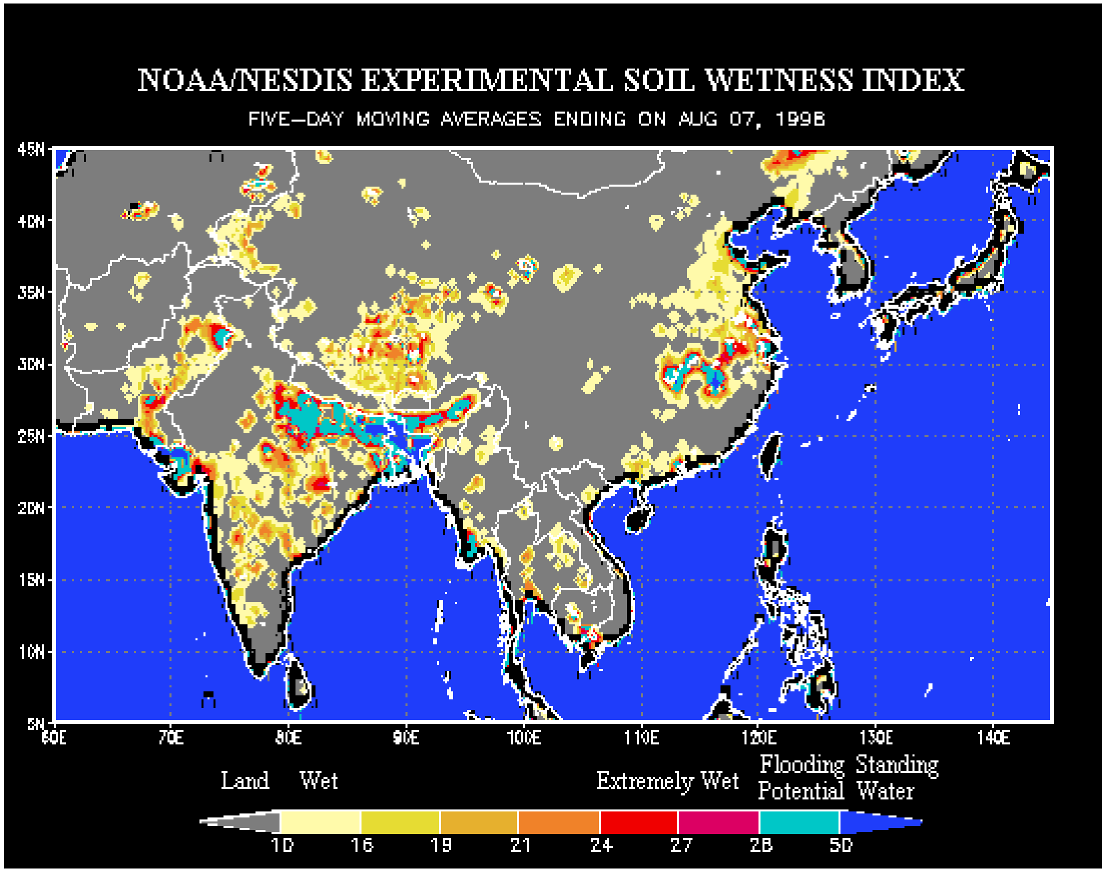
- **Satellite interpretations / signatures**
- **Satellite conceptual models**
- **satellite products**

Global to Synoptic Scale

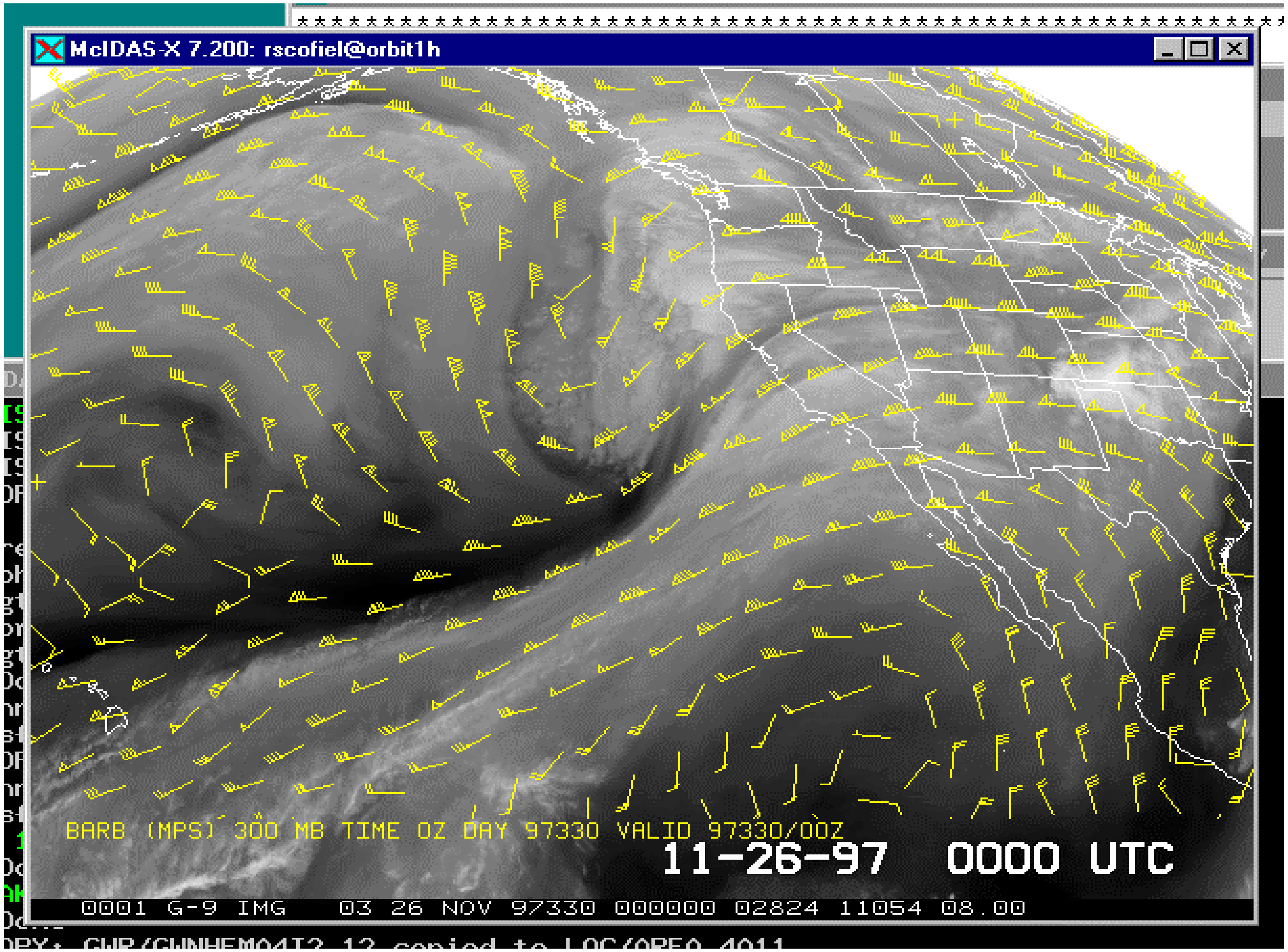
- **Wetness of ground?**
- **Pattern recognition?**



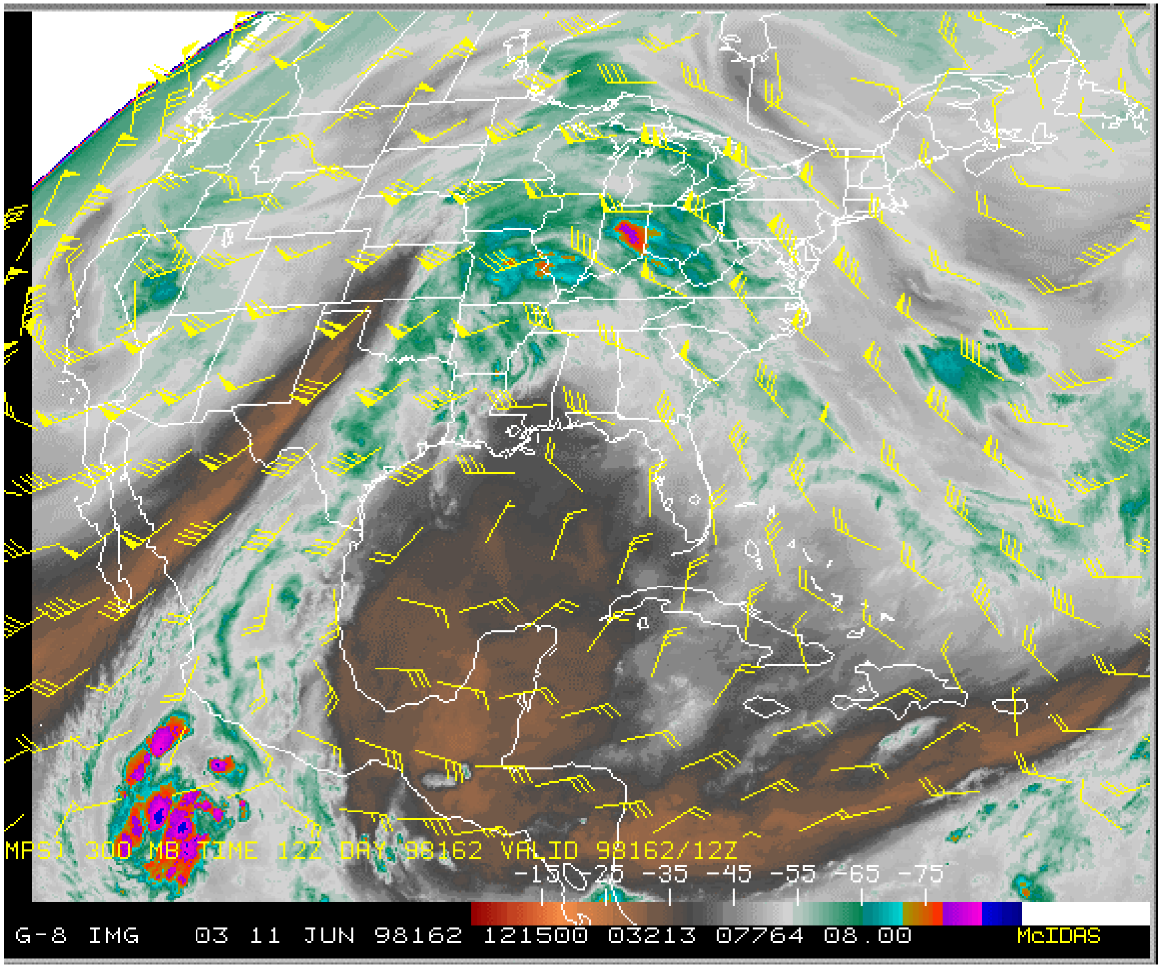
Soil (surface) Wetness Index (85 GHz - 19 GHz) (H) for January 1995



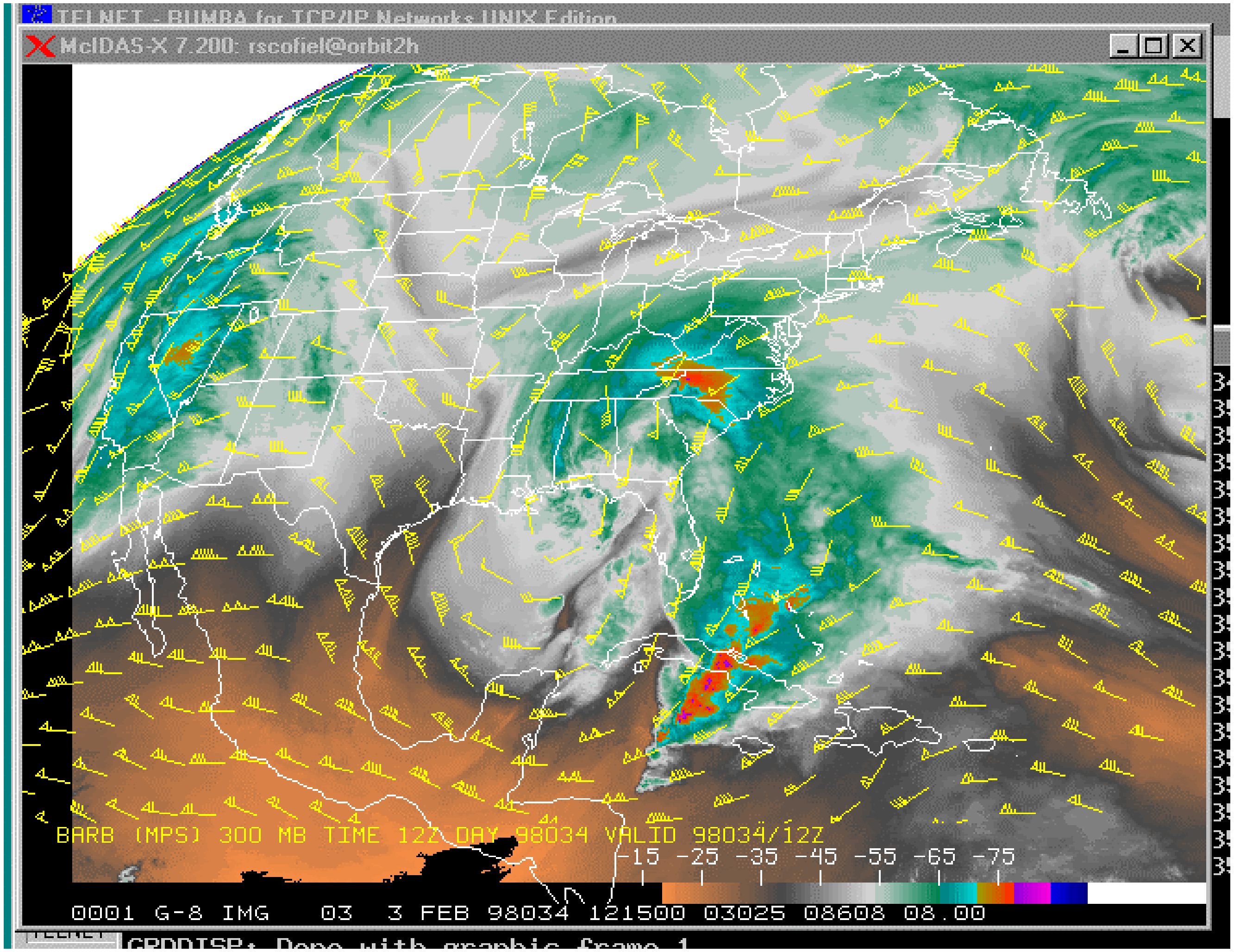
Soil (surface) Wetness Index (85 GHz - 19 GHz) (H)
5 day moving averages ending August 7, 1998



PATTERN RECOGNITION: 6.7 micron water vapor imagery for 11-26-97 0000 UTC; 300 mb winds (mps) are superimposed



PATTERN RECOGNITION: 6.7 micron water vapor imagery for 6-11-98 1200 UTC; 300 mb winds (mps) are superimposed



PATTERN RECOGNITION: 6.7 Micron for 2-3-98 1200 UTC; 300 mb winds (mps) are superimposed

Synoptic to Mesoscale

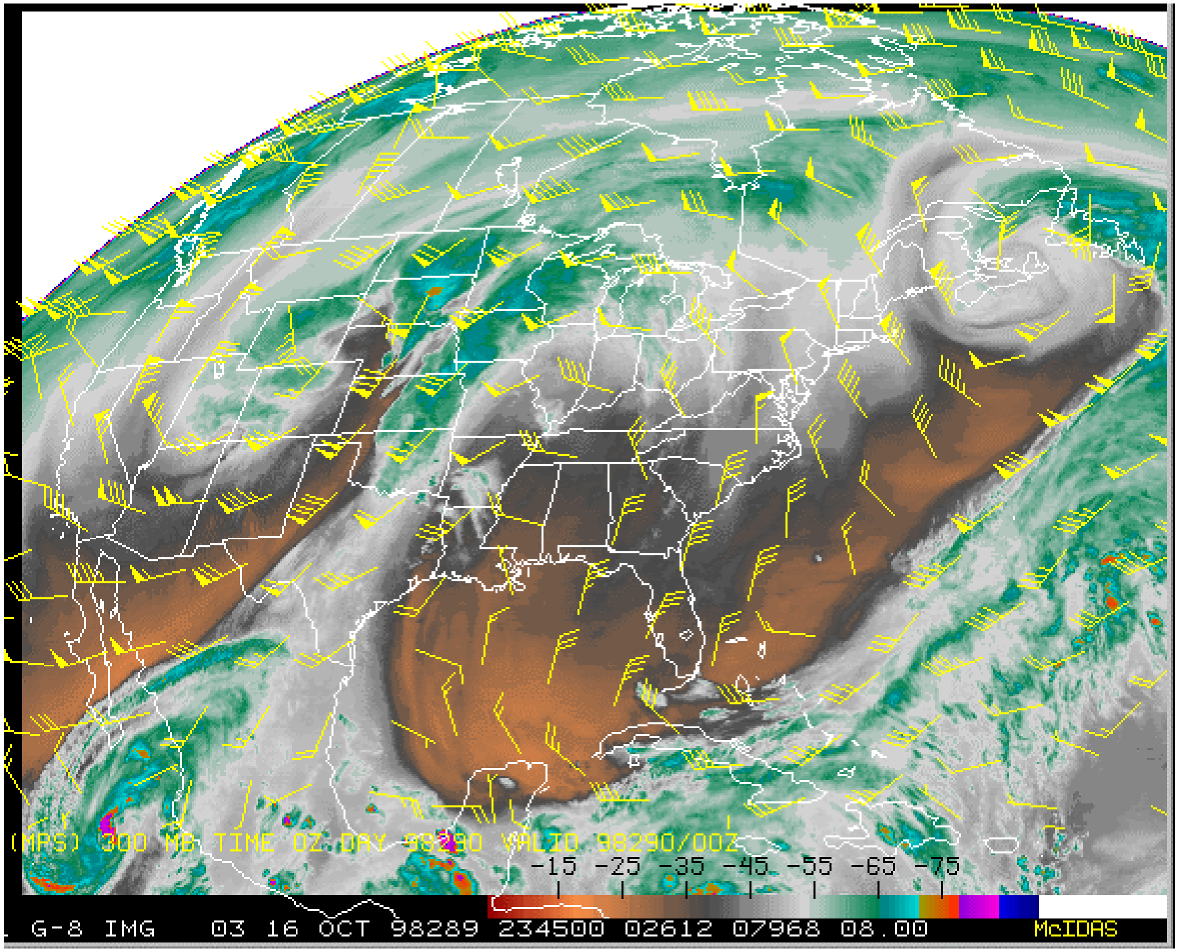
- **Available moisture and stability?**
- **Presence of lifting or lid?**
- **presence of boundaries?**
  (synoptic of mesoscale)

Use of Water Vapor (6.7 μm) Imagery

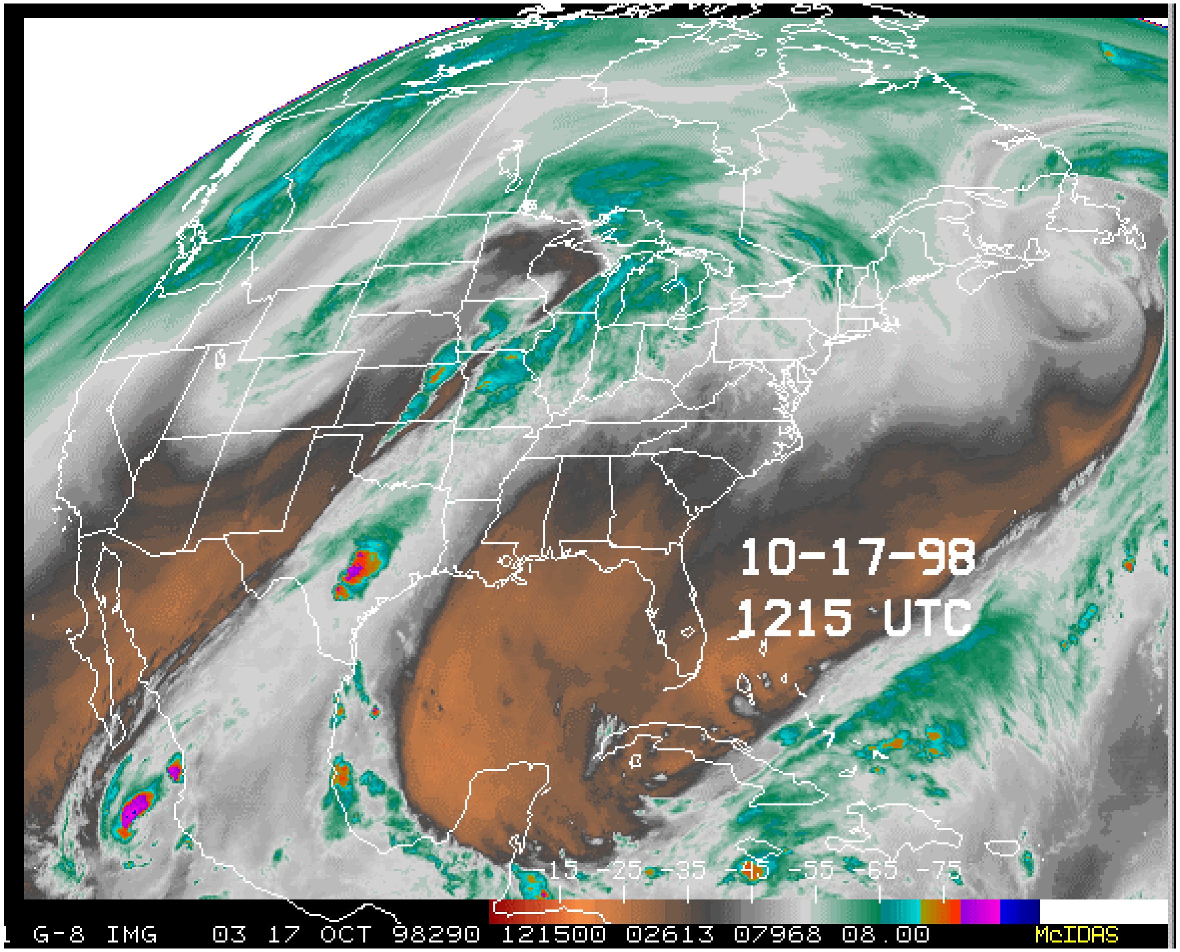
- **middle - upper level flow fields and circulations**
- **lifting mechanisms**
  - **jet streaks**
  - **cyclonic circulations/lobes**
  - **trough axes**
  - **mid-level cold air advection**
- **excellent data for pattern recognition**

6.7 μm Water Vapor Plumes

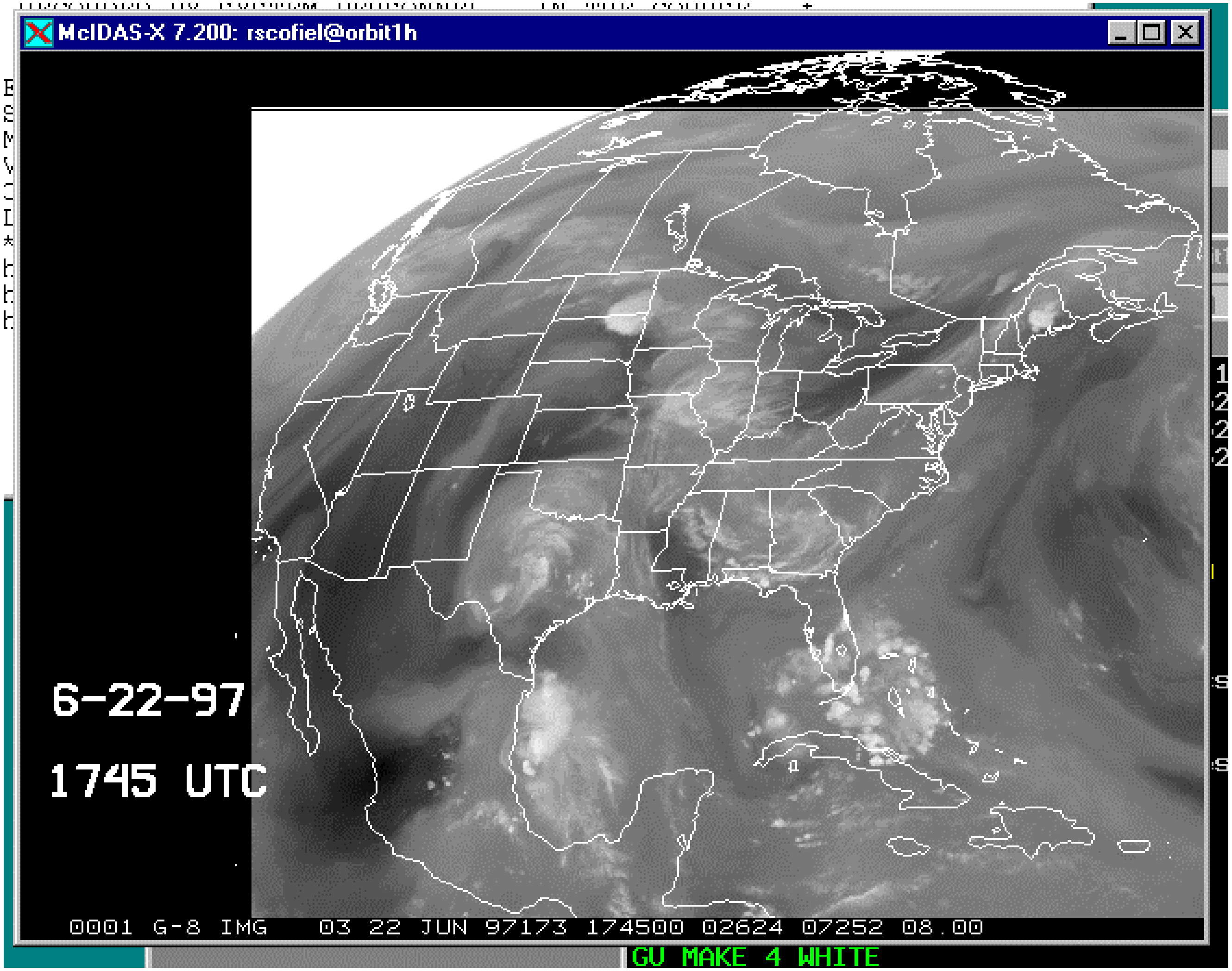
- **Makes environment more efficient?**
- **Enhances precipitation through cloud seeding?**
- **associated with favorable synoptic patterns for low-level moisture and instability**



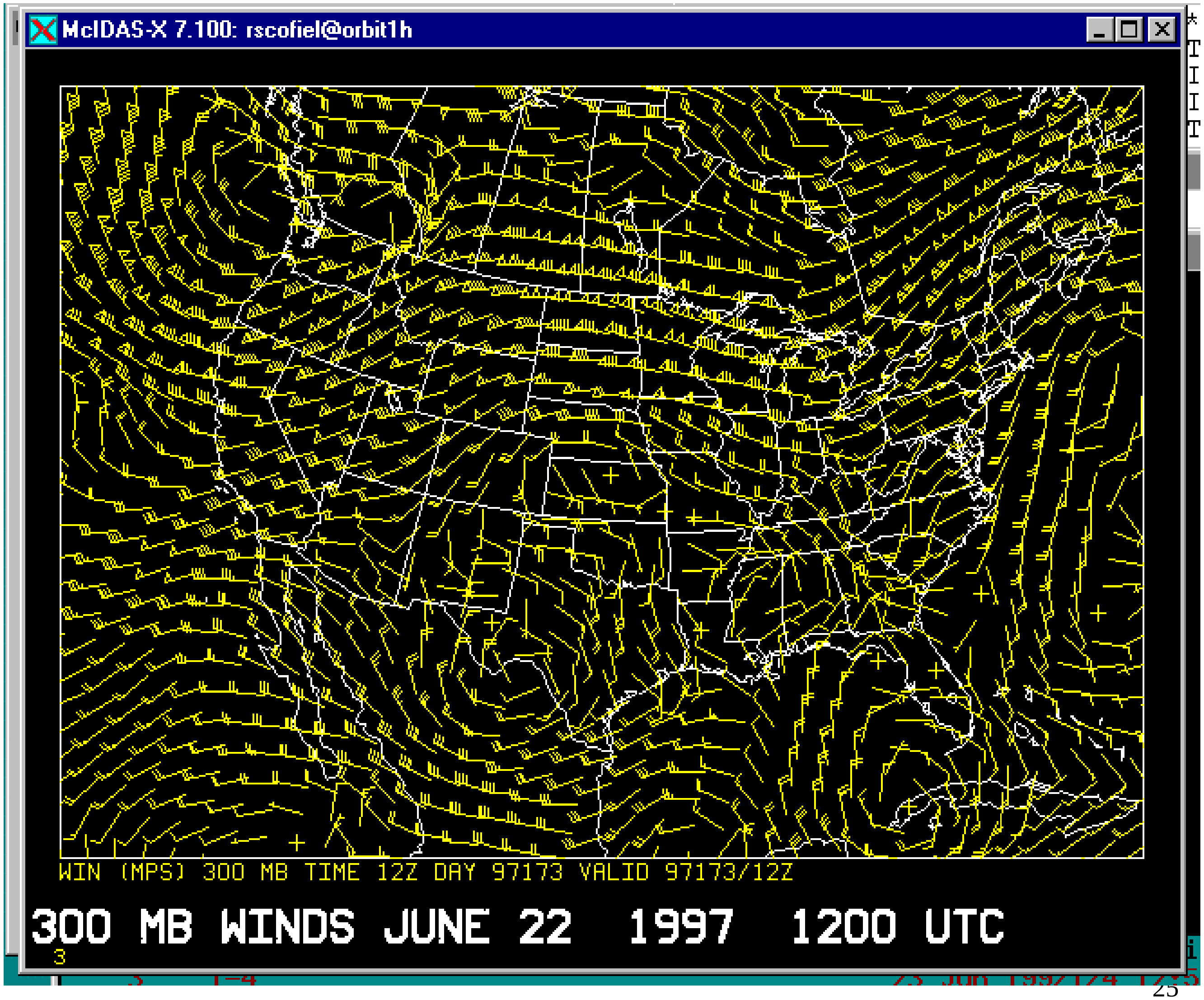
WATER VAPOR PLUME: 6.7 micron water vapor imagery for 10-16-98 2345 UTC; 300 mb winds (mps) are superimposed



WATER VAPOR PLUME: 6.7 micron water vapor imagery for 10-17-98 1215 UTC



6.7 micron water vapor imagery for 6-22-97, 1745 UTC


McIDAS-X 7.100: rscofiel@orbit1h
WIN (MPS) 300 MB TIME 12Z DAY 97173 VALID 97173/12Z
300 MB WINDS JUNE 22 1997 1200 UTC

Precipitation Efficiency Factors

- **Precipitable Water (PW) values ---- higher than 1.0 inch, enhances Precipitation Efficiency**
- **Mean environmental Relative Humidity (RH) ---- higher than 65 % results in less dry air entrainment into cloud masses**

Precipitation Efficiency Factors

- **Depth of cloud with temperatures warmer than 0 degress C enhances the collision-coalescence process by increasing residence time of droplets in clouds --- this increases rainfall intensity and improves precipitation efficiency**

Precipitation Efficiency Factors

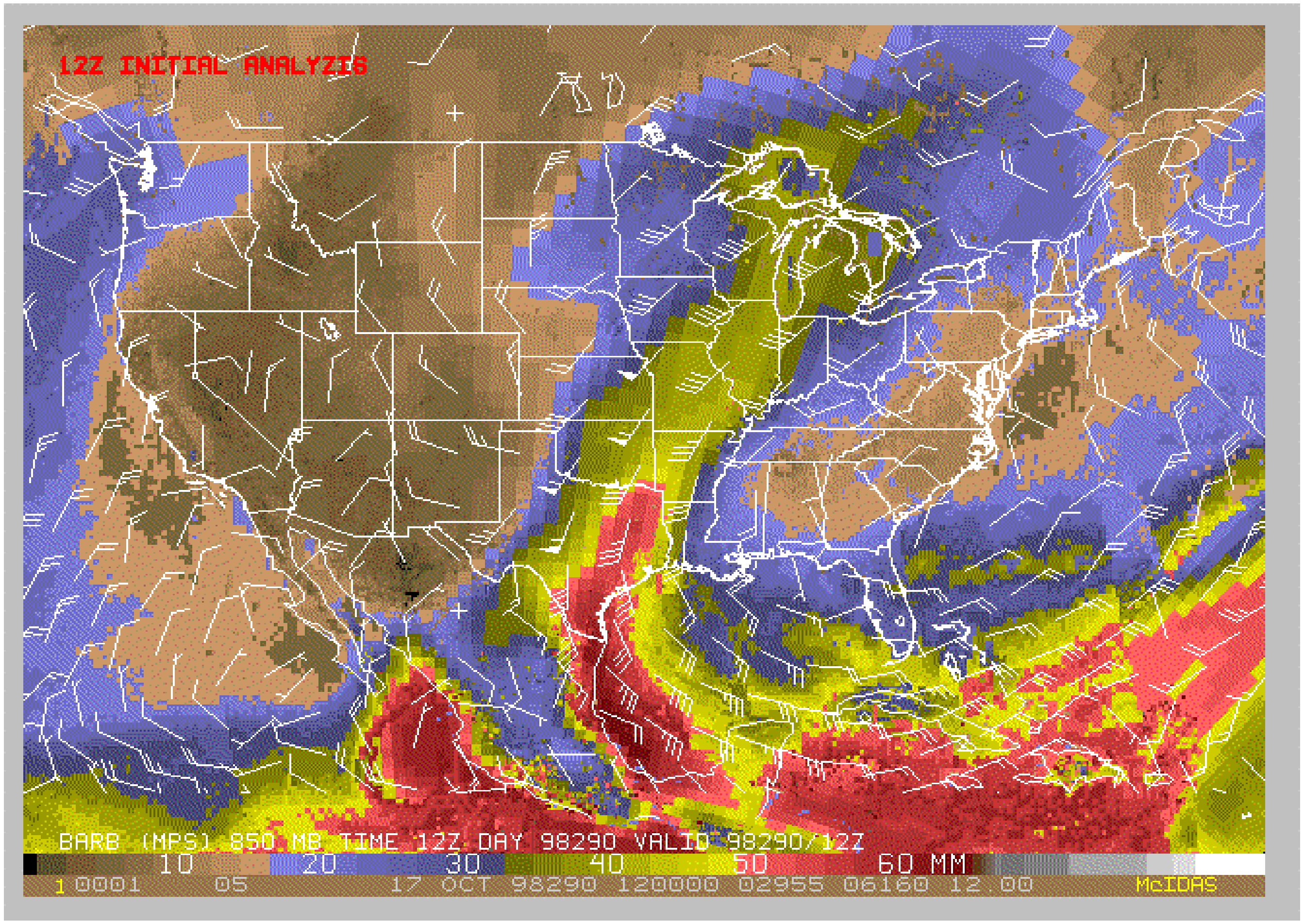
- **Vertical wind shear ---- produces entrainment and reduces Precipitation Efficiency, especially if environmental air is dry**
- **Cloud-scale vertical motion function of "CAPE" (Convective Available Potential Energy) related to condensate production and residence time of droplets**

Additional Precipitation Efficiency Factors

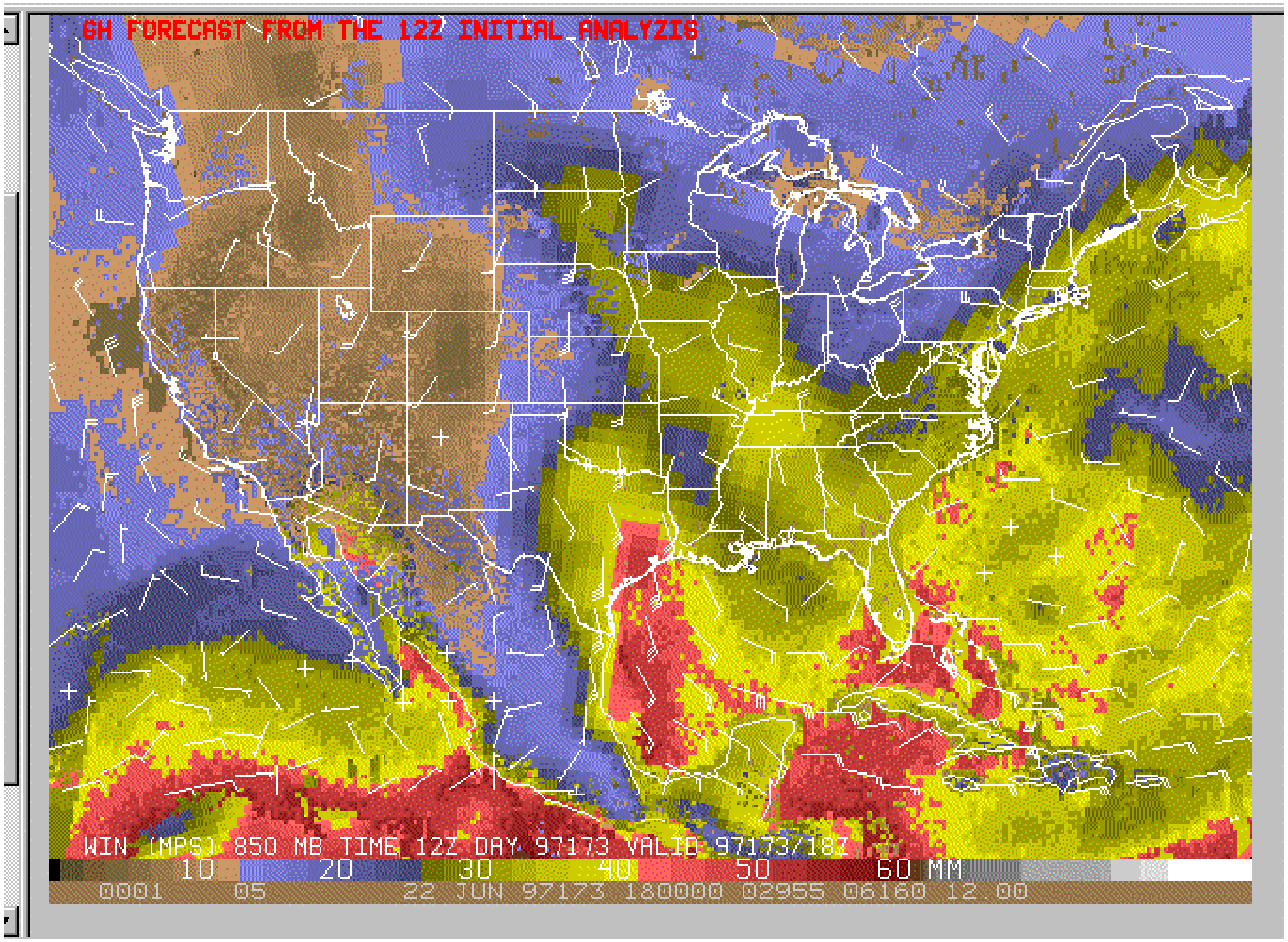
- **Storm-relative mean inflow and moisture transport into storm**
- **Duration of precipitation**

Use of Precipitable Water (PW) and Relative Humidity (RH) Data

- **magnitude**
- **transport (plumes)**
- **trends**
- **relation to equivalent potential temperature**



PW Plume: Composited PW (mm) (SSM/I + GOES + ETA model) for 10-17-98 1200 UTC; 850 mb winds are superimposed



PW Plume: Composited Precipitable Water Product (mm) for 6-22-97 1800 UTC; 850 mb winds superimposed

Precipitable Water Available

- **SSM/I (polar microwave)**
  - water only
- **GOES 8/9/10**
  - clear (cloud free) areas
- **National Center for Environmental Prediction (NCEP) "ETA" and "AVN" models**
- **Rawinsondes**
- **Composites (SSM/I + GOES 8/9/10 + ETA/AVN)**

Defense Meteorological Satellite Program/Special Sensor Microwave Imager (SSM/I) Channel most sensitive to Total Precipitable Water

22.235 GHz

GOES 8 Sounding Channels

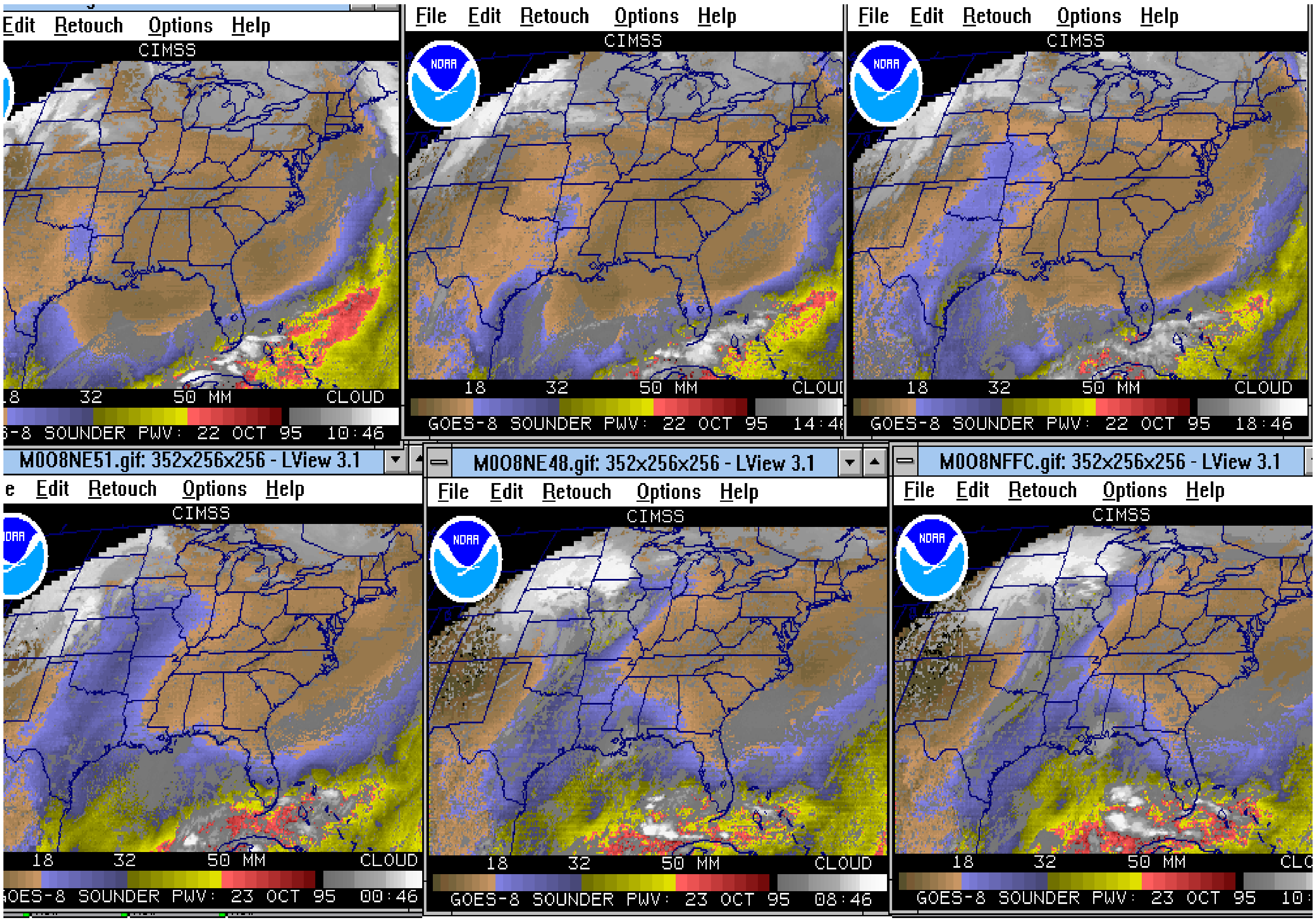
Sensitive to Precipitable Water (μm)

(over land and water, cannot calculate when clouds are present)

14.37; 14.06; 13.96; 13.37; 12.66; 12:02; 11.03;
7.43; 7.02; 6.51; 4.57; 4.52; 4.13

Cloud Detection

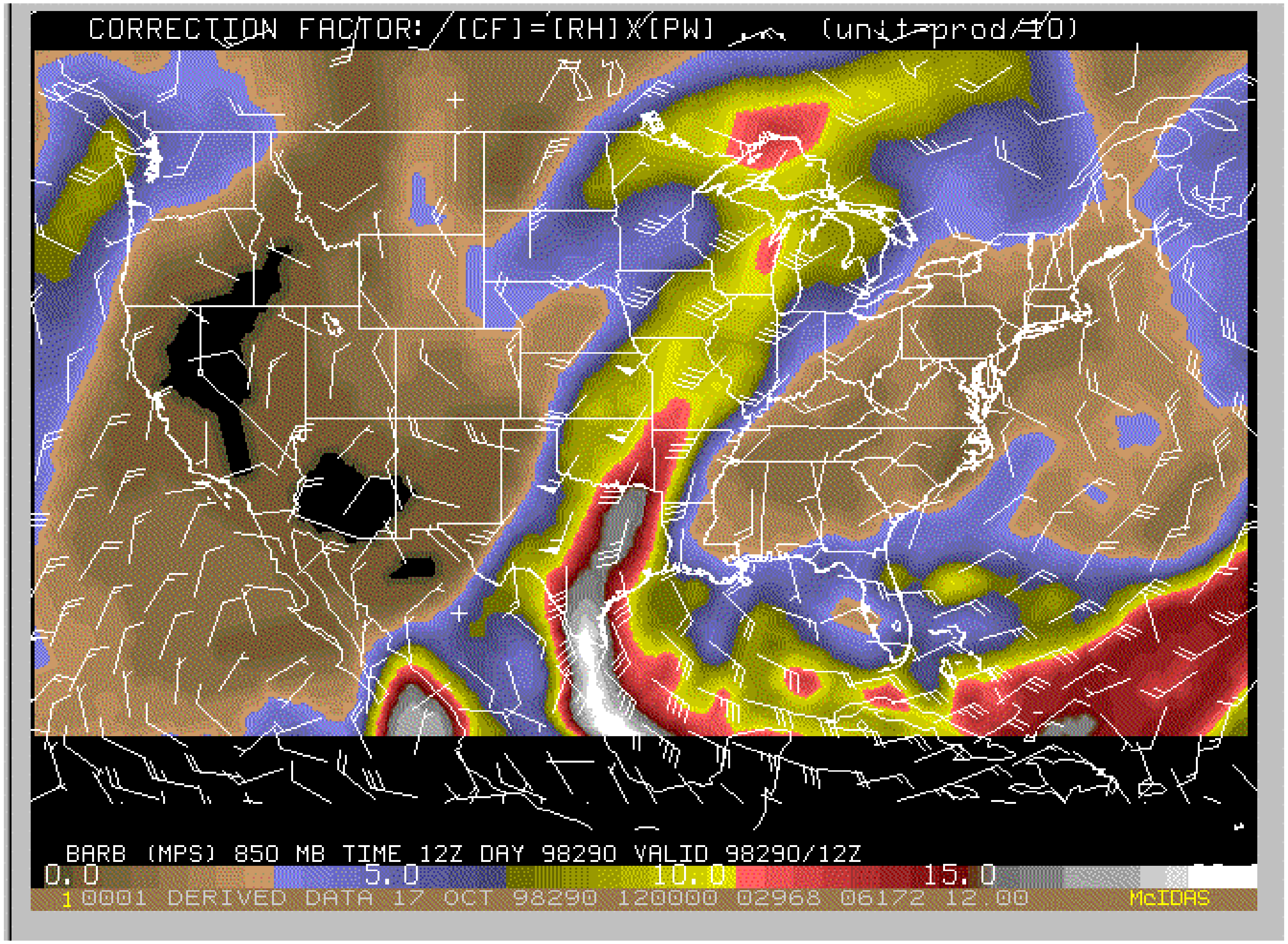
3.74 and 0.94



GOES Precipitable Water Products (mm) for October 22 - 23, 1995

Precipitable Water X Relative Humidity

- **Adjusts satellite-derived Quantitative Precipitation Estimates (QPE)**
- **Used in Quantitative Precipitation Forecasts (QPF) Techniques**



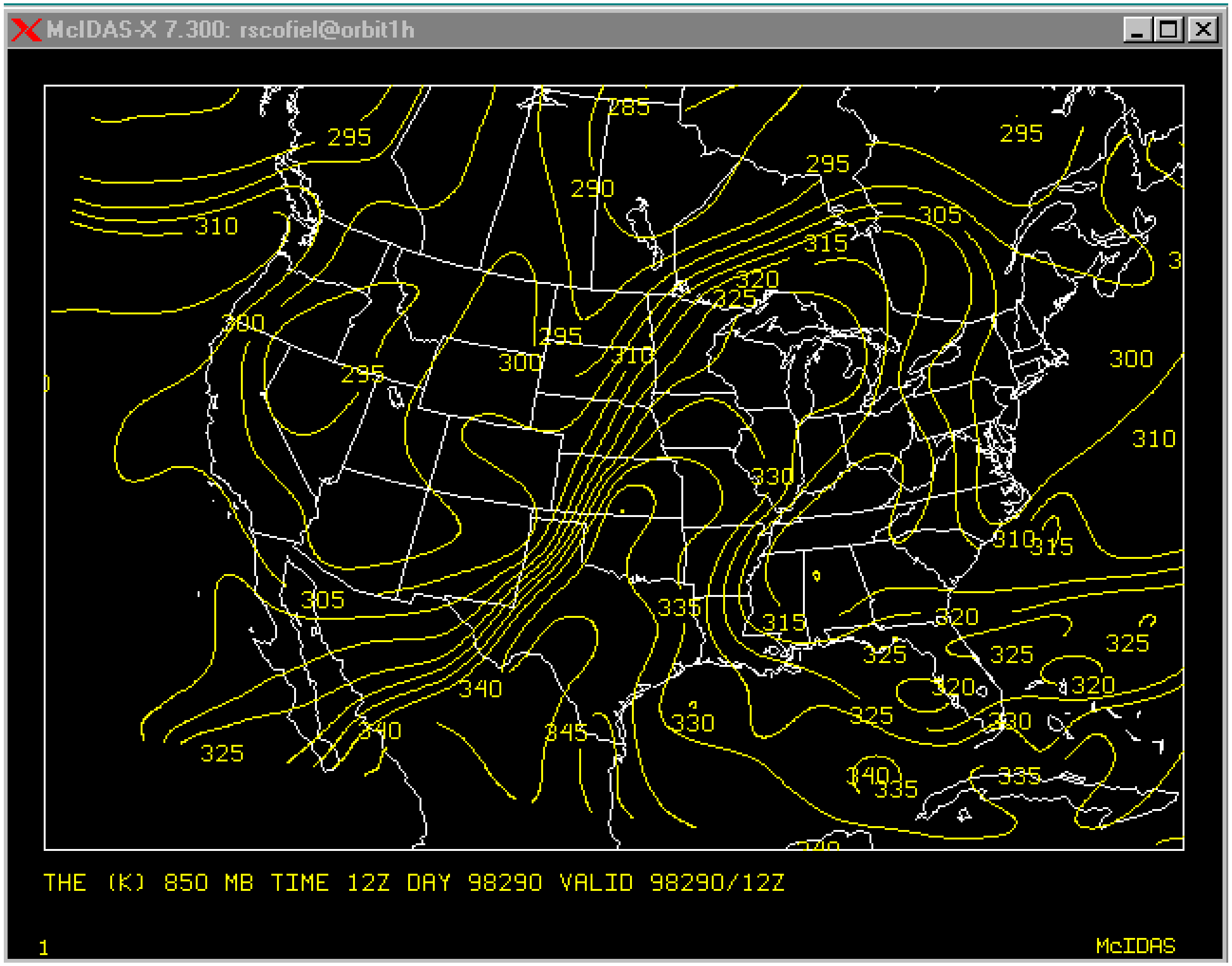
Precipitable Water (mm) X Relative Humidity for 10-17-98 1200 UTC from the ETA Model; 850 mb winds (mps) are superimposed

Equivalent Potential Temperature Ridge Axis

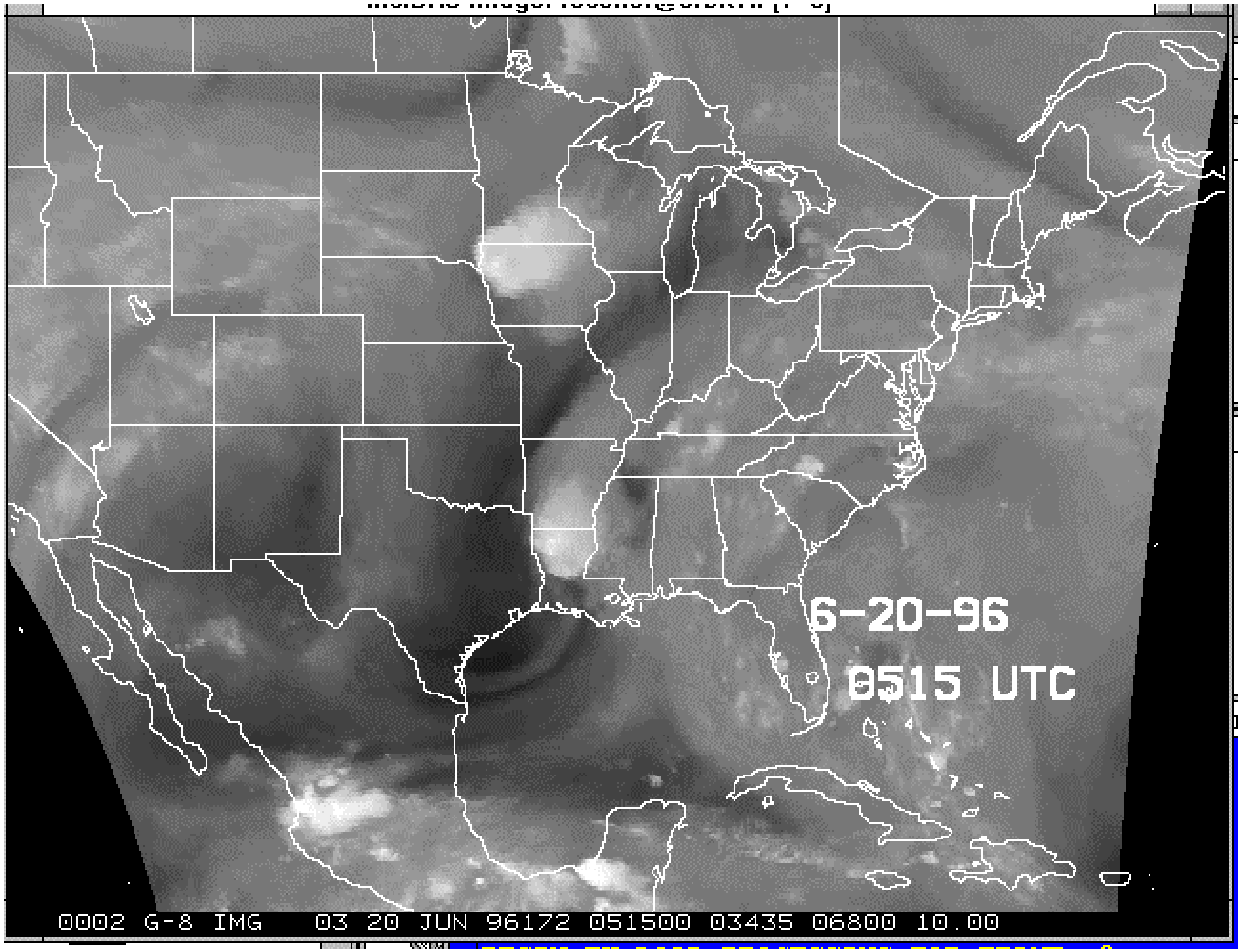
- **Represents a potential energy axis for convective development**
- **Conservative (similar to vorticity)**
- **“Maximum areas” are often associated with afternoon to evening convection**

Equivalent Potential Temperature Ridge Axis

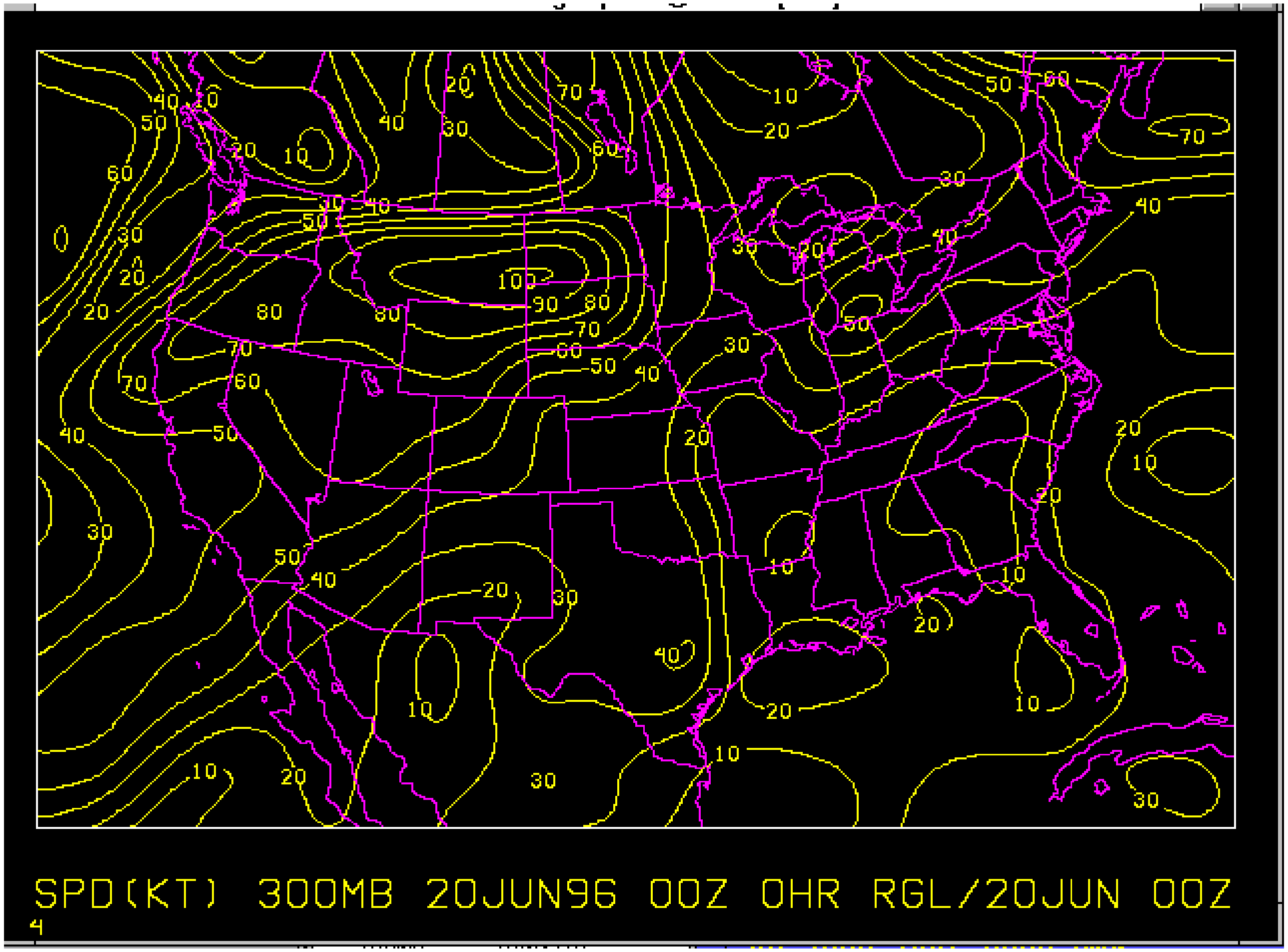
- **“Gradient areas” (especially north of the ridge axis) are often associated with “overrunning” nocturnal convection**



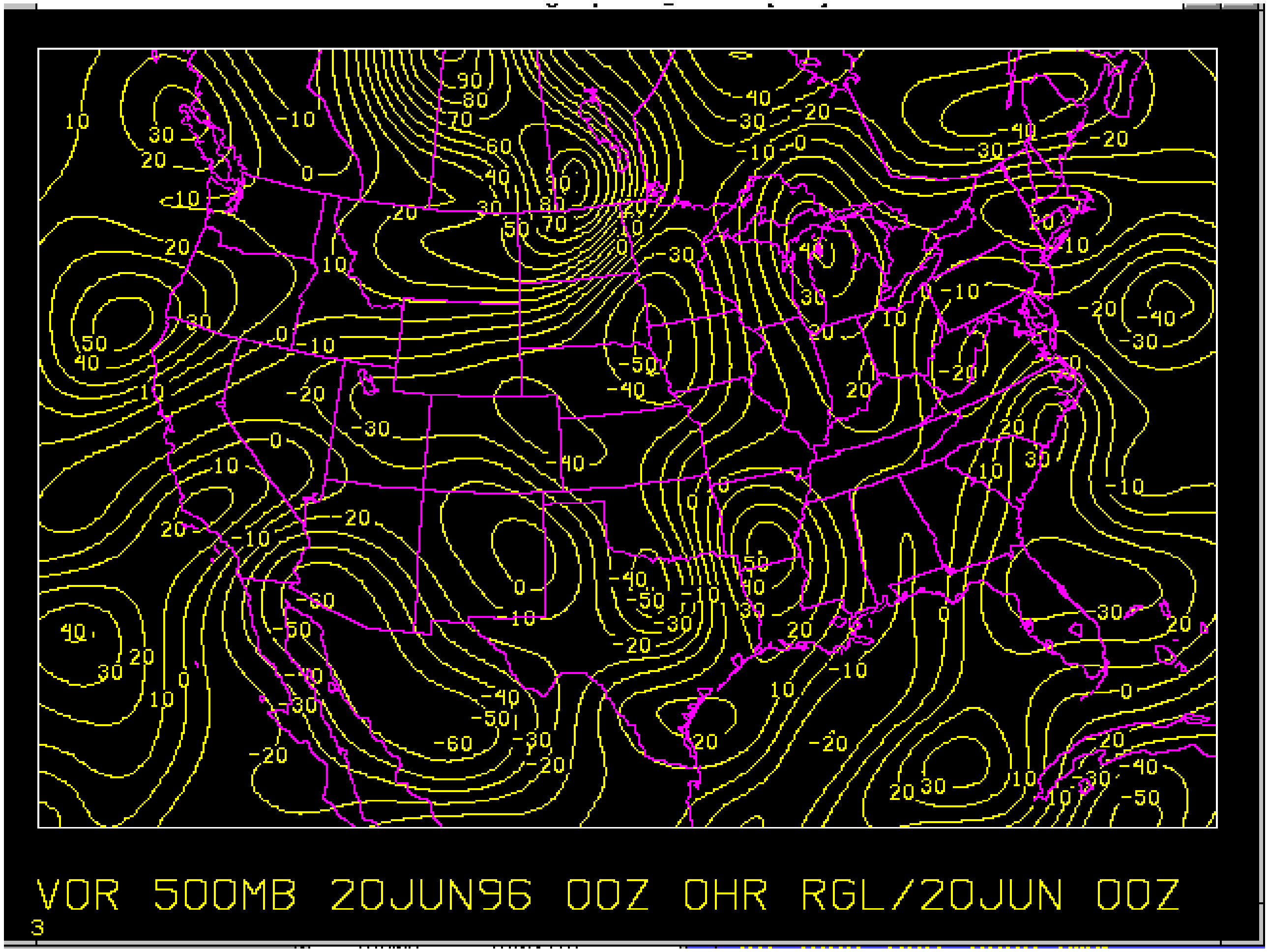
850 mb equivalent potential temperature (degrees K) for 10-17-98 1200 UTC



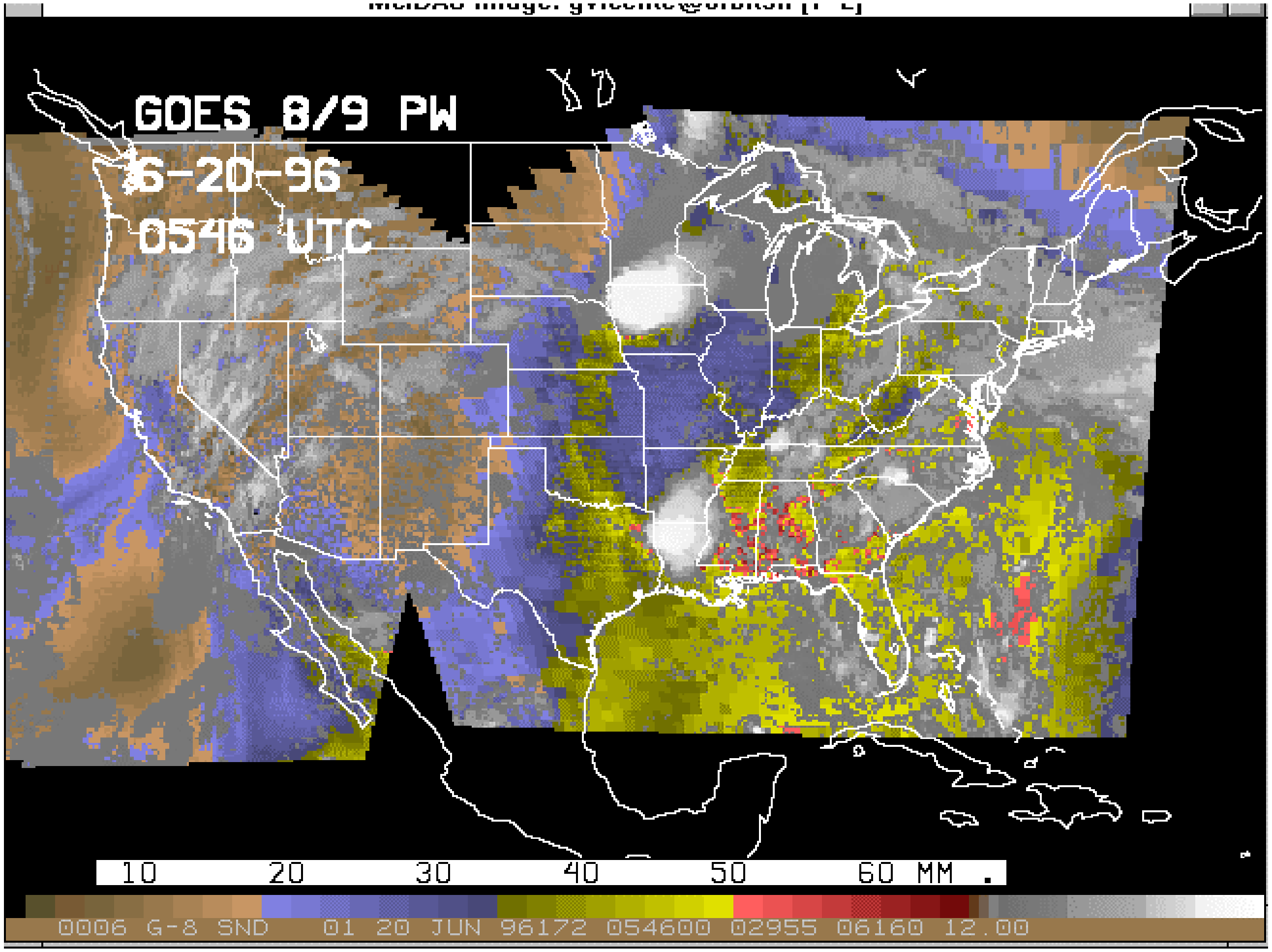
6.7 micron water vapor imagery for 6-20-96 0515 UTC



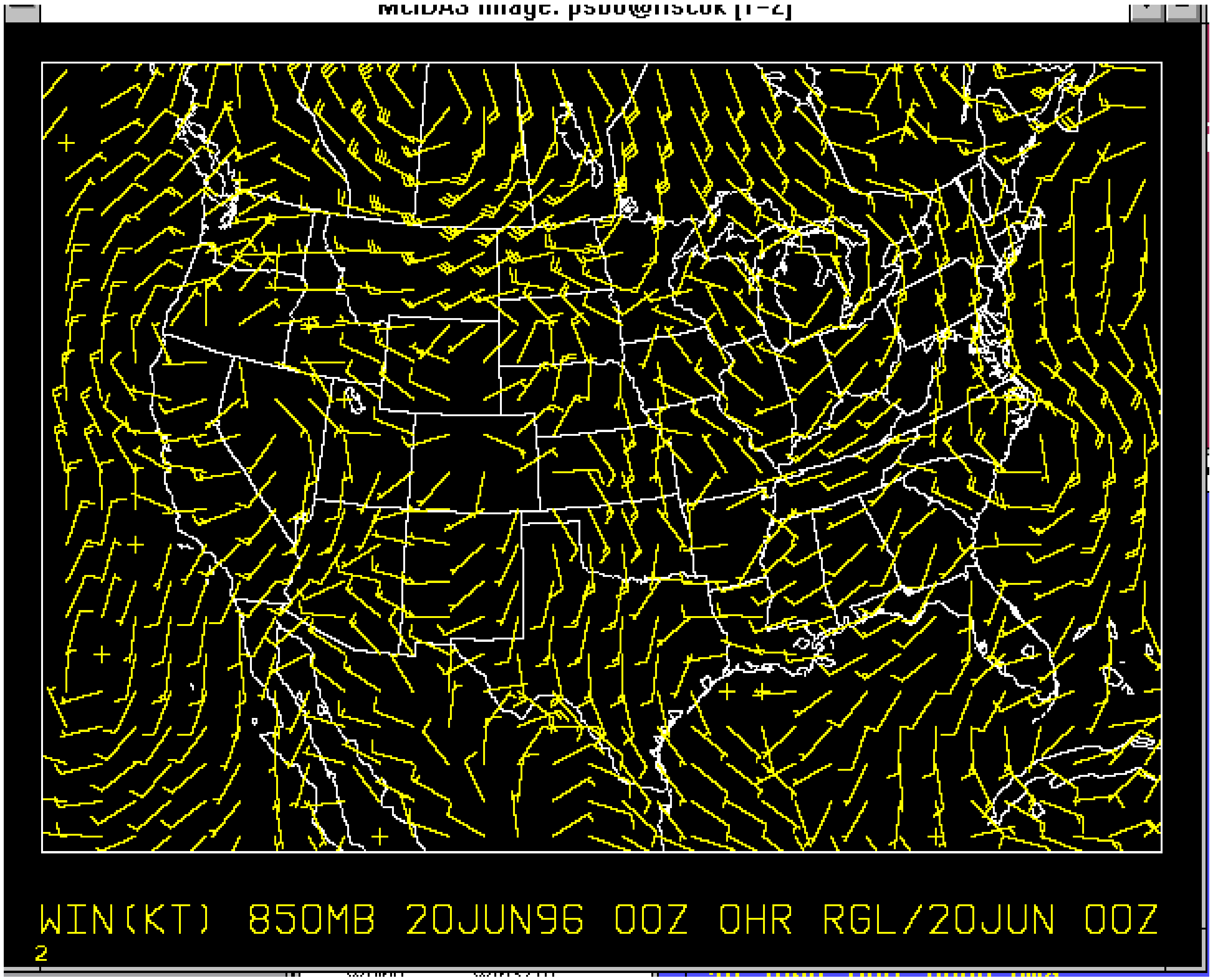
300 mb wind speed (kts) for 6-20-96 0000 UTC



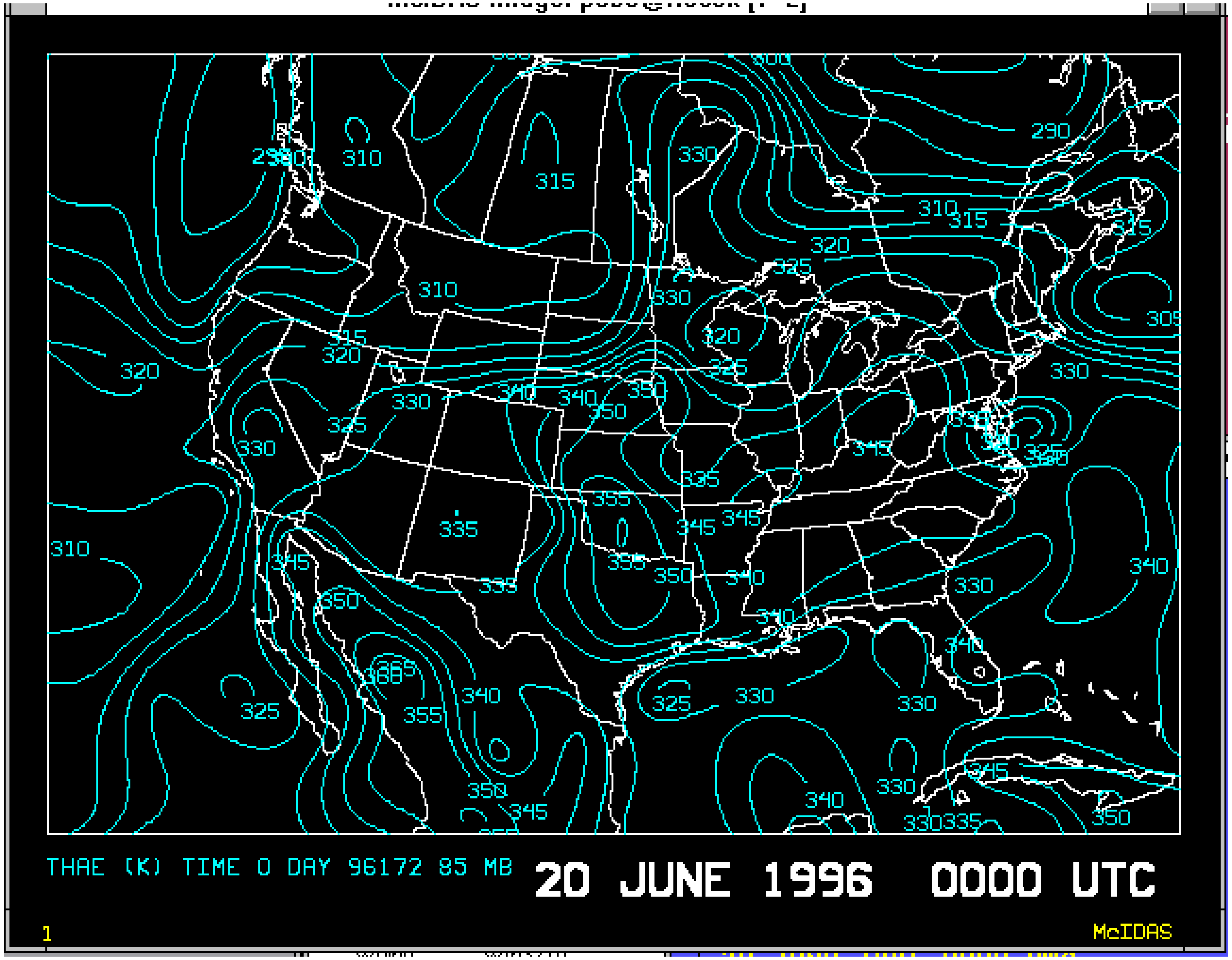
500 mb relative vorticity for 6-20-96 0000 UTC



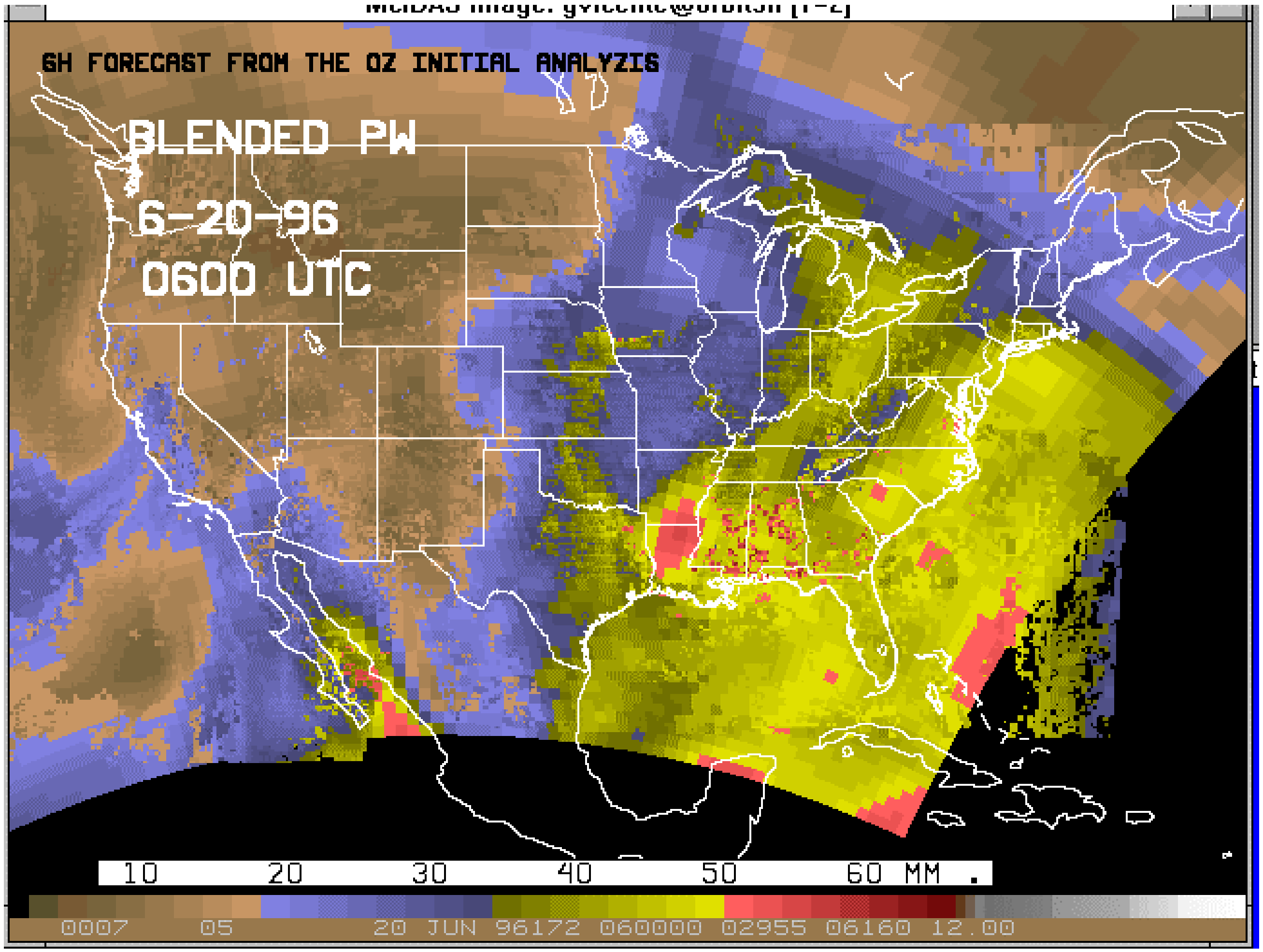
GOES 8/9 Precipitable Water Product (mm)
for 6-20-96 0546 UTC



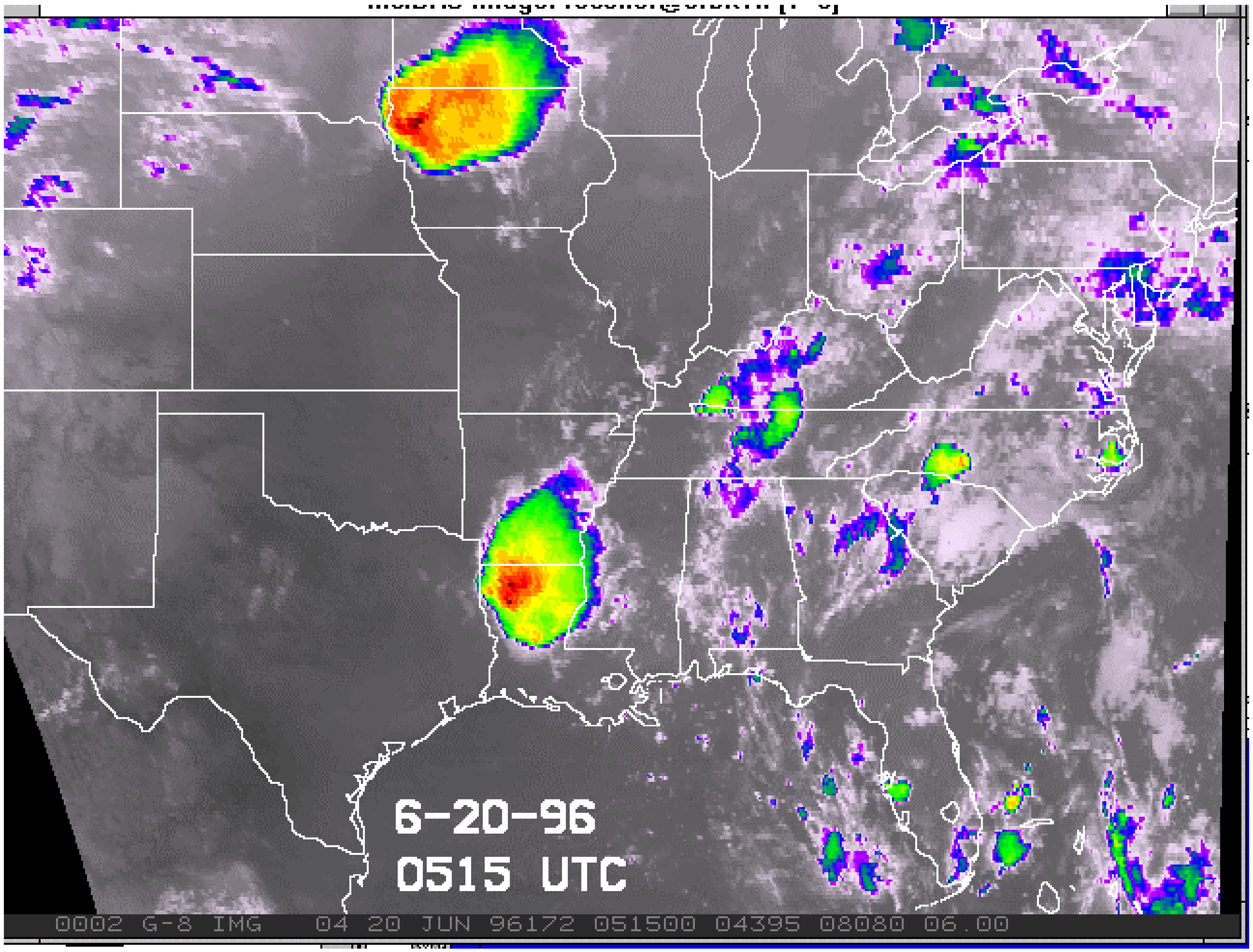
850 mb winds (kts) for 6-20-96 0000 UTC



850 mb equivalent potential temperature (degrees K) for 6-20-96 0000 UTC

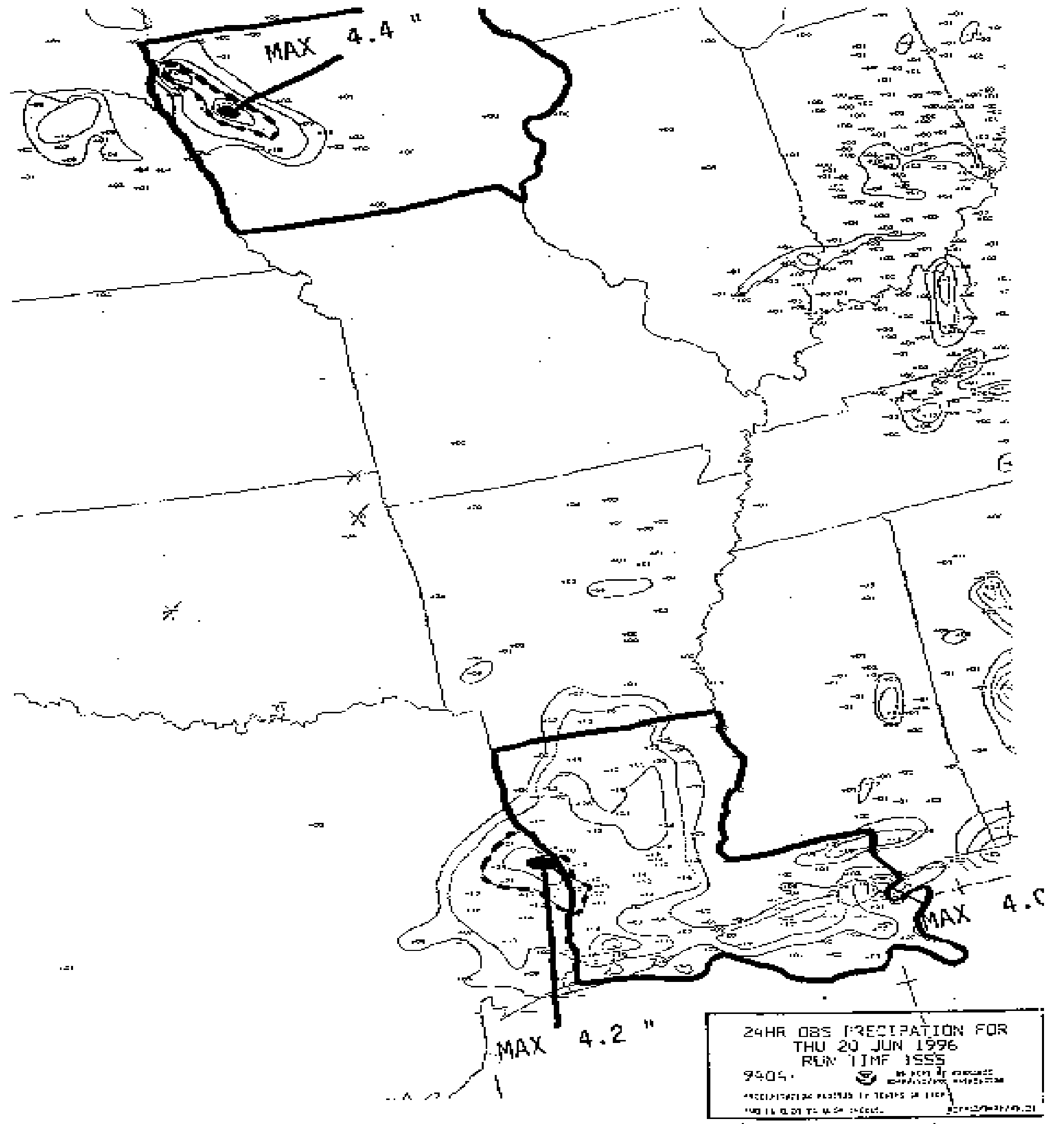


Composited Precipitable Water Product (mm) for 6-20-96 0600 UTC



Enhanced 10.7 micron infrared for 6-20-96, 1996 0515 UTC

24 hour observed rainfall (in) ending 6-20-96 1200 UTC



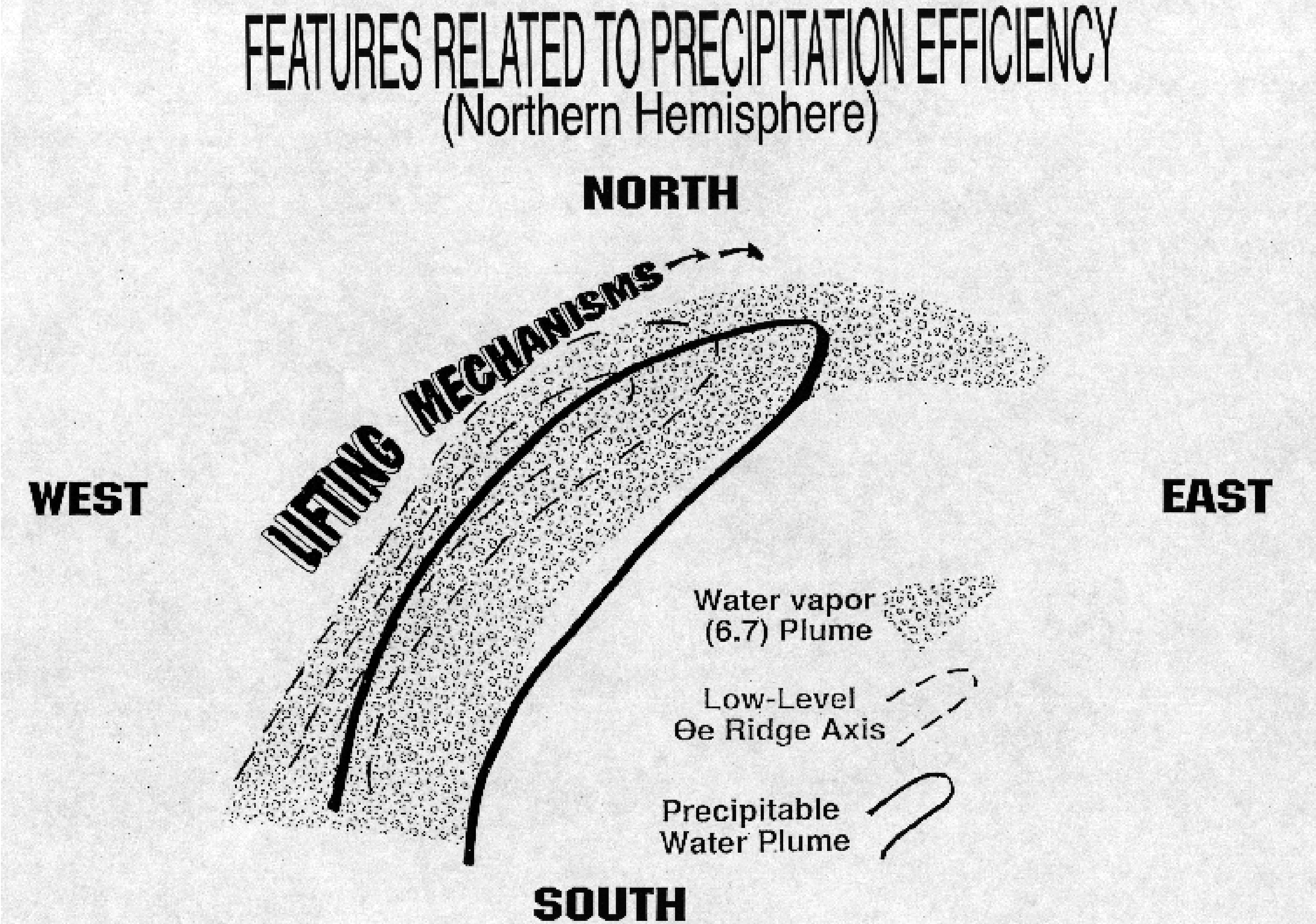


Figure 4. A conceptual model of the tropical water vapor and precipitable water plumes and

Short Waves (lifting mechanisms)

- **Dark areas detected in the 6.7 μm water vapor imagery:**
  - **mid-level cold air advection**
  - **jet streaks**
  - **positive vorticity advection**
  - **trough axes**
  - **height fall (rise) centers**

Short Waves
(lifting mechanisms)

- **Cirrus streaks (associated with jet streaks): 6.7 μm water vapor; 10.7 μm and visible**
- **Cyclonic circulation/lobes in the 6.7 μm water vapor; 10.7 μm and visible**

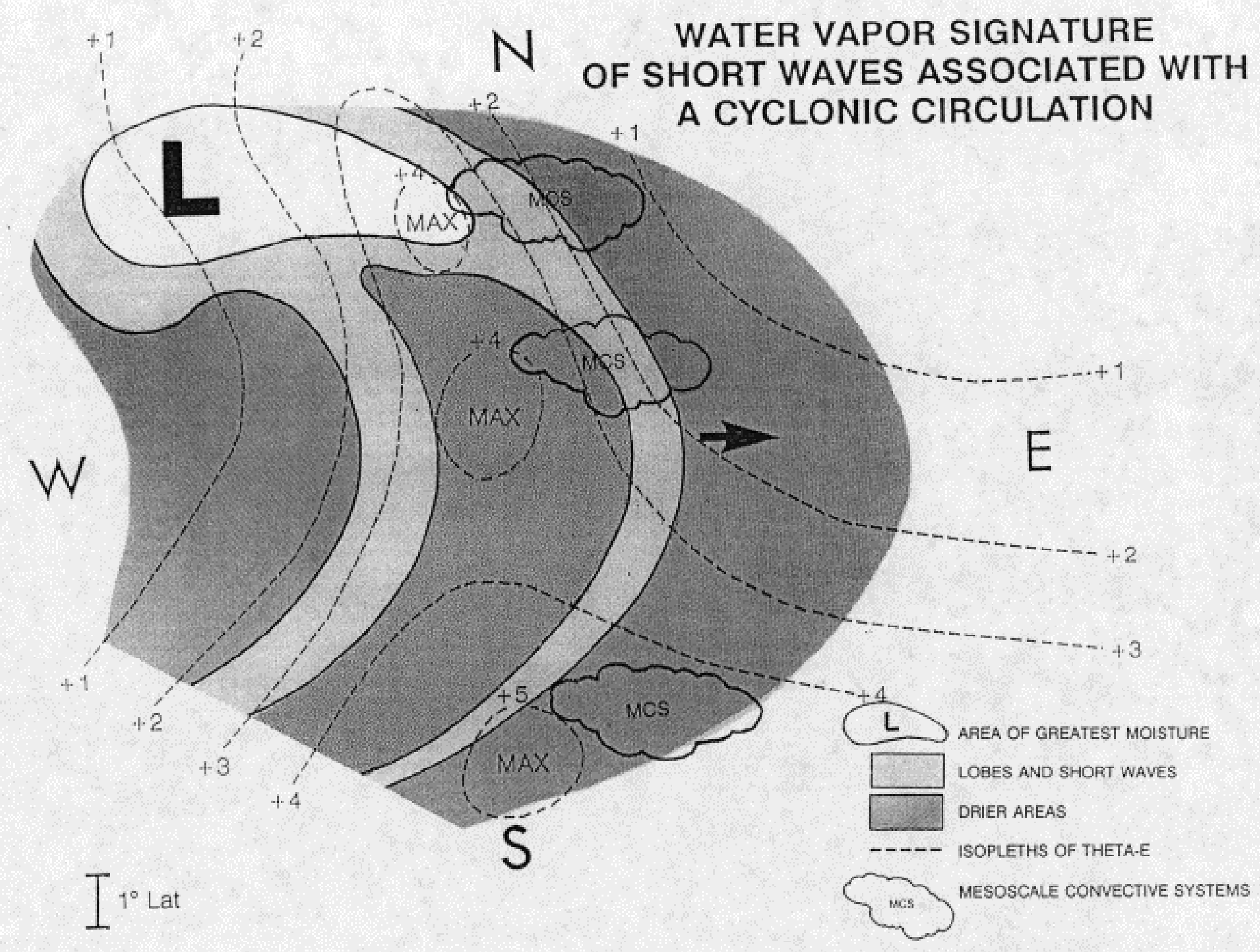
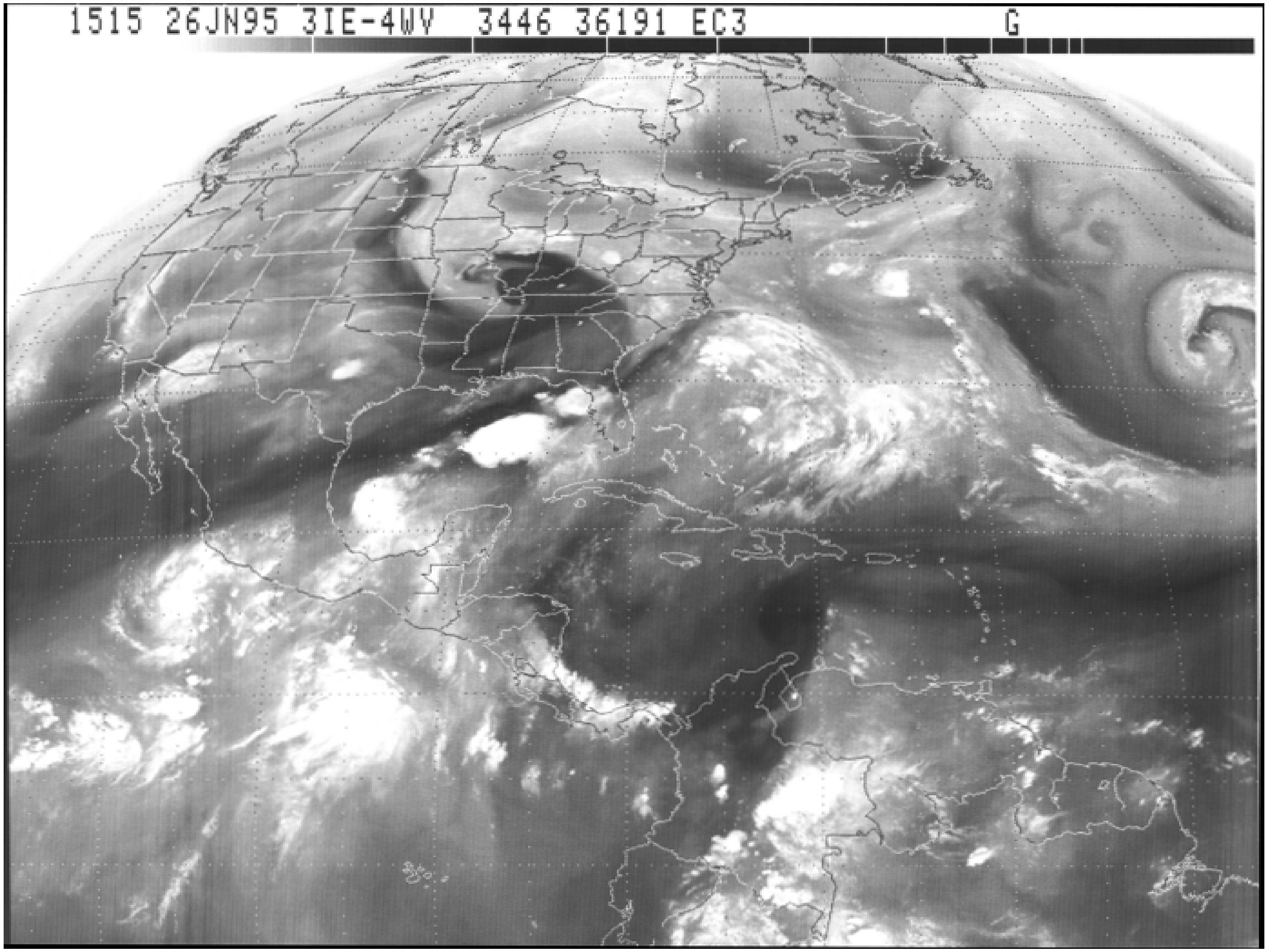
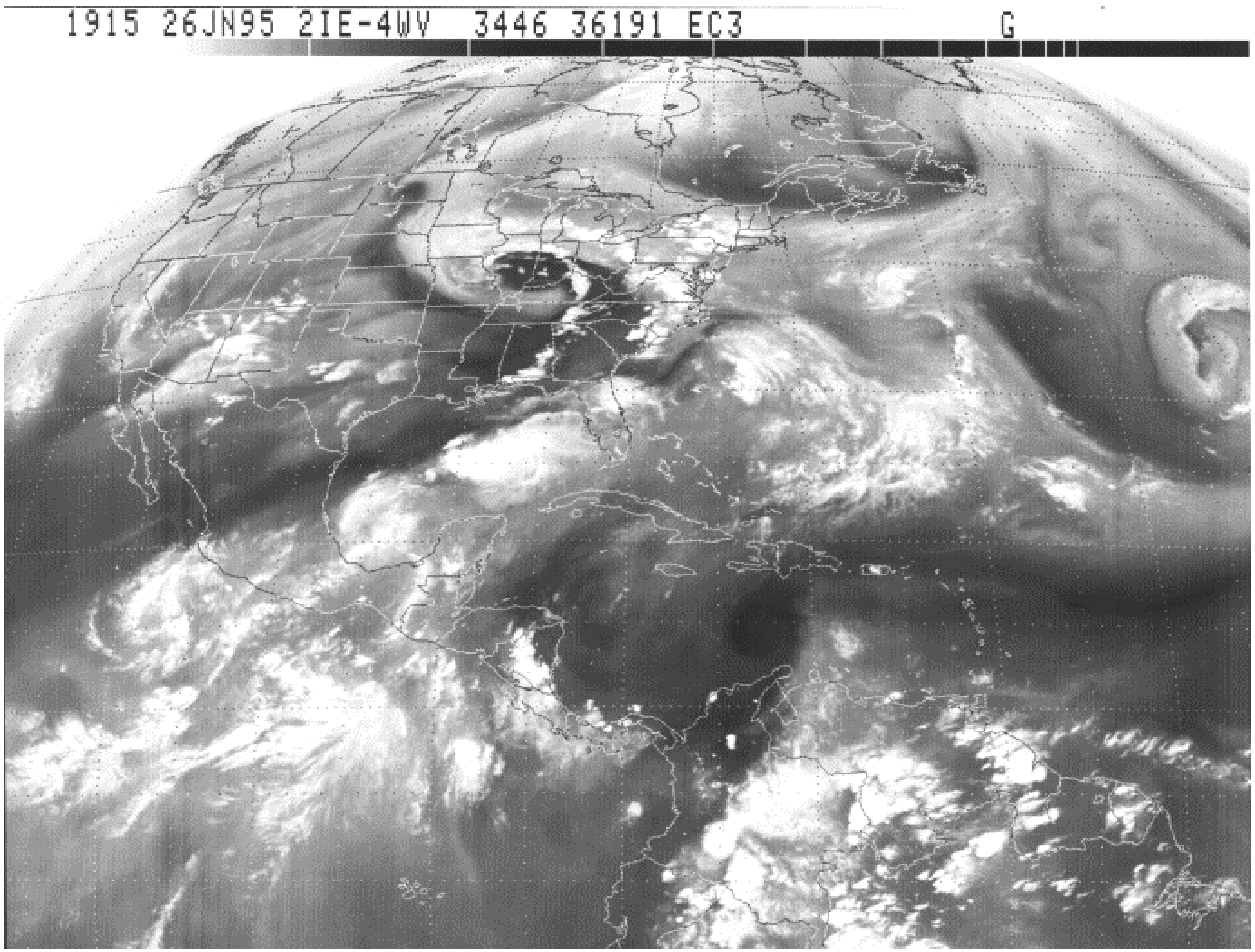


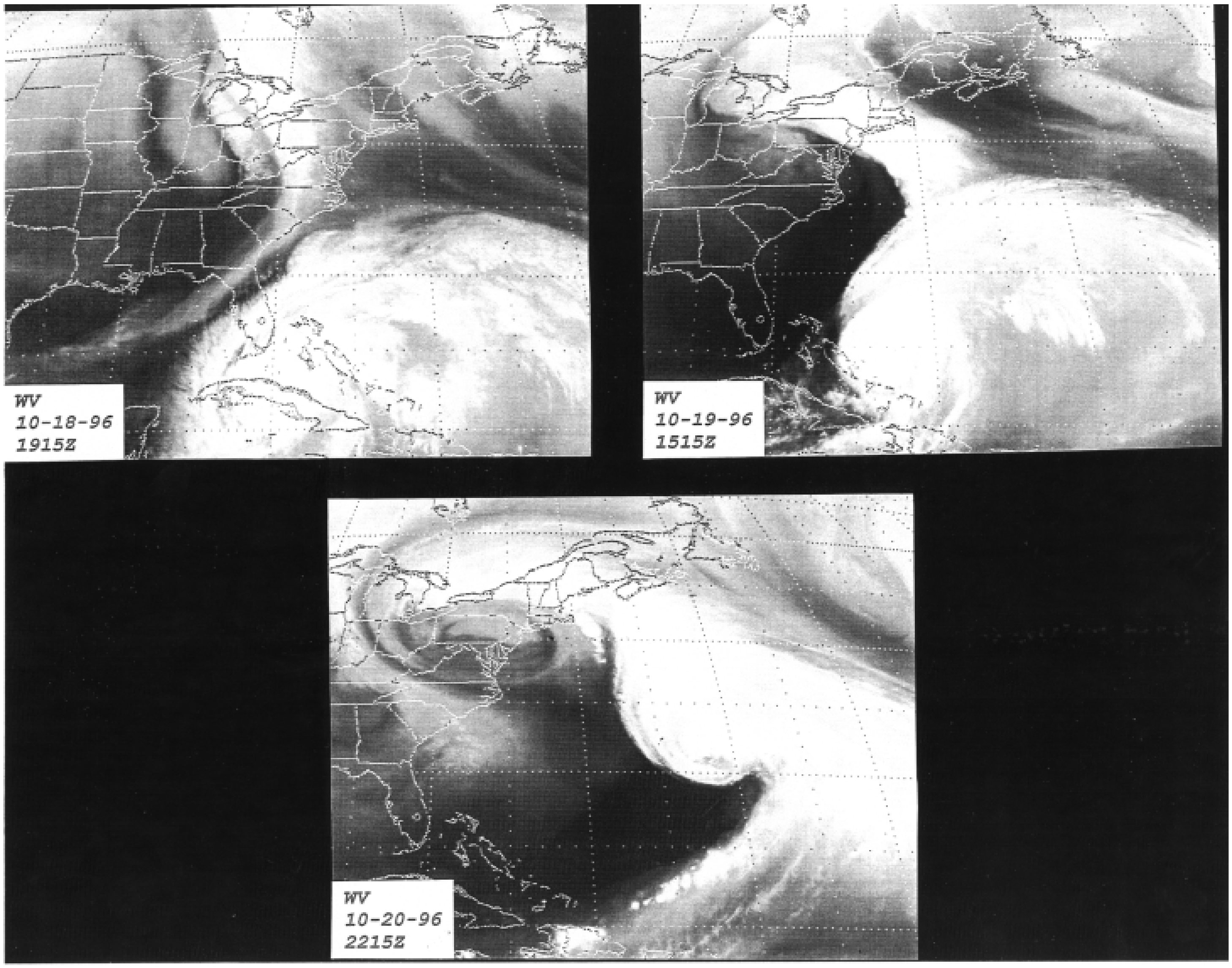
Figure 7b. Conceptual Model of vorticity lobes and short waves rotating around a cyclonic circulation --- as seen in the water vapor imagery.

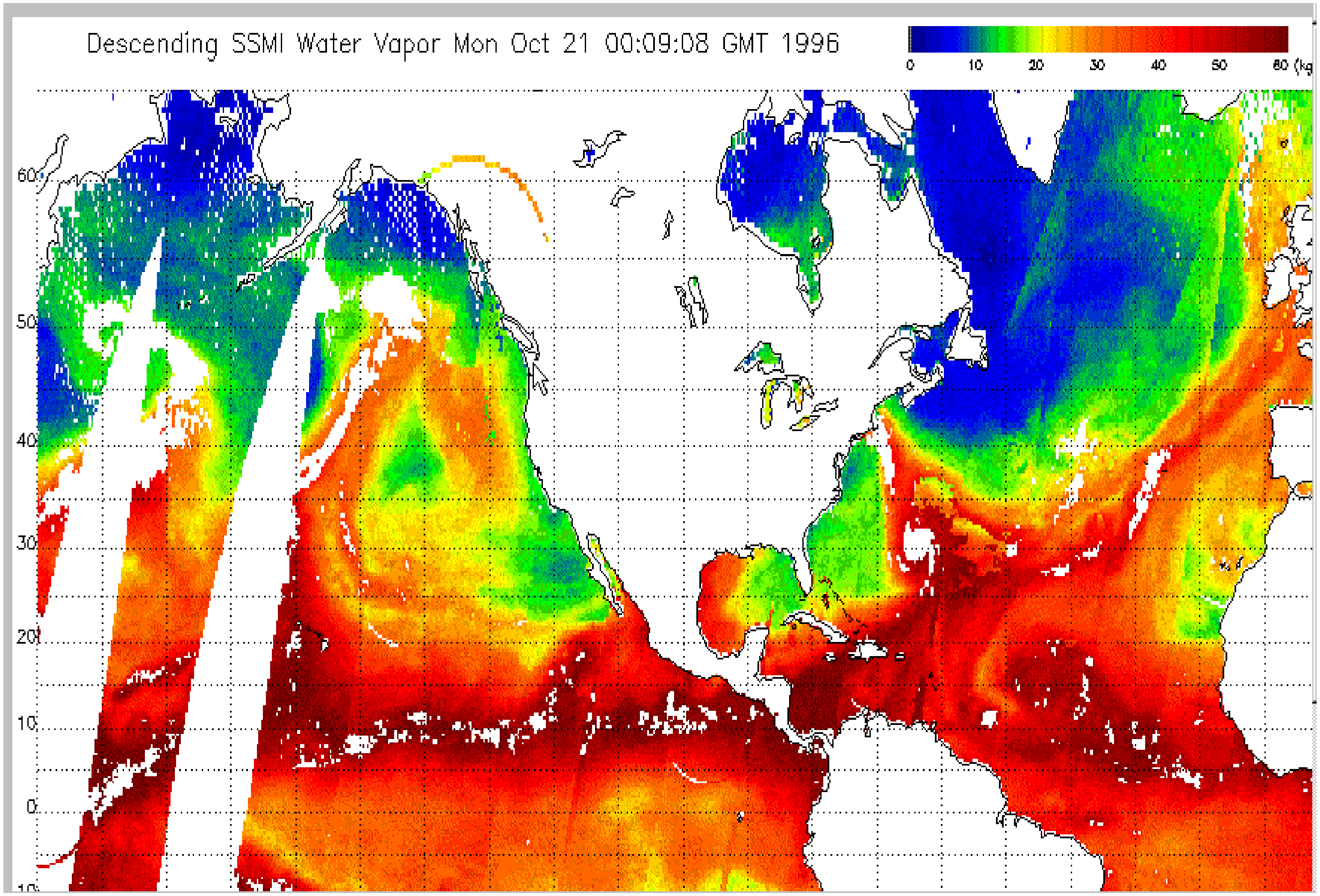


6.7 micron imagery for 6-26-95 1515 UTC

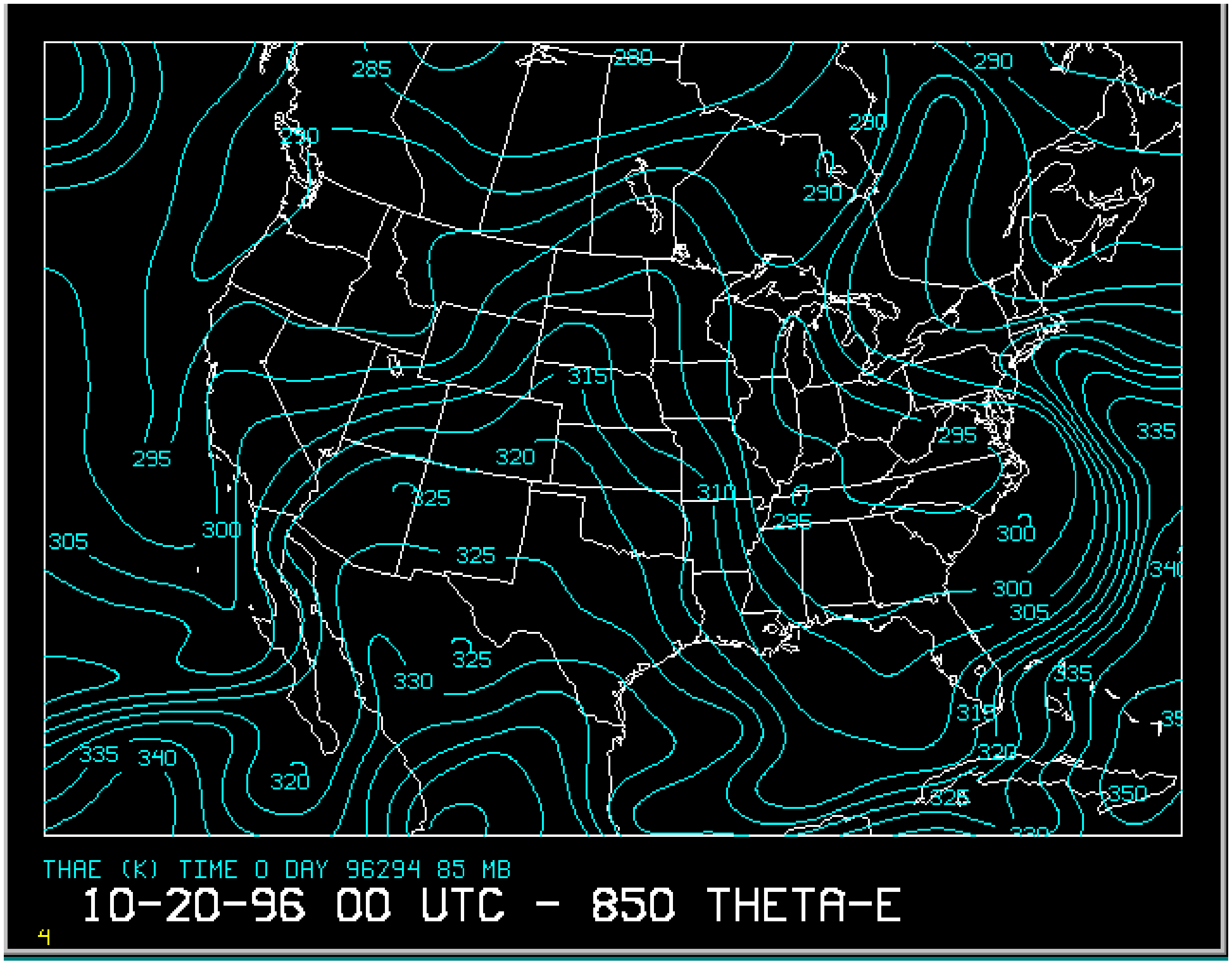


6.7 micron water vapor imagery for 6-26-95 1915 UTC

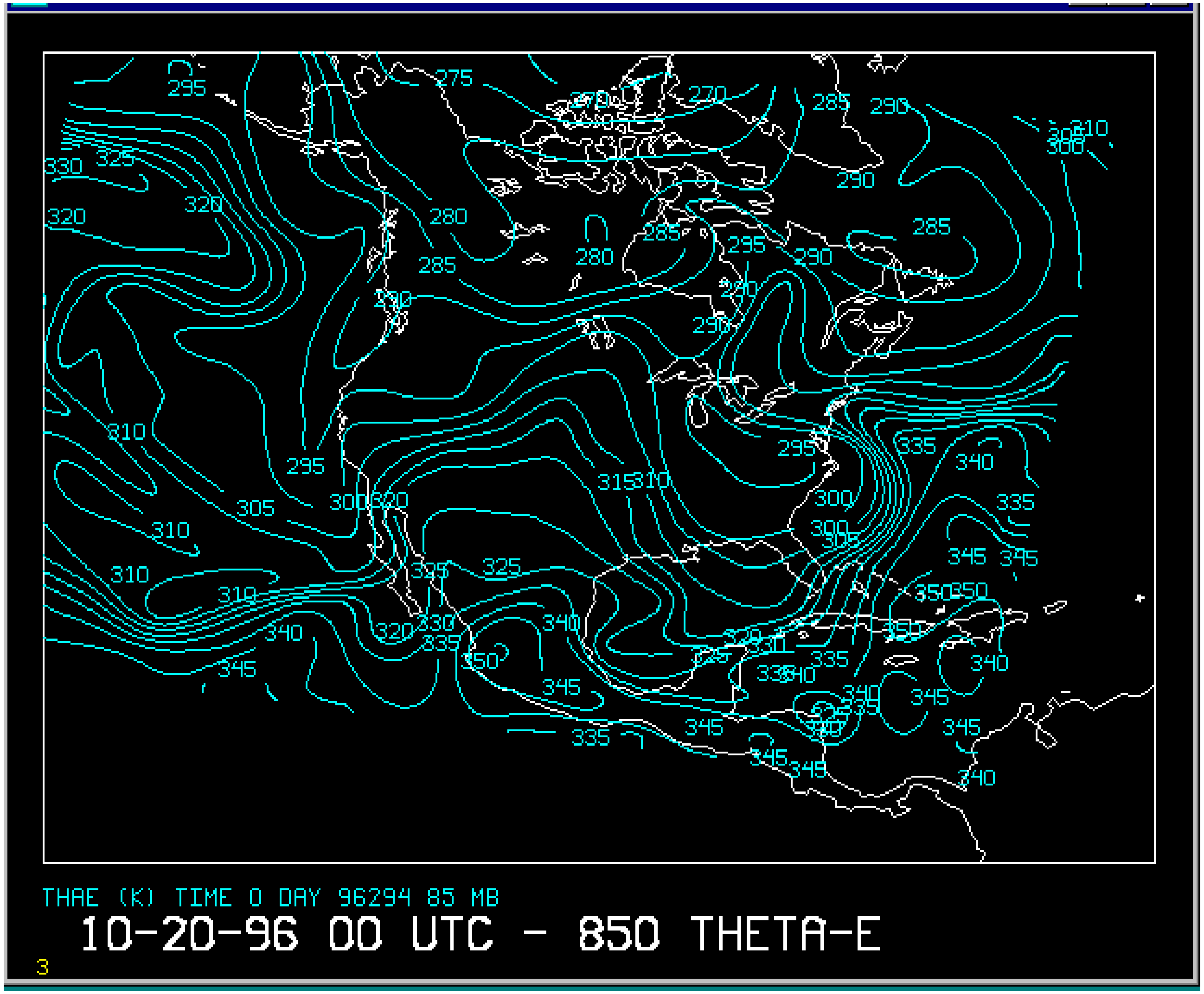

WV
10-18-96
1915Z
WV
10-19-96
1515Z
WV
10-20-96
2215Z



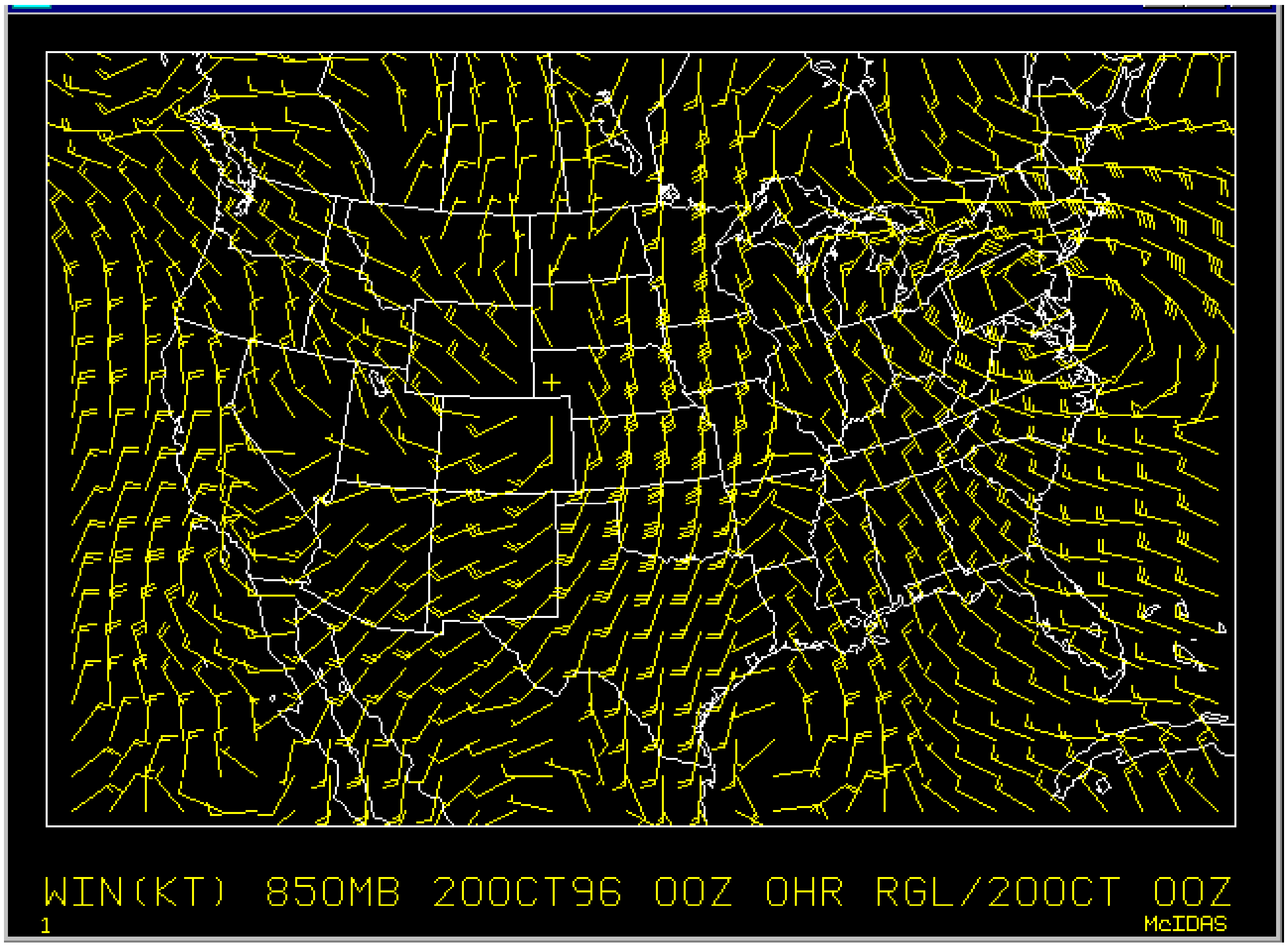
SSM/I PW (mm) for 10-21-96



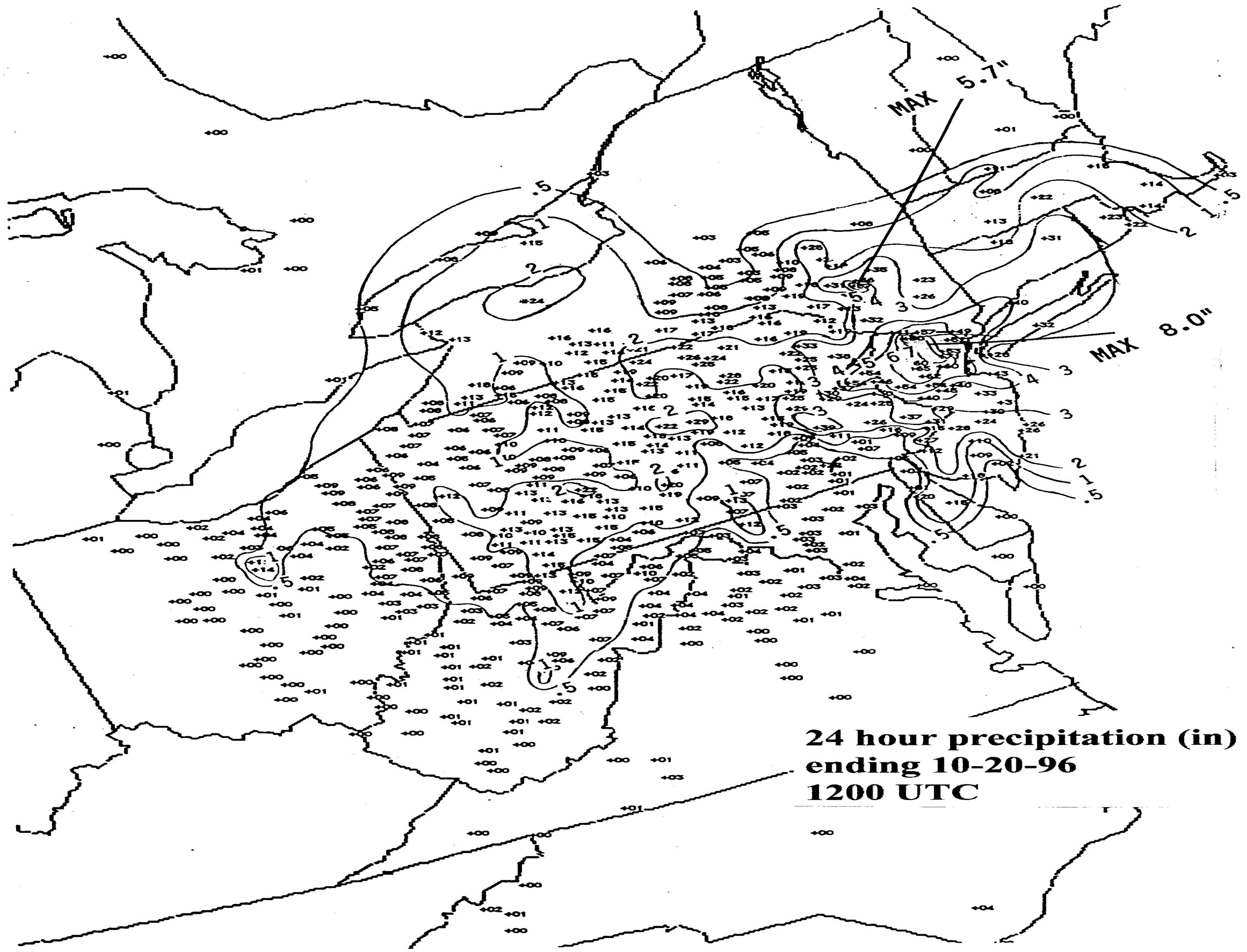
850 mb theta-e (degrees K) for 10-20-96 0000 UTC



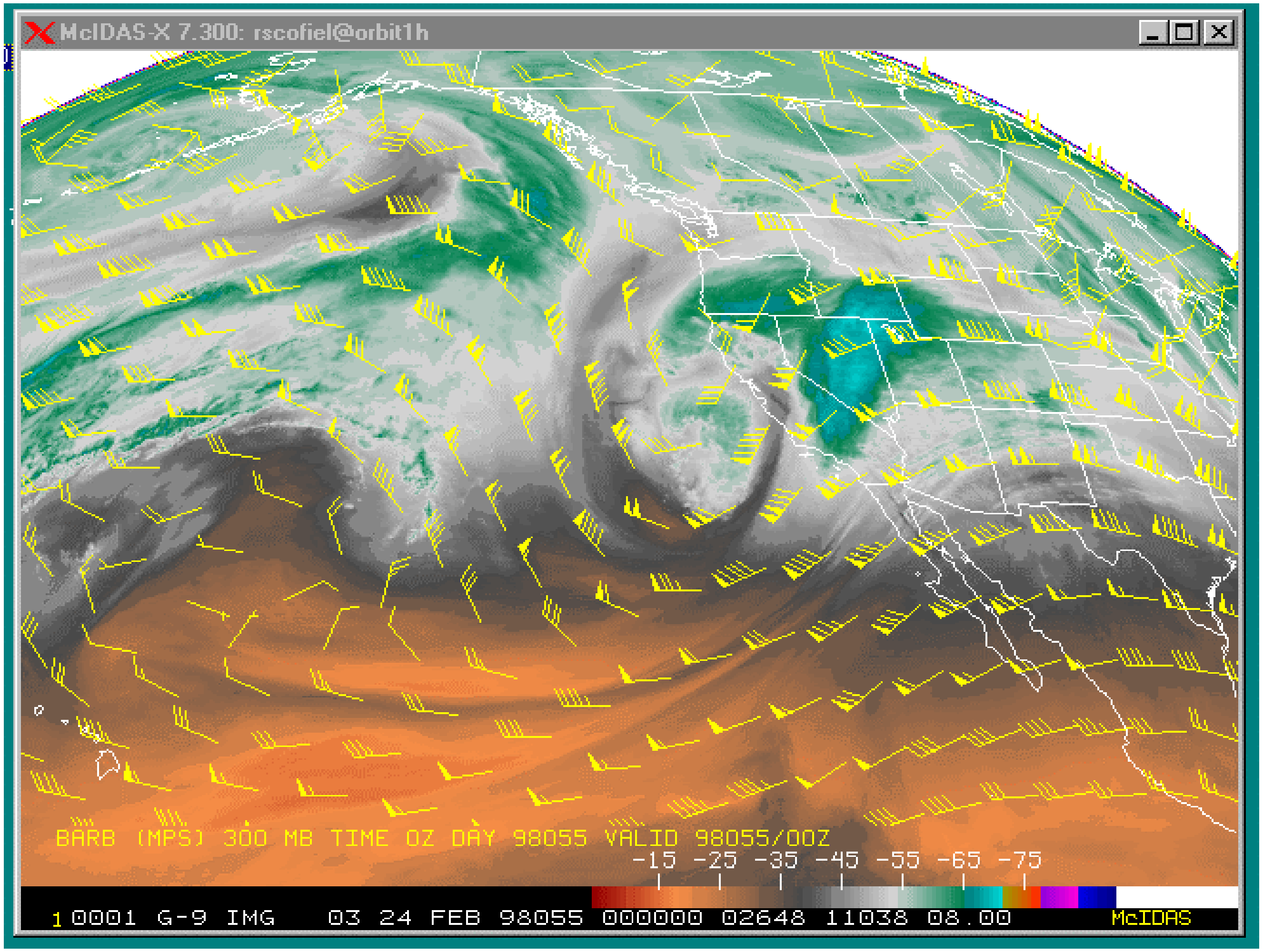
850 mb theta-e (degrees K) for 10-20-96 0000 UTC



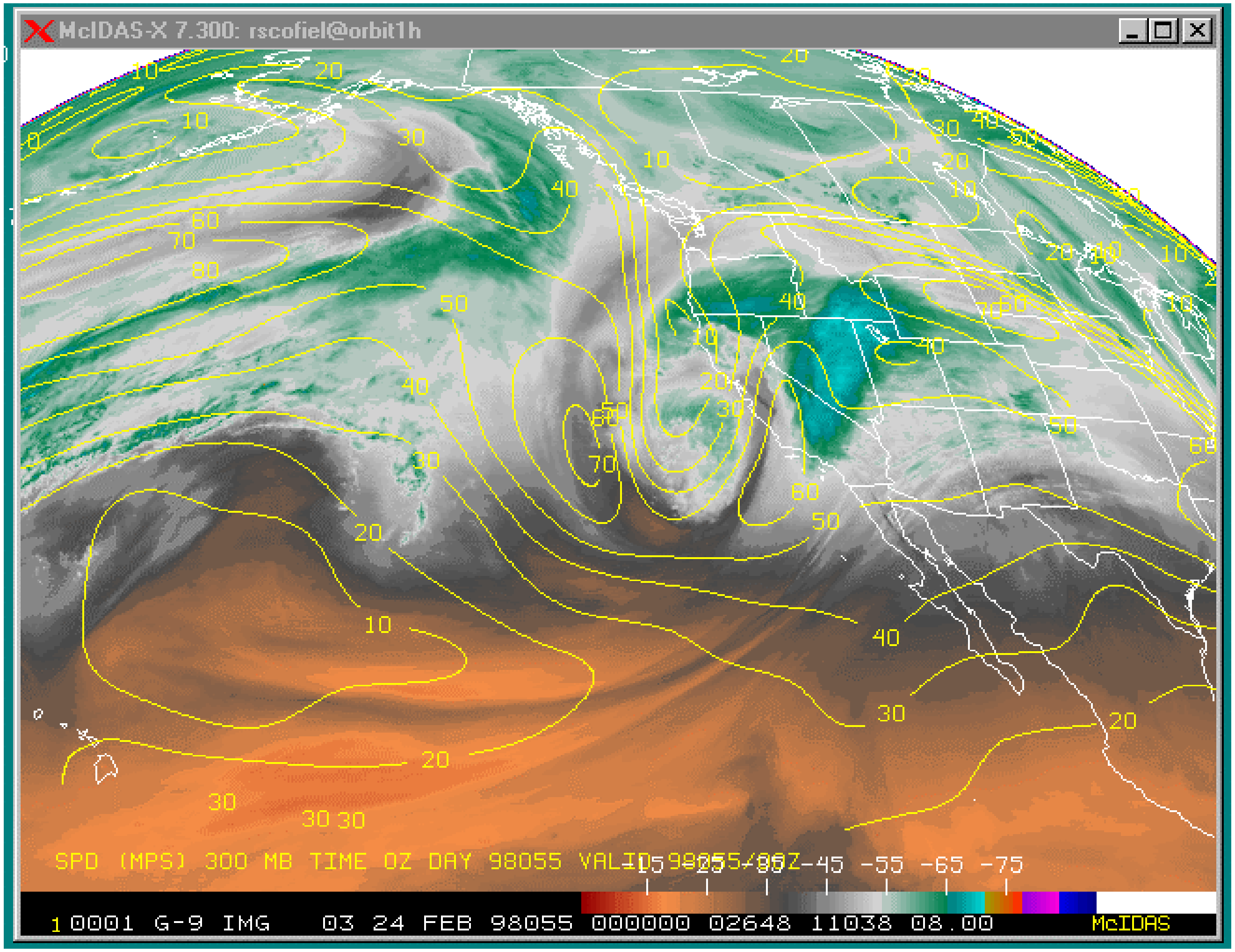
850 mb winds (kts) for 10-20-96 0000 UTC



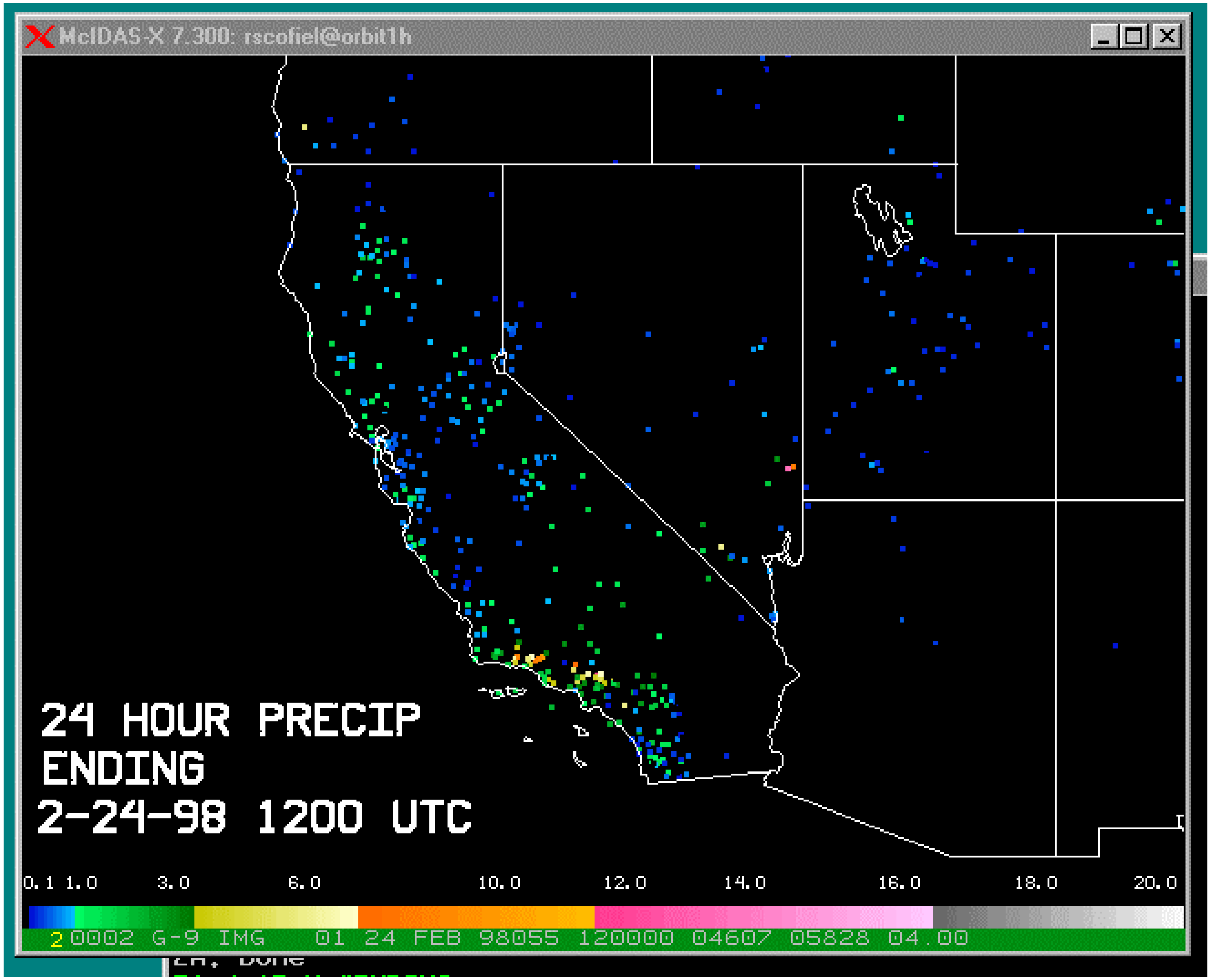
24 hour precipitation (in)
ending 10-20-96
1200 UTC



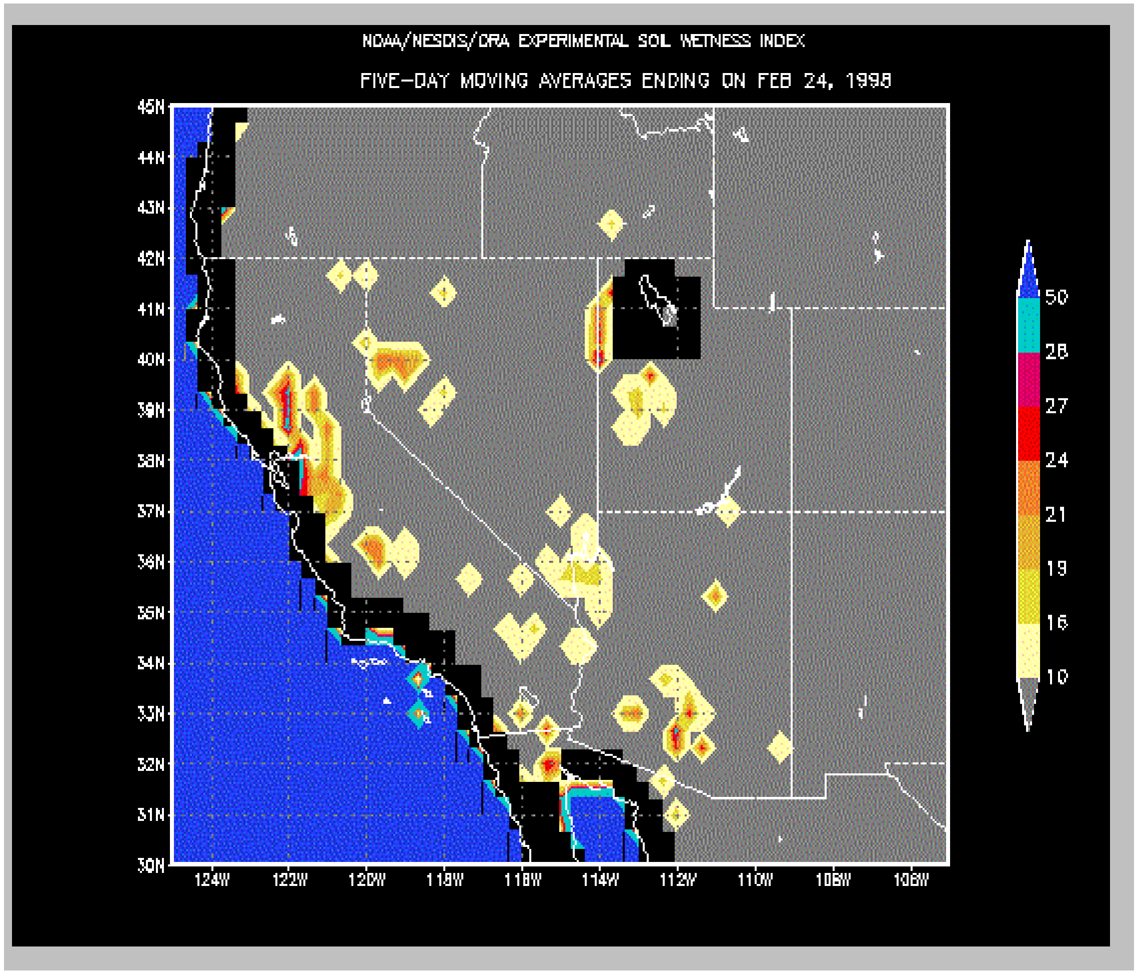
6.7 micron water vapor imagery for 2-24-98, 0000 UTC; 300 mb winds (mps) are superimposed



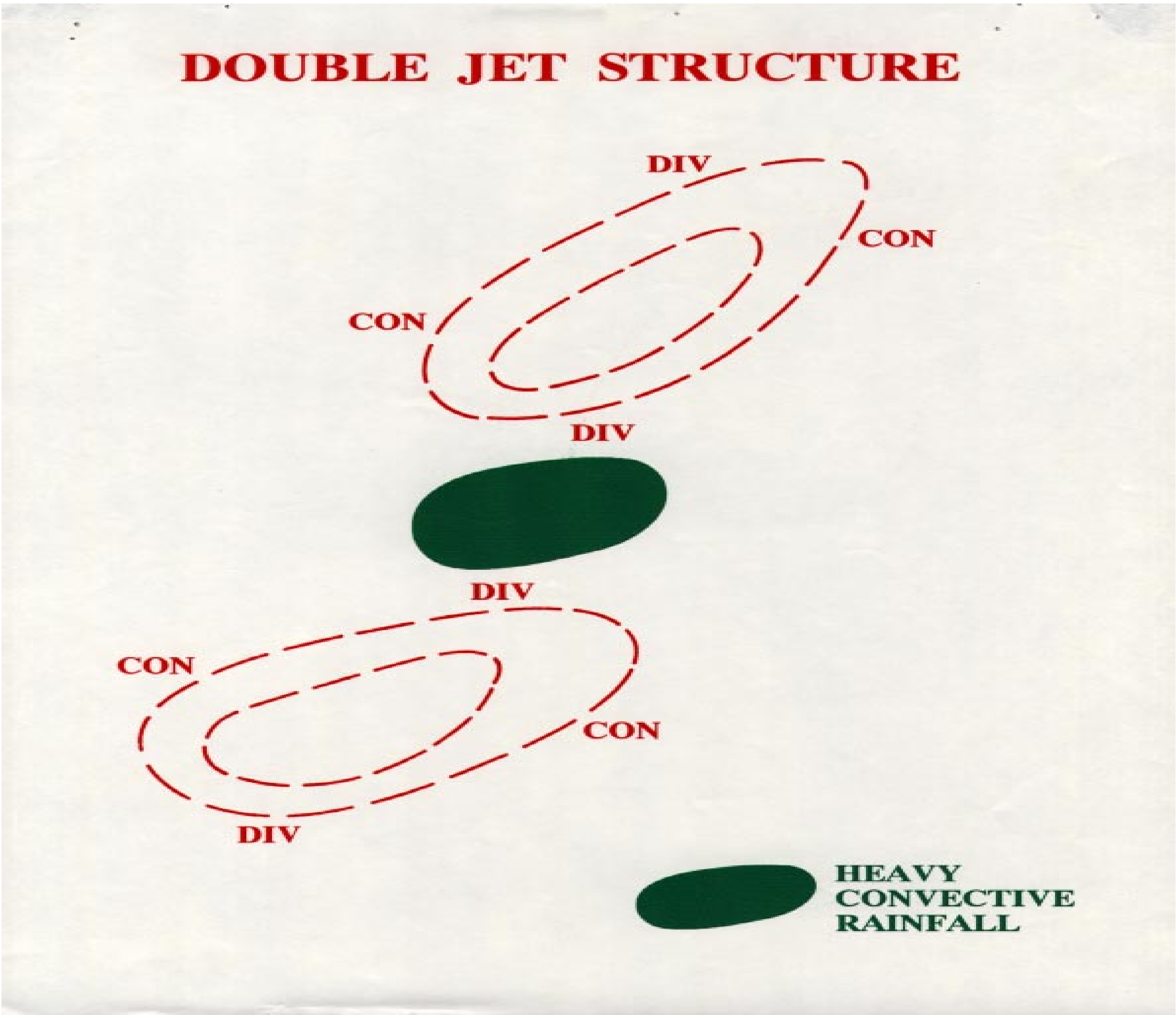
6.7 micron water vapor imagery for 2-24-98 0000 UTC; 300 mb isotachs (mps) are superimposed



24 Hour Observed Precipitation (in) ending 2-24-98 1200 UTC

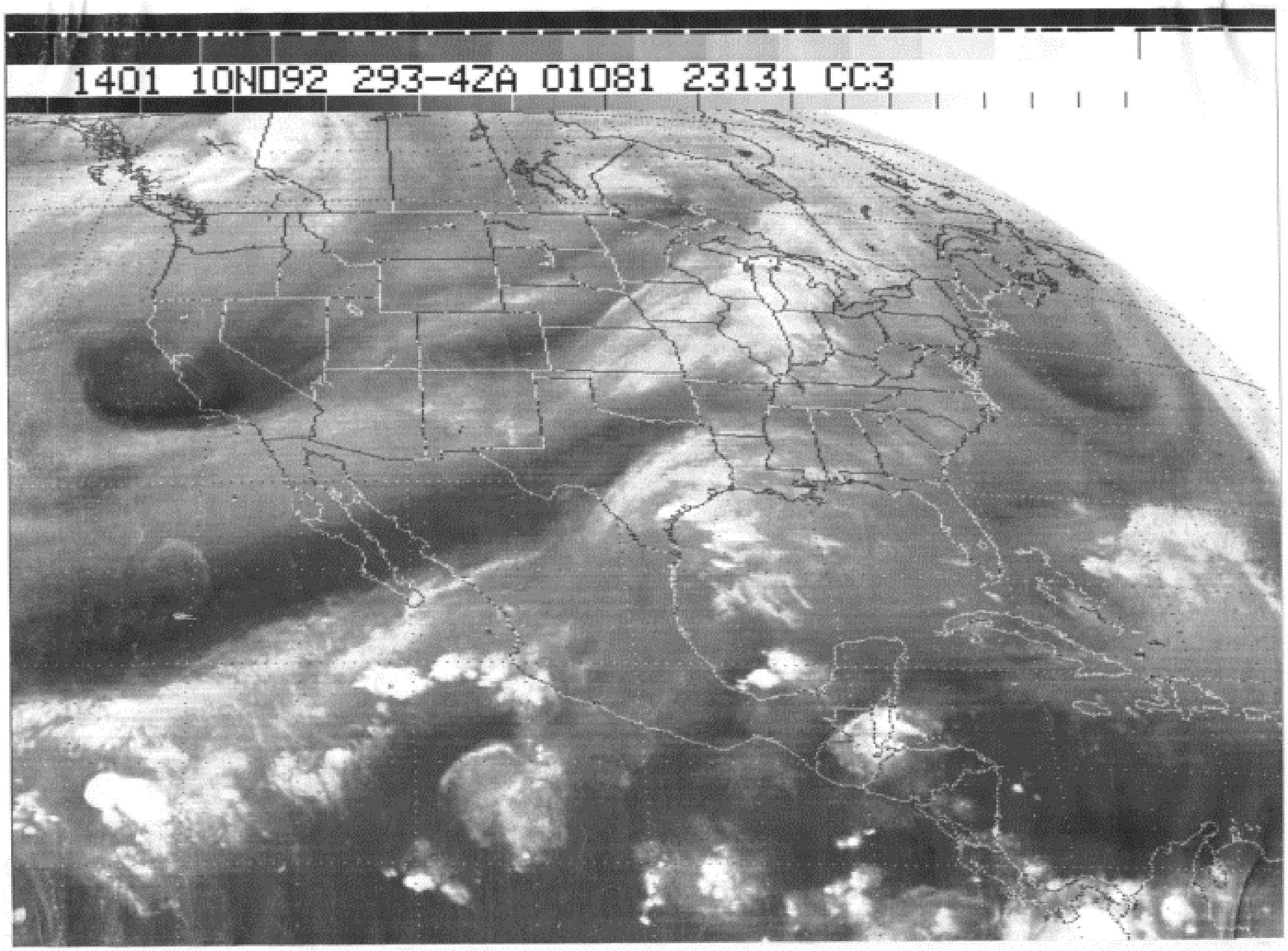


Soil (Surface) Wetness Index --- 5 day moving averages ending 2-24-98

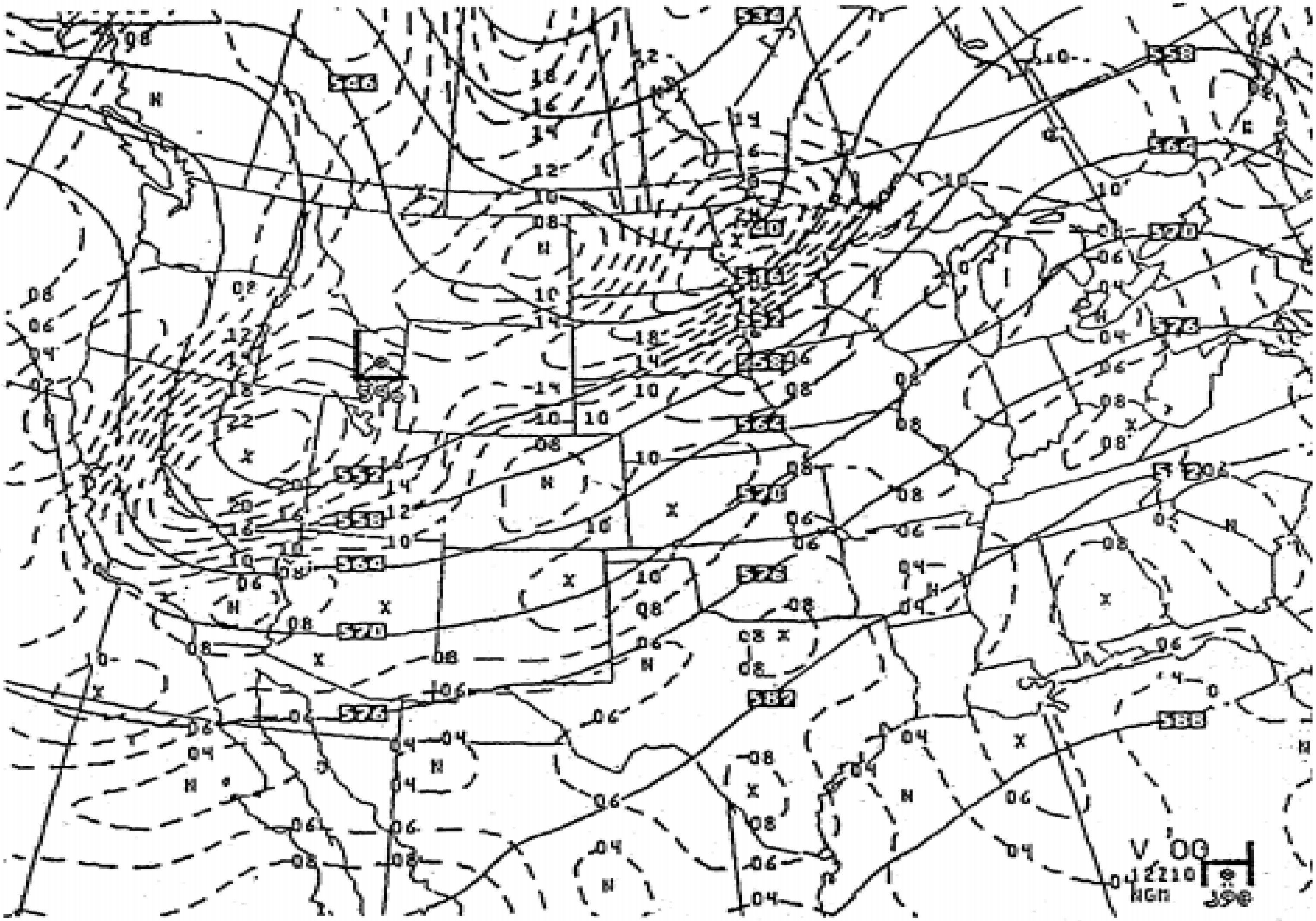


Conceptual model of double jet streaks associated with many heavy rainfall events

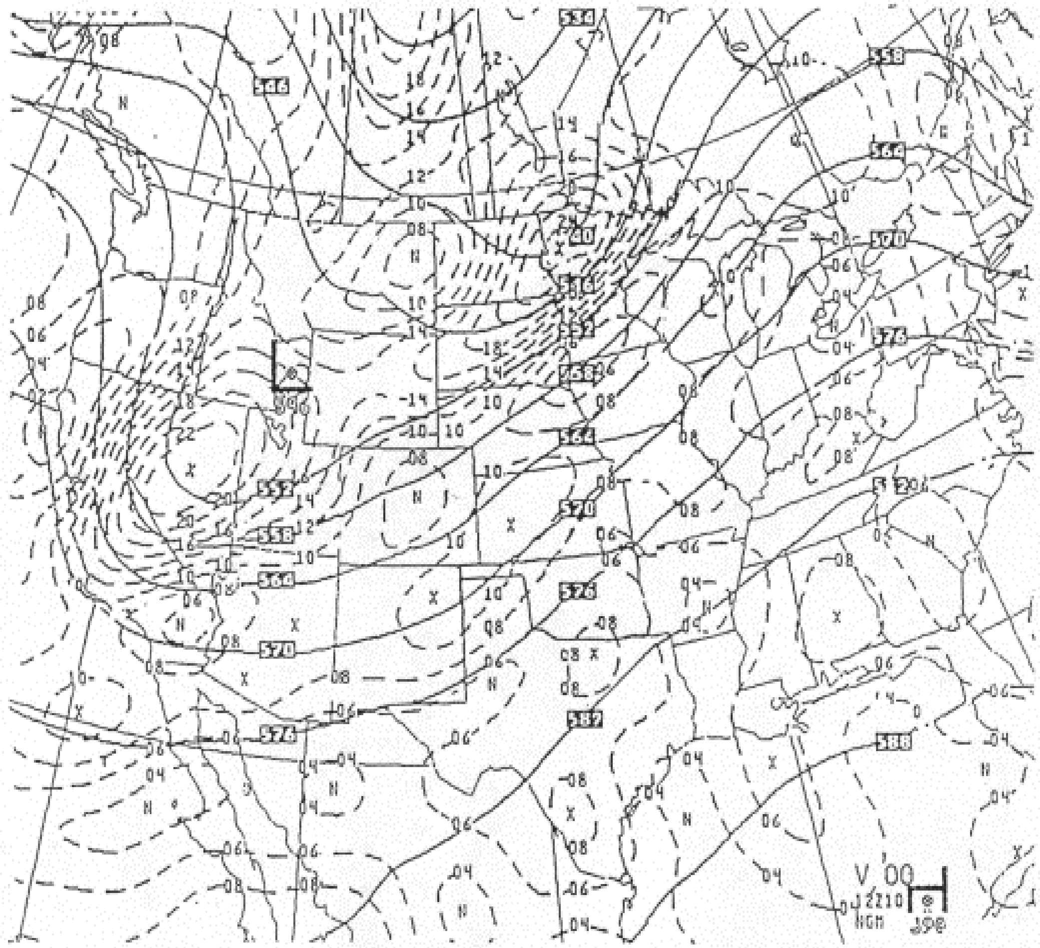
Conceptual Models of Jet Streaks in the 6.7 micron Water Vapor Imagery



6.7 micron water vapor imagery for 11-10-92 1400 UTC

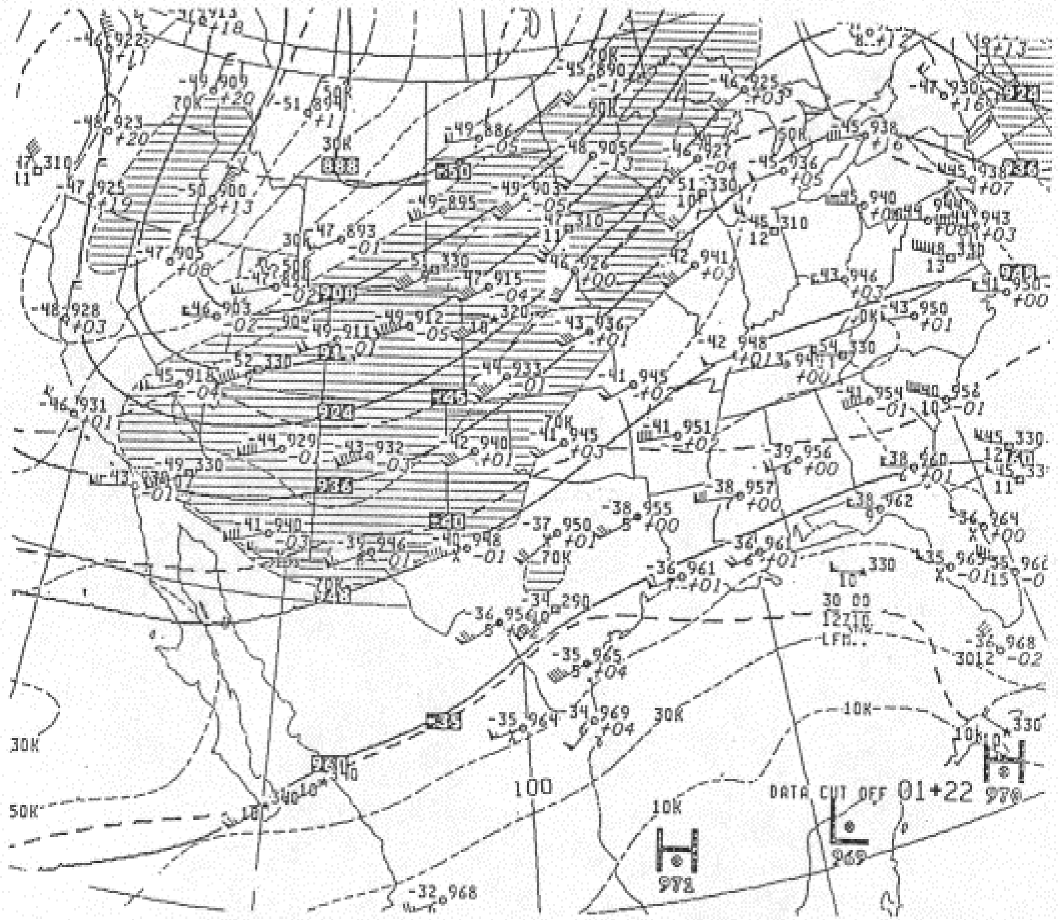


500 MB Analysis (Heights/Vorticity), 1200 GMT, November 10, 1992.



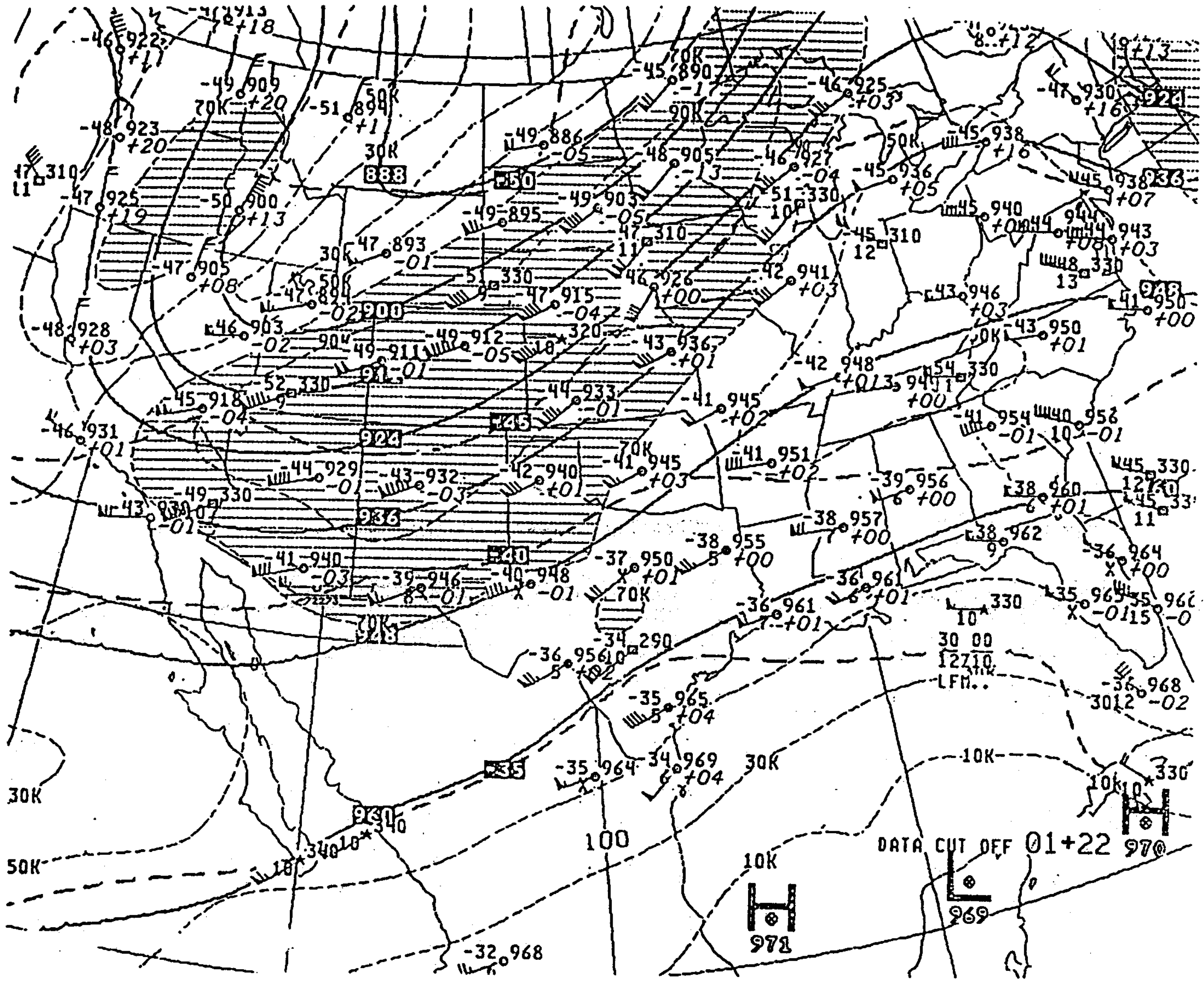
500 MB Analysis (Heights/Vorticity), 1200 GMT, November 10, 1992.

500 mb Analysis (heights/vorticity), 11-10-92, 1200 UTC

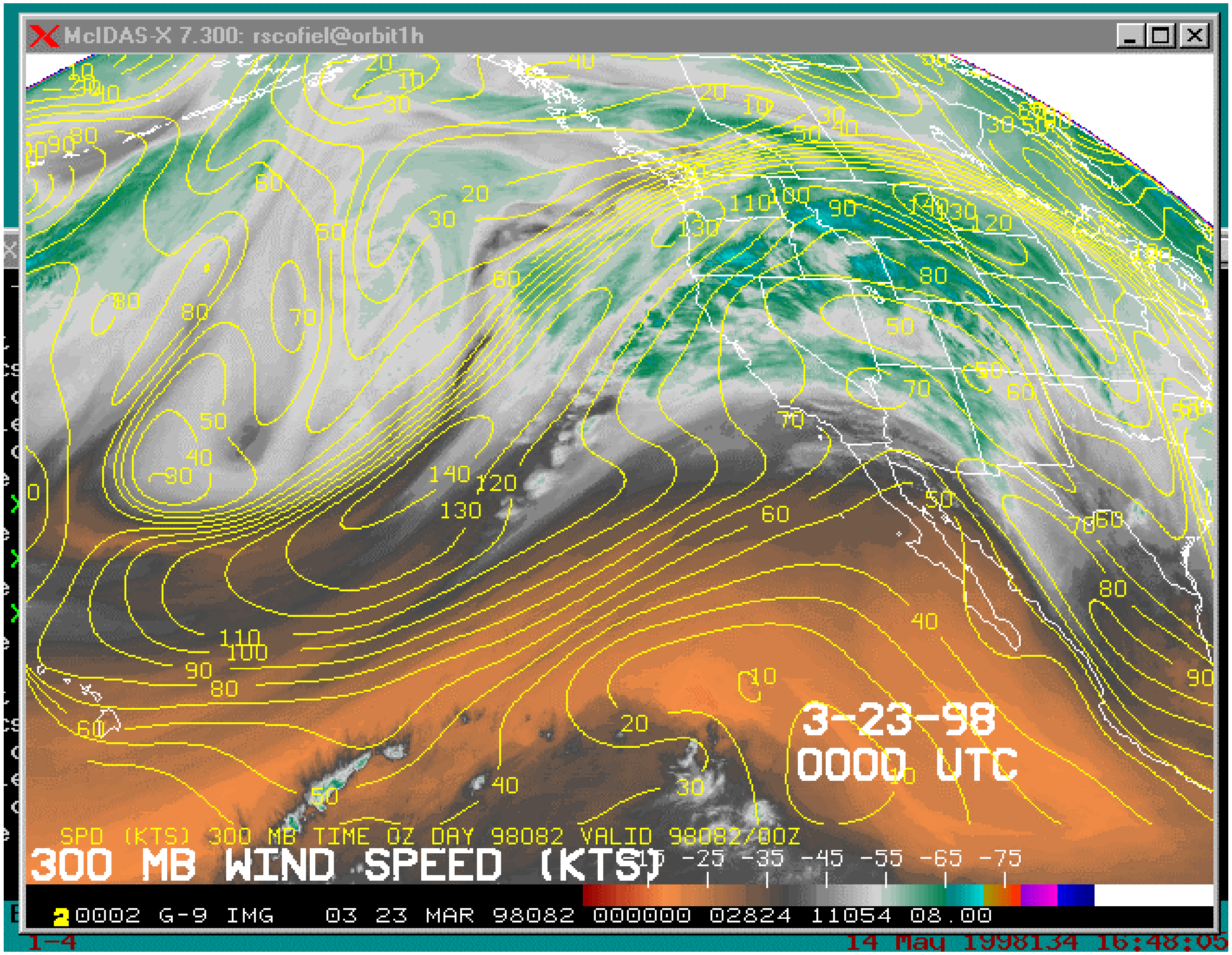


300 MB Analysis (Heights/Isotachs), 1200 GMT, November 10, 1992.

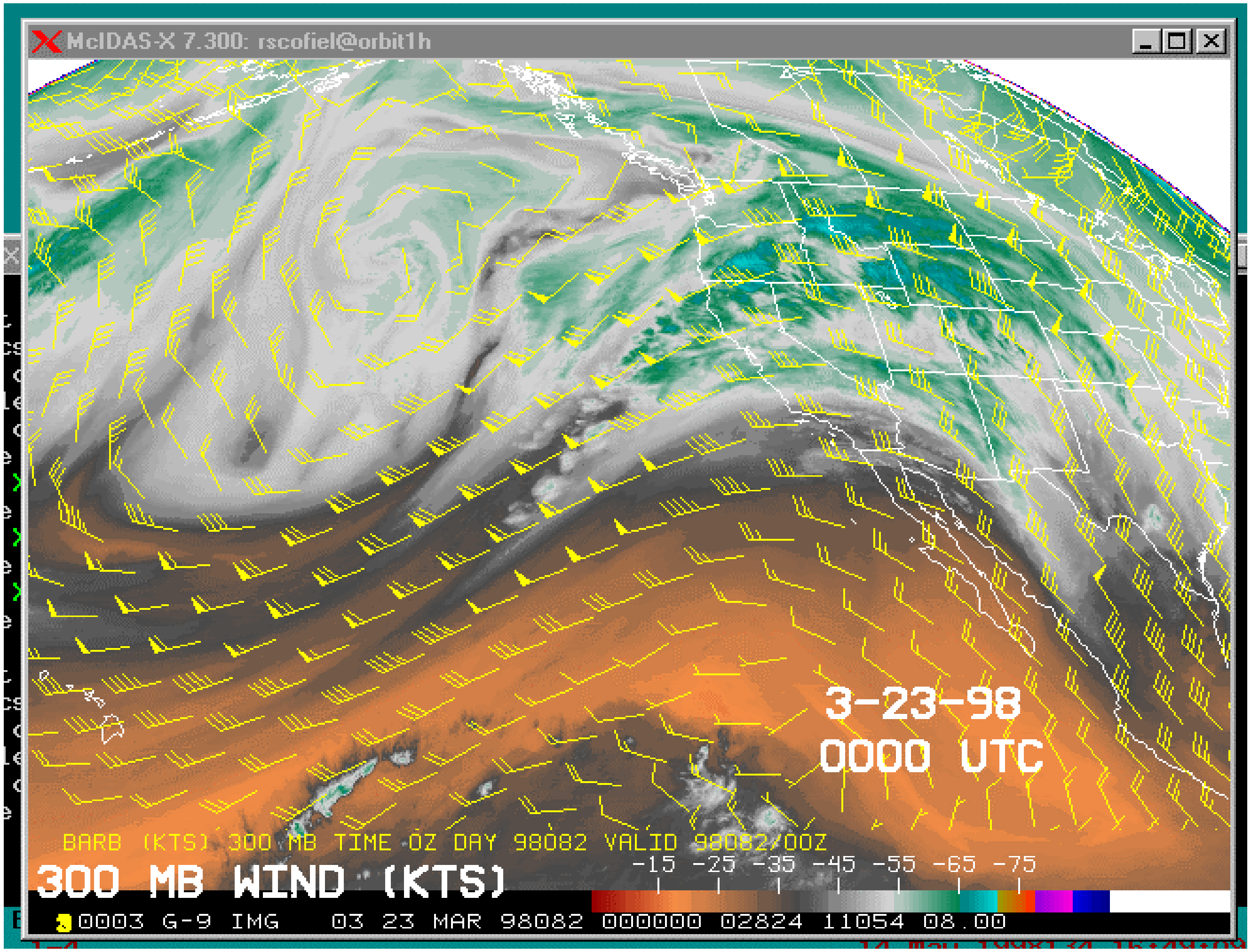
300 mb Analysis (heights/isotachs), 11-10-98, 1200 UTC



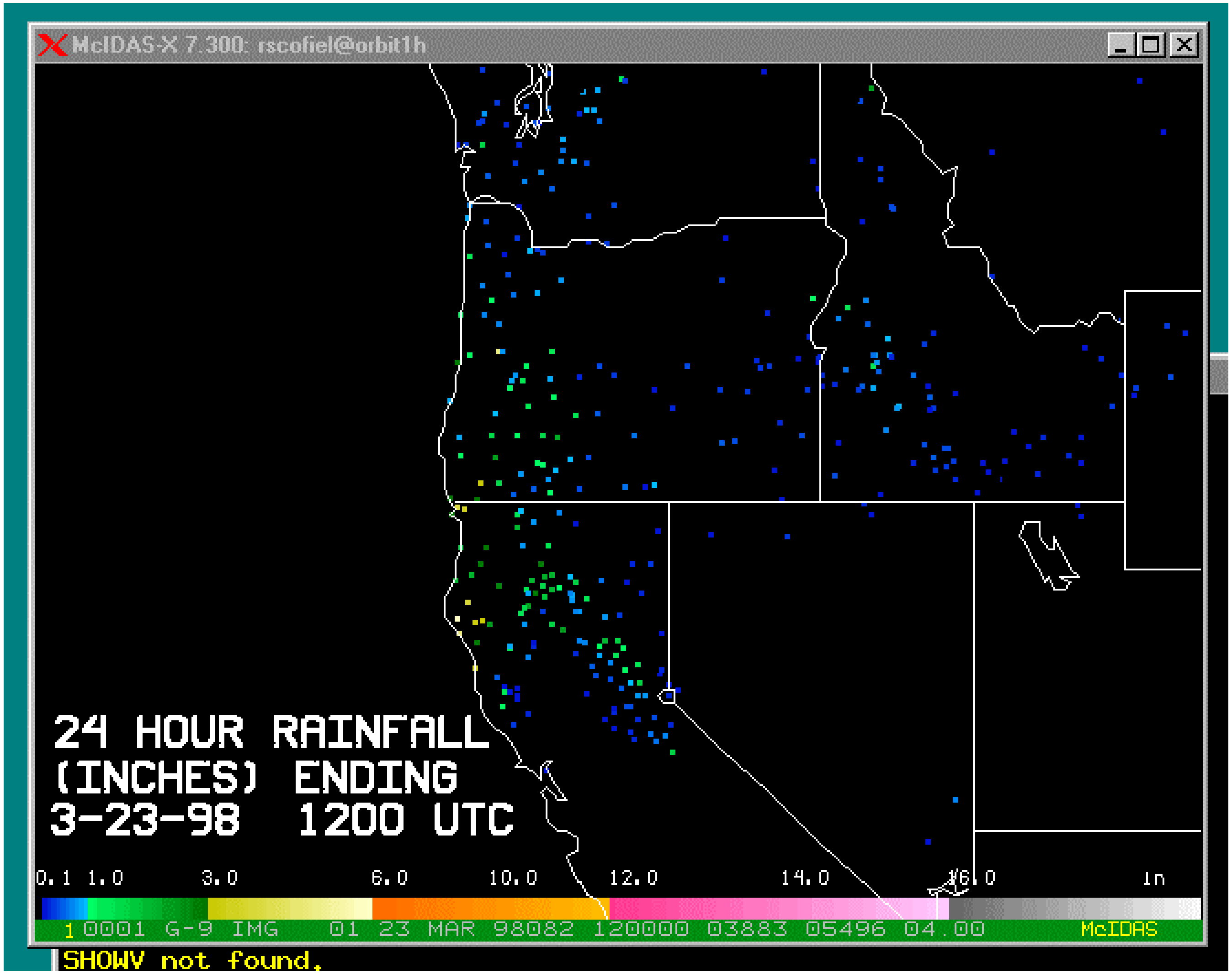
300 MB Analysis (Heights/Isotachs), 1200 GMT, November 10, 1992.



6.7 micron water vapor imagery for 3-23-98 0000 UTC; 300 mb isotachs (kt) are superimposed



6.7 micron water vapor imagery for 3-23-98 0000 UTC; 300 mb winds (kt) are superimposed



24 Hour Observed Precipitation (in) ending 3-23-98 1200 UTC

Synoptic and Mesoscale Boundaries

Characteristics in the conventional data:

- wind
- temperature
- moisture
- pressure

Characteristic in the satellite data:

- cloud line
- moisture-dry air interface
- wind

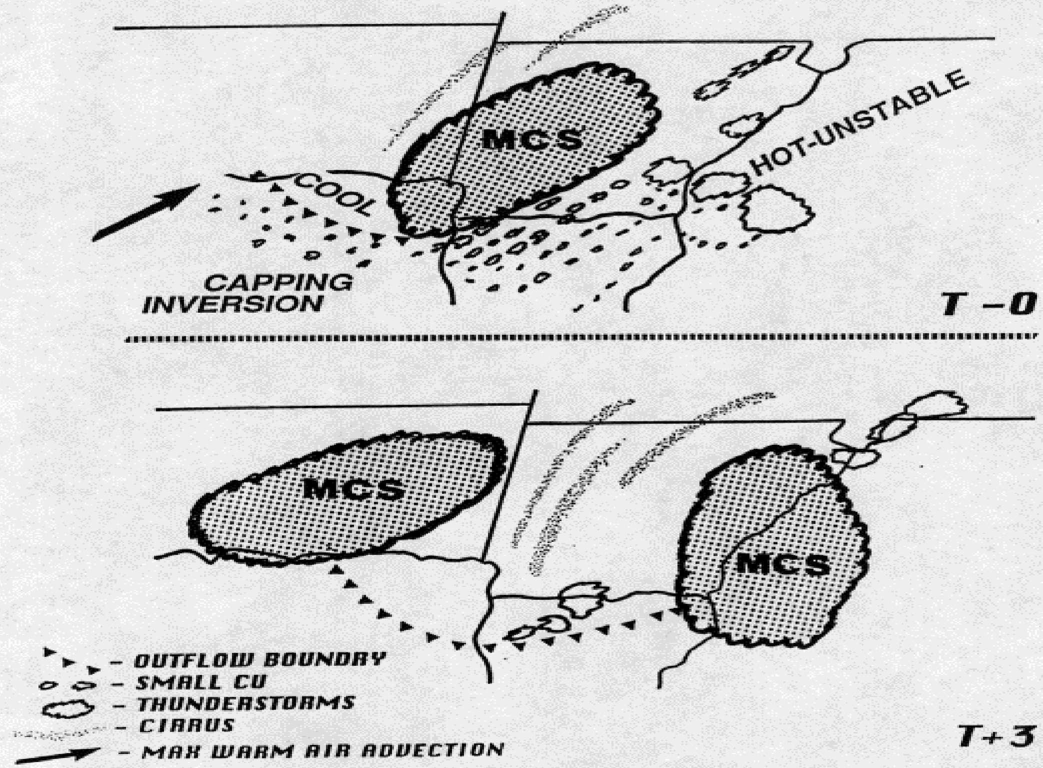


Figure 31b. *Conceptual model of an outflow boundary, convective scale interaction, and MCS initiation.*

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Conceptual Model of an Outflow Boundary intersecting an area of maximum warm air advection

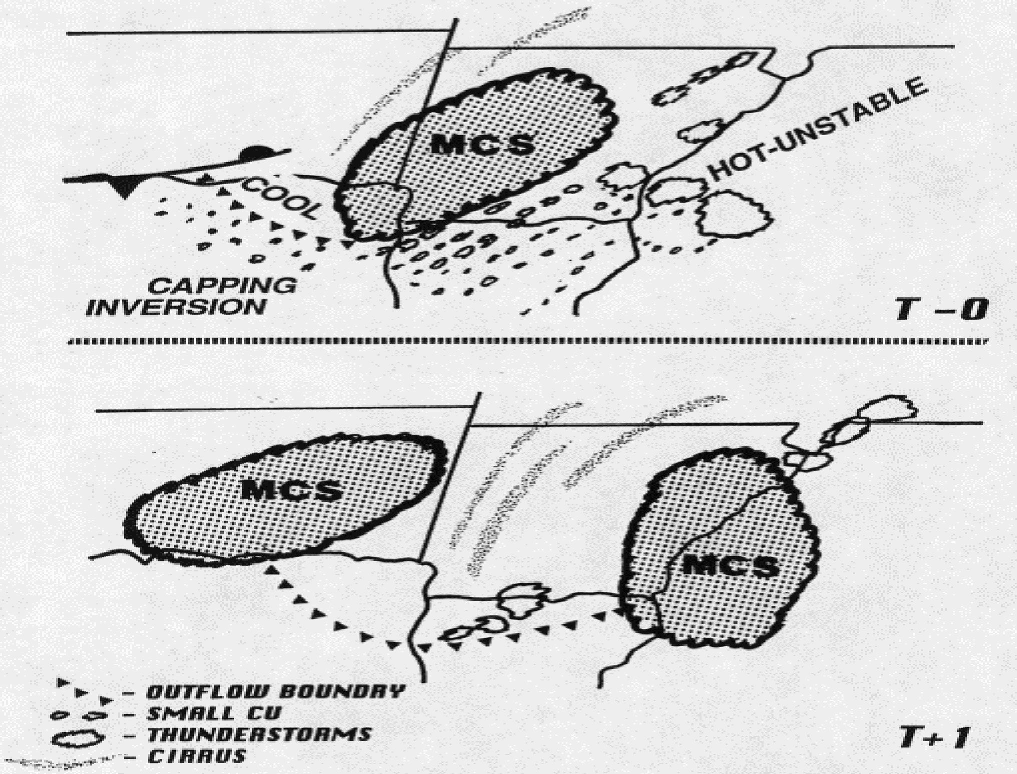

Figure 31a. Conceptual Model of an outflow boundary, convective scale interaction, and MCS initiation.

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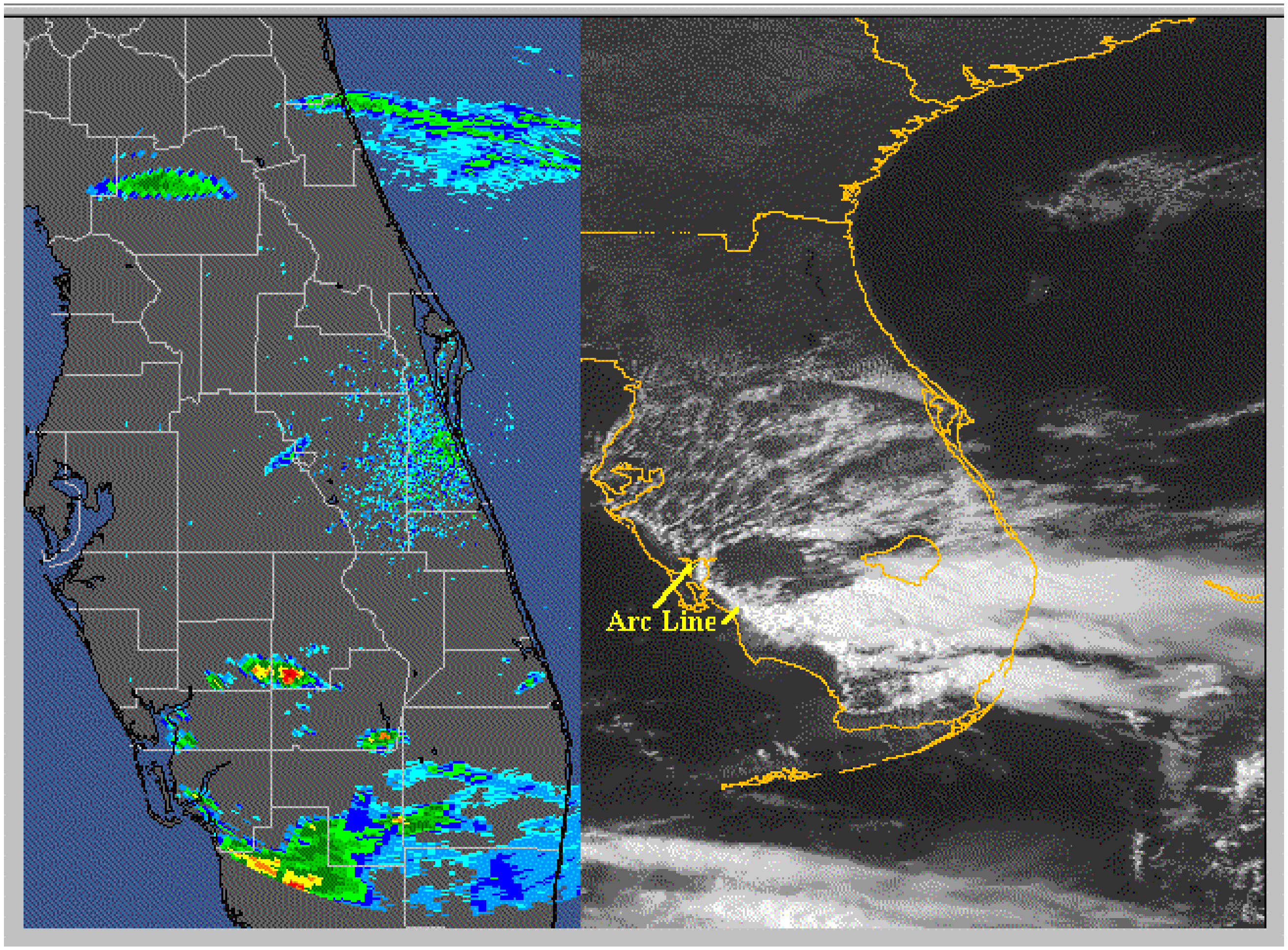
Conceptual Model of an Outflow Boundary intersecting another boundary



Example of radar and GOES visible view of " Outflow Boundaries "

Mesoscale to Storm scale

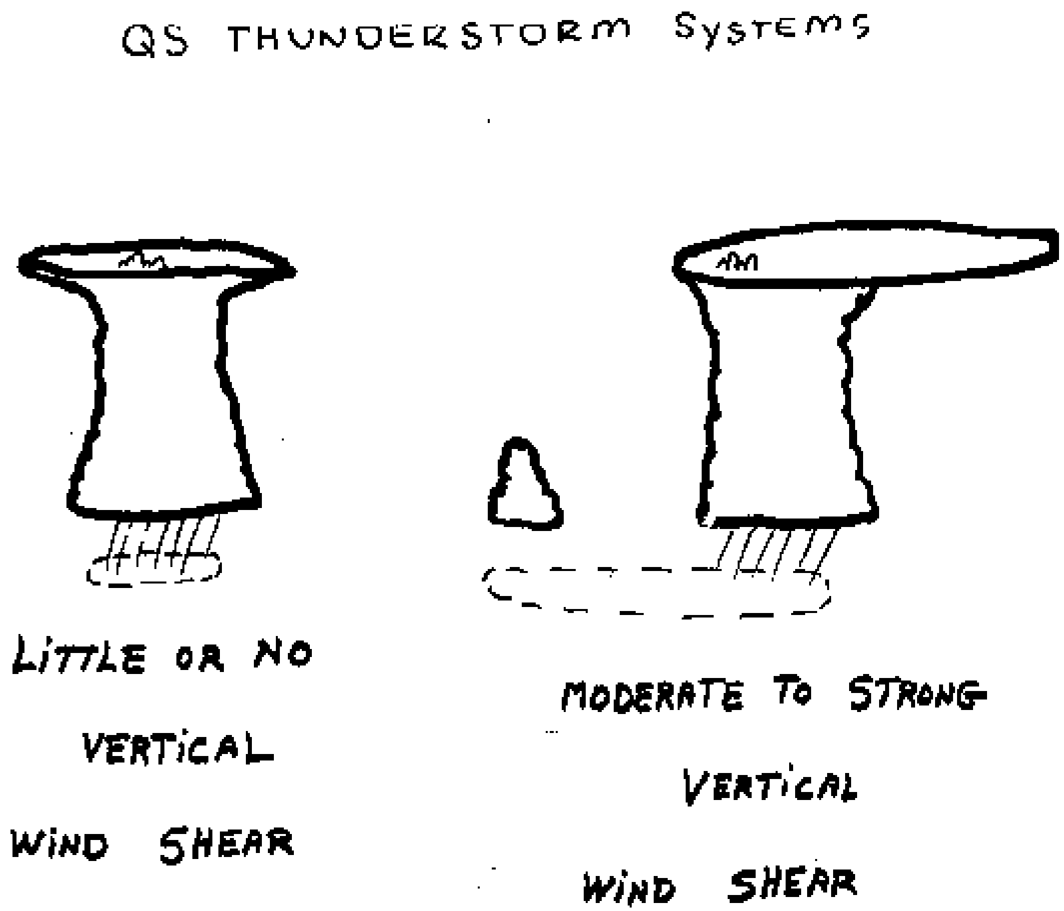
- Precipitation rate and accumulation?
- Duration of precipitation?
- Modification of the environment?
- Local effects?

Interactive Flash Flood Analyzer (IFFA) Precipitation Estimates

Assign precipitation rates to the following satellite features:

- **Cloud top temperature and cloud growth**
- **Mergers**
- **Overshooting tops**
- **Stationary Storms (speed of movement)**

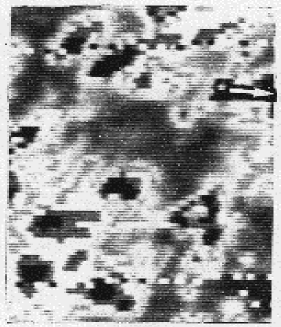
The amount of available moisture (determined by the current Precipitable Water and Relative Humidity) is used to adjust the rainfall estimates



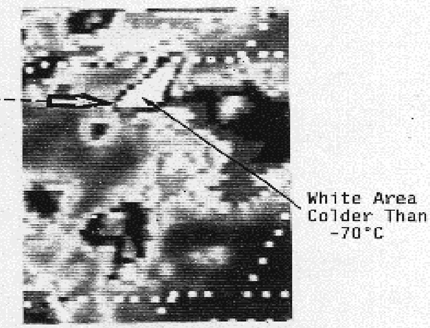
Conceptual Models of thunderstorm systems in different wind shear environments

SEVERE WEATHER FEATURES IN THE SATELLITE IMAGERY

CLOUDS GROWING RAPIDLY

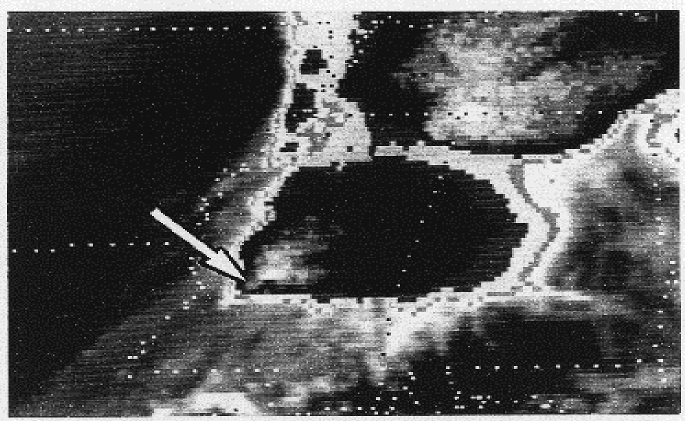


INFRARED, August 1, 5:30 PM



INFRARED, August 1, 6:00 PM

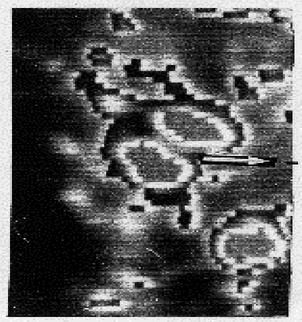
WEDGE-SHAPED OR V-NOTCHED

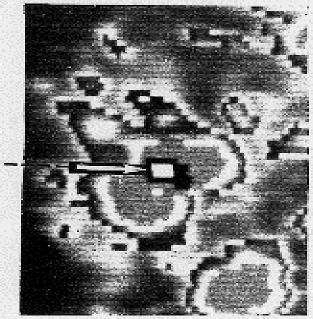


INFRARED, April 11, 11:30 PM

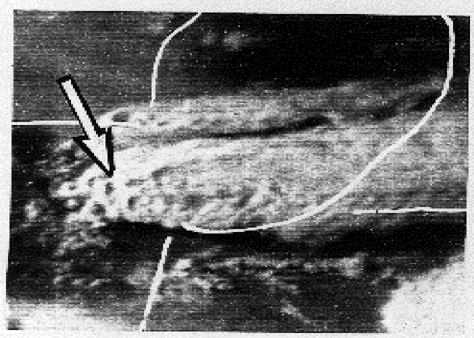
SEVERE WEATHER FEATURES IN THE SATELLITE IMAGERY

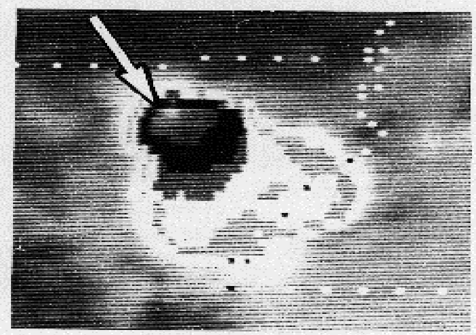
MERGERS


INFRARED, July 14, 1:00 PM

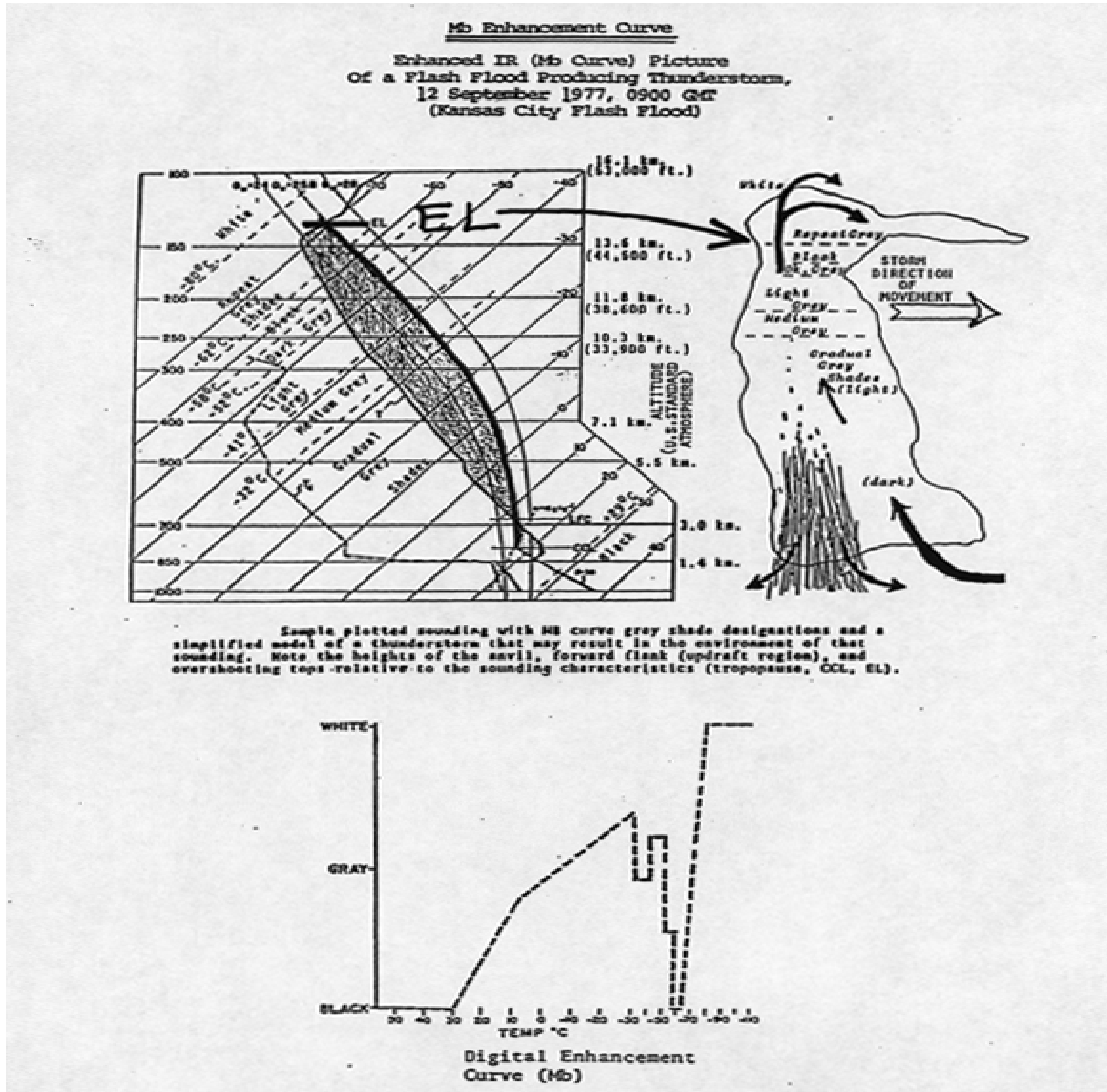

INFRARED, July 14, 1:30 PM

OVERSHOOTING TOPS

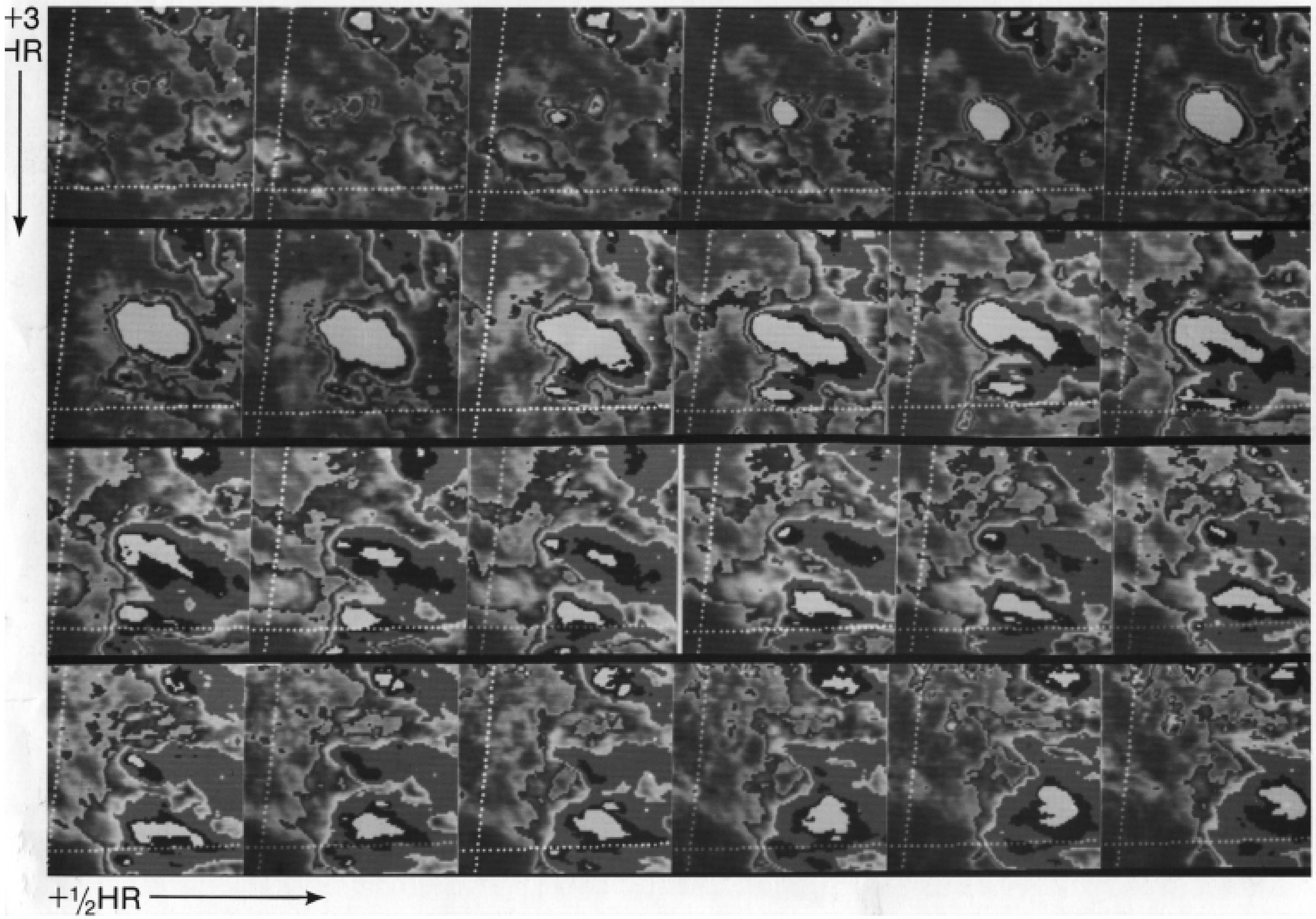

VISIBLE, June 13, 7:00 PM

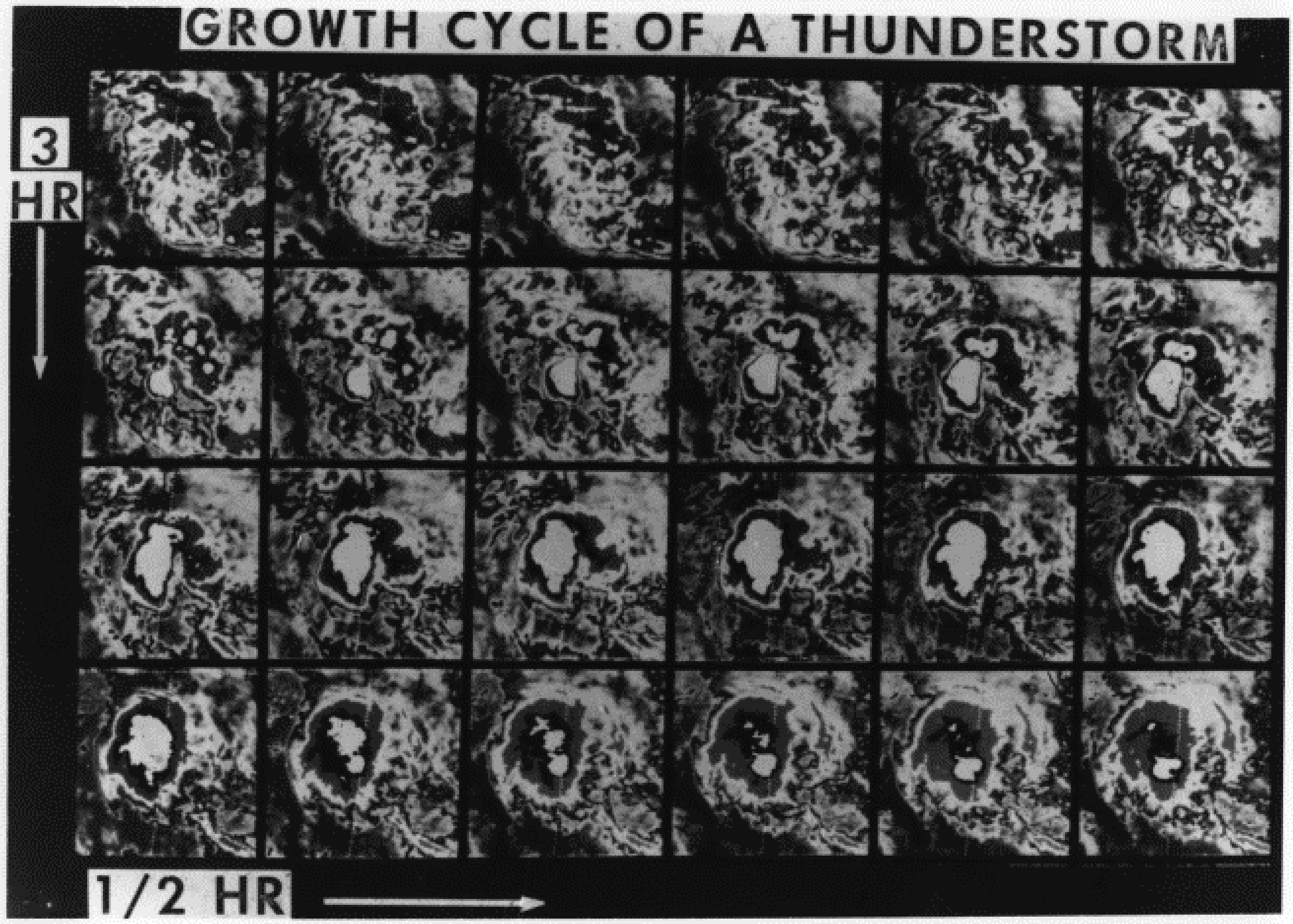

INFRARED, September 15, 6:00 AM

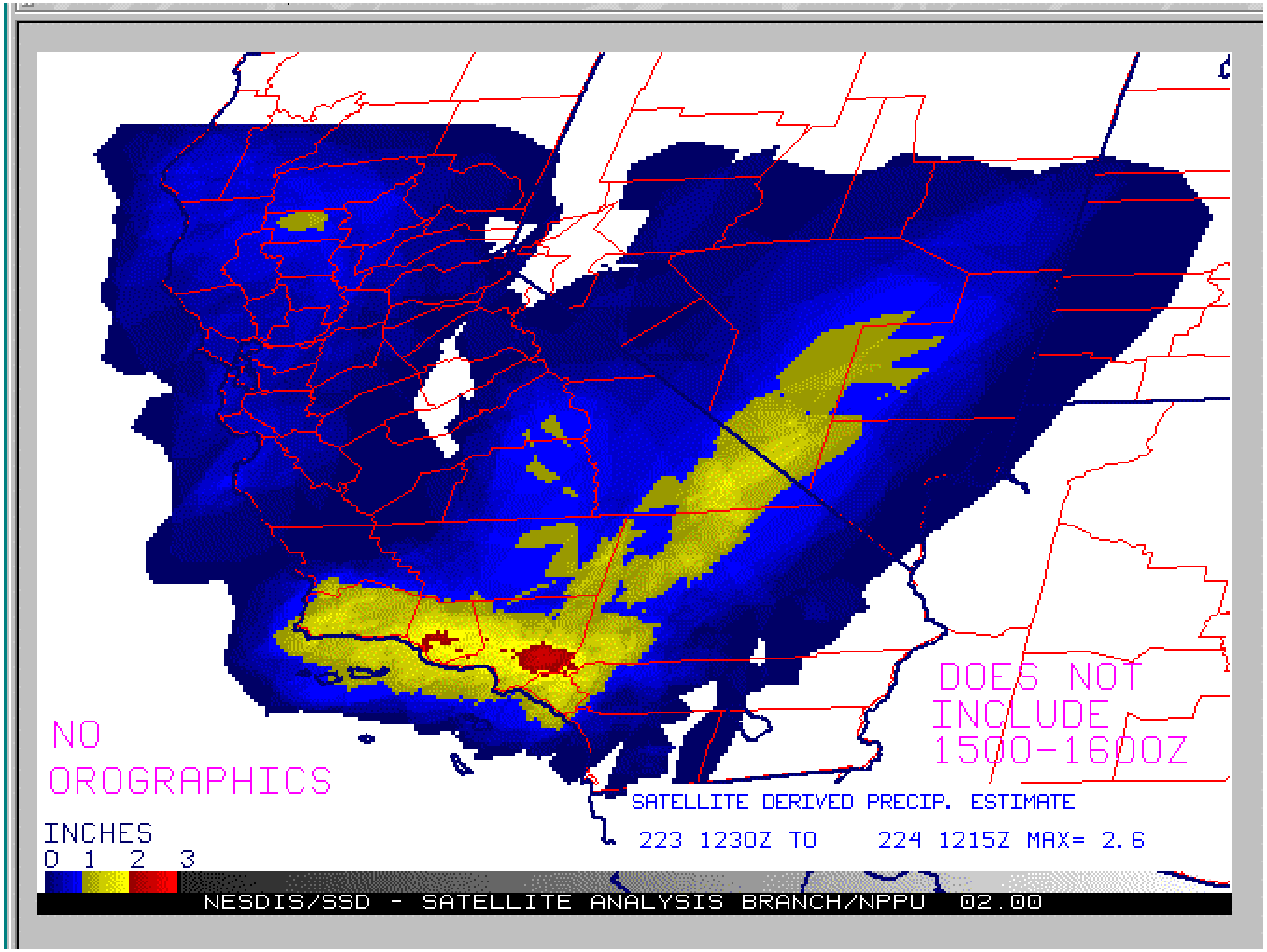
Warm Top correction using Equilibrium Level Temperature



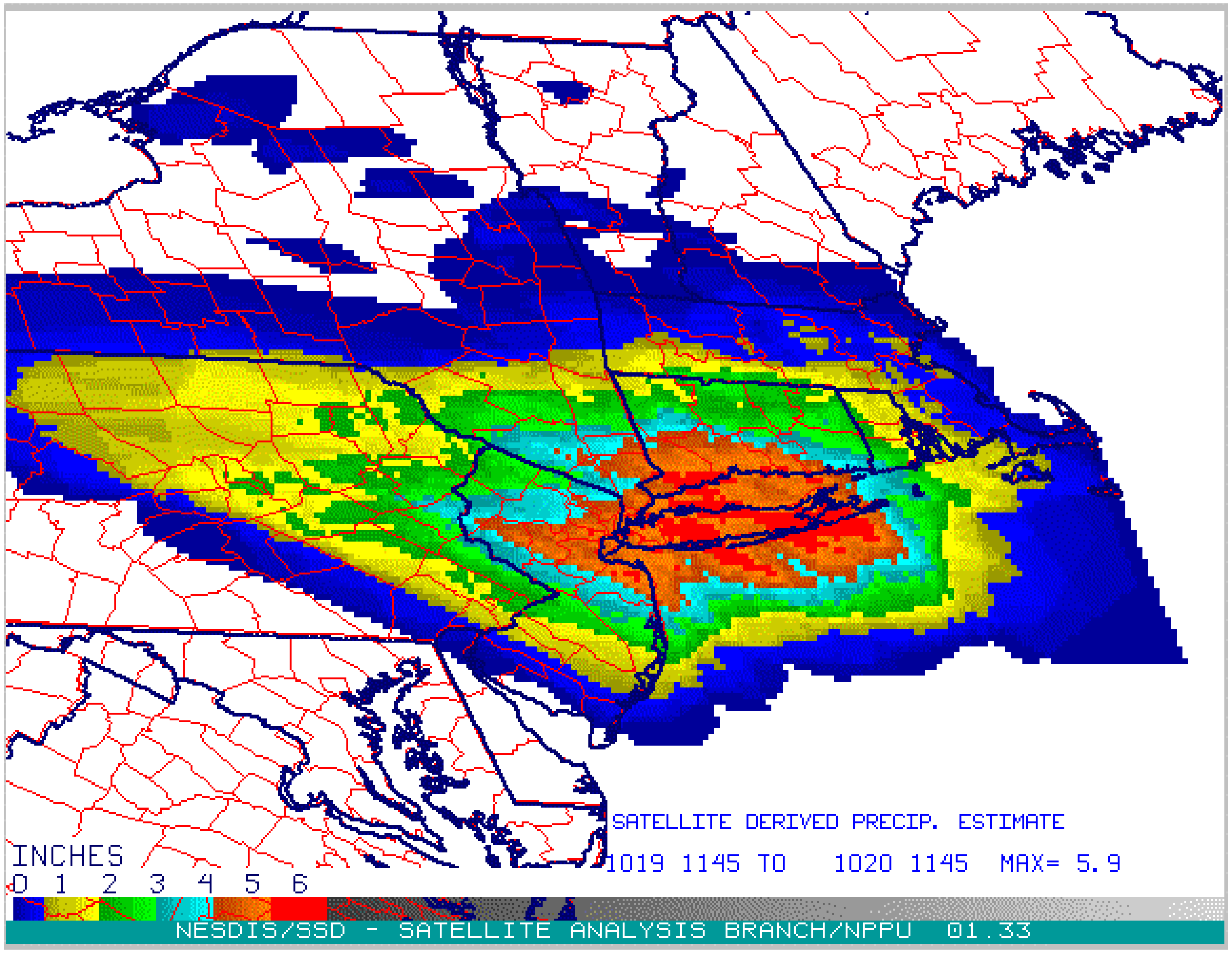
GROWTH CYCLE OF A THUNDERSTORM




GROWTH CYCLE OF A THUNDERSTORM
3 HR
1/2 HR



Interactive Flash Flood Analyzer (IFFA) Estimates (in) for Feb 23, 1230 UTC to Feb 24 1215 UTC, 1998



Interactive Flash Flood Analyzer (IFFA) rainfall estimates (in) for October 19, 1145 UTC - October 20, 1145 UTC, 1996

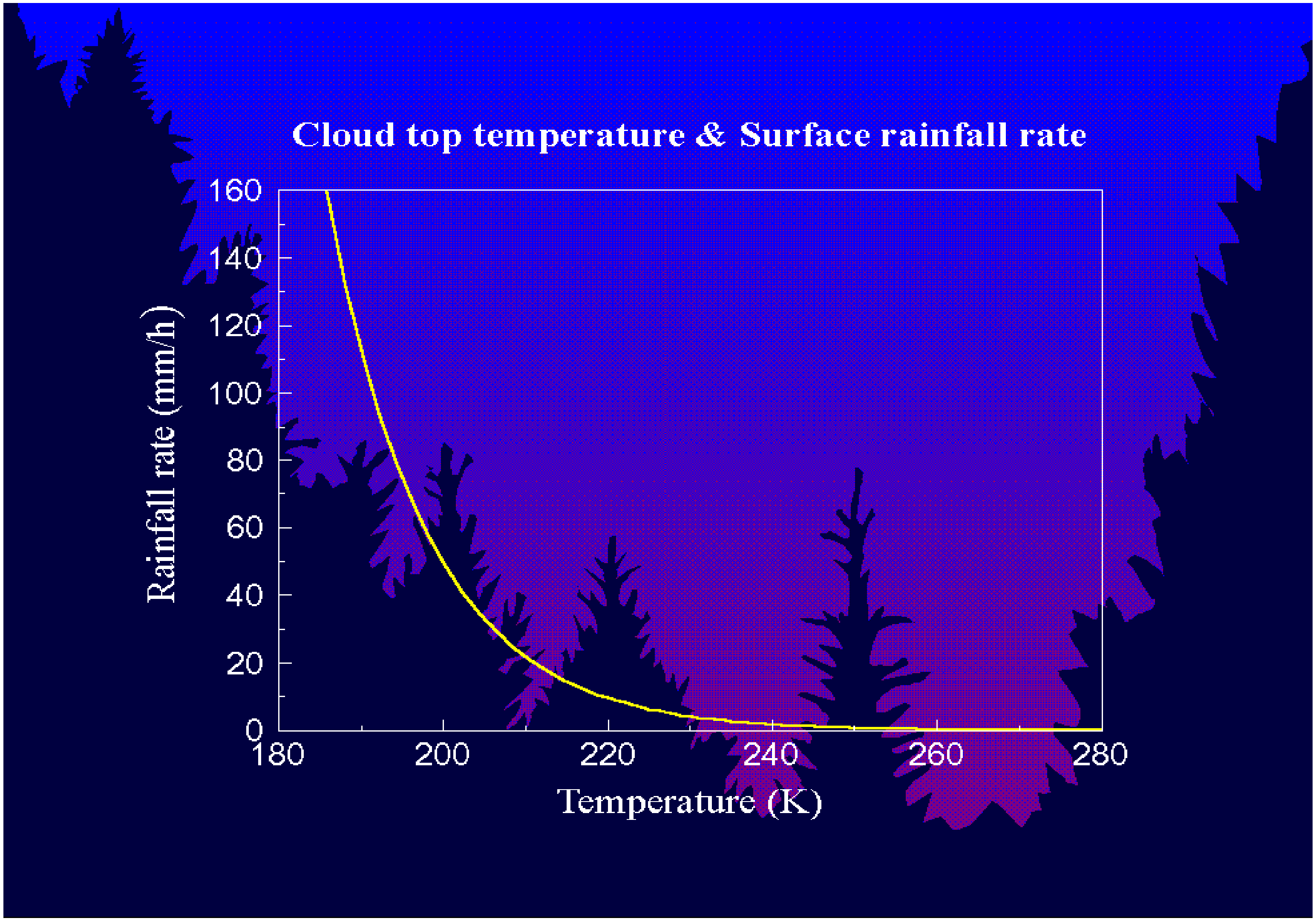
SATELLITE PRECIPITATION ESTIMATES... DATE/TIME/ 7/06/93 1935Z
PREPARED BY THE SYOPTIC ANALYSIS BRANCH/NESDIS TEL (301) 763-8444
VALUES REFLECT MAX OR SGFNT ESTS. OROGRAPHIC EFFECTS NOT ACCTD FOR.
REFER TO TPB*375 FOR DETAILS. LATEST DATA USED: 061900Z SJK

LOCATION	RATE	TOTAL	TIME
E. KS CNTYS...			
NE ALLEN/EXT NW BOURBON/SE ANDERSEN	1.0"	3.3"-3.8"	15-19Z
E LINN	1.0"	4.6" SE LINN	"
W CENTRAL MO...			
W/NW BATES	1.1"	5.0"-5.5" C BATES	"
C/SW CASS	1.0"	4.3" SE CASS	"
		3.5 S CENTRAL CASS	"

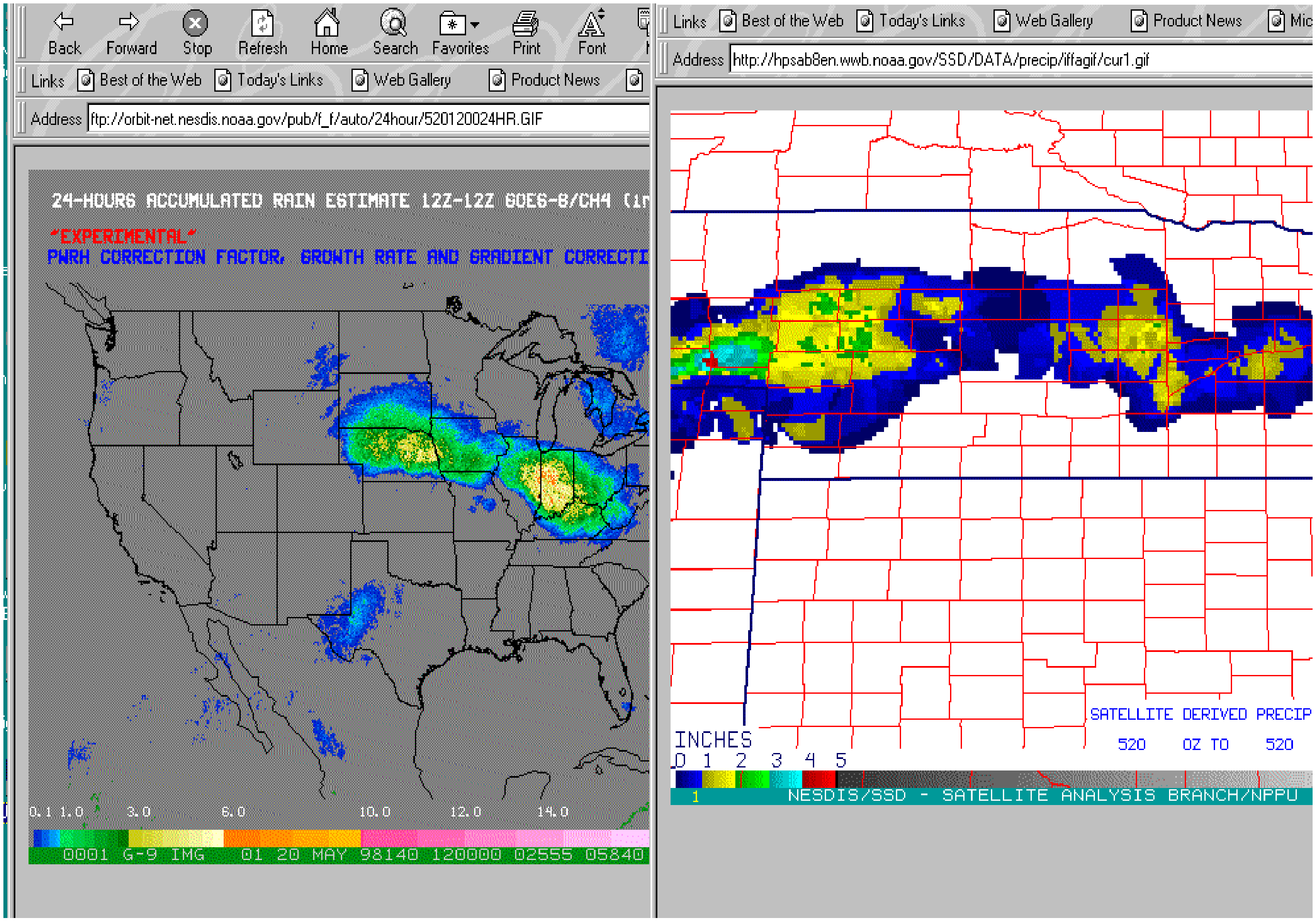
REMARKS...REDVLPMT ON BACK END OF MCS GIVING ADDTL HVYS RAIN TO E CENTRAL KS INTO W CENTRAL MO...TRAINING AND BACK BUILDING OVER E CENTRAL KS/ W CENTRAL MO...WILL MAKE FF POTNEITAL HIGH DURING THE NXT 3 HRS...WILL CONTINUE TO MONITOR WITH NXT MSG AFTER 21Z PIX...

GOES 8/9/10 Auto-Estimator

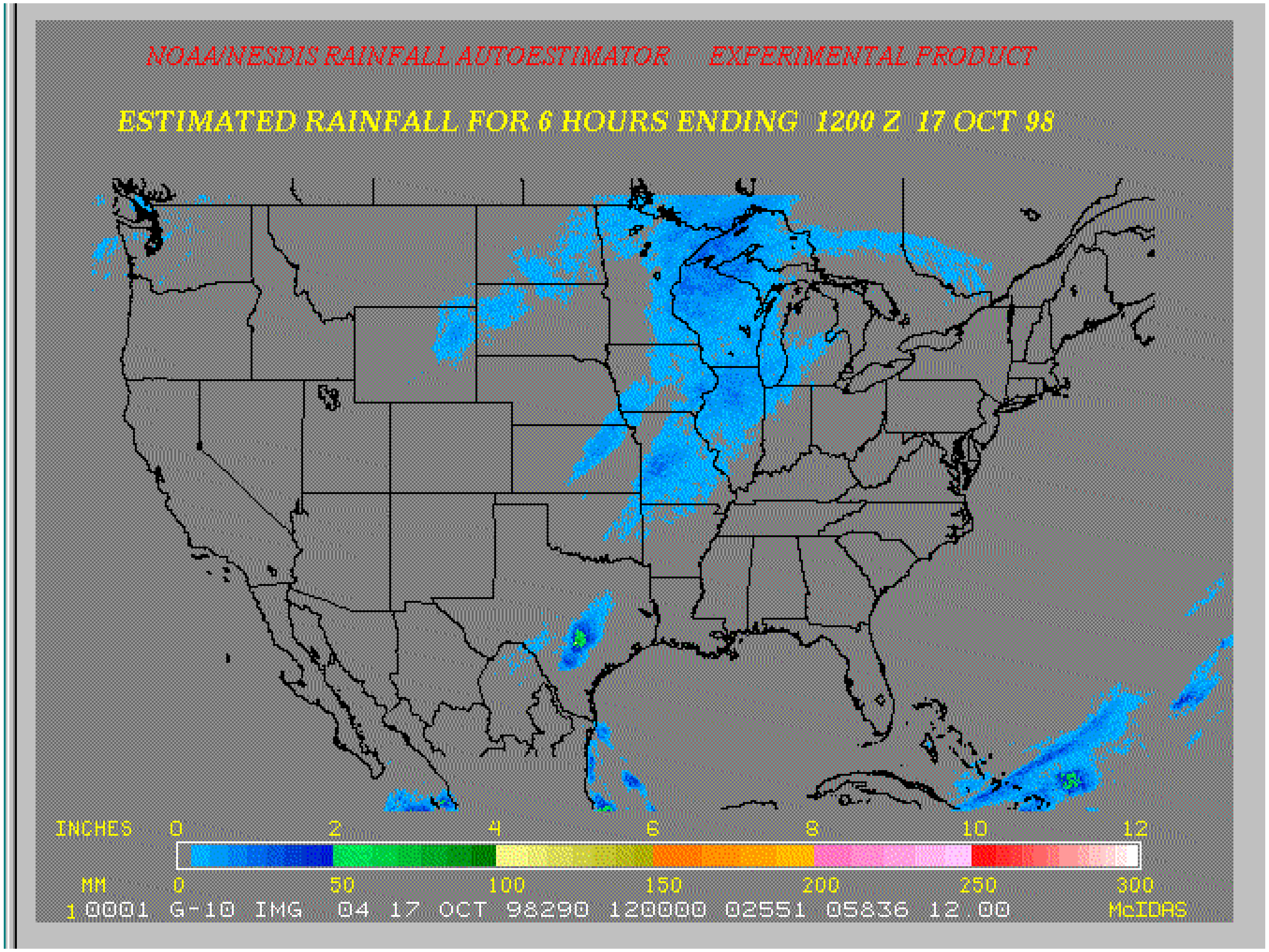
- **10.7 mm rain rate curve (can be manually adjusted ---- especially useful for warm top convection)**
- **Precipitable Water x Relative Humidity**
- **Growth**
- **Gradient**
- **Parallax**
- **Orography**



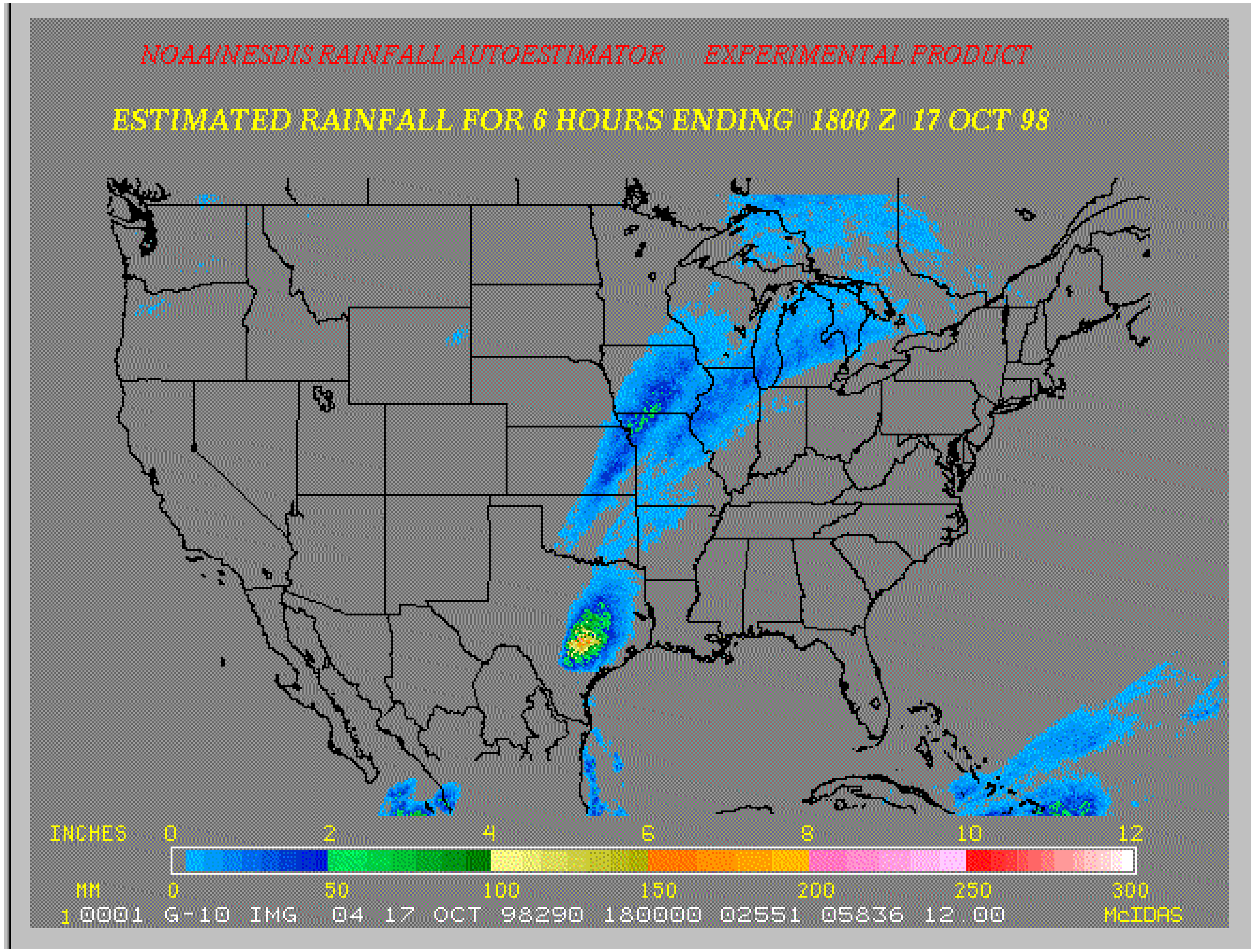
Cloud Top Temperature/Rain Rate Curve for Auto-Estimator



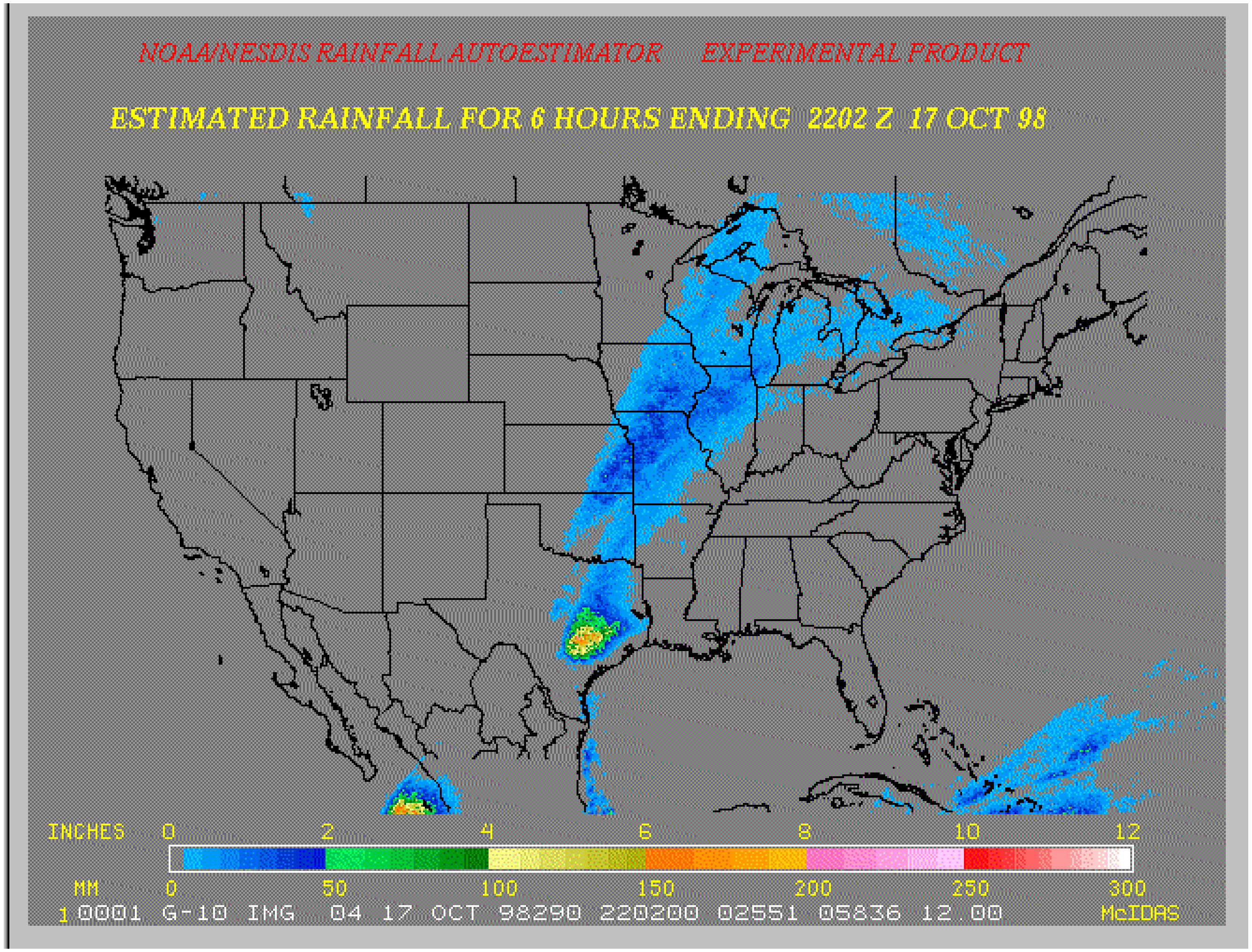
Auto-Estimator & Interactive Flash Flood Estimates (IFFA)



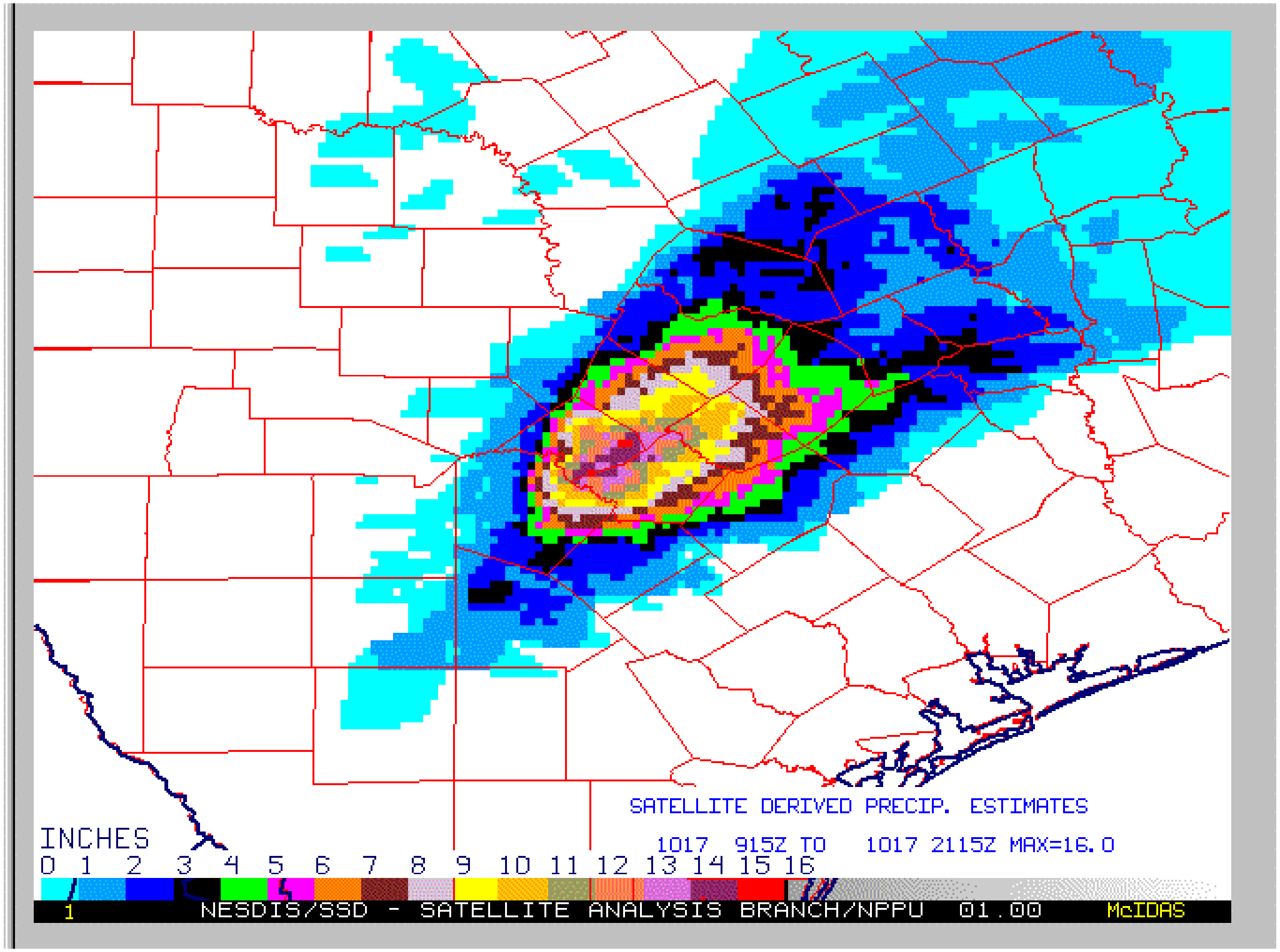
Auto-Estimator 6 hour rainfall estimates (in) ending 10-17-98 1200 UTC



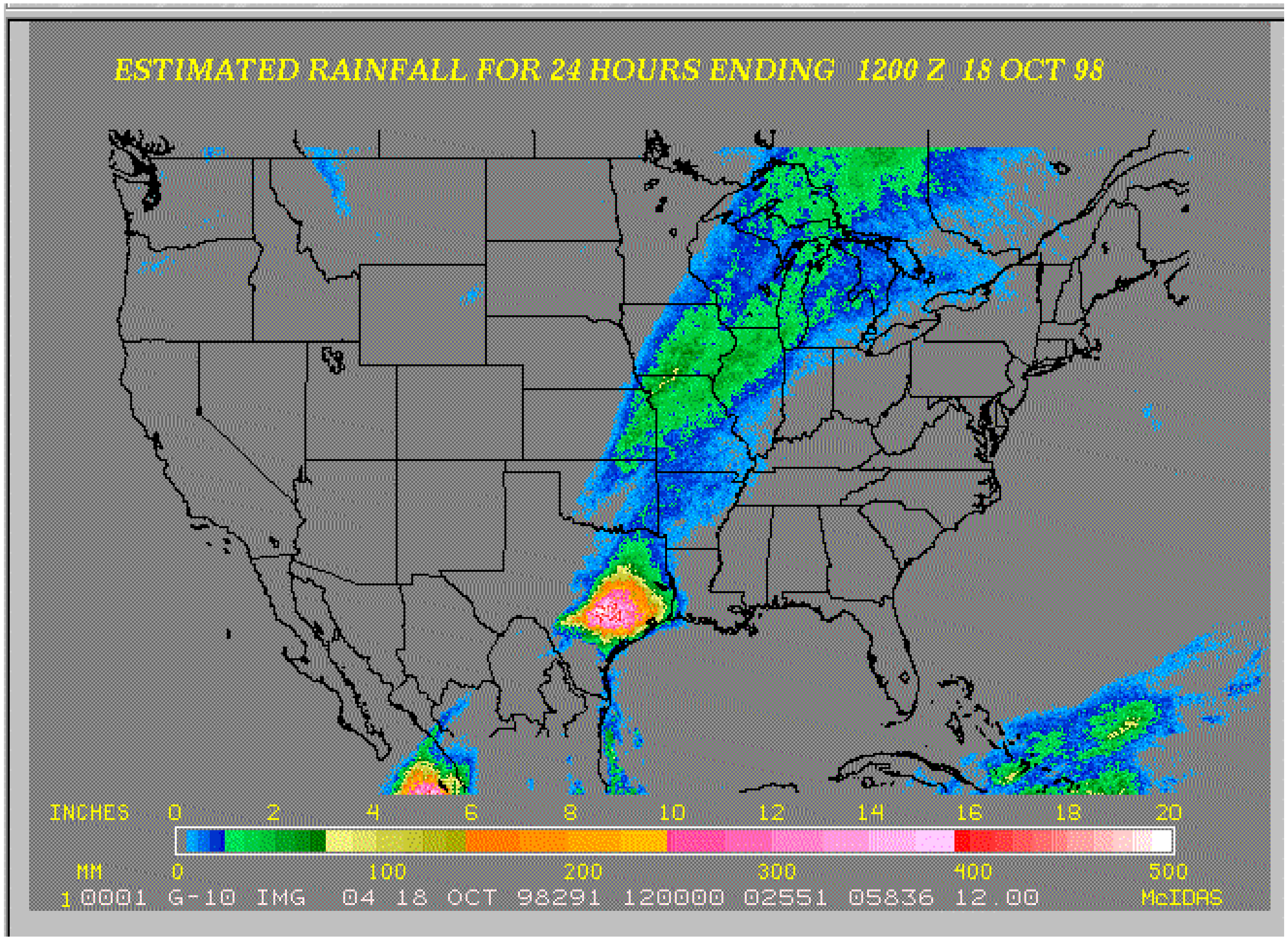
Auto-Estimator 6 hour rainfall estimates (in) ending 10-17-98 1800 UTC



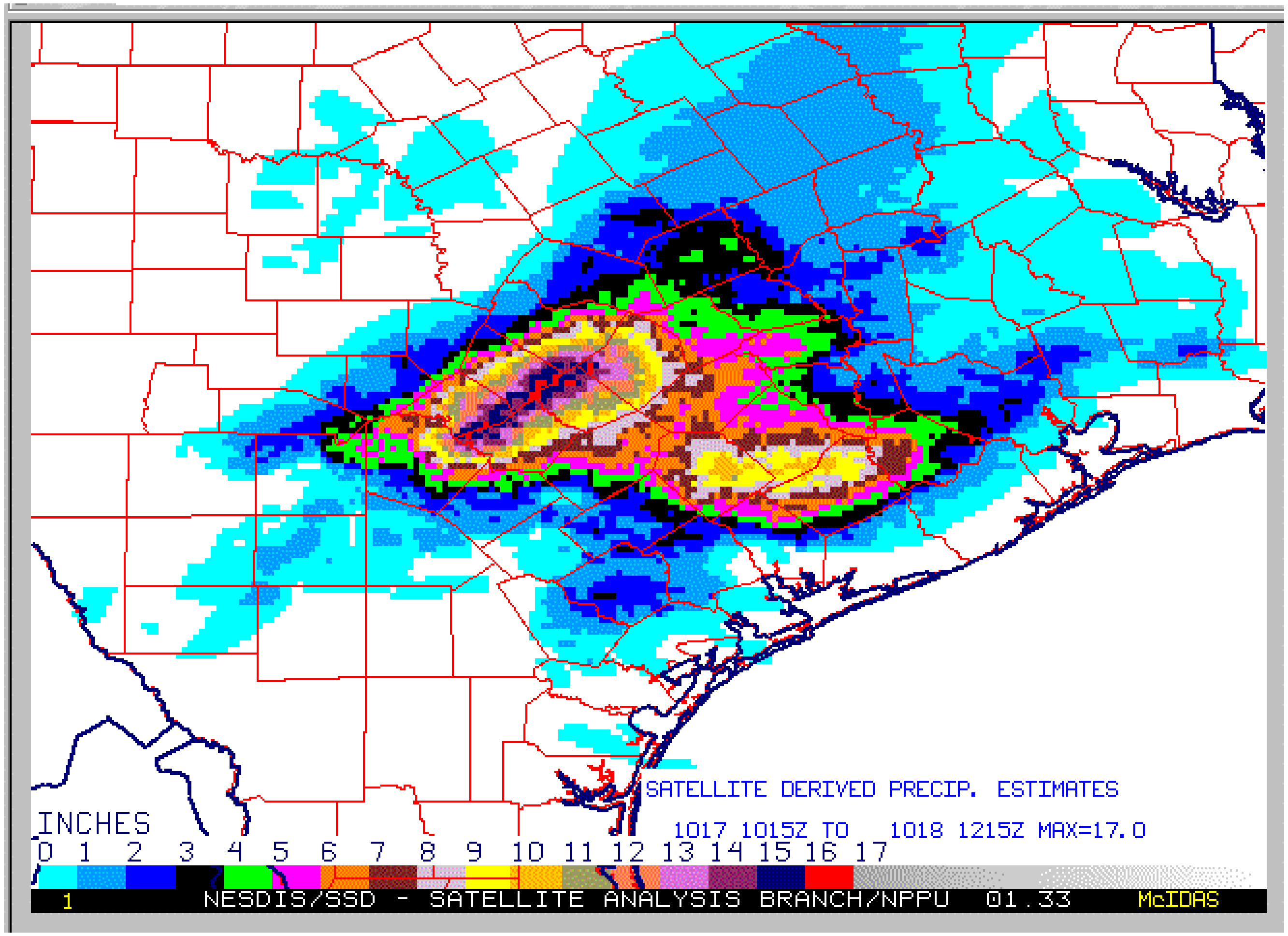
Auto-Estimator 6 hour rainfall estimates (in) ending 10-17-98 2200 UTC



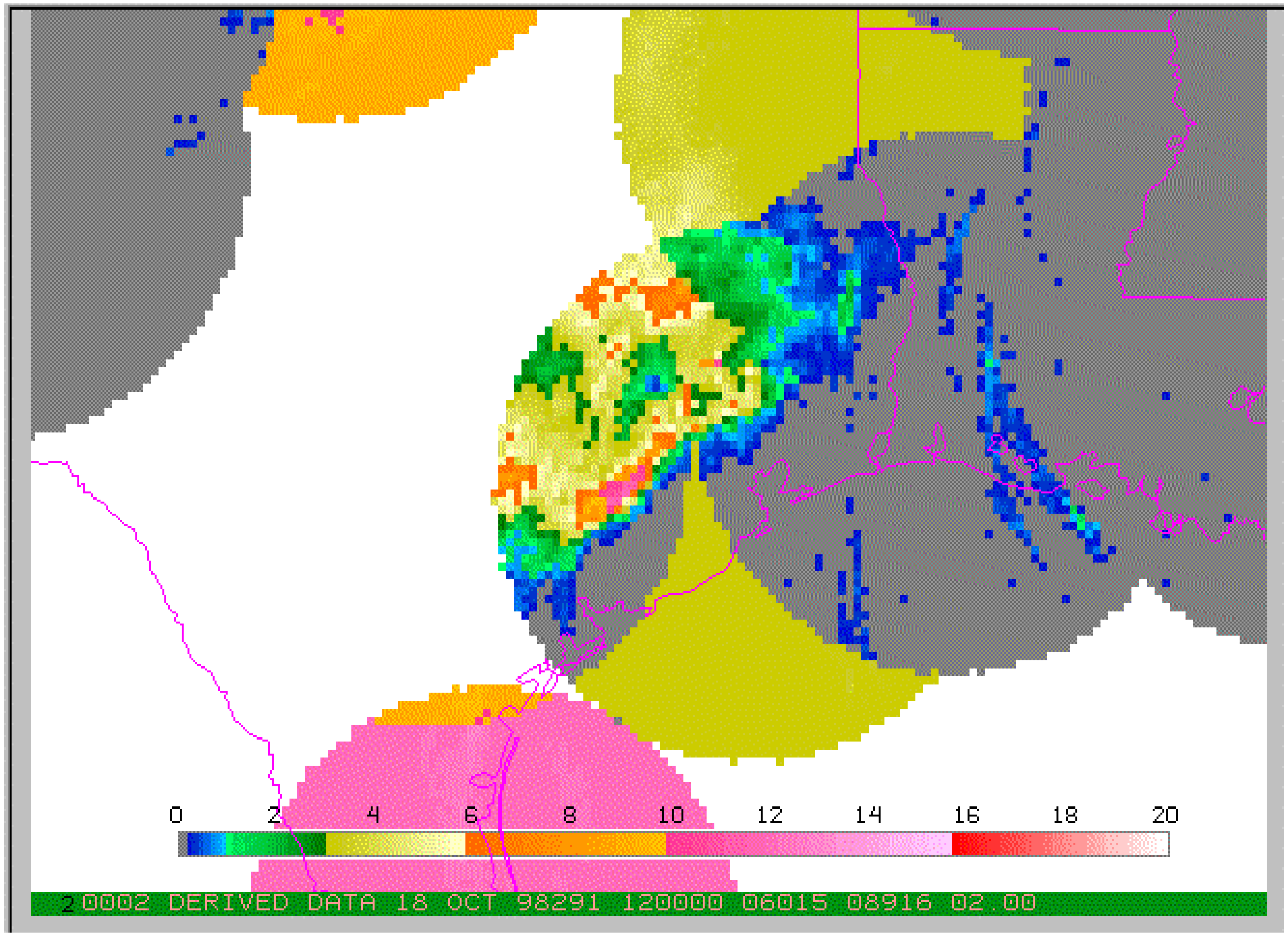
Interactive Flash Flood Analyzer (IFFA) rainfall estimates (in) for October 17, 0915 --- 2115 UTC



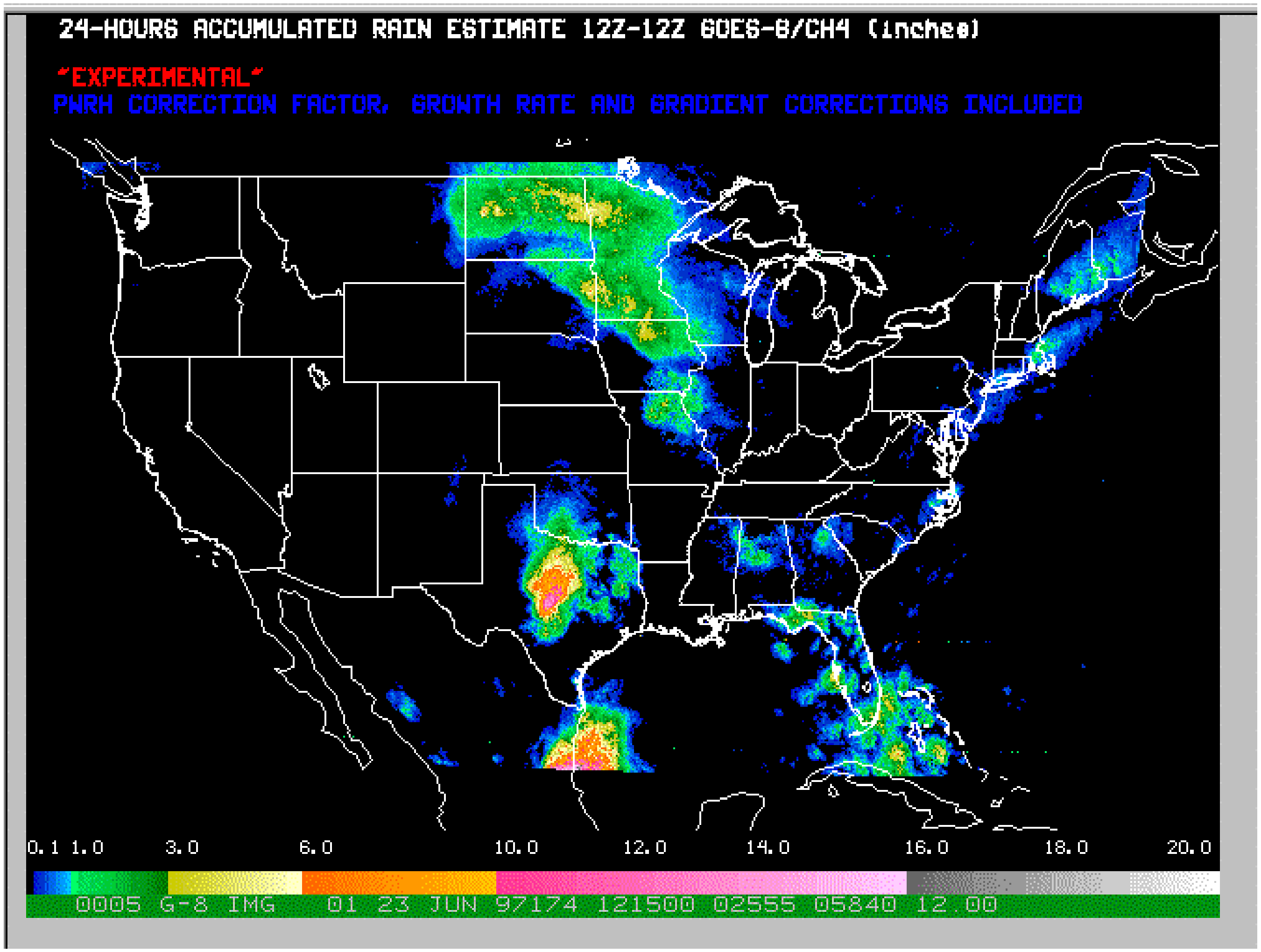
Auto-Estimator 24 hour rainfall estimates (in) ending 10-18-98 1200 UTC



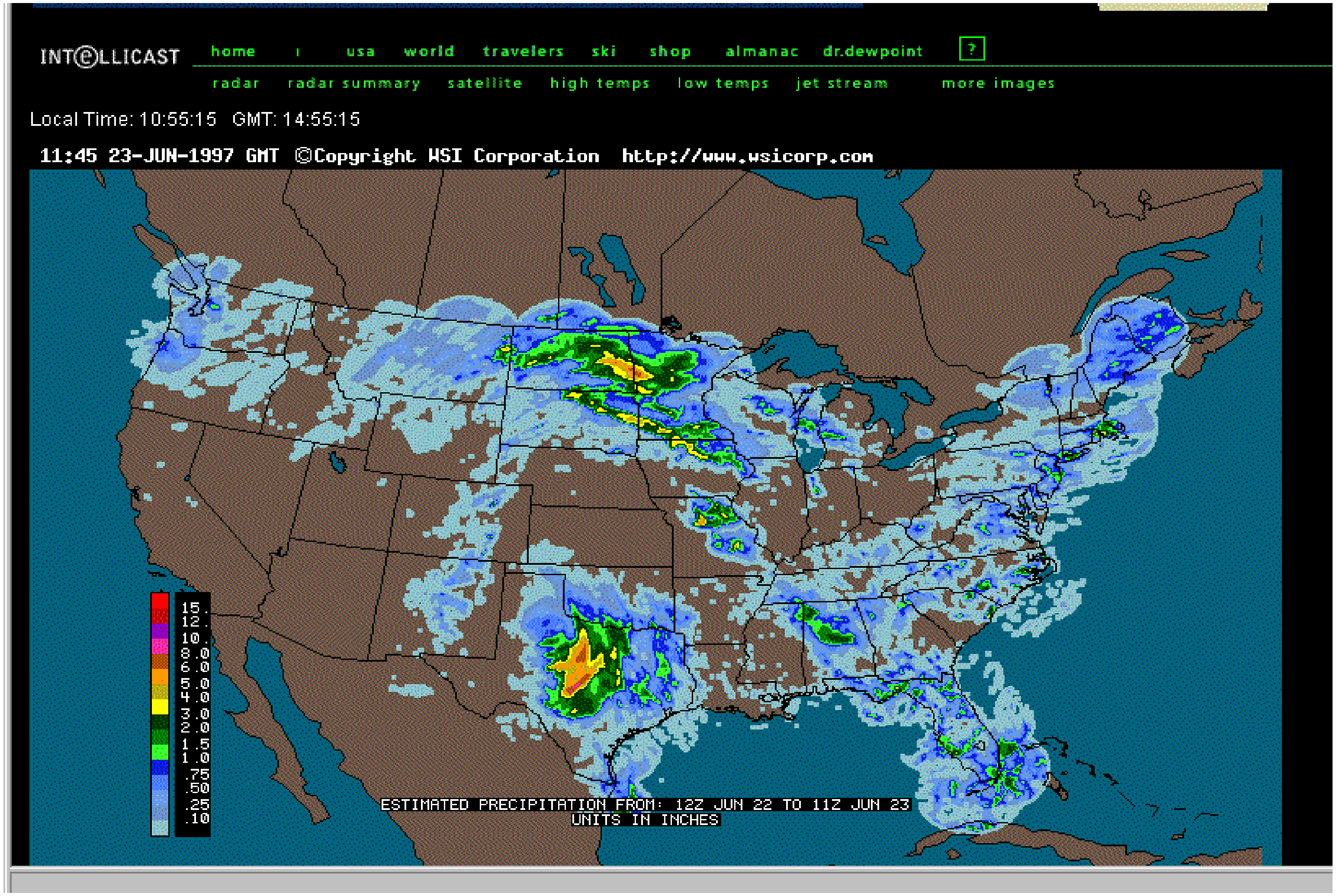
Interactive Flash Flood Analyzer (IFFA) 24 hour rainfall estimates (in) ending 10-18-98 1200 UTC



WSR 88 D 24 hour rainfall estimates (in) over Texas ending 10-18-98 1200 UTC



Auto-Estimator 24 Hour Rainfall Estimate (in) ending 6-23-97 1200 UTC



WSR 88 D 24 Hour Rainfall Estimates (in) ending 6-23-97 1200 UTC

Short Term Comparison with Radar (in mm)

July 1998
(1 - 3 hours)

cold top convection (colder than - 58º C)

Algorithm	cases	scale (Km)	corre	bias	FAR	adj RMS
Auto (std)	18	12	0.43	15.0	0.37	14.0
IFFA (Interactive Flash Flood Analyzer)	18	12	0.53	5.6	0.23	12.3

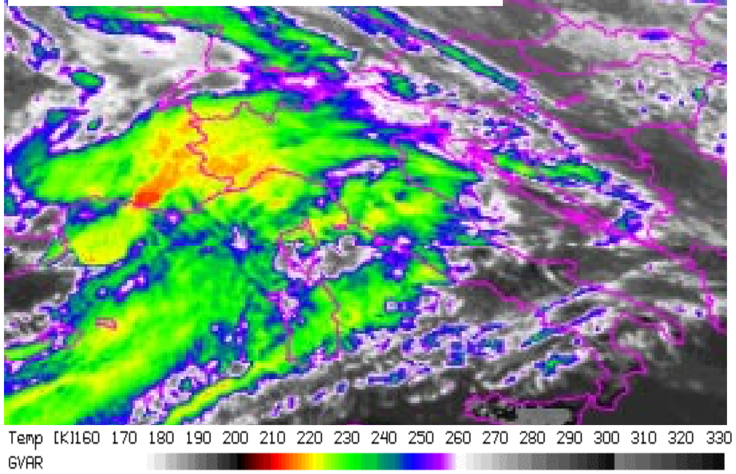
24 Hour Comparison with Gauges (in mm)

Tropical Origin, slow moving (Hurricane Bonnie / August 1998)

Algorithm	cases	corre	bias	adj RMS
Auto (std)	2	0.67	17.3	30.5
Auto (adj)	2	0.68	15.0	30.2
Radar	2	0.74	-12.4	23.0

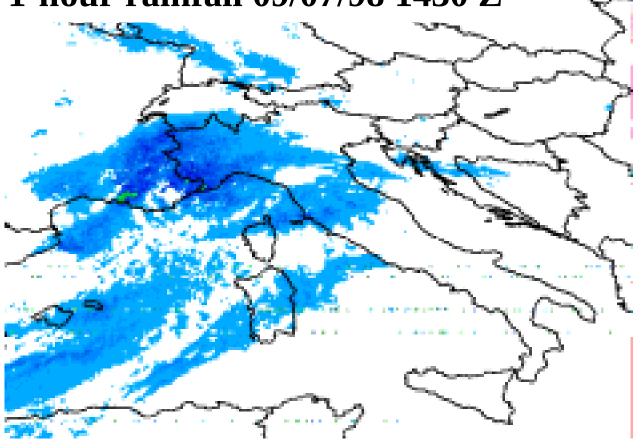
NOAA/NESDIS Automatic satellite rainfall estimation .. Auto-Estimator

Meteosat IR 09/07/98 1430 Z

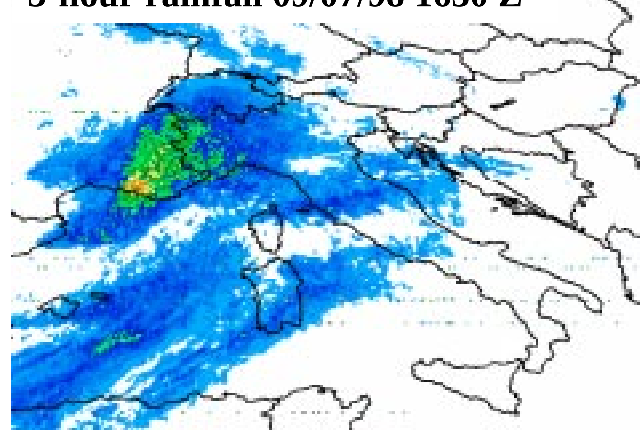


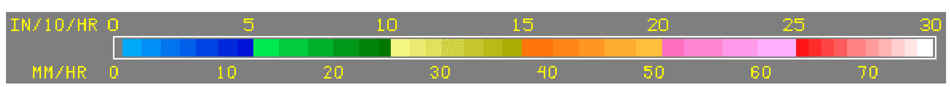
Instant. rainfall 09/07/98 1430 Z

1-hour rainfall 09/07/98 1430 Z



3-hour rainfall 09/07/98 1630 Z





Resource Requirements to “Run” Flash Flood Algorithms

- **GOES digital infrared and visible**
- **Frequency of data: 1/2 hourly to hourly**
- **Algorithms can be “run” on a RAMSDIS type system**

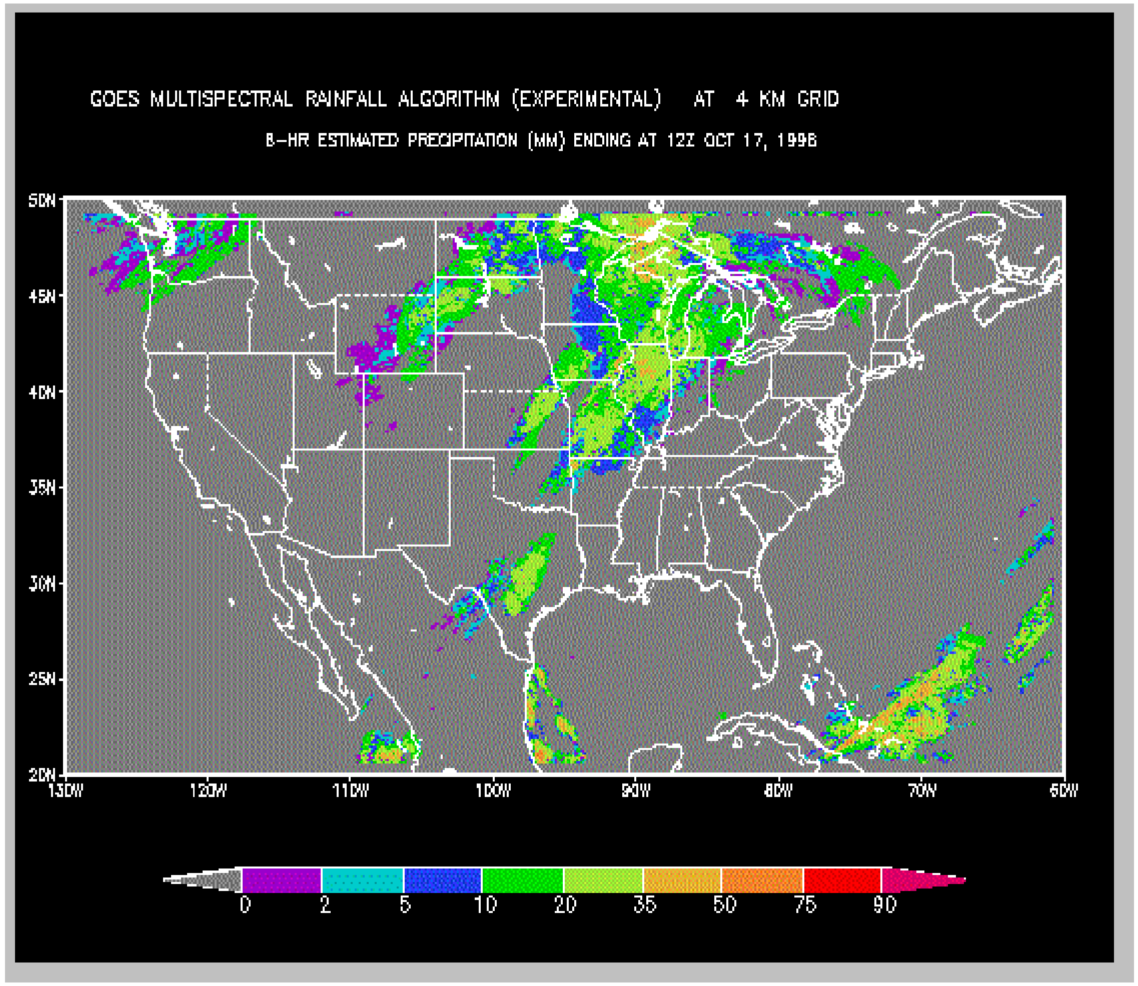
GOES MultiSpectral Rainfall Algorithm (GMSRA)

- **Step 1: Screening non-raining clouds**
- **- optically thick cloud filter:**
  visible reflectance > 0.40
- **- gradient temperature:**
  Tb4 brightness temp at 10.7 μm
- **- effective radius (reff) of cloud**
  particles > 15 μm at 3.9 μm

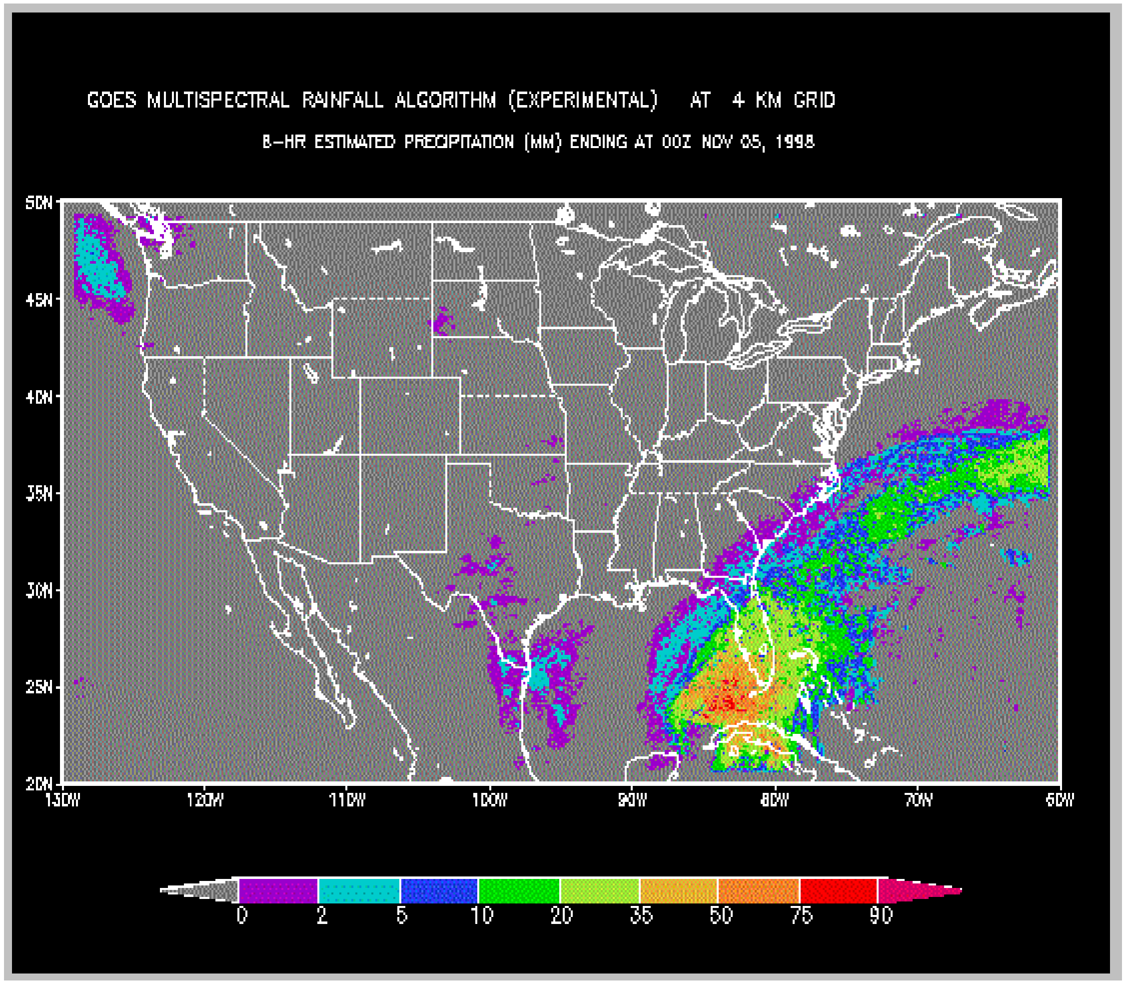
GOES MultiSpectral Rainfall Algorithm (GMSRA)

- **Step 2: Rain Rate Estimation**
- **Rain = P(Tb4,reff) * RR * Growth * PWRH**

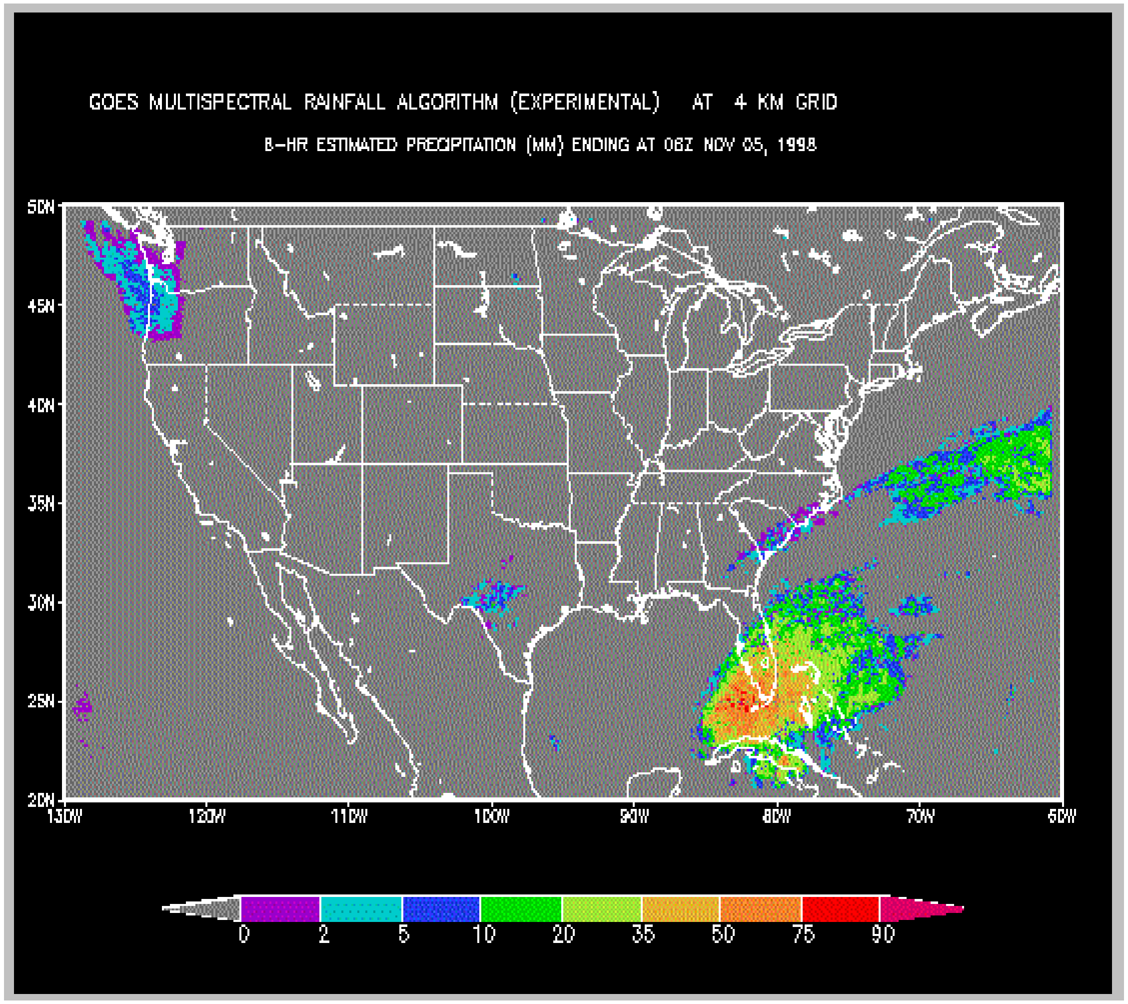
  - **RR pre-computed rain rate for give cloud top temperature**
  - **Growth: empirical cloud growth/decay adjustment**
  - **PWRH accounts for the moisture in the environment**



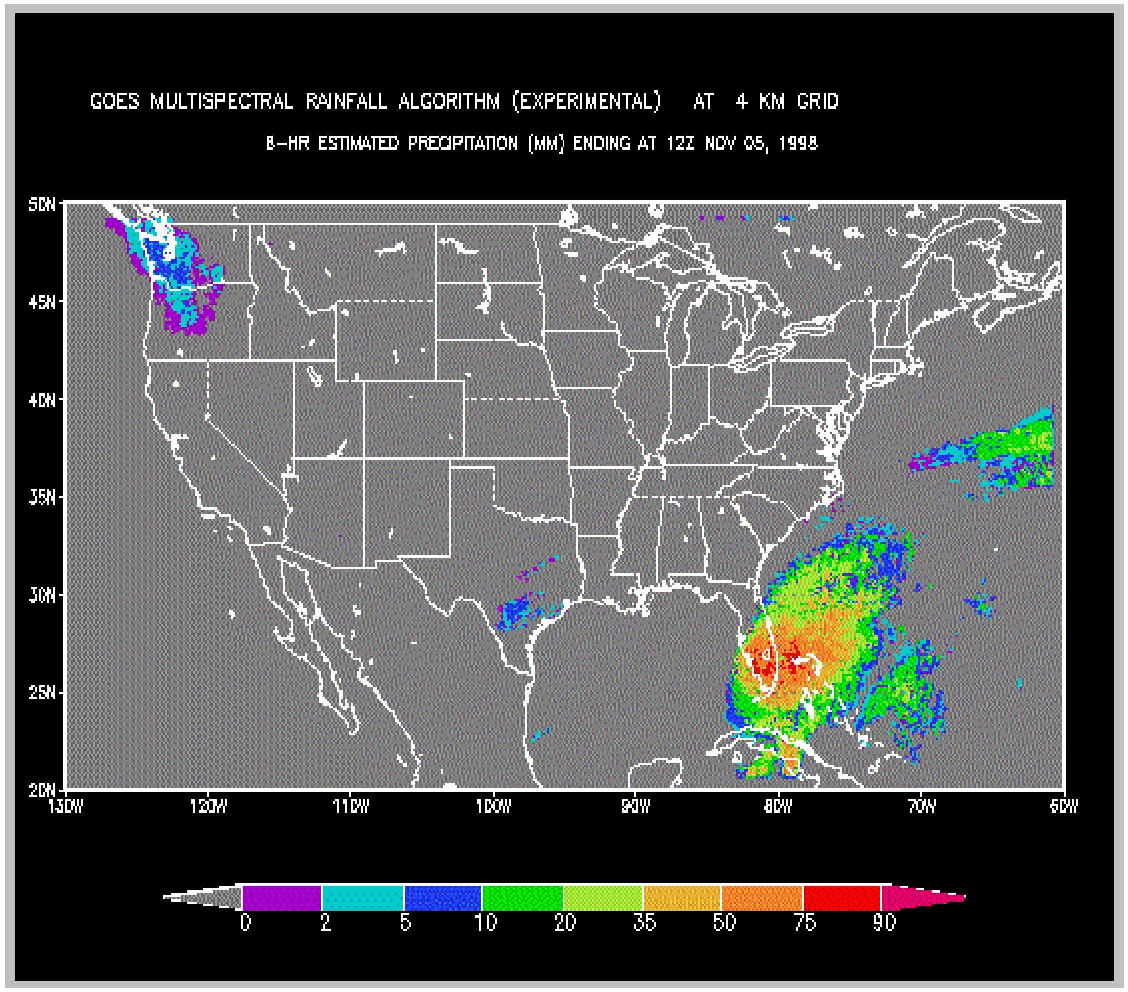
GOES Multi-Spectral Rainfall Algorithm 6 hour rainfall estimates (mm) ending 10-17-98 1200 UTC



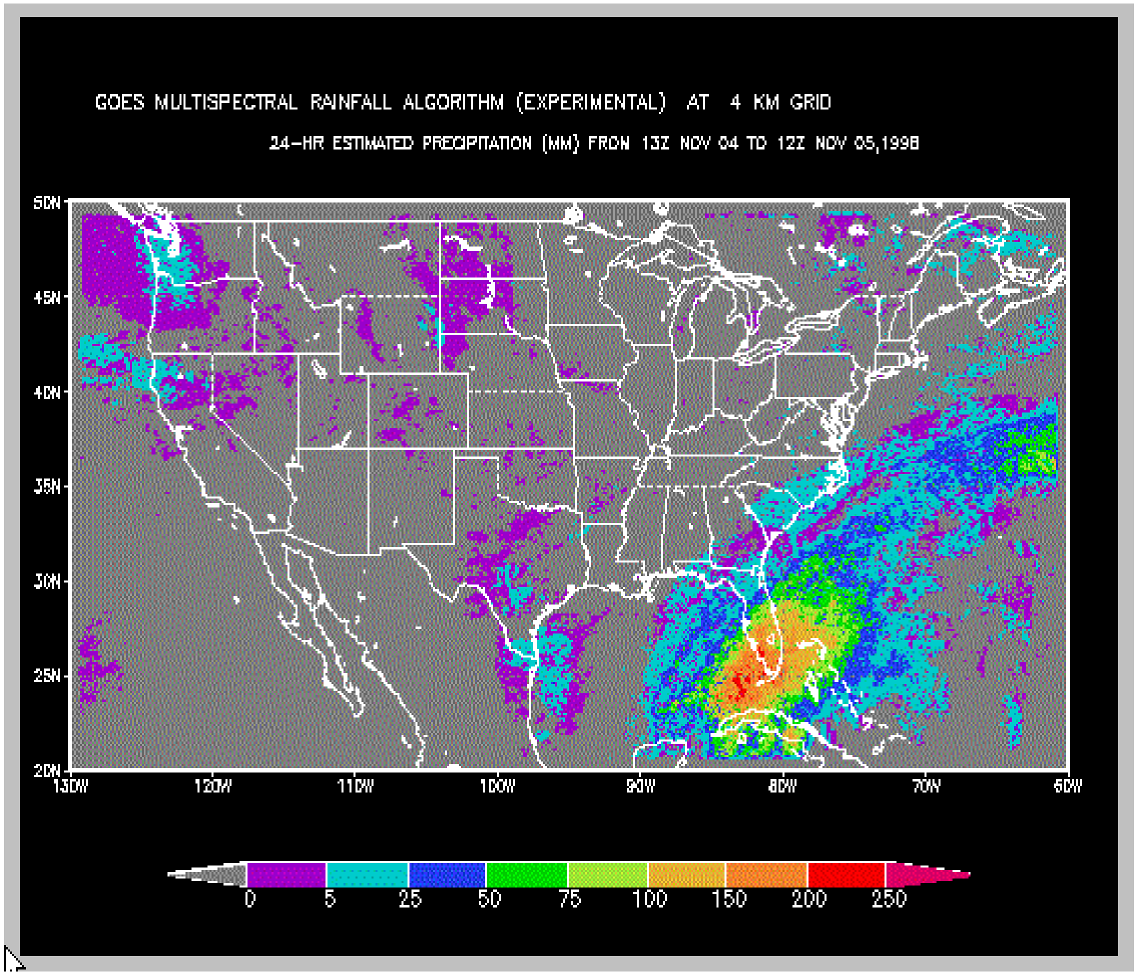
GOES Multi-Spectral Rainfall Algorithm 6 hour rainfall estimates (mm) ending 11-5-98 0000 UTC



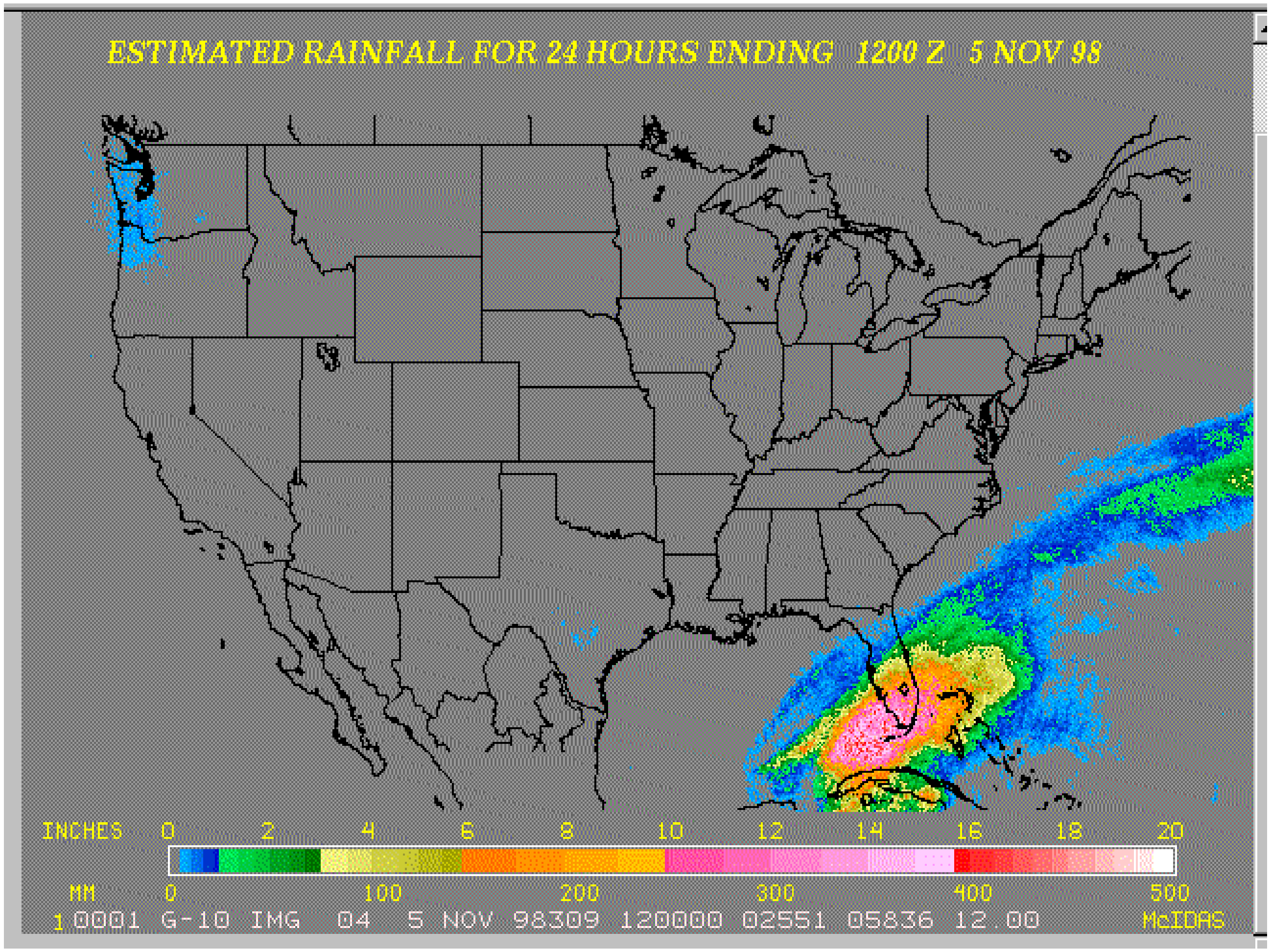
GOES Multi-Spectral Rainfall Algorithm 6 hour rainfall estimates (in) ending 11-5-98 0600 UTC



GOES Multi-Spectral Rainfall Algorithm 6 hour rainfall estimates (in) ending 11-5-98 1200 UTC



GOES Multi-Spectral Rainfall Algorithm 24 hour estimates (mm) ending 11-5-98 1200 UTC



Auto-Estimator 24 hour rainfall estimate (in) ending 11-5-98 1200 UTC

Short Term Comparison with Radar (in mm)

August 5 - September 18, 1998 (1 - 3 hours)

cold top convection (colder than - 58º C)

Algorithm	cases	scale (Km)	corre	bias	FAR	adj RMS	threat
Auto (std)	25	12	0.42	13.9	0.32	13.9	0.59
Auto (adj)	24	12	0.42	16.0	0.31	14.6	0.60
GMSRA	18	12	0.32	1.2	0.28	12.2	0.58

warm top convection (warmer than - 58º C)

Algorithm	cases	scale (Km)	corre	bias	FAR	adj RMS	threat
Auto (std)	27	12	0.36	0.30	0.29	10.0	0.49
Auto (adj)	27	12	0.36	12.8	0.32	14.5	0.55
GMSRA	23	12	0.34	1.8	0.28	11.2	0.49

Special Sensor Microwave Imager (SSM/I) (DMSP) and Advanced Microwave Sensing Unit (AMSU) (NOAA K) Precipitation Estimates

Emission - Based

- **Over water only**
- **Liquid precipitation causes brightness temperature increase over a radiometrically cold/ocean background**
- **most direct estimate of how much rainfall reaches ground**

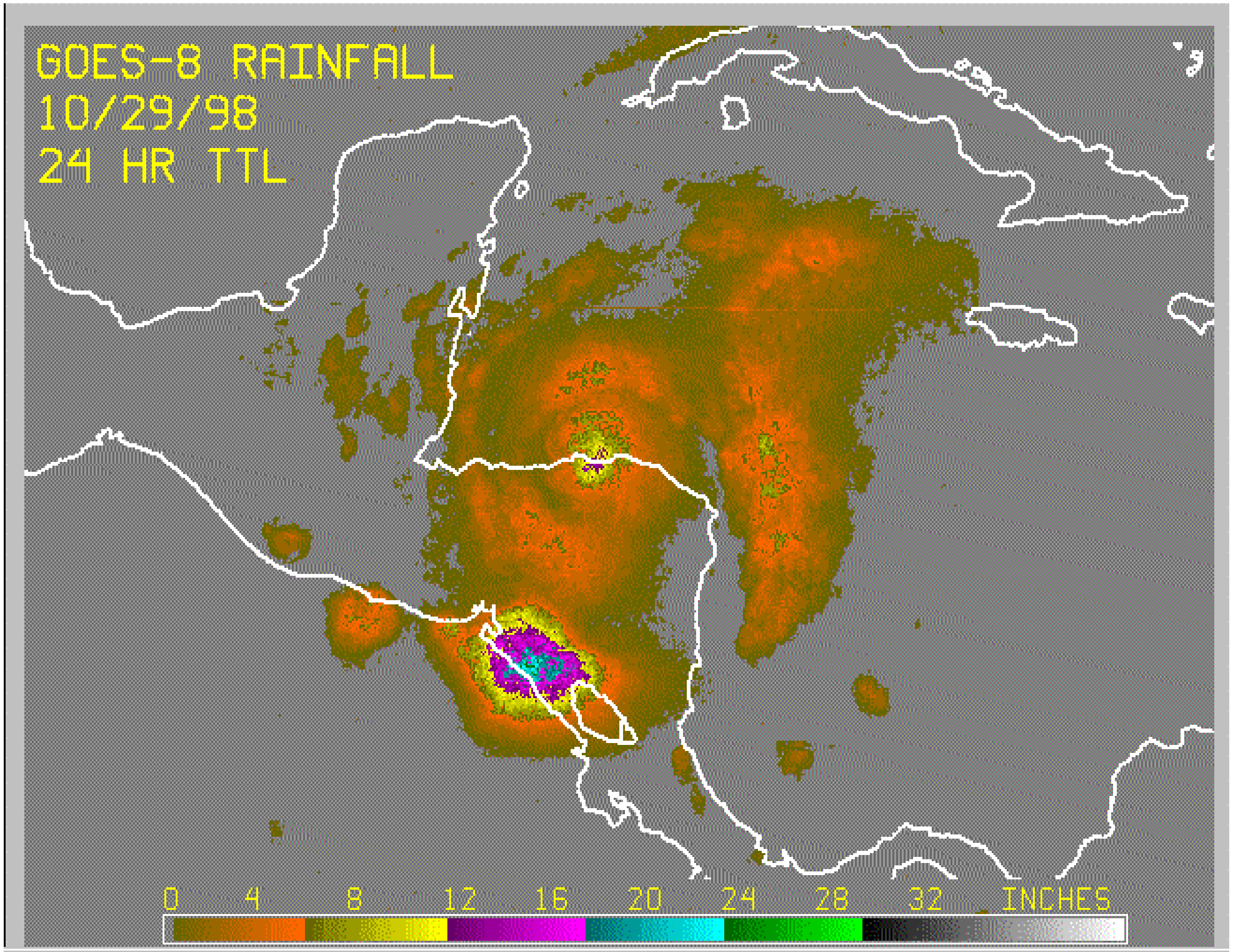
SSM/I and AMSU) Precipitation Estimates

Scattering Based

- **Over land and water**
- **Precipitation (colder than freezing level) causes brightness temperature decreases over a radiometrically warm/land background**
- **more indirect estimate of how much rainfall reaches ground**

Special Sensor Microwave Imager (SSM/I) (DMSP) Channels Sensitive to Precipitation

- **85.5 GHz**
- **37.0 GHz**
- **22.235 GHz**
- **19.35 GHz**

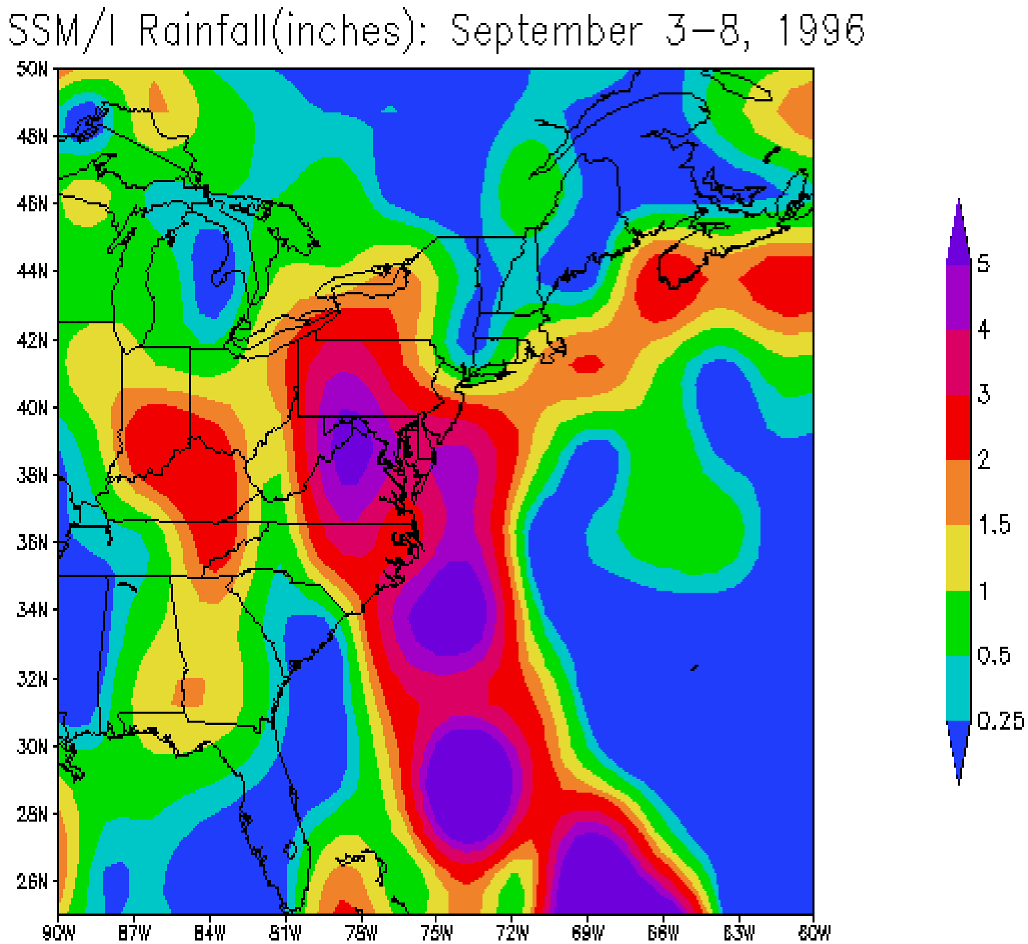


Auto-Estimator 24 hour rainfall estimates (in) for Hurricane Mitch ending 10-29-98 1200 UTC

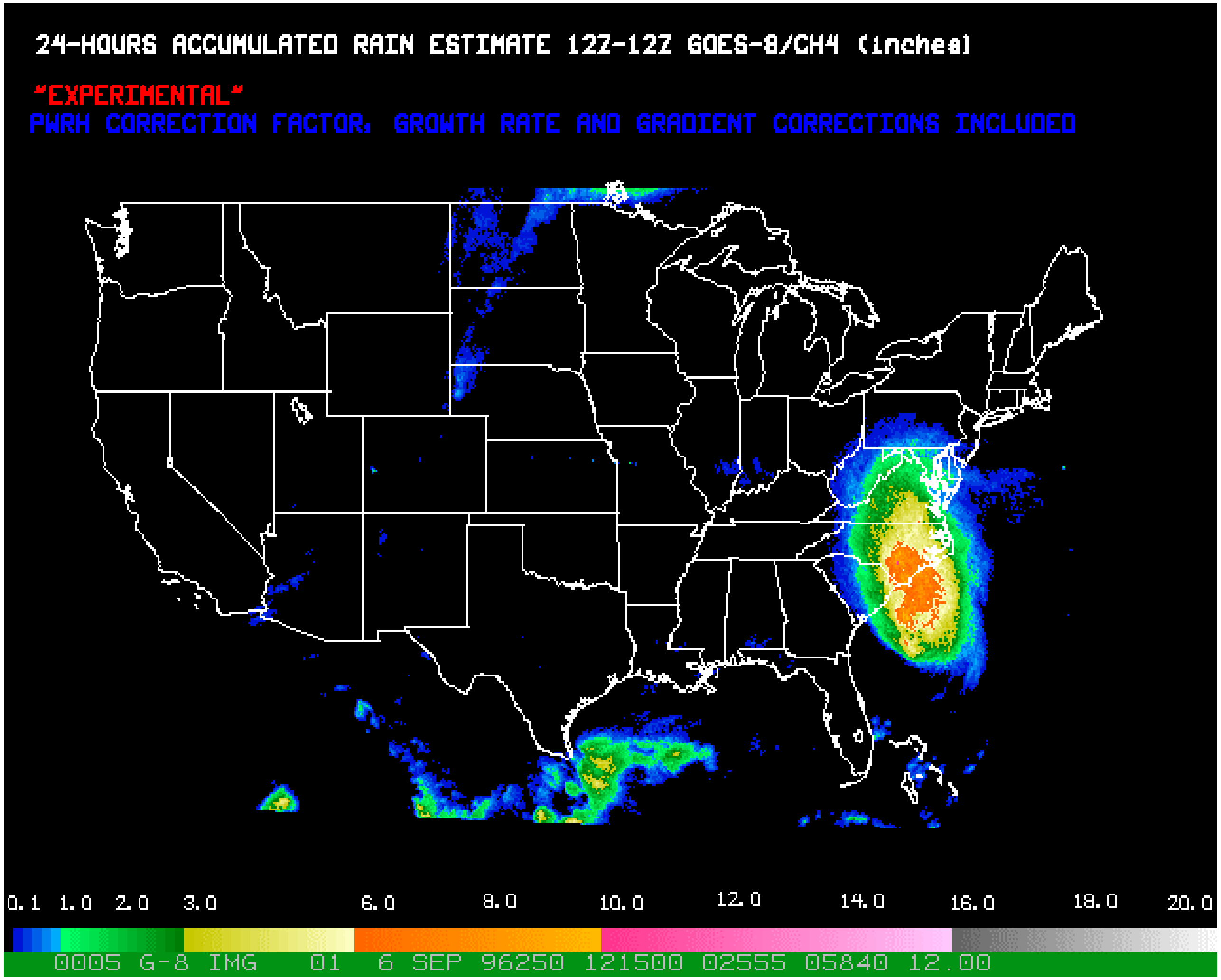
PRECIPITATION POTENTIAL (P)

$$P = \frac{E \times C}{V}$$

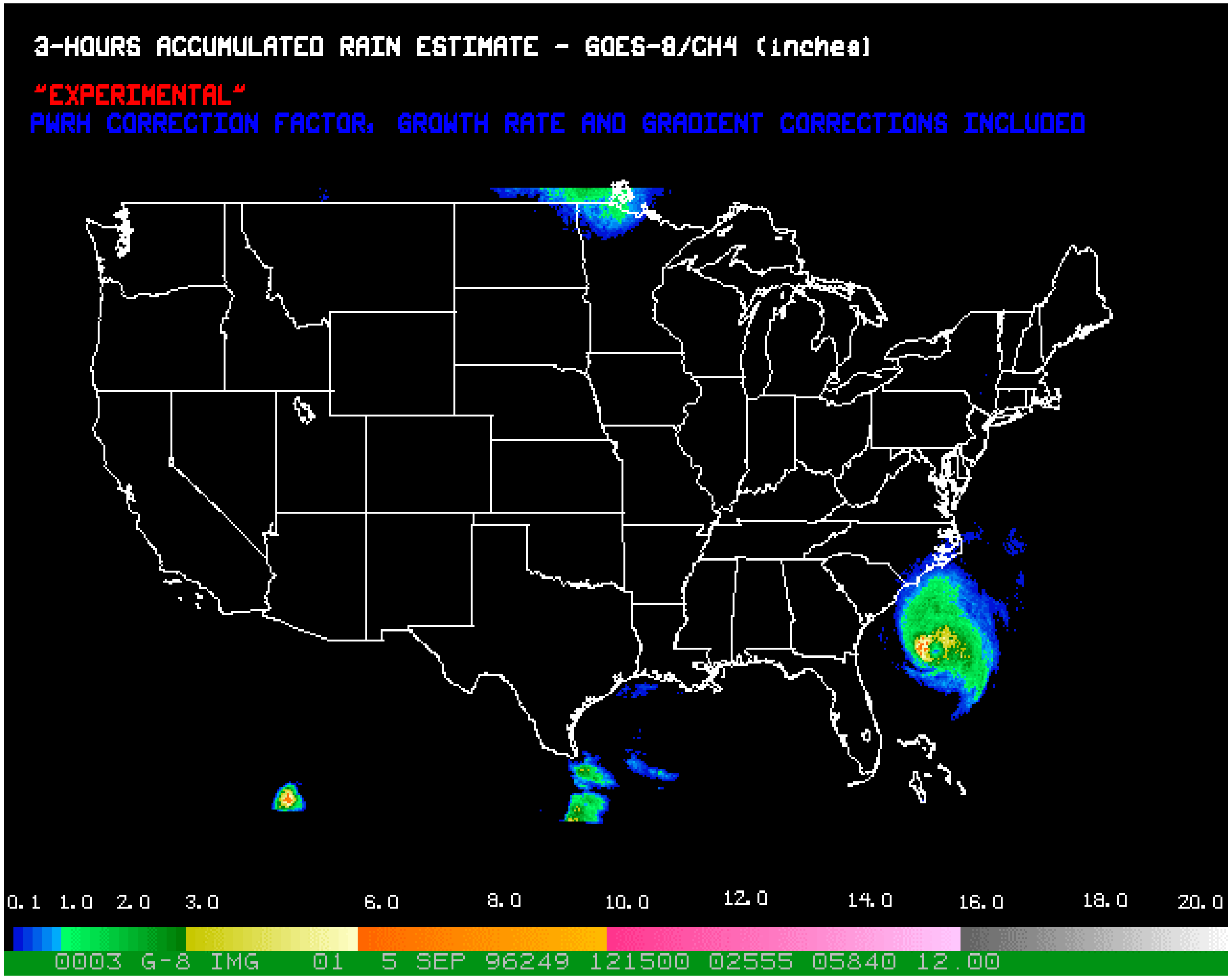
Where E = Precipitation Estimates
C = Cross-section thru storm
V = Speed of storm



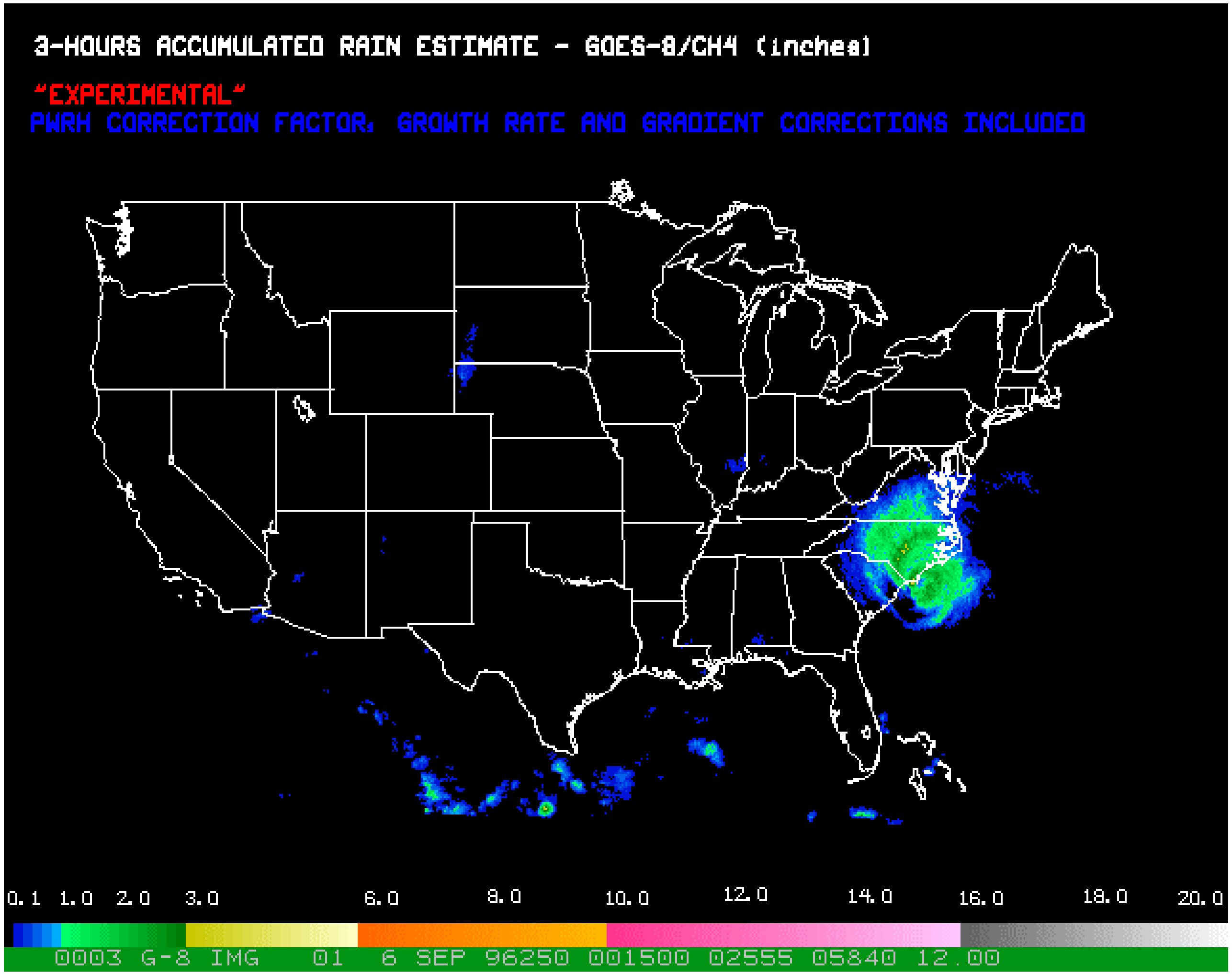
SSM/I rainfall estimates (in) for Hurricane Fran from September 3 - 8, 1996



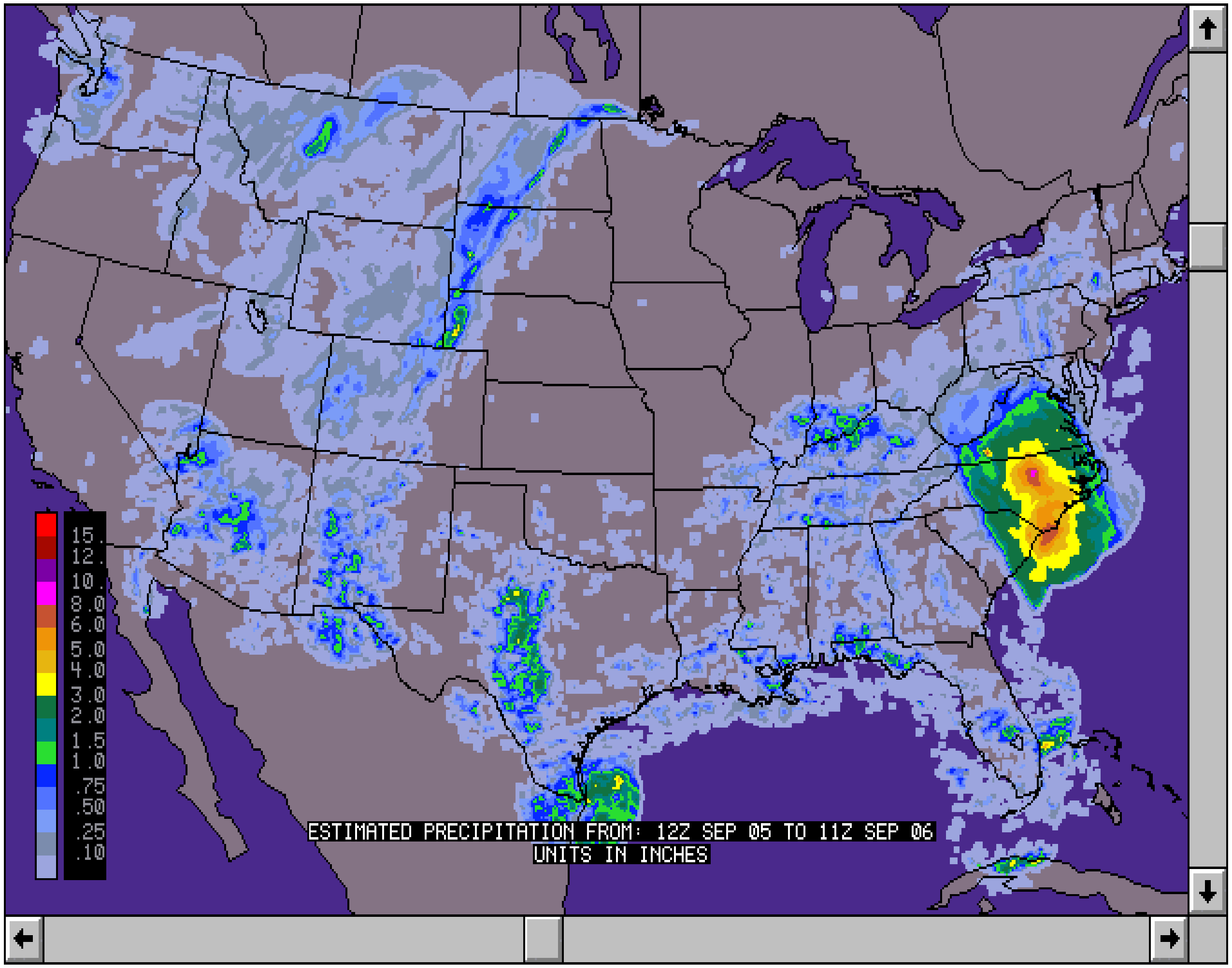
Auto-Estimator 24 hour rainfall estimates (in) for Hurricane Fran ending 9-6-96 1200 UTC



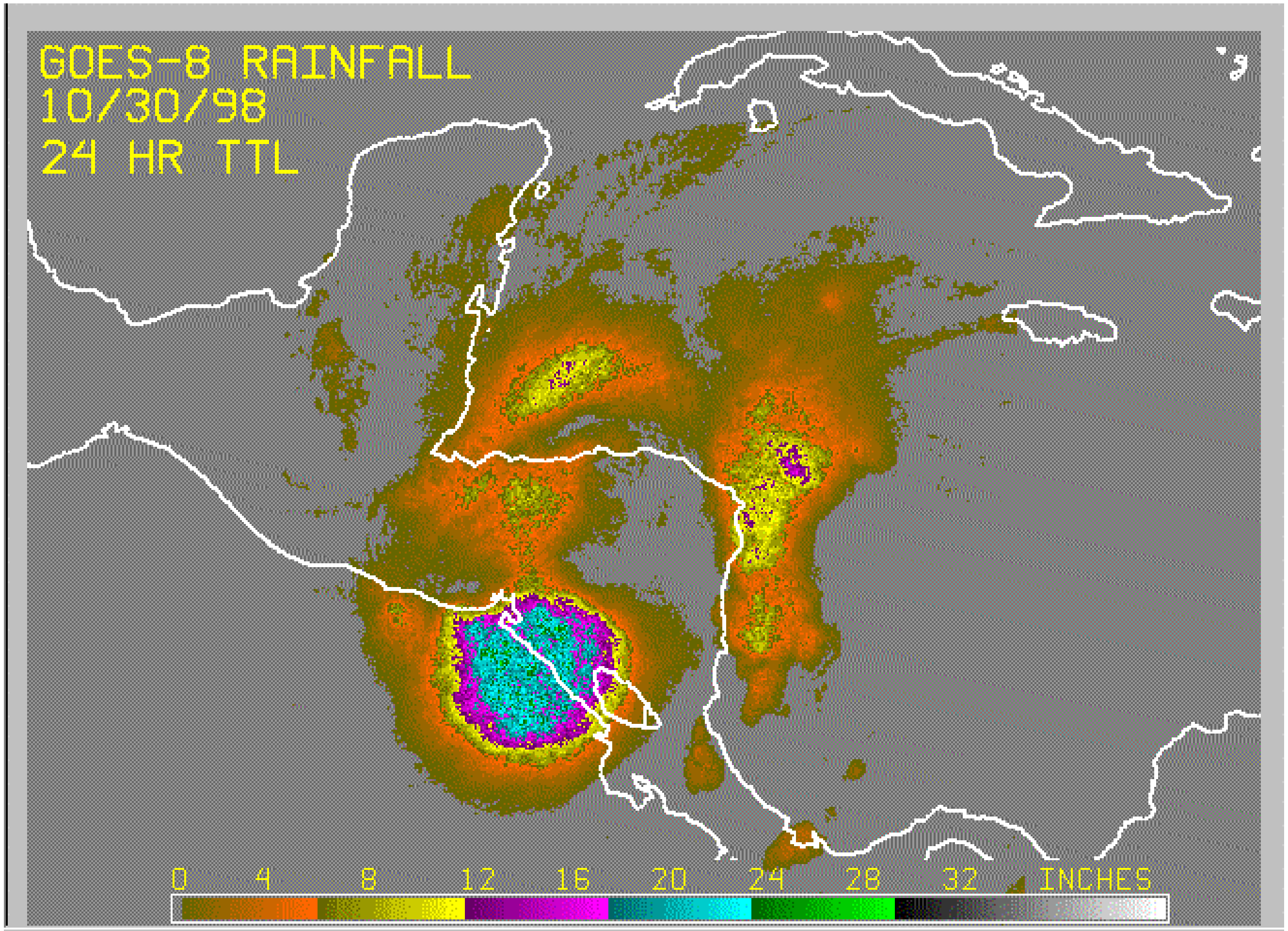
Auto-Estimator 3 hour rainfall estimates (in) for Hurricane Fran ending 9-5-96 1215 UTC



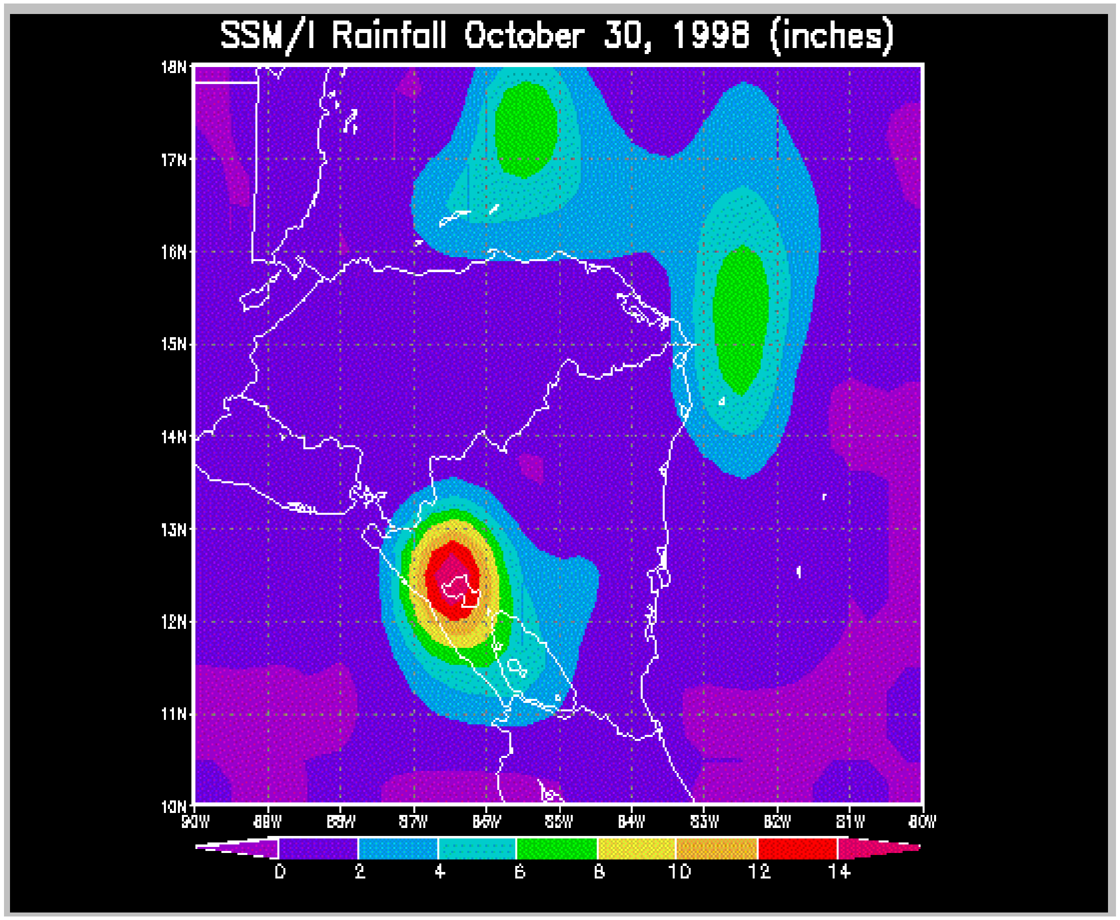
Auto-Estimator 3 hour rainfall estimates (in) for Hurricane Fran ending 9-6-96 0015 UTC



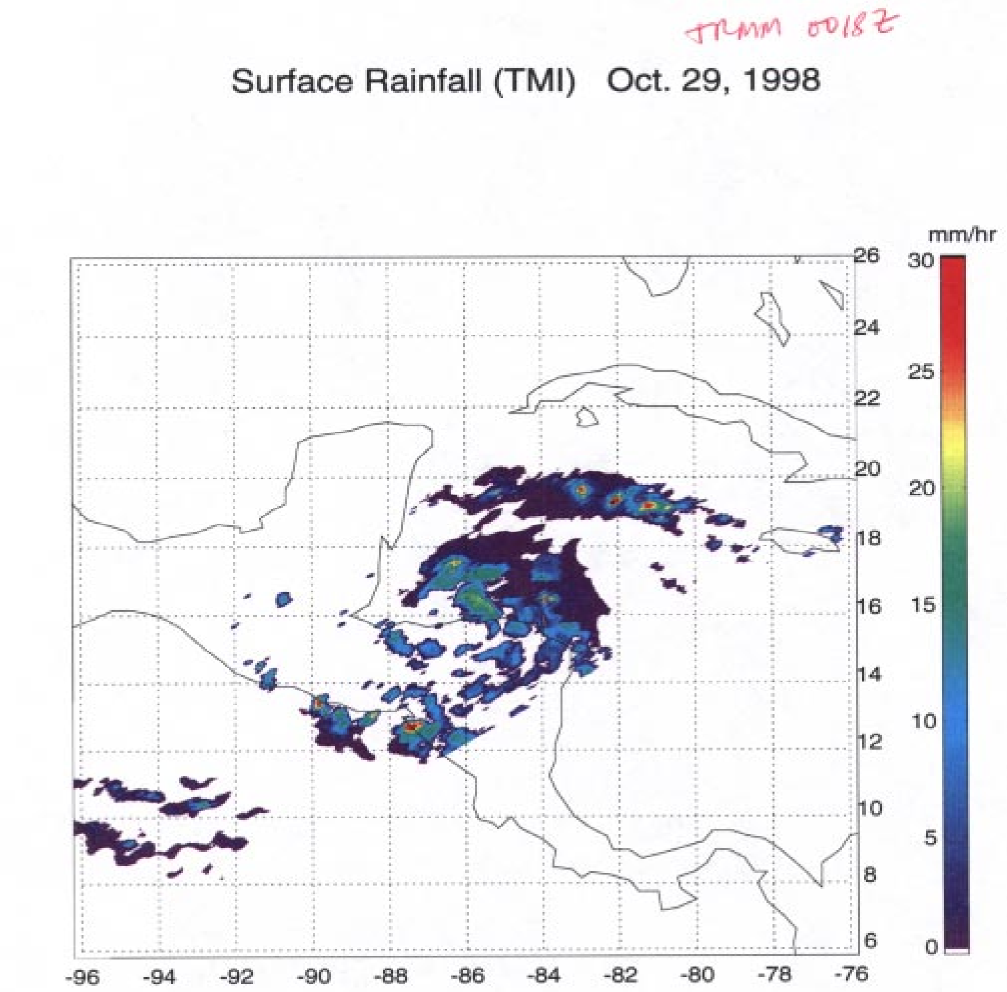
WSR 88 D 24 hour rainfall estimates (in)
for Hurricane Fran ending 9-6-96 1200 UTC



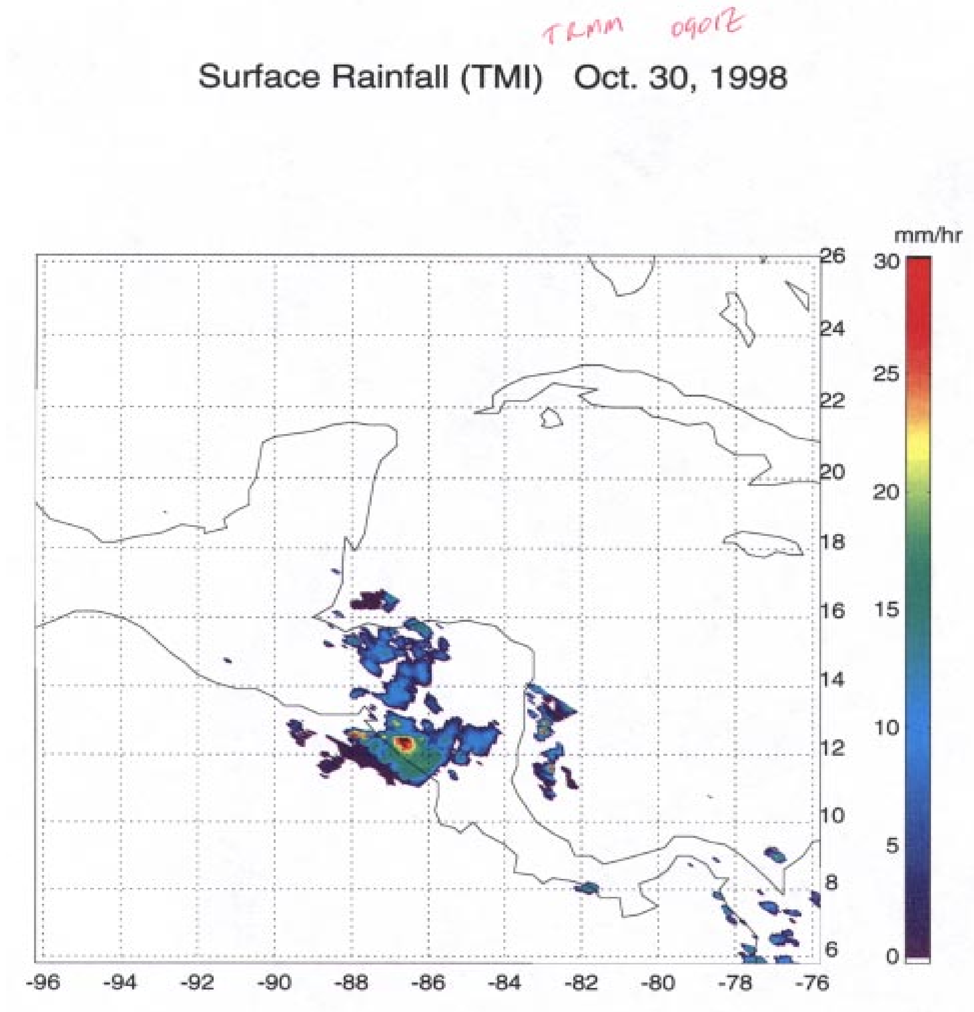
Auto-Estimator 24 hour rainfall estimates (in)
for Hurricane Mitch ending 10-30-98 1200 UTC



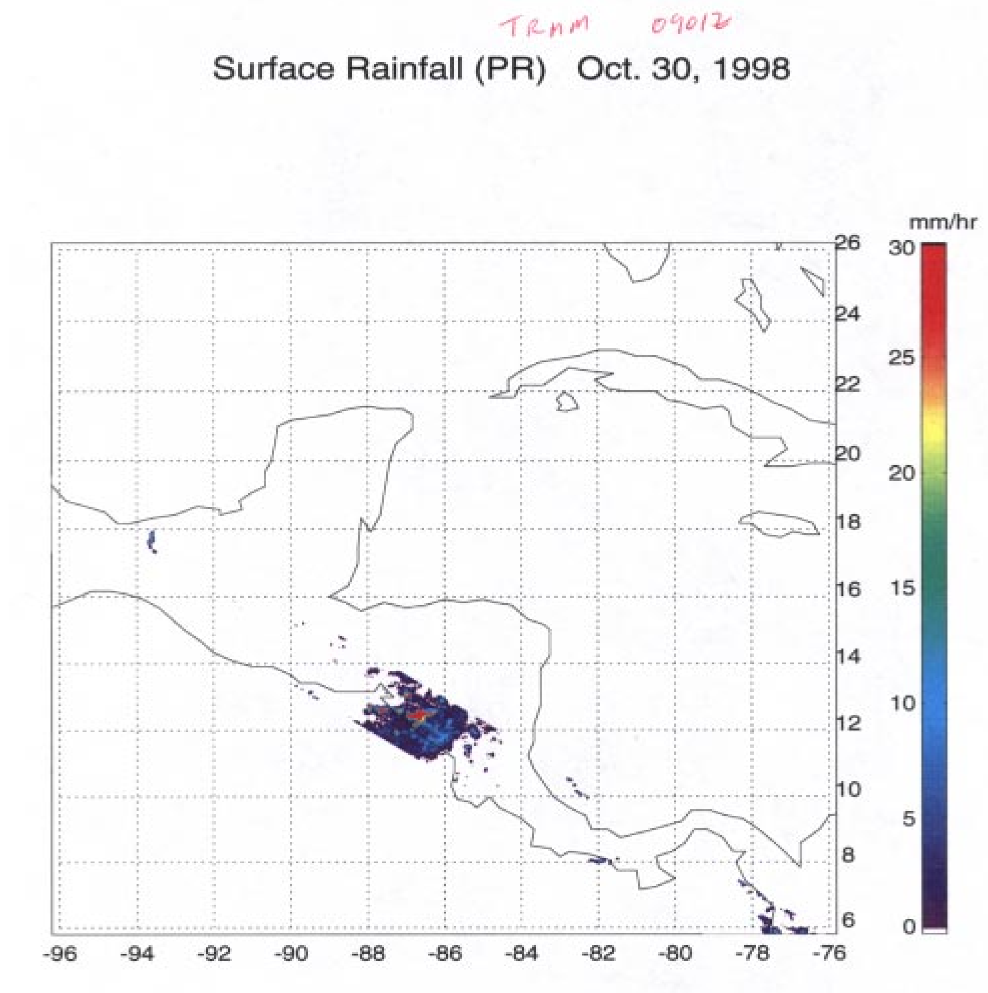
SSM/I rainfall (in) for Hurricane Mitch 10-30-98



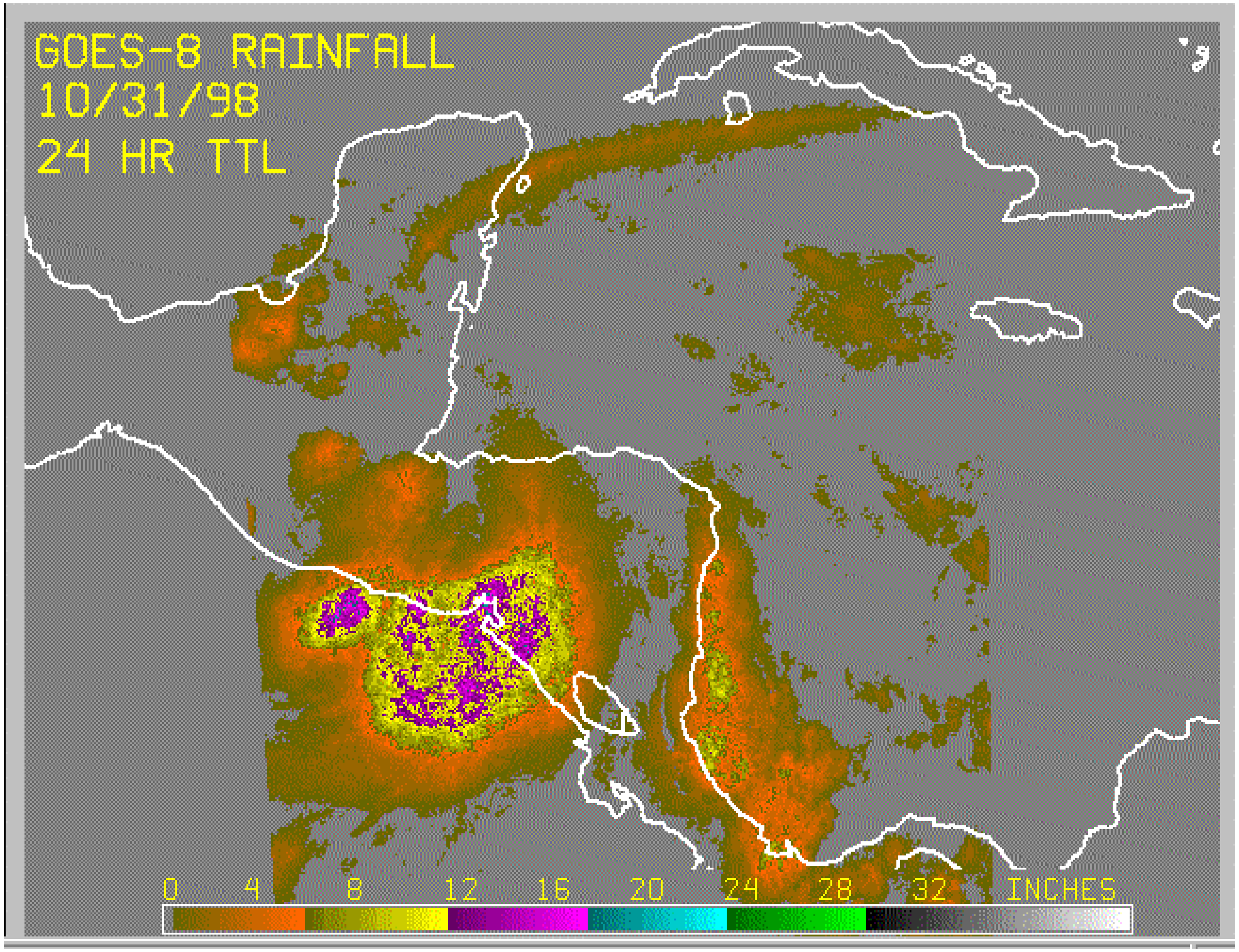
TRMM Microwave



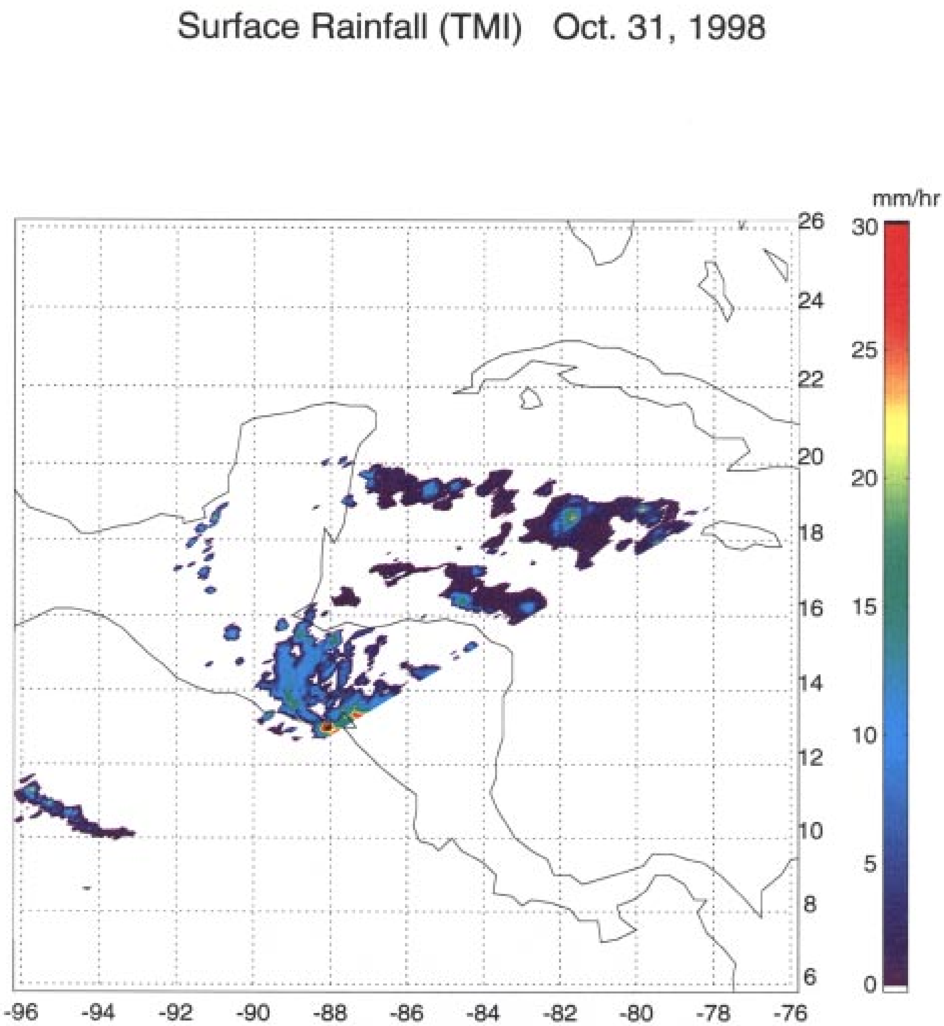
TRMM Microwave


TRMM 0901Z
Surface Rainfall (PR) Oct. 30, 1998
mm/hr
30
25
20
15
10
5
0
26
24
22
20
18
16
14
12
10
8
6
-96
-94
-92
-90
-88
-86
-84
-82
-80
-78
-76

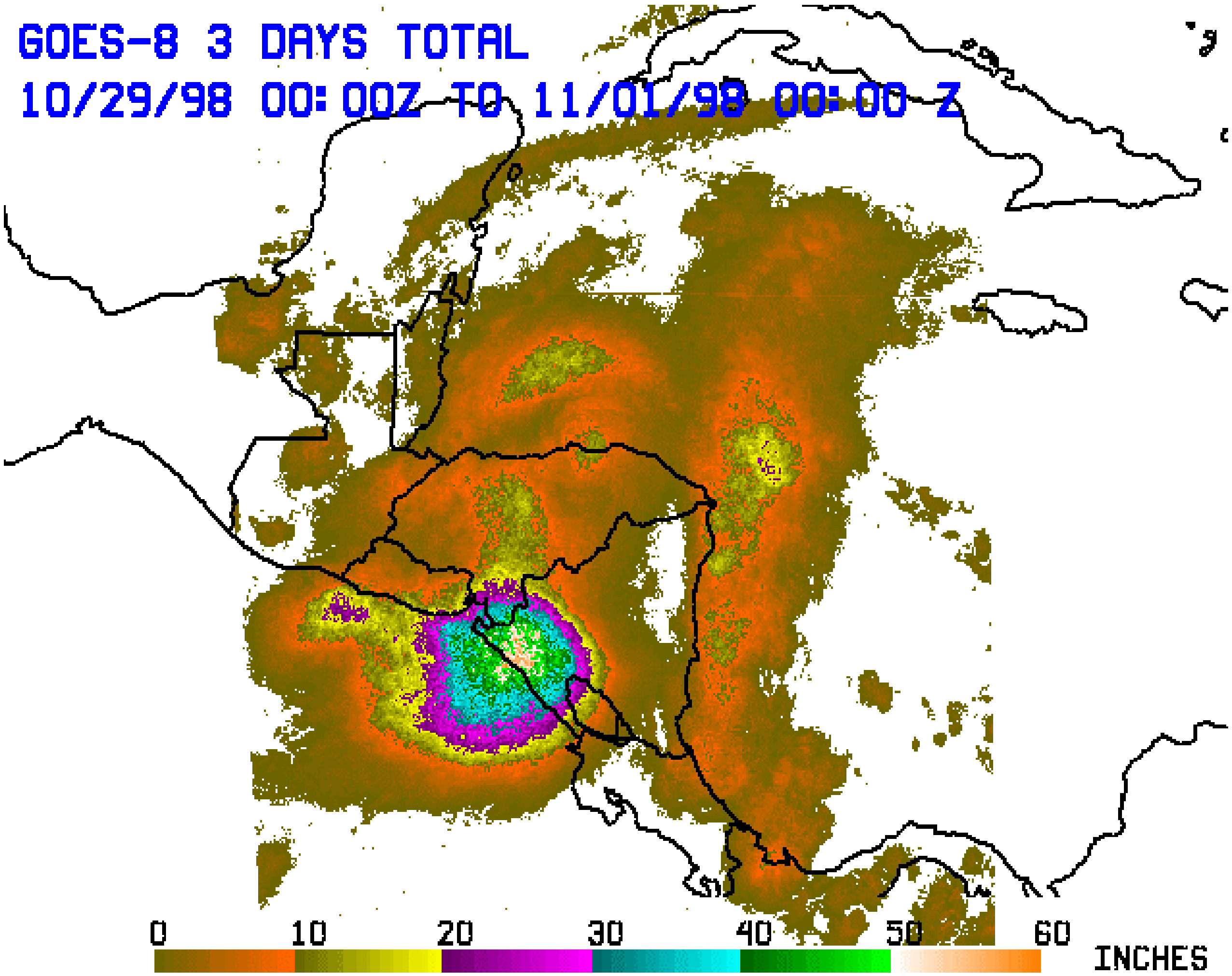
TRMM Radar



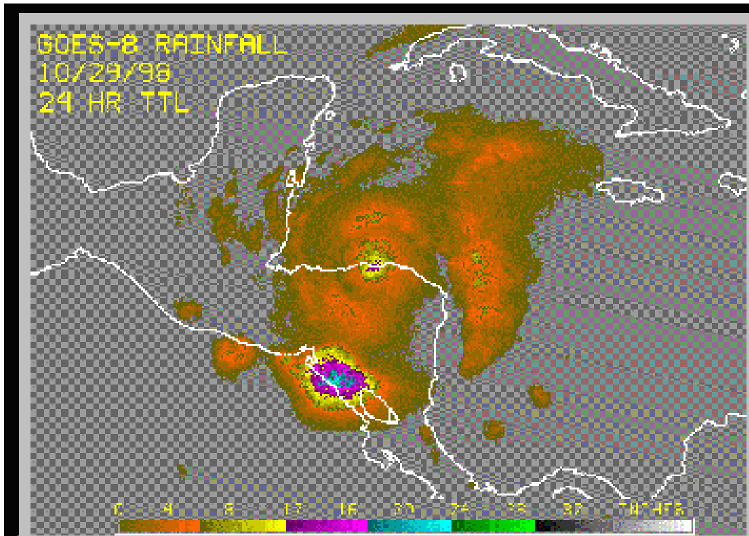
Auto-Estimator 24 hour rainfall estimates (in) for Hurricane Mitch ending 10-31-98



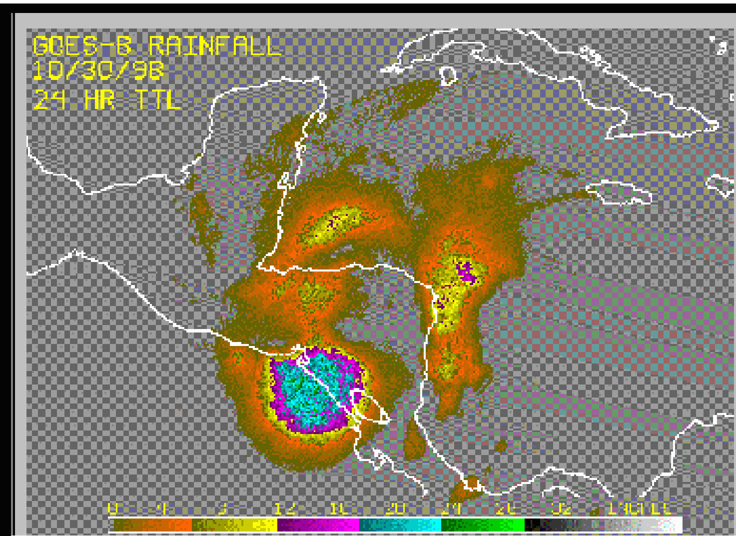
TRMM Microwave



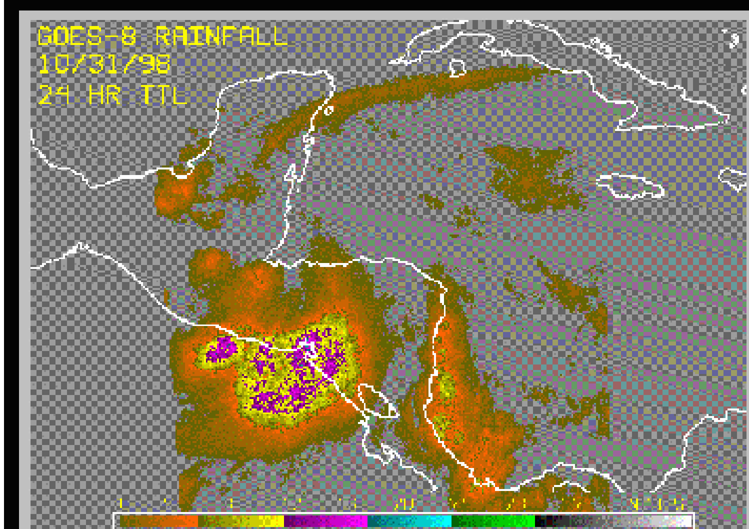
Auto-Estimator 3 day accumulations (in) for Hurricane Mitch



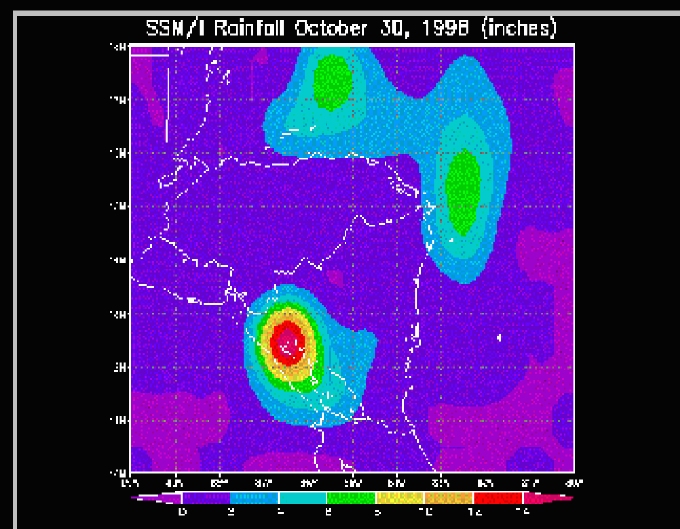
spain8.gif



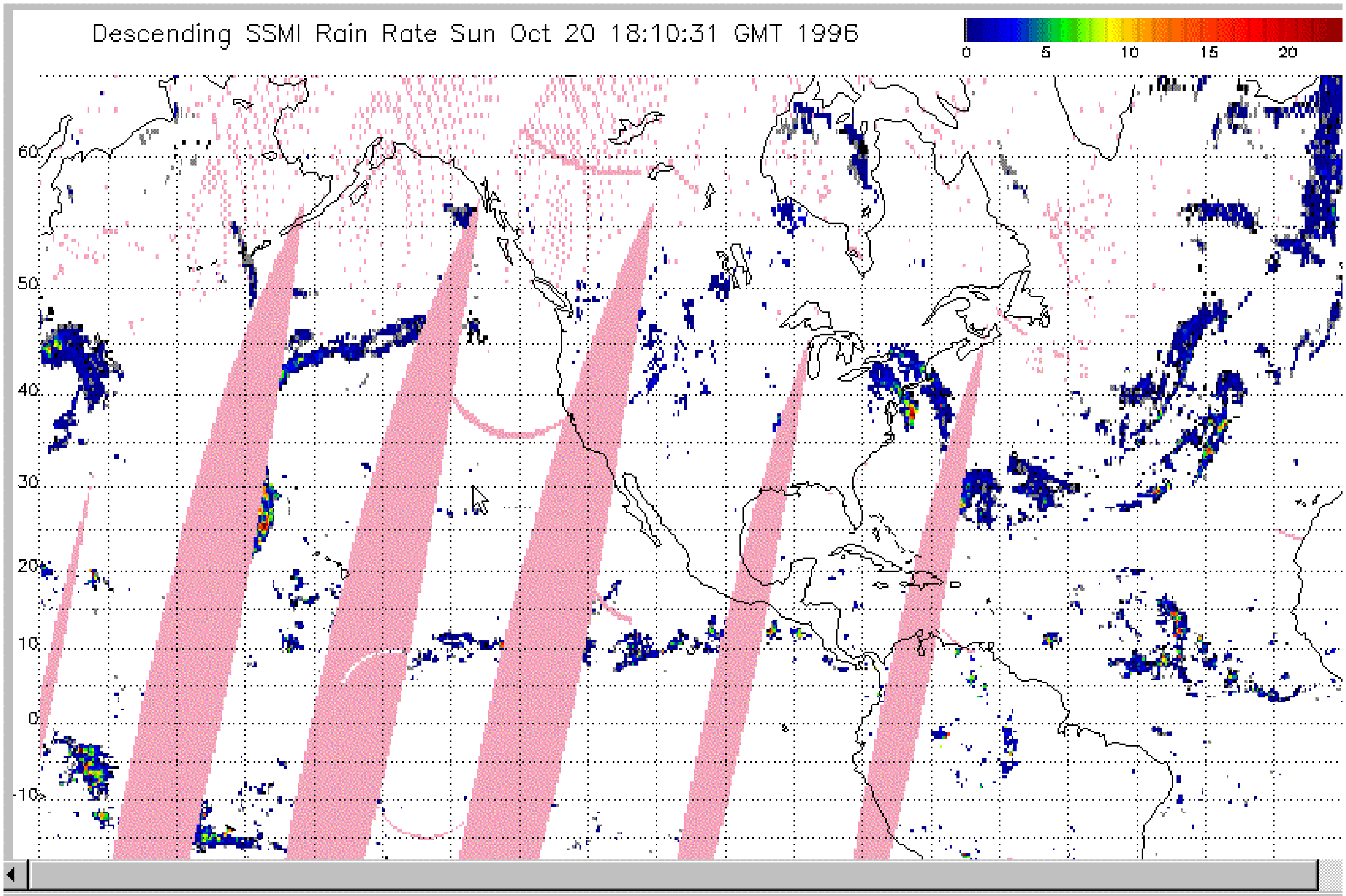
spain9.gif



spain10.gif



spain11.gif



SSM/I Rain Rate (mm/hr) for 10-20-96

How much more rain ?
How much longer ?
Where is the rain going to move?

The answer to these questions is:
"How do you expect the convection to PROPAGATE"?

Propagation

- **Movement and development**
- **Types of thunderstorm propagation**
  - **forward**
  - **regenerative**
  - **back building**
  - **forward moving meso beta storms**
  - **supercell**

Conceptual Models of Forward and Backward Propagation

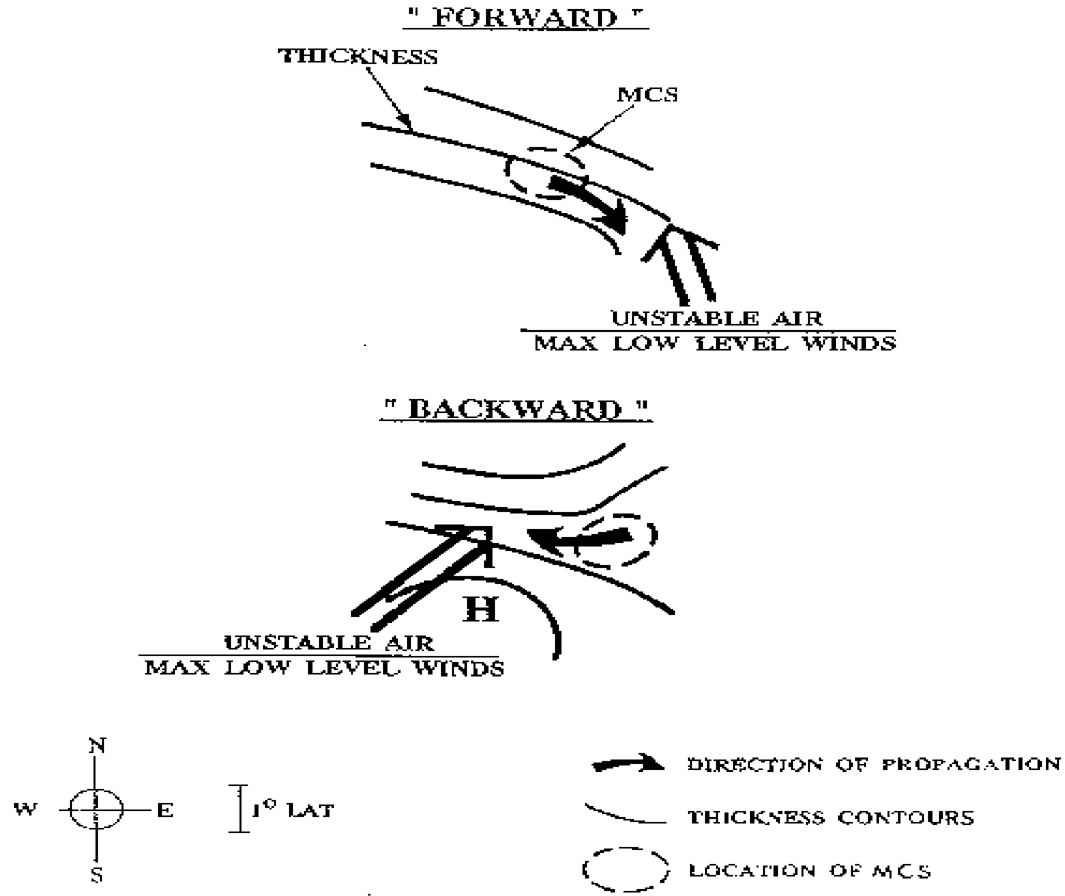
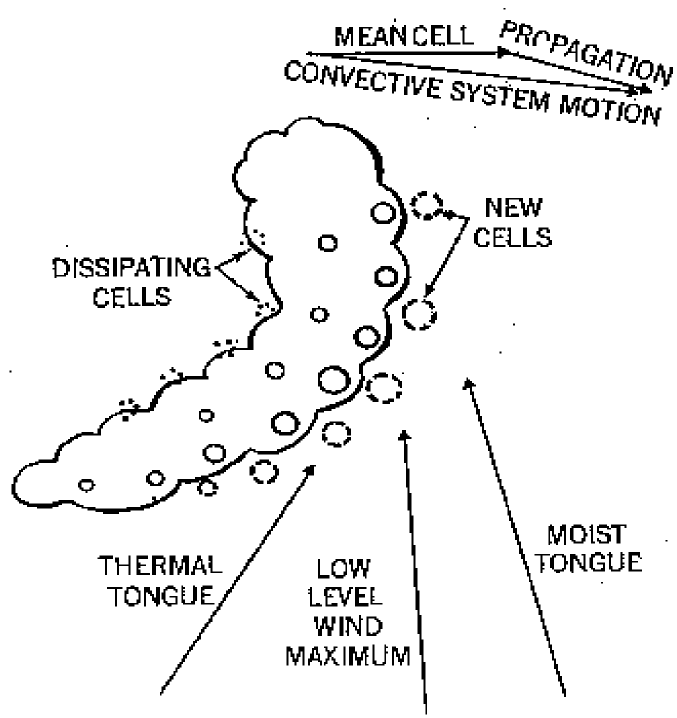


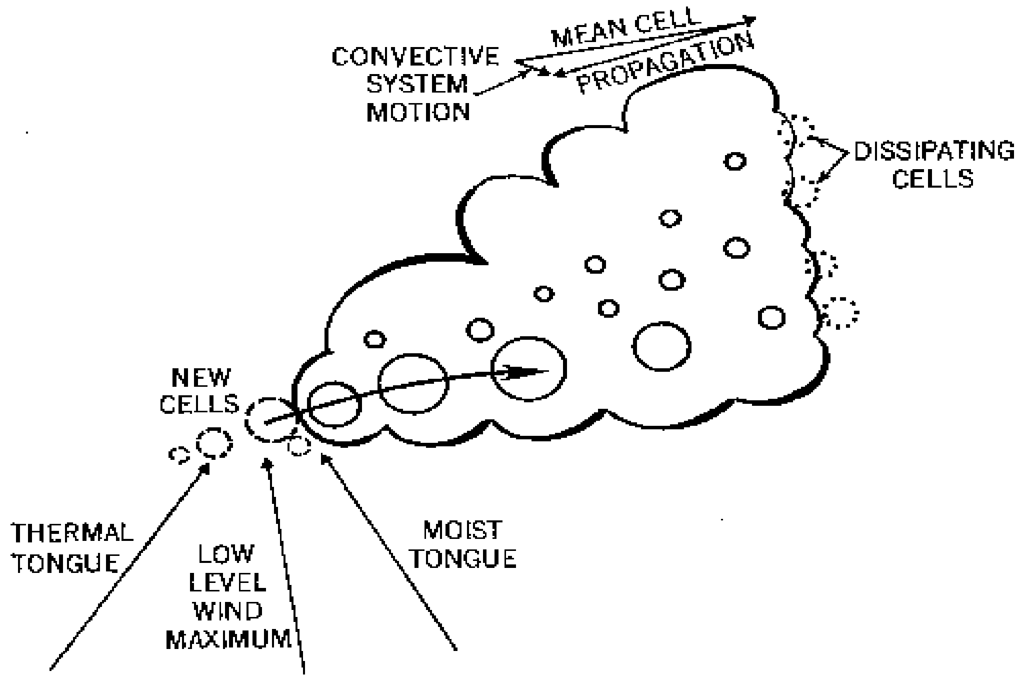
Figure 14. The relationship of thickness patterns and destabilization to MCS propagation.



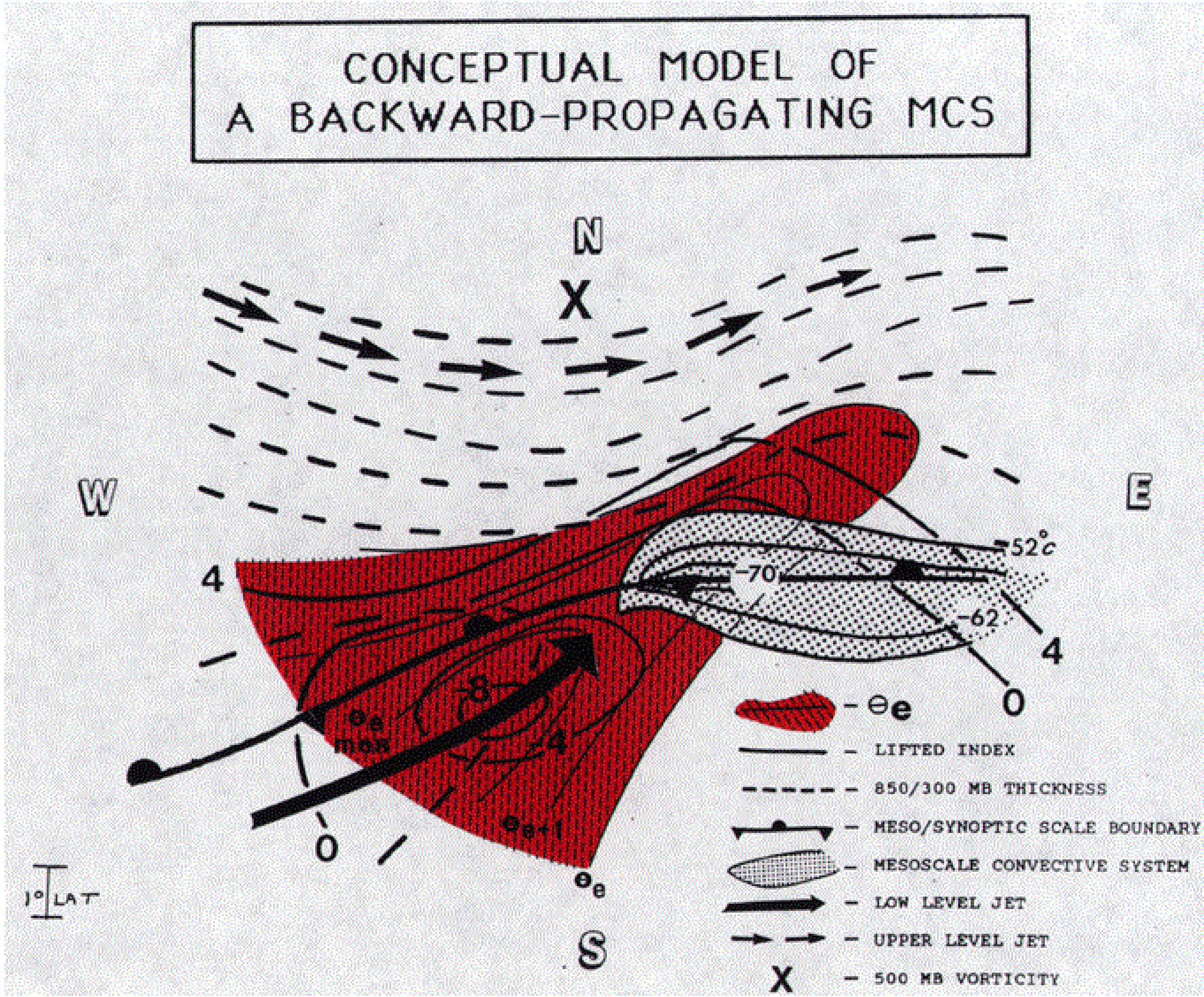
Conceptual model of forward propagating thunderstorms

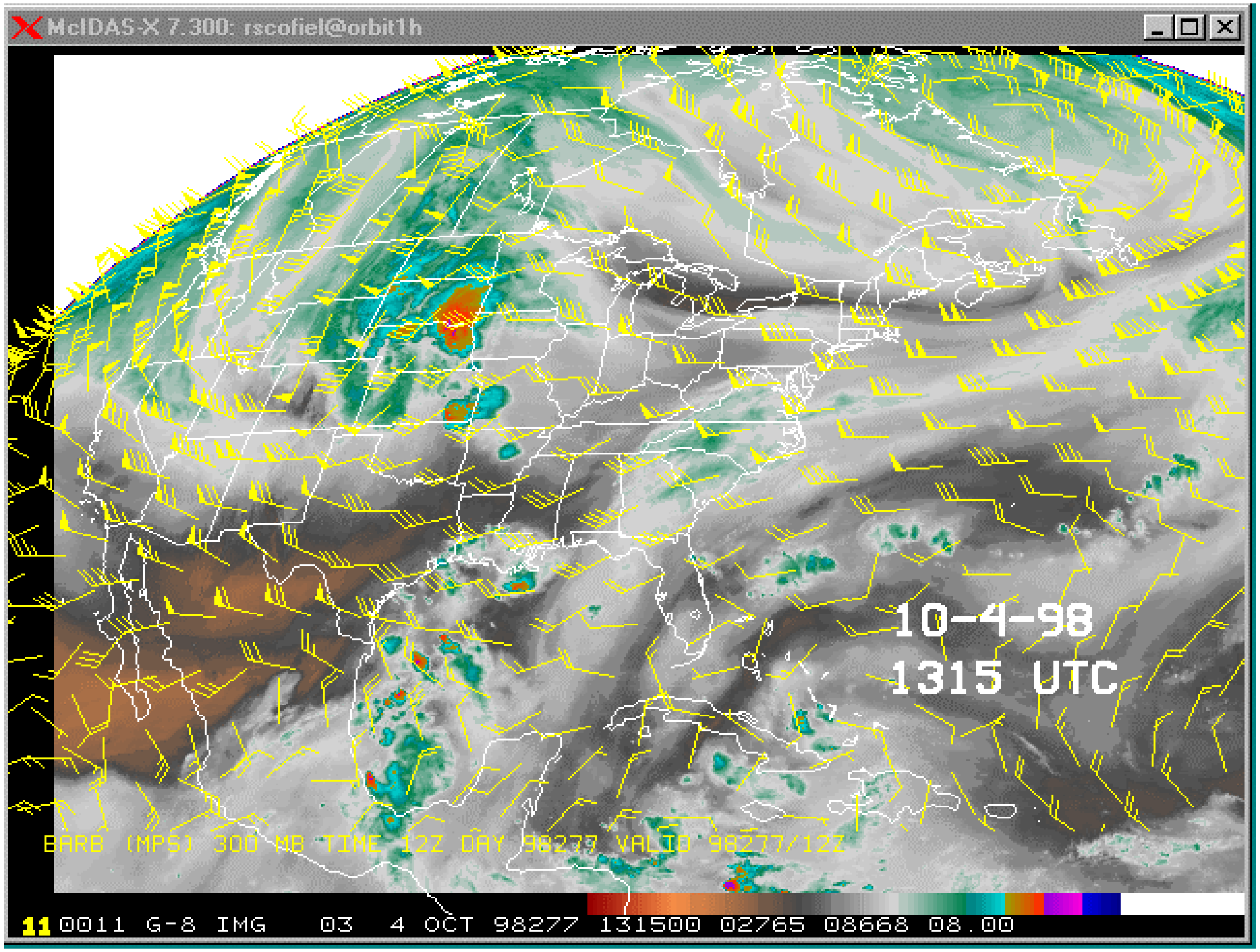
Nowcasting Flash Floods

“ Look for steady state conditions that will produce congruent paths of heavy rain cells “

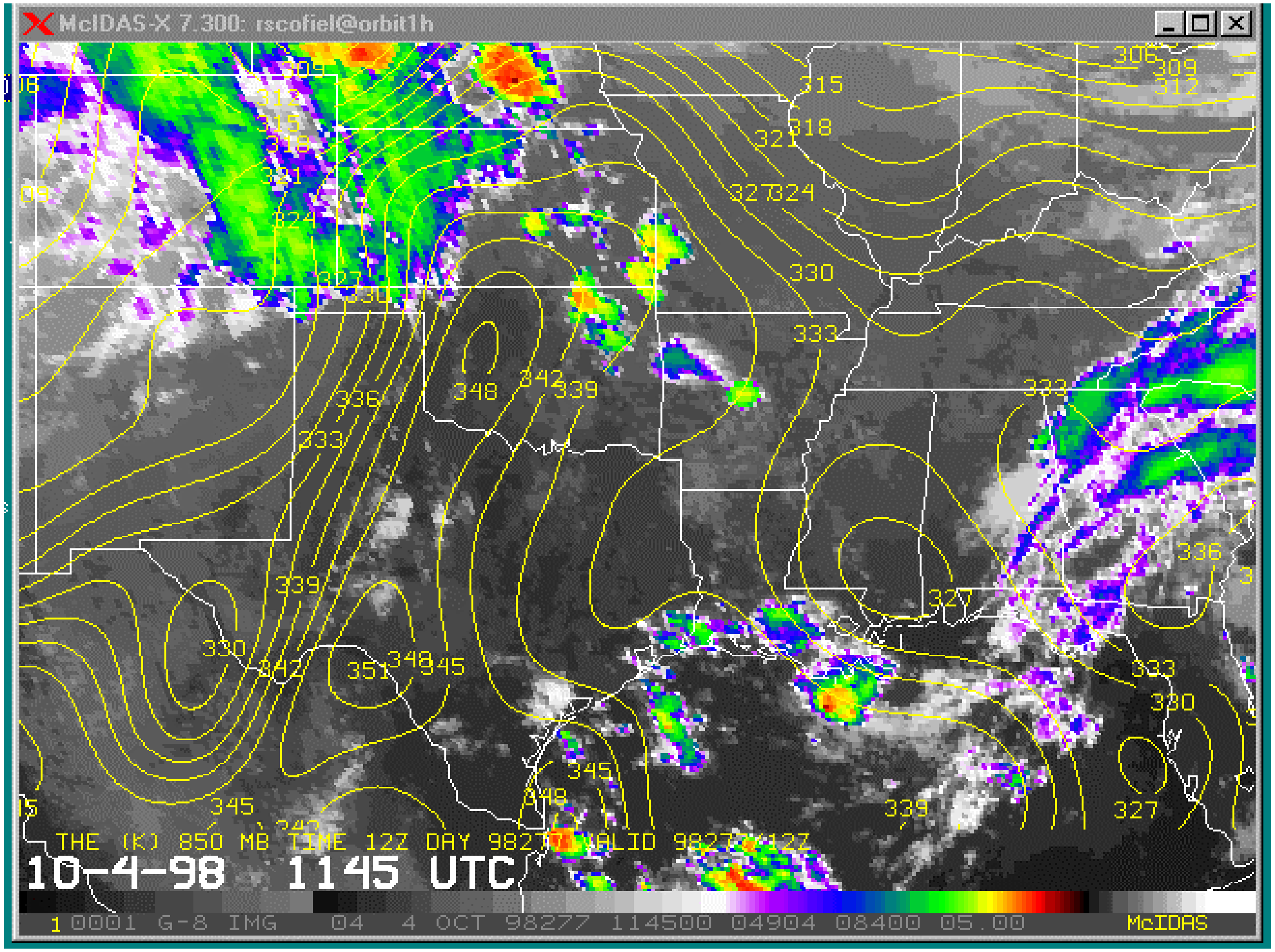


Conceptual model of backward propagating thunderstorms

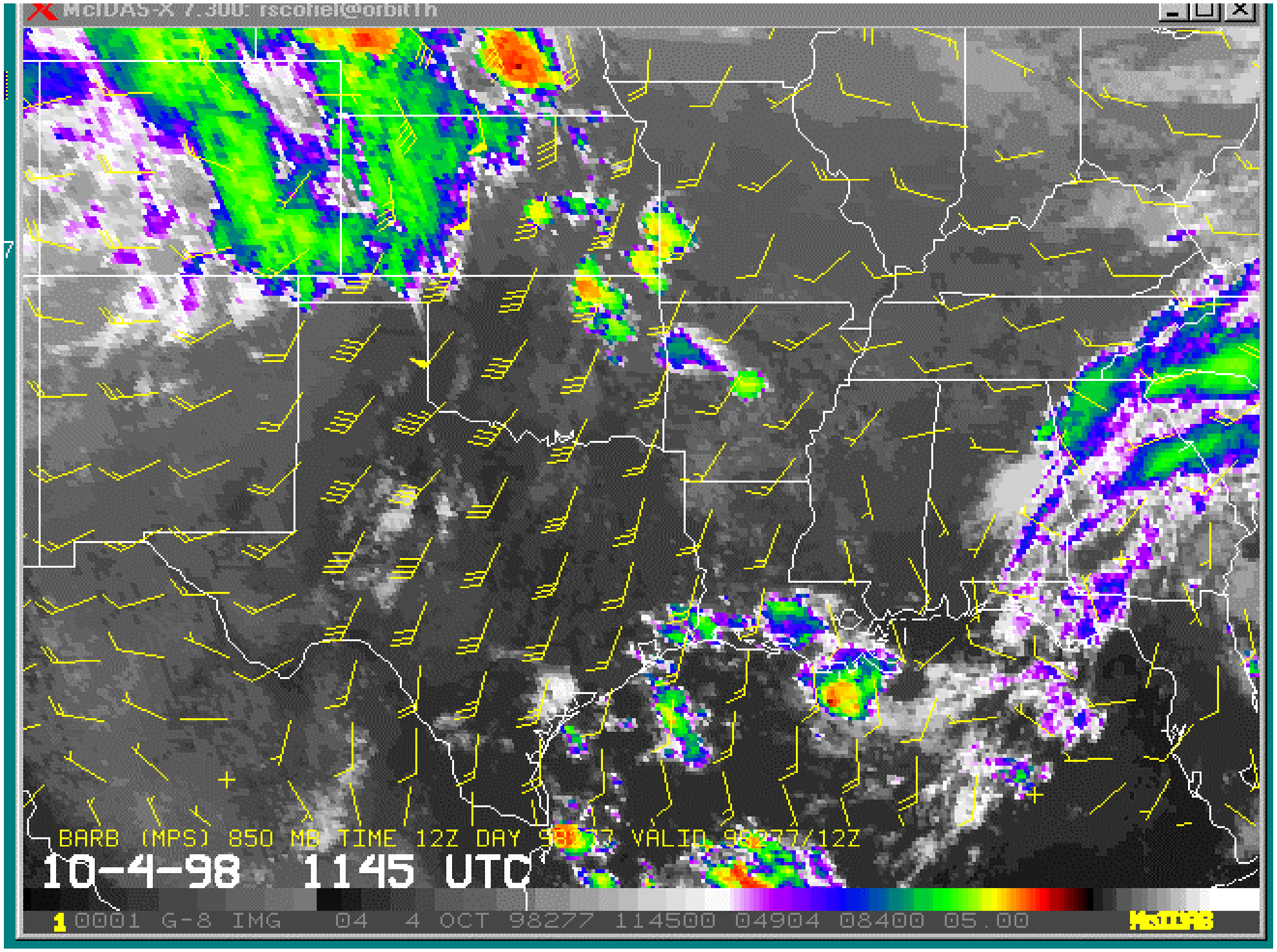

CONCEPTUAL MODEL OF
A BACKWARD-PROPAGATING MCS
N
X
W
E
S
4
0
-70
-62
-52°c
-8
-4
θ_e max
θ_e+1
θ_e
1° LAT
- θe
- LIFTED INDEX
- 850/300 MB THICKNESS
- MESO/SYNOPTIC SCALE BOUNDARY
- MESOSCALE CONVECTIVE SYSTEM
- LOW LEVEL JET
- UPPER LEVEL JET
X - 500 MB VORTICITY



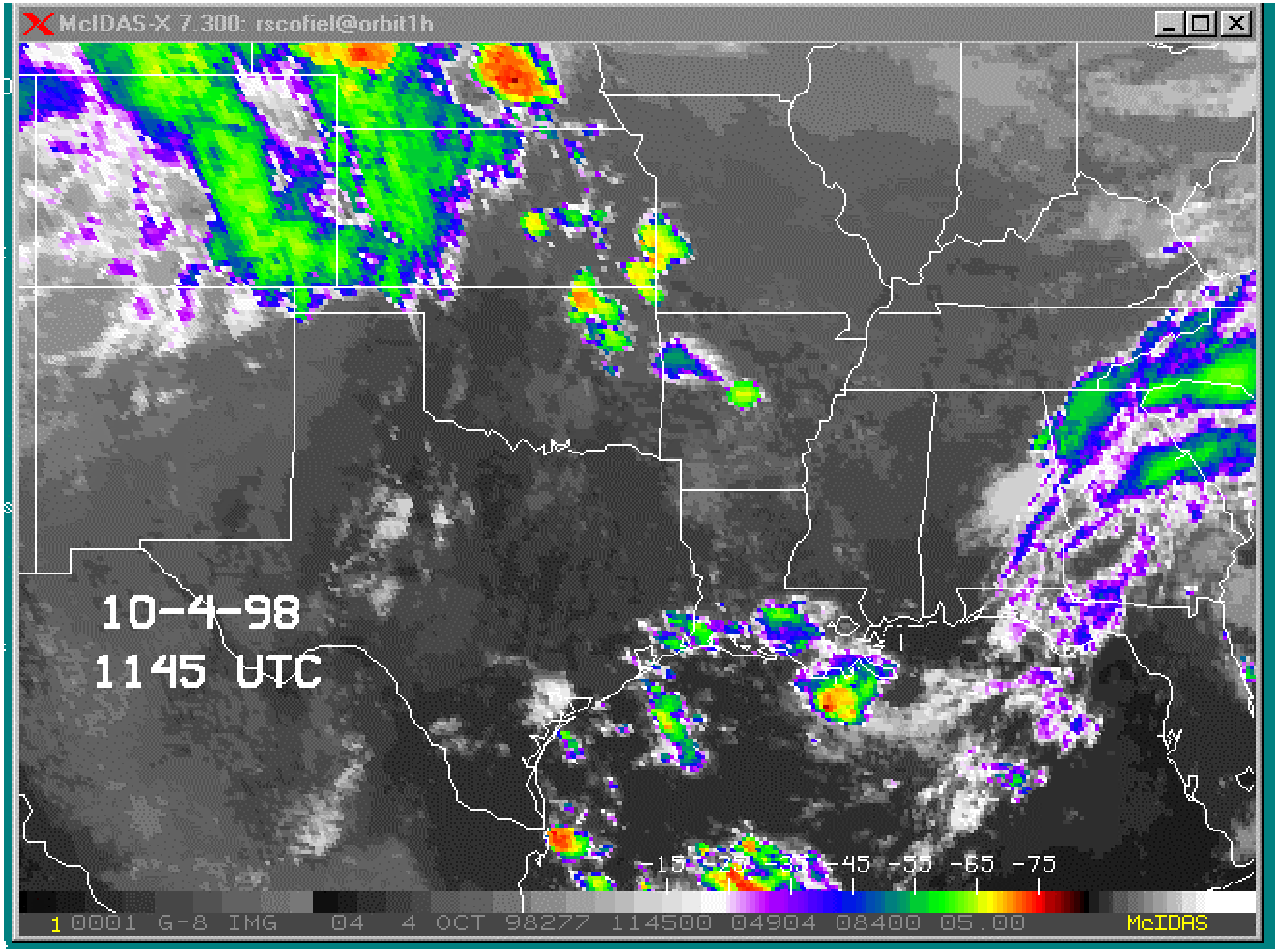
6.7 micron water vapor imagery for 10-4-98 1315 UTC; 300 mb winds (mps) are superimposed



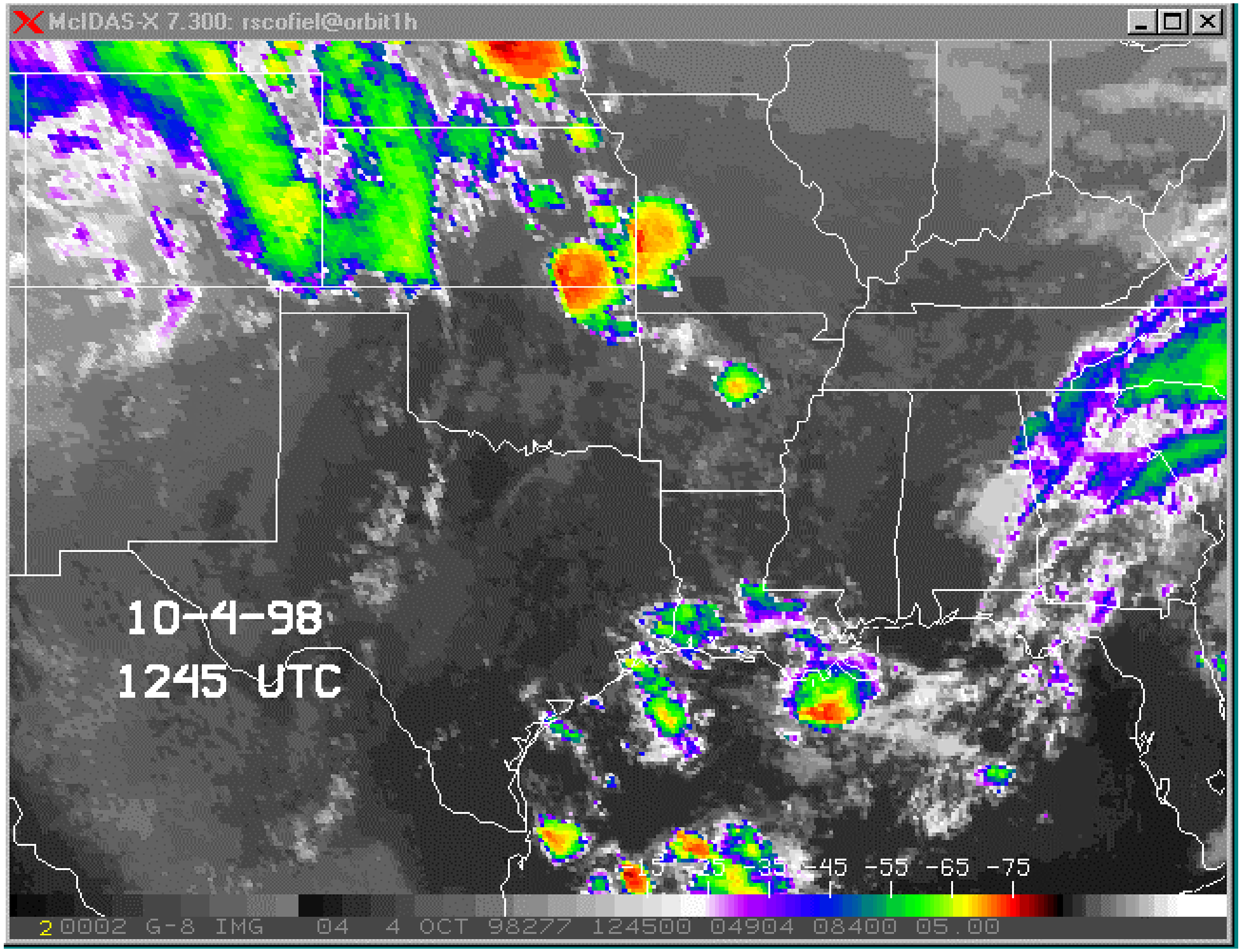
10.7 micron infrared imagery for 10-4-98 1145 UTC;
850 mb theta-e (degrees K) is superimposed



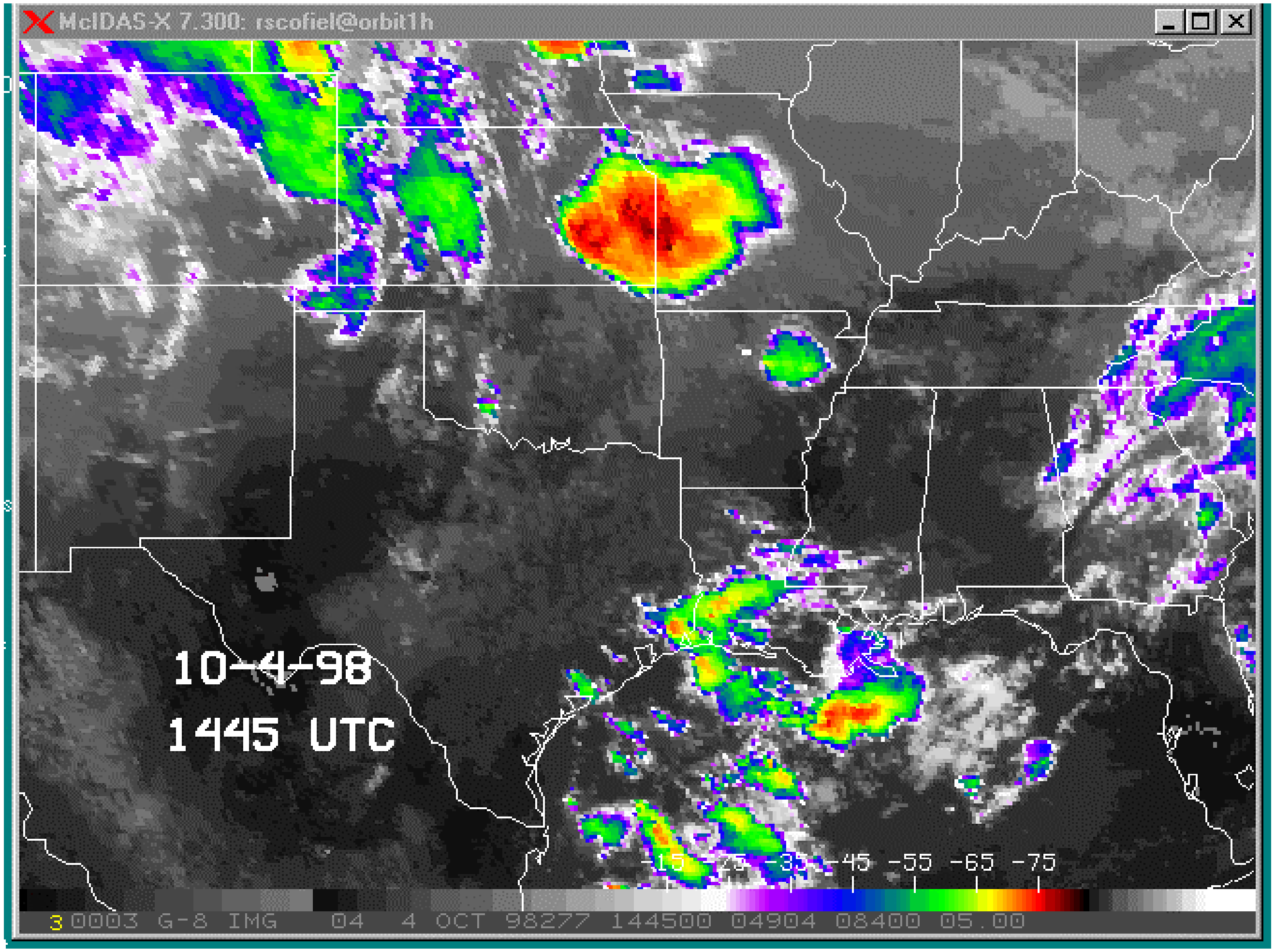
**10.7 micron infrared imagery for 10-4-98 1145 UTC;
850 mb winds (mps) are superimposed**



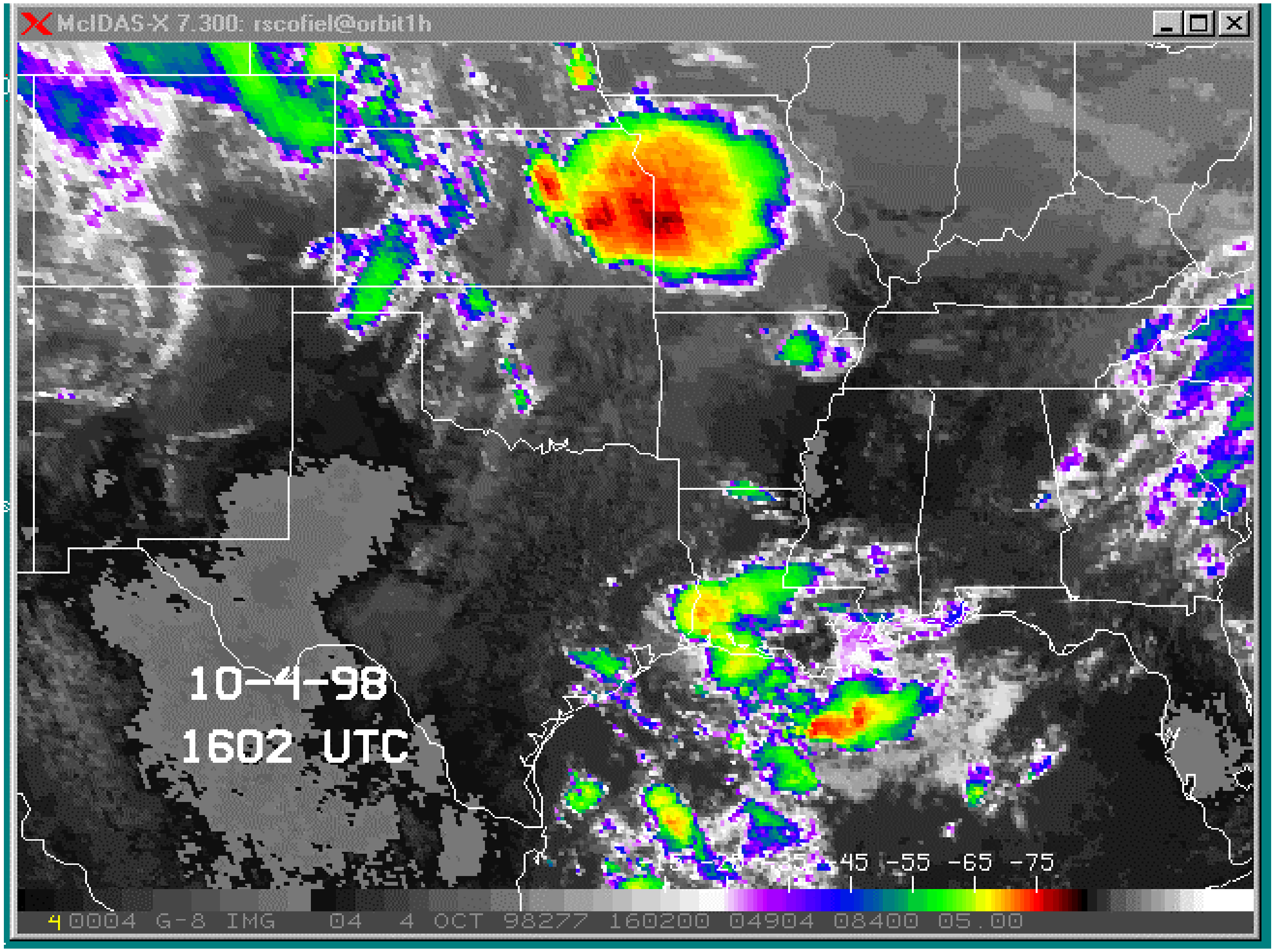
10.7 micron infrared imagery for 10-4-98 1145 UTC



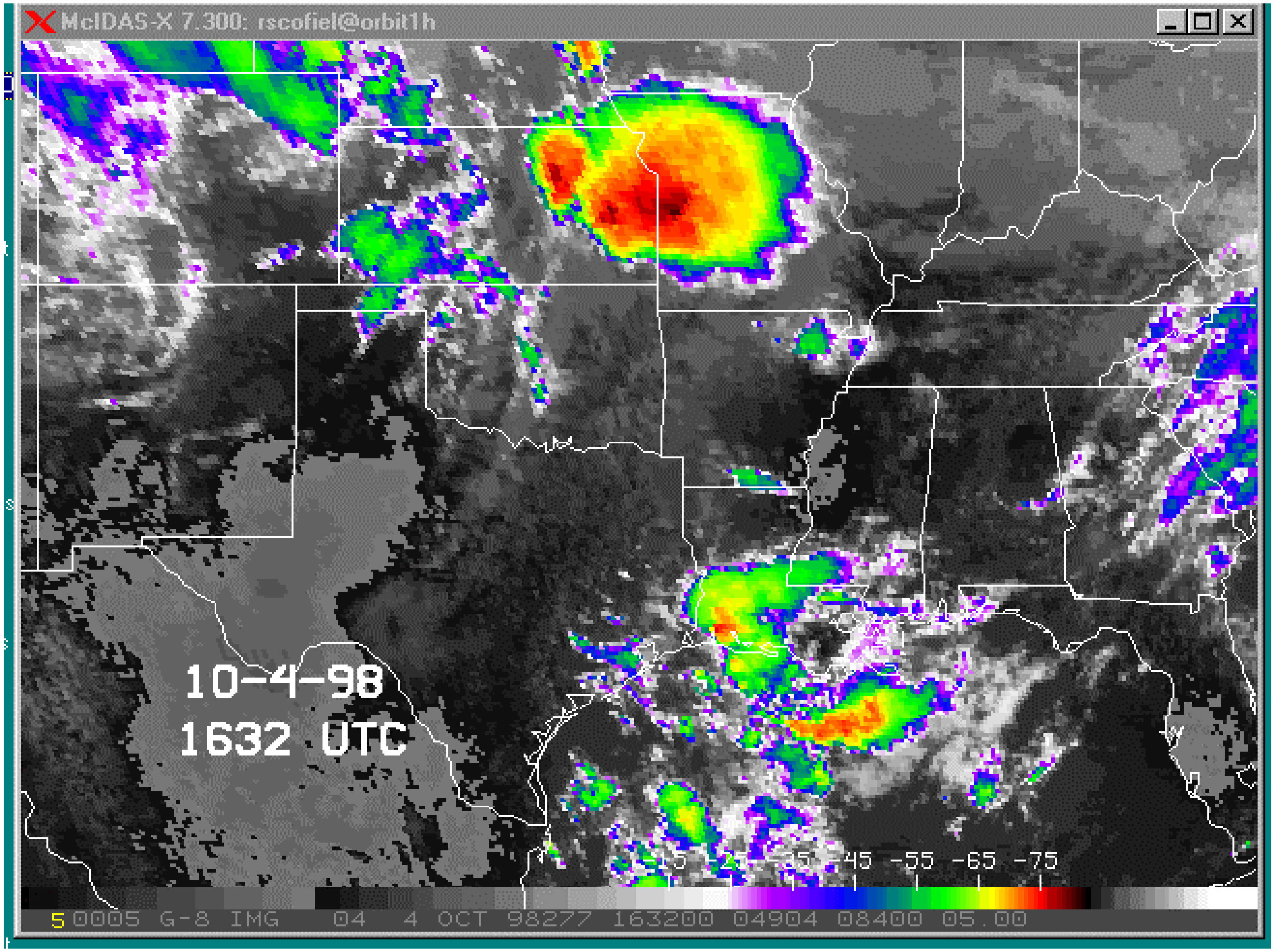
10.7 micron infrared imagery for 10-4-98 1245 UTC



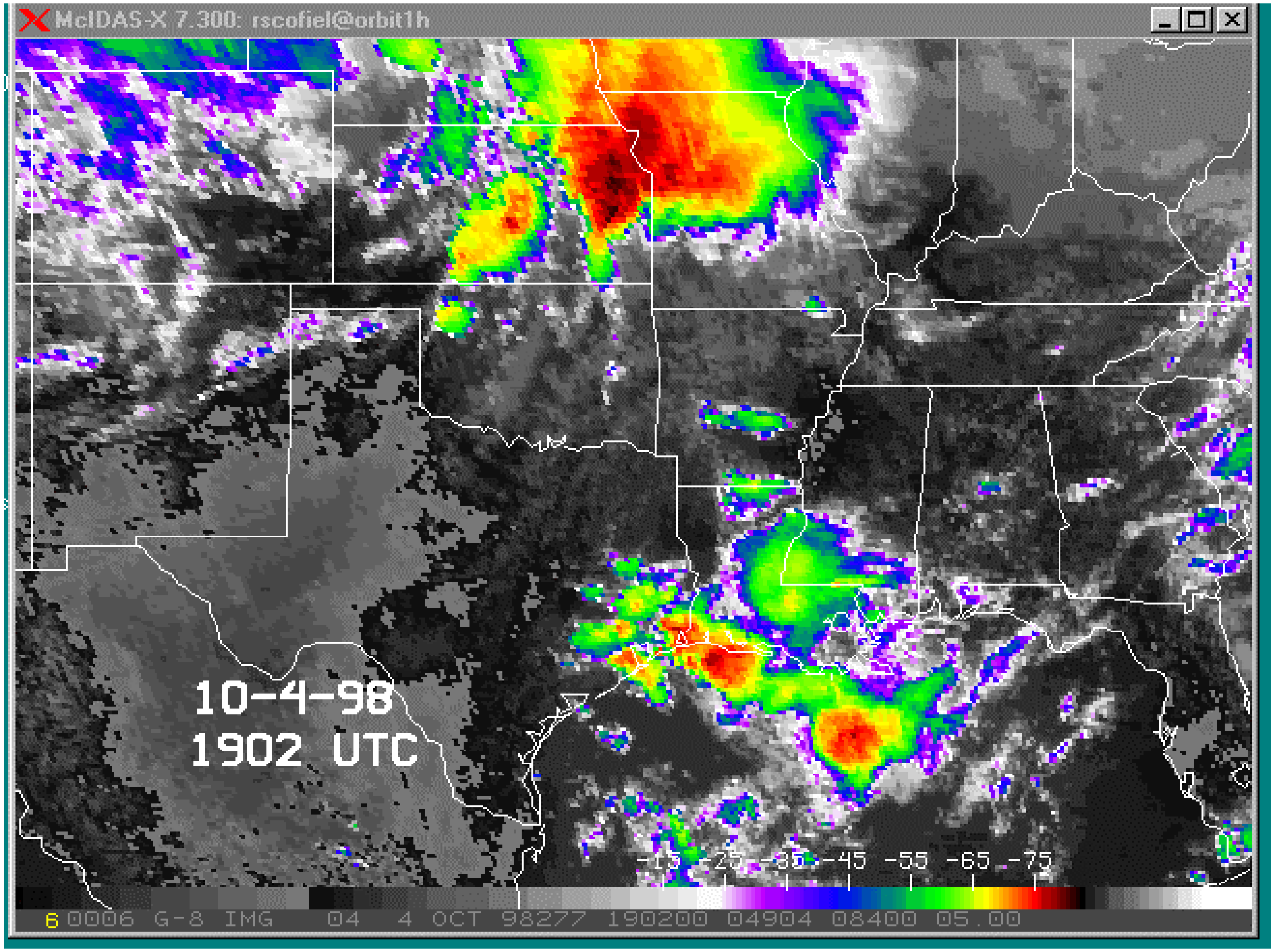
10.7 micron infrared imagery for 10-4-98 1445 UTC



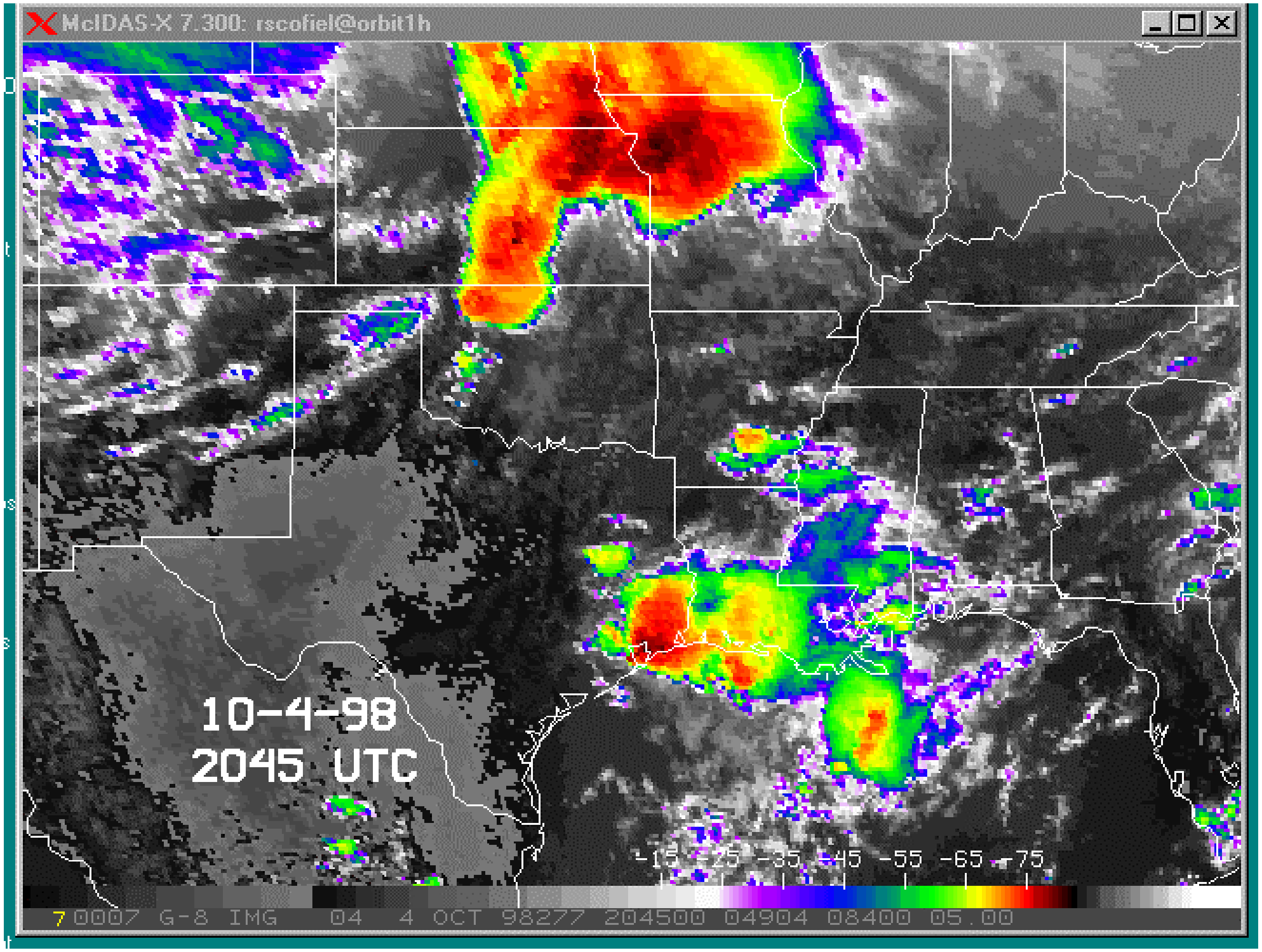
10.7 micron infrared imagery for 10-4-98 1602 UTC



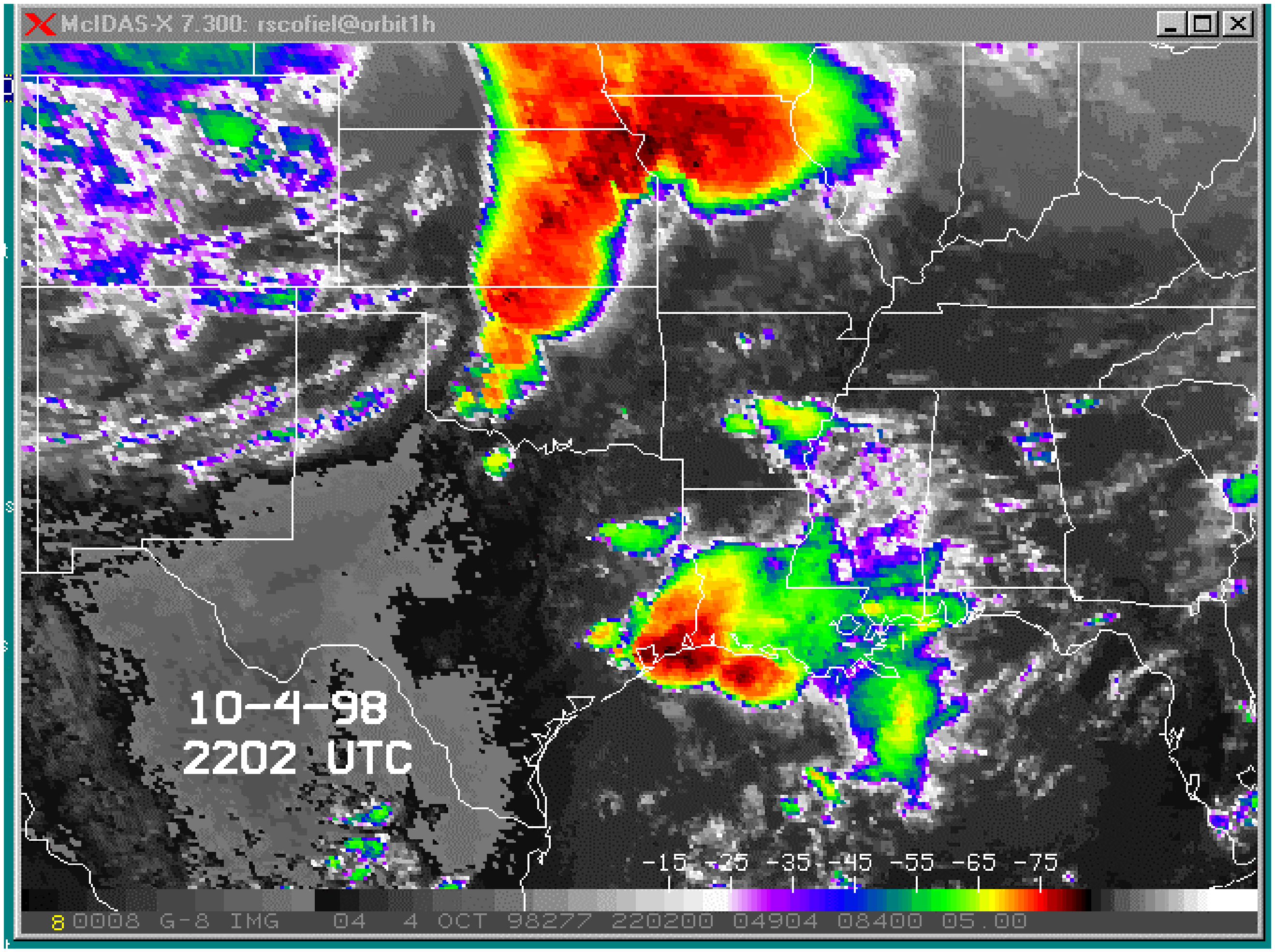
10.7 micron infrared imagery for 10-4-98 1632 UTC



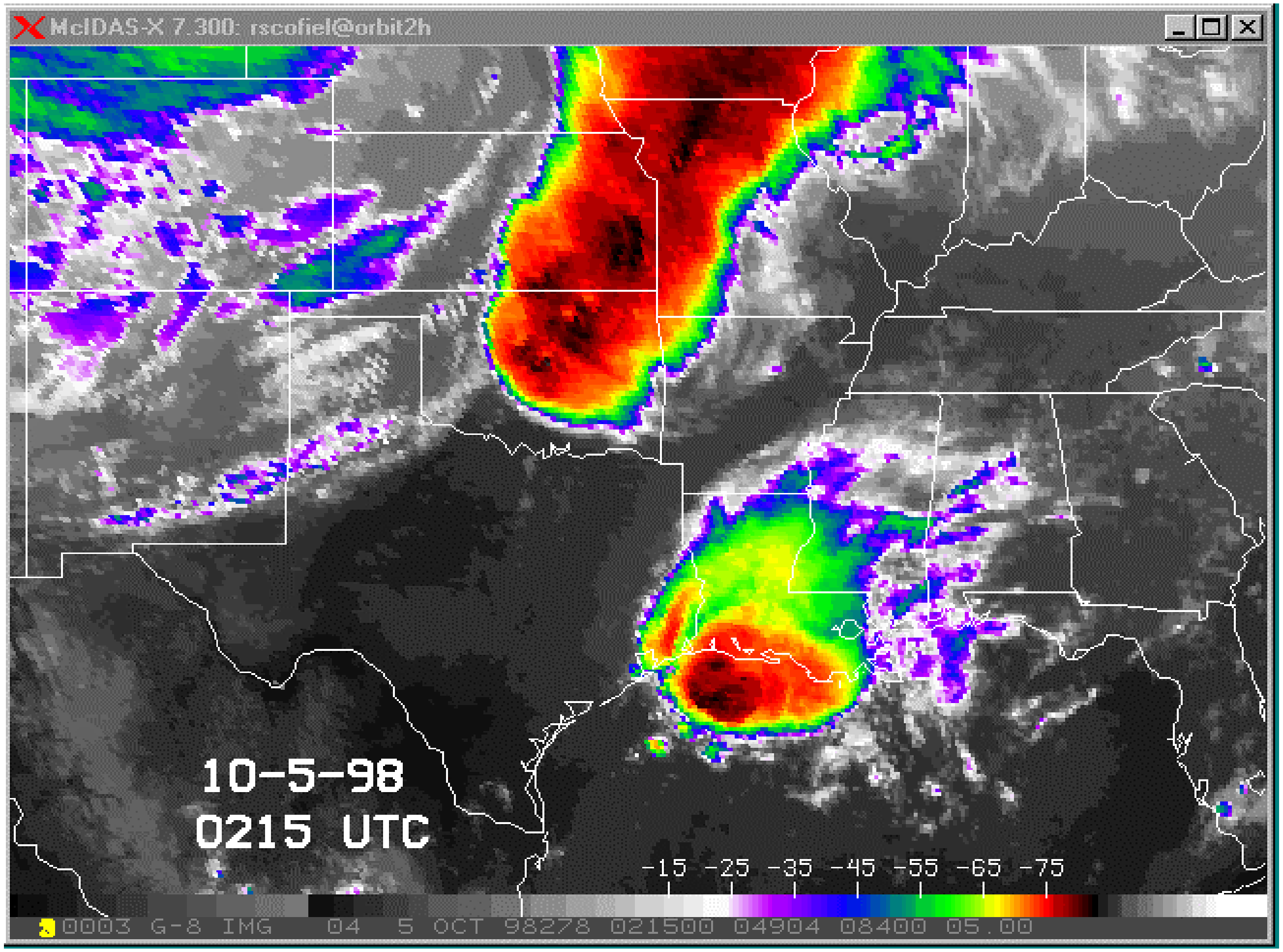
10.7 micron infrared imagery for 10-4-98 1902 UTC



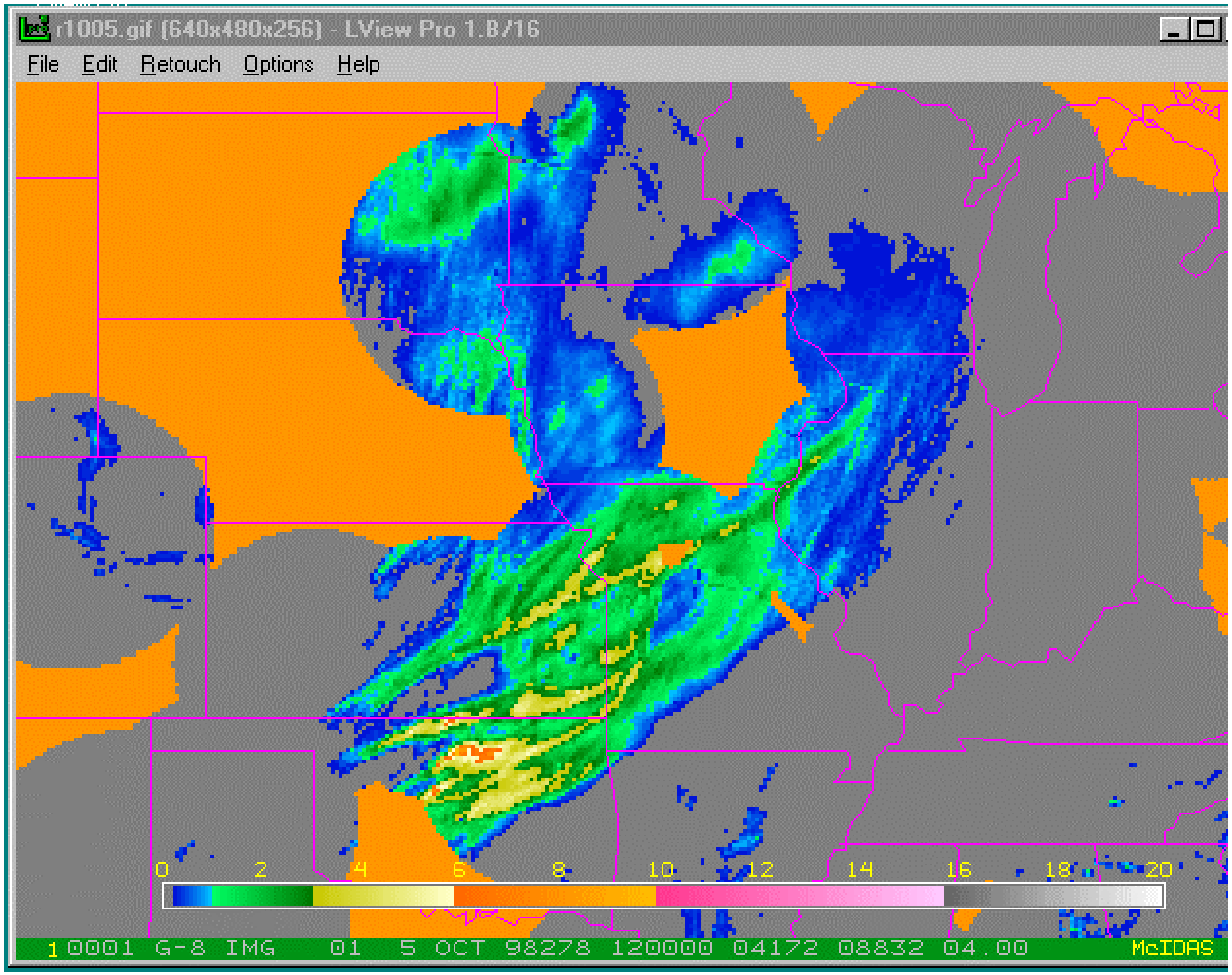
10.7 micron infrared imagery for 10-4-98 2045 UTC



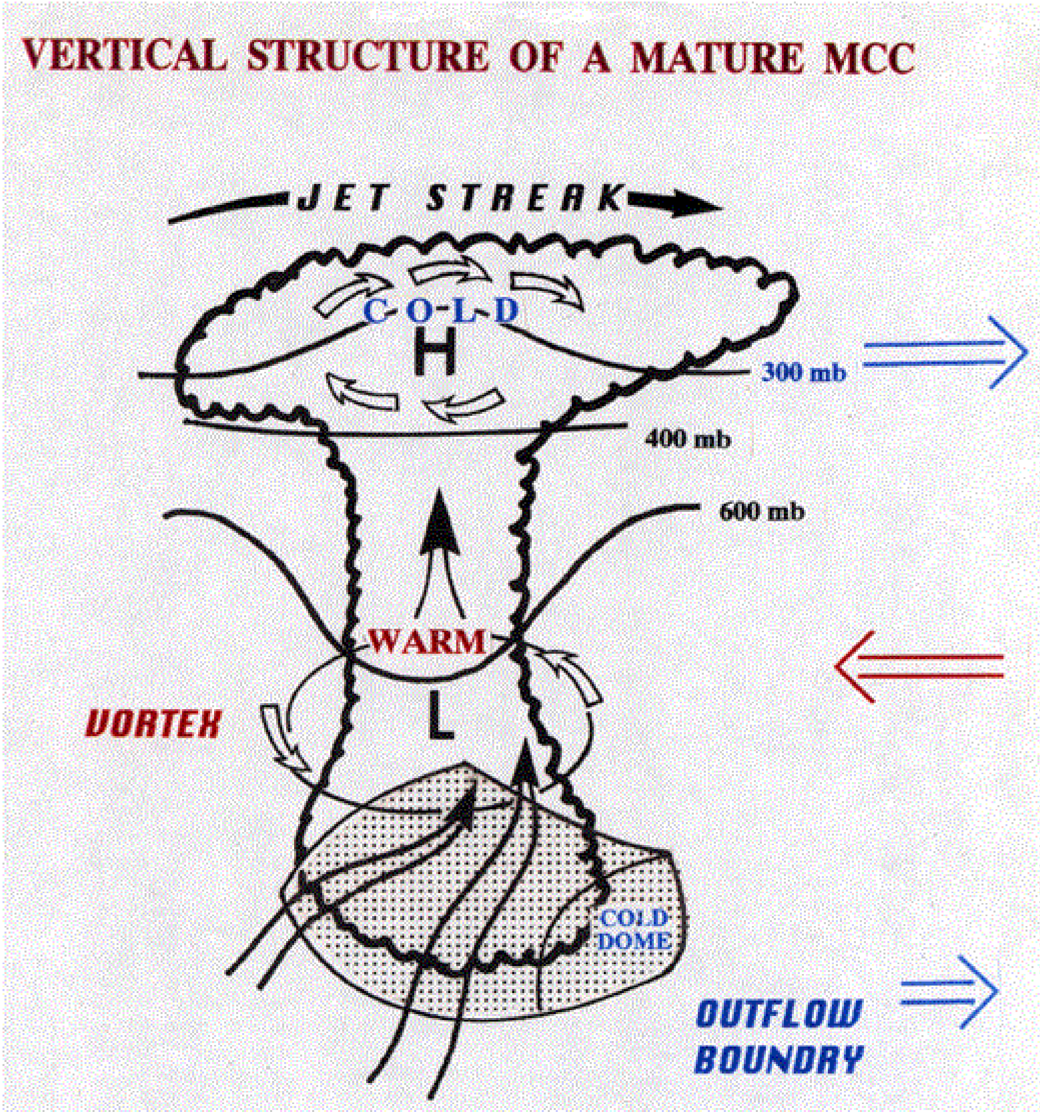
10.7 micron infrared imagery for 10-4-98 2202 UTC



10.7 micron infrared imagery for 10-5-98 0215 UTC



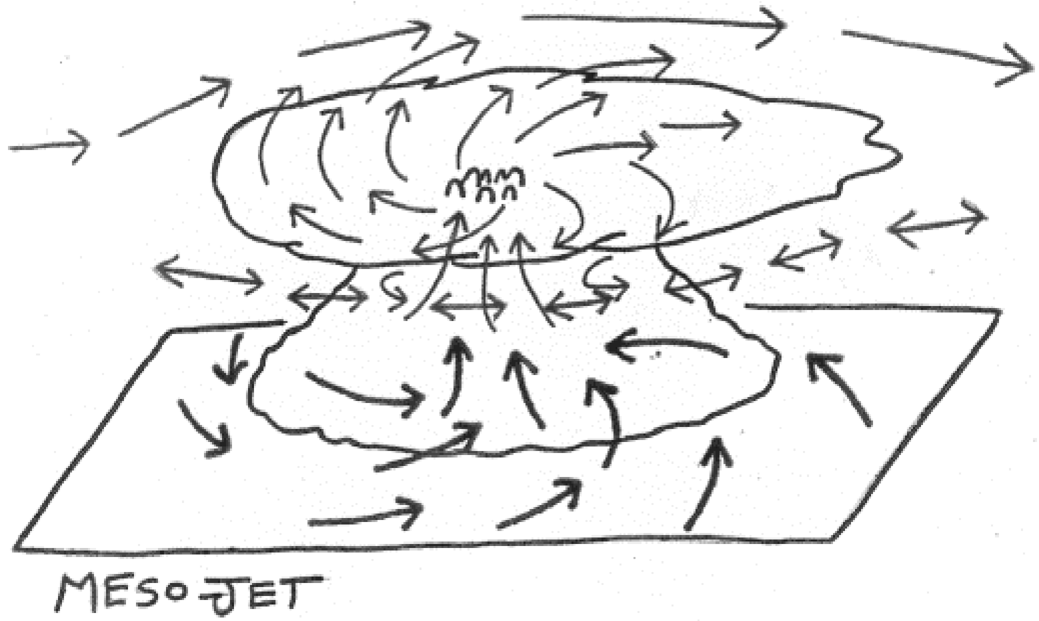
WSR 88 D 24 hour rainfall estimates (in) ending 10-5-98 1200 UTC



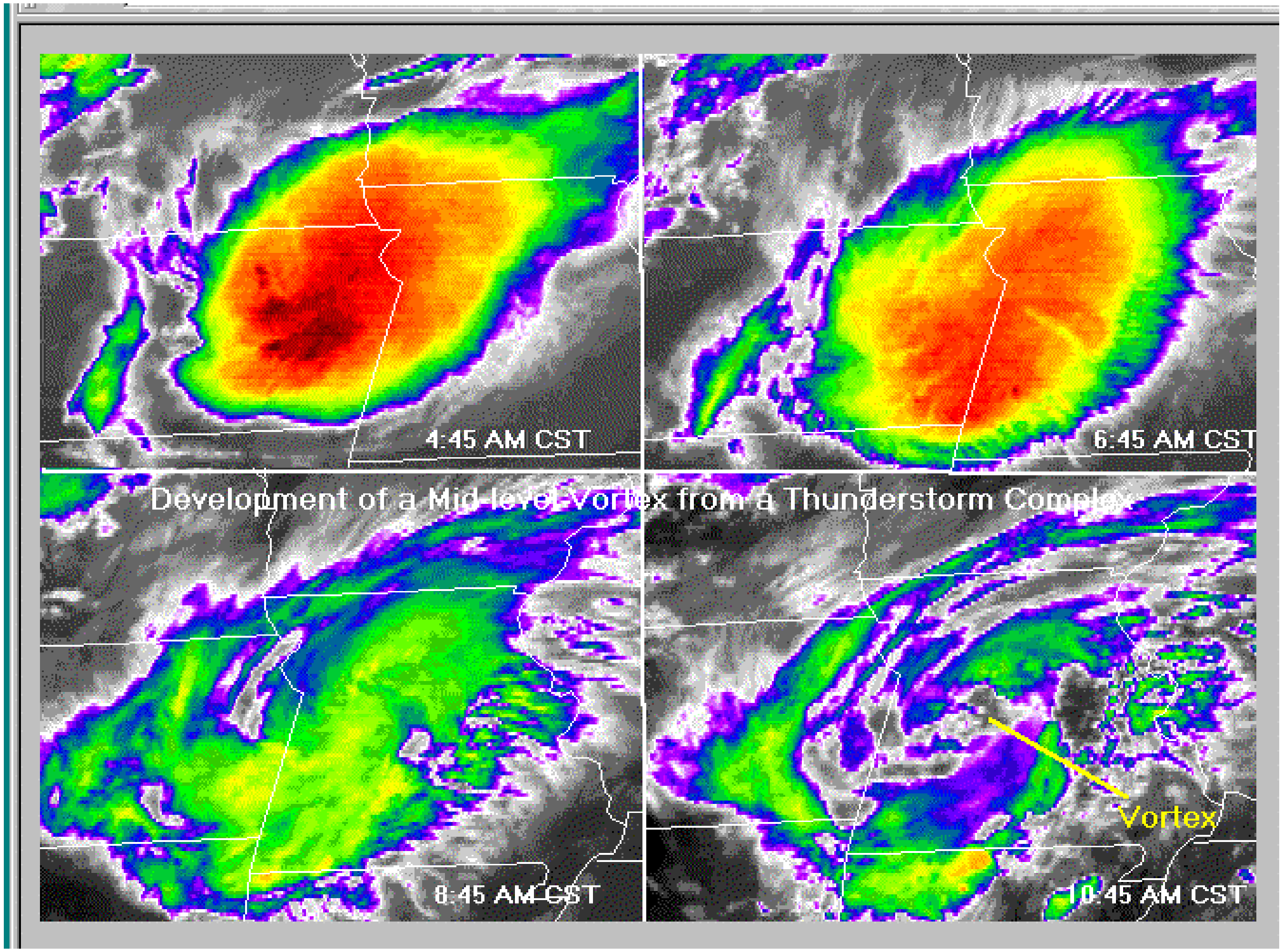
VERTICAL STRUCTURE OF A MATURE MCC
JET STREAK
C-O-L-D
H
300 mb
400 mb
600 mb
WARM
L
VORTEX
COLD
DOME
OUTFLOW
BOUNDRY

VERTICAL STRUCTURE OF

A MATURE MESOSCALE CONVECTIVE COMPLEX (MCC)



Conceptual Model of a Mature Mesoscale Convective Complex (MCC)

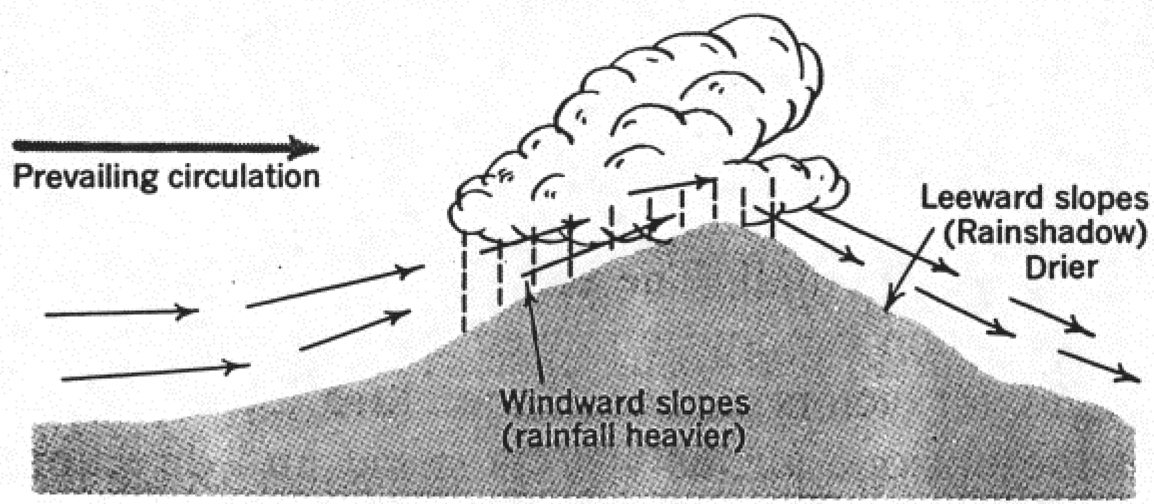


Development of a Mesoscale Convective Complex (MCC) induced vortex

Feedback Process from the Storm Scale to the Mesoscale and Synoptic Scale

- **Producing outflow boundaries**
- **Producing mid-level vortices**
- **Producing upper-level jet streaks**
- **Reducing the vertical wind shear**
- **deepening of the moisture distribution**
- **weakening of the thickness gradients and producing thickness diffluence as a result of "warming" due to latent heat release**

ATMOSPHERIC MOISTURE AND PRECIPITATION



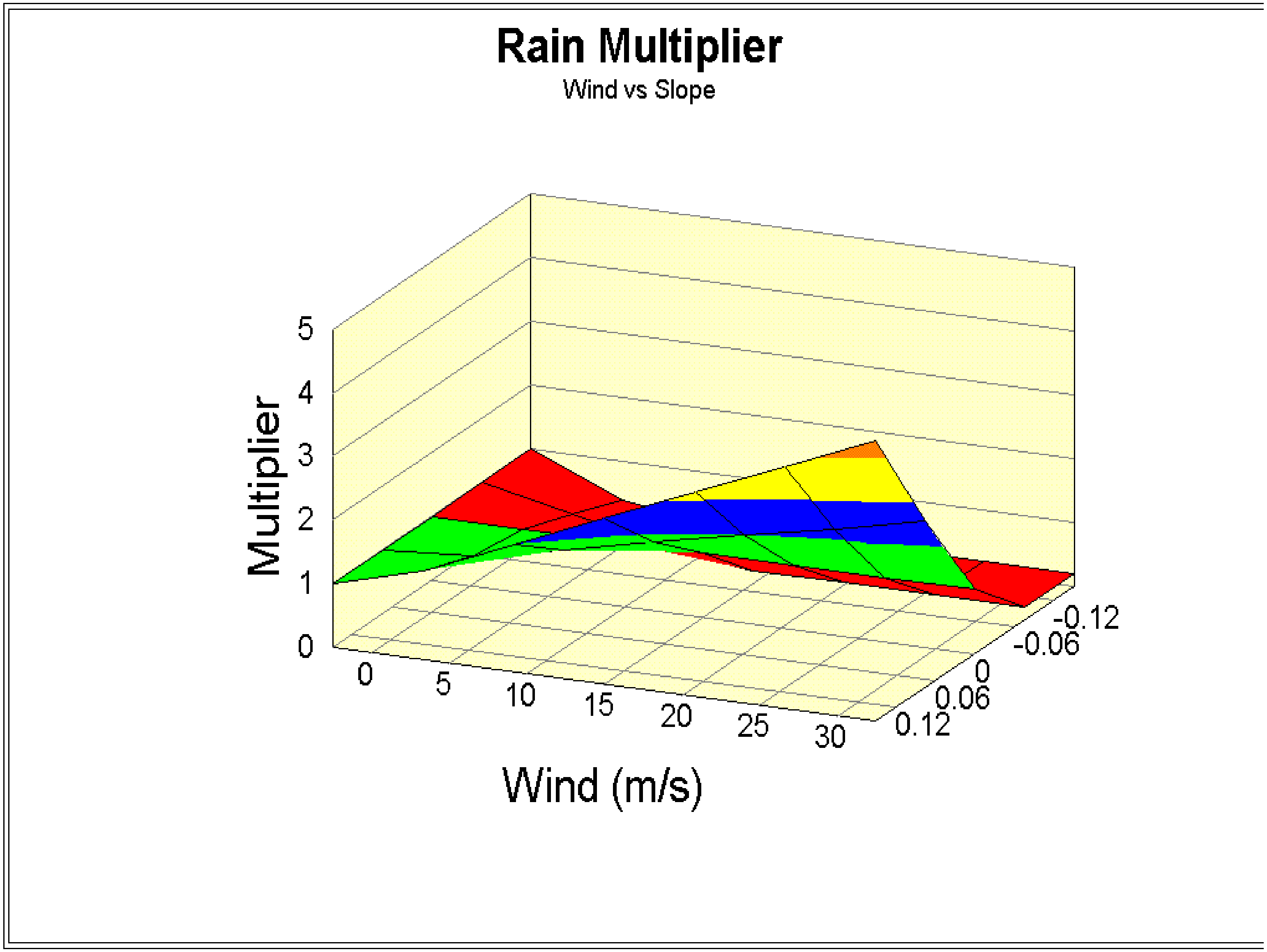
Rainfall contrasts on windward and leeward slopes.

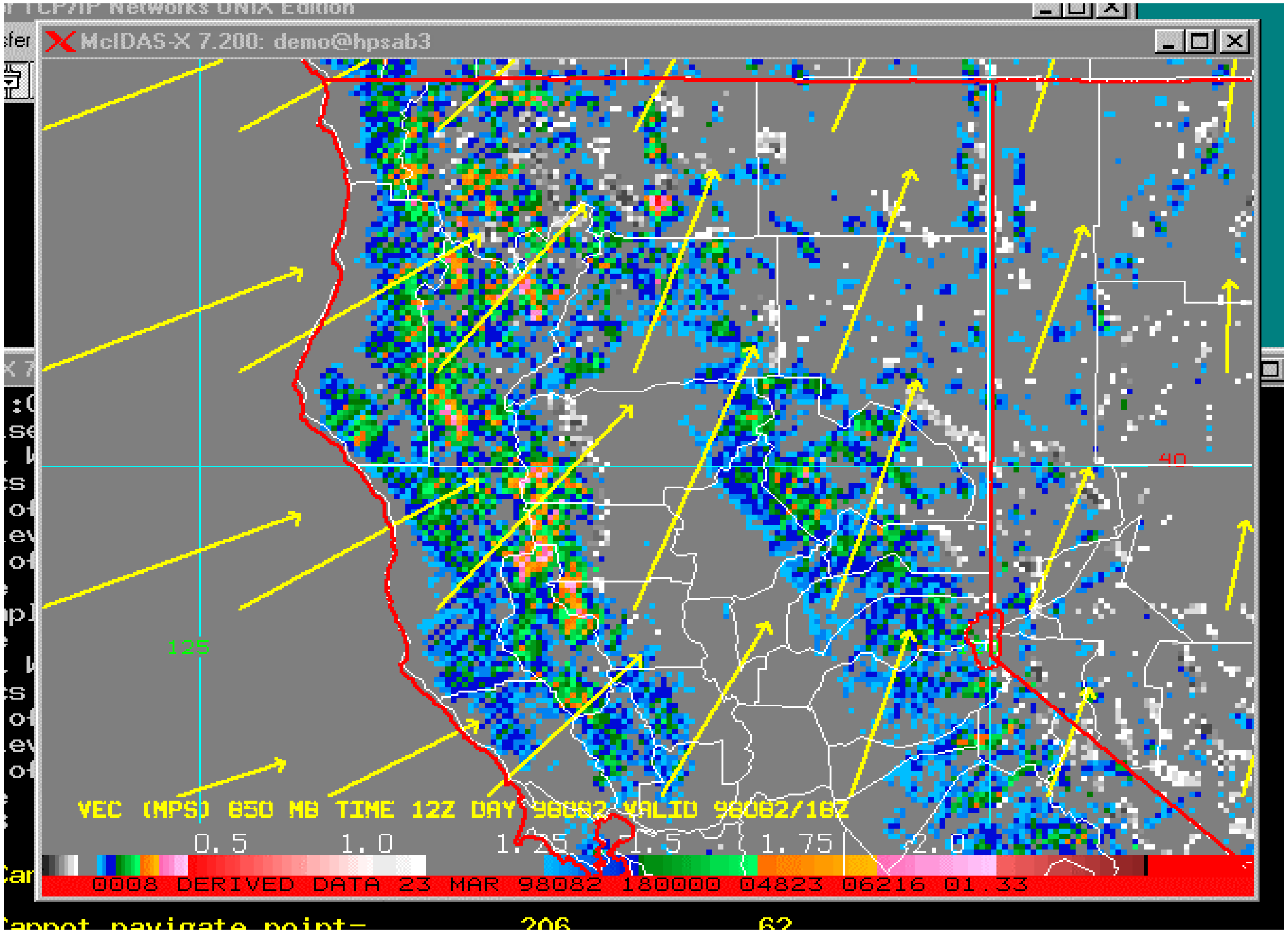
Orographic Adjustment

W = surface/850/700 wind speed x slope of terrain

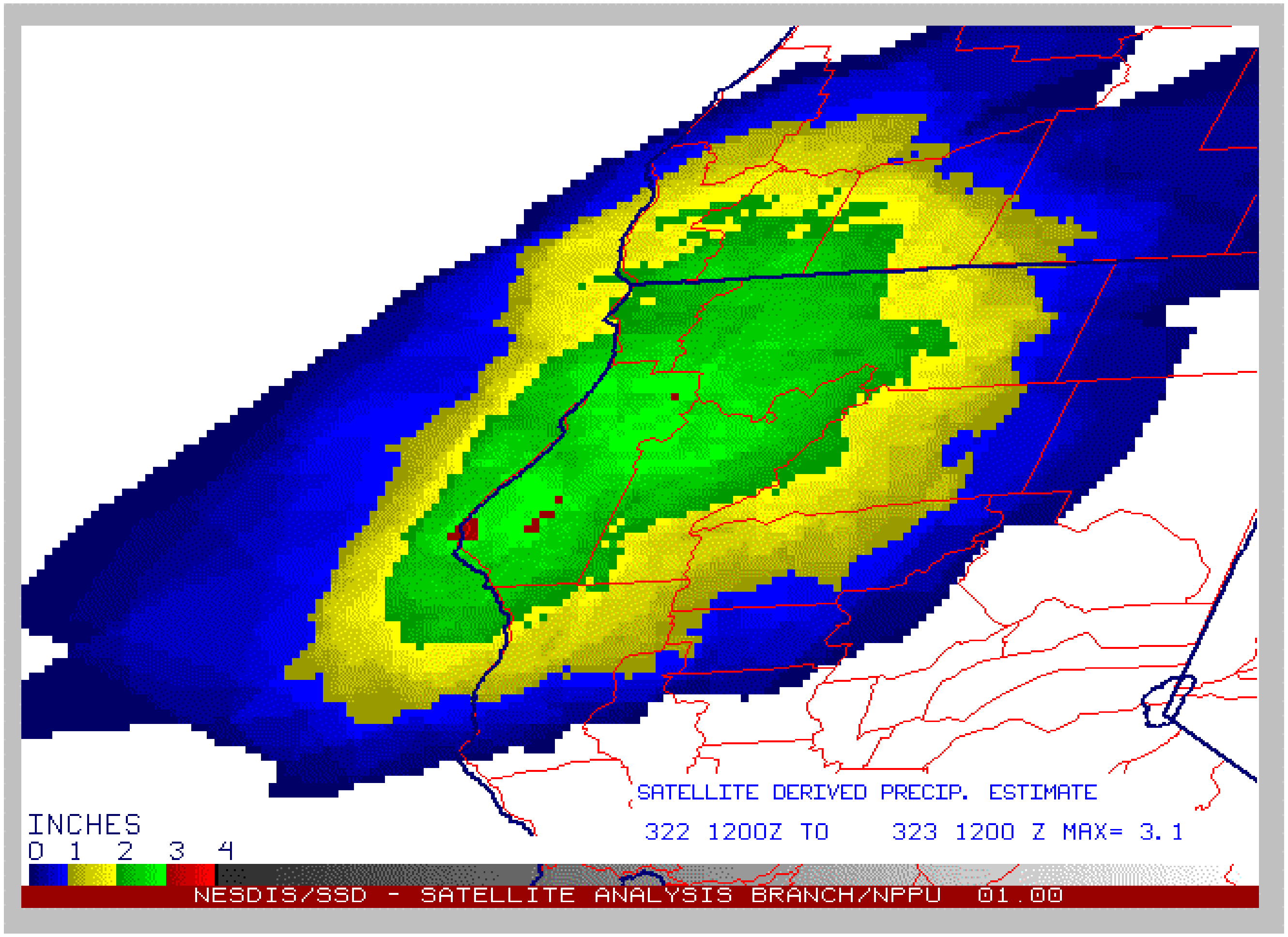
SLOPE

WIND (m/s)	-0.12	-0.06	0.00	0.06	0.12
0	1.0	1.0	1.0	1.0	1.0
5	0.4	0.7	1.0	1.1	1.4
10	0.2	0.4	1.0	1.4	2.0
15	0.2	0.2	1.0	1.7	2.6
20	0.2	0.2	1.0	2.3	3.8
25	0.2	0.2	1.0	2.6	4.4

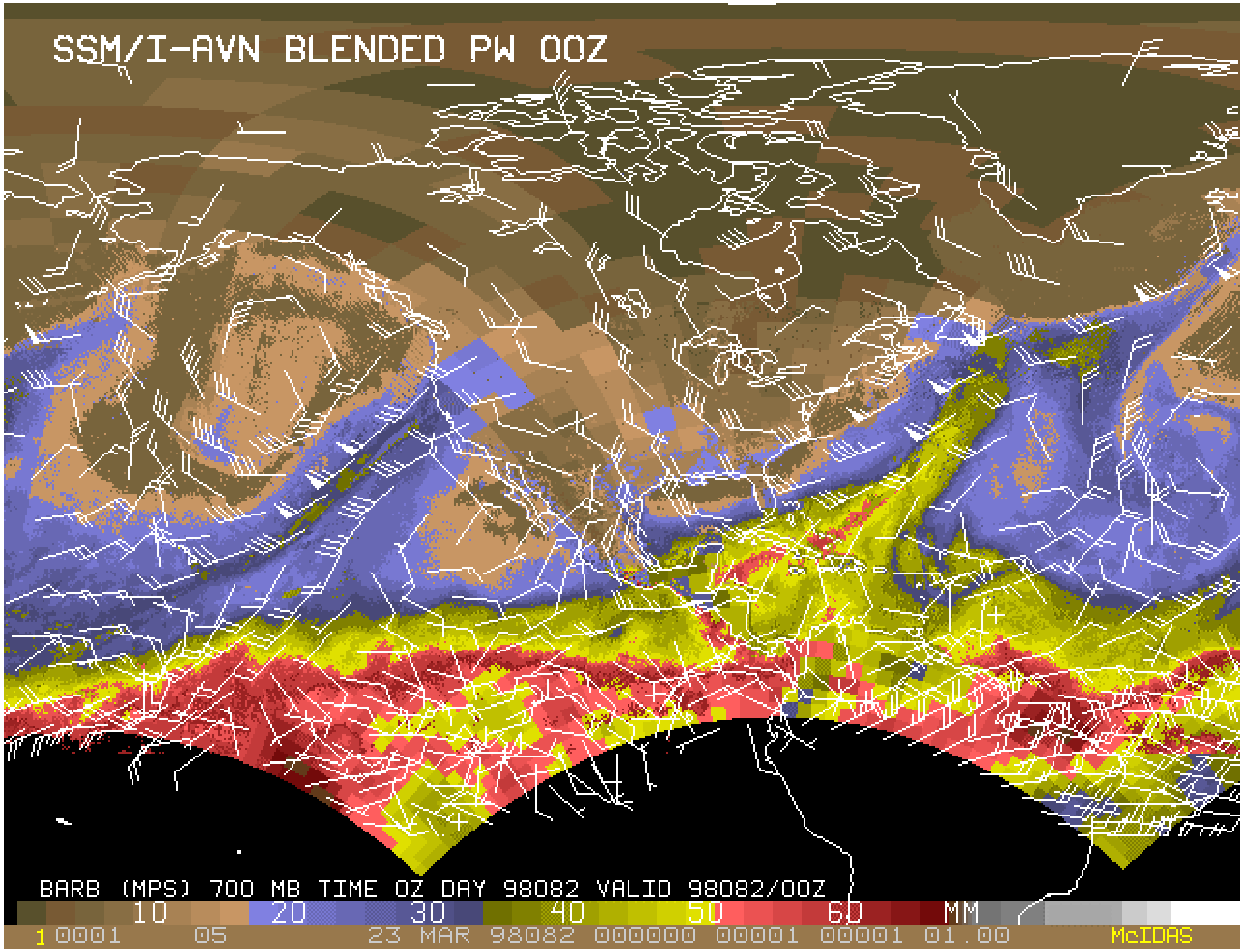

Rain Multiplier
Wind vs Slope
Multiplier
0
1
2
3
4
5
0
5
10
15
20
25
30
Wind (m/s)
-0.12
-0.06
0
0.06
0.12



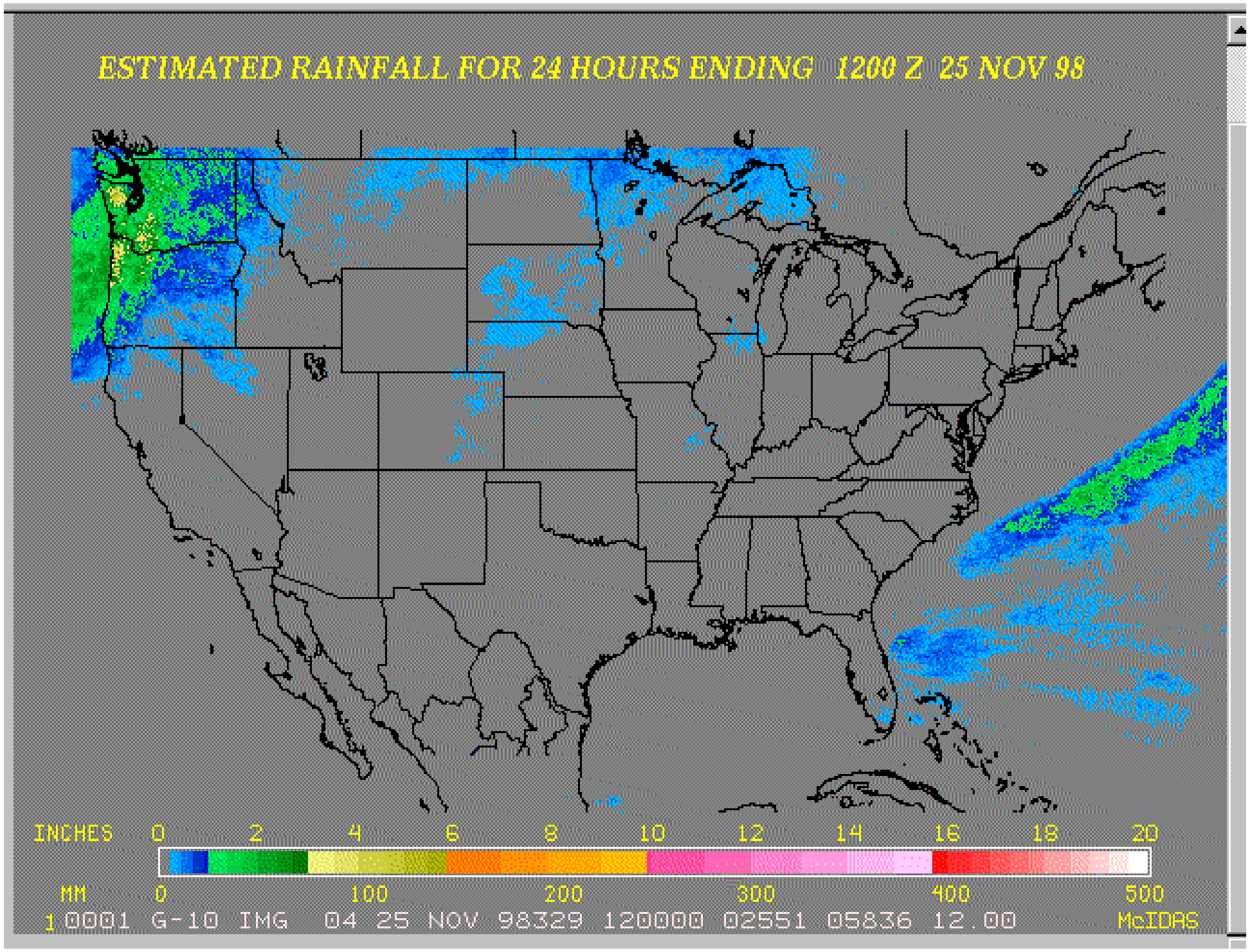
Orographic Adjustment for 3-23-98 1800 UTC



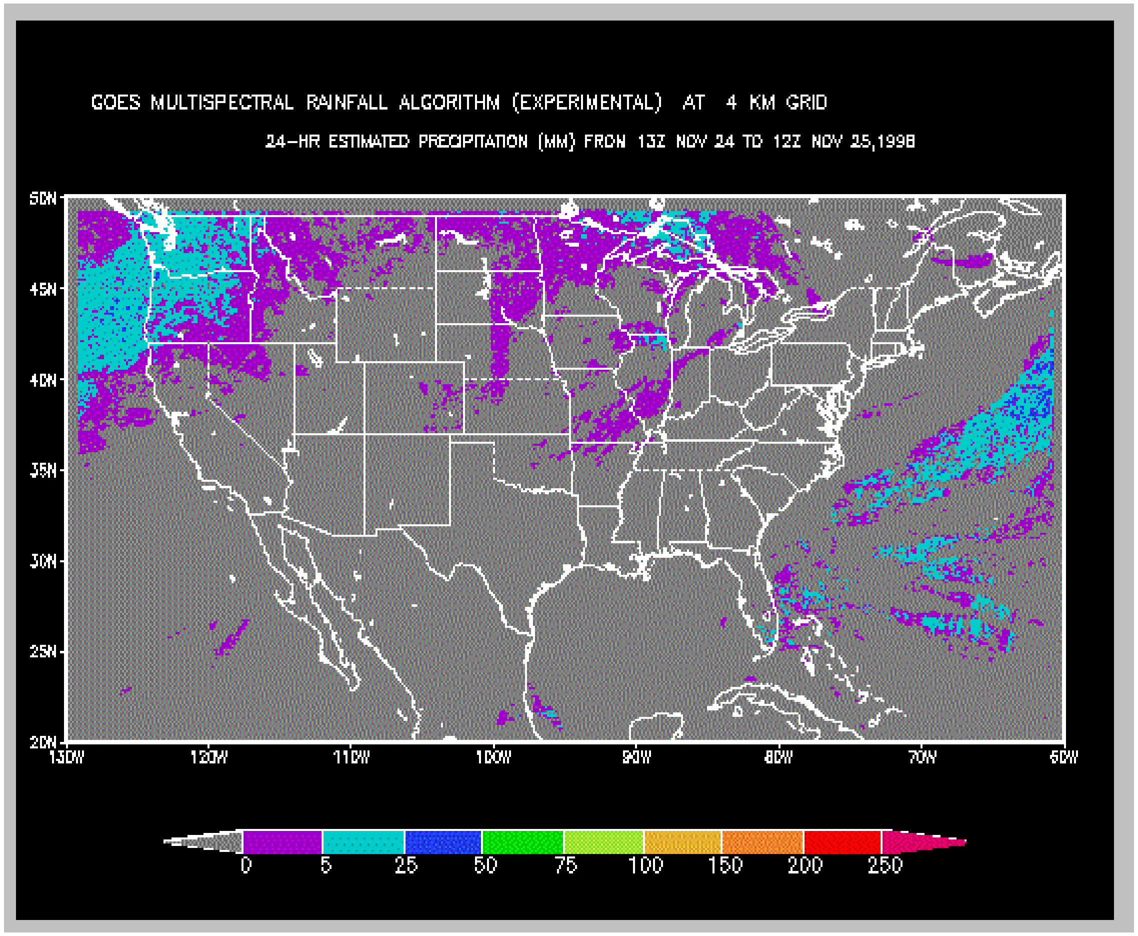
Interactive Flash Flood Analyzer (IFFA) 24 hour rainfall estimates (in) ending 3-23-98 1200 UTC



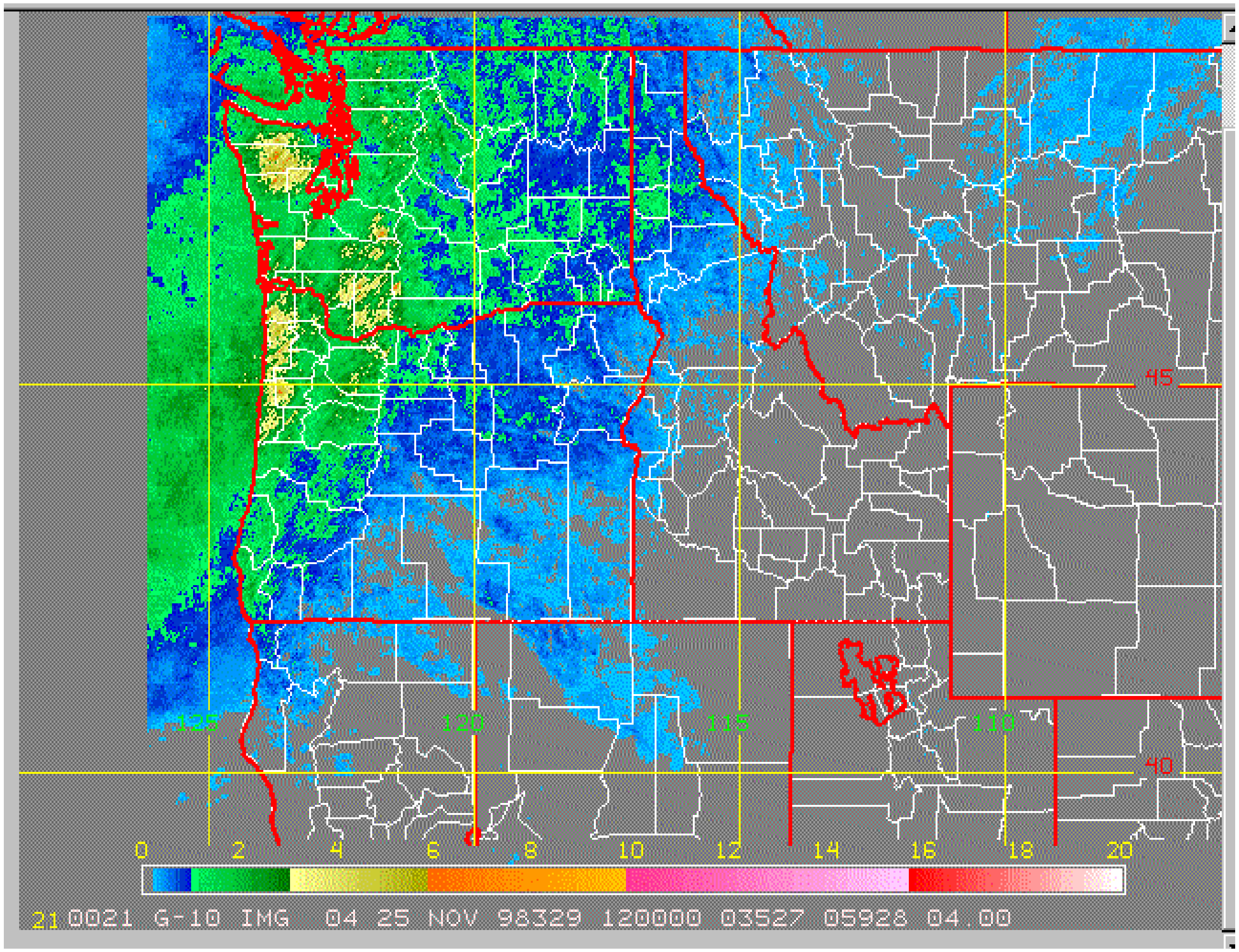
PW Plume: Composited Precipitable Water Product (mm) for 3-23-98 0000 UTC



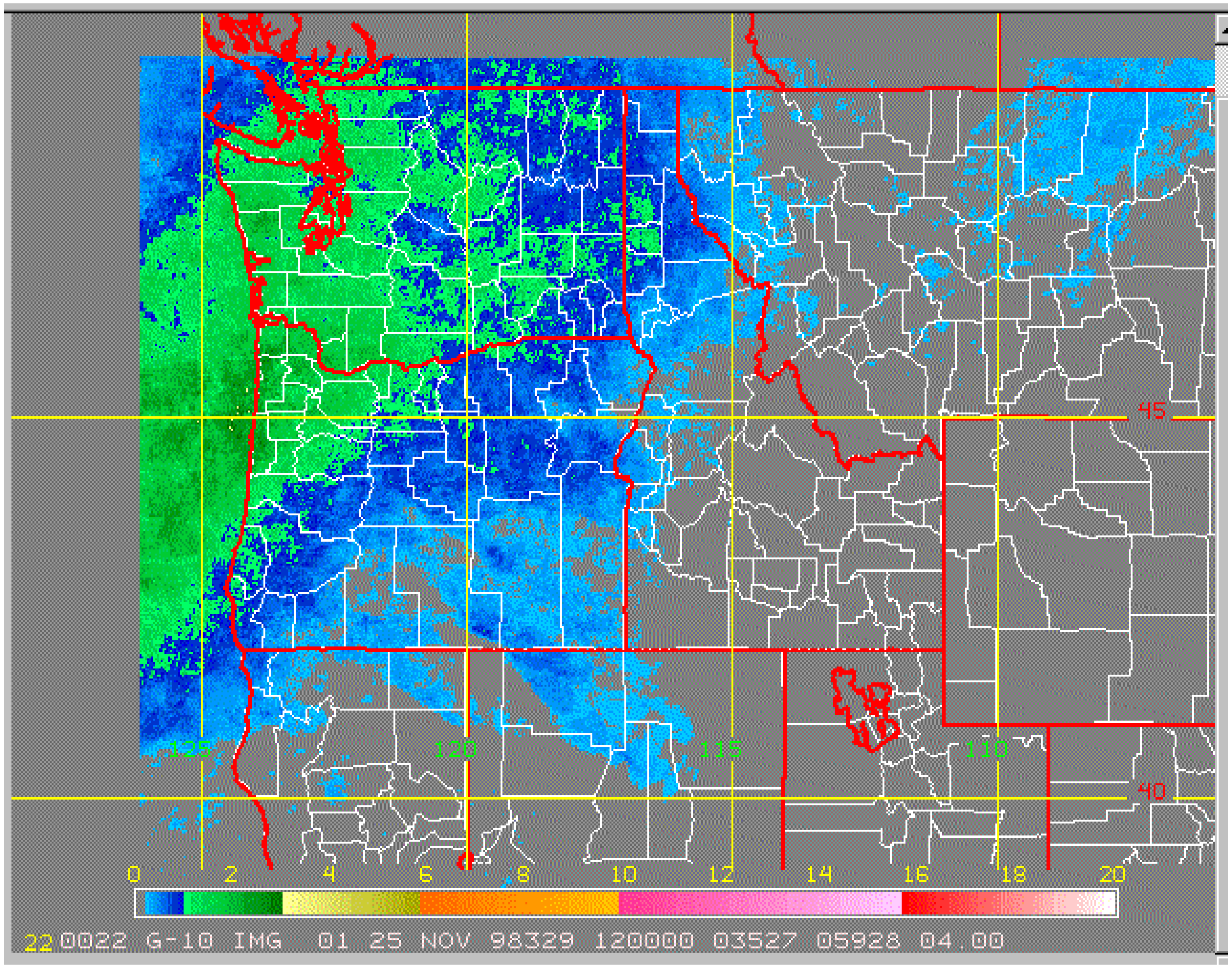
Auto-Estimator 24 hour rainfall estimates (in) ending 11-25-98 1200 UTC; adjusted for orography



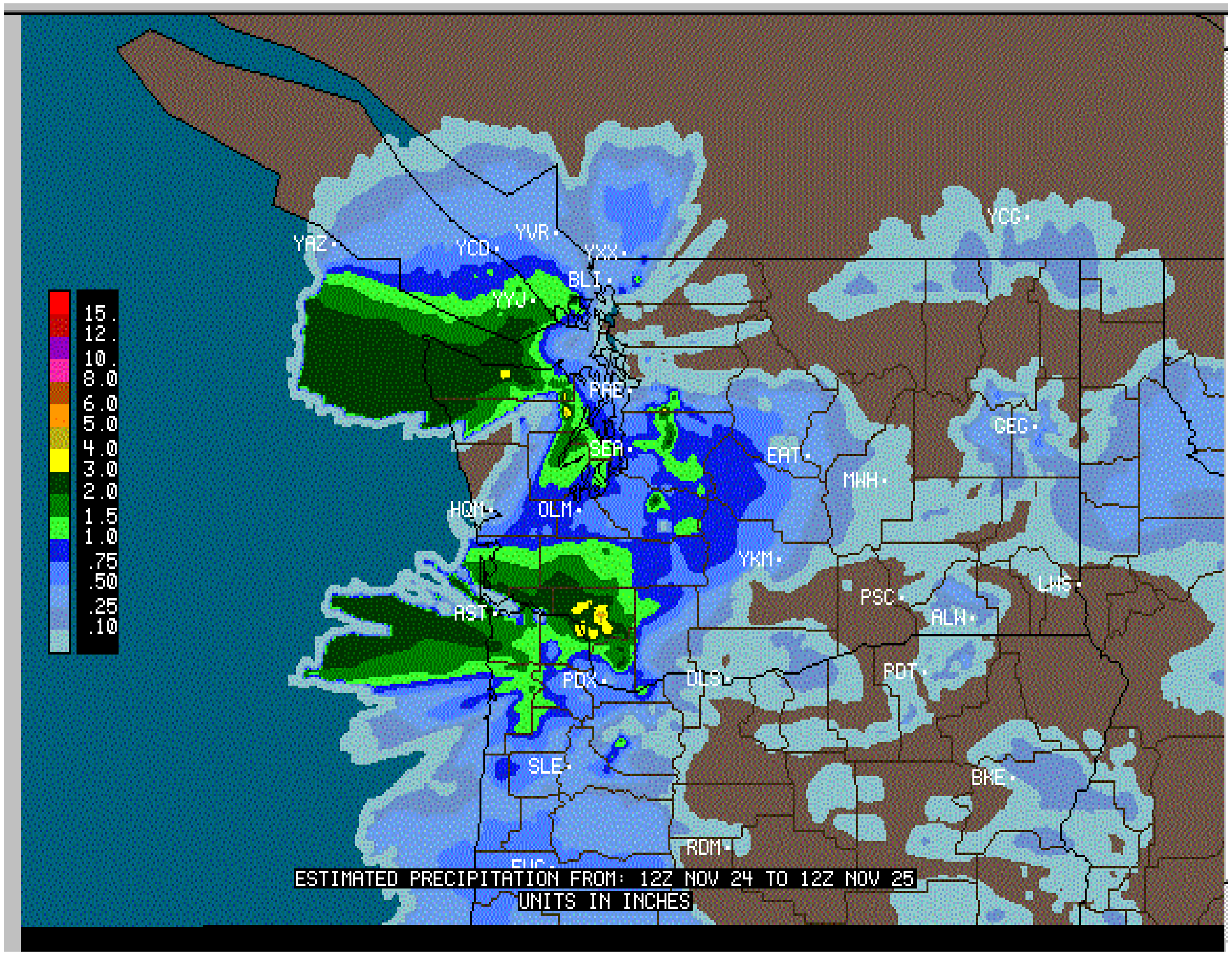
GOES Multi-Spectral Rainfall Algorithm 24 hour rainfall estimates (mm) ending 11-25-98 1200 UTC; not adjusted for orography



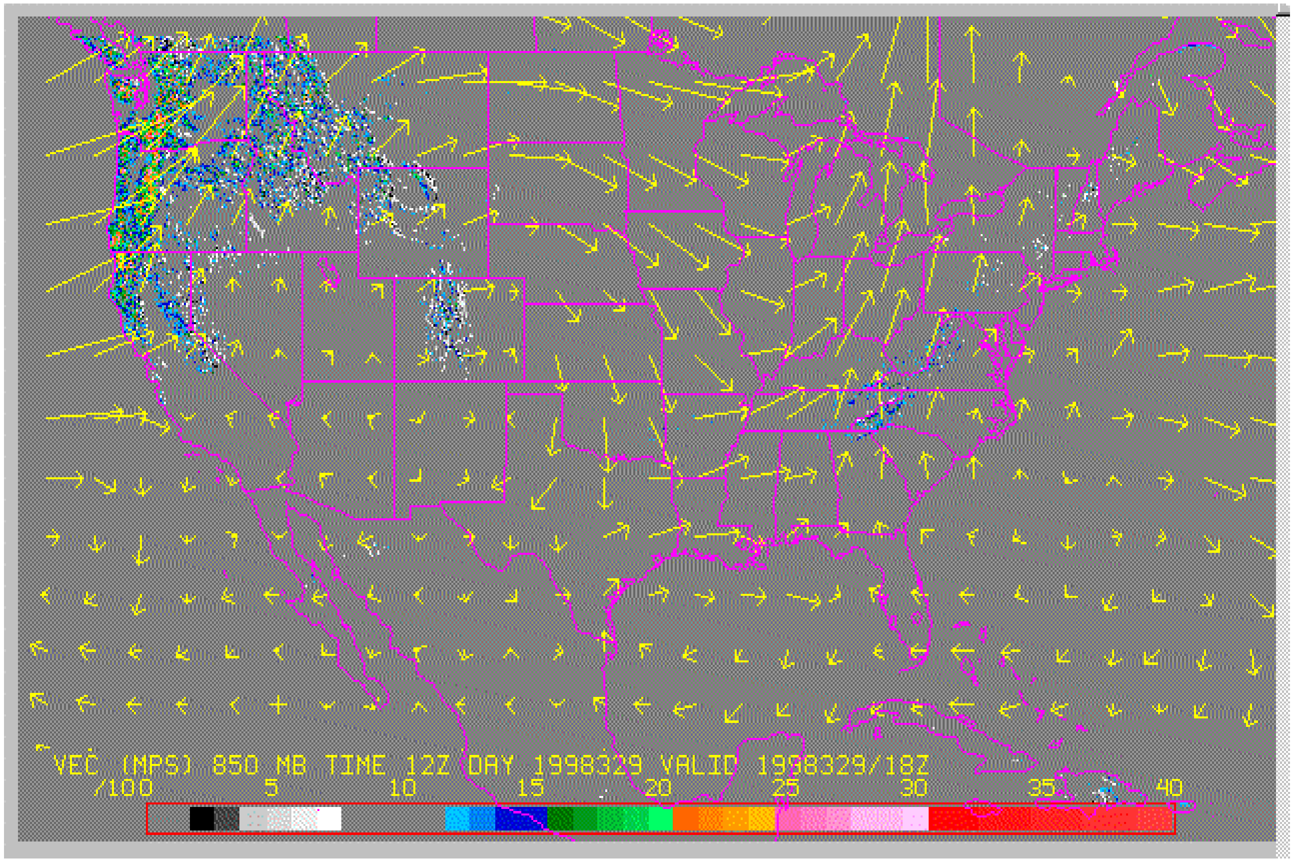
Auto-Estimator 24 hour rainfall estimates (in) ending 11-25-98 1200 UTC; adjusted for orography



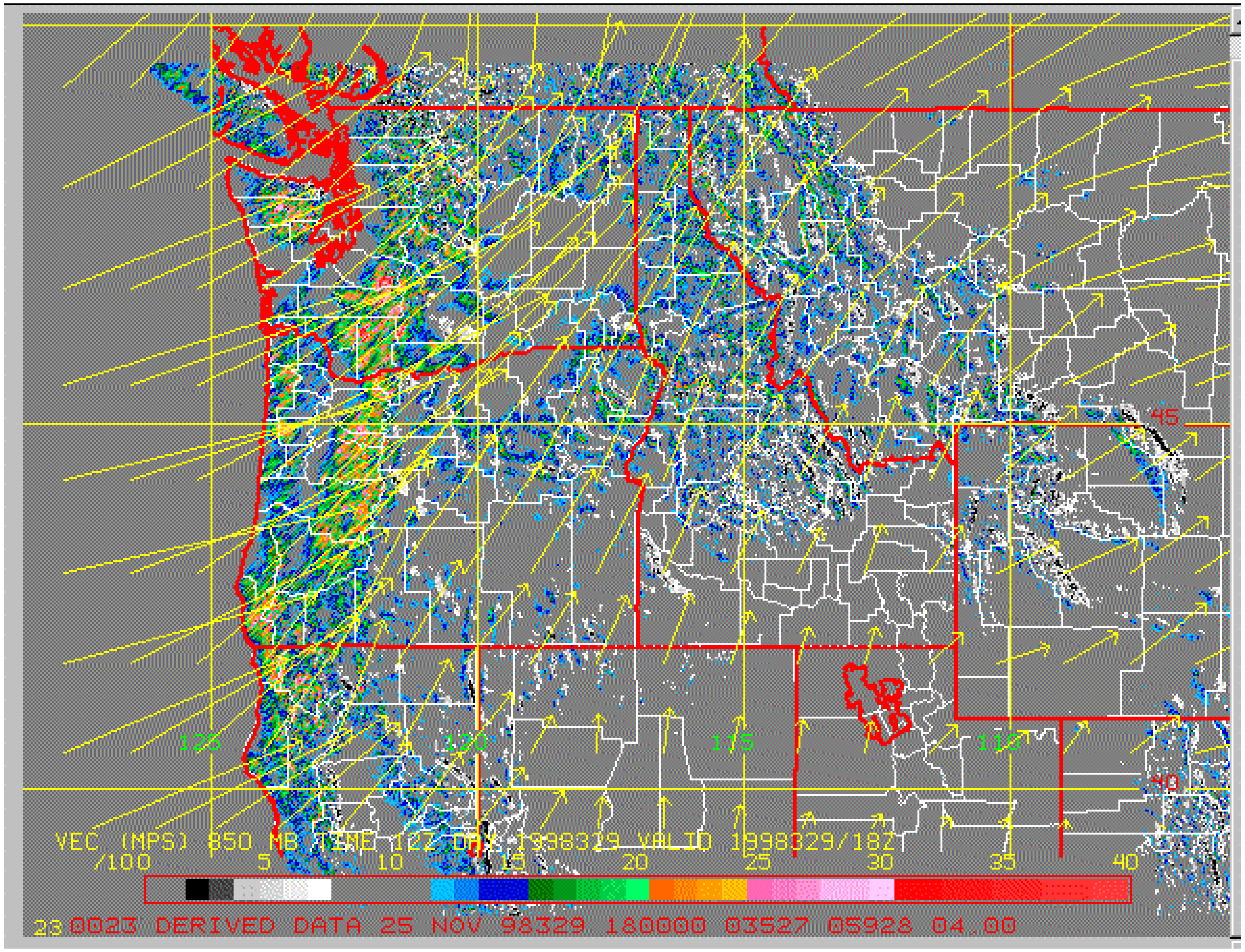
Auto-Estimator 24 hour rainfall estimate (in) ending 11-25-98 1200 UTC; not adjusted for orography



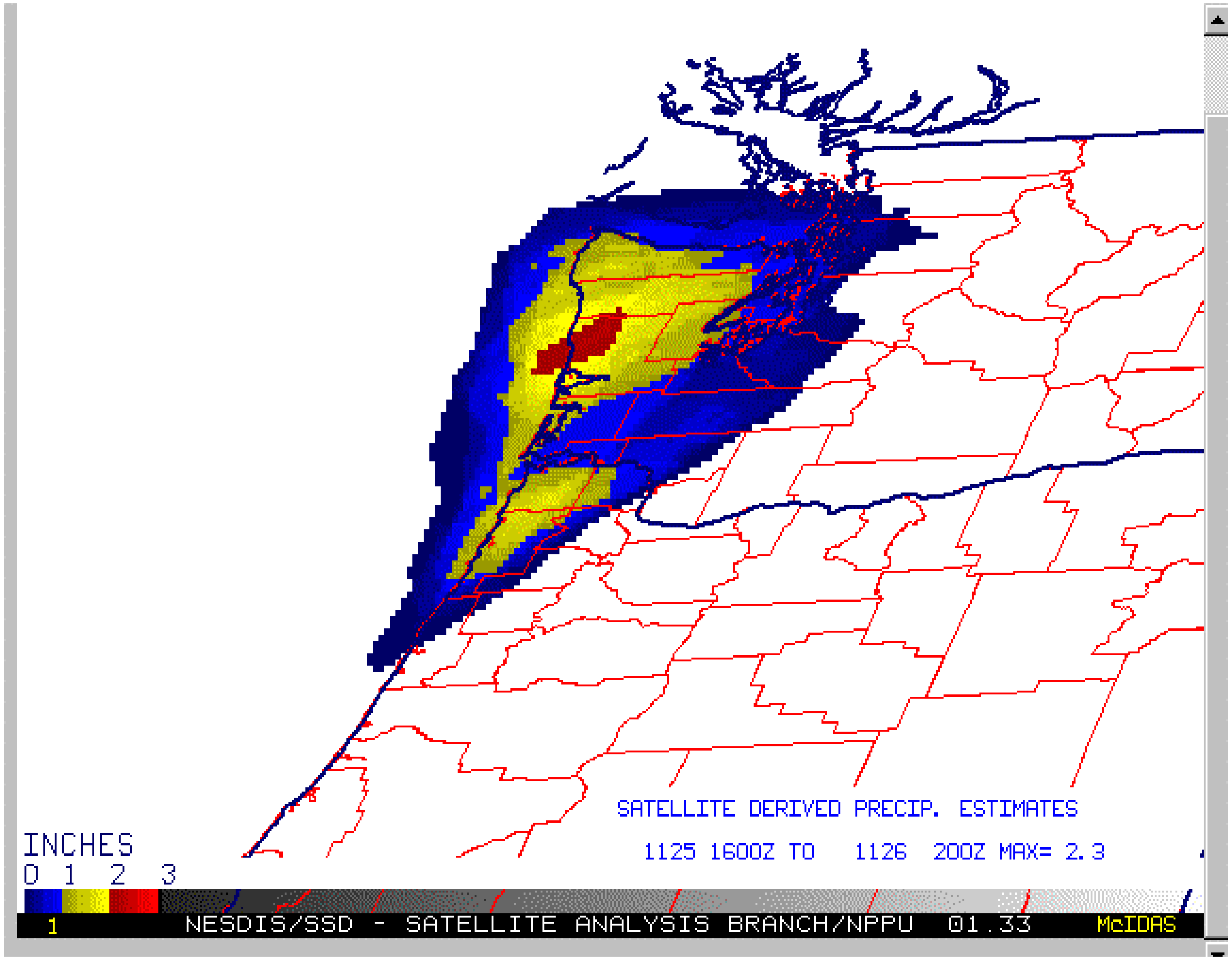
WSR 88 D 24 hour precipitation estimates (in) ending 11-25-98 1200 UTC



Orographic adjustment for 11-25-98 1800 UTC; 850 mb winds (mps) are superimposed



Orography adjustment for 11-25-98 1800 UTC; 850 mb winds (mps) are superimposed



Interactive Flash Flood Analyzer (IFFA) estimates (in) for 11-25- 1600 UTC ----- 11-26- 2000 UTC, 1998

Three Hour Rainfall Outlooks

(1) The speed and direction of movement of the coldest portions of the convective systems are measured on the latest satellite imagery

(2) This speed and direction are used to extrapolate the current estimated rainfall rates out to 3 hours

(3) Heaviest rainfall areas are correlated best to the mean cloud-layer shear vector (i.e., moves in the direction of 850-300 thickness isopleths)

(4) For regenerative convective systems, the growth and movement of individual convective clusters must be considered

(5) The following "trend and expectancy" guidelines are used to anticipate the evolution of the convective systems for the next 3 hours --- these guidelines are used to adjust the extrapolated rainfall in (2) above

Trend and Expectancy Guidelines

Adjust amounts UPWARD if:

- **The trend of the last 3 half-hourly estimates is upward**
- **The speed of the coldest tops is decreasing or if the tops are becoming quasi-stationary or building upwind**
- **New convection is developing upwind of the coldest tops**
- **Cluster/line mergers or intersections with a low level boundary are expected**
- **Warm, moist low-level inflow becomes increasingly perpendicular to the direction of movement of the coldest tops (increasing surface moisture convergence)**
- **If hourly surface data show low-level inflow increasing in dewpoint, precipitable water or increasing instability**

Trend and Expectancy Guidelines

No Adjustments if:

- **The trend of the last 3 half-hourly estimates is nearly constant**
- **The speed of the coldest tops is nearly constant, but not quasi-stationary**
- **No mergers or intersections with boundaries are expected**
- **The time of day is still favorable**
- **The system continues in the same topographic region**
- **The direction of the warm, moist, low-level inflow maintains its orientation with the direction of movement of the coldest tops**
- **Hourly surface data show no change in dewpoint, precipitable water, or stability of low-level inflow**

Trend and Expectancy Guidelines

Adjustments amounts DOWNWARD if:

- **The trend of the last 3 half-hourly estimates is downward**
- **The speed of the coldest tops increasing**
- **The time of day is becoming unfavorable**
- **The system is moving into a different topographic region that is less moist and more stable**
- **The warm, moist, low-level inflow points in the same direction as, and becomes increasingly parallel to the direction of movement of the coldest tops**
- **Hourly surface data show low-level inflow decreasing in dewpoints, precipitable water, or increasing in stability**

Forecasting Excessive Rainfall (3 or more inches) in a 12 to 24 hour period

YES	NO	
-----	-----	Is an 850/700 mb theta-e ridge present ?
-----	-----	Is the sfc-500 mb RH > 70 % and PW > 1 in and/or 120 % of normal?
-----	-----	Is a short wave, cyclonic circulation (lobe), or jet streak expected over the area?
-----	-----	Is a water vapor (6.7 μm) and Precipitable Water Plume over or approaching the area?
-----	-----	Is positive 850/700 mb theta-e advection present?
-----	-----	Is sfc-500 mb RH > 70 % and PW > 1.5 and/or > 140 % of norm?

----

other meteorological variables to consider: speed of system, regeneration, and surface features such as winds, dew points and boundaries.

Satellite Home Pages for NOWCASTING Flash Floods and Heavy Precipitation and for QPF

- **NESDIS Flash Flood:** **http://orbit-net.nesdis.noaa.gov/ora/ht/ff**
- **IFFA Precipitation Estimates:** **http://hpssd1en.wwb.noaa.gov/SSD/ML/pcpn-ndx.html**
- **Microwave TPW and Precipitation:** **http://manati.wwb.noaa.gov/doc/ssmiprecip.html**

Satellite Home Pages for NOWCASTING Flash Floods and Heavy Precipitation and for QPF

- **GOES SOUNDINGS: TPW; Lifted Index; Temperature**

  http://orbit30i.nesdis.noaa.gov/http/temp.html