17 March 2012 © H. Bluestein

- NO VERTICAL SHEAR
- BASIC BUILDING BLOCK FOR ALL CONVECTIVE STORMS

- MAINLY UPDRAFTS
$B > 0$

- MAINLY DOWNDRAFTS
$B < 0$

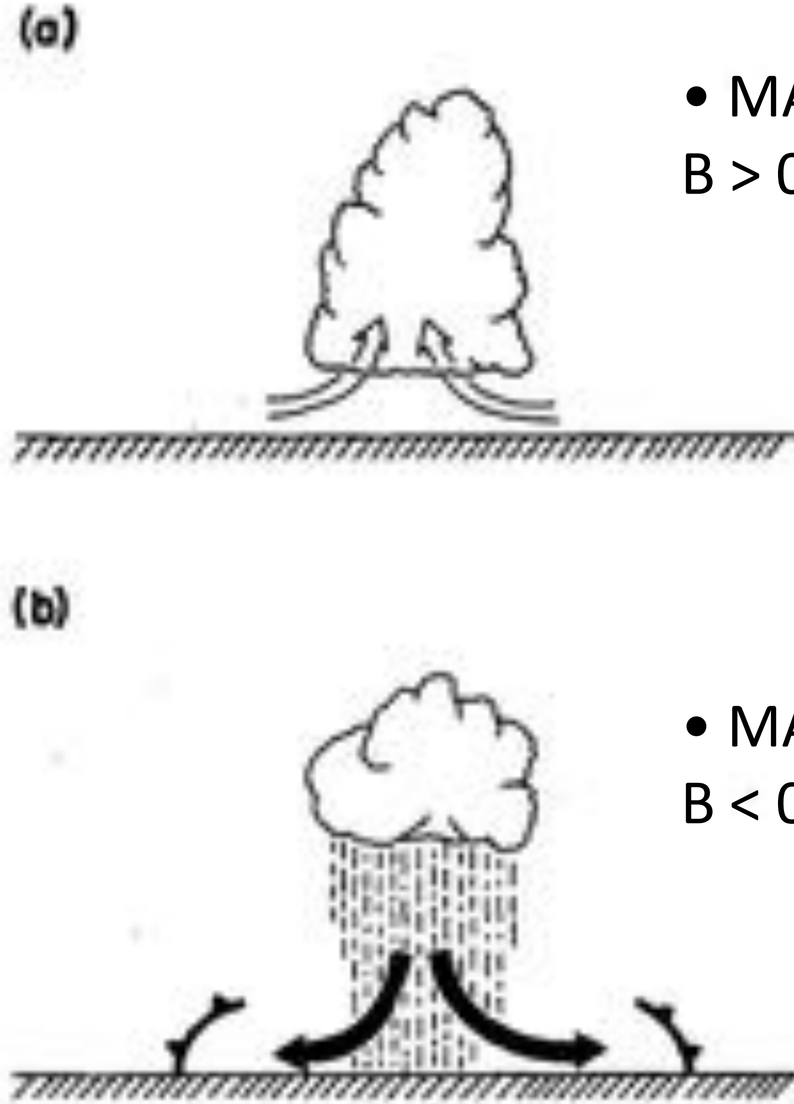


FIG. 1. Schematic illustration of the life cycle of an ordinary thunderstorm cell in which the (a) initial updraft, yields to a (b) downdraft produced by the accumulation of rain within the updraft. (Adapted from Figs. 17–18 of Byers and Braham, 1949.)

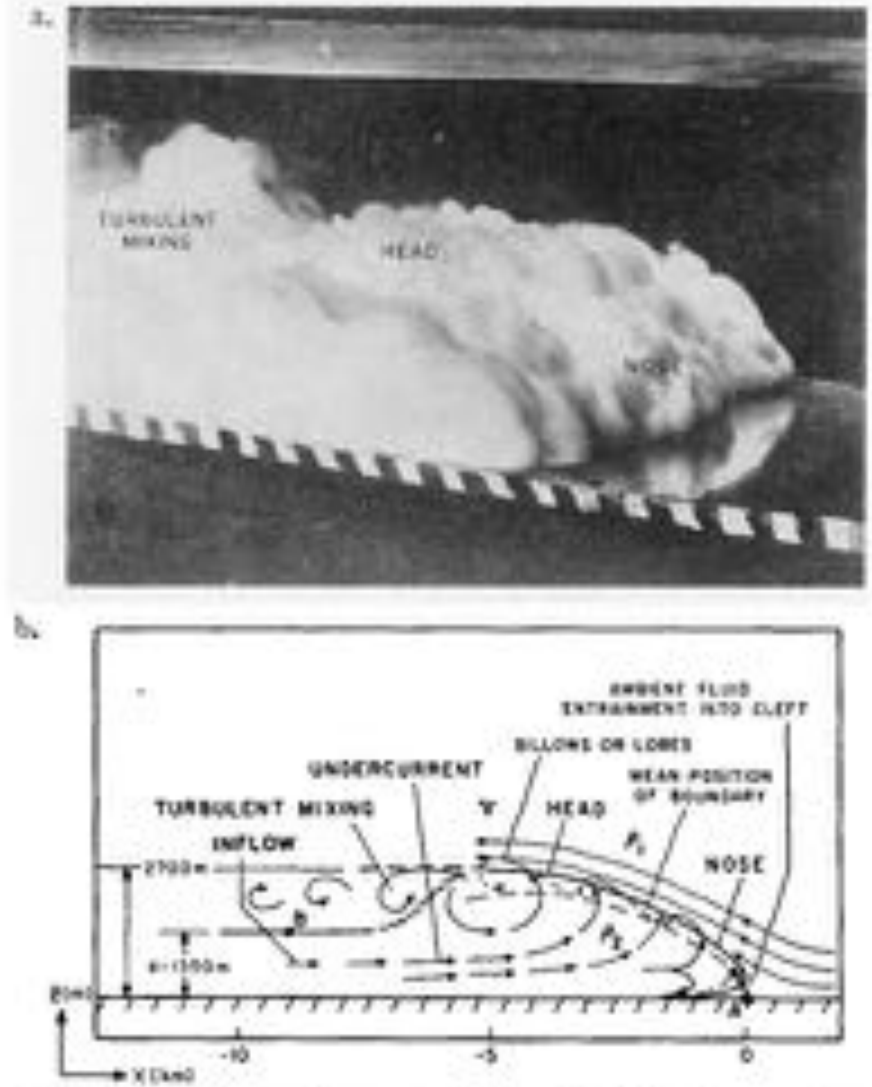
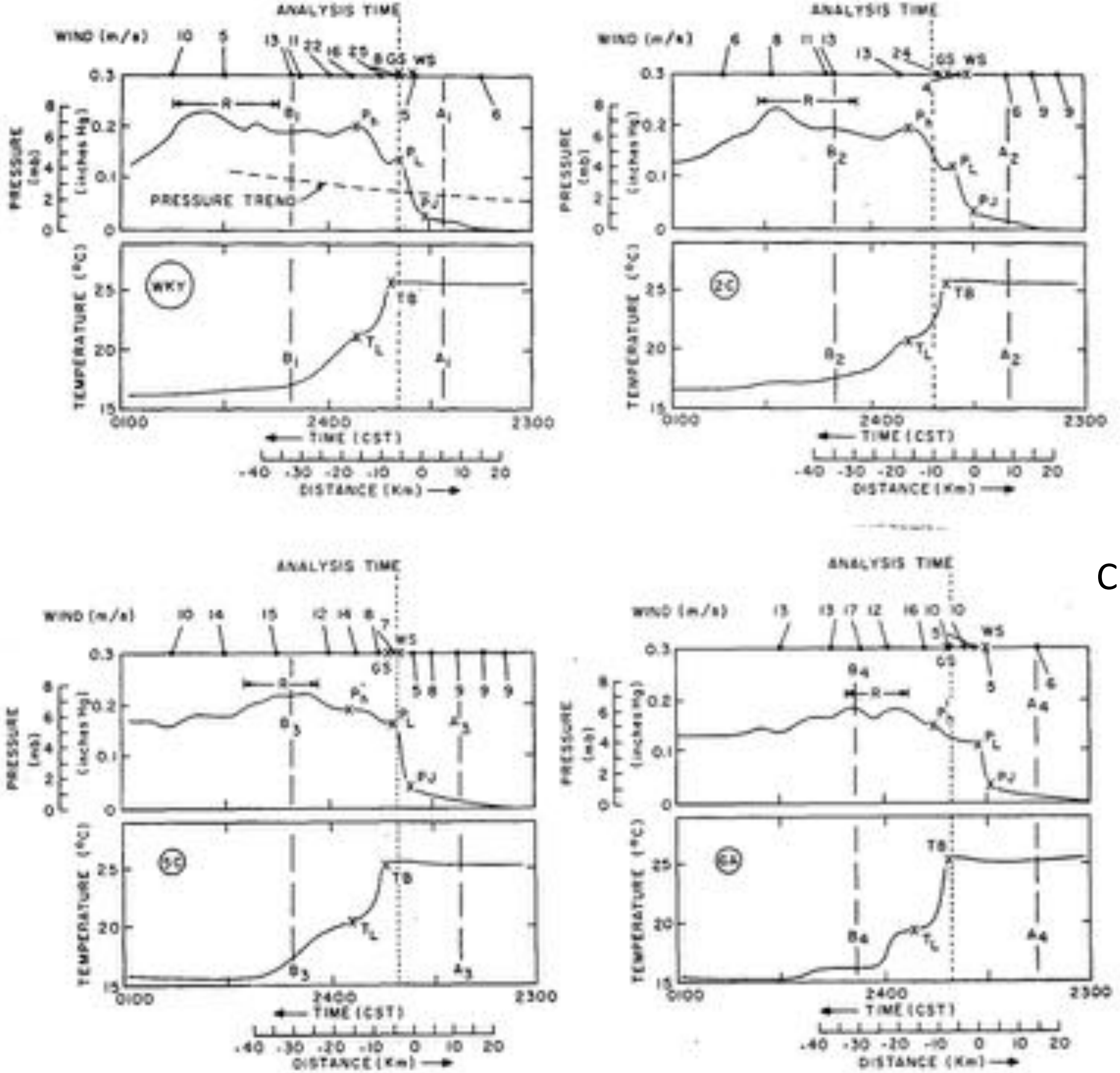


FIG. 13. (a) A gravity current (also called density current) simulated in a laboratory experiment (reproduced from Simpson, 1969). The white mass is a saline solution, flowing to the right along the bottom of a trough filled with pure water (compare with Fig. 12). (b) Schematic (laboratory) gravity current mode, (constructed from the work of Keulegan, 1958; Middleton, 1966; and Simpson, 1969; 1972). The vertical and horizontal dimensions of the model are scaled to the dimensions of the gust front.

Charba 1974



Charba 1974

FIG. 5. Time-to-space scale sections of surface wind, pressure, and temperature normal to the leading edge of the gust frontal air mass at network stations WKY, 2C, 5C, and 6A. The long-dashed vertical lines labeled A_1 and B_1 at WKY, A_2 and B_2 at 2C, etc., denote the end points of the corresponding section lines A_1B_1, A_2B_2, etc., in the network fields. The short-dashed vertical line labeled "analysis time" denotes the time of the surface network analysis (2337:30 CST). Significant points along each curve are marked and labeled; these points are located in the appropriate network fields. In all sections "R" stands for heavy rain.

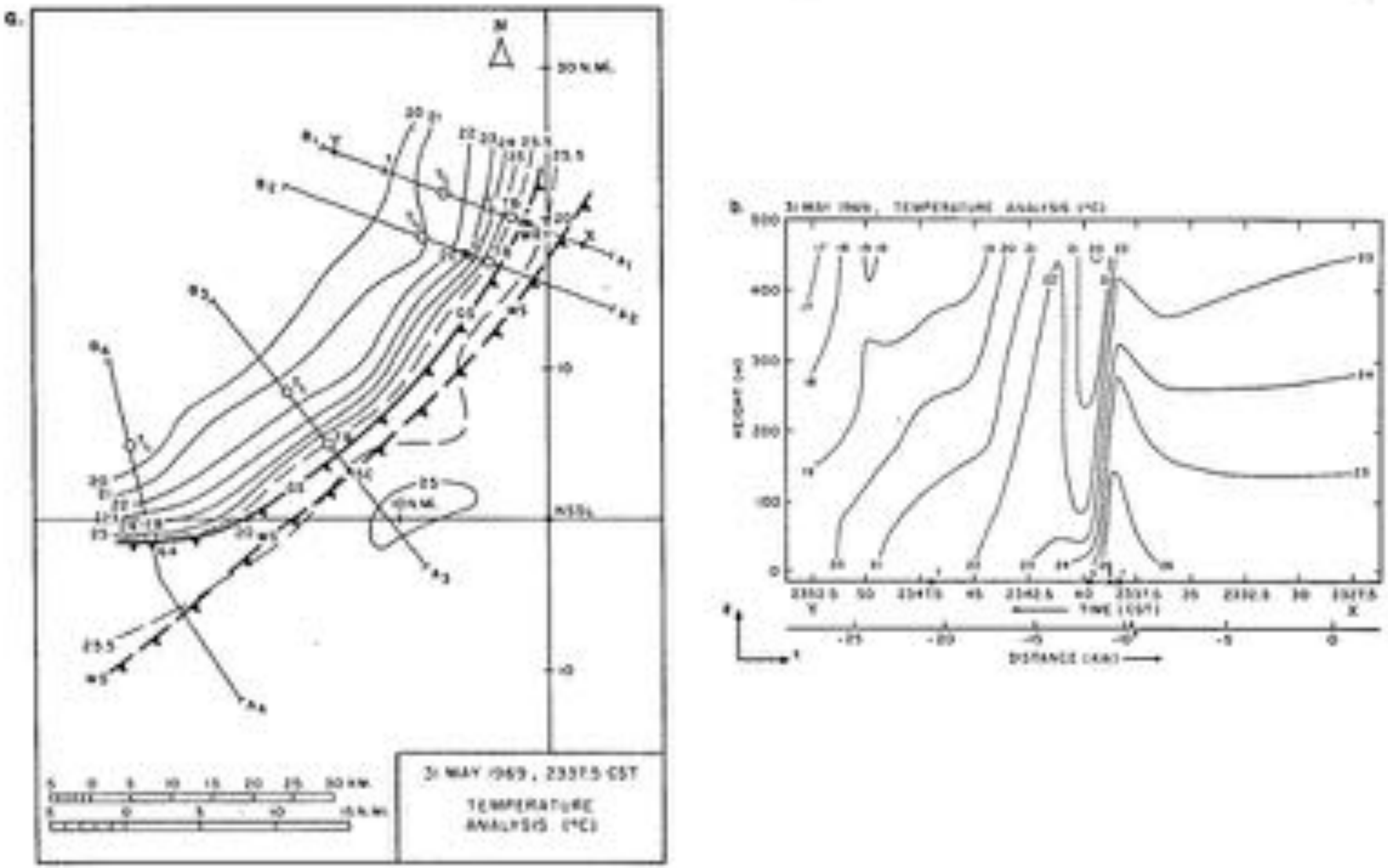
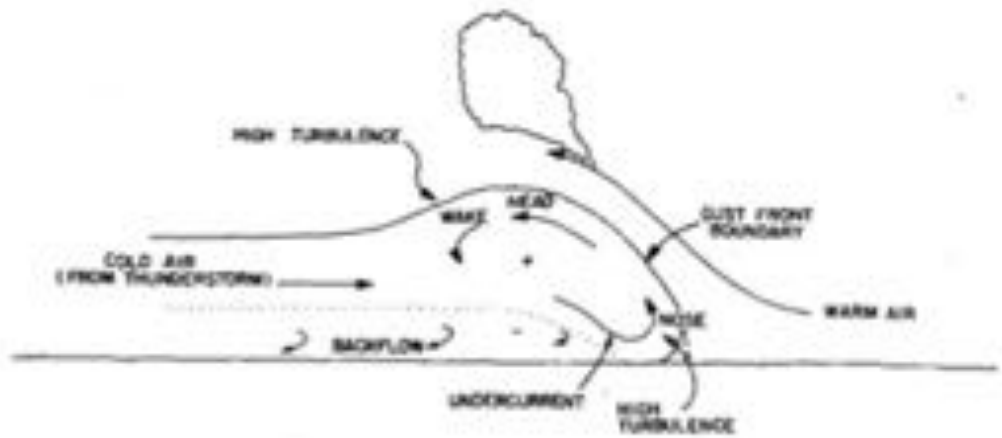


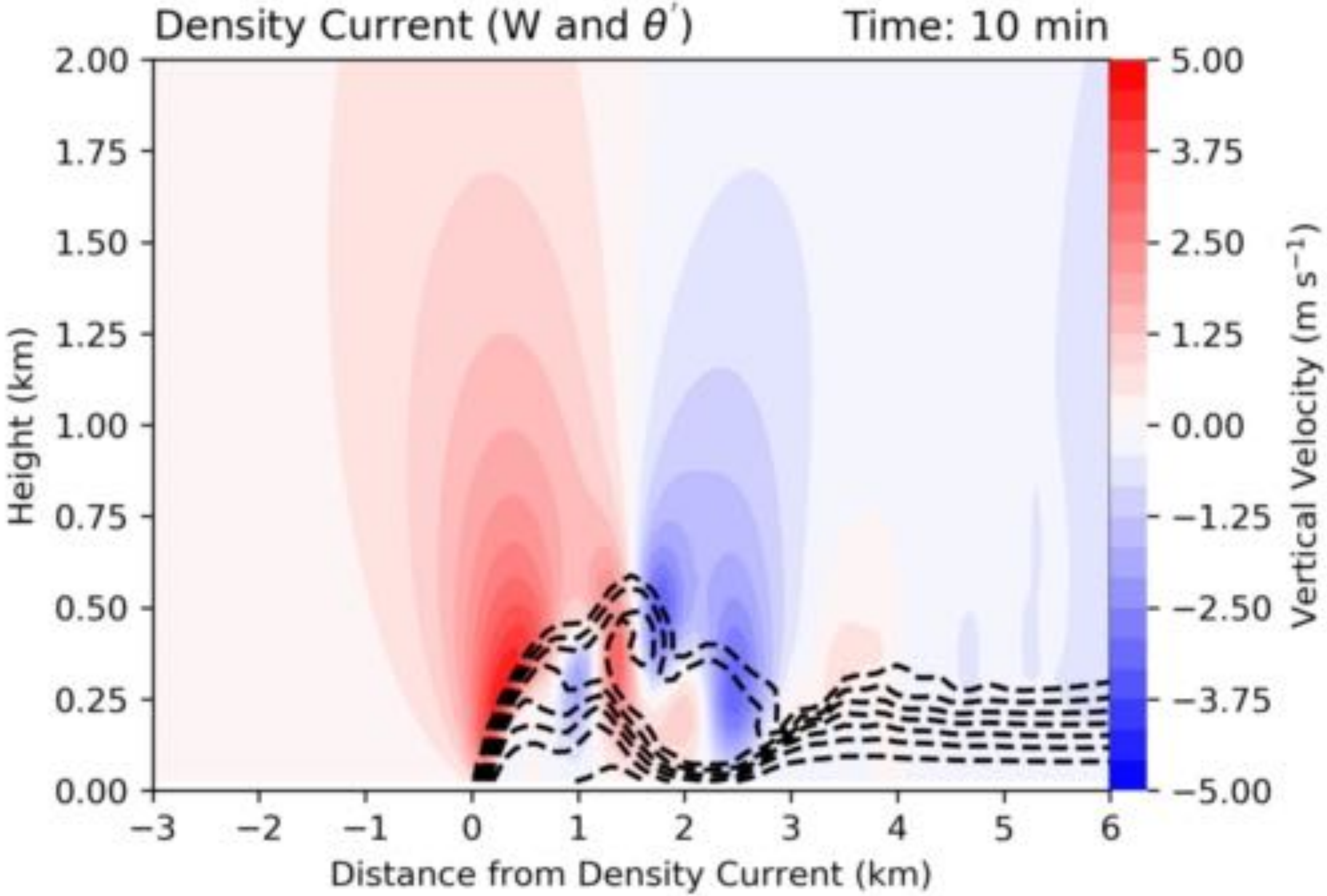
FIG. 6. Network and tower temperature analysis. Significant points along the section lines in (a) are denoted as discussed earlier (see Fig. 5).

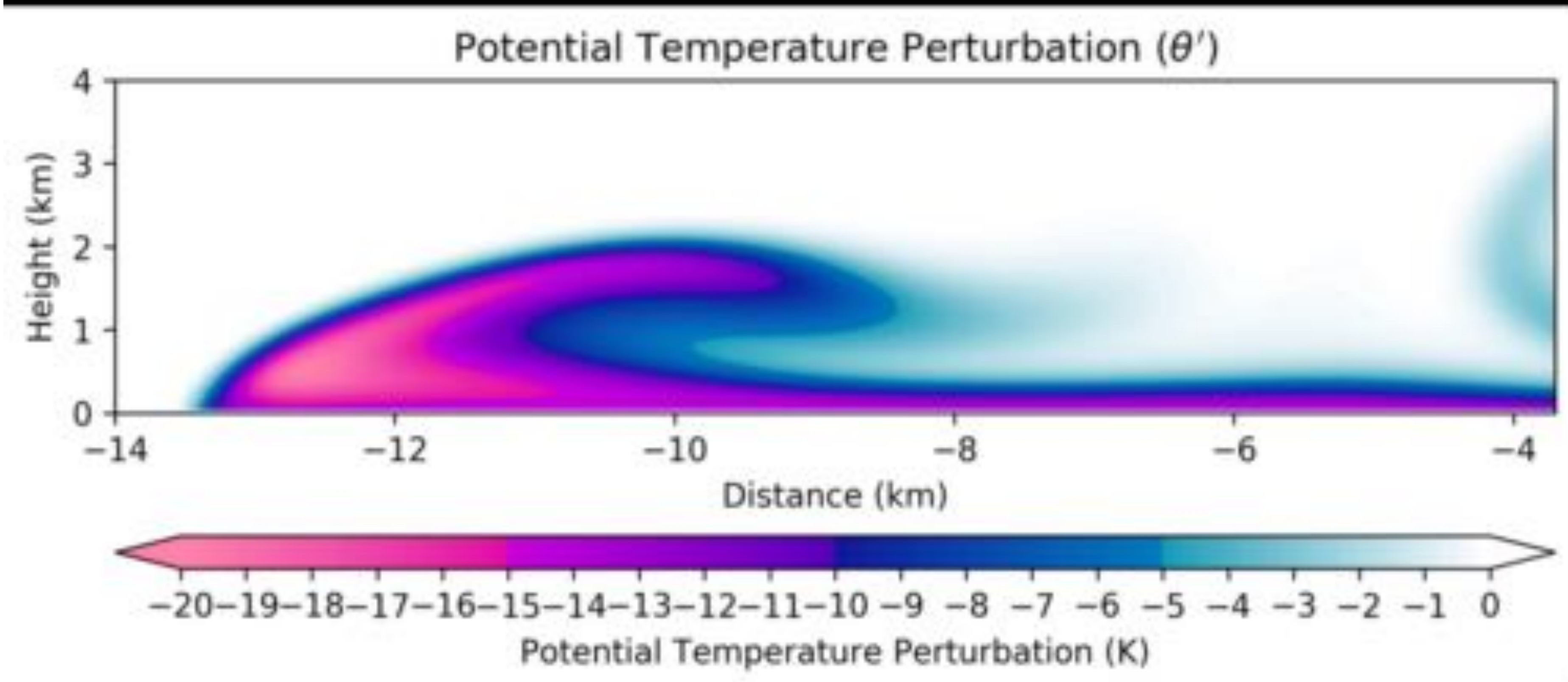
Charba 1974



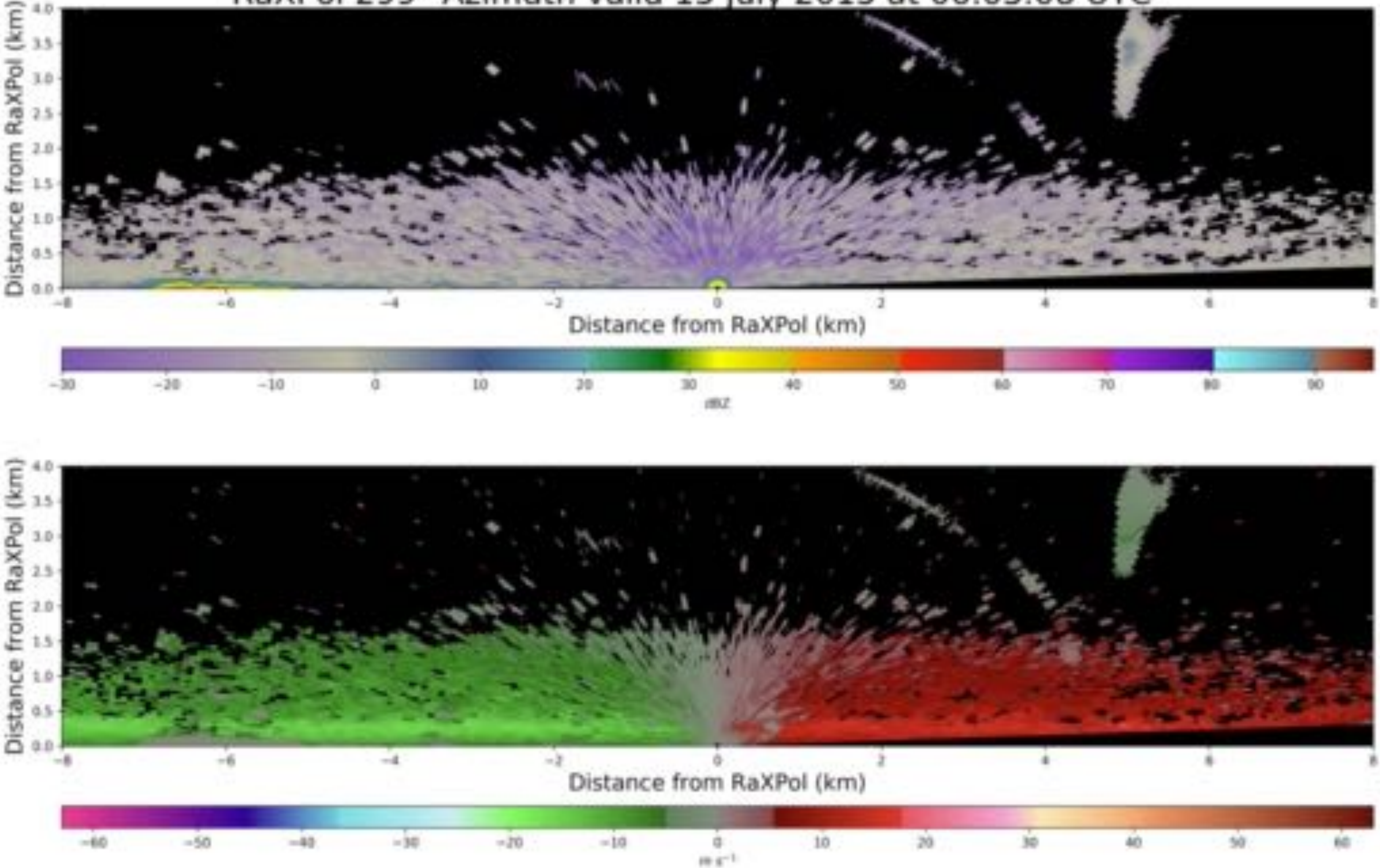
HIGH TURBULENCE
HEAD
WAKE
GUST FRONT
BOUNDARY
COLD AIR
(FROM THUNDERSTORM)
WARM AIR
NOSE
BACKFLOW
UNDERCURRENT
HIGH
TURBULENCE

Goff 1976


Density Current (W and θ′)
Time: 10 min
Height (km)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
−3
−2
−1
0
1
2
3
4
5
6
Distance from Density Current (km)
Vertical Velocity (m s⁻¹)
5.00
3.75
2.50
1.25
0.00
−1.25
−2.50
−3.75
−5.00


Potential Temperature Perturbation (θ')
Height (km)
4
3
2
1
0
−14
−12
−10
−8
−6
−4
Distance (km)
−20 −19 −18 −17 −16 −15 −14 −13 −12 −11 −10 −9 −8 −7 −6 −5 −4 −3 −2 −1 0
Potential Temperature Perturbation (K)

RaXPol 299° Azimuth valid 15 July 2015 at 06:03:08 UTC



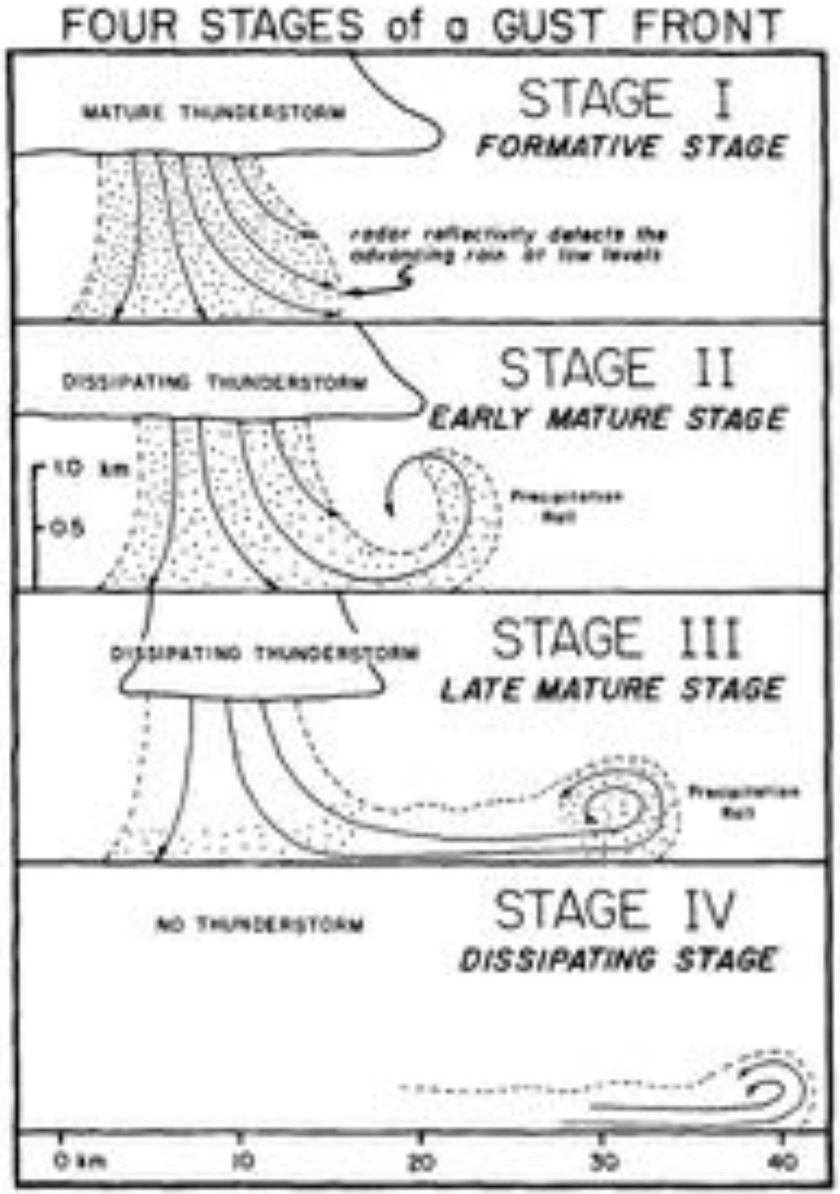


FIG. 3. The four stages of a thunderstorm gust front. The advancing precipitation at low levels is detected by the radar. The "precipitation roll" is a horizontal roll formed by airflow that is deflected upwards by the ground.

Wakimoto 1982

NIMROD 1978

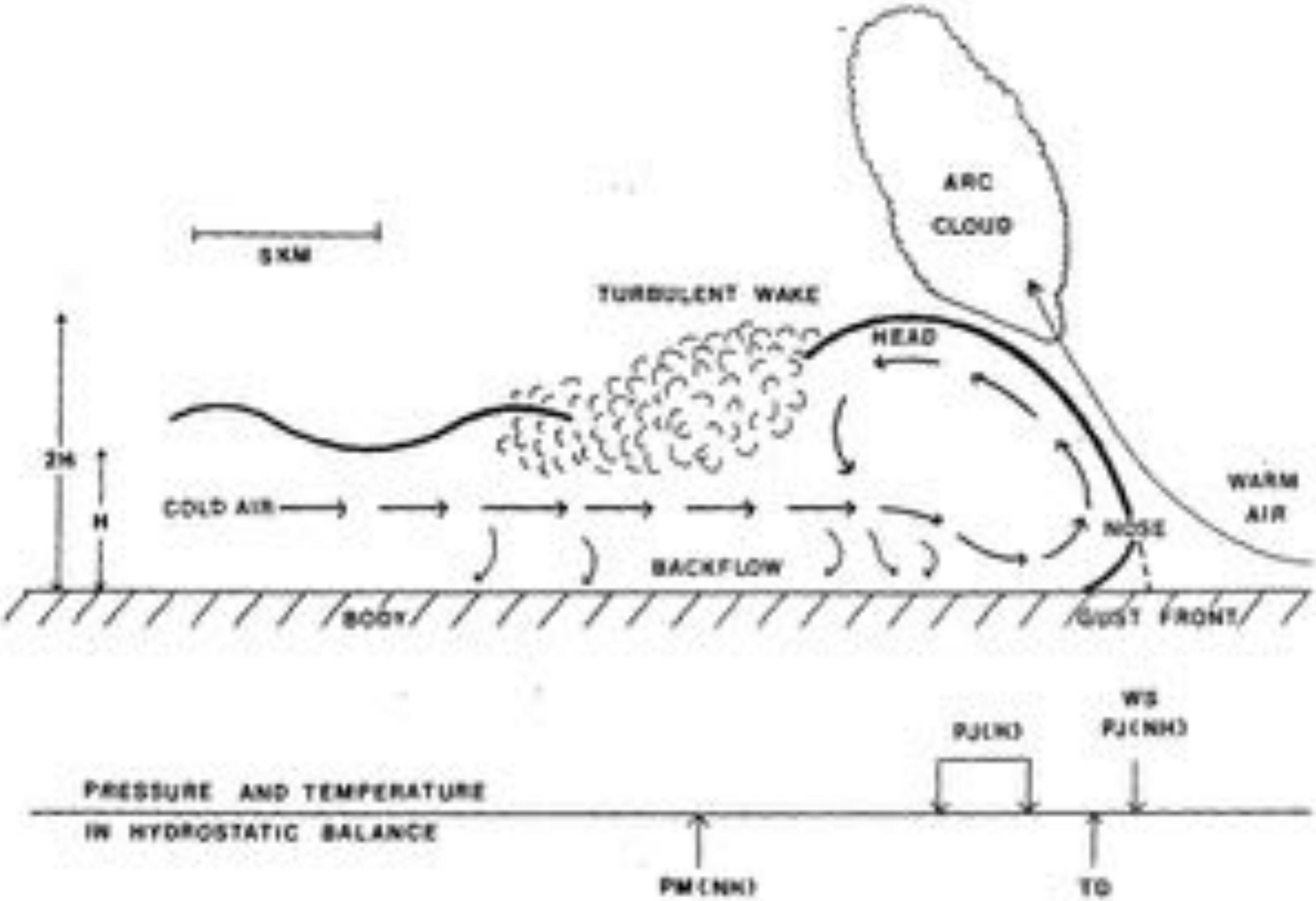
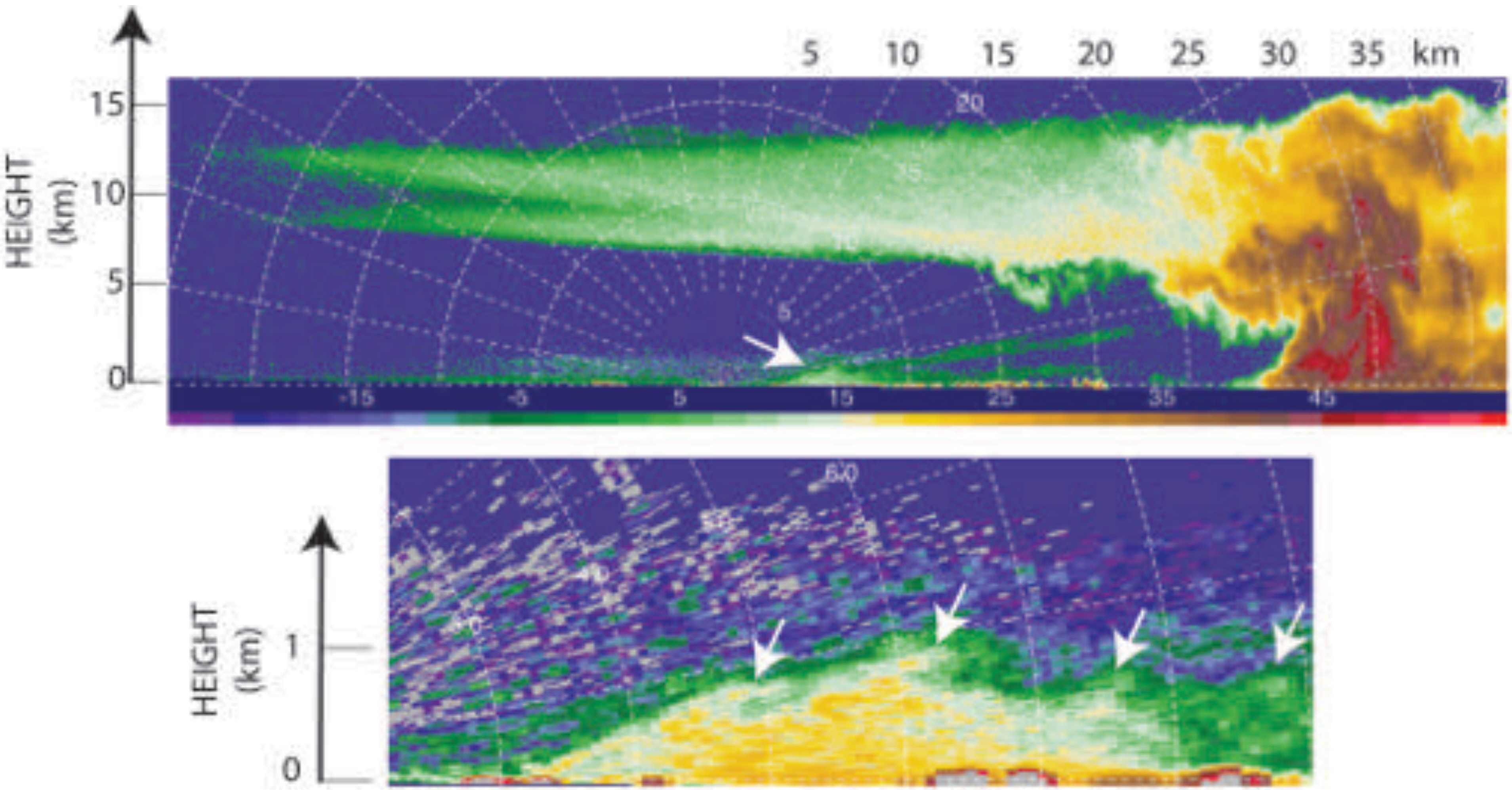
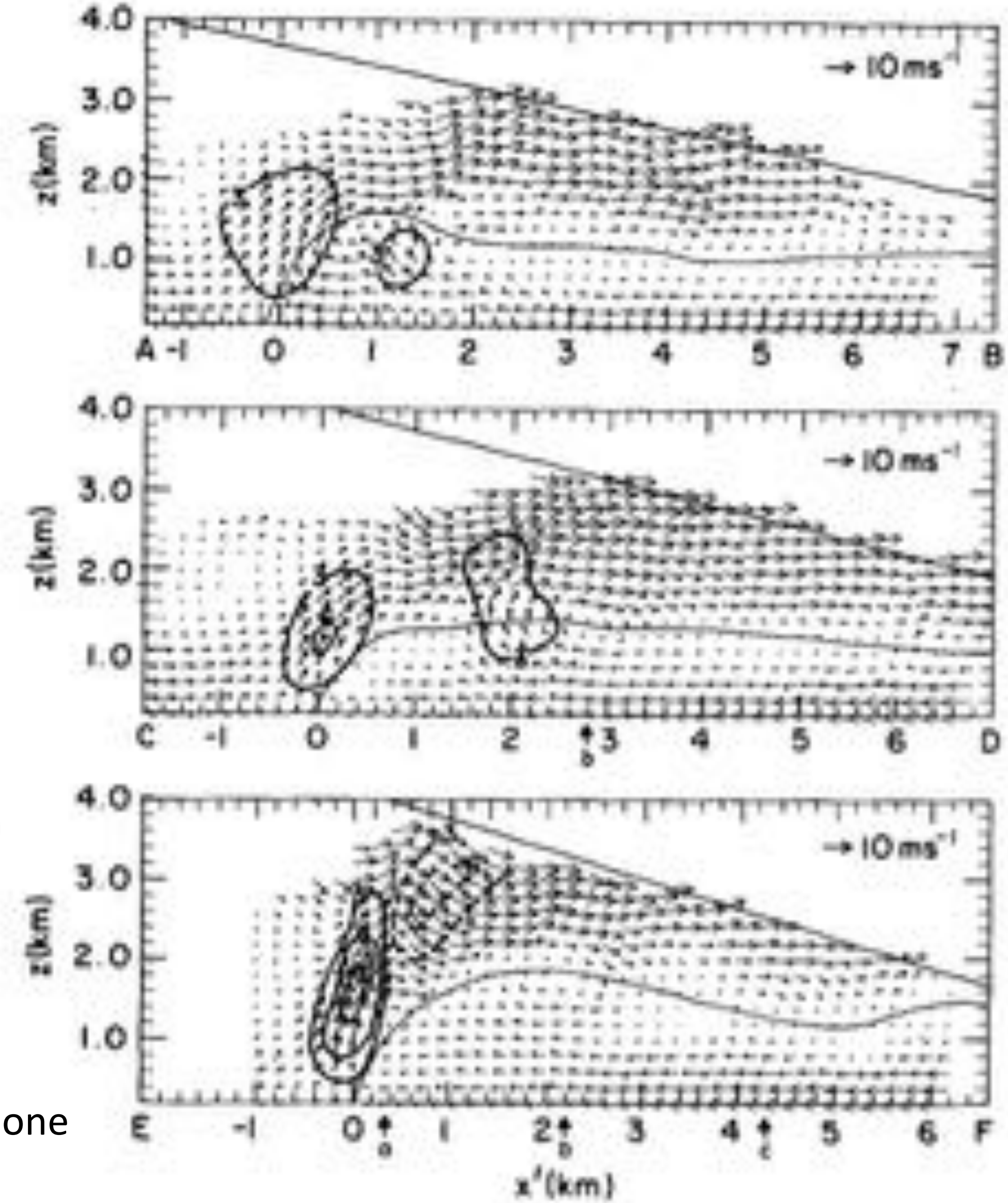


FIG. 1. Schematic vertical cross section through a mature thunderstorm outflow (vertical scale exaggerated), and the corresponding changes in surface meteorological parameters. See the text for details. (Adapted from Charba, 1974; Goff, 1975; Wakimoto, 1982; Koch, 1984).

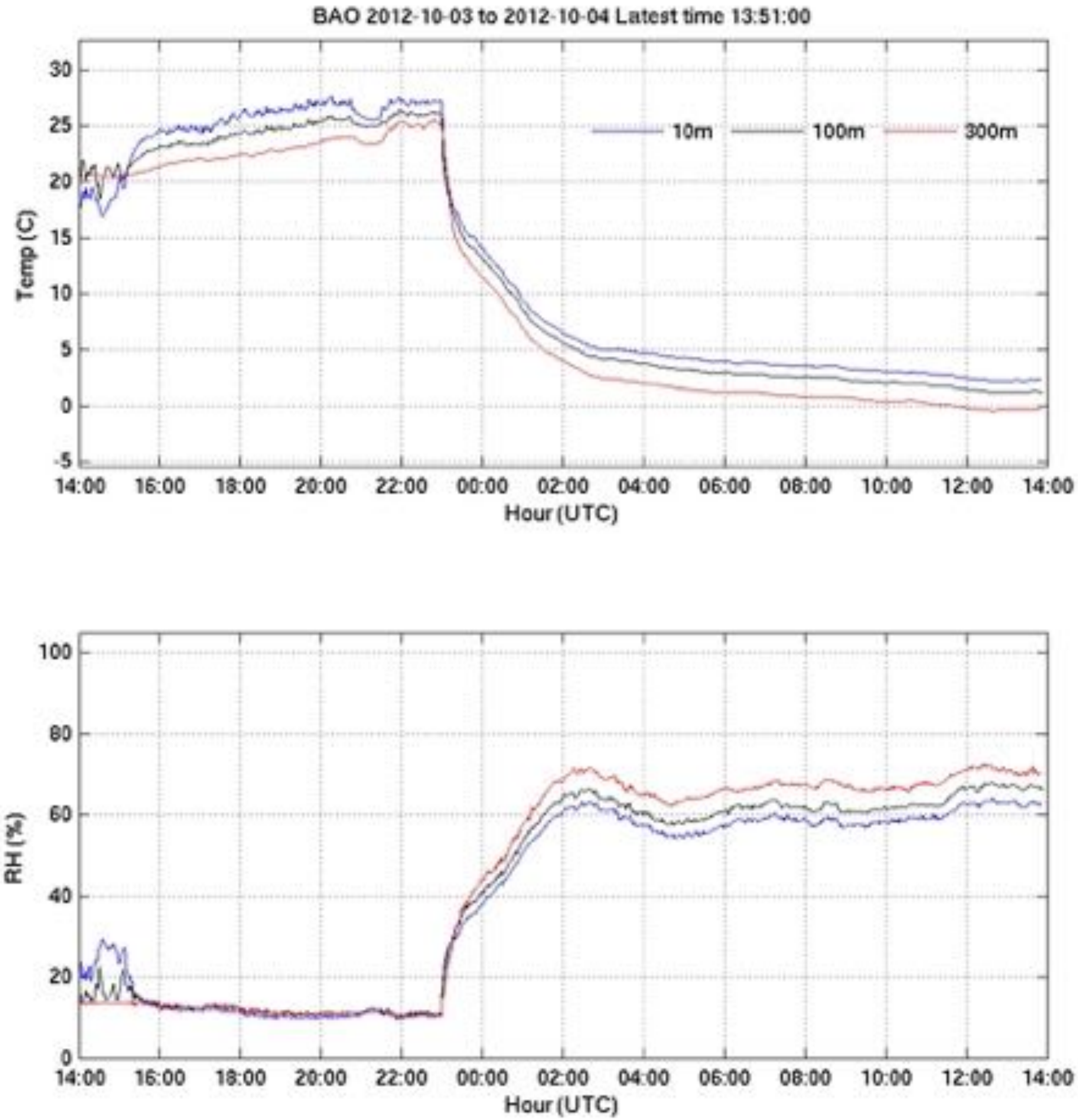
D
r



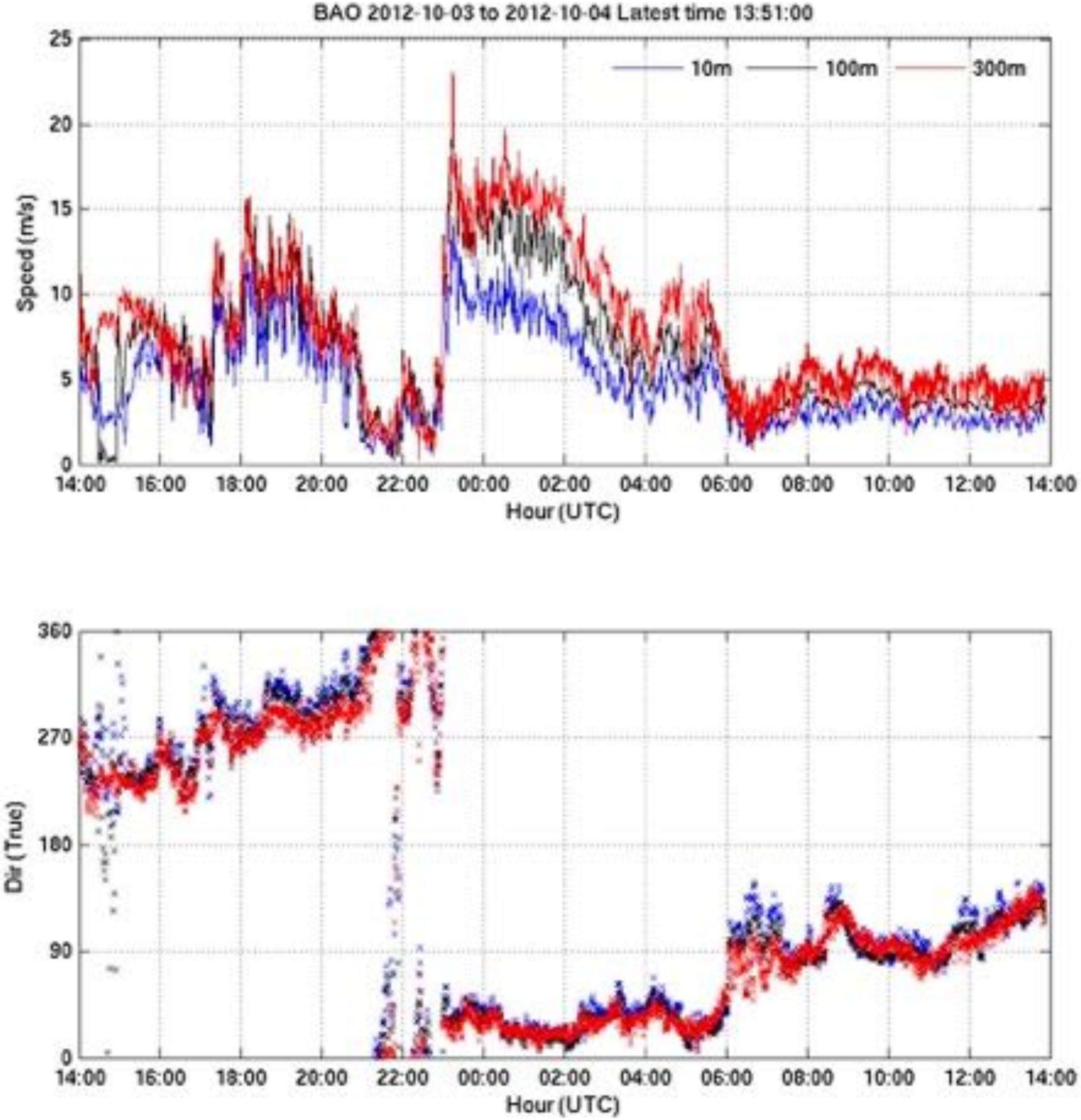
15 JULY 2015 PECAN
WESTERN KANSAS



Mueller and Carbone
1987

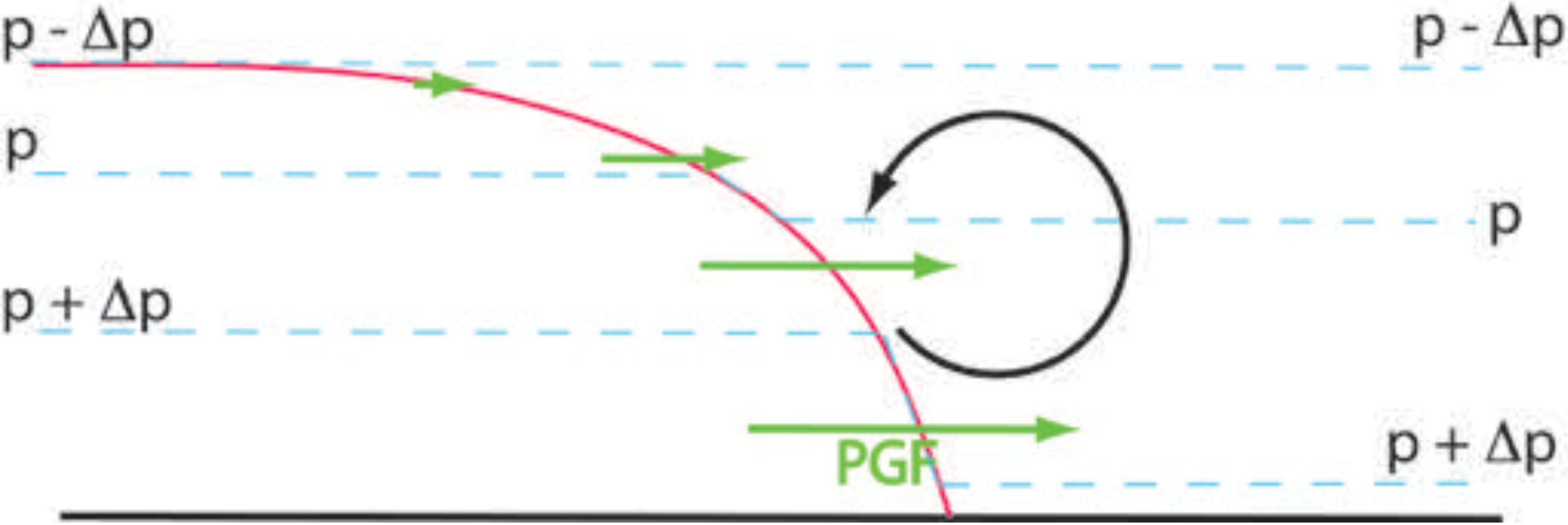


NOAA/ESRL/PSD/Weather & Climate Physics

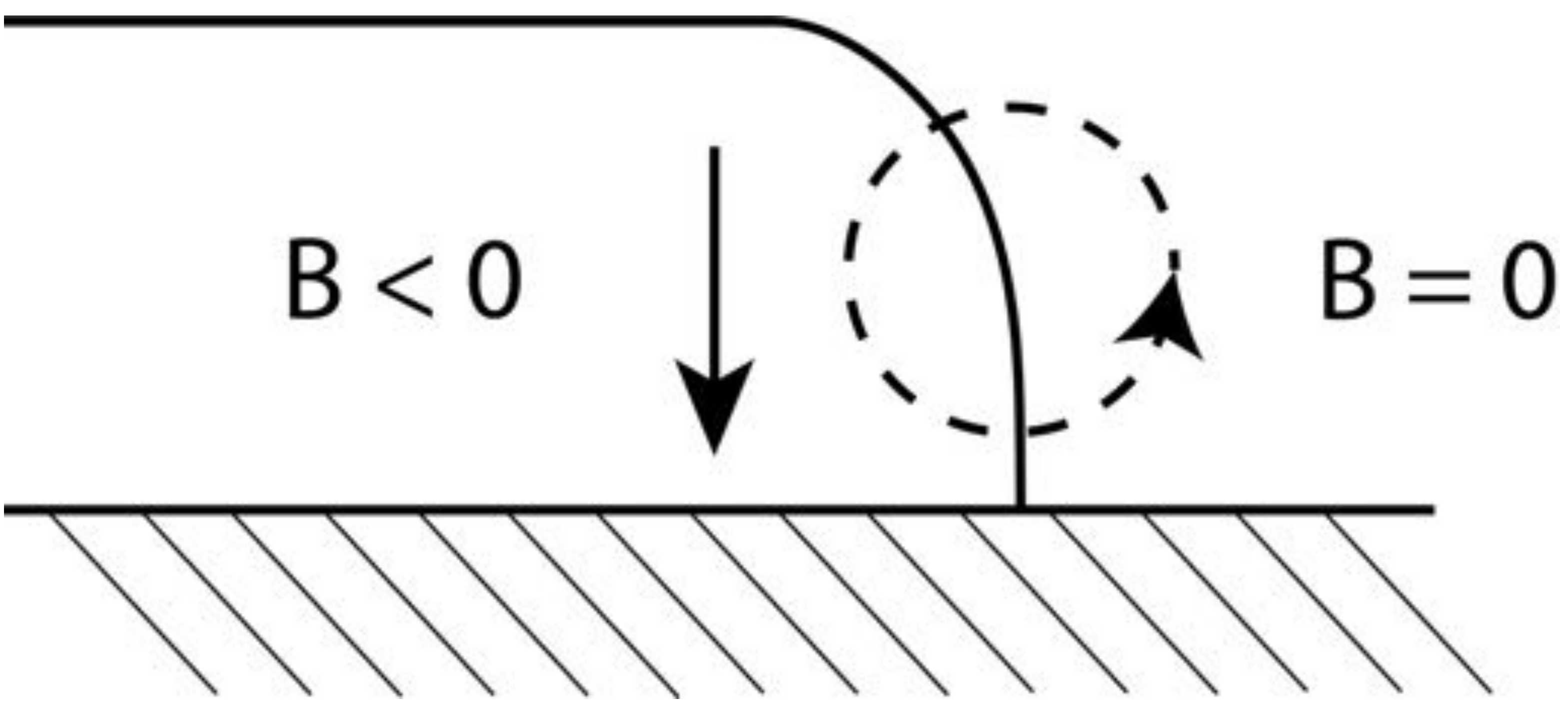


NOAA/ESRL/PSD/Weather & Climate Physics

WHALE’S MOUTHk

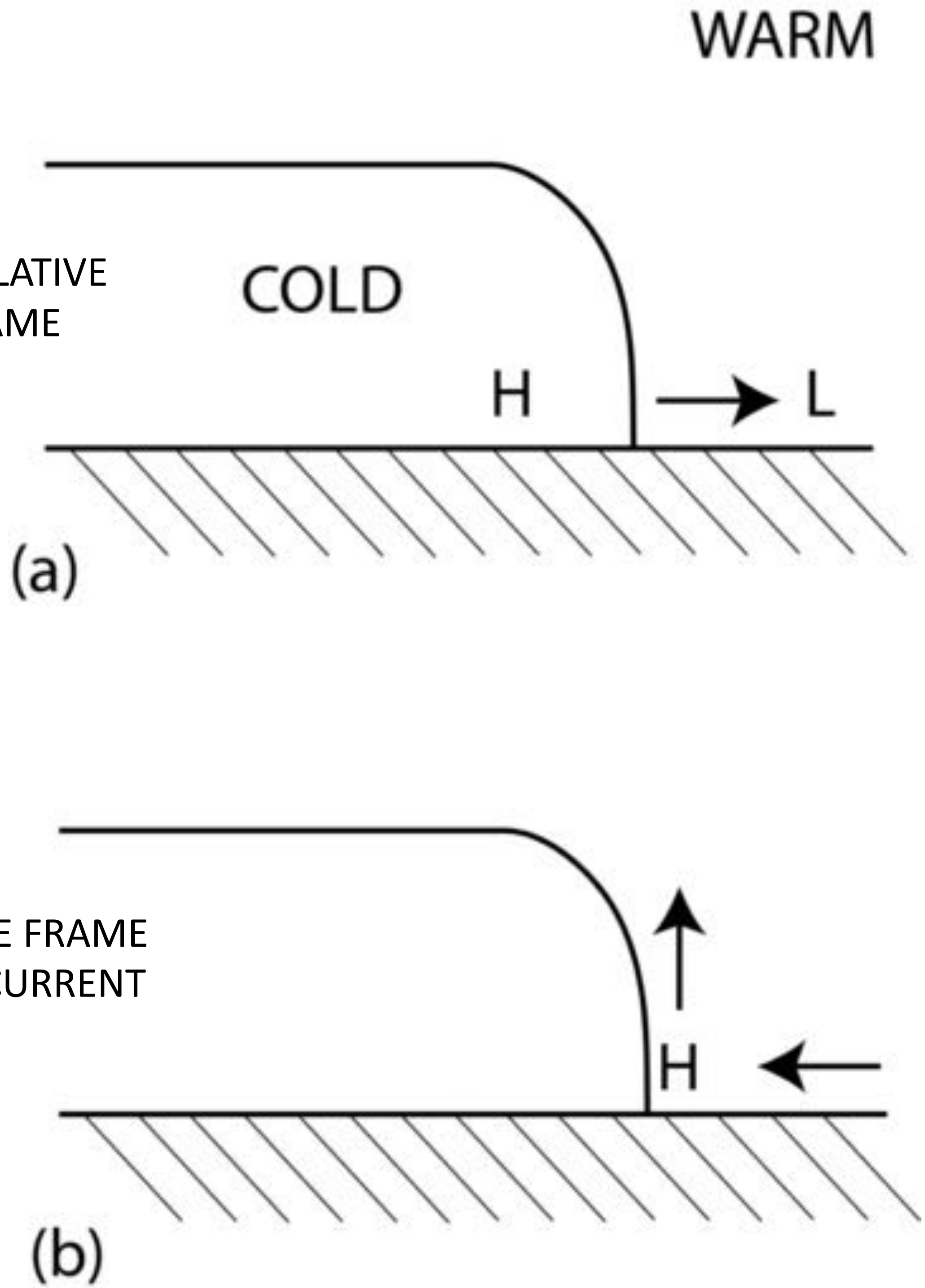


p - Δp
p - Δp
p
p
p + Δp
p + Δp
PGF


B < 0
B = 0

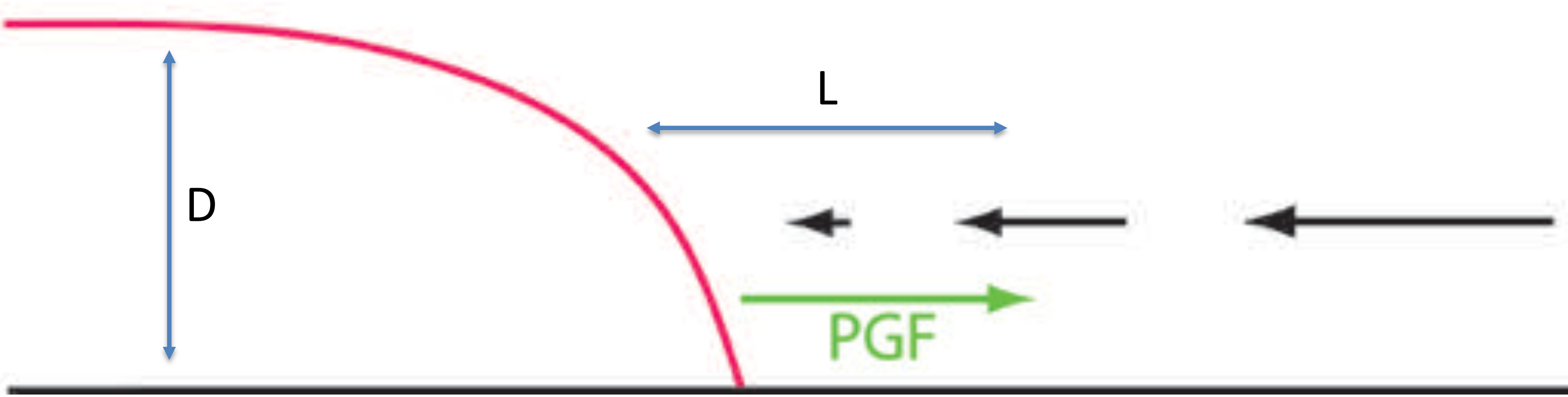
IN GROUND-RELATIVE REFERENCE FRAME

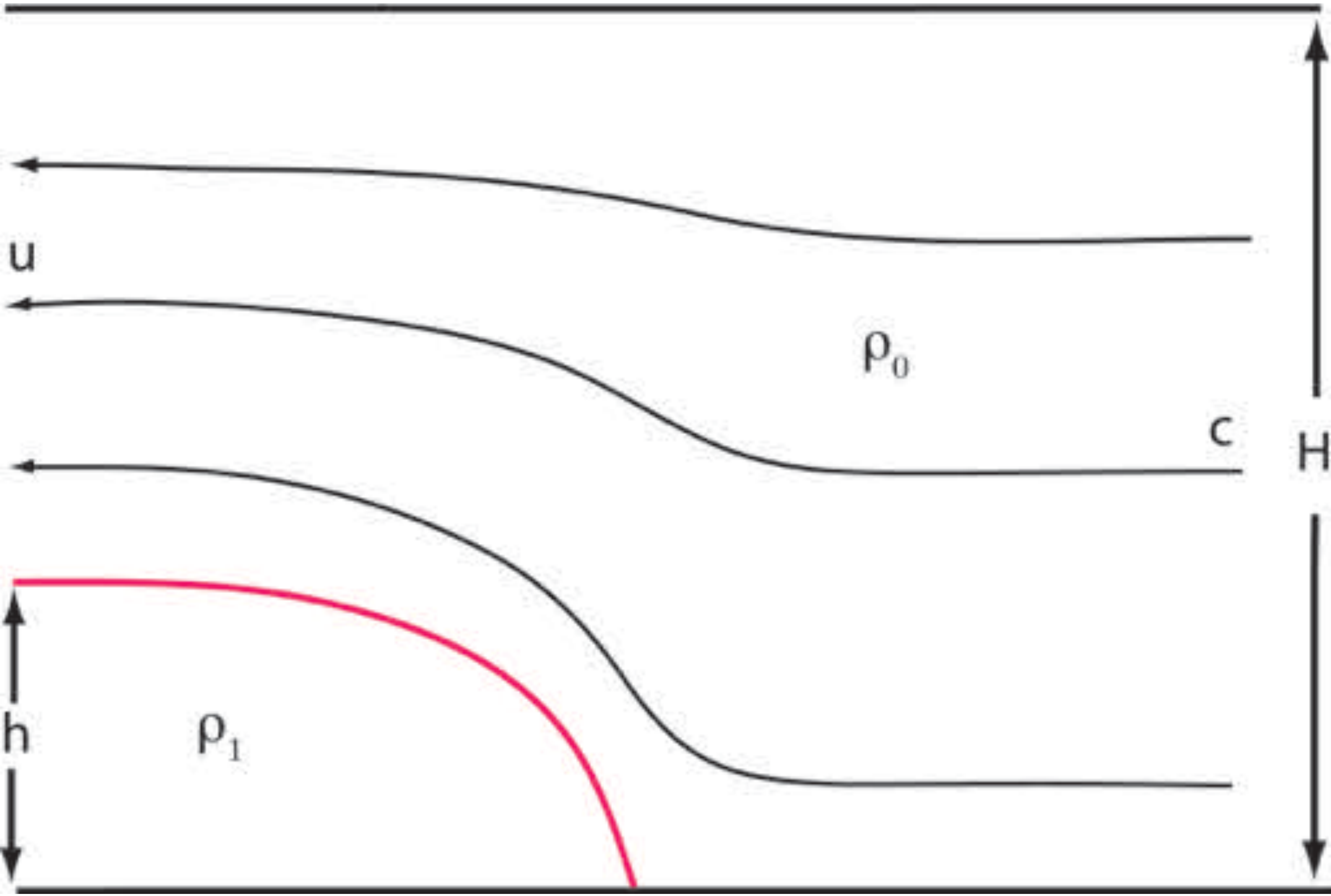
IN REFERENCE FRAME OF DENSITY CURRENT



$W/D \sim U/L$

$W \sim U$, so $L \sim D$




u
ρ0
c
H
h
ρ1

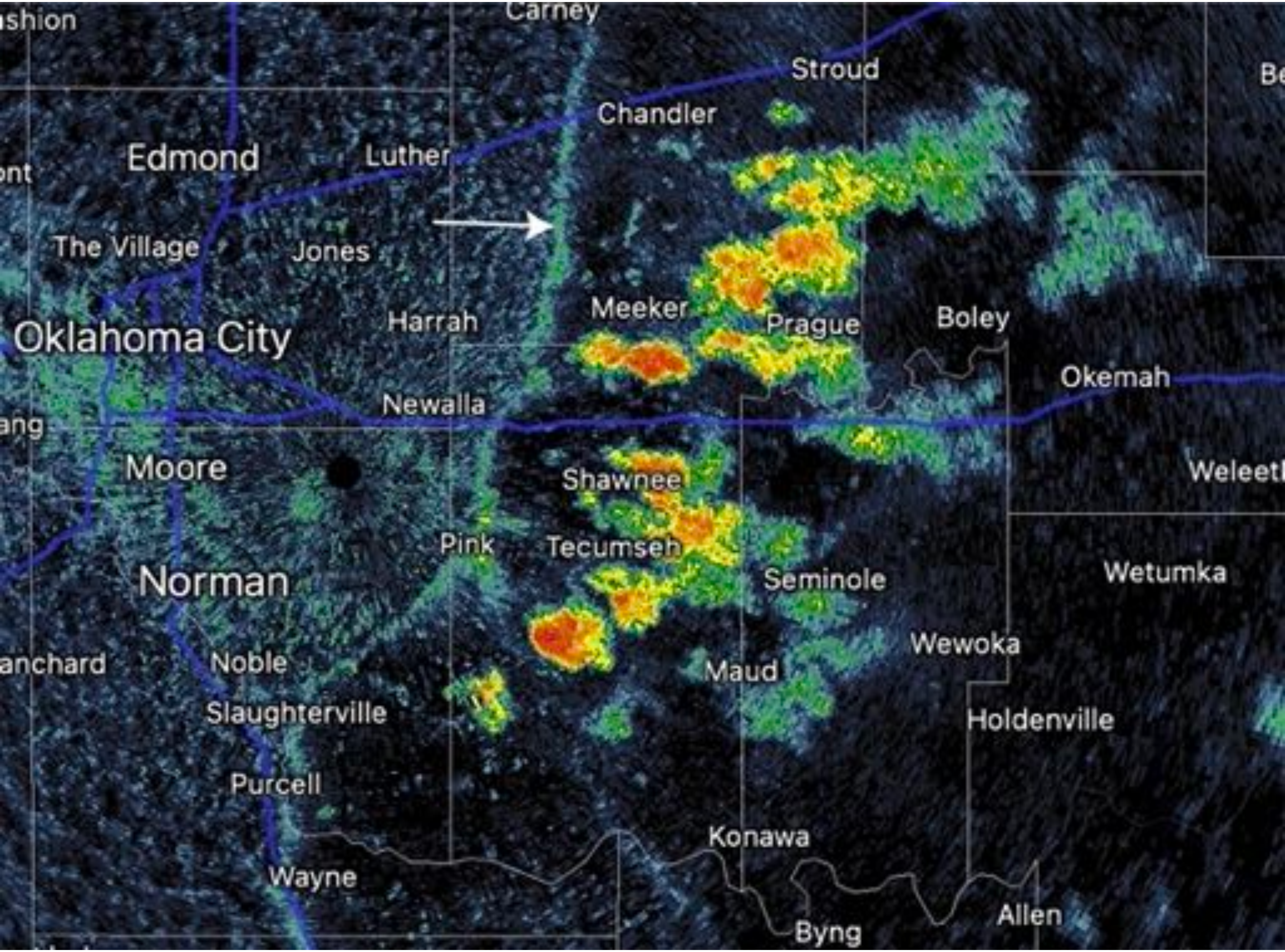

Carney
Stroud
Chandler
Edmond
Luther
The Village
Jones
Meeker
Harrah
Prague
Boley
Oklahoma City
Okemah
Newalla
Moore
Shawnee
Pink
Tecumseh
Wetumka
Norman
Seminole
Wewoka
Noble
Maud
Slaughterville
Holdenville
Purcell
Konawa
Wayne
Allen
Byng

TABLE 1. List of downdraft forcing mechanisms and corresponding radar signatures indicative of downdraft presence.

	Downdraft forcing mechanisms	Radar signatures	
	Evaporational cooling	Radial convergence below cloud base, particularly when Z_e decreases significantly towards the ground. Radial convergence above cloud base, particularly when associated with a Z_e notch and/or a very dry environmental layer.	
	Melting cooling	Radial convergence just below the 0°C level.	
	Precipitation drag	Radial convergence within a descending reflectivity core > 50 dBZ_e.	
X	Vertical pressure gradients	Azimuthal radial velocity couplet indicative of rotation, especially when vorticity increases with decreasing height.	TO BE DISCUSSED LATER

Roberts and Wilson 1989


31 May 1994 © H. Bluestein
• EVAPORATION OF PRECIPITATION DRIVES NEGATIVE BUOYANCY – DRY MICROBURST
•KICKING UP DUST – MICROBURST: DANGEROUS FOR LANDING AIRCRAFT

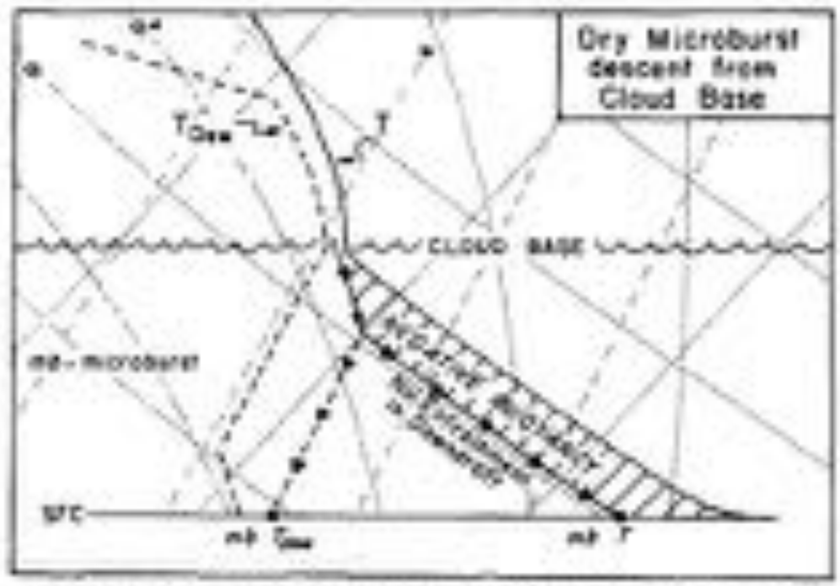
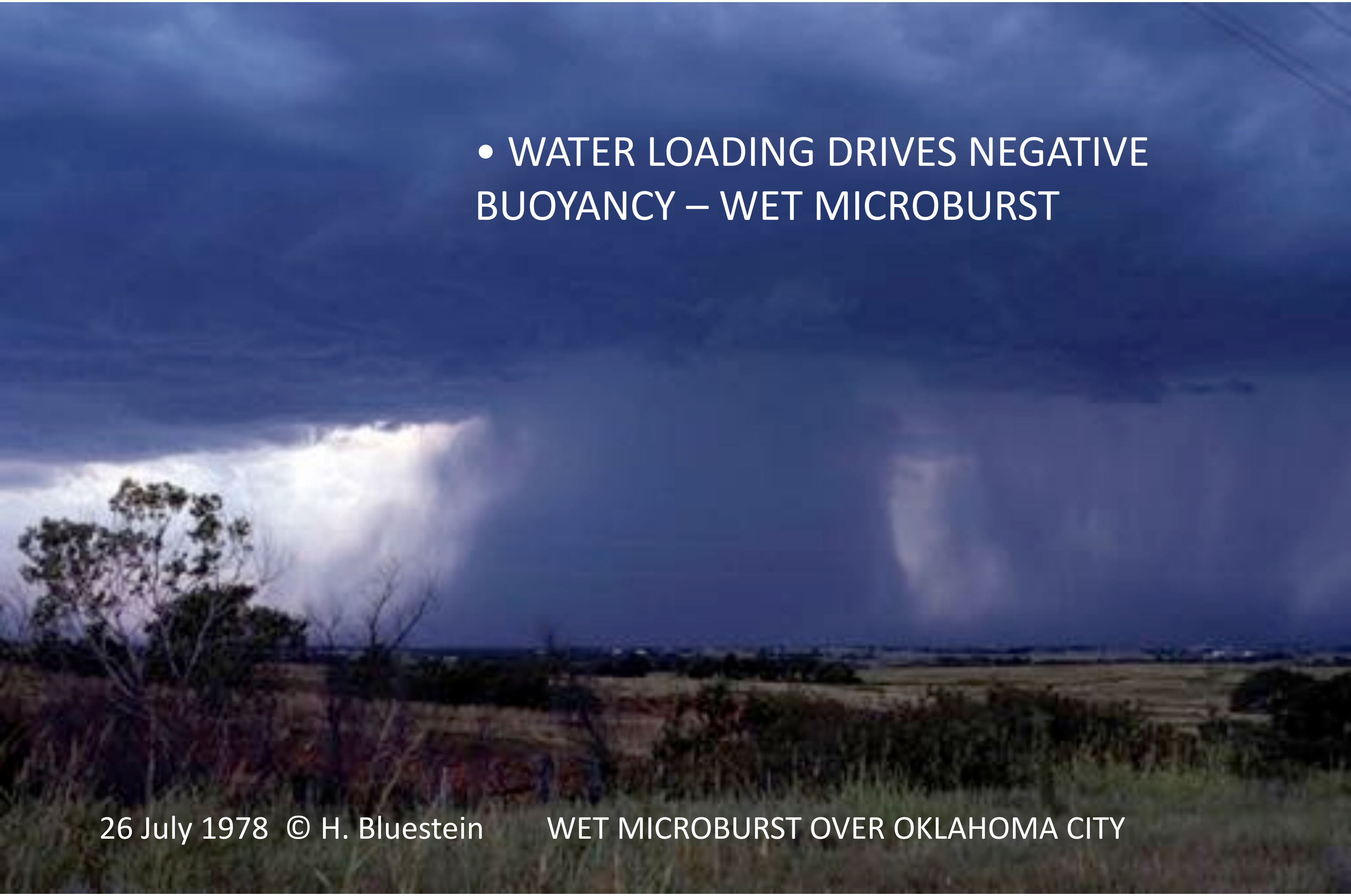


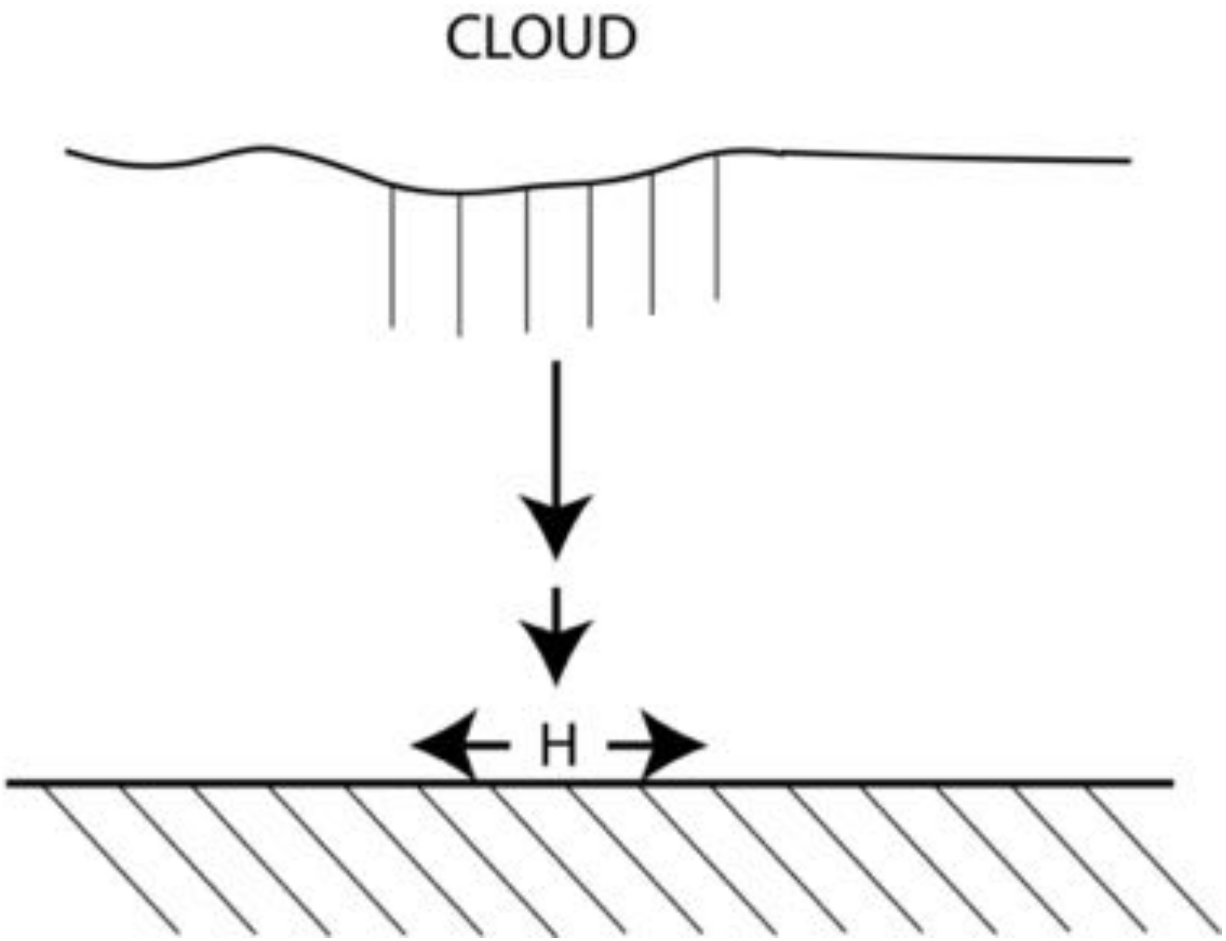
FIG. 10. Model of the thermodynamic descent of a dry microburst from cloud base. Surface temperature and dew-point temperature within the microburst are determined from PAM data. No entrainment into the downdraft is assumed.

Wakimoto 1985

AIR PARCEL FOLLOWS MOIST ADIABAT DOWN UNTIL ALL PRECIP. HAS EVAPORATED; THEN AIR PARCEL FOLLOWS DRY ADIABAT


• WATER LOADING DRIVES NEGATIVE BUOYANCY – WET MICROBURST
26 July 1978 © H. Bluestein
WET MICROBURST OVER OKLAHOMA CITY


27 Aug. 1993 © H. Bluestein


CLOUD
H

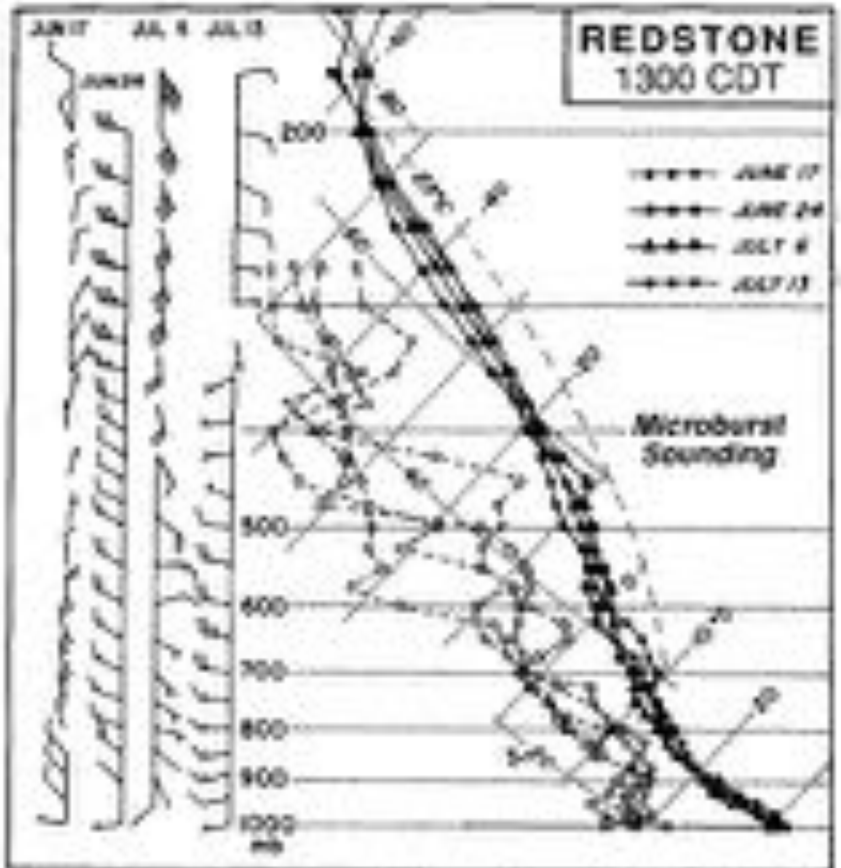


FIG. 8. Data from rawinsondes launched at 1300 CDT for 17, 24 June and 6, 13 July. As in Fig. 7, the soundings are centered on 17 June (unshifted). The other temperature profiles were shifted by: −0.5°C (24 June), −0.3°C (6 July), and −1.1°C (13 July). The moisture profiles were shifted by: −4.1°C (24 June), −2.0°C (6 July), and −3.4°C (13 July).

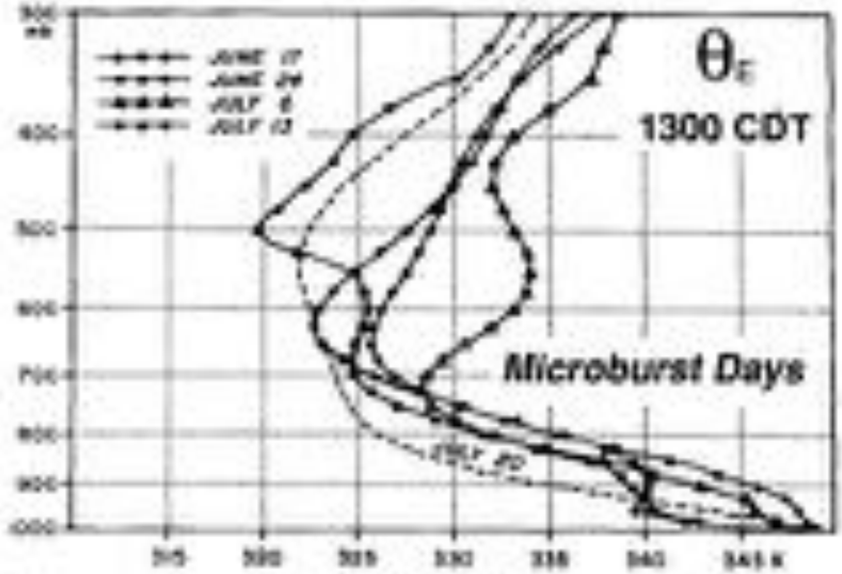


FIG. 10. Same as Fig. 9 but for 1300 CDT. The profiles have been shifted by: −6.0 K (24 June), 0.2 K (6 July), −3.2 K (13 July), and −8.6 K (20 July).

Atkins and Wakimoto 1991

WET MICROBURSTS

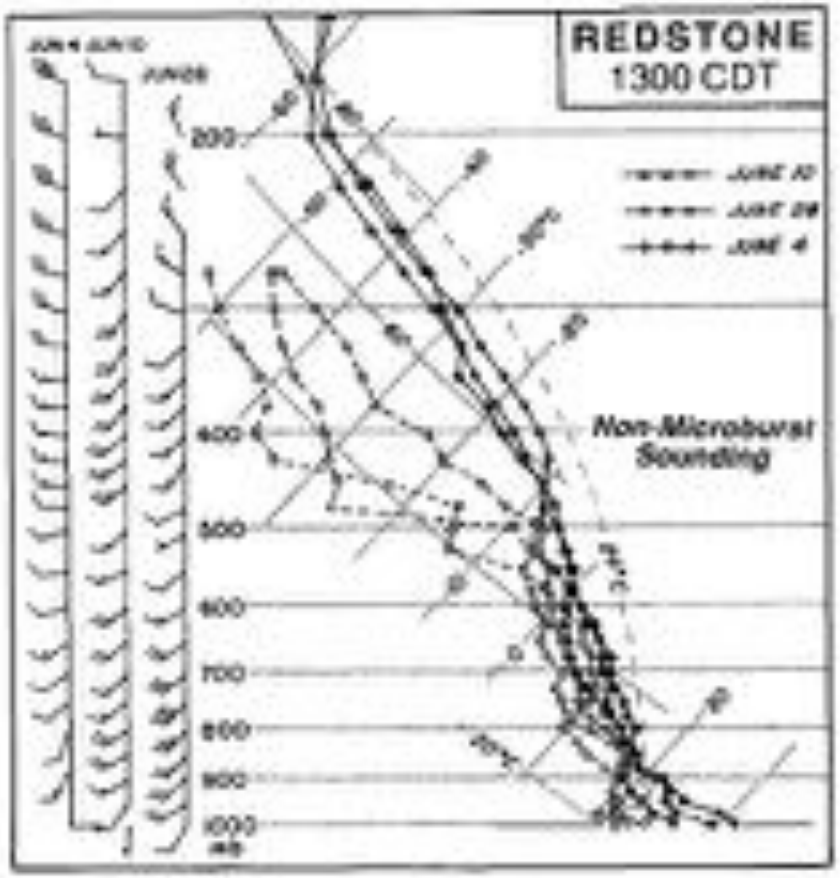


FIG. 13. Rawinsondes launched at 1300 CDT for the null days. The soundings are centered on 10 June (unshifted). The other temperature profiles have been shifted by: 3.2°C (4 June) and 0.2°C (28 June). The moisture profiles were shifted by: 3.0°C (4 June) and 2.1°C (28 June).

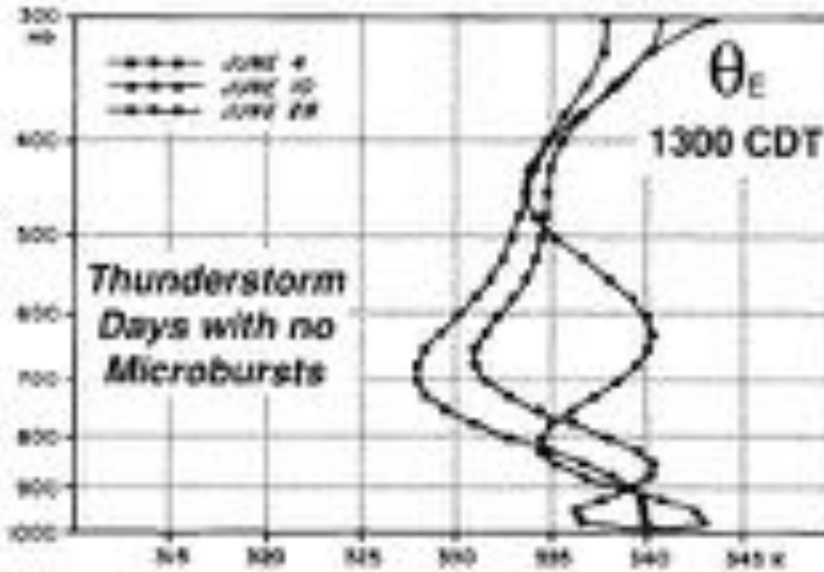


FIG. 15. Same as Fig. 14 but for 1300 CDT (including 4 June). The profiles have been shifted by: 3.4 K (4 June) and −5.6 K (10 June).

Atkins and Wakimoto 1991

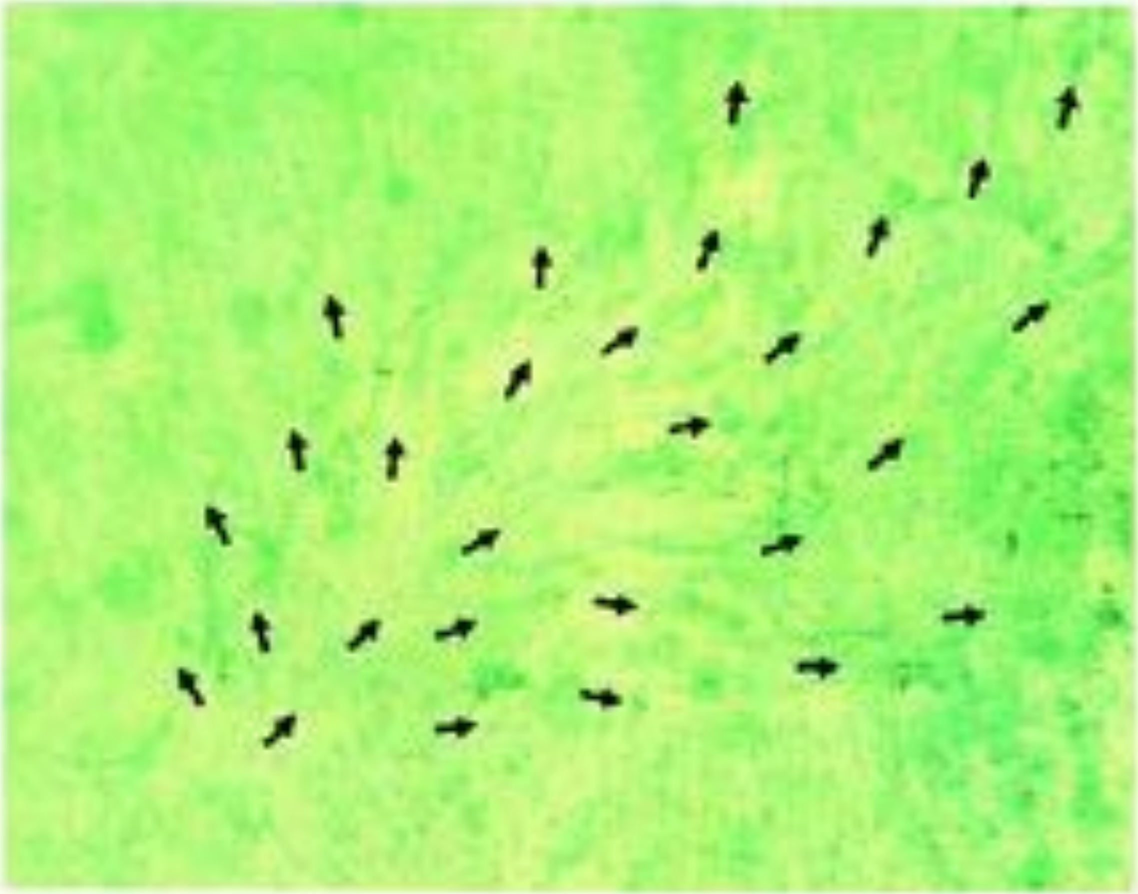


FIG. 1. Starburst pattern of uprooted trees associated with a downburst photographed by Fujita near Beckley, WV, following the superoutbreak of tornadoes on 3–4 Apr 1978. It was such damage patterns that gave Fujita the ideas for the existence of downbursts. [From Fujita (1985).]

"STARBURST PATTERN" OF GROUND DAMAGE

• DUAL-DOPPLER ANALYSIS OF A MICROBURST AT THE GROUND

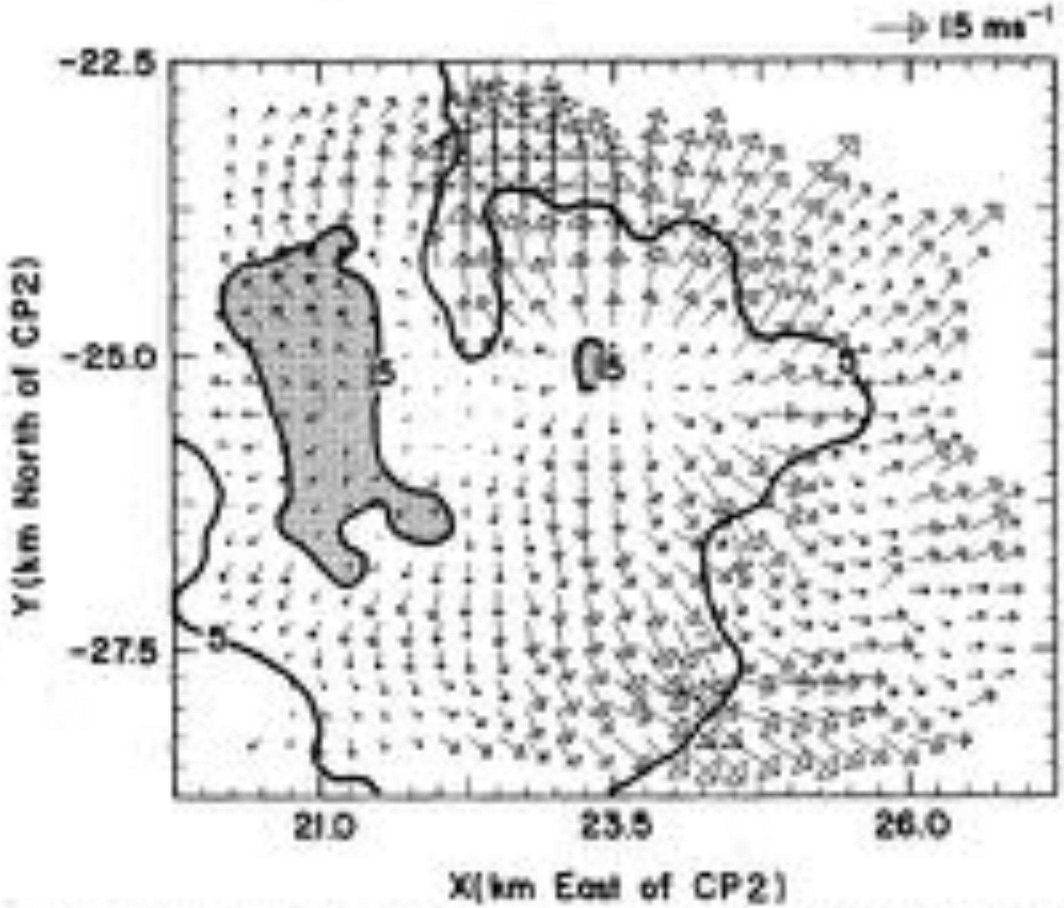


FIG. 2. Horizontal winds and reflectivity contours at lowest-level analysis (~50 m) for microburst A at 1445 MDT on 14 July 1982. Wind arrows are scaled as shown in upper right. Reflectivity contours in dBZ as shown.

Hjelmfelt 1988 ISOLATED MICROBURST

- POLARIMETRIC RADAR SIGNATURE OF MICROBURST

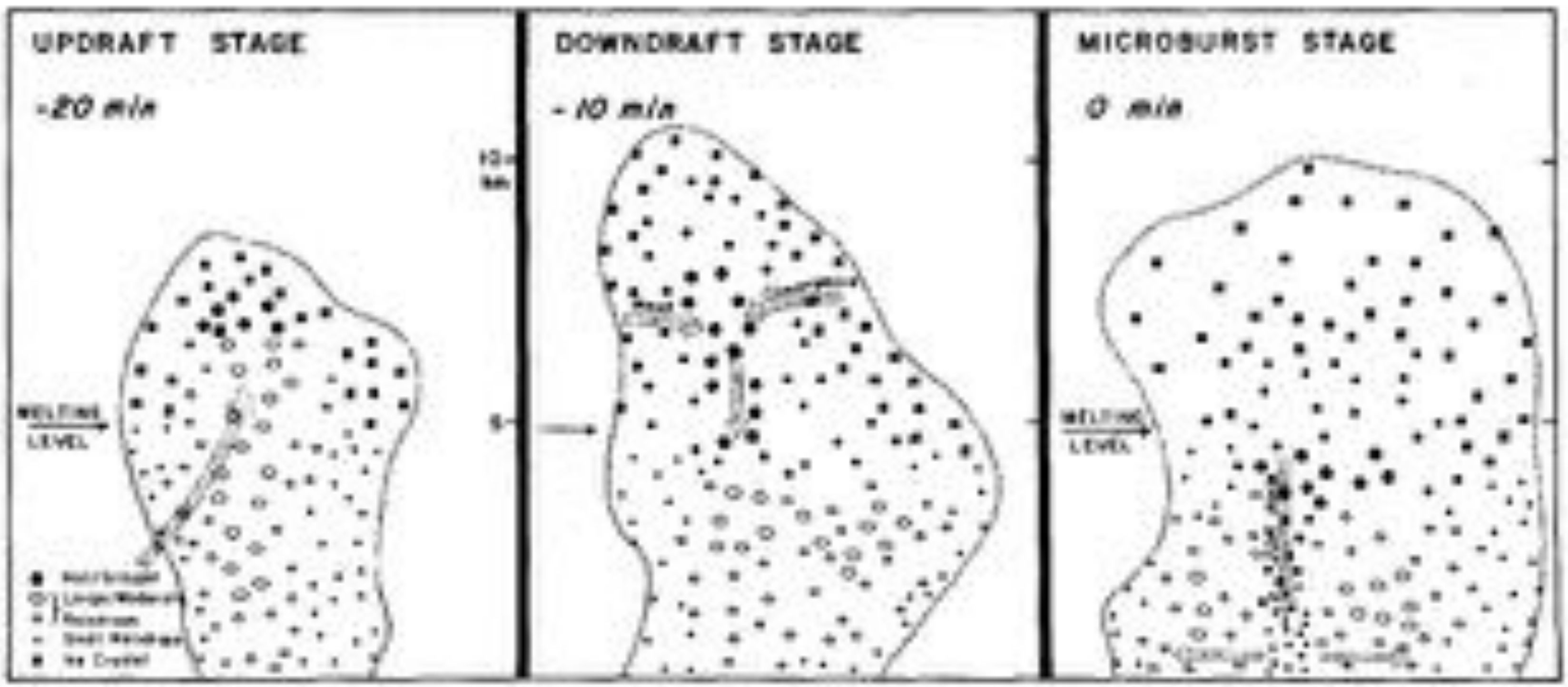
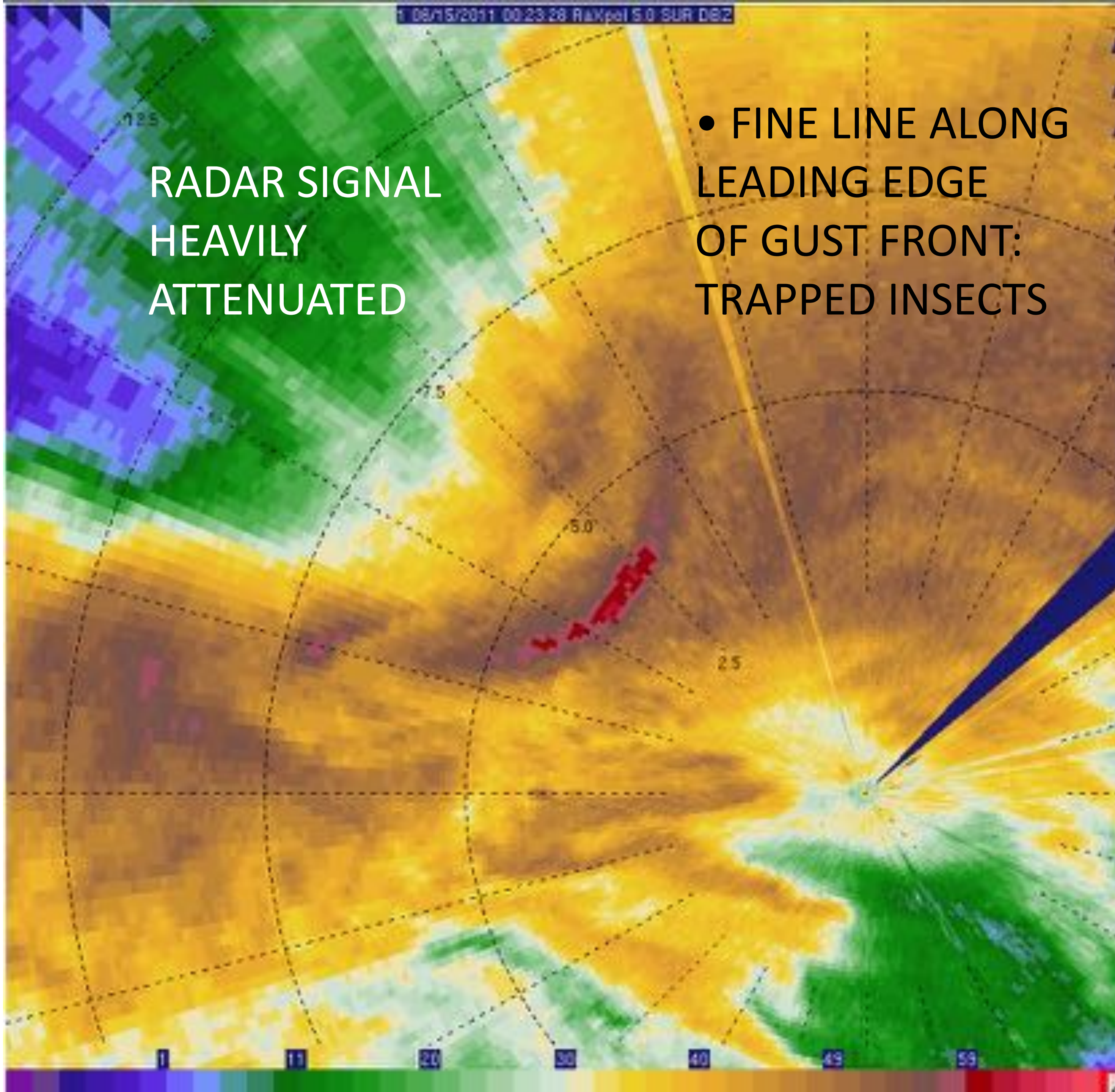


FIG. 11. Schematic model of the microphysical evolution of the 20 July storm.

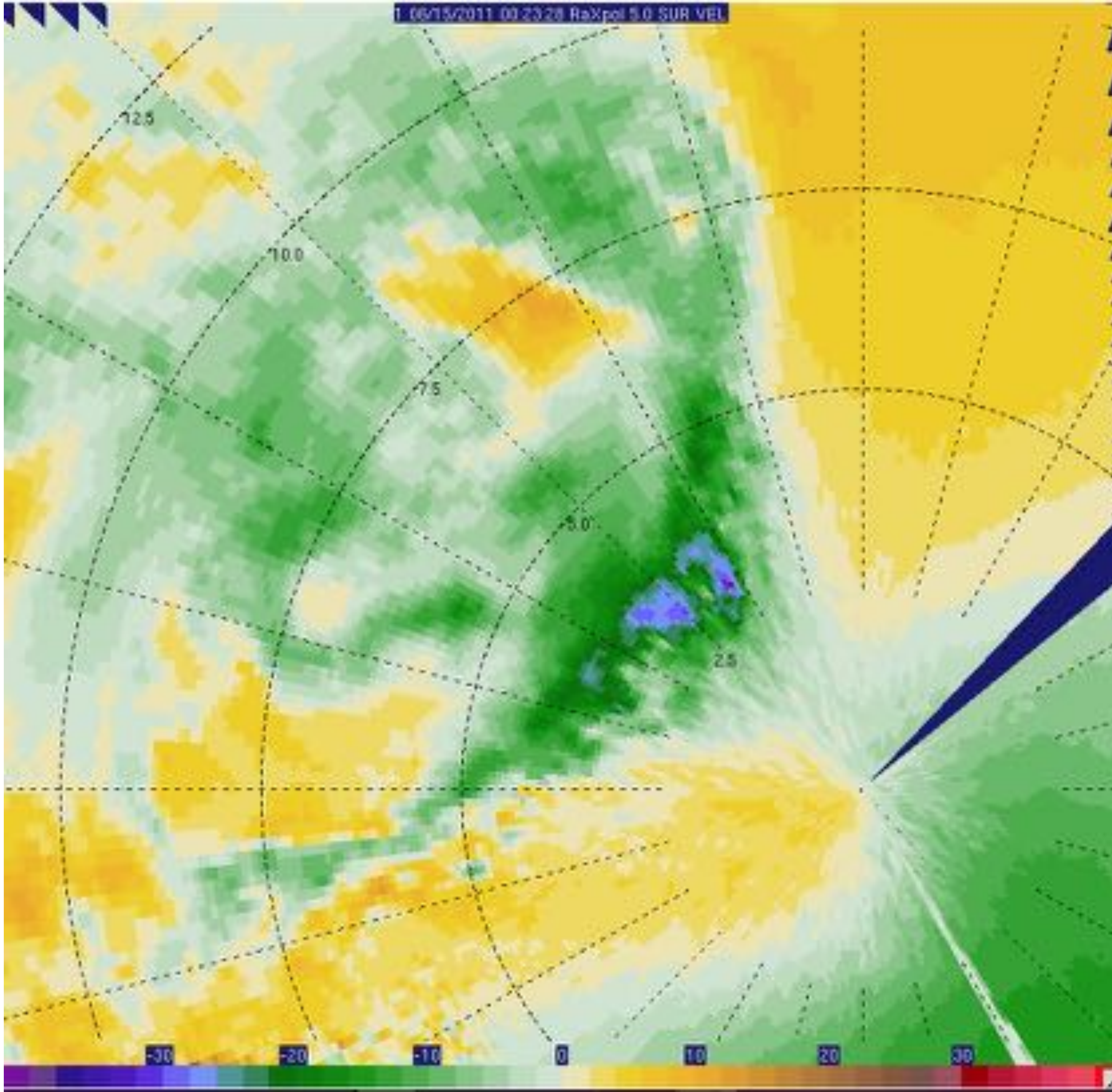
Wakimoto and Bringi 1988 Z_{DR} HOLE

14 June 2011
RaXPol

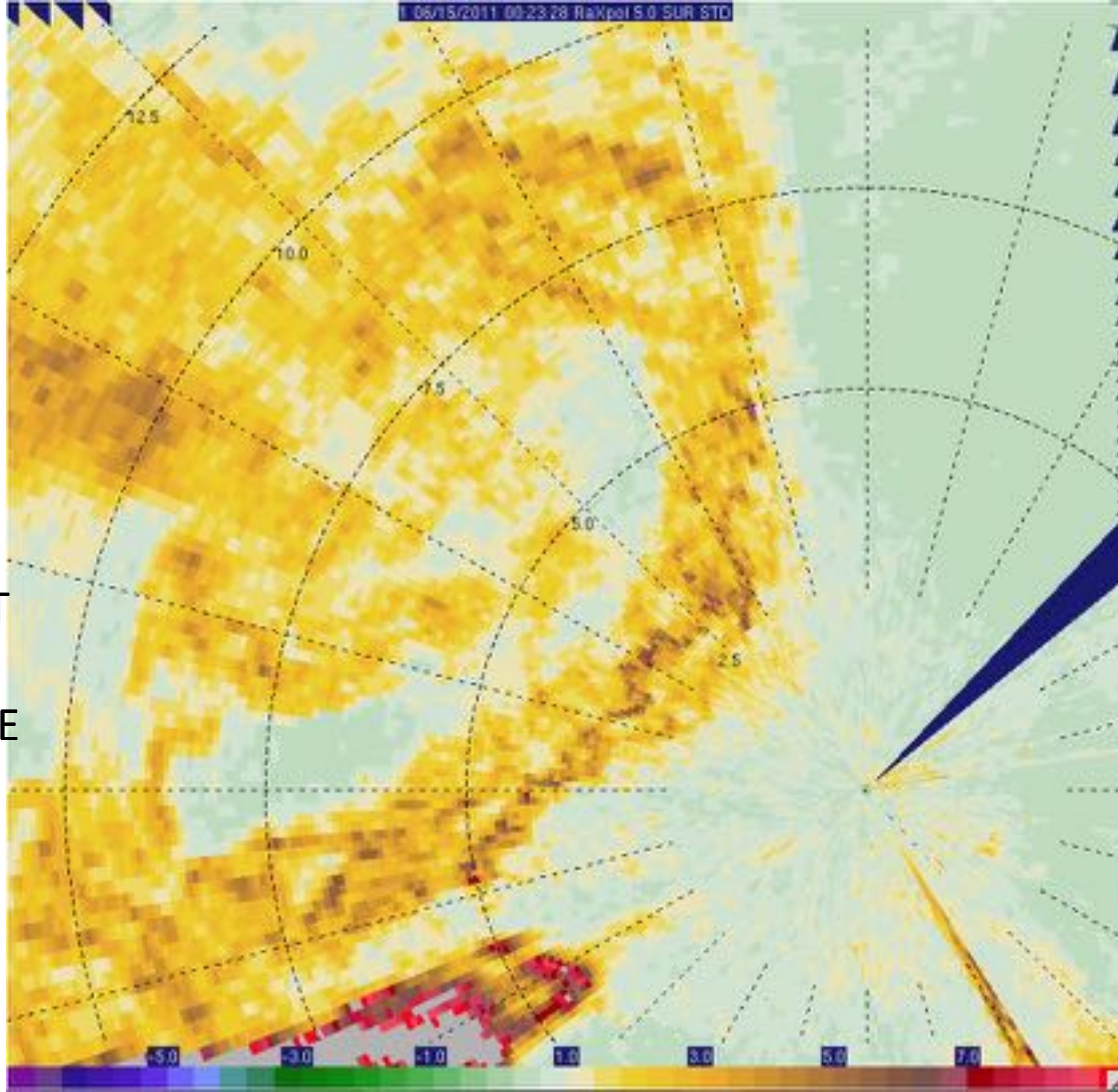
- Damaging microburst in Norman, OK



• DOPPLER VELOCITY SHOWING BOWING EDGE OF GUST FRONT

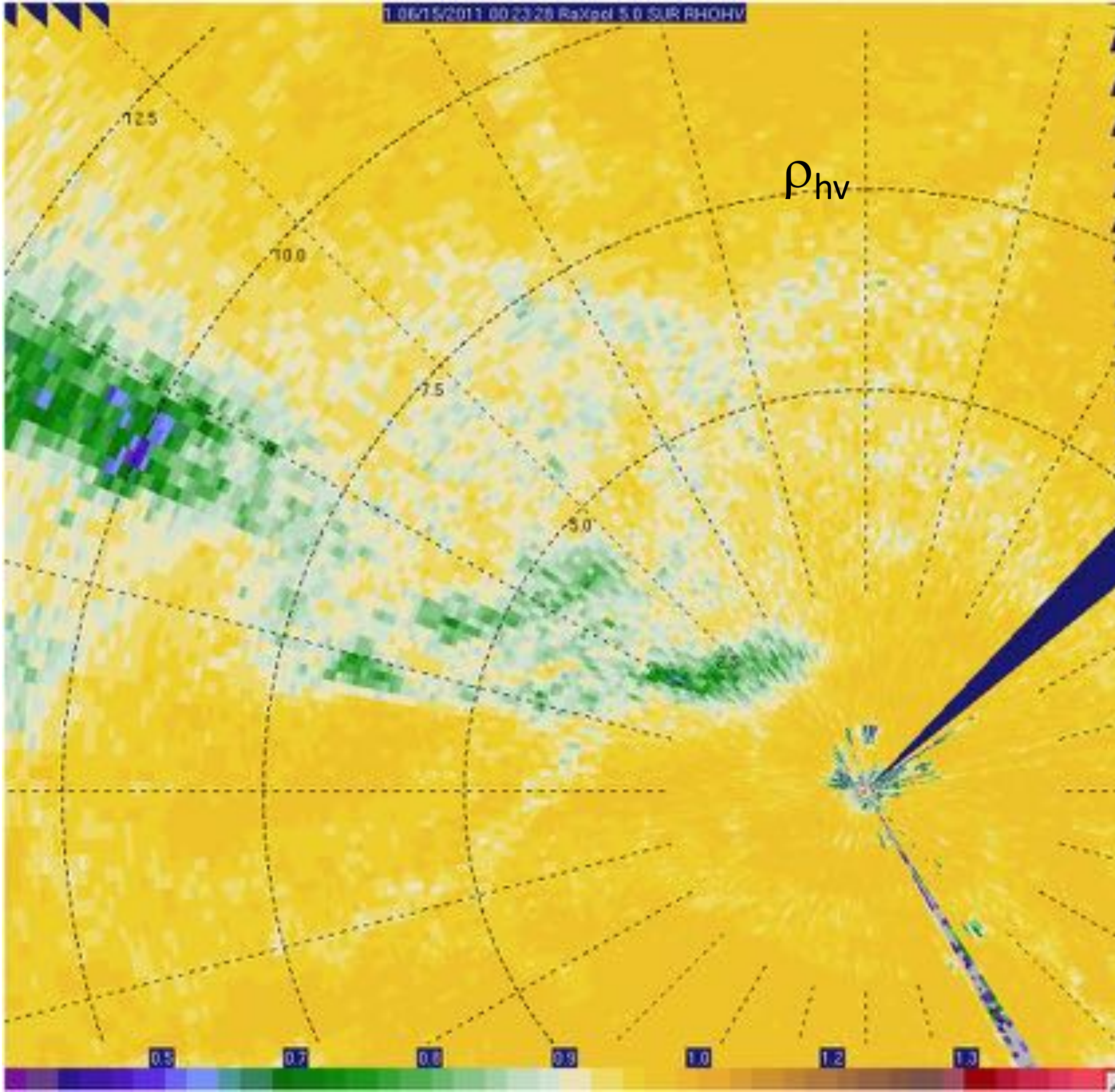


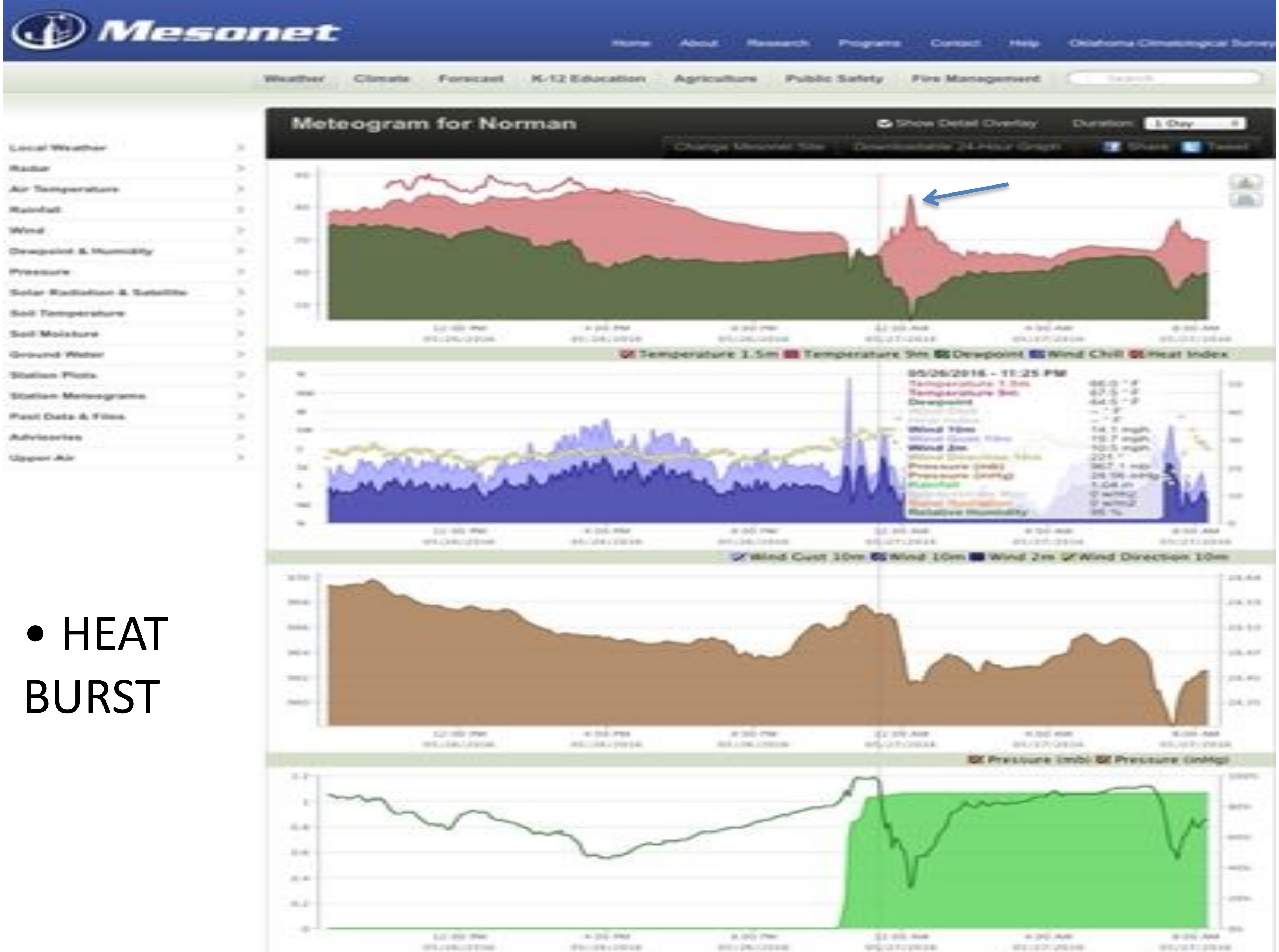
- HIGH SPECTRUM WIDTH ALONG LEADING EDGE OF GUST FRONT
  - STRONG TURBULENCE



- LOW ρ_{hv}

DUST, HAIL
(IF Z HIGH)




Mesonet
Home About Research Programs Contact Help Oklahoma Climatological Survey
Weather Climate Forecast K-12 Education Agriculture Public Safety Fire Management
Meteogram for Norman
Temperature 1.5m Temperature 9m Dewpoint Wind Chill Heat Index
Wind Gust 10m Wind 10m Wind 2m Wind Direction 10m
Pressure (mb) Pressure (inHg)

- HEAT BURST

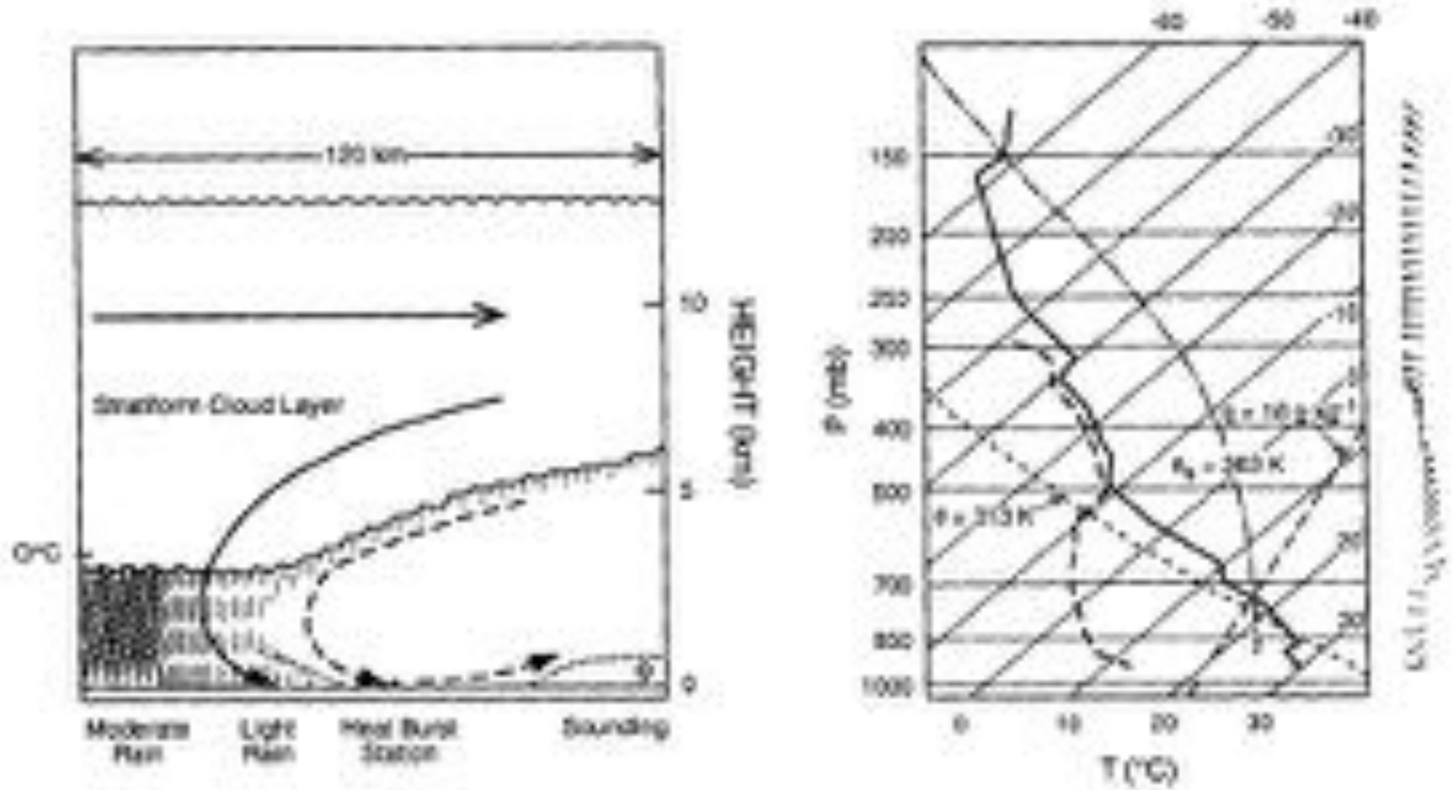
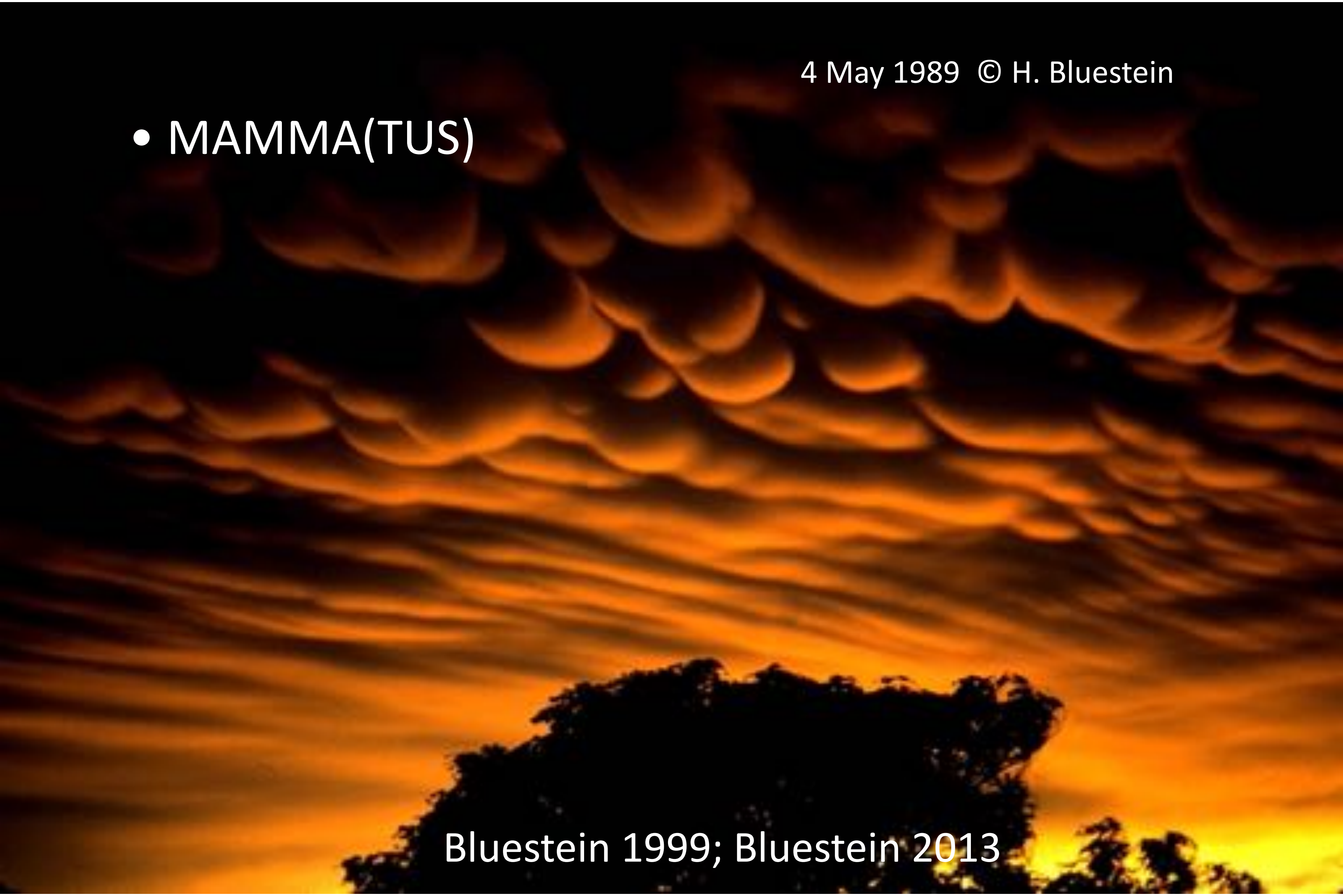
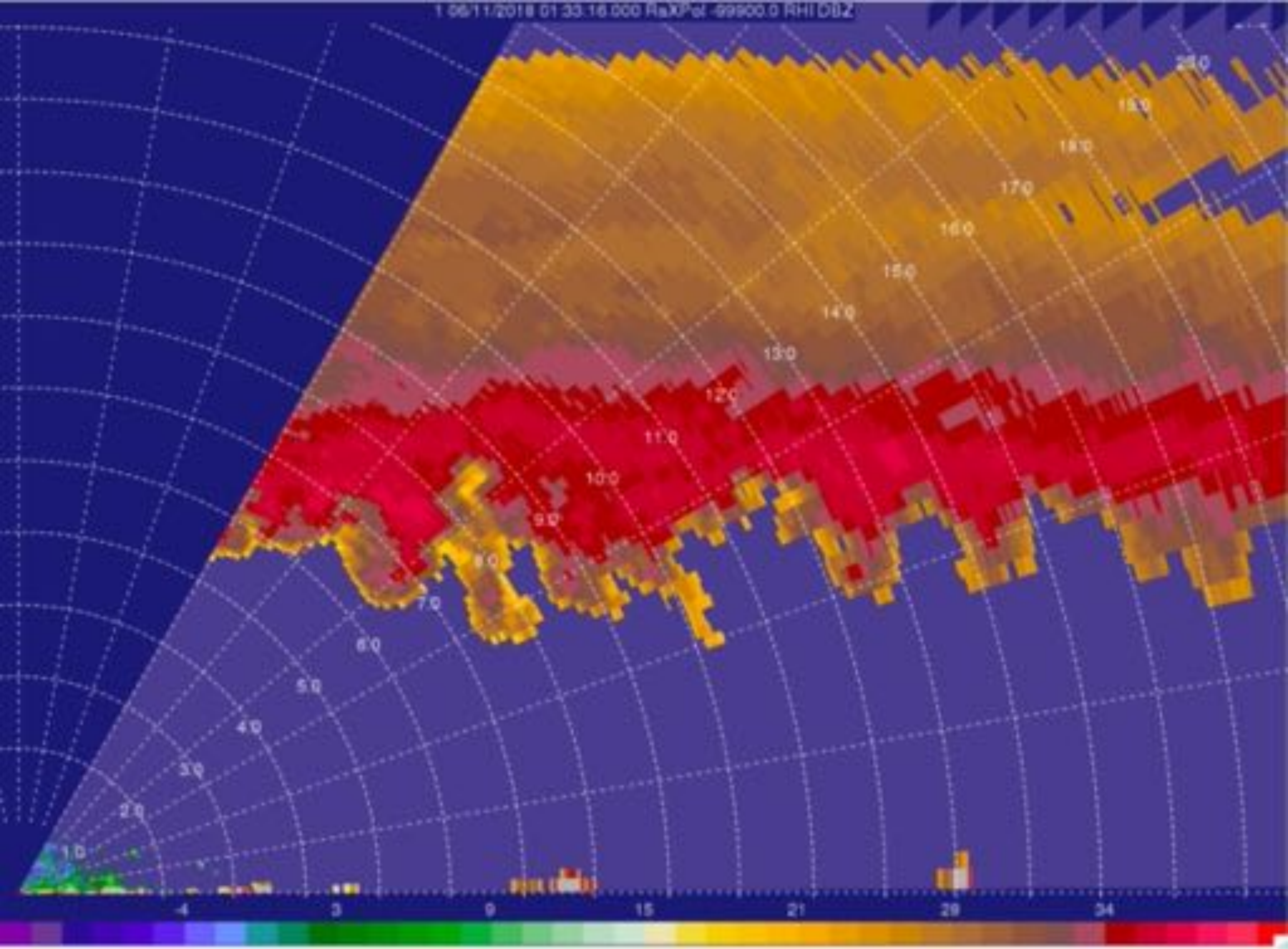


FIG. 16. Conceptual model of a heat burst as a deformation of a shallow, cool, moist stable layer at the surface by a descending circulation of warm, dry air from aloft. Solid arrows represent winds verified by dual-Doppler data. The dashed arrow represents proposed heat burst wind. Dotted lines represent the upper boundary of the moist stable layer. Heat burst conceptual sounding adapted from the 0440 UTC RSL sounding. The locations of the sounding and surface station are denoted.

Bernstein and Johnson 1994


4 May 1989 © H. Bluestein
• MAMMA(TUS)
Bluestein 1999; Bluestein 2013


26 May 1997
© H. Bluestein


1 06/11/2018 01:33:16.000 RaXPol -99900.0 RHI DBZ
1.0
2.0
3.0
4.0
5.0
6.0
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8.0
9.0
10.0
11.0
12.0
13.0
14.0
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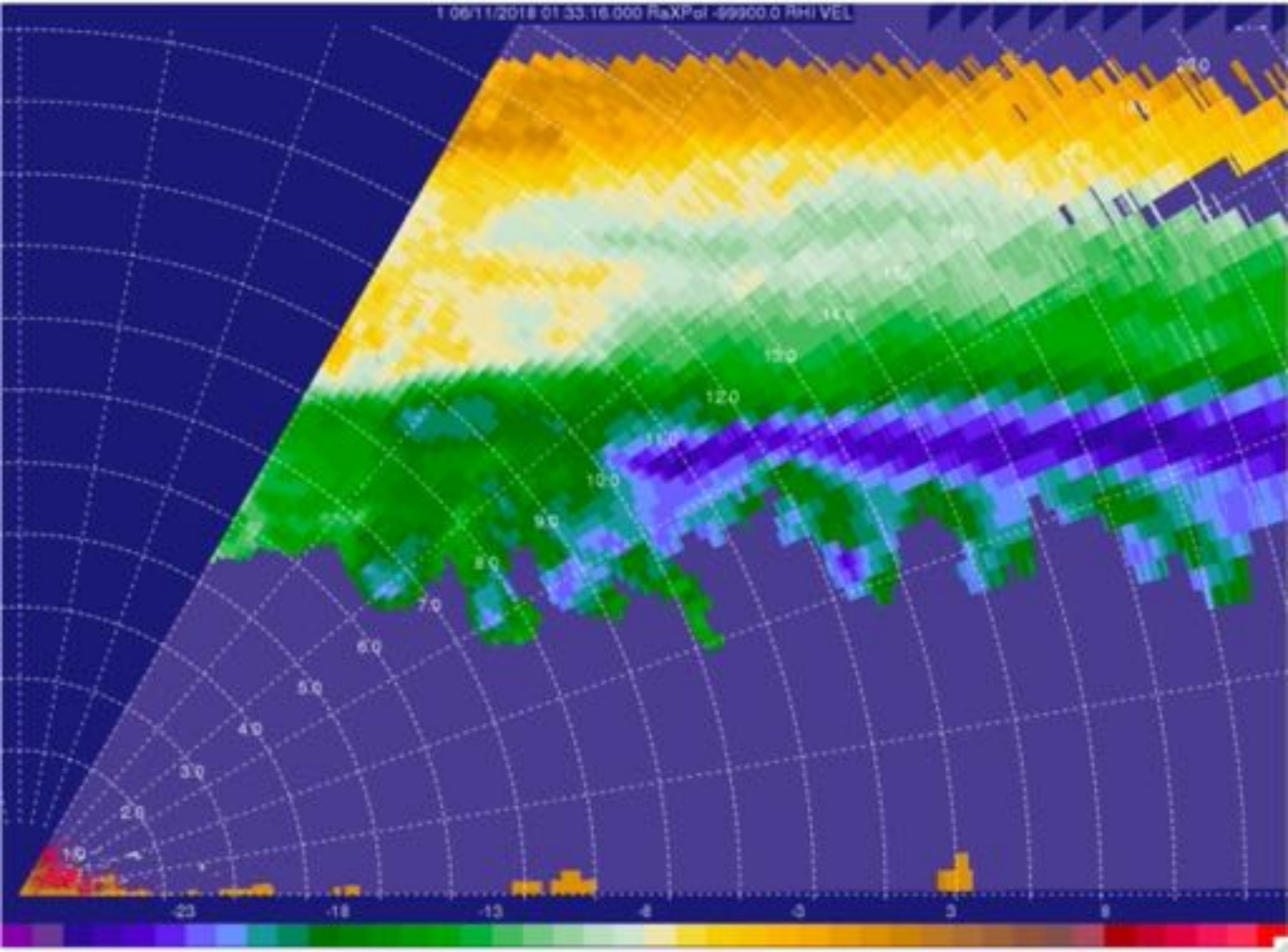
-4
3
9
15
21
28
34


1 06/11/2018 01:33:16.000 RaXPol -99900.0 RHI VEL
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
-23
-18
-13
-8
-3
3
9

FLIGHT THROUGH MAMMA

Martner 1995

- Z HIGH WHEN DOPPLER VELOCITY (DOWNDRAFTS) W < 0

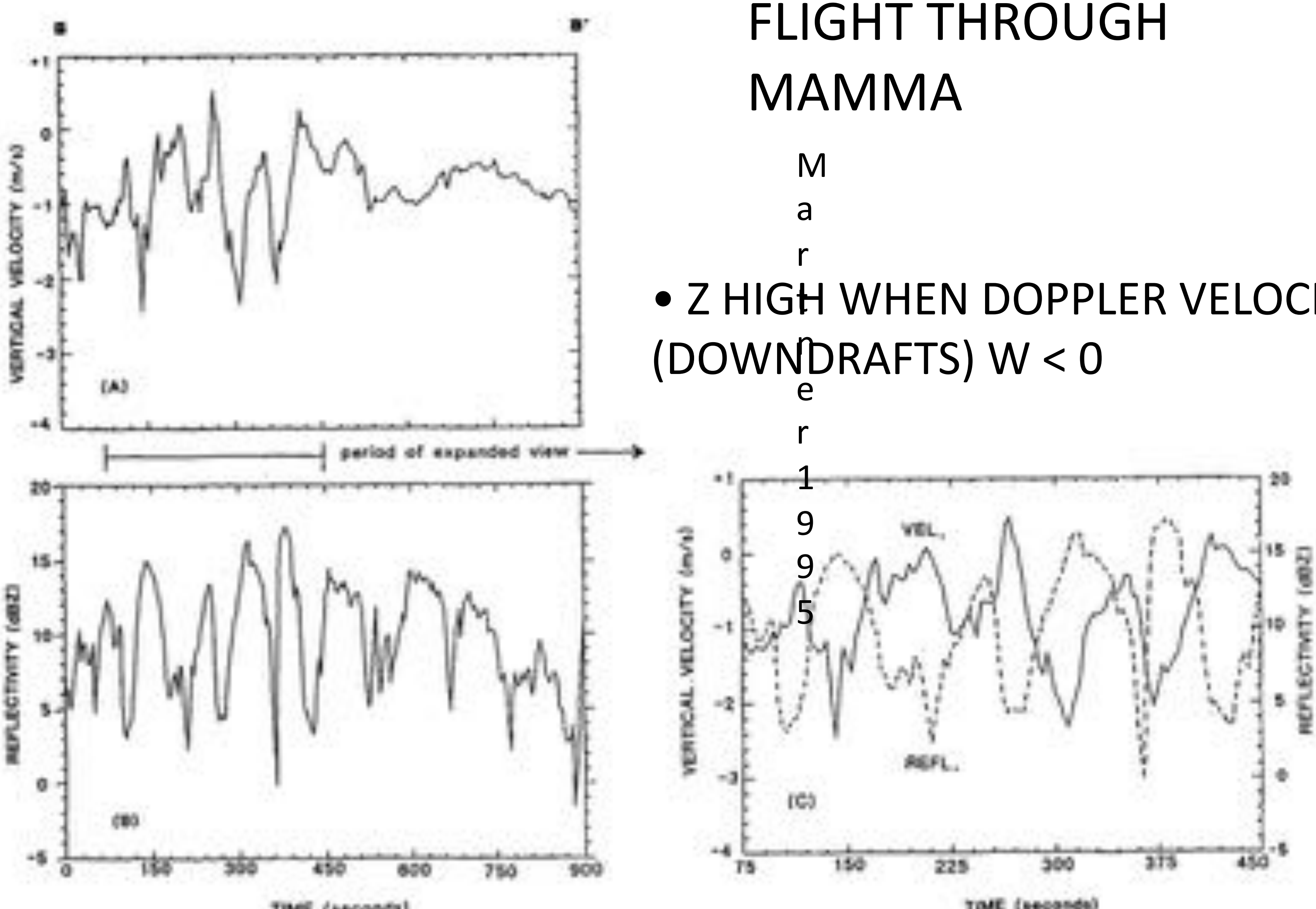


FIG. 4. Time series of data along the BB' cross section near the bottom of the mammatus elements, including (a) vertical velocity, (b) reflectivity, and (c) an expanded view of both.

W

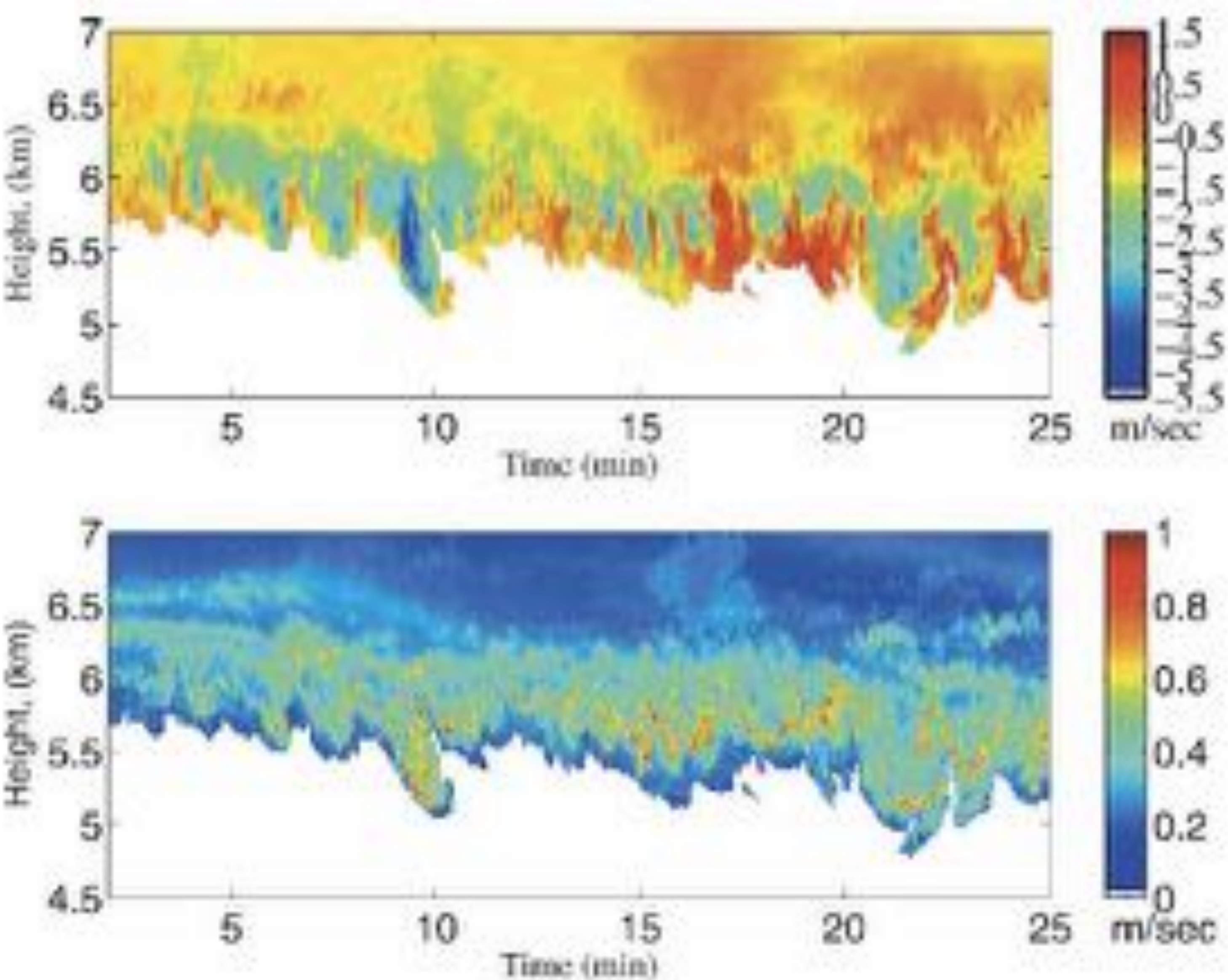


FIG. 2. High-resolution observations of (top) mammatus mean Doppler velocity and (bottom) Doppler spectrum width from the UMDCR.

Kollias et al. 2005

Kanak et al. 2008

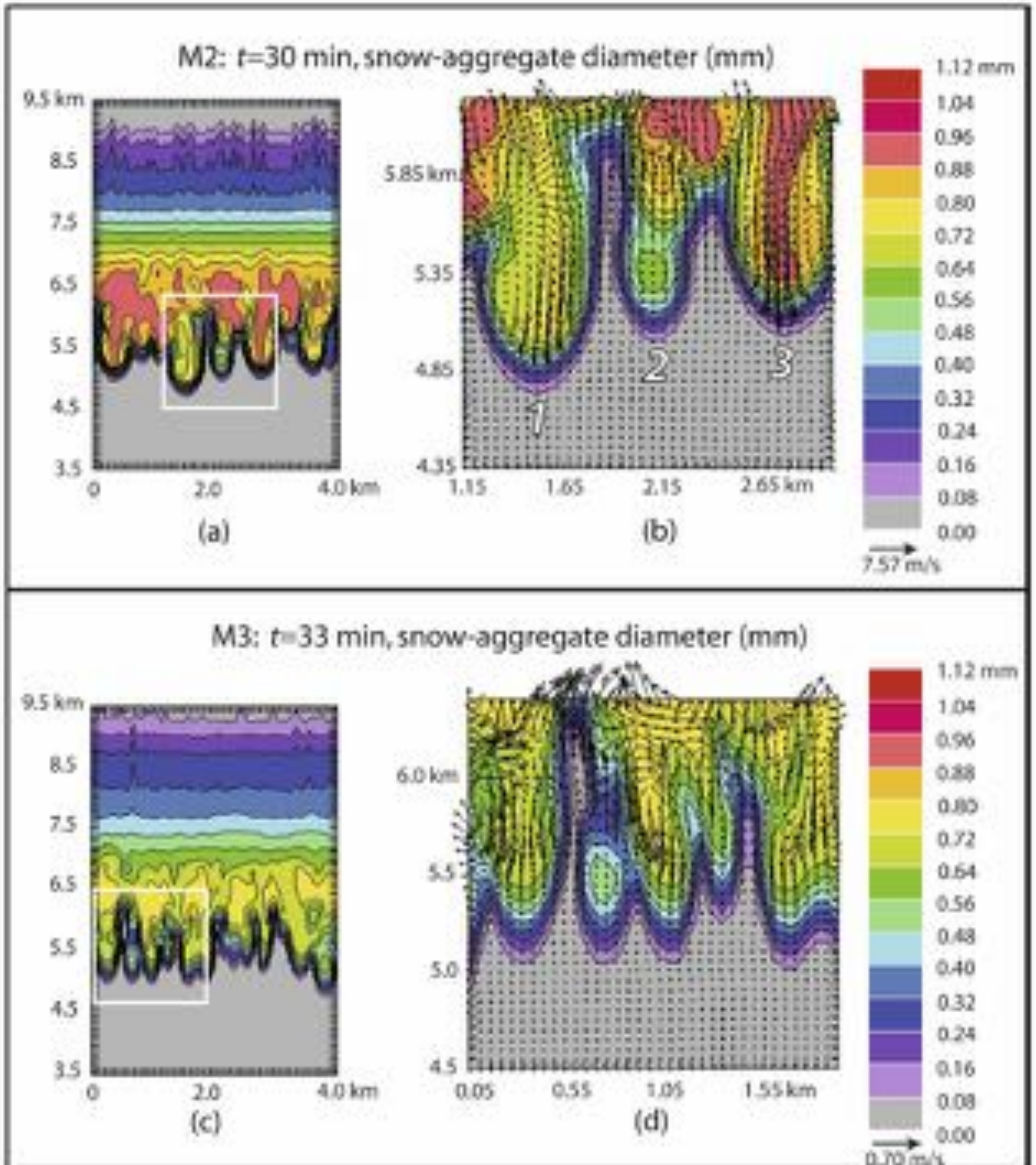
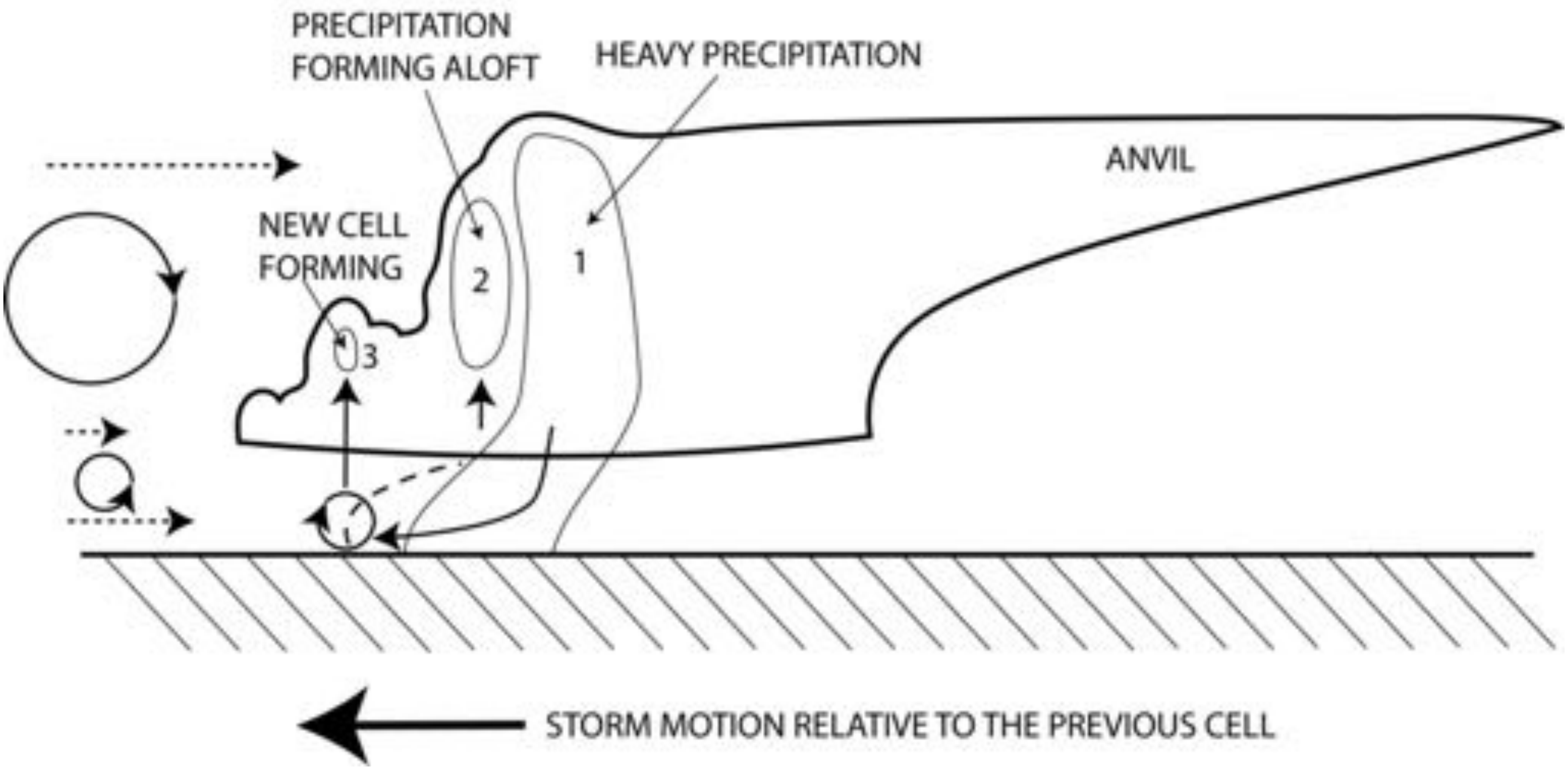
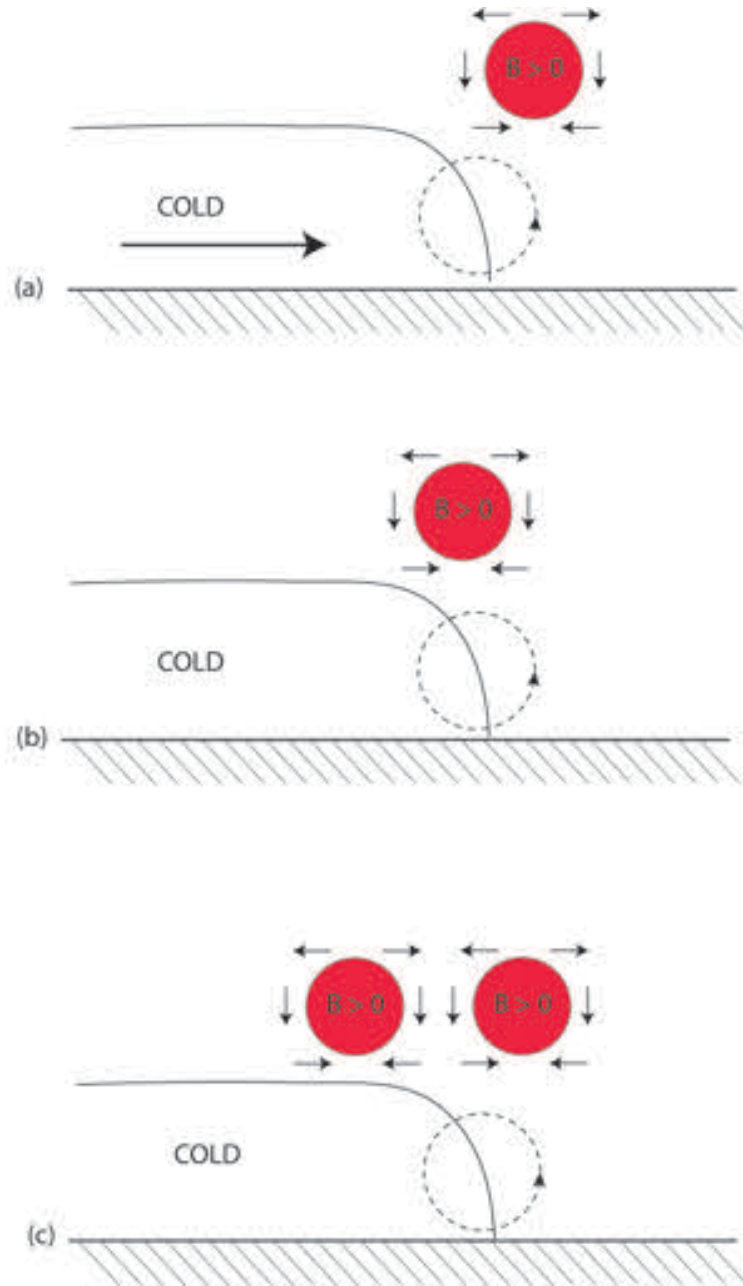


FIG. 3. Vertical cross sections of snow aggregate diameter (mm, color contours). (a) M2: whole domain at $t = 30$ min and $y = 75$ m. (b) M2: inset with velocity vectors. White box in (a) indicates inset in (b). The longest vector corresponds to a wind speed of 7.57 m s^{-1}. Large white numbers represent individual mammatus lobes described in text. (c) M3: whole domain at $t = 33$ min and $y = 1625$ m. (d) M3: inset with velocity vectors. White box in (c) indicates inset in (d). The longest vector corresponds to a wind speed of 0.70 m s^{-1}.

ANATOMY OF A MULTICELL CONVECTIVE STORM




B > 0
COLD
(a)
B > 0
COLD
(b)
B > 0
B > 0
COLD
(c)

SUMMARY:

- BUOYANCY – UPDRAFTS AND DOWNDRAFTS
- GUST FRONTS – DOWNDRAFTS HIT THE GROUND
- ORDINARY-CELL CONVECTIVE STORMS – UPDRAFT, FOLLOWED BY DOWNDRAFT WHERE UPDRAFT USED TO BE: "THAT'S ALL FOLKS!"

UPDRAFTS GONE WILD: LARGE HAIL
GUST FRONTS GONE WILD: MICROBURSTS
DOWNDRAFTS GONE EXOTIC: HEAT BURSTS
DOWNDRAFTS ALOFT GONE EXOTIC: MAMMA

NEXT: GUST FRONTS AND BUOYANCY GONE WILD!
VERTICAL SHEAR ADDED…