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Session II. Hazard Characterization

A "Numerical Field Experiment" Approach for Determining Probabilities of Microburst Intensity

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A "NUMERICAL FIELD EXPERIMENT" APPROACH FOR DETERMINING PROBABILITIES OF MICROBURST INTENSITY

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AND

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HONEYWELL, INC.

OVERVIEW

- SEVERAL INVESTIGATORS HAD DETERMINED THAT SOME ATMOSPHERIC PARAMETERS WERE RELATED TO THE FORMATION AND SEVERITY OF MICROBURSTS.

- FOR EXAMPLE, CARACENA POINTED OUT THE RELATIONSHIP BETWEEN A DRY ADIABATIC LAPSE RATE AND MICROBURSTS IN "THE CRASH OF DELTA FLIGHT 191 AT DALLAS-FORT WORTH INTERNATIONAL AIRPORT".

- THESE EARLY INVESTIGATIONS LED TO THE IDEA THAT NUMERIC MODELING OF MICROBURSTS WITH VARYING ATMOSPHERIC PARAMETERS MIGHT DEFINE "SIGNATURES" THAT COULD LEAD TO DETERMINING THE PROBABILITY OF MICROBURST INTENSITY.

- THE IDEA WAS THAT, BY USING ALREADY AVAILABLE SENSORS (SUCH AS STATIC AIR TEMPERATURE, PRESSURE ALTITUDE, RADAR REFLECTIVITY) ONBOARD AN AIRCRAFT, A RELIABLE PREDICTION OF MICROBURST EXISTENCE AND INTENSITY COULD BE FORMED.

- SUCH DATA COULD BE USED TO CREATE AN "EXPERT METEOROLOGIST" USING EITHER AI OR OTHER TECHNIQUES THAT COULD BE USED IN EITHER REACTIVE OR LOOK-AHEAD SYSTEMS TO VARY SENSITIVITY THRESHOLDS AND COORDINATE THE INPUTS FROM DIFFERENT DETECTING SYSTEMS.

OVERVIEW

- TO THIS END, HONEYWELL CONTRACTED WITH DR. KELVIN DROEGEMEIER AND THE UNIVERSITY OF OKLAHOMA IN 1990 TO RUN THE MICROBURST SIMULATIONS.

- THE QUESTIONS TO BE ADDRESSED WERE:

  USING THE SENSOR SET AVAILABLE TO THE AIRCRAFT (E.G. TEMPERATURE, RADAR REFLECTIVITY, ETC.), CAN WE CALCULATE THE PROBABILITY THAT

  (1) A MICROBURST COULD BE FORMED?

  (2) THE RESULTANT WINDS WOULD BE OF SUFFICIENT MAGNITUDE TO THREATEN THE AIRCRAFT?

- OVER A TWO YEAR PERIOD, A DATA SET OF 1800 MICROBURST SIMULATIONS WAS ACCUMULATED.

- VERIFICATION OF THE MICROBURST SIMULATION WAS OBTAINED USING THE RESULTS OF OTHER INDEPENDENT RESEARCHERS AND ACTUAL COMPARISON TO MICROBURST EVENTS IN ORLANDO AND DENVER.

- SOME OF THE RESULTS FROM THE SIMULATION HAVE ALREADY BEEN INCORPORATED INTO HONEYWELL'S WINDSHEAR DETECTION AND GUIDANCE SYSTEM WITH EXCELLENT RESULTS.

The *Numerical Field Experiment* Methodology

Use a Numerical Model to Simulate a Large Population of Physically Plausiable Scenarios Similar to What Might be Anticipated During a Field Observing Program

Goals of Study

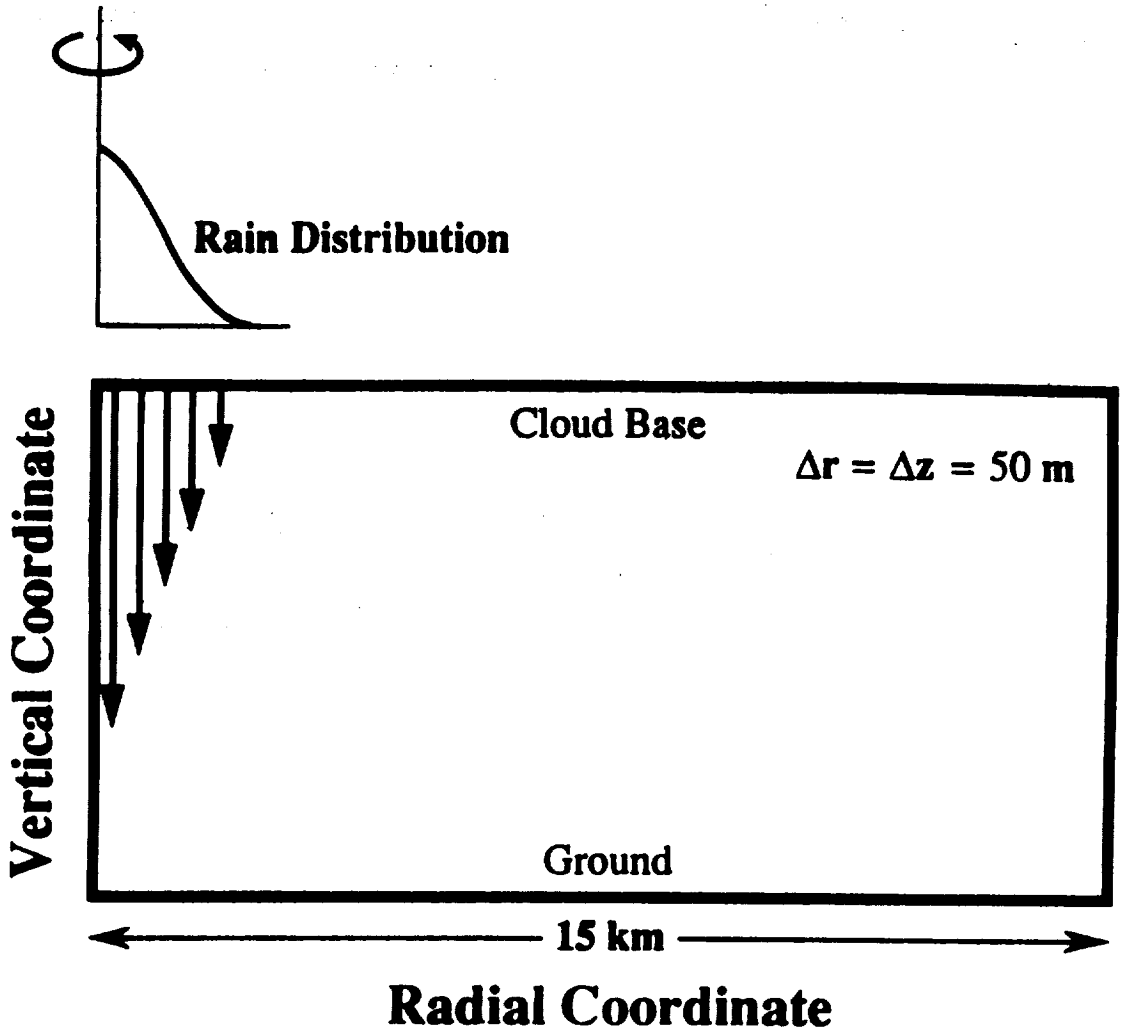
- Better understand how various physical parameters interact to determine microburst intensity

- Determine probabilities of microburst occurrence under a variety of conditions

- Validate results against observations

Experiment Design

- Axisymmetric Numerical Cloud Model
- Warm Rain Microphysics
- No Ambient Wind
- Zero Ambient Humidity
- Simulate Only the Sub-Cloud Region
- Continuous Influx of Rainwater at Model Top (Cloud Base)



Rain Distribution
Cloud Base
$\Delta r = \Delta z = 50$ m
Vertical Coordinate
Ground
15 km
Radial Coordinate

Parameter Space

Cloud Base Height (0.5, 1, 2, 3, 4 km AGL)

Sub-Cloud Lapse Rate (70, 80, 90, 100% D.A.)

Surface Temperature (55, 65, 75, 85, 95, 105 F)

Cloud Base Reflectivity (20, 30, 40, 50, 60 dBz)

Rainshaft Radius (0.5, 1.0, 2.0 km)

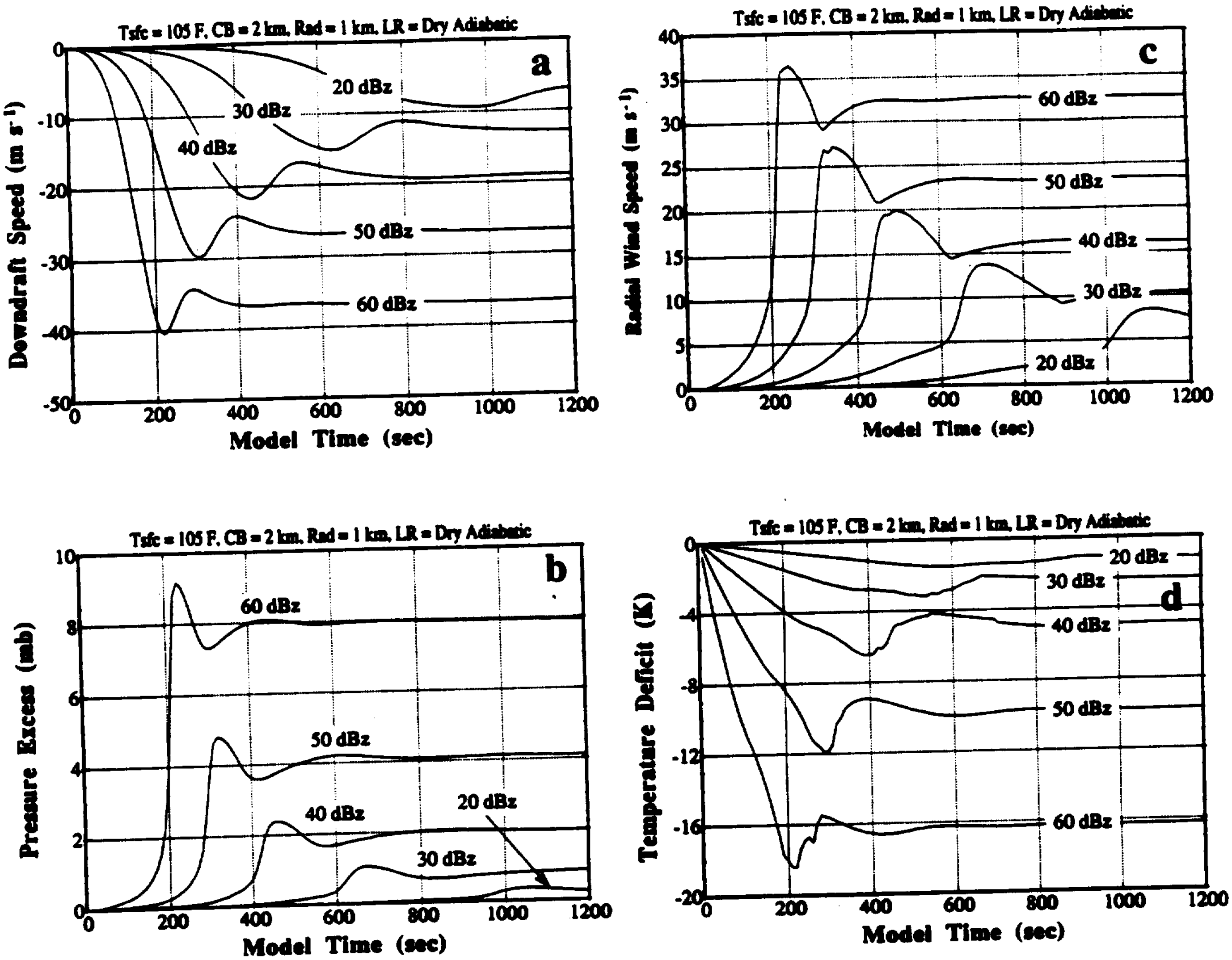
All Combinations → 1800 Simulations

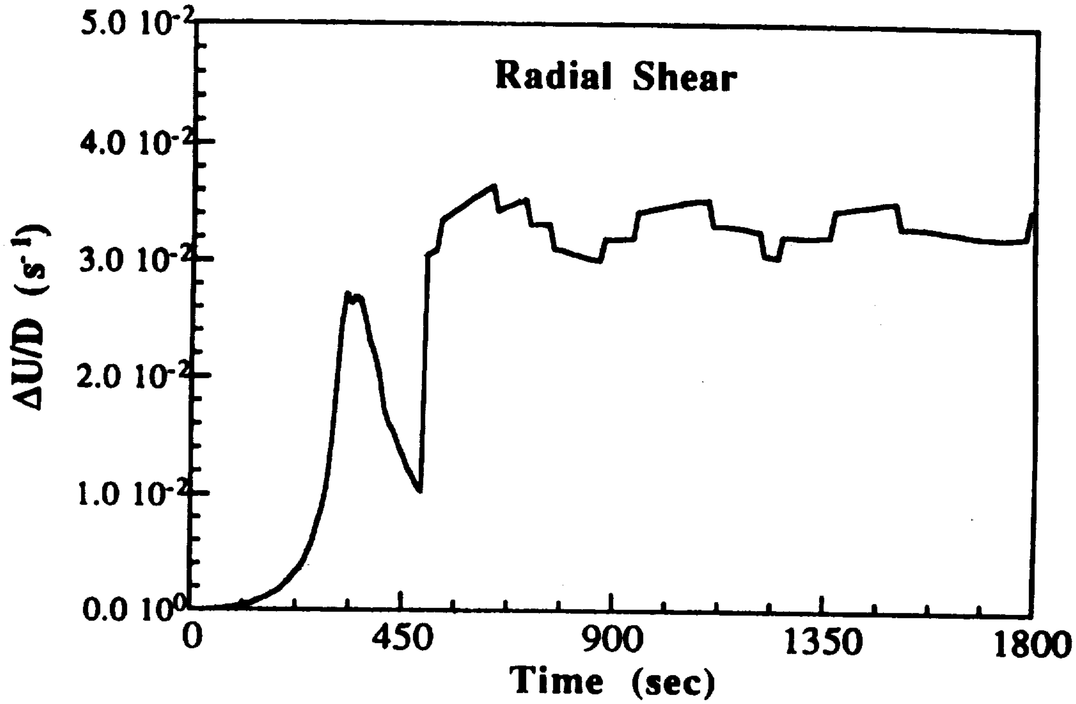
- Each Run for 20 Minutes
- Max's & Min's of all Fields Saved Every 10 s

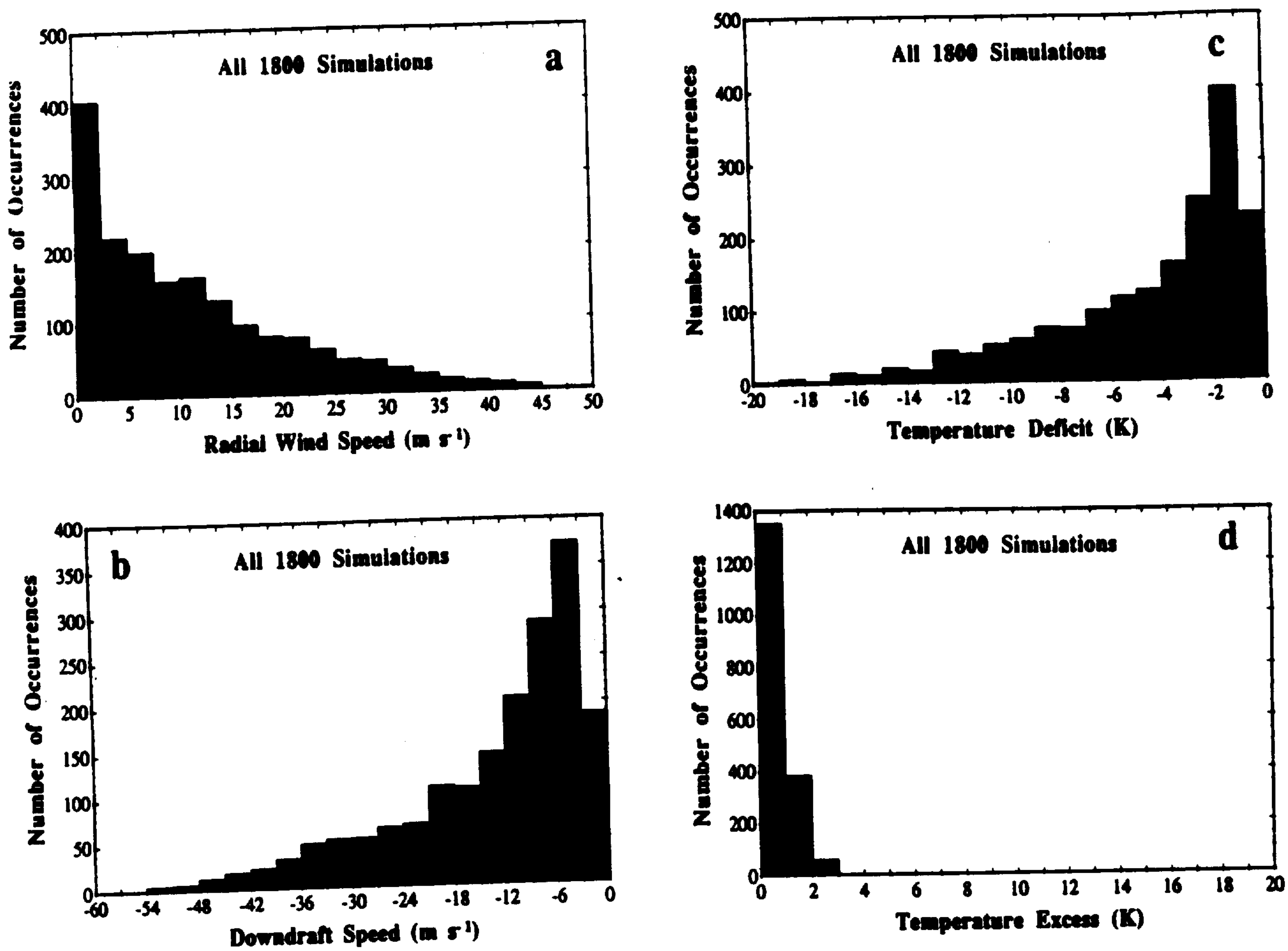
Model Validation

- NCSA Bakeoff - Tested Against Some 15 Codes
- Independent Tests with Krueger Axisymmetric and Klemp & Wilhelmson 3-D

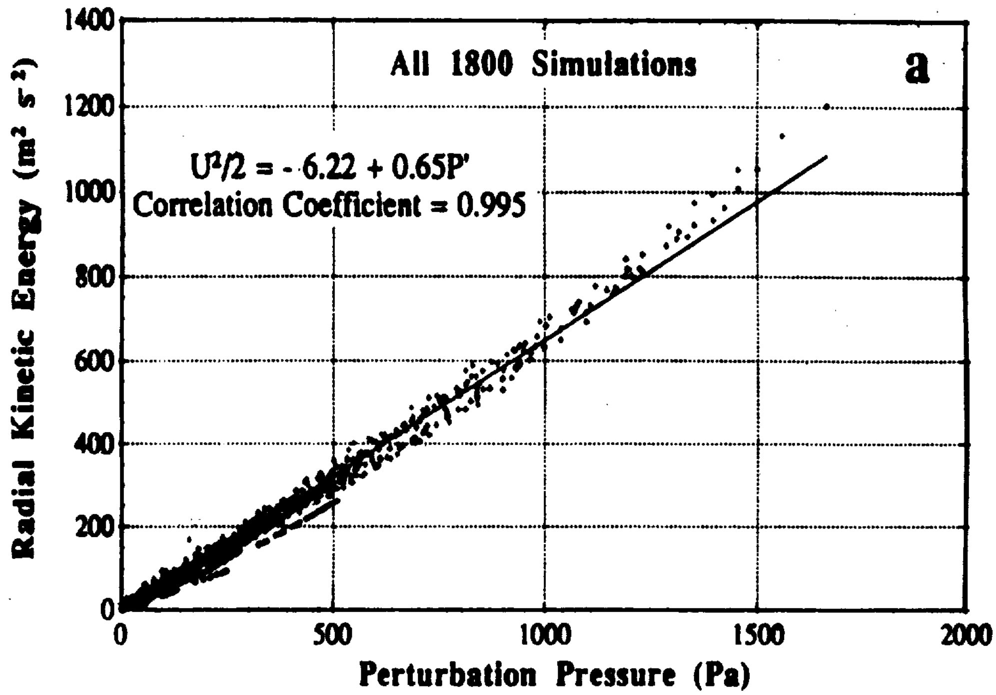
	Umax	Wmin
Droegemeier	46.7	-35.0
Krueger	45.1	-34.8
Droegemeier	52.5	-37.9
K & W 3-D	47.4	-37.9


Tsfc = 105 F, CB = 2 km, Rad = 1 km, LR = Dry Adiabatic
a
Downdraft Speed (m s-1)
20 dBz
30 dBz
40 dBz
50 dBz
60 dBz
Model Time (sec)
Tsfc = 105 F, CB = 2 km, Rad = 1 km, LR = Dry Adiabatic
c
Radial Wind Speed (m s-1)
60 dBz
50 dBz
40 dBz
30 dBz
20 dBz
Model Time (sec)
Tsfc = 105 F, CB = 2 km, Rad = 1 km, LR = Dry Adiabatic
b
Pressure Excess (mb)
60 dBz
50 dBz
40 dBz
20 dBz
30 dBz
Model Time (sec)
Tsfc = 105 F, CB = 2 km, Rad = 1 km, LR = Dry Adiabatic
d
Temperature Deficit (K)
20 dBz
30 dBz
40 dBz
50 dBz
60 dBz
Model Time (sec)

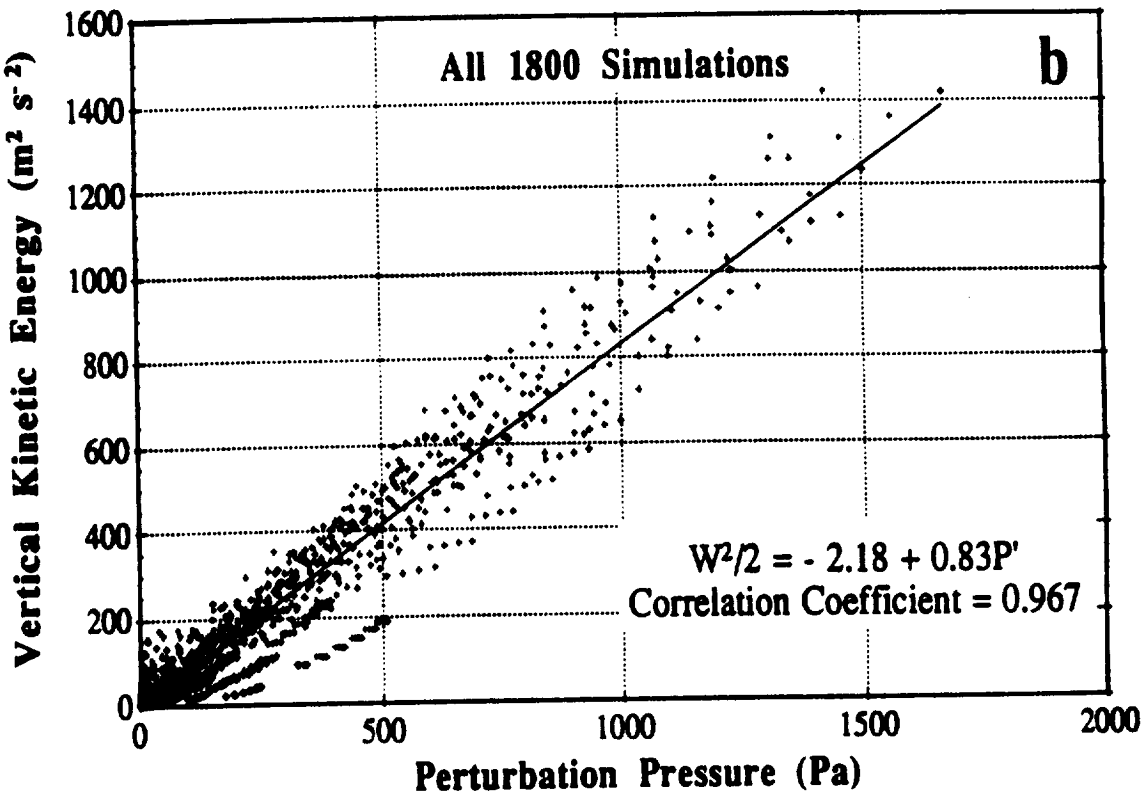

Radial Shear
ΔU/D (s-1)
5.0 10-2
4.0 10-2
3.0 10-2
2.0 10-2
1.0 10-2
0.0 100
0
450
900
1350
1800
Time (sec)



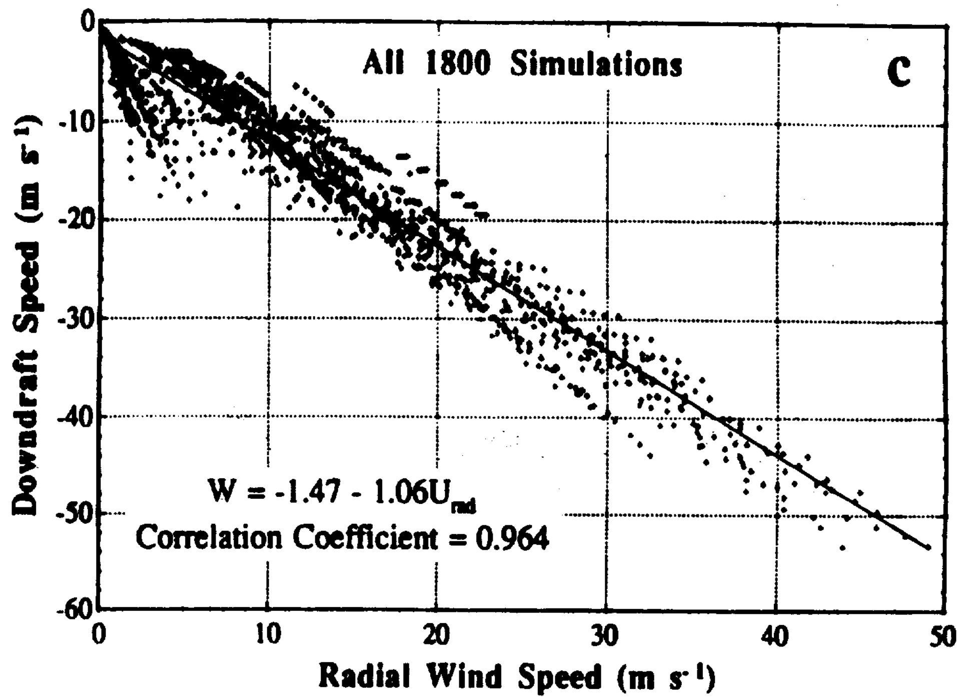
All 1800 Simulations
a
Number of Occurrences
Radial Wind Speed (m s⁻¹)
b
Downdraft Speed (m s⁻¹)
c
Temperature Deficit (K)
d
Temperature Excess (K)



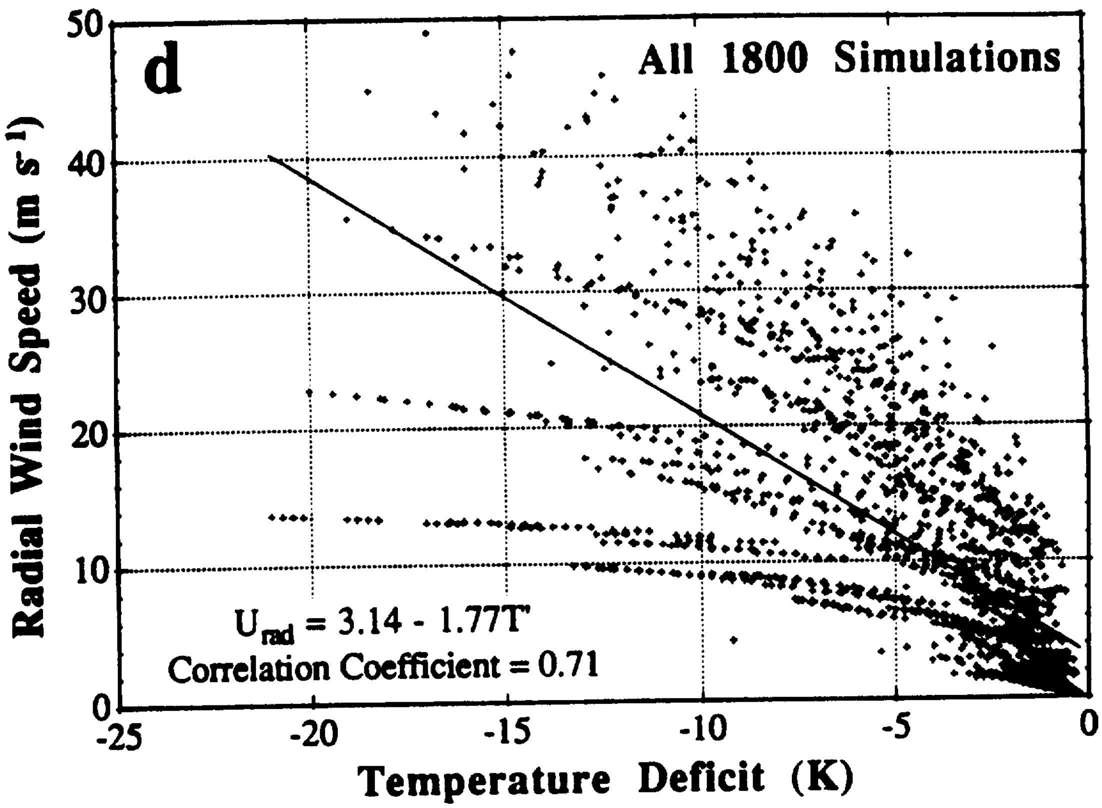
All 1800 Simulations
a
U²/2 = - 6.22 + 0.65P'
Correlation Coefficient = 0.995
Radial Kinetic Energy (m² s⁻²)
Perturbation Pressure (Pa)
1400
1200
1000
800
600
400
200
0
0
500
1000
1500
2000



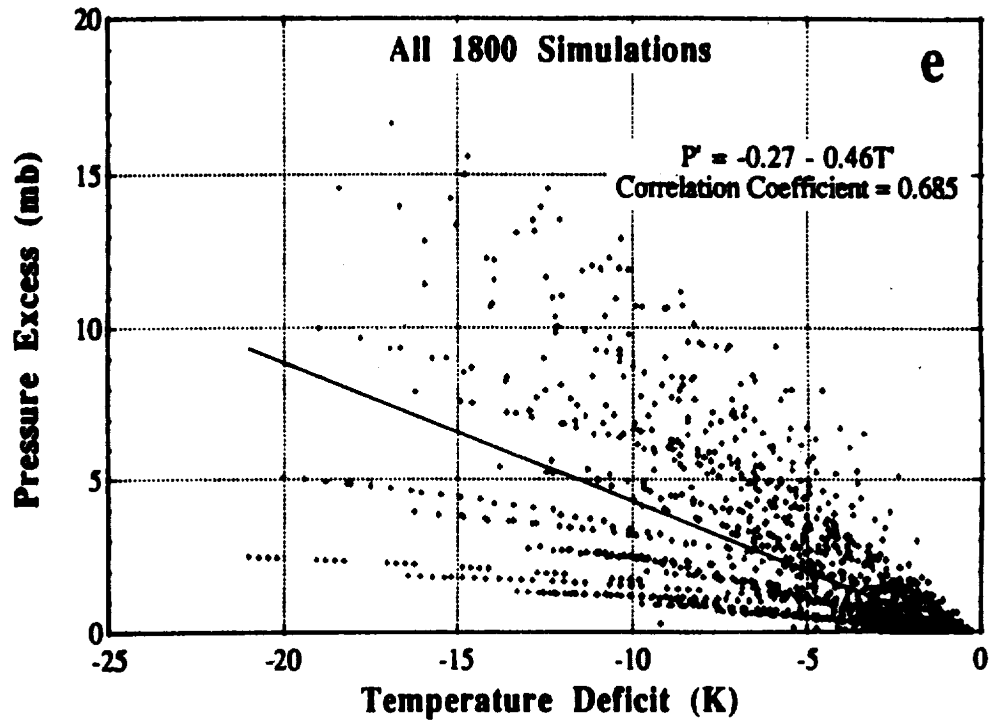
All 1800 Simulations
b
$W^2/2 = -2.18 + 0.83P'$
Correlation Coefficient = 0.967
Vertical Kinetic Energy ($m^2\ s^{-2}$)
Perturbation Pressure (Pa)
1600
1400
1200
1000
800
600
400
200
0
0
500
1000
1500
2000



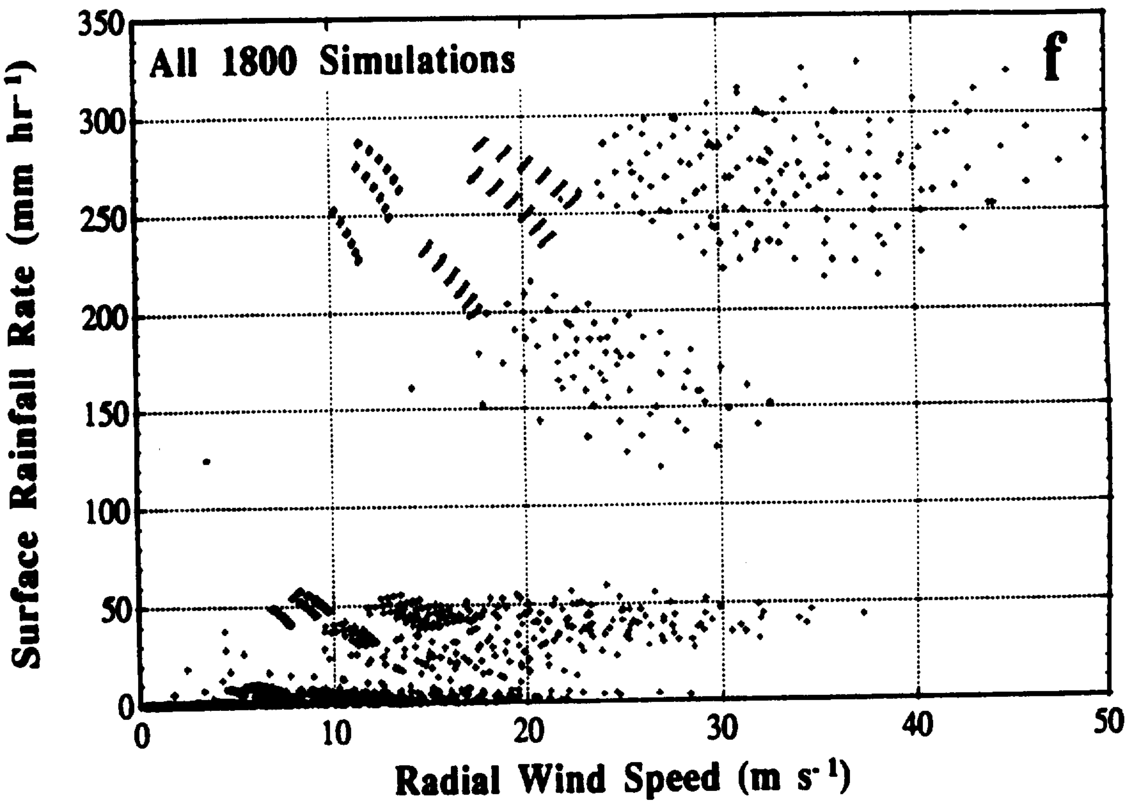
All 1800 Simulations
c
W = -1.47 - 1.06U_rad
Correlation Coefficient = 0.964
Downdraft Speed (m s⁻¹)
Radial Wind Speed (m s⁻¹)
0
-10
-20
-30
-40
-50
-60
0
10
20
30
40
50



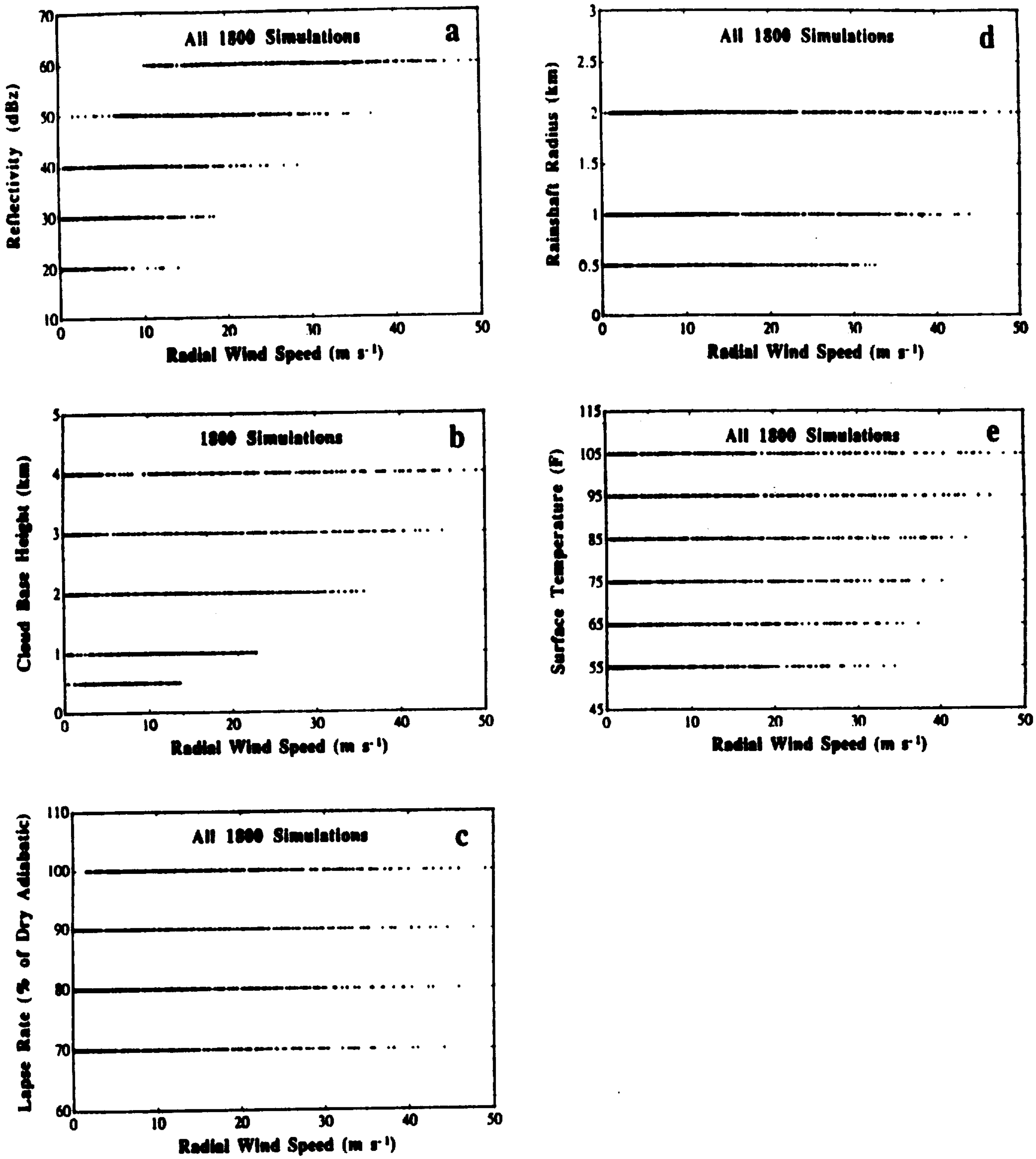
d
All 1800 Simulations
Radial Wind Speed (m s-1)
Temperature Deficit (K)
U_{rad} = 3.14 - 1.77T'
Correlation Coefficient = 0.71
50
40
30
20
10
0
-25
-20
-15
-10
-5
0



All 1800 Simulations
e
P' = -0.27 - 0.46T'
Correlation Coefficient = 0.685
Pressure Excess (mb)
20
15
10
5
0
-25
-20
-15
-10
-5
0
Temperature Deficit (K)



All 1800 Simulations
f
Surface Rainfall Rate (mm hr⁻¹)
Radial Wind Speed (m s⁻¹)
0
50
100
150
200
250
300
350
0
10
20
30
40
50


All 1800 Simulations
a
Reflectivity (dBz)
Radial Wind Speed (m s-1)
All 1800 Simulations
d
Rainshaft Radius (km)
Radial Wind Speed (m s-1)
1800 Simulations
b
Cloud Base Height (km)
Radial Wind Speed (m s-1)
All 1800 Simulations
e
Surface Temperature (F)
Radial Wind Speed (m s-1)
All 1800 Simulations
c
Lapse Rate (% of Dry Adiabatic)
Radial Wind Speed (m s-1)

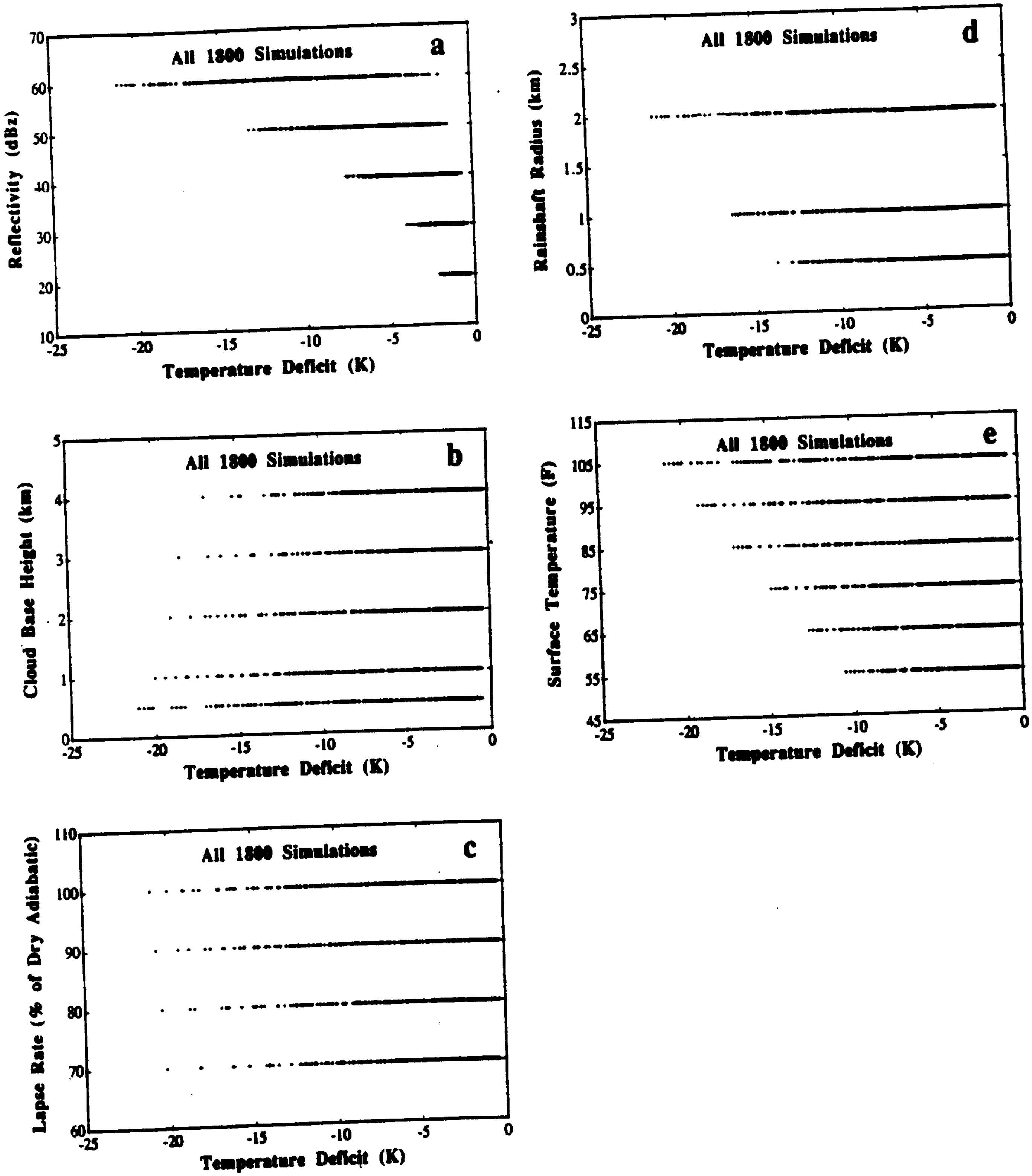

All 1800 Simulations
a
Reflectivity (dBz)
70
60
50
40
30
20
10
-25
-20
-15
-10
-5
0
Temperature Deficit (K)
All 1800 Simulations
d
Rainshaft Radius (km)
3
2.5
2
1.5
1
0.5
0
-25
-20
-15
-10
-5
0
Temperature Deficit (K)
All 1800 Simulations
b
Cloud Base Height (km)
5
4
3
2
1
0
-25
-20
-15
-10
-5
0
Temperature Deficit (K)
All 1800 Simulations
e
Surface Temperature (F)
115
105
95
85
75
65
55
45
-25
-20
-15
-10
-5
0
Temperature Deficit (K)
All 1800 Simulations
c
Lapse Rate (% of Dry Adiabatic)
110
100
90
80
70
60
-25
-20
-15
-10
-5
0
Temperature Deficit (K)

Table 5. Slope of linear fit between radial and downdraft wind speeds for all 1800 simulations as a function of rainshaft radius (R) and cloud base height (H), the ratio of which is defined as the aspect ratio (R/H).

Rainshaft Radius R (km)	Cloud Base H (km)	Aspect Ratio (R/H)	Slope
2.0	0.5	4.00	-0.60
1.0	0.5	2.00	-0.78
2.0	1.0	2.00	-0.75
2.0	2.0	1.00	-0.90
1.0	1.0	1.00	-0.93
0.5	0.5	1.00	-0.97
2.0	3.0	0.67	-0.95
2.0	4.0	0.50	-0.97
1.0	2.0	0.50	-1.03
0.5	1.0	0.50	-1.10
1.0	3.0	0.33	-1.04
1.0	4.0	0.25	-1.06
0.5	2.0	0.25	-1.16
0.5	3.0	0.17	-1.17
0.5	4.0	0.13	-1.17

Table 6. Probabilities (%) of radial wind speed classified according to model input parameters for the set of 1800 simulations.

ALL indicates that the associated parameter varies among all values used in the Subset.

Input Variable					Wind Speed			
LR	Tsfc	Refl	CB	Rad	≥ 10.3 m s^{-1} (≥ 20 kts)	≥ 12.9 m s^{-1} (≥ 25 kts)	≥ 15.4 m s^{-1} (≥ 30 kts)	≥ 18.0 m s^{-1} (≥ 35 kts)
ALL	**ALL**	**ALL**	**ALL**	**ALL**	**44.50**	**35.17**	**28.22**	**22.61**
100	ALL	ALL	ALL	ALL	59.11	45.56	36.89	29.11
90	ALL	ALL	ALL	ALL	45.33	37.11	29.78	24.00
80	ALL	ALL	ALL	ALL	39.56	31.11	24.44	19.78
70	ALL	ALL	ALL	ALL	34.00	26.89	21.78	17.56
ALL	105	ALL	ALL	ALL	48.67	40.67	33.33	26.33
ALL	95	ALL	ALL	ALL	48.00	39.33	31.33	26.00
ALL	85	ALL	ALL	ALL	46.33	37.00	29.67	25.33
ALL	75	ALL	ALL	ALL	45.33	34.33	28.00	23.00
ALL	65	ALL	ALL	ALL	42.33	31.67	25.33	20.00
ALL	55	ALL	ALL	ALL	36.33	28.00	21.67	15.00
ALL	ALL	60	ALL	ALL	98.89	85.28	78.61	70.56
ALL	ALL	50	ALL	ALL	74.17	62.50	46.94	35.00
ALL	ALL	40	ALL	ALL	36.39	22.50	13.61	7.22
ALL	ALL	30	ALL	ALL	11.11	5.28	1.94	0.28
ALL	ALL	20	ALL	ALL	1.94	0.28	0.00	0.00
ALL	ALL	ALL	4.0	ALL	49.44	45.56	39.72	34.44
ALL	ALL	ALL	3.0	ALL	53.06	46.39	41.11	35.56
ALL	ALL	ALL	2.0	ALL	56.11	46.94	38.33	31.67
ALL	ALL	ALL	1.0	ALL	45.00	31.67	21.94	11.39
ALL	ALL	ALL	0.5	ALL	18.89	5.28	0.00	0.00
ALL	ALL	ALL	ALL	2.0	52.00	43.33	35.50	29.00
ALL	ALL	ALL	ALL	1.0	45.17	37.33	29.33	25.17
ALL	ALL	ALL	ALL	0.5	36.33	24.83	19.83	13.67

LR = Lapse Rate (% of Dry Adiabatic)
Tsfc = Surface Temperature (F)
Refl = Reflectivity Factor (dBz)
CB = Cloud Base Height (km)
Rad = Rainshaft Radius (km)

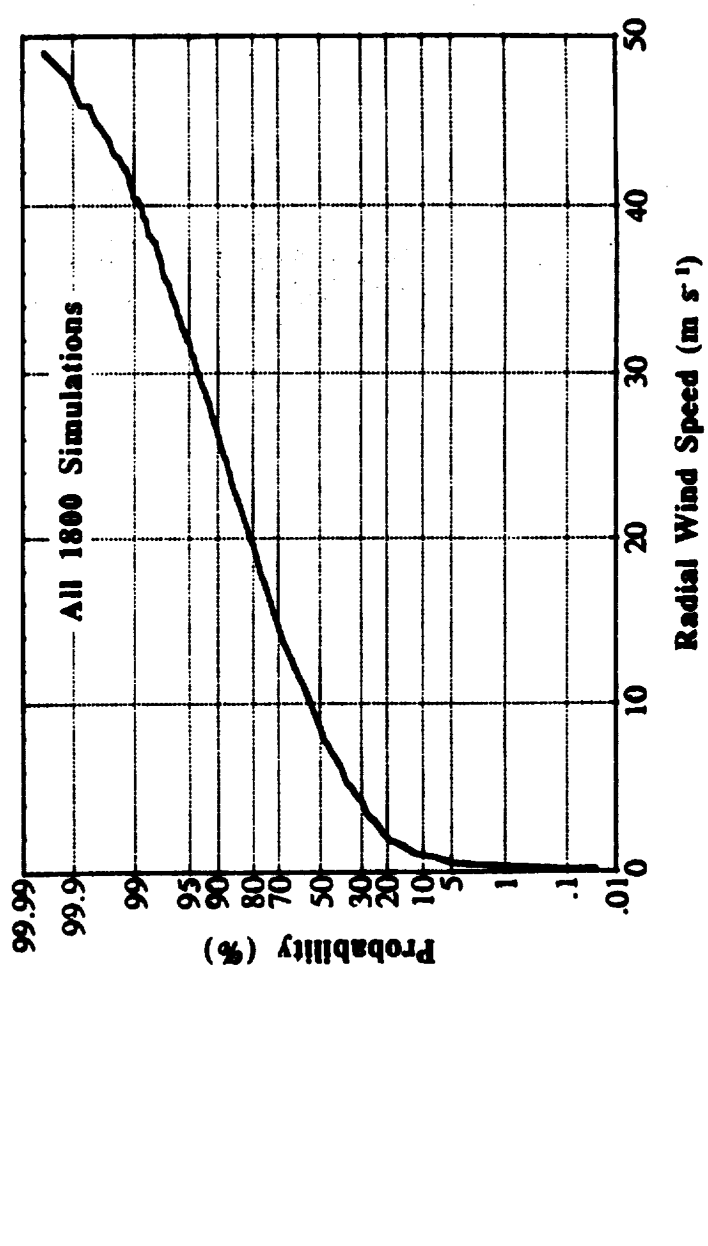

All 1800 Simulations
Radial Wind Speed (m s-1)
0
10
20
30
40
50
Probability (%)
99.99
99.9
99
95
90
80
70
50
30
20
10
5
1
.1
.01

Table 7. **Probabilities** (%) of radial wind speed classified according to model input parameters for a subset of 114 simulations defined below.
ALL indicates that the associated parameter varies among all values used in the Subset.

Input Variable					Wind Speed			
LR	Tsfc	Refl	CB	Rad	≥ 10.3 m s^{-1} (≥ 20 kts)	≥ 12.9 m s^{-1} (≥ 25 kts)	≥ 15.4 m s^{-1} (≥ 30 kts)	≥ 18.0 m s^{-1} (≥ 35 kts)
ALL	**ALL**	**ALL**	**ALL**	**ALL**	**60.53**	**41.23**	**32.46**	**21.05**
100	ALL	ALL	ALL	ALL	60.53	41.23	32.46	21.05
ALL	105	ALL	ALL	ALL	60.53	42.11	34.21	21.05
ALL	95	ALL	ALL	ALL	60.53	42.11	31.58	21.05
ALL	85	ALL	ALL	ALL	60.53	39.47	31.58	21.05
ALL	ALL	60	ALL	ALL	100.00	85.19	66.67	55.56
ALL	ALL	50	ALL	ALL	66.67	55.56	48.15	22.22
ALL	ALL	40	ALL	ALL	55.56	22.22	22.22	11.11
ALL	ALL	30	ALL	ALL	28.57	14.29	0.00	0.00
ALL	ALL	20	ALL	ALL	25.00	0.00	0.00	0.00
ALL	ALL	ALL	2.0	ALL	85.71	64.29	57.14	42.86
ALL	ALL	ALL	1.0	ALL	61.54	38.46	33.33	15.38
ALL	ALL	ALL	0.5	ALL	27.27	15.15	0.00	0.00
ALL	ALL	ALL	ALL	2.0	60.00	46.67	33.33	26.67
ALL	ALL	ALL	ALL	1.0	66.67	47.22	36.11	25.00
ALL	ALL	ALL	ALL	0.5	54.55	27.27	27.27	9.09

Lapse Rate = 100% Dry Adiabatic
85 F ≤ Surface Temperature ≤ 105 F
20 dBz ≤ Reflectivity ≤ 60 dBz
0.5 km ≤ Cloud Base Height ≤ 2.0 km
0.5 km ≤ Rainshaft Radius ≤ 2.0 km
$U_{rad} \geq 5$ m s^{-1}

Table 8. Coefficients of multivariate linear regression equations for the radial wind speed (m s^{-1}) for all 1800 simulations (1799 degrees of freedom), using various combinations of predictors. Shown are the predictors, the estimated standard deviation of model error (m s^{-1}), the leading constant, and the five regression coefficients. The units of the regressors are as shown in Table 3, except for the lapse rate, which is given by its decimal equivalent.

Predictor(s)	% Variance Explained	Est. Std. Dev. of Model Error	Regression Coefficients					
			Const	LR	Tsfc	dBz	CBHt	Rad
LR	3.7	9.8	-3.40	17.31	—	—	—	—
Tsfc	1.7	9.9	5.15	—	0.08	—	—	—
dBz	60.4	6.3	-10.69	—	—	0.55	—	—
CBHt	5.4	9.7	7.50	—	—	—	1.82	—
Rad	4.6	9.8	7.30	—	—	—	—	3.43
dBz, LR	64.1	6.0	-25.38	17.31	—	0.55	—	—
dBz, Tsfc	62.1	6.2	-16.83	—	0.08	0.55	—	—
dBz, CBHt	65.8	5.9	-14.51	—	—	0.55	1.82	—
dBz, Rad	65.0	5.9	-14.69	—	—	0.55	—	3.43
LR, Tsfc	5.5	9.7	-9.56	17.31	0.08	—	—	—
LR, CBHt	9.2	9.5	-7.22	17.31	—	—	1.82	—
LR, Rad	8.3	9.6	-7.41	17.31	—	—	—	3.43
CBHt, Tsfc	7.1	9.7	1.33	—	0.08	—	1.82	—
CBHt, Rad	10.0	9.5	3.48	—	—	—	1.82	3.43
Tsfc, Rad	6.3	9.7	1.14	—	0.08	—	—	3.43
LR, Tsfc, CBHt	10.9	9.5	-13.38	17.31	0.08	—	1.82	—
LR, Tsfc, dBz	65.9	5.9	-31.57	17.31	0.08	0.55	—	—
LR, Tsfc, Rad	10.1	9.5	-13.57	17.31	0.08	—	—	3.43
LR, CBHt, dBz	69.6	5.5	-29.22	17.31	—	0.55	1.82	—
LR, CBHt, Rad	13.7	9.3	-11.23	17.31	—	—	1.82	3.43
LR, dBz, Rad	68.7	5.6	-29.41	17.31	—	0.55	—	3.43
LR, Tsfc, CBHt, Rad	15.5	9.2	-17.39	17.31	0.08	—	1.82	3.43
LR, Tsfc, CBHt, dBz	71.3	5.4	-35.39	17.31	0.08	0.55	1.82	—
LR, Tsfc, Rad, dBz	70.5	5.5	-35.57	17.31	0.08	0.55	—	3.43
LR, CBHt, Rad, dBz	74.1	5.1	-33.23	17.31	—	0.55	1.82	3.43
LR, Tsfc, CBHt, dBz, Rad	75.9	4.9	-39.40	17.31	0.08	0.55	1.82	3.43

Table 9. As in Table 8, but assuming that the cloud base height is known (359 degrees of freedom) and takes the values shown in the left column.

Cloud Base Height	% Variance Explained	Est. Std. Dev. of Model Error	Regression Coefficients					
			Const	LR	Tsfc	dBz	CBHt	Rad
0.5 km	**94.3**	**0.8**	**-6.61**	**1.56**	**0.02**	**0.23**	—	**1.27**
	0.3	3.4	5.35	1.56	—	—	—	—
	0.9	3.4	5.17	—	0.02	—	—	—
	87.7	1.2	-2.30	—	—	0.23	—	—
	5.4	3.3	5.20	—	—	—	—	1.27
1.0 km	**95.8**	**1.2**	**-17.31**	**6.46**	**0.04**	**0.40**	—	**2.48**
	1.4	6.0	4.47	6.46	—	—	—	—
	1.2	6.0	6.89	—	0.04	—	—	—
	86.5	2.2	-5.85	—	—	0.40	—	—
	6.6	5.8	7.07	—	—	—	—	2.48
2.0 km	**92.7**	**2.6**	**-37.66**	**17.90**	**0.07**	**0.61**	—	**4.11**
	4.2	9.6	-2.38	17.90	—	—	—	—
	1.7	9.7	6.94	—	0.07	—	—	—
	79.9	4.4	-11.75	—	—	0.61	—	—
	6.9	9.4	8.04	—	—	—	—	4.11
3.0 km	**89.3**	**4.0**	**-52.66**	**25.98**	**0.11**	**0.74**	—	**4.75**
	5.8	11.7	-8.46	25.98	—	—	—	—
	2.6	11.9	4.46	—	0.11	—	—	—
	74.8	6.1	-15.86	—	—	0.74	—	—
	6.0	11.7	8.08	—	—	—	—	4.75
4.0 km	**84.4**	**5.3**	**-63.63**	**34.6**	**0.14**	**0.78**	—	**4.57**
	8.4	12.8	-15.99	34.6	—	—	—	—
	3.2	13.2	2.29	—	0.14	—	—	—
	68.2	7.6	-17.66	—	—	0.78	—	—
	4.6	13.1	8.14	—	—	—	—	4.57

Table 10. As in Table 8, but assuming that the reflectivity factor is known (359 degrees of freedom) and takes the values shown in the left column.

Radar Reflectivity	% Variance Explained	Est. Std. Dev. of Model Error	Regression Coefficients					
			Const	LR	Tsfc	dBz	CBHt	Rad
20 dBz	**60.2**	**1.5**	**-9.08**	**10.34**	**0.02**	—	**-0.46**	**1.94**
	24.8	2.0	-6.39	10.34	—	—	—	—
	1.7	2.3	0.98	—	0.02	—	—	—
	6.6	2.3	3.37	—	—	—	-0.46	—
	27.2	2.0	0.13	—	—	—	—	1.94
30 dBz	**56.3**	**2.5**	**-18.04**	**20.73**	**0.03**	—	**-0.01**	**2.49**
	37.6	3.0	-12.76	20.73	—	—	—	—
	1.8	3.8	2.30	—	0.03	—	—	—
	0.0	3.8	4.89	—	—	—	-0.01	—
	16.8	3.4	1.96	—	—	—	—	2.49
40 dBz	**56.5**	**3.7**	**-25.22**	**26.84**	**0.07**	—	**0.67**	**3.85**
	30.1	4.6	-13.77	26.84	—	—	—	—
	4.7	5.4	3.49	—	0.07	—	—	—
	2.5	5.4	7.62	—	—	—	0.67	—
	19.2	4.9	4.56	—	—	—	—	3.85
50 dBz	**66.7**	**4.0**	**-21.52**	**19.01**	**0.12**	—	**3.04**	**4.36**
	9.6	6.5	-0.27	19.01	—	—	—	—
	9.3	6.5	6.13	—	0.12	—	—	—
	32.2	5.6	9.51	—	—	—	3.04	—
	15.7	6.3	10.81	—	—	—	—	4.36
60 dBz	**83.2**	**3.8**	**-13.11**	**9.65**	**0.14**	—	**5.85**	**4.55**
	1.4	9.3	16.17	9.65	—	—	—	—
	7.2	9.0	12.69	—	0.14	—	—	—
	65.3	5.5	12.08	—	—	—	5.85	—
	9.3	8.9	19.07	—	—	—	—	4.55

Table 12. As in Table 8, but assuming that the rainshaft radius is known (599 degrees of freedom) and takes the values shown in the left column.

Rainshaft Radius	% Variance Explained	Est. Std. Dev. of Model Error	Regression Coefficients					
			Const	LR	Tsfc	dBz	CBHt	Rad
0.5 km	**77.9**	**3.8**	**-29.05**	**15.27**	**0.05**	**0.47**	**1.02**	—
	4.6	7.8	-4.60	15.27	—	—	—	—
	0.9	7.9	4.86	—	0.05	—	—	—
	69.7	4.4	-10.41	—	—	0.47	—	—
	2.7	7.9	6.25	—	—	—	1.02	—
1.0 km	**77.1**	**4.9**	**-37.28**	**18.33**	**0.07**	**0.59**	**1.91**	—
	4.0	10.0	-3.88	18.33	—	—	—	—
	1.5	10.2	5.81	—	0.07	—	—	—
	65.9	6.0	-11.80	—	—	0.59	—	—
	5.7	9.9	7.69	—	—	—	1.91	—
2.0 km	**75.7**	**5.4**	**-39.82**	**18.35**	**0.11**	**0.59**	**2.53**	—
	3.6	10.7	-1.73	18.35	—	—	—	—
	3.2	10.7	4.78	—	0.11	—	—	—
	59.9	6.8	-9.85	—	—	0.59	—	—
	8.9	10.3	8.55	—	—	—	2.53	—

Table 11. As in Table 8, but assuming that the surface temperature is known (299 degrees of freedom) and takes the values shown in the left column.

Surface Temperature	% Variance Explained	Est. Std. Dev. of Model Error	Regression Coefficients					
			Const	LR	Tsfc	dBz	CBHt	Rad
55° F	**75.1**	**4.1**	**-28.95**	**18.10**	—	**0.46**	**0.90**	**2.24**
	6.3	7.8	-6.21	18.10	—	—	—	—
	63.8	4.9	-9.07	—	—	0.46	—	—
	2.0	8.0	7.29	—	—	—	0.90	—
	3.0	8.0	6.56	—	—	—	—	2.24
65° F	**76.2**	**4.3**	**-30.71**	**17.67**	—	**0.50**	**1.30**	**2.77**
	5.0	8.6	-4.81	17.67	—	—	—	—
	63.8	5.4	-9.73	—	—	0.50	—	—
	3.5	8.7	7.48	—	—	—	1.30	—
	3.9	8.7	6.97	—	—	—	—	2.77
75° F	**76.8**	**4.6**	**-32.42**	**17.30**	—	**0.54**	**1.68**	**3.24**
	4.1	9.4	-3.61	17.30	—	—	—	—
	63.2	5.8	-10.41	—	—	0.54	—	—
	5.0	9.4	7.58	—	—	—	1.68	—
	4.5	9.4	7.32	—	—	—	—	3.24
85° F	**77.4**	**4.9**	**-34.07**	**16.93**	—	**0.57**	**2.03**	**3.72**
	3.4	10.1	-2.53	16.93	—	—	—	—
	62.5	6.3	-11.08	—	—	0.57	—	—
	6.4	10.0	7.60	—	—	—	2.03	—
	5.1	10.0	7.53	—	—	—	—	3.72
95° F	**77.8**	**5.2**	**-35.81**	**16.89**	—	**0.60**	**2.37**	**4.14**
	3.0	10.8	-1.85	16.89	—	—	—	—
	61.4	6.7	-11.64	—	—	0.60	—	—
	7.4	10.5	7.54	—	—	—	2.37	—
	5.6	10.6	7.68	—	—	—	—	4.14
105° F	**77.7**	**5.5**	**-37.43**	**17.00**	—	**0.63**	**2.65**	**4.50**
	2.7	11.4	-1.42	17.00	—	—	—	—
	60.3	7.3	-12.18	—	—	0.63	—	—
	8.7	11.0	7.47	—	—	—	2.65	—
	6.0	11.2	7.78	—	—	—	—	4.50

Table 13. As in Table 8, but assuming that the lapse rate is known (449 degrees of freedom) and takes the values shown in the left column.

Ambient Lapse Rate	% Variance Explained	Est. Std. Dev. of Model Error	Regression Coefficients					
			Const	LR	Tsfc	dBz	CBHt	Rad
70% of D.A.	**71.9**	**5.0**	**-23.63**	—	**0.08**	**0.58**	**0.62**	**3.22**
	2.0	9.3	2.73	—	0.08	—	—	—
	64.6	5.6	-12.29	—	—	0.58	—	—
	0.7	9.4	7.72	—	—	—	0.62	—
	4.6	9.2	5.26	—	—	—	—	3.22
80% of D.A.	**74.7**	**5.0**	**-25.10**	—	**0.08**	**0.61**	**1.15**	**3.28**
	1.9	9.8	3.81	—	0.08	—	—	—
	66.2	5.7	-12.44	—	—	0.61	—	—
	2.2	9.8	7.79	—	—	—	1.15	—
	4.3	9.6	6.38	—	—	—	—	3.28
90% of D.A.	**78.8**	**4.7**	**-26.20**	—	**0.08**	**0.62**	**2.01**	**3.51**
	1.7	10.1	5.49	—	0.08	—	—	—
	66.0	6.0	-11.62	—	—	0.62	—	—
	6.4	9.9	7.55	—	—	—	2.01	—
	4.6	9.9	7.66	—	—	—	—	3.51
100% of D.A.	**82.8**	**4.1**	**-23.78**	—	**0.07**	**0.51**	**3.50**	**3.73**
	1.5	9.8	8.57	—	0.07	—	—	—
	55.0	6.6	-6.38	—	—	0.51	—	—
	20.7	8.8	6.92	—	—	—	3.50	—
	5.6	9.6	9.92	—	—	—	—	3.73

<u>Preliminary</u> Comparison with JAWS Observations

- Model Data Subset Satisfying the Following:

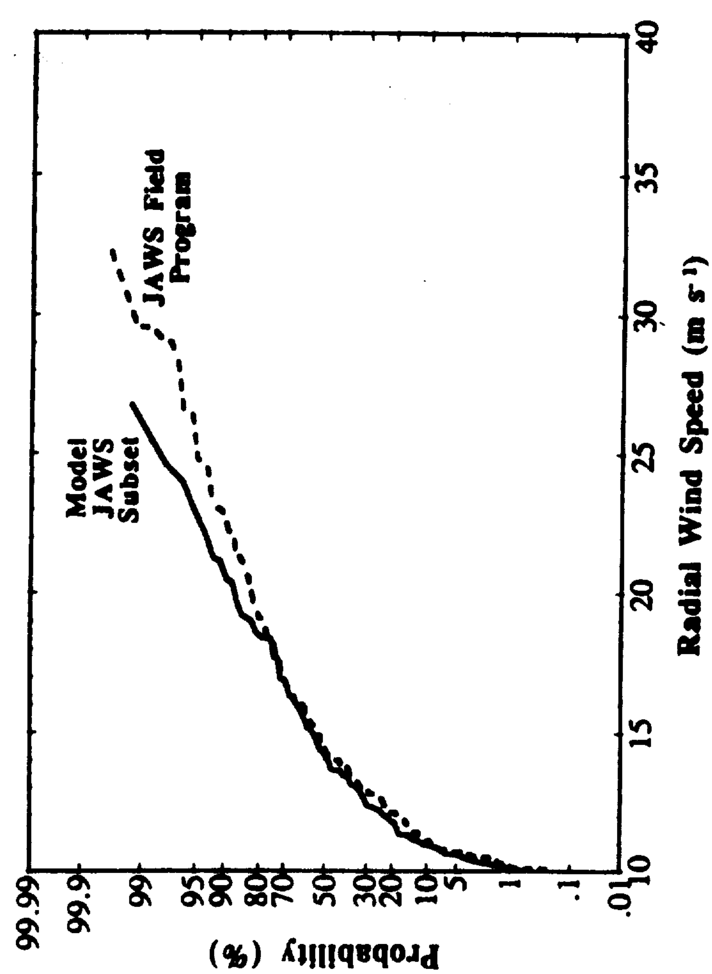
$U \geq 10 \text{ m s}^{-1}$
$2.0 \text{ km} \leq \text{Cloud Base} \leq 4.0 \text{ km}$
$75 \text{ F} \leq \text{Sfc Temp} \leq 95 \text{ F}$
$20 \text{ dBz} \leq \text{Reflectivity} \leq 40 \text{ dBz}$
$90\% \text{ D.A.} \leq \text{Lapse Rate} \leq 100\% \text{ D.A.}$
$0.5 \text{ km} \leq \text{Rainshaft Radius} \leq 2.0 \text{ km}$

- 72 Simulations (vs 186 JAWS events)

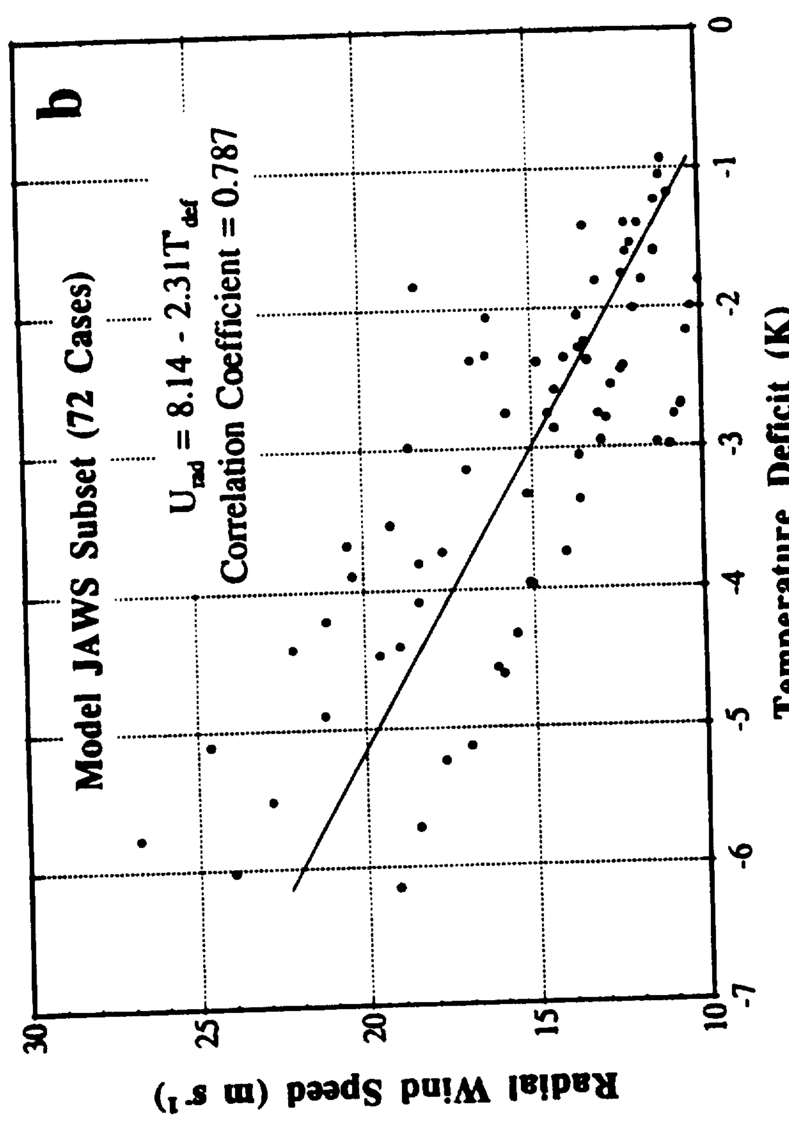
Table 6. Probabilities of horizontal wind speed computed from the model data and JAWS observations.

Dataset	Wind Speed ≥ 20 kts	≥ 25 kts	≥ 30 kts	≥ 35 kts
JAWS Observations	**98.39**	**76.88**	**42.47**	**23.12**
All 1800 Simulations	44.50	35.17	28.22	22.61
†Model JAWS Subset	**98.61**	**66.67**	**40.28**	**25.00**

† Criteria: radial wind ≥ 10 m s^{-1}
2.0 ≤ cloud base height ≤ 4.0 km
75 F ≤ surface temperature ≤ 95 F
20 dBz ≤ cloud base reflectivity ≤ 40 dBz
90% dry adiabatic ≤ lapse rate ≤ 100% dry adiabatic
0.5 km ≤ rainshaft radius ≤ 2 km
(72 cases)



Model JAWS Subset
JAWS Field Program
Probability (%)
Radial Wind Speed (m s⁻¹)
99.99
99.9
99
95
90
80
70
50
30
20
10
5
1
.1
.01
10
15
20
25
30
35
40



Model JAWS Subset (72 Cases)
b
$U_{rad} = 8.14 - 2.31T_{def}$
Correlation Coefficient = 0.787
Radial Wind Speed (m s-1)
Temperature Deficit (K)
30
25
20
15
10
-7
-6
-5
-4
-3
-2
-1
0

Preliminary Conclusions

- The Model Solution Space Contains Considerable Variability
- Solution Behavior is Physically Consistent
- Reflectivity is the Dominant Influence Most of the Time in Determining Radial Wind Speed
- Gross Statistical Comparisons with JAWS are Encouraging
- The "Numerical Field Experiment" Approach Appears Well-Suited to this Problem
- Several Avenues for Practical Application

Ongoing Work

- Inclusion of Ice Processes and Shallow Stable Layers
- "Pointwise" and Overall Statistical Comparisons with JAWS and Orlando TDWR OT&E Data
- Refinement of Parameter Space
- Evaluation of Probability Calculations for Operational Forecasting
- Further Development of Parametric Relationships Between Model Outputs and Inputs

A "Numerical Filed Experiment" Approach for Determining Probabilities of Microburst Intensity

Questions and Answers

Q: Kim Elmore (NCAR) - I am fascinated by the work you did, and specifically how much of a predictor reflectivity was in general. For the equivalent JAWS simulations, how good of a predictor was reflectivity for intensity?. Do you remember?

A: Kelvin Droegemeier (University of Oklahoma) - We haven't actually done that break down for the JAWS data yet. Based on the other results, I would say it was probably a very strong influence.

Kim Elmore (NCAR) - Our experience in JAWS was that it wasn't a very good predictor of the outflow we would see. That was one of the major conclusions. Reflectivity, for the JAWS data, was not a good predictor.

Kelvin Droegemeier (University of Oklahoma) - I just had a student finish a Master's Thesis on a study of Orlando cases. What we have found and what tended to make that conclusion seem plausible in light of the fact that the reflectivity factor was the same and apparently similar environments, was the fact that low level effects like low level inversions in stable air change the outflow intensity. It does not take much stabilization in low levels to really change the outflow intensity. In fact you will see that if you stay around and look at the animation sequence. Now I know Fred and others of us who run models have actually dropped globs of rain into stable air for a long time. What this student did, for the first time, with a 3-D cloud simulation with ice, showed that the storms themselves forming beneath the low level stable air, were virtually unaffected by it. Once the rain came down and the outflow hit, that is when the radial winds were really diminished by virtue of the stable air.

Kim Elmore (NCAR) - We have seen, when gust fronts go by, that often once you stabilize a relatively deep part of the boundary layer that they do not make it through any more.

Kelvin Droegemeier (University of Oklahoma) - Yes; it doesn't have to be but maybe four or five hundred meters. It can be pretty shallow. One of the limitations of our study is that we did not put in the shallow stable layer. If you consider the parameters, you have to figure how thick is a layer and how cold is it. That is two more parameters and that would run it up to 20,000 simulations.

Kim Elmore (NCAR) - In JAWS, we also did not stratify the cases as to was there cold surface layer or not.

Kelvin Droegemeier (University of Oklahoma) - That is a tough thing to do. Usually they just skim the mesonet and you just never know.

Kim Elmore (NCAR) - Our gut feeling was; once we had a cold surface layer, if it had been around long enough to deepen, however much it had to deepen, and we did not even really know how much that was, that tended to shut it off.

Kelvin Droegemeier (University of Oklahoma) - I completely agree, I think that is the controlling influence for attenuating that stuff.

Q: Brac Bracalente (NASA Langley) - The reflectivity values you referred to are at the cloud level right at the high altitude where the rain first starts to fall. Did you do any correlating with the reflectivity levels at the outflow region? We have found that the peak shear did not necessarily occur where the heaviest rain was.

A: Kelvin Droegemeier (University of Oklahoma) - No, we have not done that but we could. In fact. if you stay around for the video tape you will see that the reflectivity near the ground or not to far above the ground is less than it is at cloud base height. I should have mentioned, in the absence of having ice in this case, we are assuming that once the precipitation falls below cloud base the only stuff that is important for the forcing that occurs that drives that microburst is the stuff that happens below cloud base. Obviously, that is not always the case, but that was the assumption in this case here. The reason we did that is so we do not have to consider all the possible soundings and wind profiles and everything that happens above cloud base where there is a lot of variability. So that was the other assumption.

Q: Fred Proctor (NASA Langley) - Define what you mean by your cloud base height in your model studies?

A: Kelvin Droegemeier (University of Oklahoma) - It is basically just the height at which the rain begins to fall, that is the simplest explanation.

Q: Fred Proctor (NASA Langley) - Is that the top of your model then?

A: Kelvin Droegemeier (University of Oklahoma) - Yes, and the vertical velocity is zero there.

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