conf. 790101--10

DP-MS-78-49

A METHOD FOR USING ACOUSTIC SOUNDER CATEGORIES TO DETERMINE ATMOSPHERIC STABILITY

by

J. F. Schubert

Savannah River Laboratory
E. I. du Pont de Nemours & Co.
Aiken, SC 29801

For publication at the Fourth Symposium on Turbulence, Diffusion, and Air Pollution to be held in Reno, NV, on January 15-18, 1979.

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J. F. Schubert

Savannah River Laboratory
Aiken, South Carolina 29801

1. INTRODUCTION

Capabilities of the diffusion meteorologist have been expanded by the acoustic sounder, an economical tool for monitoring in real time the height of the mixed layer.

The acoustic sounder continuously measures the rate of change in the height of the mixed layer which is an important parameter in calculating the transport and diffusion of radioactive and nonradioactive air pollutants. Continuous record of convective cells, gravity waves, inversions, and frontal systems permit analysis of the synoptic (analysis of stability in terms of simultaneous weather information) and complex (analysis of the stability of a single place by the relative frequencies of various stability types or groups of such types) stabilities of the local area.

Sounder data obtained at the Savannah River Plant was compared on an hourly basis to data obtained at the WJBF-TV tower located approximately 20 km northwest of the acoustic sounder site.

2. CATEGORIZATION OF SOUNDER DATA

Facsimile records obtained by the acoustic sounder were placed into one of sixteen category types (Schubert, 1975) as determined from the signal patterns of the facsimile record (Table 1.) The signatures for each category are quite unique. (Figures 1 - 3.) Because the sounder data was categorized hourly, and at times the categories changed during the hour, a subjective assessment was made to place that hour's worth of data into the predominant category. Categories 16 and 17 were used when the sounder was out of operation for maintenance and when the record was observed by wind and/or rain noise.

3. OBSERVATIONS

Wind and temperature data obtained from the WJBF-TV tower (Figure 1) were used to compute gradient Richardson numbers (Ri), dT/dz and sigma theta (σ_θ) for different levels. These were then compared to the sounder categories. The acoustic sounder data were also compared to different wind speeds at the 10 meter level at the TV tower. The reference speeds used were below and above 5 m/s for both day and night, and above and below 2.5 m/s for both day and night.

TABLE 1

CATEGORIES OF ATMOSPHERIC BOUNDARY LAYERS IDENTIFIED BY ACOUSTIC SOUNDER DATA

Category 1:	Abrupt change from stable multiple layers to a well mixed layer
Category 2:	Back-scattered layer
Category 3:	Back-scattered layer with waves
Category 4:	Very complex; many waves in the bottom layer
Category 5:	Two layers in the bottom
Category 6:	Two layers, separate one over the other, large separation from the top to the bottom layer
Category 7:	Multiple weak layers with waves
Category 8:	Strong multiple layers with waves
Category 9:	Ascending layers from the surface
Category 10:	Ascending layers but not starting at the surface
Category 11:	Descending layers but not merging with the surface
Category 12:	Descending layers merging with the surface layer
Category 13:	Thermal plumes only
Category 14:	Stable multiple layers
Category 15:	Inversion layer with waves
Category 16:	Wind and rain noise
Category 17:	Inoperative

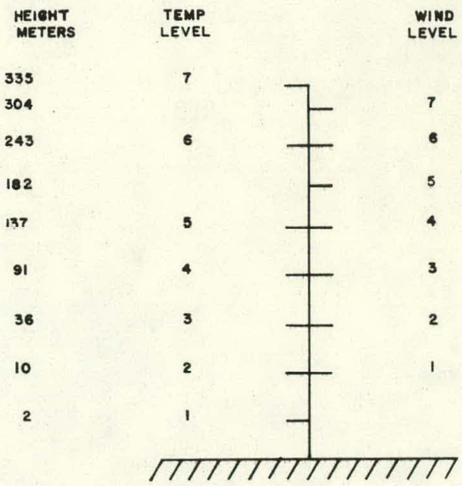

FIGURE 1. WJBF-TV Tower

Data was taken from March 1975 to December 1977. The TV tower data was averaged over 15-minute intervals and in order to compare the tower data to the acoustic categories the half-hour measurement was taken to be representative of the whole hour. Some differences are expected between the tower data and the sounder data because the atmospheric boundary layer is not homogenous (Schubert, 1977).

4. RICHARDSON NUMBER

Using Ri numbers, an unstable to neutral layer occurred during categories 2, 13, and 14 for wind speeds above 5 m/s during the daytime. The boundary layer became more neutral as we progressed up the tower except during catetory 13. During category 13, the boundary layer was unstable up to the highest levels on the TV tower.

For daytime wind speeds less than 5 m/s, all acoustic sounder categories were associated with unstable Ri numbers at the lower levels. A sharp transition to non-turbulent or stable Ri numbers occurred above 36 m.

Neutral conditions were observed for all categories except 2 and 14 during the night for winds less than 5 m/s. During categories 2 and 14 the boundary layer was neutral with a few stable to very stable periods. As we progressed up the tower, conditions became increasingly neutral to stable for all categories. At 91 m there appeared to be a decoupling from the surface layer and the Ri number profile became unstable to neutral because of the nocturnal jet, while above 137 m the profile became stable for both categories 2 and 14.

5. TEMPERATURE STABILITY

The stability data obtained from the $\partial T/\partial z$ calculations on the tower do not correlate with the acoustic sounder categories. Table 2 (Pendergast, 1974) shows that stability calculated by $\partial T/\partial z$ is different than calculating stability categories by use of the standard deviation (σ_θ) of the azimuth of the horizontal wind.

TABLF 2

Frequency Distribution of Pasquill Stability Categories[a]

Height, m	A $\sigma_\theta > 23$	B $18 \le \sigma_\theta < 23$	C $13 \le \sigma_\theta < 18$	D $8 \le \sigma_\theta < 13$	E $4 \le \sigma_\theta < 8$	F $2 \le \sigma_\theta < 4$	G $\sigma_\theta < 2$	
	Stability Categories based on σ_θ							
10	22.6	13.9	21.8	28.9	8.9	0.4	3.5	LOW
36	19.3	11.8	19.4	32.4	15.9	0.7	0.5	
91	9.6	6.7	13.5	21.7	29.6	16.4	2.5	MID
137	9.3	5.8	11.7	20.8	28.5	18.4	5.5	
182	7.0	2.9	6.8	17.1	25.9	25.6	14.7	
243	7.7	4.3	9.4	17.7	27.6	22.9	10.4	HIGH
304	7.2	3.7	8.0	17.2	28.7	23.9	11.3	

Layer	A $\gamma \le -1.9$	B $-1.9 \le \gamma < -1.7$	C $-1.7 \le \gamma < -1.5$	D $-1.5 \le \gamma < -0.5$	E $-0.5 \le \gamma < 1.5$	F $1.5 \le \gamma < 4.0$	G $\gamma > 4.0$
	Stability Categories determined from $\partial T/\partial z$, °C/100 m						
2- 10 m	49.8	0.4	0.8	4.8	8.1	6.7	29.4
2- 36	24.8	1.4	1.3	8.4	16.1	16.2	31.8
2- 91	19.1	3.7	4.0	13.4	23.0	23.0	13.8
2-137	16.5	6.1	5.3	18.7	27.7	21.1	4.6
2-243	0.0	1.1	5.9	30.7	47.5	13.8	1.0
2-335	0.0	0.2	5.9	33.5	54.7	5.5	0.2
10- 36 m	8.0	2.2	2.0	10.3	10.3	31.2	36.0
10- 91	2.9	4.0	5.9	22.3	14.8	38.8	11.3
10-137	3.2	5.6	7.7	27.0	16.4	37.6	2.5
10-243	0.0	0.0	0.0	33.7	28.9	37.3	0.1
10-335	0.1	0.0	0.0	38.2	36.4	25.3	0.0
36- 91	4.4	4.2	8.7	32.3	34.5	12.7	3.2
36-137	3.8	8.2	14.9	30.5	34.5	8.0	0.1
36-243	0.0	0.0	0.0	43.3	51.6	5.1	0.0
36-335	0.0	0.0	0.1	47.9	51.2	0.8	0.0
91-137	16.0	11.7	12.6	32.8	23.2	3.6	0.1
91-243	0.0	0.0	0.0	44.6	51.8	3.6	0.0
91-335	0.0	0.0	0.0	55.5	44.1	0.4	0.0

Stability Categories determined from Ri evaluated for the 10-91-m layer

A $Ri < -3.5$	B $-3.5 \le Ri < -0.75$	C $-0.75 \le Ri < -0.1$	D $-0.1 \le Ri < 0.15$	E $0.15 \le Ri < 0.75$	F[b] $0.75 \le Ri < +3.5$	G[b] $Ri > 3.5$
3.0	6.1	28.0	10.0	31.4	19.5	1.8

a. During the period June 22, 1973, to November 23, 1973, for the Savannah River Plant, as determined from temperature gradients, standard deviation of horizontal wind speed, and Richardson numbers. The sampling period for all data was one hour. The total number of cases equalled 3600.

b. Golder's[3] stability category F was split into two, F and G, at Ri = 3.5.

6. SIGMA THETA

The sigma theta (σ_θ) values for both day and night, for winds above and below 5 m/s, correlate well with the Ri number obtained for various categories and show the same patterns with level and category. The σ_θ's are a good indicator of atmospheric turbulence and stability (Slade, 1968).

7. CORRELATION

Using the correlation procedure of the Statistical Analysis System (SAS), Barr (1976), a cross correlation of categories, height, time of day, stability categories (Ri number) and wind speed was performed. An equation was derived from this and the GLM program to calculate a stability number:

Pasquill-Gifford Stability No. =
acoustic sounder category estimate +
hour estimate + windspeed estimate +
intercept (1)

The calculated stability number is within one stability category for the observed Pasquill-Gifford stability number 63% of the time. For the acoustic and sounder hour estimate of value and the acoustic sounder category estimate of value see the appendix. The windspeed estimate is equal to -0.06, the wind speed. The intercept is equal to 5.409.

8. CONCLUSION

A stability category can be calculated using wind speed, acoustic sounder category and time of day in Equation (1).

APPENDIX

TABLE OF VALUES FOR EQUATION (1)

Category	*Category Estimate*	*Hour*	*Hour Estimate*	*Hour*	*Hour Estimate*
1	-0.13310171	1	0.23477152	13	-2.98133178
2	-0.32414474	2	0.32910012	14	-2.88453624
3	0.16028517	3	0.24098319	15	-2.49669497
4	0.07890705	4	0.43028051	16	-2.22090465
6	-0.47234681	5	0.54353353	17	-2.00560315
9	-0.29366033	6	0.52386780	18	-1.58476029
10	-0.57766045	7	0.63078059	19	-1.41704144
11	-0.33495409	8	0.20864239	20	-1.09093929
12	0.27853631	9	-0.94913060	21	-0.42444511
13	-0.33056129	10	-2.35332579	22	-0.18005776
14	0.00000000	11	-3.09961716	23	-0.13212717
		12	-2.98851887	24	0.00000000

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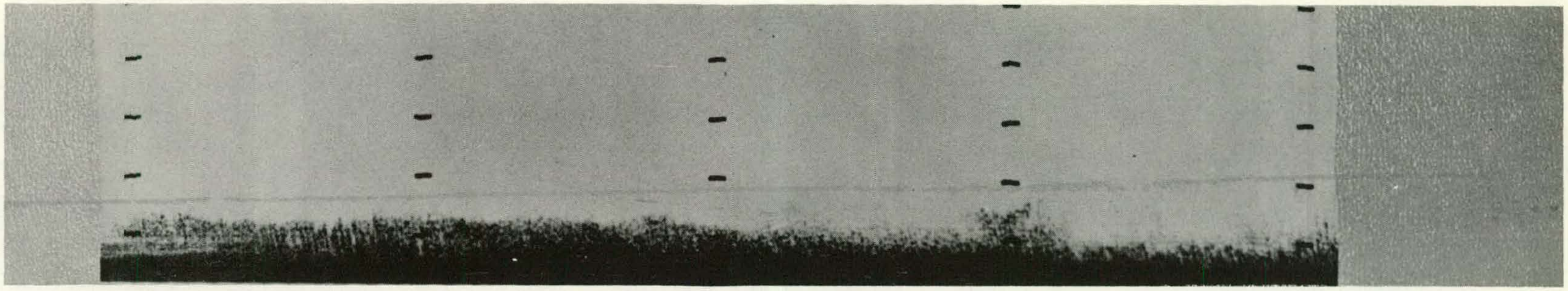

FIGURE 1. Category 2.

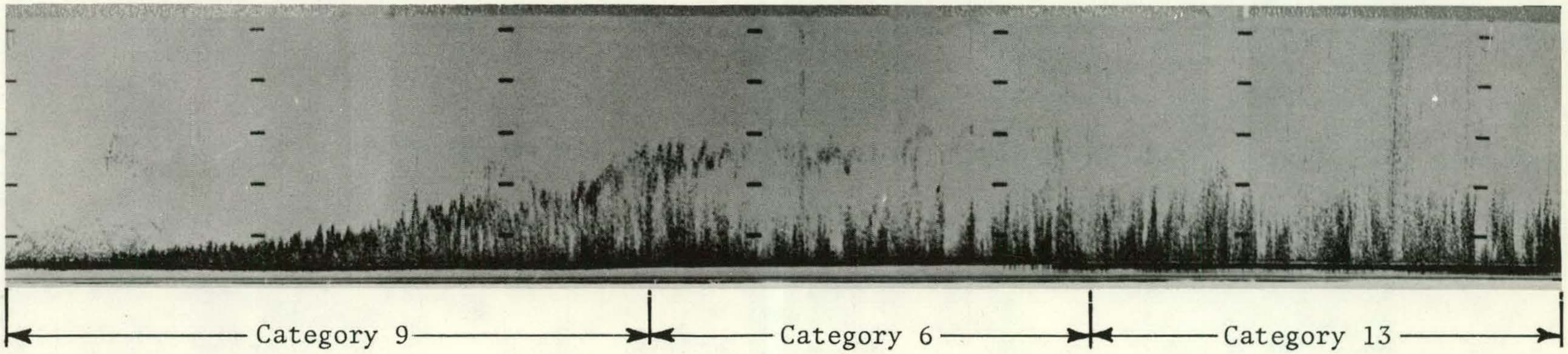

FIGURE 2.

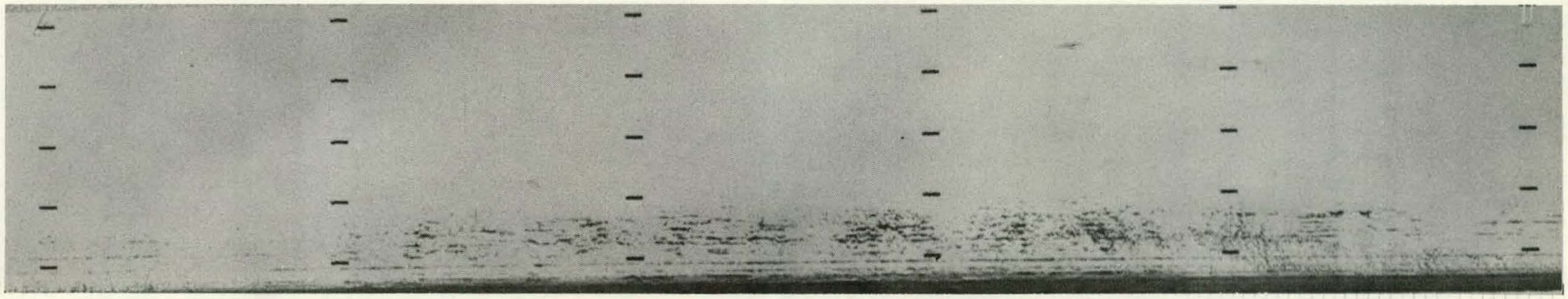

FIGURE 3. Category 14.