AN APPRAISAL ON THE STABILITY OF SURFACE LAYER OF THE ATMOSPHERE BASED ON INTERDISCIPLINARY PANTANAL EXPERIMENT (IPE-1) GRADIENT OBSERVATIONS DATA

K. P. R. Vittal Murty*, Edson P. Marques Filho*, Gannabathula S. S. D. Prasad*, Leonardo Deane de Abreu Sá
Divisão de Ciências Meteorológicas/INPE (murty@met.inpe.br)
Amaury de Souza
Departamento de Física/Universidade Federal do Mato Grosso do Sul (fax: (067)787.3093)
Bart Kruijt
Institute of Ecology and Resource Management /University of Edinburgh

Resumo

A determinação da estabilidade e da instabilidade na camada limite superficial é muito importante, pois ela inibe ou promove a tranferência vertical. Neste artigo, varios índices de estabilidade foram estimados baseados nos dados de observações dos gradientes no Pantanal Matogrossense, obtidos durante o IPE-1. Os vários indicadores são: (1) Ri - o número de Richardson; (2) L - a escala de comprimento de Monin-Obukhov; (3) σ_α - as flutuações na direção do vento; (4) o critério de estabilidade de Pasquill-Gifford. As estimativas mostram que são bons indicadores da estabilidade atmosférica e que há uma concordância entre eles.

Keywords

Micrometeorlogy, Stability Parameters, Pasquill-Gifford, Pantanal.

1 - Introduction

Stability and instability in the atmosphere inhibits or promotes respectively the vertical transport of momentum, heat and water vapour and as such the study on the stability of the atmosphere is very important in both theoretical studies and practical applications.

The surface layer which acts as a buffer zone between the atmosphere and the underlying surface below is characterised by turbulence induced by large vertical gradients of temperature, humidity and wind speed and direction. Hence, the study on stability of the surface layer also assumes an added importance.

Generally and conventionally the stability in the atmosphere is determined by, so called, parcel method. The principle is that a parcel of air moving upwards has to do work against gravity and the energy for this work comes from within and hence assuming a dry surrounding atmosphere and that there is no entrainment of air into the parcel, that is the parcel is not interacting with the surroundings (which is assumed to be an independent entity - adiabatic process) the parcel cools at a fixed adiabatic rate equal to g/c_p or 9.8^{o}C/km. If the ambient atmosphere is having a lapse rate greater than adiabatic the parcel by virtue of it being always lighter than surrounding continues to rise higher up and then the atmosphere is said to be unstable. By similar reasoning the atmosphere is stable if the ambient lapse rate is less than the parcel's adiabatic lapse rate. So, the atmosphere is stable or unstable depending on its lapse rate greather or less than dry adiabatic lapse rate (-9.8^{o}C/km). The atmosphere is neutrally stable if the lapse rate is equal to -9.8^{o}C/km. The conditions change if humidity is taken into consideration. Attempts are

(*) The authors are grateful to CNPq for providing finantial grant.

already made to improve on this concept by introducing humid atmosphere horizontal motion instability by vorticity (hydrodynamic instability) and baroclinic nature of the atmosphere (baroclinic instability)

(Holton, 1992).

However, the stability and instability in surface layer which is dominated by the turbulent forces attracts the attention of scientific workers in the fields of atmospheric sciences and fluid mechanics. The first index was provided by Reynolds number which is a ratio of kinematic and viscous force. But a more realistic index for atmospheric turbulent flows was provided by Richardson number which has taken the thermal forces into consideration and is given by (Kaimal and Finnigan, 1994)

$$Ri_g = \frac{\frac{g}{\bar{\theta}}\frac{\partial \theta}{\partial z}}{\left(\frac{\partial u}{\partial z}\right)^2}$$

Richardson number is a ratio betwen thermal and kinematic forces and the lesser the Richardson number the greater will be the turbulence. Another indicator is Monin- Obukhov length scale given by

$$L = -\frac{v_*^3}{k\frac{g}{\bar{\theta}}\left(\frac{Q_0}{\rho c_p}\right)}$$

where v_* is frictional velocity, k is von Karman constant, g acceleration due to gravity, θ is the temperature in degrees Kelvin, Q_0 is the heat input at the surface, ρ is the density of the atmosphere and c_p is the specific heat at constant pressure.

In neutral conditions of the atmosphere L approches infinity as $\frac{Q_0}{\rho c_p} \to 0$ in stable conditions L is positive and unstable conditions are marked by L being negative, and the intensity of stability or instability increases as L approches zero.

Kepping some applications of surface layer physics in air pollution in view, Pasquill and Gifford developed a detailed scheme of stability and instability indicating by alphabets A to G (Pasquill, 1974; Panofsky and Dutton, 1984). Later σ_α, the standard deviation of wind direction fluctuation was related to Pasquill-Gifford criterion (Blackadar, 1997), which is sketched in Table 1.

Table 1 - Stability classes of Pasquill-Gifford

Stability Classes of Pasquill-Gifford		σ_α
A	extremely unstable	25
B	moderately unstable	20
C	slightly unstable	15
D	neutral	10
E	slightly stable	5
F	moderately stable	2.5
G	strong stable	0

In this paper an attempt is made to study these criterion symultaneonsly based on the data obtained in Interdisciplinary Pantanal Experiment of May 1998 (IPE-1).

The IPE-1 is a part of broad experimental programe to study the weather and climate of central region of Brazil. The data collection campaign was carried out in South Mato Grosso Pantanal in the experimental site in the farm São Bento (19^{o}33S and 53^{o}8W), 1.5km from the Pantanal studies base of UFMS in Passo do Lontra, Miranda, MS. A micro meteorological tower 21m height was installed and a fast response three dimentional sonic anemometer was installed at 25m. The slow response instruments for measurements of wind speed and temperature and humidity were provided at heights 2m, 3.8m, 8.1m, 9.8m, 15.7m, 21.5m.

Ri_g was estimated using the gradient observation 3.8m and 15.7m and 8.1m and 21.5m respectively. The Monin-Obukhov lengh scale and σ_α standard deviation was determined using fast response sonic anemometer.

2 - Results and discussion

Table 2 shows the values of L, Ri_g and σ_α and the corresponding Pasquill-Gifford criterion for the julian day 144. The data clearly points out that there is a good agreement between the Pasquill-Gifford criterion σ_α and Ri_g. L is negative under unstable conditions this also reflected in Ri_g and the large value of σ_α. However there was not a good correspondense between L and σ_α between 2 and 4 a.m.. σ_α shows A class stability but L continues to be large indicating neutral stability at 2:30 a.m. and 3:00 a.m..

Stable class F was dominant in the evening and late night. The unstable casses dominated from 8 to 14 hours. This also indicates that the turbulent diffusion is high in same period.

Table 2 - Surface layer stabilities for the julian day 144.

Horas	Rig1	Rig2	L	σ_α	P-G	Horas	Rig1	Rig2	L	σ_α	P-G
0:00	34,64	98,51	28,46	10,92	D	12:00	-3,24	-7,74	-3,52	27,50	A
0:30	18,39	27,26	19,29	4,59	F	12:30	-4,95	-13,60	-6,00	22,16	B
1:00	6,46	6,09	4,67	5,60	E	13:00	-4,58	-9,59	-16,12	17,37	C
1:30	4,50	4,63	8,27	4,72	F	13:30	-3,15	-10,11	-21,32	16,19	C
2:00	4,81	5,72	7,99	148,10	A	14:00	-3,91	-8,54	-29,39	20,11	B
2:30	9,37	6,16	5,06	58,18	A	14:30	-2,29	-6,92	-48,30	10,20	D
3:00	20,01	9,18	4,46	111,30	A	15:00	-1,09	-7,10	-44,15	11,65	D
3:30	4,95	4,31	41,06	55,21	A	15:30	-1,39	-5,49	-58,15	9,91	E
4:00	2,34	2,77	62,22	23,97	B	16:00	-0,63	-3,78	-26,46	9,20	E
4:30	2,38	2,99	68,60	6,38	E	16:30	1,19	0,06			
5:00	2,20	2,09	40,88	4,24	F	17:00	3,05	3,98	-11,69	7,18	E
5:30	2,85	2,93	39,22	15,35	C	17:30	3,83	2,50	-5,72	4,35	F
6:00	3,95	4,49	33,50	10,78	D	18:00	23,90	4,95	-0,19	4,10	F
6:30	3,74	3,77	81,70	22,16	B	18:30	51,15	8,15	3,52	4,39	F
7:00	2,20	2,47	1327,00	15,92	C	19:00	23,79	5,95	-33,88	4,10	F
7:30	-1,01	-0,45	-488,80	9,71	E	19:30	13,69	8,45			
8:00	0,25	-1,08	-75,15	31,06	A	20:00	24,87	20,43	-14,11	21,07	B
8:30	-0,14	-5,63	-19,15	15,49	C	20:30	7,16	31,15	-8,62	3,04	F
9:00	0,07	-18,58	-30,90	32,11	A	21:00	12,16	50,72	-16,35	11,46	D
9:30	-1,19	-19,10	-9,32	15,48	C	21:30	6,02	10,92	-49,83	4,29	F
10:00	-2,06	-11,18	-1,29	21,03	B	22:00	9,83	10,17	-4,80	9,43	E
10:30	-4,43	-16,84	-19,37	26,22	A	22:30	6,65	5,27	12,16	4,94	F
11:00	-6,36	-14,66	-27,28	18,34	C	23:00	4,79	3,91	-5,02	3,44	F
11:30	-6,25	-12,43	-24,31	18,17	C	23:30	5,28	5,18	2,79	3,92	F

3 - Conclusions

1) L, Ri_g and σ_α and Pasquill-Gifford criterion serve as good indicators of stability and instability of the surface layer;
2) An inter comparision of the above parameters as stability indicators showed that there is a good agrement between them except in the early hours of the day where L showed neutral stability and σ_α shows instability;
3) The instability is between 8 a.m. to 2 p.m. and this is indicated by all the parameters;
4) The night time is dominated by instability class F intersparsed at times by D and E.

4 - Acknowledgement

The authors give thanks for the support received from the Fundação de Amparo à Pesquisa do Estado de São Paulo, FAPESP (proc. nº 98/00105-5) and from the Conselho Nacional de Desenvolvimento Científico e Tecnológico, CNPq (procs. nºs 381.699/97-8, 381.690/97-0, 139.164/96-0).

Acknowledgement is also given to all the people involved in the IPE-1 Project organization and data collecting: Drs. Antônio Ocimar Manzi, Regina Célia dos Santos Alvalá, Clóvis Angeli Sansigolo, Ralf Gielow, Plínio Carlos Alvalá, Clóvis M. do Espirito Santo and Mrs. Paulo Rogério Aquino Arlino, Luis Eduardo Rosa, Celso von Randow, Jorge Martins de Melo, Sabrina B. Monteiro Sambatti, Elizabete Cária Moraes of INPE, Drs. Edson Kassar, Hamilton Germano Pavão, Masao Uetanabaro and Mrs. Carla Muller, Jorge Gonçalves and Waldeir Moreshi Dias of Universidade Federal do Mato Grosso do Sul, Dr. Yadvinder Malhi of University of Edinburgh, Dr. Maria Lúcia Meirelles of EMBRAPA/CPAC, Dr. Romísio Geraldo Bouhid André of UNESP/Jaboticabal.

Special thanks are due also to Dr. Nelson L. Dias of SIMEPAR and Dr. Paulo Henrique Caramori of IAPAR who provided kindly a sonic anemometer and a hygrometer to be used during the IPE-1 campaign.

5 - References

Blackadar, A.K. **Turbulence and Diffusion in the Atmosphere.** Springer, Berlin, 185 p., 1997.

Holton, J. R. **An introduction to dynamic meteorology.** Academic press, 223 p., 1992.

Kaimal, J. C.; Finnigan, J. J. **Atmospheric boudary layer flows - Their structure and measurement.** New York,Oxford University Press, 1994, 289 p..

Panofsky, H. A.; Dutton, J. A. **Atmospheric turbulence. Models and methods for enginneering applications.** Wiley, New York, 397 p .,1984.

Pasquill, F. . **Atmospheric diffusion.** New York, Ellis Horwood Limited, 1974, 429 p..