ON TEMPERATURE AND HUMIDITY OBSERVATIONS AT THE SURFACE OF THE TROPICS

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Accurate knowledge of surface temperature and moisture in the tropics is essential for determining the heights of cloud base and of "parcel" convection as well as for computations of energy exchanges between ground and air. At a fixed surface location total energy variations are conveniently represented by changes in equivalent potential temperature (θ_e). At low altitudes in the humid tropics and at the mean values of potential and of equivalent potential temperature normally observed there, these variations can be calculated to sufficient accuracy from

$$\theta_e' = 1.17 \, (T' + 2.5 \, q'), \qquad (1)$$

where T is surface temperature (°C), q specific humidity (g/kg) and the primes denote deviations from a mean value appropriate to the location.

During the period June-September 1969 an extensive field project was carried out in eastern Venezuela[1]; one major objective was the analysis of cumulonimbus systems and their relation to synoptic scale motions. Radar and rawinsonde observations were made throughout this period on all days with enhanced convection as well as on numerous other days. For specification of surface energy variations a network of 12 stations was installed within a radius of 50 km from the headquarters at Anaco (9½ N, 64½ W). Part of the instrumentation consisted of a properly exposed instrument shelter (thermoscreen) and hygrothermograph with specifications as given in the Appendix. Analyzing the records of the instrument located at Anaco it soon became evident to this writer that the data at times were peculiar. Another station was then installed in close proximity containing an Assman aspirated dry- and wetbulb hygrometer standing free on a large covered veranda adjoining our operations building. The hourly wetbulb readings were checked by sling psychrometer observations made by the participating meteorologists. If an instrument test had been planned or even contemplated, hygrothermographs should have been operated in both locations in addition to the Assman and all instruments compared. As it is, we can only compare the "veranda" data with the observations from the 12-station network on an individual station basis or for all stations combined. The essential point should still be valid.

The problem consisted of the following. During afternoon rainshowers and in the air advected from nearby showers θ_e should at most

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[1] VIMHEX - Venezuelan International Meteorological and Hydrological Experiment, conducted by Colorado State University, the Servicio Meteorologico of the Venezuelan Air Force, the Ministerio de Obras Publicas and the National Center for Atmospheric Research, Boulder, as Manager.

remain constant if falling rain is partly evaporated within the atmosphere. Then, from equation 1, air temperature will drop and specific humidity increase in proportion. If, as will usually be the case, air is dragged down from upper levels with the rain, forming a downdraft, θ_e will normally decrease at the surface, since lower energy air is imported from the low and middle troposphere where an energy minimum exists in the tropical atmosphere (Riehl, 1969)[1]. By no reasoning can one arrive at an increase of surface θ_e; yet this is what the hygrothermograph observations seemed to indicate.

For a definitive assessment of the situation a small statistical study was carried out in post-analysis. At each of the 12 stations of the network and at the veranda the hourly observations were inspected to locate the cases with an increase of relative humidity of 10 percent or greater with one hour. Attention was confined to daytime before 5 p.m. in order to remain clear of problems with evening temperature inversions. Temperature and relative humidity were tabulated at the beginning and end of the hour of increase, and also for one hour thereafter. Then all calculations needed to evaluate equation 1 were performed. Results are given in Table 1 for the mean of all veranda cases and the mean for the 12 stations. Since the individual stations did not differ appreciable from one another, they may be considered jointly.

It is seen that temperature decreased in both records. Specific humidity increased slightly at the veranda and considerably in the first hour in the thermoscreens. This large rise in humidity results in the increase of θ_e for the network. Comparing the frequency

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[1] Riehl, H., Bull. Amer. Meteor. Soc., 50, 587-595, 1969.

distribution of the change in θ_e in the first hour (Table 2), we find that θ_e decreased in 15 percent, remained about constant in 17 percent and increased in 68 percent of the cases at the stations, while it decreased in 69 percent and remained steady in 22 percent at the veranda.

These tables are offered as conclusive proof that the hygrothermograph records are erroneous. It is suggested that the added energy comes from absorption of solar radiation by the thermoscreens and that this heat storage is used to evaporate water in showers. If so, an entirely nonexistent energy source for the atmosphere at large is made available within the thermoscreens. It is recommended to discontinue all such instrumentation in the humid tropics and install instead well ventilated dry- and wetbulb instruments; preferably the ventilation should be kept running continuously.

TABLE 1

Comparison of Veranda and Station Network Surface Energy Values Before, During and After Daytime Showers. Mean Values.

		1 Hour Before	During	1 Hour After
VERANDA				
	T'(°C)	+2.7	-0.9	-1.8
	q'(g/kg)	-0.4	+0.3	+0.1
	θ_e'(°C)	+2.0	-0.2	-1.8
	Number of cases: 32			
NETWORK				
	T'(°C)	+1.5	-0.5	-0.9
	q'(g/kg)	-1.7	+1.7	0
	θ_e'(°C)	-3.4	+4.3	-0.8
	Number of cases: 202			

TABLE 2

Frequency Distribution of Change in θ_e(°C), from One Hour Before Showers to Shower Period, for Veranda and Station Network Data, in Percent

$\Delta\ \theta_e$(°C)	n = 202 Network		n = 32 Veranda	
> -12	1		0	
-8 to -12	4	15	6	69
-3 to -7	10		60	
-2 to +2	17		22	
+3 to +7	22		9	
+8 to +12	14	68	0	9
> +12	15		0	

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APPENDIX

Hygrothermograph: Belfort Instrument Co. No. 5-594. National Weather Service specifications. Thermoshield protection, Bourdon Temperature element. Accuracy of temperature element stated as ± 1F between -20 to + 110F. Humidity element ± 3 percent relative humidity at room temperature. Sensitivity 1 percent at room temperature. Dimension 13 x 6 x 9 inches. Weight 10 lbs.

Instrument shelter (thermoscreen): Belfort Instrument Co. No. 5-970A. National Weather Service specifications. "Cotton Region type". All wood, metal leg support for mounting four feet above ground. Depth 22 in; width 33 in; height 33 in; weight 120 lbs. Flat white paint.