SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 111, NUMBER 12

NOTE ON FOWLE'S SPECTROSCOPIC METHOD FOR THE DETERMINATION OF AQUEOUS VAPOR IN THE ATMOSPHERE

(WITH ONE PLATE)

BY
L. B. ALDRICH
Director, Astrophysical Observatory

(PUBLICATION 3989)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
SEPTEMBER 20, 1949

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

NOTE ON FOWLE'S SPECTROSCOPIC METHOD FOR THE DETERMINATION OF AQUEOUS VAPOR IN THE ATMOSPHERE

By L. B. ALDRICH

Director, Astrophysical Observatory

(With One Plate)

In 1912 F. E. Fowle[1] developed a spectroscopic method for determining the amount of water vapor in a column of atmosphere vertically above the observer. This quantity he called the "precipitable water," and he defined it as "the depth of liquid water which if in the form of vapor would be contained in a column of air of the same cross-section reaching vertically to the limits of the atmosphere."

Fowle's method uses three infrared water-vapor bands, viz, $\rho(\lambda = .935\mu)$, $\phi(\lambda = 1.13\mu)$ and $\psi'(\lambda = 1.47\mu)$. With spectrobolometric energy curves obtained at Washington by passing the radiation from a bank of Nernst glowers through a known quantity of water vapor, he studied the depths of these absorption bands as affected by changes in width of bolometer strip, slit, and other variables. The depths as expressed in the ratio $\frac{\text{deflection at bottom of band}}{\text{deflection at smooth curve above the band}}$ (or in abbreviated form, ρ/ρ_{sc}, ϕ/ϕ_{sc}, and ψ'/ψ'_{sc}) he correlated with known quantities of water vapor in the path of the beam. The amount of water vapor, expressed in centimeters of precipitable water, was determined from the length of path and from wet- and dry-bulb readings taken at many points along the path of the beam. The accuracy of these water-vapor determinations he checked by absorbing with phosphorus pentoxide and calcium chloride the water vapor in known volumes of air along the path. Thus he developed a table giving for standard conditions of definition and purity of the spectrum, as controlled by slit width, bolometer strip width, time of swing of galvanometer, etc., the precipitable water corresponding to given values of ρ/ρ_{sc} and ϕ/ϕ_{sc}. This table has since been extensively used in the solar-constant work of the Astrophysical Observatory, particularly in daily determinations of the short-method function F. (see Ann. Astrophys. Obs., vol. 6, p. 66).

[1] Astrophys. Journ., vol. 35, p. 149, 1912; vol. 37, p. 359, 1913.

In 1947 the Astrophysical Observatory temporarily established at Miami, Fla., a solar field station, to carry out certain radiation measurements under contract with the Office of the Quartermaster

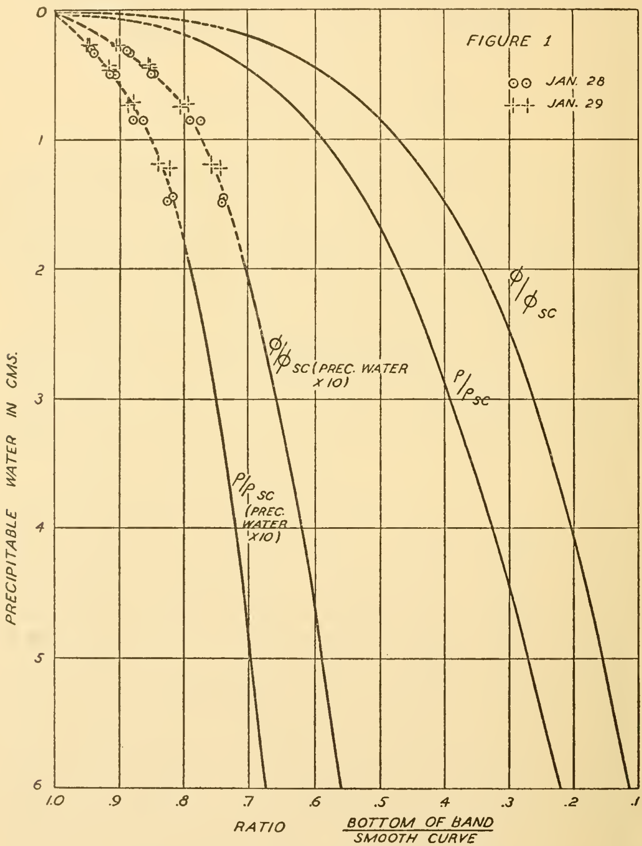


FIG. 1.—Fowle's precipitable-water curves. (See table 1.)

General. These measurements are a part of studies of the causes of deterioration of textiles, and at Miami are conducted in cooperation with the South Florida Test Service and with the General Motors Corporation on whose test field the observations are made. A part of the equipment for this work was brought from Burro Mountain near Tyrone, N. Mex., where for some years the Smithsonian Institution maintained a high-altitude solar station.

The circumstances of a Smithsonian solar field station operating at a wet, sea-level location is unique. The only previous spectrobolometric set-up at sea level was the original Washington equipment of some 40 years ago, which Fowle used in his precipitable-water studies above mentioned. The Miami set-up thus offered opportunity to check the correctness of Fowle's precipitable-water curve.

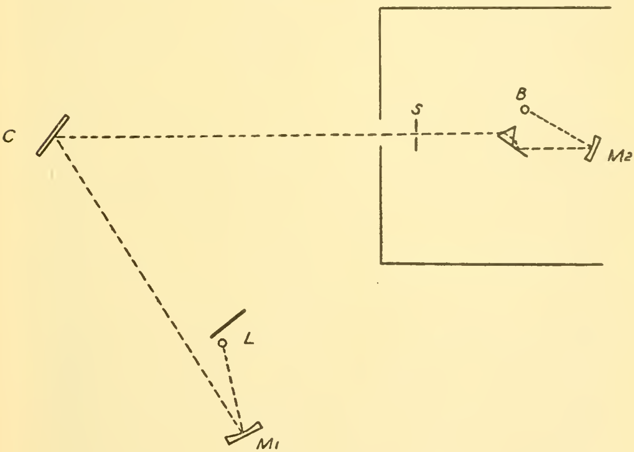


FIG. 2.—Path of beam. *L*, light source; M_1, M_2, concave mirrors, 1-m. focus; *C*, coelostat plane mirror; *S*, slit; *B*, bolometer.

We originally planned to do this in June 1948, at which time of year there is normally a maximum of atmospheric humidity. Unavoidable delays occurred, however, and bolographs were not obtained until January 1949. The following summarizes the work:

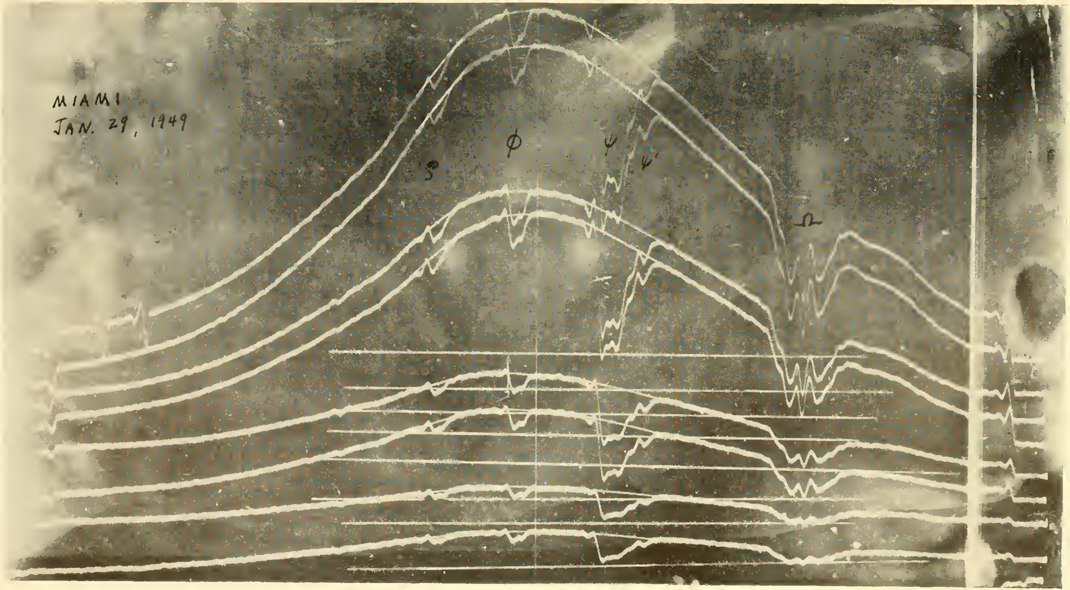
A 500-watt projection lamp was placed in the focus of a 9-inch-diameter aluminized mirror of 1 meter focal length. The assembly was mounted on a movable table in the field adjoining the station building. The approximately parallel beam from the mirror fell upon the second mirror of the coelostat and from there passed through the spectrobolometer, housed in the station building (fig. 2).

In Smithsonian solar-constant observations, standard conditions of slit width, bolometer strip width, and time of swing of the galvanometer suspension are maintained. Effort is made to keep the definition constant, as measured by the depth of the Fraunhofer line "h" ($\lambda = .4102\mu$). The ratio of bottom of this band to the smooth curve over the top is kept at .845. In the bolographs of the present work these standard conditions were fulfilled.

Constancy of the lamp source was assured by the interpolation of an electronic voltage regulator capable of holding the potential across the lamp uniform within 1/10 percent. Bolographs were made on January 28 and 29 for distances lamp source to bolometer strip varying from 19 to 80 meters. Repeated wet- and dry-bulb readings were taken at various positions along the path of the beam both indoors and outdoors, during the time bolographs were being recorded. Hand-aspirated Friez psychrometers were used, checked periodically against a sling-type psychrometer.

Figure 1 gives Fowle's curves for ρ/ρ_{sc} and ϕ/ϕ_{sc}. The dotted lines extend the curves to zero water vapor. The individual points of January 28 and 29 lie on the extended curves within experimental error. Actual deviations from Fowle's values are given in table 2. As would be expected, the deviations are generally larger as the deflections become smaller.

It is gratifying that Fowle's curve appears substantially correct for the water-vapor range here tested. On January 28 the average air temperature was 73° F. and relative humidity 80 percent. On January 29 air temperature was 67° and relative humidity 90 percent.



BOLOGRAPHS OF JANUARY 29, 1949

Table 1.—*Fowle's standard table. Precipitable water vs. depth of band*

(For standard conditions of solar-constant observations: slit width, .3 mm.; time of single swing of galvanometer, 1.4 sec.; ratio of bottom of the Fraunhofer "h" line ($\lambda = .4102\ \mu$) to smooth curve = .845.)

ρ/ρ_{sc}	ϕ/ϕ_{sc}	Precipitable water in cm.	ρ/ρ_{sc}	ϕ/ϕ_{sc}	Precipitable water in cm.
.210	.104	6.34	.510	.381	1.60
.220	.111	6.09	.520	.392	1.51
.230	.119	5.85	.530	.403	1.42
.240	.127	5.62	.540	.414	1.34
.250	.136	5.40	.550	.425	1.26
.260	.145	5.19	.560	.436	1.19
.270	.154	4.99	.570	.448	1.12
.280	.163	4.80	.580	.459	1.05
.290	.172	4.61	.590	.470	.98
.300	.181	4.43	.600	.481	.92
.310	.190	4.25	.610	.493	.87
.320	.200	4.08	.620	.504	.82
.330	.209	3.91	.630	.515	.77
.340	.217	3.75	.640	.526	.72
.350	.226	3.59	.650	.537	.67
.360	.234	3.43	.660	.548	.63
.370	.242	3.28	.670	.560	.59
.380	.251	3.13	.680	.571	.55
.390	.259	2.98	.690	.583	.51
.400	.267	2.84	.700	.594	.47
.410	.276	2.70	.710	.606	.43
.420	.285	2.57	.720	.618	.40
.430	.294	2.44	.730	.630	.37
.440	.304	2.32	.740	.642	.34
.450	.315	2.20	.750	.655	.31
.460	.326	2.09	.760	.667	.28
.470	.337	1.98	.770	.680	.25
.480	.347	1.88	.780	.693	.23
.490	.359	1.78			
.500	.370	1.69			

TABLE 2.—*Summary of January 28 and 29 data*

Date	Total distance source to bolometer (meters)	Maximum deflection (cm.)	Bolograph number	Band	Ratio	Precipitable water by Fowle's curves (cm.)	Observed value (cm.)	Difference
1949								
Jan. 28	19.44	10.80	I	ρ	.939	.032	.032	+ 0
				φ	.889	.032		0
			II	ρ	.936	.034	.032	+.002
				φ	.885	.033		+.001
	30.51	8.28	III	ρ	.905	.052	.050	+.002
				φ	.849	.050		0
			IV	ρ	.912	.048	.050	—.002
				φ	.848	.050		0
	51.81	3.13	V	ρ	.876	.080	.086	—.006
				φ	.776	.096		+.010
			VI	ρ	.867	.086	.087	—.001
				φ	.790	.082		—.005
	79.66	1.36	VII	ρ	.816	.145	.145	0
				φ	.740	.144		.001
			VIII	ρ	.825	.132	.148	—.016
				φ	.740	.144		—.004
Jan. 29	19.44	11.10	I	ρ	.949	.027	.027	0
				φ	.902	.026		—.001
			II	ρ	.947	.0275	.0278	0
				φ	.899	.029		+.001
	30.51	7.23	III	ρ	.916	.046	.045	+.001
				φ	.851	.046		+.001
			IV	ρ	.916	.045	.045	0
				φ	.854	.045		0
	51.81	2.92	V	ρ	.877	.073	.073	0
				φ	.794	.076		+.003
			VI	ρ	.884	.074	.075	—.001
				φ	.802	.074		—.001
	79.66	1.16	VII	ρ	.823	.135	.123	+.012
				φ	.742	.133		+.010
			VIII	ρ	.839	.113	.119	—.006
				φ	.756	.117		—.002
						Total Differences		+.043
								—.046