

No. 158 DAYTIME H₂O MEASURES ON MOUNTAIN SITES

by L. RANDIĆ AND G. P. KUIPER

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ABSTRACT

This paper collects measurements of the precipitable water-vapor content of the overlying atmosphere for selected stations in the Southwest. The amounts are expressed in millimeters, reduced to a pressure of 1 atm. Differential temperature effects are neglected. The measures are based on the 0.935 μ absorption band.

IN connection with the systematic study of mountain sites in the Southwestern United States, suitable for IR observations (cf. *LPL Comm.* No. 142), measures were made of the total H₂O content of the overlying atmosphere, using the sun as a source, whenever opportunities presented themselves. The meter used was constructed by Dr. F. Low and Mr. A. Davidson. It uses a photodiode, sensitive to the near-infrared, powered by a 9-volt battery. The measurements consist of obtaining readings of the solar intensity through two interference filters: one centered on the atmospheric H₂O band at 0.935 μ , the other on the nearby continuum at 0.890 μ . The ratio of the two readings determines the water-vapor absorption.

Dr. Low calibrated the ratio in 1965 and found the relationship as recorded in Table A. He obtained the zero water-vapor reading during high-altitude flights, and calibrated the other tabular values with the aid

of Weather Bureau data obtained in Washington, D.C. (essentially sea level). *The values in Table A*

TABLE A
CALIBRATION OF DR. LOW'S H₂O METER

RATIO 935/890	mm H ₂ O	RATIO 935/890	mm H ₂ O	RATIO 935/890	mm H ₂ O
0.40	11.4	0.60	5.1	0.80	2.0
0.42	10.4	0.62	4.7	0.82	1.8
0.44	9.6	0.64	4.3	0.84	1.7 ⁻
0.46	8.8	0.66	3.9	0.86	1.5
0.48	8.2	0.68	3.6	0.88	1.3
0.50	7.6	0.70	3.3	0.90	1.2
0.52	7.0	0.72	3.0	0.92	1.05 ⁵
0.54	6.5	0.74	2.7	0.94	0.9
0.56	6.0	0.76	2.5	0.96	0.8
0.58	5.5	0.78	2.2 ⁵	0.98	0.7 ⁻
				1.00	0.5
				1.14	0.0

TABLE I - Tucson, Space Sciences Bldg., 2510 ft (765 m), roof or surface(s)

Date	MST	H ₂ O(Sun)	H ₂ O(Zenith)	Mt. L.	Date	MST	H ₂ O(Sun)	H ₂ O(Zenith)	Mt. L.	Date	MST	H ₂ O(Sun)	H ₂ O(Zenith)	Mt. L.			
1969					1970					1970							
Mar 17	8:40	9.7	4.2	1.7	May 13	9:05	7.6	5.3	2.2	June 6	9:35	13.8	10.8	4.4			
28	8:57	7.7	4.2	1.7	10:20	6.4	5.5	2.2	7	10:51	11.6	10.7	4.3	10:22	9.4	8.3	3.4
30	12:27	4.8	4.2	1.7	11:09	6.35	5.9	2.4	8	10:42	10.4	9.5	3.9	11:59	7.7	7.6	3.1
31	9:12	8.6	5.1	2.1	12:00	5.8	5.6	2.3	11:59	7.7	7.6	3.1	14:26	8.0	7.0	2.8	
Apr 14	10:00	4.5	3.5	1.4	14:32	6.95	5.9	2.4	15:16	9.3	7.2	2.9	16:15	11.7	7.3	3.0	
17	9:00	9.3	5.8	2.4	15:35	7.6	4.9	2.0	17:09	15.7	7.1	2.9	15:24	10.2	7.7	3.1	
18	13:09	6.4	5.9	2.4	16:59	10.9	4.85	2.0	9:14	12.8	9.4	3.8	10:10	12.6	10.8	4.4	
18	8:45	8.0	4.7	1.9	9:02	7.7	5.3	2.2	11:09	12.8	12.1	4.9	11:09	12.6	11.8	4.8	
22	9:45	6.6	4.9	2.0	10:06	6.3	5.0	2.0	12:00	12.0	10.2	4.1	13:19	10.6	10.2	4.1	
22	8:30	4.7	2.6	1.1	15:20	6.8	4.7	1.9	14:33	12.25	10.6	4.3	15:24	13.8	10.4	4.2	
23	9:50	3.8	2.9	1.2	16:30	8.7	4.5	1.8	17:09	15.7	7.9	3.2	14:17	8.7	7.8	3.2	
23	8:40	5.6	3.3	1.3	17:24	12.3	7.5	3.0	15:01	8.3	6.7	2.7	15:53	9.3	6.4	2.6	
24	8:55	6.7	4.2	1.7	9:01	10.95	8.0	3.3	11:00	8.4	7.9	3.2	12:00	7.5	7.4	3.0	
25	9:05	5.6	3.7	1.5	10:29	9.1	6.7	2.7	13:27	10.2	9.8	4.0	14:29	9.4	8.2	3.3	
28	8:40	6.9	4.1	1.7	9:16	9.2	7.1	2.9	15:24	13.5	10.1	4.1	15:24	15.7	10.4	4.2	
29	9:00	6.4	4.2	1.7	11:26	7.4	7.1	2.9	16:16	16.7	10.4	4.2	17:08	17.4	8.1	3.3	
May 17	9:00	7.0	4.9	2.0	13:08	6.7	6.4	2.6	10:21	10.5	9.2	3.7	10:21	10.5	9.2	3.7	
1970					1970					1970							
Feb 14	12:16	10.1	7.1	2.9	15:27	6.9	5.0	2.0	11:18	10.5	10.0	4.1	12:50	8.9	8.8	3.6	
15	12:35	6.3	4.5	1.8	9:06	9.3	6.6	2.7	10:37	4.4	4.0	1.6	9:37	4.7	3.7	1.5	
16	13:26	4.7	3.3	1.3	10:04	7.9	6.6	2.7	10:37	4.4	4.0	1.6	11:01	4.1	3.85	1.6	
17	12:07	4.3	3.1	1.3	11:19	7.0	6.6	2.7	11:01	4.1	3.85	1.6	11:54	4.6	4.5	1.8	
19	13:34	4.7	3.4	1.4	12:01	7.3	7.1	2.9	13:40	4.0	3.6	1.5	13:40	4.0	3.3	1.3	
Mar 15	12:34	6.8	5.5	2.2	14:37	9.0	7.6	3.1	14:44	3.9	3.5	1.4	14:44	3.9	3.5	1.4	
16	13:30	4.5	3.6	1.5	15:54	10.55	6.9	2.8	15:29	3.45	2.6	1.1	15:29	3.45	2.6	1.1	
17	12:55	6.0	5.0	2.0	9:02	12.0	8.4	3.4	16:31	6.1	3.5	1.4	16:31	6.1	3.5	1.4	
19	13:34	4.7	3.4	1.4	10:08	10.9	9.3	3.8	17:11	6.6	3.0	1.2	17:11	6.6	3.0	1.2	
Mar 15	12:34	6.8	5.5	2.2	9:15	12.4	9.1	3.7	9:39	4.5	3.6	1.5	9:39	4.5	3.6	1.5	
16	13:30	4.5	3.6	1.5	9:15	12.4	9.1	3.7	10:23	4.6	4.1	1.7	10:23	4.6	4.1	1.7	
17	12:55	6.0	5.0	2.0	10:39	11.3	10.2	4.1	10:52	4.4	4.1	1.7	10:52	4.4	4.1	1.7	
19	13:34	4.7	3.4	1.4	11:24	10.0	9.6	3.9	16:33	5.8	3.3	1.3	16:33	5.8	3.3	1.3	
Mar 15	12:34	6.8	5.5	2.2	12:00	9.5	9.3	3.8	9:09	5.4	3.9	1.6	9:09	5.4	3.9	1.6	
16	13:30	4.5	3.6	1.5	14:03	9.2	8.3	3.4	10:23	4.1	3.6	1.5	10:23	4.1	3.6	1.5	
17	12:07	4.3	3.1	1.3	15:19	7.9	5.9	2.4	11:21	3.7	3.5	1.4	11:21	3.7	3.5	1.4	
19	13:34	4.7	3.4	1.4	16:08	8.6	5.3	2.2	11:58	3.9	3.8	1.5	11:58	3.9	3.8	1.5	
Mar 15	12:34	6.8	5.5	2.2	16:59	9.4	4.3	1.7	14:28	4.9	4.3	1.7	14:28	4.9	4.3	1.7	
16	13:30	4.5	3.6	1.5	9:04	15.5	11.0	4.5	15:18	5.0	3.9	1.6	15:18	5.0	3.9	1.6	
17	12:55	6.0	5.0	2.0	9:59	13.6	11.4	4.6	16:11	5.7	3.7	1.5	16:11	5.7	3.7	1.5	
19	13:34	4.7	3.4	1.4	11:02	12.2	11.4	4.6	17:11	6.6	3.0	1.2	17:11	6.6	3.0	1.2	
Apr 3	12:14	3.8	3.4	1.4	11:58	11.8	11.5	4.7	10:23	4.6	4.1	1.7	10:23	4.6	4.1	1.7	
Apr 11	9:33	9.8	6.8	2.8	13:55	12.9	11.8	4.8	10:52	4.4	4.1	1.7	10:52	4.4	4.1	1.7	
13:24	8.2	7.3	3.0	15:10	14.2	11.0	4.5	16:33	5.8	3.3	1.3	16:33	5.8	3.3	1.3		
15:27	6.7	4.5	1.8	16:11	14.9	9.6	3.9	9:09	5.4	3.9	1.6	9:09	5.4	3.9	1.6		
19	12:00	7.2	6.7	2.7	17:17	14.4	5.9	2.4	11:21	3.7	3.5	1.4	11:21	3.7	3.5	1.4	
22	9:21	5.6	4.0	1.6	8:58	11.1	7.8	3.2	11:58	3.9	3.8	1.5	11:58	3.9	3.8	1.5	
11:22	4.4	4.0	1.6	9:51	9.8	8.0	3.3	14:28	4.9	4.3	1.7	14:28	4.9	4.3	1.7		
13:53	5.1	4.5	1.8	11:04	8.7	8.2	3.3	15:18	5.0	3.9	1.6	15:18	5.0	3.9	1.6		
23	9:05	4.7	3.1	1.3	12:11	8.7	8.55	3.5	16:11	5.7	3.7	1.5	16:11	5.7	3.7	1.5	
24	9:10	4.4	2.9	1.2	12:52	8.7	8.5	3.5	17:11	6.6	3.0	1.2	17:11	6.6	3.0	1.2	
Apr 3	12:14	3.8	3.4	1.4	14:12	8.7	7.8	3.2	10:08	8.35	7.1	2.9	10:08	8.35	7.1	2.9	
Apr 11	9:33	9.8	6.8	2.8	15:10	9.5	7.4	3.0	11:15	7.8	7.5	3.0	11:15	7.8	7.5	3.0	
13:24	8.2	7.3	3.0	17:20	15.9	6.4	2.6	12:04	7.9	7.8	3.2	12:04	7.9	7.8	3.2		
15:27	6.7	4.5	1.8	9:01	9.6	6.8	2.8	13:43	7.4	7.0	2.8	13:43	7.4	7.0	2.8		
19	12:00	7.2	6.7	2.7	9:55	7.5	6.2	2.5	10:16	6.5	5.6	2.3	10:16	6.5	5.6	2.3	
22	9:21	5.6	4.0	1.6	11:12	8.1	7.7	3.1	11:13	6.15	5.9	2.4	11:13	6.15	5.9	2.4	
11:22	4.4	4.0	1.6	11:53	8.2	8.0	3.3	16:02	8.05	5.4	2.2	16:02	8.05	5.4	2.2		
13:53	5.1	4.5	1.8	13:27	6.8	6.5	2.6	17:29	12.4	5.0	2.0	17:29	12.4	5.0	2.0		
23	9:05	4.7	3.1	1.3	15:22	6.75	5.1	2.1	9:12	7.7	5.6	2.3	9:12	7.7	5.6	2.3	
24	9:10	4.4	2.9	1.2	16:32	10.1	5.6	2.3	10:34	6.5	5.8	2.4	10:34	6.5	5.8	2.4	
Apr 3	12:14	3.8	3.4	1.4	14:42	7.6	6.4	2.6	11:28	6.9	6.65	2.7	11:28	6.9	6.65	2.7	
Apr 11	9:33	9.8	6.8	2.8	14:12	8.7	7.8	3.2	12:04	7.9	7.8	3.2	12:04	7.9	7.8	3.2	
13:24	8.2	7.3	3.0	15:10	9.5	7.4	3.0	13:43	7.4	7.0	2.8	13:43	7.4	7.0	2.8		
15:27	6.7	4.5	1.8	17:20	15.9	6.4	2.6	10:16	6.5	5.6	2.3	10:16	6.5	5.6	2.3		
19	12:00	7.2	6.7	2.7	9:01	9.6	6.8	2.8	11:13	6.15	5.9	2.4	11:13	6.15	5.9	2.4	
22	9:21	5.6	4.0	1.6	9:55	7.5	6.2	2.5	16:02	8.05	5.4	2.2	16:02	8.05	5.4	2.2	
11:22	4.4	4.0	1.6	11:12	8.1	7.7	3.1	17:29	12.4	5.0	2.0	17:29	12.4	5.0	2.0		
13:53	5.1	4.5	1.8	11:53	8.2	8.0	3.3	9:12	7.7	5.6	2.3	9:12	7.7	5.6	2.3		
23	9:05	4.7	3.1	1.3	13:27	6.8	6.5	2.6	10:34	6.5	5.8	2.4	10:34	6.5	5.8	2.4	
24	9:10	4.4	2.9	1.2	15:22	6.75	5.1	2.1	11:28	6.9	6.65	2.7	11:28	6.9	6.65	2.7	
Apr 3	12:14	3.8	3.4	1.4	16:32	10.1	5.6	2.3	12:31	7.1	7.0	2.8	12:31	7.1	7.0	2.8	
Apr 11	9:33	9.8	6.8	2.8	14:42	7.6	6.4	2.6	14:22	6.9	6.2	2.5	14:22	6.9	6.2	2.5	
13:24	8.2	7.3	3.0	14:12	8.7	7.8	3.2	9:10	19.1	13.7	5.6	9:10	19.1	13.7	5.6		
15:27	6.7	4.5	1.8	15:10	9.5	7.4	3.0	10:									

TABLE II - Mt. Lemmon Solar Obs., 9100 ft (2770 m)

Date	MST	H ₂ O(Sun)	H ₂ O(Zenith)	Date	MST	H ₂ O(Sun)	H ₂ O(Zenith)
1969				1969			
Mar 17	12:15	2.4	2.0	May 20	12:30	2.9	2.8
18	12:18	2.3	1.9		13:30	2.7	2.5
24	12:23	0.92	.80		14:34	3.0	2.5
25	12:22	0.89	.78	23	10:58	3.4	3.2
28	11:32	1.78	1.5		12:51	3.4	3.3
	12:33	1.85	1.6		12:00	2.7	2.6
	14:32	2.5	1.9	26	11:20	3.9	3.7
29	11:19	3.15	2.6		12:25	3.6	3.6
	12:22	3.25	2.8		13:25	3.6	3.4
	13:52	3.5	2.9		14:20	3.6	3.2
	15:44	4.15	2.4		15:20	4.8	3.7
31	11:55	3.9	3.4	12	10:43	3.5	3.2
Apr 3	11:05	2.3	1.9		11:45	4.0	3.9
	12:10	2.4	2.1	14	12:13	5.1	5.05
	13:15	2.75	2.4		13:17	5.7	5.5
	13:45	2.7	2.3		15:06	5.3	4.2
4	10:35	2.9	2.3	23	12:15	7.3	7.2
	11:30	2.9	2.5		14:25	6.2	5.5
	12:30	3.3	2.9				
	13:30	3.55	3.1	1970			
	14:30	3.9	3.0	Jan 31	12:59	2.2	1.4
5	11:30	2.3	2.0	Feb 2	15:18	1.6	0.8
	12:27	2.4	2.1	8	10:09	3.1	1.7
	13:40	2.9	2.5		11:17	3.2	2.1
	14:34	3.25	2.5	18	11:15	1.1	0.75
14	12:08	1.8	1.65		12:25	1.0	0.7
	12:36	1.7	1.6	Apr 4	10:29	1.8	1.4
	13:29	2.0	1.8		11:34	1.8	1.3
	14:31	2.0	1.6		11:59	1.8	1.4
18	11:07	1.8	1.6		13:08	1.9	1.4
	11:59	1.7	1.6		14:49	2.1	1.5
	13:04	1.8	1.65	5	11:11	1.6	1.4
	13:50	2.4	2.1		12:05	1.6	1.4
	14:09	2.6	2.2		12:51	1.7	1.5
	14:27	2.7	2.2		13:27	2.0	1.7
19	11:38	1.8	1.65		14:50	2.55	1.9
	12:36	2.2	2.05	6	10:41	2.05	1.7
22	11:45	1.2	1.1		10:48	2.2	1.8
	12:25	1.0	0.9		11:28	2.2	1.9
	13:00	1.5	1.4		13:34	2.2	1.9
	13:40	1.6	1.4		14:20	2.8	2.2
	14:50	1.95	1.5		15:00	3.4	2.4
	15:20	2.1	1.5	7	11:30	2.5	2.2
	15:50	2.0	1.25		12:28	2.1	1.9
	16:15	2.25	1.2		13:16	2.0	1.8
23	10:30	1.5	1.3	10	11:27	3.8	3.4
	11:30	1.9	1.7		12:57	4.1	3.7
	12:15	1.85	1.7	21	11:58	1.7	1.6
	13:00	1.8	1.7		13:29	1.7	1.5
	13:49	1.75	1.55		14:24	1.9	1.6
	14:35	1.65	1.3		15:11	1.8	1.3
	15:44	1.7	1.1		15:58	2.6	1.6
24	10:55	1.8	1.6	23	12:11	1.5	1.4
	11:41	2.05	1.9		13:17	1.9	1.8
	12:29	2.3	2.2		14:39	1.7	1.3
	13:15	2.15	2.0		15:50	1.8	1.1
	14:01	2.6	2.3		10:27	1.7	1.4
	14:30	2.6	2.1		11:26	1.8	1.65
	15:00	2.9	2.2		12:51	1.8	1.7
	15:30	3.15	2.1		13:51	2.1	1.85
25	11:00	1.9	1.7		14:15	2.1	1.8
	11:47	1.95	1.8	26	9:55	1.7	1.3
	12:34	2.1	2.0		10:02	1.6	1.3
	12:59	2.1	2.0		10:48	1.9	1.7
	14:04	2.45	2.1		11:50	1.9	1.8
	15:06	2.6	1.9		12:49	1.8	1.7
26	10:40	1.45	1.25		14:00	2.1	1.8
	11:30	1.6	1.5		14:41	2.1	1.7
	12:15	1.7	1.6		15:46	2.5	1.6
	13:00	1.7	1.6		16:14	2.6	1.5
	13:45	1.9	1.7		16:30	3.2	1.6
	14:30	2.15	1.8	May 1	11:56	1.7	1.6
	15:15	2.2	1.6		12:37	1.5	1.4
28	10:49	2.35	2.1		13:27	1.7	1.6
	11:31	2.4	2.2		14:16	1.65	1.51
	12:15	2.3	2.2		15:14	1.5	1.1
	12:59	2.4	2.3		10:04	1.6	1.3
	13:51	2.3	2.1		10:38	1.2	1.1
29	10:30	2.5	2.15		11:05	1.5	1.4
	11:15	2.45	2.25		11:32	1.7	1.6
	12:00	2.5	2.4		12:08	1.7	1.6
	12:55	2.4	2.3		12:37	1.7	1.6
	13:45	2.4	2.15		13:05	1.8	1.7
	14:30	2.45	2.0		13:38	2.1	1.9
	10:59	2.1	1.9		14:06	2.2	1.9
30	13:06	2.3	2.15		14:38	2.3	1.9
	11:44	1.7	1.6		15:04	2.6	2.0
May 1	13:47	3.1	2.8		15:32	2.9	2.0
	10:26	1.55	1.3		15:58	3.2	2.0
2	11:58	2.7	2.6	4	11:14	2.2	2.0
	12:29	2.7	2.6		12:30	2.4	2.3
	13:29	2.6	2.4		13:45	2.6	2.4
	14:34	2.35	2.0		14:28	2.6	2.2
	15:27	2.55	1.8		15:15	2.7	2.0
17	11:15	3.15	3.0		15:50	4.1	2.6
	12:18	3.45	3.35		16:21	4.5	2.5
	13:20	3.55	3.2	14	12:05	3.3	3.2
19	12:07	2.9	2.8		13:08	3.5	3.3
	13:16	3.4	3.2		13:52	3.4	3.1
	14:05	3.1	2.8				
	14:55	3.6	2.9				

TABLE III - Catalina Observatory, 8400 ft (2560 m)

Date	MST	H ₂ O(Sun)	H ₂ O(Zenith)	Date	MST	H ₂ O(Sun)	H ₂ O(Zenith)
1969				1970			
Mar 17	11:39	2.85	2.3	Apr 30	14:40	2.8	2.3
18	11:26	3.15	2.5		15:20	2.9	2.1
24	11:28	1.0	0.8		15:37	3.3	2.2
25	11:34	1.0	0.8	May 8	11:50	3.5	3.4
26	11:46	2.65	2.3		13:15	3.1	2.9
27	11:27	2.6	2.2		13:54	3.0	2.7
Dec 21	13:25	4.9	2.6		14:32	2.8	2.3
23	12:36	6.8	3.8		15:04	5.0	3.8
	13:05	6.7	3.7		15:54	3.3	2.1
24	9:39	4.0	1.5	9	12:30	4.7	4.5
					13:44	4.2	3.8
1970					14:18	4.6	4.0
Jan 13	11:50	3.6	2.1		15:09	4.6	3.5
Jan 16	11:45	9.1	5.3		15:55	5.0	3.2
31	12:29	2.2	1.4	10	11:42	3.6	3.5
Feb 8	13:15	4.0	2.7		13:35	3.6	3.3
18	13:00	2.3	1.7	Apr 29	11:40	1.8	1.7
	12:23	1.9	1.8		12:23	1.8	1.7
	12:27	1.8	1.7		12:27	1.8	1.7
	12:35	1.9	1.8		12:35	1.9	1.8
	12:52	1.8	1.7				

TABLE IV - H₂O Measures from Aircraft
March 7, 1970 (corrected for window)

Location	Elev. (ft)	MST	H ₂ O(Sun)	H ₂ O(Zenith)
Tucson Airport	2540	11:14	7.6	5.6
S. of Catalinas	8200	11:38	2.0	1.5
near Mt. Lemmon	10000	11:55	1.5	1.2
	12000	12:04	1.2	0.9
near Graham Mt.	12000	12:26	1.2	0.9
S. of Graham Mt.	12000	12:34	1.3	1.0
	13200	12:41	1.1	0.9
	13500	12:42	0.8	0.7
N. of Huachuca Mts.	14000	12:44	0.8	0.6
near Miller Peak	12000	12:53	1.1	0.9
Tucson Airport	2540	13:36	6.4	4.9

Scale height derived from ratio Airport/14,000 ft, H = 2.18

TABLE V - Mt. Palomar, elev. 5,600 ft (1710 m)

Date	PST	H ₂ O(Sun)	H ₂ O(Zenith)	Date	PST	H ₂ O(Sun)	H ₂ O(Zenith)
1970				1970			
April 13	9:47	6.1	4.8	May 23	9:37	5.95	5.1
	10:29	5.5	4.2		10:12	6.95	6.35
14	11:17	2.1	1.8		10:44	7.75	7.35
	12:05	2.2	2.0		11:11	6.8	6.6
	13:03	2.0	1.8		13:50	7.3	6.3
	14:23	1.75	1.5		13:52	7.45	6.4
	16:03	3.2	2.0		15:28	8.0	4.95
15	9:19	2.2	1.65		16:20	10.4	4.9
	11:02	2.05	1.7	24	8:18	6.4	3.2
	12:02	3.4	3.1		9:51	5.65	4.3
May 21	13:03	4.3	4.0		11:09	5.5	5.3
	14:28	5.6	4.4		11:54	5.5	5.4
22	8:18	4.7	3.2		12:02	5.9	5.85
	9:22	4.2	3.5		13:23	6.4	5.8
	10:37	4.5	4.2		13:33	7.0	6.2
	11:54	4.7	4.6		13:35	7.6	6.7
	12:18	4.9	4.8		13:43	7.5	6.5
	13:37	7.1	6.2		14:48	8.0	5.9
	14:51	8.1	5.9		15:40	8.65	6.0
	16:43	12.3	4.9		17:09	11.9	3.7

TABLE VI - Mauna Kea, Hawaii, elev. 13,800 ft (4200 m)

Date	HST	H ₂ O(Sun)	H ₂ O(Zenith)
1970			
June 25	10:33	1.3	1.2
	11:35	1.3	1.3
	11:38	1.2	1.2
26	9:55	1.7	1.4
	9:57	1.7	1.4
	10:25	1.8	1.6
	11:52	1.15	1.1
	12:39	1.3	1.3

therefore refer to equivalent amounts of water vapor for $p = 1$ atm.

In *Communication* No. 159 a new calibration of Dr. Low's device is published. Such a calibration was desirable after the meter had been used for several years and also because some doubts had arisen regarding the calibration from observations made at another observatory. Since the new tests have essentially confirmed Dr. Low's original calibration, we are using here his original Table A for the conversion of the measured ratios to equivalent amounts of precipitable water at $p = 1$ atm. If measures are made at, e.g., 500 mb, the actual amounts will be about twice the tabular values, since for moderately-strong absorption bands (such as the 0.935μ band used) the integrated absorption is proportional to \sqrt{pW} , in which p is the pressure and W precip. H_2O .

Table I contains the measures made on the roof of the Space Sciences Building, University of Arizona. Since under normal clear weather conditions the scale height of water vapor in the lower troposphere averages about 2.2 km, the Tucson measures should give a fair indication of the values on nearby Mt. Lemmon. As indicated in the footnote to Table I, we have entered computed Mt. Lemmon values by division of the Tucson zenith values by 2.46. However, it must be noted that this ratio cannot be strictly constant during the day because of sun-induced convection both over the Valley and over Mt. Lemmon.

The data in Tables I and III are considered representative of springtime conditions in Southern Arizona. They refer to days when the sun could be observed (85% of the time, approx.). In wintertime, occasionally much lower values will occur.

Of the mountain sites, the measures made on Mt. Lemmon (Table II) are the most numerous. Most of these were made incidental to the solar IR spectral observations during the springs of 1969 and 1970. The solar spectrometer was located some 60 ft. below the summit and local snow deposits, sometimes melting, will often have increased the water-vapor readings. The presence of near-saturation of the boundary layer was considered in *LPL Comm.* No. 142. For the reasons there stated, it is estimated that nighttime water-vapor amounts will be less than the daytime readings by a factor of 1.3–1.5.

For comparison with *LPL Comm.* No. 142, Table I, the 25 percentiles for the different stations found from the above daytime observations are: Mt. Lemmon (from Tucson measures), February–April,

1.4 mm; May–June 15, 2.0 mm; from direct measures, February–April, 1.5 mm, May–June 15, 1.9 mm. Catalina Obs., 1.9 mm, Mt. Palomar, 3.3 mm. *The springtime conditions here covered are probably representative; no good winter coverage is yet available.*

The springtime data confirm in a general way the radio-sonde data of *LPL Comm.* No. 142. Supplementary information on Mt. Shasta is given in *LPL Comm.* No. 156.

Acknowledgments — We are indebted to Dr. F. Low for having made his instrument available for extended periods and for providing the original calibration. Most of the 1969 Mt. Lemmon measures were made by Mr. L. Bijl concurrently with his IR solar spectral observations. Mr. C. Benner assisted in the reductions to unit air mass. The planetary program is supported by NASA Grant NGL 03-002-002.

ADDENDUM

January 8, 1971

This Addendum contains supplementary measures of the atmospheric water-vapor content covering fall and early winter conditions. The arrangement of the Tables is the same as in the main body of the paper: Table IA, listing measures made from the roof of the Space Sciences Building in Tucson; Table IIA, measures made from Mt. Lemmon; and Table IIIA, from the Catalina Observatory. Attention is called to the occurrence of quite low humidities at times: October 8, 26–31, November 15–16, 23–25, December 11–12, January 4–7, etc.

TABLE IIA - Mt. Lemmon Solar Obs.

Date	MST	H ₂ O(Sun)	H ₂ O(Zenith)
1970			
Sep 22	11:43	1.3	1.1
	12:43	1.5	1.3
	11:15	2.1	1.7
25	11:20	2.2	1.8
	11:40	2.3	1.9
	12:03	2.7	2.3
	12:20	2.6	2.2
	12:29	2.3	1.9
	12:52	2.8	2.3
	13:15	2.9	2.3
	13:25	3.0	2.4
Oct 12	14:52	5.1	2.9
26	14:08	1.2	0.7
	14:33	1.3	0.7
Nov 2	14:00	4.5	2.6
8	14:08	2.1	1.2
	14:14	2.1	1.2
9	14:20	2.6	1.4
16	13:25	2.3	1.3
	13:47	2.4	1.4
23	14:30	5.4	2.7
24	12:33	3.05	1.8
	14:12	3.4	1.7
Dec 7	13:50	3.7	1.9
12	14:00	1.9	0.95
	16:13	5.5	1.05
1971			
Jan 4	15:40	1.5	0.5
18	15:00	6.5	3.0
25	14:45	2.8	1.6
26	16:21	3.2	0.8
30	16:29	2.0	0.5

TABLE IIIA - Catalina Observatory

Date	MST	H ₂ O(Sun)	H ₂ O(Zenith)
1970			
Sep 25	10:45	1.7	1.3
	14:20	3.5	2.5
26	15:21	3.3	1.9
Oct 12	13:05	4.3	3.2
	13:50	4.9	3.4
	13:57	5.1	3.4
21	13:34	5.2	3.5
24	13:40	5.0	3.2
26	12:54	1.1	0.75
	13:34	1.3	0.8
	15:14	1.8	0.8
30	12:19	2.7	1.9
	12:23	2.7	1.9
	13:08	2.8	1.9
	14:50	3.6	1.8
Nov 2	12:51	3.7	2.5
8	12:28	2.4	1.6
	12:35	2.6	1.7
9	12:50	2.3	1.5
11	13:39	2.0	1.1
	15:15	2.9	1.1
16	12:22	2.2	1.4
21	14:58	3.8	1.5
	15:02	3.5	1.4
23	12:50	4.8	2.8
Dec 7	13:00	3.3	1.9
1971			
Jan 4	14:15	1.2	0.6
18	13:55	5.4	3.3
25	13:30	2.4	1.5
26	14:00	2.6	1.5
30	14:31	1.5	0.8
	15:51	1.8	0.7
31	11:43	1.5	0.95
	11:52	1.4	0.9

DAYTIME H₂O MEASURES ON MOUNTAIN SITES

TABLE IA - Tucson, Space Sciences Bldg.

Date	MST	H ₂ O(Sun)	H ₂ O(Zenith)	Mt.L.*	Date	MST	H ₂ O(Sun)	H ₂ O(Zenith)	Mt.L.*	Date	MST	H ₂ O(Sun)	H ₂ O(Zenith)	Mt.L.*
1970					1970					1970				
Sep 15	9:07	10.4	6.2	2.5	Oct 20	9:00	17.4	8.1	3.3	Dec 6	12:18	9.2 s	5.3	2.2
	11:17	7.8	6.6	2.7		10:44	13.1	8.9	3.6		9:19	12.7	4.7	1.9
	11:58	6.3	5.5	2.2		11:57	12.0	8.8	3.6		10:14	9.3	4.6	1.9
	13:21	7.8	6.6	2.7		13:51	13.9	9.1	3.7		8 9:05	11.5	3.8	1.5
	15:45	13.8	7.6	3.1		15:02	15.6	7.9	3.2		10 9:02	17.2	5.6	2.3
	16:57	18.4	5.9	2.4		21 9:15	13.6	6.8	2.8		14:03	10.0	5.0	2.0
16	9:02	9.9	5.7	2.3		22 11:42	11.1	8.0	3.3		11 9:01	5.6	1.7	0.7
	10:07	7.6	5.6	2.3		14:03	13.9	8.6	3.5		10:40	3.5	1.8	0.7
	11:11	6.75	5.6	2.3		16:20	25.3	6.9	2.8		11:56	3.1	1.8	0.7
	11:53	6.6	5.7	2.3		23 8:58	13.8	6.3	2.6		14:00	3.4	1.7	0.7
	14:13	7.8	6.0	2.4		10:34	8.7	5.7	2.3		16:15	8.1	1.5	0.6
	15:14	10.4	6.6	2.7		15:54	8.6	6.2	2.5		9:17	5.2	1.8	0.7
	16:10	12.6	6.0	2.4		13:59	11.6	7.3	3.0		10:27	4.3	2.1	0.9
	17:06	18.3	5.3	2.2		16:08	19.2	5.9	2.4		11:46	4.0	2.3	0.9
17	9:18	12.6	7.8	3.2		24 10:27	11.6	7.4	3.0		13 10:56	9.5 s	5.0	2.0
	9:02	19.8	11.3	4.6		11:44	11.4	8.1	3.3		12:07	8.8 s	5.1	2.1
18	10:18	17.1	12.8	5.2		26 9:35	5.8	5.1	1.3		15 10:34	9.8	4.9	2.0
	11:15	15.9	13.2	5.4		10:26	5.0 s	5.1	1.3		11:56	8.6	4.9	2.0
	14:01	16.9	13.1	5.3		9:56	5.4	1.9	0.8		13:54	9.0	4.6	1.9
	16:07	24.4	11.5	4.7		11:00	2.9	1.9	0.8		15:59	17.1	4.1	1.7
19	8:51	22.8	12.3	5.0		11:59	3.1	2.2	0.9		16 9:09	10.5	3.3	1.3
	10:05	19.1	13.7	5.6		14:12	3.5	2.1	0.9		10:46	6.8	3.5	1.4
	12:01	16.7	14.3	5.8		28 9:03	3.9	1.8	0.7		11:58	6.2	3.6	1.5
21	9:04	20.6	11.7	4.8		10:27	2.8	1.8	0.7		14:29	7.4	3.4	1.3
	11:00	16.3	13.1	5.3		11:36	2.7	1.9	0.8		16:27	16.0	2.9	1.2
	11:56	16.4	13.9	5.3		15:37	4.6	1.7	0.7		8:59	11.0	3.2	1.3
	14:04	19.3	14.7	6.0		17:02	13.8	1.6	0.7		10:34	6.8	3.4	1.4
	15:27	19.1	11.0	4.5		29 9:01	6.2	2.8	1.1		11:55	6.4	3.7	1.5
	17:14	31.4	7.4	3.0		10:39	4.9	3.2	1.3		13:59	7.4	3.7	1.5
22	9:01	11.2	6.3	2.6		12:02	5.1	3.5	1.4		15:42	13.8	3.7	1.5
	8:56	10.7	5.8	2.4		13:52	5.8	3.5	1.4		18 14:56	14.0	5.1	2.1
	10:25	7.9	5.9	2.4		30 9:23	6.5	3.2	1.3		19 9:30	14.6	5.4	2.2
	12:00	7.0	5.9	2.4		16:31	17.3	3.1	1.3		21 16:22	23.3	4.1	1.7
	14:10	9.2	6.8	2.8		31 10:04	5.5	3.2	1.3		23 9:40	10.2	3.9	1.6
	16:02	13.0	6.0	2.5		11:14	5.4	3.6	1.5		10:55	7.6	3.9	1.6
	17:15	22.3	6.9	2.0							11:57	6.7	3.8	1.5
24	8:59	9.2	5.0	2.0	Nov 1	12:44	6.1 s	4.2	1.7		14:24	7.3	3.4	1.4
	10:59	6.3	5.0	2.0		13:49	7.9 s	4.8	2.0		16:28	17.7	2.8	1.1
	12:01	5.8	4.9	2.0	2	9:22	6.9	3.4	1.4		30 9:58	10.9	4.1	1.7
	13:31	5.4	4.3	1.7		10:52	5.8	3.7	1.5		11:05	7.7	4.0	1.6
	17:43	28.6	3.3	1.3	3	10:50	8.5	3.3	1.4		12:04	7.8	4.5	1.8
25	8:58	8.4	4.6	1.9		12:30	8.0	5.5	2.2		13:54	8.5	4.3	1.7
	16:58	14.0	3.8	1.5	4	15:34	13.1	4.7	1.9		15:13	11.7	4.4	1.8
26	9:33	13.8	8.7	3.5		4 11:50	8.8	6.0	2.4		16:05	17.5	4.4	1.8
	11:19	9.7	7.8	3.2		14:31	10.2	5.3	2.2					
	11:58	9.6	8.0	3.3	5	9:22	16.0	7.9	3.2					
27	12:36	8.6 s	7.1	2.9		11:54	12.3	8.4	3.4		1971			
28	15:34	21.9	11.4	4.6		13:59	14.1	8.1	3.3	Jan 2	10:32	9.3 s	4.5	1.8
29	9:00	19.8	10.6	4.3		16:13	26.7	6.5	2.6	3	12:25	3.3 s	1.9	0.8
	10:15	16.3	11.6	4.7	6	9:11	16.8	7.9	3.2		13:22	3.2 s	1.8	0.7
	11:15	14.8	11.7	4.8		10:39	13.2	8.3	3.4		14:58	4.4 s	1.9	0.8
	12:00	14.4	11.8	4.8		11:55	12.6	8.6	3.5	4	9:54	4.6	1.9	0.8
	13:45	15.5	11.7	4.8		13:44	13.8	8.2	3.3		10:04	4.3	1.9	0.8
	15:17	18.9	10.7	4.3		15:54	22.3	6.5	2.6		10:35	3.9	1.9	0.8
30	9:03	19.5	10.5	4.3		8 11:03	7.1 s	4.5	1.8		10:41	3.8	1.9	0.8
	10:19	16.5	11.8	4.8	9	9:14	7.5	3.3	1.3	5	10:19	4.5	1.9	0.8
	11:59	15.0	12.2	5.0		10:04	6.0	3.4	1.4		10:27	4.2	2.0	0.9
					10	9:15	9.0	4.0	1.6		11:45	3.9	2.2	0.9
Oct 1	9:08	18.6	10.3	4.2		11:51	6.6	4.3	1.7		11:52	3.5	2.0	0.8
	10:34	15.1	11.1	4.5		11:51	6.6	4.3	1.7		13:58	3.5	1.8	0.7
	11:54	14.5	11.7	4.8	11	13:55	7.7	4.3	1.7		14:08	3.4	1.7	0.7
4	12:40	14.0 s	11.1	4.5		11:50	6.9	3.5	1.4		15:41	6.7	2.1	0.9
	9:12	15.1	8.3	3.4	13	11:21	5.2	3.3	1.3		15:54	7.4	2.0	0.8
	10:03	12.7	8.5	3.5		9:28	8.8	4.1	1.7		16:43	12.1	1.7	0.7
	11:30	20.3	8.0	3.3		10:57	6.3	3.8	1.5		16:50	13.9	1.7	0.7
	11:59	9.8	7.8	3.2		11:57	5.8	3.7	1.5	6	8:57	6.3	1.7	0.7
	14:13	13.3	9.1	3.7		13:49	6.6	3.7	1.5		9:04	5.6	1.5	0.6
	15:35	16.3	7.9	3.2		15:42	11.5	3.6	1.5		10:42	3.3	1.7	0.7
	16:41	25.3	7.1	2.9		16:22	15.1	2.9	1.2		10:50	3.1	1.6	0.7
7	10:08	11.4	7.6	3.1		14 11:04	7.7	4.7	1.9		11:51	5.0	1.7	0.7
	11:08	8.6	6.5	2.6		15 12:19	4.1 s	4.3	1.7		12:01	2.8	1.6	0.7
	11:58	8.8	6.8	2.8		16 9:13	5.5	2.3	0.9		15:35	3.0	1.6	0.7
	14:18	9.8	6.5	2.7		10:15	4.2	2.2	0.9	7	9:10	5.6	1.7	0.7
	15:20	12.9	6.7	2.7		17:01	23.3	1.6	0.7		10:40	3.6	1.8	0.7
8	9:02	5.1	2.6	1.1		17 9:04	8.4	3.2	1.3		10:48	3.4	1.8	0.7
	10:30	4.3	3.0	1.2		11:06	6.1	3.7	1.5		11:54	3.1	1.8	0.7
	11:57	4.3	3.4	1.4		11:58	5.6	3.6	1.5		12:00	2.9	1.7	0.7
	14:10	5.7	3.8	1.5		14:02	6.6	3.4	1.4		14:51	5.6	1.6	0.7
	15:49	8.9	3.8	1.5		15:50	11.4	1.4	1.3		14:59	3.7	1.6	0.7
9	8:59	7.4	3.7	1.5		18 9:01	11.0	4.1	1.7		16:49	11.8	1.5	0.6
	9:59	6.1	3.0	1.1		13:59	7.3	3.9	1.6		16:57	13.0	1.4	0.6
	10:55	5.5	4.0	1.6		16:29	18.7	2.9	1.2	8	9:18	7.5	2.5	1.0
	11:56	5.3	4.1	1.7		19 9:02	8.8	3.2	1.3		9:25	7.1	2.5	1.0
	13:59	5.6	3.9	1.6		10:36	6.2	3.5	1.4		10:48	5.2	2.7	1.1
	15:21	7.7	3.9	1.6		11:58	5.5	3.5	1.4		10:55	5.1	2.7	1.1
	16:39	12.7	3.4	1.4		14:18	6.9	3.4	1.4		11:52	4.5	2.6	1.1
10	10:04	7.9	5.1											