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OBSERVING THE SUN AT 19,300 FEET ALTITUDE, MOUNT AUNCONQUILCHA, CHILE

BY
C. P. BUTLER



(PUBLICATION 3379)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
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OBSERVING THE SUN AT 19,300 FEET ALTITUDE, MOUNT AUNCONQUILCHA, CHILE

By C. P. BUTLER.

If solar observations could be made on the moon, the readings of a silver-disk pyrheliometer alone would give us the solar constant. Since this is impossible, we may approximate the solar constant by making radiation measurements at different altitudes. The highest observations made heretofore with the silver-disk pyrheliometer were those taken by Dr. C. G. Abbot on Mount Whitney, 14,500 feet.

I was invited by the International High Altitude Expedition to join them at their highest station for the purpose of making solar observations. Their object was to measure the effects of extreme high altitudes on the human body mainly through the analysis of blood taken from the men at different altitudes. All the experiments were made in northern Chile, culminating on Mount Aunconquilcha.

Ollague is a small town on the frontier between Chile and Bolivia, situated on a great level altiplano stretching many miles from the sulfur peaks. The terrain is broken into rough hummocks of salt incrustations, with here and there small salt-water marshes. It was here that the expedition kept the four railway cars which housed their heavier instruments.

I stayed the first night in one of the sleeping cars in Ollague, and the next morning I left by motor truck for the Quilcha Camp where most of the men were stationed. The truck was filled with a heterogeneous load of bundles, trunks, beds and bedding, and tools, and its passengers included 12 miners and 2 women. On top of the load were precariously perched the pyrheliometers and the theodolite, with the assurance of one of the men that he would look after it. With the load nearly double the truck's capacity and the bad curves in the road, it seemed to me that every sway would pitch some boxes off. However, nothing happened to the instruments—just to my nerves.

The Quilcha Camp is located at an altitude of 17,400 feet and is said to be the highest permanent human settlement in the world. The word "permanent" must not be taken too seriously, however, because the men and women who live here suffer from diseases peculiar

to the altitude, and consequently the population continuously shifts. Only high wages induce the men to live here, and as a rule they stay only a few weeks, after which, with a little money, they leave for the lower altitudes. Many of the men take their families with them, but so far as is known no woman has given birth to a child at this altitude. Most of the children in the camp were born in Ollague (12,000 ft.).

The day after my arrival in camp, I set up the pyrheliometers and ran a long series of observations here. The sky was very clear, with only a few wisps of cirri visible. On my second day in camp I made arrangements to go on up to the mine. Mules were available, and with the help of one of the guides I got all the instruments roped on one of the mules. We rode all the way to the top, and even with the loads and our constant prodding the mules did not seem to suffer from the height. Horses become so nervous that they cannot be used here.

We arrived at the sulfur mine at about 10 o'clock in the morning, and there I found two boys to help me carry the instruments to the top of the mine. There were no boxes or tables available to hold the pyrheliometers, so I chose a ledge of ice covered with sulfur. Little blocks of yellow sulfur served nicely to level up the legs of the pyrheliometers. Below this was a sloping ledge of clear ice on which I stood. I set up the theodolite on the ice; the only trouble encountered was that the ice would melt under the legs, and the instrument had to be releveled each time a reading was taken. This was due partly to the weight and partly to the fact that the brass points on the legs were black and served as very good absorbers of the sun's rays. Fortunately the sky here also was very clear, and there was no wind during the observing.

All readings were made with a stop watch whose second hand had an eccentricity of less than $\frac{1}{3}$ second as tested with a standard pendulum used in our regular observations. A sun reflector was attached to the back of the telescope for the solar altitudes. The constants of pyrheliometers No. 29 and No. 30 were determined before and after the trip. The silver disks were not touched during the journey. Before each set of observations the three screws holding the silver disks were loosened; after the observations they were again tightened. No severe jar or bump was given the pyrheliometers throughout the trip. On the return from the mine the theodolite box fell off the mule, but before it could roll down the mountain, the muleteer jumped from his mule and caught it. Fortunately no harm was done.

The results of the instrumental data were not apparent to the senses. At the mine even during the middle of the day the temperature hardly rose above freezing, even though Aunconquilcha is nearly 200 miles

north of the Tropic of Capricorn. We all wore heavy clothing, stocking caps, mittens, and heavy shoes. Despite the cold, one burned severely in a few hours without the protection of a sunshade. The natives are ordinarily a light brown color, but the men who work the mine were burned almost black. The data show that the amount of

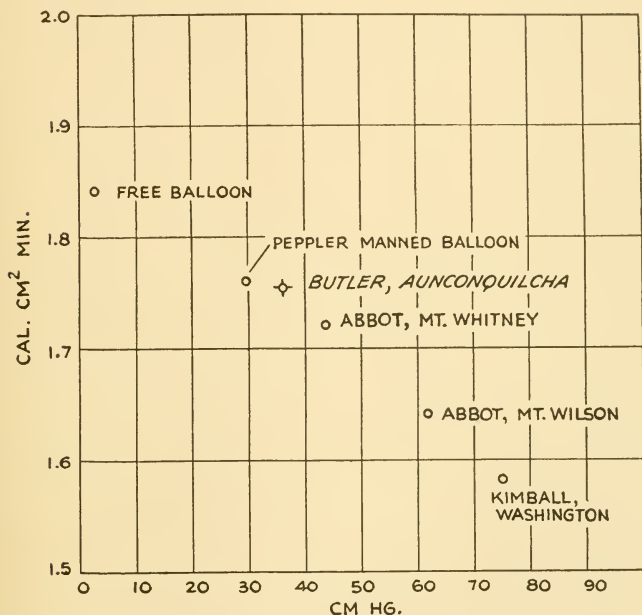


FIG. 1.—Pyrheliometry at high altitudes.

solar radiation here is greater than ever experienced at sea level, but the only way this could be felt was in a feverish feeling about the nose, cheeks, and neck.

At air-mass 1.40 the pyrheliometers gave a mean value of 1.663 calories per square centimeter per minute. A reduction of this to what it would be at vertical sun and at the earth's mean distance from the sun becomes 1.753 and shows that the value lies nearly in line with the plot in figure 58 in the *Annals of the Astrophysical Observatory*, volume 4.

Summary of the Readings Taken on the Aunconquilcha Expedition.

July 4, 1935		July 5, 1935	
Mine Camp, 17,400 feet.		Aunconquilcha, 19,300 feet	
m	Pyrh.	m	Pyrh.
1.79	4.338	1.46	4.555
1.79	4.367	1.46	4.555
1.77	4.371	1.45	4.509
1.76	4.464	1.45	4.565
1.74	4.355	1.43	4.528
1.74	4.401	1.43	4.557
1.72	4.395	1.43	4.606
1.71	4.389	1.42	4.611
1.57	4.485	1.41	4.533
1.56	4.431	1.41	4.582
1.55	4.476	1.41	4.599
1.55	4.468	1.41	4.644
1.54	4.415	1.40	4.596
1.53	4.428	1.40	4.608
1.52	4.443	1.39	4.532
1.52	4.425	1.39	4.543
1.42	4.453	1.39	4.586
1.41	4.511	1.39	4.620
		1.40	4.529
1.97	4.217	1.40	4.593
1.98	4.301	1.40	4.580
2.01	4.226	1.40	4.627
2.02	4.317		
2.05	4.283		
2.06	4.284	Pyrheliometer Constant (.3629)	
2.09	4.190		
2.10	4.245		

In order to obtain the value of the solar radiation at air-mass 1, a comparison of the slopes of the pyrheliometer at Montezuma, the Mine Camp, and at Aunconquilcha was made. Owing to the sun's declination, air-mass 1.39 was the lowest possible at this time of the year.