A History of the Zurich and American Relative Sunspot Number Indices

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Based on a paper presented at the 89th Annual Meeting of the AAVSO, October 28, 2000; revised July 2001

[Ed. note: We are sad to report that Casper Hossfield died on November 26, 2002, at the age of 84. Cap was an AAVSO member for 40 years. He was Chair of the Solar Division from 1963 to 1979, and was—for the past 3 years—the Editor of the Sudden Ionospheric Disturbances Supplement *of the* AAVSO Solar Bulletin. *An obituary will appear in a future issue of this journal. At the time of his death Cap was preparing this article for publication in the* AAVSO Journal. *We publish it now as a tribute to his many years of service and dedication to the AAVSO.]*

Abstract I trace the 133-year history of the Zurich Relative Sunspot Number Index, R_Z, from its beginning in 1848 through to 1981 when the index was terminated. I also trace the history of the American Relative Sunspot Number Index, R_A, from when it was first set to the Zurich scale in 1944 through to the present.

1. Introduction

Reliable and authoritative information on the history of the Zurich Relative Sunspot Number Index can be found in the 5-page introduction to Professor Max Waldmeier's book (Waldmeier 1961) and summarized as follows: In 1842 Rudolf Wolf, using an 80-mm refractor with magnification of 64×, initiated the Zurich index using the reduction formula, $R = k\,(10\,g + f)$, where R is the relative number, k is a scale factor, g is the number of groups, and f is the number of spots, thus defining the scale of the Zurich index. Waldmeier further describes Wolf's method of counting thusly:

> Wolf put for his countings, $k = 1$, fixing so the scale of the sunspot-relative-numbers. According to his own definition, Wolf counted each spot—independent of its size—but single. Moreover, he did not consider very small spots which are visible only if the seeing is good. In about 1882 Wolf's successors changed the counting-method, which since then has been in use up to the present. This new method counts also the smallest spots, and those with a penumbra are weighted according to their size and the structure of the umbra. From parallel observations with the old and the new method a factor $k = 0.60$ resulted for the reduction of the new records to the values obtained by Wolf. This factor has been kept constant over generations, as by each predecessor and successor in the directorship of the Swiss Federal Observatory parallel observations, which lasted for years, were carried out. Thus the author, who has made

> countings since 1936, still determines [in 1961] the sunspot-relative-number with the factor $k = 0.60$.

From the above quotation it is apparent there are two Zurich indices, an old and a new one. For the purpose of this paper I will call the old index the Wolf index and the new one that commenced in 1882, the Zurich index. Furthermore, Wolf numbers, groups, spots, and counts are understood to be made according to Wolf's system of counting and Zurich numbers, groups, spots, and counts according the new system of counting used by Wolf's successors up to and including Waldmeier. Additional important facts pertinent to this paper that can be found in Waldmeier's introduction to his book are the following: a) Neither Wolf nor his successors used the "personal reduction coeffcient" Waldmeier speaks of below. All Zurich chief observers worked to scales, 1.00 for Wolf, and always 0.60 for his successors who produced the Zurich numbers that comprise the ~100-year Zurich index, R_Z. b) Waldmeier's introduction has this to say about personal reduction coefficients:

> Foreign observations obtained with instruments and counting-methods not diverging too much of those in use at Zurich can be adapted to the Zurich scale by a personal reduction coefficient *k*. (Waldmeier 1961)

Hereafter I will refer to the personal reduction coefficients as *PRCs*. The foreign observations were only used at the end of the year to fill in a few missed days at Zurich (8 in 1944) so Zurich's PRCs have nothing to do with the preliminary indices which are the subject of this paper. c) The change to the new system of counting represented a change to a much more clearly defined index. Wolf's definition of which spots he counted was a vague definition that depended on where you thought he drew the line between good seeing and seeing that was not good. His Wolf index would therefore be hard to duplicate. The new definition: "This new method counts also the smallest spots" is a clear definition that is easily duplicated. See Schaefer (1993, 1997) for his recommendation on using small aperture and high magnification to count sunspots. Assuming that one followed that recommendation in seeing and counting all of the spots and groups, one could produce a Zurich index that would be accurate within 5% on average. According to Bondy, from what Waldmeier wrote to him in 1963, the difference is caused by Zurich's use of the size factor which increased Zurich's numbers about 5% on average (Bondy 1964).

2. The shortwave radio propagation forecasts nomograms

Starting in about 1934 the Interservice Radio Propagation Laboratory (IRPL) prepared nomograms used by the US Navy and other military organizations to determine the best frequencies for shortwave radio communication with ships at sea and overseas stations. The nomograms were based on the Zurich sunspot numbers because the strong correlation between ionospheric shortwave radio propagation conditions and the current phase of the sunspot cycle was well known by then. The forecasts were kept current by using the Zurich preliminary numbers, R_Z, only.

The final numbers issued at the end of the year were of no use because they were received too late. During World War II the R_Z numbers were received increasingly delayed so IRPL asked the Department of Terrestrial Magnetism (DTM) of the Carnegie Institute of Washington to set up an American relative sunspot number index like Zurich's. It is important to realize IRPL wanted the preliminary Zurich index, R_Z, duplicated because it was to this index that their nomograms were calibrated. The new DTM index is described in an article in *Popular Astronomy* magazine by Alan Shapley (Shapley 1944). Figure 1 shows a graph from Shapley's article where we see that the DTM used PRCs to produce the new American Relative Sunspot Number Index, R_A. From facts *a*, *b*, and *c*, above, it is clear this was a serious mistake. PRC-corrected observations could not duplicate the preliminary R_Z index IRPL was then using. For reasons described below, the only way to produce the true R_Z numbers IRPL was then using and wanted duplicated was to count sunspots according to the Zurich system of counting and multiply by the Zurich scale factor, 0.60.

3. The variable ratio of Wolf counts to Zurich counts from day to day and over time

The Zurich scale factor is a ratio which is the mean of the yearly variation of the old to the new R_Z indices over the 16-year period 1884 to 1890; the yearly means varied from 0.51 to 0.82 (Shapley 1949). The sole purpose of the scale factor was to make the Zurich index comparable and to bring it into conformity with the Wolf index over time. The intention was to preserve the conformity of the scales of the two indices to each other into the future after the Wolf index was abandoned in 1882. The clear definition of the new Zurich index makes this possible because "all of the spots" will always mean the same thing to future sunspot observers and drift of the scale over time in the future will be prevented. Use of the scale factor does not produce Wolf numbers, however—it brings the Zurich numbers (used after 1882 to define the Wolf scale) into correlation with the Wolf scale, producing a Wolf scale index by definition but not Wolf numbers.

Figure 2 shows counts of an individual observer, Neal Heines, plotted against the Zurich numbers. This graph alone proves PRCs cannot produce true Zurich numbers. The line through the points represents the ratio of Heines' counts to the Zurich numbers. It intersects the Zurich 100 line at 124, so the ratio is 100 / 124 = 0.80, which is Heines' PRC for the period plotted in the graph. This means Heines' counts were only 80% as large on average for the period plotted as the counts Waldmeier had used to produce the Zurich numbers (remember that each Zurich number in the graph was Waldmeier's count that day multiplied by the 0.60 scale factor). Notice how the points almost never fall on the line which is Heines' PRC—each scattered point represents a day when Heines' PRC, 0.80, either over- or under-corrected his count to produce a number that differed from the R_Z number that day. The graph thus shows DTM's failure to produce the R_Z numbers they wanted from Heines' daily sunspot counts. If Heines had counted all of the groups and spots according to the

Zurich system of counting instead of only 80% of them, his ratio would have been 100/164, for a PRC of 0.60, the same as the Zurich scale factor. Then his counts would have produced numbers that were very close to the true R_Z numbers that IRPL needed and wanted DTM to produce. In actual practice some scatter would be introduced by Waldmeier's use of the Zurich size factor, which raises the Zurich numbers on average about 5% (Bondy 1954), but the results would have been close enough for IRPL to use to calibrate their nomograms.

Like the daily counts, the monthly means of PRC-corrected counts will also vary from one month to the next, because during some months the daily ratio of small spots and groups to all spots and groups is lower and other months higher. This monthly variation of the ratios is seen in Figure 1 (and in Table 3 of Shapley 1946). The variation of the ratio of Wolf groups and spots to Zurich groups and spots over time is familiar to observers who count according to the Zurich system. The ratio waxes and wanes in a seemingly random way over time and the scale of a PRC-corrected index drifts accordingly, thus PRCs cannot be used to produce either Zurich numbers or Wolf numbers. The same logic also prevents producing a true Wolf number index using PRCs. The appropriate counting system and scale factor must be used to produce either index. There is no other way.

4. Why did the DTM mistake the Zurich Scale factor for a personal reduction coefficient?

I have searched the AAVSO archives and believe I have found the answer to that question. I believe it most likely had to do with the fact that Alan Shapley (son of Harlow Shapley, Director of Harvard College Observatory) grew up at Harvard College Observatory, where the American Association of Variable Star Observers (AAVSO) also had its headquarters at that time. He would have been very familiar with the AAVSO and its operations. It would not be surprising, then, that he would go to the AAVSO to find an experienced sunspot observer to become the equivalent of Waldmeier for DTM's American index. As it happened, AAVSO had just the person he was looking for, Neal Heines, an AAVSO member who had been making excellent sunspot drawings since 1934. Heines had already presented a detailed plan to set up an AAVSO Solar Division but it was not acted on by Headquarters; his plan may be found in the AAVSO archives. Heines was also one of Waldmeier's foreign observers and knew a PRC had been computed for him. Apparently he did not know what his PRC was, however, so DTM had a PRC computed for him. Heines probably thought Waldmeier's scale factor was also a PRC and that it reduced his counts to the long-abandoned Wolf number index, the scale of which Heines seemed to know was 1.00. This mistake would have been an easy one to make and under the circumstances almost unavoidable. I conclude then that it was probably Heines who mistook the Zurich scale factor for a PRC and misled DTM into setting up a PRC-corrected index that was neither the one IRPL wanted nor the Wolf index that they wrongly assumed they should set up. Certainly Heines' mistake was inadvertent and

unfortunate. Heines was considered an expert, so his advice to use PRCs to produce what he thought was supposed to be a Wolf number index was accepted and not questioned.

Heines' involvement in the AAVSO solar observing program ceased in 1952 when his job with the National Bureau of Standards (through which his AAVSO Solar Division work was funded) was terminated. Solar observer David Rosebrugh became acting Chairman of the Division and thus enabled the continuation of the American sunspot number program until Harry Bondy became Chairman in 1954.

Over the years the American numbers have always been called Wolf numbers, and sunspot observer instructions written in 1953 by acting Solar Division Chairman David Rosebrugh can be found in the AAVSO archives that say observers should try to achieve a PRC of 1.00 by observing at a magnification of 40× (see Schaefer1993 in regard to the proper magnification for sunspot counting). Rosebrugh also questioned whether it was possible to duplicate the Zurich numbers because of Waldmeier's use of a size factor. At the request of Rosebrugh and others, AAVSO solar observer Harry Bondy, who knew Waldmeier personally and could communicate with him in their mutually native language of German, wrote to Waldmeier and received his reply that his use of the size factor raised his numbers about 5% on average (Bondy 1964).

Waldmeier wrote about Rosebrough's (*i.e.*, the American) numbers that:

> Sunspot numbers differing systematically from the Zurich values are based on an erroneous reduction factor, respectively on a falsified scale, and they are only apt to evoke confusion. (Waldmeier 1961)

Rosebrugh did not respond to Waldmeier's comments.

Herbert Luft, an AAVSO solar observer who, like Bondy, knew Waldmeier personally and was a native speaker of German, and who had been a Zurich sunspot observer since 1923, said much the same thing about the AAVSO numbers as had Waldmeier, even calling them "monkey business" (Luft 1968a). Correspondence from Luft to AAVSO Director Margaret Mayall draws attention to the discrepancy between the American and Zurich numbers, and the absence of scientific justification for this discrepancy (Luft 1968b). Luft also told the author that he had discussed the matter with Dr. Robert Howard of Mount Wilson Observatory, and that Howard understood Luft's concern about the numbers (Luft 1968b). As Bondy had done, Luft tried hard, without success, to convince the AAVSO to change the method of determining the American numbers.

5. Conclusion

In 1944 the Interservice Radio Propagation laboratory wanted the Department of Terrestrial Magnetism to set up a Zurich index like the one they were then using. Instead, by mistake, DTM used personal reduction coefficients to produce an index that was neither a Zurich nor a Wolf index.

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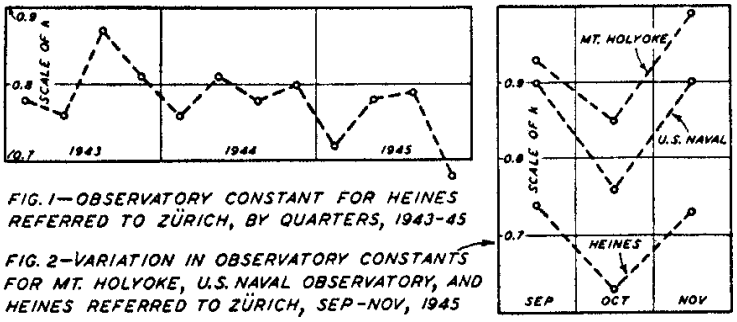

Figure 1. A graph from Shapley's article in *Popular Astronomy* that shows monthly variation in the ratio of Wolf groups and spots to Zurich groups and spots.

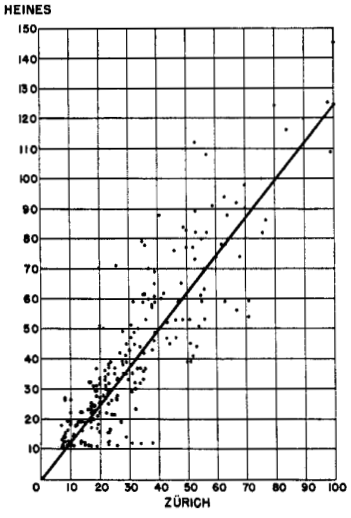

Figure 2. A graph from Shapley's 1949 paper which originally appeared in the *Publications of the Astronomical Society of the Pacific. Copyright 1949, Astronomical Society of the Pacific; reproduced with permission of the Editors.* Daily sunspot counts by N. Heines plotted against Zurich numbers; the line represents the ratio. The nearly daily deviation from the ratio demonstrates the inability of PRCs to produce true Zurich numbers.