Analysis of *Aa*-index *K*-values

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Several recent papers (list…) have shown that the aa-index is too small by 3-5 nT before 1957. The difference is ~13% of the average for mid-20th-century and at that time is likely due to erroneous weight factors applied to the amplitudes for individual stations. This cannot be the explanation for the discrepancy in the beginning of the century where 13% would represent only 1 nT. It is often believed that the aa-index is homogeneous and that it was scaled single-handed by Mayaud himself (at least before ~1970s). This is not the case as Mayaud states (ref…) that he used existing K-scalings when available - after checking and correcting if needed. The K-value most difficult to scale is K = 0 which should be scaled if the magnetograph curve over the three-hour interval deviates less than 5 nT from the curve of the "regular" daily variation, S_R, requiring the latter to be identified to correspondingly high precision. Since aa is too low by about the same amount it seems possible that many K = 1 values were misclassified as K = 0, reflecting great confidence in recognizing S_R. For example, for the year 1901, more than half of the total number of three-hour intervals were classified as K = 0.

The "raw" K-values (i.e. not weighted in any way) are available for the Northern aa-stations (GRW, ABN, HAD) and the Southern stations (MLB, TOO, CNB) since 1868. K-values are also available since 1890 from the German stations POT, SED, and NGK. There is no guarantee that any of these series are homogenous: but there is the hope that "institutional memory" might have an effect for the German series. In the present paper, we shall compare K-indices for the aa-index with K-indices for the German stations. Figure 1 compares one-day running averages of K for the English aa-station and the German station for the first quarter of the years 1901 and 2007. Although averages of K-values have no physical meaning they are a convenient presentation device.

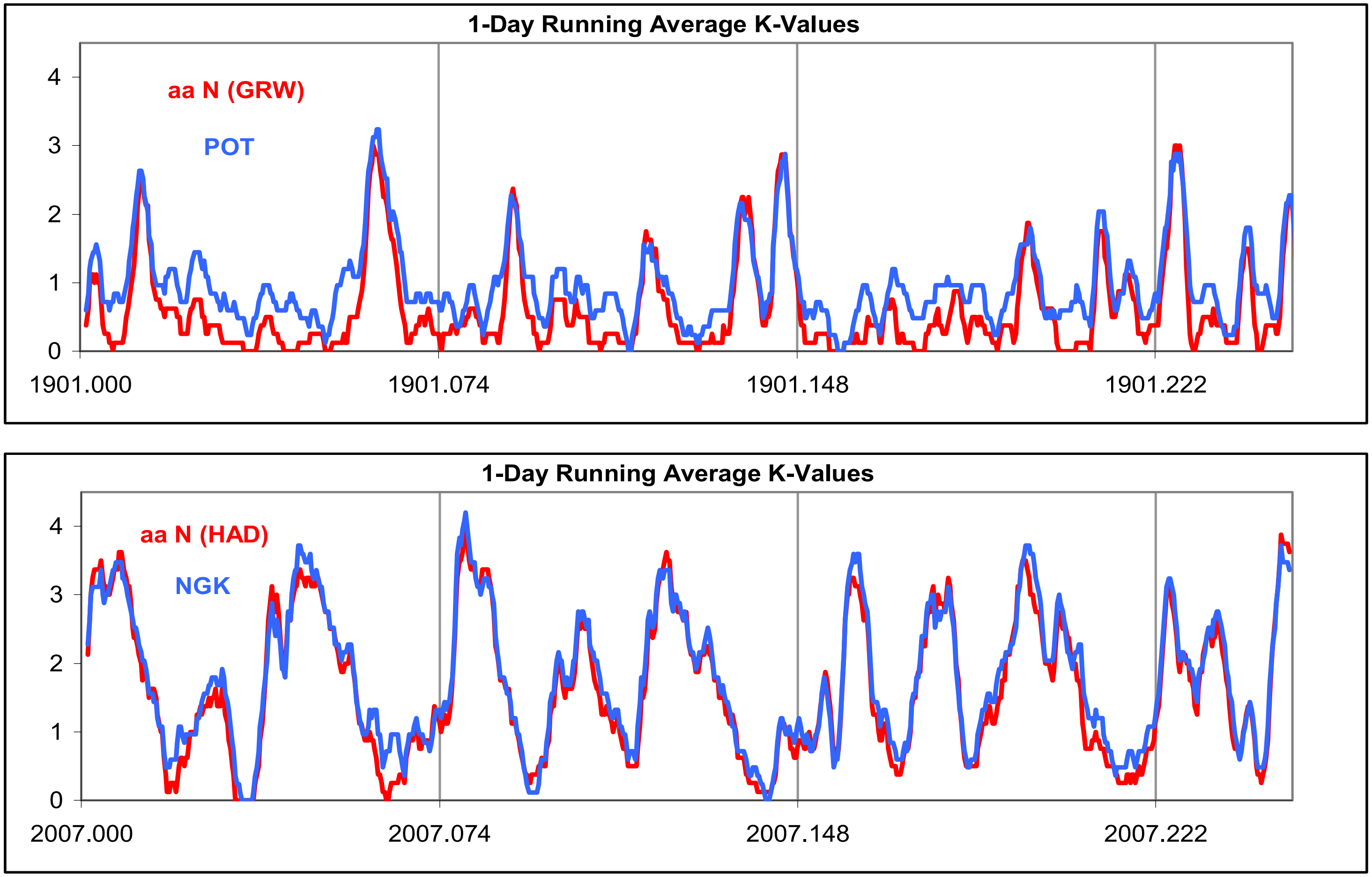

1-Day Running Average K-Values
aa N (GRW)
POT
4
3
2
1
0
1901.000
1901.074
1901.148
1901.222
1-Day Running Average K-Values
aa N (HAD)
NGK
4
3
2
1
0
2007.000
2007.074
2007.148
2007.222

Figure 1

Both years were solar minimum years. In 2007 there was a robust four-sector structure containing three high-speed recurrent streams. In 1901, the stream structure, if any, was much weaker. It is clear that for K greater than 1, both stations substantially agree, that for 2007, the agreement extends to K = 0 and 1 as well, while for 1901, the aa-station frequently has K = 0 when the German station has K = 1, thus leading to an overabundance of K = 0 values for aa.

Figure 2 shows the number of three-hour intervals per year where K = 0 (blue curves) and K = 1 (red curves) for the English aa-stations (filled circles) and for the German stations (open circles). There is general agreement from 1937 to the present (although somewhat poorer for K = 0 during the 1950s and 1960s). 1937 is the time when observers began to follow Bartels' lead and derive K-indices at individual observatories. The number of intervals with K = 0 falls to close to zero at each solar maximum for the German stations throughout the whole time from 1890, but that is not the case for the English stations before 1937; instead, the number of K = 0 intervals hovers around 500, about the same as the number of K = 1 intervals.

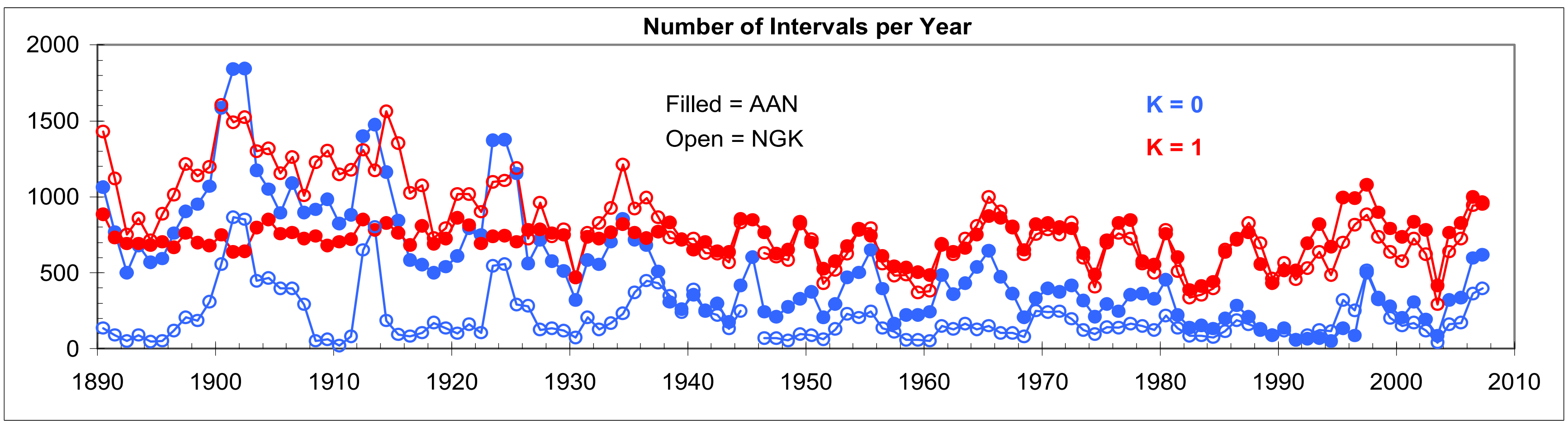


Figure 2

If we count the total number of intervals where K is either 0 or 1, then the result is nearly the same for both sets of data (allowing for a scale factor of 0.827 for aa):

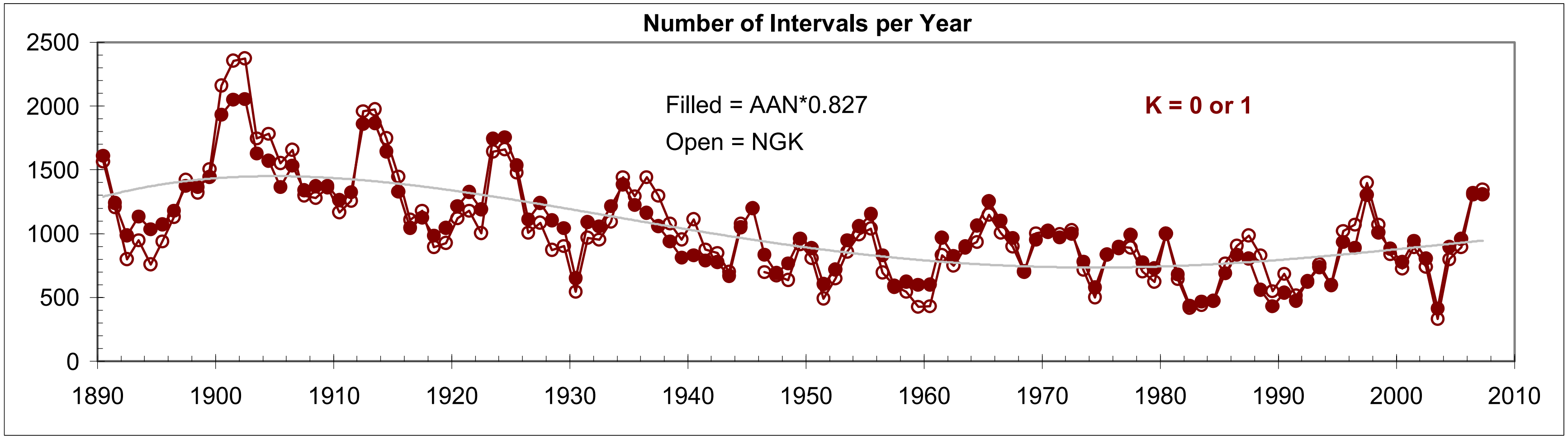
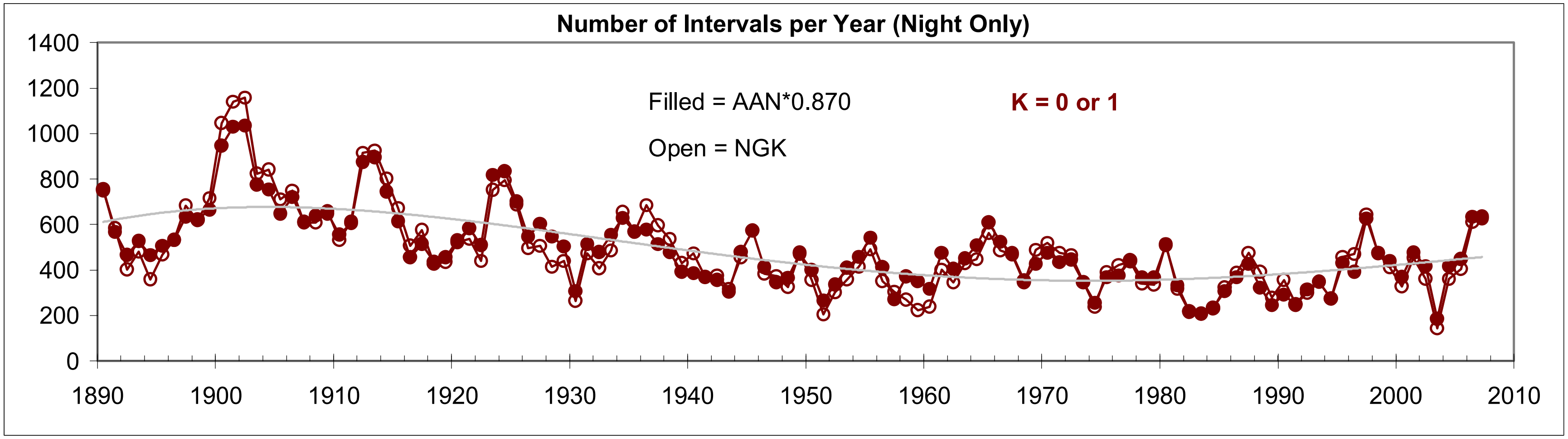


Figure 3

Together with the general agreement for K greater than 1, this result strongly suggests that, indeed, many K = 1 values were misclassified as K = 0 for the English stations before 1937 (and possibly in the 1950s and 1960s as well). As these pre-1937 values were scaled by Mayaud (and possibly some of the 1950s and 1960s as well) it would seem that the discrepancy can be traced to a personal bias or preference.

It would be of interest to know if the pre-1937 bias is related to the difficulty of determining S_R. We thus count only during the four local night intervals (number 1, 2, 7, and 8). The result is shown in Figure 4 (top). It does not seem to make any difference whether day or nighttime is considered, which is, perhaps, surprising. Similarly, it makes no difference whether the Northern or Southern aa-stations are used (Figure 4, bottom), excluding instrumental effects (Clilverd ref).


Number of Intervals per Year (Night Only)
Filled = AAN*0.870
Open = NGK
K = 0 or 1
1400
1200
1000
800
600
400
200
0
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

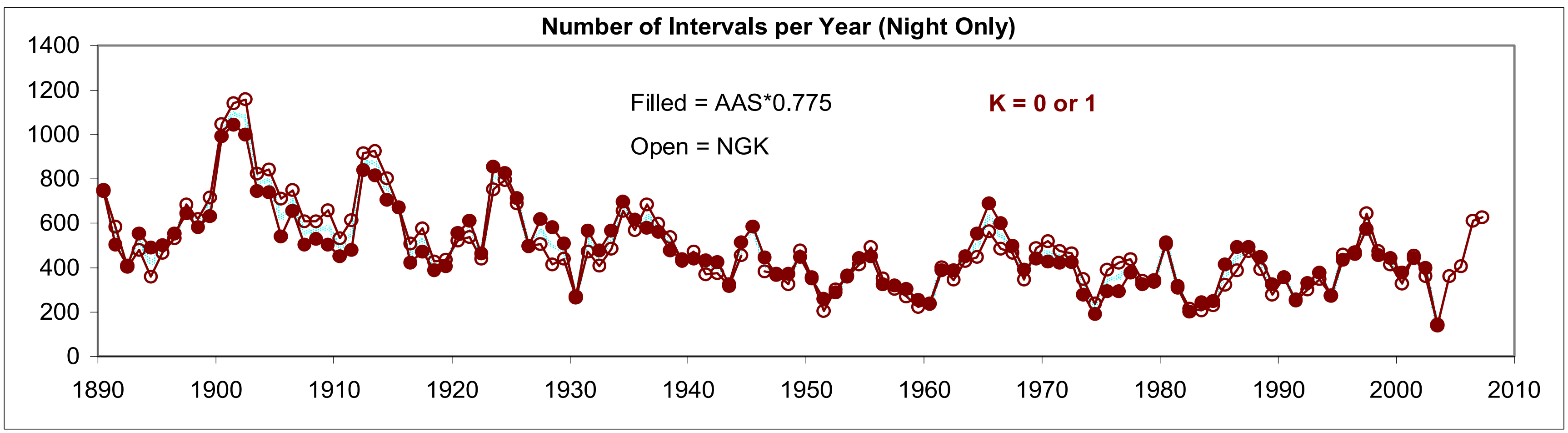

Number of Intervals per Year (Night Only)
Filled = AAS*0.775
Open = NGK
K = 0 or 1
1400
1200
1000
800
600
400
200
0
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

Figure 4

The number, N_{01}, of intervals with K = 0 or 1 per year is a measure of how “quiet” the year is. The yearly average IHV-index is a measure of how “active” the year is, so we would expect an inverse relationship between N_{01} and <IHV>. Taking the average N_{01} for the Northern aa-stations and the German stations, we find the following relationship (Figure 5):

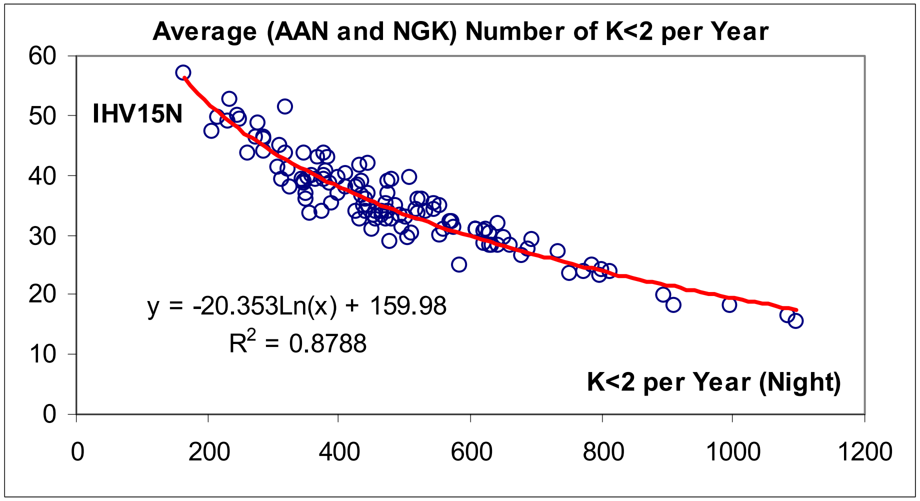


Figure 5.

We get for the individual series (full day):

$<IHV> = 176.65 - 19.975 \ln(N_{01})$; aa N

$<IHV> = 236.92 - 27.752 \ln(N_{01})$; aa S

$<IHV> = 162.94 - 18.595 \ln(N_{01})$; NGK

Similar relations hold, as shown, for N_{01} derived from aa N, aa S, and NGK (actually combined POT, SED, and NGK). This means that we can compute <IHV> from the N_{01}s for the different stations for comparison with <IHV> derived directly from the hourly mean values. Figure 6 shows such a comparison. There is generally good agreement between the various methods and stations, lending strength to our interpretation of the data. The heavy gray curve is the composite IHV from Svalgaard and Cliver (ref).

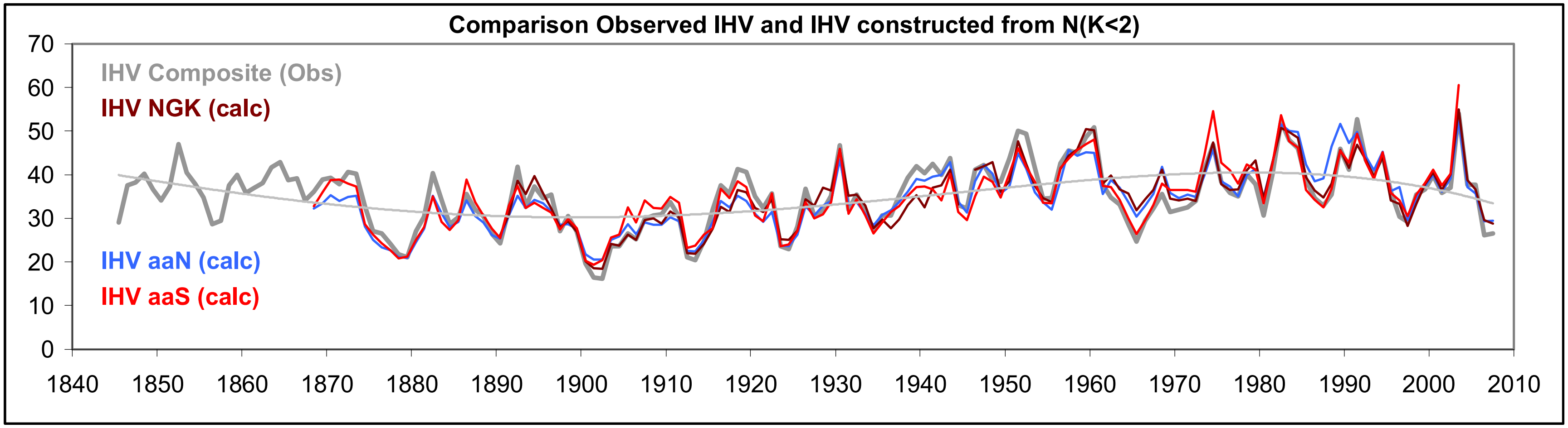


Figure 6

Summary: By treating the two lowest K-classes (0 and 1) as one class, the K-values from the aa-series (back to 1868) and from the German POT- SED-NGK series (back to 1890) are brought into agreement. The number of quiet periods ($K < 2$) per year is inversely related to the yearly average IHV. This relationship allows $\langle IHV \rangle_{year}$ to be inferred from the aa-series back to 1868, having generally good agreement with IHV from Helsinki (back to 1845). Mayaud misclassified many $K = 1$ values as $K = 0$ affecting the aa-series before 1937.