THE SOLAR Ca II K INDEX AND THE Mg II CORE-TO-WING RATIO

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ABSTRACT. The 1 Å index of the solar Ca II K line is compared with the core-to-wing ratio of satellite measurements of the Mg II h and k lines. The correlation coefficient $r = 0.976$ for the Nimbus-7 Mg II ratio during solar cycle 21 and $r = 0.99$ for the NOAA9 Mg II ratio in cycle 22. Linear regression analysis for the full dynamic range of both data sets is used to combine the Nimbus-7 and NOAA9 Mg II data. These relations permit the ground-based Ca K index to estimate the solar UV flux.

1. Introduction

Satellite measurements of the core-to-wing ratio of the Mg II h and k lines ($R_{\text{Mg}}$) are important because of their long-term precision and their use in estimating solar UV flux temporal variations as a function of wavelength in the range important to the stratosphere and ozone layer (Heath and Schlesinger, 1986). The relation between $R_{\text{Mg}}$ and the Ca K 1 Å index is important because it aids in developing the relation between the time series of $R_{\text{Mg}}$ data from one satellite with those from a later satellite and because it allows the ground-based Ca K 1 Å index to be used to estimate solar UV flux variations. So what is the relation?

Fredga (1971) and Lemaire (1984) showed that the Mg k emission core intensity correlated highly with that for Ca K as a function of spatial position on the Sun. Since the increase or decrease in area and brightness of spatial features causes the temporal changes of full-disk fluxes, the high correlation of brightness as a function of spatial position implies that the temporal variations of the full-disk fluxes for the emission cores of these Mg II and Ca II lines should be highly correlated. Avrett’s (1992) theoretical modeling of the upper photosphere, chromosphere, transition region, and lower corona for a spherically stratified, average quiet Sun shows that the emission core of the Mg II k line originates from slightly higher but similar altitudes in the chromosphere than does the emission core of the Ca K line. Therefore, the Mg II and Ca K activity brightenings should involve essentially the same source regions, which supports the expectation that the temporal variations of the full-disk fluxes for the emission cores of the Mg II h and k lines and the Ca II K line should be highly correlated.

2. The Solar Ca K and Mg II h and k Line Profiles and Indices

The Ca K line near 393 nm, shown in Figure 1, consists of the strong absorption feature that produces the overall large V shape with two small emission peaks on either side of the cen-
ter of the line (the zero location on the relative wavelength scale). The Ca K emission peaks, which originate in the chromosphere, vary strongly with solar activity. The K index is simply the full-disk intensity integrated as a function of wavelength across the 1 Å interval centered on the core of the Ca K line (between the two vertical lines in Figure 1) and then divided by a measure of the solar continuum intensity per Å at two reference wavelengths near 4020 Å and 3875 Å (White and Livingston, 1981).

Figure 1 also shows a fine-wavelength-resolution observation of the Mg II h and k lines (Allen et al., 1978). The emission cores, labeled h and k, are so close together that the short-wavelength absorption wing of the h line overlaps with the long-wavelength wing of the k line to produce the interwing maximum near 280 nm. Most of the variation with solar activity occurs in the chromospheric emission cores and not in the photospheric wings or weak lines. The lower left part of Figure 1 shows the Mg II h and k lines seen with the broad bandwidth of the Nimbus-7 measurements from the Solar Backscatter UV (SBUV) experiment (Heath and Schlesinger, 1986), which are similar to the NOAA9 SBUV2 monitoring measurements. The h and k emission cores, the broad absorption wings, and all the fine structure from weak absorption lines are smoothed into one broad absorption feature. Strong changes in the emission cores produce small variations near the minimum of the unresolved lines.

Heath and Schlesinger (1986) defined the center-to-wing ratio for the Mg II h and k solar absorption lines for solar flux measurements made by the SBUV experiment aboard the Nimbus-7 satellite as follows:

$$R_{Mg}(t) = \frac{4[F(279.8 \text{ nm}, t) + F(280.0 \text{ nm}, t) + F(280.2 \text{ nm}, t)]}{3[F(276.6, t) + F(276.8, t) + F(283.2, t) + F(283.4, t)]}$$  (1)

$F(\lambda, t)$ is the measured solar flux at wavelength $\lambda$ and time $t$. The wavelengths in the numerator were selected to have a strong signal of solar variability from the large percentage variations of the h and k emission cores. The far-wing measurements in the denominator were selected to be close in wavelength to the core of the line but to have very weak solar signals. Consequently, the ratio has a strong solar signal while being insensitive to drifts in instrumentation throughput that are weak functions of wavelength over the range involved in equation (1).

The arrows in Figure 1 mark the approximate locations of the wavelengths involved in equation (1). There are two problems evident in this figure that illustrate the difficulty in comparing $R_{Mg}$ results from measurements made by two different instruments. The center wavelength of the three core wavelengths used by Nimbus-7 does not appear to line up with the minimum of the solid or dashed curves, yet the Nimbus-7 flux values for these three wavelengths indicate that the center one is close to the minimum. This is a consequence of a difference in the wavelength scales used for these two instruments. Secondly, the maximum in the short-wavelength wing of Hall and Anderson's (1988) balloon flight data is too low for $R_{Mg}$ derived from their data, to ever be low enough to agree with Heath and Schlesinger's (1986) results. This may result from the effect of the ozone layer on the balloon measurements being incompletely corrected. Other problems in comparing $R_{Mg}$ val-