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A NEAR REAL-TIME FLARE ALERTING SYSTEM BASED ON GOES SOFT X-RAY FLUX

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ABSTRACT

We have developed a near real-time flare alerting system which (1) downloads the latest GOES-10 1-8 Å X-ray flux 1-min data by an automated ftp program and shell scripts, (2) produces a beep sound in a simple IDL widget program when the flux is larger than a critical value, and (3) makes it possible to do a wireless alerting by a set of portable transceivers. Thanks to the system, we have made successful Hα flare observations by the Solar Flare Telescope in Bohyunsan Optical Astronomy Observatory. This system is expected to be helpful for ground-based flare observers.

Key words : Sun: flare

I. INTRODUCTION

Solar flares are the most energetic and violent events taking place in the solar atmosphere. Thus the understanding of their physical characteristics through various types of observations has been regarded as a main subject in solar physics community. Solar flare occurrence is tightly associated with several solar atmospheric signs such as sunspot classification (Bornmann and Shaw 1994), flux emergence (Wang and Tang 1993), filament configurations (Kahler et al. 1988), nonpotential parameters (Moon et al. 2000a), sheared inversion line (Gary et al. 1991), magnetic field discontinuity (Moon et al. 1999a), and S-shaped loop structures (Wang et al. 2000). Recently, Moon et al. (2000b) showed that the waiting time distribution of soft X-ray flares in individual active regions can be approximated by a Poission probability function $m\exp(-mt)$ with a constant mean flaring rate, m, implying that flares themselves are independent in time among each other. When the mean flaring rate, m, is properly estimated, the probability of flare occurrence within a given time is forecasted as $1-\exp(-mt)$. However, the randomness of flare occurrence bears an unavoidable uncertainty in practical prediction. This fact seems to be associated with some difficulty in short-term flare predictions (Jakimiec and Bartkowiak 1994, Lee et al. 1999).

Solar flares emit nearly all kinds of wavelengths (gamma ray to radio wave) which are originated from different regions of the solar atmosphere. Ground-based Hα observations have been regarded as a key traditional tool for monitoring optical brightenings during flaring activity. The importance of a Hα flare is often evaluated from its magnitude and area. There are five areal categories defined by the following criteria : S (< 100), 1(100 ~ 250), 2(250 ~ 600), 3(600 ~ 1200), and 4(< 1200) in unit of millionths of the solar hemisphere. The flare intensity is indicated by the letters F, N, and B each of which stands for faint, normal, and bright, respectively. The combined area and intensity indices are given to flares by for example 2B, 1N, etc. to represent the importance of flare classes. Since 1975, GOES (Geosynchronous Operational Environmental Satellites) have also played very significant roles in monitoring solar flares by measuring real-time soft X-ray fluxes in two spectral bands : 1-8 Å and 0.5-4.0 Å passbands. At present, X-ray flares are classified according to the order of magnitude of the peak burst intensity measured in the 1-8 Å band as follows : C-class ($10^{-6} \leq I < 10^{-5} W/m^2$), M-class ($10^{-5} \leq I < 10^{-4} W/m^2$), X-class ($I \geq 10^{-4} W/m^2$).

Figure 1 shows the cross correlation of flaring times between major soft X-ray flares stronger than M1 class and Hα flares brighter than N class from January to August in 1999, whose data were collected by the National Geophysical Data Center(NGDC). As seen in the figure, soft X-ray flares precede about three minutes Hα flares. This result is in good agreement with Thomas and Teske (1971) who reported that the soft X-ray bursts begin at about 2 min on the average before the optical Hα event. The Hα emission originate in the lower chromosphere, while the soft X-ray emissions in the chromosphere-to-corona region of the solar atmosphere. According to the Kopp and Pneuman (1976) model for solar flares, the hot gas and high energy particles stream down along the magnetic loops below the reconnection region and deposit their energy in the denser lower atmosphere, which produces Hα two ribbon flares. Since the flare in this model is triggered through the reconnection of field lines from the corona, the soft X-ray emission should be observed earlier than the Hα emission. This fact suggests that the real time monitoring of soft X-ray emission should be helpful for preparing Hα flare observations.

This paper presents a near real-time flare alerting system for ground-based solar flare observation using the GOES soft X-ray fluxes. Once an initiation of solar flare is noticed, a higher cadence observation is favored for the detail monitoring of flaring activity. Thus efficient alerting for flaring events is quite useful.

II. A FLARE ALERTING SYSTEM

We have developed a near real-time flare alerting system for ground flare observation. The schematic diagram of the flare alerting system is given in Figure 2. Here we will summarize its basic functions as follows.

1) We continuously download the latest GOES-10 X-ray flux 1-min data from the NOAA anonymous ftp site (ftp://sec.noaa.gov/pub/list/xray/G10xr_1m.txt) by an automated ftp program and shell scripts in Unix. The ftp command uses a simple input file shown in Table 1, where data in parentheses can be changeable for a specific purpose. The downloaded file is duplicated for data input.

2) We have developed a simple IDL (Interactive Data Language) widget program which produces a beep sound when the flux is larger than a critical value (e.g., C2 class). This sound alerting is very effective in the case that we are not in the position of watching the real-time GOES X-ray monitoring with one minute time resolution, which is displayed via the NOAA web site (http://sec.noaa.gov/rt_plots/xray_1m.cgi). A flow chart of the IDL program is given in Figure 3 and its screen dump in Figure 4. As seen in Figure 3, there are three different status modes for flare alerting : flaring mode, non-flaring mode and network problem mode. The network problem mode is displayed in the case that input data are not updated for the last several minutes. We can also see the data input file and a simple help file under the widget program (Figure 4). The ftp and IDL programs are operated under the Unix environment in PC via the Xmanager software.

3) In addition, we have developed a wireless alerting system which consists of a speaker and a set of portable transceivers for more effective observations when an observer is in another place near observatory. One transceiver is located in the front of the speaker and the other can be at anywhere near the observatory (up to 2-3km). The former should be in VOX (Voice Operated X[trans]mit) mode, which makes it possible to

Table 1. An input file for the automated ftp program.

open (host name)
user ftp (e-mail address)
cd (target directory)
get (filename)
bye

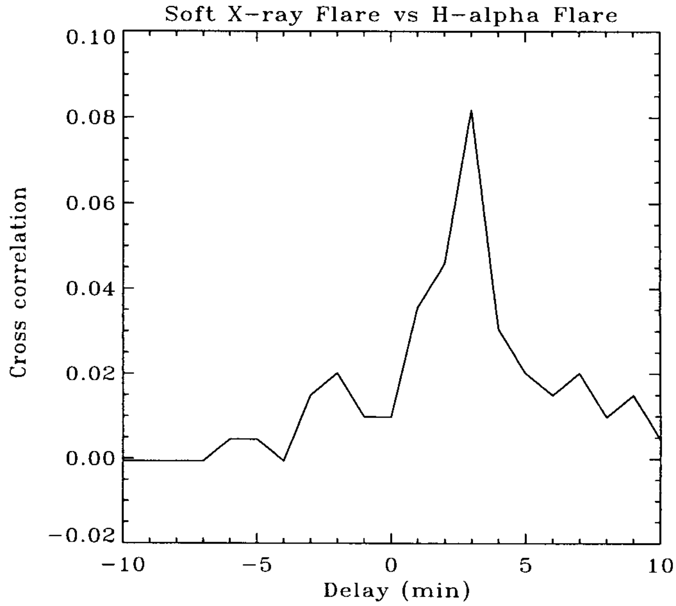

Fig. 1.— Cross correlation of flaring times between GOES soft X-ray flares and Hα flares.

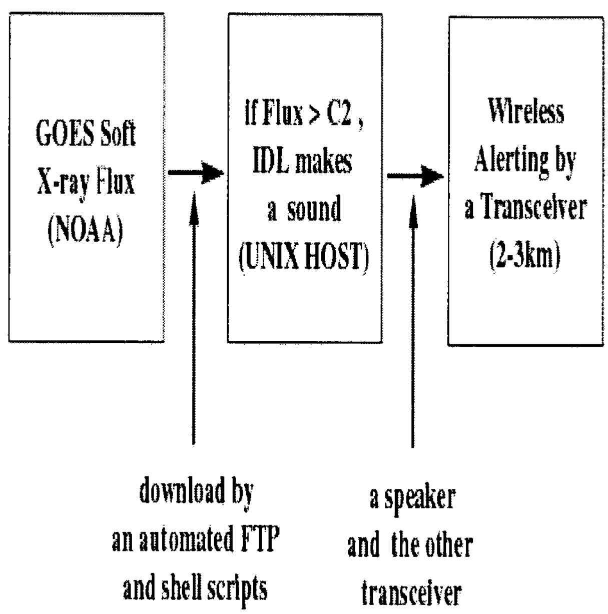

Fig. 2.— Schematic Diagram of a flare alerting system.

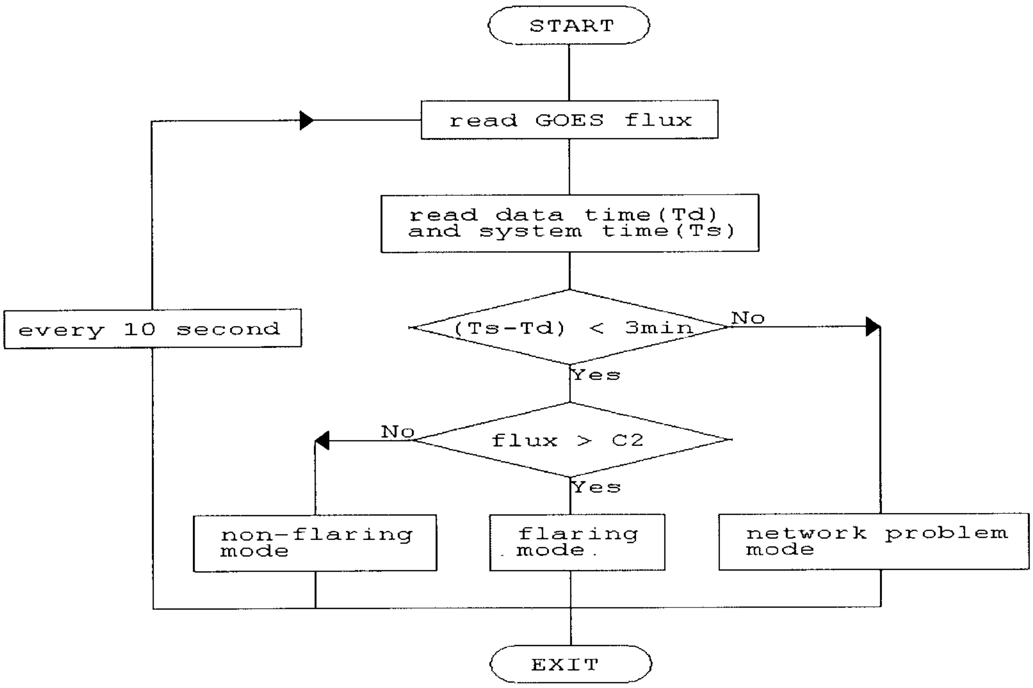

Fig. 3.— A flow chart of the IDL widget program.

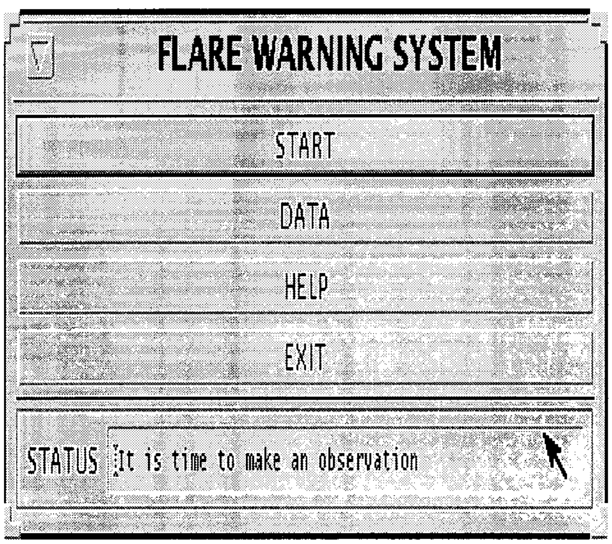

Fig. 4.— A screen dump of the IDL widget program.

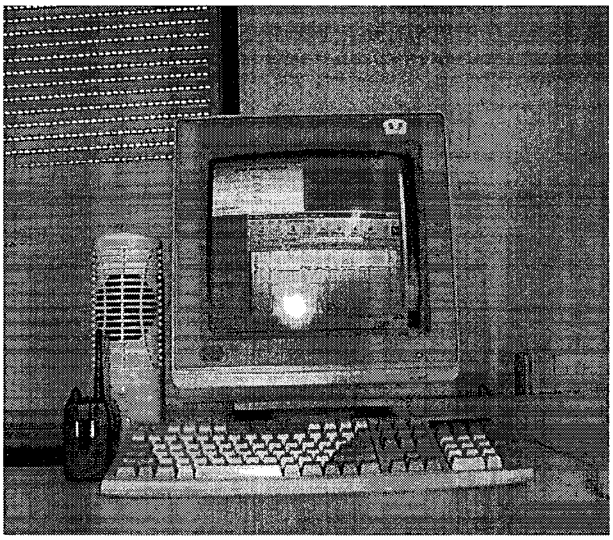

Fig. 5.— A picture of the flare alerting system.

automatically send a series of sound. The transceiver uses about 450MHz and its weight is about 100*g*. Total cost of the wireless alerting system amounts to about $100. Figure 5 shows a picture of the flare alerting system which includes a PC, a speaker, and a transceiver.

III. DISCUSSION AND CONCLUSION

The flare alerting system is being successfully used for the Solar Flare Telescope (SOFT) in Bohyunsan Optical Astronomical Observatory (BOAO) under Korea Astronomy Observatory. The SOFT is making daily observations of white light, Hα, and filter-based magnetograph for the local area ($400'' \times 300''$) of the sun (Park et al. 1997, Moon et al. 1999b). In general, the SOFT is monitoring the most potentially active region for an observing day by referring to flare occurrence probabilities of individual active region provided by the space weather prediction web site (gopher://solar.sec.noaa.gov/00/latest/daypre) as well as qualitative comments on solar active region activity by the BBSO activity report web site (http://www.bbso.njit.edu/cgi-bin/ActivityReport). Since it is not guaranteed that solar flares occur always at the active region, an on-site observer had to watch all the time the real-time GOES X-ray monitoring for effective Hα flare observations. Thus the sound alerting is meaningful as far as effective manpower operation is concerned in the observatory. Another advantage is that the wireless alerting system makes it possible to warn flare generation when an on-site observer is temporarily away from observing site. We could miss some of Hα flare observations by the SOFT if we are not in the position of watching the GOES X-ray monitor or we are temporally absent from the observing site. Thanks to the current alerting system, we have successfully made observations of major flares occurred in solar active regions such as AR8948, AR8906, AR8910, AR8977, AR9002, AR9033, AR9040, and AR9165 without any remarkable data missing.

To sum up, an efficient flare alerting system has been developed by using an automated ftp program, shell scripts, an IDL widget program, and a set of portable transceivers. This system not only produces a sound alerting when a flare initiates but also makes it possible to do a wireless alerting when an observer is in another place near the observatory. At present, we are in the period of solar cycle 23 maximum, even though its activity is lower than what is expected. Thus we think that this system helps solar observers make more efficient flare observations. In addition, this system can be applied to other alerting systems such as space weather warning.

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