The CHAIN-Project and Installation of Flare Monitoring Telescopes in Developing Countries

S. UeNo [1] *, K. Shibata [2], R. Kitai [2], K. Ichimoto [1], S. Nagata [1], H. Isobe [3], G. Kimura [1], Y. Nakatani [1], M. Kadota [1], H. Komori [1], T.T. Ishii [2], S. Morita [1], K. Otsuji [2]

[1 *1] *Hida Observatory, Kyoto University, Kurabashira, Kamitakara, Takayama, Gifu, 506-1314, JAPAN, Email:* ueno@kwasan.kyoto-u.ac.jp [2] *Kwasan Observatory, Kyoto University, Ominecho, Yamashinaku, Kyoto, 607-8471, JAPAN,* [3] *Unit of Synergetic Studies for Space, Kyoto University, Ominecho, Yamashinaku, Kyoto, 607-8471, JAPAN*

ABSTRACT

The Flare Monitoring Telescope (FMT) was constructed in 1992 at Hida Observatory in Japan to investigate the long-term variation of solar activity and explosive events. It has five solar imaging telescopes that simultaneously observe the full-disk Sun at different wavelengths around the H-alpha absorption line or in different modes. Therefore, the FMT can measure the three-dimensional velocity field of moving structures on the full solar disk. The science target of the FMT is to monitor solar flares and erupting filaments continuously all over the solar disk and to investigate correlation between the characteristics of the erupting phenomena and the geoeffectiveness of the corresponding coronal mass ejections (CMEs). We are planning to start up a new worldwide project, the Continuous H-alpha Imaging Network (CHAIN) project, as an important IHY project of our observatories. As part of this project, we are examining the possibility of installing telescopes similar to the FMT in developing countries. We have selected Peru and Algeria as the countries where the first and second overseas FMTs will be installed, and we are aiming to start operation of these FMTs by the end of 2010 before the maximum phase of solar cycle 24. To create such an international network, it will be necessary to improve the information technologies applied in our observation-system. In this paper, we explain the current status and future areas of work regarding our system.

Keywords: Sun, Space weather, Filament eruption, Flare, CME, Data archives, Automatic data processing

1 INTRODUCTION – WHAT IS THE CHAIN-PROJECT?

The space-weather environment around the earth greatly depends on the 3-D structures and velocities of the coronal mass ejection (CME), shockwave and solar-wind disturbance around the magnetosphere. To accurately understand or predict the structures and velocities of CMEs in the solar-terrestrial space, it is important to accurately observe erupting phenomena on the solar surface which determine the initial conditions or boundary conditions of all CMEs. Therefore, continuous observation of the 3-D velocity field of filament eruptions and shock-wave structures on the full solar surface is essential for space-weather research. Accordingly, we are starting up a new worldwide project, the Continuous H-alpha Imaging Network (CHAIN) project, as an important IHY project of our observatories (UeNo et al. 2007).

In the CHAIN-project, to enable 24-hr continuous observation of active phenomena across the full solar disk, telescopes from two groups of network member candidates will be used. The first group consists of existing foreign H-alpha solar full-disk telescopes. Though we have begun talks with some foreign observatories, a sticking point has been that they would have to improve their present telescopes to allow multi-wavelength observation. The second group consists of locations where H-alpha multi-wavelength telescopes could be installed. For this group, we are examining the possibility of installing flare monitoring telescopes (FMTs) in developing countries. As well as increasing the number of flare-monitoring locations, we hope this will encourage education and study related to solar-terrestrial physics in these countries. Figure 1 shows possible members of the second group. Peru and Algeria have been respectively selected as the countries where we will install the first and second overseas FMTs. With these two sites and our observatory, we can achieve 24-hr continuous observation in principle (figure 2). In Peru, a wide campus area will be developed and provided as the “Solar Station” by the national Ica University in 2009 with the cooperation of Instituto Geofisico del Peru (IGP) (Ishitsuka et al. 2007); the ground-breaking ceremony was held on June 30th, 2008. In Algeria, the Center of Research of Astronomy, Astrophysics and Geophysics (CRAAG) is planning to build a new astronomical observatory, and we are reviewing various possible sites with CRAAG regarding factors such as general climate, manpower, infrastructure and atmospheric turbulence conditions. Other sites in figure 1 show observatories or institutes that have offered to participate in our project (including offers through private communications).

In this paper, we explain the current status and characteristics of the instruments, digital image acquisition system, real-time data updating system, scientific data analysis processes and future subjects related to information technologies of this project.

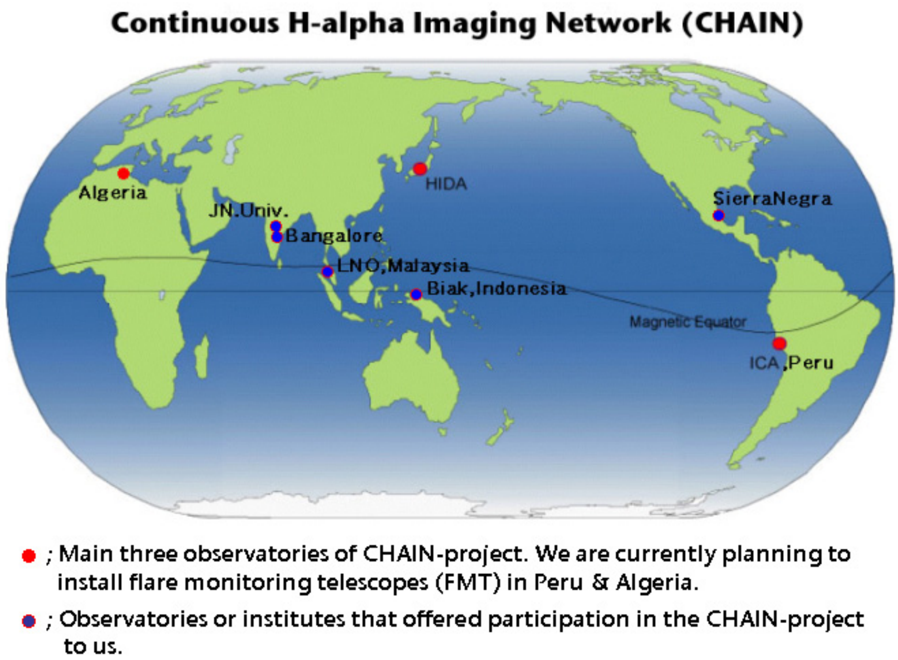


Figure 1. Map of possible CHAIN-project sites

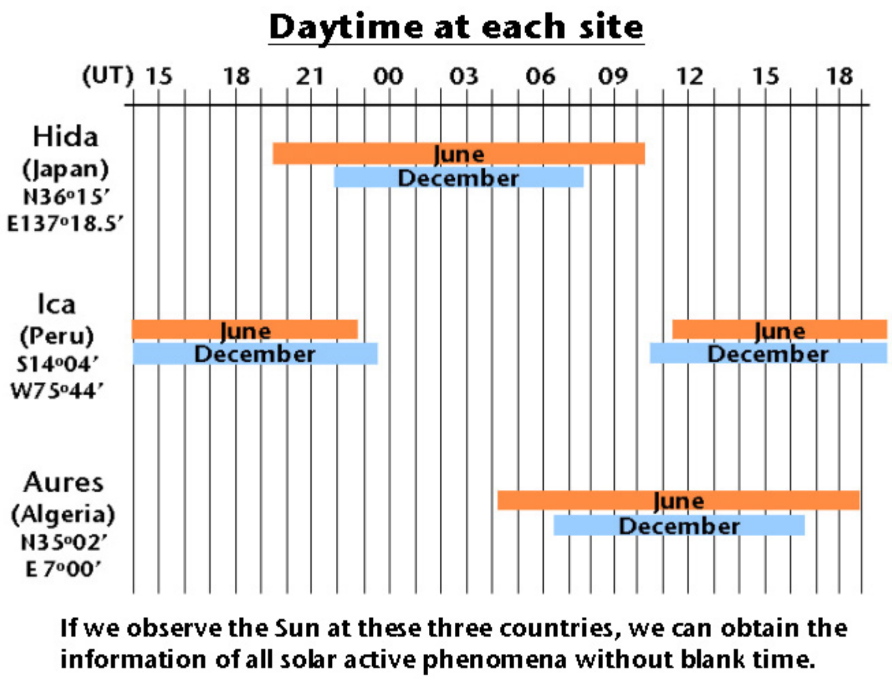


Figure 2. Observable time period at each site

2 FEATURES OF THE FMT

The original FMT was constructed in 1992 at Hida Observatory in Japan (figure 3) to investigate the long-term variation of solar activity and explosive events (Kurokawa et al. 1995). It has five solar imaging telescopes that simultaneously observe the full-disk Sun at different wavelengths around the H-alpha absorption line or in different modes (figures 4, 5). Therefore, the FMT can accurately measure the three-dimensional velocity field of moving structures on the full solar disk because it can measure the Doppler velocity field without time-variation effects caused by terrestrial atmospheric turbulence. Past studies using such FMT-data have observationally proved that all CMEs are made of chromospheric H-alpha filament eruptions (Morimoto & Kurokawa 2003a, b) and chromospheric wave-like phenomena (Moreton waves) show an aspect of the shock-waves that are spread in interstellar space (Narukage et al. 2002, Eto et al. 2002, etc.). Our next major effort will be to investigate the correlation between characteristics of the eruption phenomena and the geoeffectiveness of the corresponding CMEs by accumulating more observational data with the CHAIN.

The FMT optical system is simple and similar for each telescope. Therefore, it is comparatively easy to produce new FMTs for foreign sites. The FMT structure and specifications of the optics and CCD cameras are shown in figures 6 and 7.

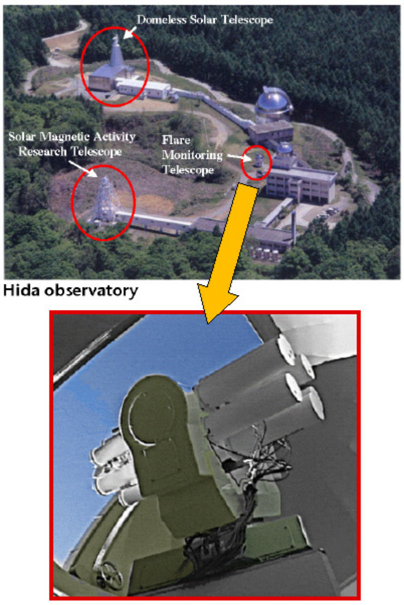


Figure 3. Hida Obs. and the FMT

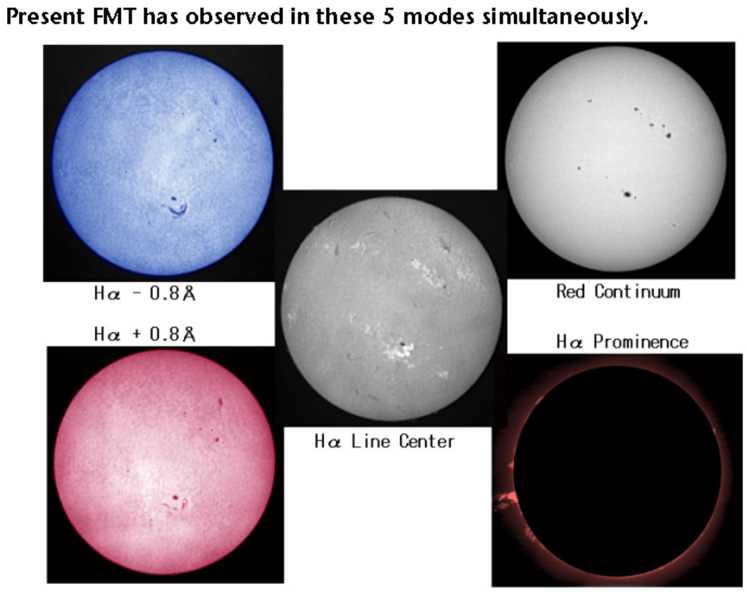


Figure 4. Sample images from each telescope

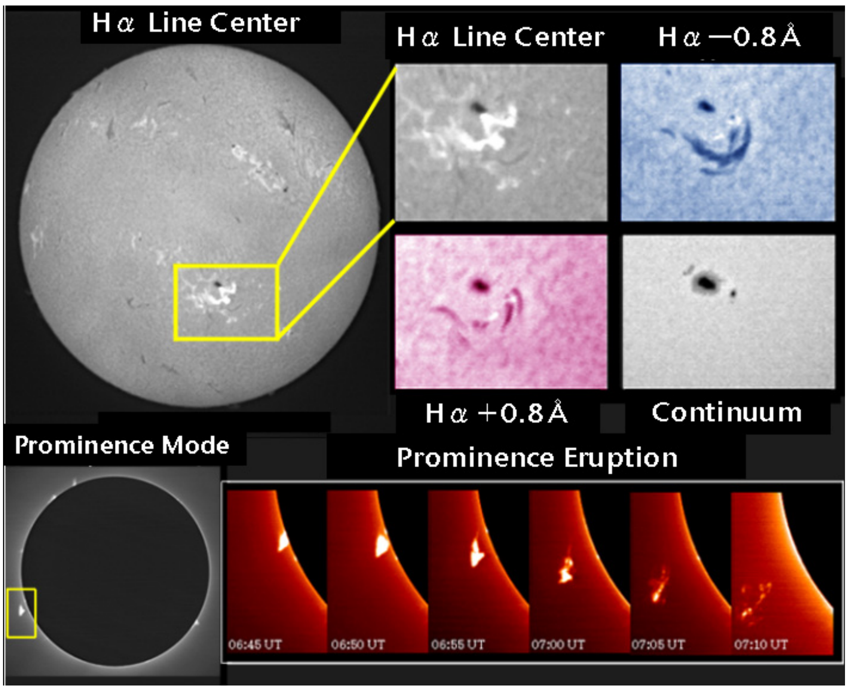


Figure 5. Active phenomena observed with the FMT

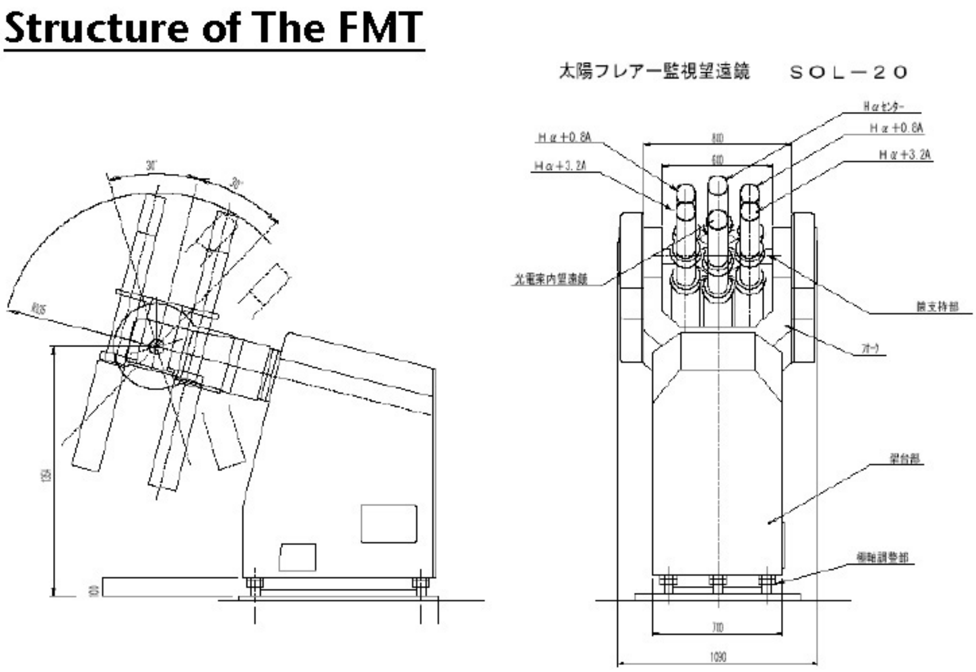
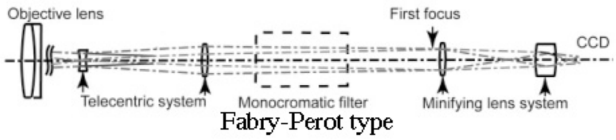


Figure 6. Drawing of the expected structure of the FMT for Peru

Optics of the Flare Monitoring Telescope (FMT)



Optics

Diameter	64 mm
F-ratio	30
Focal length	1920 mm
Spatial resolution	1.8 arcsec

Filters

Telescope name	Central / Passband
Ha center	6562.8 / 0.42 A
Ha +0.8 A	6563.6 / 0.5 A
Ha -0.8 A	6562.0 / 0.5 A
Continuum	6100 / 60 A
Prominence	6562.8 / 3 A

Telescope was manufactured	by	Nishimura Co. Ltd.
Lens system was manufactured	by	Minolta Co. Ltd. (Now:Konica-Minolta)
Filters were manufactures	by	Daystar Co.Ltd.

CCD system. [After 2006 May]

CCD	Takenaka System Co.LTD/ Digital Full Frame Shutter Camera FC1500CL (CamLink)
Time cadence	every 20 seconds in the routine observation (changeable)
Bit Depth	10 bits
Pixel Number	1392x1040 => 2.1 arcsec/pix
Typical exposure time	4 ms, Simultaneousness **64 ns** << seeing timescale
Photon noise	2.0 % (corresponds to 2 km/s of the Doppler velocity)

Figure 7. Specifications of optics of the FMT and CCD camera system

3 INFORMATION TECHNOLOGIES OF CURRENT SYSTEM

The information technology used for the FMT is not particularly advanced, and in some cases is outdated. Therefore, we are not fully satisfied with its current performance. In this section, we describe the current compositions of the digital image acquisition system, data archives on the web and scientific data analysis process, and the problems with each system.

3.1 Digital Image Acquisition System

As figure 8 shows, five CCD cameras are attached to the telescopes and these cameras use a CamLink interface. Since the distance between the dome and observation room is too long for CamLink communication, we use converters to connect to a Gbit Ethernet. These converters each have an individual IP address, so we can treat each camera as a network camera. On each PC in the observation room, an image-acquisition program written in visual basic obtains a digital image from each telescope every 20 s (this interval can be changed).

Two problems with this system are that there can be an image acquisition time lag among the five PCs and image frame loss can occur. We think these problems are due to the network conditions and the state of the PC operating system (Windows XP).

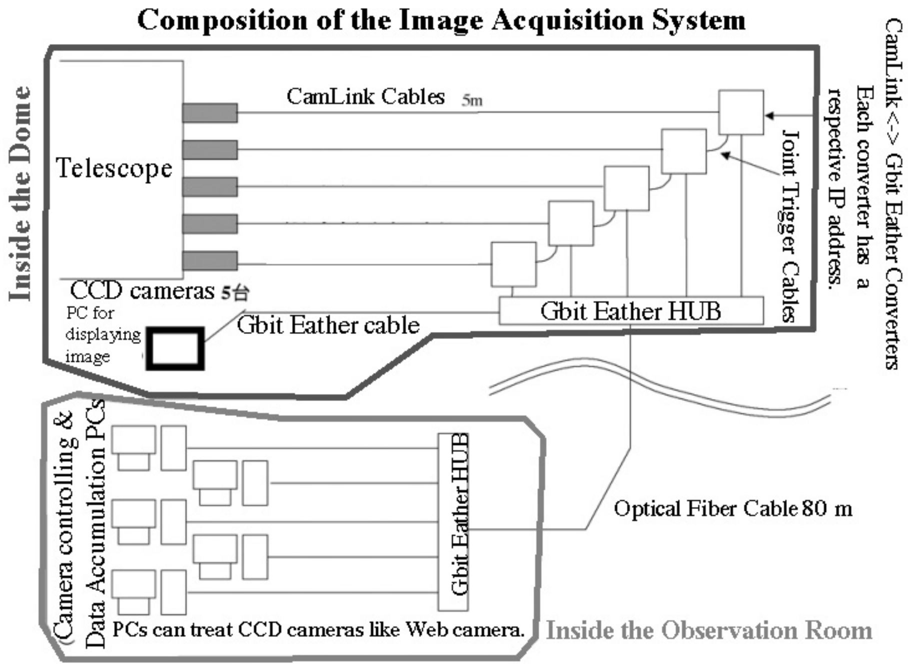


Figure 8. Composition of the image acquisition system of the present FMT

3.2 FMT Data Archives on the Web

Various data obtained with the FMT during the past 17 years is open to the public. This data archive consists of four kinds of content.

(1) Event lists (figure 9a)
All active phenomena that have been found in the FMT data are listed for each month and their physical characteristics and classifications are described in each list. GIF images of conspicuous events can also be seen with a web browser.

(2) Movies of outstanding events (figure 9b)
MPEG movies of outstanding events are separated into four categories and archived: flares, filament eruptions, surges, and prominence eruptions.

(3) Real-time images (figure 9c)
The latest images observed with the FMT are automatically updated on the web.

(4) Digital raw image download site (figure 9d)
All raw data are dated for each day, compressed, and then archived, so that they can be downloaded from web browsers.

Though the contents of (3) and (4) are automatically updated, at present we manually update the contents of (1) and (2). The automatic updating system for (3) and (4) is shown in figure 10. The problems with this system are the complexity and time delay. Operation requires many kinds of protocols and programs, and this causes a delay of about 1 – 2 min before the image is actually obtained.

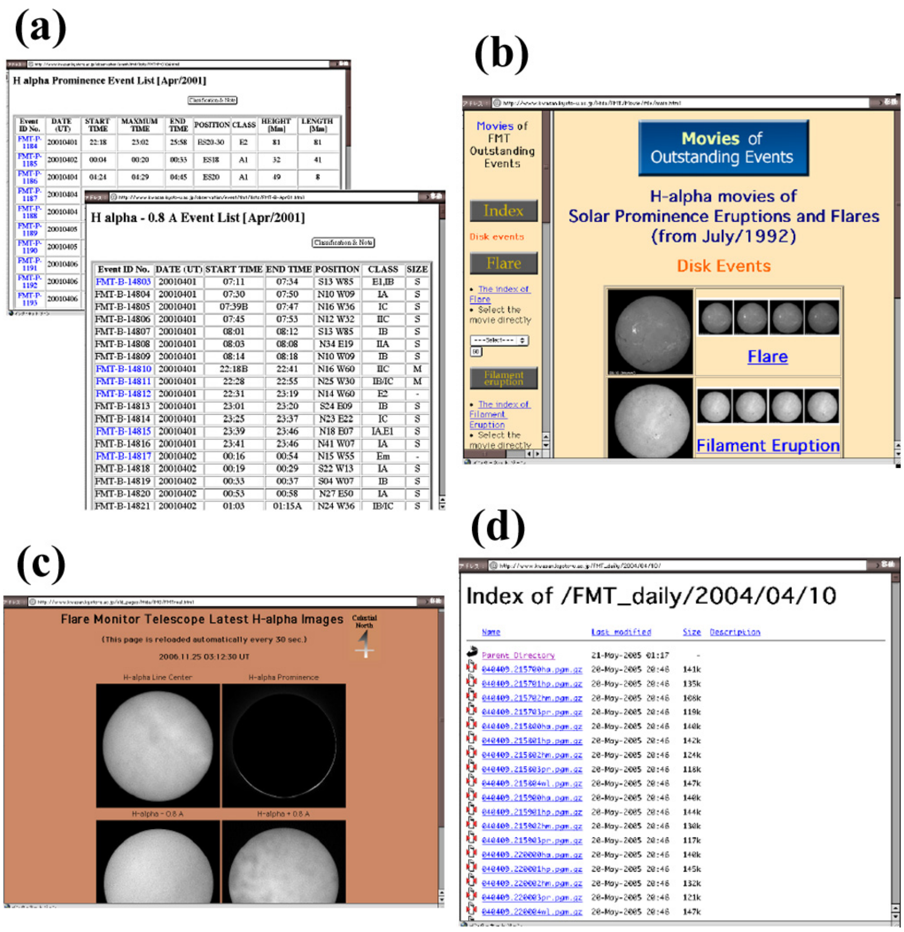


Figure 9. FMT data archives on the Web

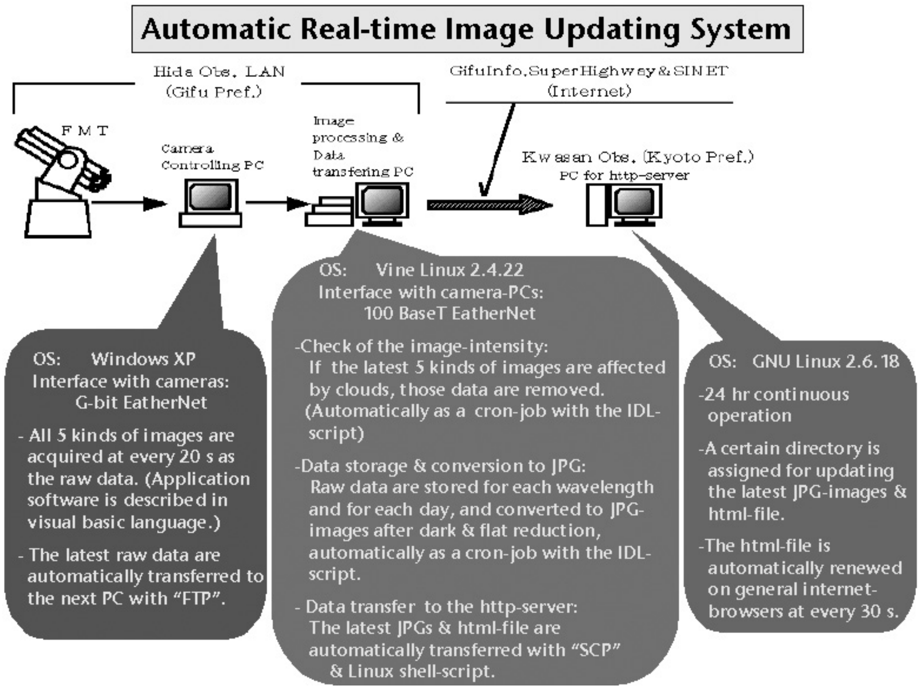


Figure 10. Composition of the automatic real-time image updating system

3.3 Process of Scientific Data Analysis

From 2-D distributions of the "contrast" calculated from observed images at multiple wavelengths, we can obtain 2-D distributions of physical parameters (Doppler velocity, etc.) of chromospheric structures (figure 11). However, since the number and range of observed wavelengths are limited, the chance of error or non-uniqueness in the automatically calculated solution for high-speed eruptions is not negligible. At present, we have to manually check the validity of the solution.

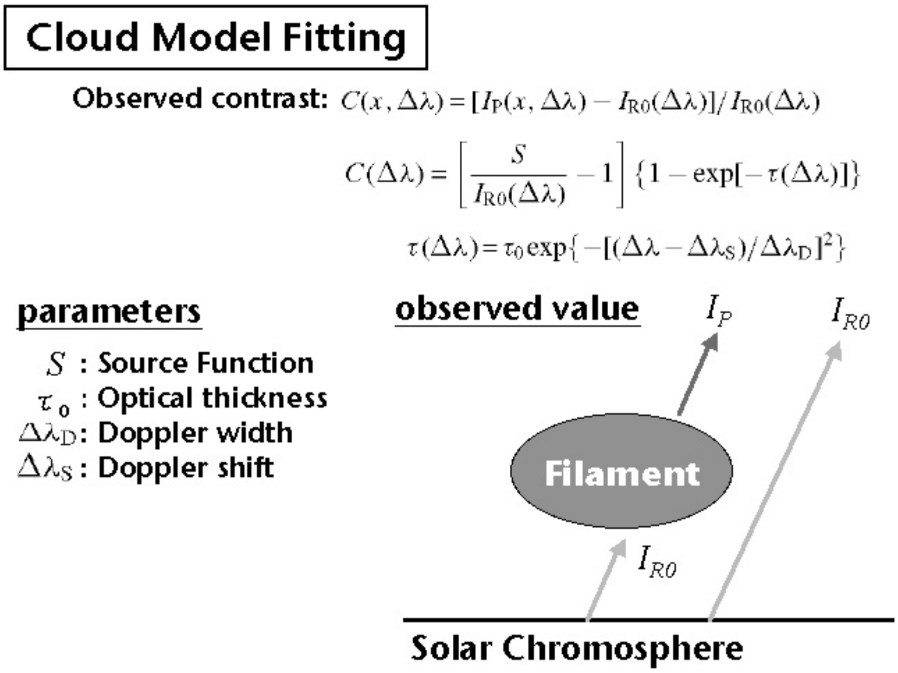


Figure 11. Principle of the cloud model fitting method for calculating physical parameters

4 CONCLUSION – FUTURE WORK

We aim to start operation of the FMTs in Peru and Algeria by the end of 2010, before the next maximum phase of solar cycle 24, for the purposes of continuous observation of more geoeffective solar eruptive phenomena and studies of the relation between solar phenomena and active phenomena around the magnetosphere. We already have a digital-data acquisition system and data-archive systems for the present FMT. However, some methods and processes among them are out-dated or need manual confirmation. Before we begin operation of the oversea FMTs, we must make the following improvements to realize highly efficient observation and data analysis.

– Improve or provide equipment for the internet-environment at Ica University, Peru and the new astronomical observatory in Algeria.
– Suppress the time-lag of the five PCs and data-loss in the image acquisition system.
– Data archive system (event list): enable automatic detection and classification of solar activity phenomena from raw images.
– Data archive system (real-time image update): simplify and speed-up the system.
– Process of scientific data analysis: Add a function to automatically check the uniqueness of physical parameter solutions. Improve the observation mode; for example, by increasing the number of observed wavelengths.

After these improvements are made, the data observed by the foreign sites will be transferred every day to the data-accumulation devices set up in the Kwasan & Hida observatories in Japan, where the data will be archived and made open to the public on the website of the Kwasan and Hida observatories. Moreover, we will simultaneously provide corresponding meta-data for general data-providing systems, such as the Virtual Solar Observatory (http://sdac.virtualsolar.org/) and STARS (http://www.infonet.cite.ehime-u.ac.jp/STARS/English/), so that space weather researchers in wider fields may easily search and acquire the data.

5 ACKNOWLEDGEMENTS

This project is supported by a Grant-in-Aid for Creative Scientific Research of the MEXT "Basic Study of Space Weather Prediction" (17GS0208 PI: K. Shibata). We greatly appreciate the very effective cooperation in this project provided by Dr. J.K. Ishitsuka, Prof. M. Ishitsuka, Dr. H.T. Aviles, et al. of Instituto Geofisico del Peru (IGP), and Dr. N. Seghouani, T. Abdelatif, N. Akacem, et al. of the Center of Research of Astronomy, Astrophysics and Geophysics (CRAAG) in Algeria.

6 REFERENCES

Eto, S., Isobe, H., Narukage, N., Morimoto, T., Thompson, B., Yashiro, S., Asai, A., Wang, T., Kitai, R., Kurokawa, H., Shibata, K (2002), “Relation between a Moreton Wave and an EIT Wave Observed on 1997 November 4”, Publ. Astron. Soc. Japan 54, 481-491

Ishitsuka, J.K., Ishitsuka, M., Aviles, H.T., Sakurai, T., Nishino, Y., Miyazaki, H., Shibata, K., UeNo, S., Yumoto, K., Maeda, G., (2007), "A solar observing station for education and research in Peru", Bull. Astr. Soc. India, 35, 709-712

Kurokawa, H., Ishiura, K., Kimura, G., Nakai, Y., Kitai, R., Funakoshi, Y. and Shinkawa, T., (1995), “Observations of Solar H alpha Filament Disappearances with a New Solar Flare-Monitoring-Telescope at Hida Observatory”, J.Geomag.Geoelectr., 47, 1043-1052

Morimoto, T. & Kurokawa, H., (2003a), “A Method for the Determination of 3-D Velocity Fields of Disappearing Solar Filaments”, Publ. Astron. Soc. Japan 55, 503-518

Morimoto, T. & Kurokawa, H., (2003b), “Eruptive and Quasi-Eruptive Disappearing Solar Filaments and Their Relationship with Coronal Activities”, Publ. Astron. Soc. Japan 55, 1141-1151

Narukage, N., Hudson, H.S., Morimoto, T., Akiyama, S., Kitai, R., Kurokawa, H. and Shibata, K., (2002), “Simultaneous Observation of a Moreton Wave on 1997 November 3 in H-alpha and Soft X-Rays”, Astrophysical Journal 572L, 109-112

UeNo, S., Shibata, K., Kimura, G., Nakatani, Y., Kitai, R., Nagata, S., (2007), "CHAIN-project and installation of the flare monitoring telescopes in developing countries", Bull. Astr. Soc. India, 35, 697-704