ALL–SKY PHOTOMETRIC COMPLEX

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This paper describes an all–sky photometric complex being developed at the Institute of Atmospheric Optics, Siberian Branch of the Russian Academy of Sciences, Tomsk. The complex is intended for the observation of distribution of scattered solar radiation over the sky. Also given in this paper are description of an operating model of such an all–sky photometer and some preliminary results of observations.

The solar radiation scattered in the atmosphere is one of the important sources of information about the optical and physical state of the atmosphere.[1] The development of means for observation of the atmospheric state based on recording of the solar radiation scattered in the atmosphere remains urgent now. Means for diagnostics of the optical and physical states of the atmosphere in real time on the basis of angular brightness distribution with allowance for the parameter variations as functions of elevation angle and time are of special interest not only for scientific research, but also for meteorological and ecological applications.[2] This is the objective to be pursued by the development of the all–sky photometric complex.

The basic idea for the scheme of the all–sky photometric complex being developed was not new, and the problem was solved at different times on the basis of available technology of imaging. As far back as 1940s Hartley[3] (USA) and Lebedinskii[4] (Russia) applied rapid very wide–angle camera systems with a field of view up to 180° (all sky cameras) for the photography of polar auroras. The main element of such camera systems was a convex or concave mirror. A virtual (real for concave mirror) image of all–sky hemisphere, produced by a mirror with reasonably large curvature and size, was photographed by the camera. One of the variants of such an optical system was applied to the development of the standard C–180 and C–180S cameras intended to photograph polar auroras in the International Geophysical Year[4] (1957–1958). The main advantages of such a system are the feasibility to obtain the all–sky brightness distribution in one picture, high luminous power, ease of implementation, reliability of operation, and possibility to use not only colour, but also polarization light filter.

Unlike the prototypes, we used a video recording in the all–sky photometric complex. A change from photography to video using the photodetectors based on a matrix of charge–coupled devices allows for color imaging of the sky, extends the range of recorded brightnesses up to three orders of magnitude,[5] and what is especially important, makes it possible to enter into a computer not only current sky images in order to obtain some preliminary results during the course of observations, but also the images prerecorded on videotape in order to select the most interesting atmospheric optical situations.

A HITACHI 600 CCD videocamera, videorecorder, and IBM 386/387 computer having a video input of color and black–and–white images were used in the all–sky photometric complex capable of imaging and image processing. The video input board digitazes the video signal in the PAL standard in all the three color channels (R, G, and B) having 256 levels of gradation in brightness and color frame format of 480×288 pixels. The format of black–and–white image was 960×576 pixels. The time required to enter one frame into the computer did not exceed 1.5 s, which is acceptable for the sky brightness field observation.

The selected optical scheme, sensitivity, and resolution of the receiving video camera together with the video input board of this complex made it possible to observe all sky with angular resolution of about 0.6° during daylight hours and twilight at the solar zenith angles up to 6° below the horizon. To estimate illumination of video camera and interference due to direct illumination of the main mirror by solar radiation, we used the mobile solar screen controlled remotely. The relative area of screening of the field of view by the solar screen and other structural elements did not exceed 3%.

To process the recorded images, we used the program complex which made it possible to obtain the R, G, and B components of the initial image, to mark the brightness in contours, and to determine the chromaticity of the scattered light in different points of the sky. The special–purpose programs for image processing oriented towards the solution of the atmospheric optics problems are being developed now.

The operating model of the all–sky photometric complex was installed on the roof of the building of the Institute of Atmospheric Optics located on the eastern outskirts of Tomsk. The high altitude of the photometer placement provided minimum screening of the field of view by buildings and trees. The location of the town west of the photometer and forest east of it make it possible to compare the optical characteristics of the ground atmospheric layers over different ecological zones.

Figures 1, 2, and 3 display the sky images obtained in summer, 1990 under different weather conditions and at different time of the day. In the images one can see the structural elements of the detector: video camera (at the center), tripod, and mobile solar screen. The center of the sky image corresponds to the zenith direction. Computer processing of these images allowed us to identify the equibrightness zones and to determine their chromaticity. The first image (Fig. 1) was obtained at noon under cloudless conditions. One can distinctly see the circumsolar aureole, the lower brightness zone in the plane of solar meridian opposite to the zenith approximately at an angle of 90° with respect to the Sun, and general increase of the brightness towards the horizon. The second image of the cloudless sky (Fig. 2) was obtained at dawn at the solar zenith angle of about 3° below the horizon. The recorded brightness distribution in these

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two cases agrees, on the whole, with classical concept of light scattering in the atmosphere.[1,6] Figure 3 displays the sky image under conditions of broken clouds at the solar zenith angle 3° above the horizon.

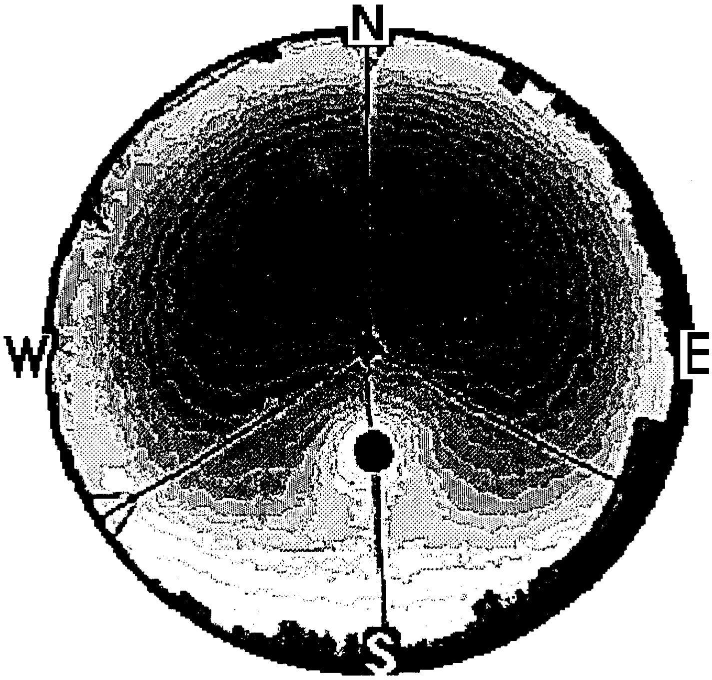

FIG. 1.

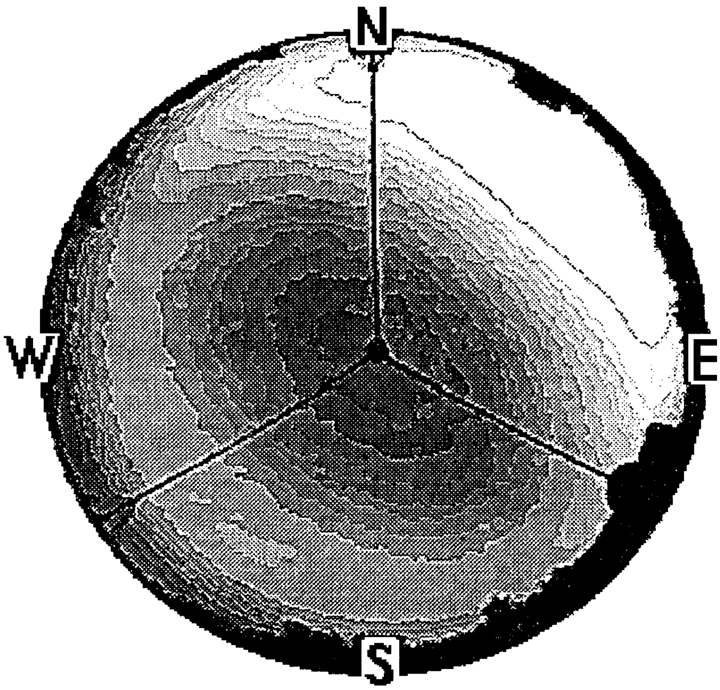

FIG. 2.

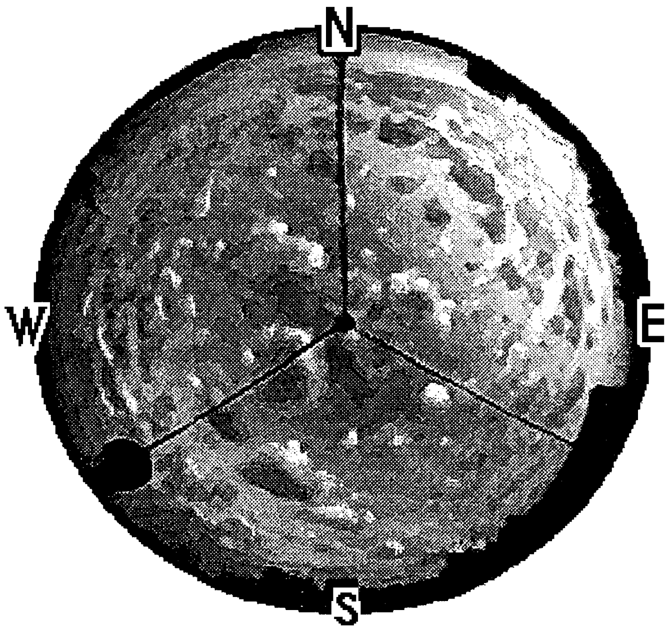

FIG. 3

As the observations show, it is not difficult to reveal the presence of cloudiness and to determine its type and amount from the colored image displayed on the monitor screen. A comparison of a series of consecutive images of the cloud field (by fast view of the video record) makes it possible to follow its evolution and direction.

The sky images obtained under clear sky weather conditions or under weather conditions characterized by a small cloud amount by using the polarization filter show the distinctly pronounced distribution of the polarization degree of scattered light. Polarization sharply increases at the scattering angles of about 70° and decreases at the angles larger than 110°. It reaches the maximum at an angle of 90° (near the zenith) with respect to the Sun and slowly decreases towards the horizon. The observed distribution of the polarization degree is in a good agreement with the available concepts.[1]

When the all–sky photometric complex is in use, the size of the controllable zone is important. For the atmospheric phenomena occurring at altitudes of from 0.1 to 10 km, the controllable horizontal distance can reach a few tens of kilometres for high atmospheric transparency. This makes it possible to use the all–sky photometric complex for meteorological and ecological monitoring of large cities.

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