The formation of the sky brightness with horizon position of the sun

Viktor P. Galileiskii, Alexey I. Elizarov*, Dmitrii V. Kokarev, Aleksandr M. Morozov
Institute of Atmospheric Optics SB RAS, Academician Zuev square 1, Tomsk 634021, Russia

ABSTRACT

This report discusses some simulation results of the angular distribution of brightness of the sky in the case of molecular scattering in the atmosphere during the civil twilight with solar zenith angles 90 ° - 94 °.

Keywords: The brightness of the sky, twilight, atmosphere, molecular scattering of light, All-Sky image

In most well-known papers on the problem of modeling the interaction of the optical solar radiation with atmospheric particles much attention is given to the field of radiation scattered in the atmosphere at various positions of the sun above the horizon. In [1-7] the basic mechanisms of the brightness of the atmosphere are considered due to scattering of solar radiation on its particles already considering geophysical factors, including the position of the sun at the horizon. This allows us to perform a simulation of the brightness of solar radiation the scattered by the field of Earth's atmosphere, not only for daytime, but also for the conditions of twilight.
Formation of the brightness of the sky in the morning and evening is of special concern. Transition from day to night and vice versa - from night to day, significantly alters not only the level of light, but here even the geometric factor is included related to the change of shading of solar radiation by the body of the planet.

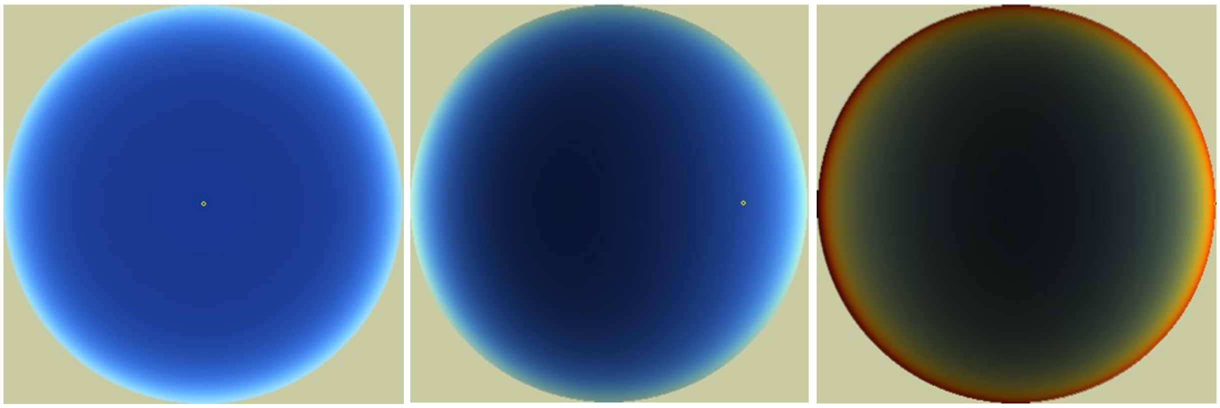
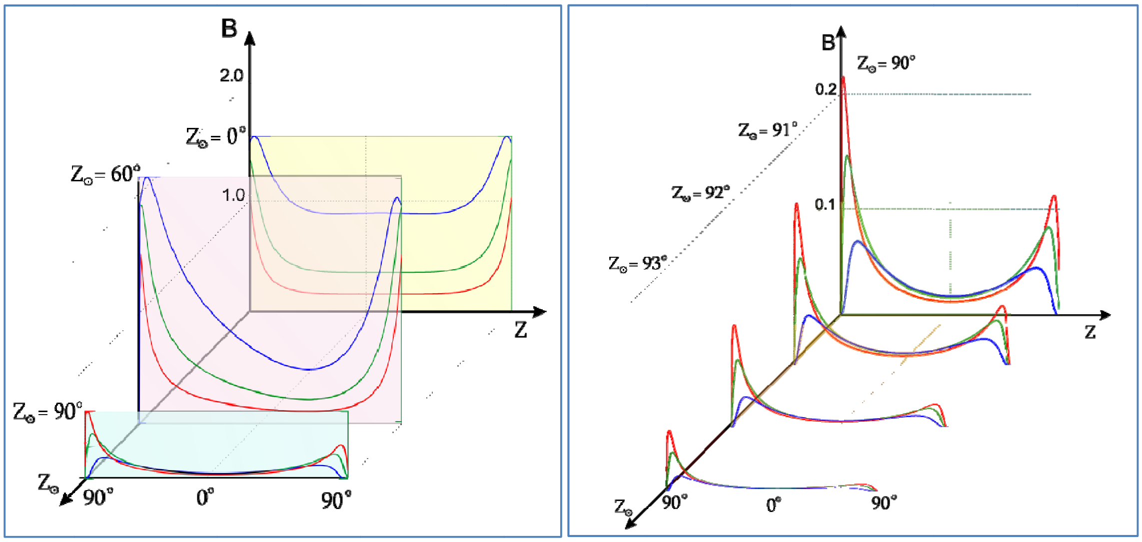


Fig. 1. The results of calculations of the angular distribution of brightness of the sky for three positions of the Sun (zenith angles: 0°, 60° and 90°) for the case of molecular scattering. The calculation results are normalized to the maximum value in the frame and are represented in the polar coordinates.

This report discusses some simulation results of the angular distribution of brightness of the atmosphere in the case of civil twilight, namely: the solar zenith angles of 90° -94°. For the calculations in the developed IAO SB RAS software package «AtModel» was used [4]. Fig. 1 shows the results of simulations carried out taking into account the spectral sensitivity of the eye.

*alex@iao.ru; phone +79528053747

21st International Symposium on Atmospheric and Ocean Optics: Atmospheric Physics,
edited by G. G. Matvienko, O. A. Romanovskii, Proc. of SPIE Vol. 9680, 96803L
 · doi: 10.1117/12.2205504



a) b)

Fig. 2. The results of calculations of the brightness distribution of the atmosphere (in relative terms) in the plane of the solar meridian at two positions of the Sun: a) the Sun above the horizon (day), and b) the sun over the horizon (twilight).

Fig. 2 shows the results of calculations of the brightness distribution in the plane of the sky with the sun's vertical position of the sun above and below the horizon. The results of these calculations in three bands in the visible range of the electromagnetic spectrum (R, G, B) shows that in the daytime:

- **The value of** maximum brightness in an image frame, with cloudless weather and **negligible** small amount of aerosol in the atmosphere, according to the **circumhorizontal** zone;
- in the solar zenith angles from 60° to 80° we see the daily maximum brightness of the atmosphere, which is observed in the sunflower field sky; At the same time, the largest drop of brightness values is noted in the solar vertical plane between **circunhorizontal** area in subsolar field sky and direction, spaced at 90° from the Sun;
- as the Sun approaches to the near-zenith region of the sky the value brightness in the blue part of the spectrum increases and it is becoming more symmetrical relative to the Sun.

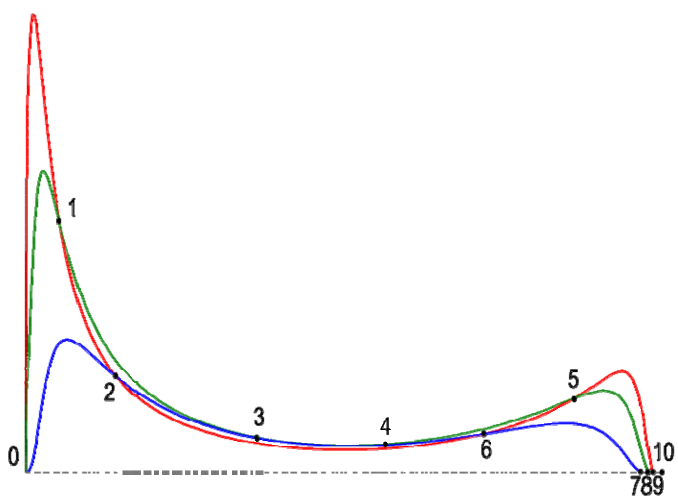


Fig. 3. On the problem of zoning areas of the sky in color criterion.

ZONE	POINT	PRIORITY AREA COLOURS
1	0 – 1	Red (R > G, B)
2	1 – 3	Green (G > R, B)
3	3 – 4	Blue (B > G, R)
4	4 – 5	Green (G > R, B)
5	5 – 9	Red (R > G, B)
6	1 – 2	G > R > B
7	2 – 3	R > B > G
8	4 – 6	R > B > G
9	6 – 5	G > R > B
10	9 – 10	The Dark Zone

As we approach the Sun to the horizon and further sinking of the sun to its line we can see:

- decrease in brightness of the sky, but there is an increase in the proportion of its radiation brightness in the red region of the spectrum;
- at zenith angles more than 91° in the antisolar side sunscreen zone appears with a minimum brightness of the sky - "dark zone"; with further sinking of the sun below the horizon increases the height of the zone;
- in the solar zenith angles greater than 90° in the antisolar side the area is seen where the brightness higher than at the zenith and the radiation in the area in the red part of the spectrum considerably prevails over radiation in the blue and green part of the spectrum; said region is located above the previously mentioned "dark" area.

Fig. 3 shows profiles of brightness of the sky in red, green and blue spectral ranges in the plane of the solar vertical at zenith distance of the sun at 92°. In this figure, there are several areas with the priority level of brightness in the red, green and blue spectral regions. The results of this zoning are given in the table.

Fig. 4 shows the results of calculations of the angular distribution of brightness of scattered sunlight by molecules of the Earth's atmosphere. Fig. 4a shows the image obtained for the solar zenith angle of 90°, and Fig. 4b, c - for the zenith angle of 92°.

To carry out further analysis of the image, in the interests of clarity, Fig. 4c shows the equal brightness levels for the three ranges of the electromagnetic spectrum - red, green and blue in accordance with the spectral sensitivity of the eye. The analysis is shown in Fig. 4b and it allows you to mark on this image the sector (anti-direction, near the horizon) with a sharply reduced brightness value - "dark zone".

In the plane of the solar vertical, above the "dark zone" due to the projection of shadow on the planet's atmosphere, it is a zone of high brightness with a predominance of red color - is the area of the optical phenomenon known as "Belt of Venus".

SUNNY SIDE	MIRRORS PARTY

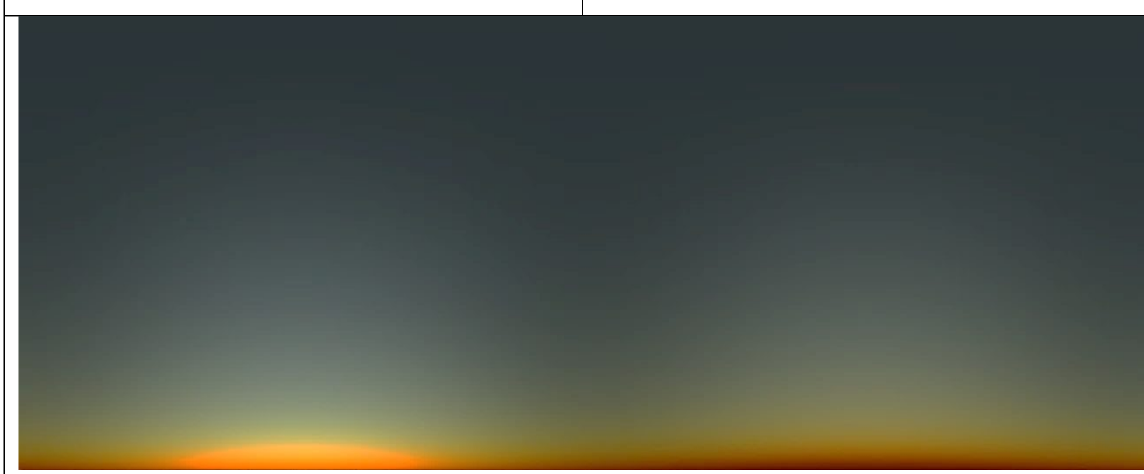
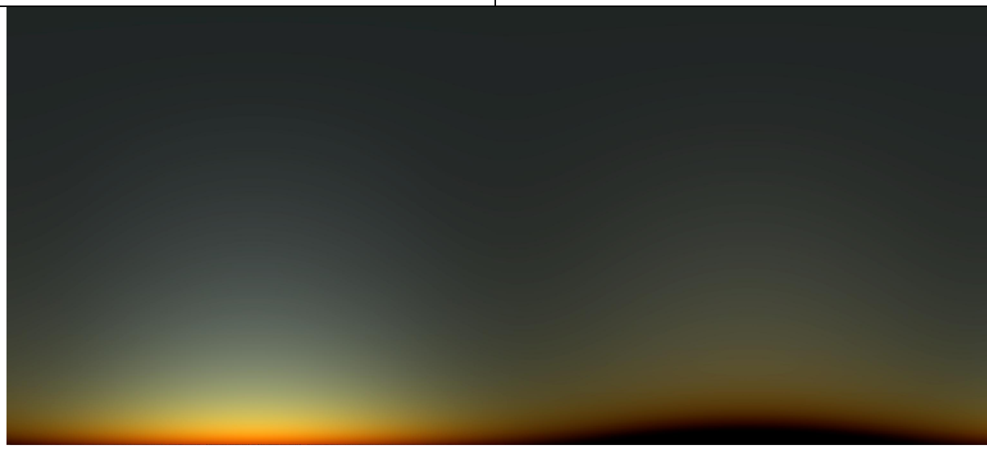
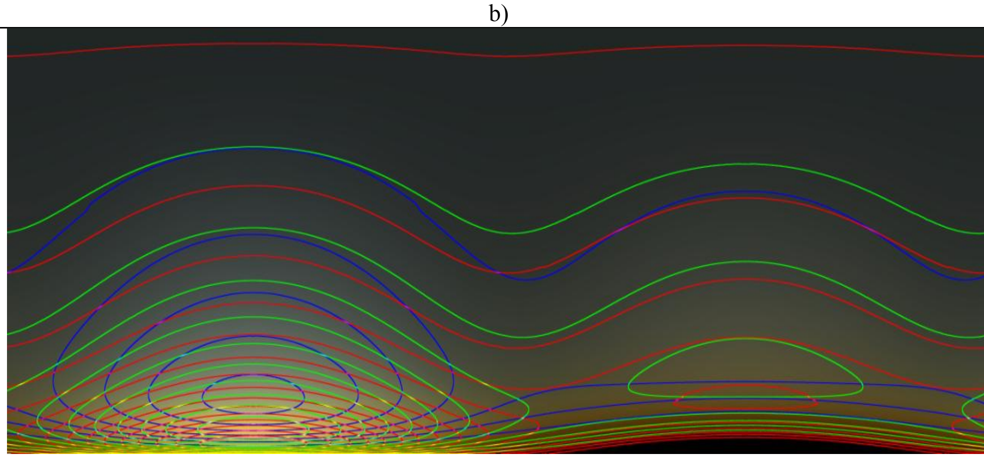


Fig. 4 a)

SUNNY SIDE	MIRRORS PARTY



b)



c)

Fig. 4. Calculation results of angular intensity distribution of the atmosphere ("whole sky" rectangular projection) at the zenith position of the Sun: a) - 90°, b) and c) - 92°.

REFERENCES

[1] Zhuravleva T.B., Nasretdinov I.M., S.M. Sakerin, "Numerical simulation of angular structure of the brightness of the sky near the horizon as seen from Earth. Part 1.Aerozolnaya atmosphere," Optics of atmosphere and ocean, №5-6, 537-545 (2003).

[2] Hosek L., Wilkie A., "An Analytic Model for Full Spectral Sky-Dome Radiance. ACM Transactions on Graphics," Proc. Of ACM SIGGRAPH 31, (2012).

[3] Galileiskii V.P., Morozov A.M., "The brightness of the atmosphere observed from the surface of the atmosphere," Dep. VINITI. Number 1172 1387, 10 p (1987).

[4] Galileiskii V.P., Zuev K.G., Morozov A.M., "The computer program «AtModel». State register of computer programs," Reg. Number 2011614925 from 23.06.2011.

[5] Galileiskii V.P., Grishin A.I., Morozov A.M., "Numerical modeling of the angular distribution of brightness of the scattered solar radiation in the atmosphere," Optics of atmosphere and ocean 26, 1005-1007 (2013).