Solar Radiation Climatic Resources in the Kirov Region Territory

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Abstract

Objectives: Data on spatial distribution of solar radiation characteristics are required in buildings thermal values modeling, as input data in climatic, ecological and agricultural models, at assessment of climatological changes long-term consequences. **Methods**: For the spatial distribution analysis of radiation balance components data of NASA Surface meteorology and Solar Energy for 1981-2003 were used. On the basis of calculation methods use the detailed assessment of solar radiation climatic resources space variability for the Kirov region (Russian Federation) is executed. Meso-climatic maps of radiation balance components and solar radiation duration are constructed. **Results**: The carried-out division into districts allowed to approach the optimum environmental management of the studied territory problem rationally. The spatial distribution of helio-energy potential indexes is considered. Research of solar radiation characteristics inter-annual variability showed that, in general, their distribution across the territory is similar to distribution of their mean values. Indexes of solar radiation differ in the greatest variability during the summer period and make 60-115 MJ/sq. m, the least in the winter – 4-17 MJ/sq.m. **Applications**: Using data on Sun height at various latitudes, the greatest possible monthly running time of solar installations on clear sky condition was defined.

Keywords: Climatic Resources, Cooperative Radiation, Direct Radiation (Sun-rays), Solar Radiation Duration

1. Introduction

The solar radiation is arriving to terrestrial surface one of the major climate factors. In turn, it is the main source of thermal energy for almost all of the natural processes are developing in the atmosphere, the hydrosphere and high layers of lithosphere causing humidity and heat exchange, the daily and annual course of meteorological elements, defining distinctions in terrestrial surface radiant heating[1,2]. Meso-climatic division into districts of solar radiation resources is carried out in system of mid-scale climatic division into districts which allows to differentiate the territory on areas differing in the meteo-mode features which are formed under the influence of active surface meso-scale inhomogeneities[3–5]. Researches of solar radiation ranks spatial structure are necessary when performing various scientific development in solar power engineering, town planning, health care, farm industry and forestry[6,7].

2. Sunshine Duration

Sunshine duration generally depends on day length, i.e. place latitude, and increases from north to south.

However, the latitudinal distribution of this characteristic is often broken by cloudy cover influence caused by features of atmospheric circulation, and local conditions; arrangement of meteorological platforms also have essential impact[8,9]. In the considered territory the increase in number of solar radiation hours occurs from northwest on southeast. If northern part of area solar radiation duration a year makes 1650-1720 hours, in the southern part it reaches 1900-2000 hours. In the central part area change of solar radiation duration is inconsiderable and makes 1700 – 1800 hours. Such change of solar radiation duration in these areas is caused, generally, by various
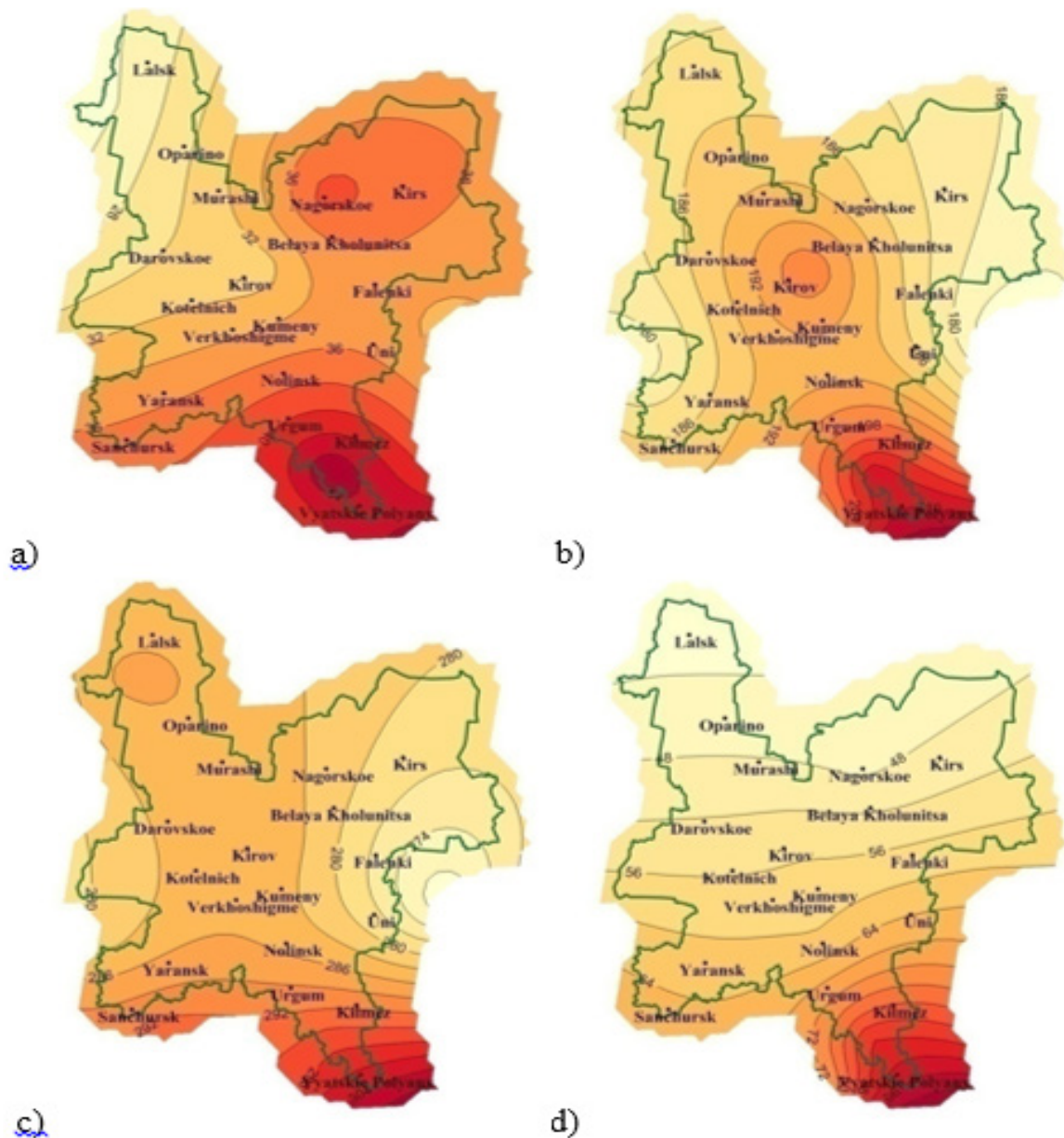
Figure 1. Distribution of solar radiation duration (hours) average monthly values in January (a), April (b), July (c), October (d).

repeatability of sky cloudy condition. The greatest number of hours with solar radiation is celebrated in June - July, the least in December. In Figure 1a in the considered territory the latitudinal distribution of solar radiation duration is observed on average: values decrease in process of advance from the south to the north territory. In the north area the least values of solar radiation duration – 20-25 hours are observed, and amounts of solar radiation durations, comparable to the maximal values are observed in the southern part of area – 40-45 hours. Sharp increase of solar radiation hour's number is noted during the period of February to March that is caused both by increase in day length and the considerable decrease of cloudy day's number in spring. The greatest growth is observed in northwest areas, in February the number of hours with solar radiation makes 60-70 hours, in March - 120-130 hours. In April sum Figure 1b of solar radiation duration continues to increase. Influence of astronomical factors on solar radiation duration is partially blocked by cloudiness influence, therefore in the north of the territory at least 175-185 hours are celebrated. The maximal amount (195-205 hours) is observed in the south territory. Sharper than in spring, increase of the solar radiation duration monthly sums with increase in Kirov region territory latitude in summer months is expressed. So in July Figure 1c the greatest solar radiation duration is observed in the south territory 290-300 hours that makes 65-70% of the possible solar radiation duration, the least 270-280 hours in the north territory, i.e. 50-55% of possible hour's number with solar radiation a month. Sharp decrease of solar radiation hour's number happens upon transition of September to October, especially in northern regions: from 110-115 hours in September to 40-45 hours in October Figure 1d, i.e. more than twice. In November and December, the least solar radiation duration is noted in the Northwest Territory – 25-30 hours (about 10% of possible duration), the greatest - in the southeast and the northeast 30-40 hours (15-20%). Great applied value has continuous solar radiation duration. During the whole year the greatest repeatability of the continuous solar radiation duration falls on the period from 2 to 6 hours. In fall it makes 20-30% of all observation cases, in the winter – 30-40%, in spring and in summer – it is slightly less, 15-25%. In summer days solar radiation duration can make 16-18 hours in a row. According to increase

in solar radiation duration from northwest to southeast there is also a decrease of days number without sun. Most of all days without sun observed in northern areas - 120-130 days a year. In process of advance to the southern areas the number of days without sun decreases to 90-100 days a year. In the summer the number of days without sun changes across the territory a little and averages 1-3 days, in the spring (April - May) 3-6 days. In December across all territory the maximal number of cloudy days, from 25 in the west territory to 15 - 20 in the southeast is observed.

3. Spatial Distribution of the Radiation Balance Components

For the spatial distribution analysis of radiation balance components data of NASA Surface meteorology and Solar Energy (The Atmospheric Science Data Center at NASA Langley Research Center) for 1981-2003 were used[10]. During the winter period in the considered territory streams of direct solar radiation on surface change from north to south. Minimum values are noted in December in northern part area and make 6-8 MJ/sq.m. The maximal inflow of direct radiation is observed in the southern part region – 12-13 MJ/sq.m. In January and February Figure 2a the value of direct radiation is slightly higher than in December. Thus the maximum and the minimum during months is noted, as well as in December – in the South and the North respectively. In the central part of area, in winter months, minor changes in direct solar radiation are noted. In spring months, nature of direct sun-rays distribution differs from the winter. If in March the latitudinal distribution of isolines with minimum in northern part of the region (making 116-120 MJ/sq.m) and maximum in southern stills traced (making 130-134 MJ/sq.m), in April Figure 2b decrease direct sun-rays comes from southeast on northwest from 245-250 MJ/sq.m to 225-230 MJ/sq.m. In May in central and southern regions of area direct sun-rays surface distribution takes latitude character. In June on the most part of the territory small gradients of direct solar radiation are noted. In July Figure 2c nature of distribution changes. In the north region the amount of direct radiation coming to surface changes a little, (5 MJ/sq.m), and in the central and south-

ern parts this change is more essential making 319 to 331 MJ/sq.m. In August and in autumn months Figure 2d the behavior of direct radiation isolines reaching surface once again gains the latitude character, with a maximum in the south area and with a minimum in the north. Cloudiness has essential impact on solar radiation distribution. Thus in winter months in the considered territory apparent

prevalence of dispelled radiation (21-90 MJ/sq.m) over a direct one (9-48 MJ/sq.m) noted. Distribution of dispelled radiation across the territory has zonal character, the increase in values occurs from north to south. In March in all territory a dominance of dispelled radiation rays still remains. In April and May streams of direct radiation prevail. Nature of dispelled radiation rays distribution during
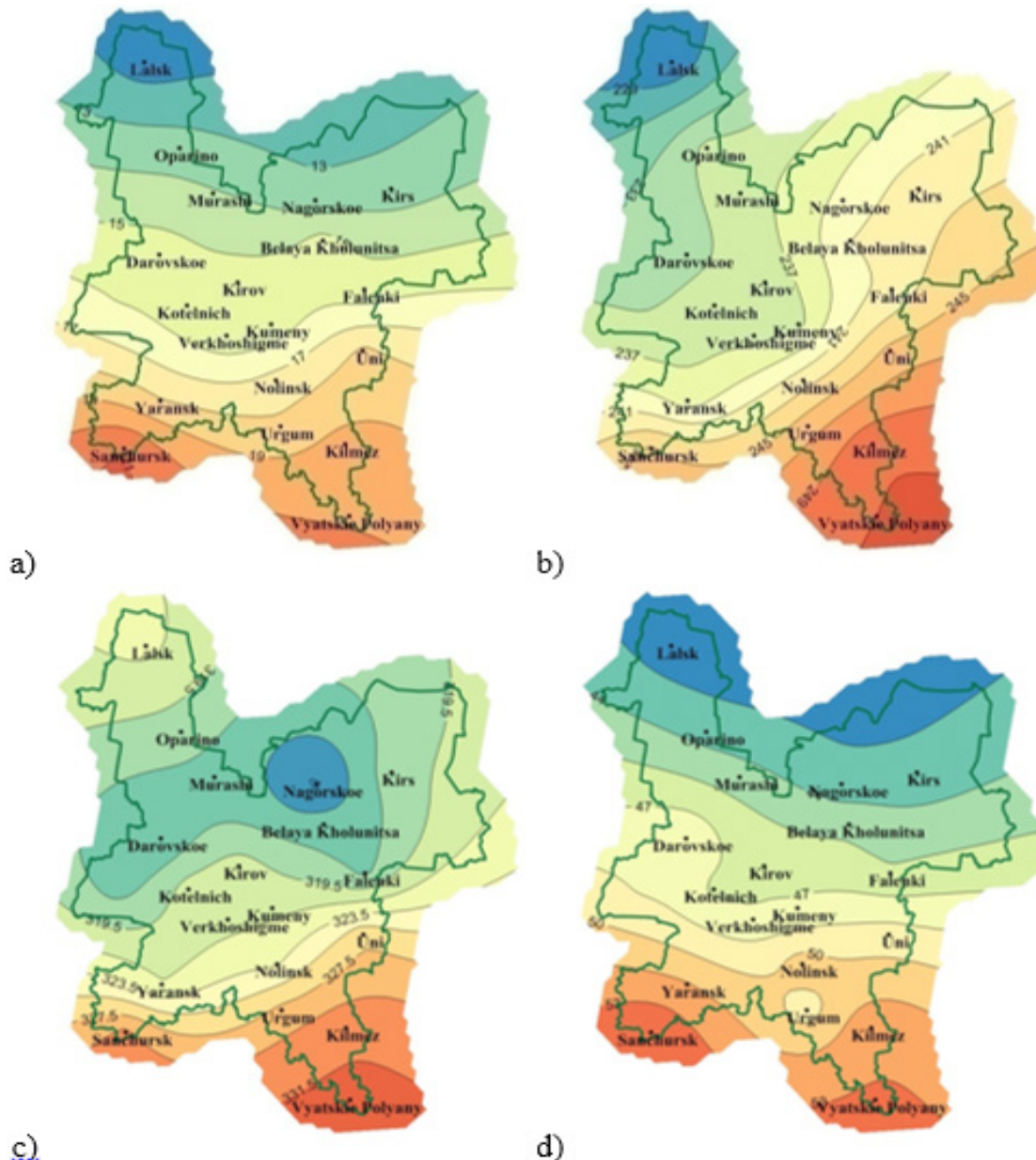
Figure 2. Average monthly values distribution of direct solar radiation (MJ/sq.m) in January (a), April (b), July (c), October (d).

these months is similar to distribution of direct radiation. In summer months, value of dispelled radiation is also less than of direct one. In July, as well as in June, in the central and southern parts of area small difference (294-300 MJ/sq.m) in values of dispelled radiation is noted. In northern part of the territory it is more – 288-298 MJ/sq.m. Starting September, the share of dispelled radiation in the common stream of a cooperative solar radiation prevails. Isolines of dispelled radiation in autumn months gains the latitude character with a minimum in the north of the considered territory and a maximum in the south. The maximal amount of average quadratic deviation of the solar radiation monthly sums is observed in summer and make 60 - 100 MJ/sq.m for direct sun-rays and cooperative radiation and 25 – 40 MJ/sq.m for dispelled radiation. In the winter mean value of quadratic deviation of the solar radiation monthly sums makes 4-17 MJ/sq.m for direct sun-rays and cooperative radiation, 15-21 MJ/sq.m for dispelled radiation. In the spring values 21-70 MJ/sq.m for direct sun-rays and cooperative radiation are equal. In fall these values are slightly less - 10-50 MJ/sq.m.

4. Spatial Distribution of the Helio Energy Potential Indexes

In our country, as well as abroad considerable attention is paid to solar energy immediate use researches[11-13]. Different types of solar power plants which are subdivided into two categories are known. One of them is "hot boxes" (without concentration of energy), which surface temperature reaches 100 — 150 °C, can be considered as the low-temperature. Others are high-temperature (over 150 °C) with the reflective mirrors concentrating energy of the sun. A number of inventories in which majority average sentry, monthly and annual characteristics of solar radiation arrival, as well as monthly solar radiation duration are generally given, has been developed so far. Sample statistics of observed maximal values, number of clear days without the sun a month and a year are given in them[12,13]. For development and operation of the majority installations data on direct solar radiation arriving on perpendicular to solar radiation and sloping surface on the dispelled and cooperative radiation received at

Table 1. Possible monthly running time of solar power plants (hours) on clear sky condition (S > 0,42 kW/sq.m)

	Months											
Latitude	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
60	0	157	273	348	428	450	453	397	306	223	84	0
59	0	168	279	348	428	444	446	391	306	229	102	0
58	62	174	279	348	422	438	440	391	306	236	120	0
57	87	179	285	348	422	438	440	391	306	236	132	0
56	105	185	285	348	415	432	434	391	312	242	144	56
55	124	190	291	348	415	432	434	384	312	248	156	81

surface are required. As one of inter-annual variability relative characteristic criteria the variation factor used. This coefficient reflects stability degree (from year to year) of the radiation mode and therefore is exponential at comparative estimates of certain areas. From other meteorological characteristics first of all data on cloudiness and solar radiation duration are important, data on air temperature and wind speed sometimes are required. According to the helio-power inventory criteria[13] solar radiation can be considered "technically accepted" since that moment when its intensity reaches 0, 42 kW/sq.m. This intensity on condition of average atmosphere transparency is observed with a sun height over 10° which is reached at latitudes of 50-60° by NL in 1-1, 5 h after rising and before sunset. On the basis the stated, using data on Sun height at various latitudes, the greatest possible monthly running time of solar installations on condition of clear sky shown in Table 1. Annual amplitude of the considered size quickly increases in the direction of high latitudes. Thus in northern regions of the Kirov region in June and July the possible running time of solar power plant can exceed 450 h, and has the pronounced annual course with a minimum in December-January and a maximum in June-July.

5. Summary

The detailed analysis of the solar radiation characteristics mode and solar radiation in the Kirov region territory allowed to reveal features of field structure and dynamics of the studied indexes in the annual course, caused, generally by steady manifestation of circulating factor. Thus there is an increase in radiation indexes from the northwest to the southeast of area: from 1600 to 2400 hours – for solar radiation and from 3345 to 4500 MJ/sq.m – for cooperative radiation. Research of solar radiation characteristics inter-annual variability showed that, in general, their distribution across the territory is similar to distribution of their mean values. Indexes of solar radiation differ in the greatest variability during the summer period and make 60-115 MJ/sq.m, the least in the winter – 4-17 MJ/sq.m.

6. Conclusion

The executed calculations showed that with increase in latitude the annual amplitude of solar power plants running time increases: in June and July at latitudes of 60-62° NL. The possible running time of solar power plant can exceed 450 h. The continuous solar radiation duration during the spring and summer period can reach more than 6 h 40-50% in the north and to 50-60% in the south of the considered territory.

7. Acknowledgement

8. References

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