Observations of solar radiation in atmosphere and ocean during 55th Russian Antarctic expedition on Academic Fyodorov research vessel

V. Malyshev ¹, A. Volchkov ¹, L. Lutsko ²

¹ – Research and Production Association “Typhoon”, 4 Pobedy str., Obninsk, Russia;
² – Main Geophysical Observatory, 7 Karbyshev str., Saint-Petersburg, Russia.

Particularly important for the study of the radiation climate are measurements of solar radiation taken above the surface of seas and oceans, since these cover 2/3 of the surface of the globe.

During the 55th Russian Antarctic expedition on Academic Fyodorov research vessel, observations were carried out during the whole itinerary, i.e., while crossing the Atlantic and Southern Oceans, staying at Cape Town port and Progress-2 Russian Antarctic stations. Measuring works were made by means of MF-19 solar radiometry station (fig. 1) consisting of solar sensors, the central measuring unit, the software and auxiliary equipment. The station was mounted on the locator desk near the vessel laboratory to avoid shadowing by the deck superstructure and enable measuring the water surface radiative balance.

![Fig. 1 – MF-19 solar radiometry station in the Antarctic](image)

As is well known, radiative balance is a difference between incoming and outgoing irradiances.
During the expedition the following types of solar radiation were measured:
- net radiation (by M-115M (Russia), Peleng SF-06 (Belarus), CM-21 (Kipp and Zonen, the Netherlands) sensors);
- reflected radiation (M-115M (Russia));
- long-wave radiation (Eppley pyrgeometer (USA));
- radiative balance (Peleng SF-06 balance meter (Belarus)).

Radiative balance is one of the main characters among other weather quantities affecting the climate of the studied territory. But there are some technical problems in its wide-scale measuring at sea, because the balance meter should be placed outboard. To use calculating methods, it is necessary to know the pattern of relationship between the balance and global radiation. Those patterns have been provided for Russian observation network by Main Geophysical Observatory (St. Petersburg).

Both momentarily and hourly mean data were put in the solar observation register while carrying out continuous observations of radiative balance components. At the same time, the routine observations on air temperature, cloudiness, visibility, waves and the vessel position finding were also made daily. As a result of the measuring work carried out in the expedition, the relationship between global radiation and radiative balance above water surface were defined (fig. 2).

Fig. 2 – Relationship between radiative balance above water surface and net radiation in continuous cloudiness
Comparison was made for one-minute mean values at overcast conditions, to eliminate disturbance caused by sunny weather like water blinks or radiation reflected by the vessel. Among those cloudy days, the smoothest sea conditions (2 – 3 grades) were taken.

Fig. 2 shows the relationship between the balance B and global radiation Q according to the data obtained on the chosen days. It confirms undoubtedly that these characters of solar radiation are connected. As we can see at the picture, variations of the data on the chosen days are rather small and do not exceed the instrumental error.

It is an interesting fact, that connection between balance and global radiation at overcast and smooth sea, but various air and water temperatures (from 21 to 0 °C) vary slightly during the whole itinerary in different latitudes. So it might be useful to continue observations in a larger scale and various conditions.

During the expedition some other quantities were computed on the basis of solar radiation observations. For example, shot-wave balance (fig. 3) was computed according to the equation

\[ B_k = Q - R, \]

where Q and R are global and reflected radiation values, respectively.

Fig. 3 – Diurnal variations of Bk and Q values for partly cloudy and clear days at Progress-2 Antarctic station
Bk quantity describes solar radiation absorbed by the surface. At the same conditions of the surface, diurnal variations of Bk and global radiation correspond to each other. Fig. 3 shows Bk and Q diurnal variations averaged over a period of one minute for partly cloudy and clear days. The curves show synchronous running.

The peaks of radiation are shifted because of BCB time. All Bk and Q values are above zero, because in December there is a polar day at Progress-2 station.

Long-wave radiation balance Bd (fig. 4) were not measured, but computed on the basis of the measured data of global and reflected radiation as well as total radiation balance.

Long-wave radiation balance Bd values were computed according to the equation

\[ Bd = B - B_k = B - (Q - R), \]

where B is a measured value of radiation balance, Q and R are net and reflected radiation values, respectively.

Bd data were computed for Progress-2 station. One-minute values differ significantly, because the total error consists of the measuring errors of all components. Hourly mean values are more visual, their diurnal variation is smoother. All the values are negative, in conformity with the determined rule of Bd variation. Each curve shows its clear minimum at midnight and maximum at noon, also corresponding to the determined rule.
Short-wave albedo $A_k$ of the underlying surface was computed using the data measured at Progress-2 station (fig. 5).

Fig. 5 – Daily variation of short-wave albedo at Progress-2 Antarctic station

$A_k$ values was computed according to the equation
\[
A_k = \frac{R}{Q},
\]
where $R$ and $Q$ are reflected and net radiation, respectively.

$A_k$ depends on direct sun radiation insignificantly, so daily variation of $A_k$ values are almost equal for all 3 days, despite the different cloudiness conditions.

$A_k$ daily variations are similar to those obtained at the surface stations of Russian observation network: after sunrise and before sunset $A_k$ values are large, then those values at noon. At the graph, the time point 7:00 according to BCB corresponds to 12:00 according to the local time.

As we can see at the graph, $A_k$ values change from 39 % at the sides of the curves to 30 % in the center (midday). The underlying surface under the pyranometers was rock and sand of the color similar to yellow. In handbooks (i.e., *Applied solar radiometry* by N.P.Rusin, Leningrad, *GidrometeoIsdat* Publishing House, 1979) $A_k$ value is 35% for yellow sand, that corresponds to the data obtained at Progress-2 station. Thus, according to $A_k$ values, the underlying surface at Progress-2 can be defined as “yellow sand”.
At fig.6 we can see, how long-wave radiation depends on cloudiness and visibility. The three curves have been compared in pairs at the following conditions:
- cloudiness 1-3 grades, visibility 20 km;
- overcast, visibility 20 km;
- overcast, visibility 0.2 - 2 km.

Fig. 6 – Cloudiness and visibility influence on long-wave radiation

As the graph shows, long-wave radiation depends on cloudiness but does not depend on visibility. It is worth paying attention, that even in the early hours (at similar cloudiness conditions) 3 curves are quite comparable.

As a result of the expedition, we can conclude:
- New solar radiometry instruments and techniques, approved for the ground-based network, are acceptable at sea.
- Ground-based relationship between radiative balance and net radiation has been confirmed at sea. It might be practical in developing the method of the balance calculation. To express that relation numerically is a subject for a further study.
- Diurnal variations of short- and long-wave balance, as well as short-wave albedo, conform to the typical ones.
- MF-19 solar radiometry station provides one-minute automatic measurements and enables to follow changing of the measured data at galloping processes at the atmosphere and the ocean.