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5.

ON THE UNIT FOR RADIATION IN OCEANIC RESEARCH.

BY

ANDERS ÅNGSTRÖM,
STOCKHOLM.

THE measurements of the radiation have, in the last twenty years, attracted a growing interest within the geophysical science. Especially within the meteorology, which deals with the physics of the atmosphere, the radiation processes are of fundamental importance, as it is through the radiation from the sun that in the last instance all processes within the atmosphere arise. As within the meteorology, the interest in the first hand attaches itself to the radiation as vehiculating a *transport of energy*, it seems natural that the common units for measuring energy have been adopted also for measuring radiation within this field: watt, or, now in almost general use: the *gram calory per square centimeter per minute.*

The use of the latter unit has the advantage that we, through the simplest possible calculations, are able to obtain an idea from the radiation as to the rise in temperature which the radiation is producing when absorbed. The unit gram calorie per square centimeter per unit of time, is therefore, when we are dealing with problems as regards the physics of the atmosphere, *natural and practical.*

The conditions as regards the most practical *unit* are not quite as simple when we leave the physical meteorology and take into consideration the more statistical part of the same science namely the *climatology.*

One of the chief tasks of climatology consists in furnishing the necessary data demanded for the purpose of technical or scientific investigations. If we look at the measurements of radiation as a *climatological element,* there are a number of special research-fields, which demand that the data given may be applicable to their special problems. Thus for illumination studies, we wish the climatology to give us the natural illumination from sun and sky, the physician wishes to know the intensity of the groups of wave lengths, which exercise a therapeutic influence, the biologist demands informations as regards the kind of radiation, which has an influence for instance upon the assimilation or growth of plants. It is evident that for these various kinds of investigations it is not always natural and in practice convenient to use the energy unit at measurements of the radiation. For illumination purposes one has thus early introduced a special unit: the lux. As regards therapeutics, one has sought to define the light intensity directly through its erythem effects. In a similar way one can imagine different definitions on the basis of various actions, every unit within its special field of research.

The principle to use within different fields of investigations different units for radiation, has however, on the side of undeniable advantages, also important drawbacks.

It is evident, that we must demand from the radiation measurements, which are intended for a general applicability, that they are booked in such a form, that they without troublesome computation by means of constants — frequently difficult to find — may be applied to a number of various problems. This is the reason why we have, within the climatology and adjacent fields of research, almost generally adopted *an energy unit* for the radiation, whereby naturally it is necessary to add a clear definition of the interval of wave lengths in question. In this connection I may refer to the resolution passed by the 2nd International Light Congress in Copenhagen, 1932, as regards the unit for light within the medical field:

Article I. De recommander la standardisation des sources utilisable en médecine en subdivisant le spectre ultraviolet en trois tranches spectrales définies provisoirement par les filtres suivantes proposés par M. Coblentz — — —

Pour chaque tranche spectrale définie par ces filtres, la mesure du rayonnement devra être fait avec un récepteur non selectif et exprimée de préférence pour les mesures médicales ou météorologiques en milli-calories grammes par cm. carré et minute (Comptes-Rendus du 2-ème Congrès International de la Lumière, Copenhague).

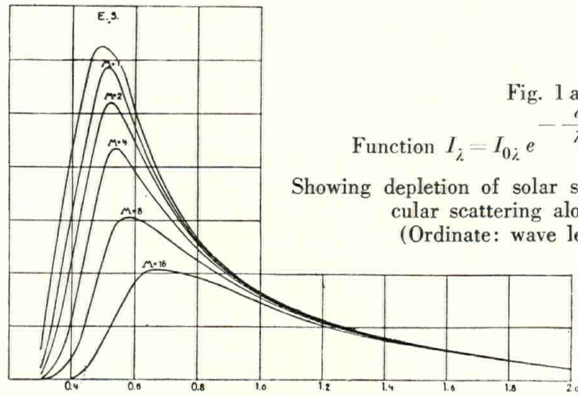

Fig. 1 a.

Function $I_\lambda = I_{0\lambda}\, e^{-\frac{a}{\lambda^4}\cdot m} = I_{\lambda 0} \cdot q_1^m$

Showing depletion of solar spectrum through molecular scattering alone. $(h = 0)$
(Ordinate: wave length in μ).

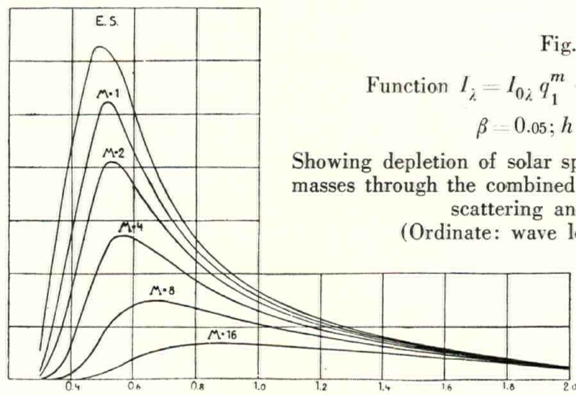

Fig. 1 b.

Function $I_\lambda = I_{0\lambda}\, q_1^m \cdot e^{-\frac{\beta}{\lambda^{1.3}}\cdot m}$

$\beta = 0.05;\ h = 0.$

Showing depletion of solar spectrum at different air masses through the combined influence of molecular scattering and dust.
(Ordinate: wave length in μ).

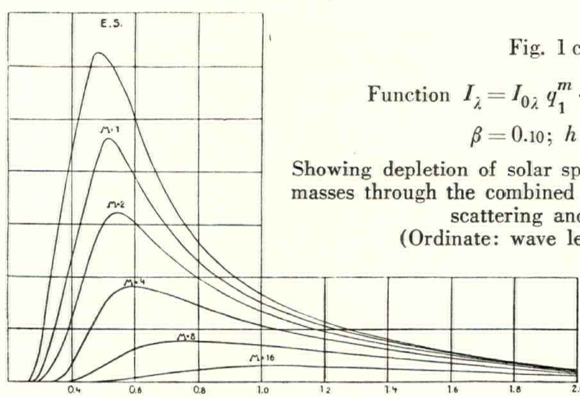

Fig. 1 c.

Function $I_\lambda = I_{0\lambda}\, q_1^m \cdot e^{-\frac{\beta}{\lambda^{1.3}}\cdot m}$

$\beta = 0.10;\ h = 0.$

Showing depletion of solar spectrum at different air masses through the combined influence of molecular scattering and dust.
(Ordinate: wave length in μ).

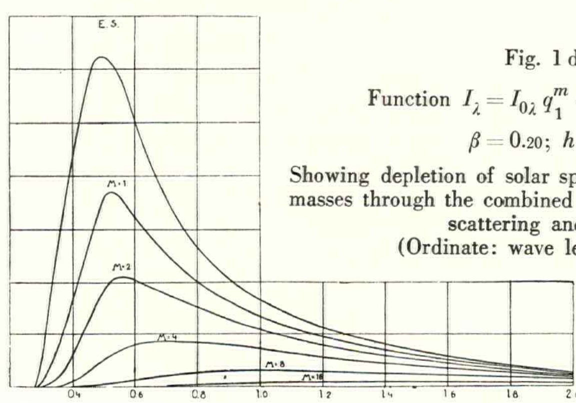

Fig. 1 d.

Function $I_\lambda = I_{0\lambda}\, q_1^m \cdot e^{-\frac{\beta}{\lambda^{1.3}}\cdot m}$

$\beta = 0.20;\ h = 0.$

Showing depletion of solar spectrum at different air masses through the combined influence of molecular scattering and dust.
(Ordinate: wave length in μ).

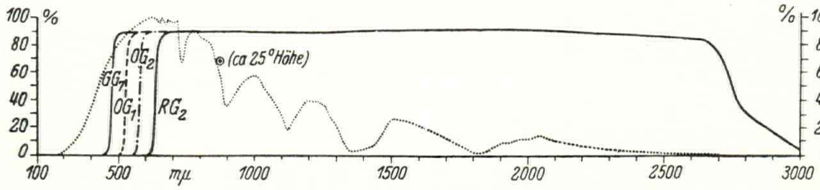

Fig. 2.

The filter for calorymetric radiation measurements from Dr. F. Albrecht.

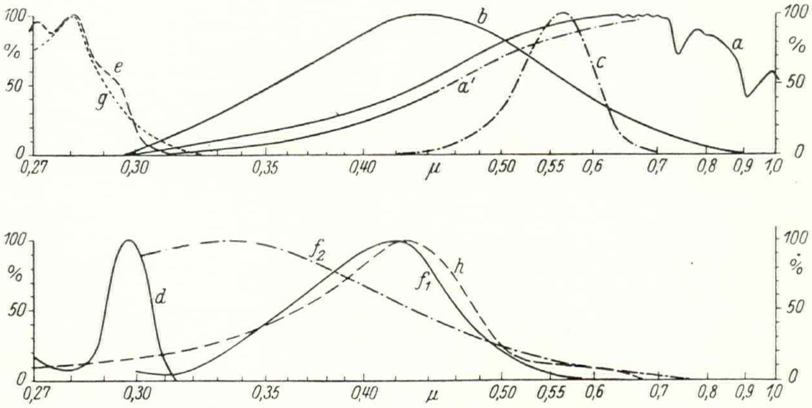

Fig. 3.

Spectral distribution curves of special importance to meteorological photometry. They give the relative spectral distributions; of the intensities of direct sun radiation at an altitude of 30° (a) and 15° (a') in relation to wave length; of the diffuse spheric radiation (b); of the eye sensitiveness (c); of the radiations forming erythem and ergosterine (e); of the sensitiveness of unsensitized calcium cells (f); of the cadmium cell (g); and of the photographic plate (h). (From Dr. F. Albrecht).

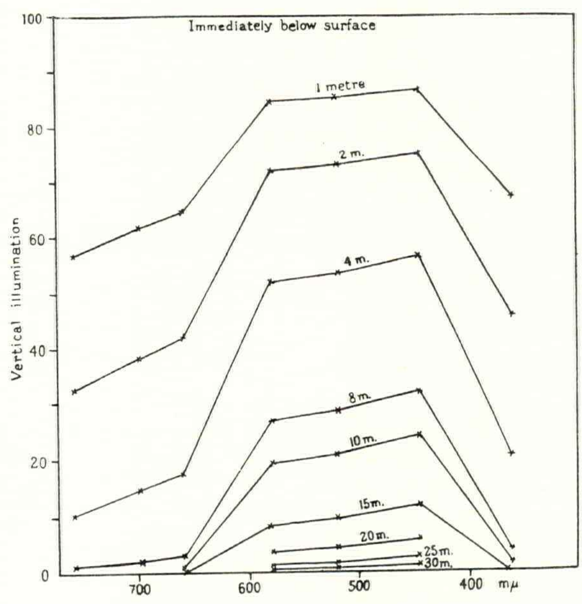

Fig. 4.

Spectral distribution of radiation penetrating in sea water according to Atkins and Poole.

If we consider the radiation measurements within the oceanography, the point of view as regards the unit to be chosen coincides in many respects with the one which has been adopted concerning the climatological radiation field. The reason that the unit *lux* here has acquired a certain popularity is evidently related to the fact that the natural radiation emanating from the sun almost exactly as its spectral extension is coinciding with the visible spectre, as soon as one comes down to depths of more than 5 metres or so. Consequently at these depths with good approximation we can put the radiation measured in *lux proportional* to the radiation measured in energy units as far as the *total* penetrating radiation is concerned. It can therefore seem to be a matter of taste, whether we wish to use the one or the other kind of units for expressing it quantitatively. But the disanvantage of the *lux*-unit is evident, when it comes to a comparison of spectrally different ranges of wave lengths with one another.

The following arguments seem therefore to me to be founded on facts, which are clearly established.

I. If we are measuring the radiation in *lux*, it seems to be a necessary condition that the sensitiveness of the measuring instrument is distributed on the different wave lengths in about the same way as the sensitiveness of the eye. If both are exactly coinciding, we may regard the instrument as a kind of artificial eye, its indications being, under all conditions, proportional to the intensity of the illumination.

An adoption of the *lux* for expressing the results is here natural and reasonable. The drawback shows itself, however, clearly if we wish to compare the indications of the instrument in question with those of another instrument, which is sensitive for instance only within the interval 600—700 μμ or in still higher degree if the new instrument is sensitive only for waves lying outside the sensibility range of the eye, for instance between 300 and 400μμ. We have then no possibility of making a comparison without transferring at first the indications of both instruments into a unit which is liable to be common for them both.

II. A standardization of an instrument for measuring radiation, characterized by selective sensitiveness for various wave lengths, ought appropriately to be made with the aid of a source of radiation which has the same or a similar spectral composition as the radiation which is to be measured. If the instrument is intended for measurements of the natural light, penetrating into the oceans, it is in many cases appropriate to use the sun radiation itself for standardization. The following circumstances are in favour hereof:

(1) Exact and easily applied instruments are at present available for measuring sun radiation with an accuracy of about 1/2 per cent.

(2) The spectral distribution within the sun radiation, which has passed the atmosphere, is not quite constant, it is true, and this includes naturally some disadvantage. But the spectral distribution may, as I have shown at another place, be easily defined through simple integral actinometric measurements.

(3) The sun radiation can easily by means of diffusing glasses and the hole-filter, introduced by H. Pettersson, be reduced to a desired small per cent. of its initial value.

If the standardization is made by means of the natural sun radiation, the unit gram calory per $cm.^{-2}$ and min., or hundredths or perhaps thousendths thereof, is the most appropriate one.

As regards the spectral distribution of the sensitiveness of the most common radiation instruments used in oceanographic research, namely the photoelectric cells, I would like to add the following remarks.

III. As soon as the general form of the spectral characteristics of instrument is known with enough accuracy one can often, for practical purposes, apply a more summaric way of investigating the sensitiveness in the special case. I would like to recommend for this purpose the standard glass filters now introduced generally in meteorological research, namely the Schott filters: OG_1 OG_2 RG_2 etc., which cut out, with almost rasor sharp limits, certain regions of the spectre. One can consequently with the aid of these filters, to a large extent, define the sensitiveness of an instrument in different spectral regions through measuring the percentage decrease of the reading, caused by the introduction of the filter, in the case of a radiation source of known wave length. In this way we may, in the case of a certain standard type of instrument (for instance a selenite or a copper oxide cell), determine the average sensitiveness for certain chief groups of wave lengths, as well as control the changes, which may occur, through a simple and convenient method.