EXPERIMENTAL STUDIES OF THE INTEGRAL CONTENT OF WATER VAPOR OVER THE OCEAN FROM SHIPBOARD RADIOMETRIC MEASUREMENTS OF THE THERMAL RADIATION OF THE ATMOSPHERE

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V. M. PLECHKOV, A. S. GURVICH, V. G. SNOPKOV

EXPERIMENTAL STUDIES OF THE INTEGRAL CONTENT OF WATER VAPOR OVER THE OCEAN FROM SHIPBOARD RADIOMETRIC MEASUREMENTS OF THE THERMAL RADIATION OF THE ATMOSPHERE

(Presented by Academician V. V. Shuleikin on 30 I 1970)

Recently there has been a sharp increase in interest in ground-based and satellite radiometric observations of the atmosphere ([1,2]). Of particular importance are measurements of the moisture content of the atmosphere over the ocean ([1,3]). In order to study the integral humidity over the Atlantic Ocean between 47° N and 23° S, from 4 II to 15 V 1969, radiometric observations were carried out on the research vessel *Akademik Kurchatov* (cruise No. 5) ([4]).

The essence of the measurements was that, from observations of the thermal radio emission of the atmosphere near the water-vapor absorption line (λ1.35 cm) at various zenith angles, as well as of the ocean surface, the vertical absorption τ_{H_2O} of radio waves by atmospheric water vapor was determined ([5,6]). This quantity is, with a good degree of accuracy, proportional to the total mass of water vapor Q (g/cm^2) in the vertical column of the atmosphere ([5,7]),

$$\tau_{H_2O} = \psi Q.$$

The coefficient ψ is determined by the absorption properties of the atmosphere and, in this wavelength range, exhibits great stability under variations of meteorological conditions ([5]). The root-mean-square error in determining Q by this method is ±10%.

Information on the apparatus and the calculated relations is analogous to that given in ([6]).

At the Scientific-Research Radiophysical Institute, values of the coefficient ψ were calculated for oceanic conditions. It subsequently turned out that the values of ψ over the ocean, found by calculation from quantum-mechanical relations, as well as over land, agree well with those found experimentally from the

Figure 1. Graph of the latitudinal variation of the total mass of water vapor in the atmosphere over the Atlantic Ocean

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graphical dependence $\tau_{H_2O} = f(Q)$, obtained from radiometric measurements of τ_{H_2O} and aerological measurements of Q. Thus, for the Atlantic Ocean, for wavelength $\lambda = 1.3$ cm, $\psi = 0.27 \pm 0.054$ (dB $\cdot$ cm^2/g).

The results of measurements of the total mass of water vapor over the ocean at various geographical latitudes, pertaining to a cloudless atmosphere in the region of operation, are presented in Fig. 1. The profile of integral humidity was constructed from data obtained on the cruise from 47° N to 23° S. The same figure also shows values of Q obtained during the repeated crossing of latitudes on the return course of the ship from 1 to 15 V 1969 (crosses). These values, within the accuracy of the measurements, coincide in the tropical zones of the ocean with the profile of Q obtained from 4 II to 1 V 1969.

Consideration of the latitudinal variation of Q indicates a number of its features. Thus, between 36° N and 25° N, a zone of reduced water-vapor content is discernible in the atmosphere over the Atlantic Ocean. Measurements of Q at these same latitudes, but shifted in time (by two months) and in longitude, however, give values of ψ that repeat its latitudinal profile obtained earlier. Table 1 gives the mean values of Q, of the absolute humidity ρ_0 measured in the near-water layer

Fig. 1. Graph of the latitudinal variation of the total mass of water vapor in the atmosphere over the Atlantic Ocean.

atmosphere, the temperature of the water in the surface layer of the ocean, and the air temperature in the near-surface layer of the atmosphere for the interval of latitudes studied.

The maximum value of Q (5-6 g/cm^2) was recorded in the convergence zone. As is seen from Fig. 1, the profile of the integral moisture content is asymmetric with respect to the geographic equator.

Round-the-clock observations in the ocean did not show a noticeably pronounced diurnal variation of Q, but large variations of Q are mainly associated with the movement of large-scale air masses.

Table 1

Latitude interval	Q, g/cm^2	ρ_0, g/m^3	t_{water}, °C	t_{air}, °C	σ, g/cm^2	$r(\rho_0, Q)$
47° N lat. – 36° N lat.	1.58	9.87	14.18	13.78	0.52	0.91
36° N lat. – 25° N lat.	1.53	13.42	20.16	19.22	0.41	0.52
24° N lat. – 5° N lat.	2.92	19.00	25.75	24.90	0.68	0.73
5° N lat. – 5° S lat.	4.95	22.12	28.40	27.70	0.64	0.02
7° S lat. – 21° S lat.	3.53	20.14	28.53	27.21	0.68	0.25

The smallest values of Q were observed, as a rule, under anticyclonic conditions. Quantitatively, the variations of Q are characterized by the root-mean-square values σ of deviations from the mean value in the selected region (Table 1). Comparisons of $\overline{Q}$ and σ show that the variations of Q are comparable with the mean values. It is interesting to note that the correlation coefficient $r(\rho_0, Q)$ (Table 1) between the total moisture content Q and the absolute humidity ρ_0 in the near-surface layer at a height of 7 m is small, and, consequently, the measurements of ρ_0 in the near-surface layer do not characterize the total moisture content in the atmosphere.

Measurements of Q by the radiometric method and by ordinary radiosonde observations in the absence of clouds gave agreement of the results with an accuracy of ±3–10%.

Measurements of the thermal radio emission of the atmosphere at different radio wavelengths in cloudy weather made it possible, using the method of ([5]), to estimate the water content of clouds, which in the tropical zone of the ocean varied within the range from 0.033 to 0.25 g/cm^2. The accuracy of determining this quantity in our case did not exceed ±50%, primarily because of the uncertainty of the data on the mean temperature of the clouds. A water content of 0.25 g/cm^2 corresponded to dense rain clouds in the convergence zone.

The correlation coefficients between the quantities Q and t_{water}, Q and t_{air} are 0.57 and 0.61. We note that in both cases these coefficients are somewhat higher for the trade-wind zone than for the near-equatorial zone. Their values are, respectively, 0.69 and 0.47; 0.73 and 0.50.

The results presented for measurements of the integral moisture content in the atmosphere over the ocean from aboard a ship agree well with satellite measurements of this quantity over the waters of the world ocean ([1]).

Research Radiophysical Institute
at Gorky State University
named after N. I. Lobachevsky

Institute of Atmospheric Physics
Academy of Sciences of the USSR
Moscow

P. P. Shirshov Institute of Oceanology
Academy of Sciences of the USSR
Moscow

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Note: Figure translations are in progress. See original paper for figures.