ON A POSSIBLE ROLE OF ELECTROMAGNETIC EFFECTS IN THE ATMOSPHERE-OCEAN COUPLING IN TROPICAL CYCLONES

Vladimir Pudov

Institute of Experimental Meteorology, Obninsk, Russia

Direct measurements of precipitation amounts at different meteorological stations under typhoon conditions give rather high values. For example, at the Chinese station "Dozhu" in typhoon 7913 more than 80cm/24hr were registered; during the flood in Xizhijang Province the precipitation amount was 9570 m^3/s [1]. Rather high precipitation amounts were obtained by us over the data of surface water freshening at the passage of different TC.

During the expedition "Typhoon-90" measurements of salinity fields were made before and after the passage of typhoon "Flo" (9019) [2]. The accuracy of salinity measurements was within $0.005\%_0$.

Fig. 1 gives a distribution of salinity anomalies in the ocean upper layer (the difference between water salinity after and before the passage of the typhoon) induced by the typhoon. The negative anomalies correspond to freshening caused by precipitation; positive ones – to an increase of salinity due to upwelling.

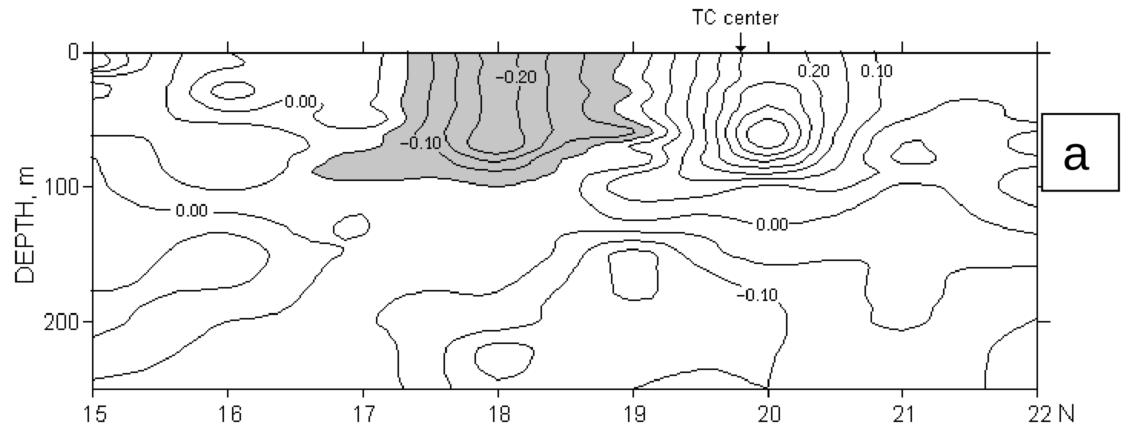
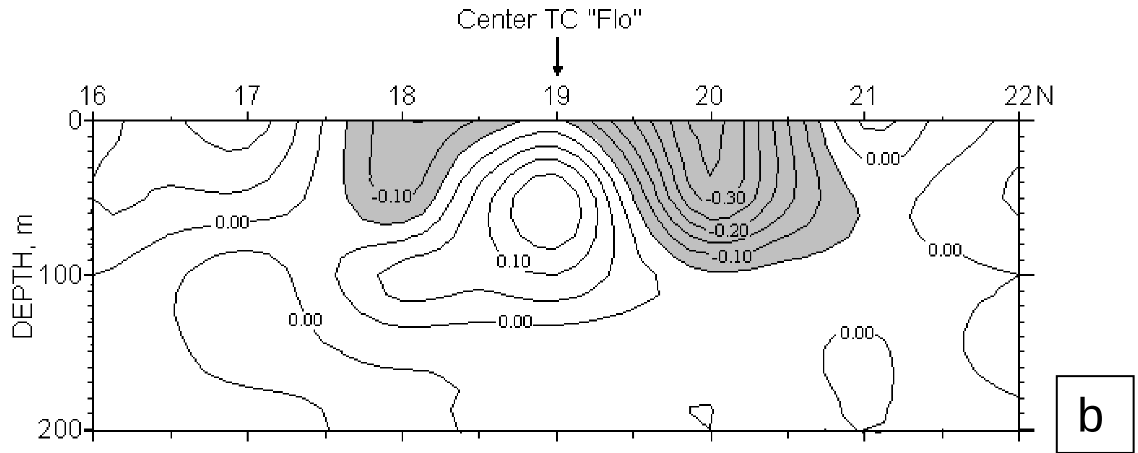


Fig.1. a) The salinity anomalies field in the wake of TC "Flo" along 136 E.
b) The same along 138 E.



An increase of salinity occurs because the maximum in salinity is not on the ocean surface but at a depth of hundreds of meters. This is seen in the profiles of salinity distribution according to depth (Fig. 2).

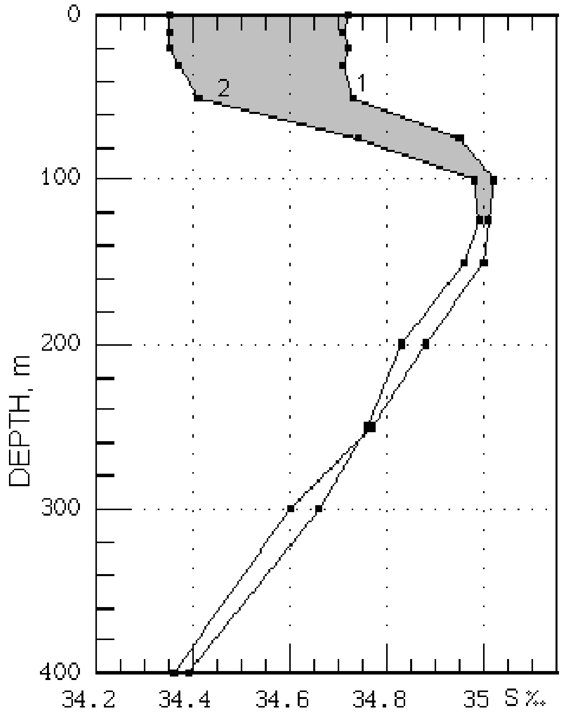


Fig.2. Salinity profiles at the point 20N, 138E before (1) and after (2) TC "Flo" passing

Fig. 1a shows salinity anomalies distribution according to depth along the cut of 136^{o} E (to the left of the typhoon trajectory); Fig. 1b is the same along 138^{o} E (to the right of the trajectory). The hatched zones are the zones of maximum freshening. It is seen that freshening of the ocean upper layer to the left of the TC trajectory occurs within almost 100 m, and maximum freshening extent is more than 0.2%$_{o}$. Most extensive freshening occurs to the right of the trajectory (Fig. 1b). It reaches the same depth but the amplitude of the anomaly exceeds 0.35%$_{0}$ and takes a large area of the ocean [2]. These data on freshening of oceanic waters make it possible to calculate the amount of precipitation that reached the surface [2]. The calculations showed that the maximum precipitation amount was at latitude 20^{o} N to the right of the trajectory. It was more than 700 mm. Taking into consideration the typhoon’s speed of motion in the territory studied (13 knots), it should be said that the time of its passage through the zone of intensive precipitation was 18 hours, i.e. the precipitation intensity was more than 40 cm/12 hours. Note that this is the minorant estimate. Actually precipitation amounts were higher because the effect of more saline waters updraft from the depths (upwelling) which is not accounted for in the calculations was dampened.

The influx of water vapor into a typhoon from the ocean alone cannot give such amounts of precipitation. In the opposite case, the temperature of the whole troposphere would have to reach fantastic values of vapor condensation. It becomes evident that the most significant portion of precipitation makes liquid water entrapped into the typhoon cloud systems. In our opinion, the increase of the intensity of the evaporation and a turbulent entrainment of spray drops from the ocean surface into the typhoon cloud structures can be enhanced by the electromagnetic interaction forces. That is:

1. Sea water – on the one hand, is a relatively good conductor moving (currents, spray droplet flight in storms) in the Earth's magnetic field. Volume telluric currents appear. As the water electric conductivity is anisotropic, the telluric currents have a predominant direction (near the coasts, along frontal interface in the open ocean, etc.) and can attain several thousands of amperes [4]. But the current specific density is low and anyhow, it cannot noticeably change the water temperature on which the evaporation intensity depends. On the other hand, the conductivity of sea water is not so high for polarization of the sea water to take place. It is known that electricity polarizes water molecules in the following way:

$$H_20 \leftrightarrows H^+ + OH^-$$

Hydrogen ions are more active and govern the positive charge at the water-air interface, where additional surface electric forces appear. The electric interaction force at the interface is proportional to the electric charge and to the intensity of the electric field. This force is always directed towards the region of a lower dielectric permeability, i.e. from the ocean into the atmosphere. The latter enhances the breakaway of water molecules (evaporation).

2. The ocean surface and cloud systems serve as a specific "condenser" with "plates" of opposite charge. The surfaces of sea water spray droplets are also polarized at the ocean surface – most of them carry a positive charge. The forces of electromagnetic interconnection affect spray droplets in the electric field between the positively charged ocean surface and the lower boundary of clouds with negative charges. They are proportional to the spray droplets' electric charge and the intensity of the electric field. It is known [5] that the spray droplets in extra-tropical convective clouds carry electric charges from 1 to 50 pC (1 pC = 10^{-12} C). If it is assumed that over the stormy tropical ocean the spray droplets are capable of carrying a charge of the same order, one can calculate the critical spray drop diameter at which the forces of electric interaction (dependent on the electric field intensity and directed from the ocean towards the clouds) balance out the gravitational forces. Fig. 3 presents calculated dependencies of spray drop critical sizes (radii) on the electric field for their three electric charges. The critical drop size is the size at which electric forces balance out gravitational forces affecting the spray drop.

We can seen that for relatively small spray droplets, the electric forces are quite commensurable with the gravitational forces. Under the action of the forces of electric interaction and turbulent atmospheric capture, the spray droplets are entrapped into

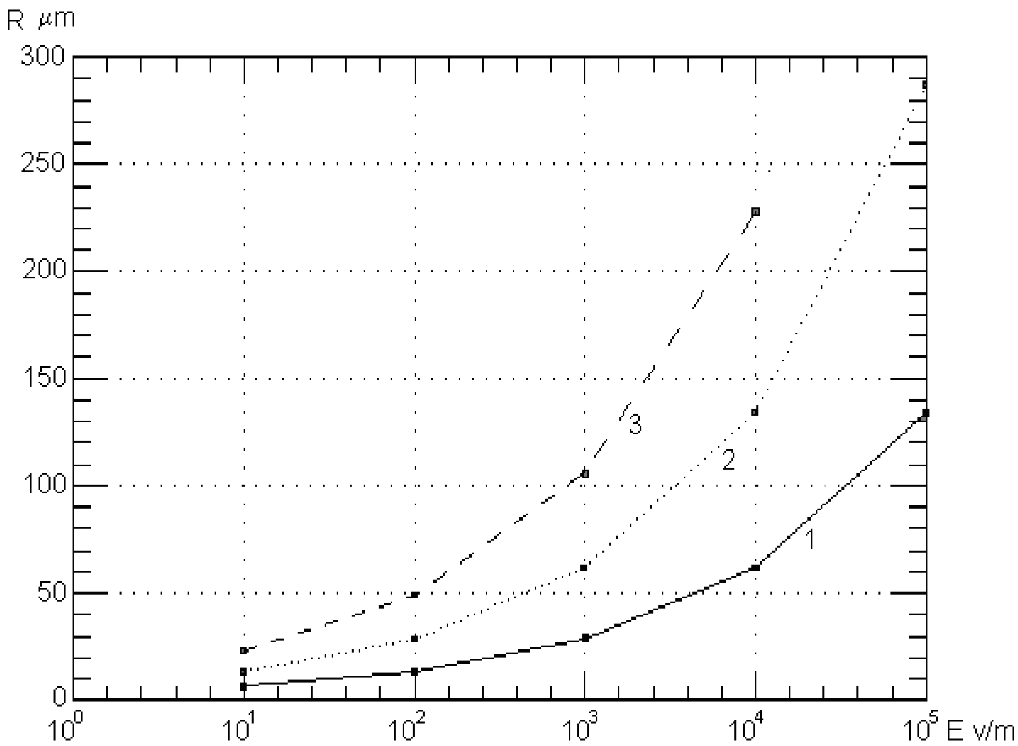


Fig 3. Dependence of drop critical size (radius-R) on electric field intensity for 3 values of drop charges: 1-1pC; 2-10 pC; 3-50 pC

cloud systems, thus increasing cloud liquid water content. Accumulation of moisture in clouds is most likely to continue until an electric charge is induced either within the clouds or between the "condenser plates".

Of course, this is only a hypothesis that needs further theoretical and experimental verification. Nevertheless, we think that this is a promising direction of investigations.

Conclusion

The problems should be outlined to be solved for testing the hypothesis mentioned above.

1. The amount of electricity carried by drops into clouds and their size dimension distribution have been relatively well understood, at least in the case of convective clouds in moderate latitudes. In view of what is said above, it would be of interest to obtain experimental data on drop size distribution function (spectrum) and on electric charges on spray drops generated by wave breaking in tropical storms and those involved into TC cloud towers (such data are likely to exist but they are not available to us).

2. The drops undergo multiple phase transitions under water vapor condensation and entrainment of liquid water into TC cloud systems (and not only into TC). When ascending to negative temperatures, the drops freeze retaining salt crystals and increasing the positive electric charge in the upper portion of the cloud. The salt crystals are the condensation nuclei. Some of them dissolve in new drops of fresh water that are formed during the phase transitions (i.e. at water vapor condensation and snow flakes melting). During coagulation, the drops attain the sizes when the gravitational forces become prevailing and fall-out of precipitation begins.

In this connection it would be of interest to have data on precipitation salinity in TC. Unfortunately, when studying TC earlier, we have not used our possibilities to obtain such data over the oven (in real conditions).

3. When great amounts of liquid water are entering a cloud, it is most likely that a part of salt crystals will not be removed from the cloud, but is accumulated in it. Therefore one can expect that in the TC outflowing air layer salt crystal can be present in the form of aerosol particles. With an increasing amount of salt, and the amount of electricity accumulated in it, the conductivity of the cloud increases and an electric charge occurs. A sharp temperature increase in the lightning "tree" can result in the decomposition of salt into its chemical elements (Na, K, Cl, etc.). In this connection it would be interesting to obtain experimental (in situ) data on aerosol and chemical composition of the air in the air layer flowing out from TC along with data on the alkali amounts (NaOH, KOH) in precipitation.

References

1. Zhang Yan: “Torrential rains in tropical cyclones,” *Tropical Cyclone Disasters.* 1993, Peking University, Beijing, China, pp 474 - 485.
2. Pudov V. , Petrichenko S. “Trail of Typhoon in the salinity field of the ocean upper layer,” *Atmospheric and Ocean Physics* (Izvestiya Acad. Sci.), 2000, v. 36, No 5, pp 700-706
3. Pudov V., Holland G. “Typhoons and Ocean. Results of Experimental Investigation.” *BMRC Research Report* No 45, July 1994, Melbourne, p 50
4. Shuleikin V. V. Fizika Okeana. 1968, *Nauka*, p 1083
5. Matveev L. T. Fizika atmosfery, 1984,*Gidrometeoizdat*, p 751