Mesoscale structure of tropical cyclones in the north-western part of the Pacific ocean according to the data of the WWLLN

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ABSTRACT

The paper investigates lightning activity in the region of tropical cyclones (TC), its structure and changeability during the process of TC development and attenuation according to the data of the World Wide Lightning Location Network (WWLLN) as well as the relation with ocean surface wind fields according to the ASCAT scatterometer data. Distribution of lightning discharges in TC regions and discharge density fields drawn up from them allowed us to detect TC structure elements, such as mesovortexes, eyewalls, cloud bands and spirals, and to trace their change in space and time.

lightning, lightning activity, tropical cyclones, typhoons, mesoscale vortexes;

INTRODUCTION

One of the problems of investigation and monitoring of tropical cyclones (TC) is the lack of observation data which is the result of poor coverage of ocean areas by standard hydrometeorological observations and the difficulties to realize them in storm conditions. In recent times, one of the developing passive methods of observations of weather systems is the registration of lightning discharges by lighting location and direction finding networks. Separate lightning discharges over oceans and seas is the consequence of local processes in convective clouds and a large number of lightning discharges over quite a large scale may be attributed to the dynamics of development of convective complexes and weather systems of meso- and synoptic scales[1,2,5]. Thus, according to the changes of lightning activity fields in a TC area of influence, we can make forecasts of changes in its structure and intensity[1,3,4,6,7].

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The present paper investigates lightning activity in TC areas of influence at different stages of their development according to WWLLN data. The paper continues the investigations[1] which showed the possibility of application of WWLLN data for monitoring of weather systems over the ocean and seas.

DATA AND METHODS

The paper applies data on TCs from the archives of Japan Meteorological Agency (JMA, http://www.jma.go.jp) and American Joint Typhoon Warning Center (JTWC, www.usno.navy.mil/JTWC), data on coordinates and times of lightning discharges from the WWLLN (http://wwlln.net/new/), data on ocean surface wind from ASCAT scatterometer of METOR-A satellite (Satellite Oceanography Laboratory of RGGMU, http://solab.rshu.ru/).

TCs which occurred in the north-western part of the Pacific Ocean during 2012-2013 and reached the super typhoon stage with the maximum wind of more than 60 m/s were chosen for the study. Data sampling was carried out along TC trajectories over the ocean open areas to exclude land effect in the interpretation of processing results. The dimensions of TC area of influence was supposed to be equal to 1000 km. “Compositions”, that are discharge distributions relatively a TC center and discharge density fields, were plotted for TC structure analysis. They were compared with ocean surface wind fields and its vertex. Characteristics of a cloud wall in a TC center, its radius, width, “eye” radius, were evaluated.

RESULTS AND DISCUSSION

As a rule, discharge point fields in a TC area have chaotic distribution at early stages of its development. However, at the stage of a mature cyclone, well identified point pattern may be distinguished. They are point clusters, parts of circular and spiral formations of mesometeorological scale. These patterns may be associated with lightning, convective complexes and systems, mesoscale vortexes and other meteorological objects.

As an example, Fig. 1 illustrates distribution of lightning discharges in super typhoon Haiyan on the day of maximum development (07.11.2013). Elements of spiral structures which are the most clearly displayed in the diurnal composition (b) are distinguished in lightning distribution. There are two regions of increased density of lightning on the compositions, they are: near the center and at the periphery, at the radii of 300-1000 km. A circular structure associated with typhoon cloud eyewall is clearly distinguished in the central area.

Estimates of geometric characteristics of the cloud wall were found from the coordinates of points in a circular structure, they are typhoon eye radius, cloud wall width and so on. They may be associated with the dynamic processes in the TC. In Fig. 2, the example of typhoon Utor, on the day of its maximum development, illustrates the discharge points in the central area plotted on the driving wind field (a), and an approximating circle (b), radii of this circle and radii of the eye and the maximum wind from JTWC archive are shown on discharge radius histogram (c).

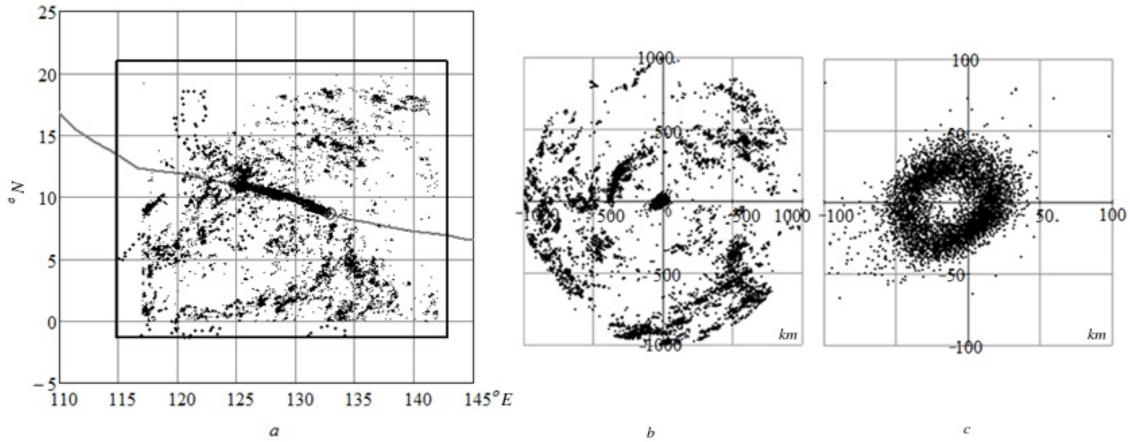

Fig. 1 - a – lightning discharges in TC Haiyan on 07.11.2013 and its trajectory; b – composition of lightning discharges relatively TC current center; c – composition of lightning discharges in TC central area

Extremums per a square unit (of the lightning activity field) were distinguished in the density fields. It is natural to suppose that maxima in this field coincide with the areas of thunderstorm cell clusters and are associated with powerful clouds of deep convection or their groups which may manifest themselves as intensive mesoscale vortexes in a wind field[2,5]. In this case, estimation of the density field with time shift allows us to calculate the velocities and directions of motions of a typhoon and of mesoscale convective complexes[1]. Thus, for TC Haiyan the estimated velocity is ~11,5 m/s.

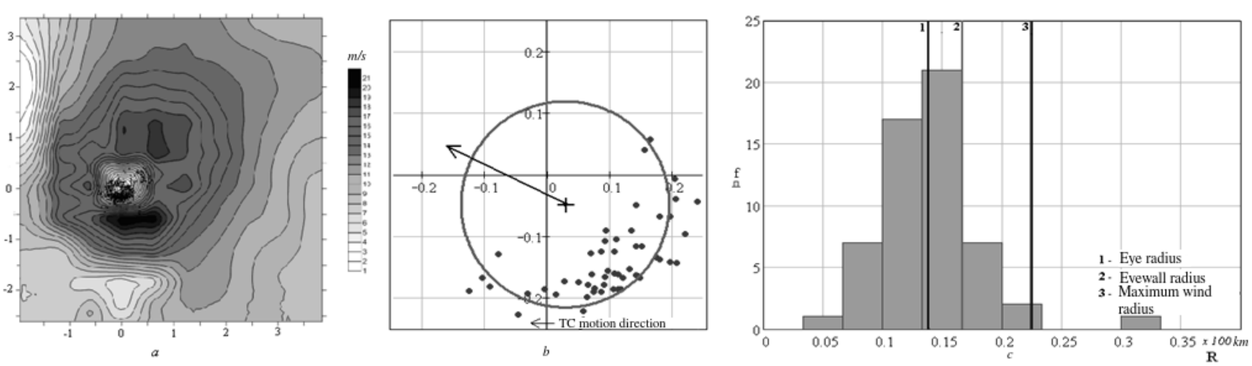

Fig. 2 – Wind velocity field (a), circle approximating discharge points (b); c – histogram of discharge distribution from the center of TC Utor (1311) on 11.08.2013 at 13 h.

According to the samplings of discharge coordinates over a definite time interval, we estimated the histograms of pair distances between the discharges. Extremums of these histograms give us the estimates of scales of lightning cells or mesoscale convective systems and the distances between them. Histograms for three TCs (Utor, Sanba, Guchol) are shown in Fig. 3.

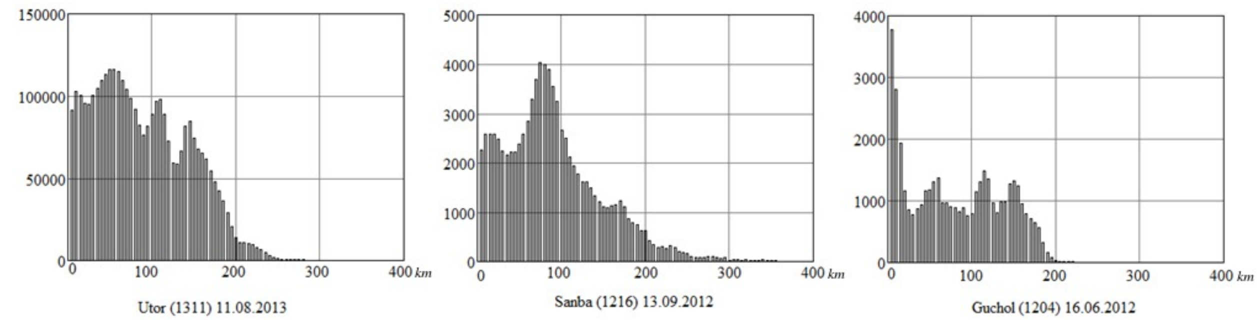

Fig. 3 – Histograms of pair distances on the day of TC maximum development

CONCLUSIONS

The paper shows that the analysis of lightning activity fields allows us to trace TC mesoscale structure and its change at different stages of development. The World Wide Lightning Location Network allows us to monitor the motion and structures of weather systems (of TC type) over the ocean almost in real time scale.

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