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Tropical cyclones tracks classification due to their characteristic

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Key words: tropical cyclone, tracks classification, distribution criteria

Abstract
Tropical cyclones tracks on the North Atlantic basin were categorized (years 1989–2009). Standard environmental patterns were used. Authors took into consideration cyclones motion parameters and their changes. Recurving, left-turning, nonrecurving, looping and erratic tracks were described.

Introduction

Tropical cyclones, because of its complex structure, predicting difficulty and accompanying heavy weather conditions are the most dangerous phenomenon in the tropics in relation to safety of navigation. They can seriously threaten the safe passage of ship and result in long delays of ETA. For this reason, special attention should be paid to the decision-making process. The crew of the ship, based on current prognosis, their knowledge of basic principles and conditions associated with the cyclone and its movement makes the safety manoeuvre of avoidance.

Decisions should be taken based on current forecasts and analysis and depending on the changes amendments should be considered immediately. It has to also note that the reliability of forecasts will decline with increasing forecast time interval and sudden changes of course and speed of the vessel in relation to long-term forecasts should be avoid [1, 2].

One of well known track classification is Kotsch one [3] (Fig. 1). However, its level of minuteness makes it useless for simple categorization. Other known classification is one used by Joint Typhon Warning Center (Fig. 2). This one was adopted for the purpose of this study.

The goal of the article is to classify tropical cyclones according to the developed criteria. Developed classification should be referred to the tracks of cyclones, whose course in the first stage of manoeuvre planning is important information affecting the way of tropical cyclone avoiding.

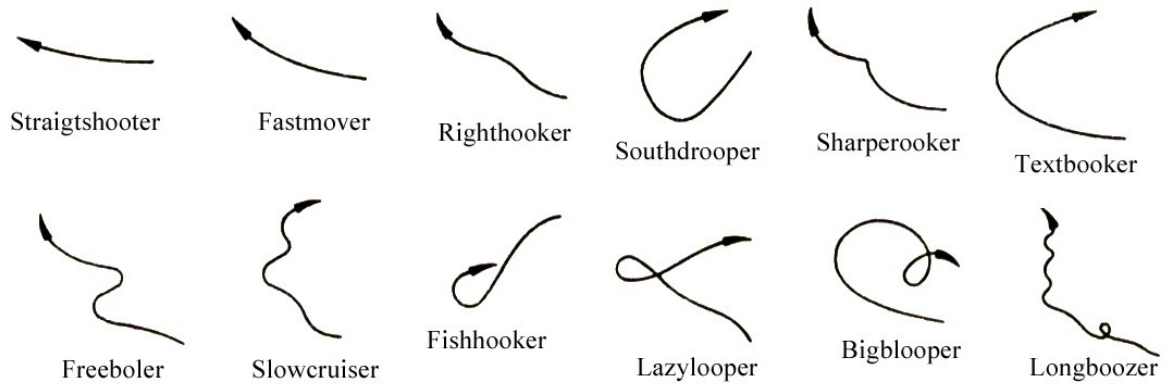

Fig. 1. Tropical cyclone tracks classification by Kotsch [3]

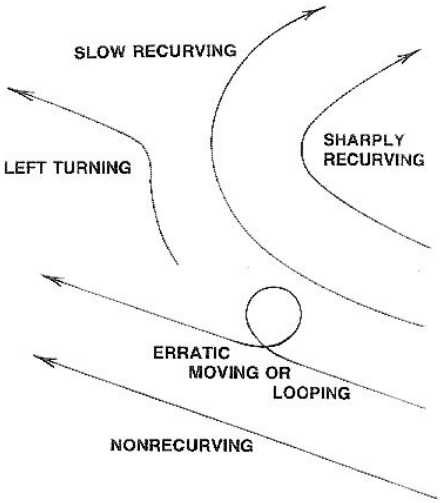

Fig. 2. Five types of tropical cyclone tracks by JTWC [4]

Data range

Analysis of cyclone tracks includes two decades 1989–2009 [5]. Tropical cyclones are considered under the following assumptions:

- Cyclones that have occurred in the area of latitude 5°N – 45°N.
- Cyclones that have occurred over the North Atlantic, Caribbean Sea, Gulf of Mexico, excluding land areas.
- Cyclones that have reached hurricane stage and at least a first degree of Saffir-Simpson scale.

Categorization of tropical cyclones tracks for the purposes of this analysis was based on the type and changes of cyclones course and includes the following types of tracks: slow recurving, sharply recurving, left turning, nonrecurving, looping and as a separate group – extant classified as erratic.

It is necessary to separate specific sections of the cyclone track. For the analysis, so-called distinctive points have been specified, which graphically shows the figure 3.

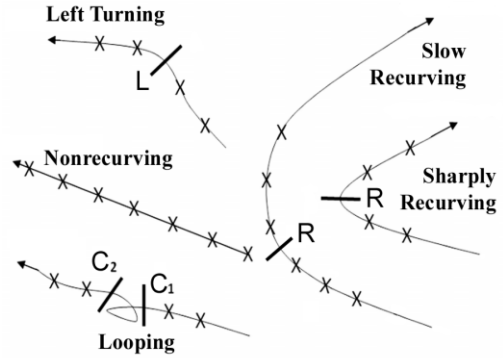

Fig. 3. Characteristic sections and distinctive points for the different variants of the track of tropical cyclones

For recurving cyclones distinctive points are described as R points. For slow recurving cyclones, these points are a starting point of a clear change in the moving trend in the right direction, while the same point for the sharply recurving cyclone determines the moment of course change from west (polar), for north-east course. Location of R points does not coincide with the location of points understood as a classical point of cyclone return (recurvature point) [6]. This procedure makes possible to predict changes in the nature of the current hurricane to a greater extent than to refer to the point of return, whose exact location we are able to determine after the occurrence of the cyclone [4].

For others tracks of cyclones distinctive points are marked in figure 3. L point for left turning cyclones is the point of changing motion trends on the western direction. For looping cyclones point C_1 represents the moment of initiating circular movement, while the C_2 point represents the moment of ending this tendency.

In further consideration 12-hours periods will be taking into account. These points are marked schematically by "X".

Criteria and obtained results

Sharply recurving tropical cyclones

Definition: "Sharply recurving cyclones are those which change rapidly from a westerly or northwesterly course to a northeasterly or easterly one" [4].

Cyclones, which substantially alter the direction of the progressive movement in relation to the initial direction at the point R. Course difference 24 hours before and 24 hours after reaching the point of R is at least 55°. Cyclone before reaching the point R moves in a fixed course of 250–350° for a period of at least 12 hours (Fig. 4).

For average values track of sharply recurving cyclone including distinctive point and designated 12-hour intervals is shown in figure 5 (average values of the course COG, progressive speed Vp, maximum winds Vw).

12-hour sections R-24 and R-12h before reaching the recurvature point R are characterized by a constant course with a deviation of 013° in the right direction. In the R point a substantial change of the course is clearly seen, which is tilted by 022°, then 037° in the first section of R+12 h and 015° in the next section of R+24 h. The average parameters of the progressive movement and intensity of cyclones in terms of time relative to the point R can be represented as graphs (Fig. 6).

Based on the graphs can be stated that:

- within 48 hours (–24 h, +24 h towards R point), average course changed from 300° to 040°;

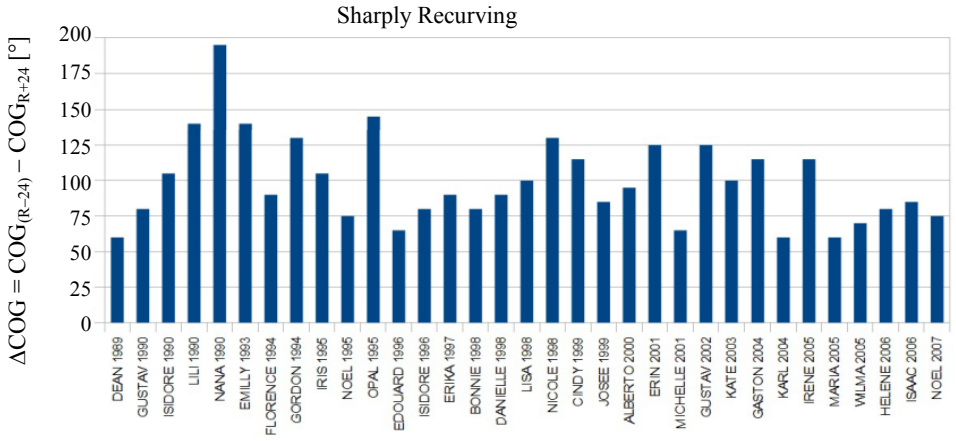

Fig. 4. Change of course in the range of 48 hours recorded 24 hours before and 24 hours after reaching the R point for tropical cyclones classified as sharply recurving (1989–2009)

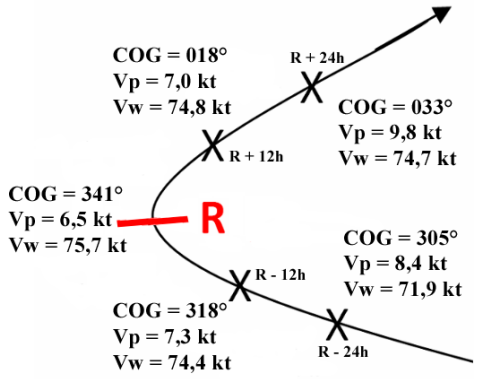

Fig. 5. Sharply recurving tropical cyclone route pattern with distinctive point R, 12-hour intervals and the averaged parameters of the course, progressive movement and wind speeds

– speed increases to the point R and is maintained for 24 h;
– before the R point cyclone speed decrease significantly (ΔVp ≈ 2 kt);
– pressure gradually decreases to the point R and beyond.

Slow recurving tropical cyclones

Definition: "Tropical cyclones changing track from westward and poleward to eastward and poleward" [4].

Slow recurving tropical cyclones significantly alter the direction of the progressive movement to the right after reaching the distinctive point R.

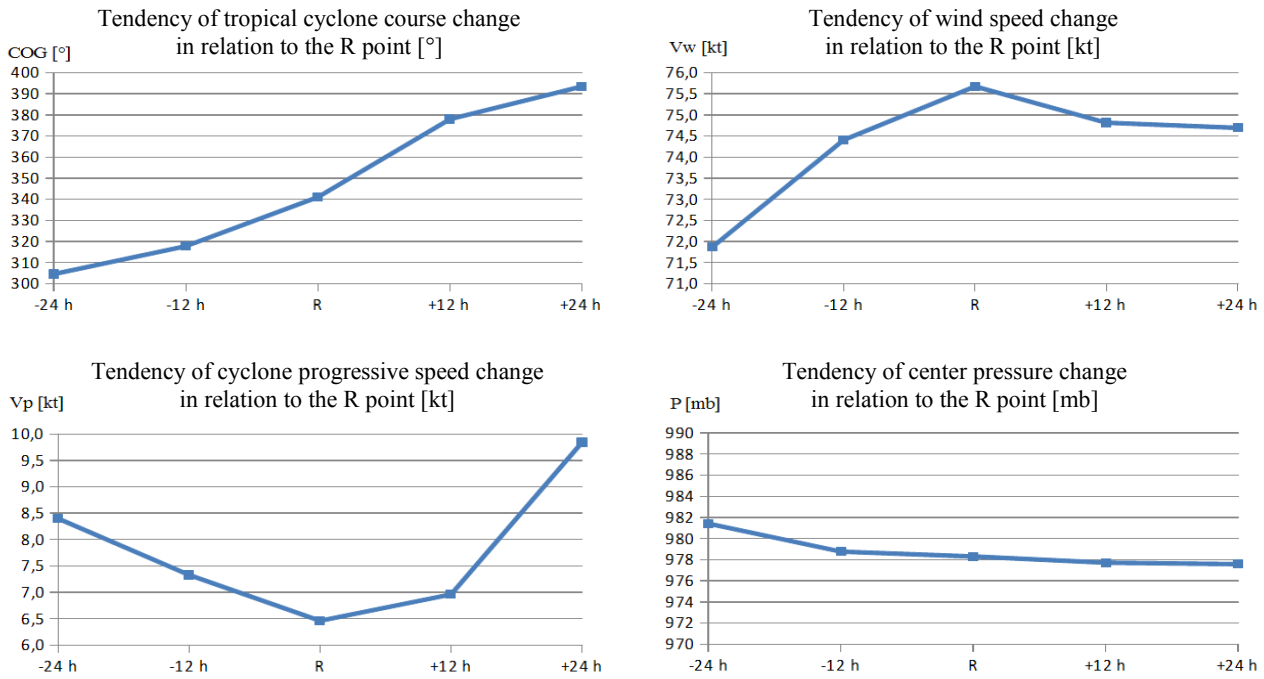

Fig. 6. The average parameters of cyclone movement and intensity in relation to the R point in the 12-hour intervals for sharply recurving tropical cyclone

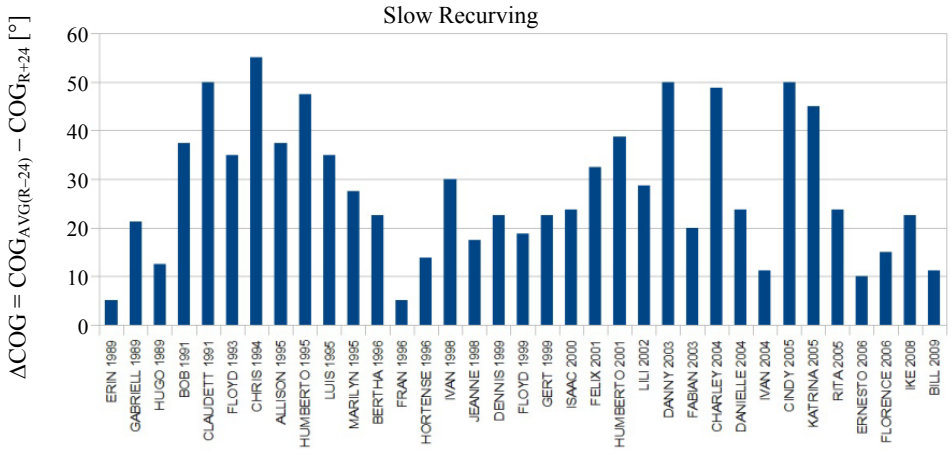

Fig. 7. Difference between the average course of the whole 24h before distinctive point, and the new course at 24th hour after reaching the R point for slow recurving tropical cyclones

The difference between the average course for whole 24 hours before the R point and the new course of the cyclone at 24th hour after reaching the R point is at least 5°, but cannot be greater than 55°. Additionally, within 72 hours after reaching the R point, tropical cyclone is still changing its course (Fig. 7).

Based on so developed average values for slow recurving tropical cyclones their track, taking into account the distinctive point of R and 12-hour intervals, is shown in figure 8.

In the first and second time period (R-24, R-12 h) before reaching distinctive point R, cyclones are moving on average relatively stable course. After reaching the R point there is visible change of course to the right by an average angle of 10–15° for each 12-hour interval. For the analysis of other parameters the graphical interpretation of the results as graphs can be used (Fig. 9).

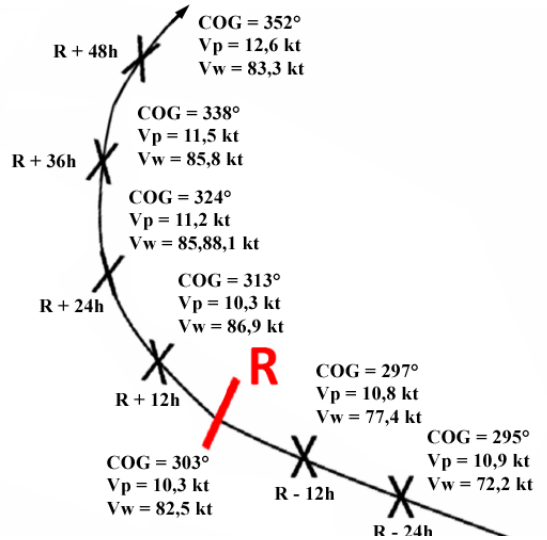

Fig. 8. Slow recurving tropical cyclone route pattern with distinctive point R, 12-hour intervals and the averaged parameters of the progressive movement and wind speeds

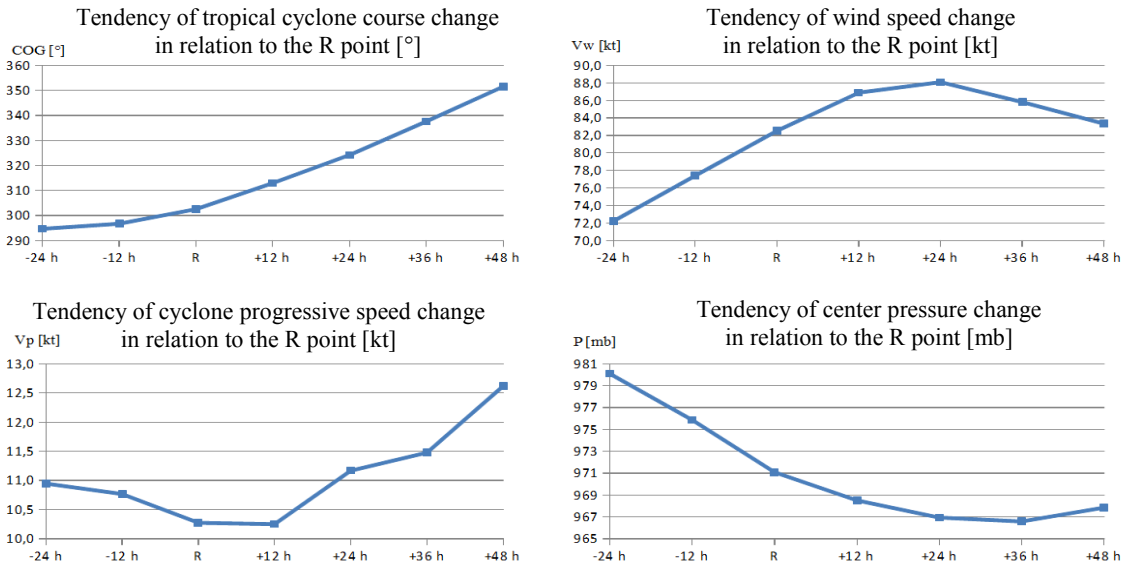

Fig. 9. The average parameters of cyclone movement and intensity in relation to the R point in the 12-hour intervals for slow recurving tropical cyclone

Considering the tendency of changes of all examined movement parameters and intensity of slow recurving tropical cyclones can be stated that they are similar to those previously analyzed (sharply recurving), but with the following remarks:

– within 48 hours (–24 h, +24 h towards R point), average course changed from 295° to 350°;
– speed increases to the point R and increase for next 24 h;
– before the R point cyclone speed decrease (ΔVp ≈ 1 kt);
– pressure gradually decreases to the point R and up to 36 h beyond.

Left turning tropical cyclones

Definition: "Turning tropical cyclone is one which is on a poleward course but instead of continuing to recurve poleward and eastward, it turns back to the left and resumes a poleward and westward course" [4].

Before the L point an average cyclone course (COG) is about 310–315°. After reaching the L point tropical cyclones instead of changing direction to the north-east turn left going back on a west course. After reaching L point the cyclone takes a course of 270–290° for at least 24 hours, the difference between the initial course (24 hours before point L) and the final (24 hours after reaching the L point) is at least 15°. Below tropical cyclones cyclones classified as left turning are listed (Fig. 10). Negative course change value means a change of course to the left.

After reaching the distinctive point there is visible increase of the average progressive speed, from

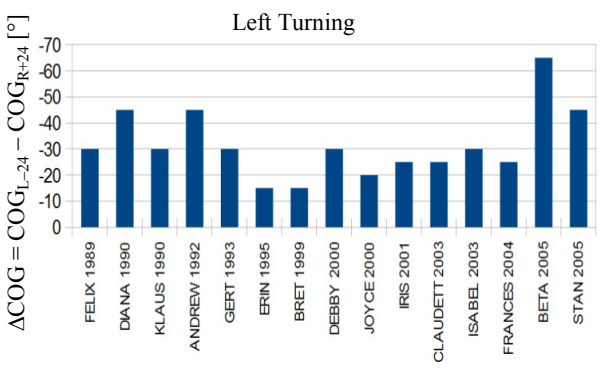

Fig. 10. Course change value in the interval of 48 hours recorded 24 hours before and 24 hours after reaching the L point for left turning tropical cyclones

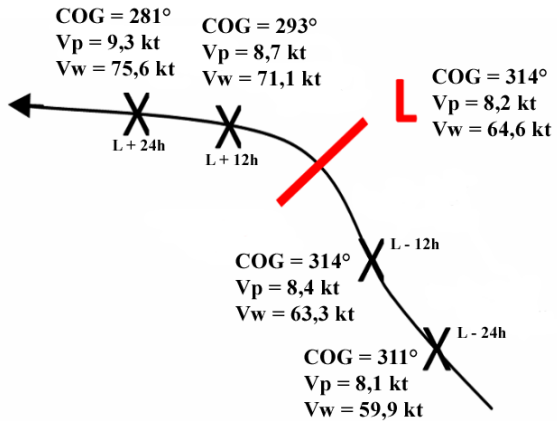

Fig. 11. Left turning tropical cyclone track with the distinctive point L, 12-hour intervals, the average parameters of the progressive movement and the average wind speeds

8.2 knots at the point L to 9.3 knots 24 h later (Fig. 11). Atmospheric pressure in the tropical cyclone center tends to decrease for all 12-hour intervals. With this pressure drop maximum wind

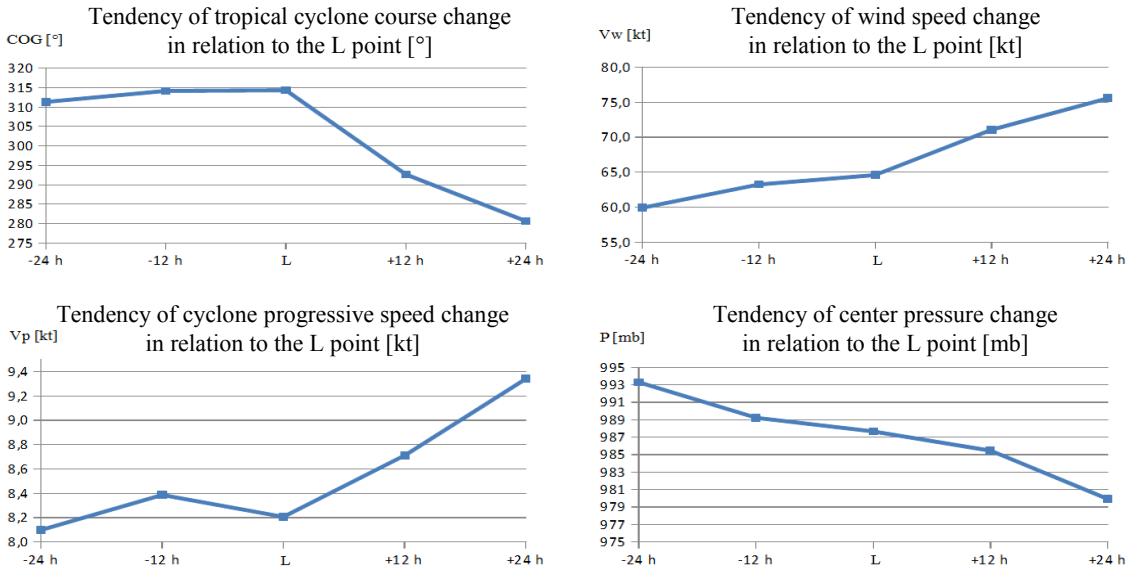

Fig. 12. The average parameters of cyclone movement and intensity in relation to the L point in the 12-hour intervals for left turning tropical cyclone

speed increase from 59.9 knots to 75.6 knots (Fig. 12).

Non-recurving tropical cyclones

Definition: "Straight moving and non-recurving tropical cyclones usually move toward northwest direction or about 260º–320º" [4].

As a non-recurving tropical cyclones can be qualified these cyclones whose tracks (for ≥1° Saffir-Simpson scale) for a period of 96h did not change its course by more than 15° (Fig. 13). Their tracks were similar to the straight line.

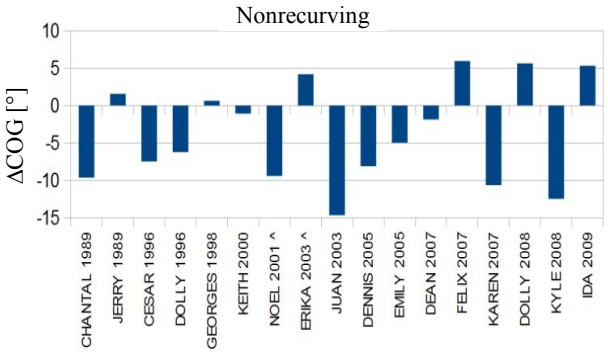

Fig. 13. The graph of the difference of the average cyclone course for whole 96 h and last 24 h period for the non-recurving tropical cyclones

Period of 96 hours counted from the first moment of developed non-recurving tropical cyclone detection was considered. If the existence of the cyclone and its registered track was shorter than 96 hours and the cyclone disappeared after this period, a time of 72 hours in relation to the last day was considered.

A characteristic feature of these tracks is to keep by cyclones relatively constant course and progressive speed (Fig. 14). At 12-hour intervals direction of movement varies around 310°. Pressure drops in the tropical cyclone center during the 72 h period and thus increases the wind speed. Graphical interpretation of the results as diagrams is on the figure 15.

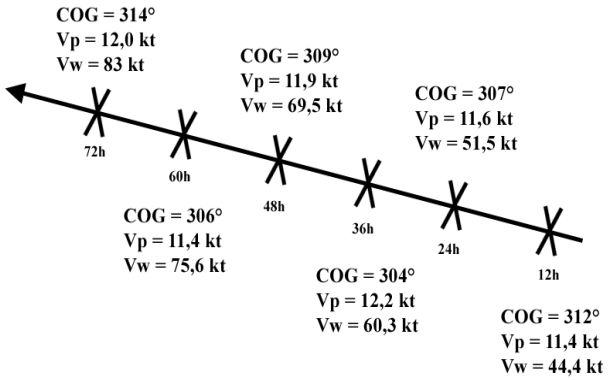

Fig. 14. Non-recurving tropical cyclone track with marked 12-hour intervals, the average course over ground, the average parameters of the progressive movement and the average wind speeds

Looping tropical cyclones

Definition: "Looping tropical cyclones are storms that move at slow speed and have significant changes in direction over short periods of time" [4].

Looping cyclones are the cyclones that move was clearly looped. As a classification criterion for this track type course change in the interval between the distinctive points C1 and C2 were adopted (the character "+" means a change in the right

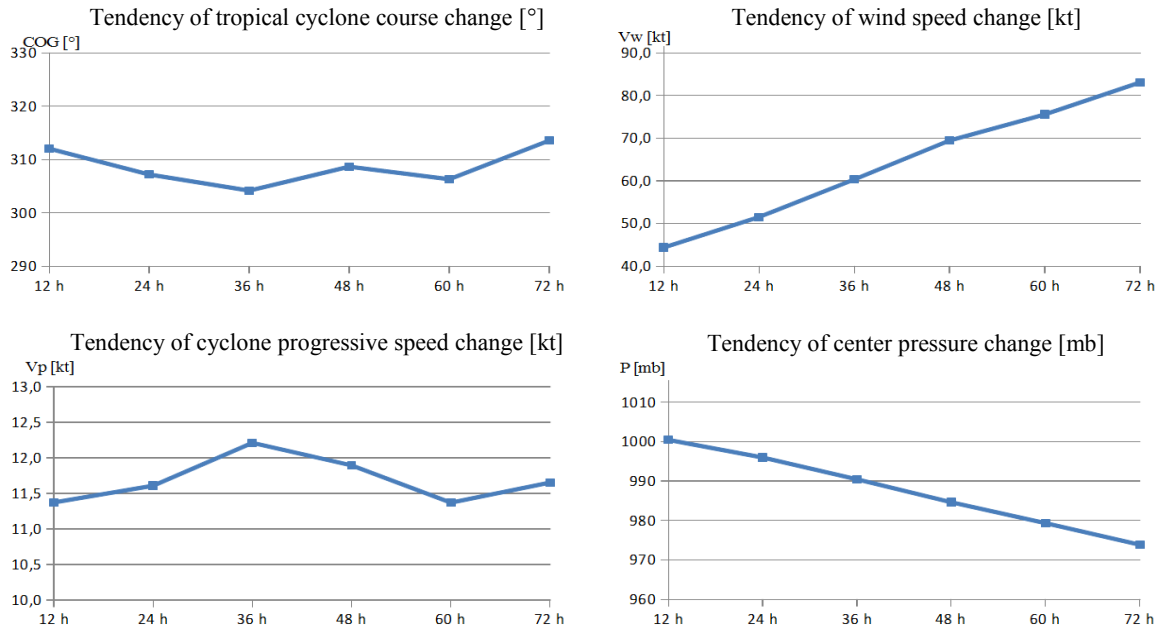

Fig. 15. The average parameters of cyclone movement and intensity in the 12-hour intervals for nonrecurving tropical cyclone

direction, while the "–" to the left). The period between the first distinctive point C1 and the point of closing the loop C2 was possible to reproduce using the best tracks and the minimum level was set at 48 h.

Values for looping tropical cyclones of the analyzed period are presented below (Fig. 16).

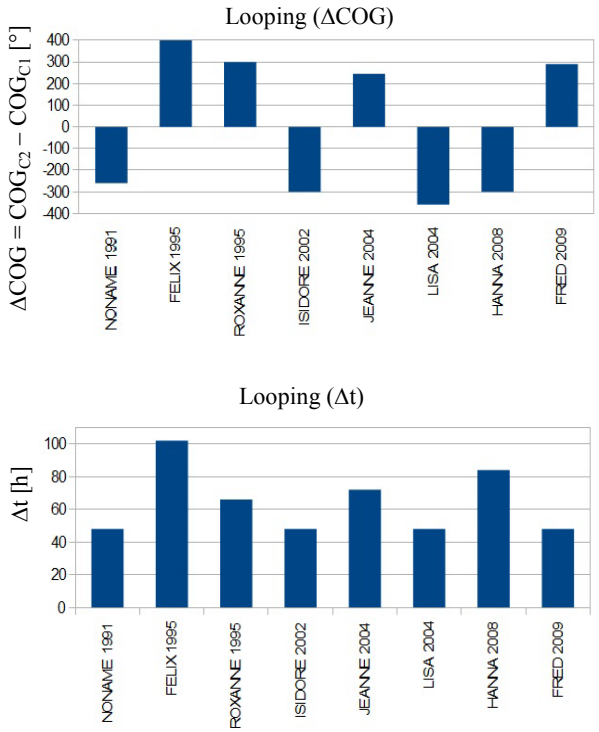

Fig. 16. Time interval and the value of course change between the points C1 and C2 for tracks classified as looping

In the first and second time interval (C1[–24 h], C1[–12 h]) before reaching the first distinctive point C1, cyclones change the course in range of 299°–310° on average. Between points C1 and C2 the track is looped over at least 48 hours (Fig. 17). Tropical cyclone courses for this section have been omitted. The average movement parameters of looping tropical cyclones are presented in graphs (Fig. 18).

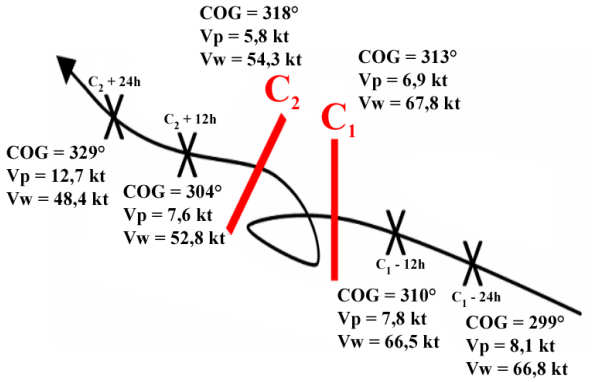

Fig. 17. Looping tropical cyclone track with marked distinctive points, 12-hour intervals, the average parameters of the progressive movement and the average wind speeds

Cyclone progressive speed falls in the range between the distinctive points C1 and C2. After reaching a distinctive C1 point, pressure begins to rise and the wind speed decreases. After passing the full loop at the point C2 there is a significant increase in progressive speed of cyclones from 5.8 kt to 12.7 kt.

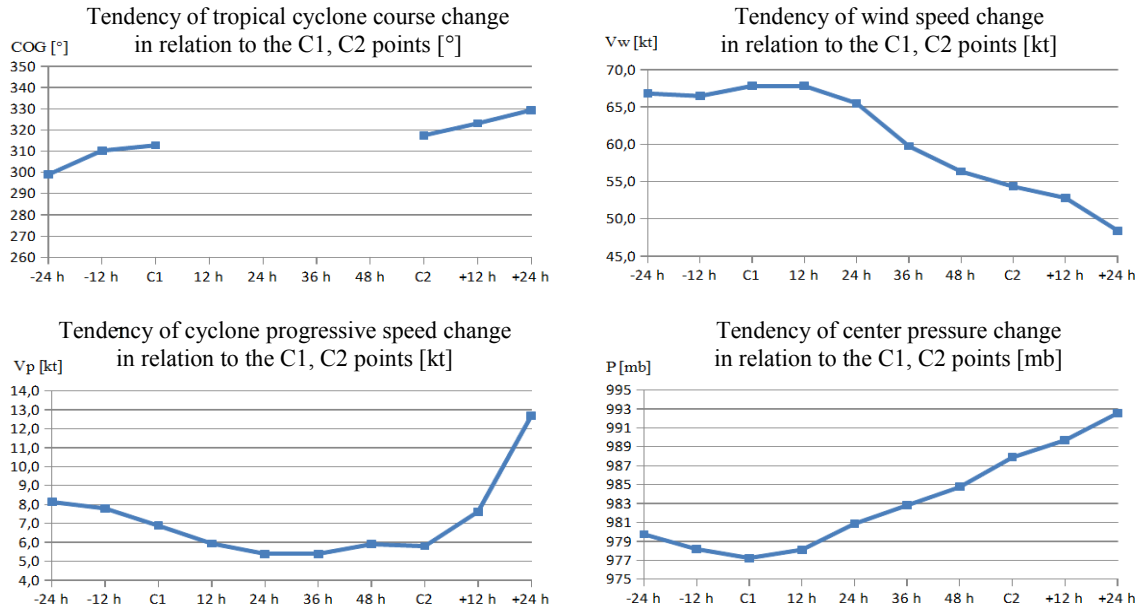

Fig. 18. The average parameters of cyclone movement and intensity in relation to the C1 and C2 points in the 12-hour intervals for looping tropical cyclone

Erratic tropical cyclones

Cyclones, whose behavior was not similar to any of these types, were classified as erratic of undetermined motion nature without specifying the distinctive points (R, L, C1, C2).

Conclusions

Based on the previously defined classification criteria 146 cyclonic systems from the period of 20 years (1989–2009) have been analyzed, which reached the stage of the hurricane, and reached at least 1st degree in the Saffir-Simpson scale.

Cyclones known as slow recurving determine 24% (35 cases), sharply recurving 23% (33 cases), nonrecurving 12% (17 cases), left turning 10% (15 cases) and looping 5% (8 cases) of all hurricanes from the period 1989 to 2009. Among all analyzed cyclones 26% (38 cases) were classified as erratic because of the high degree of disordered variability of the track and not meeting certain criteria. Among them it can distinguish e.g. cyclones, which did not have the equatorial segment, the segment with the point of recurving, or were a combination of other types of cyclones.

Determination of the distinctive points make possible to categorize different tracks of cyclones. 12-hour intervals defined in relation to those points were considered. The average parameters values for the sections were calculated, which later were used to analyze trends in their changes for the various track types. With the current meteorological information the crew is able to determine the approximate tendency of the progressive movement and intensity of the cyclone.

Based on data drawn from two decades authors can compare the character of the cyclone movement and try to predict a type of track of the current cyclone. However, do not treat the results presented as rigid rules of the cyclone behavior, because they were developed only in relation to the parameters of the progressive movement and intensity of the cyclone. Specialized meteorological centers in their forecasts take into account many more factors determining the movement of cyclones, such as, among others, the current situation of movement associated with the presence of pressure systems in the different layers of the troposphere. Advanced mathematical models and large processing power of computers in these centers generate the most reliable storm tracks in their forecasts, and should therefore be taken into account on a current basis on ships operating in tropical areas [1, 2].

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