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Tropical hurricane Charley (2004): Unpredicted rapid intensification

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Abstract

In the past decade, one of the most resonant failure of prediction service has been associated with unpredicted rapid intensification of tropical hurricane (TH) Charley attacked on high power the southern-western Florida on August, 13, 2004. In the paper the results of analysis Charley's development in the framework of so-called equilibrium translation model (ETM) are presented. ETM considers TH as an open dissipative system internally geared to maximum intensification. When this tendency is found to be aligned with large-scale environmental wind, TH gains highest efficiency in terms of conversion of the oceanic heat into the cyclonic motion of atmosphere (alignment effect), building a basis for the rapid intensification. ETM discloses crucial role of non-dimensional alignment number incorporating integral thermal and dynamical parameters of the system ocean-cyclone-atmosphere (OCA). The value of this parameter during rapid intensification (critical alignment number) turns out to be roughly constant for any TH. The analysis is made in the two approximations. The first approximation assumes circular geometry of TH without taking in account variability of its outer radius. The second approximation assumes non-circular geometry of TH with variable in time outer boundary.

1. Introduction

Characteristic scales of TH vary from the sizes of sprayed by wind water droplets to the sizes of stretched for hundreds and even thousands of miles spiral rainbands. Description of such complex and multi-scale phenomenon requires accounting great variety interrelated irreversible thermo-hydrodynamic processes. That is why numerical modeling methods became main instrument of research of TH phenomenon. By now this "great numerical attack" is in progress with certain achievements, for instance, in TH track forecasting [1-3].

At the same time, progress in TH intensity forecasting is much slower [3-4]. Besides, prediction of rapid intensification remains as particularly challenging problem. Despite permanent improvement of resolution of numerical models, regular predictions overlook or considerably underestimate practically all cases of rapid intensification [5].

In the past decade, one of the most resonant failure of prediction service has been associated with TH Charley attacked on high power the southern-western cost of Florida on August, 13, 2004.

After crossing the western part of Cuba from south to north the practical constancy of the intensity of the TH Charley (a slight strengthening from 95 to 100 kt) over the next 9 hours with a further significant decrease in intensity to 60 kt over the next 12 hours was predicted by the forecast advisory number 17 (15:00 UTC FRI AUG 13 2004) [5].

In reality, against this prediction, already after 3 hours, it became necessary to issue a special forecast advisory number 18 (18:00 UTC FRI AUG 13 2004) fixed extremely rapid build-up of Charley to 125 kt (from a medium Category 2 to a strong Category 4 on the Saffir-Simpson Hurricane Scale) for these 3 hours [5].

According the Report [6] "Charley made landfall on the southwest coast of Florida near Cayo Costa, just north of Captiva, around 19:45 UTC 13 August with maximum sustained winds near 130 kt. Charley's eye passed over Punta Gorda at about 20:45 UTC, and the eyewall struck that city and neighboring Port Charlotte with devastating results. Continuing north-northeastward at a slightly faster forward speed, the hurricane traversed the central Florida peninsula, resulting in a swath of destruction across the state. The center passed near Kissimmee and Orlando around 01:30 UTC 14 August, by which time the interaction with land caused the maximum sustained winds to decrease to around 75 kt. Charley was still of hurricane intensity, with maximum sustained winds of 65-70 kt, when the center moved off the northeast coast of Florida near Daytona Beach at around 03:30 UTC 14 August".

Additionally, noteworthy is the fact that the extremely rapid amplification of Charley took place with its replacement, consequent to crossing Cuba, to much less overheated waters. The last circumstance hardly agrees with existing ideas about the nature of TH always considering sea surface temperature (SST) and so-called hurricane heat potential (HHP) as intensifying factor. In this context, not difficult to assume, that the numerical models have predicted weakening of Charley just because of upcoming transition to the sea area with much less SST and HHP.

Here also should be noted that the situation with the prediction of TH intensity was not changed essentially over the past several years after TH Charley [5].

In our opinion, to some extent, all these challenges exhibit typical contemporary problem with proper matching of numerical methods with adequate qualitative physical models.

ETM [7-8] attempts to bridge this gap linking TH development to conformity of dynamical and thermal fields of system OCA at integral scales. At that non-dimensional alignment number, incorporating integral thermal and dynamical parameters of this system, gains the role of the main characteristic of TH development, including its rapid intensification (alignment effect).

In the paper analysis of development and rapid intensification of TH Charley is carried out in the framework of ETM in the two approximations. The first approximation assumes circular geometry of TH without taking in account variation of its outer radius in time. The second approximation assumes non-circular geometry of TH with variable outer boundary.

2. Conceptual basics of the study

ETM considers sea upper layer as a single energy source for TH development (applicability of such an approach is restricted in the range small HHPs and THs with small diameters when air inflow energy content also becomes valuable).

ETM also assumes that, at least partially, TH development always is influenced by certain internal driving mechanism thermally powered by SST asymmetry at outer boundary.

Certain initial adaptation of dynamical and thermal fields always holds in the zones of TH development. In the main tropical zones background SST elevation, as a rule, coincides with environmental wind. In trade winds zone SST elevation rate is of order $10^{-6}\,{}^{0}$C/m [9].

However, in powering internal driving mechanism leading role is played by longitudinal SST jump induced by TH itself through cooling upper sea layer gradually lowering SST to the rear. According our evaluation the resultant SST gradient is of order $10^{-5}\ {}^{0}$C/m.

Further, leaving aside the fact that TH translation mainly is determined by large-scale environmental (steering) winds, let's consider idealized case when TH undergoes influence only thermally powered internal driving mechanism.

The scheme of thermally powered internal driving mechanism is presented in Fig. 1.

SST jump (ΔT_s) leads to more intense ascending flow in the eye wall cloud frontal part with minimum air pressure. As eye wall cloud serves as a core structural component of the whole system, generated by ΔT_s pressure drop between its frontal and back parts (ΔP_s) just represents internal driving force.

Intensity of heat and mass transfer from sea surface to TH is little affected by translation speed. Here main role is played by much higher air tangent velocity. In this connection reduction of translation speed (leading to prolonging TH passage above given sea area) steps up the share of heat removed from upper sea layer, and vice versa, gathering of translation reduces cooling the layer mentioned, all other things being the same.

Such an inverse dependence introduces rather strong negative feedback into thermally powered driving mechanism. Reduction of translation speed, alongside with increasing ΔT_s, leads to elevated pressure drop ΔP_s causing, for its part, TH acceleration. And vice-versa, elevated translation speed leads to reduced ΔP_s that tends to TH slowing-down.

In such a manner, TH not only prefers to shift toward SST elevation, but it also tends to certain equilibrium between translation speed and integral heat inflow. Similar translation is named as an "equilibrium translation" [6-7]. As shown below, just equilibrium translation gains exceptional significance in the framework of ETM.

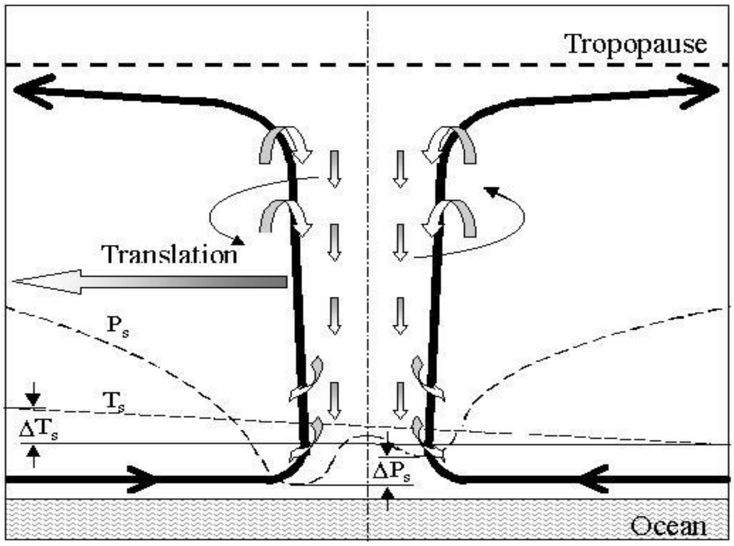

Fig. 1. The scheme of thermally powered driving mechanism.

ΔT_s and, accordingly, ΔP_s depend on TH intensity and HHP. Besides, generation the same driving force needs more slow TH translation at high HHP and vice-versa. In the case of equilibrium translation this inverse dependence allows to assume rough constancy of so-called heat involvement factor equal to the share of HHP removed by TH from sea surface through full passage given area.

Further, returning to dominant role of steering wind, conclusion should be made that equilibrium translation is possible only through favoring by large-scale environmental wind field. In this connection ETM assumes that just alignment of steering wind speed with above internal tendency leads to real equilibrium translation triggering, by its part, TH rapid intensification (alignment effect).

3. The general formulation of the problem

The scheme of translation of non-circular TH is presented in Fig. 2.

In general case, within accepted assumptions, integral heat flow (sensitive and latent) removed from sea strip left behind TH can be written in the following form:

$$A_{34} q = C_i Q \delta S_c , \qquad (1)$$

where A_{34} is area inside tangent wind velocity 34 kt; q is integral heat flux (sensitive and latent) averaged inside A_{34}; C_i is heat involvement factor; Q is HHP averaged inside A_{34}; δS_c is increment of cooled sea surface (cooled surface remaining behind TH during unit time).

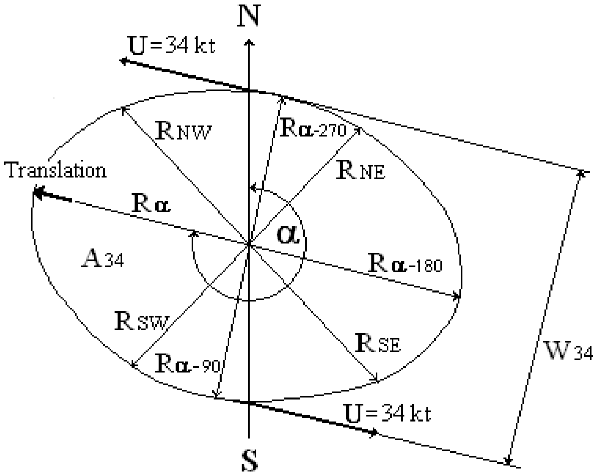

Fig. 2. The scheme of non-circular TH: A_{34} - area inside tangent velocity 34 kt (17.5 m/s); R_{NE}, R_{SE}, R_{SW} and R_{NW} - TH radii at tangent velocity 34 kt in Northeast, Southeast, Southwest and Northwest quadrants, respectively; α - TH translation azimuth; W_{34} - TH transverse size at tangent velocity 34 kt.

Here should be noted that TH outer boundary is assumed at tangent wind velocity 34 kt (17.5 m/s), i.e., at the minimum value of tangent wind specified in regular forecast advisories.

Further, neglecting sea surface drift velocity relative TH translation speed, in certain approximation, equation (1) can be transformed to the following form:

$$A_{34}q = C_i Q W_{34} U_{bb}\,, \tag{2}$$

where W_{34} is TH transverse size; U_{bb} is translation speed of TH back boundary center; the product $W_{34}U_{bb}$, to a certain approximation, determines the increment of cooled by TH sea surface.

As equilibrium translation is linked to constant involvement factor, the condition of its establishment is determined by the following equation for critical non-dimensional alignment number:

$$N_{cr} = \frac{\pi W_{34} U_{bb} Q}{2A_{34} q} = \frac{U_{bb} Q}{q R_{ef}} = Const\,, \tag{3}$$

where R_{ef} is effective radius of TH:

$$R_{ef} = 2A_{34} / \pi W_{34} \tag{4}$$

In such a manner, within ETM, characteristic length of non-circular TH is proportional to the ratio of covered by TH sea area to TH transverse size. In circular TH it is equal to TH radius.

At the same time, analysis of relevant field data in the framework of ETM requires supplementing equations (3) and (4) by relationships determining incoming parameters.

4. The first approximation

Realization of ETM in the first approximation (FAP) [6] is built upon consideration uniform straightforward translation of circular TH of invariable outer radius.

Within accepted assumptions TH back boundary translation speed turns out to be equal to the translation speed of TH centre that is specified in corresponding forecast advisory. In addition, TH effective radius turns out to be equal to TH outer radius.

Accordingly, equation (3) takes the following form:

$$N_{cr} = \frac{U_{tr}Q}{qR} = Const, \qquad (5)$$

where U_{tr} is the translation speed of TH centre; R is TH outer radius.

In [6], based at some simplifying assumptions and using TH Kenna (2000) as reference case production qR is determined by following empirical equation:

$$qR = 2.125 \cdot 10^{8} \left(\frac{U_{\max}}{145} \right)^{0.5} Wm^{-1}, \qquad (6)$$

Where U_{max} is TH intensity (maximum tangent wind velocity in kt at given position);

Finally, using parameters of the rapid intensification of TH Opal (1995) the following value of the critical alignment number is established [6]:

$$N_{cr}=25\pm30\% \qquad (7)$$

Correlation of the field data on TH Charley is presented in Fig. 3.

Data on TH intensity (maximum tangent wind - U_{max}) and timing are taken from the forecast advisories [5]. Data on Q are taken according timing and TH location from HHP maps [10]. Production qR is determined by equation (6).

As follows from Fig. 3, the alignment number approached the critical value with nearing Florida peninsula. The stage of rapid intensification (started from 54th hour) coincided with equilibrium translation at critical alignment number around 25. Alignment effect really turns out to be much stronger than weakening influence of transition to the sea area with much less HHP (HHP has reduced from around 1.0 GJ/m^2 to around 0.3 GJ/m^2 through crossing Cuba).

As follows from Fig. 3, the curve of alignment number is interrupted at the 60th hour after which increasing proportion of land surface against reducing share of sea surface in total area covered by Charley significantly affects accuracy of ETM.

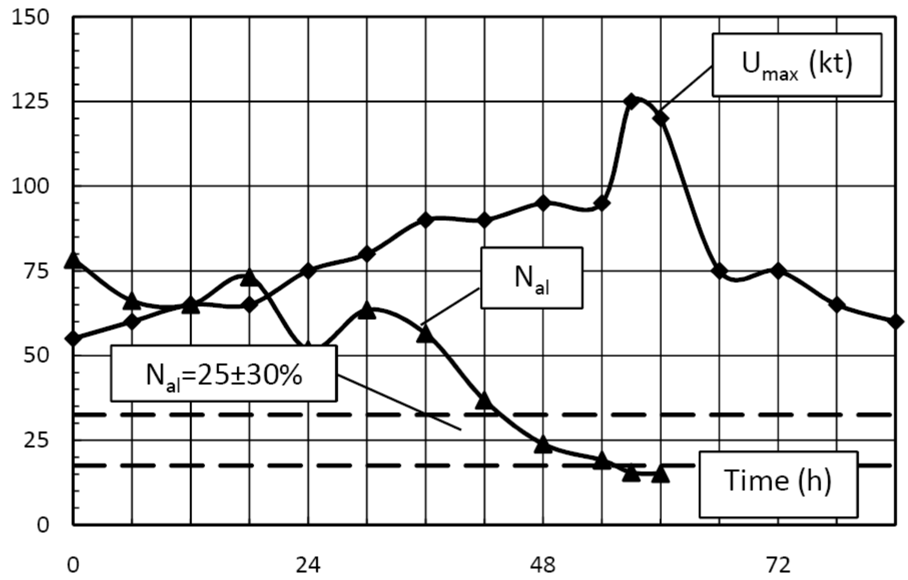

Fig. 3. Correlation of the field data on TH Charley with equation (7):
the position 0 corresponds to 09:00 hour (UTC) AUG 11 2004

In addition, noteworthy is the fact that publication date of the article [4] is for a few months ahead of the emergence TH Charley, and, theoretically, presented in Fig. 3 curve (up to 54^{th} hour) might be drawn alongside with preparation the forecast advisory number 17 with establishment, in contrast to the advisory itself, a high chance of rapid intensification. In addition, also theoretically, if the rate of implementation new scientific results would have been fantastically high, forecasters would have the efficient tool for additional independent monitoring the validity of the results of numerical simulation.

At the same time, introduced in [4] extremely simplified scheme of determination *qR* through equation (6) evidently calls for further refinement.

5. The Second Approximation

Analysis of ETM in the second approximation covers non-circular TH with variable outer boundary (Fig. 2). In contrast to the first approximation, the second approximation requires supplementing equations (3) and (4) by much more detailed relationships determining incoming parameters. Below full description of calculating procedures these parameters is presented.

5.1 TC geometrics

Presented in Fig. 2 idealized non-circular contour is based on 4 values of TH radius at tangent velocity 34 knots specified in regular advisories for Northeast, Southeast, Southwest and Northwest quadrants (*RNE*, *RSE*, *RSW* and *RNW*, to say, for 45^0, 135^0, 225^0 and 315^0 from North, respectively).

Firstly four radii R_{α}, $R_{\alpha-90}$, $R_{\alpha-180}$ and $R_{\alpha-270}$ can be determined through simple smooth trigonometric interpolation aforementioned initial data (α is TH translation azimuth):

$$R_{\alpha} = R_{SW} - \frac{R_{SW} - R_{NW}}{90}(\alpha - 315) \tag{8}$$

$$R_{\alpha-90} = R_{SE} - \frac{R_{SE} - R_{SW}}{90}(\alpha - 90 - 135) \tag{9}$$

$$R_{\alpha-180} = R_{NE} - \frac{R_{NE} - R_{SE}}{90}(\alpha - 180 - 45) \tag{10}$$

$$R_{\alpha-270} = R_{NW} - \frac{R_{NW} - R_{NE}}{90}(\alpha - 270 + 45) \tag{11}$$

Further TH transverse size (W_{34}), average radii at tangent winds 34 knots, 50 knots and 64 knots (R_1, R_2 and R_3, respectively), an area inside tangent velocity 34 knots (A_{34}) and TH back boundary center coordinates (latitude – Lt_{bb}, longitude – Ln_{bb}) can be determined:

$$W_{34} = R_{90} + R_{270} \tag{12}$$

$$R_1 = 0.25\left(R^2{}_{NE,34} + R^2{}_{SE,34} + R^2{}_{SW,34} + R^2{}_{NW,34}\right)^{0.5} \tag{13}$$

$$R_2 = 0.25\left(R^2{}_{NE,50} + R^2{}_{SE,50} + R^2{}_{SW,50} + R^2{}_{NW,50}\right)^{0.5} \tag{14}$$

$$R_3 = 0.25\left(R^2{}_{NE,64} + R^2{}_{SE,64} + R^2{}_{SW,64} + R^2{}_{NW,64}\right)^{0.5} \tag{15}$$

$$A_{34} = (\pi/4)\left(R^2{}_{NE,34} + R^2{}_{SE,34} + R^2{}_{SW,34} + R^2{}_{NW,34}\right) \tag{16}$$

$$Lt_{bb} = Lt_c \pm \left(R_{\alpha-180}/1.11\cdot 10^5\right)Cos\alpha \tag{17}$$

$$Ln_{bb} = Ln_c \pm \left[R_{\alpha-180}/\left(1.11\cdot 10^5 \cdot CosLt_{bb}\right)\right]Sin\alpha \tag{18}$$

Here Lt_c and Ln_c are TH center coordinates specified in regular advisories for given position; the length of a degree of latitude is accepted as $1.11\cdot 10^5$ m; the length of a degree of longitude is accepted as $1.11\cdot 10^5\cdot CosLt_{bb}$ m.

5.2 Translation of TH back boundary center

U_{bb} can be determined through TH back boundary center geographical coordinates of as average value for uniform straight translation at a length prior to given position that allows to performing calculations in forecasting mode:

$$U_{bb} = \left[1/(\tau - \tau_{-1})\right]\left\{\left[(Lt_{bb} - Lt_{bb-1})\cdot 1.11\cdot 10^5\right]^2 + \left[(Ln_{bb} - Ln_{bb-1})\cdot 1.11\cdot 10^5 \cdot CosLt_{bb}\right]^2\right\}^{0.5} \tag{19}$$

Here τ is time of passing by TH through given position; subscript -1 corresponds to the same parameter at TH position prior to given position at one length of standard track data.

5.3 Three-zone model of integral heat transfer

Evaluation of average integral heat flux from sea surface to TH is the most complicated problem when analyzing individual cases in the framework of ETM.

Available results of analysis and field data on integral heat fluxes [11-13] have rather wide dispersion (0.25 – 4 kW·m^{-2}). Among them the records of sensitive and latent heat fluxes made during rapid intensification of TH Opal (1995) in all its zones, including the zone close to maximum tangent winds [11] represent of special importance.

As an area covered by tangent winds in the range 17-25 m·s^{-1} makes around 80% in A_{34}, integral heat flux to greater extent depends on heat flux at outer boundary. Besides, the latter is independent from the most intense tangent winds. At the same time the zone with intense tangent winds also contributes in formation of average heat flux compensating in certain degree the zone's smallness by high local heat fluxes. In this connection adequate evaluation of average heat flux needs accounting of real tangent wind velocity distribution.

In general, integral heat flux from sea surface to TH is function of temperature, humidity and velocity fields. As it follows from corresponding analysis, the problem needs further analytical and experimental studies. Approximate two-zone empirical model of heat transfer was presented in [14].

Approximate three-zone model of heat transfer specifically fitted to main features of equilibrium translation is presented below.

As known [11], dynamical impact of TH on an ocean includes intensive vertical mixing of seawater. Besides, resultant downward heat flow exceeds sought upward integral heat flow almost at an order of magnitude. In this connection vertical mixing becomes decisive factor through transformation of SST field by TH.

On the other hand, constancy of involvement factor causes another important peculiarity of heat transfer just during equilibrium translation.

In general, removal by TH of constant share of HHP needs more time and heat removal at high HHP and vice-versa. In this connection equilibrium translation is characterized by different combinations of translation speed, TH sizes and integral heat flux resulting less intensive cooling at low HHPs and, vice-versa, more intensive cooling at high HHPs (these differences equally concern downward and upward heat flows).

This circumstance allows to assuming that SST field under TH is roughly uniform during equilibrium translation, irrespective of initial value of HHP.

Correspondingly, during equilibrium translation, to a certain approximation, average integral heat flux also turns out to be independent on initial HHP and becomes single-valued function of tangent wind distribution that essentially simplifies further analysis.

In such a manner, the subject matter reduces to near-equilibrium mode of translation restricting applicability of the approach outside of this mode. However, such a specializing is quite allowable at this stage in respect to our focusing to equilibrium translation.

Further, taking in account field data structure in forecast advisories, three-zone model of heat transfer is offered. The first (outer) zone covers the area between tangent winds 34 knots (17.5 m/s) and 50 knots (25.75 m/s). The second (intermediate) zone covers the area between tangent winds 50 knot and 64 knots (33 m/s). The third (central) zone covers the area inside tangent wind 64 knots. Within used approach maximum tangent wind influences integral heat transfer only in central zone. Besides, influence of central zone on average integral heat flux is smoothed in certain degree by comparatively small share of this zone in A_{34} (5 - 15 %).

Further, reasoning from all above and using available field data, following empirical equation is developed for average integral heat flux from sea surface to TH:

$$q = \left[400\left(R_1^2 - R_2^2\right) + 600\left(R_2^2 - R_3^2\right) + 1{,}200\left(U_{\max}/130\right)R_3^2\right]R_1^{-2}\ \mathrm{W\cdot m^{-2}} \qquad (20)$$

Here R_1, R_2 and R_3 are average outer radii of first, second and third zones in meters determined as a quarter of square root from sum of squares of corresponding radii in aforementioned four quadrants; U_{max} is maximum tangent wind velocity in knots; 130 is maximum tangent wind velocity of reference TH Opal (1995) in knots.

Characteristic for the zones average values 400 W·m^{-2} and 600 W·m^{-2} are determined through analysis and rounding the data recorded by NDBC buoy 42001 during development of TH Opal in 1995 [11]. Characteristic for the central zone average reference value (1,200 W·m^{-2}) is determined based on the same field data taking in account that the buoy 42001 was located at around 25 km from Opal's center during its maximum intensity and recorded by the buoy maximum heat flux can be accepted as average for all central zone. At the same time, possibility of linear extrapolation of this parameter to other cases is assumed.

5.4 Refinement of critical alignment number

Critical alignment number is refined through confrontation of equations (3) and (8)-(20) with 8 strongest THs selected among around 200 THs observed worldwide during 2003-2010, such as Chaba (2004), Dianmu (2004), Ma-On (2004), Monica (2006), Nida (2009), Rick (2009), Celia (2010), Megi (2010).

The results of confrontation show validity of ETM at sufficiently high HHPs (50 kJ·cm^{-2} and more). Maximum intensification of TH (alignment effect) is linked to critical value of alignment number:

$$N_{cr} = 35 \pm 20\ \% \tag{21}$$

In connection with differences in calculation schemes of average heat flux and absence of field data on TH Opal (1995) sufficient for refined calculation scheme, it is difficult to establish a degree of equivalency of (21) with the previous evaluation $N_{cr} \approx 25$ according the first approximation [6].

5.5 Correlation of the field data on TH Charley

Correlation of the field data on TH Charley is presented in Fig. 4.

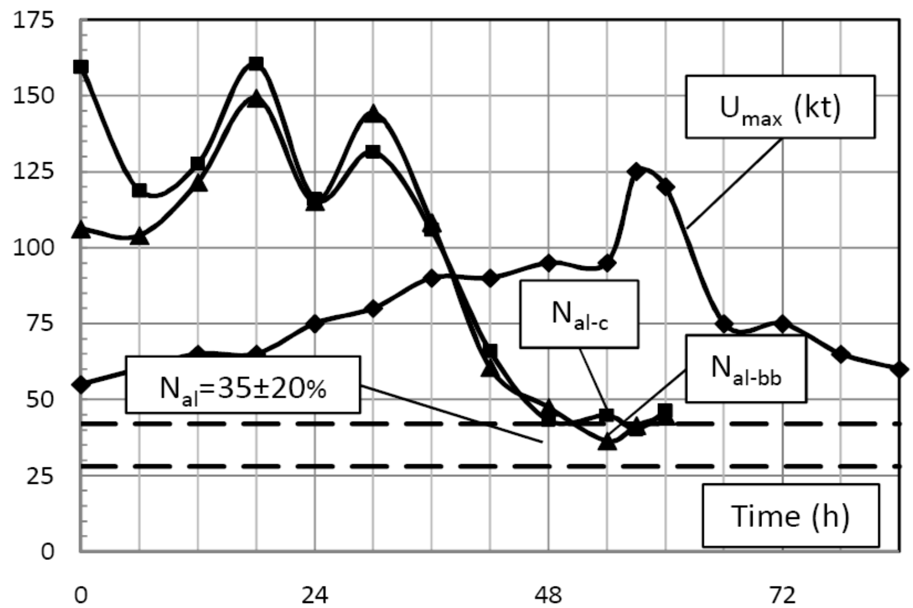

Fig. 4. Correlation of the field data on TH Charley with equation (21): the position 0 corresponds to 09:00 hour (UTC) AUG 11 2004

Similar to correlation (4), data on maximum tangent wind (U_{max}) and timing are taken from the forecast advisories [5]. Data on Q are taken according timing and TH location from HHP maps [10]. The alignment number is determined through equations (3) and (8)-(20). Besides, by the goal of clarification of the role of variability TH outer boundary, two versions of the alignment number are plotted: the first based at TH back boundary center translation ($N_{al\text{-}bb}$) and the second based at TH center translation ($N_{al\text{-}c}$).

Here some comments are necessary concerning the fact that it is not taken into account in above analysis the influence of land surface found inside TH outer boundary. The latter does not diminish the validity of the results, because Charley was located entirely on the water at a crucial stage of rapid intensification.

As a whole, as follows from Fig. 4, difference between the two versions gains principal importance only at the start of rapid intensification (54^{th} hour) when just only $N_{al\text{-}bb}$ corresponds to critical number according equation (7).

In such a manner, the second approximation quite reliably predicts the upcoming rapid intensification of the hurricane Charley.

6. Conclusions

The model of equilibrium translation gets weighty confirmation by a clear interpretation of field data on rapid intensification of Hurricane Charley on August, 13, 2004.

The model links development of tropical hurricane to conformity of thermal and dynamical fields in the system ocean-cyclone-atmosphere. The model discloses non-dimensional alignment number claiming to be the basic criterion of TH development. The number incorporates main integral parameters of the system and comprehends combined influence of full spectra of thermo-hydrodynamic factors controlling TH development.

When favored by large-scale environmental field, tropical hurricane tends to self-organized establishment of critical alignment number leading to rapid intensification and maximum intensity (alignment effect).

Presented results and conclusions deserve detailed refinement, discussion and further development. In particular, it seems important further development of the model in terms of accounting of influence of land surface and energy contribution of air inflow. It also seems important further development of the model in terms of creation of new potential for proper forecasting of intensity of tropical hurricanes.

At the same time it already can be recommended monitoring of alignment number of acting hurricanes as potential reliable indicator of character of upcoming events.

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Тропический ураган Чарли (2004): непрогнозированное быстрое усиление

Иракли Г. Шекриладзе

Резюме

В последнее десятилетие один из наиболее резонансных провалов службы прогнозов был связан с быстрым непрогнозированним усилением тропического урагана (ТУ) Чарли, на высокой мощности ударившей по юго-западной Флориде 13 августа 2004 года. В работе представлены результаты анализа развития Чарли в рамках так называемой модели равновесной трансляции (МРТ). МРТ рассматривает ТУ как открытую диссипативную систему, внутренне нацеленную на максимальное усиление. Если эта тенденция оказывается выровненным с крупномасштабным региональным ветром, ТУ становится наиболее эффективным в смысле преобразования океанического тепла в энергию циклонического движения атмосферы (эффект выравнивания), что является предпосылкой для быстрого усиления. МРТ раскрывает важную роль безразмерного числа выравнивания, включающую интегральные тепловые и динамические параметры системы океан-циклон-атмосфера (ОЦА). Значение этого параметра в период быстрого усиления (критическое число выравнивания) оказывается приближенно постоянным для любого ТУ. Анализ выполнен в двух приближениях. Первое приближение предполагает круговую геометрию ТУ без учета переменности его внешнего радиуса. Второе приближение предполагает некруговую геометрию ТУ с переменной во времени внешней границей.

ტროპიკული გრიგალი ჩარლი (2004): არაპროგნოზირებული სწრაფი გაძლიერება

ირაკლი შეყრილაძე

რეზიუმე

გასულ ათწლეულში პროგნოზირების სამსახურის ერთ-ერთი ყველაზე რეზონანსული ჩავარდნა 2004 წლის 13 აგვისტოს სამხრეთ-დასავლეთ ფლორიდაზე მძლავრი დარტყმის წინ ტროპიკულ გრიგალ ჩარლის არაპროგნოზირებულ სწრაფ გაძლიერებას უკავშირდება. სტატიაში წარმოდგენილია ჩარლის განვითარების ანალიზი ე.წ. წონასწორული ტრნსლაციის მოდელის (წტმ) ჩარჩოებში. წტმ განიხილავს ტროპიკულ გრიგალს (ტგ) როგორც ღია დისიპაციურ სისტემას, რომელიც შინაგანად მაქსიმალურ გაძლიერებაზე არის მიმართული. როდესაც ეს ტენდენცია დიდმასშტაბიან რეგიონულ ქართან თანადობაში აღმოჩნდება, ტგ ხდება

მაქსიმალურად ეფექტური ოკეანის სითბოს ატმოსფეროს ციკლონური მოძრაობის ენერგიად გარდაქმნის თვალსაზრისით (თანადობის ეფექტი), რაც სწრაფი გაძლიერების საფუძველს ქმნის. წტმ წარმოაჩენს წამყვან როლს უგანზომილებო თანადობის რიცხვისა, რომელიც სისტემის ოკეანე-ციკლონი-ატმოსფერო (ოცა) ძირითად ინტეგრალურ თერმულ და დინამიკურ პარამეტრებს შეიცავს. ამასთან, ნებისმიერი ტგ-ის სწრაფი გაძლიერება თანადობის რიცხვის მიახლოებით მუდმივი მნიშვნელობის (თანადობის კრიტიკული რიცხვის) დროს ხდება. ანალიზი ჩატარებულია ორ მიახლოებაში. პირველი უშვებს ტგ–ის წრიულ გეომეტრიას მუდმივი გარე რადიუსის პირობებში. მეორე უშვებს ტგ–ის არაწრიულ გეომეტრიას დროში გარე საზღვრის ცვლის პირობებში.