

Dynamic Prediction Model for Multi-influence Factors of Hurricane Intensity

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Abstract. In recent years, the global hurricane has intensified, which not only has a certain impact on the climate, but also has a great impact on human living environment and social and economic development. Therefore, the prediction of hurricane intensity plays an extremely important role in current climatic conditions and human development. In order to understand the change of hurricane intensity, the sea surface temperature, vertical wind shear, ocean heat content, Coriolis parameters, low-level relative vorticity and other factors are used as related factors affecting hurricane intensity. In this paper, the dynamic weighted evaluation model is combined with the Borda number to establish a hurricane intensity evaluation model, and then the hurricane intensity under the influence of various influencing factors is predicted. At the same time, in order to more clearly reveal the specific impact of various factors on the hurricane, this paper uses the Arcgis platform for mapping, which is conducive to qualitative assessment of the degree of impact.

1. Introduction

Hurricane is a tropical cyclone with a maximum wind of 12 or above near the center of the Atlantic Ocean, the Gulf of Mexico, the Caribbean Sea, and the eastern North Pacific. Hurricanes are often accompanied by strong winds and heavy rains, which can cause serious natural disasters such as storm surges and floods in the landing areas. It is one of the most devastating natural disasters on the planet. With the application and development of advanced observation methods such as satellites, the prediction of the hurricane path has made great progress in recent years (Chen Lianshou etc.,2001), while the prediction of hurricane intensity has made little progress. The main reason is that We do not know enough about the influencing factors affecting the intensity of hurricane. Therefore, studying the influencing factors of hurricane intensity change is of great significance for the prediction of hurricane intensity.

2. Analysis of various influencing factors of hurricane intensity

2.1. Sea surface temperature

As a source of tropical cyclone energy, the surface temperature plays an important role in the development and maintenance of tropical cyclones. It is generally believed that tropical cyclone formation will only occur on high temperature ocean surfaces over 26 °C.



During the tropical cyclone strengthening process in August and November, the sea surface temperature of the underlying surface showed a single peak distribution (Fig. 1), ranging from 26.5 °C to 31.5 °C, with the peak at 29 °C in August and the peak at 28.5 °C in November. The sea temperature factor is more conducive to the development of tropical cyclones in August, so the sea surface temperature is not the main factor determining the strength of tropical cyclones.

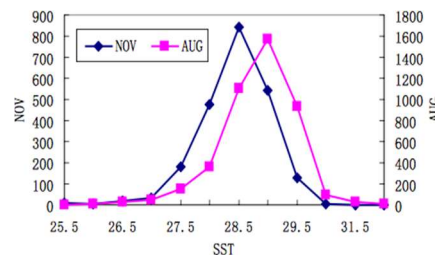


Figure 1. Sea surface temperature distribution of underlying surface during TC strengthening.

2.2. Vertical wind shear

2.2.1. Vertical wind shear calculation. In the study of tropical cyclones, the vertical shear of wind is generally defined as the difference between the average horizontal wind vector in a certain area of 200hPa and the average horizontal wind vector in the same area of 850hPa ($V_{200}-V_{850}$), and the average horizontal wind vector in a certain area can be The regional average of the regional horizontal wind U and V components is synthesized. The U and V components of the horizontal wind at all grid points on the 200 and 850hPa air pressure surfaces in the 644 km×644 km area are averaged to obtain a shear vector (Fig. 2).

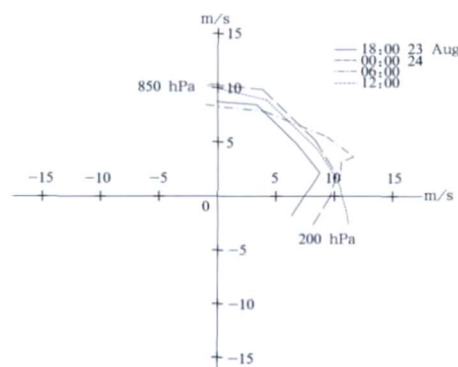


Figure 2. Simulated vertical wind shear through an area average of (644km×644km).

2.2.2. Vertical wind shear calculation. Vertical wind shear is an unfavorable factor for the formation and development of tropical cyclones. The earliest theory is that vertical wind shear will cause the heat loss in the high-level heat of the tropical cyclone warm zone to inhibit the development of tropical cyclones. The latest research indicates that the vertical wind shear of the environmental flow field inhibits the upward movement of the atmosphere in the upstream direction of the shear and the development of convection, which causes the tropical cyclone to form an asymmetric structure, thereby suppressing the development of tropical cyclones.

From the comparison between Figure 3 and Figure 4, the vertical wind shear environment in the tropical cyclone in August and November is basically the same as the vertical shear of the zonal wind. The difference between the two is mainly in the vertical cut of the meridional wind. change. The vertical shear of the meridional wind in the tropical cyclone in August was significantly larger than that in November. The vertical change of the meridional wind is conducive to the development of tropical

cyclones in November, which indicates that it may be the main factor affecting the intensity of tropical cyclones.

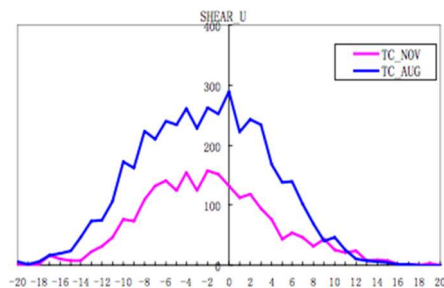


Figure 3. Zonal wind vertical shear.

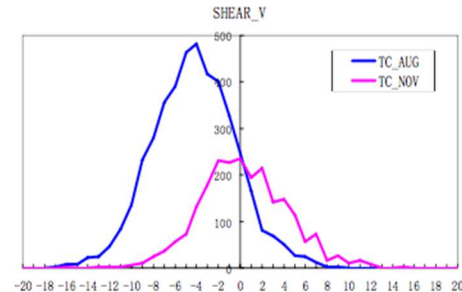


Figure 4. Vertical wind shear.

2.3. Low relative vorticity

The low relative vorticity can provide a rich initial disturbance for tropical cyclones and is a favorable condition for the formation and development of tropical cyclones. It can be seen from the comparison between Fig. 5 and Fig. 6 that in the vicinity of the average position of tropical cyclone activity, there is a larger relative vorticity in November than in August, which is more conducive to the development of tropical cyclones, so the relative vorticity of the lower atmosphere is also It may be one of the main factors affecting the intensity of tropical cyclones.

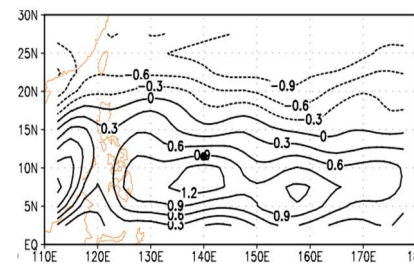
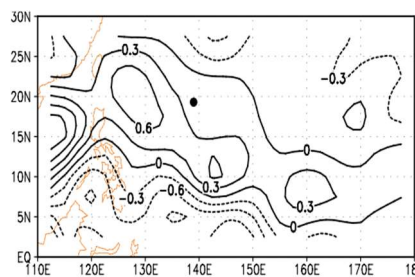


Figure 5. August 850hPa vorticity distribution. **Figure 6.** November 850hPa vorticity distribution.

2.4. Coriolis parameters

The geostrophic force is one of the necessary dynamic conditions for the formation of a tropical cyclone, which is why tropical cyclones cannot be formed near the equator. When all other conditions are the same, the distribution of the wind field will be slightly different due to the difference in Coriolis parameters. Constructing the low-pressure center as shown in Fig.7, the gradient wind caused by it will decrease as the latitude increases (Fig.8), but the difference is not large, which indicates that after the basic geostrophic force is satisfied, the Coriolis parameters The impact on tropical cyclone intensity is limited.

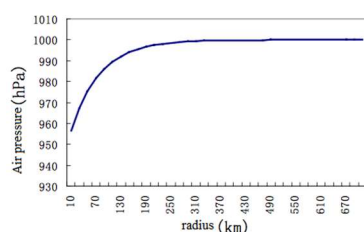


Figure7. Low pressure center pressure map.

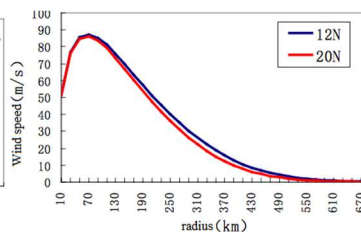


Figure8. Wind speed distribution map at different latitudes.

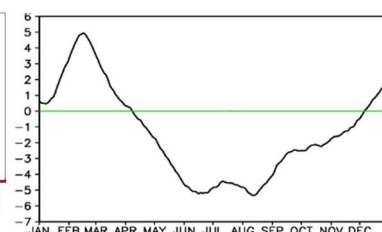


Figure9. Seasonal variation of vertical wind shear in tropical cyclone activity area.

2.5. Marine heat content

2.5.1. Calculation of ocean heat content. Calculated from the sea surface to the monthly average seawater temperature at a depth of 150m, calculate the heat content of a grid at the latitude(unit:J). According to the heat content calculation method of Masayoshi Ishii,the following formula is used:

$$OHC = \int_{-150}^0 4\pi^2 R^2 \rho(T,S) C_p T \cos\phi / 259\ 200\ dh \quad (1)$$

R is the radius of the earth, $\rho(T, S)$ is the density of seawater, and varies with the temperature T and salinity S at the depth h of the seawater, and C_p is the specific heat of seawater. Considering that the density change of each layer of seawater is less than 1%, for the convenience of calculation, R, $\rho(T, S)$ and C_p are considered as constants. make,

$$c = 4\pi^2 R^2 \rho(T,S) C_p / 259\ 200. \quad (2)$$

Then there,

$$OHC = \int_{-150}^0 c T \cos\phi dh \quad (3)$$

In this paper, the heat content is not multiplied by the constant C.

2.5.2. Analysis of ocean heat content. The climatic isoline of the upper oceanic ocean heat content in the North Pacific is basically zonal, the northern contour is relatively dense, the heat content increases from north to south, and the heat content of the western Pacific is higher than that of the eastern Pacific. Two of the high-value areas are located on the equator near the equator and 10°N, and the heat content in the southern high-value center is higher than that in the northern area. In the middle of the two high-value areas, the heat content tends to decrease relatively. Near 6°N, two relatively low-value centers appear on both the east and west sides (Fig. 10).

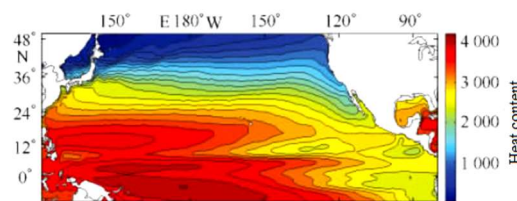


Figure10. Climatic map of the upper ocean heat content in the North Pacific Ocean.

3. Hurricane strength dynamic prediction model

3.1. Establishment of dynamic weighted evaluation function

First, the classification of hurricanes by national standards is divided as follows:

Table 1. Hurricane level distribution table.

Hurricane level	Maximum average wind speed at the bottom center (km/h)	Maximum average wind speed near the bottom center (km/h)
1	119-153	33-42
2	154-177	43-49
3	178-209	50-58
4	210-249	59-69
5	>249	≥70

According to the corresponding impact indicators of the hurricane, it can be concluded that the impact of each indicator x_i on the final strength evaluation is more consistent with the increase of the category, the first slow growth, then the rapid growth, and finally the slow growth, and finally the gradual increase tends to the maximum, so the normal distribution is applied. The large normal distribution function of the curve acts as a dynamic weighting function, that:

Where β_i is taken here as the median of the first-level concentration standard interval of indicator x_i , which is $\beta_i = (b_1^{(i)} - a_1^{(i)}) / 2$, σ_i is determined by $w_i(a_3^{(i)}) = 0.9 (1 \leq i \leq 3)$.

3.2. Borda number established

Take the comprehensive evaluation model as the dynamic weighted sum of each evaluation index, that:

$$X = \sum_{i=1}^m w_i(x_i) \cdot x_i \quad (i=1,2,3) \quad (4)$$

The comprehensive evaluation index function can obtain the comprehensive evaluation index value $X_k(j) (k=1,2,\dots,n; j=1,2,\dots,N)$ of each evaluation object, and according to the size sorting, the ranking schemes of the evaluation objects can be obtained.

The Borda function method in decision analysis is used to determine the integrated ranking scheme. If the number of the j evaluated objects in the i sorting scheme is $B_i(u_j)$, and $B_i(u_j) = n - k$ is obtained, the number of Bordas of the evaluated object u_j is:

$$B(u_j) = \sum_{i=1}^m B_i(u_j) \quad (j=1,2,3,4) \quad (5)$$

According to the calculation result of this formula, the size is sorted at the same time, and the total sorting result of the hurricane intensity at different times of the evaluated object can be obtained:

$$\left\{ \begin{array}{l} x'_{ij} = \frac{x_{ij} - m_j}{M_j - m_j}, (i=1,2,\dots,55; j=1,2,3) \\ w_i(x) = \begin{cases} 0, & \text{when } x \leq \beta_i \text{ time,} \\ 1 - e^{-\left(\frac{x - \beta_i}{\sigma_i}\right)^2}, & \text{when } x > \beta_i \text{ time,} \end{cases} \\ X = \sum_{i=1}^m w_i(x_i) \cdot x_i, (i=1,2,3) \\ B(u_j) = \sum_{i=1}^m B_i(u_j) \quad (j=1,2,3,4) \end{array} \right. \quad (6)$$

Table 2. 1982-2017 hurricane intensity table.

Years	1982	1983	1984	1985	1986	1987	1988	1989	1990
Borda-number	59.27	49.92	45.17	69.89	82.48	81.83	74.77	50.75	50.07
Ranking	23	32	36	17	3	5	14	29	31
Years	1991	1992	1993	1994	1995	1996	1997	1998	1999
Borda-number	47.92	59.84	76.32	82.35	83.13	74.51	75.86	52.65	63.39
Ranking	34	22	11	4	1	15	12	26	20
Years	2000	2001	2002	2003	2004	2005	2006	2007	2008
Borda-number	66.41	55.90	78.73	82.78	50.20	47.59	72.06	79.25	62.53
Ranking	19	25	8	2	30	35	16	7	21
Years	2009	2010	2011	2012	2013	2014	2015	2016	2017
Borda-number	76.34	51.19	48.25	58.20	52.16	68.01	77.91	81.65	74.97
Ranking	10	28	33	24	27	18	9	6	13

4. Conclusion

Through the specific analysis of the related effects of sea surface temperature, vertical wind shear, atmospheric middle layer humidity, ocean heat content, Coriolis parameters and low-level relative vorticity on hurricane intensity, it can be concluded that the lower layer relative vorticity and meridional wind Vertical shear may be the most important factor affecting the strength of tropical cyclones. At the same time, through the dynamic prediction model, combined with the influence of various influencing factors on the hurricane intensity, the borda number ranking of hurricane intensity from 1982 to 2017 was obtained.

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