A Short-Term Tropical Cyclone Intensity Forecasting Method Based on High-Order Tensor (Student Abstract)

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Abstract

Tropical cyclones (TC) bring enormous harm to human beings, and it is crucial to accurately forecast the intensity of TCs, but the progress of intensity forecasting has been slow in recent years, and tropical cyclones are an extreme weather phenomenon with short duration, and the sample size of TC intensity series is small and short in length. In this paper, we devolop a tensor ARIMA model based on feature reconstruction to solve the problem, which represents multiple time series as low-rank Block Hankel Tensor(BHT), and combine the tensor decomposition technique with ARIMA for time series prediction. The method predicts the sustained maximum wind speed and central minimum pressure of TC 6-24 hours in advance, and the results show that the method exceeds the global numerical model GSM operated by the Japan Meteorological Agency (JMA) in the short term. We further checked the prediction results for a TC, and the results show the validity of the method.

Introduction

In recent decades, with the continuous improvement of numerical forecasting technology and computational power, the path forecasting technology of TC has developed rapidly, but the intensity forecasting has made little progress, so intensity forecasting is now an urgent problem. The existing intensity forecasting methods are mainly divided into dynamical models and statistical models, with dynamical models requiring large computational power and extremely complex inputs, and statistical models requiring a large number of real-time parameters.

In this paper, it is attempted to use a small-sample data-driven approach for intensity forecasting. The BHT-based ARIMA algorithm proves to be effective in problems with small samples and short series(Shi et al. 2020), and we devolop a BHT-ARIMA model to forecast the intensity of the NW Pacific TC for 6, 12, 18, and 24 h. Since the rapid intensification(RI) phenomenon is one of the most difficult problems for TC, i.e., an increase in the maximum sustained wind speed of at least 30 knots within 24 h, it is examined separately for the RI phenomenon, and finally we compare the results with those of the operational statistical model and the dynamical model, respectively.

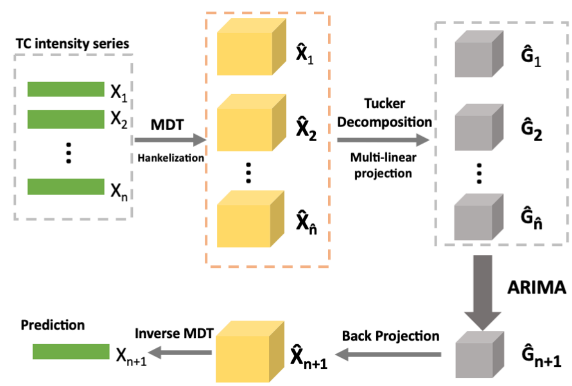

Figure 1: Workflow diagram of the TC intensity prediction model.

Study Area, Data and Proposed Model

The best track dataset released by the China Meteorological Administration is used, which contains the intensity of the northwest Pacific ocean every 6 hours from 1949 to 2020, the intensity of can be defined using the central pressure(Pmin) or the maximum sustained wind speed(Vmax), in order to examine the intensity more systematically, these two parameters are considered at the same time, since the input of the model needs to be a matrix to get the higher order tensor, so the length of each sequence was set to 40, select the sequence length greater than 40, the original length of the sequence greater than 40 select the middle 40 records, and finally get 537 sequences, the TC data involved can be obtained from guthub.

Figure 1 illustrates the workflow of the BHT-ARIMA model for predicting TC intensity, which is capable of mining the relationship between multiple time series. The model expands the data by delay embedding transform (MDT) technique, uses the Tucker decomposition technique to get the core tensor with better characteristics, inputs the core tensor to the classical time series forecasting model ARIMA species for prediction, and gets the new tensor and then ob-

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		6h		12h		18h		24h	
		RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE
Pmin	ARIMA	10.45	7.56	14.26	10.53	17.55	13.13	**20.43**	15.41
	BHT-ARIMA	**4.98**	**3.07**	**10.41**	**6.83**	**15.87**	**10.53**	22.61	**15.06**
Vmax	ARIMA	7.68	5.75	10.28	7.87	12.52	9.68	**14.49**	**11.27**
	BHT-ARIMA	**4.40**	**2.71**	**8.30**	**5.59**	**12.64**	**8.70**	18.25	12.68
Pmin (RI)	ARIMA	19.77	16.93	31.51	28.17	42.64	39.60	51.11	48.54
	BHT-ARIMA	**7.30**	**2.54**	**14.47**	**9.77**	**23.55**	**8.95**	**27.78**	**13.70**
Vmax (RI)	ARIMA	12.86	11.35	19.91	18.27	26.71	25.37	32.31	31.25
	BHT-ARIMA	**4.86**	**2.91**	**9.85**	**5.07**	**19.78**	**8.30**	**21.75**	**11.25**

Table 1: The results of comparing the BHT-ARIMA and ARIMA models.

	12h		24h	
	Pmin	Vmax	Pmin	Vmax
SHIPS	8	3.9	11.5	5.1
JMA/GSM	24	12.1	24.5	12.34
BHT-ARIMA	10.4	8.3	22.6	18.25

Table 2: Compare RMSE with JMA/GSM and SHIPS (Yamaguchi et al. 2018).

tains the final predicted value by Tucker inversion and MDT inversion respectively. Details of the code and data are available: https://github.com/MengMaxFan/BHT-ARIMA4TC.

Experiments

The last 9 time steps, i.e., 54 hours of historical data, were used in the experiment to predict the next time step, and the results of each step were added to the original series, rolling the forecast to obtain a 24-hour forecast. We use the root mean square error (RMSE) and the mean absolute error (MAE) to evaluate our forecasting results.

Table 1 demonstrates the results of comparing the BHT-ARIMA and ARIMA models. RI is the difficult point of forecasting, so the forecasting ability of RI is also examined, and the results show that the forecasting results of BHT-ARIMA are better than those of AIRMA, which proves the effectiveness of modeling TC using high-dimensional tensor. However, it is worth noting that the forecasting effect of BHT-ARIMA model at 24 hours suddenly declines seriously, which is considered to be due to the excessive accumulated errors.

Figure 2 shows the 6-18 hour forecast results for a TC with RI, Tropical Cyclone Carmen. It can be clearly seen that our model predictions at 6 hours fit the actual data very well, and RI can also be predicted at 12 and 18 hours.

Table 2 illustrates the comparison of our results with the global numerical forecast model GSM operated by JMA and the excellent statistical dynamical model SHIPS, which was derived by Yamaguchi et al. using 13 years of data(Yamaguchi et al. 2018). The results indicate that our 12-hour forecasts are better than GSM, and Pmin is similar to SHIPS, but the 24-hour forecasts are very different from SHIPS.

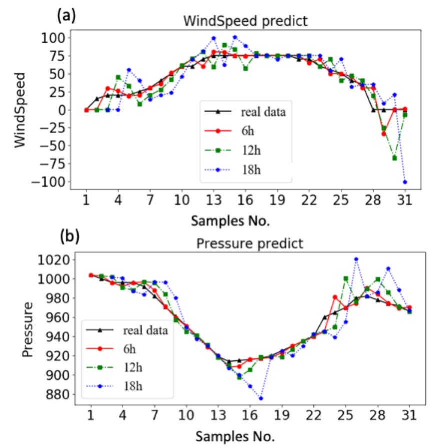

Figure 2: Forecasting results for Carmen, (a) Vmax, (b) Pmin.

Conclusions

In this study, we propose to employ BHT-ARIMA to forecast TC intensity in the northwest Pacific Ocean in response to the small sample and short series problem, and also test the Pmin and Vmax at 6, 12, 18, and 24 h ahead, and the 6-h forecast fits well with the actual value, and achieves a forecast result close to the state-of-the-art statistic model SHIPS within 12 h. It is worth noting, however, that we have demonstrated the potential of the method for TC intensity forecasting using only a very small amount of data and a very small amount of computation. Future work can combine the method of tensor construction and decomposition used in this paper with sequence prediction models such as neural neural networks, and will extend our work to the Atlantic and Indian Ocean.

References

Shi, Q.; Yin, J.; Cai, J.; Cichocki, A.; Yokota, T.; Chen, L.; Yuan, M.; and Zeng, J. 2020. Block Hankel tensor ARIMA for multiple short time series forecasting. In *Proceedings of the AAAI Conference on Artificial Intelligence*, volume 34, 5758–5766.

Yamaguchi, M.; Owada, H.; Shimada, U.; Sawada, M.; Iriguchi, T.; Musgrave, K. D.; and DeMaria, M. 2018. Tropical cyclone intensity prediction in the western North Pacific basin using SHIPS and JMA/GSM. *SOLA*, 14: 138–143.