Improving Performance of Typhoon Track Prediction over the Western North Pacific Using Machine Learning

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1. Introduction

- A tropical cyclone (TC) can cause a considerable amount of social and economic damage with torrential rainfall, flash flood, and strong wind. It have been simulated and predicted with numerical and statistical models.
- With the current emergence of machine learning technology as a new application field of supercomputing, many researchers have tried to predict TC track as well as weather and other natural disasters.
- In this study, we simulated TC cases for ten years (from 2006 to 2015) with Weather Research and Forecasting (WRF) model and trained artificial neural network (ANN) by TC information with predicted TC track by WRF.
- Output selection method, which has range based on the mean absolute error of WRF, was applied to exclude outlier of ANN results.
- Criteria about length, speed and direction of TC track were used to evaluate the results of WRF and ANN.

2. Dataset & Predictor

◆Dataset

TC Track

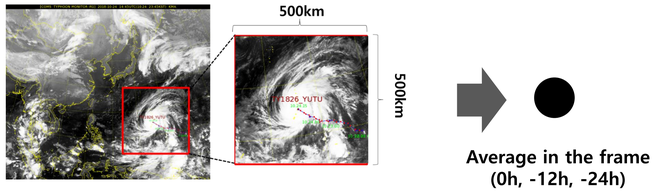
RSMC (Regional Specialized Meteorological Center)	
File Format	ASCII
Variables	Date, Latitude, Longitude, Sea Level Pressure
Period	2006-2015 year
Time interval	6 hourly

Atmospheric Dynamics

ERA-Interim Reanalysis	
File Format	Grib2
Resolution	0.7°x0.7°
Variables	U wind, V wind
Period	2006-2015 year
Time interval	6 hourly

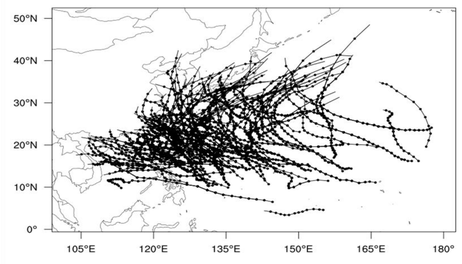
- Date was calculated as the absolute value of the initial yearday called as Julian day.
- U and V component of wind were averaged from a square frame around the typhoon center of which length is 500km

<Square frame 500km x 500km around typhoon center>



WRF 3 Days Simulation

<Domain of Typhoon Cases>



Model Prototype	WRF 3.7.1
Horizontal grids (Grid spacing)	421 x 371 (12km)
Time step	36s
Initial/Boundary condition	NCEP FNL
Microphysics	WSM 6 (Hong & Lim, 2006)
Long wave radiation	RRTM (Mlawer et al., 1997)
Short wave radiation	Dudhia (Dudhia, 1989)
Cumulus parameterization	Kain-Fritsch (Kain, 2004)
Boundary Layer	YSU (Hong et al., 2006)
Land surface	Thermal diffusion (Dudhia, 1996)

Area : western North Pacific Ocean
Period : 2006 – 2015 year from June to November

◆Predictor

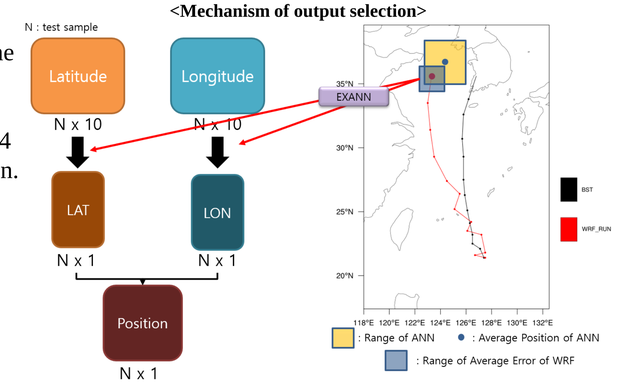
Name	Description
DAY (d)	Absolute Julian day of initial tropical cyclone
LAT0 (°)	Latitude of initial tropical cyclone
LON0 (°)	Longitude of initial tropical cyclone
SLP (hPa)	Sea level pressure of initial tropical cyclone
U0 (m s^{-1})	Averaged U component of wind of initial tropical cyclone
V0 (m s^{-1})	Averaged V component of wind of initial tropical cyclone
U-12 (m s^{-1})	Averaged U component of wind of tropical cyclone before 12-h
V-12 (m s^{-1})	Averaged V component of wind of tropical cyclone before 12-h
U-24 (m s^{-1})	Averaged U component of wind of tropical cyclone before 24-h
V-24 (m s^{-1})	Averaged V component of wind of tropical cyclone before 24-h
Lat+6 (°)	Latitude of predicted tropical cyclone after 6-h
Lon+6 (°)	Longitude of predicted tropical cyclone after 6-h
. . .	6 hourly Coordinates (Latitude and Longitude) of predicted TC center from after 6 hours to after **α (24, 48, 72)** hours
Lat+**α** (°)	Latitude of predicted tropical cyclone after **α**-h
Lon+**α** (°)	Longitude of predicted tropical cyclone after **α**-h

3. Artificial Neural Network (ANN) optimization and Output Selection

◆Artificial Neural Network (ANN)

- For ANN optimization, the number of hidden layers was fixed as two, and the number of neurons in each hidden layer from 10 to 30 at two intervals was tested.
- TCs of 2015 year were used for test datasets, and rest data from 2006 to 2014 year was divided into two parts as 80% for calibration and 20% for validation.
- ANN was trained 10 times and representative results were extracted by averaging 10 predicted values.
- Output selection was applied for excluding unreasonable output from ten ANN results. Its range was set using MAE of predicted coordinates of WRF about all TCs in 2006-2015 year. (EXANN)
- Results of ANN, EXANN and WRF were compared based on track position error (TPE), along track error (ATE), and cross track error (CTE).

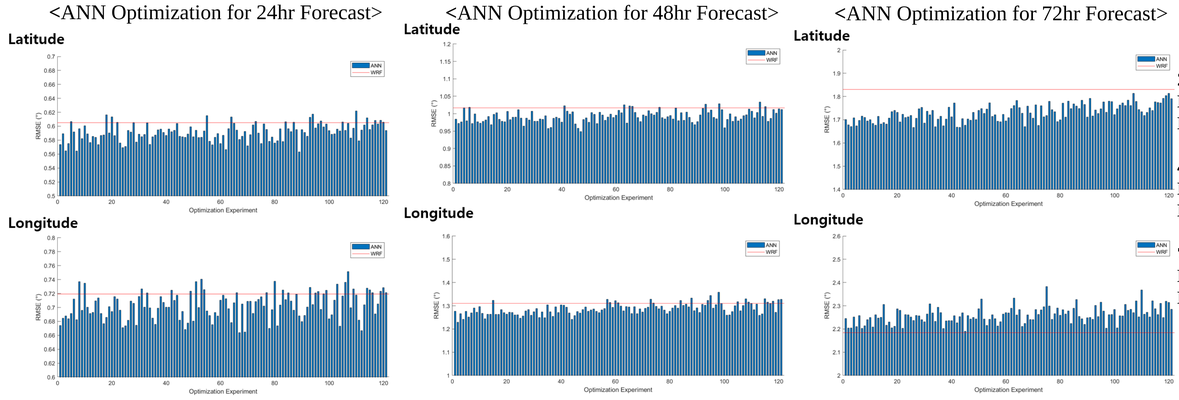
<Mechanism of output selection>



4. Result & Discussion

◆ANN Optimization

<ANN Optimization for 24hr Forecast> <ANN Optimization for 48hr Forecast> <ANN Optimization for 72hr Forecast>

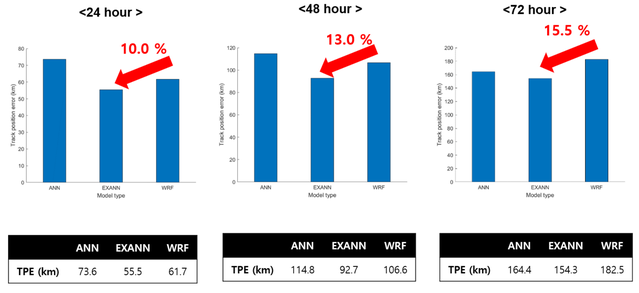


24-hour forecast
Latitude 26-neuron / 10-neuron
Longitude 22-neuron / 10-neuron

48-hour forecast
Latitude 18-neuron / 14-neuron
Longitude 10-neuron / 12-neuron

72-hour forecast
Latitude 14-neuron / 16-neuron
Longitude 18-neuron / 10-neuron

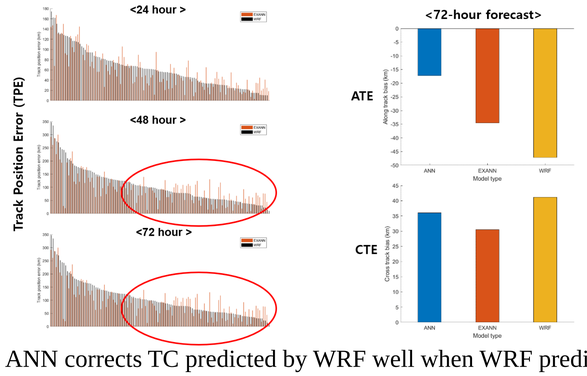
◆Blind Test (TCs in 2015 years)



	ANN	EXANN	WRF
TPE (km)	73.6	55.5	61.7

	ANN	EXANN	WRF
TPE (km)	114.8	92.7	106.6

	ANN	EXANN	WRF
TPE (km)	164.4	154.3	182.5



- Although ANN predicted TC position with lower performance than WRF for 24 –hour and 48-hour forecast, it predicted TC position well for 72-hour forecast.
- Output selection which excluded outputs out range of mean WRF error improves the performance of ANN.
- ANN corrects TC predicted by WRF well when WRF predicted TC position worse. Error of ANN is increasing with decreasing error of WRF.
- ANN has an impact on WRF by correcting the speed and direction of WRF.

5. Summary and Conclusion

- Ann was used to predict tropical cyclone position after 24, 48, and 72 hours using TC track, atmospheric dynamics and numerical model output about 106 TCs from June to November in the 2006-2015 year over the western North Pacific Ocean.
- ANN with output selection could improve the performance of WRF prediction from 10% to 15.5% and change to a tendency to move close in the direction of observation.
- It is better to simulate more TC cases to progress generalization of ANN and to test about other variables and ANN techniques.

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