Future Characteristics of Tropical Cyclones under the SSP scenarios over CORDEX-East Asia domain using Multi-RCMs

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ICRC-CORDEX 2023
Session A1: Earth System Modelling in the regional context

1. Introduction

1. Since the industrialization, the global mean temperature has increased by 1 °C as the increased concentration of greenhouse gases.
2. The increasing global temperature has the potential to cause significant changes in the frequency, intensity, and spatial distribution of extreme climate events.
3. As a result, numerous unparalleled extreme events have been observed across the world in the past few years, including tropical cyclones (TCs).
4. Coastal countries in the western North Pacific basin are susceptible to the impacts of TCs, as this area is the most probable location for TCs to make landfall.
5. Therefore, **it is crucial to estimate future changes in the activities of TCs.**
6. The CORDEX is an international initiative that facilitates the comparison and assessment of regional climate models (RCMs) and generates a novel set of climate change projections across the globe.

2. Data and Methods

- **Configuration of the RCMs**

	RegCM	GRIMs	WRF	CCLM	HadGEM3-RA
Horizontal Resolution	25-km Horizontal Resolution				
Vertical Layers	23 sigma	28 sigma	30 eta	40 hybrid	63 eta
Microphysics	SUBEX	WSM1	WSM3	Seifert and Beheng	single moment bulk
Cumulus Parameterization	Emanuel	SAS	BMJ	Tiedtke	Revised mass flux
Radiation	CCM3	Chou et al.	CAM	Ritter and Geleyn	General2
Planetary Boundary Layer	Holtslag	YSU	YSU	Davies and Turner	MOSES-II non-local
Land Surface	CLM4.5	Noah	Noah	TERRA ML	JULES
Spectral Nudging	Yes				No
Initial & Boundary data	UKESM				
Simulation Period	Historical : 1979-2014 Future (SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5) : 2015-2100				

- **Thresholds for tracking TCs**

	RegCM	GRIMs	WRF	CCLM	HadGEM3-RA
Wind speed ($m\ s^{-1}$)	14	17	14	15	14
Vorticity ($10^{-5}\ s^{-1}$)	5.0	7.0	5.0	7.0	5.0
Temperature (K)	1.0	2.0	1.0	2.0	1.0

- **Data**

Best track	Regional Specialized Meteorological Center (RSMC)
Reanalysis	ERA5

- **Analysis period**

Historical	1985-2014
Near (Far) Future SSP1-2.6, SSP5-8.5	2031-2060 (2071-2100)
Month	June-November

- **Analysis method**
  - Performance-based Ensemble Averaging (PEA)

$$Pw_i = \frac{1.0}{(RMSE_i + 1.0)} Corr_i$$

$$NPw_i = \frac{Pw_i}{\sum_{i=1}^{N_M} Pw_i}$$

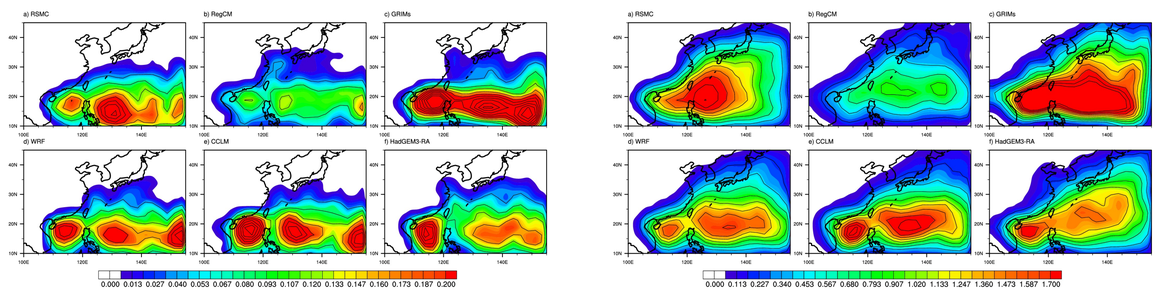
$$\bar{M} = \sum_{i=1}^{N_M} NPw_i M_i$$

Suh et al. (2012)

3. Results

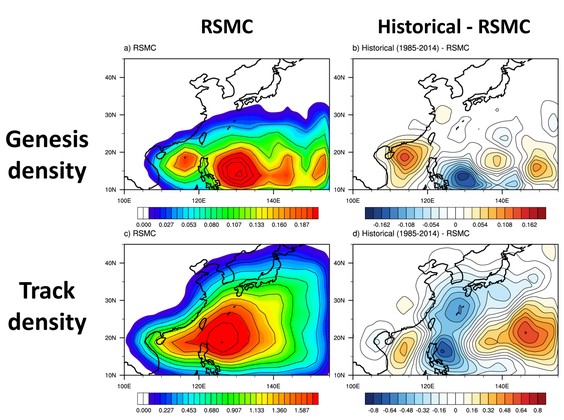
01 Regional Climate Models

RSMC RegCM GRIMs WRF CCLM HG3RA



- In RSMC best track data, TCs genesis had been more prevalent over the Philippine Sea
- Five RCMs had different characteristics of TCs simulation, with RegCM underestimating and GRIMs overestimating the genesis densities.
- Therefore, the ensemble methods are need to reduce the uncertainty of a single RCMs.

02 Historical Ensemble

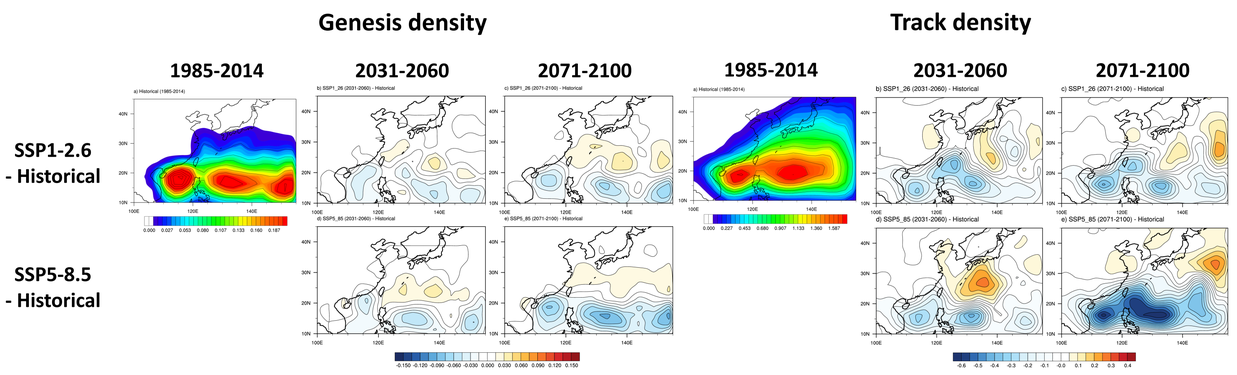


NTC : Number of Tropical Cyclone

	RSMC	Historical	Difference (Hist - RSMC)
NTC (yr^{-1})	17.2	17.8	0.6
Maximum Wind speed ($m\ s^{-1}$)	37.7	24.5	-13.2
Minimum Sea-level pressure (hPa)	956.8	987.0	30.2
Duration (day)	5.34	5.09	-0.25

- The historical ensemble simulated more (less) TCs over the South China (Philippine) Sea than the RSMC.
- NTC and duration were similar to RSMC, but the intensity was weaker than RSMC.

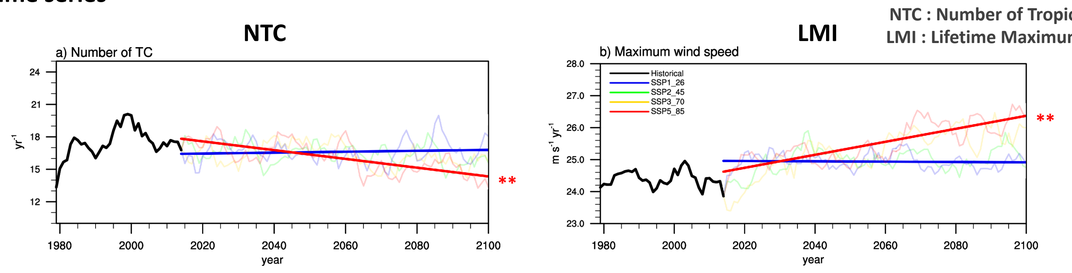
03 SSP scenarios Ensemble



- The genesis of TCs increased (decreased) above (below) 20 °N in the SSP1-2.6 and SSP5-8.5.
- The activity of TCs decreased below 30 °N, especially in the far-future of SSP5-8.5.

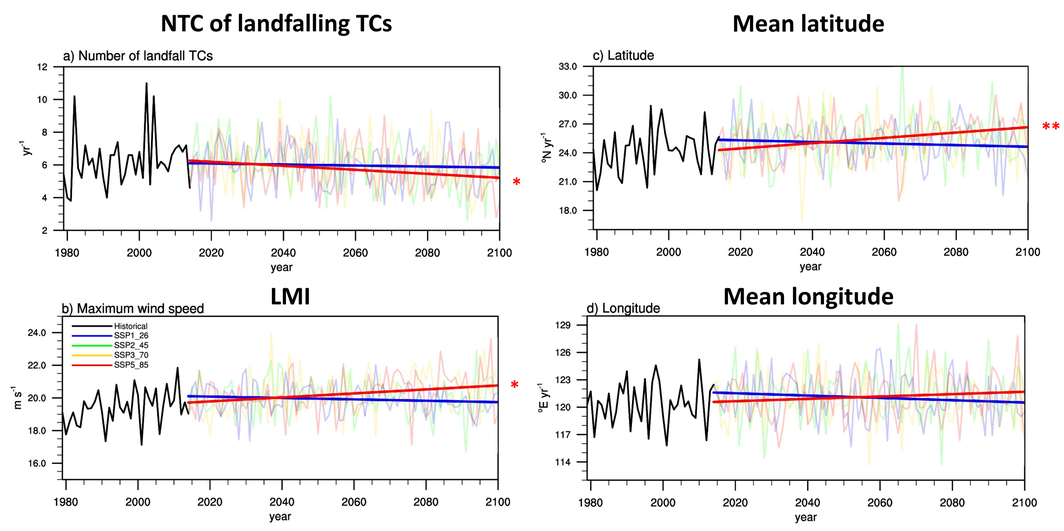
- **Time series**

NTC : Number of Tropical Cyclone
LMI : Lifetime Maximum Intensity



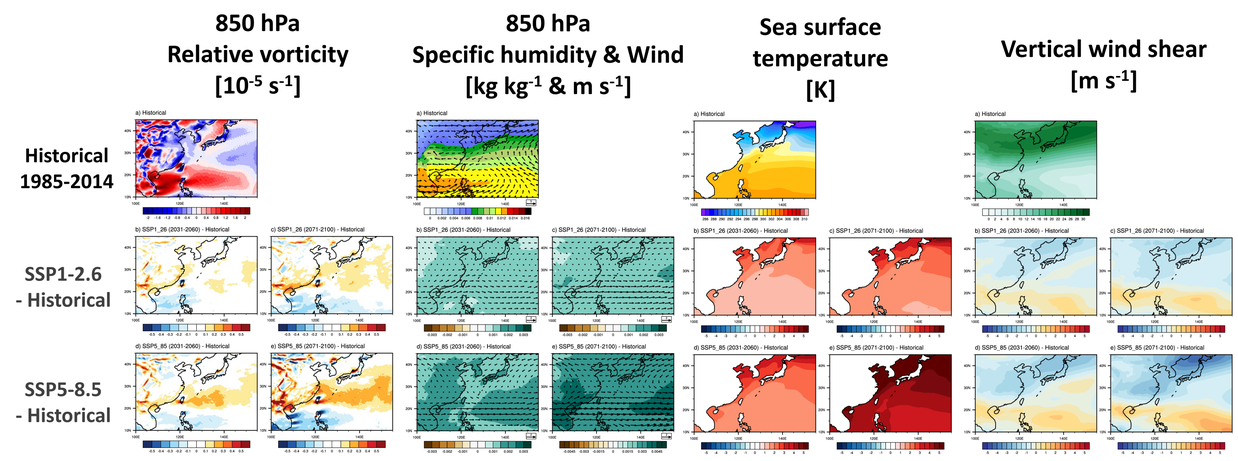
	Historical 1985-2014	Change (SSP1-2.6 - Hist) 2031-2060	Change (SSP1-2.6 - Hist) 2071-2100	Change (SSP5-8.5 - Hist) 2031-2060	Change (SSP5-8.5 - Hist) 2071-2100
NTC (yr^{-1})	17.8	-1.3	-0.9	-0.9	-3.0
Maximum Wind speed ($m\ s^{-1}$)	24.5	0.4	0.3	0.6	1.6
Minimum Sea-level pressure (hPa)	987.0	-0.3	0.1	-0.2	-1.7
Duration (day)	5.09	-0.09	-0.09	0.05	-0.06

- SSP1-2.6 did not show much variation in the NTC and maximum wind speed.
- But SSP5-8.5 showed significantly a decrease in the NTC and an increase in maximum wind speed.



- The wind speed of landfalling TCs increased as moved to the future in SSP5-8.5 than in SSP1-2.6.
- The location of landfalling migrated to the northeast.

- **Environmental fields**



- **Relative vorticity** : positive differences from 20 °N to 40 °N
- **Specific humidity & wind** : wet differences across the domain & westerly over the low latitudes
- **Sea surface temperature** : positive differences increasing from low to mid latitudes
- **Vertical wind shear** : weakening above 20 °N & strengthening below 20 °N

Favorable conditions for TC activity!

4. Summary

1. This study analyzed the characteristics of TC simulations in the CORDEX East Asia region using an ensemble of RCMs forced by UKESM based on the SSP scenarios.
2. The historical ensemble simulated generation of TCs with more (less) TCs over the South China (Philippine) Sea, compared to RSMC data.
3. In SSP scenarios, TC activities decreased below 30 °N, **especially in the far future of the SSP5-8.5 scenario.**
4. According to this change, the mean landfall point moved to the northeast.
5. **Increasing positive vorticity and SST & Weakening vertical wind shear** are the main reason for the change in TC activity.

This work was funded by the Korea Meteorological Administration Research and Development Program under Grant KMI (RS-2023-00241809).
The model simulations were performed by using the supercomputing resource of the Korea Meteorological Administration (National Center for Meteorological Supercomputer).