Future Change of North Atlantic Tropical Cyclone Tracks: Projection by a 20-km-mesh Global Climate Model (*J. Climate, In Press*)

Hiroyuki Murakami, Bin Wang, and Akio Kitoh

Advanced Earth Science & Technology Organization/ Meteorological Research Institute (MRI), Ibaraki, Japan

himuraka@mri-jma.go.jp

1. Introduction

Future changes in tropical-cyclone (TC) tracks, affected by global warming, have not been well investigated. These changes as well as intensity changes are important for socioeconomic damage in the future. However, most studies used coarse resolution models (e.g. 60-120 km mesh) for multi-year climate simulations. The low resolution deteriorates not only TC structures and intensity, but also real distributions of TC tracks and genesis positions.

In this study, we conducted multi-year climate simulations with a 20km-mesh Meteorological Research Institute and Japan Meteorological Agency AGCM (MRI/JMA AGCM) in order to investigate future change in TC tracks over the North Atlantic. The projection periods are from 1979 to 2003 for a present day simulation (PD) and from 2075 to 2099 for a global warmed future simulation (GW), which is based on the IPCC A1B scenario.

2. Model and experimental design

・JMA/MRI 20km-mesh AGCM

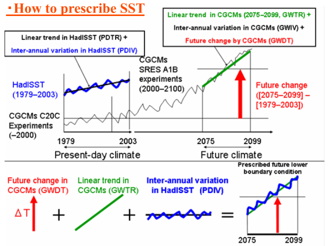
	20 km mesh global climate model
Horizontal Grids	1920x 960
Vertical Layers	60
Truncation Wave	TL959
Grid Spacing	20km
Top Layer Pressure	0.4hPa
Dynamical frame	Semi-Lagrangian scheme
Radiation Process	Shibata et al. (1999) Solar (every hour) Infrared (3 hourly)
Precipitation Process	Prognostic Arakawa-schubert Large-scale condentation Prognostic cloud water
Gravity wave drug	Iwasaki et al (1989)
Land surface	Simple Biosphere(SiB) model
PBL and surface fluxes	Mellor-Yamada level 2 Moni-Obukhov similarity

・Integration Period

Present-day (PD) : 1979-2003 (25 years)

Global-warming (GW): 2075-2099 (25 years)

・How to prescribe SST



PD : Observed sea surface temperature (SST)

GW: Based on an ensemble mean of 18 IPCC-AR4 models projected under the IPCC Special Report on Emission Scenarios (SRES) A1B

3. Detection method of tropical cyclones and GPI

・Tropical Cyclone Detection Method

1. Across the latitudinal belt of 45°S–45°N, the grid point of the candidate TC-center is defined as that where the minimum surface pressure is at least 2 hPa lower than the averaged surface pressure over the surrounding 7 °× 7 ° grid box.
2. The magnitude of the maximum relative vorticity at 850 hPa exceeds 3.0×10^{-5} s^{-1} (original value: 3.5×10^{-5} s^{-1}).
3. The maximum wind speed at 850 hPa exceeds 14.0 ms^{-1} (original value: 15.0 ms^{-1}).
4. The temperature structures aloft show a marked warm core: the sum of the temperature deviations at 300, 500, and 700 hPa exceeds 1.2 K (original value: 2 K).
5. The maximum wind speed at 850 hPa (WS850) exceeds that at 300 hPa (WS300) at the first detection (i.e., generation time) of a TC. After generation, WS850 increased by 2.5 ms^{-1} should be greater than WS300 (this latter condition was not required in the original detection).
6. The duration of a TC exceeds 36 hours.

・Genesis Potential Index

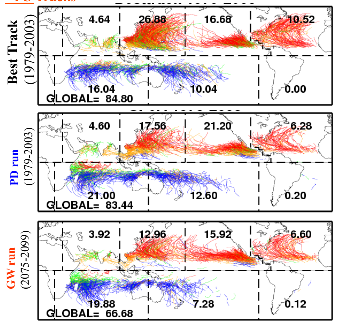
To determine the factors behind such genesis changes, we used a Genesis Potential Index (GPI) by Emanuel and Nolan (2004) with some modifications.

$$GPI' = \left|10^5 \eta\right|^{\frac{3}{2}} \left(\frac{RH}{50}\right)^3 \left(\frac{V_{pt}}{70}\right)^3 \left(1 + 0.1V_s\right)^{-2} \left(\frac{-\omega + 0.1}{0.1}\right),$$

Absolute Vorticity at 850hPa; Relative Humidity at 700hPa; Maximum Potential Intensity; Vertical Wind Shear (850-200hPa); Vertical Wind Velocity at 500hPa

4. Overall result of projected TC number and tracks for each basin

・TC Tracks



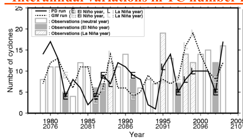
Blue: JFM, Green: AMJ, Red: JAS, Orange: OND

・Future changes in TC genesis number

Region	Obser-vation	PD	GW	GW-PD
Global	84.80	83.44	66.68	−16.76
N.Hemisphere	58.72	49.64	39.36	−10.28
S.Hemisphere	26.08	33.76	27.24	−6.52
North Indian	4.68	4.60	3.92	−0.68
western North Pacific	26.84	17.56	12.96	−4.60
eastern North Pacific	16.68	21.20	15.88	−5.32
North Atlantic	10.52	6.28	6.60	0.32
South Indian	16.04	21.00	19.84	−1.16

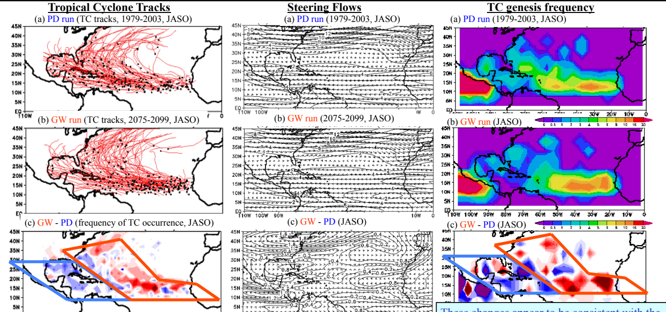
Reductions in TC genesis are seen for the most basins except for the North Atlantic.

・Interannual variations in TC number in the NA



Correlation Coefficient of interannual TC number between observations and PD run is 0.49.

5. Future changes in TC tracks, steering flows and TC genesis in the North Atlantic

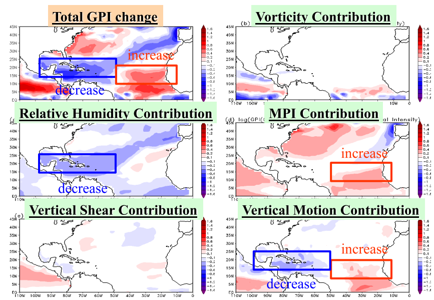


TC tracks show a significant eastward shift in future, resulting in a reduced probability of TC landfall over North America.

Change in large-scale flow does not explain TC track changes.

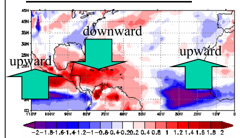
These changes appear to be consistent with the predicted change in frequency of TC occurrence, thereby indicating that the change is caused mainly by the change in frequency of genesis.

6. Reasons for future change in genesis location

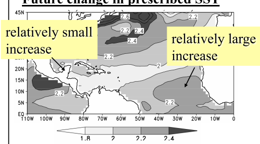


The MPI and omega terms make the dominant contribution to the increase in the GPI within the eastern North Atlantic, whereas the relative humidity and omega terms make the largest contribution to the decrease in the GPI within the western North Atlantic.

Future change in vertical motion at the 500 hPa vertical level



Future change in prescribed SST



SUMMARY

We conducted a pair of 25-year climate simulations for the present day (1979–2003, PD) and the last quarter of the 21st century (2075–2099, GW), based on the A1B scenario using a MRI/JMA 20-km-mesh high-resolution atmospheric general circulation model. The analysis focused on tropical cyclone (TC) activity, especially TC tracks, over the North Atlantic (NA).

Concerning future change, the change in frequency of TC occurrence was spatially inhomogeneous, with a marked decrease in the western NA and an increase in the eastern NA.

A comparison of large-scale flows between the PD and GW runs reveals no significant change. In contrast, we found a marked change in the locations of TC genesis between the PD and GW runs; therefore, change of genesis locations is the major reason for the predicted change in frequency of occurrence and TC tracks.

The signal of TC location shifts is well captured by Emanuel and Nolan's Genesis Potential Index (GPI) change. The main factors contributing to the predicted future increase in TC genesis in the eastern NA were changes in maximum potential intensity and vertical motion, which are related to the enhanced convective activity in the eastern Atlantic ITCZ. The decrease in TC genesis in the western NA was related mainly to reduced relative humidity and increased subsidence. Although, the prescribed sea surface temperature (SST) showed increase in the western NA, convective activities were decreased by the unfavorable environmental factors. It is inferred that the increase in convective activity in the eastern NA or in the eastern Pacific was sufficiently large to result in enhanced Hadley circulation in the NA. In turn, this led to a subsidence anomaly over the western NA, which suppressed convective activity and resulted in a decrease in TC genesis over this region.