Projection of Extreme Wave Climate and Modeling

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12th Wave Workshop, October 30 - November 4, 2011



Mori, N et al. (2011) Survey of 2011 Tohoku earthquake tsunami inundation and run-up, Geophysical Research Letters, 38, L00G14.

Mori, N., T. Takahashi and The 2011 Tohoku Earthquake Tsunami Joint Survey Group (2012) Nationwide Survey of the 2011 Tohoku Earthquake Tsunami, Coastal Engineering Journal

Background



SLR

Wave Climate (+Storm surge)

Historical study

- ✓Observation
- ✓Hindcasts

Future projection

- ✓ Statistical projection
 - Regional
 - Global

✓ Dynamical P in Global

Menendez, Mendez (2008) Wang and Swail (2000) Swail and Cox (2007) Weisse and Gunther (2007)

Static change

Dynamic change

Mennendez, Mendez et al (2011) Wang and Swail (2006) Mori et al.(2010) Hemer (2011) Guenther (2011)

is going to be summaried by COWCLIP

Methodology Wave Climate Projection



- 1. Direct wave simulation for wave climate projection
 - Model GCM -> Spectral Wave Model
 - 1 model (MRI-AGCM-3.1S), 1 scenario (A1B)
 - Target Projection of averaged and extreme wave climates at the end of 21st century
- 2. Discussion about understanding future wave climate change
 - Analyzing climate indices and tropical storms
- 3. Modeling of future tropical cyclone activity
 CMIP3+some CMIP5 ensemble



Wave climate change

- Mean wave
 Clear dependence of latitude
 - Increased: mid-latitude westerlies and the Antarctic sea
 - ✓ Decreased: the Equator and some area of mid-latitude
- Extreme wave Different from mean wave climate change
 - Slighted increased in winter at middle-higher latitude
 - Polar storm relates winter storm activity
 - Increased significantly in summer at middle latitude
 - Tropical cyclone dependence at middle latitude



Summary of Future Projection



- Polar wind system
- Future tropical cyclone

-30

TC Intensity

Increased about 15 hPa higher than 20 degree in latitude

TC Tracks

Shift 2-3 degree in longitude to center of ocean basin

 Future tropical cyclone and related extreme waves will be related with future NINO SST change.

Future TC change is very sensitive to model itself, resolution, initial perturbation of GCM and cloud scheme

BACKGROUND AND OUR PROJECT



Project of Coastal Climate Change in Kyoto University





Project of Coastal Climate Change in Kyoto University







DIRECT WAVE SIMULATION

Mori et al. (2010) Hydrological Research Letters and etc

20km resolution GCM+Wave Model

MRI AGCM-3.1S+SWAN



	Start	End	Length
Present	1979/01	2003/12	25yrs
Near Future	2015/01	2031/12	25yrs
Future	2075/01	2099/12	25yrs

GCM

- Scenario: A1B
- SST: CMIP3
- Grid size : 20km
- Time step : 6 min

Spectral wave model
 Delft SWAN version 40.51AB



Averaged Hs: Future-Present

Period averaged: Future - Present



Extreme Wave Height Change



50 yrs Return Period: Present Climate



Extreme Wave Height Change



50 yrs Return Period: Present Climate



Future Change of Extreme Hs Winter at NWP



	I	II	111	IV
Event #	-10.2%	-37.8%	-32.4%	-7.8%
50yrs Change	(A) −2.2% (B) −4.3%	(A) + 0.0% (B) +0.0%	(A) + 5.3% (B) +6.9%	(A) +1.4% (B) +1.1%
significance level (95% level)	(A) No (B) No	(A) No (B) No	(A) No (B) No	(A) No (B) No



Extreme value analysis is applied after Mann-Kendall test

IV

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Future Change of Extreme Hs Summer at NWP



	I	II	III	IV
Event #	+33.6%	+23.4%	+218.8%	+10.1%
50yrs Change	(A) +21.1% (B) +20.9%	(A) +23.1% (B) +23.5%	(A) +61.5% (B) +63.2%	(A) +13.9% (B) +17.7%
significance level (95% level)	<mark>(A) Yes</mark> (B) No	(A) No (B) No	(A) Yes (B) Yes	(A) Yes (B) Yes





Case Study Winer / Northwest Pacific

WHY WILL WAVE FILED BE CHANGED?



Projection of Future Change of Hs from EOF analysis





mode of EOF



Direction computation

WP-dSLP-Hs show good relation for future wave projection



CMIP5 (KAKUSHIN) MRI-AGCM3.1S MRI-AGCM3.2S CMIP3 CGCM3.1(T63)...Canada CSIRO-Mk3.0...Australia CSIRO-Mk3.5...Australia ECHAM5/MPI-OM...Germany GFDL-CM2.0...USA MIROC3.2(hires)...Japan

Summer / Northwest Pacific

WHY WILL WAVE FILED BE CHANGED?



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Future change of

Number of TC will be decreased at the most of ocean

Multi Model Ensemble Cyclogenesis Location Shift





* In this figure, future change vectors are 5 times larger than actual change.

Future TC centroids will be moved toward center of ocean basins.

Latitudinal Averaged Central Pressure Change



Stochastic Typhoon Model STM 90 60 Mod 30 0 ut 2D-PD df/di^{-30} e rate df/dt -60 60 120 180 240 300 360 0 T=6hr $df/dt = S(f_{in})$

We use relationship between previous time step value and its change rate at each location based on principal component analysis (PCA). The first order Markov process is considered

Future Change of TC's min Pressure at the end of 21st Century





Extreme wave, Storm Surge

TC Shift and El-Nino





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- Future tropical cyclone
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 - TC Tracks Shift 2-3 degree in longitude to ocean basin center
 - Future tropical cyclone and related extreme waves will be related with future NINO SST change.

THE END

References

Wave

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Storm Surge

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Acknowledgement

Collaborators

- Professor Hajime Mase (Kyoto University)
- Professor Elichi Nakakita (Kyoto University)
- Assistant Professor Tomohiro Yasuda (Kyoto University)
- Assistant Professor Sota Nakajo (Kyoto University)
- Dr. Yuichiro Oku (Osaka Env. Sci. Res. Inst.)
- Dr. Tracey Tom (Surflegend Co. Ltd.)
- Dr. Hiroyuki Murakami (JAMSTEC)
- Students Tomoya Shimura (Kyoto University) Yuta Hayashi (Kyoto University)

Supported by

- Innovative Program of Climate Change Projection for the 21st Century (KAKUSHIN Program) by the Ministry of Education, Culture, Sports, Science and Technology (MEXT)
- KAKENHI, The Japan Society for the Promotion of Science (JSPS)
- Japan Institute of Construction Engineering



Projection of Future Coastal Environment Target of Our Project





Averaged U₁₀: Future-Present

Period averaged: Future - Present



Extreme Wave Height Change 50yrs return period





Present

Future

Extreme analysis: Annual maxima and POT

Correlation of Monthly Averaged ∆SLP-Indices (NCEP/NCAR 1951~2000年)



△SLP in winter relates
 WP and correlation has
 longitudinal band
 structures in the North
 Pacific Ocean

WP





Future Typhoon Intensity Change Present - Future





Future Typhoon Numbers Change/yr Present - Future







STATISTICAL MODELING OF FUTURE EXTREME TC

Projection of Future Statistical TC Properties for STM



Multi-model ensemble

Assumptions: Only following TC properties will be changed

Static

✓Global cyclogenesis number

Centroid of cyclogenesis locations

Centroid of cyclolysis locations

Dynamic

TC developing area shift

- Pressure
- Moving speed
- Direction

Pressure change in middle latitude

CMIP5 (KAKUSHIN) MRI-AGCM3.1S MRI-AGCM3.2S CMIP3 CGCM3.1(T63)...Canada CSIRO-Mk3.0...Australia CSIRO-Mk3.5...Australia ECHAM5/MPI-OM...Germany GFDL-CM2.0...USA MIROC3.2(hires)...Japan

Stochastic Typhoon Model



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alidation Nodel



Future TC landfall # – Japan –



Passing number



