Future Climate Experiments on Intensity and Storm Surge of Typhoon Sanba (2012)

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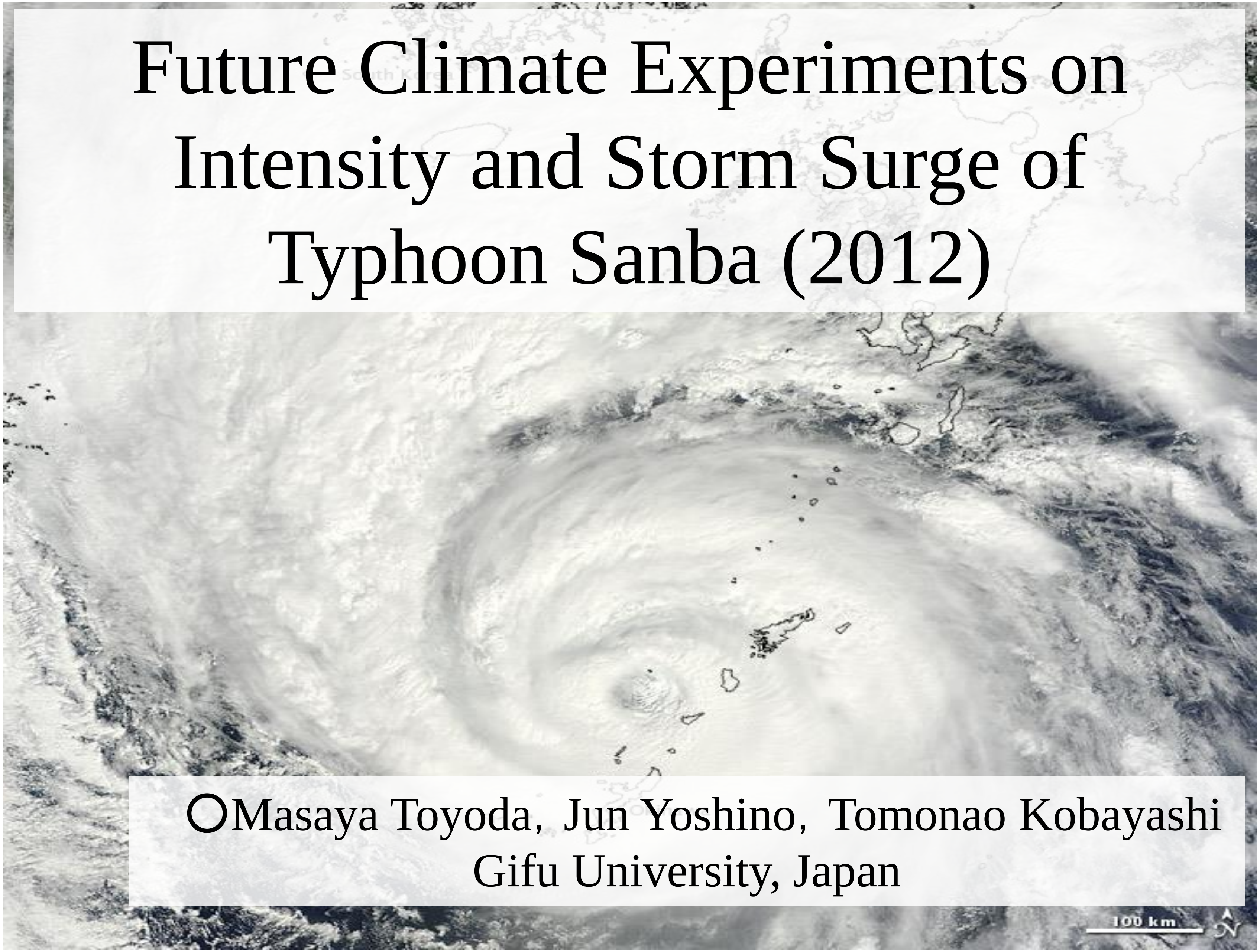


Outline

Main conclusion of our research

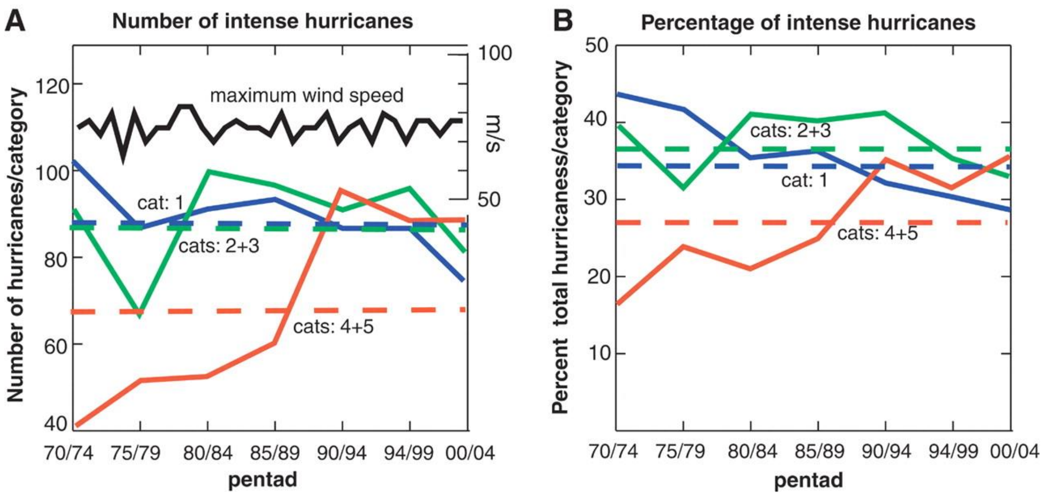
Storm surge caused by Super Typhoon under the future climate will be larger than that under the present climate. Especially, the storm surge disasters in Kyusyu Island, Japan will be severer in the end of 21^{st} century.

1. Introduction
2. Computational methods and flow
3. Results and discussion
   3-1. Future change of typhoon intensity
   3-2. Future change of storm surge
4. Conclusion

Introduction

➢ Elements that influence tropical cyclone intensity

- ☐ Temperature
- ☐ Sea surface temperature
- ☐ Ocean heat storage



Intensity of hurricanes according to the Saffir-Simpson scale (categories 1 to 5) [Webster et al., 2005]

It is concern that intensity of tropical cyclones will be stronger in end of 21st century.

Tsuboki et al (2015), Knutson et al (2015)
Walsh et al (2016), Mori et al (2016)

It is not clear how strong the typhoon

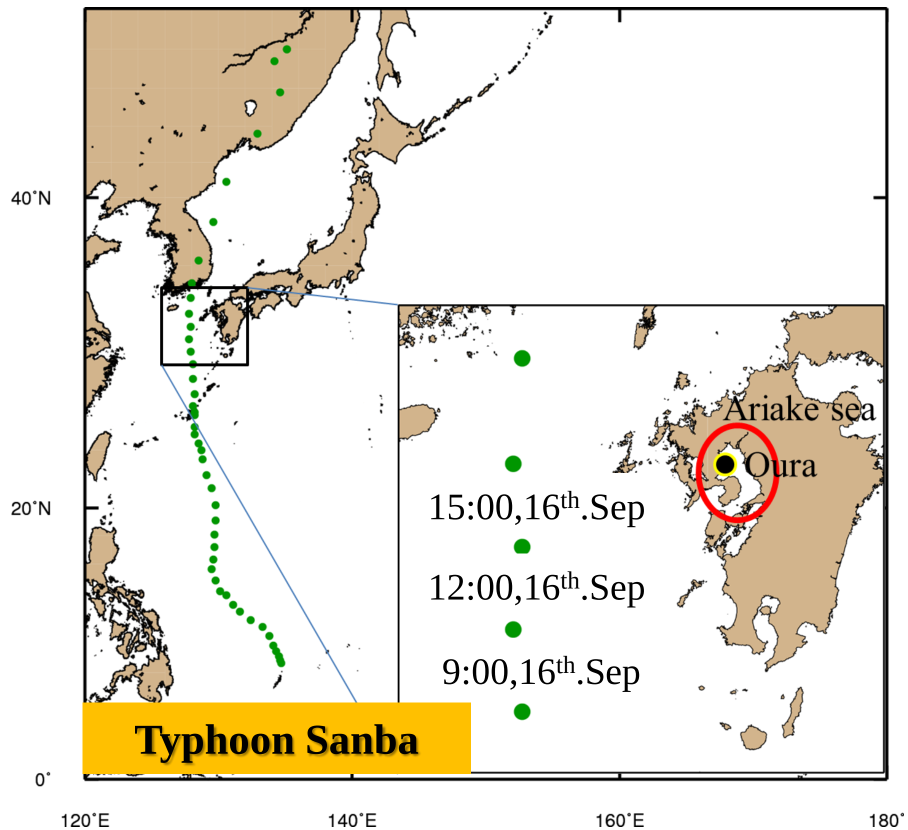
Quantitative evaluation is required

Introduction

Typhoon Sanba (11th, Sep-18th, Sep, 2012)

- Minimum central pressure : 900 hPa
- Maximum sustained wind speed : 55 m/s
- Target area : Oura, Saga Pref., Japan (Storm surge : 3.60m, 1.04m)

Sea level height | Sea level anomaly



Purpose of this research

- Quantitative evaluation of future changes in typhoon intensity and storm surge.
- Comparison of future changes due to age and season.

Using pseudo-global warming downscaling technique

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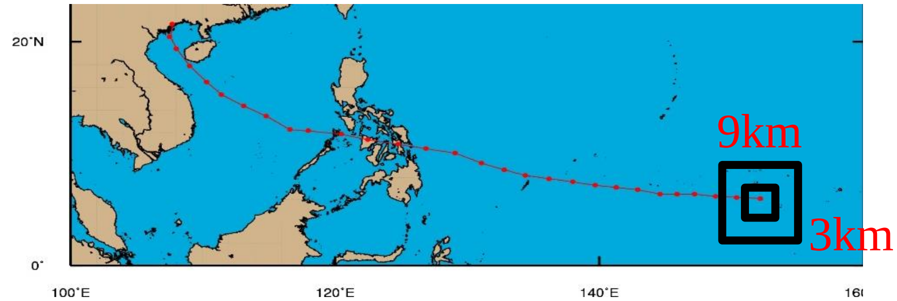
Computational method

High-resolution Typhoon Model (HTM)

✓ Based on the mesoscale meteorological model MM5 (Dudhia, 1993)

- **Automatic movable nesting technique**
  9-km mesh (D2) + 3-km mesh (D3)

- **Physical parameterizations**
  Ocean mixed layer （Shade, 1999）
  Dissipative heating （Jin et al., 2007）
  Sea-spray evaporation （Fairall et al., 1994）



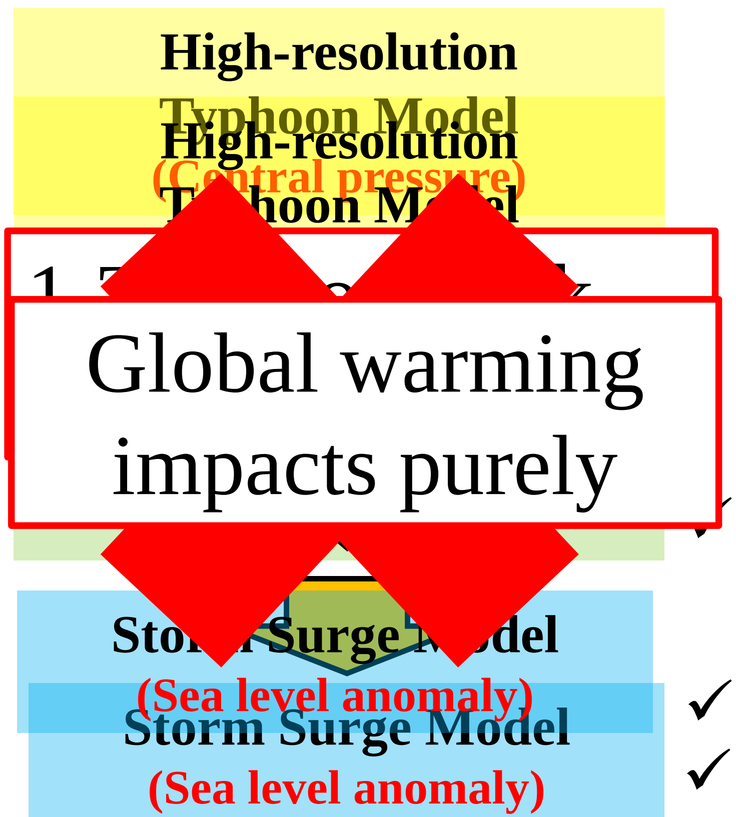
Computational setting

	Domain (D1)	Domain (D2)	Domain (D3)
TC Case	Typhoon Sanba (2012)		
Period	0:00, 11, Sep., 2012 - 0:00, 18, Sep., 2012		
Horizontal resolution	27km	9km	3km
Horizontal grids	298×349	91×91	91×91
Time step	90sec	30sec	10sec
Vertical resolution	24 layers (1000-70hPa)		
Initialization	NCEP Final Analyses (1°×1°)	D1 (27km)	D2(9km)
Movable nest	Off	On	On
Typhoon bogus	Wind speed 17.2m/s Rankin's vortex	Off	Off
Nudging (4DDA)	On	Off	Off
Cumulus convection scheme	Kain-Fritsch cumulus	Off	Off
Cloud microphysics scheme	Reisner graupel		
PBL scheme	Mellor-Yamada Level2.5 Eta PBL		
Radiation scheme	Cloud radiation		
Land surface scheme	5-layer soil		
Ocean mixed layer scheme	Shade and Emanuel(1999)		
Sea spray scheme	Fairall et al.(1994)		
Dissipative heating scheme	Jin et al.(2007)		

Computational method

- **Empirical Typhoon Model (ETM) & Storm Surge Model (SSM)**

(Kawai et al, 2015; Toyoda et al, 2016)



Computational setting

Target Typhoon	Typhoon Sanba (2012)
Calculation time	3:00,16,Sep.,2012 - 3:00,17,Sep.,2012
Horizontal resolution	1km
Time step	1sec
Vertical resolution	1layer
Seabed topography	Seabed topography: ETOPO1(1min×1min)
	Coastline: USGS Landuse (30sec×30sec)
Initial condition	zero (u=0,v=0,h=0)
Meteorological external force	Central pressures from HTM
Boundary condition	Off
Moving speed (lon.)	-0.008°/h
Moving speed (lat.)	0.296°/h

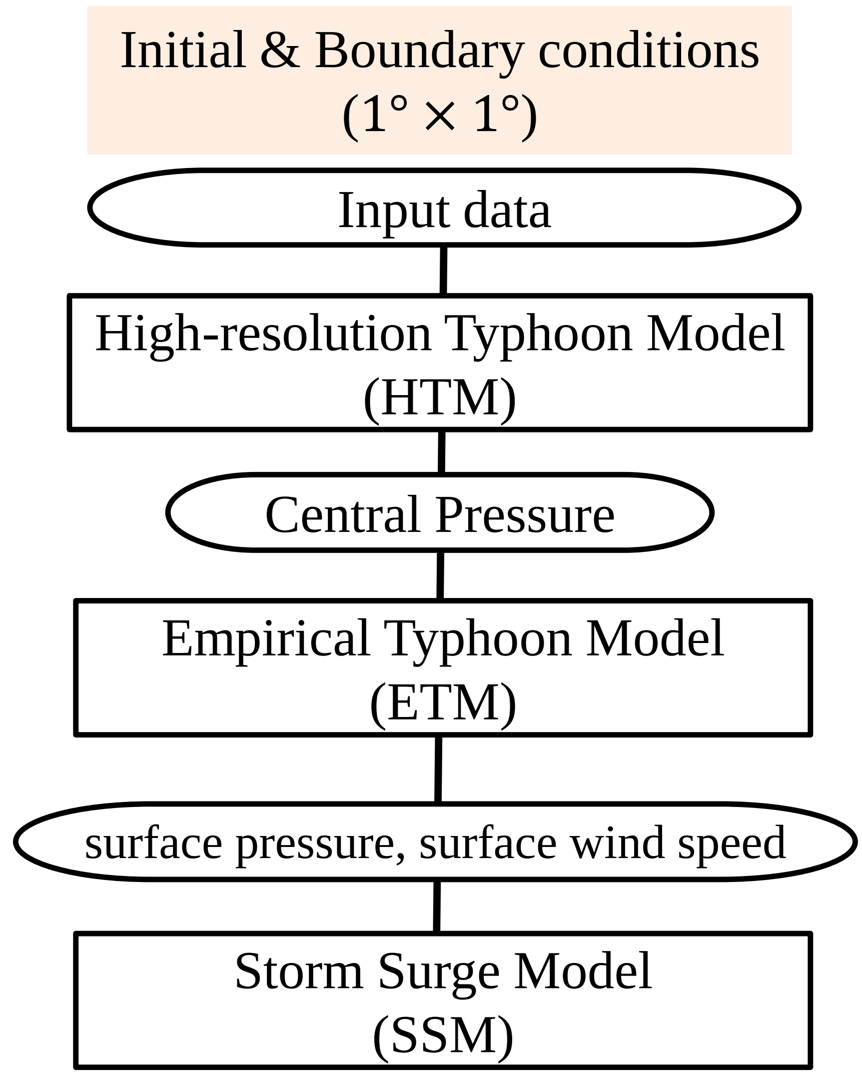
- ✓ Setting typhoon track (Japan Meteorological Agency best track)
- ✓ The nonlinear longwave equations system
- ✓ Typhoon Sanba: Oura port

Computational flow

Name	Resolution (degree)
BCCR_BCM2_0	1.9×1.9
CNRM_CM3	1.9×1.9
CSIRO_MK3_0	1.9×1.9
CSIRO_MK3_5	
GFDL_CM2_0	2.0×2.5
GFDL_CM2_1	
IAP_FGOALS1_0_G	2.8×2.8
INMCM3_0	4.0×5.0
MIROC3_2_HIRES	1.1×1.1
MIROC3_2_MEDRES	2.8×2.8
MPI_ECHAM5	1.9×1.9
MRI_CGCM2_3_2A	2.8×2.8
NCAR_CCSM3_0	1.4×1.4
UKMO_HadCM3	2.75×3.75
UKMO_HadGEM1	1.25×1.875

Downscaling and fitting the resolution to FNL (1°×1°) using by pseudo-global warming downscaling technique.

Pseudo-global warming experiments



Computational method

➢ What is Pseudo-global warming experiments?

Experiments to evaluate the impact of global warming on typhoon intensity in the future climate by pseudo-global warming downscaling.

1st STEP

Data from general circulation model (GCM)

2nd STEP

Calculation of global warming differences (GWD：ΔG)

ΔG = Future climate average − Present climate average

10-year averaged and monthly mean

[temperature, sea surface temperature, geopotential height, east-west wind speed, north-south wind speed, and relative humidity]

3rd STEP

Add GWD to FNL

FNL data + GWD ΔG = Pseudo-global warming experiments

Computational method

➢ Pseudo-global warming experiments

Ensemble averaged data of 15 GCMs under the "A1B" in CMIP3

- A2: CO_2 high emission
- **A1B: CO_2 middle emission**
- B1: CO_2 low emission

Computational setting
Age and Month
2030s (Aug.)
2030s (Sep.)
2030s (Oct.)
2090s (Aug.)
2090s (Sep.)
2090s (Oct.)
CNTRL (Sep.)

Target for calculation

I. GWD of Two ages (2030s and 2090s)

II. GWD of Three seasons (Aug., Sep. and Oct.)

✓ Difference in impact due to the degree of progress of global warming.

✓ Difference of impact by global warming difference used.

Outline

Future change of typhoon intensity

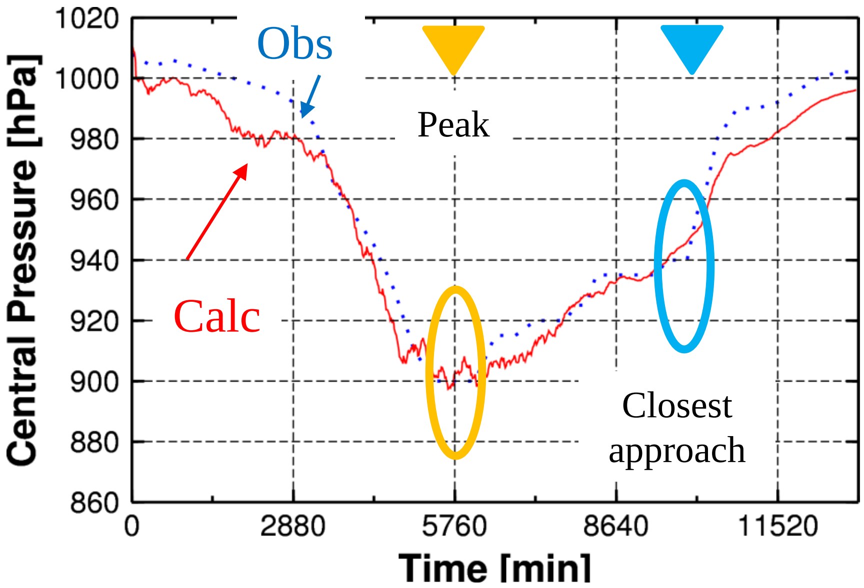
Present climate (CNTRL)

At peak time（5760min）

Obs:900 hPa Calc:902.0 hPa

At the closest approach time（9960min）

Obs:940 hPa Calc：946.9 hPa



Future change of storm surge (Oura/Sanba)

Present climate (CNTRL)

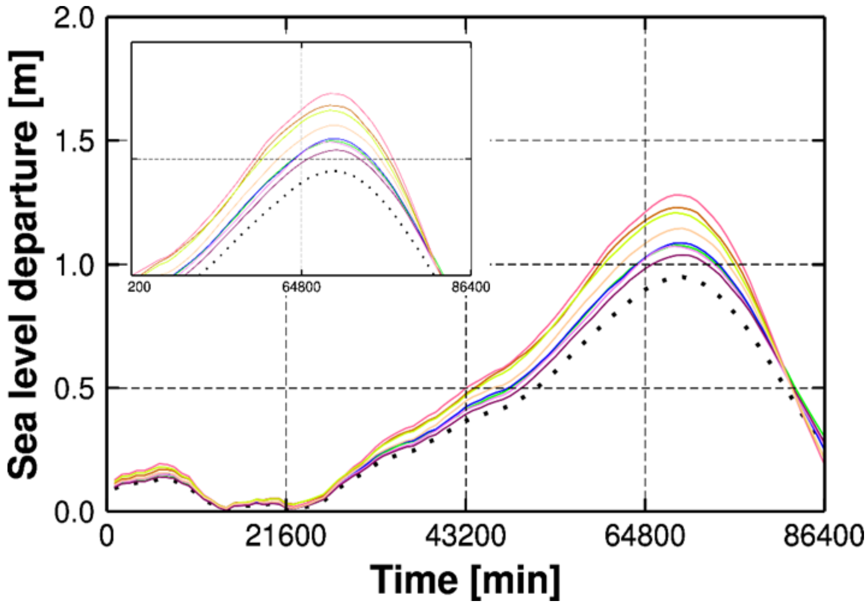
At the closest approach time（9960min）

Obs:1.04m　　Calc:0.95m

Future climate

At the closest approach time（9960min）

2030s：1.08m　2090s：1.24m
(**+0.13m**)　(**+0.29m**)



Result of storm surge in Oura port

- Storm surge tends to increase more than present climate
- The future change in the 2090s is larger than in the 2030s

The cause is the increase in typhoon intensity at closest approach time

The same trend as typhoon intensity

Summary of pseudo-global warming experiments

	present climate		near-future climate			future climate		
	Obs. (Sep.)	CNTRL (Sep.)	2030s (Aug.)	2030s (Sep.)	2030s (Oct.)	2090s (Aug.)	2090s (Sep.)	2090s (Oct.)
Central pressure at 5760 min (Future cahnge)	900hPa	902.0hPa	893.0hPa (-9.0hPa)	897.7hPa (-4.3hPa)	906.5hPa (+4.5hPa)	902.9hPa (+0.9hPa)	900.7hPa (-1.3hPa)	909.9hPa (+7.9hPa)
Central pressure at 9960 min (Future change)	940hPa	946.9hPa	941.2hPa (-5.7hPa)	940.7hPa (-6.2hPa)	942.3hPa (-4.6hPa)	937.1hPa (-9.8hPa)	934.9hPa (-12hPa)	937.4hPa (-9.5hPa)
Maximum sea level anomaly at 9960 min (Future change)	1.04m	0.95m	1.08m (+0.13m)	1.09m (+0.14m)	1.07m (+0.12m)	1.23m (+0.28m)	1.28m (+0.33m)	1.21m (+0.26m)

- The data of September has the most impact of global warming.
- This month is the busiest month in the typhoon season in Japan.
- Future storm surge at Oura increase 1.3 times larger than CNTRL .

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Conclusion

- ✓ Typhoon intensity of Sanba could be intensified under the future climate than that that of present climate.
- ✓ Month that the most impact on typhoon intensity is September, and this month is the busiest typhoon season in Japan.
- ✓ Future storm surge will also increase due to the increase in typhoon intensity.
- ✓ These results suggested that the expected storm surge disaster, especially in Japan, could be severer in the future climate than in the present climate.

Thank you
for your attention!!