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Future Increase in Super-typhoon Intensity Associated with Climate Change

Kazuhisa TSUBOKI
Hydrospheric Atmospheric Research Center (HyARC)
Nagoya University

Collaborators:
Taro Shinoda (Nagoya University)
Masaya Kato (Nagoya University)
Mayumi Yoshioka (Tohoku University)
Sachie Kanada (Nagoya University)
Akio Kito (MRI JMA/Tsukuba University)

SOUSEI

Introduction

- Tropical cyclones, including hurricanes and typhoons, are undoubtedly the most vigorous and devastating weather systems.
- A Super-typhoon, the most intense tropical cyclone category in the western North Pacific, occurs less frequently, but its landfall causes catastrophic disaster. The typhoon Haiyan is a typical example of super-typhoon.
- Great concern regarding future change in typhoon intensity in the western North Pacific is raised.
- A very high-resolution dynamical model with no convective parameterizations is necessary for quantitative prediction of the most intense category of tropical cyclone such as super-typhoons.
- In the present study, we addressed the problem to what extent super-typhoons will become intense in the global warming climate of the late twenty-first century by using a very high-resolution (2-km) cloud-resolving model.

Characteristics of the CReSS model

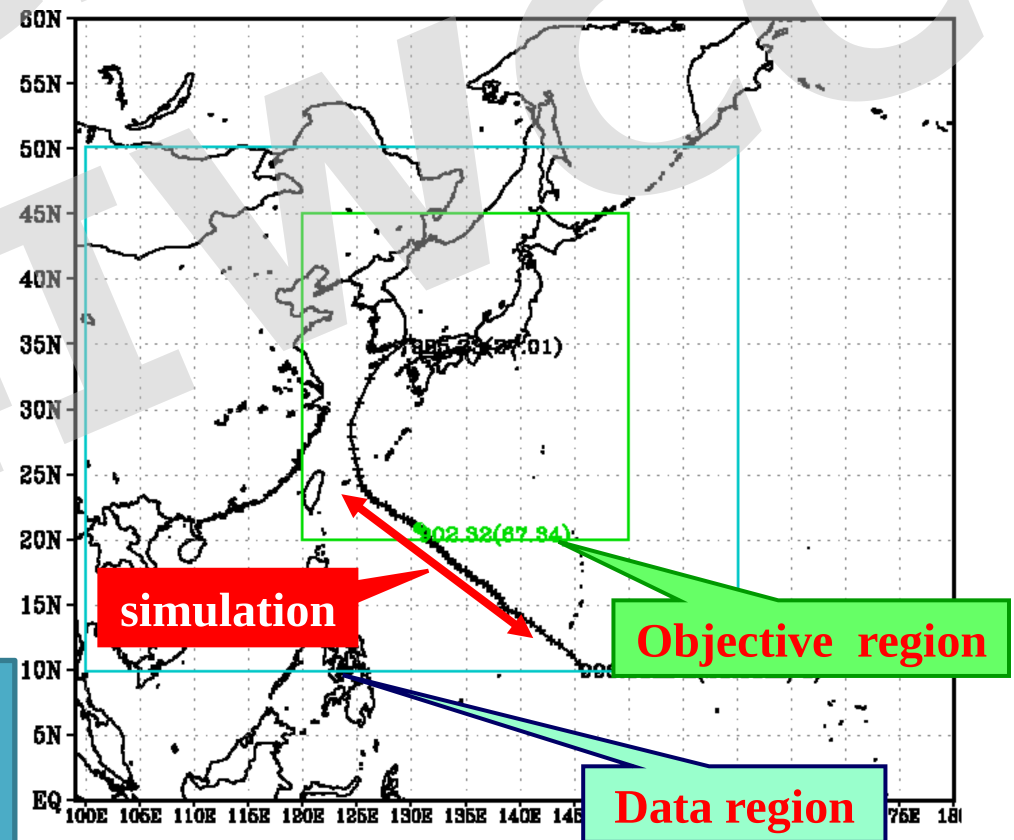
- Basic equations: **a three-dimensional, non-hydrostatic and compressible equation model.**
- Coordinate system: **a terrain-following in a two or three dimensional domain.**
- Spatial representation: **finite difference schme (Arakawa C grid in horizontal, Lorenz grid in vertical).**
- Time integration: **mode-splitting scheme (acoustic terms implicit in vertical)**
- Ground model: ***n*-layer 1-dim. thermal conductivity model.**
- Ocean model: ***n*-layer 1-dim. diffusion model.**
- Surface process: **bulk scheme (Louis scheme).**
- Map projections: **Lambert, Polar stereo, Mercator, Lat-lon.**
- Parallel processing: **inter-node: the Message Passing Interface (MPI) , intra-node: OpenMP.**
- **The CReSS model is optimized for parallel computers (parallel and serial versions).**

Downscale simulation of the most intense typhoons simulated in the MRI JMA AGCM (GSM) 20 km resolution experiments

Downscale simulations were performed using the cloud-resolving model (CReSS) for the AGCM simulated typhoons which fit the following conditions for the present and future climate conditions.

1. **The life-time minimum sea level pressure is below 970hPa in the AGCM simulation.**
2. **The position of the life-time maximum intensity is located in the area of 120－150 E and 20－45 N.**

(Green square in the figure)

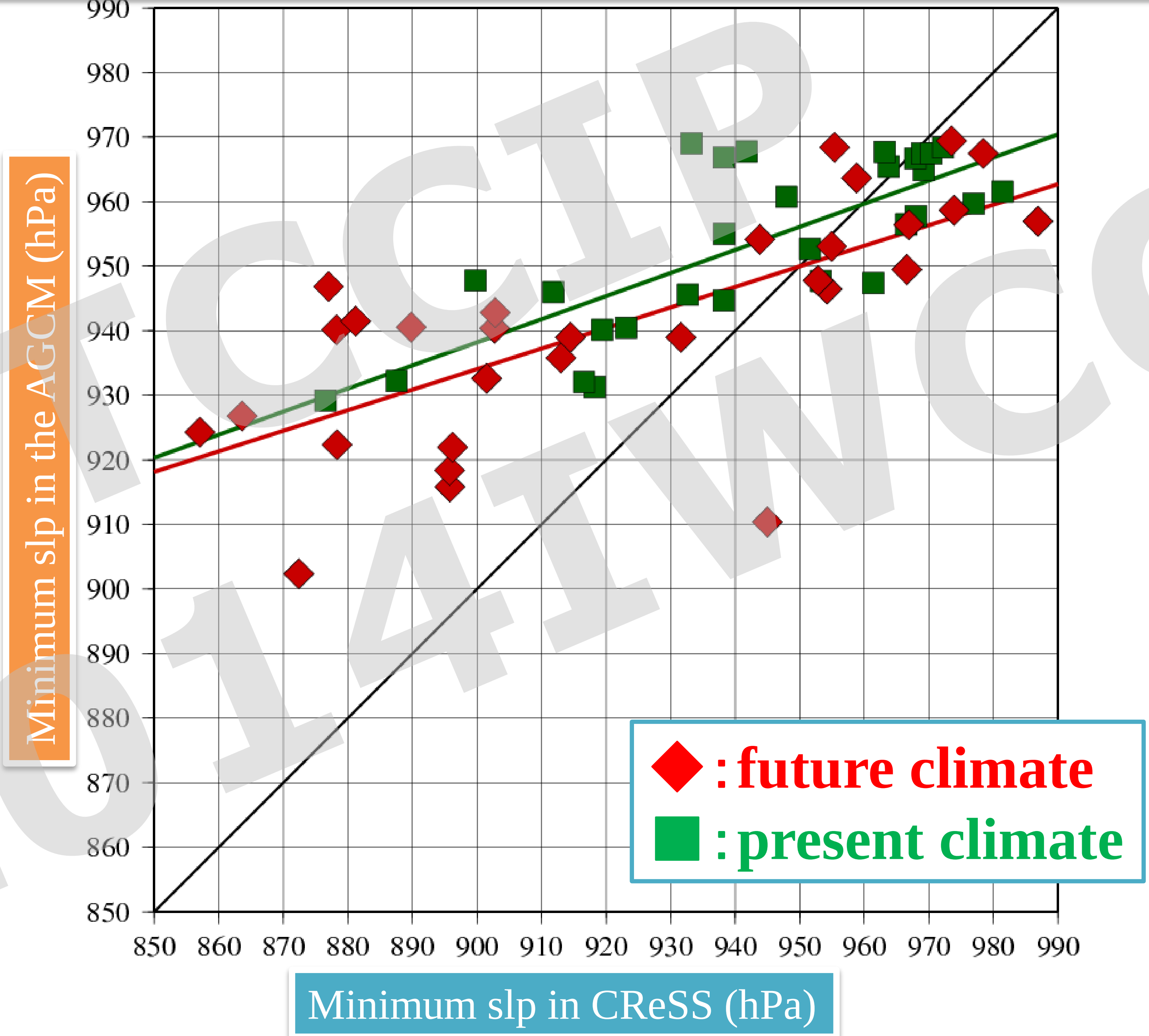


Present climate：30 typhoons
Future climate : 30 typhoons

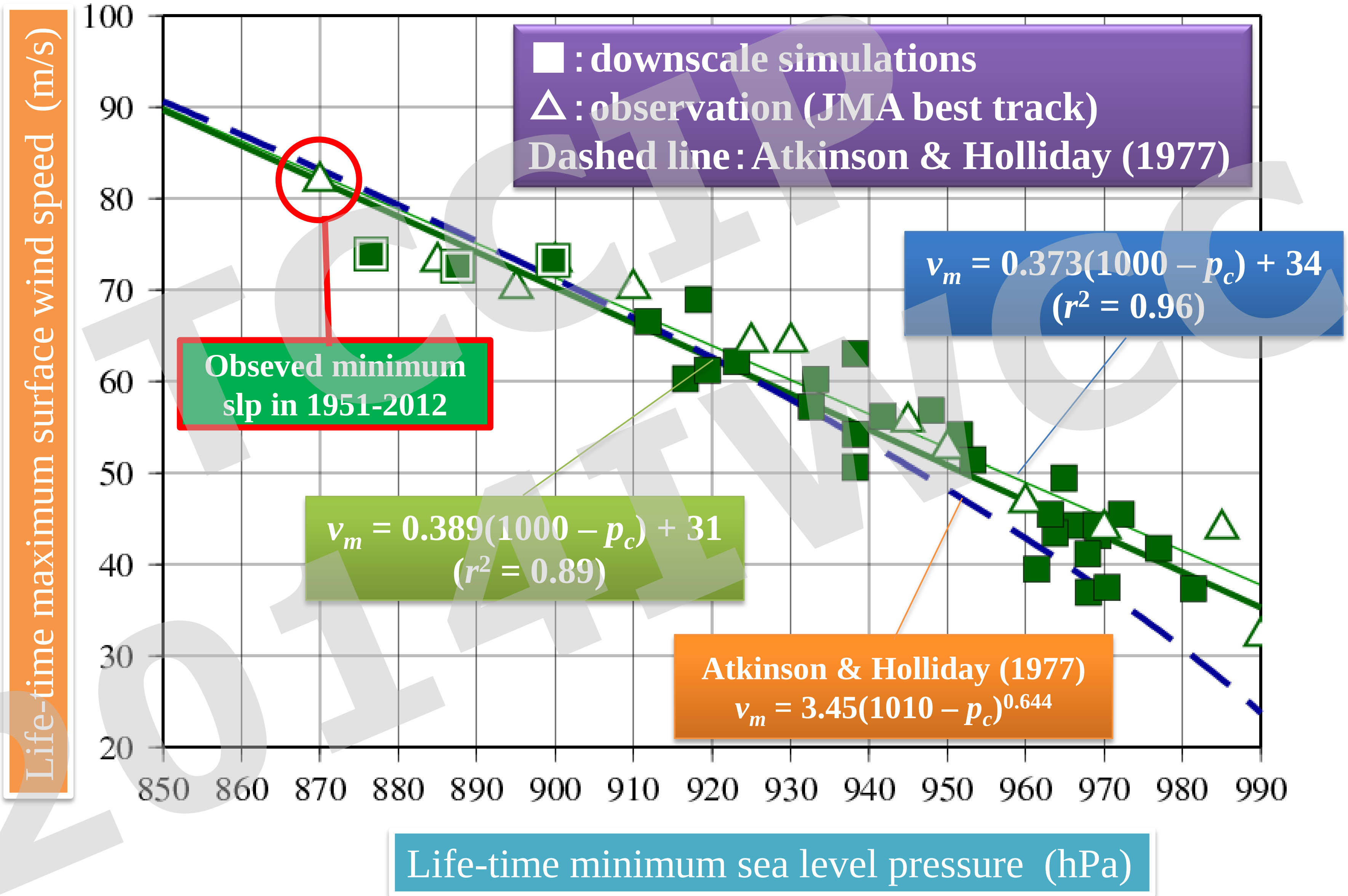
Setting of the downscale simulations using the CReSS model

- **Domain : 2000~2500 × 2000~2500 km**
- **Horizontal resolution: 2 km**
- **Grid number in vertical : 67**
- **Grid spacing in vertical: 200 ～450 m**
- **Computation period : From 3 days before maximum intensity in AGCM to 1 or 2 days after the maximum**
- **Topography and SST: real topography and GCM SST**
- **Initial and boundary conditions: MRI GSM 20km**
- **Cloud physics: bulk cold rain parameterization**
- **Radiation：MSTRNX**
- **Ocean model: one-dim model (60 layers, 30m)**
- **Land model: one-dim model (60 layers, 9m)**

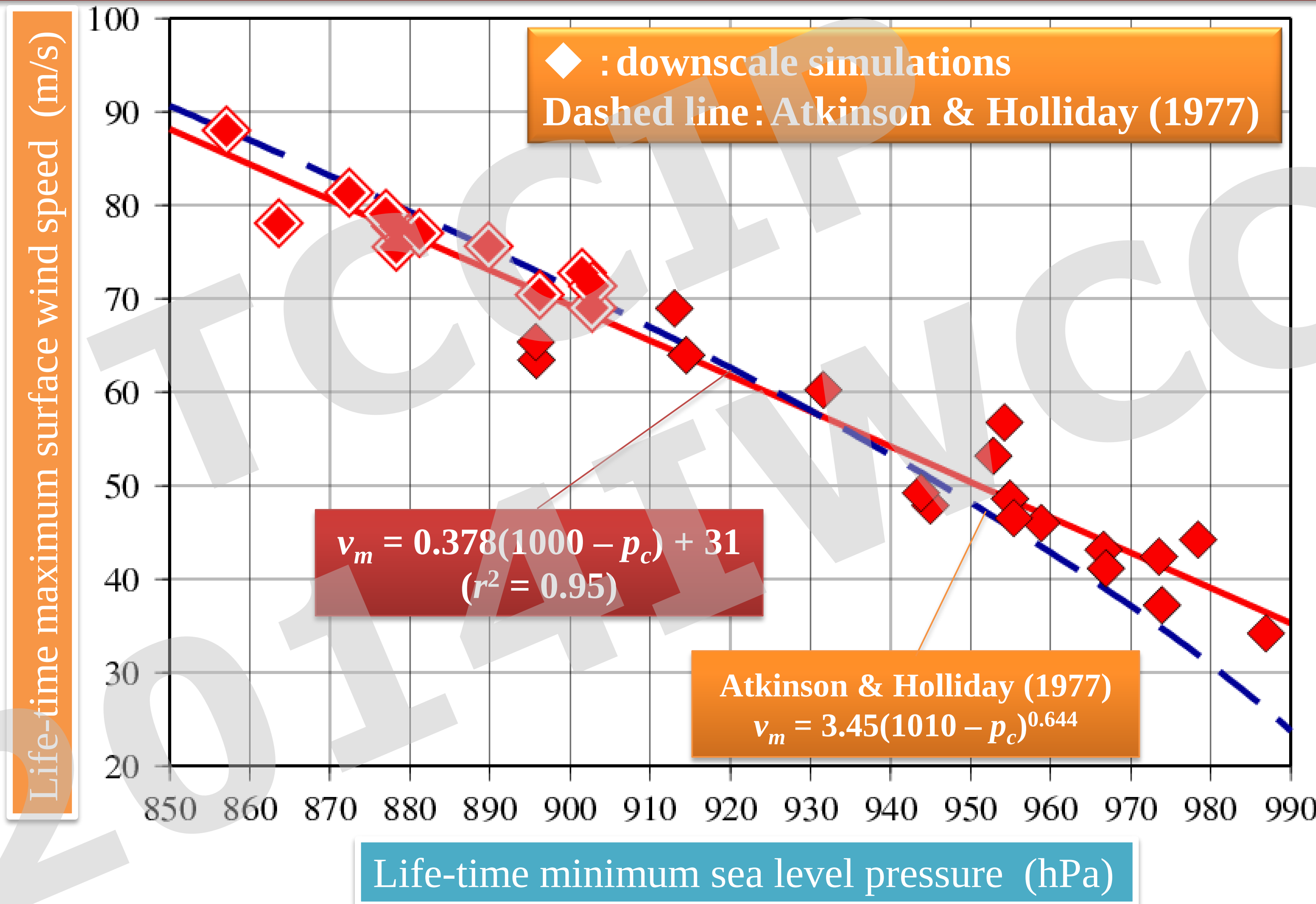
Scatter diagram minimum slp of cloud-resolving model and AGCM



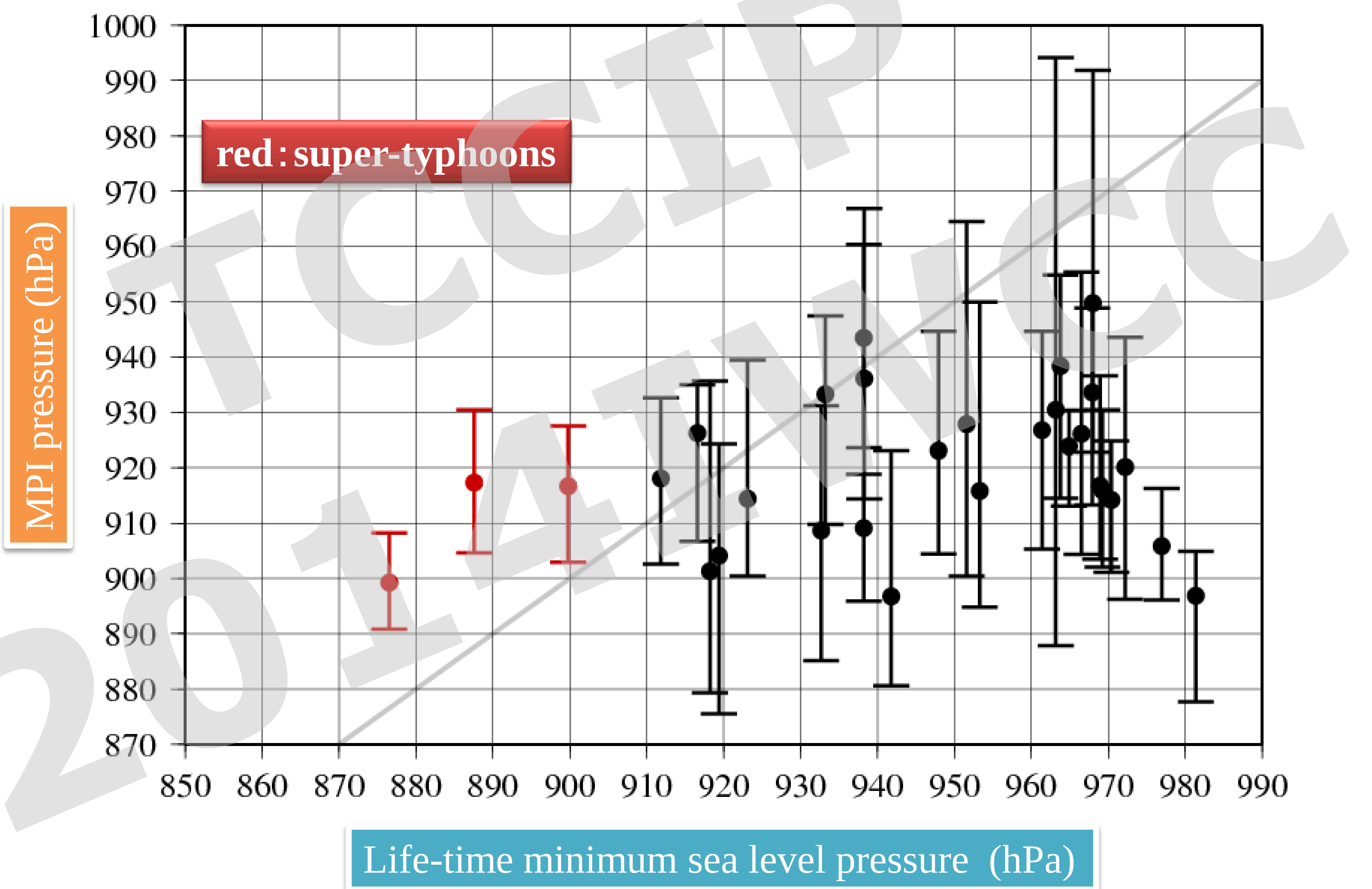
Minimum slp and maximum wind of the present climate typhoons



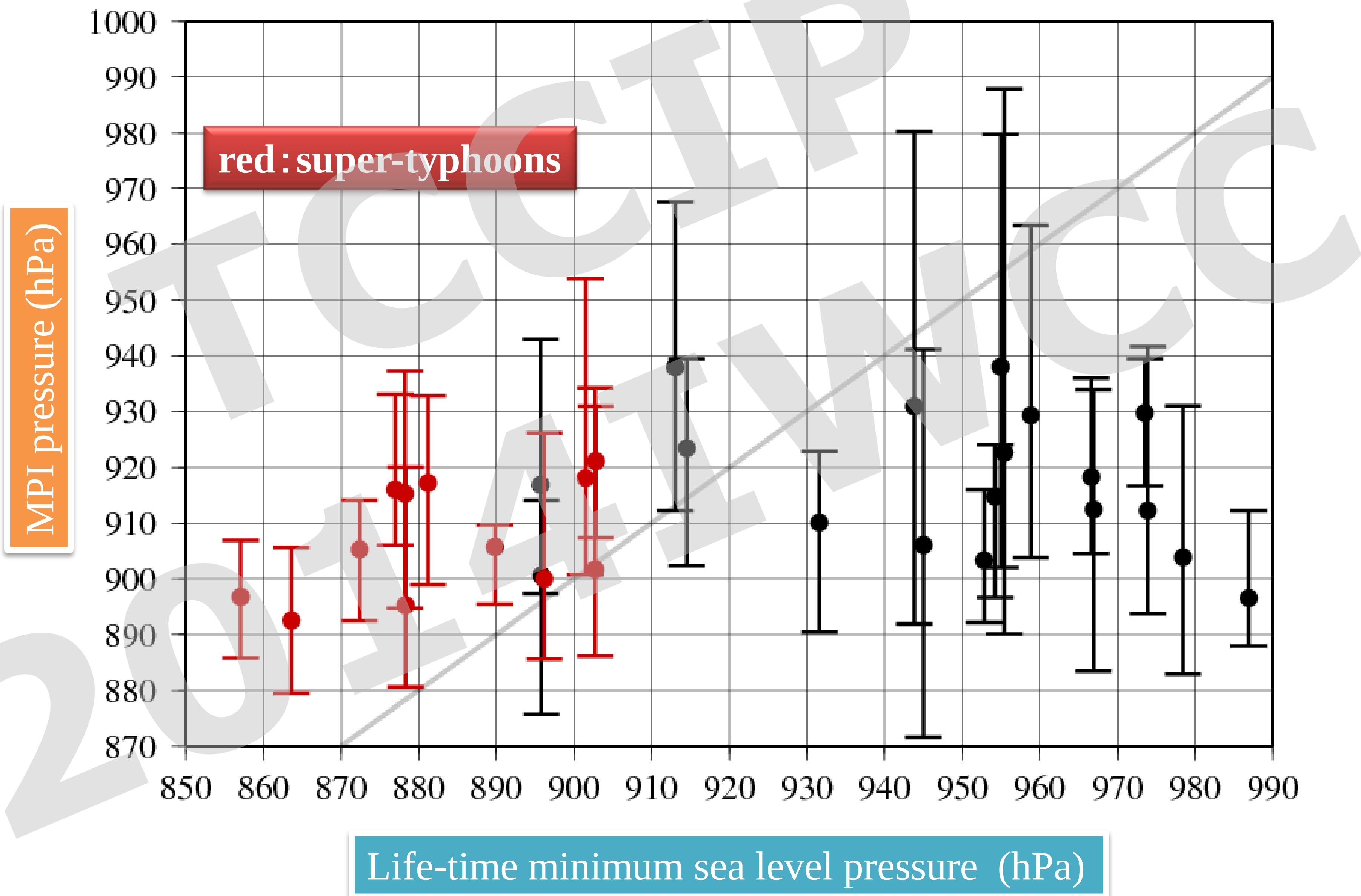
Minimum slp and maximum wind of the future climate typhoons



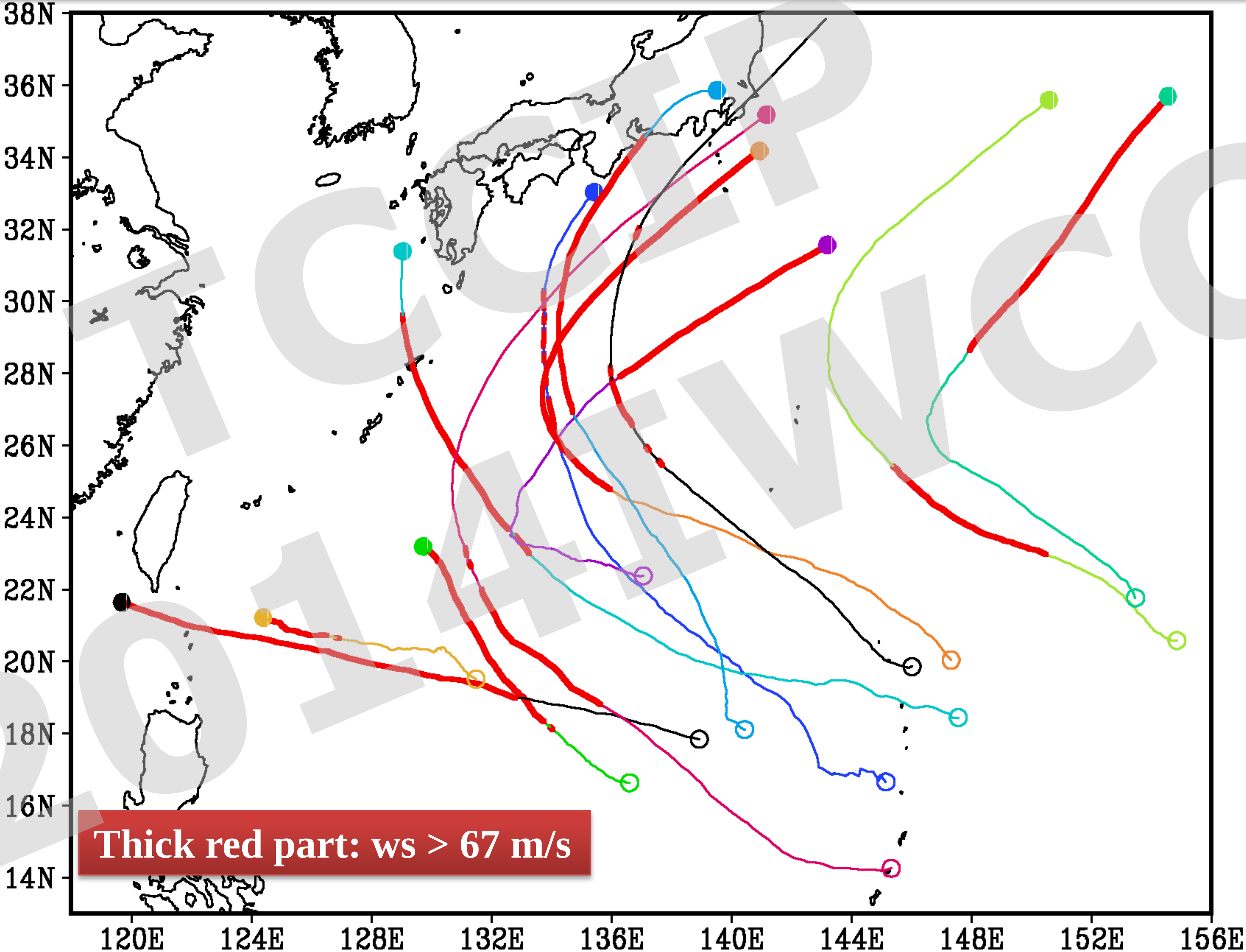
Life-time minimum slp and MPI pressure of the present climate typhoon



Life-time minimum slp and MPI pressure of the future climate typhoon



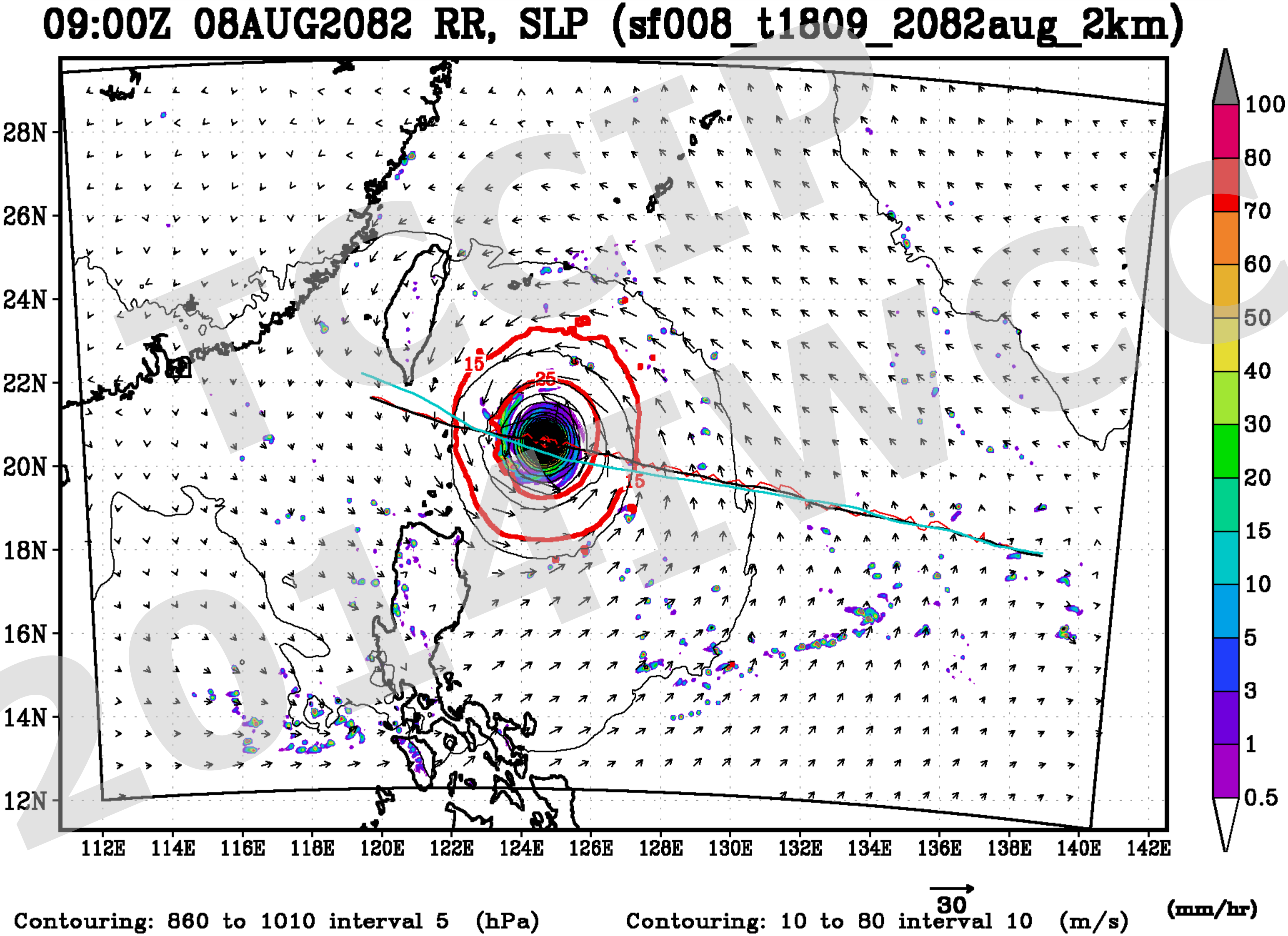
Super-typhoon tracks in the future climate simulations



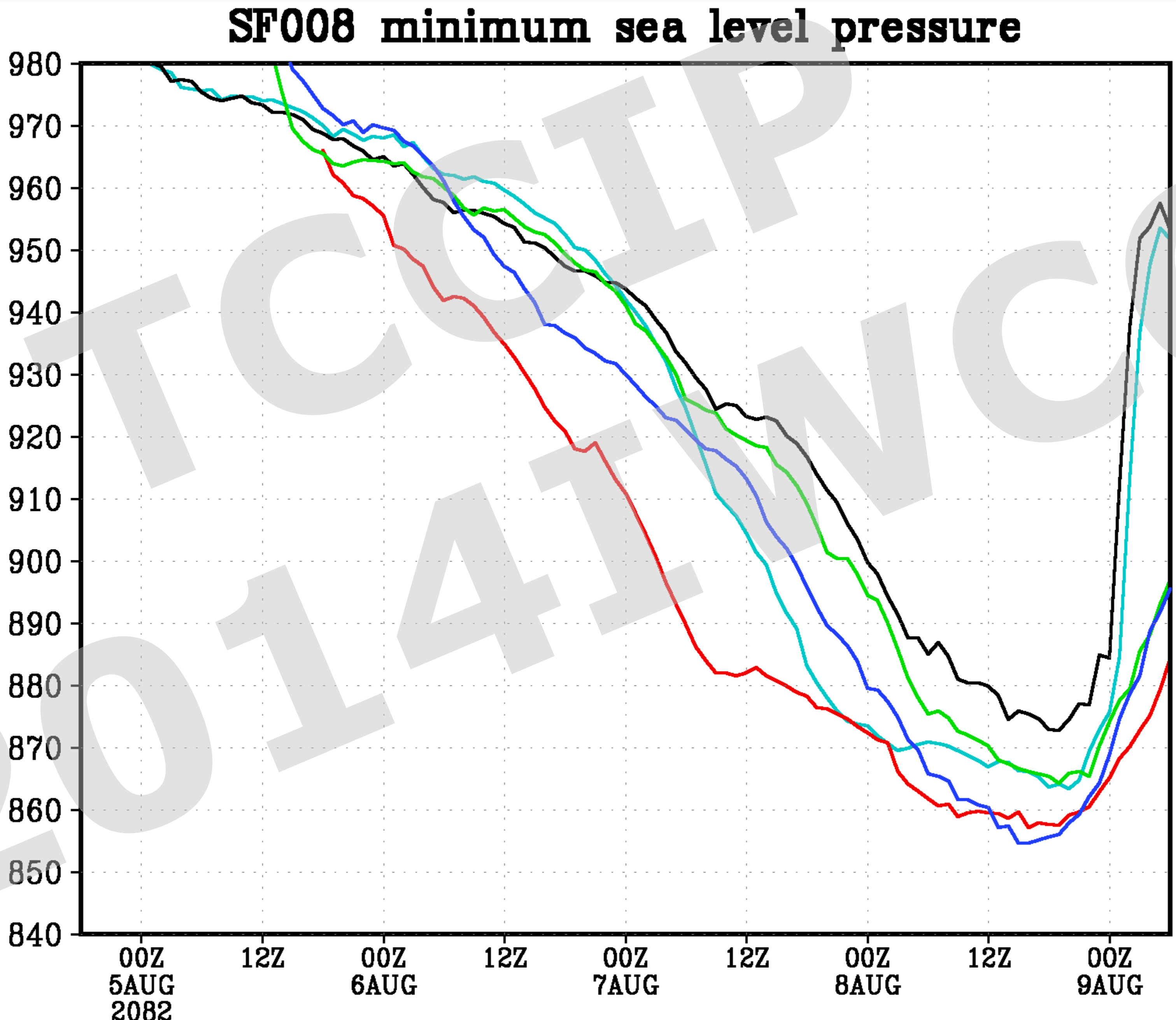
characteristic parameters of simulated typhoons and average environmental metrics

	super-typhoon (Present)	super-typhoon (Future)	all typhoons (Present)	all typhoons (Future)
Number	3	12	30	30
Minimum p_c (hPa)	877	857	------	------
Maximum V_m (m s^{-1})	74	88	------	------
Average p_c (hPa)	888	883	944	922
Average V_m (m s^{-1})	73	76	53	61
Rainfall rate (mm h^{-1})	15.9	15.3	8.9	11.1
Average SST (°C)	28	30	28	30
Average CAPE (J kg^{-1})	1390	1340	1150	1280
Average MPI p_c (hPa)	899	893	900	894
Average MPI V_m (m s^{-1})	79	82	79	81
Average shear (m s^{-1})	13.6	12.6	15.5	15.3

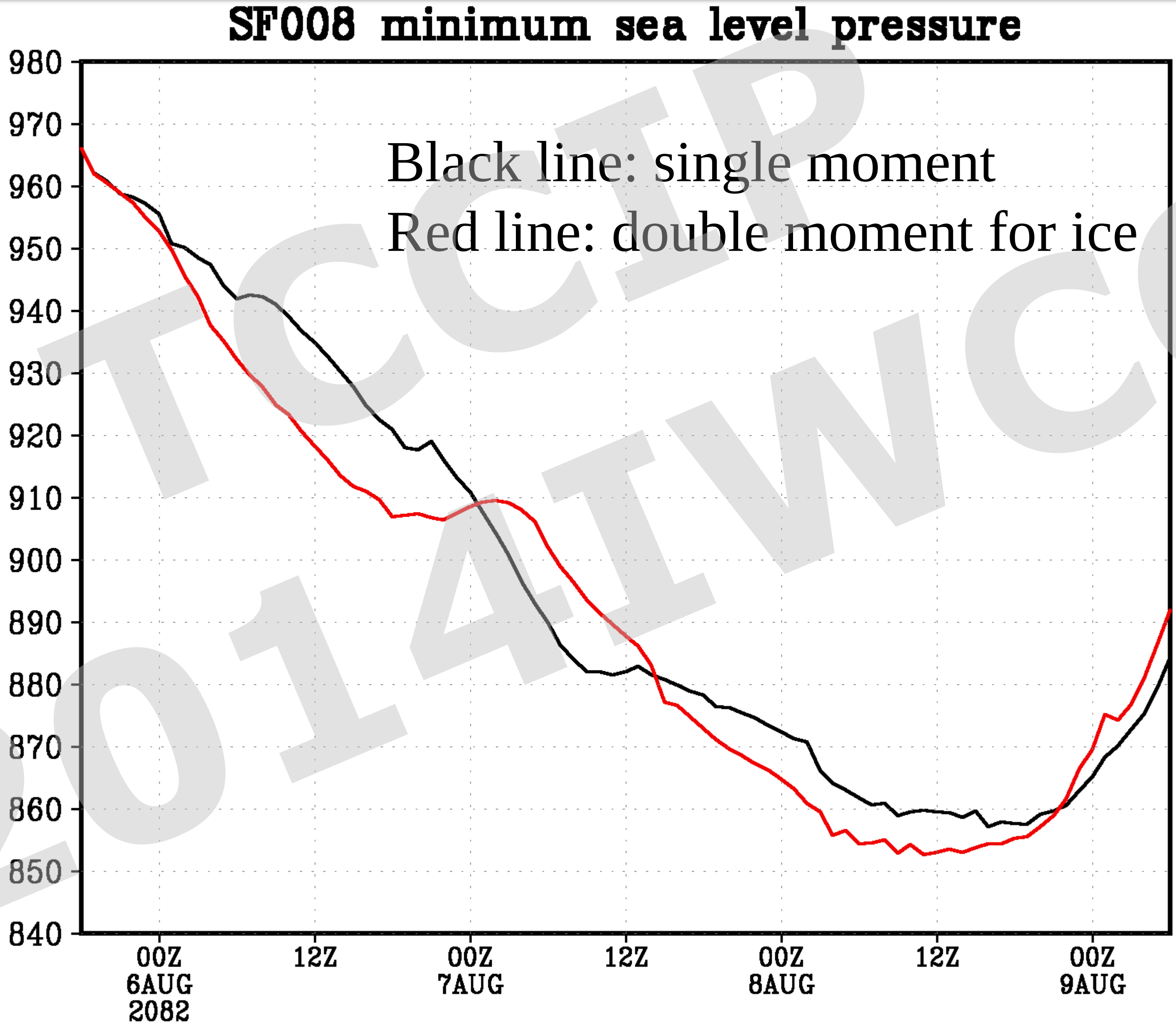
The most intense super-typhoon in the downscale simulations



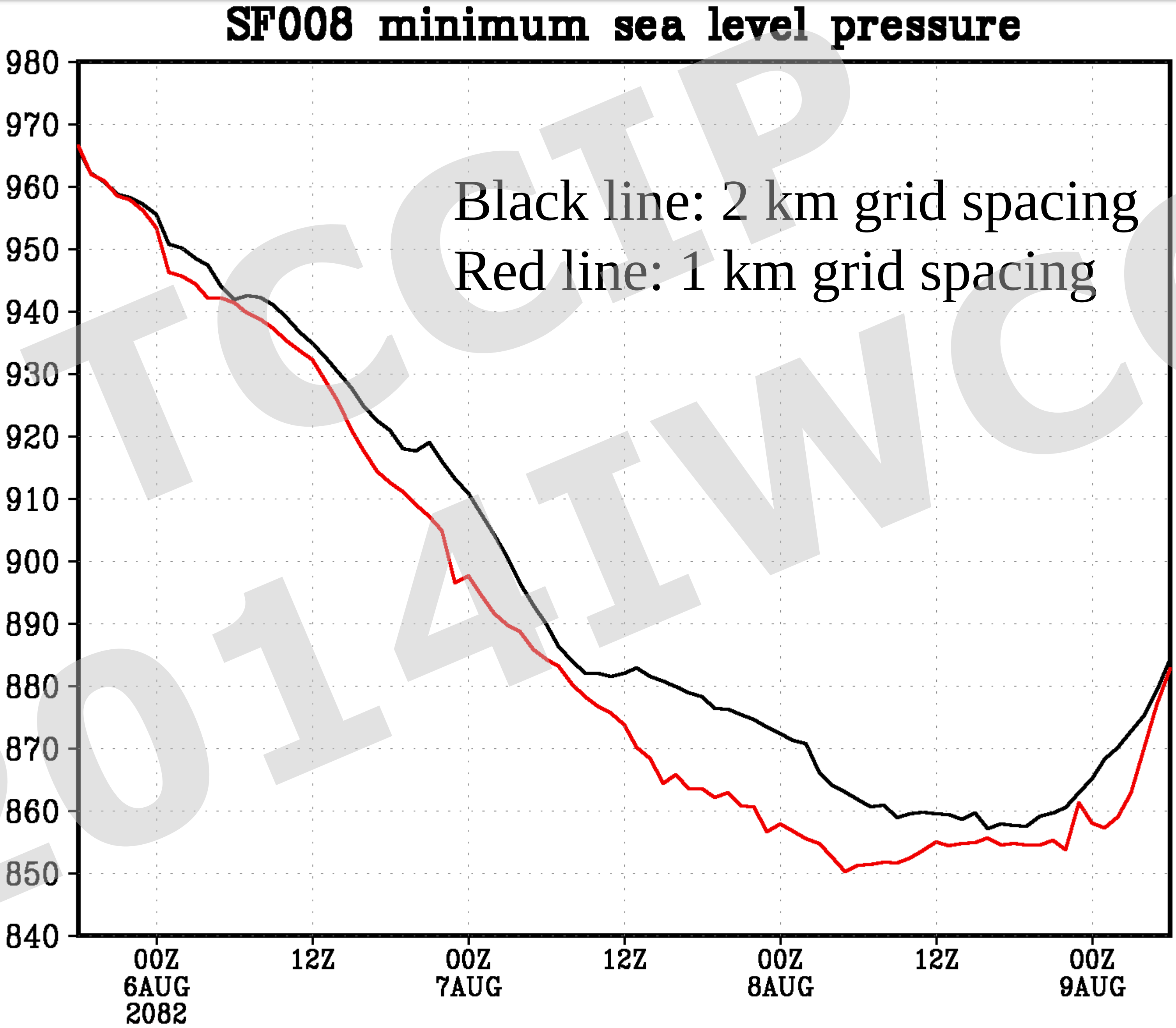
Sensitivity of the most intense super-typhoon for initial conditions



Sensitivity of the most intense super-typhoon for cloud physics



Sensitivity of the most intense super-typhoon for horizontal resolution



Summary

- We used the Cloud Resolving Storm Simulator (CReSS) which is a non-hydrostatic and compressible model designed for parallel computers, in the present study.
- The results show that number of super-typhoon increases in the future climate.
- The maximum intensity of super-typhoon will increase substantially.
- The life-time minimum sea level pressure of the most intense typhoon in the future climate is projected to reach 850-870 hPa.
- These changes correspond to the increase of SST by 2 ℃ while other typhoon environmental metrics are not changed largely.

CPU1 CPU2 CPU3 CPU4 CPU5 CPU6 CPU7 CPU8

Cloud-resolving model: CReSS (Cloud Resolving Storm Simulator)

Tsuboki and Sakakibara (2002)

HyARC, Nagoya University
DX = 4km
Initial and boundary conditions: GPV from NPD/JMA

Wave model

$\boxed{E(x,y,\theta,\sigma)}$

q **Wave direction 24 grids**
s **Frequency 36grids**

Maiami Univ.(Donelan et al., 2012)
DX = 4km
Optimized for the Earth Simulator

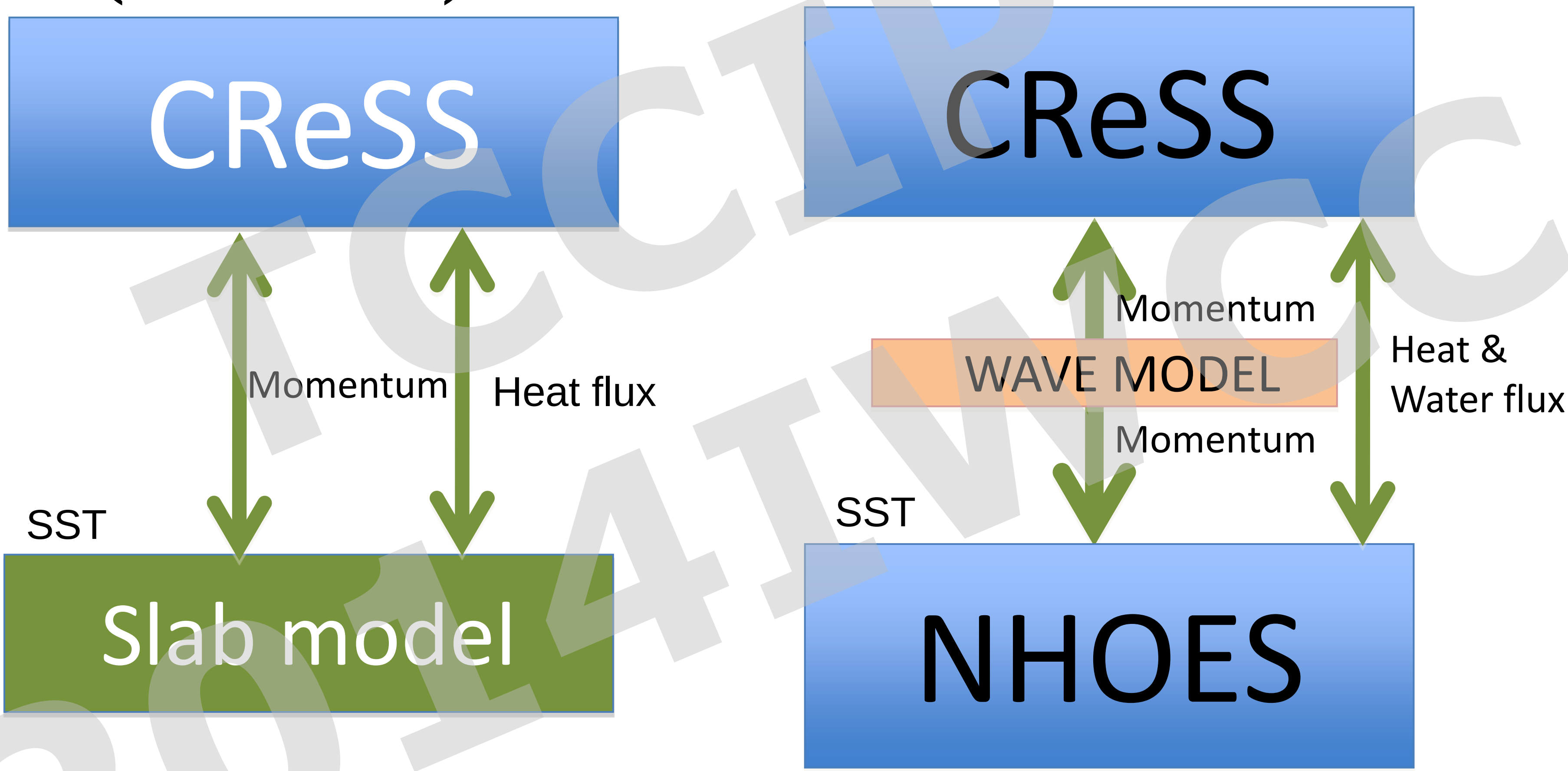
Ocean model: NHOES (NonHydrostatic Ocean model for ES)

Aiki and Yamagata (2004)
Aiki et al. (2006)

JAMSTEC
DX = 4km, DZ = 2 m for top 100 m
Initial and boundary conditions: JCOPE2 reanalysis
Ocean mixing layer model (Furuichi et al., 2012; Nakanishi & Niino, 2009)

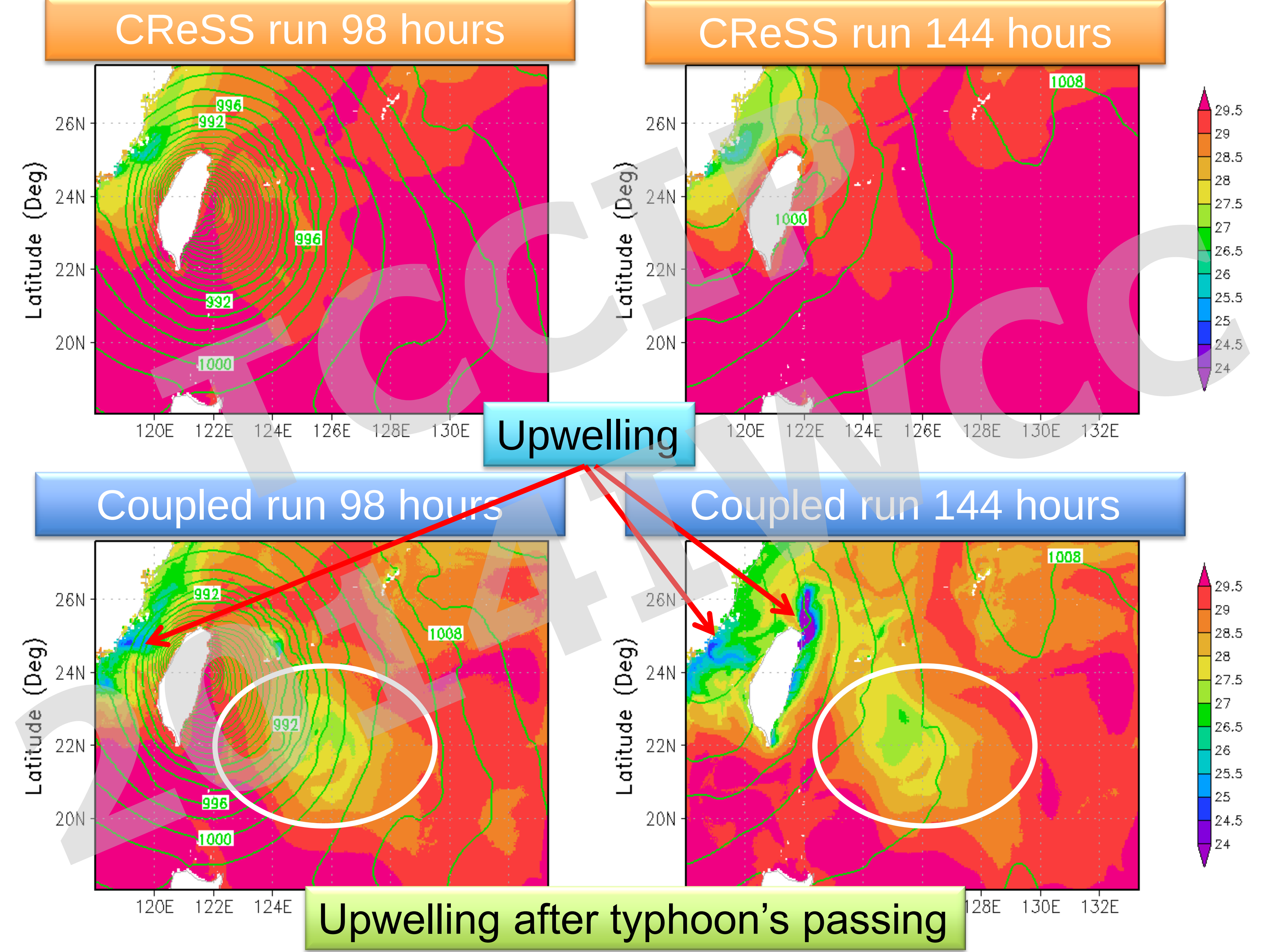
CReSS Run (1D-Ocean)

Coupled Run (3D-Ocean)



SST is set by forcing and diffusion with no Ekman upwelling

SST is cooled by diffusion and Ekman upwelling


CReSS run 98 hours
CReSS run 144 hours
Coupled run 98 hours
Coupled run 144 hours
Upwelling
Upwelling after typhoon's passing
Latitude (Deg)
26N
24N
22N
20N
120E
122E
124E
126E
128E
130E
132E
996
992
1000
1008
29.5
29
28.5
28
27.5
27
26.5
26
25.5
25
24.5
24