Future climate projection in Asian monsoon region with a high-resolution AGCM

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Today's topics

1. Projected future climate changes in East Asia in the past 5-yr program
2. A new future climate projection in the next 5-yr program

What we planned 5 years ago

The Innovative Program of Climate Change Projection for the 21st Century (KAKUSHIN (革新) Program) started 5 years ago.

- Use global 20-km mesh Atmospheric General Circulation Model (MRI-AGCM3) to project future changes in climate extremes
  - TC number and intensity
  - Rainfall intensity during the rainy season (Meiyu/Baiu)
- Perform ensemble experiments with a 60-km mesh AGCM to quantify uncertainties in climate projections
- Use a Regional Climate model (NHRCM) to further downscale the 20-km AGCM results for projections of extreme rainfall events over summertime Japan

will be talked by Dr. Sasaki

- Provide these data for impact studies on adaptation to climate change

talked by Prof. Nakakita

History of MRI-AGCM development

MRI-AGCM3.0 (before 2007) (Mizuta et al. 2006; Oouchi et al. 2006)
This model was developed from JMA operational NWP model.
First 20-km mesh climate model which simulates for multi decades.

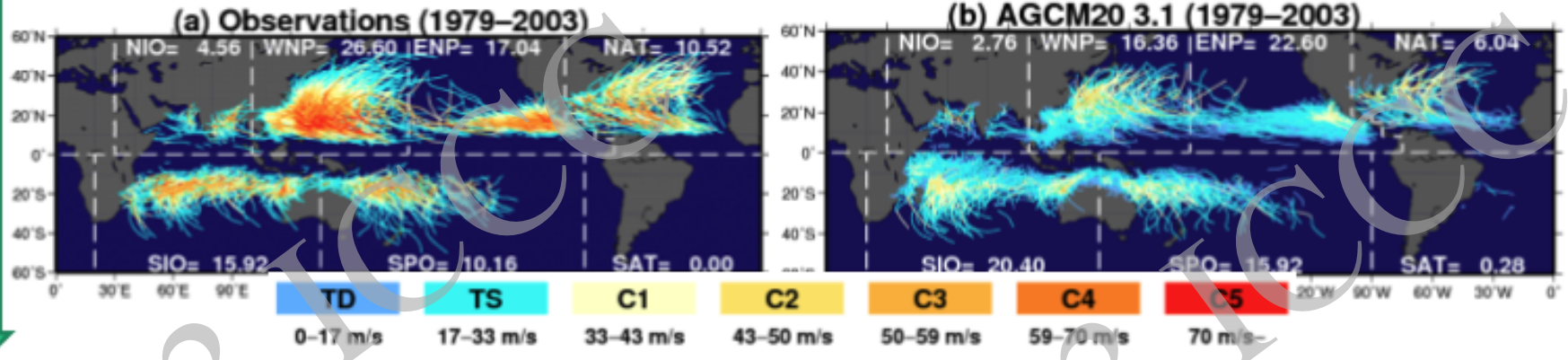
5 years ago

very minor change

MRI-AGCM3.1 (since 2007) AMIP-type experiments (Kitoh et al. 2009; Murakami and Wang 2010; Murakami et al. 2011)

Previous model

The model had marked biases in geographical distribution of TCs and TC intensity.



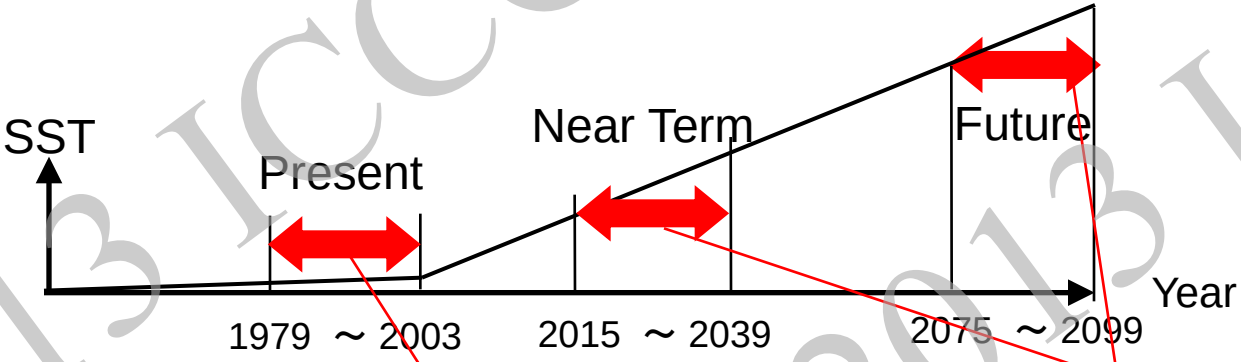
MRI-AGCM3.2 (since 2009) Current model

AMIP-type 25 years experiments are conducted using observed SST for the present-day climate.
Future projections of 25 years are conducted by prescribing CMIP3 ensemble mean SST and clustered SSTs.

MRI-AGCM 3.1 vs 3.2

	Previous model (for IPCC AR4)	Current model (for IPCC AR5)
	MRI-AGCM 3.1 (Mizuta et al., 2006, *JMSJ*)	**MRI-AGCM 3.2** (Mizuta et al., 2012, *JMSJ*)
Horizontal resolution	TL959 (20km)	
Vertical resolution	60 levels (top at 0.1hPa)	64 levels (top at 0.01hPa)
Time integration	Semi-Lagrangian	
Time step	6minutes	10minutes
Cumulus convection	Prognostic Arakawa-Schubert	Yoshimura (Tiedtke-based Arakawa-Schubert-type ensemble)
Cloud	Smith (1990)	Tiedtke (1993)
Radiation	Shibata and Aoki (1989) Shibata and Uchiyama(1992)	JMA (2007)
GWD	Iwasaki et al. (1989)	
Land surface	SiB ver0109(Hirai et al.2007)	
Boundary layer	MellorYamada Level2	
Aerosol (direct)	Sulfate aerosol	5 species
Aerosol (indirect)	No	

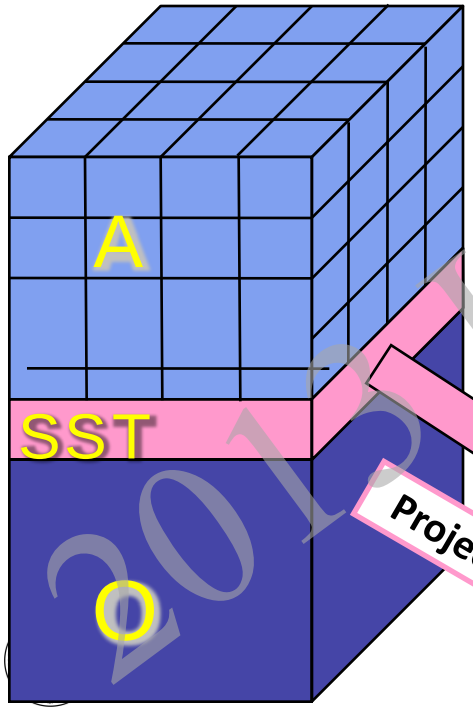
Time-slice experiments



Observed SST
(AMIP-type)

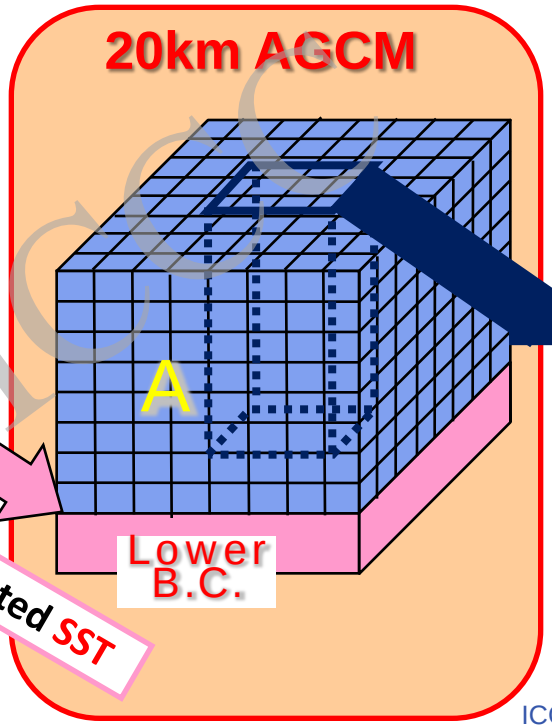
Obs + Projected
SST change

CMIP3 AOGCMs



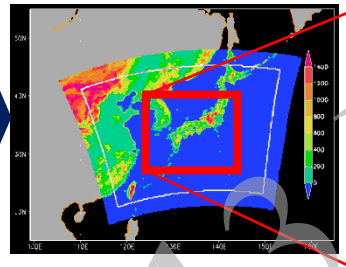
Projected SST

20km AGCM



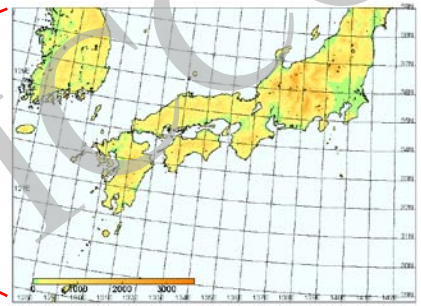
Regional Climate Model

5km NHM



Nested in the 20kmAGCM

2km, 1km NHM



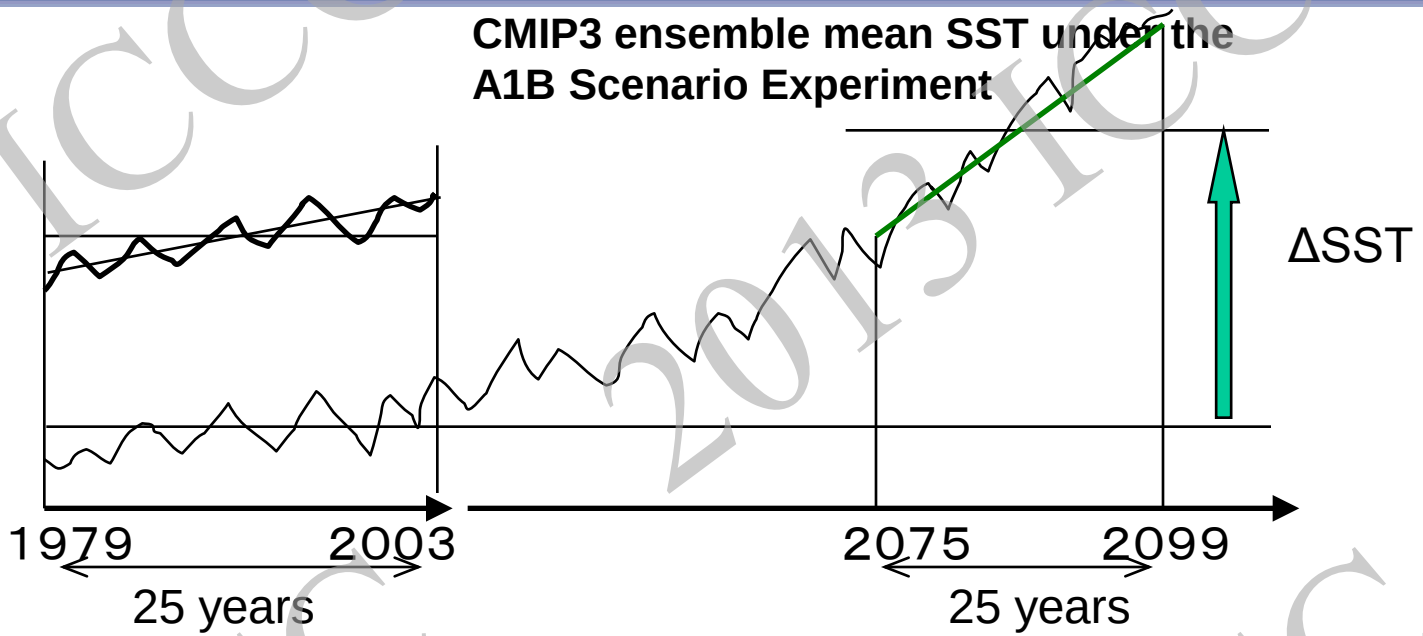
Nested in the 5km NHM

How to prescribe SST

Present SST

Observed SST
1979～2003

AR4_20thCentury
Exp. SST -2001



Future SST

also applies for 2015-2039 (Mizuta et al. 2008)

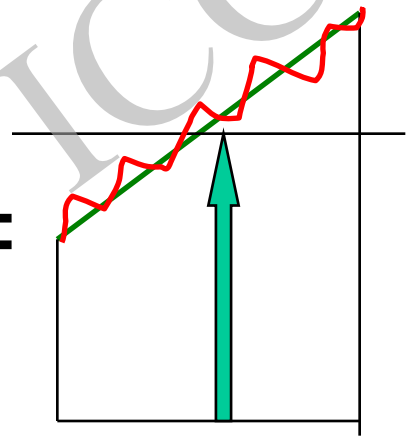
CMIP3 SST change

ΔSST

Mean SST(2075-2099) – Mean SST(1979-2003)

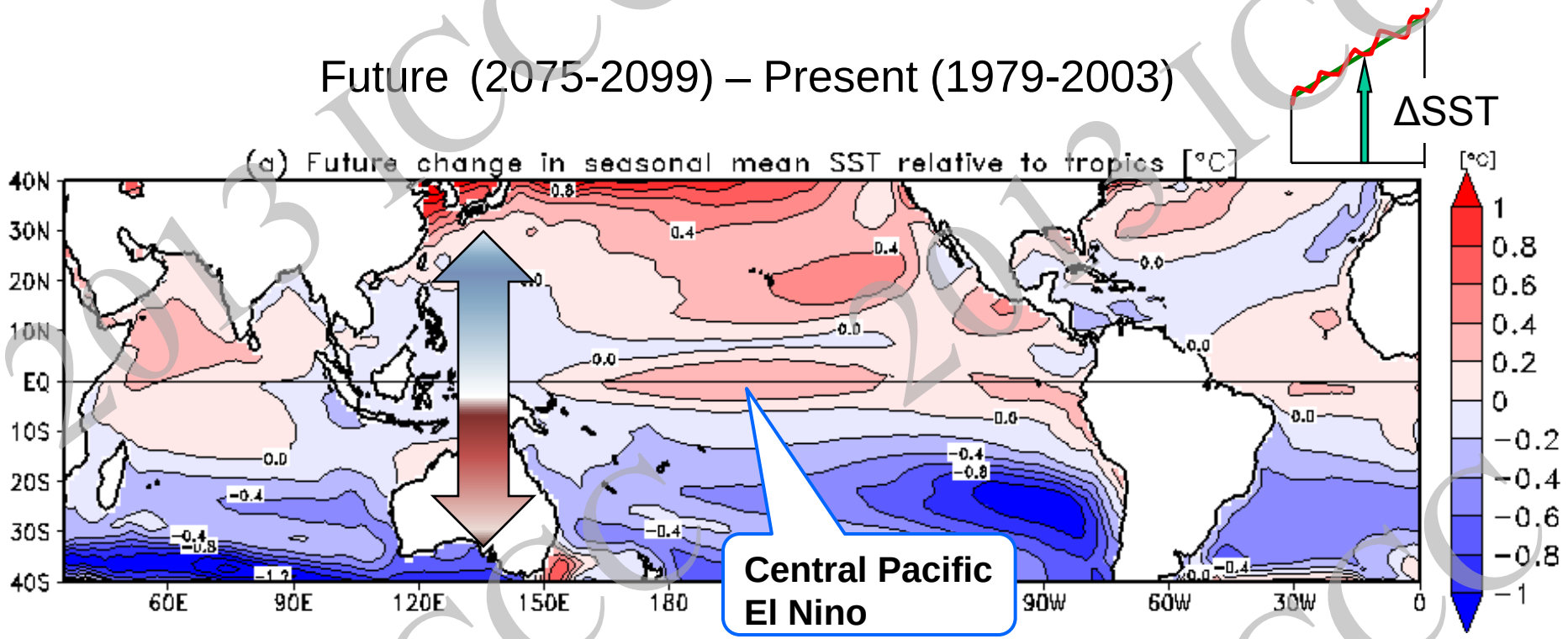
CMIP3
SST Trend
2075-2099

Inter-annual variability
of Observed SST
1979-2003



Prescribed future changes in SST

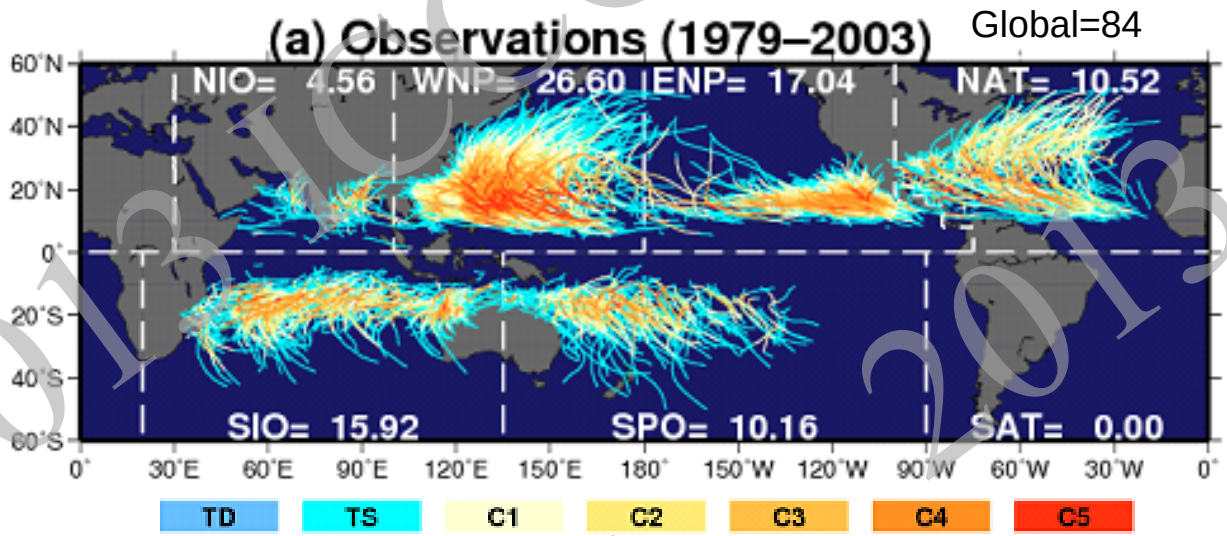
Future (2075-2099) – Present (1979-2003)



- Relatively larger increase in SST in the Northern Hemisphere than in the Southern Hemisphere.
- The SST increase is the largest in the tropical Central Pacific.

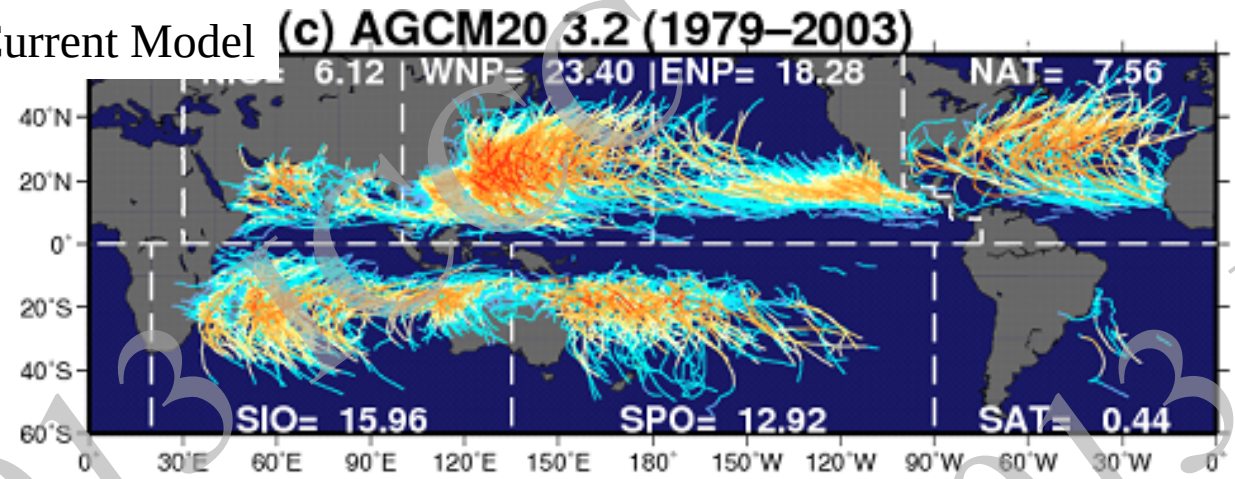
Improvement in TC simulations with the current 20-km mesh MRI-AGCM

颱風



Number for each basin denotes the annual mean TC number.

Current Model



Improvements:
- Monthly mean rainfall in WNP
- Seasonal march of summer Monsoon in East Asia

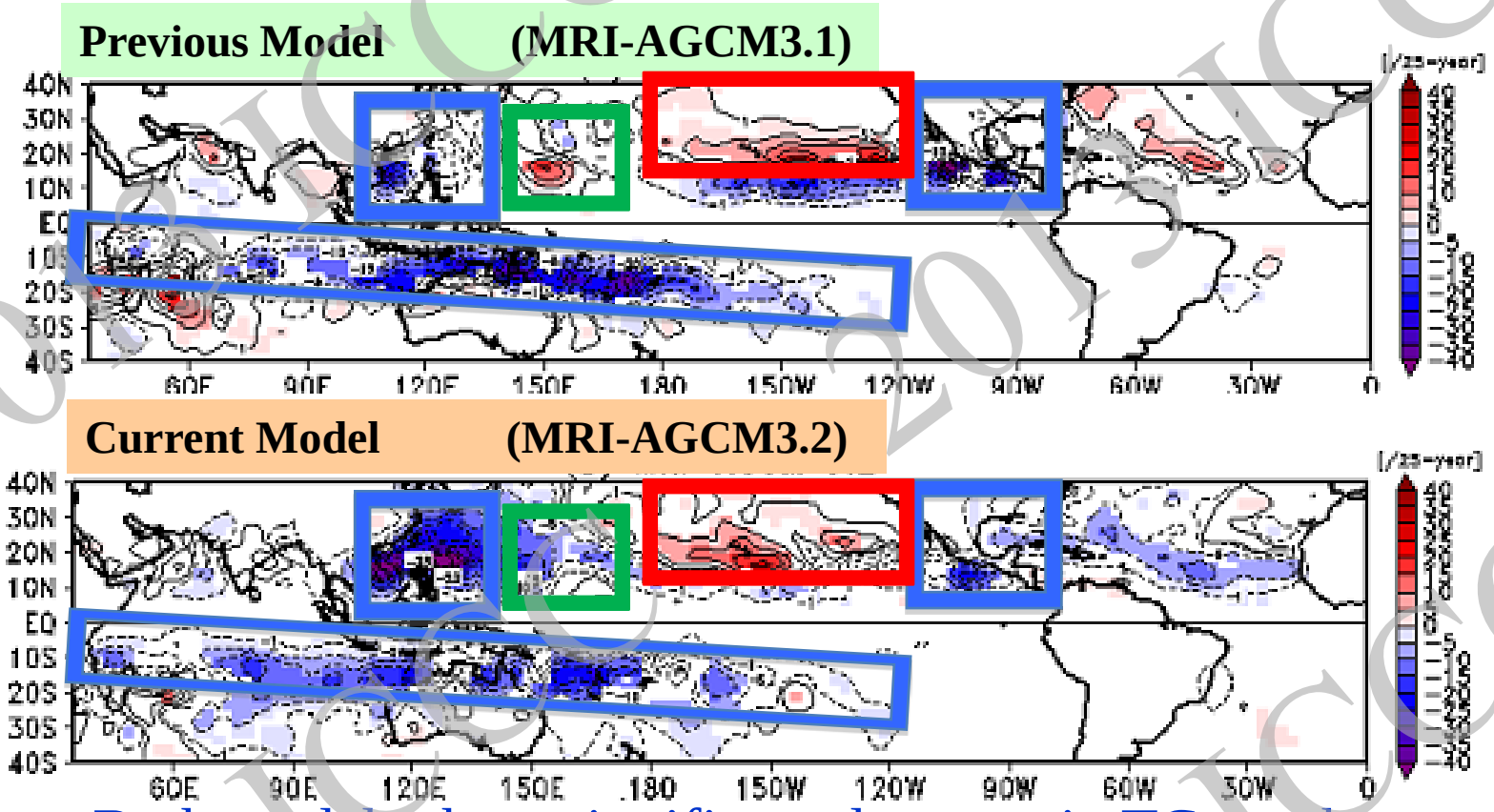
(Mizuta et al. 2012)

Simulated TC number in the WNP is underestimated — Improved

TC intensity is weak compared with observations — Improved

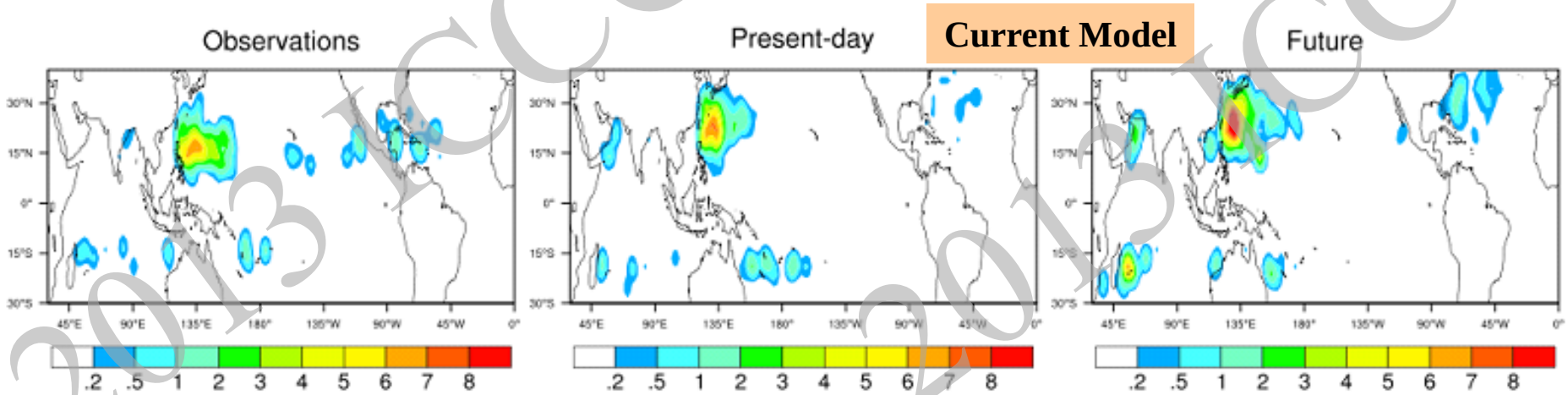
(Murakami et al. 2012)

Future changes in TC number between models



- Both models show significant decrease in TC number over the South Pacific, western portion of WNP, and CA
- Both models show significant increase in TC number over the central Pacific
- Inconsistent in the eastern quadrant of WNP

Category 5 TC frequency of occurrence
(≥70 m/s)



Unit: number per 25 years

·The frequency of C5 TCs appears to increase in the northern portion of the WNP basin.

·Note that the tracks of C5 TCs in the present-day simulation show a northward shift relative to observations.

Multi-physics & multi-SST ensemble projections using 60-km-mesh model

Quantified uncertainties must accompany with the climate projections.
The 20-km mesh model consumes huge computer resources and does not allow us to perform ensemble simulations.

60-km mesh version as low cost model

3 cumulus convection schemes

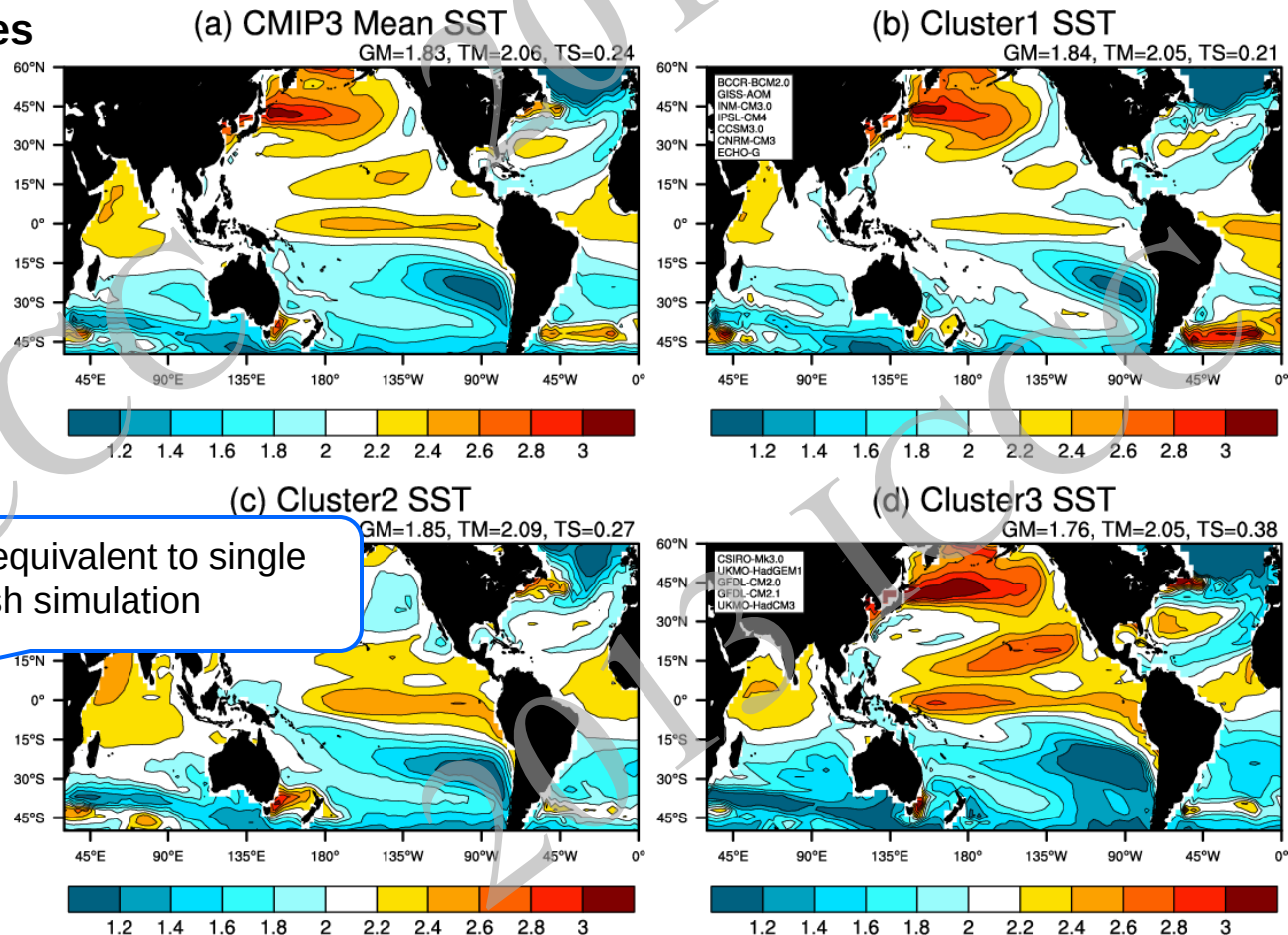
- **1: YS: Yoshimura**
- **2: KF: Kain-Fritsch**
- **3: AS: Arakawa-Schubert**

4 future SST anomalies

- **1: 18 CMIP3 model mean**
- **2: cluster 1 of 18 ΔSST**
- **3: cluster 2**
- **4: cluster 3**

CPU time equivalent to single 20-km mesh simulation

3×(1+4)=15 member



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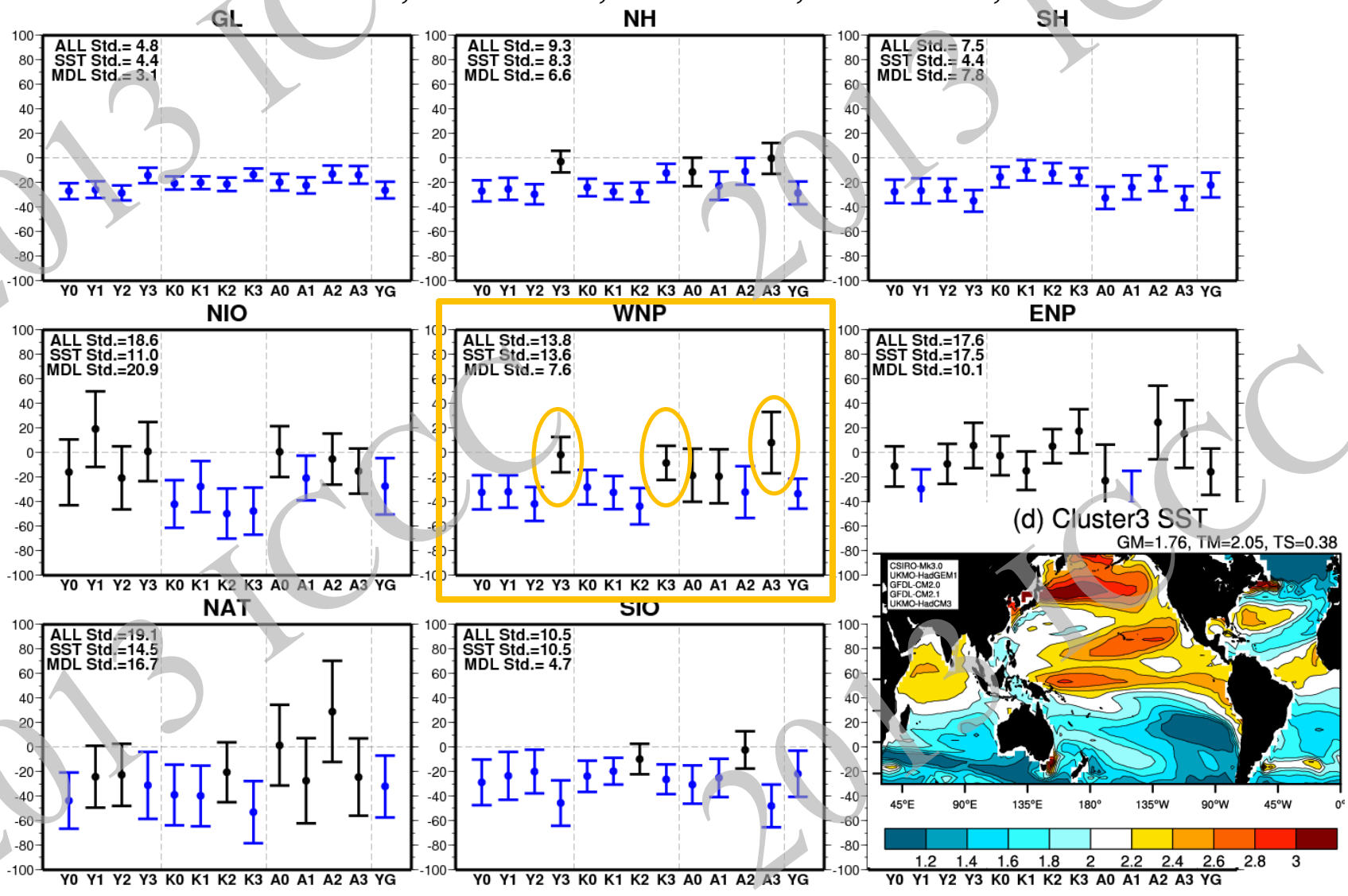
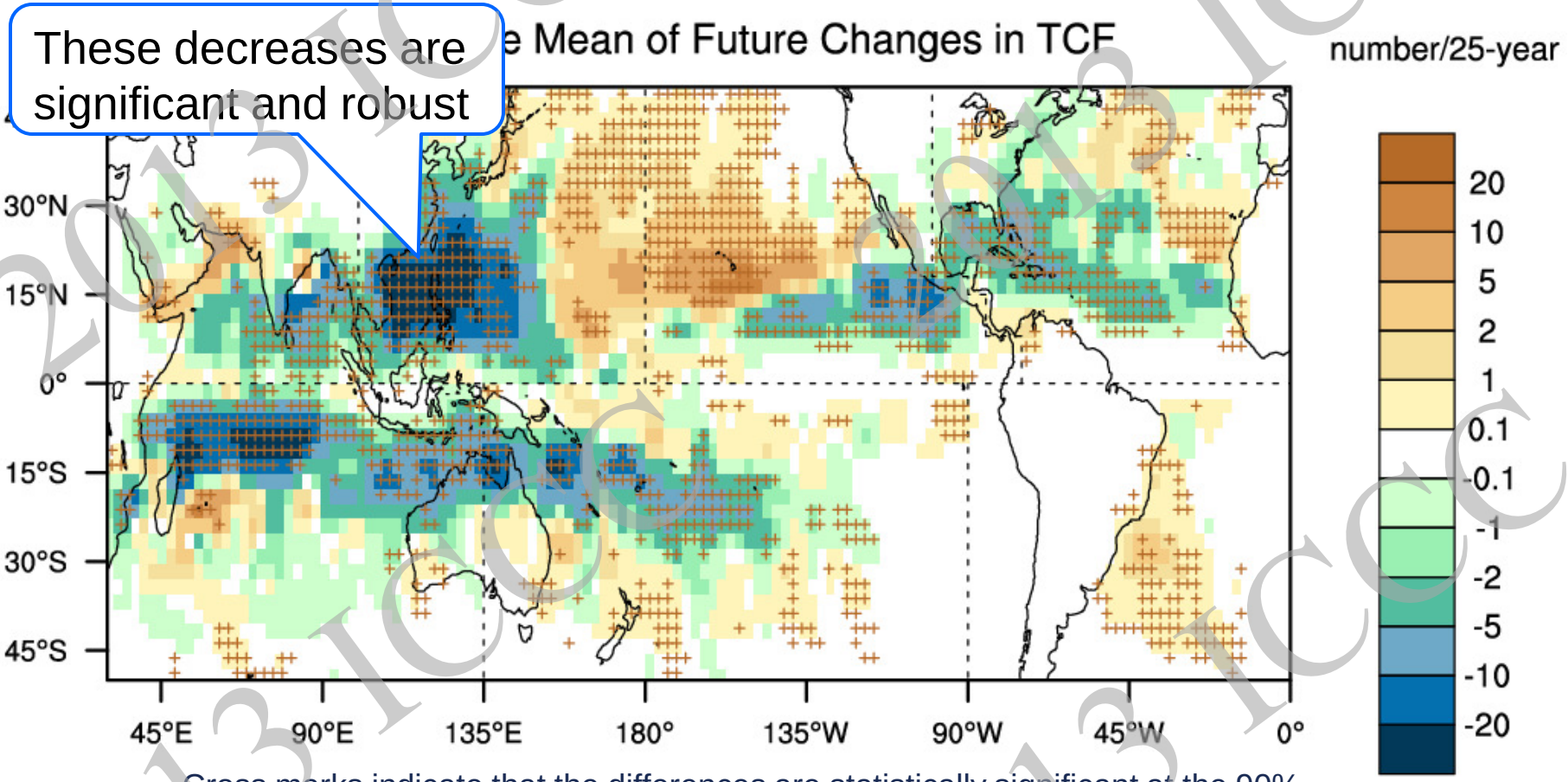
Future changes in TC number [%]

Y: Yoshimura, K: Kain-Fritsch, A: Arakawa-Schubert
0: CMIP3 SST, 1: Cluster 1, 2: Cluster 2, 3: Cluster 3, G: Global uniform



Changes in TC Number

MRI-AGCM3.2H: 2075-2099 vs 1979-2003



Cross marks indicate that the differences are statistically significant at the 90% confidence level or above according to the two-sided Student's t-test and that more than 10 experiments (approximately 80% of all ensemble experiments) project the same sign changes.

Quantified uncertainty

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Seasonal march of rainfall

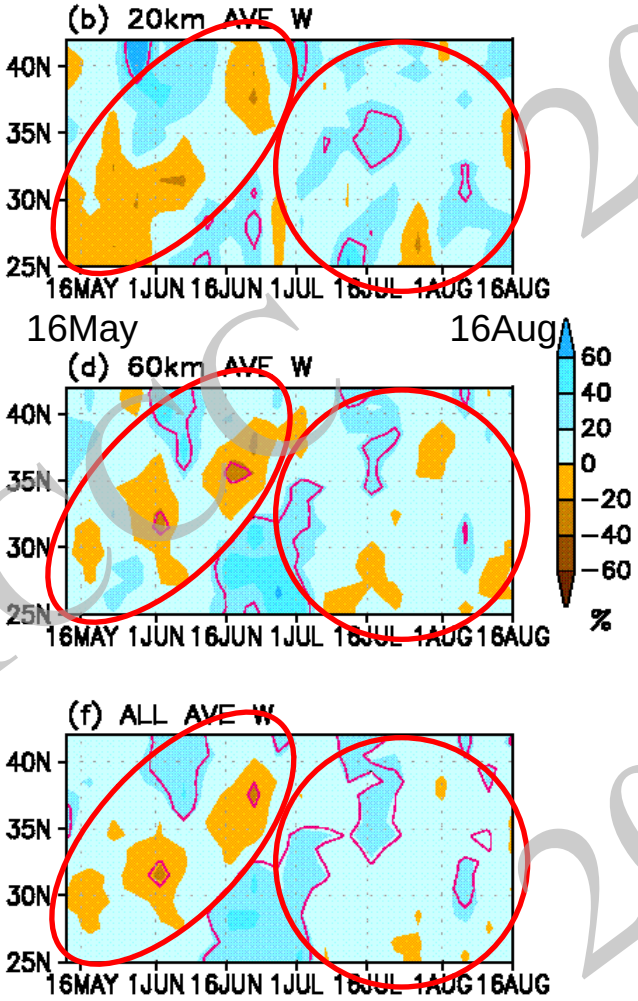
Precipitation Change=(F−P)/P (%) Lon=125−142E
Pentad = 27(11May−15May) to 46(14Aug−18Aug)
Runs = S?0A H?0A S?A H?A H?A_ks H?A_as
S = Taylor skill against GPCP1DDv1.1
Contour: 95% significant

梅雨

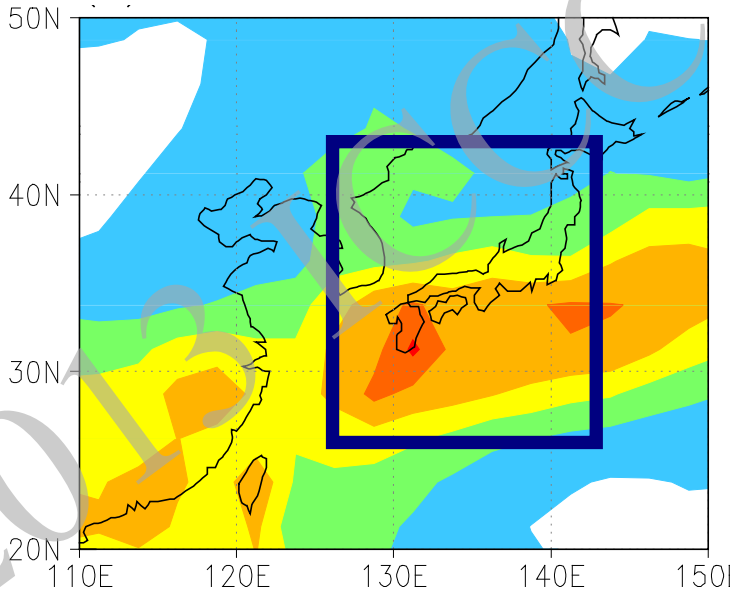
20km

60km

ALL

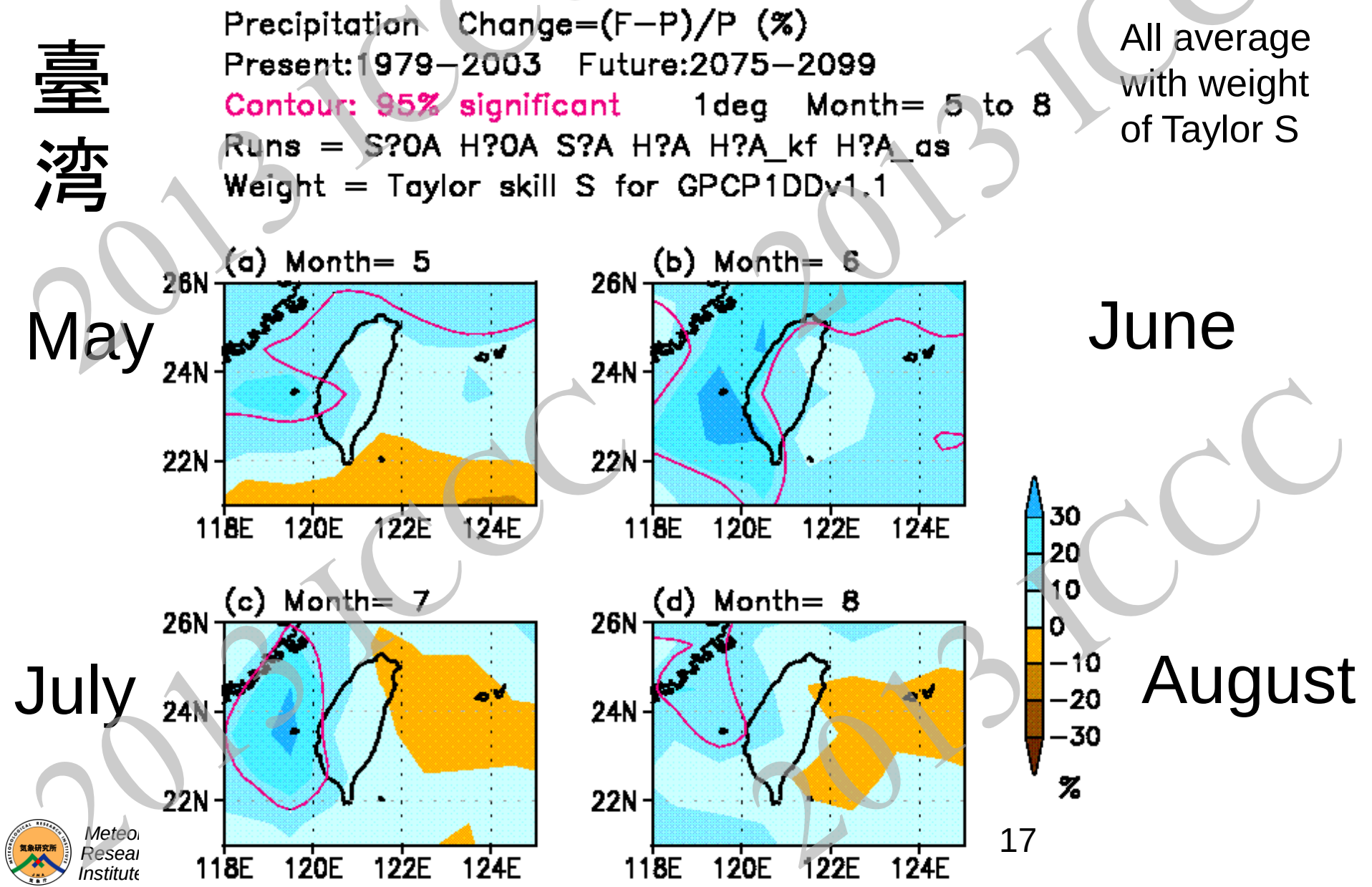


In Japan, the onset of rainy season (Baiu) tends to delay and its amount tends to increase.



Future changes in rainfall in Taiwan

臺灣



All average with weight of Taylor S

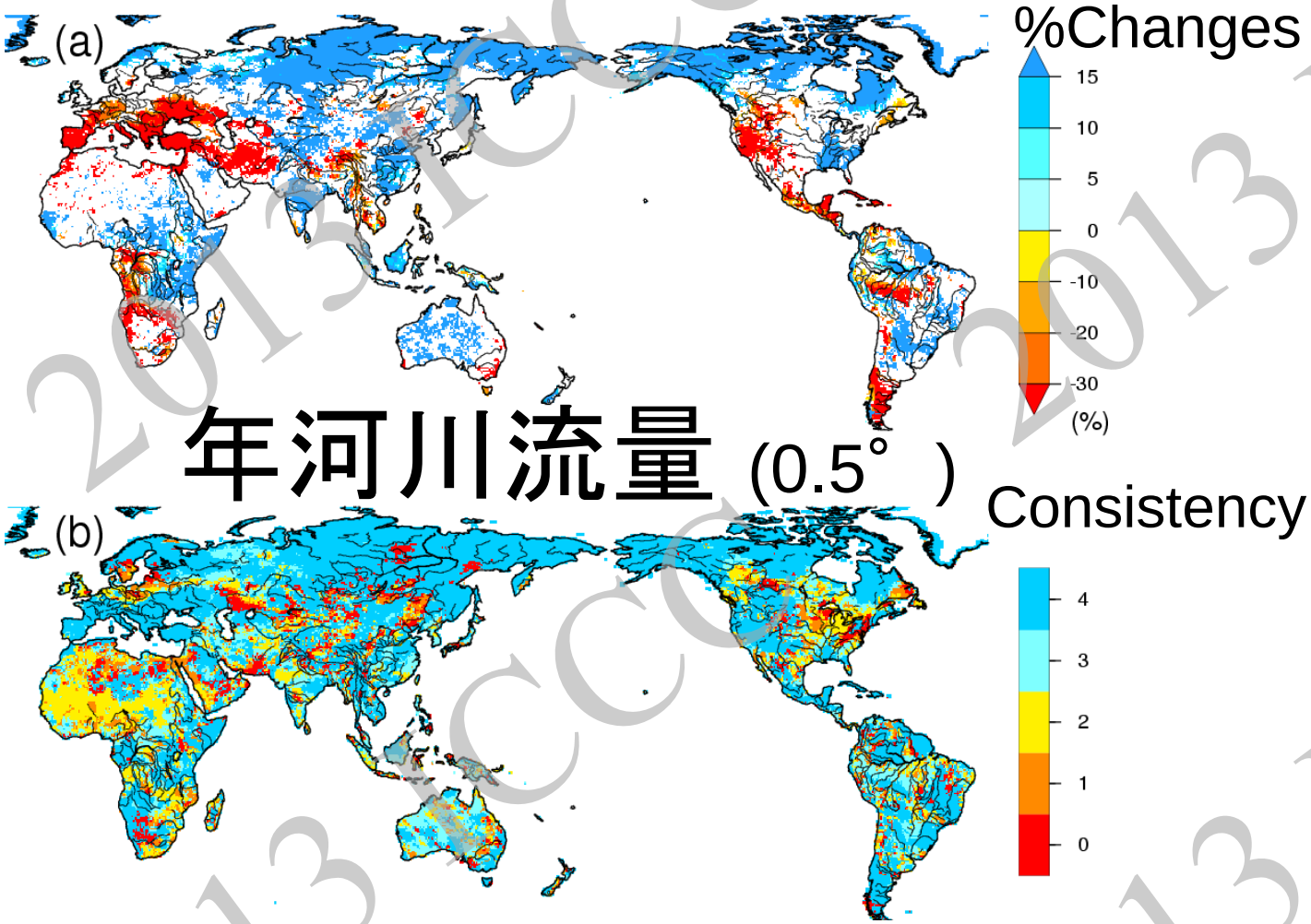
May

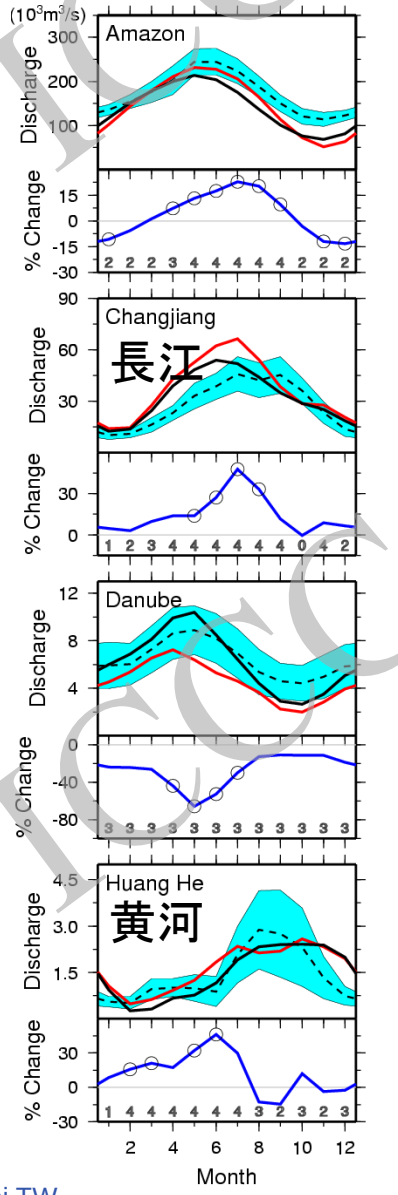
June

July

August

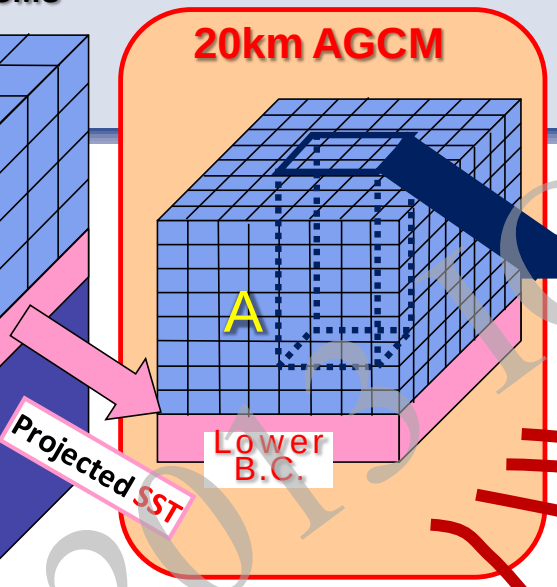
Future changes in river discharges

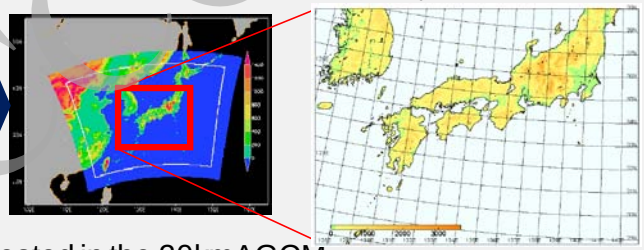




(a) Annual river discharge changes (%) in the future climate relative to the present. areas statistically significant at 95% level are colored. (b) Number of the consistent change in sign in the 4 multi-SST ensemble simulations with the 20-km mesh model. Five represent the consistent changes in the 20-km mesh model and the 4 multi-SST 60-km mesh models, while one represent the inconsistent change between the 20-km and the 4 multi-SST 60-km mesh model simulations.

CMs





Detailed Projections around Japan

will be talked by Dr. Sasaki

Impact Assessments

- Disasters
- Agriculture
- Water Resources

talked by Prof. Nakakita

Study of Future Changes in Extreme Events

- Tropical Cyclones (e.g., Murakami et al.)
  →less number, more intense
- East Asia Monsoon (e.g., Kusunoki et al.)
  →seasonal migration delayed
- Extreme Rainfall (e.g., Kamiguchi et al.)
  →more frequent
- Blockings (e.g., Matsueda et al.)
  →less frequent
- Extratropical Cyclones (e.g., Mizutai et al.)
  →less number, more intense

Regional Climate Change Projections

- Outputs provided to researchers of each region
  (Taiwan, Korea, China, Philippines, Thailand, Indonesia, Viet Nam, Bangladesh, India, Israel, Saudi Arabia, Senegal, Spain, Netherland, UK, Ireland, Denmark, Switzerland, Germany, USA, Mexico, Costa Rica, Panama, Columbia, Barbados, Belize, Bolivia, Peru, Ecuador, Brazil, Argentina, Australia, Papua New Guinea)

What we will do over the next 5 years

Four themes under the Program for Risk Information on Climate Change, **SOUSEI** (創生) program (2012 ~ 2017)

Theme C: Development of Basic Technology for Risk Information on Climate Change, led by **Izuru Takayabu@MRI**

(i) Probabilistic climate projection for risk assessment

(a) Efficient approach for climate ensemble experiment

(b) Development of statistical methodology of ensemble data on climate change

(c) Improvement in cost-efficiency of dynamical downscaling for ensemble data

(ii) A standard climate scenario production by using super high resolution models

(a) Development of quantification method for reliability and uncertainty of climate change information

(b) Downscaling of the change in future weather extremes by using high-resolution models

20-km mesh AGCM experiments in the first half

■Provision of future climate projections and lateral boundary conditions for the entire globe

- New scenarios
  CMIP3(A1B) → CMIP5(RCP8.5, RCP4.5 and +)
  (4.0℃ 2.2℃ in 36 MME mean)
- Additional outputs
  - Lateral boundary conditions for regional climate model
    * Japan region → almost the entire globe (70N-50S)
  - Additional requests from users
    * Monthly vertically integrated water vapor flux
    * 3-hr and 20-km surface runoff
    * 6-hr and 1.25º 3D outputs: 9 layers → 12 layers
- The present-day climate simulation (1979-) has already started since last October

Now integrating 1989

NCDC and other international institutions

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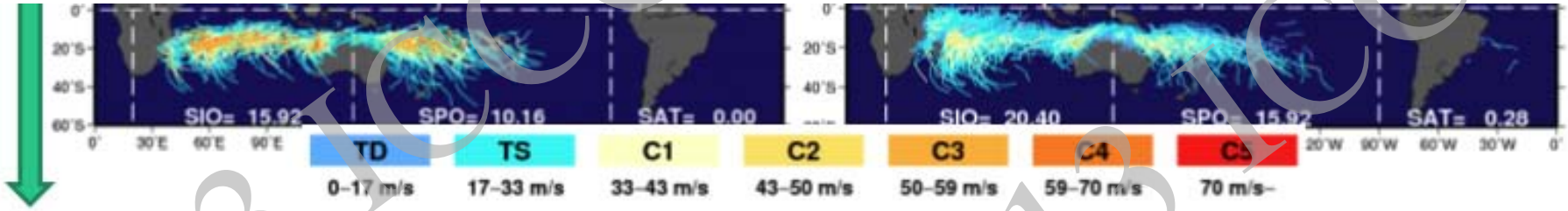
Theme D (Prof. Nakakita)

60-km mesh AGCM ensemble experiments in the first half

- Ensemble experiments to producing probabilistic projections of high frequent extremes
  - 60-km mesh AGCM is essential for reasonably producing TC and Meiyu/Baiu fronts
  - A suite of ensemble experiments:
    - Initial-condition ensemble
    - Multi-physics ensemble (cumulus schemes)
    - Projected future SST change ensemble
  - Outputs from the suite are invaluable for quantifying uncertainties in impact assessments
- Investigation of optimal ensemble experiments to producing probabilistic projections of low frequent extremes with Inst. Stat. Res. and NIED

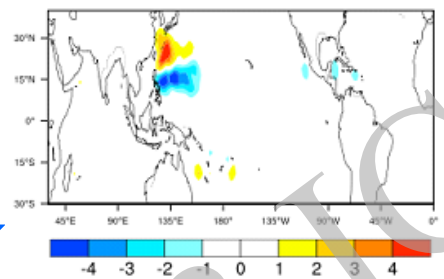
MRI-AOGCM for the second half



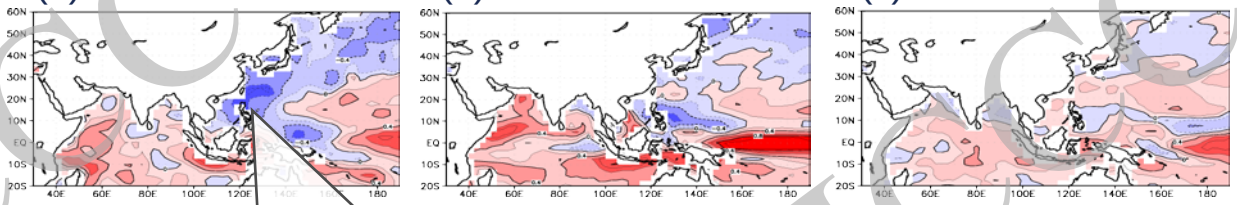
MRI-AGCM3.2 (since 2009) **Current Model** (Mizuta et al. 2012)

The model has marked biases in spatial pattern of C5 TC occurrence and fails to capture temporal correlation between SST and rainfall.

Category 5 TC



Temporal correlation between SST and rainfall for JJA



(eg. Kitoh and Arakawa 1999; Fujii et al. 2009)

60-km mesh MRI-AOGCM with restoring to prescribed SST: **under development and available in 2014**

- The same experiments as in the first half is planned.

Concluding summary

- In the past 5 years: We performed global 20-km mesh AGCM (MRI-AGCM3) simulations to project future climate changes in East Asia
  - The TC is projected to decrease in number but intensified in WNP as well as in the globe.
  - The onset of rainy season tends to delay in Japan.
- Over the next 5 years: We have already started the new program:
  - Same AGCM (3.2) with the new scenarios, RCPs for the first half.
  - AOGCM with restoration with the new scenarios for the second half.

Thank you very much for using them.

We will be very pleased if you use our outputs for your research again.