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Projection of Typhoons using high resolution MRI-AGCMs

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Outline

- The new version of MRI-AGCM
- Projection of typhoons with 20km resolution MRI-AGCMs *
- Ensemble experiments with 60km resolution MRI-AGCMs **
- Conclusions

* Murakami, H., and co-authors, 2011: Future changes in tropical cyclone activity projected by the new high-resolution MRI-AGCM. *J. Climate, in press*.

** Murakami, H., R. Mizuta, and E. Shindo, 2011: Future changes in tropical cyclone activity projected by multi-physics and multi-SST ensemble experiments using 60-km mesh MRI-AGCM. *Clim. Dyn.* In press.

History of MRI-AGCM development

MRI-AGCM3.0 (2002-2007) Original Version

Developed from JMA operational NWP model
First 20-km mesh climate model run on the Earth Simulator
Climate Change Projection for IPCC AR4 (Kyosei-project)

very minor change

MRI-AGCM3.1 (from 2007) Old version

Climate Change Projection for IPCC AR5 (KAKUSIN Program)

geographical distribution of TCs and TC intensity are insufficient

need for improvement

major change in convection scheme

MRI-AGCM3.2 (from 2009) New version

Climate Change Projection for IPCC AR5 (KAKUSHIN Program)

Comparisons between v3.1 and v3.2 MRI-AGCMs

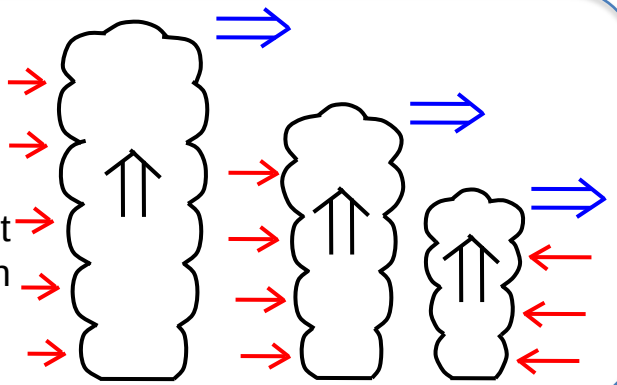
Old version **New version**

	MRI-AGCM 3.1 (Mizuta et al. 2006, *JMSJ*)	MRI-AGCM 3.2 (Mizuta et al., 2011, submitted)
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 Arakara-Schubert	Yoshimura (Tiedtke-based)
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	

New Convection Scheme

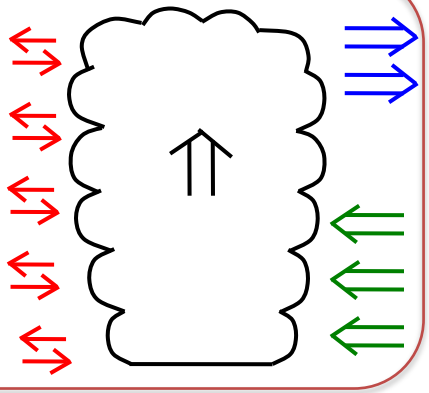
Arakawa-Schubert

Multiple convective updrafts with different heights depending on entrainment rates explicitly calculated



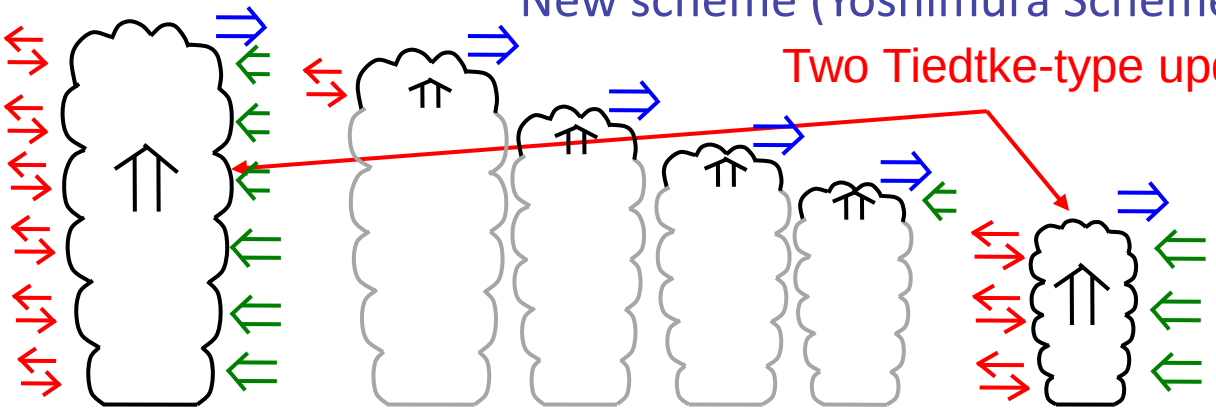
Tiedtke

Only a single convective updraft but represented as a more derailed entraining and detraining plume



New scheme (Yoshimura Scheme; Yukimoto et al. 2011)

Two Tiedtke-type updrafts are callculated



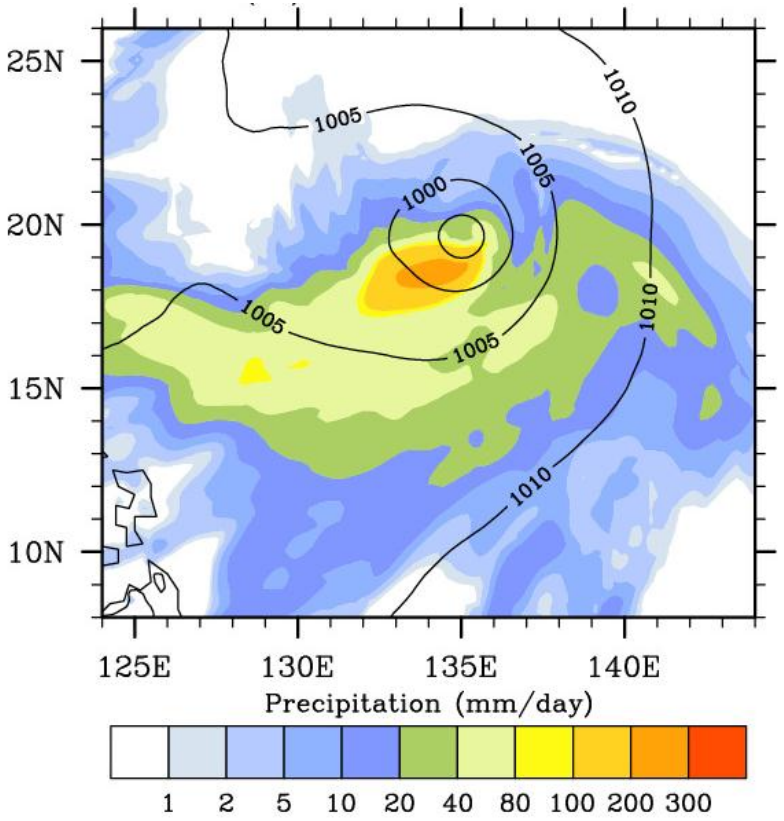
Updrafts between min. and max. rates are assumed to be continuously present.

Temperature, water vapor mixing ratio, entrainment rate etc. are obtained by linear interpolation between the two.

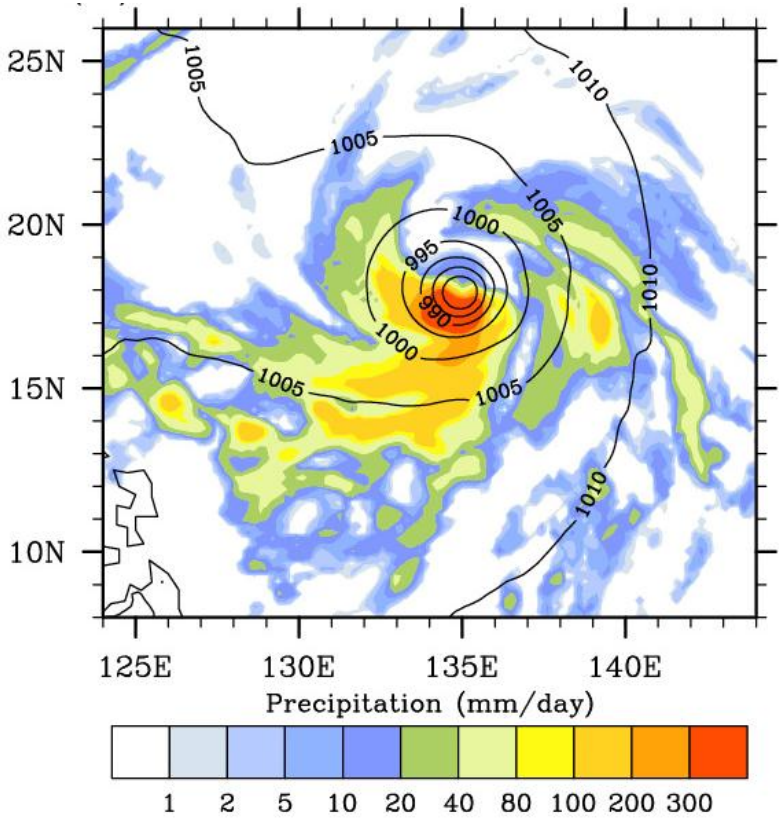
→ Multiple updrafts with different heights are represented.

Precipitation around TC

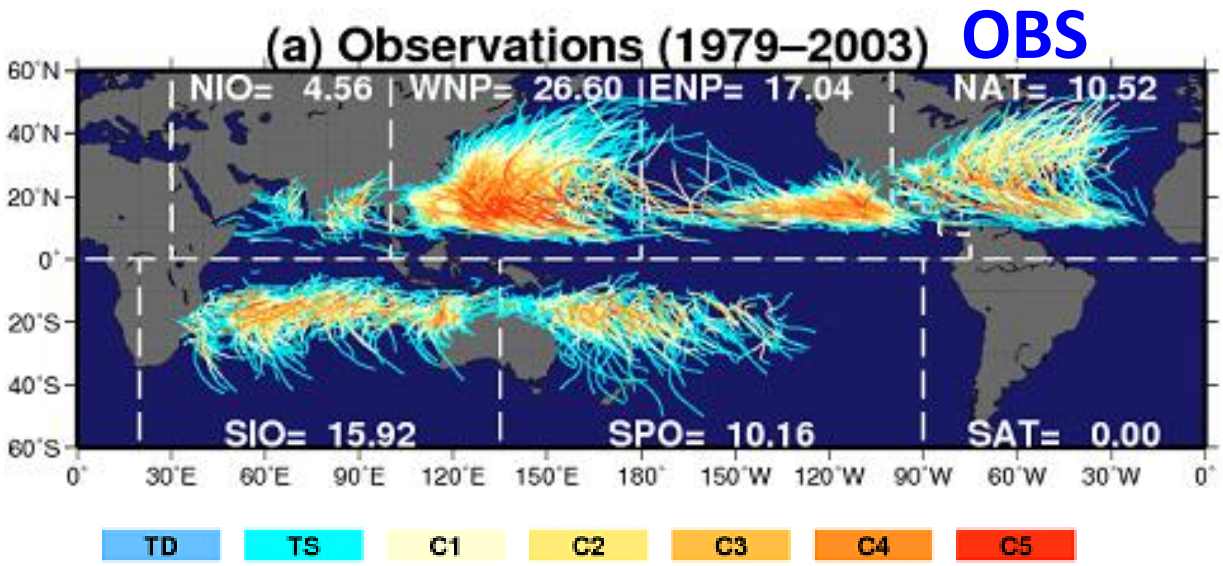
Old version



New version

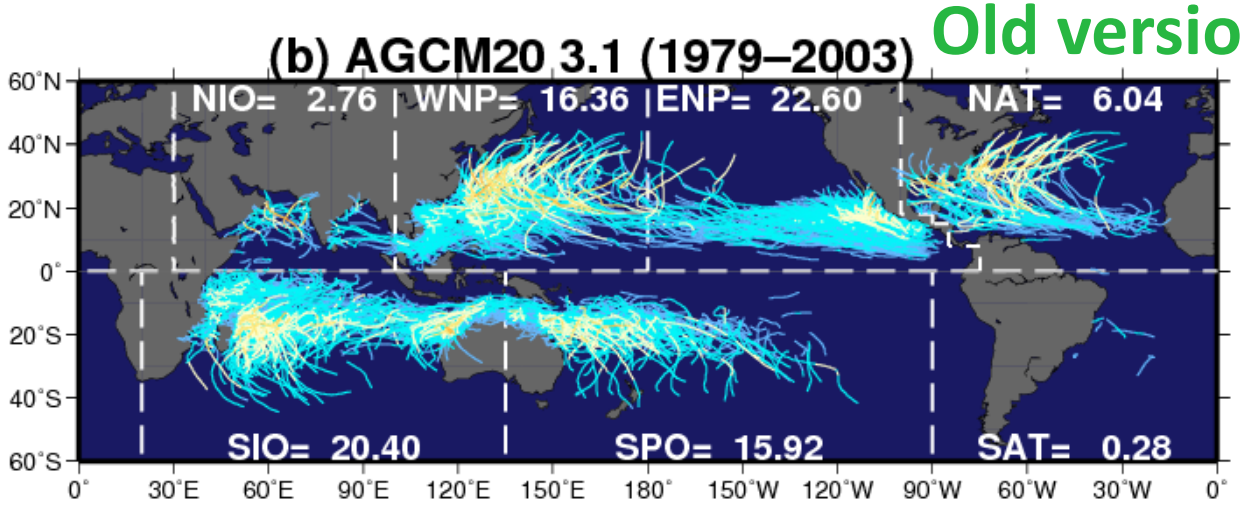


Present TC Tracks in Old Version of the new 20-km mesh MRI-AGCM



The number for each basin show the annual mean number of TCs

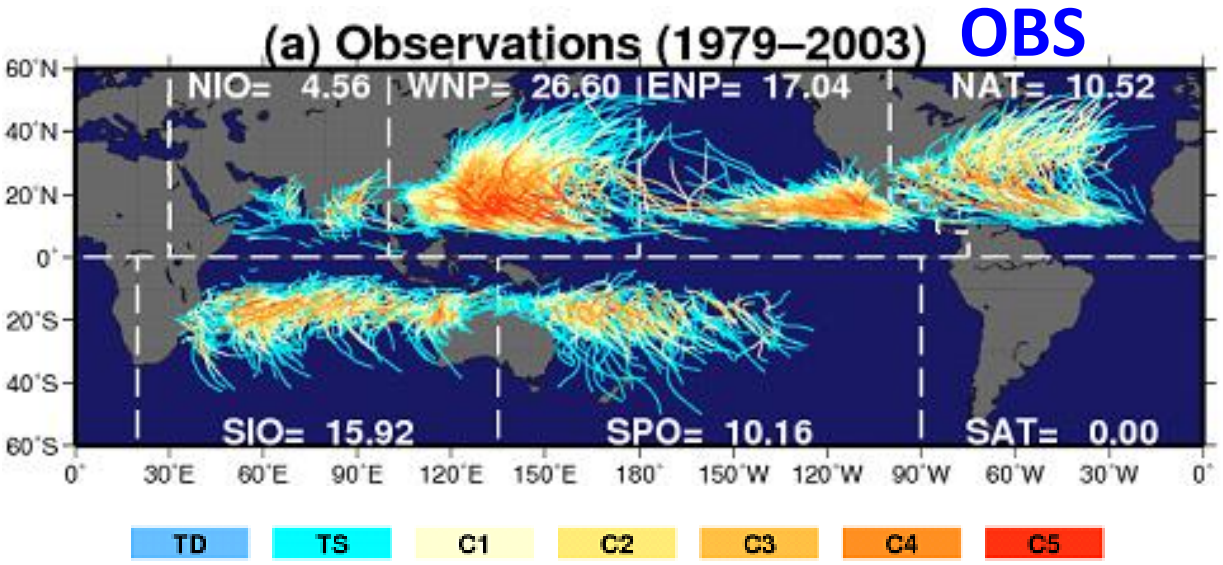
Color indicates TC intensity category



TC intensity is weak

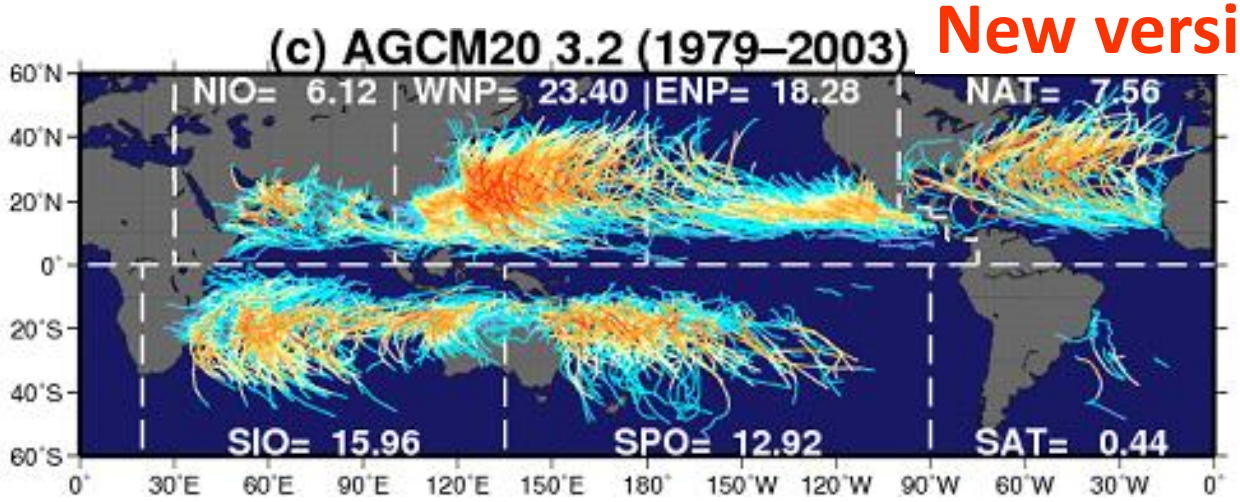
WNP TC number is underestimated

Present TC Tracks in New Version of the new 20-km mesh MRI-AGCM



The number for each basin show the annual mean number of TCs

Color indicates TC intensity category



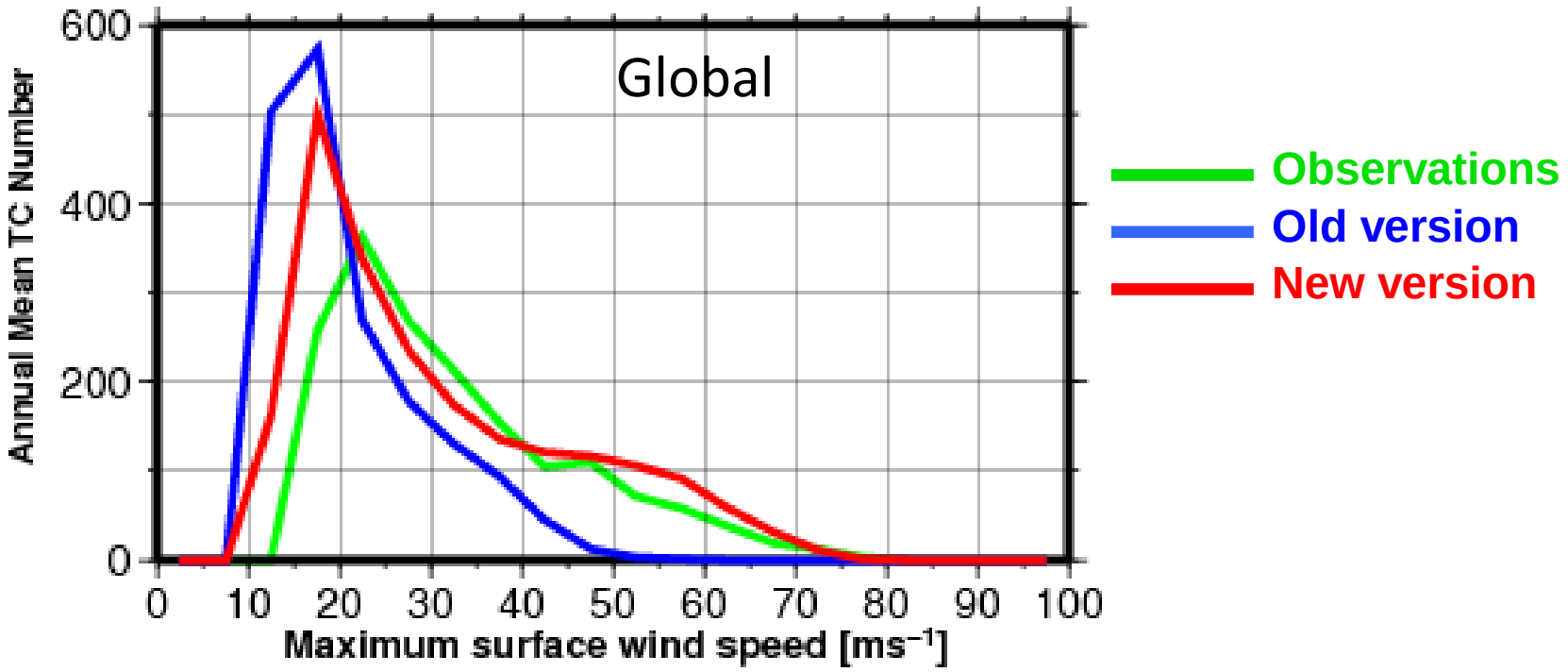
TC intensity is realistic

C5 TCs are simulated

WNP TC number is increased

Comparison of TC intensity between the two versions

Annual mean frequency of TC max wind



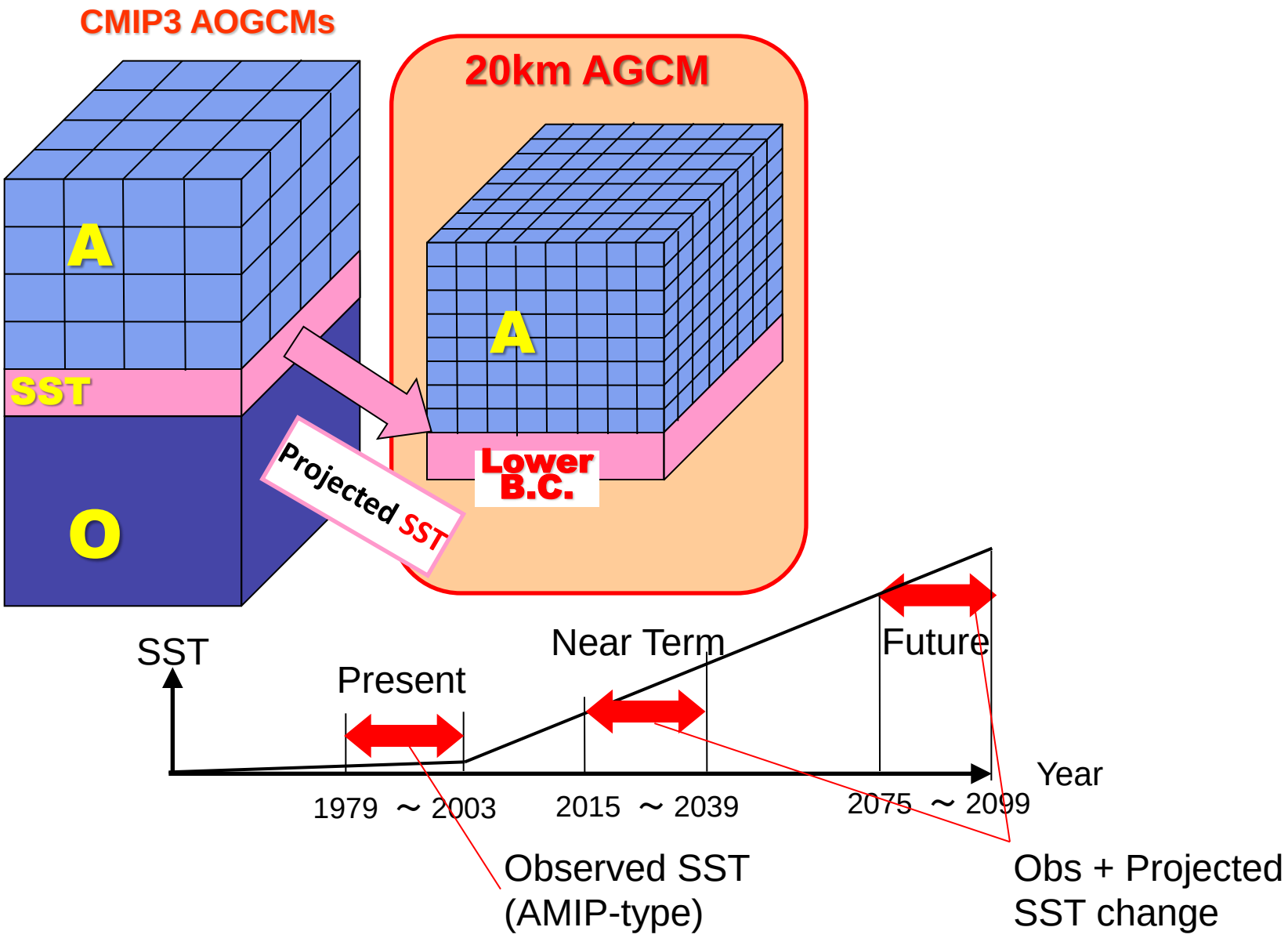
· TC intensity is substantially improved in the new version

. Too many TC with max wind weaker than 20m/s.

Projection of Typhoons with 20km resolution MRI-AGCMs

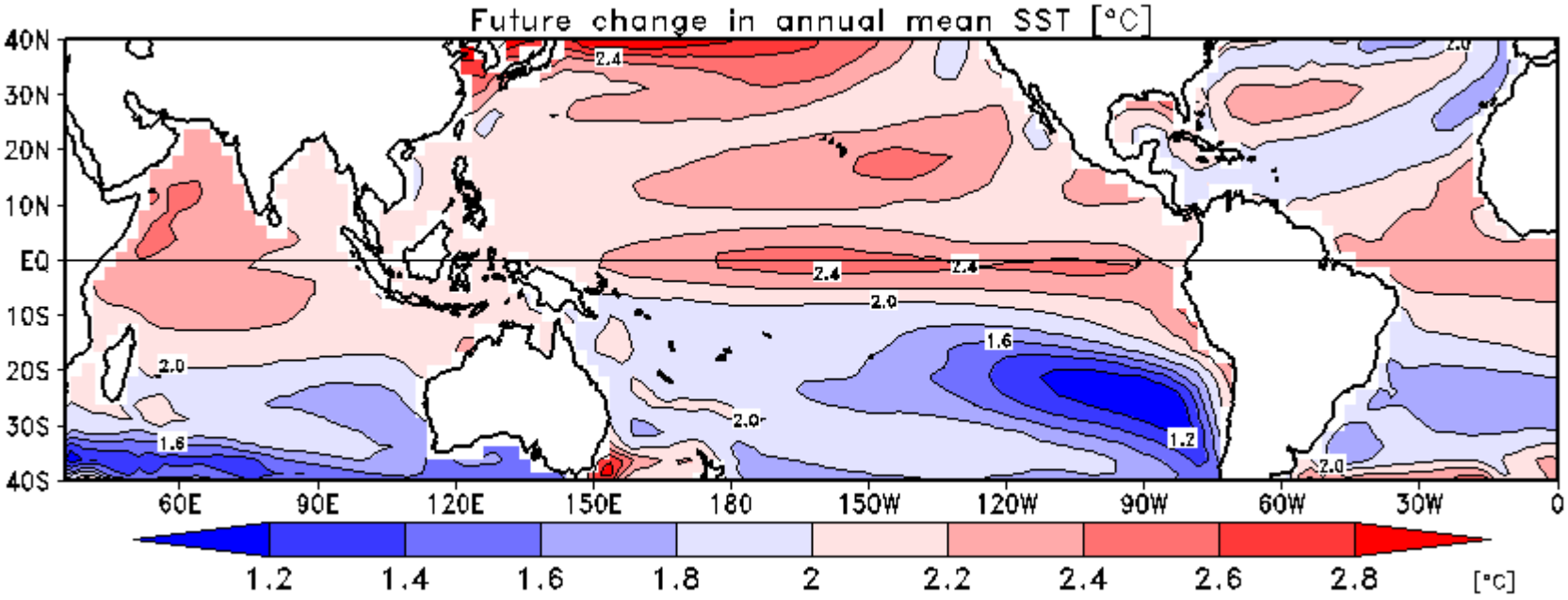
Murakami, H., and co-authors, 2011: Future changes in tropical cyclone activity projected by the new high-resolution MRI-AGCM. *J. Climate, in press*.

Time-slice Experiment



Spatial pattern of prescribed future changes in SST

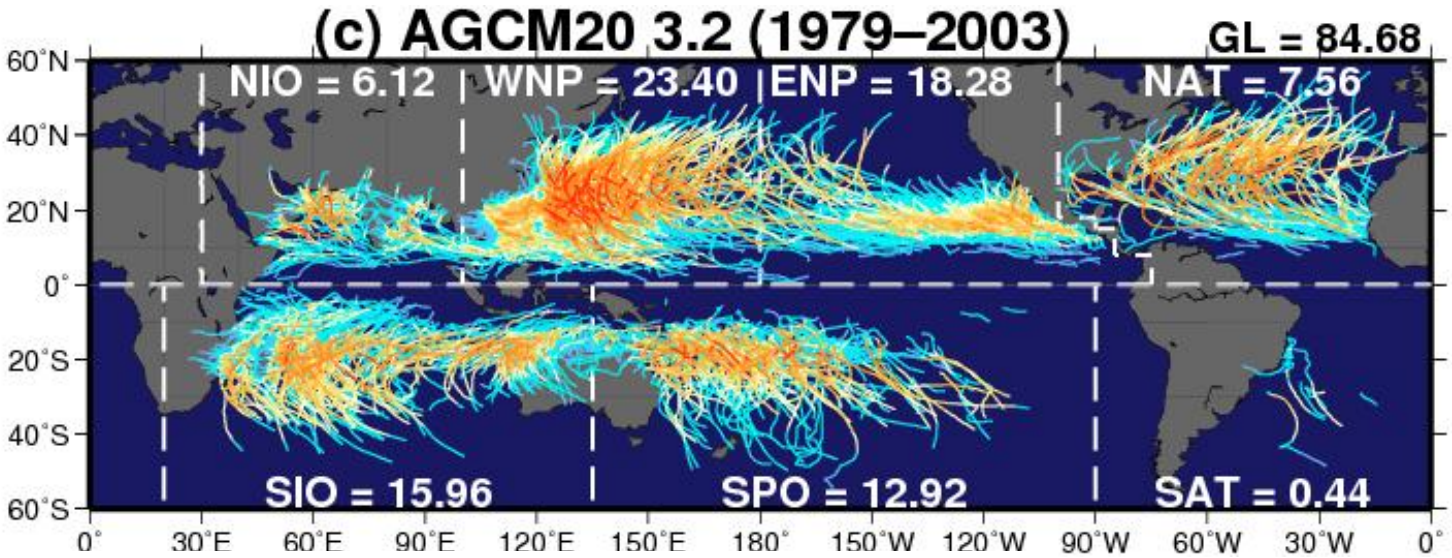
21st (2075–2099) – Present (1979–2003)



- Tropical mean SST anomaly is 2. 06˚C.
- Relatively larger increase in SST in the NH than in the SH.
- The SST increase is the largest in the tropical CP. (Xie et al. 2010).

Present and future TC Tracks in new version of 20km MR-AGCMs

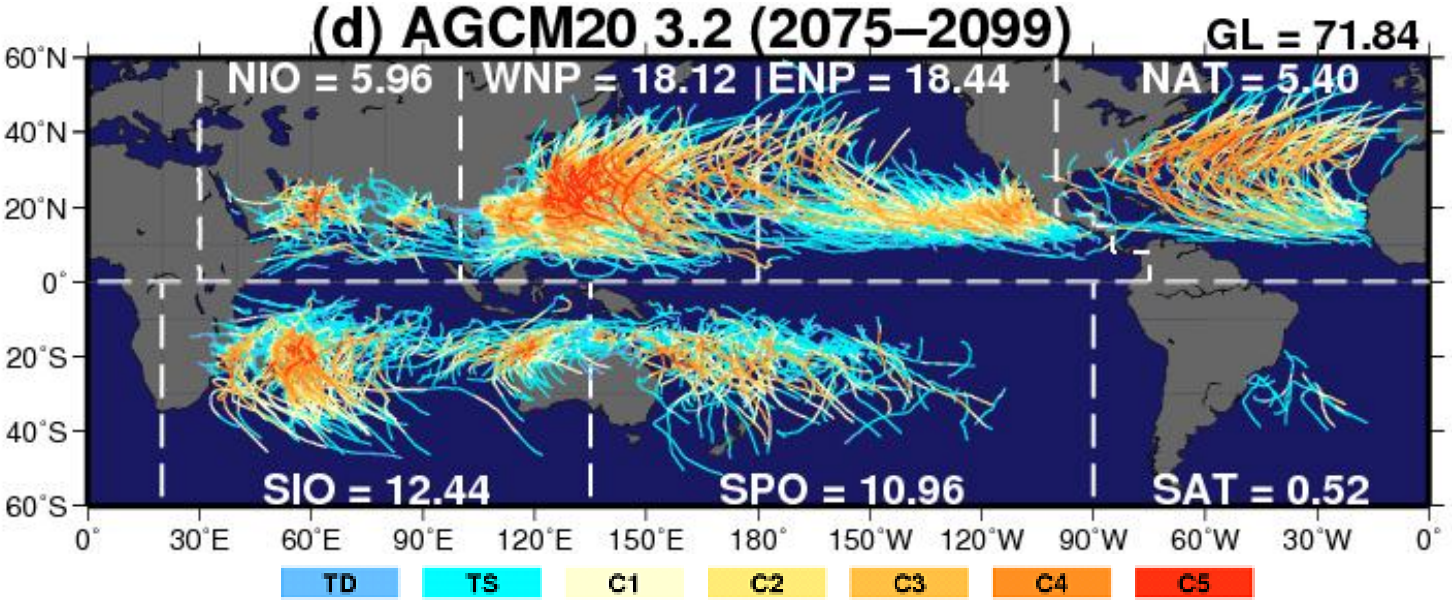
Present-day (1979-2003)



Statistically significant decrease

GL	-15%
NH	-14%
SH	-18%
WNP	-23%
NAT	-29%
SIO	-23%

Future (2075-2099



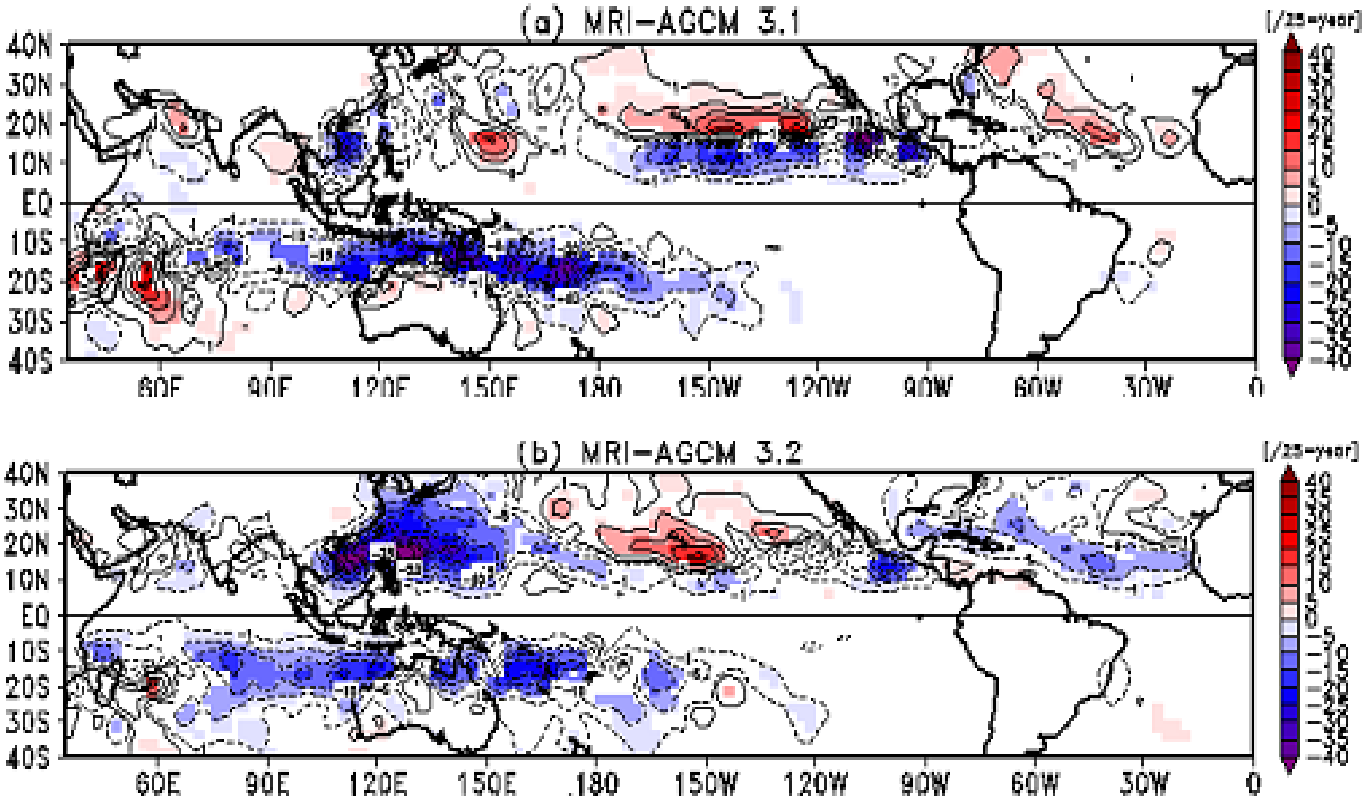
Not statistically significant change

NIO	-2%
ENP	+0.5%
SPO	-15%

Projected changes in TC frequency of occurrence (TCF)

Old version

New version



- Regional change in TC frequency in the two versions is considerably different, although the same SST anomaly is used.
- In both version, overall decrease and increase in the CNP.
- In the old version , increase in the eastern part of NAT and NWP and western part of SIO.

Projected future changes in TC intensity

Present 25year (1979-2003)

Future 25year (2075-2099)

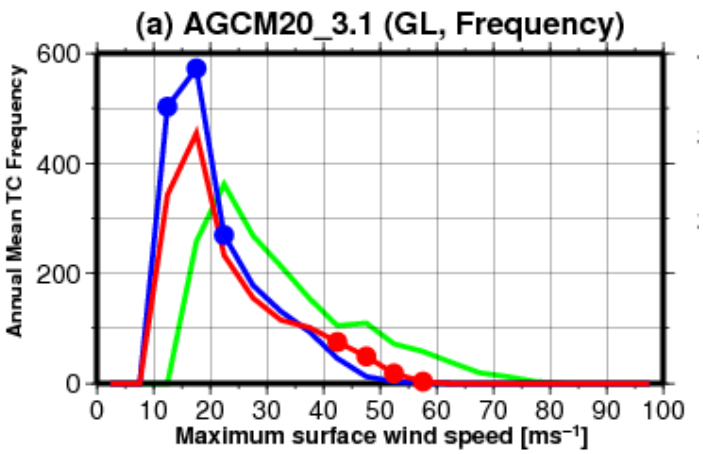
Observation 25year (1979-2003)

● : significant increase at 95% level

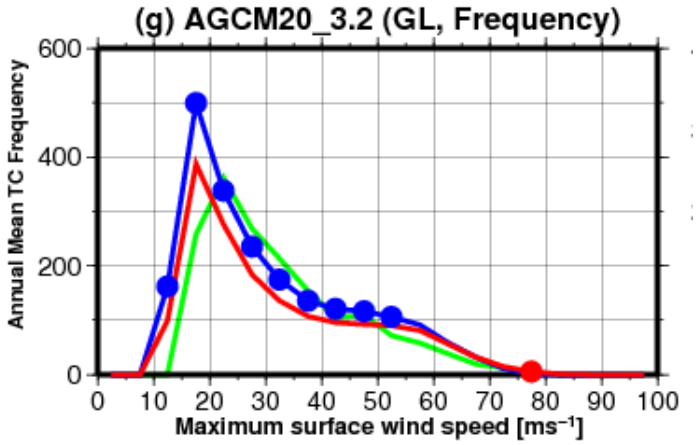
● : significant decrease at 95% level

Global frequency of TC max wind

Old version



New version

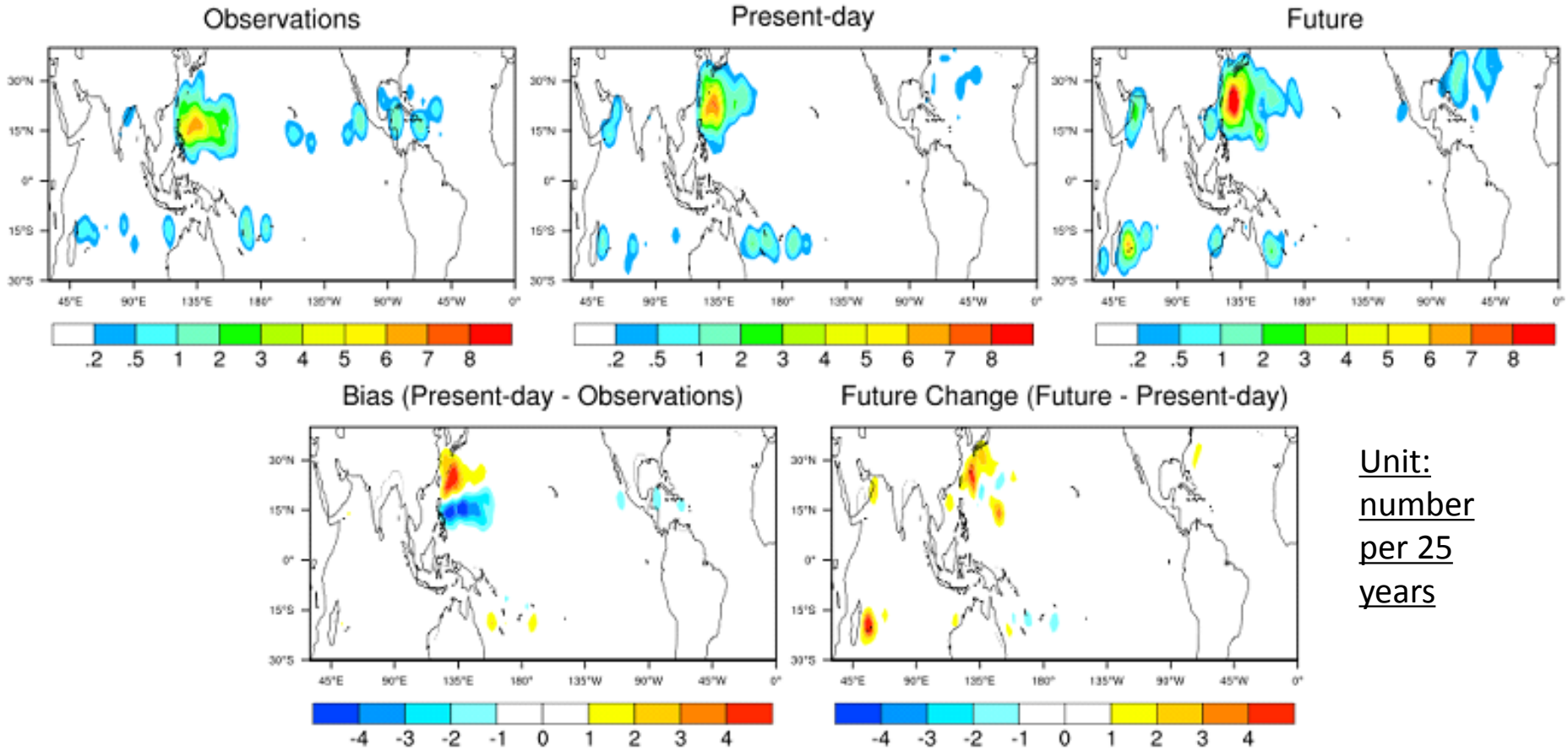


·Both versions show significant decrease in the frequency of weak TCs.

·Old version projects significant increase in the frequency of intense TCs.

· New version projects subtle increase in the frequency of intense TCs.

Spatial distribution of TCF for Category 5 TCs



Unit: number per 25 years

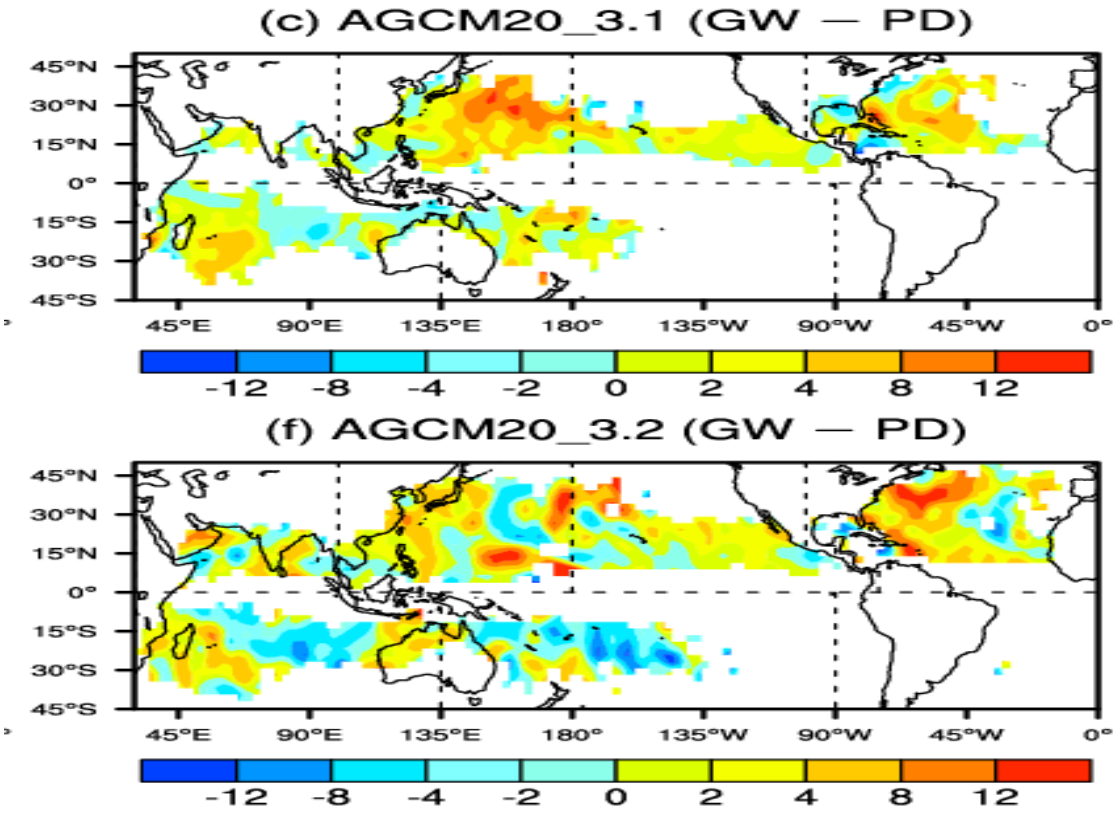
· The frequency of C5 TCs appears to increase in the northern portion of the WNP basin.

· As there is a large northward shift bias of C5 typhoons in NWP, the increase in the frequency of C5 typhoons around Japan and Taiwan is likely to be overestimated.

Spatial distribution of mean TCI change [m/s]

Old version

New version



- Regional change in TC frequency in the two versions is considerably different, although the same SST anomaly is used.
- Old version shows a large increase in TC intensity at the eastern WNP, while new version shows a large increase in NAT and large decrease in SPO.
- Both versions show a substantial increase in mean intensity of typhoons approaching Japan and Taiwan.

Ensemble experiment with 60km MRI-AGCMs

Murakami, H., R. Mizuta, and E. Shindo, 2011: Future changes in tropical cyclone activity projected by multi-physics and multi-SST ensemble experiments using 60-km mesh MRI-AGCM. *Clim. Dyn.* In press.

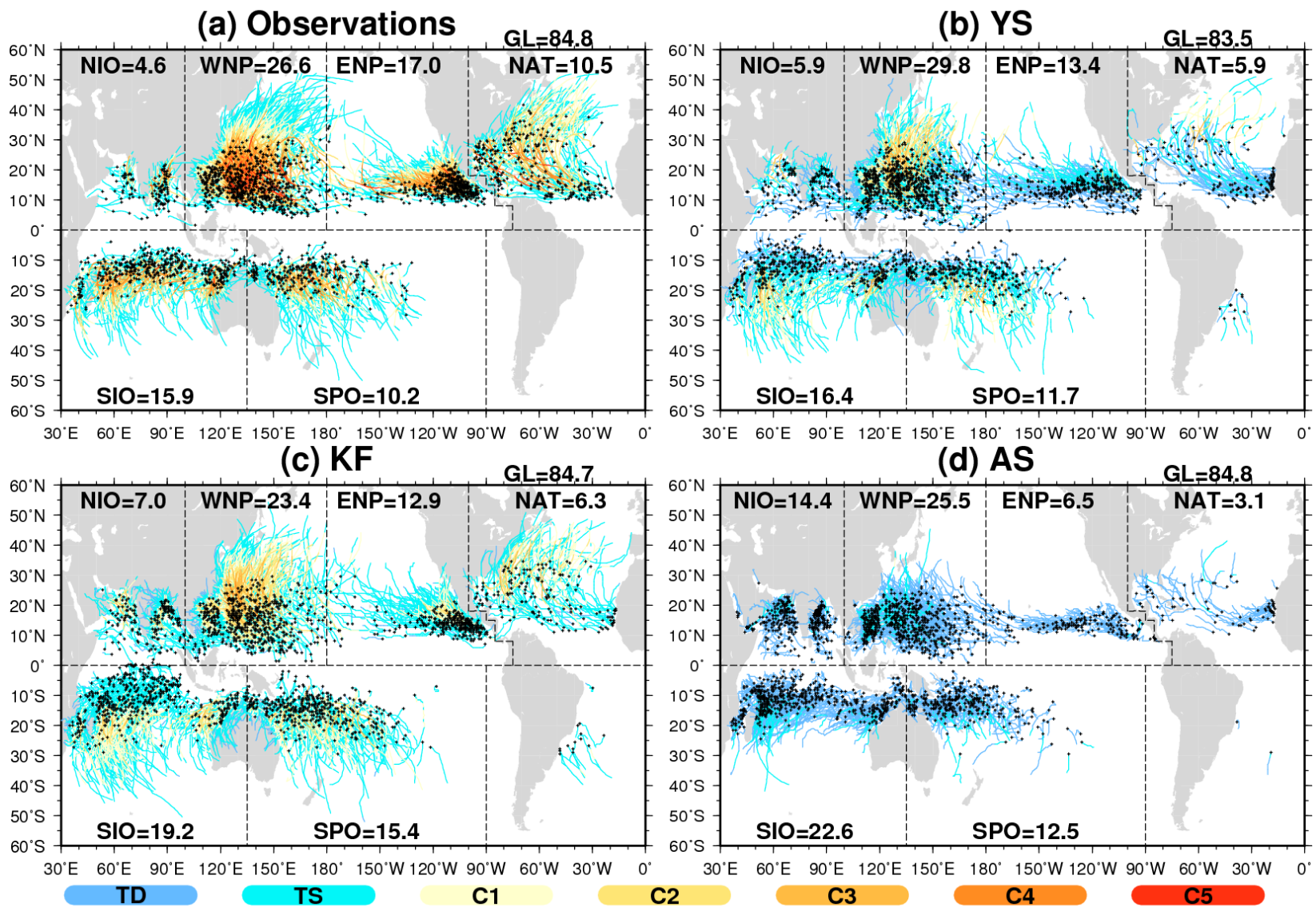
Multi-model & Multi-SST Ensemble Experiments using 60-km-mesh model

3 (cumulus) ×4 (SST) = 12 ensemble experiments

	YS scheme	KF scheme	AS scheme	Model Ensemble
CMIP3 Mean SST	Y0	K0	A0	CMIP3 SST
Cluster1 SST	Y1	K1	A1	Cluster1 SST
Cluster2 SST	Y2	K2	A2	Cluster2 SST
Cluster SST	Y3	K3	A3	Cluster3 SST
SST Ensemble	YS	KF	AS	

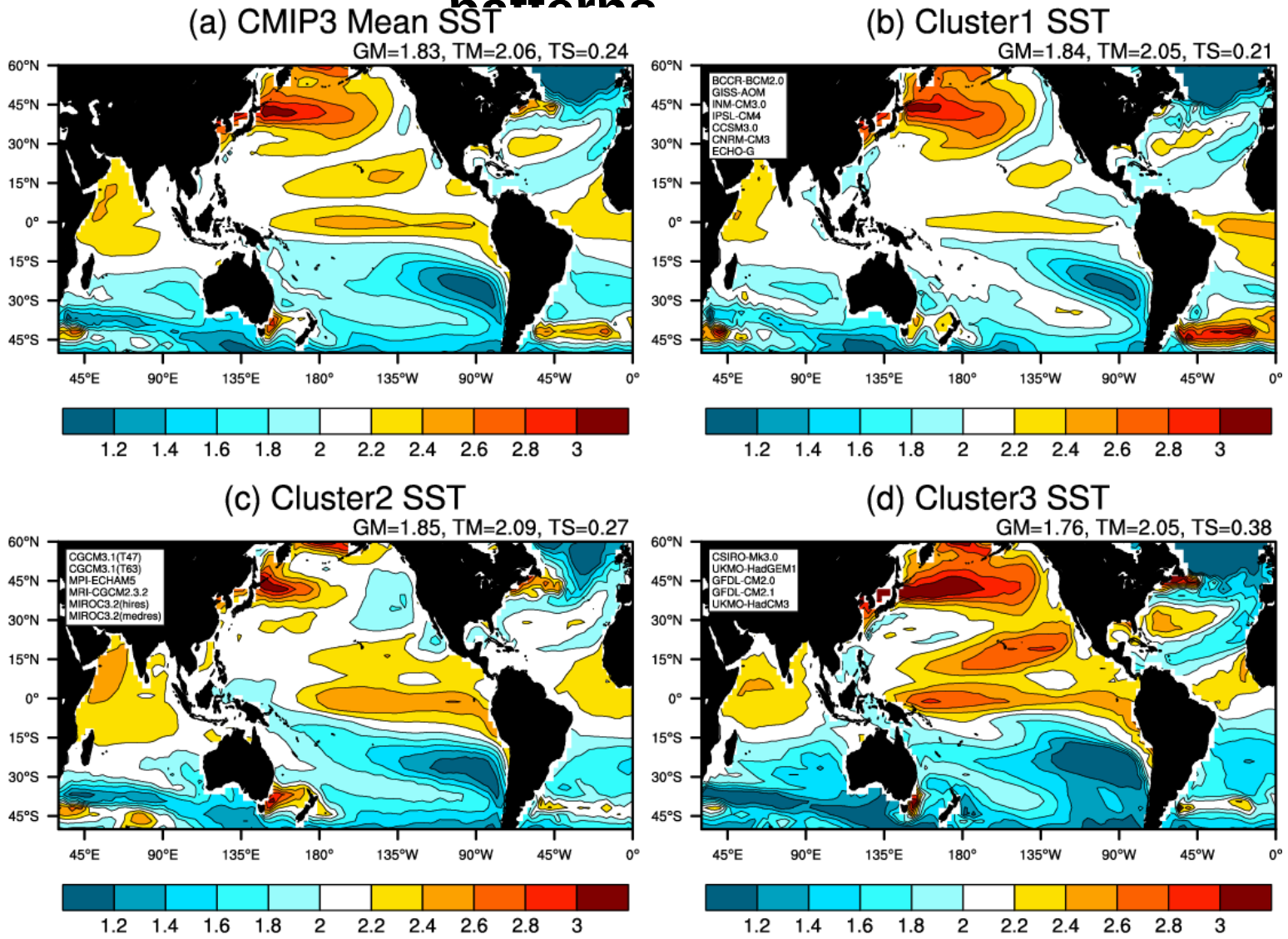
YS scheme: Yoshimura scheme
KF scheme : Kain-Fritsch scheme
AS scheme Arakawa-Schubert scheme
CMIP3 Mean: 18 CMIP3 models ensemble mean

Present -day simulations of TC with 3 convection schemes



The YS and KF simulates reasonable TC global distribution, whereas AS has pronounced biases.

4 SST anomaly patterns

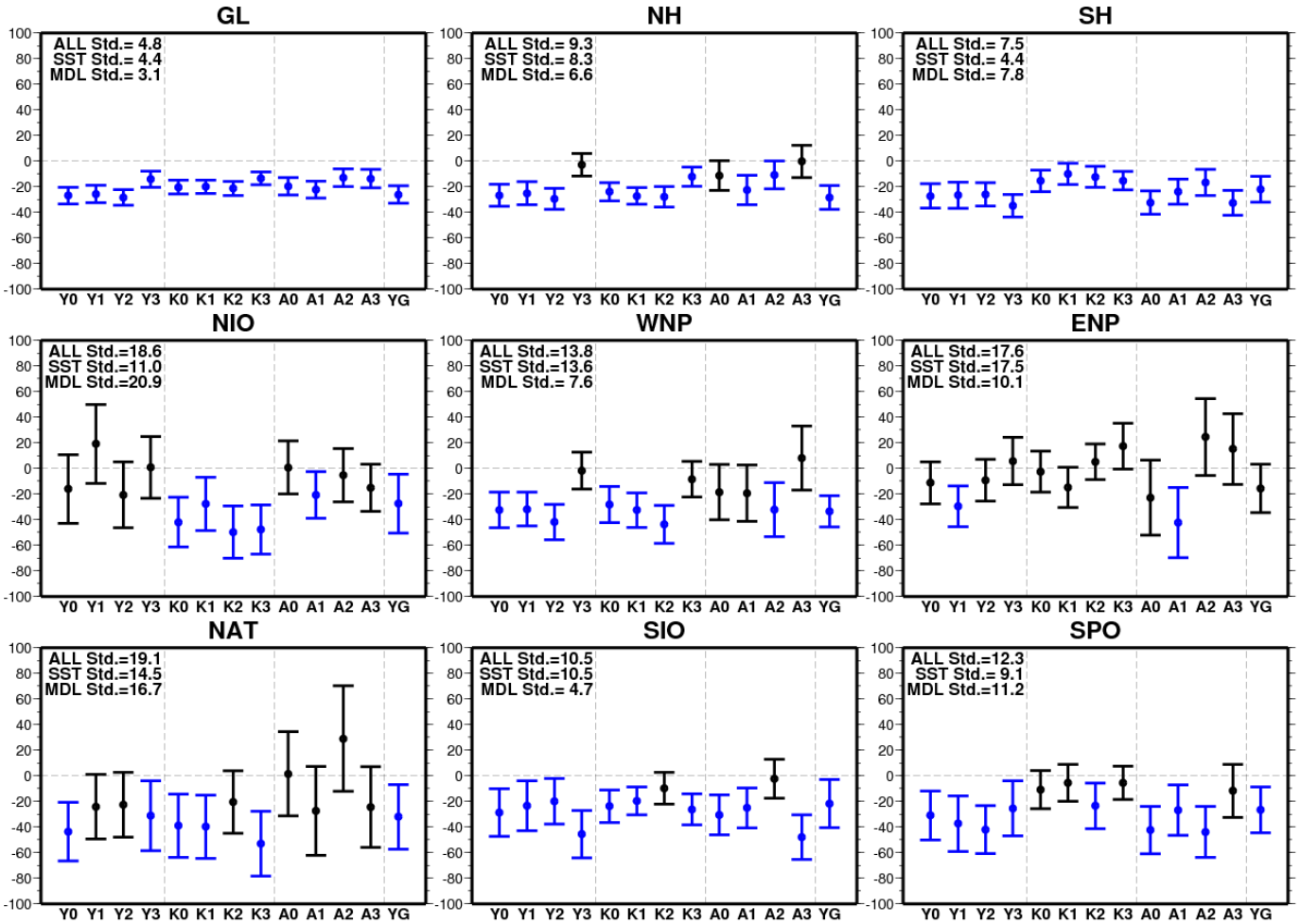


Cluster 1 shows small spatial variance in tropics, while Cluster 3 SST shows large spatial variance in tropics.

Future changes in TC Genesis Frequency (TGF) [%]

Y: Yoshimura, K:Kain-Fritsch, A: Arakawa Shubert

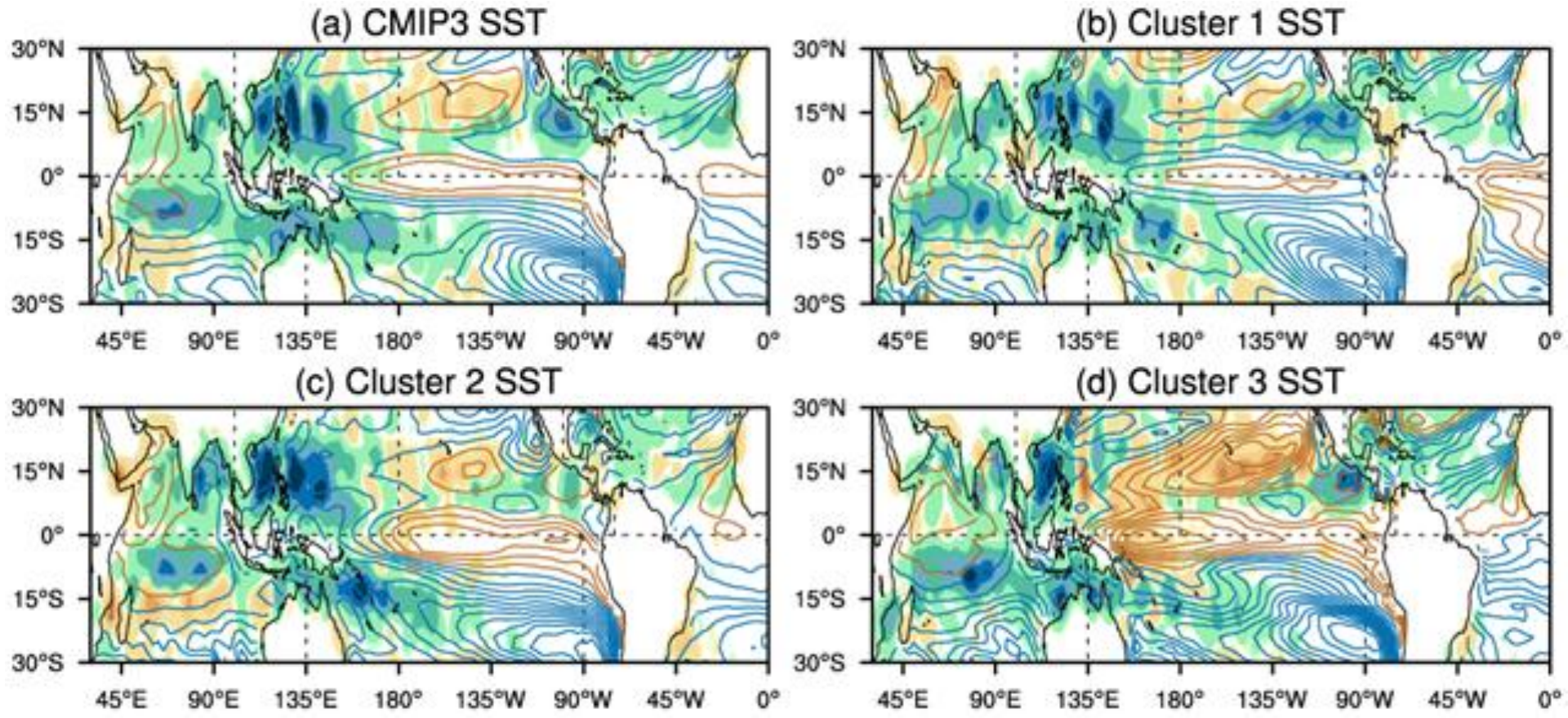
0: CMIP3 mean SST, 1:Cluster 1, 2:Cluster 2, 3: Cluster 3, G: Global uniform



Small uncertainty in the GL, NH, SH scale reduction of TC number

Large uncertainty in the ocean basin scale changes in TC number

Future changes in TGF for 4 SST patterns



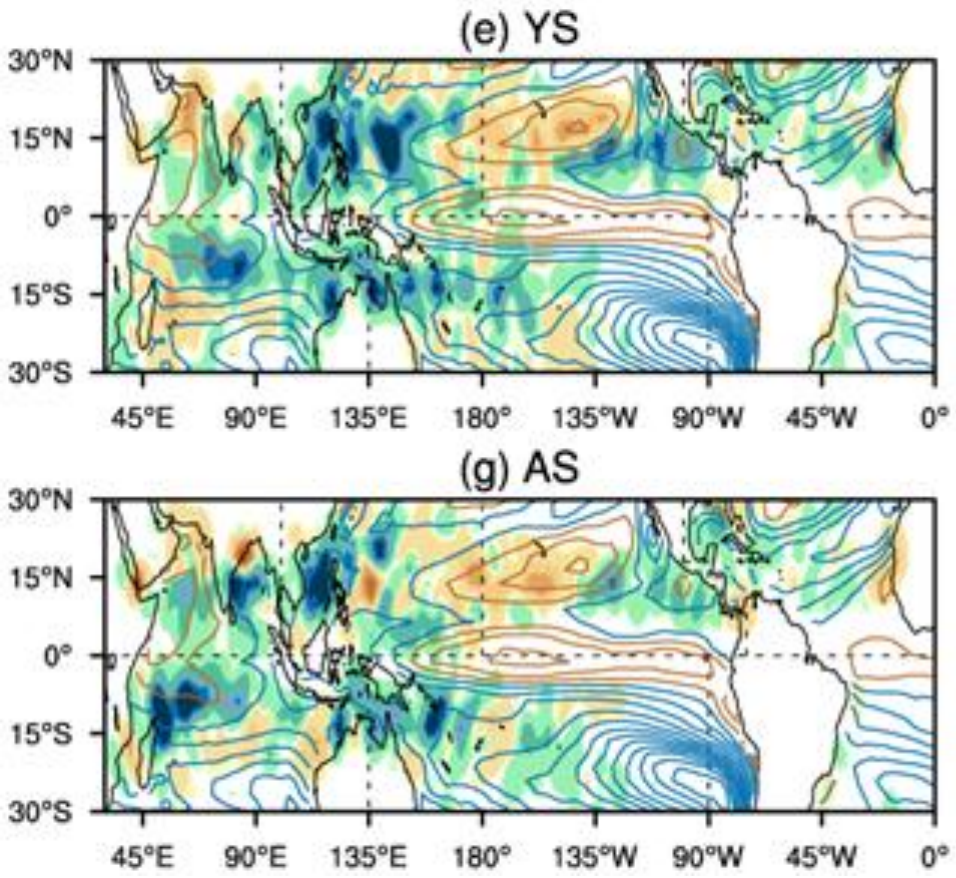
Shading : Future changes in TGF number/25-year]

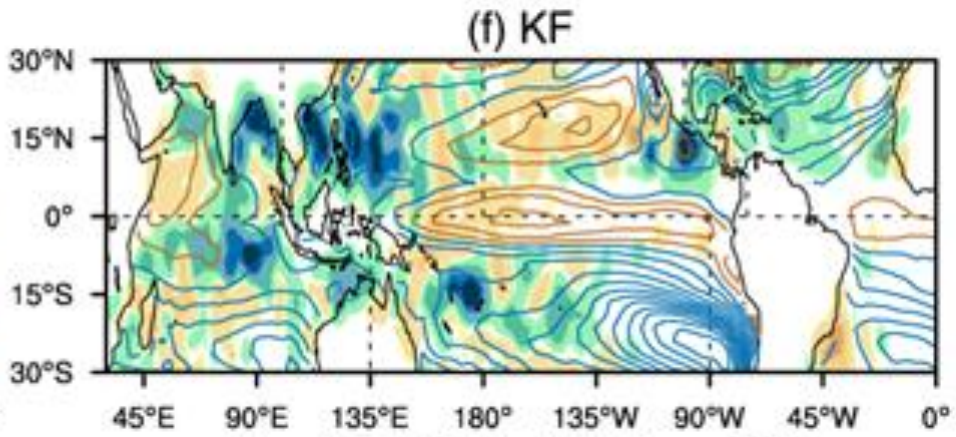
Contours: SST anomaly [K] relative to tropical (30°S–30°N) mean.

There are substantial differences among the changes in TGF for 4 SST patterns.

SST is the major source of uncertainty.

Future changes in TGF for 3 convection schemes





The changes in TGF for 3 convection schemes are similar to each other.

Uncertainty from convection scheme ≪ Uncertainty from SST

Conclusions

- In the MRI-AGCM with new convection scheme, intensity and distribution of the simulated TCs are substantially improved, although some biases remain. Category 5 TCs are simulated in the new model.
- The 20km resolution MRI-AGCMs projects that the number of typhoons will decrease but mean intensity of typhoons approaching Japan and Taiwan may increase.
- Ensemble experiments with 60km resolution MRI-AGCMs show large uncertainties in the projection of regional TC changes. The major source of uncertainty is the uncertainty of projected SST.
- Continuing effort for further improvement of the model and more ensemble experiments are needed to reduce the uncertainty and model biases.