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# Future Changes in mean and extreme precipitation projected by 20-km and 60-km mesh MRI-AGCM ensemble simulations

## extreme precipitation and tropical cyclones (TCs)

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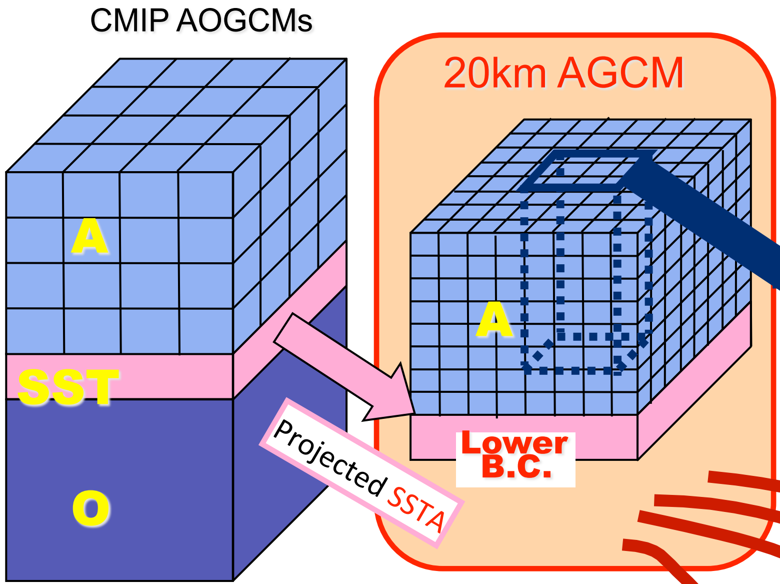
TOUGOU Integrated Research Program for Advancing Climate Models

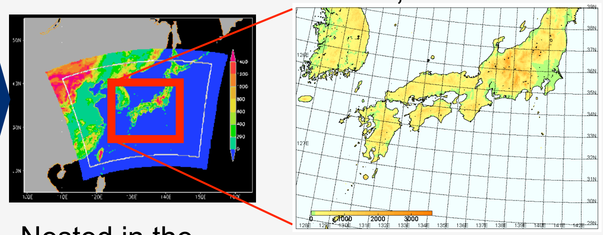
JMBSC

# MRI-AGCM (60km, 20km) + NHRCM (5km, 2km)




Regional Climate Model

**Dynamical Downscaling by RCM**




## Impact Assessments

- Disasters
- Agriculture
- Water Resources

## Study of Future Change in Extreme Events

- Tropical Cyclones (e.g. Oouchi et al., 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. Mizuta et al.)

## Regional Climate Change

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

Kitoh, Ose and Takayabu (2016 JMSJ)

# History of MRI-AGCM3

**MRI-AGCM3.0 (before 2007) (Mizuta et al. 2006; Oouchi et al. 2006)**

**developed from JMA operational NWP model**

**first 20km climate model which simulates for multi-decades**

↓ very minor change

**MRI-AGCM3.1 (since 2007) (Kitoh et al. 2009; Murakami et al. 2011)**

**AMIP-type experiment**

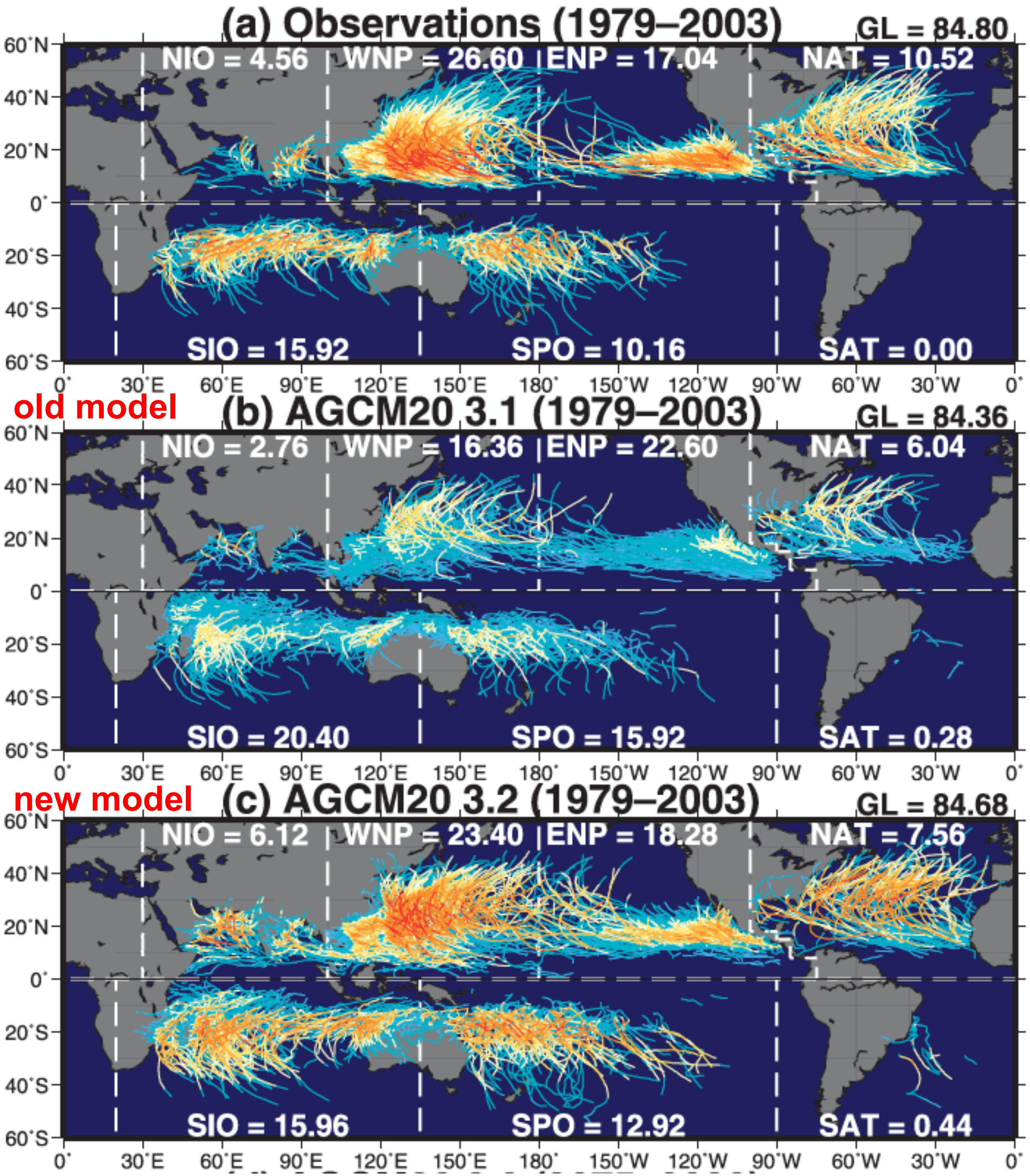
↓ introducing new parameterization schemes etc.

**MRI-AGCM3.2 (current model) (Mizuta et al. 2012)**

Reductions of the model biases of:
- insufficient precipitation amounts over the W. Pacific
- geographical distribution of tropical cyclones
- overestimated weak rain, underestimated heavy rain
- resolution dependence in terms of global-scale climate

→ Ensemble simulations with lower-resolution version

# Tropical cyclone (TC)




- Simulated TC number in the WNP is underestimated
- TC intensity is weak compared with observations

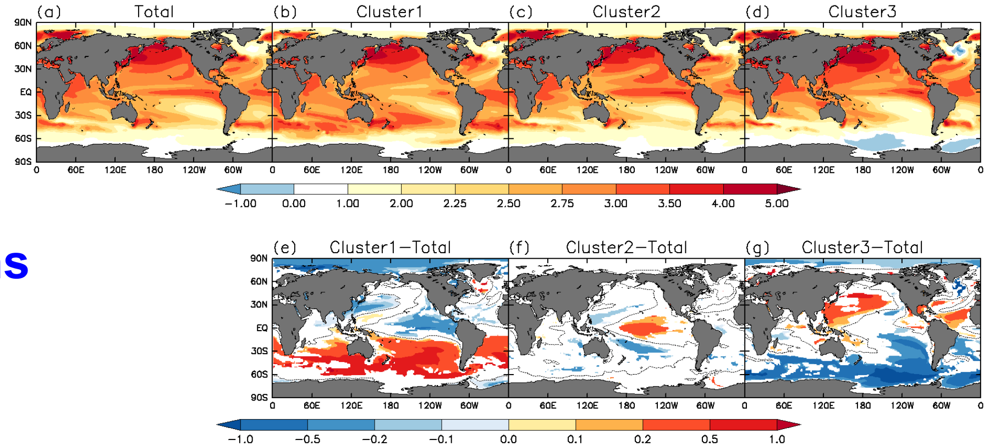
**Model development**

improved

Murakami et al. (2012)

# MRI-AGCM3.2 experiment design

- **20km-mesh AGCM: 4 projections**
  - **4 different ΔSST patterns**



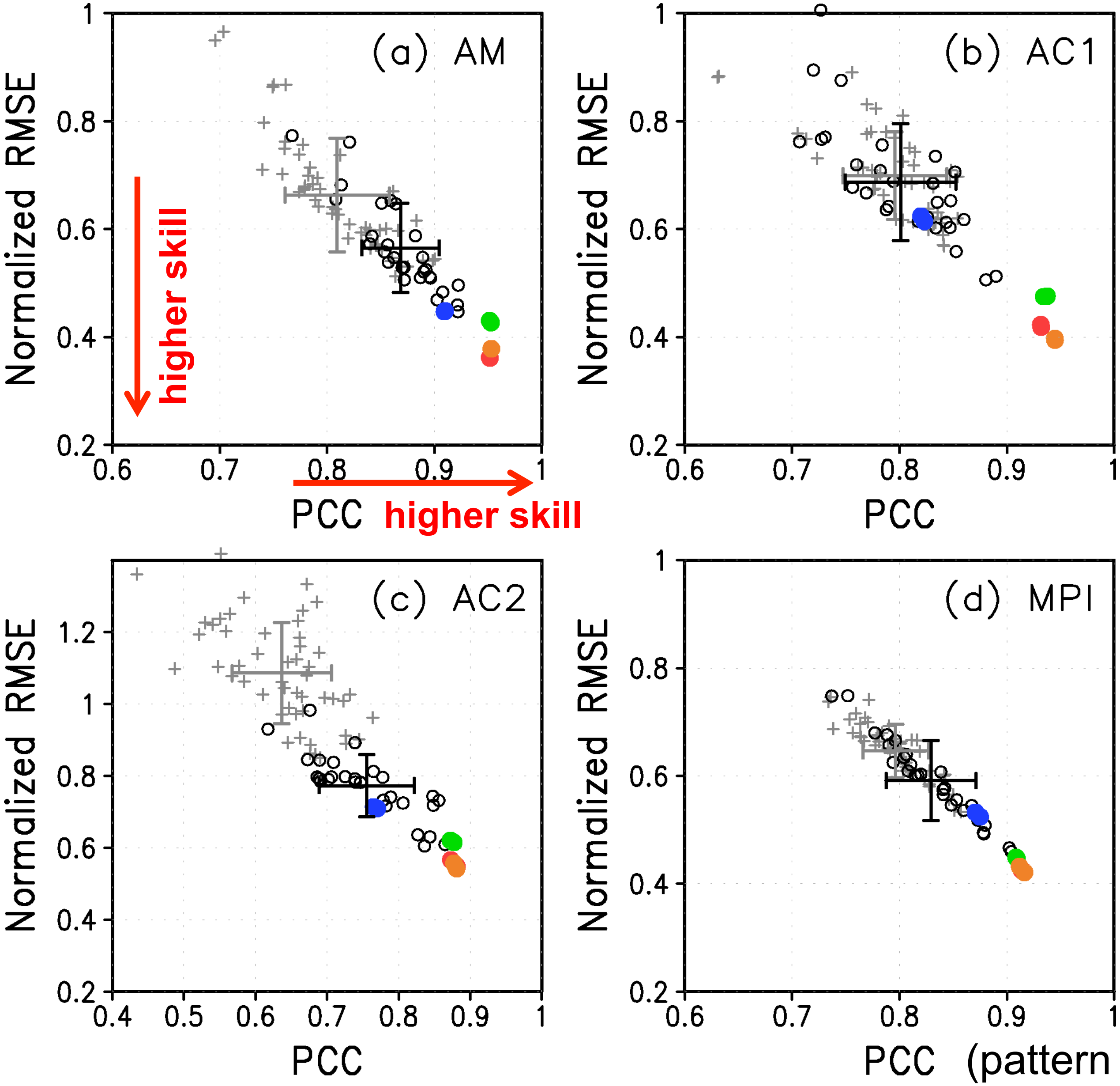

- **60km mesh AGCMs: 12 projections**
  - **4 different ΔSST patterns**
  - **3 different cumulus schemes**

ΔSST: based on CMIP5-AOGCM projections (RCP8.5 scenario) (Mizuta et al. 2014)

| Duration | SST | Cumulus convection scheme | | | |
|---|---|---|---|---|---|
| | | Yoshimura (YS) | | Arakawa-Schubert (AS) | Kain-Fritsch (KF) |
| Present 1984-2003 | Observation | SPA<br>SPA_m01 | HPA<br>HPA_m02 | HPA_as<br>HPA_as_m02 | HPA_kf<br>HPA_kf_m02 |
| Future 2080-2099 | All | SFA_rcp85 | HFA_rcp85 | HFA_as_rcp85 | HFA_kf_rcp85 |
| | Cluster 1 | SFA_rcp85_c1 | HFA_rcp85_c1 | HFA_as_rcp85_c1 | HFA_kf_rcp85_c1 |
| | Cluster 2 | SFA_rcp85_c2 | HFA_rcp85_c2 | HFA_as_rcp85_c2 | HFA_kf_rcp85_c2 |
| | Cluster 3 | SFA_rcp85_c3 | HFA_rcp85_c3 | HFA_as_rcp85_c3 | HFA_kf_rcp85_c3 |

**20km** **60km**

# Performance of global-scale monsoon precipitation




**Monsoon metrics**

(B. Wang et al. 2011)

**AM**: annual mean

**AC1**: summer − winter

**AC2**: spring − autumn

**MPI**: seasonal difference divided by ann. mean

Area: 45S-45N

Ref.: (GPCP+CMAP)/2

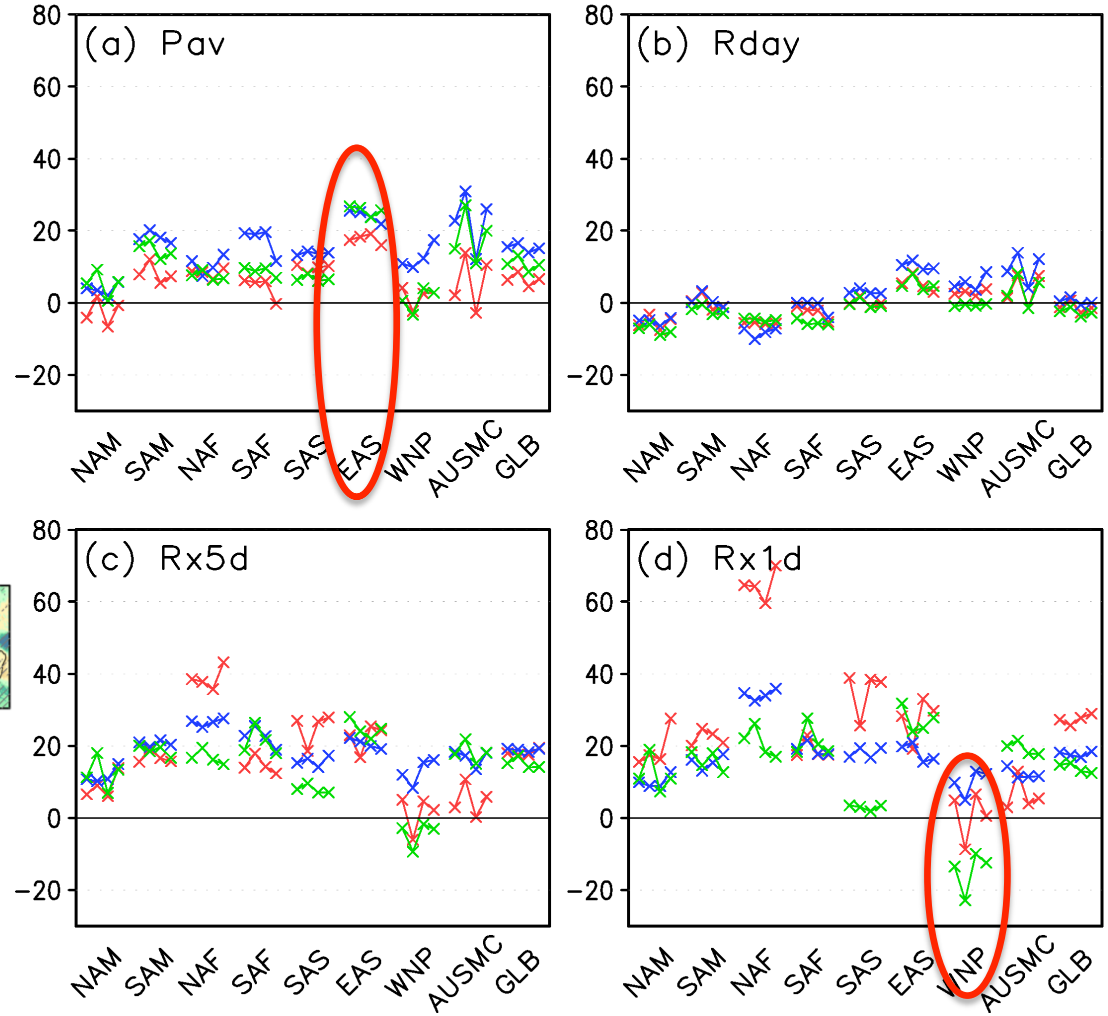
- 20kmYS
- 60kmYS
- 60kmAS
- 60kmKF
- CMIP5 AGCMs
- CMIP5 AOGCMs

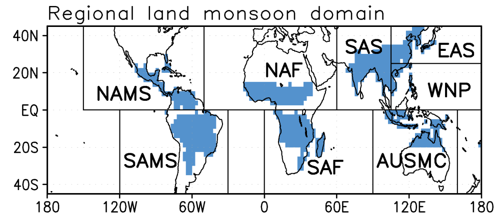
# Future percentage changes in precipitation indices over the land monsoon regions

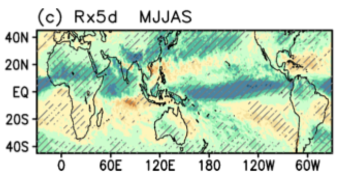
[%]

increase ↑

decrease ↓




**Pav** summer precipitation

**Rday** number of days with precipitation > 1mm

**Rx5d** summer maximum 5-day precipitation total

**Rx1d** summer maximum 1-day precipitation total

× **YS60**

× **AS60**

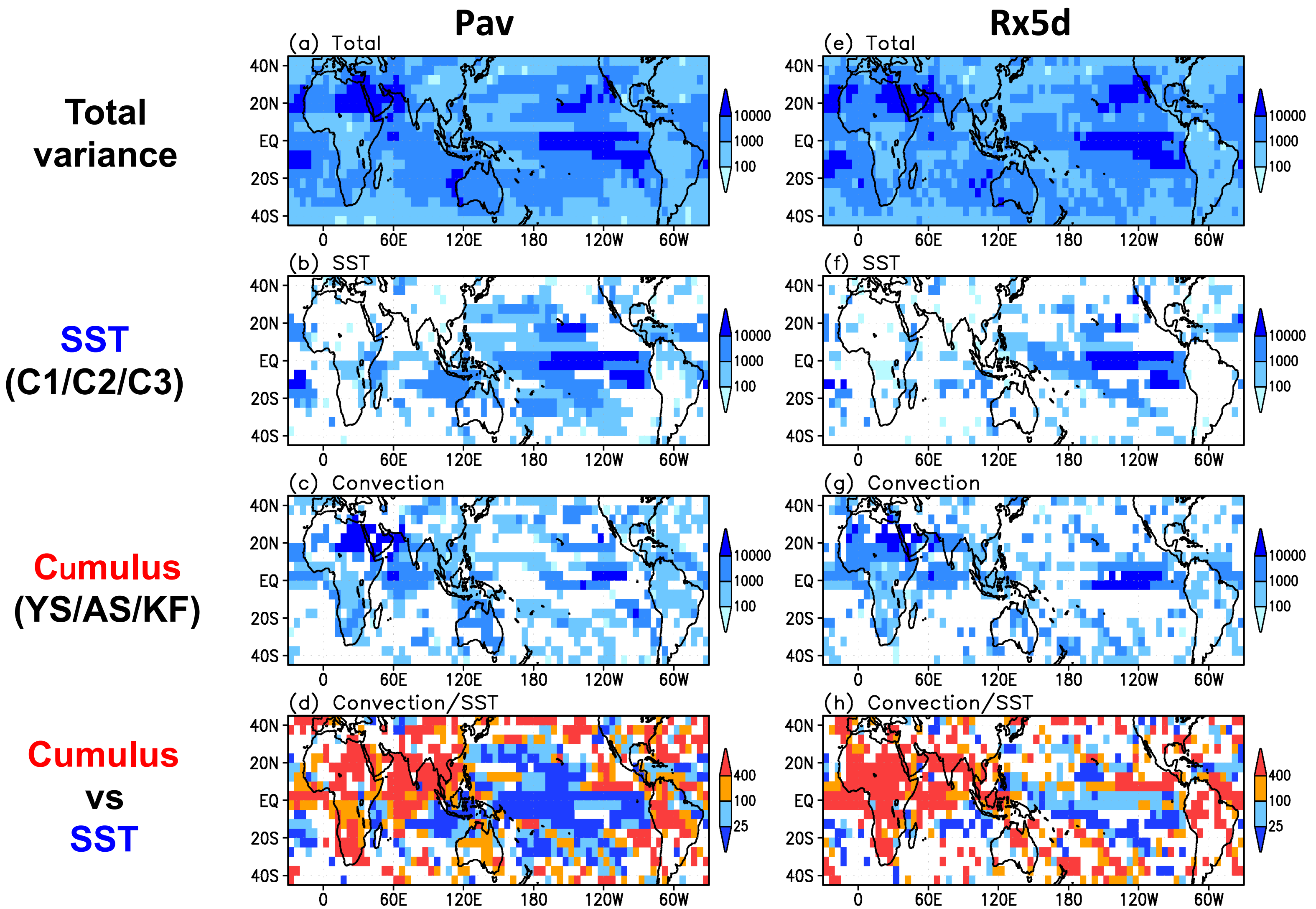
× **KF60**

Left to right:
ΔSST = Total, C1, C2, C3

- **Pav: increase in almost all regions.**
  **Large increase rate in EAS. Large scatter in AUSMC. No change in NAM.**
- **Rx5d/Rx1d: increase in all regions except WNP. Larger increase rate than Pav.**

# Two-way ANOVA for summer season

MJJAS in NH
NDJFM in SH

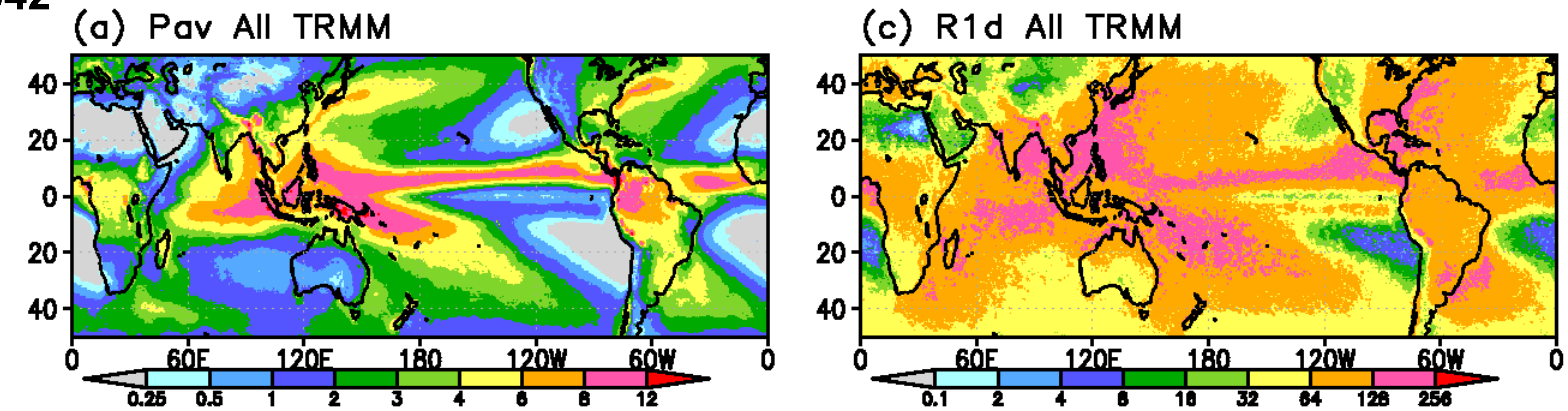



- **SST is responsible for the uncertainty of precipitation amount over the tropical Pacific**
  **> SST change pattern in future is critical**
- **Cumulus is responsible for the uncertainty of precipitation amount and extremes over most monsoon regions. More for extremes.**

# We investigate future changes in Rx1d and role of tropical cyclones (TCs)

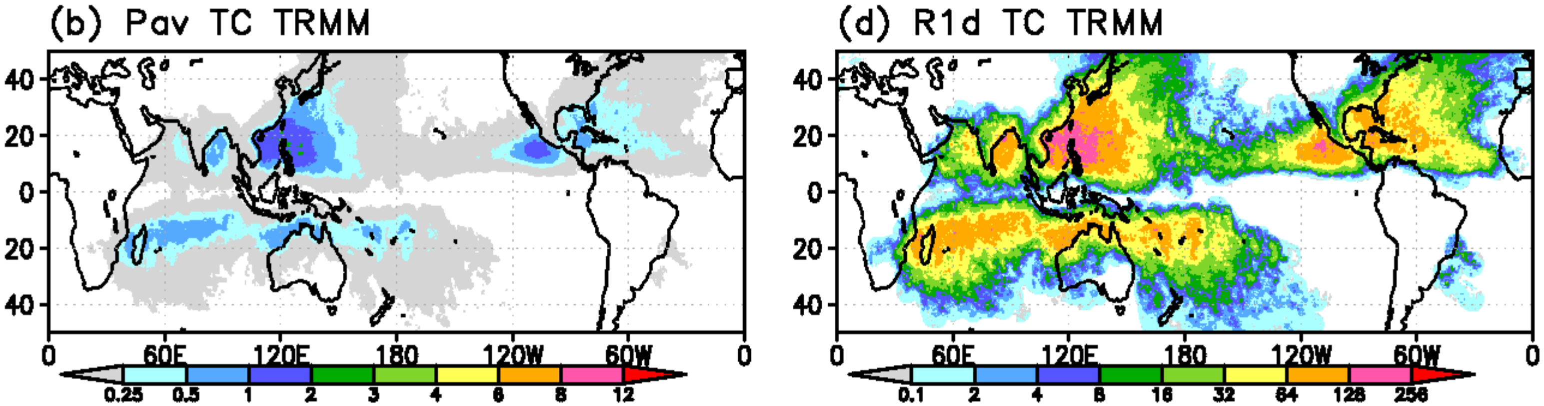
**TRMM3B42**

**Pav (total rainfall)** **Rx1d (annual max)**




**Extract rainfall within 500km from TC center**

**TC-rain**

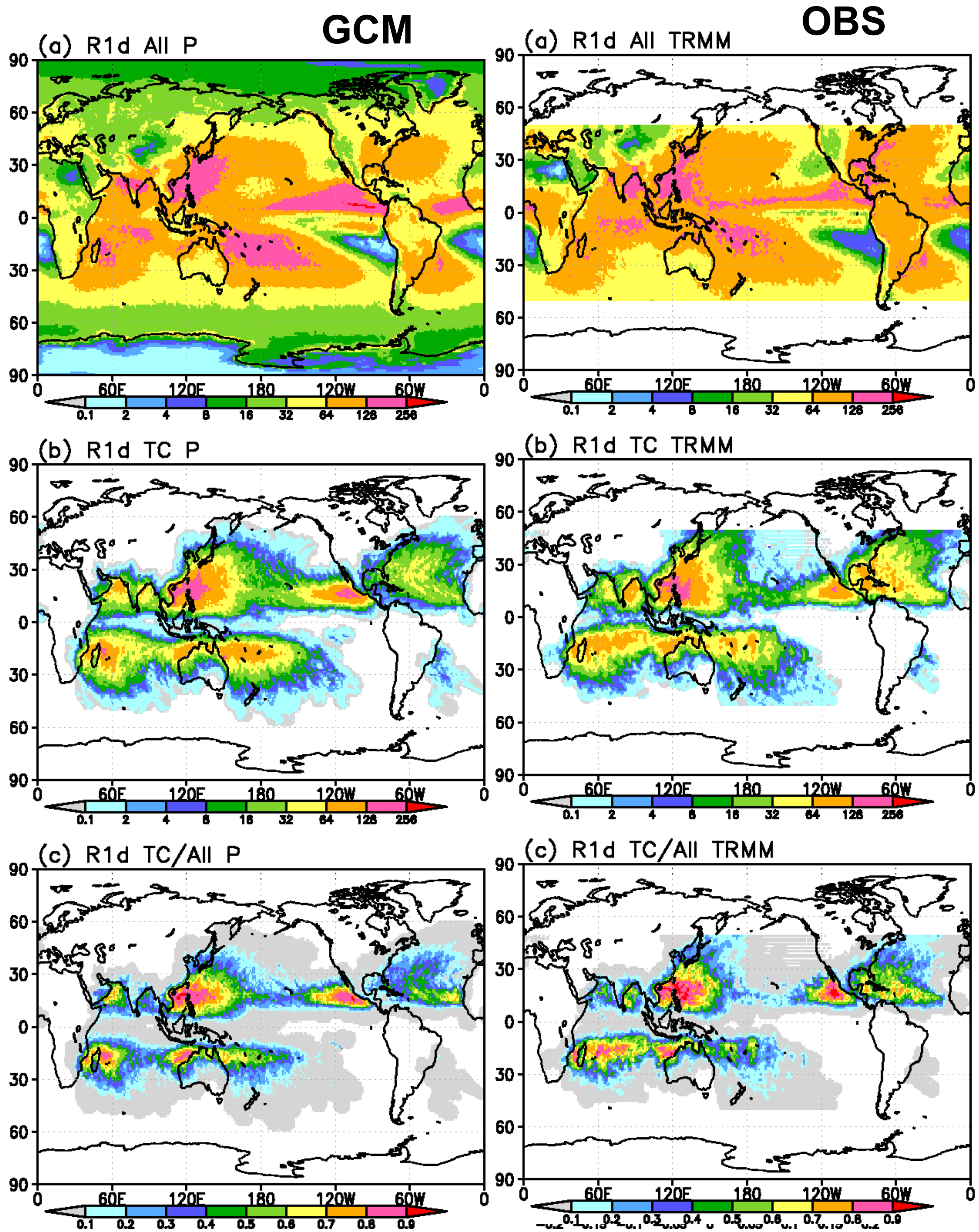


# Rx1d associated with tropical cyclones

Rx1d

Rx1dTC

Ratio
Rx1d-TC/Rx1d




**Model validation**

**20-km mesh AGCM reproduces well TC-associated Rx1d, quantitatively.**

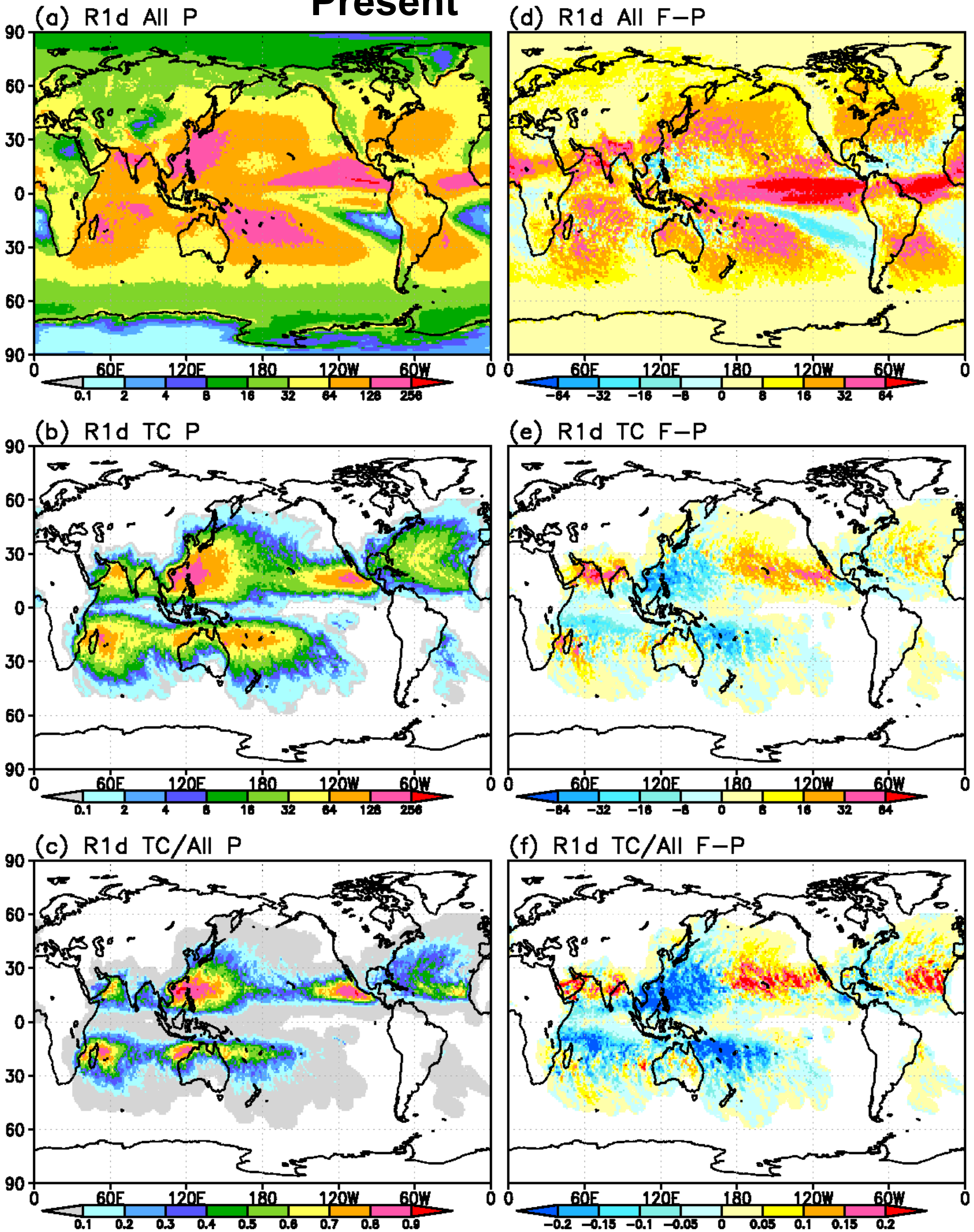
# Rx1d associated with tropical cyclones

Present

**Rx1d**

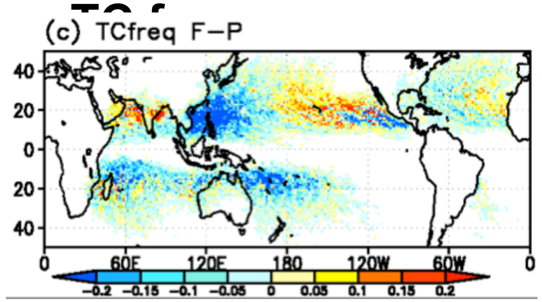
**Rx1d-TC**

**Ratio Rx1d-TC/Rx1d**




**Future change**

**TC-associated Rx1d decreases in the western Pacific,**
**due to decreasing**




Kitoh and Endo (2016 SOLA)

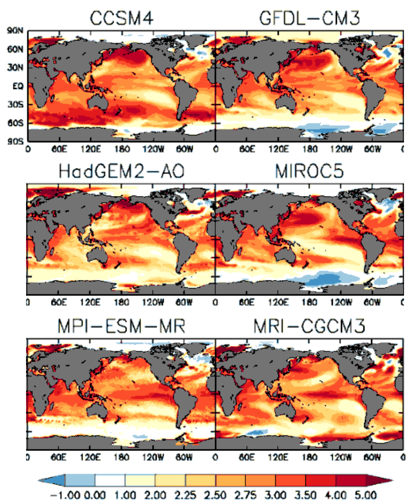
## Large ensemble future climate simulation
## Database for Policy Decision-making for Future climate change (d4PDF)

**6000 years for present and 5400 years for future**
**60-km mesh MRI-AGCM3.2**

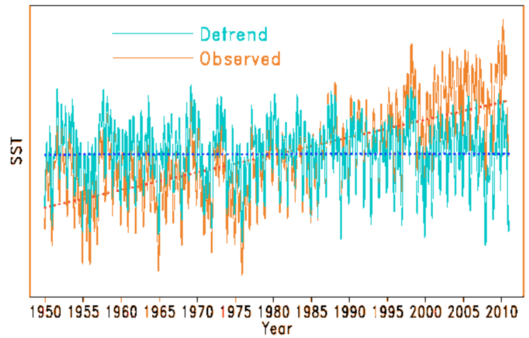
(Mizuta et al. 2017 BAMS)

- **present experiment**
  - 60 years (1951-2010) x **100 members**
- **4K warmer experiment**
  - 60 years under a 4K warmer climate than pre-industrial climate
  - SST： observed SST (detrend) ＋ **CMIP5 AOGCMs ΔSST**
  - GHG/Aerosol/Ozone： 2090 year level based on the RCP8.5 scenario
  - **90 member ensemble**
    - 6 types of ΔSST patterns
    - 15 different atmospheric initial condition / SST perturbation

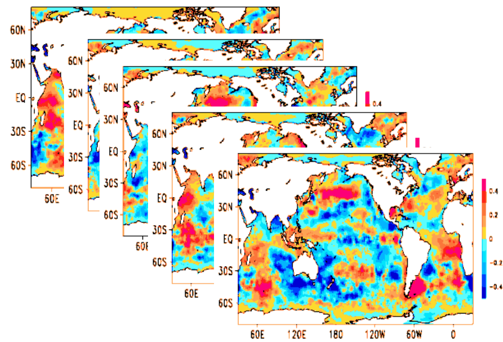
→ 6×15 = 90 members




6 types of ΔSST pattern

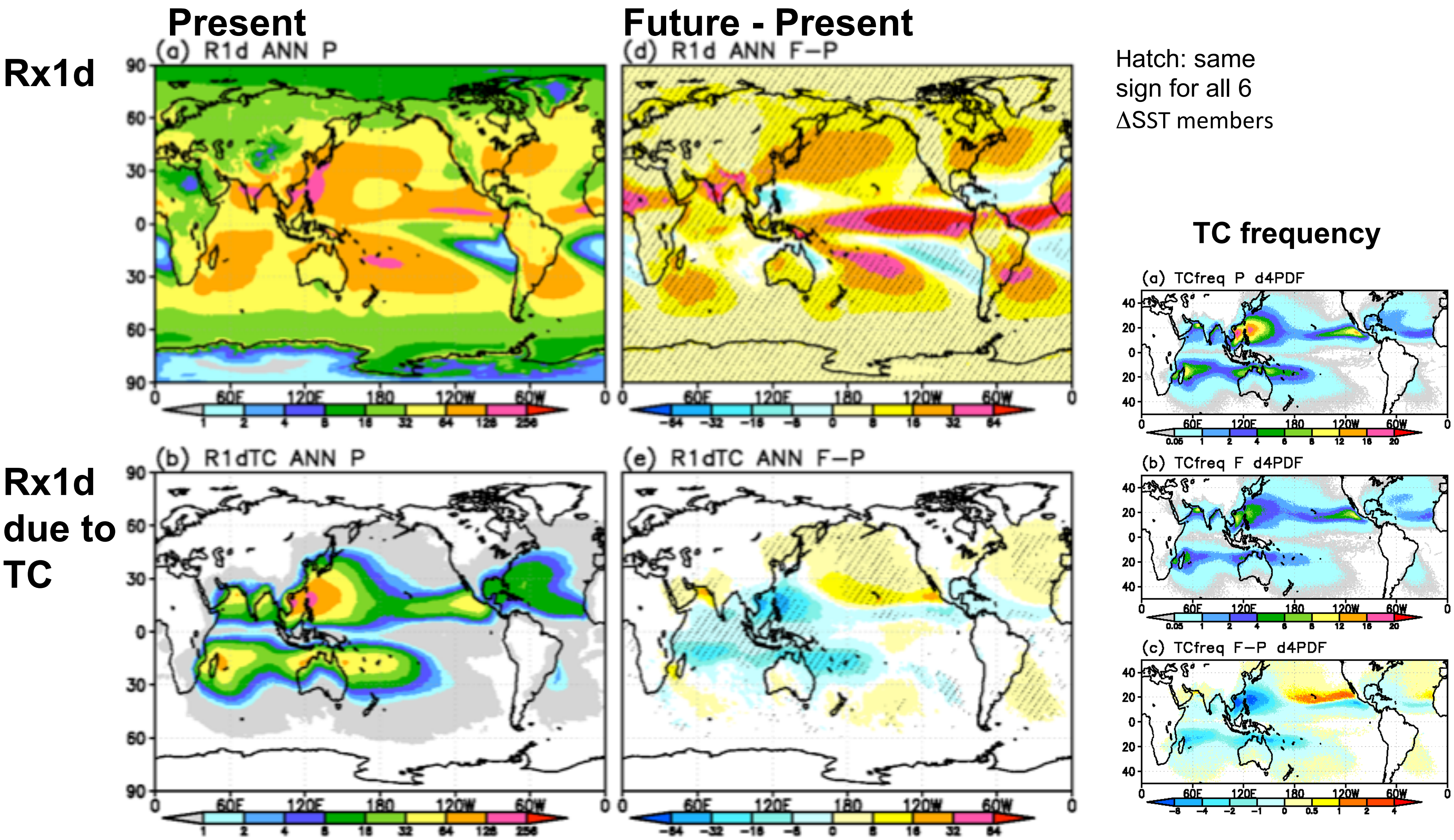



Observed SST (detrend)



Different atmospheric initial condition / SST perturbations

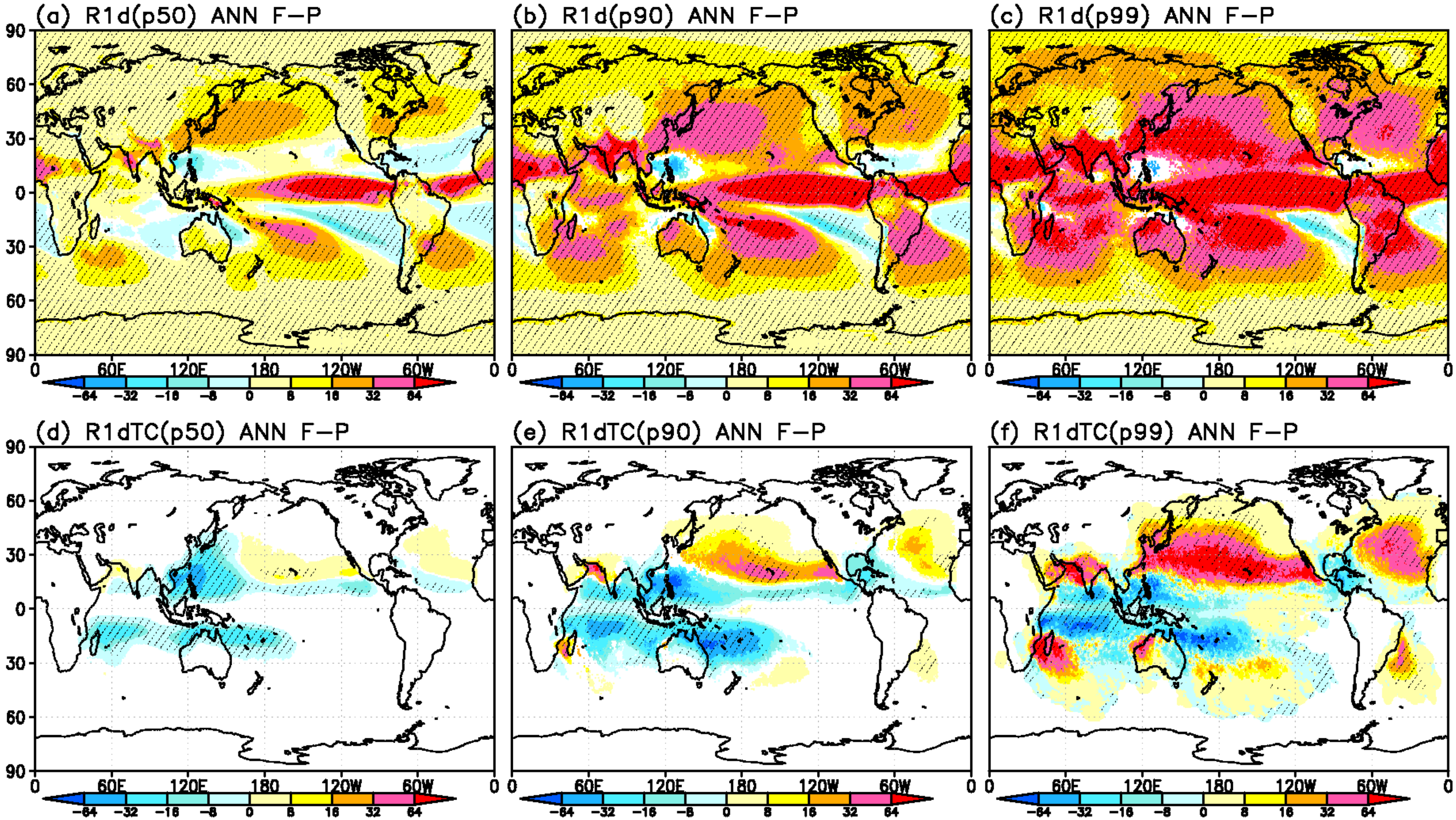
# Rx1d and tropical cyclone (TC)-associated Rx1d




**TC-associated Rx1d decrease in the western North Pacific due to TC frequency decrease**

# Future changes of (top) Rx1d and (bottom) TC-associated Rx1d

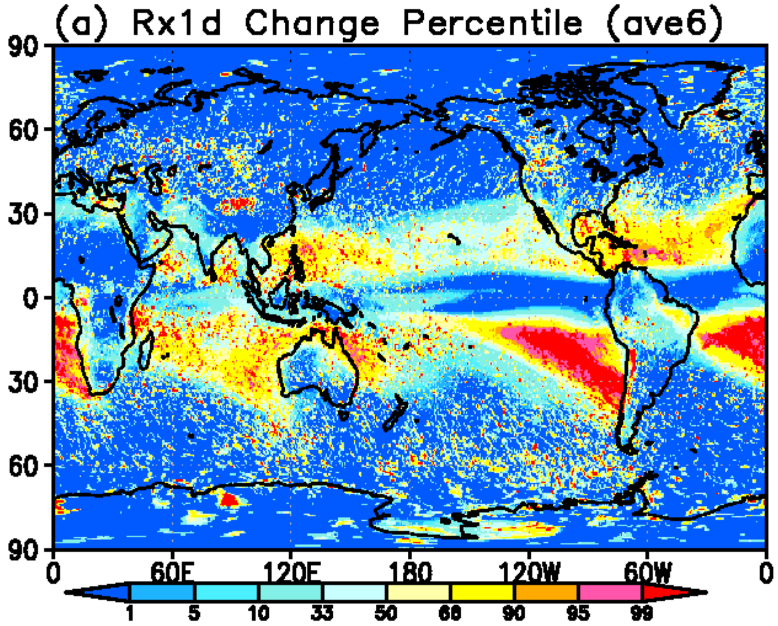
## (left) 50%-ile, (middle) 90%-ile, (right) 99%-ile




**Over the northwestern tropical Pacific, median value of TC-associated Rx1d decreases, but its 90/99%-ile value increases around Japan**

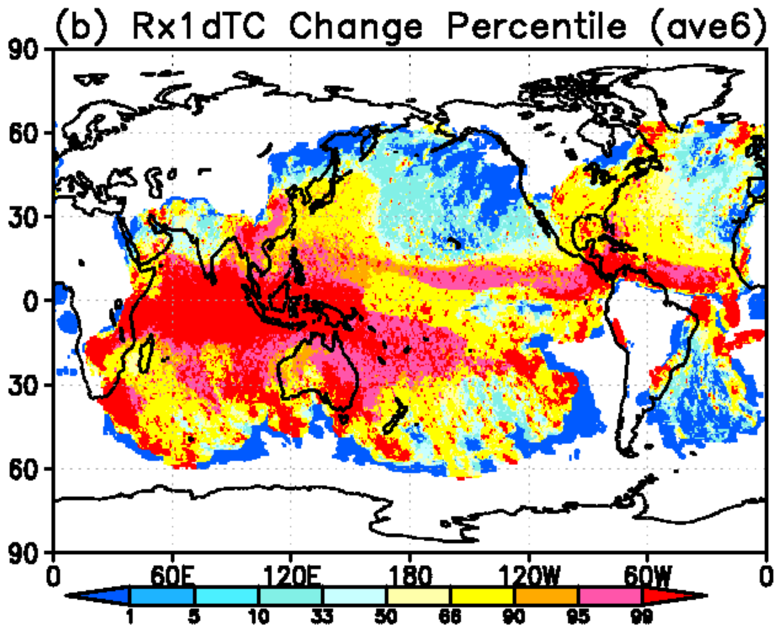
Color: 95% significant
Hatch: same sign for all 6 ΔSST members

# Percentile value at which future changes in (top) Rx1d and (bottom) TC-associated Rx1d become negative to positive




**Over most of land, the threshold is below 33-percentile.**

**Rx1d above 90-percentile will increase over the area affected by TCs and over the subtropical oceanic dry areas.**

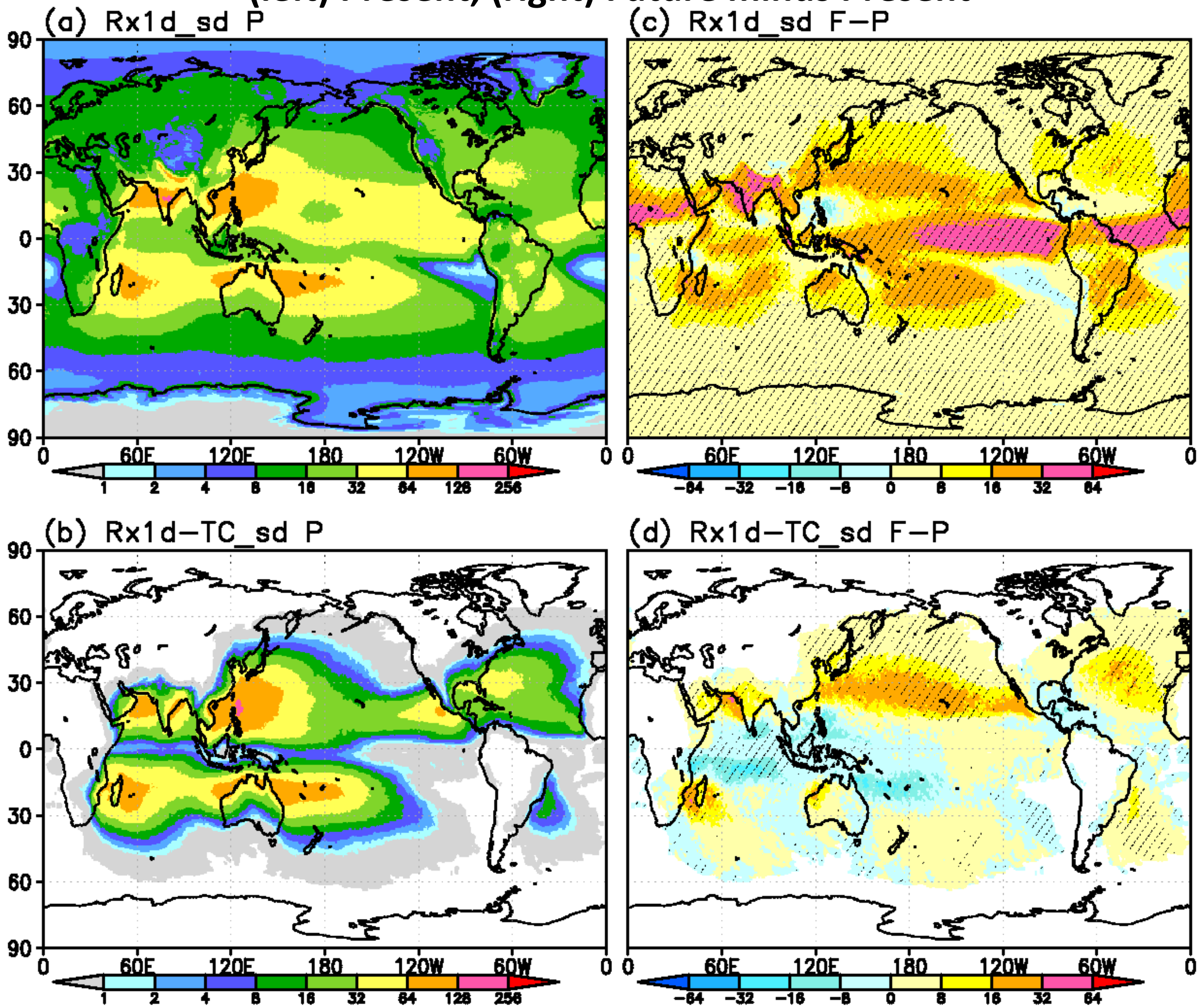



**Changes sign between 80- and 90-percentile in East Asia around Japan and eastern China.**

**Extreme TC-associated precipitation once in 5 years will become heavier in a future warmer climate.**

## Interannual standard deviation of (top) Rx1d and (bottom) TC-associated Rx1d

### (left) Present, (right) Future minus Present




Hatch: same sign for all 6 ΔSST members

**Rx1d-TC increases in the NH subtropics from Hawaii to Japan**

# Summary

**MRI-AGCM3.2 shows a high performance in simulating monsoon mean and extreme precipitation, with some dependency on the choice of convection scheme for extreme precipitation.**

**In a warmer climate, extreme precipitation (Rx1d) is projected to increase, except some regions around the western tropical Pacific. The latter is due to decreasing frequency of tropical cyclones (TC). However, interannual variability and extremes of Rx1d will increase.**

**Extreme Rx1d will increase more than the mean Rx1d. Sign of TC-associated Rx1d changes depends on the percentile threshold.**

**Interannual variability of Rx1d will increase in a region extending from Hawaii to the south Japan, implying an increasing risk of heavier rainfall events by global warming.**

**Role of TC is large in changes of precipitation extremes for some regions. Thus model's ability in simulating TC is important.**