# Evaluation and future projection of changes in extreme temperature and precipitation events in the Asia-Pacific region using AOGCMs

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# Motivation: Climate Extremes

**Has there been a change in extreme events like heat waves, droughts, floods, and hurricanes?**

"**Since 1950**, the number of *heat waves* has **increased** and widespread increases have occurred in the numbers of warm nights. The extent of regions affected by *droughts* has also **increased** as precipitation over land has marginally decreased while evaporation has increased due to warmer conditions. Generally, numbers of heavy daily precipitation events that lead to *flooding* have **increased**, but not everywhere. *Tropical storm and hurricane* frequencies vary considerably from year to year, but evidence suggests **substantial increases** in intensity and duration since the 1970s. In the extratropics, variations in tracks and intensity of storms reflect variations in major features of the atmospheric circulation, such as the North Atlantic Oscillation."

*(IPCC, Climate Change 2007: The Physical Science Basis, Frequently Asked Question 3.3)*

# Motivation: What we need to know …

**We seek to answer the scientific questions:**

1. How the spatial and temporal trends in temperature and precipitation extremes are changing, with focus on the ability of a global climate model to reproduce observed patterns of climate extremes?

   - Comparison of model- and observation-based indices for extreme events (for the present climate, **20C3M**)

2. What changes in trends in climate extremes can be expected under projected future climate change?

   - Changes in extremes in future climate projections (for the future climate, **SRES**)

# Methodology: Climate Extreme Indices(1)

## Extreme temperature climate indices used in this study

| Abbreviation | Name | Definition | Units |
|---|---|---|---|
| **SU** | Summer days | Annual count of days when Tmax > 25°C | days |
| **TR** | Tropical nights | Annual count of days when Tmin > 20°C | days |
| **ID** | Icing days | Annual count of days when Tmax < 0°C | days |
| **FD** | Frost days | Annual count of days when Tmin < 0°C | days |
| **TN10p** | Cool nights | Percentage of days when Tmin < 10$^{th}$ percentile | % |
| **TX10p** | Cool days | Percentage of days when Tmax < 10$^{th}$ percentile | % |
| **TN90p** | Warm nights* | Percentage of days when Tmin > 90$^{th}$ percentile | % |
| **TX90p** | Warm days* | Percentage of days when Tmax > 90$^{th}$ percentile | % |
| **WSDI** | Warm spell duration* | Annual count of days with at least 6 consecutive days when Tmax > 90$^{th}$ percentile | days |
| **DTR** | Diurnal temperature range | Monthly mean difference between Tmax and Tmin | °C |

* The percentage of temperature is calculated for the base period 1961-1990.

# Methodology: Climate Extreme Indices(2)

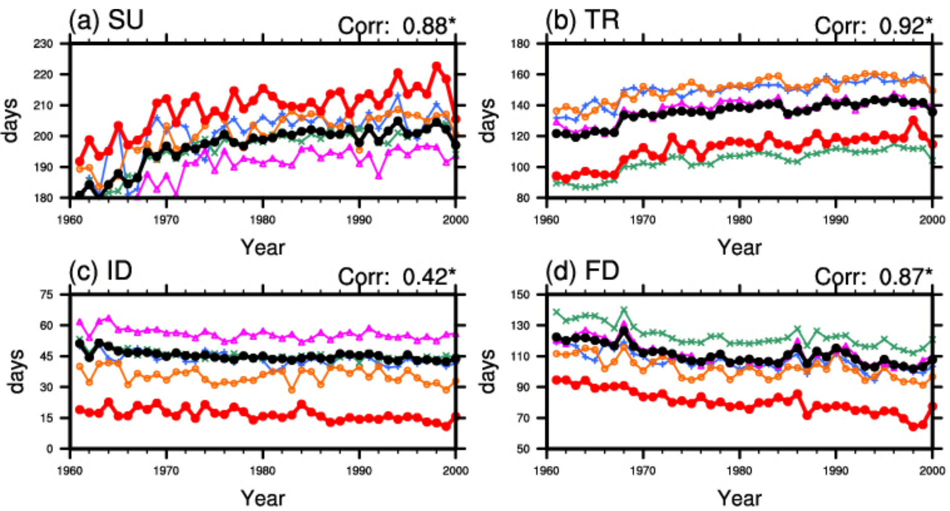
## Extreme precipitation climate indices used in this study

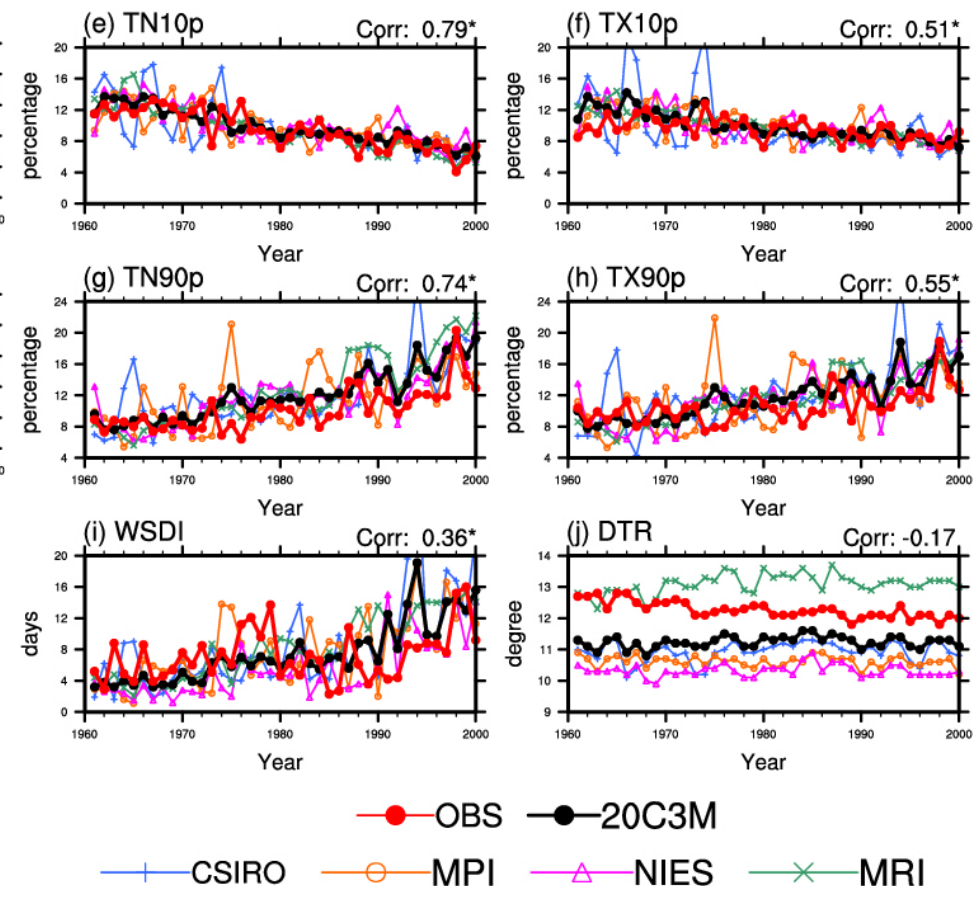
| Abbreviation | Name | Definition | Units |
|---|---|---|---|
| **RX1day** | Monthly maximum 1-day precipitation amount | Monthly maximum 1-day precipitation | mm |
| **SDII** | Simple precipitation intensity | Daily precipitation amount on wet days (>1mm) divided by the number of wet days | mm/day |
| **R10mm** | Number of heavy precipitation days | Annual count of days when PRCP ≥ 10mm | days |
| **PRCPTOT** | Annual total precipitation | Annual total precipitation | mm |
| **R95pTOT** | Annual total precipitation in very wet days* | Annual total precipitation when PRCP > 95$^{th}$ percentile | mm |
| **R99pTOT** | Annual total precipitation in extremely wet days* | Annual total precipitation when PRCP > 99$^{th}$ percentile | mm |
| **CDD** | Consecutive dry days | Maximum number of consecutive days with PRCP < 1mm | days |
| **CWD** | Consecutive wet days | Maximum number of consecutive days with PRCP ≥ 1mm | days |

* The percentage of precipitation is calculated for the base period 1961-1990.

# Temporal trends in temperature extremes

averaged over all land-only grid points in the APEC region for 40 year: 1961-2000




Observed warming trends in temperature extreme indices are well represented in the model simulation except for diurnal temperature range.

# Decadal OLS trends and Mann-Kendall statistic

[Linear Trend, Trend/10yrs]

| Variable | Index | OLS trends (1960-2000) | | Mann-Kendall statistic ($Z_c$) | |
|---|---|---|---|---|---|
| | | OBS | 20C3M | OBS | 20C3M |
| Temperature | SU | 1.77 | 2.29 | 1.48 | 1.32 |
| | TR | 3.45 | 2.22 | **2.38**** | **1.93*** |
| | ID | -1.64 | -0.97 | **-2.27**** | -1.08 |
| | FD | -3.46 | -1.94 | **-3.15***** | -1.50 |
| | TN10p | -1.70 | -1.58 | **-3.72***** | **-2.38**** |
| | TN90p | 1.55 | 2.34 | **3.28***** | **2.83***** |
| | TX10p | -0.55 | -1.16 | -1.39 | **-1.66*** |
| | TX90p | 0.95 | 1.87 | **1.67*** | **2.21**** |
| | WSDI | 0.69 | 2.48 | 0.88 | **1.79*** |
| | DTR | -0.17 | 0.00 | **-2.44**** | -0.29 |

cool tails
Night (Tmin) indices
Day (Tmax) indices
warm tails

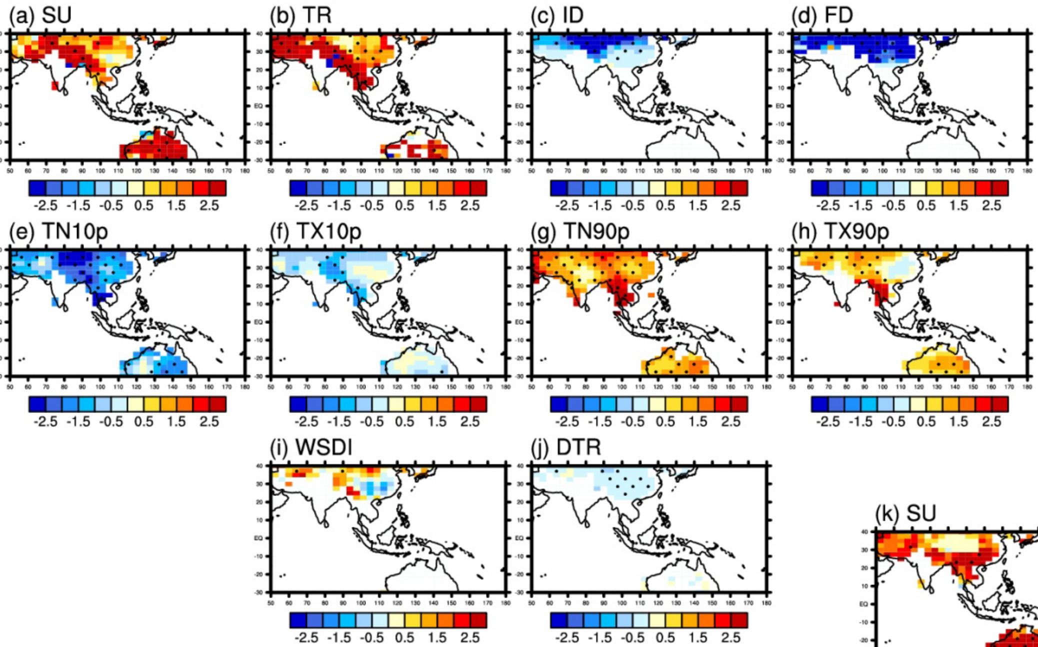
*Trend of each index is significant at the level of* ** 0.1,* *** 0.05,* **** 0.01*

① The indices of temperature extremes indicate **comparable warming** between the tails and warm tails of the distributions of daily minimum and maximum temperature in the reference period. ➔ unchanged temperature variance

② Changes in the nighttime indices appear larger than those in the daytime indices, which result in the observed **decreasing changes in the DTR**. However, the global climate models cannot capture the DTR trend because …

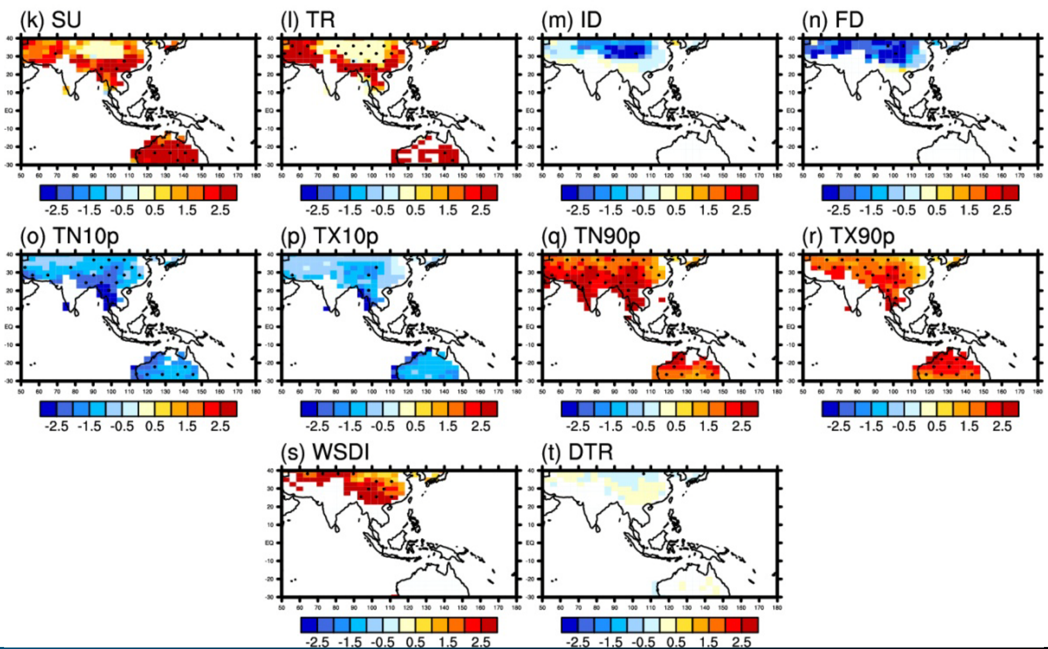
# Spatial trends in temperature extremes

OBS




**Stippling:**
Significant at the 0.05 significance level

20C3M

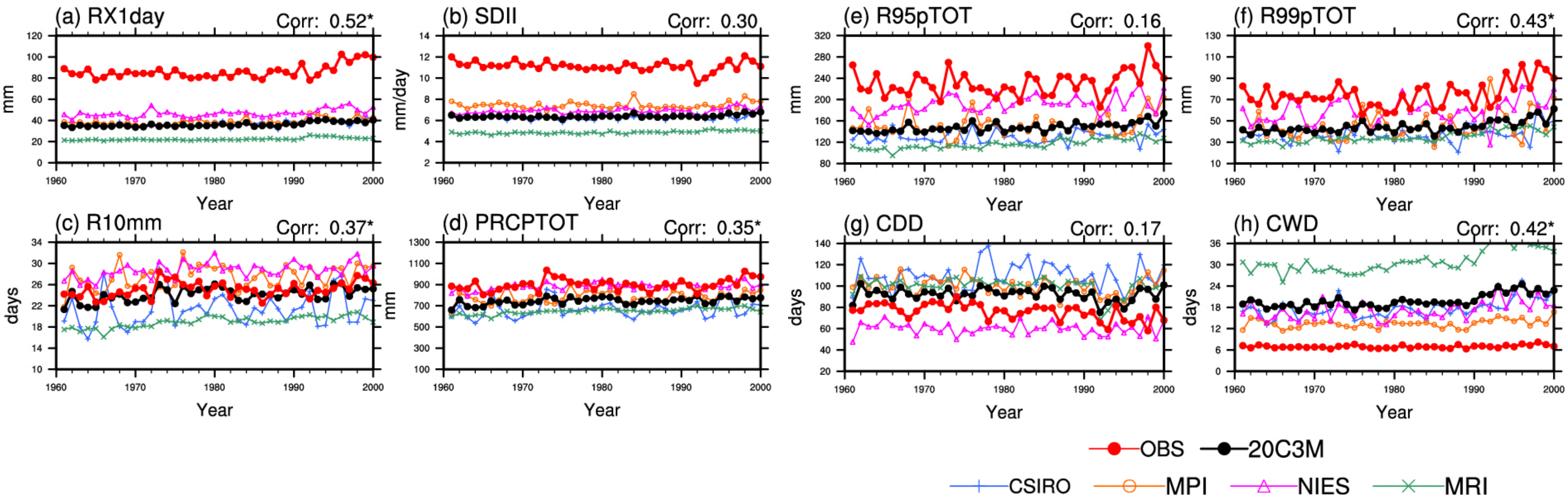



The observed warming trend is spatially comparable to the simulated trends with the exception of **Tibetan Plateau** region.

① pre-defined absolute threshold
② the tendency of temperature underestimation in the GCMs

# Temporal trends in precipitation extremes

averaged over all land-only grid points in the APEC region for 40 year: 1961-2000



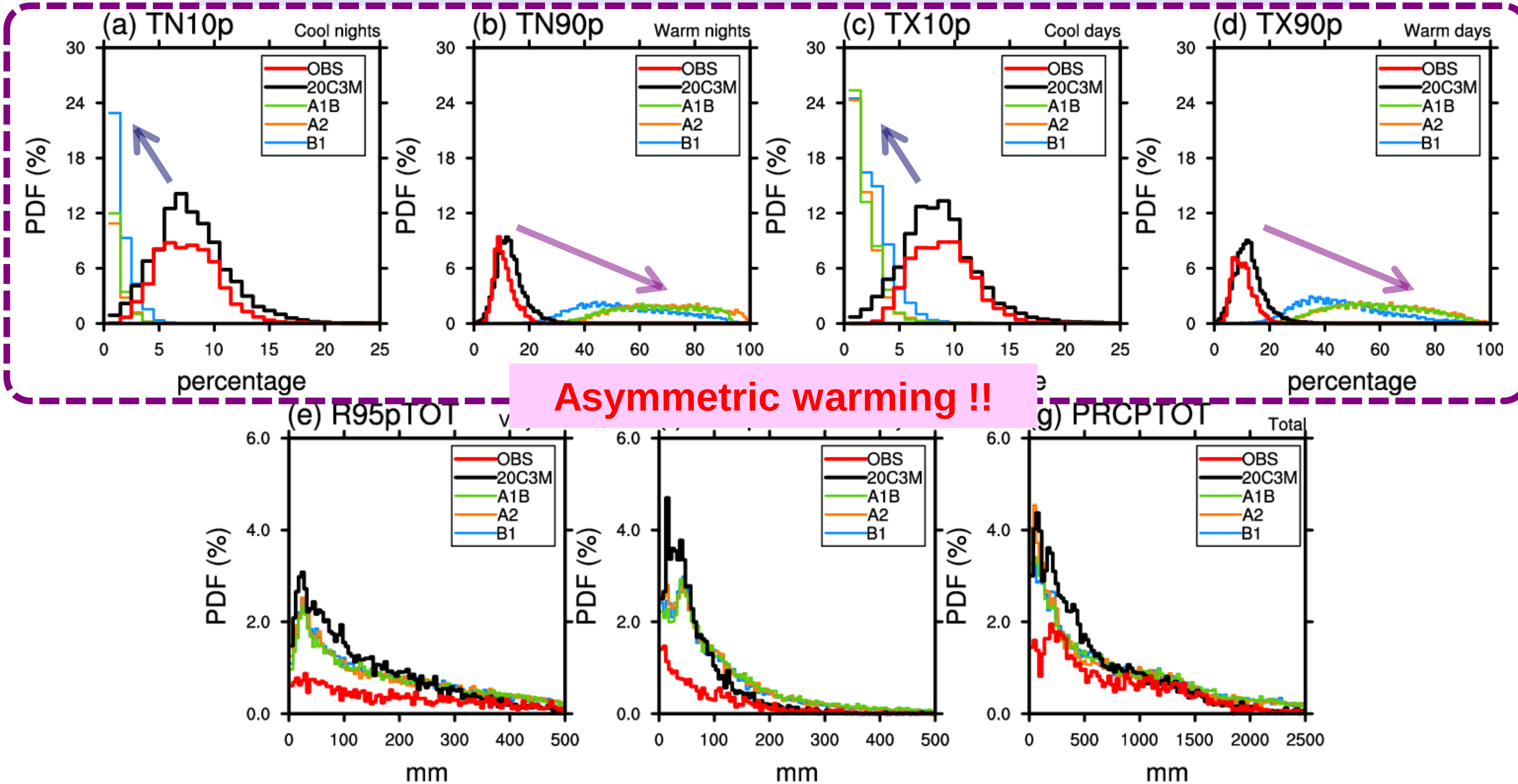

Compared to the uncertainty of global models to capture temperature extremes, the models show more uncertainty in simulating changes in precipitation extremes.

Larger simulated magnitude of CDD and CWD compared to the observation indicate that precipitation variability is larger in the models than observations.

# Ensemble mean PDFs of the annual frequency of extreme temperature and precipitation

for grid points over the APEC terrestrial region for two 20-year periods:
(1) 1981-2000 (20C3M, OBS), and (2) 2081-2100 (A1B, A2, B1)

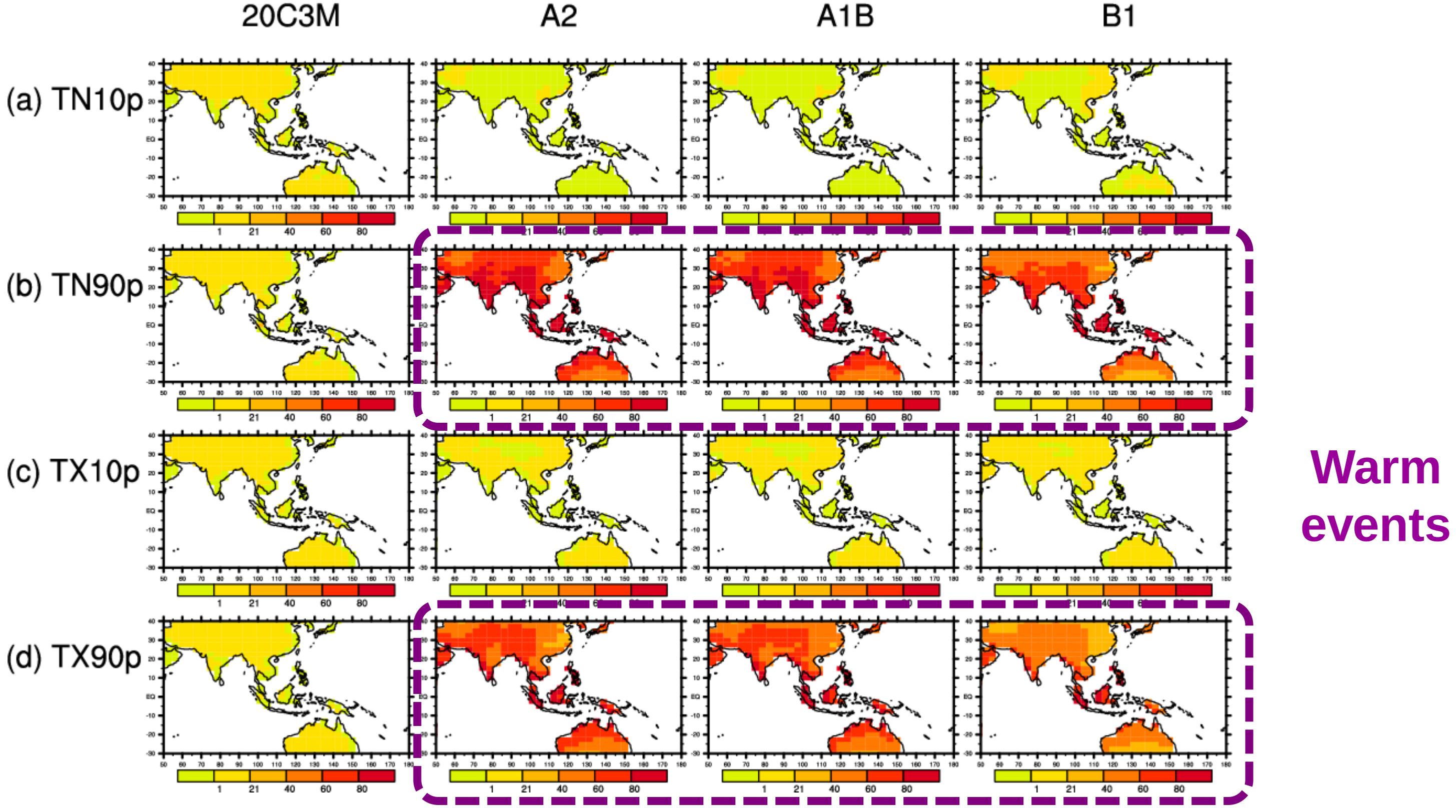
***Warm events*** (TN90p, TX90p) are expected to show ***more increase and large variance*** compared to the cool events (TN10p, TX10p).




**Asymmetric warming !!**

# Spatial distribution of model ensemble average

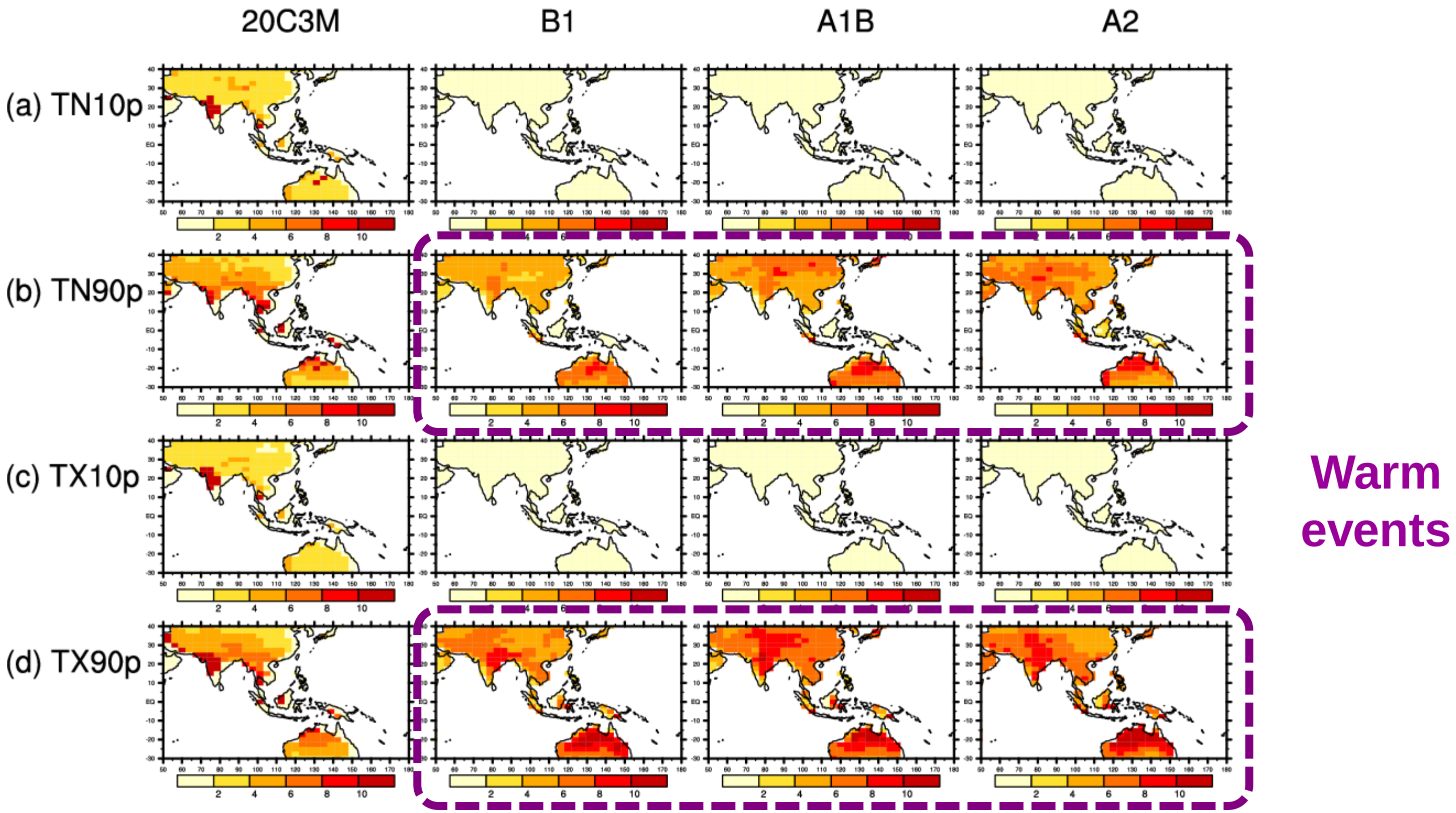
average for **20C3M**(1981-2000) and **SRES**(2081-2100)




**Warm events** are expected to show **more increase** compared to the cool events and **tropical regions** may make a considerable contribution to the **large increase** of warm events compared to the extra-tropical regions.

# Spatial distribution of model standard deviation

standard deviation for 20C3M(1981-2000) and SRES(2081-2100)



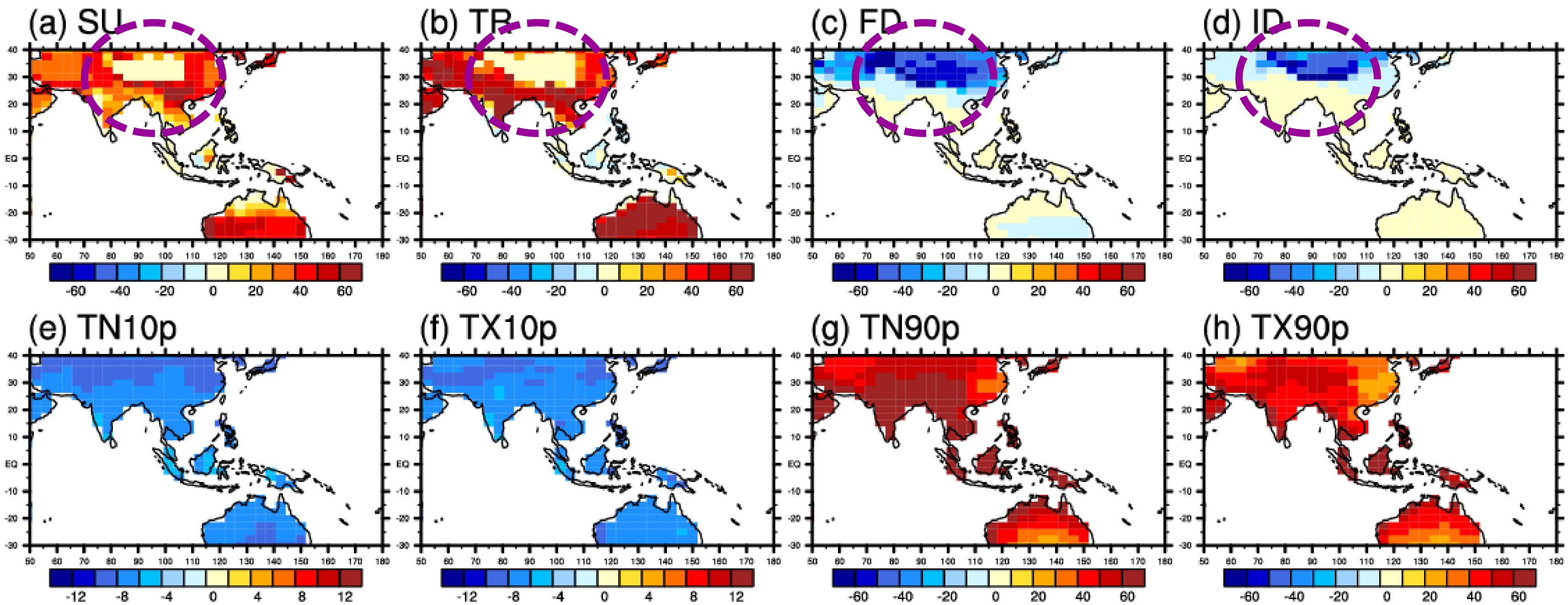

**Interannual variability** is expected to be **large for warm events** compared to the cool events. (increase in temperature variability) **Standard deviation of warm events** appears **varied from region to another**; more specifically, it is expected to be **large in the extra-tropical regions** compared to the tropical regions.

**Large variance** of warm events may be attributable to the **increase of temperature extreme variability in the extra-tropical regions**.

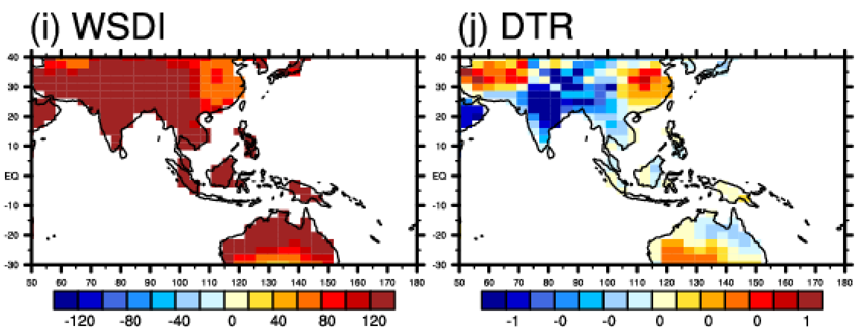
# Ensemble mean projected changes in temperature

difference between **A1B**(2081-2100) and **20C3M**(1981-2000)

Why SU and TR is expected to show less changes **in the Tibetan Plateau region**?




① model uncertainty?
(geographical features)
② a threshold itself



# Ratios of the 2081-2100 changes in temperature across the APEC terrestrial region

## relative to changes in the globe for the same scenario

| Variable | Index | A1B/GLOBE | A2/GLOBE | B1/GLOBE |
|---|---|---|---|---|
| Temperature | SU | 2.27 | 2.30 | 2.29 |
| | TR | 2.42 | 2.42 | 2.49 |
| | FD | 0.55 | 0.58 | 0.69 |
| | ID | 0.67 | 0.69 | 0.77 |
| | TN10p | -0.10 | -0.09 | -0.22 |
| | TX10p | -0.52 | -0.49 | -1.12 |
| | TN90p | 1.54 | 1.46 | 1.64 |
| | TX90p | 1.38 | 1.37 | 1.43 |
| | WSDI | 1.38 | 1.37 | 1.41 |
| | DTR | 3.63 | 3.82 | 3.74 |

| Variable | Index | A1B/GLOBE | A2/GLOBE | B1/GLOBE |
|---|---|---|---|---|
| Precipitation | RX1day | 2.04 | 2.03 | 2.05 |
| | SDII | 3.05 | 0.48 | 4.81 |
| | R10mm | 2.79 | 2.69 | 2.85 |
| | PRCPTOT | 1.65 | 1.54 | 1.67 |
| | R95pTOT | 1.73 | 1.64 | 1.74 |
| | R99pTOT | 1.85 | 1.76 | 1.86 |
| | CDD | 1.43 | 1.62 | 1.38 |
| | CWD | 2.65 | 2.51 | 2.70 |

# Summary and Conclusions

## Comparison between observed and simulated extremes over APEC region

- The indices of temperature extremes indicate **comparable warming** between the cool tails and warm tails of the distributions of daily minimum and maximum temperature in the reference period. This result corresponds to the assumption of shifted temperature distributions with no change in the scale parameters other than the mean in the reference period. (**unchanged temperature variance**)

- The observed symmetric **warming trend** is overall comparable to the simulated trends despite differences in the magnitude of trends. The obvious distinction between observations and simulations is found in high topographic region (i.e., **Tibetan Plateau region**) and it is due to ① pre-defined absolute threshold indices, and ② the tendency of temperature underestimation in the GCMs. Careful consideration of this aspect is needed for model-based extreme projections.

- Percentile-based indices represent spatially consistent warming trends both in the observations and in the models. As shown in the observations, the global models also exhibit thinner lower tails and thicker upper tails of Tmin-related indices (nighttime indices, TN10p and TN90p) better than those of Tmax-related indices (daytime indices, TX10p and TX90p).

# Summary and Conclusions

## Projected future changes in extremes over APEC region

- It is interesting that the annual number of warm extreme events (TX90p and TN90p) is expected to show **more increase and larger variance** compared to the cool extreme events (TX10p and TN10p). This **asymmetrical warming** indicates that the chance of occurrence of intense temperature extremes would be more likely to **shift to warm extremes** in future climate conditions.

- From model ensemble averages and standard deviations of percentile-based extreme indices, it is clear that **tropical regions** may make a considerable contribution to the **large increase** of warm events compared to the extra-tropical regions, and **large variance** of warm events may be attributable to the increase of temperature extreme variability in the **extra-tropical regions**.

- Comparisons of future changes in temperature and precipitation extremes across the Asia-Pacific terrestrial region compared to the whole globe show that shift to intensified warmer extreme events is expected to be larger in the Asia-Pacific region compared to the global average. In addition, it is expected to experience increased frequency, intensity and duration of precipitation extremes in the Asia-Pacific region compared to the global average.

Thank you for your attention !!

# Methodology: Model and Data

## IPCC AR4 Simulations

| Modeling Center | CMPI I.D. | AGCM resolution | OGCM resolution | Number of ensembles | Acronym |
|---|---|---|---|---|---|
| Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) | Mk3.5 | T63L18 | 1.875x0.925 L31 | 1 | CSIRO |
| Max-Plank-Institut for Meteorology (MPI-M) | ECHAM5-OM | T63 L32 | 1 x 1 L41 | 1 | MPI |
| National Institute for Environmental Studies (NIES) | MIROC3.2 (hires) | T106 L56 | T106 4x6 | 1 | MIRO-H |
| Meteorological Research Institute (MRI) | CGCM2.3.2 | T42 L30 | 2 x 0.5-2.5 L23 | 5 | MRI |

** A total of 4 Multi-Models and 8 ensemble members for each simulation (20C3M and A1B, A2, and B1)*

** The SRES A2 simulation using NIES-MIROC3.2 (hires) model is not used because, as of writing, the output is not available on the PCMDI website.*

## HadEX dataset for observation

The observed extreme indices for extreme events calculated on the basis of a worldwide weather observational dataset from the Hadley Centre (3.75° x 2.5° horizontal resolution, 1951-2001 time coverage).

# Spatial trends in precipitation extremes