

# Climate Extreme

## : Modeling & Trend Analysis

**Eun Soon IM**

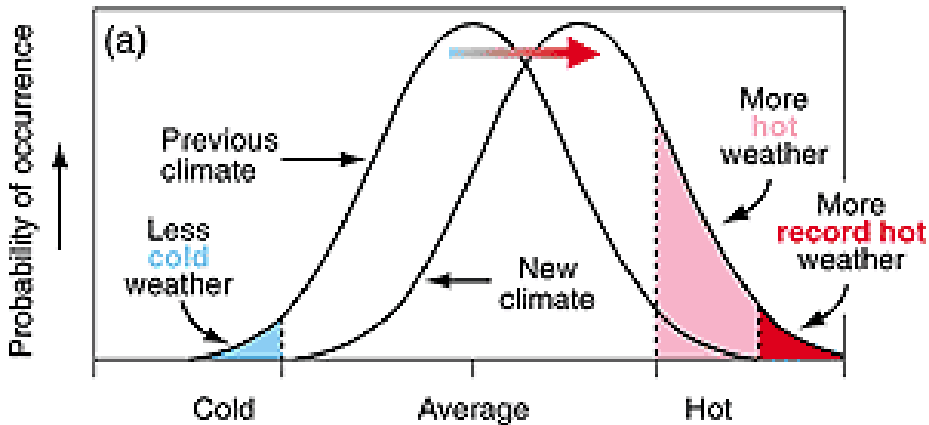
**Singapore-MIT Alliance for Research and Technology**

# Key References

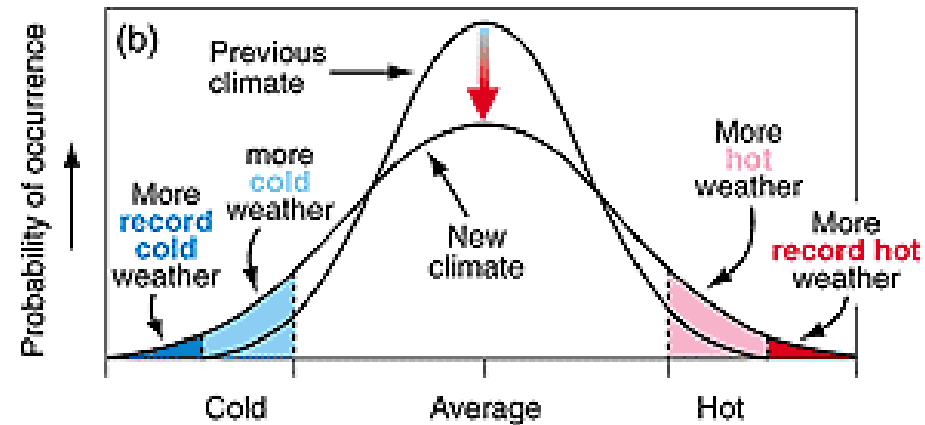
- Im et al., 2011: The temporal and spatial structures of recent and future trends in extreme indices over Korea from a regional climate projection. *Int. J. Climatol.*, 31, 72–86
- Im & Kwon, 2007: Characteristics of extreme climate sequences over Korea using a regional climate change scenario. *SOLA*, 3, 017–020

# Changes in Mean & Variability & Extremes

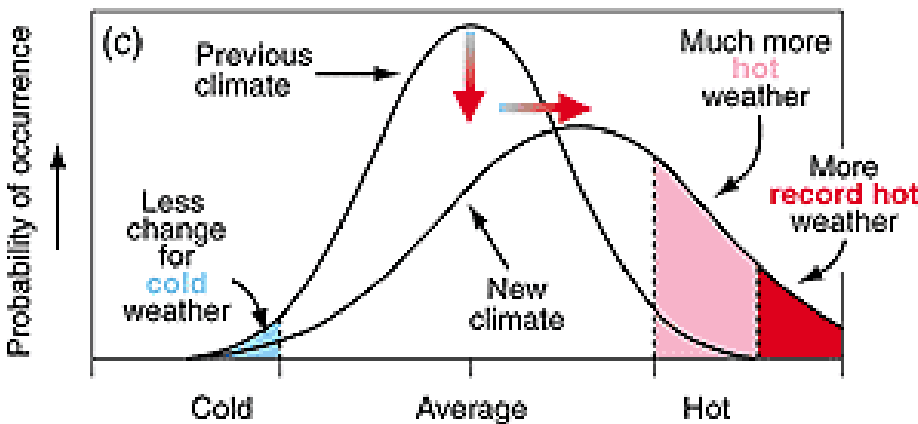
## Increase in mean



## Increase in variance



## Increase in mean & variance



- An increase in the mean leads to new record high temperatures
- An increase in variability without a change in the mean implies an increase in the probability of both hot and cold extremes as well as the absolute value of the extremes.
- Increases in both the mean and the variability are also possible, which affects the probability of hot and cold extremes, with more frequent hot events with more extreme high temperatures and fewer cold events.

# Extreme Analysis : Frequency & Intensity & Duration

**How often!**

**How strong!**

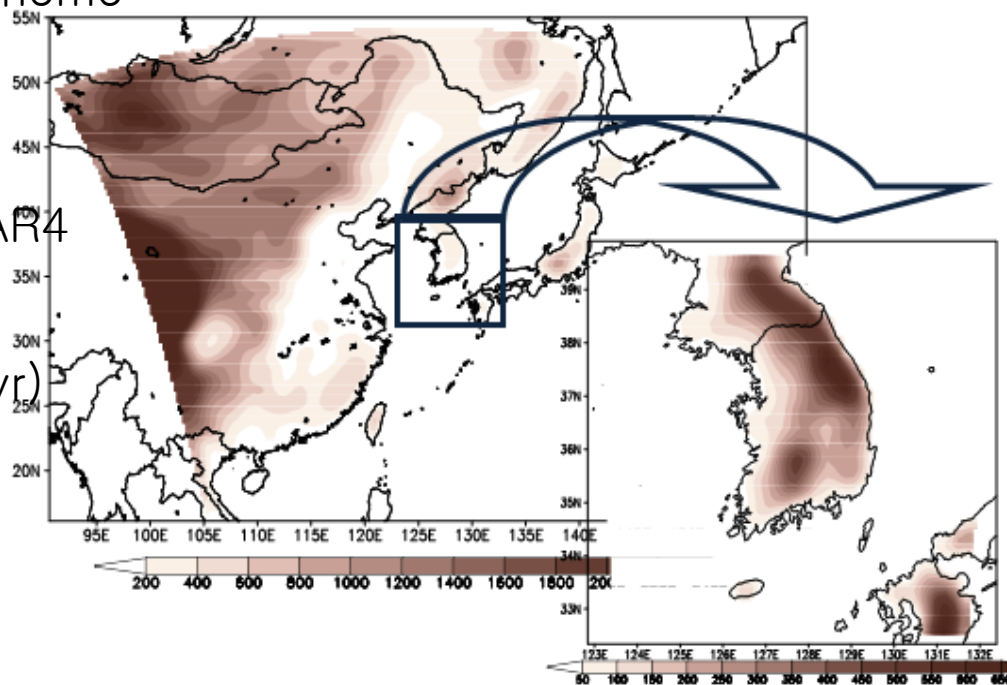
**How long!**

- To accurately investigate the characteristics of climate extremes, it is necessary to consider frequency, intensity and persistence of extreme events (i.e. duration) comprehensively.
- The behaviour of extremes can be quite nonlinear. For example, the rate of increase in the number of warm days and the corresponding magnitude of warming could have different trends even though they tend to evolve towards the same direction. Therefore, it is important to examine changes in frequency and magnitude of climate extremes as well as changes in the mean state.
- Because persistence of weather events may lead to extremes such as flood, drought and so on, successive duration is crucial for a realistic assessment in application of hydrological and agricultural models.

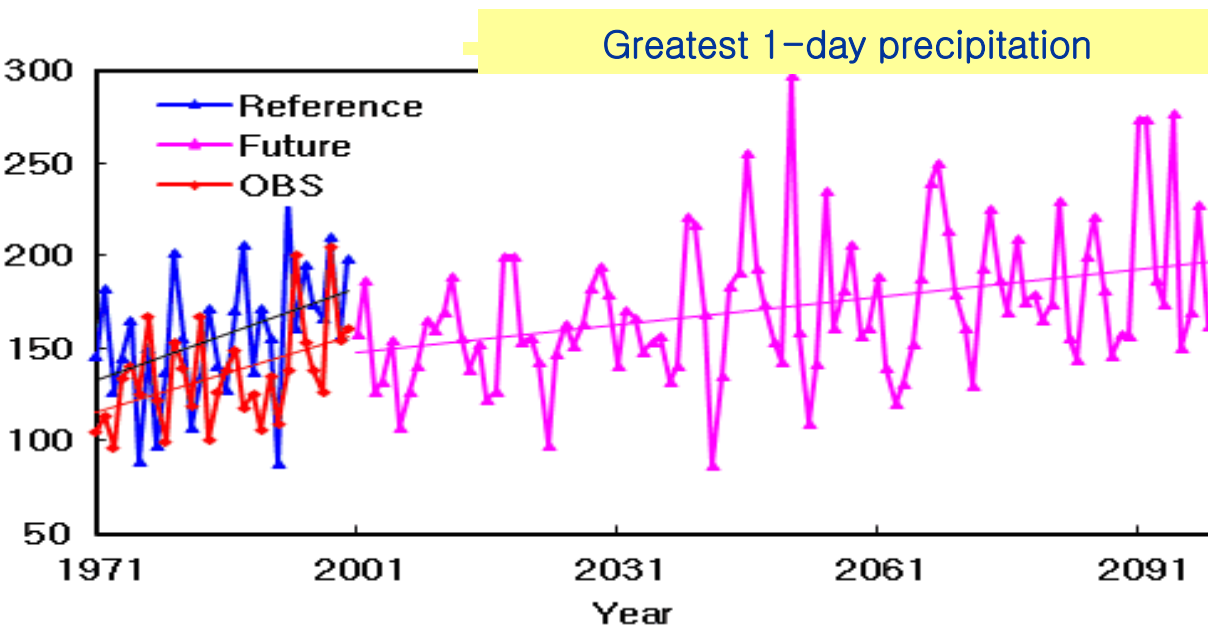
# Daily Fine-scale Climate Scenario

## □ RegCM3 One-Way Double-Nested System

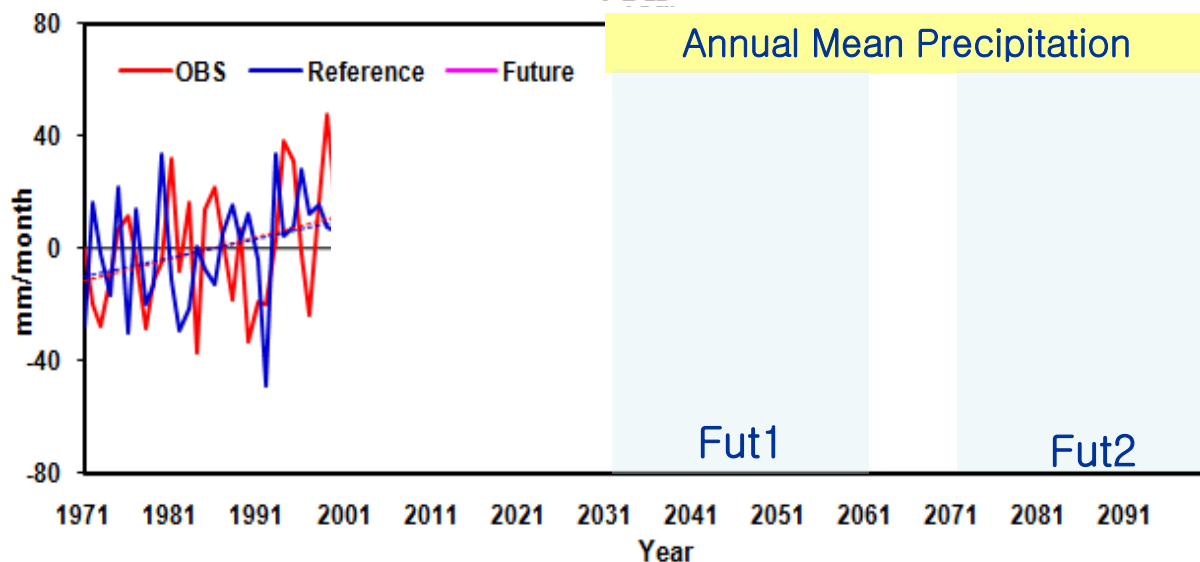
- ICTP Regional Climate Model Ver. 3
- Resolution: Mother domain – 60km / Nested domain – 20km
- Physical parameterization
  - MIT Emanuel Convection Scheme
  - BATS Land Surface Scheme
- Initial & Boundary :
  - ECHAM5 A1B(1.875)–IPCC AR4
- Integration Period :
  - [Reference] 1971–2000 (30yr)
  - [Future] 2000–2100 (100yr)



# Temp. & Precipiti. Long-term Trend & Variability

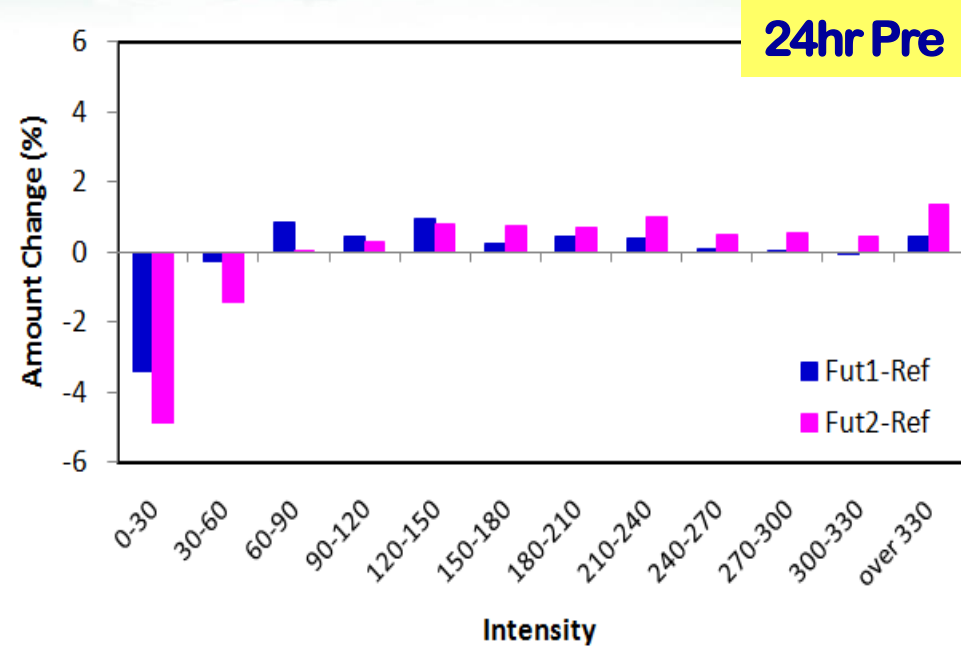
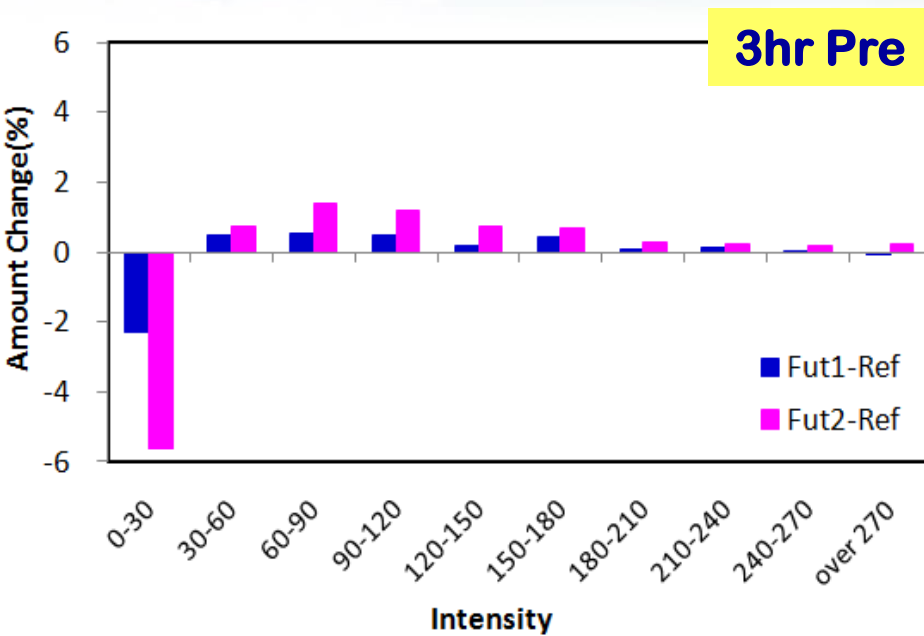


- Remarkable similarity between observation and simulation
- The degree of warming is sharply accelerated with well-defined increasing trend
- Projection derived for a short certain period could produce misinterpretation skewed by interdecadal variability.



- Even though mean precipitation didn't show significantly increasing pattern, the frequency and intensity of heavy precipitation clearly show increasing trends

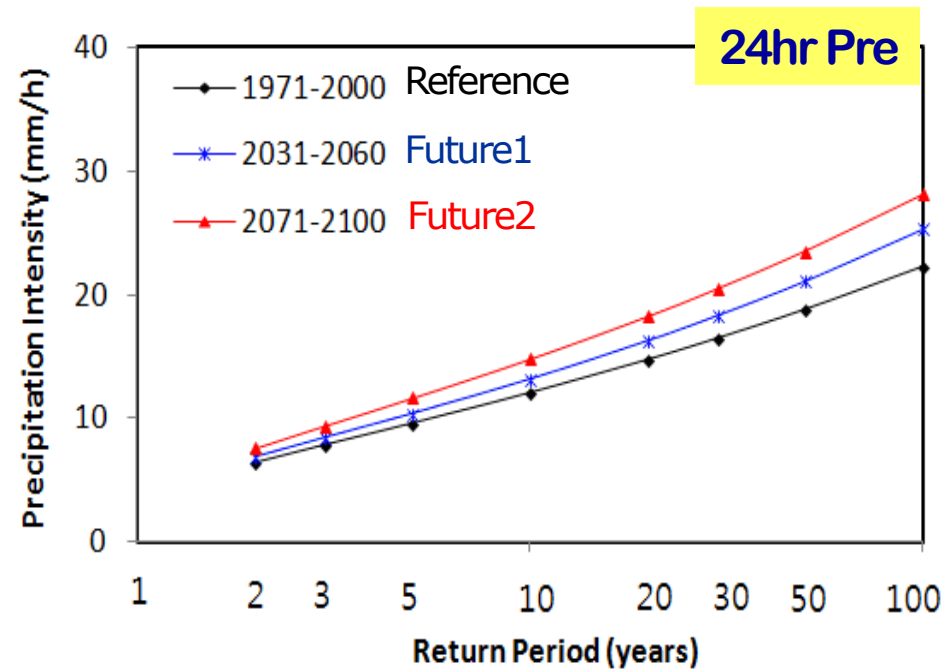
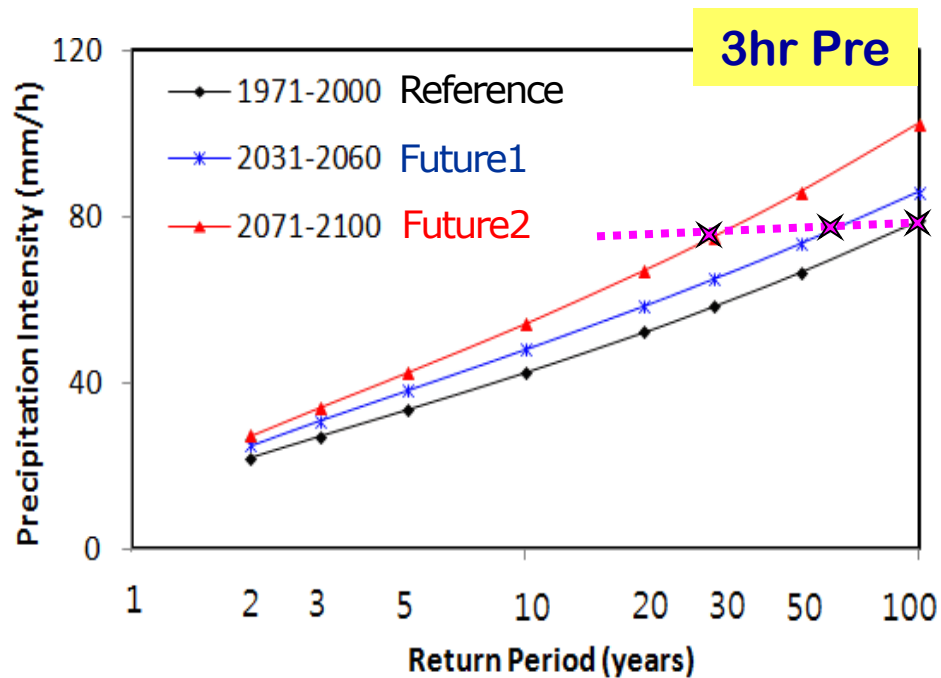
# Characteristics of Precipitation Change



- Despite the fairly large differences in 30-year temporal evolution of annual mean precipitation, both change behaviors of 3-hour and 24-hour precipitation show a similar pattern and sign.
- An **enhancement of relatively high intensity precipitation** and a **reduction of weak intensity precipitation** are discernible.

# Statistical Likelihood of Extremes

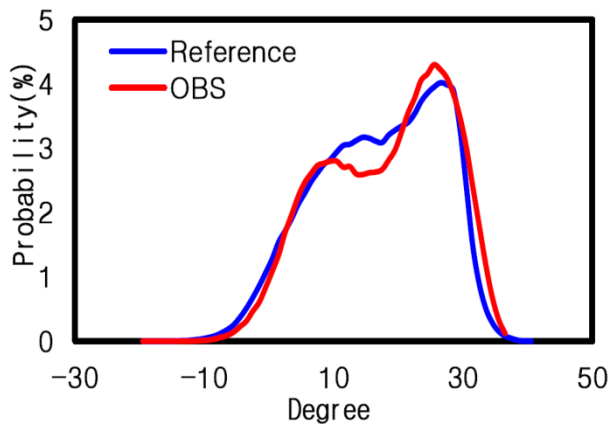
## Intensity-Duration-Frequency (IDF)



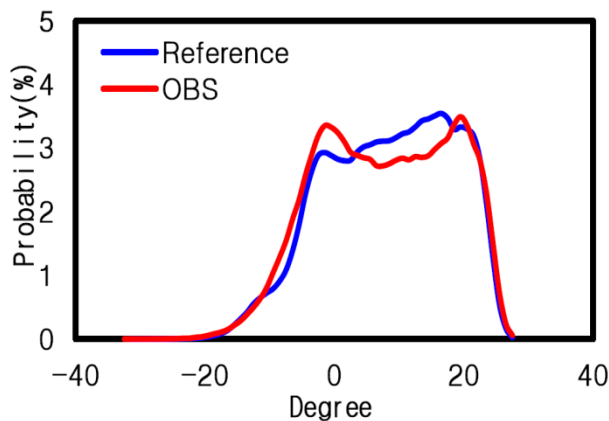
- Intensity–Duration–Frequency (IDF) curve shows that **significant reduction in the return period** of extremes is visible in response to global warming.
- The intensity enhancement is more pronounced in 3–hour duration, which implies more vulnerability against flood hazards.

# Probability Density Function

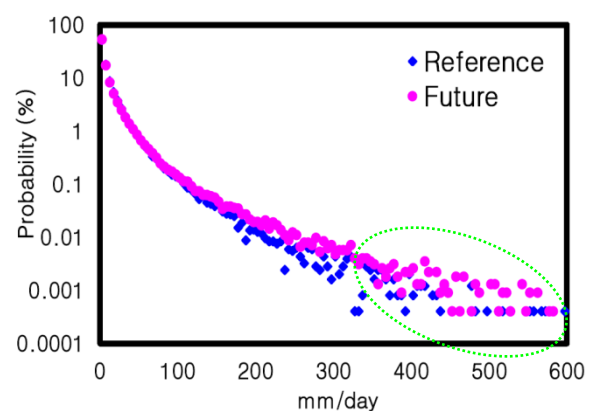
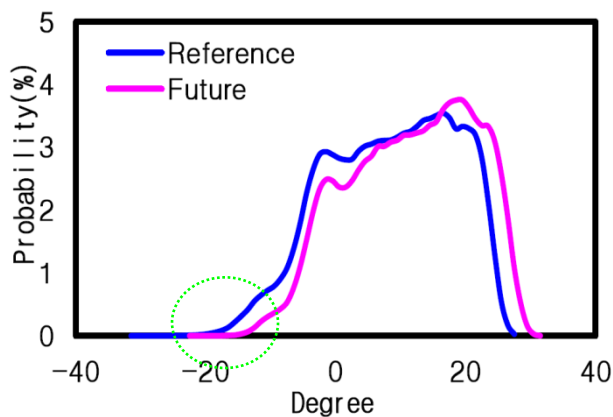
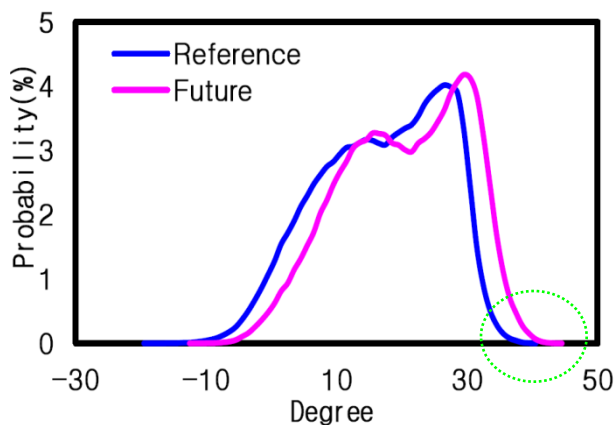
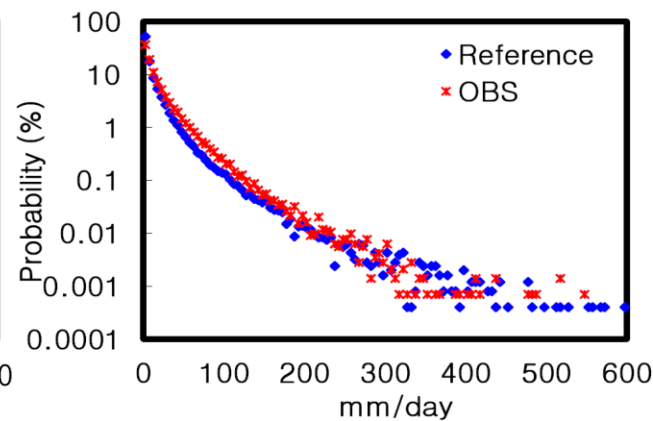
## Maximum Temp.



## Minimum Temp.



## Precipitation



# Extreme Indices

## Temperature-based Index

## Definition of extreme indices

FD (days)	Number of FDs with $T_{min}$ below 0
HD (days)	Number of HDs with $T_{max}$ below 30
TX95 ( $^{\circ}C$ )	Averaged $T_{max}$ above 95 <sup>th</sup> percentile
TN5 ( $^{\circ}C$ )	Averaged $T_{min}$ below 5 <sup>th</sup> percentile
HW (days)	Maximum duration of consecutive hot days

## Precipitation-based Index

## Definition of extreme indices

PN80 (days)	Number of days with precipitation above 80 mm intensity
PPL95 (%)	Percentage of total rainfall from events above long-term 95 <sup>th</sup> percentile
PX1D (mm)	Greatest 1-day total precipitation
MRDY (days)	Maximum duration of consecutive dry days
MWET (days)	Maximum duration of consecutive wet days

# Parametric vs. Non-parametric Statistics

## □ Parametric tests

- Assume the distribution of  $X_t$  (often Gaussian)
- Example: linear regression (with time)

## □ Non-parametric tests

- Non-parametric statistic tests refer to the collection of statistic tests that do not require any assumption on the distribution of the data.
- Most non-parametric tests are designed to assess the presence or absence of a given statistic characteristic (e.g. trend) and therefore do not provide the magnitude of the statistic characteristic of interest.
- Example: Mann-Kendall test

# Mann-Kendall test

## □ Mann-Kendall trend test hypotheses

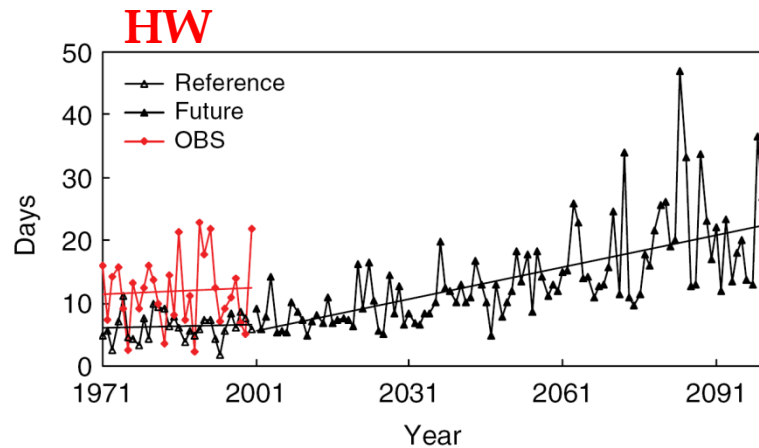
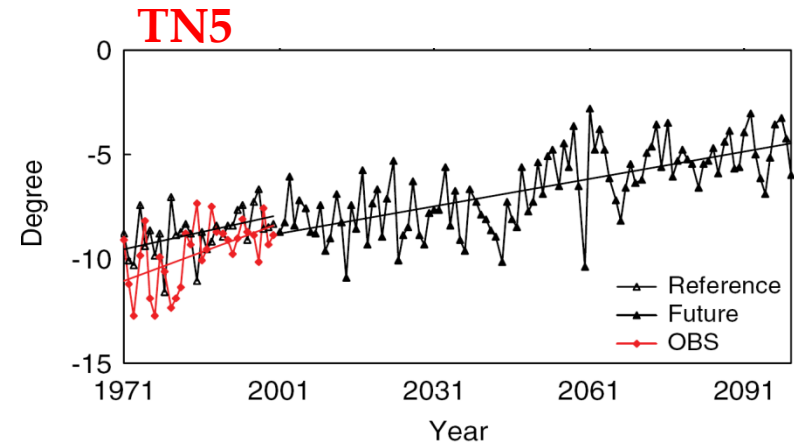
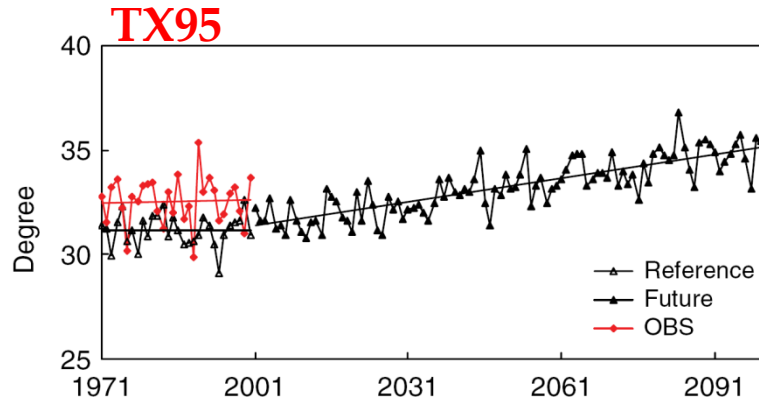
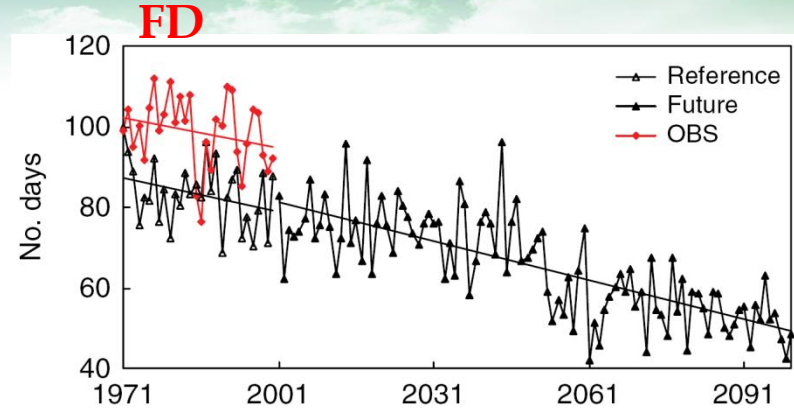
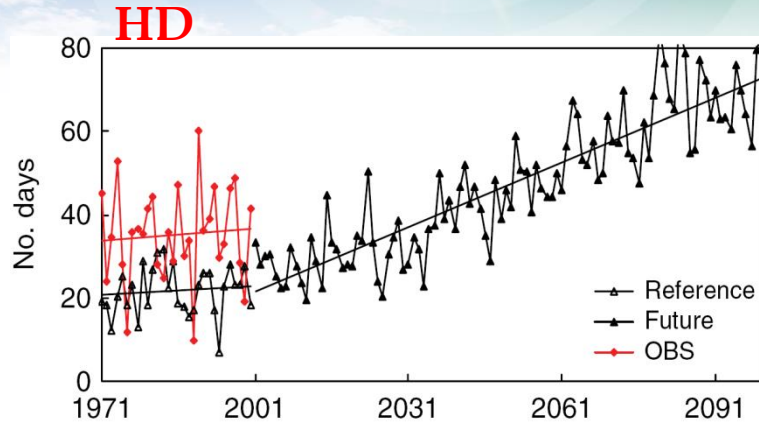
- The null hypothesis  $H_0$  for the test is that there is no trend in the series.
- The three alternative hypotheses are that there is a negative, non-null, or positive trend.
- The Mann-Kendall tests are based on the calculation of Kendall's statistics of association between two samples, which is itself based on the ranks with the samples.
- Kendall's statistics  $S$  is computed as follow:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^n \text{sgn}(x_j - x_k) \quad \text{Where, } \text{sgn}(x_j - x_k) = \begin{cases} 1 & \text{if } x_j - x_k > 0 \\ 0 & \text{if } x_j - x_k = 0 \\ -1 & \text{if } x_j - x_k < 0 \end{cases}$$

- $S$  is expected to have normal distribution with mean 0 and variance  $S$  with the null hypothesis  $H_0$  that is no trend displayed by the time series.
- A positive value of  $S$  indicates that there is an upward (increasing) trend.
- A negative value of  $S$  indicates that there is a downward (decreasing) trend.
- The Mann-Kendall test statistic  $Z_c$  is estimated as follows:

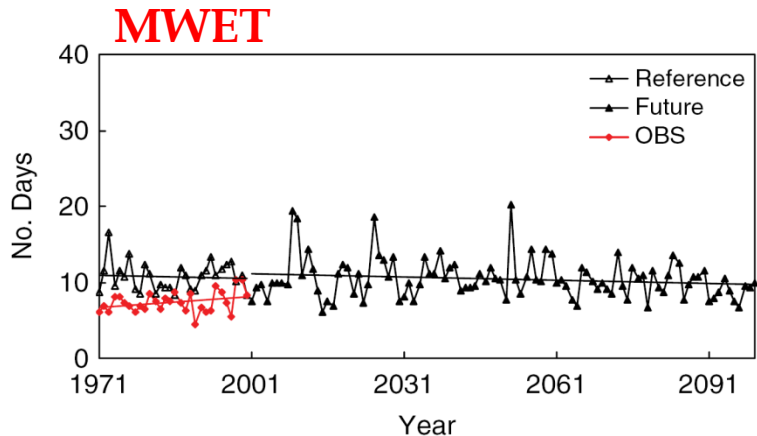
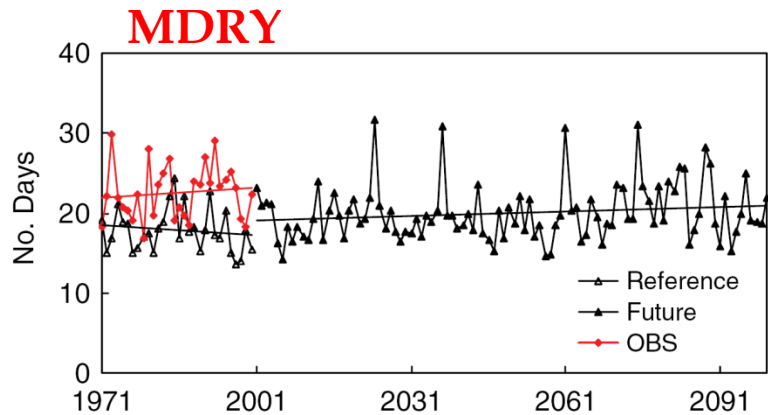
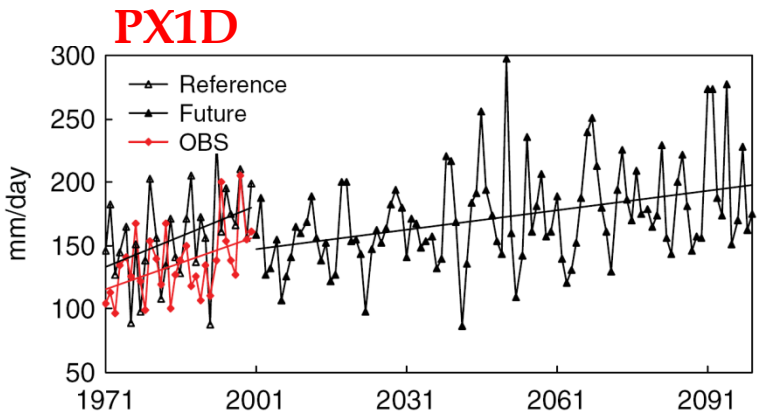
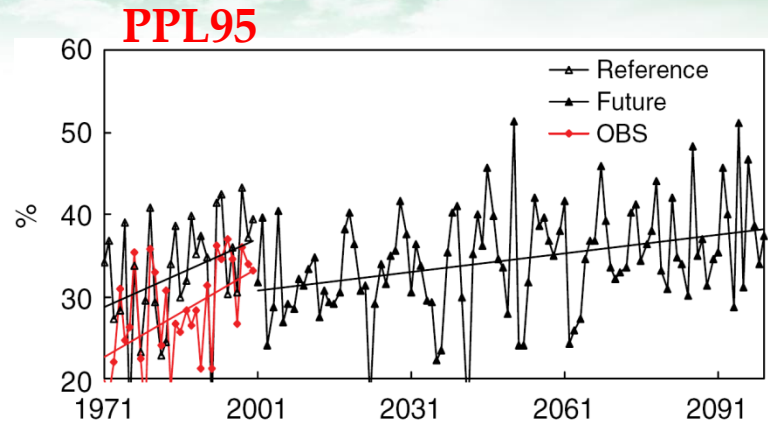
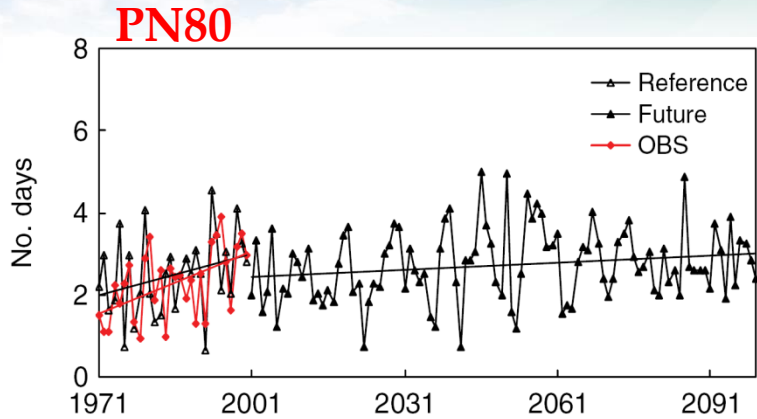
$$\begin{aligned} Z_c &= \frac{S - 1}{\sqrt{\text{var}(S)}} & S > 0 \\ Z_c &= 0 & S = 0 \\ Z_c &= \frac{S + 1}{\sqrt{\text{var}(S)}} & S < 0 \end{aligned}$$

# Temperature-based Extremes



	OBS	Ref	Fut	OBS	Ref	Fut
FD	98.7	83.2	65.3	-1.231	-1.409	-7.883*
HD	35.2	21.6	47.2	0.553	0.571	10.378*
TX95	32.6	31.2	33.2	0.071	0.143	9.500*
TN5	-9.7	-8.8	-6.6	2.622*	2.765*	7.010*
HW	11.9	6.2	14.0	-0.232	0.535	7.853*

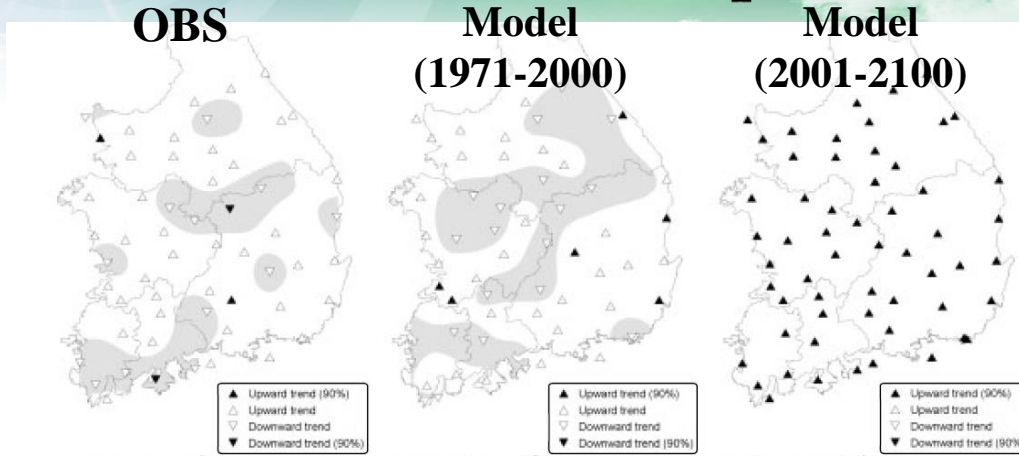
# Precipitation-based Extremes



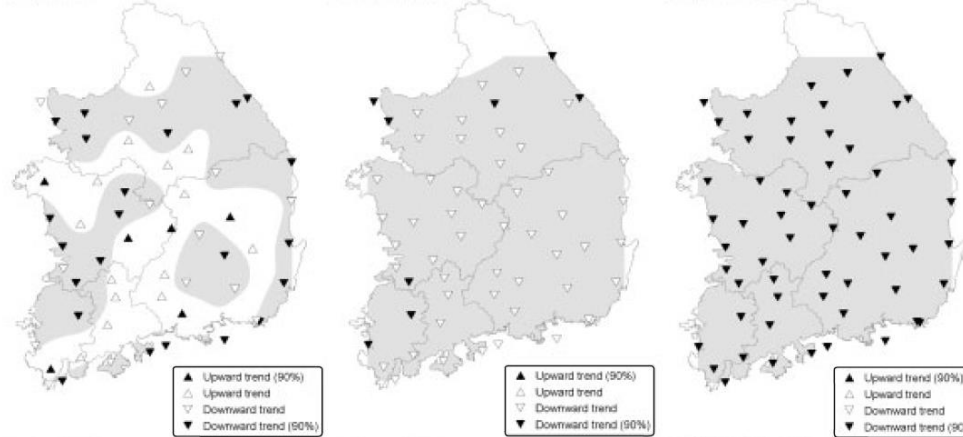
	OBS	Ref	Fut	OBS	Ref	Fut
<b>PN80</b>	2.3	2.5	2.7	2.873*	1.803*	1.954*
<b>PPL95</b>	27.9	32.7	34.4	2.784*	2.266*	3.344*
<b>PX1D</b>	135.9	156.9	172.3	2.373*	2.301*	3.615*
<b>MDRY</b>	22.5	17.8	20	0.642	-0.892	1.415
<b>MWET</b>	7.4	10.7	10.7	1.464	0.268	-1.176

# Spatial Distribution of Trend in Temp.-based Extremes

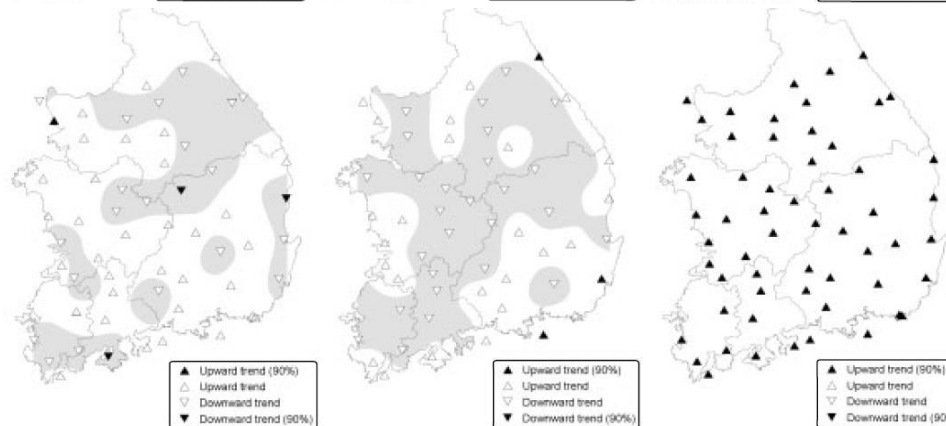
HD



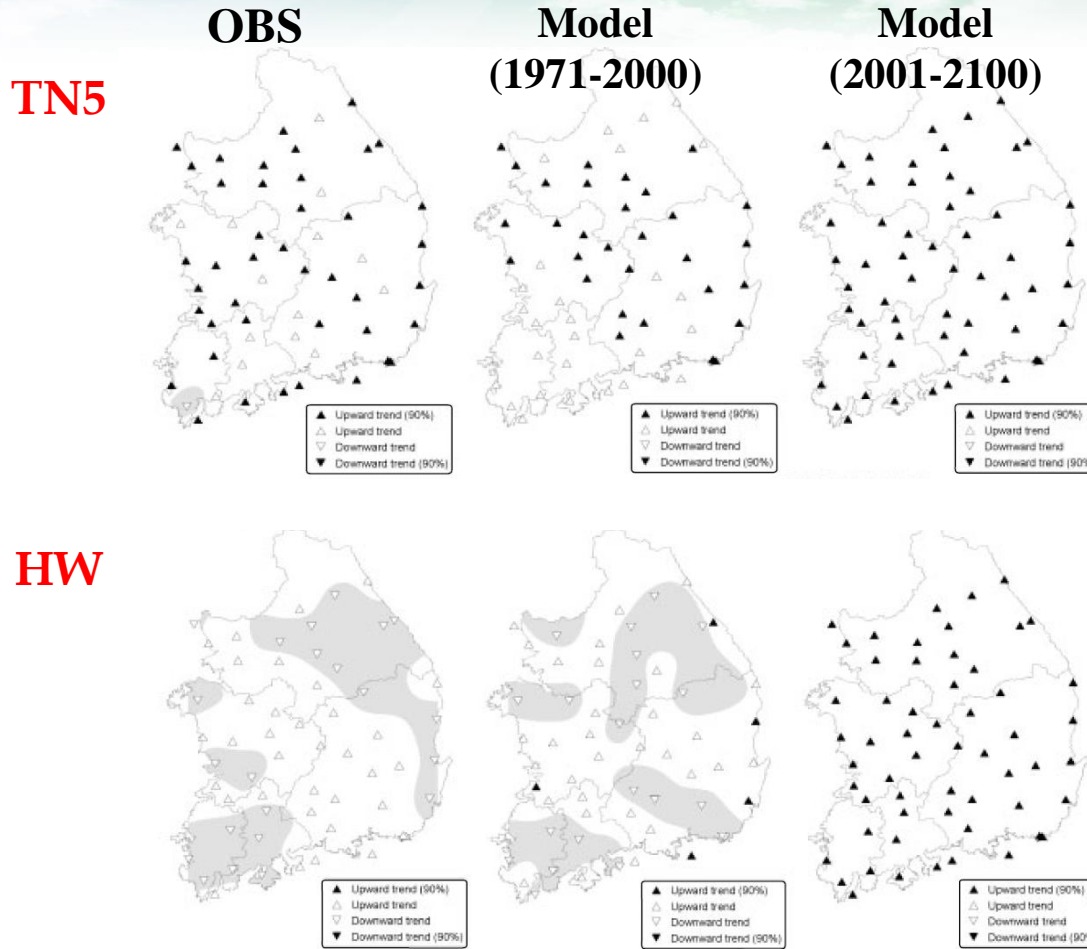
FD



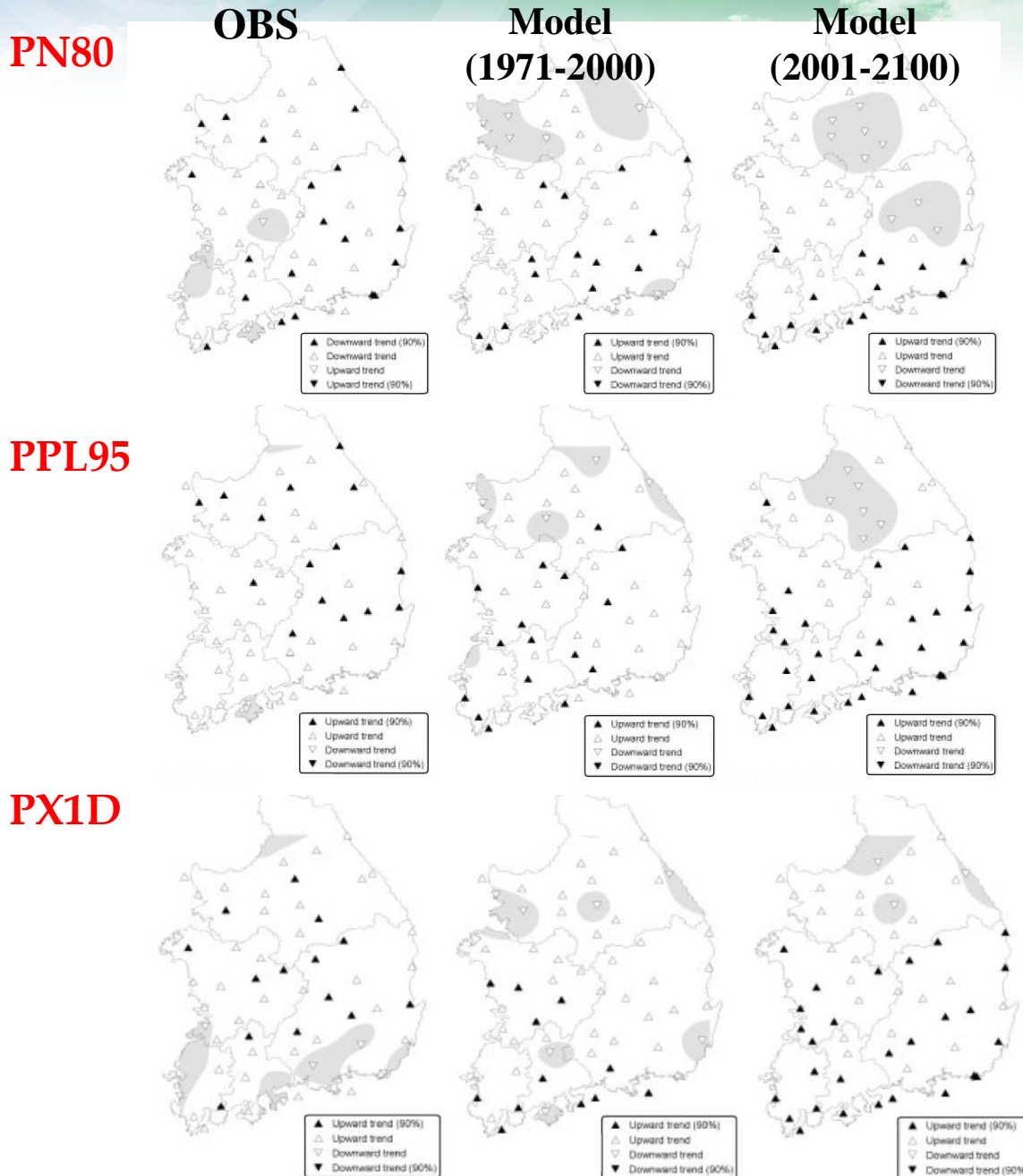
TX95



# Spatial Distribution of Trend in Temp.-based Extremes



# Spatial Distribution of Trend in Precip.-based Extremes



# Spatial Distribution of Trend in Precipi.-based Extremes

**MDRY**

**OBS**



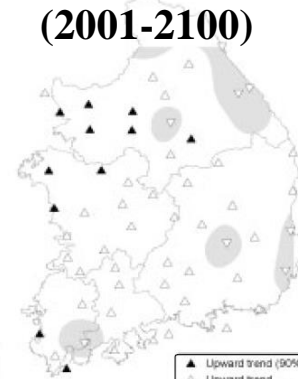
▲ Upward trend (90%)  
△ Upward trend  
▽ Downward trend  
▼ Downward trend (90%)

**Model  
(1971-2000)**



▲ Upward trend (90%)  
△ Upward trend  
▽ Downward trend  
▼ Downward trend (90%)

**Model  
(2001-2100)**



▲ Upward trend (90%)  
△ Upward trend  
▽ Downward trend  
▼ Downward trend (90%)

**MWET**



▲ Upward trend (90%)  
△ Upward trend  
▽ Downward trend  
▼ Downward trend (90%)



▲ Upward trend (90%)  
△ Upward trend  
▽ Downward trend  
▼ Downward trend (90%)



▲ Upward trend (90%)  
△ Upward trend  
▽ Downward trend  
▼ Downward trend (90%)

# Extreme Climate Sequences

## □ Dry & Wet Spells

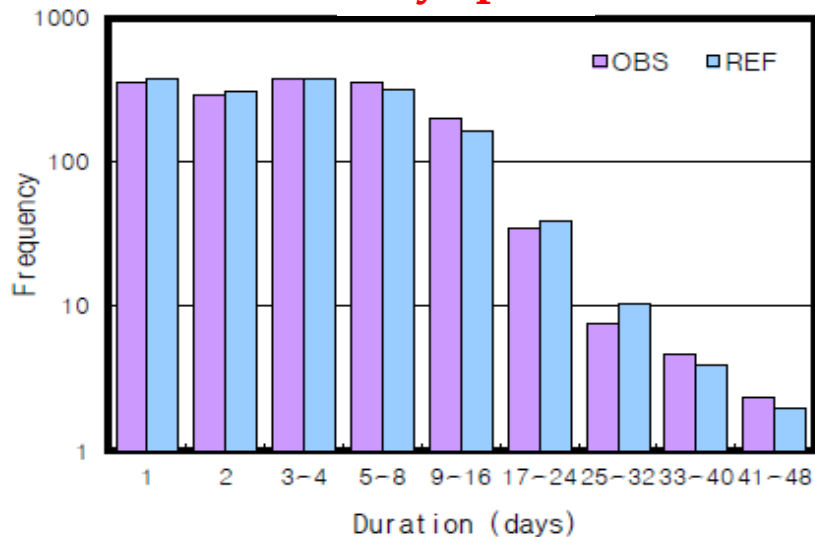
: A wet day is defined as a day with precipitation accumulation greater than or equal to 1.0 mm, whereas a dry day represents a day without precipitation or with too little precipitation (less than 1.0 mm) within a day. At least one dry (wet) day is referred to as a dry (wet) spell. It means there are alternating occurrences of wet and dry spells over the whole record.

## □ Frost & Hot Spells

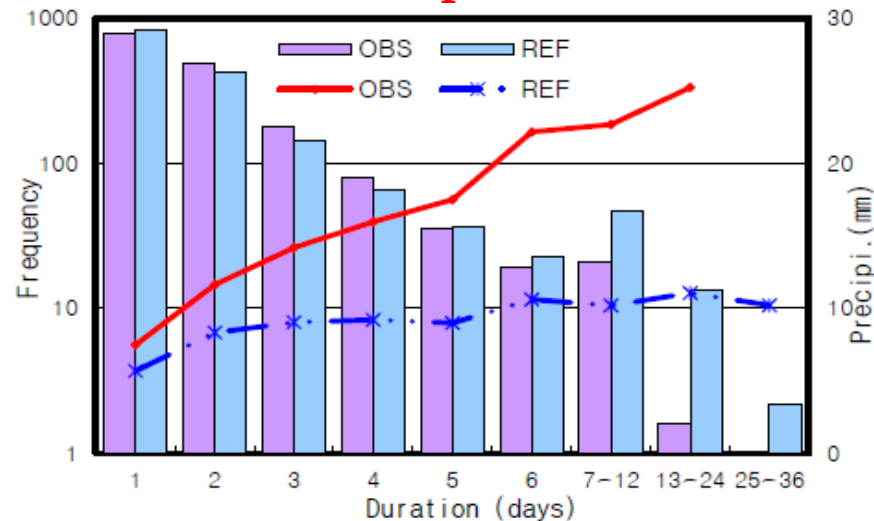
: A frost day is defined as a minimum temperature less than 0°C, while a hot day occurs if the maximum temperature exceeds 30°C.

# Frequency Distribution of Dry & Wet & Frost & Hot Spells

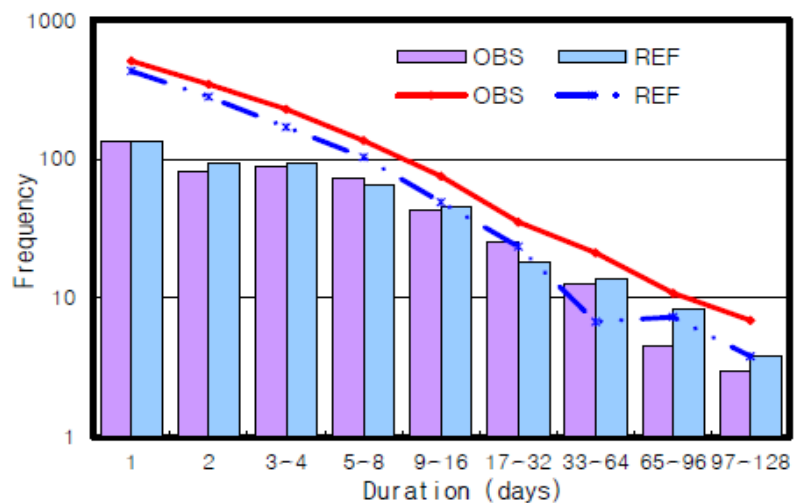
## Dry spell



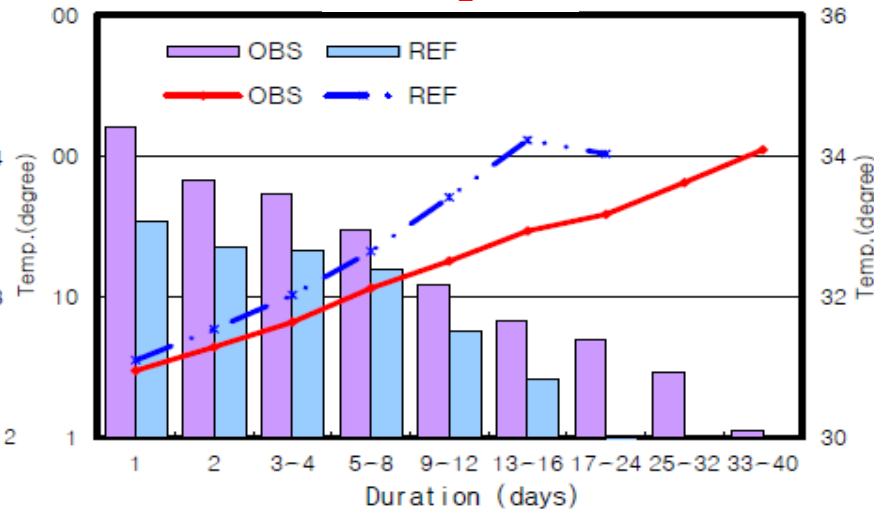
## Wet spell



## Frost spell

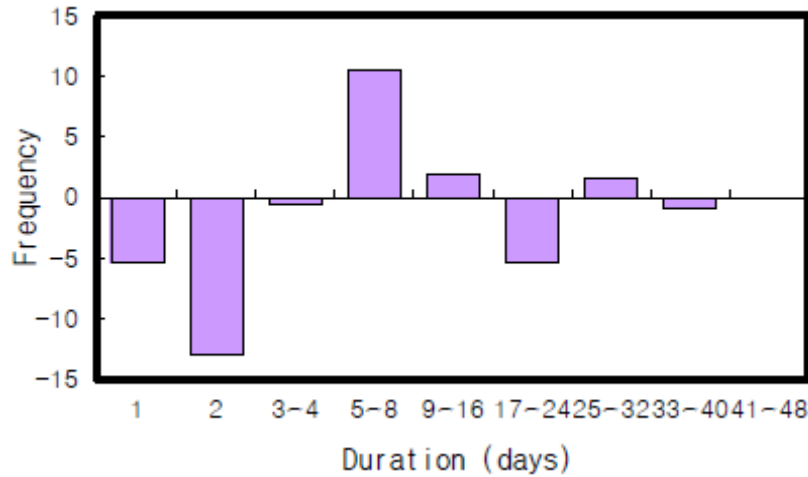


## Hot spell

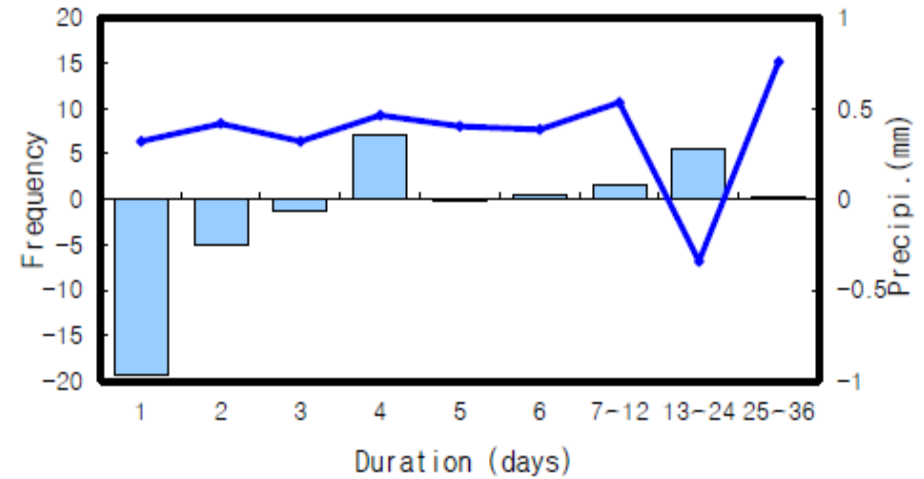


# Future Changes in Dry & Wet & Frost & Hot Spells

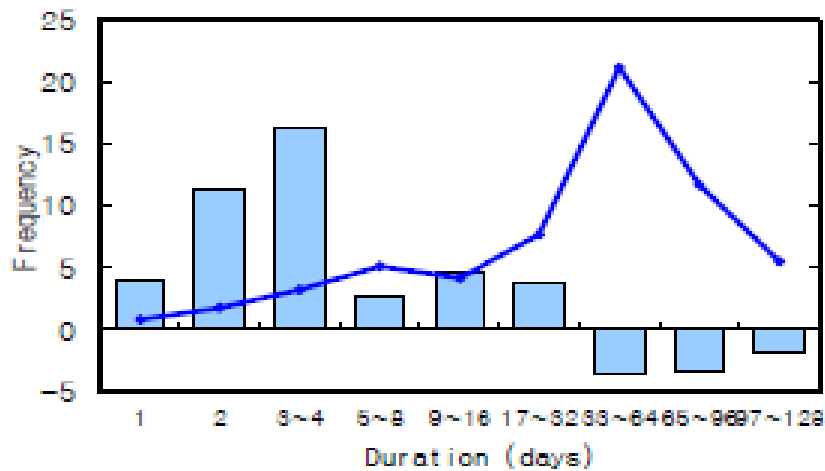
## Dry spell



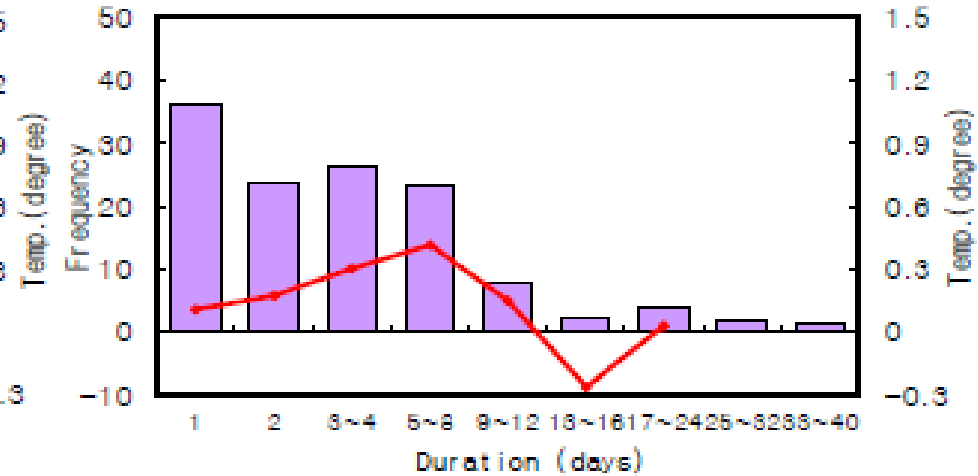
## Wet spell



## Frost spell

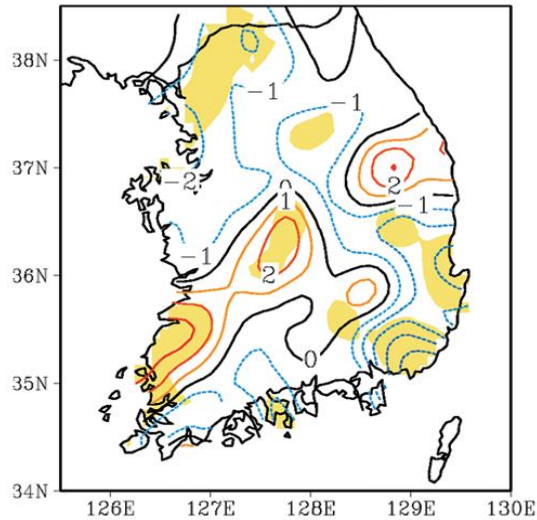


## Hot spell

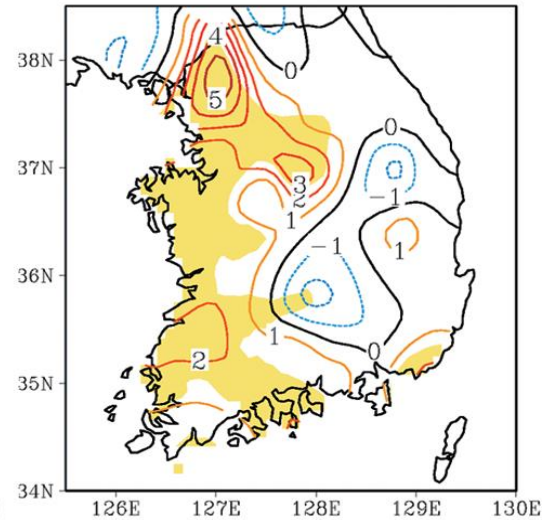


# Maximum Duration Change in Dry & Wet & Frost & Hot Spells

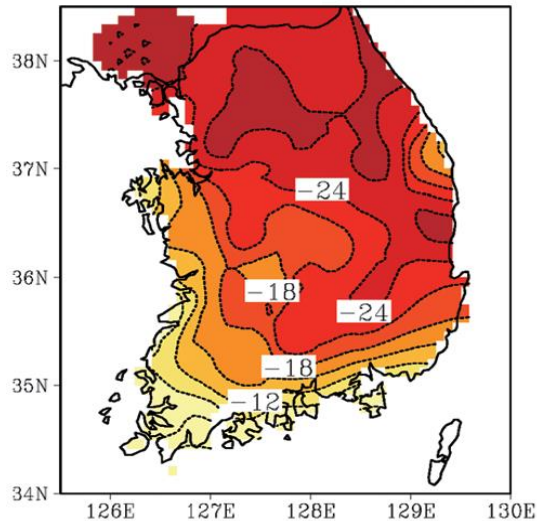
## Dry spell



## Wet spell



## Frost spell



## Hot spell

