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Projection of drought characteristics according to future climate and hydrological change in the Korean Peninsula

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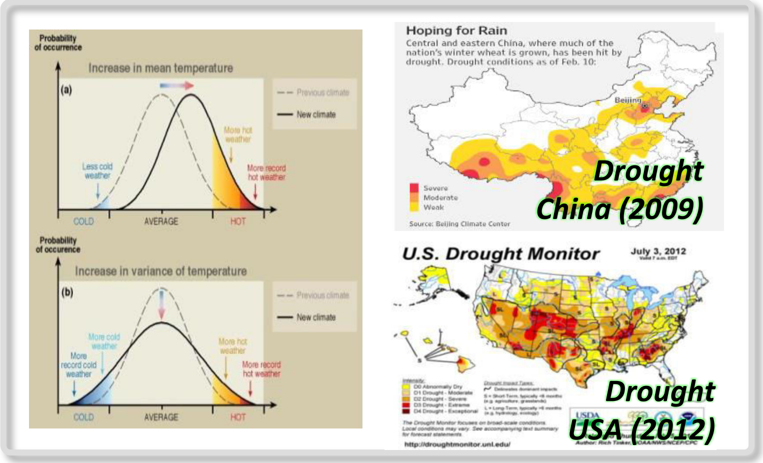
Introduction

Necessities of this study

- Drought is one of the serious natural disasters along with the floods, and that of South Korea with 2-3 year cycle is no exception
- Understanding of drought characteristics in North Korea is very limited due to the lack of meteorological and hydrological information
- Drought is projected to be more severe due to climate change impact
- It is useful to project future drought conditions in Korea and to compare their characteristics in South and North Korea

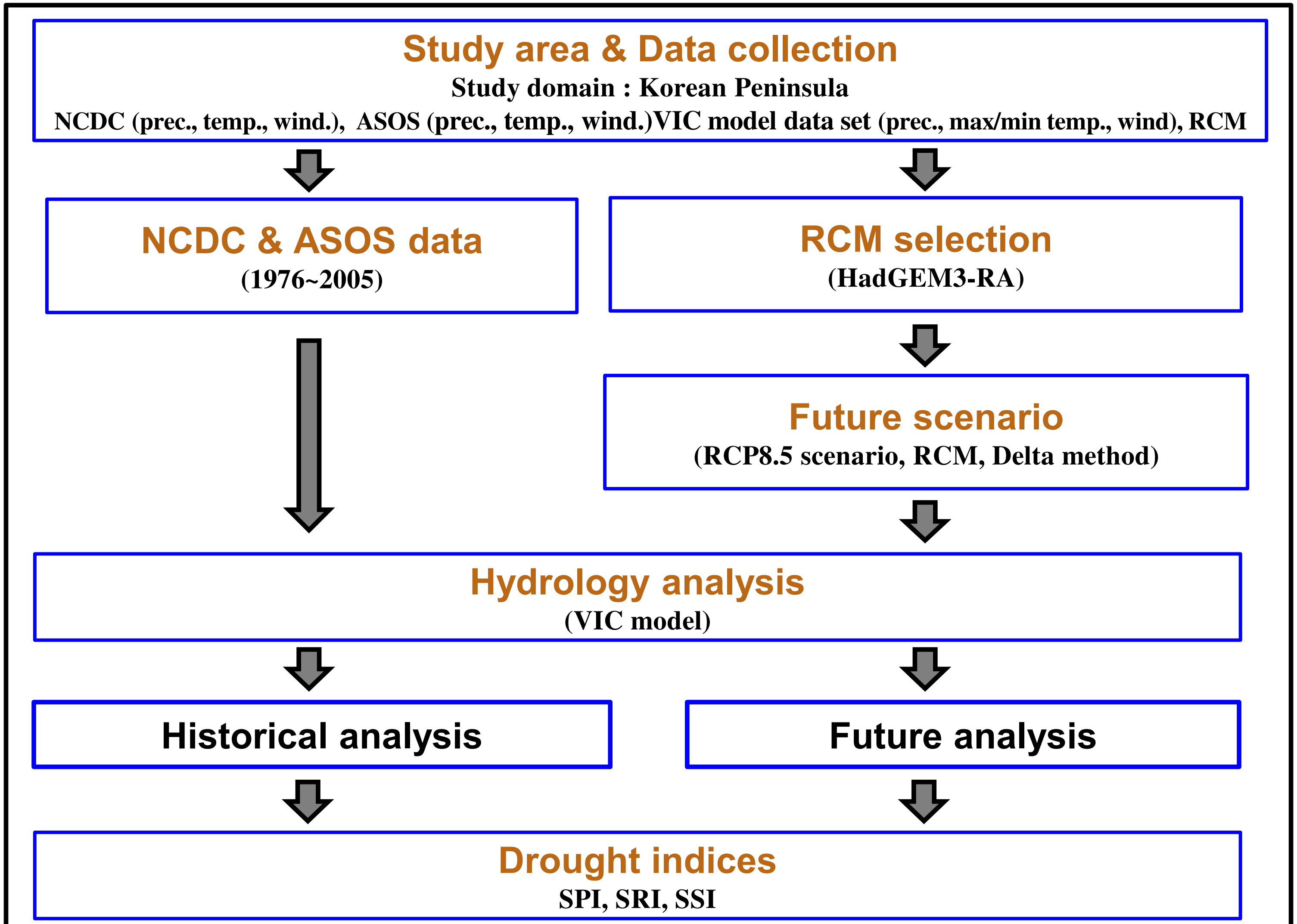
Objectives of this study

- To project drought conditions using future global-scale climate & hydrological information in Korea
- To analyze the changes of drought trend and frequency in the region



Methodology

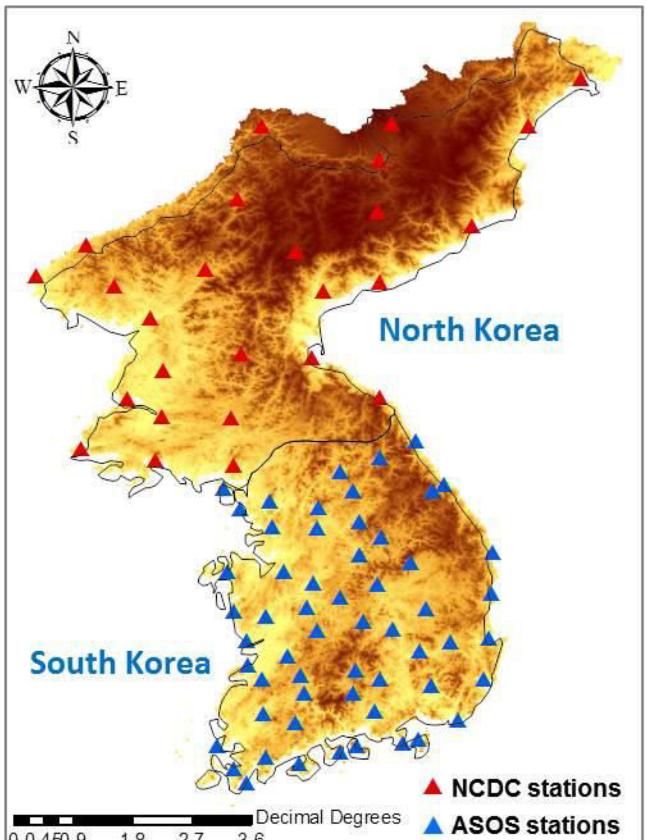
Procedure of this study



Study Area & Data Collection

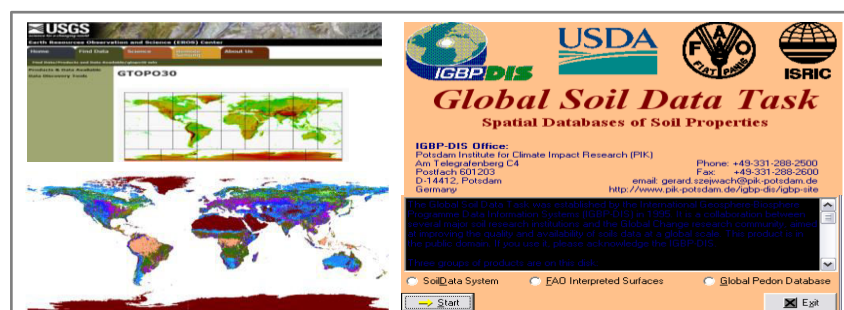
Study area

- Korean Peninsula with South and North Korea
  - South Korea area : 120,500km^2
  - North Korea area : 99,720km^2



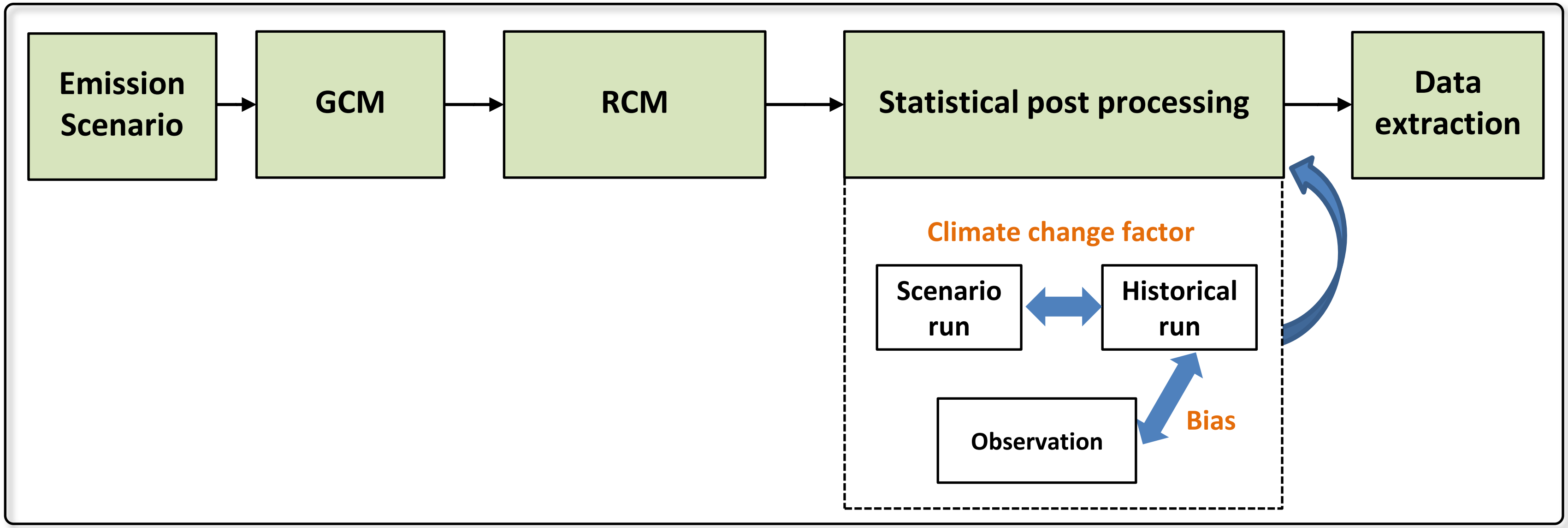
Meteorological & topographical data

- Meteorological data
  - S. Korea : 59 ASOS of KMA (Korea Meteorological Administration)
  - N. Korea : 24 NCDC (National Climate Data Center) data
- Topographical data
  - DEM
    - United States Geological Survey (USGS)
    - Resolution : 30″×30″
  - Land use
    - University of Maryland (UMD)
    - Resolution : 1km×1km
  - Soil properties
    - Food Agriculture Organization (FAO)
    - Resolution : 5′×5′



Climate change scenario & Climate variables

- Emission scenario : RCP8.5 (Radiative force, 8.5 W/m^2, 2099yr)
- GCM &RCM : HadGEM3-A0 & HadGEM3-RA
- Statistical post processing : Delta method
  - Reference period (S0) : 1977-2006yr.
  - Projection periods (S1, S2, S3) : 2020s(2010~2039yr.), 2050s(2040~2069yr.), 2080s(2070~2099yr.)
  - Meteorological variables : Precipitation, Max. & Min. temperature, Wind speed

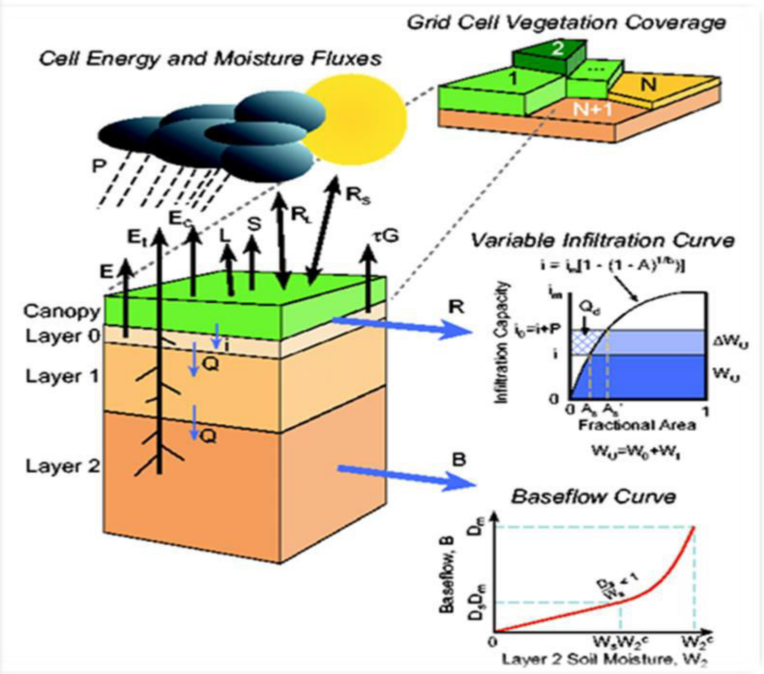


Hydrological model

- VIC (Variable Infiltration Capacity) model : a soil-vegetation-atmospheric transfer scheme that considers both energy and water balances

- A grid-based macro-scale model : usually implemented at various spatial scales from 1/8° to 2°

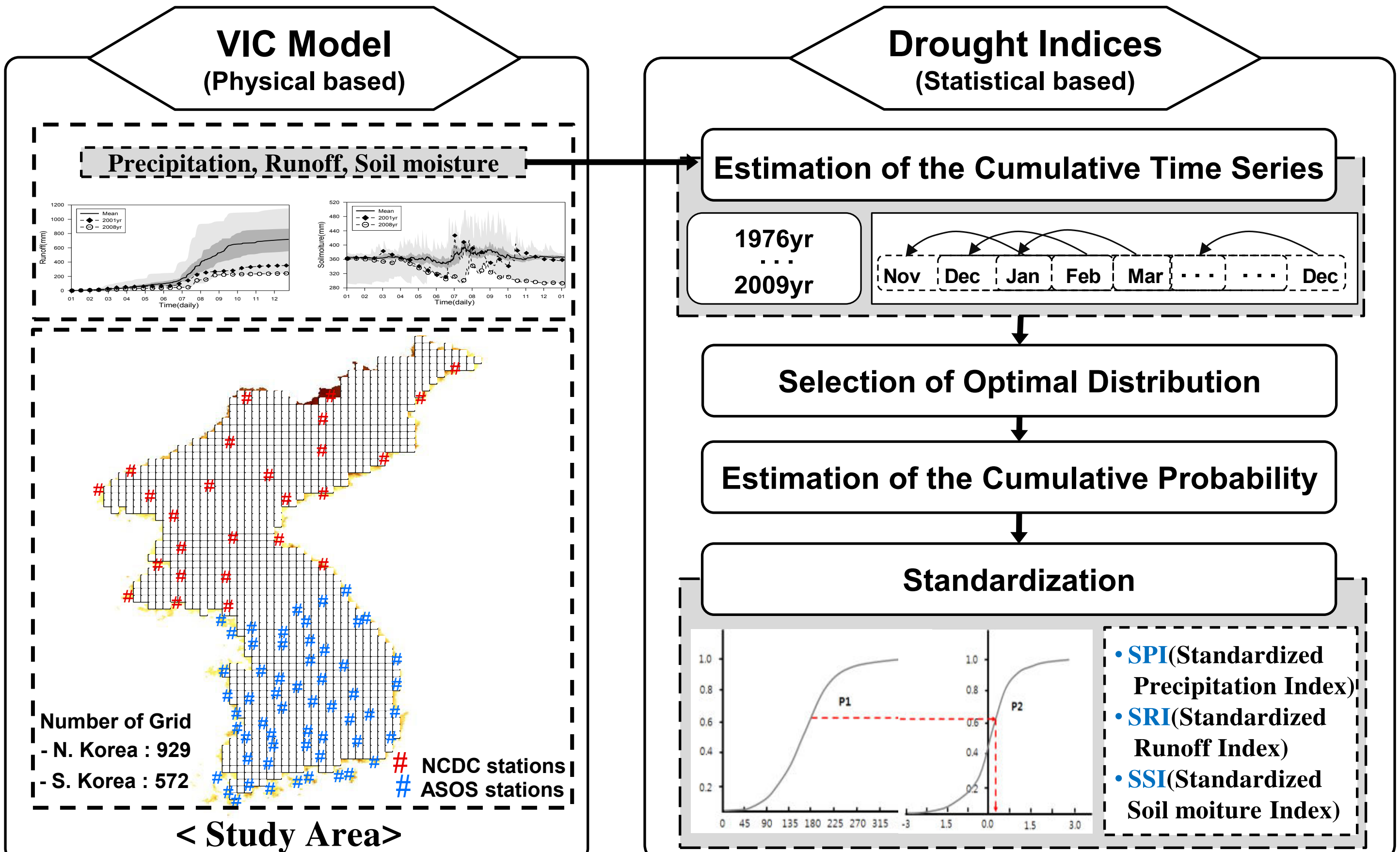
- Widely used for analyzing the variations of water resources on climate change



Parameter	Input Data
Basin	DEM
Forcing	Precipitation Maximum Temperature Minimum Temperature Wind Speed
Soil	Soil Properties
Vegetation	Land use

Drought index calculation

- Use 3-month cumulative precipitation, runoff and soil moisture at each grid
- Select the appropriate distribution for the variables
- Compute the drought indices (SPI, SRI, SSI) by using normalization process



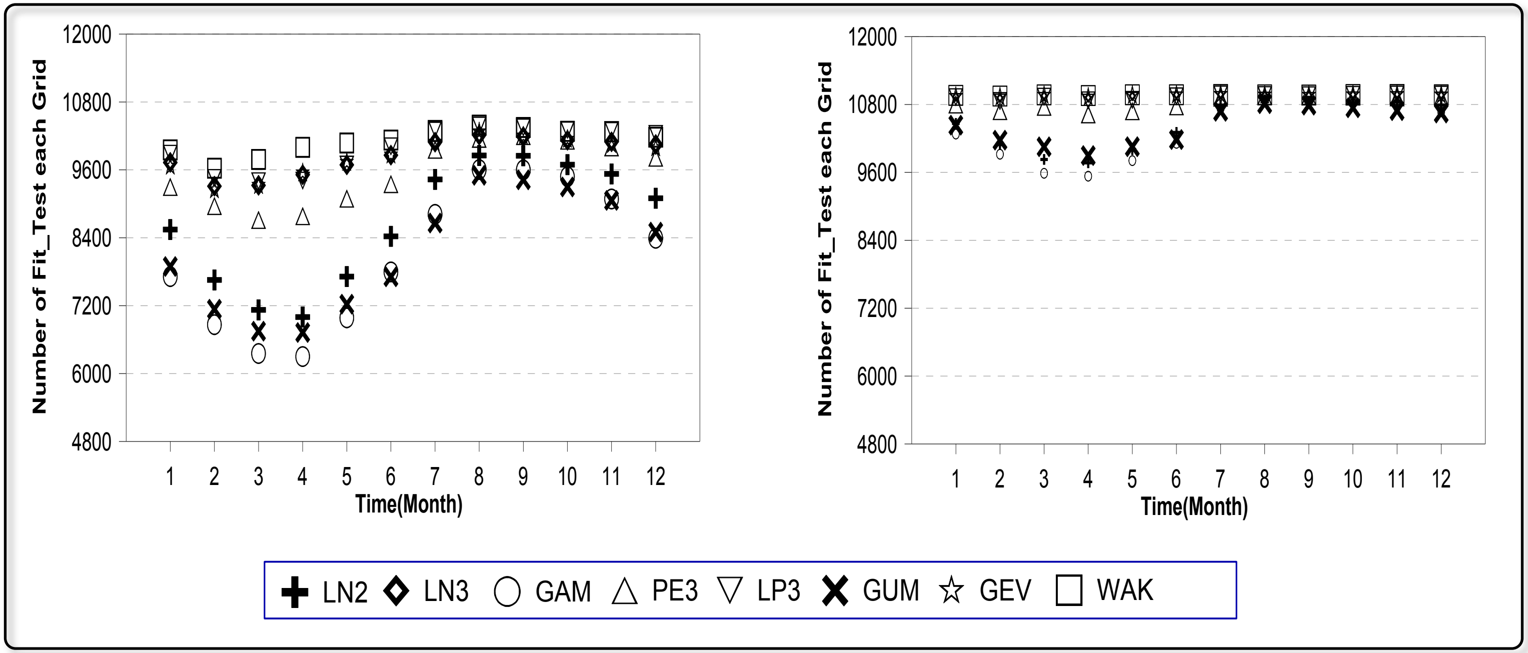
Estimation of optimal distribution for hydro-climate variables

Application of pdf and their parameter estimation

- **Probability distributions : Lognormal(2p), Gamma(2p), Log-pearson type-3, Gumbel, GEV, Wakeby(5p)**
- **Parameter estimation methods : L-moment method (Hosking and Wallis, 1993)**

Selection of suitable distribution

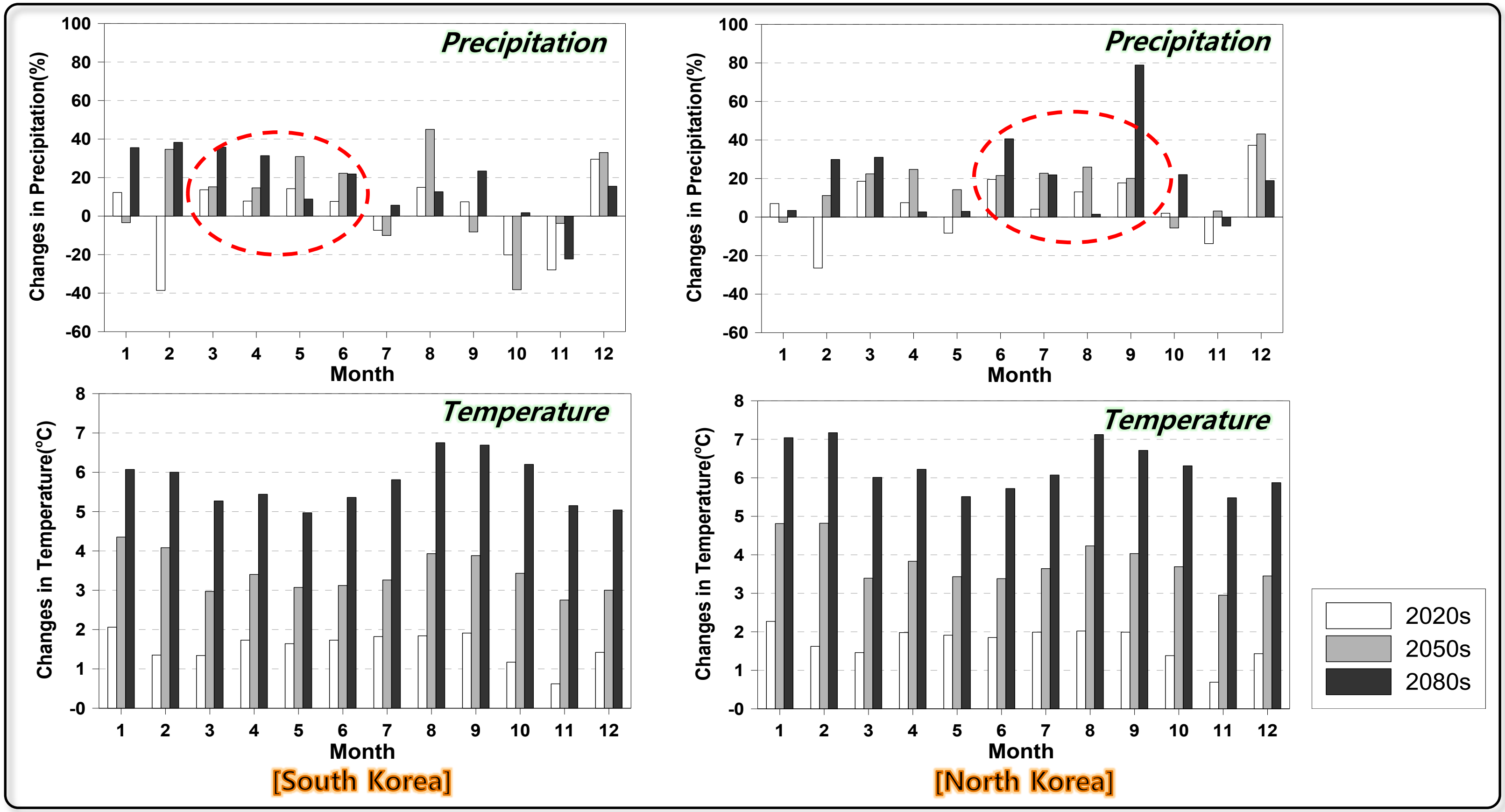
- **Precipitation : Gamma, Runoff : Log-pearson type-3, Soil moisture : Wakeby (5 parameters)**



Results & Analysis

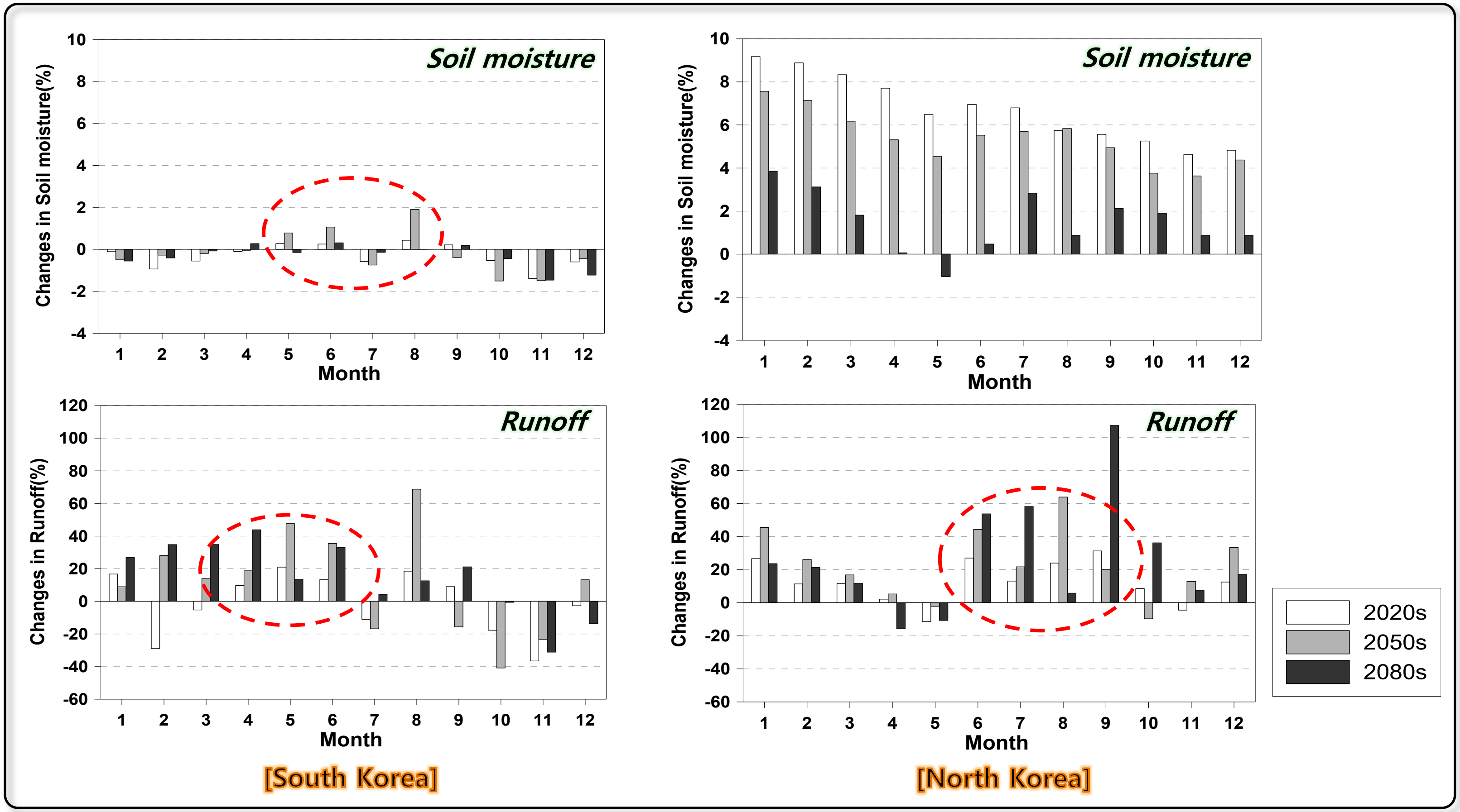
Future climate and hydrology projections

- **Monthly average precipitation (P), temperature (T) in the region**
  - **P increases in Mar. ~ Jun., and T rises in all the month in South Korea,**
  - **In North Korea, P increases in Jun. ~ Sep., and T rises with similar pattern of South Korea**



➤ **Monthly average soil moisture (SM), runoff (Q) in the region**

- **SM increases in May, Jun., Aug., and Q increases in Apr. ~ Jun. in South Korea**
- **SM increases in almost all the month, and Q increases in jun. ~ Sep. in North Korea**



The increase of Q are directly related to the increase of P

Future drought trend analysis by Mann-Kendall test

SPI3 : Meteorological drought

- Increasing trend, but not statistically significant on all the months of South and North Korea for S1, S2, S3
- Spring drought increase is significant compared to the other seasons in South Korea
- Summer drought increases, but not statistically significant in North Korea

-	South Korea				North Korea			
	▲(95%↑)	△(95%↓)	▽(95%↓)	▼(95%↑)	▲(95%↑)	△(95%↓)	▽(95%↓)	▼(95%↑)
Jan.	1.9	79.9	18.2	0.0	0.1	83.1	16.8	0.0
Feb.	17.7	79.0	3.3	0.0	19.1	60.1	20.9	0.0
Mar.	60.7	39.3	0.0	0.0	6.4	75.6	18.1	0.0
Apr.	46.2	53.3	0.5	0.0	0.2	78.5	21.3	0.0
May	5.2	91.1	3.7	0.0	1.4	82.7	15.9	0.0
Jun.	12.4	86.9	0.7	0.0	13.1	80.6	6.2	0.0
Jul.	9.6	85.8	4.5	0.0	33.5	63.1	3.4	0.0
Aug.	10.1	88.5	1.4	0.0	10.0	80.8	9.1	0.0
Sep.	7.2	92.8	0.0	0.0	16.7	78.1	5.2	0.0
Oct.	10.0	90.0	0.0	0.0	4.8	89.2	5.9	0.0
Nov.	6.5	92.8	0.7	0.0	30.0	68.9	1.1	0.0
Dec.	0.0	75.9	24.1	0.0	0.0	86.3	13.7	0.0
Spr.	60.8	38.1	1.0	0.0	4.0	77.8	18.2	0.0
Sum.	26.2	72.9	0.9	0.0	26.2	67.1	6.8	0.0
Aut.	13.1	86.9	0.0	0.0	19.9	77.7	2.4	0.0
Win.	1.2	43.5	51.2	4.0	18.7	71.4	9.1	0.8

SRI3 : Hydrological drought

- Increasing trend, but not statistically significant on all the months of South and North Korea for S1, S2, S3
- Autumn drought increases, but not statistically significant In South Korea
- Summer drought increases, and relatively statistical significance compared to other seasons in North Korea

-	South Korea				North Korea			
	▲(95%↑)	△(95%↓)	▽(95%↓)	▼(95%↑)	▲(95%↑)	△(95%↓)	▽(95%↓)	▼(95%↑)
Jan.	0.0	57.5	42.5	0.0	6.5	78.6	15.0	0.0
Feb.	1.0	71.5	27.4	0.0	14.3	72.2	12.7	0.8
Mar.	11.7	80.8	7.5	0.0	5.6	69.8	23.6	1.1
Apr.	5.8	81.8	12.4	0.0	0.2	68.4	26.6	4.8
May	1.9	83.4	14.7	0.0	1.3	65.2	30.7	2.8
Jun.	4.2	86.0	9.8	0.0	11.0	66.7	22.3	0.0
Jul.	3.5	88.5	8.0	0.0	23.1	65.4	11.4	0.0
Aug.	7.3	83.0	9.6	0.0	5.3	79.4	15.3	0.0
Sep.	2.3	89.2	8.6	0.0	7.5	78.1	14.3	0.0
Oct.	4.5	90.0	5.4	0.0	5.1	82.8	12.2	0.0
Nov.	0.2	92.3	7.5	0.0	7.2	86.3	6.5	0.0
Dec.	0.0	68.0	32.0	0.0	8.7	77.8	13.5	0.0
Spr.	8.6	82.2	9.3	0.0	3.0	70.5	24.2	2.3
Sum.	11.0	83.7	5.2	0.0	22.4	63.2	14.3	0.1
Aut.	2.6	94.6	2.8	0.0	10.5	78.5	11.0	0.0
Win.	0.7	25.0	72.4	1.9	1.5	90.2	5.8	2.5

SSI3 : Agricultural drought

- **Not statistically significant increasing trend on all the months of the region, but decreasing trend in spring season of South Korea**
- **Autumn drought increases, but not statistically significant in South Korea**
- **Winter drought increases, but not statistically significant in North Korea**

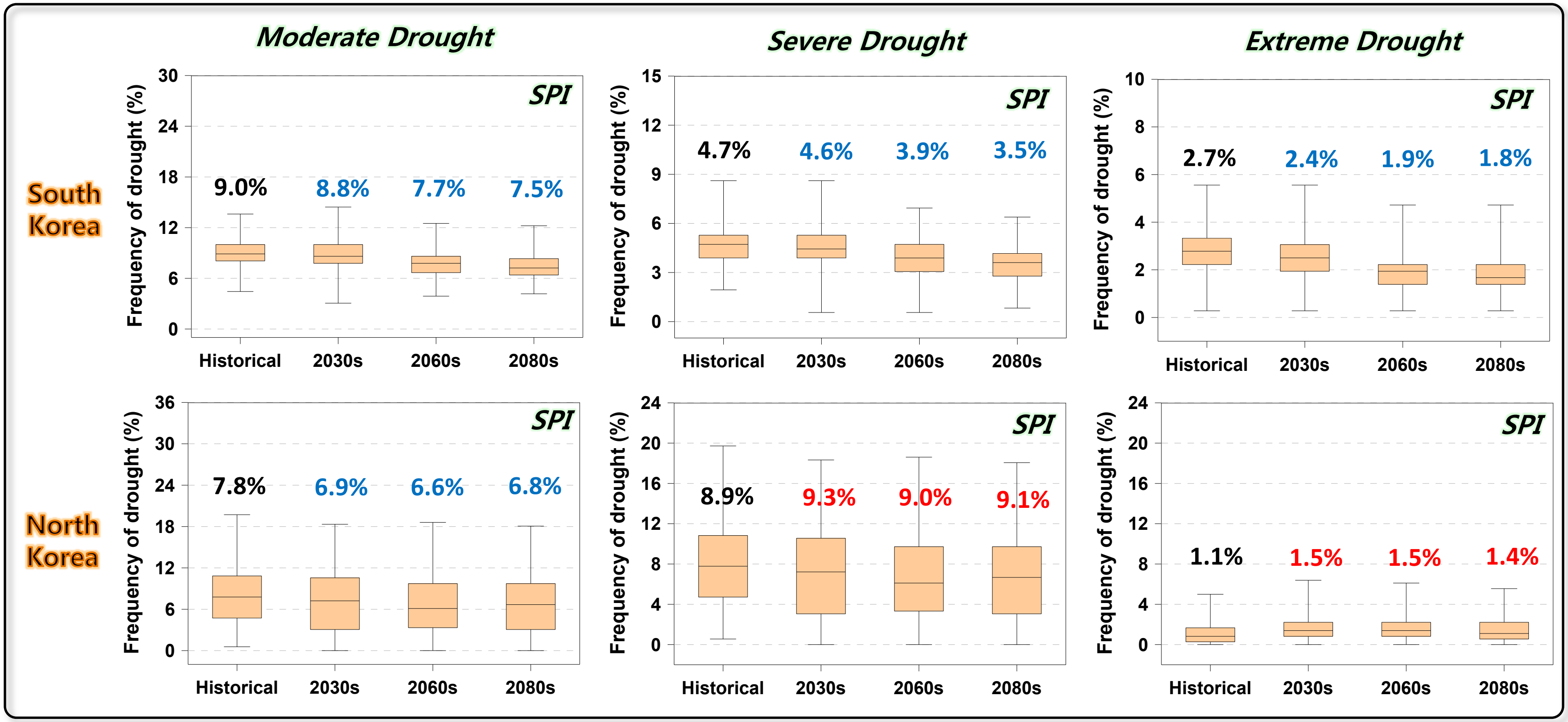
-	South Korea				North Korea			
	▲(95%↑)	△(95%↓)	▽(95%↓)	▼(95%↑)	▲(95%↑)	△(95%↓)	▽(95%↓)	▼(95%↑)
Jan.	0.0	29.9	69.8	0.3	2.9	57.5	36.7	2.9
Feb.	0.0	45.1	54.4	0.5	2.7	51.9	42.0	3.4
Mar.	2.4	60.5	36.5	0.5	2.6	60.4	34.3	2.7
Apr.	1.9	60.1	37.8	0.2	1.1	60.8	33.4	4.7
May	0.5	59.1	40.4	0.0	1.6	57.6	35.0	5.8
Jun.	0.0	58.0	42.0	0.0	2.7	57.2	34.1	6.0
Jul.	0.0	59.3	40.7	0.0	4.8	57.3	34.6	3.3
Aug.	0.2	64.7	35.0	0.2	7.1	57.6	34.1	1.2
Sep.	0.2	73.4	26.4	0.0	7.3	52.3	39.2	1.2
Oct.	0.3	89.0	10.7	0.0	6.9	62.0	30.5	0.6
Nov.	0.2	60.8	39.0	0.0	7.4	60.5	31.0	1.1
Dec.	0.5	44.4	55.1	0.0	7.2	56.8	34.1	1.8
Spr.	1.4	42.8	59.8	0.2	3.7	57.7	34.4	4.2
Sum.	0.0	63.6	36.4	0.0	9.5	53.9	32.3	4.3
Aut.	0.2	79.7	20.1	0.0	8.9	59.1	30.8	1.2
Win.	1.0	70.1	28.7	0.2	10.2	82.7	6.9	0.2

The critical increasing seasons of drought are different for each SPI3, SRI3 and SSI3 and each region

Future drought frequency according to severity

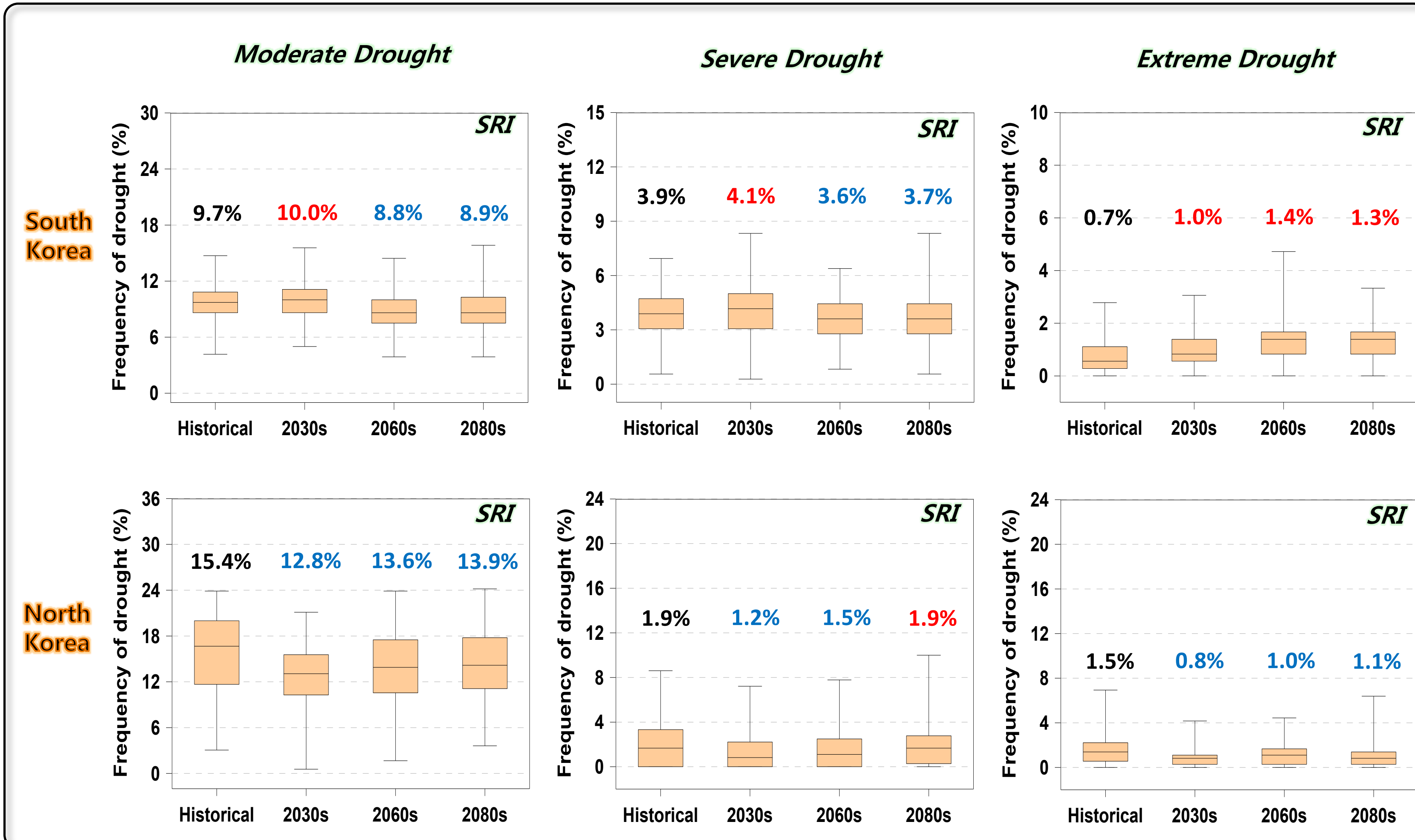
SPI3

- Future drought frequencies for S1, S2, S3 decreases on *all the cases* in South Korea
- The frequency on *Moderate drought* decreases, but increases for the rest of two cases in North Korea



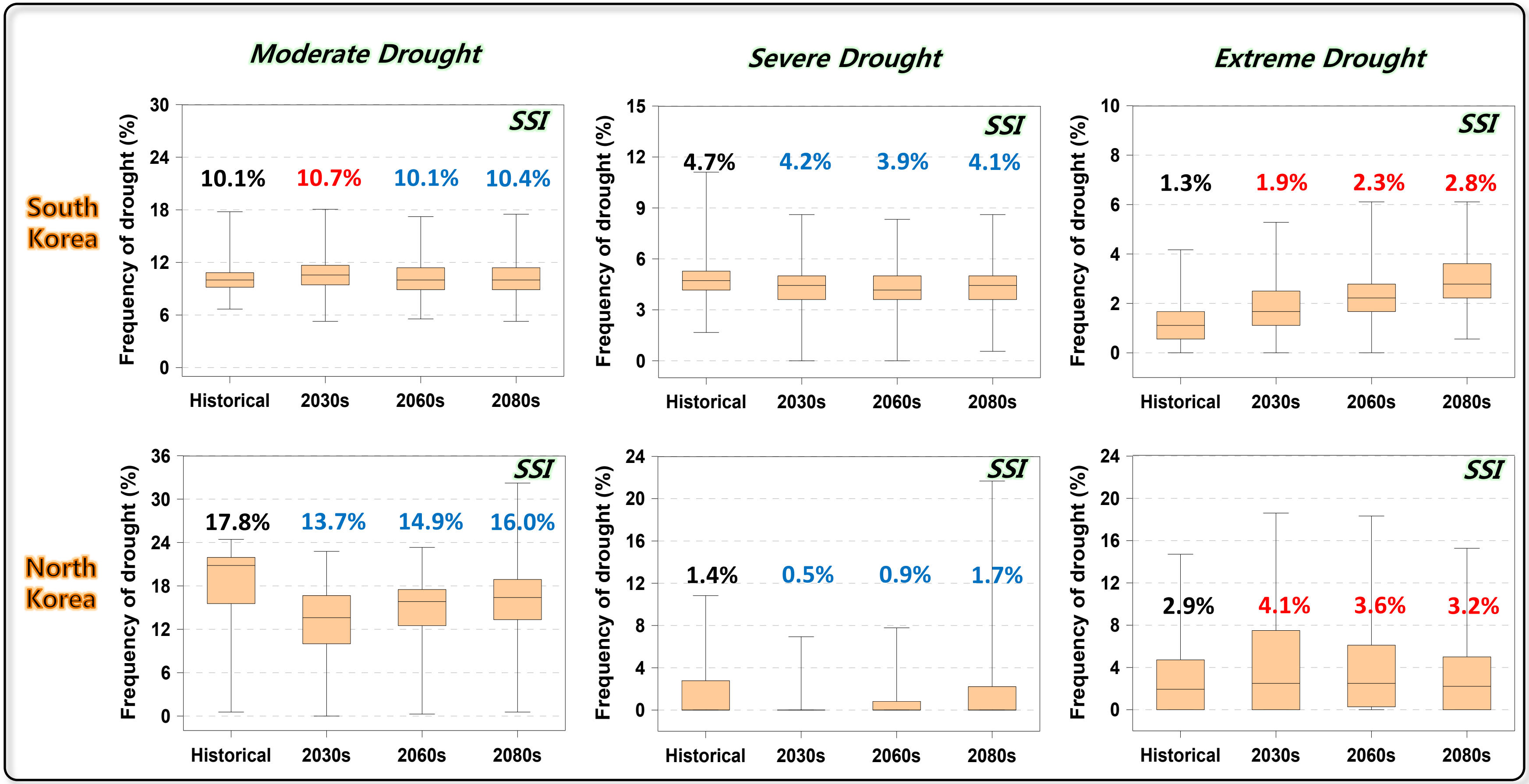
SRI3

- **Future drought frequency on *extreme drought* increases in South Korea, but decreases in North Korea**



➤ SSI3

- Future drought frequency on *extreme drought* increases in South and North Korea
- Those on *moderate and severe drought* decreases in South and North Korea



The extreme drought frequencies between North & South Korea are different for SPI3, SRI3 and SSI3

Conclusions and Recommendations

Analysis of future climate and hydrology projections

- The increase of Q are directly related to the increase of P

Future drought trend analysis

- The critical increasing seasons of drought are different for each SPI3, SRI3 and SSI3 and each region
- The future trend of SPI3, SRI3, and SSI3 may be related to the trend of their input variables
- Further researches will be necessary to figure out the cause and effect

Future drought frequency analysis

- The extreme drought frequencies between North & South Korea are different for SPI3, SRI3 and SSI3
- Those are related to the extreme variables of P, SM and Q, but further research for finding the cause and effect is required in the near future


Thank you for your attention!