

The 9th Meeting of the GEOSS/AWCI International Coordination Group and the Workshop on Climate Change Adaptation organized by APWF

APN Project Report: Climate Change/ARCP

September 29, 2012

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Backgrounds of this study

Title of project

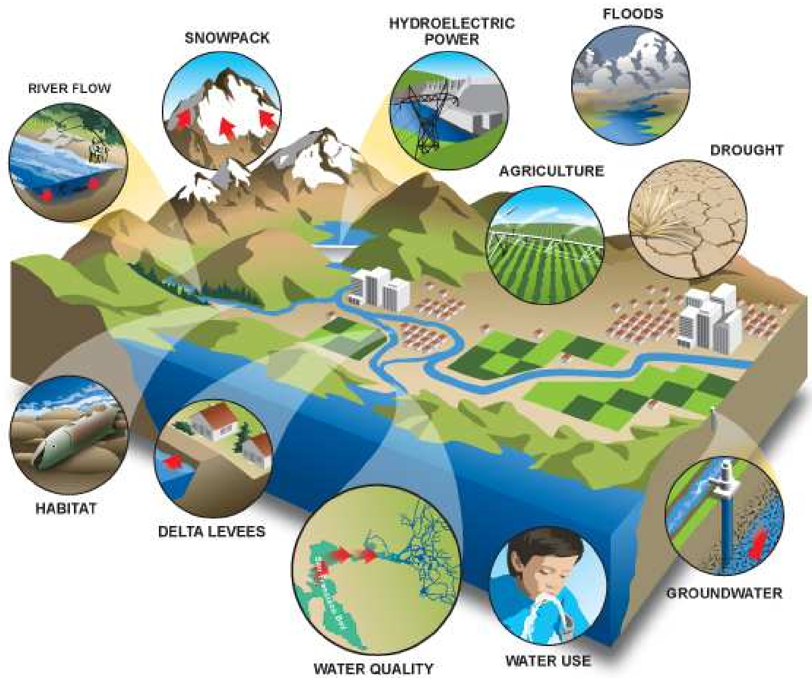
- Climate change impact assessment on the Asia-Pacific water resources under GEOSS/AWCI

Project period

- 2010.10.15 - 2013.08.31

Motivations of this study

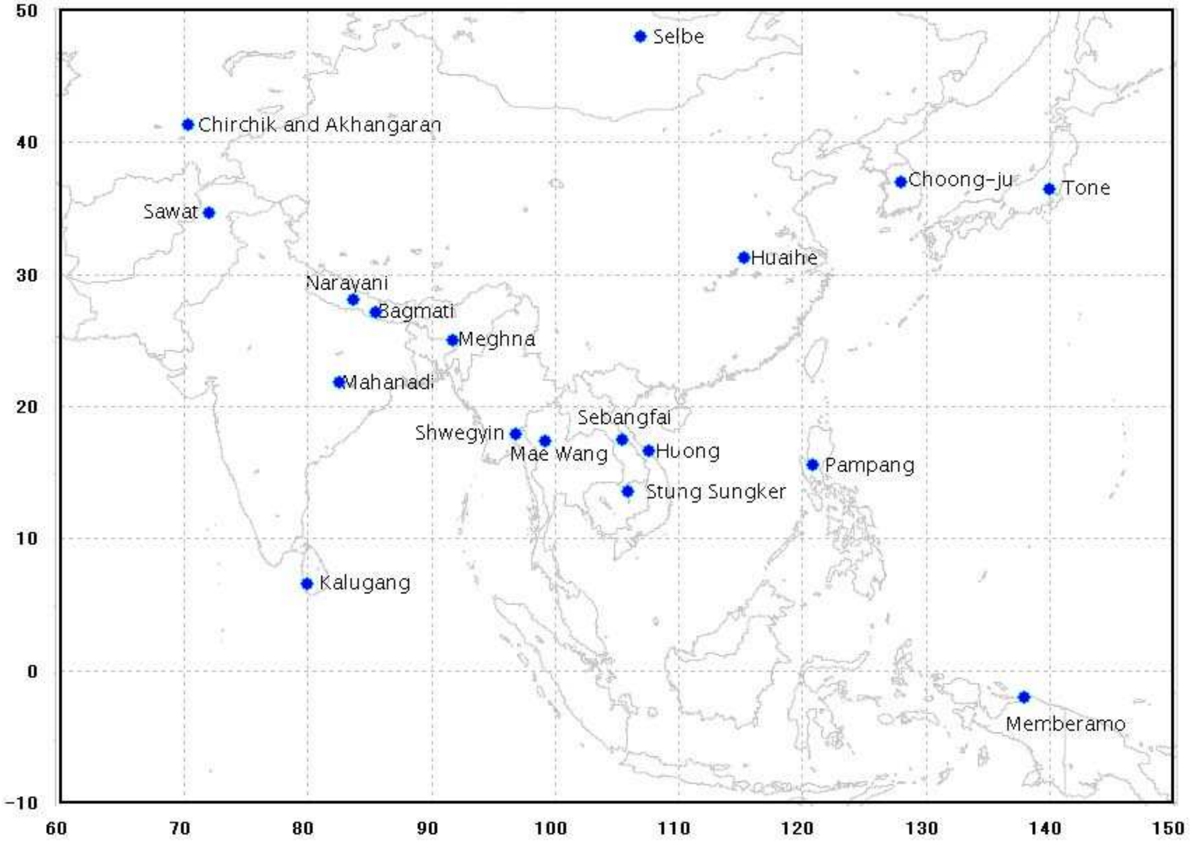
- Asia monsoon plays an important role on global water cycle
  - Provides substantial rainfall and water resources
  - Provides many benefits, but causes serious water-related disasters
- Various reasons for the disasters, but the current climate change makes difficult to manage them



www.climatechange.water.ca.gov

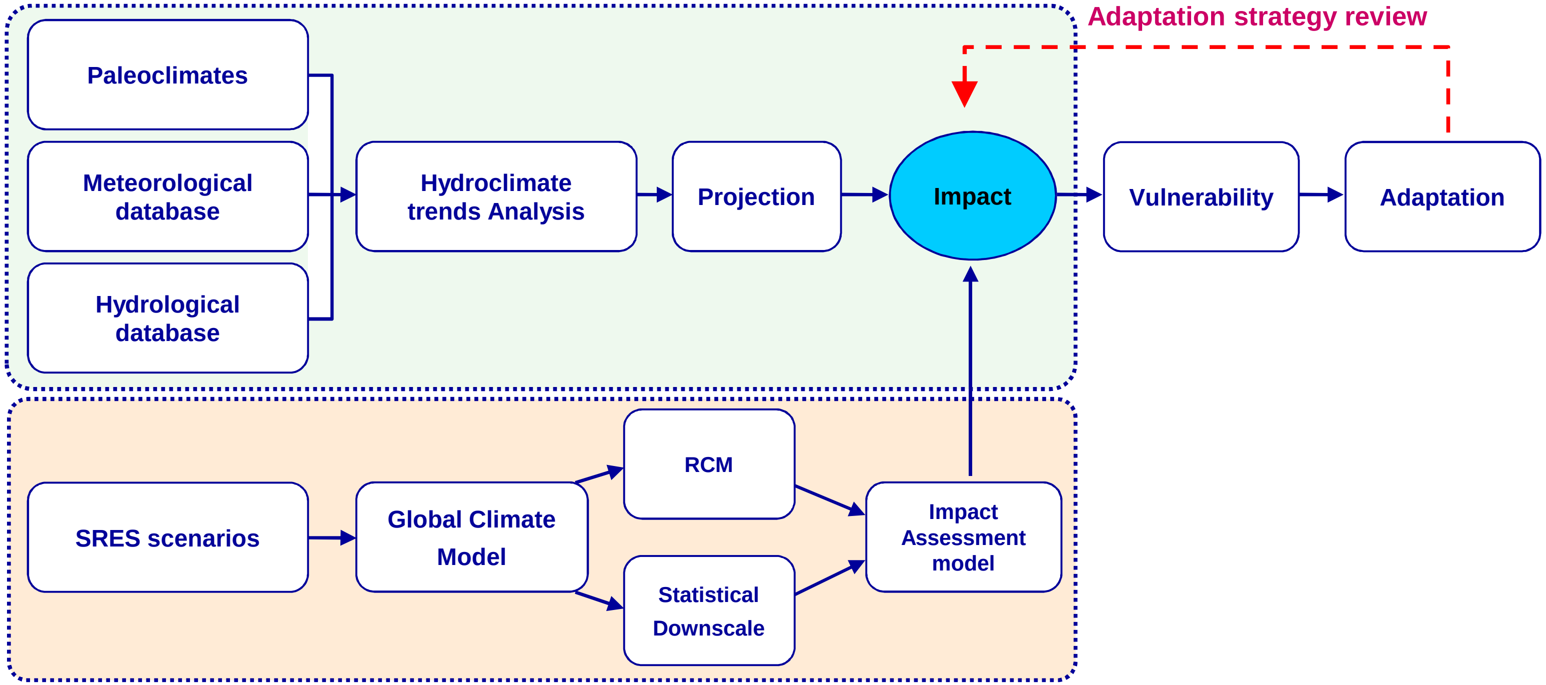
The objectives

- To evaluate the climate change impact assessments on water resources **over the Asia-pacific regions joining GEOSS/AWCI**
- To promote the capacity building **for climate change impact assessment technology**



Approaching method

- The analysis of past historical hydrologic and meteorological observation data to detect some climate change trends
- The use of GCM outputs with downscaling and hydrologic models under the future greenhouse gas emission scenarios



General procedure for CC impact and vulnerability assessment on water resources

Historical data analysis for detecting trends

- Use linear regression analysis & Mann-Kendall's test on the study domain
- Linear regression method were used to characterize the existence of a linear trend
- Mann-Kendall test is a non-parametric test for detecting trends in time series data

$$S = \sum_{i=1}^{n-1} \sum_{k=i+1}^{n} \mathrm{sgn}(x_k - x_i)$$

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} e_i(e_i - 1)(2e_i + 5)}{18}$$

$$Z_c = \frac{S-1}{\sqrt{\mathrm{var}(S)}} \quad S > 0$$

$$Z_c = 0 \quad S = 0$$

$$Z_c = \frac{S+1}{\sqrt{\mathrm{var}(S)}} \quad S > 0$$

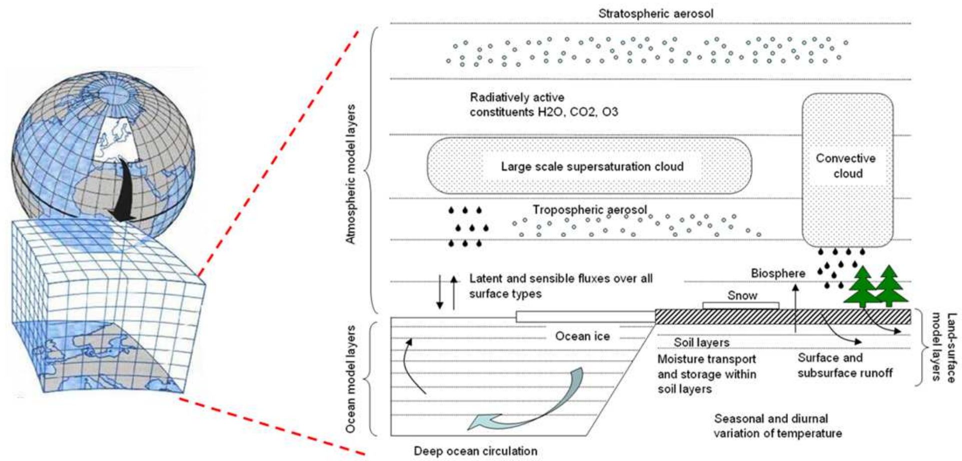
- If $-Z_{1-\alpha/2} \le Z_c \le Z_{1-\alpha/2}$, Z_c is not statistically significant or no significant trend.

- Indices of temperature, precipitation
  - Temperature : TANU(Annual average temperature), TSEA(Seasonal average temperature)
  - Precipitation : PANU(Annual precipitation), PSEA(Seasonal precipitation)

Emission scenario and GCM model

- A2 emission scenario
- ECHO-G model

ECHAM4



HOPE-G

OASIS

Atmospheric component
(MPI Rep. 218, 1996)

- ECMWF ➔ MPI
- ~ECHAM3
  - \+ fresh water on glaciers
  - \+ river runnoff + partial ice cover
- T30 ~ 3.75 x 3.75 °lat x °lon
- 19 vertical levels:
  - Highest: 10 hPa ~ 30 km
  - Lowest: ~ 30 m

Ocean component
(DKRZ Rep. 13, 1997)

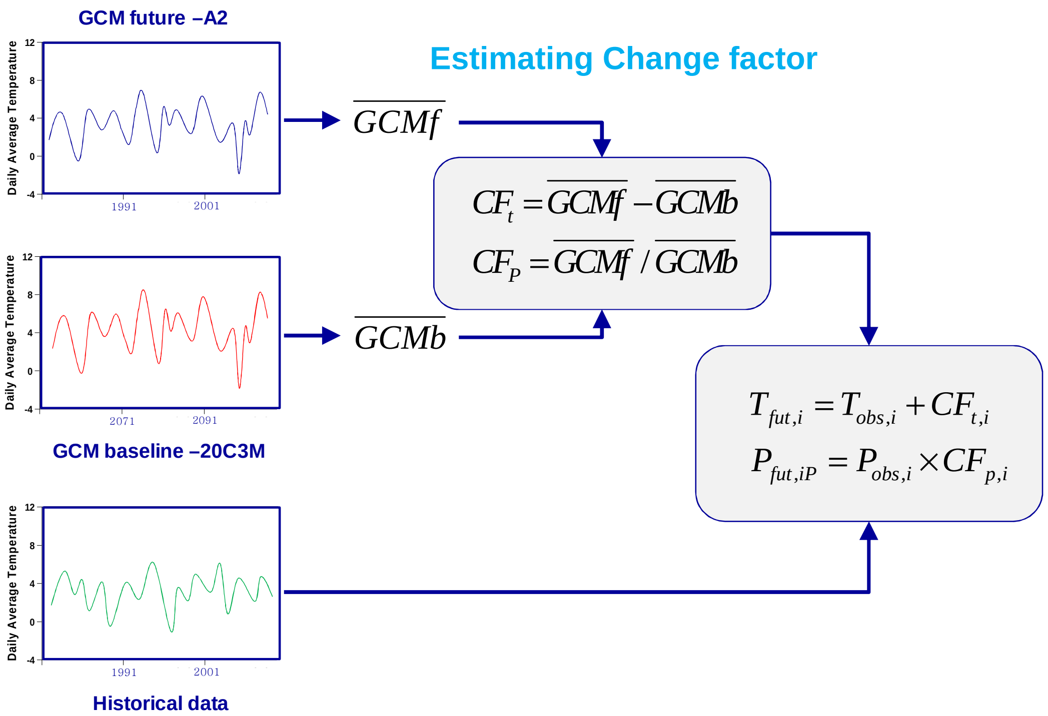
- Prim. Eq. & Thermodyn.
  - \+ sea ice model with snow cover
- Gauss. T42 ~ 2.8 x 2.8 °lat x °lon
  - ➔ 0.5 °lat x °lon Equator
- 20 levels

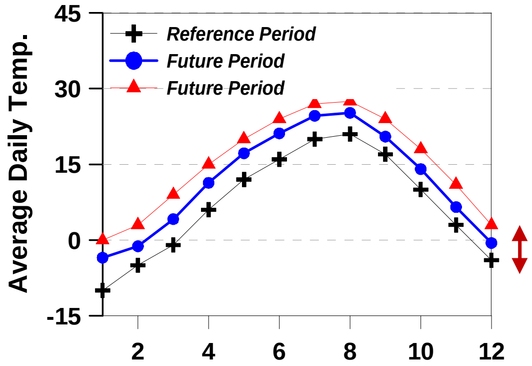
Coupler
(CERFACS Rep. CMGC/98-05, 1998)

- Coupling: 1 day
- Atm ➔ Oce: Heat, fresh watter, momentum fluxes
- Oce ➔ Atm: Surface conditions
- Grid interpolation

Change factor method

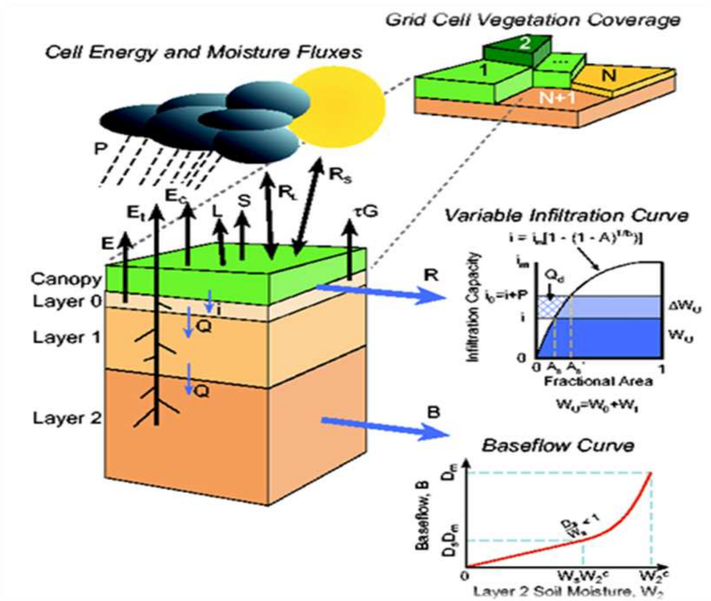
- The simulated GCM anomalies between reference and future scenario runs are superimposed upon the observational time series
- Adds simulated monthly data to the daily historical data
  - Reference period: 1991-2010
  - Projection periods: 2020s, 2040s, 2060s, 2080s
  - Minimum, maximum temperature, and precipitation





Hydrologic model

- The VIC(Variable Infiltration Capacity) model is soil vegetation atmospheric transfer scheme that considers both energy and water balances
- A grid-based macro-scale model that is usually implemented at various spatial scales from 1/8 °to 2°
- Widely used for analyzing the variations of water resources on climate change

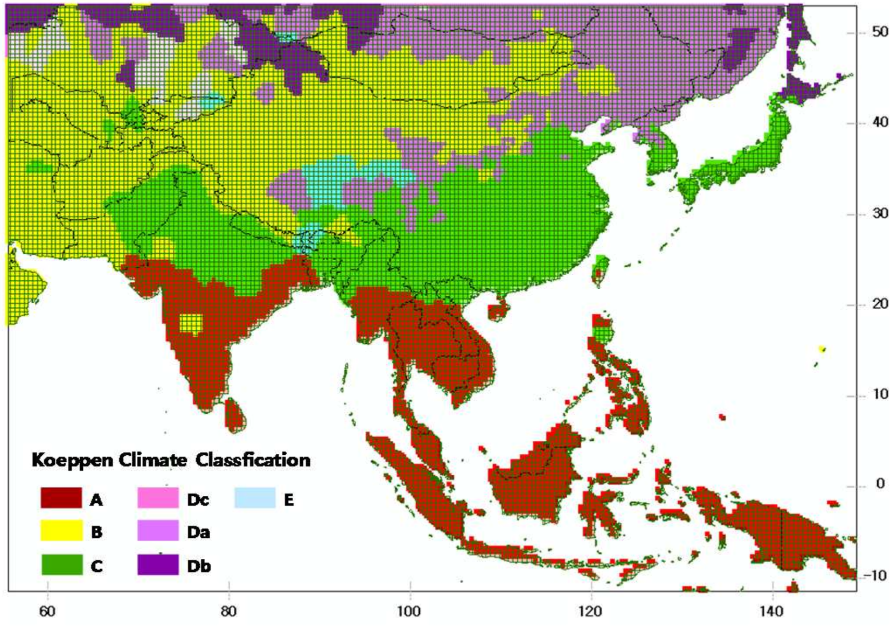


Parameter	Input Data
Basin	DEM
Forcing	Precipitation Maximum Temperature Minimum Temperature Wind Speed
Soil	Soil Properties
Vegetation	Land use

Regionalization method

- Model calibration at gauged basins and then regionalize the model parameters to ungauged basins in AWCI domain
- Climate characteristics defined by the Köppen climate classification is used for regionalization method
- Dominant climate types are Arid B (32%), Cold D (27%), Temperate C (21%), Tropical A (18%), Polar E (2%)

Köppen climate zone in Asia regions



Parameter transfer zone	Köppen climate zone	Climate characteristics
Tropical climate	A	Not a B climate and $T_{min} \geq 18℃$
Arid climate	B	$P_{ann} < 10P_{th}$
Temperate climate	C	Not a B climate and $-3℃ < T_{min} \leq 18℃$
Cold climate with hot summer	Da	Not a B climate and $T_{min} < -3℃$ and $T_{max} > 22℃$
Cold climate with cool summer	Db	Not a B climate and $T_{min} < -3℃$ and $T_{max} > 10℃$ for at least 4months
Cold climate with short cool summer	Dc	Not a B climate and $T_{min} < -3℃$ and $T_{max} > 10℃$ for less than 4months
Polar climate	E	Not a B climate and $T_{max} < 10℃$

- The B climates are defines as those climates.

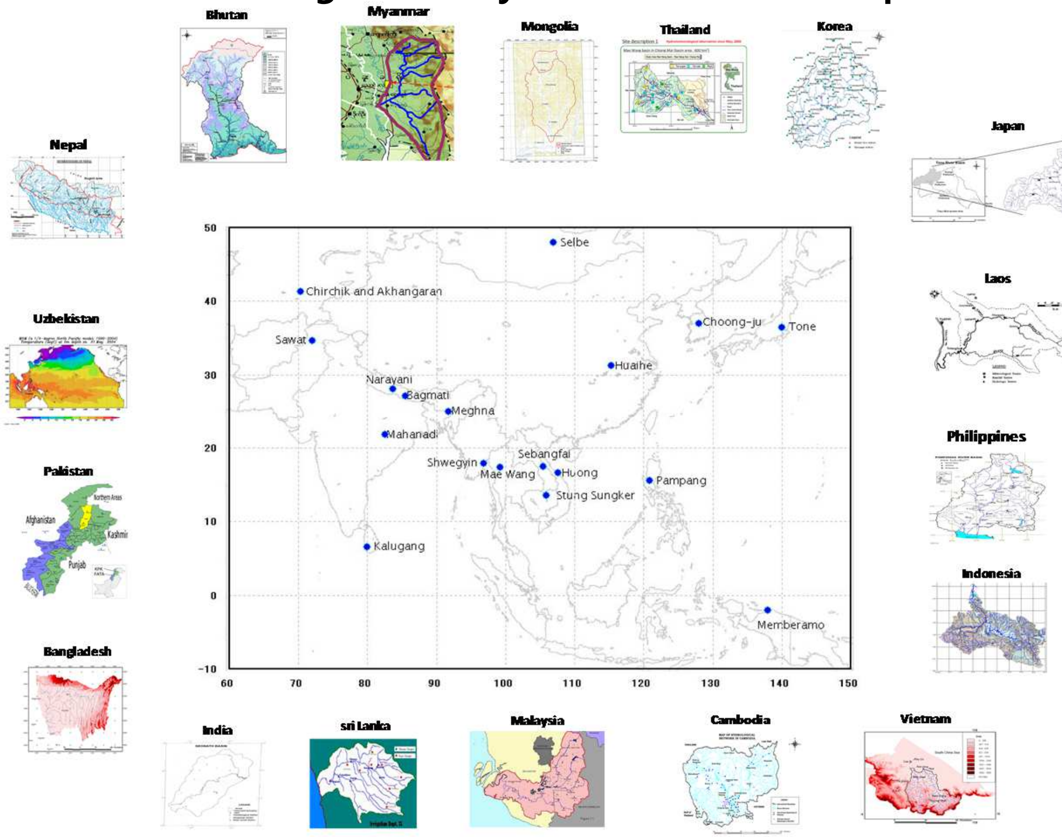
$$P_{th} = 2 \times T_{ann}$$: if 70% of Pann occurs in winter

$$P_{th} = 2 \times T_{ann} + 28$$: if 70% of Pann occurs in summer

$$P_{th} = 2 \times T_{ann} + 14$$: otherwise

Study area and Data collection

- **The AWCI domain with 18 demonstration basins from 18 Asian countries are selected in this study**
  - **River basin area : 303~78,992 ㎢**
  - **Land use : Agriculture, Forest, Grasslands etc.**
  - **Climate regime : Very humid, Humid, Temperate, Semi-arid etc.**



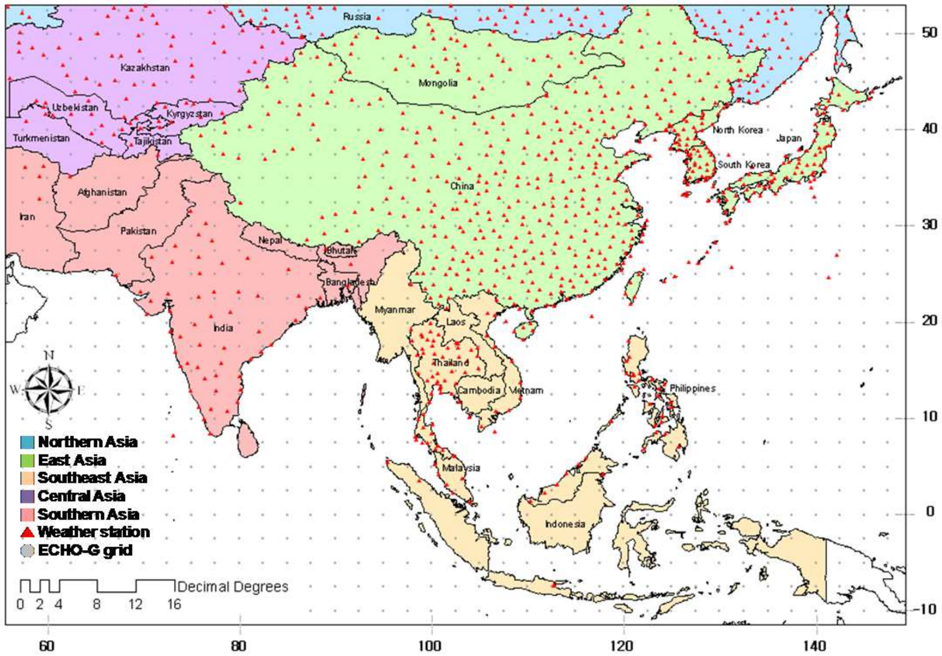
No.	Country	Basin name	Area (km²)	Land use	Climate regime	Annual precipitation
1	Bangladesh	Meghna	61021	Agriculture Forest	Humid	3000
2	Bhutan	Punatsangchhu	13263	Agriculture	Temperate	500~5000
3	Cambodia	Sangker	2961		Very Humid	
4	India	Seonath	30760	Cultivation	Humid	
5	Indonesia	Mamberamo	78992	Forest	Humid	3500~5000
6	Japan	Upper Tone River	3300	Forest Grasslands	Humid	1500
7	Korea	Upper Chungju-dam	6662	Forest	Temperate	1250
8	Lao PDR	Sebangfai	8560	Forest	Very Humid	2300
9	Malaysia	Langat	2350	Agriculture	Very Humid	2470
10	Mongolia	Selbe	303	Forest	Semi-arid	
11	Myanmar	Shwegyin	1747		Very Humid	3552
12	Nepal	Bagmati	3700	Forest	Humid	
13	Pakistan	Swat			Humid	
14	Philippines	Pampanga	10540		Humid	4200
15	Sri Lanka	Kalu Ganga	2720	Forest	Very Humid	3000
16	Thailand	Mae Wang	600	Forest	Humid	
17	Uzbekistan	Chirchik-Okhangaran	20160		Humid	
18	Vietnam	Huong	2830	Forest	Very Humid	3000

Meteorological data

- Requires long-term (at least 20years) meteorological data for climate change study
- Collects 1013 weather station data in this study area
  - Source : National Climate Data Center (NCDC)
  - Precipitation, Max & Min Temperature, Mean wind speed
  - Data period : 20 years (1991~2010)

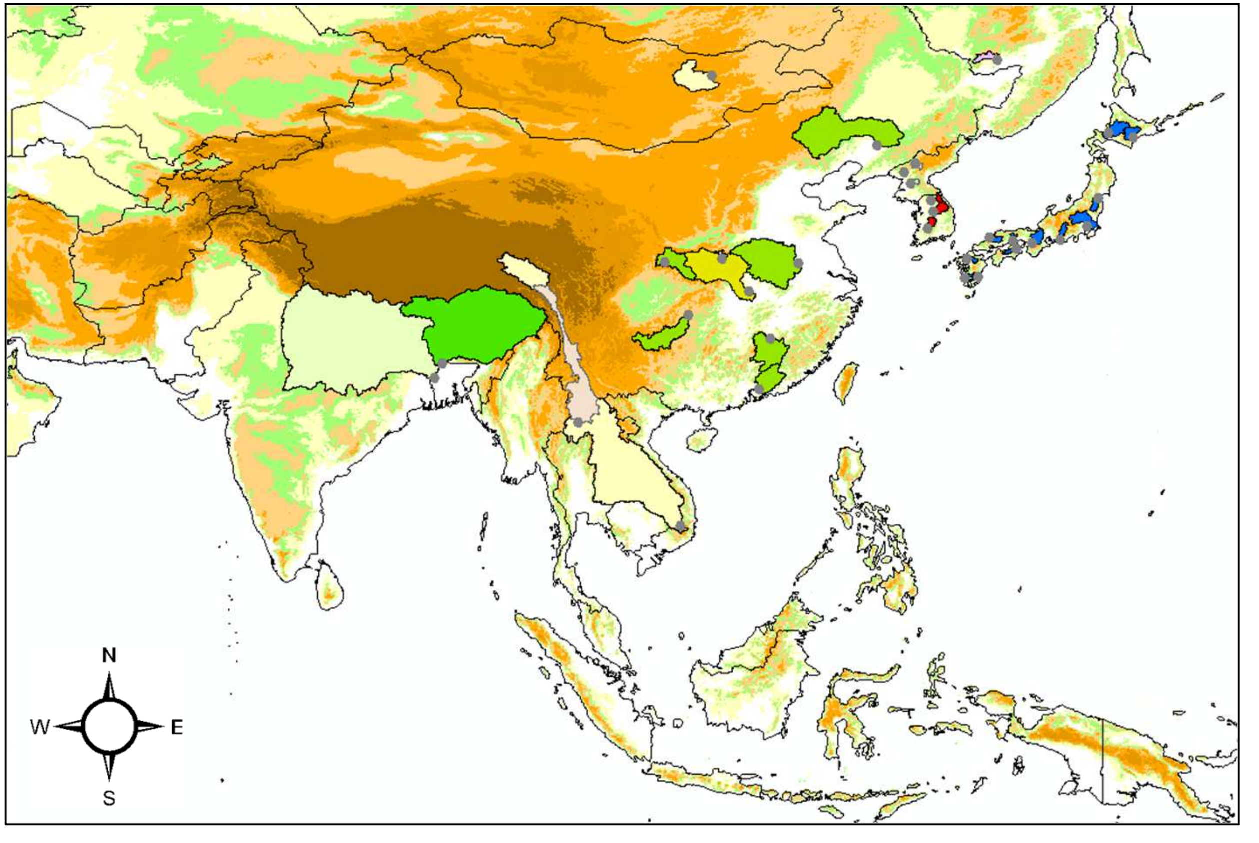
Geomorphological data

- DEM
  - United States Geological Survey (USGS)
  - Resolution : 1km×1km
- Land use
  - University of Maryland (UMD)
  - Resolution : 1km×1km
- Soil properties
  - Food Agriculture Organization (FAO)
  - Resolution : 8km×8km



Streamflow data

- Data Source : GRDC (Global Runoff Data Center)
- Time interval : Monthly
- Data Period : 20 years (1984~2004)
- Number of selected basins : 40



Country	Number of bains
Russia	1
Mongolia	1
China	11
North Korea	3
Japan	12
South Korea	8
Tailand	2
India	2

Hydrogic model performances

- Evaluate LSM model performance under the assumption that some gauged basins are ungauged basins
- The performance are CC : 0.61~0.94, ME : 0.41~0.84, VE : under 32%

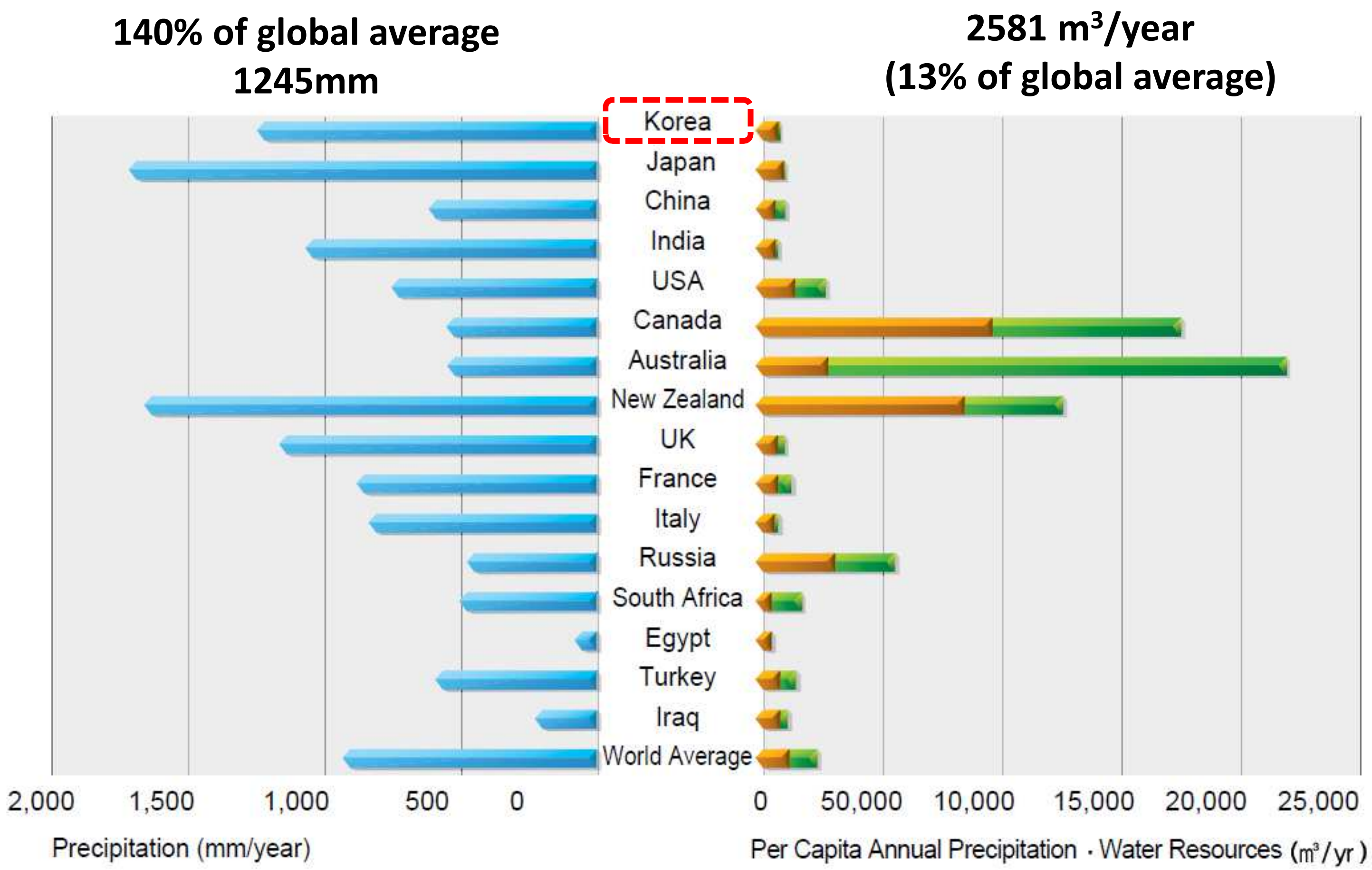
❖ Statistical analysis of runoff simulation results

Basins		Period (year)	CC	ME	RMSE (mm/mon)	VE (%)
Russia	Bolshaya Bira	1982~1986	0.84	0.60	22.50	24.40
China	Han Shui	1982~1986	0.93	0.84	22.72	-5.71
	Huai He	1982~1997	0.76	0.41	20.27	29.08
	Hongshui He	1982~1987	0.94	0.77	26.42	9.20
	Songhua Jiang	1982~1986	0.70	0.41	13.81	-7.35
N. of Korea	Sangwan	1982~1984	0.61	0.41	40.01	-28.15
Japan	Abukima	1993~2003	0.81	0.50	26.85	-21.26
	Hirakata	1993~2003	0.81	0.64	34.19	1.88
	Ishikari	1993~2003	0.82	0.62	26.24	-2.71
	Tone	1993~2003	0.80	0.62	26.75	-10.20
Tailand	Mekong	1991~1994	0.77	0.60	35.26	-17.68
	Chiang Saen	1982~1993	0.70	0.41	18.48	-11.70
India	Hardinge Bridge	1985~1992	0.68	0.40	34.56	-32.30
	Brahmaputra	1985~1992	0.88	0.65	29.40	-26.40
Average			**0.79**	**0.60**	**26.96**	**-7.06**

Results and Analysis

Trend analysis of historical observation data (Korean case)

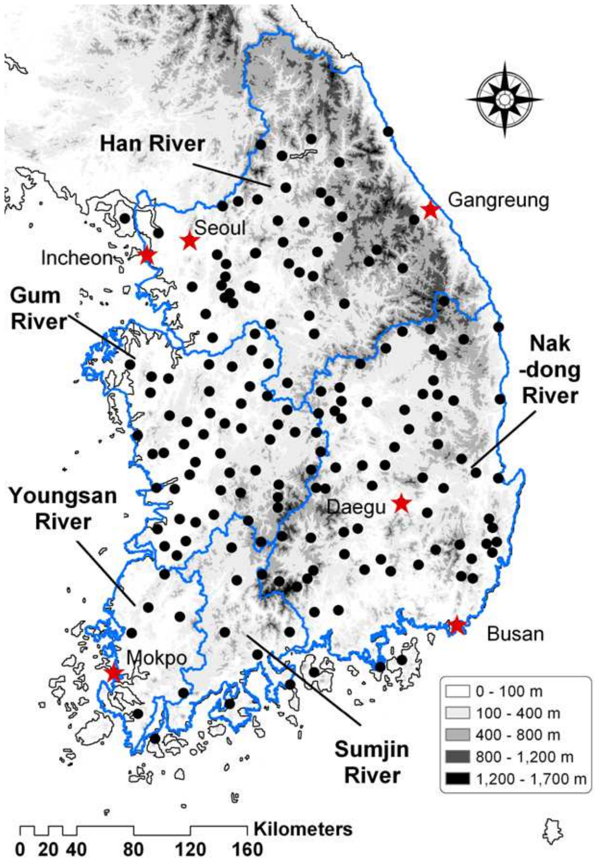
- Status of Korean water resources



| Water Resources in Major Countries |

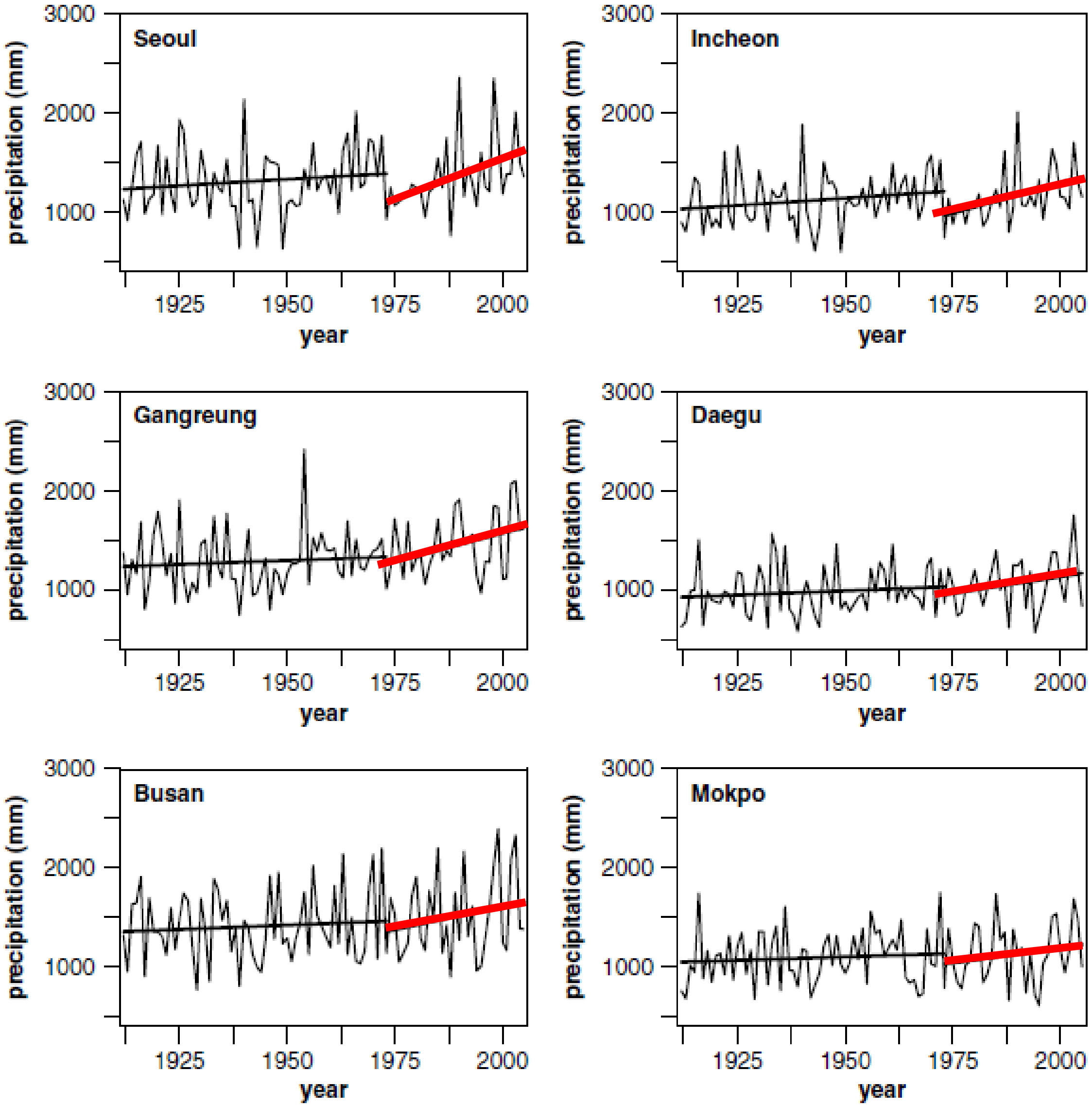
Source: *Water resources in Korea 2007*. MLTM

- **Increasing annual precipitation**



183 weather stations

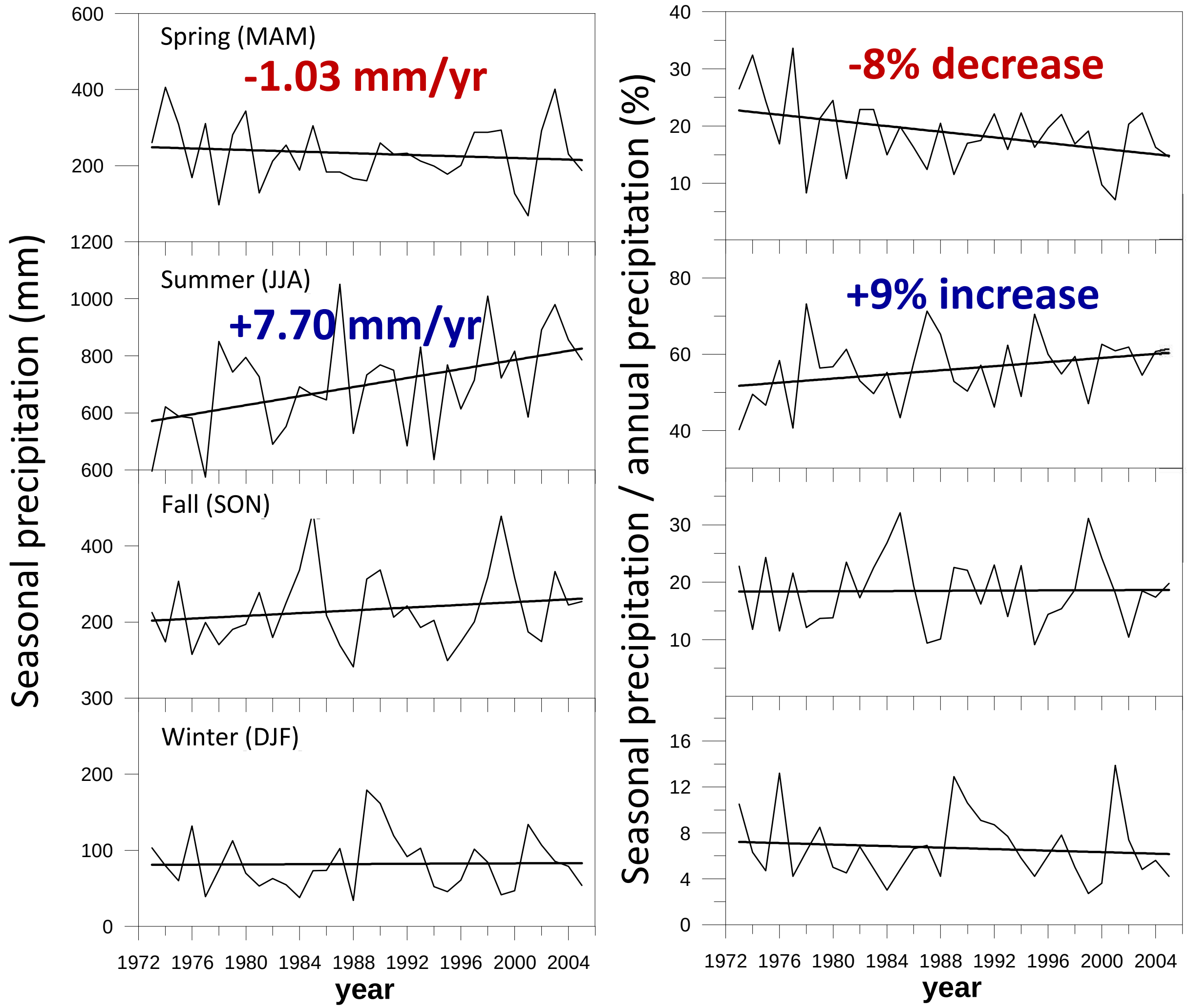
1910-2005



Source: Jung et al. (2011)

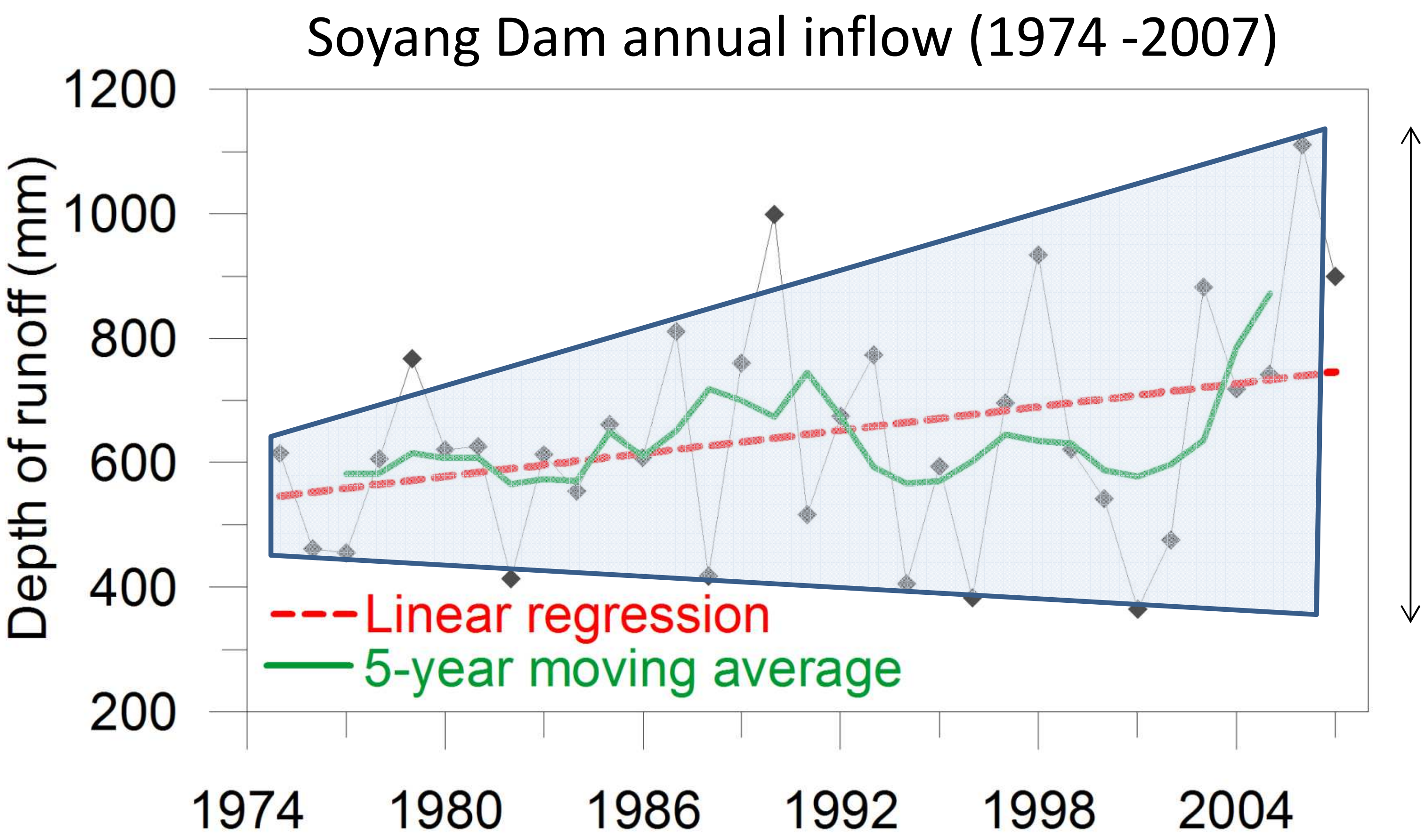
➢ Increasing seasonality in precipitation

Averaged seasonal precipitation using 183 station data for 1973 – 2005



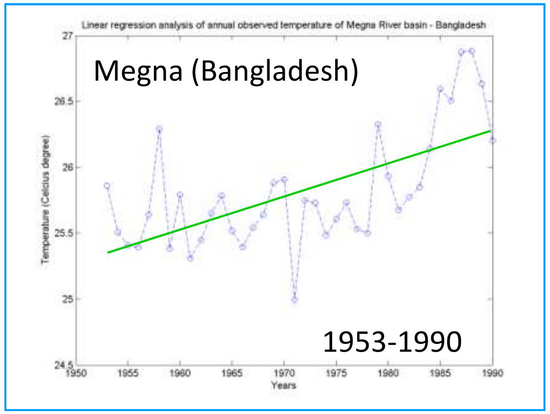
Source: International Journal of Climatology (2011)

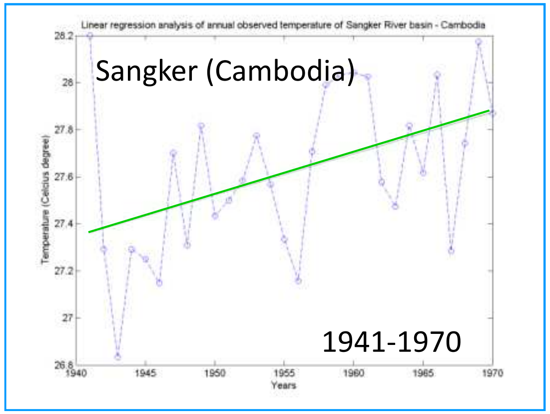
➢ **Trend and variation of annual streamflow**

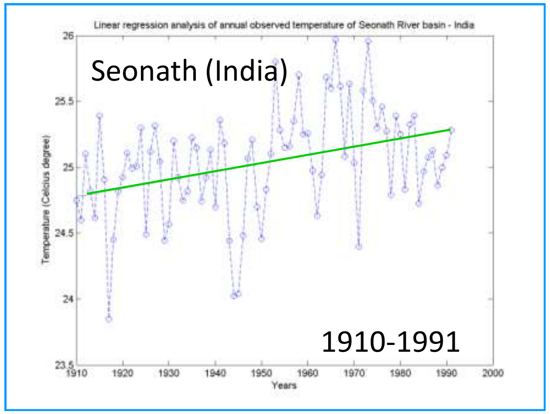


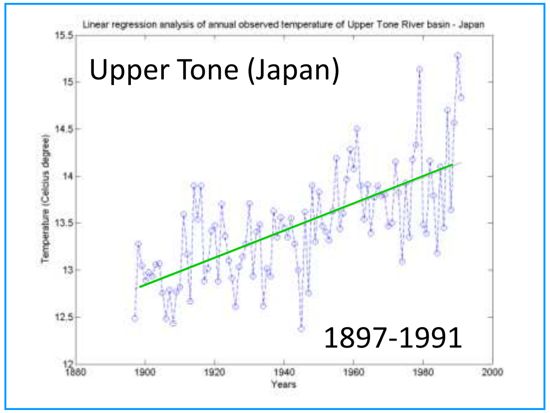
Trend analysis of historical observation data (AWCI demo basins)

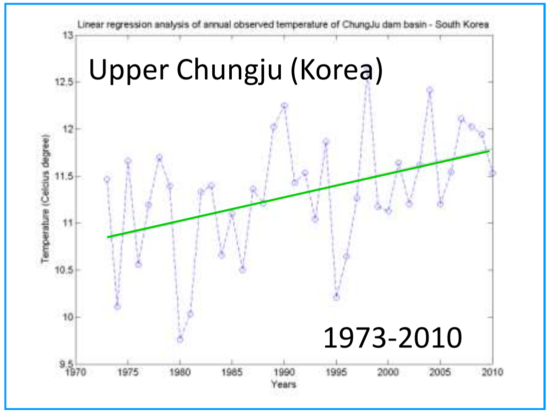
- All basins except for Pampanga basin of Philippines show increasing trend of temperature

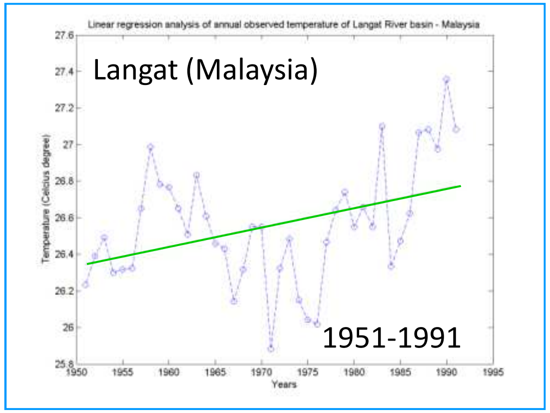




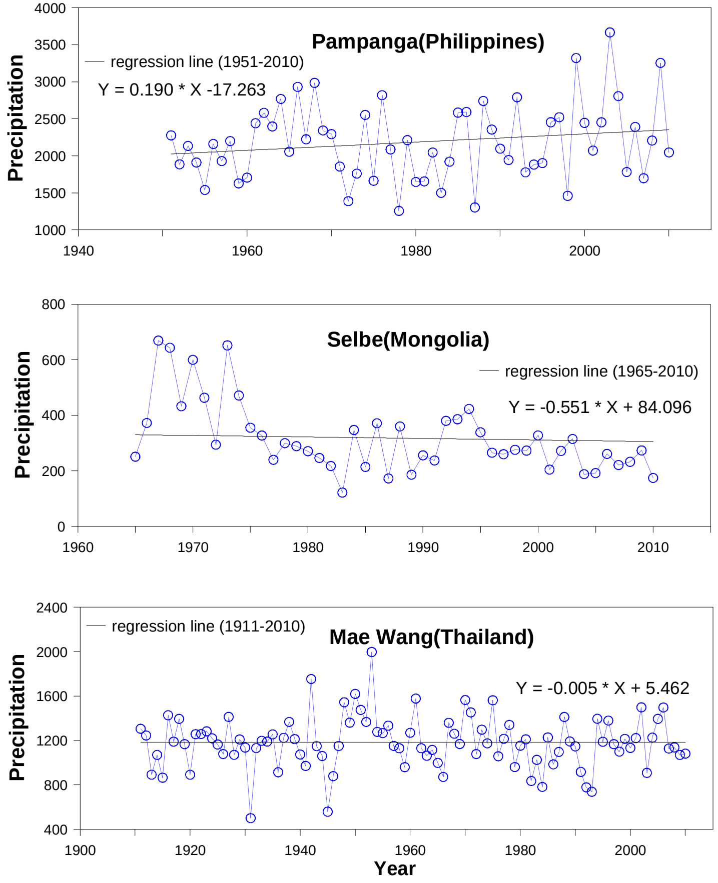








- Most of basins have increasing trend of annual precipitation
- Three basins (Sangker ,Cambodia; Seonath, India; Selbe, Mongolia) have decreasing trend of precipitation, while two basins (UpperTone River, Mae Wang) have no trend

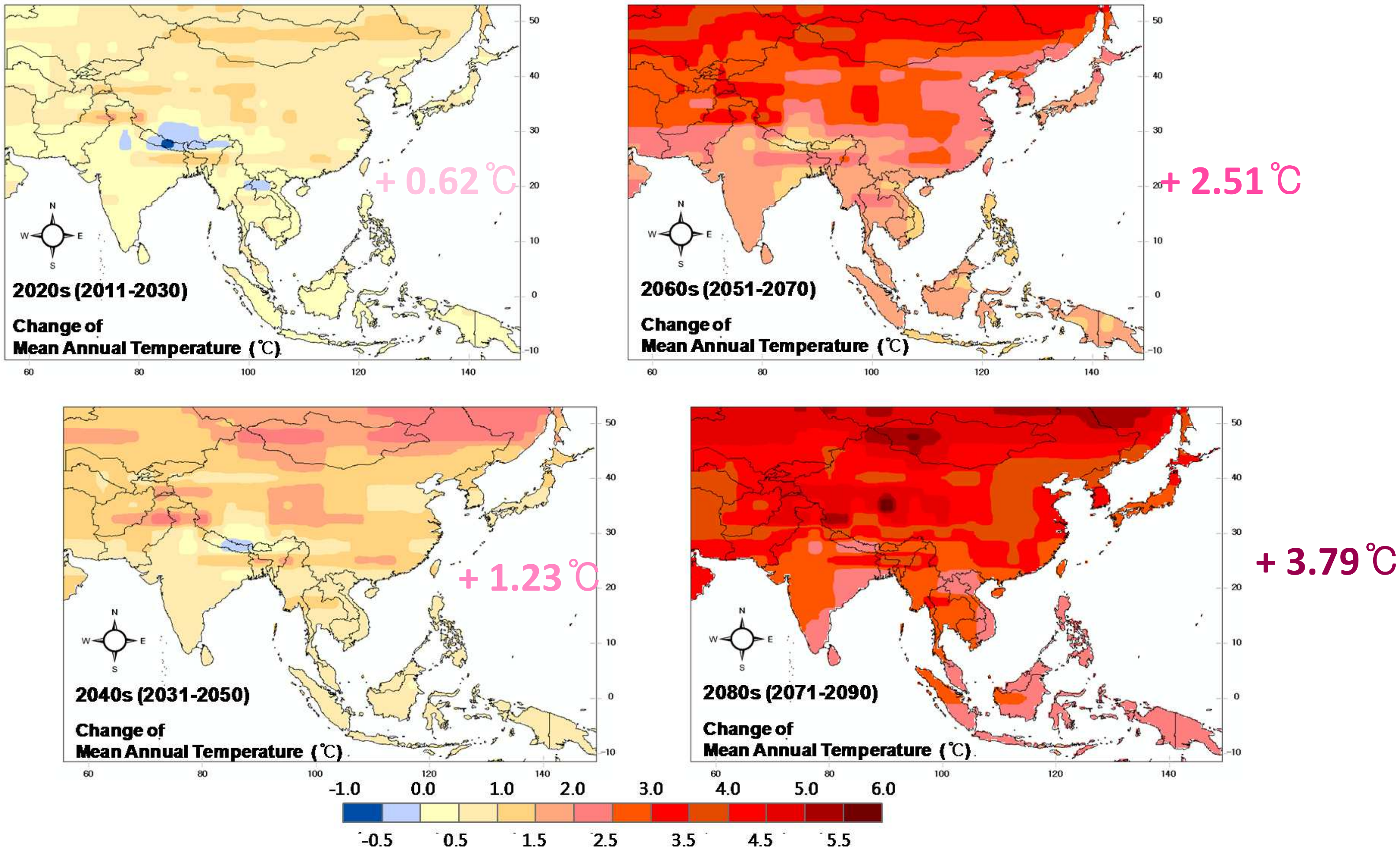


Station	Time	Linear regression		Mann-Kendall test	
		b(slope)	p-value	β	p-value
Pampanga (Philippines)	Spring	-0.033	0.598	-1.062	0.84
	Summer	0.052	0.654	1.141	0.663
	Fall	0.274	0.983**	3.267	0.979**
	Winter	0.368	0.998	0.617	0.868
	Annual	0.19	0.927	4.66	0.868
Selbe (Mongolia)	Spring	-0.05	0.629	-0.069	0.633
	Summer	-0.408	0.998**	-2.499	0.994**
	Fall	-0.537	1**	-1.848	1**
	Winter	-0.404	1**	-0.135	1**
	Annual	-0.551	0.997**	-4.191	0.974**
Mae Wang (Thailand)	Spring	0.235	0.99	-0.959	0.996
	Summer	-0.04	0.653	-0.224	0.665
	Fall	-0.148	0.928*	-1.019	0.989**
	Winter	0.011	0.544	-0.03	0.795
	Annual	-0.005	0.521	-0.302	0.663

We need more detailed information for seasonal analysis with water availability

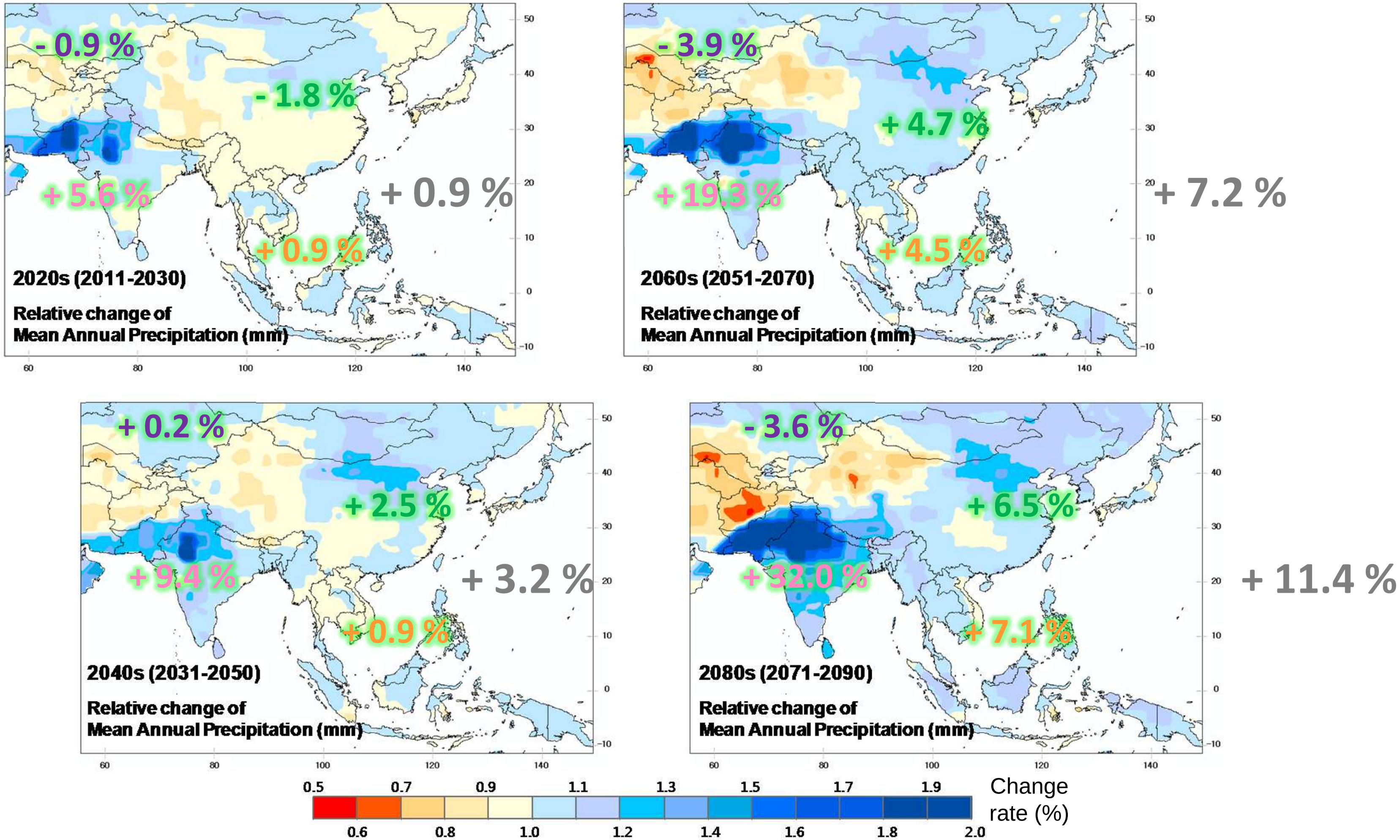
Future projections of water resources under A2 scenario

- Change in annual mean temperature
  - The temperature increase is expected to higher at high latitude regions than low latitude regions

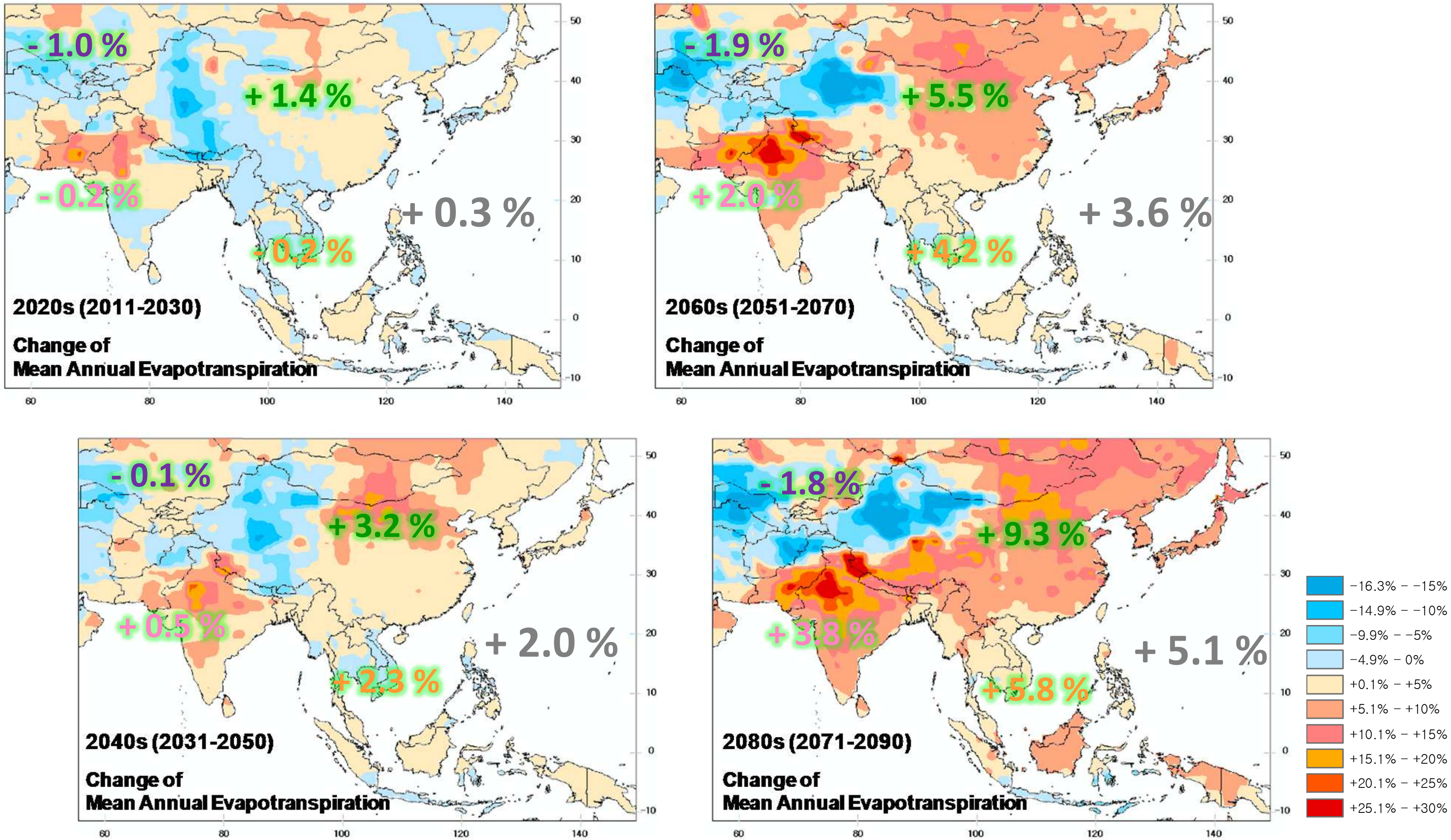


Change in annual mean precipitation

- The average precipitation (2011-2090) is expected to be increasing in AWCI region
- However, average precipitation (2020s, 2060s, 2080s) in Central Asia will be decreasing

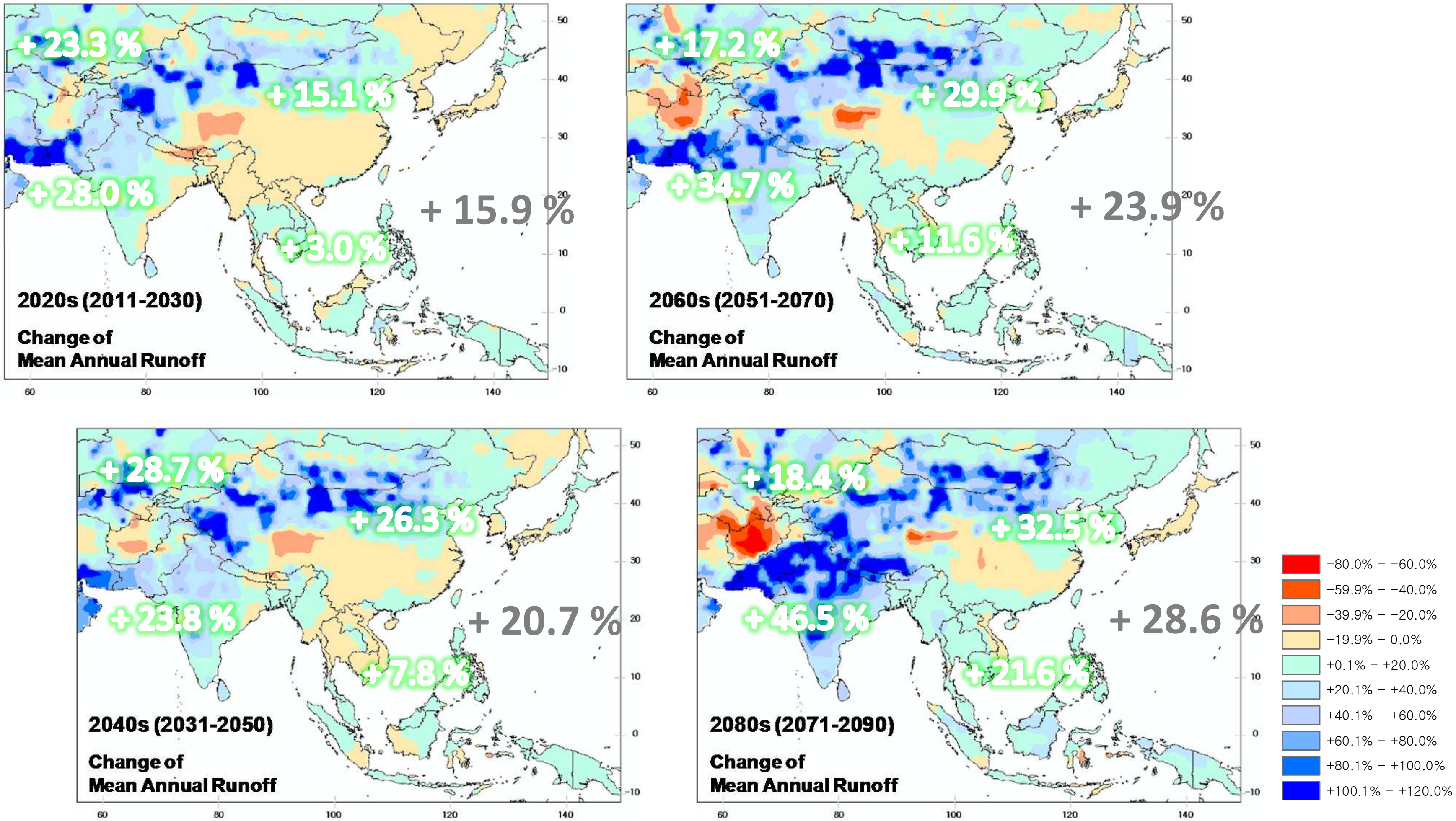


- **Changes in annual mean evapotranspiration**
  - **The annual average evapotranspiration PET (2011-2090) is increasing in AWCI regions**
  - **However, annual average PET in Central Asia (2011-2090) is expected to be decreasing**



➢ Change in annual mean streamflow

- The average streamflow in Asia regions (2011-2090) is increasing
- Especially, the increases in Southeast Asia regions are significant (31%~66%)



On-going and future plan to be taken

The analysis of past historical observation data to detect some climate change trends

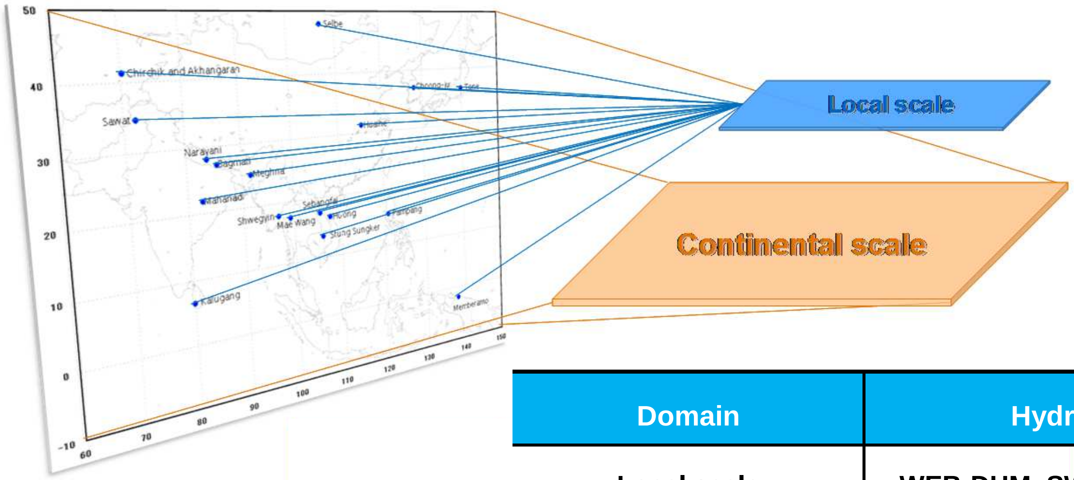
- **Performed linear regression and Mann-Kendall test on annual average precipitation and temperature for AWCI demonstration basins**
- **Needs to do the seasonal analysis and inter annual variability studies of precipitation and river discharges**

Country	Basin Name	Data availability	Country	Basin Name	Data availability
Bangladesh	Meghna	○	Mongolia	Selbe	×
Bhutan	Punatsangchhu	×	Myanmar	Shwegyin	×
Cambodia	Sangker	×	Nepal	Bagmati	○
India	Seonath	○	Pakistan	Swat	×
Indonesia	mamberamo	×	Philippines	Pampanga	○
Japan	Upper Tone River	×	Sri Lanka	Kalu Ganga	×
Korea	Upper Chunju-dam	○	Thailand	Mae Wang	×
Lao PDR	Sebangfai River	○	Uzbekistan	Chirchik-Okhangaran	×
Malaysia	Langat	×	Vietnam	Huong	○

- **Meteorological data : Daily precipitation, Max & Min Temperature (at least 30 years)**
- **Hydrological data : Streamflow data with hydraulic structure condition**

The analysis of future projections on water resources under climate emission scenarios

- Obtained changes in annual mean T, P, ET and Q in the whole AWCI domain, and provided spatial variations of the variables for future 4 periods compared to the reference period.
- Needs to do the seasonal analysis in the domain and compare them with some other published results if available.
- Needs more detailed analysis on the 18 AWCI demonstration basins using basin-scale hydrologic models



Domain	Hydrological Model	Spatial resolution
Local scale	WEB-DHM, SWAT, PRMS, SLURP, VIC	20 - 100 km
Continental scale	VIC	20 - 50km

Thank you