APEC Climate Symposium 2014, Nanjing, China

# Utilizing APCC multi model seasonal forecast to support planning & operation of dams in South Korea

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# Multi-purpose dams in South Korea

- **The role of multi-purpose dams**
  - Water supply 65% (12.2 billion m$^3$)
  - Flood control 95% (4.9 billion m$^3$)
  - Hydropower generation
  - Water quality control
  - Recreation activities
  - Navigation
  - Debris control

# General multi-purpose dam operations

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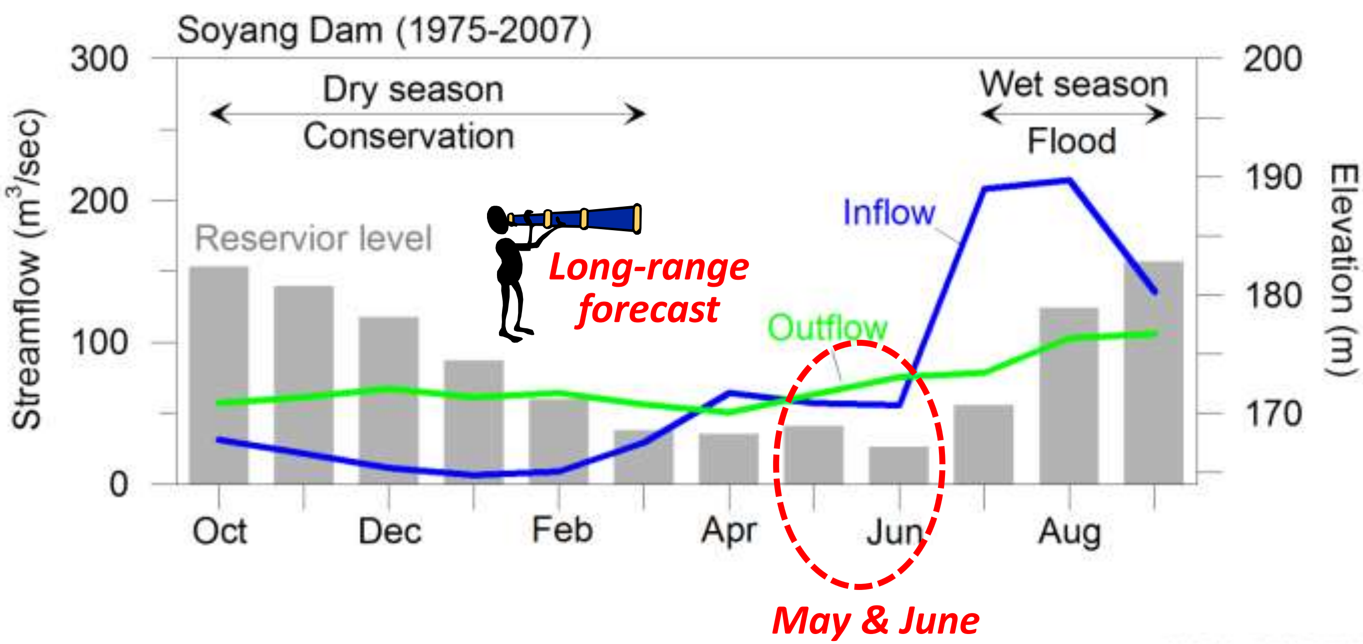
- Approximately 60% of the annual dam inflow is concentrated during the wet season (July through September)
- The extreme seasonality causes periodic shortages of water during the dry season (October through early June) and floods during the wet season
- To control flood and supply water, dams start to store inflow around Sep. 20th, after the period of frequent rainstorms & occasional typhoons has ended



# Potential threats to sustainable water supply due to climate variability and change

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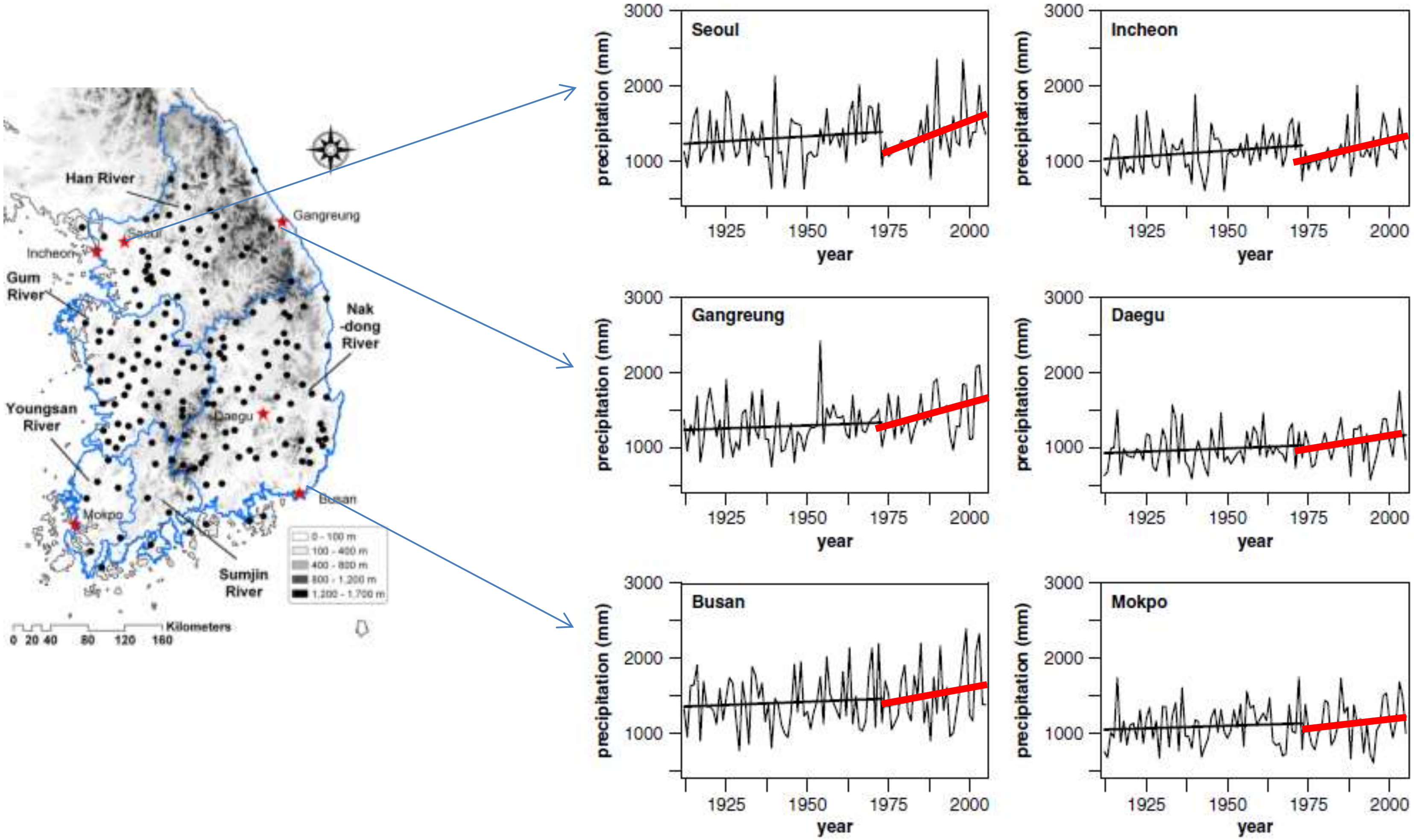
- **Trends in annual precipitation for 1911-2005**




*Source: Jung et al. (2011), International Journal of Climatology*

# Potential threats to sustainable water supply due to climate variability and change

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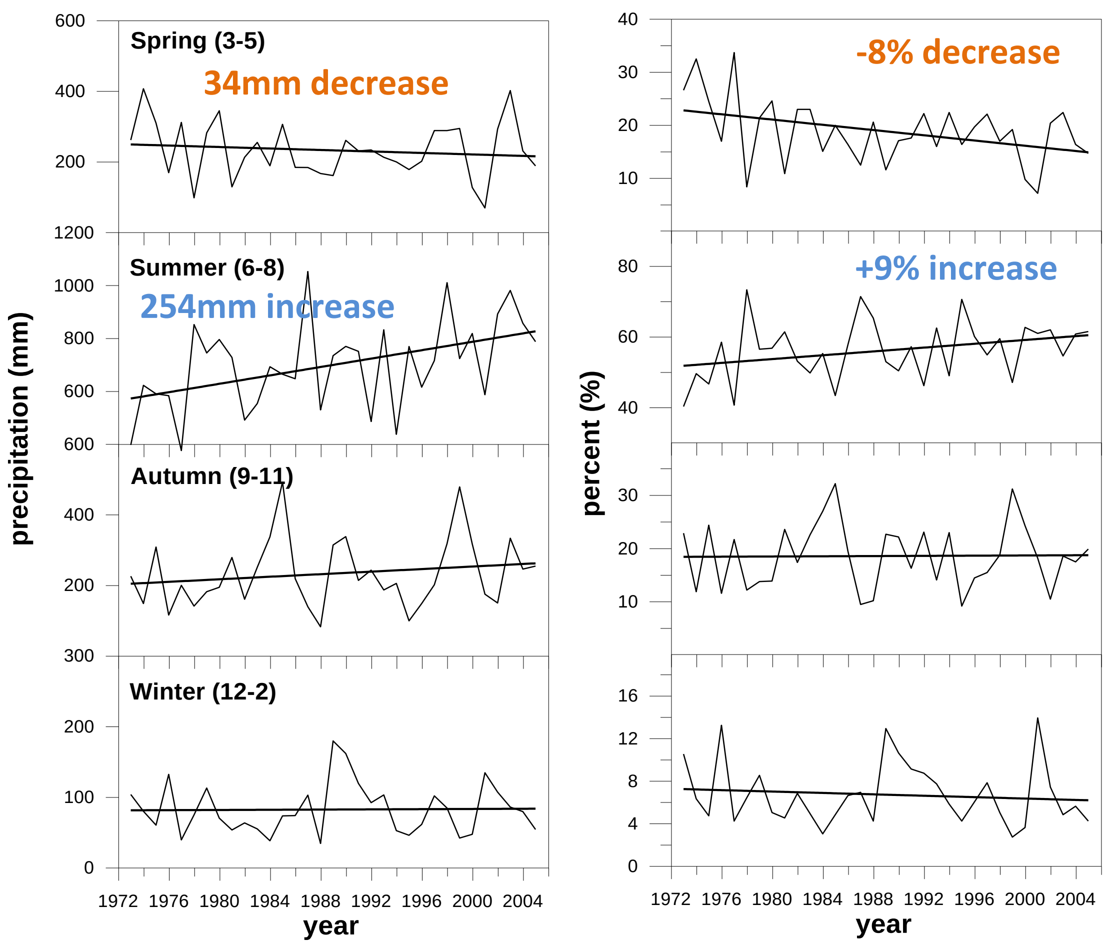
## ➢ Trends in seasonal precipitation for 1975-2005




*Source: Jung et al. (2011), International Journal of Climatology*

# Potential threats to sustainable water supply due to climate variability and change

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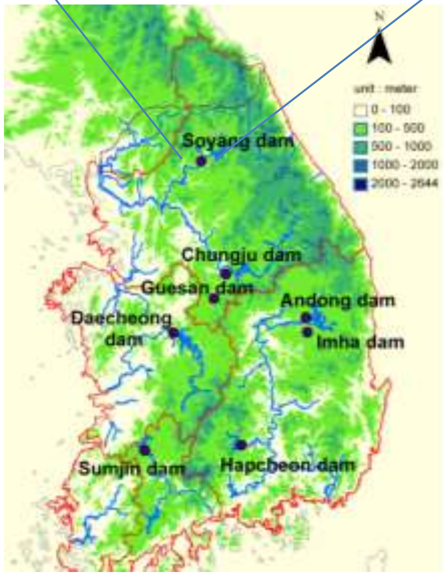
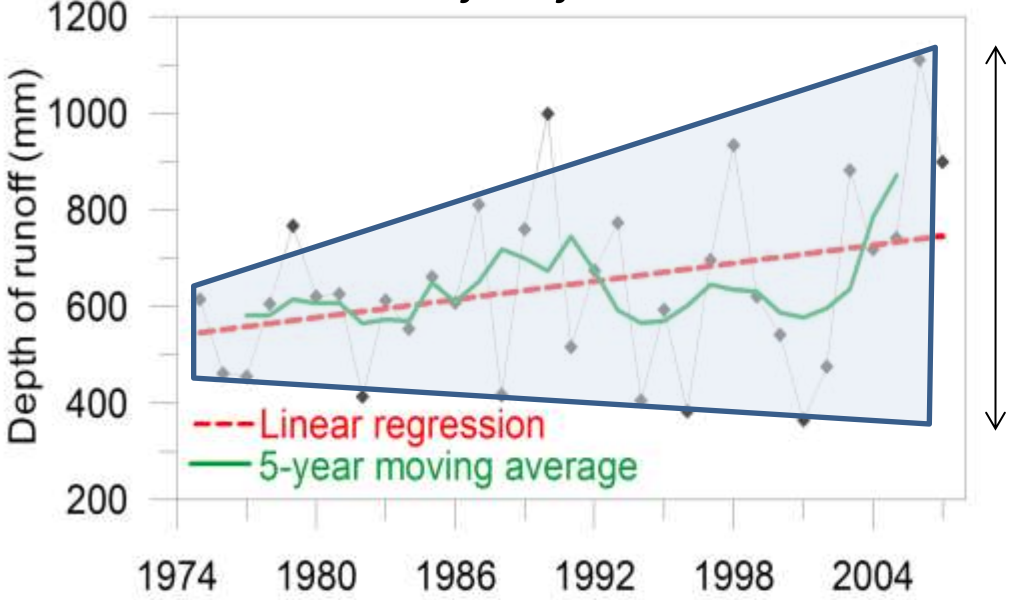
➢ **Trends in annual dam inflow (Soyang Dam)**




*Annual dam inflow for 1974 -2007*



# Potential threats to sustainable water supply due to climate variability and change

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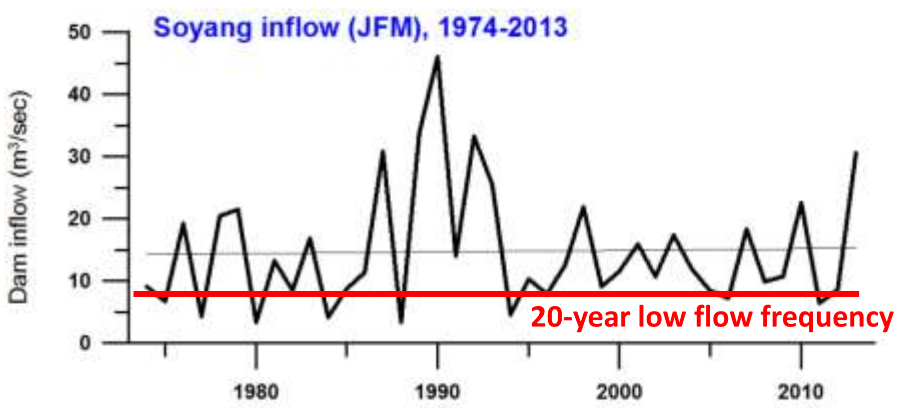
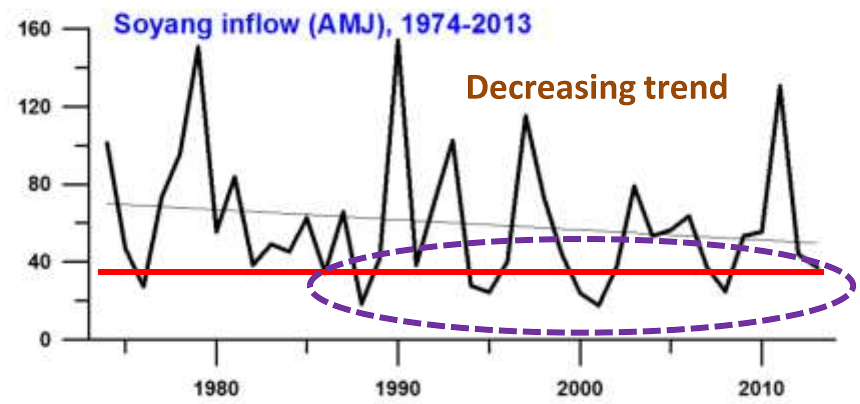
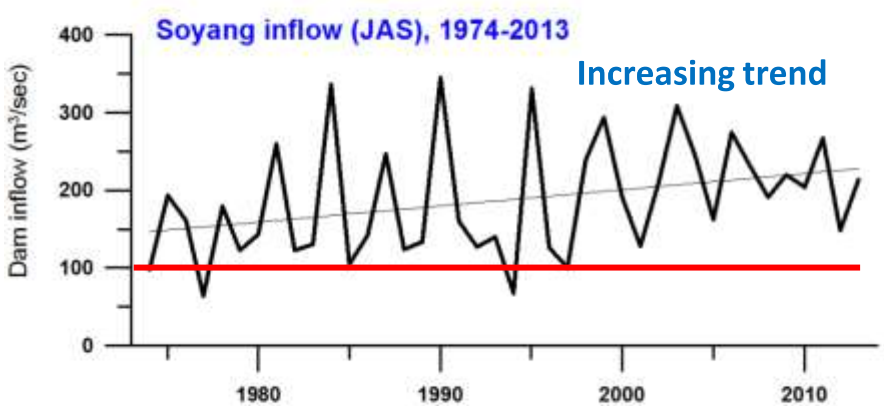
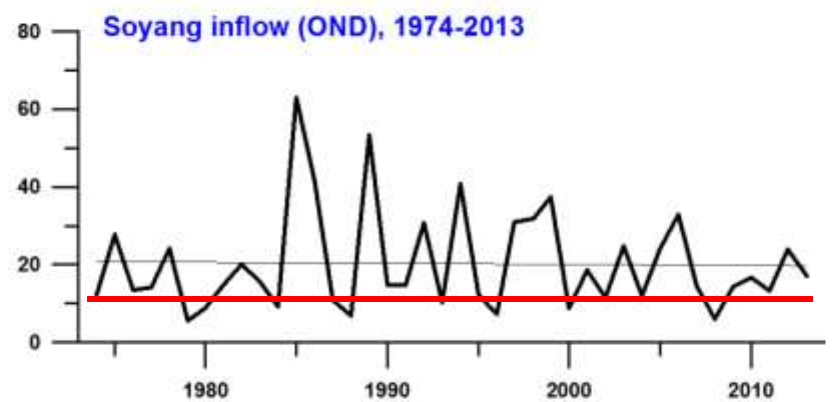
- Trends in dam inflow of Soyang dam



# Spring and early summer drought in 2014




***<u>Drought broke records in the lowest dam storage levels</u> in Soyang, Chungju, Hoengseong, and Boryeong dams***

**Grand Forum for coping with drought (K-water)**


**Restriction of the water supply**

# Seamless hydrometeorological and climate services for various applications

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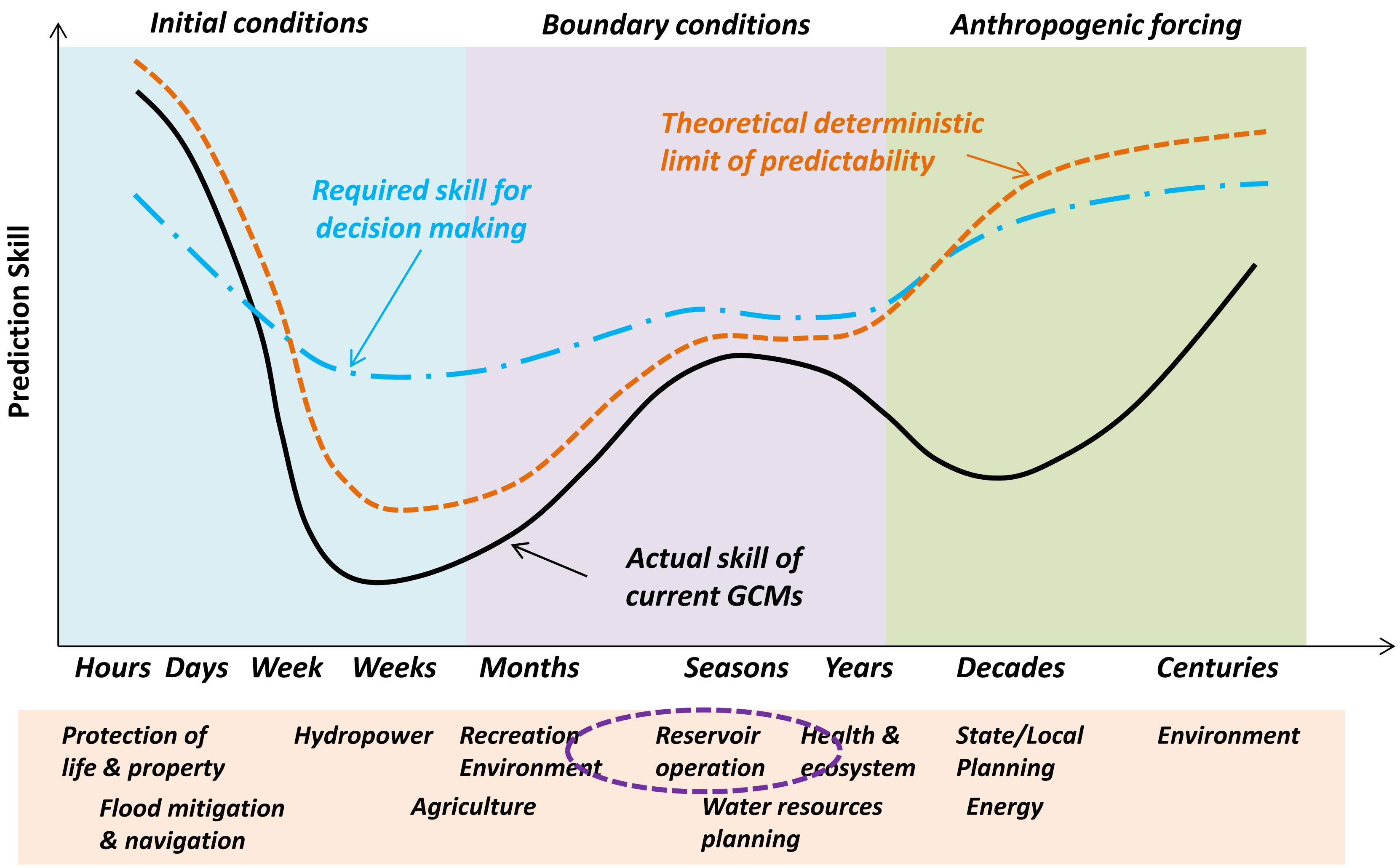


Source: WMO & NOAA
https://www.wmo.int/pages/prog/dra/eguides/index.php/en/5-functions/5-4-research

# APCC Multi-model ensemble seasonal forecast

- **APCC is providing high quality climate data by operating a real-time and well-validated climate prediction system based on the MME technique**
- **APCC services include:**
  - **(1) Monthly 3-month MME forecast**
  - **(2) 6-month MME forecast**
  - **(3) Sub-seasonal forecast (BSISO)**
- **Climatic variables:**

  Precipitation (prec),
  2m temperature(t2m),
  Temperature at the 850hPa (t850)
  Sea level pressure (slp)
  Wind speed at the 850hPa (u850 & v850)
  Geopotential height at 500hPa (z500)


*16 organizations in ten countries (2014)*

# Challenges in seasonal hydrologic prediction using APCC MME forecasts products

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- The first challenge is to create reliable daily climate forcing for hydrologic modeling from the monthly information provided by GCMs **(temporal scale problem)**

  ☞ ***Using monthly water balance model***

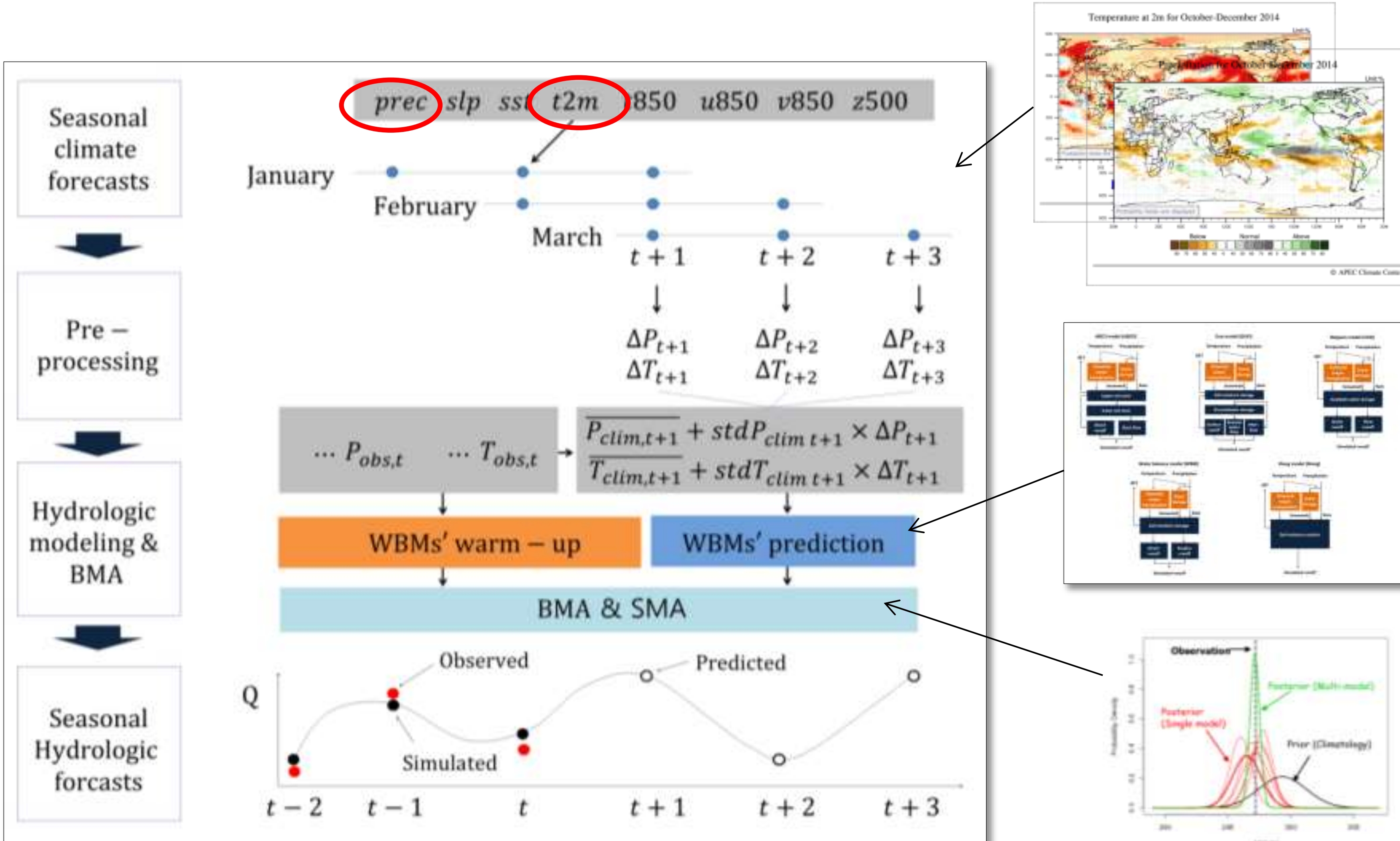
- The second challenge is to correct the systematic biases in CGCM products **(systematic bias problem)**

  ☞ ***Using simple bias correction***

- The third challenge is to resolve the discrepancy in spatial scales between climate models (2.5° x 2.5°) and hydrologic model applications **(spatial scale problem)**

  ☞ ***Using lumped watershed concept***

# Seasonal hydrologic forecast framework



# GCMs used for APCC MME

| Model; acronym | Institution (country) | Resolution | Forecast range | Reference |
|---|---|---|---|---|
| HMC | Hydrometeorological Centre of Russia (Russia) | 2.5 X 2.5 | 3 month | Tolstykh et al. (2010) |
| GDAPS_F | Korea Meteorological Administration (Korea) | | | Park et al. (2002) |
| MSC_ CANCM3 | Meteorological Service of Canada (Canada) | | | Kim et al. (2002) |
| MSC_ CANCM4 | Meteorological Service of Canada (Canada) | | | Simmons et al. (2004) |
| NCEP | Climate Prediction Center / NCEP / NWS / NOAA (USA) | | | Saha et al. (2010) |
| POAMA | Centre for Australian Weather and Climate Research /Bureau of Meteorology (Australia) | | | Zhong et al. (2005) |
| BCC | Beijing Climate Center (China) | | | Ding et al. (2000) |
| PNU | Pusan National University (PNU) | | | Sun and Ahn (2011) |
| CWB | Central Weather Bureau (Taipei) | | | Liou et al. (1997) |
| APCC | APEC Climate Center (Korea) | | | Jeong et al. (2008) |

# Correlation NCEP reanalysis & hindcast of GCMs

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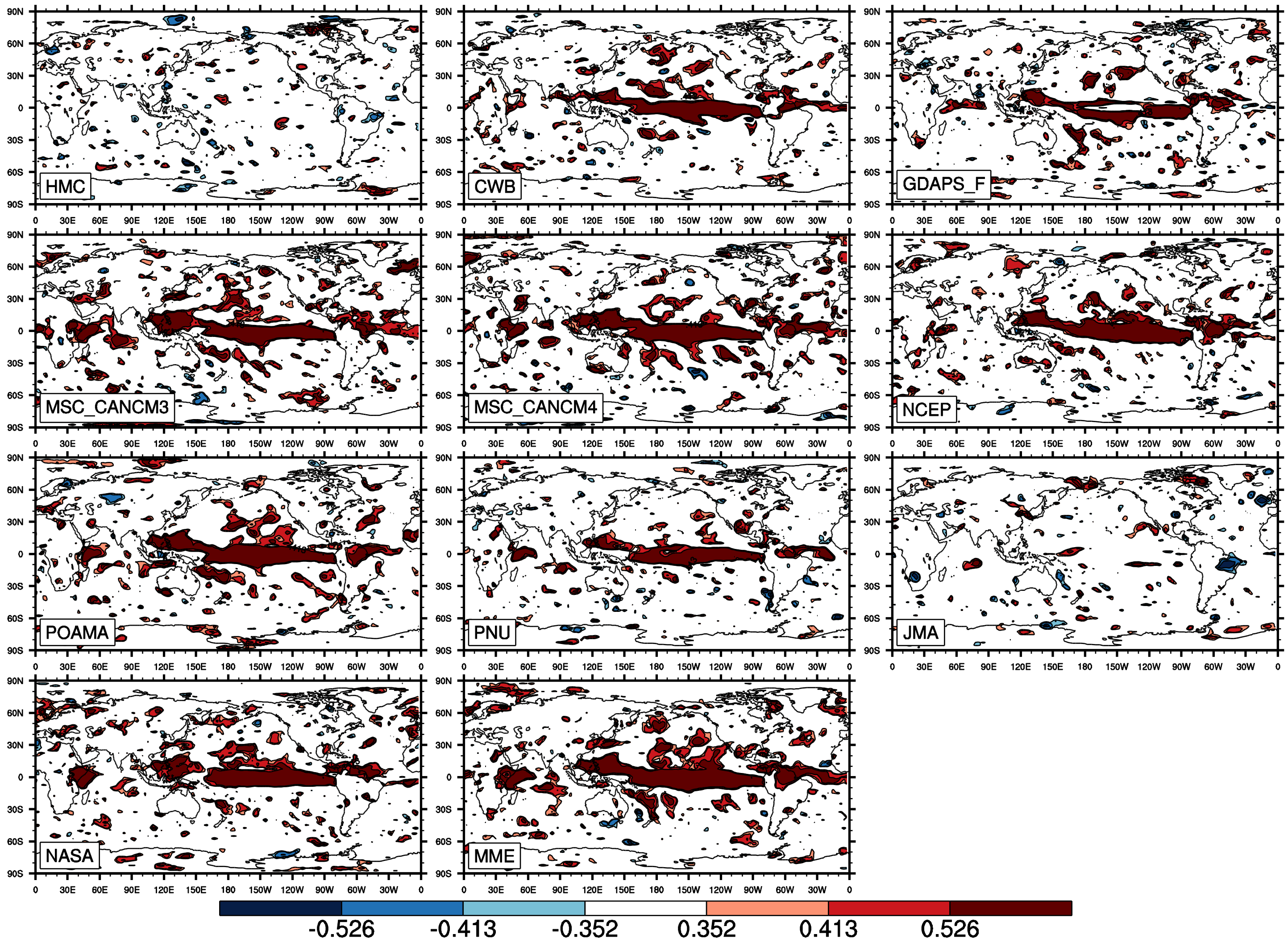
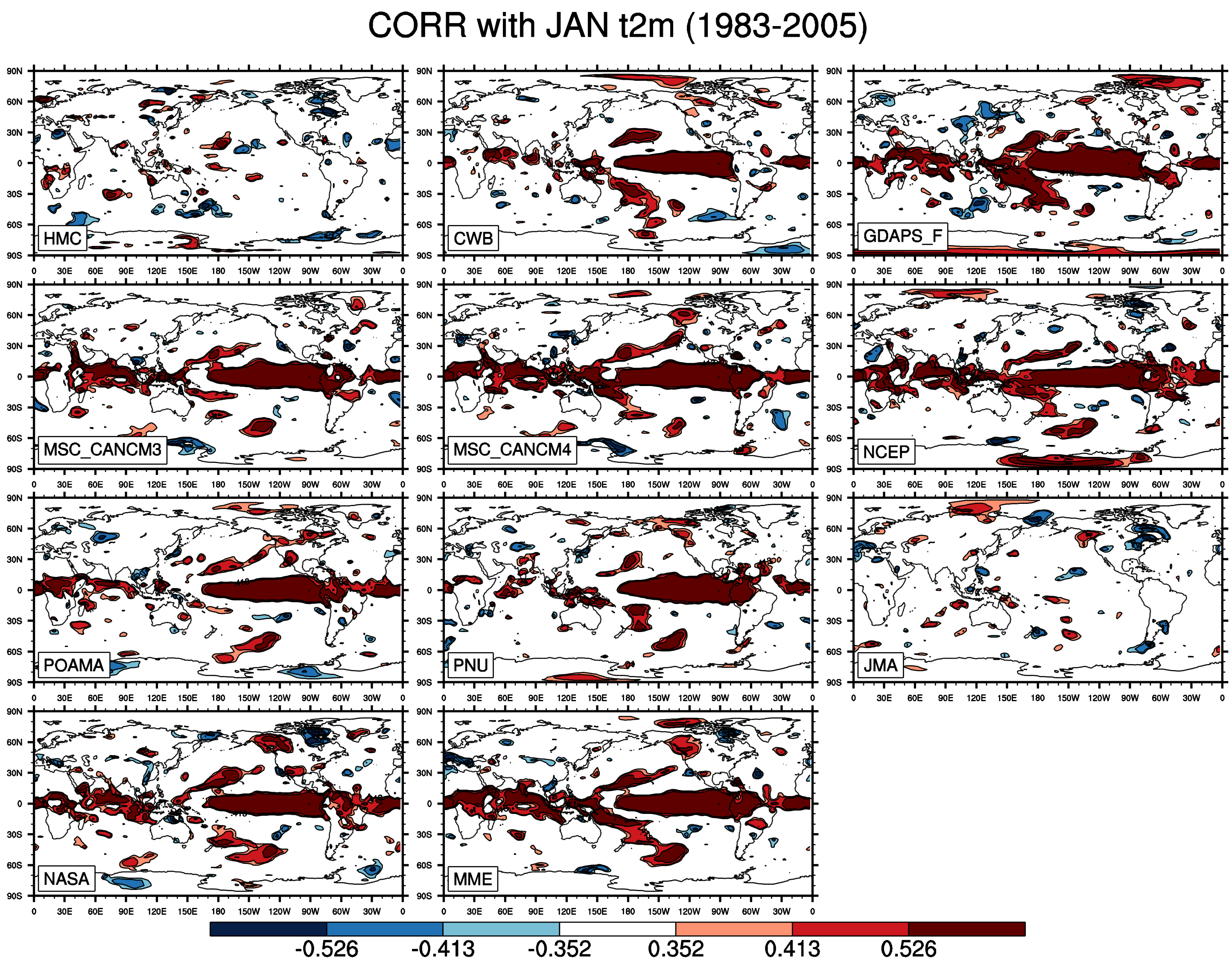
CORR with JAN prec (1983-2005)



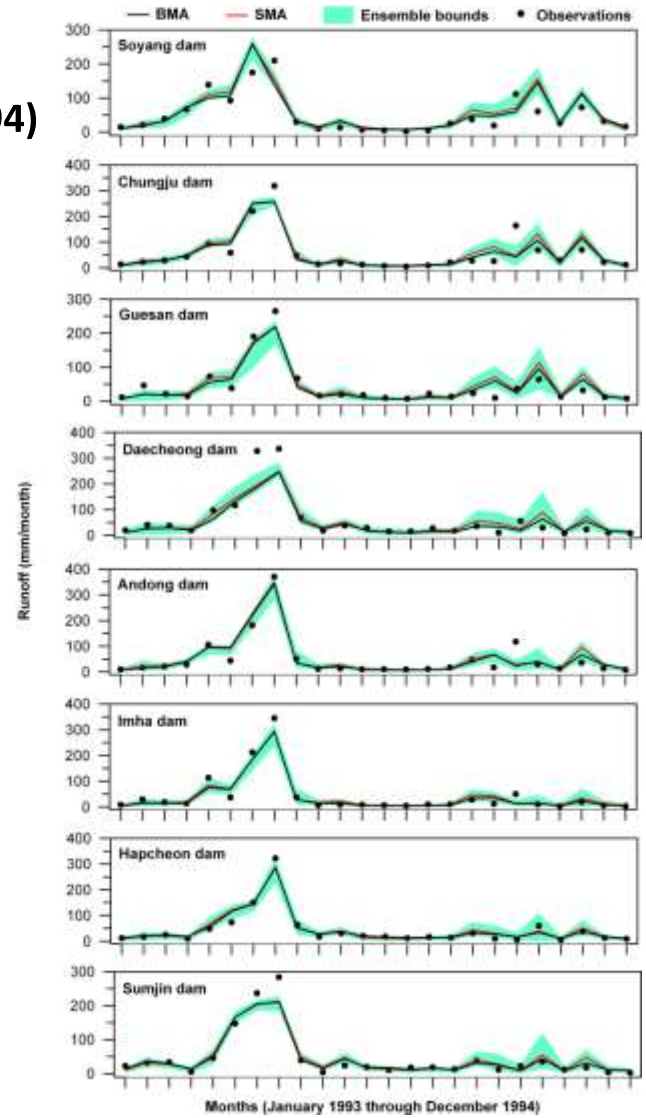
# Correlation NCEP reanalysis & hindcast of GCMs



# Performance of water balance models

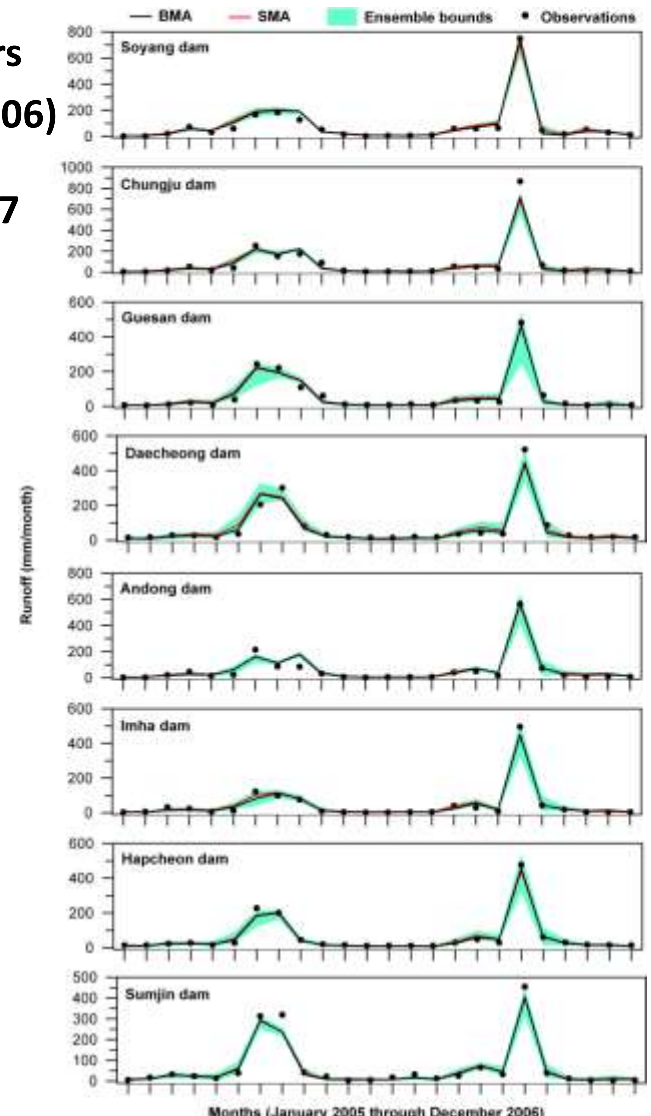
**Dry years (1993-1994)**

$R^2 > 0.85$

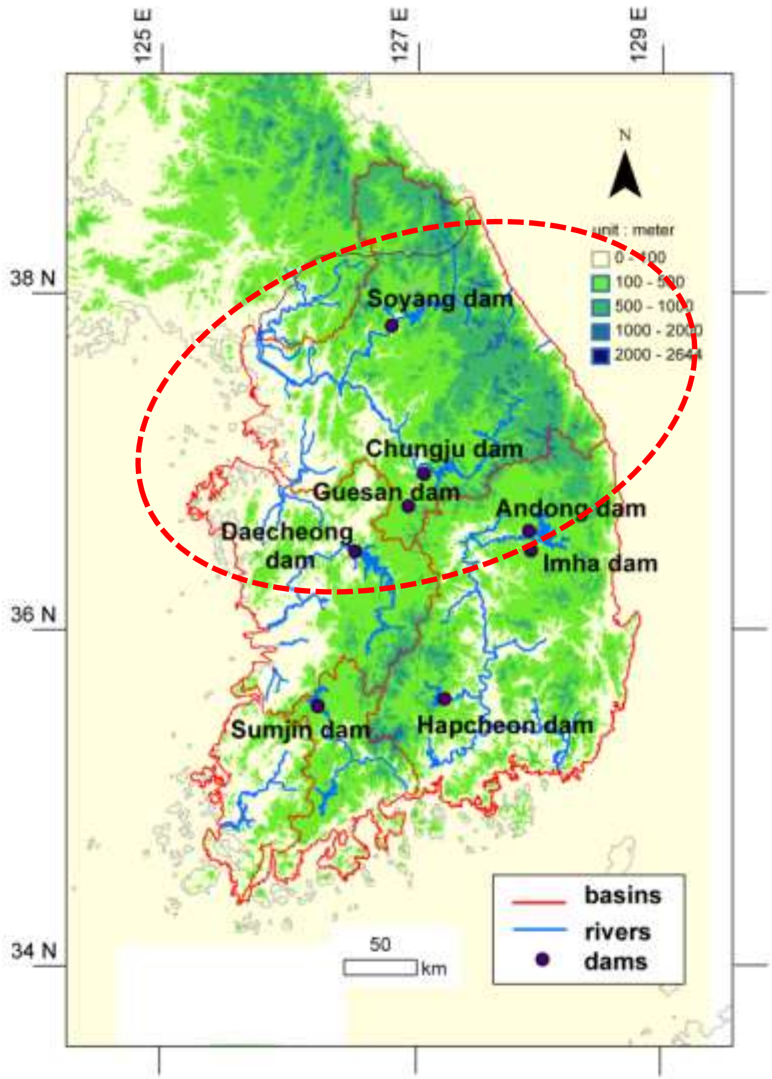



**Wet years (2005-2006)**

$R^2 > 0.87$



# Spearman rank correlation btw SSF & OBS




| Month | Soyang BMA | Soyang SMA | Chungju BMA | Chungju SMA | Hapcheon BMA | Hapcheon SMA | Sumjin BMA | Sumjin SMA |
|---|---|---|---|---|---|---|---|---|
| 01-Jan | 0.444 | 0.415 | 0.533 | 0.38 | 0.191 | 0.314 | 0.508 | 0.451 |
| 02-Jan | 0.171 | 0.008 | 0.419 | 0.305 | 0.134 | 0.282 | 0.233 | 0.149 |
| 03-Jan | 0.352 | 0.311 | 0.231 | 0.281 | -0.292 | -0.191 | -0.358 | -0.305 |
| 01-Feb | 0.635 | 0.57 | 0.629 | 0.636 | 0.439 | 0.338 | 0.538 | 0.433 |
| 02-Feb | 0.429 | 0.35 | 0.348 | 0.342 | -0.26 | -0.365 | -0.087 | -0.101 |
| 03-Feb | 0.182 | 0.128 | 0.188 | 0.157 | 0.358 | 0.426 | 0.323 | 0.302 |
| 01-Mar | 0.795 | 0.729 | 0.738 | 0.763 | 0.483 | 0.512 | 0.238 | 0.247 |
| 02-Mar | 0.528 | 0.49 | 0.439 | 0.412 | 0.478 | 0.449 | 0.346 | 0.379 |
| 03-Mar | 0.468 | 0.388 | 0.597 | 0.531 | 0.408 | 0.509 | 0.459 | 0.444 |
| 01-Apr | 0.668 | 0.647 | 0.741 | 0.711 | 0.522 | 0.554 | 0.38 | 0.405 |
| 02-Apr | 0.247 | 0.248 | 0.361 | 0.402 | 0.305 | 0.325 | 0.089 | 0.068 |
| 03-Apr | -0.311 | -0.272 | 0.12 | 0.02 | 0.25 | 0.179 | 0.062 | 0.053 |
| 01-May | 0.263 | 0.15 | 0.565 | 0.451 | 0.502 | 0.483 | 0.217 | 0.266 |
| 02-May | -0.1 | -0.076 | 0.274 | 0.2 | 0.333 | 0.404 | 0.189 | 0.218 |
| 03-May | 0.398 | 0.373 | 0.242 | 0.242 | -0.108 | -0.108 | -0.131 | -0.077 |
| 01-Jun | -0.344 | -0.442 | -0.027 | -0.153 | -0.01 | -0.022 | -0.122 | -0.029 |
| 02-Jun | -0.153 | -0.153 | -0.238 | -0.238 | -0.265 | -0.267 | 0.065 | 0.048 |
| 03-Jun | 0.126 | 0.126 | 0.048 | 0.11 | -0.238 | -0.184 | -0.323 | -0.224 |
| 01-Jul | 0.084 | 0.059 | 0.289 | 0.359 | 0.412 | 0.407 | 0.444 | 0.627 |
| 02-Jul | 0.332 | 0.341 | 0.205 | 0.214 | -0.397 | -0.429 | -0.143 | -0.102 |
| 03-Jul | 0.251 | 0.23 | 0.212 | 0.224 | 0.456 | 0.407 | 0.347 | 0.329 |
| 01-Aug | -0.335 | -0.359 | -0.427 | -0.445 | -0.233 | -0.154 | -0.46 | -0.215 |
| 02-Aug | 0.492 | 0.484 | 0.546 | 0.516 | 0.495 | 0.483 | 0.468 | 0.429 |
| 03-Aug | -0.011 | 0.03 | 0.033 | -0.036 | 0.275 | 0.341 | -0.017 | -0.11 |
| 01-Sep | -0.032 | 0.026 | 0.206 | 0.311 | 0.191 | 0.463 | -0.107 | 0.147 |
| 02-Sep | 0.135 | 0.141 | 0.027 | 0.017 | 0.169 | 0.233 | -0.138 | -0.251 |
| 03-Sep | -0.123 | -0.162 | -0.135 | -0.153 | 0.27 | 0.262 | 0.266 | 0.262 |
| 01-Oct | 0.295 | 0.161 | 0.259 | 0.217 | 0.387 | 0.529 | -0.015 | 0.132 |
| 02-Oct | -0.104 | -0.209 | 0.271 | 0.217 | 0.559 | 0.603 | 0.09 | 0.319 |
| 03-Oct | 0.147 | 0.044 | 0.114 | -0.168 | 0.735 | 0.797 | 0.367 | 0.338 |
| 01-Nov | 0.483 | 0.429 | 0.586 | 0.654 | 0.314 | 0.684 | 0.624 | 0.758 |
| 02-Nov | 0.405 | 0.341 | 0.49 | 0.254 | 0.456 | 0.696 | 0.254 | 0.22 |
| 03-Nov | 0.249 | 0.146 | 0.071 | -0.117 | 0.555 | 0.615 | -0.105 | -0.146 |

# Skill scores for wet and dry seasons

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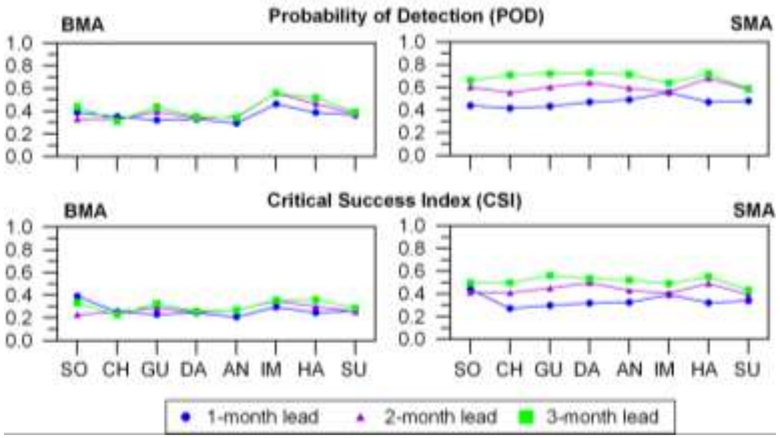
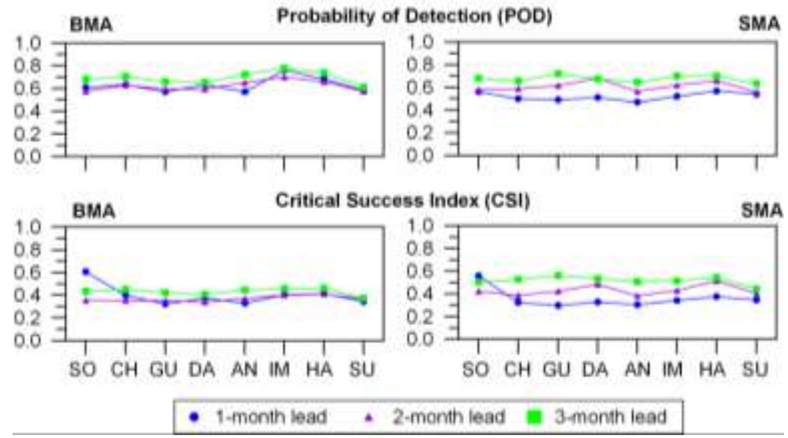
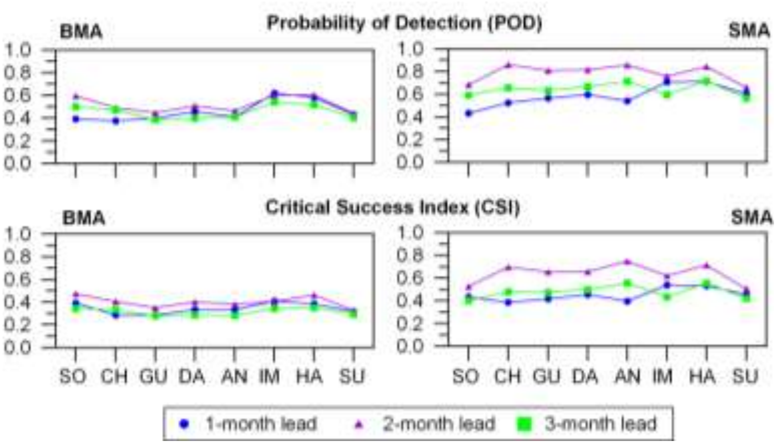
## *Above* normal flow in the *wet* season



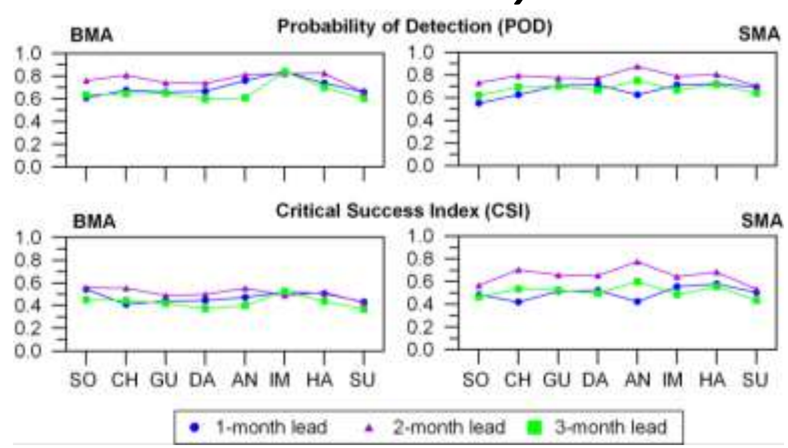

## *Below* normal flow in the *wet* season




## *Above* normal flow in the *dry* season




## *Below* normal flow in the *dry* season



# Empirical hydrologic prediction using teleconnection

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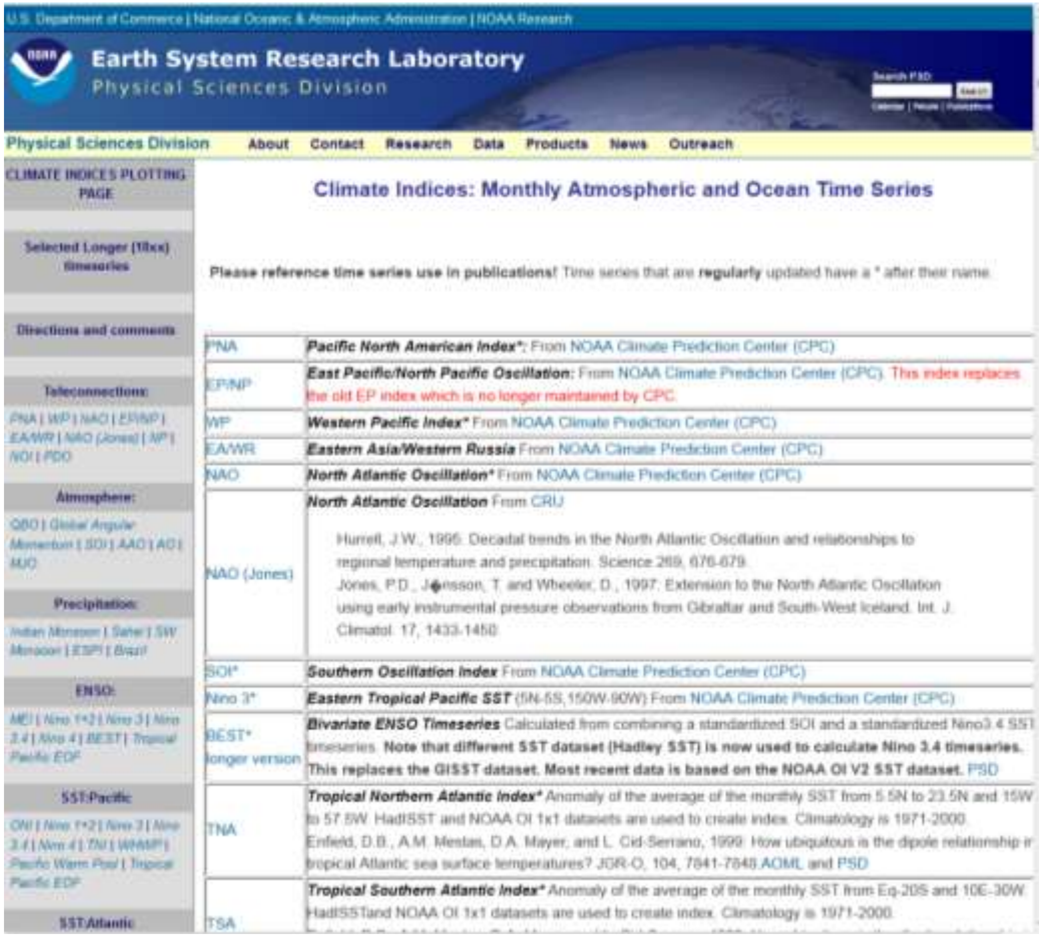


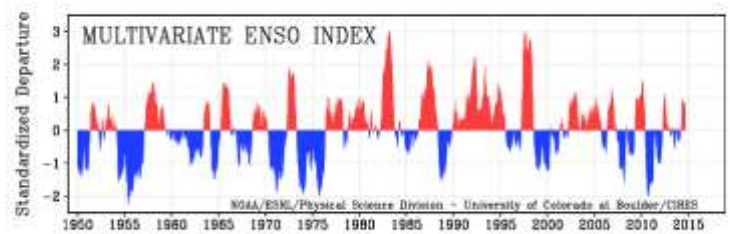


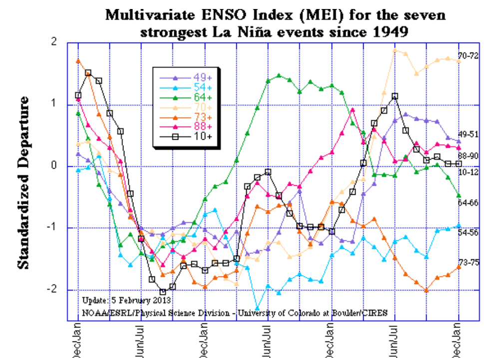


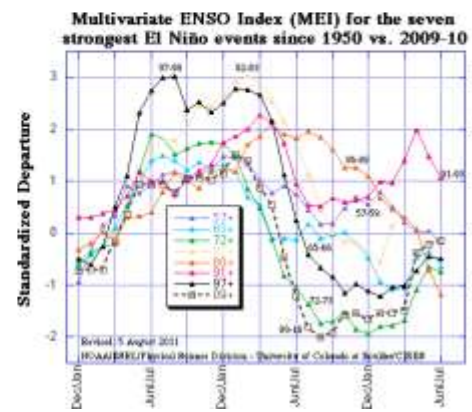


*Source: http://www.esrl.noaa.gov/psd/data/climateindices/list/*

# Empirical hydrologic prediction using teleconnection

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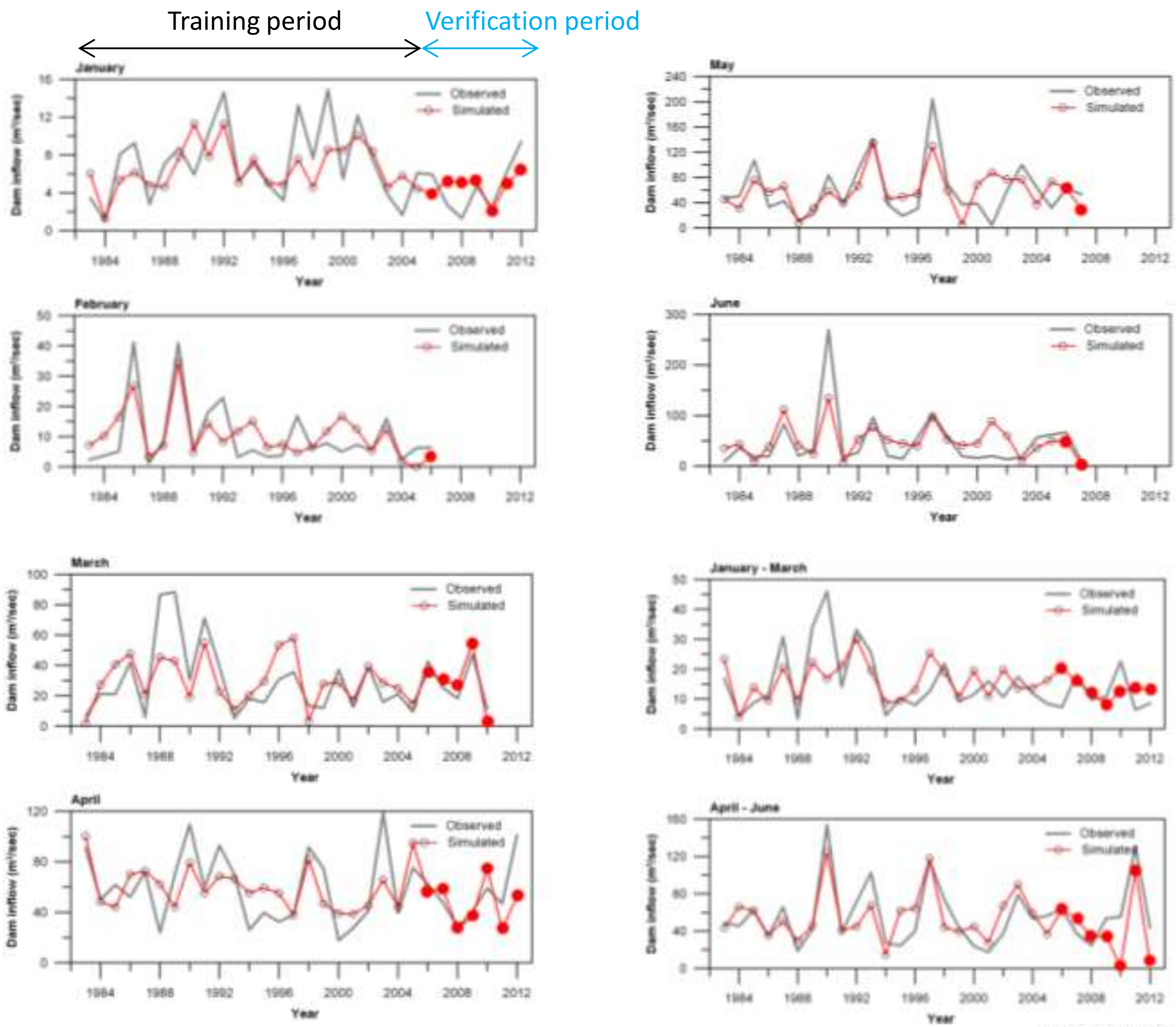
## Empirical regression models (Soyang dam)

| Mon. | Equation | $R^2$ | Adj. $R^2$ |
|---|---|---|---|
| Jan | Q1 = 4.378+0.002*Solar(-2)-3.162*TSA(-5) +1.249*EA(-8) | 0.43 | 0.34 |
| Feb | Q2 = 11.49+3.283*NOI(-7)-13.35*TNA(-10) | 0.54 | 0.50 |
| Mar | Q3 = 8.28-12.21*PNA(-12)+30.57*SWM(-9) | 0.44 | 0.39 |
| Apr | Q4 = 58.05-7.01*SOI(-2) | 0.38 | 0.36 |
| May | Q5 = 54.06-10.65*NOI(0)-18.44*WPO(-12) | 0.49 | 0.43 |
| Jun | Q6 = 46.38-11.13*NOI(-1)+23.12*NOI(-11) | 0.47 | 0.41 |
| Jan-Mar | Q13 = 15.78+5.755*EA(0) | 0.33 | 0.30 |
| Apr-Jun | Q46 = 59.82+60.49*AO(-9)-10.71*NAO(-4) | 0.64 | 0.61 |
| Jan-Jun | Q16 = 35.30+8.96*EA(0) | 0.23 | 0.20 |

Solar: solar flux, TSA: Tropical Southern Atlantic Index, EA: Eastern Asia/Western Russia
NOI: Northern Oscillation Index, TNA: Tropical Northern Atlantic Index, PNA: Pacific North American Index
SWM: SW Monsoon Region Rainfall, SOI: Southern Oscillation Index, WPO: West Pacific Oscillation, AO: Antarctic Oscillation, NAO: North Atlantic Oscillation

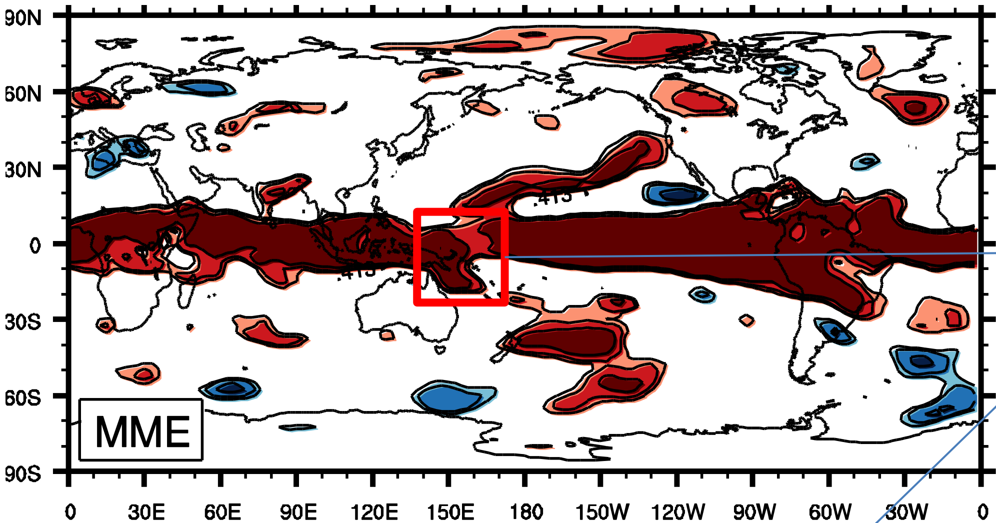
*Source: http://www.esrl.noaa.gov/psd/data/climateindices/list/*

# Empirical hydrologic prediction using teleconnection

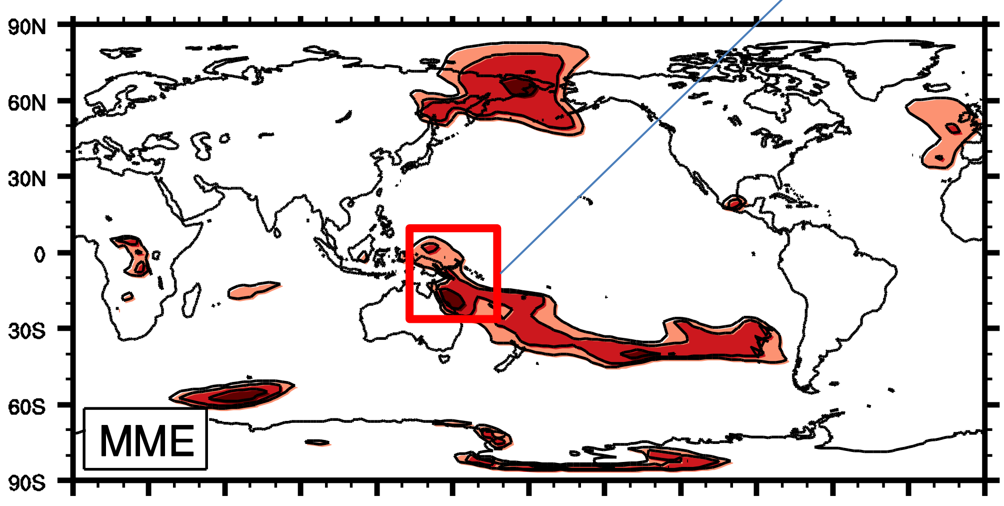


# Toward improving predictability of seasonal hydrologic forecast in South Korea

**Predictability of *T850* in January**




**Teleconnection(correlation) between *dam precipitation* and *T850***




**Development of statistical models based on the forecast of selected regions**

⇩

**Verification of the statistical model using cross-validation**

⇩

**Prediction of streamflow forecast using hydrologic models**

# Conclusions



- **Our results showed the potential utility of seasonal dam inflow prediction during dry season, indicating APCC MME seasonal climate forecast can be useful information for developing proactive water supply plans and better preparing periodic seasonal droughts in South Korea.**

- **However, there was no significant forecast skill for the wet season, especially June and September. To improve the predictability of seasonal dam inflow prediction we need to develop a hybrid technique that integrates APCC MME-driven forecast and Teleconnection-driven forecast.**

- **This approach can play an important role in bridging the gaps between climate information produces and forecast consumers, such as water managers and operational agencies.**

# Thank you for your attention !

*"Typical numerical weather forecasts attempt to predict atmospheric conditions several days into the future. This capability is highly valuable for aviation, severe weather alerts, and everyday weather-related decisions.* ***However, predictions on such a short time horizon cannot inform decisions relevant to water resource planning, agriculture management, drought preparation, or other activities that require knowledge of weather conditions weeks to months in advance****." (Eric Wood et al., 2008)*


***Golden gate bridge, San Francisco, USA***