Stochastic analysis & simulation of hydrometeorological extremes

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Contents

- Statistical downscaling of daily precipitation to hourly for the impact assessment of hydrometeorological extremes from climate change
- Long & Mid-term forecasting of hydrometeorological extremes with Nonstationary Oscillation Resampling (NSOR)

Nonparametric Temporal Downscaling from Daily Precipitation to Hourly

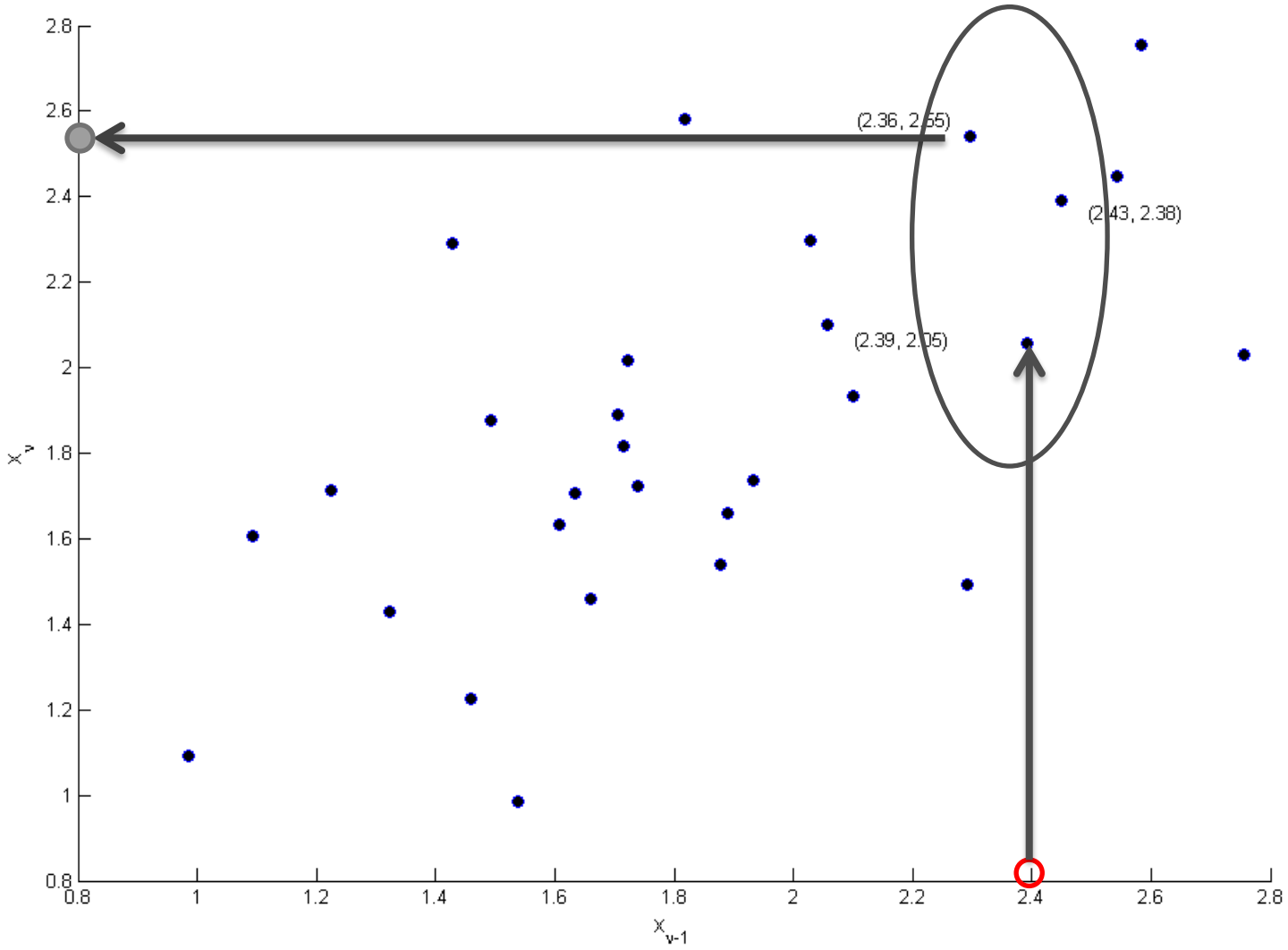
Temporal downscaling from daily to hourly

- Why hourly?
- Concentration time is only few hours for most of the basins in S. Korea

Employed Nonparametric Techniques

- K-nearest neighbor resampling (KNNR)
- Kernel density estimate (KDE)
- GA-based mixing process

K-nearest neighbor resampling(KNNR)



Distance measurement (KNNR)

- **Distance measurement**
- **Find the weather or climate condition**

$$D_i = \{[\mathbf{C}_t - \mathbf{C}_i]\Psi\}^T [S]^{-1} \{[\mathbf{C}_t - \mathbf{C}_i]\Psi\}$$

  - $\mathbf{C}$ **: condition (e.g. large scale climate variables) at current time t, with the observed time i**
  - S**: scaling weight**
  - Ψ**: influence weight (Adaptive Metropolis Algorithm)**

Kernel density estimate (KDE)

- **KDE with gamma kernel**
  - $\mathrm{f}(\mathrm{R_t}) = \sum_{i=1}^{N} K_{\alpha,\beta}(R_t)$

    - $K_{\alpha,\beta}(R_t)$~Gamma(α, β)

$$\hat{f}(x) = \frac{1}{N}\sum_{i=1}^{N} K_{x^2/h^2,\,h^2/x}(X_i)$$

$$K_{x^2/h^2,\,h^2/x}(t) = \frac{t^{x^2/h^2-1}e^{-t/(h^2/x)}}{(h^2/x)^{x^2/h^2}\,\Gamma(x^2/h^2)}$$

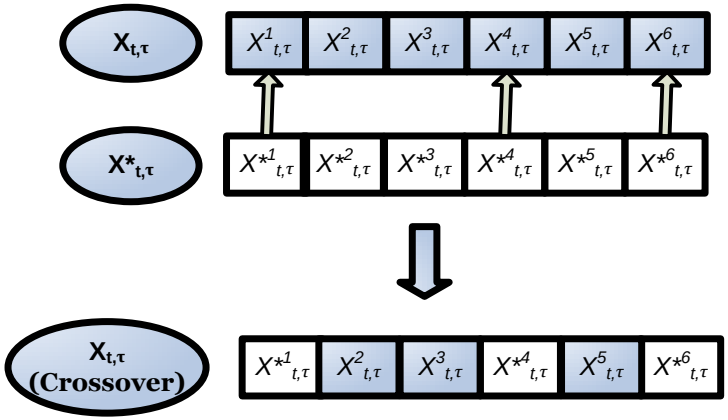
$$\mu(t) = x$$

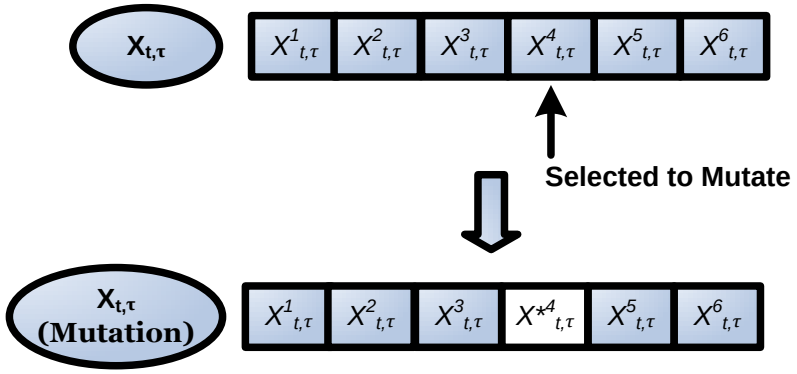
$$\sigma^2(t) = h^2$$

Genetic Algorithm

- Directed search algorithms based on the mechanics of biological evolution

1. Reproduction
2. Crossover
3. Mutation





Nonpara. Temporal Downscaling (Lee2014)

- Objective: Downscale daily precip. to hourly
- Procedure

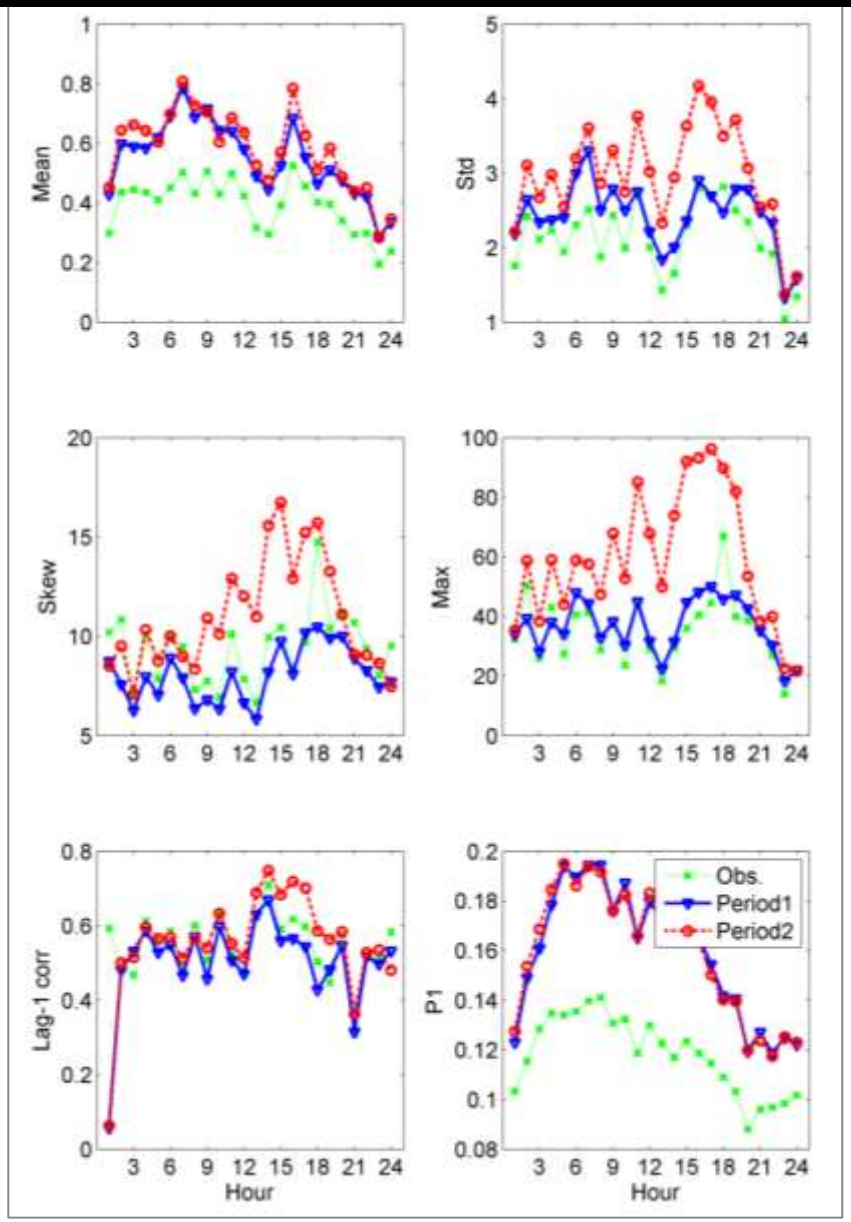
1. Selection of k number of candidate sets with smallest distance Δ

$$\Delta_v = \sqrt{\varphi_1\left(D_t - d_v\right)^2 + \varphi_2\left(H_{t-1,24} - h_{v-1,24}\right)^2}$$

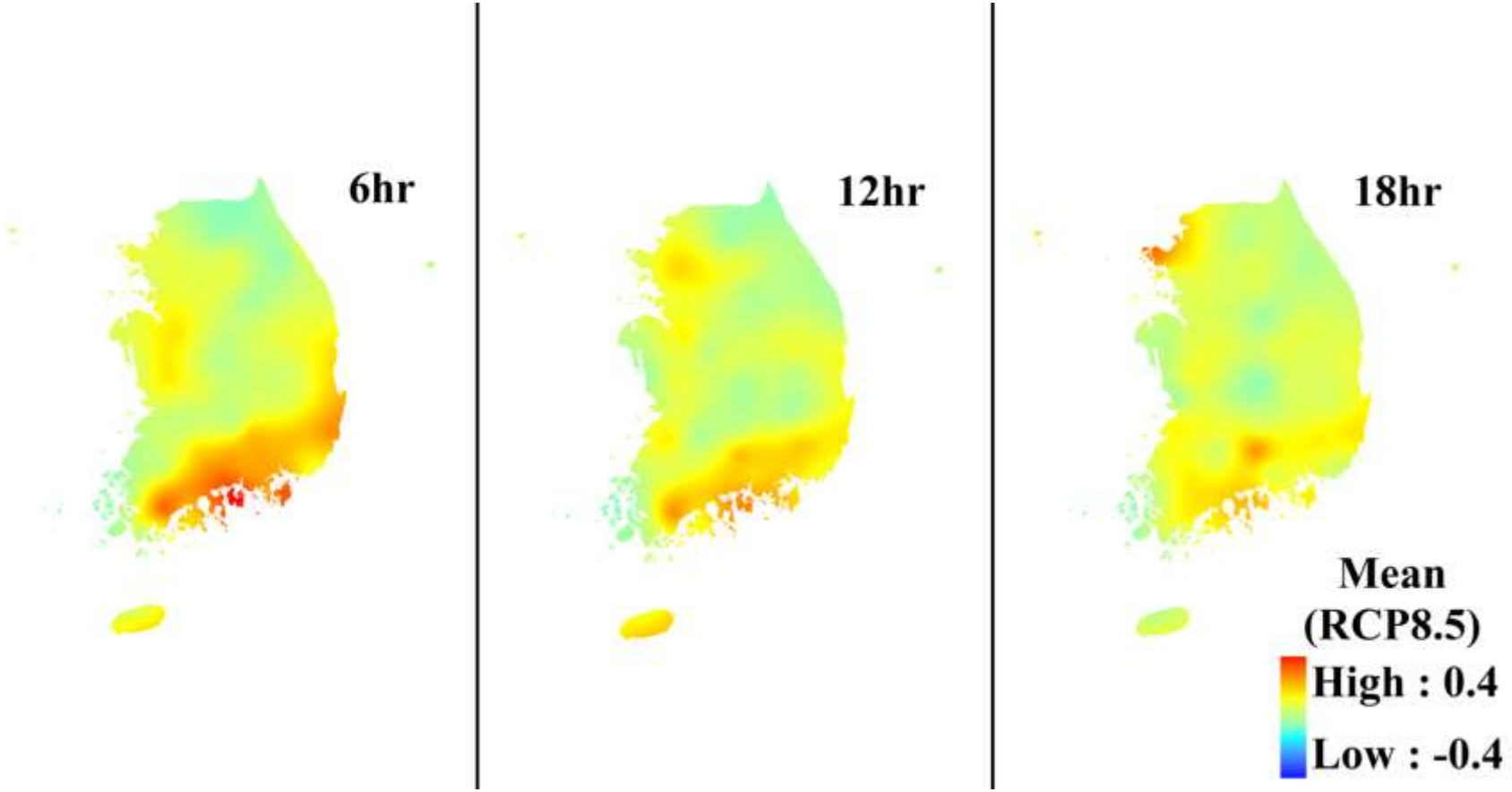
2. Select two among k sets $$w_m = \frac{1/m}{\sum_{j=1}^{k} 1/j}$$
3. Crossover & mutate the two selected hourly precipitation datasets
4. Adjust the final hourly precipitation as $$H*_{t,ih} = \frac{H_{t,ih}}{\sum_{ih=1}^{24} H_{t,ih}} D_t$$

Nonpara. Temporal Downscaling (NTD)

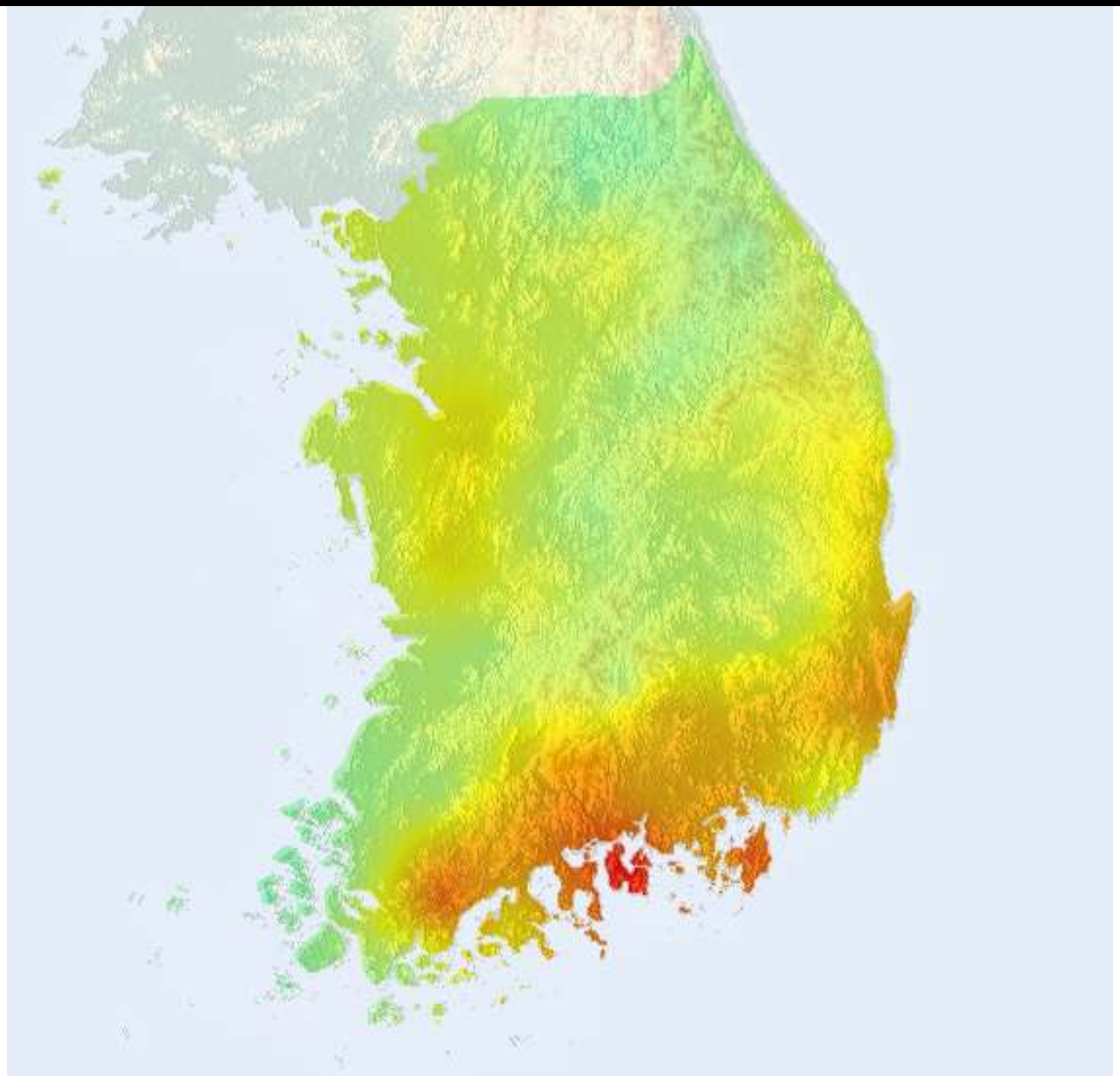
- Target Data:
  Jinju daily precip.
  (August)
- RCP8.5
- Period1: 2011-2055
- Period 2: 2056-2099



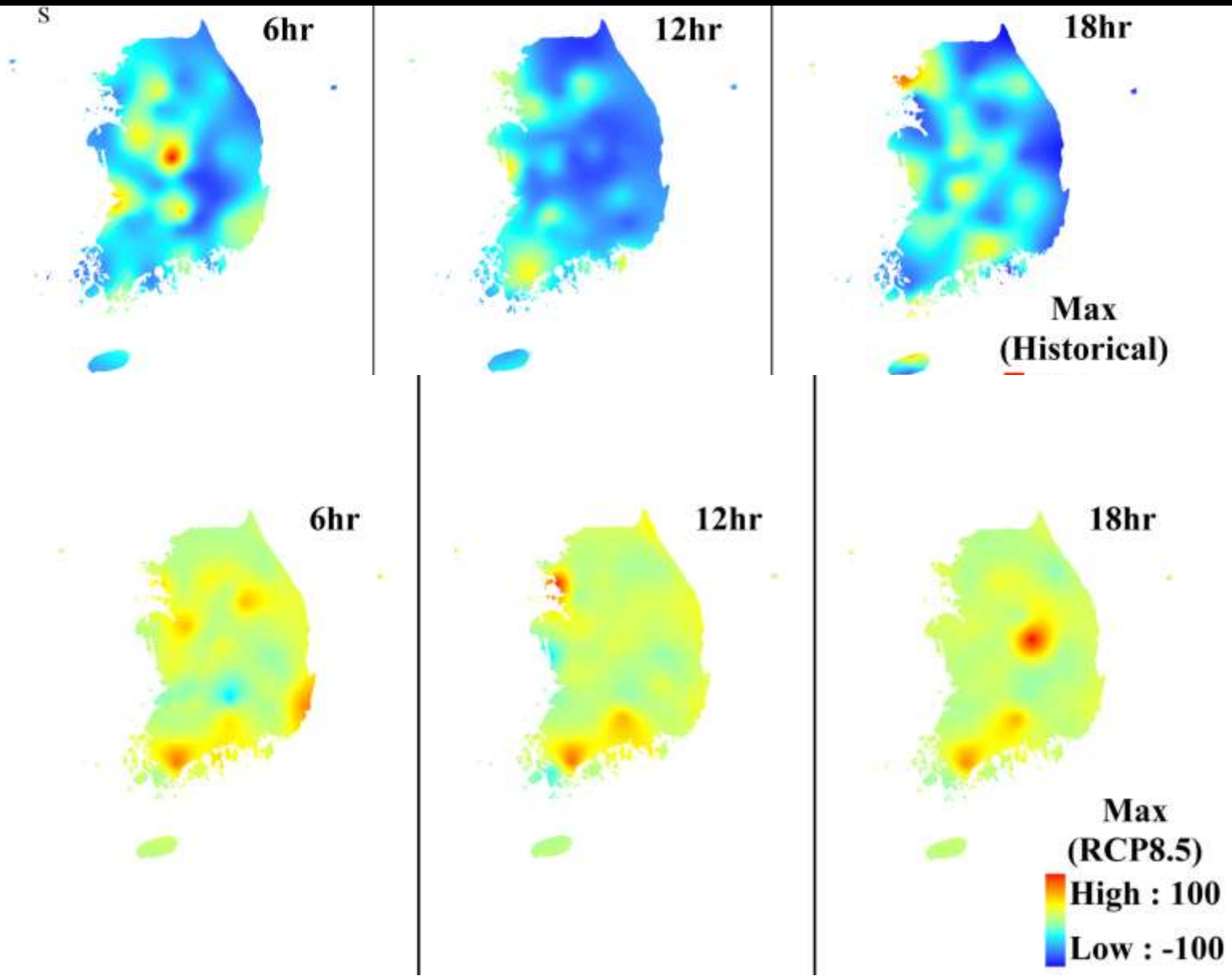
Mean Diff. b/w Hist and Dowscaled



Geological relation of mean changes

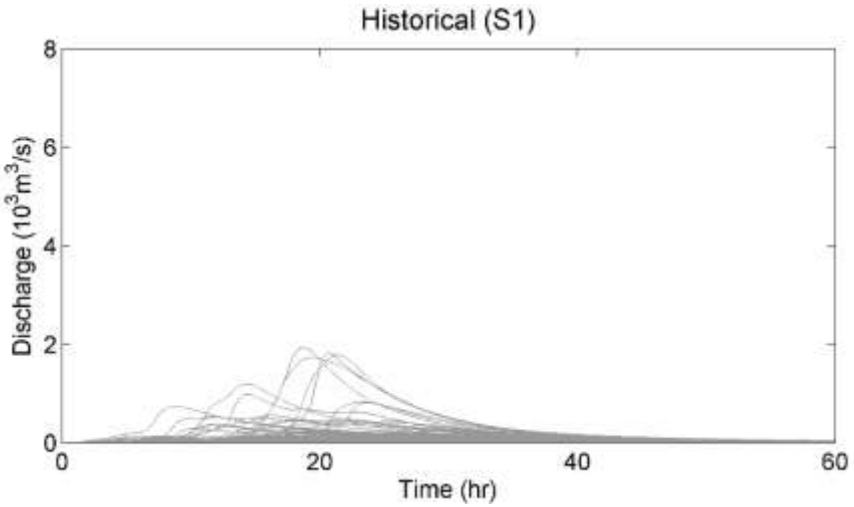


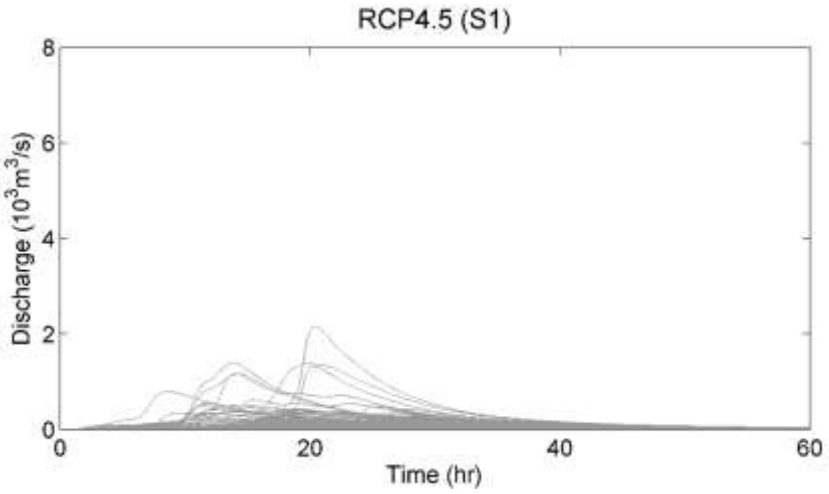
Hourly Extremes

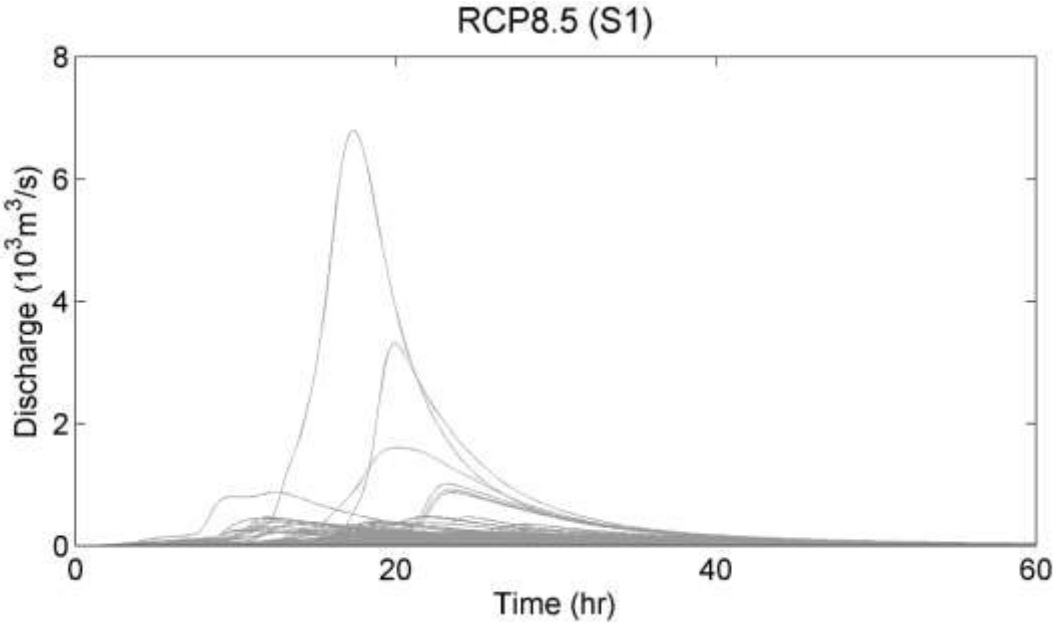


Application to Nam River Basin

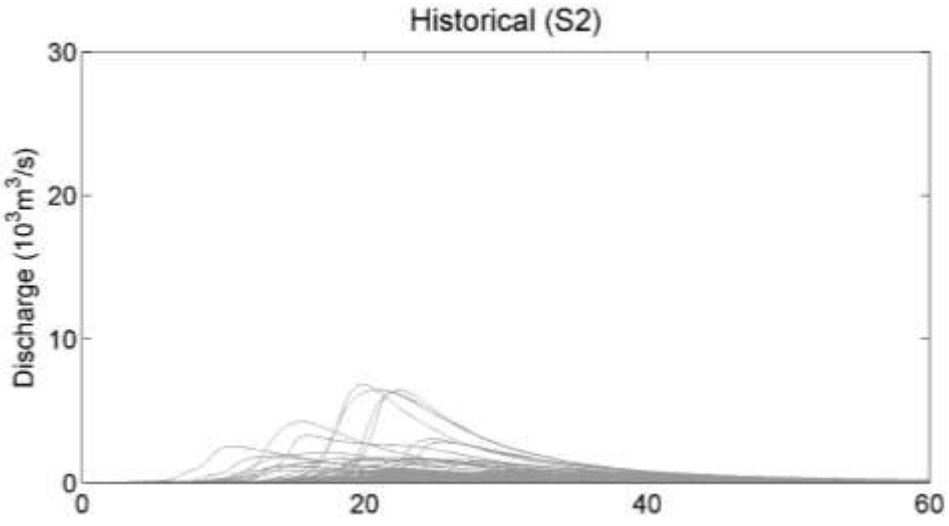
Streamflow scenarios of Nam River

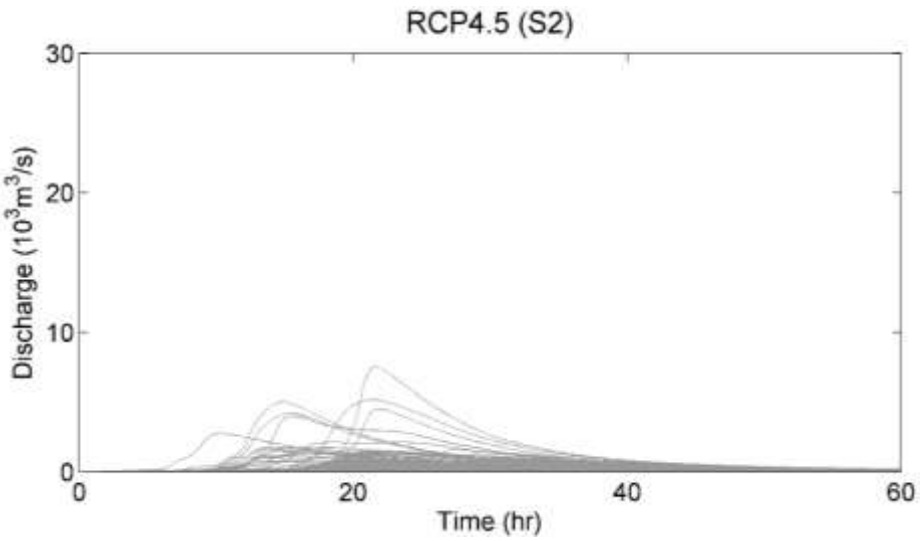


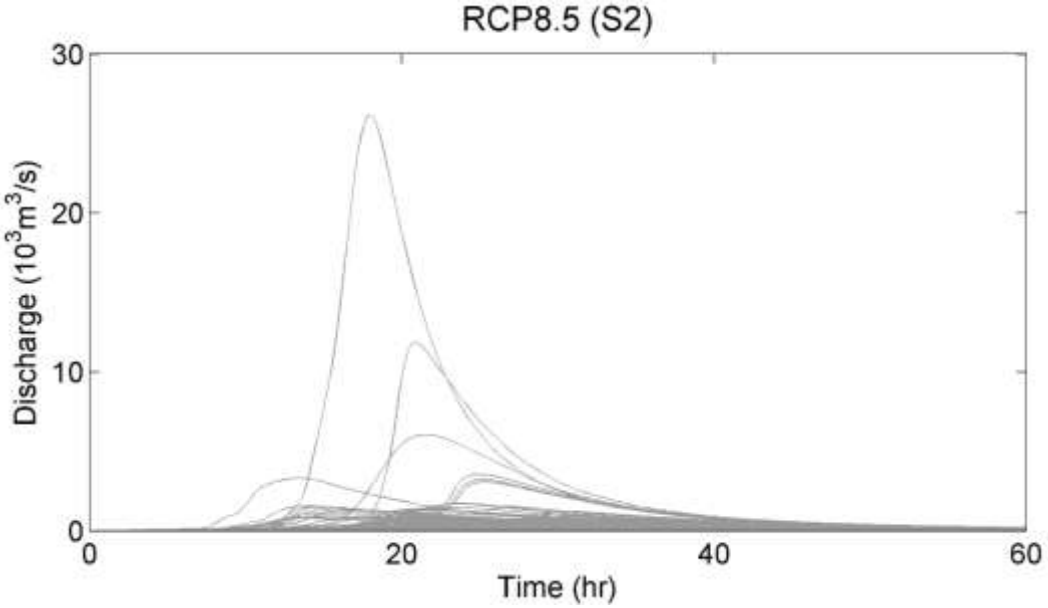




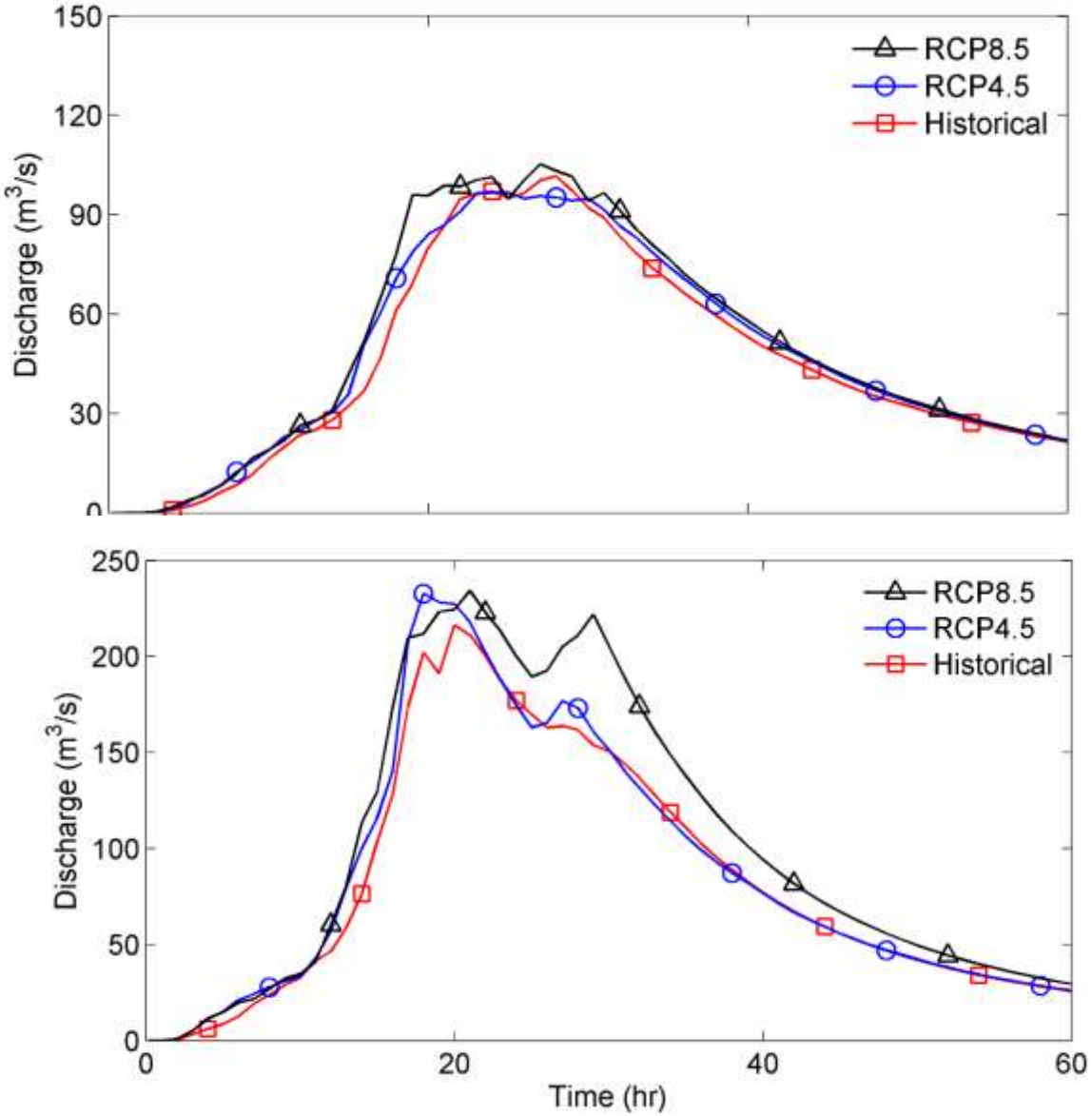
Streamflow scenarios of Nam River



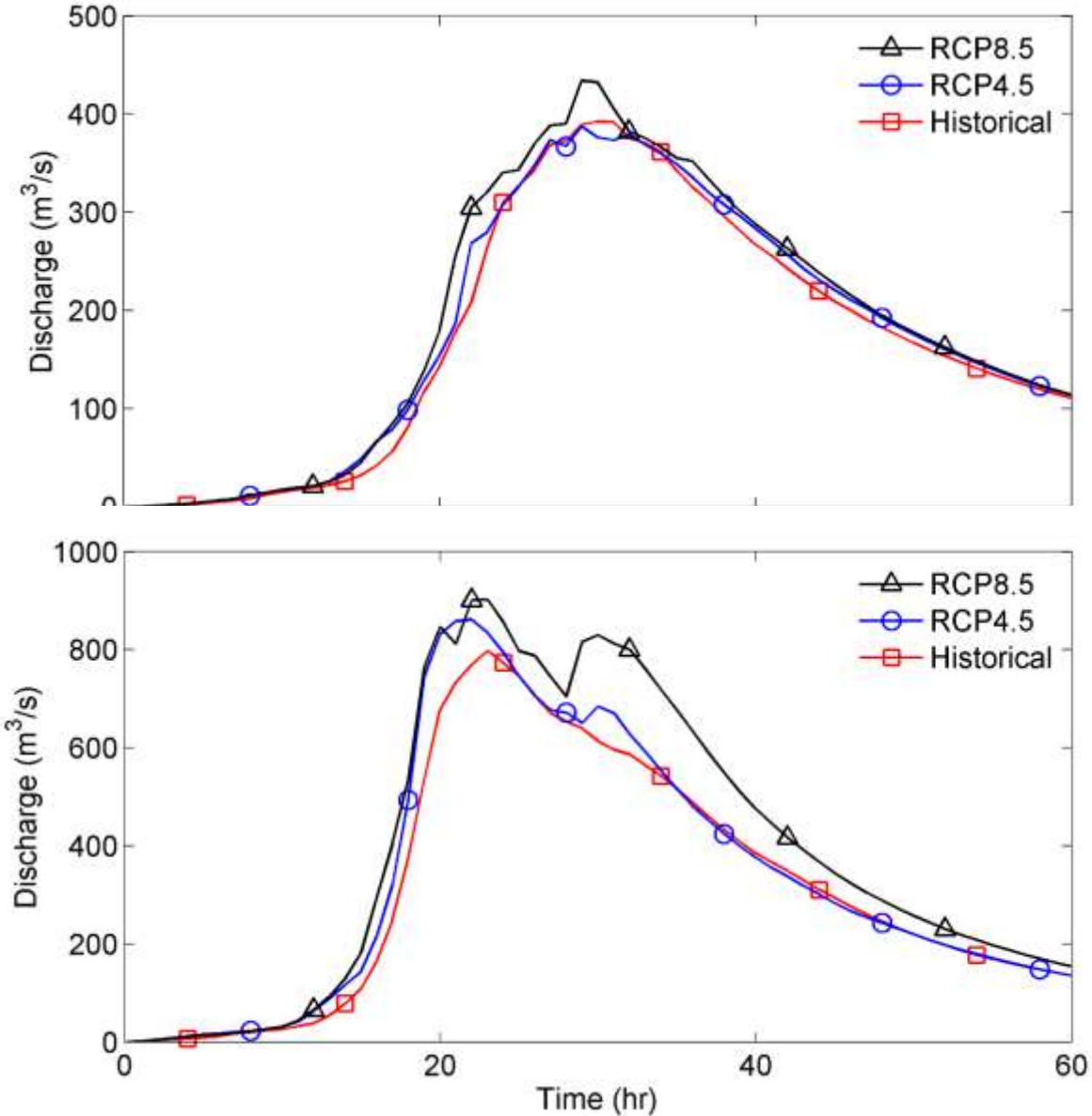




75 & 90 Percentiles of Streamflow for S1



75 & 90 Percentiles of Streamflow for S2



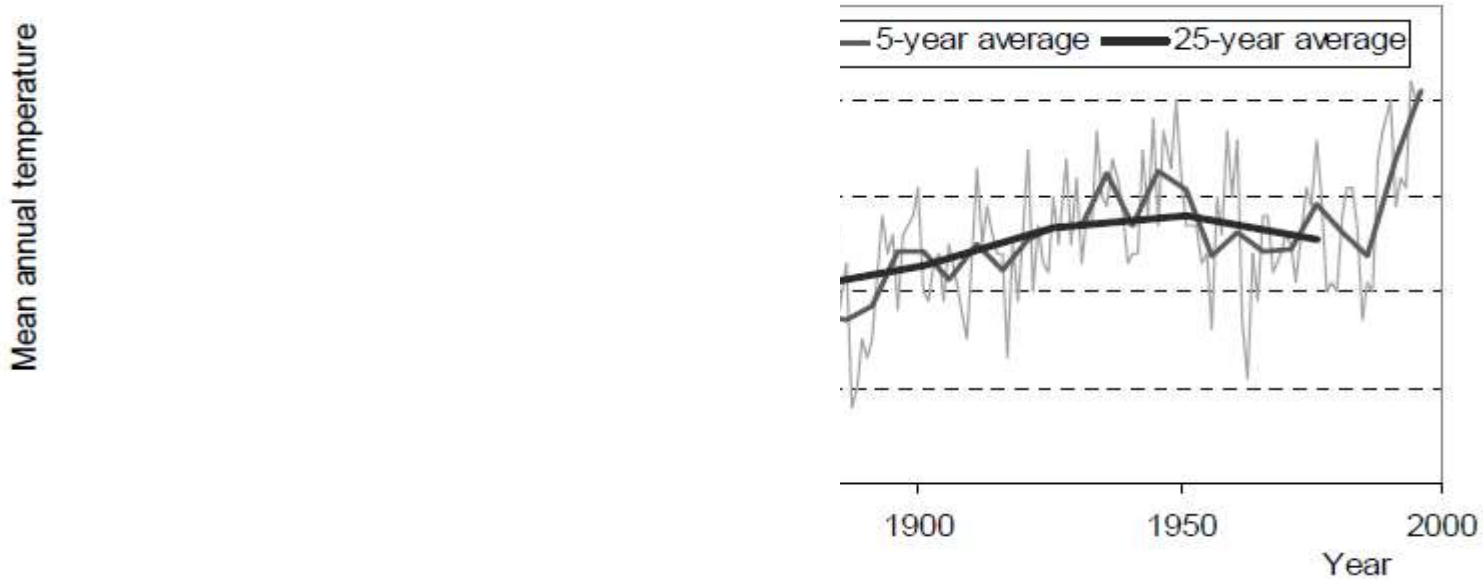
Pros and Cons of NPD

- **Pros**
  - **Avoid the need to estimate the parameters**
  - **Assuming a parametric distribution or relation is not necessary**
  - **Complex non-linear relations in observed data can be reproduced in downscaled data**
- **Cons**
  - **Not to capture a climate pattern that is not in the observed data**

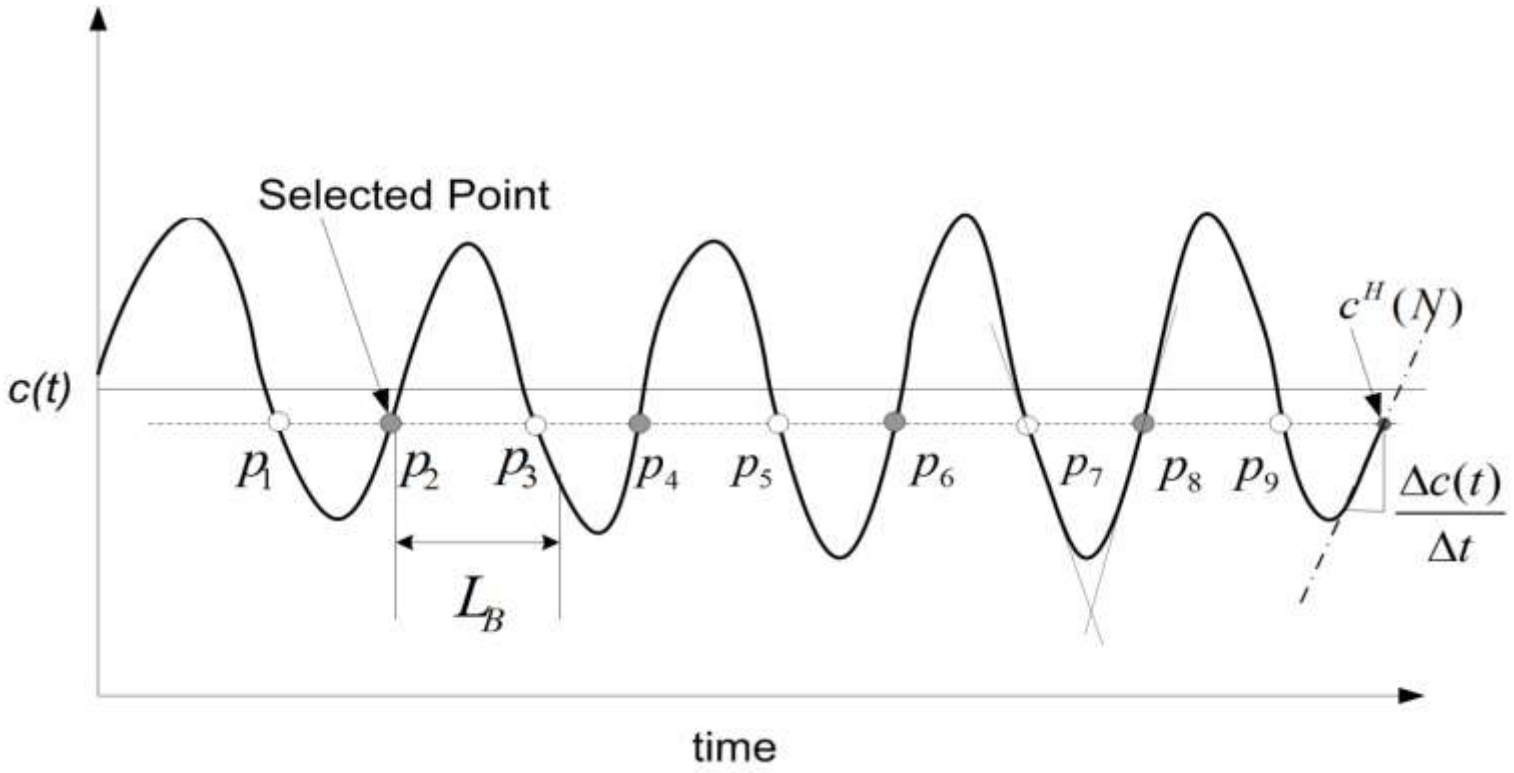
Empirical Mode Decomposition (EMD) and Nonstationary Oscillation Resampling (NSOR)

Applied to Hydrometeorological Extremes

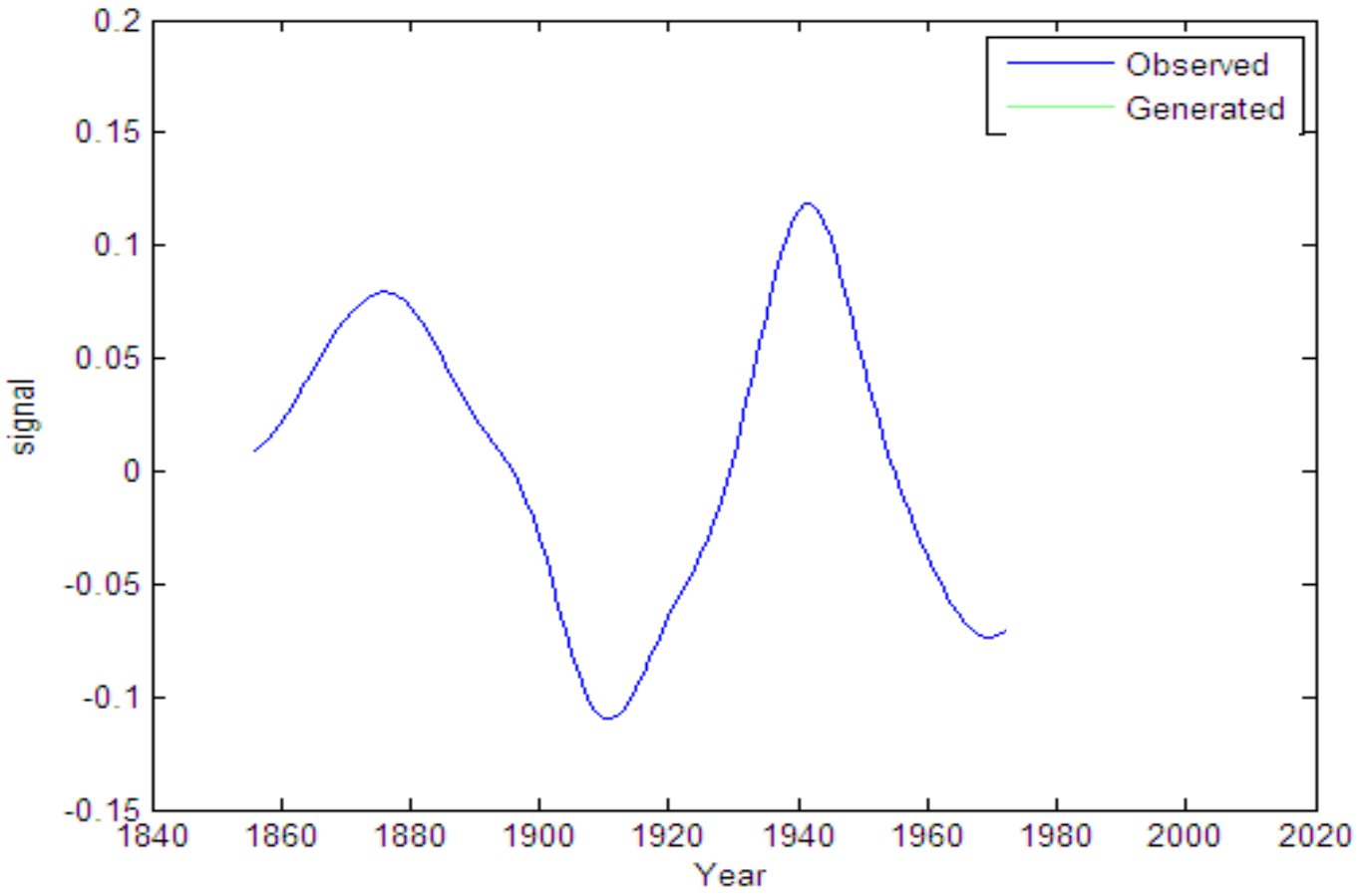
Opening


Mean annual temperature
5-year average
25-year average
1900
1950
2000
Year

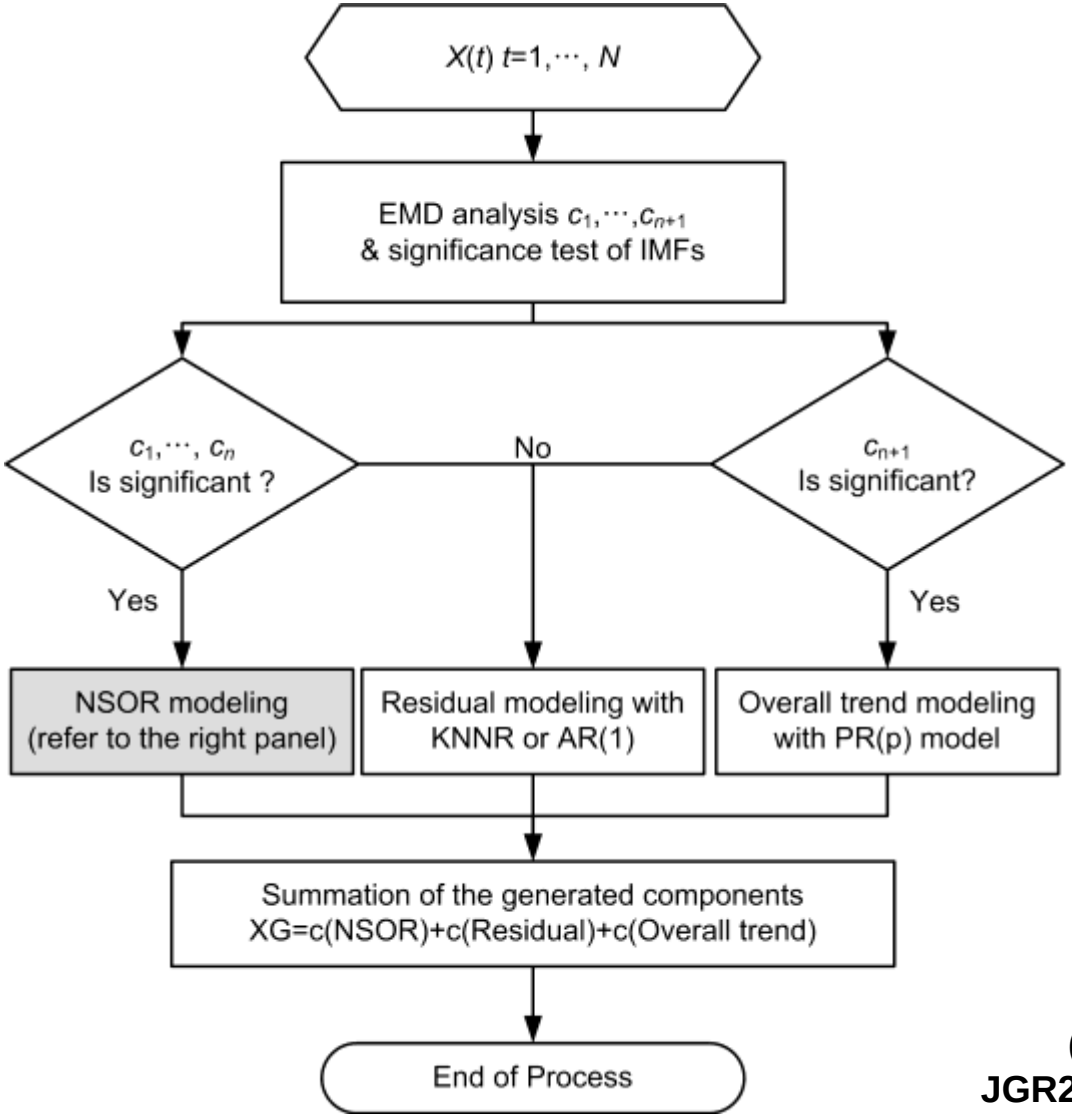
Nonstationary Oscillation Resampling (NSOR)



NSOR

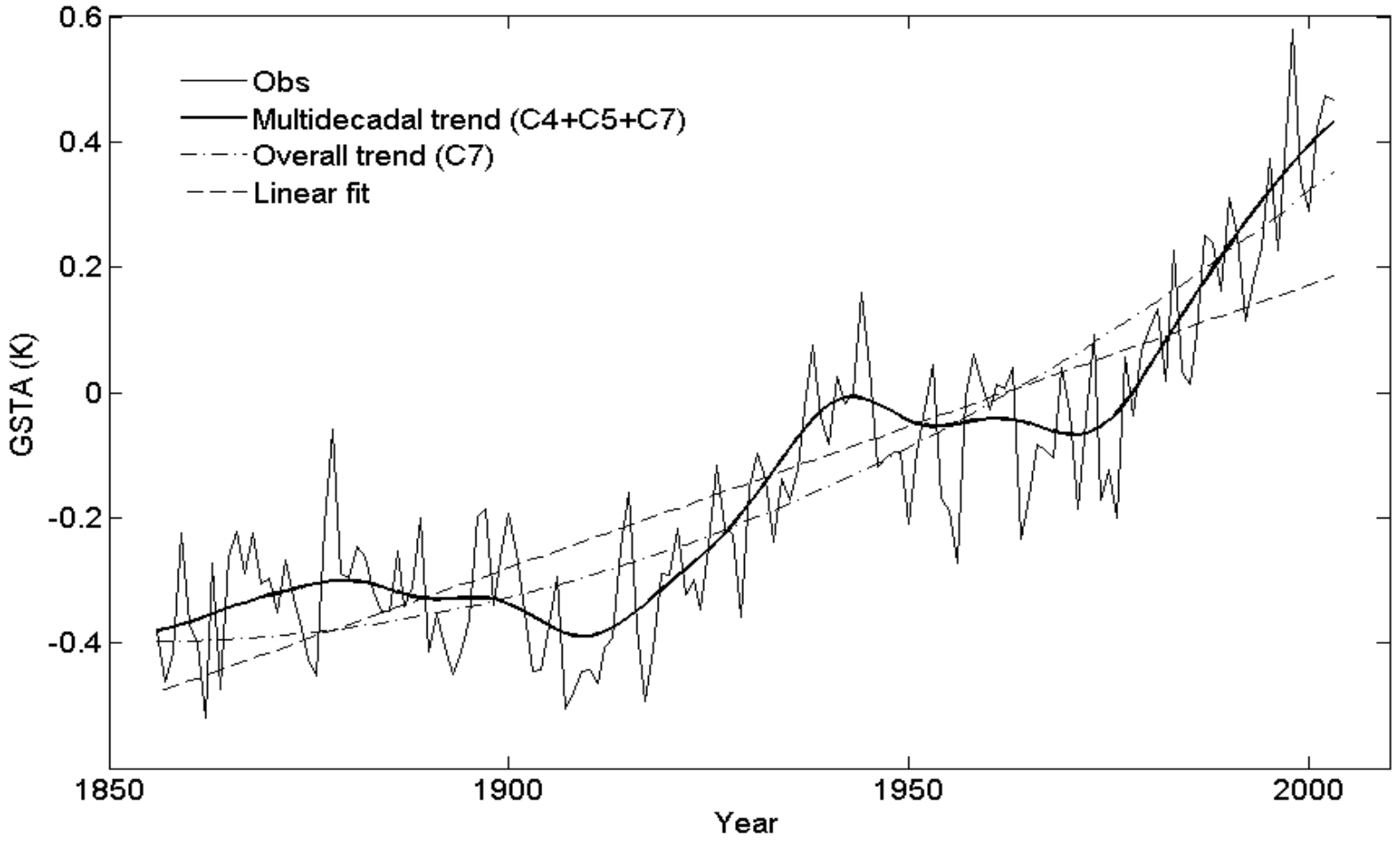

Observed
Generated
signal
Year
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020

Procedure for EMD-NSOR modeling

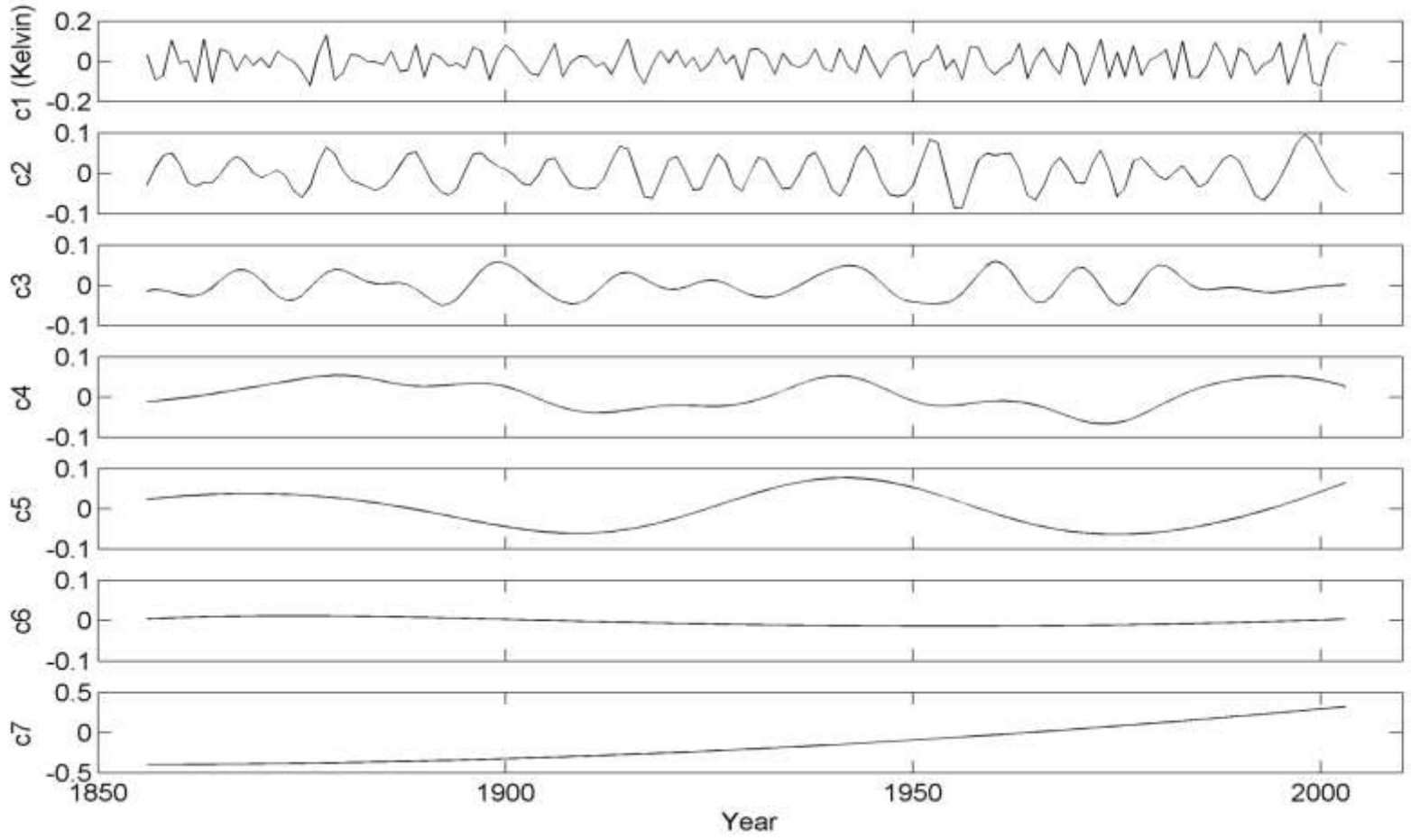


(Lee&Ouarda JGR2011a,b;WRR2012)

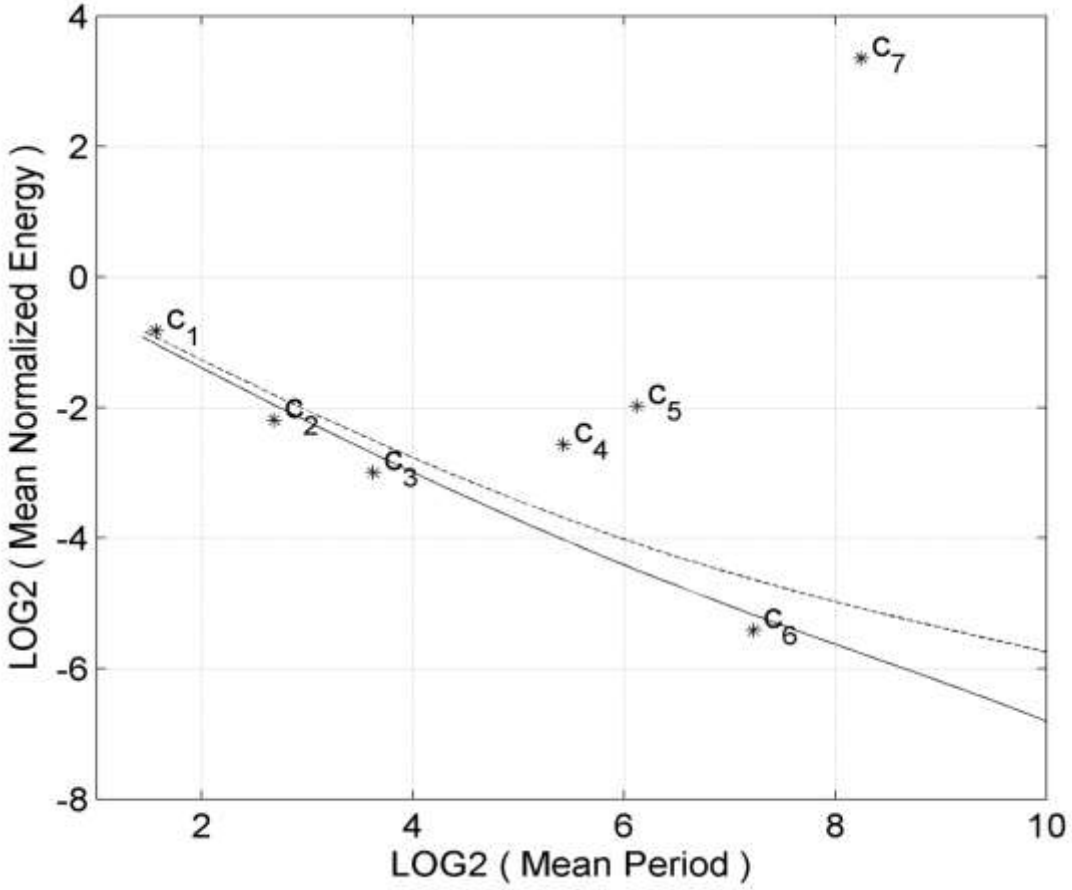
Global Surface Temperature Anomaly (GSTA)



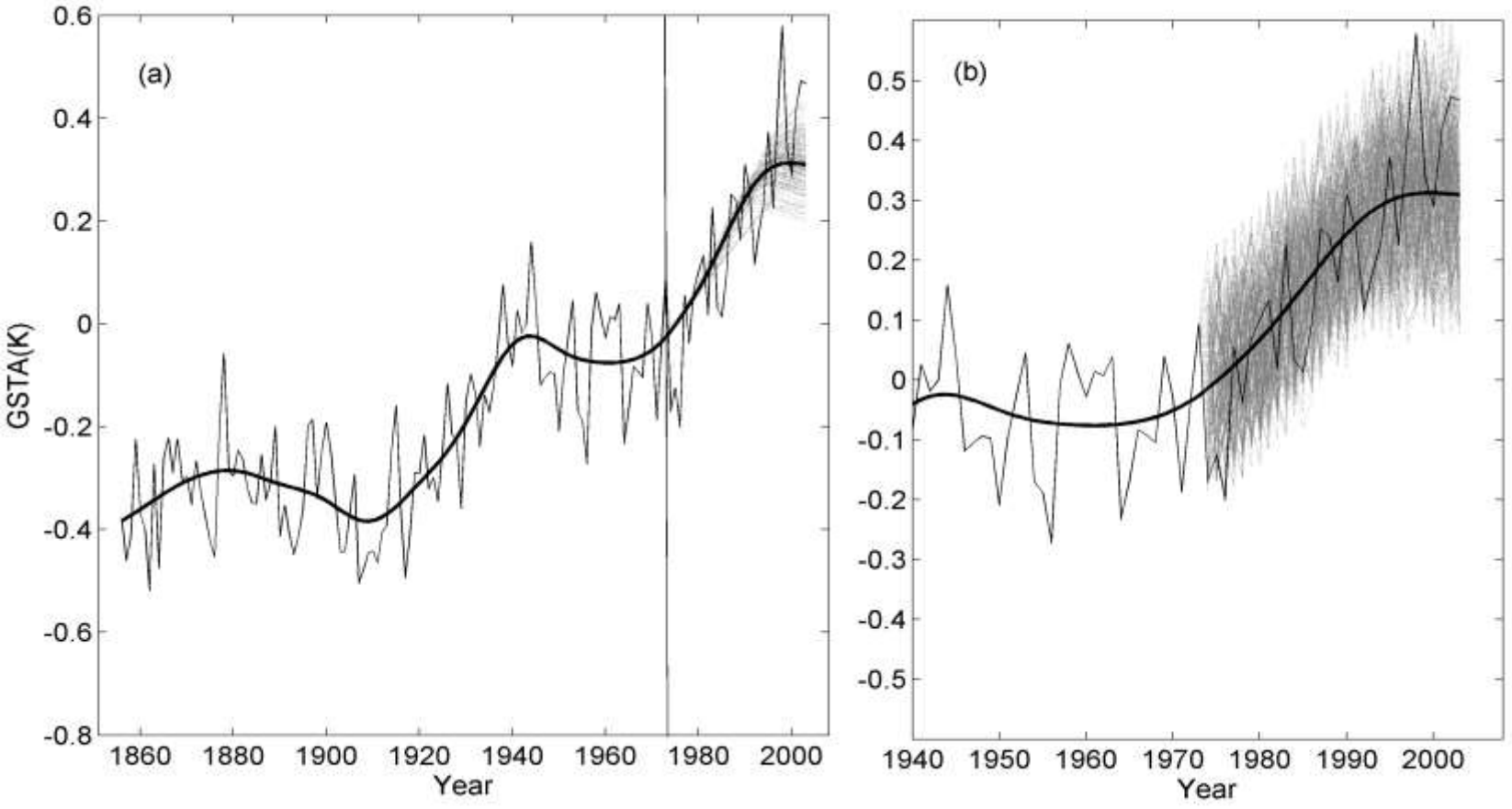
IMF components of GSTA



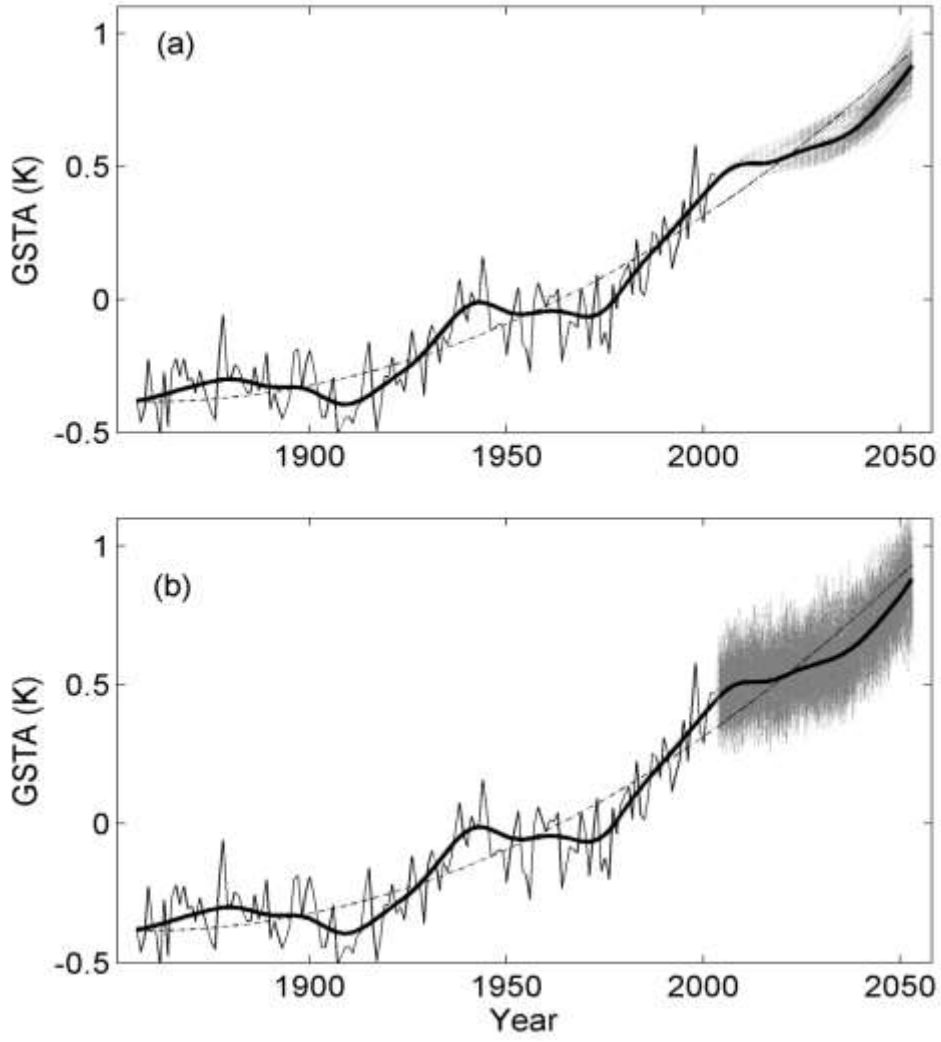
Significance Test



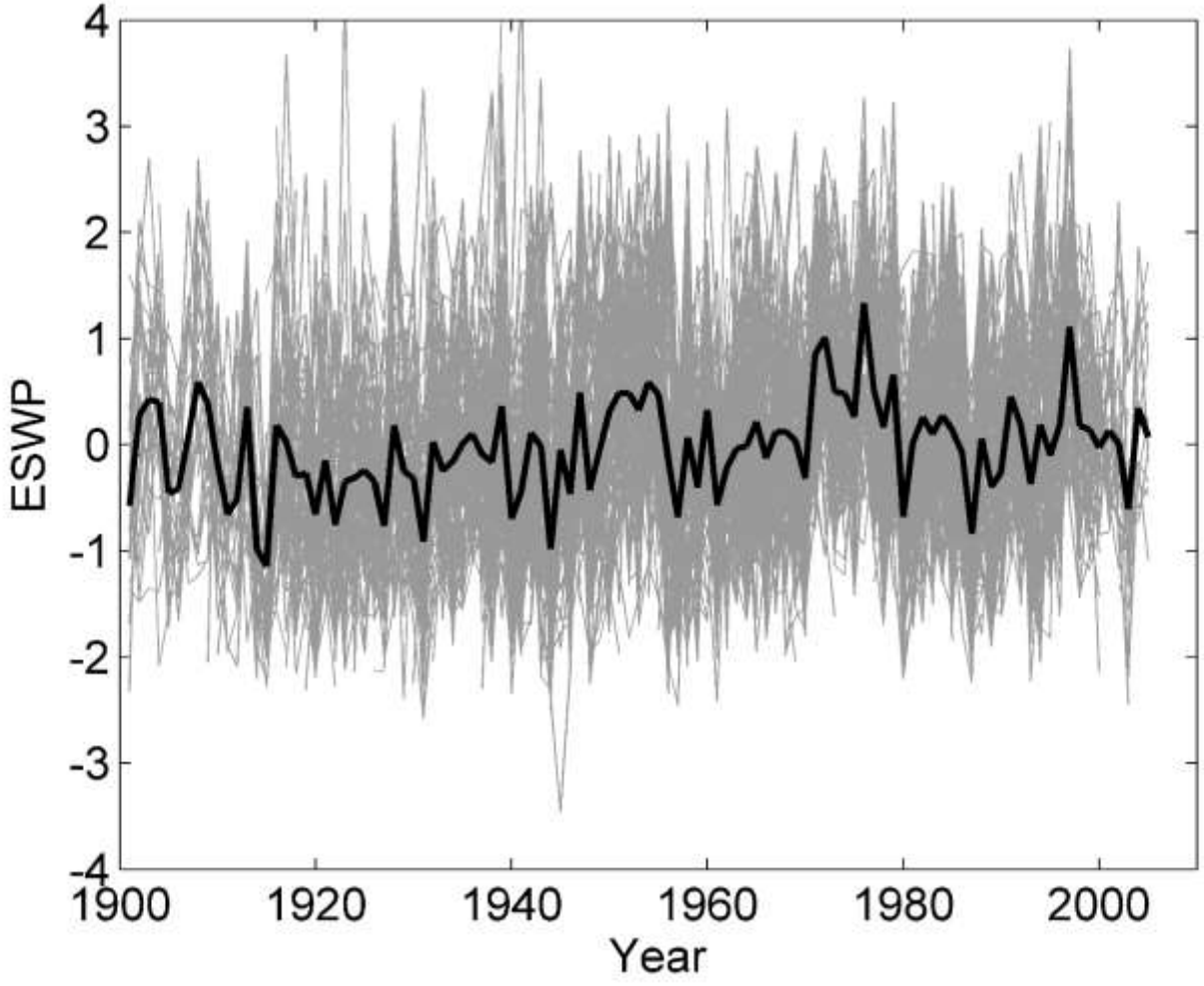
EMD-NSOR Projection



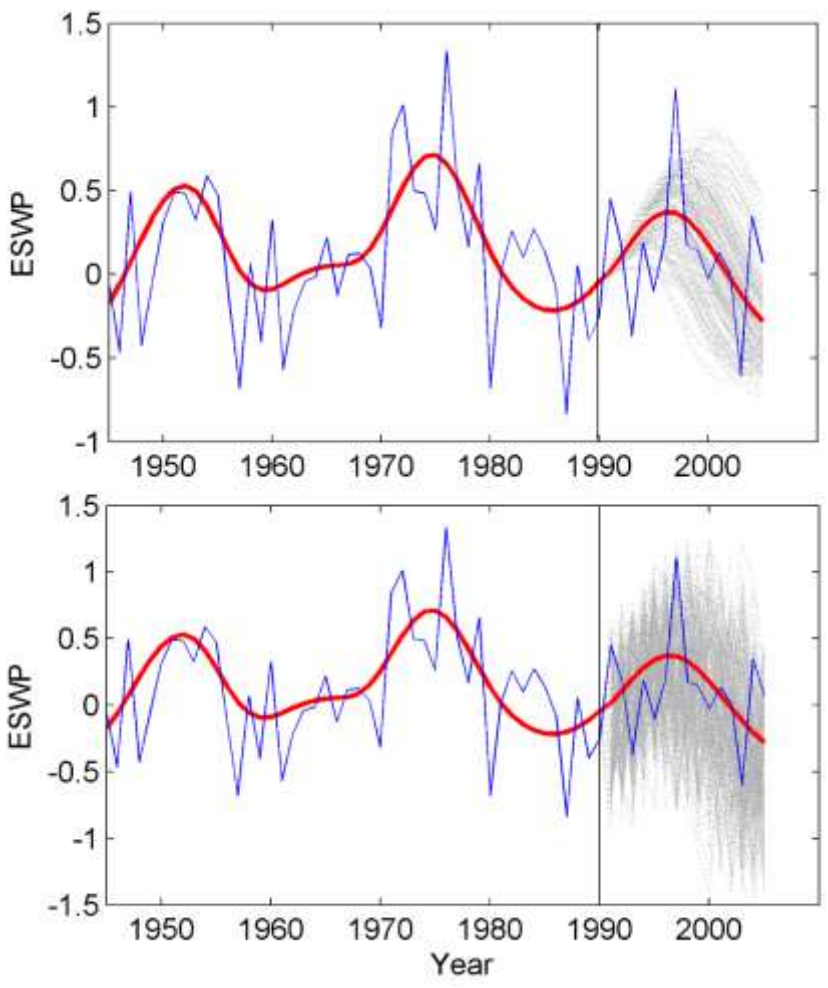
Future Projection of GSTA (Lee&Ouarda,JGR2012)

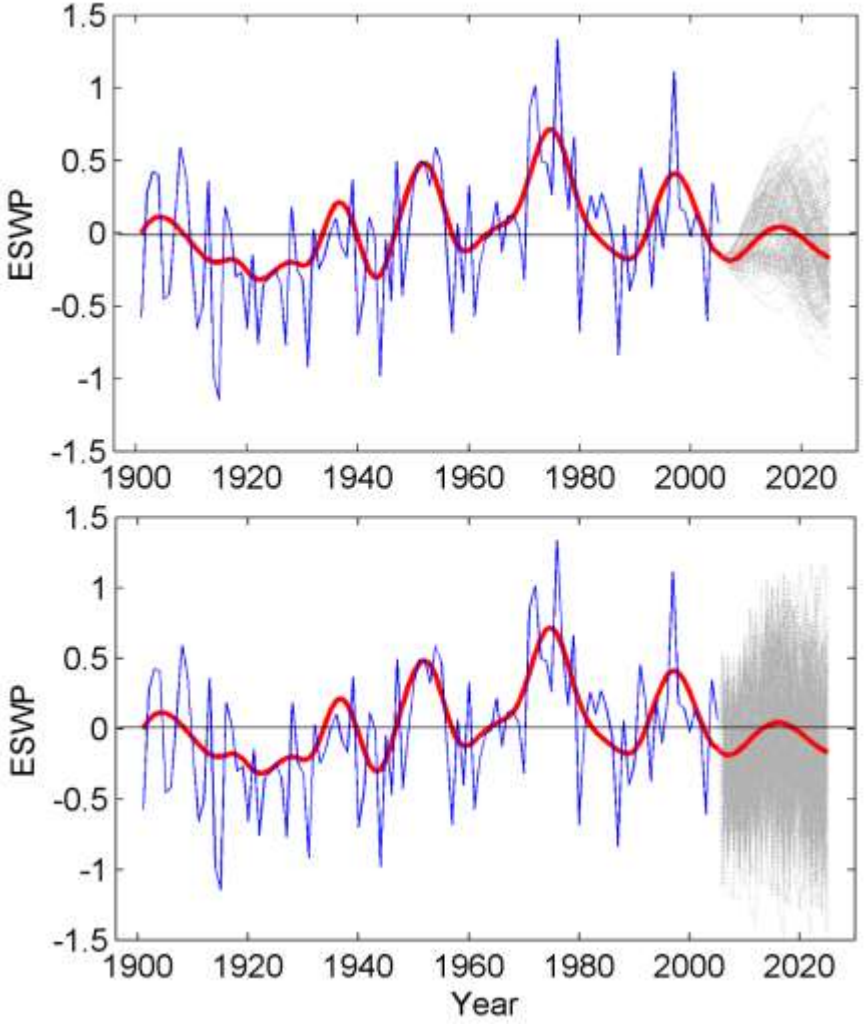


Eastern Canada Scaled Mean Winter Precipitation (ESWP)



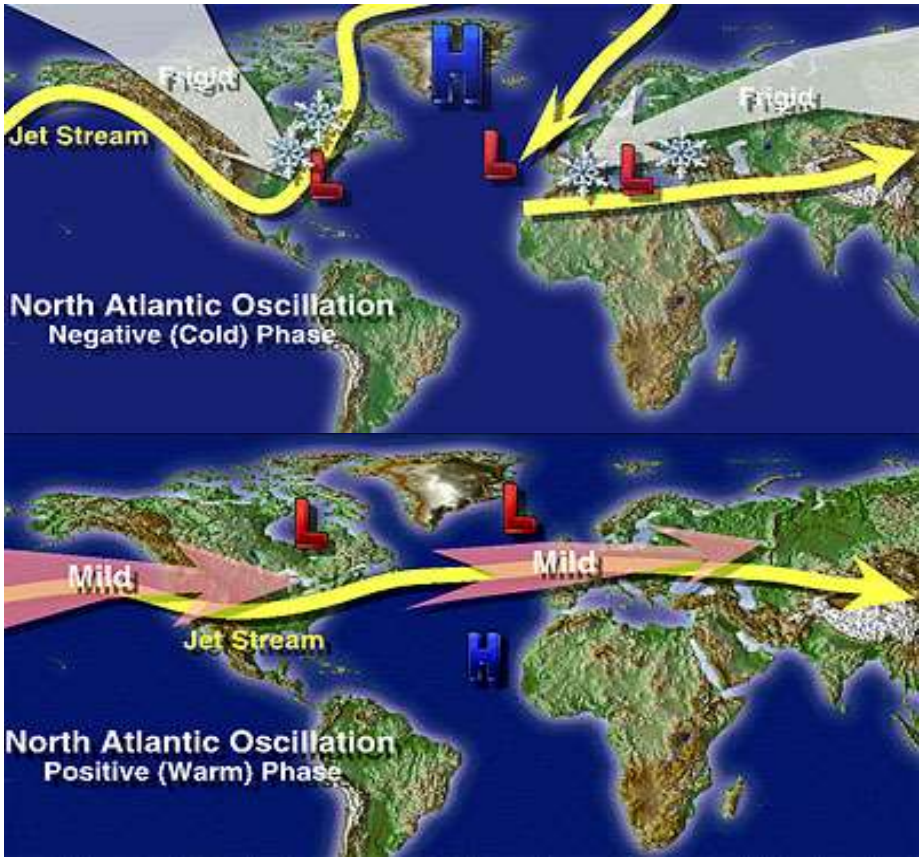
Extension of ESWP (Lee&Ouarda,JGR2011)



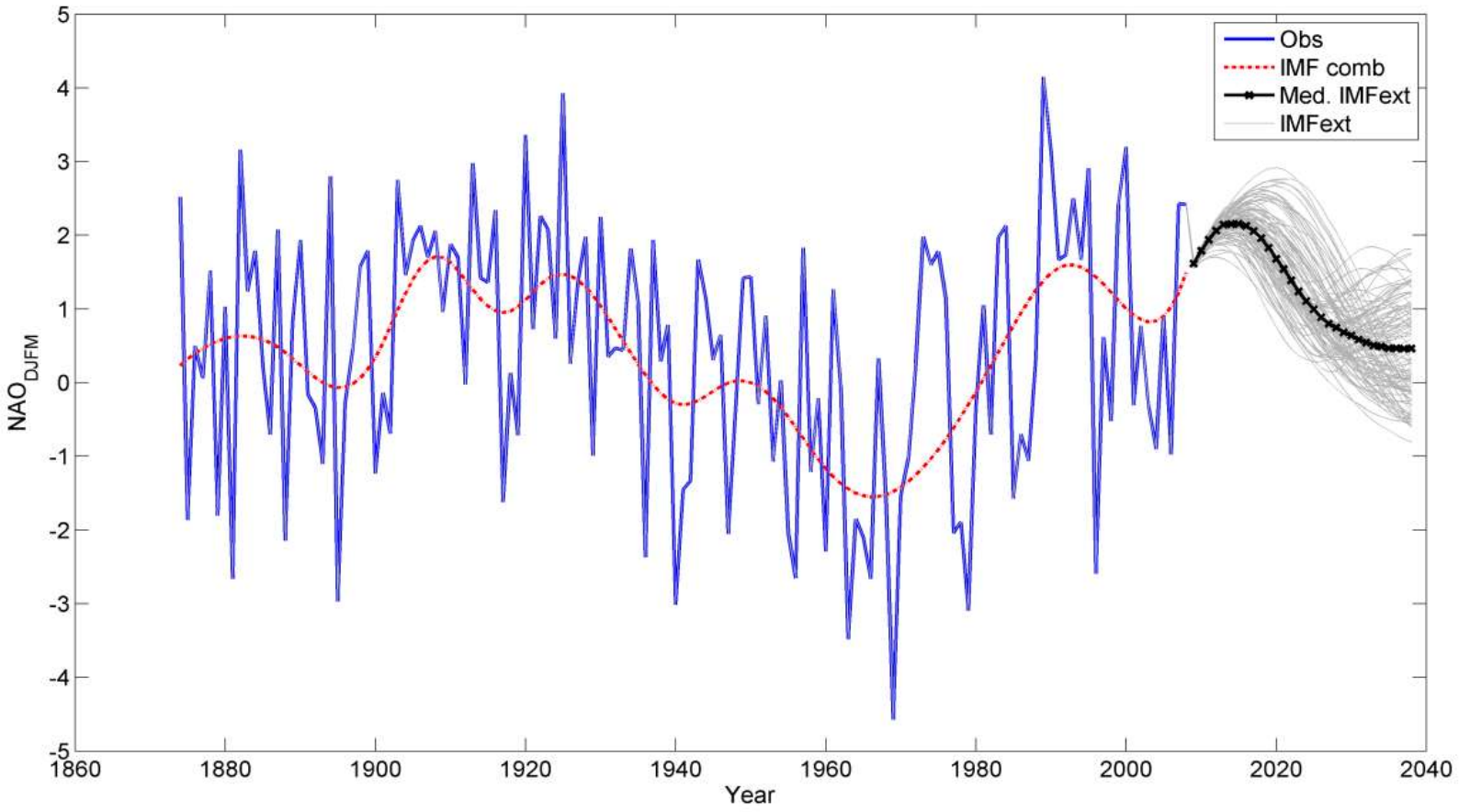


Future evolution of hydrologic extremes in Quebec

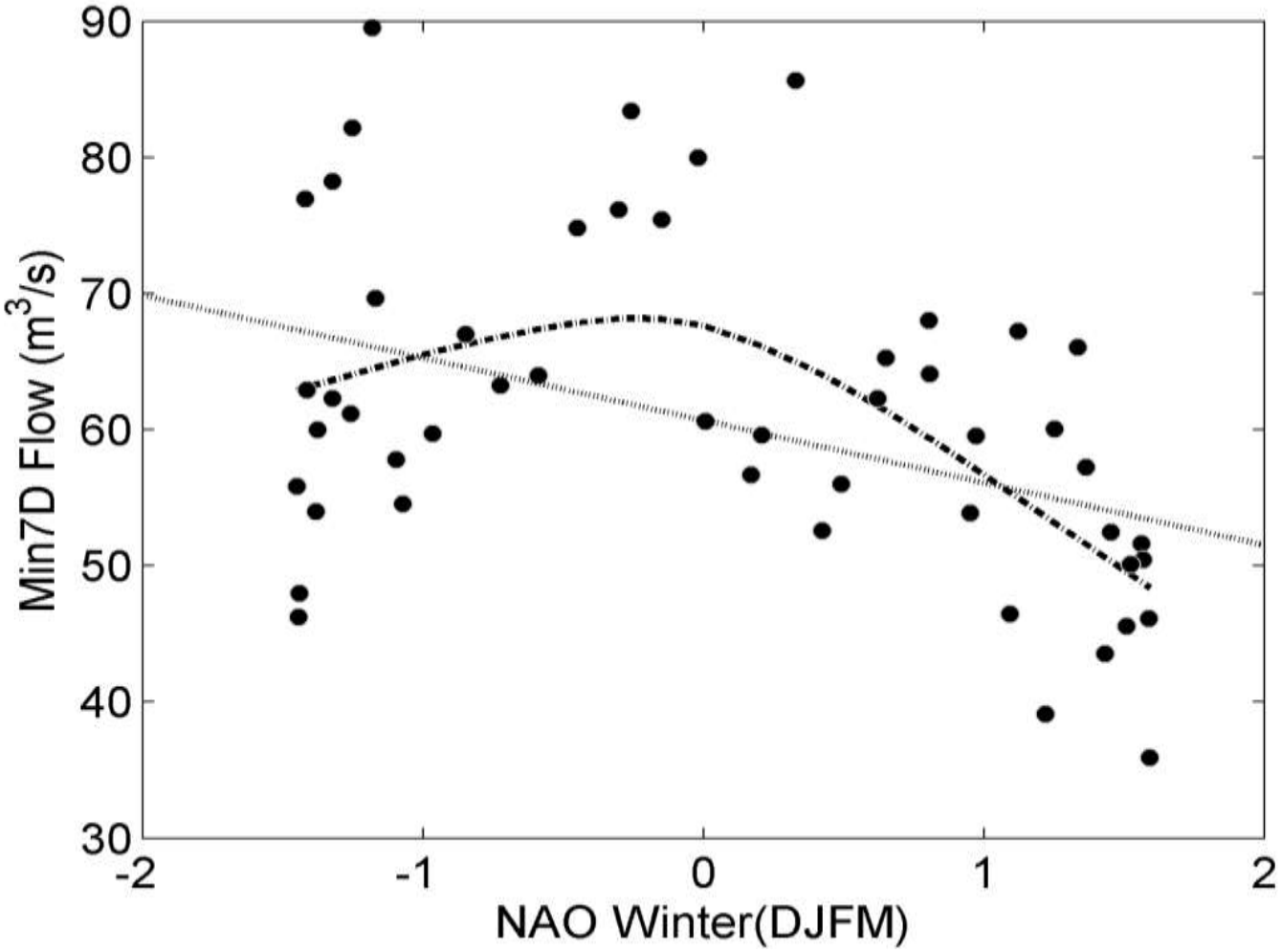
- NAO: large-scale oscillator between the Azores High and the Icelandic Low in the North Atlantic region
- Hydrology in Quebec



Future evolution of NAO through NSOR



Relation between NAO & Min7D Flow



KNN-based Local Linear Regression

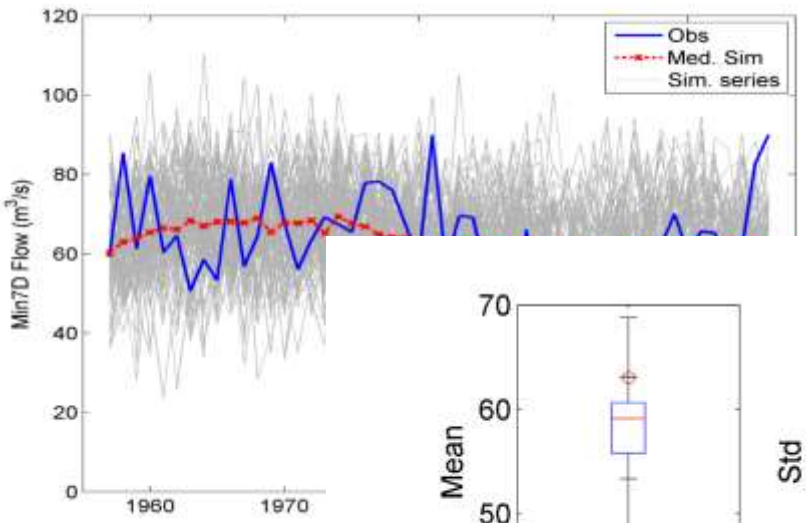
$$X_t = \vec{\mathbf{y}}_t^T \hat{\boldsymbol{\beta}}_t^{KLR} + \varepsilon_t$$

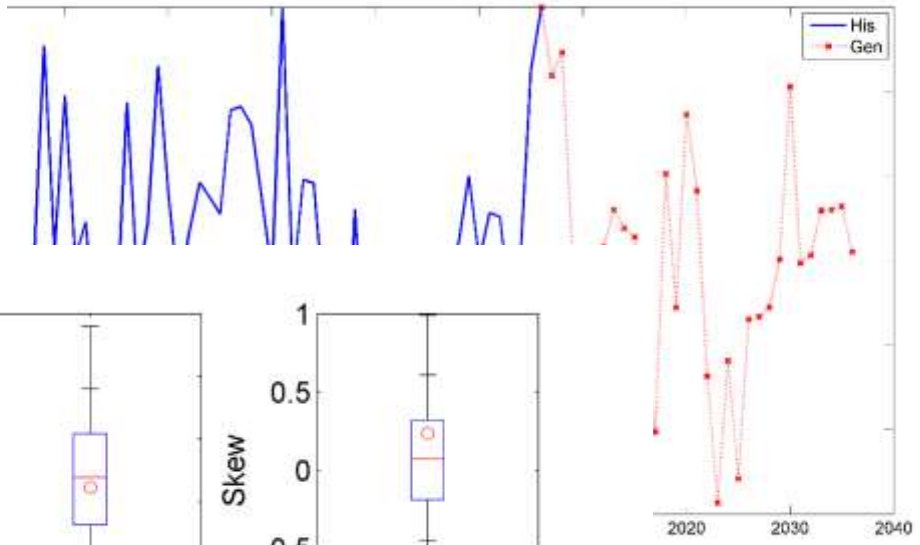
$$\hat{\boldsymbol{\beta}}_t^{KLR} = (\overleftrightarrow{\mathbf{Y}}_t^T \mathbf{W}_{KLR} \overleftrightarrow{\mathbf{Y}}_t)^{-1} \overleftrightarrow{\mathbf{Y}}_t^T \mathbf{W}_{KLR} \mathbf{x}_{KLR}$$

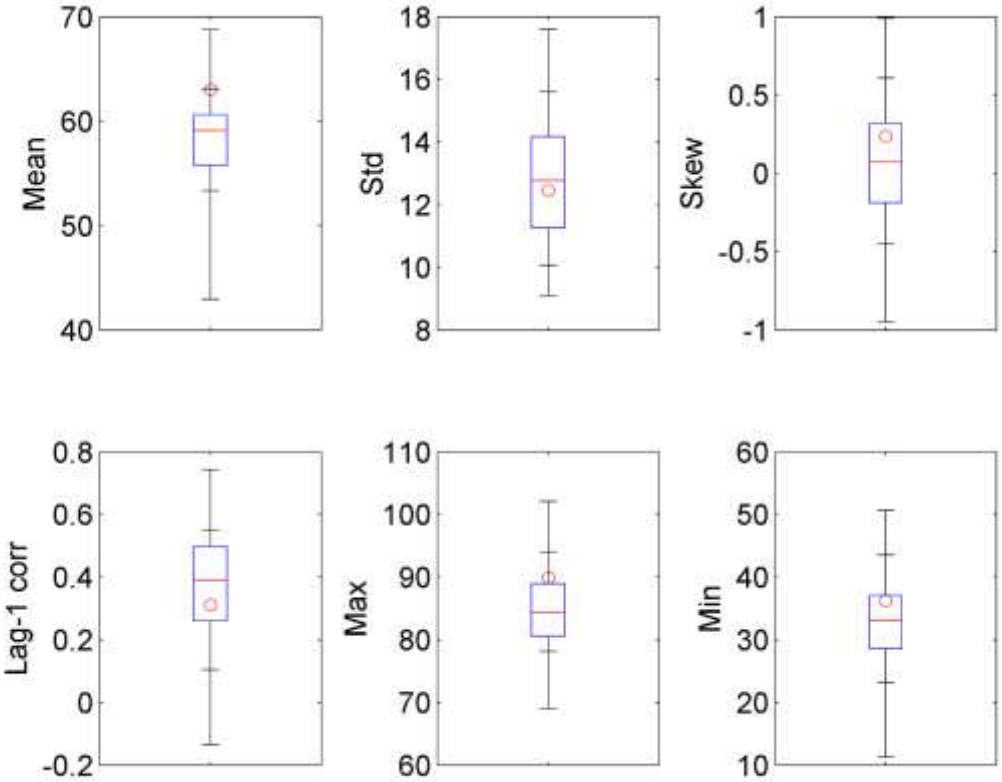
$$\overleftrightarrow{\mathbf{Y}}_t = \begin{pmatrix} 1 & y_t^1 - y_{(1)}^1 \cdots & y_t^S - y_{(1)}^S \\ 1 & y_t^1 - y_{(2)}^1 \cdots & y_t^S - y_{(2)}^S \\ 1 & \vdots \quad \cdots & \vdots \\ 1 & y_t^1 - y_{(k)}^1 \cdots & y_t^S - y_{(k)}^S \end{pmatrix}$$

$$\mathbf{W}_{KLR} = diag\left[\frac{1}{\delta}, \frac{1/2}{\delta}, ..., \frac{1/k}{\delta}\right]$$

KNN-based Local Linear Regression







Lee and Yoon,
WRR submitted

Future Direction

- Hourly spatial-temporal downscaling for flood impact assessment from climate change

- Long & mid-term forecasting of flood probability based on

  (a) Extending the evolution of long-term NSO processes for the climate variable

  (b) Forecasting the hydrometeorological extremes based on KNNR-based LLR model

감사합니다

謝 謝

Thank you