[2019년 2월 27일]

기상정보 활용 앙상블 유량 및 가뭄 예측

- 국내 기술 진단 및 향후 연구 방향 -

서울대학교 건설환경공학부
기후변화 적응 수자원연구실
교수 김영오

2019 APCC

서울대학교
SEOUL NATIONAL UNIVERSITY

잠시 77개월 전으로 시간 여행을 …

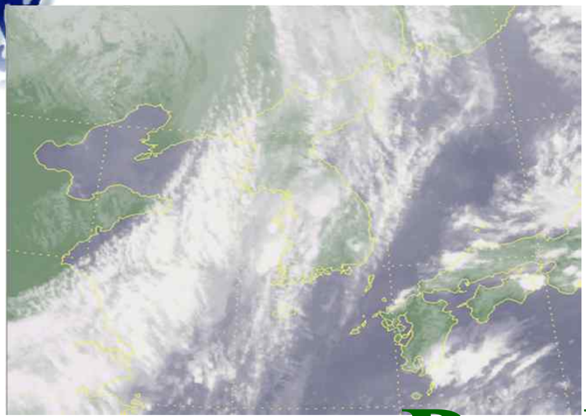
Use of Seasonal Climate Forecasts for Water Resources Management in Korea : Limitation and Future

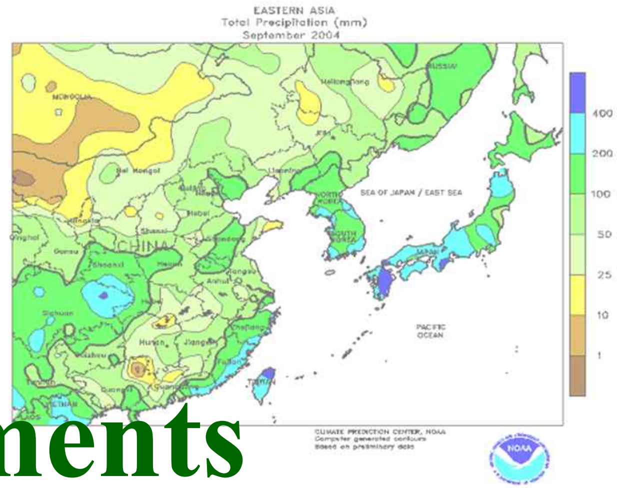
September 12th, 2012

Young-Oh Kim
Department of Civil & Environmental Eng.
Seoul National University
Korea

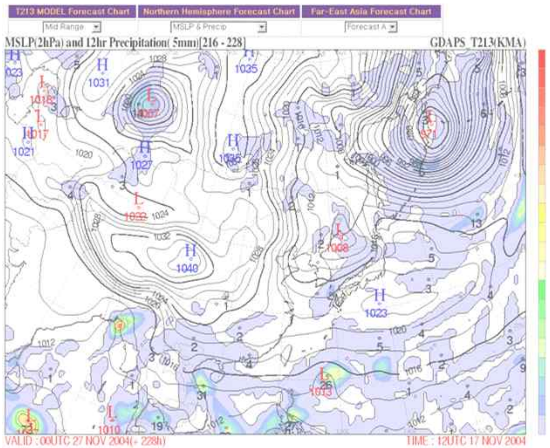
International Conference on Climate, Water and Policy 2012

서 울 대 학 교
SEOUL NATIONAL UNIVERSITY



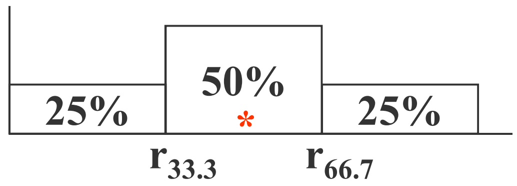


Problem Statements

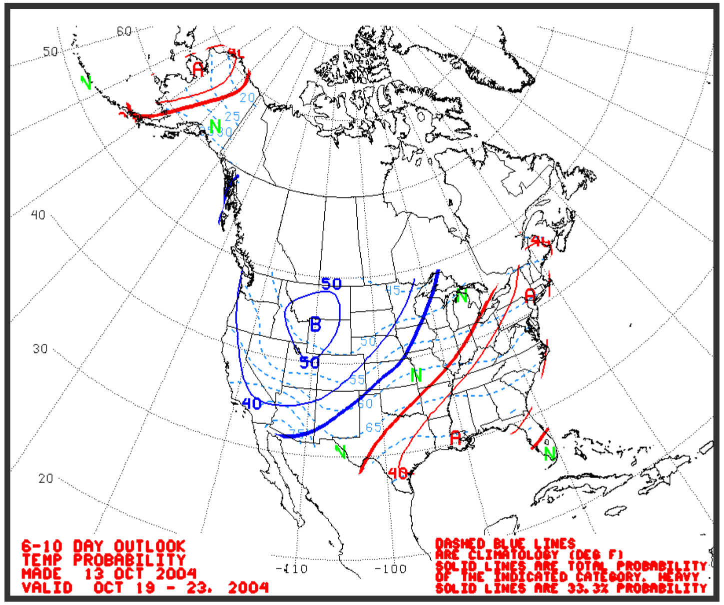


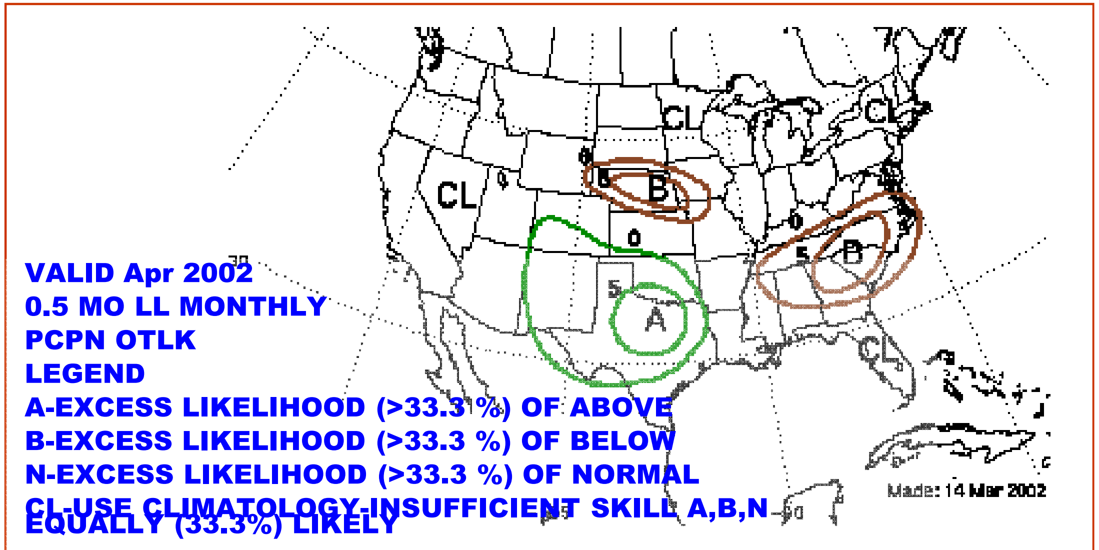
Climate Forecasts in US

- ❖ Categorical (below normal, normal, above normal)
- ❖ with **probabilities**



- ❖ Examples





NOAA 1-month probabilistic precipitation outlook for April 2002

Climate Forecasts in Korea

- Also categorical (below, near, above normal)
- with verbal expression ("Temperature this month would be near normal")
- Examples

1개월예보

1개월간의 기상 예보를 제공합니다

기압계전망 | 순별예보 | 참고자료 | 계절추이 | 내용다운받기

기간 : 2004년 11월 21일 ~ 2004년 12월 20일 (발표일 : 2004년 11월 18일)

요약

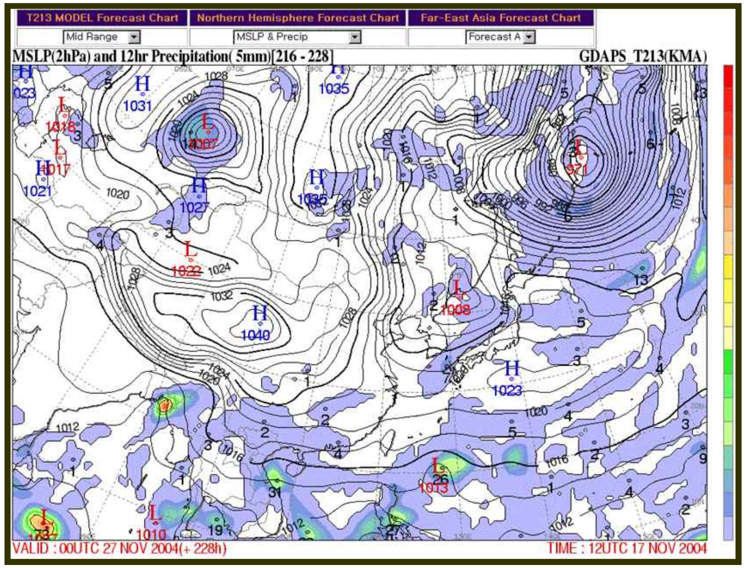
기 온	평년(-3~10℃)보다 높겠음. 평년보다 기온이 높은 날이 많겠으나, 11월 하순과 12월 상순에는 한두 차례 한기 남하로 추운 날이 있겠음.
강수량	평년(20~71㎜)과 비슷하겠음.

월 및 순별 기온 · 강수량의 예보 표현 기준표

구분	발생확률	기온편차(℃)		강수량 평년비(%)	
		순	월	순	월
높음(많음)	30%	> 0.7	> 0.5	> 130	> 120
비슷	40%	-0.7 ~ 0.7	-0.5 ~ 0.5	50 ~ 130	70 ~ 120
낮음(적음)	30%	< -0.7	< -0.5	< 50	< 70

MIMI
(Monthly Industrial Meteorology Information)

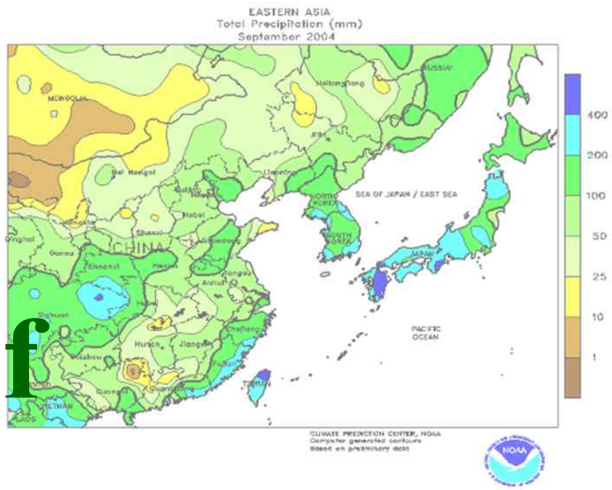
GDAPS
(Global Data Assimilation and Prediction System)



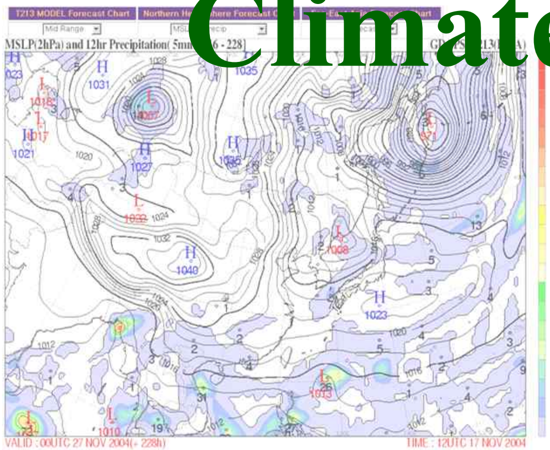
What We Need Are …

- **Meteorology**
  - ✓ To assess and improve the forecasting accuracy

- **Hydrology**
  - ✓ To come up with our own methodologies that can handle characteristics of the Korean climate forecasts
  - ✓ To assess the value of the climate forecasts for water resources management



Diagnosis of Climate Forecasts Accuracy



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Study 1: Accuracy of Climate Forecast

- **Citation**
  - ✓ **Lee et al. (2006). "Use of Climate Information for Improving Extended Streamflow Prediction in Korea." *Journal of KWRA*, 39(9)**

- **Objectives**
  - ✓ **Investigate climate forecast information available for the Korean Peninsula**
  - ✓ **Measure the accuracy of climate forecasts**

韓國水資源學會論文集
第39卷 第9號 · 2006年 9月
pp. 755~766

중장기 유량예측 향상을 위한 국내 기후정보의 이용

Use of Climate Information
for Improving Extended Streamflow Prediction in Korea

이 재 경* / 김 영 오** / 정 대 일***
Lee, Jae-Kyoung / Kim, Young-Oh / Jeong, Dae-Il

Abstract

Since the accuracy of climate forecast information has improved from better understanding of the climatic system, particularly, from the better understanding of ENSO and the improvement in meteorological models, the forecasted climate information is becoming the important clue for streamflow prediction. This study investigated the available climate forecast information to improve the extended streamflow prediction in Korea, such as MIMI(Monthly Industrial Meteorological Information) and GDAPS(Global Data Assimilation and Prediction) and measured their accuracies. Both MIMI and the 10-day forecast of GDAPS were superior to a naive forecasts and performed better for the flood season than for the dry season, thus it was proved that such climate forecasts would be

MIMI (Monthly Industrial Meteorology Information)

- Provider: Korea Meteorological Agency (KMA)
- Variable: temperature and precipitation
- Lead time: monthly and 10-day
- Format: categorical forecast with verbal expression
  - ✓ Below-normal: below 0.7 times 30-year average
  - ✓ Near-normal: 0.7~1.2 times 30-year average
  - ✓ Above-normal: above 1.2 times 30-year average
- Spatial resolution: 6 major cities in Korea

Accuracy: MIMI

- Test period: Jan, 1991 ~ Dec, 2002
- Measures: hit number and hit ratio by season

	Lead-time	Spring	Summer	Autumn	Winter	Average
Precipitation	1-month	0.273	0.306	0.250	0.287	0.279
	10-day	0.319	0.347	0.292	0.236	0.299
Temperature	1-month	0.389	0.419	0.338	0.328	0.369
	10-day	0.378	0.379	0.455	0.500	0.428

✓ Monthly and 10-day precipitation forecasts:

inferior to the naïve forecast

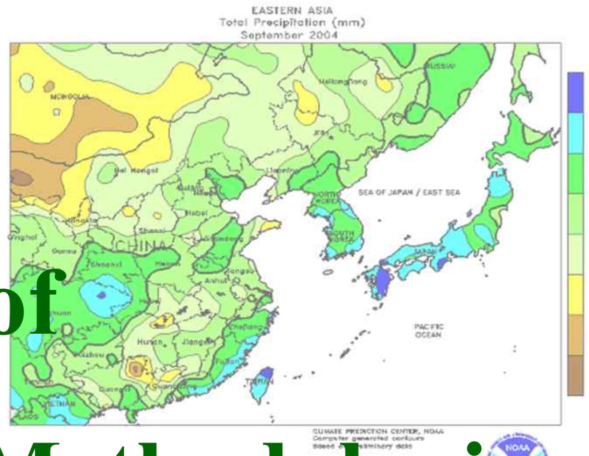
✓ Monthly and 10-day temperature forecasts:

superior to the naïve forecast

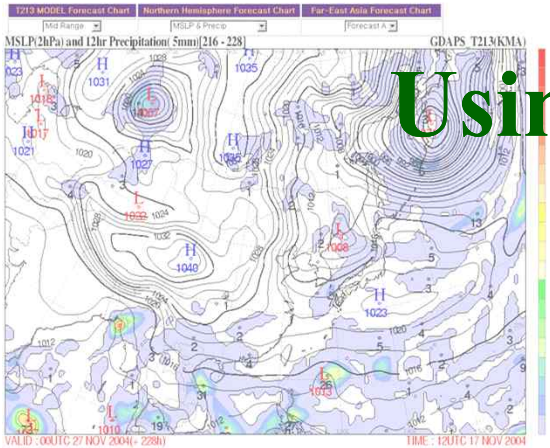
Conclusion

MIMI is the climate forecast information that can be currently utilized for the hydrological forecasting in Korea

- ✓ **Temperature forecast is superior to the naïve forecast**
- ✓ **Precipitation forecast is inferior to the naïve forecast, BUT superior to the naïve forecast in the flood season**



Development of Hydrological Forecasting Methodologies Using Climate Forecasts



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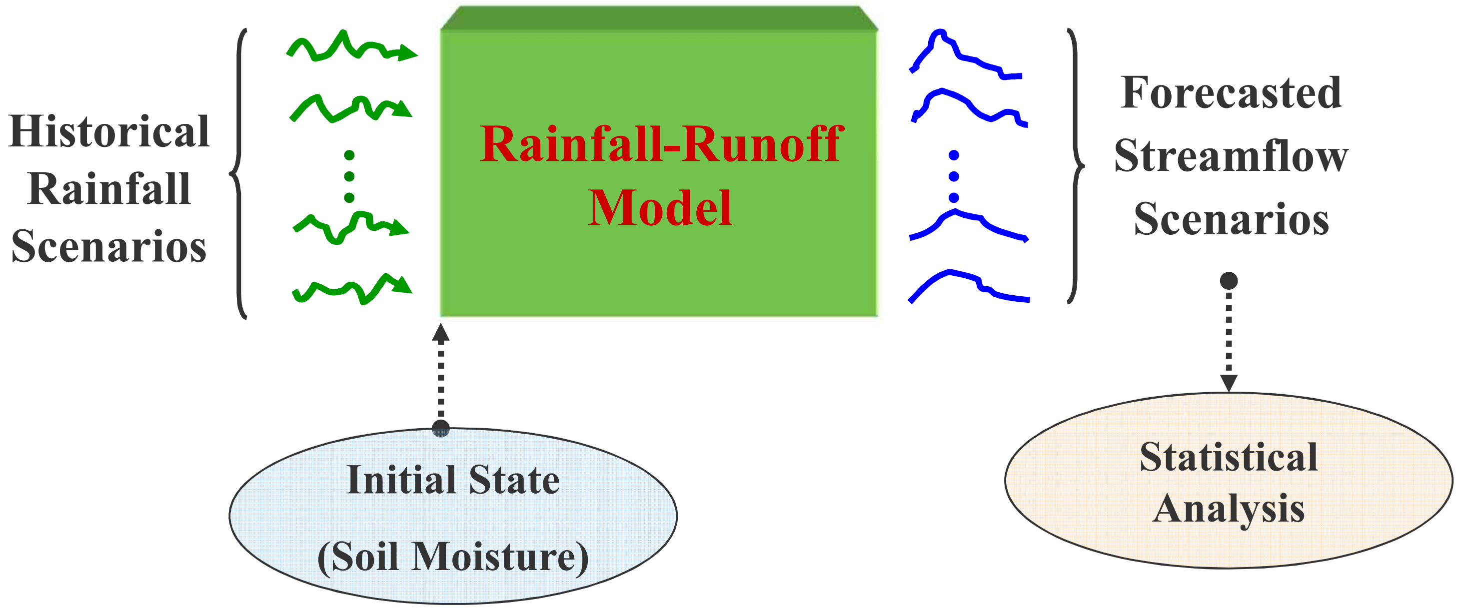
ESP: Basic Concept

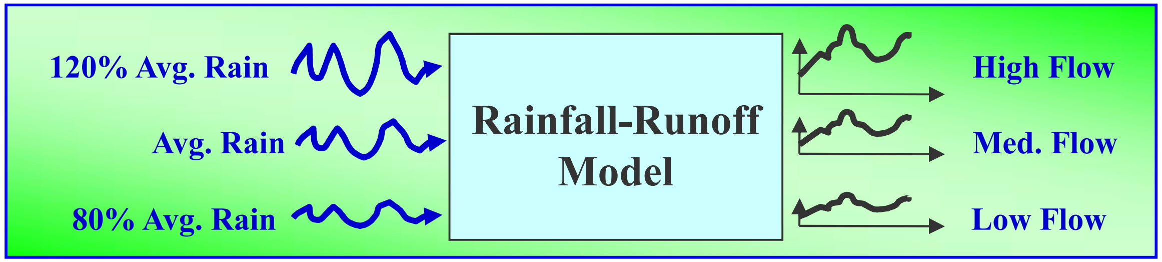
- ESP: **E**nsemble **S**treamflow **P**rediction



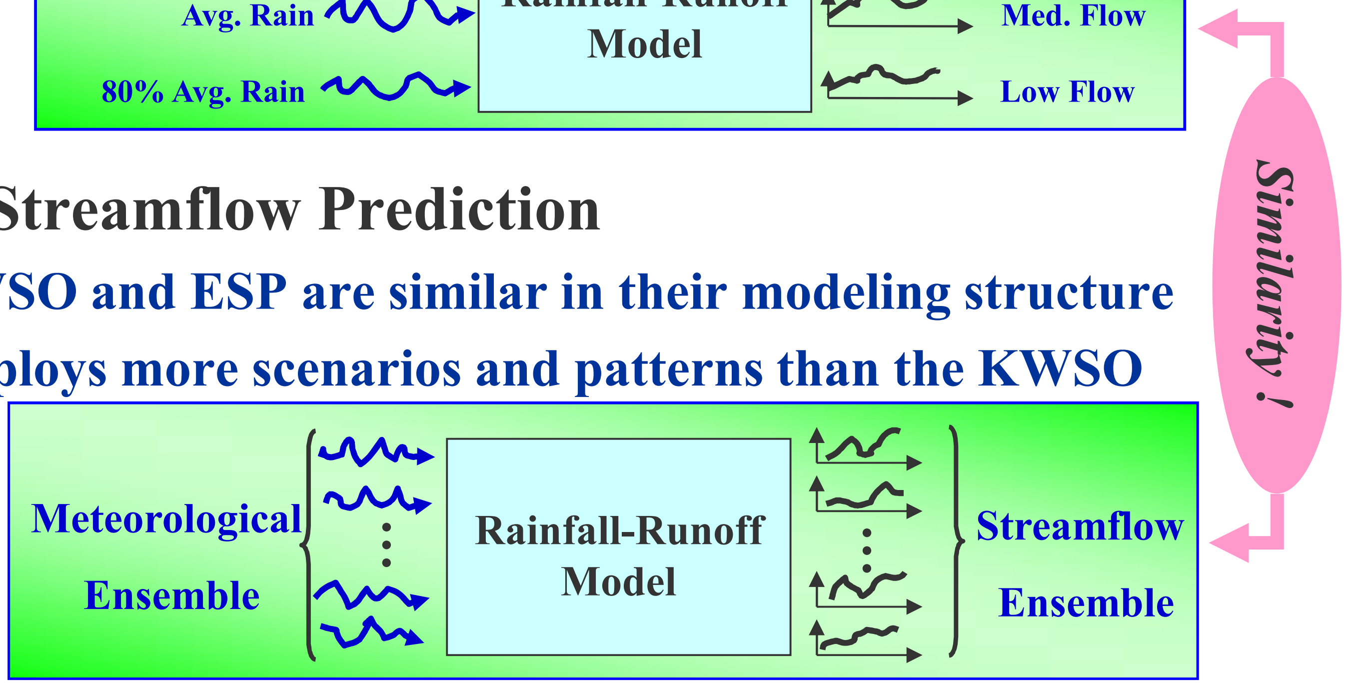
- **Deterministic** + **Probabilistic** approach
- Conditional Monte Carlo simulation approach

The first ESP Application in Korea

- Korea Water Supply Outlook (KWSO)
  - ✓ Using only three rainfall scenarios
  - ✓ Patterns of the three rainfall scenarios are same



- Ensemble Streamflow Prediction
  - ✓ The KWSO and ESP are similar in their modeling structure
  - ✓ ESP employs more scenarios and patterns than the KWSO



Study 2: EPS using MIMI

- **Citation**
  - ✓ Lee et al. (2006). "Use of Climate Information for Improving Extended Streamflow Prediction in Korea." *Journal of KWRA*, 39(9)

- **Objective**
  - ✓ Propose a methodology that can incorporate Korean climate forecast information into ESP

韓國水資源學會論文集
第39卷 第9號 · 2006年 9月
pp. 755~766

중장기 유량예측 향상을 위한 국내 기후정보의 이용

Use of Climate Information
for Improving Extended Streamflow Prediction in Korea

이 재 경[*] / 김 영 오[**] / 정 대 일[***]
Lee, Jae-Kyoung / Kim, Young-Oh / Jeong, Dae-Il

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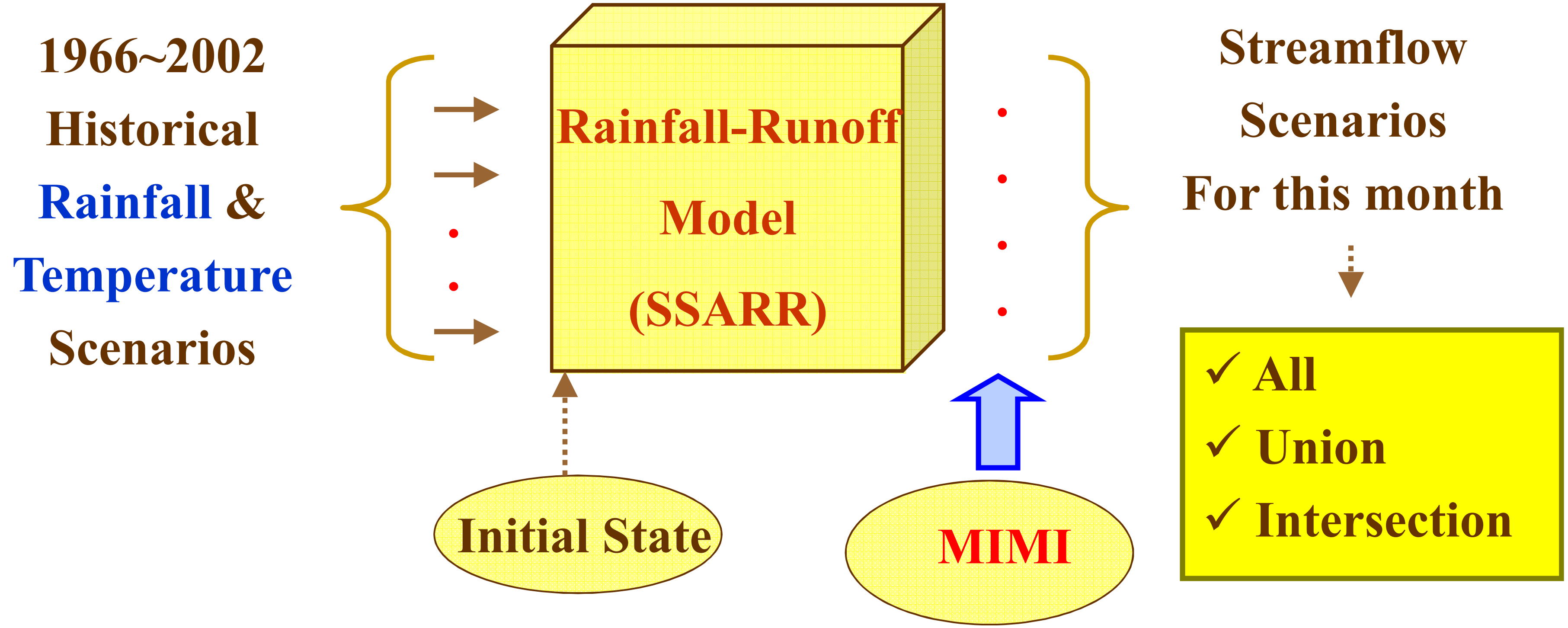
Since the accuracy of climate forecast information has improved from better understanding of the climatic system, particularly, from the better understanding of ENSO and the improvement in meteorological models, the forecasted climate information is becoming the important clue for streamflow prediction. This study investigated the available climate forecast information to improve the extended streamflow prediction in Korea, such as MIMI(Monthly Industrial Meteorological Information) and GDAPS(Global Data Assimilation and Prediction) and measured their accuracies. Both MIMI and the 10-day forecast of GDAPS were superior to a naive forecasts and performed better for the flood season than for the dry season, thus it was proved that such climate forecasts would be

ESP using MIMI

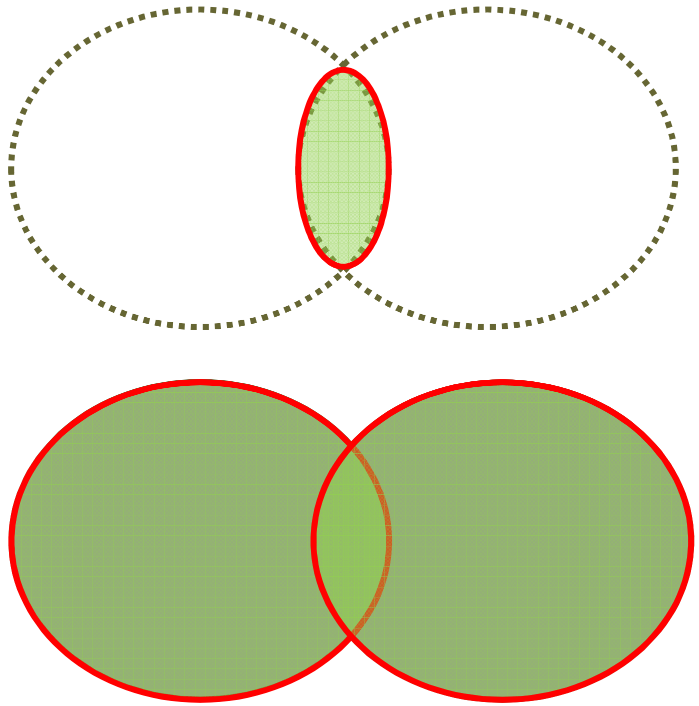
✓ Basic Application



Selection of Scenarios

- ✓ **All:** All the historical scenarios
- ✓ **Intersection:**

Rainfall scenarios matching MIMI



Temperature scenarios matching MIIMI

- ✓ **Union:**

Conclusion

When these methods were applied to Chungju Dam,

- ✓ The accuracies with all three methods are better than the naïve forecast,
- ✓ The Intersection and Union scenarios are superior to the All scenarios for the flood season,
- ✓ The Intersection and Union scenarios are superior to the All scenarios if the forecast accuracy is improved

Study 3: Scenario Weighting with Pdf-ratio

- **Citation**
  - ✓ **Stedinger and Kim (2010). "Probabilities for ensemble forecasts reflecting climate information."** ***Journal of Hydrology*****, 391(1-2)**

- **Objective**
  - ✓ **Update probabilities associated with meteorological and hydrologic series using forecast information**

Journal of Hydrology 391 (2010) 9–23

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

ELSEVIER

Probabilities for ensemble forecasts reflecting climate information

Jery R. Stedinger [a], Young-Oh Kim [b,*]

[a] School of Civil and Environmental Engineering, Cornell University, Ithaca, NY, USA
[b] Department of Civil and Environmental Engineering, Seoul National University, Seoul, Republic of Korea

ARTICLE INFO

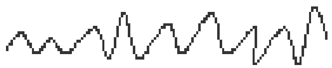
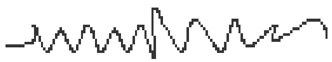
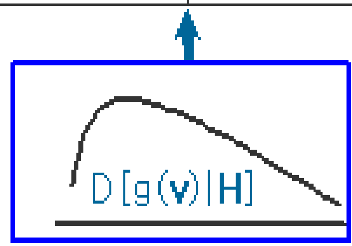
Article history:
Received 12 August 2009
Received in revised form 16 June 2010
Accepted 27 June 2010

This manuscript was handled by A. Bardossy, Editor-in-Chief, with the assistance of Alin Andrei Carsteanu, Associate Editor

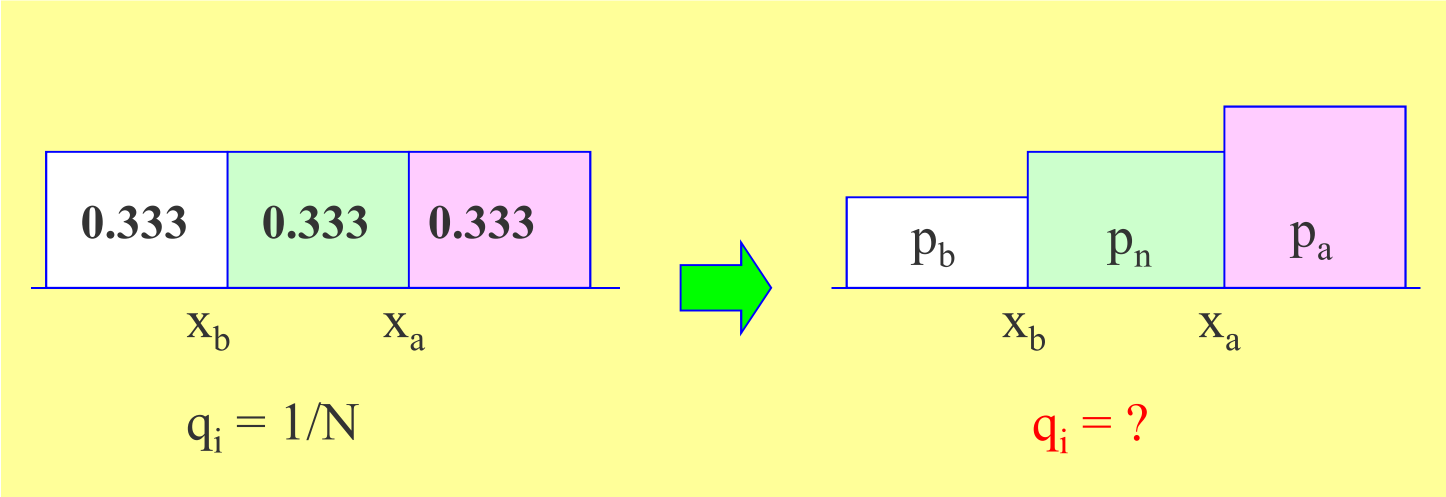
SUMMARY

A simple but general probability adjustment procedure is proposed for creating climate-series/probability sets that reflect historical frequencies adjusted for climate forecast information. Often forecast information is given as the conditional probability of below-normal, normal, and above-normal temperature or rainfall depths, though forecast information also can be described by the conditional mean and standard deviation of key variables such as seasonal runoff. Probability adjustment methods developed by Croley and by Wilks assign the same probability to all climate series in selected categories. This results in a discontinuity at the interval boundaries, and can seriously misrepresent the mean and variance of the conditional distribution of key variables. The proposed adjustment is based on a frequency model of the

Scenario Weighting Methods

	$\{v_i\}$	$x_i = g(v_i)$	Equal Probability	Updated Probability
v_1		x_1	1/N	q_1 = ?
v_2		x_2	1/N	q_2 = ?
⋮	⋮	⋮	⋮	⋮
v_N		x_N	1/N	q_N = ?
ex.	historical daily flow	monthly average flow		

Scenario Weighting Methods



- **x_b and x_a: the below-normal and above-normal terciles, respectively,**
- **p_b, p_n, and p_a: the probabilities of the below-normal, normal, and above-normal ranges, respectively**

Croley-Wilks Method: Theory

- Proposed independently by Croley (1996, 1997, 2000, 2001) and Wilks (2001)

- The two approaches are identical for the univariate problem

Let S_b, S_n, S_a = set of indices for which $x_i < x_b$, $x_b < x_i < x_a$, $x_a < x_i$

N_b, N_n, N_a = number of elements in S_b, S_n, S_a

where $N = N_b + N_n + N_a$

Then for points x_i in S_b, S_n, S_a, the probability for x_i is changed to

$$q_i = p_b/N_b,\ \ p_n/N_n,\ \ p_a/N_a$$

Croley-Wilks Method: Limitation

- The block adjustment:
  - ✓ The same constant adjustment to all the points $x_i < x_b$
  - ✓ A completely different adjustment to all points for which $x_b < x_i < x_a$, and $x_b < x_i$
- No physical importance associated with the values of x_b and x_a
- A discontinuity in the probabilities assigned to points on either side of x_b and of x_a

The expectation of G(X):

$$E\{G(X)\} = \int G(X) f_0(X) dX$$

The new interest:

where f_1(X) is the pdf for X corresponding to f(x|H)

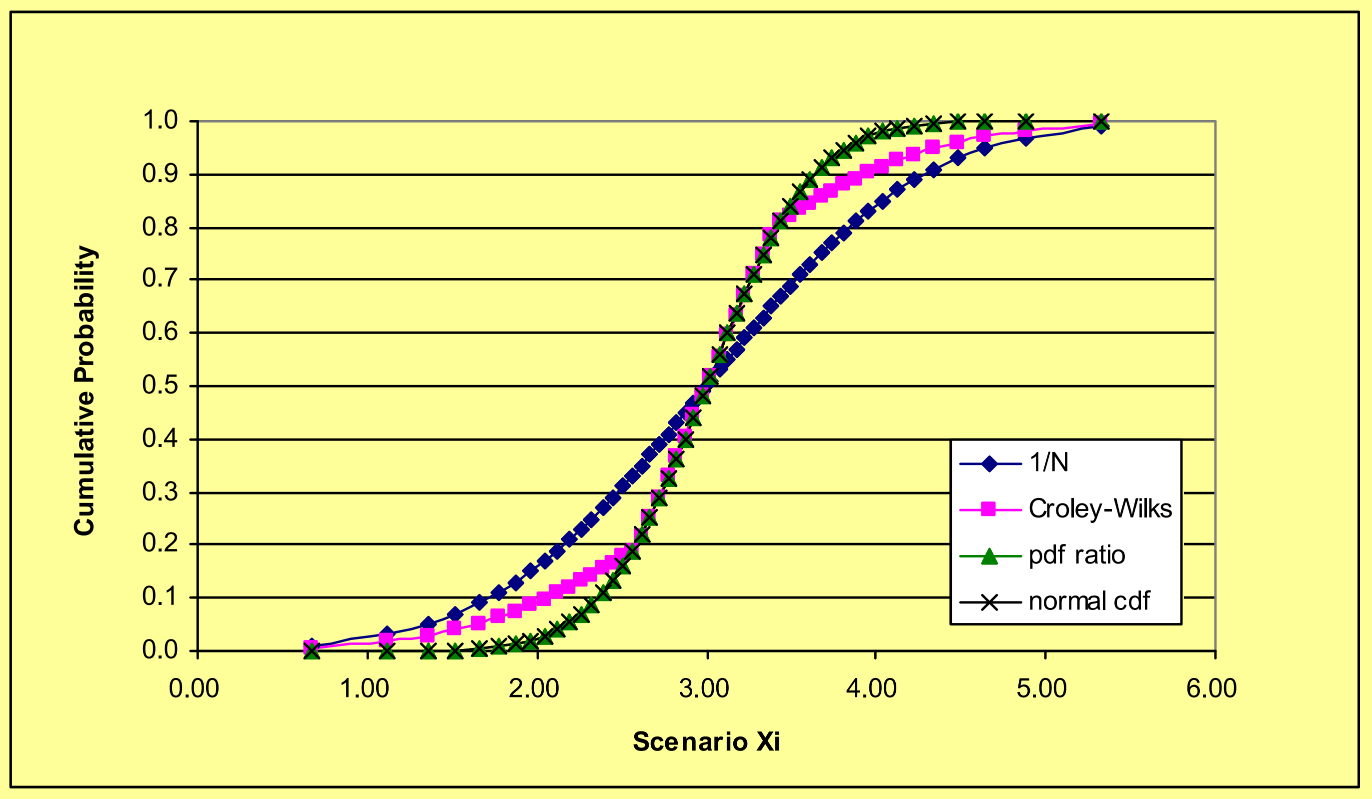
The needed revisions of the original probabilities {1/N}:

The revised probabilities for each x_i corresponding to v_i:

- Computational Concern: normalization Pdf-Ratio

Estimated vs. True CDF

❖ Case: $\{\mu_0 = 3, \sigma_0 = 1\} \rightarrow \{\mu_1 = 3, \sigma_1 = 0.5\}$



Advantages of the Pdf-Ratio Method

- very simple and flexible
- makes use of the entire D[g(v)|H] distribution
- generally provides an adequate description of the target conditional distribution if the initial sample is large enough
- can be used with different families of distributions describing the initial and target distributions for climate variables
- can deal with the multivariate forecast case without any difficulty

Study 4: ESP using Pre- & Post-processor

- **Citation**
  - ✓ **Kang et al. (2010). "Comparison of pre- and post-processors for ensemble streamflow prediction."** ***Atmospheric Science Letters*****, 11(2).**
- **Objectives**
  - ✓ **Test the applicability of the KMA forecasts to reduce the ESP uncertainty**
  - ✓ **Compare various pre- & post- processors for the Korean ESP**

ATMOSPHERIC SCIENCE LETTERS
Atmos. Sci. Let. **11**: 153–159 (2010)
Published online 1 June 2010 in Wiley InterScience
(www.interscience.wiley.com) **DOI:** 10.1002/asl.276

RMetS
Royal Meteorological Society

Comparison of pre- and post-processors for ensemble streamflow prediction

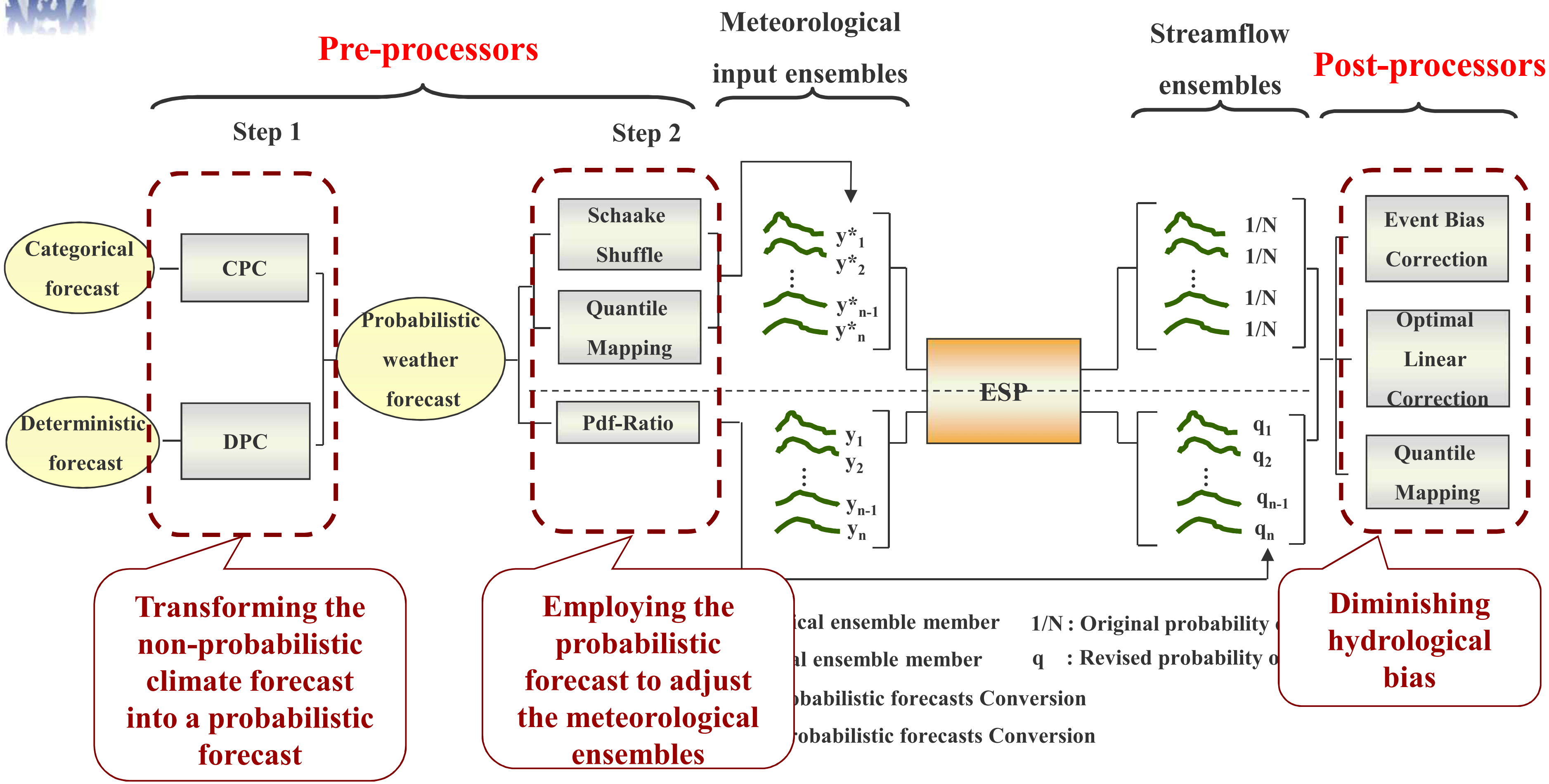
Tae-Ho Kang,[1] Young-Oh Kim[2]* and Il-Pyo Hong[1]
[1] *Water Resources Research Division, Korea Institute of Construction Technology, 1190, Siminidae-Ro, Ilsanseo-Gu, Goyang-Si, Gyeonggi-Do, 411-712, Republic of Korea*
[2] *Department of Civil and Environmental Engineering, Seoul National University, 599 Gwanak-Ro, Gwanak-Gu, Seoul 151-742, Republic of Korea*

**Correspondence to: Young-Oh Kim, Department of Civil and Environmental Engineering, Seoul National*

Abstract

This study conducted a broad review of the pre- and post-processor methods for ensemble streamflow prediction using a Korean case study. Categorical forecasts offered by the Korea

ESP with Various Pre- & Post- Processors



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Study Basin: C- & S-Dam

- **The Chungju Dam (C-Dam)** and the **Soyanggang Dam (S-Dam)** basin in Korea, which have no other dams in their upper stream region, were applied
- S-Dam, having the largest storage capability in Korea, is currently supplying 1.2 billion m^3/year of water to Seoul
- C-Dam has the second largest storage capability

• Features of S-Dam

Basin area: 2,703 km^2

Average rainfall: 1,100 mm

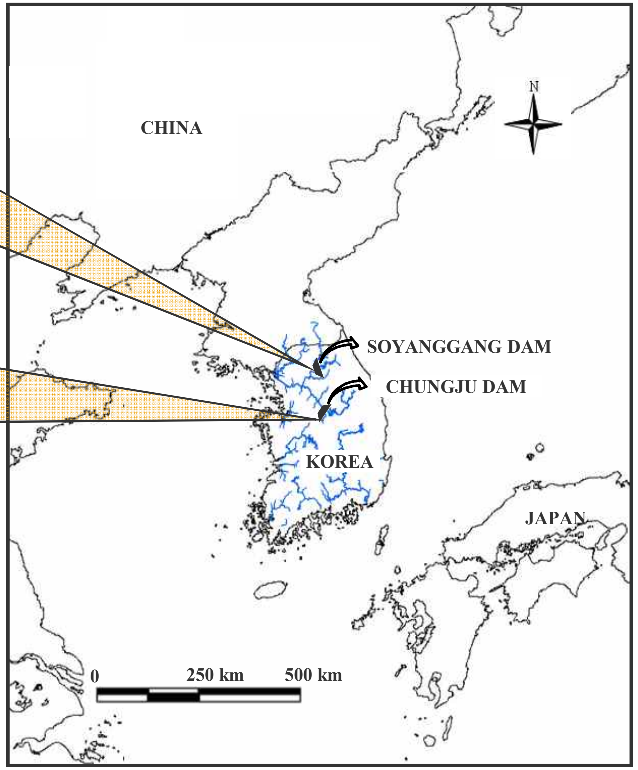
Average runoff: 55.5 m^3/sec

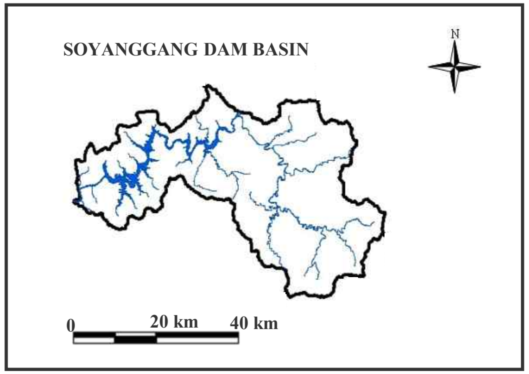
• Features of C-Dam

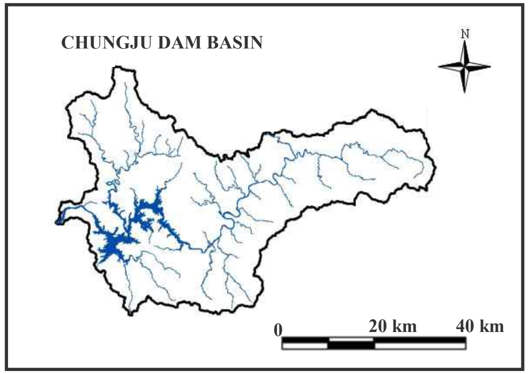
Basin area: 6,648 km^2

Average rainfall: 1,197 mm

Average runoff: 154 m^3/sec







Results: RPS

- The post processor is more effective in **the dry season** than in the wet season because TANK is more biased in dry season
- When the hydrologic bias is diminished effectively, **uncertainty of the probabilistic climate forecast mainly contributes to ESP uncertainty**

season	Basin (Pre \ Post)	Soyanggang Dam No post	Soyanggang Dam EBC	Soyanggang Dam QM	Soyanggang Dam OLC	Chungju Dam No post	Chungju Dam EBC	Chungju Dam QM	Chungju Dam OLC
Wet season	No pre	0.431	0.435	0.424	0.426	0.504	0.495	0.414	0.484
	QM	0.446	0.464	0.433	0.441	0.432	0.398	0.439	0.408
	SS	0.437	0.458	0.421	0.429	0.437	0.393	0.392	0.395
	PR	0.491	0.485	0.470	0.449	0.474	0.451	0.437	0.446
Dry Season	No pre	0.847	0.414	0.507	0.525	0.729	0.476	0.455	0.575
	QM	0.813	0.418	0.501	0.550	0.649	0.502	0.512	0.56
	SS	0.828	0.456	0.540	0.589	0.713	0.515	0.509	0.611
	PR	0.822	0.413	0.526	0.511	0.713	0.458	0.457	0.546

Conclusion

- QM generally performs well except the wet season of S-Dam
- Without post-processors, pre-processors alone can not show significant improvement
- A good pre-processor should be used together with a good post-processor that could effectively remove or at least reduces the hydrological model uncertainty

Study 5: Drought Outlook with ESP

- **Citation**
  - ✓ Kim et al. (2012). "A drought outlook in Korea." *Hydrological Science Journal* (in press)
- **Objective**
  - ✓ Propose a drought outlook methodology appropriate to the Korean drought index (Modified SWSI)

Hydrological Sciences Journal – Journal des Sciences Hydrologiques, **57**(6) 2012 1141

A drought outlook study in Korea

Young-Oh Kim[1], Jae-Kyoung Lee[1] and Richard. N. Palmer[2]

[1] *Department of Civil and Environmental Engineering, Seoul National University, 599 Gwanak-ro, Gwanak-gu, Seoul 151-742, Korea*
yokim05@snu.ac.kr

[2] *University of Massachusetts Amherst, 222 Marston Hall, 130 Natural Resources Road, Amherst, Massachusetts 01003, USA*

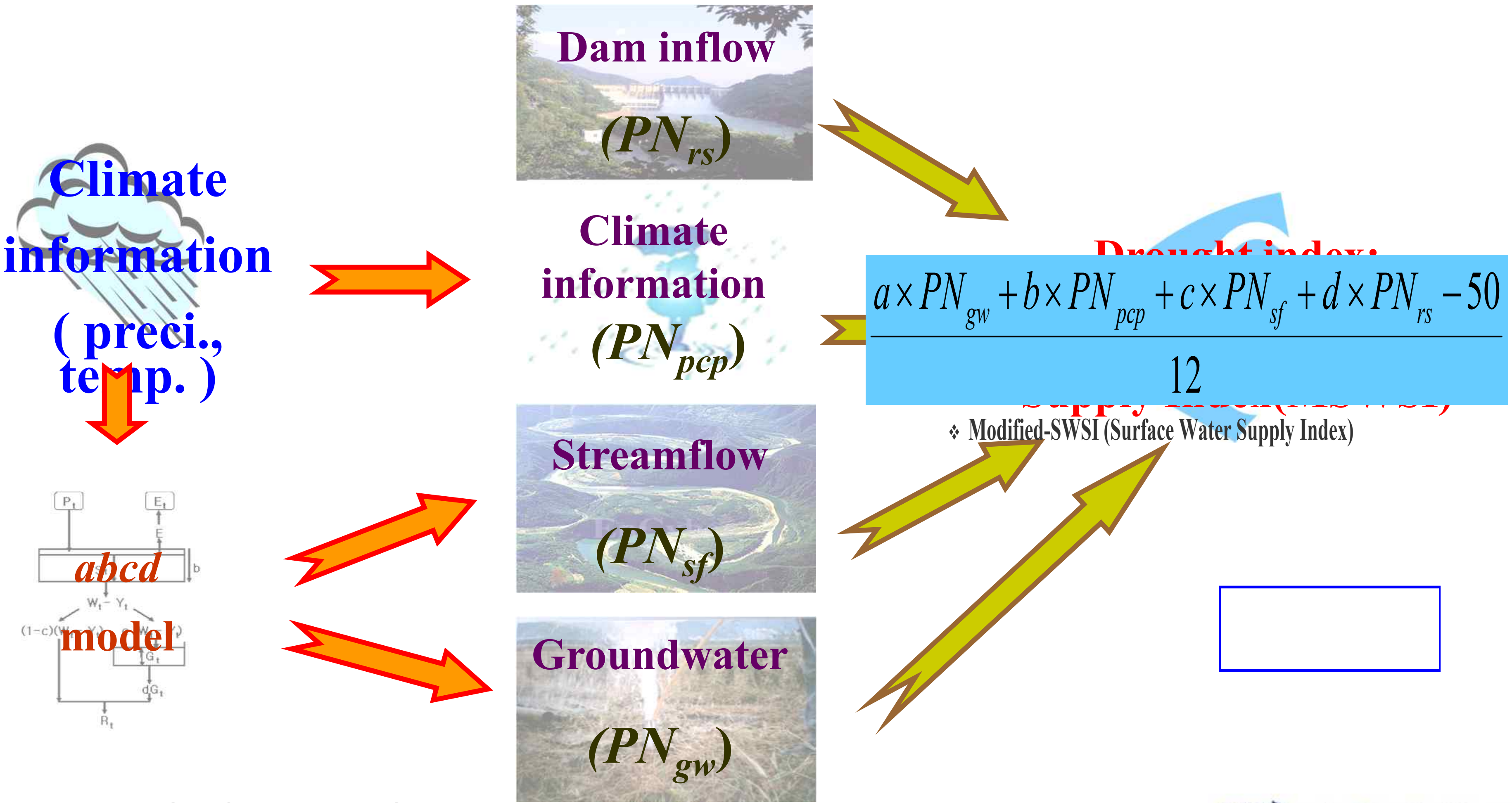
Received 28 December 2010; accepted 16 December 2011; open for discussion until 1 February 2013

Editor Z.W. Kundzewicz; **Associate editor** D. Hughes

Citation Kim, Y.-O., Lee, J.-K., and Palmer, R.N., 2012. A drought outlook study in Korea. *Hydrological Sciences Journal*, 57 (6), 1141–1153.

Abstract Techniques are proposed for developing a monthly and weekly drought outlook and the drought outlook components are evaluated. A drought index, the surface water supply index (SWSI) was modified and used for the drought outlook. A water balance model (*abcd*) was successfully calibrated using a regional regression, including

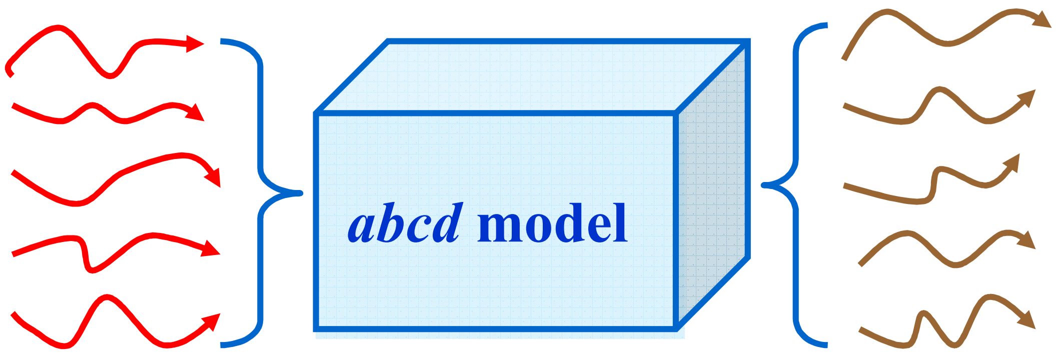
Drought Index: M-SWSI



$$\frac{a \times PN_{gw} + b \times PN_{pcp} + c \times PN_{sf} + d \times PN_{rs} - 50}{12}$$

Monthly Drought Index Outlook

historical precipitation & temperature ensemble



streamflow & groundwater level ensemble

MSWSI equation

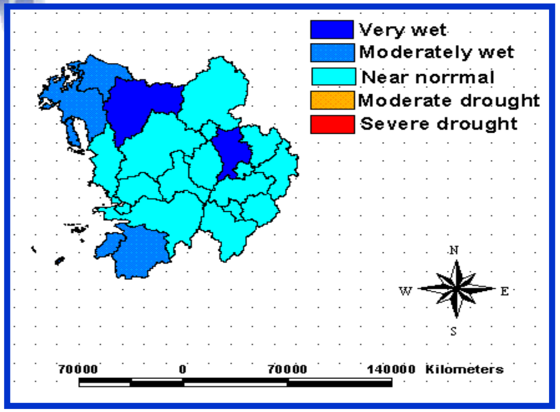
$$\frac{a \times PN_{pcp} + b \times PN_{gw} + c \times PN_{sf} + d \times PN_{rs} - 50}{12}$$

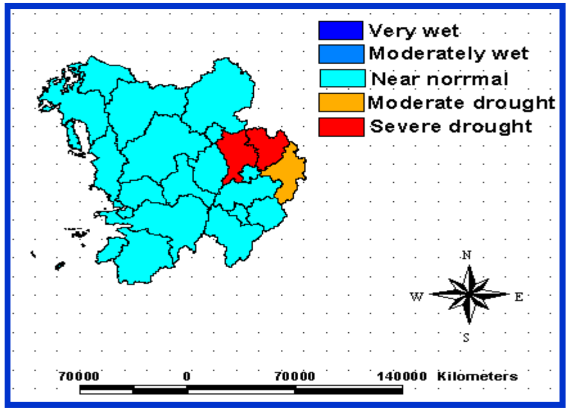
Development of Hydrological Forecasting

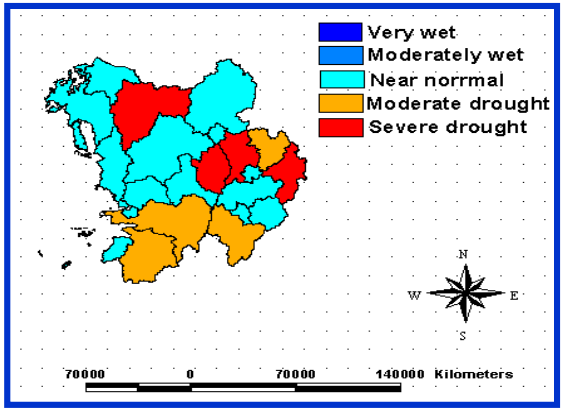
drought index ensemble

Results: Monthly MSWSI Outlook

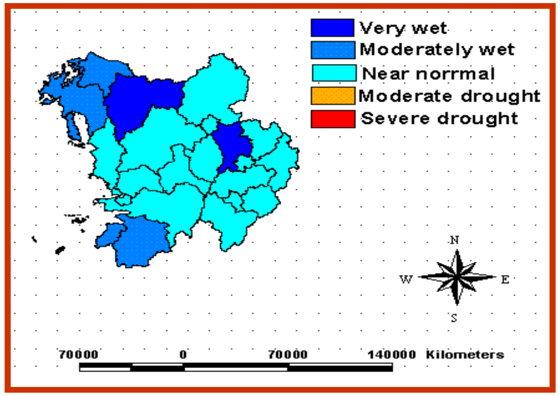
Drought outlook

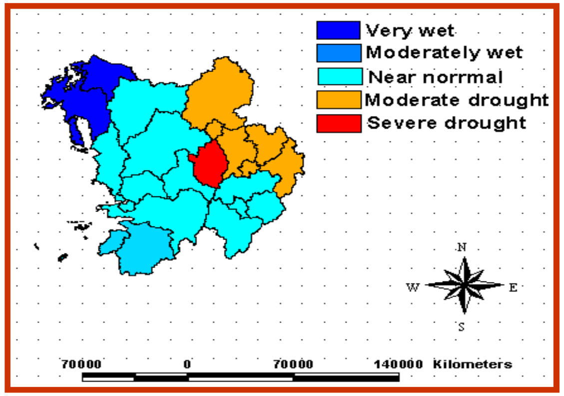


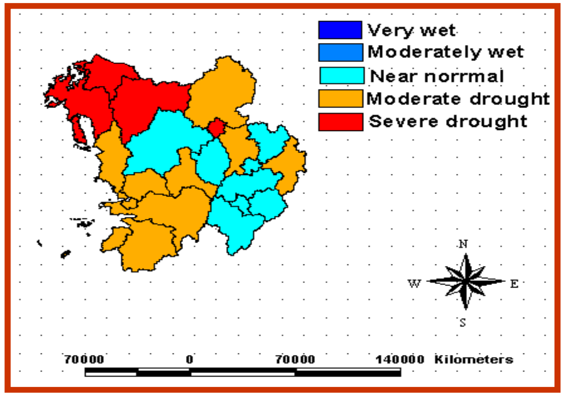




January 2001 **July 2001** **November 2001**







Observation

Conclusion

- The monthly drought outlook with ESP is superior to the naïve forecast during the dry season
- Therefore, the ensemble approach is appropriate for the monthly drought outlook in the Korean Peninsula
- However, MIMI does not improve the proposed drought outlook with ESP because the current MIMI does not have skill

Study 6: Qualitative Meteorological Information for Drought Outlook

- **Citation**
  - ✓ Ahn et al. (2012). "Manipulating large scale qualitative meteorological information for drought outlook." *Monthly Weather Review* (on-line published).

- **Objectives**
  - ✓ Investigate domestic meteorological information applicable to drought outlook
  - ✓ Propose a technique to utilize the given meteorological information for drought outlook in practice

Monthly Weather Review 2012 ; e-View
doi: http://dx.doi.org/10.1175/MWR-D-11-00146.1

Manipulating Large-Scale Qualitative Meteorological Information for Drought Outlook

Kuk-Hyun Ahn,* Young-Oh Kim,+ Sang Jin Ahn#

* *School of Civil Engineering, Purdue University, Indiana, USA*

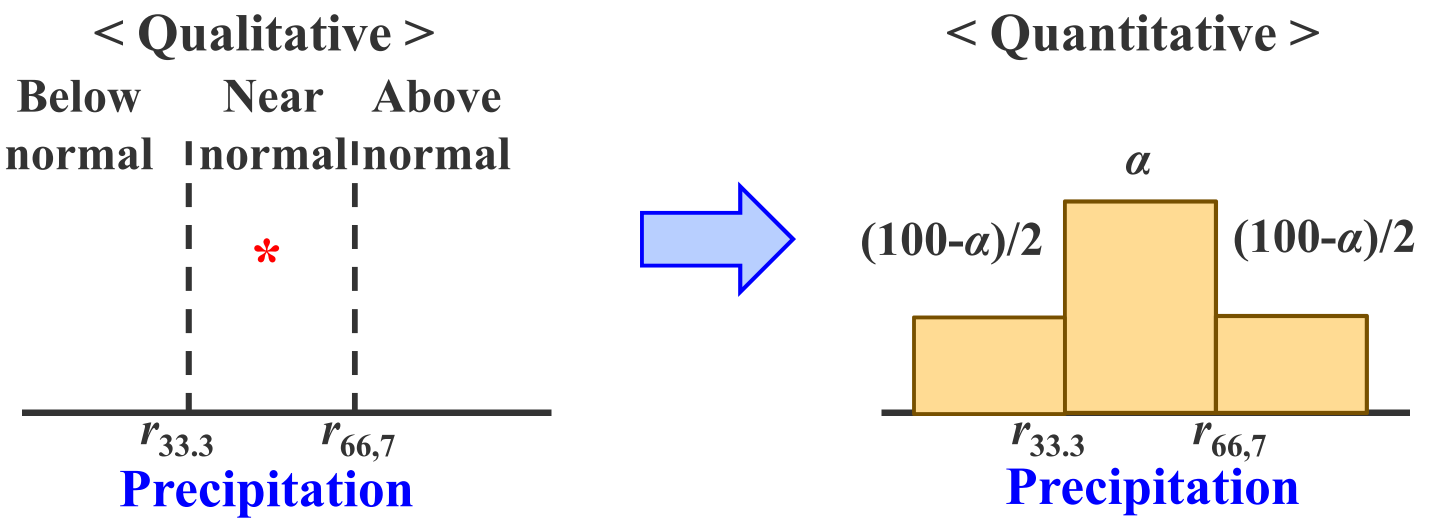
+ *Department of Civil and Environmental Engineering, Seoul National University, Seoul, Korea*

Department of Civil Engineering, Chungbuk National University, Chungcheongbuk-do, Korea

Abstract

Despite many strides made in the development of global circulation models as well as the expansive understanding of meteorological phenomena, still many countries lack sufficient meteorological information that can be conveniently

Transforming to Quantitative Forecasts

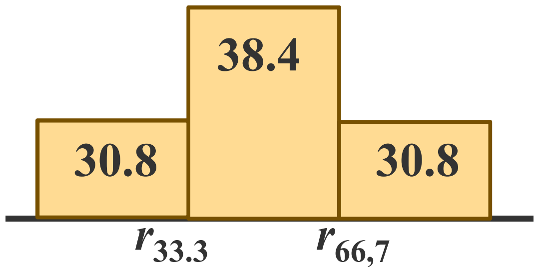


- Determination of "*alpha*"
  - ✓ For each basin, change the value of "*alpha*" from 33% to 100% and
  - ✓ Find the optimal value of "*alpha*" that maximizes a given accuracy measure (ex. RPSS) of the transformed probabilistic forecasts

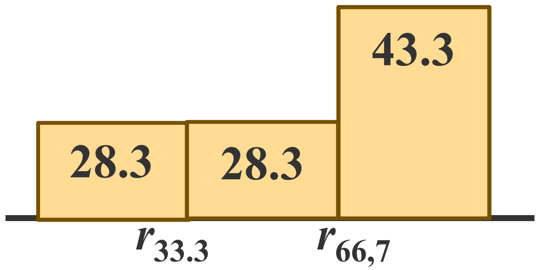
Conclusion

- **Propose a methodology that can convert the verbal expression of the current climate forecast to the quantitative probabilistic forecast**

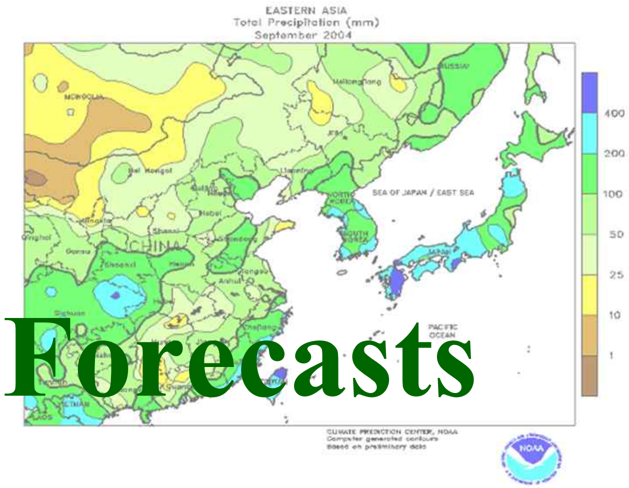
- **Determine "*alpha*" for each basin with which the probabilistic forecasts can be made**
  - ✓ **Sub-basin 2001: *alpha* = 38.3%**

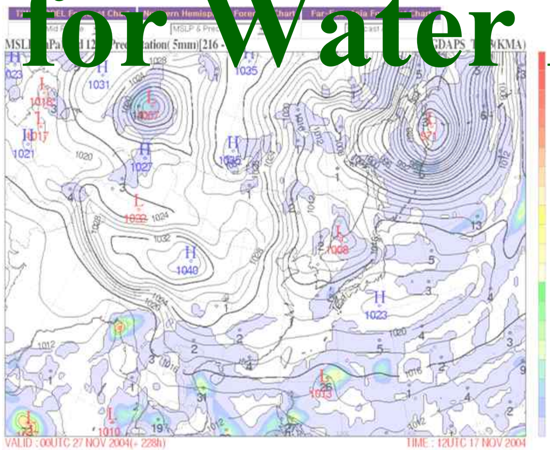


  - ✓ **Sub-basin 2016: *alpha* = 43.3 %**



The Value of Using Forecasts for Water Resources Management





International Conference on Climate, Water and Policy 2012

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Study 7: Reservoir Operation with ESP

- Citation
  - ✓ Eum et al. (2010). "The value of updating ensemble streamflow prediction in reservoir operations." *Hydrological Processes*, 24(20).

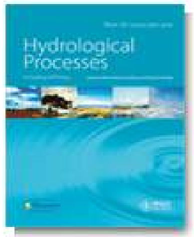
- Objectives
  - ✓ Propose a methodology that can update the monthly ESP scenario and also the SSDP-derived operating rule
  - ✓ Examine the value of updating the ESP scenarios in reservoir operation

The value of updating ensemble streamflow prediction in reservoir operations

Hyung-Il Eum[1], Young-Oh Kim[2,*]

Article first published online: 29 MAY 2010
DOI: 10.1002/hyp.7702

Issue



Hydrological Processes
Volume 24, Issue 20, pages 2888–2899, 30 September 2010

Keywords:
ensemble streamflow prediction; sampling stochastic dynamic programming; forecast accuracy; reservoir operations

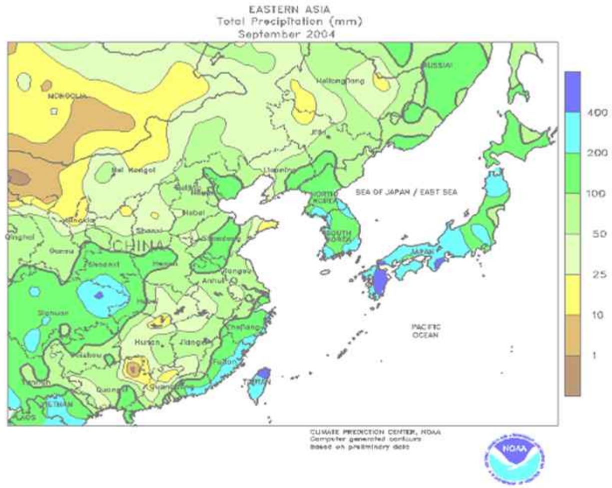
Abstract
This study proposes a new monthly ensemble streamflow prediction (ESP) forecasting system that can update the ESP in the middle of a month to reflect the meteorological and hydrological variations during that month. The reservoir operating policies derived from a sampling stochastic dynamic programming model using ESP scenarios updated three times a month were applied to the Geum River basin to measure

Outline of the Study

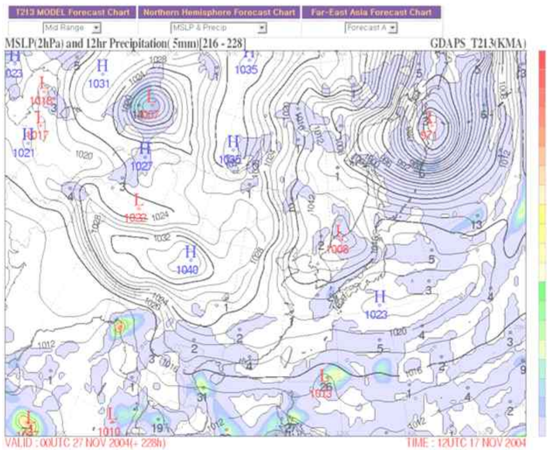
- The monthly operating rules were developed using SSDP (Sampling Stochastic Dynamic Programming) optimization algorithm
  - ✓ To minimize primarily the water shortage in the Geum River Basin
- The monthly inflow forecasts were made with ESP and updated twice a month
- The value of the monthly inflow forecasts and also of updating those forecasts were assessed

Conclusion

- Updating the ESP scenario improves the forecast accuracy by up to 26 %
- Updating the operating policies every month is valuable: it reduces the water shortage by 0.6×10^6 m^3/year compared to the policy without updating. It is more valuable when the initial storage combinations are low
- Updating within a month is also valuable: on average each update of ESP has the value equivalent to a decrease of 0.2×10^6 m^3/year in the water shortage
- The water shortage in the well-forecasted years is reduced by 20% as compared to that in the poorly-forecasted year


EASTERN ASIA
Total Precipitation (mm)
September 2004
CLIMATE PREDICTION CENTER, NOAA

Closing


T213 MODEL Forecast Chart
Northern Hemisphere Forecast Chart
Far-East Asia Forecast Chart
MSLP(2hPa) and 12hr Precipitation(5mm)[216 - 228]
GDAPS_T213(KMA)

Summary

- The current KMA climate forecasts should be improved in the future but some products are already skillful for the hydrological forecasting and also for the water resources management
- The direct use of the current KMA climate forecasts seem impossible for the hydrologic forecasting but it must be possible to utilize them for the operation hydrological forecasting with some modification ideas
- Therefore, development of our (Korean) own methodologies in hydrology is important

다시 2019년 2월 27일에 서서 …

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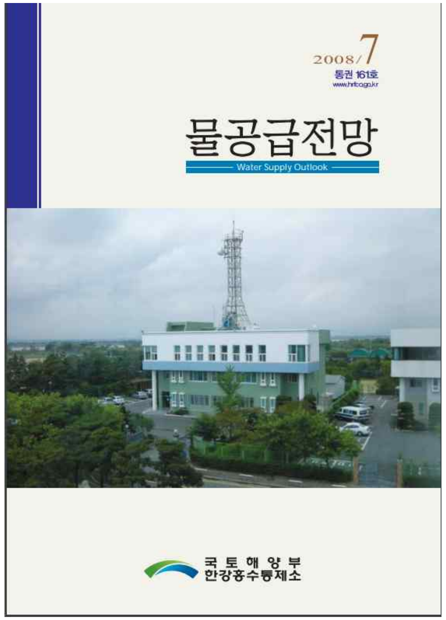
PAST ESP PROJECTS WITH SNU

- ❖ SSDP with ESP by K-water (2004.07. ~ 2006.03.)
  - ✓ Kim, Y.-O., Eum, H.-I., Lee, E. G., and Ko, I. H., (2007) Optimizing operational policies of a Korean multi-reservoir system using sampling stochastic dynamic programming with ensemble streamflow prediction. *Journal of Water Resources Planning and Management*, vol. 131, no. 1, pp. 4-14, published

- ❖ Monthly Water Supply Outlook (2007.09. ~ 2008.07.)



INTERNATIONAL ESP ACTIVITIES

Most Recent HEPEX Workshops

The 2018 HEPEX workshop took place in Melbourne, Australia in February 2018.

SPECIAL ISSUES

hepex

he following is a list of special journal issues related to HEPEX:

- Sub-seasonal to seasonal hydrological forecasting, 2016-2017, Hydrology and Earth System Sciences
- Ensemble prediction and data assimilation for operational hydrology, 2014, Journal of Hydrology
- Hydrological Ensemble Prediction Systems (HEPS), 2013, Hydrological Processes
- Precipitation uncertainty and variability, 2012, Hydrology and Earth System Sciences
- Latest advances and developments in data assimilation, 2011-2012, Hydrology and Earth System Sciences
- Towards practical applications in ensemble hydro-meteorological forecasting, 2011, Advances in Geosciences
- Downscaling NWP products and propagation of uncertainty, 2010, Atmospheric Science Letters
- HEPEX Workshop in Stresa, 2008, Atmospheric Science Letters
- Hydrological prediction uncertainty, 2006, Hydrology and Earth System Sciences

IS ONE FORECAST MODEL BETTER THAN ANOTHER?

February 7, 2019 Andy Wood 0 Comment

Blog post contributed by: Tim DelSole* The Sign Test Is one forecast model better than another? A natural approach to answering this question is to run a set of forecasts with each model and then see which set has more skill. This comparison requires a statistical test to ensure that the estimated difference represents a real difference in skill, rather than a random

LESSONS FROM CALIBRATING A GLOBAL FLOOD FORECASTING SYSTEM

December 12, 2018 Rebecca Emerton 0 Comment

Contributed by Feyera Hirpa, University of Oxford. Hydrological models are key tools for predicting flood disasters several days ahead of their occurrence. However, their usability as a decision support tool depends on their skill in reproducing the observed streamflow. The forecast skill is subject to a cascade of uncertainties originating from errors in the models' structure, parametrization, initial conditions and meteorological forcing. The Global Flood Awareness System (GloFAS) is an operational flood forecasting system that produces ensemble streamflow forecasts with…

HTTPS://HEPEX.IRSTEA.FR/

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A NEW PROJECT BY K-WATER: BAYESIAN ESP

- **Objectives**
  - ✓ **Develop a hydrologic forecasting model based on Bayes' theorem**
  - ✓ **Utilize climate forecast information for updating prior distribution**

Hydrology Research

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Article Contents

RESEARCH ARTICLE | JANUARY 23 2019

Improvement in long-range streamflow forecasting accuracy using the Bayes' theorem

Seung Beom Seo; Young-Oh Kim; Shin-Uk Kang; Gun Il Chun

Hydrology Research nh2019098.

https://doi.org/10.2166/nh.2019.098 **Article history**

Views PDF Share Tools

$f(q) \sim N(\mu_o, \sigma_o^2)$

Prior distribution

$f(y|q) \sim f(y|\bar{y}) f(\bar{y}|q)$

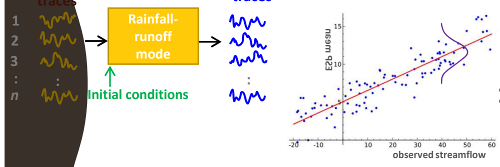
$f(\bar{y}|q) \sim N(\alpha + \beta q, \sigma_\varepsilon^2)$

$f(y|\bar{y}) \sim N(\bar{y}, \sigma_y^2)$

$f(y|q) \sim N(\alpha + \beta q, \sigma_\varepsilon^2 + \sigma_y^2)$

❖ Bayes' theorem

$f(q|y) = f(q|\bar{y}, \sigma_y^2) \sim N(\mu_p, \sigma_p^2)$



Likelihood function

$$= \frac{f(y|q)\,f(q)}{f(q)}$$

❖ **Prior distribution:**
estimated from historical streamflow series

❖ **Likelihood function: the probability of the ESP given the observed streamflow**
estimated from historical performance of the ESP based on hindcasts.

Posterior distribution

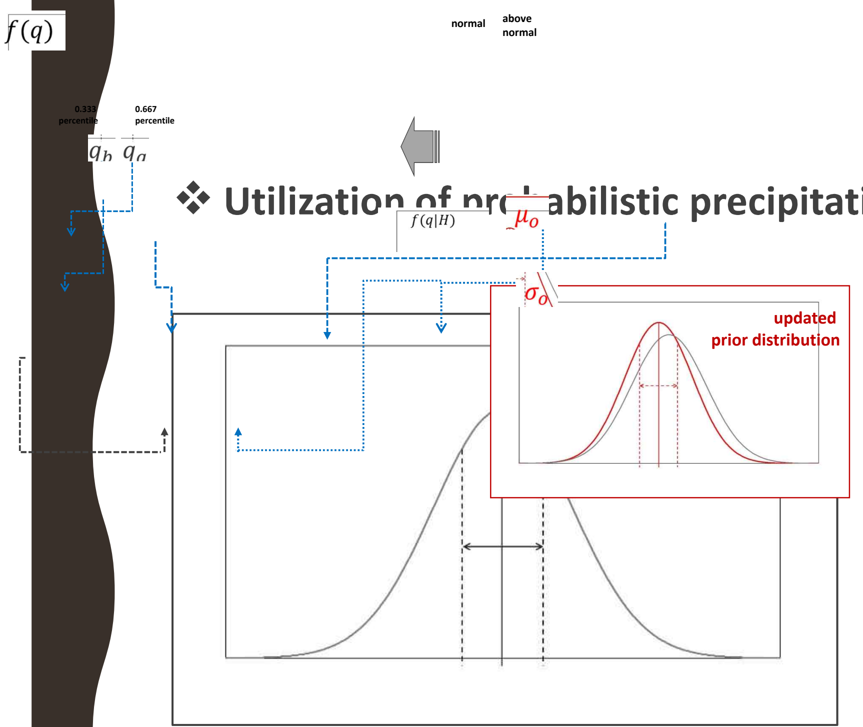
❖ Posterior distribution

variance of the residuals

current forecast variance

Bias Correction

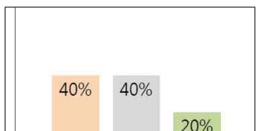
❖ Utilization of probabilistic precipitation forecast (issued by Korea Meteorological Administration)



$$\sigma_o = \{q_a - q_b\} / \{\Phi^{-1}(1 - p_a) - \Phi^{-1}(p_b)\}$$

prior distribution

probabilistic precipitation forecast from KMA



A NEW PROJECT BY K-WATER: BAYESIAN ESP

❖ **Results**

[1 month ahead forecast for 35 dam basins (2014.6 ~ 2017.12)]

		ESP	Bayesian ESP	Bayesian ESP w/ climate forecast
	특성	ESP	Bayesian ESP (without probabilistic precipitation forecast)	Bayesian ESP (WITH probabilistic precipitation forecast)
Good ↓	N-RMSE[1)]	1.06	1.07	**0.98**
Good ↑	POD[2)]	37.6 %	37.4 %	**41.2 %**
Good ↑	POD (below normal only)	18.2 %	15.4 %	**23.2 %**

1) **N-RMSE: Normalized - Root Mean Squared Error**
2) **POD: Probability of Detection (categorical forecast accuracy in terms of terciles-below normal, normal, above normal)**

❖ **Utilizing probabilistic climate forecast can lead to additional improvement in forecast accuracy**

FUTURE ESP IN KOREA:
FROM ESP TO EDP (ENSEMBLE DROUGHT PREDICTION)

REVIEW ARTICLE
10.1002/2016RG000549

Key Points:
- Review drought prediction based on statistical, dynamical, and hybrid methods
- Summarize advances in predicting different types of drought
- Discuss current challenges and future prospects in drought prediction

Correspondence to:
Z. Hao,
haozc@bnu.edu.cn

Citation:
Hao, Z., Singh, V. P., & Xia, Y. (2018). Seasonal drought prediction: Advances, challenges, and future prospects. *Reviews of Geophysics*, *56*, 108–141. https://doi.org/10.1002/2016RG000549

Received 15 NOV 2016
Accepted 22 DEC 2017
Accepted article online 5 JAN 2018
Published online 27 JAN 2018

Seasonal Drought Prediction: Advances, Challenges, and Future Prospects

Zengchao Hao[1], Vijay P. Singh[2], and Youlong Xia[3]

[1]Green Development Institute, College of Water Sciences, Beijing Normal University, Beijing, China, [2]Department of Biological and Agricultural Engineering and Zachry Department of Civil Engineering, Texas A&M University, College Station, TX, USA, [3]I.M. System Group at Environmental Modeling Center, National Centers for Environmental Prediction, College Park, MD, USA

Abstract Drought prediction is of critical importance to early warning for drought managements. This review provides a synthesis of drought prediction based on statistical, dynamical, and hybrid methods. Statistical drought prediction is achieved by modeling the relationship between drought indices of interest and a suite of potential predictors, including large-scale climate indices, local climate variables, and land initial conditions. Dynamical meteorological drought prediction relies on seasonal climate forecast from general circulation models (GCMs), which can be employed to drive hydrological models for agricultural and hydrological drought prediction with the predictability determined by both climate forcings and initial conditions. Challenges still exist in drought prediction at long lead time and under a changing environment resulting from natural and anthropogenic factors. Future research prospects to improve drought prediction include, but are not limited to, high-quality data assimilation, improved model development with key processes related to drought occurrence, optimal ensemble forecast to select or weight ensembles, and hybrid drought prediction to merge statistical and dynamical forecasts.

FUTURE ESP IN KOREA:
FROM ESP TO EDP (ENSEMBLE DROUGHT PREDICTION)

Hydrol. Earth Syst. Sci., 21, 1573–1591, 2017
www.hydrol-earth-syst-sci.net/21/1573/2017/
doi:10.5194/hess-21-1573-2017

Hydrology and Earth System Sciences
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EGU

Seasonal streamflow forecasting by conditioning climatology with precipitation indices

Louise Crochemore[1,a], Maria-Helena Ramos[1], Florian Pappenberger[2], and Charles Perrin[1]

[1]IRSTEA, Catchment Hydrology Research Group, UR HBAN, Antony, France
[2]ECMWF, European Centre for Medium-Range Weather Forecasts, Shinfield Park, Reading, UK
[a]now at: Hydrology Research Unit, Swedish Meteorological and Hydrological Institute (SMHI), Norrköping, Sweden

Correspondence to: Louise Crochemore (louise.crochemore@smhi.se)

Received: 4 June 2016 – Discussion started: 15 June 2016
Revised: 7 February 2017 – Accepted: 20 February 2017 – Published: 14 March 2017

Abstract. Many fields, such as drought-risk assessment or reservoir management, can benefit from long-range streamflow forecasts. Climatology has long been used in long-range streamflow forecasting. Conditioning methods have been proposed to select or weight relevant historical time series from climatology. They are often based on general circulation model (GCM) outputs that are specific to the forecast date due to the initialisation of GCMs on current conditions. This study investigates the impact of conditioning methods on the performance of seasonal streamflow forecasts. Four conditioning statistics based on seasonal forecasts of cumulative precipitation and the standardised precipitation index were used to select relevant traces within historical streamflows and precipitation respectively. This resulted in

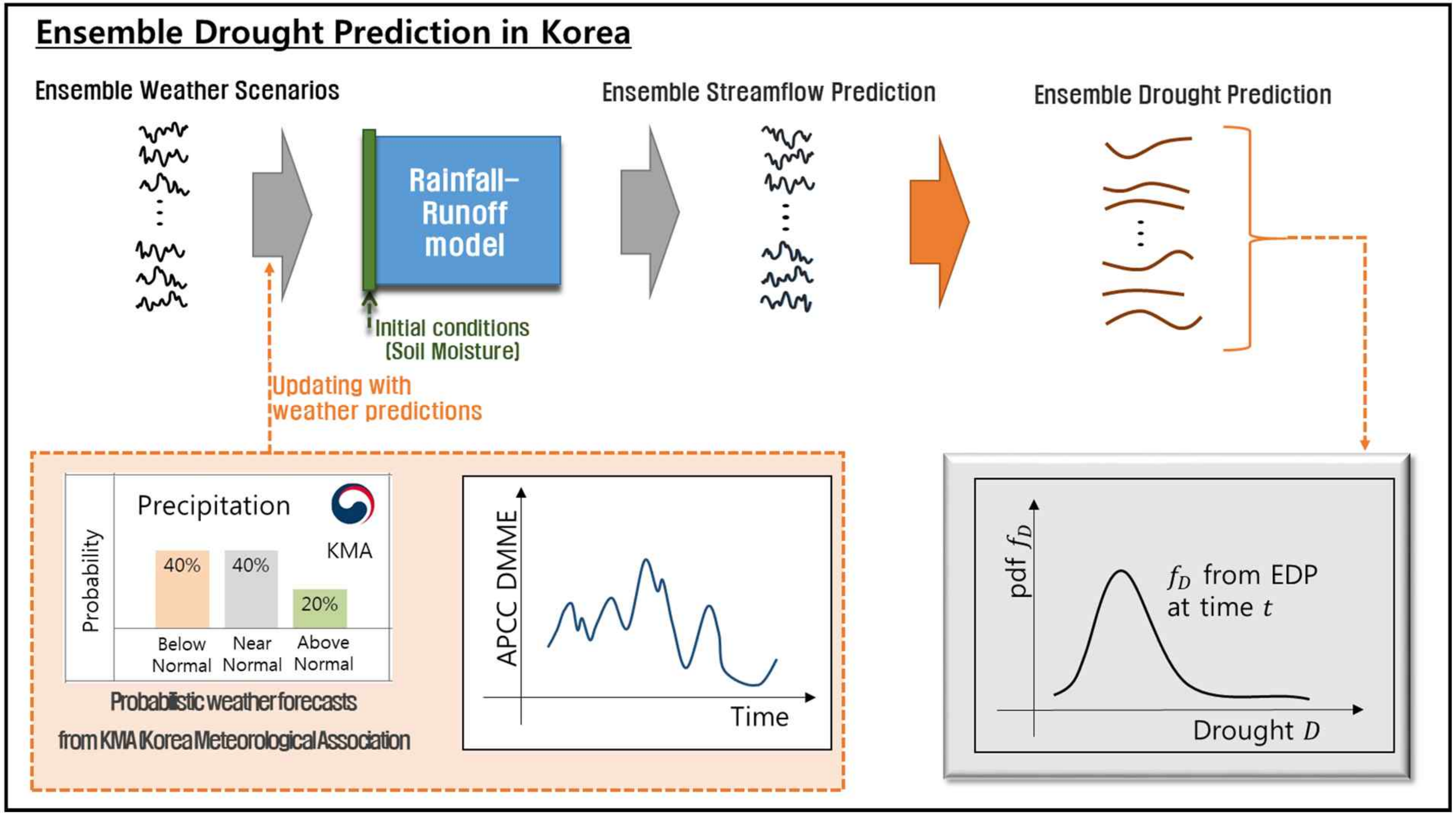
weekly deficit volumes and durations over a wider range of lead times.

1 Introduction

1.1 Approaches to seasonal streamflow forecasting

Numerical prediction is valuable to proactively manage risks in areas such as hydropower, drinking water production and drought preparedness (Wilhite et al., 2000). Regardless of the application, probabilistic forecasts are preferred over deterministic ones to convey uncertainties (Krzysztofowicz, 2001;

FUTURE ESP IN KOREA:
FROM ESP TO EDP (ENSEMBLE DROUGHT PREDICTION)



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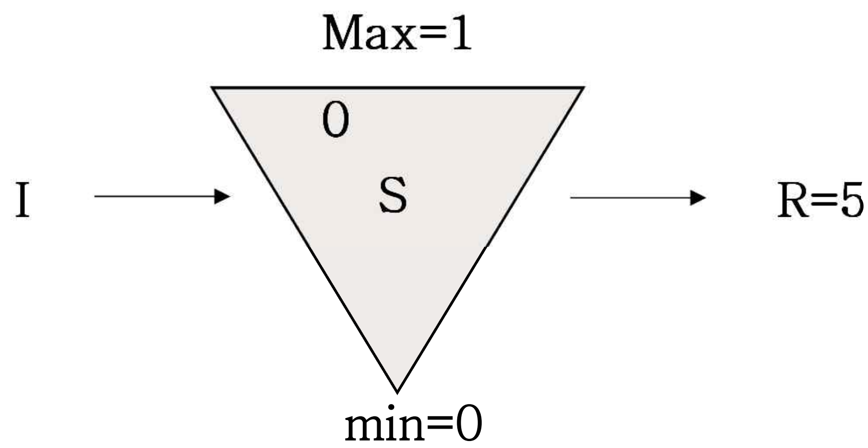
FUTURE ESP IN KOREA:
FROM HYDROLOGY TO PLANNING

- **Overview**
  - ✓ **Maximum Storage = 10**
  - ✓ **Minimum Storage = 0**
  - ✓ **Average Inflow = 7**
  - ✓ **Release = 5 (Constant)**
  - ✓ **Time Period $t = 3$**
  - ✓ **Initial Storage S_0 =10**



FUTURE ESP IN KOREA:
FROM HYDROLOGY TO PLANNING

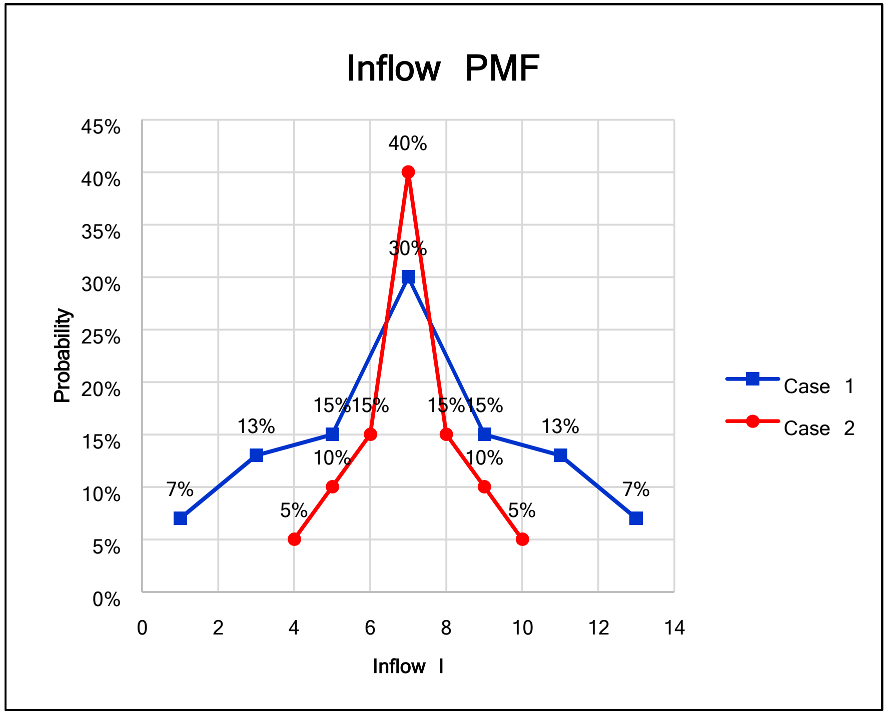
❖ Inflow Scenarios

✓ **Case 1**

Inflow	Probability(%)
1	7
3	13
5	15
7	30
9	15
11	13
13	7

✓ **Case 2**

Inflow	Probability(%)
4	5
5	10
6	15
7	40
8	15
9	10
10	5



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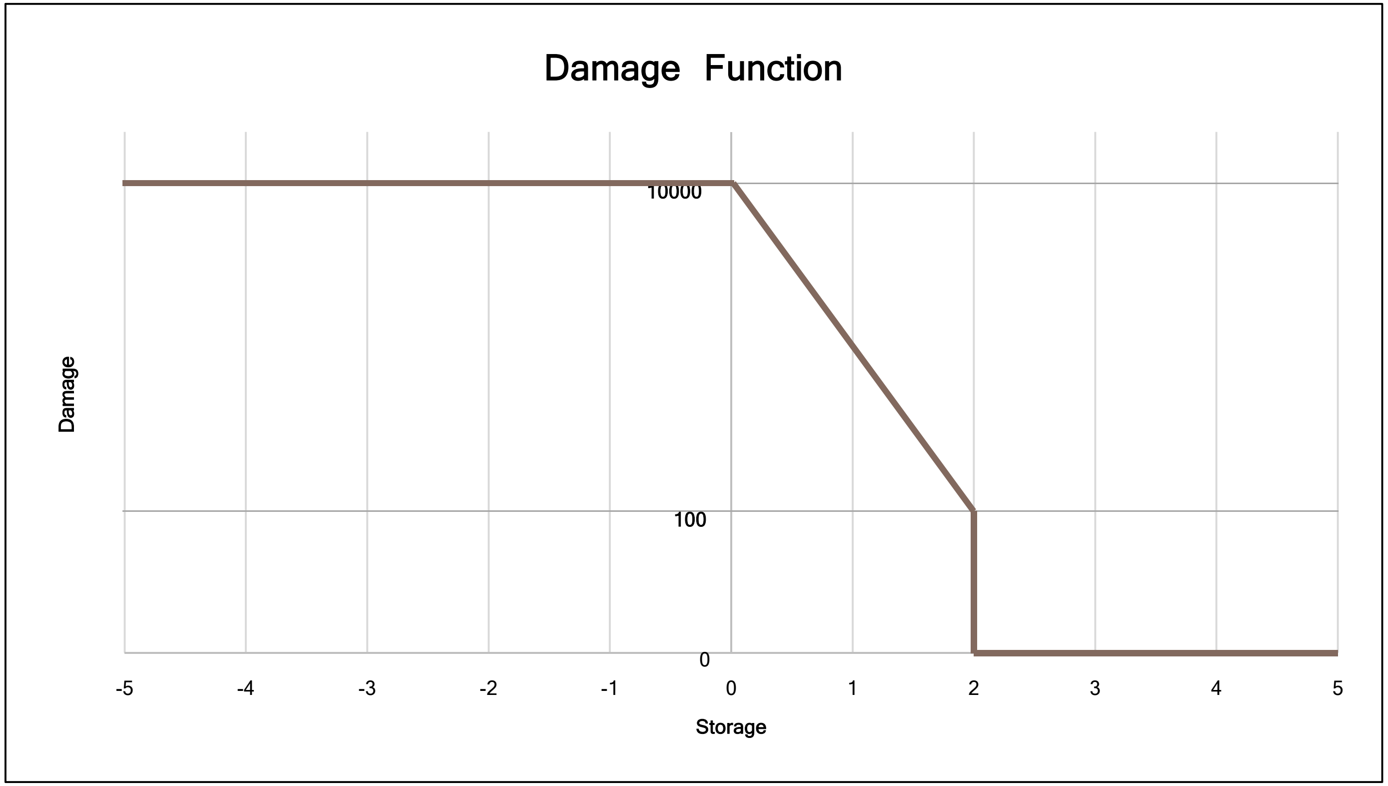
FUTURE ESP IN KOREA:
FROM HYDROLOGY TO PLANNING

❖ **Damage Function**



FUTURE ESP IN KOREA:
FROM HYDROLOGY TO PLANNING

- **Reservoir Operation Example**
  - ✓ Inflow Scenario Case I

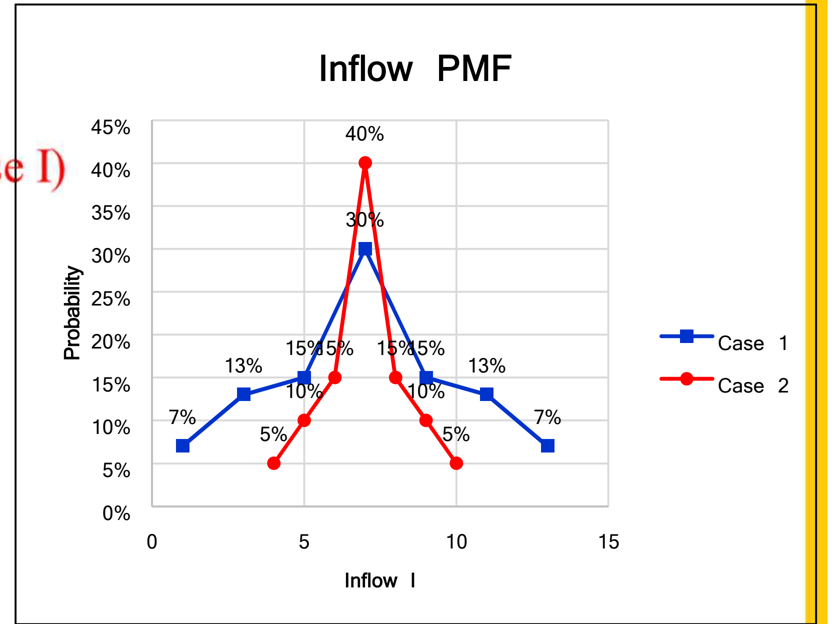
① $I(t) = 1,1,1$ (Worst Case Scenario of Case I)

$Pr(\sum I) = 0.07^3 = 0.000343$

$S_3 = 10 + (3 - 15) = -2 \rightarrow 0$

$S_1 = 6, S_3 = 2, S_3 = 0$

$Damage = 0 + 100 + 10000 = 10100$



② $I(t) = 3,1,1 \ or \ 1,3,1 \ or \ 1,1,3$

$Pr(\sum I) = 0.07^2 \times 0.13 \times 3 = 0.001911$

$S_3 = 10 + (5 - 15) = 0$

$S_1 = 8, S_2 = 4, S_3 = 0 \,/\, S_1 = 6, S_2 = 4, S_3 = 0 \,/\, S_1 = 6, S_2 = 2, S_3 = 0$

$Damage \ = 10000 \ or \ 10000 \ or \ 10100$

FUTURE ESP IN KOREA:
FROM HYDROLOGY TO PLANNING

- **Reservoir Operation Example**
  - ✓ Inflow Scenario Case II

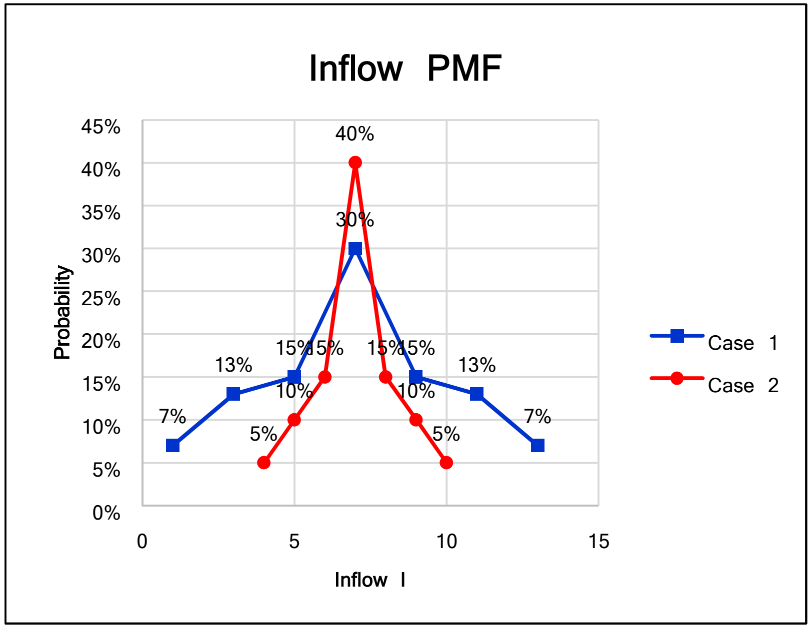
① $I(t) = 4,4,4$ (Worst Case Scenario of Case II)

$Pr(\sum I) = 0.05^3 = 0.000125$

$S_3 = 10 + (12 - 15) = 7$ (Final Storage)

$S_1 = 9, S_3 = 8, S_3 = 7$

$Damage = 0$, <u>**No Damage in all cases**</u>



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Thank you for your Attentions!

Questions?