Long-Term Rainfall-Runoff Flow Prediction Using GloSea5 System Based on Meteorological Forecasts and Distributed Hydrologic Model (K-DRUM)

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Keywords : GloSea5, Distributed Hydrologic Model, Bias-correction, Quantile mapping

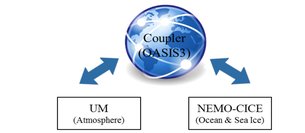
1. Introduction

- Along with a recent climate change, the uncertainty regarding precipitation levels and the frequency and severity of floods, droughts, and other natural disasters has increased. This makes raise the awareness in the social needs for stable water management and leads a greater demand for meteorological forecasts for water supply and flood control.
- This research aims to connect the Korea Meteorological Administration (KMA)'s probabilistic long-term forecasts and K-water (Korea Water Resources Corporation)'s hydrological forecasting model. The 42 precipitation ensemble forecasts of GloSea5 (Global Seasonal forecasting system version 5) were modified using statistical downscaling method and were converted into inputs for hydrological model, K-DRUM (K-water Distributed Rainfall RUnoff Model).
- Case studies were conducted in two basins: Yongdam (YD) Dam and Namgang (NG) Dam watersheds. After evaluating the precipitation forecast levels and hydrologic model performance for the period of GloSea5's HCST (Hindcast; 1996 to 2009), the data for GloSea5's FCST (Forecast; 2014 to 2015) were used to evaluate the long-term rainfall-runoff flow prediction using K-DRUM model.

2. GloSea5 and Bias-correction with quantile mapping

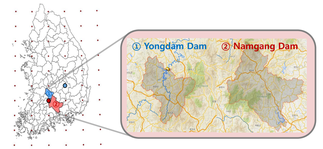
GloSea5

- The GloSea5 model is used in the cutting-edge seasonal prediction system by the UK's Met Office and is based on the agency's climate model HadGEM3 (Hadley Centre Global Environment Model version 3).
- The model consists of four models, UM (atmosphere), JULES (land surface), NEMO (ocean), and CICE (sea-ice) connected into one system by the OASIS coupler.
- In 2016, it was upgraded to GloSea5 GC2 and is the model currently in use.



Classification	Atmosphere	Ocean & Sea Ice
Model	UM N216L85 Based on GA3.0	NEMO-CICE ORCA025L75 (NEMO, CICE)
Horizontal Res.	0.83° X 0.56° (~60km)	ORCA tri-polar grid at 0.25°
Vertical Res.	85 levels (~85km)	75 levels

<A model configuration of the GloSea5>



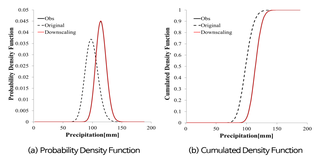
<Study areas; Yongdam & Namgang Dam>

Bias-correction with quantile mapping

- The extracted GloSea5 data shows significant systematic biases.
- Quantile mapping technique was used to correct systematic biases in the GloSea5 precipitation outputs as

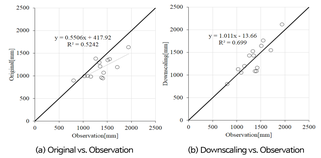
$$X_i' = F_{obs}^{-1}(F_m(X_i))$$

Where, X_i : Original GloSea5 precipitation data
X_i' : Bias-corrected Glosea5 precipitation data
F_m : CDF for X_i
F_{obs}^{-1} : Inverse of CDF for X_i'



(a) Probability Density Function (b) Cumulated Density Function

<The differences of PDF and CDF of Probability distribution (YD)>

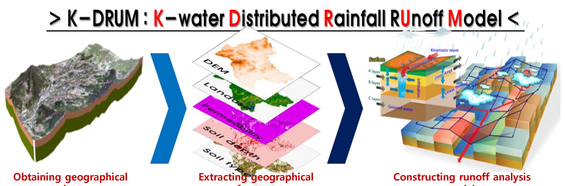


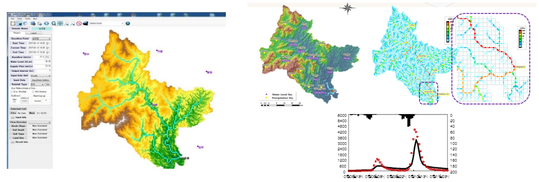
(a) Original vs. Observation (b) Downscaling vs. Observation

<QQ-plot to detect deviations between obs. and sim. (YD)>

3. Distributed Hydrologic Model (K-DRUM)

- Developed independently at K-water, K-DRUM is a physics- and grid-based distributed rainfall-runoff model, which enables short- and long-term analyses on rainfall-runoff, sediment, and water quality parameters.
- This model is actively utilized in dam management; its features include applying topography and soil characteristics, estimating the melt, accumulation, and evapotranspiration of snow, auto-compensation for initial soil water, parallel processing, spatial distribution of rainfall, and operating reservoirs.

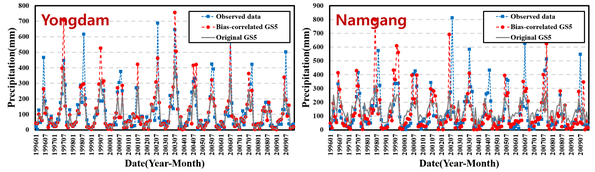




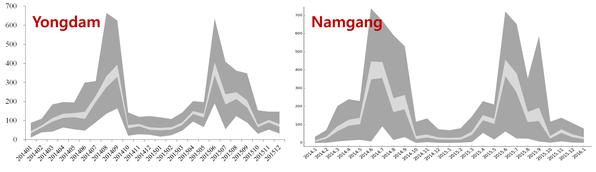
<Interface introduction of K-DRUM software (NG)>

4. Results

Bias-correction for precipitation in GloSea5



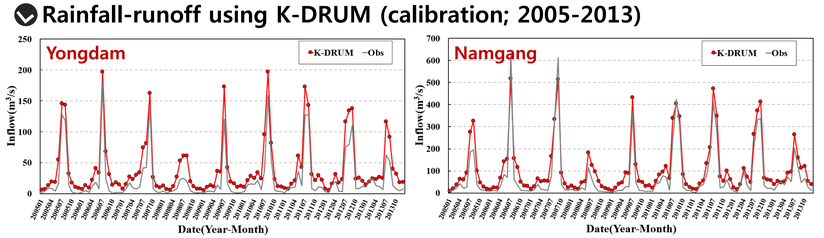
<Time series of monthly precipitation for observation, original, and bias-corrected data (Hindcast, 1996-2009)



<Time series of bias-corrected GloSea5 data with 42 ensembles (Forecast, 2014-2015)>

- Bias-correction of GloSea5's precipitation data resulted in quantitatively similar outcome to observations.

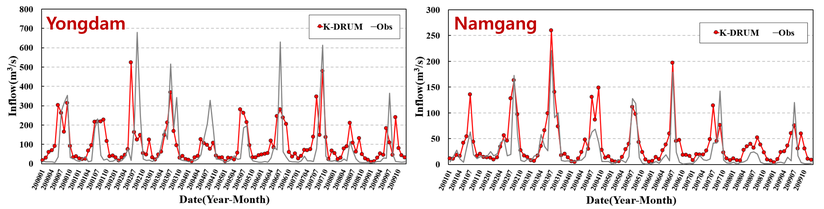
Rainfall-runoff using K-DRUM (calibration; 2005-2013)



Reliability analysis	Yongdam Dam	Namgang Dam
Percent	176.85	145.49
R^2	0.94	0.93
NSE(Nash-Sutcliffe efficiency)	0.67	0.85
PBIAS(Percent BIAS)	-76.85	-45.49
RMSE(Root Mean Square Error)	21.48	46.19
RRMSE(Relative Root Mean Square Error)	0.96	0.63
MAE(Mean Absolute Error)	17.22	37.71
RSR(RMSE obs. Std. Ratio)	0.58	0.38
MAPE(Mean Absolute Percentage Error)	2.52	1.44
TIC(Theil Inequality Coefficient)	0.21	0.15

- The result of K-DRUM's runoff simulation showed R^2 over 0.94 (YD, monthly) and 0.93 (NG, monthly).

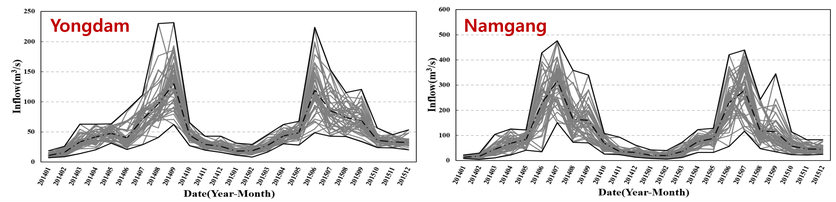
Runoff simulation using GloSea5 data (Hindcast; 1996-2009)



Reliability analysis	Yongdam Dam	Namgang Dam
Percent	159.31	129.84
R^2	0.69	0.28
NSE(Nash-Sutcliffe efficiency)	0.47	0.21
PBIAS(Percent BIAS)	-59.31	-29.84
RMSE(Root Mean Square Error)	28.91	116.87
RRMSE(Relative Root Mean Square Error)	1.16	1.51
MAE(Mean Absolute Error)	20.09	70.02
RSR(RMSE obs. Std. Ratio)	0.73	0.89
MAPE(Mean Absolute Percentage Error)	2.79	2.65
TIC(Theil Inequality Coefficient)	0.27	0.4

- The result found quantitative differences (YD 0.69, NG 0.28) but confirmed the representation of overall inflow patterns.

Runoff prediction using GloSea5 ensembles (Forecast; 2014-2015)



- The analysis found quantitative differences between the results from the 42 ensembles but the seasonal characteristics are preserved in general.

4. Summary and Conclusions

- The results showed appropriate outcomes of reproducibility for precipitation and runoff compared to specifically designated years in the past and can present ensembles in forecast period. Therefore, this research approach can be applied to a long-term water management, particularly for the planning of dam reservoir operations in order to secure stable water supply.

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31st Conference on Hydrology | Seattle, WA
Precipitation Processes and Observations for Atmospheric, Land Surface, and Hydrological Modeling, Poster 1107 | January 25, 2017

Acknowledgement This work was funded by the Korea Meteorological Administration Research and Development Program under Grant KIMPA 2015-2120.