CROSS VALIDATION OF SPATIAL INTERPOLATED RAIN GAGE AND SATELLITE-RAINFALL OVER CHAO PHRAYA RIVER BASIN THAILAND

NELSON STEPHEN L. VENTURA, & PIYATIDA RUANGRASSAMEE
Department of Water Resource Engineering, Faculty of Engineering
Chulalongkorn University
Bangkok, Thailand

OUTLINE OF THE PRESENTATION

- Introduction
- Study Area and Data
- Methodology
- Results and Discussion
- Conclusion and Recommendation

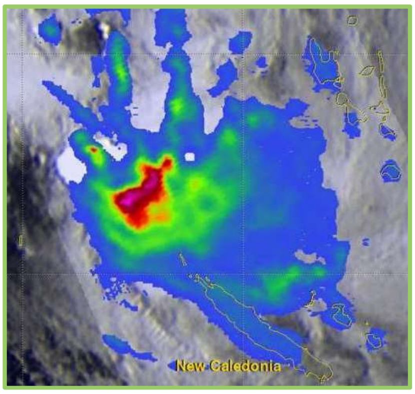
INTRODUCTION

SPATIAL RAINFALL

SPATIAL RAINFALL

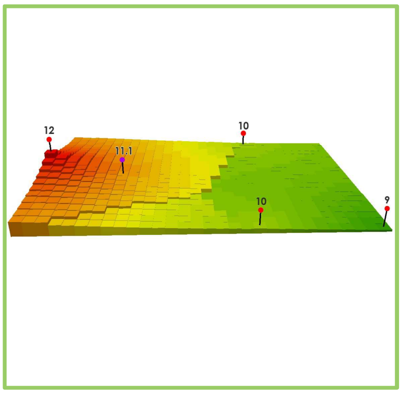
- Presents the spatial distribution of precipitation in a given time period

SATELLITE PRECIPITATION

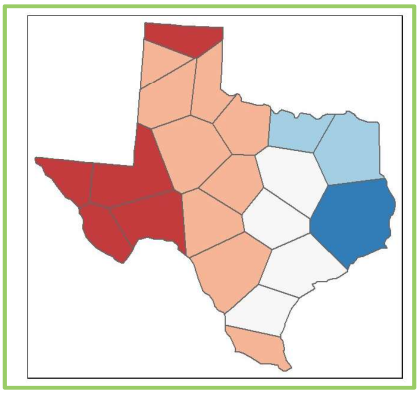


Source: https://phys.org/news/2018-01-gpm-satellite-tropical-cyclone-fehi.html

SPATIAL INTERPOLATION



Source: https://gisgeography.com/kriging-interpolation-prediction/



Source: https://mgimond.github.io/Spatial/spatial-interpolation.html

SATELLITE BASED RAINFALL

SATELLITE PRECIPITATION ESTIMATES

- Using satellite images to estimate the amount of rainfall in a designated time and area

SOME SATELLITE RAINFALL PRODUCTS

CHRS PERSIANN

JAXA GSMaP

NASA GPM IMERG

- Contains biases or errors that need to be corrected using ground-based data

SPATIALLY INTERPOLATED RAINFALL

SPATIAL INTERPOLATION

- Data from rain gages used as points to interpolate the amount of precipitation in locations without known values

INTERPOLATION APPROACHES

DETERMINISTIC

- Computes unknown values using mathematical functions
- Example: Thiessen Polygons, Inverse Distance Weighing (IDW)

STOCHASTIC

- Computes unknown values using the statistical properties of the dataset
- Example: Kriging

- For determining accuracy of the various methods, Cross Validation would be used to assess the interpolated data

OBJECTIVE OF THE STUDY

The aim of the study is to…

- Identify the most adequate spatial interpolation method for Chao Phraya River Basin in Thailand
- Determine the correlation of the satellite-based precipitation to the interpolation output
- Identify how significant the bias of the satellite precipitation for correction

STUDY AREA AND DATA

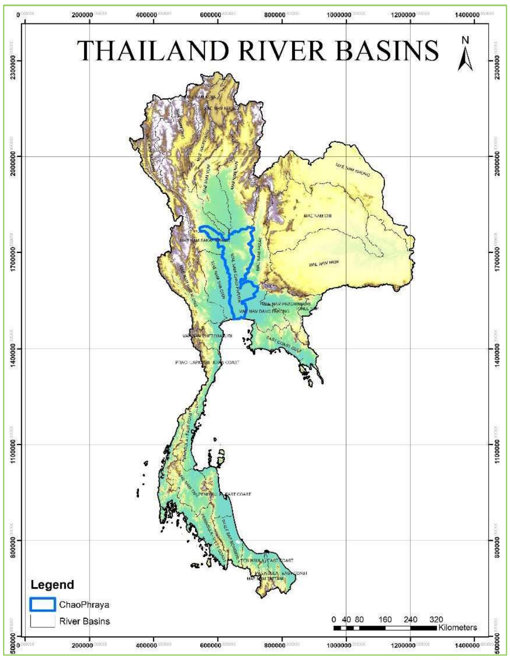
CROSS VALIDATION OF SPATIAL INTERPOLATED RAIN GAGE AND SATELLITE-RAINFALL OVER CHAO PHRAYA RIVER BASIN THAILAND

N.S. VENTURA, & P. RUANGRASSAMEE
CHULALONGKORN UNIVERSITY

STUDY AREA – CHAO PHRAYA RIVER BASIN

CHAO PHRAYA RIVER BASIN

- Being the 9th largest of the 25 major river basins in Thailand (20,526.37 sq.km)
- Where majority of the country's total productivity (agricultural, industrial, and service) is situated
- The Chao Phraya River passes through Bangkok, the capital of Thailand



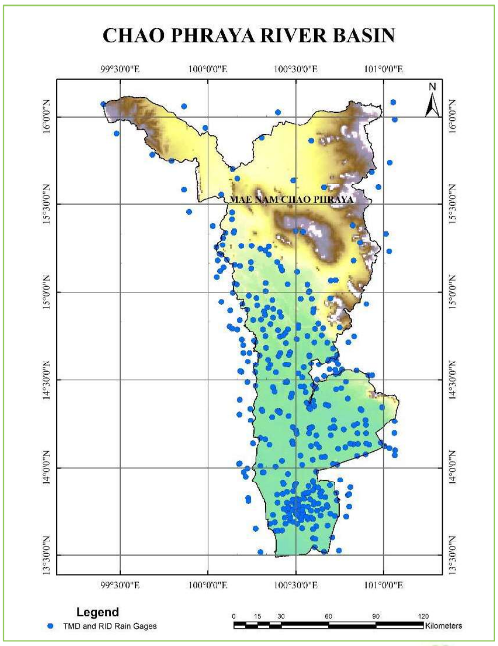
RAINFALL DATA

RAIN GAGE DATA

- Rain gages of Thai Meteorological Department (TMD) and Royal Irrigation Department (RID)
- From 381 stations with daily precipitation records from 2000 to 2010

SATELLITE DATA

- Satellite-based rainfall data from Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks - Cloud Classification System (PERSIANN-CCS)
- Resolution of 0.04 degree by 0.04 degree (approximately 4km by 4km) of year 2010



CROSS VALIDATION OF SPATIAL INTERPOLATED RAIN GAGE AND SATELLITE-RAINFALL OVER CHAO PHRAYA RIVER BASIN THAILAND
N.S. VENTURA, & P. RUANGRASSAMEE
CHULALONGKORN UNIVERSITY

METHODOLOGY

SPATIAL INTERPOLATION

INVERSE DISTANCE WEIGHING (IDW)

- Using the inverse of the distance from the known point to the unknown point to estimate the precipitation

INVERSE DISTANCE WEIGHING (IDW) EQUATION

$$z^*(u) = \frac{\sum_{i=1}^{n} \frac{z(u_i)}{d(u_i)^k}}{\sum_{i=1}^{n} \frac{1}{d(u_i)^k}}$$

where:

$z^*(u)$ is the predicted value at the location, u;
$z(u_i)$ are the actual values at each known location, u;
$d(u_i)$ is the distance of the each known location, u, from the predicated value location;
k is the exponent of the distance weight

- In the study, two IDW interpolations were computed with values of the exponents; k=1 and k=2

SPATIAL INTERPOLATION

KRIGING AND SEMIVARIOGRAMS

- Similar to IDW, distance from known points to unknown points would be considered in Kriging but using Semivariogram models
- A Semivariogram is the representation of the spatial correlation of every point to each other in a given dataset

EMPERICAL SEMIVARIOGRAM EQUATION

$$\gamma(h) = \frac{1}{2n(h)} \sum_{i=1}^{n(h)} [z(u_i) - z(u_{i+h})]^2$$

where:

$\gamma(h)$ is the variogram at the lag distance, h;

n(h) is the number of data pairs falling in the same lag distance, h;

z(u) is the value at location, u

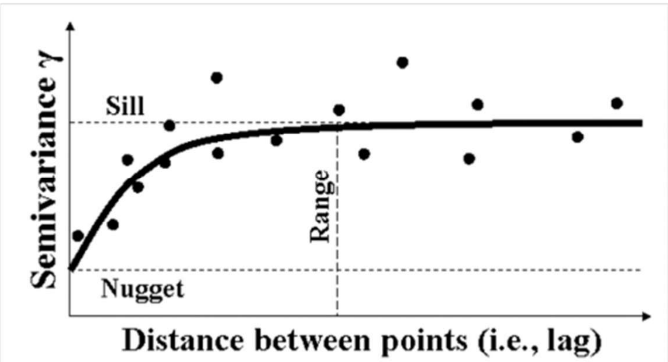
SPATIAL INTERPOLATION

SEMIVARIOGRAM MODELS

- Empirical semivariograms are non continuous; theoretical semivariograms from mathematical models would be used to fit the dataset to the function

- The theoretical semivariogram parameters are the sill, range, and nugget

- The Spherical, Exponential, and Gaussian semivariogram models were used in this study



Source: https://wiki.landscapetoolbox.org/doku.php/spatial_analysis_methods:semivariogram_analysis

CROSS VALIDATION OF SPATIAL INTERPOLATED RAIN GAGE AND SATELLITE-RAINFALL OVER CHAO PHRAYA RIVER BASIN THAILAND

N.S. VENTURA, & P. RUANGRASSAMEE
CHULALONGKORN UNIVERSITY

SPATIAL INTERPOLATION

SEMIVARIOGRAM MODELS

SPHERICAL SEMIVARIOGRAM

$$\gamma(h)=\begin{cases} c\left(\dfrac{3h}{2a}-\dfrac{1h^3}{2a^2}\right), & h\leq a \\ c, & h>a \end{cases}$$

EXPONENTIAL SEMIVARIOGRAM

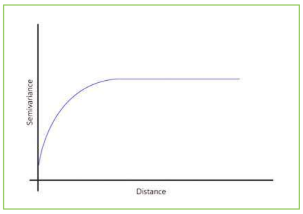
$$\gamma(h)=\left\{c\left[1-e^{-\left(\frac{h}{a}\right)}\right],\ h>0\right.$$

GAUSSIAN SEMIVARIOGRAM

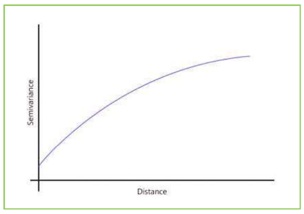
$$\gamma(h)=\left\{c\left[1-e^{-\left(\frac{h}{a}\right)^2}\right],\ h>0\right.$$

where: c is the sill; a is the range

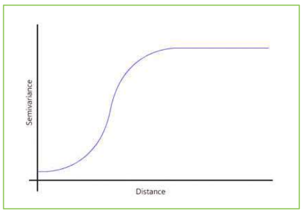
SPHERICAL



EXPONENTIAL



GAUSSIAN



SPATIAL INTERPOLATION

KRIGING AND SEMIVARIOGRAMS

- The study also tried to bin the pairs not only spatially but also temporally (monthly)
- Once the semivariogram parameters have been determined,

KRIGING EQUATION

$$z^*(u)=\sum_{i=1}^{n}\lambda_i\cdot z(u_i)$$

where:

λ_i is the Kriging weight for each known value determined from the semivariogram model
$z(u)$ is the value at location, u

- The study considered the closest 5 points for the interpolation

CROSS VALIDATION OF SPATIAL INTERPOLATED RAIN GAGE AND SATELLITE-RAINFALL OVER CHAO PHRAYA RIVER BASIN THAILAND
N.S. VENTURA, & P. RUANGRASSAMEE
CHULALONGKORN UNIVERSITY

CROSS VALIDATION

LEAVE-ONE-OUT CROSS VALIDATION

- Each data point is removed from the dataset one by one and would be treated as an unknown point to be computed using the interpolation method
- Computed and actual values were statistically compared using Mean Absolute Error (MAE), Root-Mean-Square Error (RMSE), and its Correlation Coefficient (CORR).

$$\text{MAE}=\frac{1}{n}\sum_{i=1}^{n}\left|z(u_i)-z^*(u_i)\right| \qquad \text{RMSE}=\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[z(u_i)-z^*(u_i)\right]^2}$$

$$\text{CORR}=\frac{\sum_{i=1}^{n}\left[z^*(u_i)-\bar{z}^*\right]\left[z(u_i)-\bar{z}\right]}{\sqrt{\sum_{i=1}^{n}\left[z^*(u_i)-\overline{z^*}\right]^2}\times\sqrt{\sum_{i=1}^{n}\left[z(u_i)-\bar{z}\right]^2}}$$

- Only days with occurrence of rainfall for both observed and computed was considered

SATELLITE DATA ANALYSIS

COMPARING SATELLITE DATA

- Similar to the cross validation, MAE, RMSE, and CORR were used
- The interpolated output and satellite data would be considered as observed and as computed respectively

CROSS VALIDATION OF SPATIAL INTERPOLATED RAIN GAGE AND SATELLITE-RAINFALL OVER CHAO PHRAYA RIVER BASIN THAILAND

N.S. VENTURA, & P. RUANGRASSAMEE
CHULALONGKORN UNIVERSITY

RESULTS AND DISCUSSIONS

MONTHLY SEMIVARIOGRAM PARAMETERS

SEMIVARIOGRAM PARAMETERS

- The data pairs were binned for every month from 2000 to 2009.
- This method provided faster computations compared to traditional Kriging methods

MON	2000 - 2009					
	SPHERICAL		EXPONENTIAL		GAUSSIAN	
	RANGE	SILL	RANGE	SILL	RANGE	SILL
JAN	0.02033	2.56	0.00662	2.56	0.00877	2.56
FEB	0.12217	8.10	0.04941	8.12	0.04867	8.09
MAR	0.20371	20.46	0.10798	20.72	0.06924	20.35
APR	0.08366	38.18	0.05352	38.47	0.02984	38.10
MAY	0.14748	59.27	0.12965	60.72	0.05586	59.11
JUN	0.32412	61.89	0.95885	84.74	0.10901	61.32
JUL	0.17929	47.79	0.09810	48.36	0.06445	47.60
AUG	0.26584	54.26	0.14834	55.29	0.09059	53.87
SEP	0.22198	108.11	0.32225	117.20	0.06145	107.12
OCT	0.05289	62.95	0.77177	81.79	0.01868	62.88
NOV	0.02484	12.77	0.01074	12.78	0.00921	12.77
DEC	0.00658	2.54	0.00138	2.54	0.00313	2.54

CROSS VALIDATION OF SPATIAL INTERPOLATED RAIN GAGE AND SATELLITE-RAINFALL OVER CHAO PHRAYA RIVER BASIN THAILAND

N.S. VENTURA, & P. RUANGRASSAMEE
CHULALONGKORN UNIVERSITY

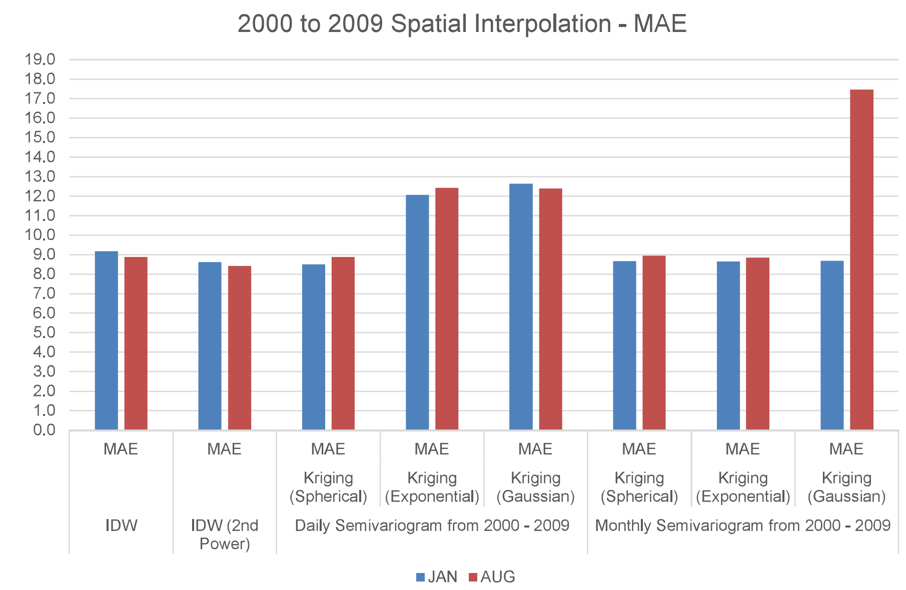
CROSS VALIDATION AT 2000 TO 2009

CROSS VALIDATION RESULTS

- Generally, IDW had faster computations than Kriging
- Kriging using the monthly semivariogram parameter was faster than the traditional daily Kriging which took twice as long

MONTH	IDW			IDW (2nd Power)			Daily Semivariogram from 2000 - 2009									Monthly Semivariogram from 2000 - 2009								
							Kriging (Spherical)			Kriging (Exponential)			Kriging (Gaussian)			Kriging (Spherical)			Kriging (Exponential)			Kriging (Gaussian)		
	MAE	RMSE	CORR	MAE	RMSE	CORR	MAE	RMSE	CORR	MAE	RMSE	CORR	MAE	RMSE	CORR	MAE	RMSE	CORR	MAE	RMSE	CORR	MAE	RMSE	CORR
JAN	9.2	16.9	0.41	8.6	15.9	0.47	8.5	13.3	0.59	12.1	18.2	0.35	12.6	19.0	0.33	8.7	13.7	0.56	8.6	13.6	0.56	8.7	13.7	0.56
FEB	10.4	17.9	0.57	10.0	16.7	0.61	10.2	16.0	0.66	13.9	22.2	0.43	13.5	21.4	0.44	10.2	16.1	0.66	10.3	16.3	0.65	12.7	23.3	0.49
MAR	10.4	17.6	0.42	9.9	16.5	0.49	10.2	16.5	0.51	13.6	20.7	0.36	13.7	20.6	0.36	10.3	16.5	0.51	10.2	16.5	0.51	20.1	72.3	0.19
APR	12.3	20.0	0.49	11.7	19.0	0.53	12.3	19.5	0.53	17.1	25.7	0.32	16.9	25.5	0.33	12.4	19.6	0.53	12.3	19.4	0.53	16.2	42.3	0.26
MAY	9.4	15.3	0.46	8.9	14.6	0.51	9.4	15.0	0.51	13.0	20.0	0.31	12.9	19.7	0.32	9.4	15.0	0.51	9.4	15.0	0.51	18.1	103.0	0.09
JUN	8.9	14.9	0.45	8.5	14.3	0.51	8.9	14.6	0.51	12.0	19.2	0.31	12.1	19.4	0.31	9.0	15.0	0.49	9.0	14.9	0.50	28.0	214.7	0.06
JUL	8.3	14.6	0.47	7.8	13.8	0.53	8.2	13.8	0.54	11.1	17.5	0.36	11.1	17.7	0.36	8.3	13.8	0.54	8.2	13.7	0.55	13.1	41.9	0.20
AUG	8.9	14.8	0.50	8.4	14.1	0.54	8.9	14.6	0.54	12.4	19.3	0.35	12.4	19.3	0.35	9.0	14.7	0.53	8.9	14.5	0.54	17.5	66.2	0.16
SEP	10.9	18.9	0.53	10.4	18.2	0.57	10.9	18.2	0.58	15.0	25.2	0.38	15.0	25.4	0.38	11.0	19.0	0.56	11.0	19.0	0.56	25.8	150.6	0.11
OCT	10.3	16.9	0.46	9.7	16.0	0.52	10.2	16.4	0.53	14.1	21.6	0.35	14.1	21.6	0.35	10.2	16.3	0.53	10.4	16.8	0.52	34.6	232.8	0.07
NOV	10.5	17.0	0.51	9.9	16.1	0.55	10.2	16.2	0.55	14.3	21.7	0.38	14.4	21.9	0.38	10.2	16.1	0.56	10.1	16.0	0.56	10.2	16.5	0.54
DEC	9.1	15.7	0.38	8.7	14.7	0.43	8.2	13.8	0.50	10.7	16.4	0.35	11.0	17.1	0.32	8.5	14.2	0.47	8.5	14.2	0.47	8.5	14.2	0.47

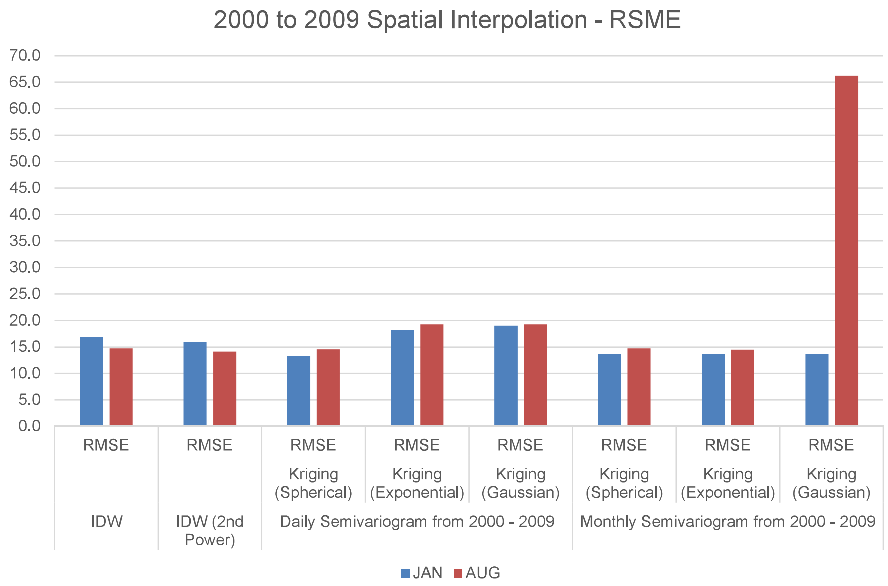
CROSS VALIDATION AT 2000 TO 2009



CROSS VALIDATION OF SPATIAL INTERPOLATED RAIN GAGE AND SATELLITE-RAINFALL OVER CHAO PHRAYA RIVER BASIN THAILAND

N.S. VENTURA, & P. RUANGRASSAMEE
CHULALONGKORN UNIVERSITY

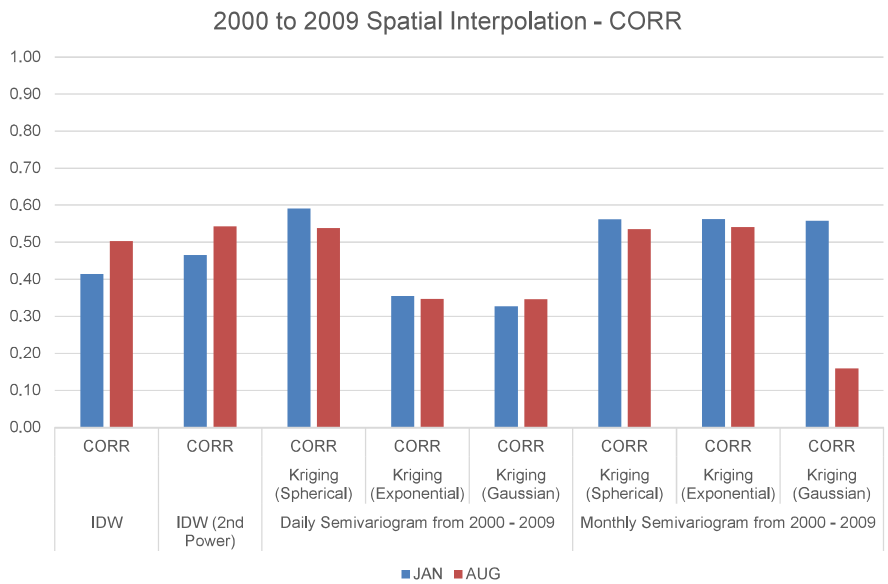
CROSS VALIDATION AT 2000 TO 2009



CROSS VALIDATION OF SPATIAL INTERPOLATED RAIN GAGE AND SATELLITE-RAINFALL OVER CHAO PHRAYA RIVER BASIN THAILAND

N.S. VENTURA, & P. RUANGRASSAMEE
CHULALONGKORN UNIVERSITY

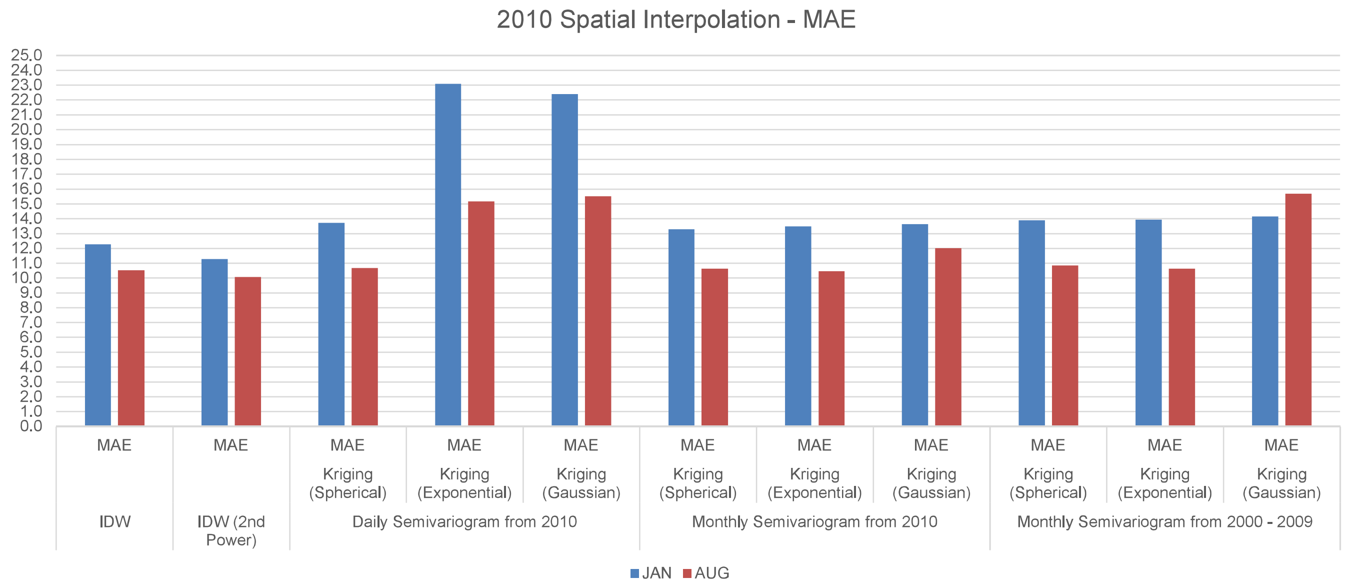
CROSS VALIDATION AT 2000 TO 2009



CROSS VALIDATION OF SPATIAL INTERPOLATED RAIN GAGE AND SATELLITE-RAINFALL OVER CHAO PHRAYA RIVER BASIN THAILAND

N.S. VENTURA, & P. RUANGRASSAMEE
CHULALONGKORN UNIVERSITY

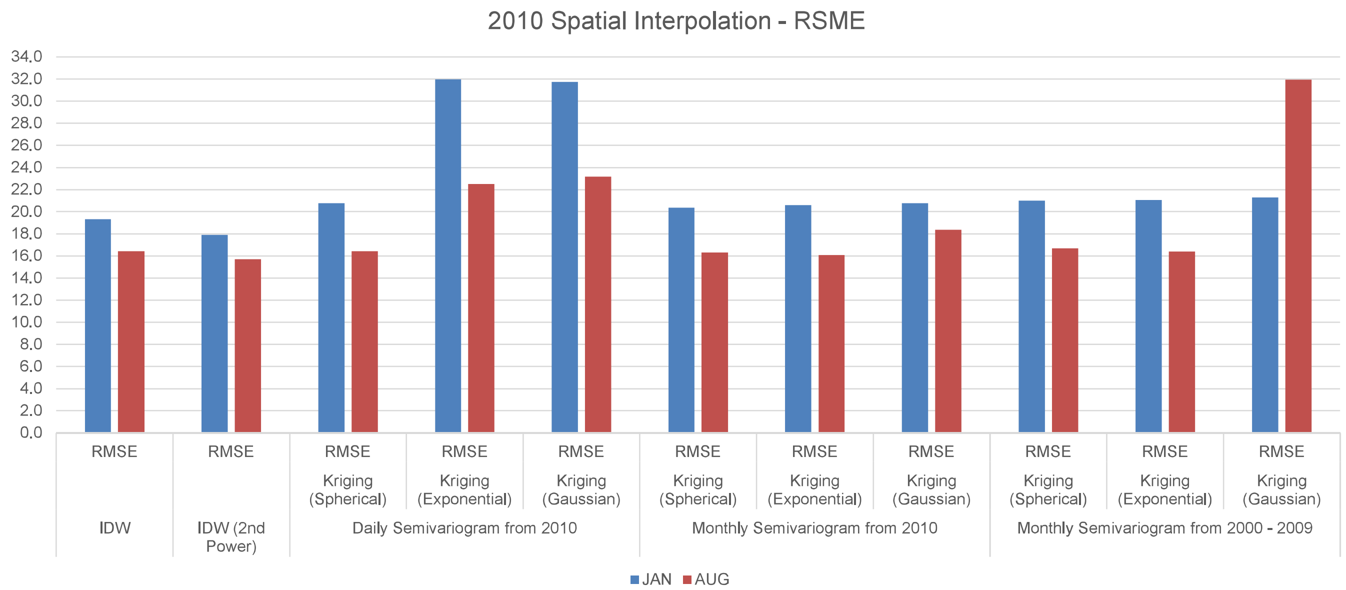
CROSS VALIDATION AT 2010



CROSS VALIDATION OF SPATIAL INTERPOLATED RAIN GAGE AND SATELLITE-RAINFALL OVER CHAO PHRAYA RIVER BASIN THAILAND

N.S. VENTURA, & P. RUANGRASSAMEE
CHULALONGKORN UNIVERSITY

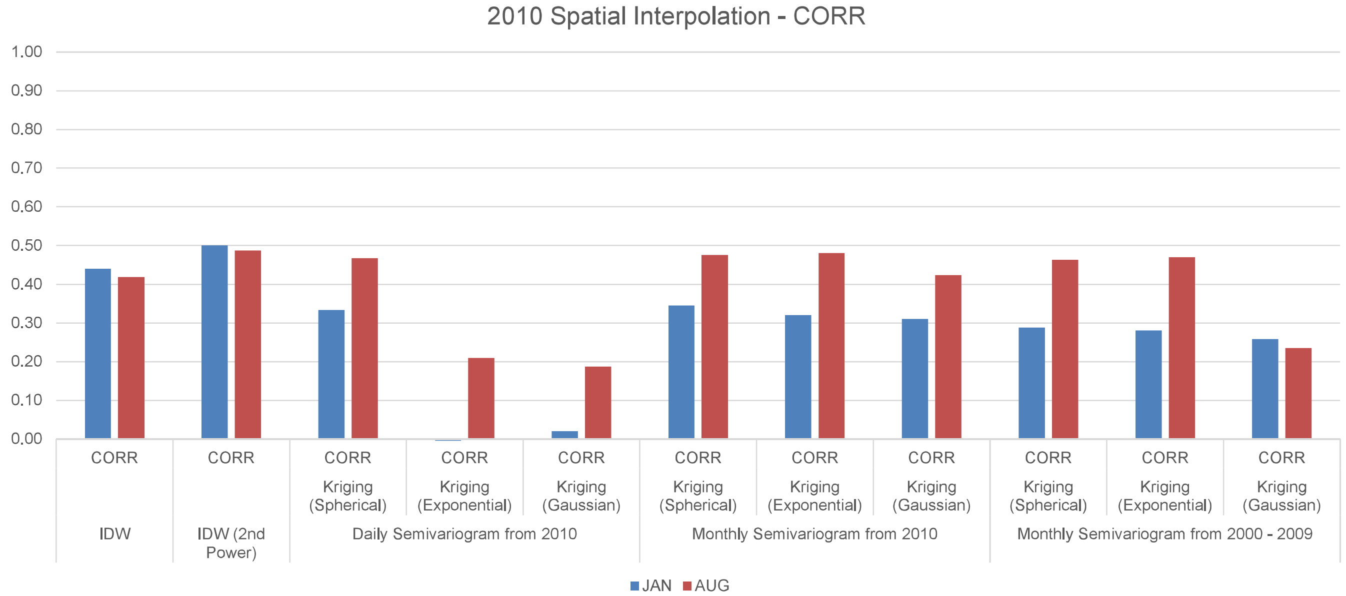
CROSS VALIDATION AT 2010



CROSS VALIDATION OF SPATIAL INTERPOLATED RAIN GAGE AND SATELLITE-RAINFALL OVER CHAO PHRAYA RIVER BASIN THAILAND

N.S. VENTURA, & P. RUANGRASSAMEE
CHULALONGKORN UNIVERSITY

CROSS VALIDATION AT 2010

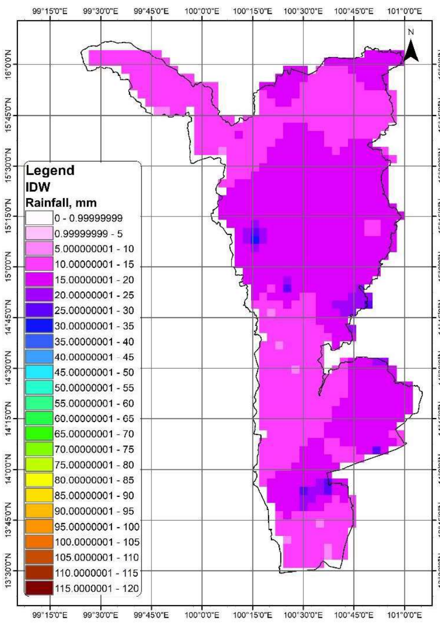


CROSS VALIDATION OF SPATIAL INTERPOLATED RAIN GAGE AND SATELLITE-RAINFALL OVER CHAO PHRAYA RIVER BASIN THAILAND

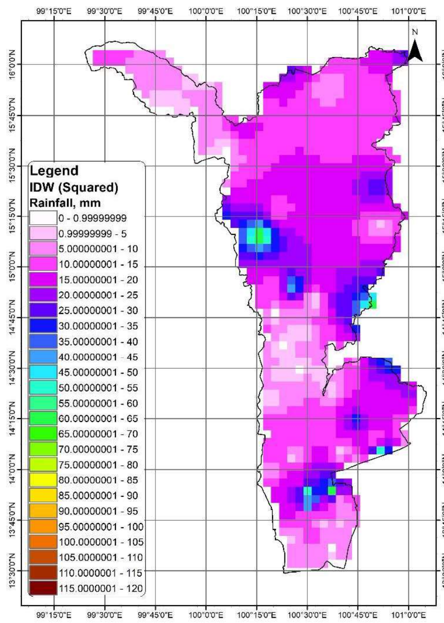
N.S. VENTURA, & P. RUANGRASSAMEE
CHULALONGKORN UNIVERSITY

CROSS VALIDATION AT 2010

IDW



IDW2

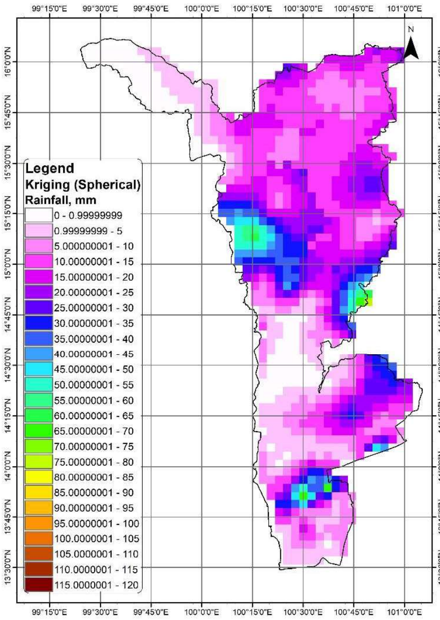


CROSS VALIDATION OF SPATIAL INTERPOLATED RAIN GAGE AND SATELLITE-RAINFALL OVER CHAO PHRAYA RIVER BASIN THAILAND

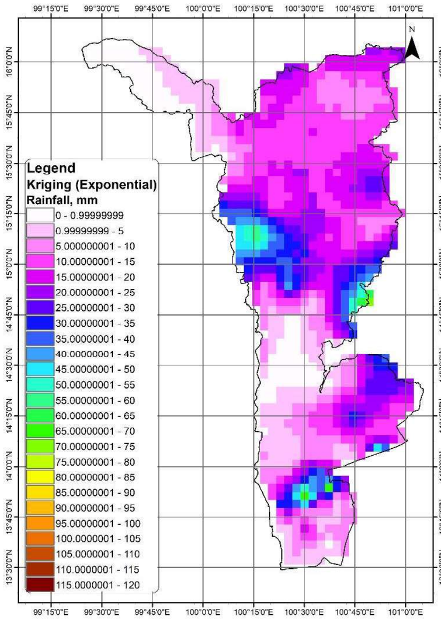
N.S. VENTURA, & P. RUANGRASSAMEE
CHULALONGKORN UNIVERSITY

CROSS VALIDATION AT 2010

Kriging Spherical

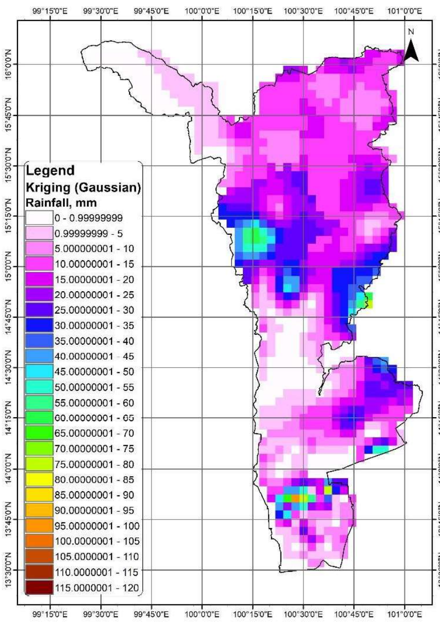


Kriging Exponential

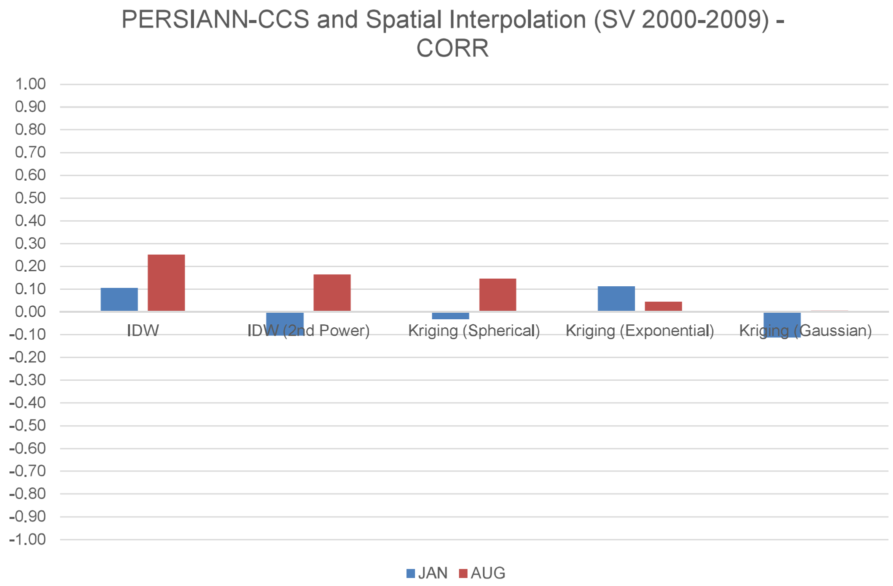


CROSS VALIDATION AT 2010

Kriging Gaussian

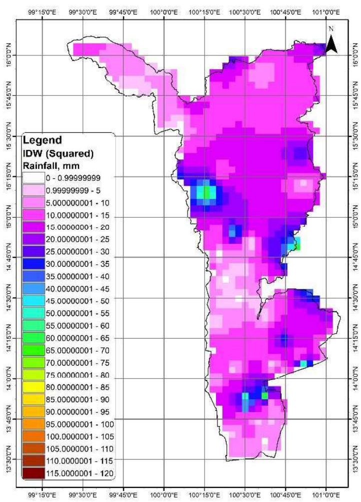


COMPARISON OF PERSIANN-CCS AND SPATIALLY INTERPOLATED DATA

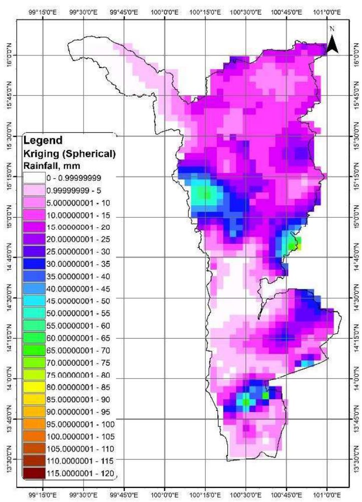


COMPARISON OF PERSIANN-CCS AND SPATIALLY INTERPOLATED DATA

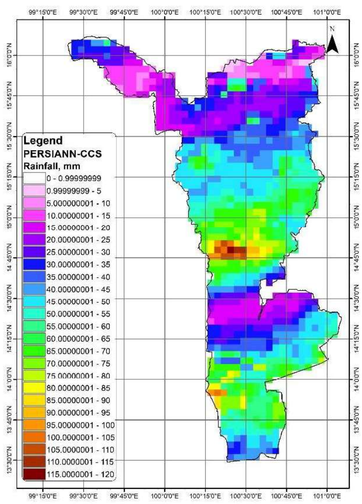
IDW2



Kriging Spherical



PERSIANN-CCS



CROSS VALIDATION OF SPATIAL INTERPOLATED RAIN GAGE AND SATELLITE-RAINFALL OVER CHAO PHRAYA RIVER BASIN THAILAND

N.S. VENTURA, & P. RUANGRASSAMEE
CHULALONGKORN UNIVERSITY

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSION AND RECOMMENDATION

CONCLUSION

- The Kriging with Spherical Semivariogram resulted the highest correlations and lower error values among the selected methodologies
- On the other hand, IDW interpolation provided more consistent results than Kriging with Exponential and Gaussian Semivariogram
- Of the three Kriging methods, the one with Spherical Semivariogram performed the best followed by with Exponential Semivariogram and then with Gaussian Semivariogram
- Using the monthly semivariogram for the same dataset instead of the daily semivariogram would be acceptable.
- The correlation between the satellite data and the interpolation output is quite low which demonstrate the need for bias correction.

CONCLUSION AND RECOMMENDATION

RECOMMENDATIONS

- Using other more advanced interpolation techniques would be recommended as it may reduce the errors and increase the correlation of the cross validation and also the comparisons.

- Accounting for the temporal characteristic of rainfall in the interpolation would also be recommended.

THANK YOU VERY MUCH FOR YOUR ATTENTION!

CROSS VALIDATION OF SPATIAL INTERPOLATED RAIN GAGE AND SATELLITE-RAINFALL OVER CHAO PHRAYA RIVER BASIN THAILAND

N.S. VENTURA, & P. RUANGRASSAMEE
CHULALONGKORN UNIVERSITY