2010 International SWAT Conference

Modification of stream water temperature calculation equation of SWAT for the Han River Korea using regression analysis

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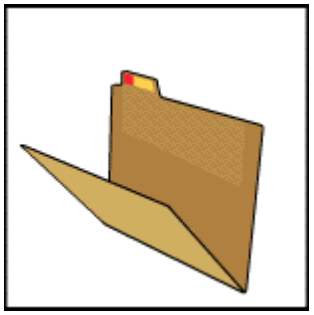
INTRODUCTION



BACKGROUNDS

- ✓ **Water temperature** is an important physical variable in **aquatic ecosystems**.
- ✓ It can affect both **chemical and biological processes** such as **dissolved oxygen concentration** and both the metabolism and growth of aquatic organisms.

(Loubna Benyahya et al., 2007)

BACKGROUNDS

- ✓ SWAT uses an equation developed by Stefan and Preud'homme (1993) to calculate daily water temperature. (SWAT 2005 – Theoretical Documentation)

Stream – air temperature relationship

$$Tw = 5.0 + 0.75\,Ta$$

Tw : water temperature for the day (°C)

Ta : average air temperature on the day (°C)

- ✓ Derived from records of 11 streams in the **Central U.S.** (Mississipi River basin) (Stefan and Preud'homme, 1993)

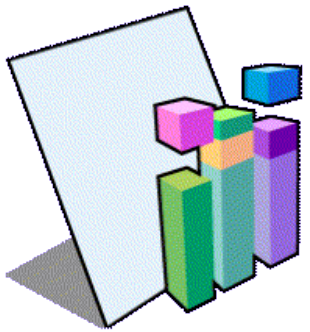
BACKGROUNDS

- ✓ How is stream water temperature related with air temperature in KOREA?
- ✓ Are there any other factors affecting water temperature?
- ✓ Is stream-air temperature relationship uniform according to the magnitude of river?
- ✓ Which factors are sensitive to water temperature change?

PROCEDURE

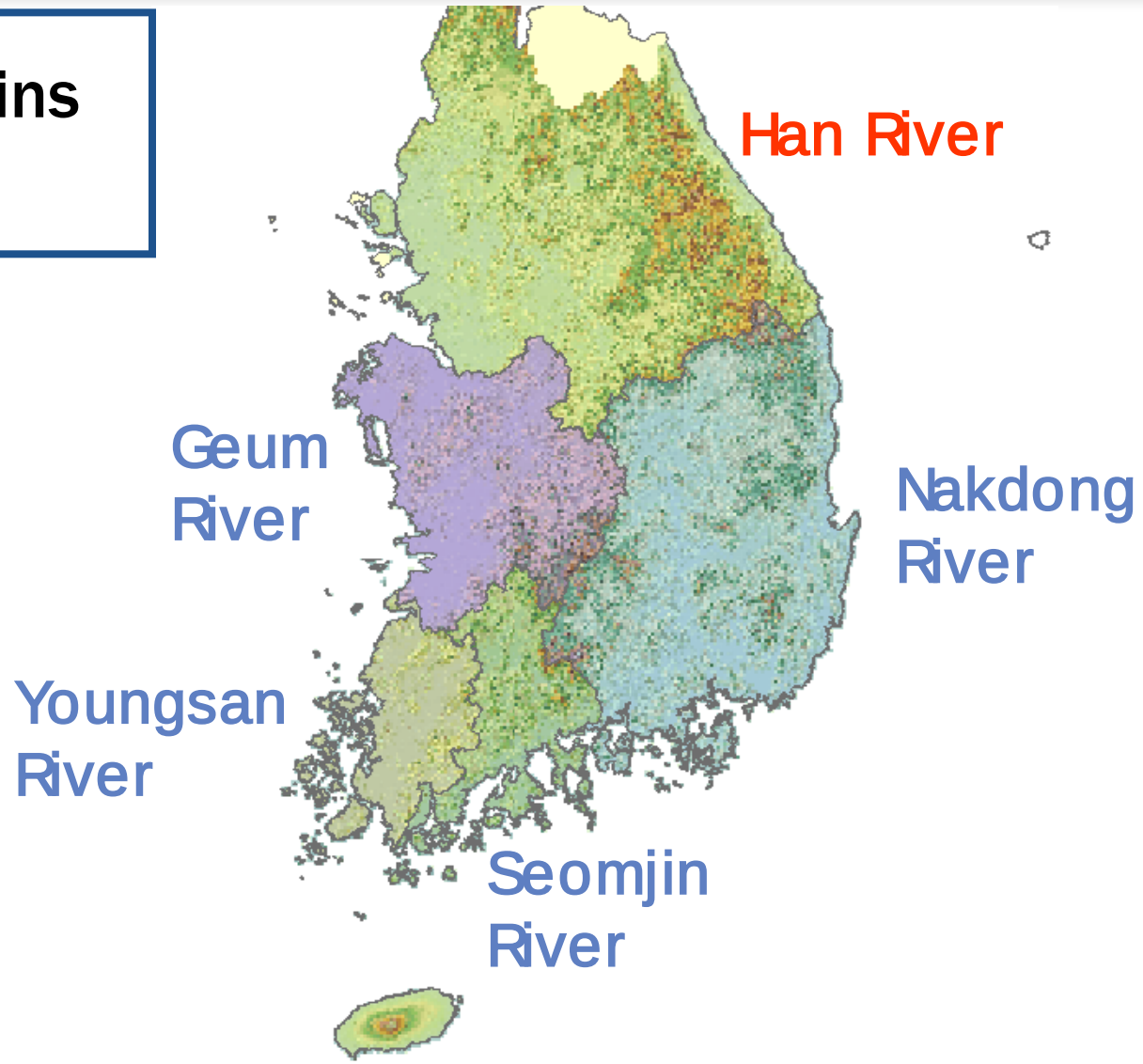
- ✓ Selection of test basin
- ✓ Stream, air temperature data collection
- ✓ Stream-air temperature relationship derivation
- ✓ Comparison of results
- ✓ Application to dissolved/saturation oxygen concentration estimation

STREAM-AIR TEMPERATURE RELATIONSHIP IN HAN RIVER BASIN, KOREA

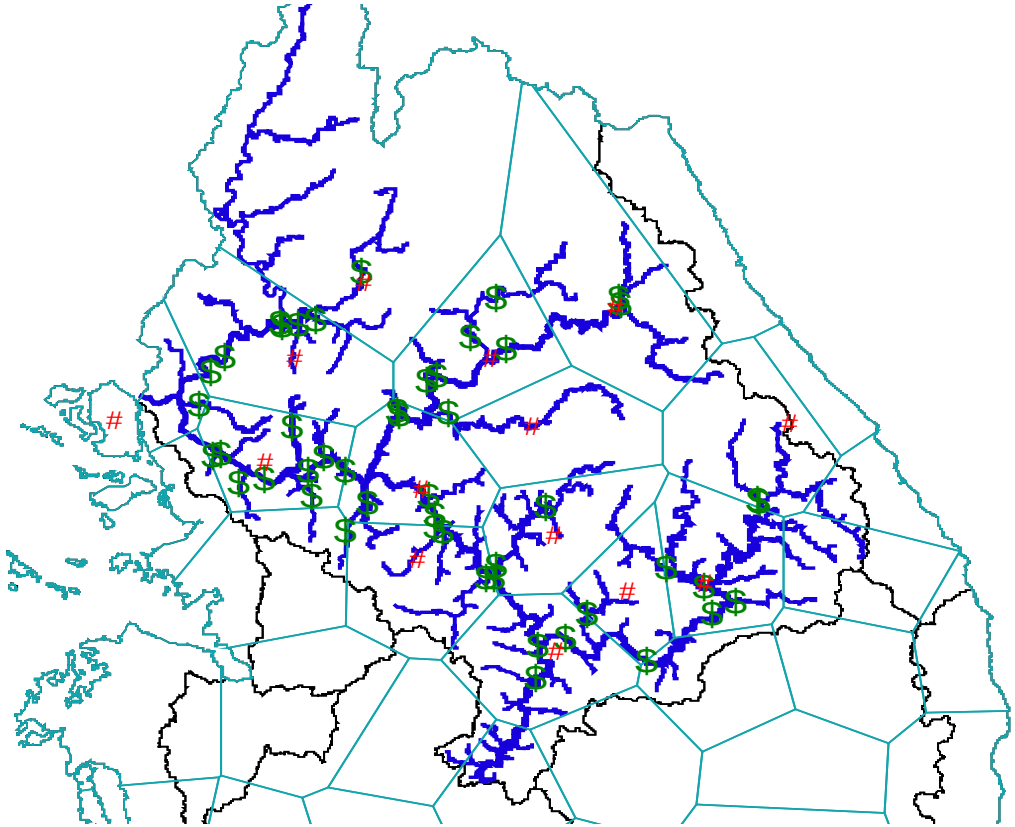


TEST BASIN

- ✓ 5 Major River basins of KOREA

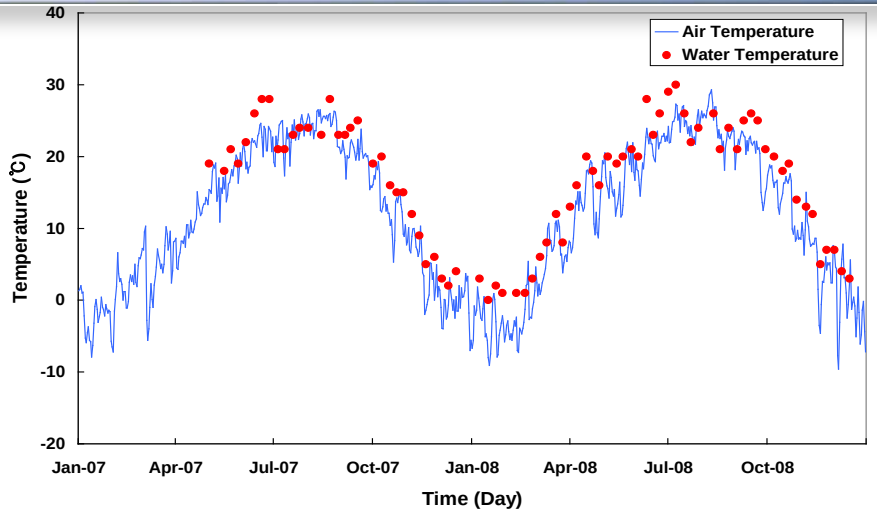


DATA COLLECTION

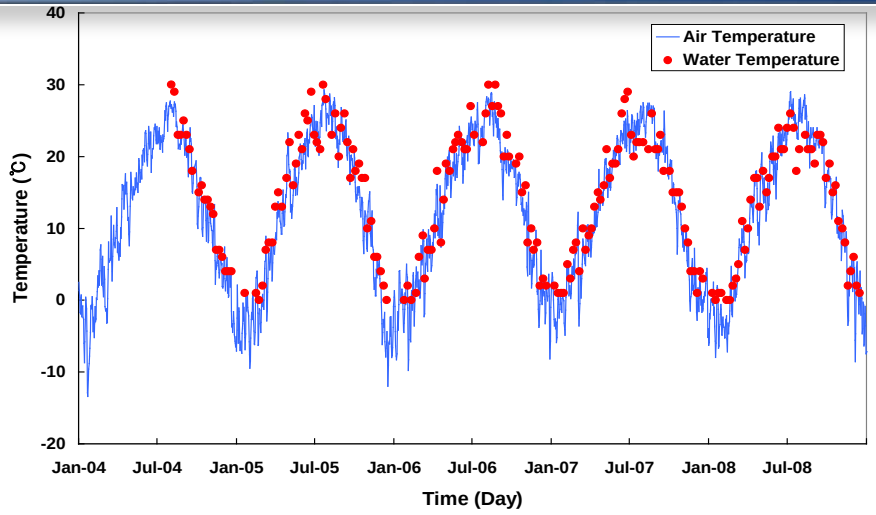


- ✓ 14 weather stations (KMA): daily average air temperature
- ✓ 48 water quality measuring points (ME): (8 days interval)

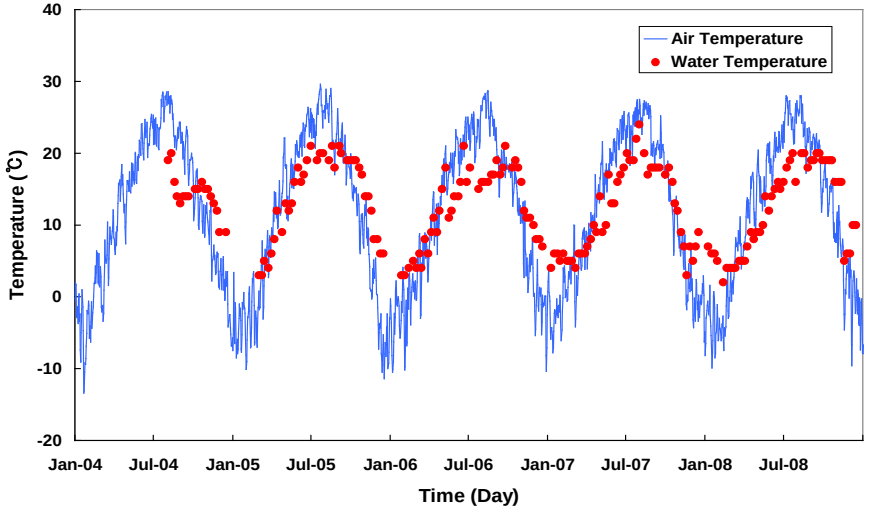
DATA COLLECTION



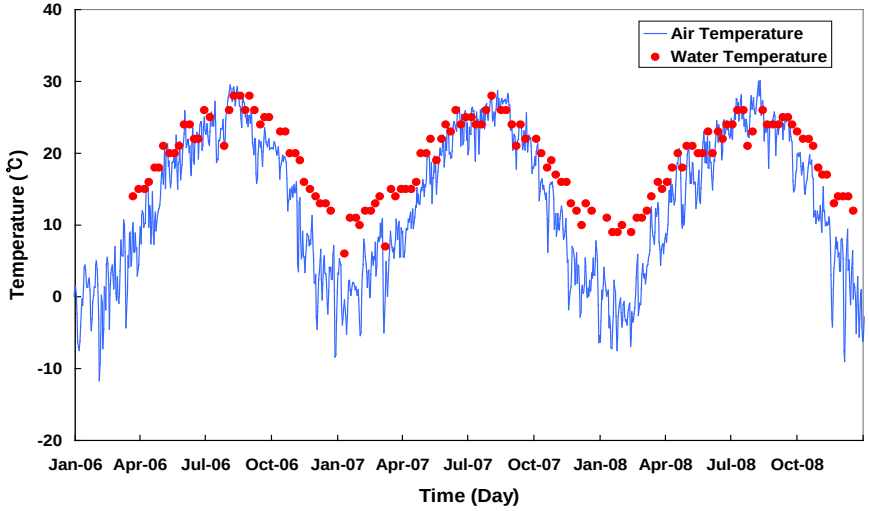
Hantan B



Jojong A



Bukhan A (Hwacheon Dam)

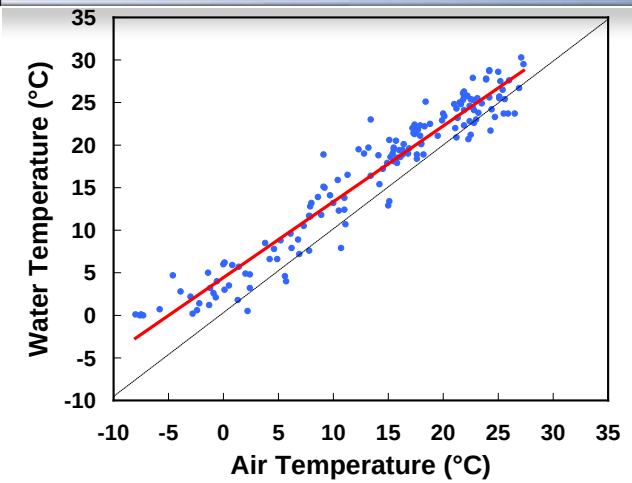


Tancheon A (Urban area)

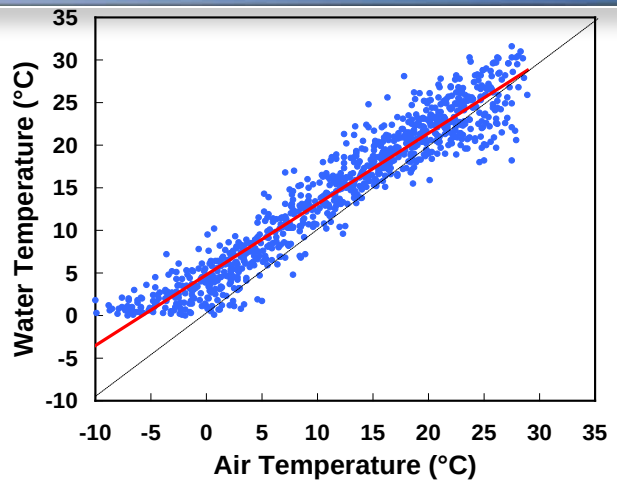
DATA COLLECTION

✓ Selection of 33 points among 48 water quality measuring points except dams (7) and urban areas (8)

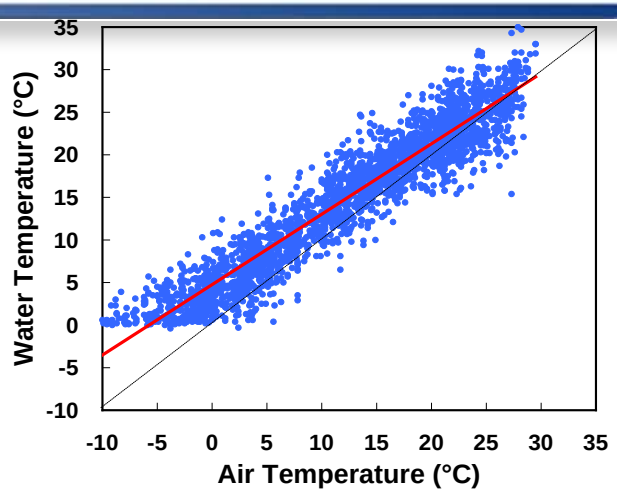
DATA ANALYSIS



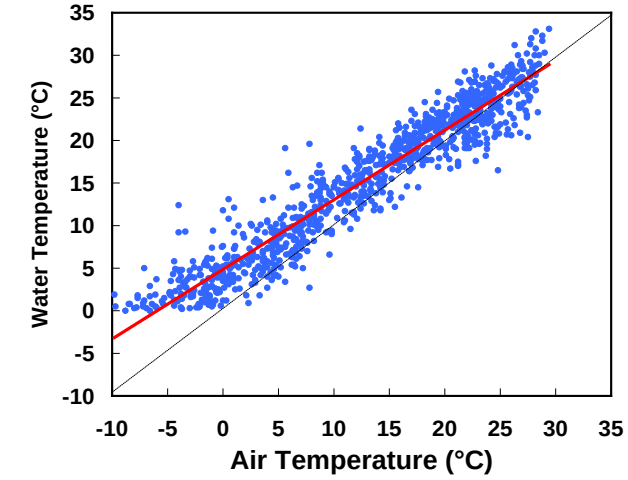
Stream Order 3, 4



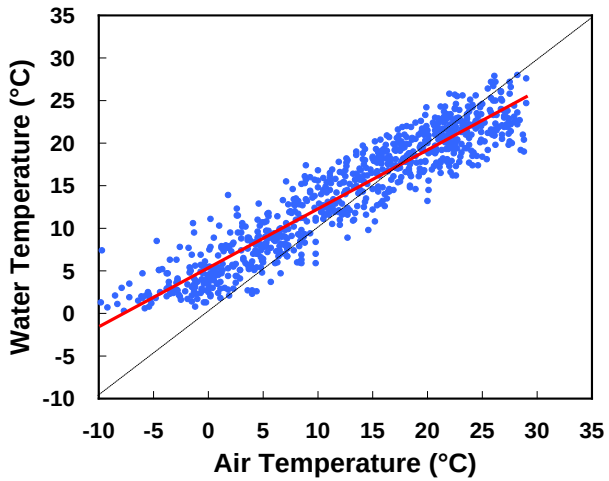
Stream Order 5



Stream Order 6



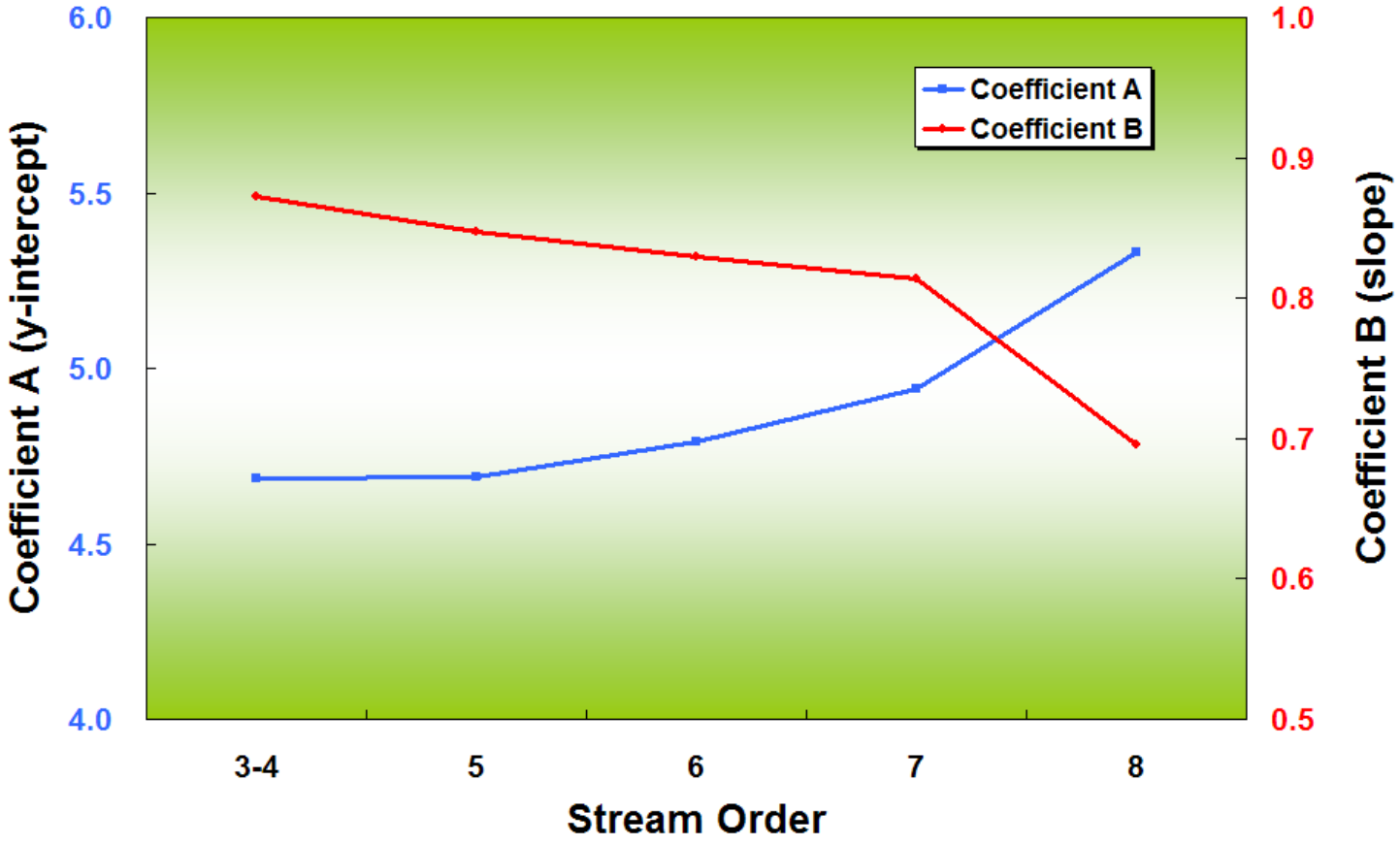
Stream Order 7



Stream Order 8

- ✓ Tw = A + B Ta
- ✓ As stream order ↑
- ✓ A: ↓ B: ↑

DATA ANALYSIS



Variation of coefficients A and B (Tw = A + B Ta)

LINEAR REGRESSION

Measuring Point	Stream Order	R				NSC			
		D	D-1	D-2	D-3	D	D-1	D-2	D-3
Hantan B	3	0.9673	0.9639	0.9591	0.9419	0.8329	0.8319	0.8198	0.7898
Munsan A	4	0.9649	0.9572	0.9607	0.9494	0.8320	0.7833	0.7977	0.7768
Gapyeong A	5	0.9604	0.9587	0.9407	0.9257	0.8644	0.8535	0.8265	0.8128
Gyeongan A	5	0.9673	0.9666	0.9593	0.9532	0.8370	0.8240	0.8142	0.8135
Gokleung A	5	0.9711	0.9722	0.9618	0.9501	0.7829	0.7634	0.7582	0.7398
Odae A	5	0.9411	0.9334	0.9223	0.9168	0.6625	0.6419	0.6181	0.6056
Jojong A	5	0.9680	0.9691	0.9553	0.9351	0.9051	0.9036	0.8825	0.8527
Golji A	6	0.9539	0.9530	0.9342	0.9287	0.5834	0.5642	0.5205	0.5116
Bokha A	6	0.9605	0.9384	0.9127	0.8975	0.5989	0.5635	0.5314	0.4896
Seomgang A	6	0.9710	0.9663	0.9511	0.9404	0.8909	0.8777	0.8617	0.8409
Soyang A	6	0.9585	0.9610	0.9539	0.9381	0.9057	0.9108	0.8997	0.8701
Sincheon A	6	0.9607	0.9514	0.9355	0.9269	0.7649	0.7496	0.7042	0.6741
Yangwha A	6	0.9823	0.9713	0.9468	0.9342	0.8129	0.7888	0.7467	0.7110
Yeongpyeong A	6	0.9523	0.9512	0.9359	0.9281	0.8618	0.8589	0.8223	0.7997
Okdong A	6	0.9613	0.9560	0.9443	0.9268	0.8113	0.7989	0.7735	0.7531
Inbuk A	6	0.9595	0.9530	0.9406	0.9190	0.8809	0.8686	0.8512	0.8117
Imjin A	6	0.9649	0.9643	0.9640	0.9462	0.8830	0.8832	0.8796	0.8491
Jecheon A	6	0.9699	0.9689	0.9593	0.9369	0.8546	0.8565	0.8330	0.8102
Jucheon A	6	0.9616	0.9625	0.9436	0.9268	0.8401	0.8370	0.7985	0.7788
Cheongmi A	6	0.9707	0.9599	0.9421	0.9262	0.7831	0.7549	0.7317	0.7003
Hantan A	6	0.9693	0.9823	0.9760	0.9633	0.8842	0.9018	0.8804	0.8656
Hongcheon A	6	0.9594	0.9722	0.9623	0.9591	0.8705	0.8908	0.8778	0.8799
Heukcheon A	6	0.9600	0.9590	0.9453	0.9330	0.8859	0.8819	0.8613	0.8364
Gyeongan B	7	0.9673	0.9759	0.9657	0.9561	0.8685	0.8794	0.8617	0.8533
Dalcheon A	7	0.9684	0.9669	0.9542	0.9340	0.8226	0.8039	0.7882	0.7718
Dalcheon B	7	0.9319	0.9231	0.9123	0.8974	0.6833	0.6550	0.6329	0.6339
Seomgang B	7	0.9686	0.9648	0.9548	0.9441	0.8596	0.8440	0.8371	0.8098
Imjin B	7	0.9638	0.9651	0.9662	0.9649	0.8825	0.8807	0.8866	0.8759
Pyeongchang A	7	0.9623	0.9655	0.9565	0.9417	0.8861	0.8889	0.8652	0.8506
Hangang A	8	0.9652	0.9656	0.9630	0.9510	0.8771	0.8792	0.8696	0.8449
Hangang D	8	0.9033	0.8993	0.8970	0.9071	0.7215	0.7116	0.7121	0.7227
Hangang E	8	0.9587	0.9604	0.9475	0.9447	0.8465	0.8460	0.8365	0.8322
Hangang F	8	0.9453	0.9434	0.9414	0.9438	0.8462	0.8362	0.8314	0.8391

LINEAR REGRESSION

- ✓ Stream-air temperature relationship of each sub basin
- ✓ 33 regression equations for 33 sub basins

- ✓ Then, one averaged equation representing entire Han River basin was derived (Time lag was neglected).

$$Tw = 4.861 + 0.816\ Ta$$

$Tw = 5.0 + 0.75\ Ta$ (Stefan and Preud'homme)

MULTIPLE LINEAR REGRESSION

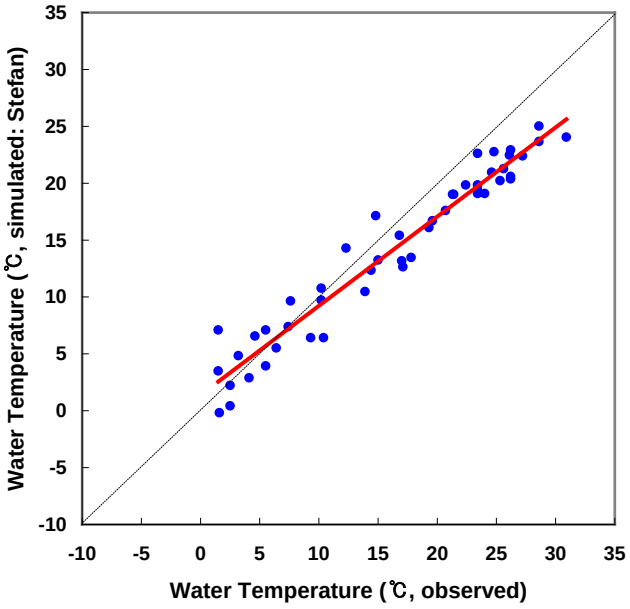
- ✓ Air temperature, wind speed, relative humidity, solar radiation, discharge

- ✓ Correlation with water temperature
  Air temperature > solar radiation, discharge > wind speed, relative humidity

- ✓ Selection of independent variables
  Air temperature + solar radiation

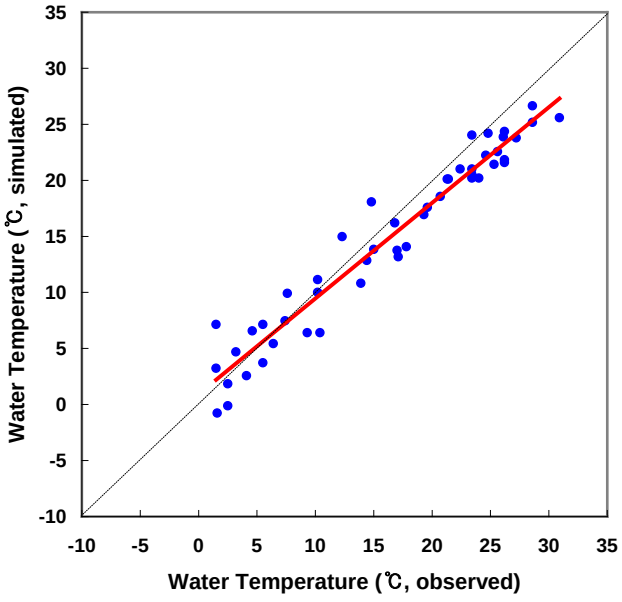
MULTIPLE LINEAR REGRESSION

NSC: 0.86 RMSE: 3.33



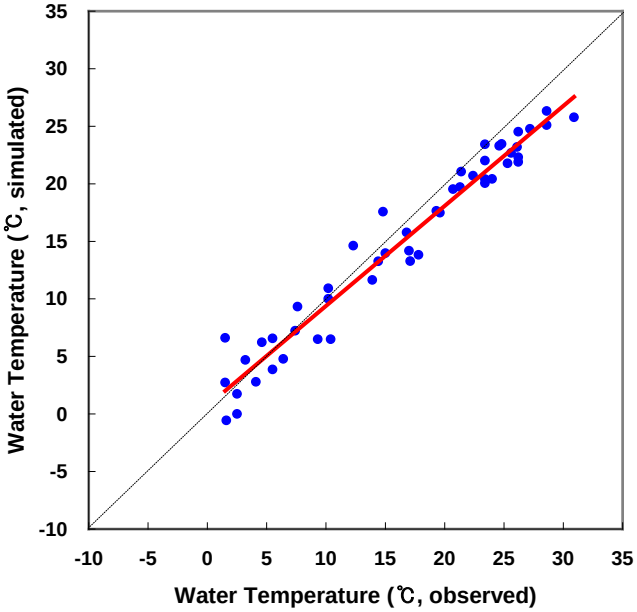
Stefan and Preud'homme

NSC: 0.91 RMSE: 2.70



REGRESSION (Ta)

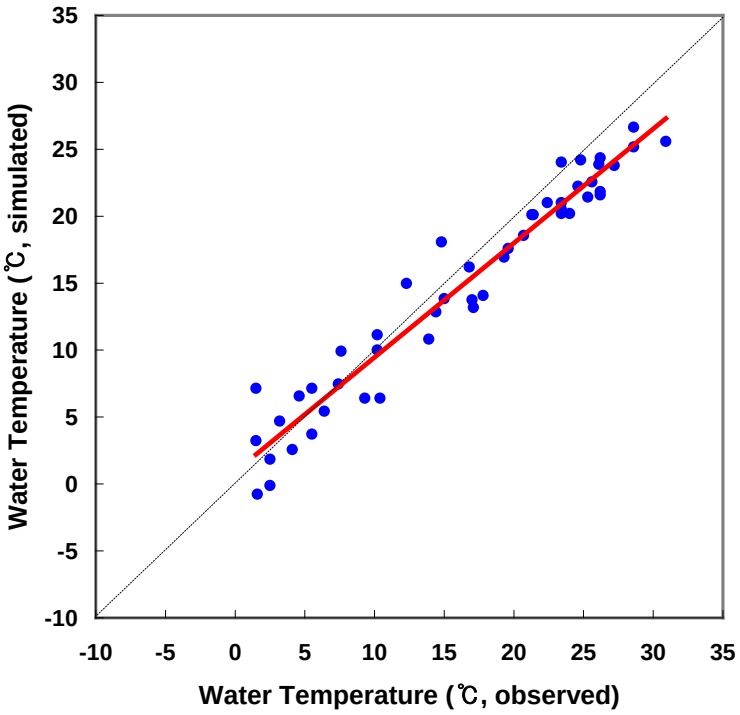
NSC: 0.92 RMSE: 2.50



MULTIPLE REGRESSION (Ta+SLR)

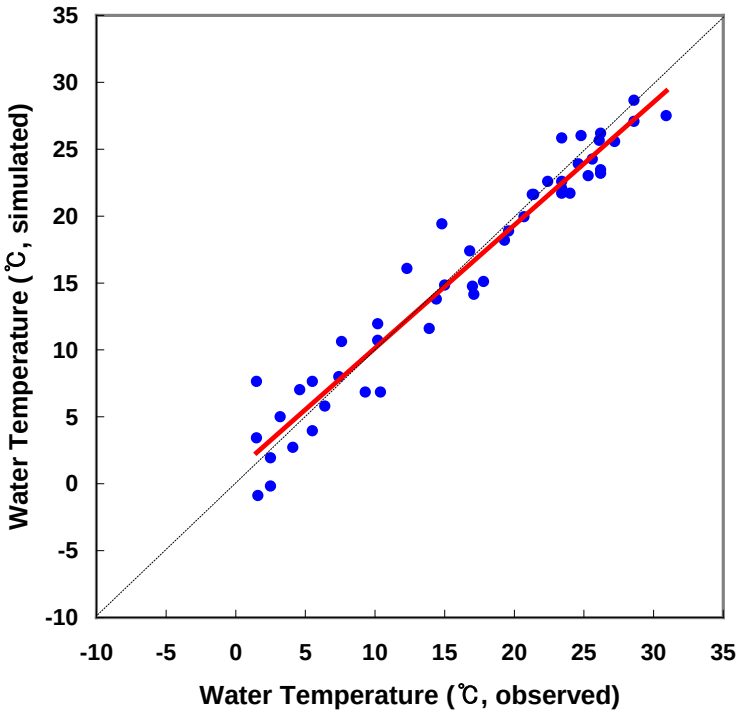
MULTIPLE LINEAR REGRESSION

NSC: 0.91 RMSE: 2.70



REGRESSION (Ta)

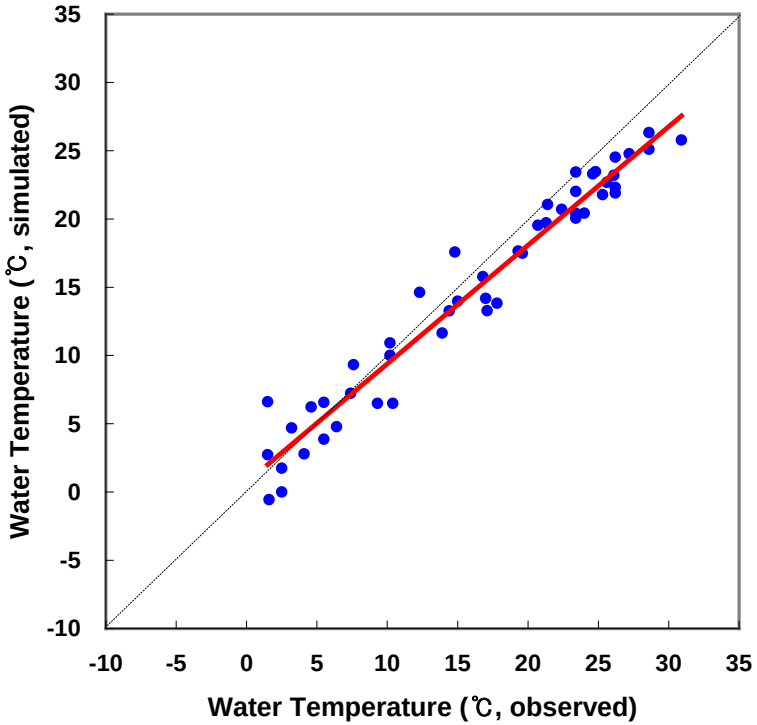
NSC: 0.94 RMSE: 2.16



REGRESSION (Ta): Sub basin

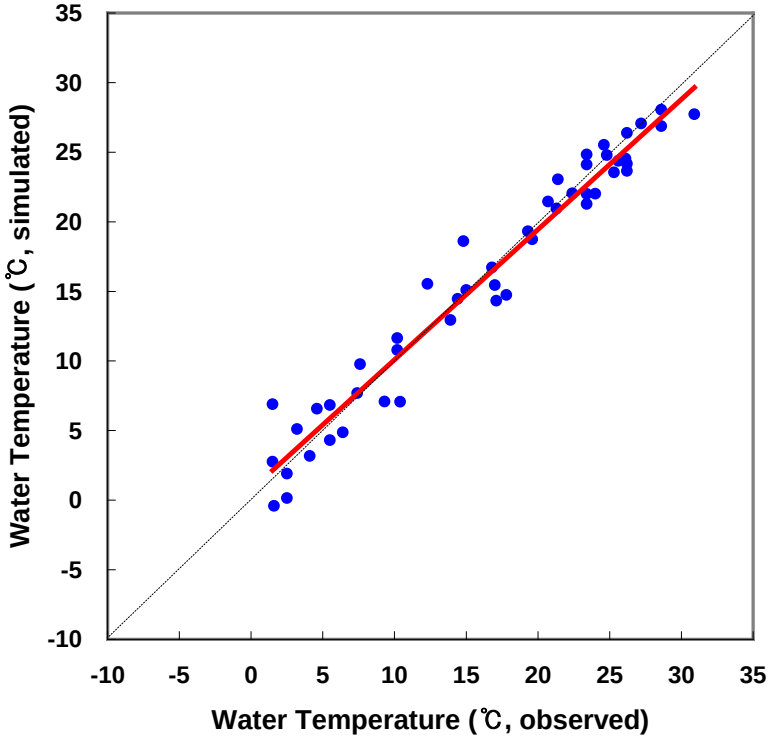
MULTIPLE LINEAR REGRESSION

NSC: 0.92 RMSE: 2.50



MULTIPLE REGRESSION (Ta+SLR)

NSC: 0.96 RMSE: 1.88



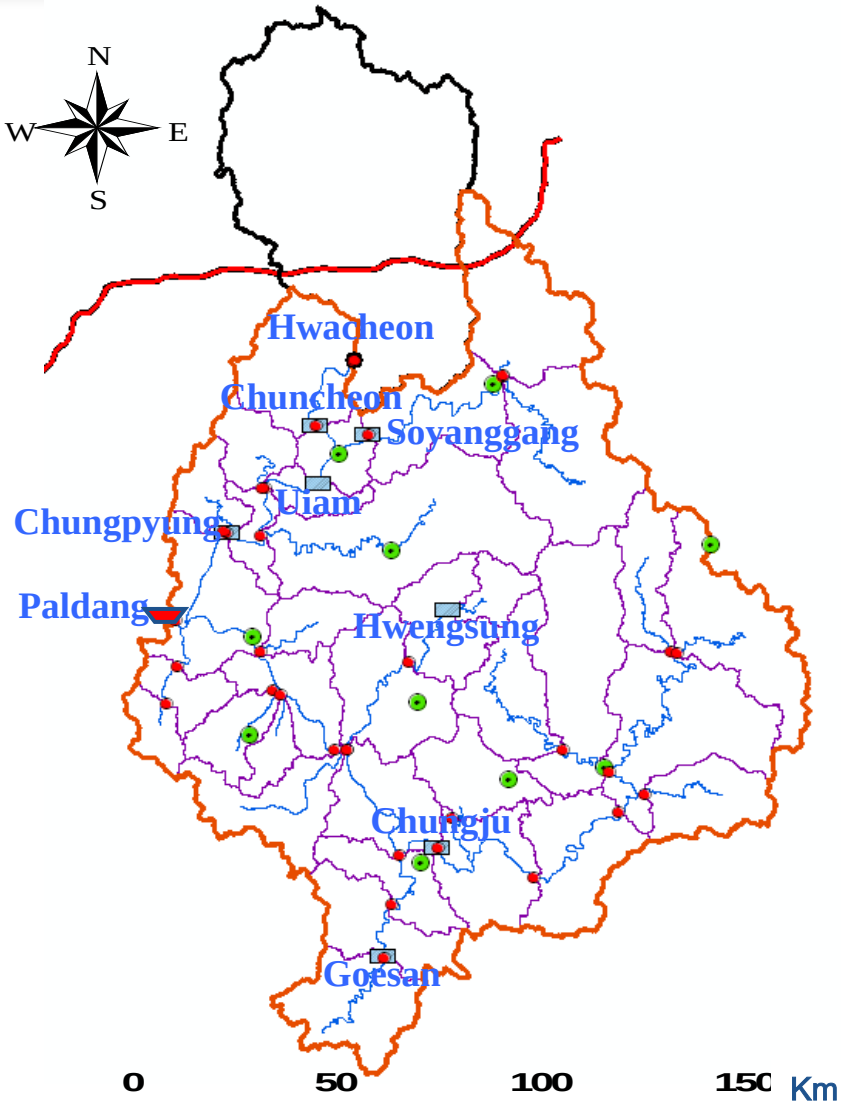
MULTIPLE REGRESSION (Ta+SLR): Sub basin

MULTIPLE LINEAR REGRESSION

✓ NSC, RMSE of each method

Measuring point	Stream Order	NSC					RMSE				
		Total (Ta)	Local (Ta)	Stefan	t SR (Total)	t SR (Local)	Total (Ta)	Local (Ta)	Stefan	t SR (Total)	t SR (Local)
Hantan B	3	0.9186	0.9264	0.8900	0.9307	0.9384	2.508	2.384	2.916	2.314	2.182
Munsan A	4	0.8820	0.9027	0.8414	0.8960	0.9229	3.154	2.863	3.656	2.961	2.598
Gapyeong A	5	0.8849	0.9004	0.9056	0.8884	8.9960	2.740	2.548	2.481	2.698	2.559
Gyeongan A	5	0.9156	0.9237	0.8754	0.9297	0.9373	2.519	2.394	3.061	2.298	2.17
Gokleung A	5	0.8773	0.9124	0.8273	0.8982	0.9305	3.086	2.607	3.661	2.811	2.322
Odae A	5	0.8397	0.8649	0.8146	0.8469	0.8680	3.256	2.990	3.502	3.182	2.388
Jojong A	5	0.9193	0.9057	0.8954	0.9323	0.9203	2.463	2.663	2.803	2.256	2.448
Golji A	6	0.8187	0.8868	0.7840	0.8325	0.8937	3.444	2.721	3.759	3.311	2.638
Bokha A	6	0.6865	0.8925	0.5937	0.7114	0.9425	4.821	2.823	5.488	4.625	2.065
Seomgang A	6	0.8841	0.6490	0.8631	0.8924	0.8903	3.019	5.255	3.282	2.909	2.938
Soyang A	6	0.8475	0.8889	0.8714	0.8452	0.8861	3.080	2.629	2.829	3.103	2.662
Sincheon A	6	0.9252	0.9218	0.8992	0.9280	0.9155	2.187	2.235	2.538	2.144	2.323
Yangwha A	6	0.9082	0.9412	0.8601	0.9212	0.9557	2.699	2.160	3.333	2.501	1.875
Yeongpyeong A	6	0.8664	0.8929	0.8857	0.8641	0.8738	3.106	2.781	2.873	3.133	3.018
Okdong A	6	0.8363	0.9402	0.9097	0.8148	0.9349	2.620	1.583	1.946	2.787	1.652
Inbuk A	6	0.8886	0.9089	0.9009	0.8932	0.9097	2.647	2.394	2.497	2.592	2.383
Imjin A	6	0.9099	0.9154	0.8963	0.9157	0.9211	2.590	2.510	2.779	2.505	2.423
Jecheon A	6	0.8975	0.9020	0.8701	0.9117	0.9097	2.914	2.851	3.282	2.705	2.383
Jucheon A	6	0.9132	0.9130	0.8905	0.9201	0.9211	2.426	2.430	2.725	2.328	2.314
Cheongmi A	6	0.9398	0.9203	0.9199	0.9446	0.9173	2.228	2.564	2.572	2.138	2.612
Hantan A	6	0.8970	0.9110	0.9091	0.8965	0.9129	2.627	2.442	2.467	2.633	2.416
Hongcheon A	6	0.8767	0.8825	0.8556	0.8859	0.8908	3.039	2.968	3.290	2.924	2.861
Heukcheon A	6	0.9092	0.9018	0.8824	0.9231	0.8983	2.750	2.860	3.130	2.531	2.518
Gyeongan B	7	0.9097	0.9135	0.9091	0.9162	0.9404	2.444	2.391	2.452	2.354	1.985
Dalcheon A	7	0.9220	0.9266	0.8943	0.9285	0.9329	2.486	2.411	2.895	2.38	2.306
Dalcheon B	7	0.8266	0.8543	0.8007	0.8283	0.8491	3.260	2.897	3.494	3.243	3.04
Seomgang B	7	0.9175	0.9220	0.9012	0.9264	0.9304	2.584	2.514	2.829	2.442	2.374
Imjin B	7	0.8745	0.8857	0.8699	0.8794	0.9418	3.081	2.941	3.137	3.021	2.098
Pyeongchang A	7	0.8888	0.8993	0.8885	0.8888	0.9435	2.874	2.735	2.877	2.874	2.048
Hangang A	8	0.8652	0.8917	0.8837	0.8644	0.9251	2.961	2.655	2.750	2.79	2.208
Hangang D	8	0.7237	0.8407	0.8105	0.7122	0.8404	3.487	2.648	2.887	3.558	2.65
Hangang E	8	0.9364	0.9159	0.9236	0.9414	0.9001	2.007	2.308	2.200	1.926	2.516
Hangang F	8	0.7835	0.8480	0.8316	0.7785	0.8345	3.520	2.949	3.104	3.561	3.078
Hangang I	8	0.8827	0.8921	0.8983	0.8860	0.8823	2.704	2.593	2.518	2.665	2.708

APPLICATION

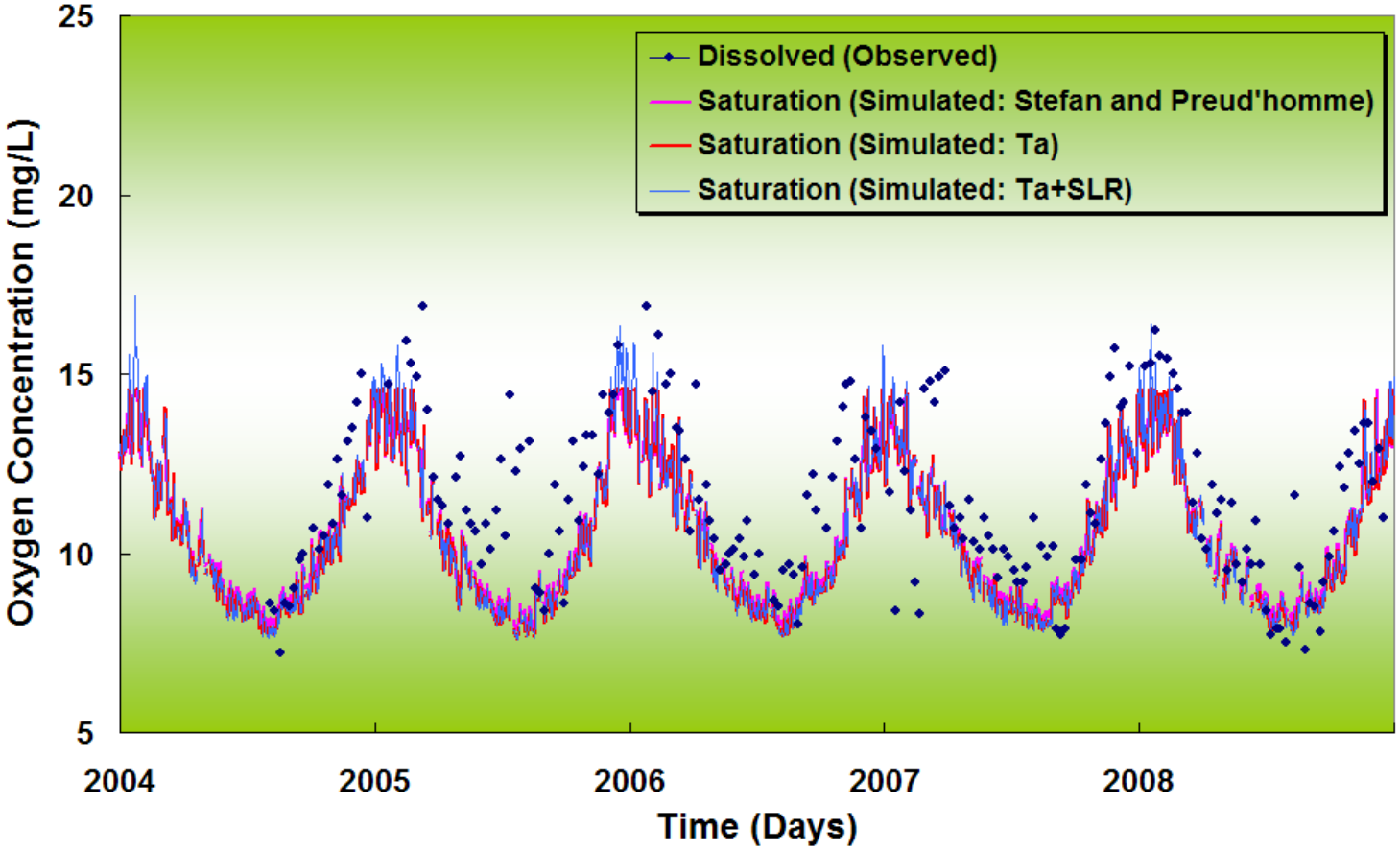


✓ Upstream of Paldang Dam

- water qulality measuring point
- MonitoringPoint
  - <all other values>
  - Type
  - Table added Outlet
  - Manually added Inlet
  - Reservoir
  - Precipitation Gage
  - Temperature Gage
  - Humidity Gage
  - Solar Gage
  - Wind Gage
- Basin
- Inland
- Watershed
- Reach
- 38_line

APPLICATION

✓ Dissolved oxygen/Saturation oxygen concentration



CONCLUSIONS

✓ Modified stream-air temperature relationship in Han River basin

✓ Time lag is rather proportional to the Stream Order

✓ Linear regression/Multiple linear regression → key factors affecting water temperature: air temp., SLR

✓ When simulate water quality variables affected by water temperature, stream-air temp. relationship should be carefully investigated to attain more accurate results


THANK YOU