Validation of EDEN Water-Surface Model and Ground Digital Elevation Model (DEM) for the Everglades, Florida

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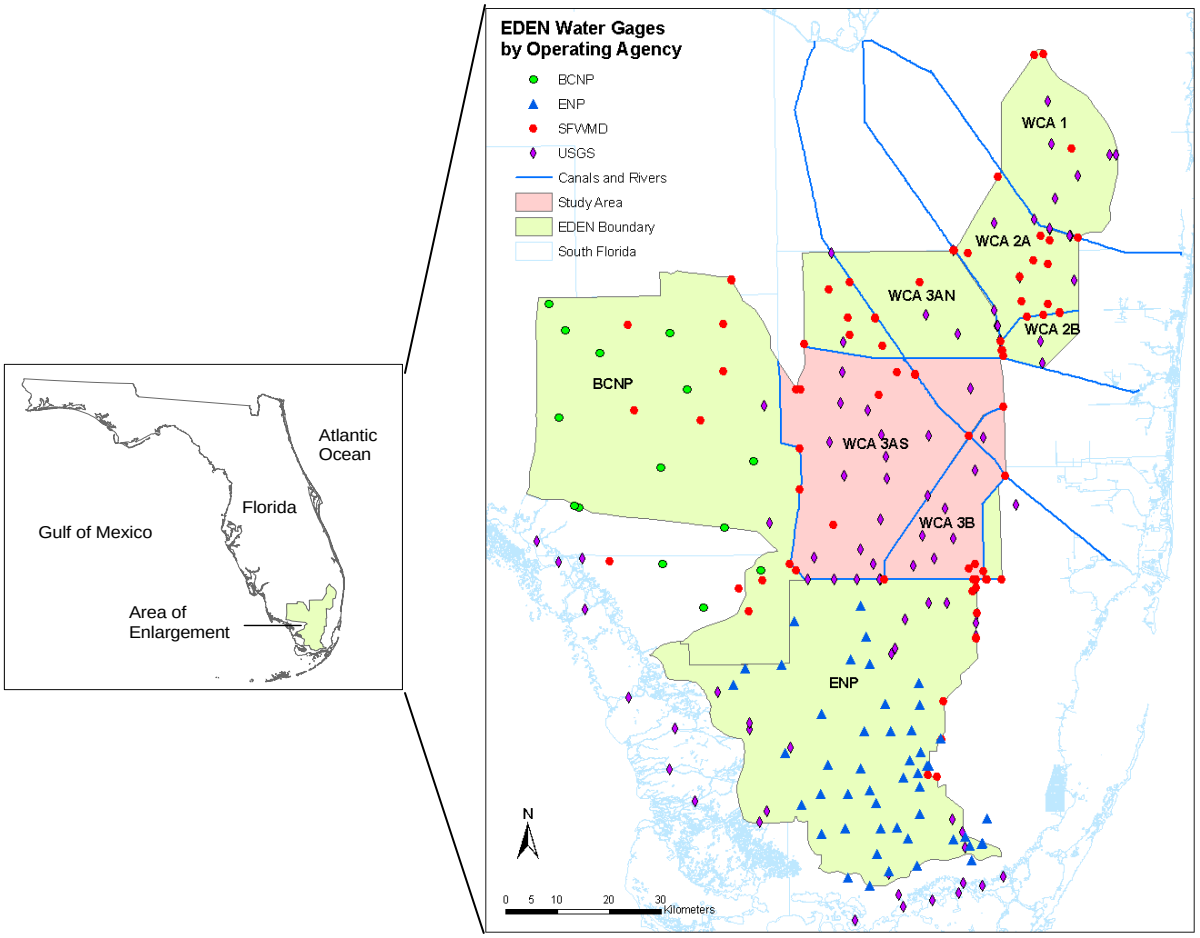
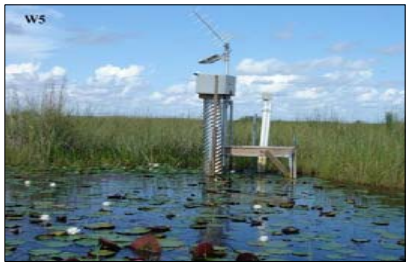
I. Introduction: Everglades Depth Estimation Network (EDEN)

- Integrated network of real-time water level monitoring, ground elevation modeling, and water-surface modeling
- Daily water level/stage data from 253 gage stations
- Three types of gage stations: marsh, canal, and coastal





A marsh gage station

EDEN Water-Surface Model

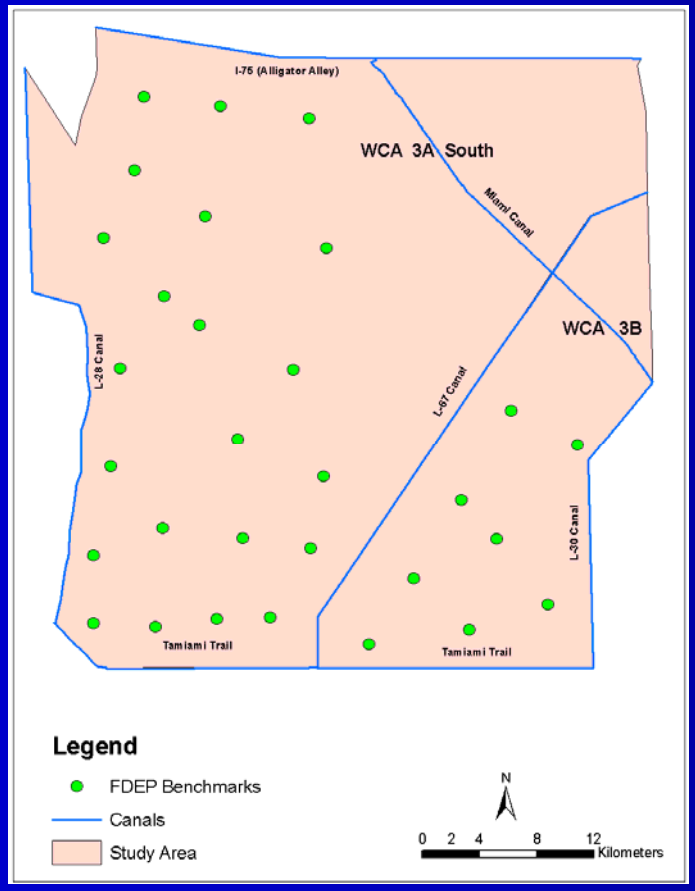
- Developed by Pearlstine et al. (2007)
- Spatial interpolation of 240 gage stations in ArcGIS: radial basis function (RBF)
- Basic model outputs (from 2000 - present; resolution: 400 m)
  - Water level/stage
  - Water depth (= water level – DEM)

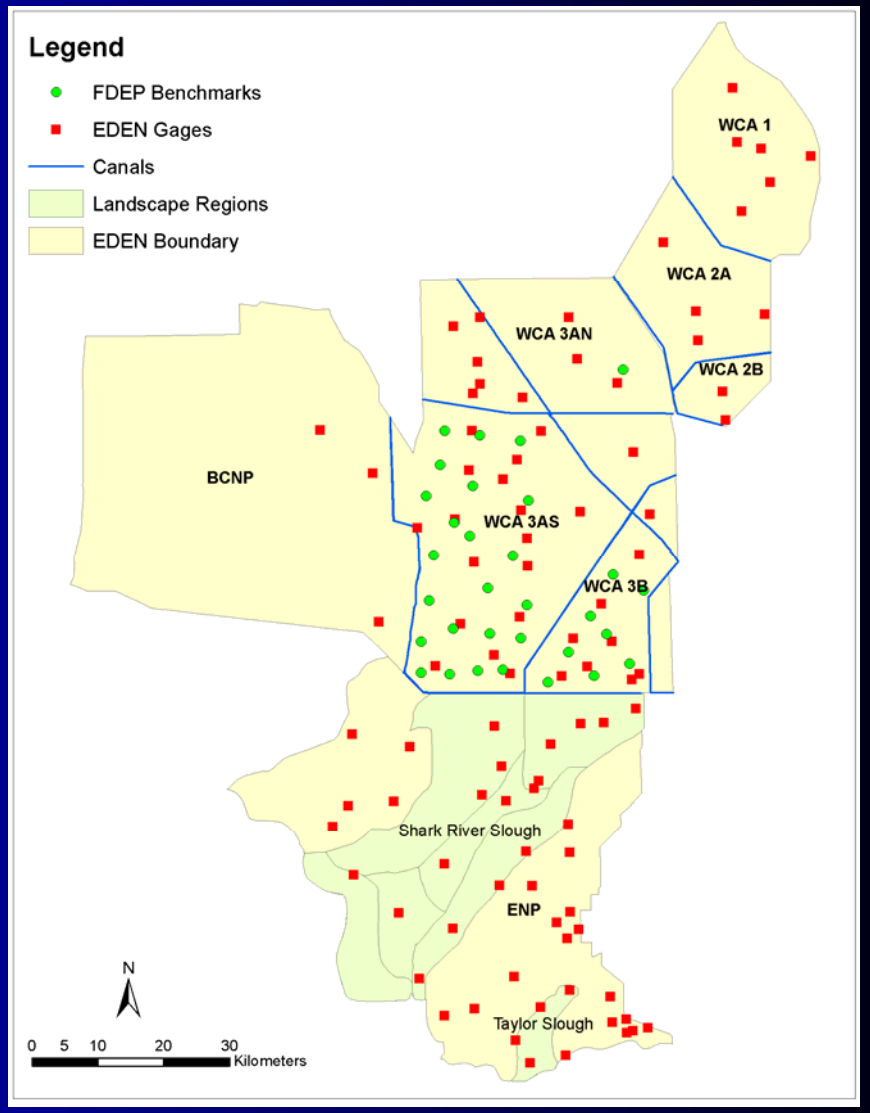
DEM (Digital Elevation Model)

- Developed by Jones and Price (2007)
- Spatial interpolation of Airborne Height Finder (AHF) and airboat-surveyed elevation points in ArcGIS: kriging
- Cell resolution: 400 m

II. Methodology

➢ Study area





EDEN Water-Surface Model validation:
Florida Department of Environmental Protection (FDEP) benchmark network

DEM validation:
FDEP benchmarks and EDEN gages

Field Water-Level Data Collection

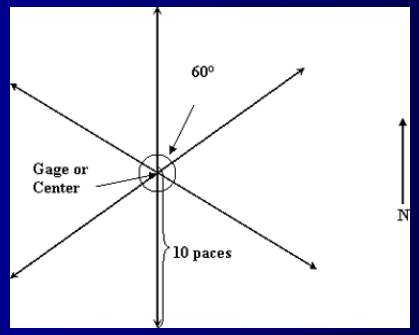
- Collected by Florida Atlantic University
- At 24 FDEP benchmarks
- Apr. - Sept., 2007
- Via airboat and helicopter

Total obs.: 91	Region	WCA 3A South 83	WCA 3B 8
	Season	Dry 16	Wet 75

Field Ground Elevation Data Collection

- FDEP benchmark ground elevations
  - at 24 benchmarks
  - 4 measurements within a 1 m radius
  - 2007

- EDEN gage station ground elevations
  - at 94 marsh gage stations
  - >= 6 measurements within a 10 m radius
  - 2005 and 2007



(Source: www.sofia.usgs.gov/eden/geprotocol.php)

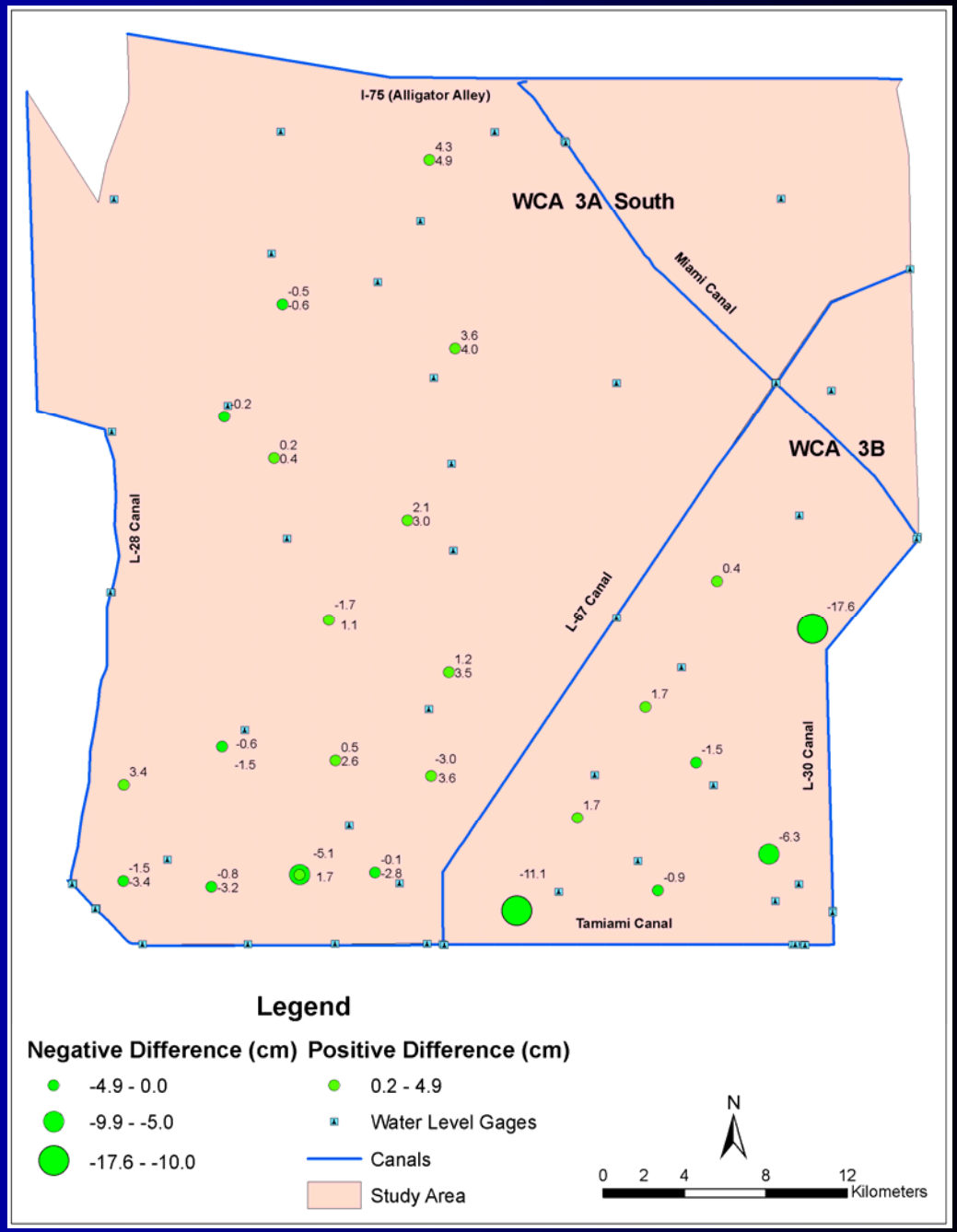
Analysis Methods

- **GIS**
  - Spatial analysis
- Error statistics
  - MAE (Mean Absolute Error)= $\frac{1}{N}\sum_{i=1}^{N}\left|P_i - O_i\right|$
  - MBE (Mean Biased Error)= $\frac{1}{N}\sum_{i=1}^{N}\left(P_i - O_i\right)$
  - RMSE (Root Mean Squared Error)= $\left[\frac{1}{N}\sum_{i=1}^{N}\left(P_i - O_i\right)^2\right]^{1/2}$
- Nonparametric statistical methods
  - Spearman's rank correlation
  - Wilcoxon's signed rank test

III. Results

(i) EDEN water-surface model validation

- Water level difference = predicted water level – observed water level
- Underestimates and overestimates are represented by negative and positive values, respectively.



Major statistics of interpolation errors for water stage/level validation

Type	N	MIN (cm)	MAX (cm)	Standard deviation	Standard error [b]	MAE	Mean (MBE)	RMSE
WCA 3A South, 3B	91	-17.6	4.9	3.32	0.35	2.38	-0.08	3.30
WCA 3A South	83	-5.1	4.9	2.47	0.27	2.11	0.32	2.48
WCA 3B	8	-17.6	1.7	6.97	2.46	5.15	-4.2	7.76

[a] Interpolation error (water-stage difference) = predicted water stage – observed water stage.

[b] Standard error = standard deviation / $\sqrt{N}$.

Spearman's rank correlation analysis

Type	Variable	Normality test *p*-value (Shapiro-Wilk)	Spearman's rank correlation coefficient (r_s)	*P*-value of r_s
WCA 3A South, 3B	Observed	<0.0001	0.98	<0.0001
	Predicted	<0.0001		
WCA 3A South	Observed	<0.0001	0.98	<0.0001
	Predicted	<0.0001		
WCA 3B [a]	Observed	0.71	0.83	0.01
	Predicted	0.25		

[a] For WCA 3B, the parametric Pearson's correlation coefficient is 0.90 (p = 0.002).

Type	Spearman's rank correlation coefficient	Corrected df [a]	Corrected p-value
WCA 3A South, 3B	0.91	17.29	<0.001
WCA 3A South	0.88	5.54	<0.001
WCA 3B	0.83	5.28	<0.004

[a] Corrected degrees of freedom.

Wilcoxon's signed rank tests

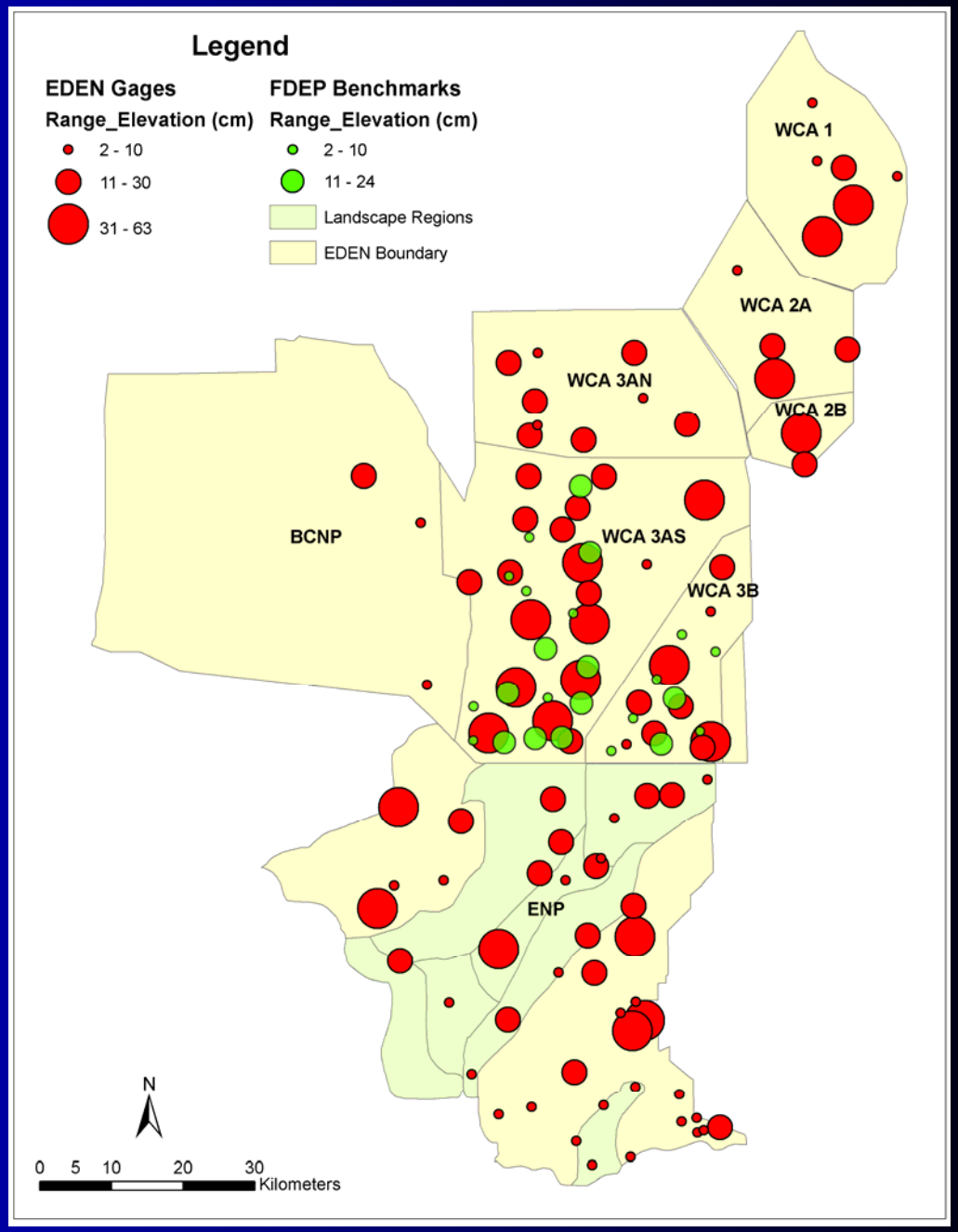
Type	Normality test *p*-value (Shapiro-Wilk)	Wilcoxon's signed rank test statistic	*P*-value (Wilcoxon)
WCA 3A South, 3B	<0.0001	166.5	0.51
WCA 3A South [a]	0.10	263.0	0.23
WCA 3B [b]	0.08	-8.0	0.30

[a] For WCA 3A South, the test statistic of pairwised t-test is -1.19 (p = 0.24).

[b] For WCA 3B, the test statistic of pairwised t-test is 1.7 (p = 0.13).

Natural variations of ground elevations

- Range_Elevation: the range/difference between the highest and lowest measured ground elevations at each gage/benchmark site.
- The average observed ground elevation was used to compare with DEM ground elevation.



(ii) DEM validation

- Major statistics of interpolation errors

Type	N	MIN (cm)	MAX (cm)	Standard deviation	Standard error [b]	MAE	MBE	RMSE
EDEN gages and FDEP benchmarks	118	-23.06	56.18	12.94	1.19	9.16	2.35	13.1
EDEN gages	94	-23.06	56.18	14.01	1.44	9.85	2.04	13.93
FDEP benchmarks	24	-16.78	26.38	8.04	1.64	6.45	3.58	8.65
WCA 1	6	0.15	56.18	22.52	9.19	24.96	24.96	32.33
WCA 2A	4	-11.4	12.55	10.02	5.01	7.44	-1.16	8.75
WCA 2B	2	-8.83	11.2	14.16	10.02	10.02	1.19	10.08
WCA 3A North	9	-20.51	20.91	11.7	3.9	8.52	2.66	11.35
WCA 3A South	34	-23.06	11.01	8.85	1.52	7.19	-2.39	9.04
WCA 3B	17	-11.98	26.38	8.7	2.11	7.15	3.71	9.22
BCNP	4	-4.98	6.7	4.94	2.47	3.97	1.48	4.53
ENP	42	-23.04	39.18	13.67	2.11	10.06	2.81	13.79

[a] Interpolation error (ground elevation difference) = DEM – observed ground elevations.

[b] Standard error = standard deviation / $\sqrt{N}$.

Type	N	MIN (cm)	MAX (cm)	Standard deviation	Standard error [b]	MAE	MBE	RMSE
Shark River Slough - NE	6	-6.5	3.21	3.48	1.42	2.43	0.05	3.18
Shark River Slough - Mid	2	-0.26	20.52	14.69	10.39	10.39	10.13	14.51
Shark River Slough - SW	1	-23.04	-23.04	----	----	23.04	-23.04	23.04
Marl Transition - E	4	-5.63	12.15	7.71	3.86	5.52	1.58	6.87
Marl Transition - W	3	-3.4	22.82	13.21	7.62	12.89	10.63	15.14
Fertile Crescent	1	-9.42	-9.42	----	----	9.42	-9.42	9.42
Taylor Slough	3	-0.84	4.79	3.02	1.74	3.16	2.6	3.58

[a] Interpolation error (ground elevation difference) = DEM – observed ground elevations.

[b] Standard error = standard deviation / $\sqrt{N}$.

Wilcoxon's signed rank tests

Type	Normality test p-value (Shapiro-Wilk)	Wilcoxon's signed rank test statistic	P-value (Wilcoxon)
EDEN gages and FDEP benchmarks	<0.0001	523.5	**0.16**
EDEN gages	<0.0001	156	**0.55**
FDEP benchmarks [a]	0.10	82	0.02
WCA 3A South [a]	0.24	-75.5	**0.18**
WCA 3B [a]	0.30	37.5	**0.08**
ENP	0.046	66.5	**0.41**

[a] For FDEP benchmarks, WCA 3A South, and WCA 3B, the test statistics of pairwised t-test are -2.18 (p = 0.04), 1.57 (p = 0.12), and -1.76 (p = 0.10), respectively.

IV. Discussion and Conclusions

EDEN water-surface model:

- Boundary problems
- Data collection
- Missing/faulty gage data
  - Localized impacts on water surface

DEM:

- Natural variability of the ground surfaces
- Scale issue: 10 m, 1 m, 400 m
- Site-specific water-depth estimation without using DEM
  - More accurate
  - More cost-effective

Conclusions

EDEN water-surface model:

- We found there are no statistically significant differences between model-predicted and field-observed water-stage data (p-value = 0.51).

- Overall, the model is reliable by a RMSE of 3.3 cm.

DEM:

- There are no significant differences between the DEM and observed ground elevations at gage/benchmark sites (p-value = 0.16) except for FDEP benchmarks.

- The overall RMSE is 13.1 cm.

Future Studies

- More field observations of dry and wet seasons, and in other areas with new benchmarks
- Examine WCA 3B / boundary to improve the model
- NAVD 88 datum surveys at some gages
- A better regional ground DEM
  - Field water-depth measurements
  - New vegetation map from Ken Rutchey at SFWMD
- Other interpolation techniques
  - Spatial - temporal interpolation (Li et al., 2006) with NexRAD rainfall data

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