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Wave Modeling Test Bed for Resource Assessment

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INTRODUCTION

Hindcasts from third generation (3G) phase-averaged wave models are commonly used to estimate standard statistics for energy resource assessment and characterization. It is, therefore, important to investigate wave models and best modeling practices to evaluate and improve hindcast accuracy. We present results from hindcast simulations using two of the most widely used 3G phase-averaged wave models, WaveWatchIII (WWIII) and Simulating WAves Nearshore (SWAN). Results from the WWIII ST2 and ST4 physics packages are compared to investigate new source term formulations within the ST4 package, which, unlike its ST2 counterpart, models swell dissipation effects, and includes different growth and wave dissipation formulations. Results from the stationary (SWAN-S) and nonstationary (SWAN-NS) modes of the SWAN model are also compared to evaluate benefits of modeling the unsteady term in the spectral wave action balance equation..

METHODS

The model domain, which serves as the test-bed site, encompasses an area of 60 km x 60 km located near Newport, Oregon, which is shown in Figure 1 as the Central Oregon Domain. Figure 1 also shows the NDBC buoy locations, and the boundaries of the nested model grids. Three nested grids, within a global model grid, generate open wave boundary conditions for the test-bed domain. The nested grid scaling ratio is set to a value of approximately five to six to maintain a smooth transition between model results along the nested grid boundaries. This ratio results in a grid resolution of 265 m × 308 m for the test-bed domain. The baseline models use 24 direction bins and 29 frequency bins with a logarithmic increment factor of 1.1 and a minimum frequency of 0.035 Hz, which results in a maximum frequency of 0.505 Hz. To the extent possible, the source term models for SWAN were selected to agree with those in WWIII.

Model skill is evaluated by comparing model results with observed data for six wave resource parameters specified in the International Electrotechnical Commission Technical Specification, IEC-TS 62600-10Ed. 1.0 ©2015, including omnidirectional wave power (J), significant wave height (H_s), energy period (T_e), spectral width (ϵ_0), direction of maximum directionally resolved wave power (θ), and directionality coefficient (d_θ). Statistical error metrics include root-mean-square-error (RMSE), scatter index (SI), percent error (PE), correlation coefficient (R), bias (BIAS) and percentage bias (BIAS(%)). Computational requirements are assessed by calculating and comparing CPU-hours.

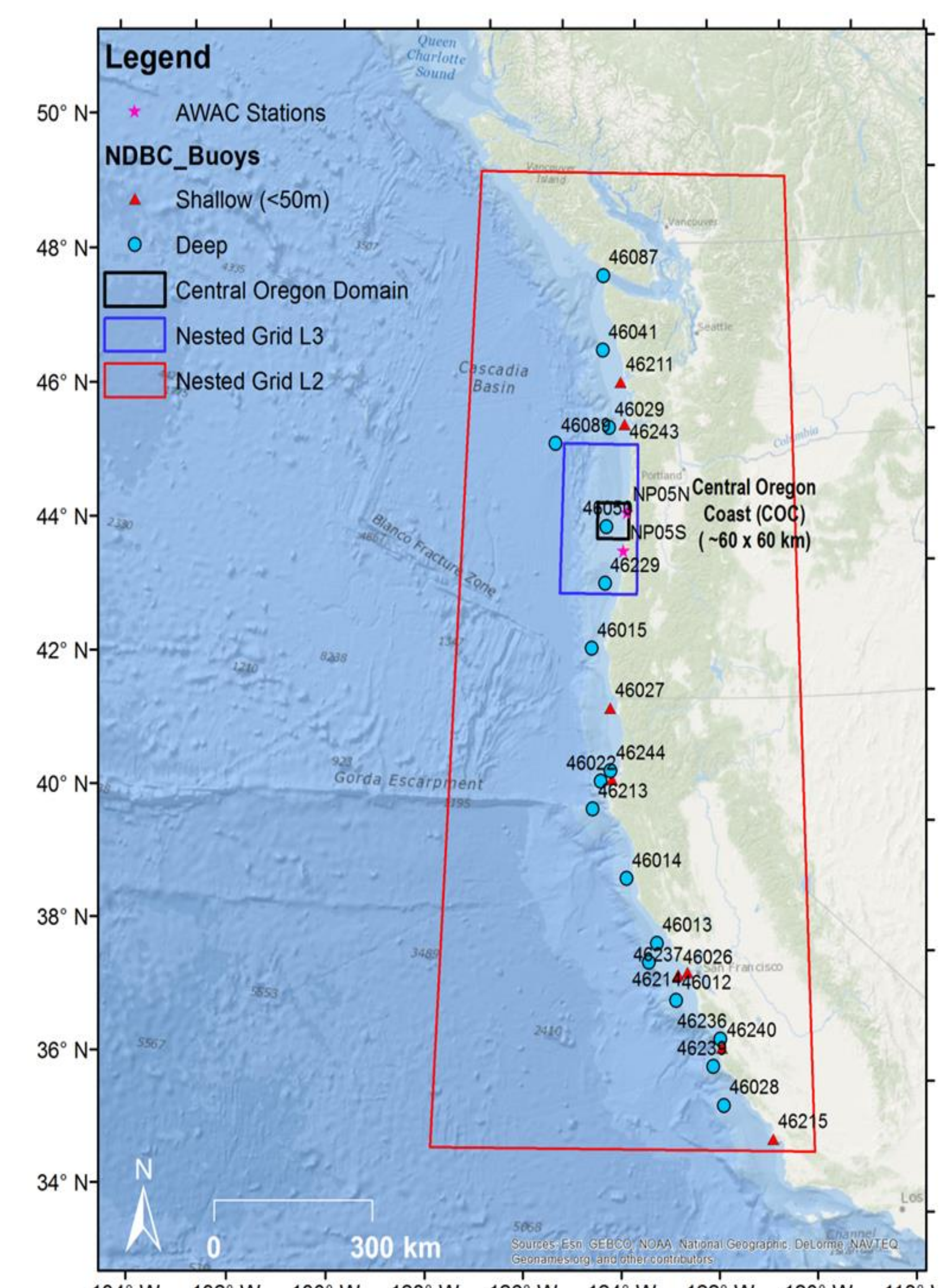

Figure 1 Model Boundaries of nested grids (L2-L4) and NDBC/AWEC buoy locations at the model test bed.

RESULTS

- The computed performance metrics for each of the six IEC parameters, shown in Table 1, indicate that the model skills for all three baseline model runs are similar. There is good agreement between parameters derived from WWIII, SWAN hindcasts, and NDBC buoy measurements.
- Model skill is only slightly improved when modeling the unsteady term in the action balance equation.
- Modeling swell dissipation effects with the WWIII ST4 package improves predictions of significant wave height (Figure 2). Error bias for omnidirectional wave power is significantly reduced, whilst those for energy period were slightly increased (Table 1).
- The WWIII simulations required 31,488 CPU-hours, more than twice those required for the SWAN-NS simulations (13,572 CPU-hours), and more than forty times those required for the SWAN-S simulations (739 CPU-hours).

Table 1 Performance metrics for baseline simulations

Statistic	Model	RMSE	PE (%)	SI	Bias (%)	R
J (kW/m)	WWIII	20	59	0.64	19.7	0.91
	SWAN-NS	19	62	0.62	20.2	0.91
	SWAN-S	20	65	0.63	20.9	0.91
H_s (m)	WWIII	0.42	19	0.19	7.3	0.94
	SWAN-NS	0.44	21	0.20	8.1	0.94
	SWAN-S	0.45	22	0.20	8.4	0.94
T_e (s)	WWIII	0.98	12	0.11	5.6	0.90
	SWAN-NS	0.95	12	0.11	5.8	0.91
	SWAN-S	0.96	12	0.11	5.7	0.91
ϵ_0 (-)	WWIII	0.07	20	0.20	1.6	0.68
	SWAN-NS	0.06	20	0.19	0.7	0.72
	SWAN-S	0.07	20	0.20	1.1	0.71
θ (degree)	WWIII	22.8	8	0.08	-2.4	0.74
	SWAN-NS	22.2	12	0.08	-2.3	0.75
	SWAN-S	22.6	13	0.08	-2.3	0.74
d_θ (-)	WWIII	0.10	15	0.13	6.2	0.48
	SWAN-NS	0.10	14	0.12	5.1	0.55
	SWAN-S	0.10	14	0.12	5.0	0.55

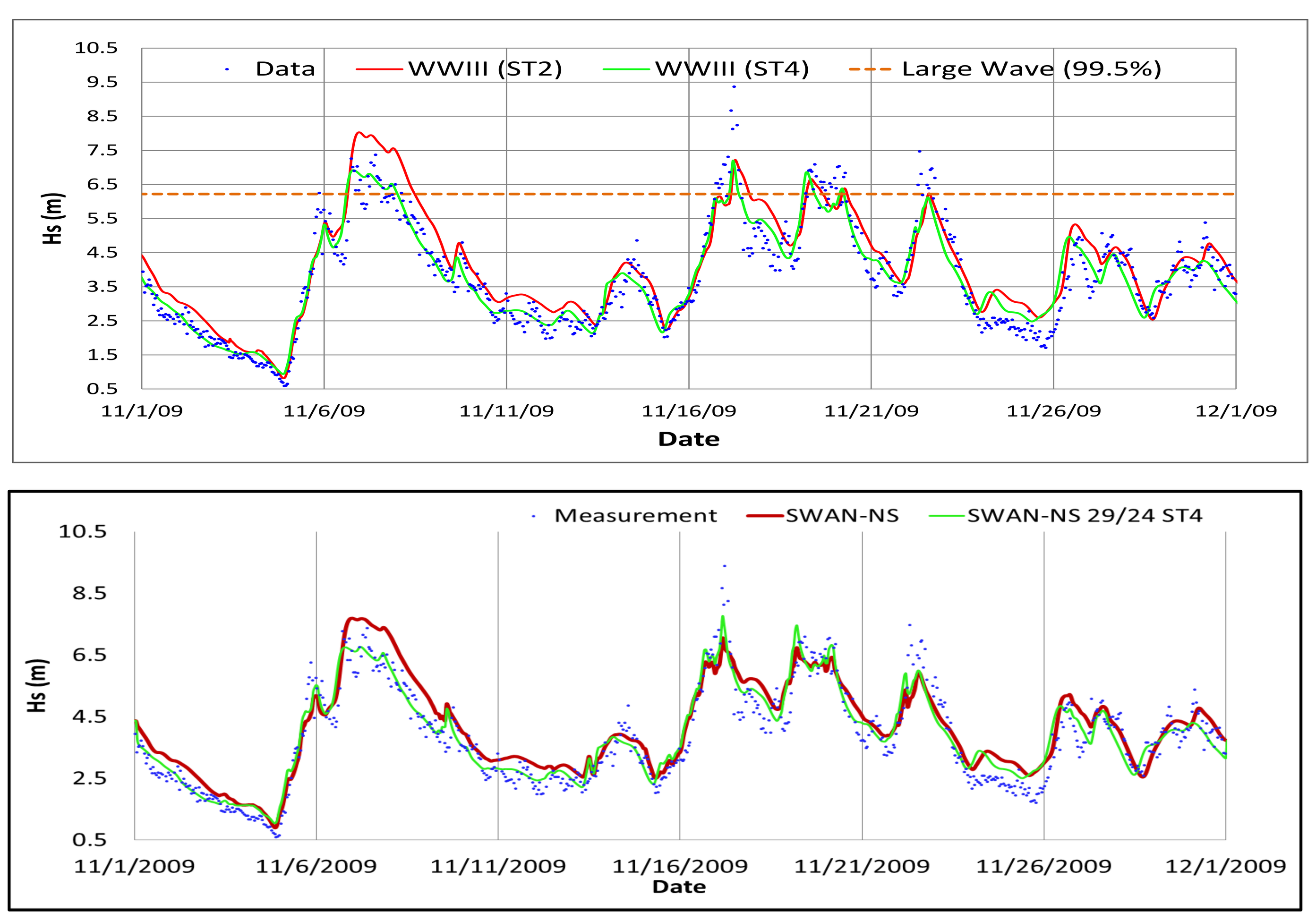

Figure 2 Comparison of significant wave heights from model simulations and buoy measurements. Top: WWIII-ST2 (Red) , WWIII-ST4 (Green); Bottom: SWAN-NS-ST2 (Red), SWAN-NS-ST4 (Green); Buoy (Blue points).

CONCLUSIONS

A wave model test bed is established to benchmark, test and evaluate spectral wave models and modeling best practices for predicting the wave energy resource parameters as specified in the IEC TS 62600-101Ed. 1.0 ©2015. Initial investigations indicate that significant improvements in model accuracy can be gained with improved modeling of growth and dissipation effects with the ST4 physics package. The computational efficiency of SWAN relative to WWIII indicates that SWAN is better suited for design and feasibility class resource assessments when model domain dimensions are under ~100 km, and for operational forecasting for seastate-to-seastate control of wave energy converters to increase annual energy production.

ACKNOWLEDGEMENTS

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