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CO-PRODUCTION of WAVE and WIND POWER and its INTEGRATION into ELECTRICITY MARKETS

Case study: Wavestar and 525kW turbine

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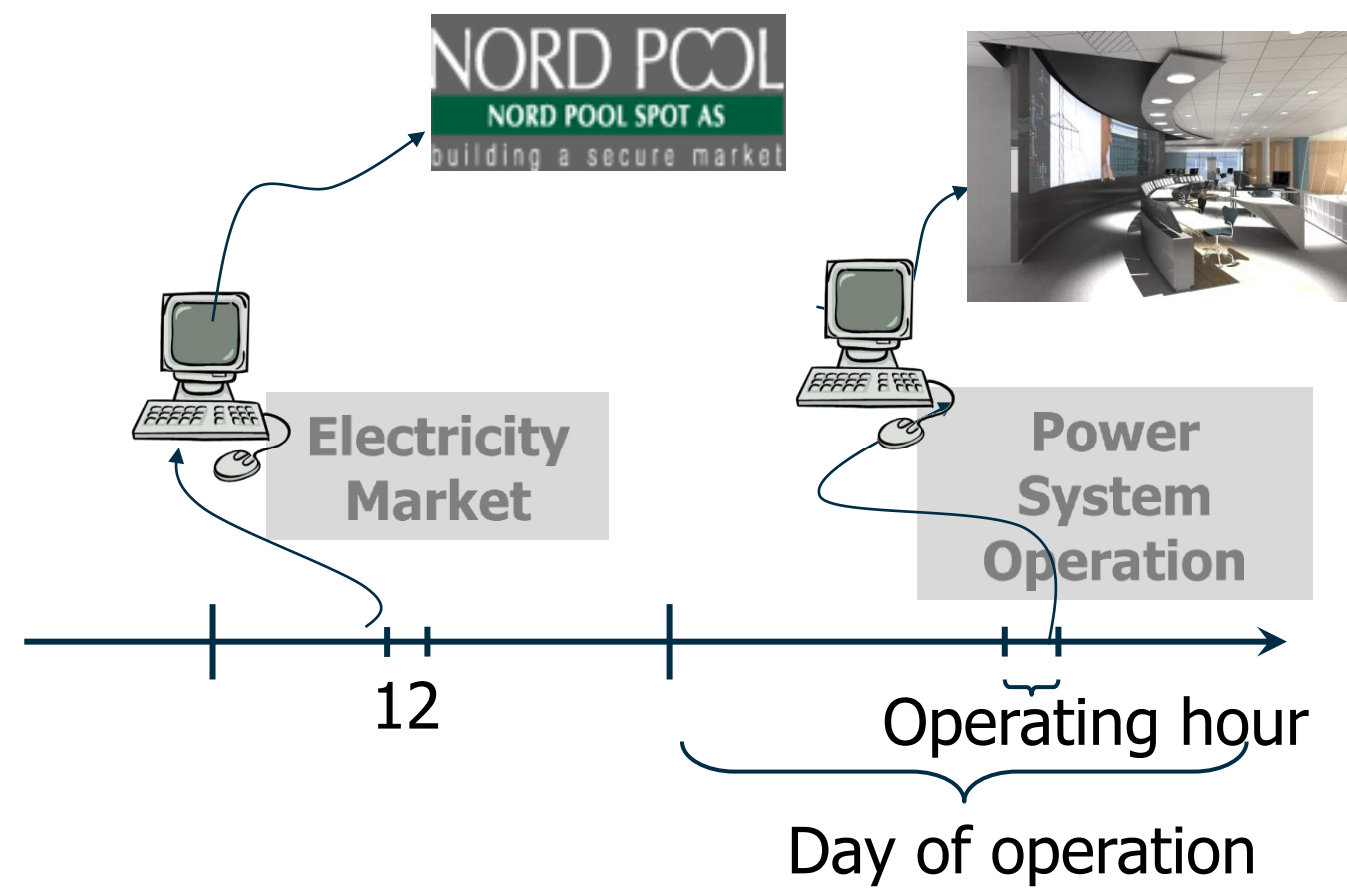
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CO-PRODUCTION of WAVE and WIND POWER and its INTEGRATION into ELECTRICITY MARKETS –Case study: Wavestar and 525kW turbine

Julia Fernández Chozas (PhD Student)

BACKGROUND

- Waves are delayed to winds
- Waves are more constant than winds
- Several benefits if combining wave and wind: shared cable-costs, consenting process and EIA; reduced cost of energy; less variability in power output; increased predictability

- This study focuses on the 12 to 36 hours forecast and studies the advantages of a combined wind and wave system based on real production data
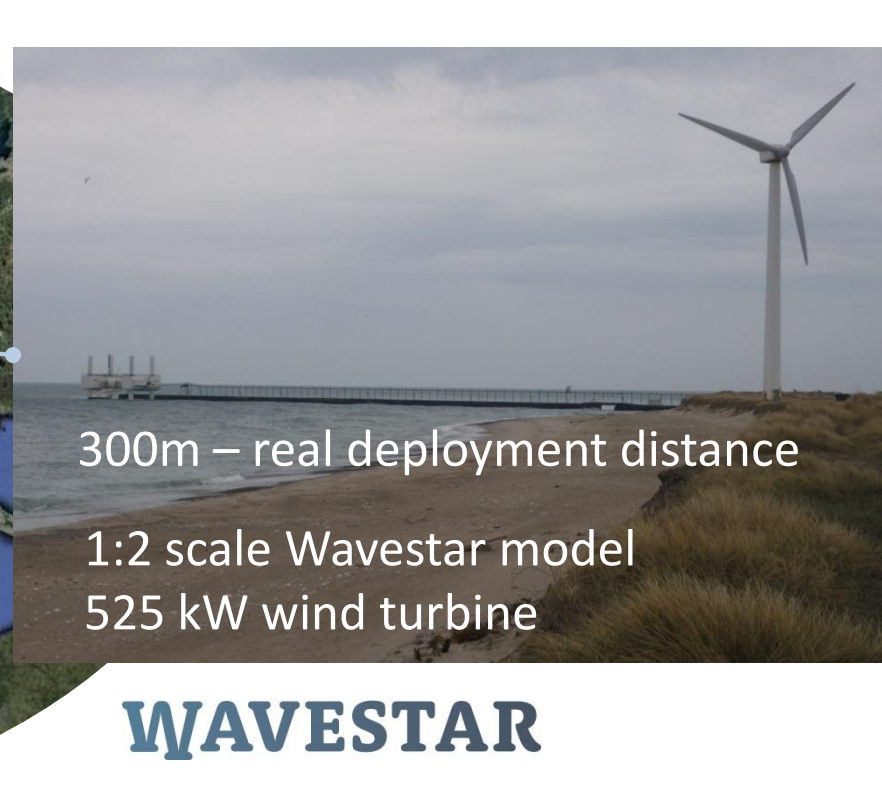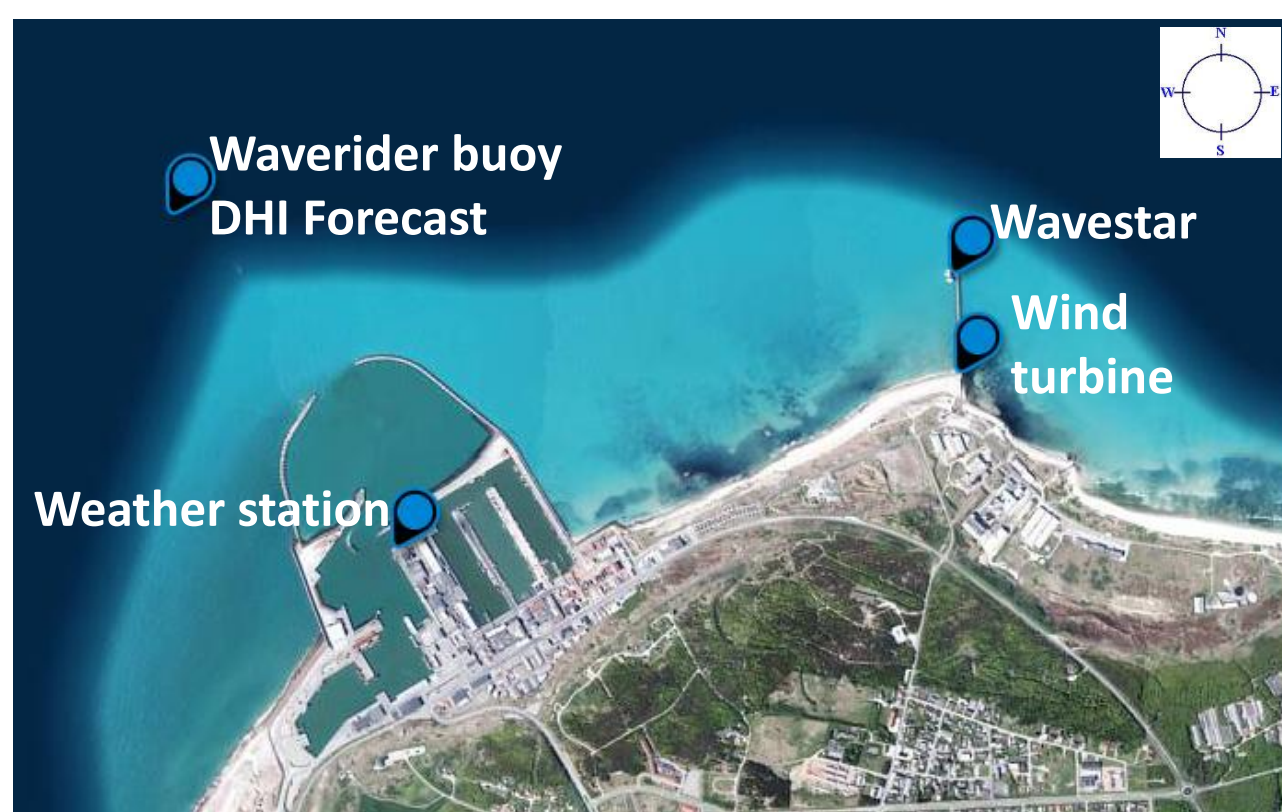

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Electricity Market

Power System Operation

12 · Operating hour

Day of operation

Short-term forecasting of wave and wind

	Mean	Bias	MAE	MAE/Mean	RMSE
H_{m0} (m)	1.4	0.2	0.3	0.2	0.4
H_{max} (m)	2.3	0.8	0.9	0.4	1.0
T_{02} (s)	4.7	-0.2	0.4	0.1	0.5
P_{wave} (kW/m)	7.4	1.5	2.9	0.4	5.3

	Mean	Bias	MAE	MAE/Mean	RMSE
u (m/s)	7.8	0.7	2	0.3	2.5
Pwind (W/m^2)	500	67	308	0.6	491
MWD (deg)	172	19	33	0.2	67

(time period: October 2010 to February 2011)

METHODOLOGY

Waverider buoy DHI Forecast

Wavestar

Wind turbine

Weather station

Hanstholm Danish North Sea (17m depth, 1.3km off)

300m – real deployment distance
1:2 scale Wavestar model
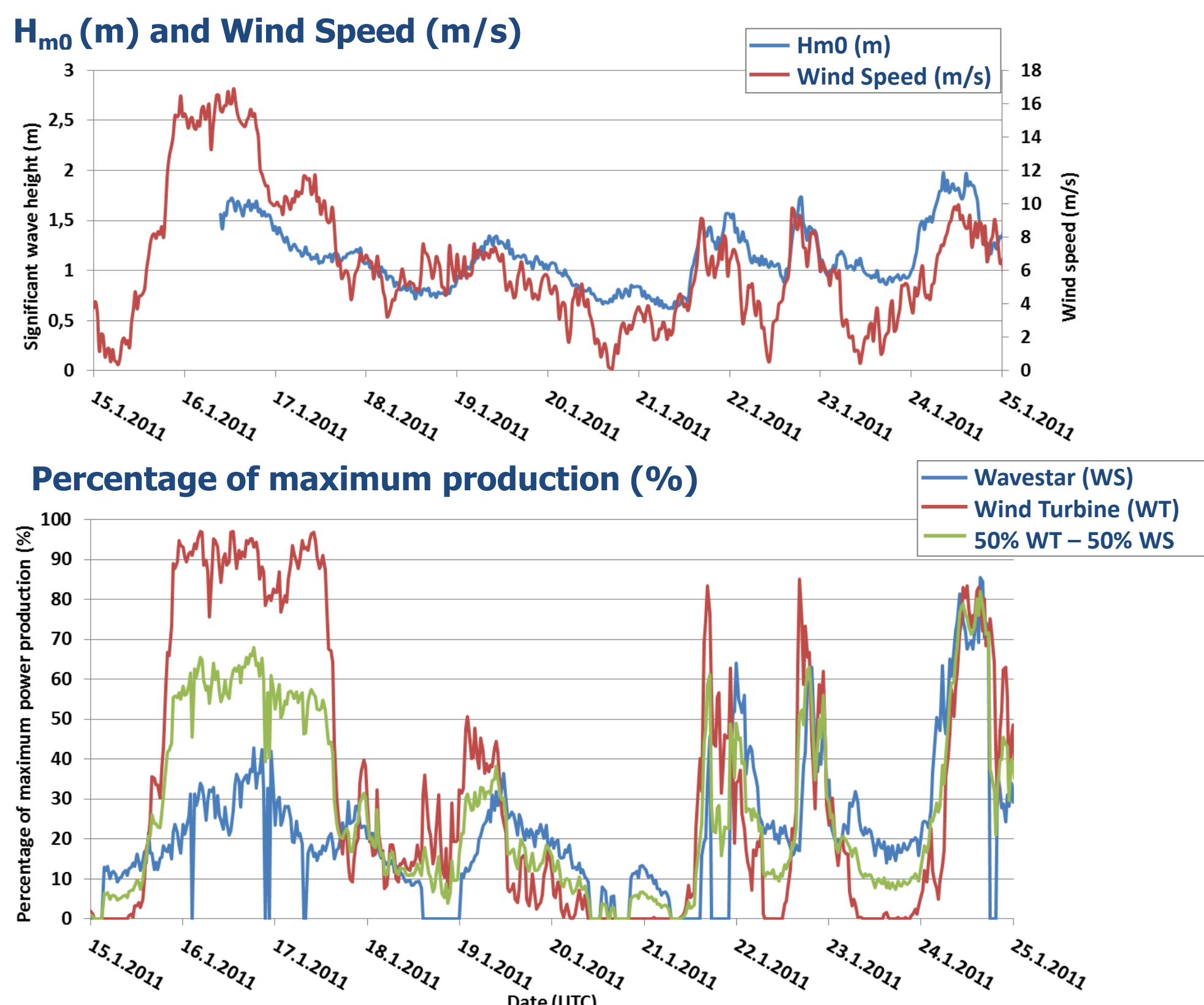525 kW wind turbine

WAVESTAR

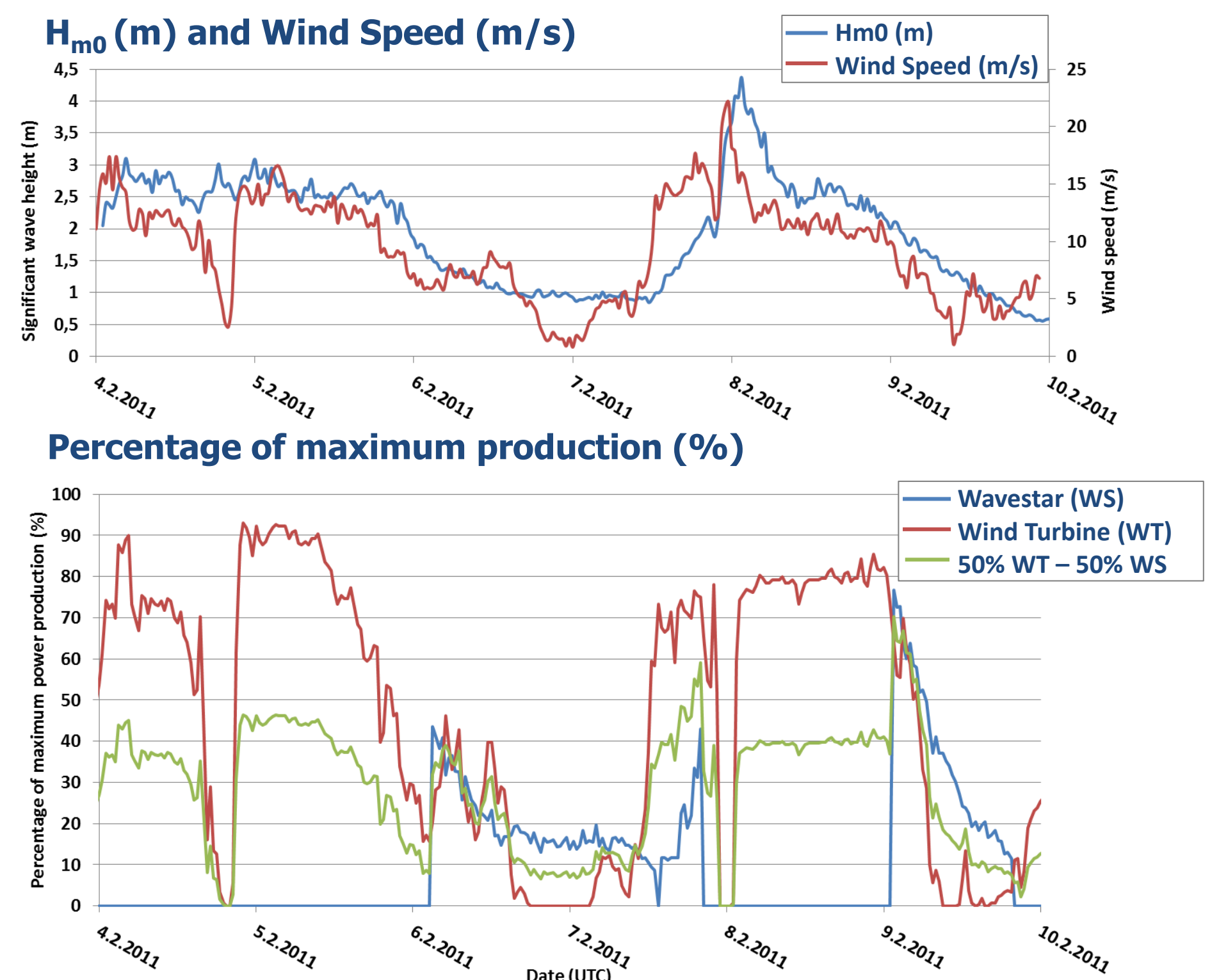### Sea states contribution (%) to P_{wave}
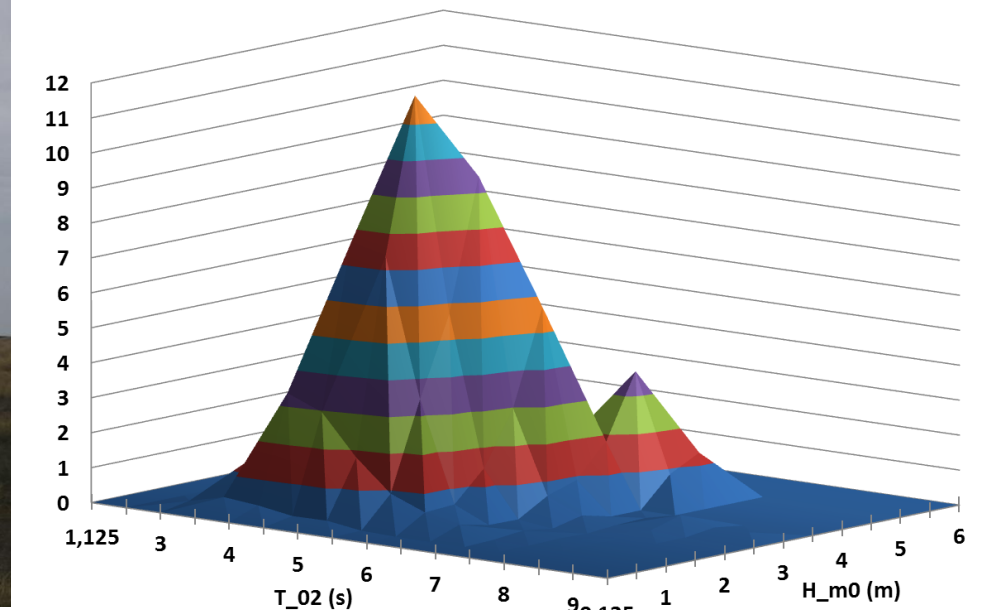
→ Particular conditions for the study period (October 2010 to February 2011)

WAVESTAR and WIND Turbine REAL sea-measured Co-Production

Normal Operating Conditions

H_{m0} (m) and Wind Speed (m/s)

Percentage of maximum production (%)

Storm Conditions

H_{m0} (m) and Wind Speed (m/s)

Percentage of maximum production (%)

Production of different combinations of Wavestar and turbine

	Mean	σ	=0	0<x<20	20<x<40	40<x<60	60<x<80	80<x<100	=100	N
100% Wind Turbine (WT)	33	43	15	27	20	16	14	8	0	4307
75%WT- 25%WS	31	51	11	31	22	20	16	0	0	4307
50% WT - 50% WS	24	30	9	40	29	17	4	1	0	4307
25%WT - 75%WS	22	39	11	46	27	12	4	1	0	4307
100% Wavestar (WS)	16	31	46	23	18	8	4	1	0	4307

(time period: January 2011 - May 2011)

Short-term forecasting of Wavestar and turbine productions

	NMean	NBias	NMAE	NRMSE
Real Wavestar	0.30	0.24	0.28	0.33
Real Wind turbine	0.37	0.06	0.18	0.26
Real WS + WT	0.31	0.13	0.17	0.22
Modelled WS	0.44	0.04	0.15	0.24
Modelled WT	0.35	0.07	0.17	0.24
Modelled WS + WT	0.38	0.05	0.14	0.19

→ Short-term forecasting of other WECs combined with wind based on modelled power productions

	NMean	NBias	NMAE	NRMSE
Pelamis	0.33	0.08	0.11	0.14
Wave Dragon	0.33	0.04	0.09	0.13
Wavestar	0.44	0.04	0.15	0.24
P+WD+WS	0.37	0.05	0.11	0.14
P+WD+WS +WT	0.36	0.06	0.11	0.14

(time period: October2010- February2011)

CONCLUSIONS

- ✓ Short-term forecasting (H=12-36 hours) of wave parameters 10% more accurate than for wind parameters
- ✓ Predictability of WECs individual power production 5-10% more accurate than for wind turbines
- ✓ Short-term forecasting of wind production 6% improved when wave production added
- ✓ Best combination 50% wave & 50% wind: → barely no zero production, small standard deviation, less fluctuating power than wind
- → Results are very dependent on the chosen location and case study: Wavestar 1:2 model and 525 kW wind turbine
- ❑ Further work: economic evaluation of wave energy production into electricity day-ahead bids, alone and in combination with wind energy