

Marine Energy Sector Industry Use of Wave Data

Robin Stephens – ABPmer

Mark Calverley – Blue Ocean Consulting

IMarEST Offshore Renewables Special Interest Group

Gus Jeans – Oceanalysis

IMarEST Operational Oceanography Special Interest Group

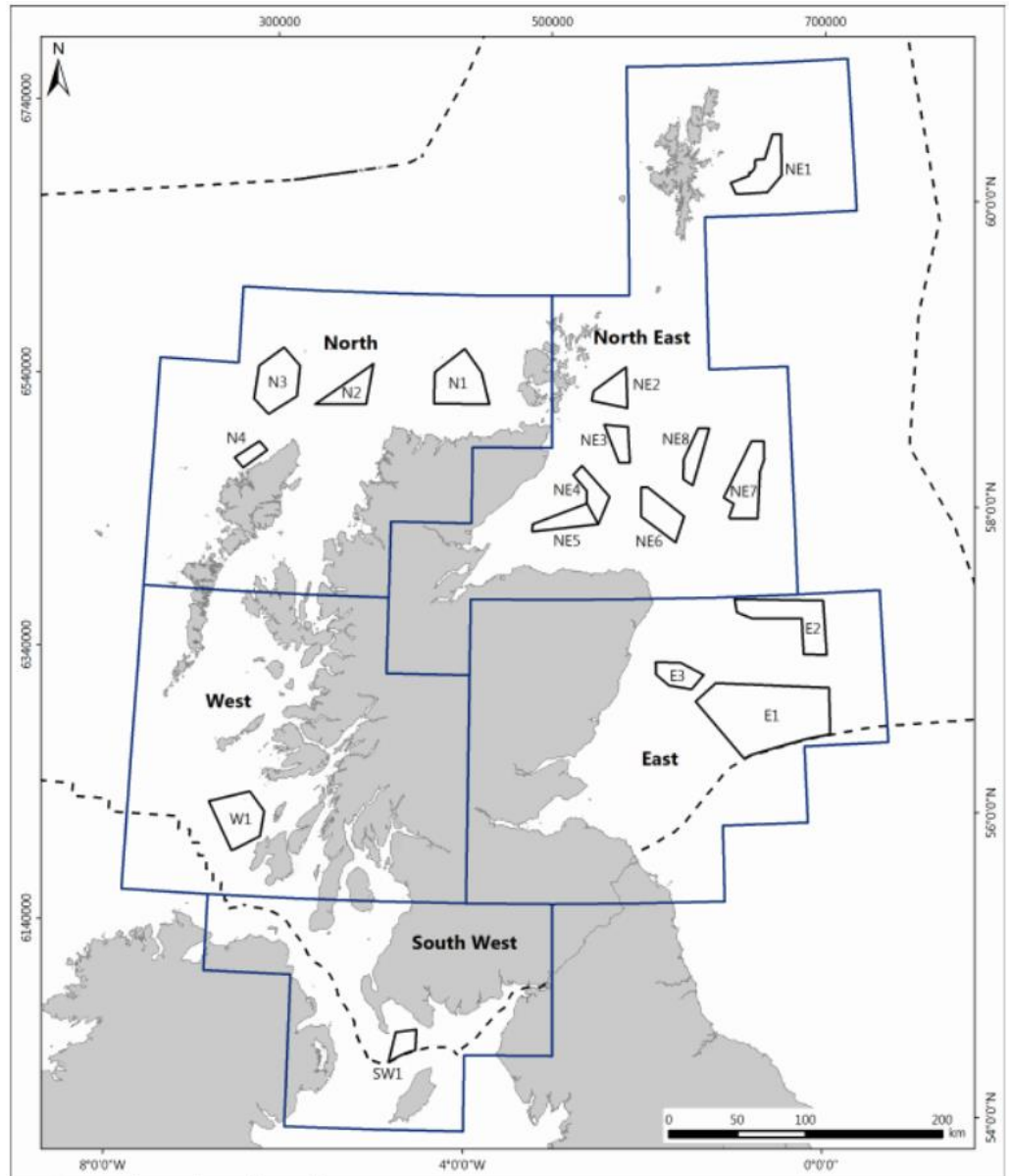
Contents

- Wave characterisation through the project lifecycle
- Wave data sources
- User engagement and case studies

Project Lifecycle



Governmental Planning of License Concessions



Source: Marine Scotland Sectoral Marine Plan for Offshore Wind Energy

License Bidding



Resource
evaluation



Feasibility
assessment



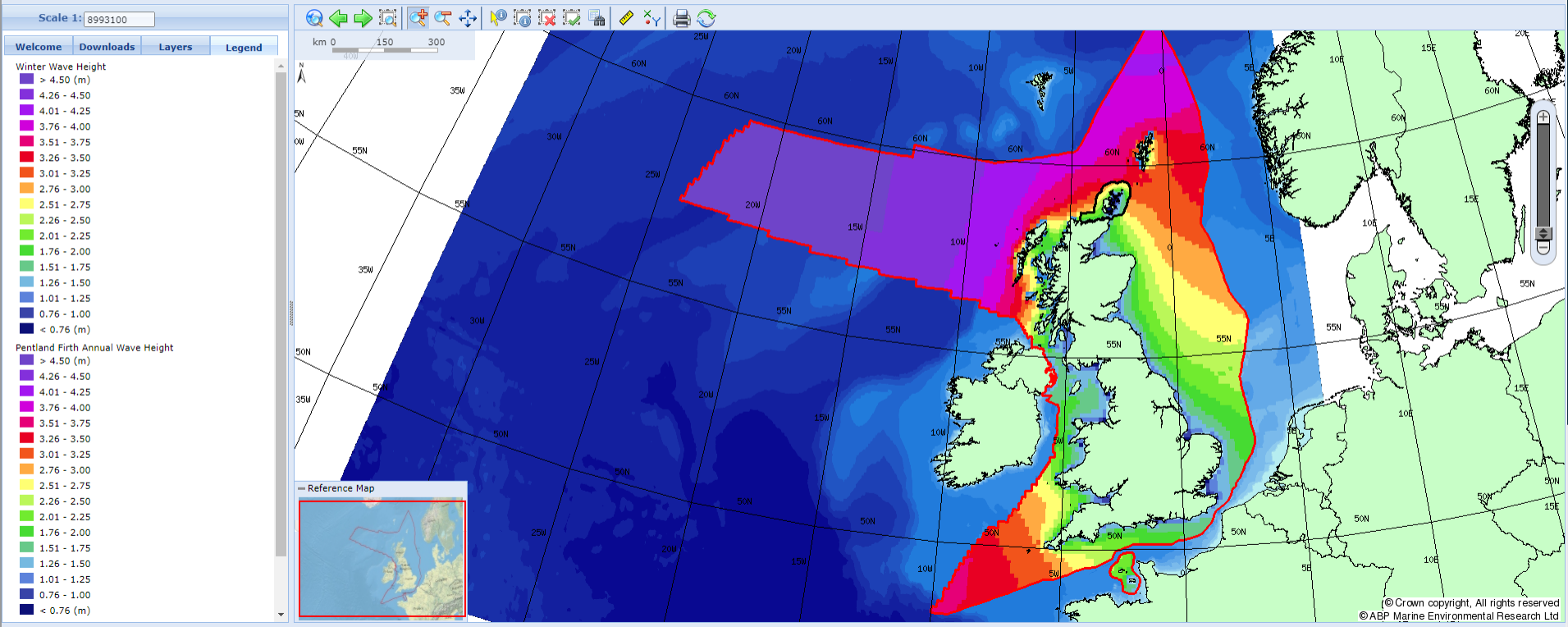
Conceptual
engineering



Cost estimation

WEBvision - Renewables (Wave)

Select Resource Wave Renewables Atlas Help



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Source: The Atlas of UK Marine Renewables Energy Resources

Preliminary Engineering

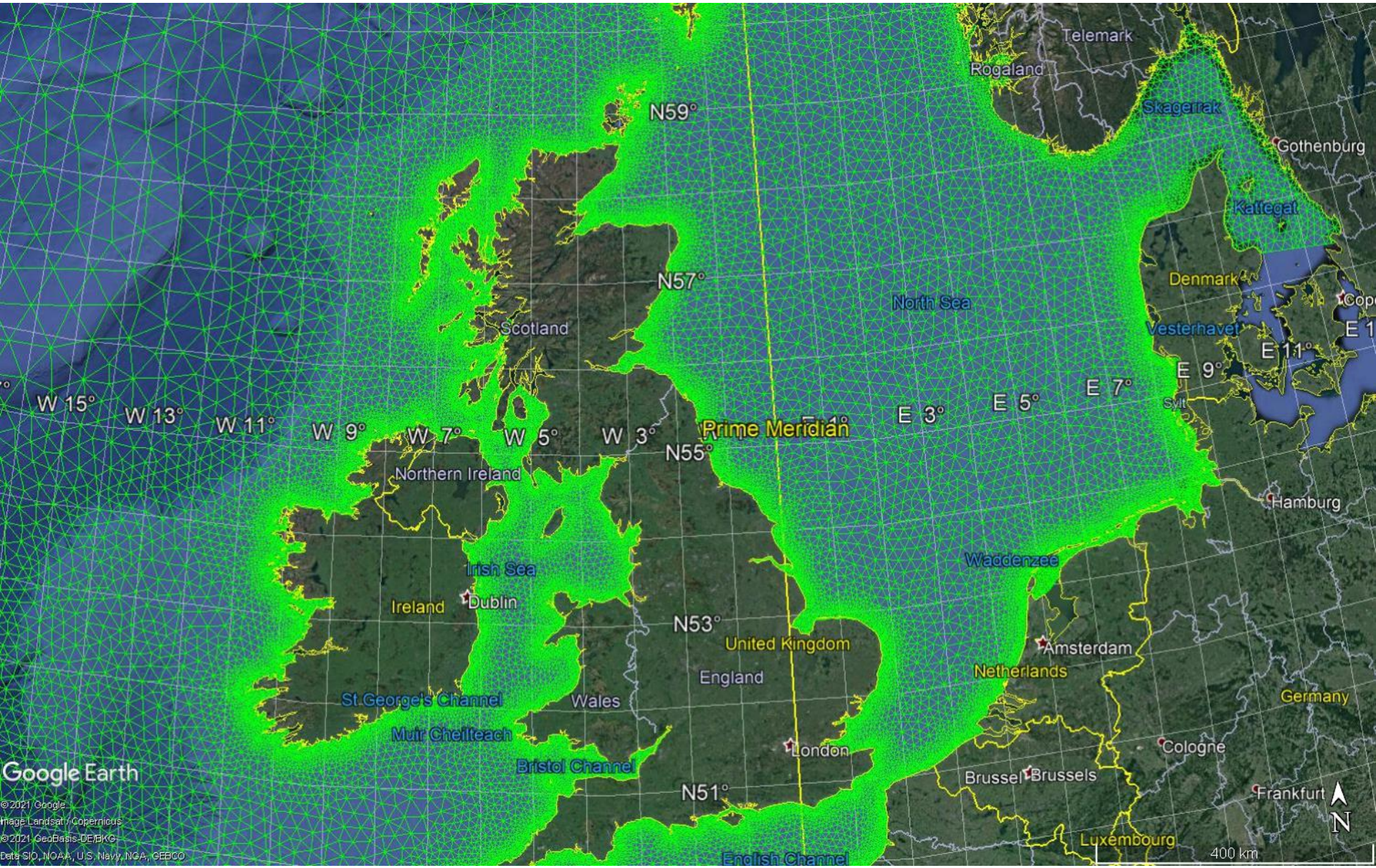


Source: U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy

Annual Omnidirectional Waves				
	Return Period (years)			
	1	10	50	100
Hs (m)	7.7	9.6	10.5	10.8
Tz (s)	7.9	8.9	9.3	9.4
Tp (s)	10.3	11.5	12.1	12.2
Hmax (m)	16.1	20.2	22.0	22.6
Tass (s)	11.0	12.4	12.9	13.1
Cmax (m)	10.0	12.7	13.8	14.2

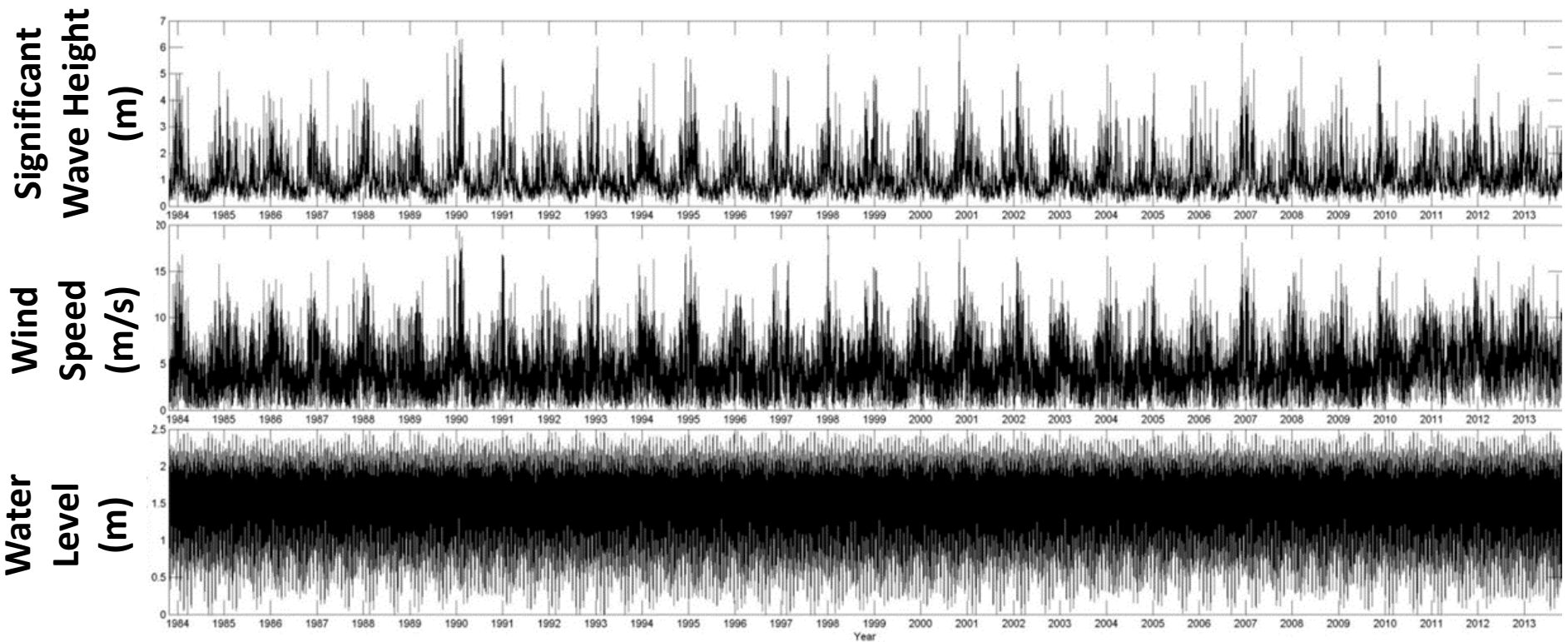
Wave Criteria for Engineering Design

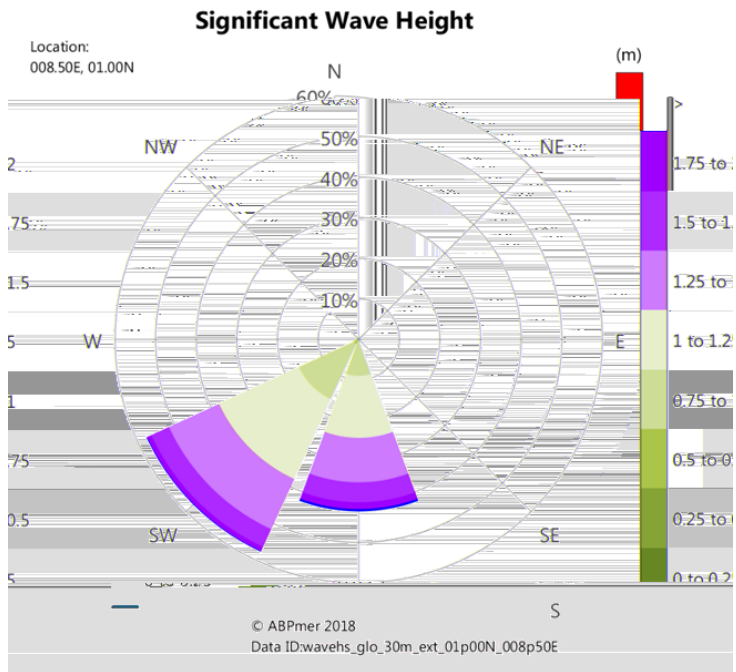
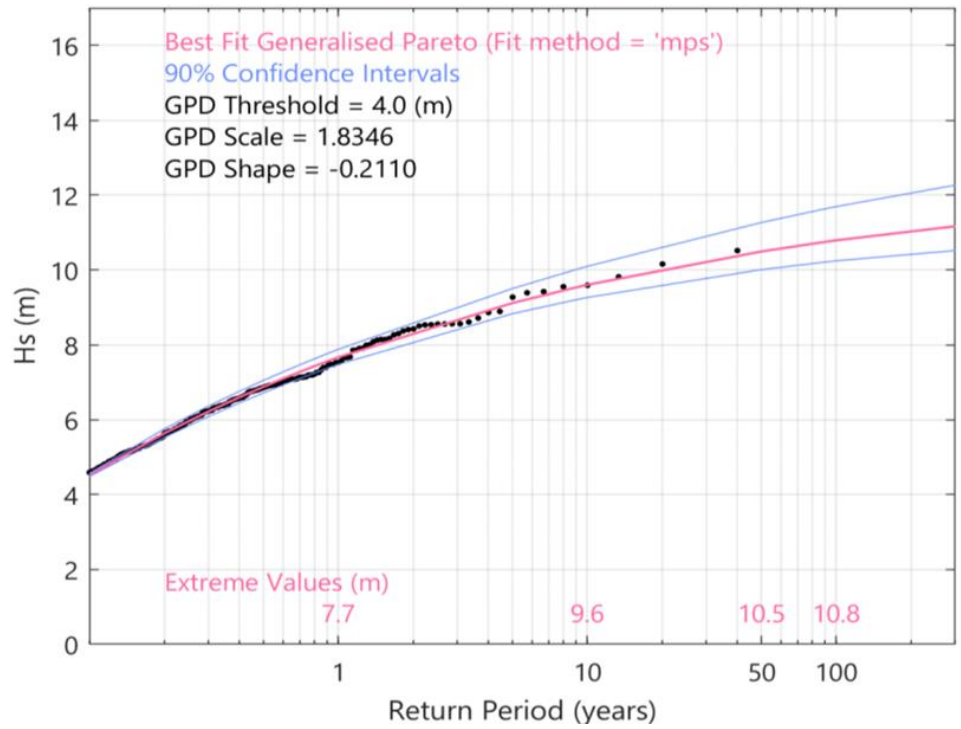
Distribution of Individual Wave Heights for Fatigue (1-Year)											Directions are FROM	
H_lower (m)	H_upper (m)	N	NE	E	SE	S	SW	W	NW	OMNI	Tz (s)	
0.0	0.5	2,133,210	45,190	33,305	136,335	123,975	40,149	2,289	7,767	2,522,220	4.1	
0.5	1.0	1,926,498	38,335	39,717	121,607	125,903	24,741	1,761	5,650	2,284,212	4.6	
1.0	1.5	848,090	14,888	22,833	53,274	61,706	7,934	779	2,500	1,012,004	5.2	
1.5	2.0	388,669	6,112	12,202	25,693	30,935	3,141	343	1,181	468,276	5.5	
2.0	2.5	185,659	2,759	6,593	13,245	16,097	1,379	152	562	226,446	5.8	
2.5	3.0	94,712	1,419	3,711	7,252	8,801	655	69	275	116,894	6.1	
3.0	3.5	50,924	794	2,159	4,111	4,973	329	33	140	63,463	6.3	
3.5	4.0	28,603	466	1,292	2,391	2,889	174	16	75	35,906	6.5	
4.0	4.5	16,635	282	789	1,420	1,720	96	9	41	20,992	6.7	
4.5	5.0	9,940	173	488	857	1,048	56	5	23	12,590	6.9	
5.0	5.5	6,069	107	304	525	652	33	3	13	7,706	7.1	
5.5	6.0	3,769	67	190	326	413	20	2	7	4,794	7.2	
6.0	6.5	2,373	42	119	205	265	13	1	4	3,022	7.3	
6.5	7.0	1,511	27	74	130	172	8	1	2	1,925	7.5	
7.0	7.5	972	17	46	83	112	5		1	1,236	7.6	
7.5	8.0	630	11	28	54	73	3		1	800	7.7	
8.0	8.5	411	7	17	35	48	2			520	7.8	
8.5	9.0	270	4	10	23	31	1			339	7.9	
9.0	9.5	179	3	6	15	21	1			225	7.9	
9.5	10.0	119	2	4	10	14	1			150	8.0	
10.0	10.5	79	1	2	6	9				97	8.1	
10.5	11.0	53	1	1	4	6				65	8.2	
11.0	11.5	36		1	3	4				44	8.3	
11.5	12.0	24			2	3				29	8.3	
12.0	12.5	16			1	2				19	8.4	
12.5	13.0	11			1	1				13	8.5	
13.0	13.5	7				1				8	8.5	
13.5	14.0	5				1				6	8.6	
14.0	14.5	3								3	8.6	
14.5	15.0	2								2	8.7	
15.0	15.5	2								2	8.7	
15.5	16.0	1								1	8.7	
		5,699,482	110,707	123,891	367,608	379,875	78,741	5,463	18,242	6,784,009		



Google Earth

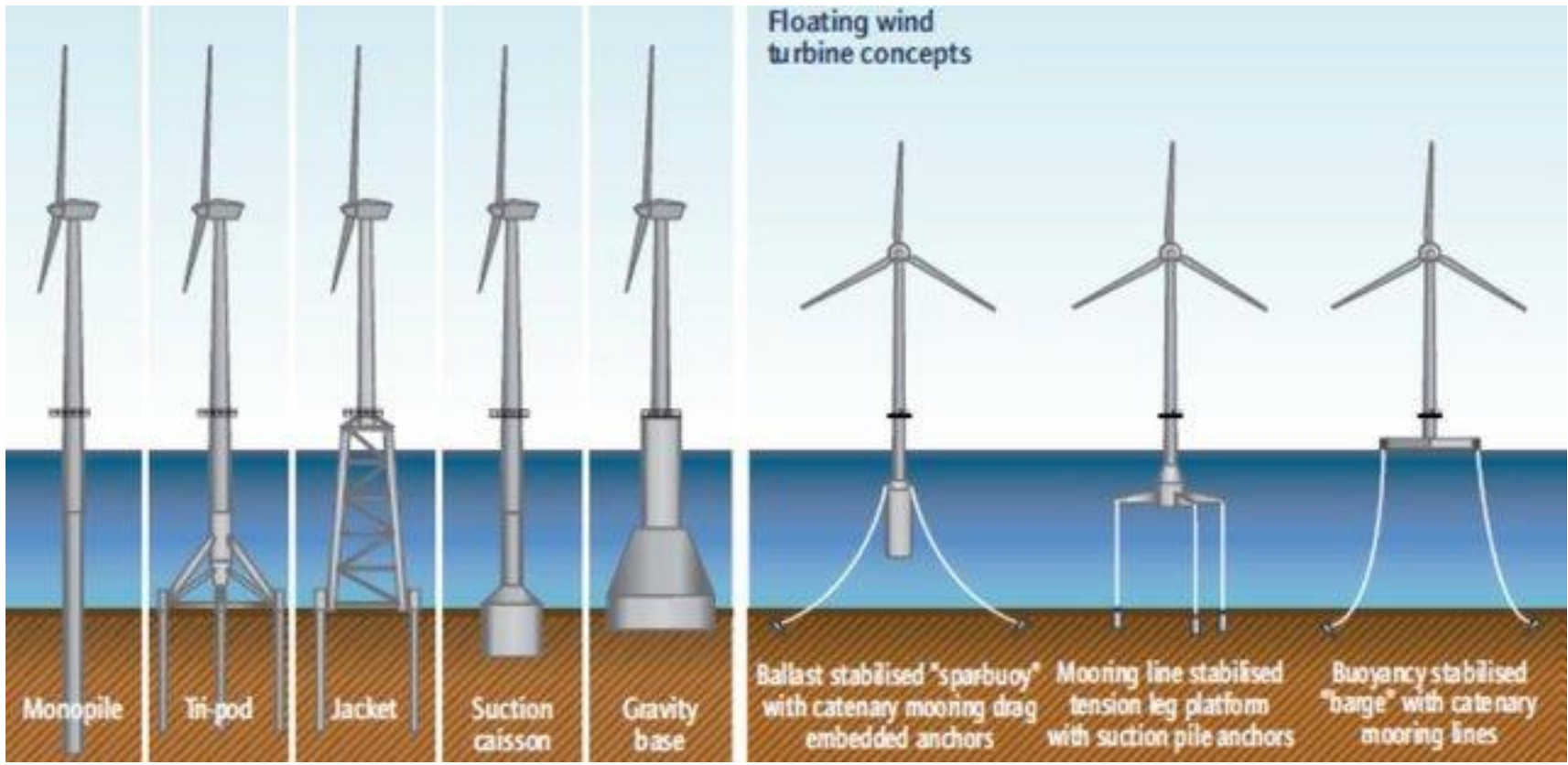
© 2021 Google
Image Landsat / Copernicus
© 2021 GeoBasis-DE/BKG
Data SIO, NOAA, U.S. Navy, NGA, GEBCO





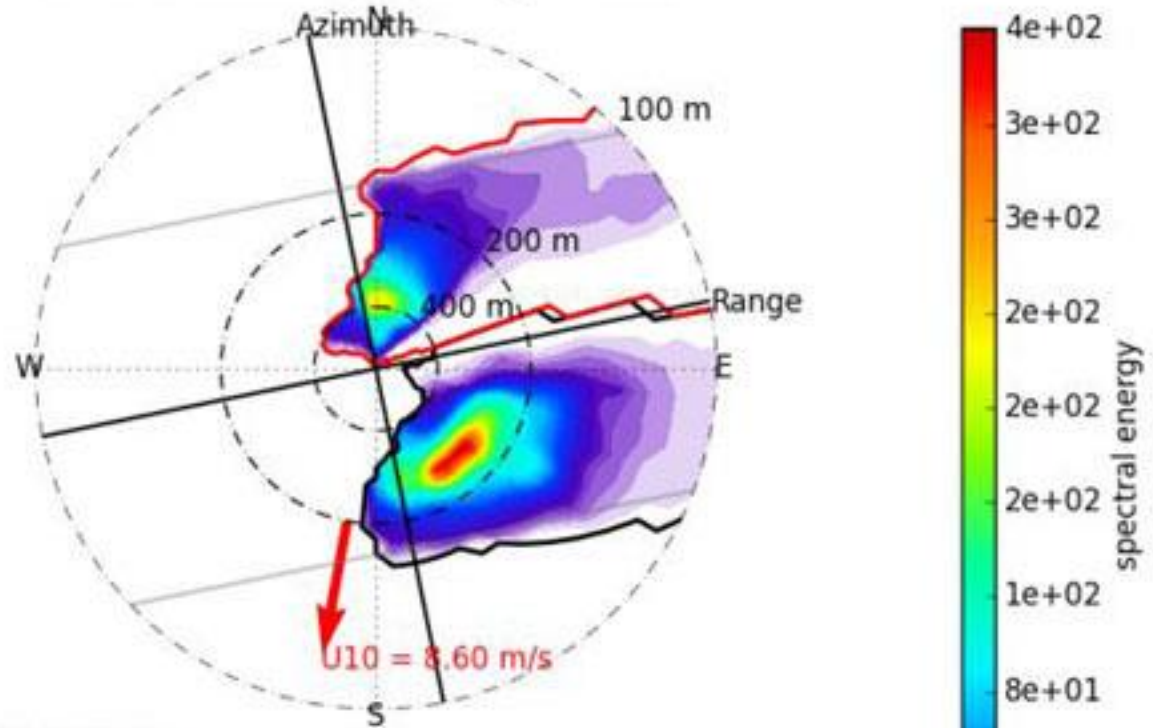


More floating structures
Increased sensitivity to wave motion
Quantitation of wave energy by period and direction
Full directional wave spectra



Source: E I Konstantinidis and P N Botsaris 2016 IOP Conf. Ser.: Mater. Sci. Eng. 161 012079.
Wind turbines: current status, obstacles, trends and technologies. DOI: 10.1088/1757-899X/161/1/012079

S1A Ocean Wave Spectrum

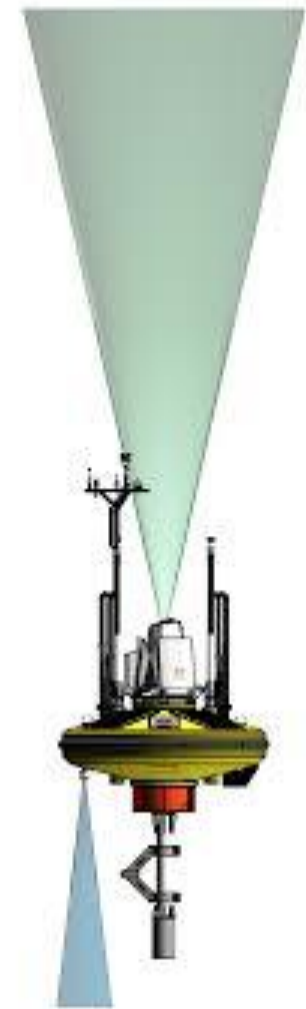


Wl: 248.26 m	Wl: 367.62 m		
Dir: 135.81 °	Dir: 2.25 °		
Hs: 1.27 m	Hs: 0.89 m		
Lon : -131.42 deg	SnR : 25.52	NRCS : -6.09 dB	Az. Cut Off : 187.0 m
Lat : 21.63 deg	Nv : 1.40	Heading : 348.5 deg	Incidence : 24.3 deg

Detailed Engineering Design and Certification

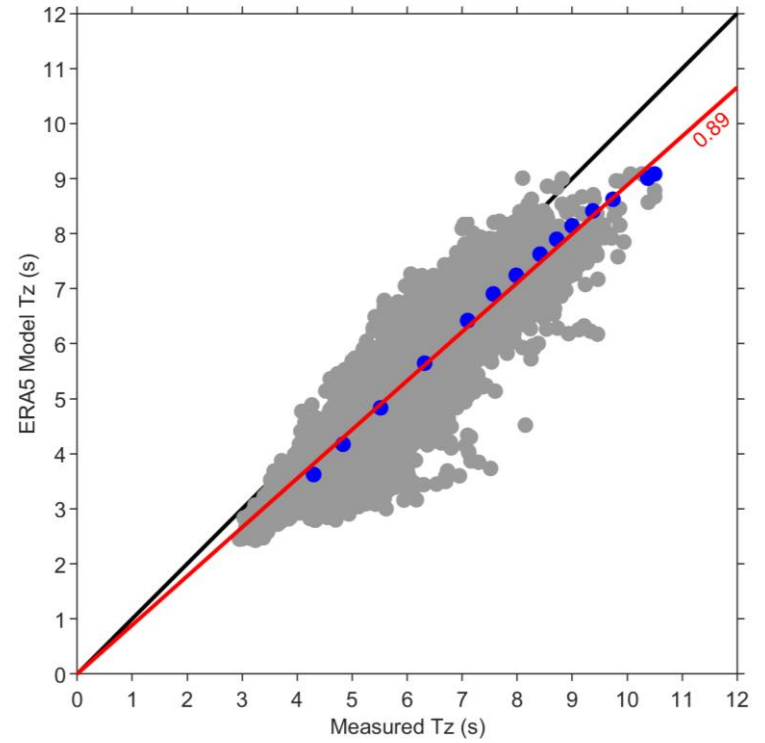
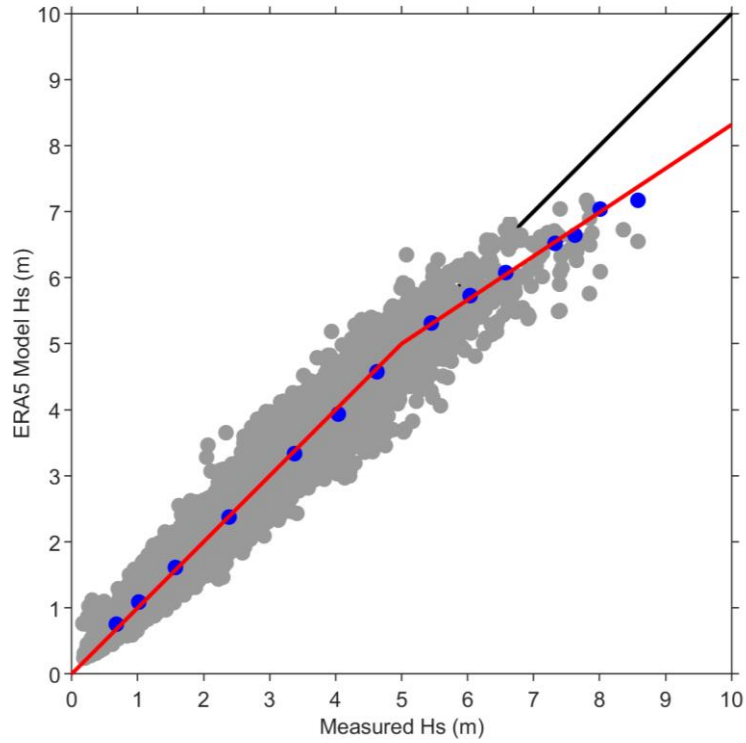
STANDARD	FULL REFERENCE
ISO 19901-1:2015	International Organization for Standardization (2015). International Standard, Petroleum and natural gas industries - Specific requirements for offshore structures - Part 1: Metocean design and operating considerations. Second edition, 2015-10-15, ISO 19901-1:2015.
DNVGL-RP-C205	DNVGL (2017). Recommended Practice, Environmental Conditions and Environmental Loads, August 2017, DNVGL-RP-C205.
IEC 61400-3:2009	International Electrotechnical Commission (2009). International Standard, Wind turbines - Part 3: Design requirements for offshore wind turbines, Edition 1.0, 2009-02, IEC 61400-3:2009.
IEC TS 62600-2:2016	International Electrotechnical Commission (2016). Technical Specification IEC TS 62600-2:2016. Marine energy - Wave, tidal and other water current converters - Part 2: Design Requirements for marine energy systems.

In-Situ Measurements

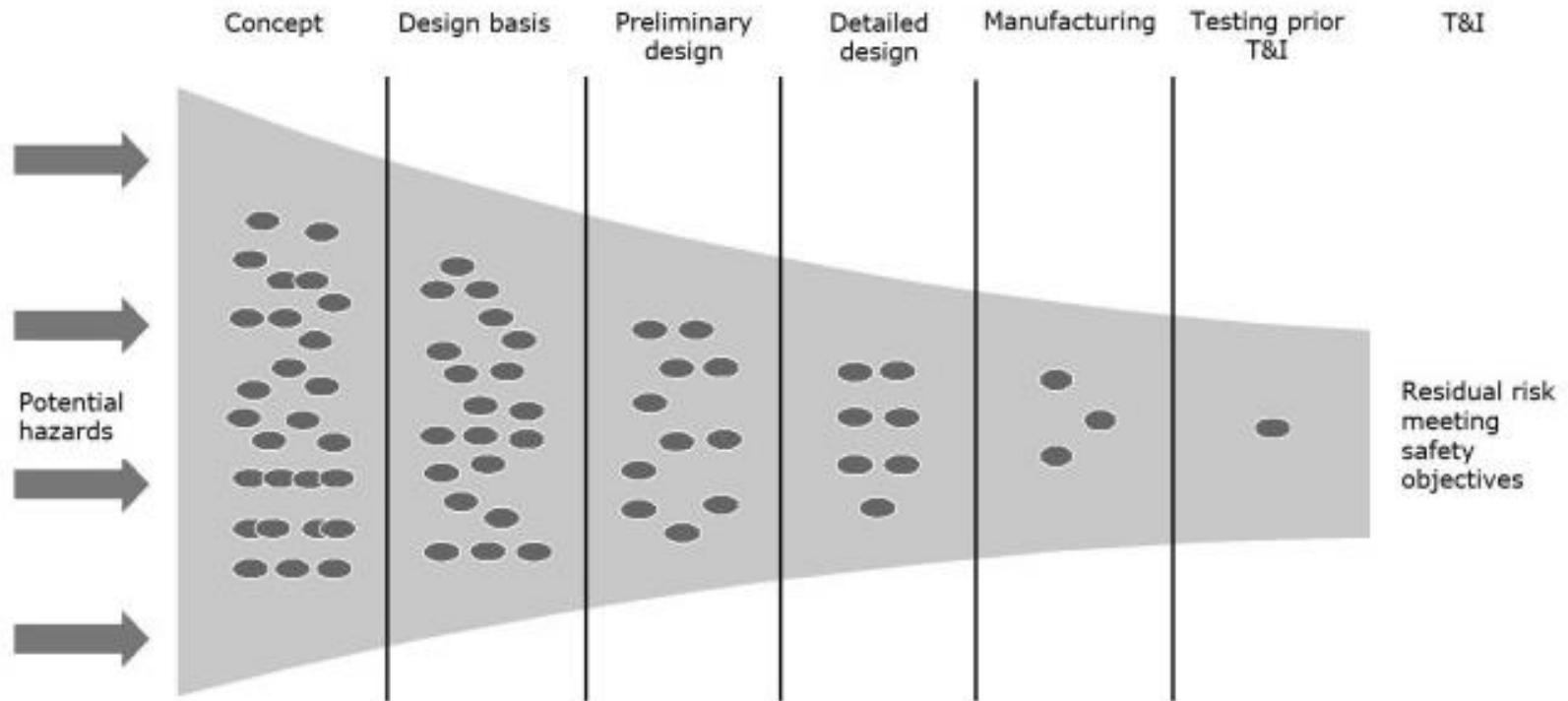


Source: Fugro

Validation



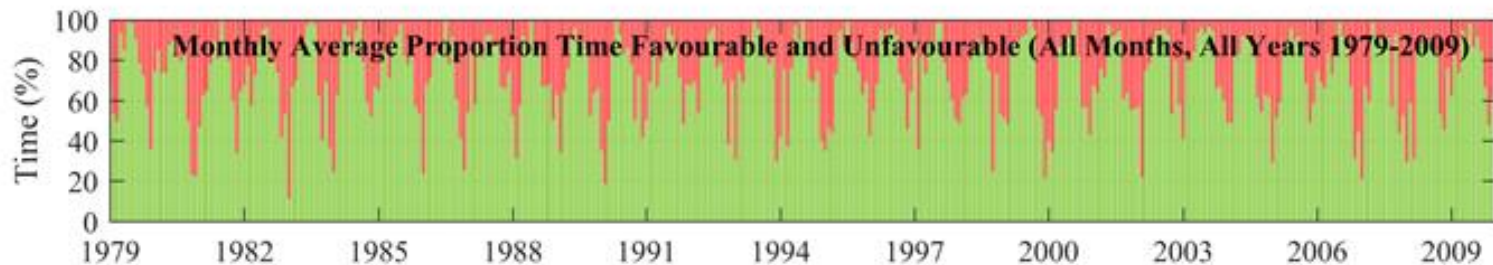
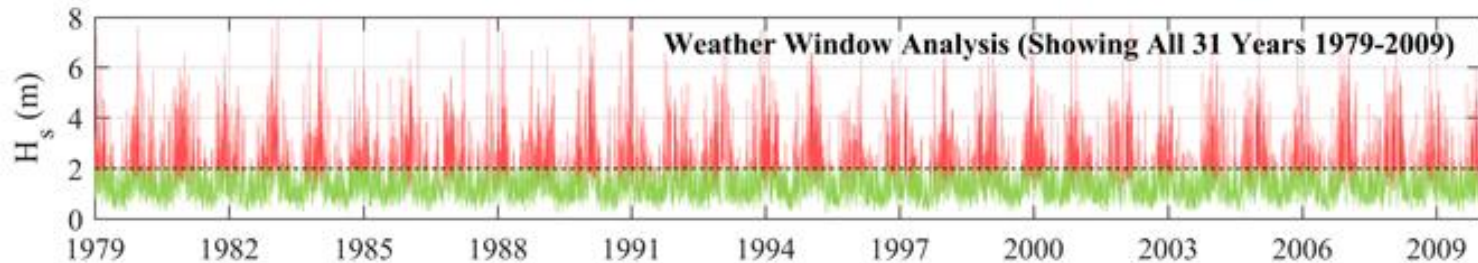
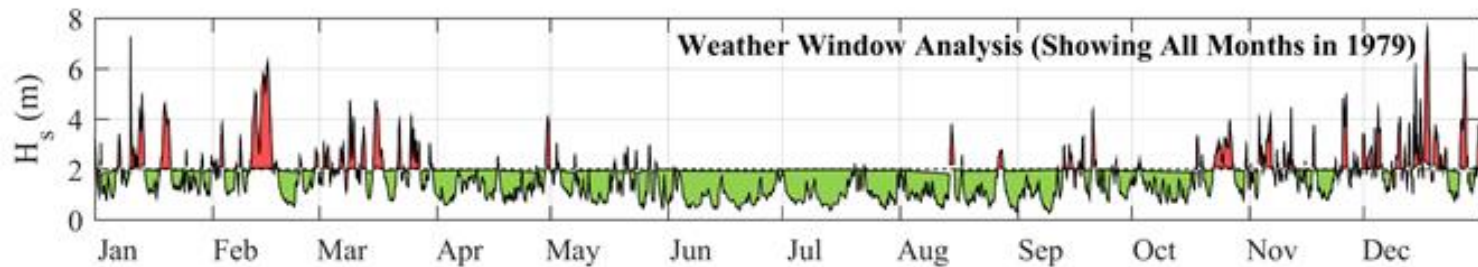
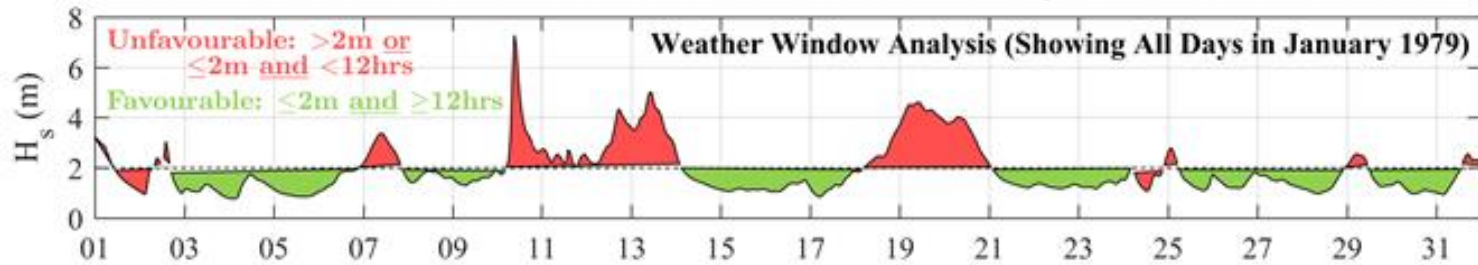
Progressively Reducing Uncertainty



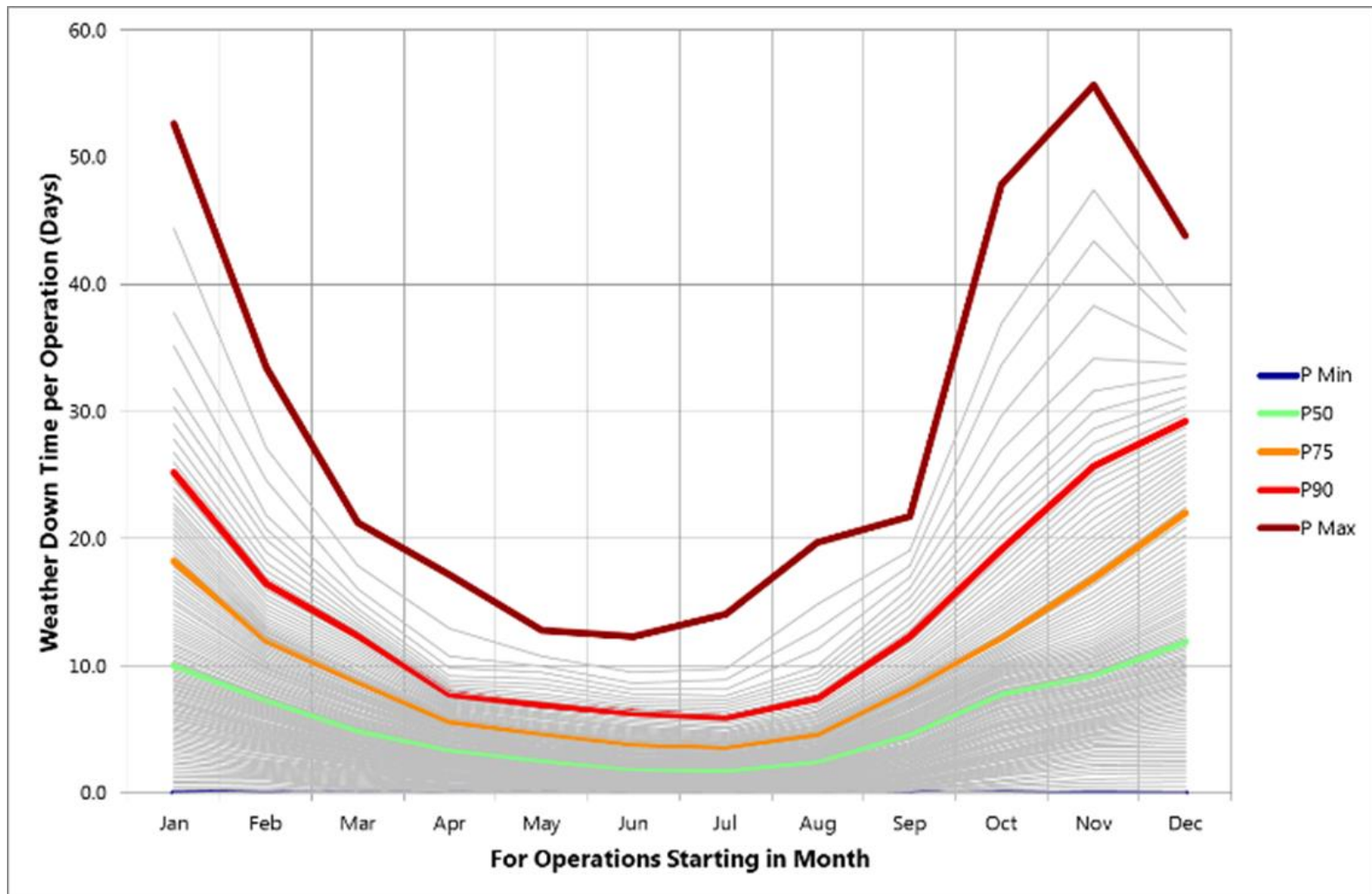
Installation



Example: Proportion of time in month that the significant wave height (H_s) is $\leq 2\text{m}$ for at least 12 hours.

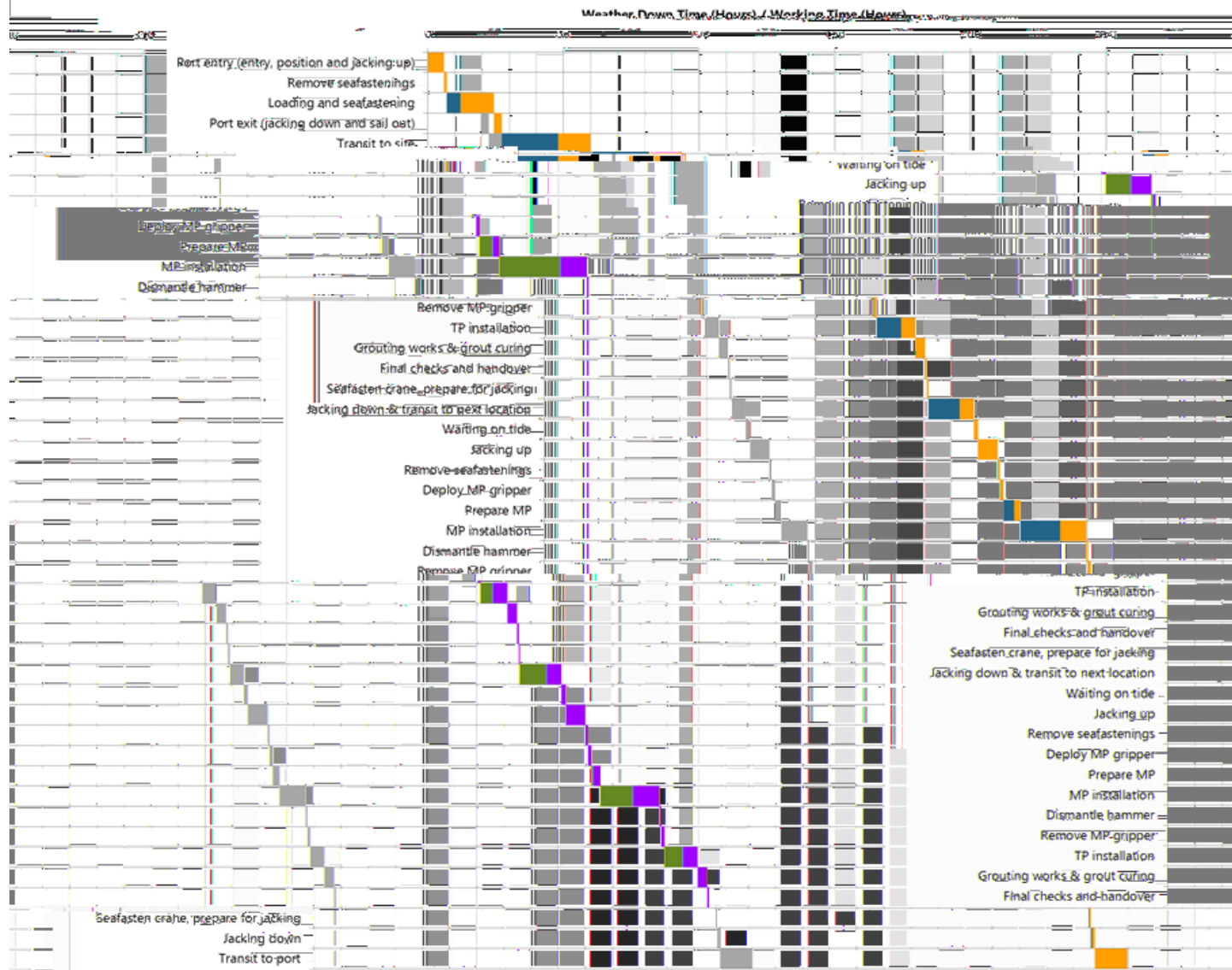


Tasks Task name	Location		Durations		Thresholds (not to be exceeded whilst working)						
	Location of task		Task dur	Weather	Wave heigh	Wave perio	Wave perio	Wind speed	Wind ref. h	Wind avg. p	Current spe
	Longitud	Latitude	(hrs)	(hrs)	(m)	(s)	Allow work	(m/s)	(m)	(s)	(m/s)
Enter port and position	8.267	55.445	3	3.5	3			15	10	60	
60	8.43	55.468	8.43	55.468	0.5			12		100	
60	8.43	55.468	8.43	55.468	1	2		12		100	
60	8.43	55.468	8.43	55.468	1	2		12		100	
60	8.43	55.468	8.43	55.468	1	2		12		100	
60	8.43	55.468	8.43	55.468	1	2		12		100	
60	8.43	55.468	8.43	55.468	1	2		12		100	
60	8.43	55.468	8.43	55.468	1	2		12		100	
60	8.43	55.468	8.43	55.468	1	2		12		100	
60	8.43	55.468	8.43	55.468	1	2		12		100	
60	8.43	55.468	8.43	55.468	2	3		12		100	
60	8.43	55.468	8.43	55.468	2	3		12		100	
60	8.43	55.468	8.43	55.468	2	3		12		100	
60	8.43	55.468	8.43	55.468	3	5		12		100	
60	8.43	55.468	8.43	55.468	3	5		12		100	
60	8.43	55.468	8.43	55.468	3	5		12		100	
60	8.43	55.468	8.43	55.468	0.5	1		12		100	
60	8.43	55.468	8.43	55.468	6	8		12		10	
	7.853	55.23	7.853	55.23	4	6	3				
	6.708	54.782	6.708	54.782	4	6	3				
	5.611	54.4	5.611	54.4	4	6	3				
60	4.94	54.129	4.94	54.129	8	10	2	14		14	10



Example Programme for a Single Cycle Starting in June, P90 Probability of Non-Exceedance

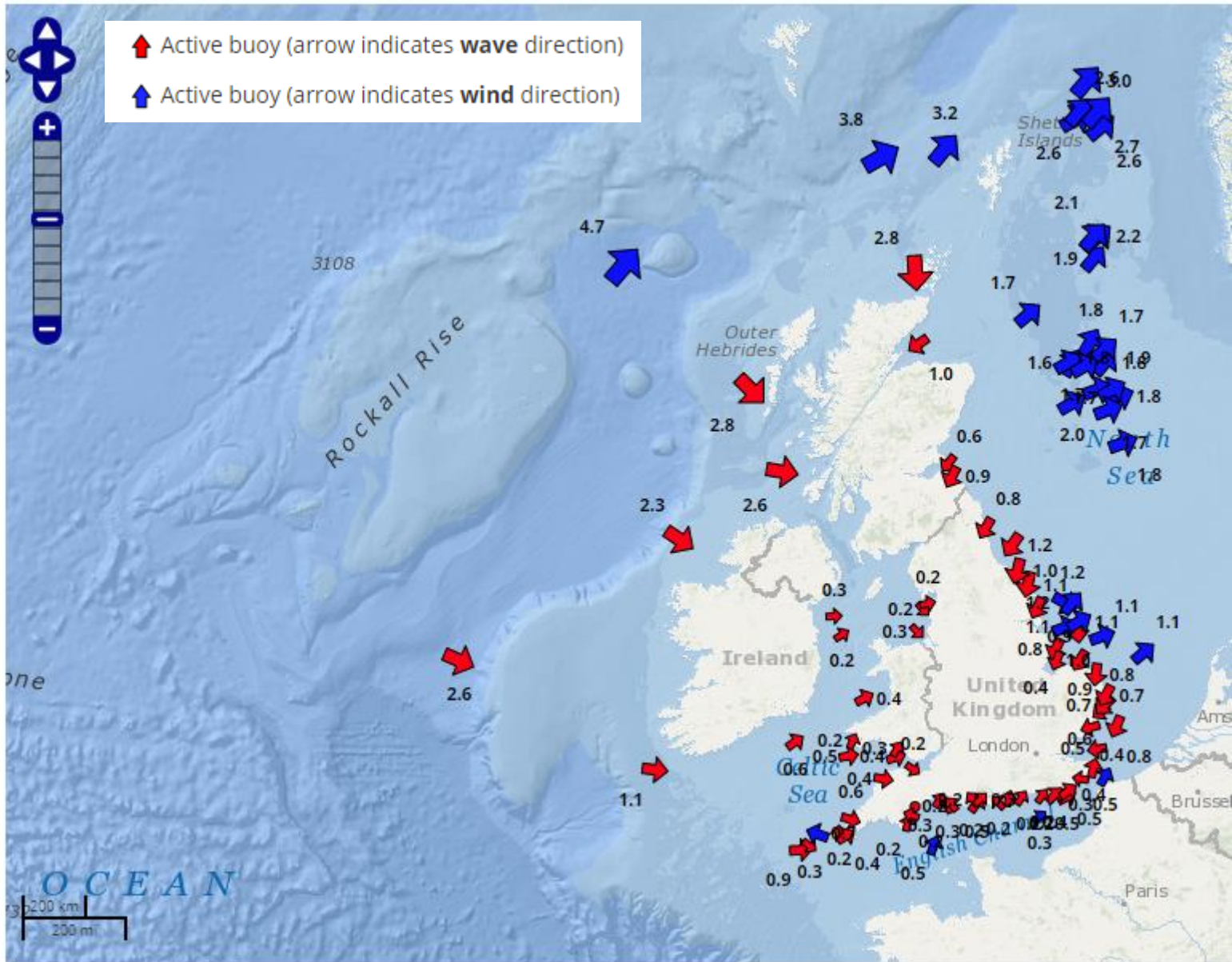
■ Net Duration (Hours) ■ Weather Down Time (Hours) ■ Extended Total Duration (Hours)



Operations & Maintenance

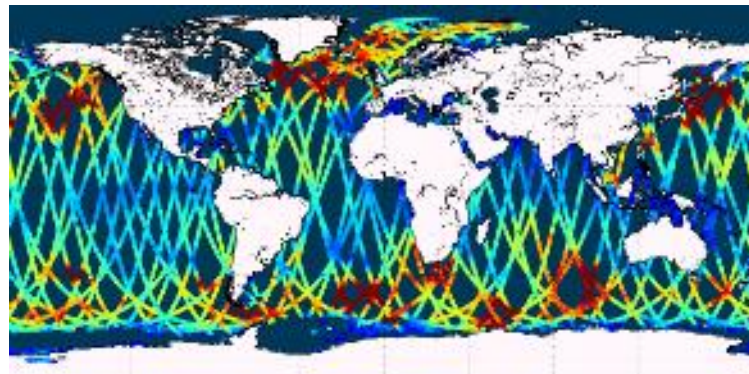


Source: Incat Crowther

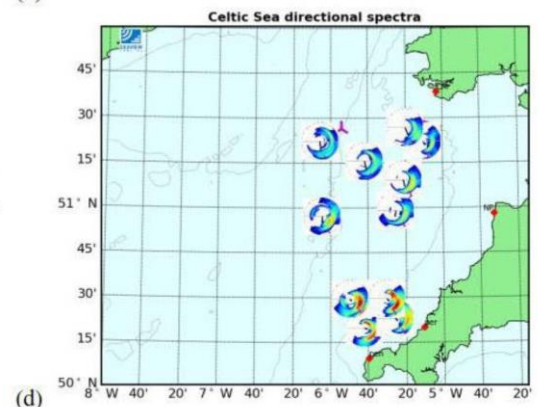
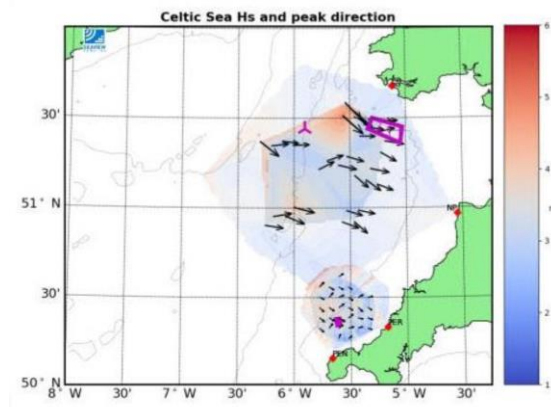


DELIVERABLE	ACTIVITIES	SITE SELECTION AND FEASIBILITY	DEVELOPMENT AND CONSENTS	DESIGN AND CERTIFICATION	INSTALLATION	O&M	DECOMMISSIONING
Metocean briefing note	Literature review ^D						
	Data collation from free sources and gap analysis ^D						
Preliminary engineering dataset and analyses	Purchase of data ^D						
	Modelling ^M (calibrated with publicly available data or uncalibrated)						
	Data analysis ^D						
	Environmental impact analysis ^{DMS}						
Full engineering dataset and analyses	<i>In-situ</i> measurement ^S						
	Fully calibrated modelling ^M						
	Data analysis ^D						
Other	Weather forecast modelling ^M						
	Real-time <i>in-situ</i> measurement ^S						
	Strategy optimisation and condition monitoring ^{DMS}						
	End of life assessment						

Sources of wave data



Remote sensing data

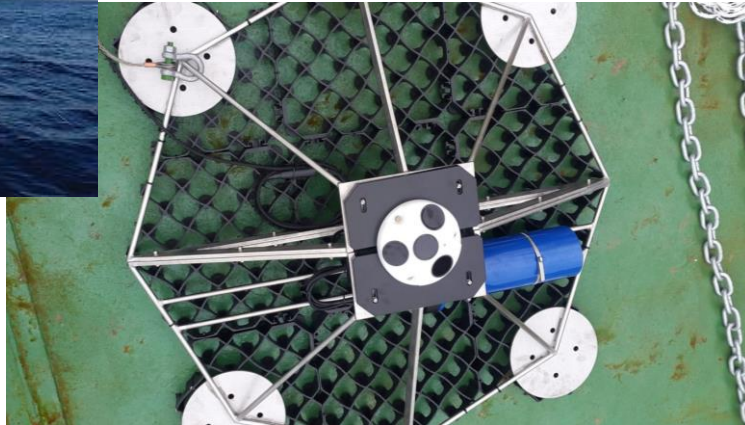


'Provided by Lucy Wyatt, Seaview Sensing Ltd', doi:10.21926/jept.2101005

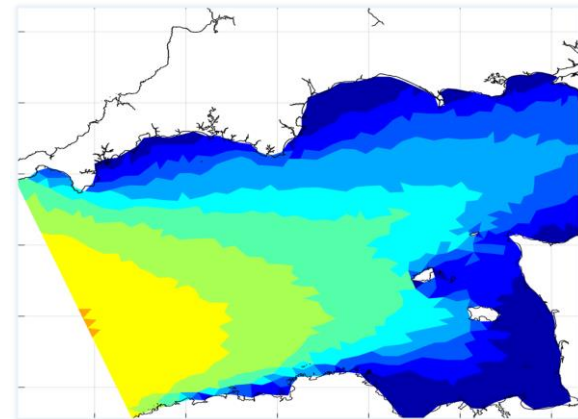
Sources of Wave Data



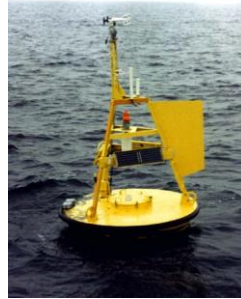
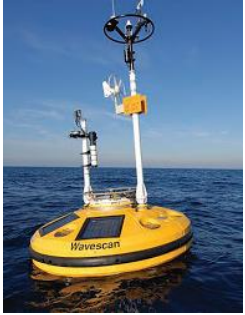
In-situ data



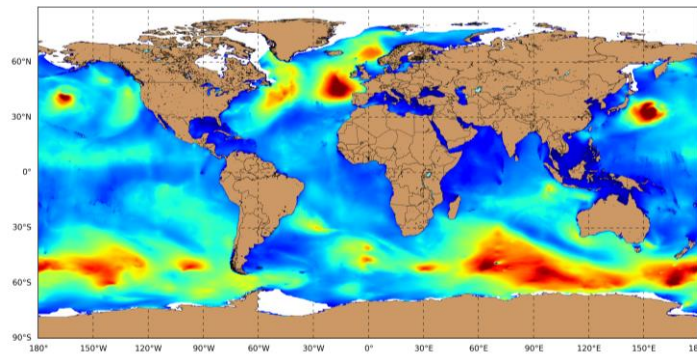
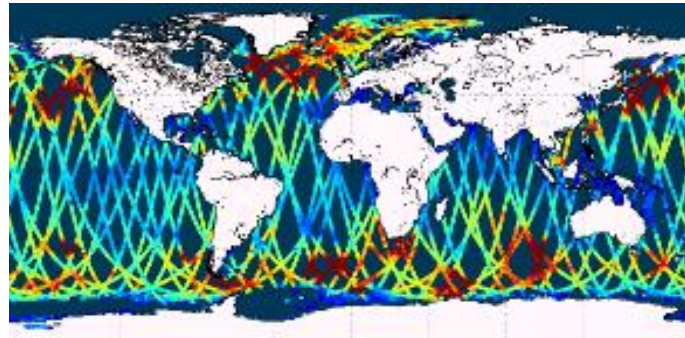
Modelled data



Validation



<https://www.ndbc.noaa.gov/hull.shtml>



Types of wave data

Parameter data

Total energy: H_s , H_{max} , H_c , T_z , T_p , θ_{peak}

Partitioned Parameter data

Wind sea: H_s , H_{max} , H_c , T_z , T_p , θ_{peak}

Swell 1: H_s , H_{max} , H_c , T_z , T_p , θ_{peak}

Swell 2: H_s , H_{max} , H_c , T_z , T_p , θ_{peak}

Spectral Data

Omnidirectional

Directional

For engineering and operational planning,
data types highlighted in **green** are required.

Source	Total energy parameters	Partitioned parameters	Omnidirectional spectra	Directional spectra
Altimeter	Y ¹			
SAR	Y ²	Y ²	Y ²	Y ²
HF Radar	Y	Y	Y	Y
Vertical Radar	Y	Y		
Wave buoy	Y	Y	Y	Y
ADCP	Y	Y	Y	Y
Pressure sensor	Y	Y	Y	
Model	Y	Y	Y	Y

Notes

1. Altimeter data only provide significant wave height
2. SAR provides limited coverage of spectra in both wave period and direction

Temporal considerations

Sampling interval

A high sampling interval (10-30-mins) is required to properly capture extreme events and support operational analyses such as weather windows.



Duration

A long time series (20-30 years) is required to capture a number of extreme events for design and to characterise inter-annual variability for operating and maintenance planning.



Limits value of 10-14 day repeat cycle data.

Validation of model data at large scale – application to wave resource modelling

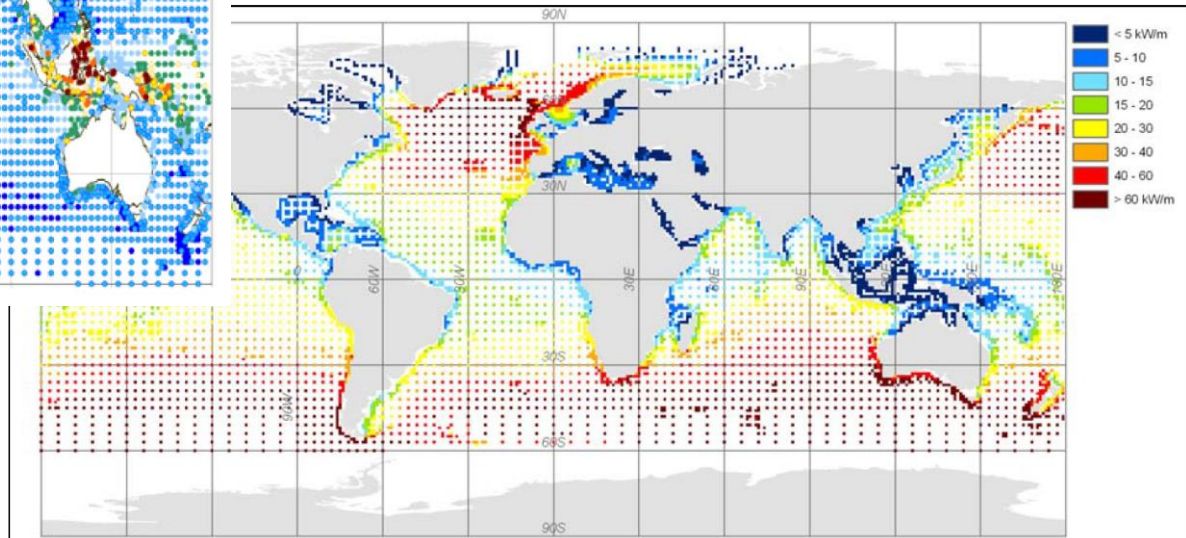
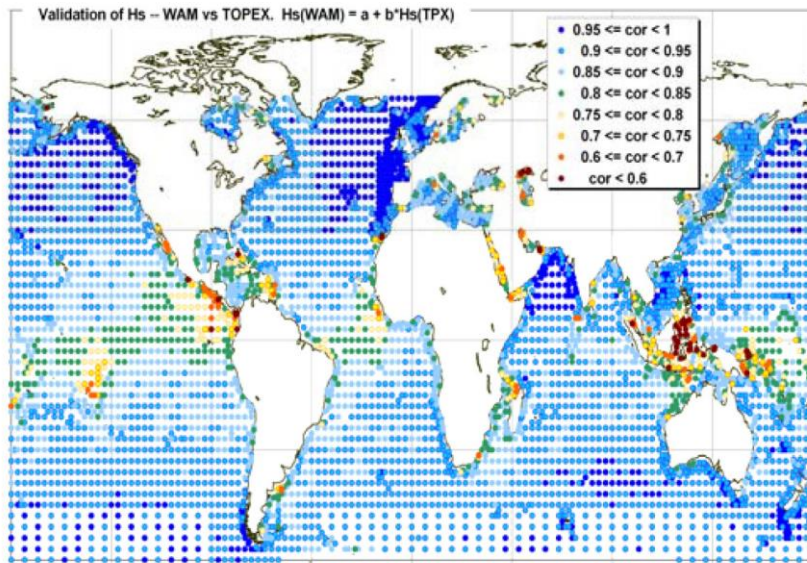


Figure 2 – Annual global gross theoretical wave power for all WorldWaves grid points worldwide.

ESA
SeaState CCI

Some
potential roles

Improving temporal consistency of re-analysis data sets

Ability to support early phase validation of wave energy resource modelling, using shoreward along track data

Reduce swell related uncertainty in global numerical models

Verification of spectral shape for early validation of deepwater modelling for floating wind

2015 : Bring Together Wide Range of Users

Oceans of Knowledge: Realising the Benefits of Ocean Information

A one day event exploring the economic, safety and environmental benefits of improved observation and prediction of our oceans and seas

The event will conclude with the World Hydrography Day Drinks Reception

WEDNESDAY 11 NOVEMBER 2015

The Royal Institution, 21 Albemarle Street, London, W1S 4BS

User Case Studies

Oil & Gas

Oil Spill Response

Offshore Renewables

Ports & Harbours

Coastal Flood Risk

Insurance

Ocean Passage Planning

Leisure Boats

Ship Emergency Response

Security of Navigation

2017 : User Benefits via Weather Forecasts

Oceans of Knowledge:

Exploring the benefits of improved ocean observation and measurement

TUESDAY 7TH NOVEMBER 2017

Royal Institution, London, 21 Albemarle Street, London, W1S 4BS

Organised by the Operational Oceanography Special Interest Group of the IMarEST
in association with the Partnership for Observation of the Global Oceans.

User Case Studies

Search & Rescue

Ship Routing

Aviation

Offshore Wind

Electrical Energy Distribution

Aquaculture

Tropical Agriculture

Insurance & Reinsurance

Retail & Logistics

2019 : Enabling Growth of the Blue Economy

Oceans of Knowledge:

Ocean Observations and Emerging Technologies Enabling the Blue Economy

WEDNESDAY 20 NOVEMBER 2019

The Royal Institution, London

High Growth Uses

Autonomous Shipping

Open Water Aquaculture

Marine Mining

Offshore Wind

Enabling Technologies

Communication at Sea

Advanced Sensors

Earth Observation

Machine Learning

Robotics and Automation

2021 : Climate Change and the Ocean

Oceans of Knowledge 2021:
Climate change and the ocean

**26-27
October 2021**
Institute of Physics, London, N1 9BU
*with remote participation
worldwide*

4th biennial conference organised by the Operational Oceanography Special Interest Group of the IMarEST

A two day conference addressing three key themes:

- Climate change and sustainable use of the ocean and ocean resources
- The role of the ocean in natural and engineered climate mitigation
- Rising sea levels and coastal vulnerability

Renewable Energy Transition

Challenges of rapid growth

Increasing demands of many users

Strategic ocean data requirements

Follow on workshop

COP26



2021
2030 United Nations Decade
of Ocean Science
for Sustainable Development



RMets
Royal Meteorological Society



Benefits of Ocean Observations Catalog

Community developed Community driven Community benefit

Community Engagement



Building on work begun at OceanObs 19, the BOOC project aims to engage with the entire ocean observation, measurement, and modeling community.

Collecting Case Studies



The BOOC will be continuously updated with new use case studies that demonstrate the benefits of ocean observing worldwide.

Developing Standards



The BOOC will provide the community with access to a comprehensive, consistent, and constantly improving view of the benefits of ocean observing that can be easily searched by location, benefit area, and type of observation.

www.booc.info