Project - MyWave

Ensemble harbour forecast performance

Reference: MyWave-D3.3

Project N°: FP7-SPACE-2011- 284455	Work programme topic: SPA.2011.1.5.03 – R&D to enhance future GMES applications in the Marine and Atmosphere areas
Start Date of project : 01.01- 2012	Duration: 36 Months

WP leader: Luigi Cavalieri	Issue: 1.0		
Contributors : Cristina Toledano Lozano, Marta Gómez Lahoz			
MyWave version scope : All			
Approval Date :	Approver:		
Dissemination level: PU			

DOCUMENT

VERIFICATION AND DISTRIBUTION LIST

Name	Work Package	Date
	Name	Name Work Package

CHANGE RECORD

Issue	Date	§	Description of Change	Author	Checked By
0.1		all	First draft of document	Cristina Toledano	
1.0		all	Document finalization		

TABLE OF CONTENTS

I Introduction	
I.1 Work Package and report objectives	10
II LOCAL WAVE-EPS CONFIGURATION AND RUN CYCLE	11
II.1 DESCRIPTION OF ATLANTIC LOCAL MODELS	11
II.2 DESCRIPTION OF MEDITERRANEAN LOCAL WAVE MODEL	13
III DETERMINISTIC WAVE MODEL VALIDATION	
III.1 Introduction	15
III.2 Barcelona-CNMCA Application	16
III.3 Barcelona – UKMO Application	17
III.4 Tenerife – UKMO Application	19
IV Harbour ensemble	
IV.1 Introduction	
IV.2 Ensemble consistency	
V Results	
VI CONCLUSIONS	

LIST OF FIGURES

FIGURE1 – LOCAL WAVE FORECAST SYSTEM FOR SPANISH HARBOURS OPERATED BY PDE
FIGURE2 – CONFIGURATION OF LOCAL WAVE FORECAST MODEL FOR GIJON11
FIGURE3 – CONFIGURATION OF LOCAL WAVE FORECAST MODEL FOR TENERIFE .12
FIGURE4 – CONFIGURATION OF LOCAL WAVE FORECAST MODEL FOR BARCELONA
FIGURE5 – BARCELONA-CNMCA: SCATTERPLOTS SIG.WAVE HEIGHT
FIGURE6 – BARCELONA-UKMO: SCATTERPLOTS SIG.WAVE HEIGHT
FIGURE7 – TENERIFE-UKMO: SCATTERPLOTS SIG.WAVE HEIGHT
FIGURE8 – BARCELONA-CNMCA SPREAD MAPS21
FIGURE9 – BARCELONA-UKMO SPREAD MAPS
FIGURE10 – TENERIFE-UKMO SPREAD MAPS23
FIGURE11 – GIJON-UKMO SPREAD MAPS
FIGURE12 – RANK HISTOGRAM BARCELONA-CNMCA
FIGURE13 – RANK HISTOGRAM BARCELONA-UKMO
FIGURE14 – RANK HISTOGRAM TENERIFE-UKMO 26
FIGURE15 – BARCELONA PLUMES
FIGURE16 – TENERIFE AND GIJON PLUMES
FIGURE17 – EXAMPLE OF GIJON EPS-GRAM
FIGURE18 – EXAMPLE OF GIJON PROBABILITY MAPS

	Ensemble harbour forecast performance		: MyWave—D3.3	
		Date	: 2 Jan 2014	
		Issue	: 1.0	
FIGURE19 – EXAMP	PLE OF TENERIFE EPS-GRAM		32	
FIGURE20 – EXAMP	PLE OF TENERIFE PROBABILITY MAPS		32	
FIGURE21 – EXAMP	PLE OF BARCELONA EPS-GRAM		33	
FIGURE22 – EXAMP	PLE OF BARCELONA PROBABILITY MAPS		33	

LIST OF TABLES

TABLE1 – DEPTH AND LOCATION OF BUOYS	15
TABLE2 – STATISTIC RESULTS SIG.WAVE HEIGHT BCN-CNMCA	16
TABLE3 – STATISTIC RESULTS MEAN DIRECTION BCN-CNMCA	17
TABLE4 – STATISTIC RESULTS SIG.WAVE HEIGHT BCN-UKMO	18
TABLE5 – STATISTIC RESULTS MEAN DIRECTION BCN-UKMO	19
TABLE6 – STATISTIC RESULTS SIG.WAVE HEIGHT TENERIFE-UKMO2	20
TABLE5 – STATISTIC RESULTS MEAN DIRECTION TENERIFE-UKMO	21

GLOSSARY AND ABREVIATIONS

AEMET	Spanish Meterological Agency (Agencia Estatal de Meteorología , Spain)
CNMCA	Stato Maggiore Aeronautica – Ufficio Generale Spazio Aereo e Meteorologia
EPS	Ensemble Prediction System
ISMAR	Instituto di Science Marine (Institute of Marine Science, Italy)
PDE	Puertos del Estado
SMC	Spherical Multi-Cell grid
UKMO	United Kingdom Met Office

Table 1

APPLICABLE AND REFERENCE DOCUMENTS

Applicable Documents

	Ref	Title	Date / Issue
DA 1	MyWave-A1	MyWave: Annex I – "Description of Work"	September 2011
DA 2	MyWave-D3.1	MyWave: Met Office Wave Model Ensemble Prediction Systems in the 'Atlantic-Euro Zone'	December 2012
DA 3	MyWave-D4.2a	MyWave: Proposal of metrics for user focused verification of deterministic wave prediction systems	
DA 4	MyWave-D4.2b	MyWave: Proposal of metrics for developer and user focused verification of wave ensemble prediction systems	

Reference Documents

	Ref	Title	Date / Issue
DR 1	Burgers et al. (1998)	Burgers, G., P. J. van Leeuwen and G. Evensen, 1998:Analysis Scheme in the Ensemble Kalman Filter. <i>Mon. Wea. Rev.</i> , 126, 1719–1724.	
DR 2		Callado, A., Escribà, P., García-Moya, J.A., Montero, J., Santos, C., Santos-Muñoz, D. and Simarro, J. (2013) Ensemble Forecasting, Climate Change and Regional/Local Responses, Dr Pallav Ray (Ed.), ISBN: 978-953-51-1132-0, InTech	
		GARCÍA-MOYA, JA., CALLADO, A., ESCRIBÀ, P., SANTOS, C., SANTOS- MUÑOZ, D. and SIMARRO, J. (2011), Predictability of short-range forecasting: a multimodel approach. Tellus A, 63: 550–563. doi: 10.1111/j.1600-0870.2010.00506.x	

	Issue	: 1.0
	Date	: 2 Jan 2014
Ensemble harbour forecast performance	Ref	: MyWave—D3.3

_



This report documents Task WP3.4, which is a direct application by Aemet-PdE to determinate the advantages of the ensemble approach for the management of commercial harbours. Three locations are to be considered, one on the European Atlantic coast (Gijon), one on the Canarias (Tenerife), and one on the Mediterranean coasts (Barcelona). In order to develop the system, these applications have been adapted to receive boundary conditions and wind fields from the UKMO and CNMCA systems.

Those applications are wave prediction systems on a local scale, developed specifically for harbours and their immediate surroundings. The system is based on the SWAN model and takes into consideration the changes the wave undergoes as it nears the coast.

Figure 1 - Local wave forecast system for Spanish harbours operated by PdE (red points). In the boxes, new ensemble applications: Barcelona, Gijon and Tenerife.

II LOCAL WAVE-EPS CONFIGURATION AND RUN CYCLE

II.1 DESCRIPTION OF ATLANTIC LOCAL MODELS.

II.1.1. GIJON APPLICATION

Gijon application has been configured taking the wave boundary conditions and the forcing windfields from MetOffice Model Ensemble Prediction which domain uses a Spherical Multi-Cell grid (SMC) which has variable resolution around the coast.

The local system has been defined on a computational grid of 51x51 points and with resolution of 529x511 meters each cell (WEST -5.93, EAST -5.54, SOUTH 43.54 and NORTH 43.77). The wind fields grid has a resolution of 0.45°x0.3°. Boundary conditions grid has a variable resolution due to SMC grid.



Figure 2 - Configuration of local wave forecast model for Gijon: computational grid (yellow), wind fields (red) and boundary conditions (black).

II.1.2. TENERIFE APPLICATION

Tenerife application has also been configured taking the wave boundary conditions and the forcing windfields from UKMO Model Ensemble Prediction.

The local system has been defined on a computational grid of 61x71 points and with resolution of 571x554 meters each cell (WEST -16.26, EAST -15.91, SOUTH 28.3 and NORTH 28.65). The wind fields grid has a resolution of 0.45°x0.3°. Boundary conditions grid has a variable resolution due to SMC grid.



Figure 3 - Configuration of local wave forecast model for Tenerife: computational grid (red), wind fields (green) and boundary conditions (blue).

II.1.3. UKMO wave-EPS Local models

Tenerife and Gijon Harbour applications are generated by applying forcing files from UKMO, so they run with the same time resolution as UKMO wave-EPS is defined:

- 4 runs: 0z/6z/12z/18z
- Control member and 22 members :
 - 0z/12z: Members 1-11 run out to full 72h forecast, 12-22 perform short update cycle.

- 6z/18z: Members 2-22 run out to full 72h forecast, 1-11 perform short update cycle.
- Restart dumps produced at T+6

Therefore, only the control and half of 22 forecast members run out to full forecast horizon at any one forecast cycle, the remaining members run in a short cycle step of 7 hours in order to maintain continuity. During the next cycle, the members that ran a short-step previously are now run to full forecast and vice-versa. The full 22 member ensemble product can then be generated using overlapping full forecast members from the last two runs.

From August the local systems are operationally running in a four day cycle. Each application starts connecting with the FTP server hosted at UKMO were daily wind and spectral forcing data are transferred.

Once PdE has the forcing file, after separate the archives of the 23 members, it creates a directory for each one where the model individually runs.

II.2 DESCRIPTION OF MEDITERRANEAN LOCAL WAVE MODEL.

II.2.1. BARCELONA APPLICATION.

Barcelona application has been configured taking the forcing windfields from CNMCA and the boundary conditions from NETTUNO ensemble model. Those forcing files are defined in a grid with a resolution at 0.05 degrees (WEST 2.05, EAST 2.4, SOUTH 41.2 and NORTH 41.45).

The local system has been defined on a computational grid of 50x71 points and with resolution of 600x500 meters each cell. The grids of wind fields and boundary conditions have a resolution of 3'.

At Madrid meeting (April 2013) it was decided to develop another Barcelona application taking forcing files from Met Office ensemble model to compare the results. Met Office has interpolated the wind to the CNMCA locations and waves to the NETTUNO locations for Barcelona domain so that application has the same spatial resolution.





Figure 4 - Configuration of local wave forecast model for Barcelona: computational grid (black), wind fields (yellow) and boundary conditions (red).

The NETTUNO-EPS consists of 40+1 members, integrated at 00 UTC up to 48 hours forecast in the Mediterranean basin. The ensemble is run once a day at 00 UTC.

Barcelona-CNMA application runs with the same time resolution as NETTUNO-EPS is defined. The system is operationally running once a day and starts at 8:30 UTC connecting with a SFTP server hosted at ISMAR to collect the forcing files. If forcing files are not yet on the server, the application will try again 15 minutes later. The application is programmed to do 5 tries.

Once PdE has the forcing file, after separate the archives of the 41 members, it creates a directory for each one where the model individually runs.

Barcelona–UKMO application runs in a four day cycle with the same time resolution as UKMO wave-EPS Local models.

III DETERMINISTIC WAVE MODEL VALIDATION

III.1 Introduction

Deterministic models are operational since August 2013. The validation study presented in this document has been done with the results from January to October 2014.

The operational model is provided with a routine that generates the time series in a specific point of the application. The wave parameters of those time series are significant wave height, mean direction, mean period, peak period, wind speed and wind direction. The point of the time series is the location of the buoy that has been used to compare the model with the observed data

In September 2013 Gijon Buoy stopped working so the validation study has been done only for the other 3 applications: Tenerife, Barcelona-CNMCA and Barcelona-UKMO. These results give an idea of the behaviour of the member 0 (deterministic model) prior to development the ensemble forecasting framework.

Buoy	Lat	Lon	Depth	
Barcelona Buoy	41,32° N	2,20°E	68 m	
Santa Cruz Tenerife Buoy	28,46° N	16,23⁰W	56 m	

Table 1 - Depth and location of the buoys used for validation.

Statistics presented in this section are based on the analysis of the significant wave height and mean direction parameters to evaluate how the system works. The scatterplots comprise the behaviour of the models for the period before next cycle, and at lead time 24, 48 and 72 hours. The metrics of the validation table are parameter root mean square error (RMSE) value, error mean (bias), slope regression coefficient and spread.

III.2 Barcelona-CNMCA Application

Significant wave height data and mean direction from Barcelona-CNMCA application are compared with Barcelona Buoy data with 3 groups of samples: one with the model values that covers the first 24 hours (up to next cycle), other with the values at forecast range +24 and the last one at forecast range +48.

In Figure 5, the left panel is the scatterplot of the first group is the scatterplot with the values +24 and the right panel is the scatterplot with the values at lead time +48. It is observed a good correlation between the model and observed data and the root mean square error increases with the time horizon.



Figure 5 – Barcelona-CNMCA: Scatterplots significant wave height of deterministic model against buoy data.

Significant Wave Height	Num data	Corr.	Slope	RMSE	Bias	Spread
SWAN - Barcelona Buoy	4831	0.86	0.73	0.26	0.03	0.37
SWAN 48 -Barcelona Buoy	4808	0.84	0.70	0.28	0.01	0.39

Table 2 – Statistical results of significant wave height for Barcelona-CNMCA model

Mean Direction	Num. data	Corr.	Slope	RMSE	Bias	Spread
SWAN - Barcelona Buoy	591	0.61	0.55	128	-34.5	0.61
SWAN 24 -Barcelona Buoy	583	0.63	0.57	126	-45,24	0.59
SWAN 48 -Barcelona Buoy	577	0.63	0.57	126.5	-45.2	0.59

Table 3 – Statistical results of mean direction for Barcelona-CNMCA model

III.3 Barcelona – UKMO Application

Significant wave height data and mean direction from Barcelona-UKMO application are compared with Barcelona Buoy data with 4 groups of samples: one with the model values that covers the first 6 hours (up to next cycle), and the others with the values at forecast range +24, +48 and +72 hours.

In Figure 6, the top left panel is the scatterplot of the first group; the top right panel is the scatterplot with the values +24, the bottom left panel is the scatterplot with values at lead time +48 and the bottom right panel is the scatterplot with the values at lead time +72.

The results are worse than in CNMCA model, being underestimated the significant wave height parameters by the model. It is observed high values of root mean square error parameter.



Figure 6 – Barcelona-UKMO: Scatterplots significant wave height of deterministic model against buoy data

Significant Wave Height	Num.	Corr	Regre	RMSE	Bias	Spread
	data					
SWAN - Barcelona Buoy	7022	0.84	0.87	0.30	0.19	0.58
SWAN 24 - Barcelona Buoy	7005	0.82	0.83	0.30	0.18	0.57
SWAN 48 - Barcelona Buoy	6980	0.80	0.79	0.30	0.15	0.54
SWAN 72 – Barcelona Buoy	6956	0.76	0.78	0.32	0.16	0.59

Table 4 – Statistical results of significant wave height for Barcelona-UKMO model

Mean direction	Num.	Corr	Regres	RMSE	Bias	Spread
	data					
SWAN - Barcelona Buoy	2402	0.78	0.81	35.5	26.1	0.24
SWAN 24 - Barcelona Buoy	2672	0.97	0.96	34.3	-0.77	0.25
SWAN 48 - Barcelona Buoy	2612	0.93	0.94	46.5	3.4	0.35
SWAN 72 – Barcelona Buoy	2506	0.87	0.86	37.4	7.7	0.54

 Table 5 – Statistical results of mean direction for Barcelona-UKMO model

III.4 Tenerife – UKMO Application

Significant wave height data and mean direction from Tenerife-UKMO application are compared with Barcelona Buoy data with 4 groups of samples: one with the model values that covers the first 6 hours (up to next cycle), and the others with the values at forecast range +24, +48 and +72 hours.

In Figure 7, the top left panel is the scatterplot of the first group; the top right panel is the scatterplot with the values +24, the bottom left panel is the scatterplot with values at lead time +48 and the bottom right panel is the scatterplot with the values at lead time +72.

It is observed a good correlation between the model and observed data and the model has a reasonably low overall bias (between 0.1 and 0.01).



Figure 7 – Tenerife - UKMO: Scatterplots significant wave height of deterministic model against buoy data.

Significant Wave Height	Num.data	Corr	Regres	RMSE	Bias	Spread
SWAN - Tenerife Buoy	6822	0.85	0.83	0.22	0.05	0.29
SWAN 24 - Tenerife Buoy	6803	0.86	0.83	0.21	0.02	0.27
SWAN 48 - Tenerife Buoy	6783	0.86	0.81	0.22	0.01	0.27
SWAN 72 – Tenerife Buoy	6753	0.84	0.79	0.22	0.01	0.28

Table 6 – Statistical results of significant wave height for Tenerife-UKMO model

Mean direction	Num.	Corr	Regres	RMSE	Bias	Spread
	data					
SWAN - Tenerife Buoy	2665	0.69	0.62	32.6	-19	0.12
SWAN 24 - Tenerife Buoy	2646	0.69	0.64	32.1	-17.6	0.12
SWAN 48 - Tenerife Buoy	2642	0.75	0.72	30.3	-17.4	0.12
SWAN 72 – Tenerife Buoy	2632	0.72	0.74	30.0	-16.3	0.11

Table 7 – Statistical results of m	an direction for Tenerife-UKMO model
------------------------------------	--------------------------------------

perational since September 2013. The first validation study rom October to December 2013. To estimate reliability to a ensemble of 20 members a sample size of approximately this basis a recommended sample period for wave-EPS is. In this document the validation for wave-EPS has been ry to May 2014 (4 months).

ensemble mean value has been implemented.

For applications with the forcing files from MetOffice, which have only half of their members running in a full forecast, spread has been calculated taking into account lagged members (instead of using members in short cycle, takes those members of the cycle before). With this system, lead time prediction is H+66.

Figure 8 – Sig. wave height (m) ensemble mean (contour) and spread (shaded).

Barcelona-CNMCA application. Run: 17/12/2013 at 00 UTC. Lead time +48H

CONTEN, WAT FORCEST BASES OF DWARE (2008) Wat F730305 at 64 UTC Vela: 17103053 at 64 UTC Vela: 17103053 at 64 UTC (-64 N) Signature Meght speed 0 0 0 1 0 1 0 10 20 10 0 0 0 0 0 0 0 0 0	CONSTSU. WHAT FORCEAST BASED ON INVALVE (20080) PAIN: 17/03/051 H 61 UTC Yeal: 17/03/051 H 61 UTC Sig annih Might spread Sig annih Might spread Sig annih Might spread	CONTEL WINT FORCEST BASED OF WARDS (WARD Amil 1703051 H of WTC Viele 1713051 H of WTC JURN) Signature height queues 1, 00 H 1, 10 10 10 H 0, 10 H 0, 10 H 10 H	CONSTAL WAYE FORCEOST EXCESS IS SUBJECT ON SWARE TO UNADO MARIO 1012/2004 AF UTO Vales 1012/2013 af 54 UTO (JAB A) Siggarate begint operated 20 Bit UTO 101 JAI 30 JAI 40 AI 46 AF AF A Anno 101	CONTINUE WAY FORCENT AND DO AND OF LOWID THAN 1770300 K 4 CV TC Velo 1770300 K 4 CV UTC JOHN Big anno Meght apoes Dig an of Line Velo 100 K 4 CV K 4	COASTS, WHY FORCEST BASE OF DWARES UNDER WHIL FROMUNE HOUTE Vale 17/03063 wild for UTC (-06 N) By annie beigt speed 0 4 4 4 5 10 4 5 20 10 4 5 4 4 4 4 4 7	COATTSL WAVE FORECAST BALE - O SWINN BE UNIXO Men: (11)2010 al BI UTS Vale: 11122813 al BI UTS Siguron bright grand 0 0 0 10 10 10 10 10 10 10 10 10 10 10 1	
ere the second s	err Terrer	eration of the second s	era Maria Carlos Carlo	e Terreration of the second seco	era Maria Salaria Maria Salaria M	cra results for the second se	nance
			4779	erer Veren artificario francesco	era ji		
Num: 17/123013 at 61 UTC Valid: 17/123013 at 51 UTC 15 Nj Sigurare height openad 00 Bit 13 Ni 20 30 39 42 48 56 66 67 7 14000 Bit	Pure 177023053 at 64 UTC Valid 177023053 at 18 UTC (-)48 m Sig avant beight opmad 00 04 UT 18 20 30 34 40 46 46 49 3 standa (-)	Main 17/22013 and suite Veel 17/22013 and 17 470 (- 1/17) Signamb Meight spread Signamb Meight spread	Next (3122013 and UTC Vale): 13122013 and UTC (Jill B) Signeous height spread (Signeous height spread (Signeous height spread)	Num (Friddels at ei urt) Yule: (Friddels at the stric) (at ei) Signare height queued Signare height queued Signare height queued	Punt: 17:123013 at 61 UTC Vale: 17:123050 at 21 UTC (-21 N) Utguarne beight spead 00 at 10 UTC (-11 N) 00 at 10 UT	Park (31228/34191075 Vales (31228/34191075 Siganos heijit canad Siganos heijit canad	
	error The second secon	erar Terre	4127 Transformer Participation Transformer Par			erter Terres de la constante	
Signature beight speed () () () () () () () () () () () () () (Signare height speed	Signaran bulgir spress 	Signatura beight spread 50 - 50 - 50 - 50 - 50 - 50 - 50 - 50 -	50 and 50 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	big and here by speed the set of	isjann heljft spend Federa 9	
ET2P	erm New Parlson New Parlson	4170 	4720 File File News, File F	erre Marine Participation of the transmission No. 1992 of the transmission No. 1992 of the transmission	erry		
Valle: 18/330/3 al 64 UTC (-2014) Big.anne helpfit giread 00 64 07 08 20 00 20 00 00 00 00 00 00 00 00 4eerth (0)	Vale 19/320/3 e 0* UTC (-21 N) Big.xve NegV speed 	Voter 19/32013 of 69 UTC (-32 N) Big.aven height gored 7. <u>66 09 UT 19 20 District</u> of 09 UTC (-32 N)	Vale: 16122013 at 36 (715 (+30 k)) Sigurous height spend 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Vene 19/32003 et 19 UTC (Joka) Big anne beight gread Di de un de un de un de un de un de un de Researce (p)	Veder 18/32013 at 11 UTC (JOR N) Big wave beight gread 0 0 00 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Vote: 18/12/810 at 12/072 (-9.16) Išg anna beljit sprad Internet (-9.16)	
err	err	ere and a second	erro	ere <u>Land</u>	era	ATTER AND	
Signane bejot quest (0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	5g.ave 5eg9 goesd eterns () ()	lig soon heijit spool 7. Terene 9	50,2000 1000 0,0000 0,00	lig was held i grand 	5ig.area bigt quad are () 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	50 anno 5400 quest 	
	erze Marine Terrere Terrere Large Construction and the second s	4/27 Territoria	era Tana tana tana tana tana tana tana tana	erg		ere	
Signawa Saliyit qoread anawa (0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	50g.auwr 50g97 gonad 90 90 97 97 97 90 98 97 99 96 99 7 94awrt 94	59,2496 5497 49465 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	Signana heijit sprad Na 10 10 10 11 21 20 20 40 10 10 10 10 10 Na 10 10 10 10 10 10 10 10 10 10 10 10 10	Sigana bigt goad	Signere beigt opend and () ()	Signano beliji (sposi Refereta pj	
679	e 79	e79	erg				
Prof. Prof. Prof. Prof. Creation: CONSTRUE WAVE PROFERENCE OF REAL OF UNIT. CONSTRUE WAVE PROFERENCE OF UNIT OF UNI	Weinfork IPAG STREET, IPAG STRE	Vectors: 1944 ANSIST Public Constant CONSTRUMENT FOR CONSTANT CONSTRUMENT FOR CONSTANT From 170-2003 of 64 UTC (-43 N) Signame height spread	2107 2207 Wedness Heard Restorm COMPTERL WAVE FORESANT READERS ON INVESTIGAT MANUEL READERS AND UTST Readers 101722013 with UTST (A44 H) Silgunous height spread	РИФ РУУ Чивана: Внизтот Ров Сектора содити, иние попасската влават се изво на: попасската влават се изво на: попасската на чито учик попасока на се что с ник на бар илие height quest	Vesters: 19-06 P297 Pair (restant Poir (restant CONSTRUMENTE POIRCENT BARED OR INVANI- BC UNDO Poirs (F7-02004) 44 64 047 Vede: 19-02.0013 at 64 0470 Jen Nj Sig anve beigt openad	VIEW VIEW VIEW VIEW VIEW VIEW VIEW VIEW	
		Areas A					

Ref	: MyWave—D3.3
Date	: 2 Jan 2014
Issue	: 1.0

Figure 9 – Sig. wave height (m) ensemble mean (contour) and spread (shaded). Barcelona-UKMO application. Run: 17/12/2013 at 00 UTC. Lead time +66H

		MARKAN CARACTERISTICS	And the second s	Market was a series of the ser	Re: recarment of the second se	Hard Barrier Hard Hard Hard Hard Hard Hard Hard Har		
MY 87 MY 87 My 100 My 100	10/10/2 30/10/2 30/10/2 30/10/2 10/10/	19 27	197 Mar Wass desister Mar Wass desister Da 5.3 8.4 0.5 4 405 441 Constants wass researched to state	19 27 Mar delater formation on environment of the	10 Mar 20		Ref	: MyWave—D3.3
Mare 1112 2010 of 01100 Valid 1112 2010 of 01100 Valid 1112 2010 of 0100 Ogame Magile agene Research 00	Ale 11 12 2010 of 0 100 March 11 12 2010 of 0 100 Big and 100 100 (100) Big and 100 (1	Anno 1112000 ar 01 cm Tana 1112000 ar 01 cm Banas an ang anna Banas ang anna Anna 1112000 ar 111200 an	Mart 1112003 al 07 905 Vala establistica de 1798 (nº 18) Bysene tergit special	And Compared and Price	Ban Hinder and Annual Annua		Date	: 2 Jan 2014
**	N 10		and the second s		870	HW COMPANY	Issue	: 1.0
			N 10 ⁷	SUTO NATIONAL STATE	90'20 <u>Mol 40'</u> Technic Mater double: Technic Mater double: National Section Secti			
Tenders Musicipation (1996) COLITER WAY FOREING STORE (1996) Service 1992 (1994) (1997) Name 1992 (1994) (1997) Name 1992 (1994) (1997) Signaron Height gama Signaron Height gama Haranak (1)	Telefonia Materia Antonia Antonia Antonia Antonia Construit. National Antonia Antonia Antonia Antonia Statistica Antonia Antonia Materia Statistica Antonia Signature Insight general Antonia	Tedele Mar Destant Contrast, established on texture (and Mar 11/2/01/2 at 07 UN Bar 11/2 at 07 UN Bar 11	COLUMN, WARF FORMULAR BALES OF BRANK DO UNDO MARE 15122011 at 07 UTC WARF 15122011 at 07 UTC WARF 15122011 at 09 UTC (+10 H) DEpartment Maget agreest DEpartment Maget agreest	COLUMN UNDER CONTRACT OF CONTR	COLUMN LINE IN CALL AND AND CALL			
NT OF THE OF			878 - A - A - A - A - A - A - A - A - A -	17 A 19 A		8.2		
		800	*** L	870	×	8.50		
All of Marchen Marchen Allen Andre Marchen Marchen Marchen Allen Andre Marchen Marchen Allen Andre	Martin Wast decision Martin Wast decision	All W March Marker And Andrew Marker Marker Marker Marker Marker Andrew	100 CE 10	ABU'RE BALLON BALLON ABUTON Meret Carlon Control Productions Control Control Carlon Control	All Werter Mar Wer	Number Number Pack-double Number M1 0.2 0.3 0.4 0.5 6.4 Contents March March Mark (1970) Mark (1970) 6.4 0.6 6.4 Mark (1970) Mark (1970) Mark (1970) Mark (1970) Mark (1970) Mark (1970)		
Equipartie (partie)	For start taget appear					By and highly called		
AND THE AND	And the second s	49 100 AND AND AND AND AND AND AND AND AND AND	19 30 Anti Aliano de Carlos de Carlo	20 30 20 40 20 40 20 40 20 40 20 40 20 40 20 40 20 20 40 20	All of the standard Ball of th	49.00 March 1990 March		
	Equate height quard							
		-				. A M		
NO TO NAME AND A DATE OF A	ar no 100 00 there denotes an Part State Constant on Part State	ner 1900 de la constante de la	AD 47 Marc dectors 340 00 Ped dectors 040 00 Ped dectors 040 00 Ped dectors 040 00 Ped dectors 040 Ped dectors	197 302 40 Unit deut on 1997 Tool Statemen Data deut deut on 1997 Tool Statemen Gal Gal Alexandre Statemen Gal Contral, Ways Production 1998 Deut Balance Unitson	317 80 Max decks MI SW Petrol MI SW Value 000 4 4 4 6 4 4 4 4 4 4 4 4 4 4 4 4 4 4	19 77		
Re: 112003.01 VC 1980 123053.41 V/C.o.Mr.0 59 Alexandre 10 VC 59 Alexandre 10 VC Research 10 VC	Naci 1132003 al PUC Naci 1232003 al PUC Naci 1232003 al PUC Sg. anni hogi sprad Nacional N	Net 112003-00 VPC water trades at UPC-any Sg.wee heldt great	Next 11230334154/C Web 121200541514/C Sig.resc height gread	Net 112003-00 VPC value 122000-12 (VPC-entry) Sg.wee helpt great	Rec 1132053410 VPC was 1132055410 VPC was 1122055410 VPC- 5g.woo height gread	Australization and under County of the Count		
N 10	жи (Сарана) (Сар	**	**	**	**	8.9		
5.7	5.0	80	57	50	50	878		
Set 49 54130 24130 Model teaching Core Providential March 1120013 and Units March 1120013 and	Mar 49 Next All Annual	Server Severation of the server of the serve	Set 45 Vedox Exectored 2019 Prod Celebor Prod Celebor P	Marrier 54390 Descarson Marrier Services and Provide Section 2010 Section 2010 Section 2010 Section 2010 Section 20	50170 50130 50130 Maddat test of the best function of the second output of the best of t	And the design of the design o		
Reisel N		Procession of the second				Proved D		
HI P MARK NOT A CONTRACT OF CO	10 M 34 M <td< td=""><td>10 M 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td><td>10 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>M M M M<!--</td--><td>M TO TO LAND T</td><td>0 0 000 40 101 30 Feed address 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td></td><td></td></td></td<>	10 M 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	10 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	M M M M </td <td>M TO TO LAND T</td> <td>0 0 000 40 101 30 Feed address 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td> <td></td> <td></td>	M TO TO LAND T	0 0 000 40 101 30 Feed address 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0		
Valie the sense ar white your of your of Signature height spread Heatands () () () () () () () () () () () () ()	Varie to ESSERIE 4 (H V FO H V) Biguren hegdt spreet Paraleset (K H V FO H V)							
				**	**			
60 20 100 Million Set 20 Values dealloy Paul Andrea Tanta	66 20 Million Control (Million Control) Million Control (Million Control) Team Factor (Mil	69 20 Market Lange and Lan	And the second s	1970 State Control State	10 TO 141 M Version deal OF Factor and Factor and Fa	872 Table State S		
G2 G3 G4 G3 E CDATAL WWY PORCH INSEE DO BUNKS LIMING MARK 1152053 JH 19 U/C	10 0.2 0.3 0.4 0.5 0.4 00.017 0.0017 0.0010 0.0010 0.001 Rut 1152003.8 19 0/C 0.40 0. 0.0015 0.012003 0.4 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0	C2 0.3 0.4 0.4 0.4 1 CMATAL WART FORCEAST BASED ON REALESCARED Real 1172/05/3.01 PT/C Haste 1172/05/3.	0.2 0.3 0.4 0.4 0.4 0.4 0.4 0.4 0.4 0.4 0.4 0.4	COLUMN AND POINT OF A SUBDIVISION OF AN ADDRESS OF AN ADDRESS OF A	03 03 04 034 CIMATAL WAY WORK T SUBJECT ON THE SAME OF UNKNO AUX 11/3/2005 at 20 UTC - MAN OF WARE 13/2005 at 20 UTC - MAN OF Same height gread			
Production	Prost	and and and						
00 00 00 DAT 40 00 00 00 00 00 00 00 00 00 00 00 00	07.07 Minute Service Service Press Service Press Service Press Service	8737 Mill RF Wedge: Beer director Peer director	36737 36737 96400 96400	Set ref: Set ref: Set	MP 70 MP 70 <th< td=""><td>1970 1000 1000 1000 1000 1000 1000 1000</td><td></td><td></td></th<>	1970 1000 1000 1000 1000 1000 1000 1000		
Audits, start rotacist data da Bana e Custo Basci (2003) and Vice Velas 12(2004) and Vice (2004) Eguardo la picto da Audits Basanto (2004) and 2004 and 2004 and 2004 Hamanto (2004) and 2004 and 2004 and 2004	0 0	And a second sec						
	8.0							
80				to an	en'n	1727-74		

Figure 10 – Sig. wave height (m) ensemble mean (contour) and spread (shaded). Tenerife-UKMO application. Run: 11/12/2013 at 06 UTC. Lead time +66H

Marel Nellox

14710



Figure 11 – Sig. wave height (m) ensemble mean (contour) and spread (shaded). Gijon-UKMO application. Run: 12/12/2013 at 00 UTC. Lead time +66H

IV.2 Ensemble consistency.

Taking into consideration the sample period for was only 2 months in December 2013 and a recommended sample period for wave-EPS verification is at least 3-6 months, this validation study has been repeated for the period January-April 2014 to have an idea how ensemble local models are working.

The first step in the validation of an EPS, as a probabilistic prediction system, is to check its statistical consistency with observations. The rank histogram can be used to check if verifying observation is statistically indistinguishable from the set of forecast values (or if any ensemble member, as well as the verifying observation, can be considered equally likely to be the truth). Such a system must show an approximately flat-shaped rank histogram.

In Fig. 11 rank histograms corresponding to Barcelona-CNMCA at lead time T+06, T+24 and T+48 show how the model starts with low spread and as the forecast horizon increases, spreads increases too, with a rank histogram under-dispersive at lead time +6 and consistent at lead time +24, +48.

In Fig. 12 rank histograms corresponding to Barcelona-UKMO at lead time T+06, T+24, T+48 and T+66 show spread does not increase with the forecast horizon and most of the days the wave-EPS system subpredict (negative bias). This histogram is done using the lagged members for the short cycle.

In Fig. 13 rank histograms corresponding to Tenerife-UKMO at lead time T+06, T+24, T+48 and T+66 show the ensemble is statistically consistent (calibrated) with a flat-shaped rank histogram. This histogram is done using the lagged members for the short cycle.



Figure 12 - Rank histogram of sig.wave height Barcelona-CNMCA at lead time T +06, T+24, T+48.



0.8

0.7

0.

0.3

0.0

3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

Figure 13 - Rank histogram of sig.wave height Barcelona-UKMO at lead time T +06, T+24, T+48, T+66.

2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

0.8

0.7

0.6

0.

0.1

0.0



Figure 14 - Rank histogram of sig.wave height Tenerife-UKMO at lead time T +06, T+24, T+48, T+66



Figure 15 – Barcelona-CNMCA (top) and Barcelona-UKMO (bottom) sig. wave height time series.



Figure 16 – Atlantic harbour sig. wave height time series. Gijon-UKMO wave EPS (left) and Tenerife-UKMO wave EPS.

V RESULTS

The two main new products obtained with the ensemble wave forecast are the EPS gram and the probability maps. Examples of both for the three harbours, Gijón, Tenerife and Barcelona are shown in figures 17, 18, 19, 20, 21 and 22.

The EPS gram, figures 17, 19 and 21, gives the ensemble information at an individual grid – point location, which indicates the time evolution of the given parameter. In the case of harbour applications, the represented parameters are the significant wave height and the mean direction.

The spread is indicated by the range of forecast values. 50% of the members are distributed evenly around the median to define a vertical rectangle. The remaining members define the extreme 25 % spikes. The box-epsgram thus provides a discrete probability information in the intervals 0-25%, 25-50% and 75-100%. The deterministic member (control member) is included as a reference. The continue-epsgram gives hourly information that is the time resolution of the model.

The probability maps show the probability that a certain parameter exceeds a given threshold. Figure 18 shows the probability that Hs exceed 4.5 meters at Gijón harbour, and figures 20 and 22 show the probability that Hs exceed 1.8 meters at Tenerife and Barcelona harbours.

Ref	: MyWave—D3.3
Date	: 2 Jan 2014
Issue	: 1.0



Fig 17 – Example of Gijon EPSgram for the significant wave height, above, and wave direction, below. Run: 2014111400



Fig 18 – Gijon probability maps. Hs thereshold: 4.5 meters Lead time +30h, +36h, +42h and +48h. Run:2014111400

Ref	: MyWave—D3.3
Date	: 2 Jan 2014
Issue	: 1.0



Fig 19 – Example of Tenerife EPSgram . for the significant wave height, above, and wave direction, below Run: 2014111400



Fig 20 – Tenerife probability maps. Hs thereshold: 1.8m Lead time +6h, +12h, +18h and +24h. Run:2014111400



Fig 21 – Example of Barcelona-CNMCA EPSgram for the significant wave height, above, and wave direction, below. Run: 2014111300



Fig 22 – Barcelona CNMCA probability maps. Hs thereshold: 1.8 m.

Lead time +6h, +12h, +24h and +48h. Run:2014111300

VI CONCLUSIONS

Generating an ensemble wave forecast has provided a number of options for new products and visualization. The probabilistic information instead of deterministic one, provided to Barcelona, Gijon and Tenerife harbours has been adapted to their necessities.

Wave-EPs local models are operational from September 2013 with the mainly purpose of providing categorical forecast with the highest possible accuracy and a quantitative basis for reliable and useful probability forecast.

Routines that generate EPS grams, probability and spread maps have been added to the operational models.

If the purpose of the EPS was just to produce accurate categorical forecasts, there would be needed less members to define sufficient accurate ensemble mean. The reason why the EPS has so many members is the need to obtain accurate probabilistic estimates of the risk of extreme and rare events.

The probability maps developed for the 3 harbour authorities are an important tool to add to the system alert that the harbours already have with their deterministic forecast.

Although Wave-EPS local models could produce more outputs for the commercial ports, the epsgrams with the wave direction or the significant wave height and the probability maps are the most useful tools to start to introduce the predictability to the users, adding a categorical forecast to the deterministic information.