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## **Integrated in situ experimental monitoring and modelling of wave agitation in a marina**

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**CUGRI**  
*University Centre for the Prediction  
and Prevention of Major Hazards  
University of Salerno  
and  
"Federico II" University of Naples*





## **VIRGIL**

seated between Clio Melpomene  
(Bardo Museum, Tunis)

**“statio male fida carinis”**

(An unsafe harbour to ships, Aeneides Book II)

“statio male fida carinis”

# What is “unsafe”?

According to PIANC:

“*comfort*”  $H_s > 0.15$  m 5 days/year

“*safety*”  $H_s = 0.30$  m Return time 5 years

“*limit*”  $H_s = 0.50$  m Return timee 5 years

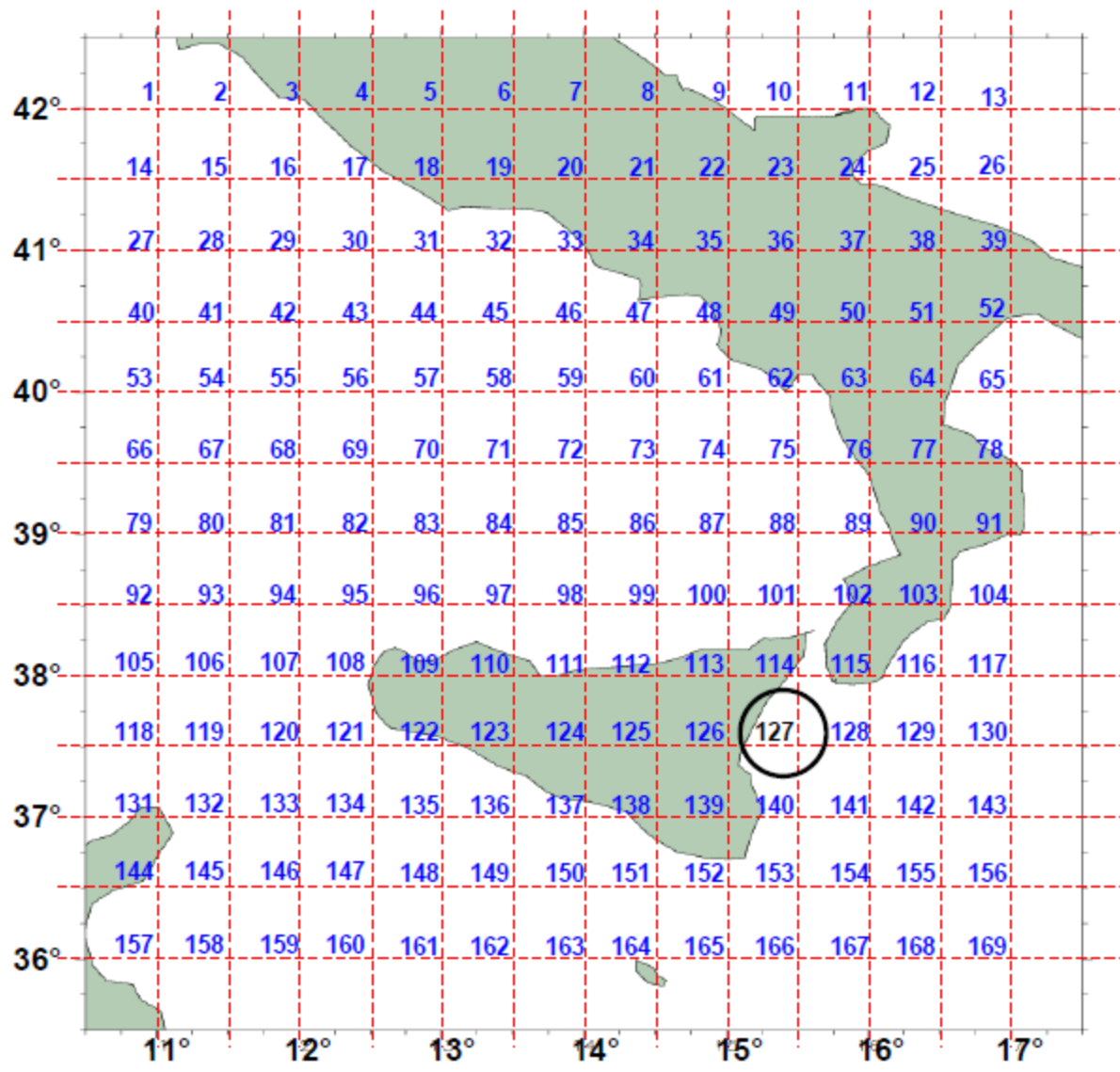


Acoustic Surface Gauge



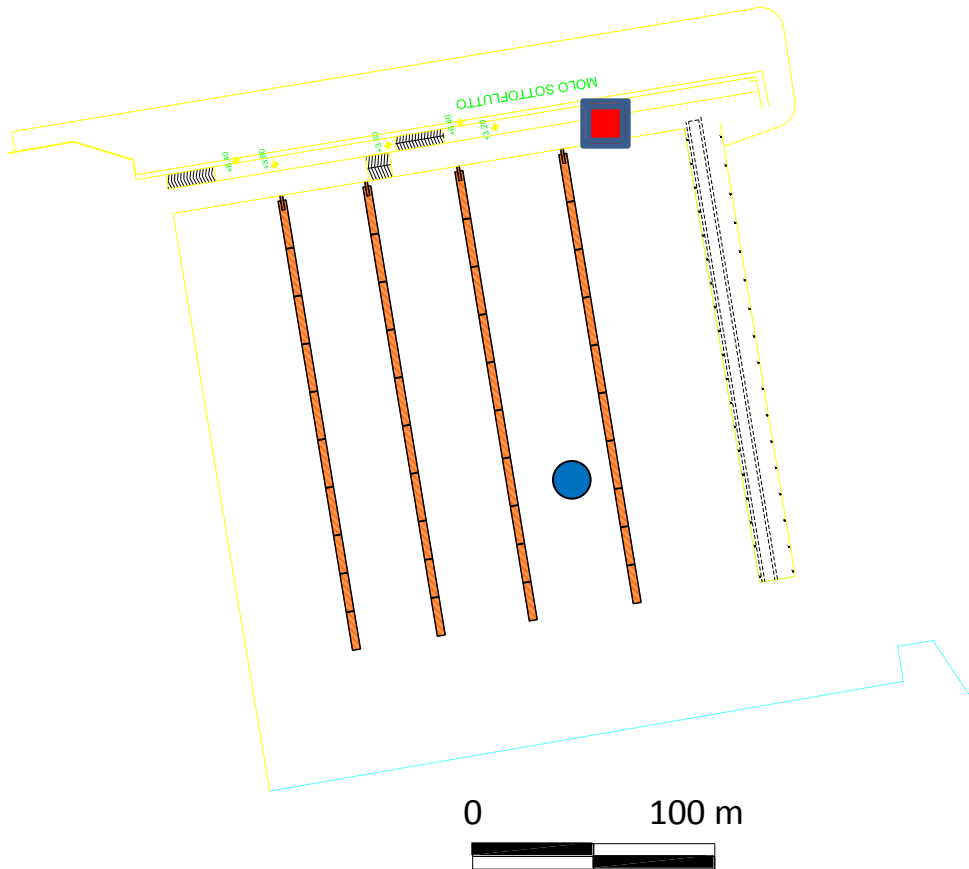
Bottom Mounted Meter



ECMWF grid point locations

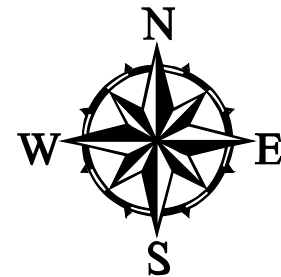


# Riposto Marina outer basin

## Instrument layout



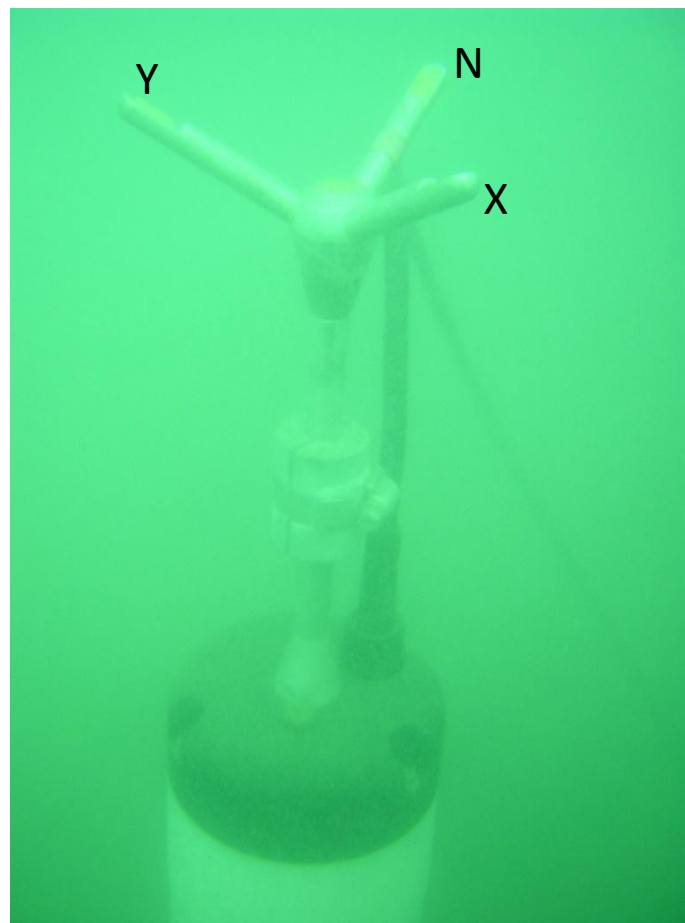
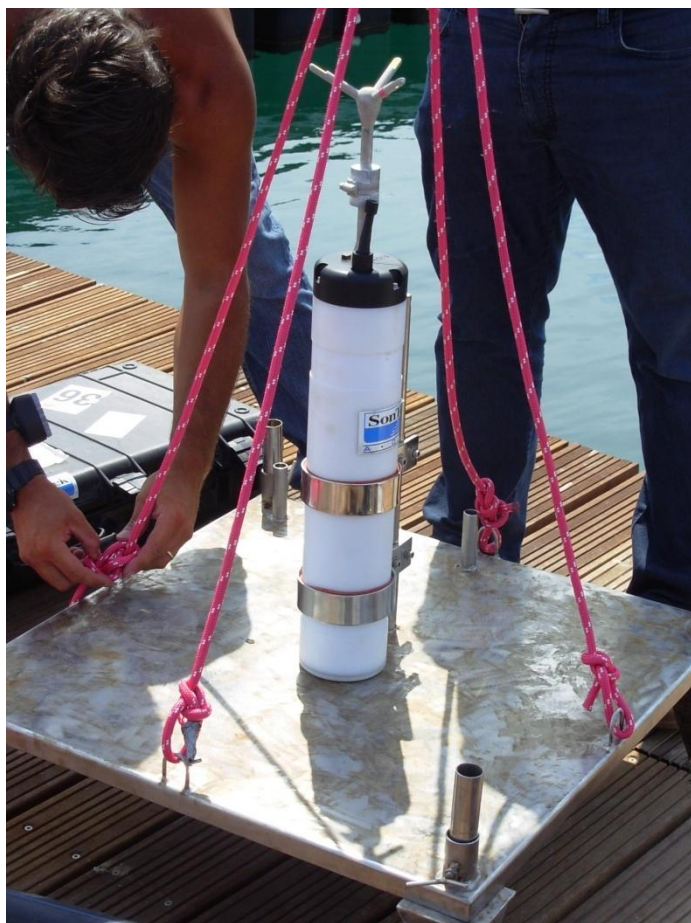
-  ADV Wavemeter – av . depth 8.80
-  Acoustic surface height range meter



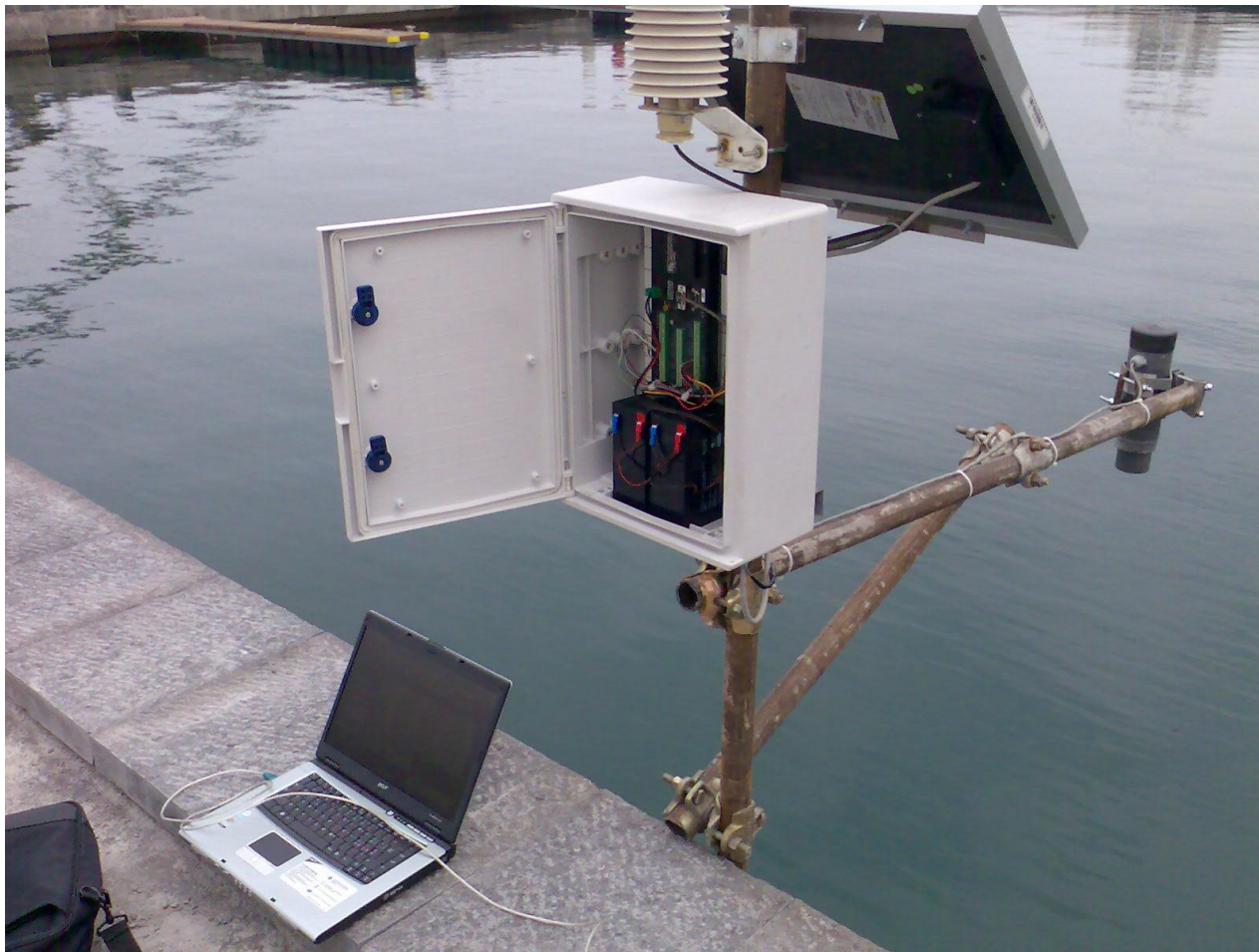
# Doppler Bottom Wavemeter

## SONTEC TRITON-ADV –

av . depth 8.80 - sampling interval 30'

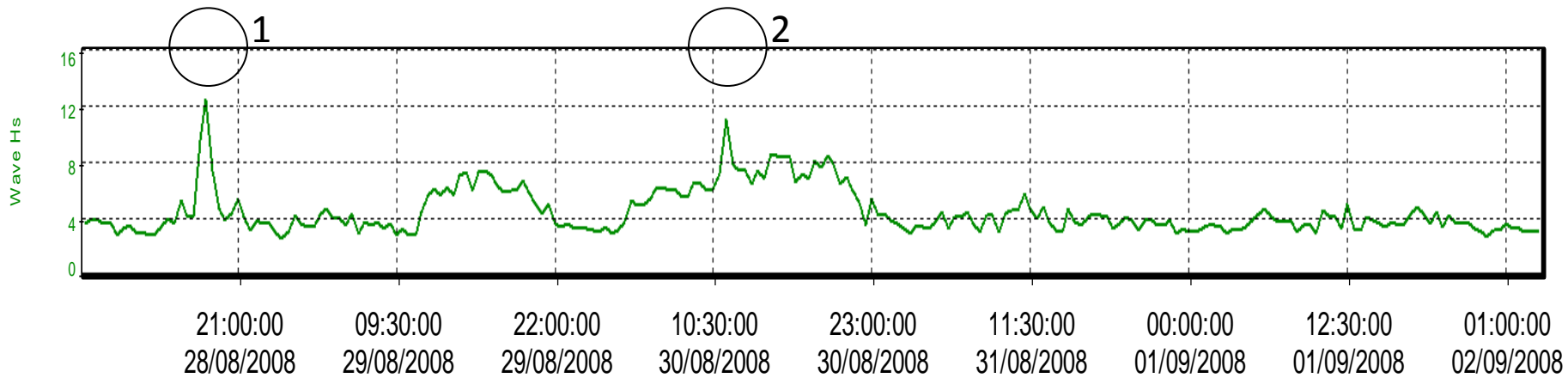


## Quay-side installation – Acoustic range finder

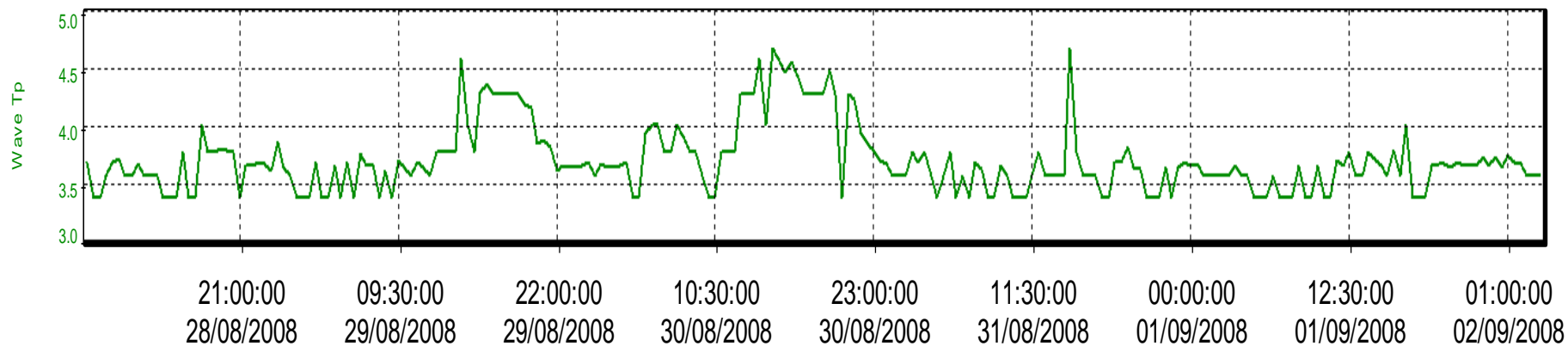




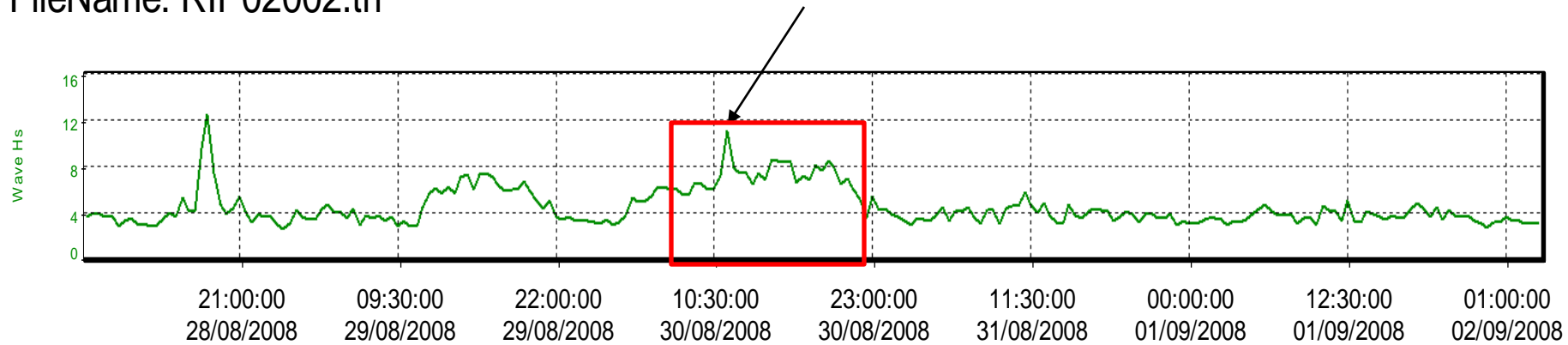
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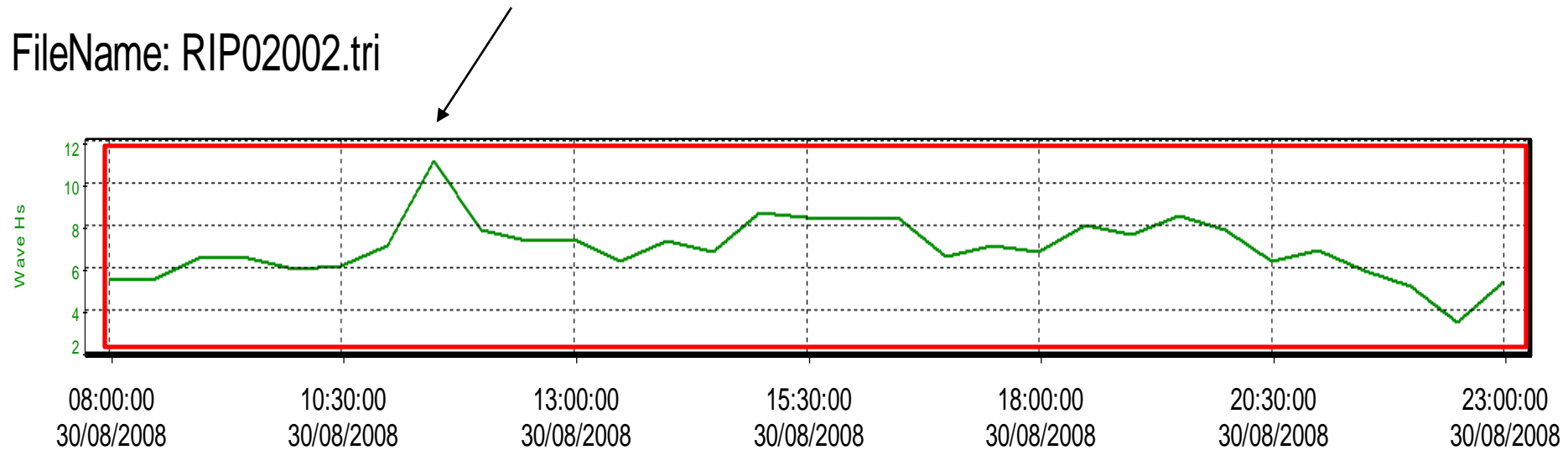
FileName: RIP02002.tri



FileName: RIP02002.tri

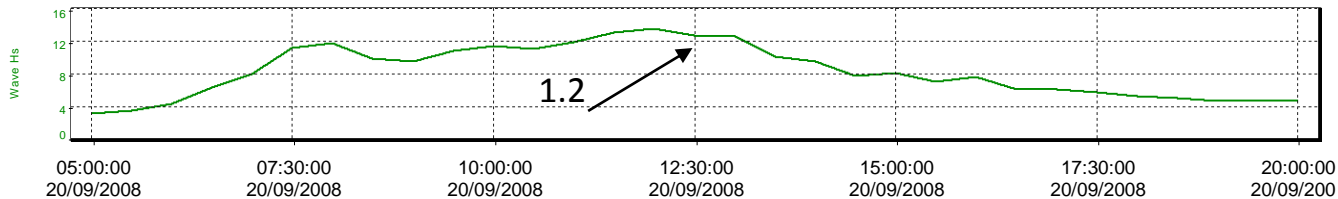


FileName: RIP02002.tri



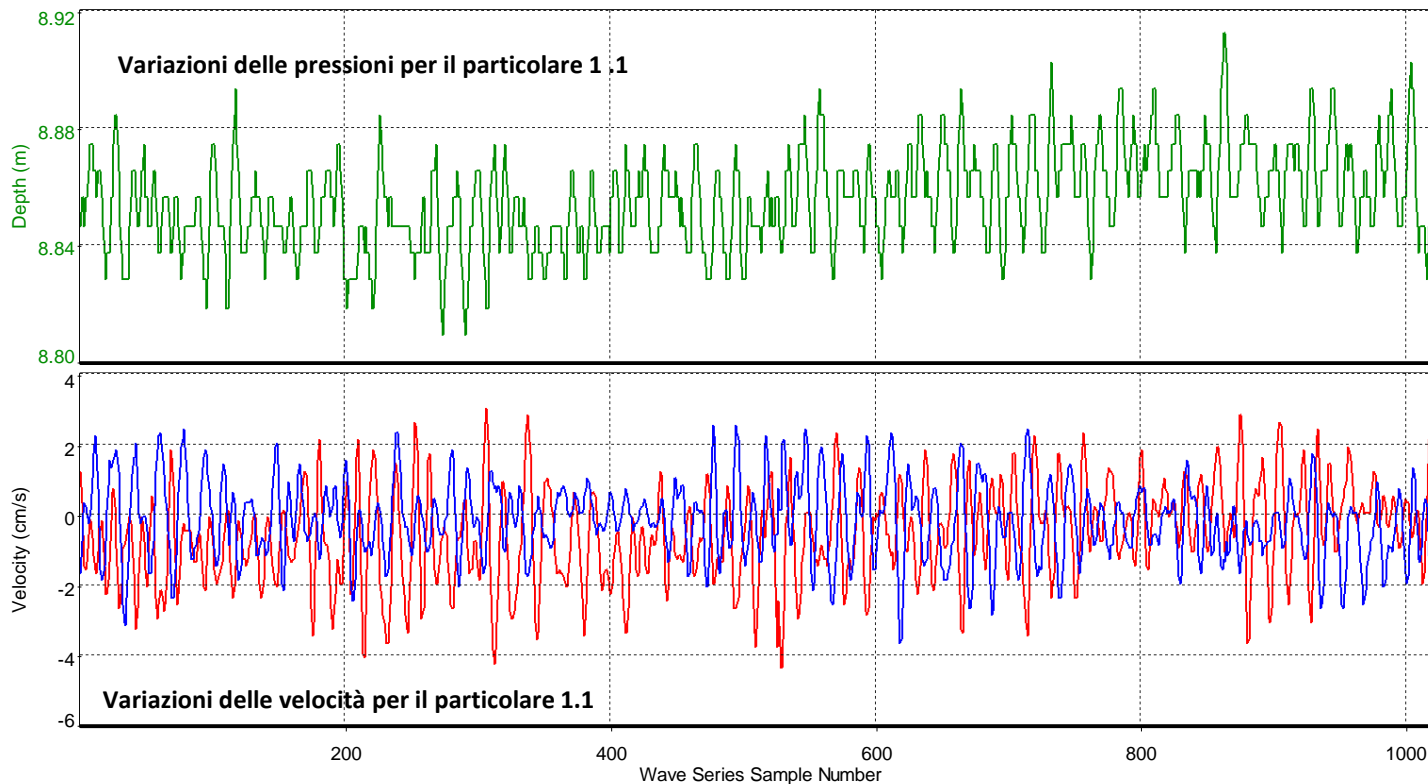
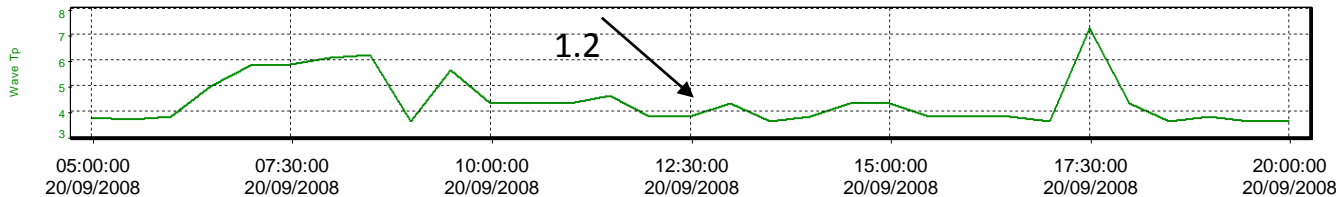
Sampling: 30'

RIP02004 Hs



Particolare  
20/09/08 time 12:30

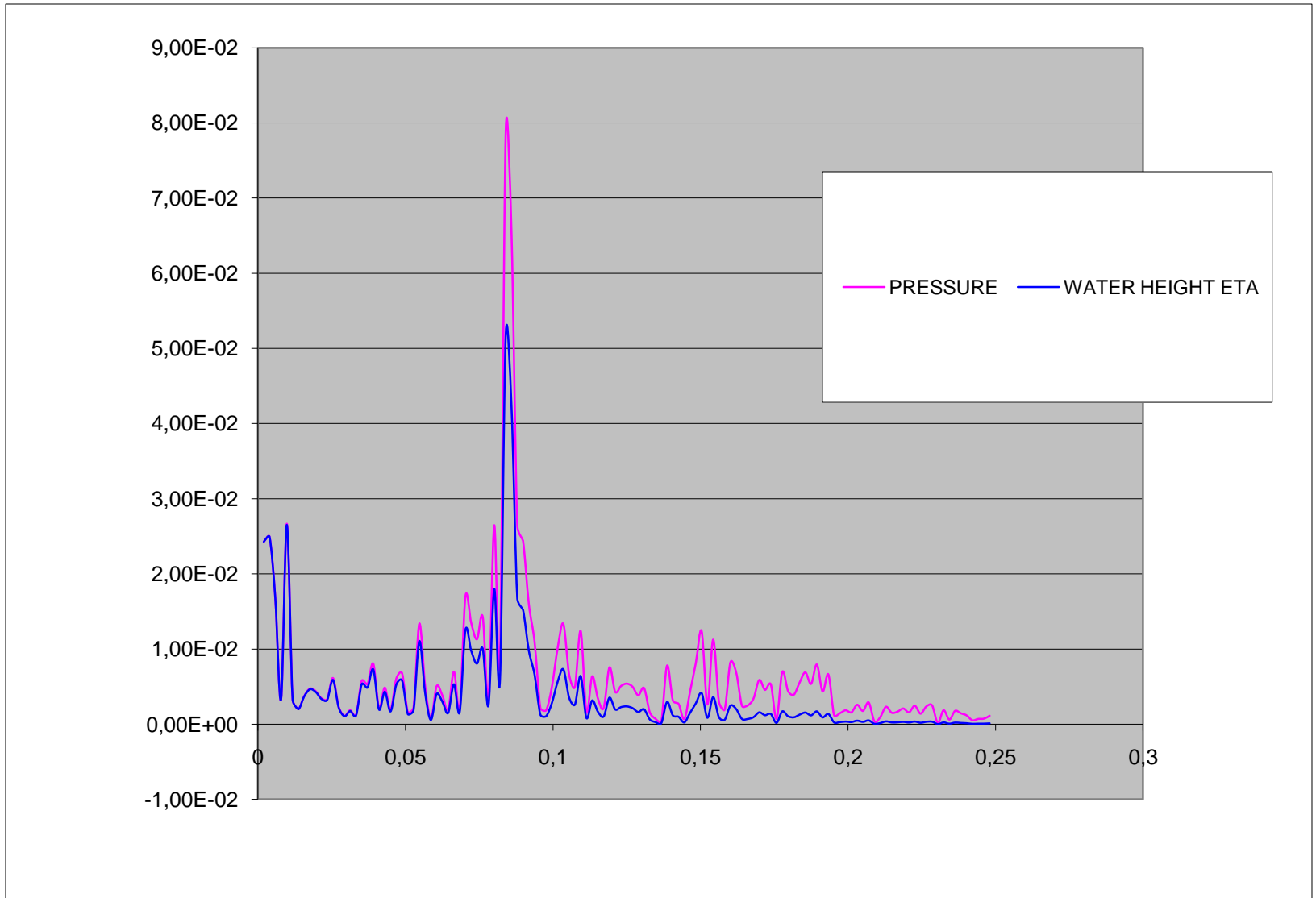
RIP02004 Tp



Beam1/X/E

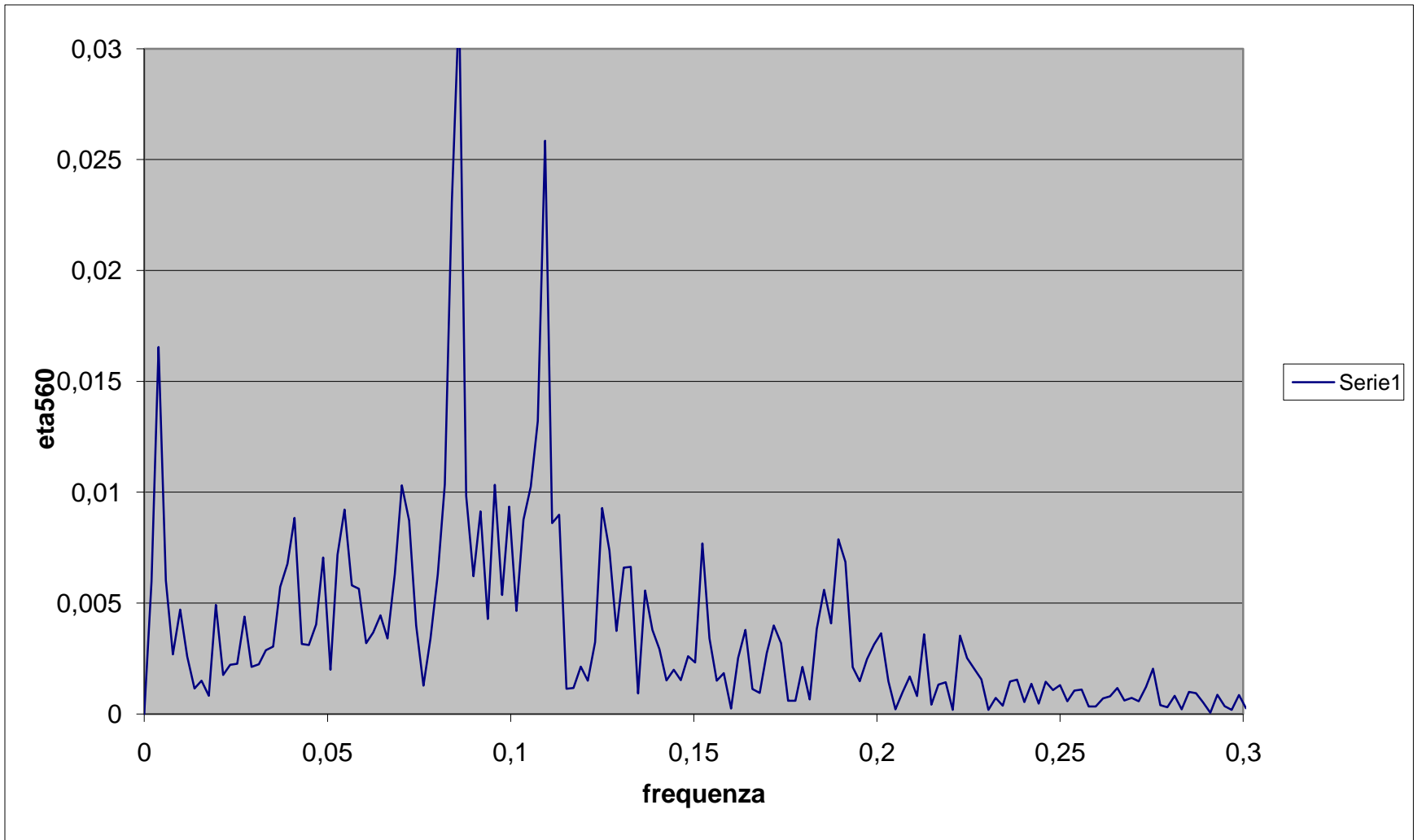
Beam2/Y/N

Beam3/Z/Up



**A harbour basin is a filter**

Spectrum is very peaked (Around 12 seconds)



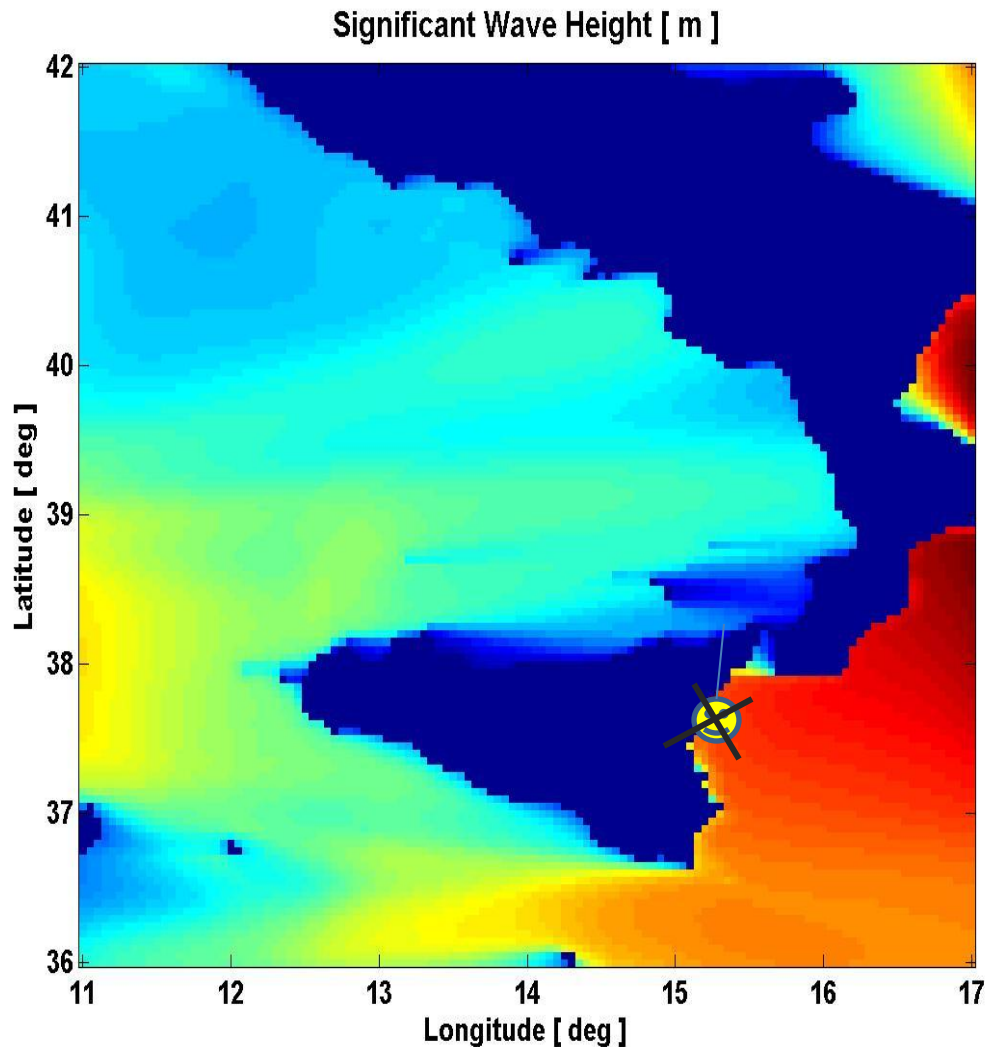
And sometimes two peak frequencies (around 12 and 8 seconds)

## Offshore Wave data:

Italy has (...had) a very efficient national wave measuring network **RON**  
And one of the buoys is very conveniently located (off **Catania**)

**BUT**

it has **NOT** been working the last few years



Weather/wave models publicly available in the area include :

- **ECMWF** Mediterranean Model (WAM)
- (6 Hours Analyses, forecast not easily available)
- **NETTUNO**, WAM implemented by Cavaleri (ISMAR-CNR) and the Italian Air Force Meteorological Centre (CNMCA) (6 Hour Analyses + 1 hr forecasts)



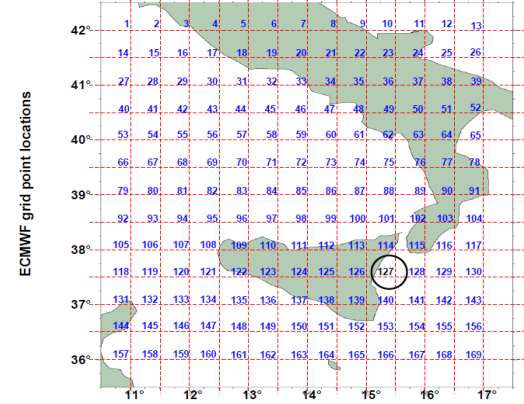
The latter is based on a (roughly) 4.5 km WAM grid driven by COSMO-ME local area weather model

BUT:

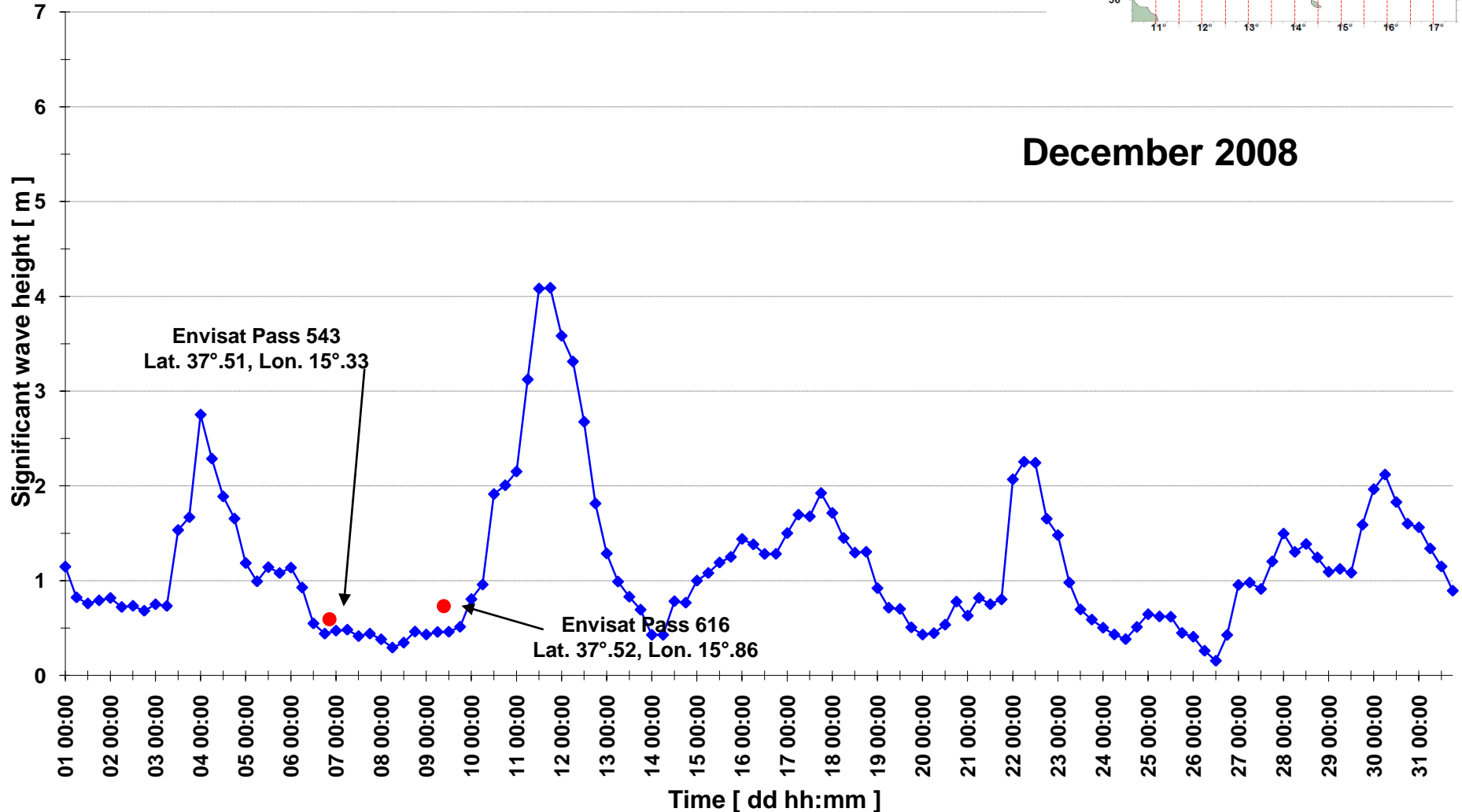
- It does not - as yet - include any satellite wave data assimilation
- Its archive is very short (2-3 years)

# ECMWF Mediterranean Model (of course) includes Satellite altimeter data assimilation

ECMWF Significant wave height (grid point 127)  
Lat 37.5°, Lon 15.5°

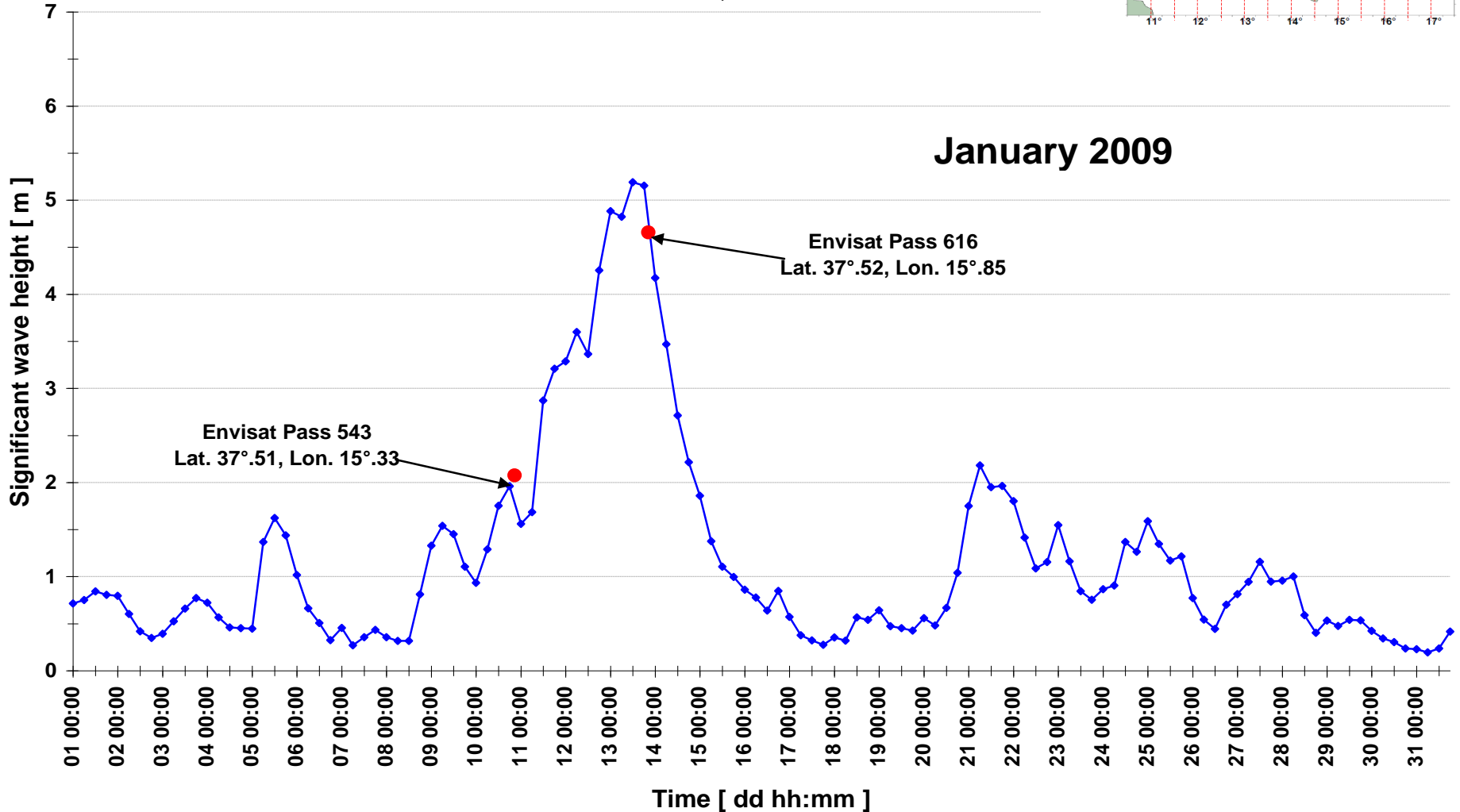
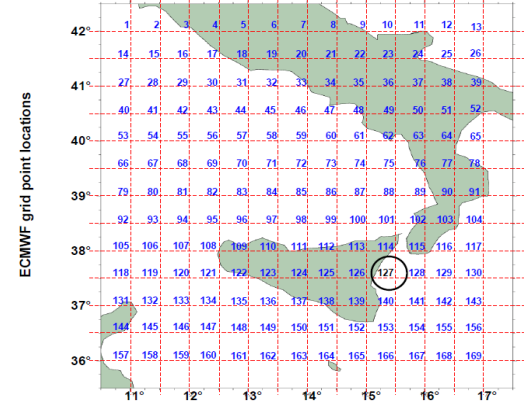


December 2008



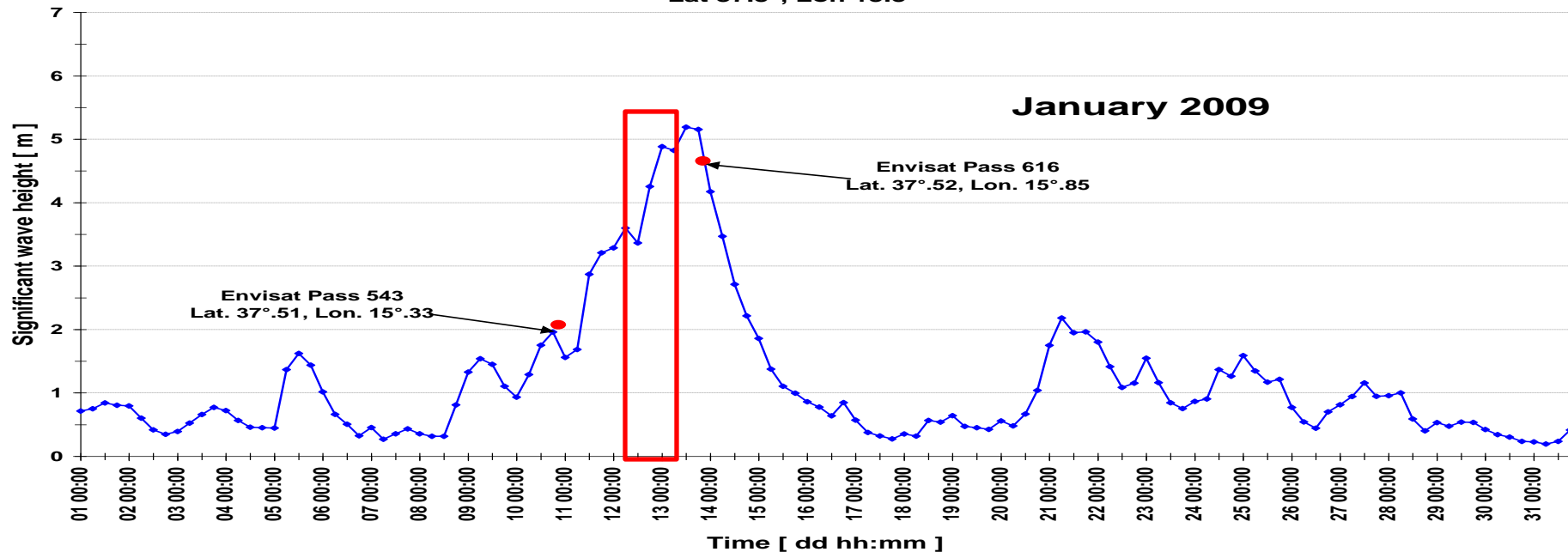


**ECMWF Significant wave height (grid point 127)  
Lat 37.5°, Lon 15.5°**

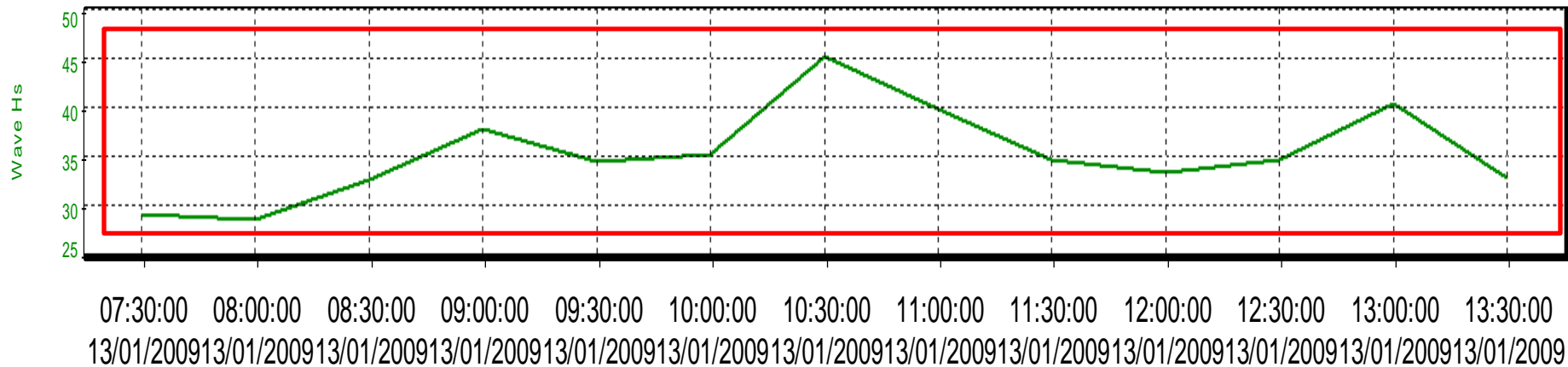


# Very different time sampling

ECMWF Significant wave height (grid point 127)  
Lat 37.5°, Lon 15.5°



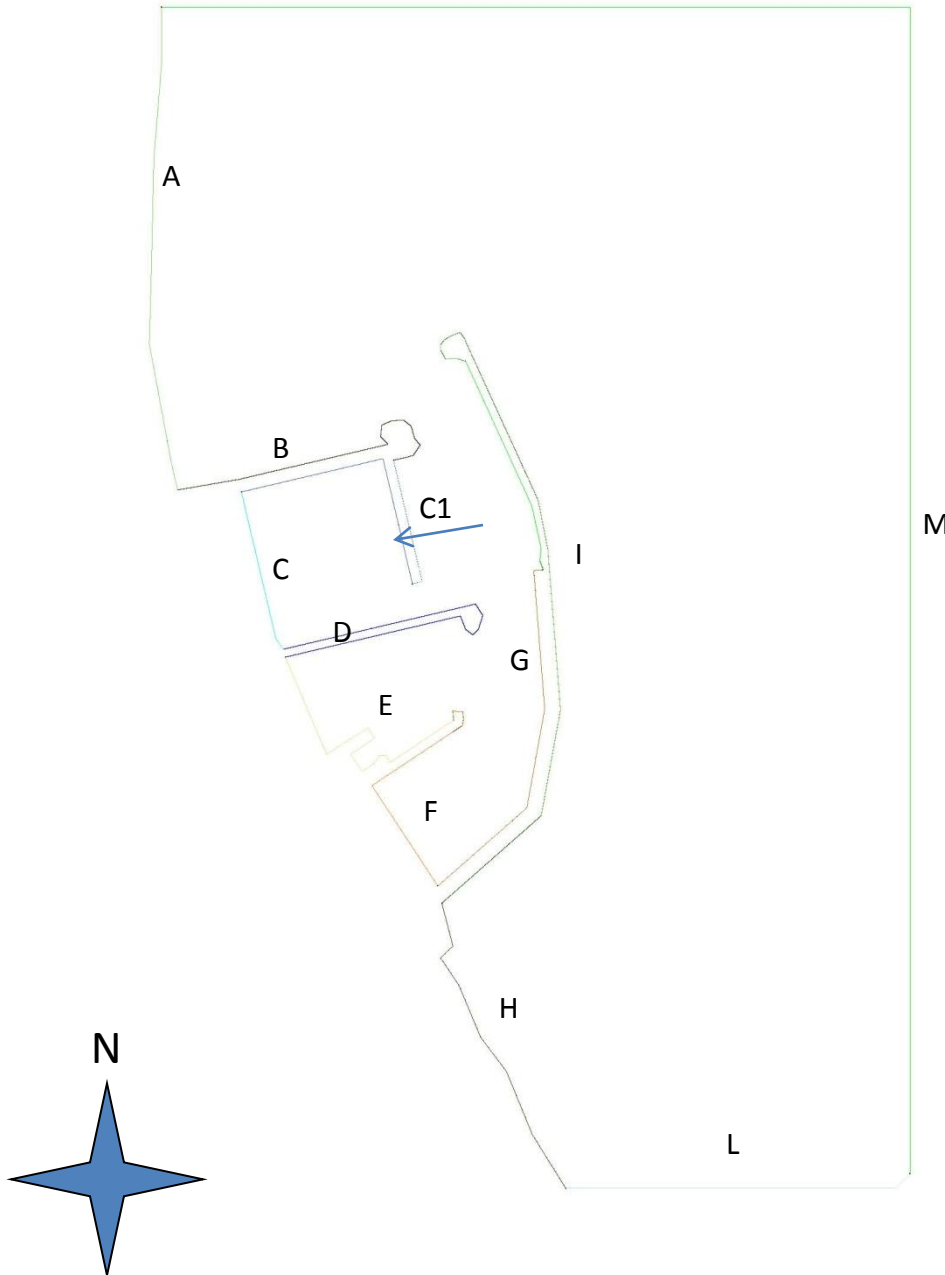
FileName: RIP11001.tri



# Modelling waves

## Mild Slope Equations

PHAROS (by DELTARES/Delft WL)



### Coefficienti di riflessione nei settori

A costa 20 %

B mantellata 35%

C1 porto\_a1 60 %

C porto 100%

D porto\_a2 100%

E porto\_b1 60%

F porto\_b2 50%

G molo 70%

H mantellata\_2 35%

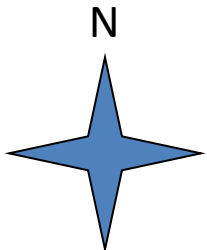
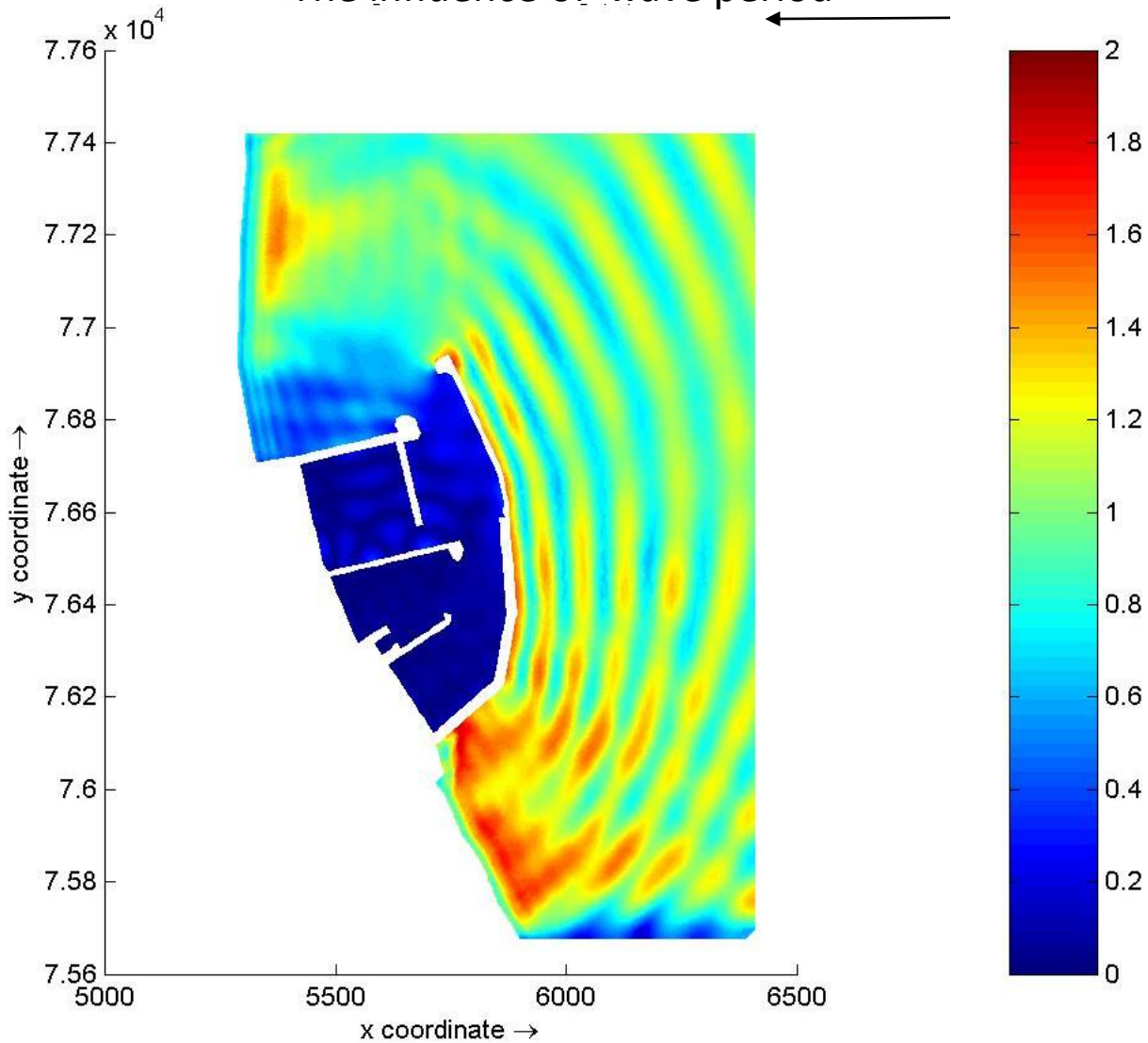
I spiaggia 10%

L uscita 0%

M ingresso

# Modelling waves ( Mild Slope Equations )

The influence of wave period

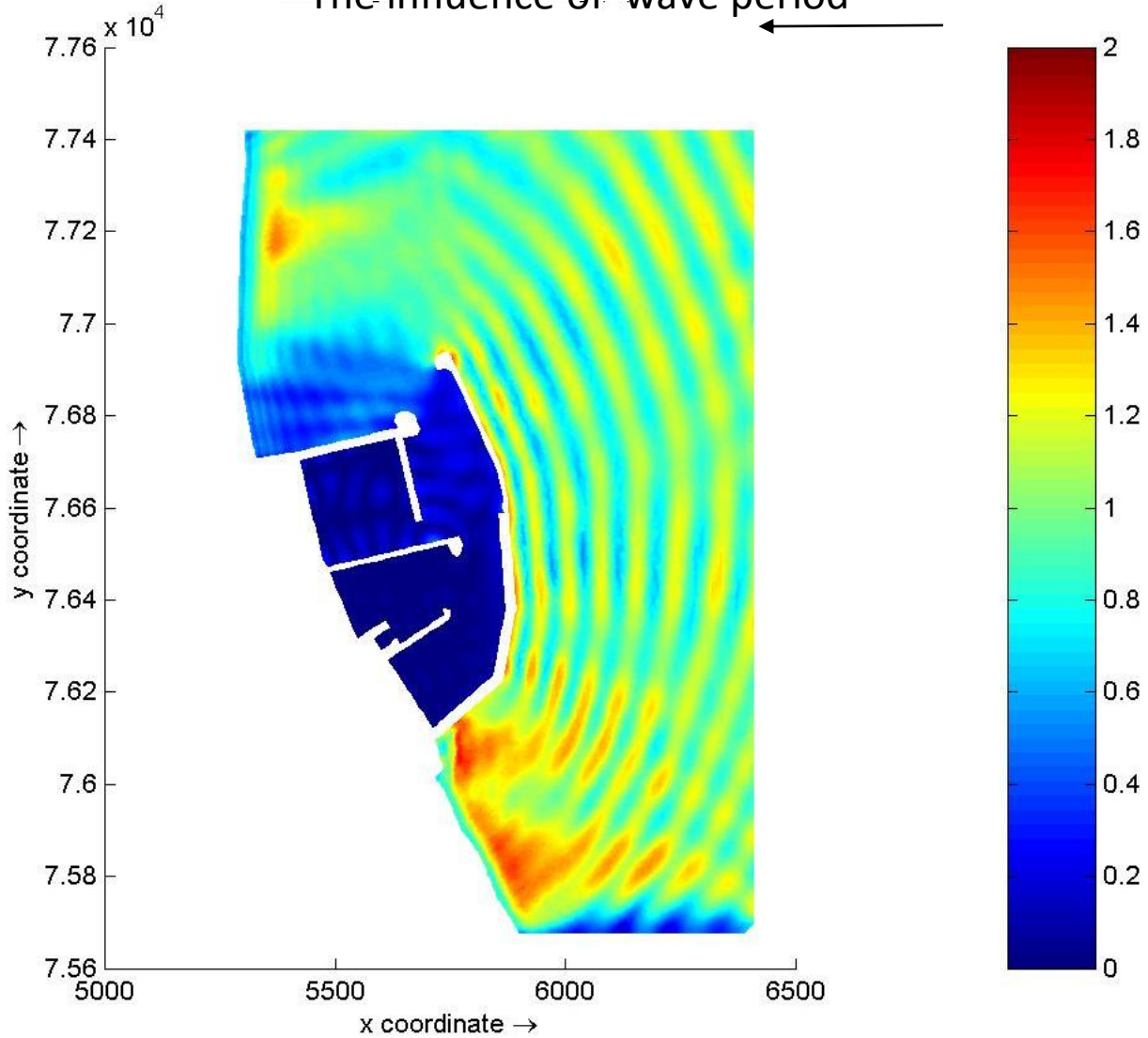
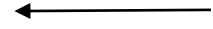


H = 1 m; T = **13"**; D = 90° da N

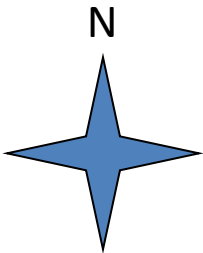
**MONOCHROME!**

# Modelling waves with Mild Slope Equations

The influence of wave period



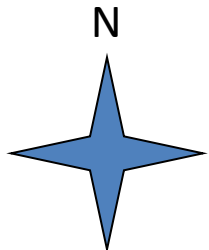
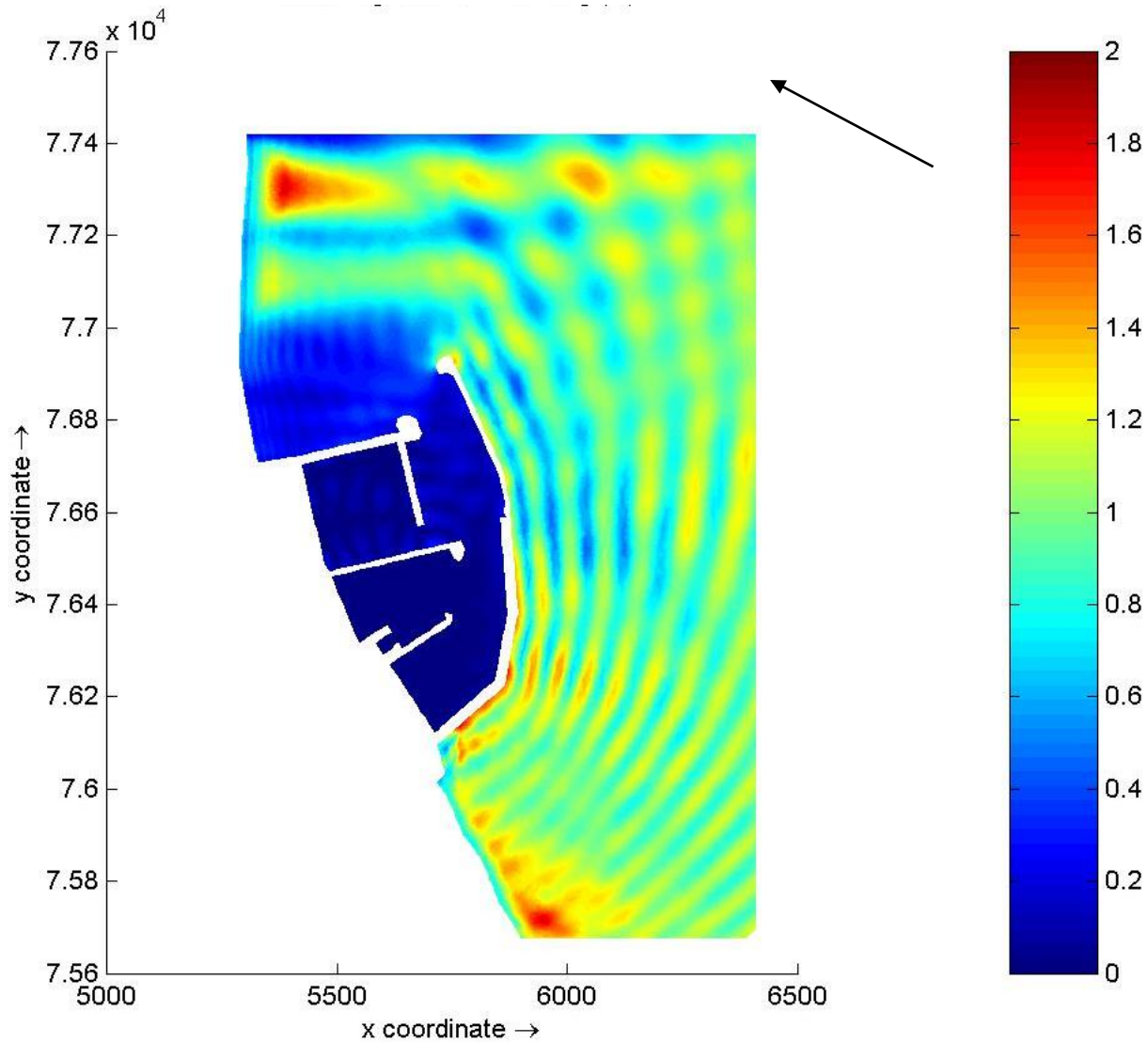
**MONOCHROMATIC wave!**



$H = 1 \text{ m}$ ;  $T = 11''$ ;  $D = 90^\circ$  da N

# Modelling waves with Mild Slope Equations

The influence of wave direction



$H = 1 \text{ m}$ ;  $T = 11''$ ;  $D = 120^\circ$  da N

**MONOCHROME!**

# Modelling waves with Mild Slope Equations

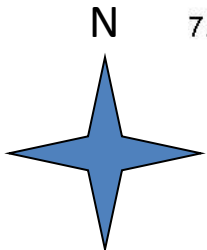
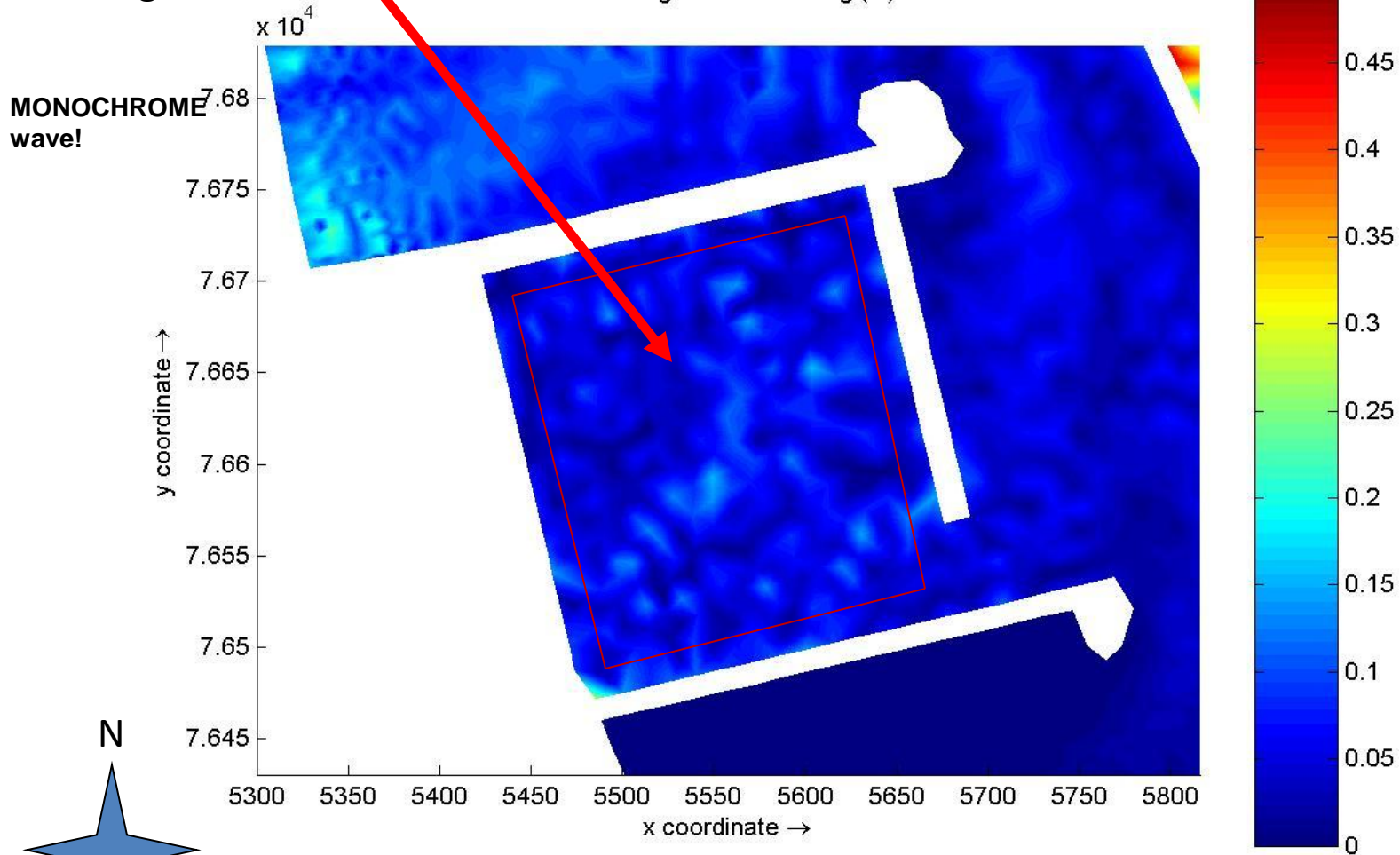
## Target area

The influence of wave period

Crid= Hin/Hoffshore

Within the  
Target Area

wave height: 5 s - 150 deg (m)

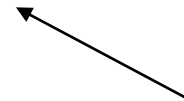


H = 1 m; T = 5"; D = 120° da N

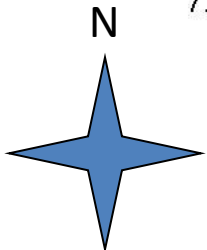
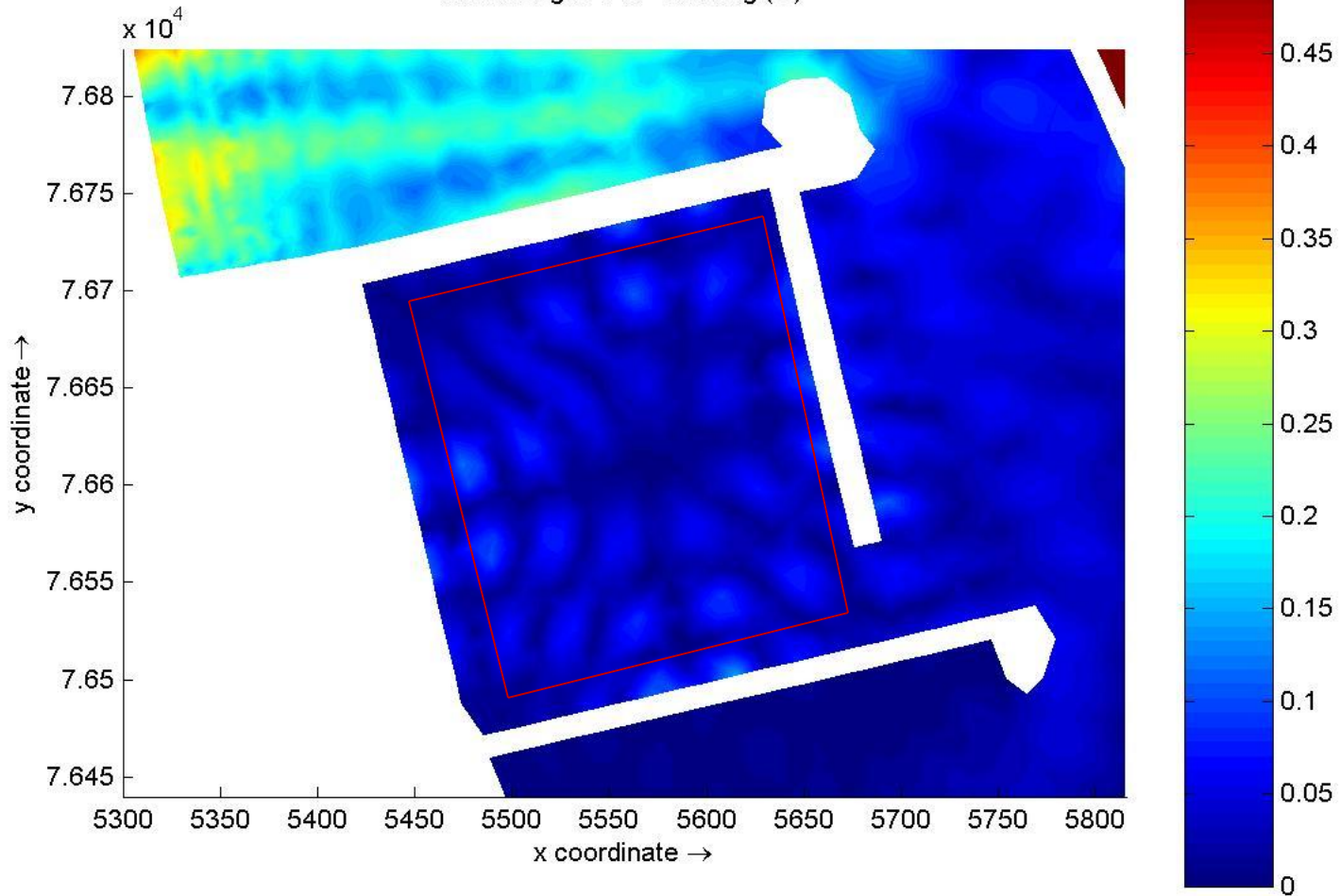
# Modelling waves with Mild Slope Equations

## Target area

The influence of wave period



wave height: 7 s - 150 deg (m)



H = 1 m; T = 7"; D = 120° da N

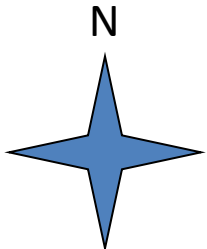
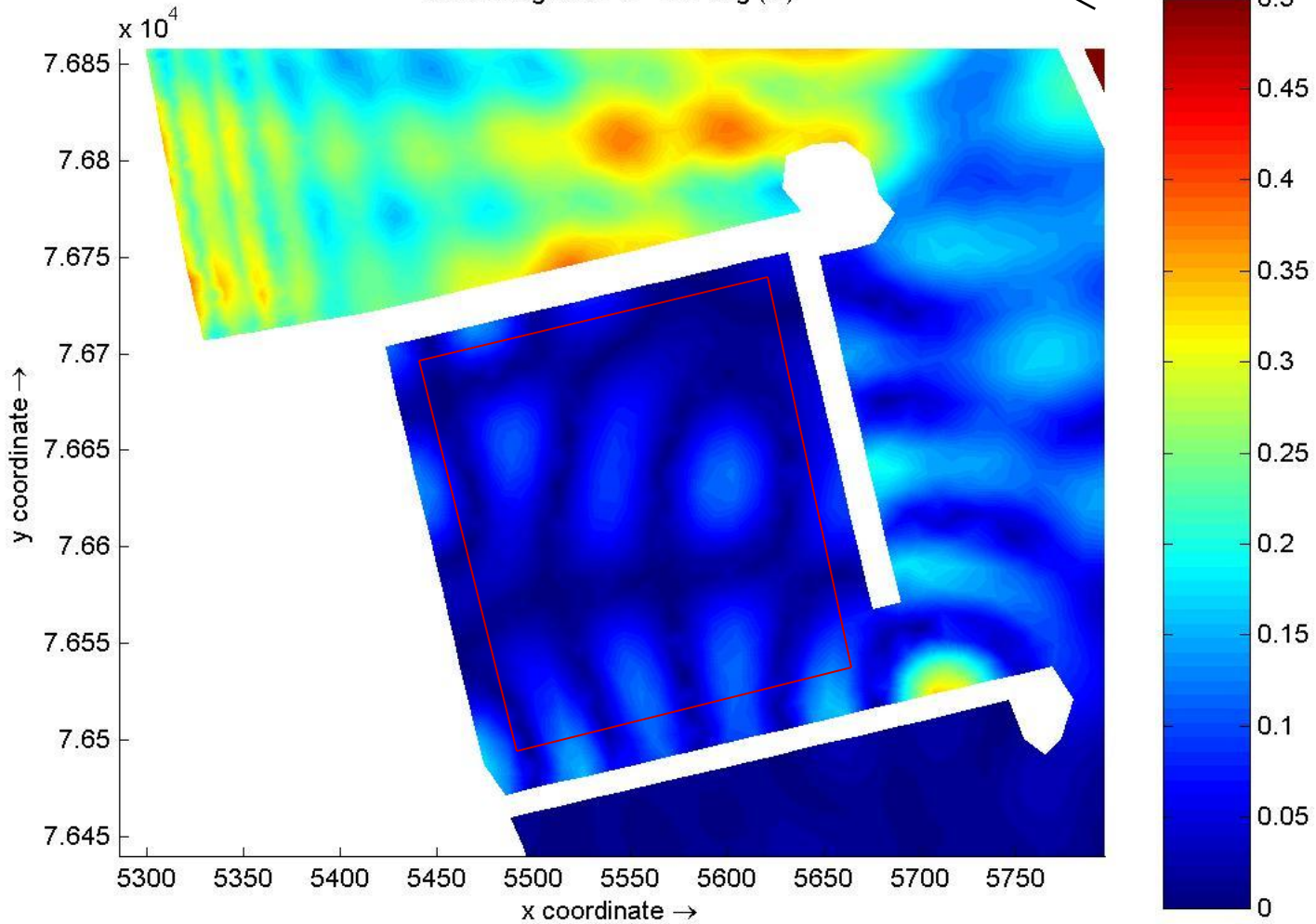


# Modelling waves with Mild Slope Equations

## Target area

The influence of wave period

wave height: 11 s - 150 deg (m)



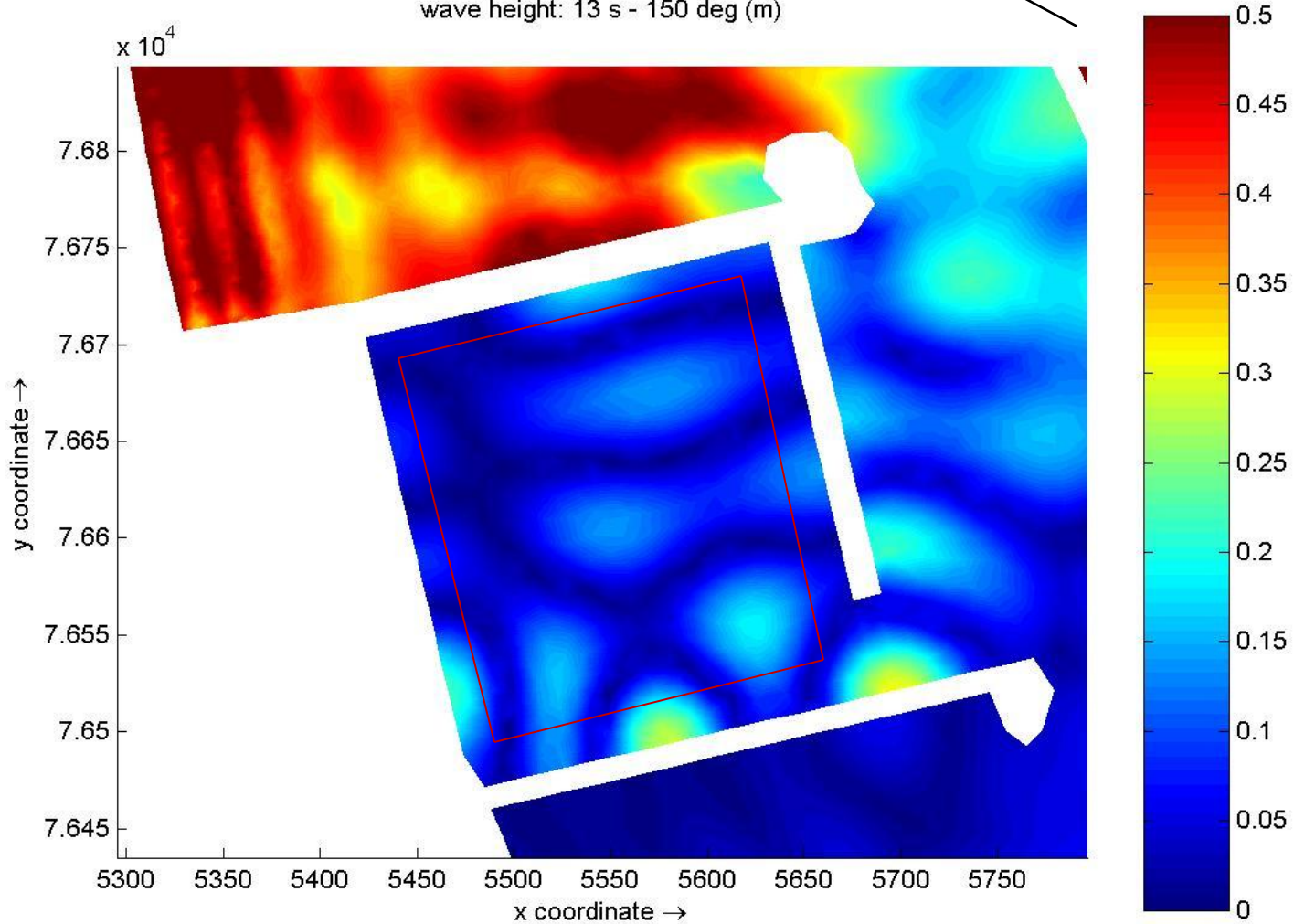
$H = 1 \text{ m}$ ;  $T = 11''$ ;  $D = 120^\circ \text{ da N}$

# Modelling waves with Mild Slope Equations

## Target area

The influence of wave period

wave height: 13 s - 150 deg (m)



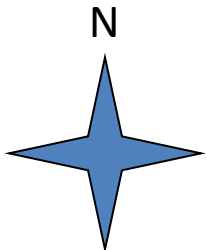
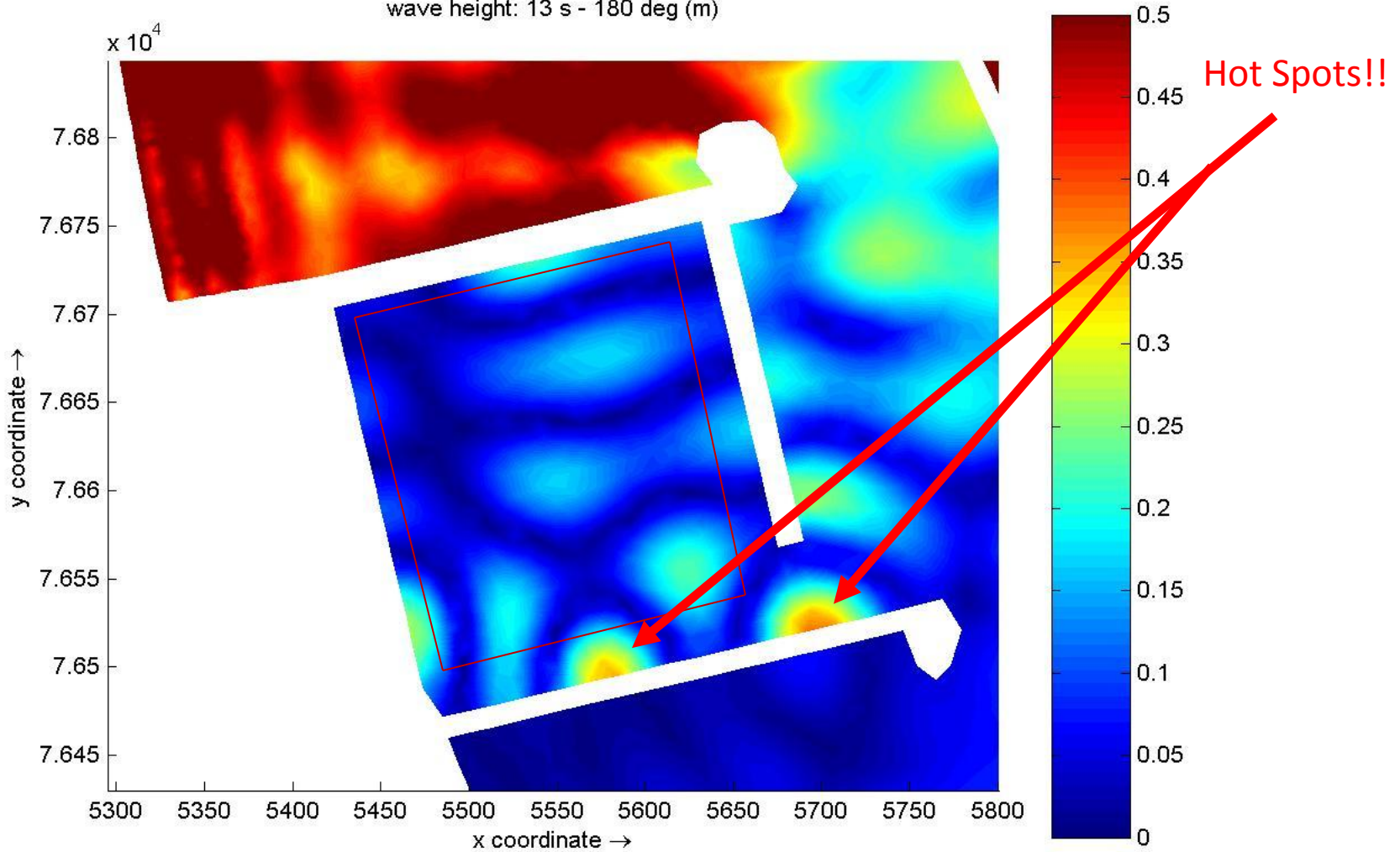
H = 1 m; T = 13"; D = 120° da N

# Modelling waves with Mild Slope Equations

## Target area

The influence of wave direction

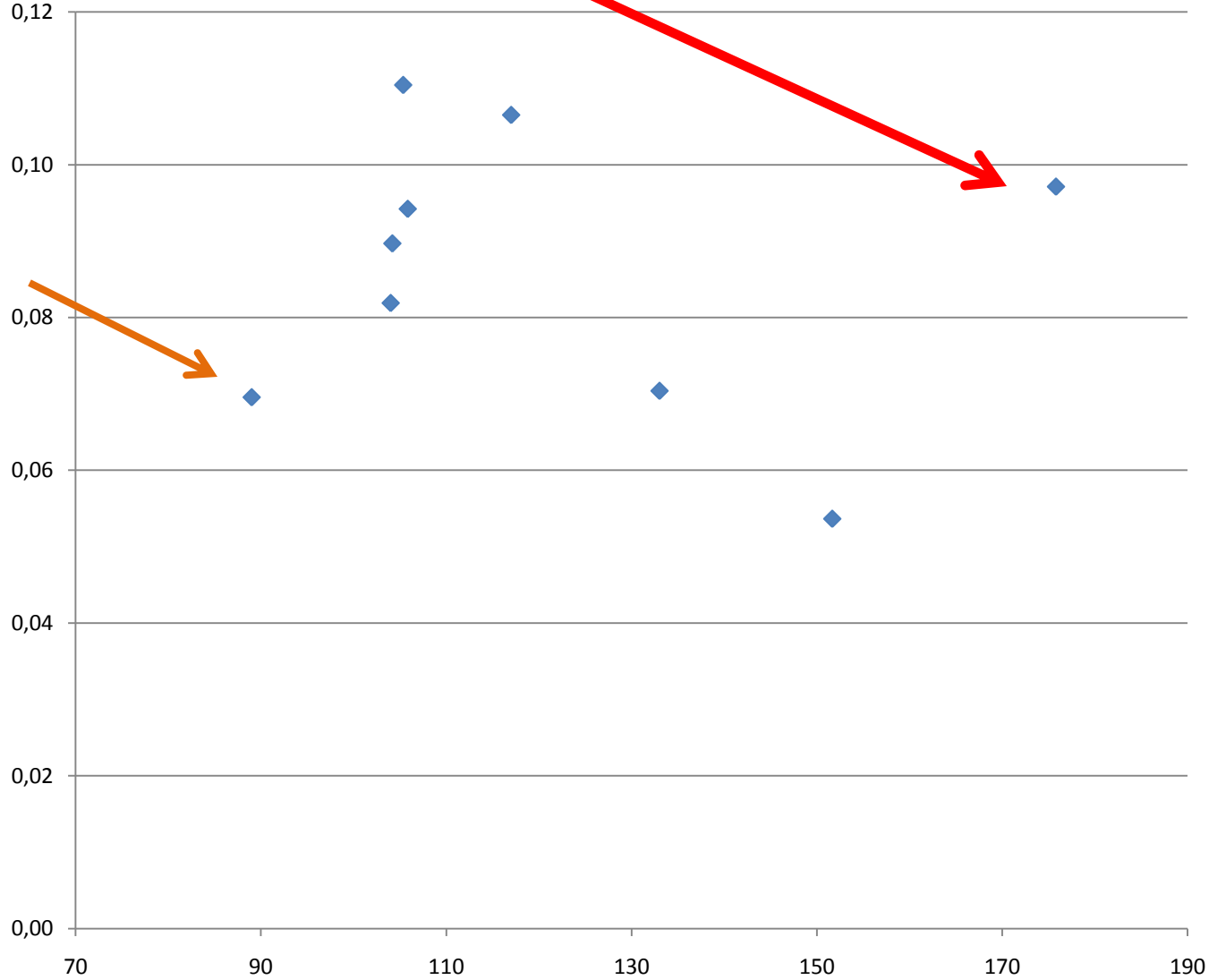
wave height: 13 s - 180 deg (m)



H = 1 m; T = 13"; D = 90° da N

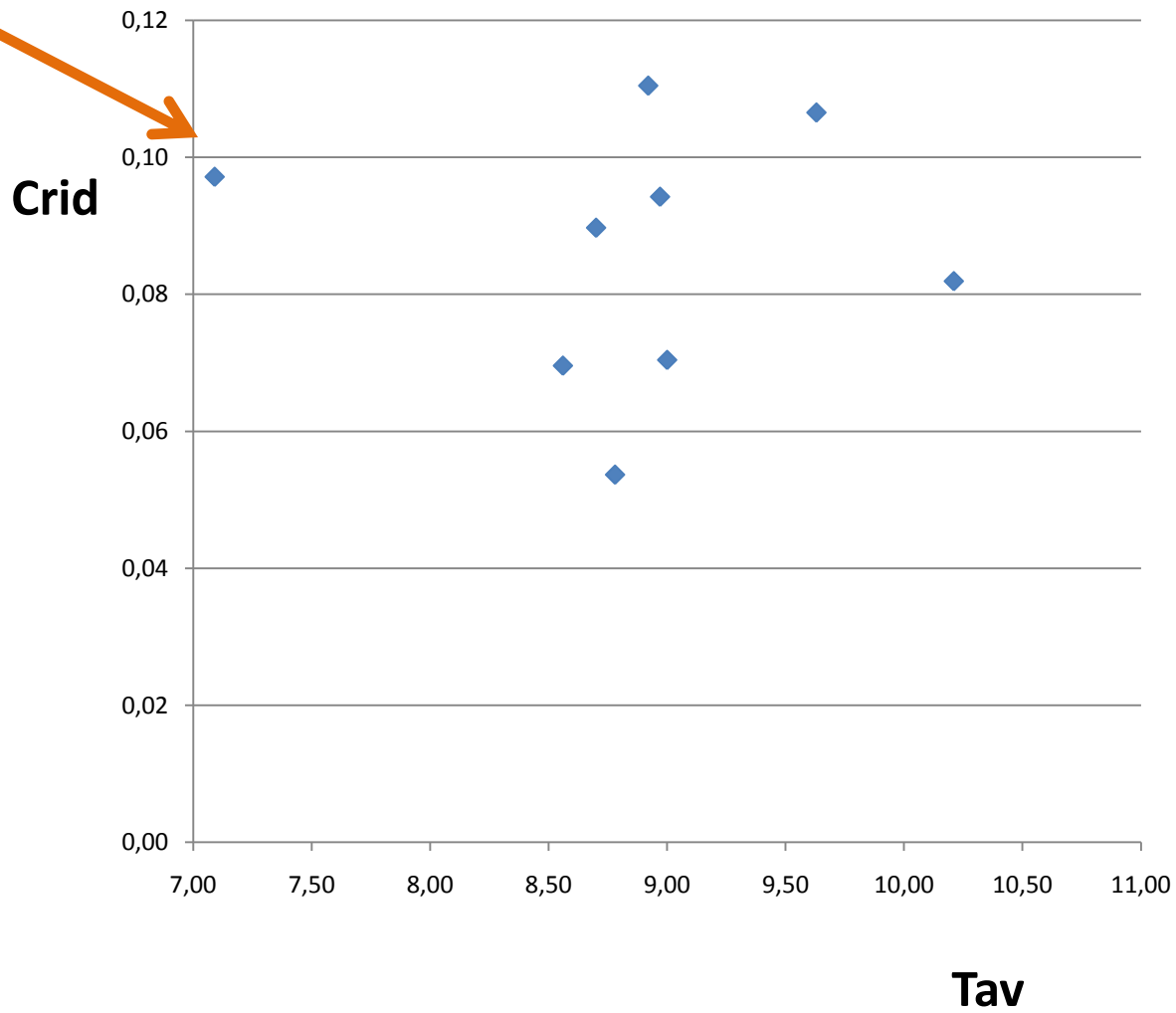
**Crid= Hin/Hoffshore  
At the TRITON-ADV**

**Crid**



**Direction  
(from)**

**Crid= Hin/Hoffshore  
At the TRITON-ADV**



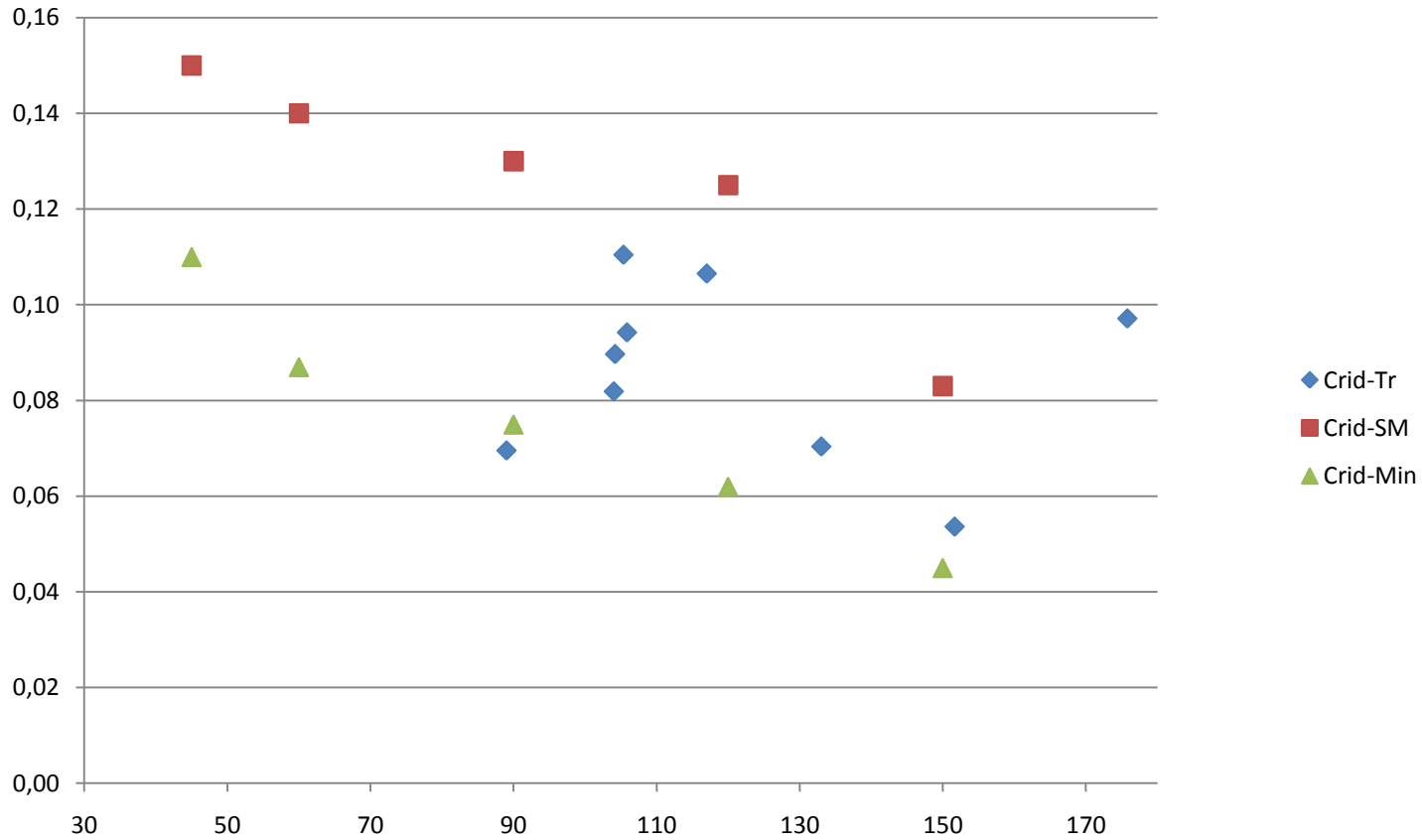
04/12/2008 Nettuno (37.5;15.5)				04/12/2008 Triton				
Time	Hs	Dir	Tav	Time	Hs	Dir	T	Red.Coeff.
0.00	2.7689+-7		8.56	0.00	0.192		9.6	0.070
6.00	3.1598+-6		10.21	6.00	0.258		10.5	0.082
12.00	2.91	117	9.63	12.00	0.31		10.8	0.107

12/12/2008 Nettuno (37.5;15.5)				12/12/2008 Triton				
Time	Hs	Dir	Tav	Time	Hs	Dir	T	Red.Coeff.
0.00	4.38	151.7	8.78	0.00	0.235		10.5	0.054
6.00	3.48	133	9	6.00	0.245		11.5	0.070
12.00	2.45	175.8	7.09	12.00	0.238		12.3	0.097

17/12/2008 Nettuno (37.5;15.5)				17/12/2008 Triton				
Time	Hs	Dir	Tav	Time	Hs	Dir	T	Red.Coeff.
0.00	2.04	104.2	8.7	0.00	0.183		9.2	0.090
6.00	2.2	105.4	8.92	6.00	0.243		9.2	0.110
12.00	2.08	105.84	8.97	12.00	0.196		10	0.09

# Measured/vs Model

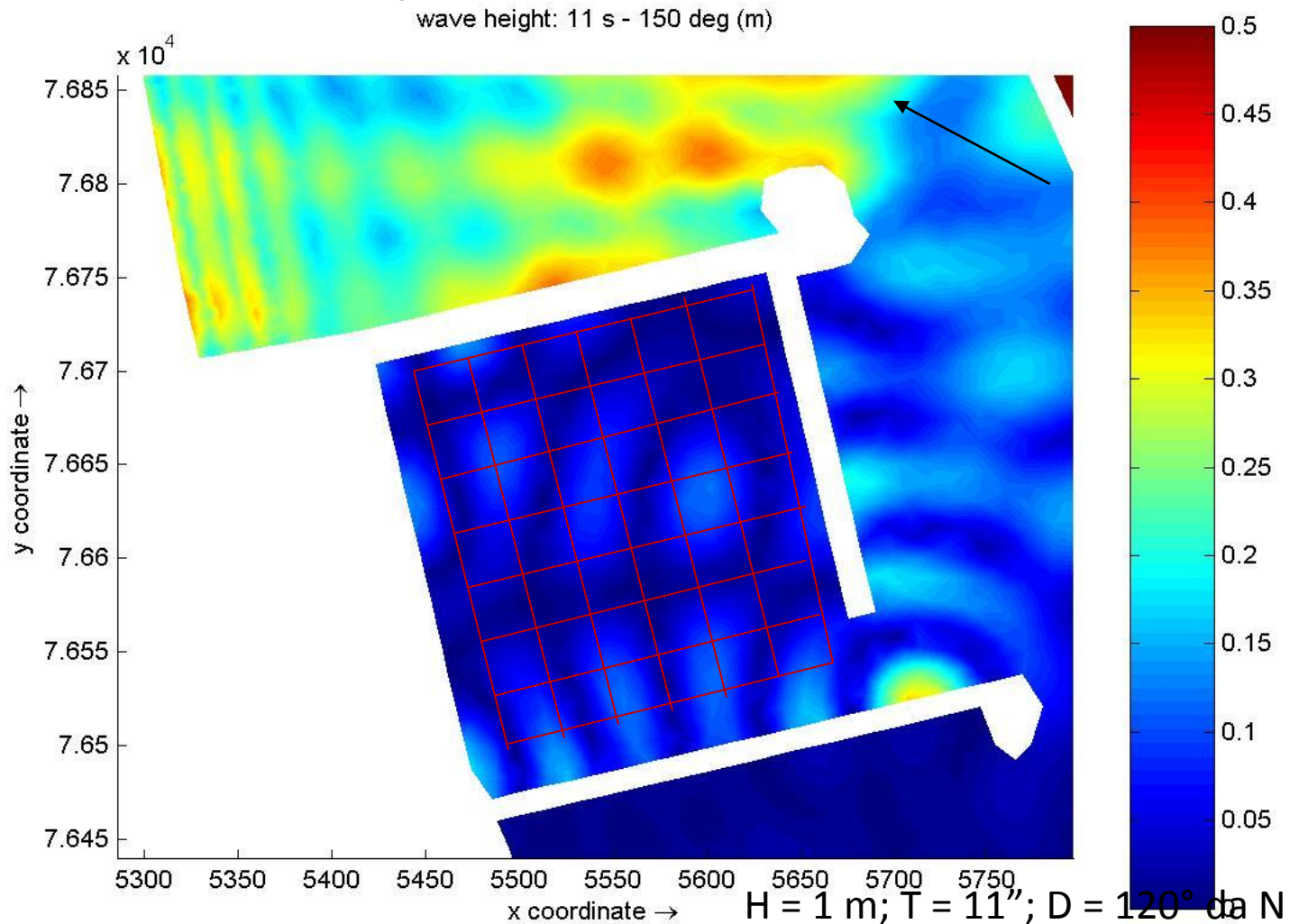
**Crid= Hin/Hoffshore**  
Within the  
Target Area



Hin = Average OR Max Sub-area? Which sub area?

Crid= Hin/Hoffshore

Will Integrated Spectrum Analysis make things better (i.e. more uniform field)?





**SO.....**

While **none** of the single steps of the monitoring programme is entirely **new in itself**, the **integration** of different methods and technologies, over different time and space scales provides essential information.

**When offshore measured data are lacking**, a careful **integration** of in situ data and **up-to-date** weather and wave simulation can provide a satisfactory evaluation of harbour confort and safety *as long as the target area is well defined*

AND

Yes, even a properly designed marina could be unsafe according to modern standards

AND

Should the regulations be more specific ?(open to discussion)

# THANK YOU

A shipping company from *Syllectum*, Tunisia  
(Ostia, Rome Harbour, II Century AD)



## Acknowledgements

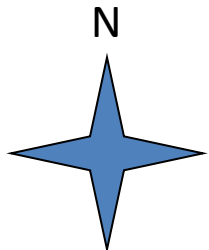
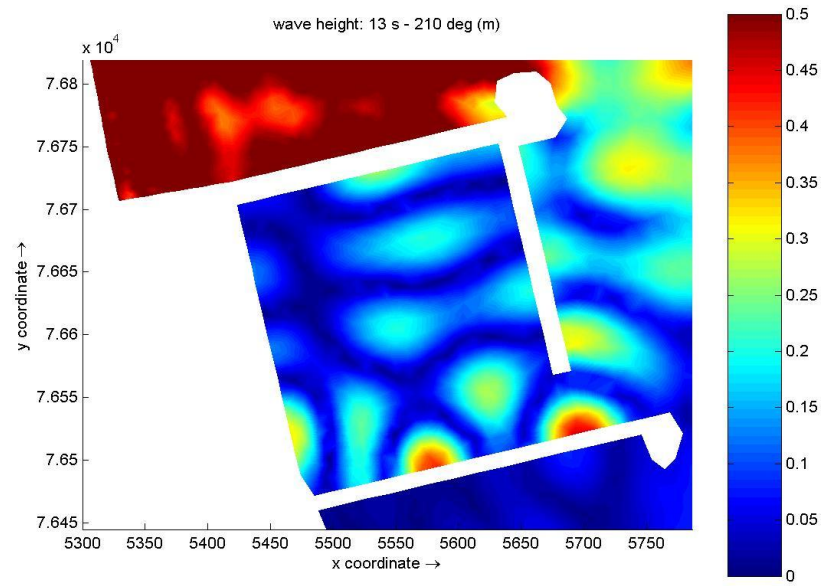
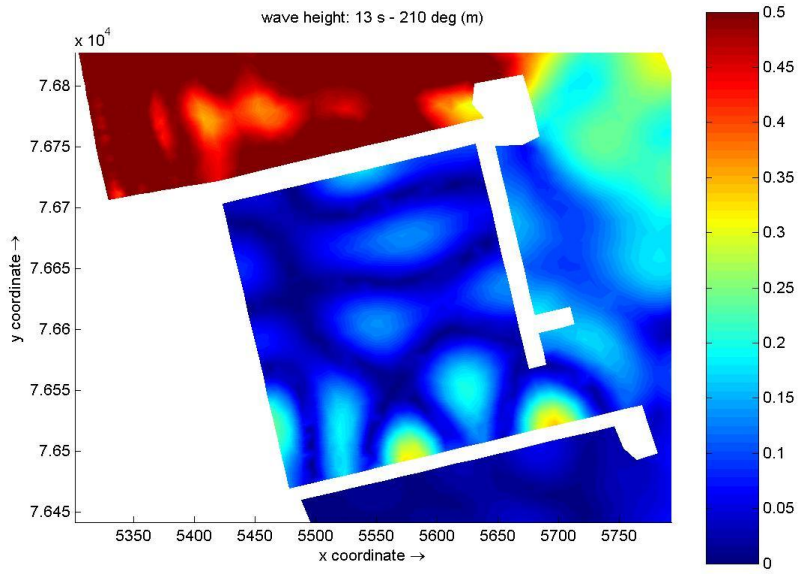
Italian Air Force Meteorological Centre (CNMCA) provided important data;  
Lt. Colonel Torrisi's precious help and advice was particularly appreciated.



Two private companies:

"Mediterraneo Scarl" and

"Walcom Italy" provided a useful occasion to improve the understanding of marina harbour wave agitation problems.



Per tutti casi esaminati:

$H = 1 \text{ m}$   $D = 60^\circ$  da N