



## MEDITERRANEAN DAYS OF COASTAL AND PORT ENGINEERING

Palermo, October 7th – 9th 2008

# SATELLITE APPLICATIONS TO SEA STATE EVALUATION IN ENCLOSED SEAS

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# Site wave climate analysis is based on

Global Weather Model archive data  
(Local Area Model)

+

Wave Generation and Propagation Model  
(Coastal Wave model)

+

Wave buoys, where available  
Satellite altimeter

**Altimeter data are now routinely assimilated into wave models**

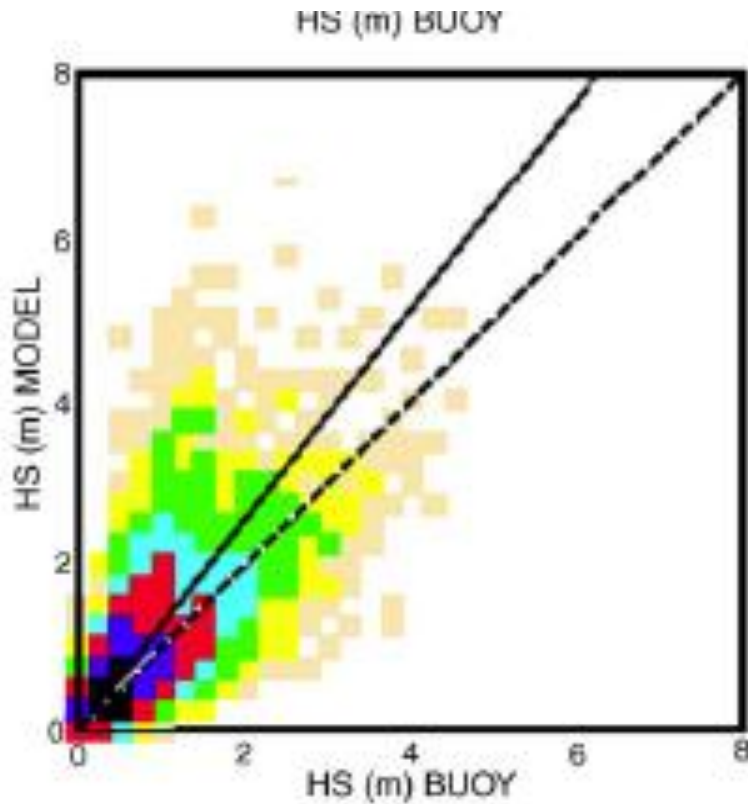
**Altimeter/buoy (wind, waves) data calibration: 1988 (Monaldo)**

**Altimeter/Model comparison:**

**2006 ( Abdalla & Cavaleri)**

**(2007) (Ardhuin, Bertotti, Bidlot, Cavaleri, Filipetto, Lefevre, Wittmann)**

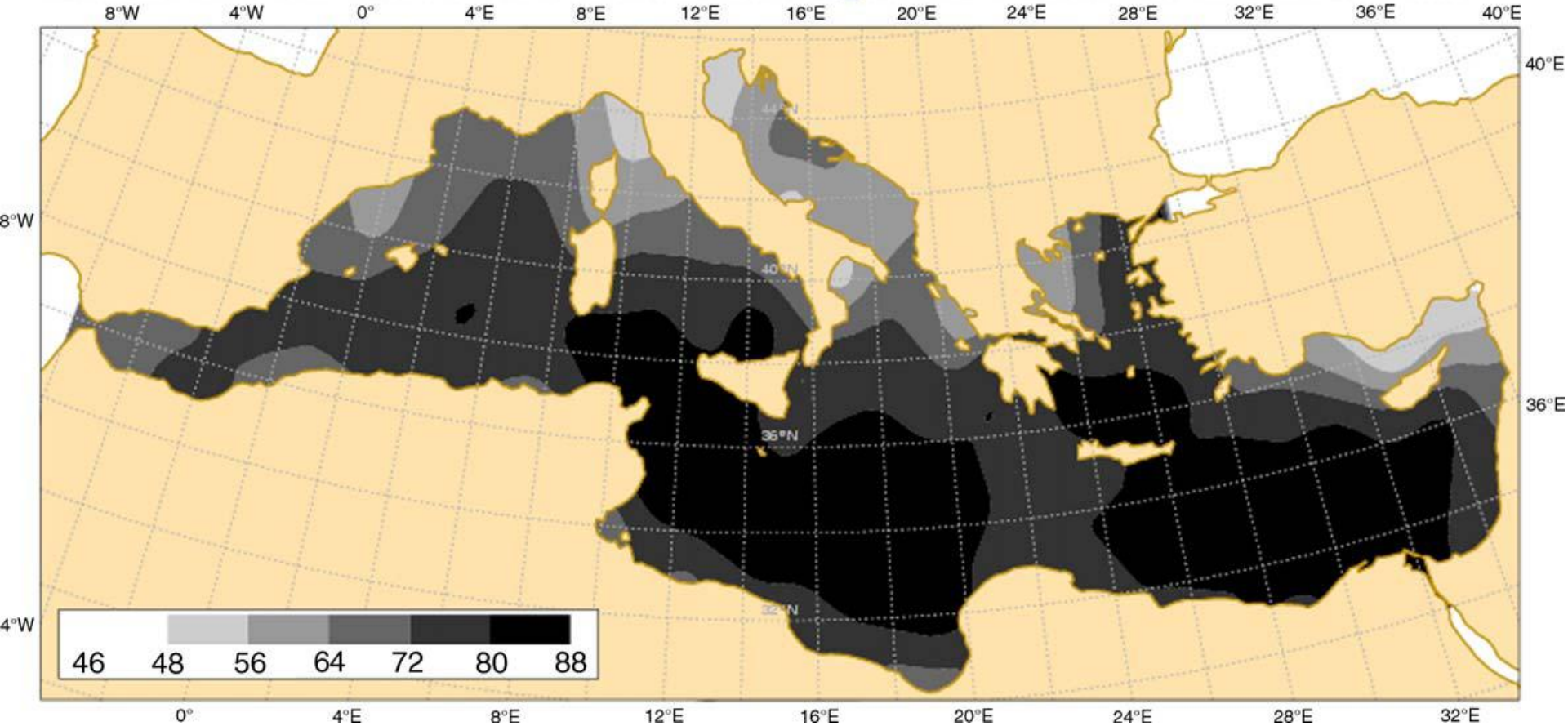
Cavaleri and Sclavo  
Coastal Engineering 53 (2006) 613–627



Model vs. Buoy  
Still considerable scatter  
On a large scale



# MEDITERRANEAN SEA - BEST-FIT SLOPE\*100 BETWEEN MODEL\_T213 AND OVERALL MEASURED WAVE HEIGHTS

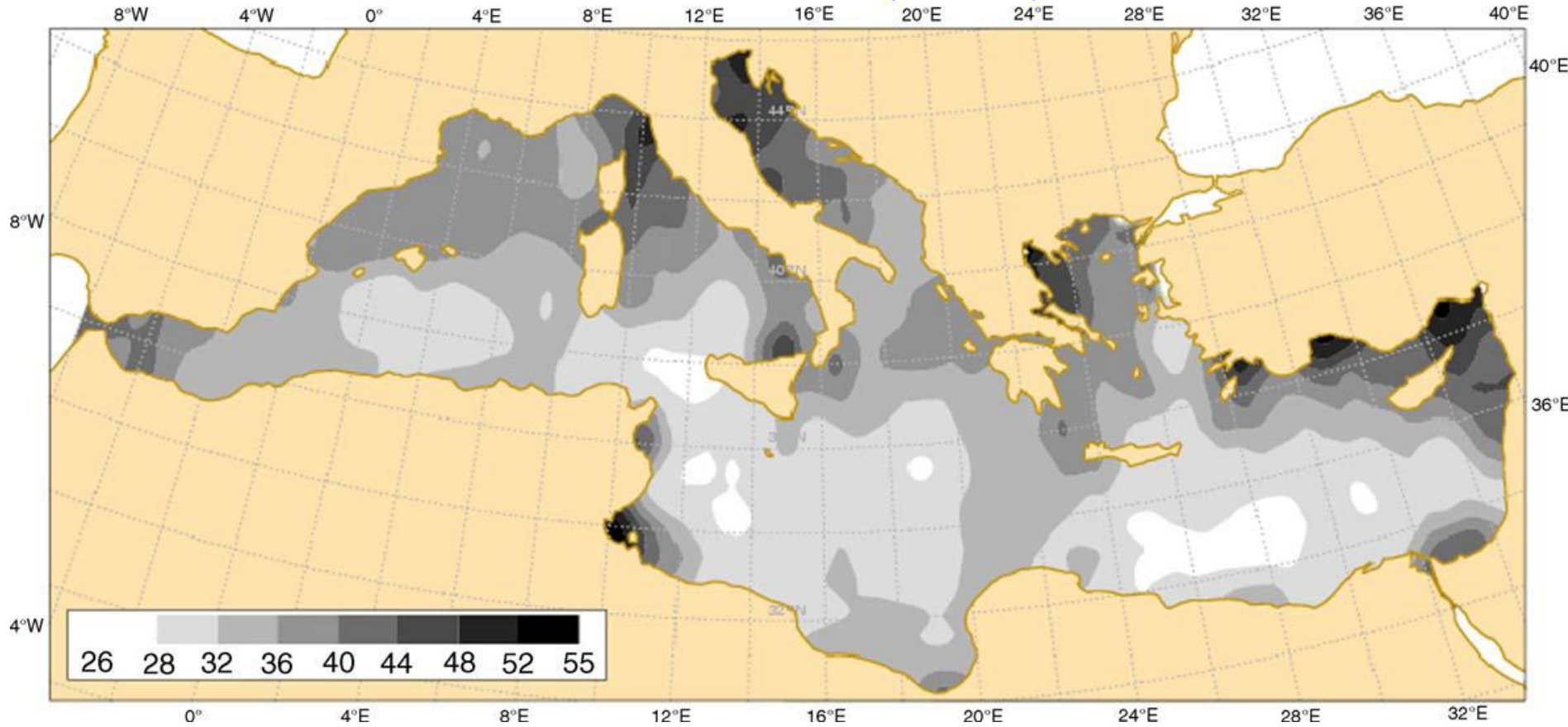


*Cavaleri and Sclavo. Coastal Engineering 53 (2006) 613–627*



You could correct model results with satellite data, but...

## MEDITERRANEAN SEA - SCATTER INDEX\*100 BETWEEN MODEL (<20001121) AND SATELLITE WAVE HEIGHTS



*Cavaleri and Sclavo. Coastal Engineering 53 (2006) 613–627*

... there would still be a considerable scatter



*It is worth to analysing single events with the help of altimeter data*

a) SAR Frame 2781 26/12/1999 time 09:54

b) SAR Frame 801 29/12/1999 time 21:17

a) ERS-2 STR 079 26/12/1999 time 09:55

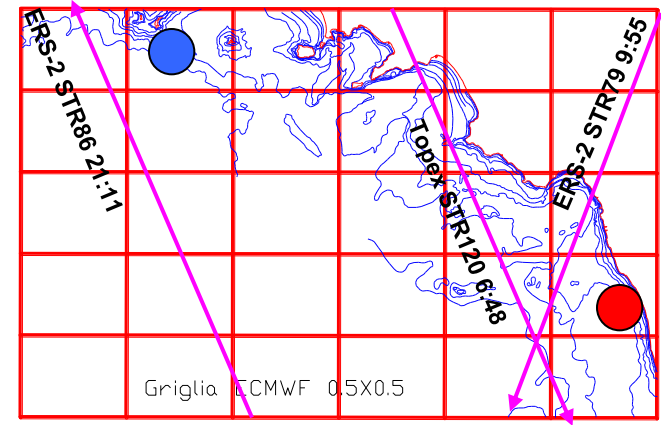
b) ERS-2 STR 086 26/12/1999 time 21:11

a) TOPEX STR 120 28/12/1999 time 06:48

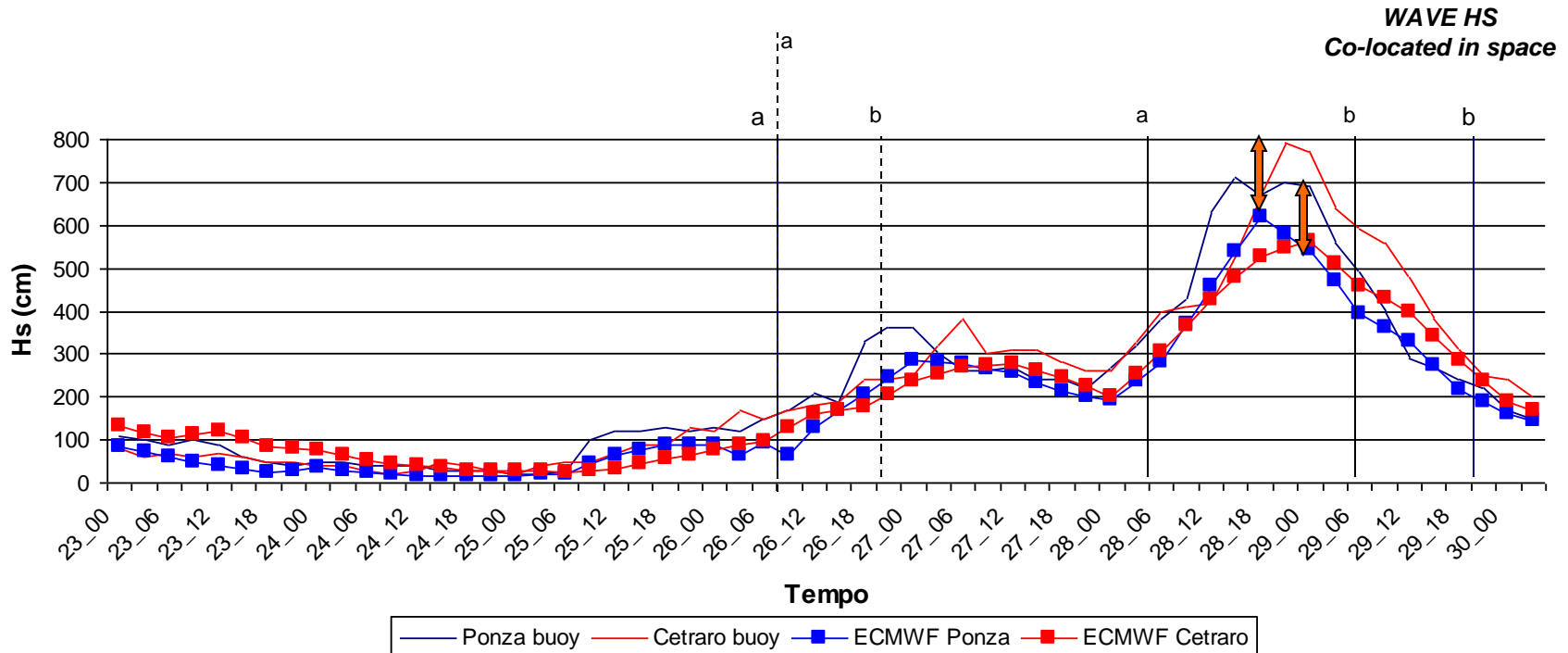
b) TOPEX STR 122 29/12/1999 time 10:00

● Ponza buoy

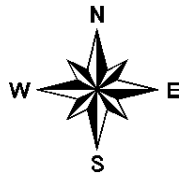
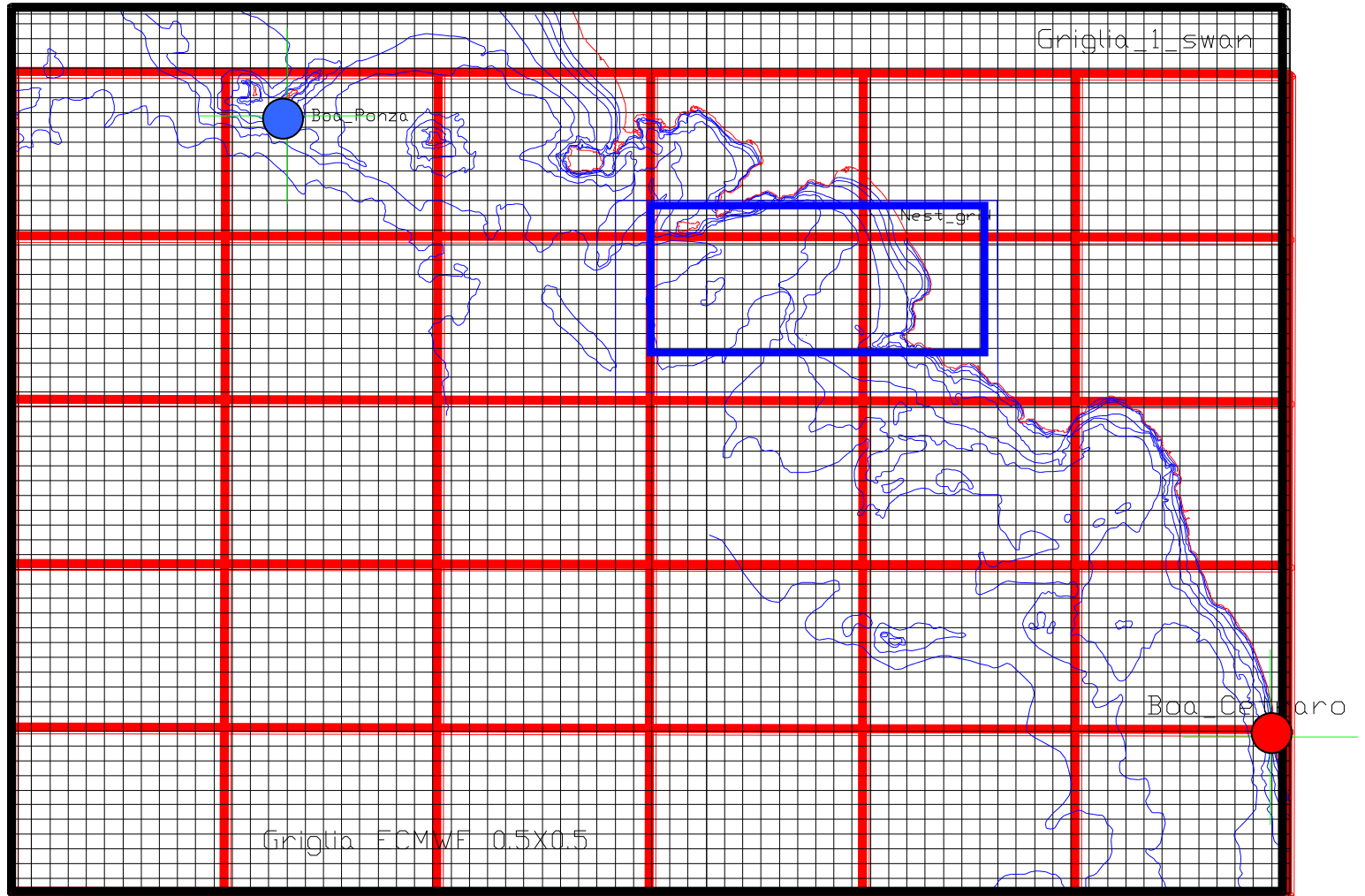
● Cetraro buoy

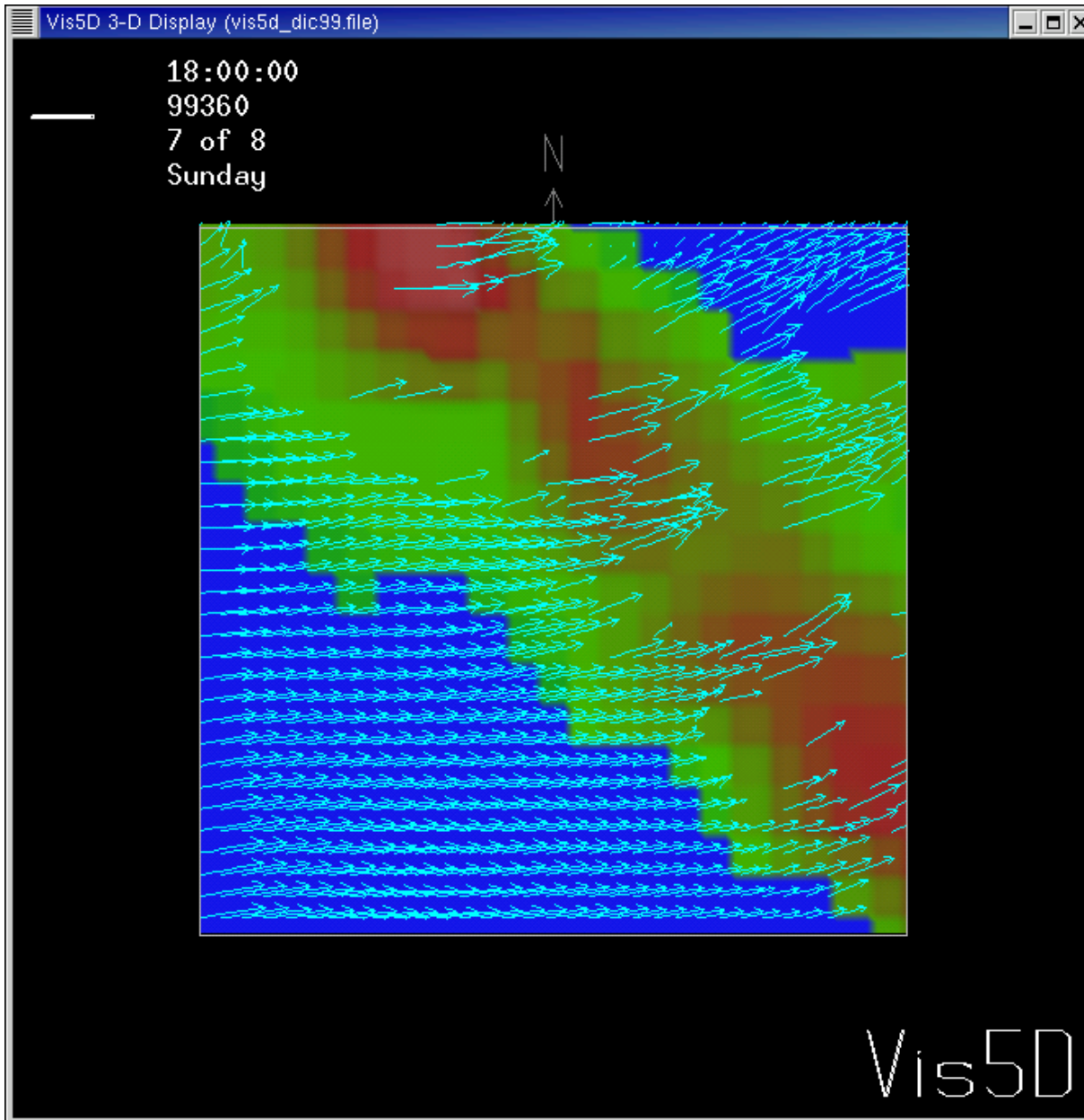


## December 1999 Tyrrhenian Sea



# Embedded Swan grid





MM5 Wind time  
28/12/1999 alle  
ore 18:00



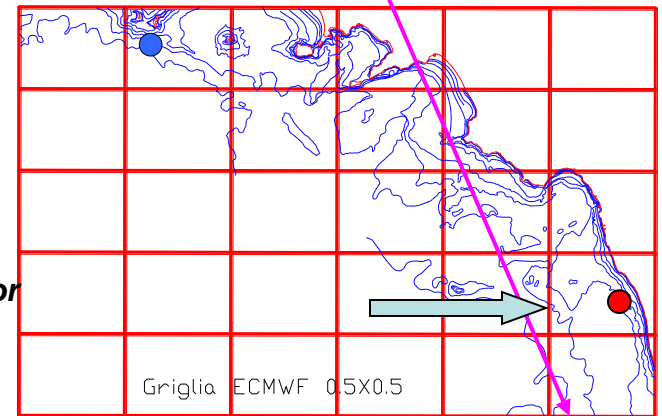
Cycle 268 Pass-120  
28/12/1999 Time 06:48

WAVE HS  
Co-located in space

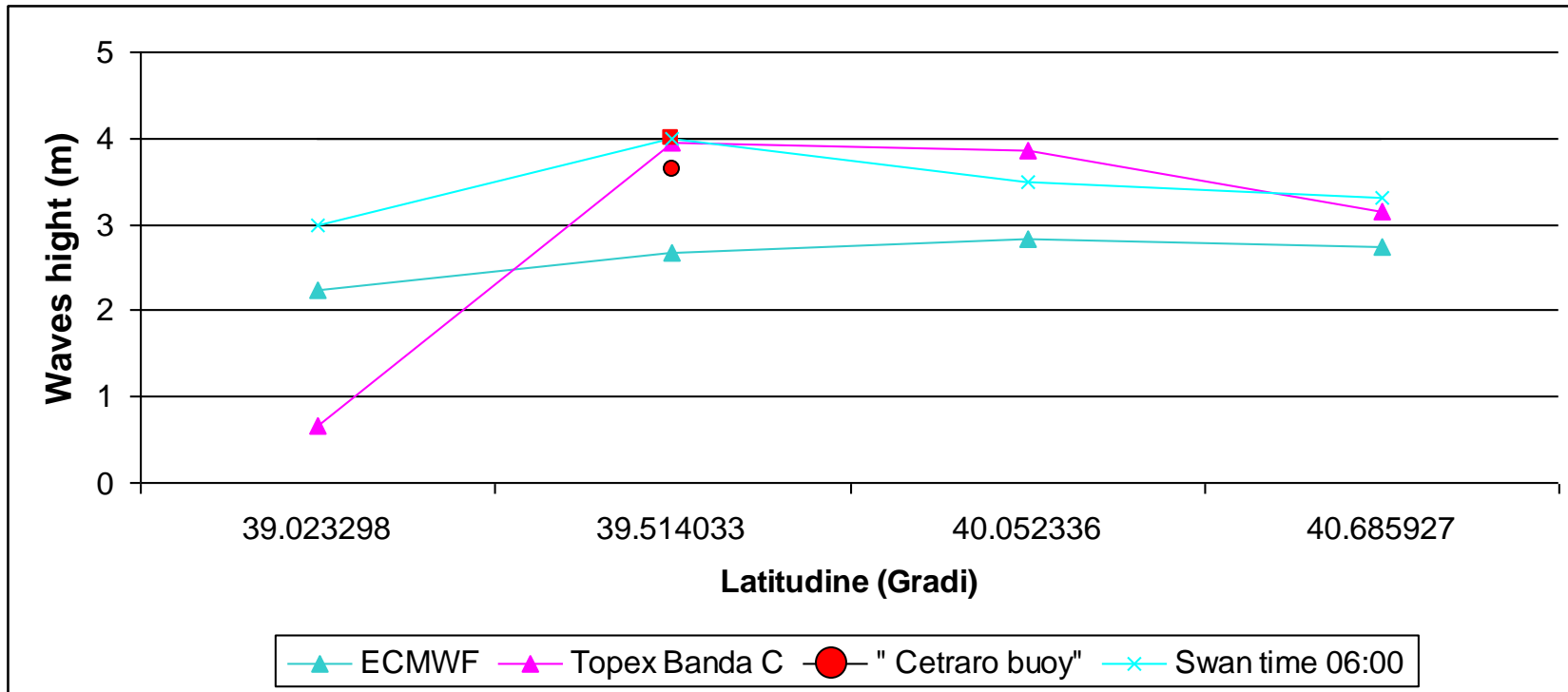
 Cetraro buoy



Co-location on a lee shore poor  
SWAN "Interpolates" better



TOPEX STR-120 (06:48) 28/12/1999  
versus ECMWF (06:00), ECMW/SWAN (06:00) and buoy (06:00)

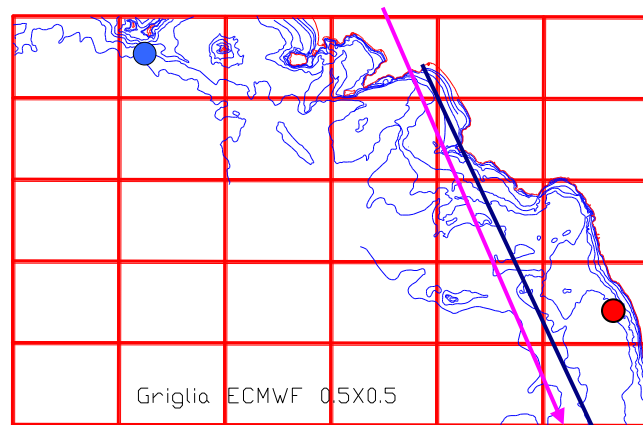


SWAN

28/12/1999

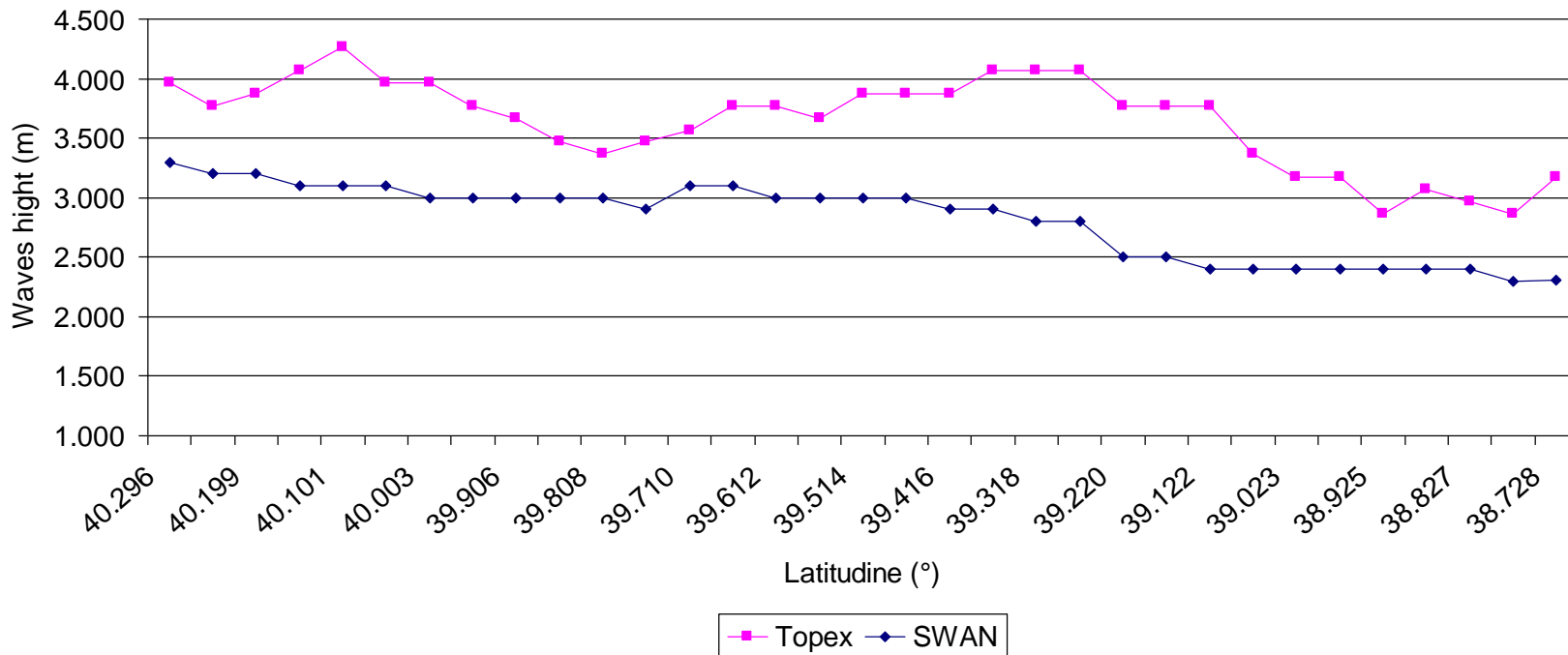
 Cetraro buoy

Cycle 268 Pass-120  
28/12/1999 Time 06:48



### TOPEX STR-120 (ore 06:48) versus ECMWF/SWAN (ore 06:00)

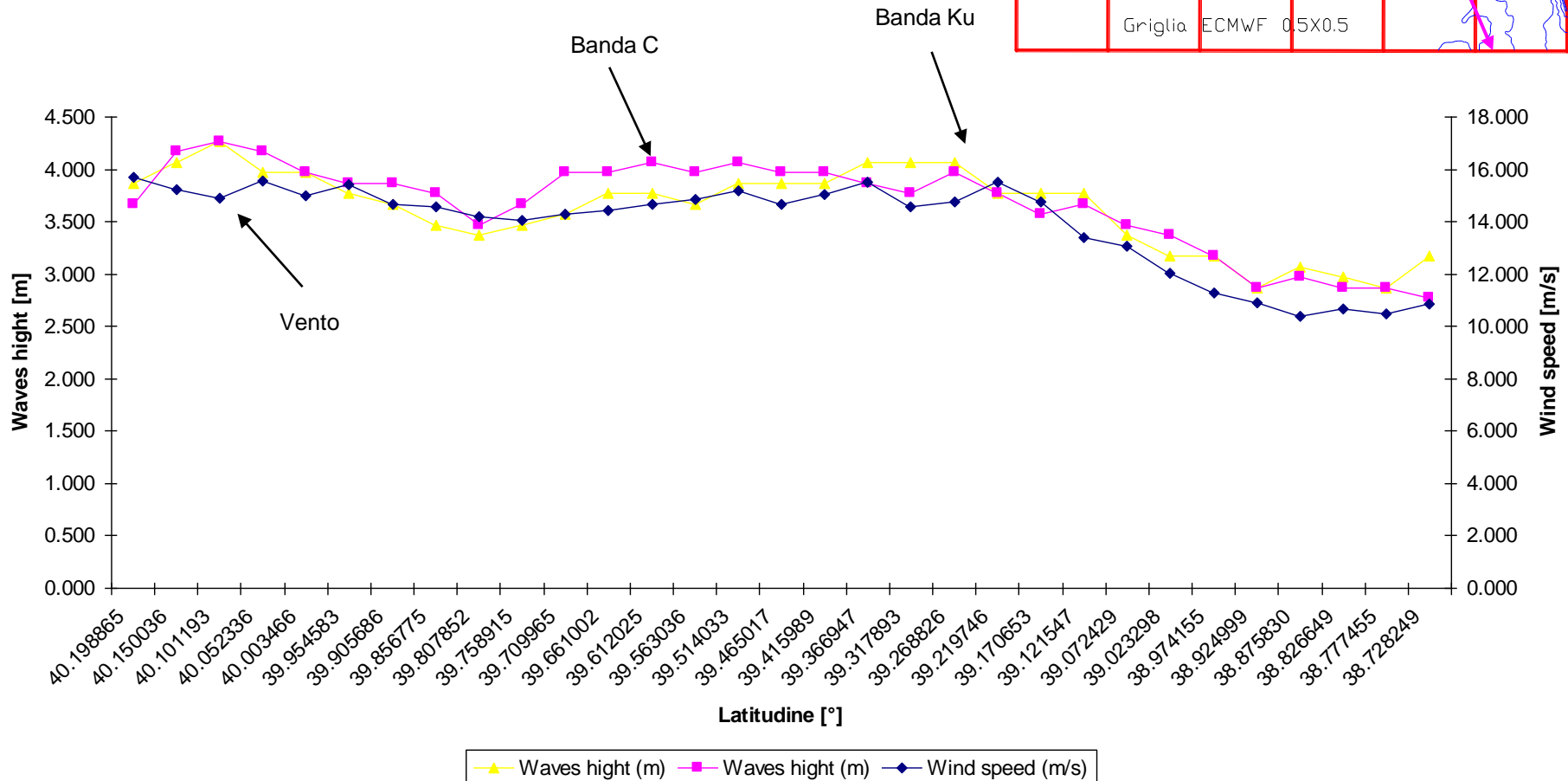
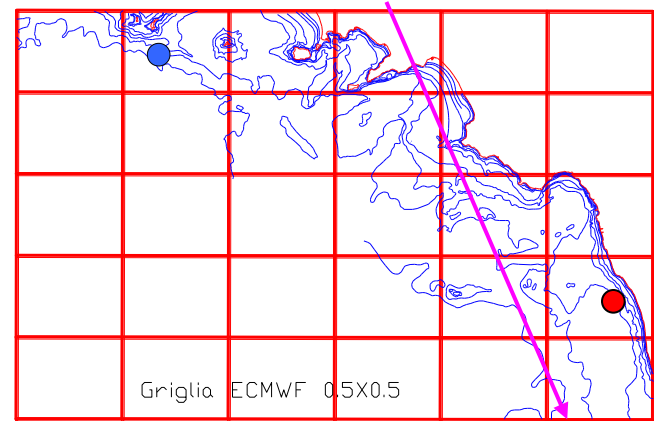
*Co-located in latitude*



# Wind/Waves (Ku,C) Topex

## CYCLE 268 PASS 120 28/12/1999 TIME 06:48

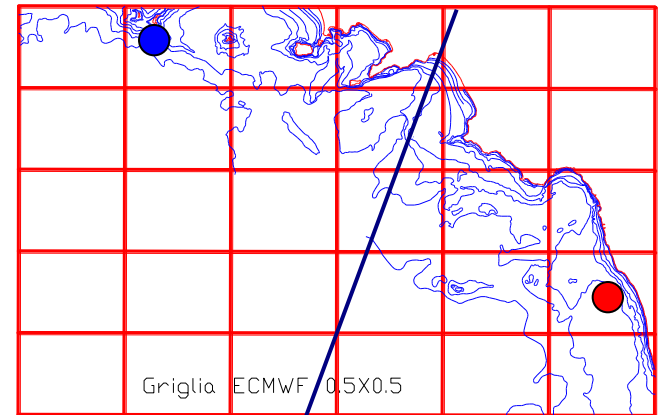
 Cetraro buoy



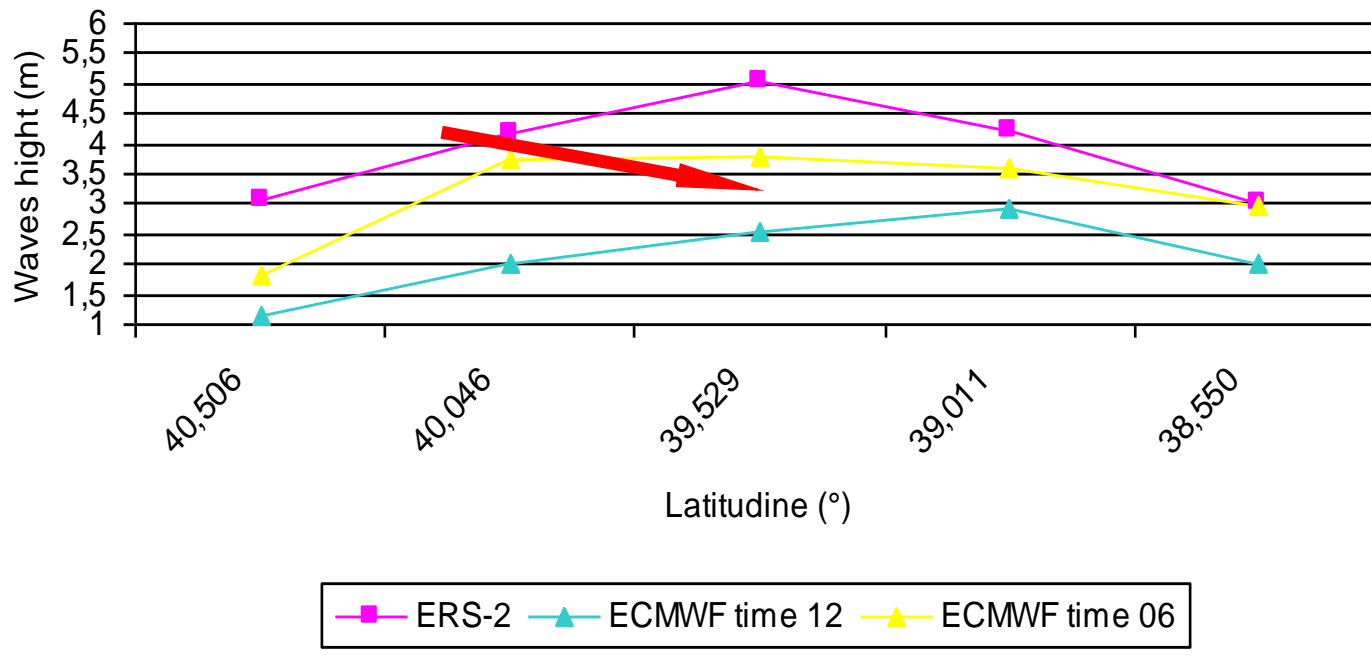
(No buoy data -too far)

Track 122 Orbit 24525  
29/12/1999 Time 10:11

Waves  
Co-located in space  
(not time)

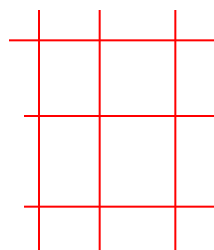


Confronto dati ERS-2\*\* STR-122 (ore 10:11) del 29/12/1999  
con i dati dell'ECMWF (ore 06:00 e ore 12:00)



# March-April 2008 Thyrrrenian Sea

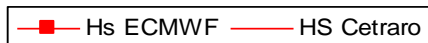
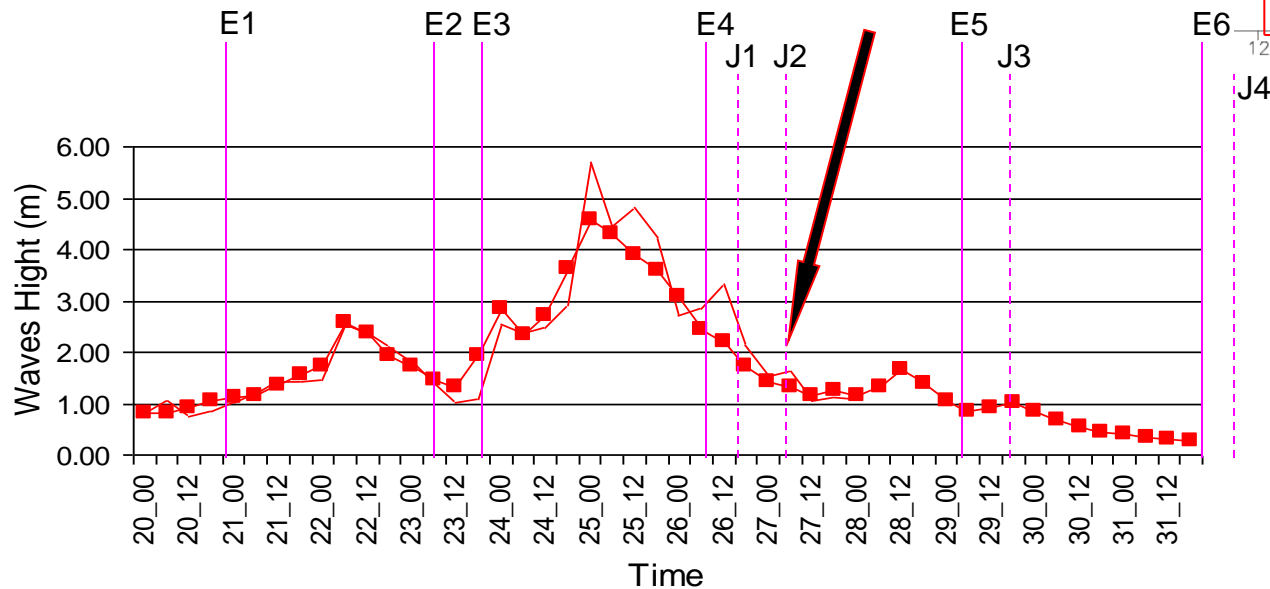
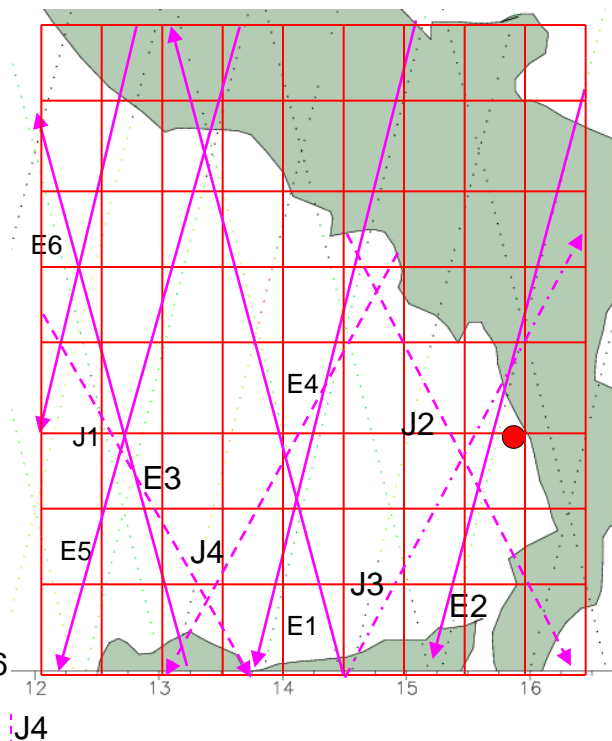
- E1) ENVISAT1 Ascendente 20/03/08 ore 20:44 N1p0085C067
- E2) ENVISAT1 Discendente 23/03/08 ore 09:36 N1p0158C067
- E3) ENVISAT1 Ascendente 23/03/08 ore 20:30 N1p0171C067
- E4) ENVISAT1 Discendente 26/03/08 ore 09:42 N1p0244C067
- E5) ENVISAT1 Discendente 29/03/08 ore 09:47 N1p0330C067
- E6) ENVISAT1 Discendente 01/04/08 ore 09:53 N1p0416C067
- J1) JESON 1 Discendente 26/03/08 ore 16:20 p0044c229
- J2) JESON 1 Discendente 29/03/08 ore 15:33 p0120c229
- J3) JESON 1 Ascendente 27/03/08 ore 06:23 p0059c229
- J4) JESON 1 Discendente 03/04/08 ore 05:10 p0237c229



Griglia

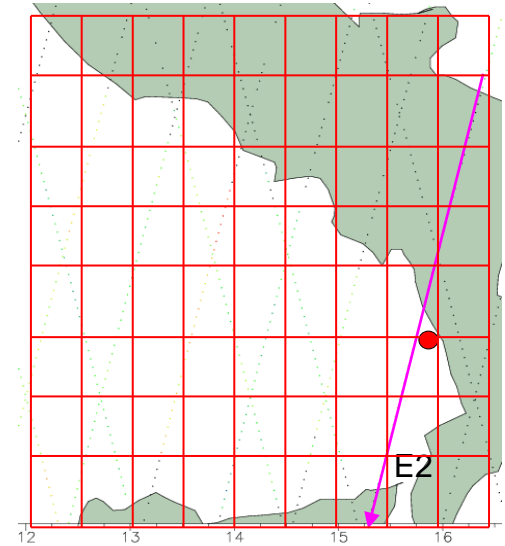
0.5° x 0.5°

End of buoy  
Data

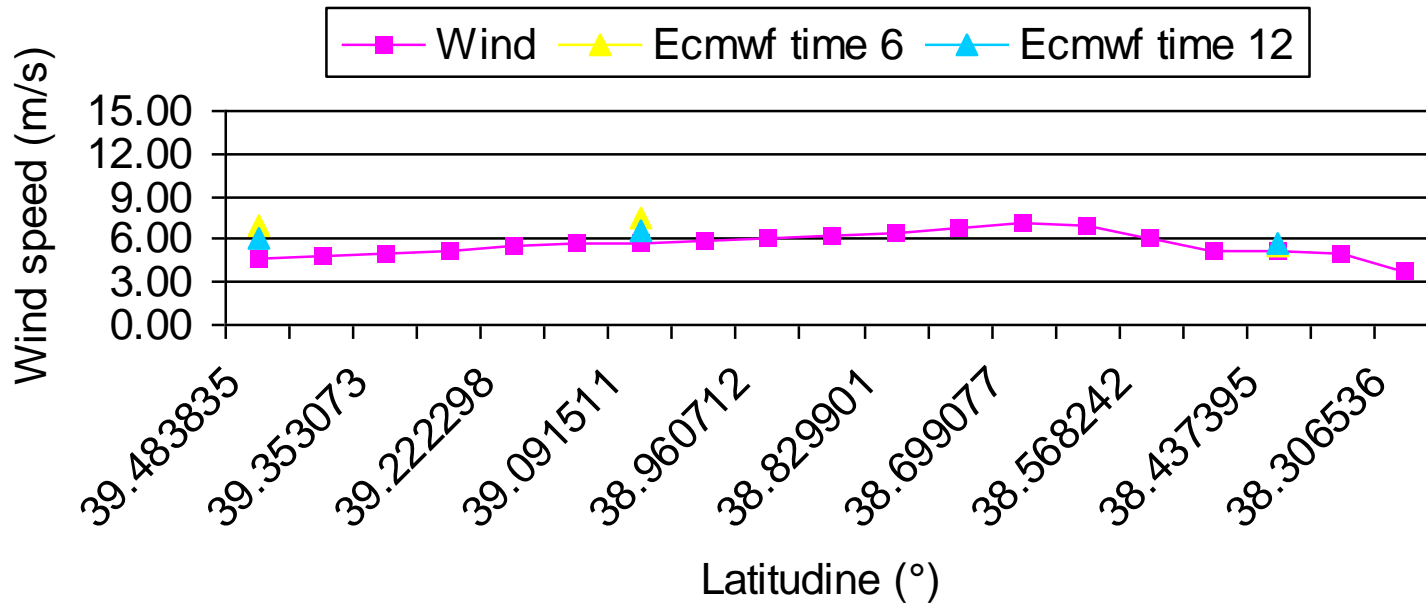


● Boa di Cetraro

E2) ENVISAT1 Discendente  
23/03/08 time 09:36 N1p0158C067



**WIND –**  
ENVISAT (09:36) 23/03/2008  
versus ECMWF (06:00, 12.00)

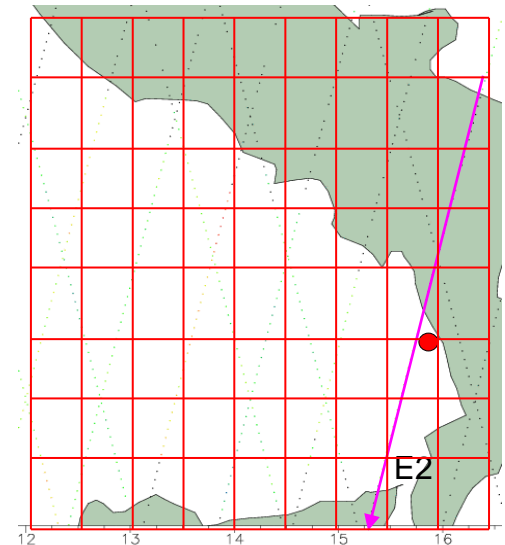


E2) ENVISAT1 Discendente

23/03/08 time 09:36 N1p0158C067

It is worth while using altimeter data to cross check model results  
*but there is more...*

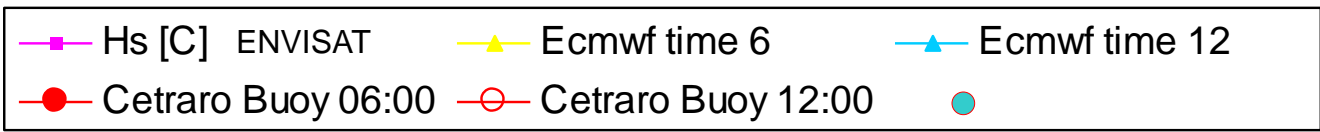
● Cetraro Buoy



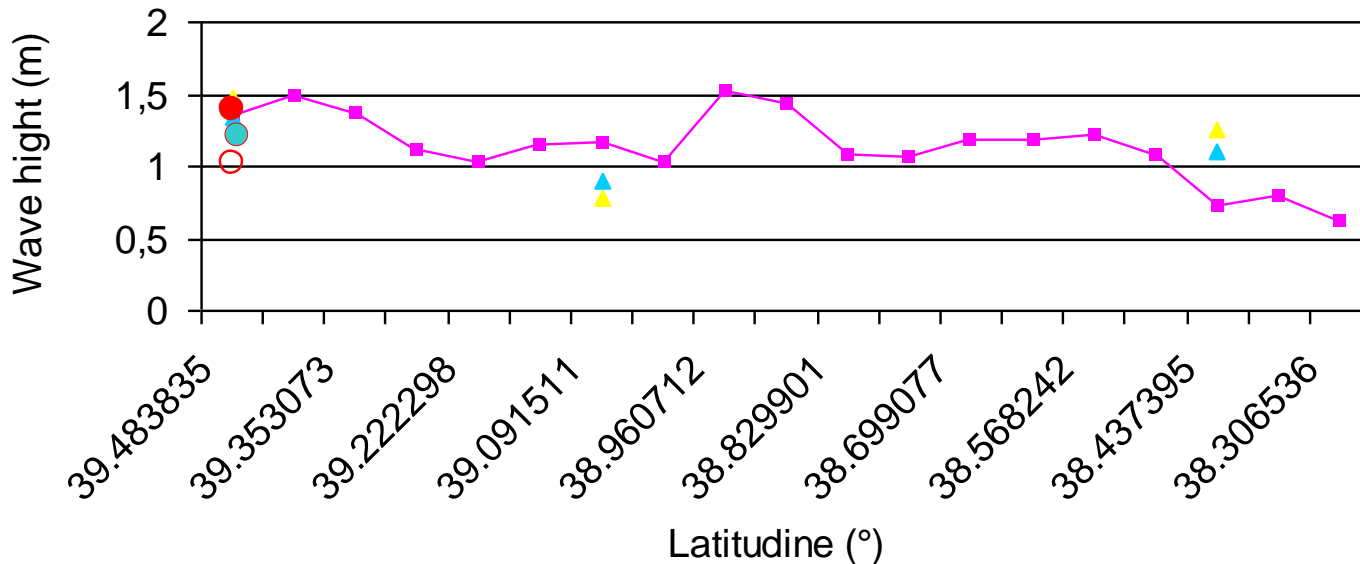
### WAVES

ENVISAT (09:36) 23/03/2008

versus ECMWF (06:00,12.00), and buoy ( 06:00,09:00,12:00)



Waves  
Co-located in space  
(not time)



Most of the time wave buoys confirm altimeter data

It is worth while using altimeter  
data to cross check model results

often altimeter data differ from model data

It is often worth while refining global (or even regional) model results with  
Local models (... better interpolation)



***but there is more to say about sub-grid scale...***



E2) ENVISAT1 Discendente

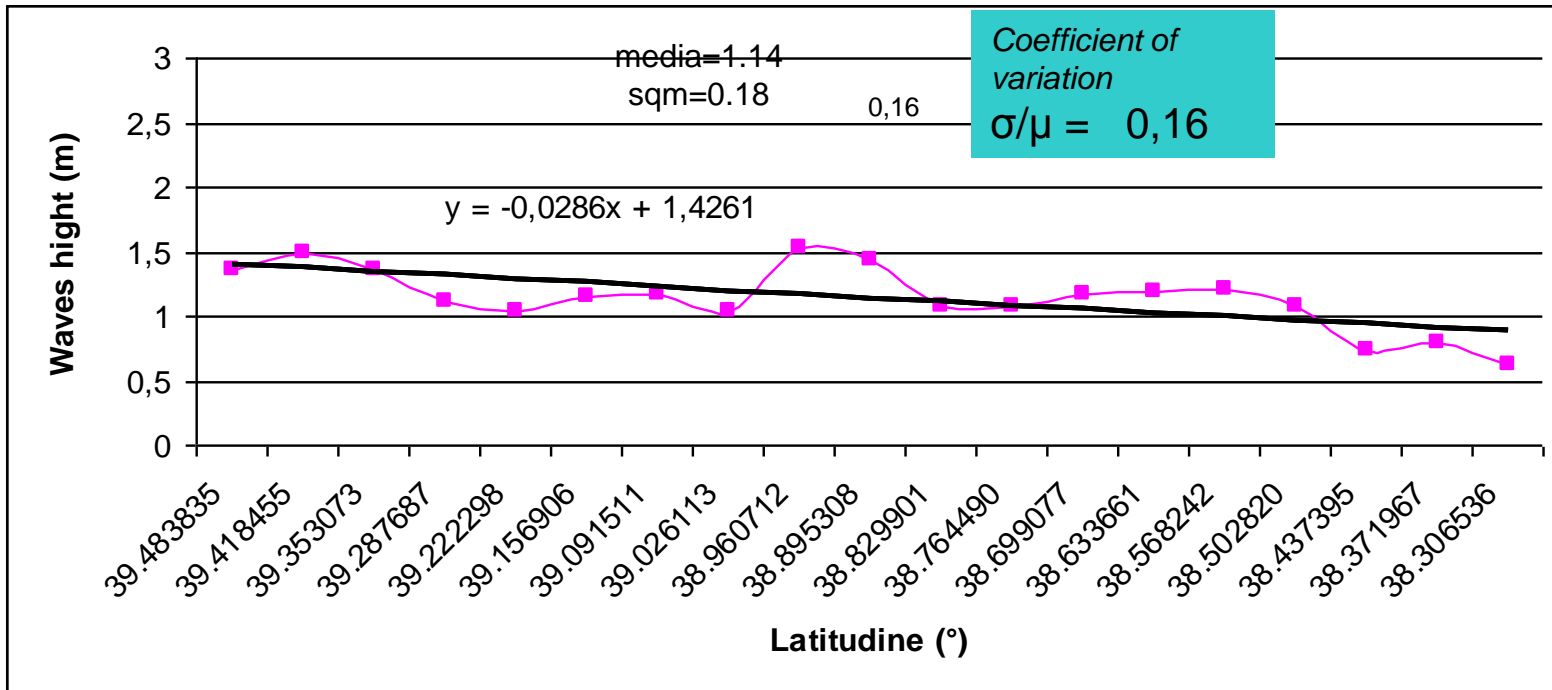
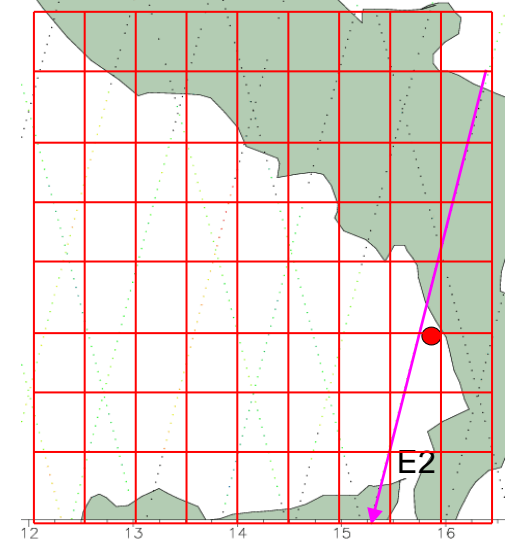
23/03/08 time 09:36 N1p0158C067

● Cetraro Buoy

# WAVES

ENVISAT (09:36) 23/03/2008

Gustyness?  
!?



E2) ENVISAT1 Discendente  
23/03/08 time 09:36 N1p0158C067



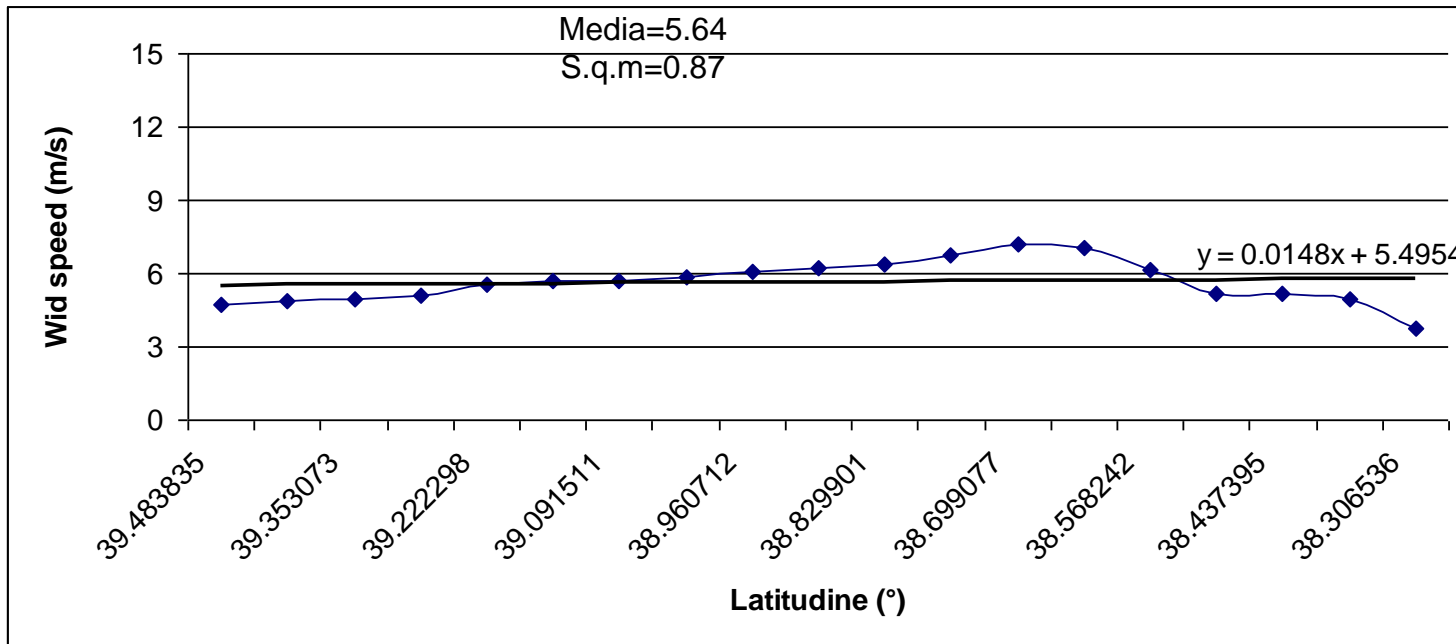
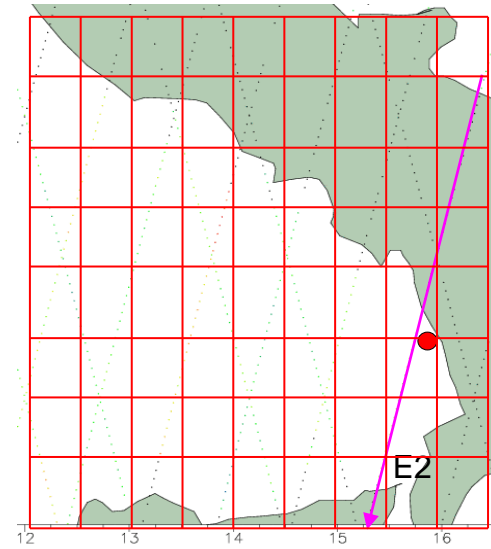
● Cetraro Buoy

# Wind ENVISAT (09:36) 23/03/2008

Wind  
Gustyness?  
!?



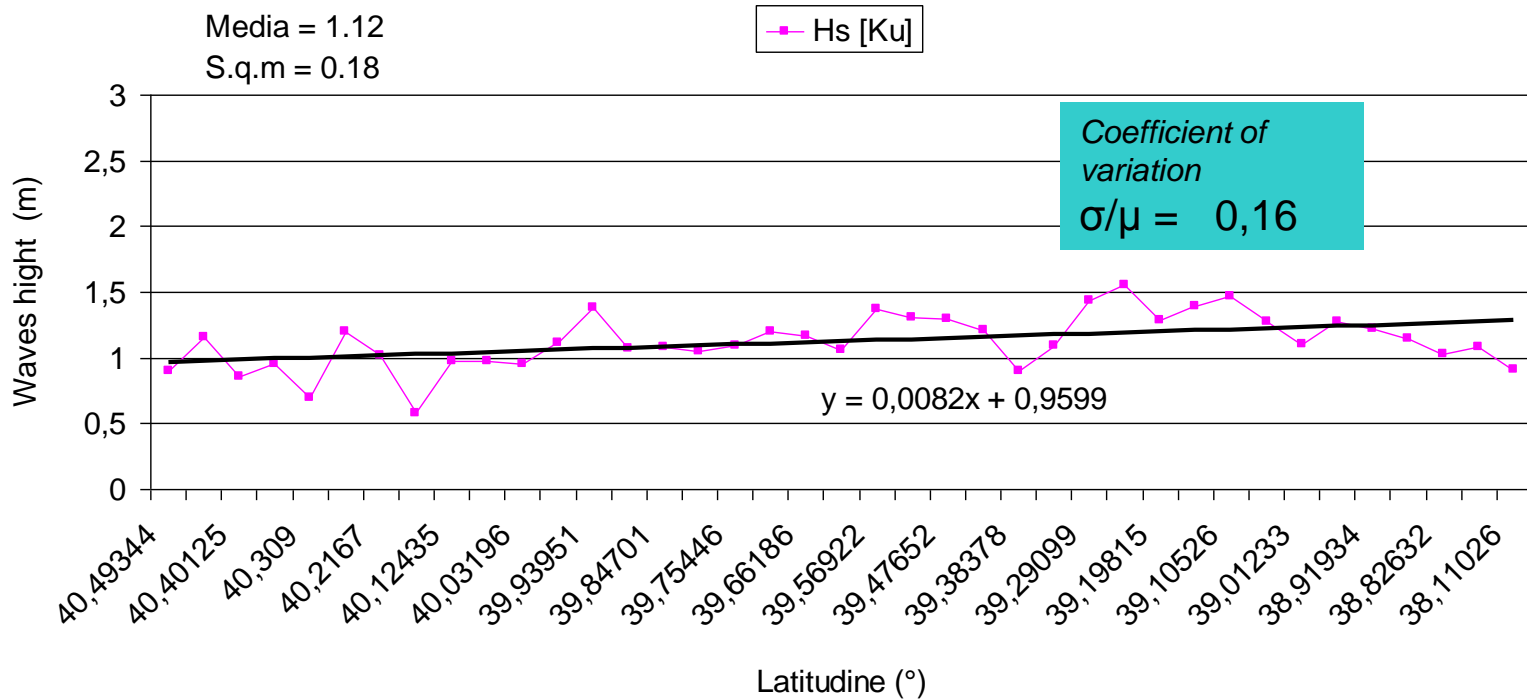
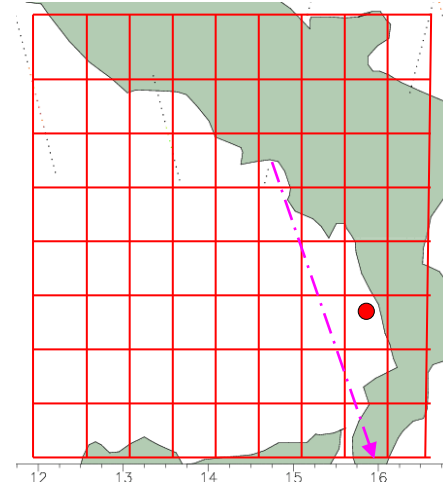
Coefficient of  
variation  
 $\sigma/\mu = 0,15$



● Cetraro Buoy

# Waves JASON 1-fase A

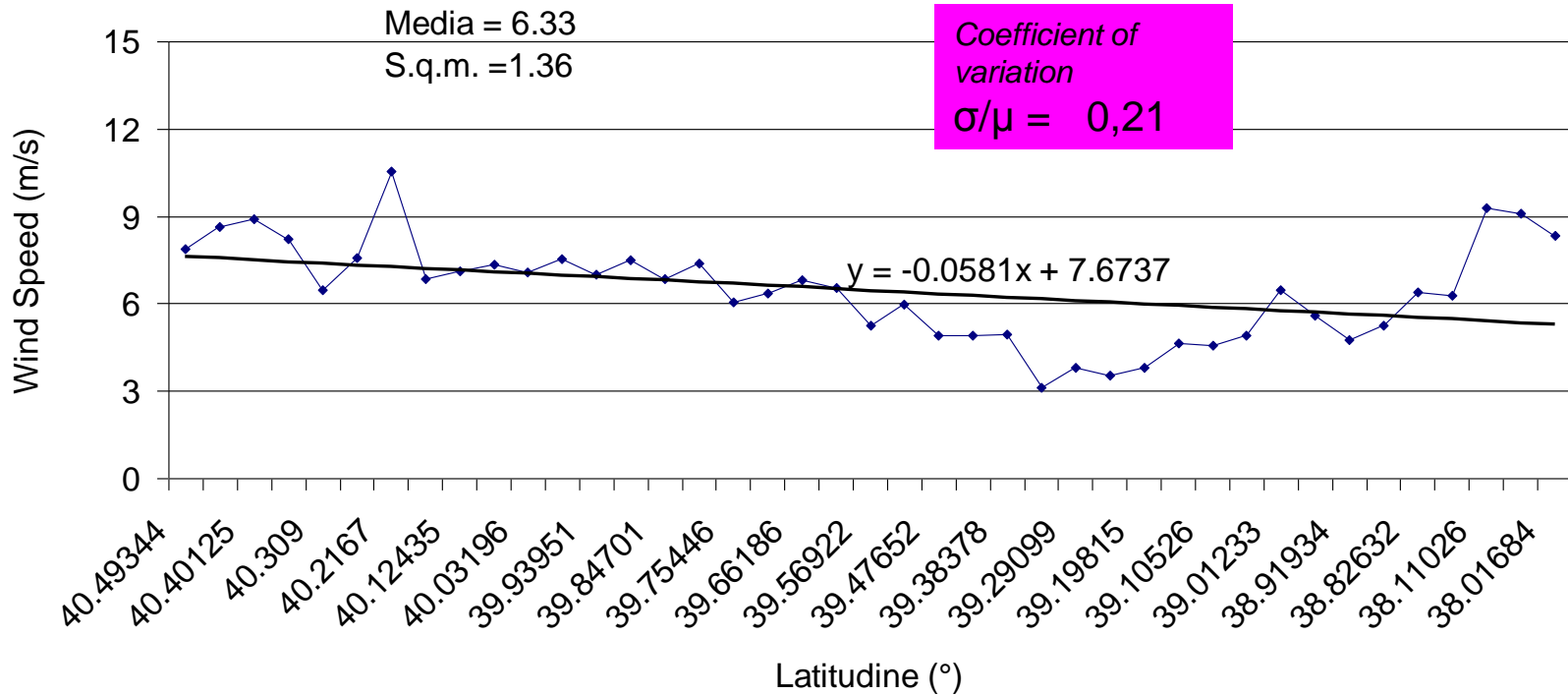
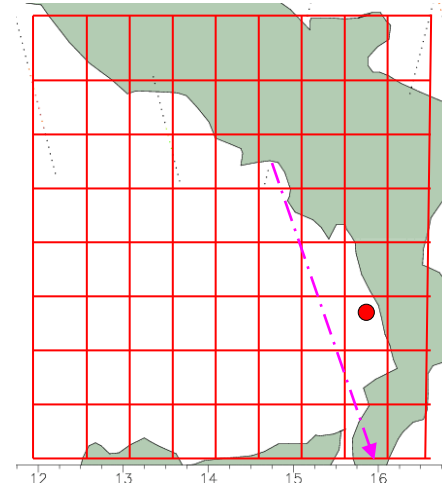
J2 p0120c229 (29/03/08 – time 15:33)



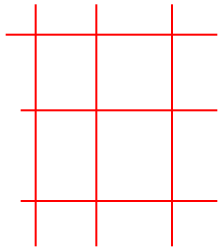
● Cetraro Buoy

# Wind JASON 1-fase A

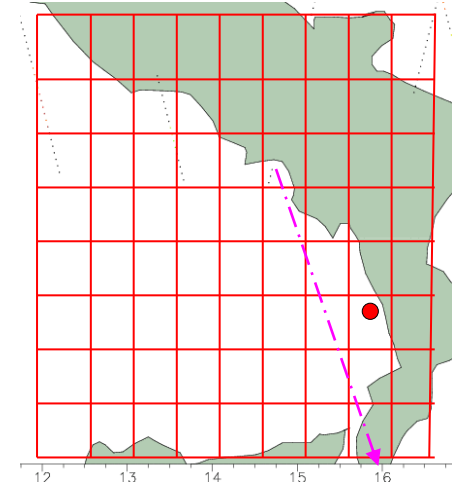
J2 p0120c229 (29/03/08 – time 15:33)



● Cetraro Buoy      No buoy data

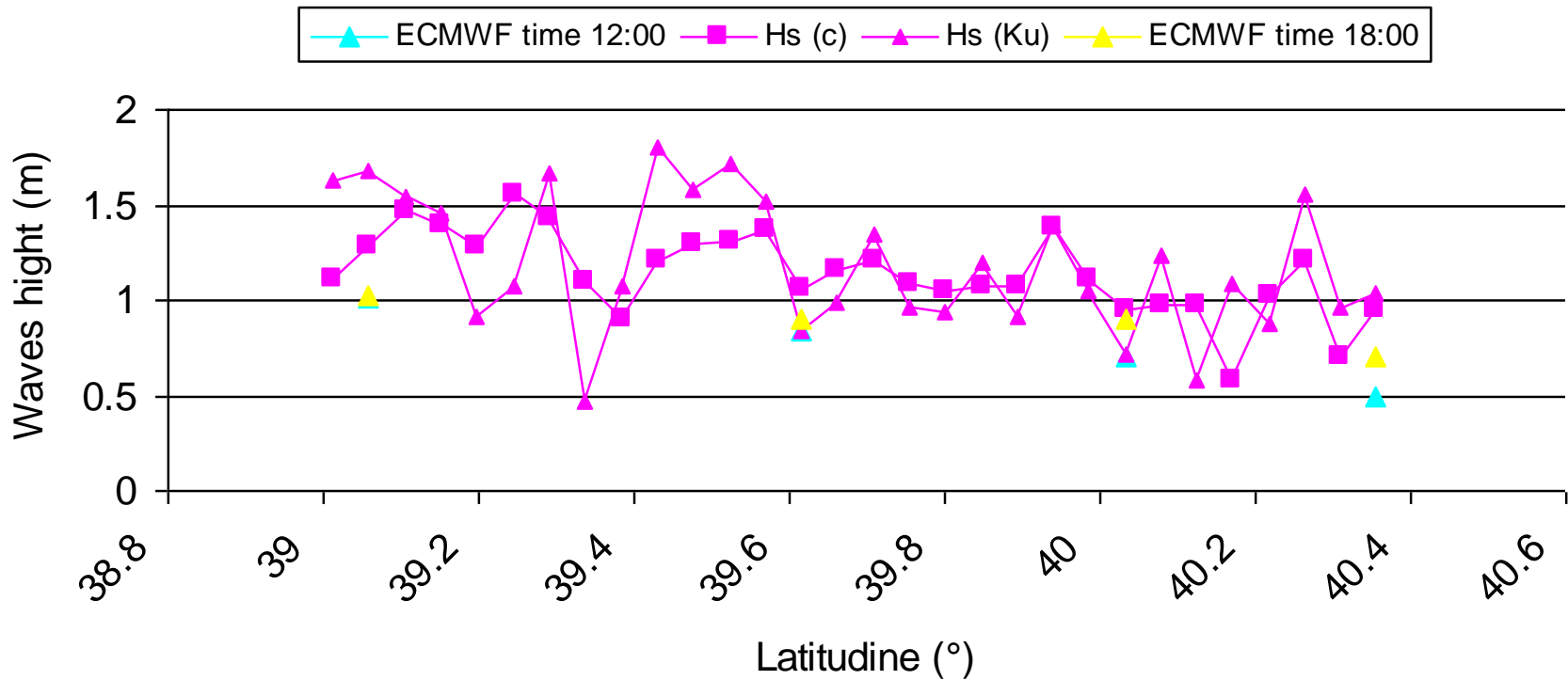


ECMWF grid  
0.5° x 0.5°



# Waves JASON 1-fase A

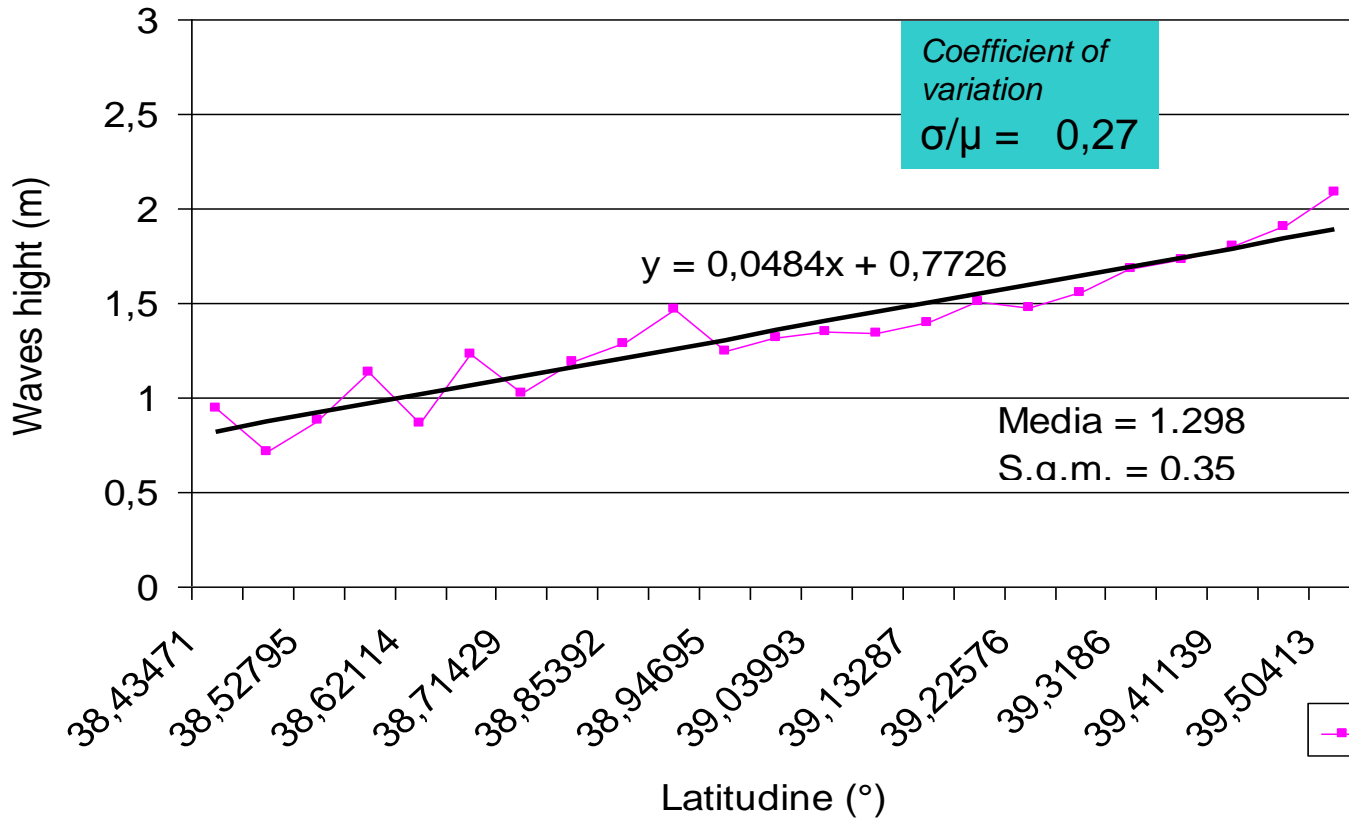
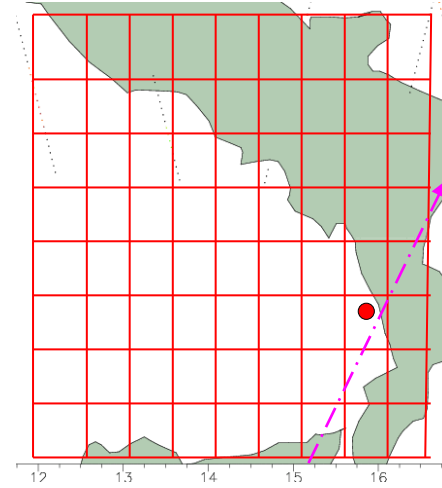
J2 p0120c229 (29/03/08 – time 15:33)



● Cetraro Buoy

## WAVES JASON 1-fase A

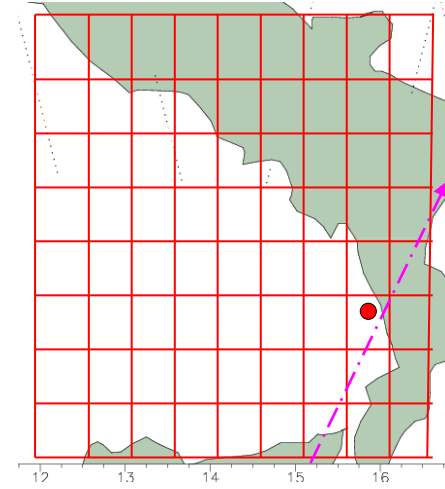
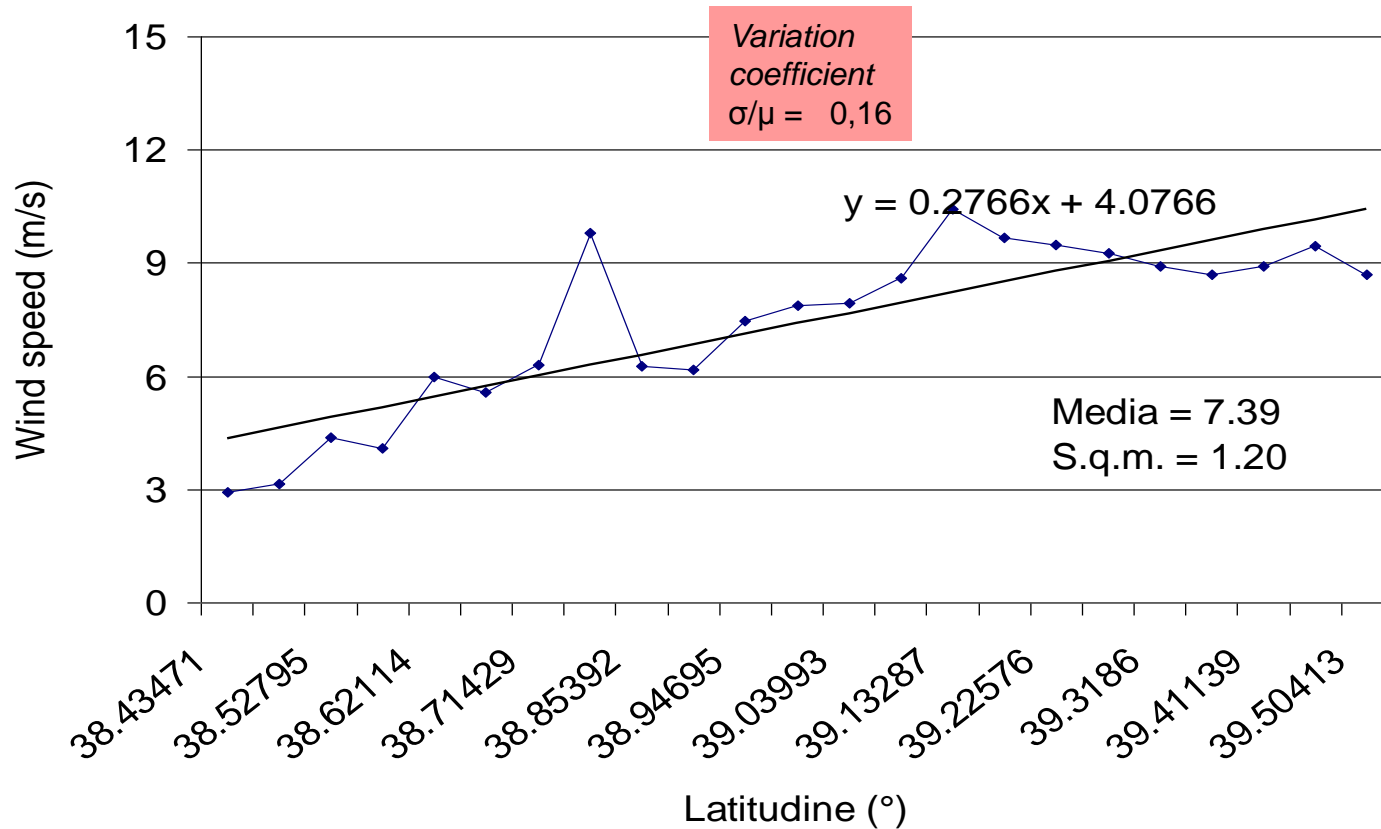
J3 p0059c229 (27/03/08 – time 06:23)



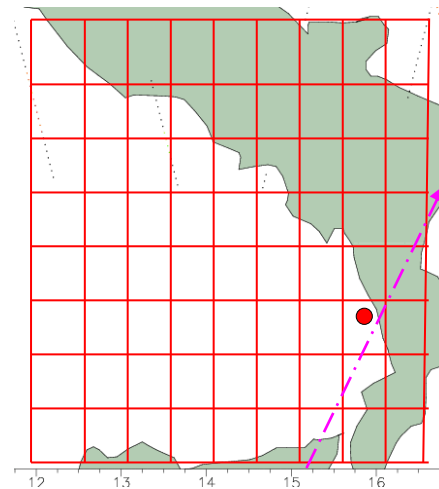
● Cetraro Buoy

## WIND JASON 1-fase A

J3 p0059c229 (27/03/08 – time 06:23)

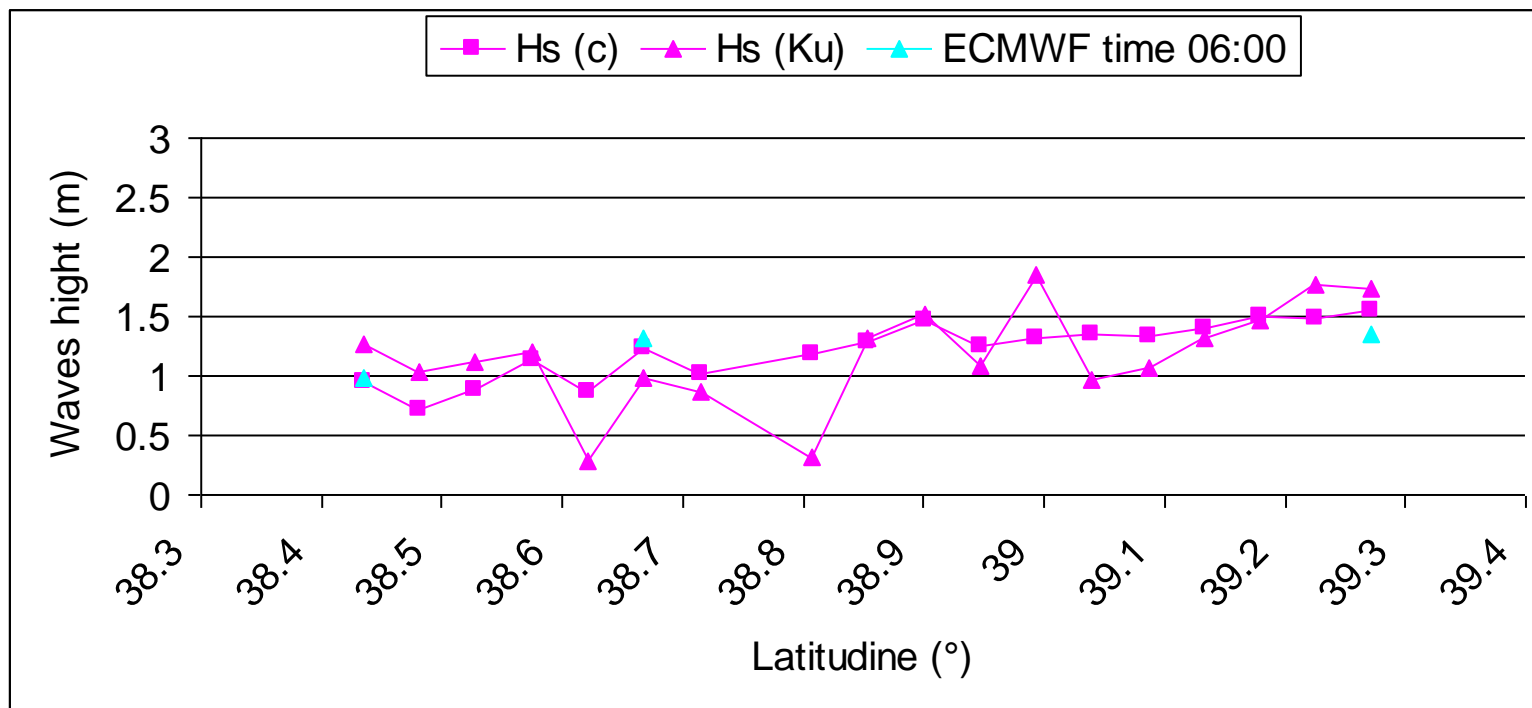


● Cetraro Buoy (No buoy data)



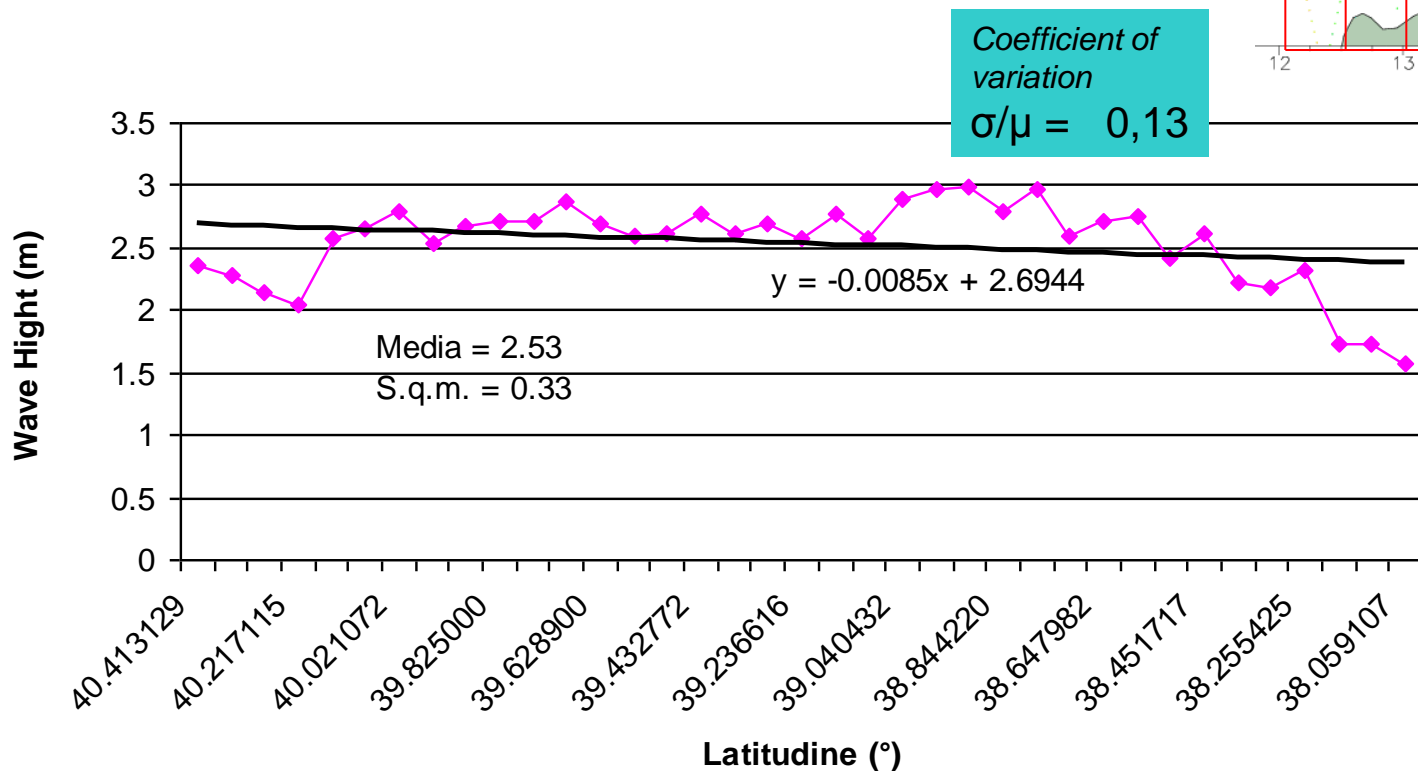
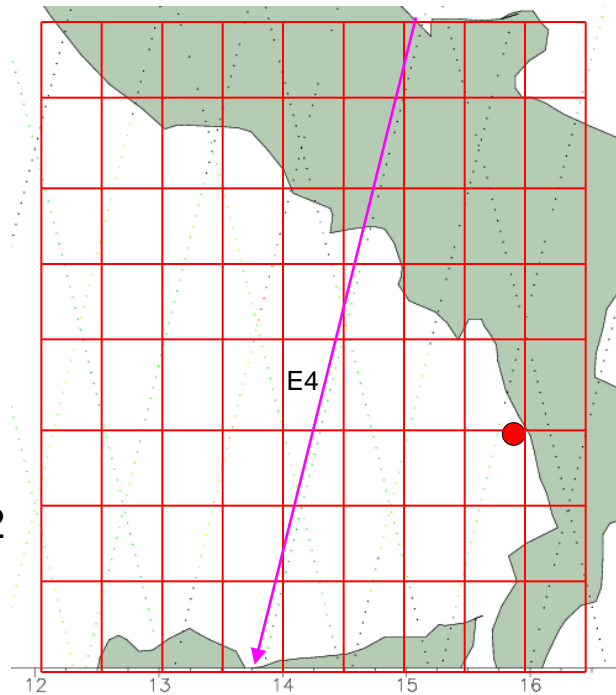
## WAVES JASON 1-fase A

J3 p0059c229 (27/03/08 – time 06:23)

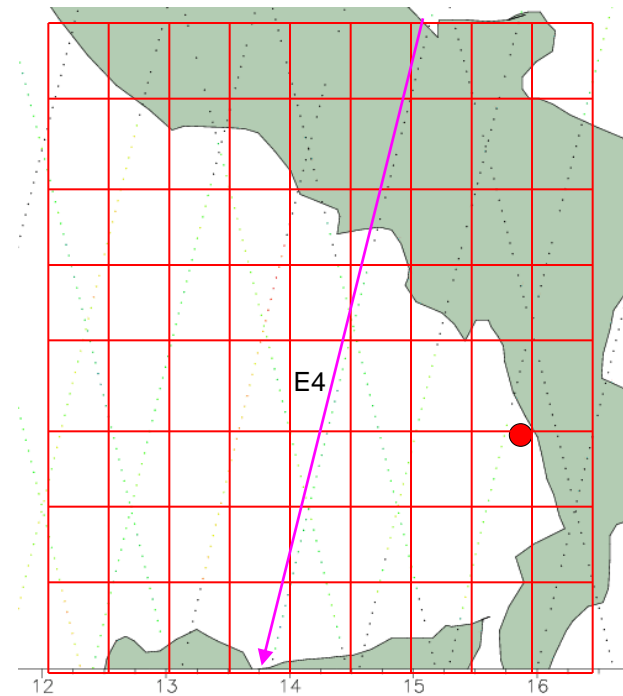
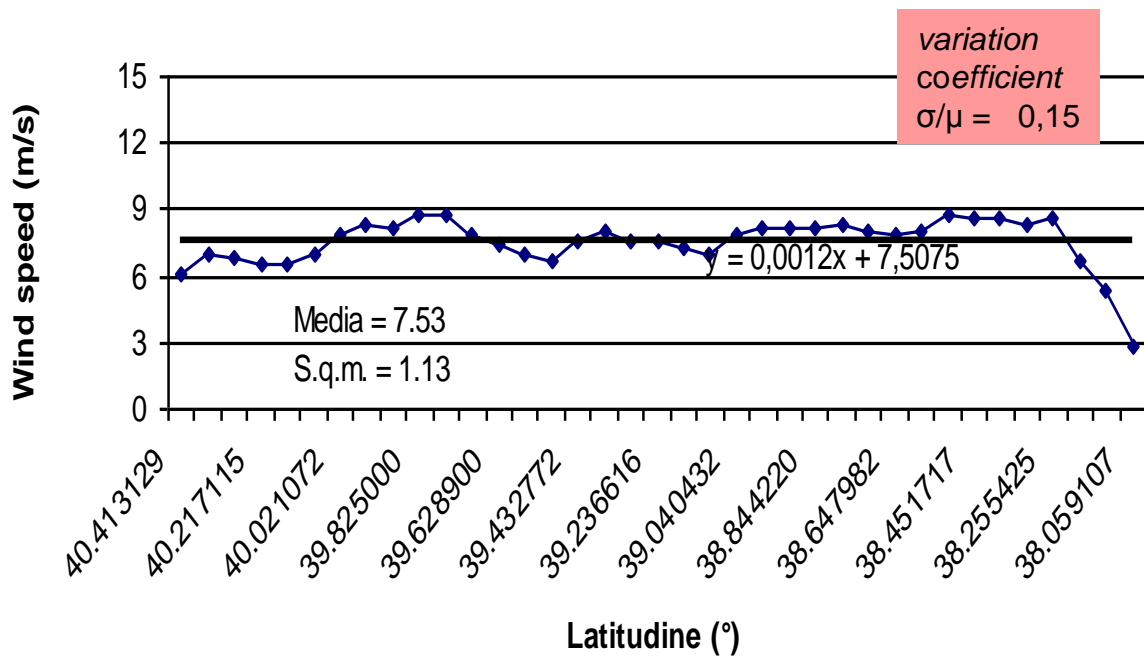




# WAVES ENVISAT1 Discendente 26/03/08 ore 09:42



# WIND ENVISAT1 Discendente 26/03/08 ore 09:42



**“Gustyness”  
Has been  
explored  
before**

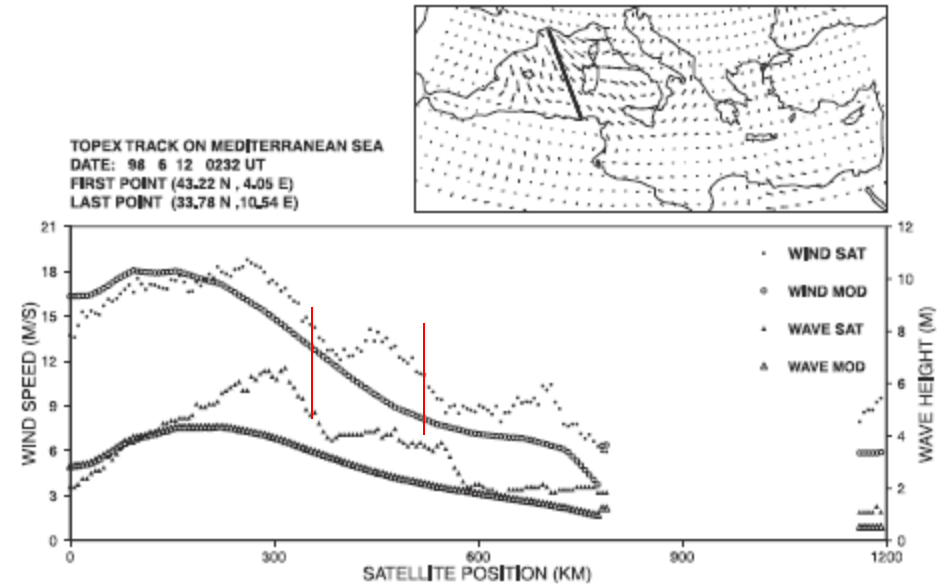


ABDALLA AND CAVALERI: GUSTINESS AND AIR DENSITY EFFECTS ON WAVES



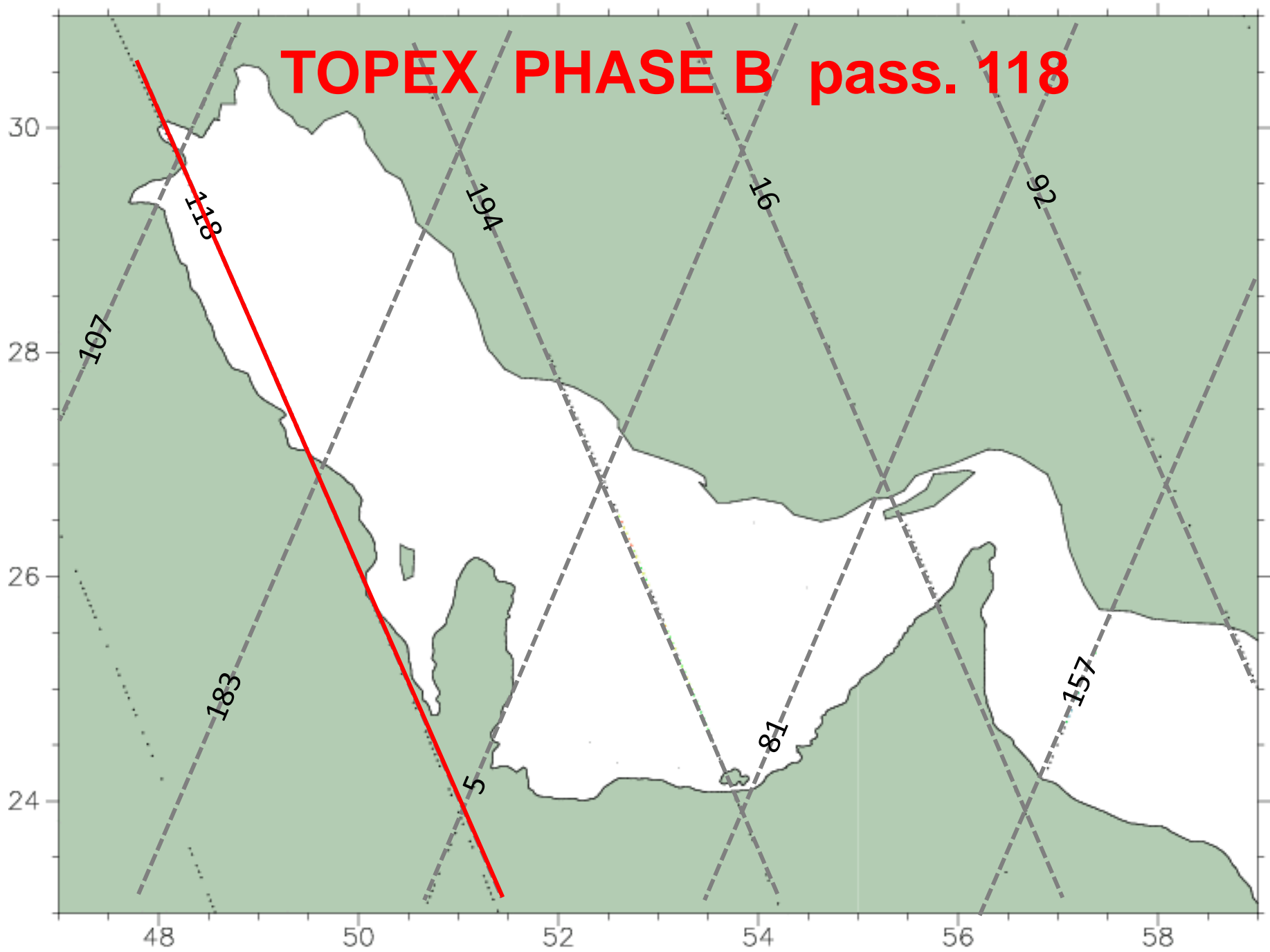
**On a larger  
scale**

**And then,  
Wind  
“smoother”  
than  
waves**



**Figure 1.** Comparison between model and TOPEX altimeter-measured wind speeds and significant wave heights during a Mistral storm in the western Mediterranean Sea. The thick line in the small map shows the satellite ground track.

# TOPEX PHASE B pass. 118





Al Kūwayt

Lat. 29.28 ; Long. 48.40

BOA (Lat.29.0 ; Long. 48.7)

**KISR**

**KISR**  
Kuwait Institute for Scientific Research

Khark Island

Golfo Persi

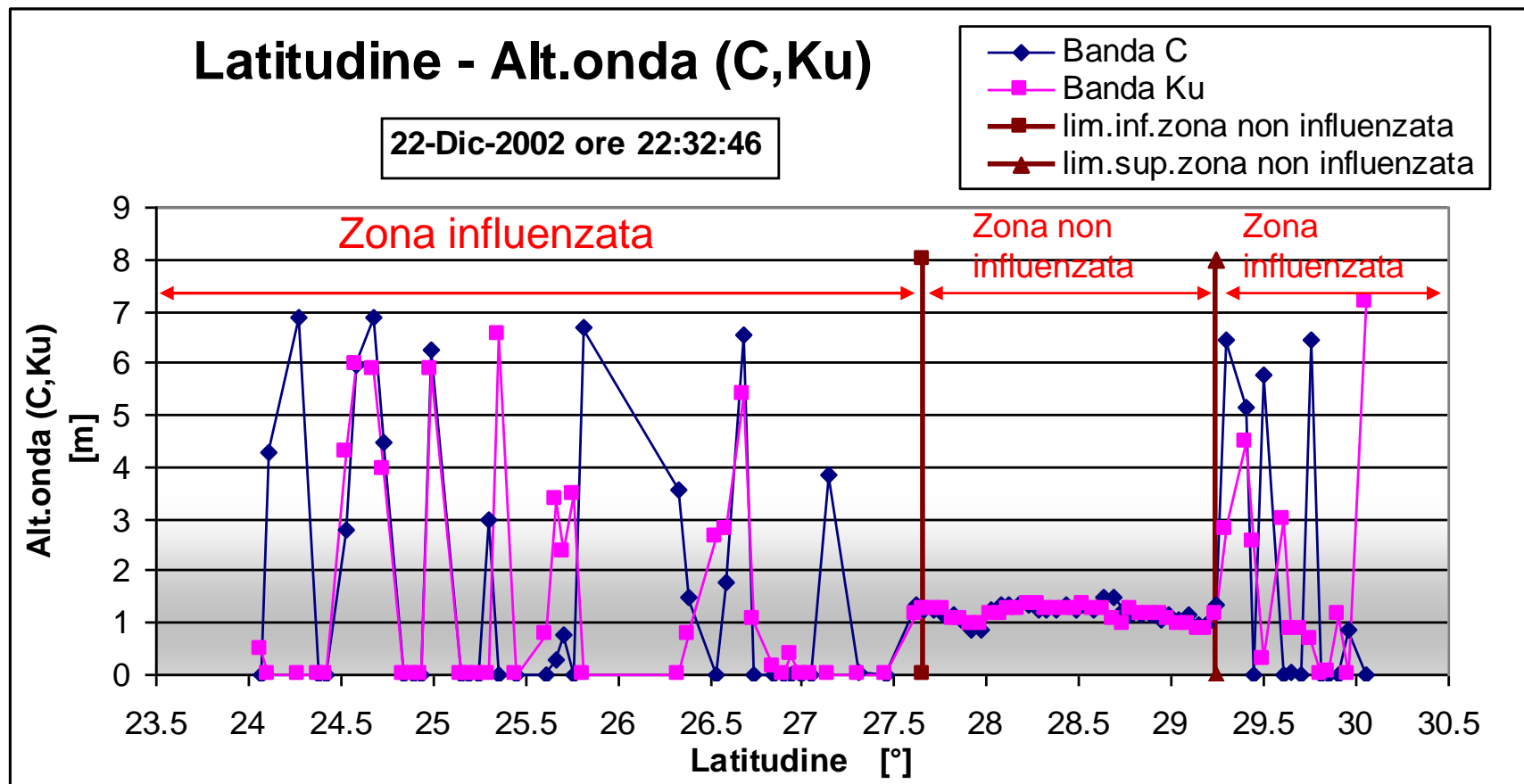
Lat. 27.64 ; Long. 49.23

Image © 2008 DigitalGlobe  
Image NASA  
© 2008 Europa Technologies  
Image © 2008 TerraMetrics  
Streaming 100%

©2007 G

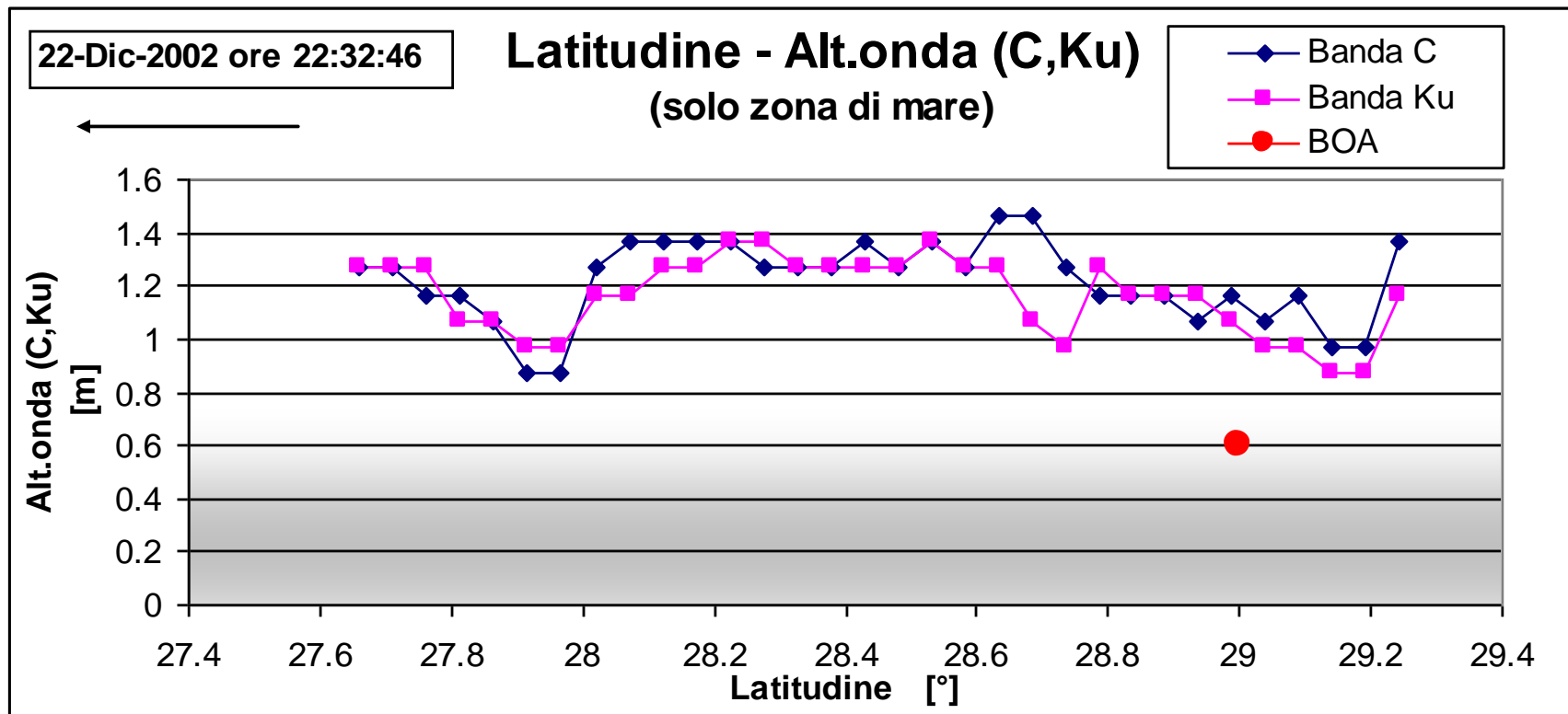
8°46'35.29" E elev 0 m

# Ciclo 378



# Ciclo 378

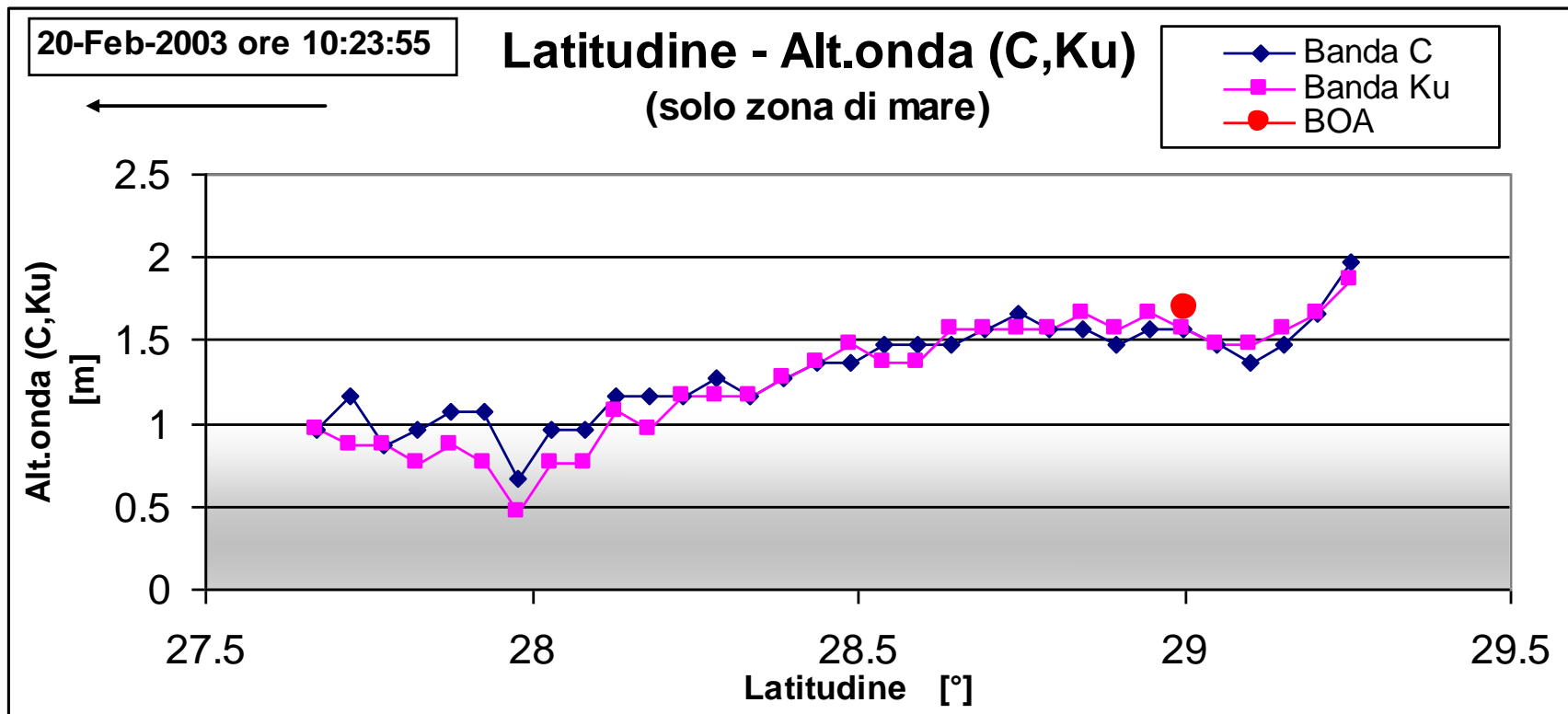
KISR Kuwait Institute for Scientific Research Wavemeter data



← *Passaggio discendente*

# Ciclo 384

Wavemeter data from  
KISR Kuwait Institute for Scientific Research

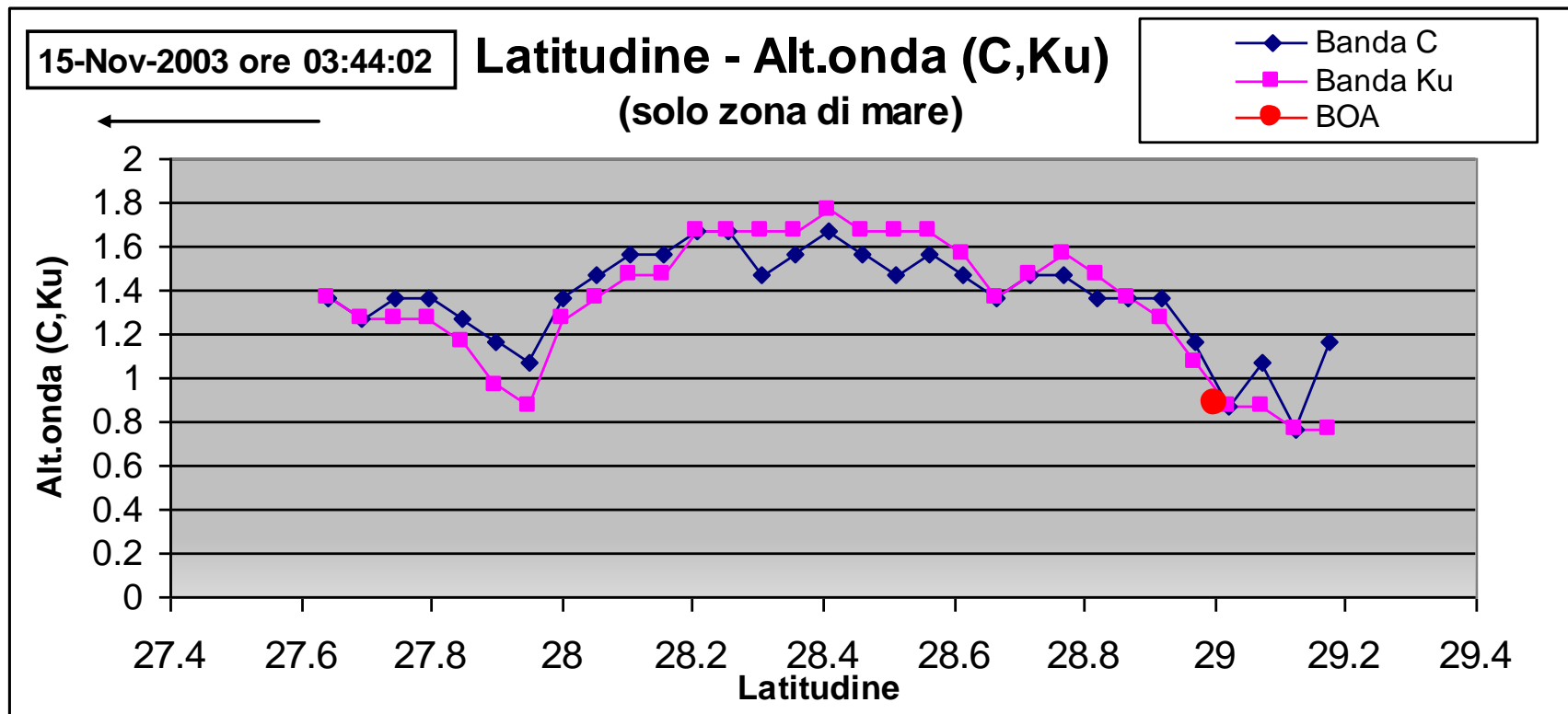


← Passaggio discendente



# Ciclo 411

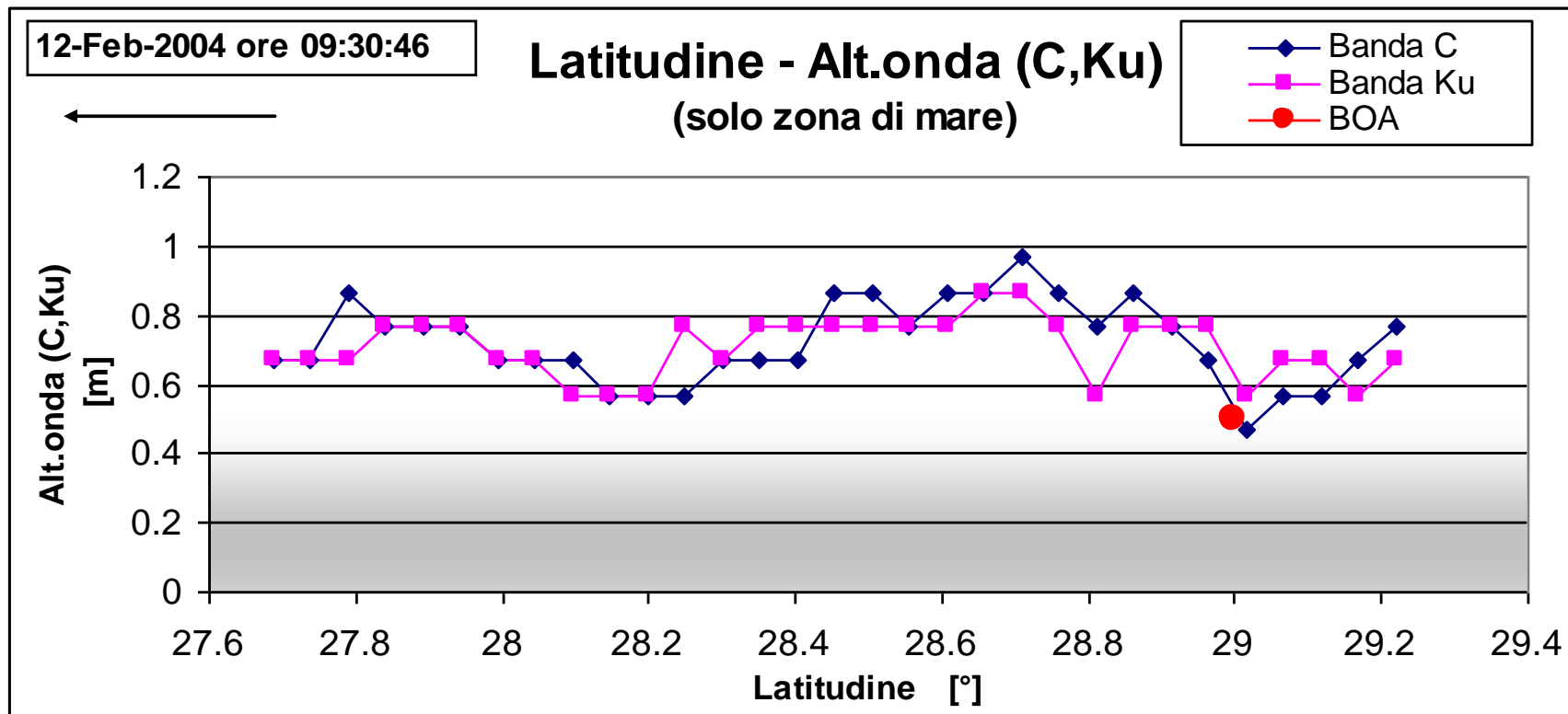
Wavemeter data from  
KISR Kuwait Institute for Scientific Research



← *Passaggio discendente*

# Ciclo 420

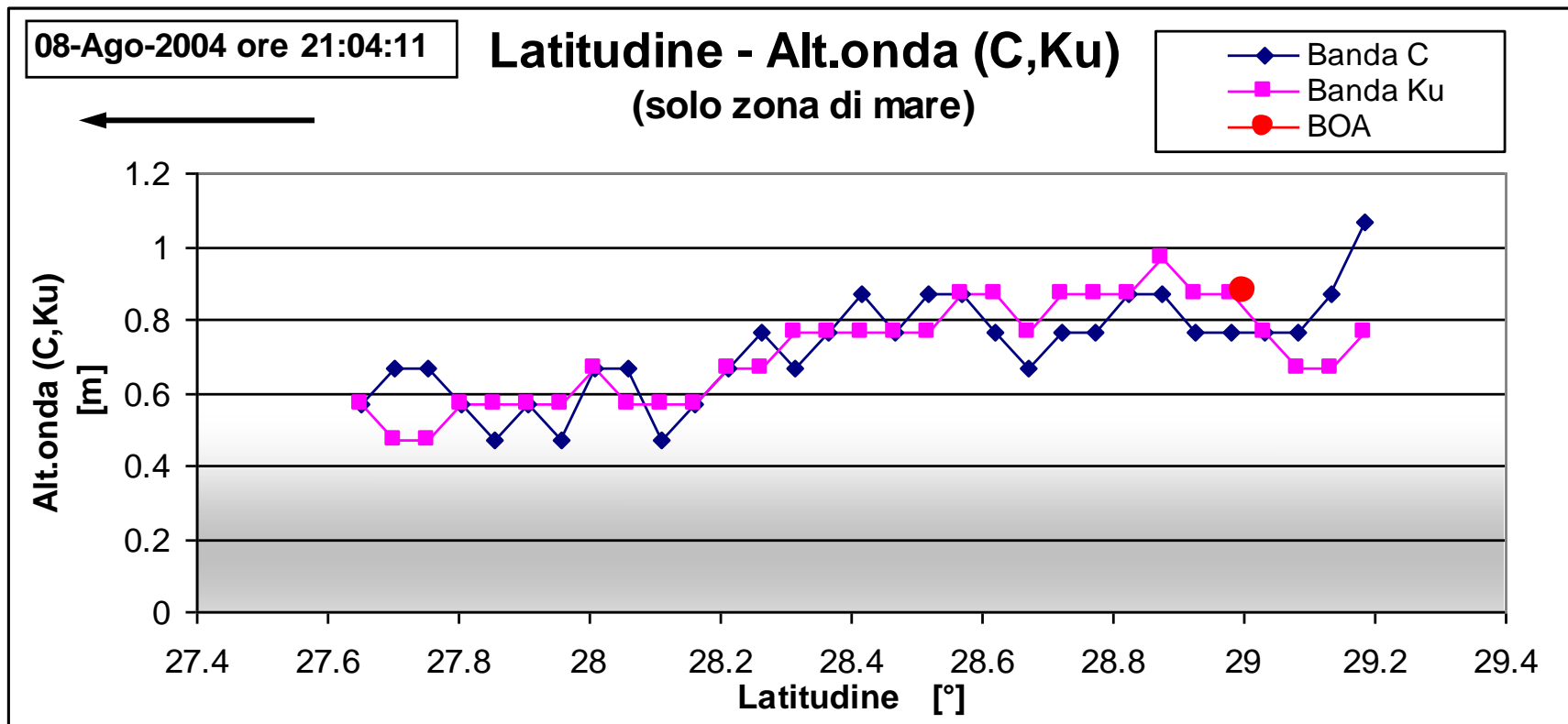
Wavemeter data from  
KISR Kuwait Institute for Scientific Research



← *Passaggio discendente*

# Ciclo 438

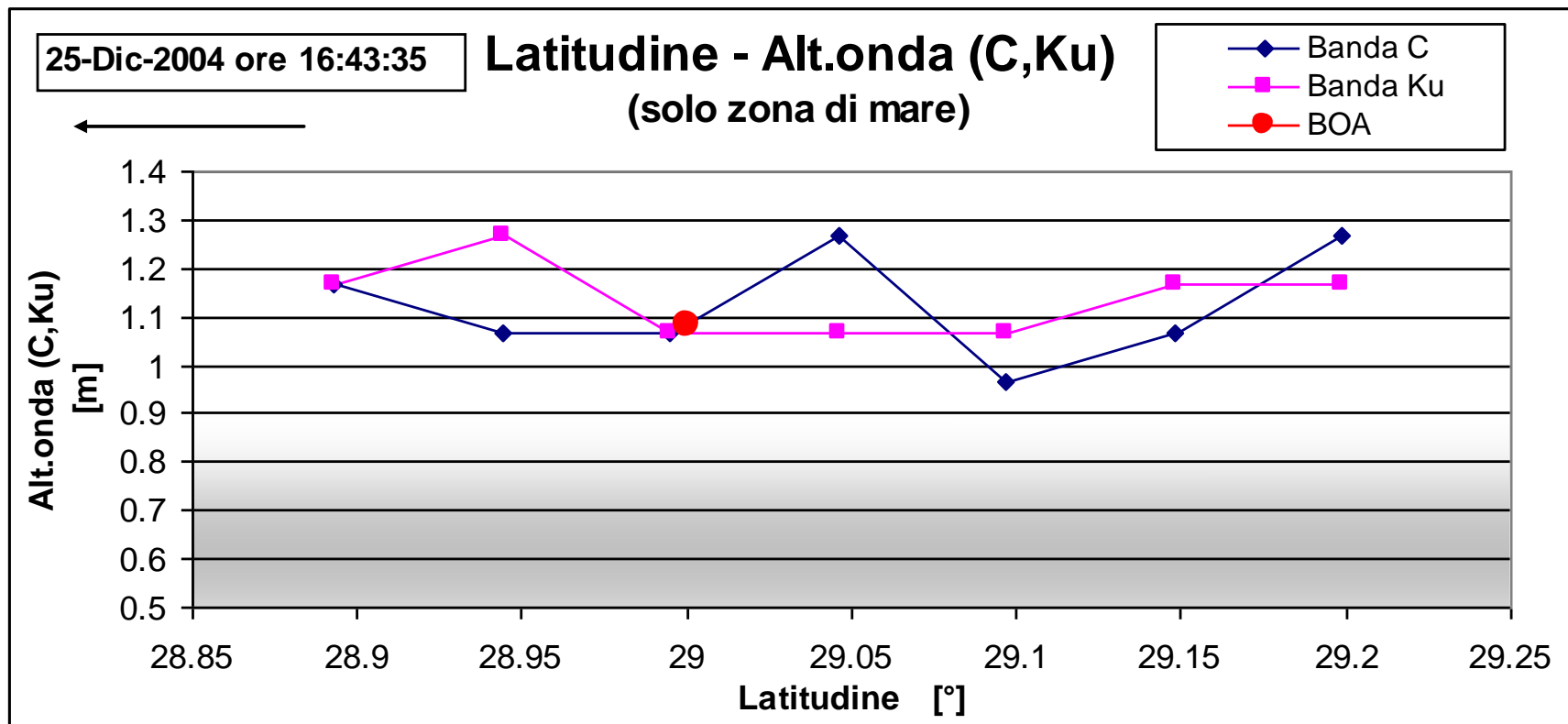
Wavemeter data from  
KISR Kuwait Institute for Scientific Research



← *Passaggio discendente*

# Ciclo 452

Wavemeter data from  
KISR Kuwait Institute for Scientific Research



← *Passaggio discendente*

\*Synthesized wave data must be taken with a pinch of salt, specially for extreme events

Altimeter data may provide a good check

\*\*It's worth while using smaller scale (Sub Global ECMWF) wave modelling, specially for near shore locations

\*\*\*Fluctuations ("Gustyness") as shown by altimeter data on the scale of a few miles might be more important than expected



## **ACKNOWLEDGEMENTS**

**Thank you for useful data and interesting discussion to**

KISR (K. Rakha)

APAT (S. Corsini, R. Inghilesi, S. Morucci)

Italian Air Force Meteo Office (R. Tajani)

ESA/ESRIN (J. Benveniste)

### **Altimeter data from**

Radar Altimeter Database System (RADS) <http://rads.tudelft.nl/rads/rads.shtml>

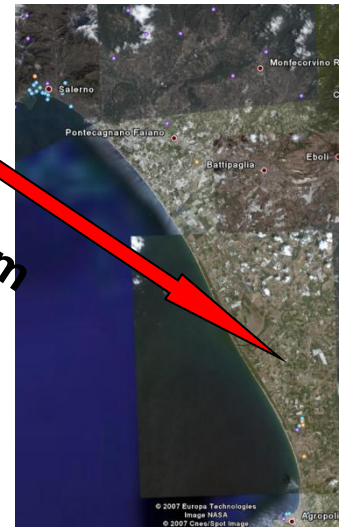
and through ESA/EO Project 1172 "Remote Sensing of Wave Transformation"

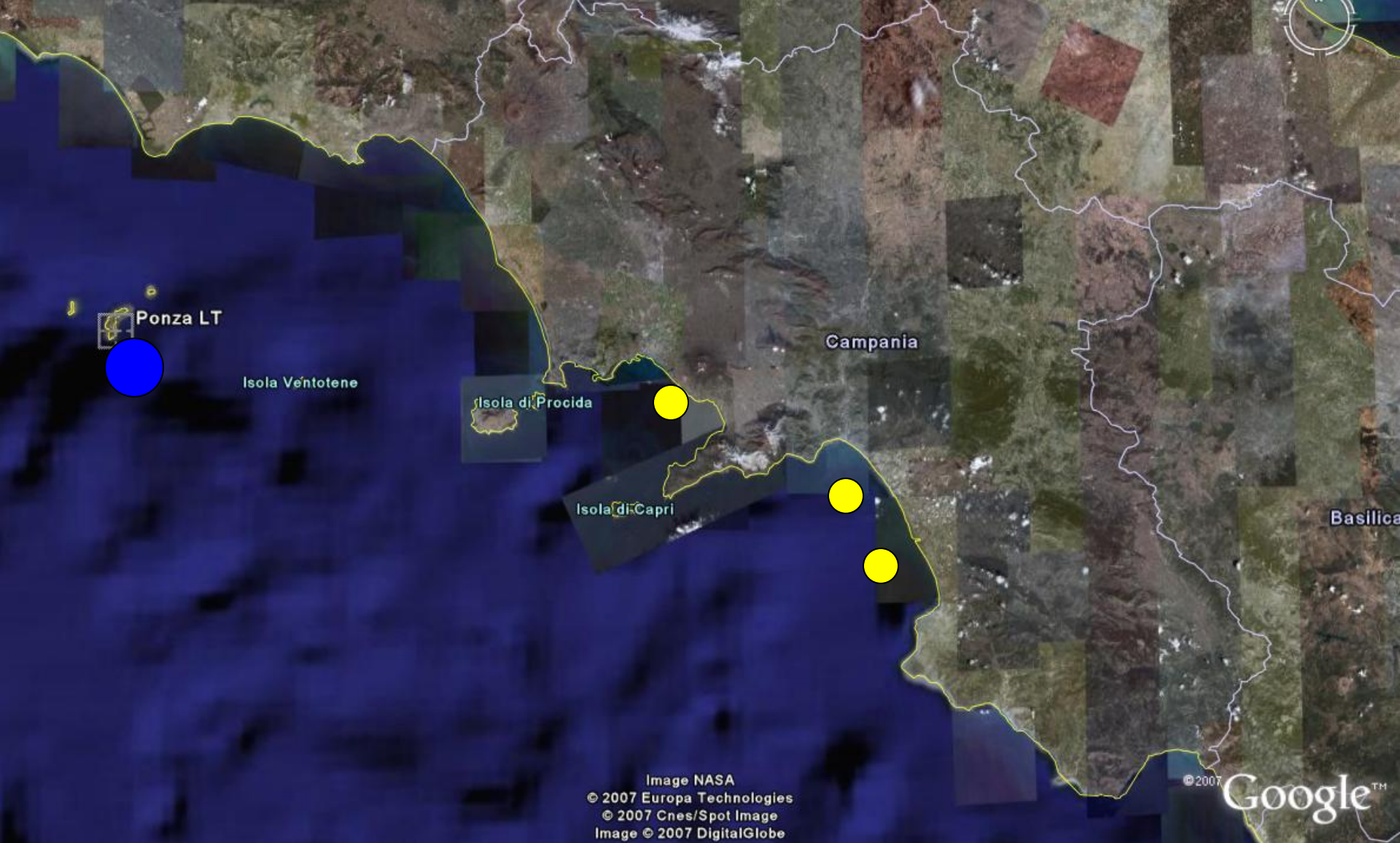


**The diver's tumb  
Paestum  
(ca. 480-470 BC)**



**Paestum**

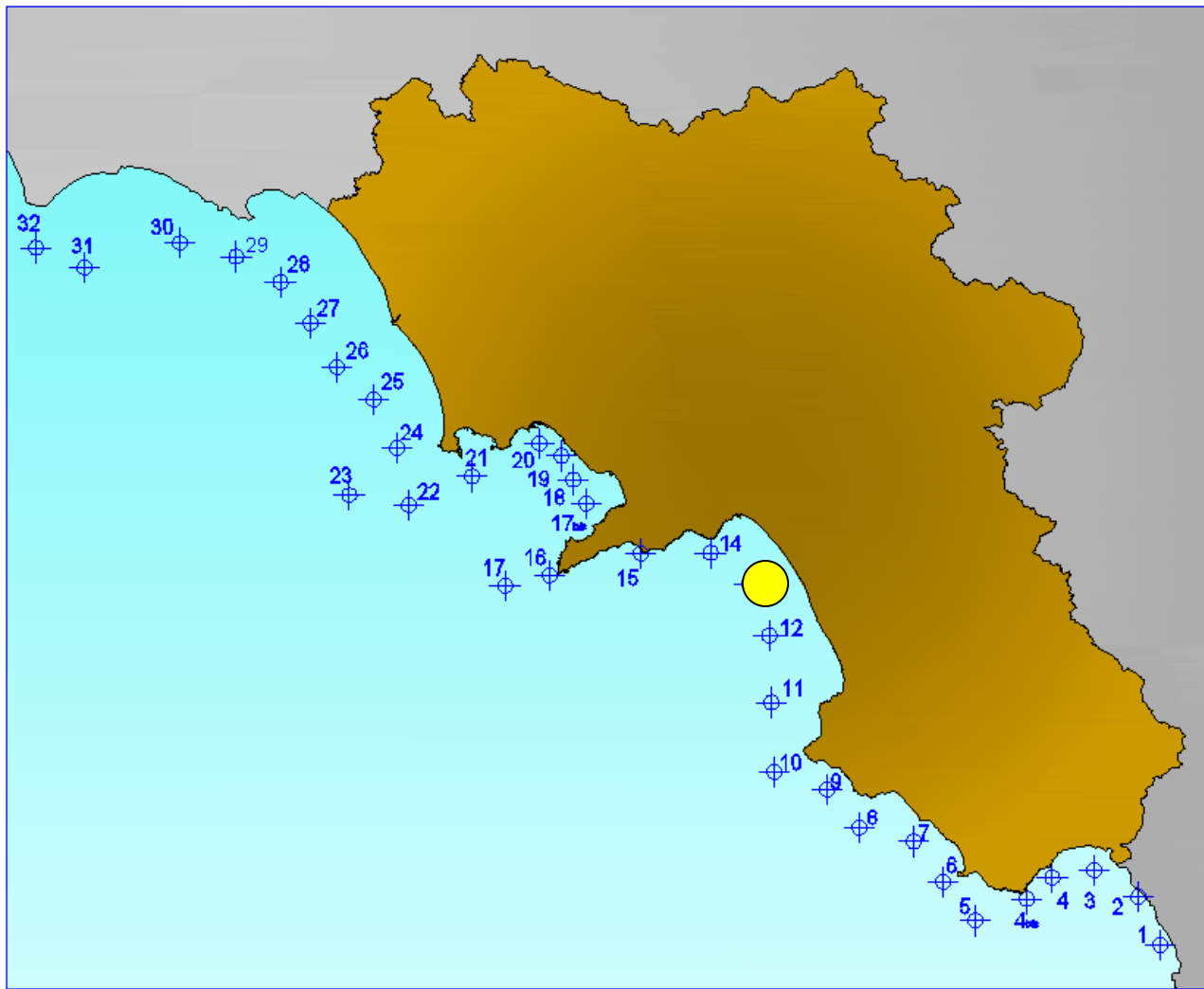




“Sentry” Wave meter



“Virtual” Wave meters

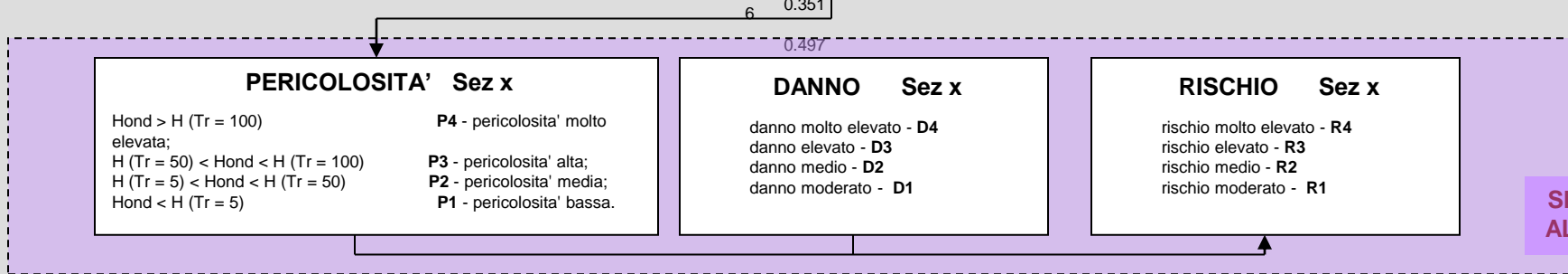
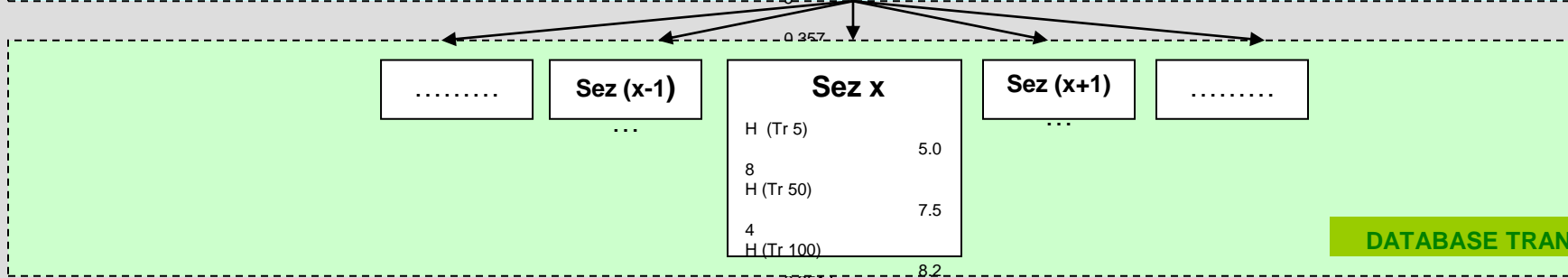
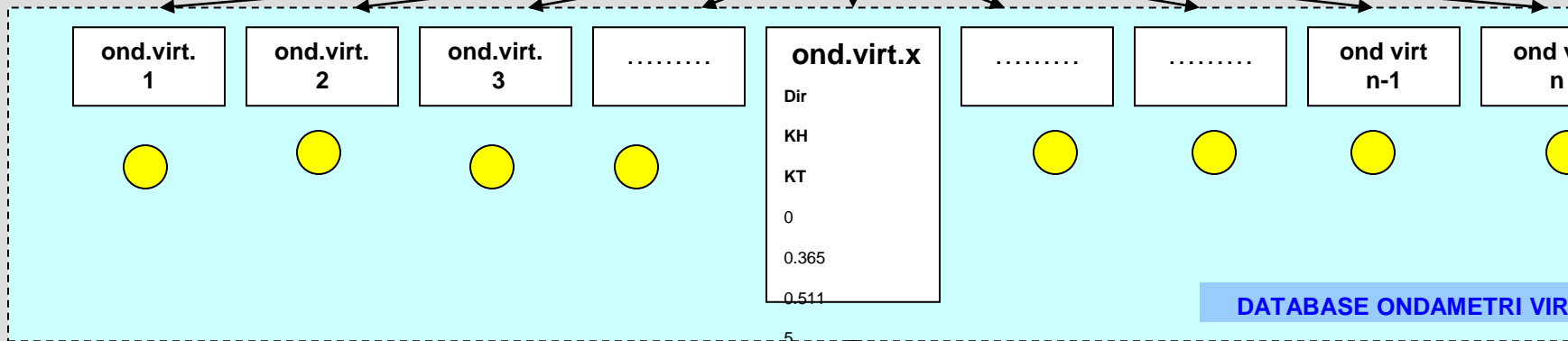


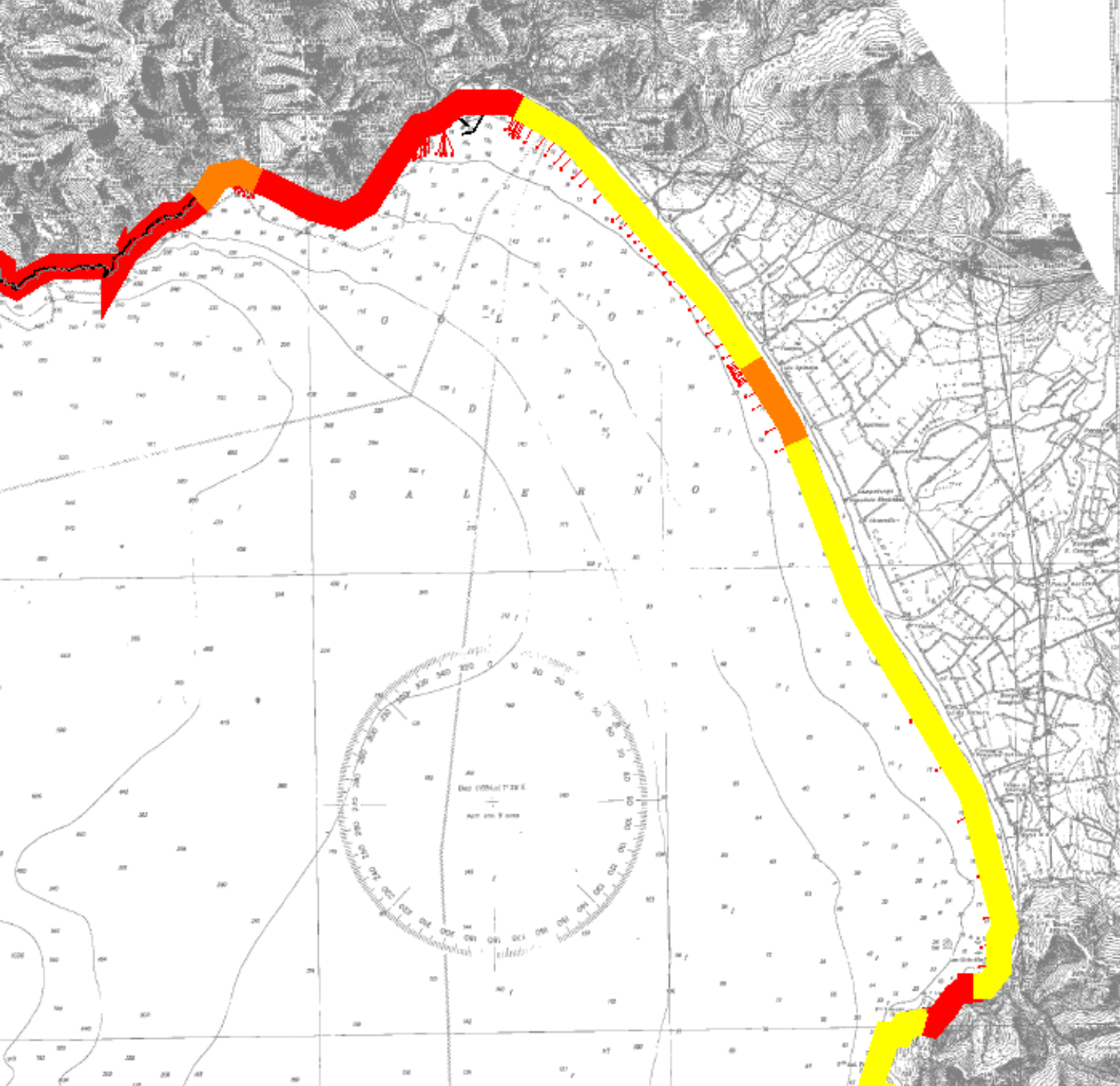


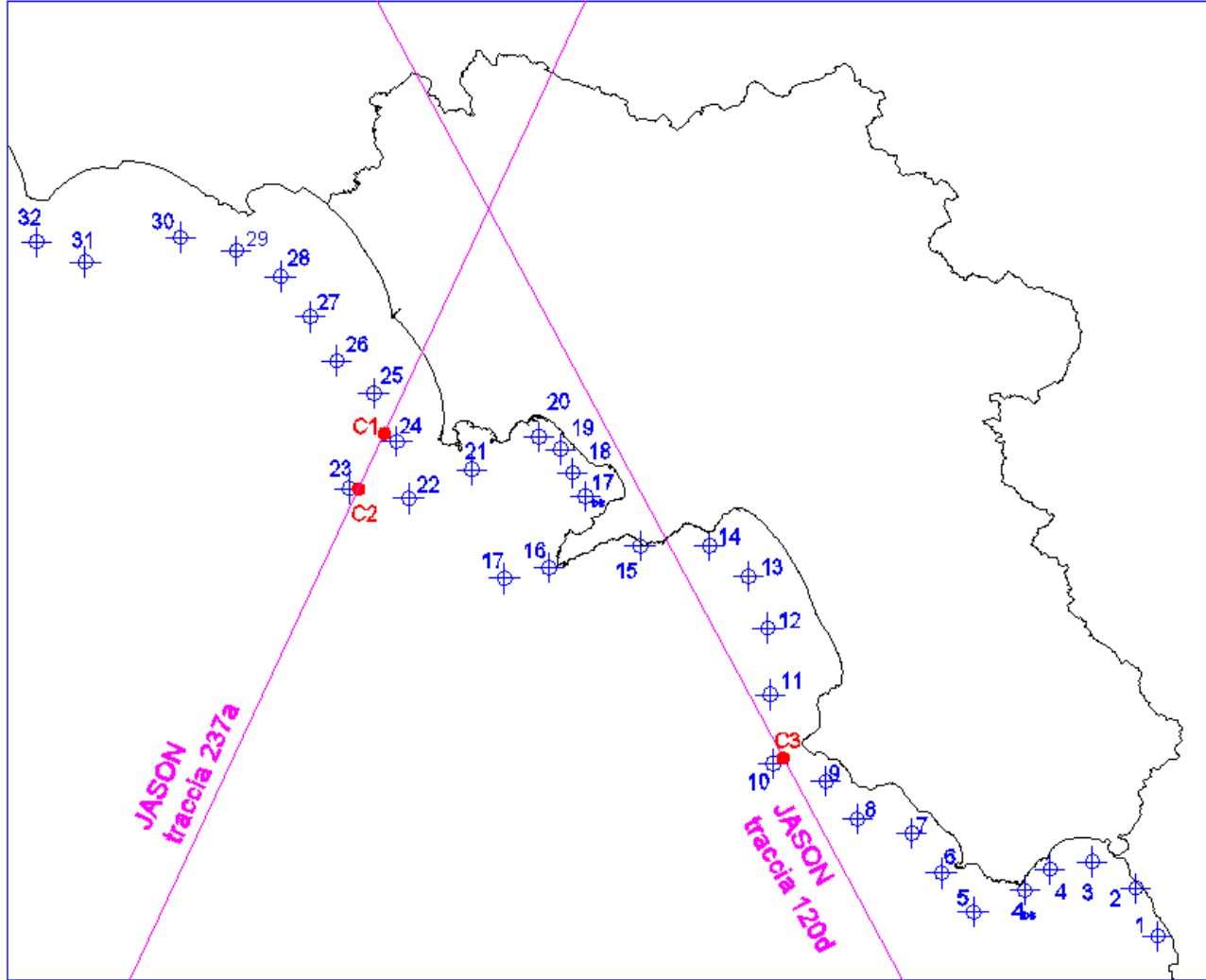


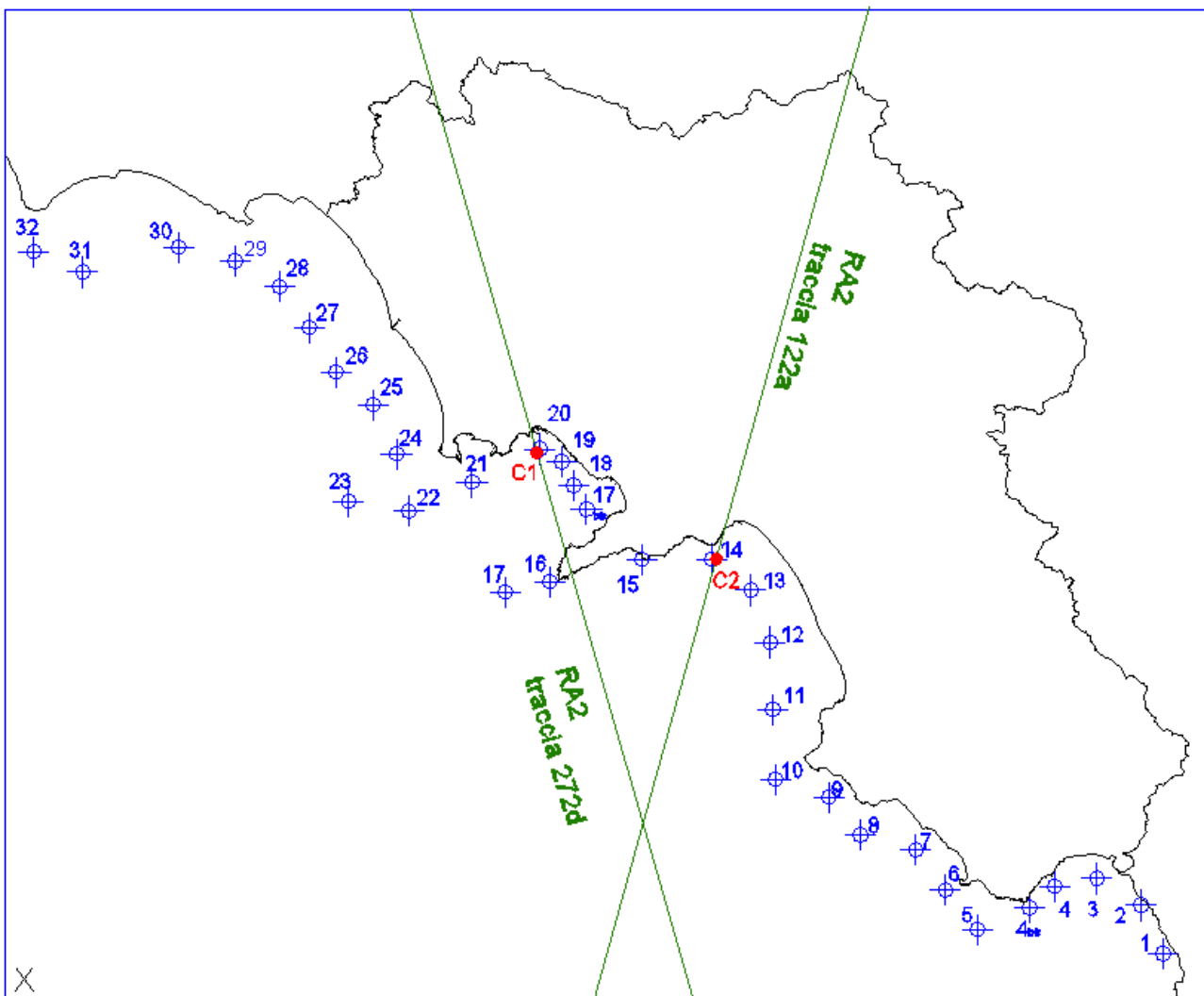
**ONDAMETRO PONZA-CETRARO**  
 Dati: H, T, dir

**TRASPOSIZIONE GEOGRAFICA**

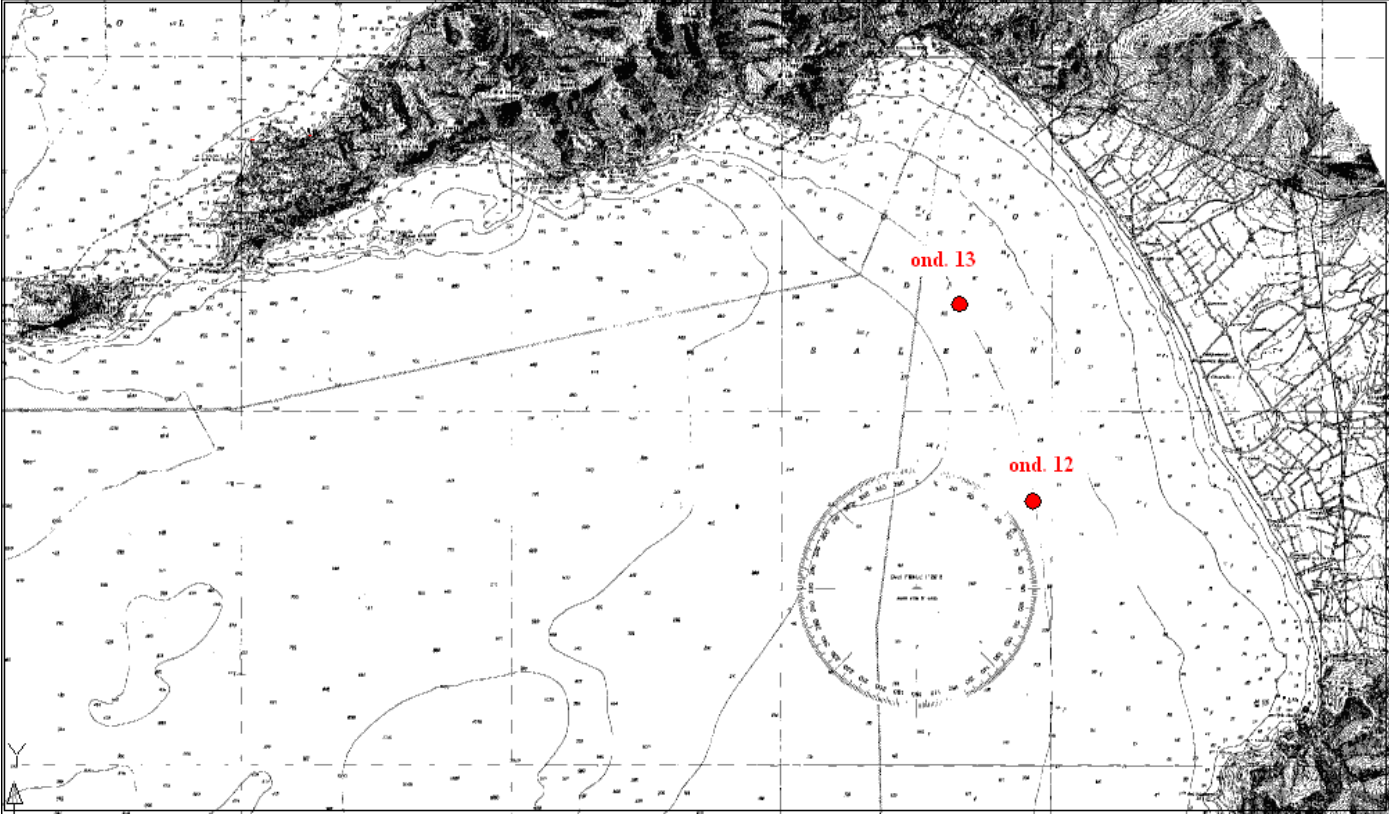








**Fig.14: Individuazione punti di calibrazione su tracce 122 e 272 del radar altimetro RA2 di Envisat**



There is another problem using the ERS2 wave height data. We have mentioned (see previous section) a permanent malfunctioning of the altimeter, when measuring the wave heights. Whichever the sea state, the reported measured data are almost always above 1–1.2 m. Therefore, the low wave height data are biased towards higher values. At ECMWF this was realised in 1996, with a consequent bias of the ECMWF analysis data available from the archive. Because the  $H_s$  correction done when assimilating the ERS2 altimeter data was reflected also in the correction of the period, this is biased as well