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# **HF radar wave measurements in the Malta-Sicily Channel - Targeting users now and in the future**

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**MARINE INTELLIGENCE – THE VALUE OF DATA FOR SEA-BASED APPLICATIONS - Malta**

# Why studying waves?

- ✓ Understanding and mitigate impact on living conditions and livelihoods of people living along the coast
- ✓ Improving safety in navigation
- ✓ Understanding how much energy invests the coast to predict the effects of storm surges
- ✓ Improving knowledge in the design of coastal defense works
- ✓ Identifying better security policies
- ✓ Understanding pollutants and oil spill dispersion along the coast
- ✓ Understanding sediments distribution along the coast
- ✓ Identifying useful parameters for fishing and tourism
- ✓ Supporting search and rescue at the sea
- ✓ Studying impact on marine environment due to industrial and aquaculture facilities, discharges into the sea, etc

# Data necessary for the implementation of some European Directives

- ✓ Sea Surface Temperature
- ✓ SeaBottom Temperature
- ✓ Turbidity
- ✓ Upwelling
- ✓ Mixing characteristics
- ✓ Salinity
- ✓ Current velocity
- ✓ Sea level
- ✓ Wave Exposure
- ✓ ResidenceTime
- ✓ Nutrients
- ✓ Sea Surface Oxygen
- ✓ Seabottom Oxygen
- ✓ Chlorophyll a



- Water Framework Directive
- Habitats Directive
- Marine Strategy Framework Directive
- Bathing waters Directive
- Nitrates Directive
- Flood Directive

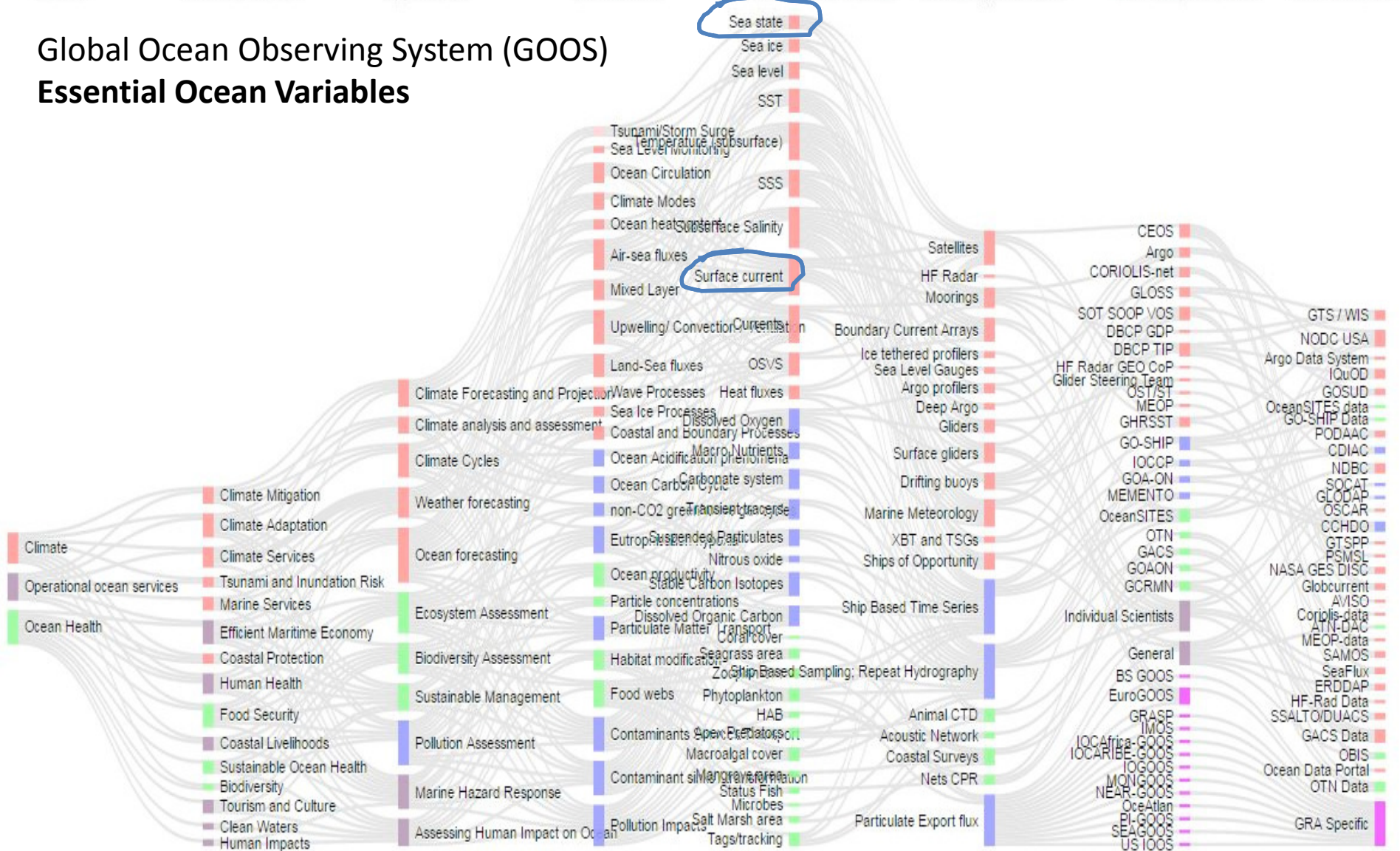
OBSERVATIONS

REQUIREMENTS

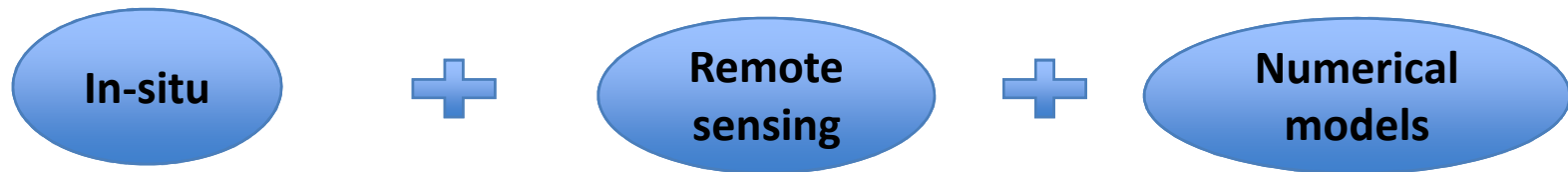
DATA & PRODUCTS

Themes Societal Benefits Applications Phenomena Essential Ocean Variable Observing Platforms Observing Networks Data Networks

Global Ocean Observing System (GOOS) Essential Ocean Variables



# Integrated waves monitoring system



● A system able to:

- ✓ observe the sea state with a good temporal and spatial resolution with operational purposes
- ✓ Reconstruct the wave climate to preview possible scenarios
- ✓ Create, around the observation / reconstruction / forecasting system, high added value applications and services, with strong implications for very important economic sectors

# Integrated waves monitoring system

## **Why using different sensors/instruments?**

- ✓ Reply to different aims
- ✓ Difficulty of managing some types of sensors
- ✓ Scarce funds availability
- ✓ Optimising resources vs scientific targets

In-situ

+

Remote sensing

+

Numerical models

Buoys



Pressuremeter



Accelerometer and GPS



ADCP



In-situ



Remote sensing



Numerical models

X-band Radar



HF-band Radar



SAR



Altimeter





In-situ



Remote sensing

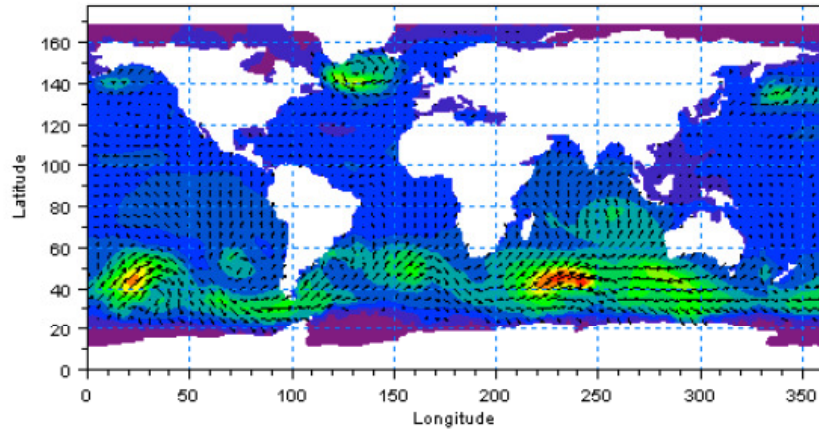
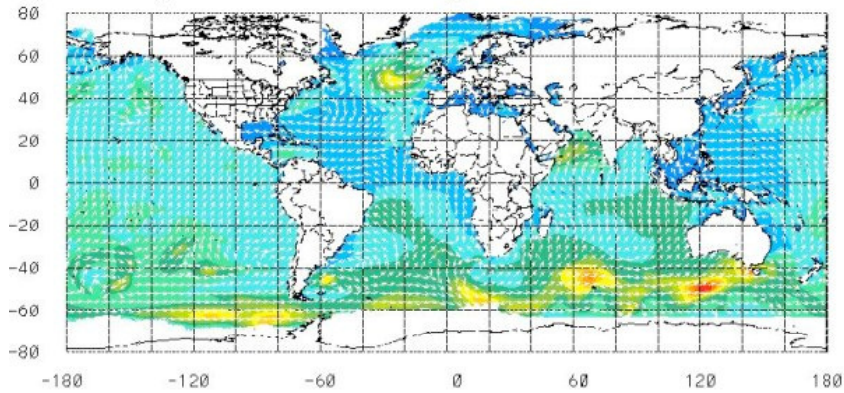


Numerical models

# Numerical models

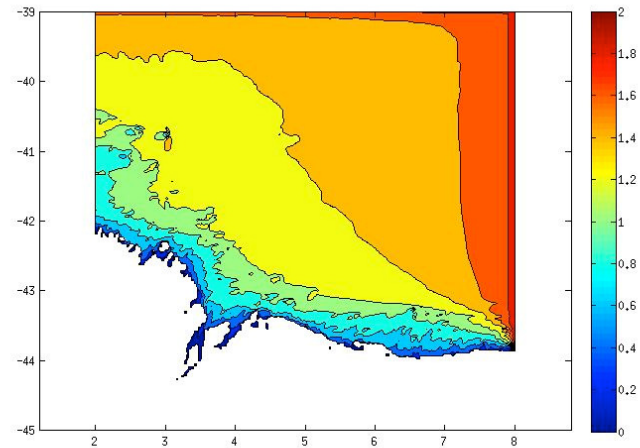
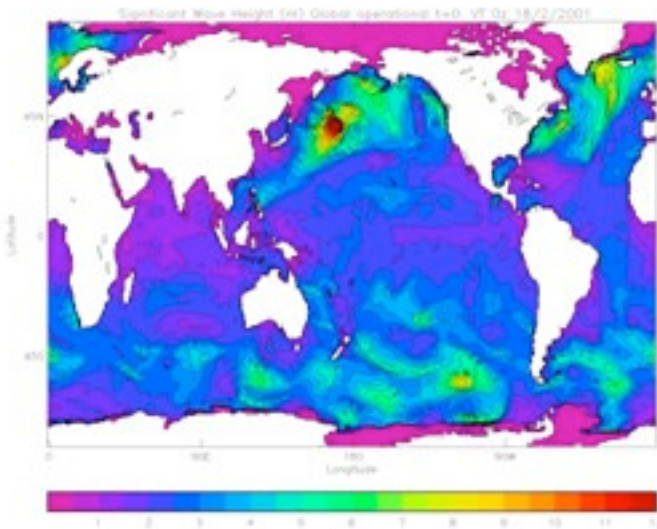
WAM

MIKE 21



Wave Watch III

SWAN



# Main uses of wave measurements HF radar

- ✓ Assistance to many operational activities
- ✓ Coastal zone planning, protection, and management
- ✓ Characterization of wave-current interactions
- ✓ Safety at the sea (oil spill, ship routing, search and rescue)
- ✓ Part of national ocean observing systems (possible assimilation of HF radar data in numerical wave models to improve weather forecasts)
- ✓ Environmental protection benefits (ship routing, oil spill)
- ✓ Improve the level of awareness of the marine conditions within the community (fishermen, tourist operators, general public, marine researcher)
- ✓ Measure wave energy resource potential

# Users and target of waves data

in complement to already in use ocean parameters

## MAIN **USERS** NOW AND IN THE FUTURE

- ✓ Maritime transport sector
  - ✓ Shipping industry
  - ✓ Fishermen
  - ✓ Coast guards
  - ✓ Port authorities
  - ✓ Energy industry
- ✓ Research and academic community
- ✓ Sea tourism and recreational sectors

## MAIN **TARGETS** NOW AND IN THE FUTURE

- ✓ Minimizing risks for operations at sea
- ✓ Save fleet fuel consumption
- ✓ Using more accurate routing
- ✓ Prevent from potential ship and platform oil spill drift
- ✓ Mitigation of coastal erosion
- ✓ Estimation of ocean energy resources
- ✓ Environmental monitoring of offshore ocean and wind energy sites
- ✓ Ocean-atmosphere interaction studies or applied science

Main CMEMS wave products users come from business sector (50%) -> relevancy of the product in their operational chains

# HF radar wave measurements

## SeaSonde HF radar system

- ✓ Measurements of ***ocean surface currents*** are obtained from the dominant first order peak in the radar echo spectrum.
- ✓ ***Wave*** information derive from the second order radar spectrum, fitting a model (Pierson-Moskowitz) of the ocean wave spectrum to give estimates of wave height, centroid period and direction



BUT the second order radar spectrum ....

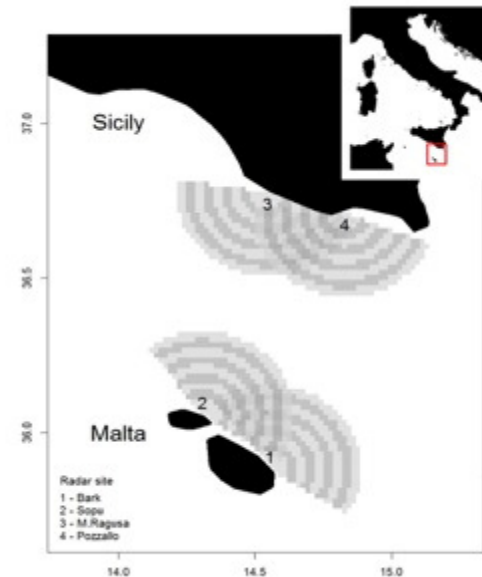
....close to the noise floor....

....saturation effect for high waves...

# HF radar wave measurements

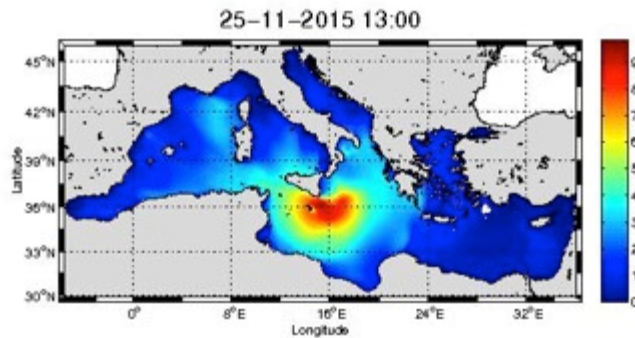
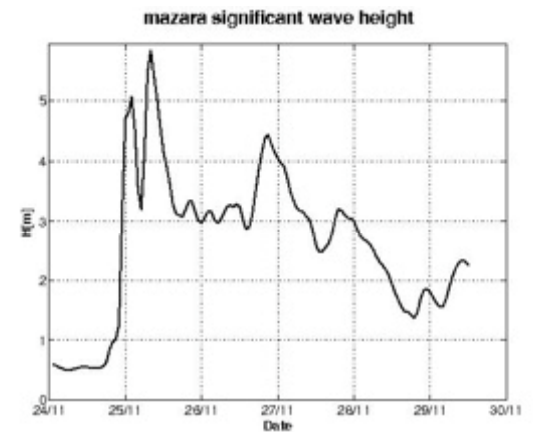
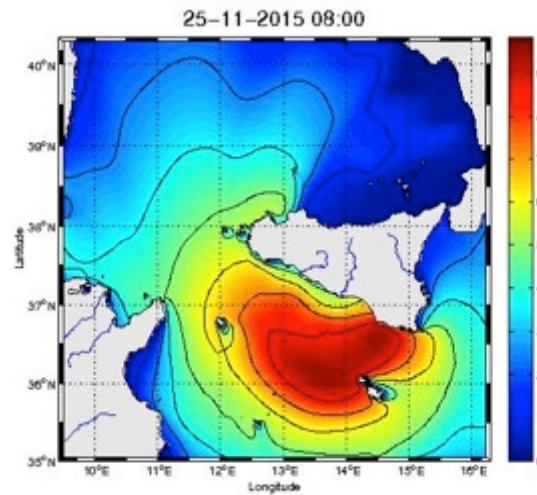
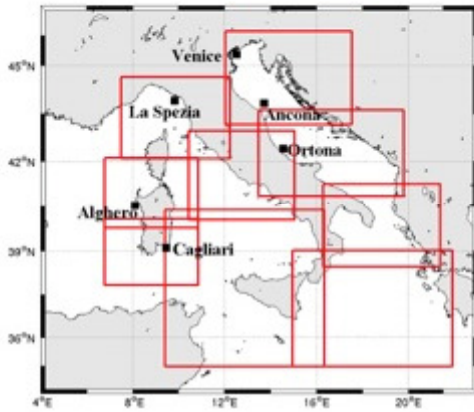
## The CALYPSO Wave Data Set:

- ✓ Half-hour sea main wave parameters (Significant Wave Height, Central Period, Mean direction) averaged at each annular sector
- ✓ 3 km of spatial resolution
- ✓ Wave data delivered since 2012 at both Malta sites, since 2014 at Pozzallo and since 2016 at Ragusa
- ✓ Radar transmit frequency 13.5 MHz



# Inter-comparison of wave HF radar

Comparison of HF radar data versus numerical sea wave model



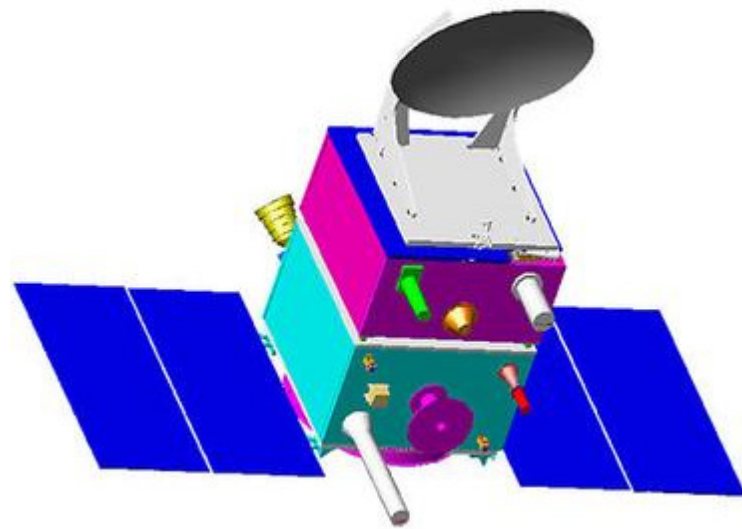
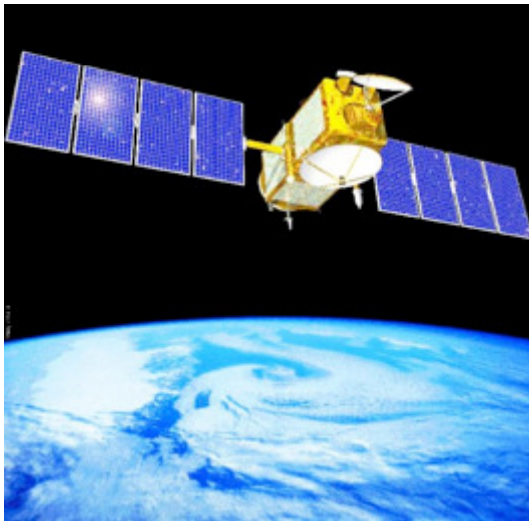
WAM from ISPRA Mc-WAF system  
1/60 deg resolution



# Inter-comparison of wave HF radar

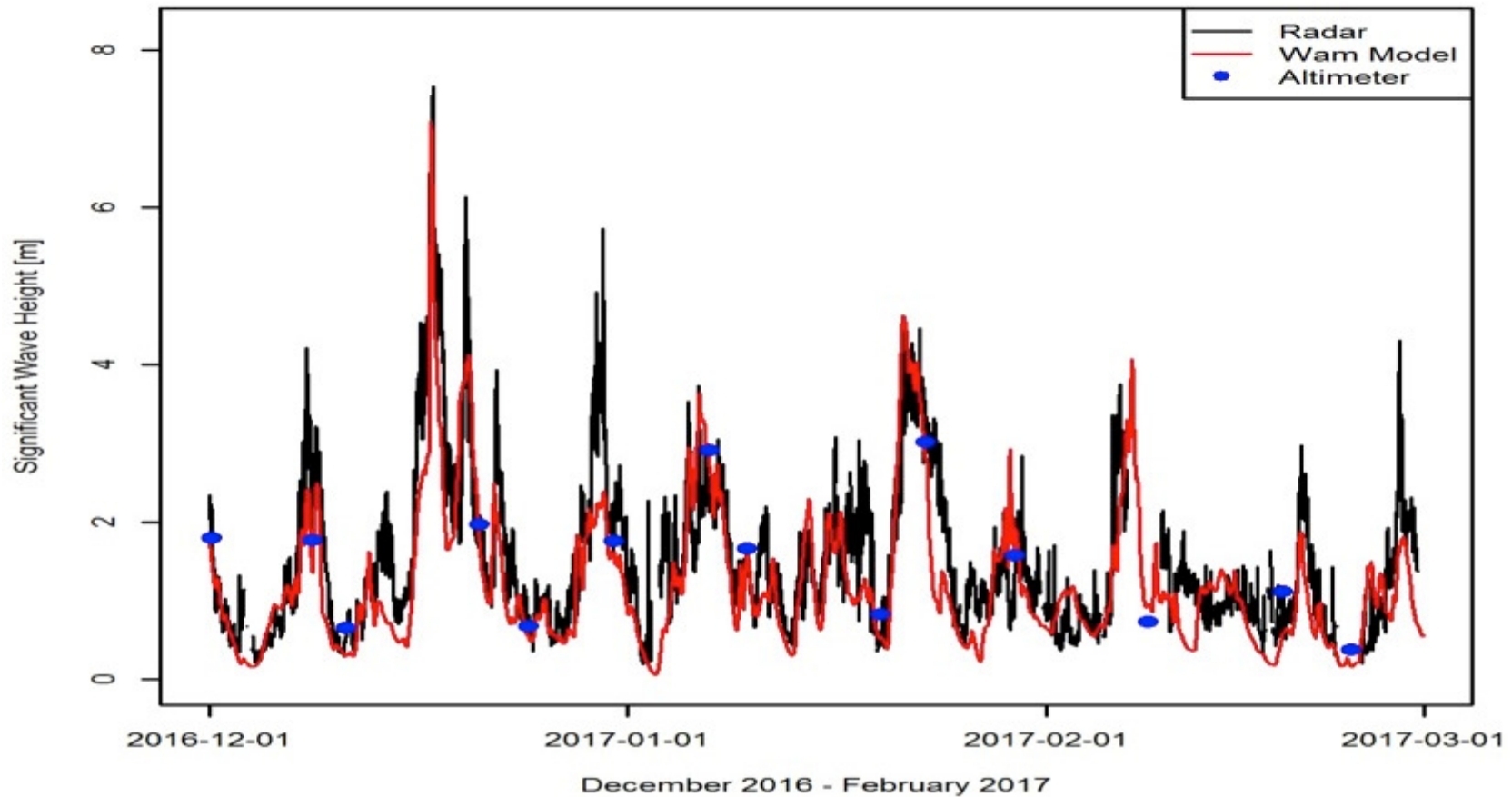
Comparison of HF radar data versus satellite altimeter data

SWH from altimeters Jason2, Jason3 and SAR Saral Altika



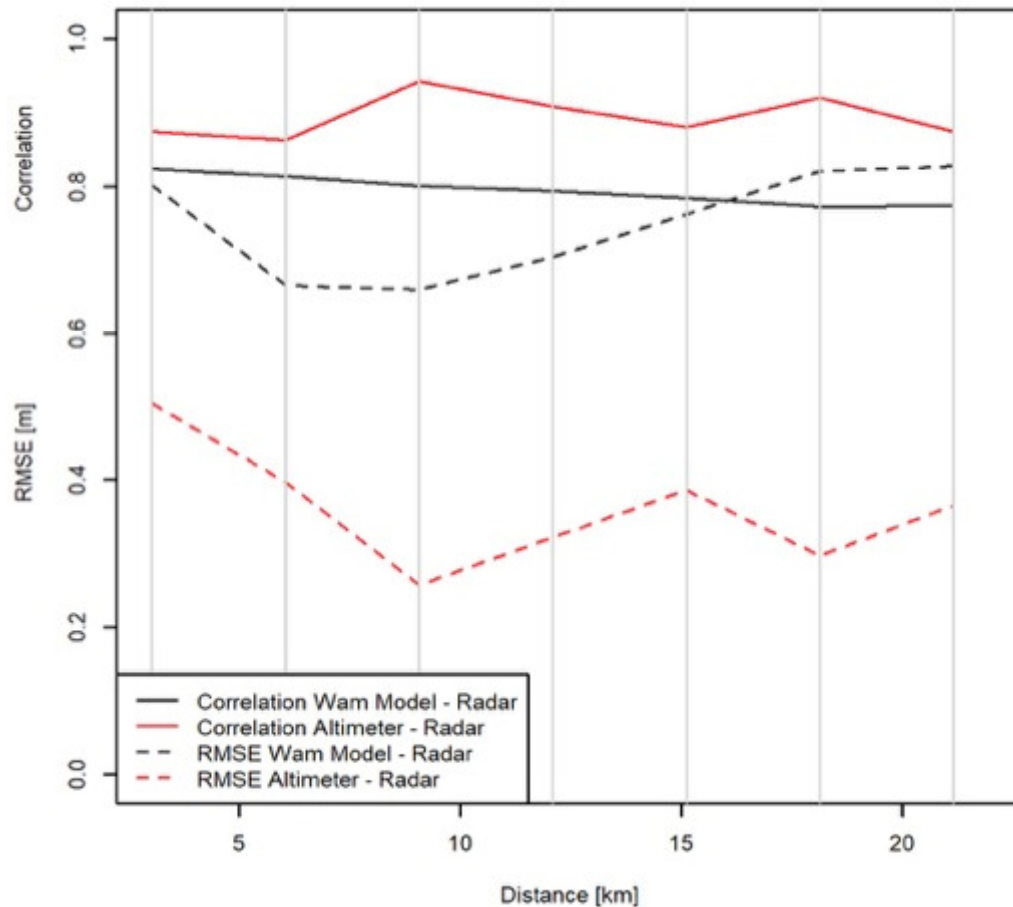
# Inter-comparison of wave HF radar

SWH - 3<sup>rd</sup> annular sector at Ta' Barkat





# Inter-comparison of wave HF radar

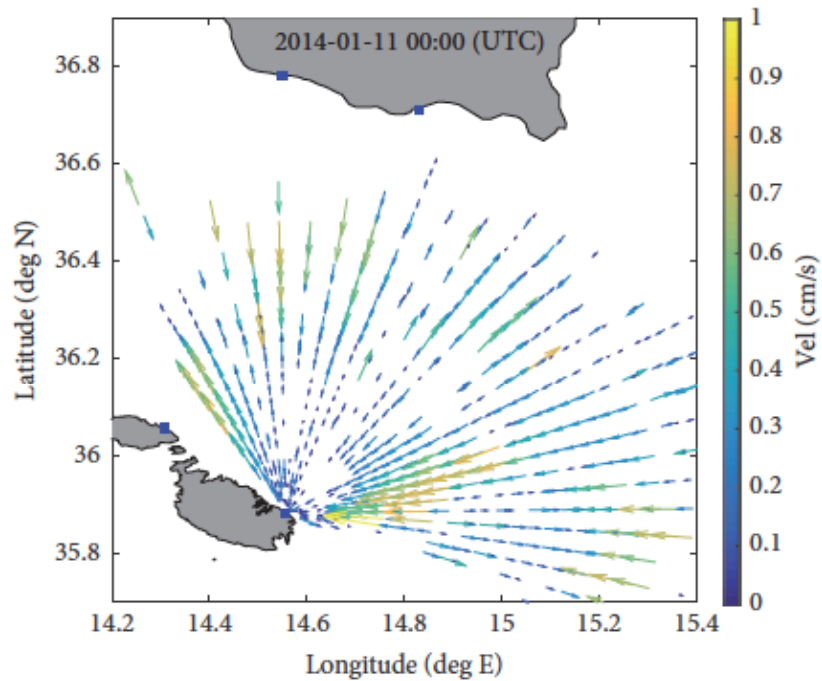


The agreement between SWH series depends on the distance from the radar origin

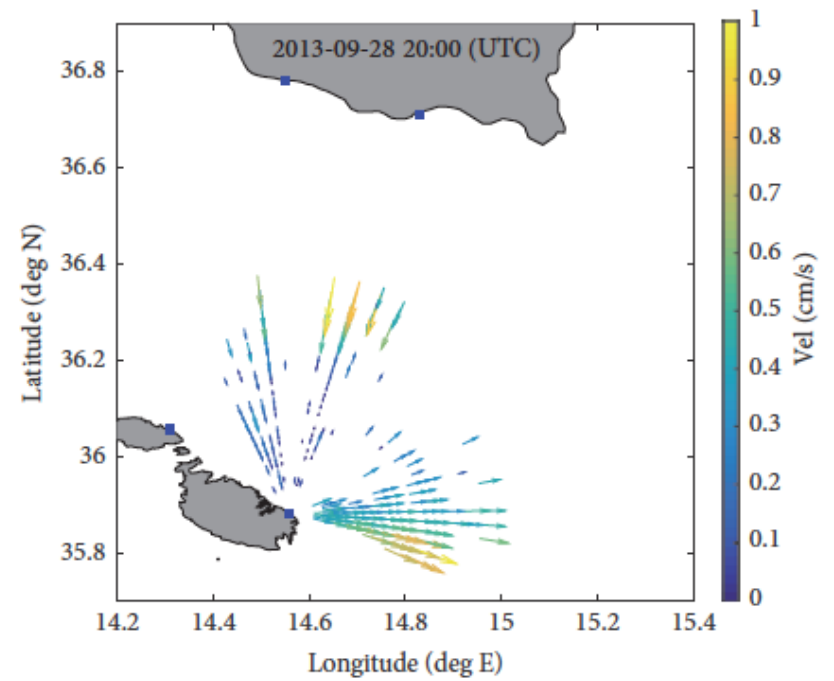
# Results

- ✓ Better agreement is achieved in the intermediate rings respect to the radar origin
- ✓ Tendency of the HF radar to register higher values of SWH with respect to the WAM model, whereas the agreement with altimeter data seems to be higher
- ✓ One key drawback concerns the sporadic inconsistency in the spatial coverage of radar data which is dictated by the sea state as well as by interference from unknown sources that may be competing with transmissions in the same frequency band

# Results

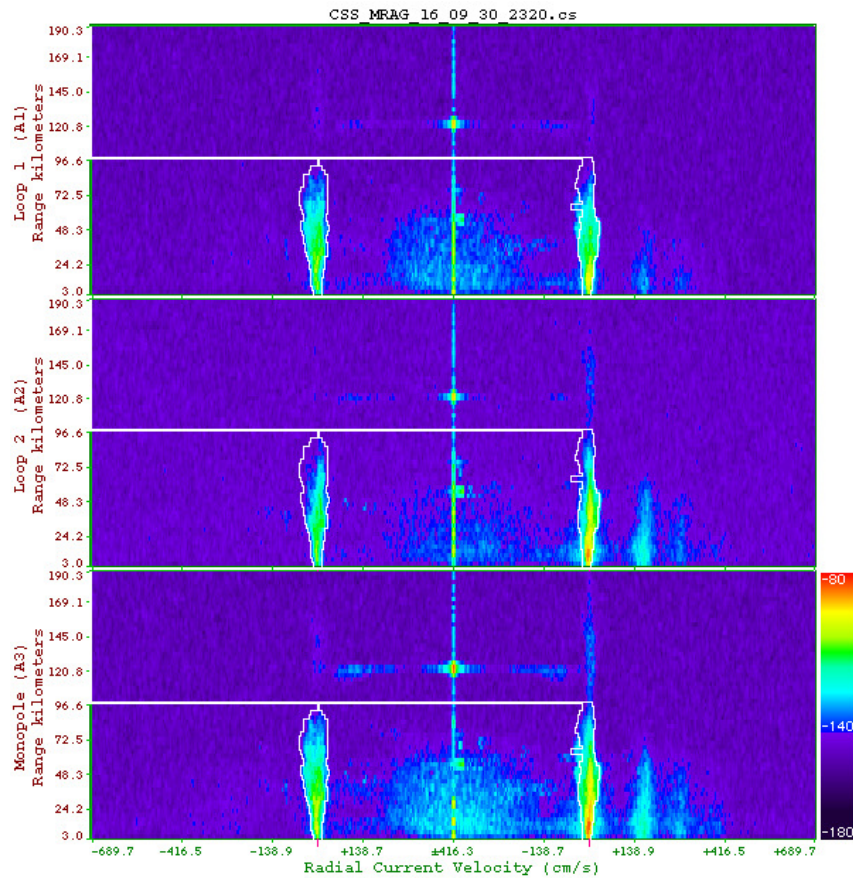


Normal radial coverage at Ta' Barkat

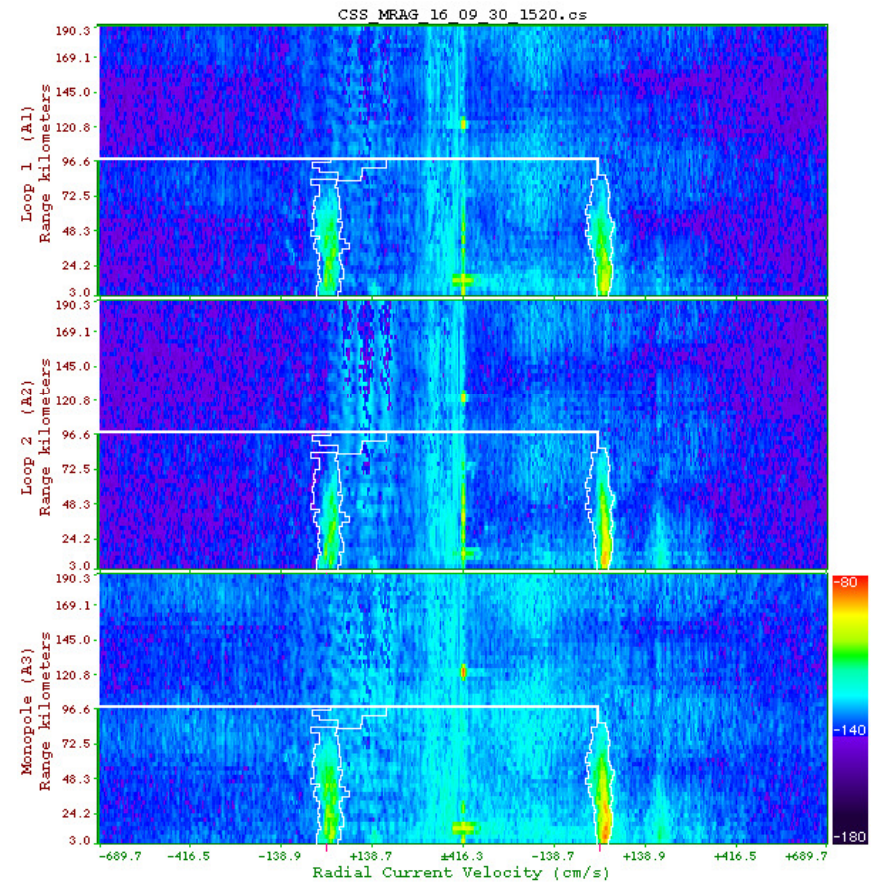


Reduced radial coverage at Ta' Barkat due to external interference

# Results



Typical spectra at Ta' Barkat



Noisy spectra at Ta' Barkat due to external interference

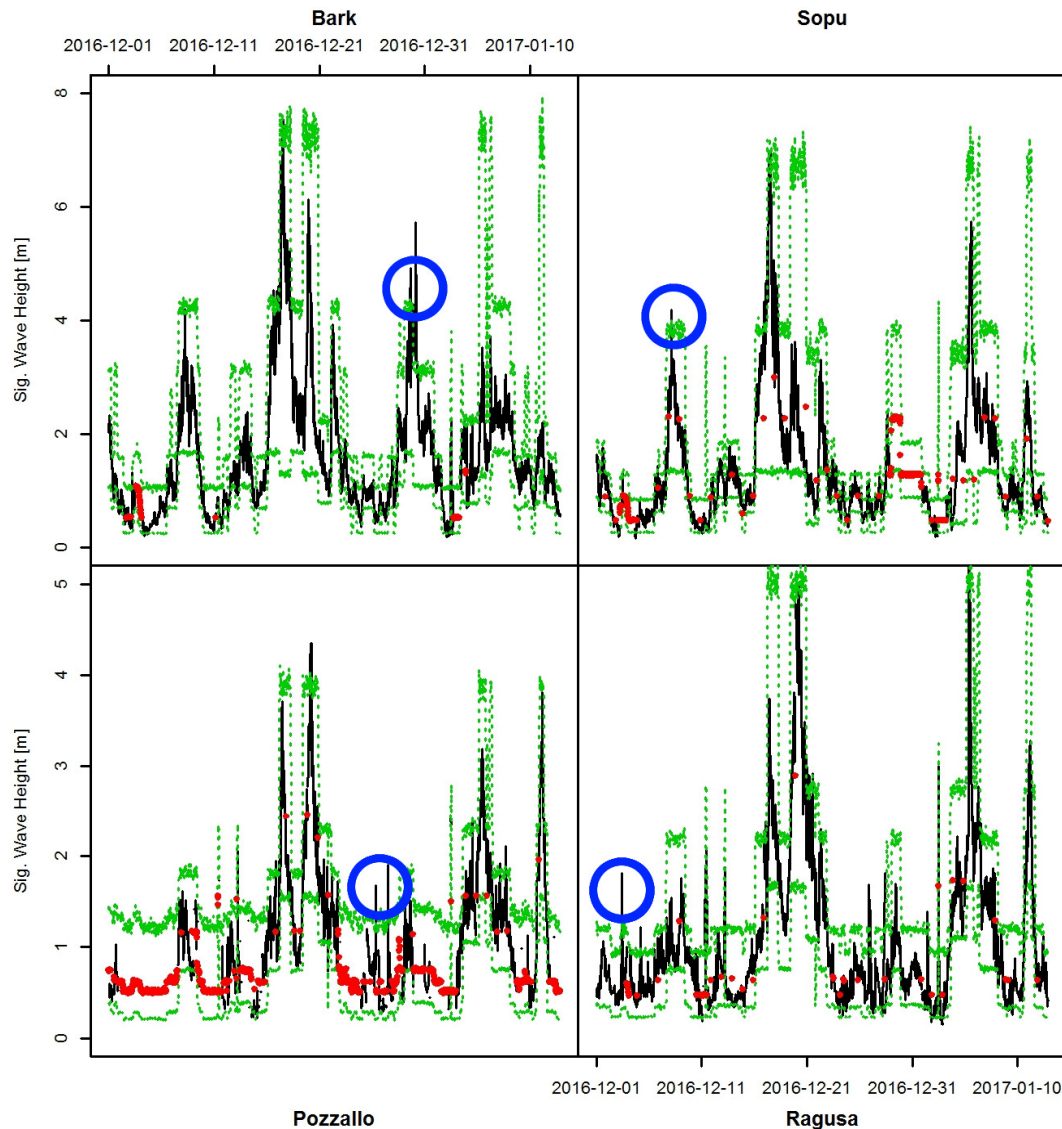
# Work in progress

- ✓ Validate data and fill gaps as done for sea current fields (Gauci et al. 2016\*, Picone et al. 2018\*\*)
- ✓ Investigate central period and mean direction
- ✓ Extend the study by direct correlation to wave buoy measurements

\*Gauci A., Drago A., Abela J., Gap Filling of the CALYPSO HF Radar Sea Surface Current Data through Past Measurements and Satellite Wind Observations, Int. J. Navigation Observation, vol.2016

\*\*Picone M., Orasi A., Drago A., Capodici F., Ciruolo G., Nardone G., Azzopardi J., Gauci A., Galea A., A wave measurements HF radar data set in the Malta-Sicily channel: data quality, validation and gap filling, Accepted for Workshop HIC2018, Palermo

# Data quality, validation and gap filling



2.5° and 97.5° percentiles (green) for observed data (black) and computed data (red) according to the estimated Markov chain mixture model at the four HF radar sites. Possible outliers to be investigated are shown in blue circles

# References

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