Verification of an integrated meteo-marine modeling chain with quantitative and qualitative methods

S. Mariani [(1)], M. Casaioli [(1)], B. Lastoria [(1)], A. Orasi [(1)], and F. Catini [(2)]

[(1)] ISPRA – Institute for Environmental Protection and Research, Dept. for Protection of Inland and Marine Waters, Rome, Italy

[(2)] University "Roma Tre", Dept. Civil Engineering, Rome, Italy

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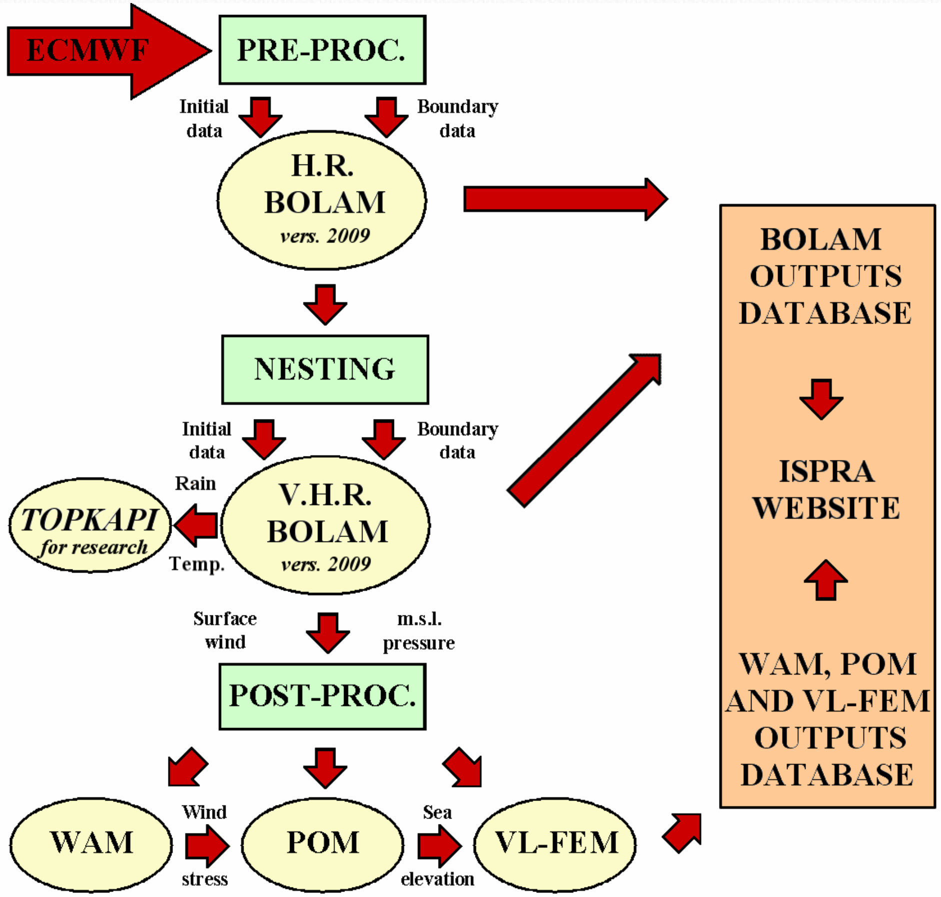
Outline

- **Overview of SIMM forecasting system**
- **The system upgrading**
- **Forecast verification**
- **Results**

SIMM – *Sistema Idro-Meteo-Mare*

ISPRA's Hydro-Meteo-Marine forecasting system (**SIMM**) → a chain of meteorological and marine models operational over the Mediterranean Basin

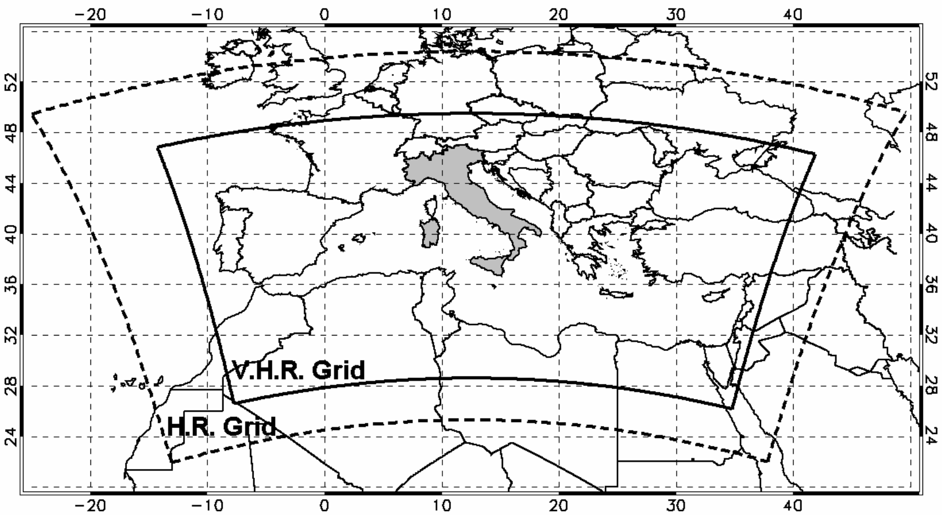
- Developed (end of '90s) within a cooperation among DSTN, CNR, ENEA;
- BOLAM: 10-km hydrostatic LAM;
- Wave model (WAM) on Mediterranean Sea and sea elevation model on Ionian/Adriatic seas (POM) and Venice Lagoon (VL-FEM);
- TOPKAPI distributed rainfall/runoff model over two Italian river basins (Adige and Reno) in research configuration;
- Tailored to resolve simultaneously the wide range of scales involved in the complex Mediterranean atmospheric phenomena.



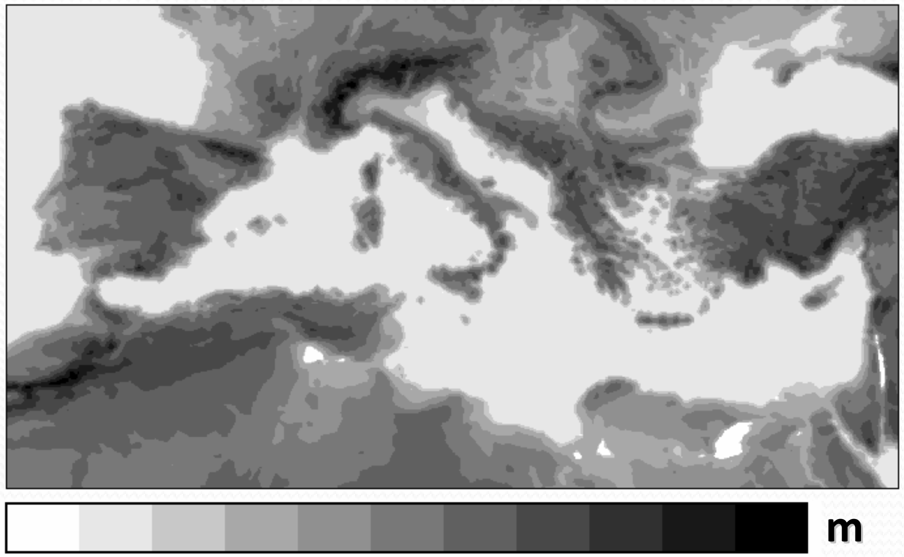
"SIMM produced the first systematic, integrated hydro-meteorological and sea-state forecasts over the entire Mediterranean area, bridging from planetary to local scales of atmospheric motion" (Speranza* et al*, 2007)

SIMM – *Sistema Idro-Meteo-Mare*

- Originally designed for the massively parallel supercomputer QUADRICS;
- The synchronous (SIMD) architecture of QUADRICS implied severe constraints on the code, so that many physical schemes were simplified (e.g., Kuo convection scheme).
- In 2006 porting the system on the new SGI ALTIX parallel platform;
- On SGI Altix, implementation of the Kain-Fritsch convection scheme in a research configuration
  → ***reforecasting activity***;
- 2009: implementation into SIMM of a parallel version of the last version of BOLAM, in collaboration with ISAC-CNR
  → ***new config. operational since Oct. 2009***;
- major configuration (e.g., increase of the BOLAM time-space resolution) and hardware enhancements ongoing;



BOLAM domains: 33-km "father" (dashed); 11-km "son" (solid) and topography (in m).



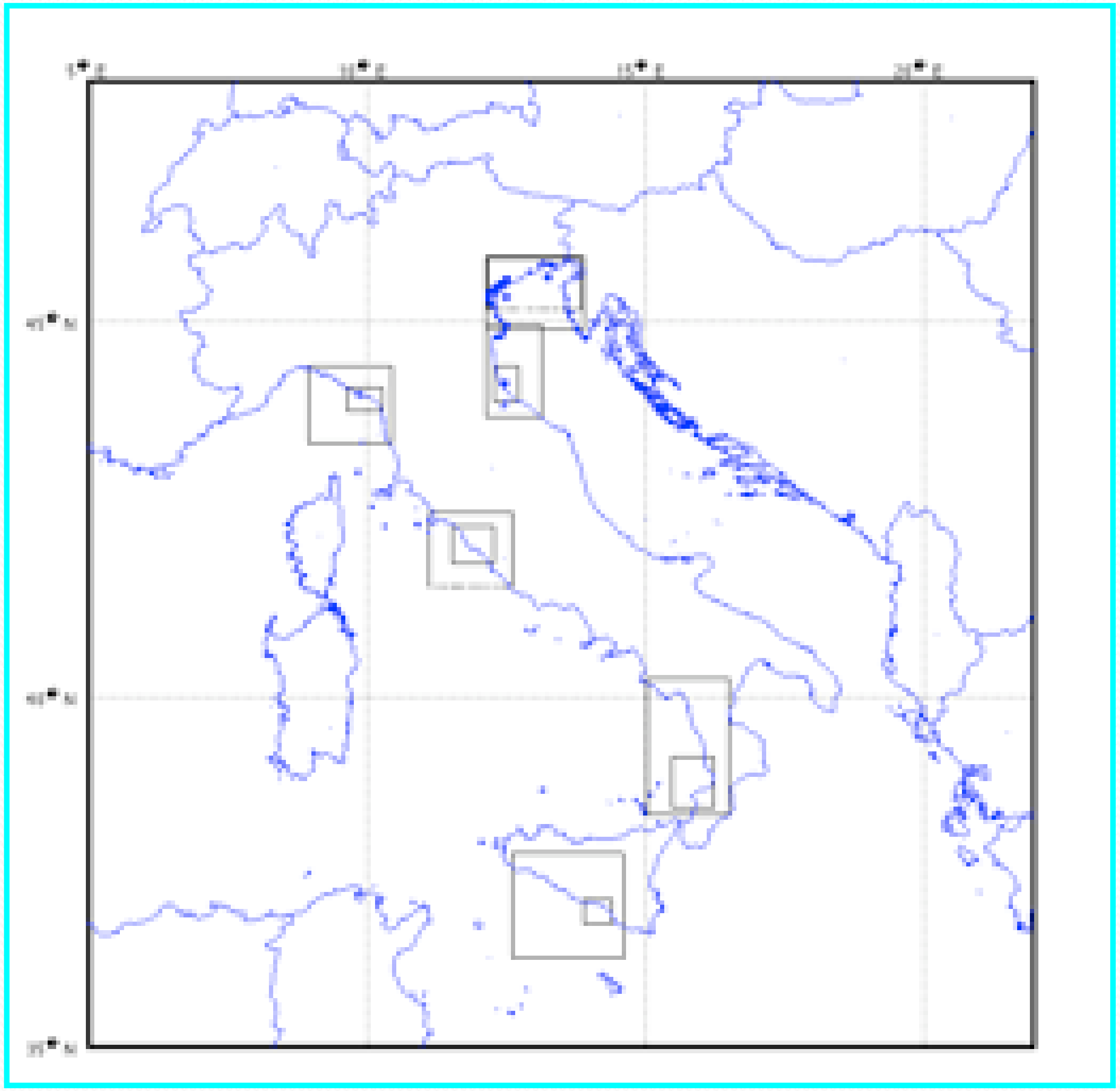
QBOLAM vs. BOLAM 2009

QBOLAM		BOLAM 2009
U, V, q, θ, p_s; sigma levels	prognostic variable; vertical level	U, V, q, θ, p_s + 5 hydrometers; hybrid levels
Forward-backwards advection scheme	advection scheme	Weighted Average Flux
	Parameterizations:	
Kuo	Convection	Kain-Fritsch
Page	Radiation	Geleyn + Morcrette
Louis	Turbulence	E-l
2 levels +1	Soil	Moloch (3 levels +1)

Major improvements
- ► increasing res. (up to 7/8 km); domain ext.; forecast time
- ► upgrade of marine models/new modules

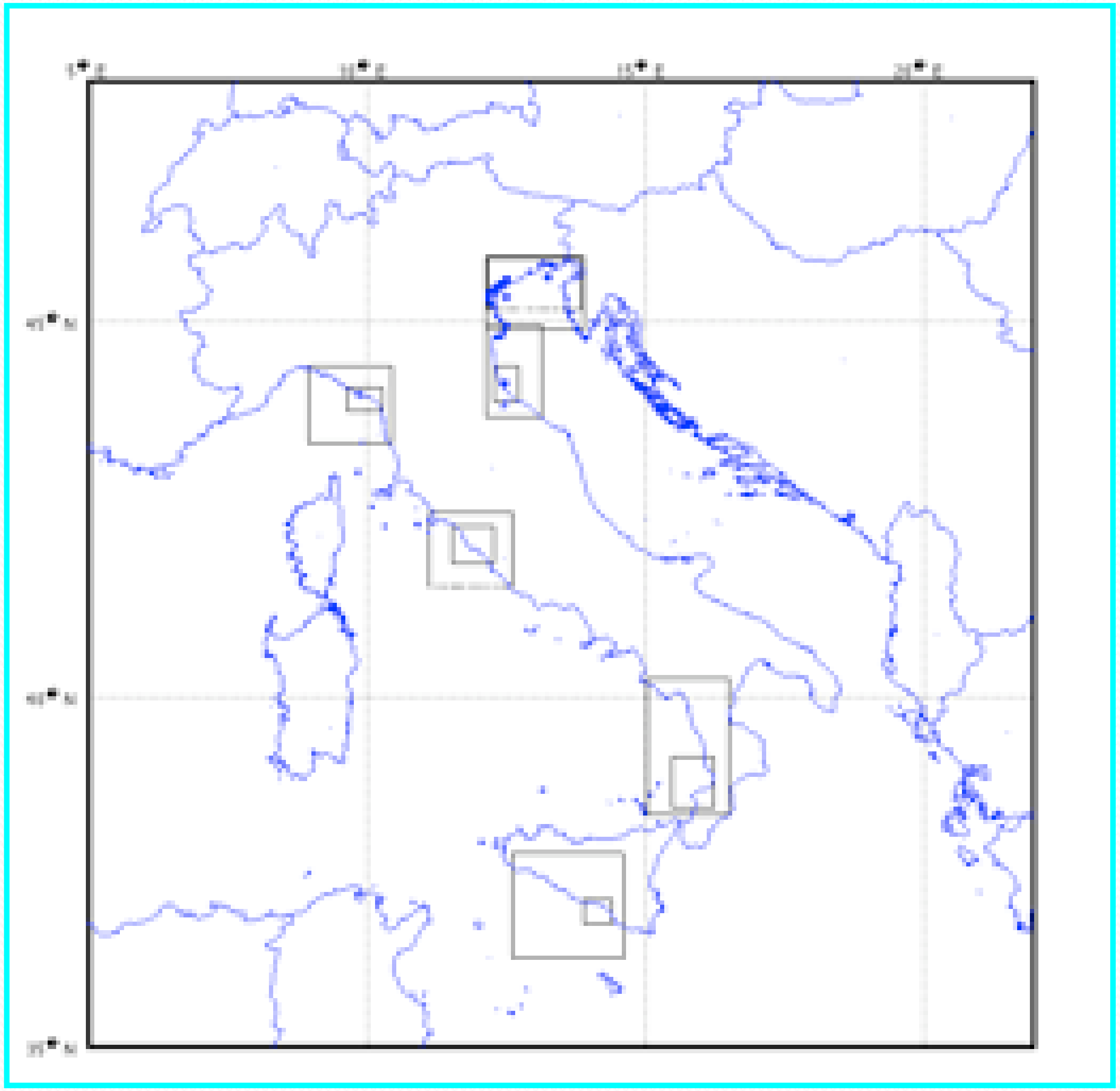
Coastal forecasting system

- The marine part of SIMM is going to be upgraded to allow a coastal prediction system, as well;
- This will be a major improvement, since it will cover scales between the Mediterranean Sea to selected Italian regional and coastal areas;
- In order to meet the necessity of going through a cascade of nesting, a parallel version (4.5) of WAM model has been implemented;
- The coarse grid runs on a resolution of 1/30 of degree and is nested on **6 selected areas** with an higher resolution:
  - **Ligurian Sea**,
  - **Central Tyrrhenian**
  - **South Sicily**
  - **South Tyrrhenian**
  - **Lower Adriatic Sea** and
  - **Northern Adriatic Sea**.

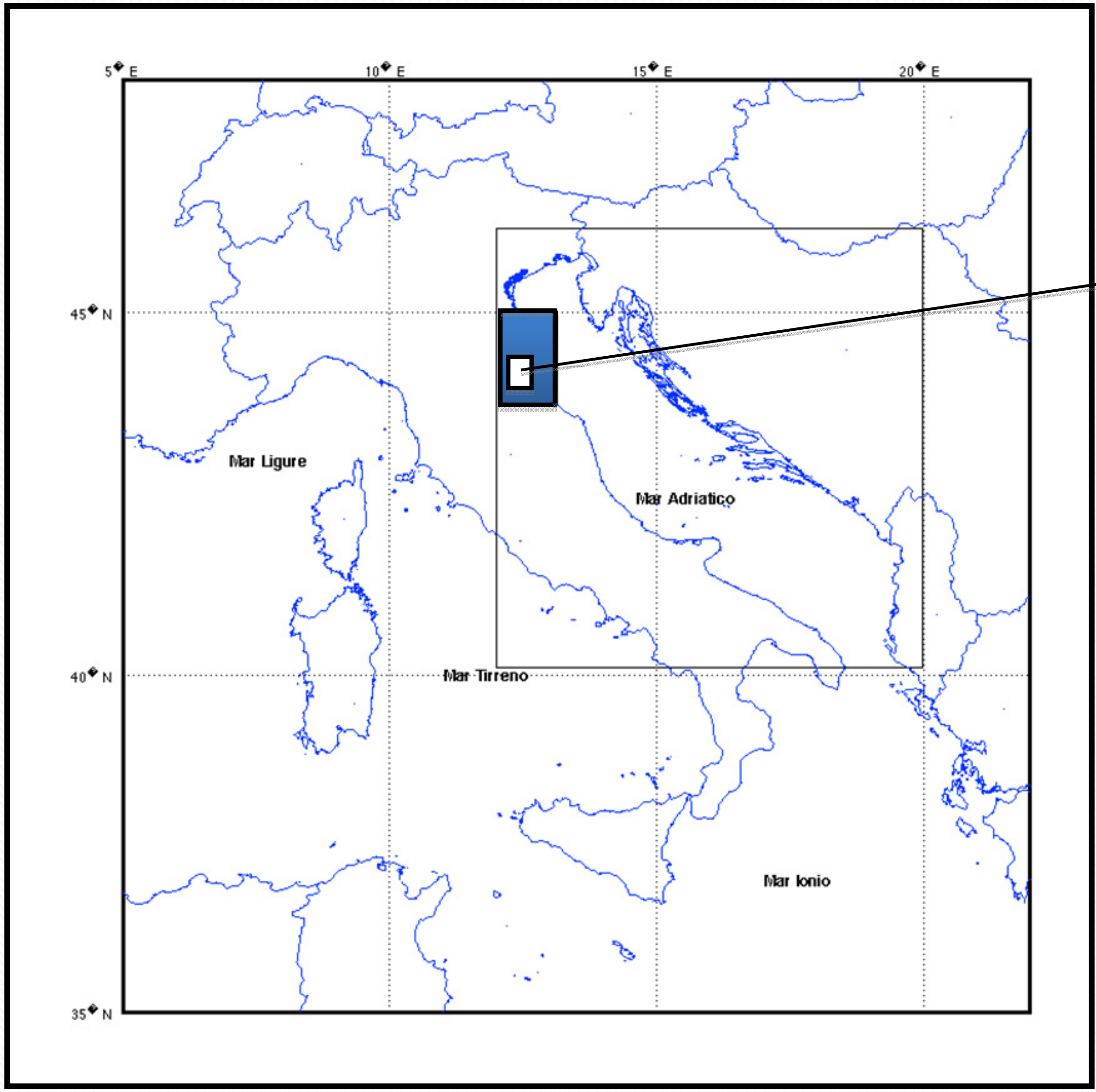


Coastal forecasting system

- Each area has been nested to smaller coastal areas at very high resolution (1/240 degree – 400m) to take into account the influence of the changes in bathymetry.
- The wave propagation in coastal areas is simulated by means of the MPI version of the SWAN (**Simulating Wave Nearshore**) model.
- Wind forecasts (remapped over the gridded domains) provided by BOLAM.
- The coastal forecast system is being tested on several key studies in order to optimise the performances and will be operational shortly.
- Research activity in cooperation w. University of "Roma 3".



Coastal forecasting system for the Northern Adriatic Sea: Comparison w. Nausicaa buoy

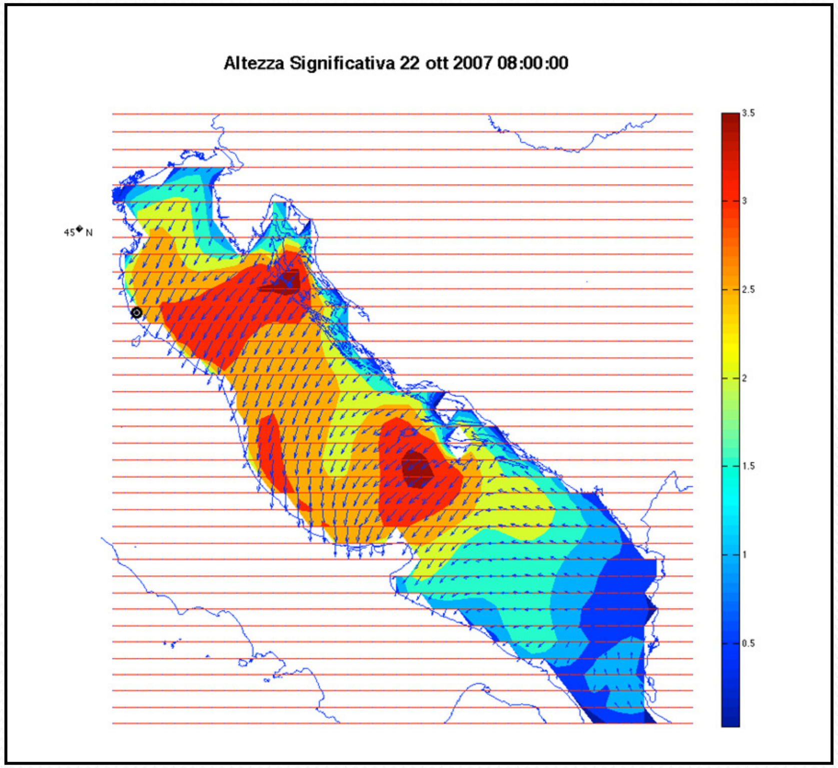


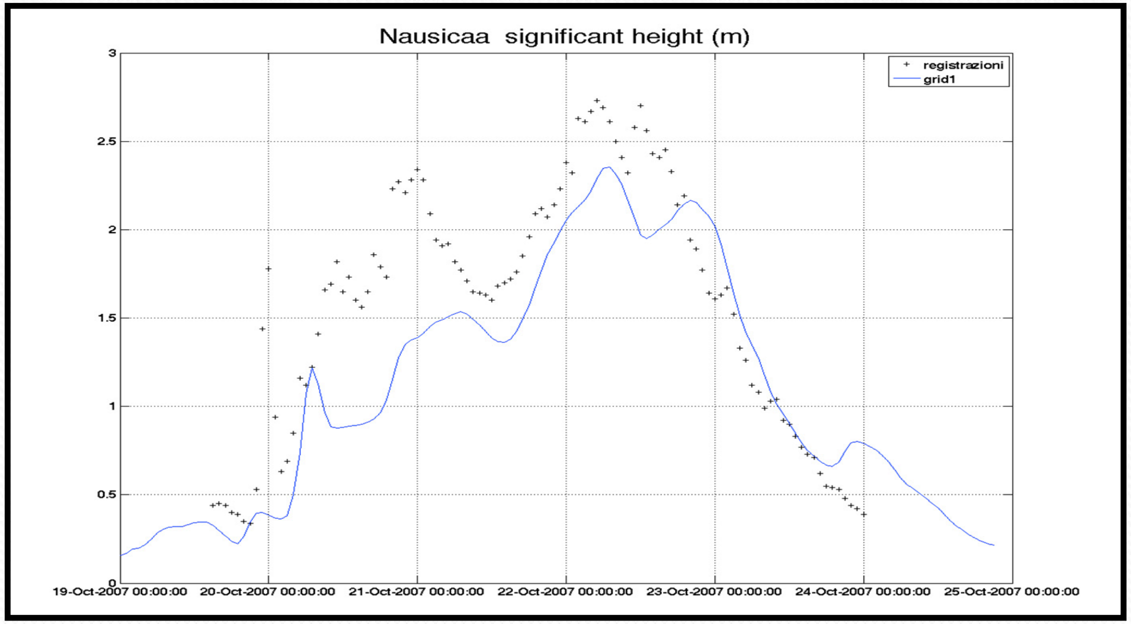
Nausicaa **buoy from *"Servizio Idro Meteo Clima"* of ARPA Emilia Romagna (Datawell Directional wave rider MkIII 70 buoy, operational since 2007)**
Anchorage depth: 10 m
Geographic position: 44.2155 °N 12.4766°E

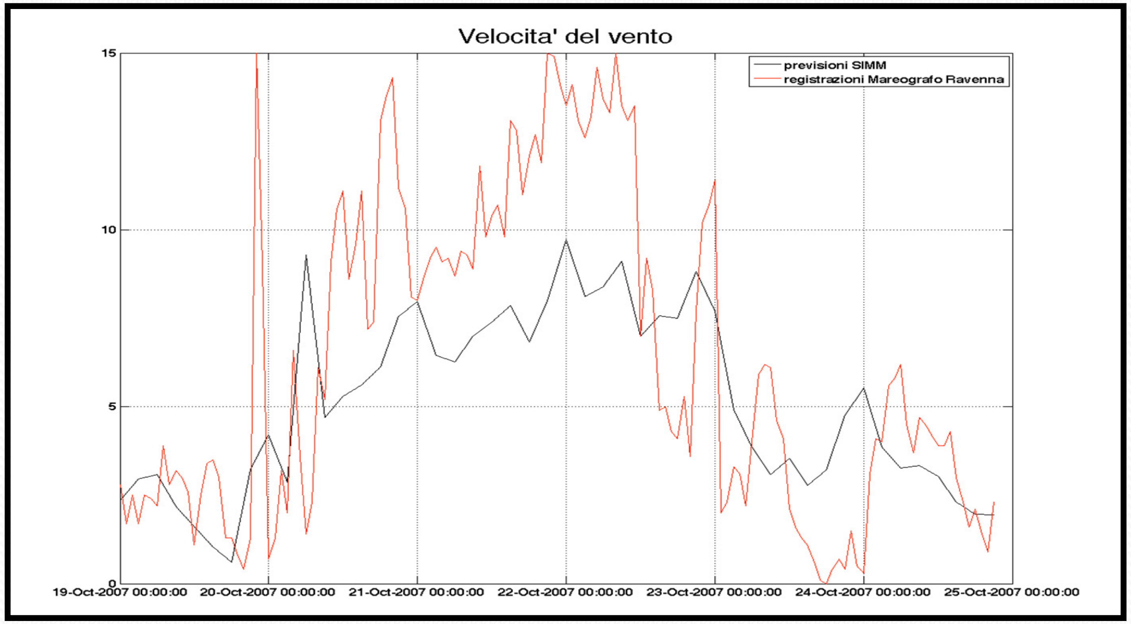
EMILIA ROMAGNA					
	origine (Lat)	origine (Lon)	Passo (gradi)	Passo (m)	N° celle
Grid1	40,1088	11,9878	1/30	3000	180x240
Grid2	44,9172	12,15	1/120	800	110x210
Grid3	45,1565	12,155	1/240	400	156x408

Two sea storm events considered:
- ✓ 22 October 2007
- ✓ 5 March 2008

Sea storm event on 22 October 2007







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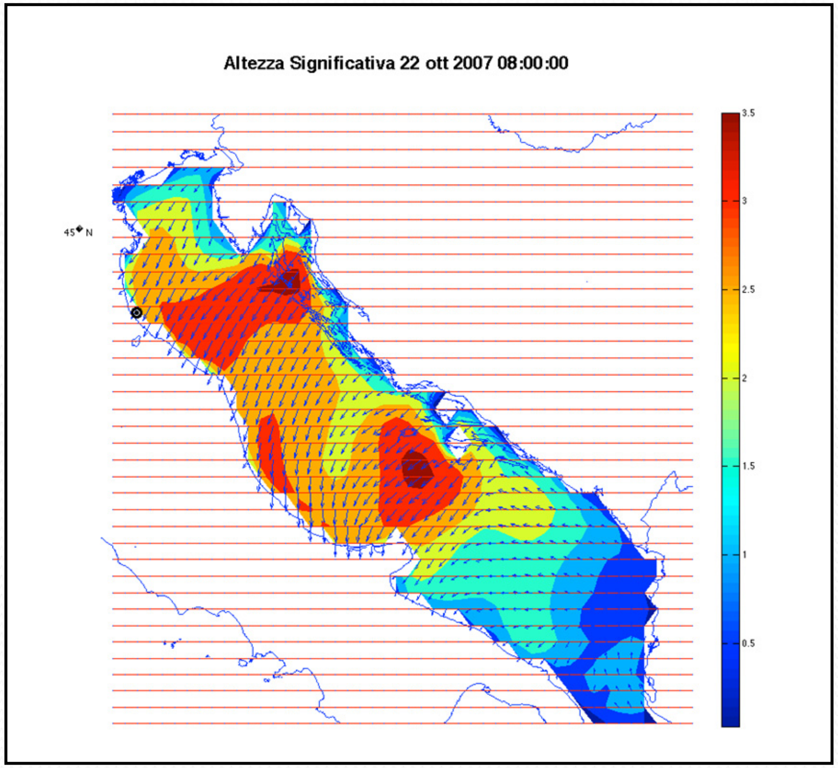
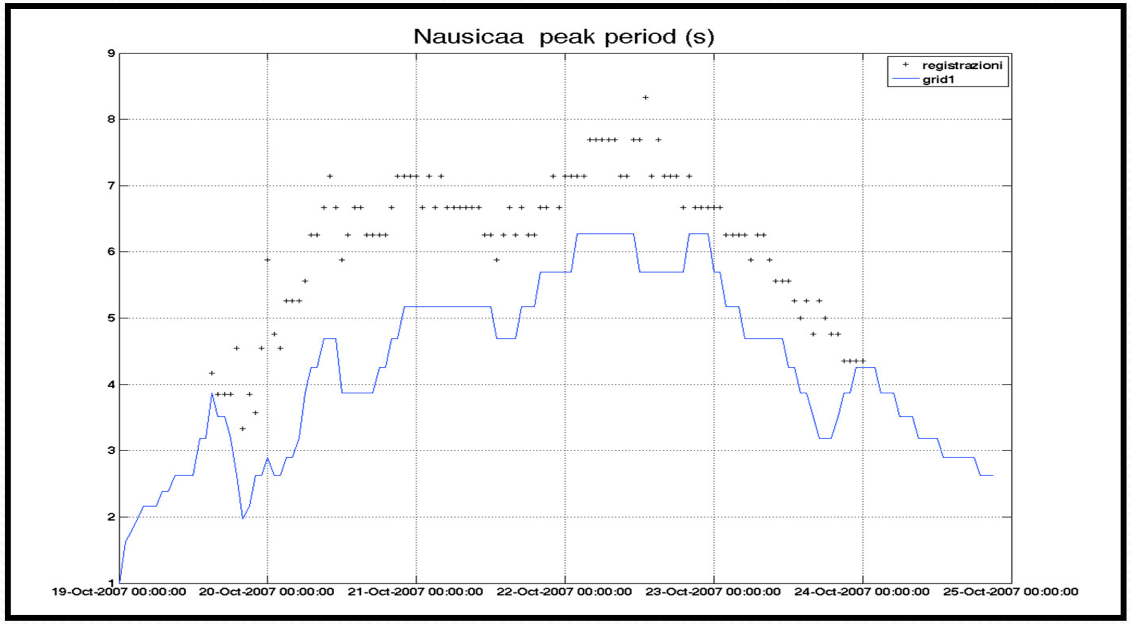
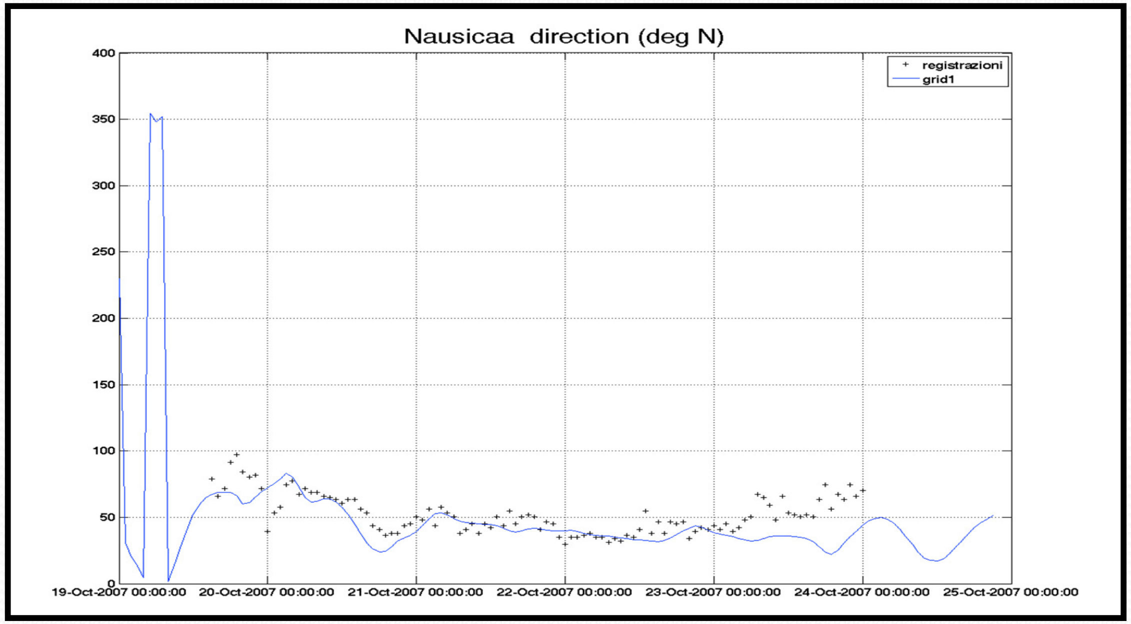
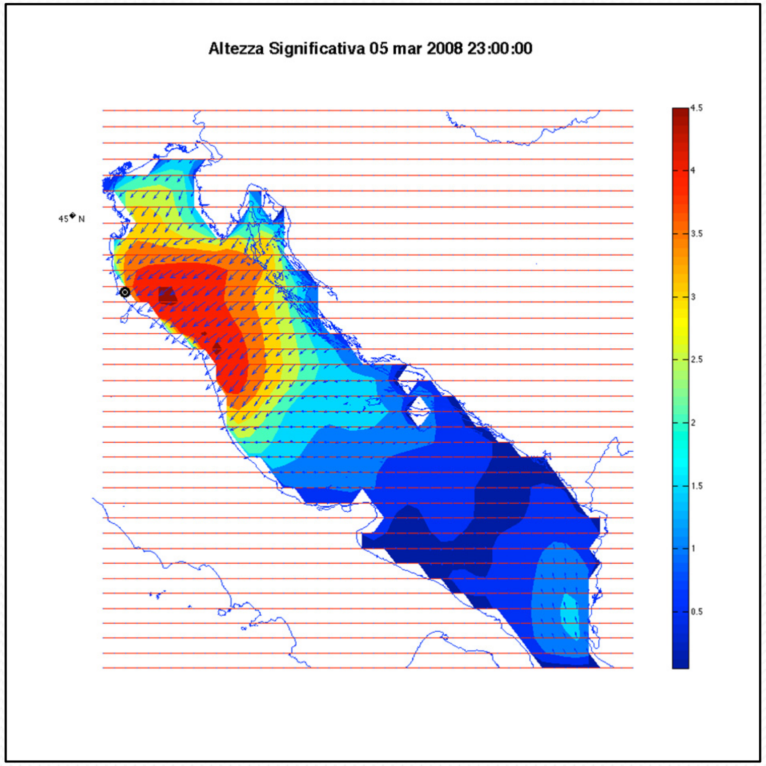
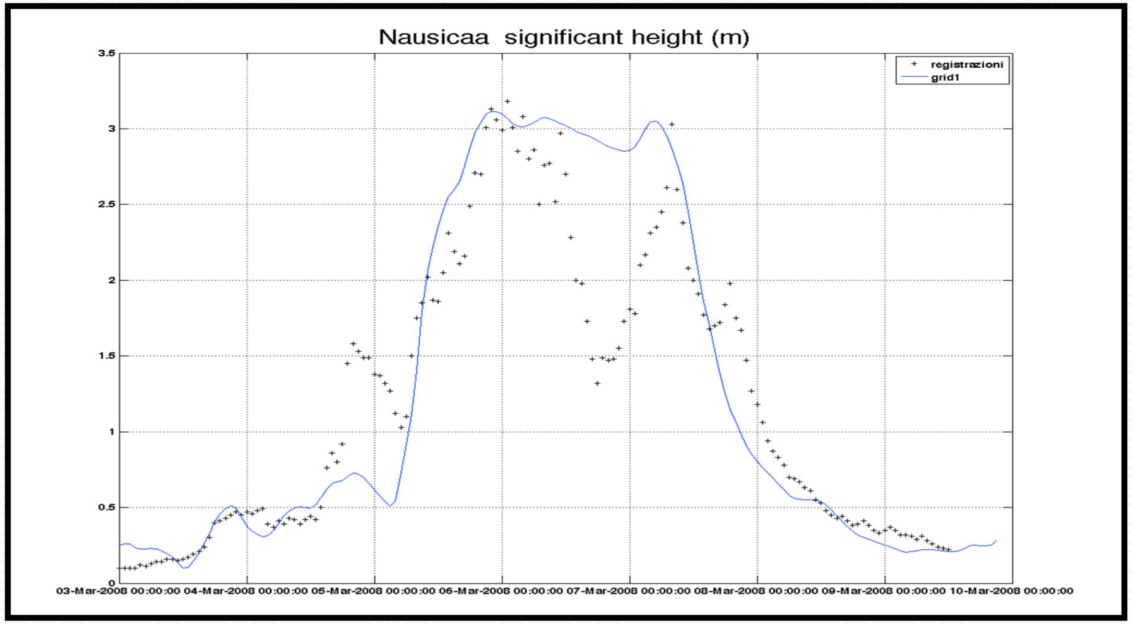


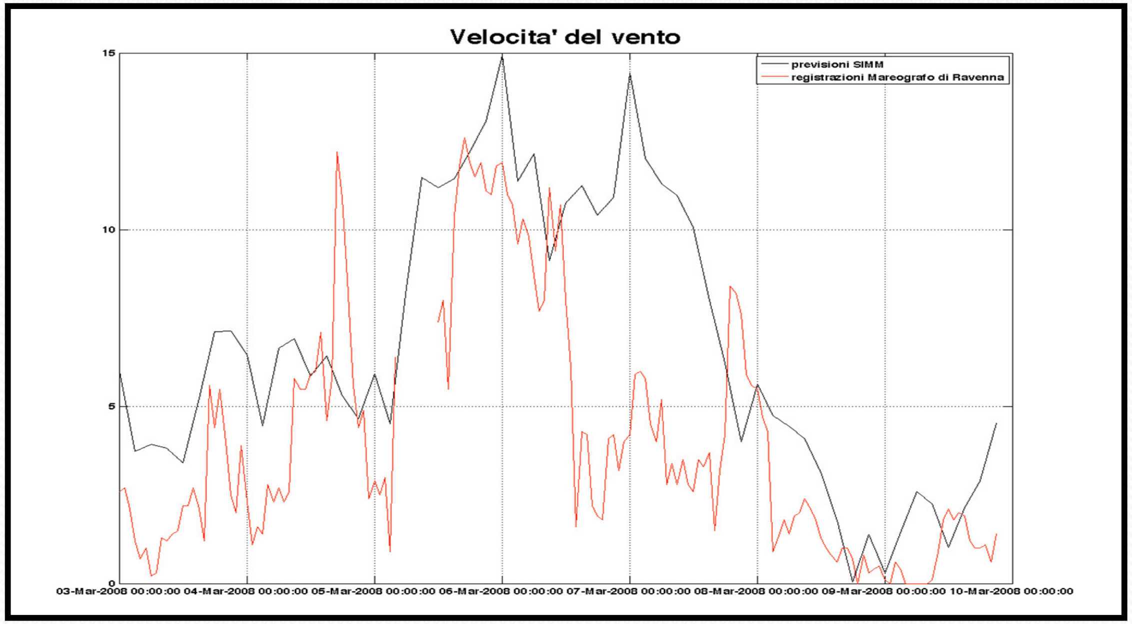




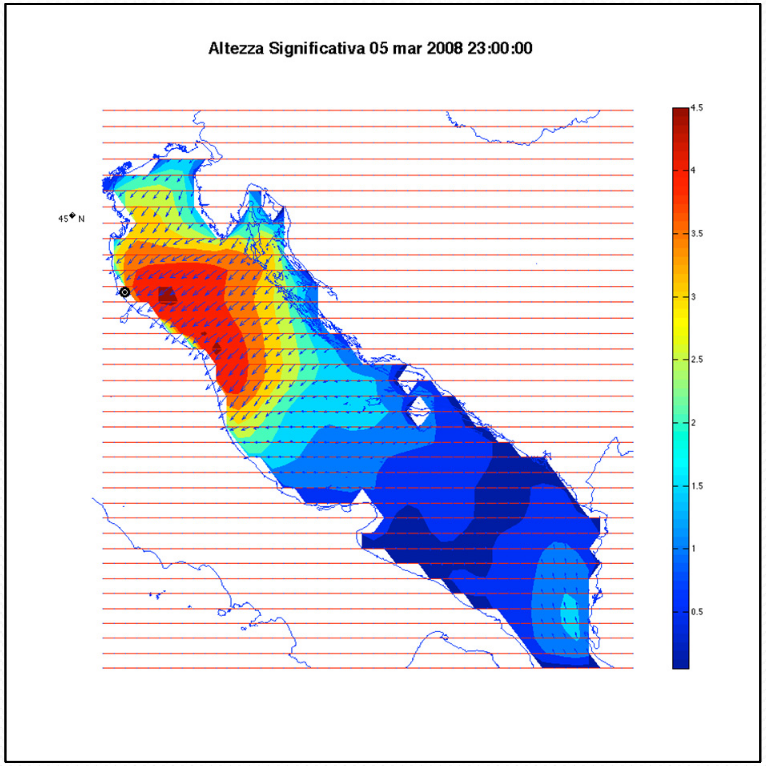
Sea storm event on 5 March 2007

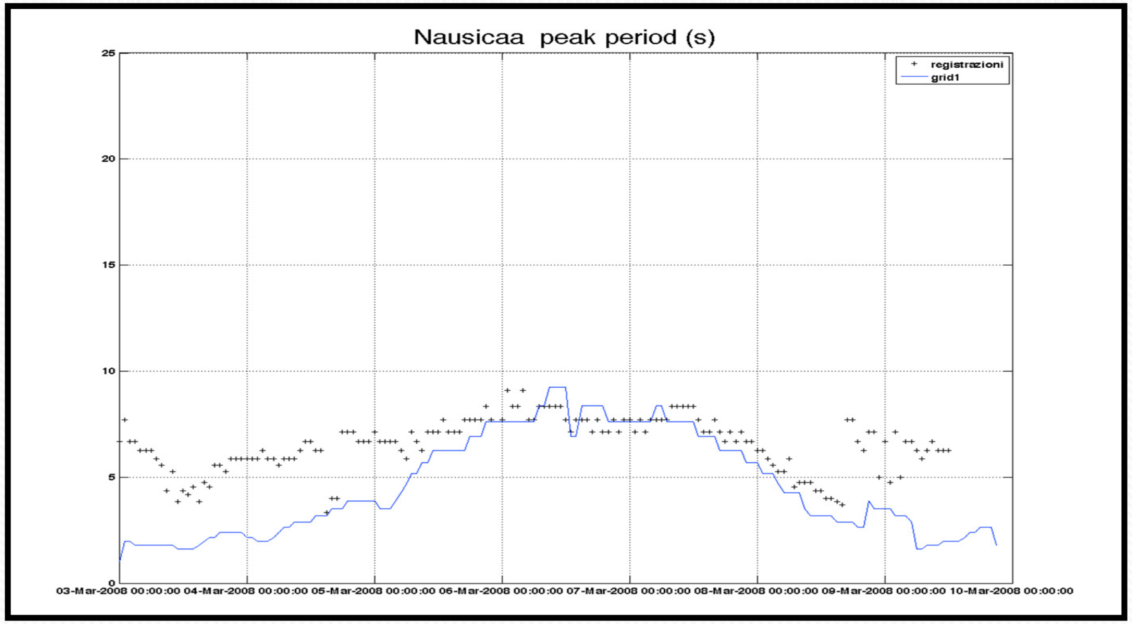


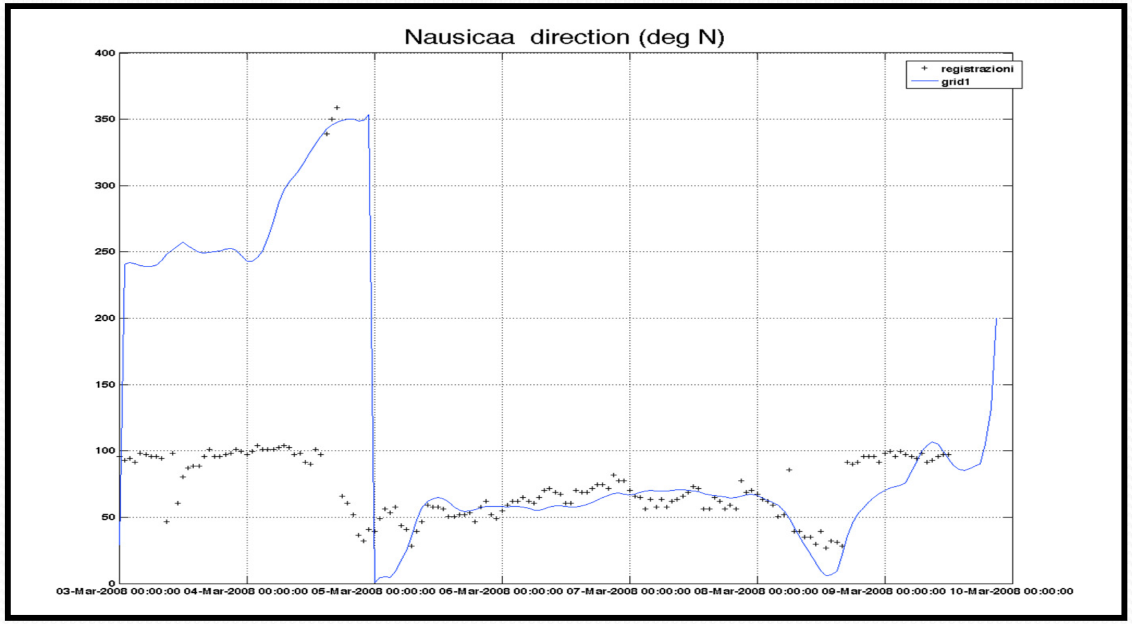




Sea storm event on 5 March 2007

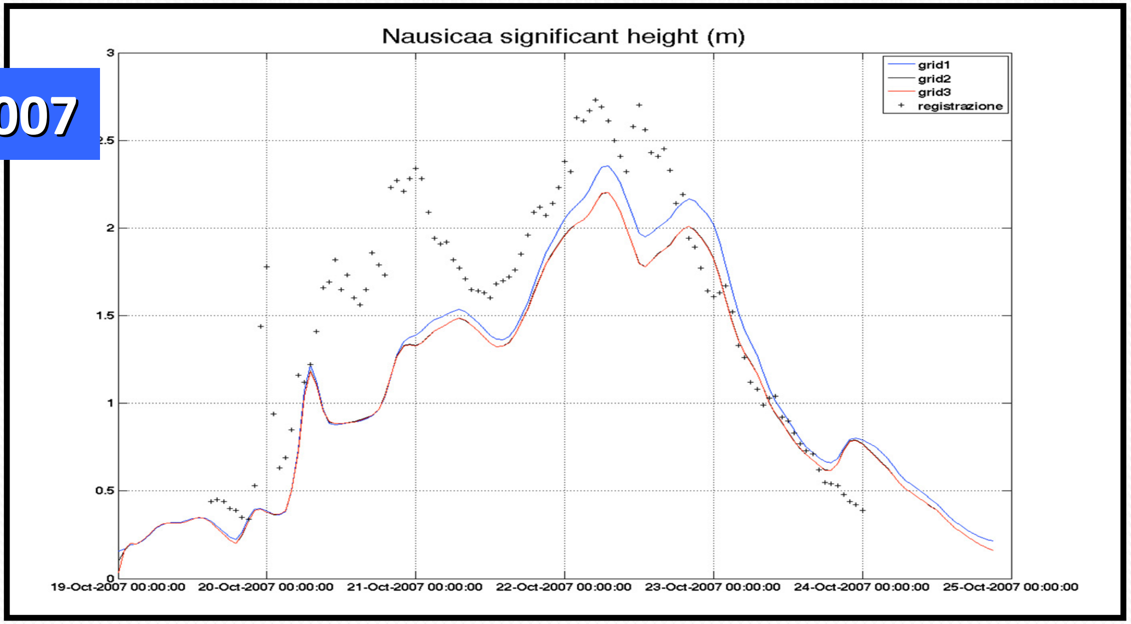


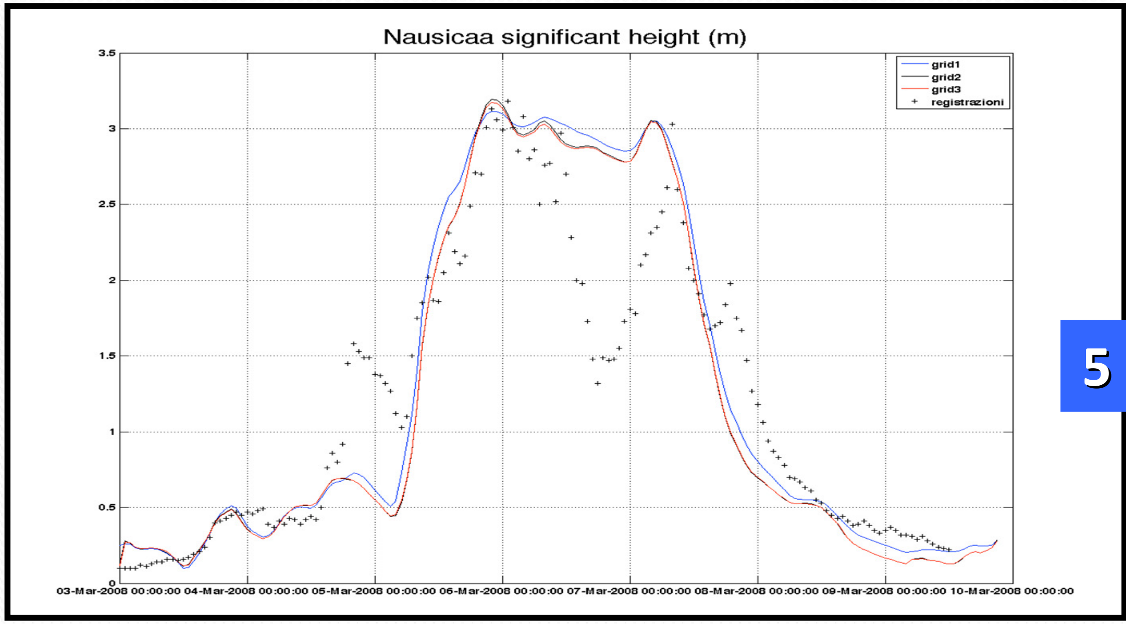




Nesting over the very-high resolution grid

22 October 2007





5 March 2008

Forecast verification is an essential component of any scientific forecasting system (Murphy and Winkler, 1987), it provides *a posteriori* evaluation of how qualitative and valuable is the forecast *f* (**predictor**) with respect to the corresponding observation *o* (**predictand**).

What are we actually comparing?

A **numerical approximation** of the atmosphere
(areal mean quantities)

vs.

a **good estimation** of the "true" weather state
(e.g., point measurements from *standard* network)

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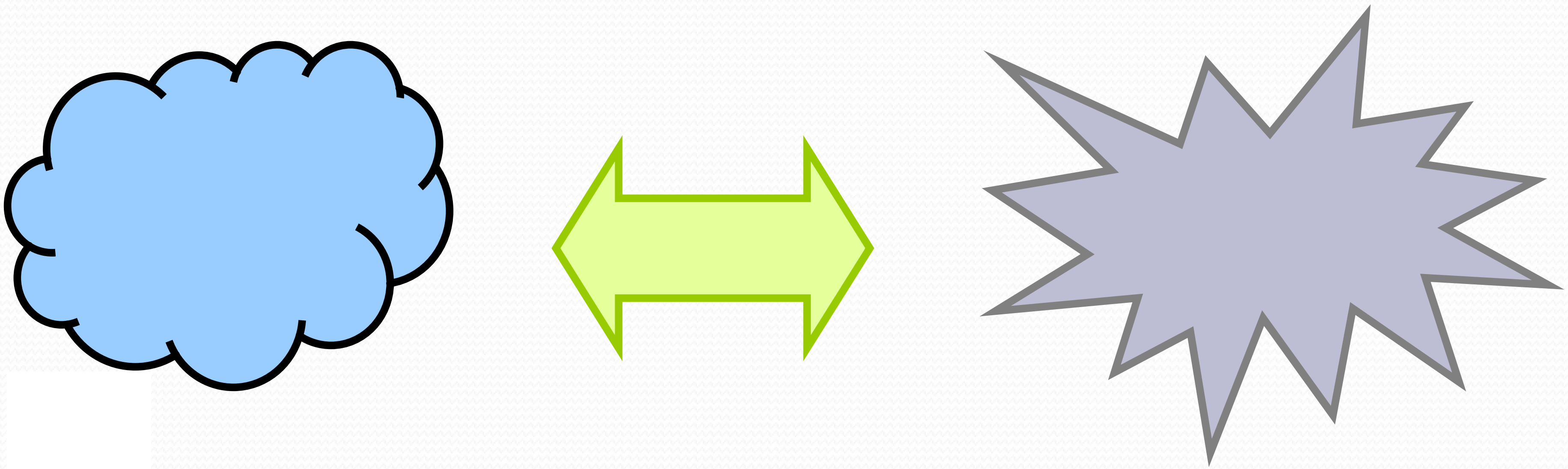


LAM Verification

- The representativeness of the fields compared (**obs. *vs.* forecasts.** & **obs. *vs.* "competing" forecasts**) need to be addressed before applying any kind of forecast verification (e.g., Göber 2008; Lanciani et al. 2008; Chèruy et al. 2004).

- For a fair comparison, both observations and forecasts need to be optimally interpolated (**remapping *vs.* bilinear interpolation**; **observational analysis**) at the same scale (e.g., Accadia et al. 2003; Lanciani et al. 2008; Baldwin 2000; Barnes 1964).

- Several forecast verification methods (for **administrative**, **economic** and **scientific** tasks):

  - **Subjective:**

1) eyeball comparisons (maps & time series; Speranza et al. 2007) in order to provide a physical interpretation of the quantitative verification findings;

2) qualitatively check of the impact of initialization on model error growth; etc.

  - **Objective:**

1) comparison of "competing" forecasts by means of scores and skill scores (BIAS, ETS, HK, FAR, etc.) in order to measure point-to-point matching w.r.t. to given thresholds (e.g., Accadia et al. 2005, Mariani et al. 2005);

2) providing confidence intervals to score differences by applying hypothesis tests (e.g., bootstrap resampling method; see Accadia et al. 2003);

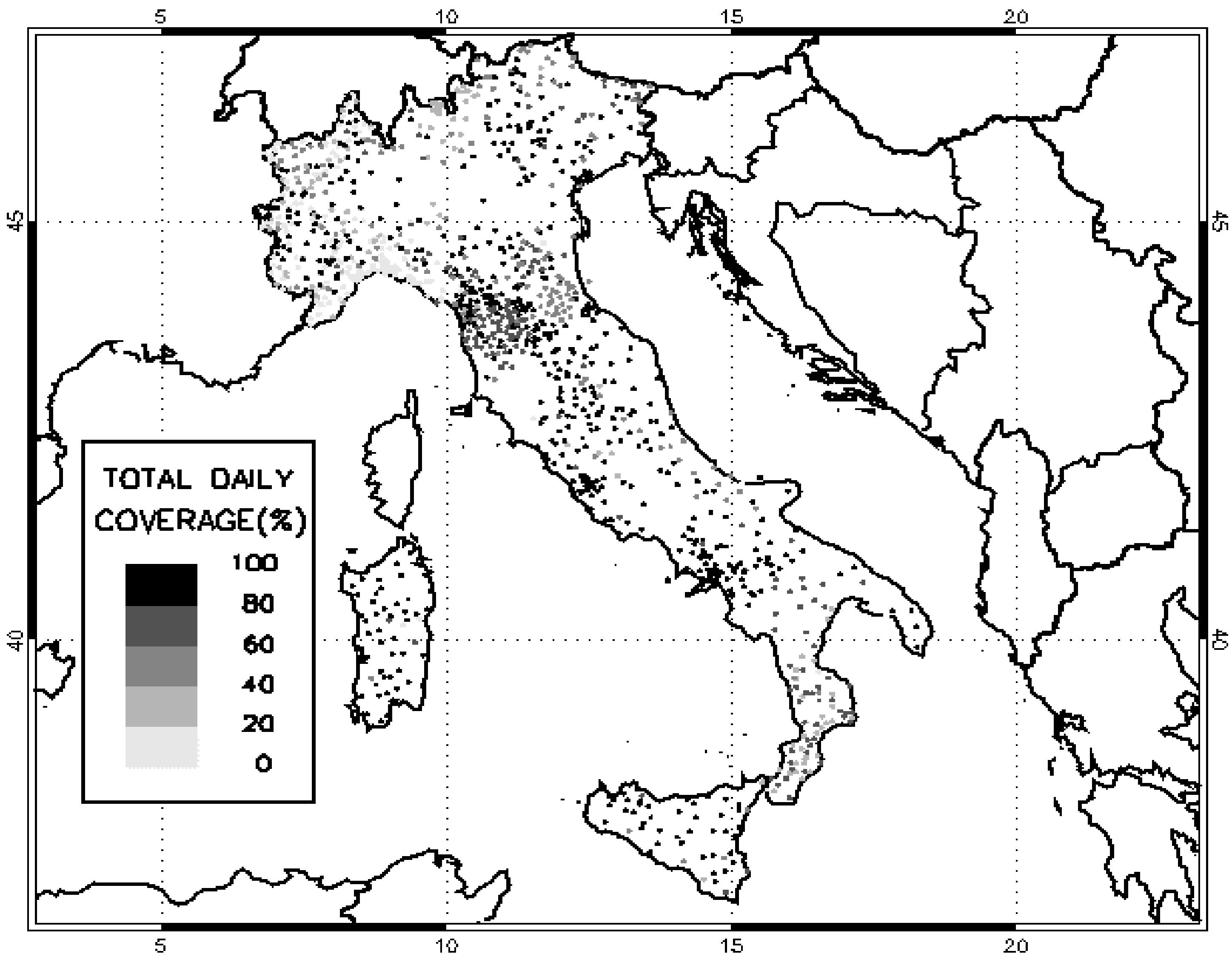
3) use of object-oriented method (e.g., the contiguous rain area analysis; CRA) to quantify the forecast horizontal displacement (Mariani et al. 2008, 2009; Tartaglione et al. 2005).

BOLAM QPF verification: October 2000 – October 2002

More than **1500** rain gauge stations over Italy.

Stations from:

- ex SIMN network
- Regional networks
    - ❖ Emilia Romagna
    - ❖ Piemonte
    - ❖ Liguria
    - ❖ Valle d'Aosta
    - ❖ Marche
    - ❖ Sicilia
    - ❖ Sardegna



Categorical score approach

Contingency table of possible events for a selected threshold.

		Rain observed	
		Yes	No
Rain forecast	Yes	a	b
	No	c	d

Categorical scores & skill scores
Wilks, 1995; Schaefer, 1990; Stephenson, 2000; Hanssen and Kuipers, 1965; and Murphy, 1990 (→ Dimensionality)

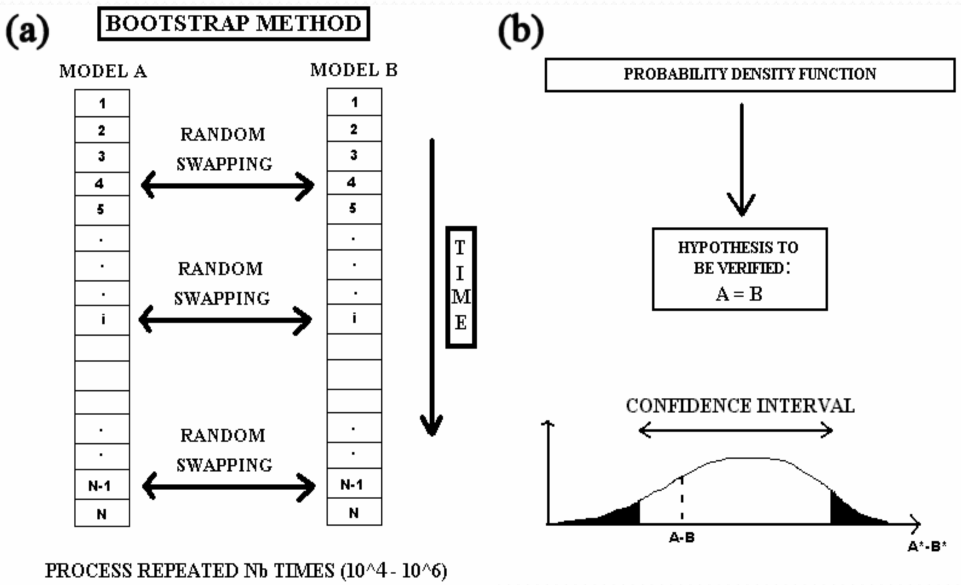
Contingency Table

$$\mathrm{BIA} = \frac{a+b}{a+c}$$

$$\mathrm{ETS} = \frac{a-a_r}{a+b+c-a_r} \quad \text{with} \quad a_r = \frac{(a+b)(a+c)}{a+b+c+d}$$

$$\mathrm{HK} = \frac{(ad-bc)}{(a+c)(b+d)} = \mathrm{POD} - \mathrm{F} = \frac{a}{a+c} - \frac{b}{b+d}$$

$$\mathrm{ORSS} = \frac{\mathrm{ODDS}-1}{\mathrm{ODDS}+1} = \frac{ad-bc}{ad+bc} \quad \text{where} \quad \mathrm{ODDS} = \frac{ad}{bc}$$

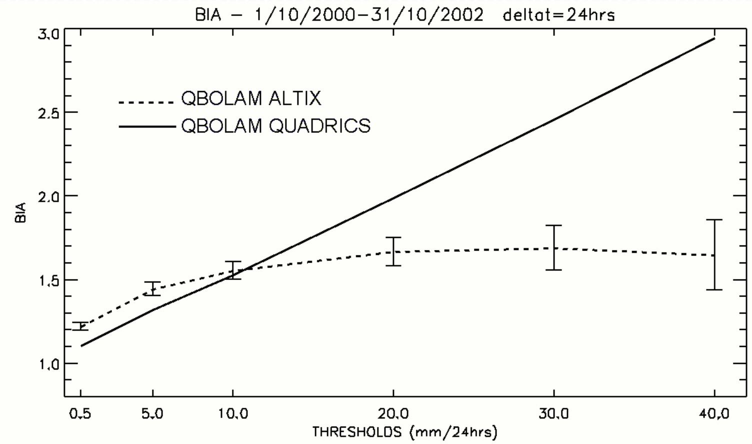


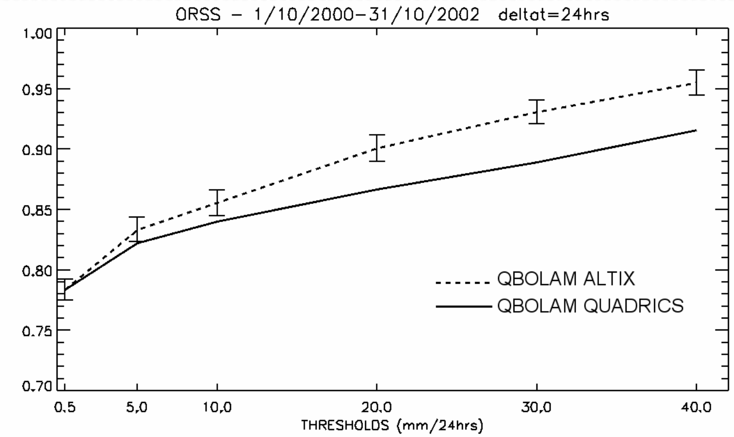
Confidence intervals on skill scores
→Bootstrap
(Diaconis and Efron, 1983; Hamill, 2000)

ETS and HK sensitivity to the (frequency) BIAS values
→ BIAS adjustment (Hamill, 1999)

QBOLAM Altix vs. QBOLAM Quadrics: Oct. 2000 – Oct. 2002

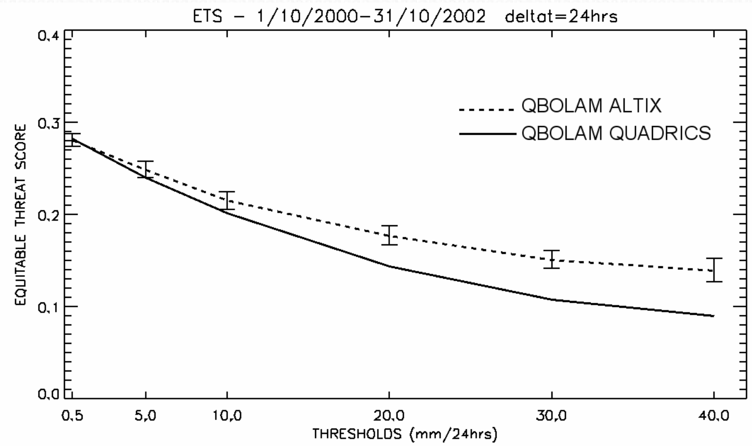
BIAS

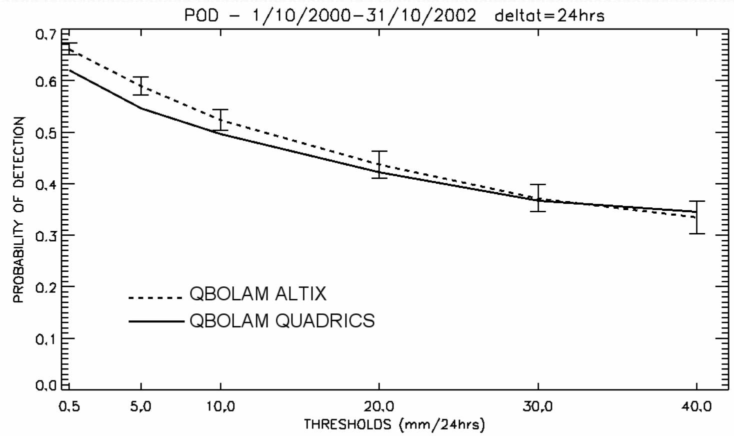




ORSS

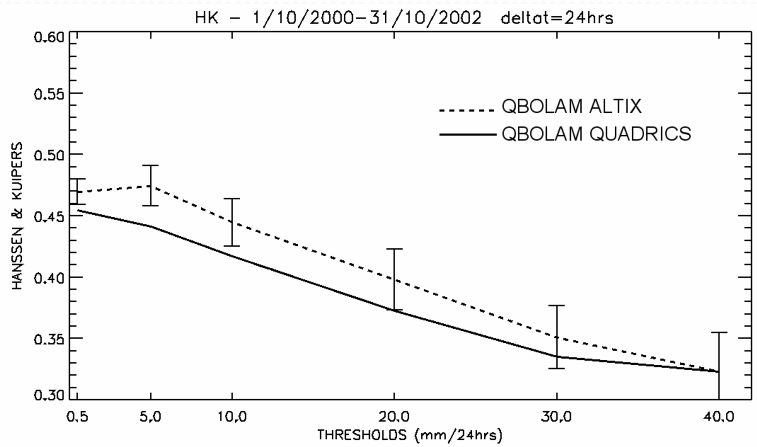
ETS

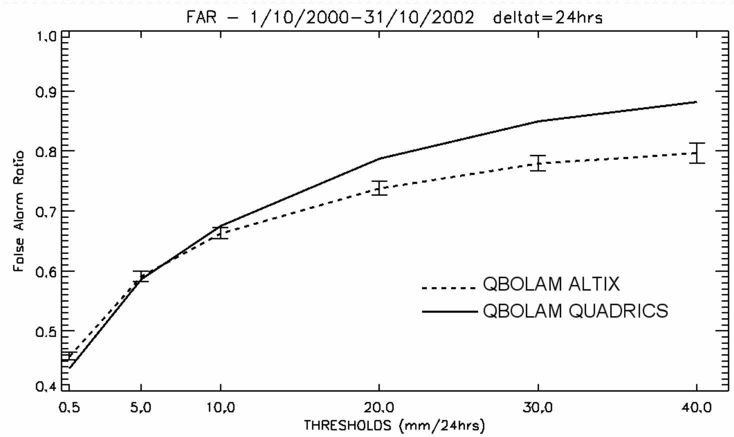




POD

HK

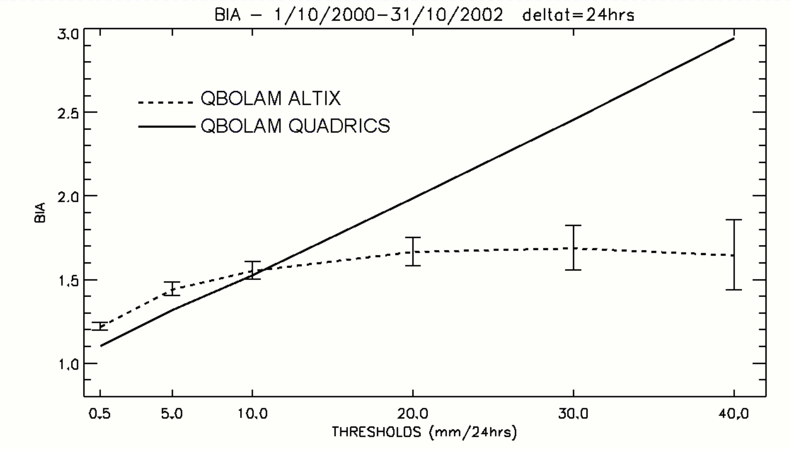




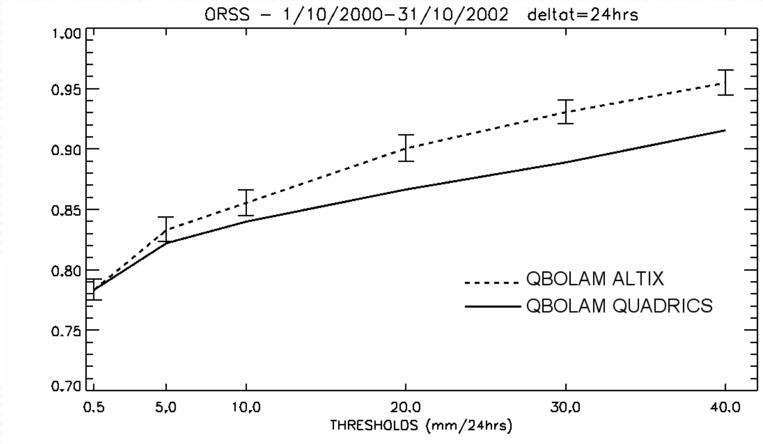
FAR

QBOLAM Altix vs. QBOLAM Quadrics: Oct. 2000 – Oct. 2002

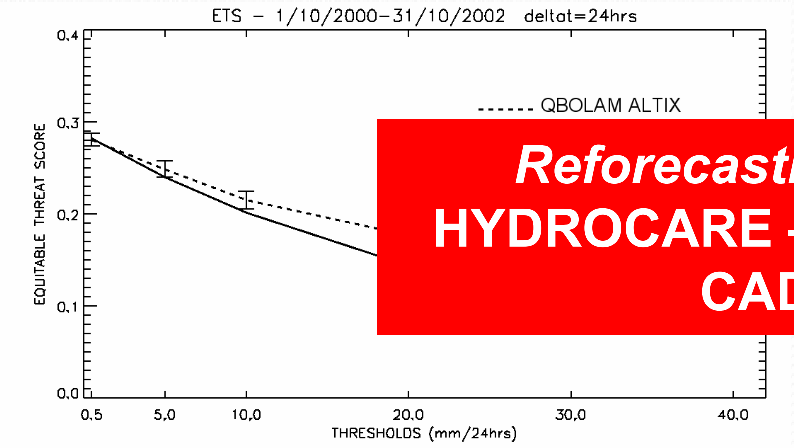
BIAS



ORSS

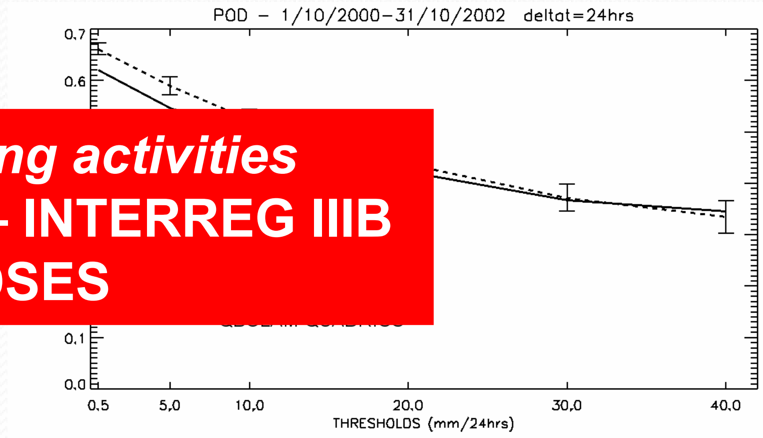


ETS

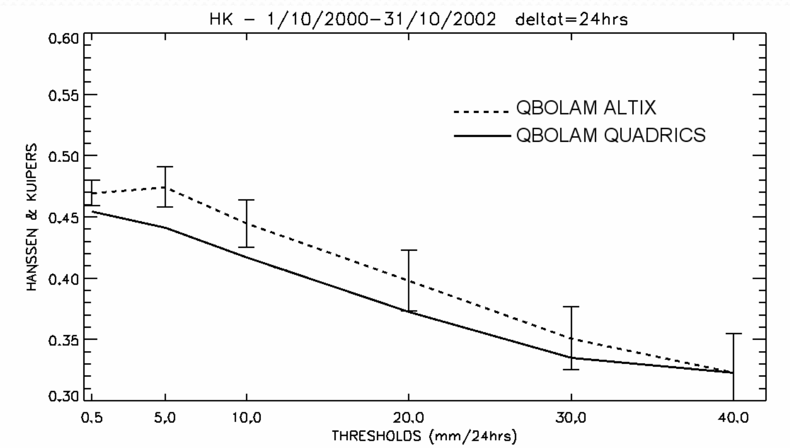


Reforecasting activities
HYDROCARE – INTERREG IIIB CADSES

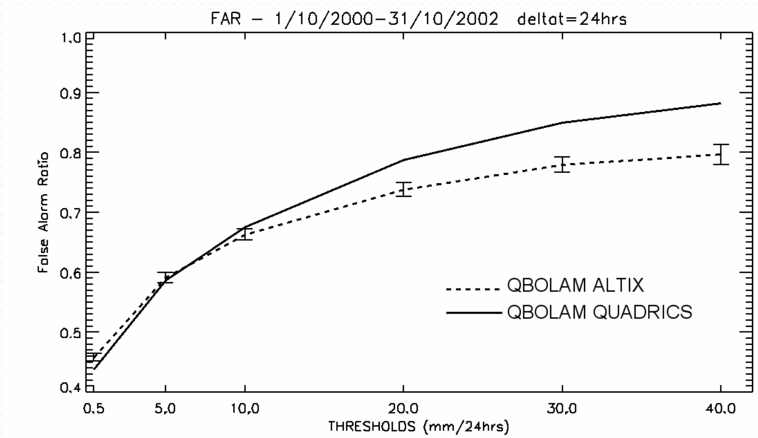
POD



HK

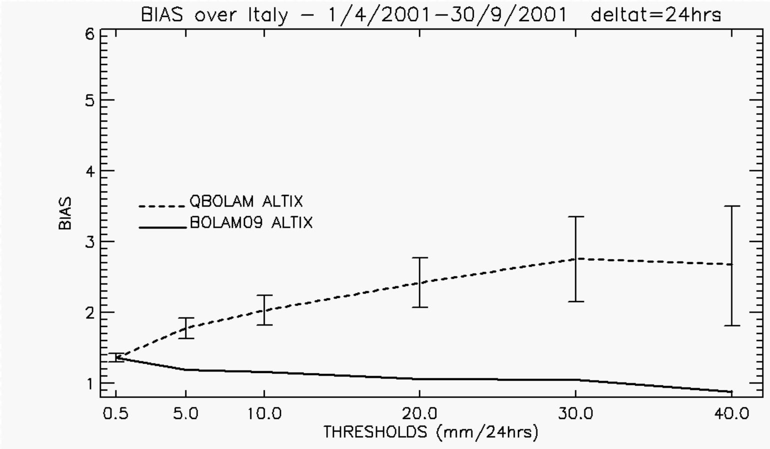


FAR

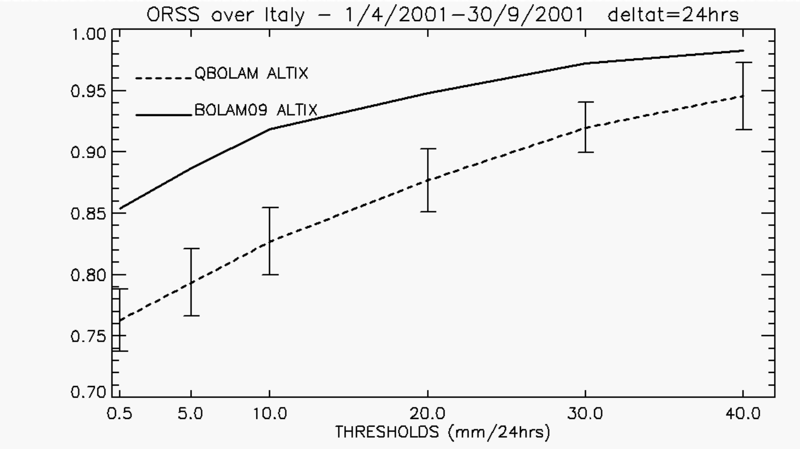


BOLAM09 Altix vs. QBOLAM Altix: Apr. 2001 – Sep. 2001

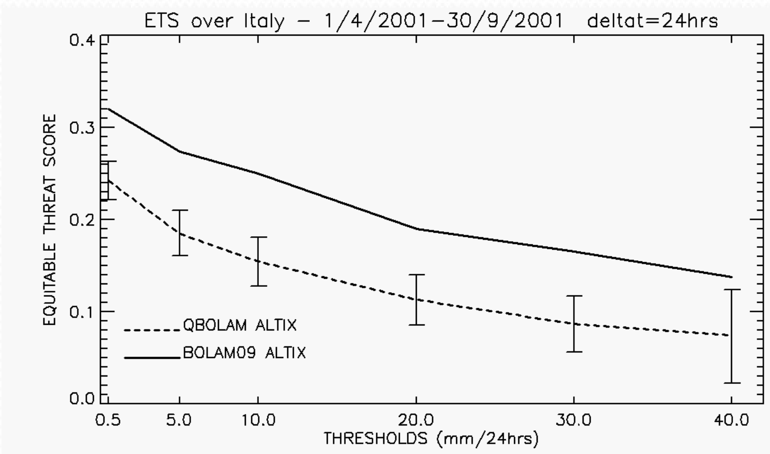
BIAS



ORSS



ETS



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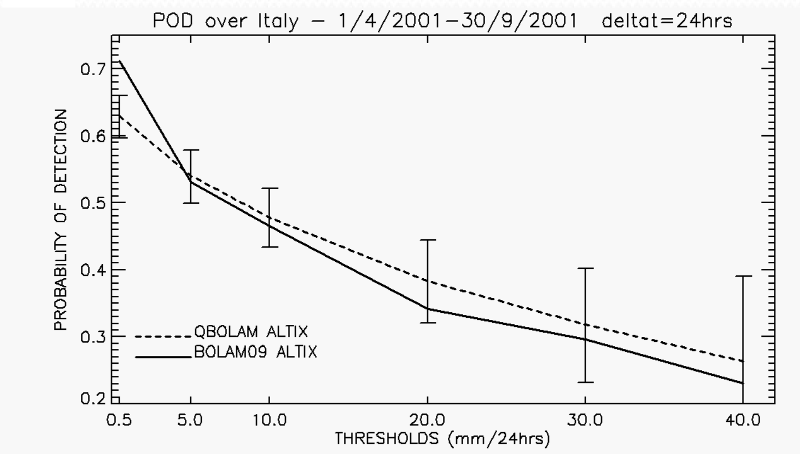
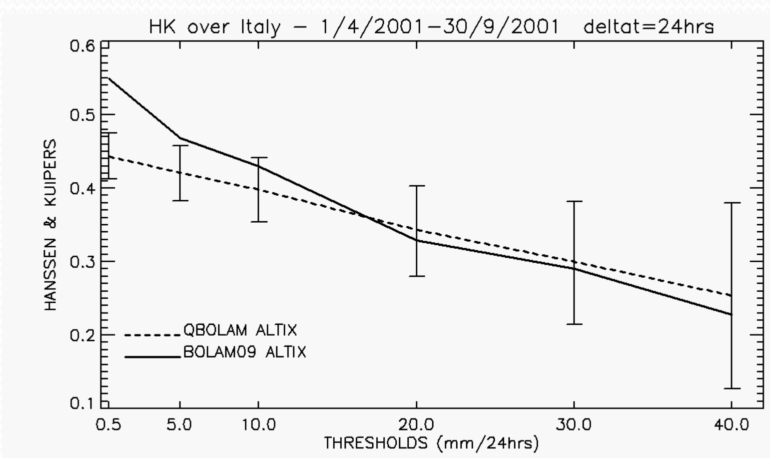


HK



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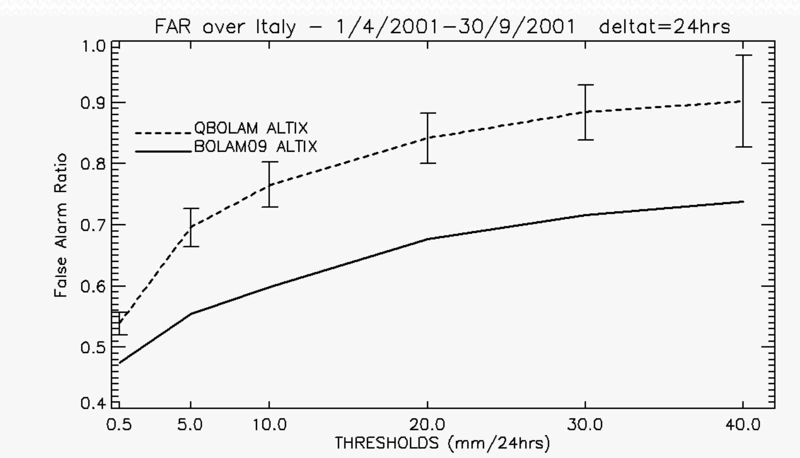


How to take into account the BIAS differences?
→The BIAS adjustment procedure

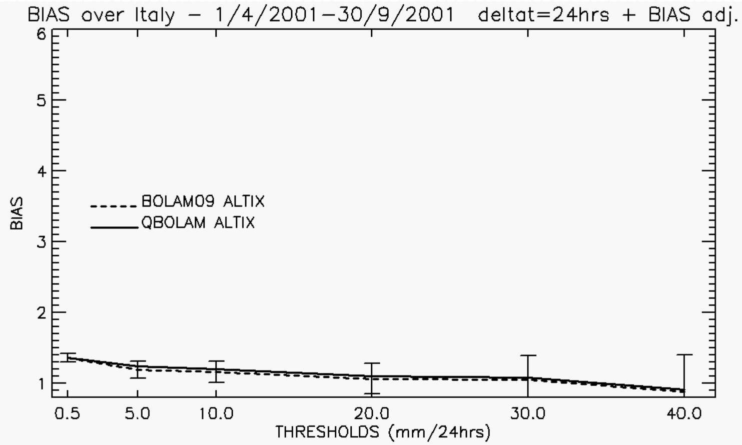
When evaluating the performance of competing models ("competitor" & "reference"), attention should be given to the differences in the BIAS values.

Relative high differences in BIAS among competing models may result in an erroneous or ambiguous evaluation of the scores differences.
The BIA adjustment procedure (Hamill, 1999) proposes the introduction of forecast thresholds (≠ *obs. thresholds*) to get similar BIAS (i.e., $|BIAS_r - BIAS_c| \leq \varepsilon$) for the competing models and to determine the effect of BIAS differences on categorical scores.

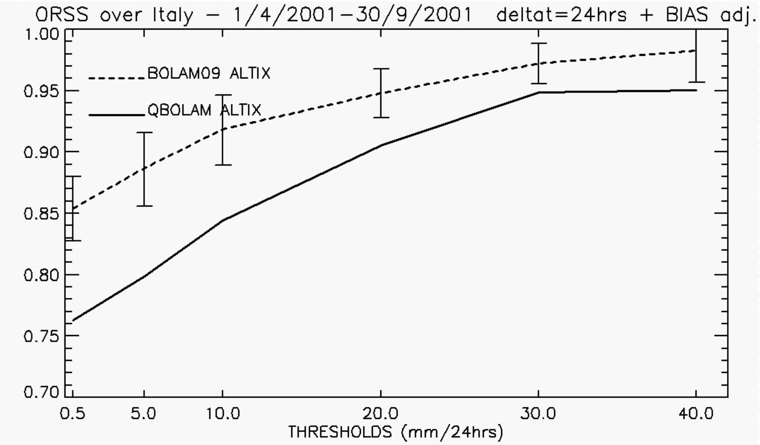
→ Contingency tables of the competitor model are re-calculated by adjusting the forecast threshold, while maintaining unchanged the observation threshold unchanged.

BOLAM09 Altix vs. QBOLAM Altix w. BIAS adj.

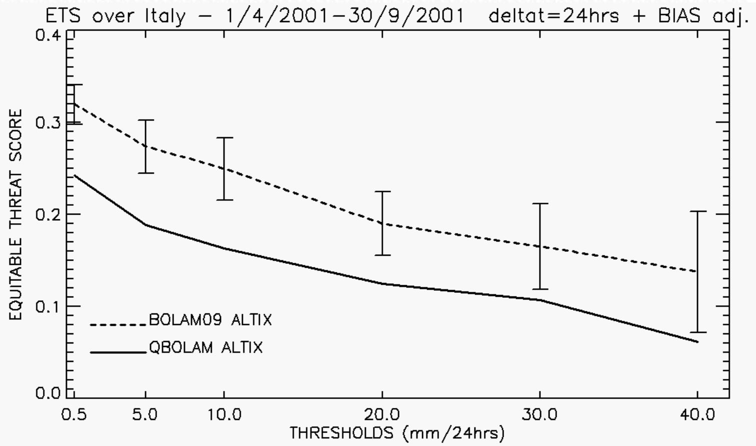
BIAS



ORSS



ETS



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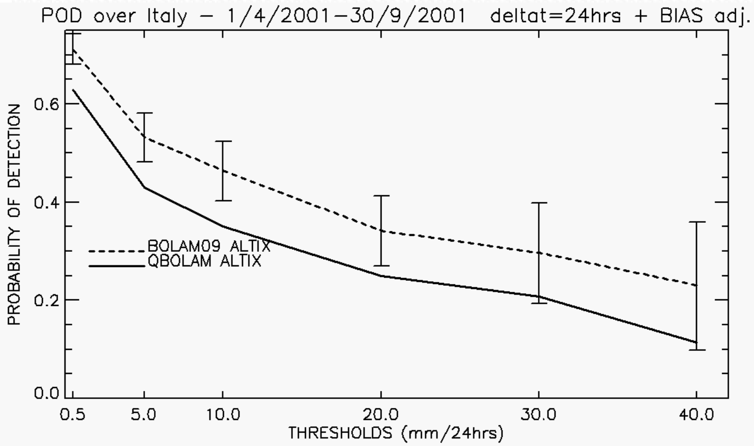

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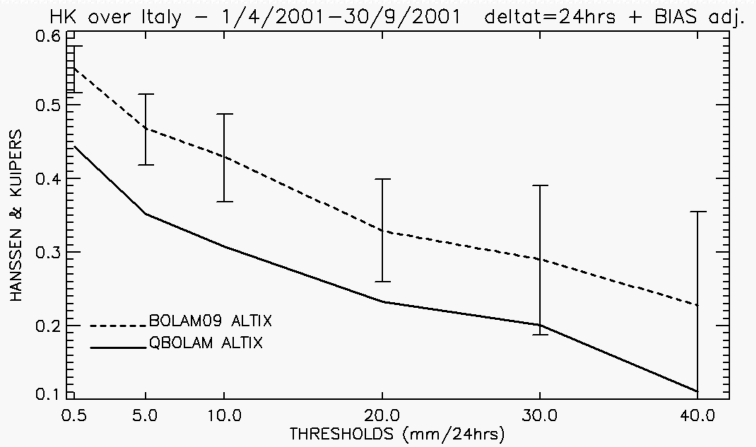

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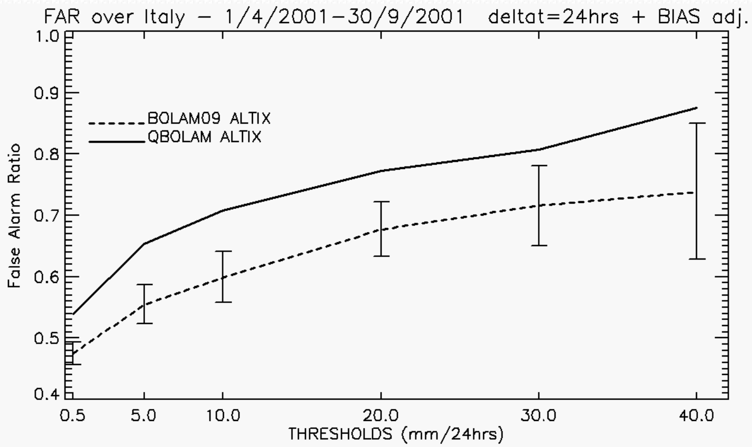
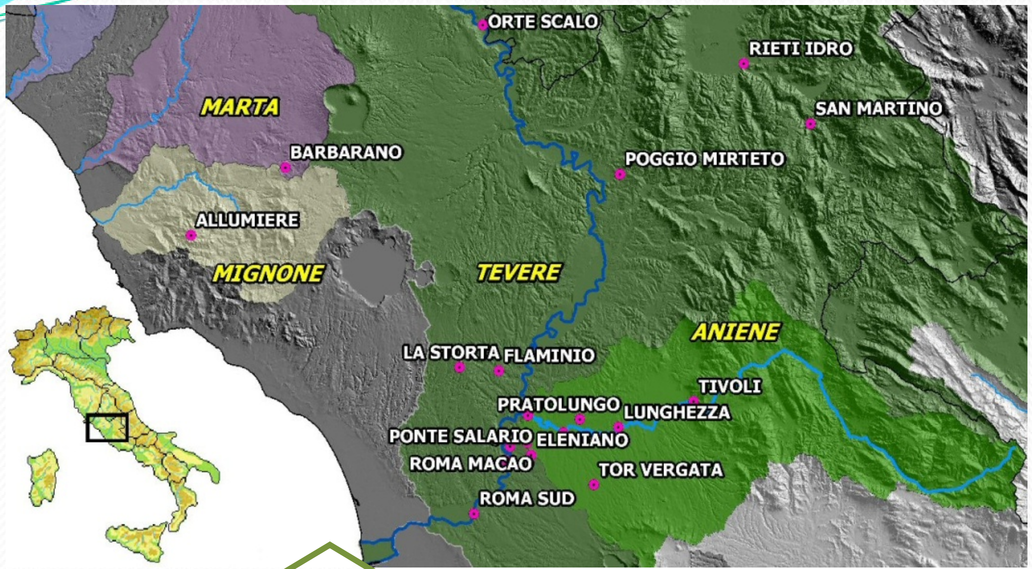
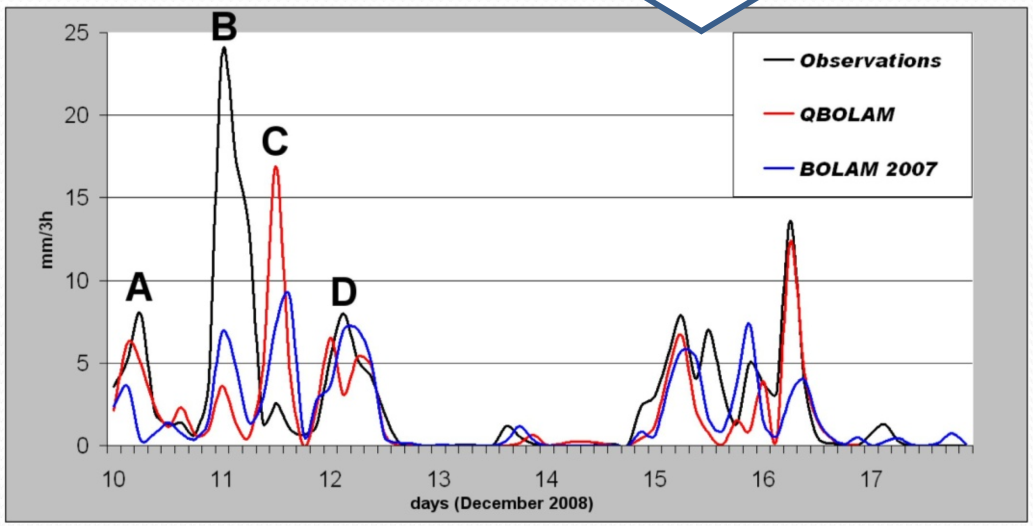


The Dec. 2008 "Tiber" event: qualitative verification



Location of rain gauges

Average rainfall time series



- Intense rainfall over low Tiber valley on 10-12 December 2008 resulted in one casualty and relevant damages.
- W.r.t. QBOLAM, BOLAM produces a better forecast, even if not completely satisfactory: the rainfall peak **B** was underestimated and a major rainfall peak **C** was predicted 12h later.
- This weather system, displaying strong interaction with local features, is hard to be forecast by LAMs.
- METEOSAT water-vapor imagery can be useful to identify the error (sources) in forecasting the Mediterranean cyclone responsible for the event.

M. Casaioli, B. Lastoria, S. Mariani, and M. Bussettini, 2010: Evaluating the improvements of the BOLAM model of the ISPRA Sistema Idro-Meteo-Mare on the December 2008 flood event in Rome. *Adv. Geosci.*, 25, 135–141.

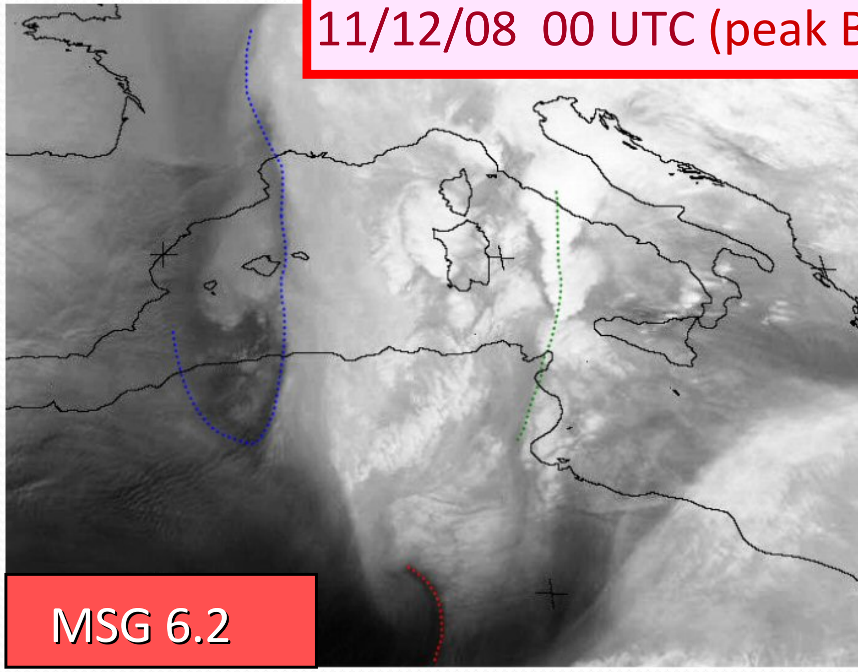
Pseudo-water vapor qualitative model verification

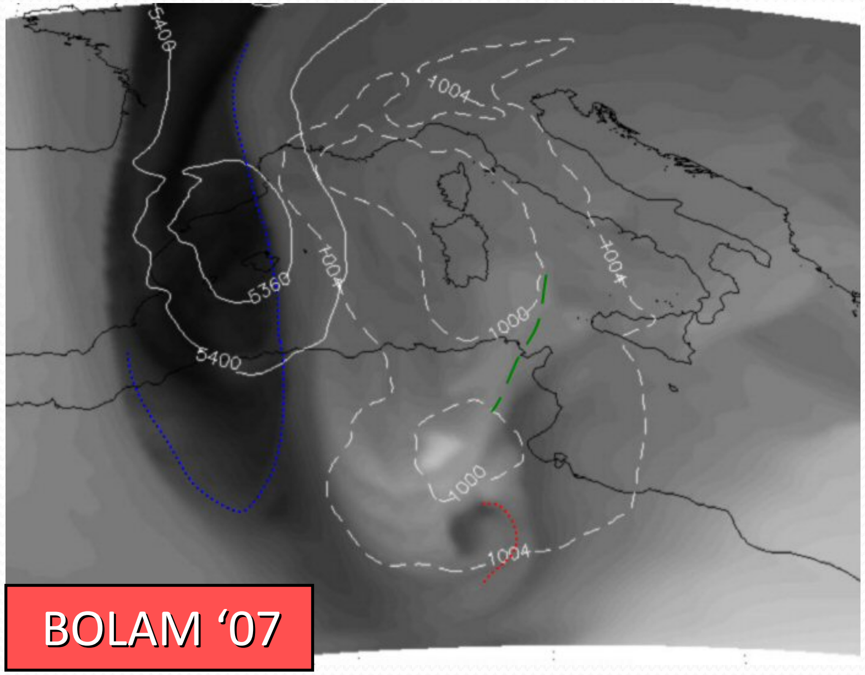
METEOSAT water-vapor imagery can be compared to a synthetic model field (pseudo-water vapor) and employed to identify the structural element connected to cyclone evolution and the formation of mesoscale precipitating systems.

In our case, the peak **B** is connected to the formation of a squall line in the middle of the warm sector (dashed green line).
The black tongue (high-potential vorticity air intrusion) is suitable to check the position and development of the cyclone (dotted blue line).
The secondary minimum (dotted red line) plays also a role in producing the event.

The forecast image evidences an error in the position of the secondary minimum and an insufficient development of the squall line (white + no clouds = moist air ascent) which nevertheless is at least partly reproduced (it was completely absent in the old model version's forecast).

11/12/08 00 UTC (peak B)





That's all folks!

Thanks for your kind attention.