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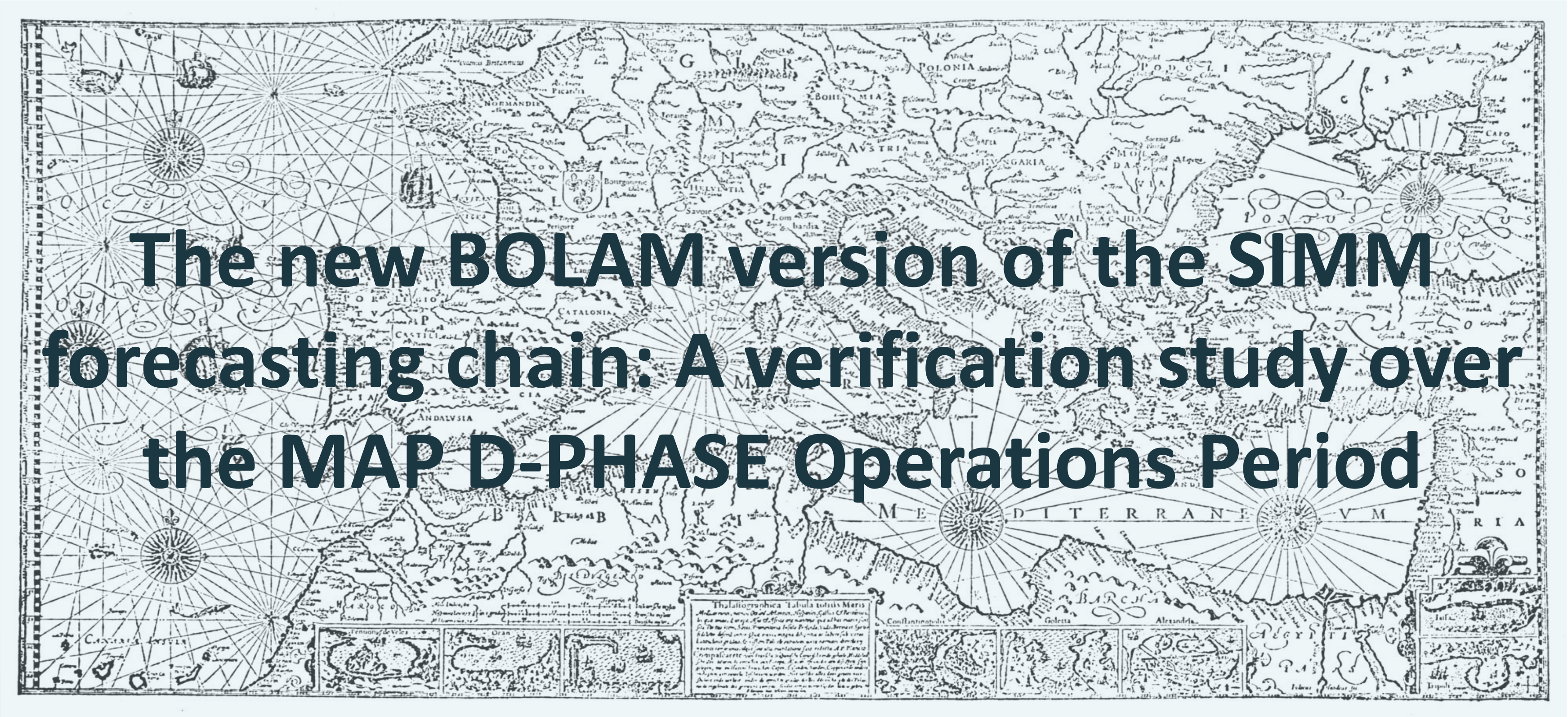


The new BOLAM version of the SIMM forecasting chain: A verification study over the MAP D-PHASE Operations Period

Stefano Mariani and Marco Casaioli

Institute for Environmental Protection and Research (ISPRA)
Rome, Italy

Presentation Outline

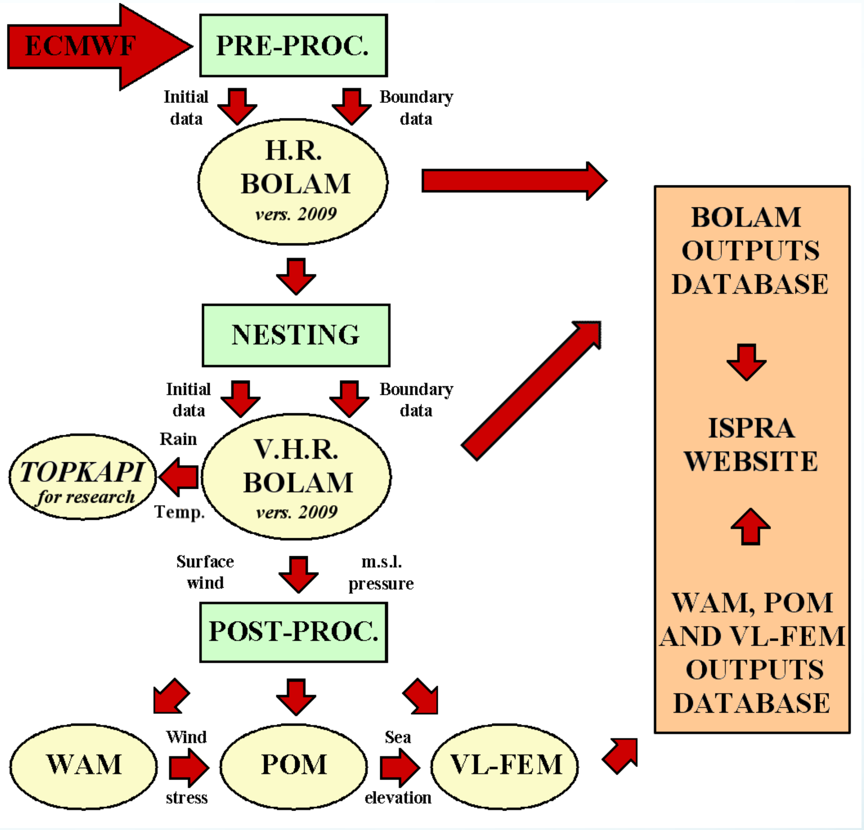
- The Hydro-Meteo-Marine forecasting system at the Italian Institute for Environmental Protection and Research (ISPRA, Rome)
- Recent SIMM development, including updated parallel BOLAM meteorological model
- Verification of the new BOLAM's precipitation forecast over the MAP D-PHASE DOP (June-November 2007) period: methodology, experiment and dataset
- Verification results*
- Conclusions*
- Future work

** Up to now… …it's a work in progress!*

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

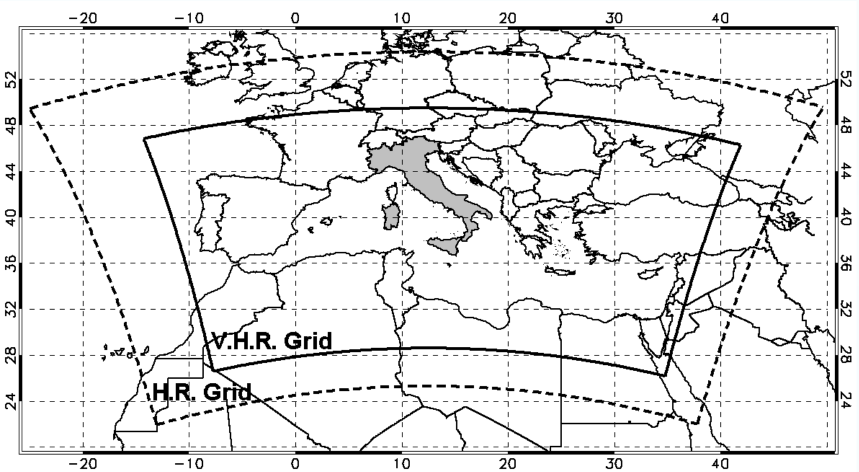
- Developed (end of '90s) in the framework of a cooperation with DSTN, CNR, ENEA;
- BOLAM: 10-km hydrostatic LAM;
- Wave model (WAM) on Mediterranean Sea and sea elevation model on Ionian/Adriatic seas (POM) and Venice Lagoon (VL-FEM);
- TOPKAPI distributed rainfall/runoff model over two Italian river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



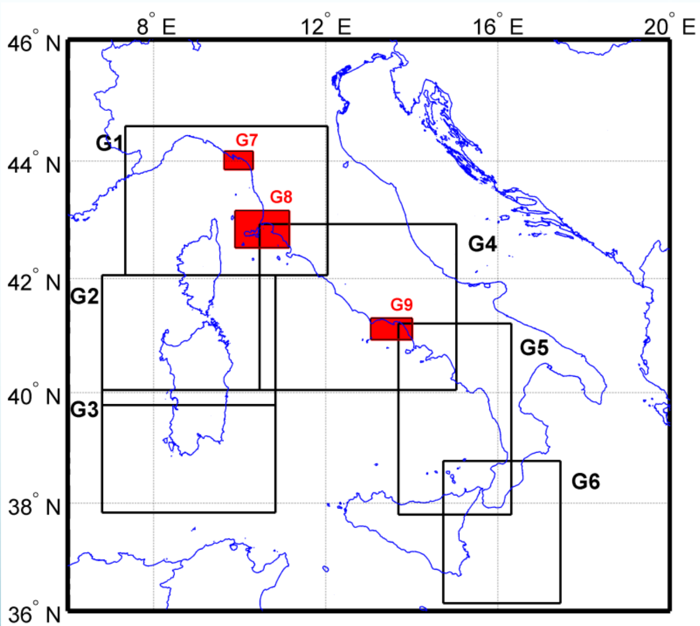
"SIMM produced the first systematic, integrated hydro-meteorological and sea-state forecasts over the entire Mediterranean area, bridging from planetary to local scales of atmospheric motion" (Speranza et al, 2007)

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 the SGI Altix, implementation of the Kain-Fritsch convection scheme in a research configuration → ***reforecasting activity***;
- 2009-11: parallelization of the up-to-date BOLAM version and implementation into the SIMM chain (in collaboration with ISAC-CNR)
- **Ongoing**: implementation of coastal wave forecasting system (SWAN model) on 6 selected areas; parallel WAM
- **Forecoming**: higher-resolution BOLAM and WAM, 3D POM over Thyrrenian Sea



BOLAM nested domains: 0.3° (father) and 0.1° (son)



SWAN areas

QBOLAM *vs.* BOLAM 2011

QBOLAM		BOLAM 2011
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
bulk	Large scale precipit.	Schultz microphysics
Page	Radiation	Geleyn + Morcrette
Monin-Obukhov	Surface layer	Monin-Obukhov
Louis (*O(1)*)	Vertical diffusion	E-*l* (*O(1.5)*)
bulk (2 levels +1)	Soil	FAO landuse, icing (3 levels +1)

Future improvements ► increasing res. (up to 6/7 km); domain ext.; forecast time

► Coupling with new/higher resolution marine models

BOLAM Verification

- Since 2000, several verification studies have been performed to assess the performance of the SIMM meteorological and marine forecasts.

- The present work focuses on a intercomparison between QPFs from the QBOLAM (KF-) version available during the MAP D-PHASE Operations Period (Jun.-Nov. 2007) and the corresponding QPFs obtained from BOLAM 2011 through a *reforecasting* campaign.

- A combined (multi-scale, objective and subjective) approach has been applied:

  - For a *fair* comparison, observations and forecasts need to be optimally interpolated at the same scale → observational analyses using a **two-pass Barnes** (1964) analysis & forecasts post-processed using **remapping** when compared over coarser verification grids (e.g., Accadia et al. 2003; Lanciani et al. 2008; Baldwin 2000).

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

  - **Subjective**: **eyeball comparisons** (maps & time series) to provide a physical interpretation of the quantitative verification findings.

  - **Objective**: **scores** and **skill scores** (BIAS, ETS, HK, FAR, etc.) comparison to measure point-to-point matching w.r.t. given thresholds (e.g., Accadia et al. 2005, Mariani et al. 2005), with confidence intervals to score differences through a **bootstrap**-based hypothesis tests (see, e.g., Accadia et al. 2003); **ROC** curves.

  - **Object-oriented/spatial methods** (e.g., CRA analysis) on case studies to quantify the forecast displacement (Mariani et al. 2008, 2009; Tartaglione et al. 2005) – *not addressed here*.

Categorical score approach

Contingency table of possible events for a selected threshold.

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

Contingency Table

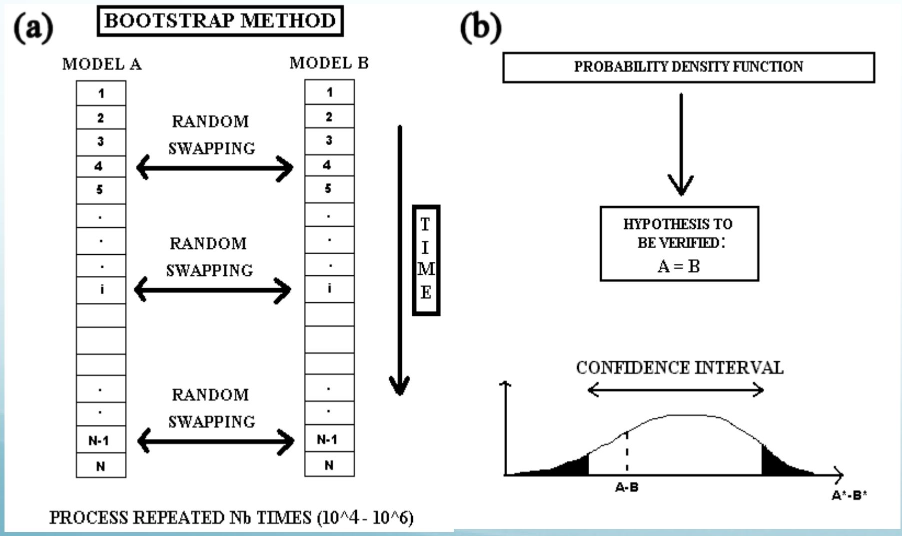
Categorical scores & skill scores
Wilks, 1995; Schaefer, 1990; Stephenson, 2000; Hanssen and Kuipers, 1965; and Murphy, 1990 (→ Dimensionality)

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

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

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

$$\mathbf{ORSS} = \frac{\mathbf{ODDS}-1}{\mathbf{ODDS}+1} = \frac{ad-bc}{ad+bc} \quad \textbf{where} \quad \mathbf{ODDS} = \frac{ad}{bc}$$



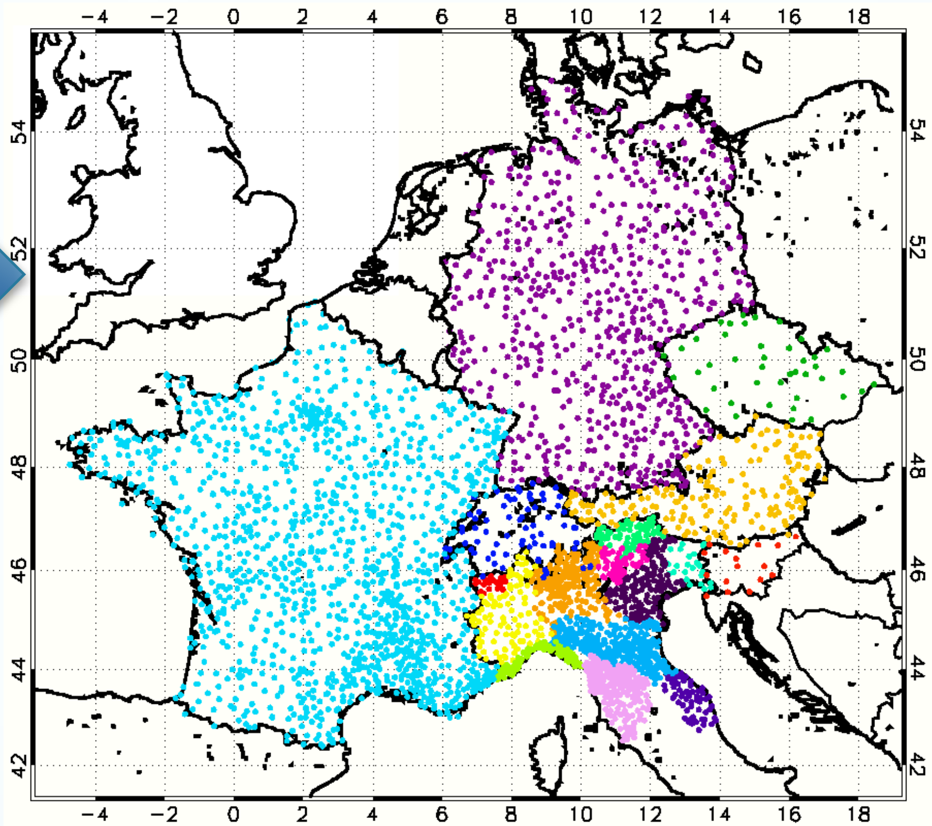
Confidence intervals on skill scores
→ Bootstrap
(Diaconis and Efron, 1983; Hamill, 2000)

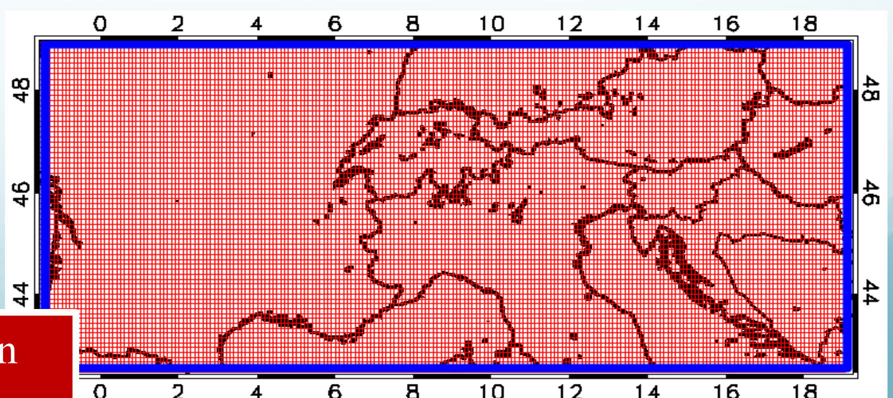
ETS and HK sensitivity to the (frequency) BIAS values
→ BIAS adjustment (Hamill, 1999) – *not addressed here*

Rain gauge dataset from MAP D-PHASE Operations Period (DOP)

- Austria: ZAMG
- Czechs Republic: CHMI
- France: Météo France
- Germany: DWD
- Italy:
  - Region Valle d’ Aosta
  - Autonomous Province of Bolzano
  - ARPA Emilia Romagna (COSMO dataset)
  - OSMER – ARPA Friuli Venezia Giulia
  - ARPA Liguria
  - ARPA Lombardia
  - Region Marche – Dept. Civil Protect.
  - ARPA Piemonte (COSMO dataset)
  - Autonomous Province of Trento
  - ARPA Veneto
  - Region Tuscany – Dept. Civil Protect. / LAMMA (no MAP D-PHASE dataset)
- Slovenia: EARS
- Switzerland: MeteoSwiss

ca. 3900





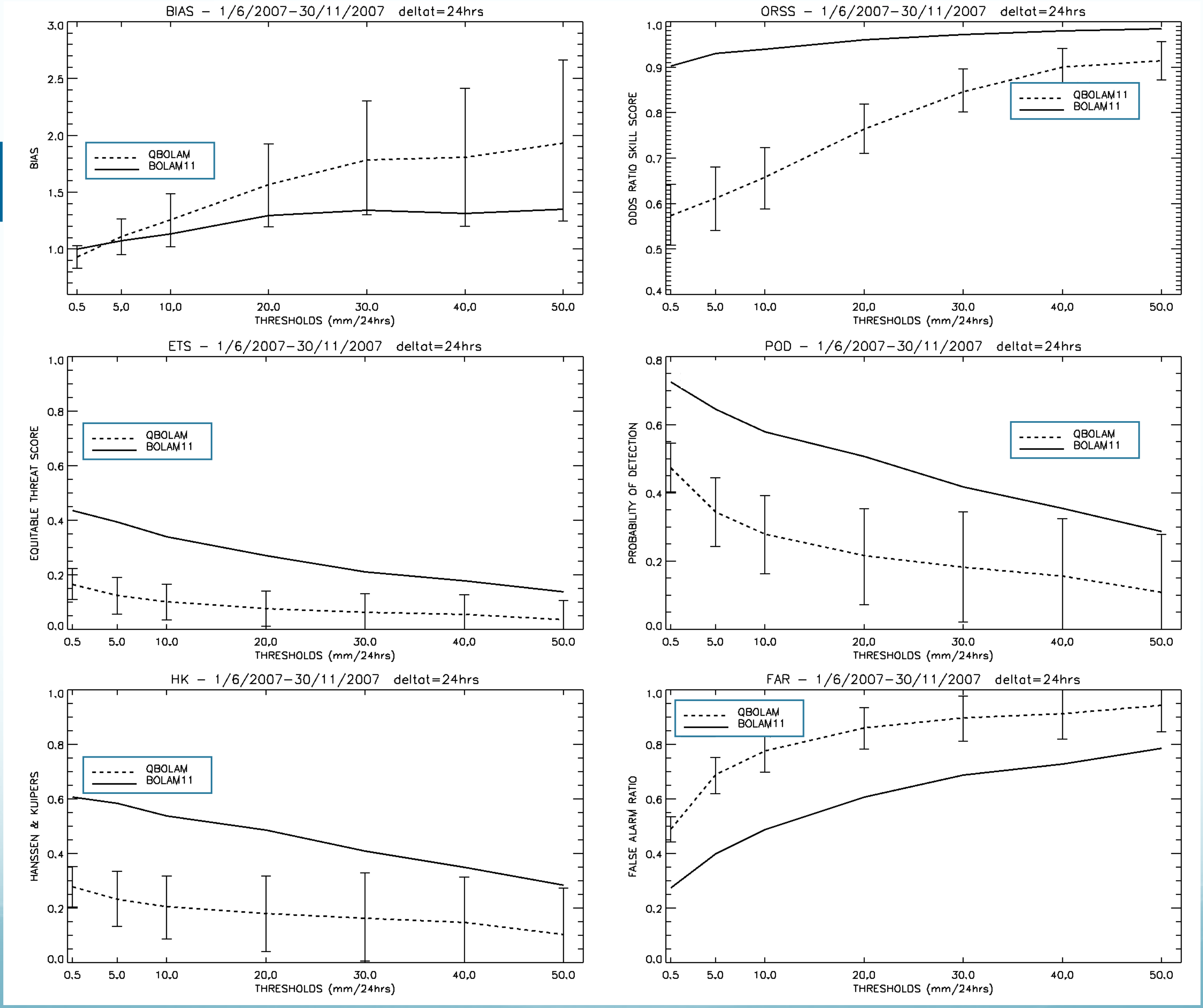
Verification domain

BOLAM 2011 vs. QBOLAM Altix-KF: DOP (Jun.-Nov. 2007) Categorical skill scores – 0.1° grid

BIAS

ETS

HK

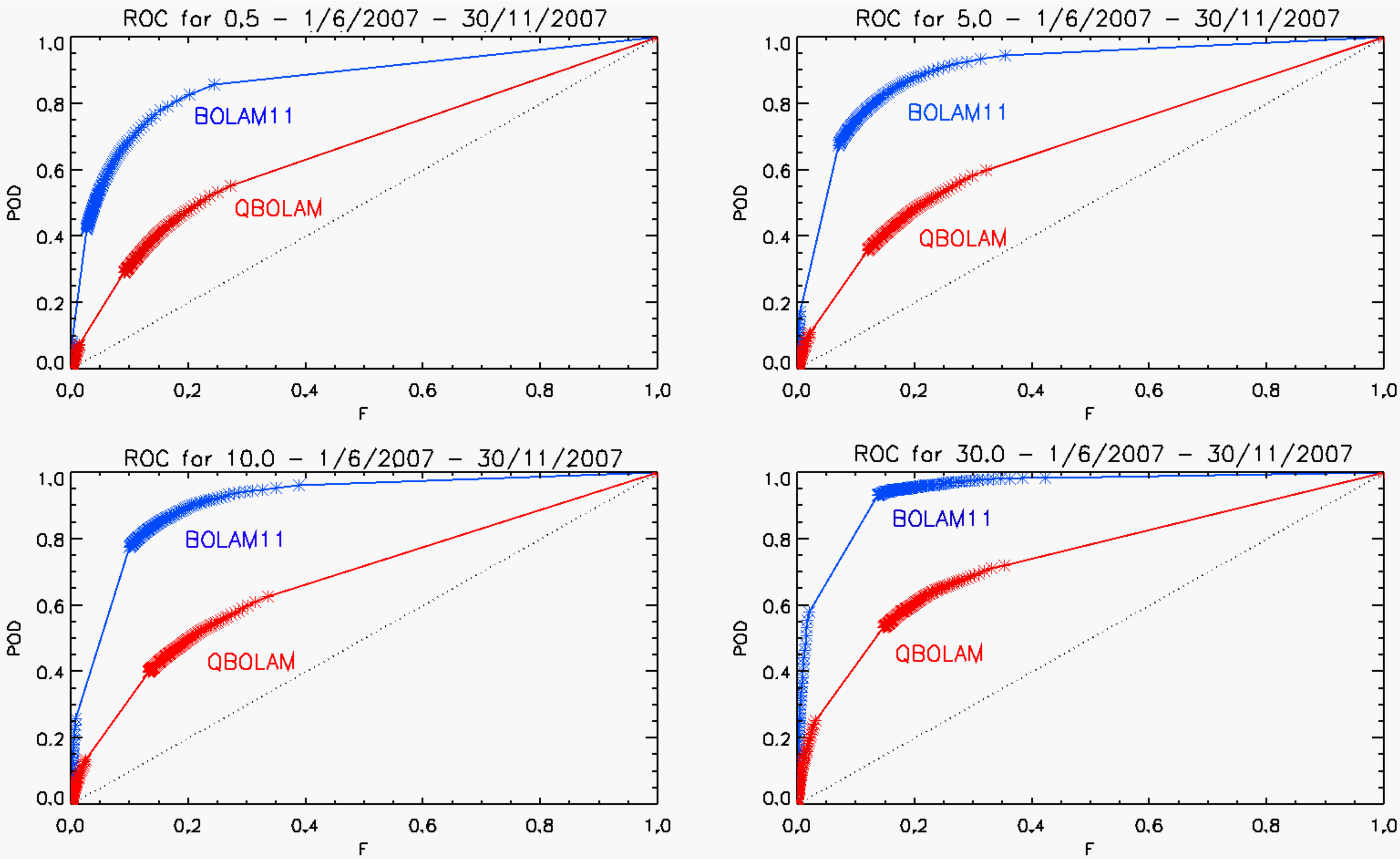


ORSS

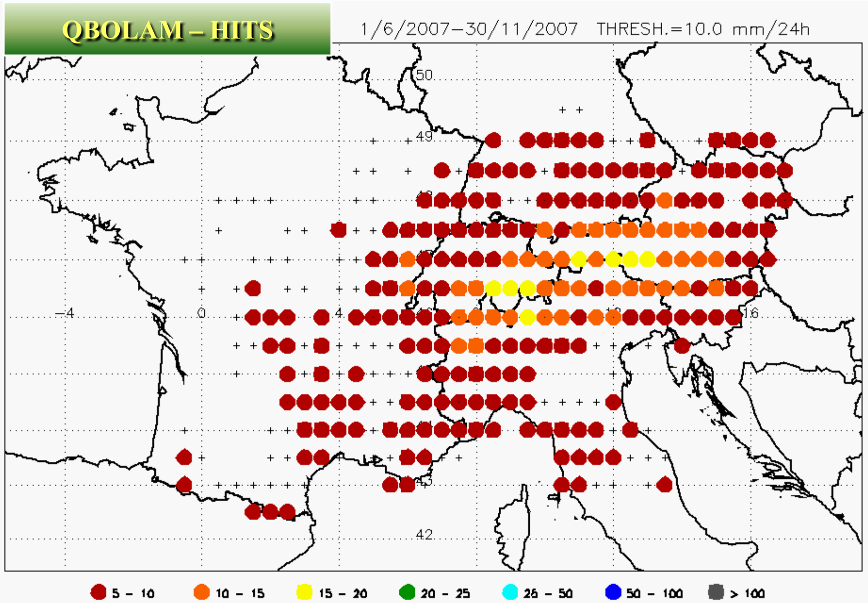
POD

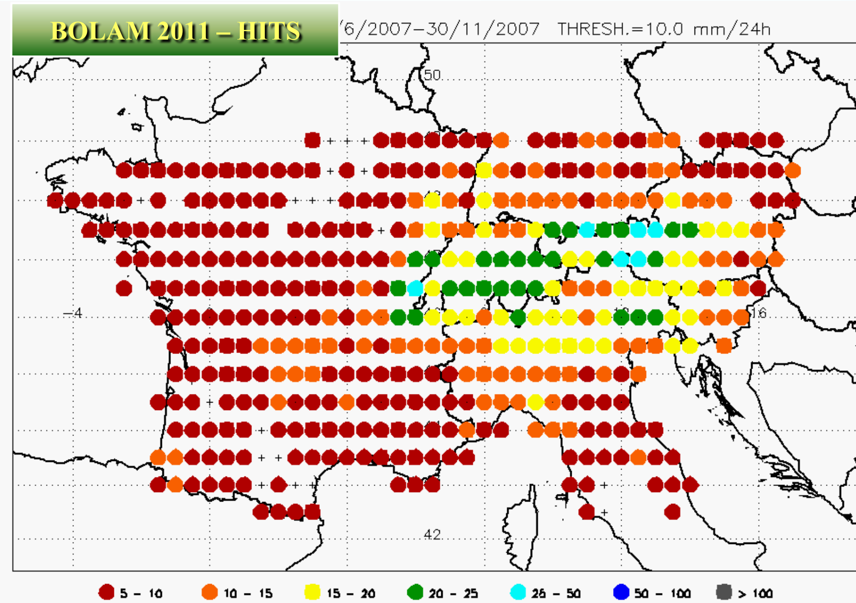
FAR

BOLAM 2011 vs. QBOLAM Altix-KF: DOP (Jun.-Nov. 2007)
ROC curves – 0.1° grid



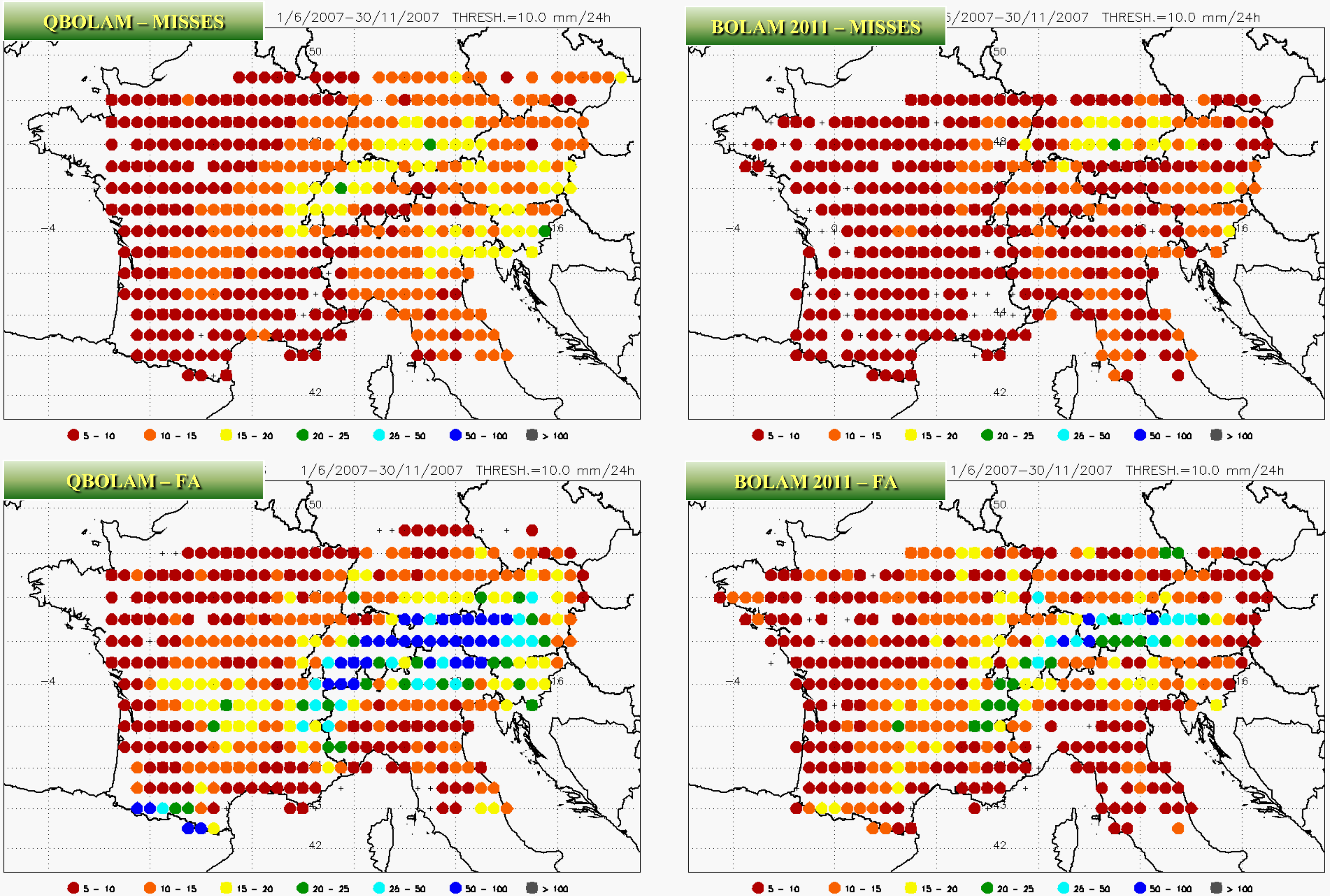
BOLAM 2011 vs. QBOLAM Altix-KF : DOP (Jun.-Nov. 2007)
Geographical display of CT elements





- Localize HITS increase & MISSES/FA reduction over the domain
- Critical areas: where still HITS ~ MISSES + FA
- Possible link to phenomenology ⇨ insight for forecast improvement
- Statistically significant on a coarse grid (50 km)
- More qualitative assessment on higher-resolution grid (10 km)

Geographical display of CT elements (follows)



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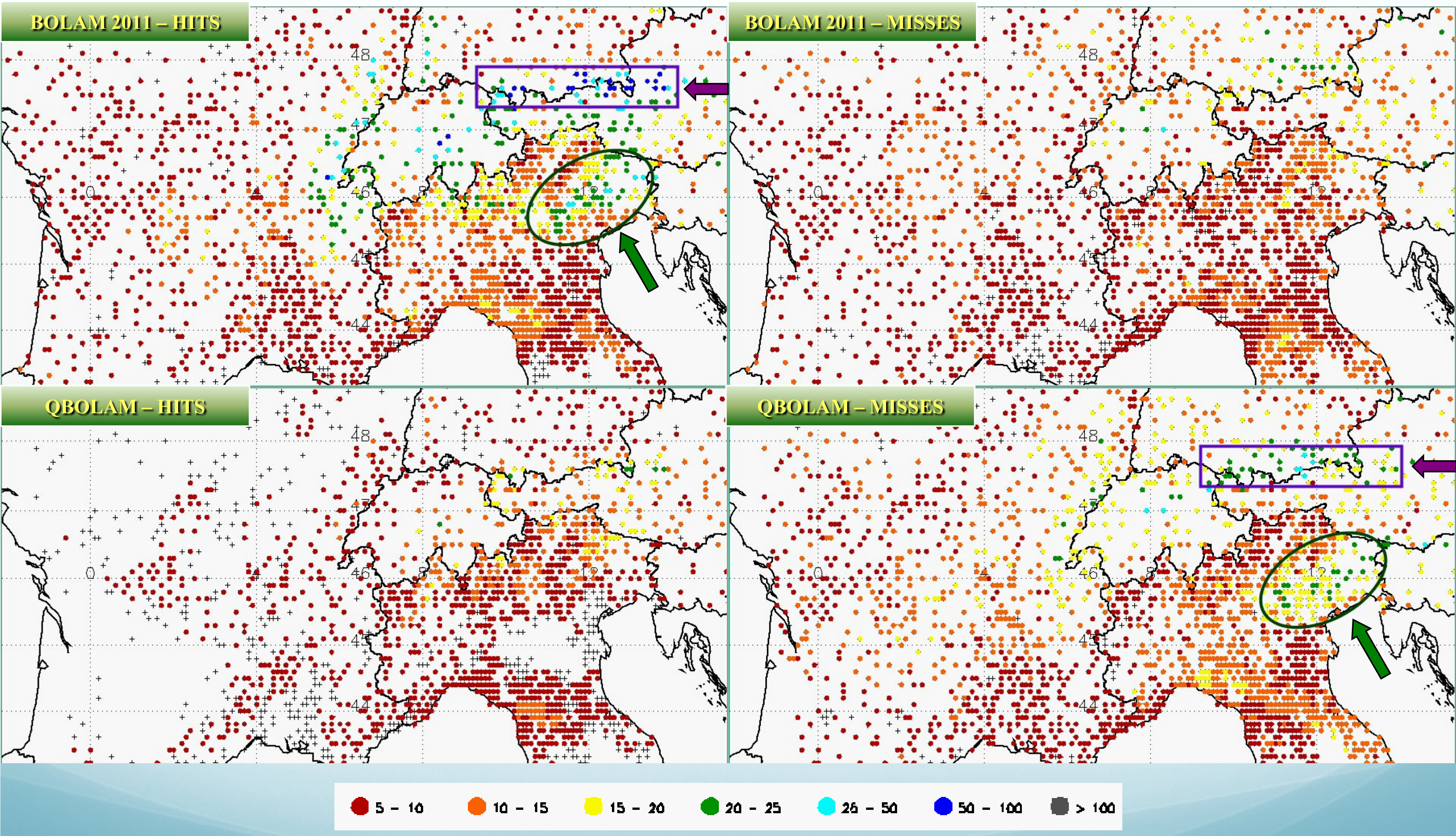

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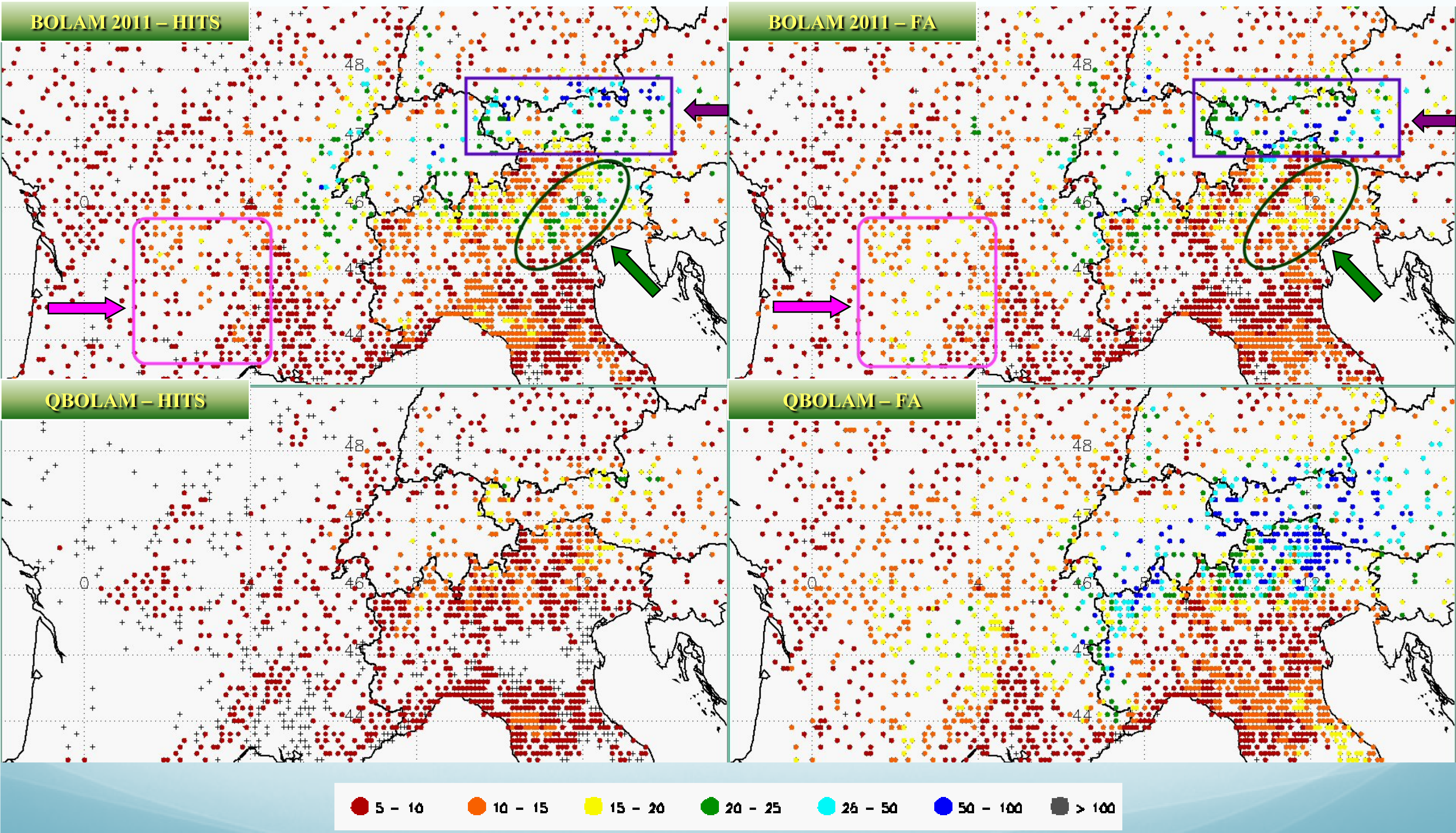


(Small-)Scale analysis through power spectra

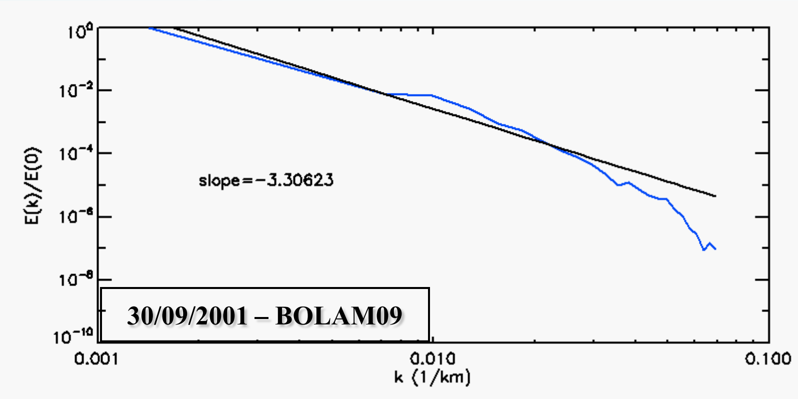
Forecasts ***not*** comparable when models have:

1. Different amount of small-scale detail
2. Different native grid
3. (Major) differences in BIAS

1) ⇨ need for *spectral analysis*

Previous results (Apr.-Sep. 2000) show that QBOLAM(-KF) spectra have more small-scale structure than BOLAM2009 ones

➔ Intercomparison on a coarser (0.5°) grid



How to take into account the structure of the fields compared? Multi-scale analysis:

Point-to-point matching is sensitive to small displacement errors (→ **double penalty effect**).

Power spectrum analysis is studied to assess if the fields being compared are defined on grids with the same resolution and if they have the same amount of small scale detail.

According to the Wiener-Khinchin theorem:

$$E(k_x, k_y) = \frac{1}{2\pi}\left|\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} e^{-i(xk_x + yk_y)}\, f(x, y)\,dx\,dy\right|^2$$

The maximum resolvable frequency (Nyquist) $1/(2\Delta x)$, where Δx is the physical grid size.

The 2-D spectra were averaged angularly to give an isotropic power spectrum $E(k)$, where $k = (k_x^2 + k_y^2)^{1/2}$. Scaling occurs when $E(k) \sim k^{-\beta}$. The higher β the smoother is the structure.

→ Lanciani et al., 2008, *Adv. Geosci.*, 16, 3–9.

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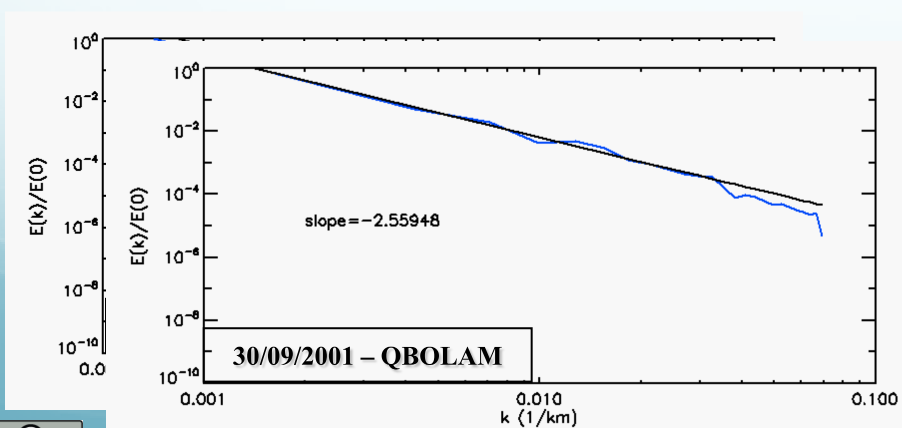

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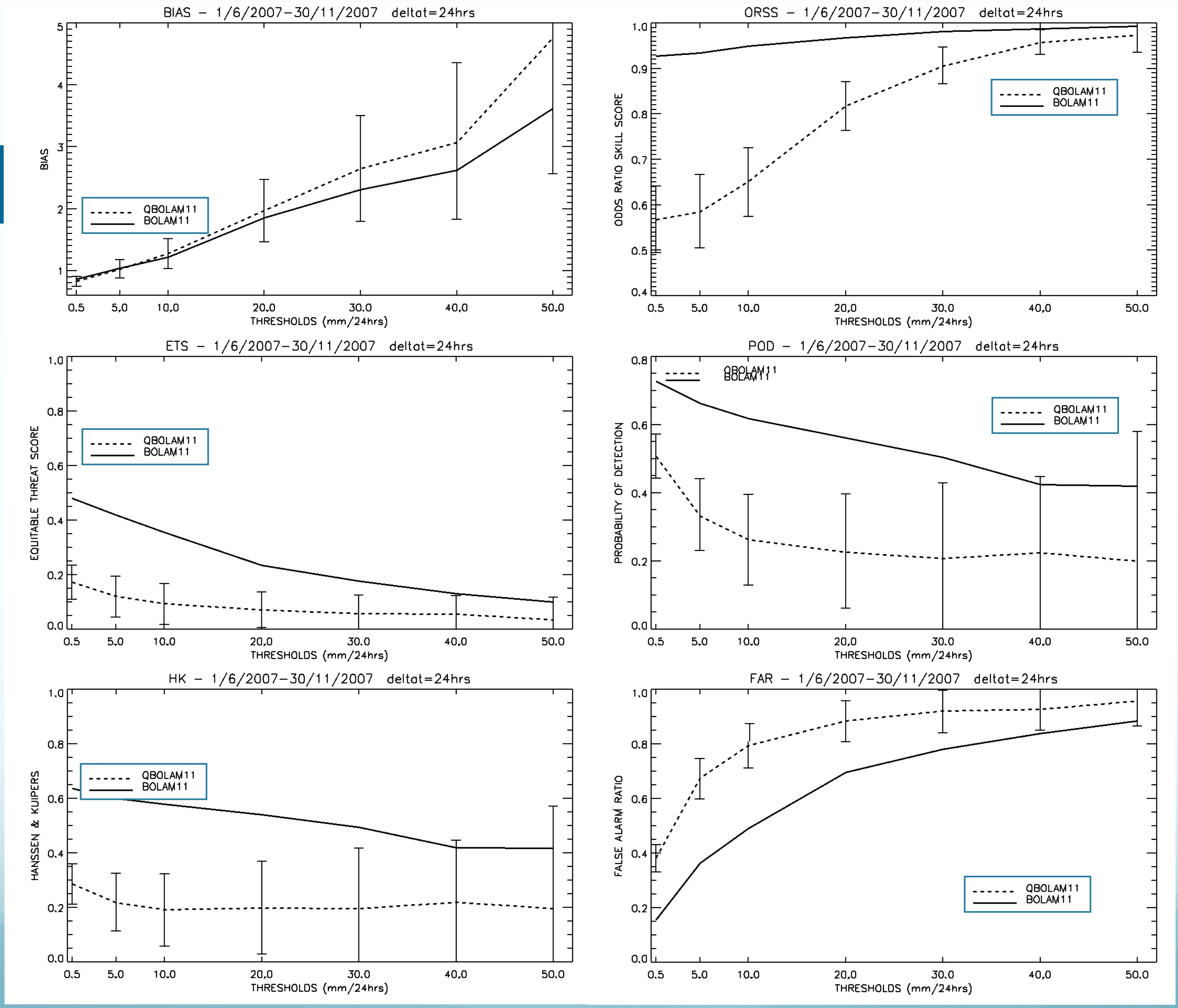
BOLAM 2011 vs. QBOLAM Altix-KF on 0.5° grid (Jun.-Nov. 2007)

BIAS

ORSS



ETS

POD

HK

FAR

Results summary and conclusions

- *Skill scores & ROC*: dramatic increase in model performance and "accuracy". Mostly solved previous QBOLAM (even with KF) criticalities (e.g., high BIAS)
- *CT geo-location*: net improvement in forecast quality both over the previously-critical areas (high mountains) and in the heavily-flooded areas (e.g., NE Italy). Need to assess robustness of these results. Despite general improvement, in some areas (e.g., S France) skill is still not high.
- *Spectral analysis* (over another period) need for *comparison over coarser grid* ⇨ skill scores mostly unchanged, but higher BIAS for both models.

Results encourage us to move towards higher resolution

More research is needed to identify error sources and margins for further improvement of forecast quality

… actually, that's a work in progress…

We will complete this work:

- Performing spectral analysis on the D-PHASE dataset
- Accounting for the BIAS differences: BIAS adjustment procedure
- Deterministic verification: case studies during DOP (radar, satellite, CRA…)

…and then…

- Extension of the verification study to the whole MAP D-PHASE domain
- Intercomparison with the other models in the MAP-DPHASE DB, or included afterwards (LAMMA)

In the meanwhile:

Verification of the sensitivity to initial condition improvement and to model domain size and resolution increase over the D-PHASE DOP: to be presented at ECSS, Palma de Mallorca, Spain 3-7/10/2011

Verification of the marine model chain

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That's all folks!!!

For major details on SIMM:

- http://www.isprambiente.gov.it/pre_meteo/
- http://www.isprambiente.gov.it/pre_mare/
- simm-pre-meteo@isprambiente.it