arpa
agenzia regionale prevenzione e ambiente dell'emilia-romagna

La Modellistica Previsionale ad ARPA-SIMC

Carlo Cacciamani e Tiziana Paccagnella
ARPA-ER - Servizio IdroMeteoClima

ARPA-SIMC: Gruppo di Modellistica

Responsabile del gruppo:

- Tiziana Paccagnella

Modellistica Meteorologica numerica:

- Davide Cesari
- Chiara Marsigli
- Andrea Montani
- Paolo Patruno

Prodotti modellistici/Verifica:

- Maria Stefania Tesini (e coop. Con Sala Operativa Meteo)

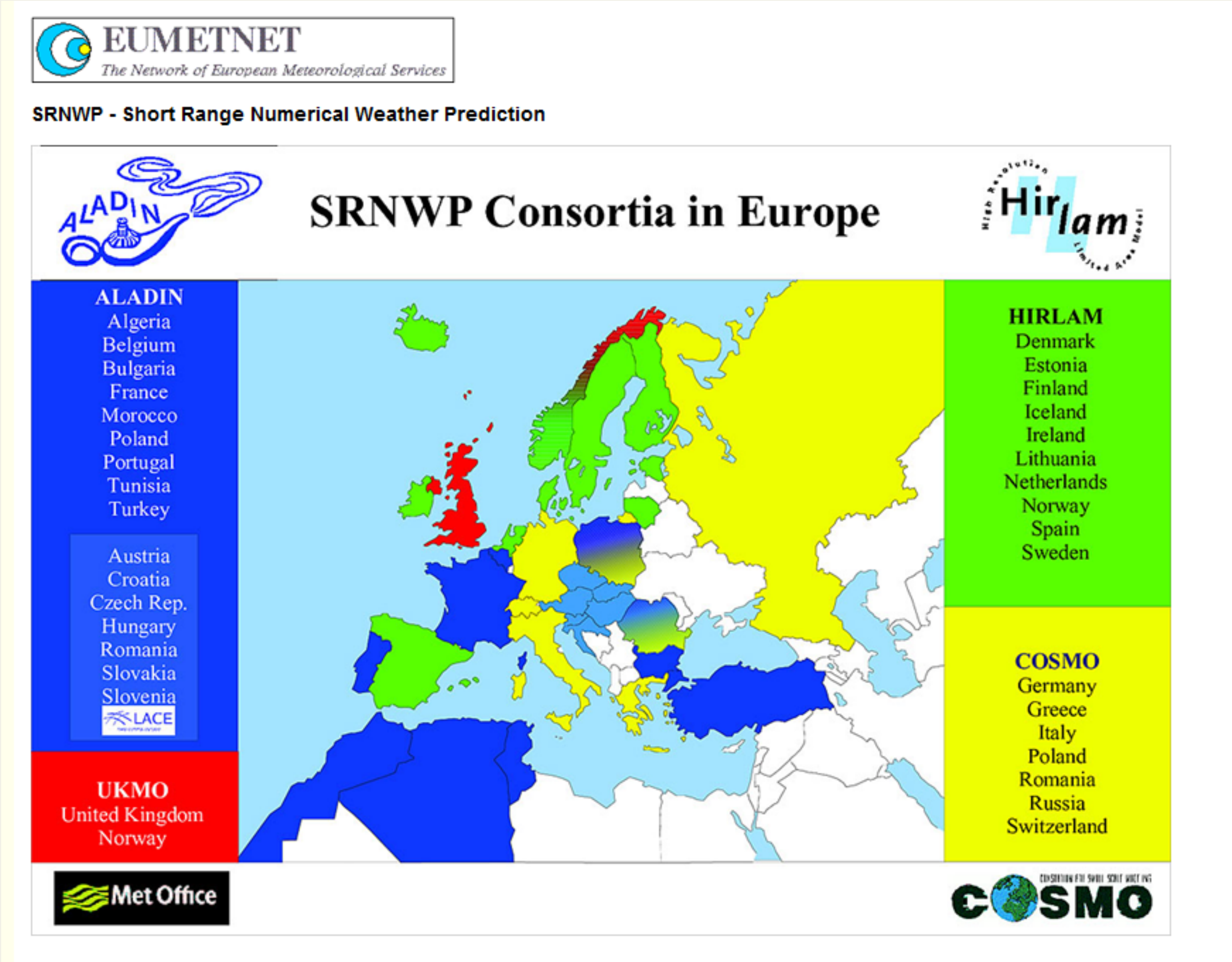
Previsioni Stato del Mare e applicazioni marine:

- Tommaso Diomede (e coop. con Sala Operativa Meteo)
- Andrea Valentini (e coop. con Sala Operativa Meteo)

SCHEMA

1. Il Consorzio COSMO e la Cooperazione LAMI
2. La “suite” LAMI gestita da ARPA-SIMC
3. Attività nel settore dell’Ensemble Forecating
4. Esempi di Prodotti
5. Verifica
6. Applicazioni
7. Sviluppi futuri

NUMERICAL WEATHER PREDICTION IN EUROPE



EUMETNET/SRNWP E NWP IN ITALIA

L'Italia partecipa al Consorzio COSMO attraverso un accordo internazionale
USAM ha siglato tale accordo

CONSORTIUM FOR SMALL SCALE MODELING
COSMO

www.cosmo-model.org

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Consortium for Small-scale Modeling

created: 1998

The Consortium for Small-scale Modeling (COSMO) was formed in October 1998. It's general goal is to develop, improve and maintain a non-hydrostatic limited-area atmospheric model, to be used both for operational and for research applications by the members of the consortium. Moreover, within a licence agreement, the COSMO model may be used for operational and research applications by other national (hydro-)meteorological services, universities and research institutes.

Participating national meteorological services

Today, the consortium, has as members these national meteorological services (presented in date-of-join order):

DWD MCH USAM HNMS IMGW NMA RHM

Germany	DWD	Deutscher Wetterdienst
Switzerland	MCH	MeteoSchweiz
Italy	USAM	Ufficio Generale Spazio Aereo e Meteorologia
Greece	HNMS	Hellenic National Meteorological Service
Poland	IMGW	Institute of Meteorology and Water Management
Romania	NMA	National Meteorological Administration
Russia	RHM	Federal Service for Hydrometeorology and Environmental Monitoring

Other major members

Additionally, these regional and military services within the member states are also participating:

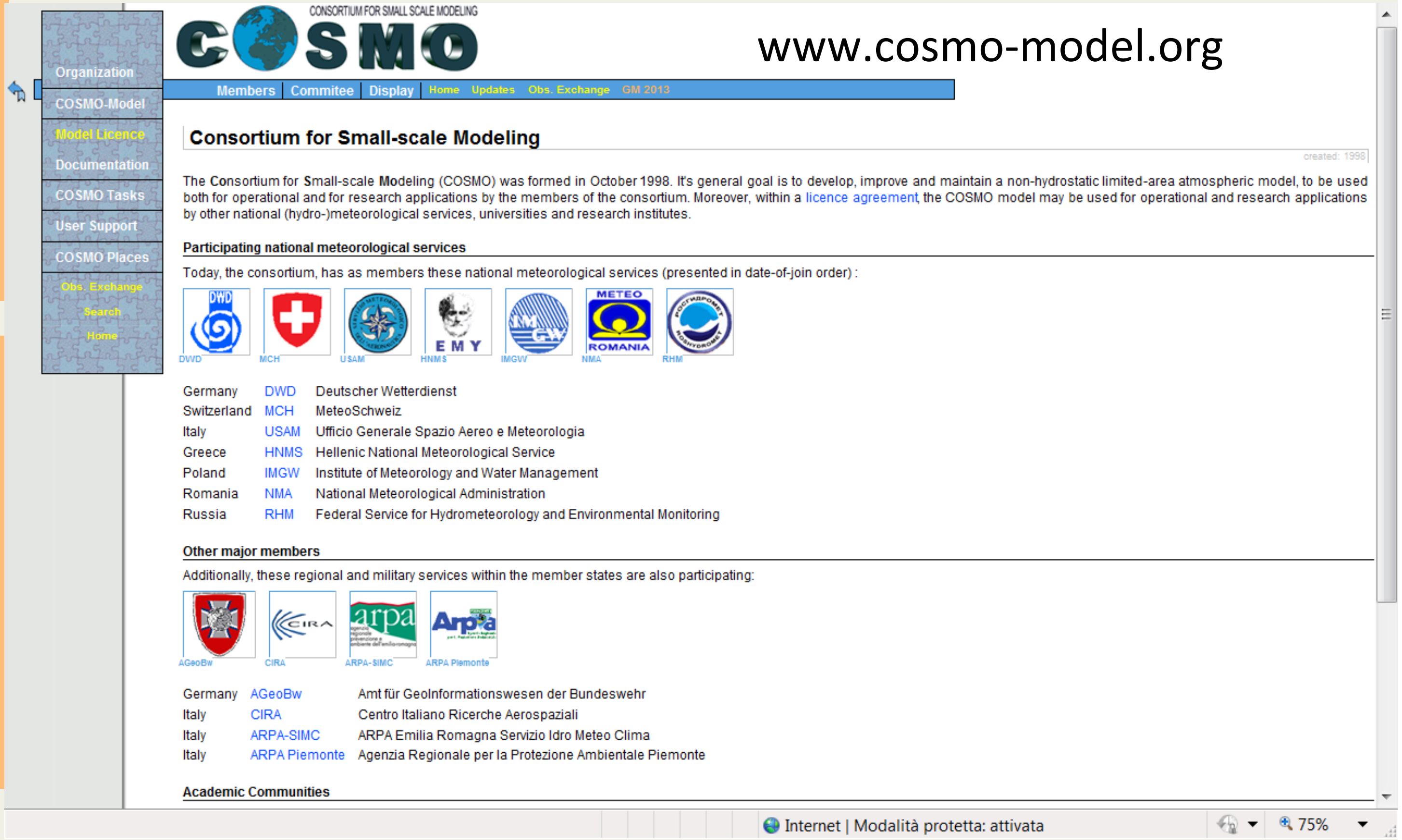
AGeoBw CIRA ARPA-SIMC ARPA Piemonte

Germany	AGeoBw	Amt für Geolnformationswesen der Bundeswehr
Italy	CIRA	Centro Italiano Ricerche Aerospaziali
Italy	ARPA-SIMC	ARPA Emilia Romagna Servizio Idro Meteo Clima
Italy	ARPA Piemonte	Agenzia Regionale per la Protezione Ambientale Piemonte

ARPA SIMC e la NWP in Italia

A livello Nationale
USAM, ARPA SIMC e ARPA Piemonte shanno siglato l'accordo LAMI per cooperare sulla gestione e lo sviluppo della modellistica nazionale su base operativa

Dal 2004 (DPCM 27/2/2004) , LAMI è il sistema nazionale "di riferimento" a supporto della Protezione Civile.
ARPA-SIMC è Centro di Competenza Nazionale del Sistema di Protezione Civile



IL MODELLO COSMO

CONSORTIUM FOR SMALL SCALE MODELING

General Description: Model Dynamics and Numerics

see also: basic design | initial and boundary conditions | physical parameterizations | external parameters | code and parallelization | data assimilation

Last updated: September 2011

The COSMO-Model is based on the primitive hydro-thermodynamical equations describing compressible non-hydrostatic flow in a moist atmosphere without any scale approximations. A basic state is subtracted from the equations to reduce numerical errors associated with the calculation of the pressure gradient force in case of sloping coordinate surfaces. The basic state represents a time-independent dry atmosphere at rest which is prescribed to be horizontally homogeneous, vertically stratified and in hydrostatic balance.

The basic equations are written in advection form and the continuity equation is replaced by a prognostic equation for the perturbation pressure (i.e. the deviation of pressure from the reference state). The model equations are solved numerically using the traditional finite difference method. In the following we summarize the dynamical and numerical key features of the COSMO-Model.

Model Equations

- nonhydrostatic, full compressible hydro-thermodynamical equations in advection form
- subtraction of a hydrostatic basic state (reference atmosphere) at rest. Options for
  - a reference atmosphere defined with a constant Δt, with an increasingly negative vertical temperature gradient in the stratosphere and a limit to the vertical model extent.
  - a reference atmosphere based on a temperature profile
    $T_0(z) = T_{00} + \Delta t \, EXP(-z/h\_scal)$,
    approaching an isothermal profile in the stratosphere and no limits of the vertical model extent.

Prognostic Variables

- horizontal and vertical cartesian wind components (u,v,w)
- temperature (t)
- pressure perturbation (p', deviation from the reference state)
- specific humidity (q_v) and specific cloud water content (q_c)
- optionally: cloud ice content (q_i), specific water content of rain (q_r), snow (q_s) and graupel (q_g)
- optionally: turbulent kinetic energy (tke)

Diagnostic Variables

- Total air density
- 2 meter temperature
- 10 meter wind speeds
- maximal wind gust in 10 meter
- precipitation fluxes of rain and snow
- and much more ....

Coordinate System

- rotated geographical (lat/lon) coordinate system horizontally
- generalized terrain-following height-coordinate with user defined grid stretching in the vertical. Options for
  - base-state pressure based height coordinate
  - Gal-Chen height coordinate and
  - exponential height coordinate (SLEVE) according to Schär et al. (2002)

Internet | Modalità protetta: attivata 75%

Il Modello COSMO

CONSORTIUM FOR SMALL SCALE MODELING

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COSMO-Model | Model Management | COSMO Tasks | Coding Standards | Home

General Description: Model Physical Parameterizations

see also: dynamics and numerics | initial and boundary conditions | basic design | external parameters | code and parallelization | data assimilation

Last updated: September 2011

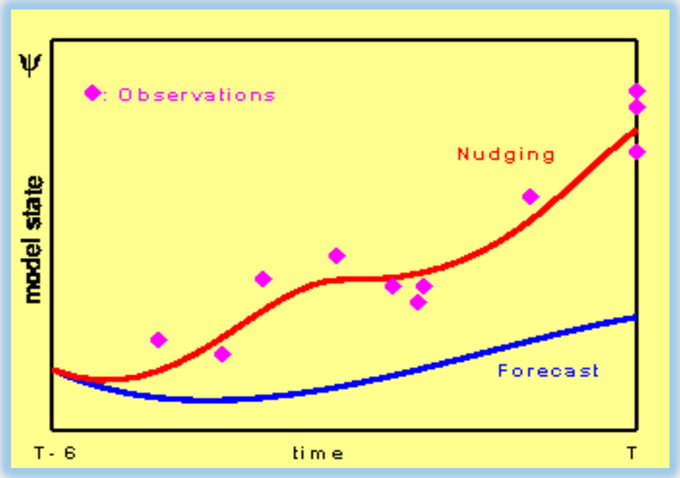
A variety of subgrid-scale physical processes are taken into account by parameterization schemes. Some parts of the present physics package of the COSMO-Model have been adapted from the former operational hydrostatic models EM/DM, but some are based on new developments or have been taken over by GME or the IFS. The following table gives a short overview on the parameterization schemes used operationally and on additional options implemented so far.

Grid-Scale Clouds and Precipitation	• Cloud water condensation and evaporation by saturation adjustment. • Precipitation formation by a bulk microphysics parameterization including water vapour, cloud water, cloud ice, rain and snow with 3D transport for the precipitating phases. • Option for a new bulk scheme including graupel. • Option for a simpler column equilibrium scheme.
Subgrid-Scale Clouds	• Subgrid-scale cloudiness is interpreted by an empirical function depending on relative humidity and height. A corresponding cloud water content is also interpreted. Option for a statistical subgrid-scale cloud diagnostic for turbulence.
Moist Convection	• Tiedtke (1989) mass-flux convection scheme with equilibrium closure based on moisture convergence. Option for a modified closure based on CAPE. • Reduced Tiedtke scheme for shallow convection only.
Radiation	• δ-two stream radiation scheme after Ritter and Geylen (1992) for short- and longwave fluxes (employing eight spectral intervals); full cloud-radiation feedback.
Subgrid-Scale Orography	• Subgrid-scale orography (SSO) scheme by Lott and Miller (1997) which deals explicitly with a low-level flow that is blocked when the subgrid-scale orography is sufficiently high.
Subgrid-Scale Turbulence	• Prognostic turbulent kinetic energy closure at level 2.5 including effects from subgrid-scale condensation and from thermal circulations. • Option for a diagnostic second order K-closure of hierarchy level 2 for vertical turbulent fluxes. • Preliminary option for calculation of horizontal turbulent diffusion in terrain following coordinates (3D Turbulence).
Surface Layer	• A Surface layer scheme (based on turbulent kinetic energy) including a laminar-turbulent roughness layer. • Option for a stability-dependent drag-law formulation of momentum, heat and moisture fluxes according to similarity theory (Louis, 1979).
Soil Processes	• Multi-layer version of the former two-layer soil model after Jacobsen and Heise (1982) based on the direct numerical solution of the heat conduction equation. Snow and interception storage are included. • Option for the (old) two-layer soil model employing the extended force-restore method still included.
Sea Ice Scheme	• Based on work by Mironov and Ritter (DWD)
FLake Model	• A Fresh-water Lake model by Mironov (2008)

Internet | Modalità protetta: attivata 75%

ASSIMILAZIONE DATI - NUDGING

Adattamento continuo del modello alle osservazioni durante l'integrazione (Fig.1).



Analysis of Atmospheric Fields: Nudging-Based Data Assimilation

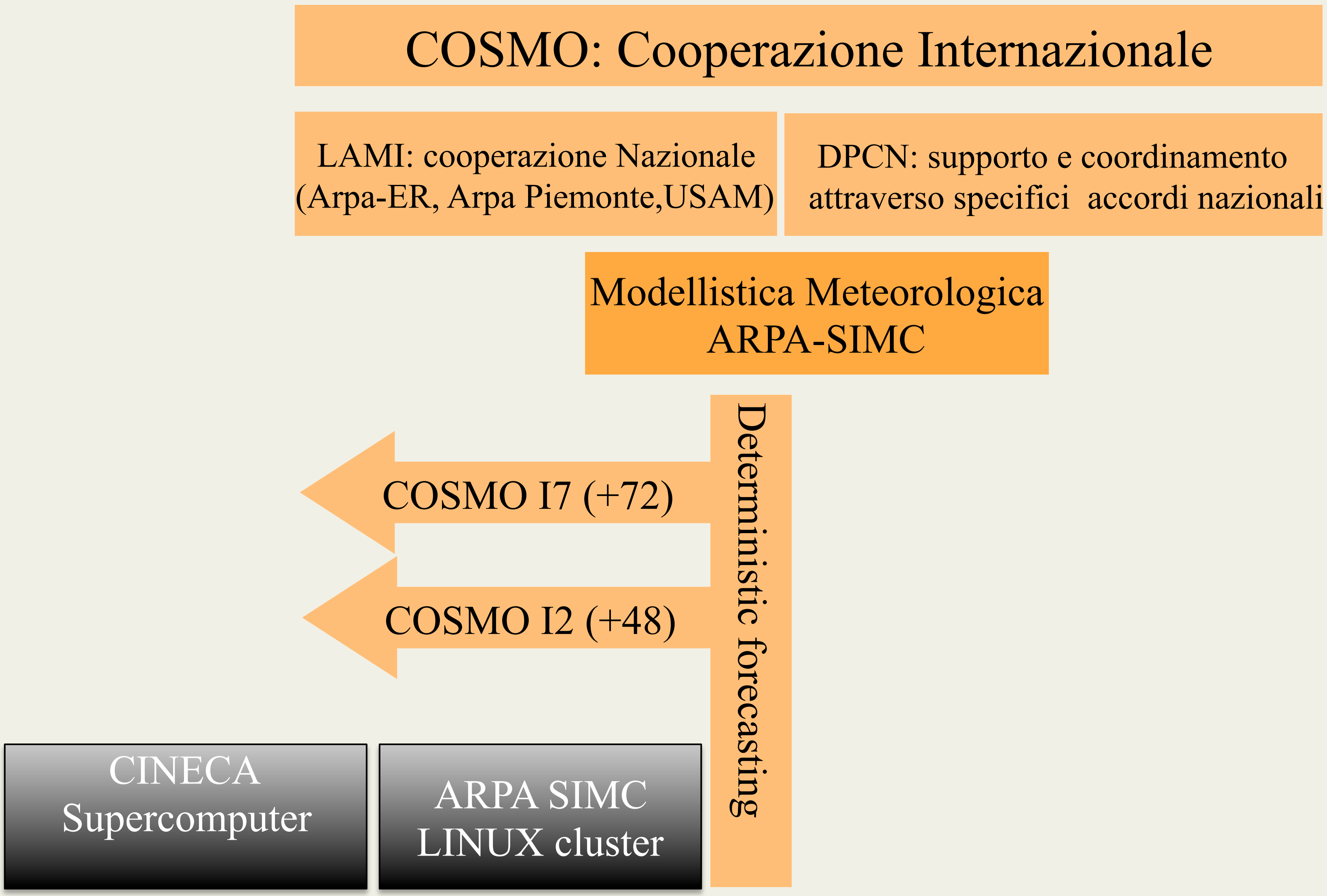
3.1 Concept and Basic Ideas

Nudging or Newtonian relaxation consists of relaxing the model's prognostic variables towards prescribed values within a predetermined time window. Detailed descriptions of the technique can be found e.g. Anthes (1974), Davies and Turner (1977), and Stauffer and Seaman (1990). In the present scheme, nudging is performed towards direct observations, which is more appropriate for asynoptic data (Stauffer and Bao (1993)) and high-resolution applications than nudging towards 3-dimensional analyses (Stauffer and Seaman (1994)). A relaxation term is introduced into the model equations, and the tendency for the prognostic variable $\psi(\mathrm{x},t)$ is given by

$$\frac{\partial}{\partial t}\psi(\mathrm{x},t) = F(\boldsymbol{\psi},\mathrm{x},t) + G_{\psi} \cdot \sum_{k_{(obs)}} W_k(\mathrm{x},t) \cdot [\psi_k^{obs} - \psi(\mathrm{x}_k,t)] \qquad (3.1)$$

F denotes the model dynamics and physical parameterizations, ψ_k^{obs} the value of the k^{th} observation influencing the grid point x at time t, x_k the observation location, G_ψ a constant called nudging coefficient (currently set to $12 \cdot 10^{-4} s^{-1}$ for surface pressure and $6 \cdot 10^{-4} s^{-1}$ for the other assimilated quantities), and W_k an observation-dependent weight. This weight always takes values between 0 and 1 (except for surface pressure, cf. Section

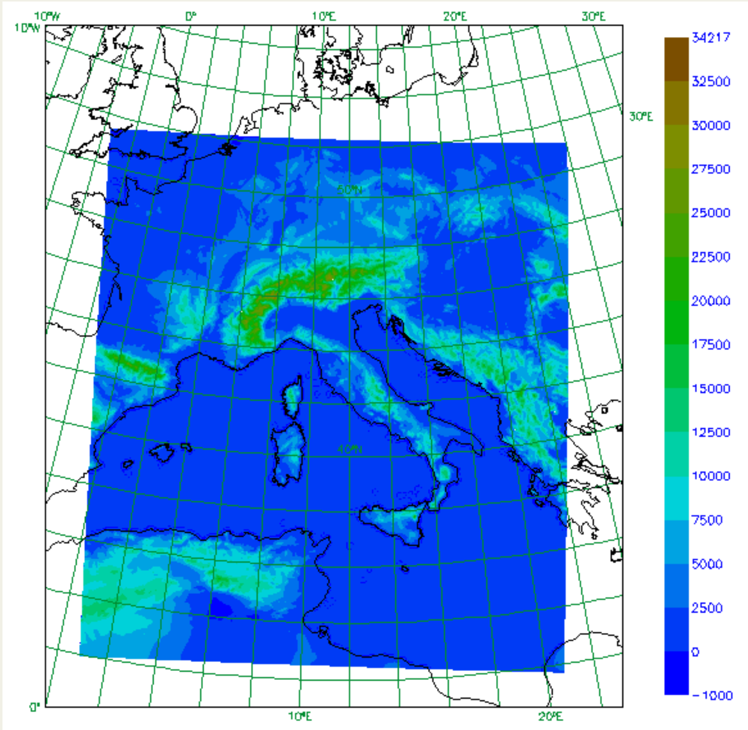
MODELLISTICA NUMERICA AD ARPA-SIMC



COSMO I7

Operativo al CINECA

- Due corse al giorno alle 00 e alle 12 UTC
- Scadenze: + 72 ore
- Risoluzione orizzonatle: 7km
- BCs da ECMWF IFS (15 km h.r.); frequenza 3 hours
- IC : Nudging (Aof files)



Back-up al SIMC

- Due corse al giorno a 00 e a 12 UTC
- Scadenza + 72 ore
- Risoluzione Orizzontale: 7km
- BCs daDWD GME (20 km h.r.); BC ogni 1 ora
- IC Nudging (Aof files)

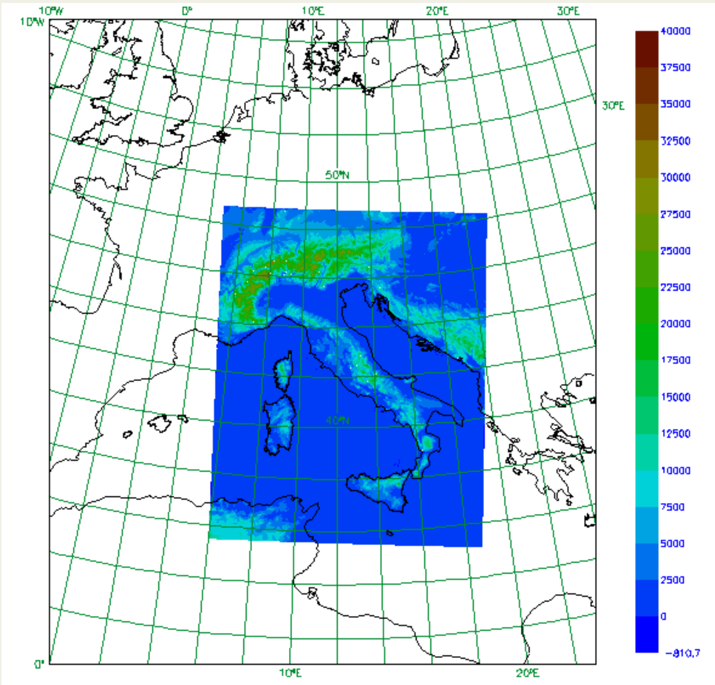
Test Suite al CINECA

Hot Back-up al CINECA

COSMO I2

Operativo al CINECA

- Due corse al giorno a 00 and 12 UTC
- Scadenza: + 48 hours
- Risoluzione orizzontale: 2.8km
- BCs da COSMO I7; BC ogni 1 ora
- IC: Nudging

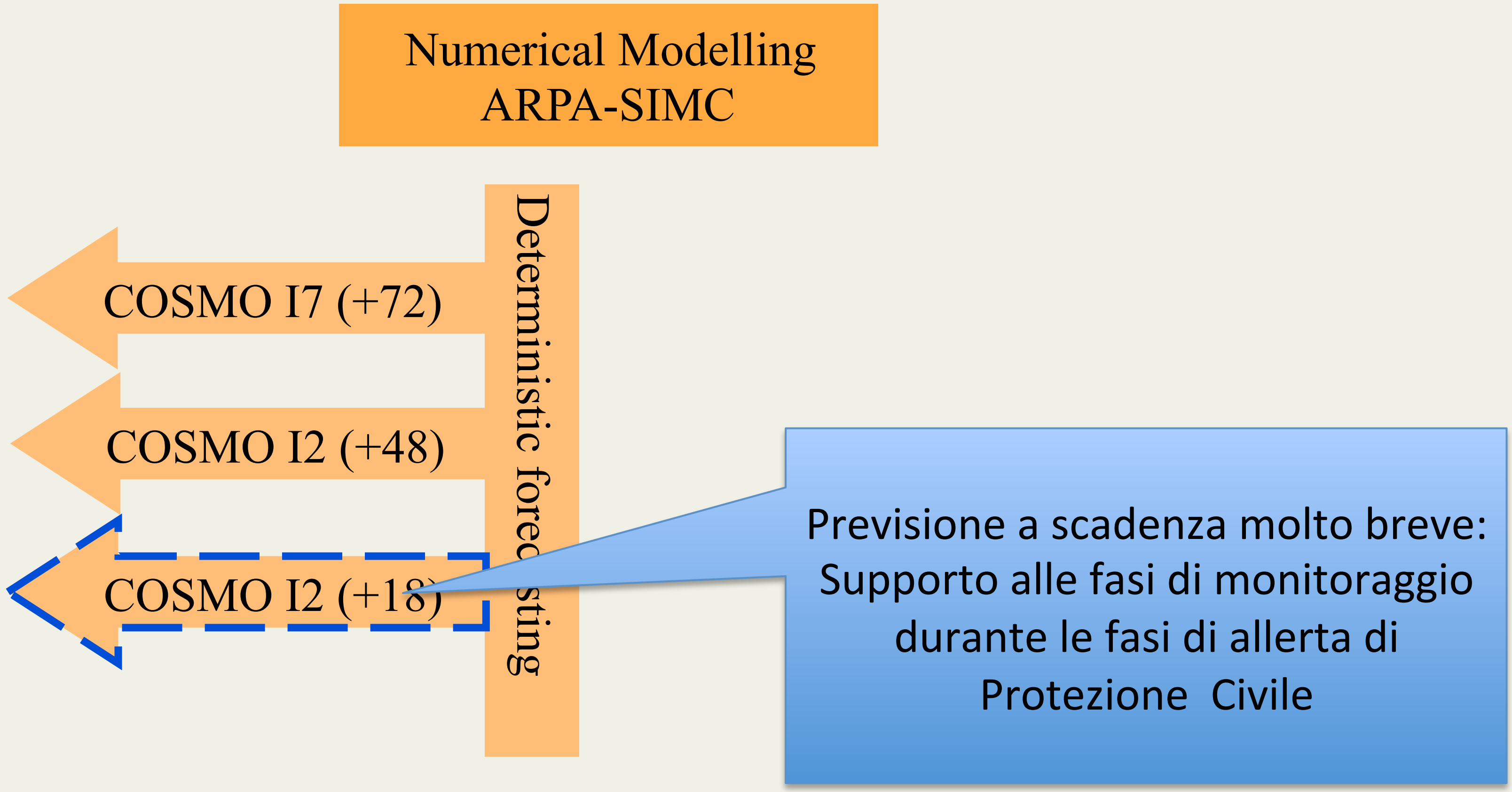


Maggiore differenza rispetto a COSMO I7 è lo switch-off della parametrizzazione della convenzione

Test Suite al CINECA

Hot Back-up al CINECA

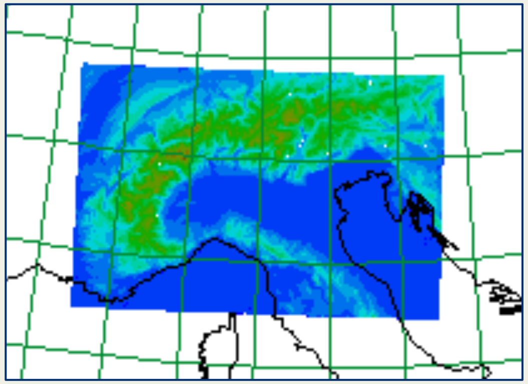
MODELLISTICA NUMERICA AD ARPA-SIMC:
SVILUPPI PIU' IMPORTANTI



COSMO RUC

Pre-operativo al SIMC

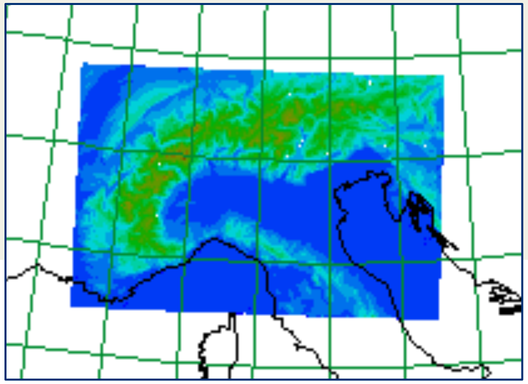
- Otto volte al giorno alle: 00,03,06,09,12,15,18,21 UTC
- Scadenza: + 18 ore
- Risoluzione orizzonatle ~ 2.8km
- BCs da COSMO I7; BC ogni 1 ora
- IC attraverso Nudging delle osservazioni

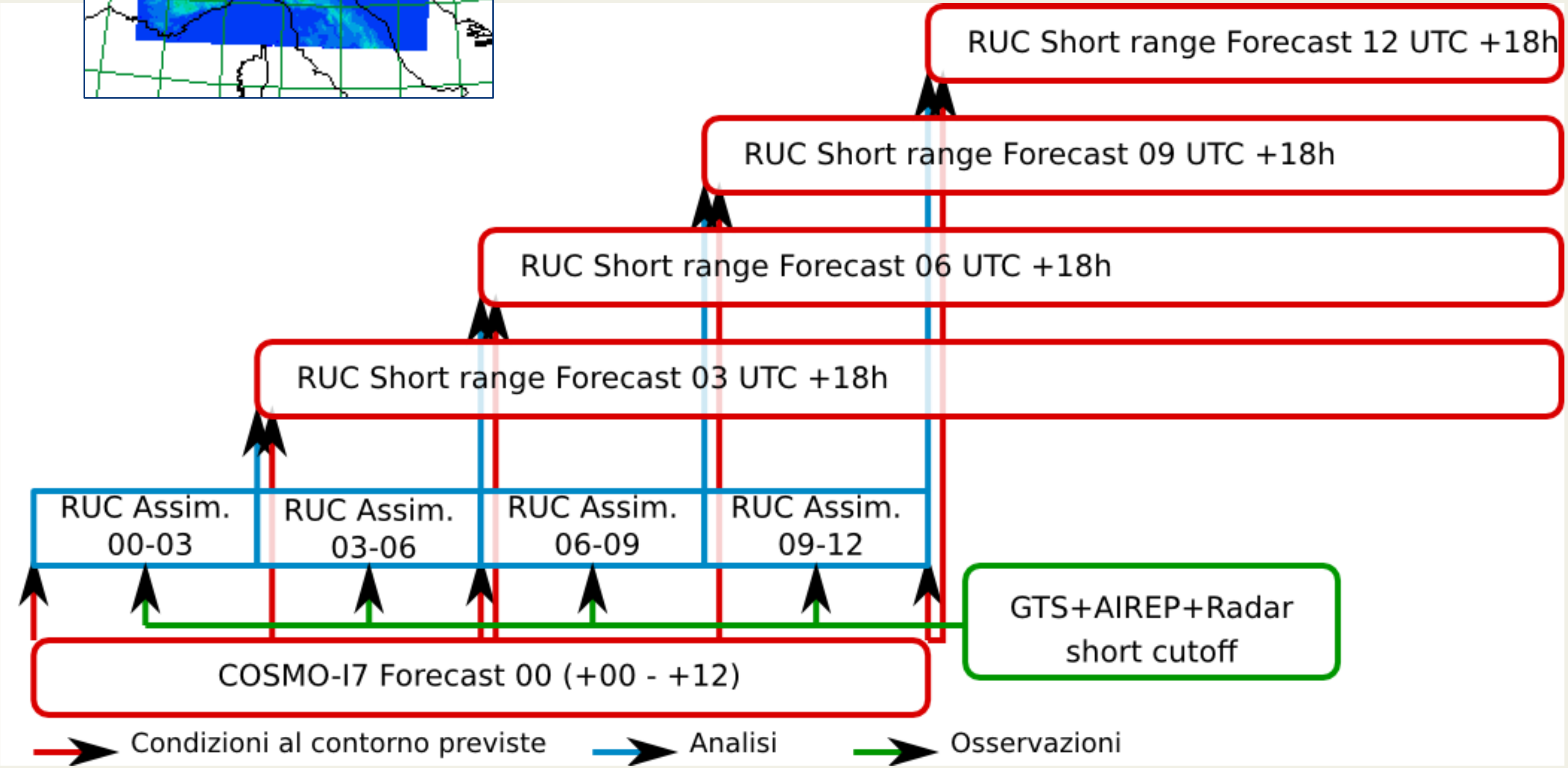


Maggiore differenza rispetto a COSMO I2 è l'assimilazione dei dati Radar attraverso Latent Heat Nudging

Forecasts disponibili dopo 2 ore dall'inizio della previsione

COSMO RUC schema





MODELLISTICA METEOROLOGICA AD ARPA-SIMC: SVILUPPI RILEVANTI:

IMPLEMENTATION AND TEST OF THE NEW ENSEMBLE BASED DATA ASSIMILATION SCHEME KENDA

CONSORTIUM FOR SMALL SCALE M

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Priority Project "KENDA"
Km-Scale Ensemble-Based Data Assimilation

Last updated: 6 Jun 2012

Project leader: Christoph Schraff (DWD)

Introduction

SET EDIT ON

The **aim** of the project is to develop a novel ensemble-based data assimilation system for the convective scale (i.e. 1 - 3 km model mesh-size) and to show that it works scientifically and gives a systematic positive impact (compared to nudging), in particular in convective situations, but also for low stratus conditions and near steep orography. The system has to be able to provide the initial conditions for convective-scale ensemble forecasting.

Two approaches have been envisaged at the beginning of the project, that is the Local Ensemble Transform Kalman Filter (**LETKF**, see Hunt et al., 2007) and the Sequential Importance Resampling (**SIR**) filter (van Leeuwen, 2003). The distribution of the resources should depend on the relevance of **non-Gaussianity**. In some preliminary investigation, only moderate deviations from Gaussianity have been found in most observation minus forecast statistics. Therefore, all the resources from the weather services in COSMO are being devoted to the LETKF in view of the fact that for this method, successful meteorological data assimilation applications exist and less practical problems are expected than for the SIR approach. Then, the more basic research required for the latter should rely mainly on resources from cooperating universities and research institutes.

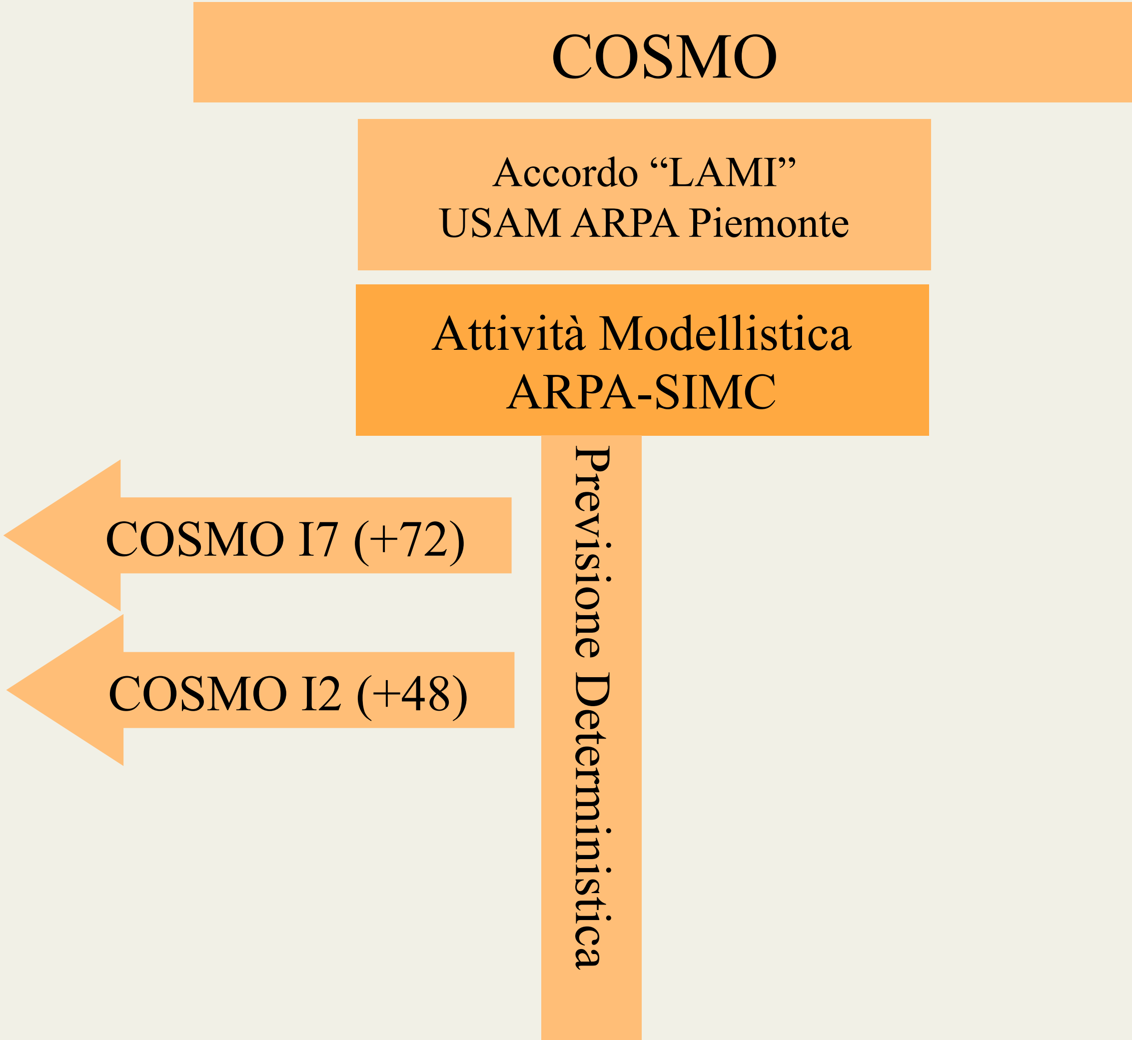
Motivation

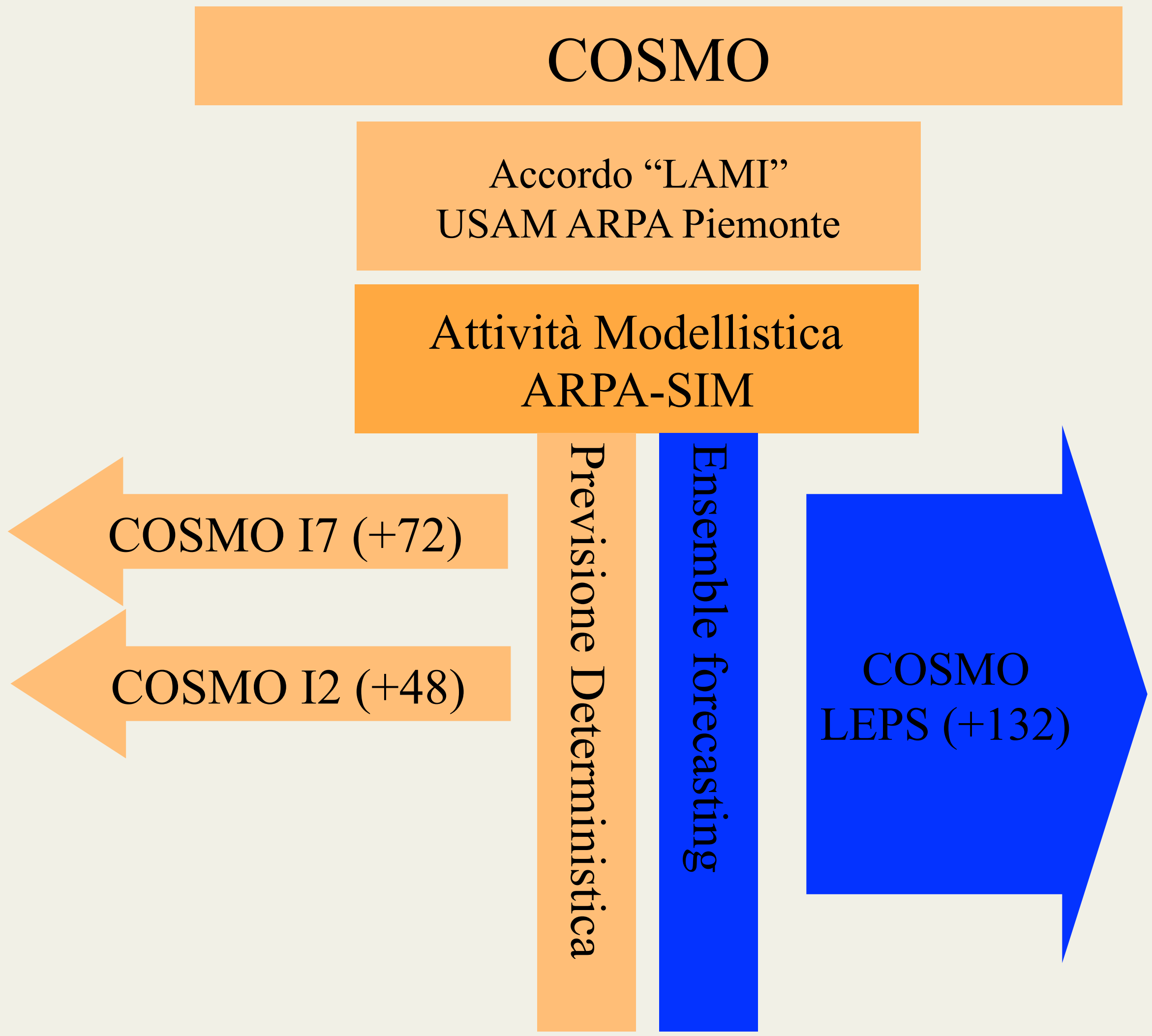
Our strategy for (very) short-range NWP in the coming years is to deliver not only deterministic forecasts, but a representation of the probability density function (PDF) for the atmospheric state, e.g. in the form of probabilities assigned to members of an ensemble running at a mesh-size of about 1 - 3 km. Furthermore, the use of indirect observations at high frequency is considered to become more important in the future.

Compared to larger scales, several conditions relevant for data assimilation are much more predominant in the convective scale. These include non-Gaussian PDFs, flow-dependent and poorly-known balance, and strong non-linearity. Therefore, it is considered more appropriate for the future **to develop a separate data assimilation scheme for the convective scale** and use a potentially different (but in practice similar) approach for a generalised system for global and regional modelling. Such a system combining global and regional modelling is being developed in the form of a global non-hydrostatic model with regional grid refinement at DWD and MPI Hamburg in the project ICON. Its analysis component will be based a hybrid 3DVAR (PSAS - physical space analysis system) - LETKF system.

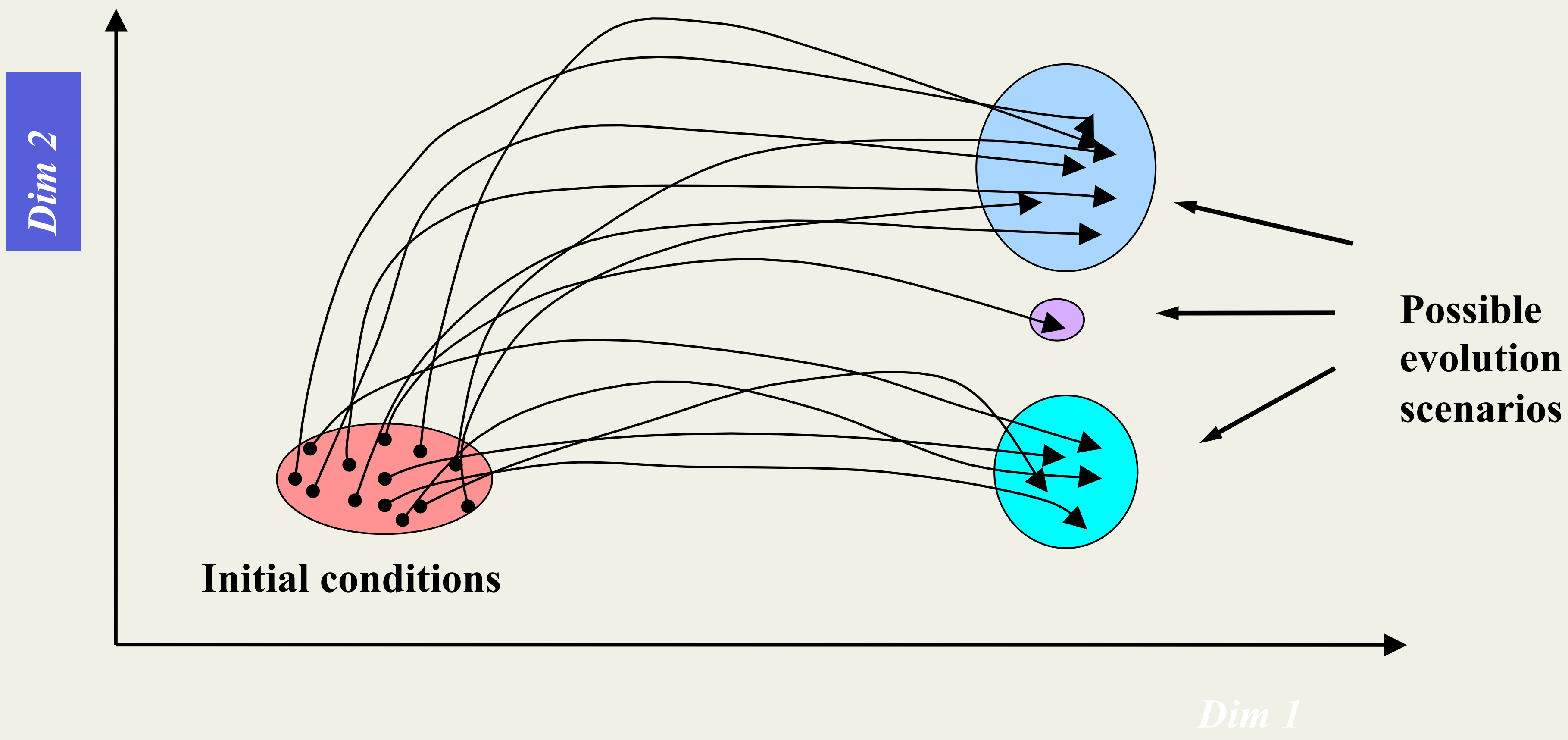
Thus, an alternative data assimilation technique appropriate for the convective scale needs to be developed. However, the problem of convective-scale data assimilation is far from being solved nowadays. The main efforts by other groups and weather services in Europe are directed mainly towards 3D- and 4DVAR, but it is not clear how well this will work on these scales. For sure, developing a new 4DVAR system would require huge efforts. In the light of the human resources in COSMO, which are more limited than within MeteoFrance/HIRLAM/HARMONIE, let alone the UK Met Office, embarking on this approach would imply the risk of always lagging behind the other groups.

More recently, ensemble approaches, and in particular (variants of) the Ensemble Kalman Filter, have received increased attention (above all in USA). They usually require significantly less resources for development. Moreover, they can naturally be used to provide the initial conditions for convective-scale Ensemble prediction systems and are therefore much better suited for forecasting and delivering representations of the PDFs. By embarking on this approach, COSMO can attain a strong position within Europe with a chance for leadership in this area.


COSMO
Accordo "LAMI"
USAM ARPA Piemonte
Attività Modellistica
ARPA-SIMC
Previsione Deterministica
COSMO I7 (+72)
COSMO I2 (+48)


COSMO
Accordo “LAMI”
USAM ARPA Piemonte
Attività Modellistica
ARPA-SIM
Previsione Deterministica
Ensemble forecasting
COSMO I7 (+72)
COSMO I2 (+48)
COSMO
LEPS (+132)

ENSEMBLE FORECASTING



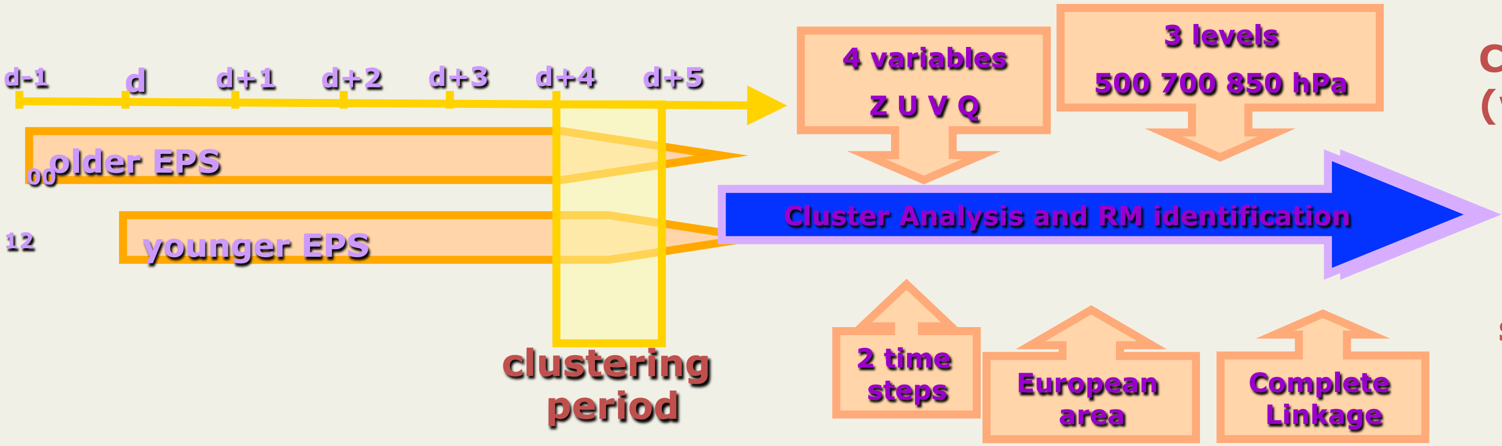
ENSEMBLE FORECASTING

Errori del Modello

Tiene conto dell‘incertezza associata alla Previsione meteorologica numerica

Analisi dell’errore

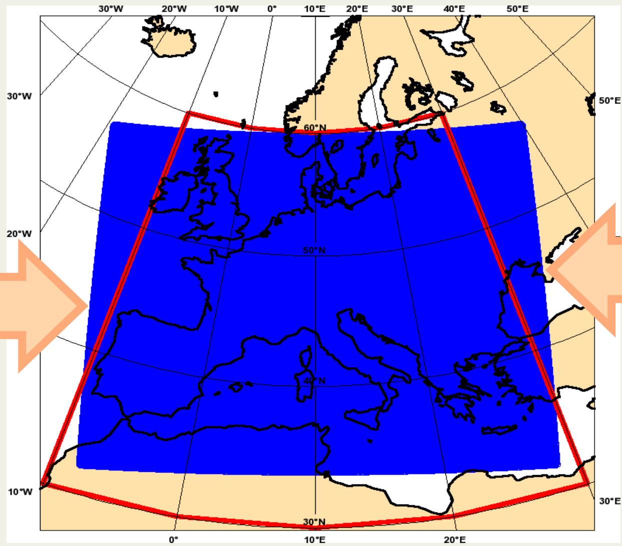
COSMO-LEPS suite @ ECMWF: stato attuale



16 Representative Members driving the 16 COSMO-model integrations (weighted according to the cluster populations)

using either Tiedtke or Kain-Fristch convection scheme (members 1-8 T, members 9-16 KF)
+
perturbations in turbulence scheme and in physical parameterisations

COSMO-LEPS clustering area



COSMO-LEPS Integration Domain

- suite runs twice a day (00 and 12UTC) as a "time-critical application" managed by ARPA-SIMC;
- Δx ~ 7 km; 40 ML; fc+132h;
- COSMO v4.21 since July 2012;
- computer time (30 million BUs for 2012) provided by the ECMWF member states in COSMO.

COSMO-HYBrid Ensemble Prediction System: suite parallela in sviluppo

Genera 20-member hybrid ensemble (COSMO-HYBEPS), dove:

a) 16 members comes from COSMO-LEPS,
b) 1 member is nested on IFS (uses Tiedtke scheme),
c) 1 member is nested on IFS (uses Kain-Fritsch scheme),
d) 1 member is nested on GME,
e) 1 member is nested on GFS.

All members have **Δx ~ 7 km; 40 ML; fc+132h;**

Visualizzazione dei Prodotti

Examples of deterministic and probabilistic weather forecast

Previsioni

Modelli ad area limitata

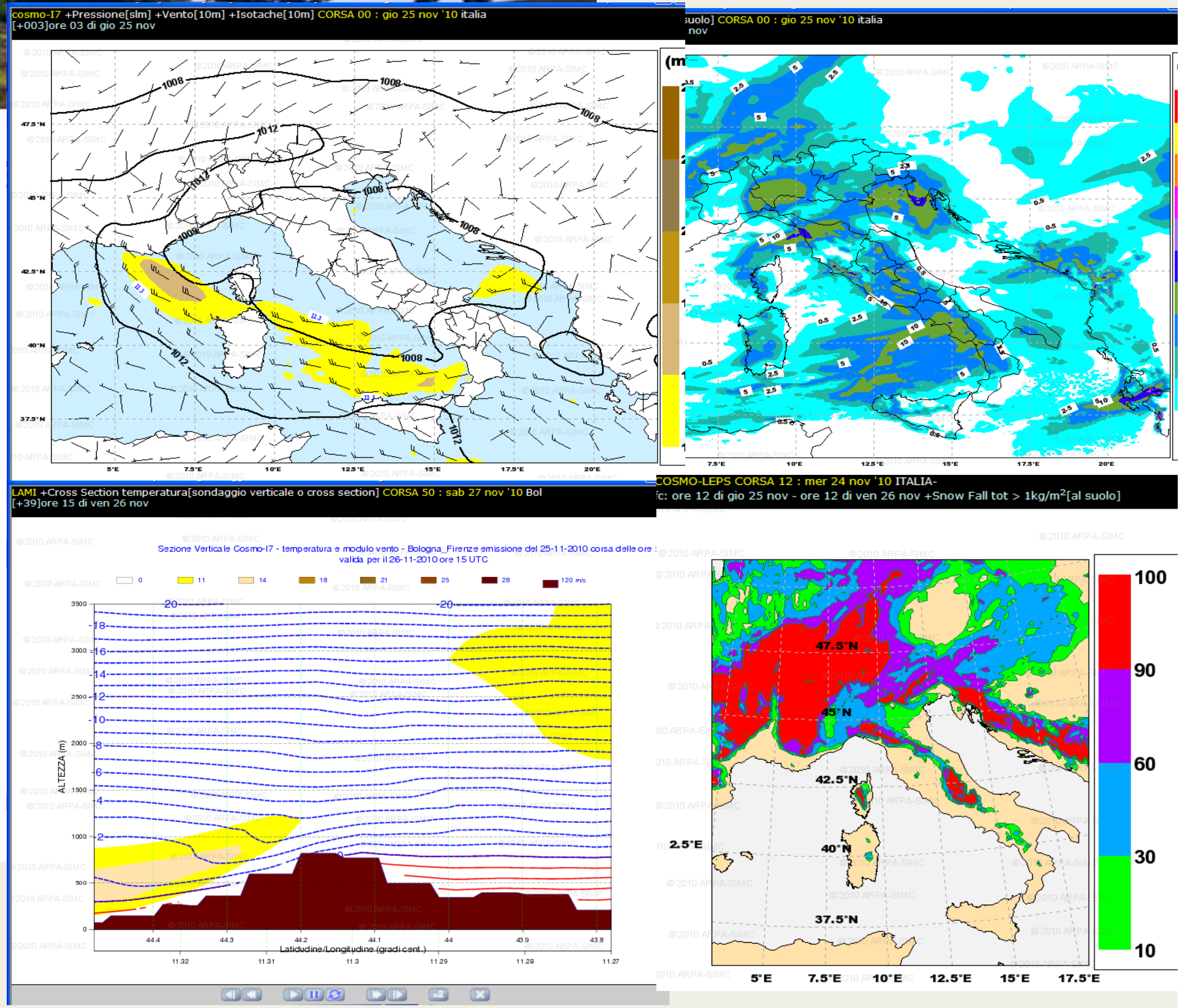
- **Cosmo-I7**
  - ultima corsa disponibile
  - corsa 00
  - corsa 12
- Lami e-suite
- **Cosmo-I2**
  - ultima corsa disponibile
  - corsa 00
  - corsa 12
- Cosmo-I7 corsa SIMC di backup
- **Cosmo LEPS (probabilistico)**
  - corsa 12
- Almo (Alpine-Model Meteo-Swiss)
- **Cosmo LEPS - (corsa deterministica)**
  - corsa 12
- PPPF COSMO I2
- cosmo sreps

Modelli globali di circolazione generale

Previsioni Stagionali

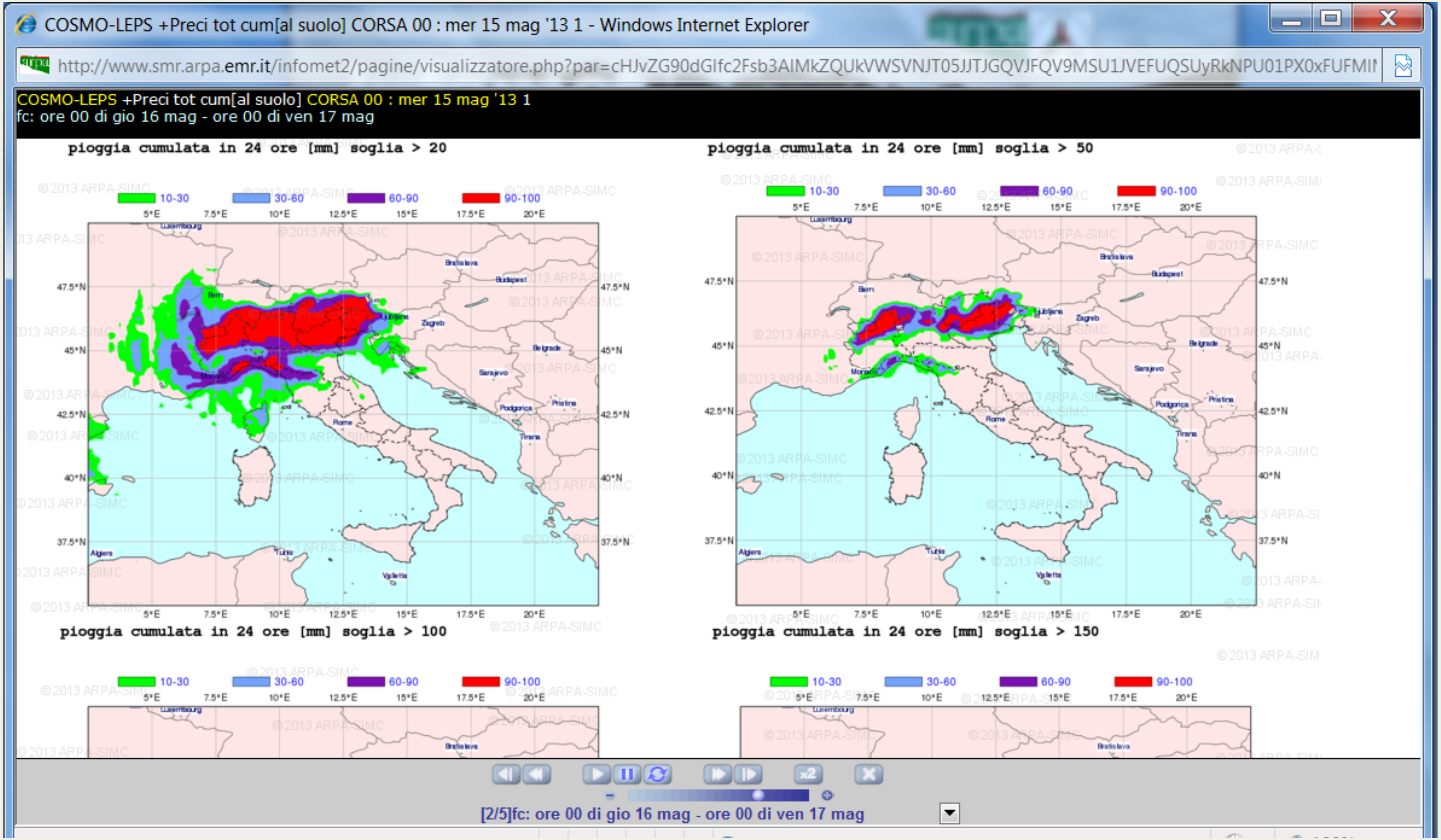
previsioni di temperatura - Kalman filter -- dati

stampe

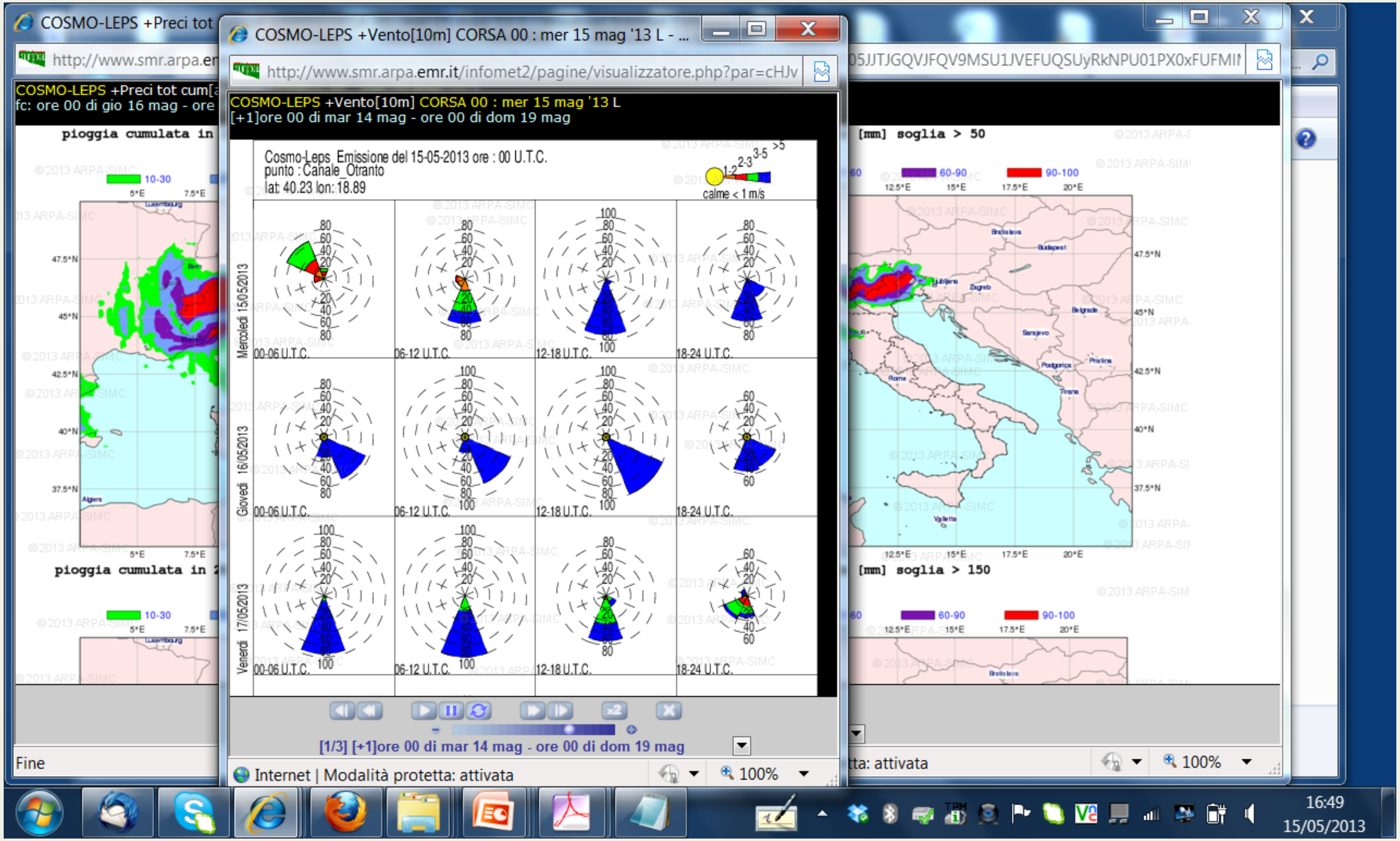


www.smr.arpa.emr.it/infomet2

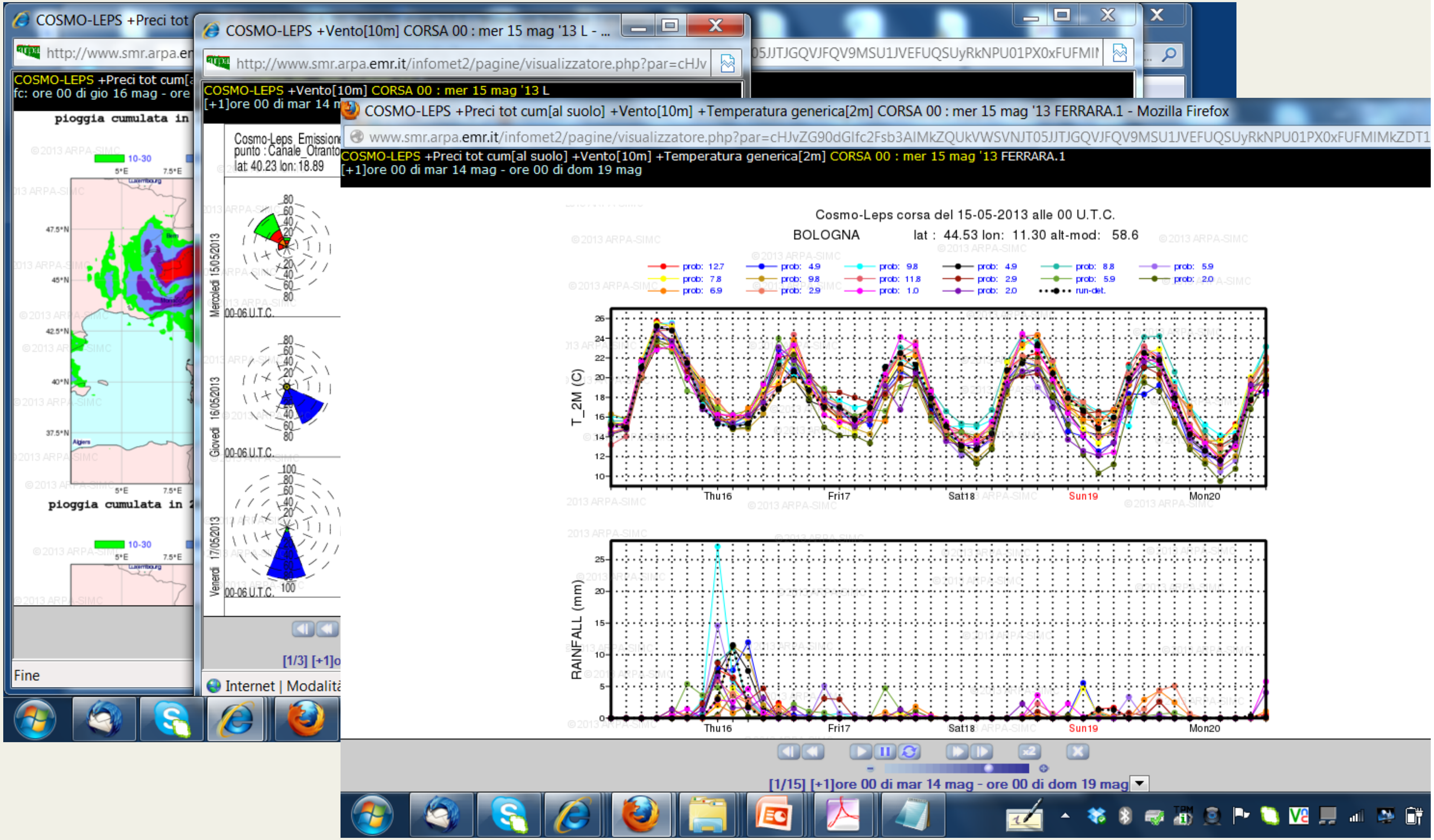
Visualizzazione dei prodotti



Product visualization



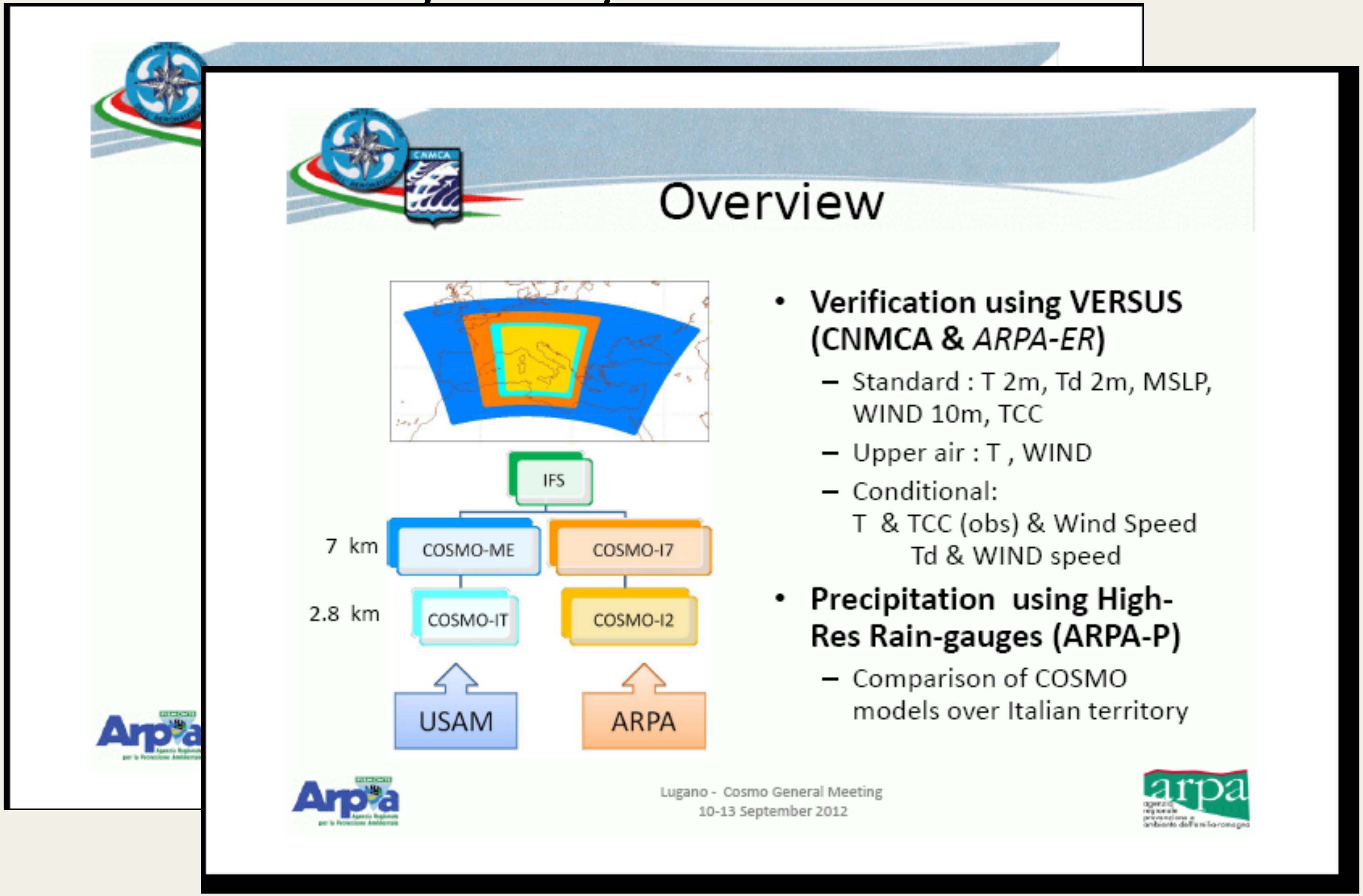
Product visualization



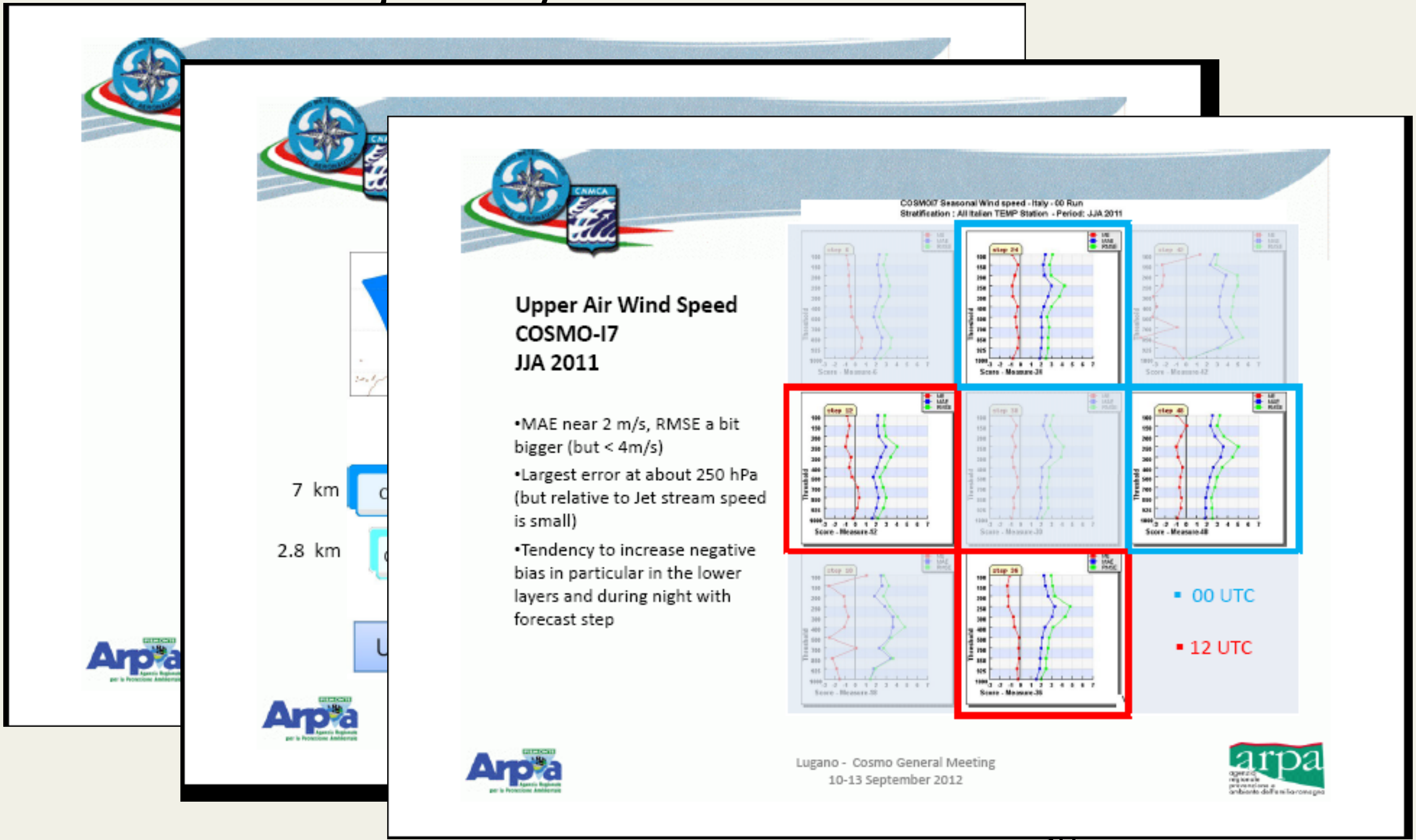
Objective/statistical verification

http://www.cosmo-model.org/content/consortium/generalMeetings/general2012/wg5-versus.htm

Objective/statistical verification



Objective/statistical verification

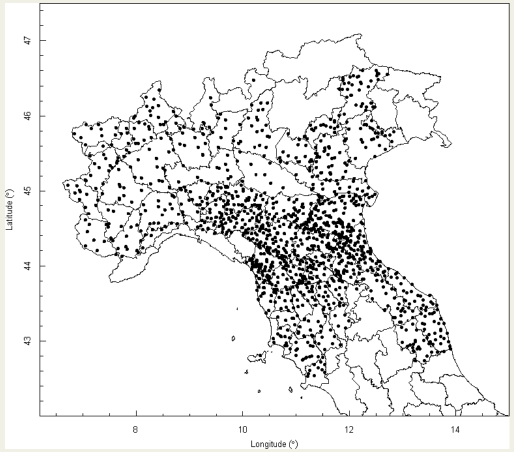


VERIFICA DELLA QPF AD ALTA RISOLUZIONE

Risoluzione molto alta ⇨ bassa predicibilità all’area del pixel

↓

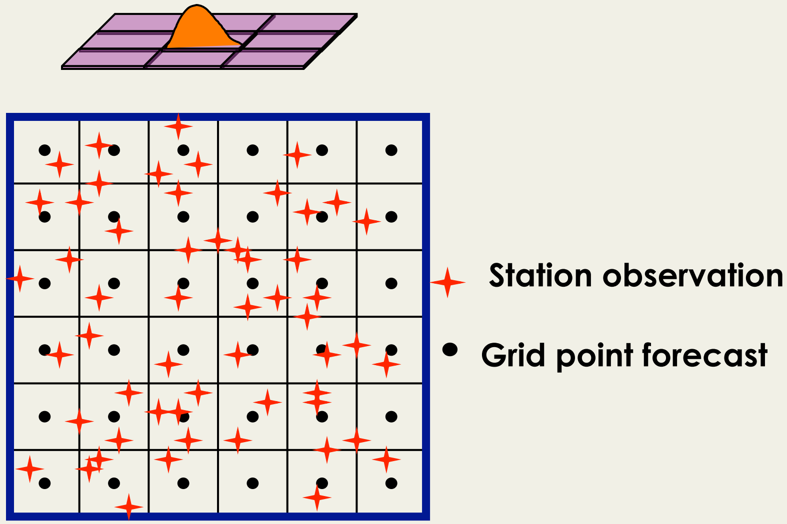
Verifica su aree che includono più pixels



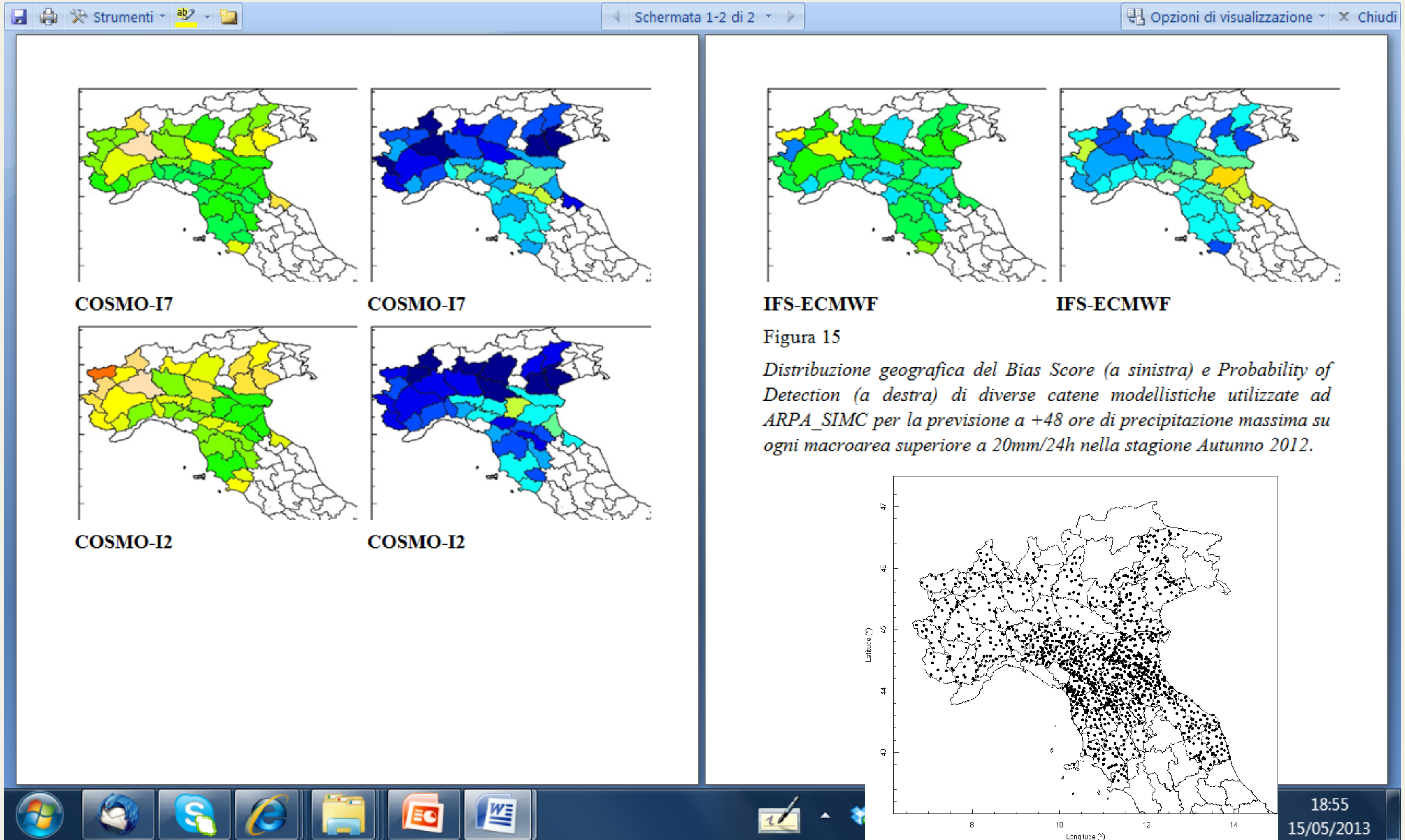
Verifica fatta in termini di:

- **Valori medi**
- **Valori massimi**
- **50th percentile (median)**
- **90th percentile**

Su box con più pixels



QPF Verifica: un esempio



Verifica precipitazioni:metodologia

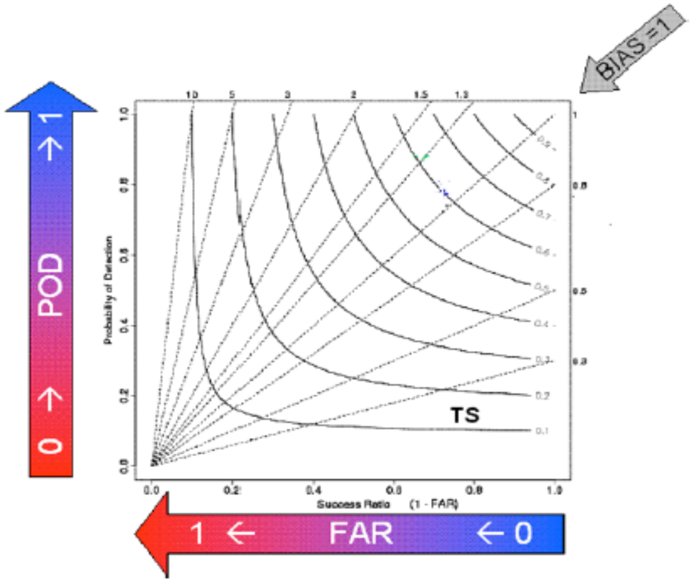
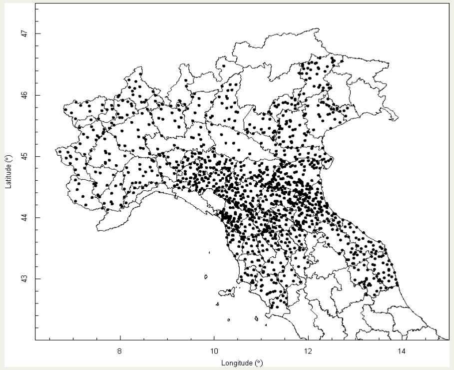
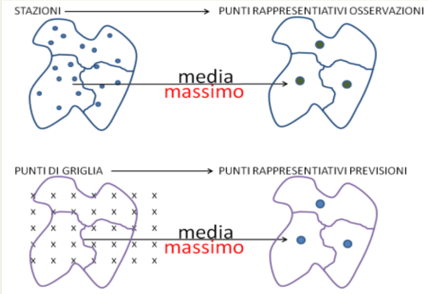


Figura 52: Performance Diagram

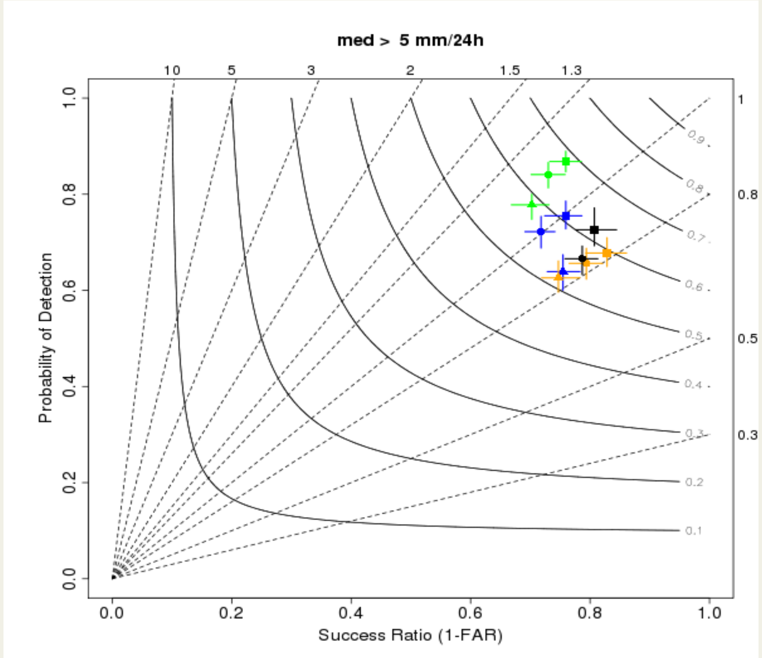
Il ***performance diagram*** permette di riassumere in un unico grafico POD, SR(success ratio = 1-FAR), BS e TS, sfruttando le relazioni geometriche tra questi indici.
In ascissa il Success Ratio (1-FAR), in ordinata la Probability Of Detection , le linee tratteggiare rappresentano il Bias Score mentre le linee curve rappresentano il TS.
La previsione risulta tanto più buona quanto più si avvicina all'angolo in alto a destra.
L'influenza della variabilità di campionamento è stimata utilizzando un ricampionamento con sostituzione mediante bootstrap.
Le barre di errore rappresentano l'intervallo di confidenza del 95% per il SR e POD calcolato sulla base degli *n* indici ricavati generando *n* nuove tabelle di contingenza della stessa dimensione dell'originale tenendo fisse le frequenze marginali.

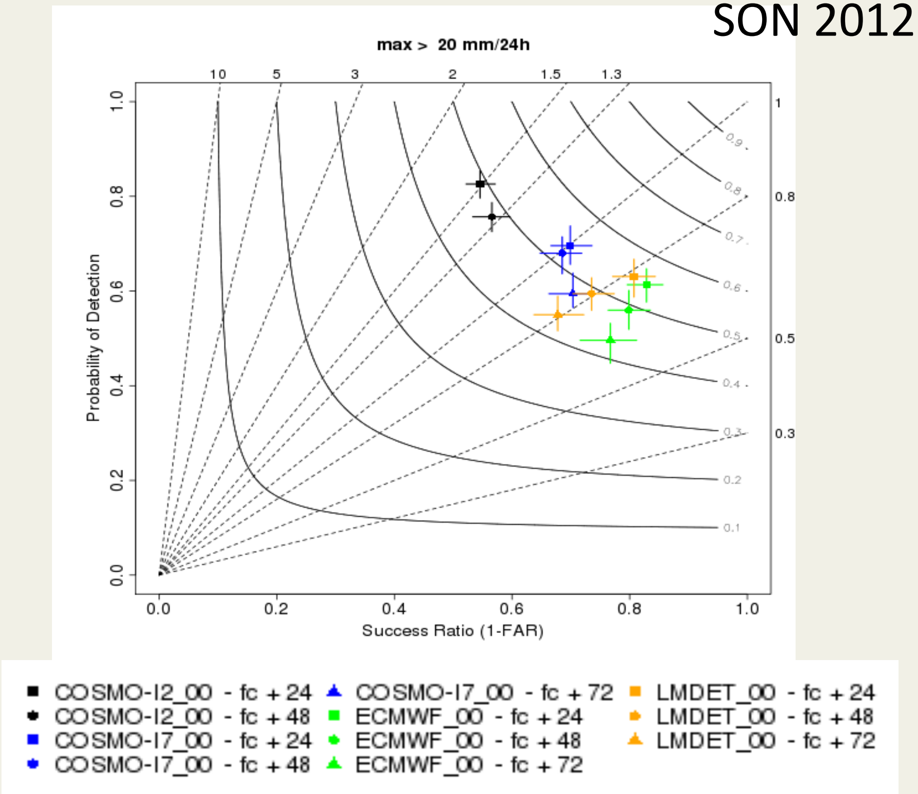
Performance diagram

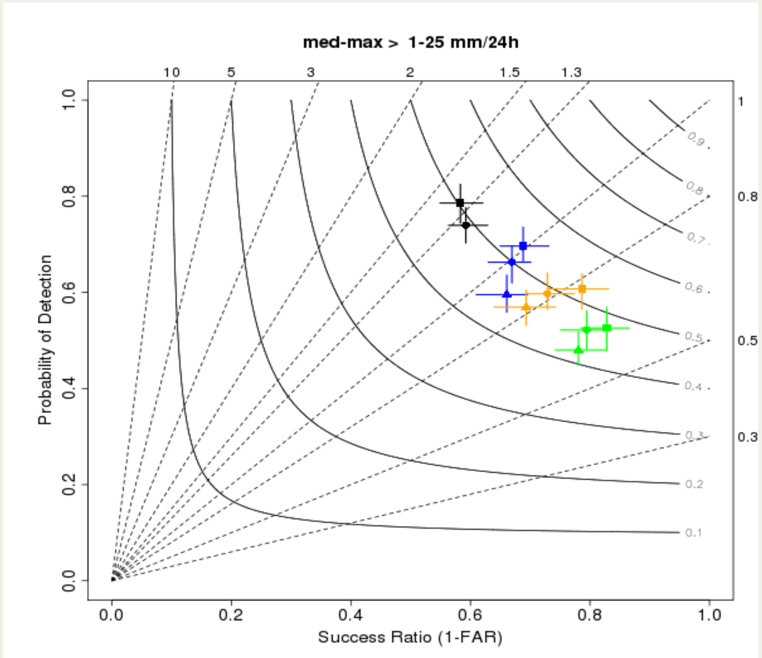




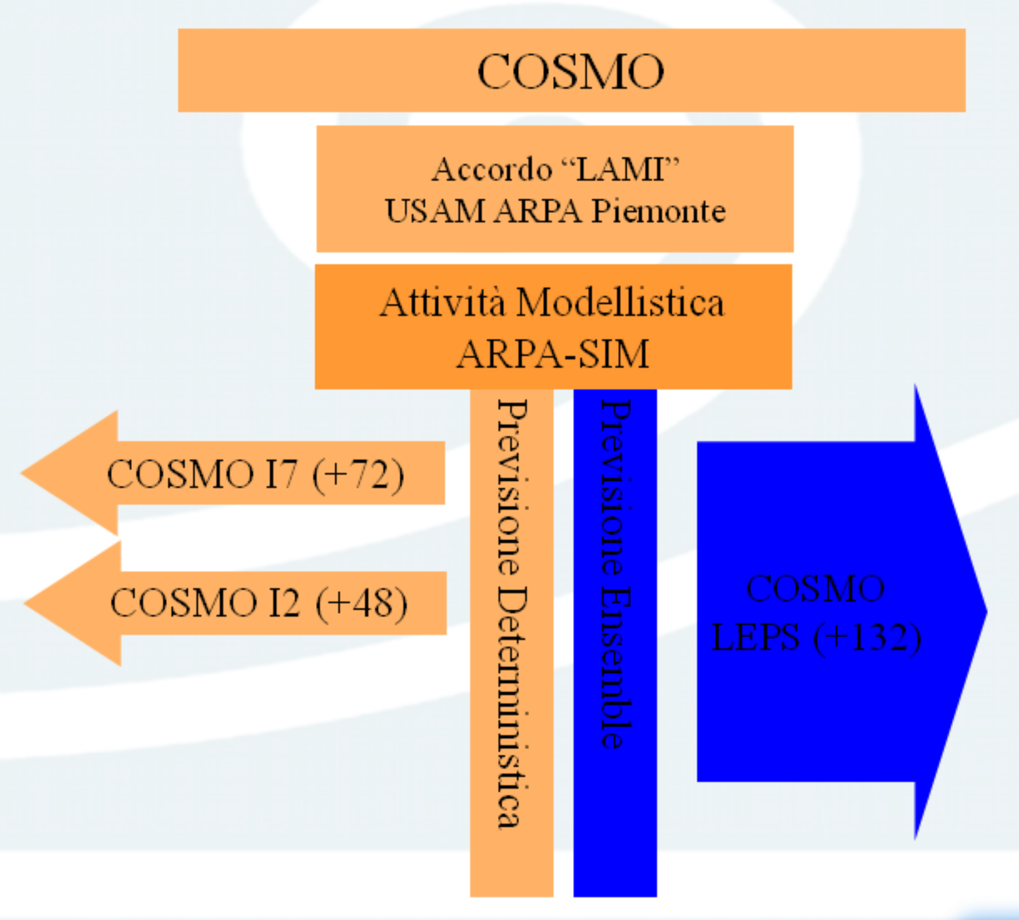
SON 2012







Utenti e Applicazioni



Marina
Modelli e applicazioni

Qualità dell'aria
Modelli e applicazioni

Modellistica Idrologico-
Idraulica
Modelli e applicazioni

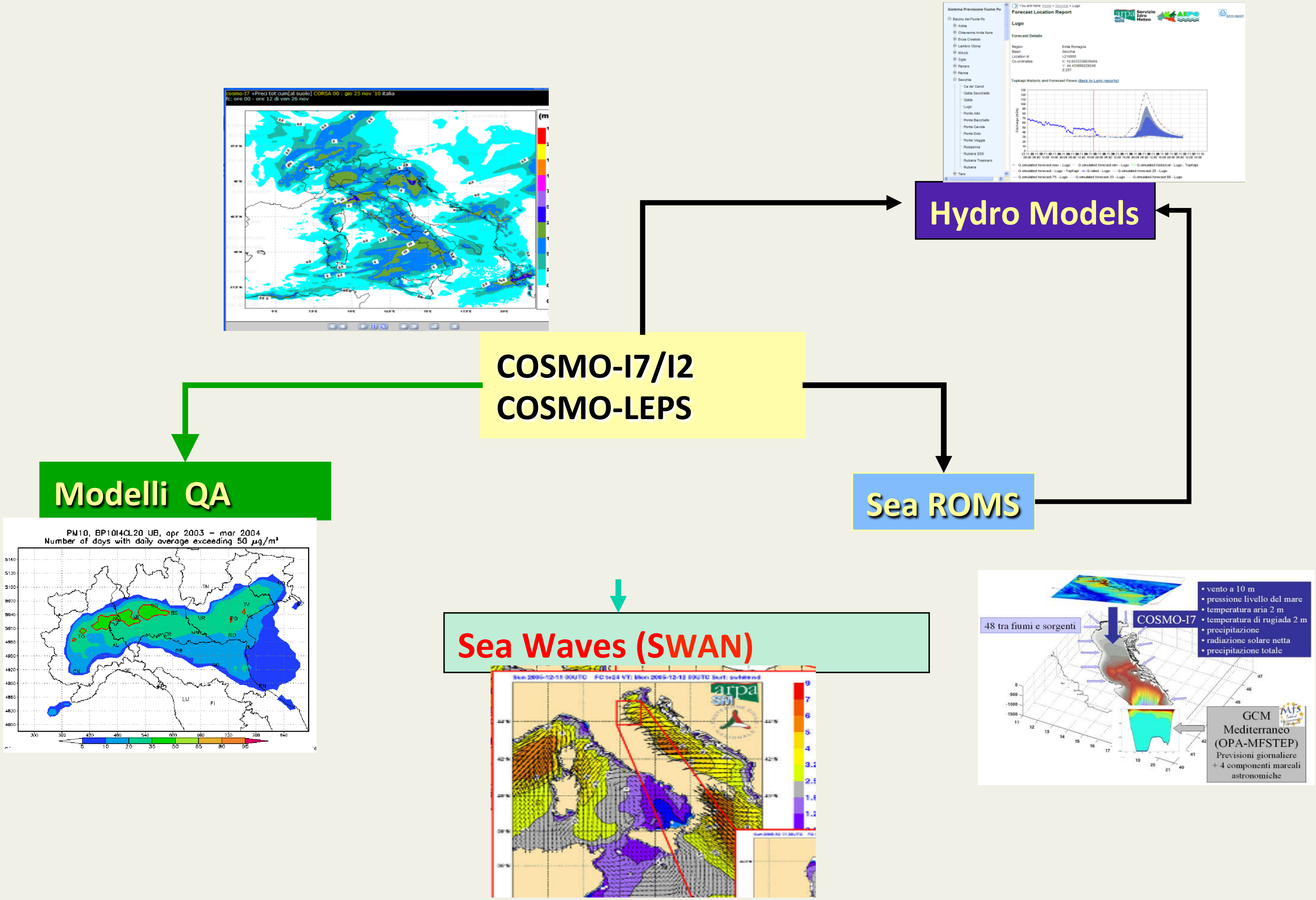
ENERGIA

Sistema di Protezione Civile (nazion.&reg.)

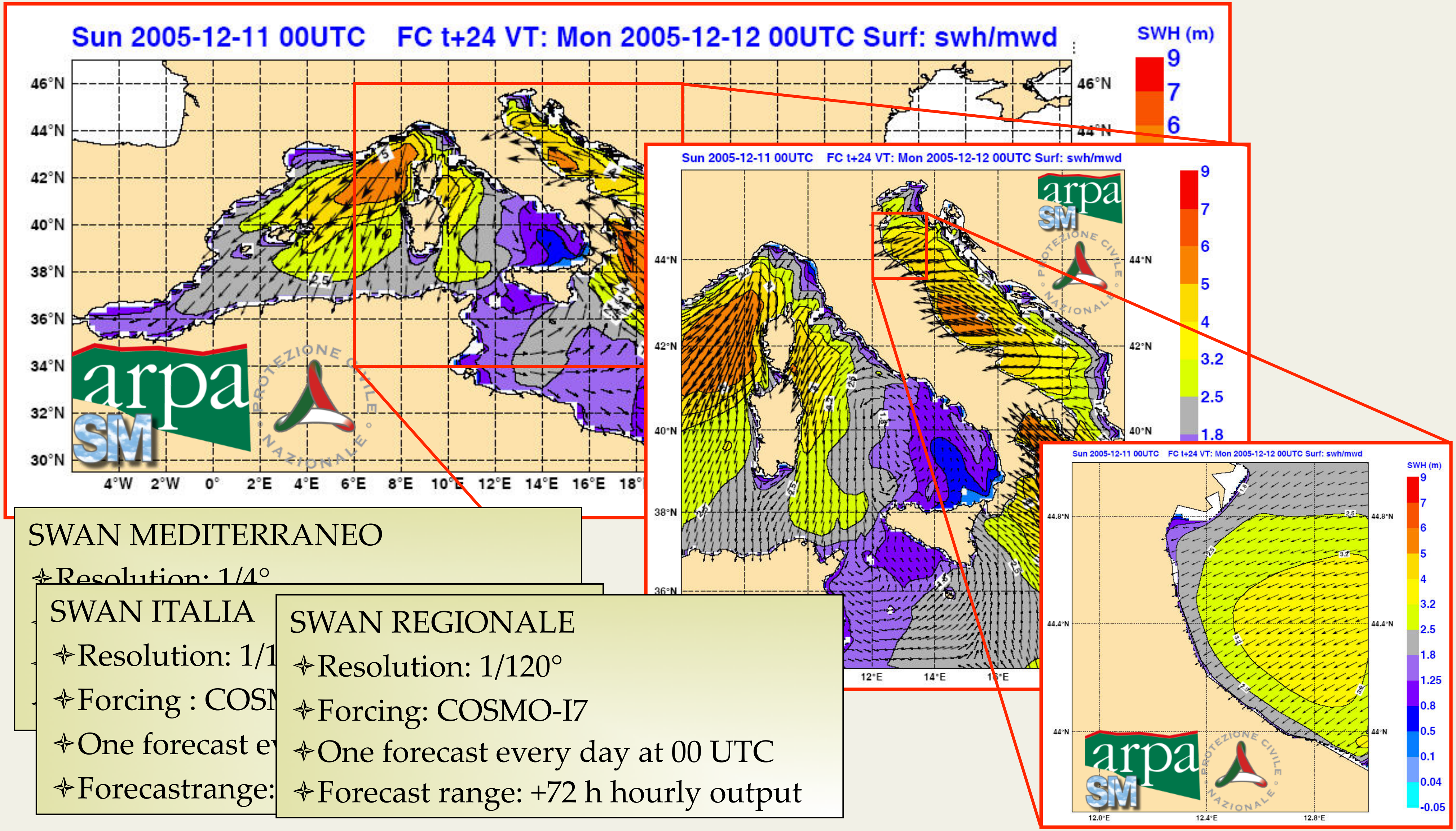
Previsori e uso diretto o dopo post-proc.

Altri servizi

Integrazione delle catene modellistiche ad ARPA-SIMC



SWAN MED-ITA-RE



SWAN MEDITERRANEO

✧Resolution: 1/4°

SWAN ITALIA

✧Resolution: 1/1

✧Forcing : COSM

✧One forecast ev

✧Forecastrange:

SWAN REGIONALE

✧Resolution: 1/120°

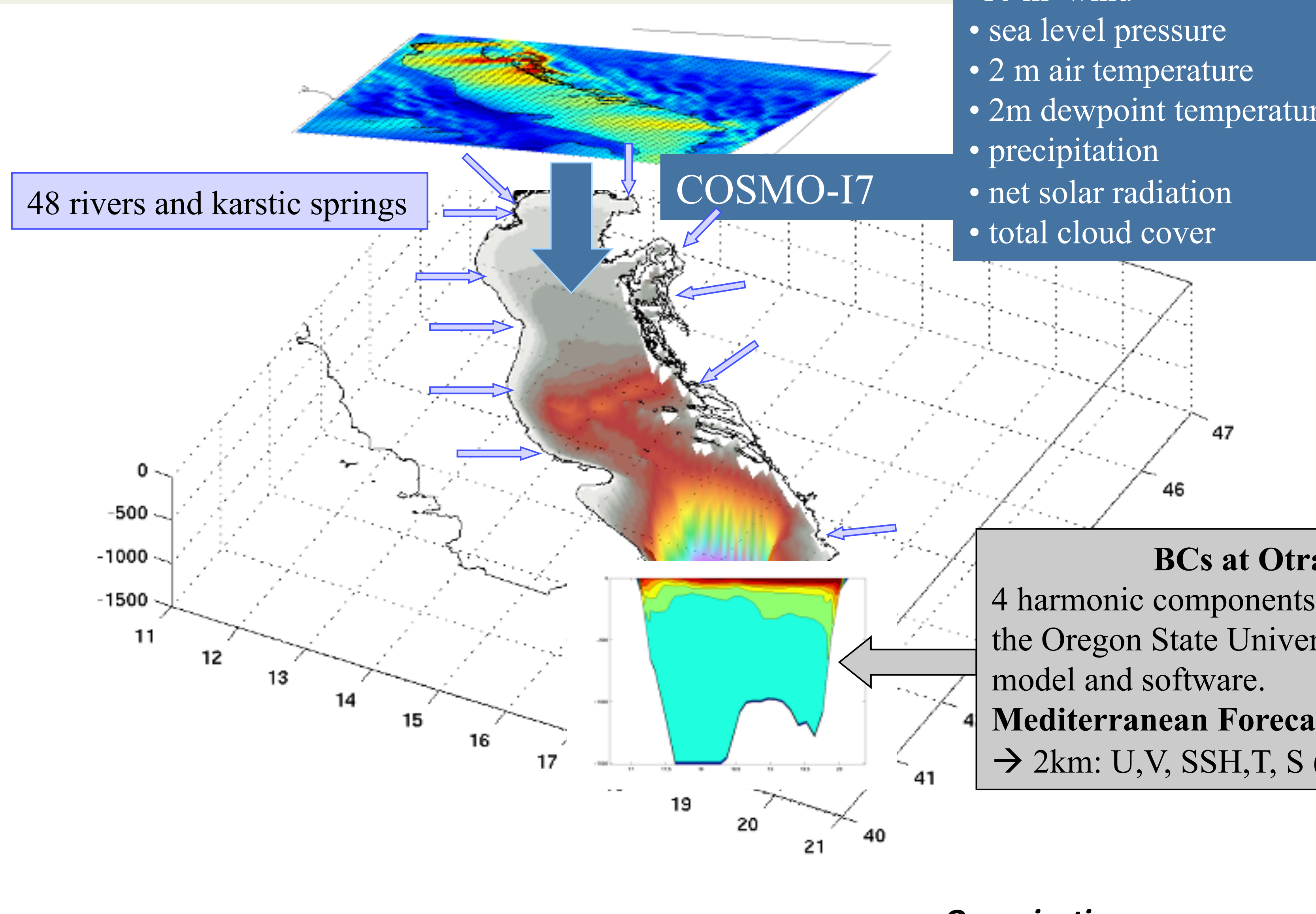
✧Forcing: COSMO-I7

✧One forecast every day at 00 UTC

✧Forecast range: +72 h hourly output

Author *Organization* *Organization logo* *Ancona, May 2013*

ADRIAROMS



48 rivers and karstic springs

COSMO-I7

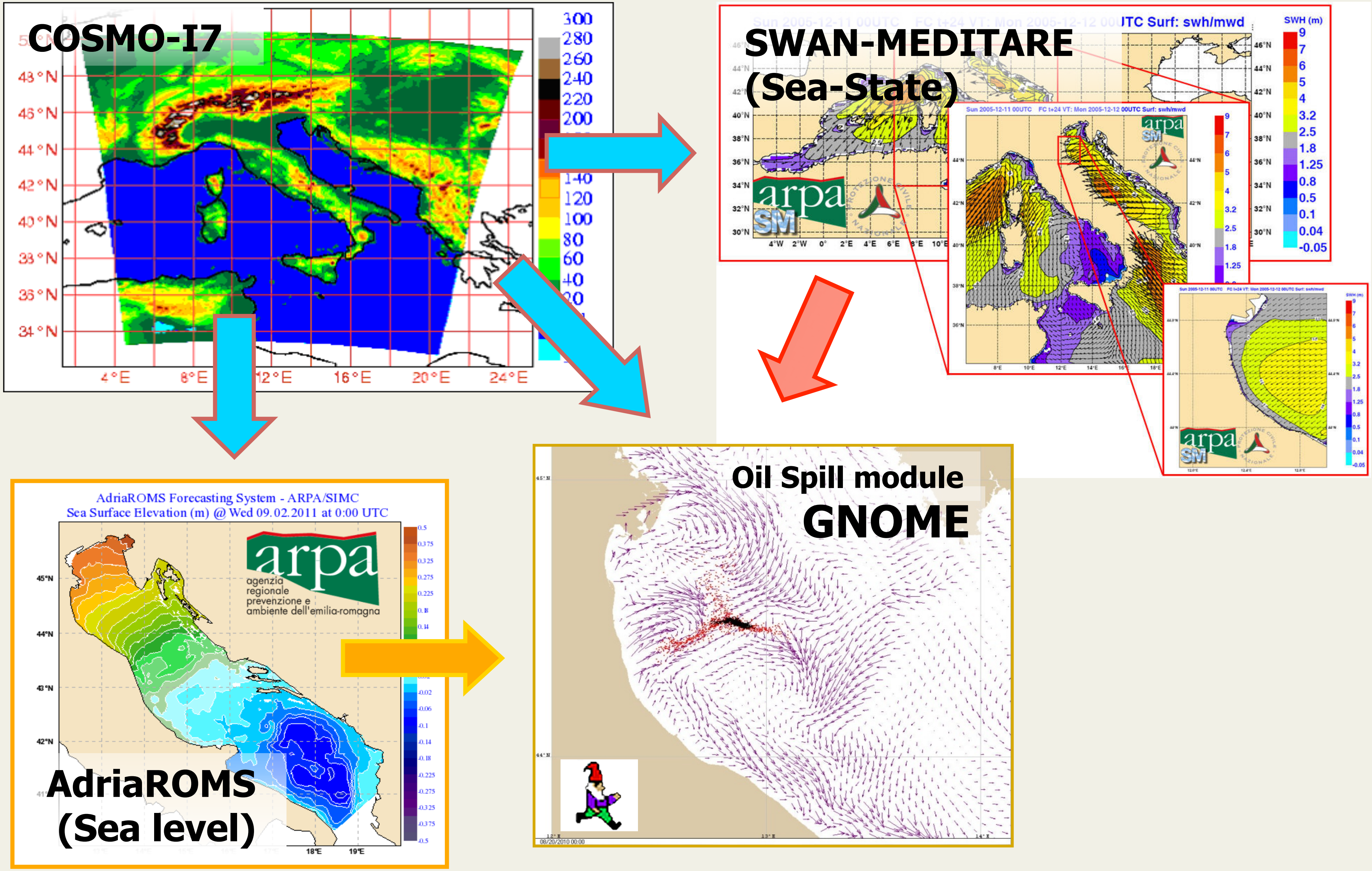
- 10 m wind
- sea level pressure
- 2 m air temperature
- 2m dewpoint temperature
- precipitation
- net solar radiation
- total cloud cover

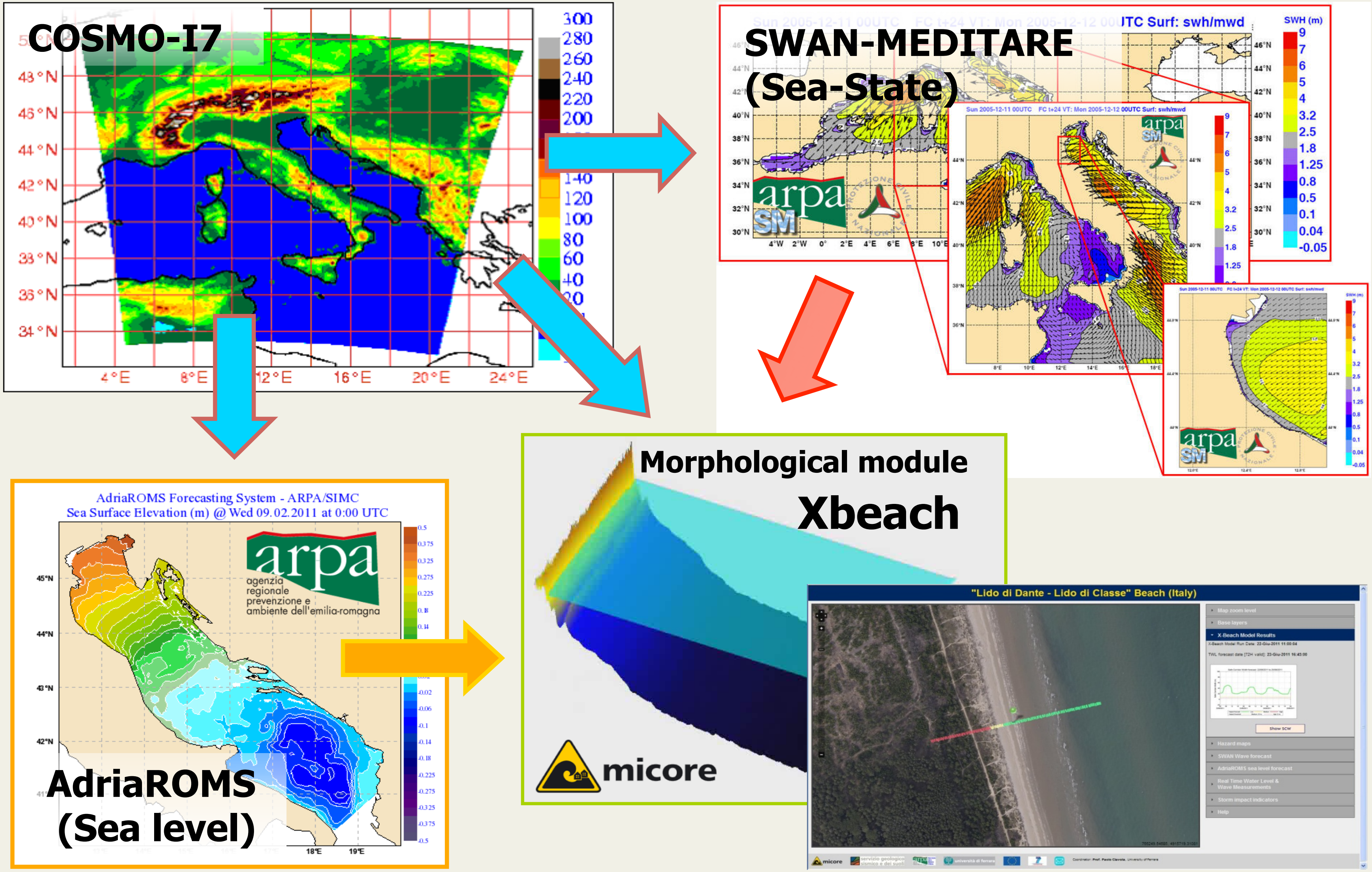
BCs at Otranto strait

4 harmonic components (M2, S2, O1, K1) by the Oregon State University (OSU) model and software.

Mediterranean Forecasting System (MFS)

→ 2km: U,V, SSH,T, S (…myOCEAN…)


COSMO-I7
SWAN-MEDITARE
(Sea-State)
SWH (m)
AdriaROMS Forecasting System - ARPA/SIMC
Sea Surface Elevation (m) @ Wed 09.02.2011 at 0:00 UTC
arpa
agenzia regionale prevenzione e ambiente dell'emilia-romagna
AdriaROMS
(Sea level)
Oil Spill module
GNOME


COSMO-I7
SWAN-MEDITARE
(Sea-State)
SWH (m)
AdriaROMS Forecasting System - ARPA/SIMC
Sea Surface Elevation (m) @ Wed 09.02.2011 at 0:00 UTC
arpa
agenzia regionale prevenzione e ambiente dell'emilia-romagna
AdriaROMS
(Sea level)
Morphological module
Xbeach
micore
"Lido di Dante - Lido di Classe" Beach (Italy)

CONCLUSIONI

Grazie alle cooperazioni COSMO e LAMI, e grazie al supporto della Protezione Civile Nazionale, ARPA SIMC sta gestendo da più di 15 anni, e ulteriormente sviluppando un sistema modellistico meteorologico stato dell'arte su standard europei.

Il futuro della Modellistica ad Area Limitata è verso la scala del chilometro. Anche se la NWP-LAM ha fatto enormi progressi negli ultimi anni, la bassa predicibilità intrinseca dei processi a piccola scala è ancora un grande obiettivo da raggiungere.

I modelli numerici di previsione devono sicuramente essere migliorati per migliorare la rappresentazione dei processi a piccola scala;

I sistemi di Data Assimilation devono essere sviluppati in modo da rendere ottimale la…"digestione" dell'enorme quantità di dati osservati disponibili, e proveniente da un multiforme spettro di vecchi e nuovi sistemi osservativi (es: dati al suolo delle reti ad alta risoluzione, dati dalla rete radar nazionale, dati da satellite, strumentazione speciale ecc…)

CONCLUSIONI

La consapevolezza dei nostri attuali limiti nella previsione “deterministica” alimenta l’ulteriore sviluppo dei sistemi probabilistici basati sull’ Ensemble Forecasting, che appare essere una adeguata modalità di gestire l’incertezza

Grandi sforzi devono ancora essere fatti dalla comunità scientifica per migliorare questi sistemi modellistici e soprattutto per valutare bene l’incertezza della previsione. Questo processo si può attuare attraverso una più adeguata conoscenza del legame esistente tra l’incertezza previsionale e gli errori di previsione (relazione skill/spread). Molta ricerca in questo settore è da sviluppare.

Grazie