Aeronautica Militare

Centro Operativo per la Meteorologia – C.O.Met.

Italian Air Force Meteorological Centre

ECMWF visit, 7th April 2016

The Italian Air Force operational Numerical Weather Prediction System

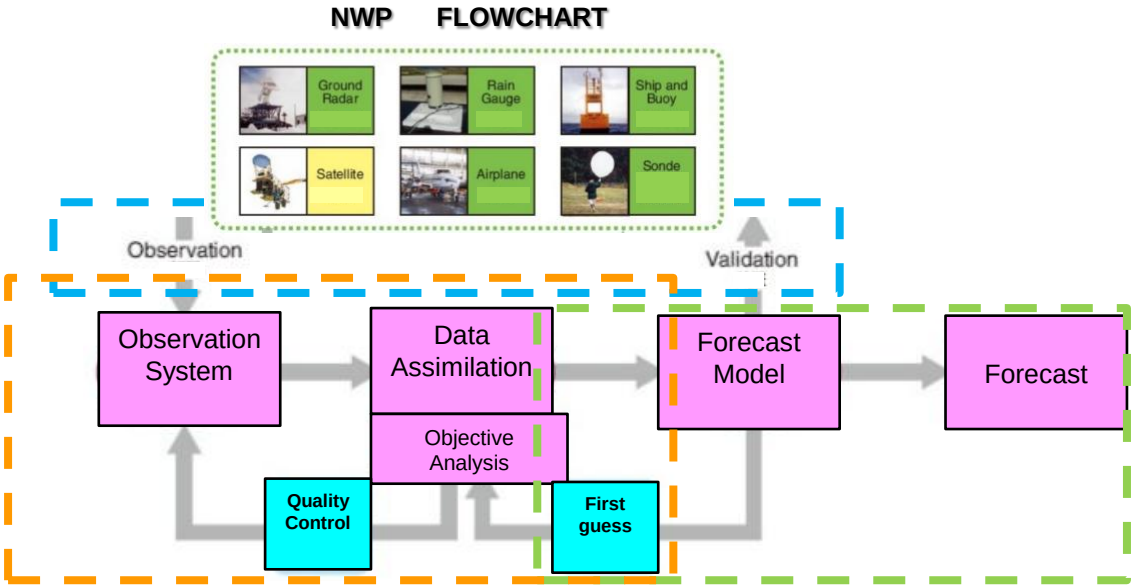
Lt.Col. Antonio Vocino
NWP Modelling Section

Outline

- ITNWP facts and figures
- Operational suites
- ICT assets
- Recent developments and future plans
- Communication and reporting activities

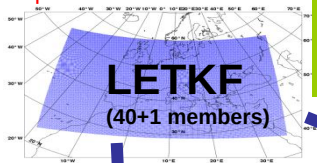
Numerical Weather Prediction Branch

Data Assimilation | **Numerical Modelling** | **Model Verification**



Operational Numerical Weather Prediction System

Ensemble Data Assimilation:
Operational since June 2011



10 km
45 v.l.

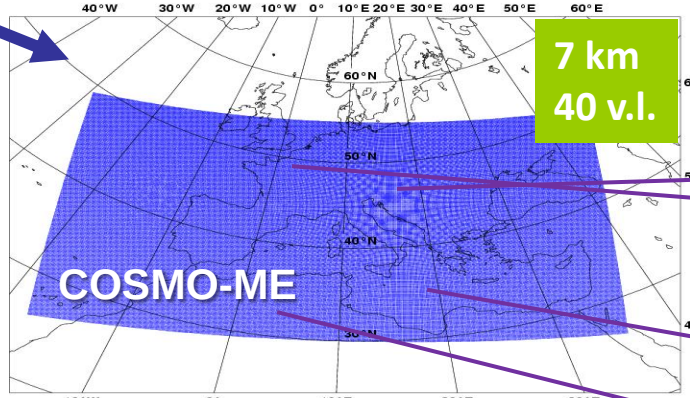
ECMWF Boundary Conditions

Ensemble Analysis

Deterministic Analysis

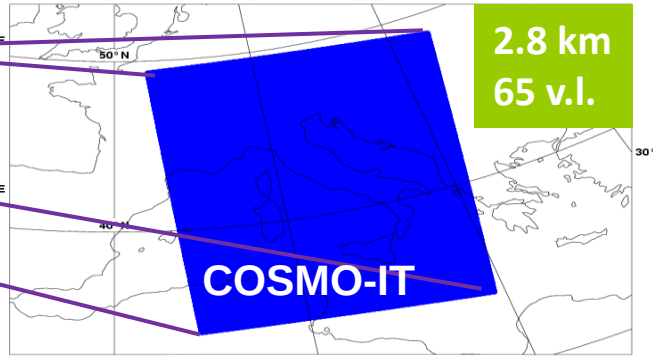
Local Area Modeling:

COSMO-ME (7km) ITALIAN MET SERVICE



7 km
40 v.l.

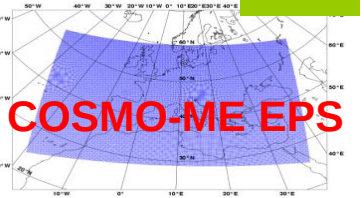
COSMO-IT (2.8Km) ITALIAN MET SERVICE

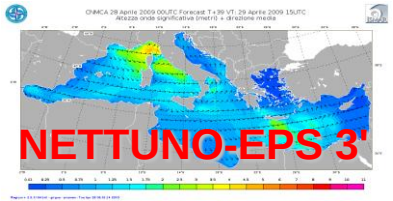


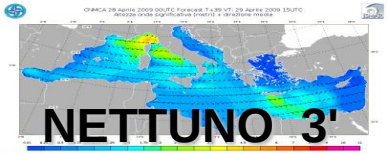
2.8 km
65 v.l.

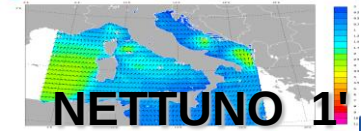
Ensemble Prediction System:

10 km
45 v.l.

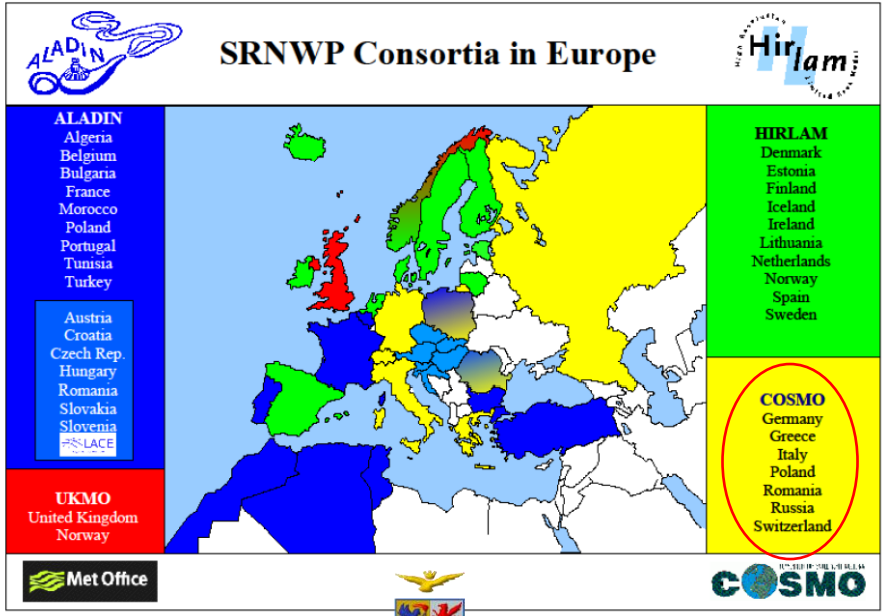


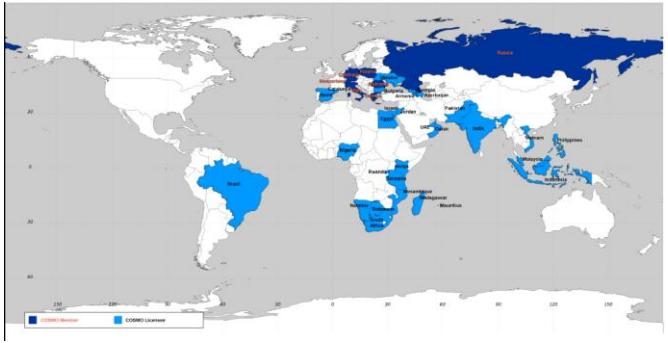






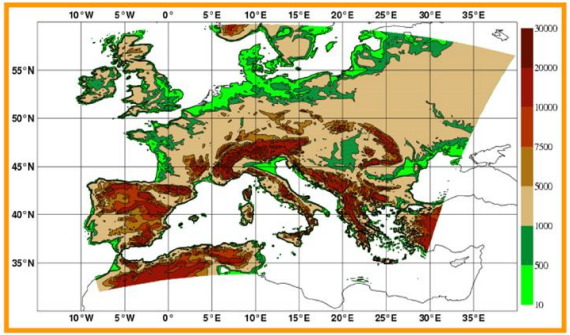
Operational NWP model: COSMO



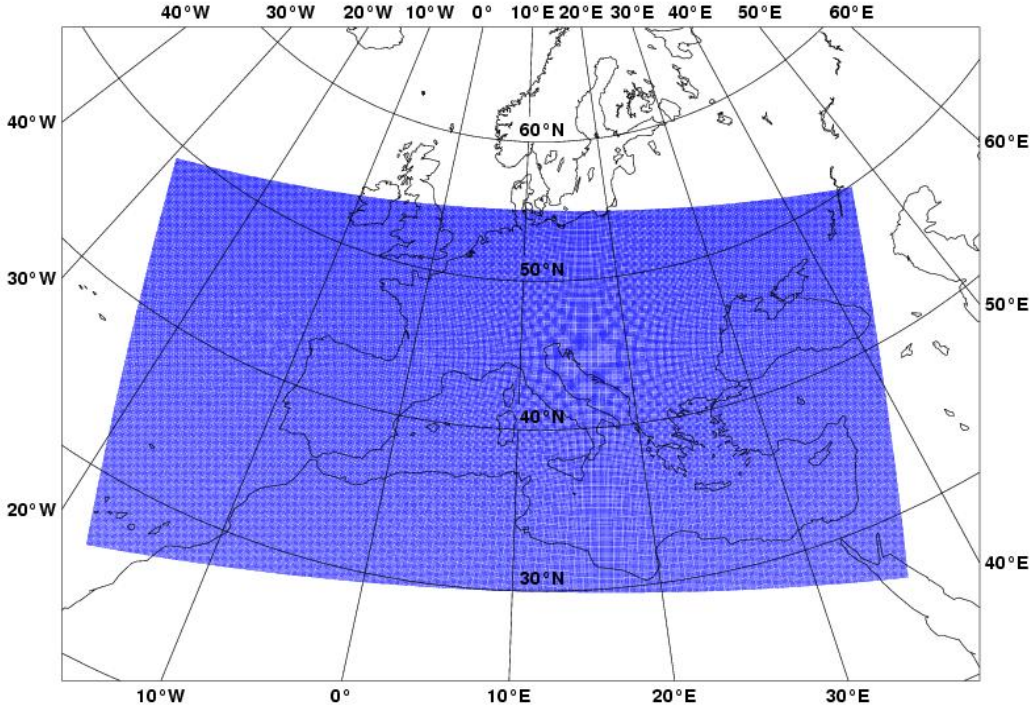


COSMO-LEPS

downscaling of selected ECMWF EPS members

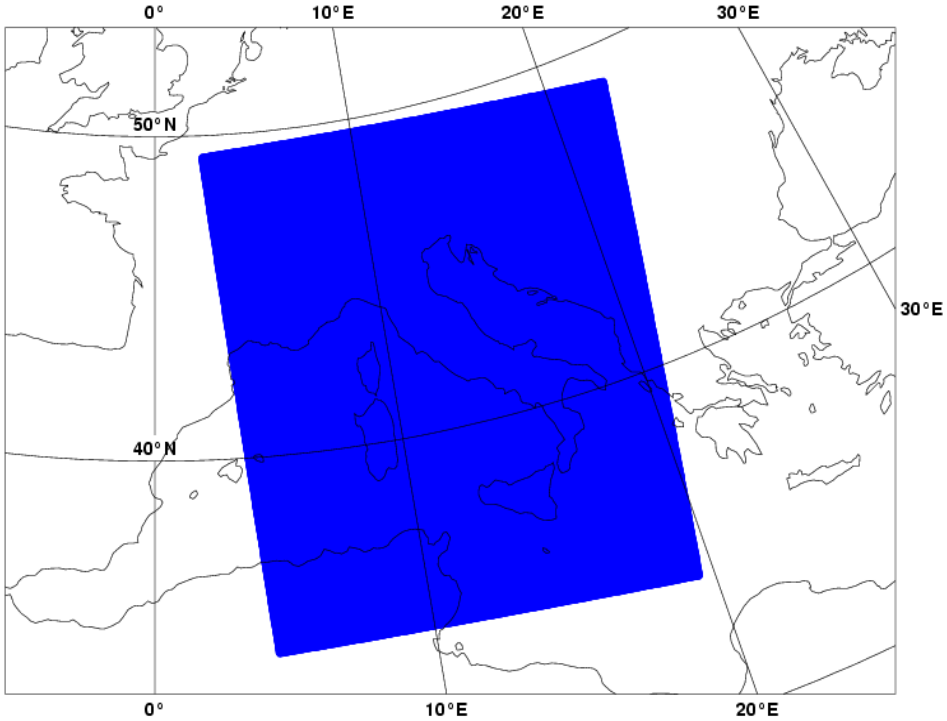


COSMO-ME (7 km)



Domain size	779 x 401
Grid spacing	0.0625 (7 km)
Number of layers / top	40 / ~22 km
Time step	40 s
Forecast range	72 hrs
Initial time of model run	00/06/12/18 UTC
Lateral bound. condit.	IFS
L.B.C. update freq.	3 hrs
Initial state	Interpol. LETKF
Initialization	None
External analysis	T,u,v, qv,ps, snow mask
Special features	Filtered topography
Status	Operational

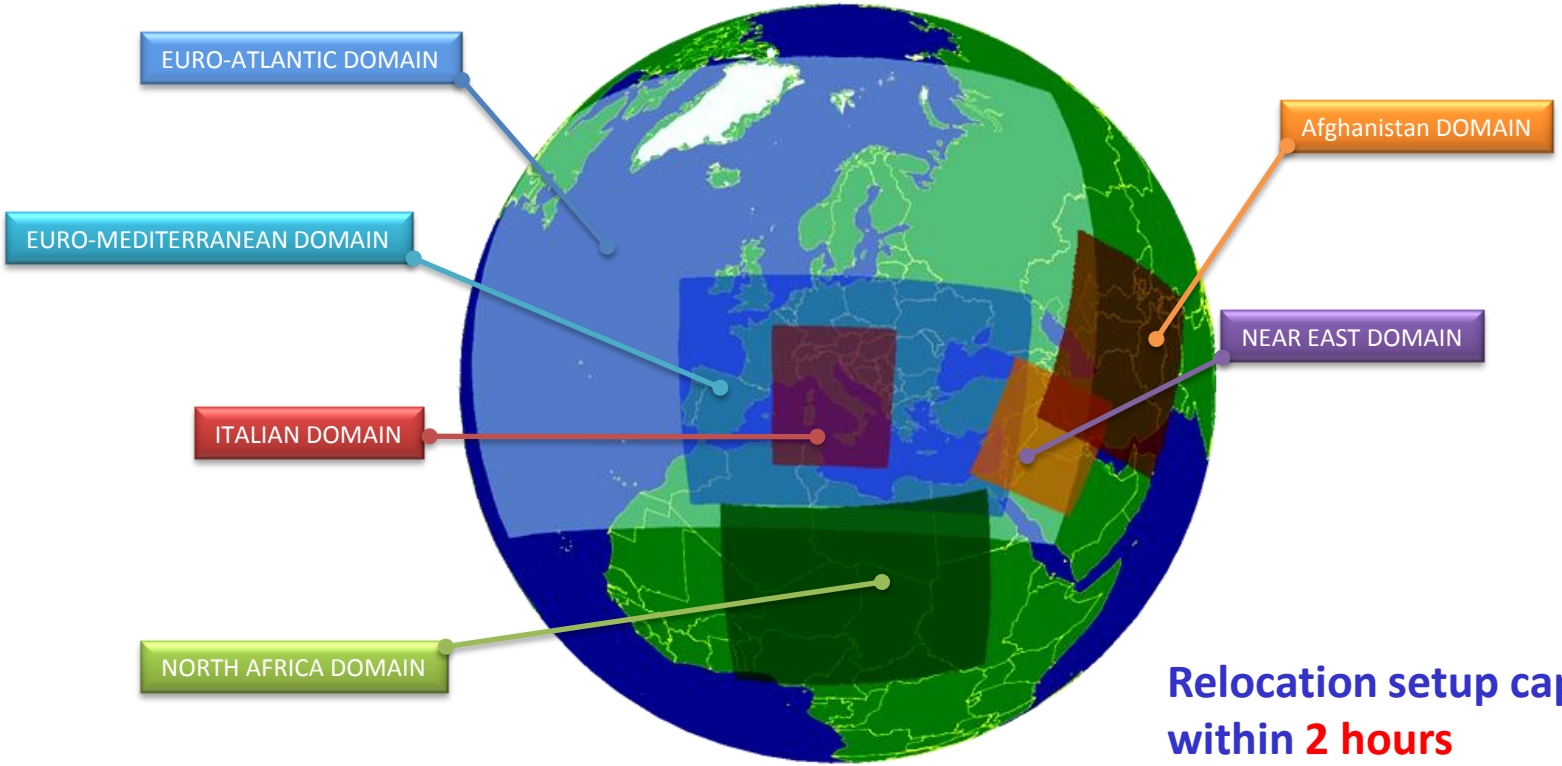
COSMO-IT (2.8 km)



Domain size	542 x 604
Grid spacing	0.025 (2.8 km)
Number of layers / top	65 / ~22 km
Time step and scheme	25 s
Forecast range	24 hrs
Initial time of model run	00/12 UTC
Lateral bound. condit.	COSMO-ME
L.B.C. update frequency	1 hr
Initial state	Nudging
Initialization	None
External analysis	None
Special features	Filtered topography
Status	Operational

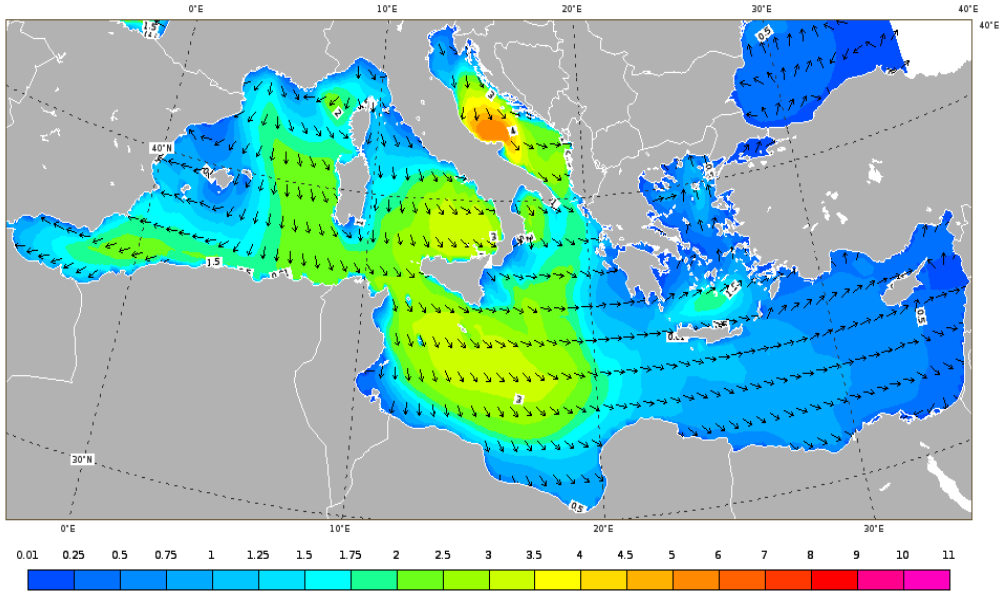
- COSMO models can be relocated for specific areas of interest, e.g.:
  - Lebanon
  - Afghanistan
  - Japan
  - Syria
  - Lybia
  - METOC support to:
    - NATO Response Force (NRF)
    - European Union Naval Force Mediterranean (EUNAVFOR Med)

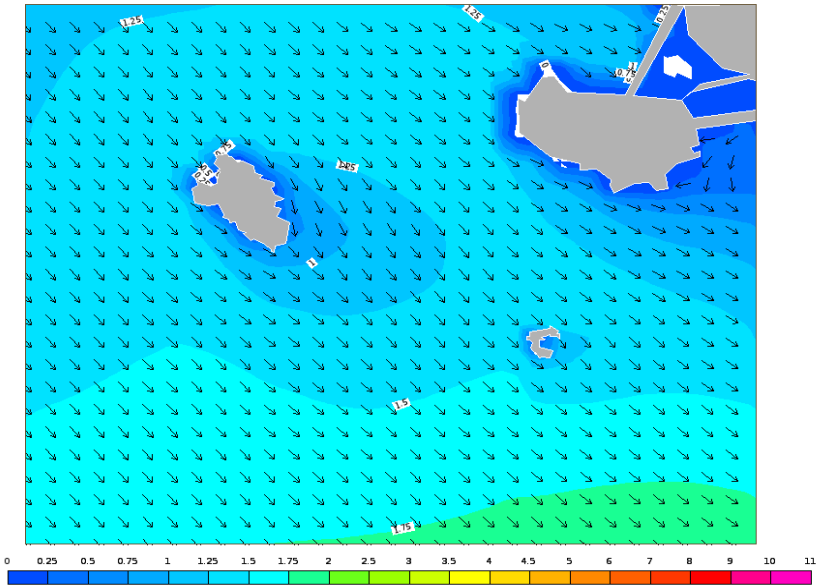
NWP LIMITED AREA MODELS – OPERATIONAL SCENARIOS



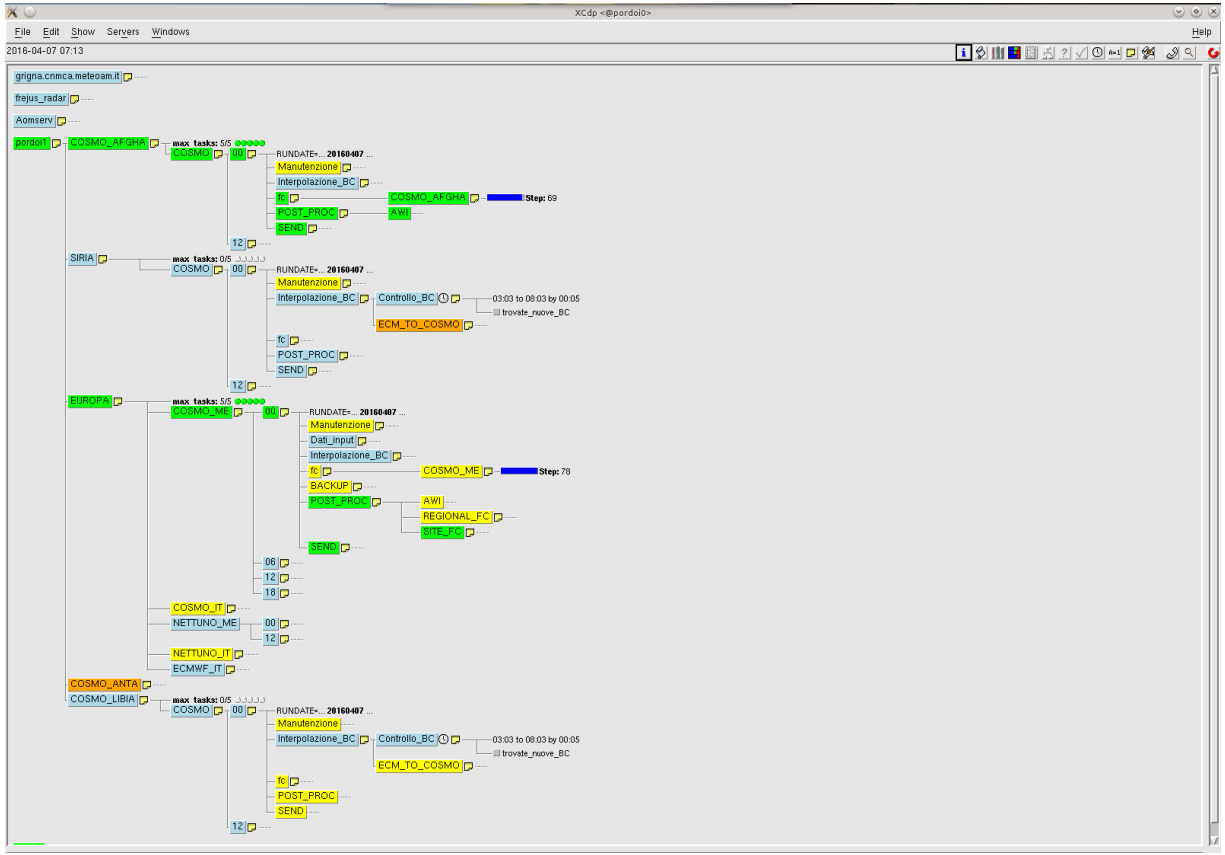
Relocation setup capability within 2 hours

COSMO-DRIVEN WAVE MODELS - NETTUNO





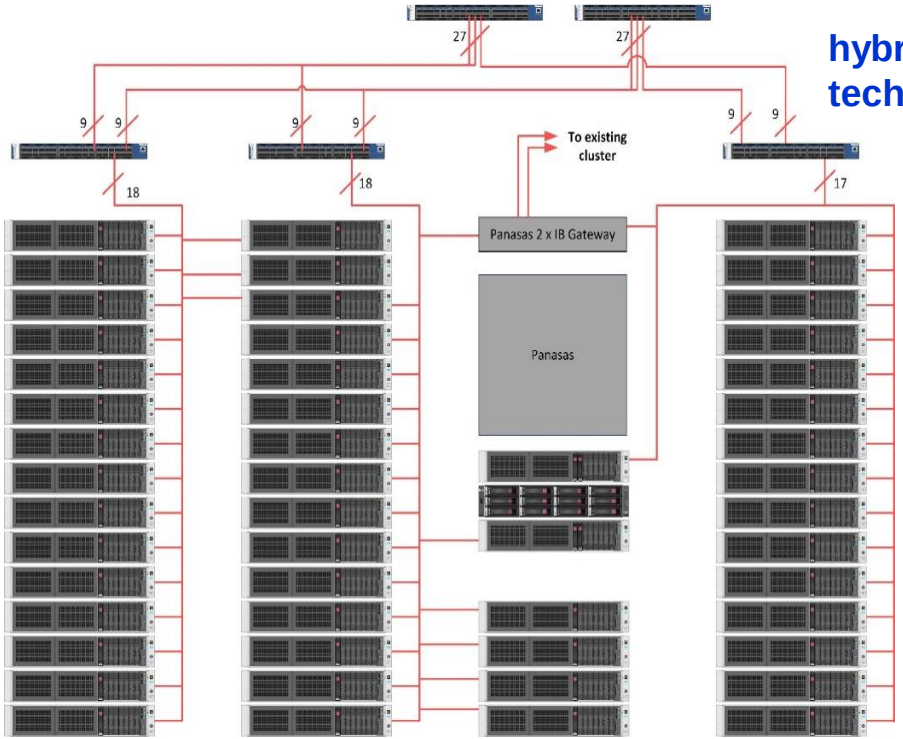
NWP operational suites running at COMET



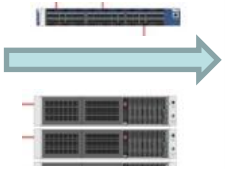
CLUSTER PORDOI

(the past...)

The future: new HPCF environment



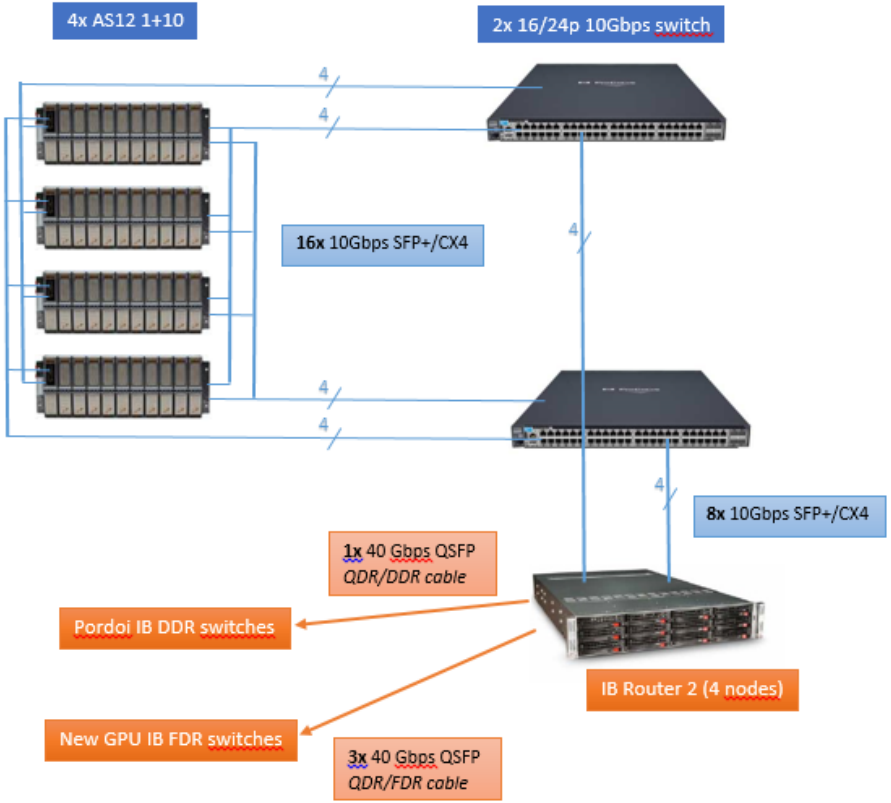
hybrid CPU/GPU technology



- 51x DL380 G9 Computing Nodes
- 2x DL380 G9 Management Nodes (2x12 Haswell cores - 64 GB)
- 1x MSA2040 DAS
- 6x Infiniband 36p FDR switches
- 102x Kepler K80 GPUs (24 GB) (204 GPU units ≈ 500K GPU cores)
- 9 TB RAM

- 190 TFLOPS peak
- 308 TFLOPS peak (BOOST)
- → #300 TOP500 world
- → #5 in Italy
- → #1 in Italy with GPU

New HPCF – I/O subsystem



- 4x AS12 1+10 w/ 40 TB
  → 160 TB RAW
- 2x 16p 10 Gbps switches
- 4x Infiband Router2 nodes
- PANFS + NFS over Infiniband QDR

- 6.0 GB/s sustained READ
- 6.4 GB/s sustained WRITE

- FULLY REDUNDANT Configuration

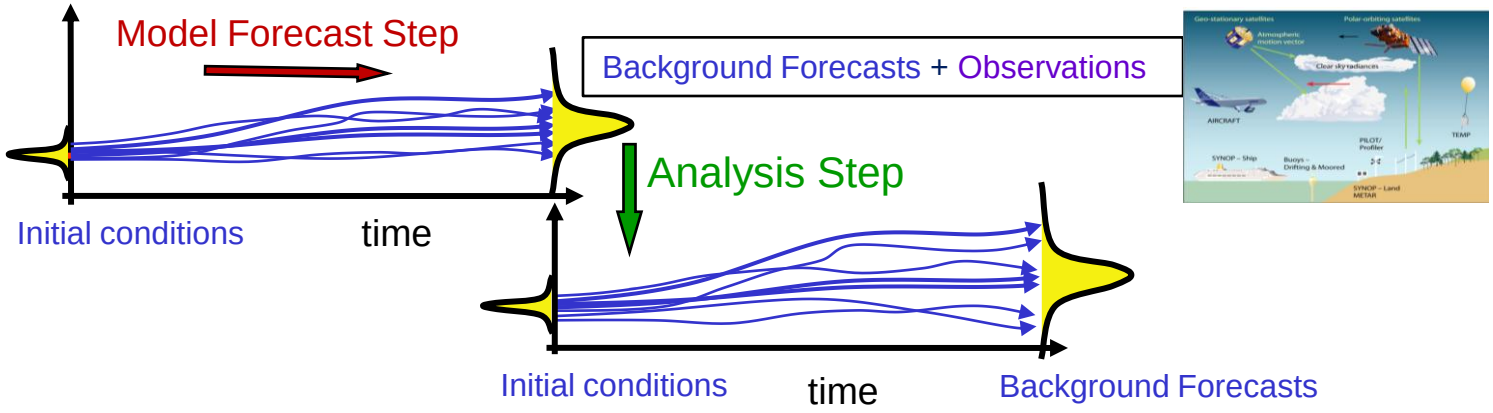
Progresses on Data Assimilation

Optimal Interpolation (OI) — 3D-VAR* — Local Ensemble Trasform Kalman Filter (LETKF)

1999 — 2002 — 2011

* 3D-VAR: 3 Dimensional Variational Assimilation

Ensemble Data Assimilation System (LETKF)



Competitive alternative to variational methods providing "optimal" analysis errors estimates for ensemble forec.

CNMCA – LETKF analysis

(*Bonavita, Torrisi and Marcucci, Q.J.R.M.S.,2008,2010)*

- ***OPERATIONAL SINCE 1 JUNE 2011***
- ***LETKF Formulation*** *(Hunt et al,2007)*

- 6-hourly assimilation cycle
- 40 ensemble members + deterministic run with 0.09° (~10Km) grid spacing (COSMO model), 45 hybrid z-sigma vertical levels (top at ~27km)
- (T,u,v,pseudoRH,ps) set of control variables
- Observations: using RAOB (also 4D), PILOT, SYNOP, SHIP, BUOY, Wind Profilers, AMDAR-ACAR-AIREP, MSG3-MET7 AMV, MetopA-B scatt. winds, NOAA/MetopA-B AMSUA/MHS and NPP ATMS radiances + LandSAF snowmask,

MODEL ERROR

- "Relaxation-to-Prior Spread" Multiplicative Inflaction according to Whitaker et al (2010)
- Additive noise from EPS

BOUNDARIES PERTURBATION

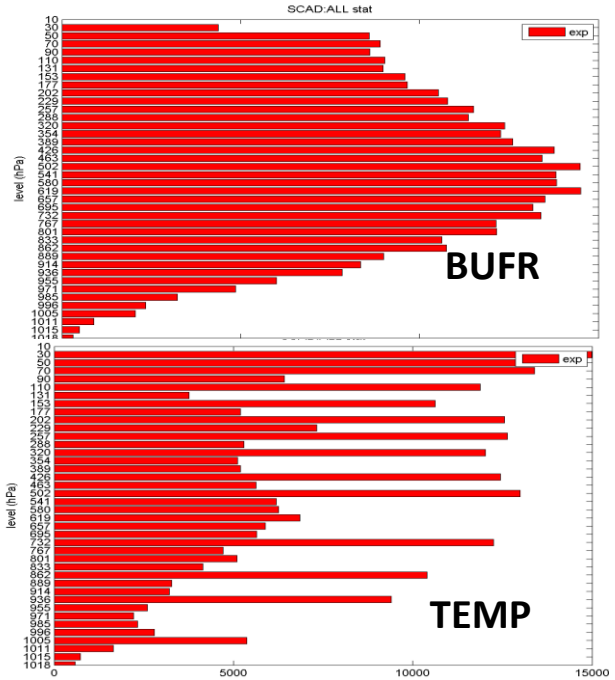
- Lateral Boundary Condition from deterministic IFS perturbed with ECMWF-EPS
- Climatological Perturbed SST

- Adaptive selection radius using a fixed number of effective observations (sum of obs weights)

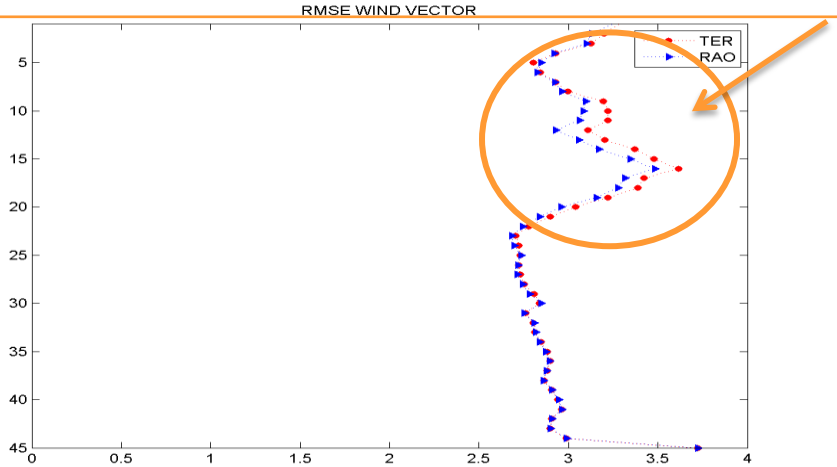
Radiosounding Assimilation

RAOB in BUFR are operationally assimilated in CNMCA-LETKF system.
Time and space displacements are taking into account. A vertical thinning is applied in order to reduce large amount of data mantaining “significant” levels

2 months statistics



RAOB (RAO) vs RAOB “no displacement” (TER)



Monitoring using COMET-LETKF

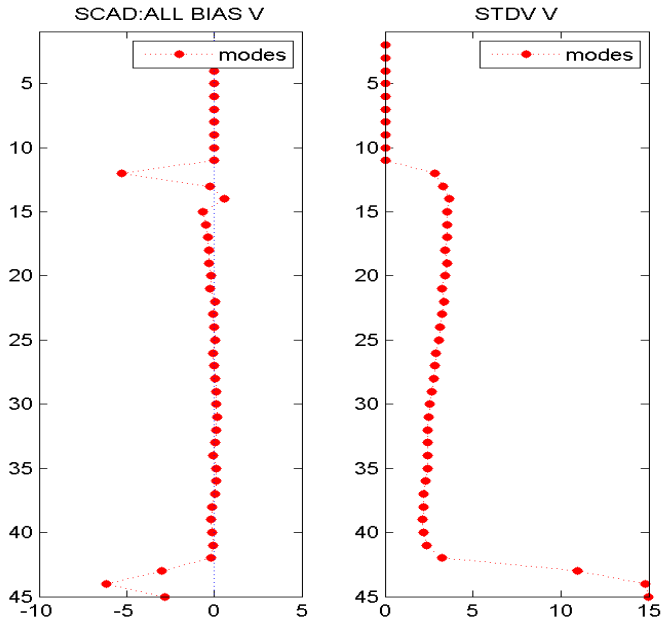
From 1 apr to 28 apr 2014

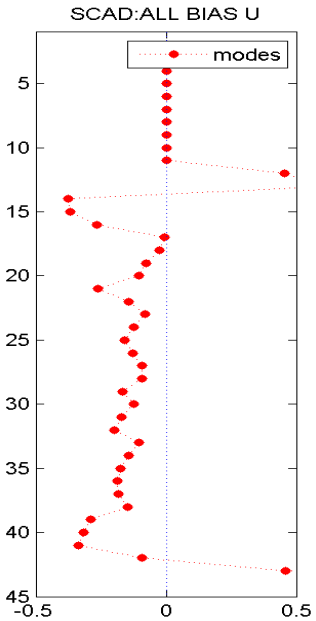
MODE-S Monitoring

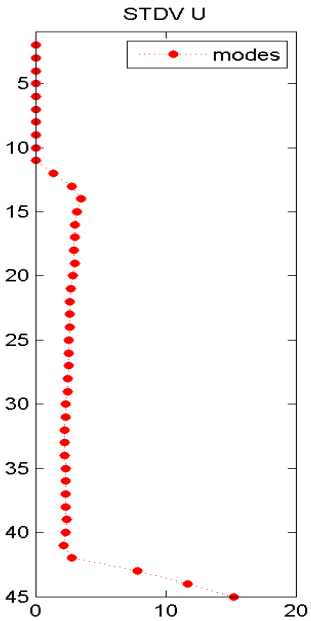
1 JAN – 1 APR 2015

MODES in BUFR format from KNMI

Monitoring using CNMCA-LETKF system





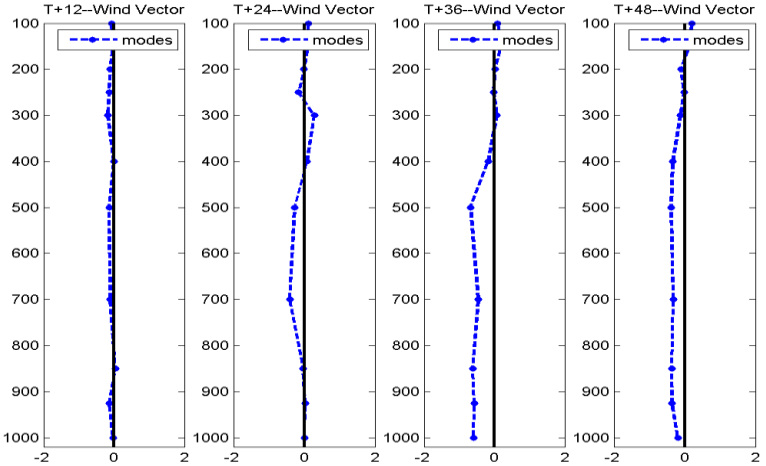


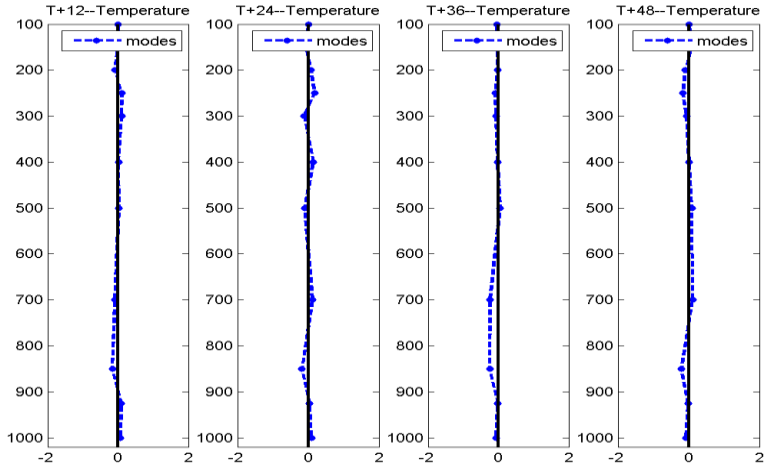
MODE-S Assimilation

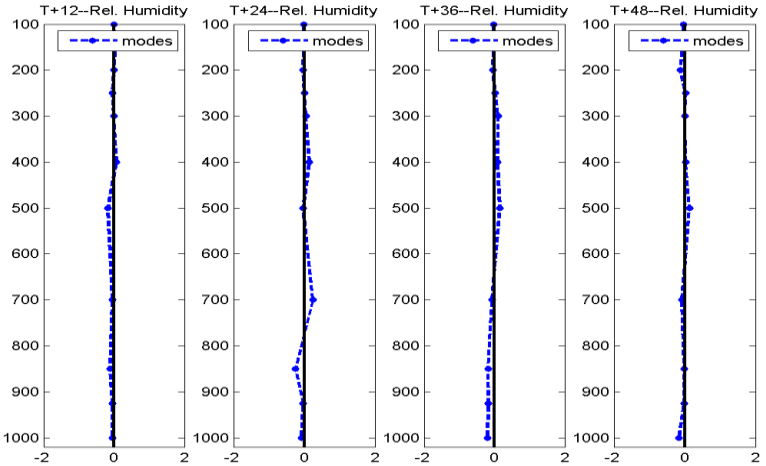
Forecast verification

Thinning: 30 km

Relative difference (%) in RMSE,
computed against IFS analysis with respect to the experiment without MODE-S
for 00 UTC COSMO forecasts from
11-nov 2014 to 10 dec 2014
negative value = positive impact





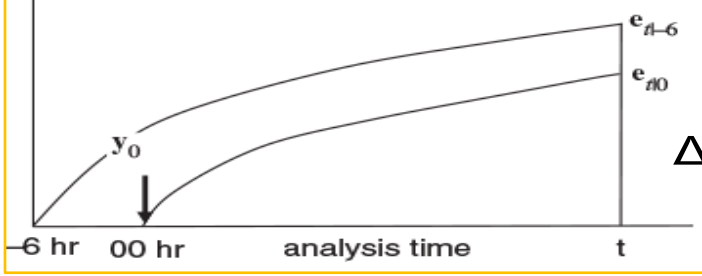


Forecast Sensitivity to Observations

(by V. Cardinali)

Perceived Forecast Errors

$$e_{t,0} = x^f_{t,0} - x^a_t$$



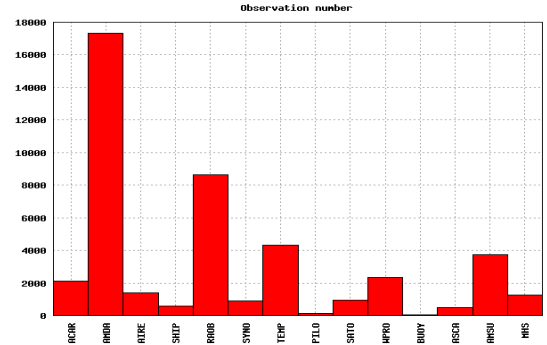
Following Kalnay et al (2012) the observation impact on the reduction of forecast error:

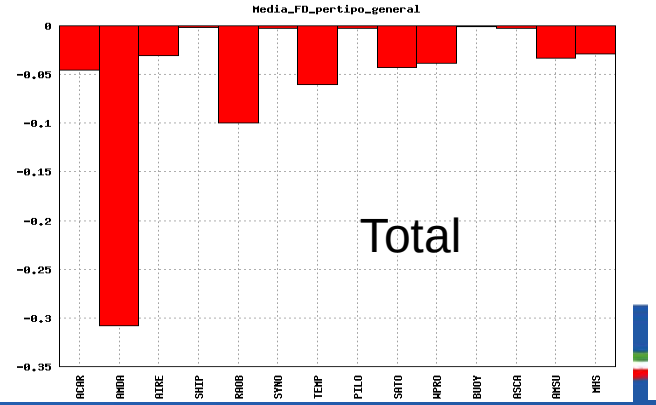
$$J = \Delta e^2 = e^T_{t,0} C e_{t,0} - e^T_{t,-6} C e_{t,-6}$$

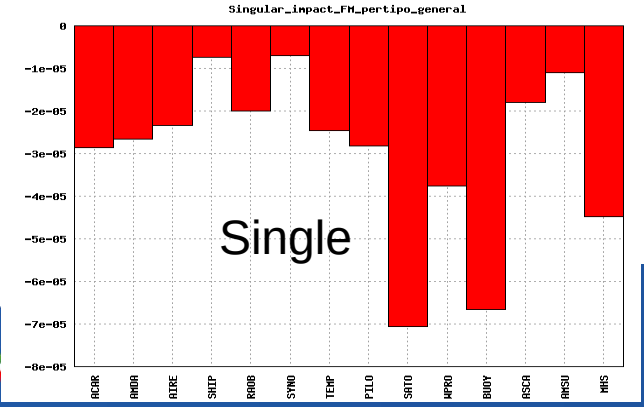
$$\Delta e^2 \approx 1/(K-1)[y_0 - H(x^b_{0,-6})]^T R^{-1} Y^a_0 X^{f\,T}_{t,0} C (e_{t,0} + e_{t,-6})$$

C = moist total energy norm (fractional mass weight)

November 2014 – March 2015







COSMO KENDA Priority Project

COSMO: Consortium for **S**mall-scale **Mo**deling (Germany, Switzerland, Italy, Greece, Poland, Romania and Russian)

KENDA
(Km-Scale Ensemble-Based Data Assimilation)

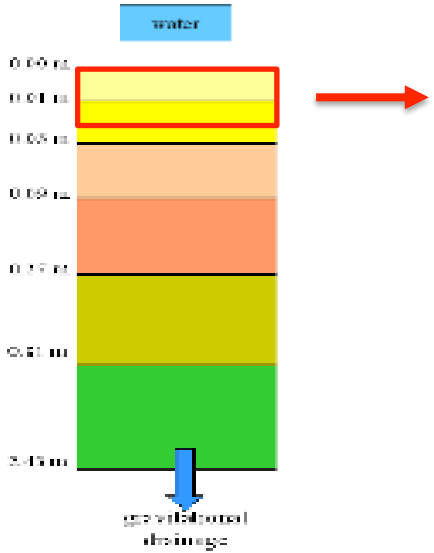
TASK: To develop a separate DA scheme for the convective scale (in which conditions such as non gaussianity, strong non linearity, flow dependent and poorly know balance are much more dominant), and to use a similar approach for a generalized system for global and regional modelling.

The main FOCUS of the KENDA project has been on the algorithmic development of the LETKF

Assimilation of conventional observations and (work in progress) high resolution remote sensing data (radiances, RADAR data, screen level observations, ground based GNSS slant path delay, **ASCAT soil moisture**)

Transformed SOIL MOISTURE

- ASCAT derived Soil Moisture: **degree of saturation** (%) in the first 2 cm
- COSMO TERRA_ML model soil moisture: **liquid water content** (m H2O) in the various model layers



layer structure of the hydrological part of the COSMO TERRA_ML soil model

To compare observed and model values the model values are transformed (to have quantities independent from the thickness of the layers) in **volumetric water content** (m^3/m^3) and then interpolated in the first 2 cm

+

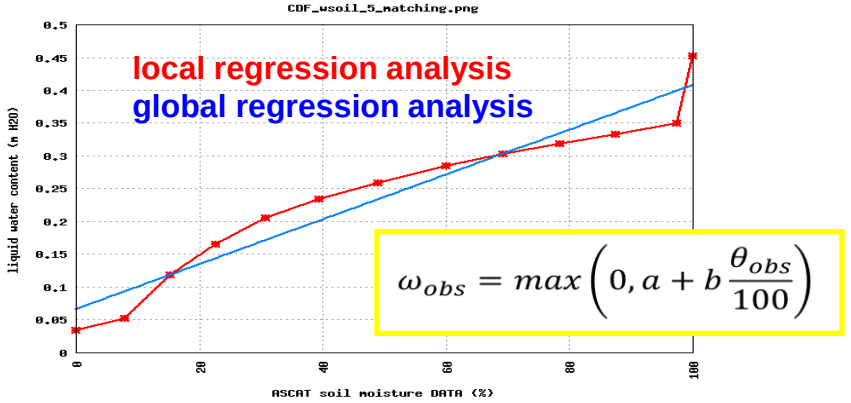
NEED TO RESCALE THE SATELLITE OBS TO THE MODEL VALUES

- CDF matching method
- Normalization methods

Transformed SOIL MOISTURE

CDF matching:

To scale the ASCAT derived soil moisture to the model climatology so that the cumulative distribution functions (CDF) of satellite and model soil moisture match.



$$\omega_{obs} = max\left(0, a + b\frac{\theta_{obs}}{100}\right)$$

Normalization method:

$$\omega_{obs} = \omega_{ADP} + \frac{\theta_{obs}}{100}\left(\frac{\omega_{PV} + \omega_{FC}}{2} - \omega_{ADP}\right)$$

soil type	1 ice	2 rock	3 sand	4 sandy loam	5 loam	6 loamy clay	7 clay	8 peat
volume of voids w_{PV} [1]	-	-	0.364	0.445	0.455	0.475	0.507	0.863
field capacity w_{FC} [1]	-	-	0.196	0.260	0.340	0.370	0.463	0.763
permanent wilting point w_{PWP} [1]	-	-	0.042	0.100	0.110	0.185	0.257	0.265
air dryness point w_{ADP} [1]	-	-	0.012	0.030	0.035	0.060	0.065	0.098

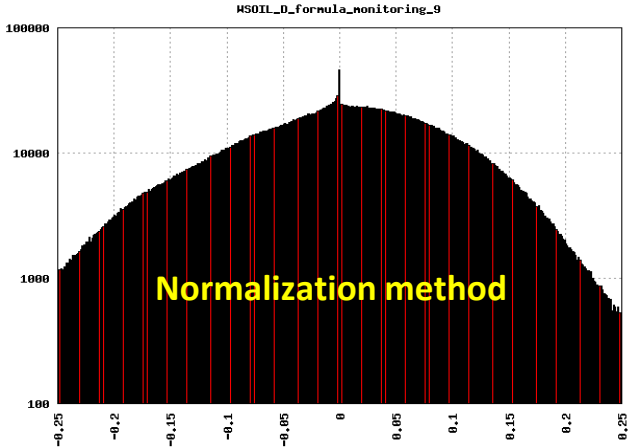
OR

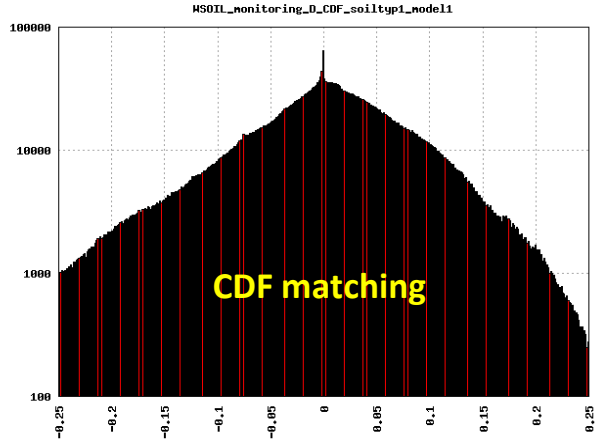
$$\omega_{obs} = \omega_{ADP} + \frac{\theta_{obs}}{100}(\omega_{PV} - \omega_{ADP})$$

Quality Control before assimilation of ASCAT soil moisture DATA

- an observation is discarded if its observation increment is larger (in absolute value) than a value which is typically in a range between 2 and 3 times a typical climatological standard deviation

- The standard deviation is calculated considering a long period of data (observation increments) and pulling out the **gaussian distribution** that best fits them



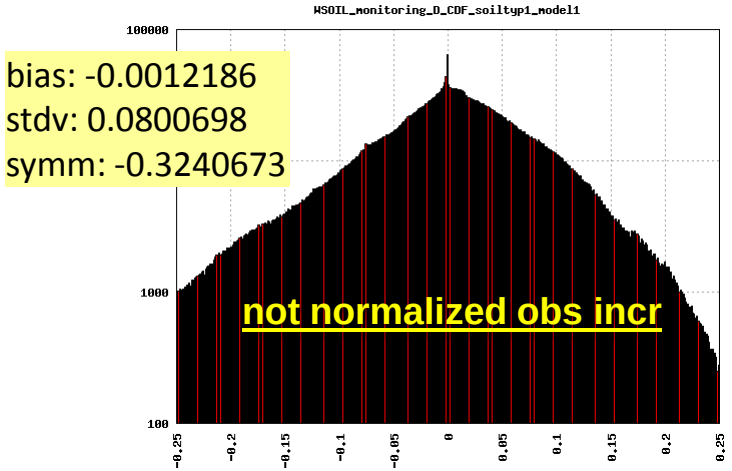


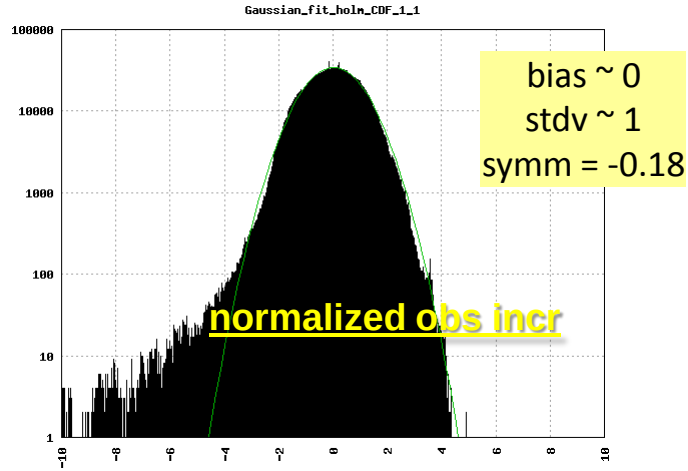
*The soil moisture's obs increments are **highly non gaussian**, too concentrated around the value 0 (due to the fact that the obs incr are very close to the 0 value in dry and saturated condition)*

Construction of a gaussian control variable

- *Method proposed by **Holm (2001)** to find a variable for humidity with gaussian forecast differences*
- *The Holm method is applied to the obs increments instead of to the forecast differences*

obs increments (CDF technique) (january 2015 - january 2016)





Ensemble Prediction at CNMCA

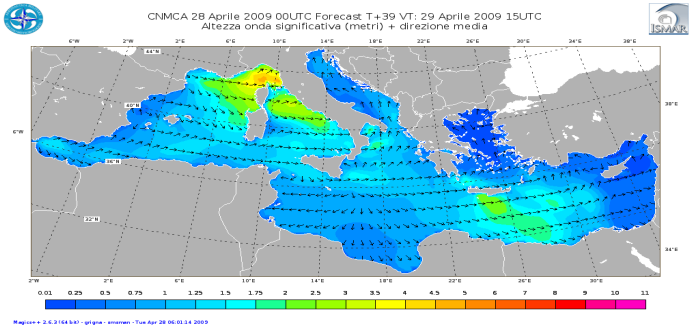
COSMO-ME EPS

The atmospheric short-range ensemble prediction system based on the CNMCA-LETKF system and the COSMO model has been testing at CNMCA since july 2013. Now it is operational.

- **MAIN CHARACTERISTICS**
- 40 members
- IC and BC: initial conditions are derived every 6 hours from the CNMCA-LETKF system. Lateral boundaries conditions are from IFS deterministic run perturbed using ECMWF-EPS.
- Surface perturbations: climatological perturbed sea surface temperature.
- Model error: added the stochastics physics perturbation tendencies.
- Forecast range: the 40+1 COSMO forecast members run up to 72 hours at 00/12 UTC.

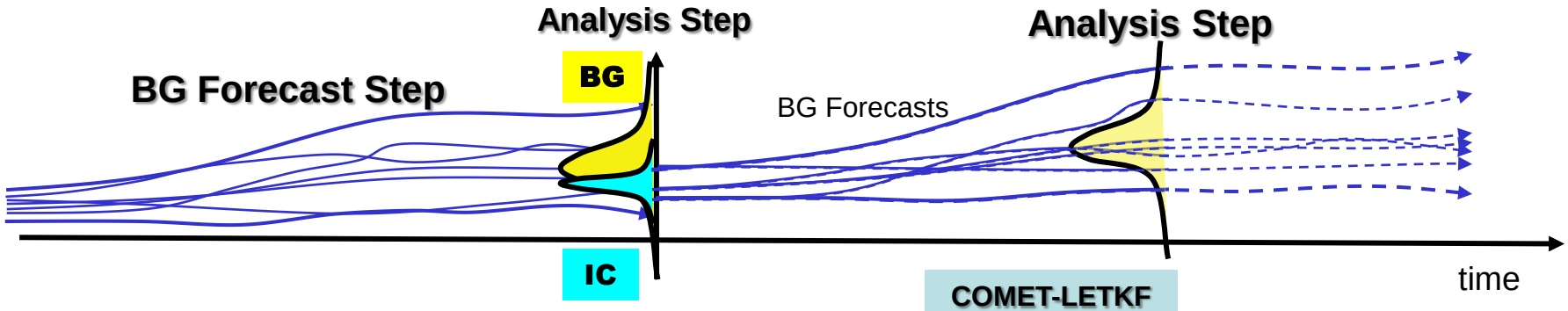
NETTUNO-EPS

NETTUNO is a high resolution local scale wave forecast system operational in the Mediterranean Sea based on the COSMO-ME and WAM models (In cooperation with ISMAR-CNR of Venice).
The sea state probabilistic forecast is obtained driving the wave model using the hourly COSMO-ME EPS wind forecast members



Validation of sea-state forecast has been done at ISMAR-CNR

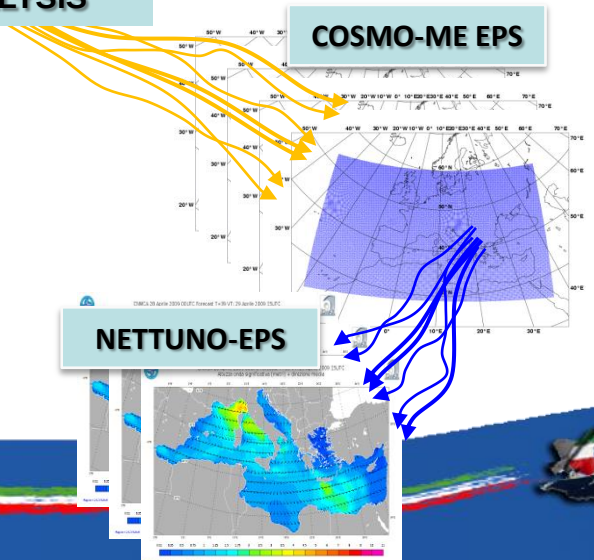
Ensemble Prediction System



COMET-LETKF ANALYSIS

COSMO-ME EPS (running since july 2013)
IC and BC: initial conditions are derived every 6 hours from the COMET-LETKF system.
Lateral boundaries conditions are from IFS deterministic run perturbed using ECMWF-EPS
Model error: stochastics physics perturbation tendencies is switched on from 1 May 2014
Forecast range: the 40+1 COSMO forecast members will run up to 72 hours at 00/12 UTC

NETTUNO EPS (In cooperation with ISMAR-CNR of Venice)
NETTUNO is a high resolution local scale wave forecast system operational in the Mediterranean Sea based on the COSMO-ME and WAM models
The sea state probabilistic forecast is obtained driving the wave model using the hourly COSMO-ME EPS wind forecast members

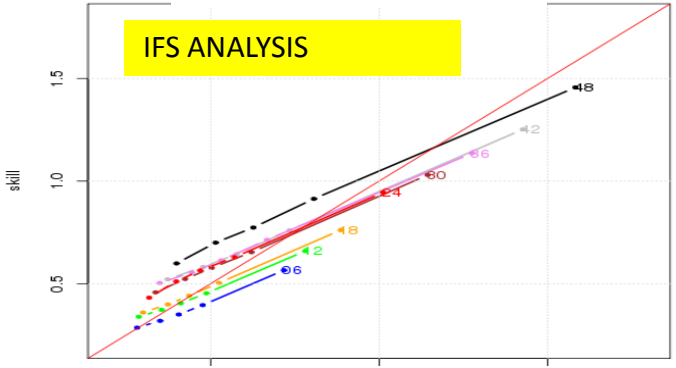


COSMO-ME EPS

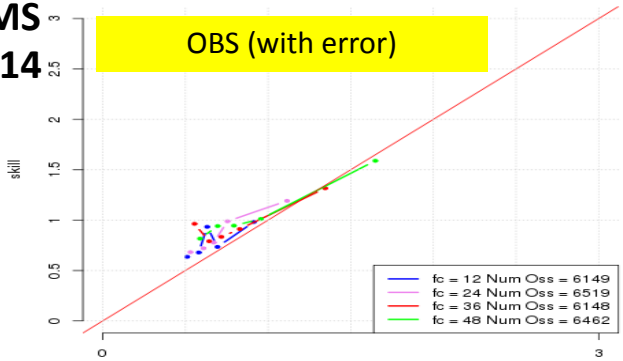
SPREAD-SKILL DIAGRAMS
1 JAN 2014 – 31 DEC 2014

by S.Sebastianelli

T@500hPa



T@500hPa



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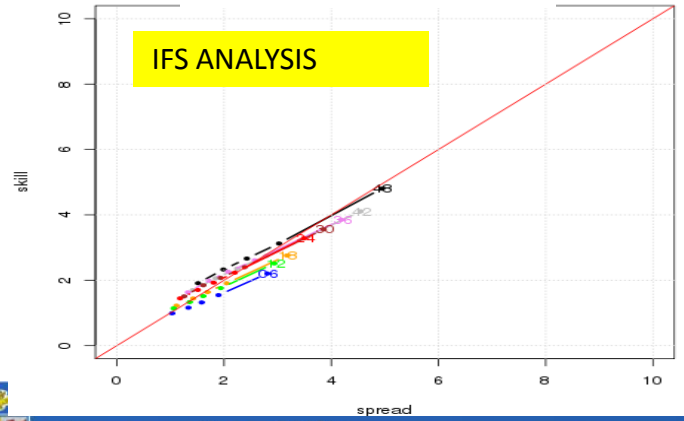

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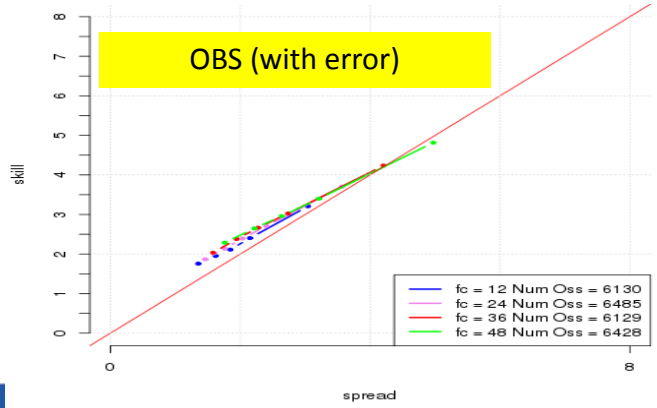
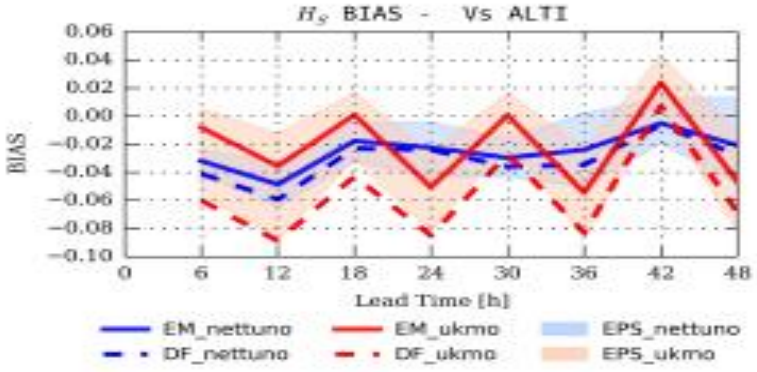


NETTUNO - EPS

Courtesy of P. Pezzutto (ISMAR-CNR)



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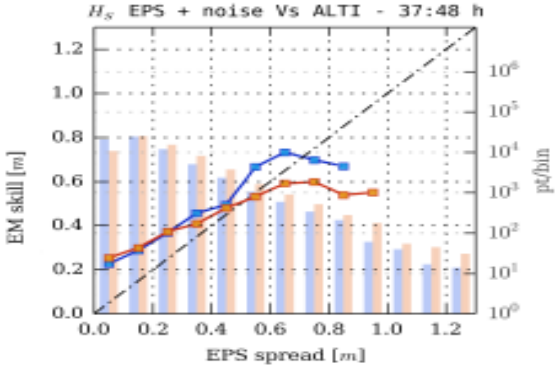

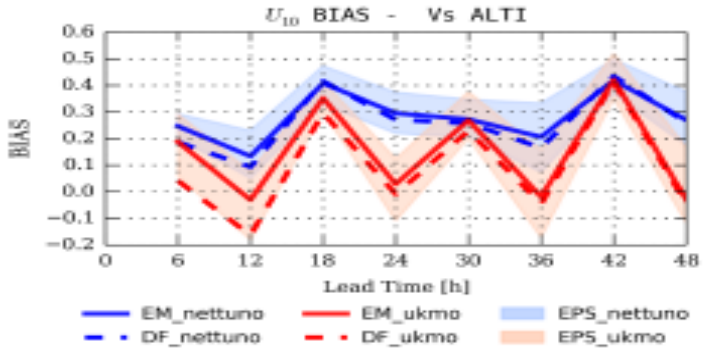

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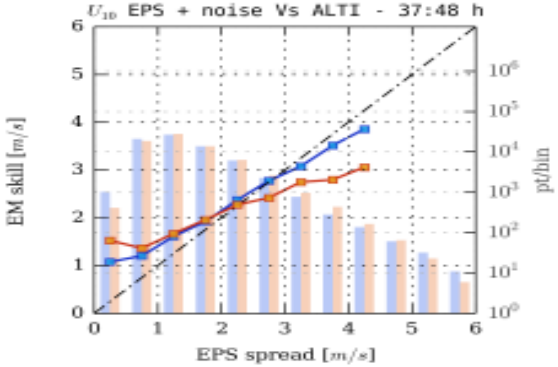
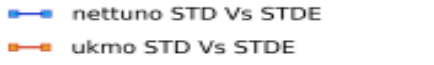
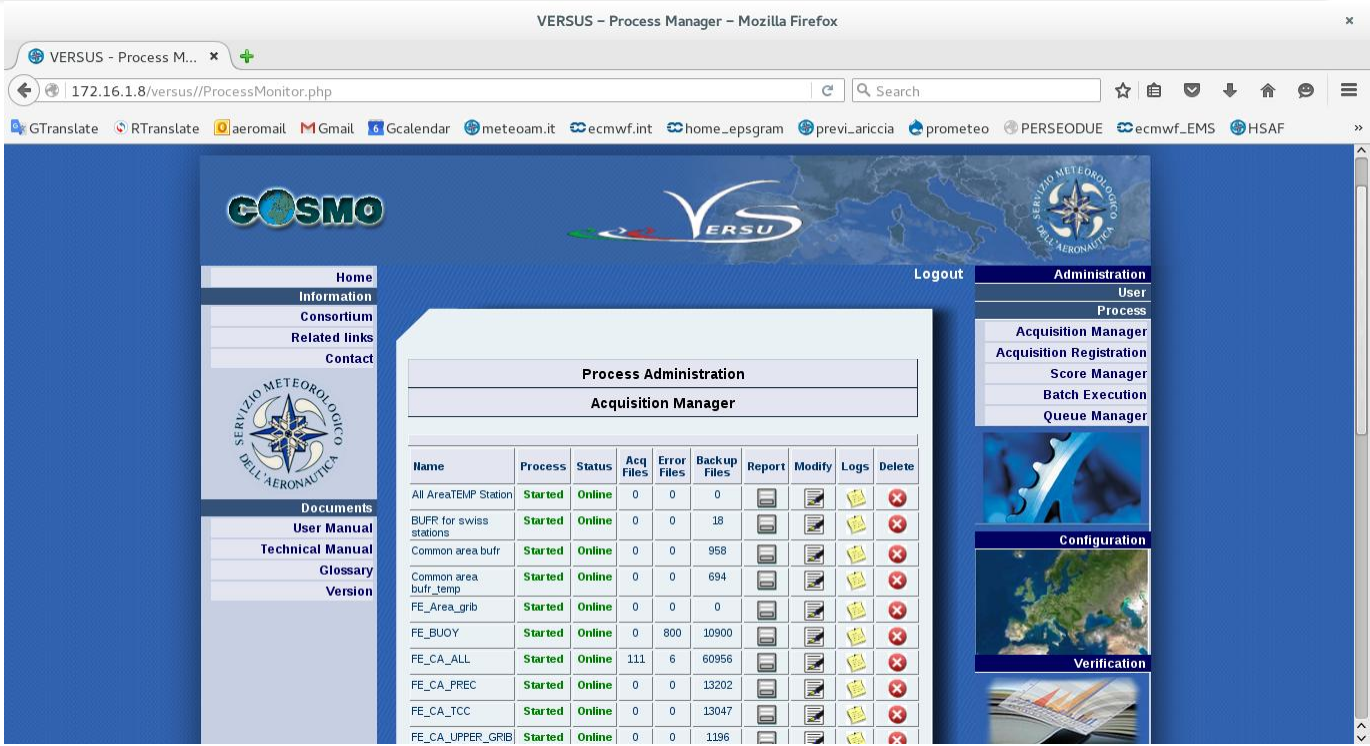




NWP MODEL VERIFICATION



For details, results,

reports, etc. see:

http://www.meteoam.it/page/verifiche-modelli

ITNWP – Current developments

- Further tests using DFI and COSMO single precision
- Investigation of assimilation of GPS ground stations and MODE-S
- Monitoring of local automatic stations and satellite derived soil moisture from H-SAF
- Improvementent of radiance vertical localization
- Self-evolving additive inflaction/SPPT
- H-SAF soil moisture assimilation affecting low level variables
- Shorter assimilation window using KENDA

ITNWP – HPC and ICT challenges

- Migration and adaptation of operational suites to new HPC system
- Increase of horizontal resolution
- Implementation of Pre-Processing & Data Assimilation systems (currently running at ECMWF) on new HPC cluster
- Implementation of COSMO-GPU model (experimental version)
- Investigation of Virtualised HPC Environment for R&D activities
- Data Handling and Archiving issues

ITNWP - Reporting activities

WORLD METEOROLOGICAL ORGANIZATION

ANNUAL JOINT WMO TECHNICAL PROGRESS REPORT ON THE GLOBAL DATA-PROCESSING AND FORECASTING SYSTEM (GDPFS) INCLUDING NUMERICAL WEATHER PREDICTION (NWP) RESEARCH ACTIVITIES FOR 2014

TABLE OF CONTENTS

Introduction

[National Contributions and/or Consortia]

1. **Summary of highlights**

- Consolidation of a very high resolution local area model integrated over the Italian domain (COSMO-IT, 2.8 Km grid spacing) every 6 hours.
- Consolidation of the ensemble Kalman filter based data assimilation algorithm (CNMCA-LETKF), operational since june 2011.
- Operational implementation of an atmospheric short-range ensemble prediction system (COSMO-ME EPS) based on CNMCA-LETKF analysis and COSMO model (pre-operational since july 2013)

2. **Equipment in use at the Centre**

- ***GTS management***:
  Message Switching System (MSS)

  Computer type: cluster of 2 HP Proliant ML350

  OS: Linux RH 4.0

  RDBMS: MySQL in High Availability.

- ***Data collecting and processing system:***
  The data collecting and processing system relies upon three RDBMS. In the very first one the data received from the GTS-connected systems are inserted for later use. A second one is being used for filtering, collecting and processing data for daily operational activity. A third RDBMS is being used for collecting weather data when they become aged and are made available for climatological studies. An High Availability HP Tru64 cluster (in active/active failover configuration) is being used for this task. It is composed of
  - 2 Compaq Alphaserver GS60E each with 4 processors EV6 and EV67 onboard;
  - 2 HP ES 45 each with 4 processors EV68C onboard.

  The operating system in use is UNIX in the HP Tru64 version, while IBM Informix RDBMS are being used. The mentioned cluster has dedicated storage shaped in a 5+1 RAID configuration.

  Since October 2009 a non-convetional observations collecting system is in pre-operational mode. The focus is to extend the number of observations provided to the data assimilation system. The equipment in use is composed of
  - 1 HP Server with 2 Intel Xeon 5310 4 cores processors;

This is (not) the end…

"We do not research, we make it work"

(former Capt. E. Fucile, 2001)

Thank You!