Numerical Weather Prediction at the Italian Air Force Meteorological Centre

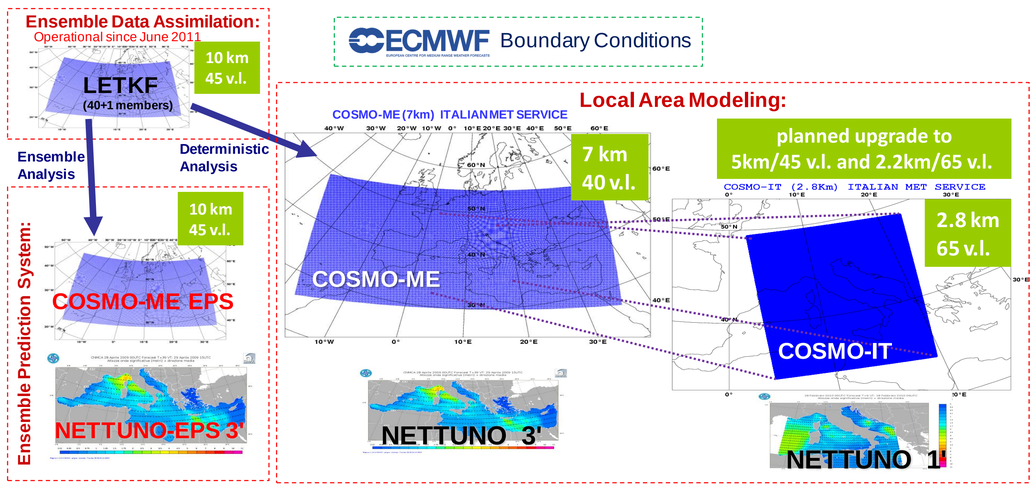
Antonio Vocino, Marco Alemanno, Francesca Marcucci, Emanuele Regoli and Lucio Torrisi
COMET - Italian Air Force Meteorological Centre
Airport of Pratica di Mare , Rome, Italy
Corresponding author: antonio.vocino@aeronautica.difesa.it

ABSTRACT: The main activities carried out at the COMET on NWP and in particular on COSMO model are shown. Together with the operational NWP suites running daily on HPC facilities, first experiments with the GPU-enabled version of COSMO on the new hybrid CPU-GPU supercomputer of the Centre are being performed. Preliminary results show that the boost of computing capability, exploiting the GPU technology, allows to optimally run the new generation of very high-resolution atmospheric models and ensemble-based NWP systems.

KEYWORDS: Numerical Weather Prediction, atmospheric models, High Performance Computing, hybrid CPU-GPU programming.

NWP System

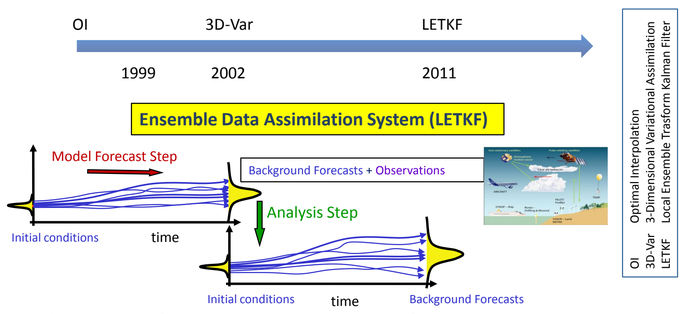
Ingested Observations: RAOB (also 4D), PILOT, SYNOP, SHIP, BUOY, Wind Profilers, AMDAR-ACAR-AIREP, MSG3-MET7 AMV, MetopA-B scatt. winds, NOAA/MetopA-B AMSUA/MHS and NPP ATMS radiances
Boundary Conditions: IFS global model



Operational NWP System

The Italian Air Force Meteorological Centre operates a complete NWP system, including an ensemble based data assimilation system and a set of nested, limited area atmospheric and wave models, in both deterministic and ensemble configurations, providing the high-resolution forecasting fields feeding the generation of timely and accurate meteorological products for the end users.

Data Assimilation



Quality control of incoming observations is performed on-line through ECMWF pre-processing tool (SAPP) and background QC in LETKF assimilation system

Mediterranean Sea Forecasting (NETTUNO)

in collaboration with ECMWF **and** ISMAR

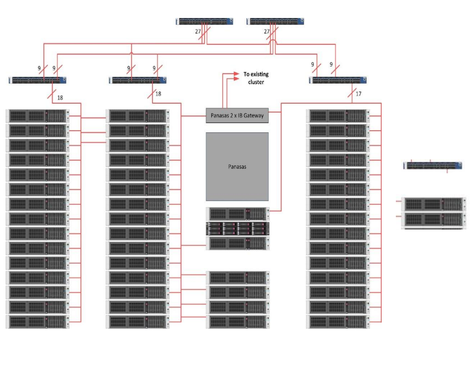
Surface winds from **COSMO-ME** and **COSMO-IT** are used as atmospheric forcing in **WAM 4.0** model *(Komen et al, 1994)*

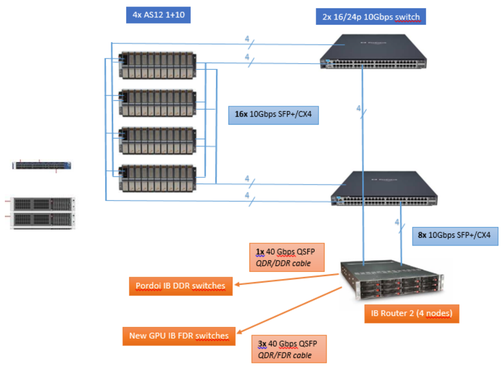
CONFIGURATION:
Lat-Lon regular grid, mesh size 3' (NETTUNO-ME) / 1' (NETTUNO-IT)
Spectral discretization with 30 frequencies and 36 directions
Initial state from previous run (warm start)
Initial time of model run 00/12 UTC
Forecast range to 72 h (NETTUNO-ME) / 48 h (NETTUNO-IT)
OUTPUT FIELDS:
Significant wave height, Mean wave direction, mean wave period

LIMITED AREA DETERMINISTIC MODEL – COSMO-ME	
MODEL	COSMO
Domain size	779x 401
Grid spacing	0.0625° (7km)
Number of layers / top	40 / ~22 Km
Time step and integration scheme	60 sec Runge-kutta HE-VI time splitting
Forecast range/step	72 hrs/1 h
Initial time of model run	00/06/12/18 UTC
Lateral boundary conditions	IFS (ECMWF)
L.B.C. update frequency	3 hrs
Initial state	LETKF deterministic analysis
Initialization	Digital Filter (Work in progress)
External analysis	snow cover,SST
Status	Operational
ADDITIONAL FEATURES	Provides atmosferic forcing to the NETTUNO sea state model (WAM) 3' resolution

LIMITED AREA ENSEMBLE MODEL – COSMO-ME-EPS	
MODEL	COSMO
Number of ensemble members	40+1
Domain size	577x 347
Grid spacing	0.09° (10km)
Number of layers / top	45 / ~28 Km
Time step and integration scheme	90 sec Runge-kutta HE-VI time-splitting
Forecast range/step	72 hrs/3 hrs
Initial time of model run	00/12 UTC
Lateral boundary conditions	most recent IFS deterministic run perturbed using ECMWF-EPS
L.B.C. update frequency	3 hrs
Initial state	LETKF analysis
Model Uncertainty Perturbations	"Relaxation-to-prior spread"multiplicative inflation; Additive noise from scaled ECMWF EPS pertubations; Stochastics physics perturbation tendencies
Surface Boundary Perturbations	Climatologically perturbed SST, soil moisture perturbations in progress
ADDITIONAL FEATURES	Provides atmosferic forcing to the NETTUNO-EPS sea state probabilistic model - 3' resolution

HPC Facilities

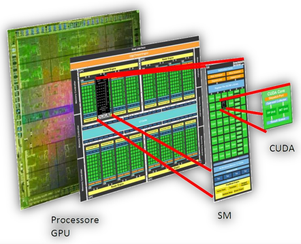


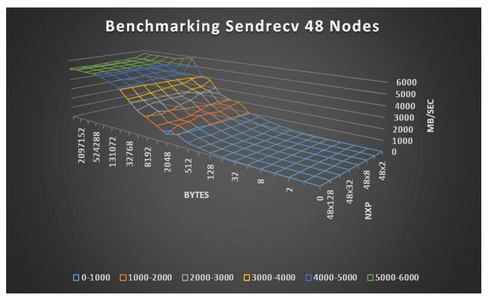


- 4x AS12 1+10 w/ 40 TB
  → 160 TB RAW
- 2x 16p 10 Gbps switches
- 4x Infiband Router2 nodes
- PANFS + NFS over Infiniband QDR

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

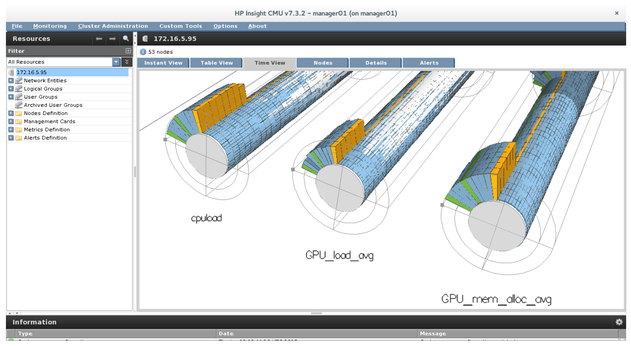
- FULLY REDUNDANT Configuration

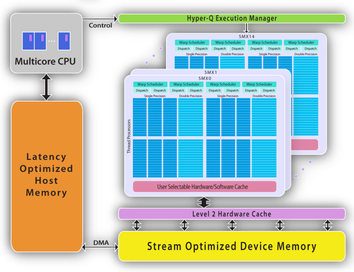


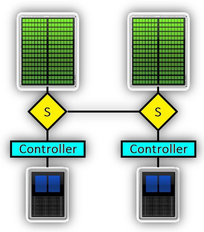


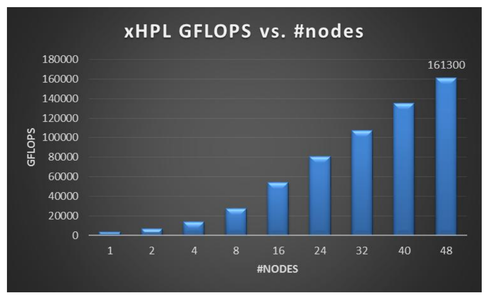
- 51x DL380 G9 Computing Nodes
- 2x DL380 G9 Management Nodes
- 1x MSA2040 DAS
- 6x Infiniband 36p FDR switches
- 102x Kepler K80 GPUs
  (204 GPU units ≈ 500K GPU cores)
- 9 TB RAM

- Nominal performances:
  190 TFLOPS peak
  308 TFLOPS peak (BOOST)
- TOP500 ranking:
  → #5 in Italy
  → #1 in Italy with GPU





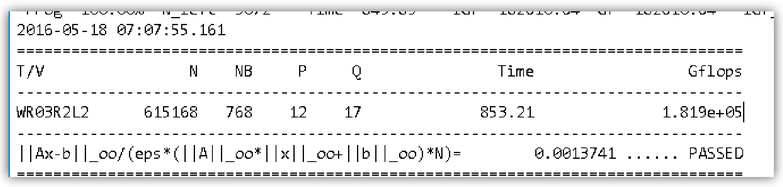




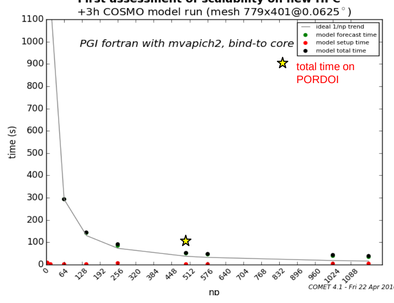
xHPL Benchmark on 51 nodes ≈ **181900 Gflops**
(N = 615168, Nb = 768, RAM = 64 GB)

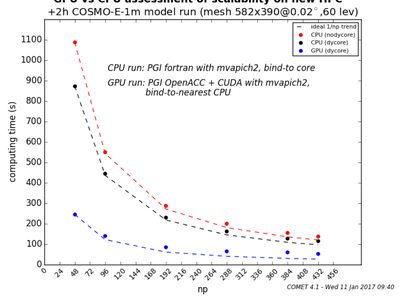
New HPC cluster

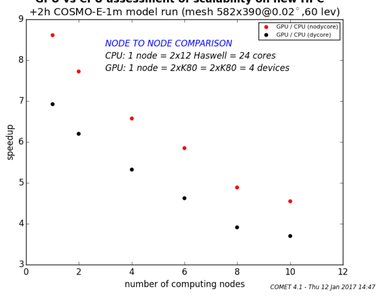
The new HPC cluster of the Italian Air Force Meteorological, released in 2016, is planned to host the major part (in terms of computational cost) of the operational NWP suites. Based on hybrid CPU-GPU architecture, coupled with very high-performance network and parallel storage, it is a state-of-art, reliable and scalable system for the next generation of computing applications.

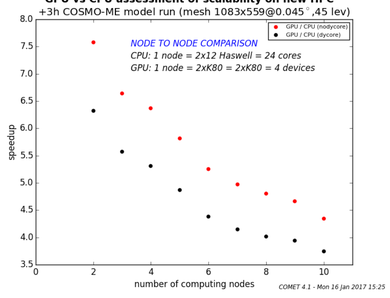


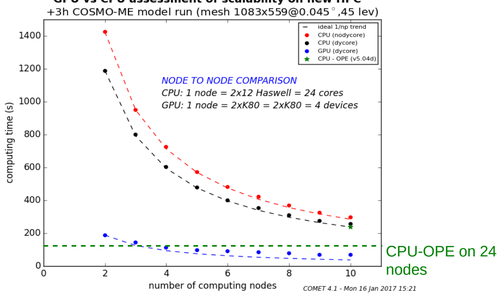
Developments











COSMO-ME@5km

The new COSMO-ME suite (ref. model version: 5.04d_3) running at 5 km horizontal resolution and 45 vertical levels is running in pre-operational mode on the new HPC cluster since September 2016.
Current activities include the testing of some physical parameterizations (e.g. convection scheme) and the implementation of the new version of the interpolation software int2lm .

COSMO-GPU

In the framework of the COSMO Project "POMPA" (Performance On Massively Parallel Architectures), the GPU-enabled version of the COSMO model has been successfully implemented on the new HPC cluster. The measured computational efficiency of the test-suite released with the package is in line with the expected performance, based on the timings of the operational MeteoSwiss COSMO-E suite running at CSCS.
The POMPA code has been recently configured and tested in offline mode for the COSMO-ME setup, showing an impressive computational efficiency – in particular at low number of computing nodes – of the CPU-GPU runs with respect to the CPU-only mode.
Regarding the implementation and the optimization of the future COSMO-GPU operational suites on the new HPC cluster, a set of experiments are on-going, with the support of the MeteoSwiss team, aiming at the setup of the deterministic model on the COSMO-ME and COSMO-IT scenarios (at 5km/45 v.l. and 2.2km/65 v.l. mesh size, respectively), as well as of the probabilistic model COSMO-ME-EPS.

Conclusions

In parallel with the operational NWP suites managed by the Italian Air Force Meteorological Centre and configured to deploy a complete cascading forecasting process, the development activities on the new hybrid CPU-GPU HPC cluster gave green light to the experimental implementation of the new generation of massively computational applications for weather forecasting.

References

Official web site: http://www.meteoam.it
WMO Progress Report on the GDPFS and NWP research activities of the Italian Met. Service, available on-line at:
http://www.wmo.int/pages/prog/www/DPFS/ProgressReports/2014/documents/2014_Italy.pdf

Acknowledgements.
This poster is just a picture of what the efforts of many people made possible, with their vision, long-lasting experience and silent work, day by day.
The author thanks all of you.

CONSORTIUM FOR SMALL SCALE MODELING COSMO