MareNostrum to Mareincognito - vertiginous speed

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MareNostrum one of the most powerful supercomputers in Europe, is housed with architectural panache in the Barcelona Supercomputing Center–Centro Nacional de Supercomputació. It is working on Kaleidoscope for the oil business, Caliope for air quality predictions, with PRACE on Saharan dust intrusion and with IBM on the nextgen of vertigionously fast super2 computers.

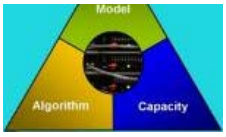
MareNostrum players, left to right José María Baldasano, Jesús Labarta, Mateo Valero and Jose M. Cela, all four are directly or indirectly involved in supercomputing research.

MareNostrum, one of Europe's most power supercomputers, has a processing capacity of 94.21 Tflops, is located at the Barcelona Supercomputing Center-Centro Nacional de Supercomputación (BSC-CNS) directed by Mateo Valero, PhD in telecommunications engineering and professor at the UPC. Since it was launched in 2005 it has provided support to numerous high-quality research projects of international impact.

Kaleidoscope

One of the initiatives the BSC-CNS is currently working on is the **Kaleidoscope** project, developed in collaboration with Repsol. The project works to generate seismic images of the subsoil, which are then processed 14 times faster than with other technologies in order to determine the viability of offshore oil extraction in the Gulf of Mexico.

The oil industry uses algorithms to analyze and interpret the maps generated by seismic imaging. Technically, what differentiates this



project from others is that the team, led by José M. Cela, member of the BSC-CNS and professor at the UPC, uses the RTM (reverse time migration) algorithm, currently the method that generates the most accurate images of the physical world.

"We have created the first commercial RTM", explains Cela. (*right)* "Basically, what we've managed to do is accelerate the algorithm, which can now be run in a few hours, thus creating a functional technique that Repsol can use for production. And we've done so using all possible levels of parallelism", he explains.

The first version of the RTM was developed using the MareNostrum JS21 processors, 4,000 of which were working on it for three months. The following step was to migrate the algorithm to another platform, the Cell processor. The project code was executed using MariCel-a supercomputer prototype based on Cell and developed by the BSC-and now the algorithm can be computed in just a few hours.

This puts Repsol at the vanguard in exploration of geologically complex areas where the presence of saline layers act as mirrors that prevent a view of what is underneath if using conventional technology. Proof of the impact the project has had is the multinational's great exploratory success in 2009.

Caliope predicts air quality

The project, dubbed **Caliope**, is funded by the Spanish Ministry of the Environment and coordinated by José María Baldasano, director of the BSC's Earth Sciences Section and professor at the UPC. It aims to develop a system to predict air quality in Spain.

To develop a modelling system like this one, three key elements have been taken into account: meteorology, emissions of pollutants and atmospheric dispersion and reaction. This great amount of data is processed thanks to the computational capacity of MareNostrum, until images are obtained that show a forecast of air quality for the next 48 hours.

To add the necessary improvements to the model developed, the results obtained are compared with the real data obtained through the different measuring stations.

And what makes Caliope different is being designed to work with a 12-km grid resolution over Europe, and a 4-km one over the Iberian Peninsula and the Balearic Islands. The level of detail places it at the vanguard of similar systems, the majority working with 10-20 km/2. grids.

Caliope involves a great many elements. "It is a highly complex project," says Baldasano, "which employs atmospheric science and chemistry to keep the models adjusted; elements of supercomputing to make them function faster and provide daily forecasts; a great deal of management, analysis and interpretation of data to obtain a detailed emissions inventory; and finally, a visualisation, communication and data management effort is also required to verify that everything is operating properly. All of this is done because we not only model data, but we also constantly compare the model results with real observations".

The end users of this pioneering system accessible via internet are the Public Administrations, responsible for managing air quality, the population at large and the world of research and development The aim: to gain a powerful information and management tool. After three years of running, Caliope will be fully operative by July.

Burgeoning supercomputation

To enable European researchers to meet major scientific and technological challenges using supercomputing is the strategic mission of the PRACE (Partnership for Advanced Computing in Europe) consortium, which needs to consolidate Barcelona as the epicenter of supercomputing on the continent, with the BSC-CNS as the Partnership's main actor.

PRACE will create a permanent office for high-performance supercomputing for Europe that will lead to the installation of computers with a computing power much higher than that of current HPCs. The office will coordinate three to five centers, among them the BSC-CNS, supported by local and national supercomputing institutions that will work jointly.

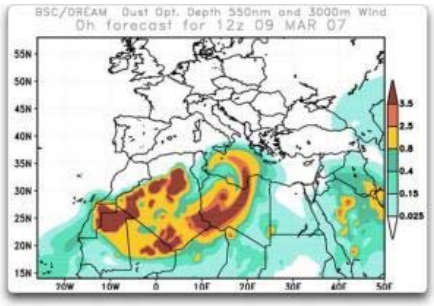
Dangerous incursions of Saharan sand

Sandstorms or natural dust are a habitual phenomenon in arid zones of our planet, especially in the Sahara and Gobi deserts and those of Australia, which have particularly negative effects on

atmospheric pollution or health, as they transport particles that aggravate chronic respiratory diseases.

The Mediterranean area suffers regular Saharan dust intrusion episodes, which is why the Spanish Meteorological Agency (AEMET) has a storm prediction system to know in advance its characteristics and the areas to be affected, ito take the necessary precautionary measures.

The operational system that models the transport of natural dust from the Sahara to Europe was developed by BSC-CNS



*(Right). The **DREAM** model, developed at the BSC–CNS, models the effects of Saharan dust particles reaching the Iberian Peninsula and other parts of Europe*

Its research has led the World Meteorological Organisation to promote a global framework for storm prediction & alert to obtain comparative forecasts from different models.

The system is configured based on the observations provided by NASA satellites and a network of ground-based remote sensing stations, data which is processed with the help of supercomputers like MareNostrum.

MareIncognito: the vertiginous speed

The BSC-CNS is also working on the MareIncognito project, a research project in conjunction with IBM to define the characteristics and design of the new generation of supercomputers, which will reach a computing capacity of 10 petaflops (10,000 trillion operations /second), or one hundred times greater than MareNostrum's current capacity.

Head of the project is *(left)*Jesús Labarta, of UPC's Department of Computer Architecture and director of the Science and Computation Department at the BSC-CNS. "The aim", says Labarta, "was to study the possibilities of designing machines based on the Cell processor developed by IBM, in conjunction with Sony and Toshiba to equip the Play Station 3 video console.

Aware of the difficulties that this involved, you could say we made a virtue of necessity: in attempting to make things work with Cell, we've reached more interesting solutions developing technology for more general applications. At the same time, we are collaborating with the team that's designing the next version of the Cell processor to see what characteristics it should have".

This is not the only line of work in a project the scope of MareIncognito. One team is studying programming models, that is, how these machines should be programmed in the future. "The aim is to be sure of the important concepts. The programmers should abstractly define what needs to be computed, such that the software, that is, how this is translated or is mapped on a specific hardware, is as automatic as possible. Conventional programs do not usually offer these possibilities, and this makes them difficult to migrate to new architectures", he indicates.

After a year of developing the performance analysis and simulation infrastructures, followed by another year to complete it and start obtaining results, we now need to apply it to real situations, to real programs.