

Meteorological Applications Cluster HPC for Change Climate Research

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Abstract. This paper is about a project developed by SENAMHI ¹ and a group of Peruvian institutions as part of a project of research of climate change known as PROCLIM², with the purpose of to build a tool for the running of meteorological applications that usually consume big quantity of computing resources. SENAMHI is involved in this project with the order to do climate change scenarios using forecasts in the long term. The proposed time is 50 years, which means that we need a big capacity of calculation. This work is about our experience in the successful use of free software in a scientific application that will allow us to reach the target of the project, which will benefit thousands of persons who are affected by climatic extreme phenomena as the phenomenon of "El Niño".

1. Introduction

CPN (Numerical Prediction Center) is an office belongs to SENAMHI. This office is in charge of to run numerical models for prediction of weather and climate and we have some models as ETA model³ RAMS model⁴ each one applied to different regions and with different initials conditions too. SENAMHI is involved in a project for to make climate scenarios with forecasts to long time. The time proposal is to 50 years, it means what we require a great calculation capacity.

Climate change is one of the most critical world problems in the last years due to the changes happened in the planet as a consequence of the emission of pollutants realized by the developed countries who across the industrial development contribute to the contamination of the environment.

The computational capacity of SENAMHI is limited because we have two workstations Alpha with 4 processors each one only and now these workstations are working in your maximum capacity running other models and is producing forecasts daily for our users.

¹ SENAMHI is Servicio Nacional de Meteorología e Hidrología, institution in charge of meteorological topics in Perú.

² PROCLIM is a project of research of climate change in Peru.
<http://www.conam.gob.pe/proclim>

³ ETA model is an application for forecast of weather used at SENAMHI.

⁴ RAMS model is an application for forecast of weather in high resolution used at SENAMHI.

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After evaluate the options available, we take the decision of build a cluster based on Linux and Intel processors for to realize this task on our project.

2. Design of Cluster

The design of this cluster is based in the clusters Beowulf methodology with adds about performance and improvement of network that will be detailed in this work.

2.1 Purpose

This cluster was designed as result of an evaluation of different proposals, since the implementation of a cluster using Alpha processors to commercial solutions as Blade server of HP or Sun. The intention was to build a robust infrastructure to be able to use applications of high performance with low cost, that is to say, to obtain good performance with limited resources. Finally we take the decision of to realize a solution based in Intel processors using Linux as operative system. To continuation some reasons on which we based our decision.

2.2 Objectives

To obtain a technological solution that allows us to improve the current capacity of calculation of Numerical Prediction Center and that simultaneously is scalable, secure, powerful and reliable.

To realize forecasts of weather and climate in the long term obtaining minor times of response to the reached ones at present with the installed infrastructure.

2.3 Why a cluster Linux?

- Because Linux is a stable and secure operative system.
- Because a cluster using Intel processors and Linux is very much cheap that another commercial solution.
- The use of software of free distribution allows to build a stable, administrable solution and of low cost. Besides the use of free software would allow us to reach level of experience and knowledge of the technology very higher than other solutions.
- Linux allows us to obtain a reliable, robust solution that allows us to reach comparable performance to another commercial solution but to a much smaller cost.

2.4 Proposed solution

Our solution is based in Linux as operative system and Intel processors as technological platform:

- 30 processors Intel Pentium IV 2.4 GHz.
- 256 Mb RAM (8 GB Total)
- 60 GB HD (1.8 TB total)
- Network card 10/100 and 10/100/1000.
- 2 Switch 3Com 48 ports.
- Red Hat Linux.
- Mpich passing of messages library
- RAMS model.
- Fortran PGI compiler.

Our cluster is composed by 30 nodes connected in two networks. One network (10.0.0.255) is for IPC and process communication. The network (10.0.1.255) is for transmission of data on the network (I/O) and NFS connections.

In addition to it exist two server nodes or master node those who take charge sending the processes to other nodes components of the cluster.

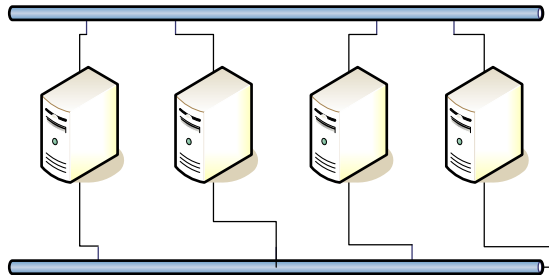


Fig. 1. In the figure the implemented connection appears. Two networks are connecting using two cards of network in every node. In this case eth0 is a network used for the communication interprocess and eth1 is a network used for the communications of I/O, NFS and network administration.

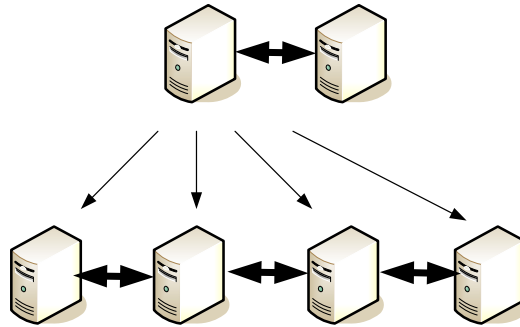


Fig 2. In the figure the process communication internode appears. It is possible to appreciate that the communication is realized between nodes: master - slave, slave to slave and slave – master.

Our cluster use mpich for process communication, our application is a weather and climate model that uses Fortran PGI for your compilation. The process communication between nodes is using mpich and the communication of data is using NFS and mounting discs in accordance with the need of space needed by our application.



Fig. 3. In the picture it appreciates the physical disposition of the cluster. This is a rack with 19 nodes.

3 Using free software on the solution

The principal objective of this solution is to obtain equal or better performance than the solutions based on commercial architectures of software and hardware and that generally are based on processors RISC. For that we had to research before deciding that we were going to use applications to implement the choice solution.

3.1 Operating System

The operating system choice was Linux since begins, that is because there was consensus to the moment to take a decision in this point of the implementation. We decide to use Red Hat Linux for the following reasons:

- Linux is an operating system in growth; it offers security, stability, performance and reliability.
- We have experience and knowledge in the administration of this distribution.
- Other applications of free software that we use are proved and certified on this distribution.
- Facility of installation, administration and distribution of packages.

3.2 Clustering Tools

One of the first problems that we had was as realizing the installation of 30 equipments in the minor possible time using free software tools.

It is as well as we were trying with some tools for to build clusters as ROCKS⁵, SCE⁶, and OSCAR⁷. This tool was valued at terms of facility of installation, configuration and additional software.

After having realized these evaluations, we decide to use OSCAR for following motives:

- OSCAR allows having an interface that shows step by step the sequence of the installation of the tool.
- It allows selecting the bundles necessary for the installation in accordance with the needs of the user.
- Configure automatically bundles as mpich, lam.
- It is very easy to add more nodes to the system.
- It is possible to support multiple configurations of clusters in the same server.

⁵ ROCKS is an application that is used for to build clusters, it is in <http://www.rocksclusters.org/Rocks/>

⁶ SCE (Scalable Cluster Environment) is an application that is used for to build clusters <http://sourceforge.net/projects/sce/>

⁷ OSCAR is a set of tools for to build clusters of computers. It is a free software and it is in [http:// http://oscar.openclustergroup.org/](http://oscar.openclustergroup.org/)

4 Our Application

Our application is a numerical model that being based on differentials equations and associating it with different variables realizes an analysis of the state of the atmosphere and allows us to infer forecasts in the long term. The model RAMS was developed by ATMET⁸ with the purpose of realizing forecasts in domains with very high resolution.

The development of a parallel version of RAMS began in 1990 and has continued since then. While RAMS contains a number of features which makes it amenable for modification to distributed memory platforms, such as the use of explicit numerical schemes in the horizontal finite-differencing algorithms, there are also a number of features that make the parallelization more difficult. These include a large number of numerical and physical options. The major complicating factor, however, is the interactive (or two-way) nesting procedure that allows the user to specify any number of telescoping grids or even moving grids that could float through a larger grid while calculating, for example, transport and dispersion of a pollutant or the propagation of a thunderstorm. This also allows a high resolution forecast for a target area while simultaneously providing coarser resolution forecasts for a much larger surrounding area.

The code was first developed using PVM in a master-node configuration where all nodes only communicated with the master process. As communication hardware became more sophisticated, this was seen as a bottleneck. The code has subsequently been changed to node-to-node communications using MPI, retaining the concept of the master process for output files and dynamic domain decomposition.

For parallel execution serial code was divided in two types:

- Master process: (initialization and all input/ output functions).
- Node compute processes (all computation).

Is not necessary that the files output are stored in the nodes since these come back to the main node. This makes possible to keep storage centralized, which facilitates the backups.

Our task is to realize forecast of climatic change using the out of this model for next 50 years. This task involves normally a demand of calculation that with the previous infrastructure that we had had been reached in major time.

⁸ ATMET developed the numerical model used in this project. <http://www.atmet.com>

5 Some Results

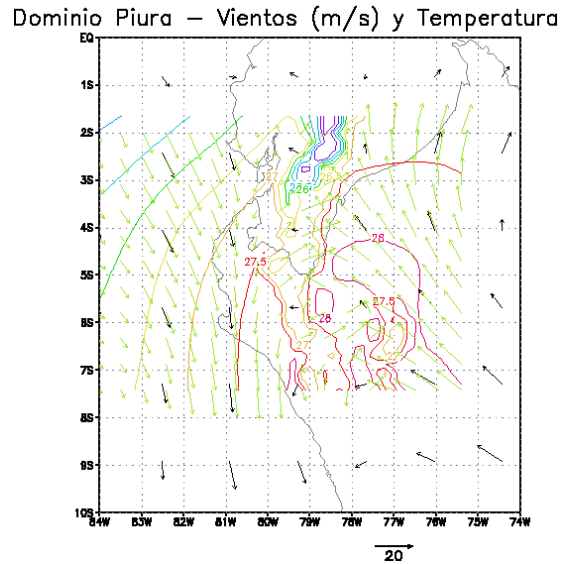


Fig. 4. Forecast of wind and temperature on Piura domain for April 2016.

The project involves the study of two domains or regions from Peru, Piura and Mantaro domains. Piura and Mantaro are two regions from Peru so much affected by the phenomenon El Niño and therefore they are a center of attention of scientists and meteorologists for this type of studies.

As was said previously, the target is to strengthen capacities of tasks of prevention before natural disasters for what we need to realize forecasts in the long term on the above mentioned regions.

These results permit us be in the capacity of recommending to government authorities, some prevention actions for mitigating the impact in population. Also we can determine dangerous areas for agriculture and other productive activities.

For example, Piura is an area where the cultivation of fruits is very important for the region and the knowledge of the variability of climate in this area can help us for avoid economic losses. The information obtained by SENAMHI using numerical modeling is provided to other institutions in charge of prevention task in the affected area.

Dominio Mantaro – Vientos (m/s) y Temperatura (C)

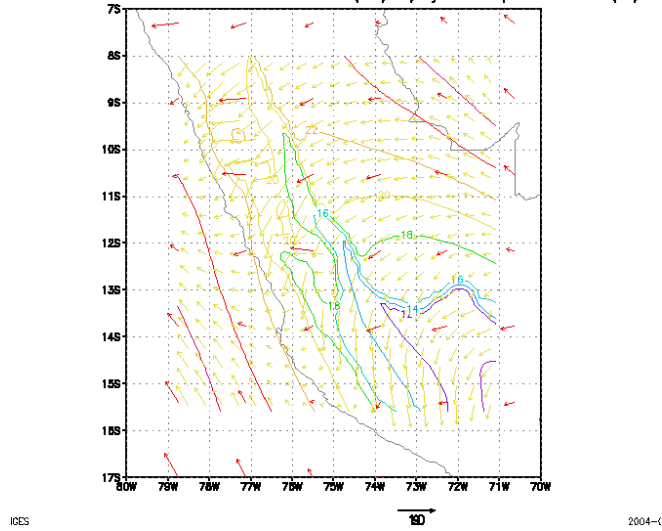


Fig. 5. Forecast of wind and temperature on Mantaro domain for April 2016.

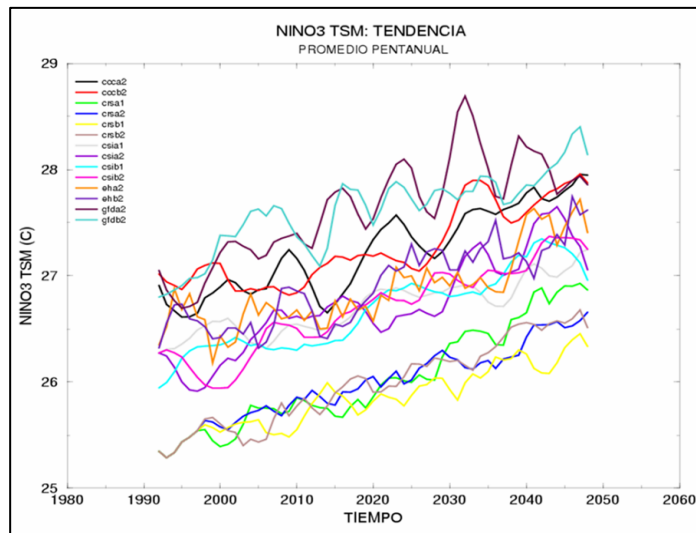


Fig. 6. Tendency of temperatures of sea during phenomenon of El Niño (1992 - 2050)

6 Performance of our application in cluster

In the first tests of performance with our application we configure the RAMS model to realize a simulation of forecast of 1 day for the domain Peru to 60 Km and the result can be appreciated in the fig 7.

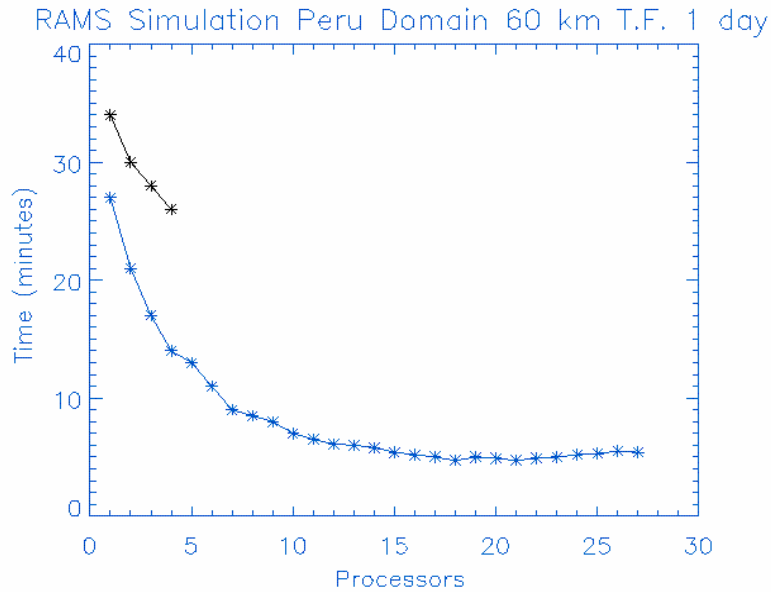


Fig. 7. Test of simulation Forecast Time: 1 day, Peru domain, 60 km resolution. Black line is the test with Alpha processors, and blue line is the test with Intel processors.

The same configuration of domain is used with the same time of forecast and a simulation is realized using 1 Alpha processor and 1 processor Intel later, obtaining a time of response of 35 minutes in the first case and of 28 minutes in the second one.

Later we were adding nodes to the cluster and repeated the experiment up to reaching 27 nodes in this test and we have achieved as less time of response appears in the figure using 16 nodes and with a time of 5 minutes and a half.

After the seventh or eighth node the time of response does not diminish significantly therefore, we decide to realize a logical division of the cluster in groups of 7 machines executing different process for different times in each of the groups of machines in parallel form.

This solution was the most ideal for us but not necessarily it might be the best for another type of applications.

7 Progress and Future Tasks

7.1 New Cluster in Numerical Prediction Center

This year, SENAMHI has acquired new equipments with the purpose of improve the current capacity of calculation of Numerical Prediction Center. We decide to build a cluster based on equipments HP DL140 (Dual processor Intel Xeon), 1GB RAM, HD 80 GB, 2 NIC 10/100/100 each one. Additionally we have a SAN HP MSA1000 with 7 HD SCSI 146.8 GB each one.

The design of the cluster was done in a way similar to the previous one. In this project it was decided to use a network Gigabit Ethernet with the intention of improving the performance of the communications internodes, the desirable is to go so far as to implement a network of high speed as Myrinet, but by some problems of budget a network Gigabit was chosen.

This will allow us to complement the work realized in the project of Generation of climatic scenarios with a new project that has related with forecasts of droughts. This information will allow improving the take of decisions on behalf of the corresponding authorities.



Fig. 8. The figure shows to the cluster of the new project for forecasts of droughts and that complements himself with the previous one.

7.2 Future Tasks

- To assure high availability in the master node finishing this way the vulnerability in the single point of failure.
- To integrate both projects of clustering in a project of grid computing with the intention of research this technology.
- To realize other tests of performance with other applications of scientific use to determine the potential of this cluster in other areas of the science.

8 Conclusions

- Implementing clusters based on Linux is a viable alternative for developing countries.
- To use clustering tools facilitates so much the work of installation and configuration of the cluster.
- The obtained results indicate that not always there is obtained a decrease of the time of response proportional to the number of processors used.
- The costs of implementation are very low in relation to other solutions.
- Grid computing is a technology very interesting for future tasks of research.
- Is important to say that numerical simulation is a necessary tool for the prediction of weather and climate. However, is important to say too, that results of this work can not be taken as definitive because the simulation to long time is really a set of probabilities.

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