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Assessing the Amazon Cloud Suitability for CLARREO's Computational Needs

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Abstract

In this document we compare the performance of the Amazon Web Services (AWS), also known as Amazon Cloud, with the `clarreo` cluster and assess its suitability for computational needs of the CLARREO mission. A benchmark executable to process one month and one year of PARASOL data was used. With the optimal AWS configuration, adequate data-processing times, comparable to the `clarreo` cluster, were found. The assessment of alternatives to the `clarreo` cluster continues and several options, such as a NASA-based cluster, are being considered.

Contents

1 Introduction

This study was motivated by the need to explore the alternatives to the expiring maintenance contract for the `clarreo` cluster. Amazon Web Service (AWS) was chosen for this study due to the potential savings on the IT support and maintenance costs, as well as the easy configurability of the CPUs, memory and storage. An additional advantage of the AWS is the accessibility to the collaborators offsite. In what follows, we benchmark the performance of the virtual AWS-based cluster against the performance of the similarly-configured `clarreo` cluster based at NASA/LaRC. In both cases, the 2006 dataset collected by the PARASOL microsatellite flying as a part of A-Train formation and active between the years 2004 and 2013 was used. The executable merged and filtered the data, producing ROOT ntuples as output. A total of one month (250 GB) and 1 year (3 TB) of 2006 PARASOL data were processed and compared. For both clusters roughly 90% of the executable's running time was found to be spent on the I/O operations, while the rest of time was spent on CPU processing. On AWS the performance with two types of storage, the NFS shared filesystem and S3 storage, was assessed. On the `clarreo` cluster the GPFS filesystem and the local disk storage was used to read and write the data.

2 AWS Cluster Setup and `clarreo` Cluster Configuration

The virtual AWS cluster [1] was set up as seven C3.8xlarge [2] compute optimized instances of EC2 cloud [3]. The setup relied on the open-source toolkit from MIT, called StarCluster [4], which has been designed to automate and simplify the process of building, configuring, and managing (i.e., starting and stopping the individual nodes) clusters of virtual machines. StarCluster features support for EBS-Backed Clusters, Open-MPI and languages like R, Python, C and C++. The fully redundant AWS Simple Storage System (S3) [5], as well as the NFS [6], filesystems were installed as well and their performance was compared in this study. For the parallel job submission the Sun Grid Engine (SGE) [7] with 168 slots (168 CPUs) was installed. The number of the slots was set to be roughly equivalent to that on the `clarreo` cluster.

The NASA/LaRC-based `clarreo` cluster consists of 15 IBM iDataPlex [8] compute nodes with 12 CPUs each. The cluster nodes are GPFS-mounted [9]. For the tests discussed in this document the number of available slots varied between 150 and 154.

3 Processing Steps and Data Description

PARASOL (Polarization and Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations from a Lidar) mission [10] was active between 2004 and 2013 and consisted of the microsatellite flying as a part of A-Train formation at 705 km altitude. The mission's primary aim was to study aerosols and clouds. Measured data from a single PARASOL orbit are distributed among several datafiles. For this study three datastreams, L1-B [11], RB2 and OC2 [12], were used as input. The three datafiles corresponding to one orbit are read by the executable, whose job is then to merge and filter the data and output the results as a single file. In the second processing step, which was *not* performed in this study, the filtered and merged output data can be used to produce the desired plots.

L1-B (Level-1B) PARASOL input data files contain, among other measurements, geometric parameters, such as solar and viewing zenith angles, relative azimuth, and the Stokes vector components describing polarization measured by PARASOL. The remaining two types of input files contain Level-2 data corresponding to the Radiation Budget (RB2) and Ocean Color (OC2) streams with cloud and aerosol parameters. The input data files are in the binary format while the output data are in the form of ROOT [13] ntuples [14].

To test the performance and scalability of the AWS we used one month (January) and the entire year of 2006 PARASOL data. The sizes and the number of files in each of the three input streams is shown in Table 1. For January 2006 there were a total of 394 files corresponding to 394 PARASOL orbits for each data stream. The total disk usage for the three streams was 224 GB. For one year the number of files was 4642 per stream, with the three streams occupying 2.8 TB of disk space. The number of *output* files is the same is the same as the number input files in one stream (Table 2). The combined disk space to store the output was 57 GB and 660 GB for one month and one year, respectively.

Data stream	Single file (MB)	Num. of files (one mo.)	Disk space (GB) (one mo.)	Num. of files (one year)	Disk space (GB) (one year)
L1-B binary	560	394	212	4642	2700
RB2 binary	20	394	12	4642	100
OC2 binary	0.1-0.6	394	0.127	4642	1.5
Total input	**580-581**	**1182**	**224**	**13926**	**2800**

Table 1. Disk space and the number of files occupied by L1-B, RB2 and OC2 **input** data streams by one month (January 2006) and one year (2006) of PARASOL data.

Data stream	Single file (MB)	Num. of files (one mo.)	Disk space (GB) (one mo.)	Num. of files (one year)	Disk space (GB) (one year)
ROOT ntuple	**50-250**	**394**	**57**	**4642**	**660**

Table 2. **Output** file sizes corresponding to the input data in Table 1.

4 Performance Comparison of the Amazon Cloud *vs* the `clarreo` Cluster Using PARASOL Data

In this section we describe the tests performed on the Amazon Cloud using two types of storage, S3 and NFS. These results are then compared against two tests performed on the `clarreo` cluster: one, using the GPFS filesystem and the second, using local disks.

4.1 AWS S3 Test

For this test the S3 filesystem was used to store input data. L1-B, RB2 and OC2 datafiles were copied to the local SSD volume where it was processed by the executable. Once the output ROOT ntuple was created, it was copied back to the S3 filesystem. At the end of the execution all the input files and the ROOT output files were deleted from SSD.

Sun Grid Engine (SGE) was used to process the January 2006 and the entire 2006 PARASOL datasets in batch. The total number of submitted jobs on the cluster was equal to the number of orbits/files in a stream. The execution was timed from the beginning of submission till the last file was processed. The average run time to process one month of data was found to be **7 minutes**. For the entire 2006 dataset the running time was found to be **57 minutes**.

We also assessed the cluster's processing speed (see the first row of the last two columns in Table 3). To quantify this rate we used the one month of 2006 data, running the test twice with January data and once with June data. Within the C++ executable we used the `ctime` library calls to record the transfer rates from a local SSD volume to S3 of the three input files and from the SSD volume to S3 of the output ROOT ntuple. The *execution time* is then the *total running time* of the executable *minus the time to transfer* the input and output files.[1] The processing time was computed for each job, and the percentages quoted in the last two columns in Table 3 are averages over the number of submitted jobs.

4.2 AWS NFS Tests

For the AWS NFS test the cloud 7 nodes were configured with 32 SGE slots, for a total of 224 SGE slots. Two Amazon volume types were used:

[1] The execution time is thus composed of the pure CPU processing time, plus the time spent reading the input and writing the output files (I/O).

the Provisioned IOPS (`io1`) and the General Purpose (`gp2`) volumes. Two tests, one for each volume type, were run. The total time to run the January 2006 dataset was **27 min** on IOPS (Table 3). In the case of `gp2` the run time was deemed to be too long and the run was terminated after 50 min. Compared to the AWS S3 and the `clarreo` cluster the performance on the NFS filesystem is considered to be inadequate. Due to the slow performance of one month processing the entire-year run was not attempted.

4.3 `clarreo` GPFS Test

In this test we ran the January 2006 and the dataset with the entire year of data on the `clarreo` cluster. The input, output and the executable were located on three separate devices linked through GPFS [9]. Sun Grid Engine with approximately 150 slots[2] was used to process January 2006 data. The submission scripts and the executable were analogous to the AWS NFS test. For timing consistency the same January 2006 dataset was processed three times. The average run time to process the January 2006 dataset was found to be **5 minutes**. The time to process the entire 2006 dataset was **45 minutes**.

4.4 `clarreo` Local Disk Read/Write Test

The input data in this case were copied from the GPFS shared filesystem onto each node local disk for processing. The output was written to the same local disk. As in the GPFS test above approximately 150 slots were used to process January 2006 data. Within the precision of our timing the average run time to process the January 2006 dataset was longer than the GPFS test by about one minute, at **6 minutes**. The time to process was found to be **49 minutes**. Similar to the AWS S3 test, we calculate the processing and data transfer rates to and from the local disk. The results are shown in the last row of the last two columns of Table 3.

4.5 The Amazon Cloud *vs.* the `clarreo` Cluster Performance Summary

In Table 3 we summarize the performances for the four test configurations described above. Of the two tests performed on the Amazon cloud, only the S3 test yielded acceptable results. Although transfering data in and out of the S3 filesystem slowed the throughput, the overall run time of 57 minutes on the cloud is comparable to the `clarreo` GPFS test which ran for 45 minutes. We note (see the last two columns) that roughly

[2]Other users were executing jobs on the `clarreo` cluster, so for the three time trials the maximum number of available slots allocated for our test varied between 150 and 154. This difference didn't significantly affect the execution times for the January 2006 dataset.

half of the total running time on AWS was spent transfering the data from S3 onto an local SSD volume. This is noticeably slower than our benchmark test of copying the GPFS mounted data to a local disk on the `clarreo` cluster which took about one quarter of the total execution time.

Test type	Total run time (min) (1 month)	Total run time (min) (12 months)	Percentage execution time	Percentage file transfer time
AWS S3	7	57	55	45
AWS NFS	27	-	-	-
`clarreo` GPFS	5	45	-	-
`clarreo` Local Disk	6	49	73	27

Table 3. Total running times to process one month and one year of PARASOL data for the four test configurations. Also shown are the percentages (averaged over the number of SGE jobs) of the total running time of each job spent on execution (CPU time + I/O) and transfering data for AWS S3 and the benchmark `clarreo` Local Disk tests.

5 Conclusions

We have shown using our test executable that the Amazon Cloud-based cluster configured with S3 storage results in processing times comparable to the `clarreo` cluster, while the performance with the NFS storage is found to be significantly inferior. Since one can easily configure a virtually unlimited number of nodes, the advantage of the AWS over the `clarreo` cluster is its scalability, which may result in faster processing time for large datasets. Among the disadvantages of the Amazon Cloud is the latency in opening remote GUI-based application, as we have found that opening remote windows, such as Emacs, can take up to 30 seconds. Another drawback of using the AWS is the need to transfer data into and out of the cloud. In conclusion, the use of the AWS as a CLARREO science computing facility remains a possibility, however, other options, such as using a NASA-based cluster, are also under consideration.

References

1. AWS Cluster: https://aws.amazon.com/.
2. Amazon EC2 Cluster Instances: https://aws.amazon.com/ec2/instance-types/
3. Amazon EC2: https://aws.amazon.com/ec2/.
4. StarCluster: http://star.mit.edu/cluster/.
5. Amazon S3: http://aws.amazon.com/s3/.
6. The Network File System: http://www.tldp.org/LDP/nag/node140.html#SECTION0013000000.
7. Sun Grid Engine (SGE): http://star.mit.edu/cluster/docs/0.93.3/guides/sge.html.
8. IBM Platform Computing Solutions Redbook: http://www.redbooks.ibm.com/redbooks/pdfs/sg248073.pdf.
9. General Parallel File System (GPFS): http://www-03.ibm.com/software/products/en/software.
10. Fougnie B. et al., PARASOL in-flight calibration and performance, Appl. Opt. **46** (2007) 5435–5451, http://ao.osa.org/abstract.cfm?URI=ao-46-22-5435. PARASOL mission homepage: http://smsc.cnes.fr/PARASOL/.
11. Bréon, F.-M. et al., Parasol level-1 product data format and user manual. **Ed.1 - Rev. 3**, 2006. http://www.icare.univ-lille1.fr/drupal/projects_data/parasol/docs/Parasol_Level-1_format.pdf.
12. Bréon, F.-M. et al., Parasol level-2 product data format and user manual. **Ed.1 - Rev. 6**, 2011. http://www.icare.univ-lille1.fr/drupal/projects_data/parasol/docs/Parasol_Level-2_format.pdf
13. ROOT - An Object Oriented Data Analysis Framework, Proceedings AIHENP'96 Workshop, Lausanne, Sep. 1996, Nucl. Inst. Meth. in Phys. Res. A **389** (1997) 81-86. http://root.cern.ch/.
14. ROOT Ntuple Tree Description: http://root.cern.ch/root/html/TTree.html.

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