Performance, Power, and Energy of In-Situ and Post-Processing Visualization: A Case Study in Climate Simulation

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1. INTRODUCTION

Our work is motivated by two observations. First, the per-byte energy consumption of off-chip data movement for an exascale system is projected to be two orders of magnitude higher than on-chip data movement [4]. Second, scientists run increasingly high-fidelity simulations, which produce large amounts of data for visualization and analysis. Consequently, the I/O subsystem is expected to consume a significant chunk of the power budget available for a supercomputer.

Earlier attempts to address the above include *temporal sampling* which runs the risk of missing out on important events. More recently, researchers have proposed in-situ techniques as an alternative where the visualization is performed alongside the simulation. In this study, we seek to quantify the savings in performance, power, and energy from adopting in-situ visualization. We improve upon previous work by Adhinarayanan et al. [1] by running a *real* climate simulation application known as MPAS-O [3] on a server-grade node and by looking at the power consumption of individual system components including the disks. We also present preliminary results obtained from a 128-node cluster.

2. METHODOLOGY

In this section, we describe the application, the hardware, and the power measurement methodology used in this study.

2.1 Application

We use the ocean component of Modeling for Prediction Across Scale (MPAS-Ocean), which is a climate simulation application. This application solves an unstructured mesh problem, then calculates the Okubo-Weiss metric which helps in identifying eddies in the ocean (shown in Figure 1). We run the simulation for a simulated period of one month using a 240 km grid size. The images are produced by the *Paraview Cinema* framework [2].

For the cluster-level experiment, we ran the simulation using a 60 km grid size for six simulated months. We use temporal sampling on both visualization pipelines with the output written once per simulated day.

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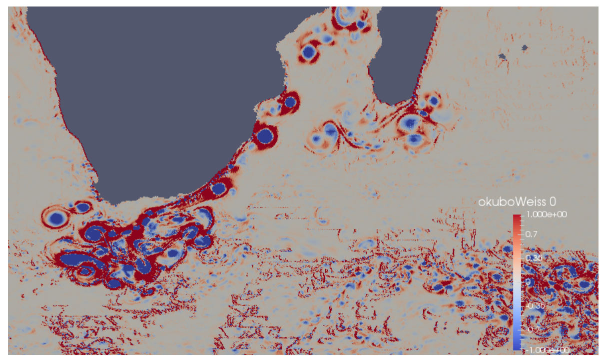


Figure 1: Visual representation of eddies in the ocean using the Okubo-Weiss metric

2.2 Hardware

Our experiments are run on a node with two Intel Xeon E5-2665 processors, 64GB of RAM and a 500GB, 7200rpm Seagate hard disk.

For the cluster-level experiment, we used 128 nodes of the Caddy supercomputer at LANL. Each node consists of two 8-core Intel E5-2670 Sandy Bridge CPU and 64 GB of RAM. For storage, we used a 5-node cluster running Lustre file system and configured as follows: 1 master node, 2 metadata server (MDS) and 2 object storage servers (OSS).

2.3 Power Measurement Methodology

We measure node power consumption using a WattsUp Pro power meter. The processor's and DRAM's power consumption is measured using Intel's RAPL interface. The power consumption of the disk is modeled using well-established statistical regression techniques using *iostat* statistics as the input parameters. The model used in this poster paper is presented in Figure 2.

We used a cage power meter to measure the power consumption of ten nodes of the compute cluster. This was later extrapolated to 128 nodes. The power of the storage cluster was measured using a Raritan intelligent power distribution unit at a resolution of one reading per two minutes.

3. RESULTS

Figure 3 shows that even though the in-situ pipeline consumes 3% more power than the post-processing pipeline, it

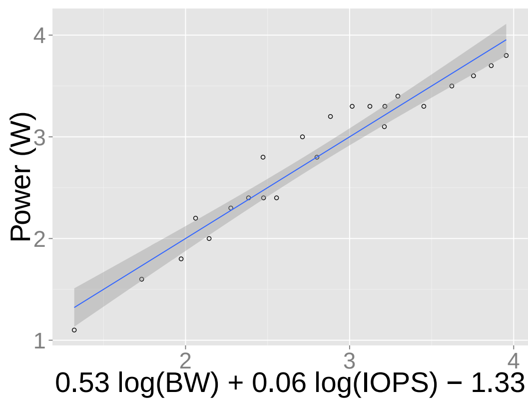
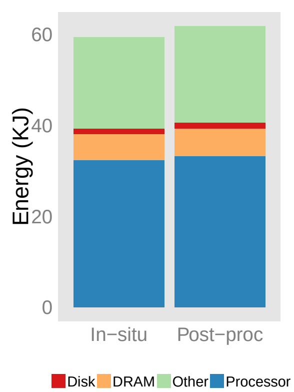
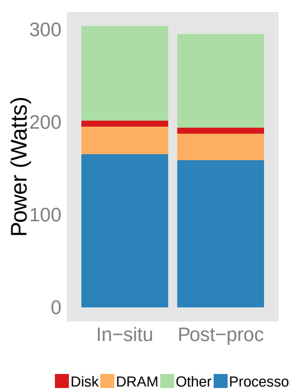


Figure 2: Modeling the dynamic power consumption of disk

actually ends up saving more than 4% energy. This is due to the 6.7% lower execution time (210 s for post-processing vs 196 s for in-situ) from the reduced I/O wait time. The energy savings is expected to be significant for applications with larger proportion of disk access time. The breakdown on energy consumption (Figure 3) shows that the actual energy saved from the disk subsystem is negligible. That is, most of the savings come from avoiding system idling.



(a) Energy



(b) Power

Figure 3: Power and Energy consumption of in-situ and post-processing pipelines

Discussion: Despite the modest improvements to energy and performance on a single-node, we expect that transitioning to in-situ techniques will have a notable impact on supercomputers, even for applications such as MPAS-O. First, the I/O wait time, which contributes to energy consumption by means of idle compute resources, is expected to be higher. This is because the storage subsystem is separated from the compute subsystem by a network. Second, there is an additional energy consumption from data movement through the network. Third, while the storage component (i.e., the hard disk) in the single-node experiment is shared with the compute node, in a cluster it requires its own dedicated set of resources such as CPU, memory, cooling, etc. This additional overhead for storage is expected to increase the power and energy consumption. To concretely illustrate the above, we performed our experiments on LANL's Caddy supercomputer. The post-processing pipeline consumed 42.7 MJ of energy and the in-situ pipeline consumed 19.1 MJ of energy, which corresponds to an energy saving of 55%.

To illustrate the other advantages further, we perform the following experiment. In-situ pipeline uses 97.5% less storage than the post-processing pipeline. That is, the number of storage nodes can be reduced by 97.5%. Assuming that typically 10% of the nodes in a HPC data center is reserved for storage and assuming that storage nodes consume about the same power as compute nodes, we have a 10% higher budget for the compute nodes. A 10% higher budget can result in up to 6.3% improvement in performance for MPAS-O using Intel RAPL's power capping feature as shown in Figure 4 .

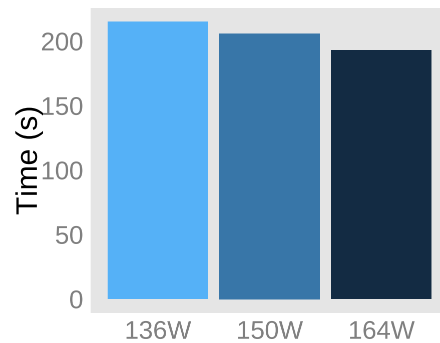


Figure 4: Impact of 10% additional power budget for processors on performance

4. CONCLUSION

In this work we have demonstrated that in-situ techniques could reduce energy consumption (by reducing wait time), reduce power (by using fewer storage nodes), and improve performance (by reducing I/O wait time and by making more power available for compute nodes). We will expand this study with more applications in a large-scale system in the near future.

5. REFERENCES

[1] Adhinarayanan, V., Feng, W., Woodring, J., Rogers, D., and Ahrens, J. On the Greenness of In-situ and Post-Processing Visualization Pipelines. *Proceedings of the 11th Workshop on High-Performance Power Aware Computing (HPPAC)* (2015).

[2] Ahrens, J., Jourdain, S., O'Leary, P., Patchett, J., Rogers, D. H., and Petersen, M. An Image-based Approach to Extreme Scale In-Situ Visualization and Analysis. In *Proceedings of the International Conference for High Performance Computing, Networking, Storage and Analysis (SC)* (2014), pp. 424–434.

[3] Ringler, T., Petersen, M., Higdonc, R. L., Jacobsena, D., Jonesa, P. W., and Maltruda, M. A Multi-Resolution Approach to Global Ocean Modeling . *Ocean Modelling 69*, 0 (2013), 211 – 232.

[4] Sachs, S. R., Yelick, K., et al. Exascale Programming Challenges. *2011 Workshop on Exascale Programming Challenges* (2011).