National Aeronautics and Space Administration

Are Cloud Environments Ready for NASA HPC Applications?

May 30, 2012

NASA Advanced Supercomputing Division

Outline

- Cloud computing
- Systems tested
- Benchmarks and Applications used
- Performance results
- Conclusions

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Cloud Computing

Cloud computing environments provide compute, storage and software resources with the following characteristics (as defined by NIST):

- *On demand self-service*
- *Broad network access*
- *Resource pooling*
- *Rapid elasticity*
- *Measured services*

- *Service Model:* X as a Service – Infrastructure as a Service (Iaas), Platform as a Service (PaaS), Software as a Service (SaaS), …
- *Deployment Model:* public, private, hybrid

"The NIST Definition of Cloud Computing", NIST Special Publication 800-145, September 2011

http://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf

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Cloud Computing (contd.)

- Cloud computing is becoming ubiquitous
  - Allows organizations to outsource hardware acquisition and maintenance
  - Satisfies burst computational demands at the cost of performance
  - Provides support for customized execution environments
  - Supports an Increasing catalog of useful software services
- Extensively being used for enterprise/business tasks
- Increasing use for scientific and engineering (S&E) tasks, e.g., bioinformatics, oil exploration, data analytics, etc.
  - Embarrassingly parallel or loosely coupled parallel tasks
- To attract the High Performance Computing (HPC) market Amazon EC2 provides HPC instance types

Are Clouds ready for NASA's HPC applications?

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Systems Tested

	Pleiades	*Amazon HPC cc1.4xlarge*	*SGI Cyclone*
CPU	Intel Xeon X5570 Nehalem	Intel Xeon X5570 Nehalem	Intel Xeon X5570 Nehalem
Clock Speed	2.93 GHz	2.93 GHz	2.93 GHz
No. of cores/node	8	8	8
RAM	24 GB	23 GB	24 GB
Hyper-threading	Enabled	Enabled	Enabled
Network	InfiniBand 4XQDR	10 GigE	InfiniBand 4XQDR
Interconnect Topology	Hypercube	Unknown	Enhanced Hypercube
OS Type	SLES11SP1	SLES11SP1	SLES11SP1
Virtualization	No	Yes	Physical Provisioning
Multi-tenancy	No	No	No
Compiler	Intel 12.0.4	Intel 12.0.4	Intel 12.0.4
MPI Library	MPT 2.04	Open MPI 1.4.4	MPT 2.04
File Structure	Lustre	NFS	Parallel NFS

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Benchmarks/Applications

- HPCC Benchmarks
  - DGEMM – floating point rate measurement
  - Bandwidth and latency tests
- NPBs:
  - Kernel benchmarks
    - **MG:** multi-grid on a sequence of meshes, long- and short-distance communication, memory intensive
    - **FT:** discrete 3D FFTs, all-to-all communication
    - **IS:** integer sort, random memory access
    - **CG:** conjugate gradient, irregular memory access and communication
    - **EP:** embarrassingly parallel with some communication
  - Compact Application benchmarks
    - **BT:** block tri-diagonal solver
    - **SP:** scalar penta-diagonal solver
    - **LU:** lower-upper Gauss Seidel

- Applications:
  - **Cart3D:** high-fidelity inviscid CFD code; multiple cartesian grids
  - **DDSCAT:** embarrassingly parallel code to calculate the absorption and scattering properties of targets
  - **ENZO:** Simulation of cosmological structure formulation using adaptive mesh refinement
  - **MITgcm:** Global ocean circulation model

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Performance Results

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HPCC results (64 cores)

	Pleiades	Amazon HPC	SGI Cyclone
EP DGEMM N=5773 (Gflops)	11.417	10.758	10.68*
Single DGEMM N=5773 (Gflops)	12.252	11.062	11.114*
Max Ping Pong Latency (usec)	2.574	73.999	2.243
Min Ping Pong Latency (usec)	0.238	0.626	0.256
Avg Ping Pong Latency (usec)	1.954	61.535	1.890
Naturally Ordered Ring Latency (usec)	1.597	58.293	1.788
Randomly Ordered Ring Latency (usec)	4.466	180.786	5.148
Max Ping Pong Bandwidth (Gbytes)	5.044	6.982	6.536
Min Ping Pong Bandwidth (Gbytes)	1.538	0.406	1.832
Avg Ping Pong Bandwidth (Gbytes)	2.171	0.952	2.072
Naturally Ordered Ring Bandwidth (Gbytes)	1.768	0.299	1.139
Randomly Ordered Ring Bandwidth (Gbytes)	0.283	0.070	0.071

*N=1493

Access to Cyclone provided by SGI

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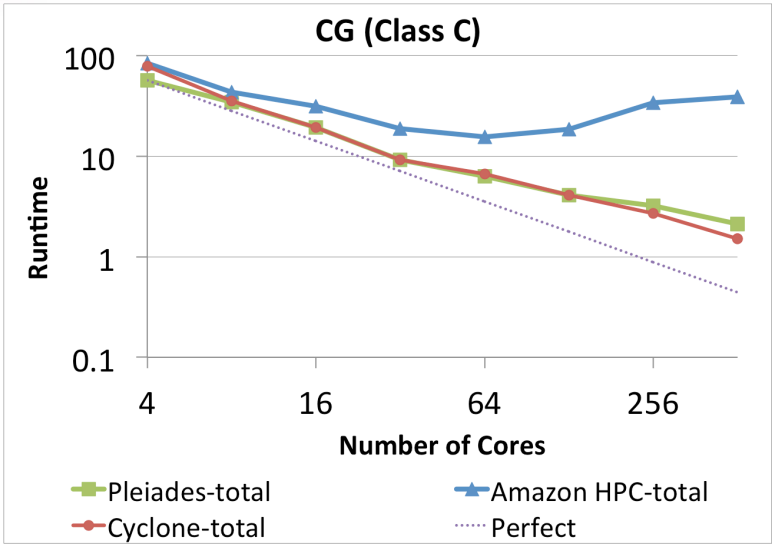
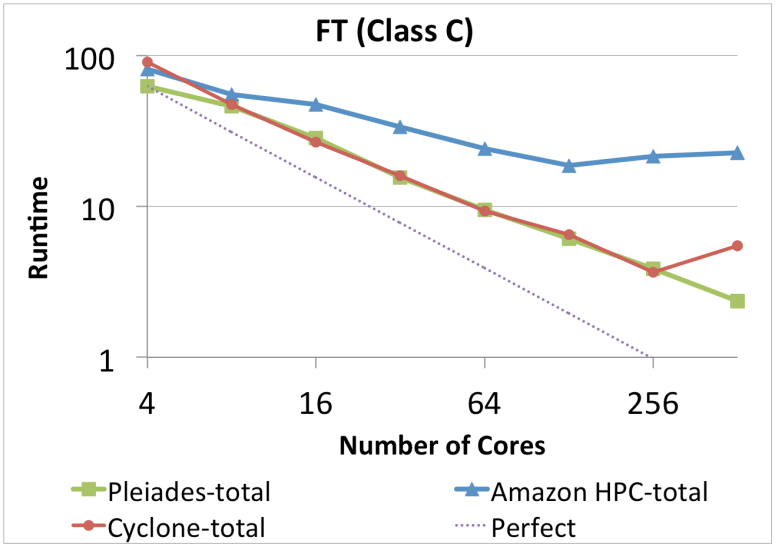
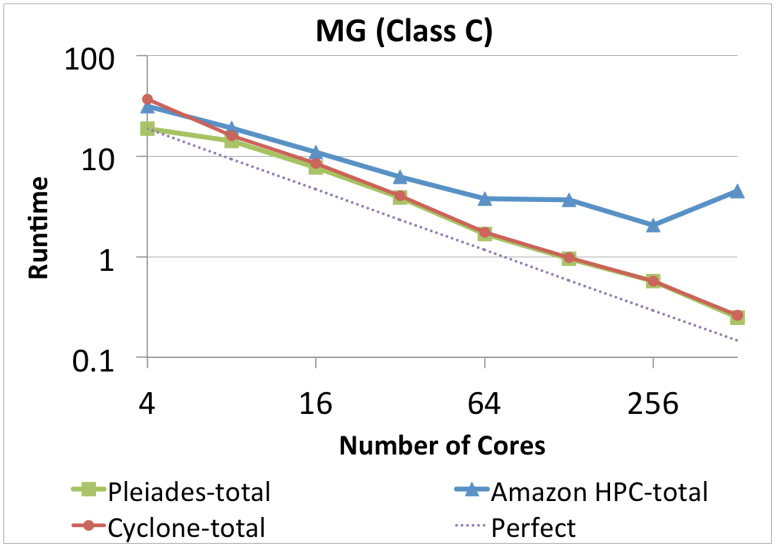
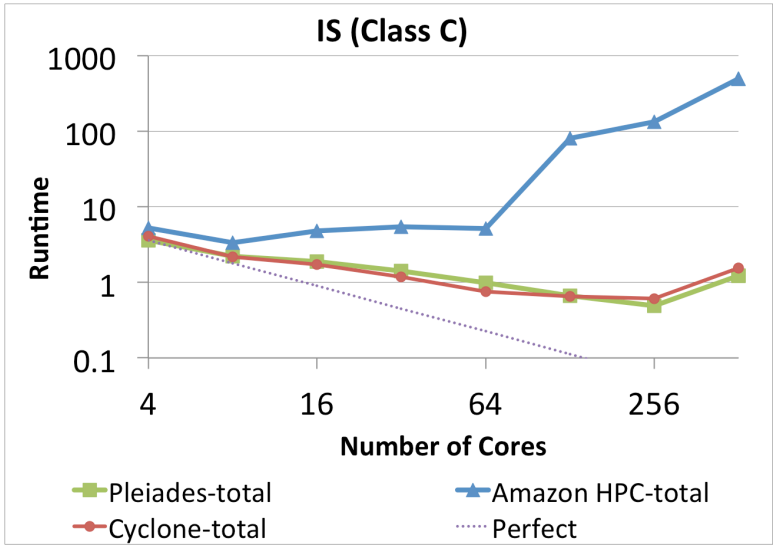
NPB Results









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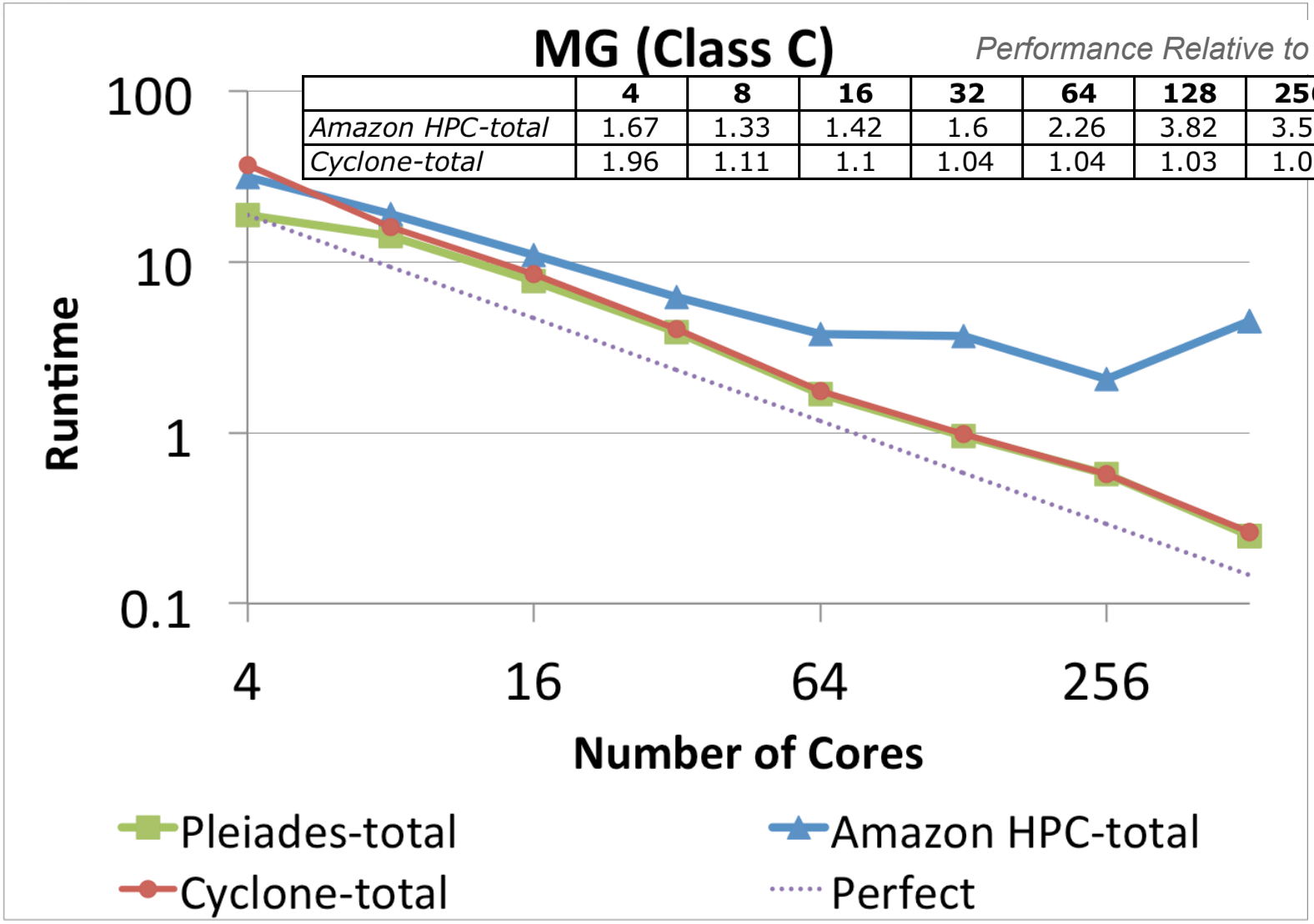
NPB Results

MG (Class C)

Performance Relative to Pleiades

	4	8	16	32	64	128	256	512
Amazon HPC-total	1.67	1.33	1.42	1.6	2.26	3.82	3.58	18.03
Cyclone-total	1.96	1.11	1.1	1.04	1.04	1.03	1.01	1.05



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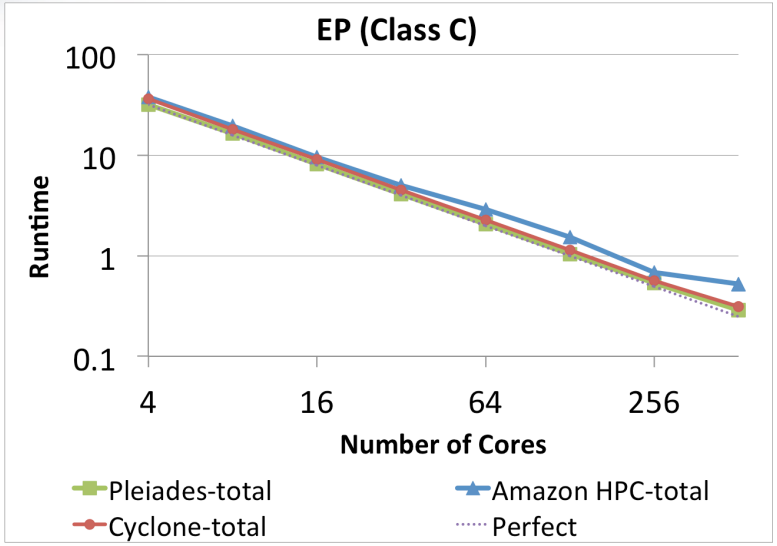
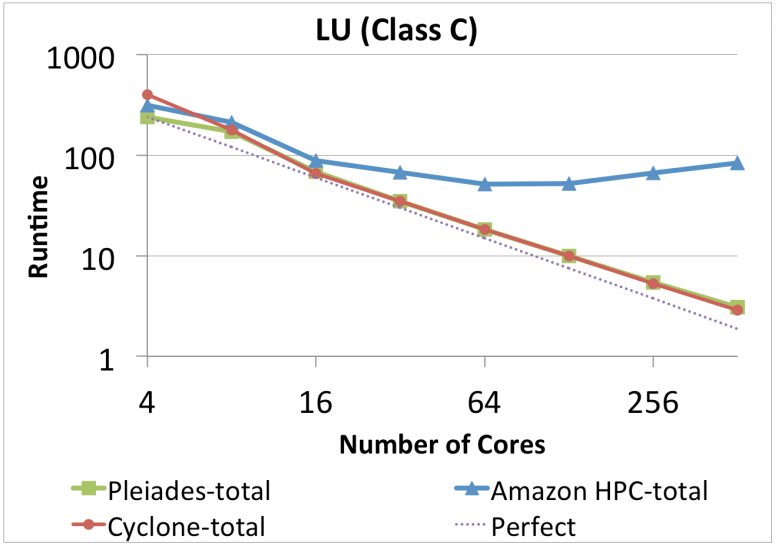
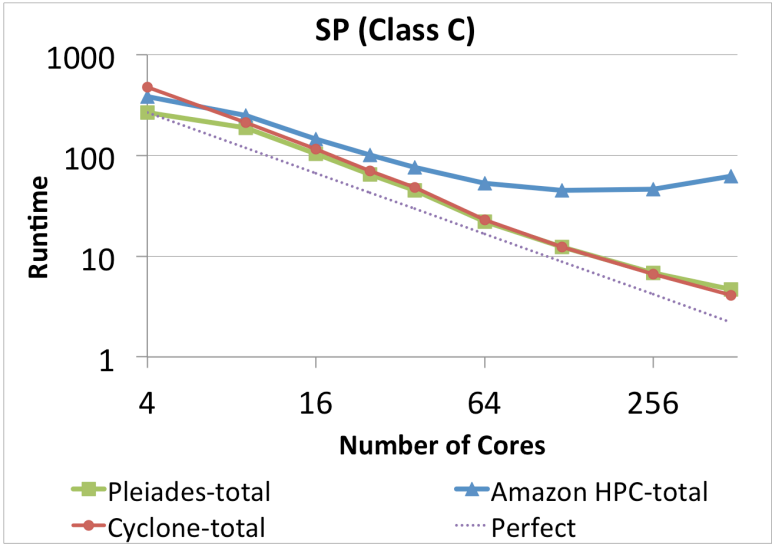
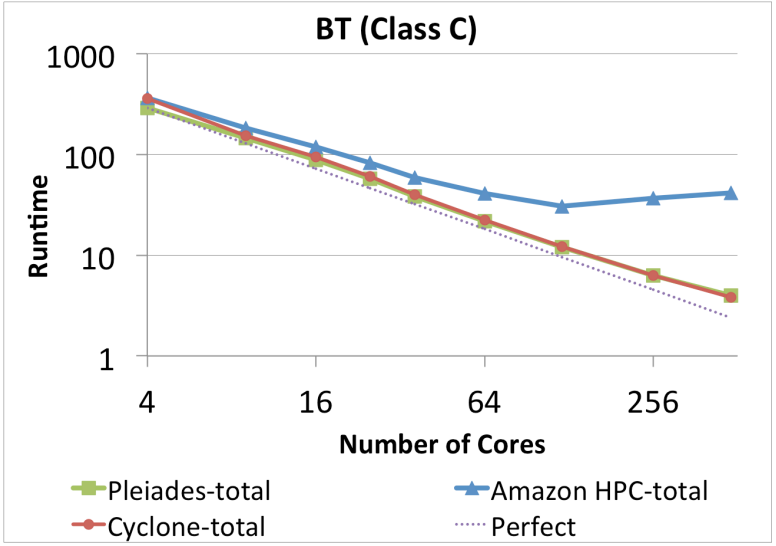
NPB Results









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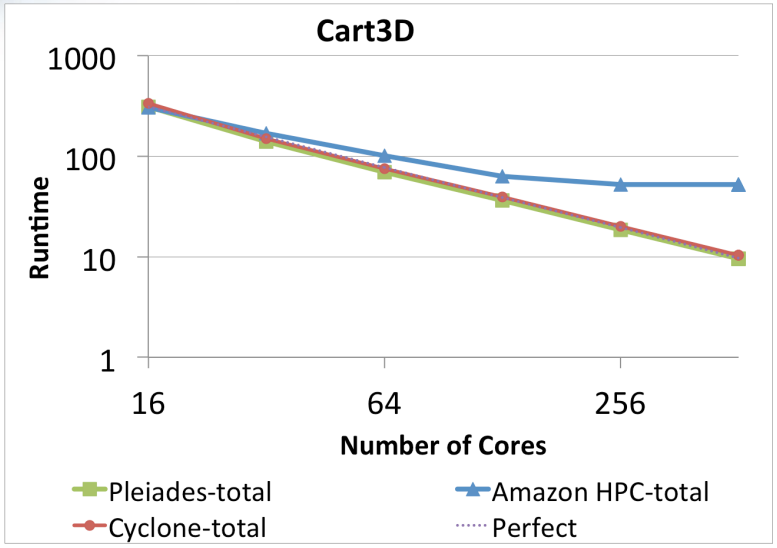
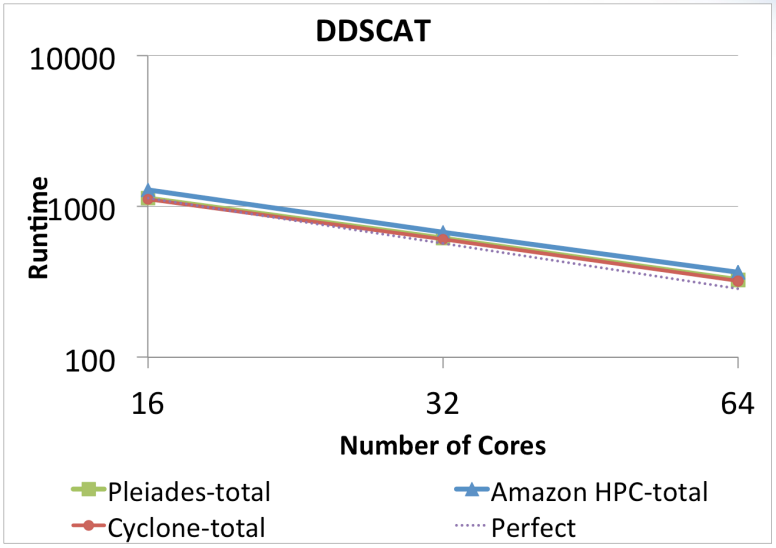
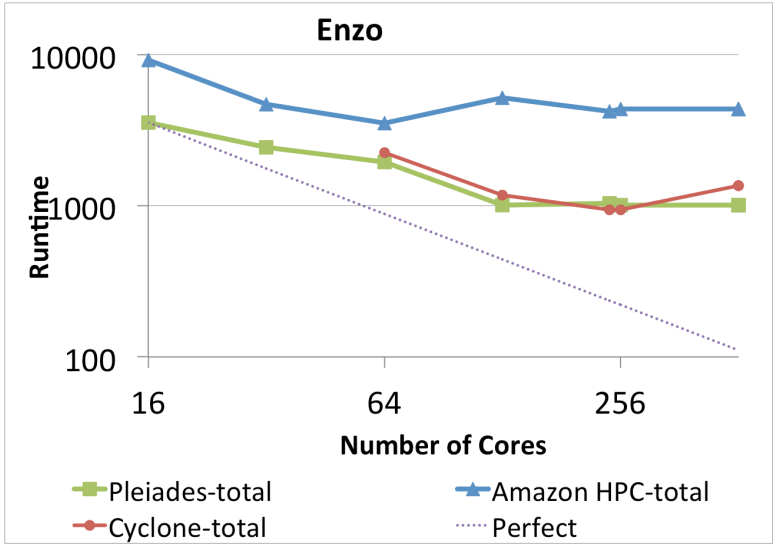
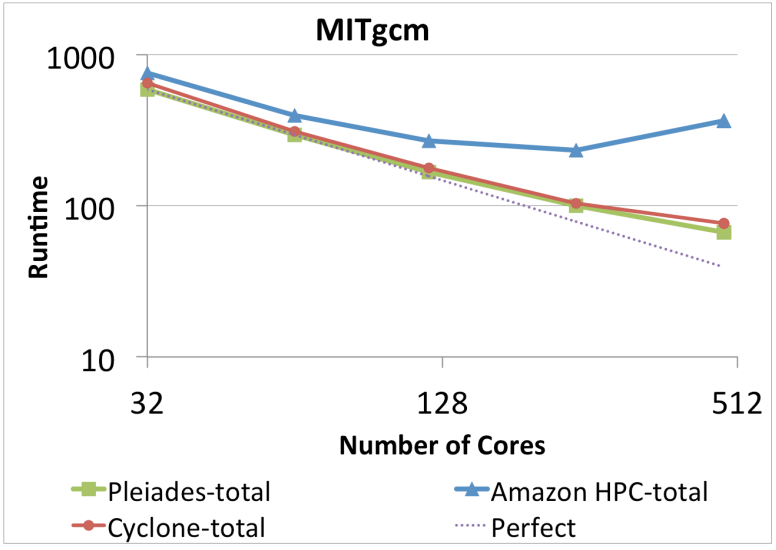
Application Performance









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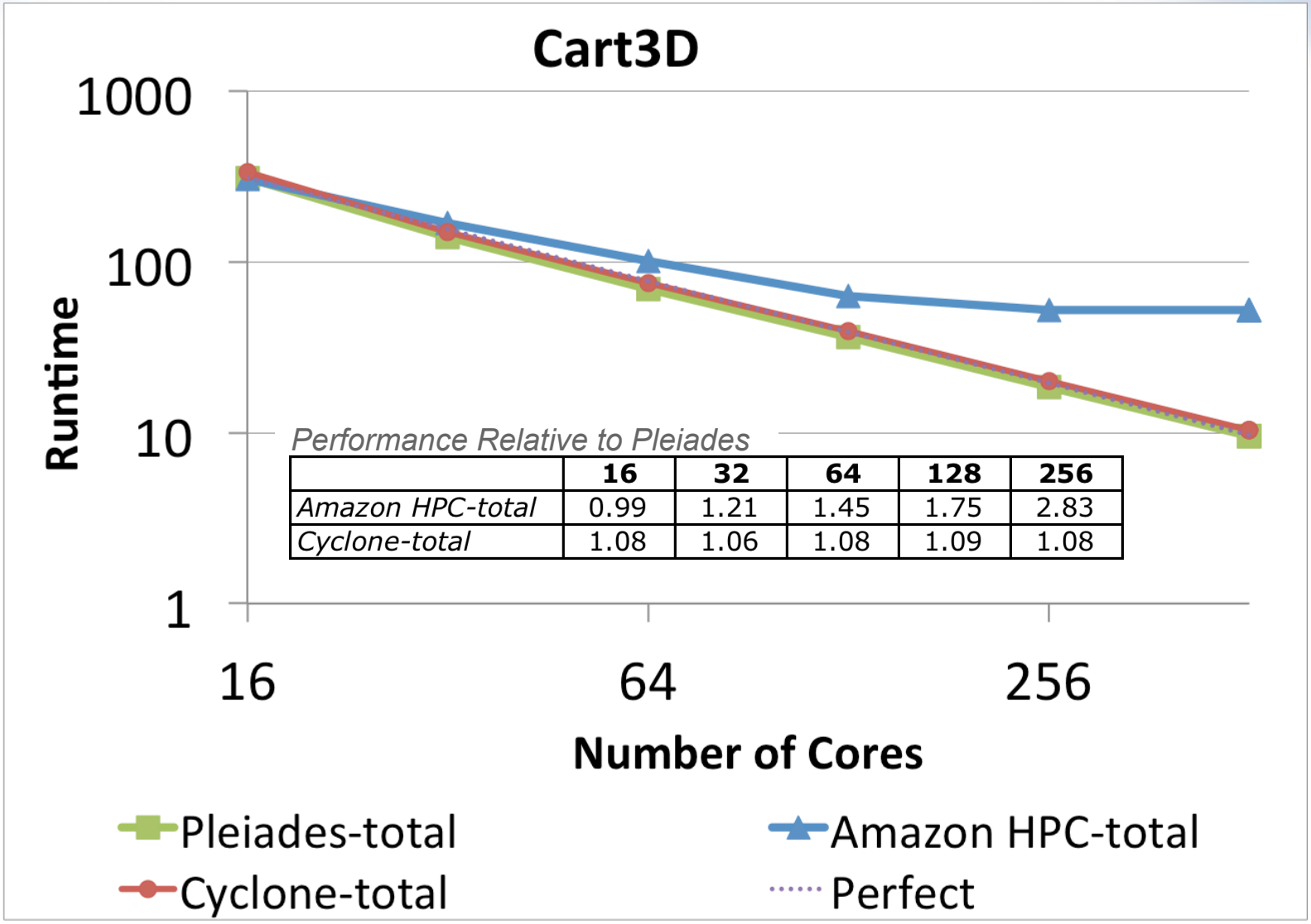
CART3D Performance



Performance Relative to Pleiades

	16	32	64	128	256
Amazon HPC-total	0.99	1.21	1.45	1.75	2.83
Cyclone-total	1.08	1.06	1.08	1.09	1.08

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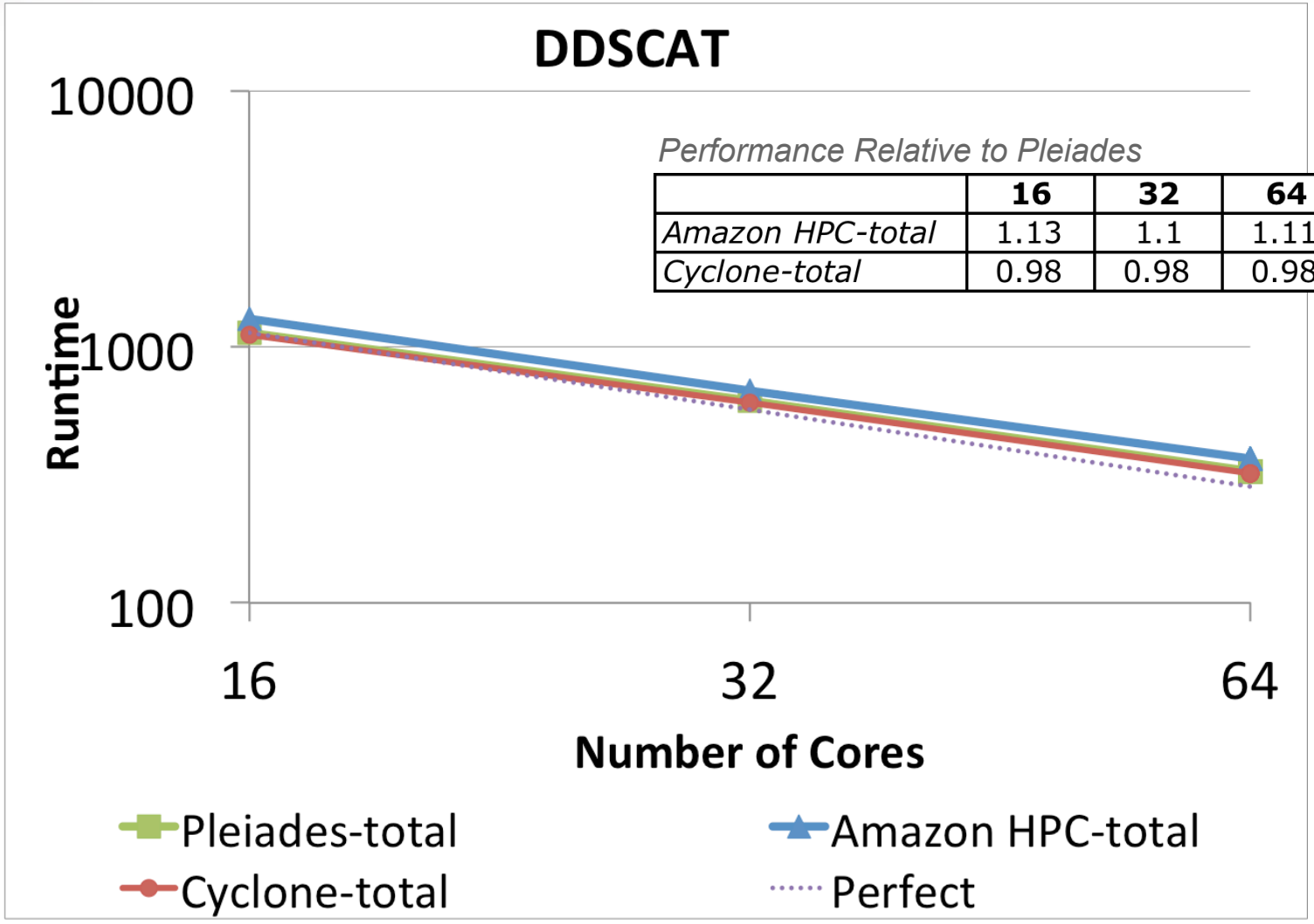
DDSCAT Performance



Performance Relative to Pleiades

	16	32	64
Amazon HPC-total	1.13	1.1	1.11
Cyclone-total	0.98	0.98	0.98

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Amazon Performance Relative to Pleiades

	4	9	16	25	36	64	121	256	484
BT	1.25	1.25	1.35	1.44	1.55	1.9	2.55	5.82	10.44
SP	1.43	1.32	1.41	1.57	1.71	2.4	3.65	6.81	13.19

	4	8	16	32	64	128	256	512
CG	1.48	1.26	1.62	2.06	2.46	4.54	10.65	18.41
EP	1.2	1.19	1.16	1.22	1.39	1.48	1.29	1.82
FT	1.31	1.2	1.67	2.18	2.53	3.06	5.58	9.61
IS	1.48	1.51	2.51	3.83	5.26	121.73	275.14	403.26
LU	1.31	1.24	1.29	1.93	2.83	5.25	12.15	27.31
MG	1.67	1.33	1.42	1.6	2.26	3.82	3.58	18.03

	32	64	120	240	480
MITgcm	1.28	1.35	1.62	2.33	5.47

	16	32	64
DDSCAT	1.13	1.1	1.11

	16	32	64	128	256
Cart3D	0.99	1.21	1.45	1.75	2.83

	16	32	64	128	240	256
Enzo	2.59	1.94	1.81	5.16	4.06	4.34

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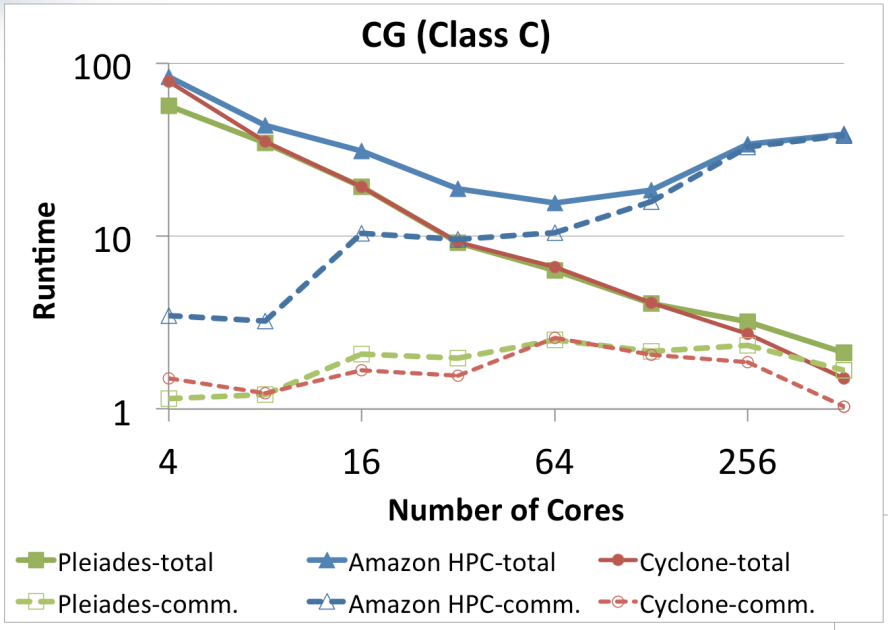
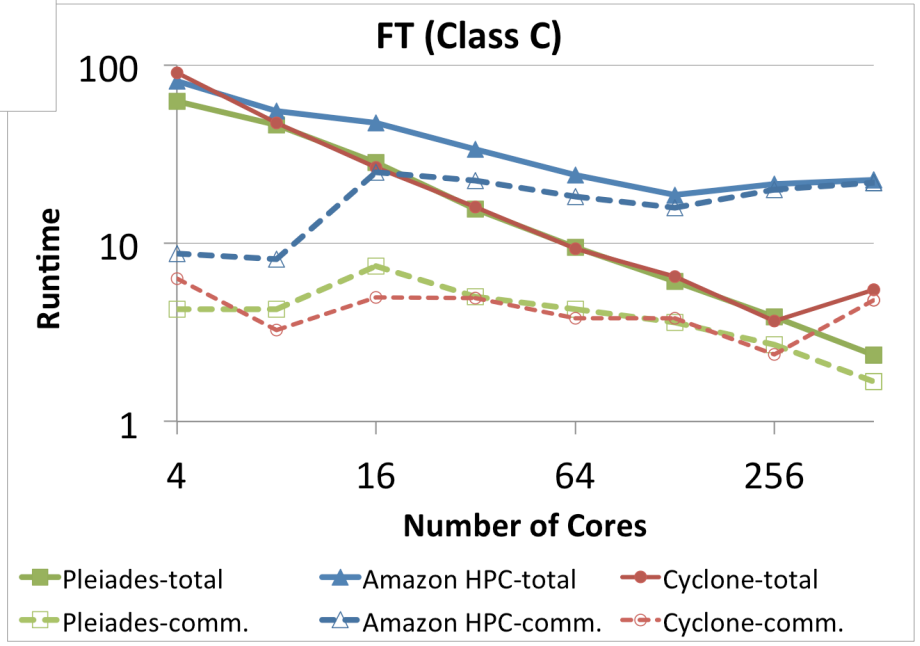
Communication Impact





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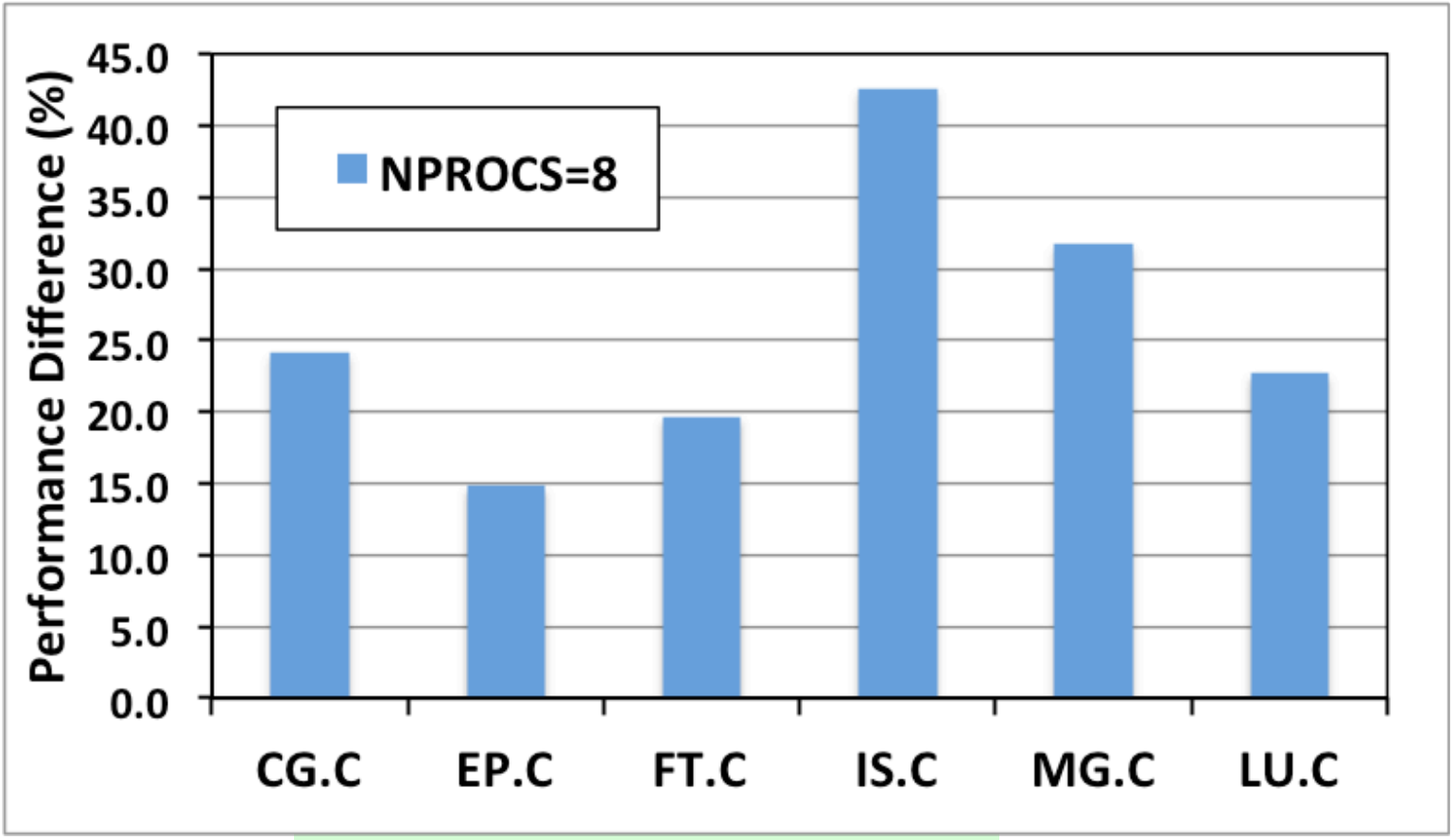
Virtualization Overhead

	Pleiades	*Amazon HPC*	*Perf. Diff.*
EP DGEMM N=5773 (Gflops)	11.417	10.758	5.8%
Single DGEMM N=5773 (Gflops)	12.252	11.062	9.7%



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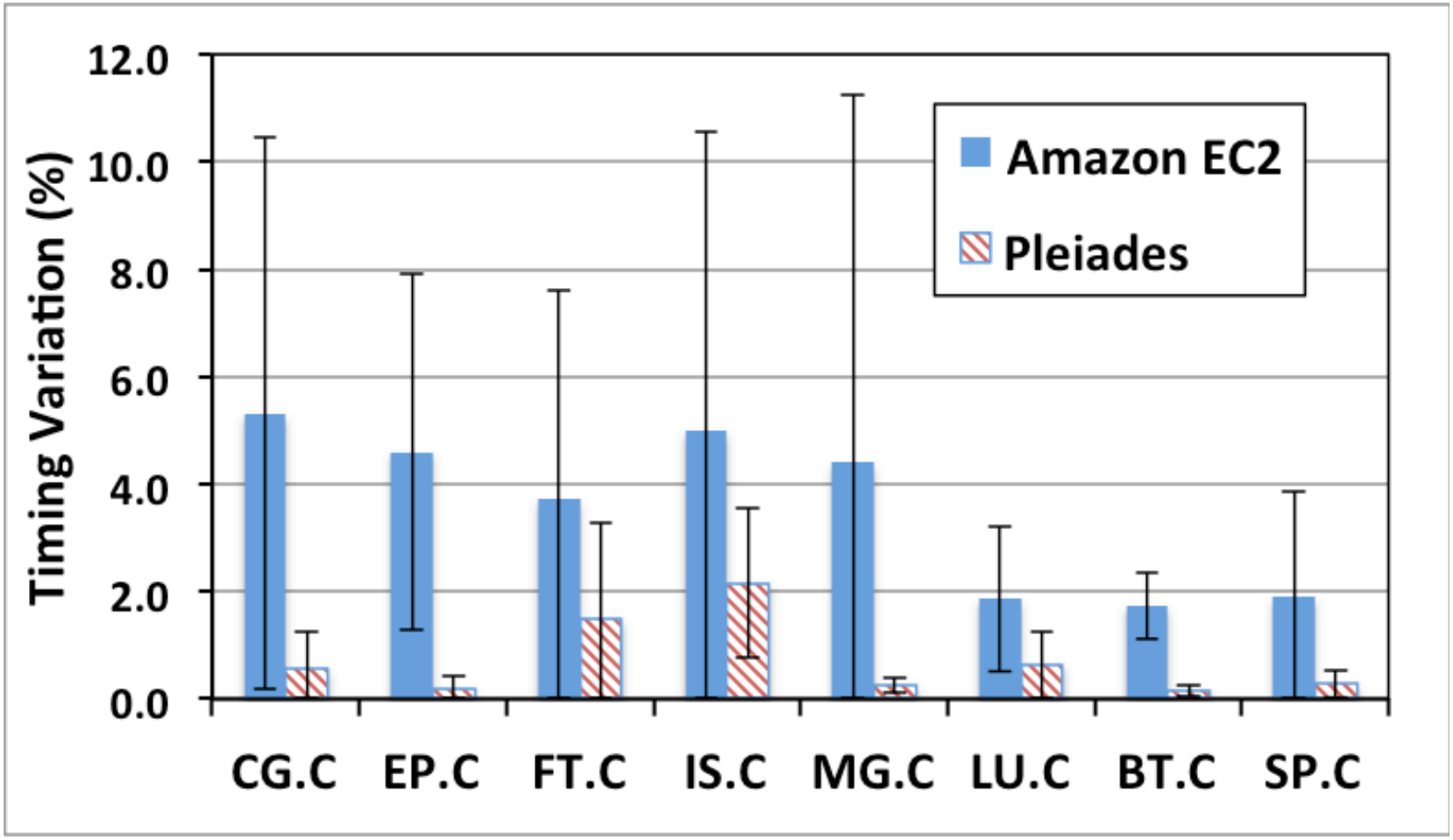
Performance Variability



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Summary

- Cyclone's performance close to Pleiades
  - Overhead of initially booting nodes with the requested image
- Amazon performance lags Pleiades for HPC applications
  - Network technology
  - Virtualization overhead
- Other issues with clouds for NASA scientists
  - Cost, Security, Usability, Reliability (not examined here)

Cloud computing *currently* not a viable solution for NASA HPC applications
… but they are catching up fast!!!

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Acknowledgements

Work done by:

J. Djomehri, S. Heistand, R. Hood, H. Jin, A. Lazanoff, P. Mehrotra, S. Saini, R. Biswas

Slides provided by:

Piyush Mehrotra

Reference:

P. Mehrotra, J. Djomehri, S. Heistand, R. Hood, H. Jin, A. Lazanoff, S. Saini, R. Biswas. *"Performance Evaluation of Amazon EC2 for NASA HPC Applications,"* Science Cloud 2012, Delft, The Netherlands, June 2012