WRF Scaling and Performance Assessment

Comparison of Compilers and MPI Libraries on Cheyenne

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Outline

- Background
  - WRF
  - Cheyenne
  - Benchmark Cases
- Compilers
- Message Passing Interface Libraries
- Run Time Scaling
- Computation Time Scaling
- MVAPICH scaling

Background

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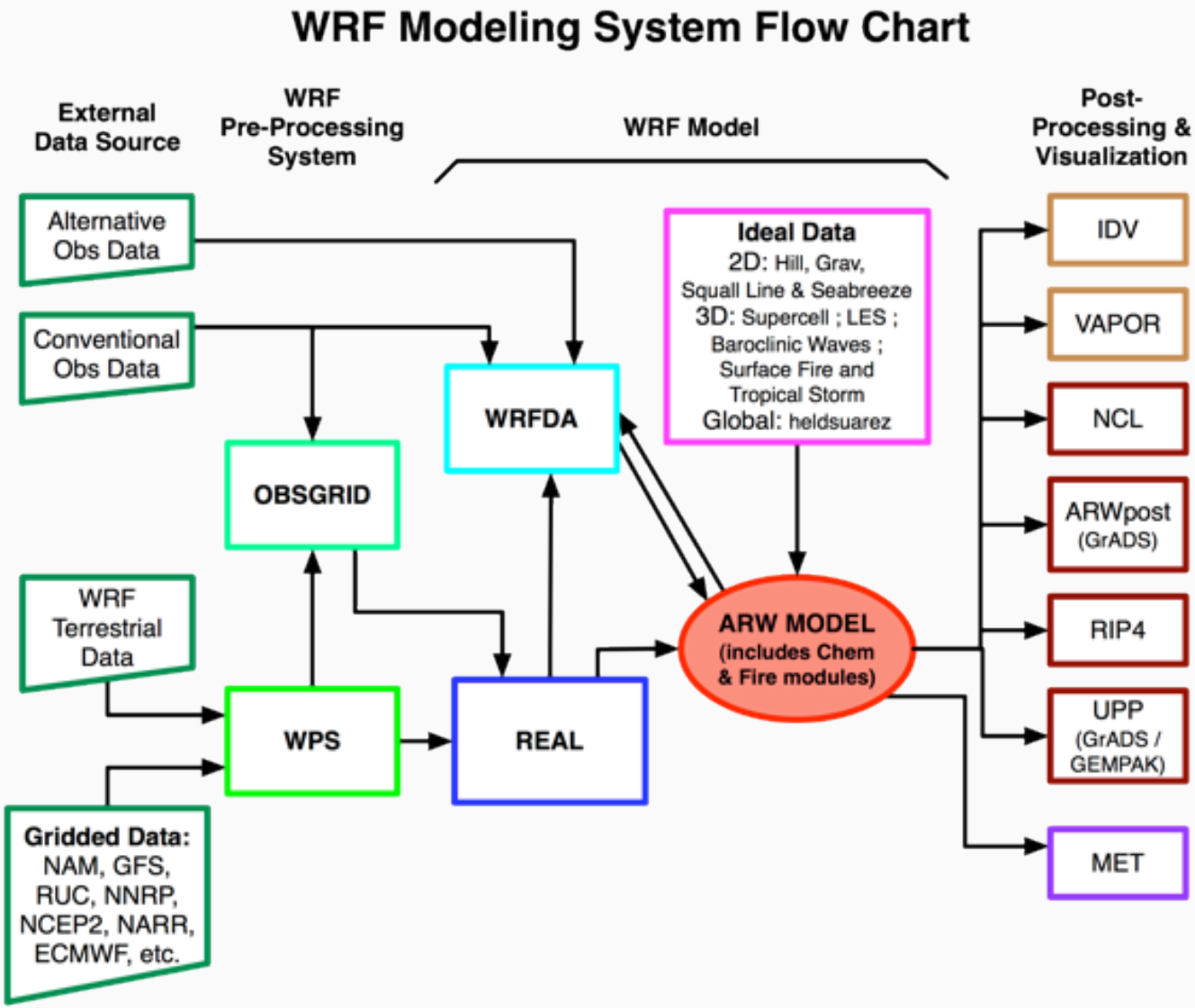
- WRF is among the more commonly run codes by atmospheric scientists on NCAR's Cheyenne supercomputer.
  - Thus it is very important for WRF's users to know how to obtain the best performance of WRF on Cheyenne, especially as users scale their runs to larger core counts.

WRF System Flowchart



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  - Latency: MPI ping-pong < 1 µs; hardware link 130 ns

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    - But `cu_physics` disabled and `sf_sfclay_physics = 1` for both resolutions.

Summary of Benchmark Cases

Region	Resoultion	Horizontal Gridpoints	Vertical Gridpoints	Total Gridpoints	Time step	Run Hours
CONUS	12 km	425	300	127,500	72	6
CONUS	2.5 km	1901	1301	2,473,201	15	6
Maria	3 km	1396	1384	1,932,064	9	3
Maria	1 km	3665	2894	10,606,510	3	1

Compilers

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  - `-fp-model fast=2` : similar to GNU's `-Ofast` optimization

Compiler Performance Results

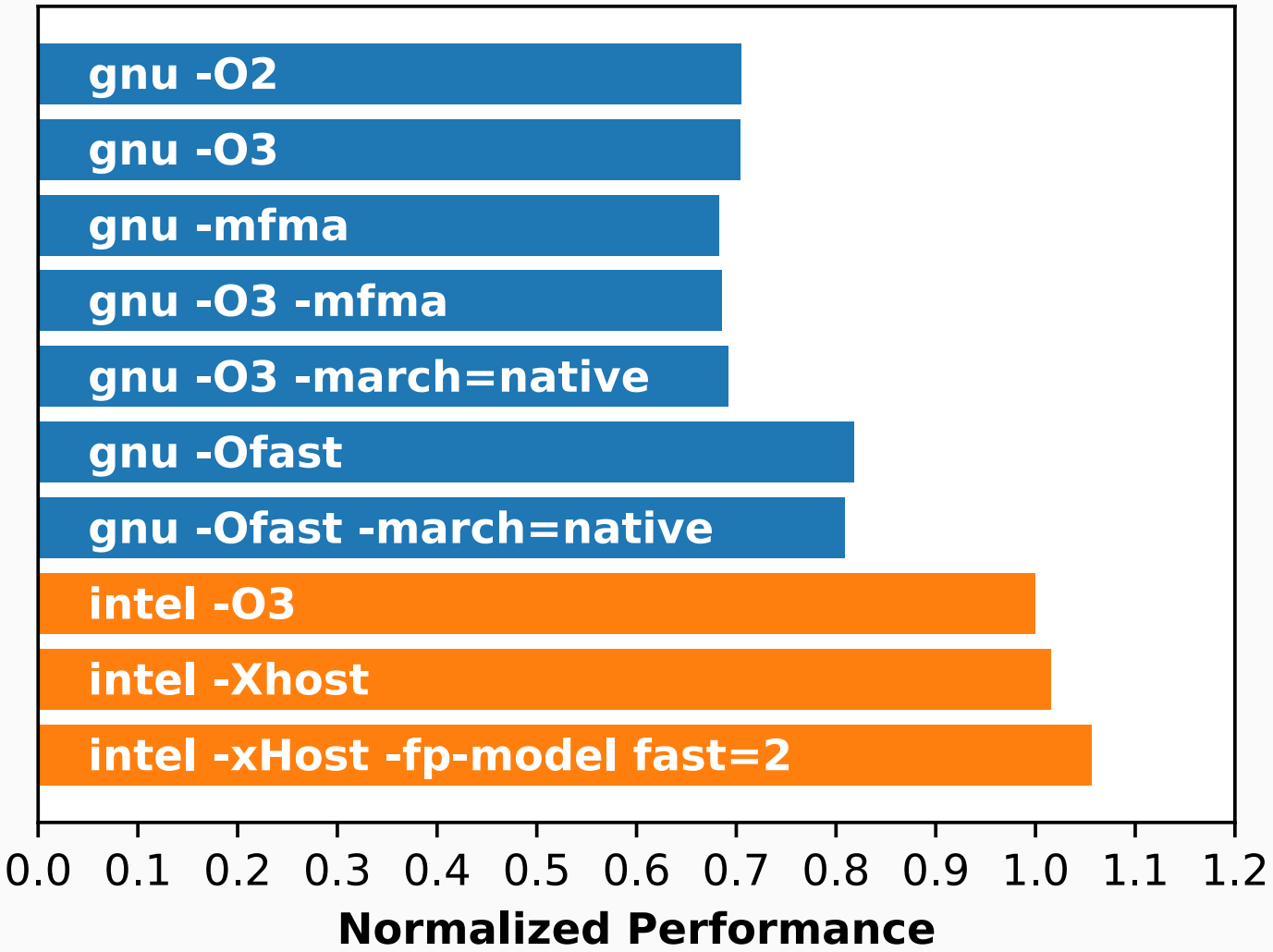

Fig. 1: Comparison of Intel 18.0.1 and Gnu 8.1.0 compilers with various compilation flags normalized to default Intel WRF compilation

Runs made using CONUS 12 km Benchmark Case on 2 Nodes

Compiler Performance Summary

- Intel compiler is consistently 25-30% faster than the Gnu compiler across all flags tried.
- We also see that for both Intel and Gnu, the `-Ofast` (for Gnu) or `-fp-model fast=2` (for Intel) are the only flags that make a significant difference in speed.
- Other flags tried such as `-mfma` or `-march=native -Xhost` made little to no difference in WRF's speed.

Message Passing Interface Libraries

MPIs Tested on Cheyenne

- SGI's MPT version 2.18 (Default MPI for Cheyenne)

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MPI Comparison Results

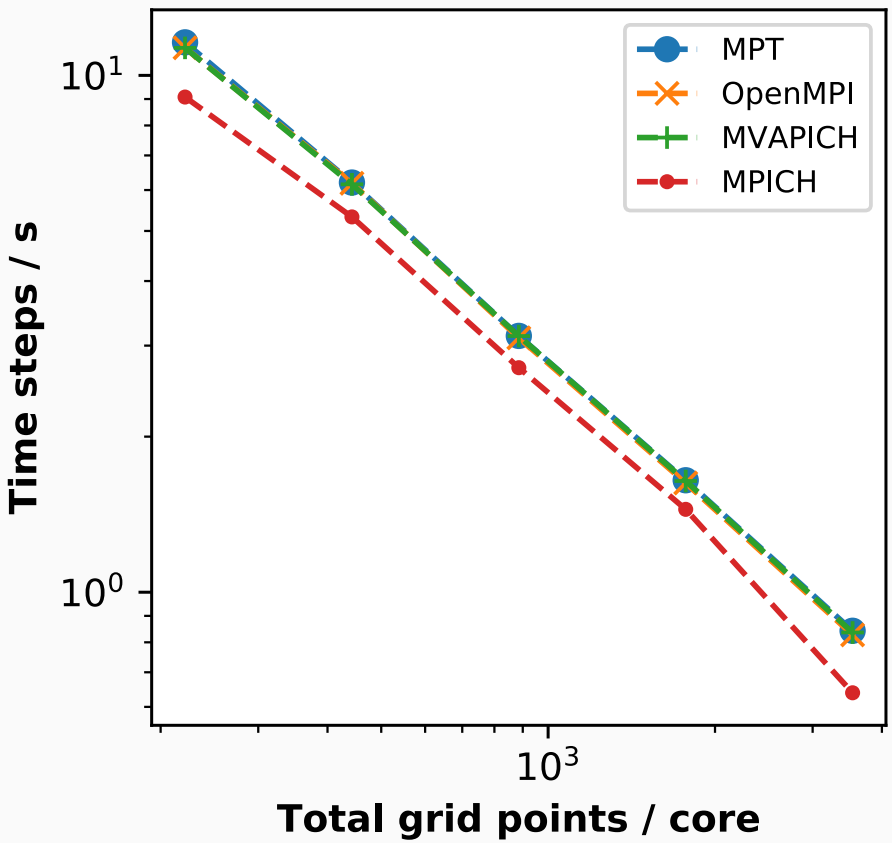

Fig. 2: MPI comparison using **Gnu 8.1.0**

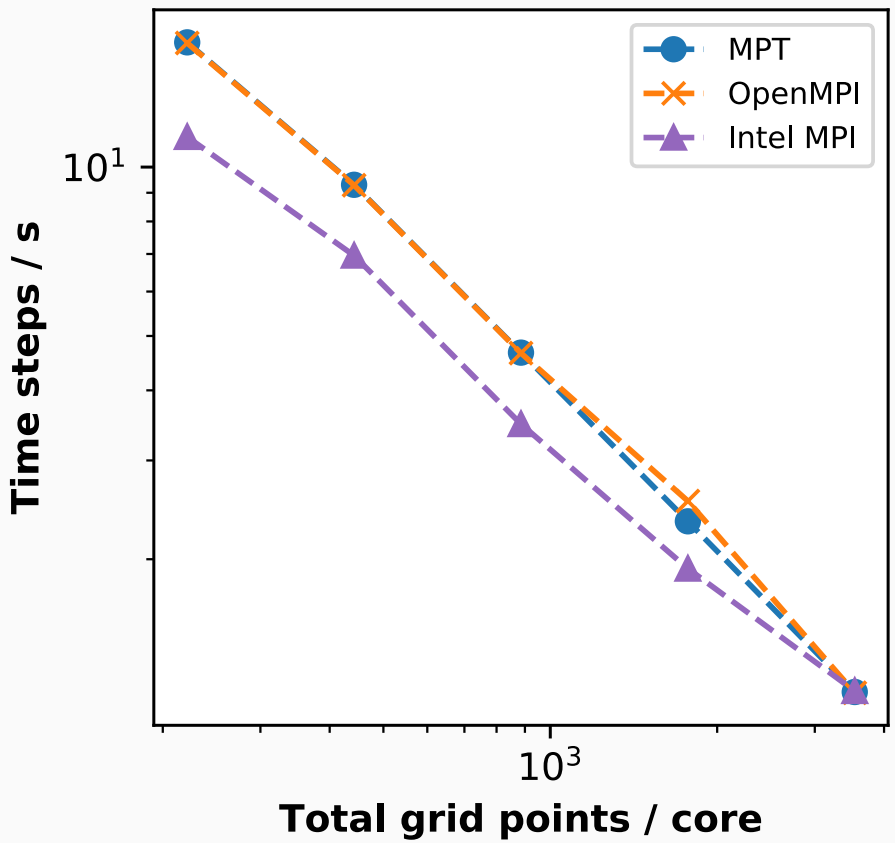

Fig. 3: MPI comparison using **Intel 18.0.1**

Runs made using CONUS 12 km Benchmark Case

MPI Comparison Summary

- MPT, MVAPICH and OpenMPI all have similar performance.
- MPICH has overall poor performance and the performance.
- Intel MPI does not scale well to large node counts.

Total Run Time Scaling

Run Time Scaling Comparison

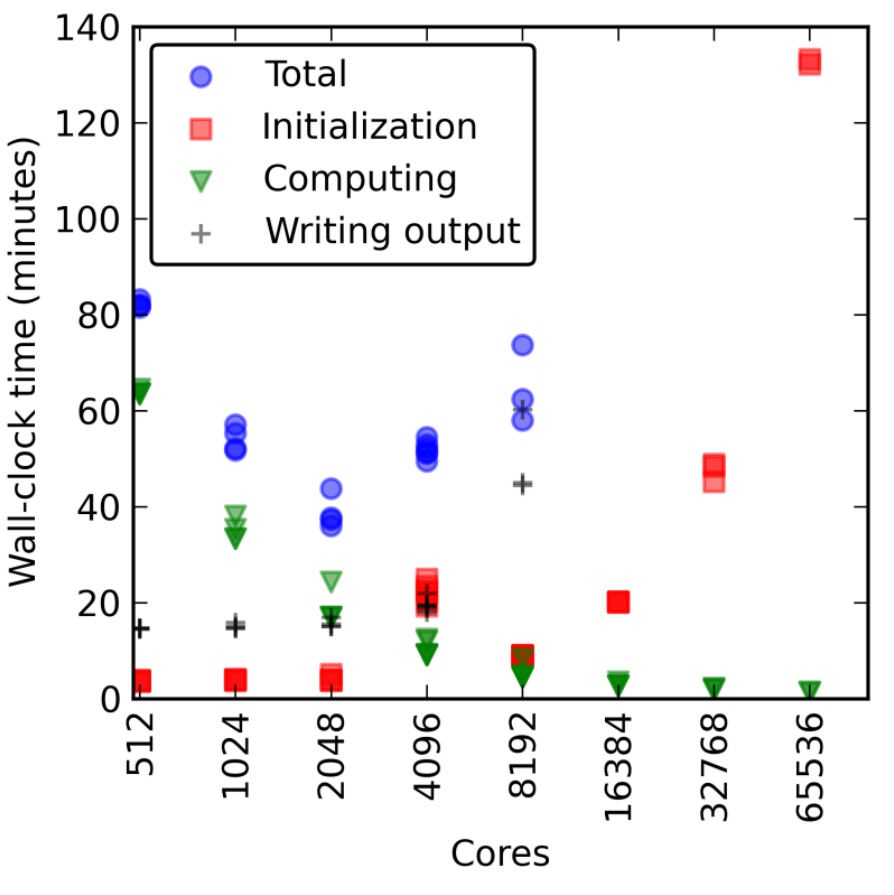

Fig. 4: Run Time Scaling on **Yellowstone**

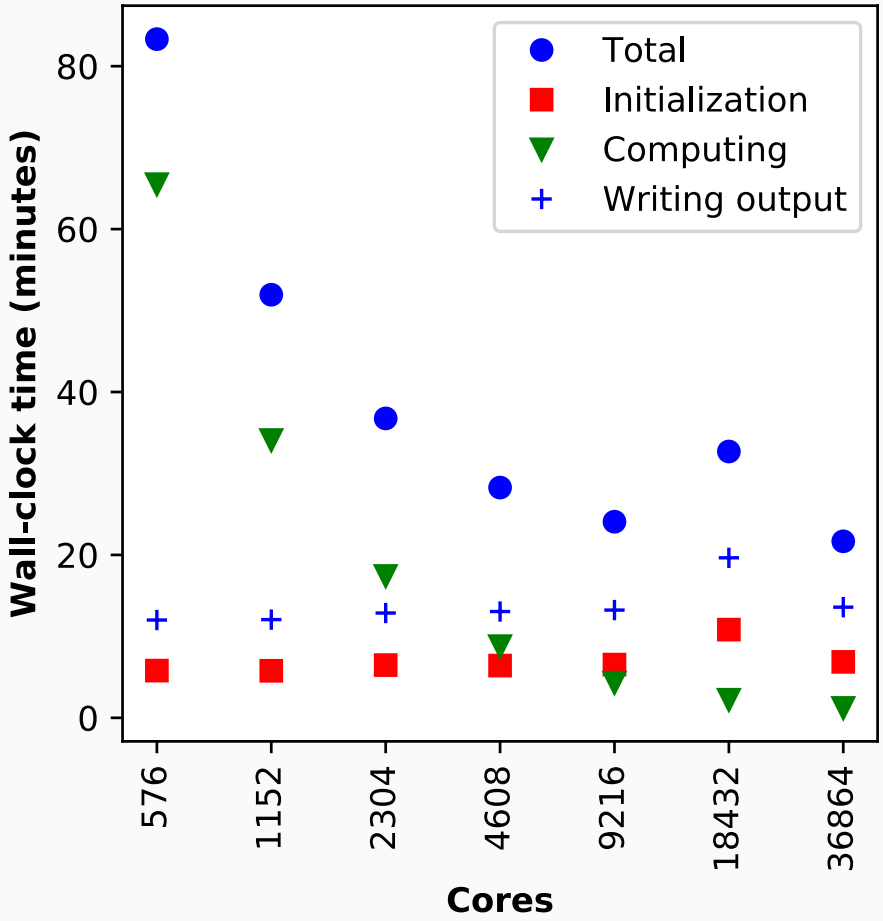

Fig. 5: Run Time Scaling on **Cheyenne**

Runs made using Hurricane Maria 1 km Benchmark case.

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- In Fig 4 for Yellowstone, the initialization time scaled much poorer at large node counts, eventually leading to unfeasible long jobs.
  - This improvement in the scaling of the initialization time is likely due to the improvements made to WRF's initialization code with how the MPI calls are performed along with improvements in the MPI used in Cheyenne versus Yellowstone.

Computation Time Scaling

Computation Time Scaling Results

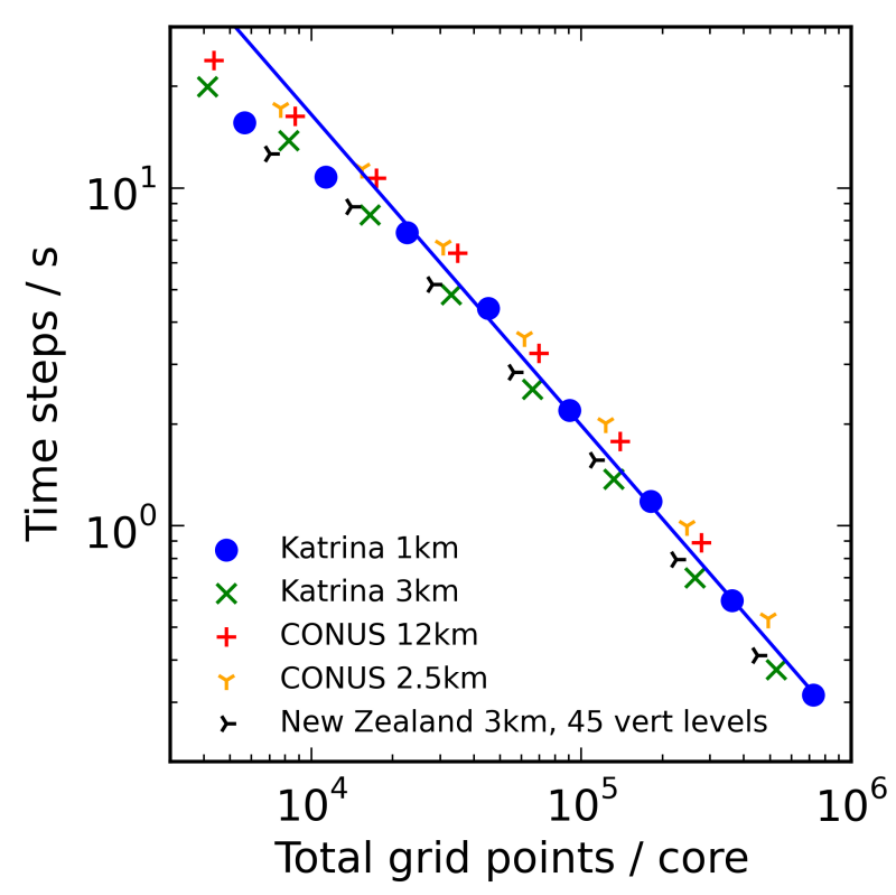

Fig. 6: Computation Scaling on **Yellowstone**

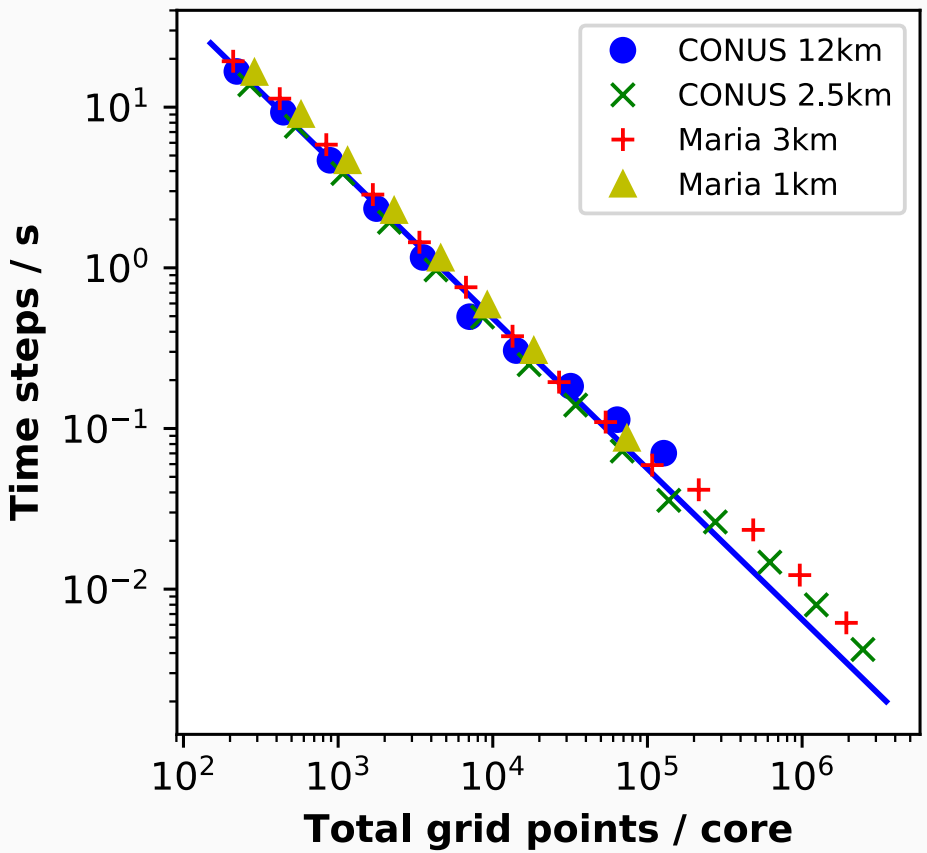

Fig. 7: Computation Scaling on **Cheyenne**

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  - In Fig 7 on Cheyenne, WRF does not significantly depart from linear strong scaling
    - Likely due to improvements in WRF's MPI code along and a better network interconnect on Cheyenne than Yellowstone

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MVAPICH Scaling

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  - HW
    - `MV2_USE_MCAST=1`
    - `MV2_ENABLE_SHARP=1`

MVAPICH Scaling Results

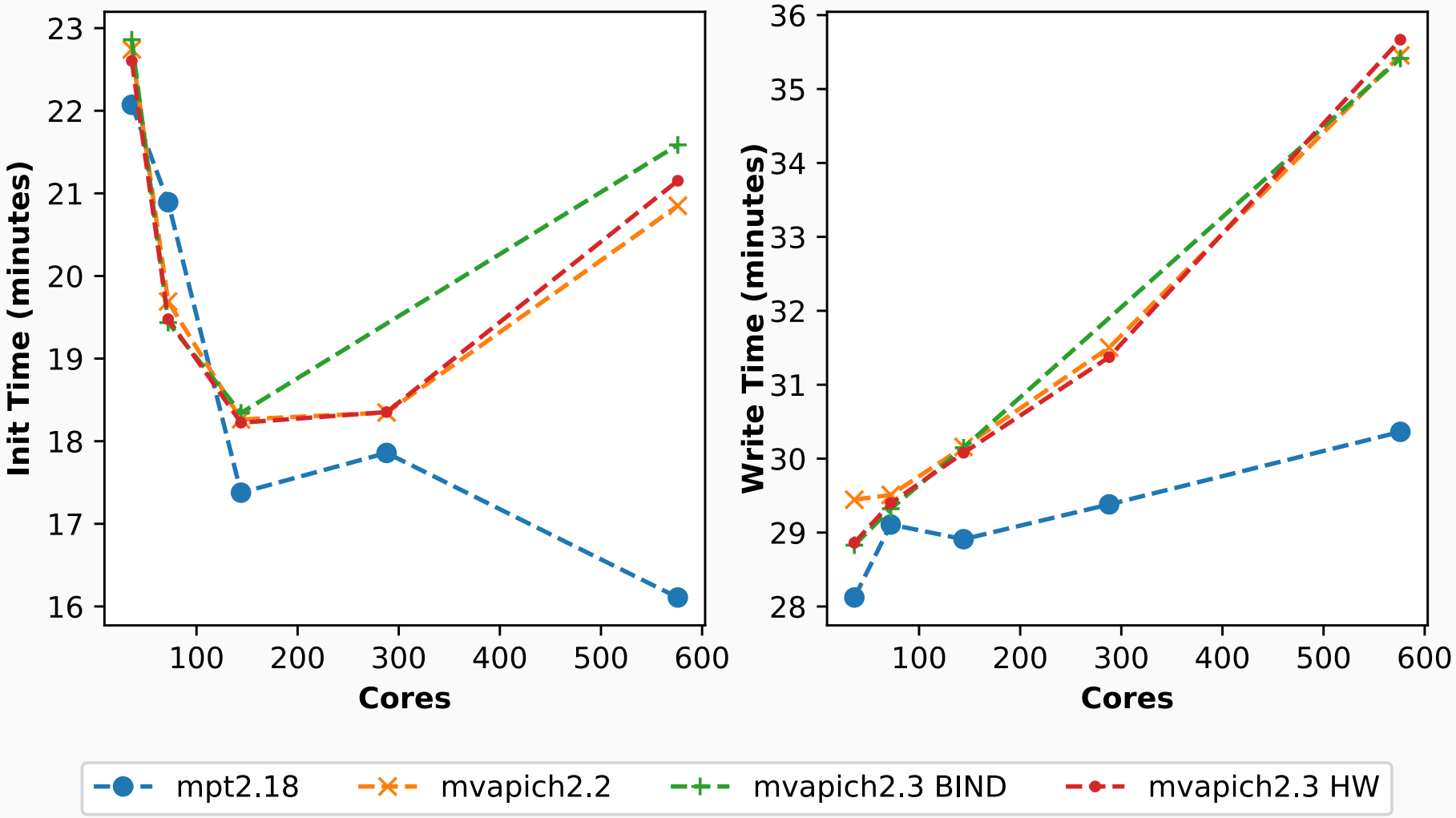

Fig. 8: MVAPICH CONUS 12 km Init and Write Scaling

MVAPICH Scaling Results

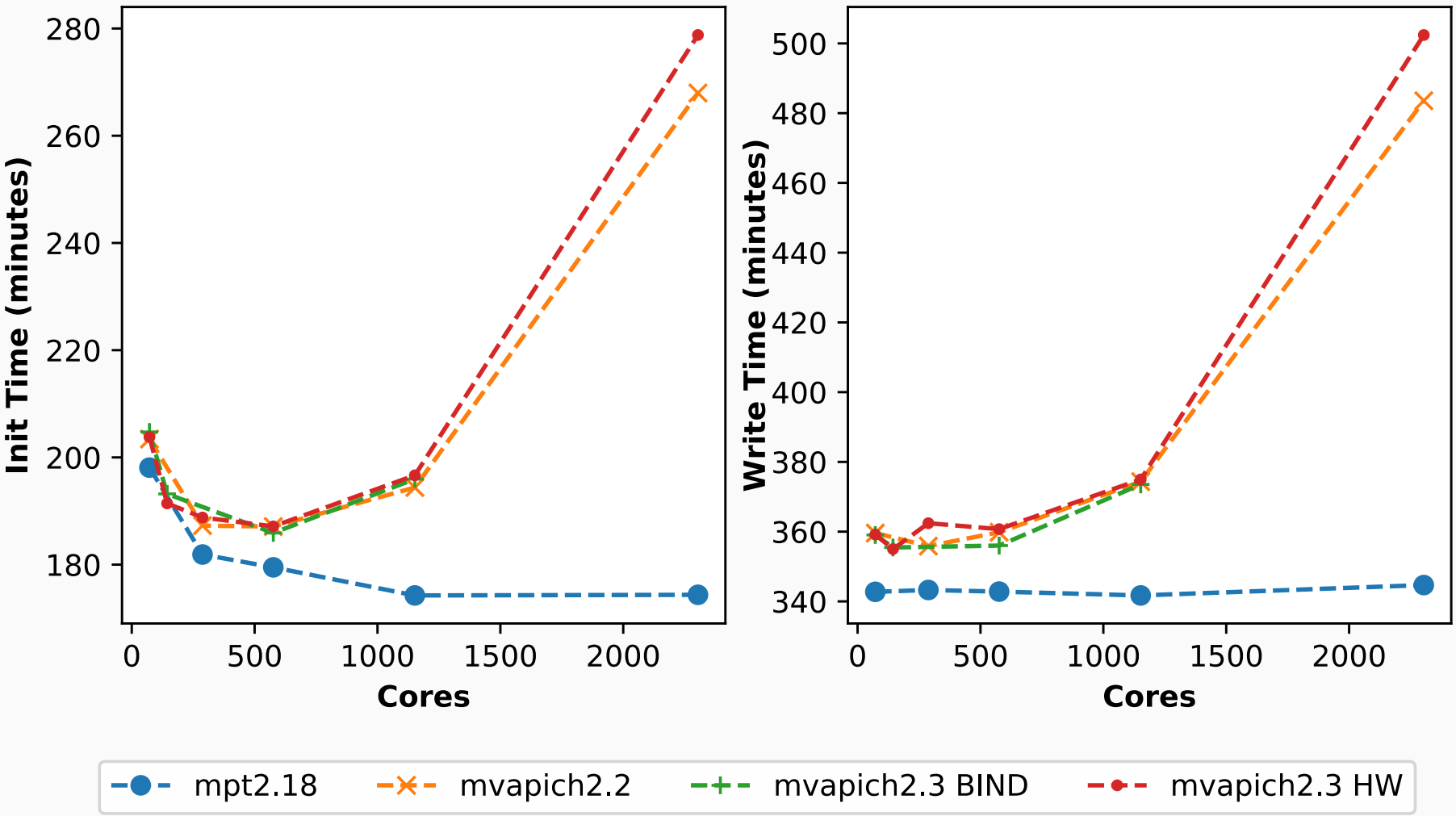

Fig. 9: MVAPICH Maria 1km Init and Write Scaling

Conclusion

Summary

- Intel compiler consistently faster than Gnu compiler
  - Users should use `-fp-model fast=2` or `-Ofast` for a modest performance increase
- MPT, OpenMPI, and MVAPICH show similar performance while Intel MPI and MPICH have poorer performance
- WRF's initialization and writing time show improvements compared to previous results on Yellowstone with a previous WRF version
- WRF V4.0 scales well across entire run-able region
  - Will run out of memory on runs with too many of gridpoints per core
  - WRF will prevent runs with too few of gridpoints per core

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- Davide Del Vento
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