
TempoQuest™
Acceleration of WRF on the GPU
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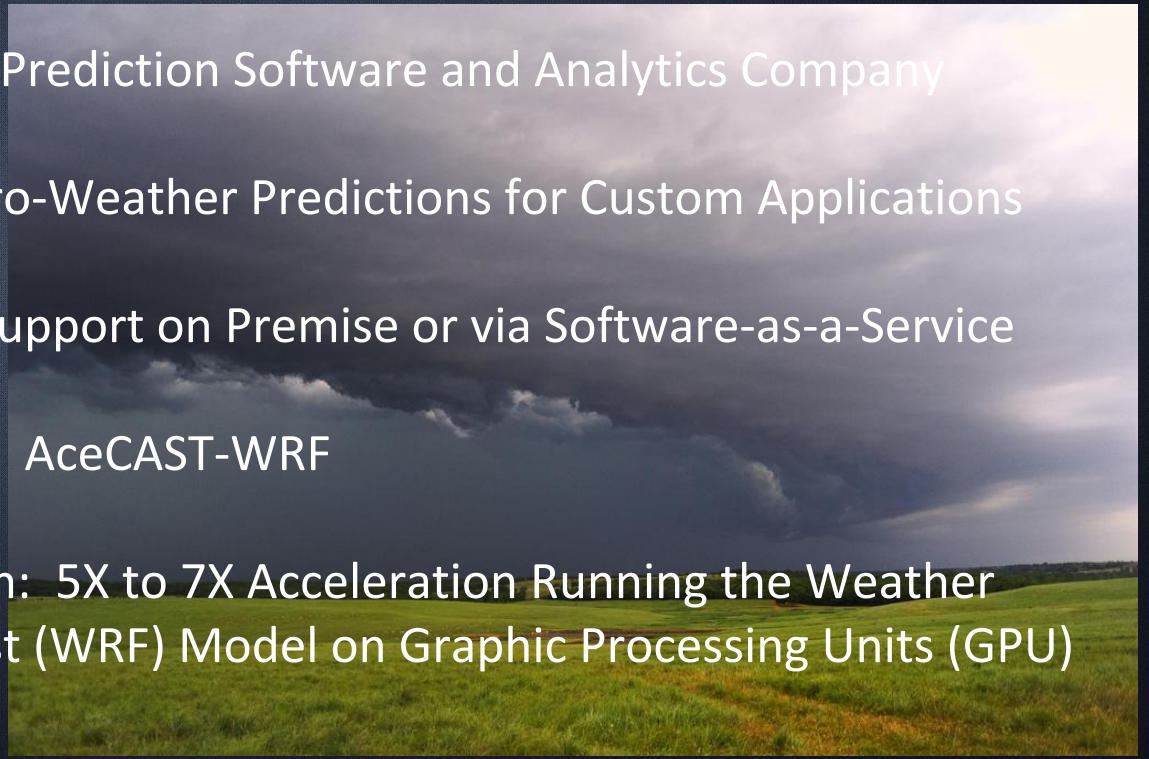
THE WORLD'S FASTEST MOST PRECISE FORECASTS

Our Product

Our Product

- TQI is a Weather Prediction Software and Analytics Company
- We Produce Micro-Weather Predictions for Custom Applications
- We Deliver and Support on Premise or via Software-as-a-Service
- Flagship Product: AceCAST-WRF
- The Breakthrough: 5X to 7X Acceleration Running the Weather Research Forecast (WRF) Model on Graphic Processing Units (GPU)



Our approach

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Our approach to Re-factoring

- WRF ported to run entirely on the GPU
- Profile and optimize most time consuming parts
- Avoid/minimize data transfer to/from GPU
- Leverage WRF registry to produce GPU code
- Pack halo data on GPU and send via infiniband
- Process multiple tiles and columns in a kernel
- Tiling to reduce memory consumption for radiation

Our approach

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Our approach to Re-Factoring

- Two branches : hybrid CPU + GPU vs pure GPU
- 7x difference in speedup between those two
- “Premature optimization is the root of all evil”
- Parallelize->Profile->Optimize->Rewrite & Repeat
- Try to avoid rewriting code->Harder to upgrade

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Physics code refactoring

- Existing code not suitable for GPU
  - Turn 1D processing to 3D processing manually -> fast but cumbersome + unmaintainable
  - Keep the 1D processing format -> convenient but slow most of the time.
  - Keep the 1D format but minimize data allocations in routines -> Efficient + maintainable

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Horror code -> rewrite

Example horror code in nesting

```
CALL rsl_lite_to_child_info( ic, jc, flag)
DO WHILE (flag)
    Pack hundreds of fields
    ....
    CALL rsl_lite_to_child_info( ic, jc, flag)
ENDDO
```

Profile

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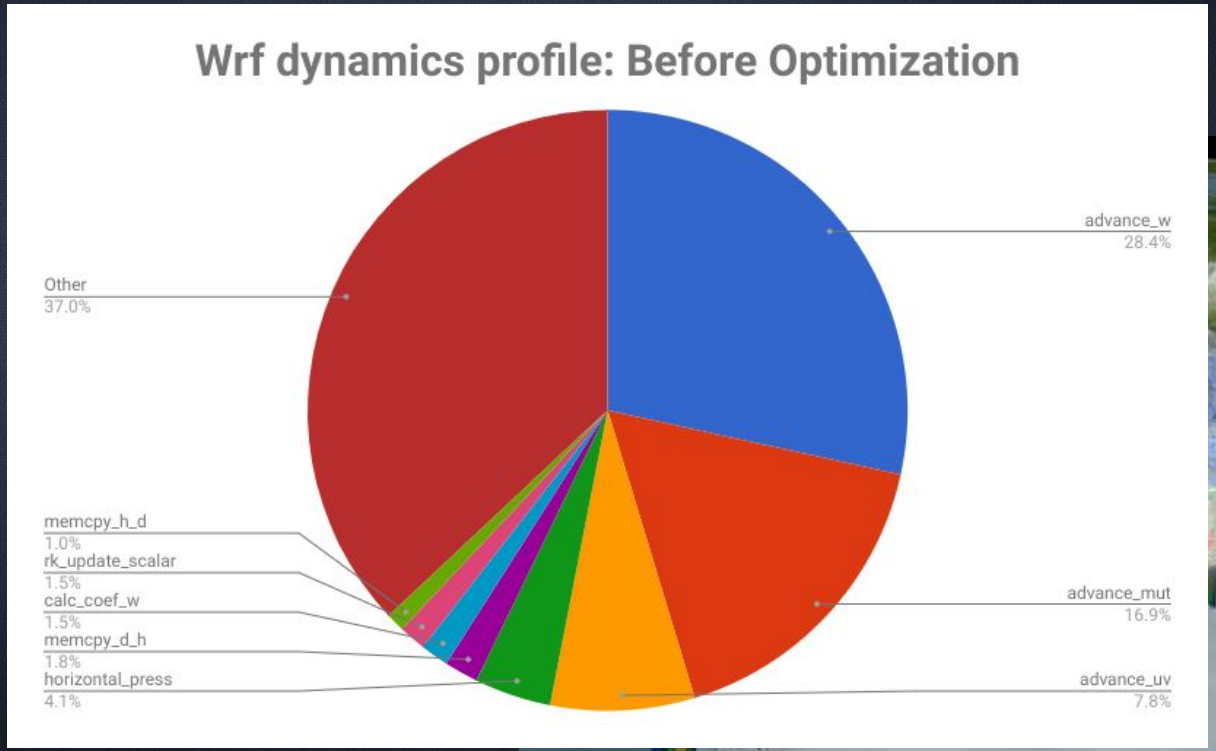
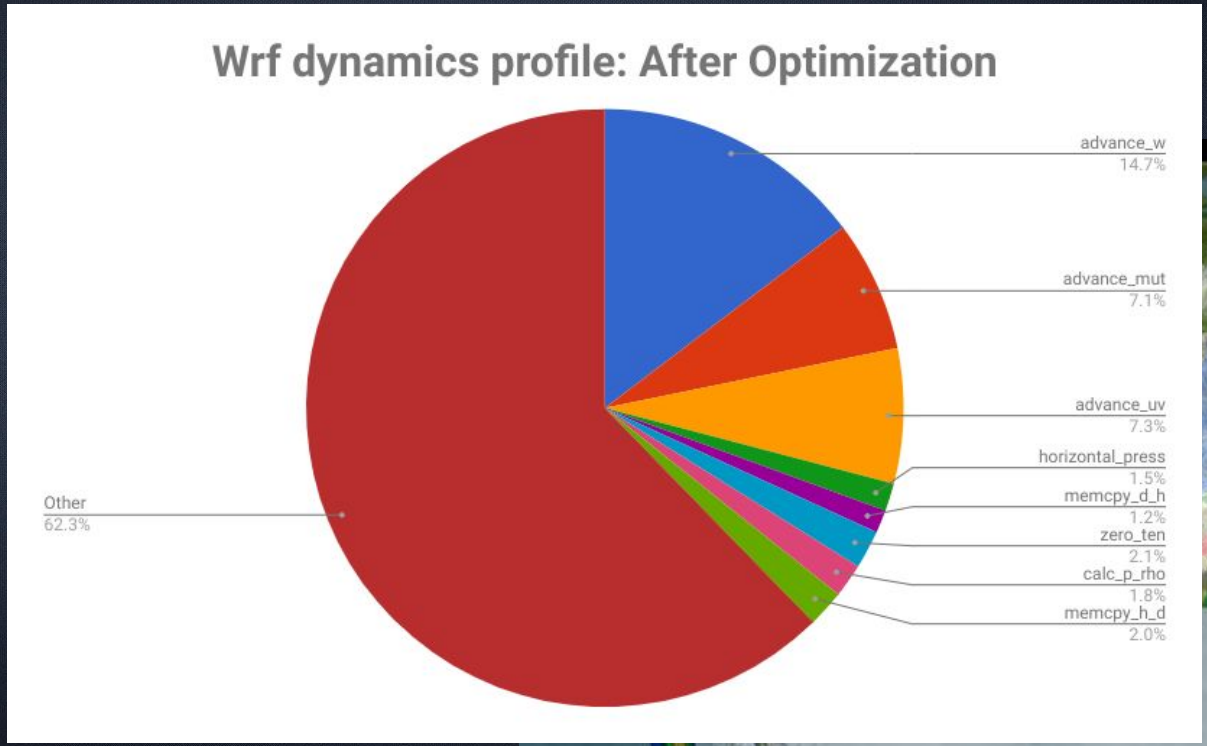
Profile on P100 GPU - Before Optimization



Optimize

Profile on P100 GPU - After Optimization



Avoid data transfers

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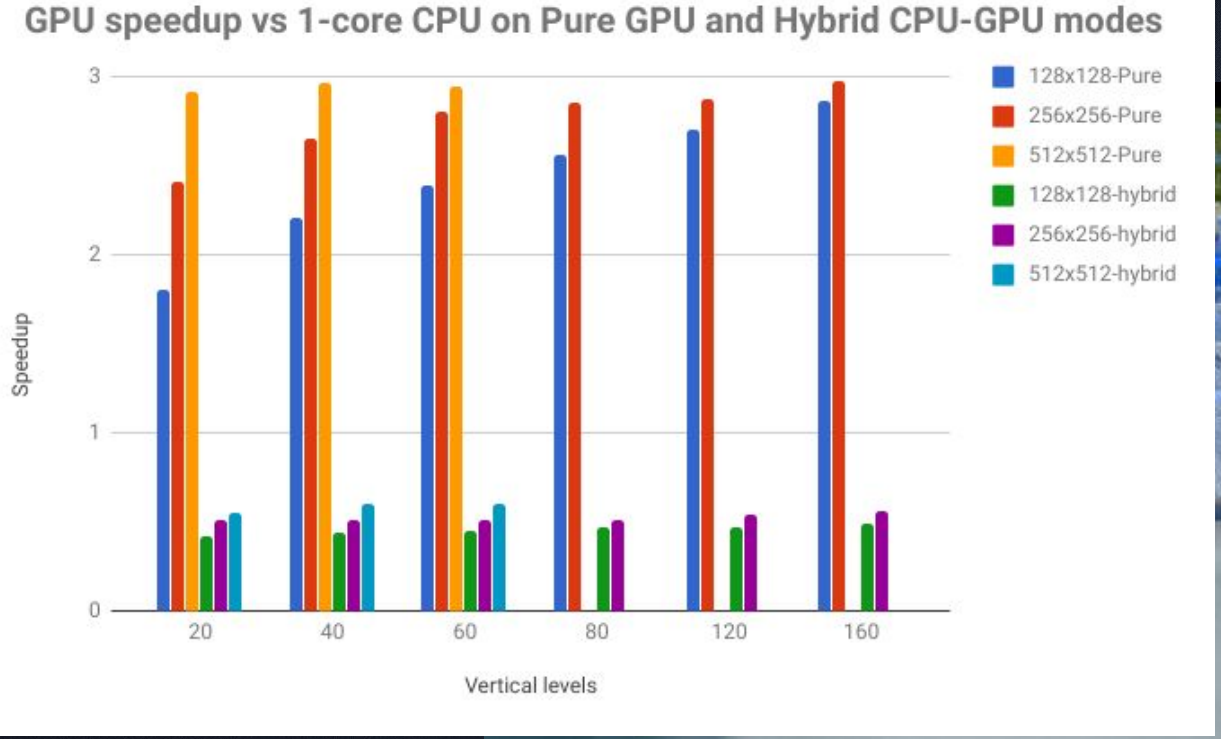
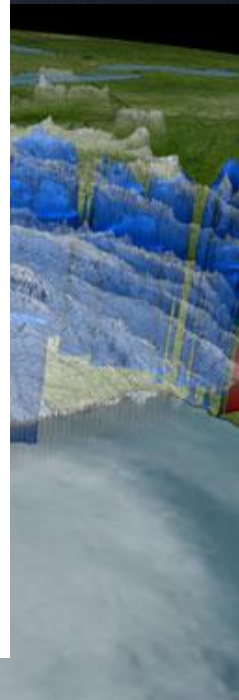
Cost of data transfer- P100 GPU + Haswell CPU





Conus timing results

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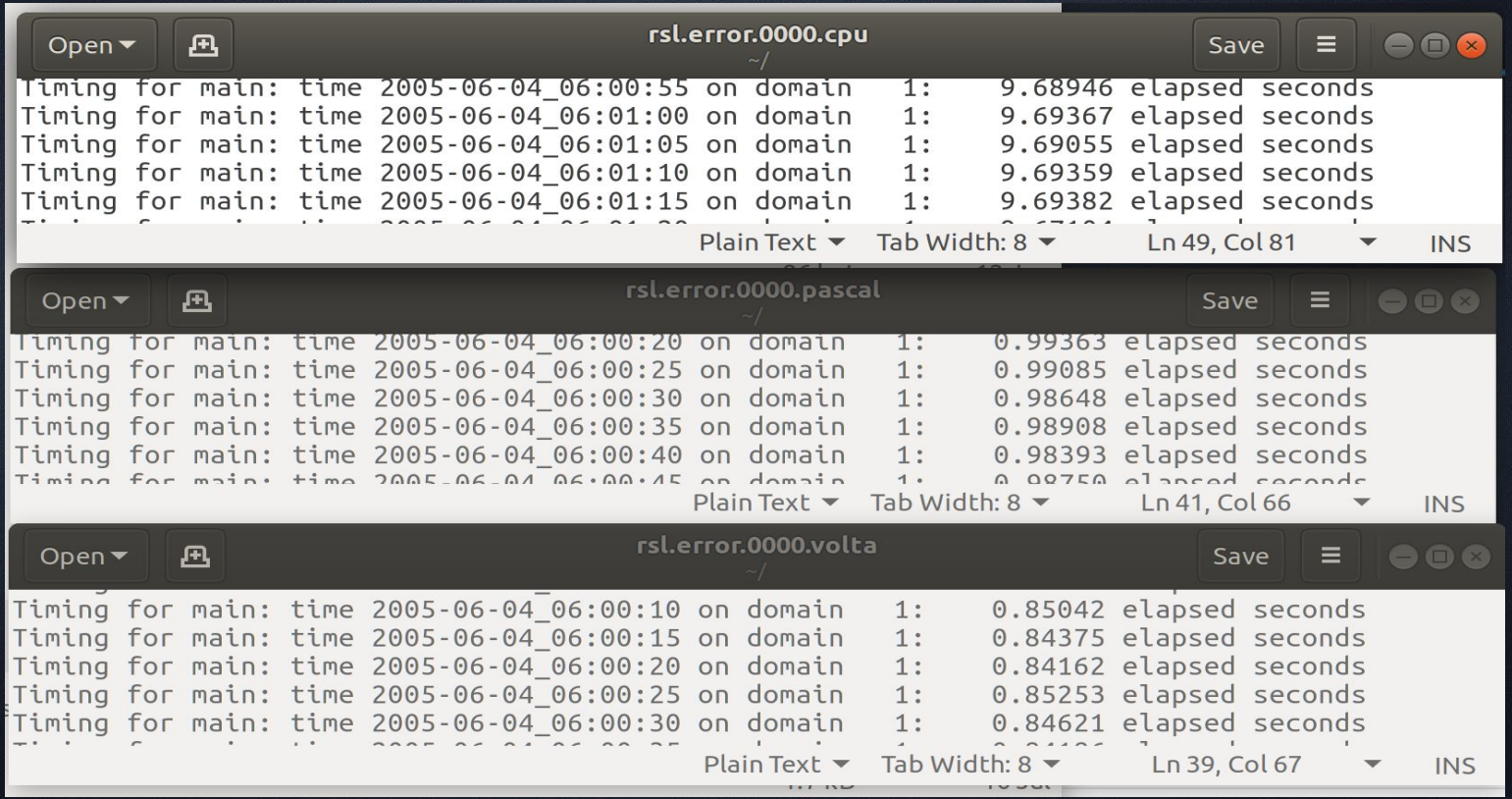
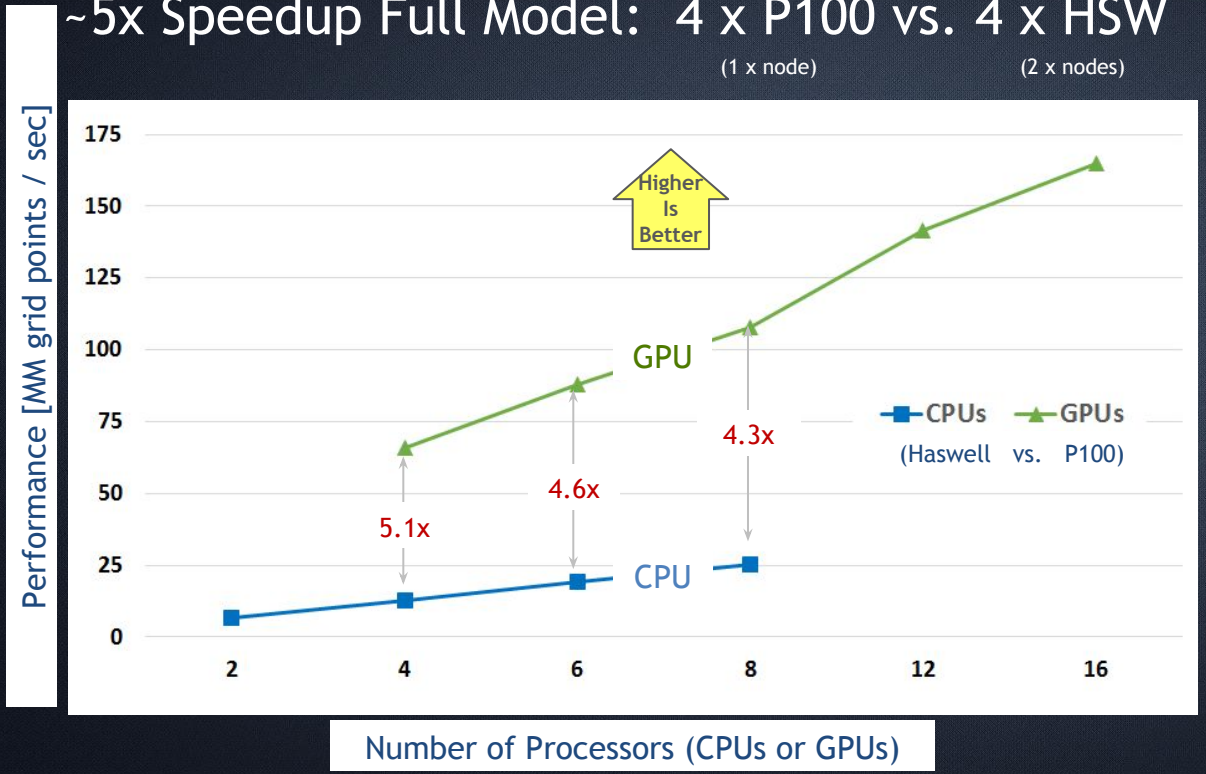
CONUS results - Elapsed seconds / timestep



Results: GPU WRF Strong Scaling for CONUS 2.5 km

~5x Speedup Full Model: 4 x P100 vs. 4 x HSW



CONUS 2.5km Source: http://www2.mmm.ucar.edu/wrf/bench/benchdata_v3911.html (Note "Physics options modified" in side bar)

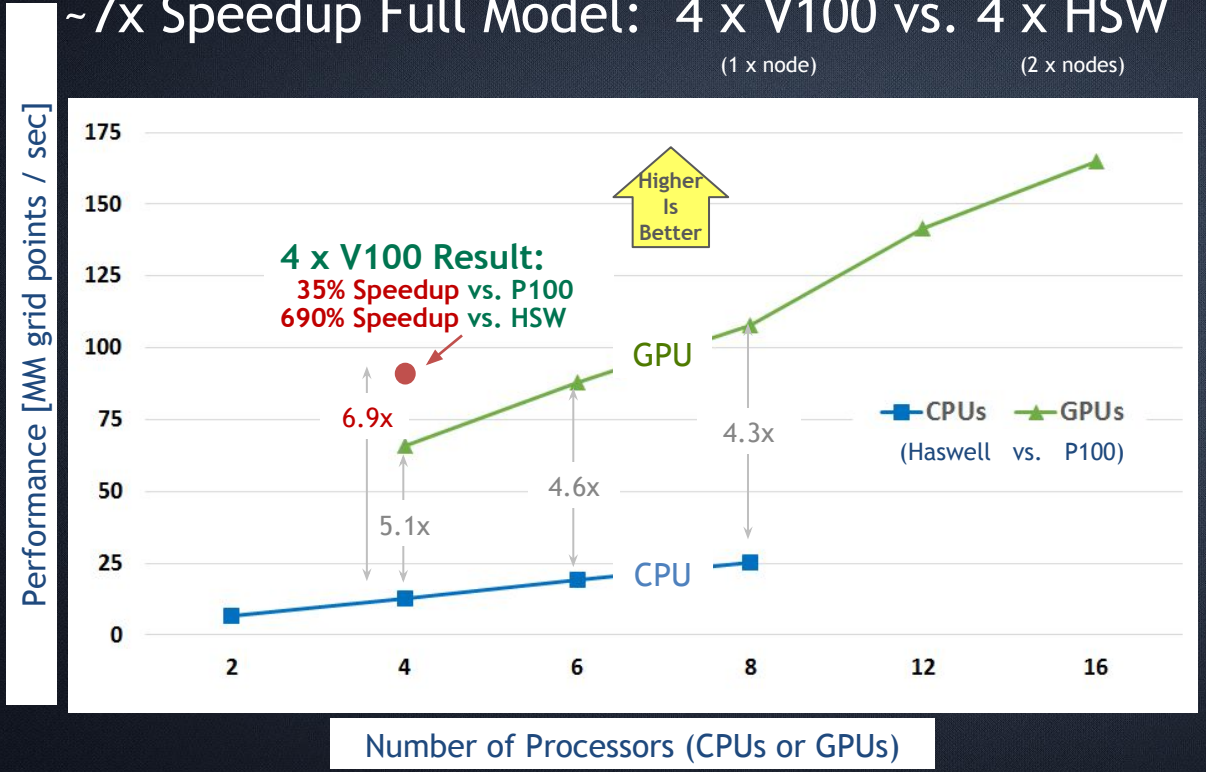
CONUS 2.5 km Case on PSG Cluster - 4 nodes

Source: TQI – Abdi; Apr 18

- Based on WRF 3.8.1 trunk
- 1501 x 1201 grid x 35 levels
- Total 60 time steps, SP run
- Physics option modified:
  - WSM6
  - Radiation *off*
  - 5-layer TDS
- All WRF runs single precision
- PSG cluster node configuration:
  - 2 CPUs, 16 cores each
  - 4 x P100 GPUs
  - Or 4 x V100 GPUs
- CPU-only 1 MPI task each core
- CPU+GPU 1 MPI task per GPU

Results: GPU WRF Strong Scaling for CONUS 2.5 km

~7x Speedup Full Model: 4 x V100 vs. 4 x HSW



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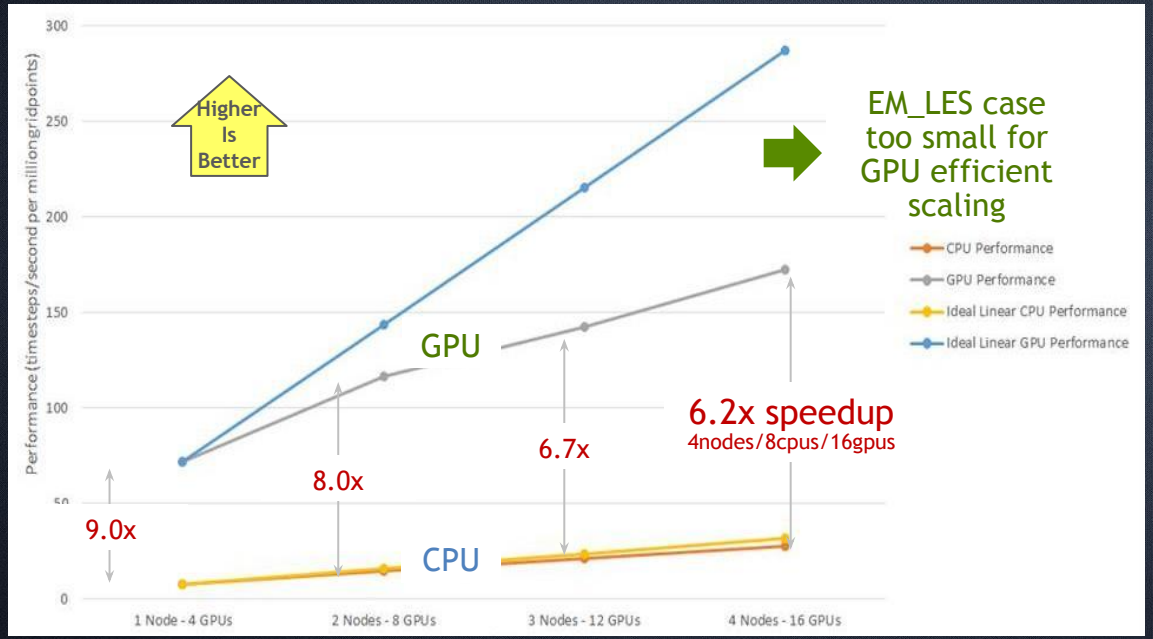
Results: GPU WRF Strong Scaling for EM_LES

Performance [(time steps/sec)/MM grid points]

~5x Speedup: 4 x P100 vs. 4 x HSW



Number of Nodes

Results for EM_LES Case on PSG - 4 nodes

Source: TQI – Abdi; Dec 18

- Based on WRF 3.8.1 trunk
- 1024 x 1024 grid x 60 levels
- Physics options:
  - Kessler
  - *Mostly dycore time*
- PSG cluster nodes:
  - 2 CPUs, 16 cores each
  - 4 x P100 GPUs
- CPU-only MPI task each core
- CPU+GPU MPI task per GPU

Customer namelist results

Other customer namelist speedup results

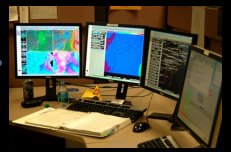
- ROKAF
  - Volta: 6.6x faster
  - Pascal: 4.74x faster
  - K80: 2.83x faster
- Weatherbell
  - Volta: 7x faster
- Agriculture
  - Pascal: 5x faster

TempoQuest Systems Architecture

Data Sources

Cloud Hardware
Multi-node GPU (Pascal/Volta)
NVLINK
Shared Memory
Storage

Software
AceCAST WRF CUDA
Weather Workflow and System Interface
O/S
Visualization
Deep Learning/Analytics



Weather Service Providers

Transportation

Energy

Agriculture

Wild Fires

Conclusions

Conclusions

- TQI is a micro-weather prediction company with the goal of accelerating WRF by up to 10x using NVIDIA GPUs
- We had a breakthrough with acceleration of end-to-end WRF runs by 5x to 7x
- We deliver on-premise or software-as-service on the cloud
- Future goal: we feel the need for more speed ...