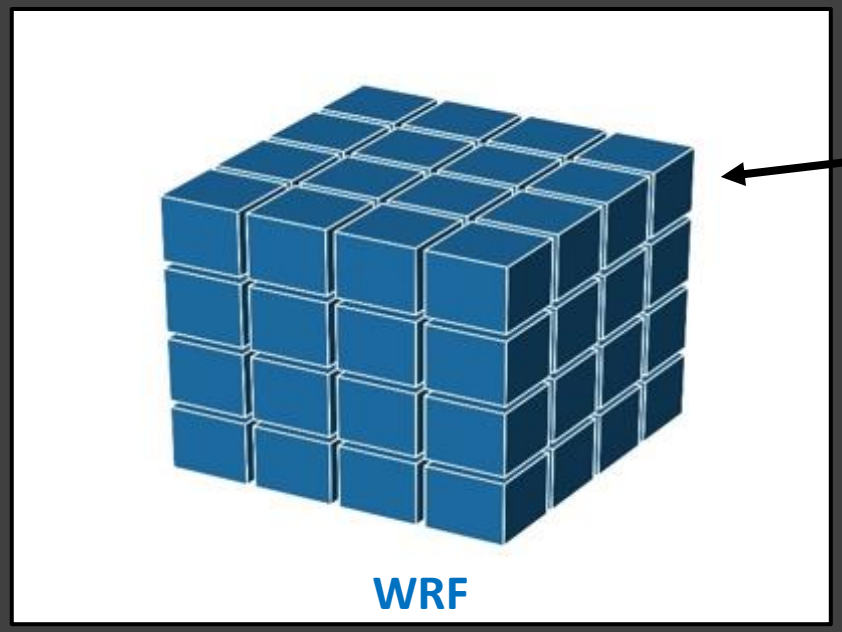
AceCAST Results

Case studies, validation, and nesting

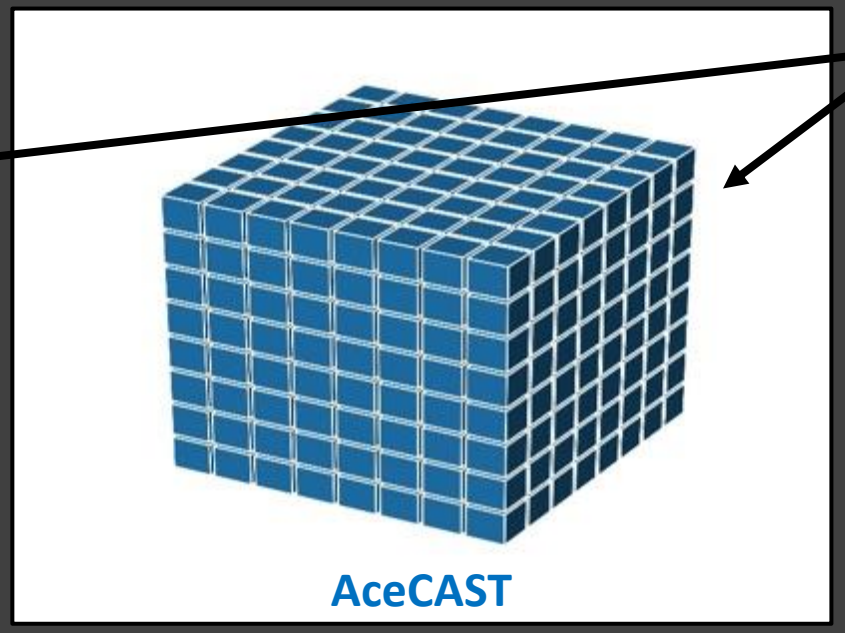
WRF vs. AceCAST – Single Node Capabilities

ID	nx	ny	nz	dx&dy	dt	wallclock
WRF 3.8.1	512	512	64	200	2	8026
AceCAST 1.2	1024	1024	128	100	1	6494

$2^4 = 16X$ the computational workload



WRF



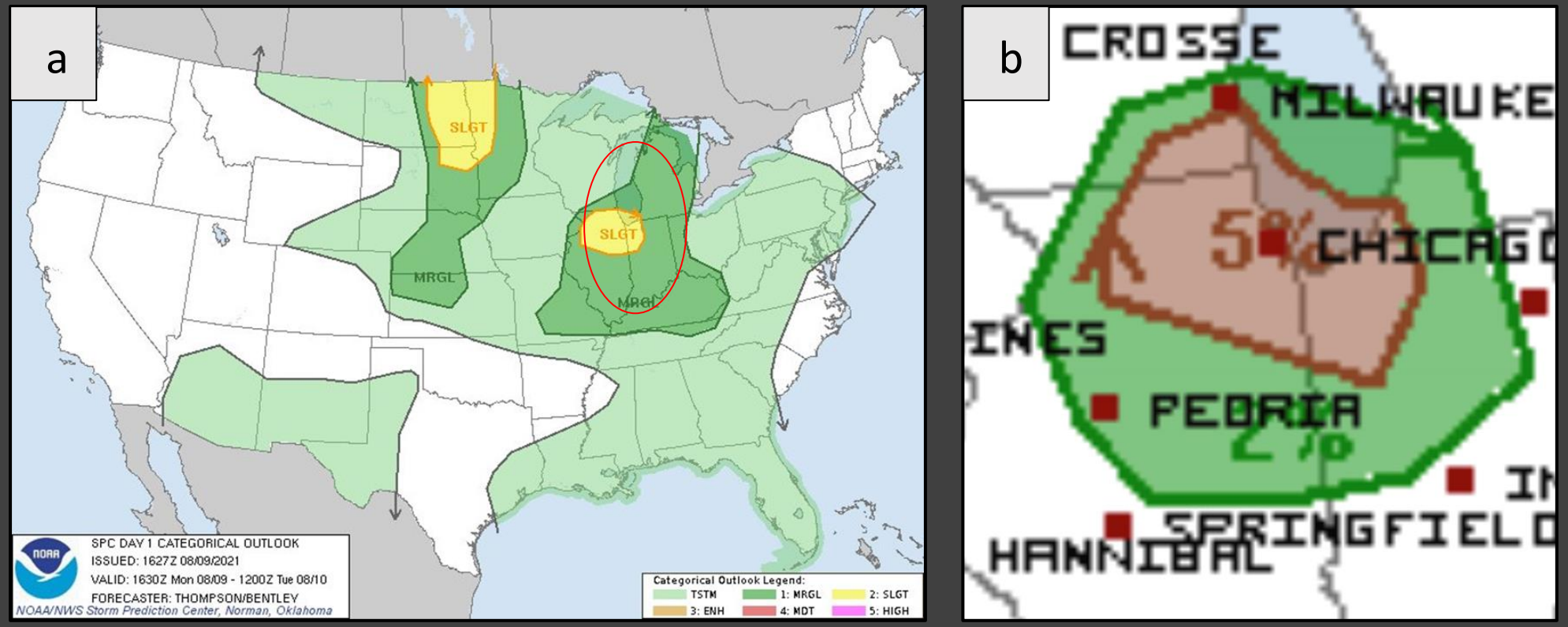
AceCAST

With AceCAST it's possible to obtain **2x** or higher-resolution forecast faster than WRF-CPU

Note: Timings are based on AceCAST (4 V100s) and WRFV3.8.1 (Haswell 32-cores)

Case Study: Illinois Tornado Outbreak

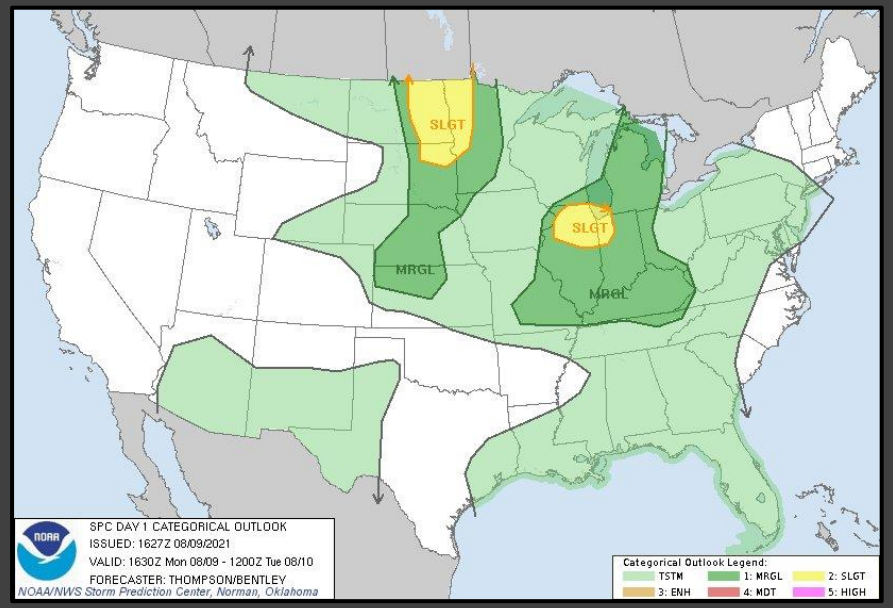
- During the early to mid-morning hours, a round of heavy rain and thunderstorms moved through. With another robust upper-level disturbance expected late in the afternoon and evening, it was uncertain if and where tornado formation would occur (red circle).

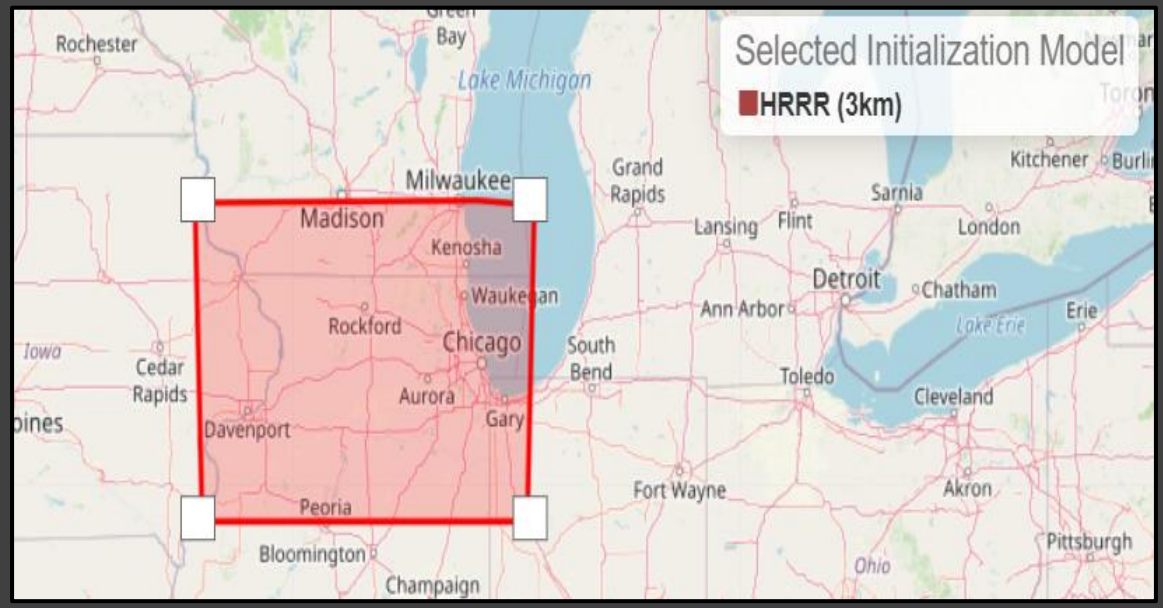


(a) Day 1 Categorical Outlook (b) Day 1 Tornado Outlook from the Storm Prediction Center

Case Study: Illinois Tornado Outbreak

Forecast from the Storm Prediction Center the late morning of 8/9/2021





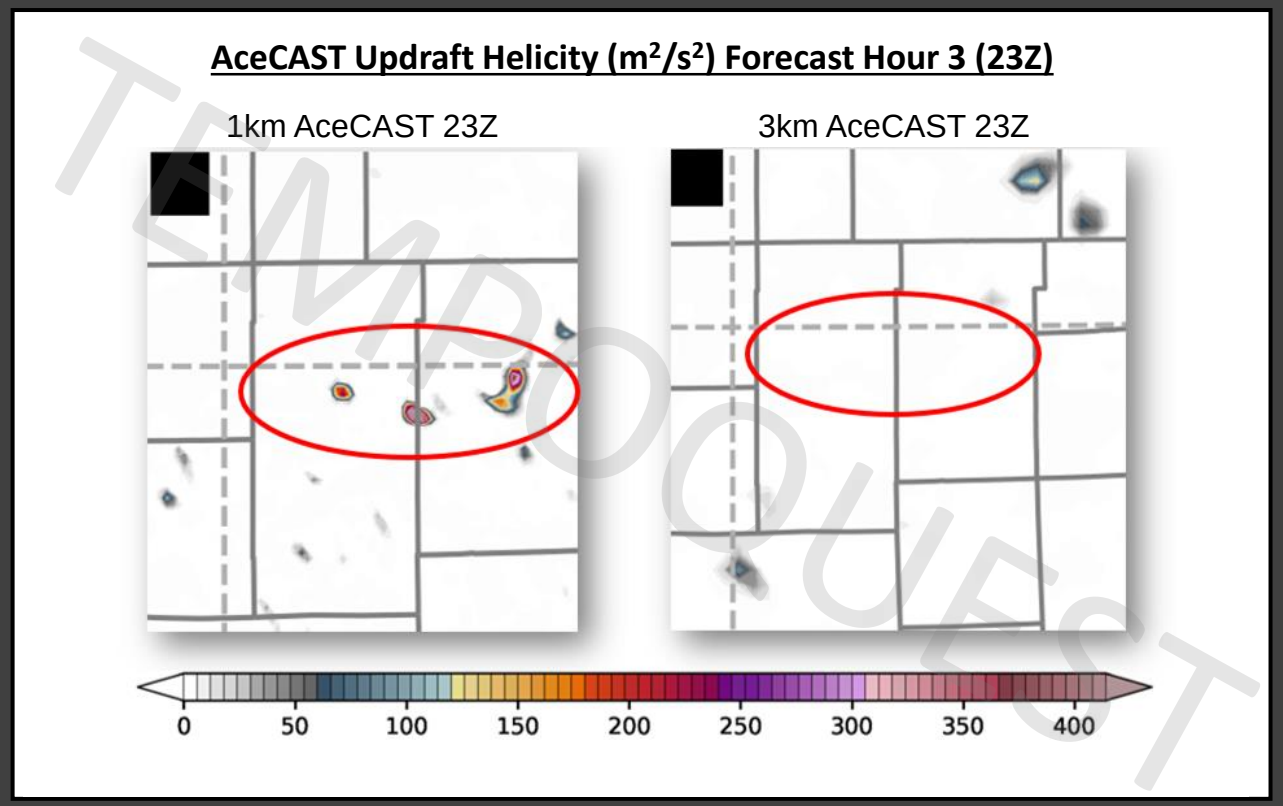
Model Details

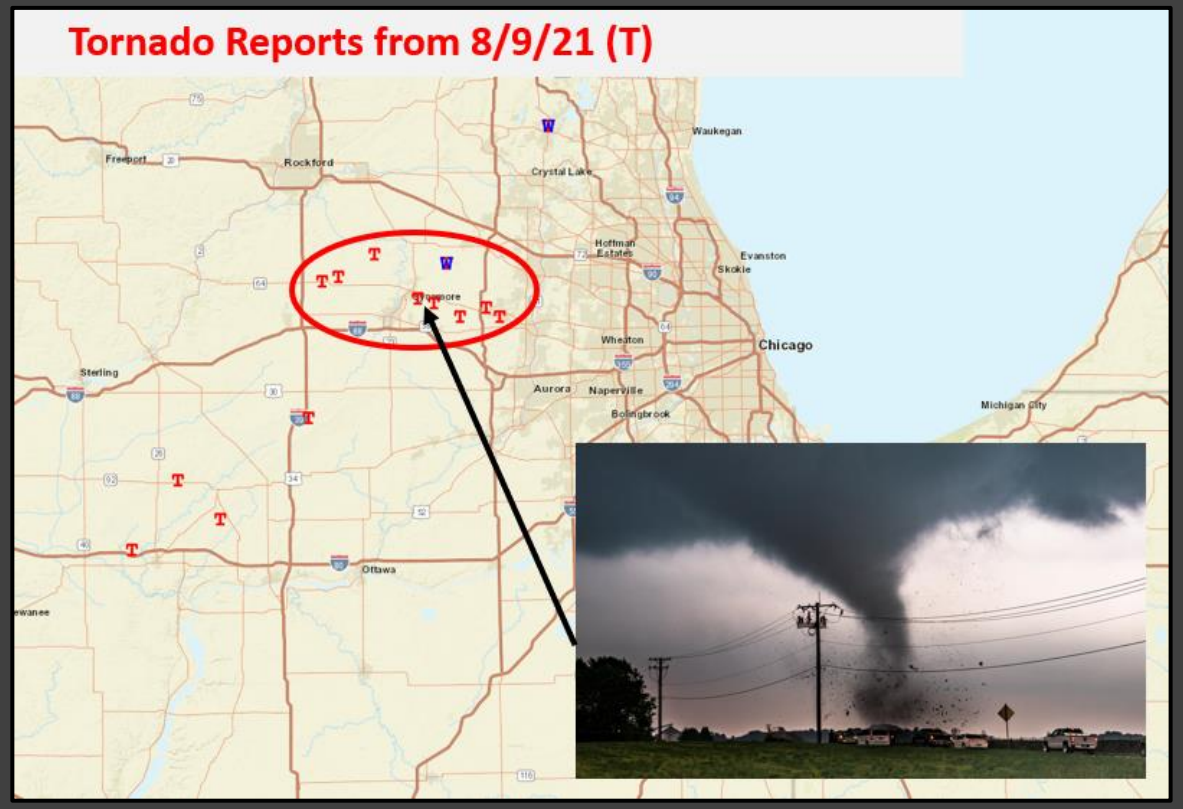
Hours out: 12 hours
Time step: Hourly
X: 350 Y: 250

Model Run Time

2 GPUs: **1 hour 1 minute 12 seconds**

Case Study: Illinois Tornado Outbreak

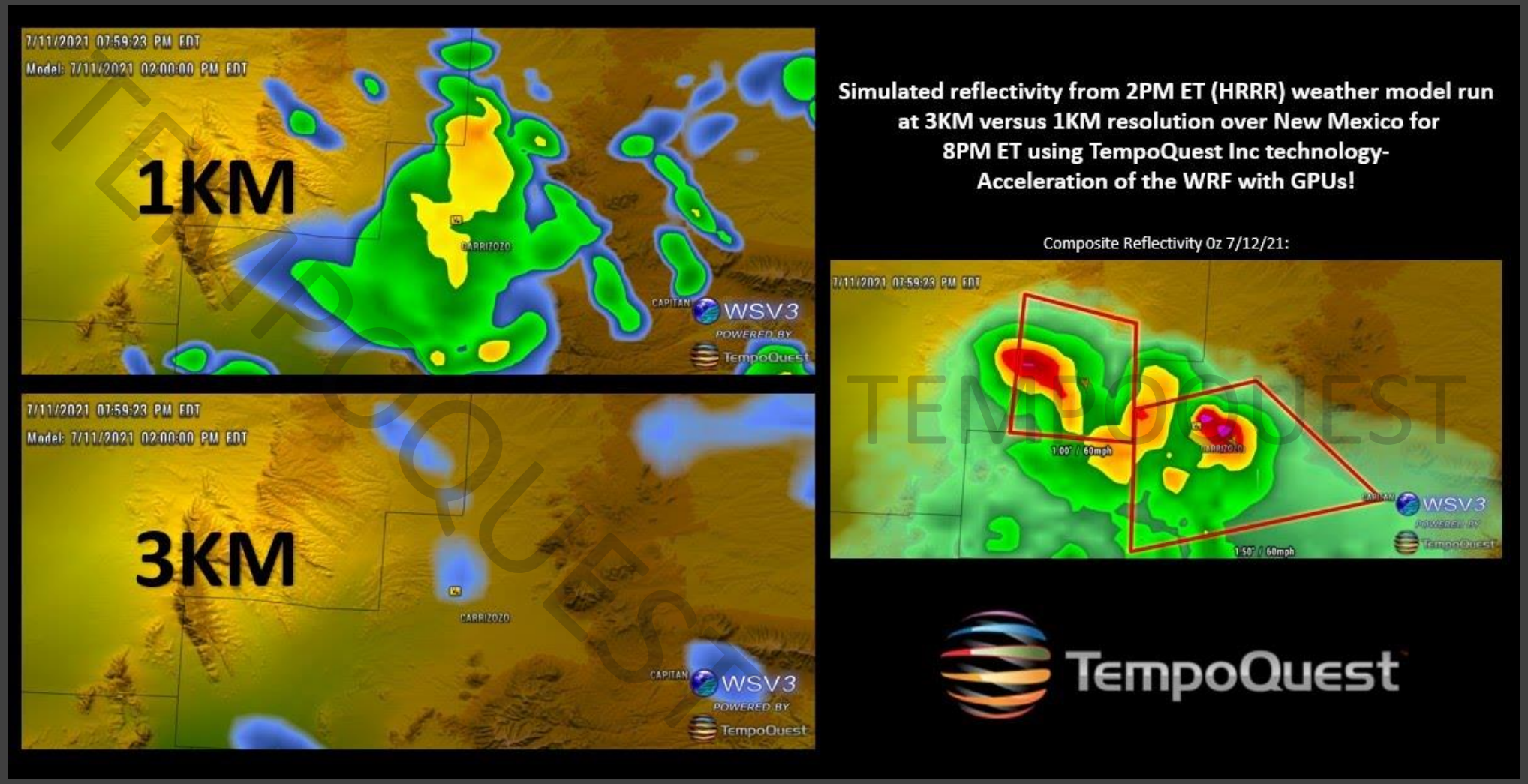




Resolution	WRF on 2 x Intel Skylake	AceCAST on 4x V100	Speedup
3km	14 min	3 min	x4.2
1km	249 min	25 min	x10x

3km completely misses any significant updraft helicity

Simulation over New Mexico Summer 2021

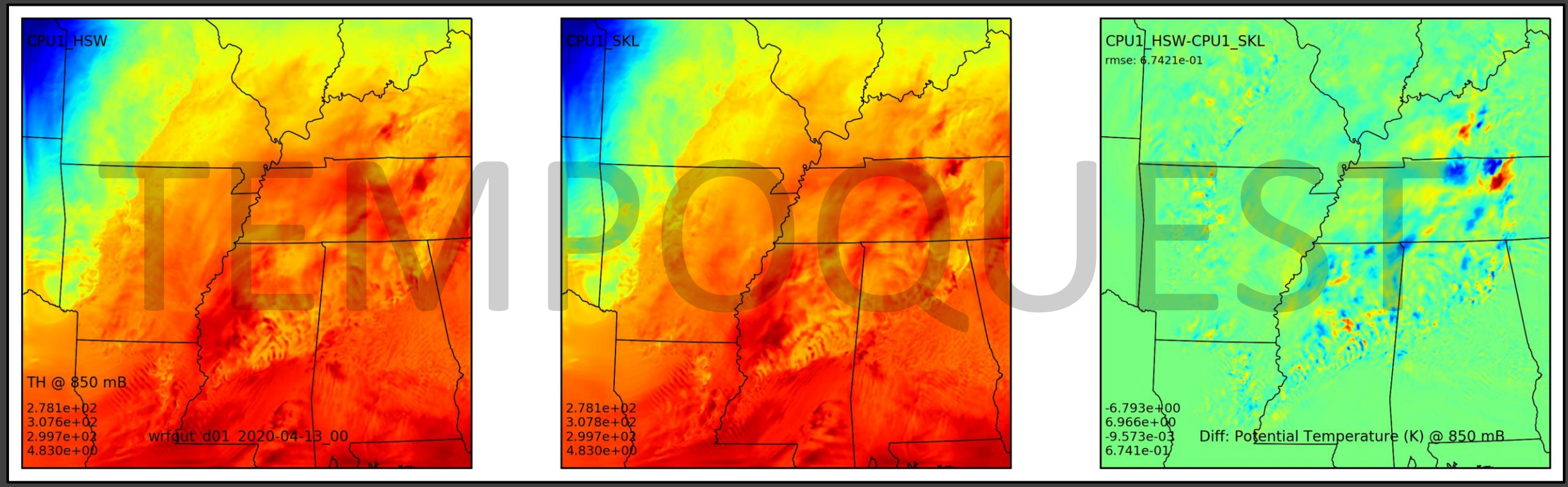


The 1 km forecast shows severe convection vs zero convection in the 3km forecast.

AceCAST Validation

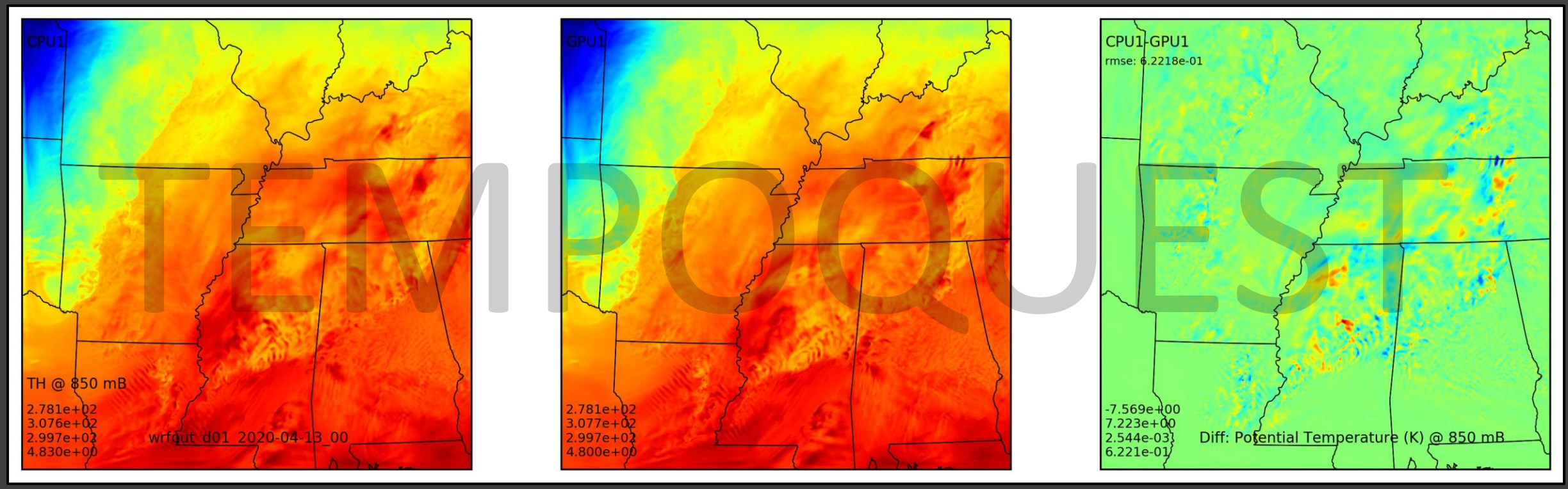
- AceCAST is designed to be fast (5x or more) and ready to replace the WRF-CPU setup
- AceCAST contains over 100k lines of CPU and GPU code for communication routines, IO functions, dynamics and physics packages
- Testing the model performance over a wide variety of environmental and regional conditions is critical
- Over 100s ideal and real simulations conducted to test numerical and computational aspects
- A severe weather simulation is conducted to validate accuracy of AceCAST results

Plots of Potential Temperature (K) at 850 mb at t = 24h (for CPU1_HSW-CPU1_SKL)



- Left: The field from CPU1_HSW run (optimized WRFV381 on Intel Haswell CPU)
- Center: The field from CPU1_SKL run (optimized WRFV381 on Intel Skylake CPU)
- Right: The difference between these runs, which is the baseline result

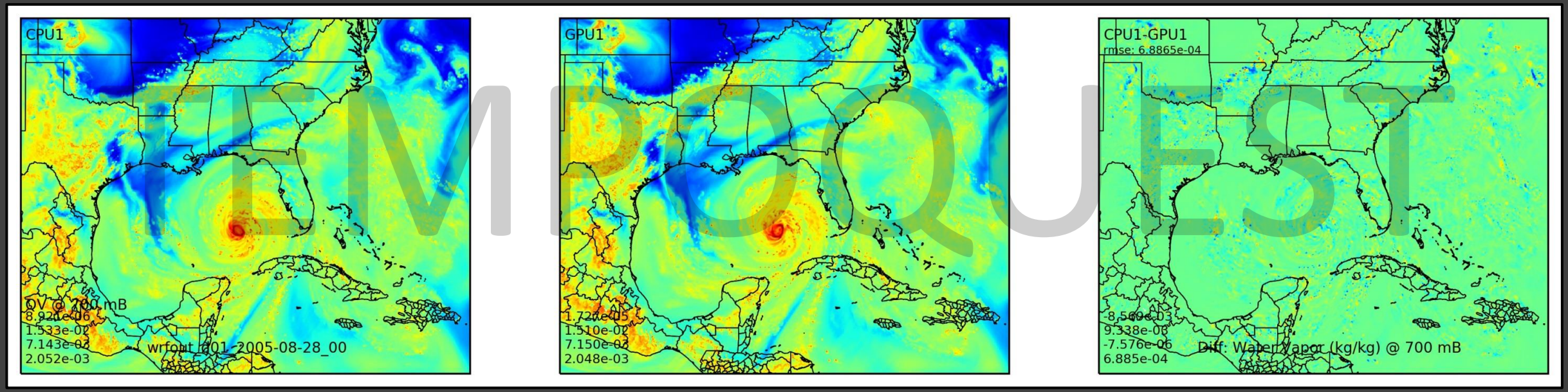
Plots of Potential Temperature (K) at 850 mb at t = 24h (for CPU1_HSW-GPU1)



- Left: The field from CPU1 run (optimized WRFV381 on Intel Haswell CPU)
- Center: The field from GPU1 run (optimized AceCAST)
- Right: The RMSE differences are consistent for CPU1-GPU1 and CPU1_HSW-CPU1_SKL setups

Verification Results

Plots of Water Vapor (qv; kg/kg) @ 700 mb at t = 24h (for CPU1-GPU1)

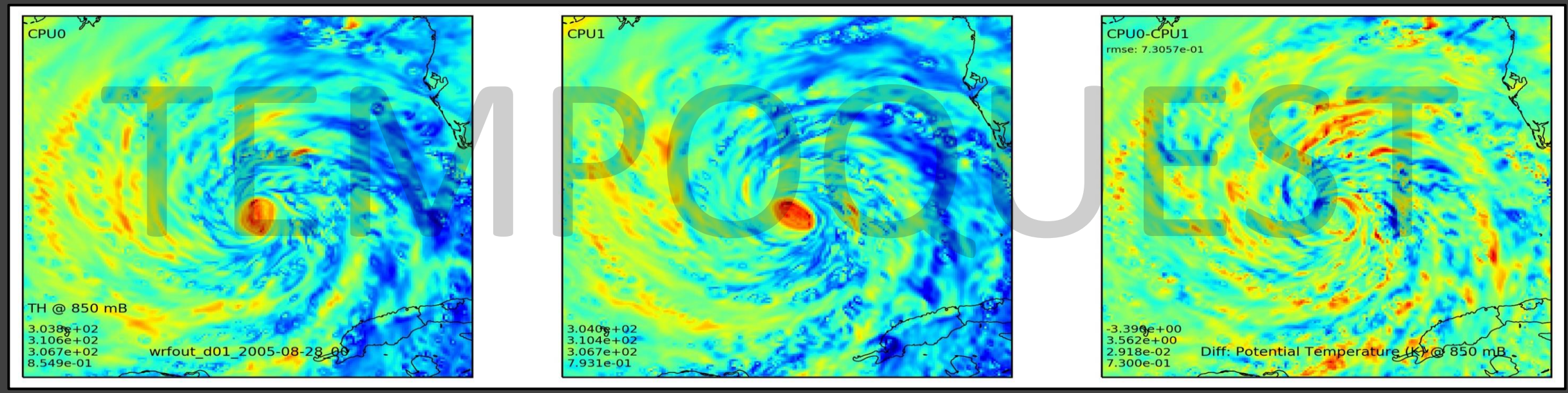


- This case is a GFS-driven 4.5 km simulation (834x660x44 domain ~ 24 M grids) of August 27-28 2005 (1-day)
- Depicted is Hurricane Katrina which is a category 5 tropical storm which is by far the costliest storm to make landfall in the contiguous United States.

- Left: The field from CPU1 run (optimized WRFV381 CPU)
- Center: The field from GPU1 run (optimized AceCAST)
- Right: The difference between CPU1 and GPU1 runs.
- RMSE differences are consistent for CPU1-GPU1 and CPU0-CPU1 setups. Accuracy of results is within acceptable levels.

Verification Results

Zoomed-in plots of Potential Temperature (θ; K) @ 850 mb at t = 24h (for CPU0-CPU1)

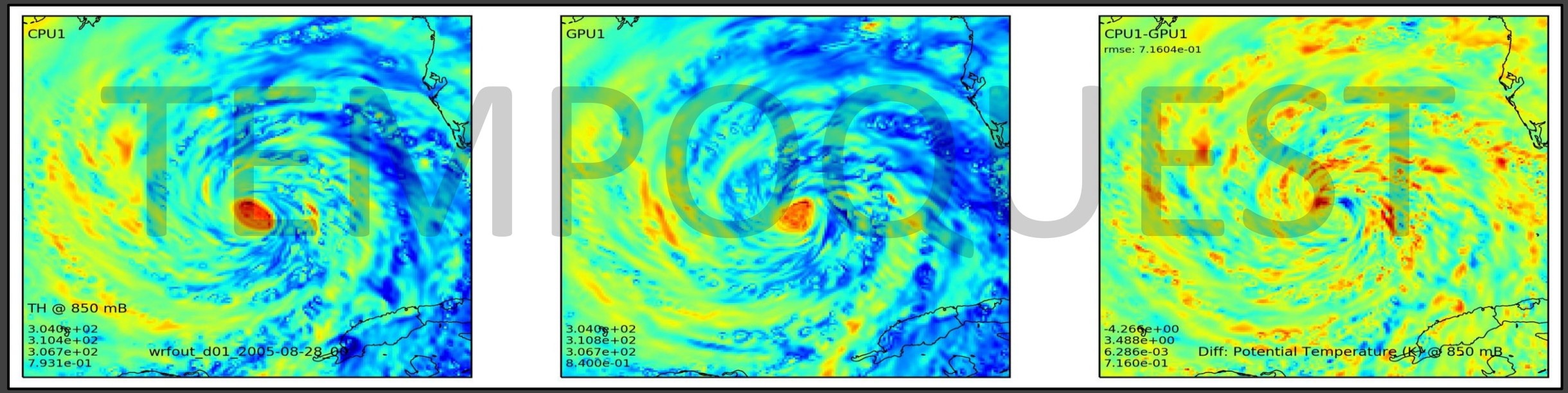


- Left: The field from CPU0 run (non-optimized WRFV381 CPU)
- Center: The field from CPU1 run (optimized WRFV381 CPU)
- Right: The difference between CPU0 and CPU1 runs

- The numbers in the lower left corners are: min, max, mean, and stddev of fields in display
- RMSE difference of fields are indicated under CPU1-GPU1 label

Verification Results

Zoomed-in plots of Potential Temperature (θ; K) @ 850 mb at t = 24h (for CPU1-GPU1)

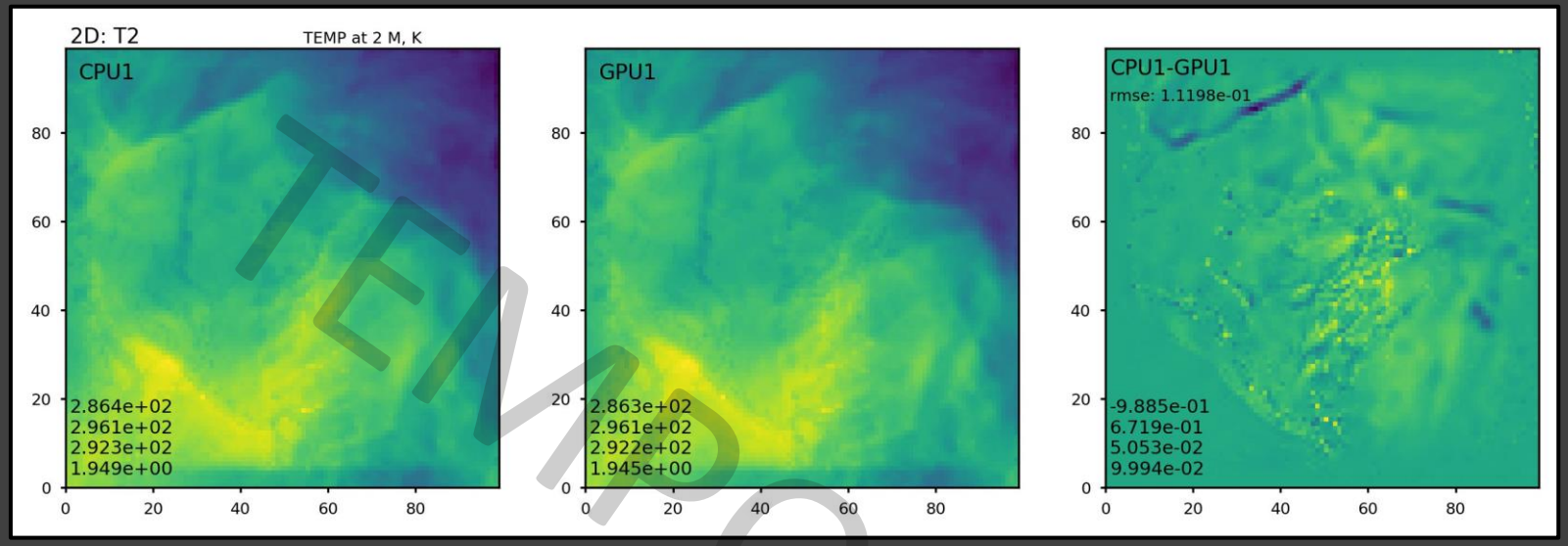


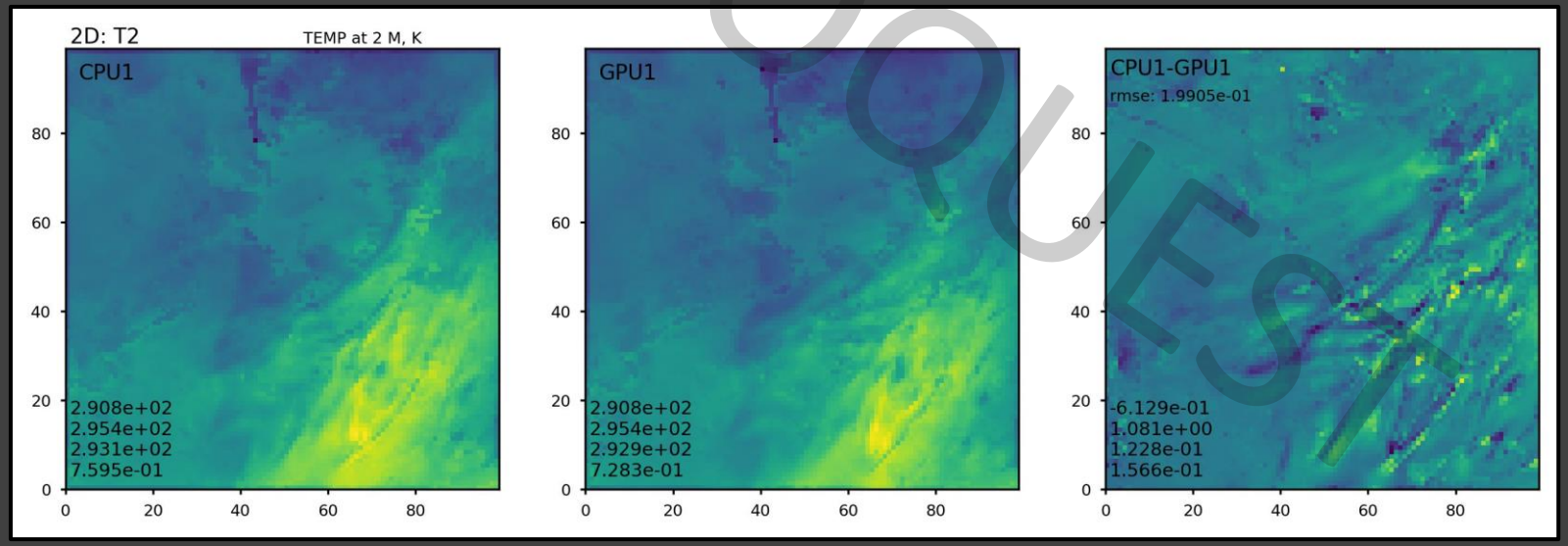
- Left: The field from CPU1 run (optimized WRFV381 CPU)
- Center: The field from GPU1 run (optimized AceCAST)
- Right: The difference between CPU1 and GPU1 runs

- RMSE differences are consistent for CPU1-GPU1 and CPU0-CPU1 setups
- The model delivers accurate and reliable results, a key criteria for adaptation by customers

Verification Results – Nesting*

- D01:
  - 100 x 100
  - dx&dy = 3km
- D02:
  - 100 x 100
  - dx&dy = 1km





*Preliminary results from 2-domain nested run

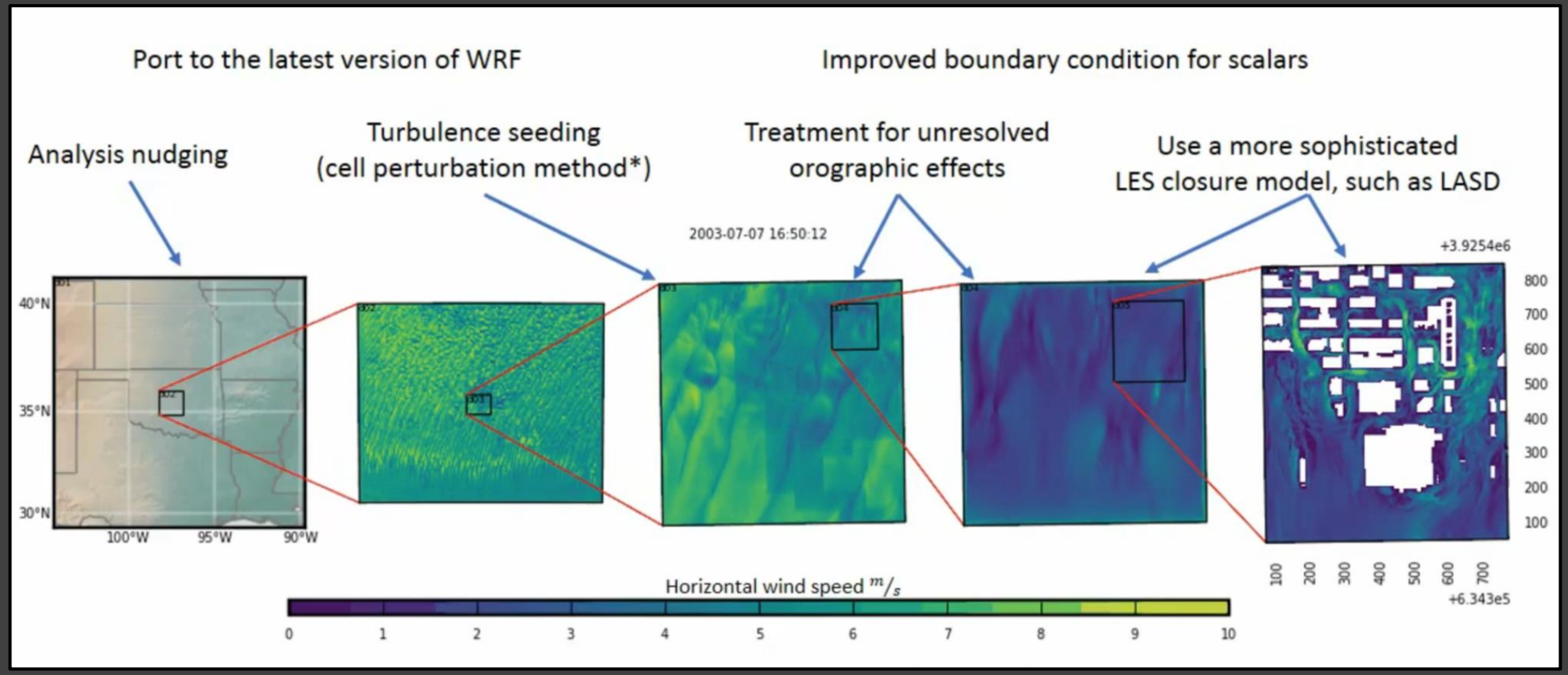
Preliminary benchmarks using 3-domain easter500 simulations

- **Setup**: 1h run - nesting ratio 3 - feedback=1
- Domain1: 500 x 500 x 51 - dx = 2000m, dt = 12s
- Domain2: 499 x 499 x 51 - dx = 666m, dt = 4s
- Domain3: 499 x 499 x 51 - dx = 222m, dt = 1.33s

Case	1-domain	2-domain	3-domain
AceCAST_nesting	132.4	457.8	1352.7
WRFV381_HSW	987.9	3514.5	10485.2
WRFV381_SKL	617.4	2182.0	6422.9
vs. HSW	**7.5**	**7.7**	**7.8**
vs. SKL	**4.7**	**4.8**	**4.7**

Nesting possibilities

- AceCAST with nesting opens possibilities to better address forecasting issues for 1.) urban meteorology, 2.) Fire meteorology, 3.) and renewable energy such as solar and wind



Courtesy of Weirsama et al, 2018: Development of a Multi-Scale Modeling Framework for Urban Simulations in the WRF Model