GPU - Next Generation Modeling for Catchment Floodplain Management

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BMT WBM

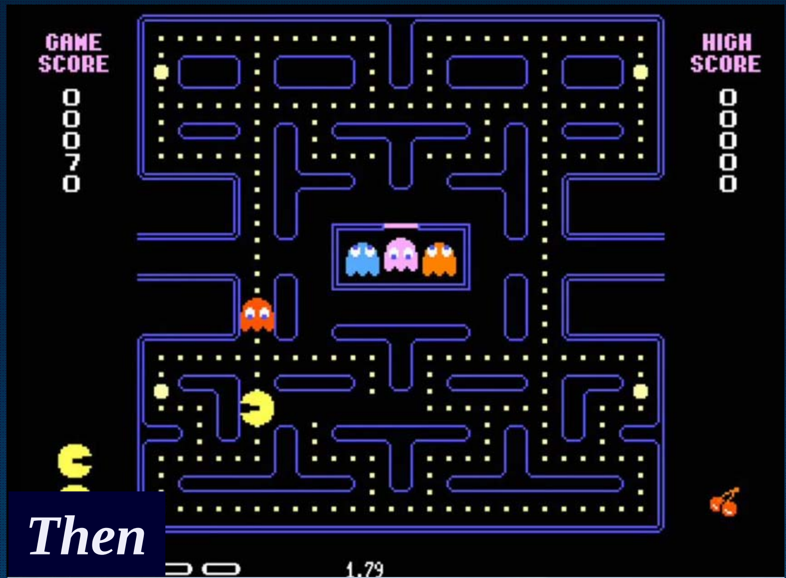
TUFLOW

Presentation Overview

1. What is GPU flood modeling?
2. What is possible using it?
3. Direct rainfall modeling approach validation
4. Hardware benchmark results and advice

What is GPU?

- Graphics Processing Unit (GPU) used for scientific calculations
- Parallel computing is used to achieve computation gains
- Accelerated hardware development!
  - 2013 = 1500 Cuda Cores 6GB
  - 2016 = 6000 Cuda Cores 12GB
- Note: 1 GPU is less powerful than 1 CPU
- GPU models can run well over 100x faster than CPU



What is TUFLOW GPU? How fast is it?

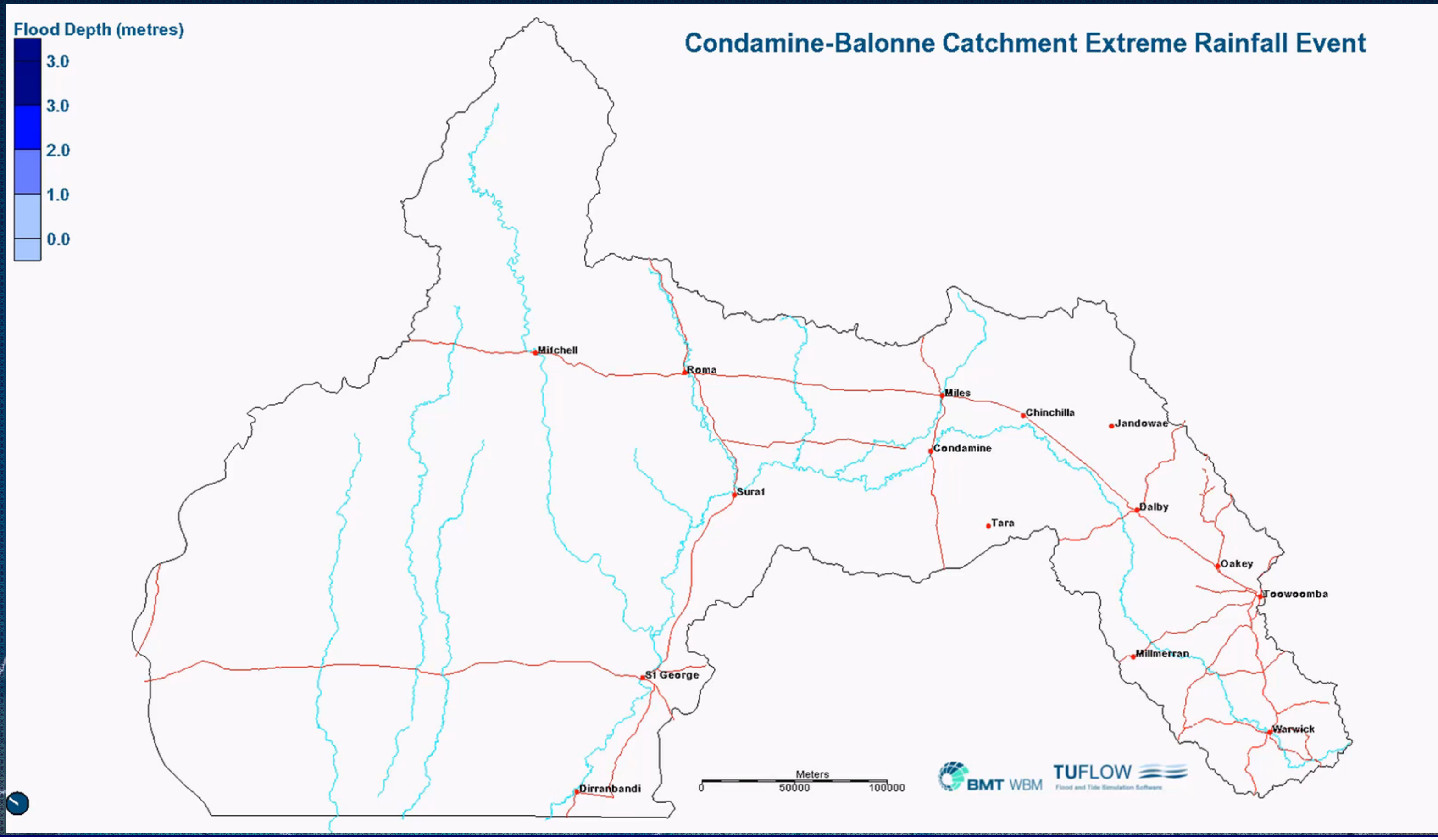
- TUFLOW Classic is the fastest CPU 2D SWE flood software available
- UK EA Benchmarking - Test Case 7 (real world scenario)
  - TUFLOW Classic (1 CPU) = **3.3 min**
  - MIKE Flood (8 CPU) = 3.8 min 1CPU equivalent ≈ **30 min**
  - HECRAS (8 CPU) = 34.0 min 1CPU equivalent ≈ **270 min**
- TUFLOW GPU is over 100 times faster than TUFLOW Classic!!
- Well suited to models with high computing demands (millions of cells) or requiring quick simulation
  - Large broad scale regional assessments
  - High resolution fine scale assessments
  - Real time flood forecasting

What is possible??

Condamine-Balonne Catchment

- Large Scale – 1/2 the size of Texas!
- 90ft resolution grid
- Over 400,000,000 2D cells
- Direct rainfall application
  - Alternative to Hydrologic Modelling
- Infiltration: Green-Ampt

Condamine-Balonne Catchment



Direct Rainfall Modeling Uncertainty?

- Hydraulic direct rainfall modeling applies rainfall hyetograph depth information to each 2D cell every calculation timestep
  - There is no need to use hydrology modeling to derive inflow hydrographs
- This assessment approach has significant potential
- However… There is limited industry model parameterization guidance!
  - This is a still considered a new style of assessment approach
  - What hydraulic model roughness parameters are applicable at shallow depths?
  - Are the shallow water equations applicable on steep slopes?

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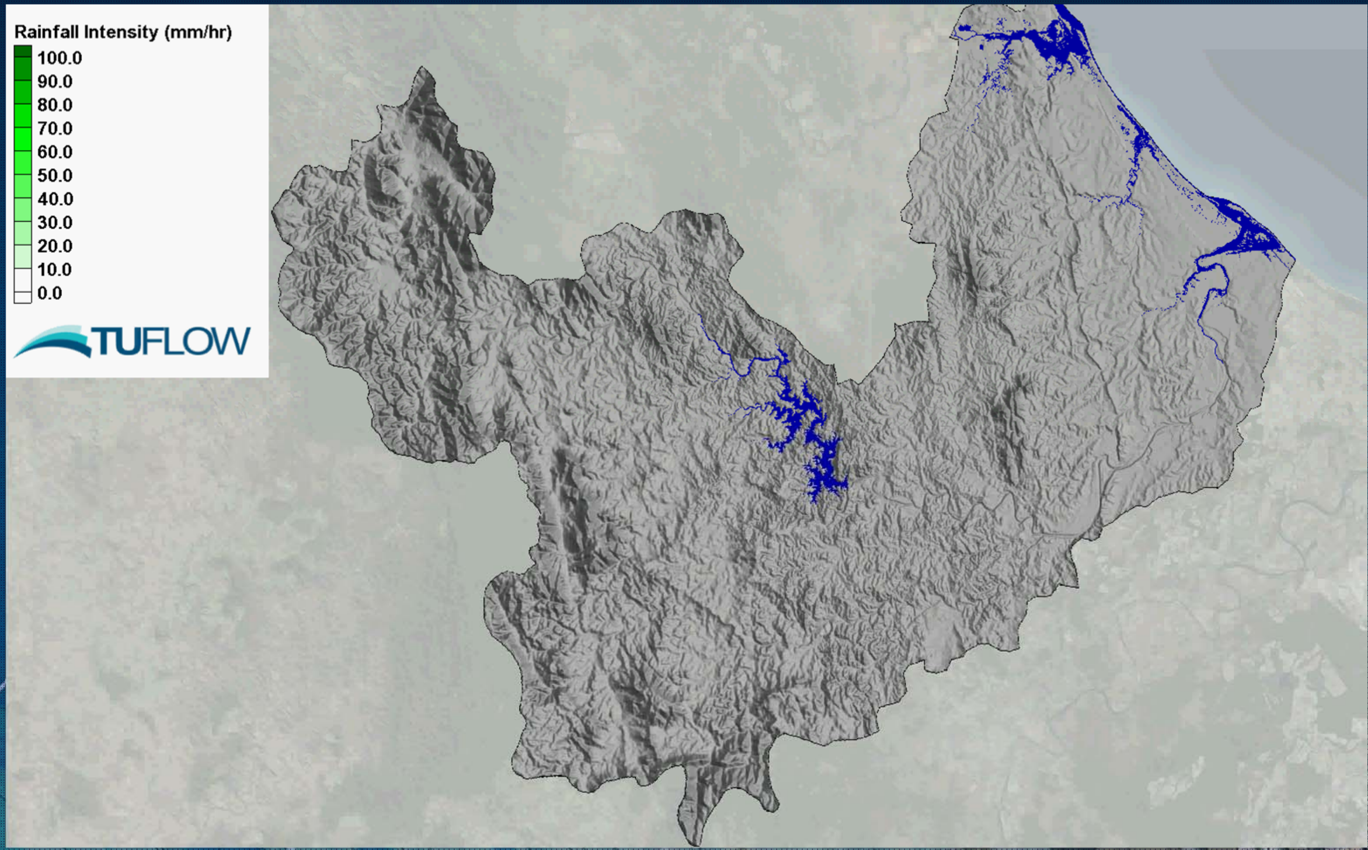
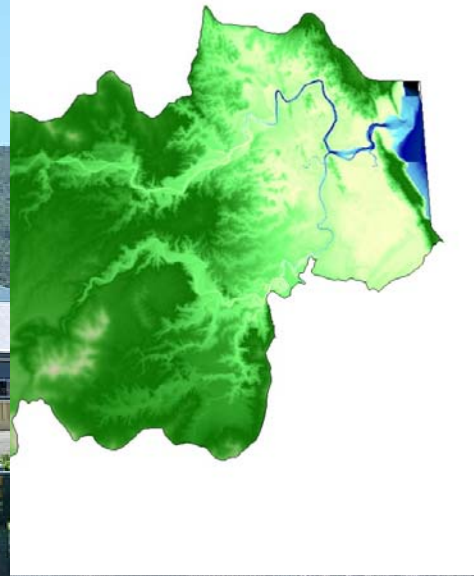
Direct Rainfall Model Validation?

- Spatial and temporal varied rainfall grid
- Rainfall is applied to every cell
- Infiltration loss from all wet cells (not rainfall continuing loss)
- Depth varying roughness approach



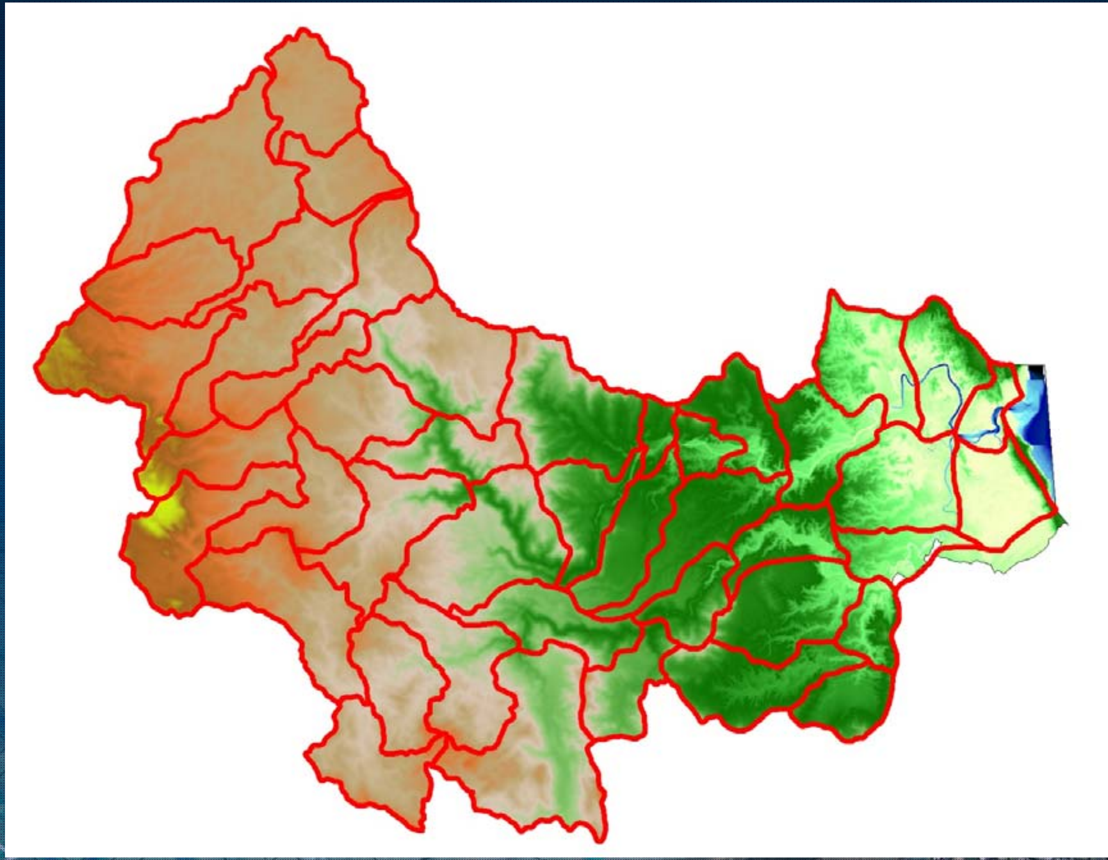
Direct Rainfall Approach Validation?

- South Johnstone River Catchment
  - Australia’s wettest region!



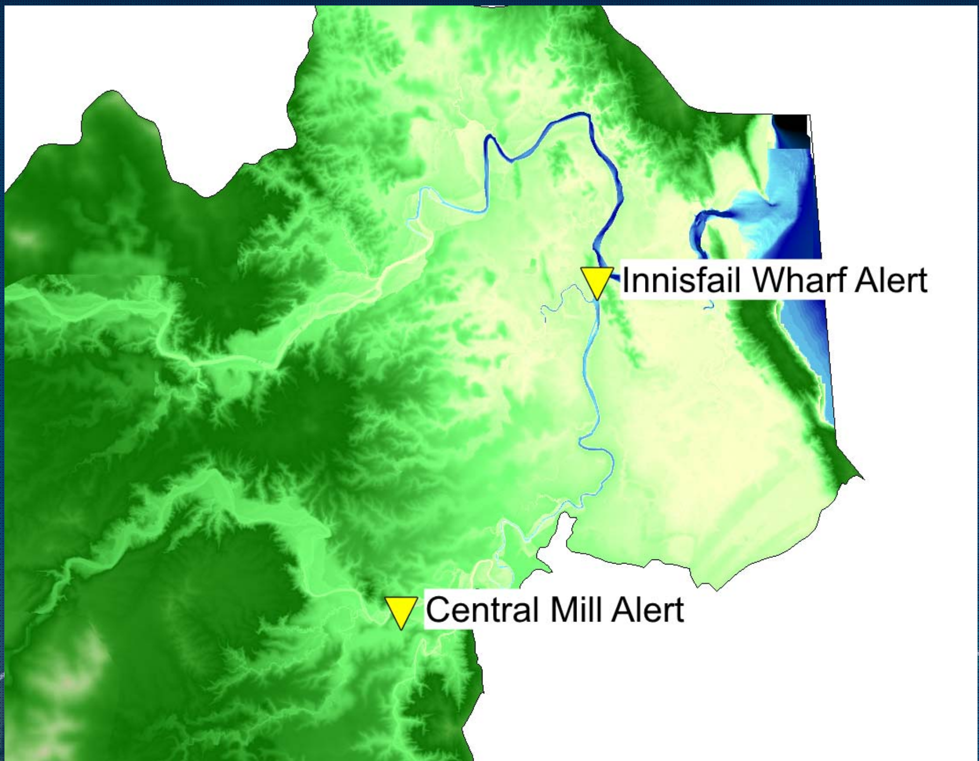
Direct Rainfall Approach Validation?

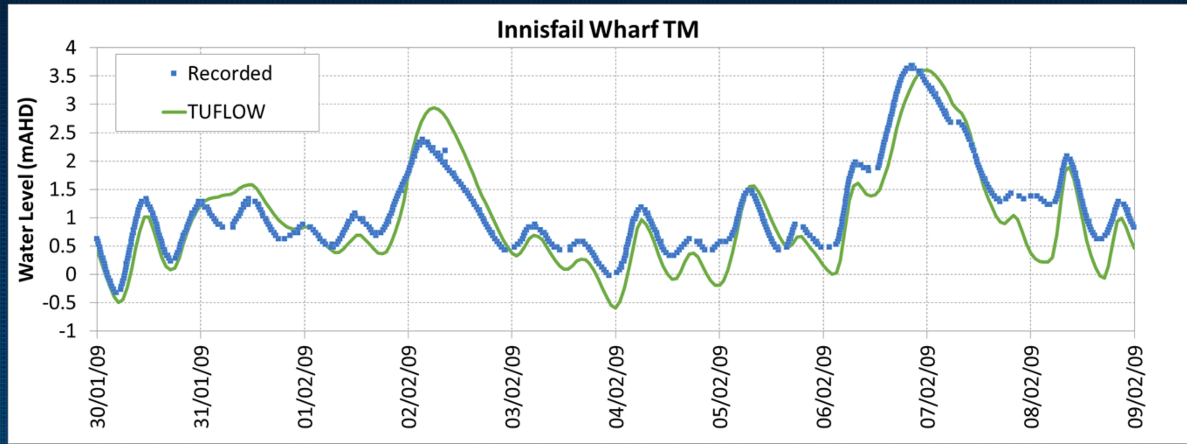
- South Johnstone River Catchment
  - Australia’s wettest region!
- Data availability
  1. Input Data:
     1. SRTM elevation data in upper catchment. LiDAR elevation and bathymetry data in lower catchment
     2. Good rainfall pluviograph coverage
  2. Validation Data: Gauge water level recorders
  3. Model Comparison: BoM hydrology model

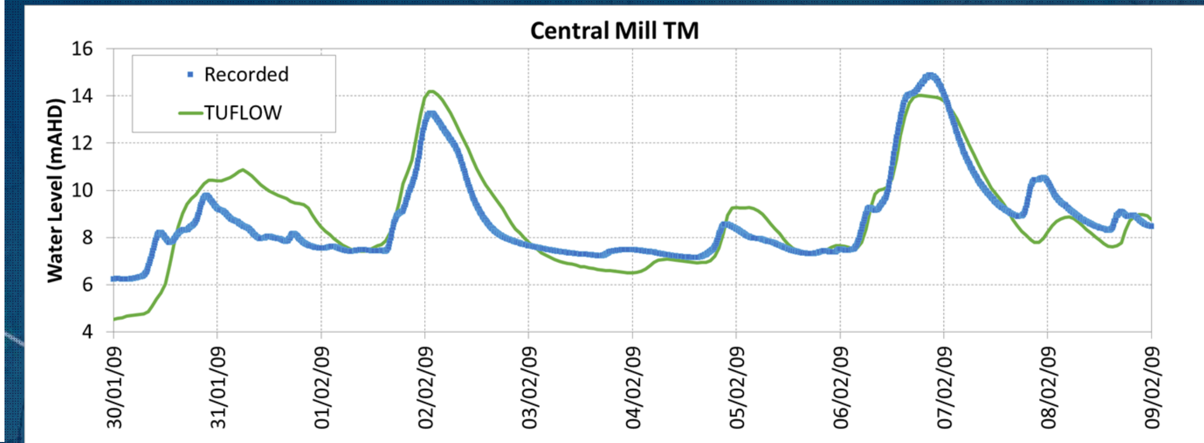


TUFLOW GPU Results (2009)

- Good water level calibration

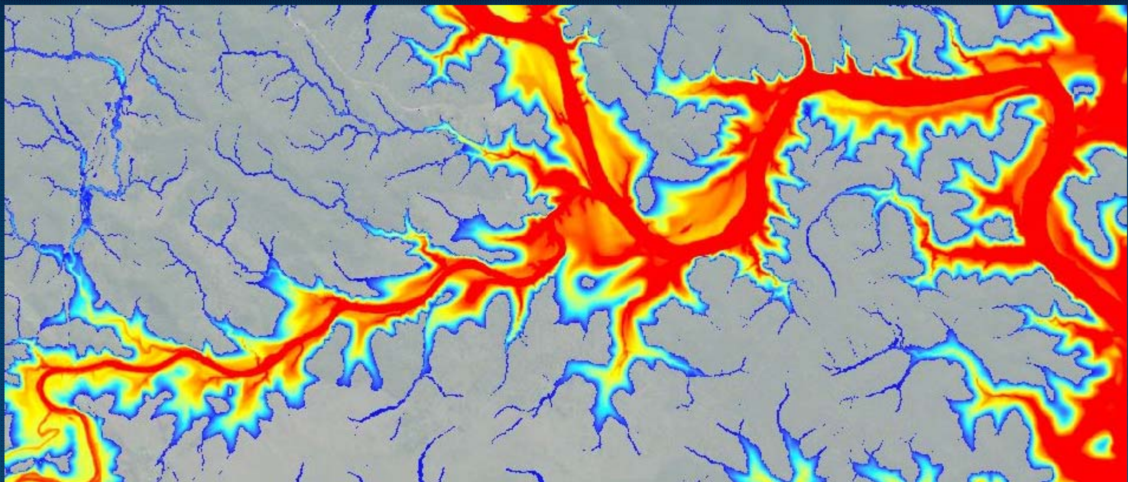


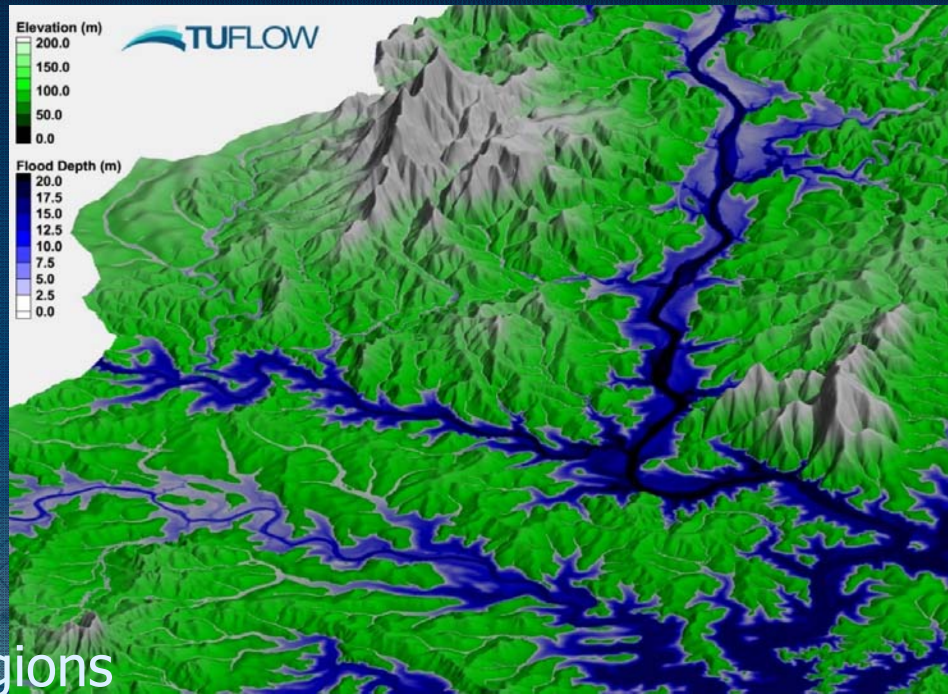




TUFLOW GPU Results (2009)

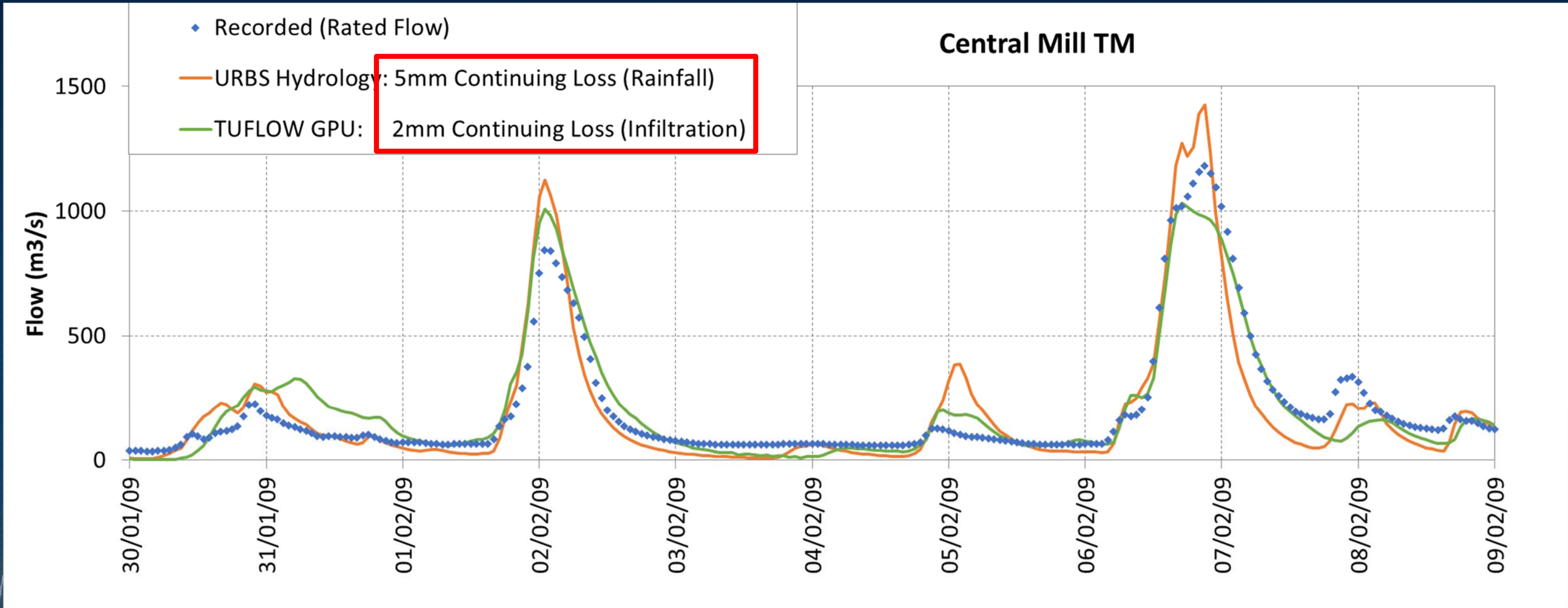
- Excellent flood model result data coverage (the entire catchment)

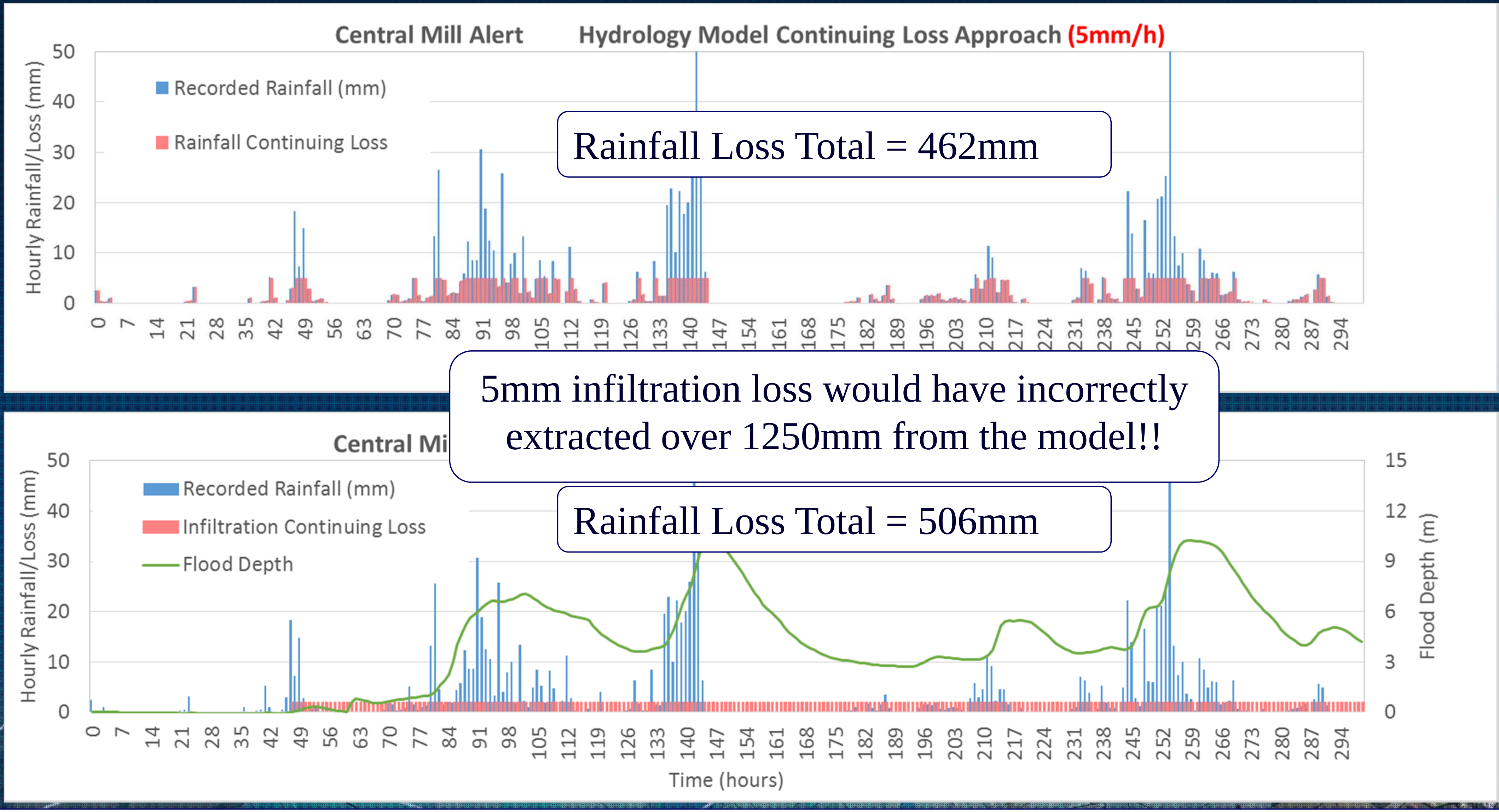




- Accurate results in LiDAR coverage areas
- Significantly reduced accuracy in SRTM regions

TUFLOW GPU vs URBS Hydrology




Central Mill Alert
Hydrology Model Continuing Loss Approach (5mm/h)
Recorded Rainfall (mm)
Rainfall Continuing Loss
Hourly Rainfall/Loss (mm)
Rainfall Loss Total = 462mm
5mm infiltration loss would have incorrectly extracted over 1250mm from the model!!
Central Mi
Recorded Rainfall (mm)
Infiltration Continuing Loss
Flood Depth
Rainfall Loss Total = 506mm
Flood Depth (m)
Time (hours)

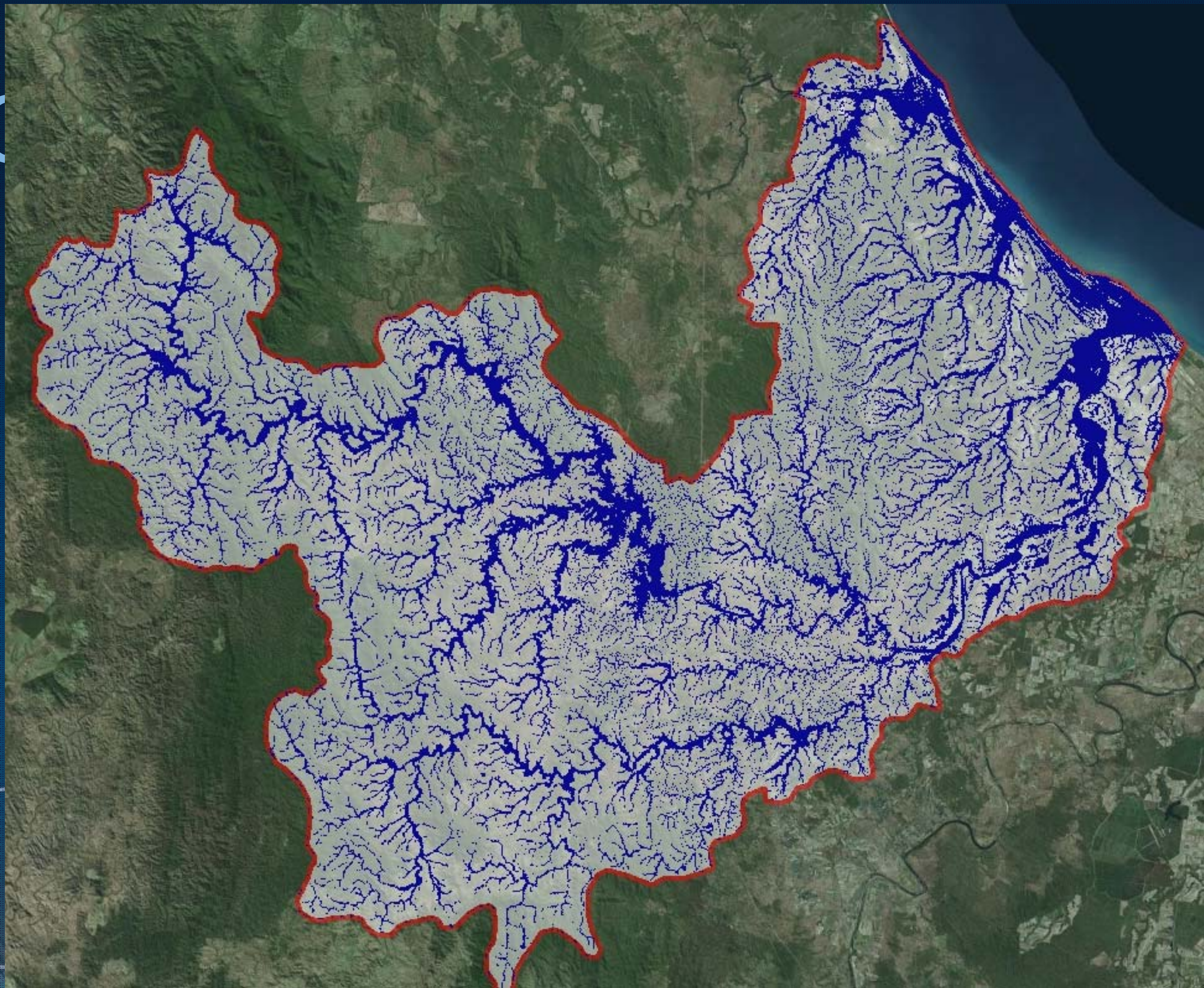
Model Calibration – Findings

- Model calibration to past events is an essential task for all modeling projects
- The TUFLOW GPU direct rainfall model calibrates well and compares nicely with URBS hydrology model
- Model build time favors hydrology modeling (1 week vs 2.5 weeks)
- Result detail and coverage favors direct rainfall modeling
  - TUFLOW GPU provides catchment wide flood information (level, depth, velocity, flow)
  - Hydrology models only provide point location flow estimates
- Direct rainfall modeling warning!
  - Upstream depression storage in topography datasets can cause an artificial initial loss artifact
  - Infiltration continuing loss parameterization isn’t directly transferable from rainfall continuing loss

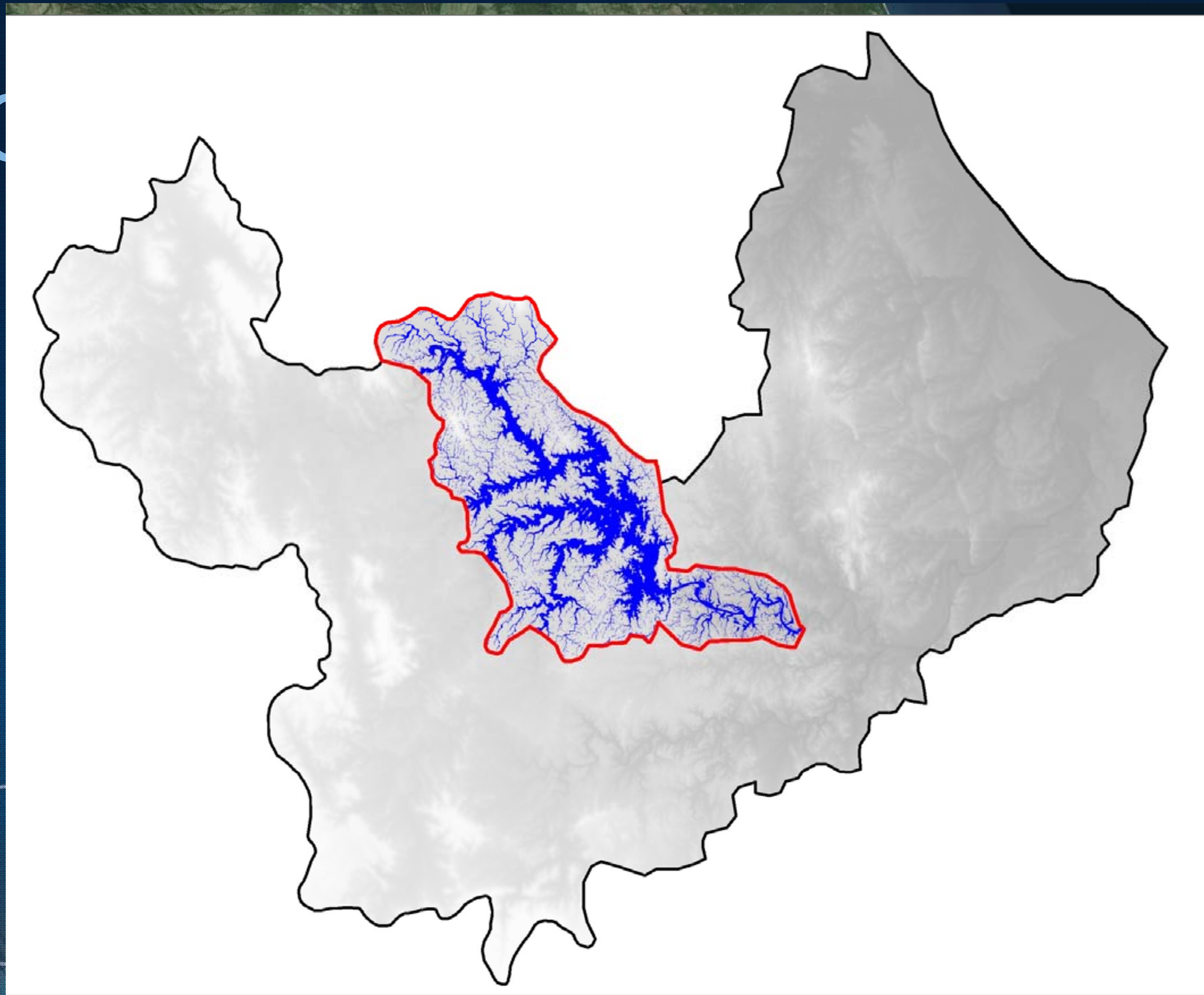
Data Management Challenges?

- >10,000,000 cell model result visualisation can be challenging!
- TUFLOW 2016 includes new data compression features
  - up to 80% result file size reduction
- Direct write to GIS format: Netcdf, ASC or FLT
- Use "Region Output" options for key areas of interest

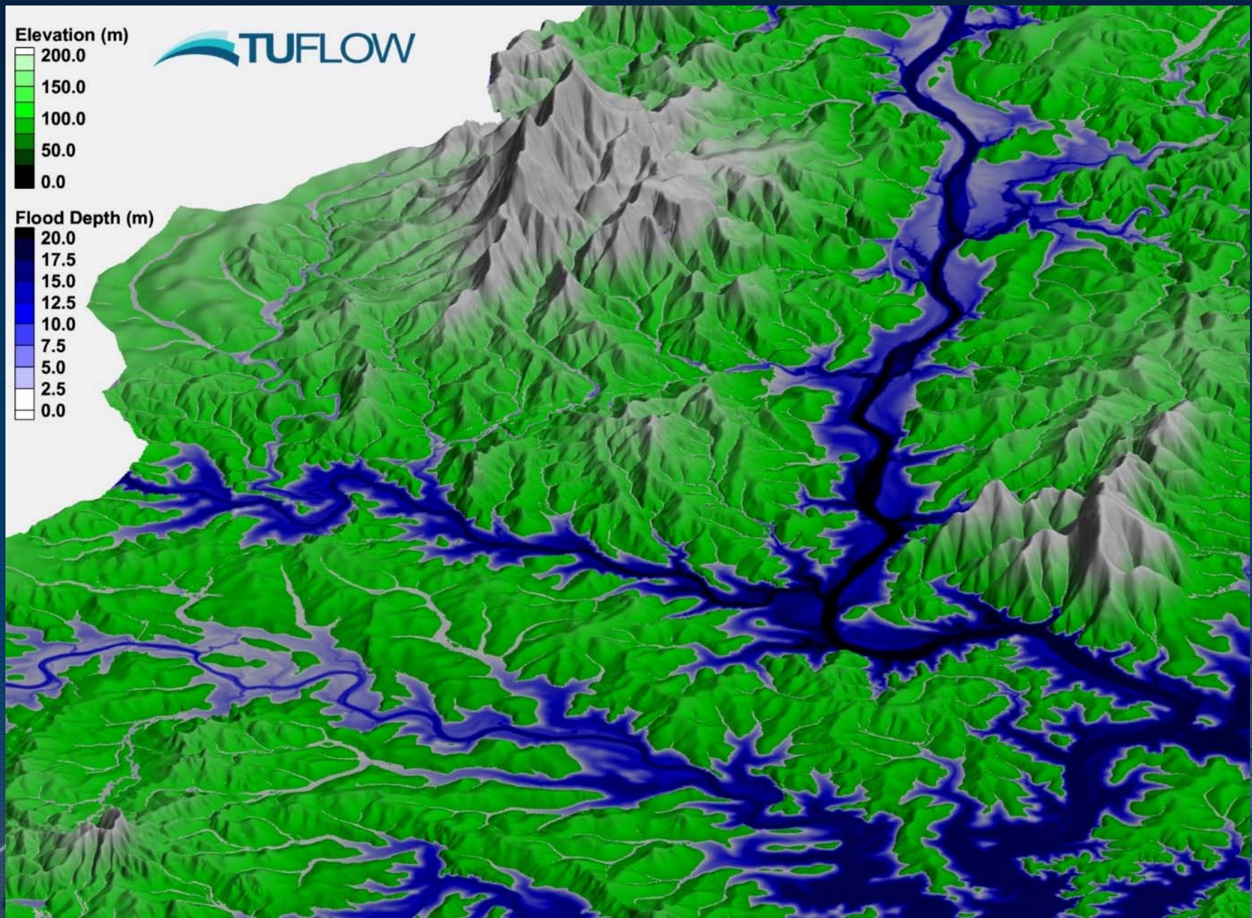
Region C

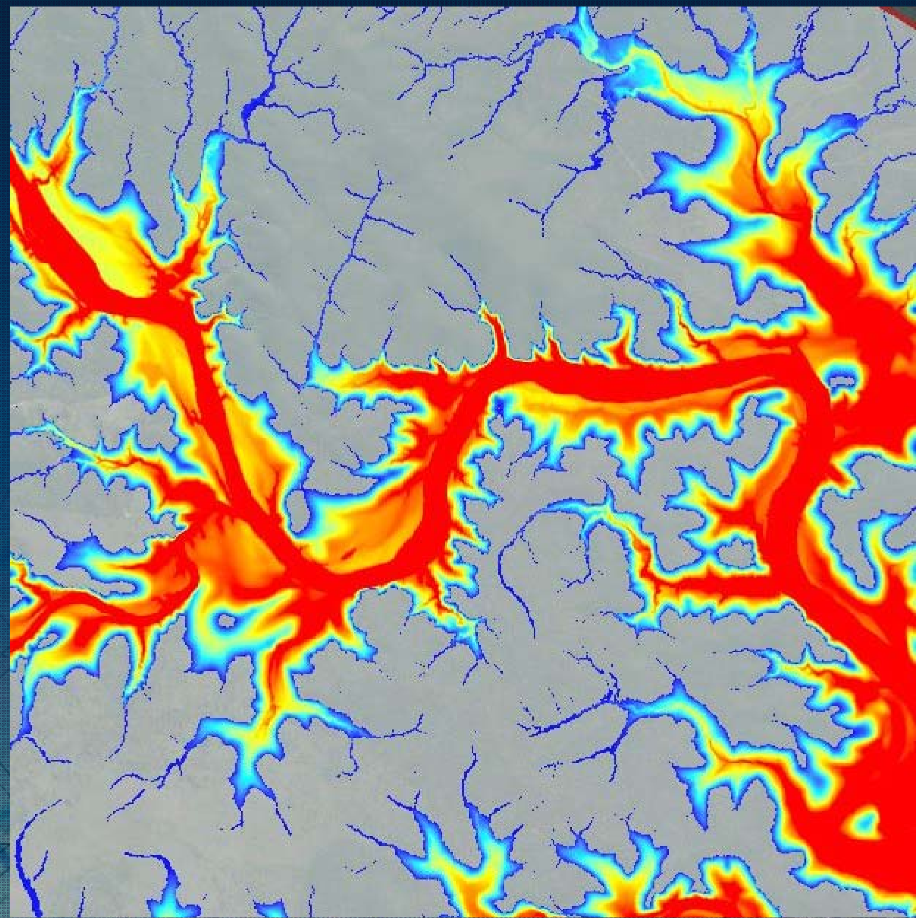


Region C



Region Output Example

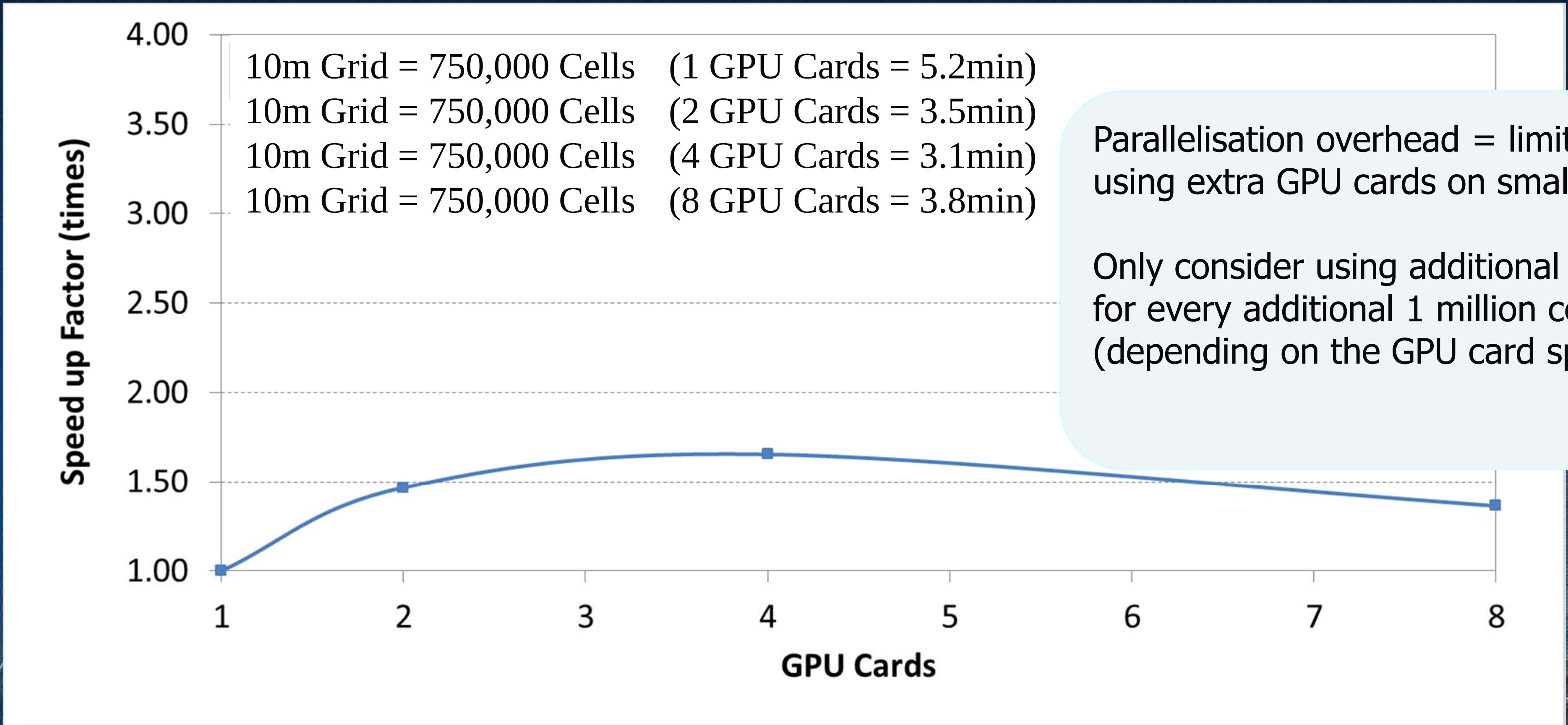




GPU Hardware Optimization

- Gold Coast City Council: 8 GPU Card computer: 4992 CUDA cores/Card
  - 40,000 available CUDA cores!
- Hardware / Software optimization
  - Influence of multiple GPU cards on simulation efficiency?
    - 1, 2, 4 or 8 GPU cards in parallel
  - Model resolution influence on simulation time?
    - 10m = 750,000 cells
    - 2m = 1,900,000 cells
    - 1m = 75,000,000 cells

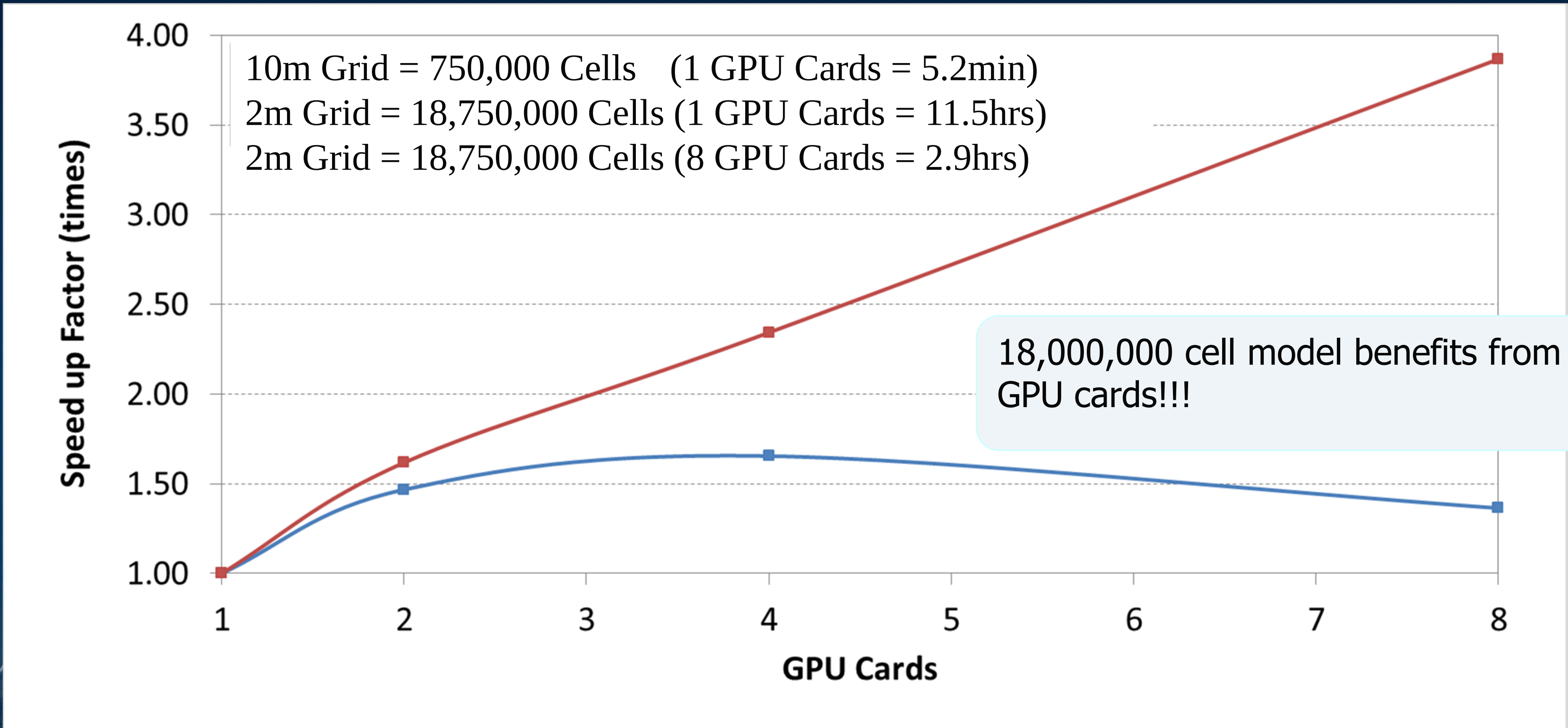
GPU Hardware Optimization



Parallelisation overhead = limited benefit using extra GPU cards on small models

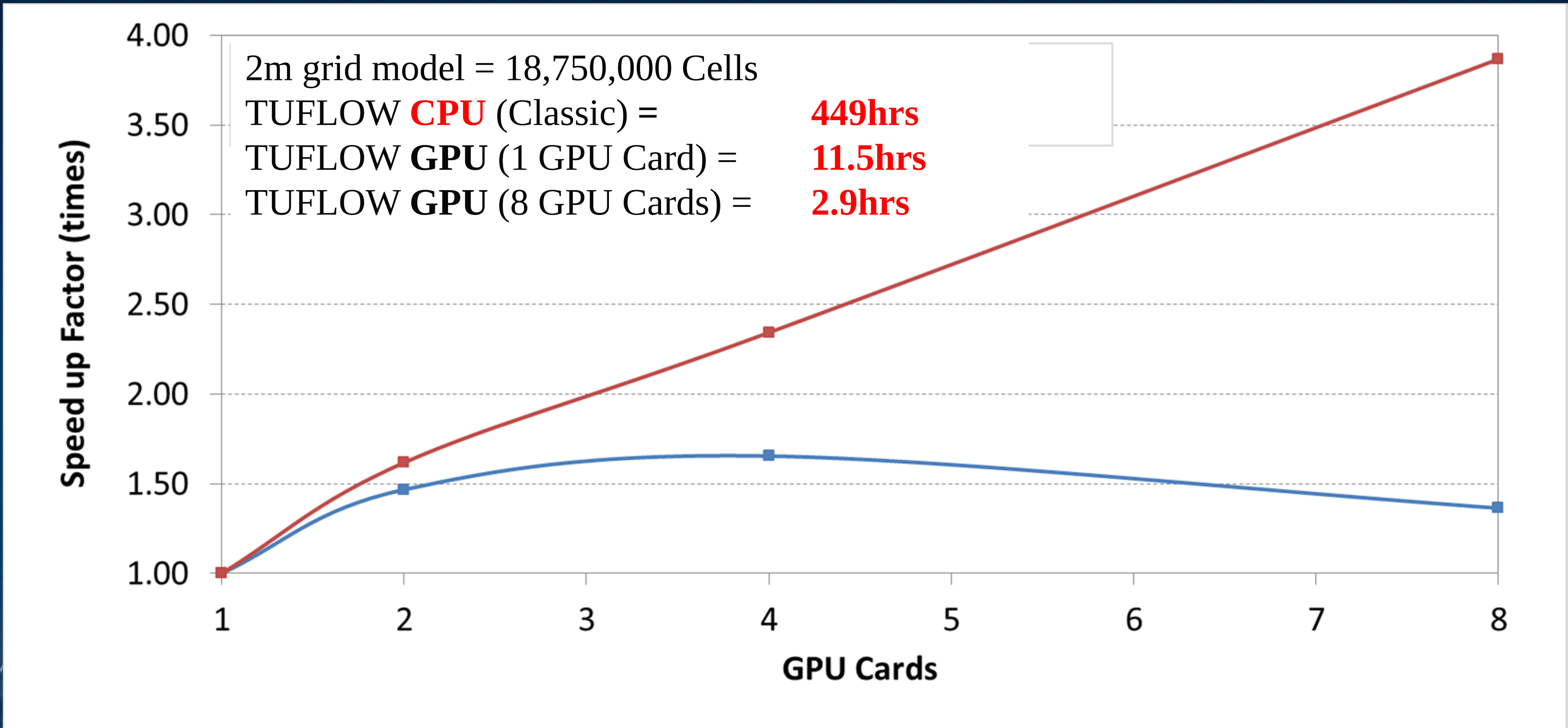
Only consider using additional GPU cards for every additional 1 million cells (depending on the GPU card specs).

GPU Hardware Optimization

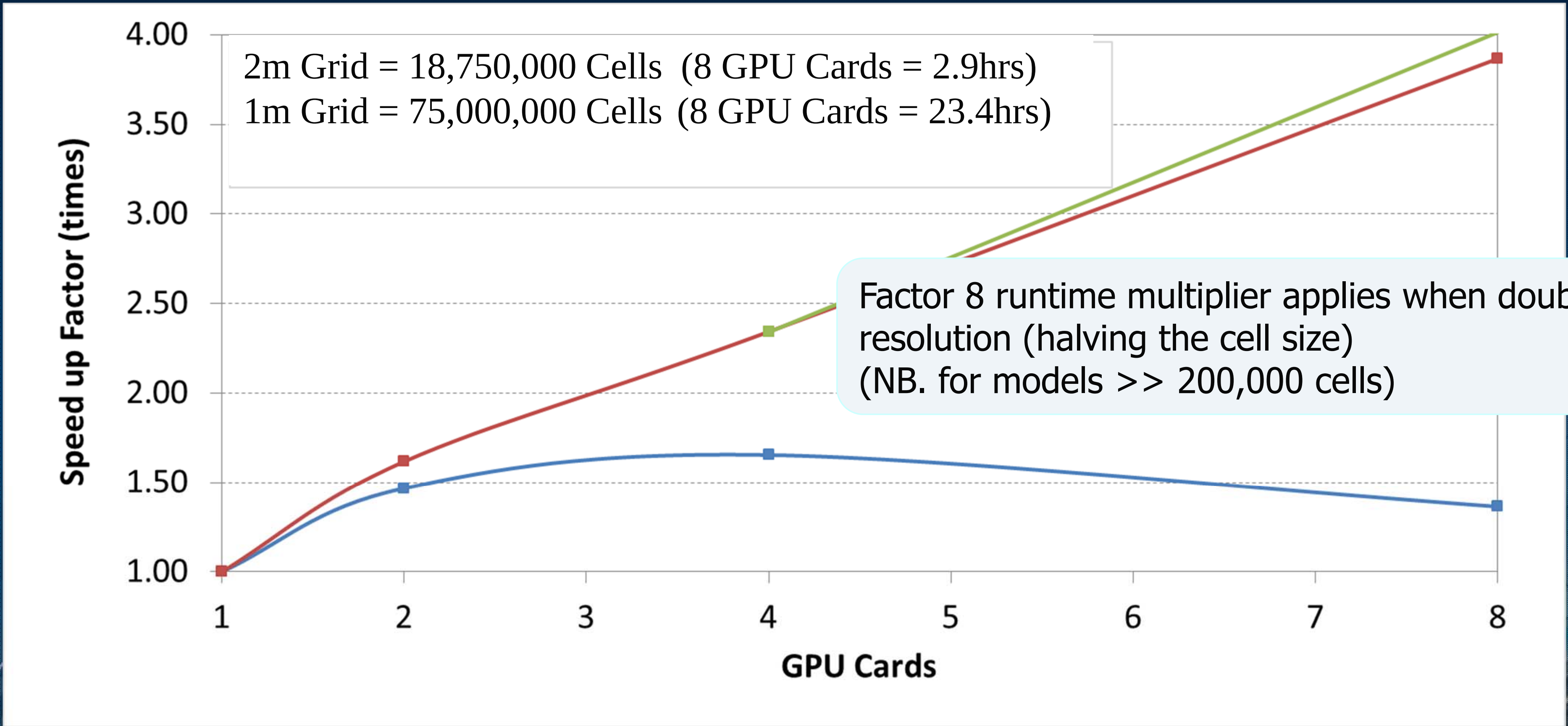


18,000,000 cell model benefits from multiple GPU cards!!!

GPU Hardware Optimization



GPU Optimization – Gold Coast City Council



Factor 8 runtime multiplier applies when doubling model resolution (halving the cell size)
(NB. for models >> 200,000 cells)

GPU Optimization – Findings

- GPU is best suited to larger models (>200,000 cells)
- GPU is fast! Multiple GPU cards >100 times faster than CPU
- Multiple GPU cards… Consider parallel processing overheads
  - More cards doesn't necessarily mean faster run times!
  - Consider the size of your model before blindly allocating hardware.
  - 1 million cells per GPU card appears to be a reasonable recommendation

Questions?

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