GPU - Next Generation Modeling for Catchment Floodplain Management

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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
  - Real time flood forecasting
  - High resolution fine scale assessments
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?
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
TUFWLOW GPU Results (2009)

- Good water level calibration
TUFLLOW GPU Results (2009)

- Excellent flood model result data coverage (the entire catchment)
- Accurate results in LiDAR coverage areas
- Significantly reduced accuracy in SRTM regions
Rainfall Loss Total = 462mm

5mm infiltration loss would have incorrectly extracted over 1250mm from the model!!

Rainfall Loss Total = 506mm
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 Output Example
Region Output Example
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

10m Grid = 750,000 Cells  (1 GPU Cards = 5.2min)
2m Grid = 18,750,000 Cells (1 GPU Cards = 11.5hrs)
2m Grid = 18,750,000 Cells (8 GPU Cards = 2.9hrs)

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

- 2m grid model = 18,750,000 Cells
- TUFLOW CPU (Classic) = 449hrs
- TUFLOW GPU (1 GPU Card) = 11.5hrs
- TUFLOW GPU (8 GPU Cards) = 2.9hrs
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)

2m Grid = 18,750,000 Cells (8 GPU Cards = 2.9hrs)
1m Grid = 75,000,000 Cells (8 GPU Cards = 23.4hrs)
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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