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
- 1 GPU has 1/3 to 1/5 the power of 1 CPU
- The large number of GPU Cuda cores means 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
  - There is no need to use hydrology modeling to derive inflow hydrographs
- This assessment approach has significant potential...However...
  - This is still considered a modelling approach worthy of research
  - What hydraulic model roughness parameters are applicable at extremely shallow depths (e.g. 1/100th of an inch)?
  - 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
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- Input Data
  1. Satellite sourced elevation data in upper catchment. (SRTM)
  2. Airborne Laser survey (LiDAR) elevation and bathymetry data in lower catchment
  3. Good rainfall pluviograph coverage

- Validation Data: Gauge water level recorders
- 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
- NOTE: Reduced accuracy in SRTM regions
TUFLOW GPU vs URBS Hydrology

- Recorded (Rated Flow)
- URBS Hydrology: 5mm Continuing Loss (Rainfall)
- TUFLOW GPU: 2mm Continuing Loss (Infiltration)
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) if your focus is limited to point location flow estimation
- Result detail and coverage favors direct rainfall modeling if more detailed spatial results are the objective (level, depth, velocity, flow, hazard... etc.)
- **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
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 (72hr event)?
    - 10m = 750,000 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 – 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 if your model is small.
  - Consider the size of your model before blindly allocating hardware.
- 1 million cells per GPU card appears to be a reasonable recommendation for current GPU technology
TUFLOW GPU - What’s Next?

- Further code updates to increase software speed
TUFLOW GPU - What’s Next?

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- 1D culverts and underground pipe networks
TUFLOW GPU - What’s Next?

- Further code updates to increase software speed
- 1D culverts and underground pipe networks
- Nested 2d mesh
Questions?

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