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EMERGENCY MANAGEMENT ISSUES SPECIAL INTEREST GROUP

Launching Emergency Management Leadership

Model Optimization Using GPUs and Other Tricks

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Early days…

ANCIENT HISTORY

Early CAPARS Systems

- 1996: SGI Workstations (195 MHz 64-bit) RISC
- 2000: Dual 600 MHz Pentium III (32-bit)
  - 512 MB RAM
  - 1 wind field (670 x 670 cells – 120m)
  - Implemented Finite Plume Immersion
  - All sub-systems on same computer
    - Model, User Interface, Meteorological Data
    - Graphics (GRASS-based)

2002 Optimization & Upgrades

- Optimization for:
  - Extended releases (up to 12 hours)
  - Multiple isotopes (30 or more)
- Dual 2.4 GHz Pentium V Xeon (32-bit)
  - 1 GB RAM

2002 Optimization Tasks

- Upgraded hardware
- Internal caching of meteorological data
- Indexing of receptors to release location
- Limit # receptors for long plume duration
- Vary frequency of puff impact evaluation

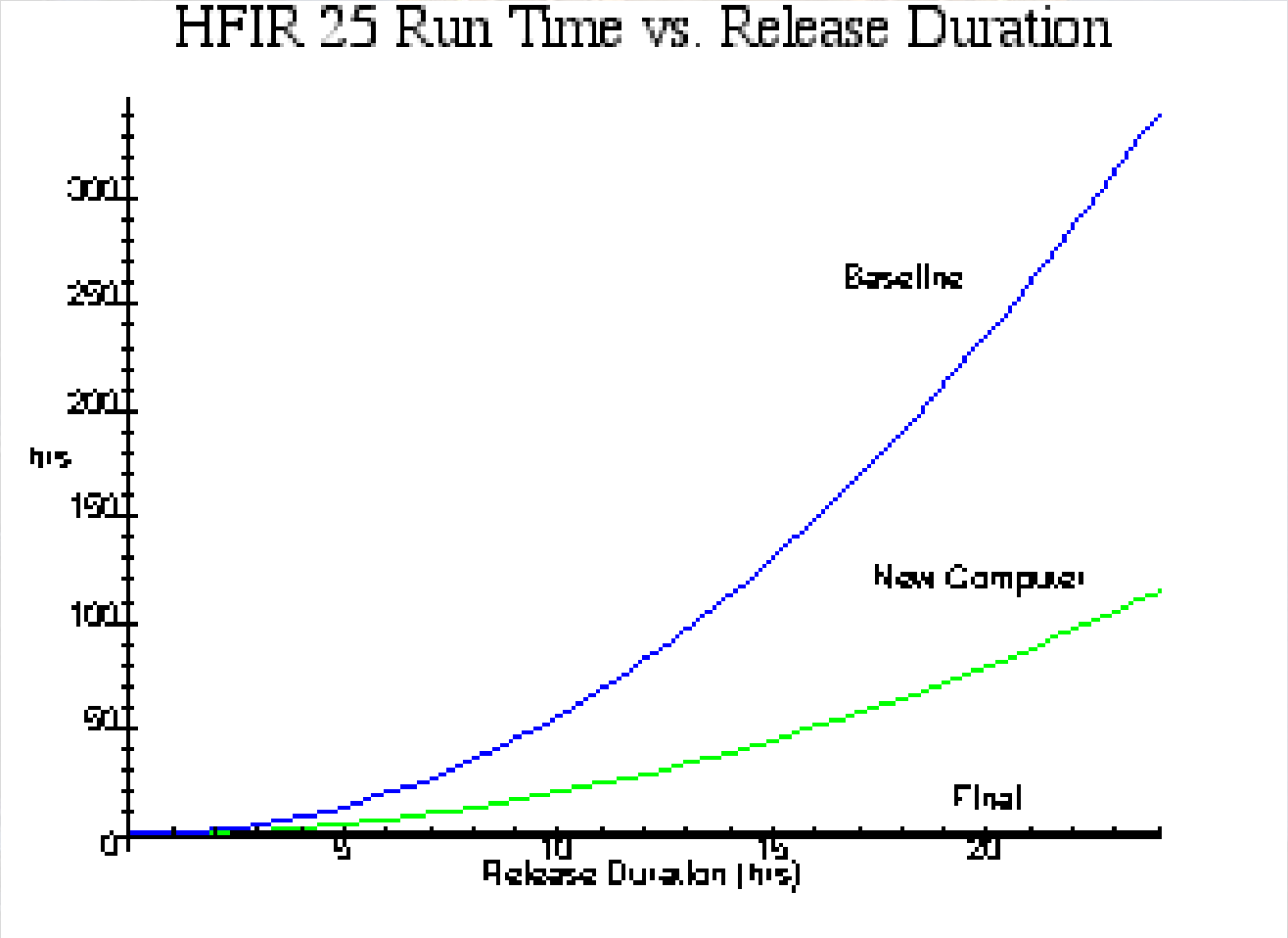
2002 Feature Additions

- Made run times longer
- Better map feature labeling
- Added dedicated map server
  - Windows-based computer
  - ArcGIS map server
- Various improvements
  - Better treatment of hot fires
  - Output product access

Final Performance Improvements

Release Time	Initial	Final	Optimization
1 hour HFIR Release	36 minutes	1 minute	36 times faster
3 hour HFIR Release	4.5 hours	3 minutes	90 times faster
5 hour HFIR Release	13.5 hours	6 minutes	135 times faster
12 hour HFIR Release	80 hours	21 minutes	228 times faster
24 hour HFIR Release	340 hours	46 minutes	443 times faster

Performance Graph



Adding more horsepower…

SECOND COMPUTER UPGRADE

2006 CAPARS System Upgrade

- Added “X5” CAPARS machine
  - 4-core 3.4 GHz 32-bit Intel Xeon
  - 4 GB RAM
- More meteorological data added
  - MADIS
  - Additional surface stations and towers
  - MAPS profiles

2008 Hardware Upgrade

- Added “X6” and “X7” computers
  - 4-core 3 GHz 32-bit Intel Xeon
  - 8 GB RAM
- Faster than the “X5” computer

2010 - New System Requirements

- Multiple (nested) domains
- Extended releases and run times
  - 6 to 24 hours
- Enhanced resolution near source
  - Stopped eliminating close-in receptors
- Incorporate late-arriving met data
- Move mapping servers back to main machine

Technology as of 2012…

CURRENT SYSTEMS

2012 CAPARS Systems

- Two 6-core Xeon X5680 3.33 GHz 64-bit
  - Hyperthreaded = 24 CPU cores!
  - Can be overclocked (not tried yet)
  - 36 GB RAM
- High-end graphics card
  - For GPU modeling
- Notice: CPU speeds leveling off, # cores increasing

CAPARS v5.11 Computer

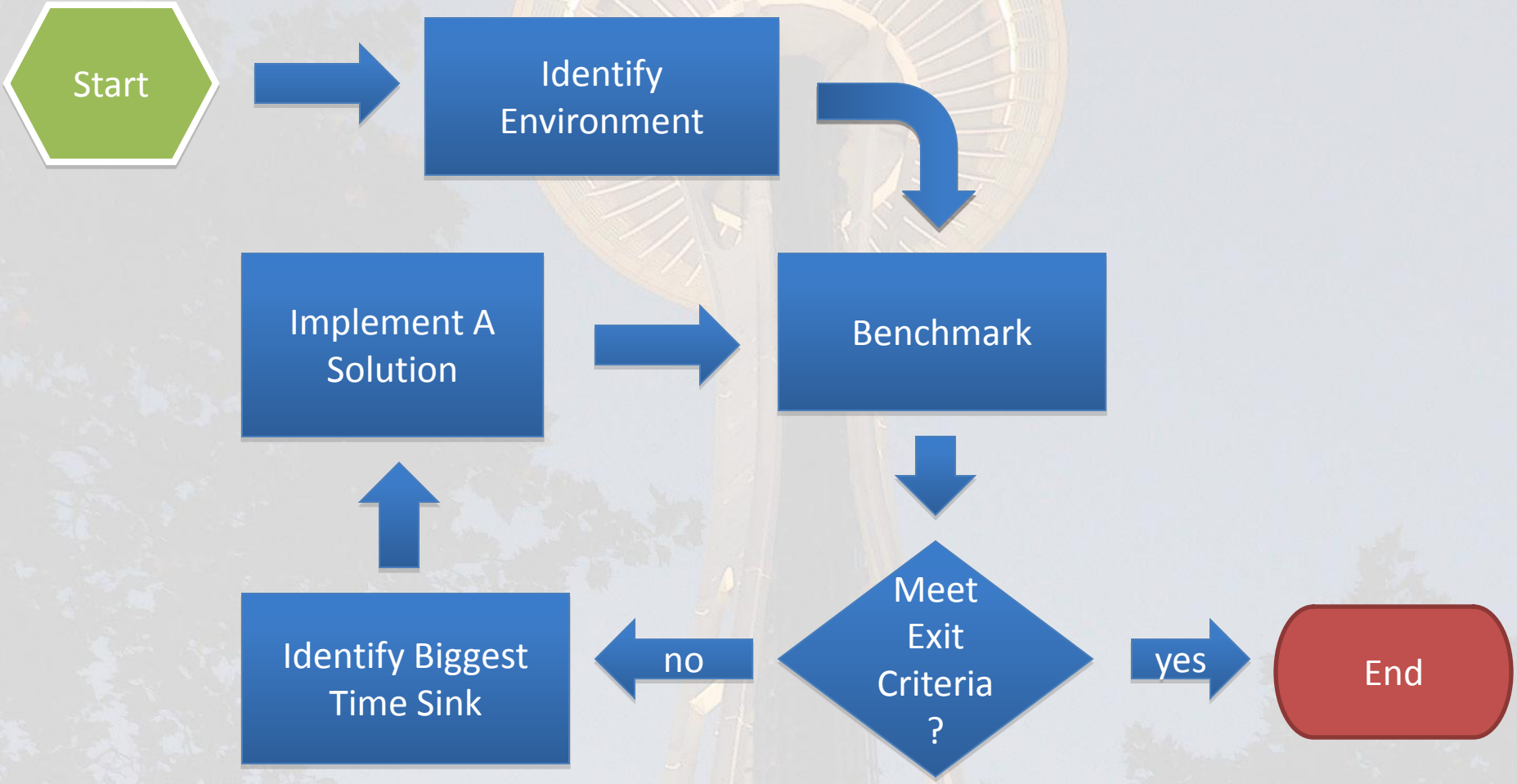
Performance Improvements I

- Hardware upgrades only (2012)
- No good direct comparison
  - Different domains
  - Different met data sets
- Speedup from 2.0 to 5.0
- Long multiple isotope runs still take too long
  - About 35 minutes for 6-hour simulation/release
  - Single substance releases are still fast (1-5 min.)

Reducing run time…

OPTIMIZATION

Optimization Process



Optimization Environment

- 29 isotope areal release
- Run duration = release time
- 60, 120, 180, 240, 300, 360, 420, 480 minutes

First Target

- Each map takes ~ 30 seconds (no action)
  - About 1% of total run time
- Model Processes:
  - Transport & Diffusion 1 - 5%
  - Deposition 90 - 95%
  - Health Effects ~ 4%
- Focus on the deposition process!

A Profiler: Your New Best Friend

ingrowth_and_decay	16,949.5	= 79%	86,837,418	= 4%
deposition	3,005.52	= 14%	1	= 0%
drydpp	543.887	= 3%	520,767,728	= 25%
concen	402.758	= 2%	209,370,798	= 10%
pxform	333.405	= 2%	418,741,596	= 20%
drydpg	198.083	= 1%	737,219,323	= 36%
rough	80.6454	= 0%	86,837,418	= 4%
store_puff	4.17623	= 0%	120,510	= 0%
get_puff	2.9366	= 0%	120,511	= 0%
transf	2.81282	= 0%	120,510	= 0%
ludcmp	1.72908	= 0%	120,510	= 0%
lubksb	1.20571	= 0%	361,530	= 0%
ellipsoid	0.78322	= 0%	120,510	= 0%
indexcalc	0.614251	= 0%	482,040	= 0%
get_area_receptors	0.351182	= 0%	120,510	= 0%
set_plume_timing	0.326301	= 0%	3	= 0%

Sort By Time

Display: Process | Thread | Process.Threads

Process	Time	Count
0 (ingrowth_and_decay)	16,949.5 =100%	86,837,418 =100%

The Target: Optimize Initialization

pgprof

Settings Processes View Sort Search

Find: HotSpot: Time

prof.out | ingrowth_and_deca...

Line	ingrowth_and_decay.f	Time		Count
146	C ZERO OUT data from full isotope database.			
147	C			
148	DO 60 JK = 1, MAX_ISOTOPES	1,956.2	= 12%	8
149	C			
150	QINGRT(JK) = 0.0	2,318.19	= 14%	86,83
151	QTIME(JK) = 0.0	2,346.55	= 14%	86,83
152	QZERO1(JK) = 0.0	2,350.41	= 14%	86,83
153	C			
154	60 CONTINUE	4,088.86	= 24%	86,83
155	C			
156	DO 65 JK = 1, NUM_ISOTOPES	66.4213	= 0%	8
157	C			
158	QZERO1(ISOREL(JK)) = QZERO(JK)	99.5506	= 1%	2,51
159	C			
160	65 CONTINUE	127.947	= 1%	2,51

Sort By

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First Modification

- Initialized arrays in ingrowth and decay module
  - Speed improvement: about 32 times speedup!
- Look for more low-hanging fruit
  - No more apparent targets
- Check for GPU targets:
  - Linear algebra & library routines (none)

Next Modifications

- Try compiler optimization settings
- Vectorize all code
- Use compiler parallelization switches
  - Concurrent process attempt

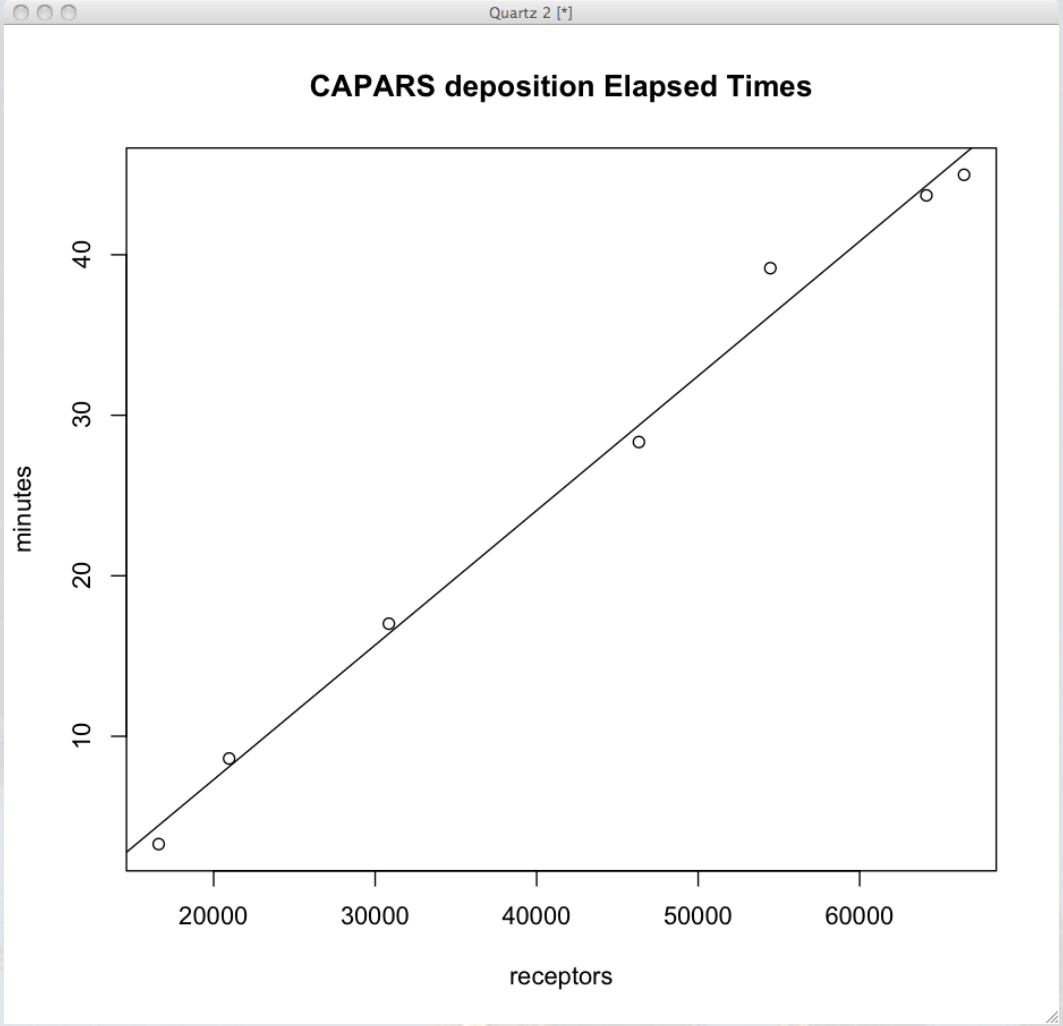
Deposition Run Times

Scenario Name	receptors	puffs	Benchmark	Initialize	Vectorize	Concurrent
1-60minRel	16595	604	0:07:10	0:03:16	0:03:17	
1-120minRel	20959	878	0:19:49	0:09:22	0:08:37	0:09:18
1-180minRel	30849	1128	0:39:05	0:17:36	0:17:01	
1-240minRel	46330	1416	1:20:00	0:29:24	0:28:20	
1-300minRel	54470	1576	1:28:42	0:40:27	0:39:10	
1-360minRel	64134	1846	1:58:24	0:45:20	0:43:42	0:45:18
1-420minRel	66464	1910	1:32:13	0:44:31	0:44:59	
1-480minRel	65380	1882	0:59:14	0:29:40	0:28:41	

Observations

- Notice limit on run time after 360 minutes
  - Probably due to receptor/puff limitations built into design of CAPARS
- Array initialization in ingrowth and decay routine significantly improved performance
- No performance gain from vectorization
- Worse performance using concurrent parallelization switch

Deposition Time Predictors



Next Optimization Options

- Examine GPUs
  - No easy numerical routines to target
  - Examine cost of re-coding deposition module for use on GPUs
    - Cost prohibitive due to size of code, SQA requirements, time constraints
- Examine breaking up puffs and using multiple CPU cores
  - Successful concept demonstration

Breaking Up Puff Data

- Only for multiple isotope releases
- Break up puff data set into multiple files
- Modify deposition process to work in parallel
  - Minimal changes to SQA accepted code
- Combine results of multiple deposition runs
- Requires a “control” process to manage everything

Multi-core Results

- Results are preliminary
  - Subject to SQA analysis
- Depends on number of CPU nodes used
- Can get runs < 30 seconds

Considerations

- Converting code to GPUs > $10K
- GPUs not beneficial in this situation
- Use of multiple CPU threads worked better
- Development of multi-core control process took a long time
- Following SQA process really slows down work