Demonstrating Innovative Reservoir Modeling Workflows Enabled by a GPU-Accelerated Implicit Simulator

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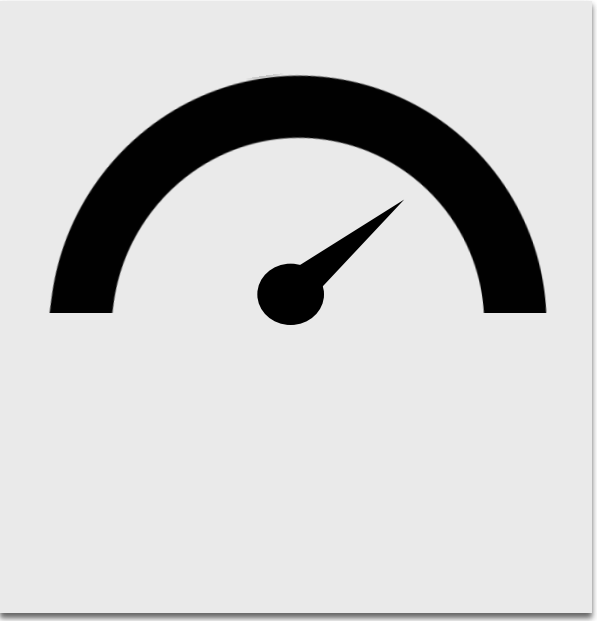
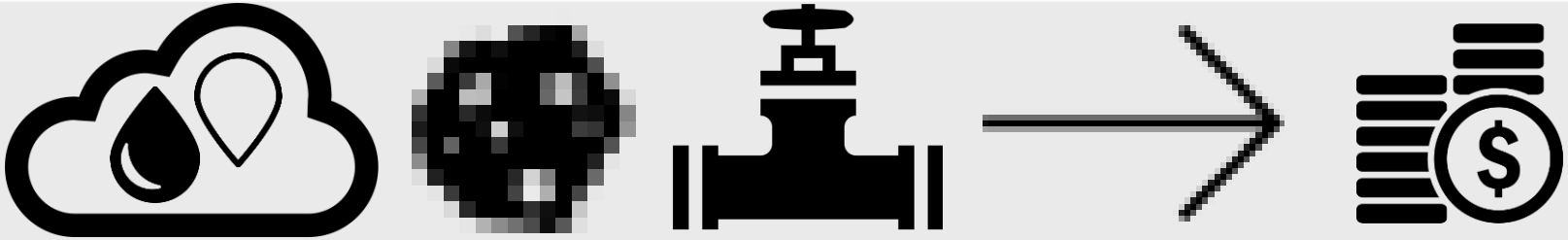
- First fine-grained implementation of petroleum reservoir simulator



- Talk focuses on implications of exceptional speed in workflows

Background : Reservoir Simulation

- Reservoir Simulation

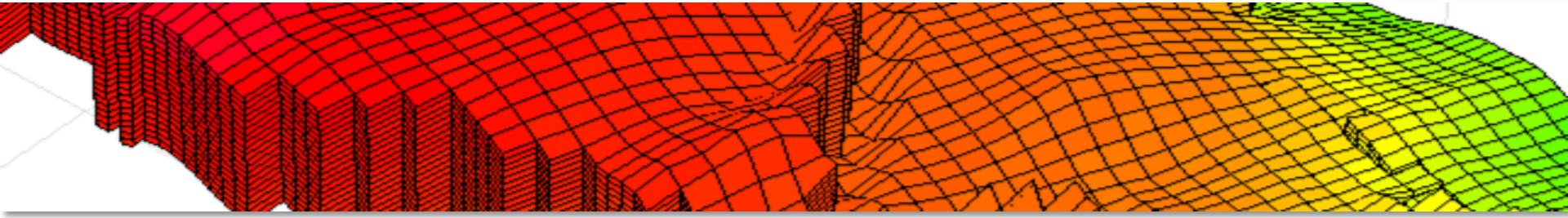


- Generate a (predictive) model of production for economic recovery

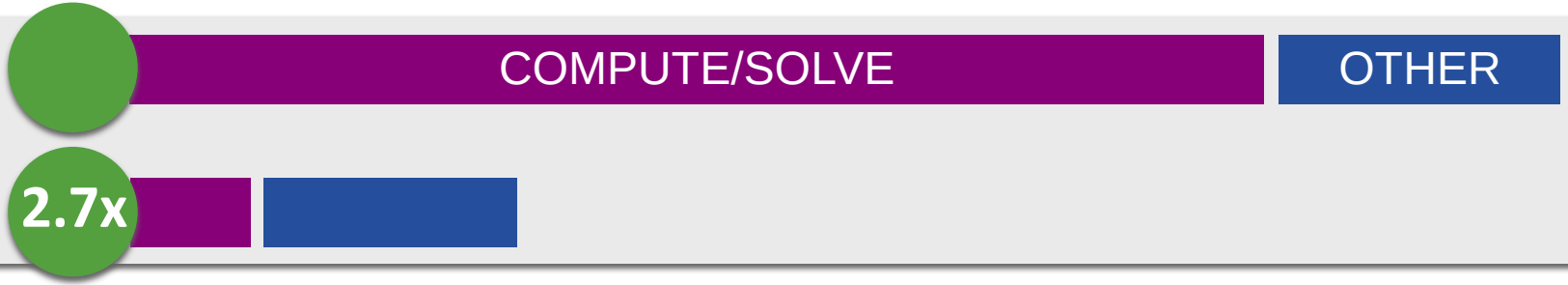
- The workflow is more than just compute cycles…

Motivation for Compute Acceleration

- Unstructured grids; irregular memory access patterns



- Linear solver ≈80% of total time, hundreds of other kernels

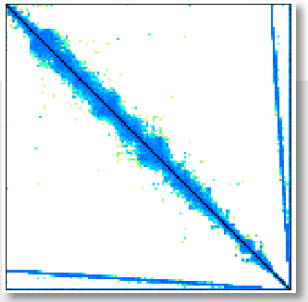


- Very many simulation realizations are required for most workflows

Algorithms Come First

- Choose the right GPU solvers (GAMPACK, AMGx)

Method	GPU	CPU	Iterations
CG Solver	24.6 s	246.6 s	4589
AMG Solver	0.7 s	5 s	8

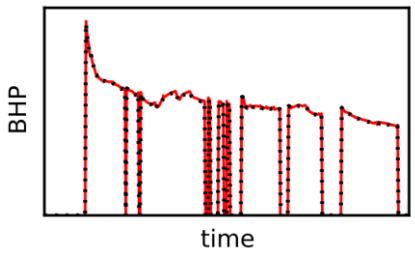


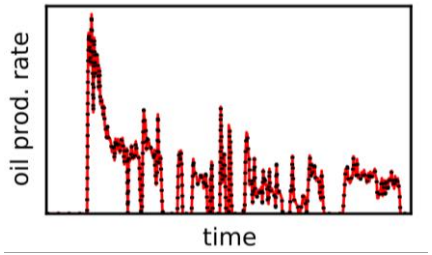
- …then confront Amdahl's law directly to achieve >10x

Example Performance on Real Assets

Model	# cells	#CPU cores	#K40s	time	Speedup
A	1.36M	32 (1)	2	26h/53m	45x
B	20M	48 (2)	8	14h/1.2h	12x

- **Total** application acceleration + better-suited solvers = >10x factor

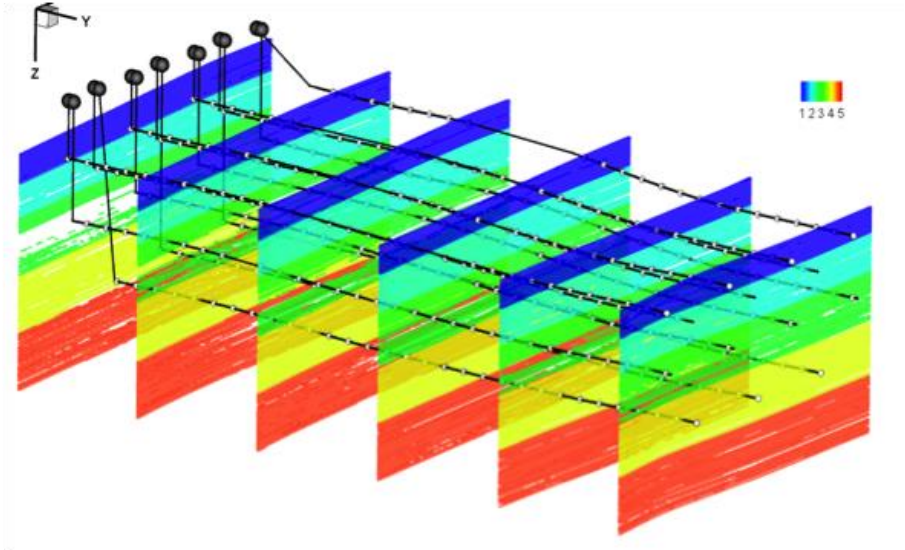


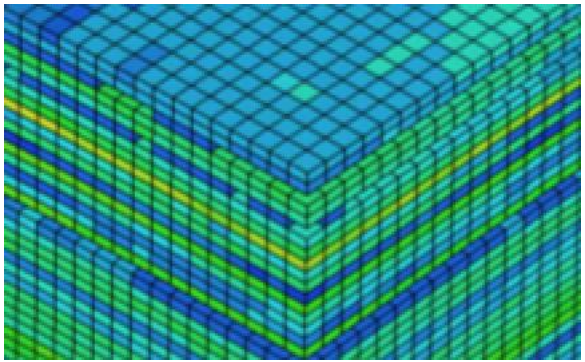


- Validation within 1% of current commercial standard

Example Problem

16M cells for 20 years @31 day intervals

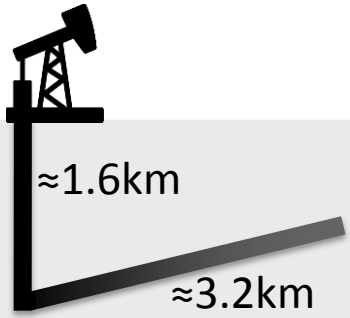


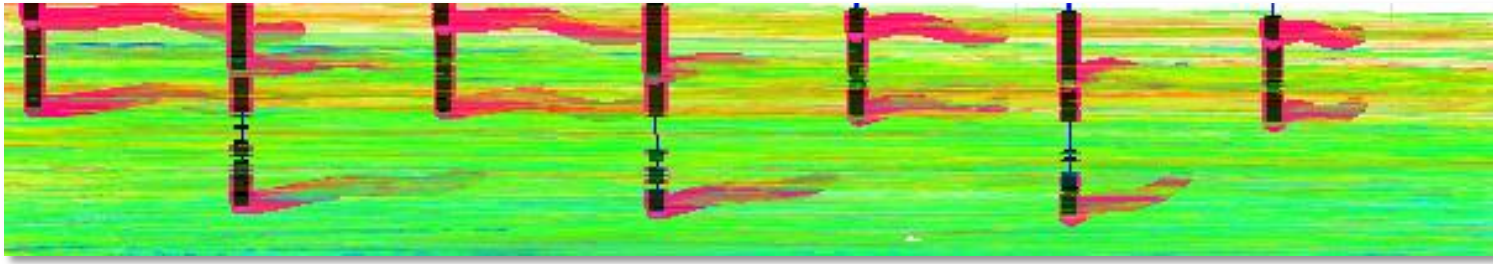


40ft x 40ft x 4ft
12.2m x 12.2m x 1.2m

Many uncertainties in model; want to explore them

Example Problem





4 GPUS

20 MIN

32 X

Total Compute Time For Workflow

12 x E5-2687	45 d
vs	
4 x K40s	1.5 d

Total Compute Cost For Workflow

CPU	$1.44/hr	=	$1536
	VS		
GPU	$9.28/hr	=	$310

Creating a Downstream Deluge

- 600 mins : commercial simulator runs once, creates 6 min of work

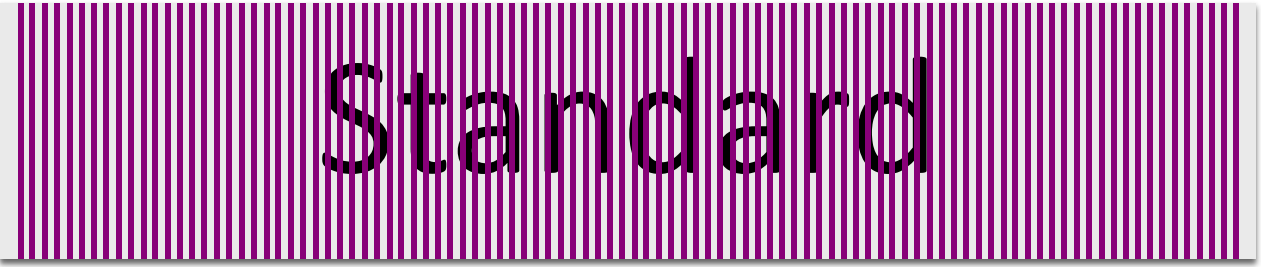
- 600 mins : our simulator runs 32 times, creates 192 mins of work

Everything new is newer again

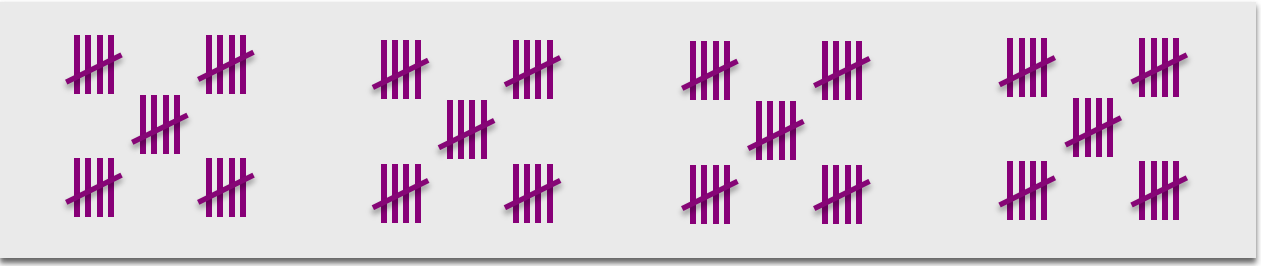
- **Total** workflow acceleration from the ground-up…

What Now?

- How can we deal with 100 files?



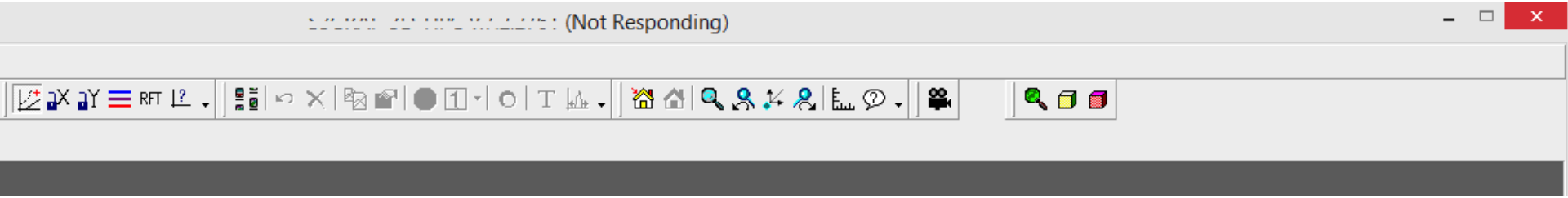
- How can we represent data in clear, compelling ways?



- How do we share and collaborate?

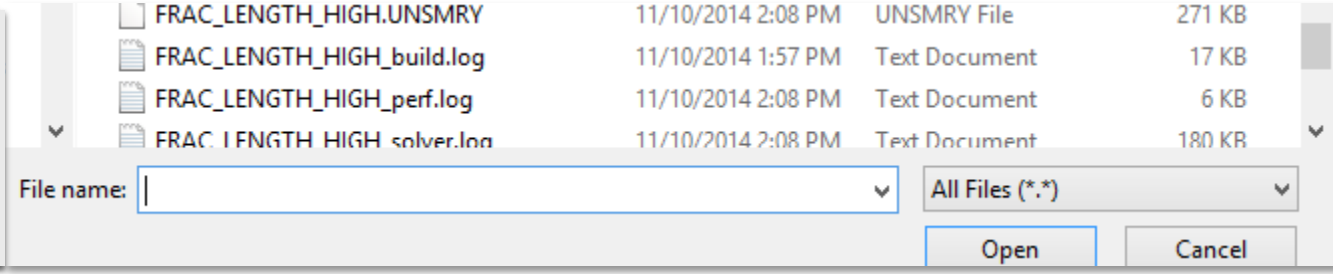
Implication for Workflow

- Loading a model grid can be painful - 109s for this model



- (Most) existing tools are not designed to (help you) work this way…

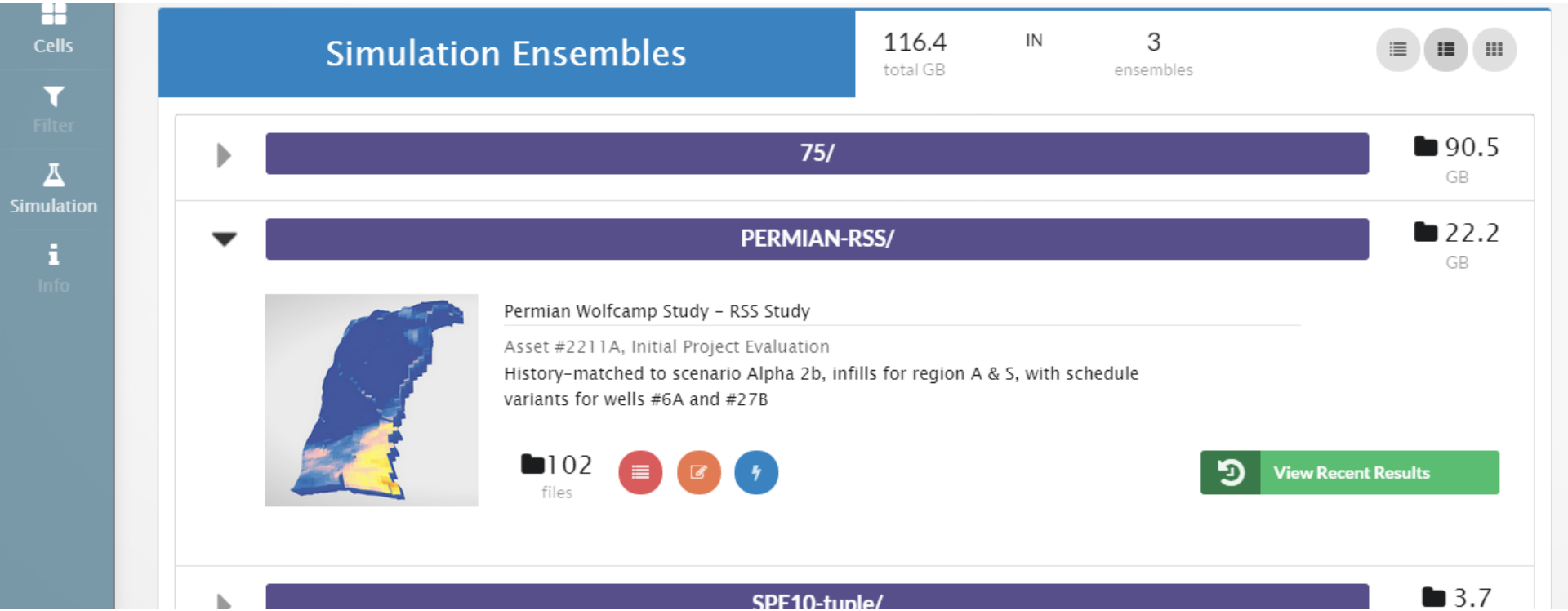
100 X



- Fundamentally : How can we help but stay out of the way?

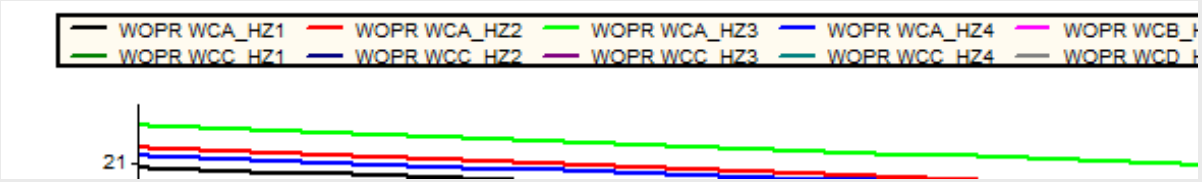
Implication for Workflow

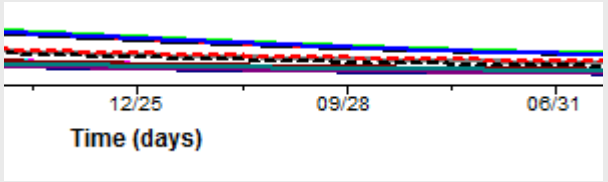
- Make choosing/loading many simulations easier



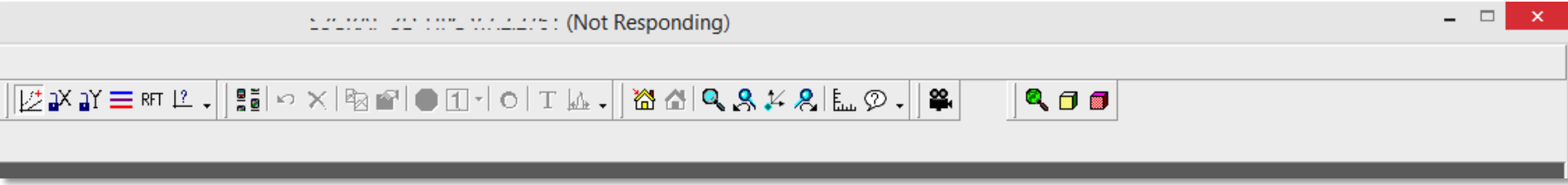
Typical User Interface

- Legend clutter, disambiguation





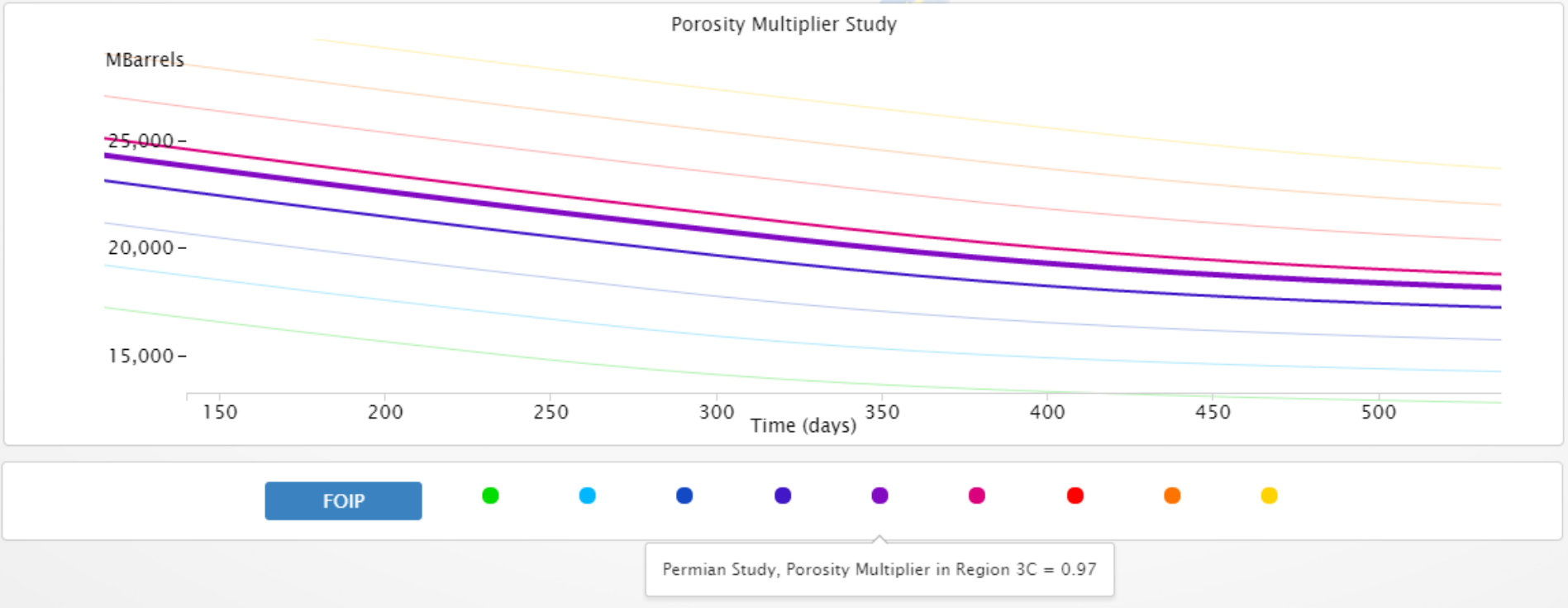
- Lack of plot interactivity, traditional loading styles, anti-aliasing



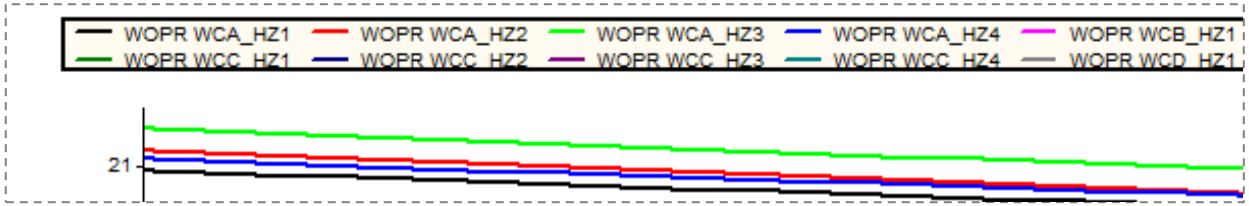
- Can we make this accessible or (ideally) unnecessary?

Instead Consider…

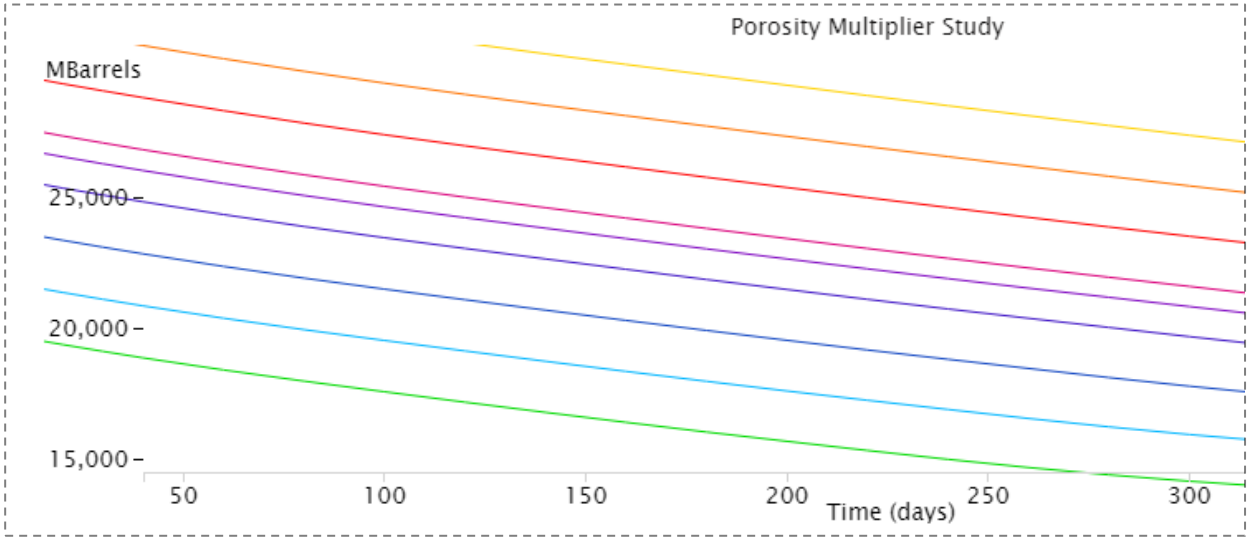
- Provide a means to disambiguate large ensemble results



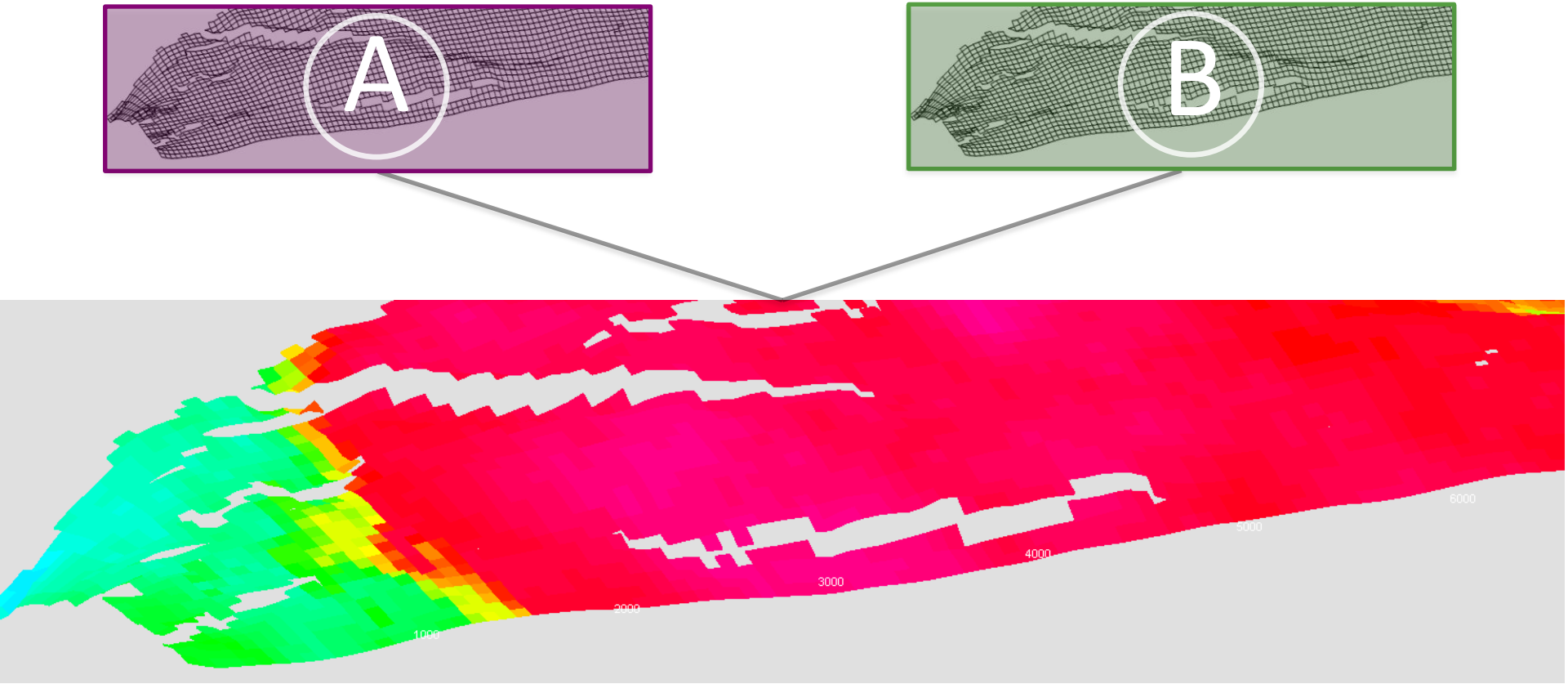
Clarity of Results



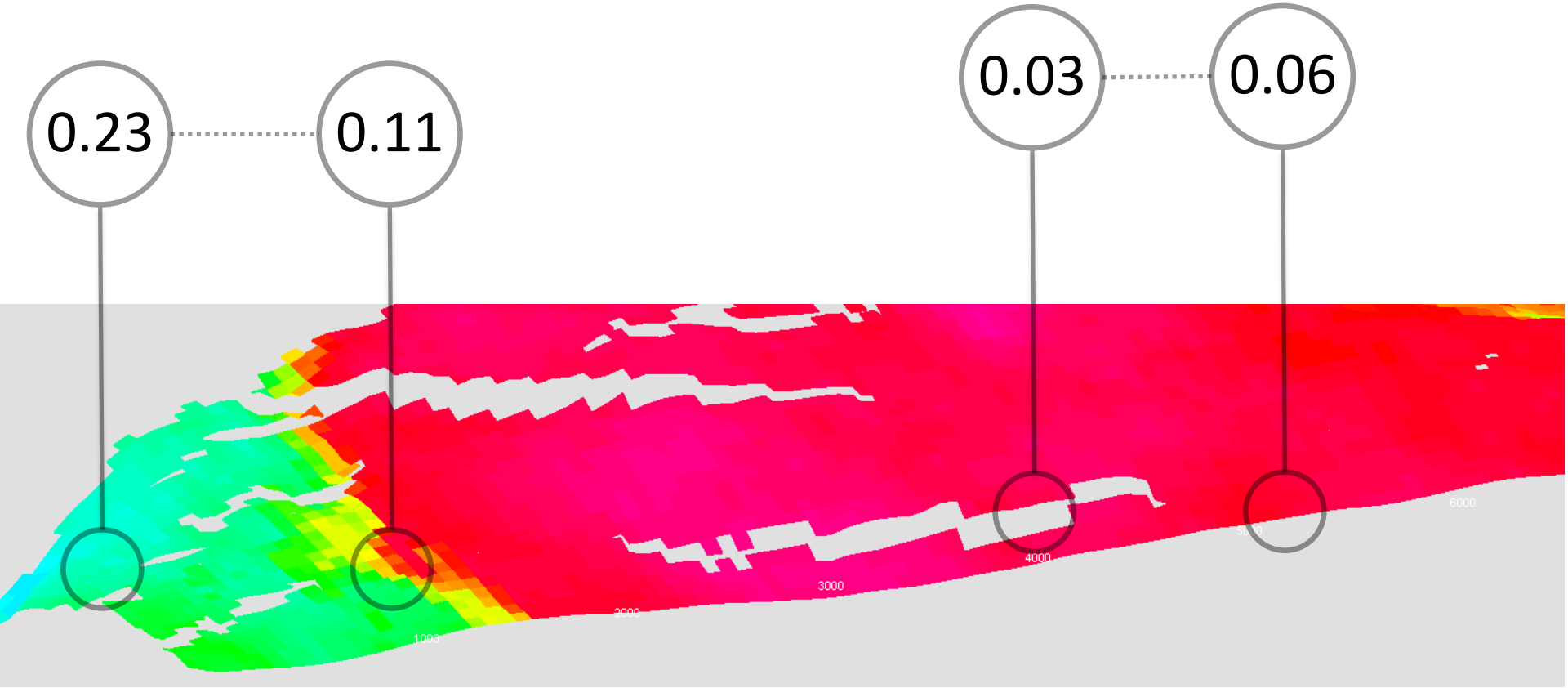
- Pixel vs vector plotting, anti-aliasing, interactivity



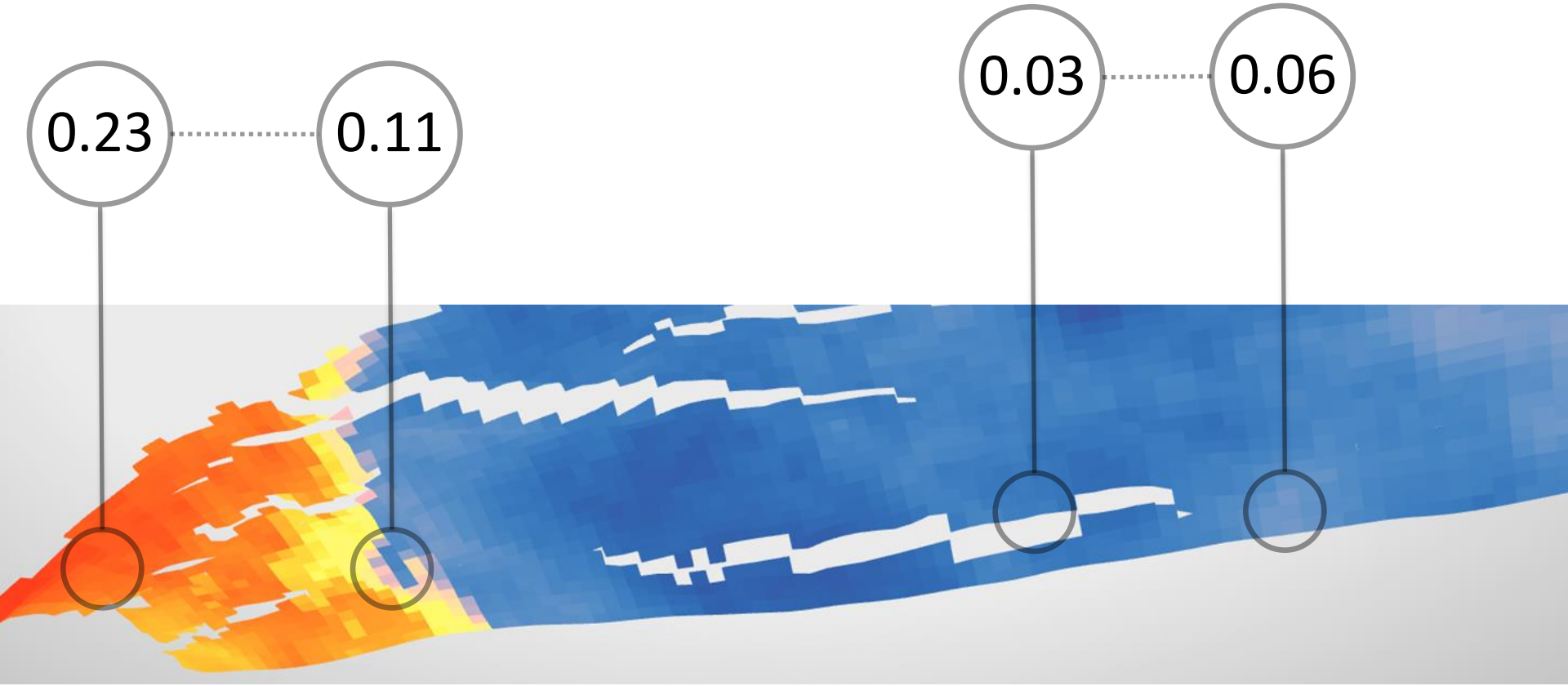
Typical Color Palette (Difference Plots)



Typical Color Palette (Difference Plots)

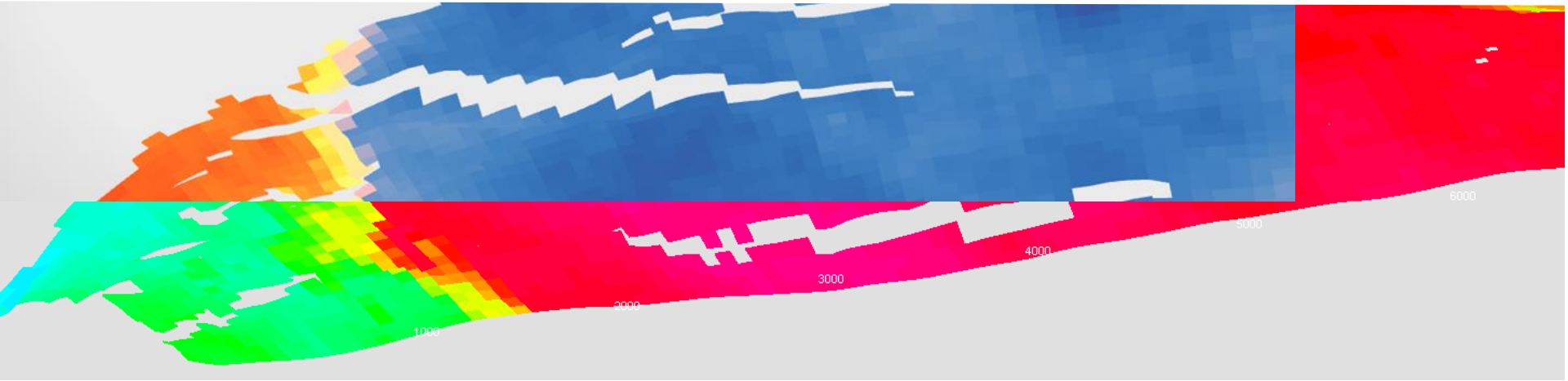


Better Color Choices, Faster Interpretation



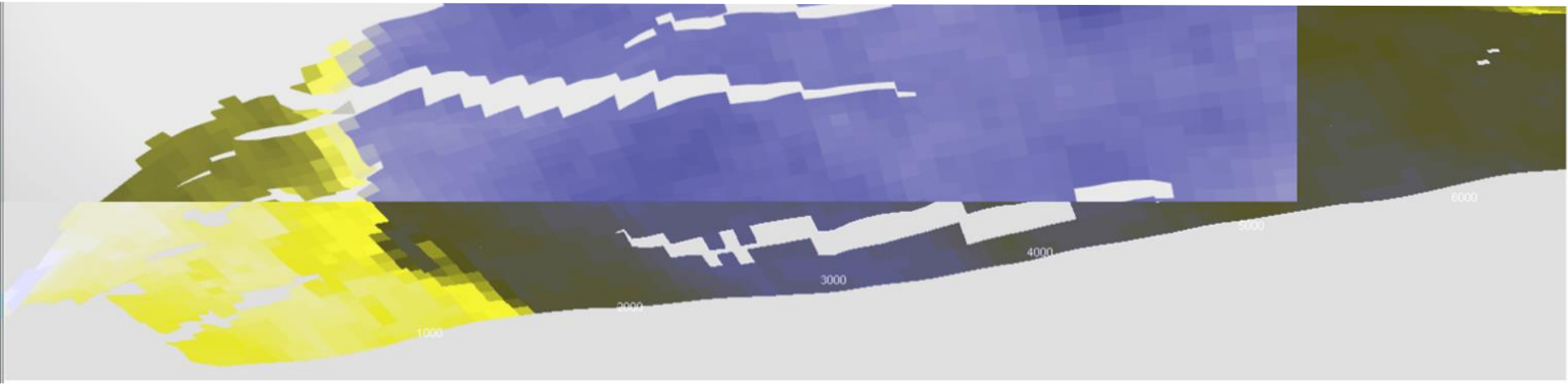
Color Choices (1)

- Preserve local relative differences, design for color-blindness



Color Blindness : 8-12% Males

Tritanopia (blue deficiency)



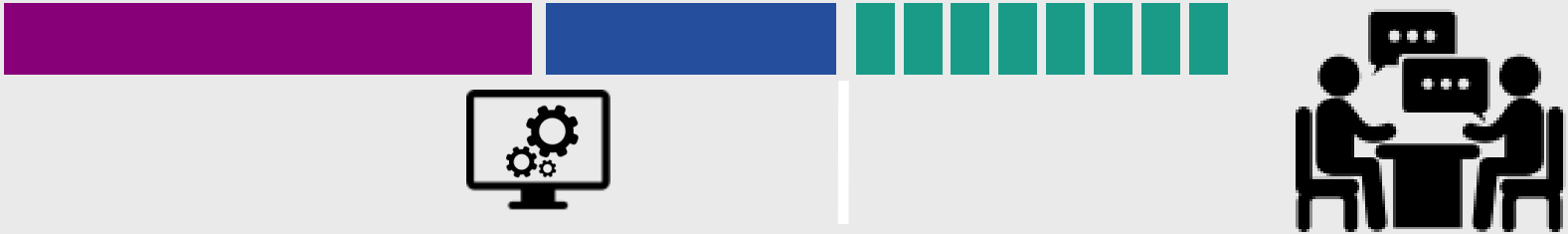
Results Anywhere

- Distributed workload, remote clients, results anywhere

- Send colleagues an interactive graph; not static PDFs

A New Approach to Workflows

- Accelerated applications can cause post-processing data deluges

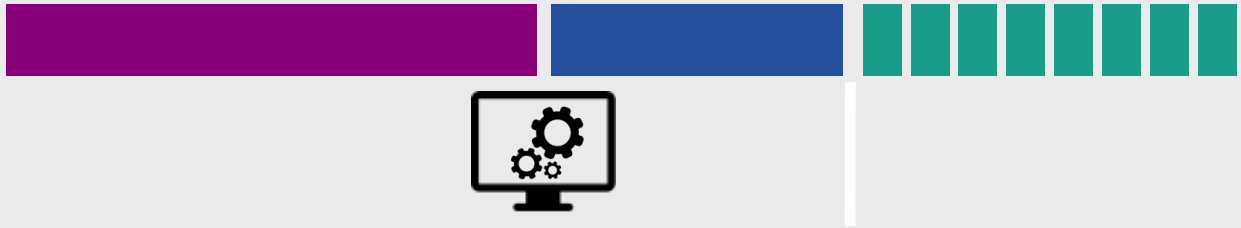


- Total application acceleration : new workflow/interaction challenges!

- We are re-thinking the way the tools behave, interact with GPU apps

Whole Systems Approach

- Key is understanding workflow impacts



- Fresh thinking on engineering tools around workflow optimization

The Team

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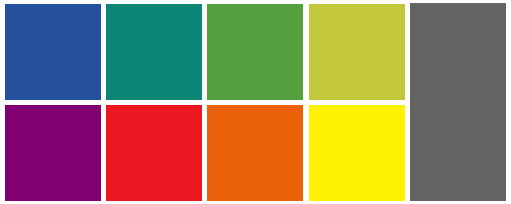
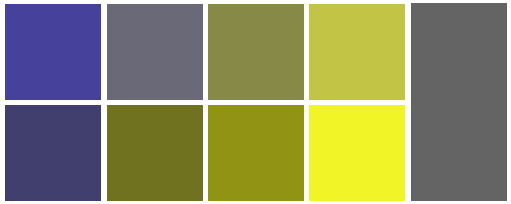
Slide Vault : Color Acuity

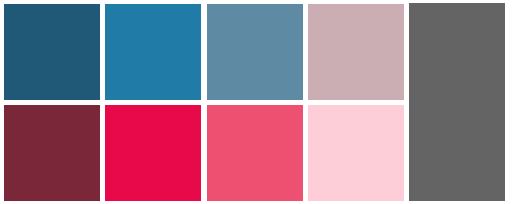
- Paul Tol's work on palettes is a great resource!



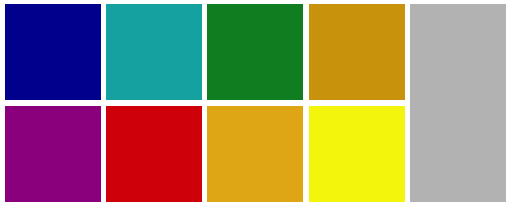
Normal

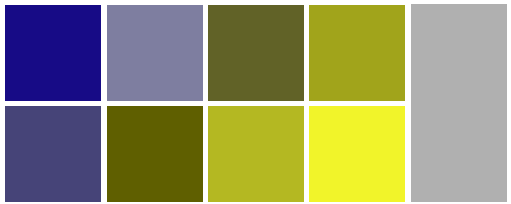


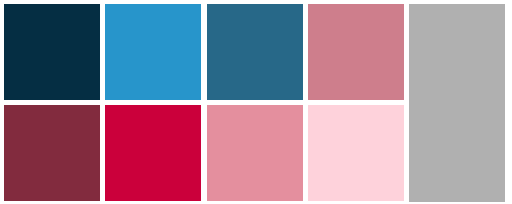
Deuteranopia



Protanopia



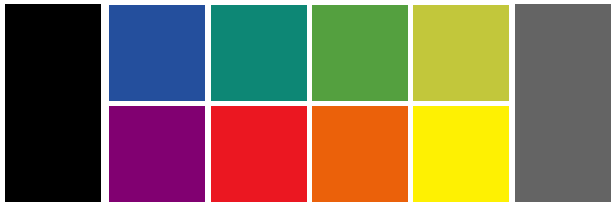


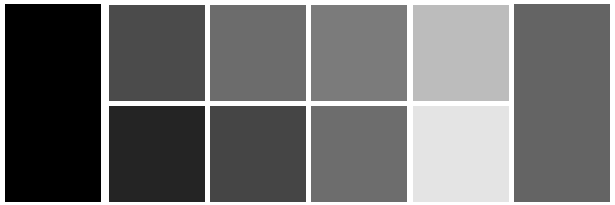


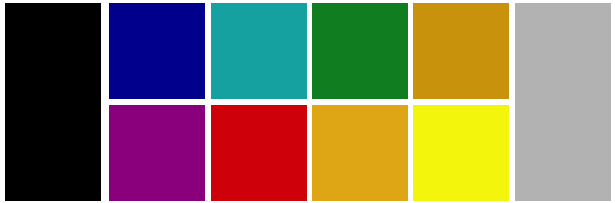
- Can choose colors such that printers can reproduce : ISO-12647-2

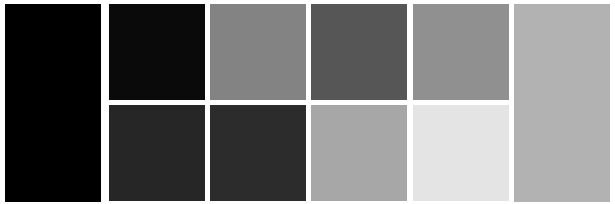
Slide Vault : Color is more than perception!

- Publication-quality figures need well-chosen color spaces









- What happens when great color figures are printed in B&W?