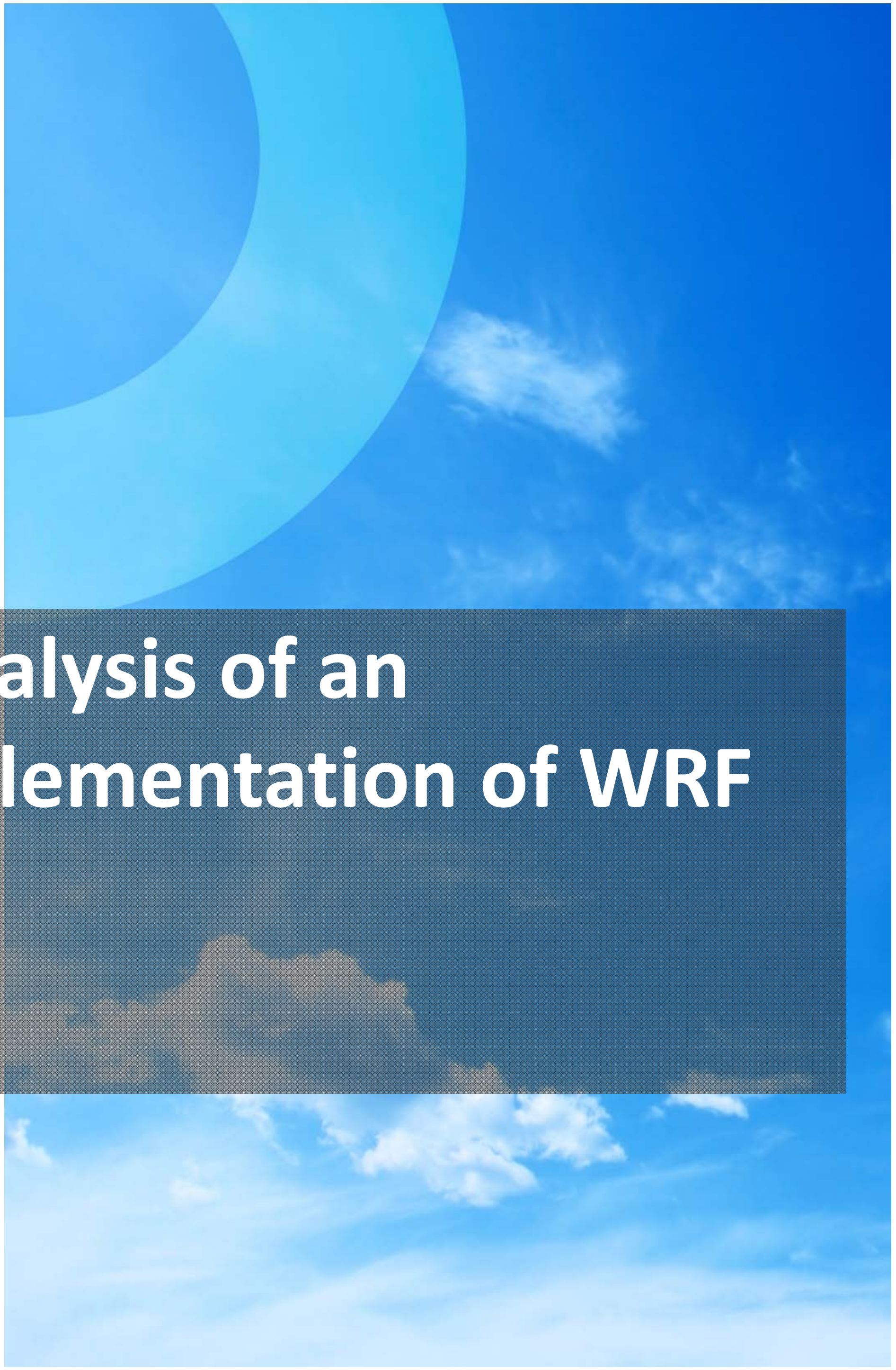


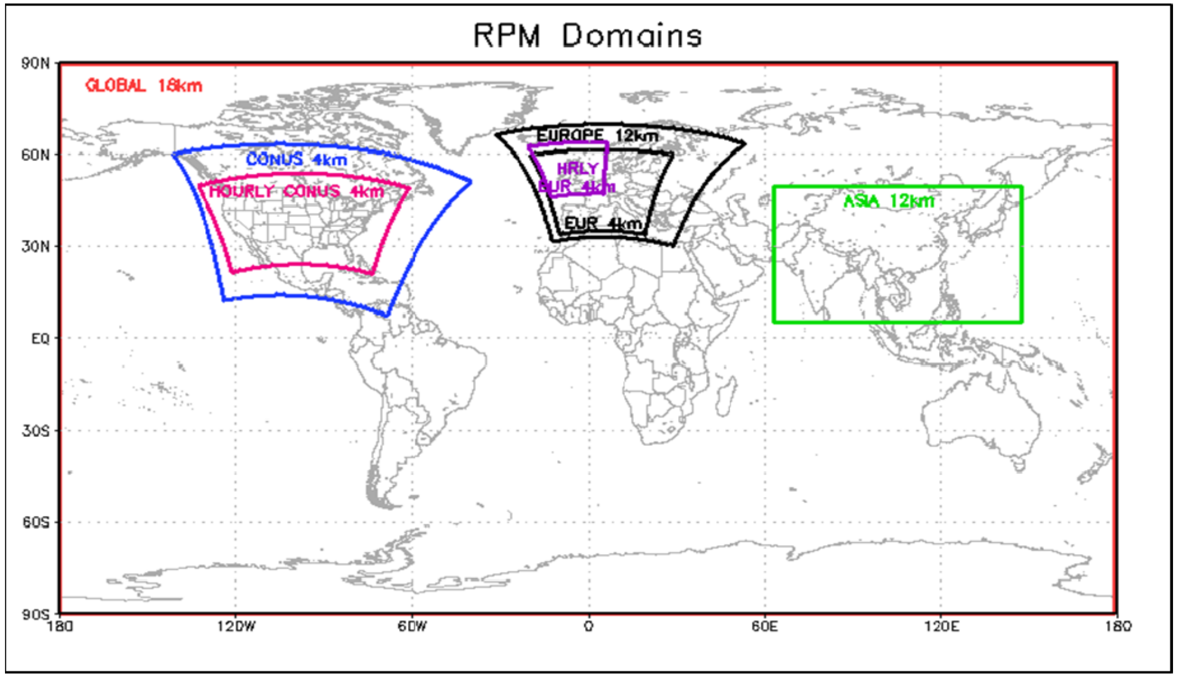
Performance analysis of an operational implementation of WRF

Todd Hutchinson

WSI Corporation

Purpose

- **Analyze operational configuration of WRF to find potential for performance improvement**



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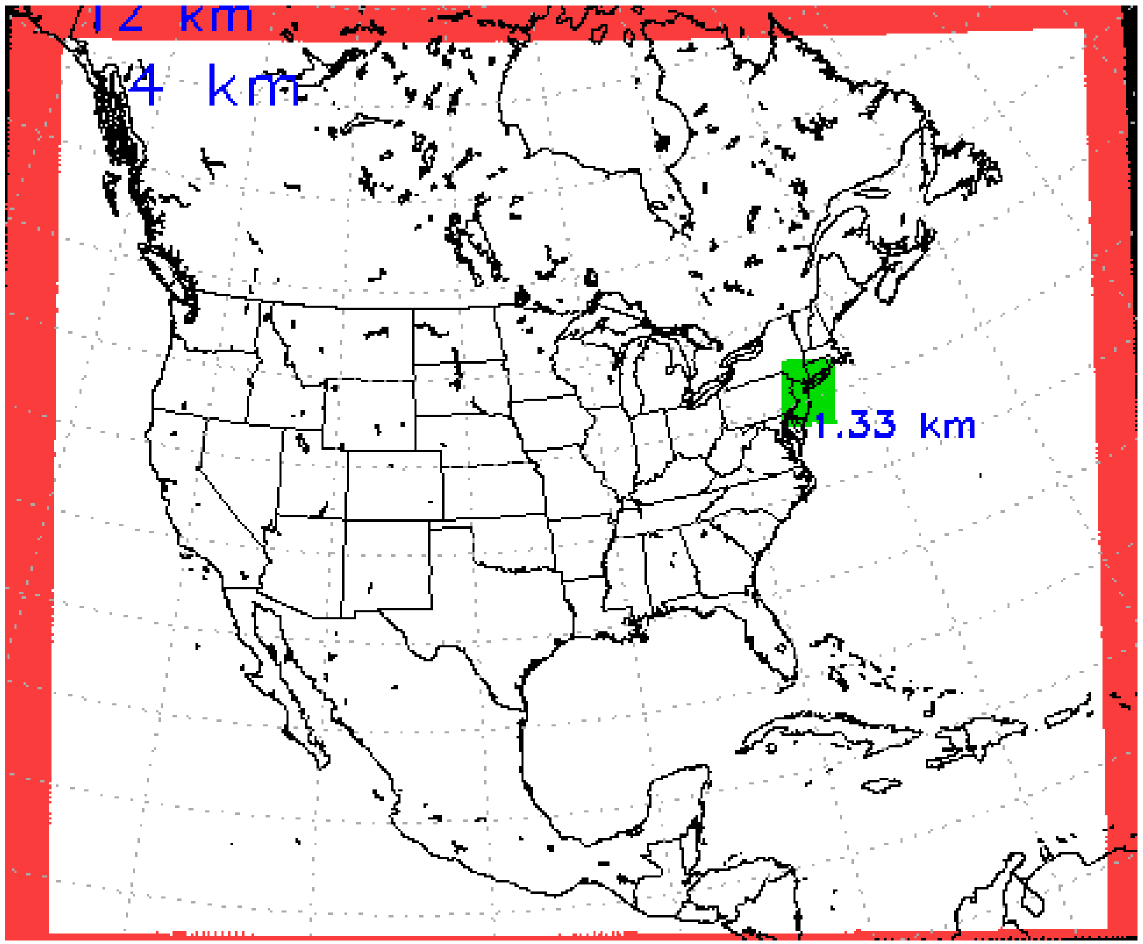
Hardware and Software Used

- **Hardware:**
  - Infiniband FDR (56 Gb/s, 0.7 µs)
  - 18 Compute Nodes, each with:
    - 2 Intel E5-2697 Processors = 24 cores/node
    - 64 GB memory
  - Total of 432 cores
- **Software:**
  - Intel compilers version 15.0.0.90
  - Intel mpi 5.0 Update 1
  - Intel Trace Analyzer and Collector 9.0 Update 1

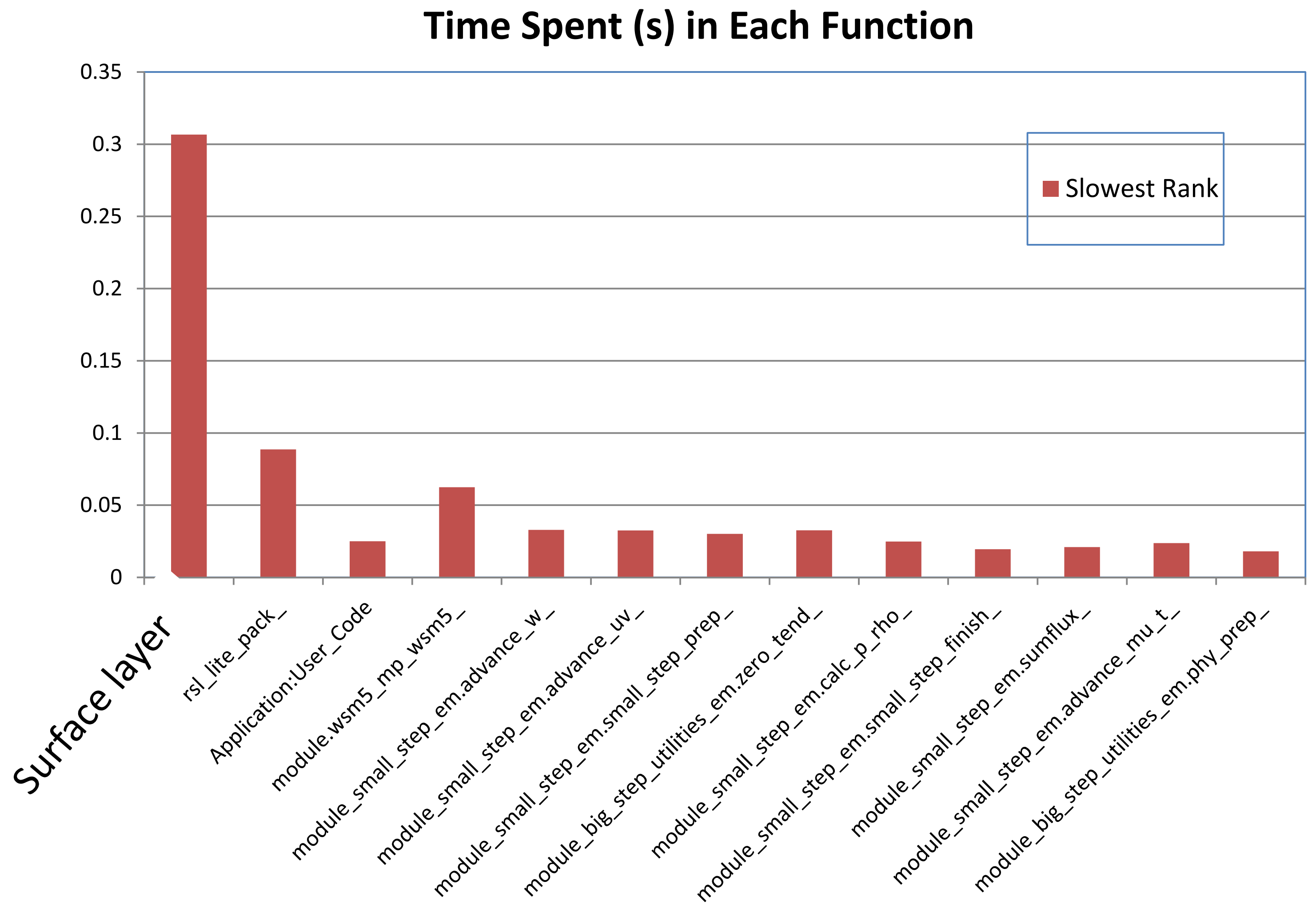
WRF Configuration



Model Setup:

- **WRF ARW v3.6.1**
- **12/4 km, 38 levels**
- **4k feeds back to 12k**
- **Physics:**
  - CU: KF on 12k
  - PBL: YSU
  - MP: WSM5
  - RA: RRTM/Goddard
- **MPI only (no OpenMP)**
- **51/72 hr model runs:**
  - We'll look at first 12 hrs here

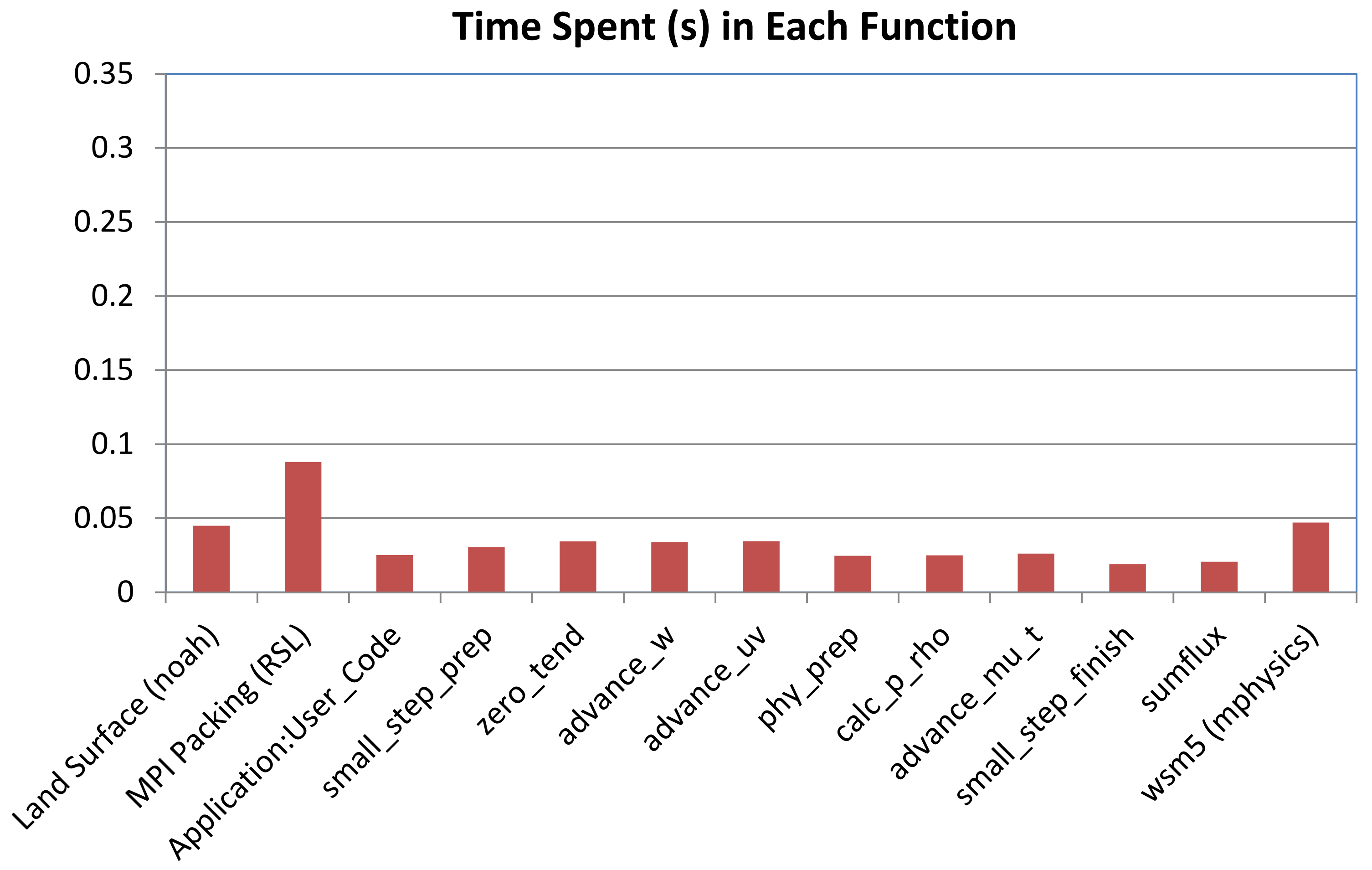
A quick profile of one rank, one time step



The profile reveals:

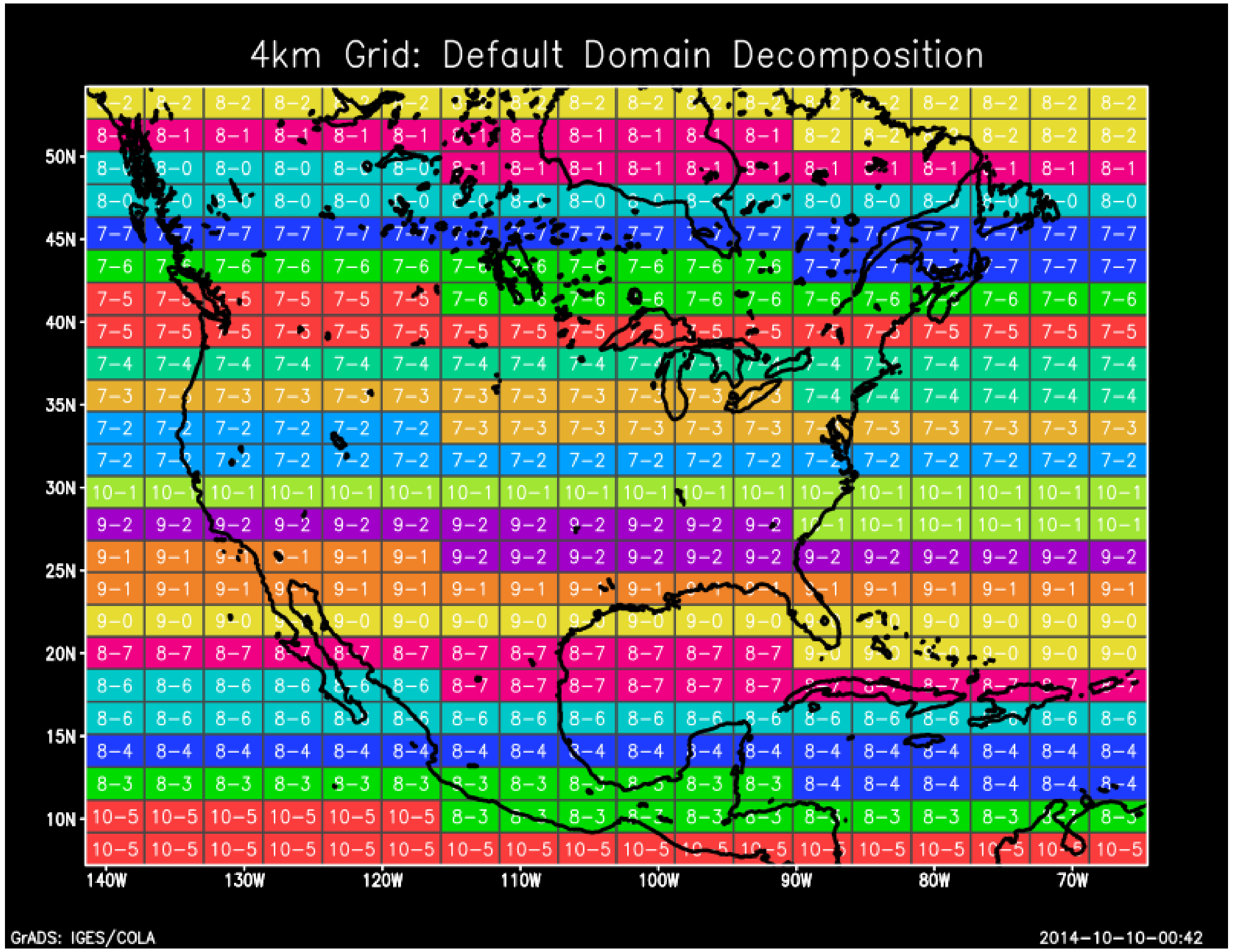
- The surface layer calculation (sf_sfclay=1) is taking up 40% of the run time!
- Further analysis showed that this was an issue introduced in WRF3.6
- WRF Developers at NCAR are investigating
- The quick fix is to set sf_sfclay=91 (the older version of this surface layer scheme)

The profile again, with sfclay=91



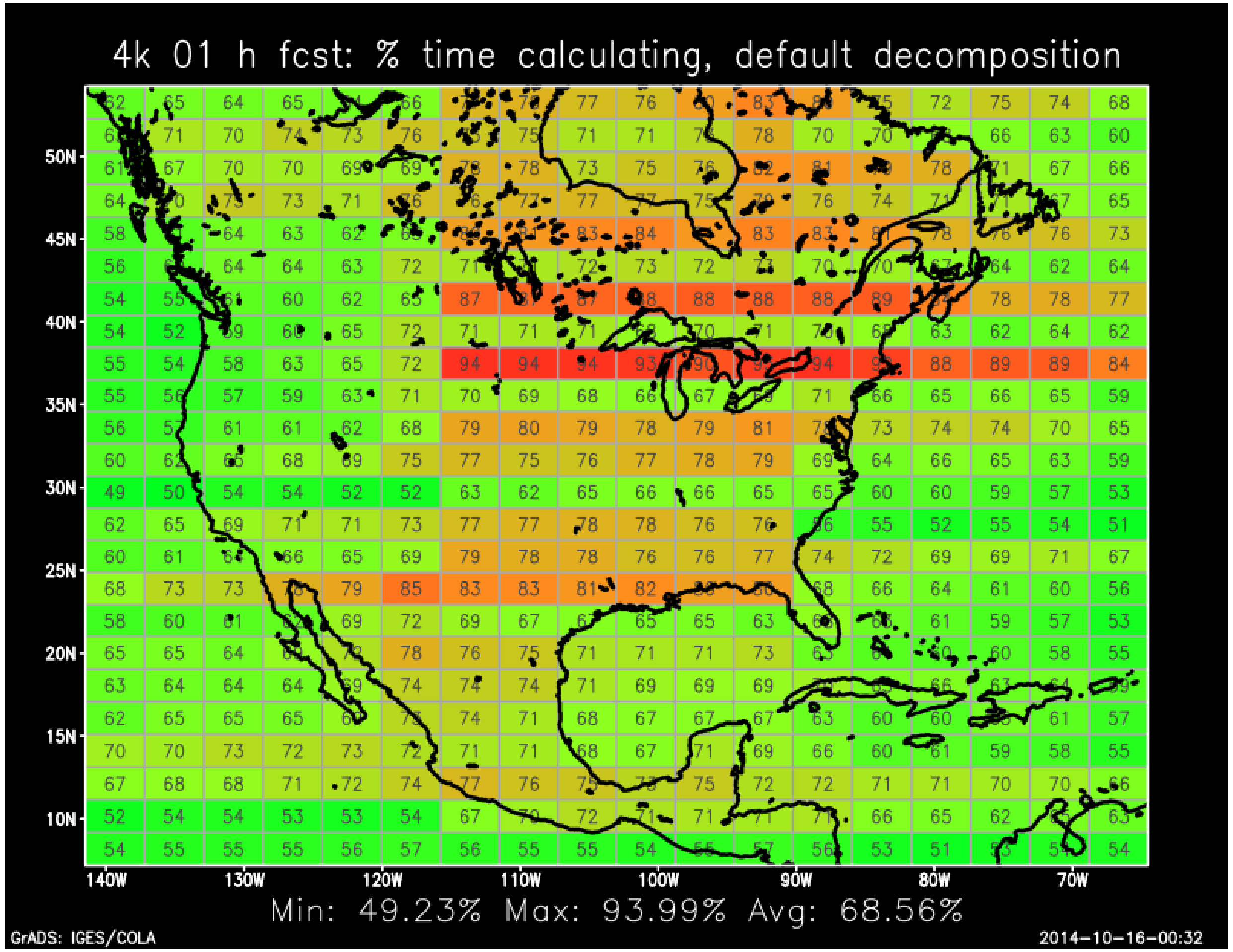
Now, the surface layer doesn't make the top 13!

Default Decomposition of 4km Domain



- **Each Patch is a different cpu core**
- **Each color a different compute node**

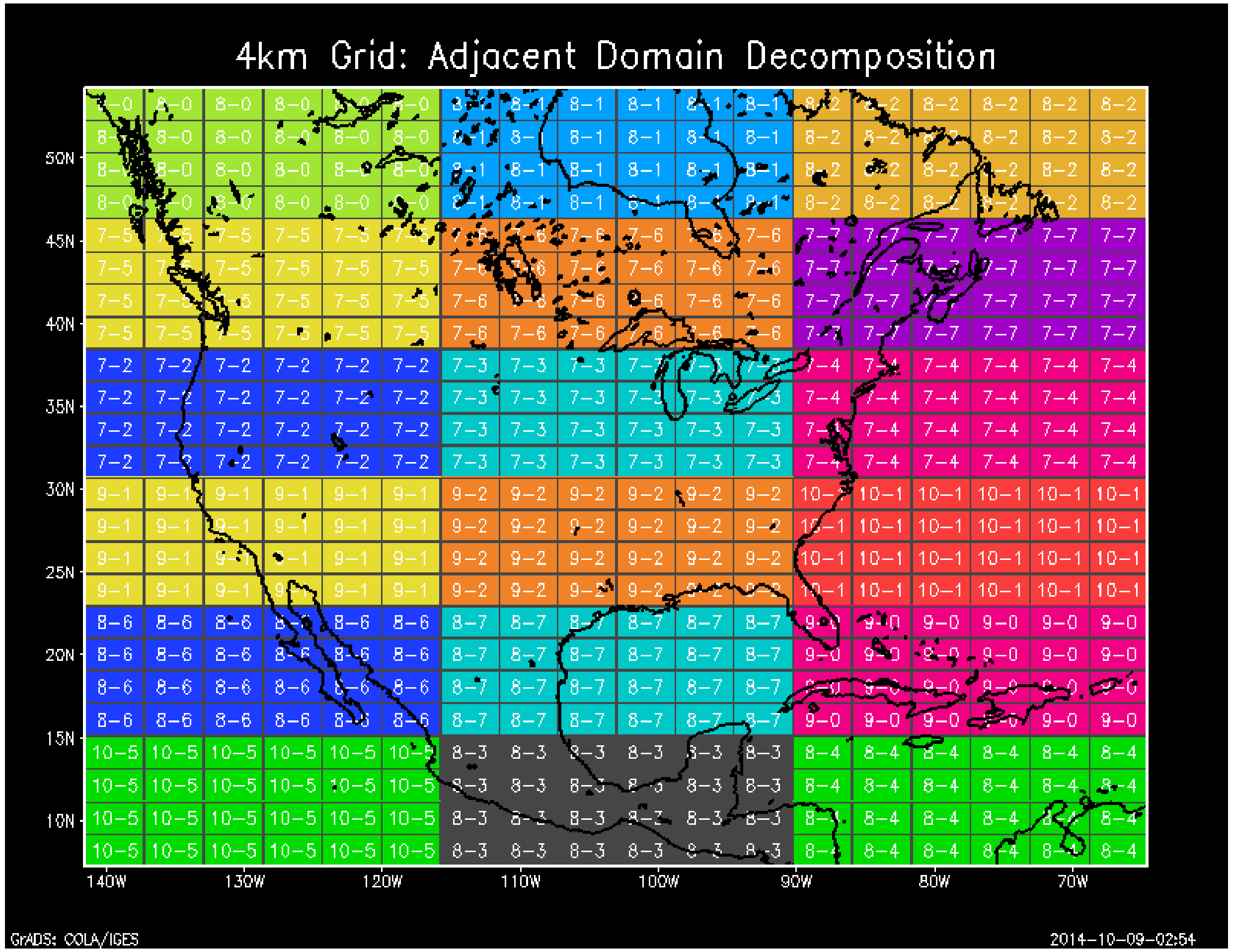
Default Decomposition: Relative Run Time for patches



4k 01 h fcst: % time calculating, default decomposition
50N
45N
40N
35N
30N
25N
20N
15N
10N
140W
130W
120W
110W
100W
90W
80W
70W
Min: 49.23% Max: 93.99% Avg: 68.56%
GrADS: IGES/COLA
2014-10-16-00:32

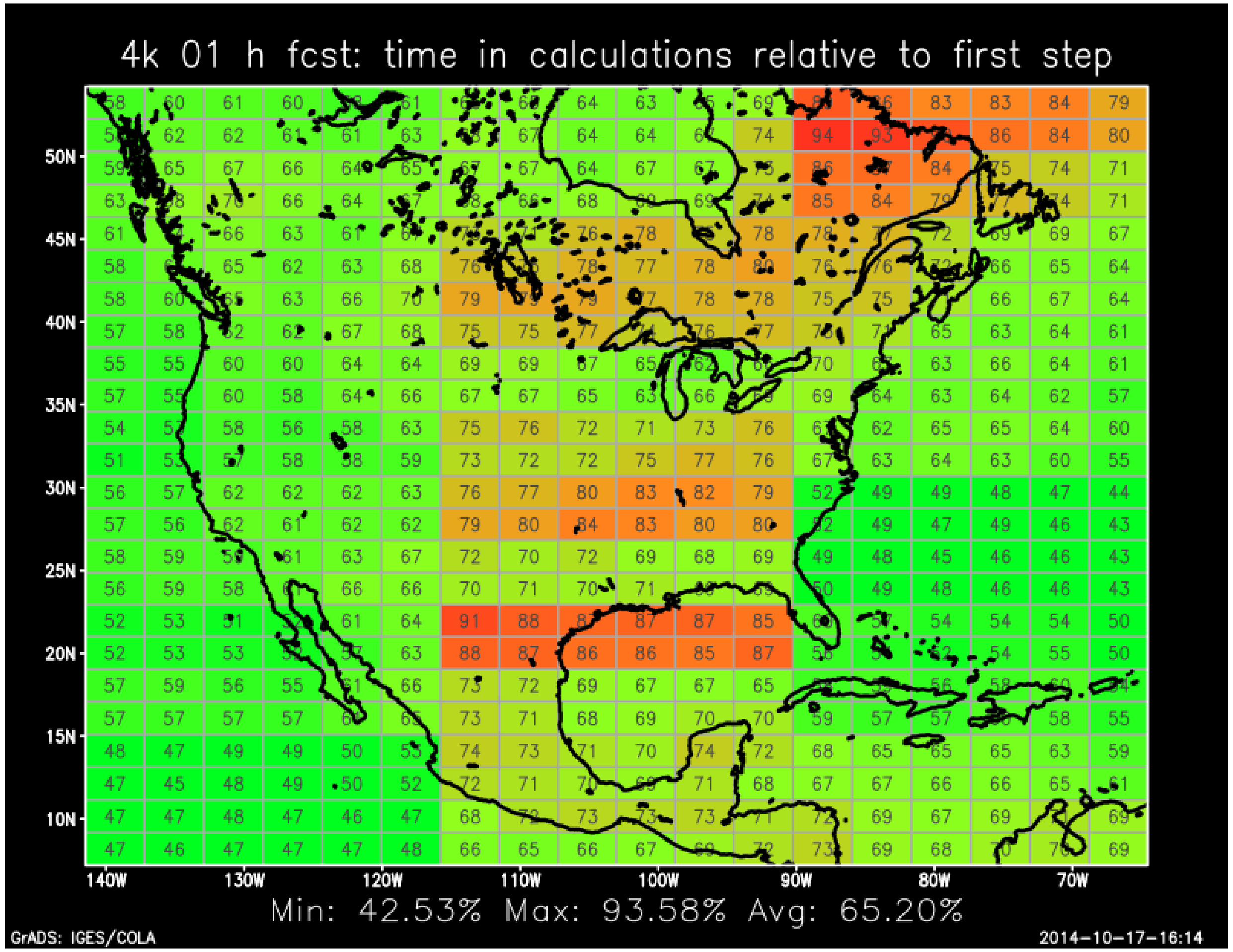
- **Relative (%) time that is spent computing**
- **Green: Low compute time**
- **Red: High compute time**

Adjacent Decomposition



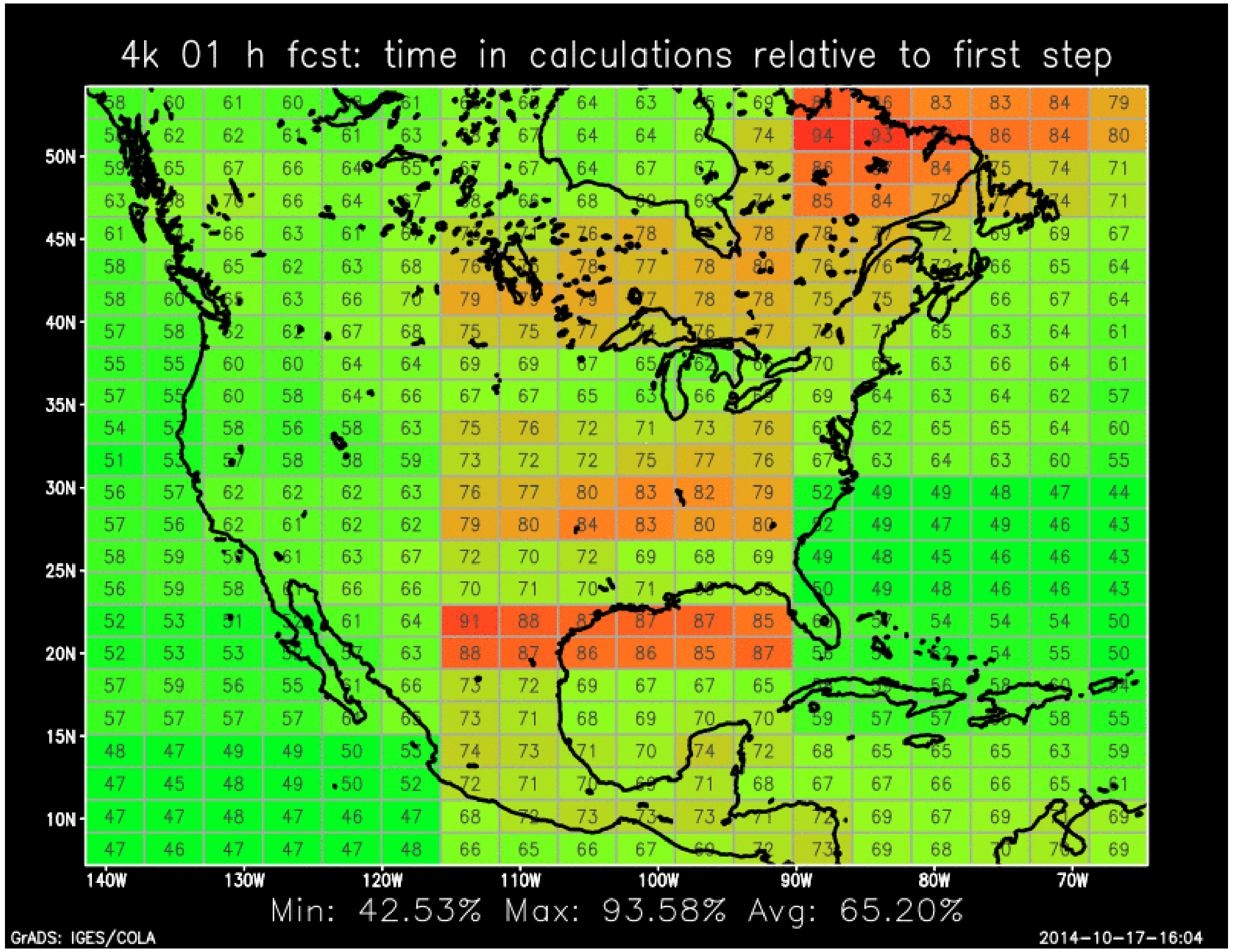
- That’s easier to see!

Adjacent Decomposition Timing


4k 01 h fcst: time in calculations relative to first step
50N
45N
40N
35N
30N
25N
20N
15N
10N
140W
130W
120W
110W
100W
90W
80W
70W
Min: 42.53% Max: 93.58% Avg: 65.20%
GrADS: IGES/COLA
2014-10-17-16:14

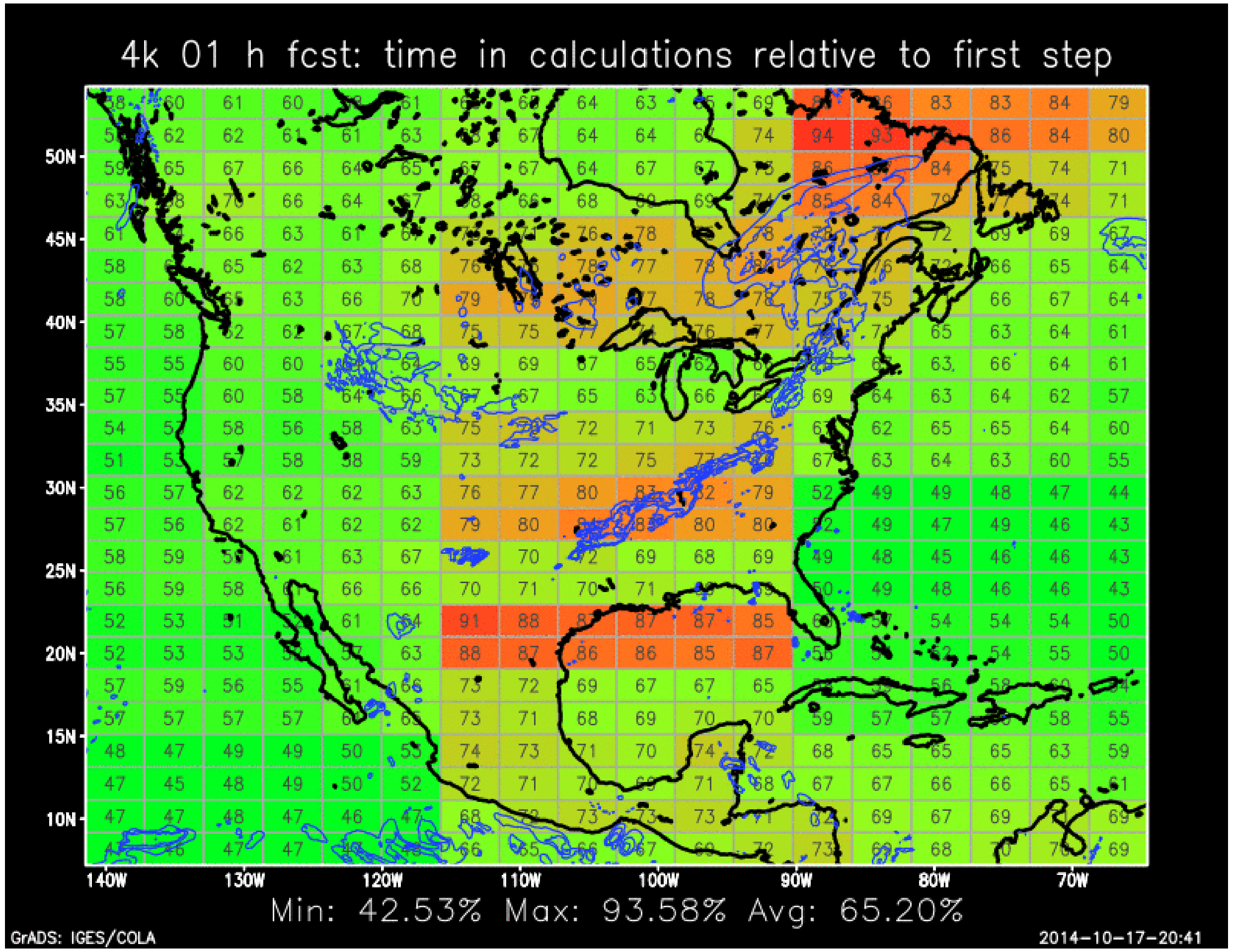
- And now we see some dependence on processor
- Total run-time same as before, average decreased by 2%

Patch timing every hour


4k 01 h fcst: time in calculations relative to first step
50N
45N
40N
35N
30N
25N
20N
15N
10N
140W
130W
120W
110W
100W
90W
80W
70W
Min: 42.53% Max: 93.58% Avg: 65.20%
GrADS: IGES/COLA
2014-10-17-16:04

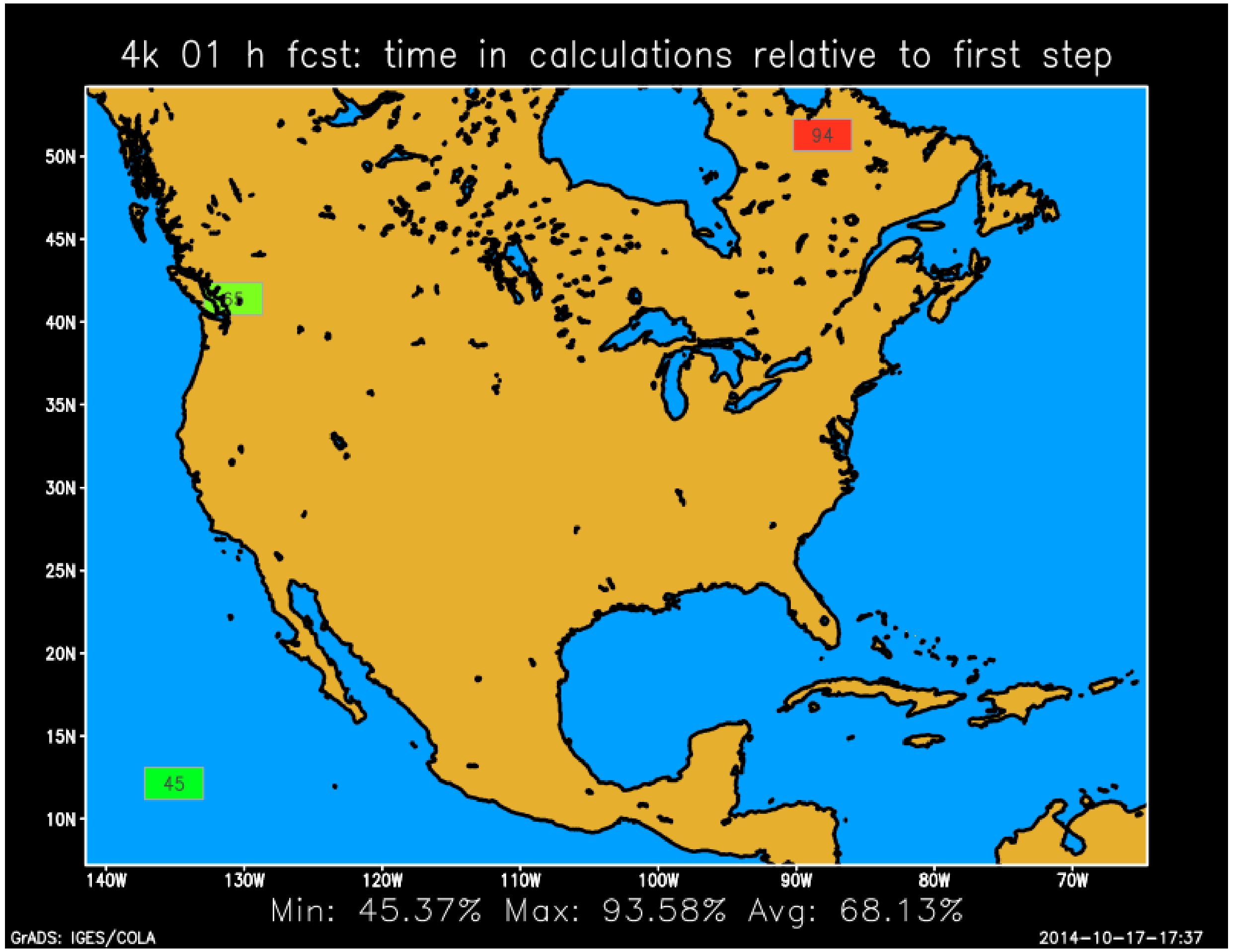
- **Patch timing relative to first 1 hour step time**

Patch timing with precip

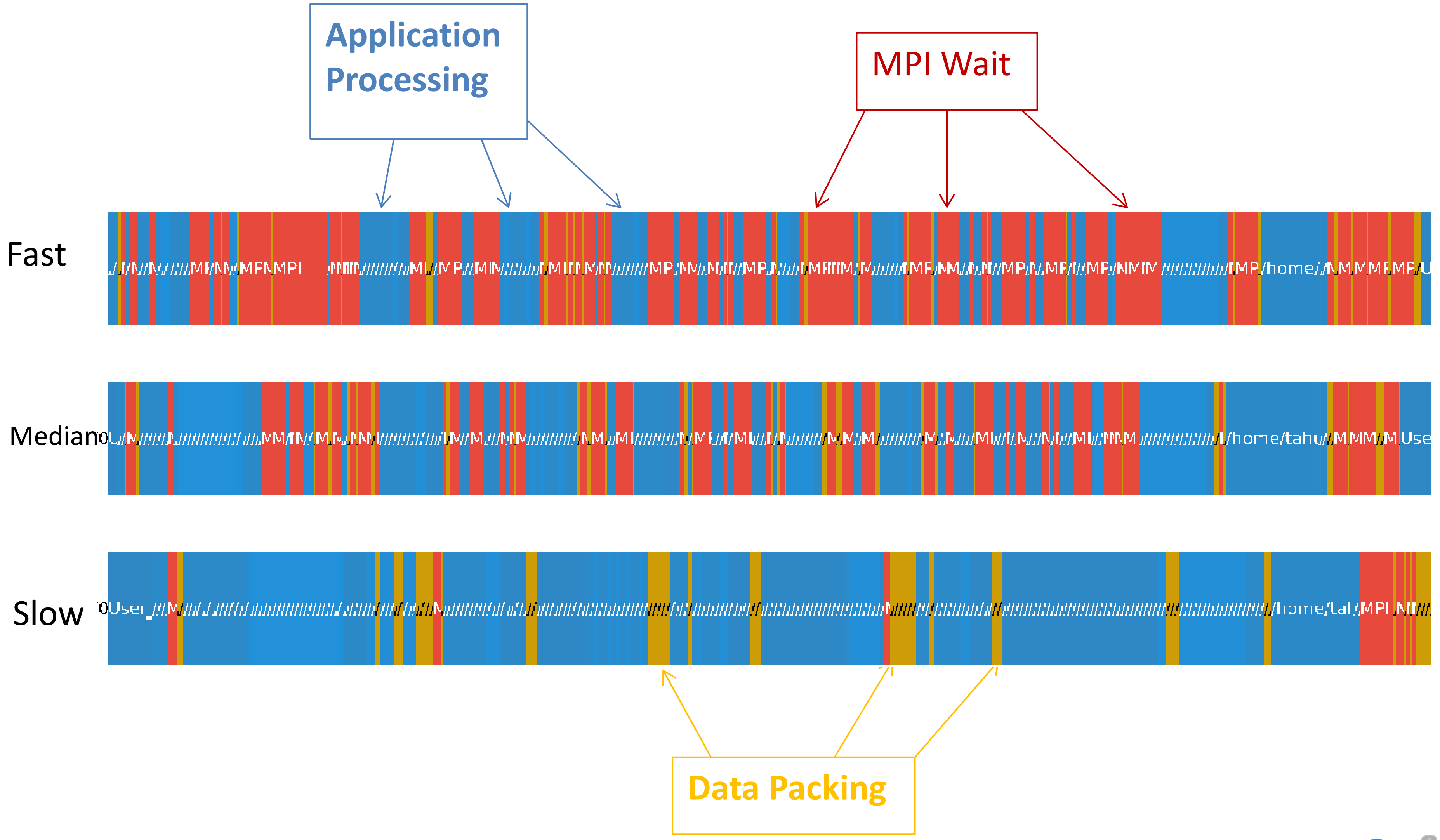

4k 01 h fcst: time in calculations relative to first step
50N
45N
40N
35N
30N
25N
20N
15N
10N
140W
130W
120W
110W
100W
90W
80W
70W
Min: 42.53% Max: 93.58% Avg: 65.20%
GrADS: IGES/COLA
2014-10-17-20:41

- **60-minute precip accumulation overlaid**

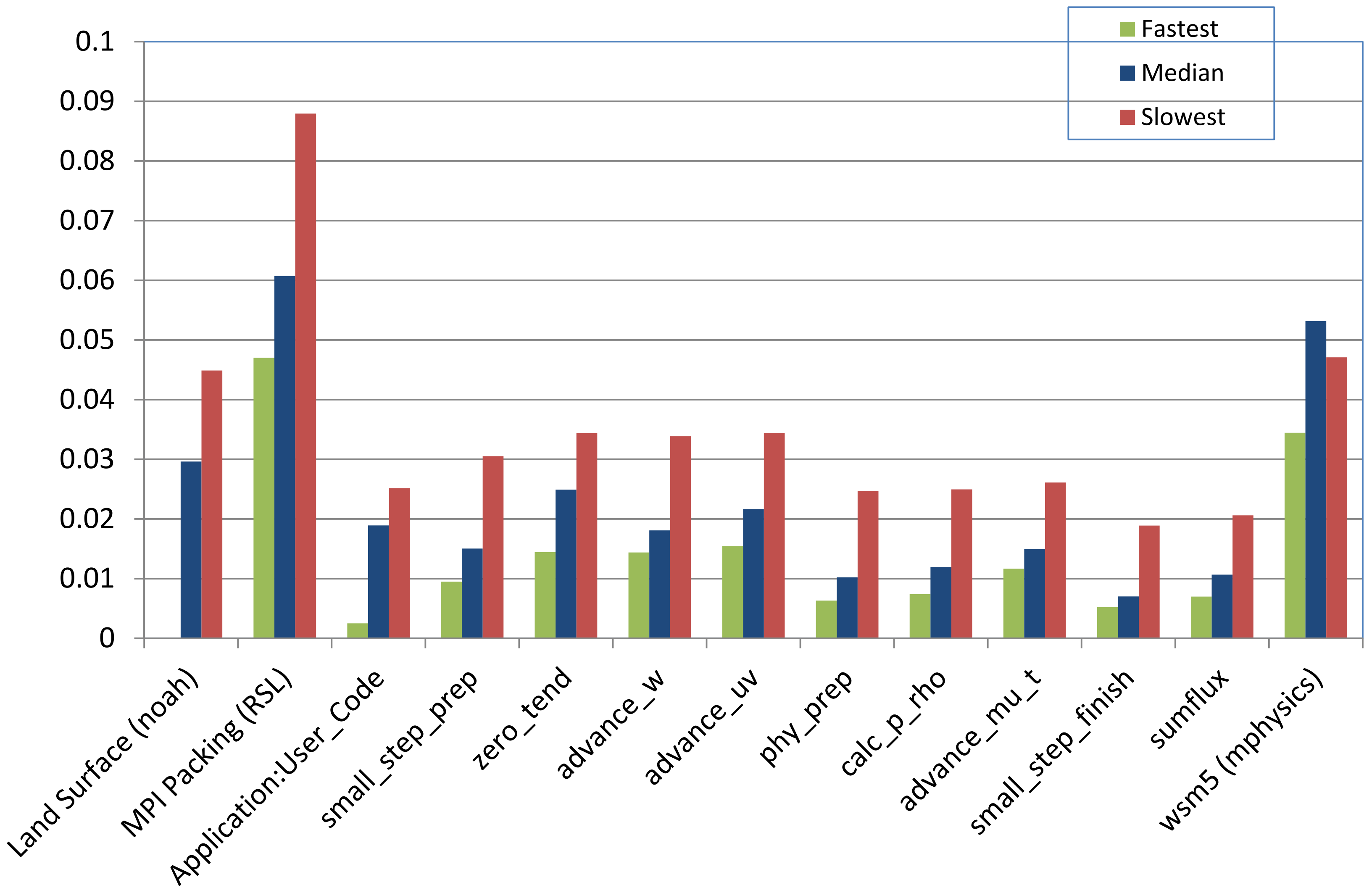
Slowest, Median, Fastest Patches



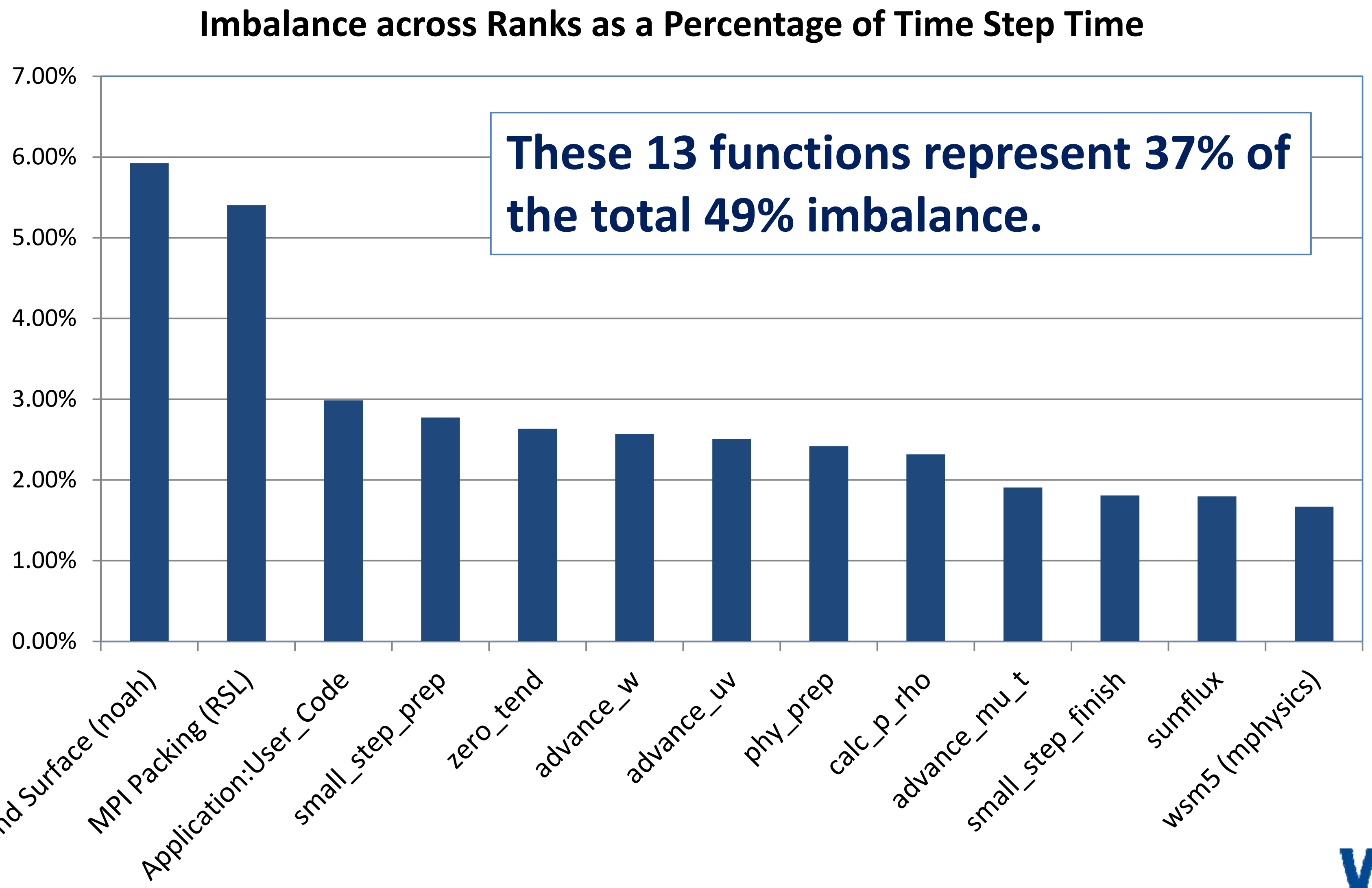
Traces over 1 time step



Profile of the 3 traces



Imbalance across the three Patches



These 13 functions represent 37% of the total 49% imbalance.

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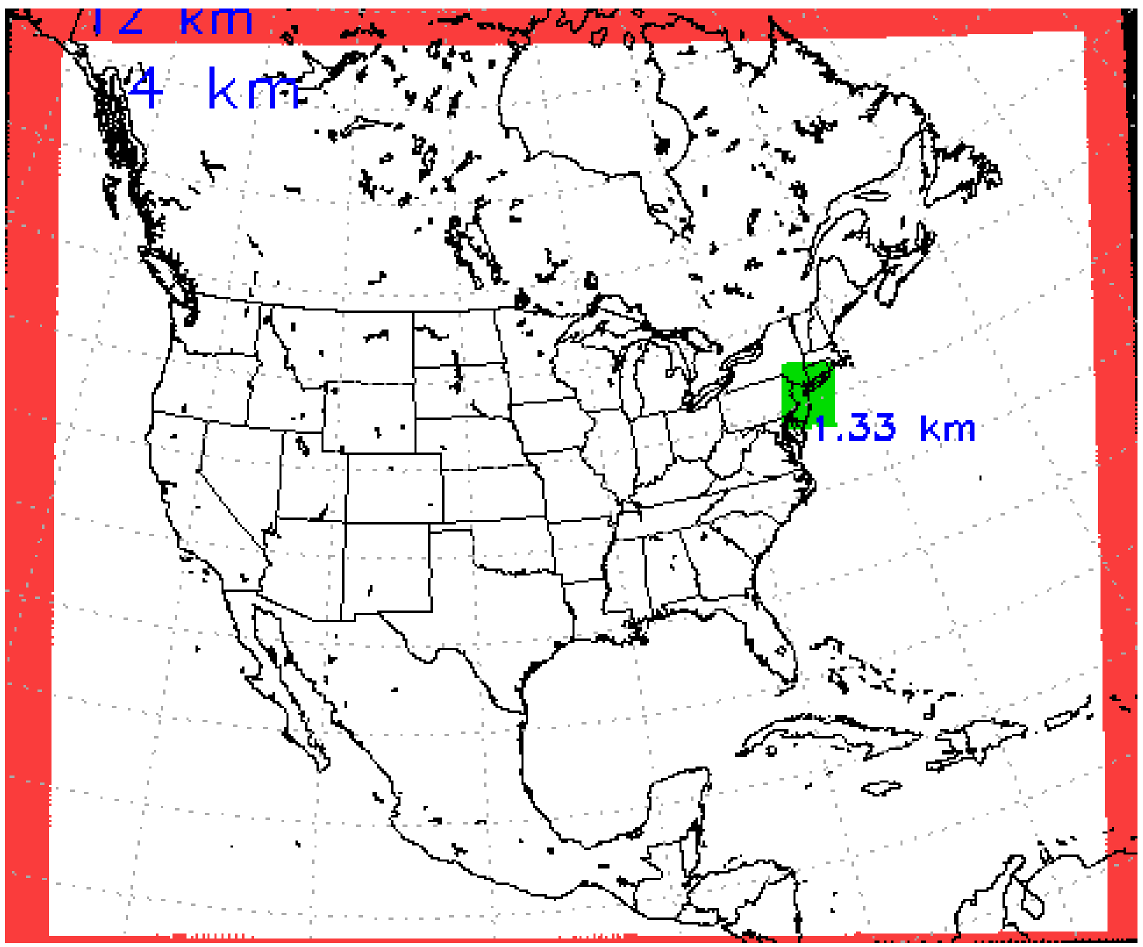
WRF Configuration



Model Setup:

- **WRF ARW v3.6.1**
- **12/4/1.33 km, 38 levels**
- **4k feeds back to 12k**
- **Physics:**
  - CU: KF on 12k
  - PBL: YSU
  - MP: WSM5
  - RA: RRTM/Goddard
  - 38 levels
- **MPI only (no OpenMP)**
- **51/72 hr model runs:**
  - We'll look at first 12 hrs

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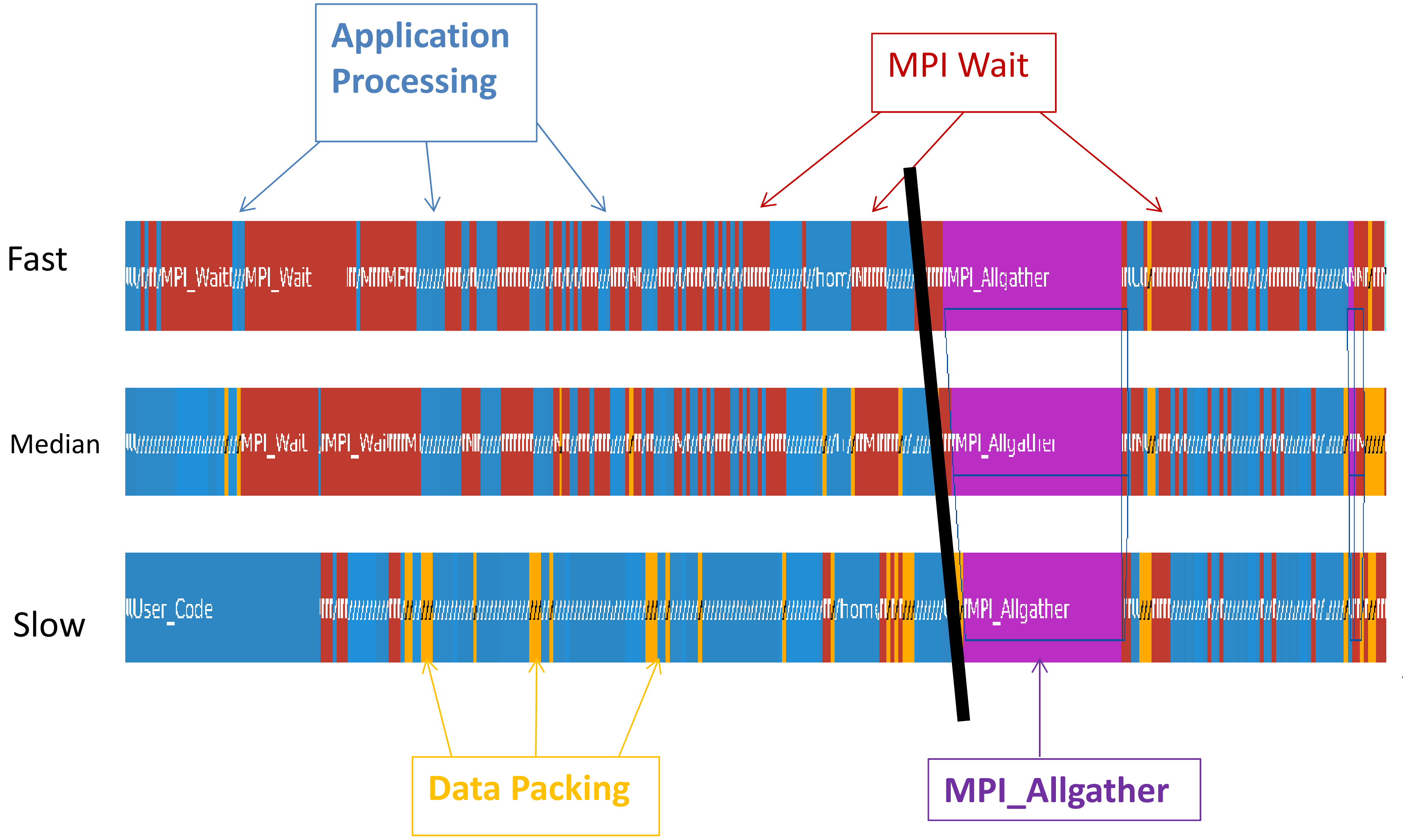
Time of a Single Parent Step

	Time (s)	Increase Size x # steps	Cumulative increase in grid points	Cumulative % increase in time
12k	0.131	555x473 x 1	--	--
12k + 4k	2.941	1525x1309 x 3	22.8x	22.5x
12k + 4k + 1.3k	**5.123**	229x280 x 9	1.092x	**1.74x**

Having a small nest within a large parent appears to be expensive!

Trace of 4km and 1.3km steps



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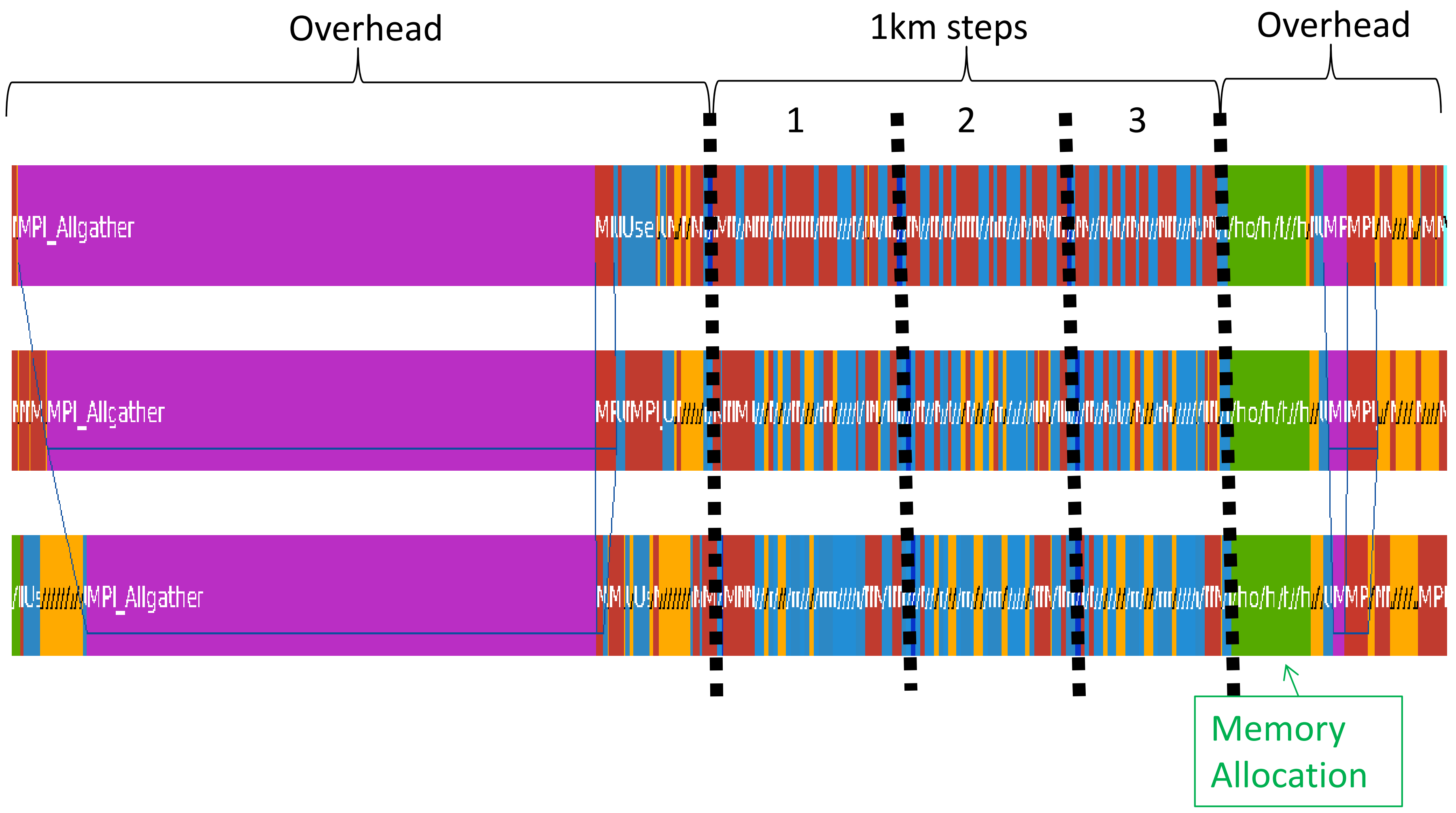
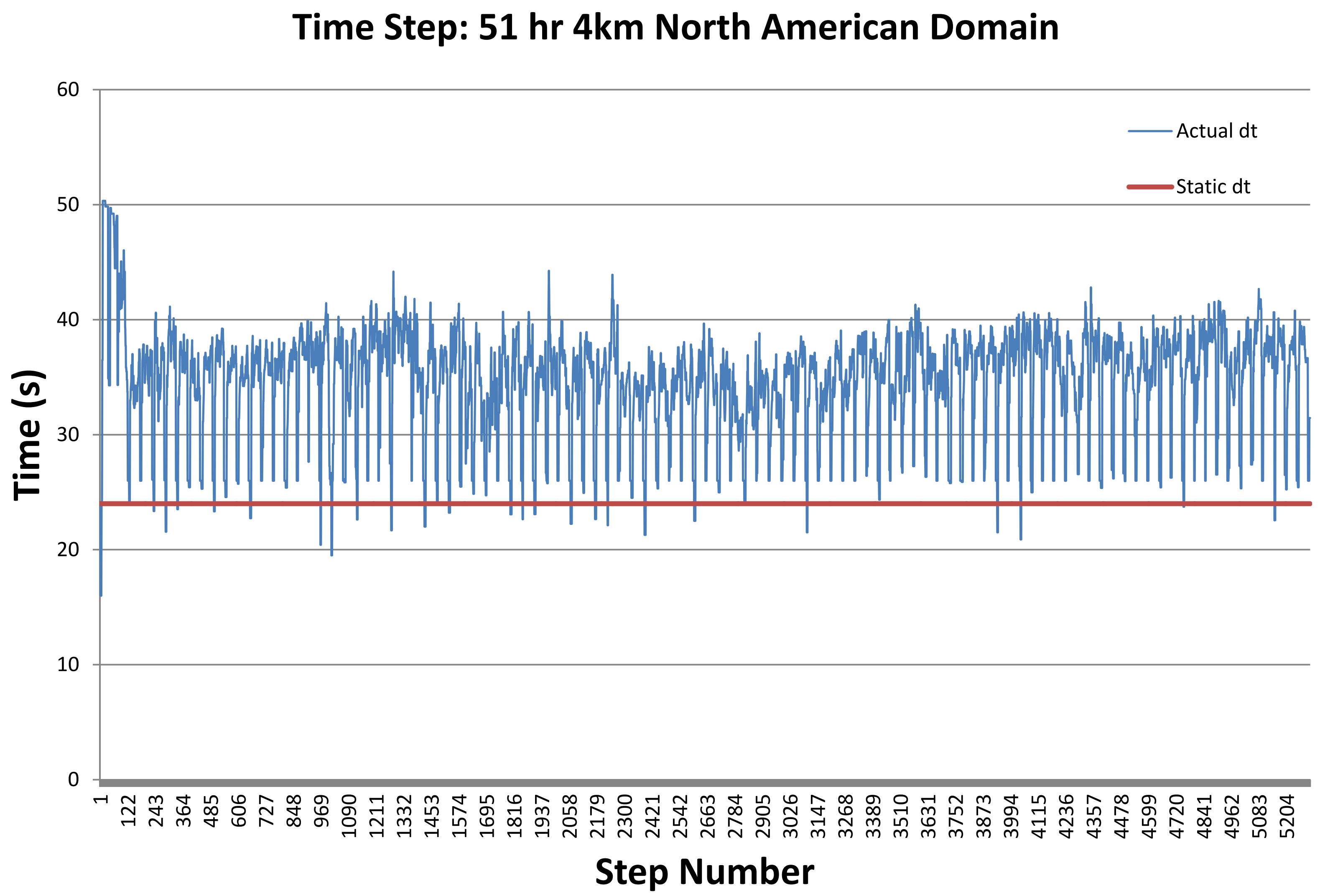
Analysis of 1.33km step



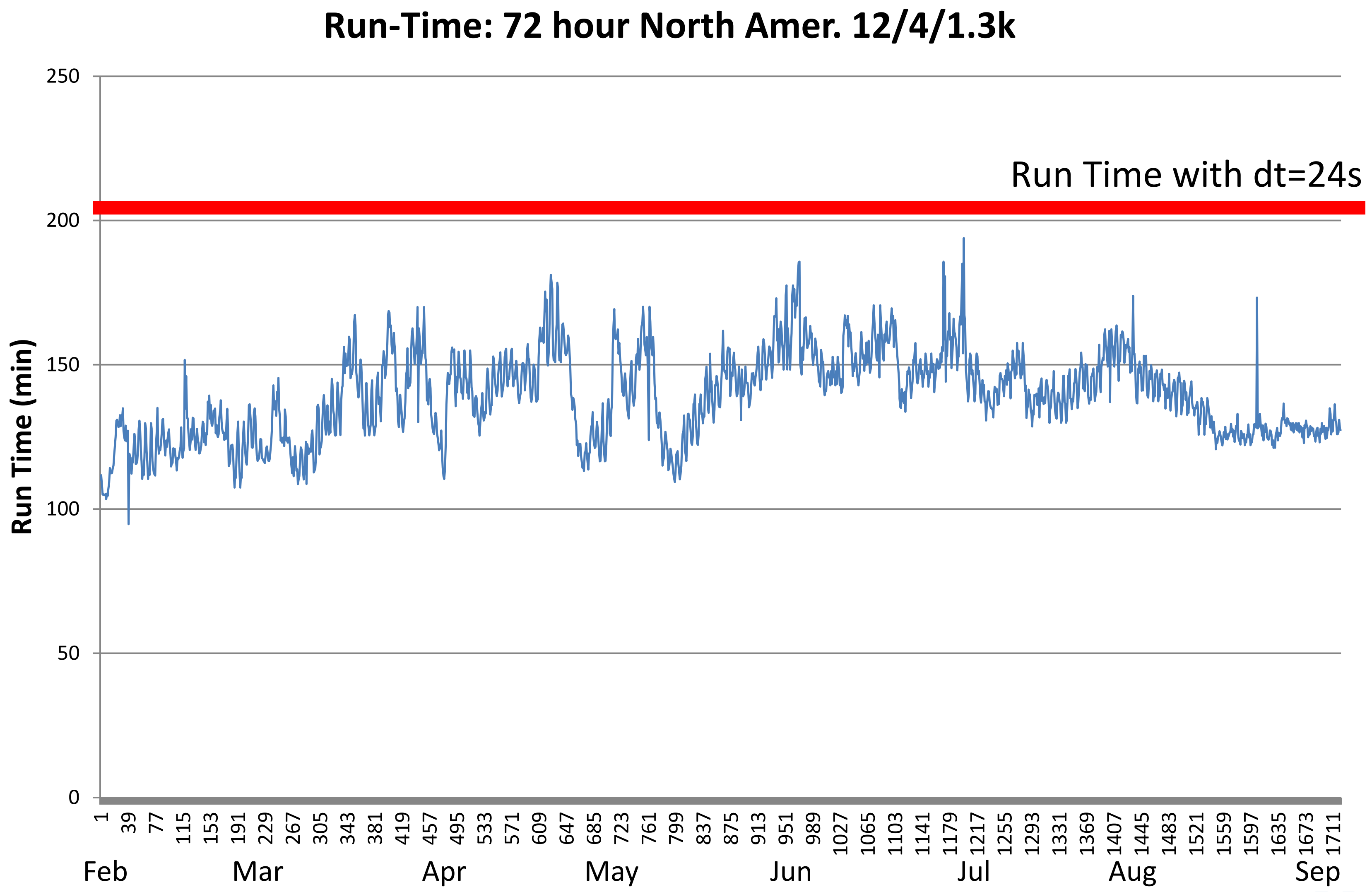
Adaptive Time-Step

- **Automatically adapt the time-step to support maximum horizontal and vertical motions**
- **Adaptation assures stability**
- **Total Run-time reduced if average time-step exceeds static time-step**

Time Step: Operational Run 26 Oct 2014



Run Time



Run-Time: 72 hour North Amer. 12/4/1.3k
Run Time with dt=24s
Run Time (min)
250
200
150
100
50
0
1
39
77
115
153
191
229
267
305
343
381
419
457
495
533
571
609
647
685
723
761
799
837
875
913
951
989
1027
1065
1103
1141
1179
1217
1255
1293
1331
1369
1407
1445
1483
1521
1559
1597
1635
1673
1711
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep

Implementation Details/Challenges

- **Look-ahead and adjust time-step to fall upon "history" and boundary input times**
  - Look ahead 2 steps to prevent very short steps
- **Nesting: Assure that nest and parent are sync'ed:**
  - Parent step adjusted to be a multiple of nest step
  - Let most expensive domain control the time-step
- **Very steep topography (Mt. St. Elias…):**
  - Have seen crash (on order of 1-2x per year out of 3000 model runs)
  - Recent adjustments to "look-ahead" with nesting may have resolved this

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Summary/Findings

- **Performance:**
  - WRF runs faster over oceans than land
  - There's a lot of "noise" across the domain that needs to be better understood
  - Nesting Can be Expensive!
- **Adaptive time-step can be used to optimize performance**

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