Performance and Usage Analytics for NCAR's Climate Model

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Summer Internships in Parallel Computational Science (SIParCS)

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Overview

1. Background on Community Earth System Model (CESM)

2. Model's configuration

3. Data preparation and analysis

4. Key findings

5. Conclusion and future work

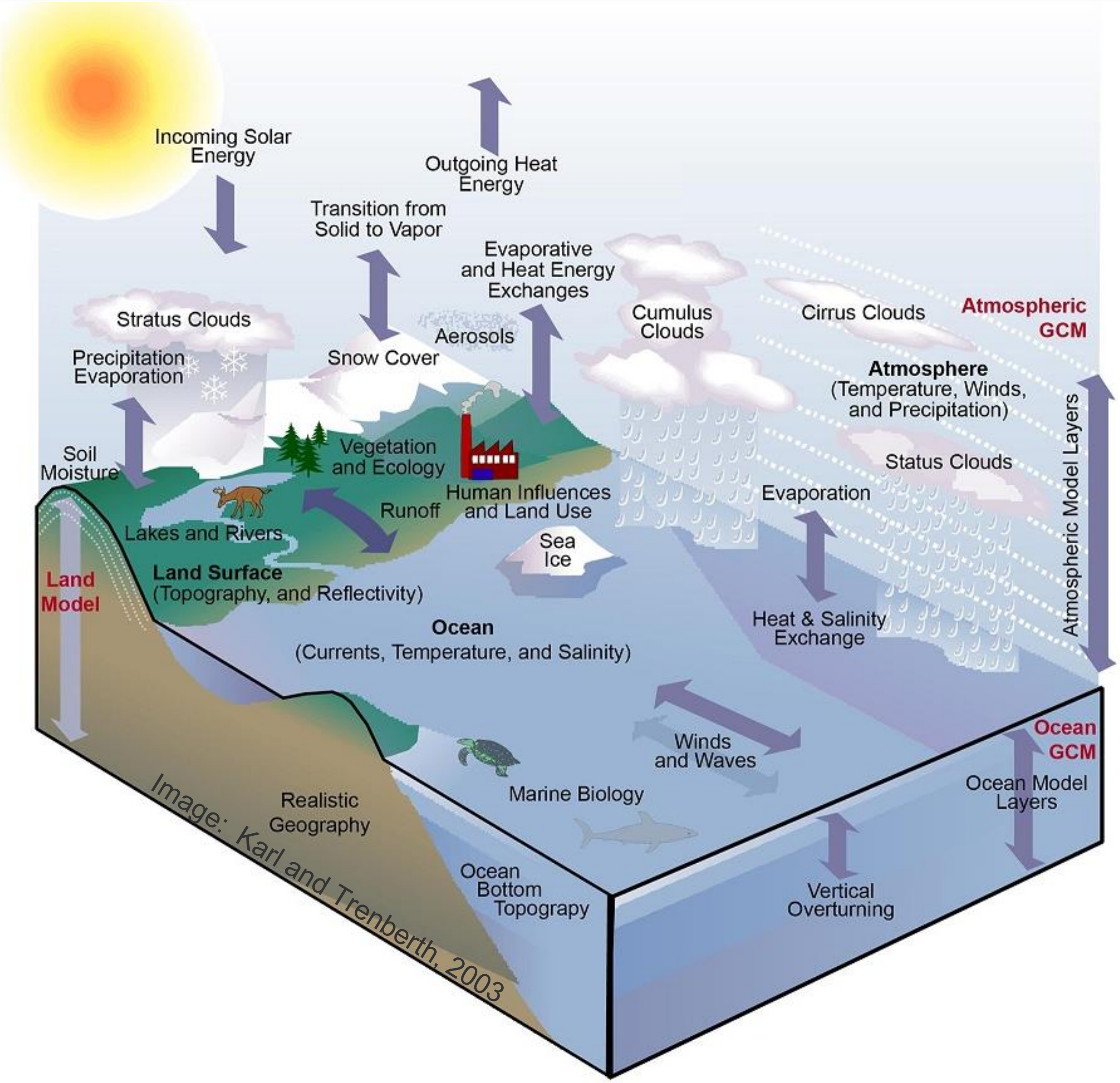
Image: http://www.cesm.ucar.edu/models/

Goal

Analyze CESM performance metadata

- ❑ Establish basic metrics
- ❑ Effect of a system upgrade on performance

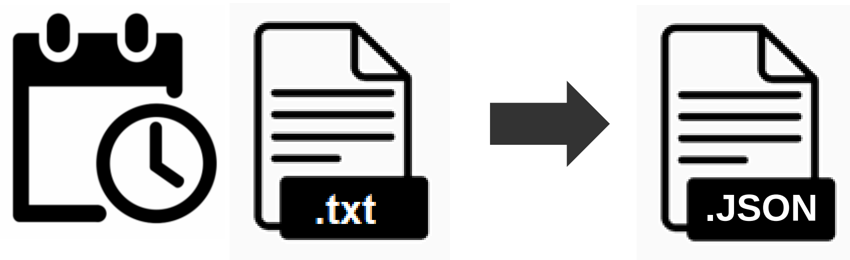
CESM Climate Model



- **Virtual laboratory**
- **Freely available**
- **Components:**
  - Atmosphere
  - Land
  - Ocean
  - River
  - Sea and Land Ice
  - Wave

CESM = Community Earth System Model

Method



1

Data Engineering

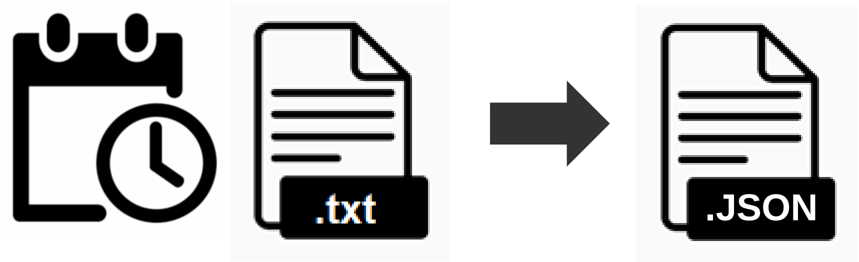
- **Acquiring**
- **Saving**

```
|---------------- TIMING PROFILE ---------------------
  Case          : b.e21.BHIST.f09_g17.CMIP6-historical.001
  LID           : 2979765.chadmin1.181015-050236

  User          : cmip6
  Curr Date     : Mon Oct 15 10:01:22 2018
  grid          :
a%0.9x1.25_l%0.9x1.25_oi%gx1v7_r%r05_g%gland4_w%ww3a_m%gx1v7
  compset       : HIST_CAM60_CLM50%BGC-CROP_CICE_POP2%ECO%ABIO-
                  DIC_MOSART_CISM2%NOEVOLVE_WW3_BGC%BDRD
  run_type      : hybrid, continue_run = TRUE (inittype = FALSE)
  stop_option   : nyears, stop_n = 5
  run_length    : 1825 days (1825.0 for ocean)

  Init Time     :       63.817 seconds
  Run Time      :    17837.627 seconds        9.774 seconds/day
  Final Time    :        0.057 seconds
```

Method



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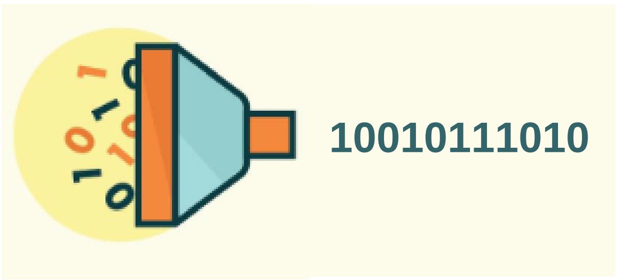

2

Data Wrangling
- Reindexing
- More parsing
- Set data types
- Intuitive columns
- Calculations

Data Wrangling

Parse Run_Length

```
3650 days (3650.0 for ocean)
```

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#1. Strip everything after "days" in run_length column
df['run_length_temp'] = df['run_length'].str.split('(').str[0]

#Confirm every run_length contains the same units of days
substr = 'days'
print ("Rows in df:", len(df))
print ("Rows with units of days:", df.run_length_temp.str.count(substr).sum())
```

```
Rows in df: 5160
Rows with units of days: 5160
```

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#2. Strip "days" in run_length column
df['run_length_days'] = df['run_length_temp'].str.split('d').str[0]
df.run_length_days.unique()
```

```
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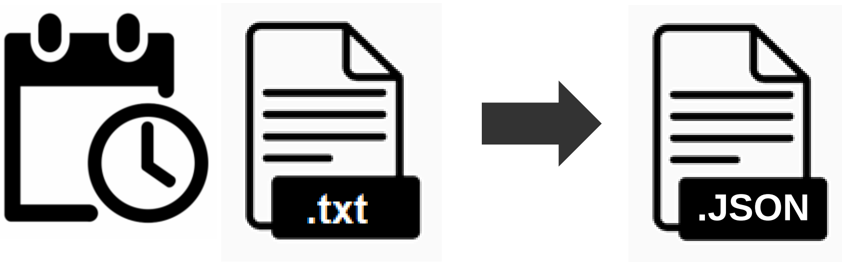
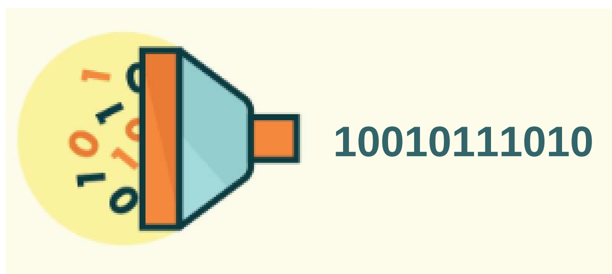
Method



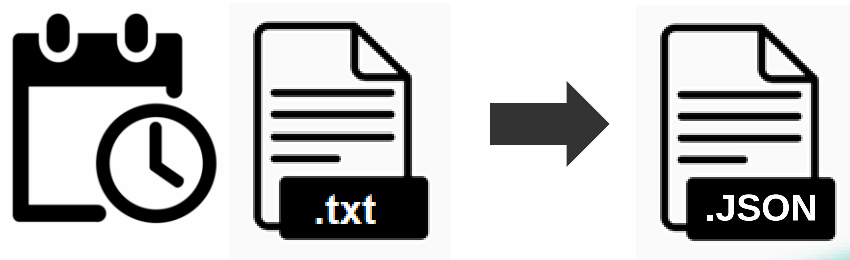
1. **Data Engineering**
   - Acquiring
   - Saving



2. **Data Wrangling**
   - Reindexing
   - More parsing
   - Set data types
   - Intuitive columns
   - Calculations

3. **Data Storage**

Method



1

Data Engineering
- Acquiring

ling

ata types
- Intuitive columns
- Calculations

USABLE DATA!!

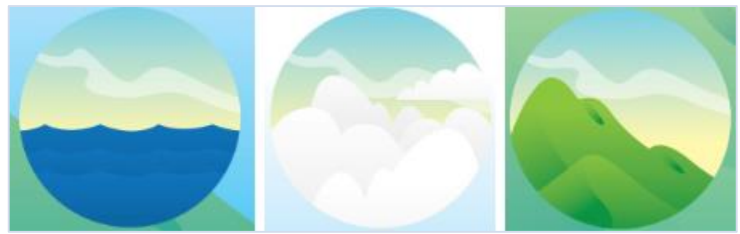
3

Data Storage

Method

4

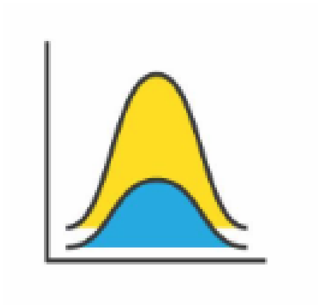
Exploratory Data Analysis



52 unique
component configurations

Method

4 Exploratory Data Analysis

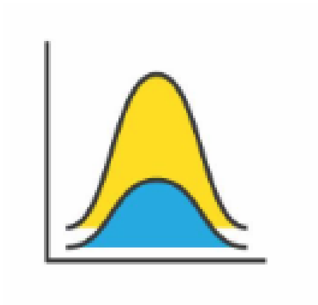


5 Statistical Analysis

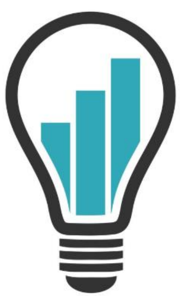
Pandas
Numpy
Scipy Stats
StatsModels

Method

4 Exploratory Data Analysis



5 Statistical Analysis



6 Visualization

MatPlotLib
Seaborn
Plotly

Analysis: Dataset Totals

416 Days

948
Unique Cases

21,785
Simulated Years

137,112,802
CPU Hours

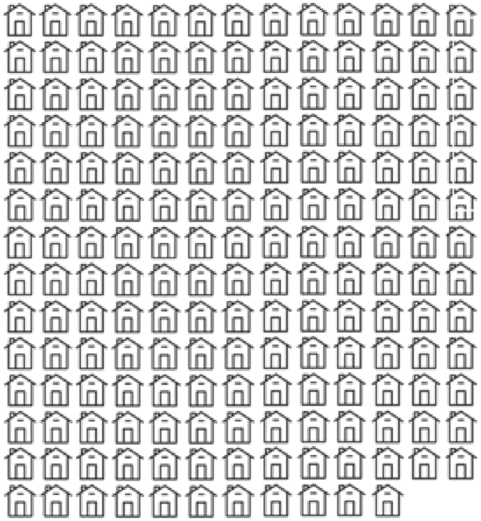
Power Equivalence

137,112,802

CPU Hours

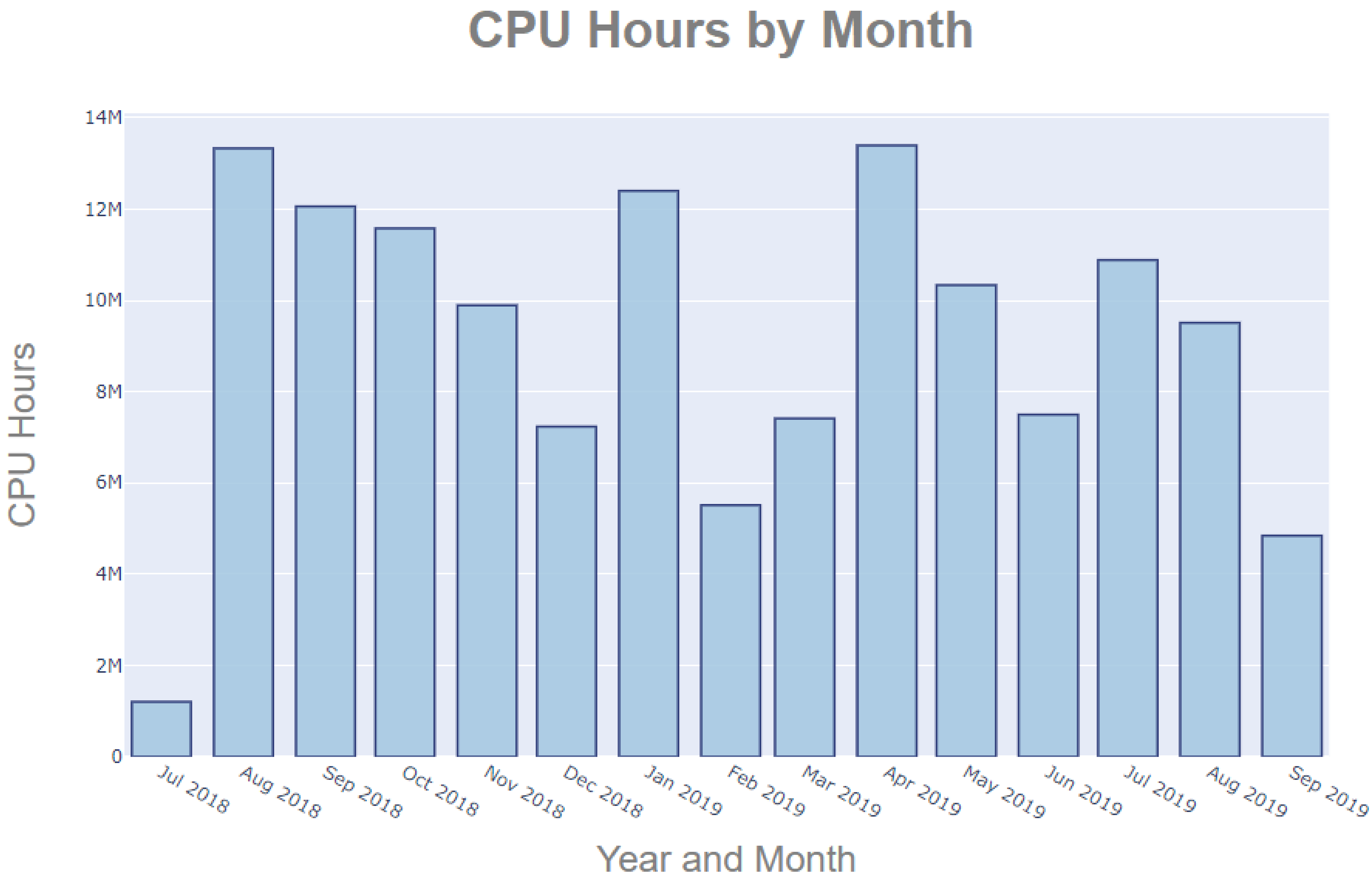
218 trips around the equator in a Nissan Leaf

or



Annual power for 180 Colorado homes

Analysis: Monthly Totals



Analysis: Grouping Atmospheric Configurations

Component string = compset

`'1850_CAM60%1PCT_CLM50%BGC-CROP_CICE%CMIP6_POP2%ECO_MOSART_CISM2%EVOLVE_WW3_BGC%BDRD'`

Init **Atm** **Land** **Sea Ice** **Ocean** **River** **Land Ice** **Wave** **OBGC***

14 unique atmospheric components

***OBGC = Ocean Bio-geo-chemsitry**

Analysis: Grouping Atmospheric Configurations

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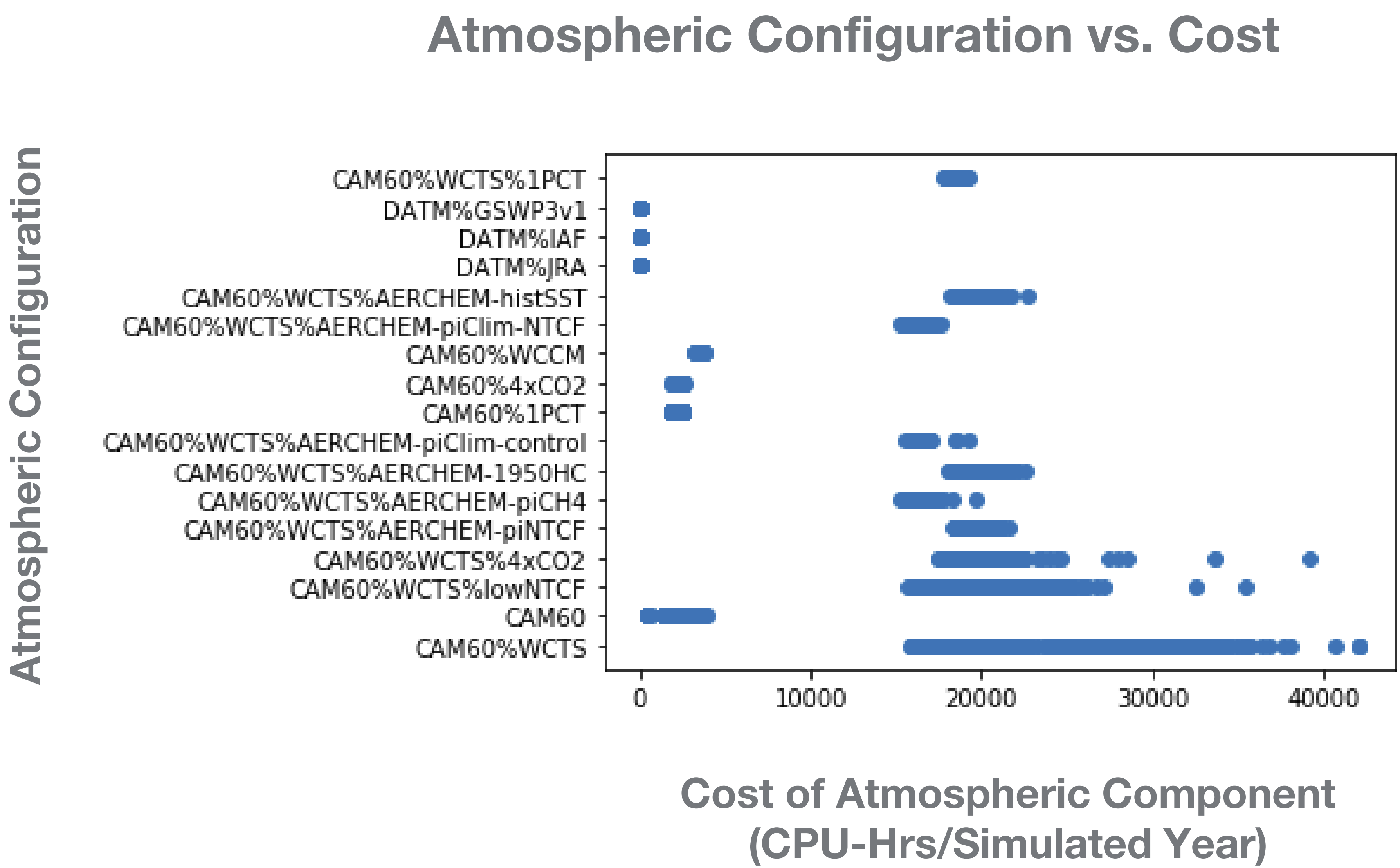

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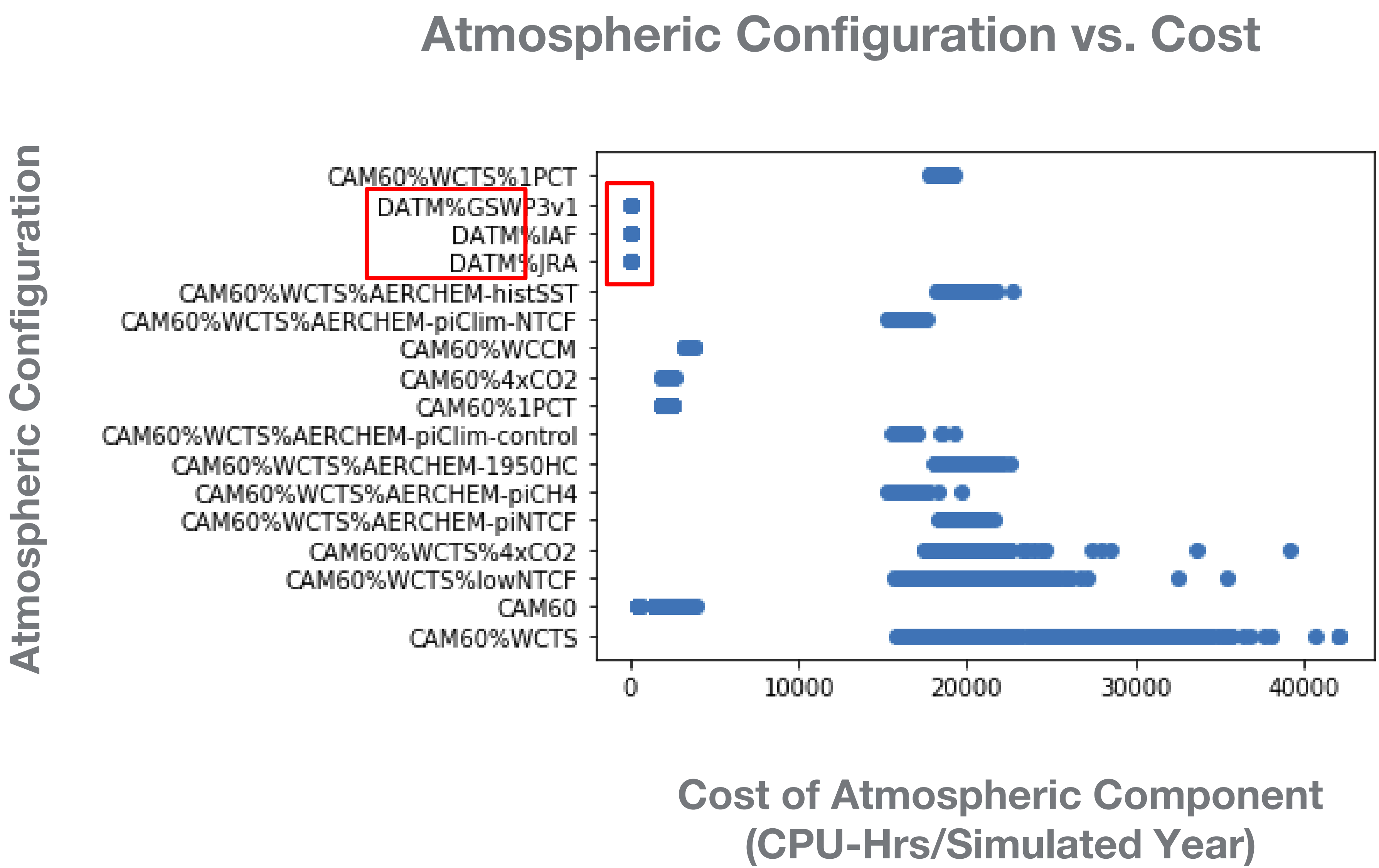

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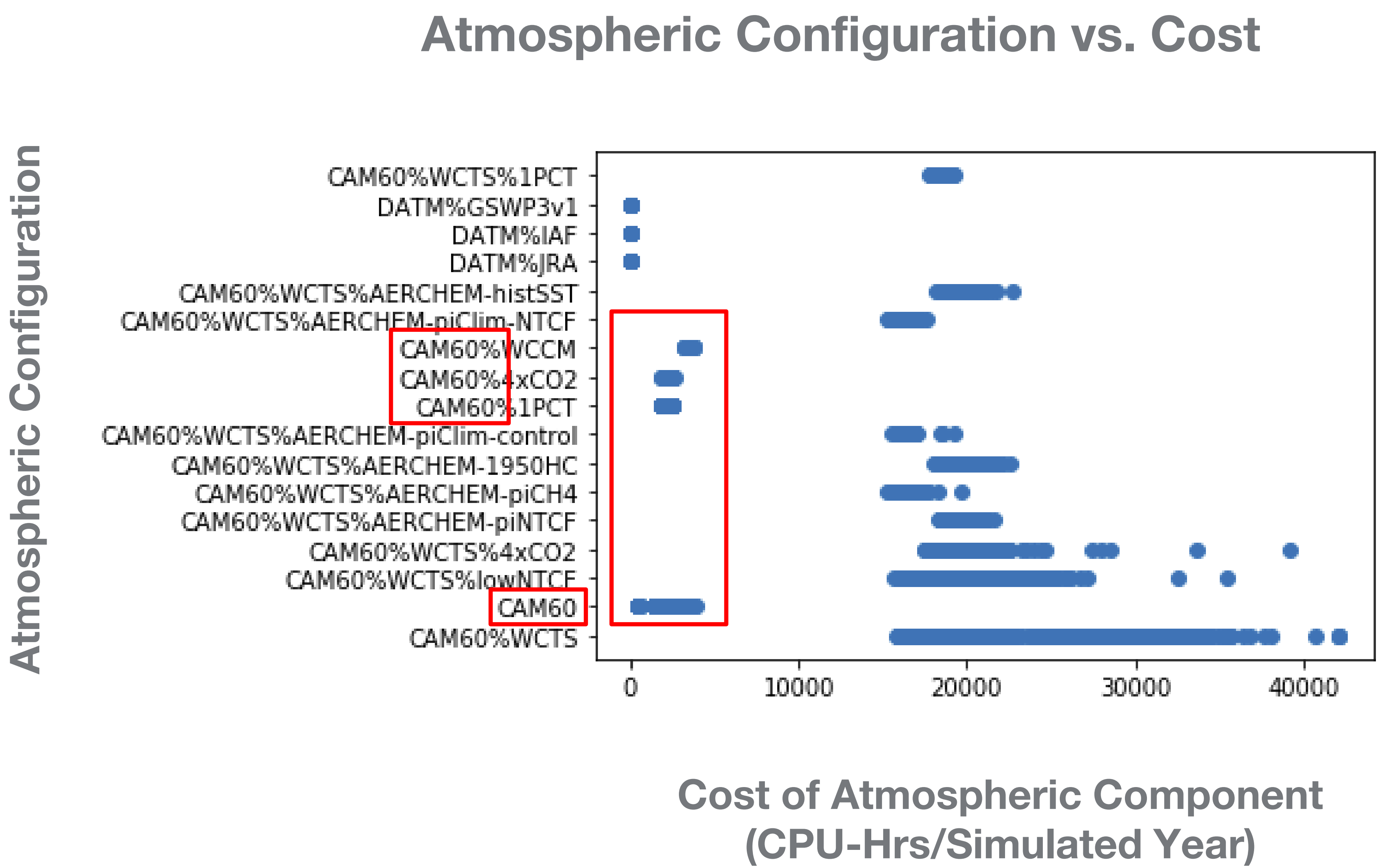

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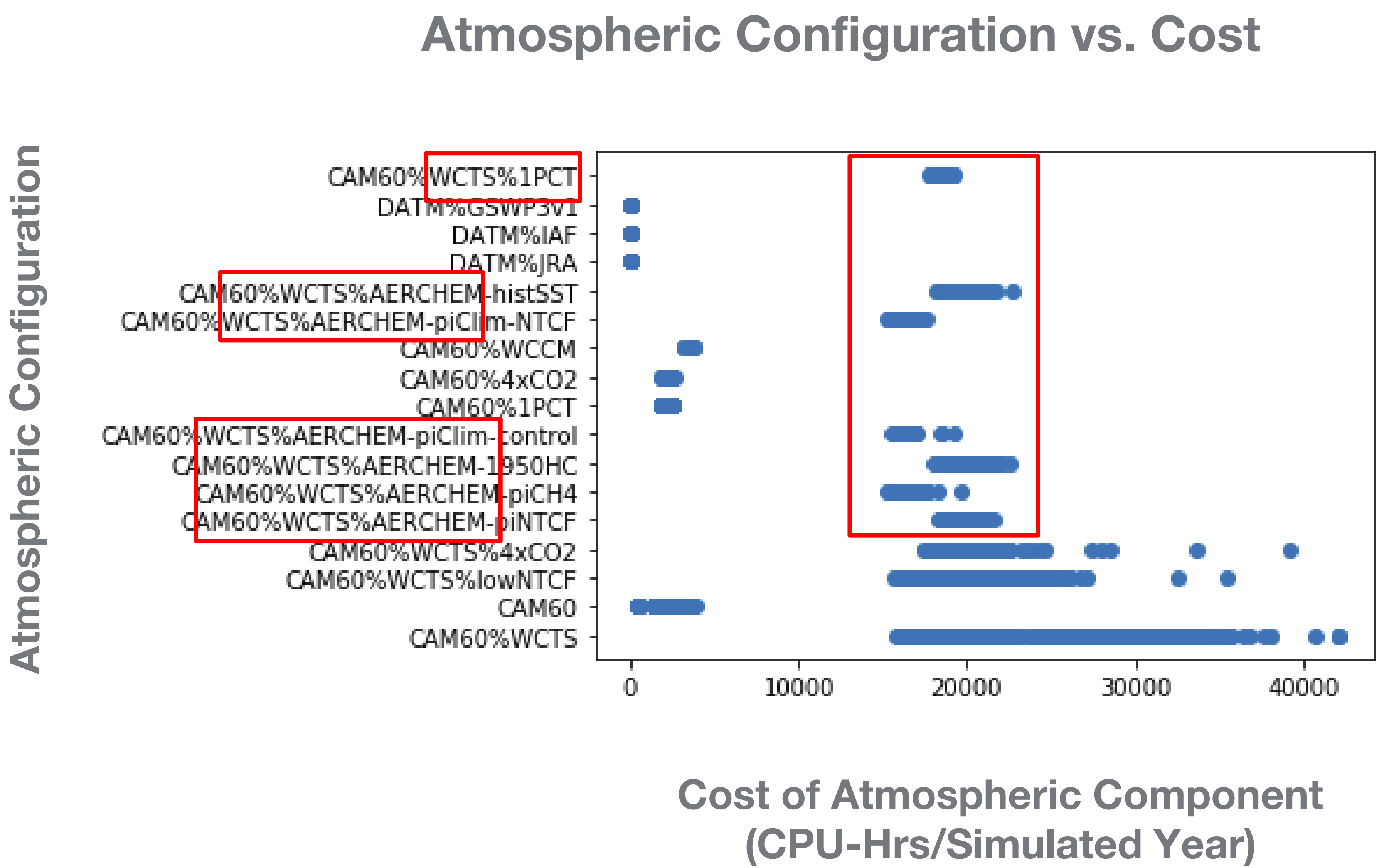

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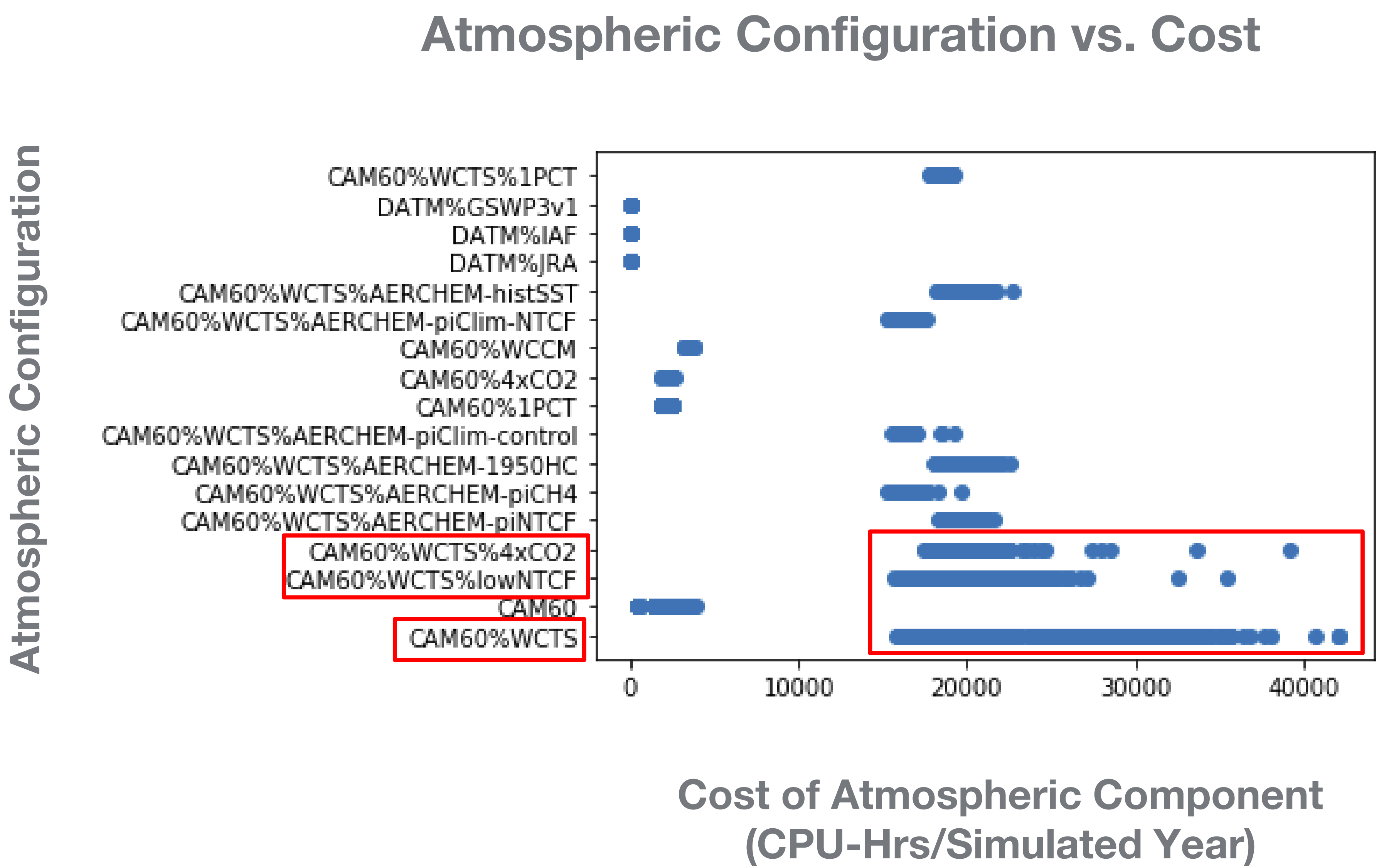
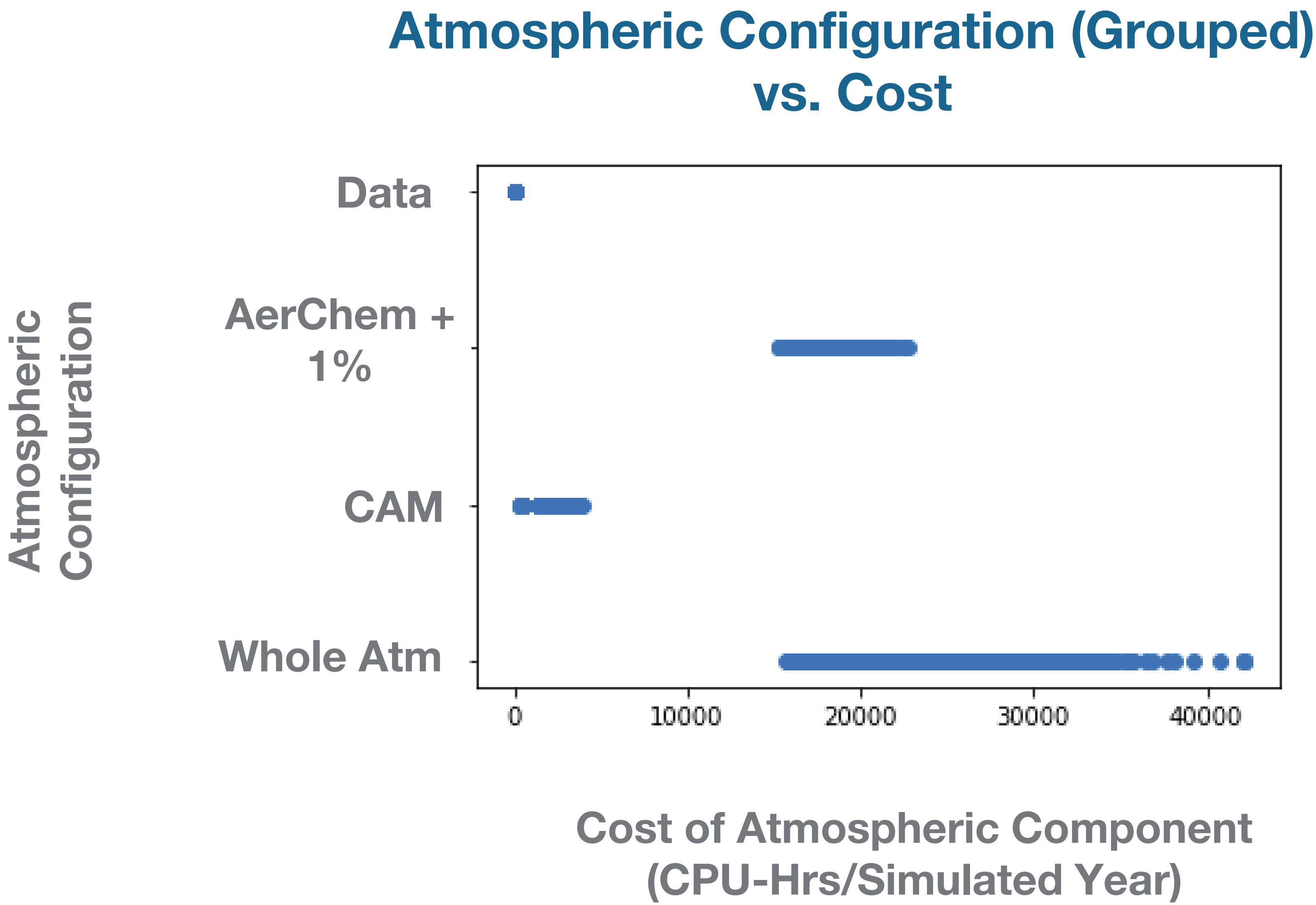
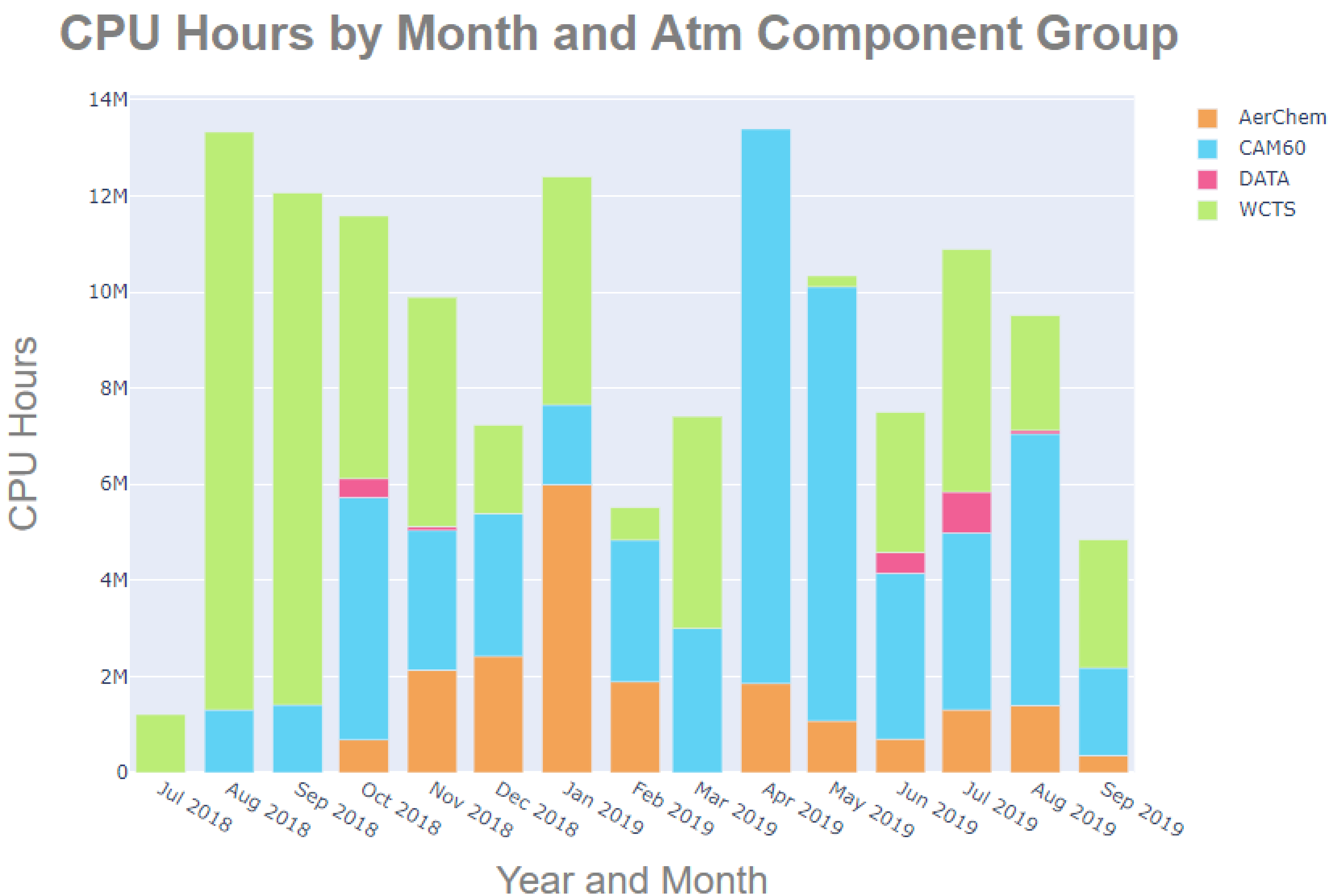


Analysis: Grouping Atmospheric Configurations



Analysis: Atmospheric Components



Analysis: System Upgrade

- Cheyenne Supercomputer: 145,152 processors
- Upgrade: June 25-July 5, 2019
- Install SUSE Linux Enterprise Server Service Pack 4 to update security and support

Spoiler Alert!
Name of new supercomputer!

Analysis: System Upgrade

More maniacal subsetting . . .

By Case

```
b.e21.B1850G.f09_g17_gl4.CMIP6-1pctCO2to4x-withism.001
```

Analysis: System Upgrade

More maniacal subsetting . . .

By Case

```
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```

By Base

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Analysis: System Upgrade

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By Base

`b.e21.B1850G.f09_g17_gl4.CMIP6-1pctCO2to4x-withism~~.001~~`

By atmospheric component + atmospheric processors + oceanic processors

compset_atm	comp_pes_atm	comp_pes_ocn	total_submits
CAM60	576	144	10
CAM60	900	751	66
CAM60	1080	1080	912
CAM60%1PCT	1800	432	5
CAM60%1PCT	3456	1536	49
CAM60%WCCM	3456	432	98
CAM60%WCTS	1728	1728	41
CAM60%WCTS%4xCO2	3456	72	64
CAM60%WCTS%4xCO2	3456	108	168

Analysis: System Upgrade

More maniacal subsetting . . .

By Case (811 data points, 3445 sim years, 14 cases)

`b.e21.B1850G.f09_g17_gl4.CMIP6-1pctCO2to4x-withism.001`

By Base (1206 data points, 4271 sim years, 14 bases)

b.e21.B1850G.f09_g17_gl4.CMIP6-1pctCO2to4x-withism~~.001~~

By atmospheric component
+ atmospheric processors
+ oceanic processors
(3113 data points,
12,493 sim years,
9 groups)

compset_atm	comp_pes_atm	comp_pes_ocn	total_submits
CAM60	576	144	10
CAM60	900	751	66
CAM60	1080	1080	912
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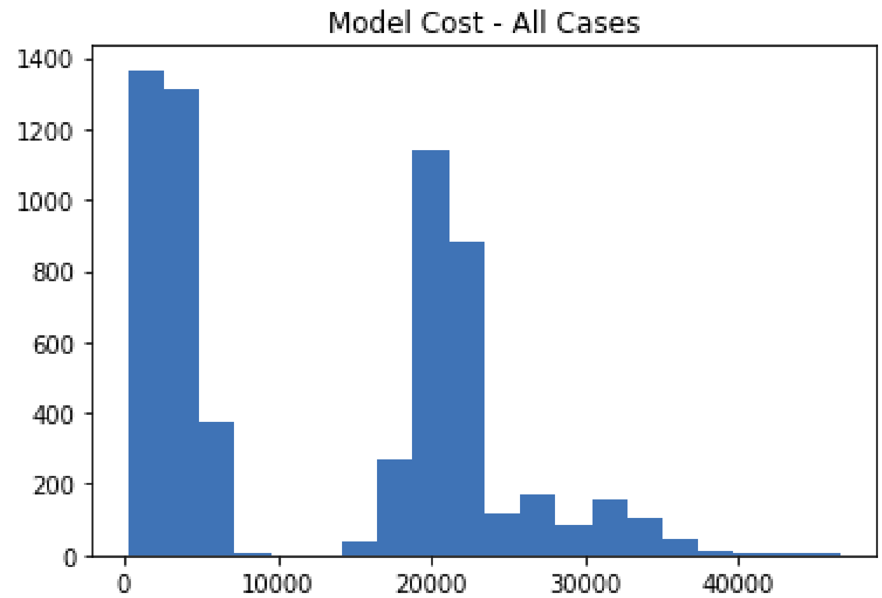
Analysis: System Upgrade

Tests for Normality

All
All - normalized
All - before/after

By case

By base



By group:
(atm compset/atm + ocn processors)

Analysis: System Upgrade

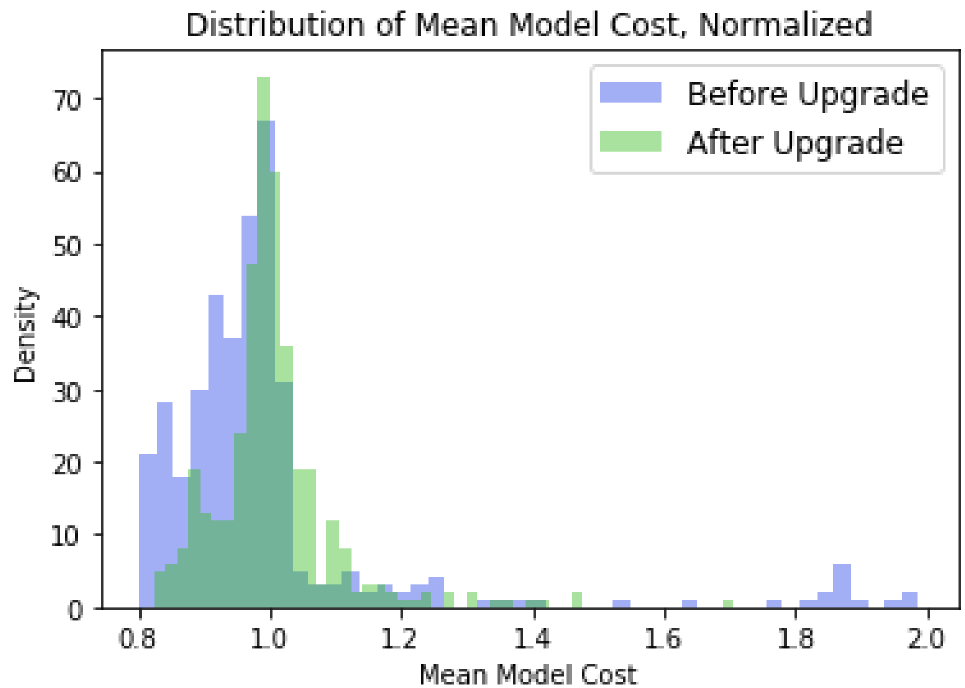
Tests for Normality

All
All - normalized
All - before/after

By case

By base

By group:
(atm compset/atm + ocn processors)



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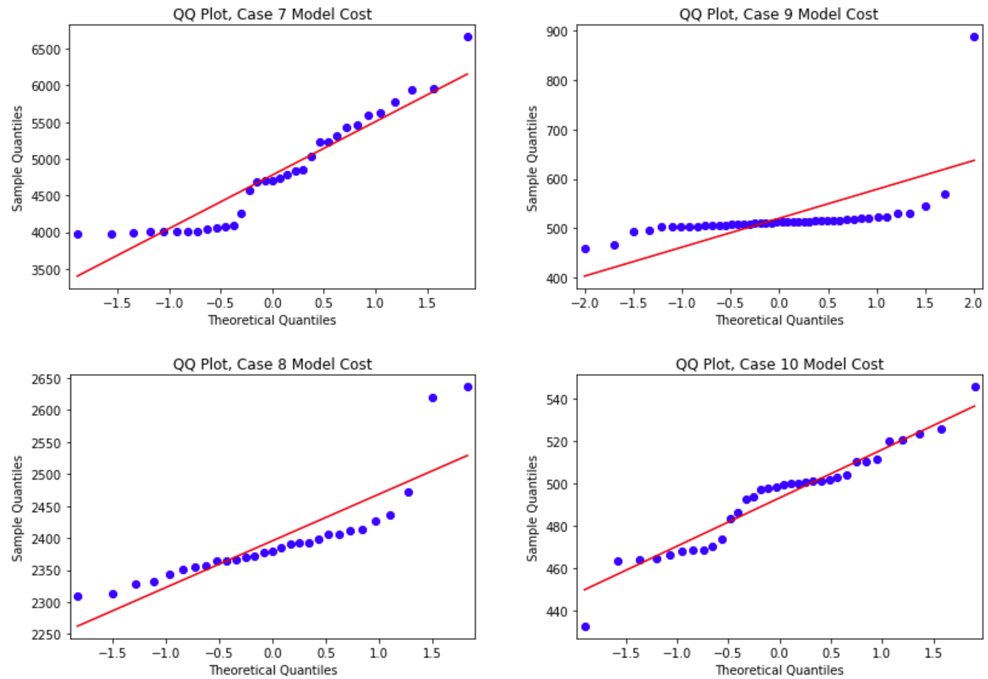


By case

By base

By group:
(atm compset/atm + ocn processors)

Statistical Tests for Normality:

- Kolmogorov-Smirnoff
- Shapiro-Wilk

Analysis: System Upgrade

Mean Model Cost Before Upgrade

vs.

Mean Model Cost After Upgrade

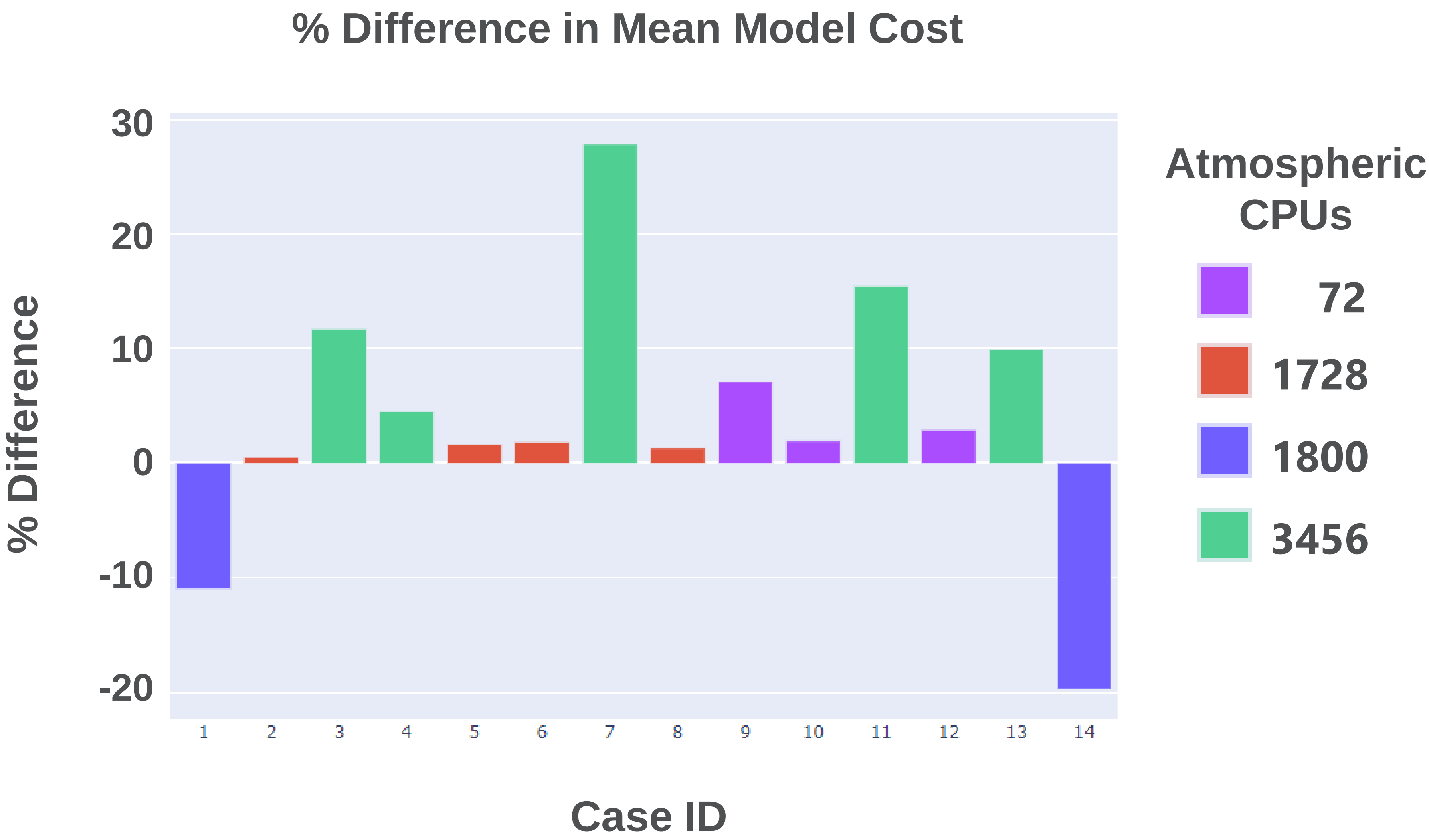
Calculated percent difference (% change) in means before and after the upgrade:

- **By case**
- **By base**
- **By group**

Determined whether there was statistical significance in the means using Kruskal Wallis test

Analysis: System Upgrade

Cases that span the upgrade



Analysis: System Upgrade

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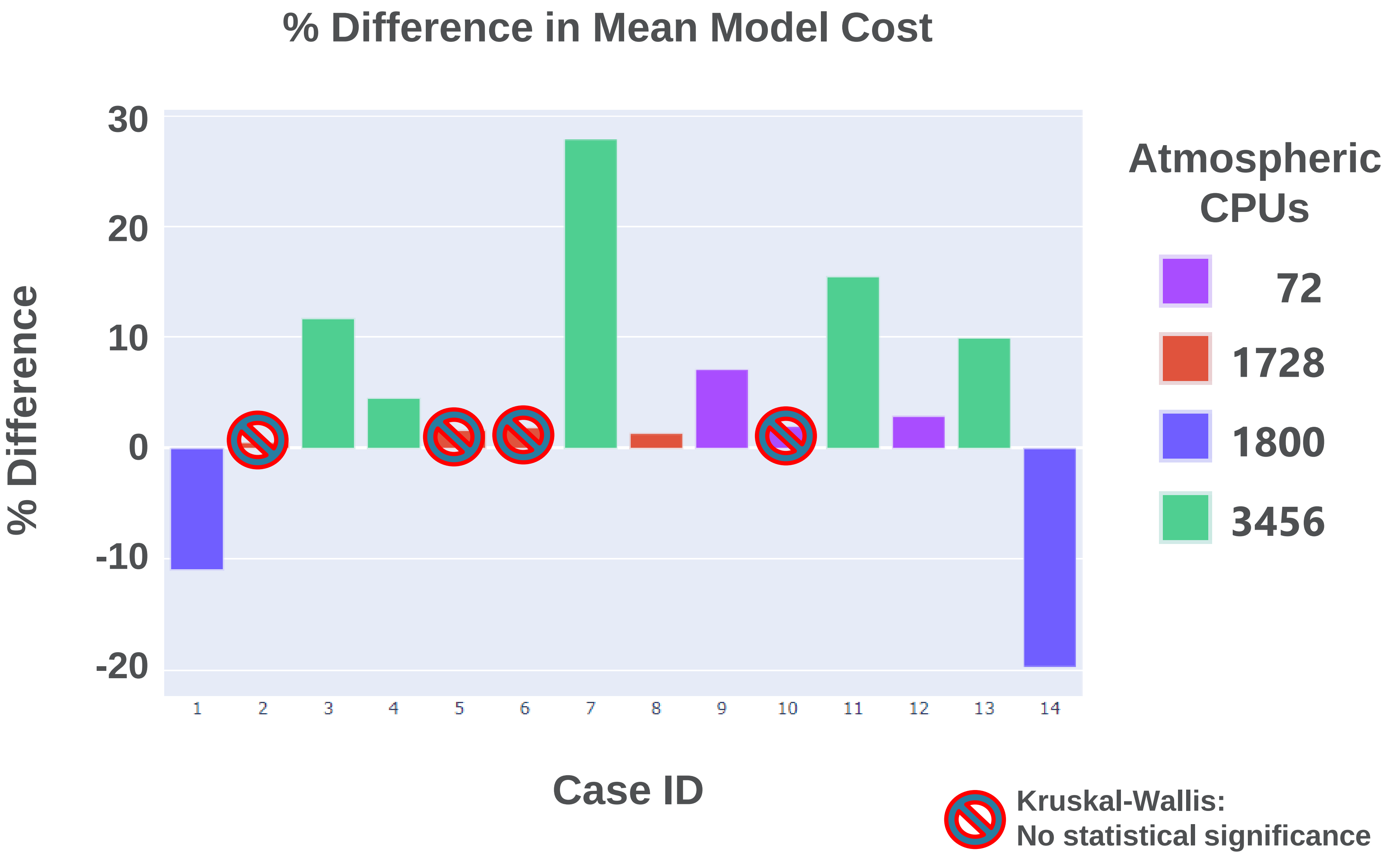

Analysis: System Upgrade

Bases that span the upgrade

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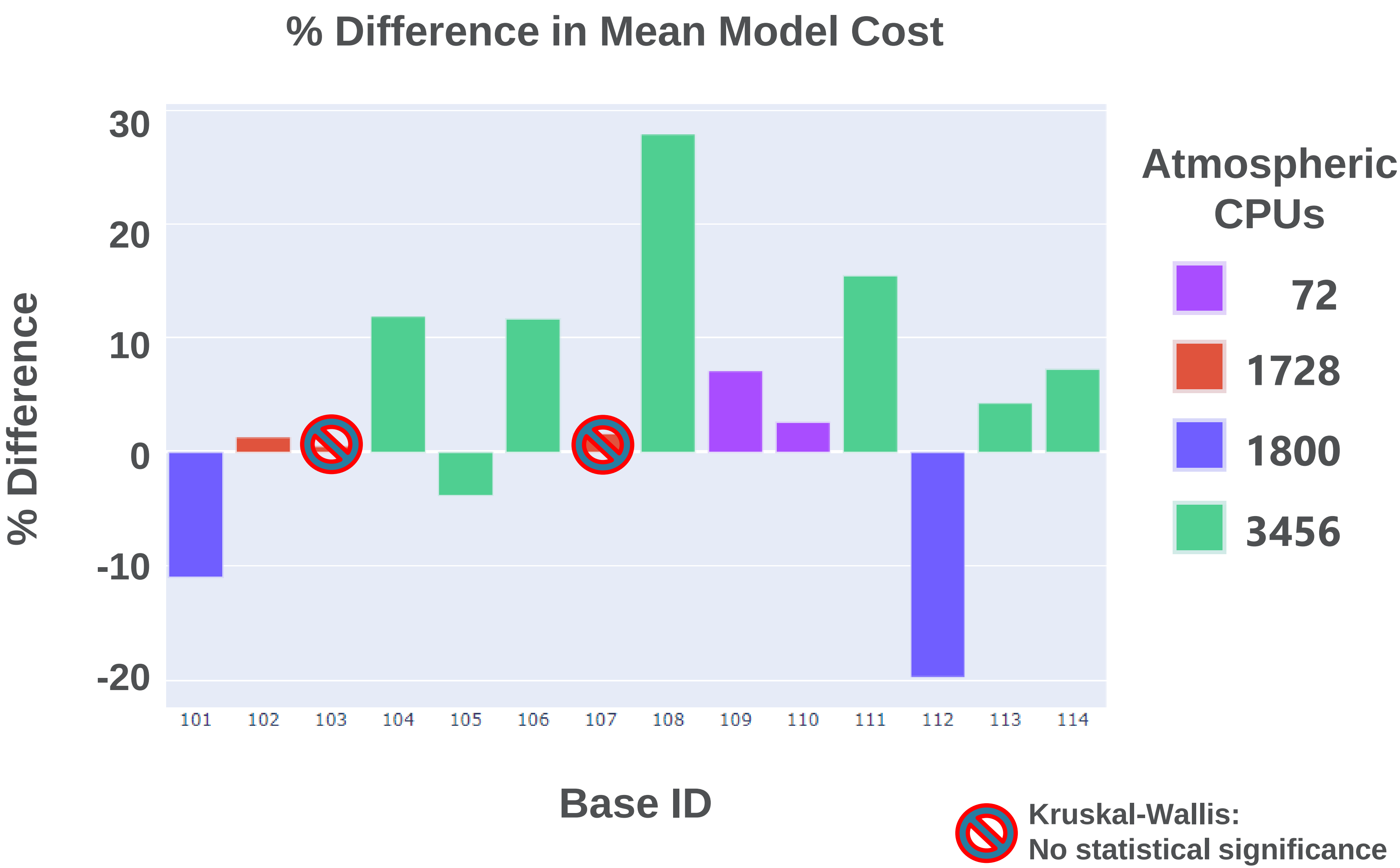
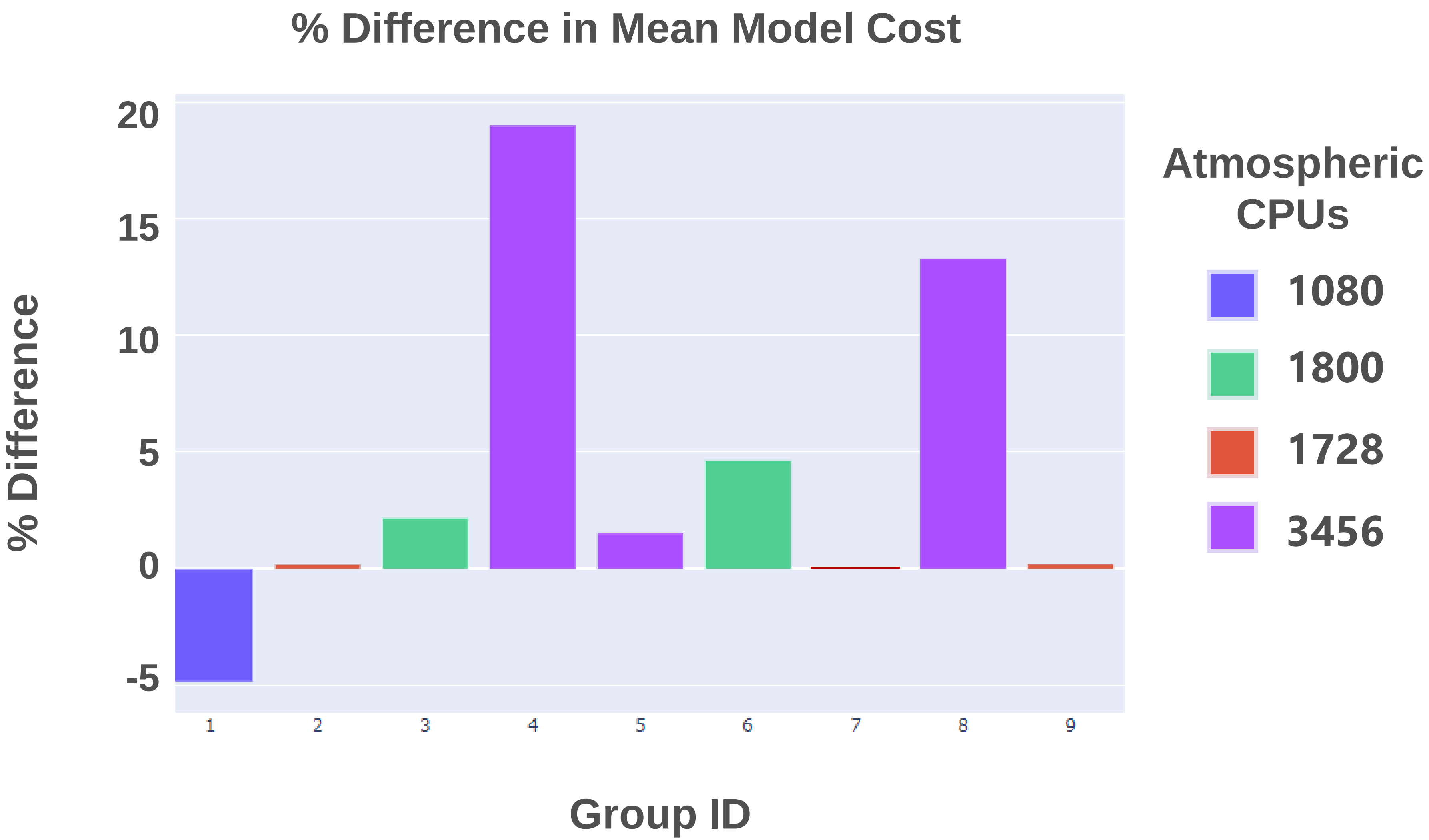


Analysis: System Upgrade

Groups that span the upgrade



Analysis: System Upgrade

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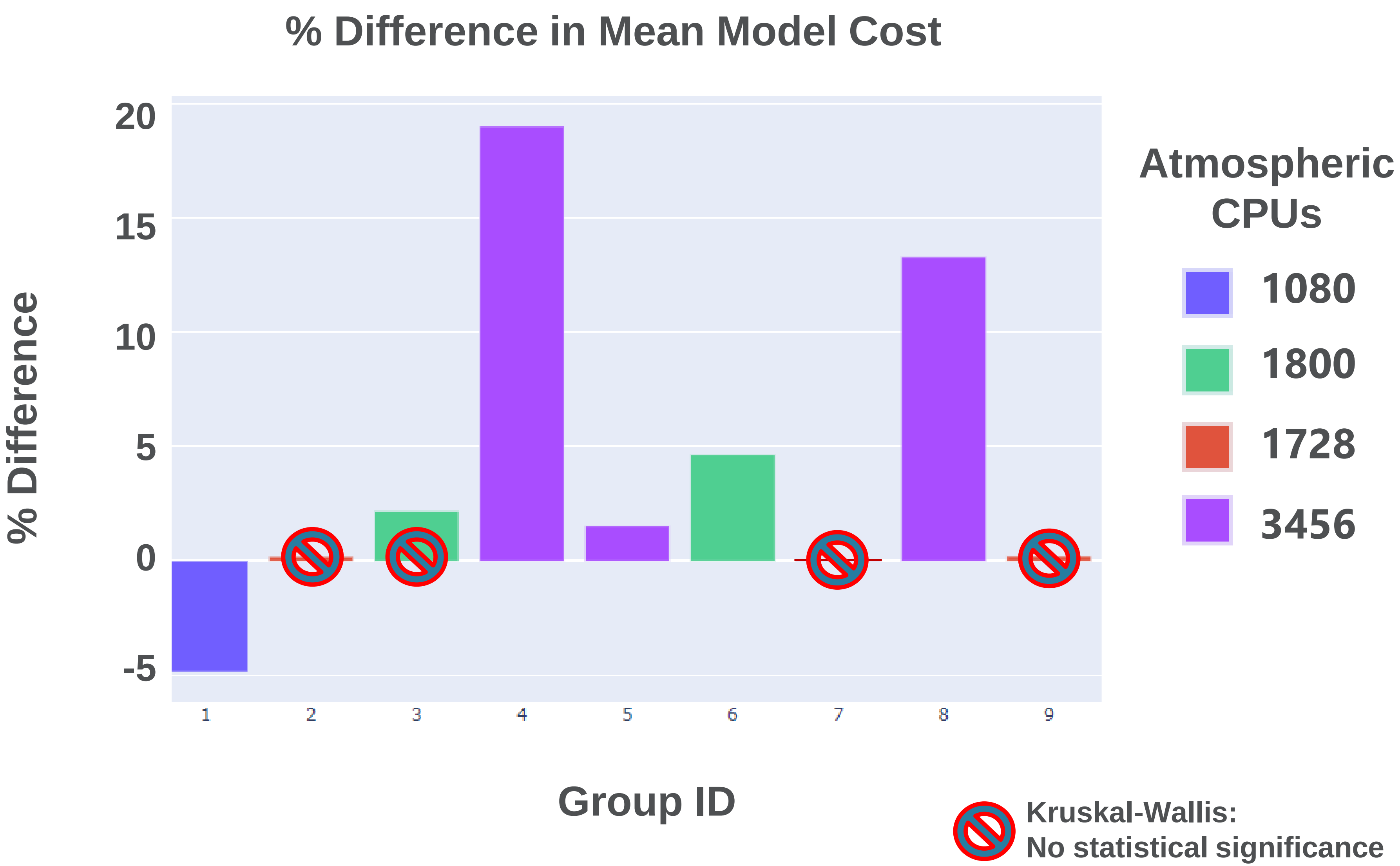
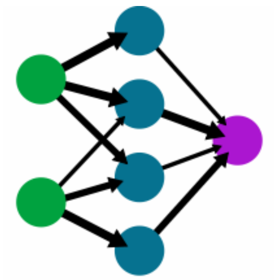


Conclusion

- More analysis in my Jupyter Notebook that points to performance degradation after the upgrade
- Enormous amounts of information to be sliced and diced by each component, physics module, number of processors, and other settings specific to parallel computing
- Answers lead to more questions

Future Work

Machine Learning



- Correlation Plots
- Feature Engineering
- Supervised Learning to Predict Performance (Model Cost)
- Unsupervised Learning (K-Means) to reveal patterns

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References

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Questions?

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