CESM Usage Metrics and Machine Learning

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Summer Internships in Parallel Computational Science (SIParCS)

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Goal

Demonstrate what we can do with CESM performance metadata

- ❑ Track versions over time
- ❑ Track performance over time
- ❑ Predict performance

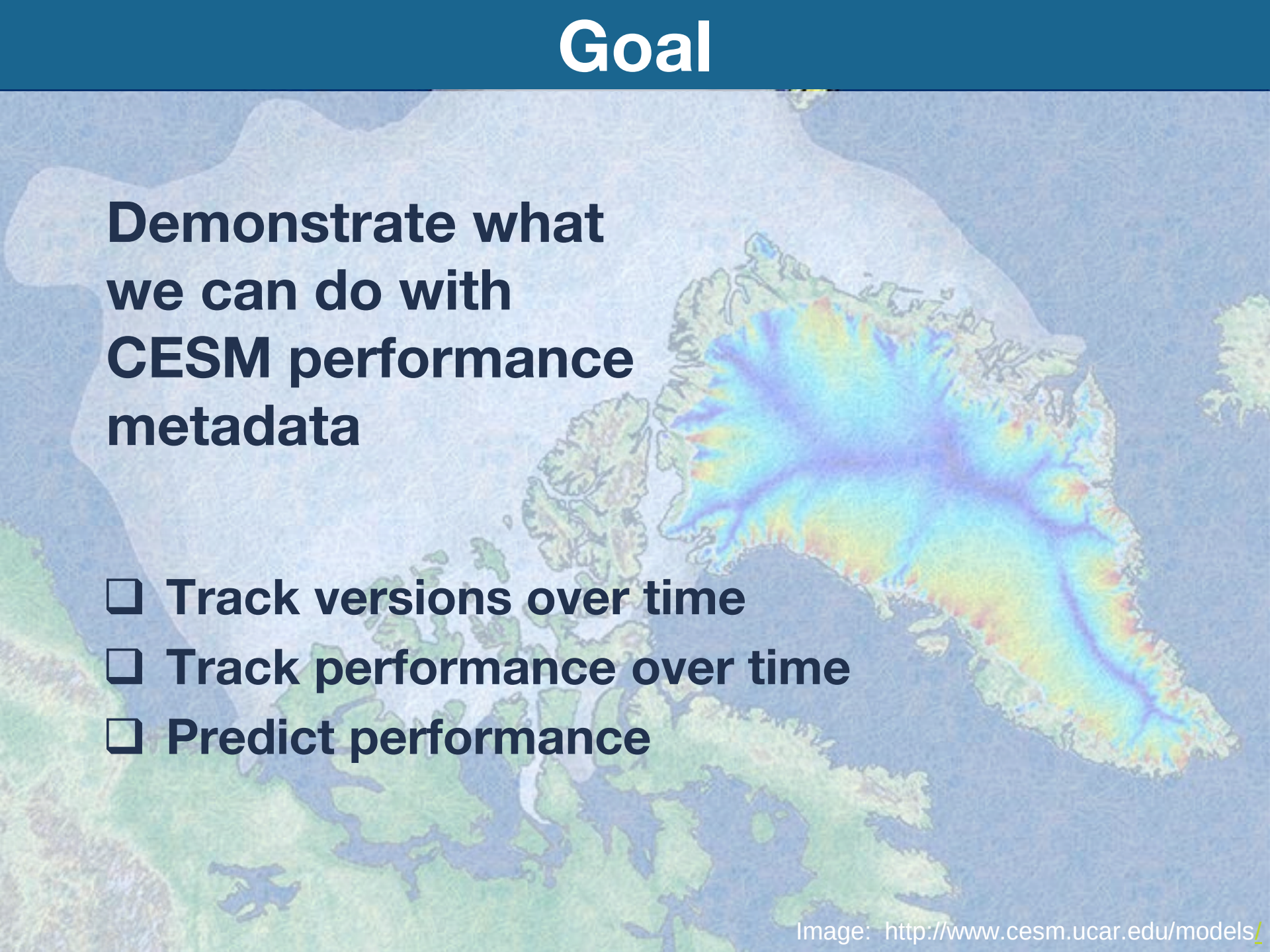


Image: http://www.cesm.ucar.edu/models/

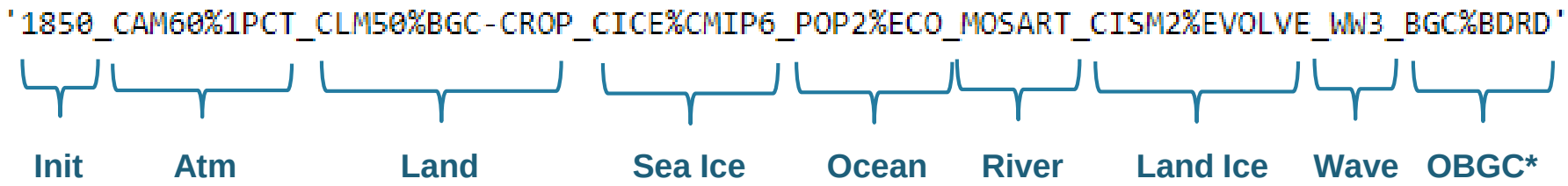
Method


```
---------------- TIMING PROFILE ---------------------
  Case        : b.e21.BHIST.f09_g17.CMIP6-historical.001
  LID         : 2979765.chadmin1.181015-050236
  Machine     : cheyenne
  Caseroot    : /gpfs/fs1/work/cmip6/cases/b.e21.BHIST.f09_g17.CMIP6-historical.001
  Timeroot    : /gpfs/fs1/work/cmip6/cases/b.e21.BHIST.f09_g17.CMIP6-historical.001/Tools
  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)

  component       comp_pes    root_pe   tasks  x threads instances (stride)
  ---------        ------     -------   ------   ------  ---------  ------
  cpl = cpl        3456        0        1152   x 3       1      (1     )
  atm = cam        3456        0        1152   x 3       1      (1     )
  lnd = clm        2592        0        864    x 3       1      (1     )
  ice = cice       864         864      288    x 3       1      (1     )
  ocn = pop        768         1152     256    x 3       1      (1     )
```

Data Prep: Parsing

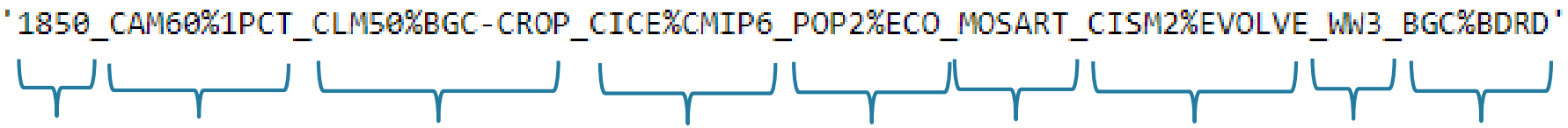
Component string = compset

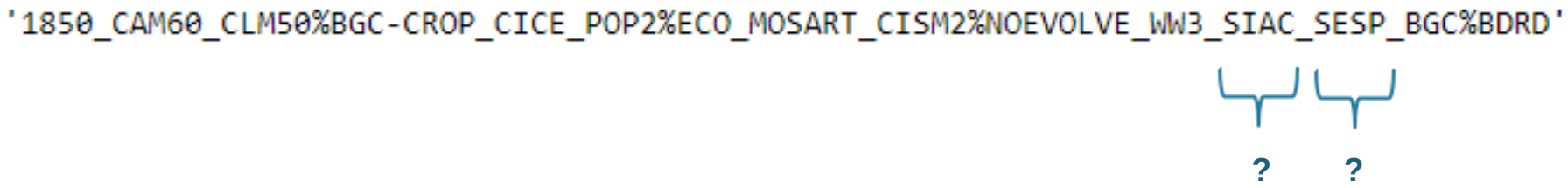


OBGC = Ocean Bio-geo-chemistry

Data Prep: Parsing

Component string = compset



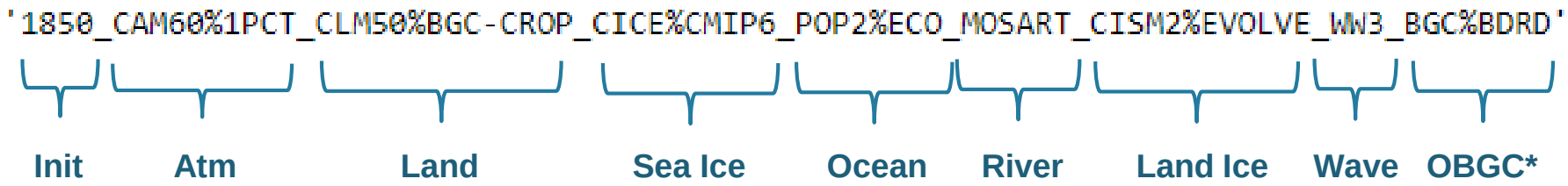


Problems: Manual inspection
Components not in the same order

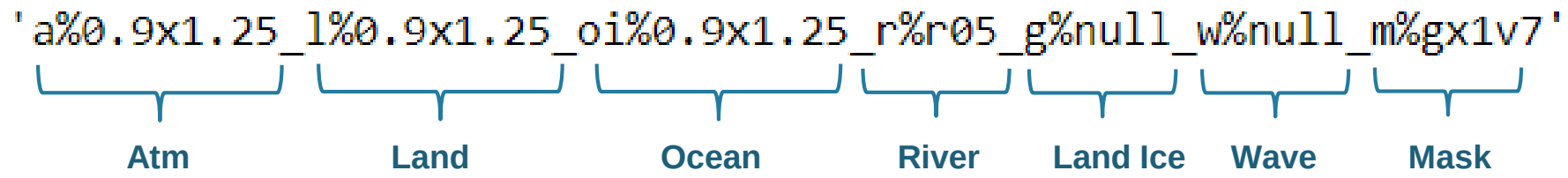
OBGC = Ocean Bio-geo-chemistry

Data Prep: Parsing

Component string = compset

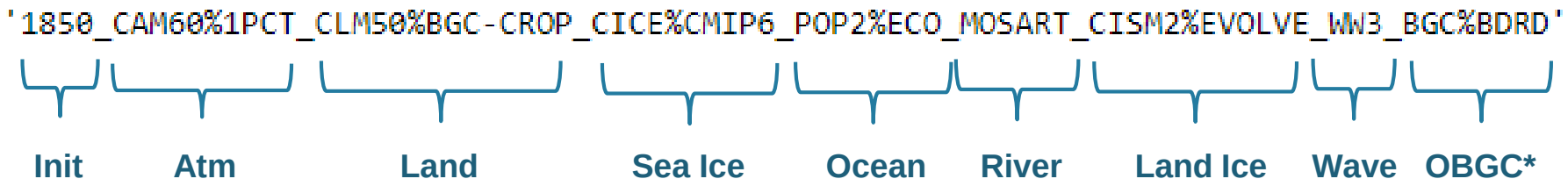


Grid string has prefixes

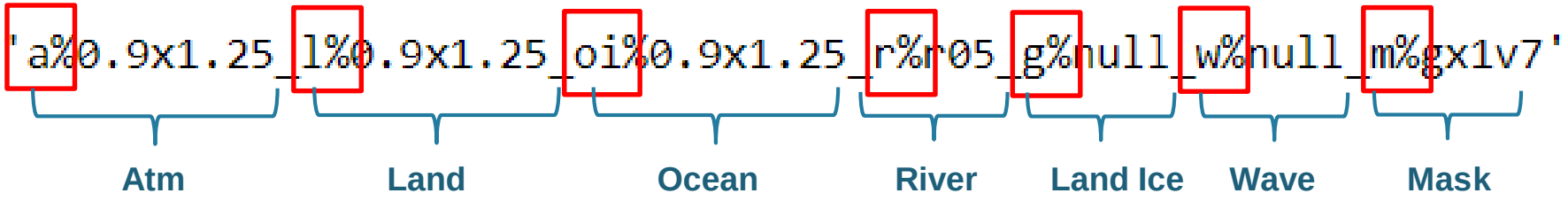


Data Prep: Parsing

Component string = compset



Grid string has prefixes



Data Prep: Parsing

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*

Grid string has prefixes

'a%0.9x1.25_l%0.9x1.25_oi%0.9x1.25_r%r05_g%null_w%null_m%gx1v7'

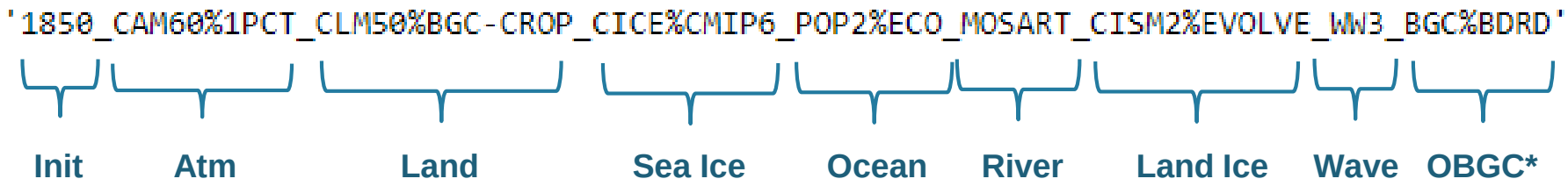
Atm | Land | Ocean | River | Land Ice | Wave | Mask

Random location:

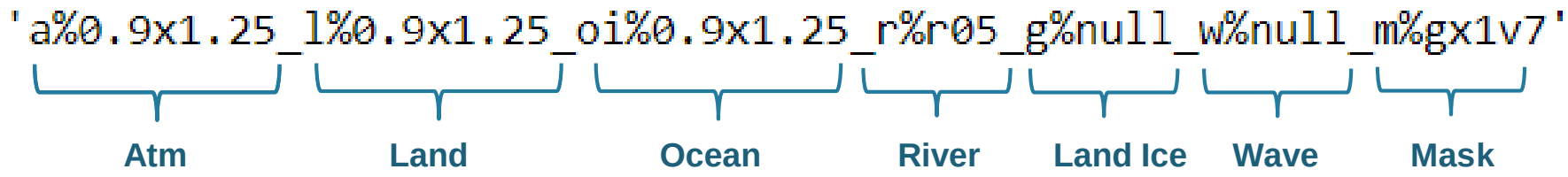
'a%1x1_vancouverCAN_l%1x1_vancouverCAN_oi%null_r%null_g%null_w%null_m%null'

Data Prep: Parsing

Component string = compset



Grid string has prefixes



Random location:

'a%1x1_vancouverCAN_l%1x1_vancouverCAN_oi%null_r%null_g%null_w%null_m%null'

Data Prep: Parsing

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*

Grid string has prefixes

'a%0.9x1.25_l%0.9x1.25_oi%0.9x1.25_r%r05_g%null_w%null_m%gx1v7'

Atm | Land | Ocean | River | Land Ice | Wave | Mask

Random location:

'a%1x1_vancouverCAN_l%1x1_vancouverCAN_oi%null_r%null_g%null_w%null_m%null'

'a%ne0np4colorado.ne30x16'

Analysis: CMIP Totals

416 Days

948
Unique Cases

21,785
Simulated Years

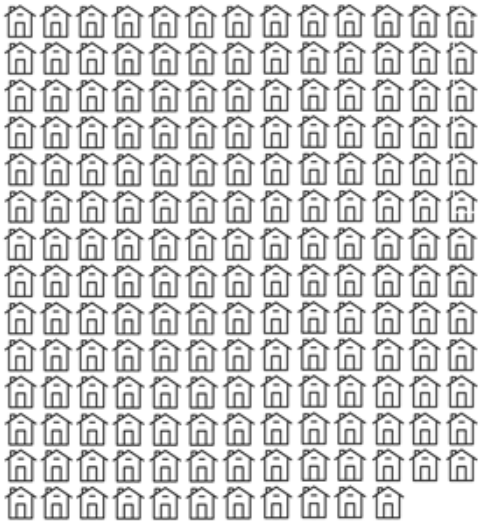
137,112,802
CPU Hours

Power Equivalence

137,112,802
CPU Hours

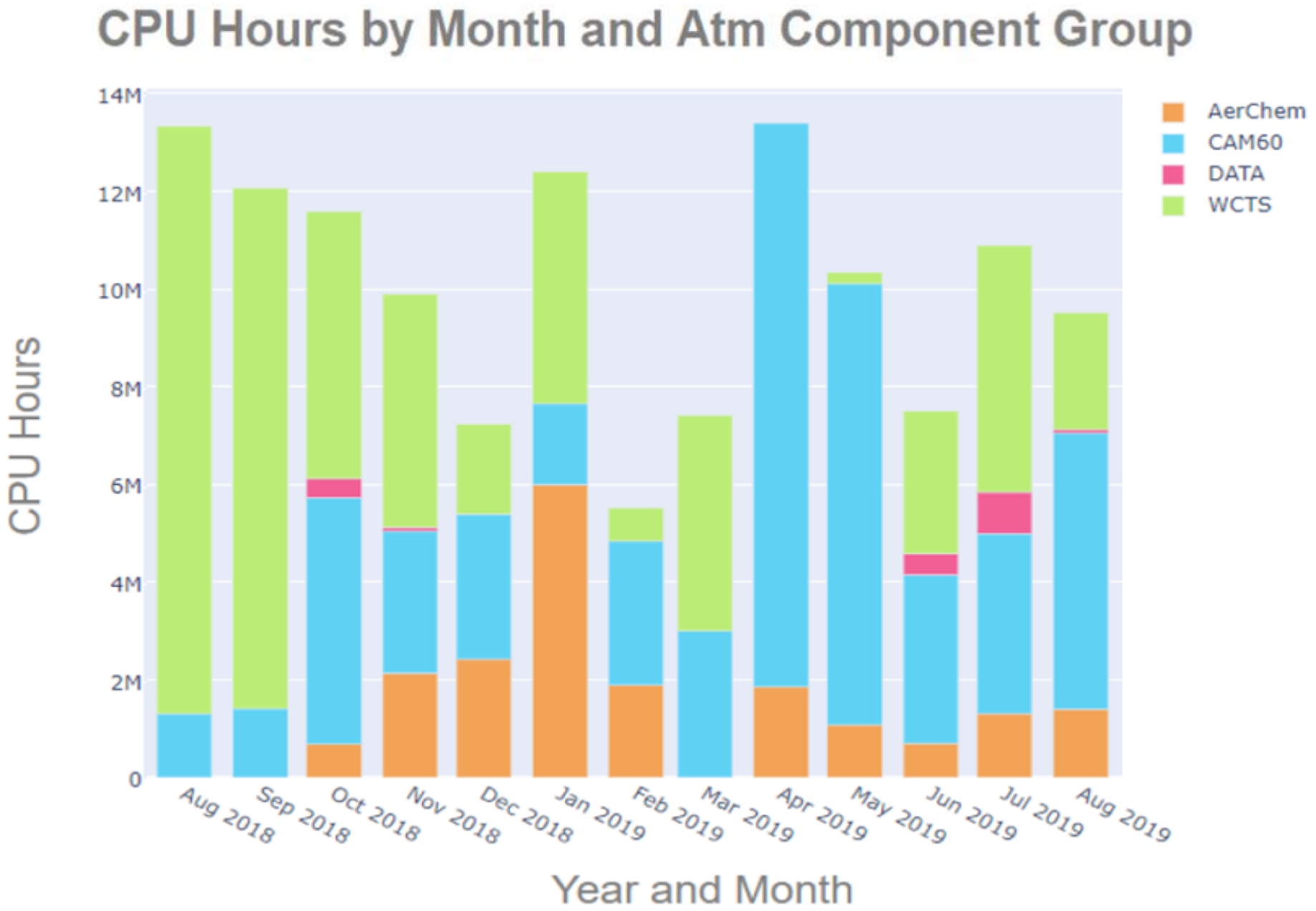
218 trips around the equator in a Nissan Leaf

or



Annual power for 180 Colorado homes

Analysis: Monthly Totals - CMIP



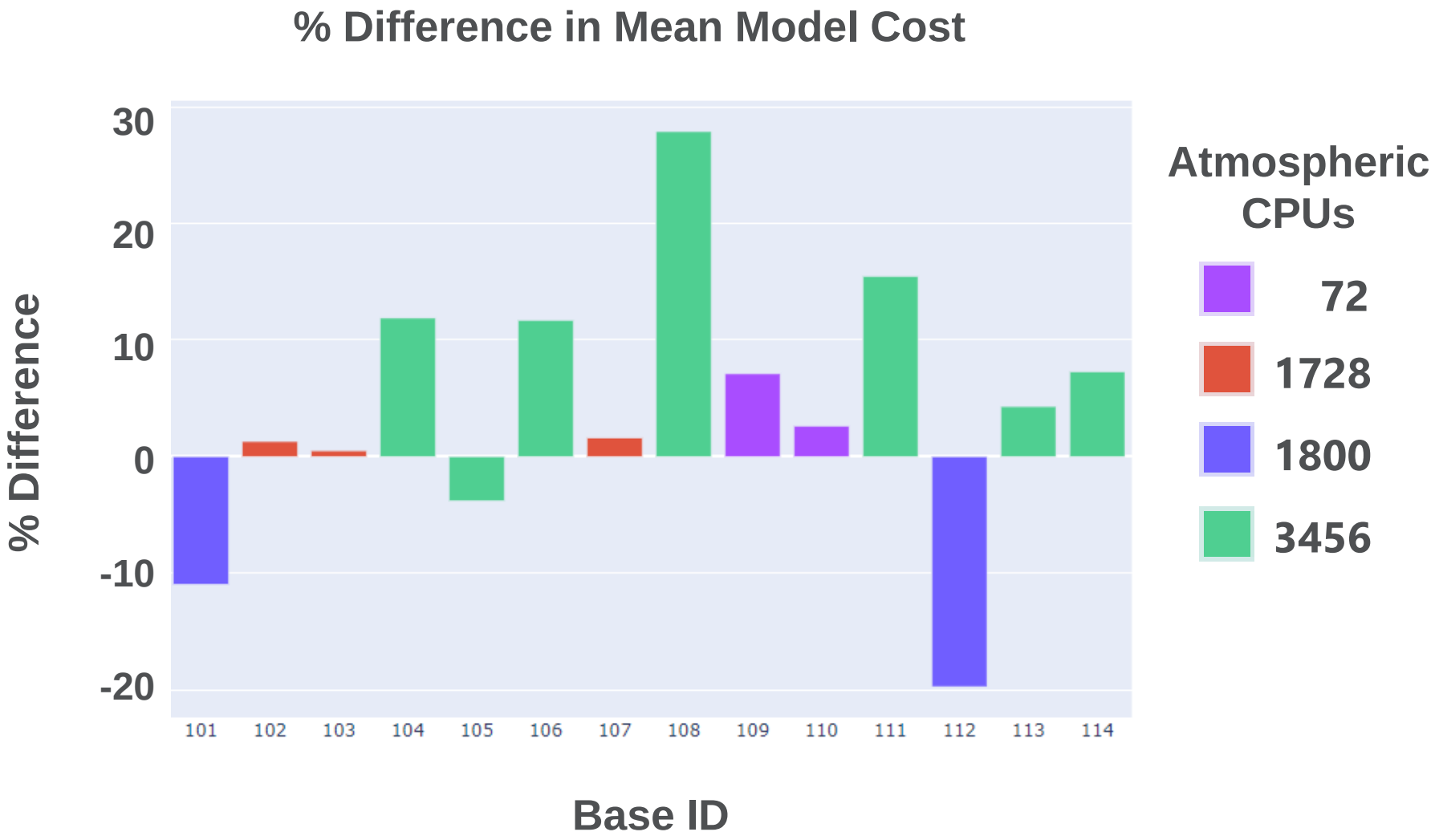
Analysis: System Upgrade

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

Subset by ensemble (like cases)
(1206 data points, 4271 sim years, 14 bases)

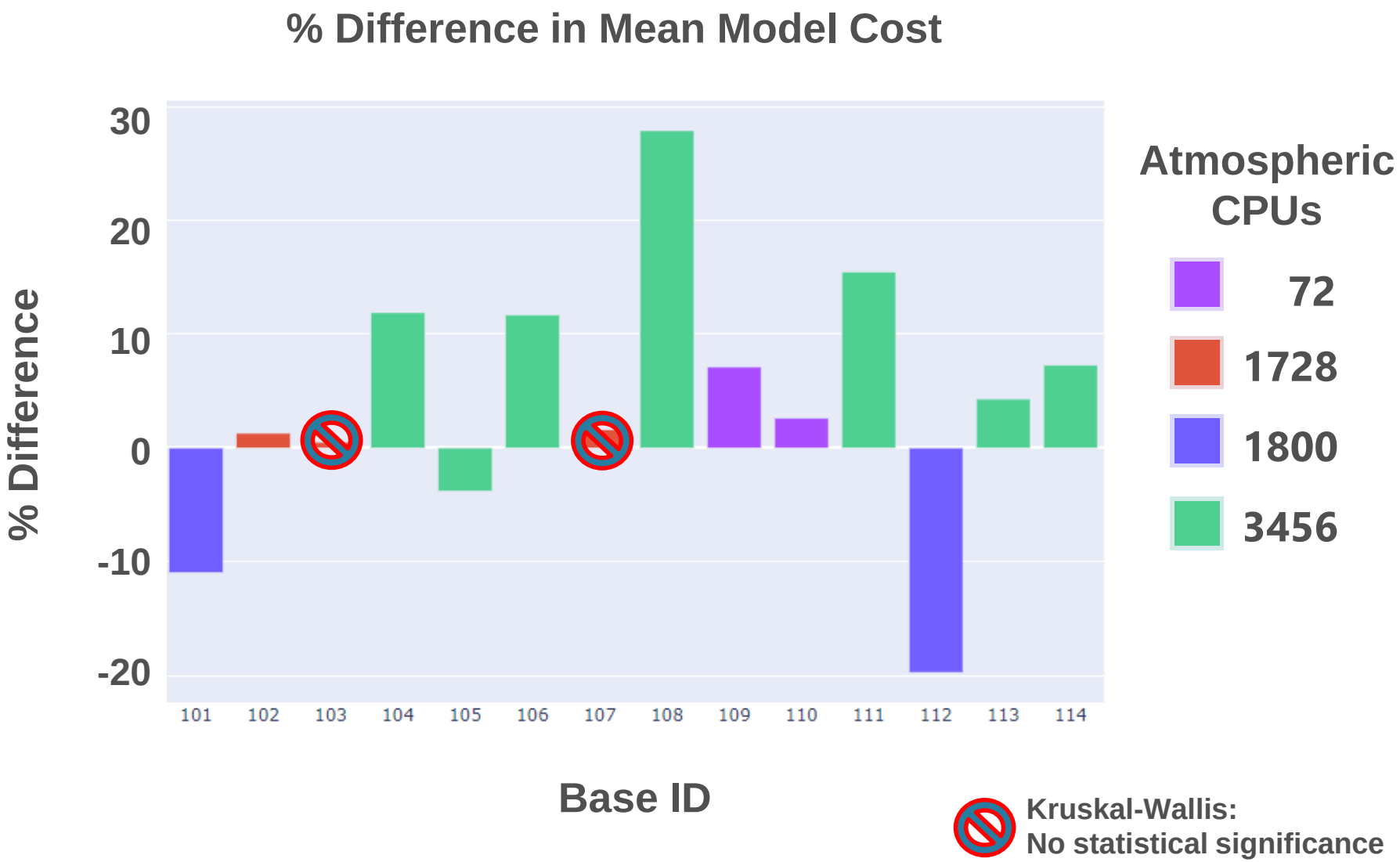
Analysis: System Upgrade

Ensembles that span the upgrade



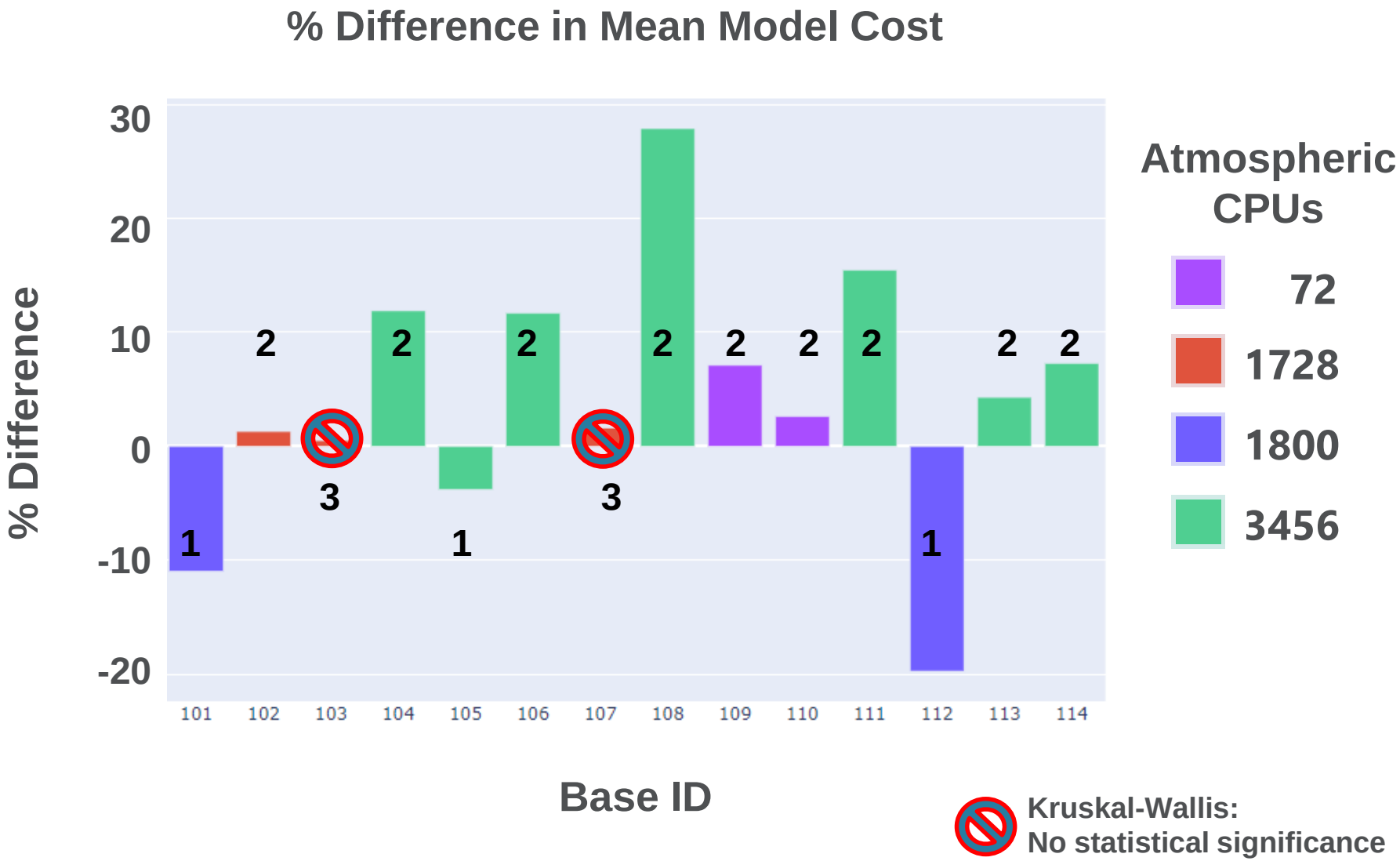
Analysis: System Upgrade

Ensembles that span the upgrade



Analysis: System Upgrade

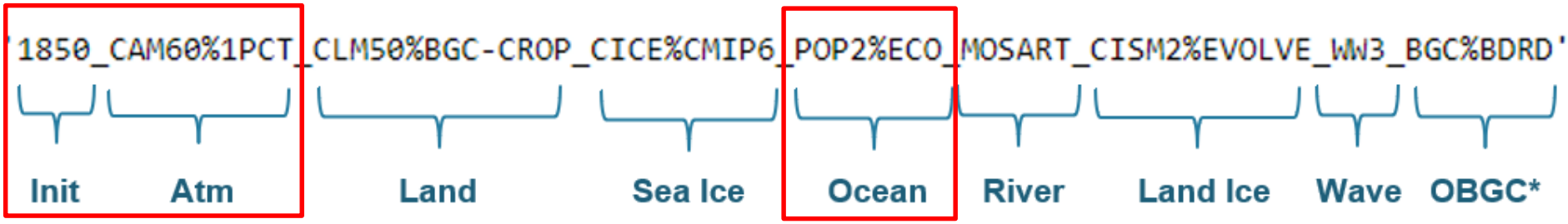
Ensembles that span the upgrade



Analysis: System Upgrade

Machine Learning

Logistic Regression
Random Forest

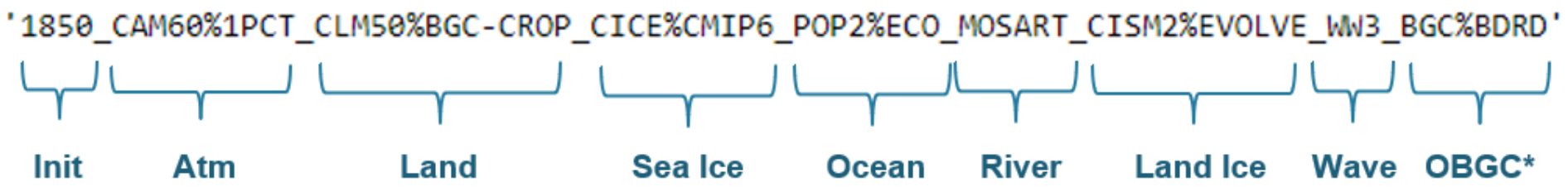


compset_init + compset_atm + compset_ocn + comp_pes_atm + RandNum ~ Performance (1, 2, or 3)

Analysis: System Upgrade

Machine Learning

Logistic Regression
Random Forest

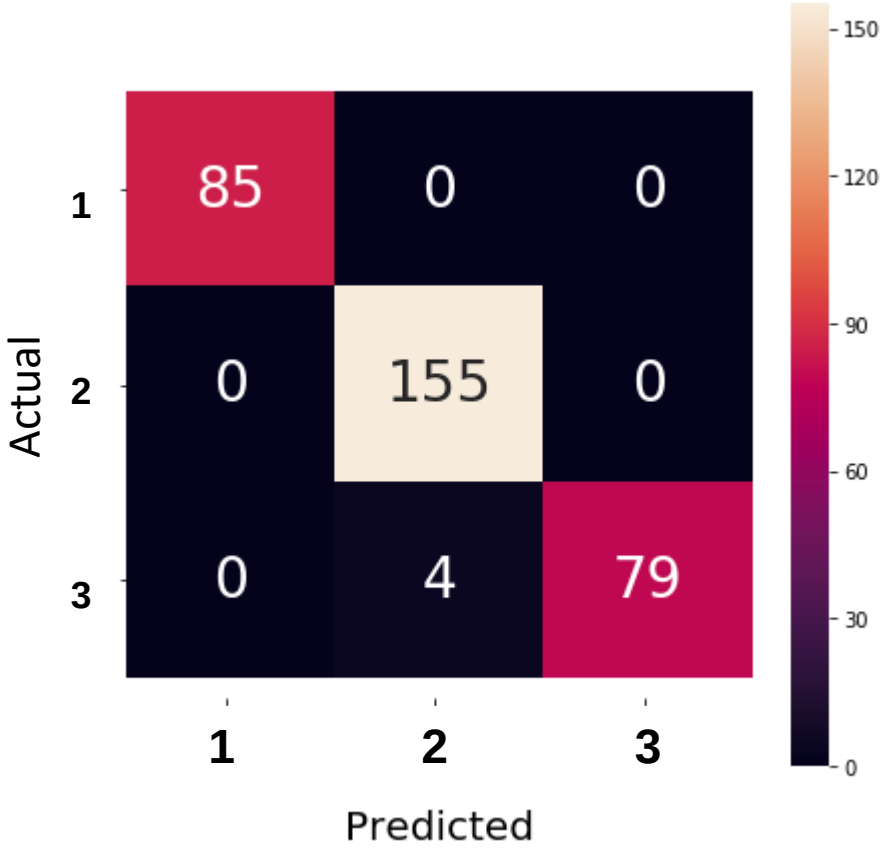


compset_init + compset_atm + compset_ocn
+ comp_pes_atm + RandNum ~ Performance (1, 2, or 3)

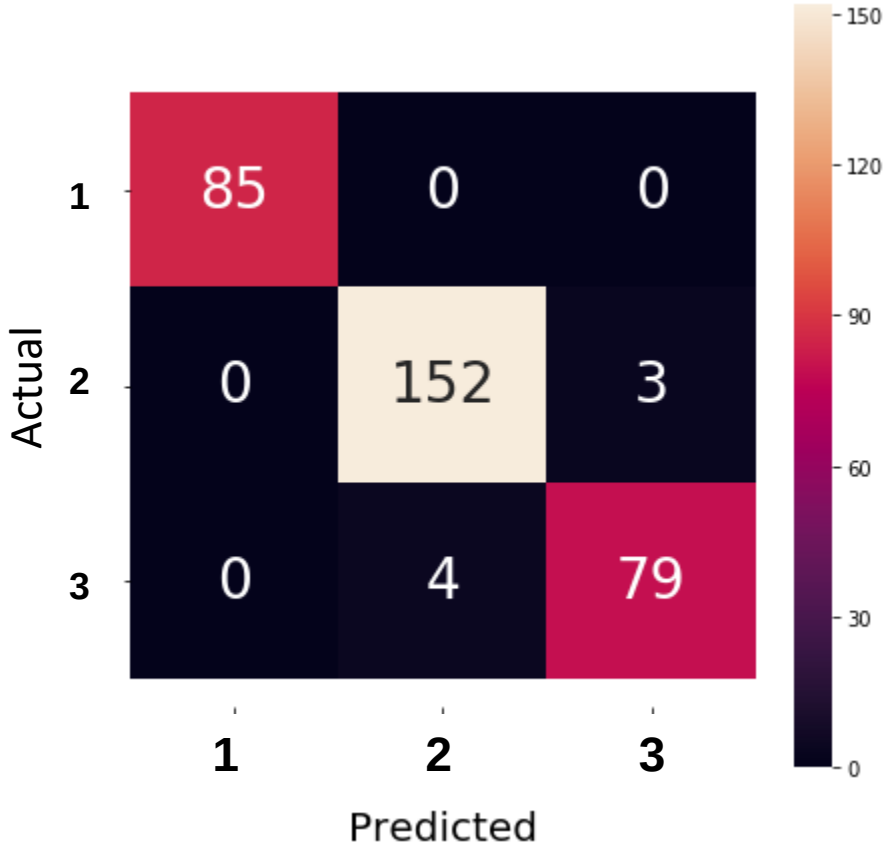
Analysis: System Upgrade

Machine Learning

Logistic Regression

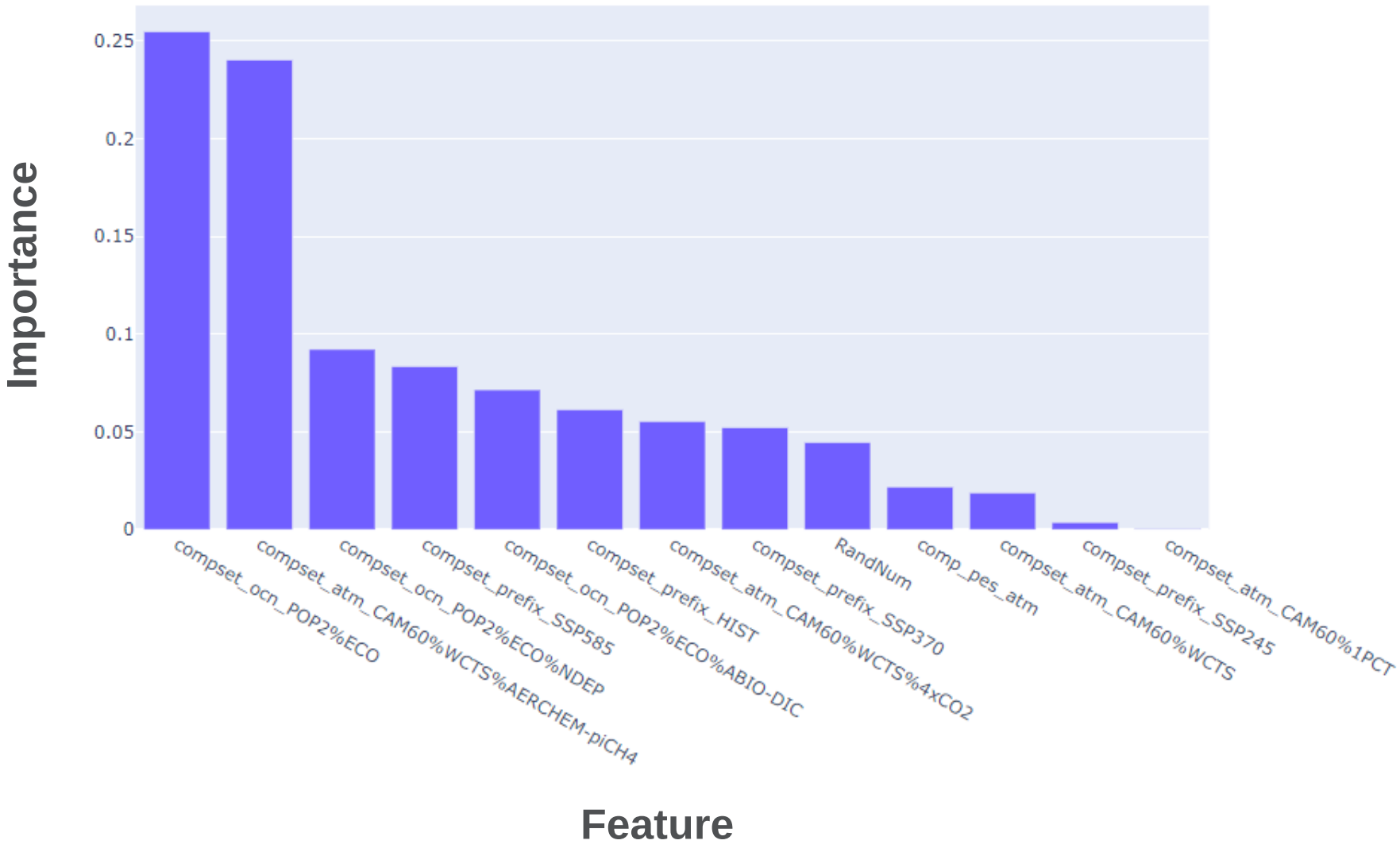


Random Forest



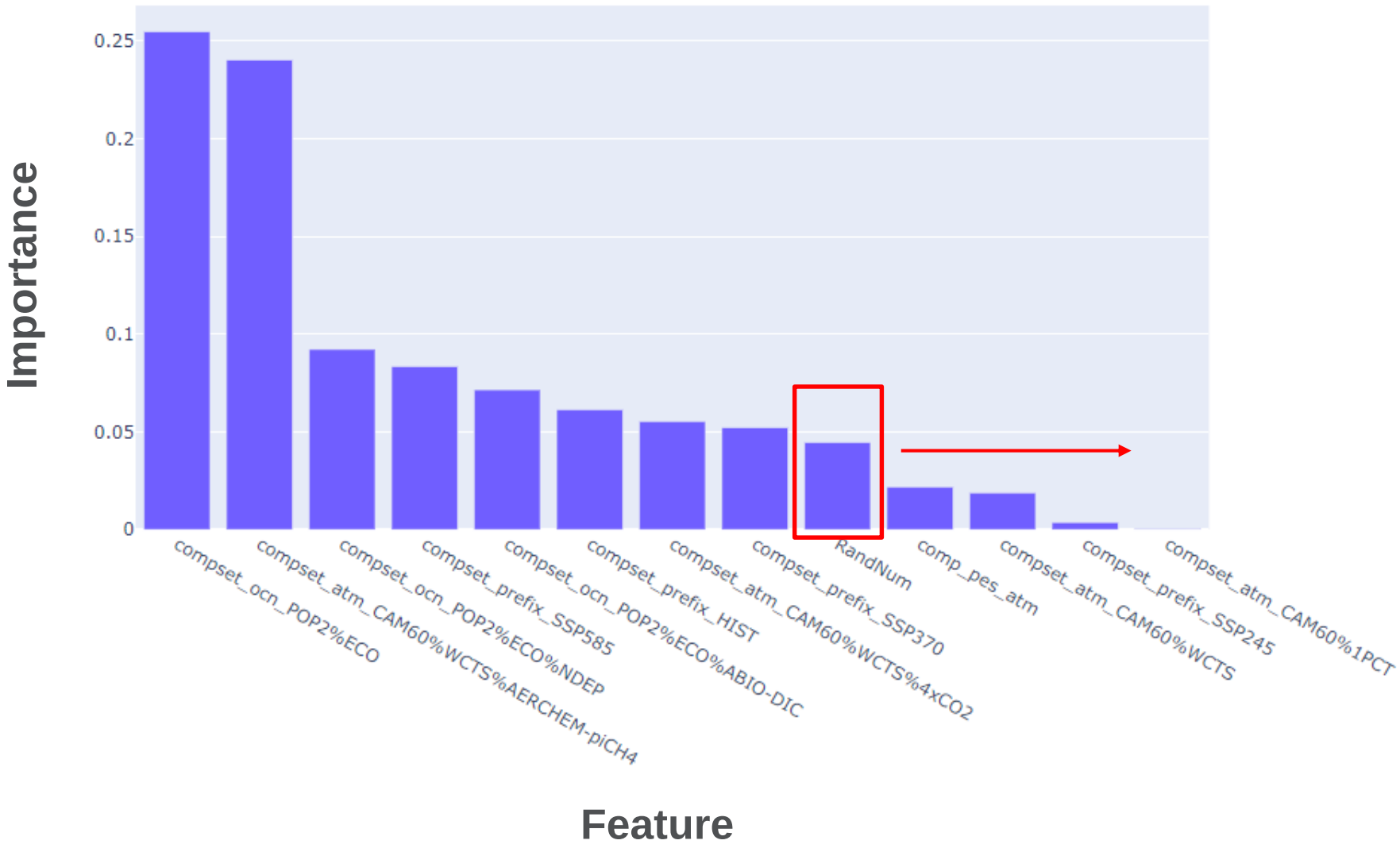
Analysis: System Upgrade

Feature Importance



Analysis: System Upgrade

Feature Importance



Analysis: System Upgrade

Final Report

	BaseNum		Change (%)	Prefix	ATM	OCN
Improved	101	b.e21.B1850G.f09_g17_gl4.CMIP6-piControl-withism	-10.94	1850	CAM60	POP2%ECO
	105	b.e21.BWSSP585cmip6.f09_g17.CMIP6-SSP5-8.5-WACCM	-3.8	SSP585	CAM60%WCTS	POP2%ECO%NDEP
	112	b.e21.B1850G.f09_g17_gl4.CMIP6-1pctCO2to4x-withism	-19.73	1850	CAM60%1PCT	POP2%ECO
Degraded	102	f.e21.FHIST_BGC.f09_f09_mg17.CMIP6-GMMIP	1.3	HIST	CAM60	DOCN%DOM
	104	b.e21.BWSSP370cmip6.f09_g17.CMIP6-SSP3-7.0-WACCM	11.86	SSP370	CAM60%WCTS	POP2%ECO%NDEP
	106	b.e21.BWCO2x4.f09_g17.CMIP6-G1-WACCM	11.7	1850	CAM60%WCTS%4XCO2	POP2%ECO%NDEP
	108	b.e21.B1850.f09_g17.CMIP6-DAMIP-hist-nat	27.87	1850	CAM60	POP2%ECO%ABIO_DIC
	111	b.e21.BSSP585_BPRPcmip6.f09_g17.CMIP6-esm-ssp585-ssp126-Lu	15.46	SSP585	CAM60	POP2%ECO%ABIO_DIC
	113	b.e21.BSSP245cmip6.f09_g17.CMIP6-SSP2-4.5	4.3	SSP245	CAM60	POP2%ECO%ABIO_DIC
	114	b.e21.B1850cmip6.f09_g17.DAMIP-hist-ghg	7.27	1850	CAM60	POP2%ECO%ABIO_DIC
Stayed the Same	103	f.e21.FWaerchem-piCH4.f09_g17.CMIP6-histSST-piCH4-WACCM	0.51	HIST	CAM60%WCTS%AERCHEM-piCH4	DOCN%DOM
	107	f.e21.F1850_BGC.f09_f09_mg17.CFMIP-piSST	1.59	1850	CAM60	DOCN%DOM

Analysis: Greedy CESM Data

9 years + 3 months

483,003 runs

38,062
Unique Cases

1,406,545
Simulated Years

1,054,615,678

CPU Hours

Analysis: Greedy CESM Data

9 years + 3 months

483,003 runs

38,062

Uniqu

Cases

6,5454

Simulated

Years

10 Parsers!

1,054,615,678

CPU Hours

Analysis: Greedy CESM Data

Predictive Modeling – Linear Regression

- Compset (parsed out)
- Grid (parsed out)
- Run type
- Simulated years

For each component:

- Instances
- Tasks
- Threads
- Root

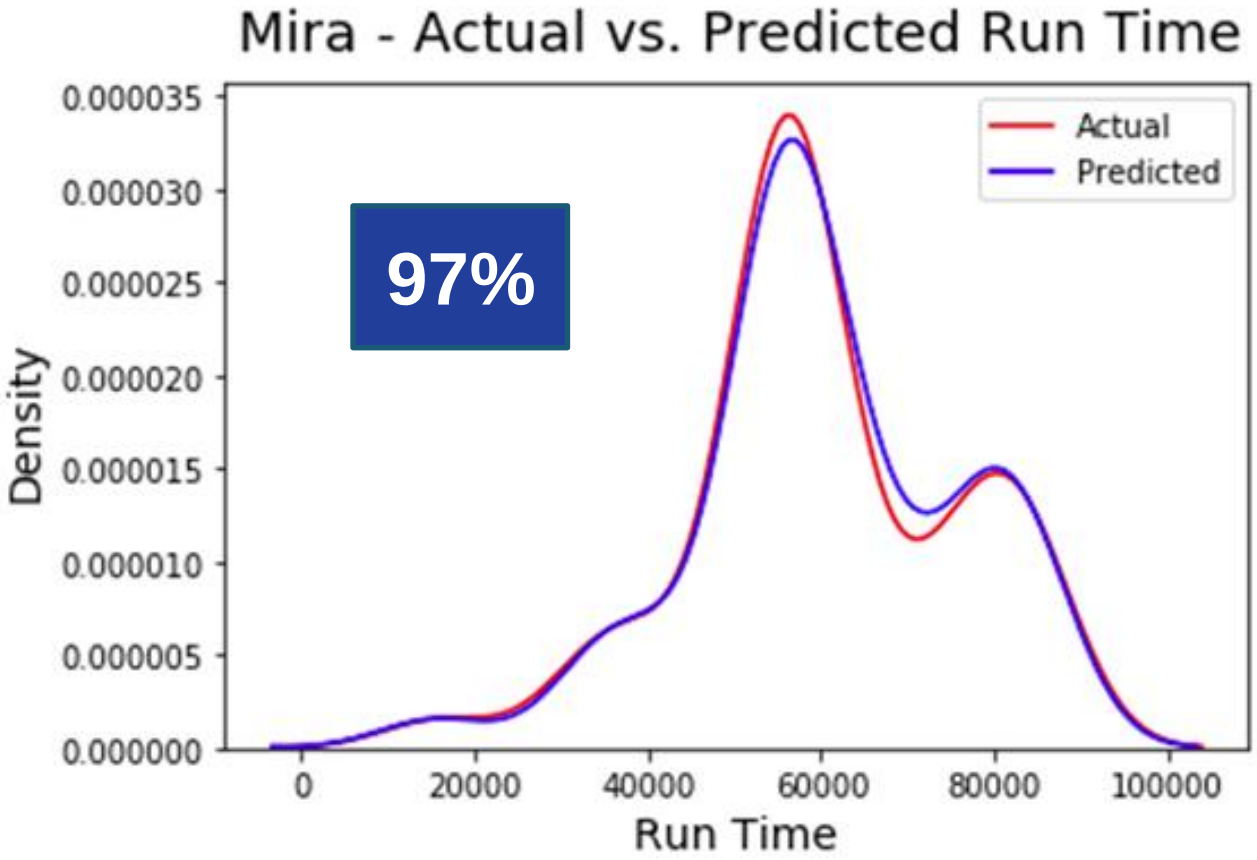
Can I predict total run time?

$$\text{Model cost} = \frac{\#\text{ of processors} \times \text{run time}}{\text{simulated years}}$$

Analysis: Greedy CESM Data

Predictive Modeling – Linear Regression

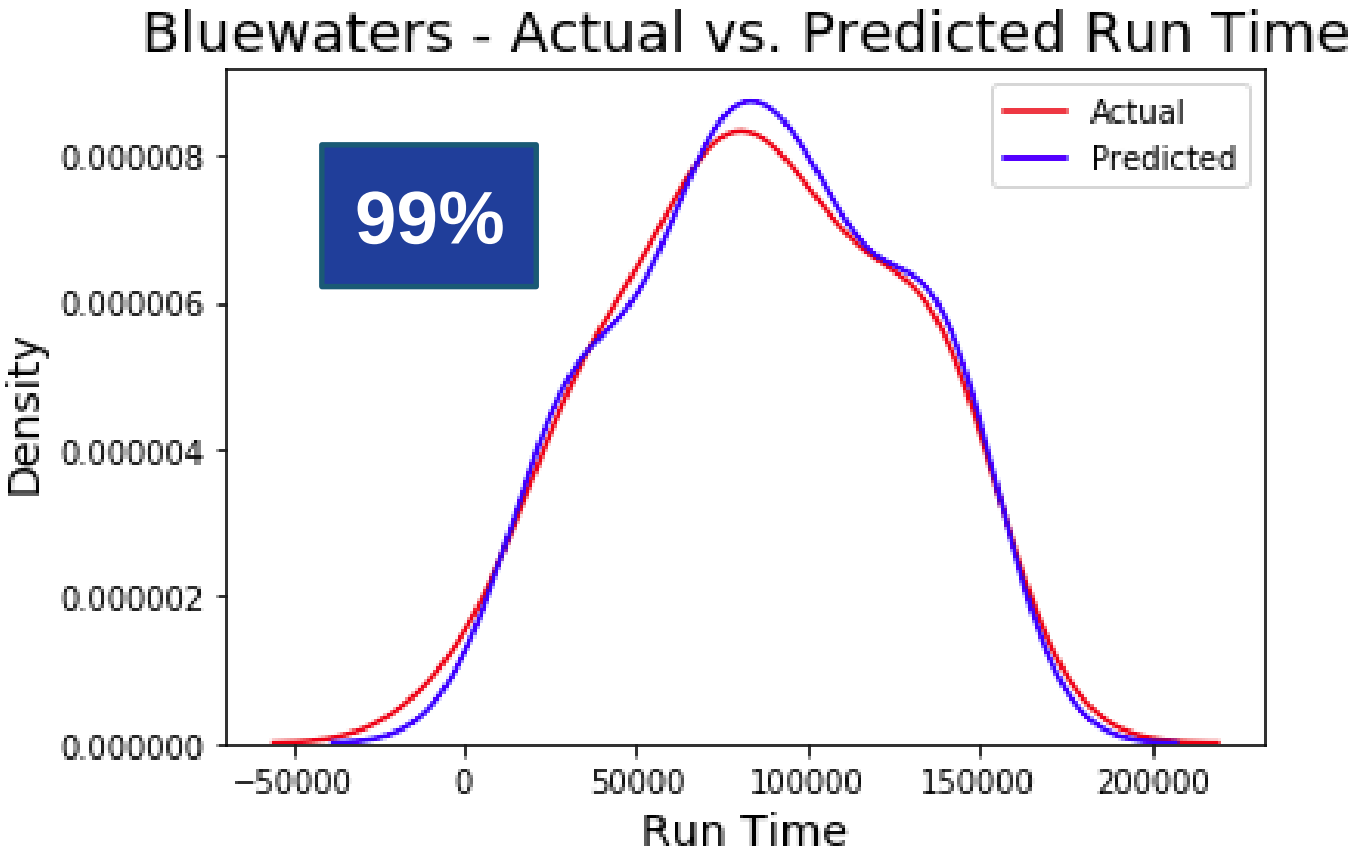
Mira (202 runs)



Analysis: Greedy CESM Data

Predictive Modeling – Linear Regression

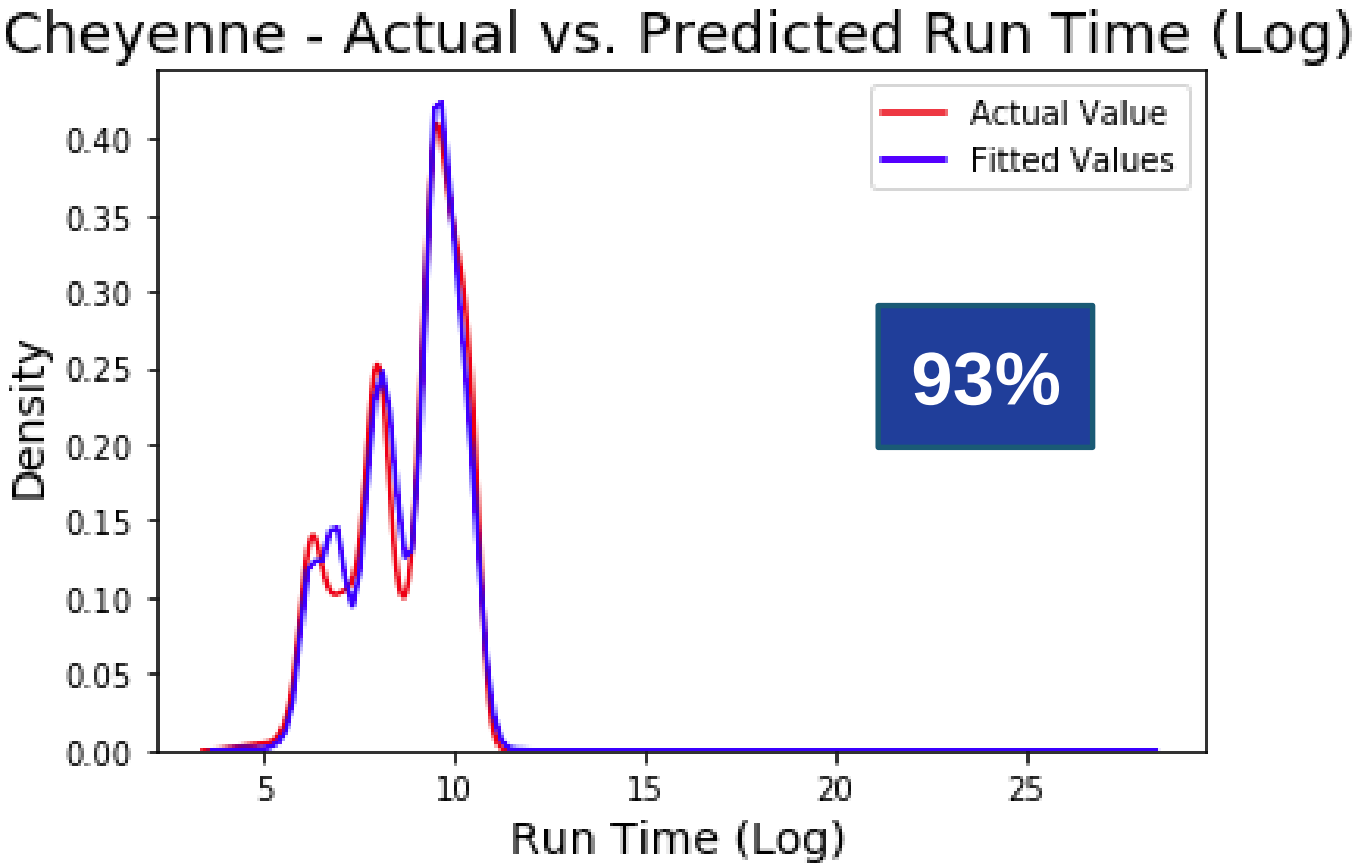
Bluewaters (305 runs)



Analysis: Greedy CESM Data

Predictive Modeling – Linear Regression

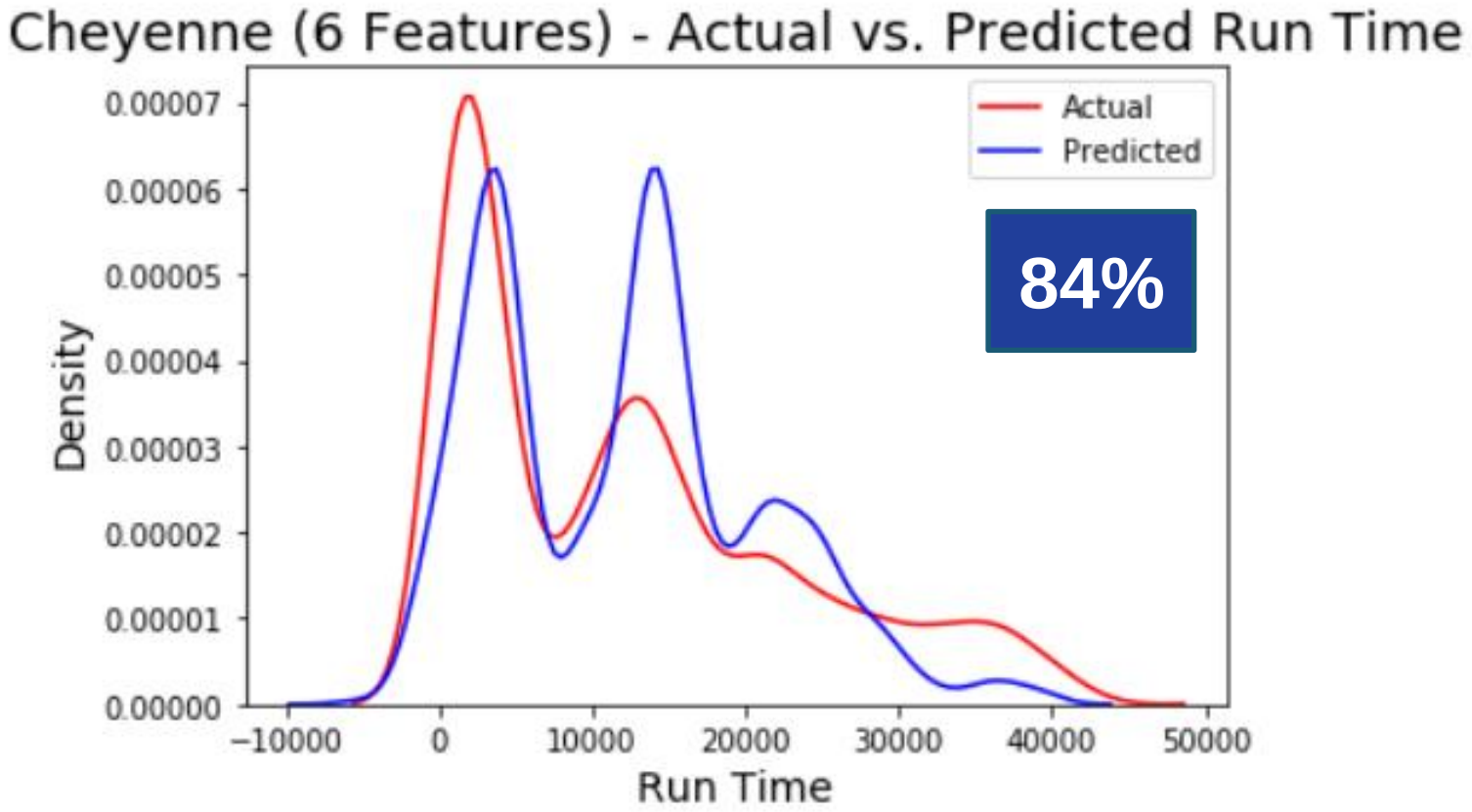
Cheyenne (48,313 runs)



Analysis: Greedy CESM Data

Predictive Modeling – Linear Regression

compset_init + compset_atm + compset_ocn +
grid_atm + grid_ocn + run_length_years ~ Run Time



Conclusion

Why do we care about predicting performance?

CPU hours are *expensive* and *limited*

If scientists can enter their configuration into a form and see the expected run time, they could:

- **Plan their computing allocation**
- **Eliminate the need for some performance test runs**

Conclusion

Why do we care about predicting performance?

CPU hours are *expensive* and *limited*

If scientists can enter their configuration into a form and see the expected run time, they could:

- **Plan their computing allocation**
- **Eliminate the need for some performance test runs**

Example: Cheyenne had 276,000 total runs;

103,000+ runs were less than 10 simulated days

= 4.4M CPU hours

Future Work

Ongoing analytics

- Model tuning on feature importance
- Track performance over time
- Track new version adoption rates

Automated tool that learns from performance data:

- Help inform scientist computing budgets
- Detect issues that reduce performance, such as misconfiguration, bad hardware, etc.

Acknowledgements

John Dennis
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Virginia Do
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Michael Busch
Nate George
Professors at Regis University

References

Balaji, et. al. CPMIP: Measurements of Real Computational Performance of Earth System Models in CMIP6. Geoscience Model Development Issue 10. January 02, 2017. https://www.geosci-model-dev.net/10/19/2017/

Images

Unless otherwise noted, graphics are from www.vecteezy.com

Questions?

Lolita Mannik – 4winds@mannik.com

This presentation, the data, and my Jupyter Notebooks will be posted at:
https://github.com/ChihuaWars/CESM-Analytics