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NATIONAL RENEWABLE ENERGY LABORATORY

Prediction and Characterization of Application Power Use

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August 25, 2016

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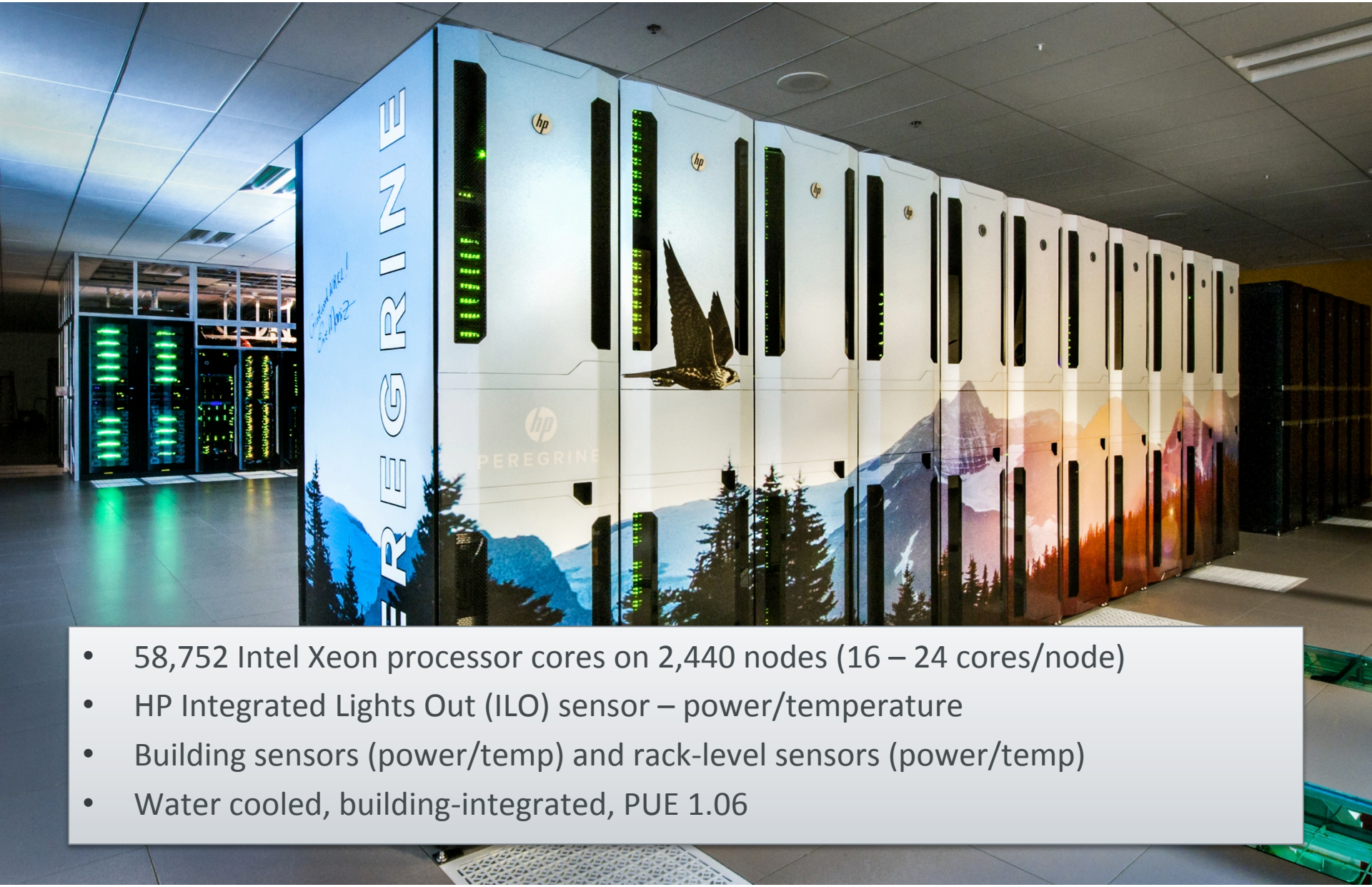
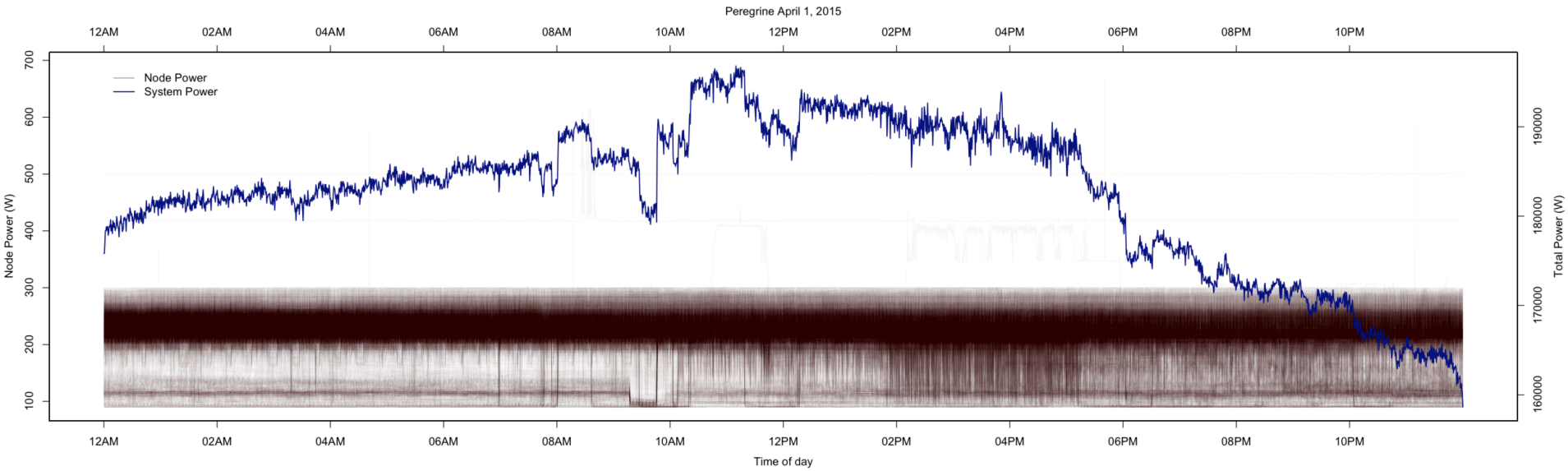
NREL HPC System - Peregrine



- 58,752 Intel Xeon processor cores on 2,440 nodes (16 – 24 cores/node)
- HP Integrated Lights Out (ILO) sensor – power/temperature
- Building sensors (power/temp) and rack-level sensors (power/temp)
- Water cooled, building-integrated, PUE 1.06

One Day in the Life of Peregrine



STM Photovoltaic Field

Peregrine Power Use v.s. PV Power Production

Building Knobs for HPC System Power Use

Power

Building Knobs for HPC System Power Use

- Data Collection
  - Sensors, code, databases, APIs
- Exploratory Data Analysis
  - What **opportunities** are there?
  - **Structure** and covariates
  - Modalities, periodicities, **variability**
- Modeling
  - **Predicting and forecasting** power needs and energy use
- Application
  - Utilize predictions to control system or queue-level power use by **altering the schedule** (delaying jobs)

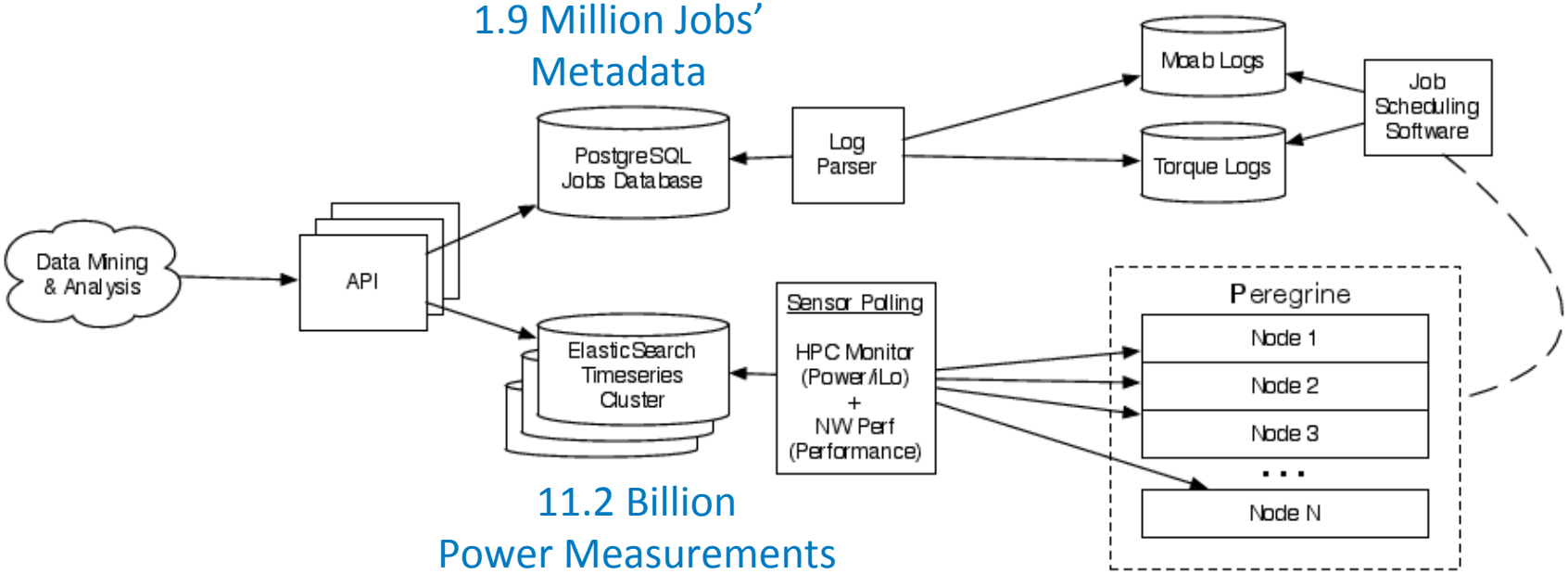
1) Data Collection

(briefly)

http://www.nrel.gov/docs/fy16osti/65392.pdf

NREL HPC Power Informatics System

1.9 Million Jobs' Metadata

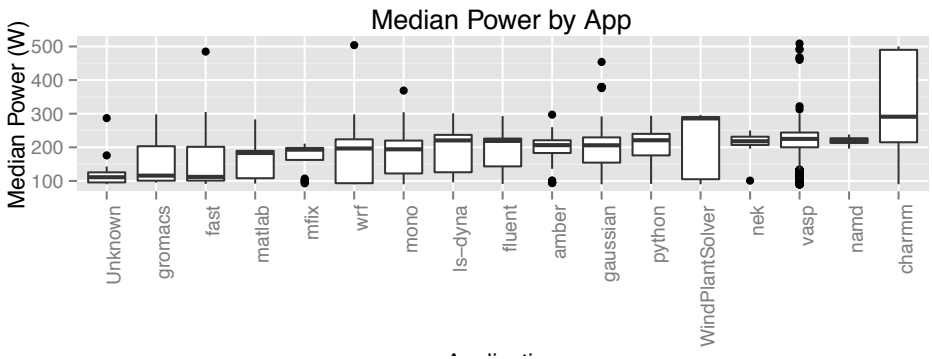


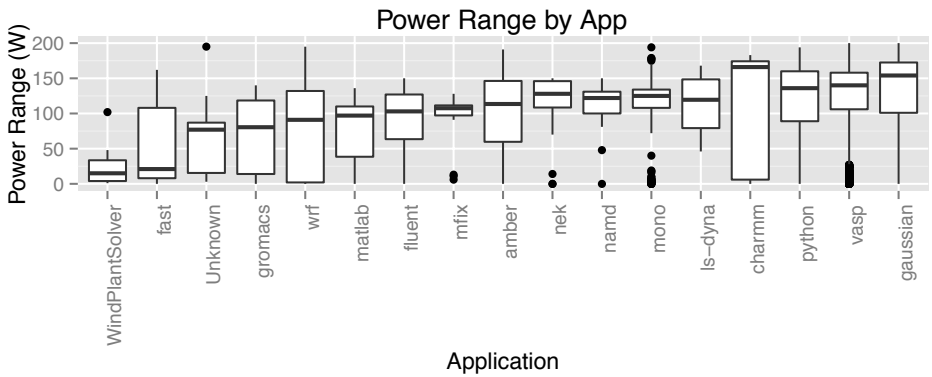
11.2 Billion Power Measurements (10 sec resolution)

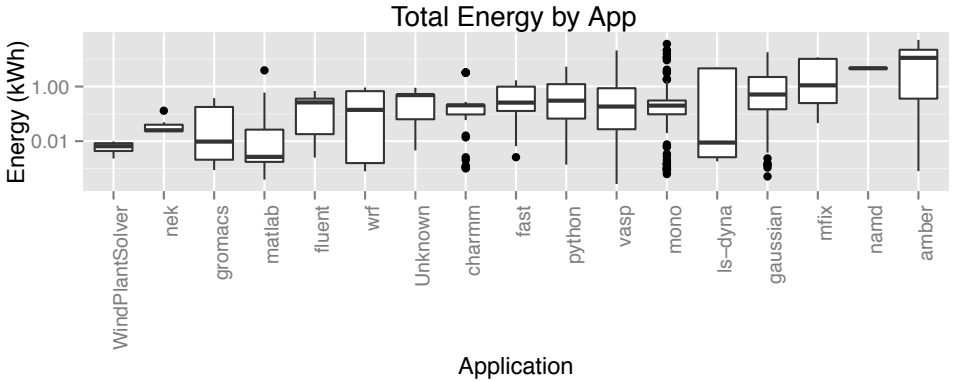
2) Exploratory Data Analysis

(selected)

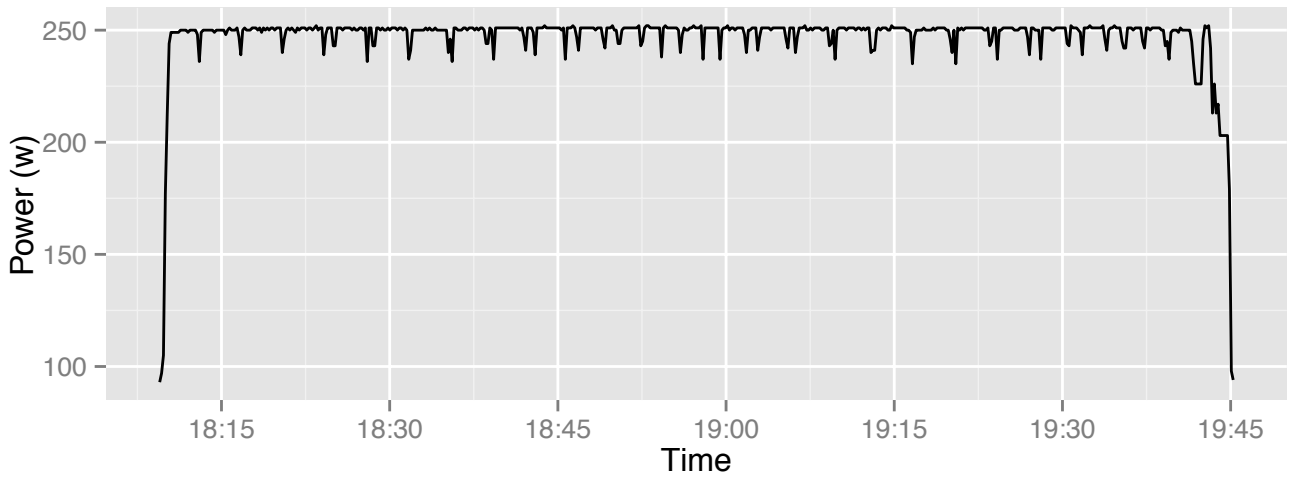
Power Use by Application

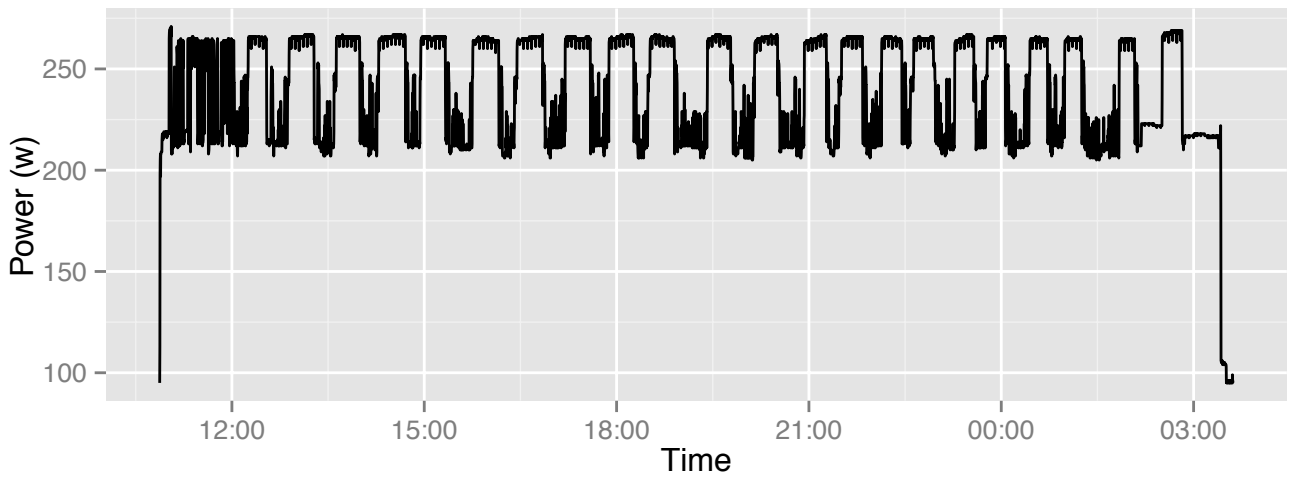




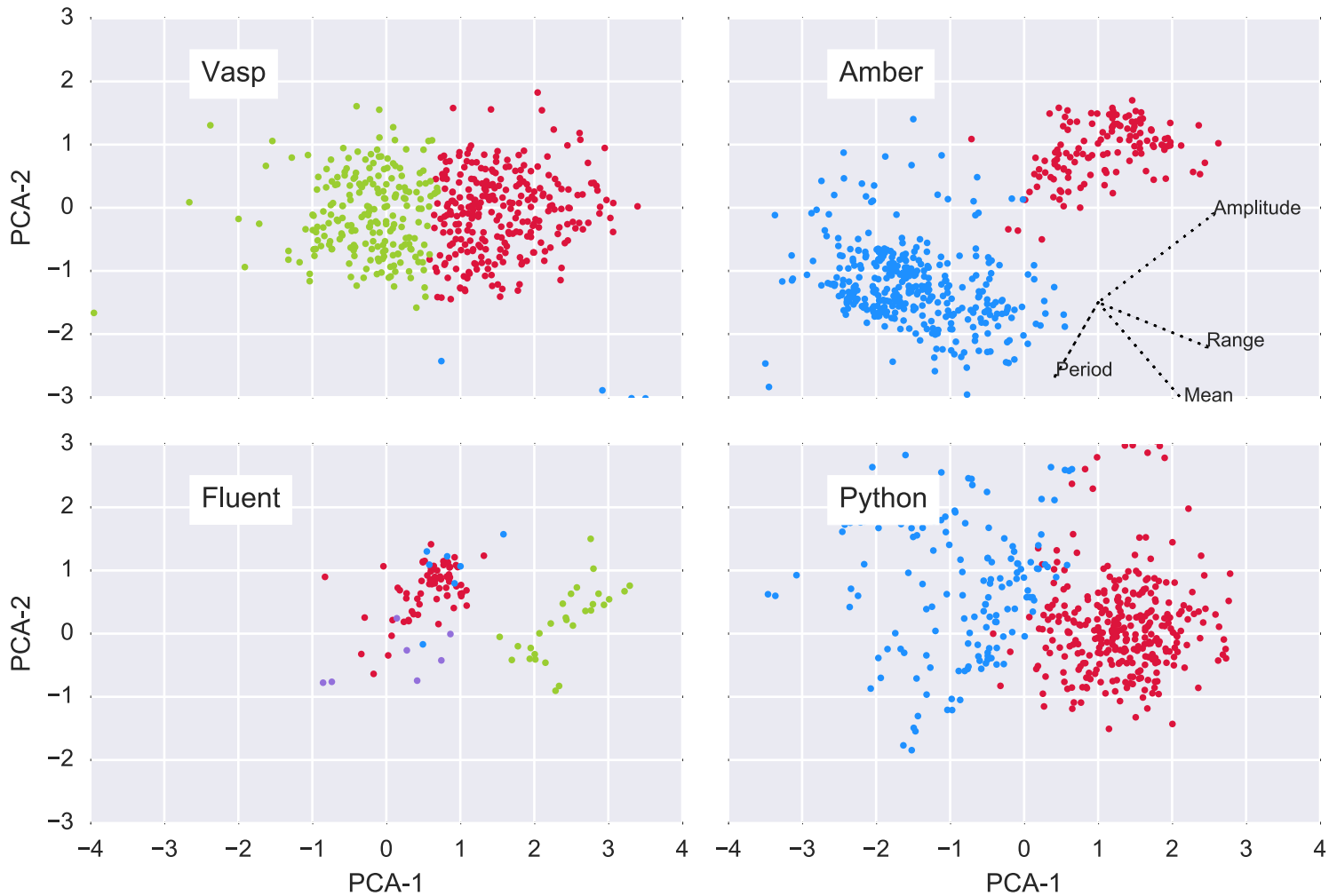


Per Job Power Use / Periodic Structure





Clustering Jobs



3) Modeling (Prediction)

Prediction

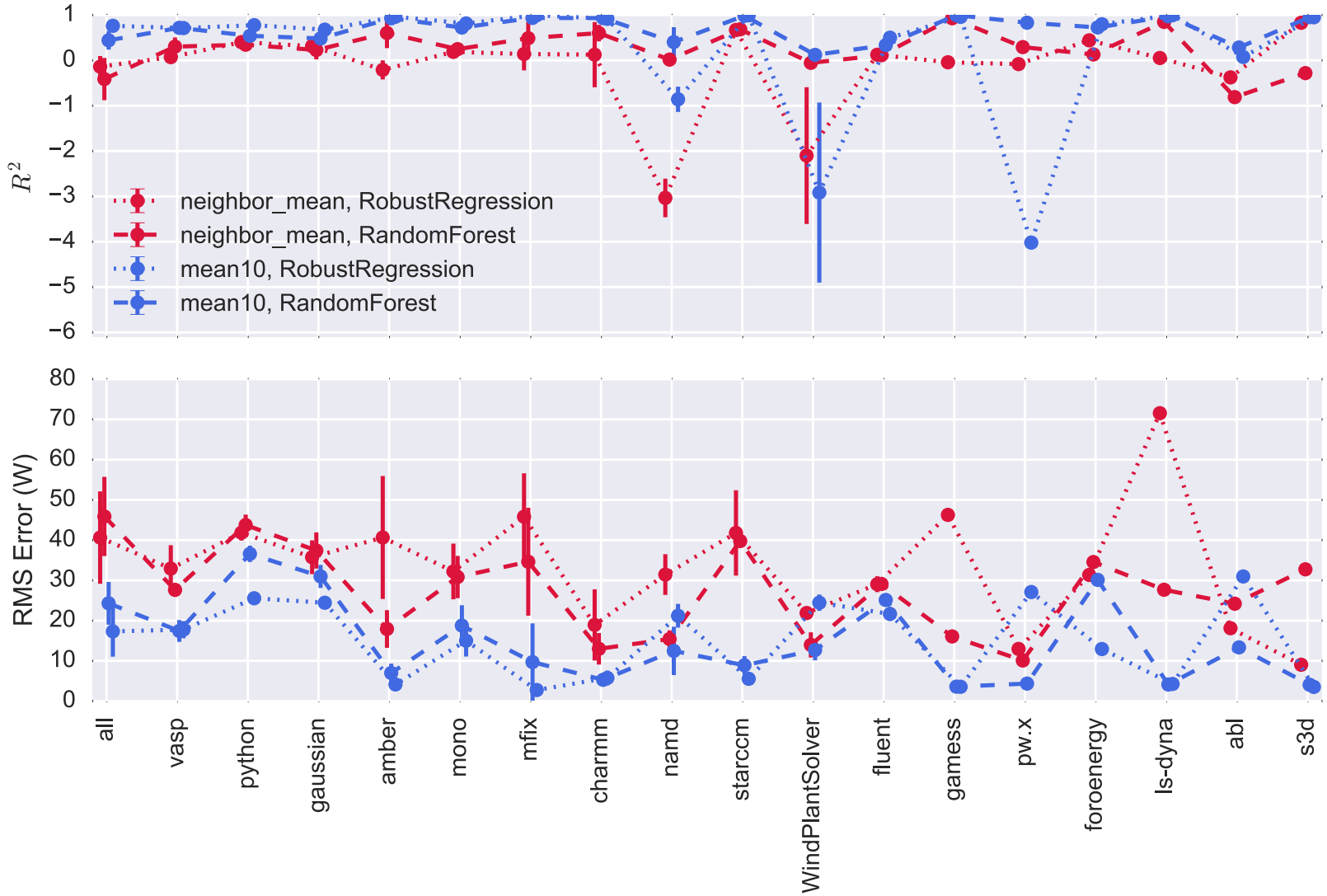
- Goal: Predict job's future energy usage characteristics at time of submission
  - **Inputs**: User, group, allocation, script, application, requested resources
  - **Outputs**: Mean/median/min/max power, periodicities, cluster membership

- *Relaxed versions*
  - *Allow observation of first N minutes of job*
  - *Include information from 'nearest neighbor' jobs*

Predicting Job Power Use

- Model Shootout, 10 fold cross validation
  - Train/Test data from 1 month to 2.5 years of continuous metric and job information collection
- Winners:
  - Robust Regression
  - Random Forest
- Lessons Learned:
  - Grouping by application matters
  - Recent information is most useful

Individual Job Prediction



4) Application

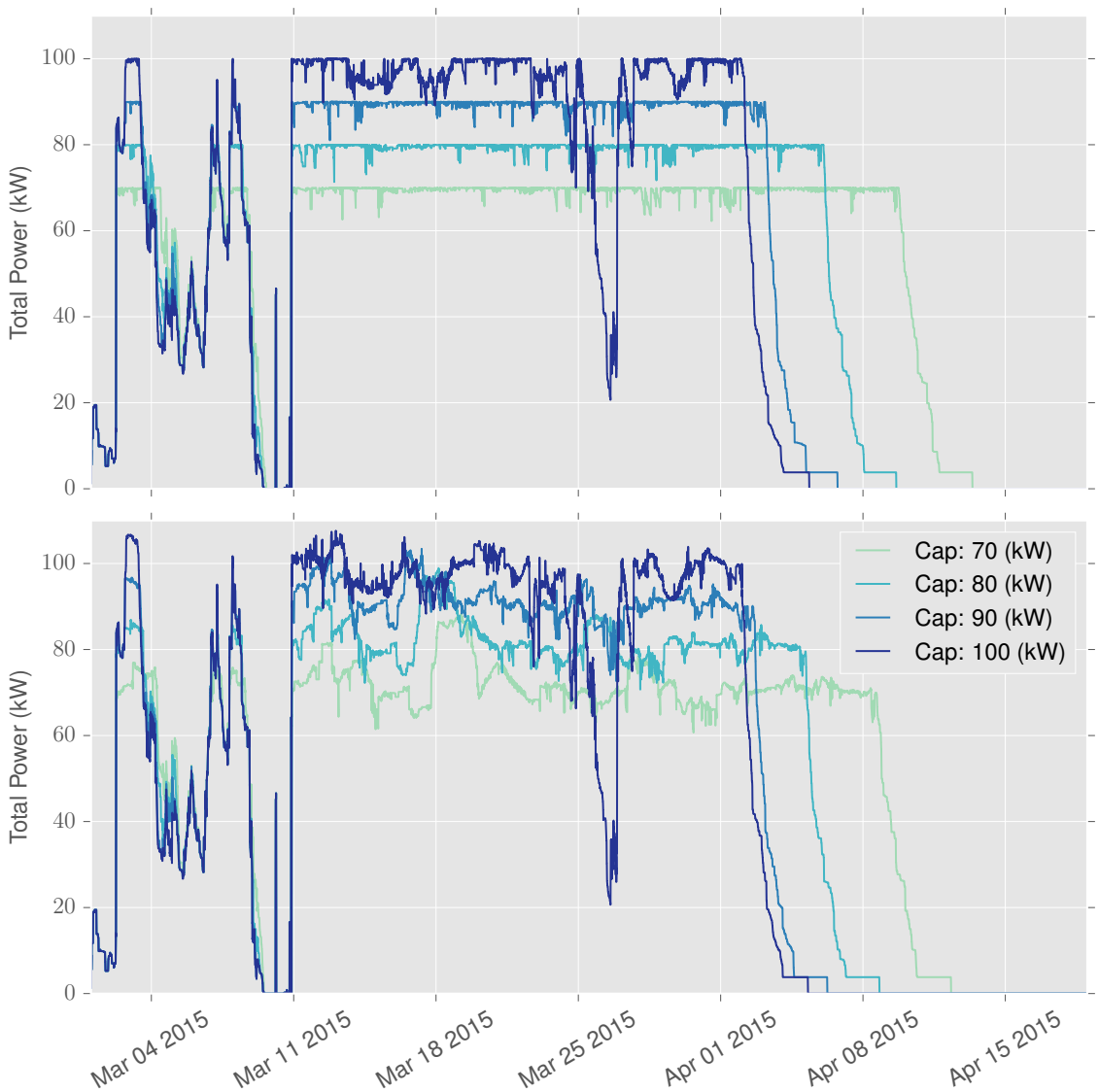
Applying Predictions for System Power Capping

- **Goal**: Alter job schedule using predicted power information to keep entire system power use under some threshold.

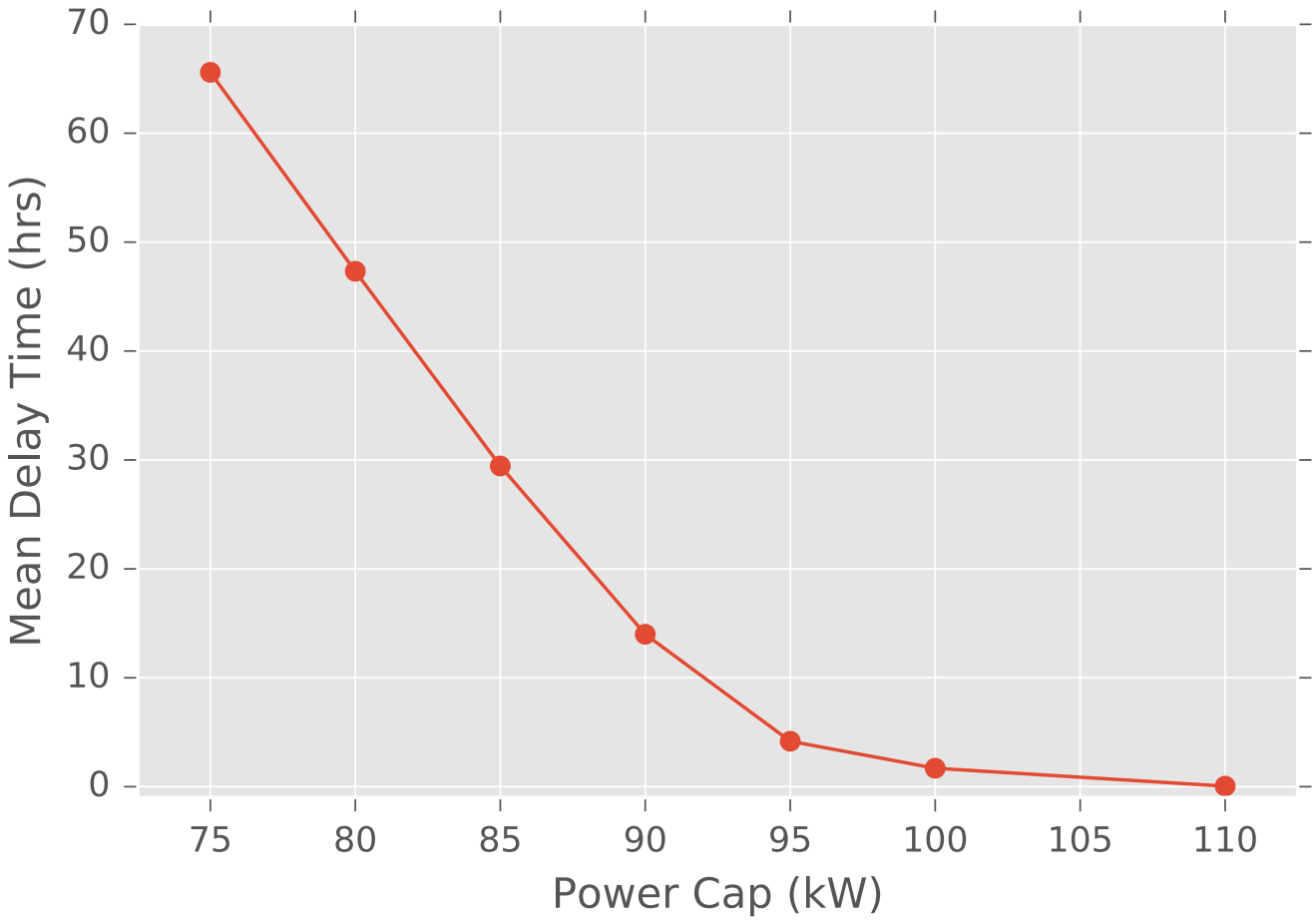
- **Approach**: Simulate MOAB-like FIFO scheduler with backfill, use predictions to delay jobs that would push us over threshold.

Using True Power:

Using Predictions:



Job Delay Due to Power Capping



Summary

- An **informatics system** is necessary for building a deep understanding of system dynamics through data collection and indexing
- There is **substantial variation** between jobs' power use which provide opportunities for intelligent optimization and classification
- Even with limited information at the time of submission, we can **predict mean power** for most jobs to within 35 W
  - A tiny amount of observation improves prediction. There may be opportunities for *pre-emption and reruns* in a power constrained environment.
- Predictions allow for **adaptive power capping** and integrate naturally into existing FIFO+backfill schedulers.

Other things, ongoing work

- CWT can be used to extract power time-series **periodic structure**.
  - Constructive interference between periodic jobs' power use may lead to (avoidable) power spikes.
- Systems without power sensors may be able to infer their power use with **proxy metrics** (CPU, etc.)
- Ongoing: Node level metrics can be used to identify **anomalous and failure** states in real time. Apply models for noticing problems in the **system-wide data stream**.

Wish list

- Better, ubiquitous (power, …) sensors
  - DOE DCOI moving towards this?
  - More sensor data sharing between HPC centers
- "Monkey queue"
  - Incentives for users to participate
- Clear interface and tools for node-level controls
- More collaboration between cloud/cluster and HPC

Acknowledgements

- **Students**
  - **Hilary Egan** – *CU Boulder (DOE GCS Fellow)*
  - Kalvin Ogbuefi – *Cal Long Beach (DOE SULI)*
- **NREL**
  - **Bruce Bugbee** – *Statistics*
  - Ryan Elmore – *Statistics*
  - Kenny Gruchalla – *Visualization*
  - Avi Purkayastha – *HPC*
- **SNL**
  - **Jim Laros**
  - Kevin Pedretti

Thank you!

Questions? Collaboration? Data?

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