Computing Electricity Consumption Profiles from Household Smart Meter Data

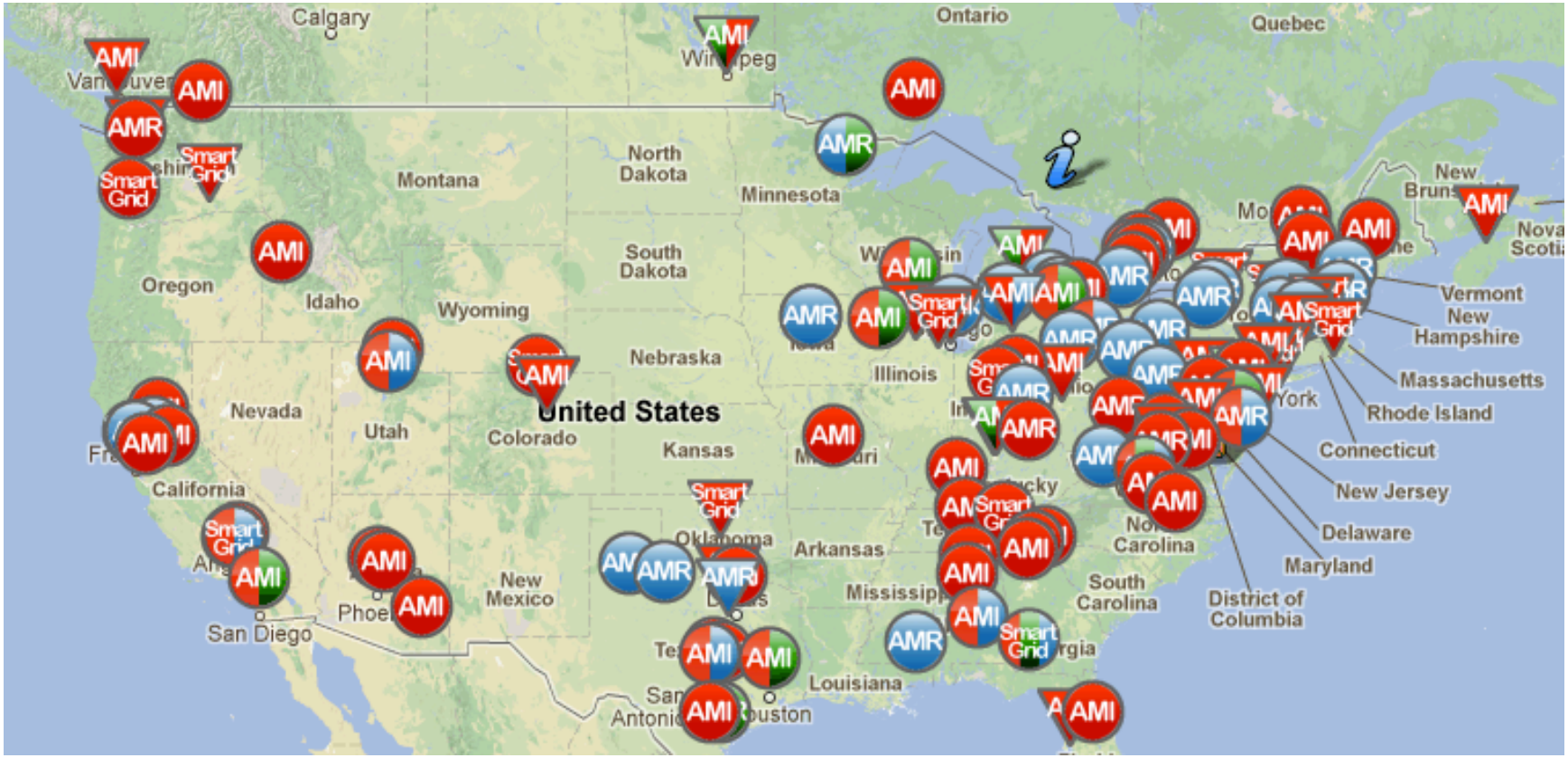
O. Ardakanian, N. Koochakzadeh, R. P. Singh, L. Golab, S. Keshav
University of Waterloo

3rd Workshop on Energy Data Management
March 2014

Your Smart Meter is Watching!

From: http://www.thestar.com/opinion/2009/11/17/your_smart_meter_is_watching.html

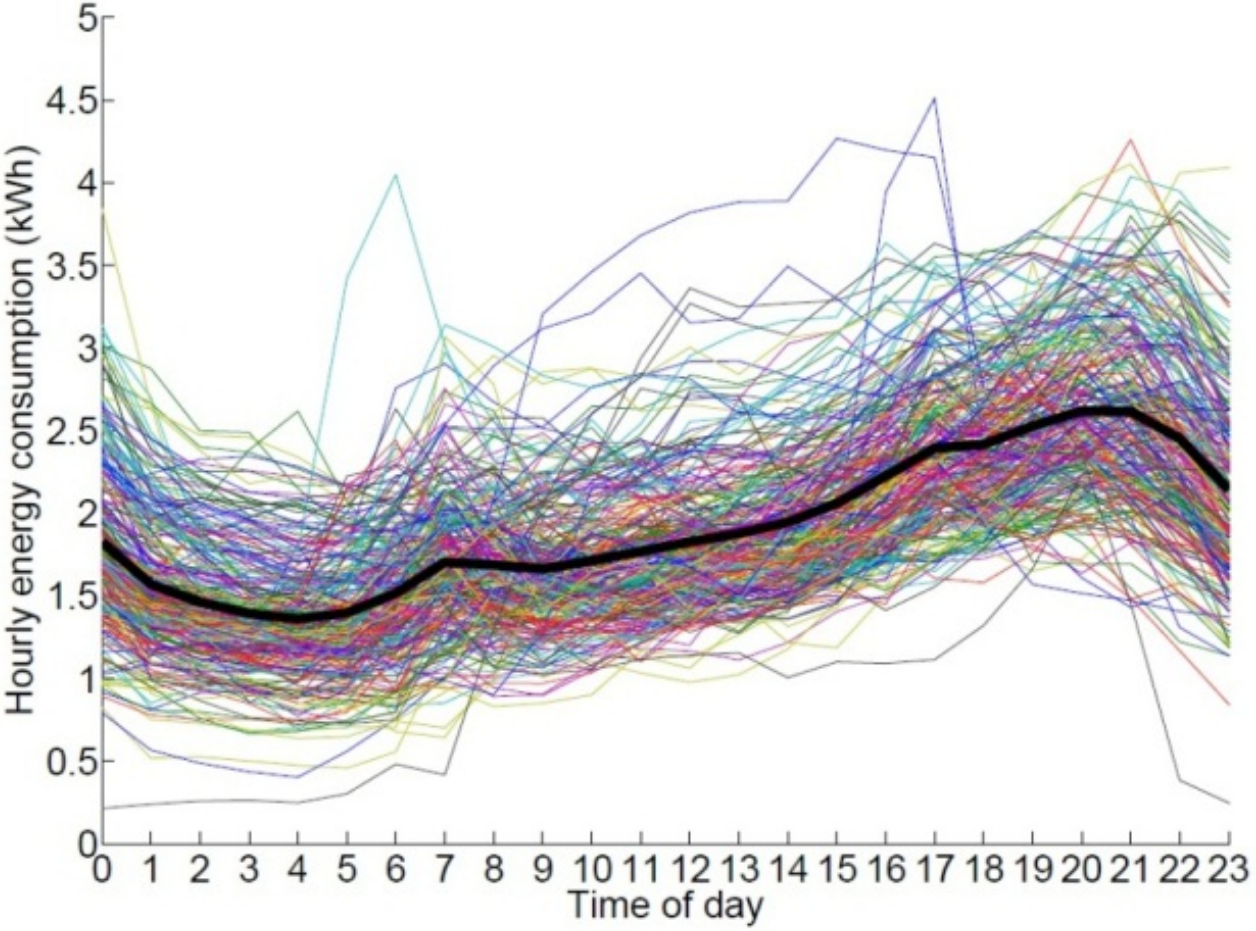
Smart Meters are Ubiquitous



Electricity Gas Water Trials Projects

Motivation for Smart Metering

Electricity Consumption Profiles



The Need for Electricity Consumption Profiles

Prior Work on Electricity Consumption Profile Generation

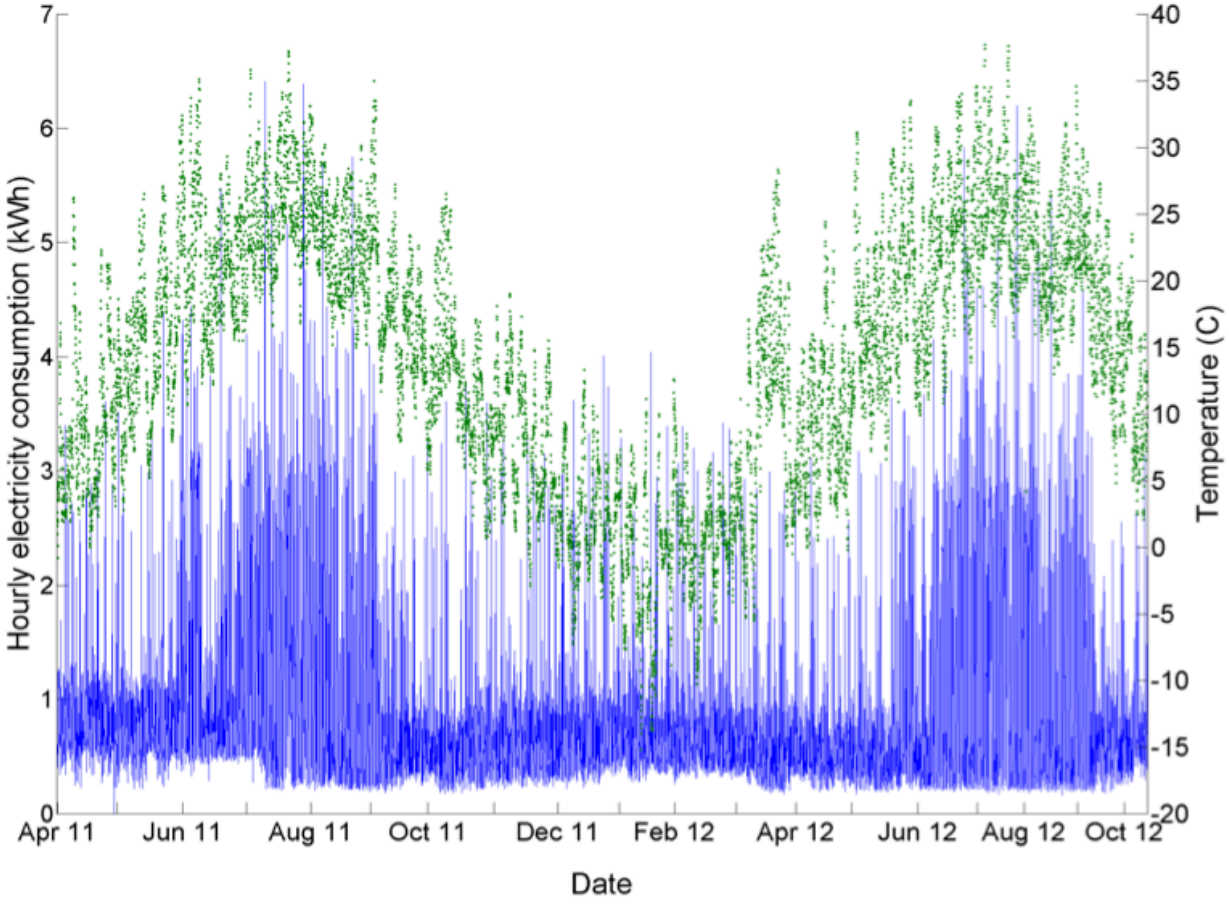
- Rely on data that is not easily available
- Use a black box method which is not interpretable
- Are not robust to noise
- Do not remove the effect of temperature and activity
  - cannot be extended to other regions and activity patterns

Takeaways

- Electricity consumption profile generation has several applications
- A profiling framework must be simple, interpretable, yet practical
- Time series analytics can be used to generate such consumption profiles

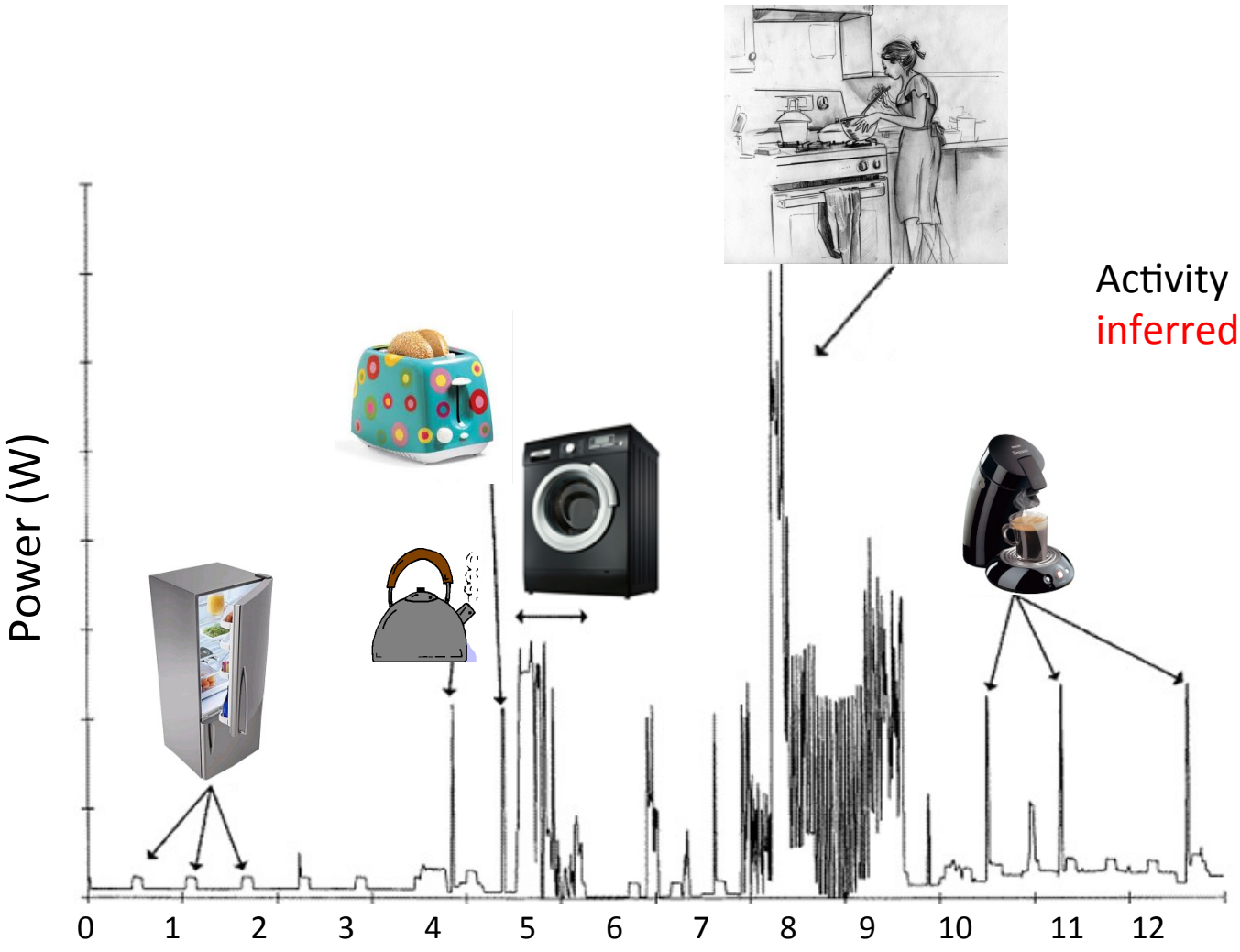
Key Observations

Residential Load Varies with Temperature



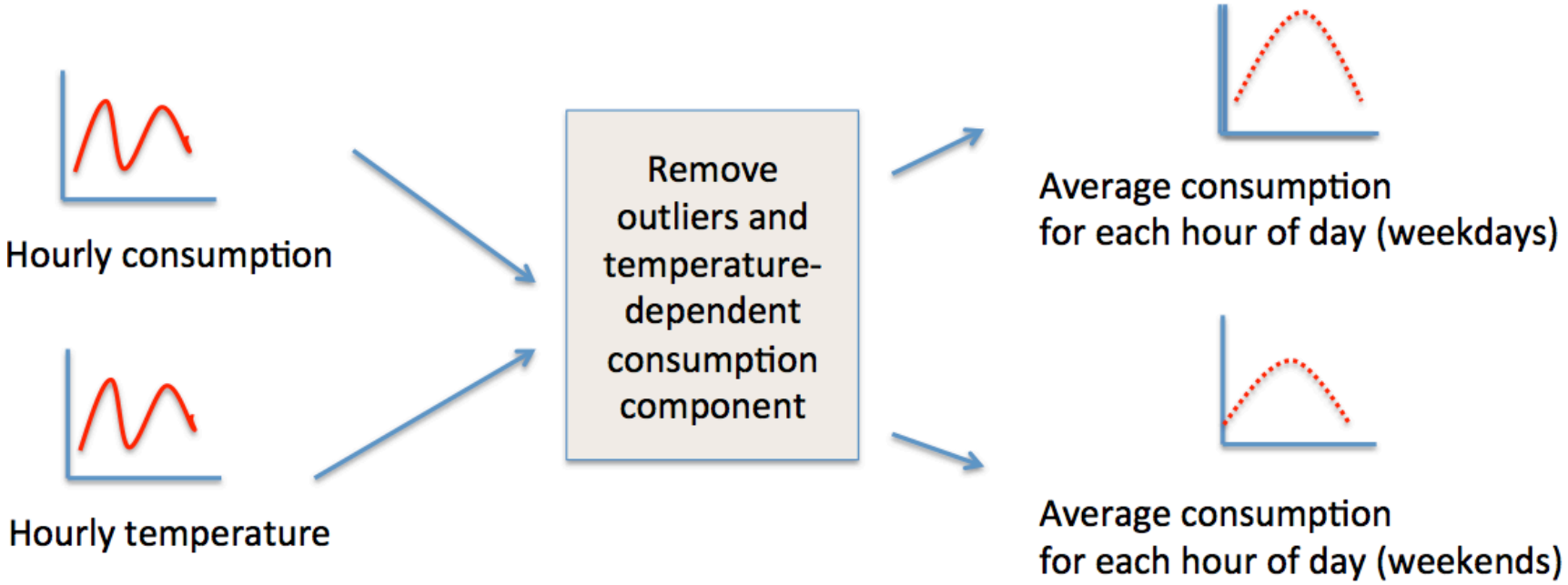
Residential Load Varies with Activity

Residential Load Varies with Activity



Activity level must be inferred from data

Our Methodology



PARX Model

recent history **temperature-sensitive load**

$$Y_t = \sum_{i=1}^{p} \phi_{i\,s} Y_{t-i} + \psi_{1\,s} XT1_t + \psi_{2\,s} XT2_t + \psi_{3\,s} XT3_t$$

$$+ \psi_{4\,s} XO1_t + \psi_{5\,s} XO2_t + C_s + \epsilon_t, \qquad \text{for } t \in s$$

outliers **intercept and noise terms** **season index**

PARX Model – cont'd

Cooling

$$XT1 = \begin{cases} T - 20 & \text{if } T > 20 \\ 0 & \text{otherwise} \end{cases}$$

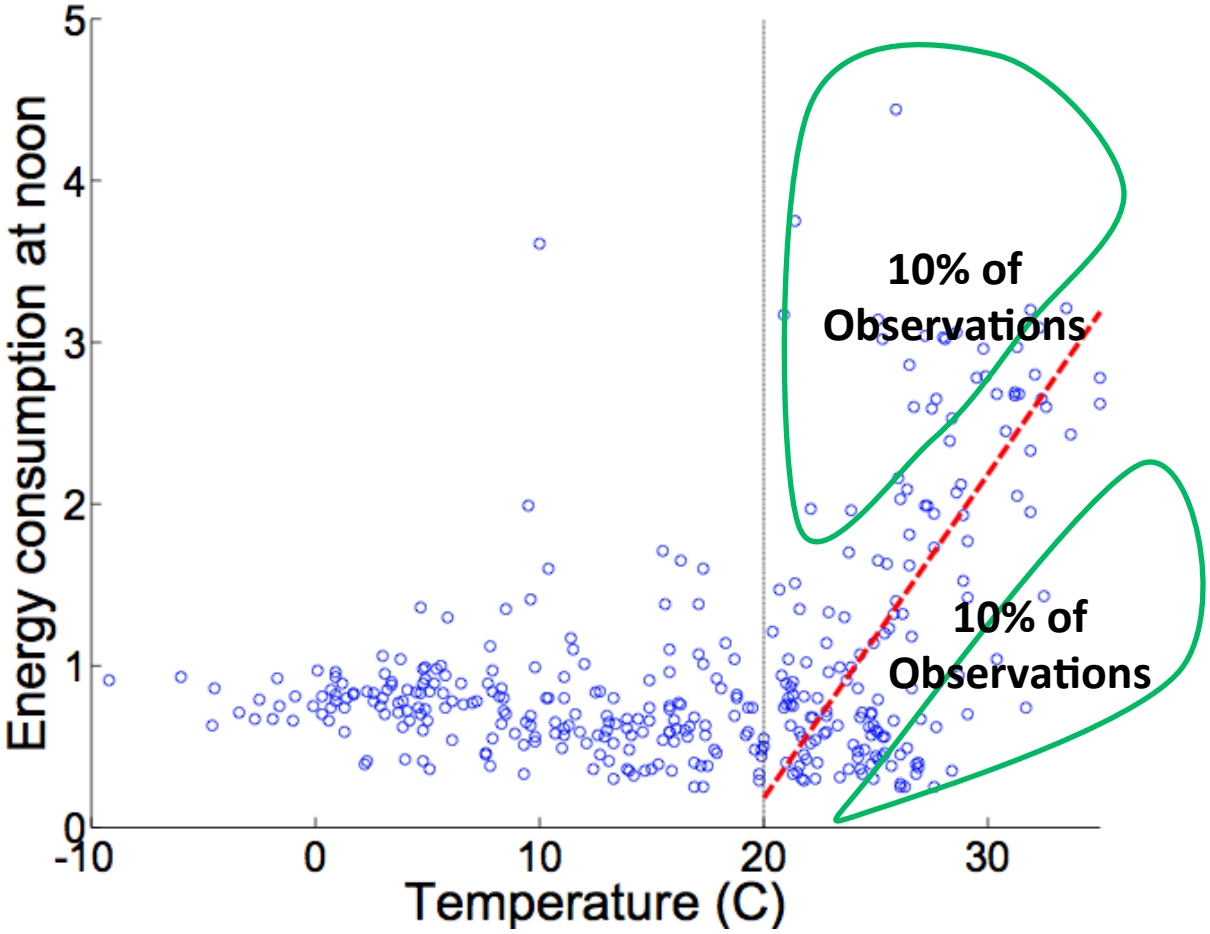
Heating

$$XT2 = \begin{cases} 16 - T & \text{if } T < 16 \\ 0 & \text{otherwise} \end{cases}$$

Overheating

$$XT3 = \begin{cases} 5 - T & \text{if } T < 5 \\ 0 & \text{otherwise} \end{cases}$$

Handling *Outliers*



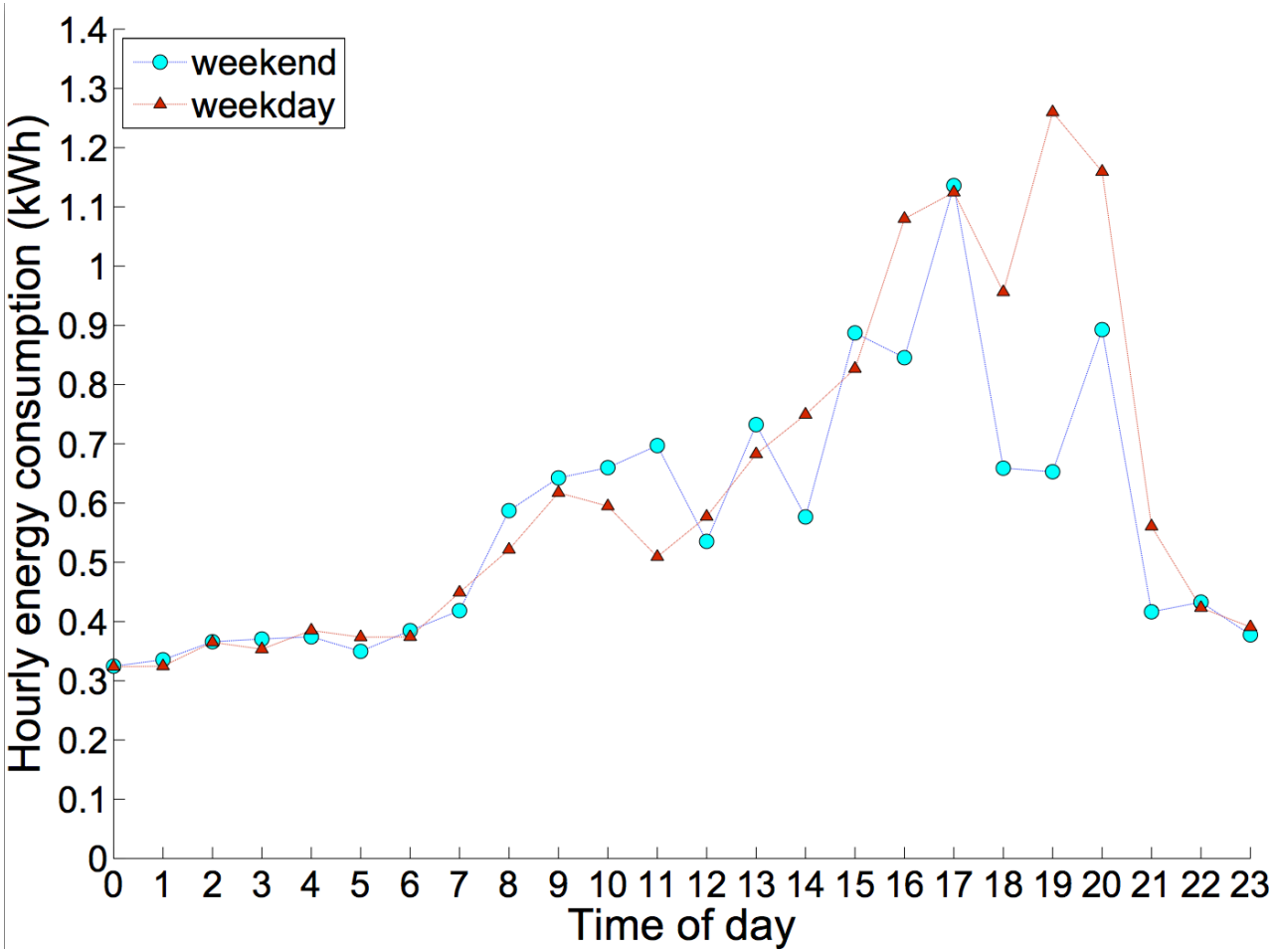
Computing Consumption Profiles

- Parameter Estimation
  - Number of seasons
  - Coefficients

- Subtracting the effect of exogenous variables

$$Y_t^* = Y_t - \psi_{1_s} XT1_t - \psi_{2_s} XT2_t - \psi_{3_s} XT3_t - \psi_{4_s} XO1_t - \psi_{5_s} XO2_t \qquad \text{for } t \in s$$

Weekday and Weekend Profiles

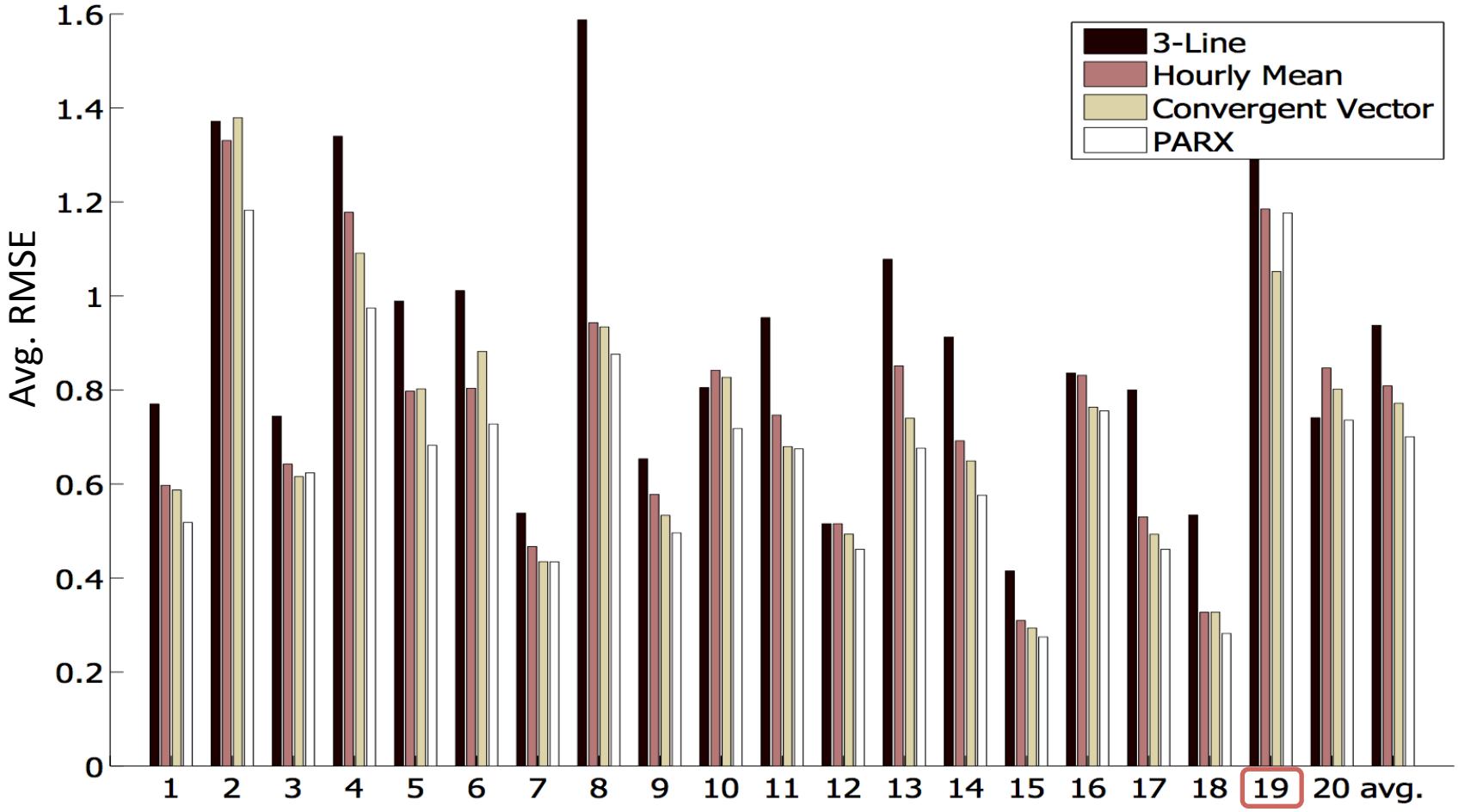


Comparison – Predictive Power

- Data set
  - Residential hourly electricity consumption data of 1000 homes from March 2011 to October 2012
  - Hourly air temperature data of that region

- Prior work
  - 3-Line Method
    - Fits a tree-piece linear regression after removing outliers
  - Hourly Mean
  - Convergent Vector
    - The same as ours but does not remove the effect of exogenous variables

Results


Avg. RMSE
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
3-Line
Hourly Mean
Convergent Vector
PARX
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
avg.

Conclusions

- Electrical consumption profile generation is important and has many applications
  - water and gas consumption
- Time series auto-regression framework enables us to remove the effects of temperature and activity
- We demonstrated a simple, interpretable, and practical profiling model with high predictive power