UCSD Master of Advanced Study Data Science & Engineering Capstone: CalTrans Traffic Analysis

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UC San Diego
Jacobs School of Engineering

Outline

- Business Objective
- Project Execution Overview
  - Data Sources & Acquisition
  - Data Preparation
  - Exploratory Data Analysis
- Analysis and Results
- Demo
- Conclusion
- Future Work

Business Objective

Among traffic congestion in America, California areas ranks among the worst

1. Los Angeles
2. San Francisco
5. San Jose
14. San Diego
24. Riverside
25. Sacramento

Source: http://tomtom.com/en_us/trafficindex/list

Better Insight → Better Solutions

What traffic patterns exist?
What factors have most influence on traffic?

Project Execution Overview

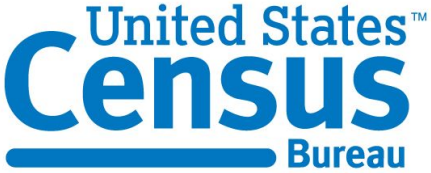
Data Source & Acquisition

Data Source & Acquisition

- Caltrans PeMS
  - 5-minute station readings
  - CHP incidents
  - Station Metadata

- Zillow
  - Monthly Home Value index (ZHVI)

- U.S. Census
  - Population (2010)
  - TIGER/Line Shapefiles



Data Source & Acquisition

1000s of Files & > 100 GB

PeMS

CHP

Python Web Scraper
BeautifulSoup & Mechanize

S3 (Simple Storage Service)

10s of Files & < 100 MB

Zillow

United States Census Bureau

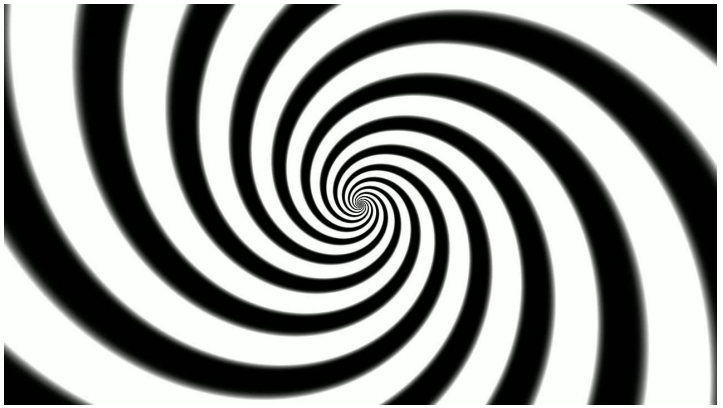
Manual Download

Data Preparation

Data Preparation

- Extract
  - Source Locations
    - S3
    - Websites
  - Source Formats
    - CSV
    - Shape Files
    - JSON

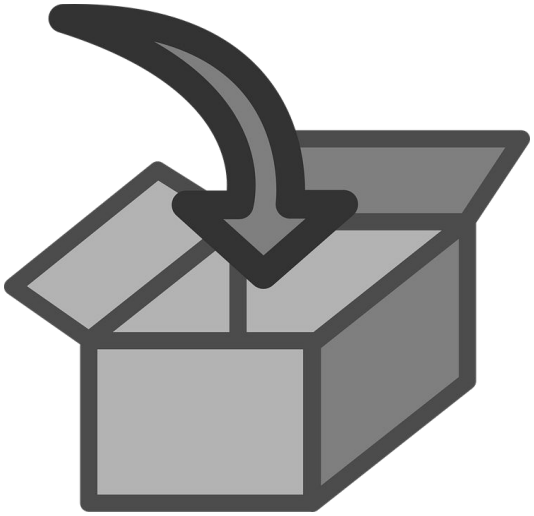
Data Preparation



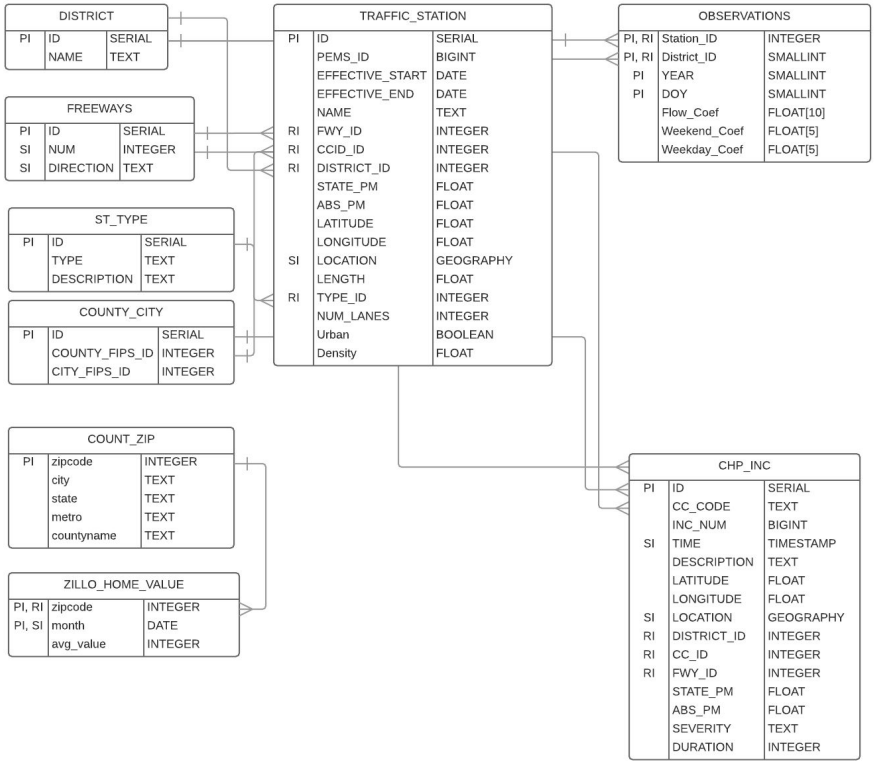
- Transform
  - Missing Fields
  - Bad Data Dropped
  - Time
    - Different Granularity per source
    - Effectivity Dates
  - Sensor Data Pivoted

Station Id	District Id	Year	Day of Year	Day of Week	Total Flow (288)	Avg. Occupancy (288)	Avg. Speed (288)

Data Preparation



- Load
  - Data Warehouse - Postgres
  - Target Schema - Snowflake



Exploratory Data Analysis

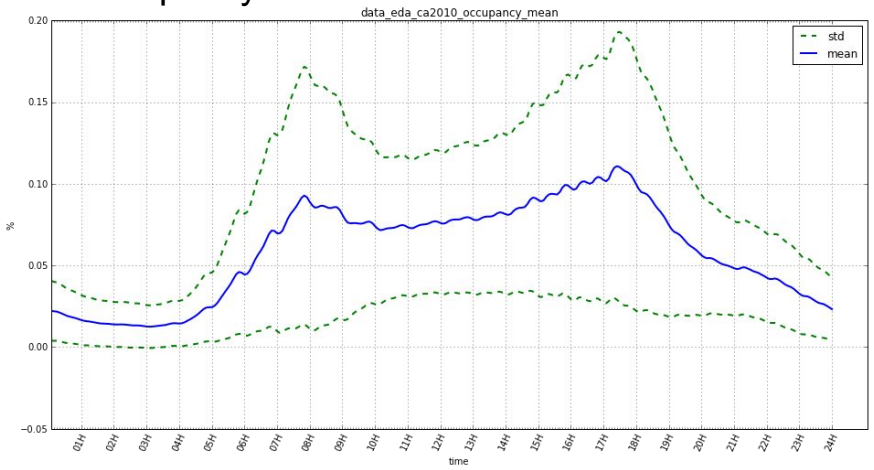
Exploratory Data Analysis

- Mean + Standard Deviation
- Top 4 Eigenvectors
- Scatter Density Plot (Total Flow)

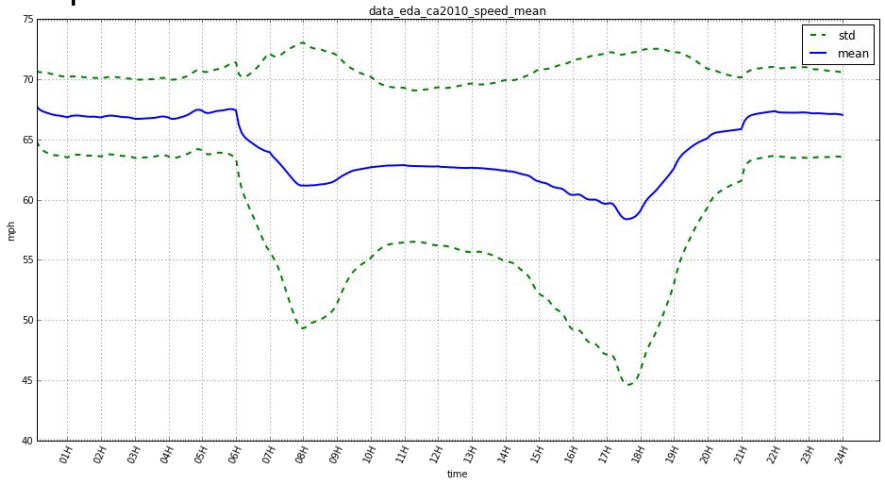
Exploratory Data Analysis

Total Flow

Occupancy

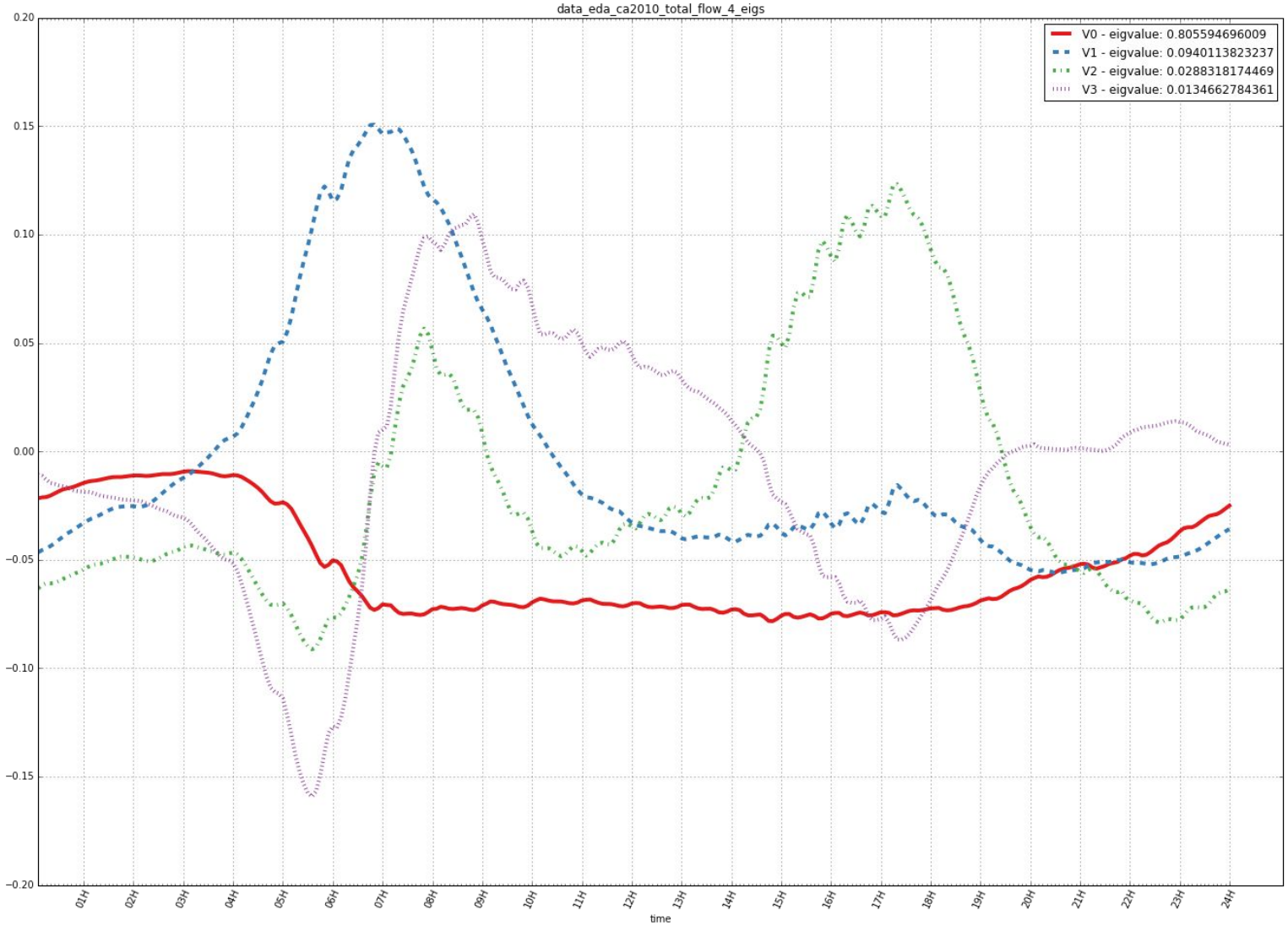


Speed

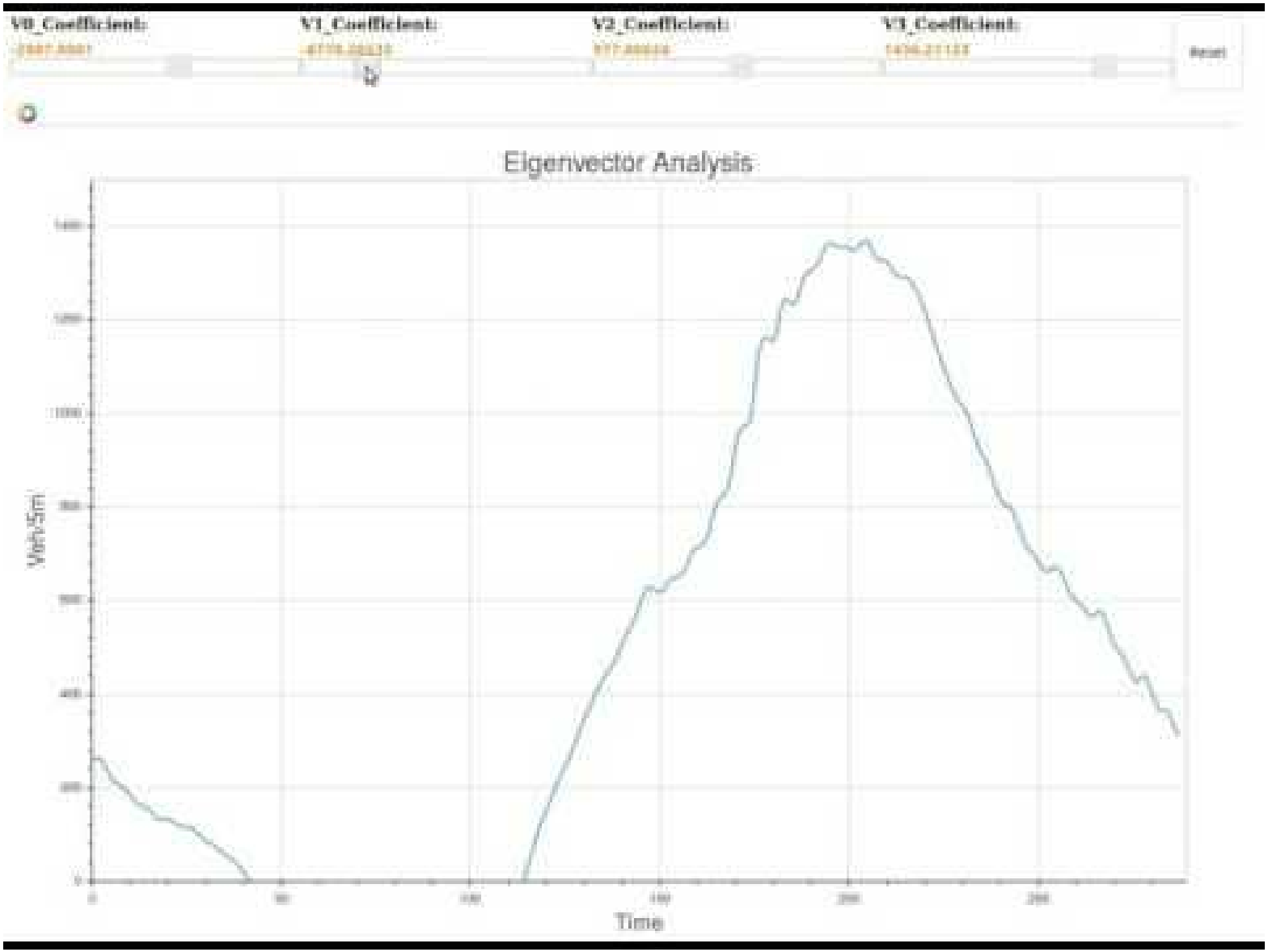


- Total Flow - measures traffic volume
- Occupancy - measures vehicle occupancy across lanes
- Speed - measures velocity of vehicles across lanes
- Preliminary analysis:
  - Total flow - directly proportional to occupancy
  - Total flow - inversely proportional to speed
  - Traffic volume - high between the hours of 6AM and 9PM

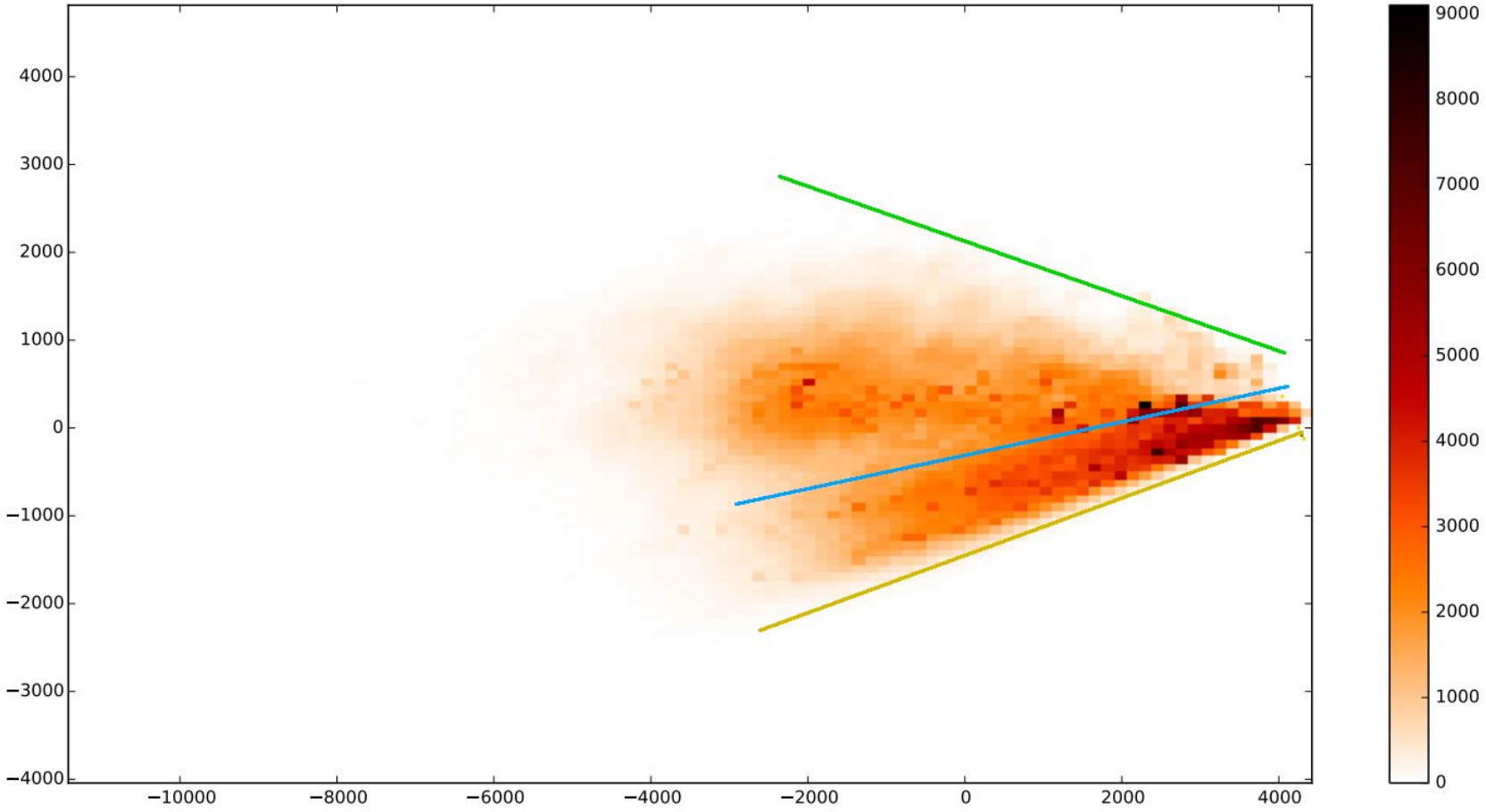
Exploratory Data Analysis



Exploratory Data Analysis



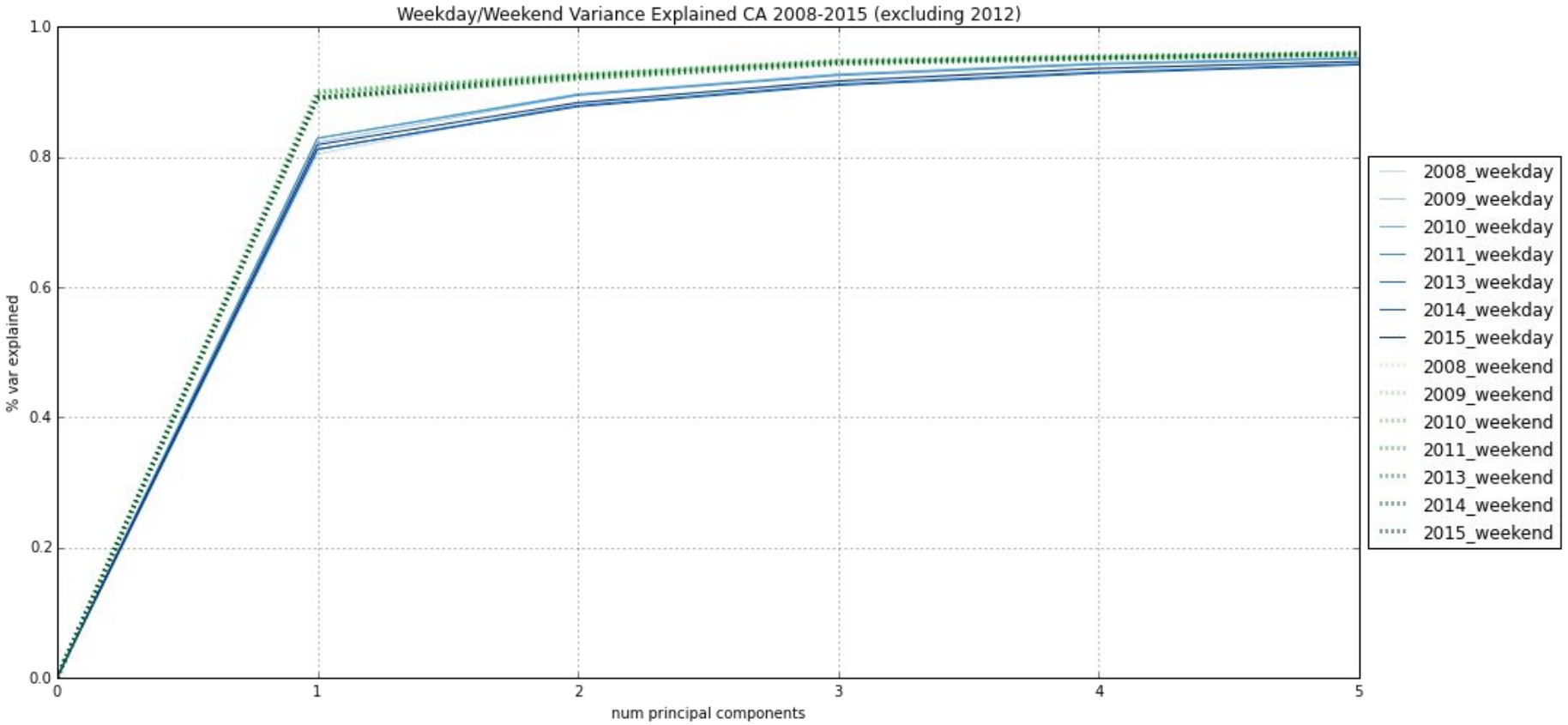
Exploratory Data Analysis



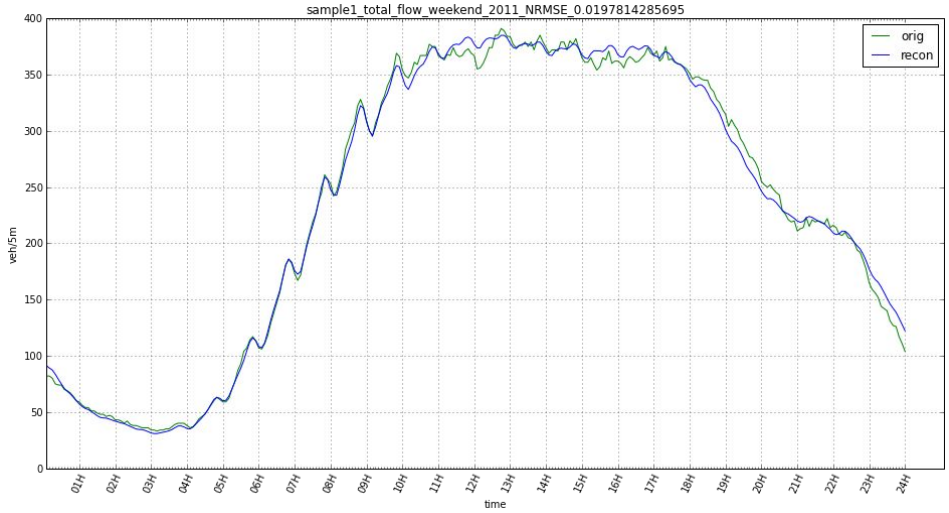
Analysis and Results

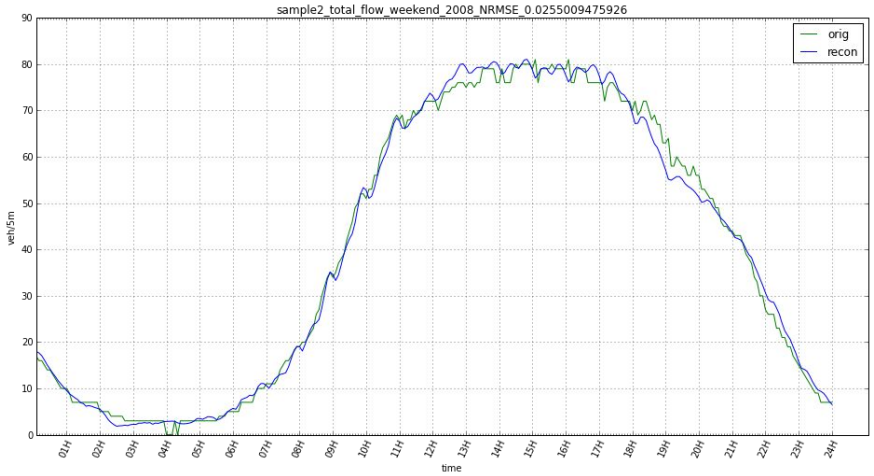
PCA

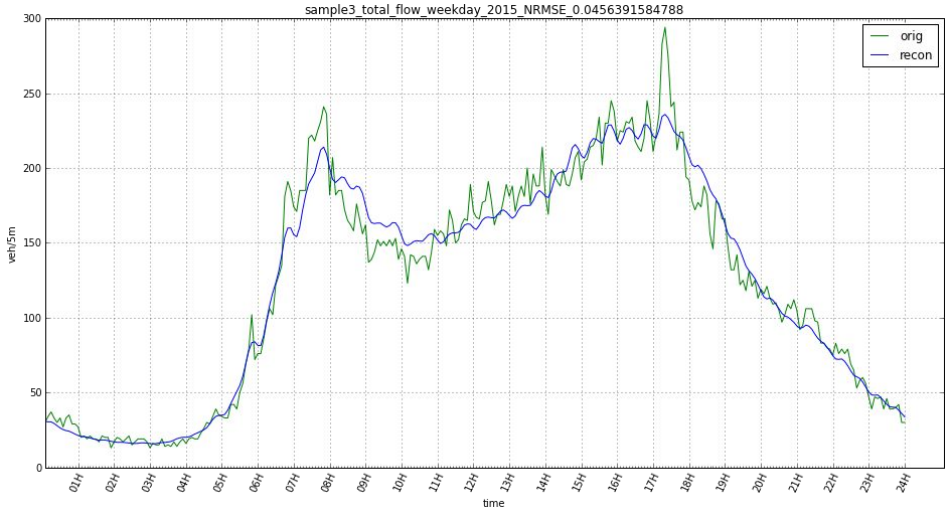
- Traffic Pattern Modeling and Prediction
- Assessment Criteria: NRMSE



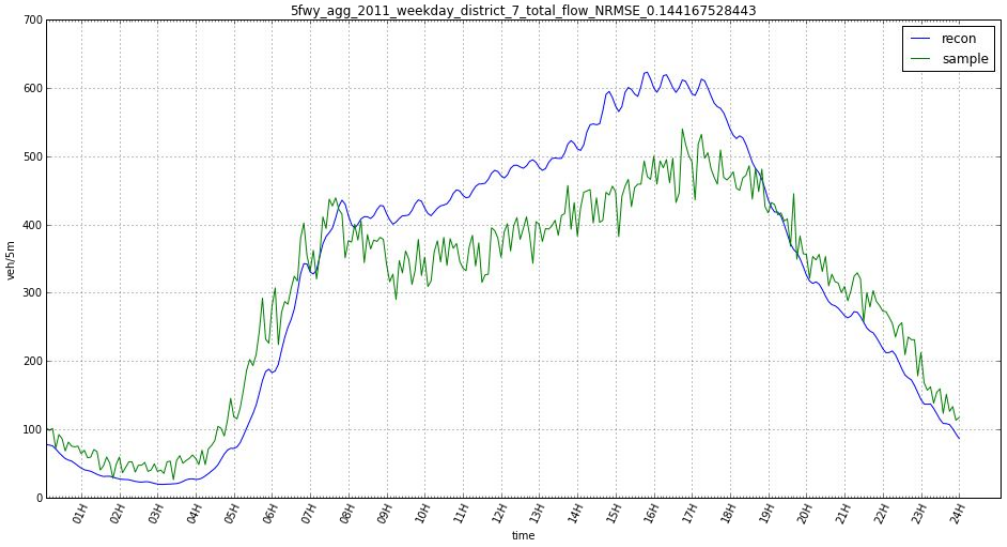
- 5 eigenvectors
  - Over 90% variance explained
  - Sufficient in modeling total flow

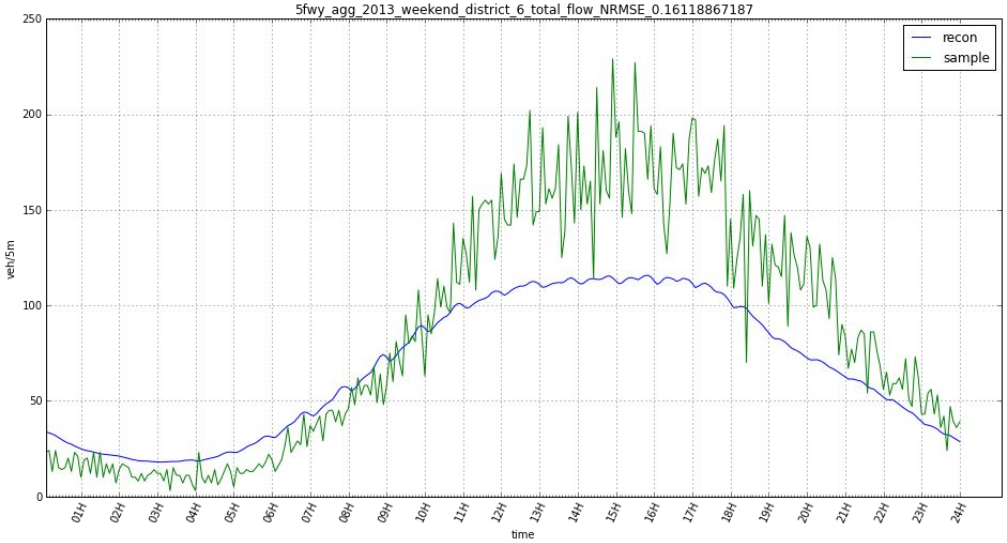






- Execution
  - station+day combination
  - Random samples taken from station+day combinations
  - Projection and Reconstruction using top 5 eigenvectors
- Low NRMSE → Model Total Flow w/ Sufficient Accuracy



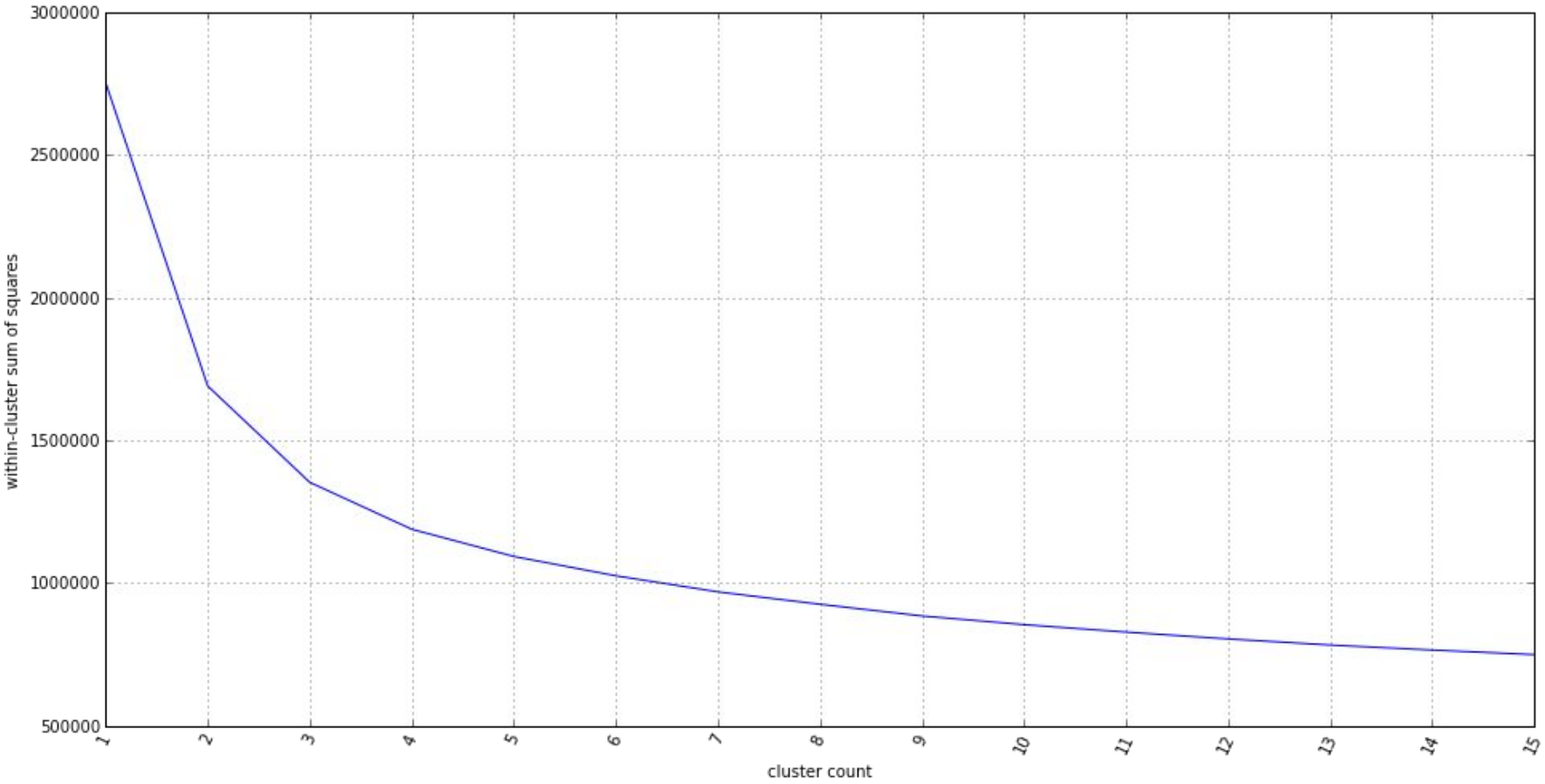


- Execution
  - station+day combination grouped by district+freeway; aggregated across 5 Fwy to obtain 5 Fwy eigenvector
  - Random samples taken from station+day combinations from 5 Fwy
  - Projection and Reconstruction using 5 Fwy eigenvector

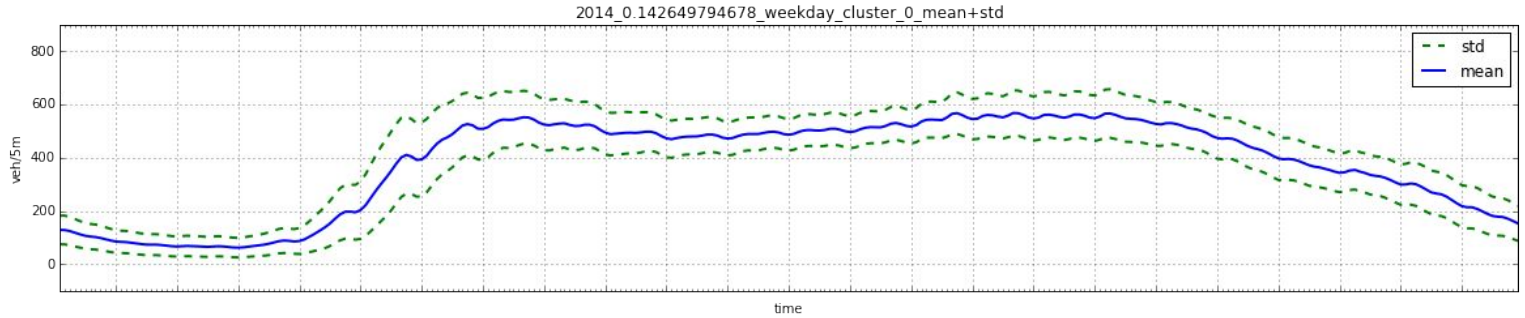
- Reasonable NRMSE → Model Total Flow for a Highway w/ Sufficient Accuracy

KMeans++

- Traffic Pattern Behavior Clustering
- Assessment Criteria: None



- Using CA 2014 as a sample, determine optimal cluster count
  - Identify “elbow” in within-cluster sum of squares plot → about 7 clusters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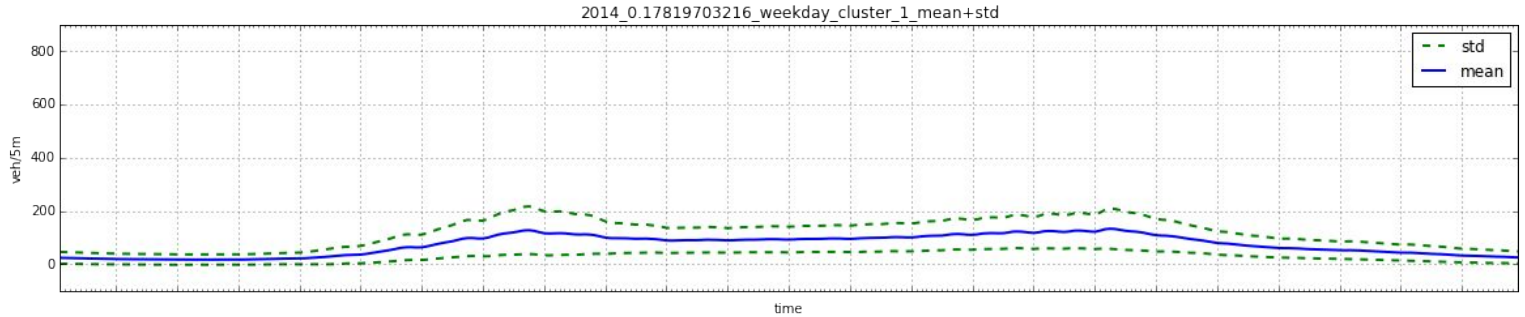
std
mean
veh/5m
time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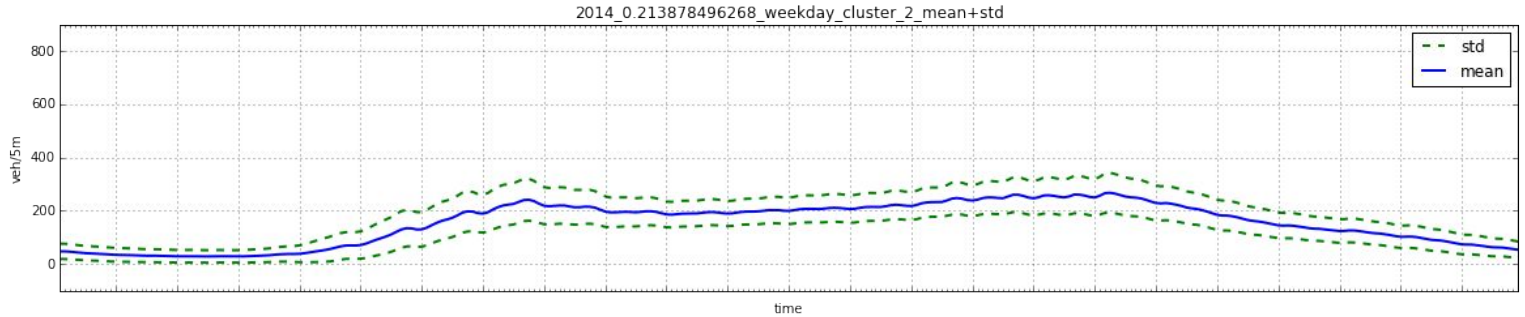
std
mean
veh/5m
time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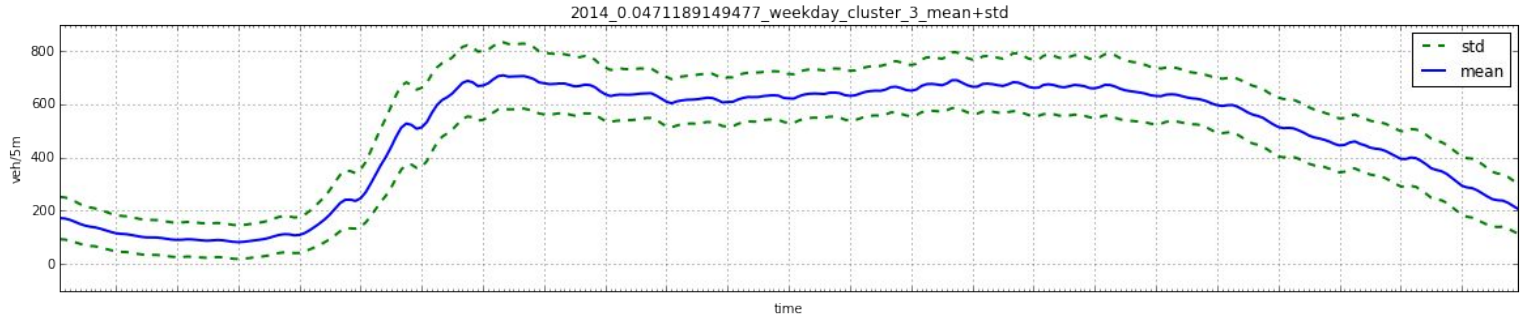
std
mean
veh/5m
time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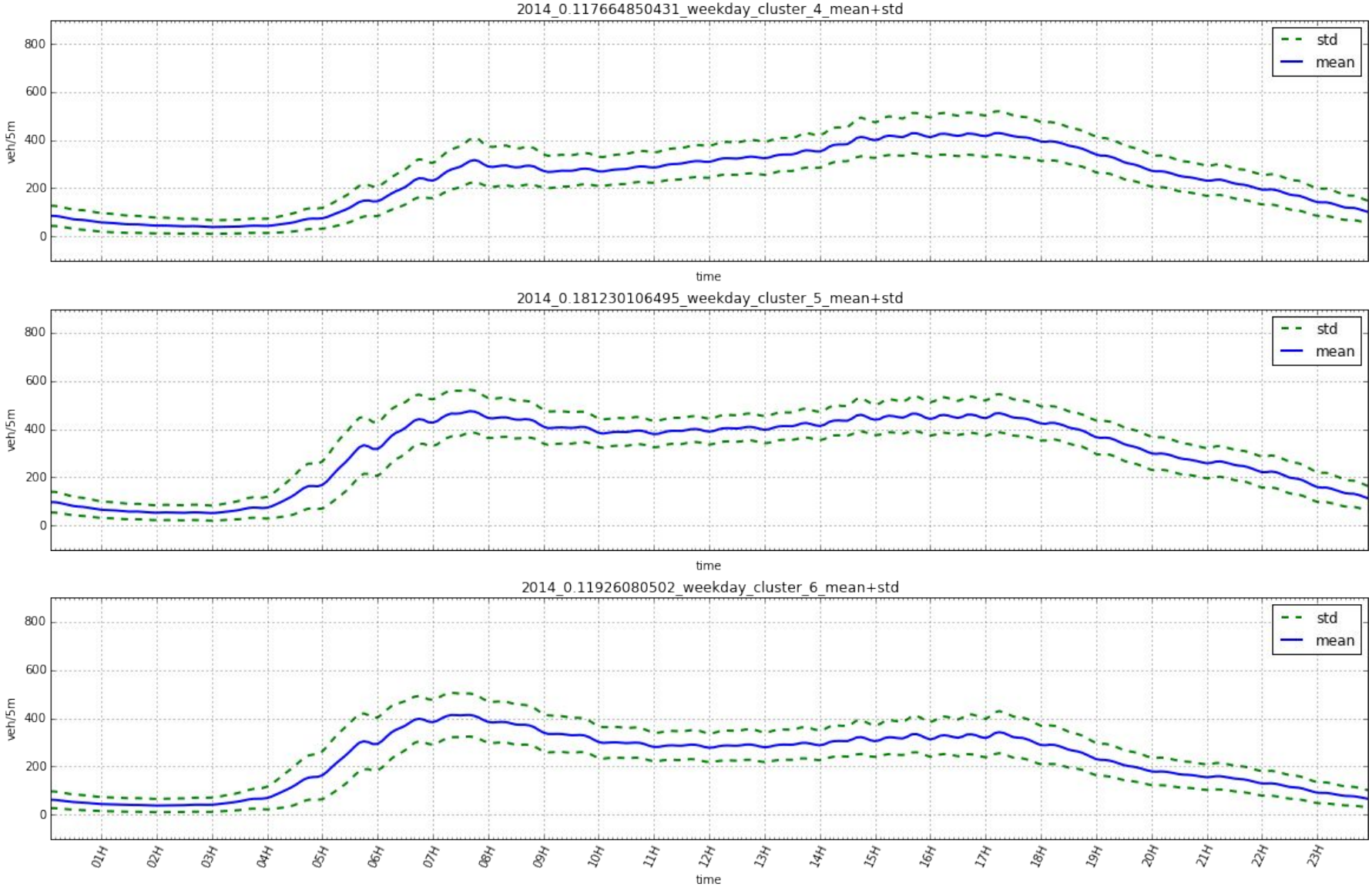
std
mean
veh/5m
time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mean
veh/5m
time
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std
mean
veh/5m
time
2014_0.11926080502_weekday_cluster_6_mean+std
std
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veh/5m
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04H
05H
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18H
19H
20H
21H
22H
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Yolo
Nap
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CC
Cal
San Joaquin
Tuolumne
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Mono
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Ala
Stan
Mariposa
San Mateo
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Merced
Santa Cruz
Madera
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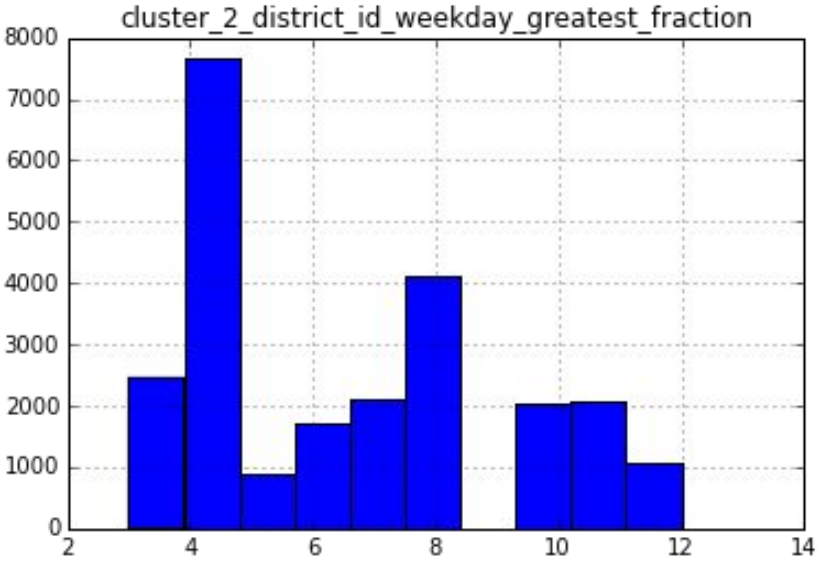
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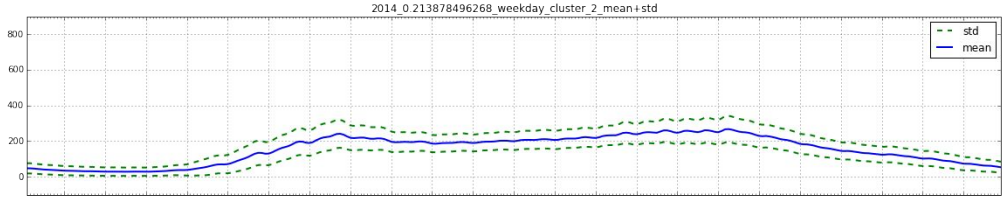
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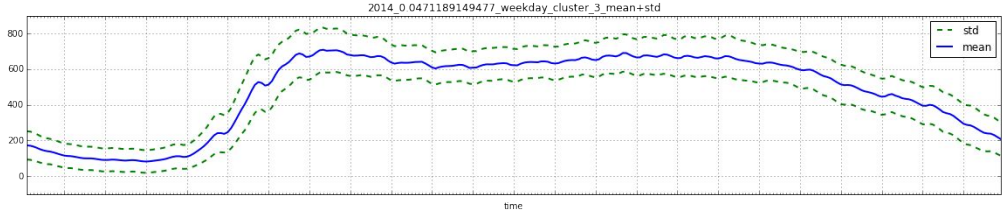
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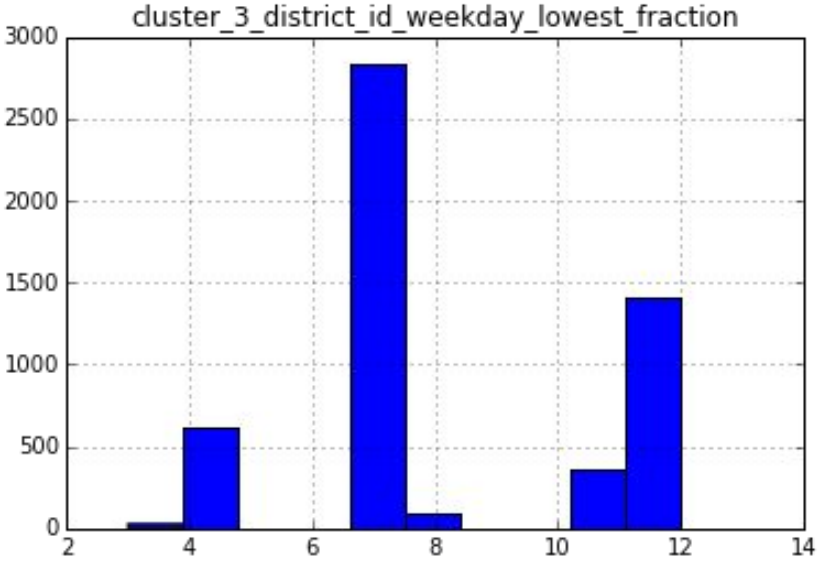
time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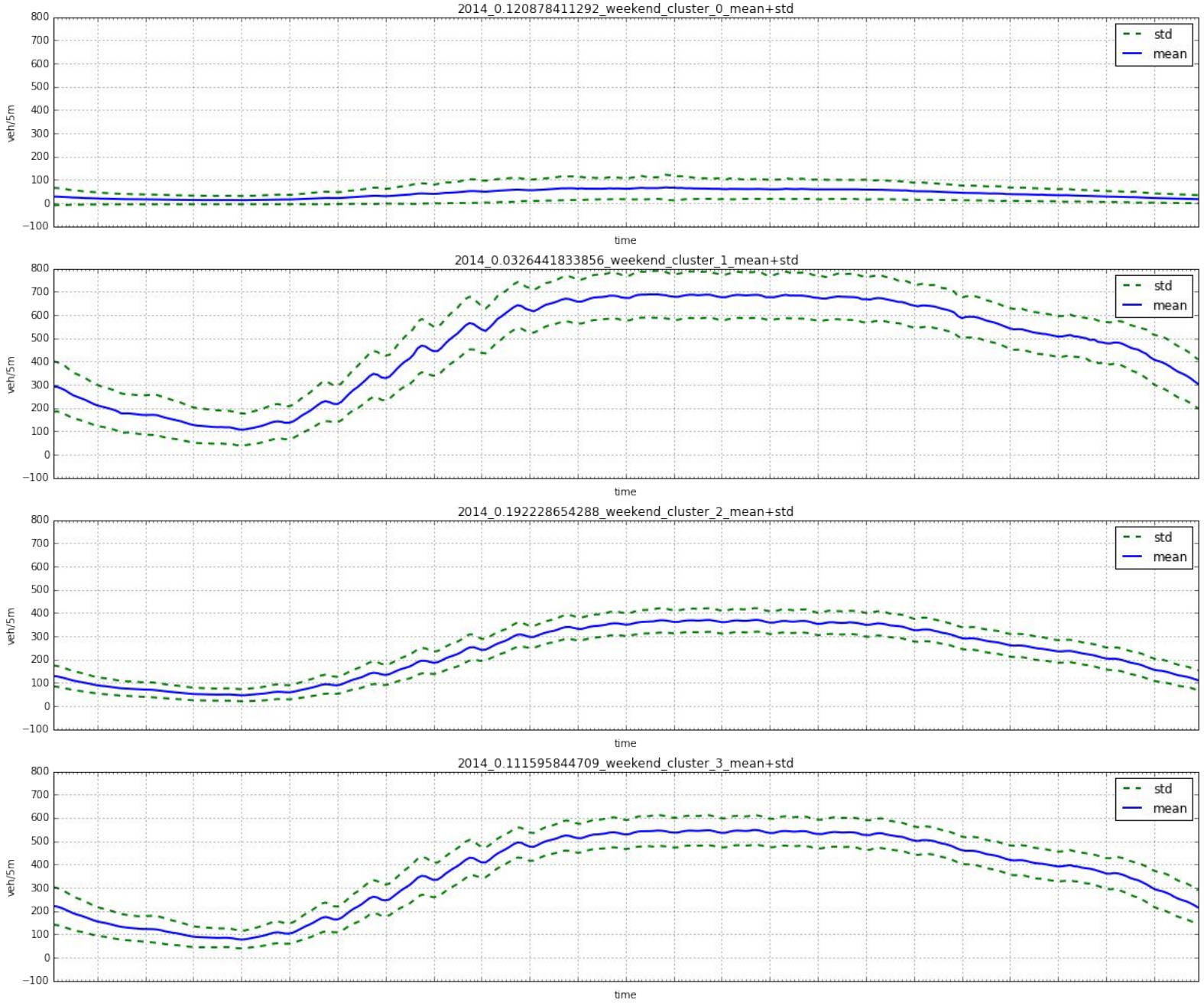
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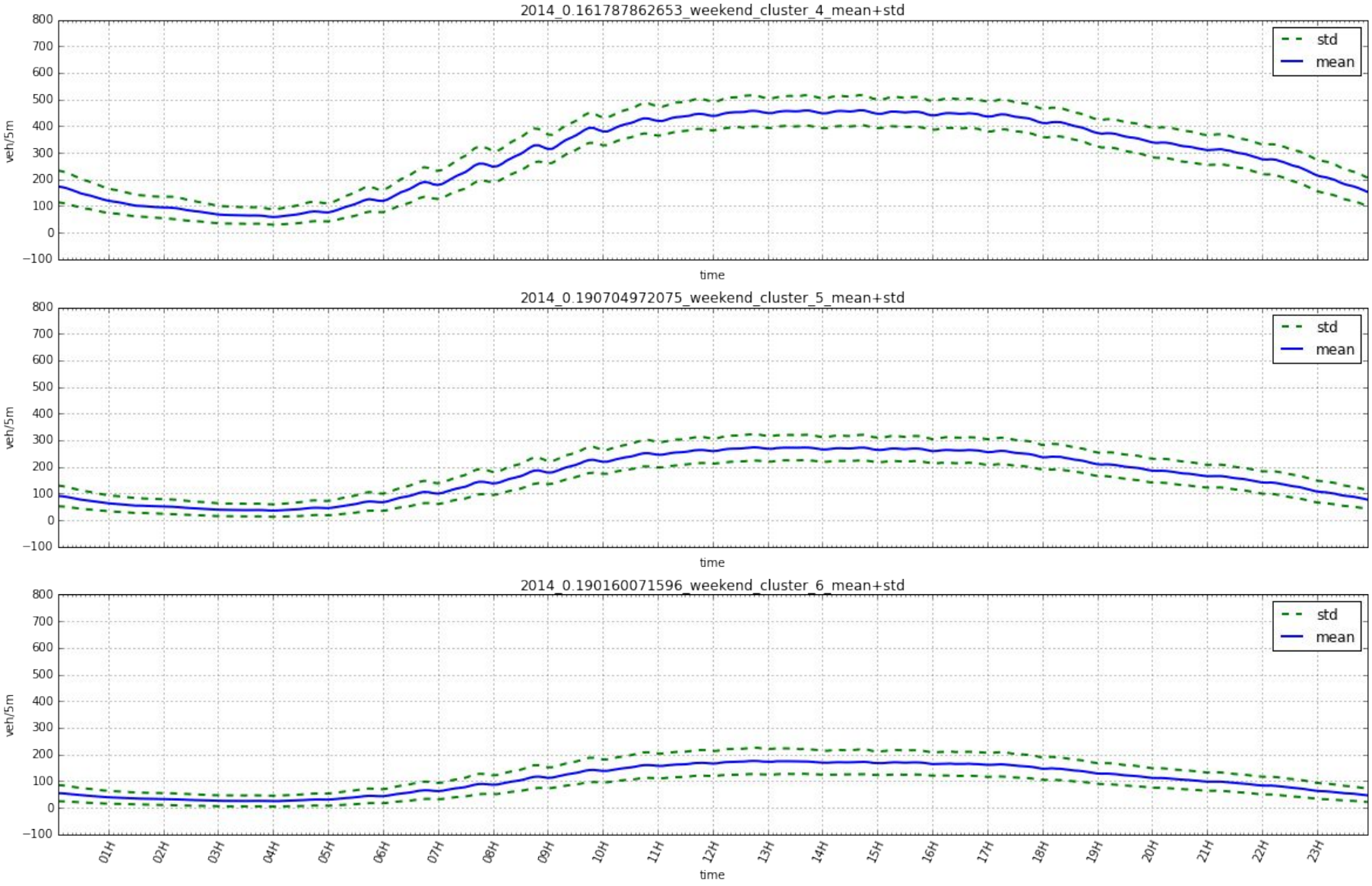
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veh/5m
time
2014_0.190704972075_weekend_cluster_5_mean+std
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mean
veh/5m
time
2014_0.190160071596_weekend_cluster_6_mean+std
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Tuolumne
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Ala
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SCl
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Merced
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Luis
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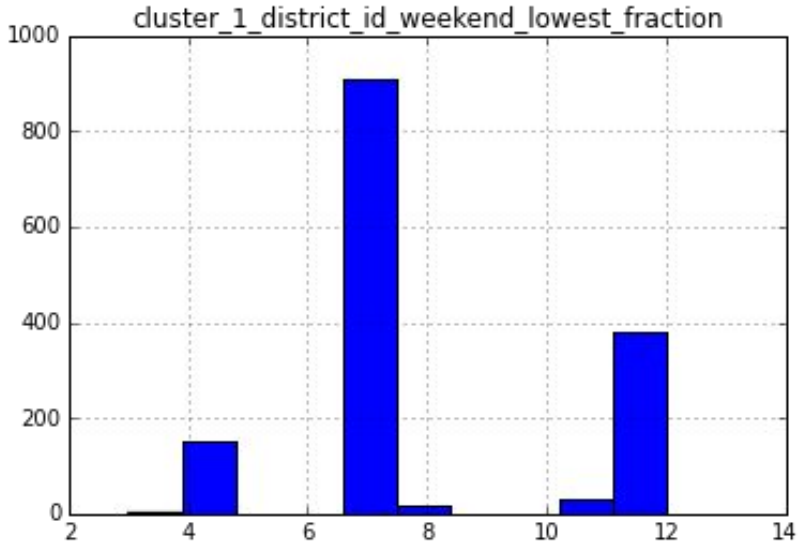
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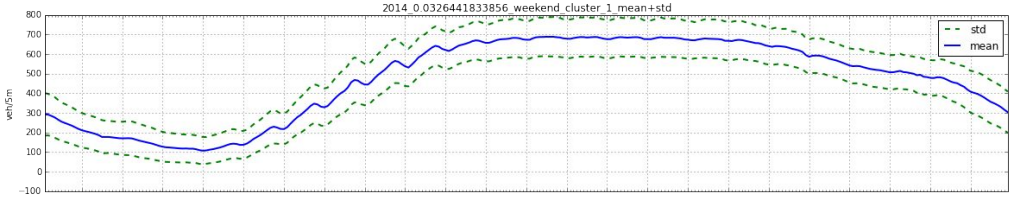
2014_0.0326441833856_weekend_cluster_1_mean+std
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veh/5m
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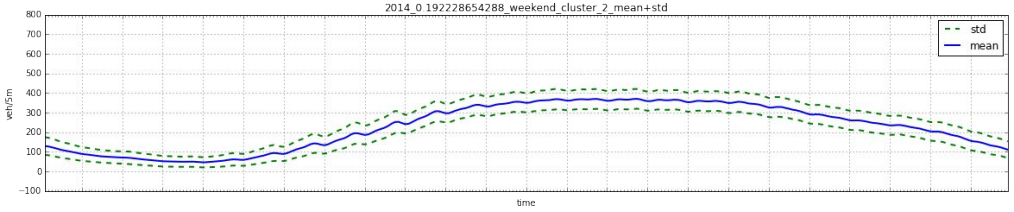
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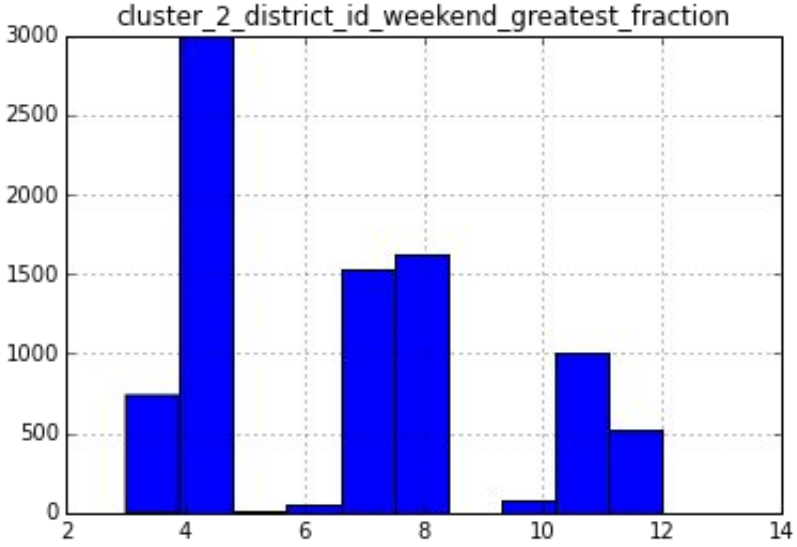
mean
veh/5m
time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3000
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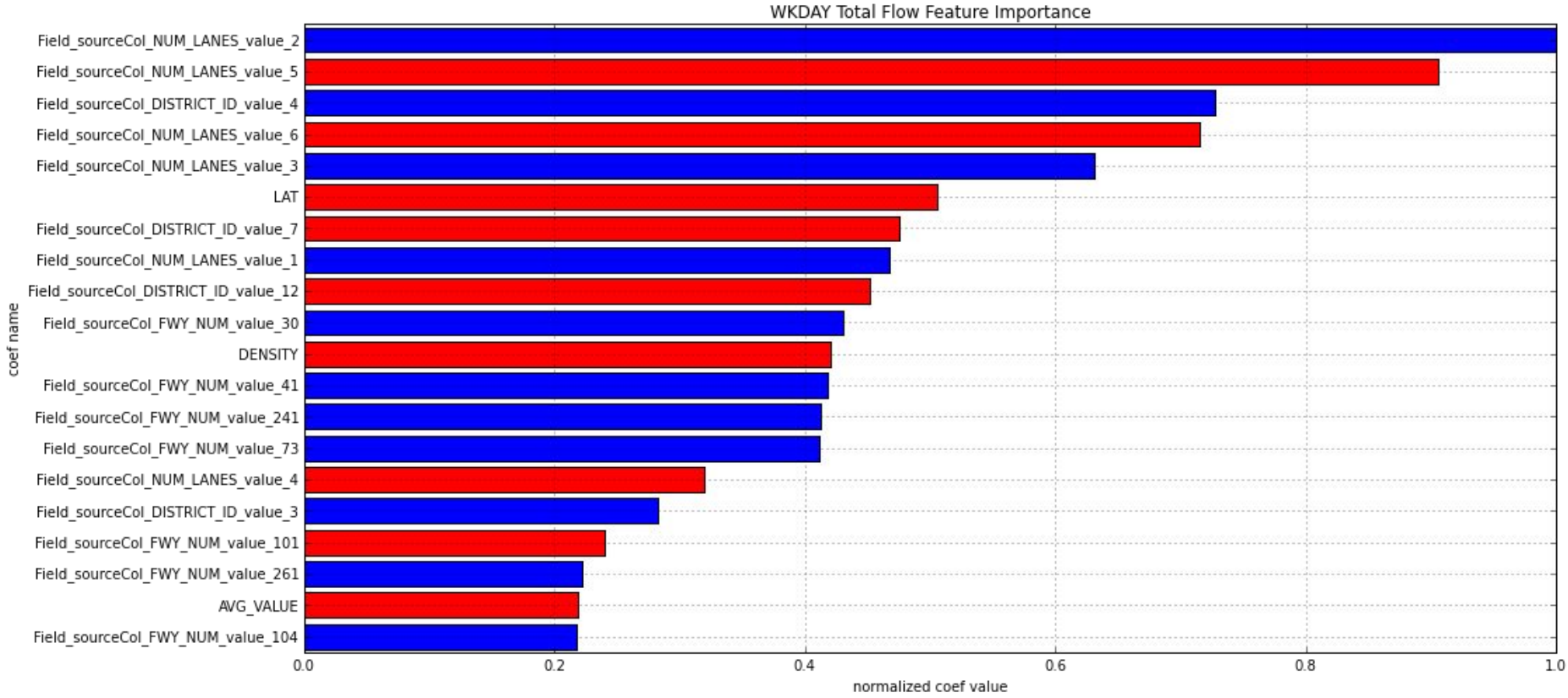
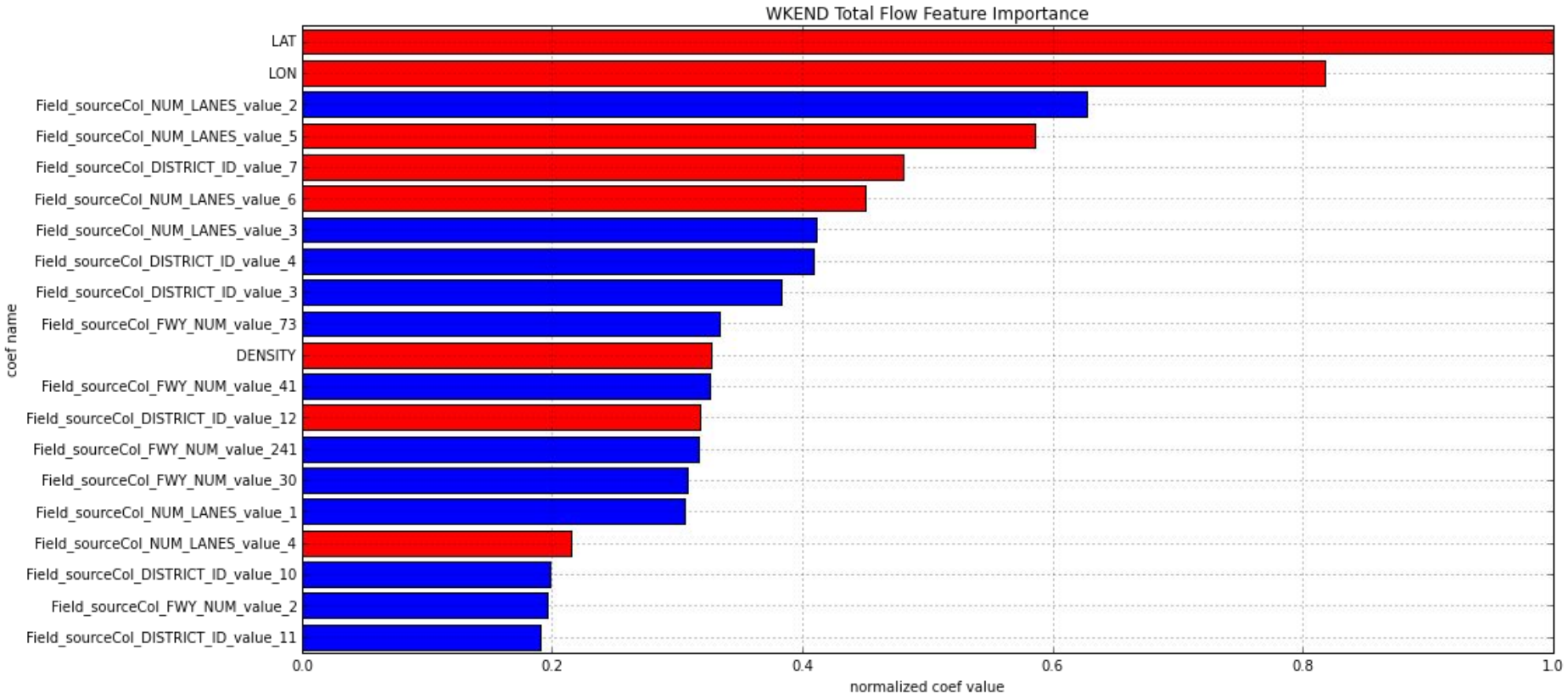
Elastic Net Regression

- Influential Traffic Factors
- Assessment Criteria: None

Weekday Partition



Weekend Partition



Demo

Analysis

- Traffic GIS Visualization
  - Display each PeMS traffic station on a map using its latitude/longitude
  - Load yearly (2008-2015) traffic volume data sets
  - Color-encode traffic stations using its V0 and V1 eigenvector coefficients via a diverging color scheme
  - Filter traffic stations by direction, freeway number, or coefficient value
  - Find traffic stations by ID and zoom to station
  - Reconstruct traffic volume readings of a station for any day

Traffic GIS

Conclusion

Better Insight → Better Solutions

What traffic patterns exist?
What factors have most influence on traffic?

Future Work

- Expand External Data Sources → Influential factors
- Modeling and Analysis of other CalTrans PeMS features
  - Occupancy
  - Speed
- Expansion on GIS visualization → Directional Arrows along freeway: North+South, East+West
- Effect distance of CHP incident has on Traffic Flow
- Outlier Detection
  - KMeans Clustering
  - Mahalanobis Distance

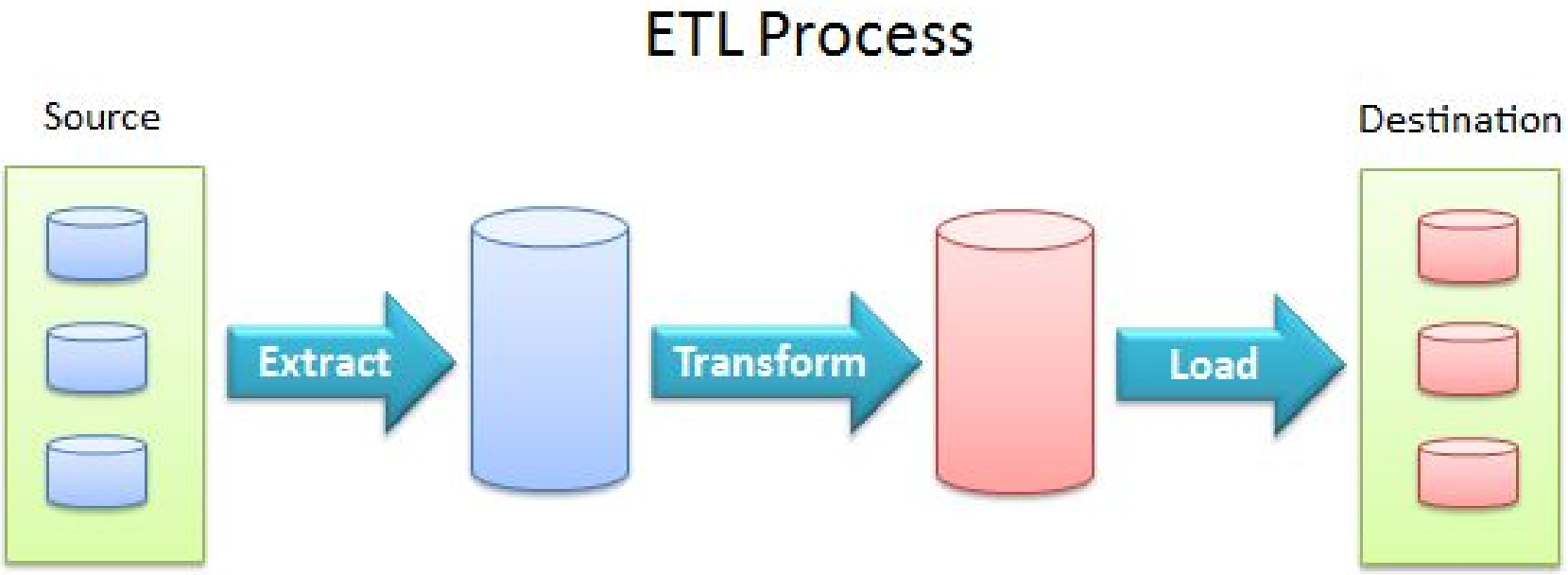
Acknowledgements

- Yoav Freund
- Friends
- Family
  - Girlfriend
  - Fiancee
  - Wife
- Kevin Coakley
- Ilkay Altintas

Questions?

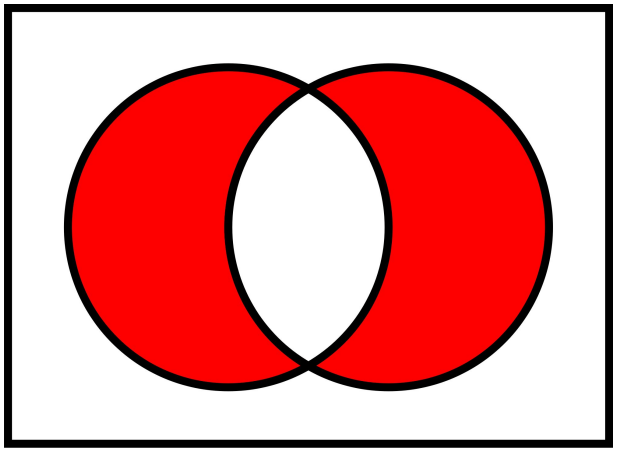
Backup Slides

Data Preparation



Query / Join

- Temporal Data
- Geospatial Data
- Multiway Joins



```
SELECT t.ID, t.Num_Lanes, t.Length, t.Urban, t.Density,
       f.Num,
       CASE f.Direction WHEN 'N' THEN 1 WHEN 'E' THEN 3 WHEN 'S' THEN 2 WHEN 'W' THEN 4 ELSE -1 END,
       z.Avg_Value,
       CASE WHEN chp.ID IS NULL THEN 'F' ELSE 'T' END,
       CAST(chp.CC_CODE AS CHAR(4)), CAST(chp.Description AS CHAR(78)), chp.Duration,
       YearDOYToDate(o.year, o.DOY),
       o.Flow_Coef[1], o.Flow_Coef[2], o.Flow_Coef[3], o.Flow_Coef[4], o.Flow_Coef[5],
       o.Flow_Coef[6], o.Flow_Coef[7], o.Flow_Coef[8], o.Flow_Coef[9], o.Flow_Coef[10]
FROM Observations o
        INNER JOIN Traffic_Station t ON (o.Station_ID=t.ID)
        INNER JOIN ST_Type st ON (t.Type_ID=st.ID AND st.type='ML')
        INNER JOIN Freeways f ON (f.ID=t.Fwy_ID)
        LEFT OUTER JOIN Zillo_Home_Value z ON
            ((EXTRACT(YEAR FROM z.month)=o.year) AND
             EXTRACT(MONTH FROM z.month)=EXTRACT(MONTH FROM YearDOYToDate(o.year, o.DOY)))
        INNER JOIN County_Zip cz ON (t.ZIPCODE=cz.ZIPCODE AND cz.ZIPCODE=z.ZIPCODE)
        LEFT OUTER JOIN CHP_INC chp ON (
            CAST(chp.time AS DATE)=YearDOYToDate(o.year, o.DOY)
            AND chp.Fwy_ID=t.Fwy_ID
            AND ST_Distance(chp.Location, t.Location) < 804.672 -- Half-Mile away
        )
WHERE o.year={y}
ORDER BY 1, 13;
```