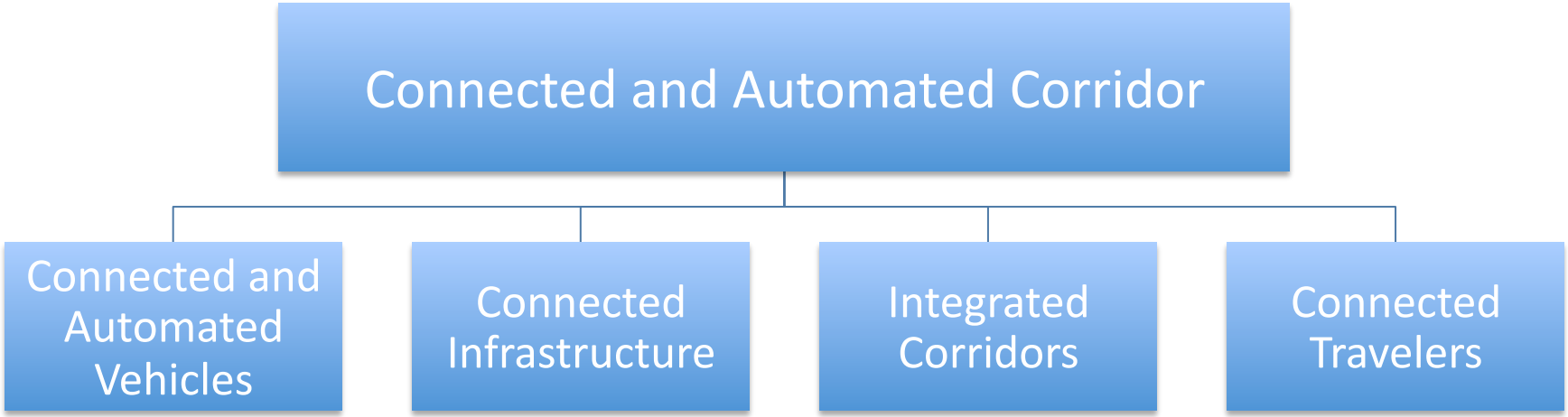
Model-based prediction of freeway traffic conditions using PeMS loop detector data

CALIFORNIA PATH

Connected Corridors 2020 Pilot

Vehicles, Infrastructure and People



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Connected Corridors 2020 Pilot

Vehicles, Infrastructure and People

- Corridor decision support component:
  1. Estimation of current conditions
  2. Prediction of near-future conditions
  3. Generation of control advice for operators

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Subcomponent Progress Report

Model-based prediction of freeway traffic conditions

1. Estimate current state of traffic along entire length of freeway, using PeMS loop detector data where available
2. Run calibrated model one hour forward in time, using predicted demands and "split ratios"(*)

(*) A "split ratio" is the fraction of mainline vehicles that exit the freeway at a particular offramp at a particular time.

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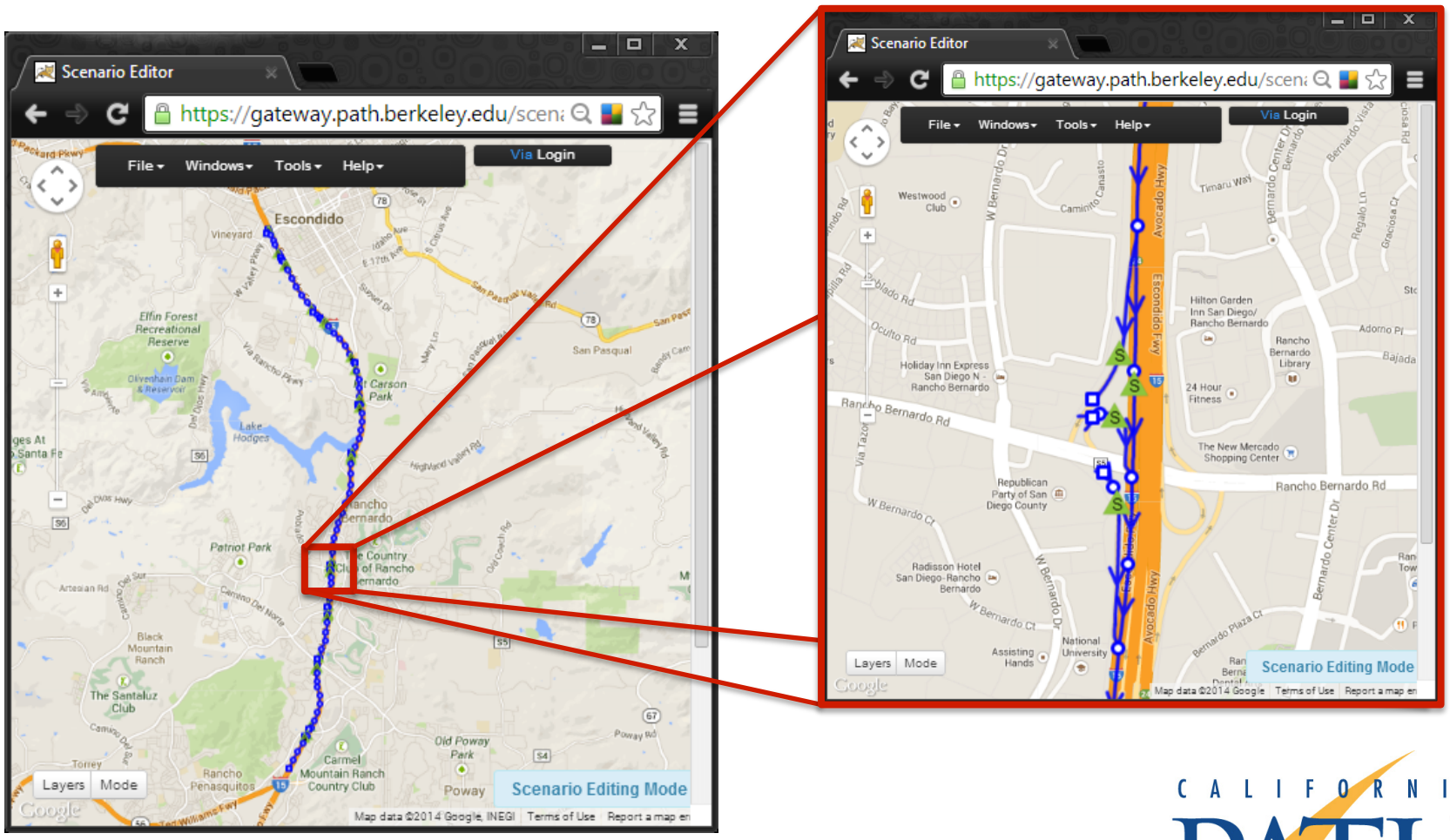
Model building:
Freeway geometry



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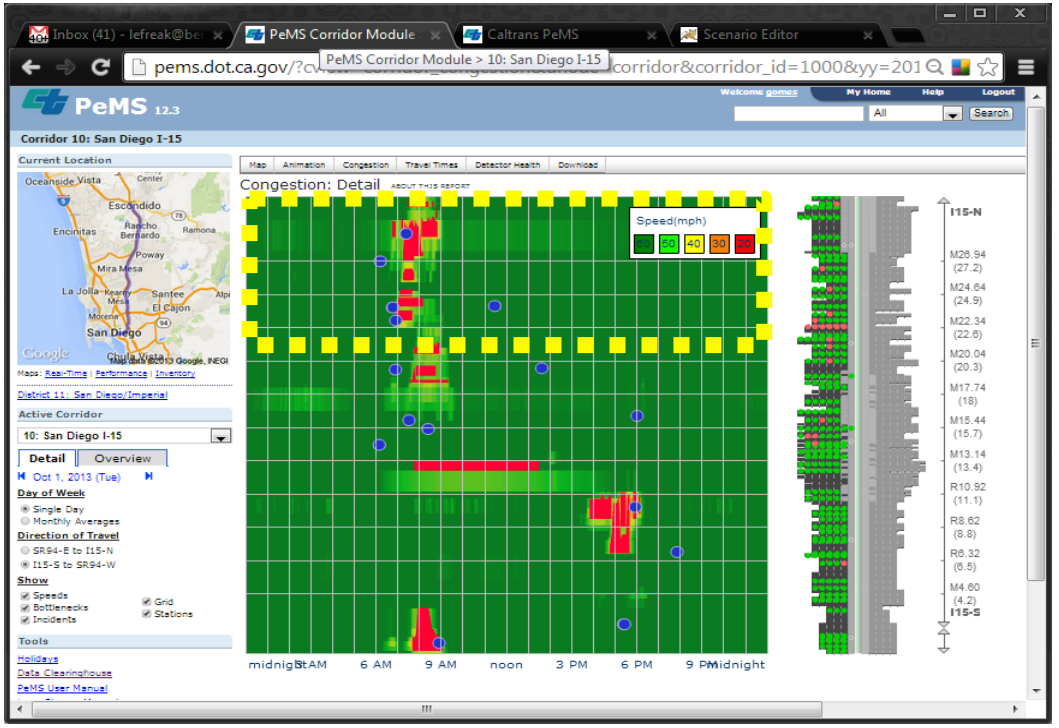
Model building:
PeMS data for calibration



<u>Selection criteria:</u>

- Healthy detection
- Free flow downstream boundary,
- Sufficient congestion
- No major incidents

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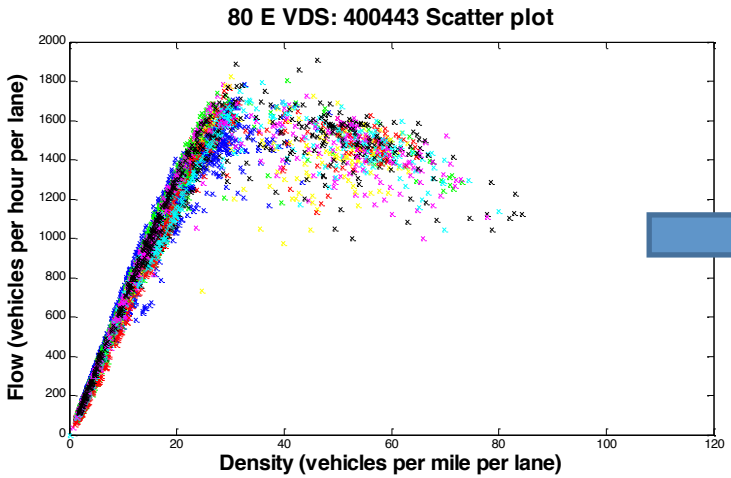
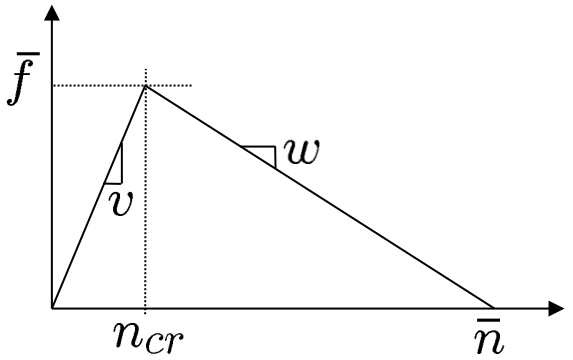
Model building:
Calibration of fundamental diagram parameters





- Calibration: Process of fitting fundamental diagram to many days of density/flow data from PeMS for each modeled network segment (link)

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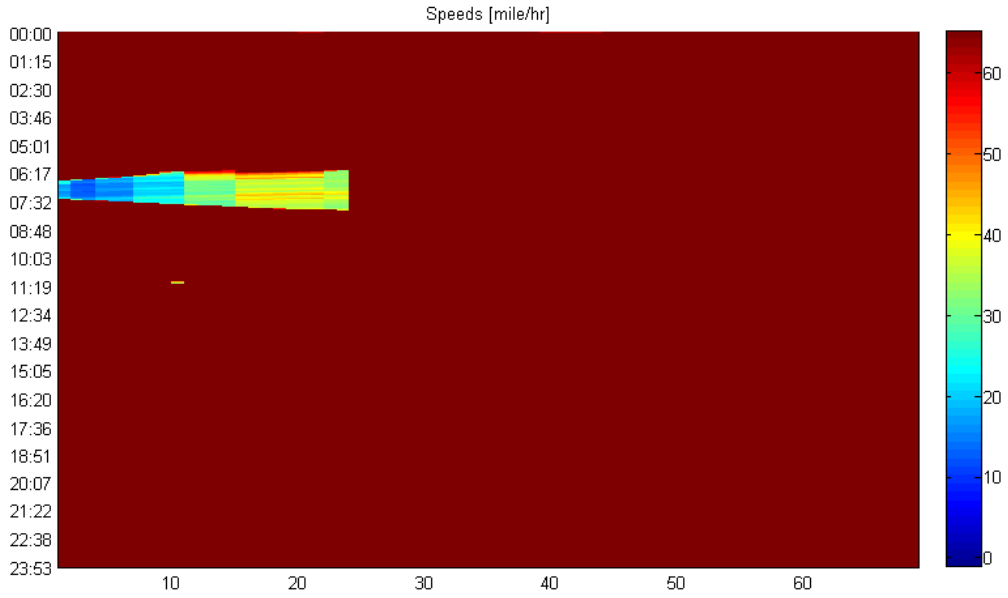
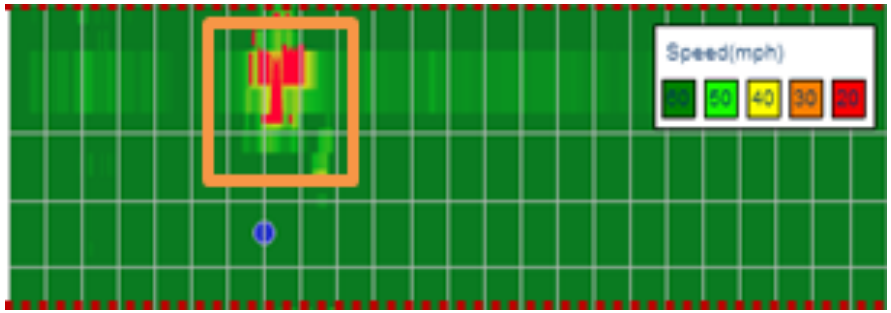
Model building:
Test and compare (10/15/2013)





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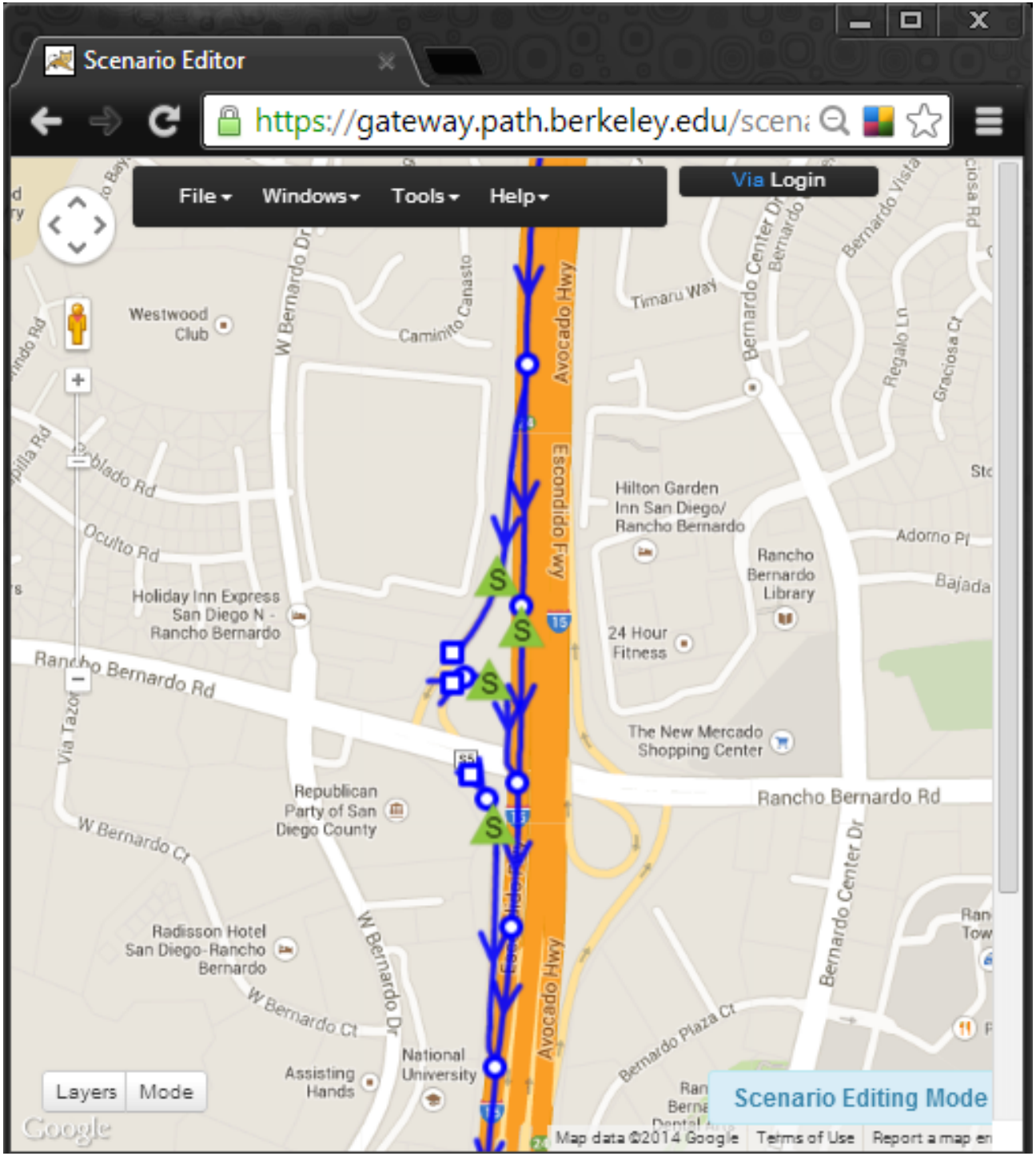

Estimation of Current Traffic Conditions

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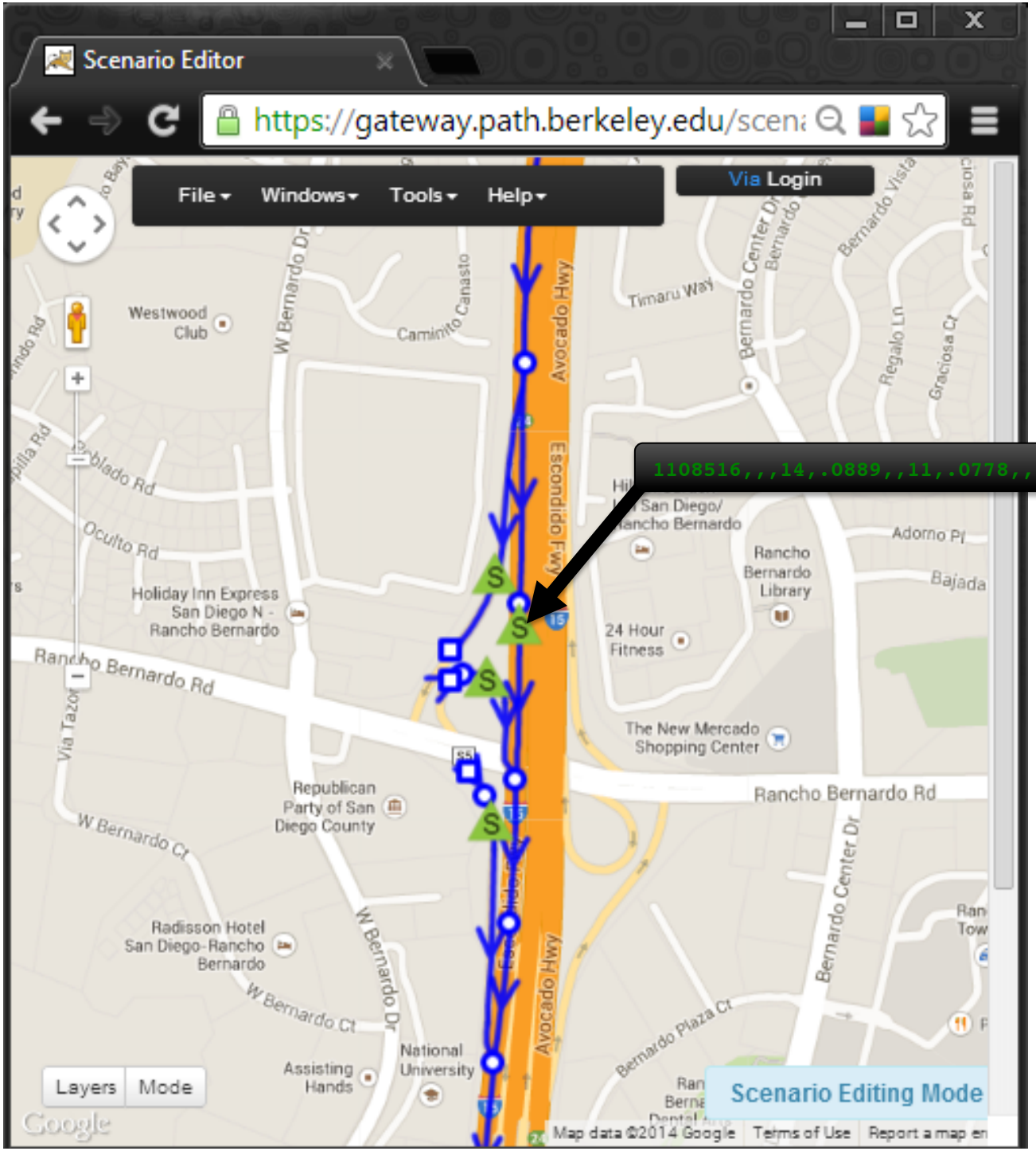

Estimation of Current Traffic Conditions

All available new mainline data is assimilated…

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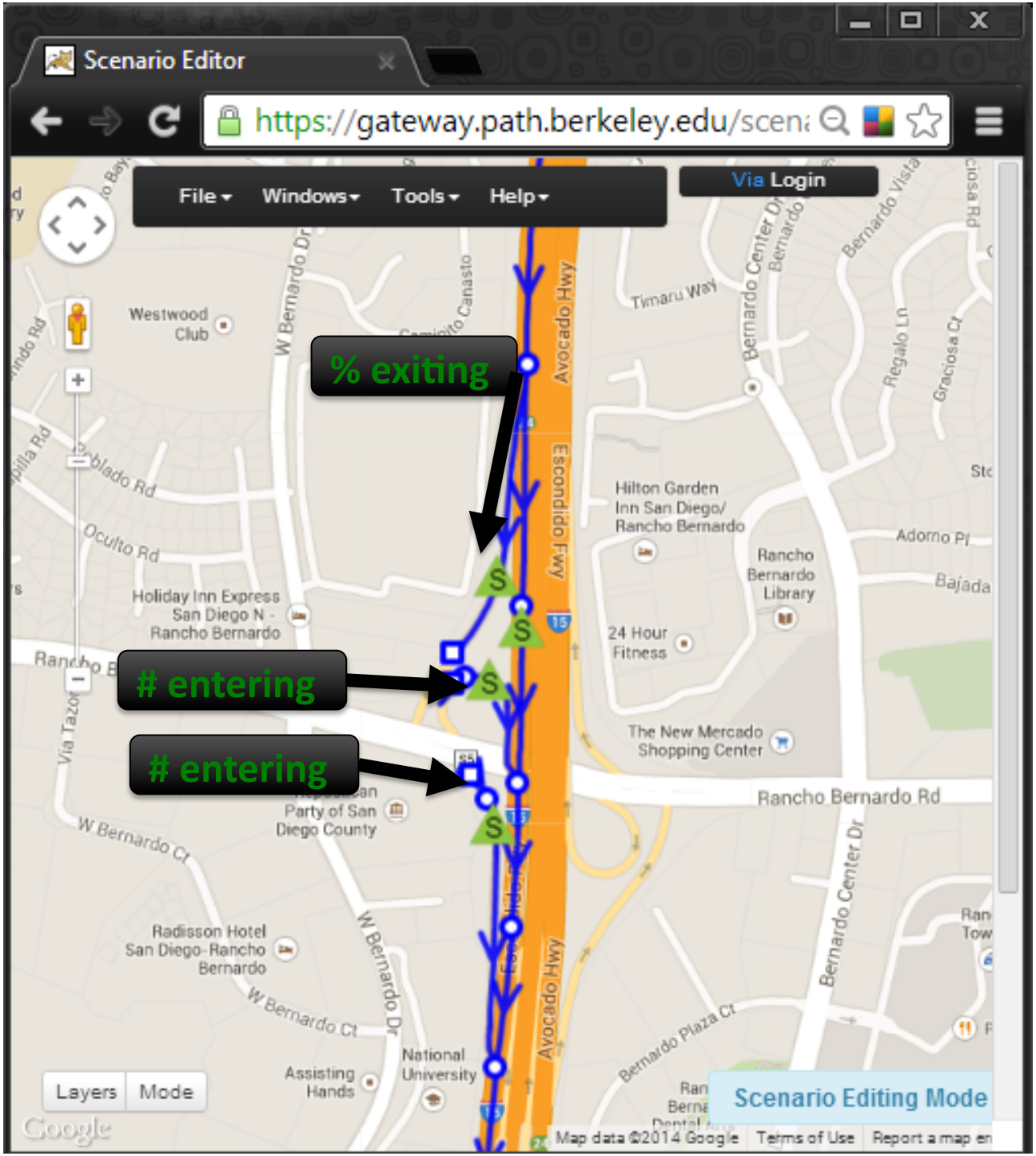

Estimation of Current Traffic Conditions

...model is run forward 30 seconds…

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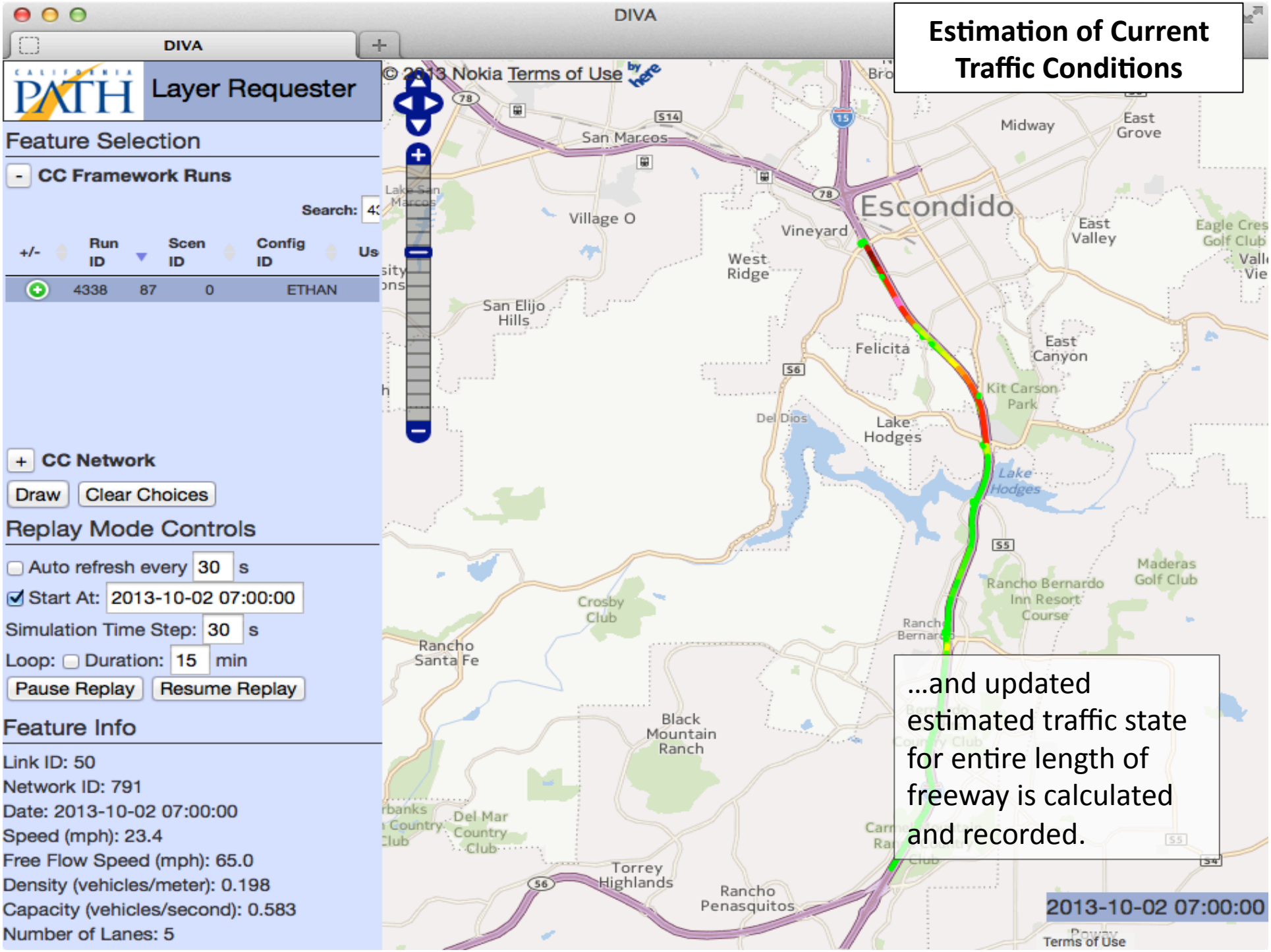
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Clear Choices
Replay Mode Controls
Auto refresh every 30 s
Start At: 2013-10-02 07:00:00
Simulation Time Step: 30 s
Loop: Duration: 15 min
Pause Replay
Resume Replay
Feature Info
Link ID: 50
Network ID: 791
Date: 2013-10-02 07:00:00
Speed (mph): 23.4
Free Flow Speed (mph): 65.0
Density (vehicles/meter): 0.198
Capacity (vehicles/second): 0.583
Number of Lanes: 5
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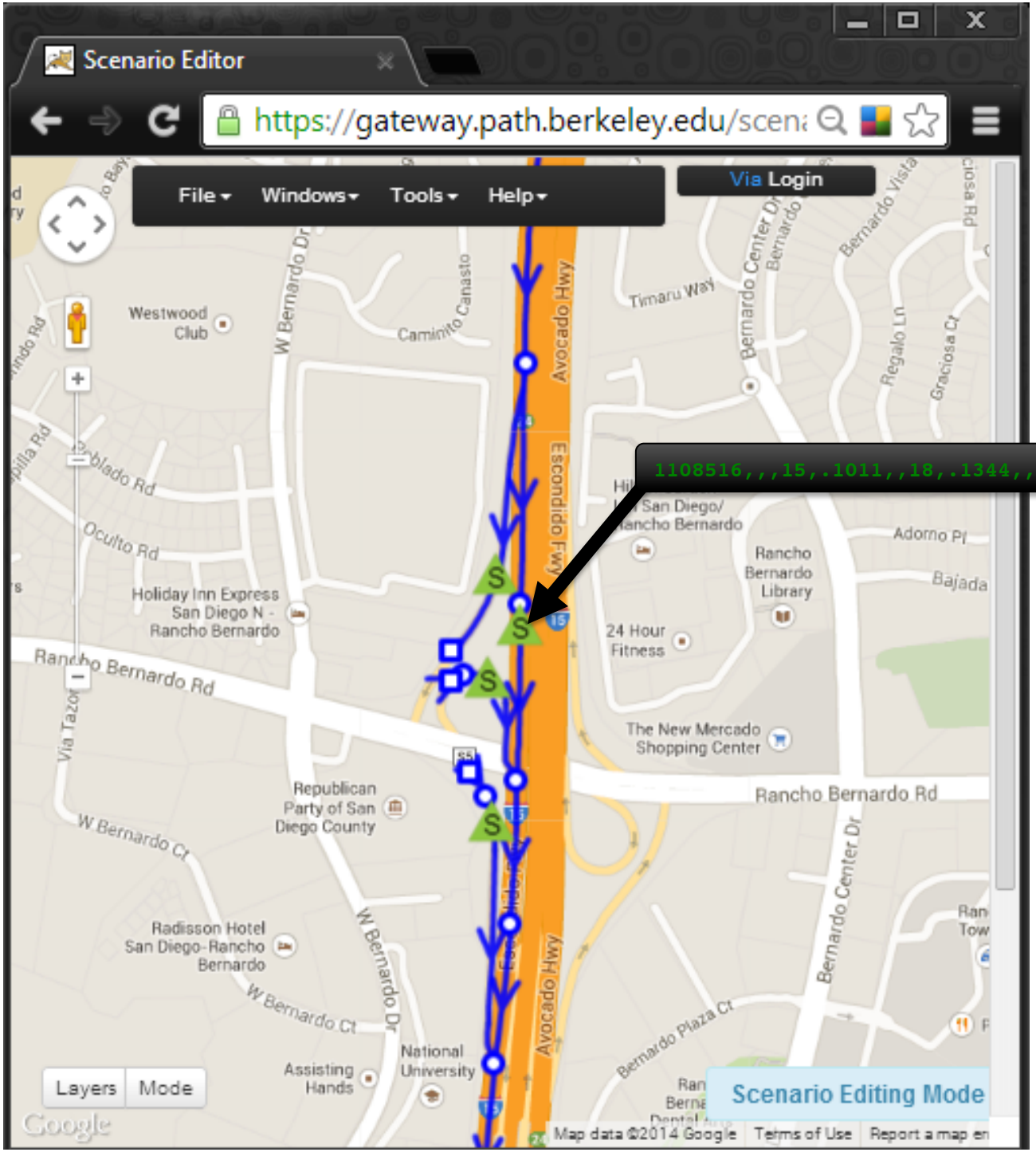
Escondido
San Marcos
Village O
Vineyard
West Ridge
San Elijo Hills
Felicita
East Canyon
Kit Carson Park
Lake Hodges
Del Dios
Midway
East Grove
East Valley
Crosby Club
Rancho Santa Fe
Black Mountain Ranch
Rancho Bernardo Inn Resort Course
Maderas Golf Club
Del Mar Country Club
Torrey Highlands
Rancho Penasquitos
…and updated estimated traffic state for entire length of freeway is calculated and recorded.
2013-10-02 07:00:00
Terms of Use



Estimation of Current Traffic Conditions

Every 30 seconds, all newly-available mainline data is assimilated, and the process repeats.

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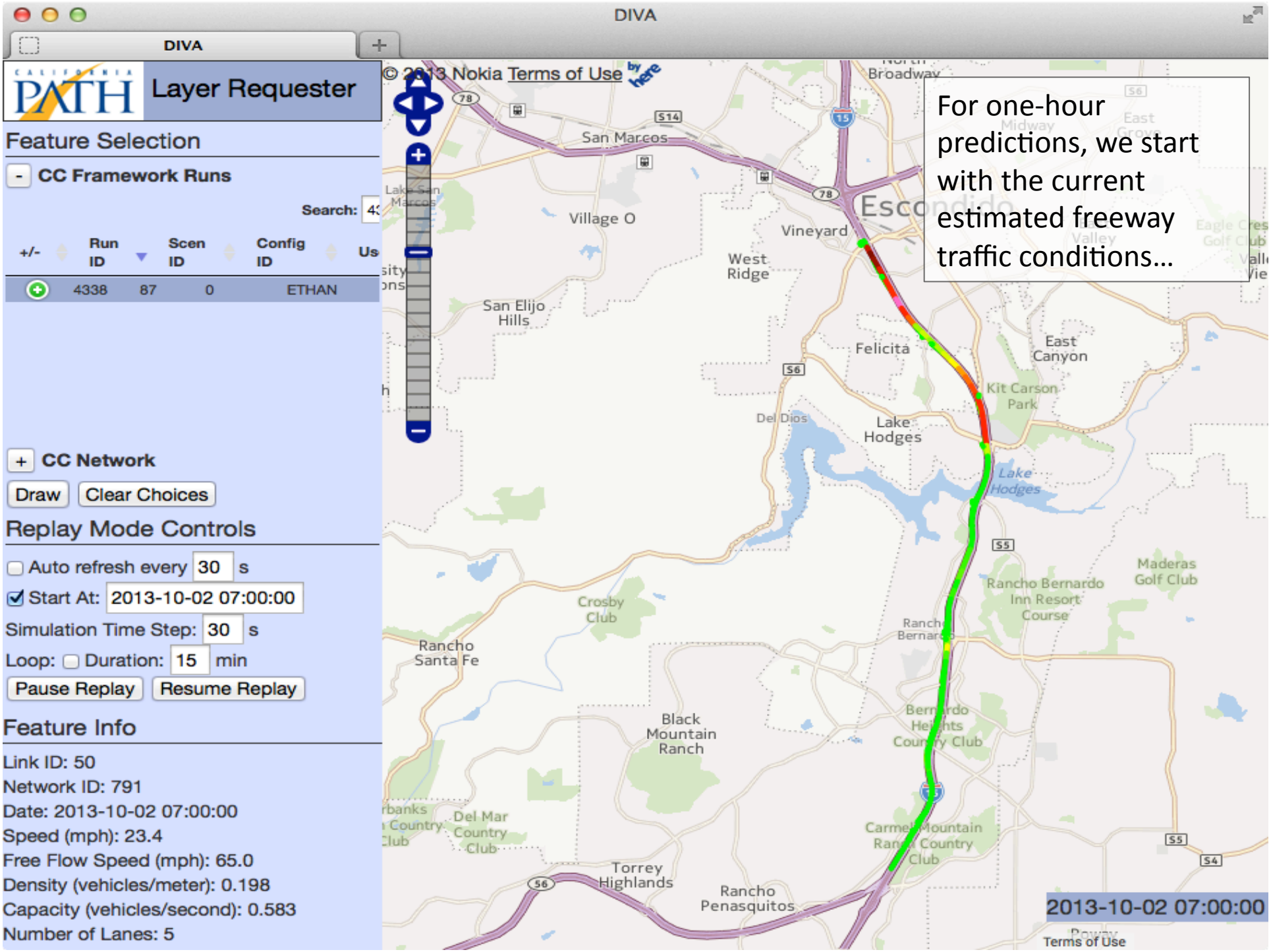
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Free Flow Speed (mph): 65.0
Density (vehicles/meter): 0.198
Capacity (vehicles/second): 0.583
Number of Lanes: 5
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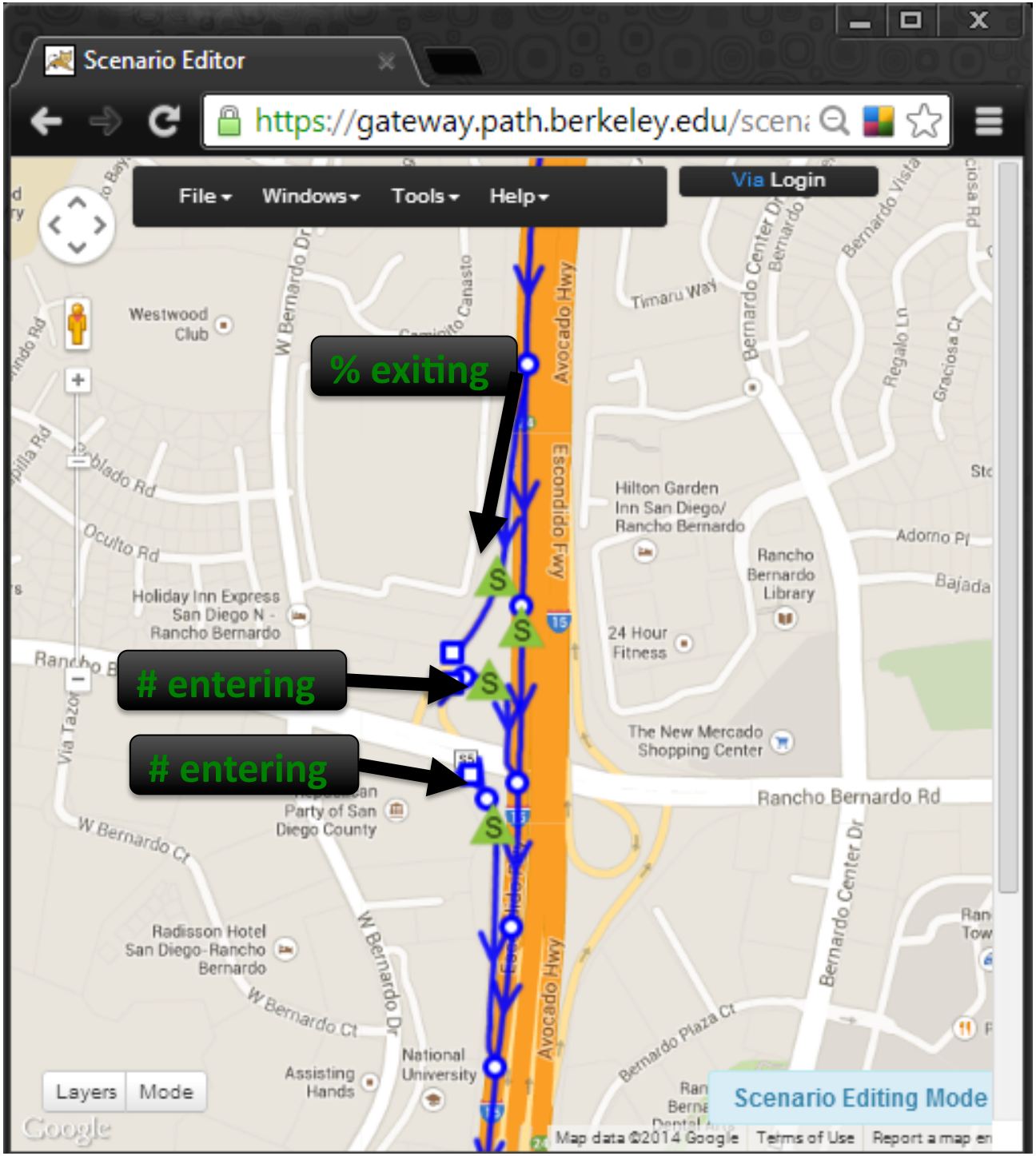
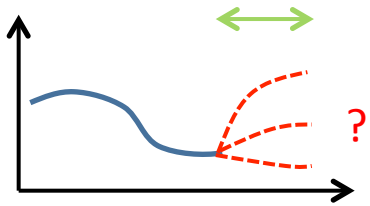
For one-hour predictions, we start with the current estimated freeway traffic conditions…
San Marcos
Village O
Vineyard
West Ridge
San Elijo Hills
Felicita
East Canyon
Kit Carson Park
Del Dios
Lake Hodges
Crosby Club
Rancho Santa Fe
Rancho Bernardo Inn Resort Course
Maderas Golf Club
Black Mountain Ranch
Del Mar Country Club
Torrey Highlands
Rancho Penasquitos
2013-10-02 07:00:00
Terms of Use



...and run the model forward for one hour, feeding it predicted boundary flows (# entering at each onramp) and split ratios (% of mainline exiting at each offramp).



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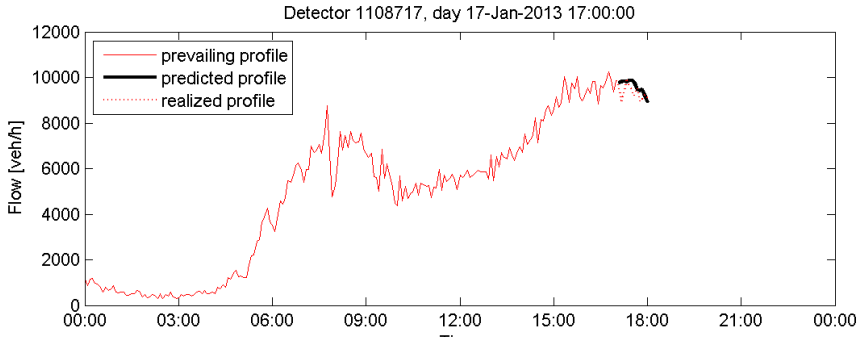
How do we get onramp and offramp predictions to feed the model?

- We use *clustered, averaged historical PeMS data* at each location, *tuned by PeMS data from the last hour*.



See following sections for additional detail about PeMS-based Boundary Flow and Split Ratio predictions.

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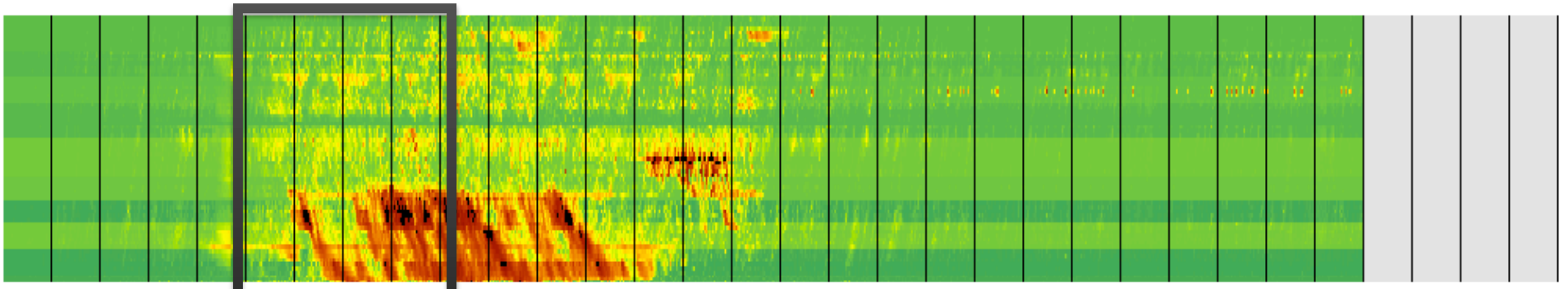
gateway.path.berkeley.edu/~gregm/forecast/velocity/Run4249_10-15_0500-1200/Run4249_10-15_0500-1200.html

Estimation Run

Velocity

Density

0500 - 1200

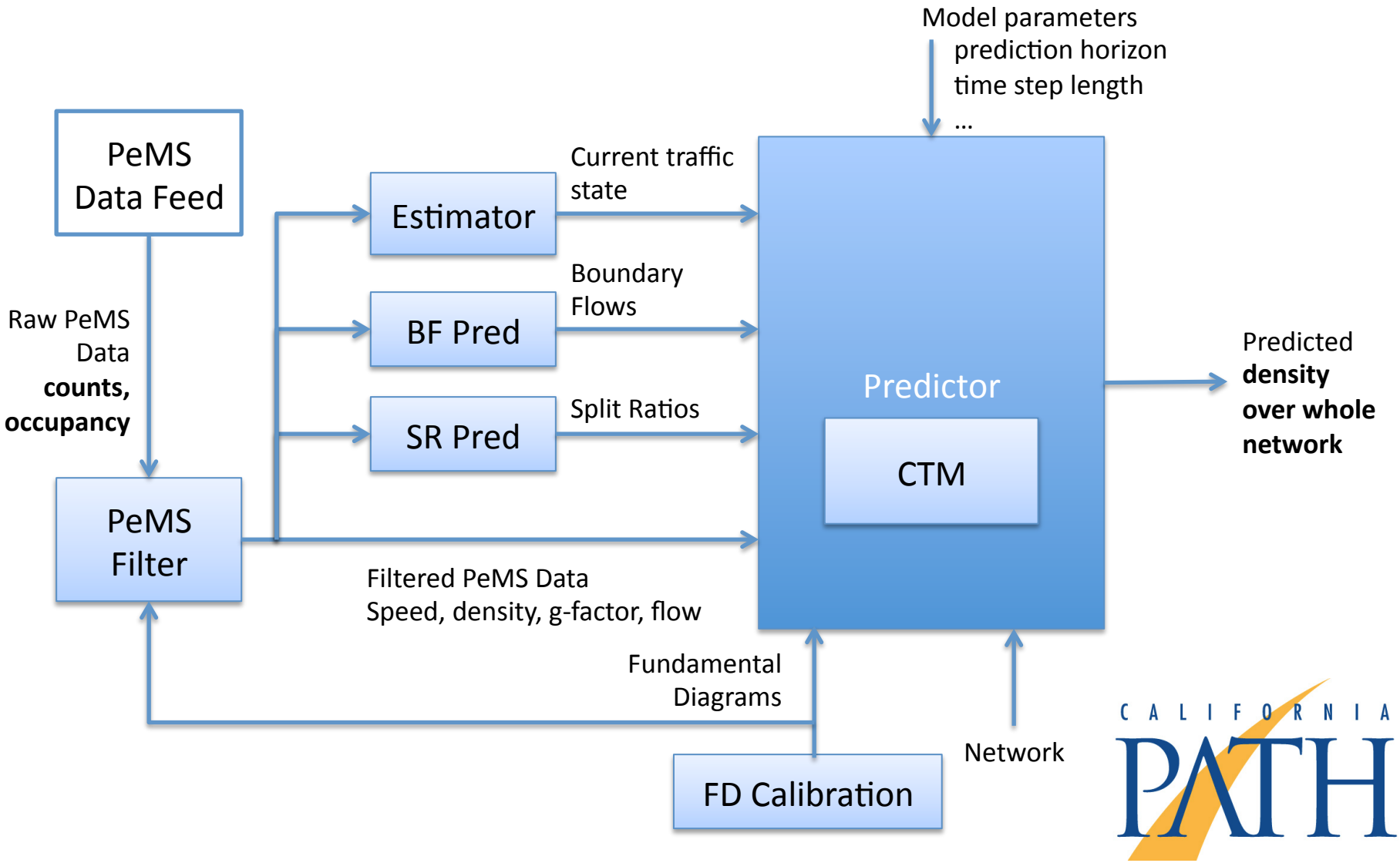


0615 - 0715

http://gateway.path.berkeley.edu/~gregm/forecast/

PATH

Corridor-wide Traffic Prediction – Architecture



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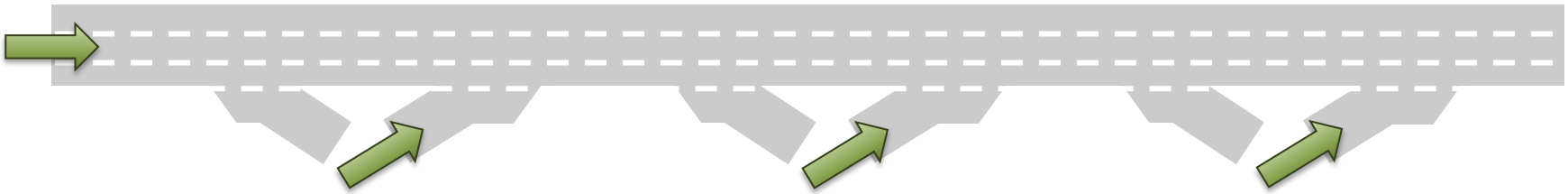
Boundary Flows



Poster Presentation: *"Fast Boundary Flow Prediction using Optimal Autoregressive Moving Average with Exogenous Inputs (ARMAX) Predictor"*, Paper-No.: TRB'14-4645, **Wednesday** 15 January 2014, **14:45 - 16:30**, Marriott **Salon** 2, D03, TRB Session 841: "Advances in Traffic Flow Theory and Characteristics, Part 2" (AHB45)

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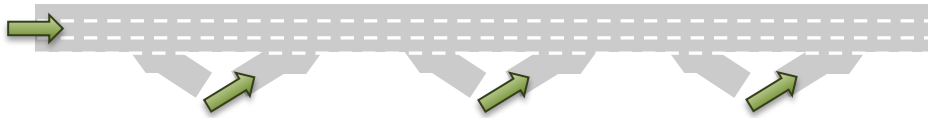
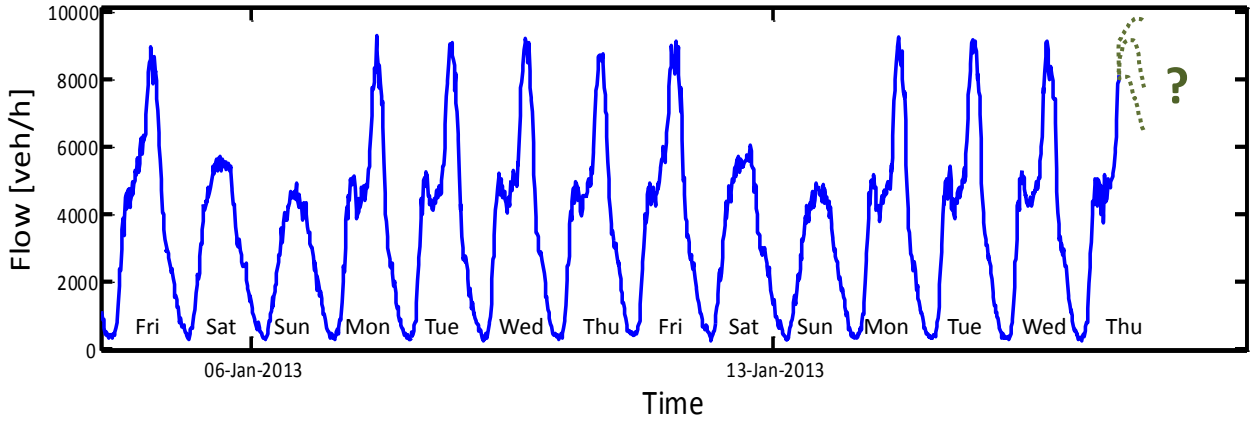
Boundary Flows



- **Predict near-future traffic inflow at network boundaries** to provide boundary condition for corridor-wide traffic flow predictor
  - On-ramp flow, mainline flow at beginning of corridor
  - For practical purposes: method must be fast and reliable

- Example of Loop Detector Data:



→ Traffic flow repeats daily and weekly

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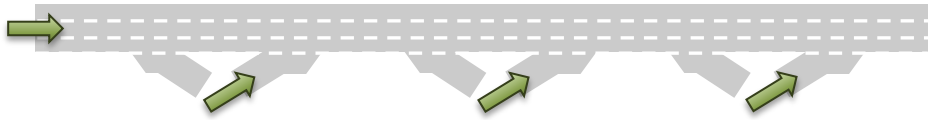
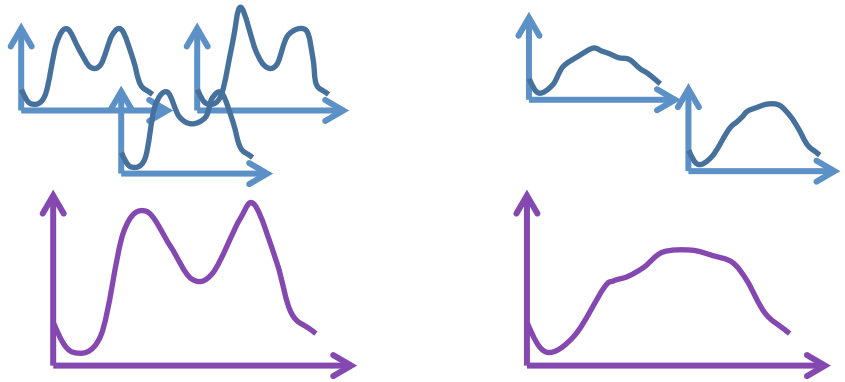
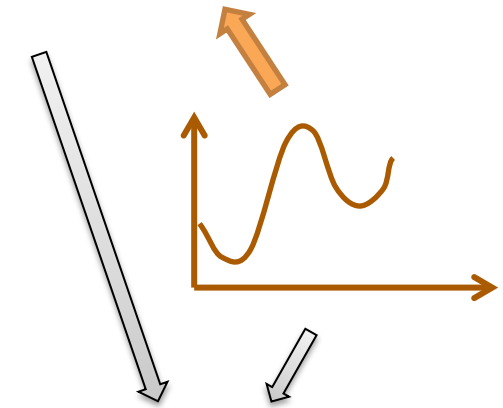
Boundary Flows – Algorithm



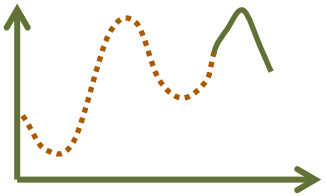
1. **Analyze historic profiles** (offline)
   - One profile = one day of measured flow data; use months of data
   - Classify by day-of-the-week
   - Calculate centroids as **median** profile for each class
   - Robust w.r.t. outliers



2. **Load prevailing partial profile and match to centroids** (online)
   - Prevailing profile = todays measured flow data from midnight to now
   - Load respective median centroid



3. **Forecast** based on best-matching cluster and prevailing profile (online)
   - By scaling historical profile according prevailing traffic flow of last hour
   - Robust w.r.t. to irregular traffic conditions



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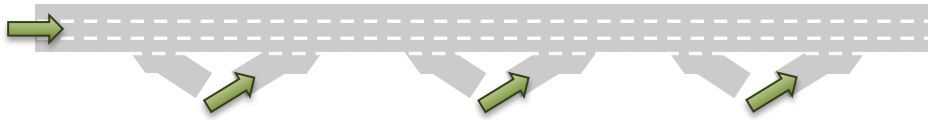
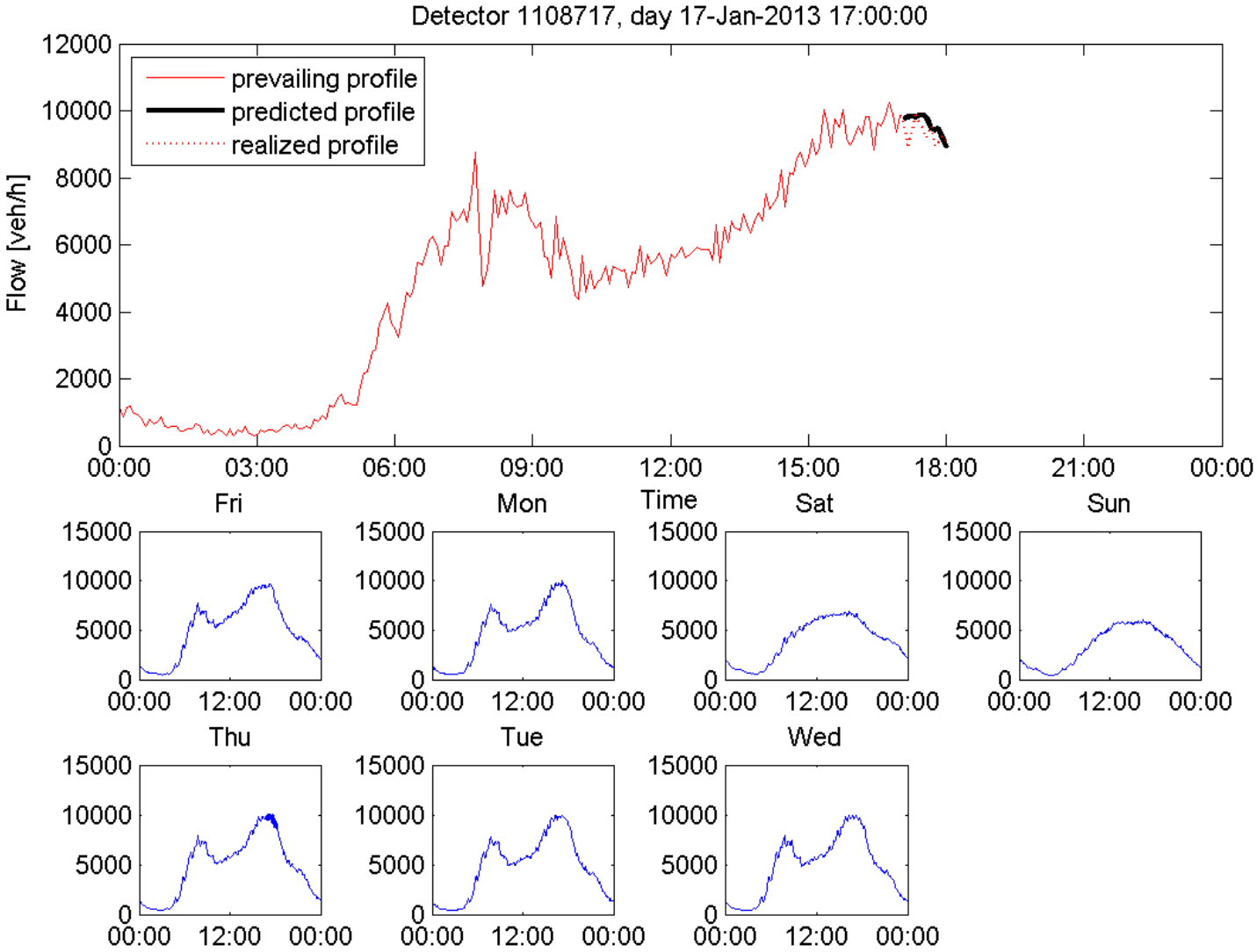
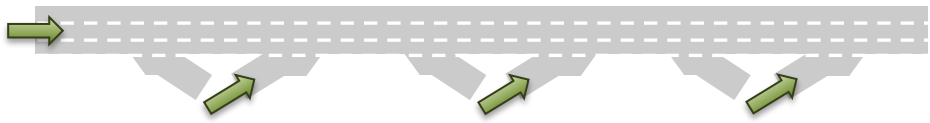
Boundary Flows – Results





Boundary Flows – Current Research



- In Clustering Step:
  - Use K-Means
    - ➔Special days get special clusters, e.g. on-ramp near football stadium

- In Cluster-Matching Step:
  - Use nearest-neighbor, in conjunction with K-Means Clustering

- In Forecasting step:
  - Combine recent (*y*) and historical (*u*) data by Autoregressive Moving Average with Exogenous Input Model (ARMAX)

$$y^{pred}(k+1) = b_{-1}u(k+1) + b_0u(k) + b_1u(k-1) + \ldots + a_0y(k) + a_1y(k-1) + \ldots + c_0w(k) + c_1w(k-1) + \ldots$$

y^{pred}: prediction; *y:* recent data; *u:* centroid; *w:* estimation residual; *k*: time step; a_i, b_i, c_i: ARMAX parameters

➔ Closer prediction of boundary flow

Poster Presentation: *"Fast Boundary Flow Prediction using Optimal Autoregressive Moving Average with Exogenous Inputs (ARMAX) Predictor"*, Paper-No.: TRB'14-4645, **Wednesday** 15 January 2014, **14:45 - 16:30**, Marriott **Salon** 2, D03, TRB Session 841: "Advances in Traffic Flow Theory and Characteristics, Part 2" (AHB45)

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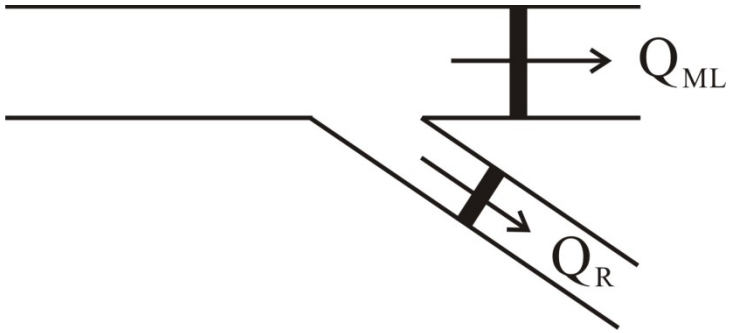
Split Ratio Prediction

Split Ratio (SR)

- What is SR
  - The proportion of flow heading to different directions at diverging nodes



- Why predict SR
  - A necessary part of traffic prediction based on cell transmission model (macroscopic simulation)
  - Models origin-destination together with boundary flows

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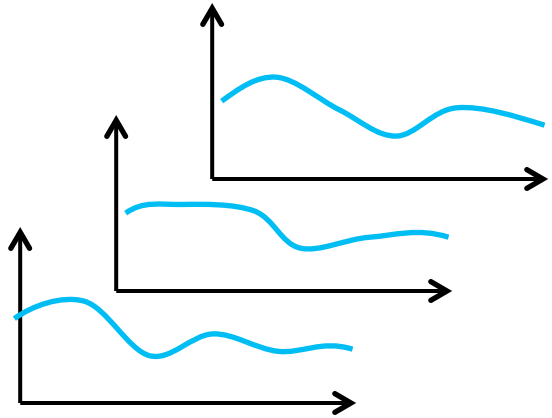
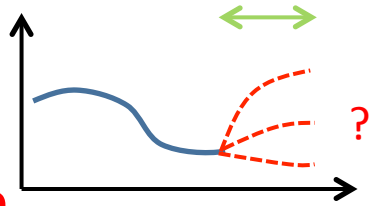
SR Prediction

- Input:
  - Historical SR profiles
    - e.g. over one year
  - Prediction horizon
    - e.g., over 1 hour
- Output:
  - Predicted SR for the given horizon





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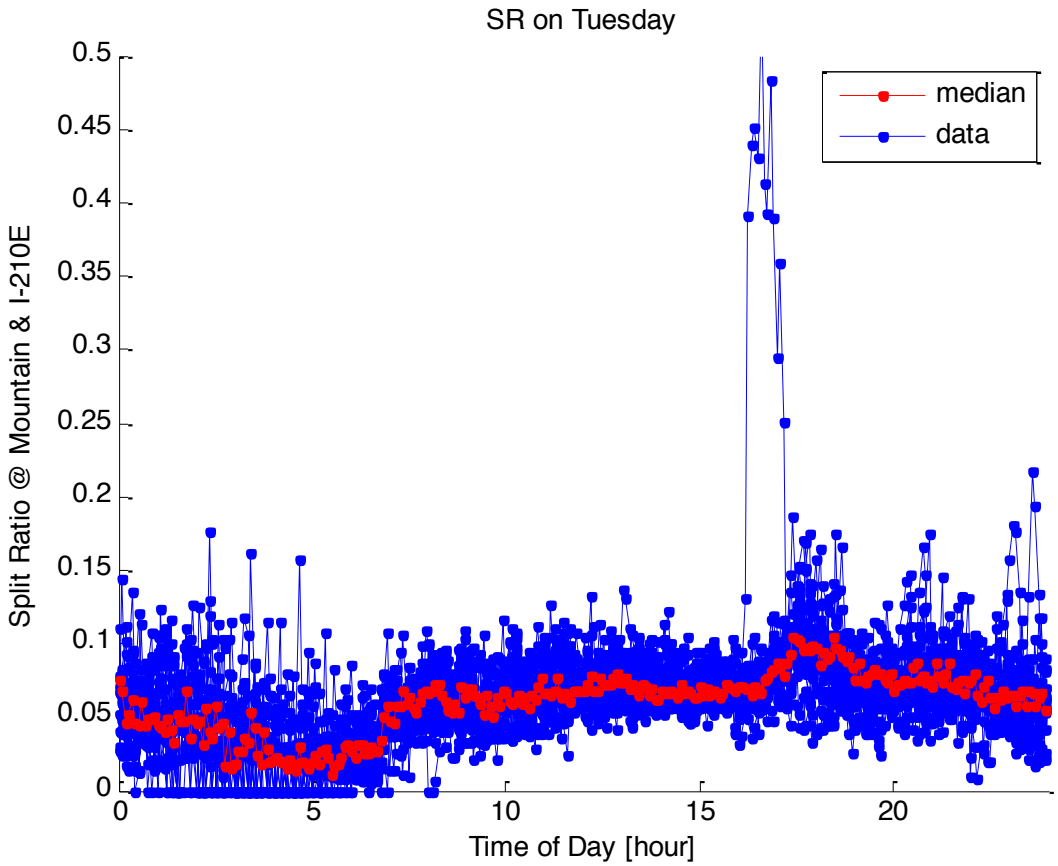
SR Prediction

- Current algorithm
  - Cluster SR by day of week
  - Calculate the median of SR within each cluster
  - Use the cluster median as the prediction



Off-ramp Flow RMSE [veh/hr]	Overall	In congestion
Current Deployment	69	258
New Model (work in progress)	63	172

More details on new model

OK to skip

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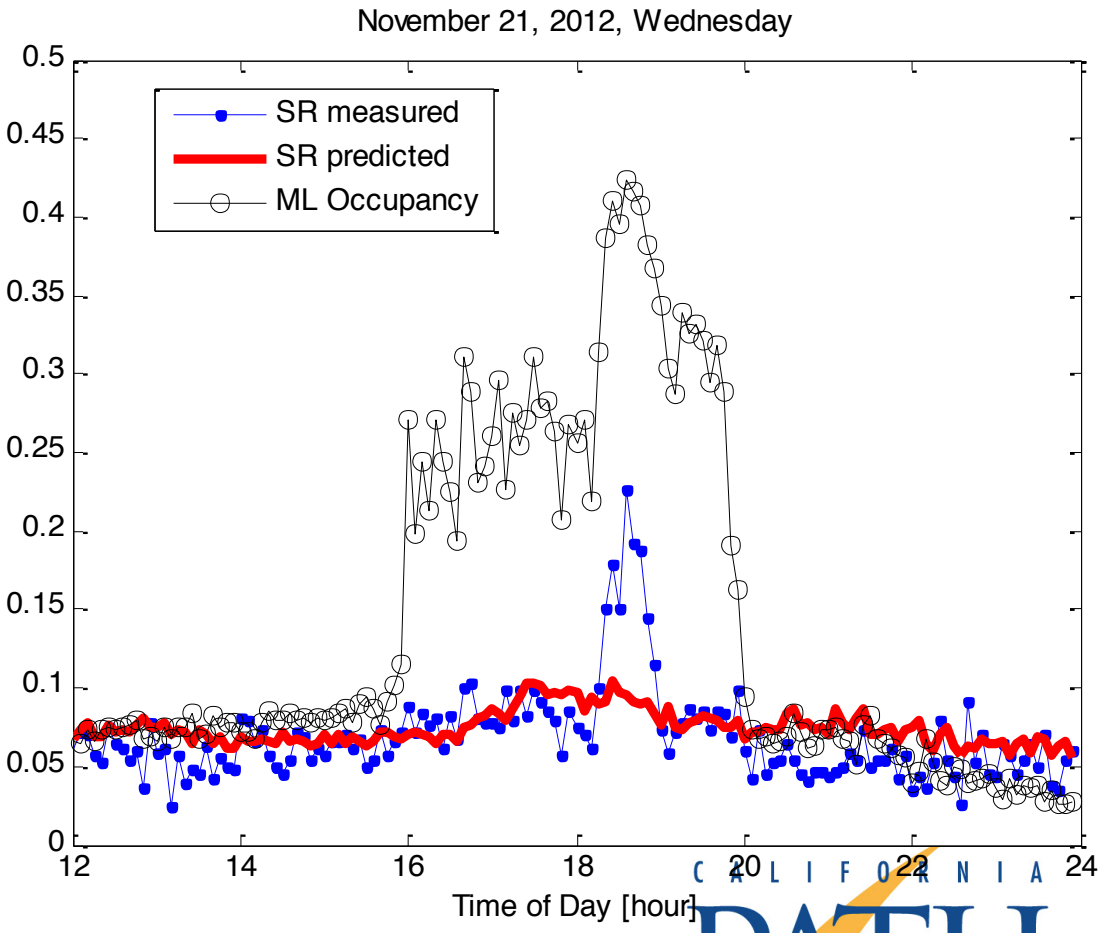
SR Prediction

- Known issue
  - Diversion increases significantly (therefore poor prediction) when mainline is congested



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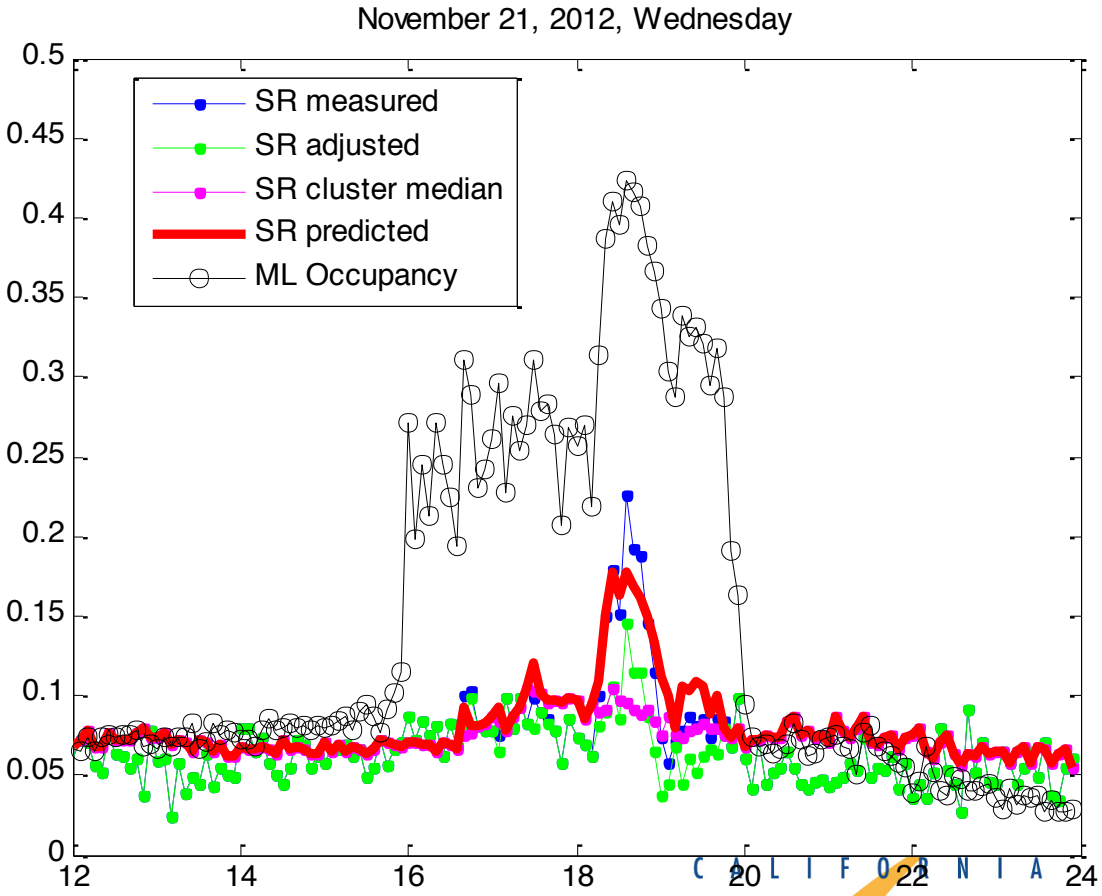
SR Prediction

- Augmented (dynamic) algorithm
  - Cluster SR by day of week
  - Adjust SR with mainline occupancy
  - Calculate the median of the adjusted SR within each cluster
  - Adjust the cluster median with mainline occupancy as the prediction



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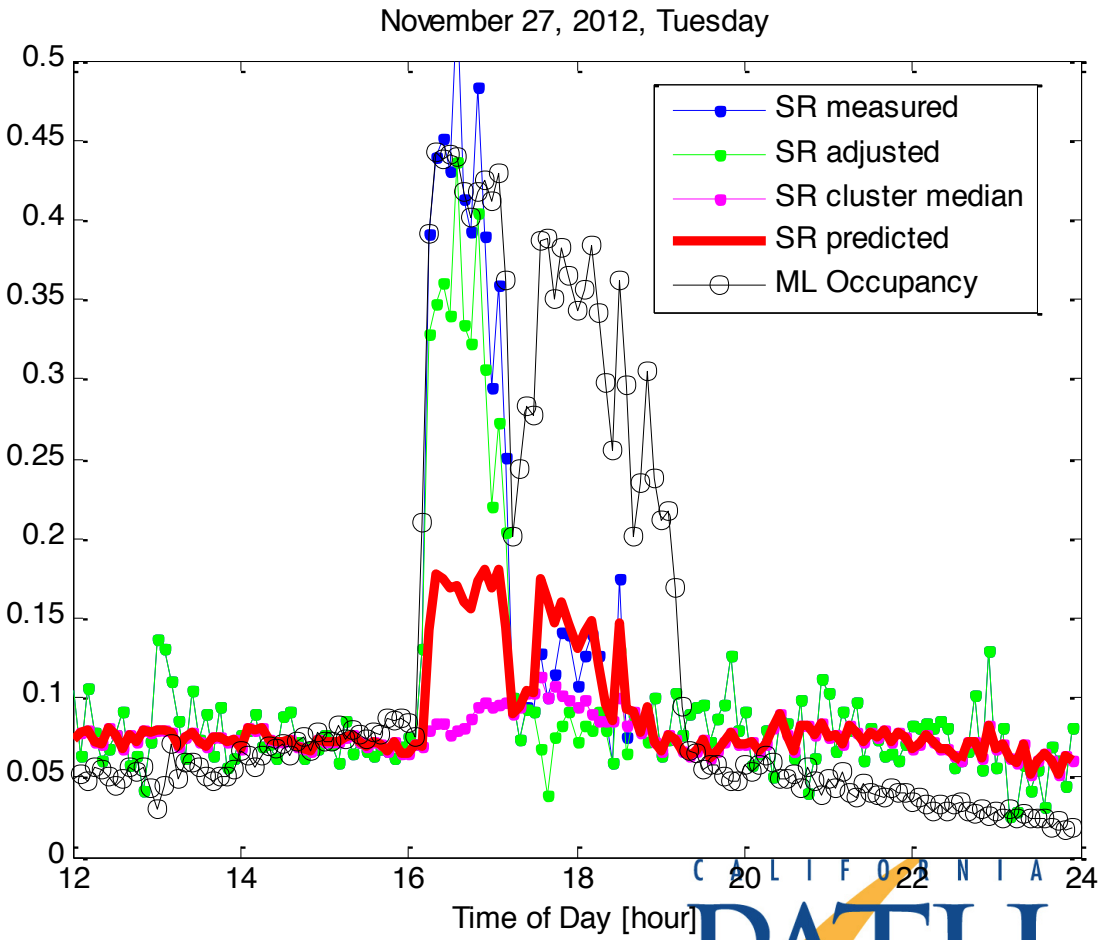
SR Prediction

- Known issue
  - Diversion during accident-induced congestion is more severe than that during recurrent congestion → underprediction



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