Improving Spatial Resolution of Wildland Fire Location and Fuel Biomass Data Inputs to NOAA's NAQFC

Kenneth J. Craig, ShihMing Huang, Nathan Pavlovic, Shih Ying Chang, Anthony Cavallaro
Sonoma Technology, Petaluma, CA

Stacy Drury
U.S. Forest Service, Davis, CA

for

17th Annual CMAS Conference
Chapel Hill, NC

October 23, 2018

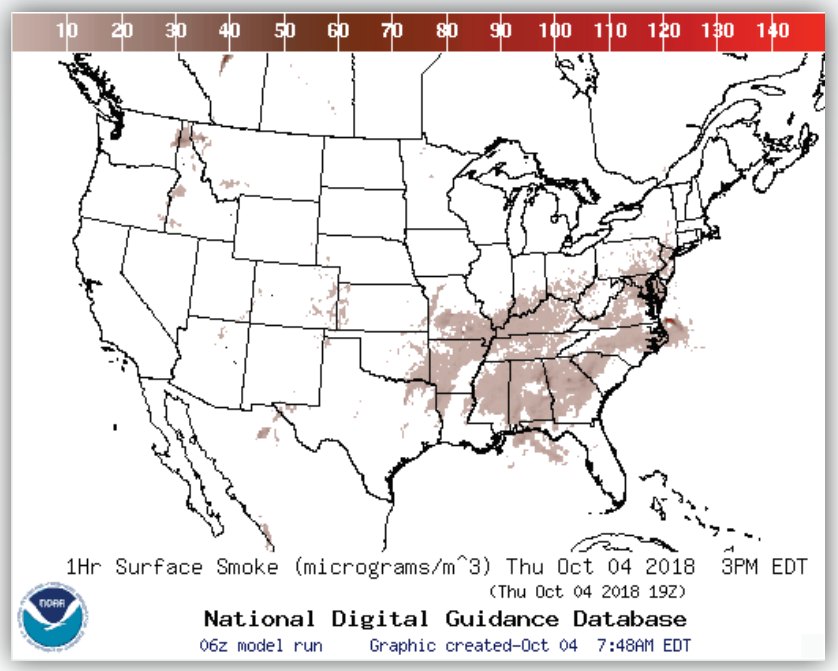
STi | Sonoma Technology

Acknowledgments

- NOAA National Air Quality Forecast Capability Team: Ivanka Stanjer, Jeff McQueen, Ho-Chun Huang
- USDA Forest Service AirFire Team: Sim Larkin, Robert Solomon
- Funded through a NOAA Air Quality Research and Forecasting opportunity (NOAA-OWAQ-2016-21004717)

Motivation

- NOAA's National Air Quality Forecast Capability (NAQFC) program provides forecasts about air quality conditions that may pose a significant risk to human health.
- Wildfires can contribute a significant fraction of total $PM_{2.5}$ during severe smoke episodes.
- Quantifying fire emissions and their impact on air pollution remains an important challenge as wildfire activity increases in the United States.

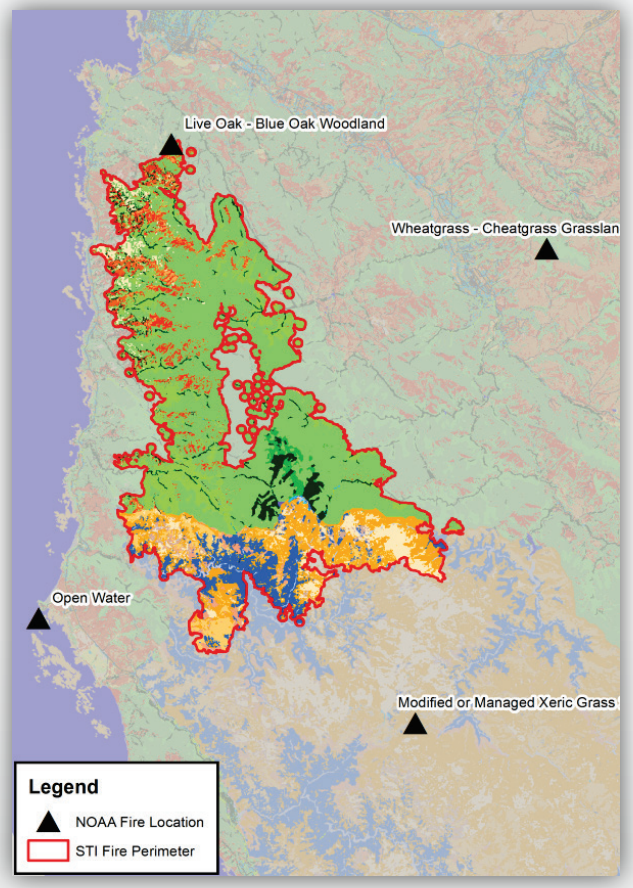


HYSPLIT-based smoke forecast from the NOAA NAQFC

Motivation

- Fire emissions depend on:
  - Fire type and size
  - Meteorology and fire activity
  - Available fuel (biomass) to burn
  - Fraction of fuel consumed
  - Fuel moisture
  - Fire behavior

- Current NAQFC methodology does not fully account for the spatial heterogeneity of fuel loading across the fire footprint.

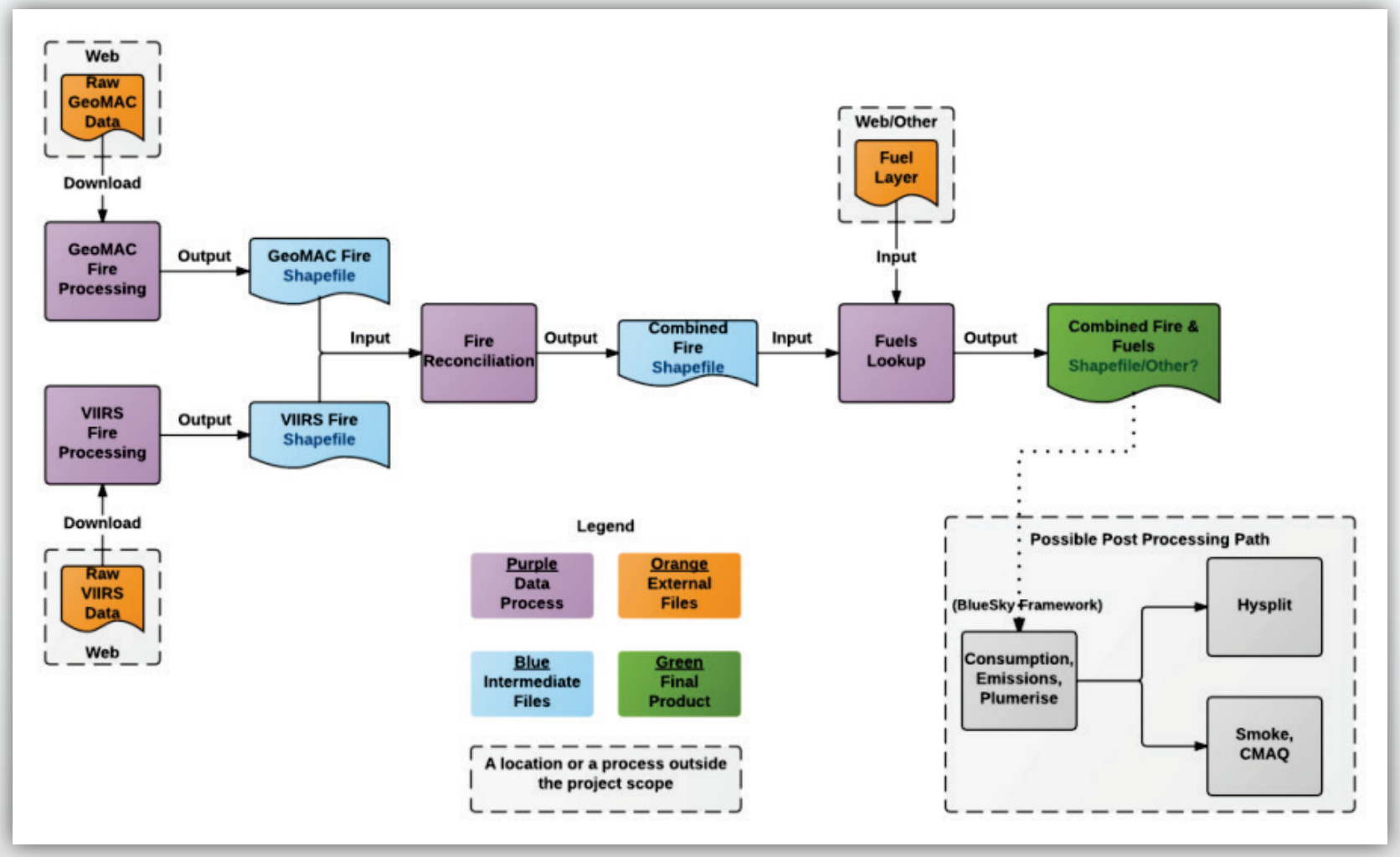


The perimeter of the Soberanes Fire in California in July 2016 showing the FCCS fuel beds and NAQFC fire emissions grid points.

Project Goals

- Improve NAQFC HYSPLIT smoke forecasts through
  - Improved characterization of biomass burning conditions
  - Use of the best available data on fire activity, daily fire progression, and fuel loading.
- Implement a modeling pathway through prototype software that (1) interfaces with BlueSky Framework and (2) can be tested and used in the NAQFC.
- Test and evaluate for July 2016.

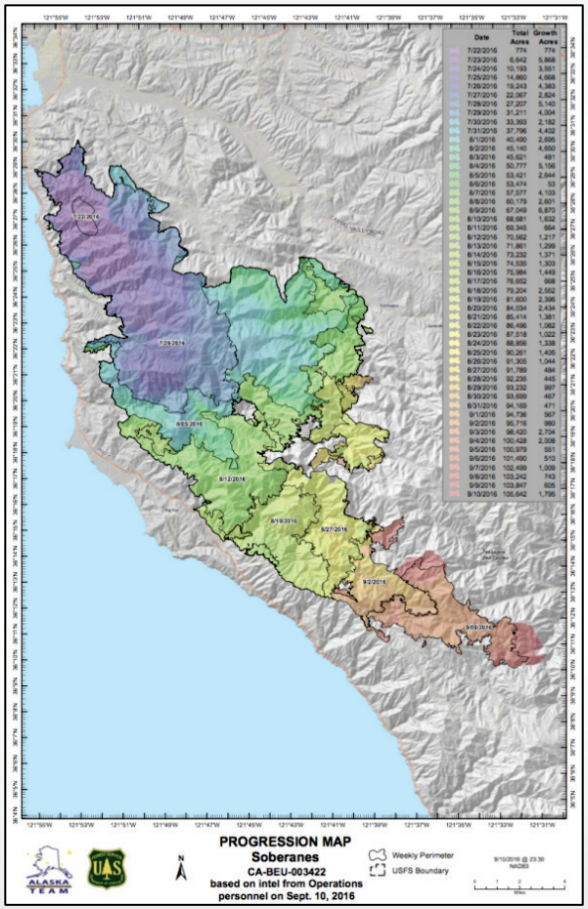
Project Goals



Overview of Python data processing software.

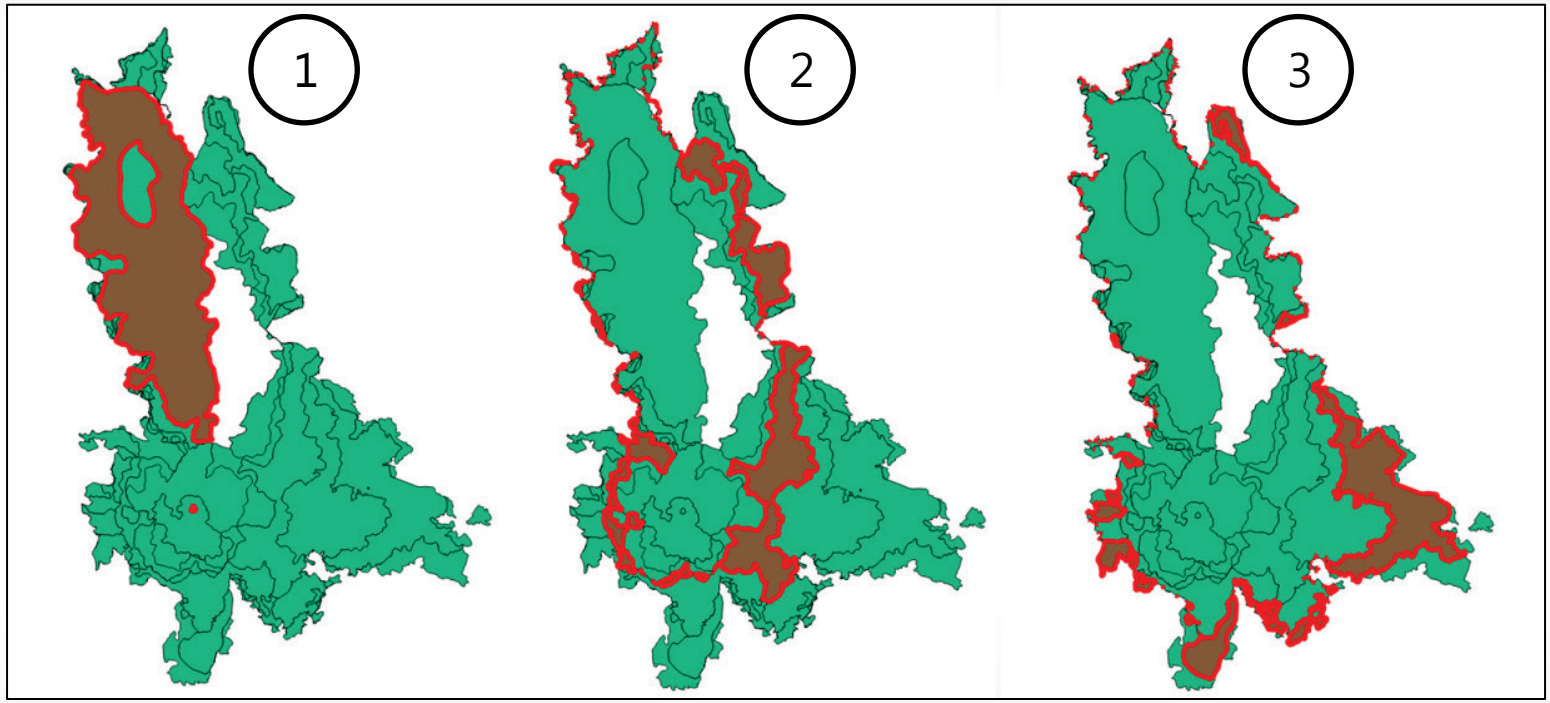
Fire Information Data

- Geospatial MultiAgency Coordination (GeoMAC) fire perimeters for large wildfires with an active firefighting response.
- Suomi-NPP VIIRS I-Band 375 m active fire detections product.
- NOAA Hazard Mapping System (HMS) hotspot product with manual analysis to support NAQFC HYSPLIT forecasts.



Soberanes Fire progression map.

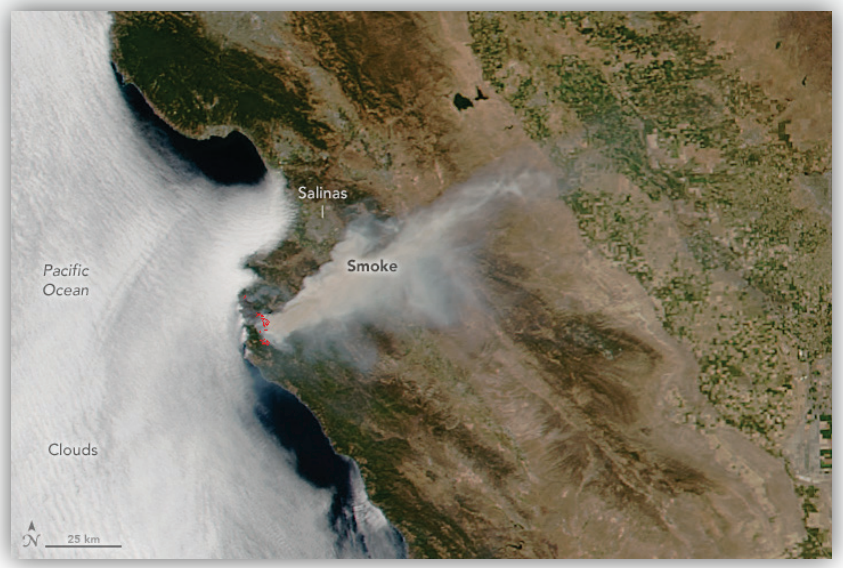
GeoMAC Fire Progression



GeoMAC fire perimeters for the Soberanes Fire on (1) July 23, (2) July 28, and (3) July 30, 2016.

Analysis Approach

- Acquire and process fire activity data.
- Estimate fuel loading (FCCS 30 m data from LANDFIRE).
- Link fuel loading to BlueSky Framework.
- Estimate fuel consumption and smoke emissions within BlueSky Framework.
- Estimate smoke concentrations using HYSPLIT.
- Compare to NAQFC results and evaluate against $PM_{2.5}$ observations.



VIIRS satellite image showing smoke from the Soberanes Fire on July 24, 2016. From NASA LANCE/EOSDIS Rapid Response.

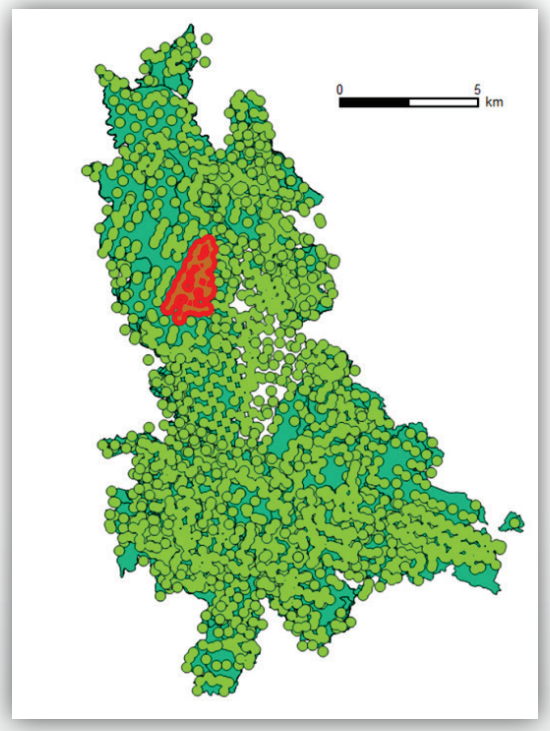
Smoke Modeling Approach

- HYSPLIT v4.9 (revision 504)
- BlueSky Framework version 3.5.1
- FCCS 30 m
- Particle mode
- Meteorology: NAM12
- Receptor grid: 0.15 x 0.15 degrees (similar to NAM12)
- Output surface (0-100 m AGL) and column (0-5 km AGL) $PM_{2.5}$ concentrations

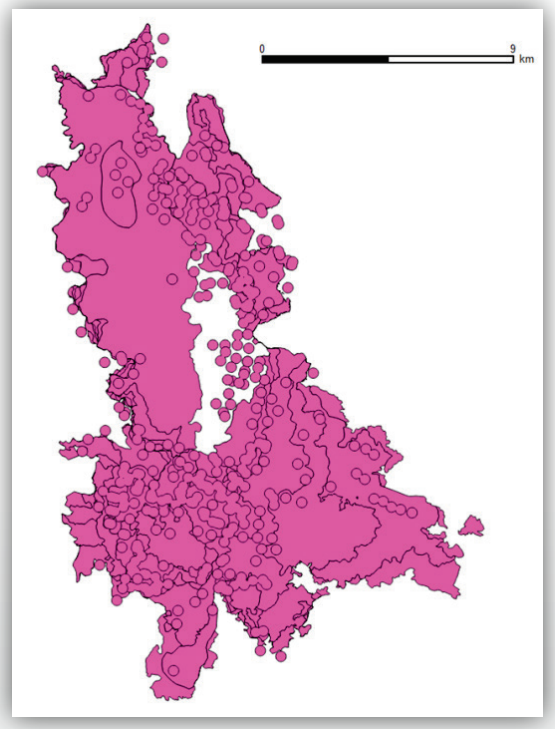
Clumping and Reconciliation

Soberanes Fire, July 2016

Before Clumping

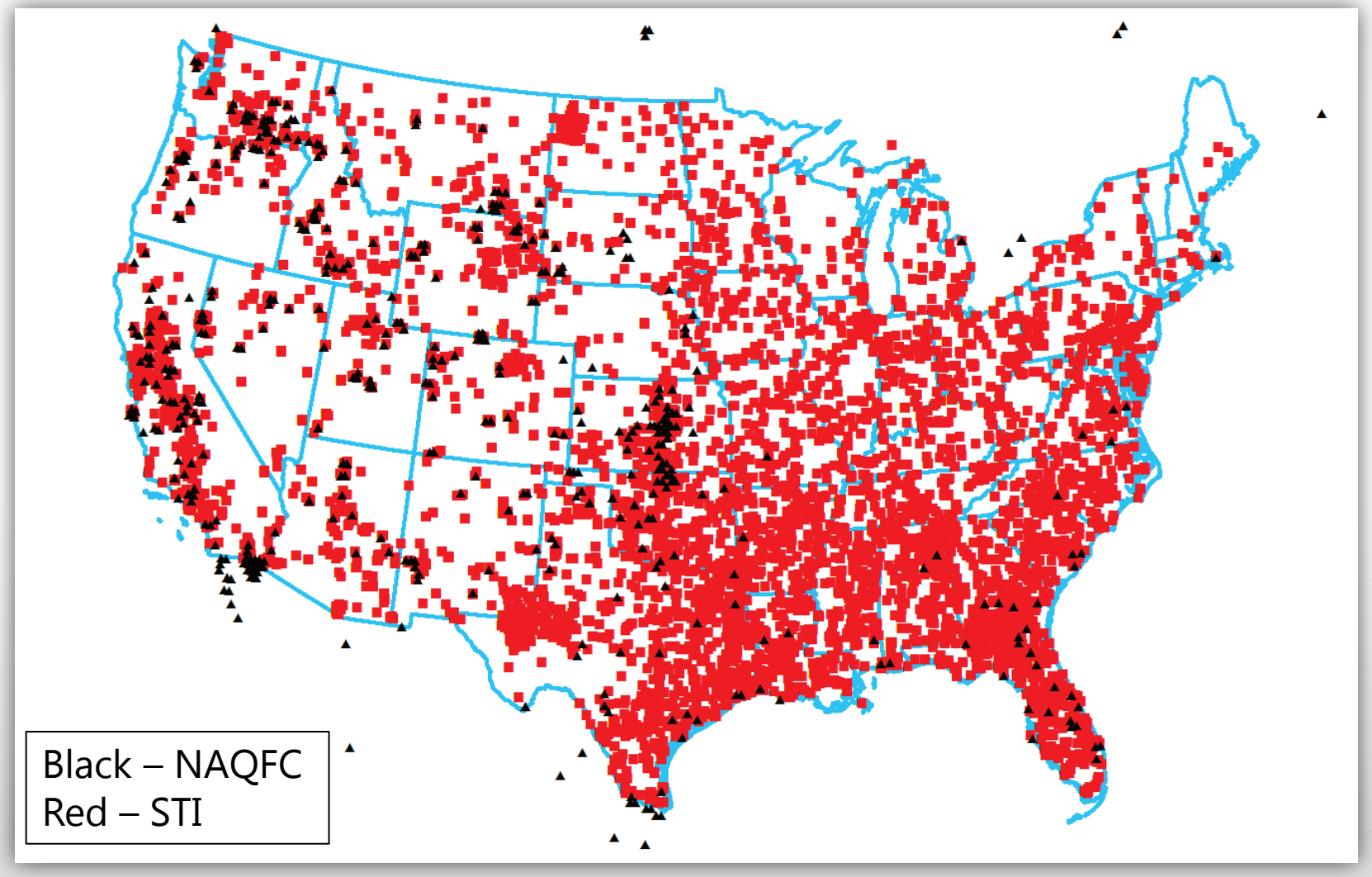


After Clumping

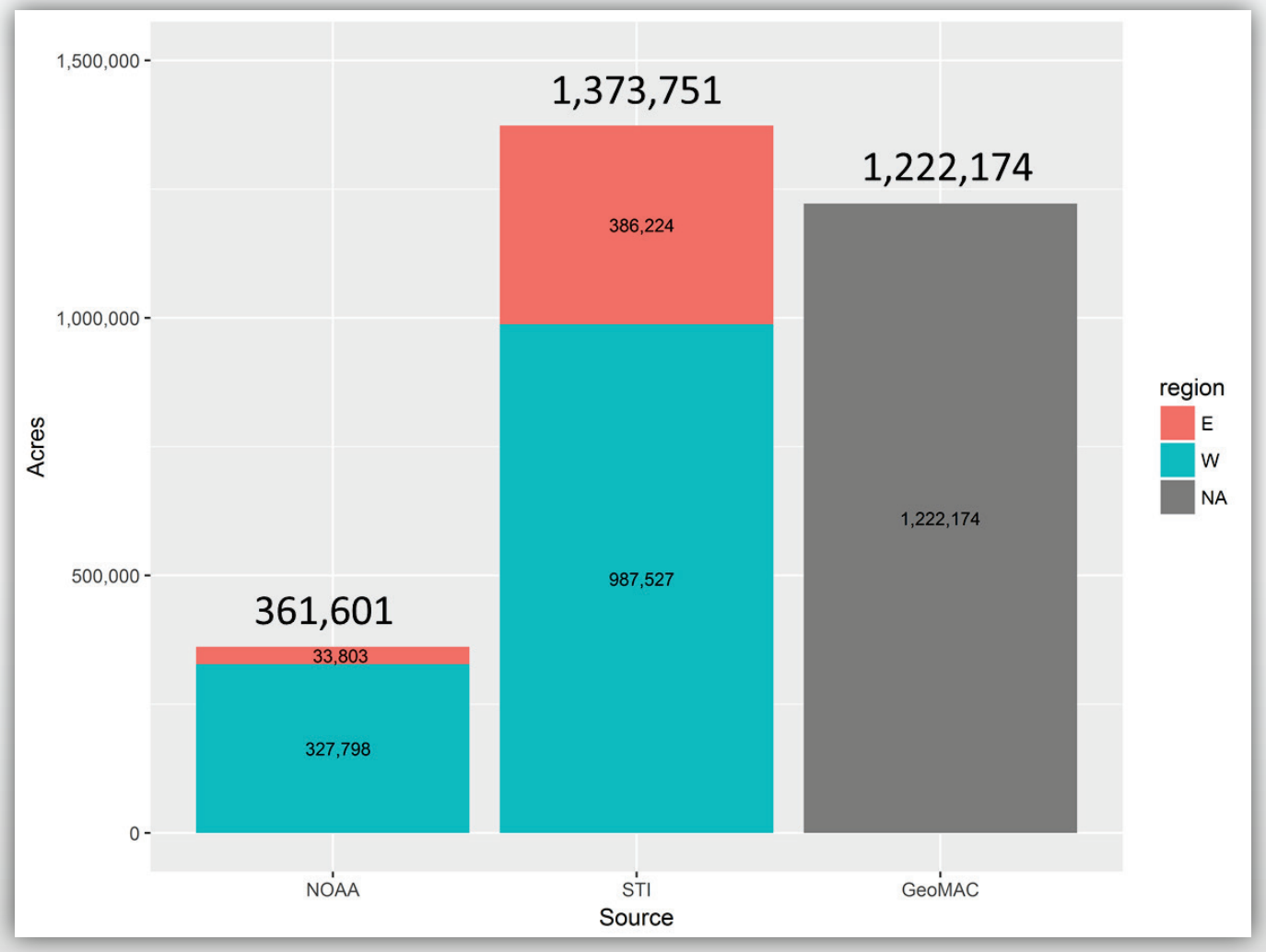


After Reconciliation

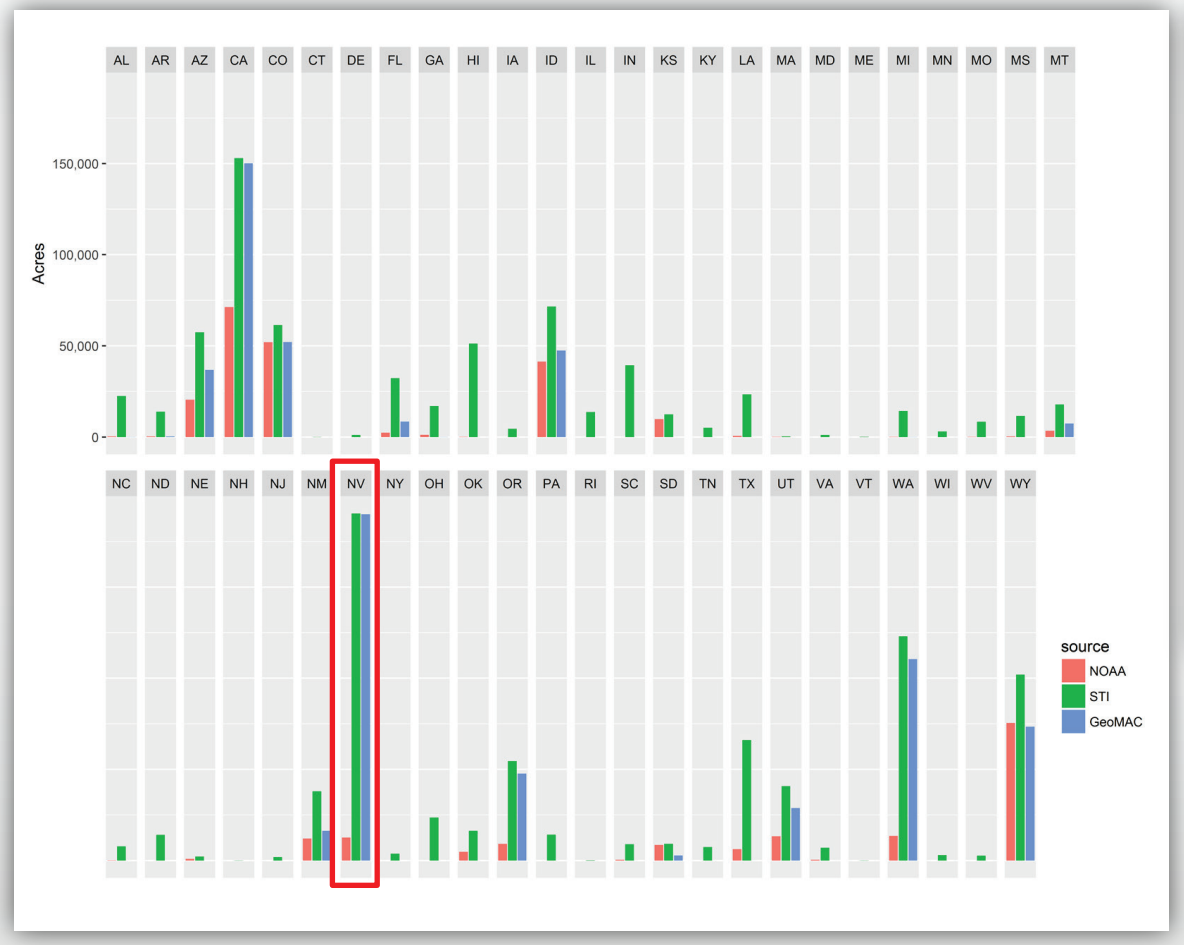
July 2016 Daily Fire Locations

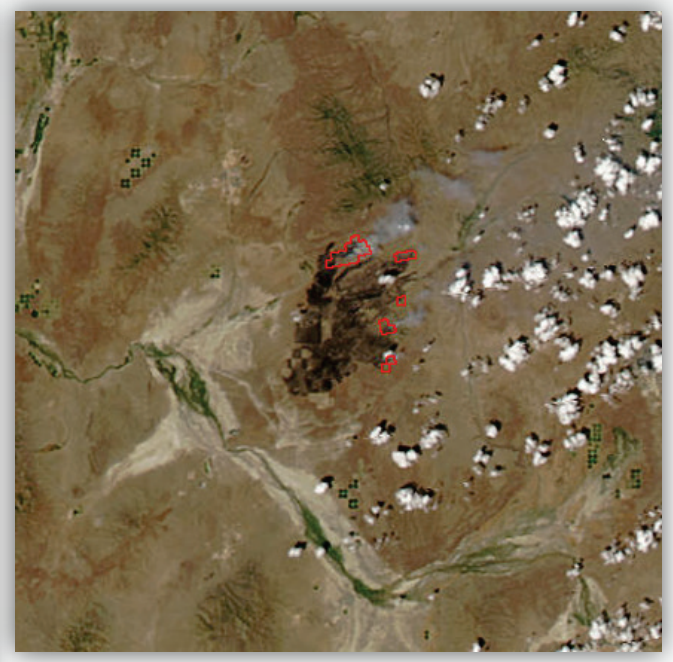


Acres Burned in July 2016



Area Burned by State

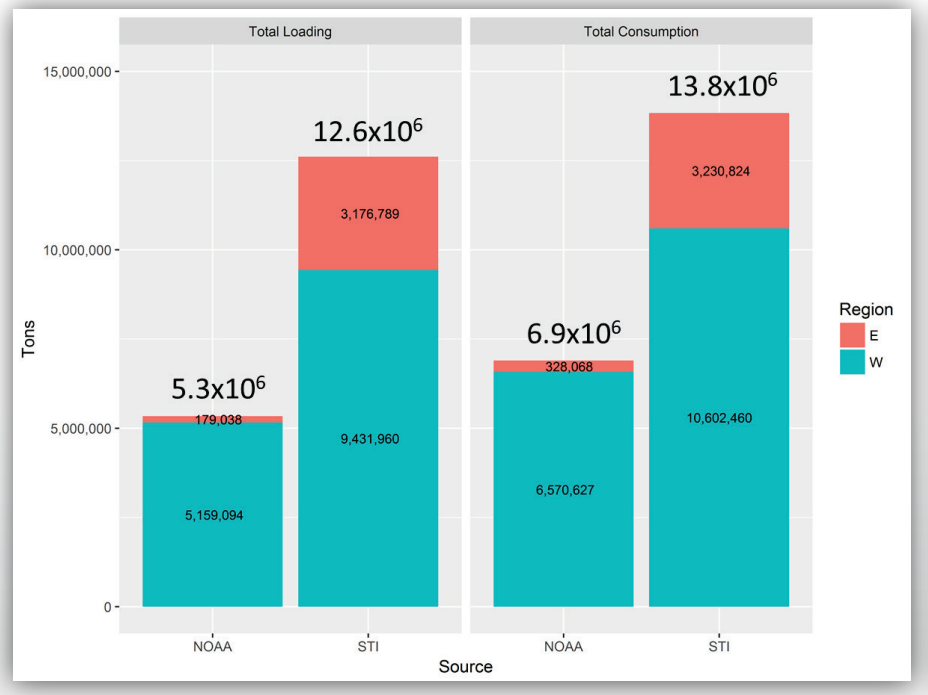




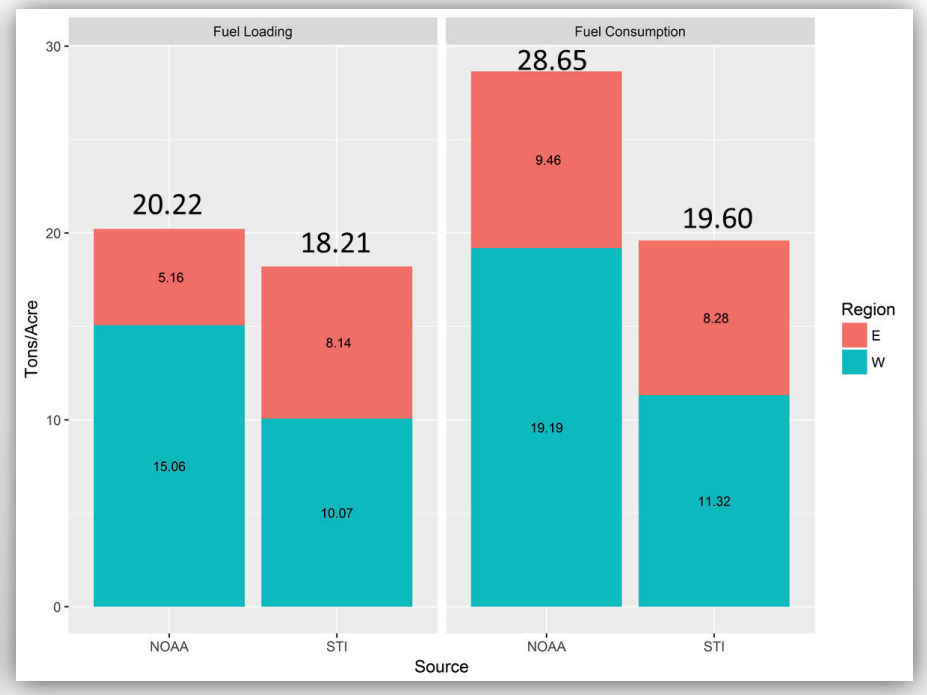
MODIS Aqua satellite image from July 3, 2015, showing a burn scar from the Hot Pot Fire in northern Nevada.

Fuel Loading and Consumption

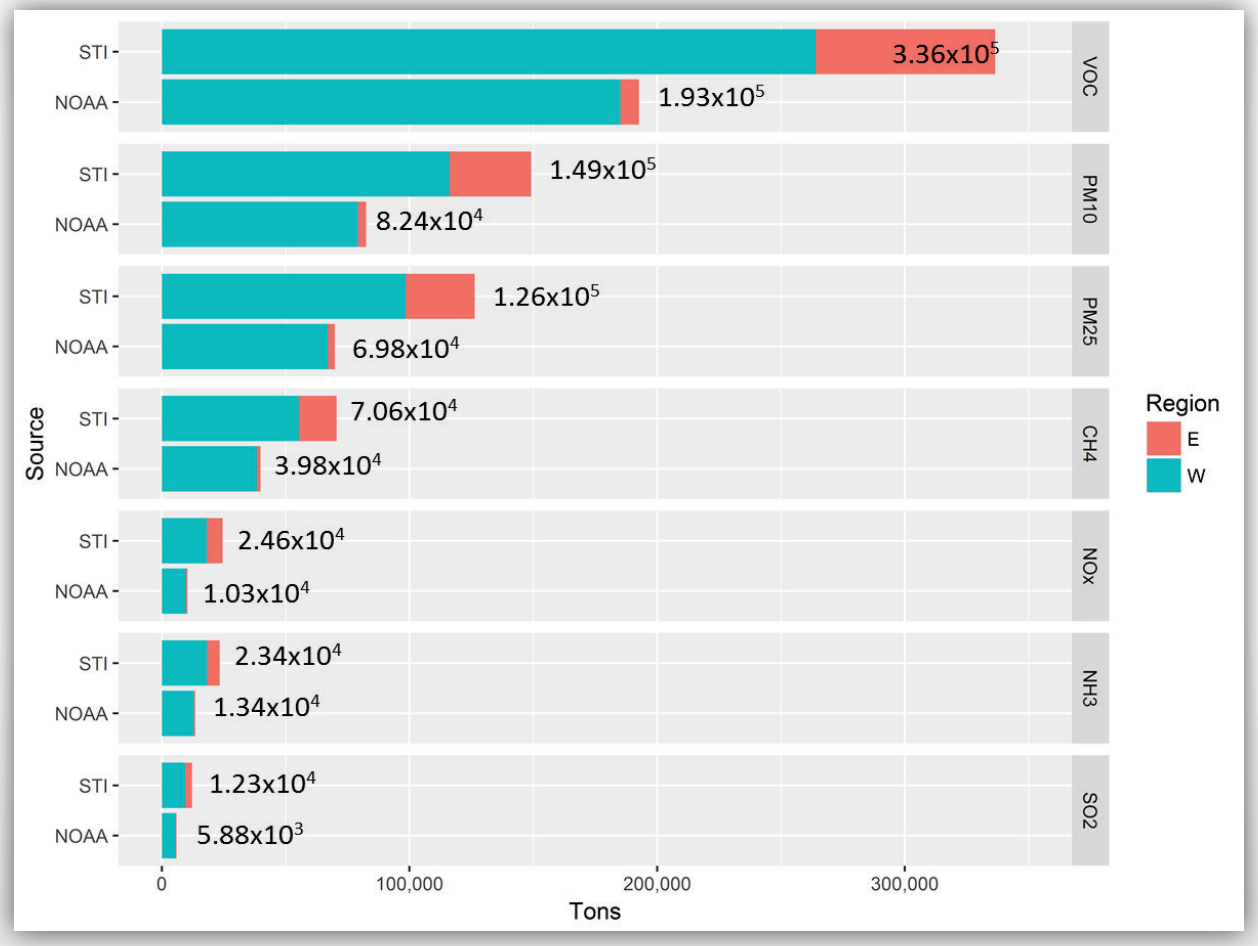
Tons



Tons/acre

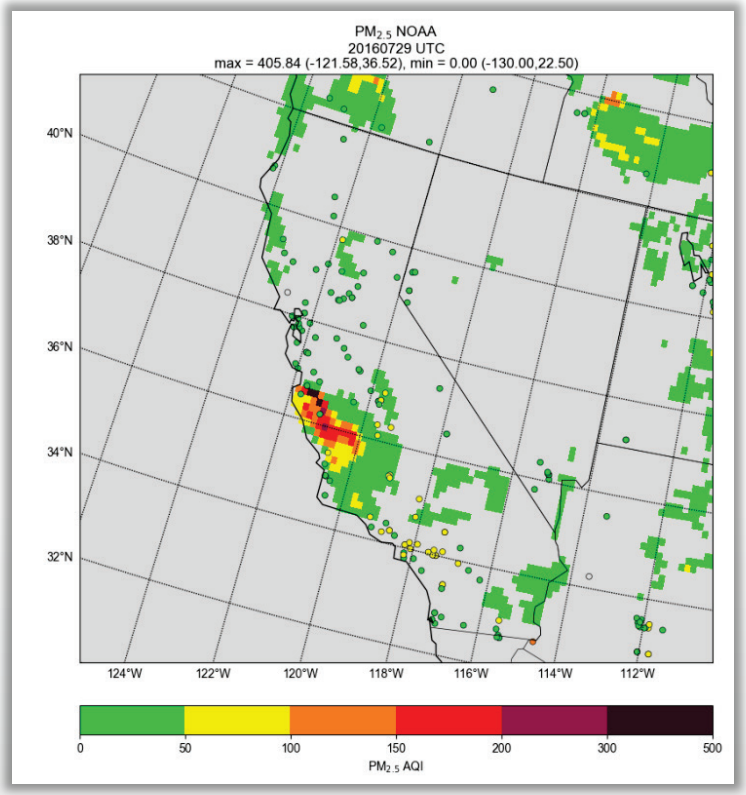


Emissions

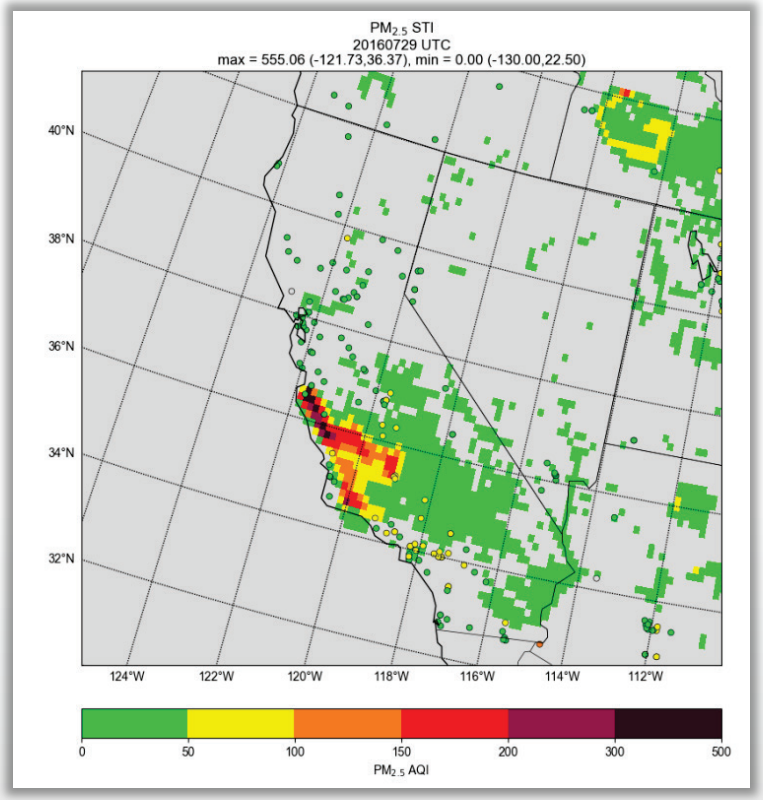


July 2016 Emissions Estimates

HYSPLIT Smoke Predictions
July 29, 2016



Operational NAQFC

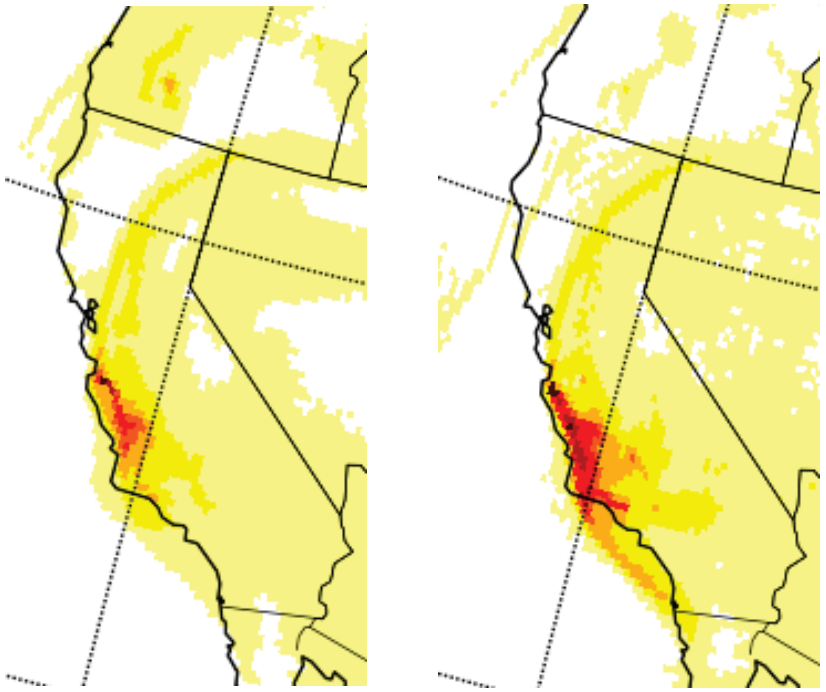


Revised Modeling Pathway

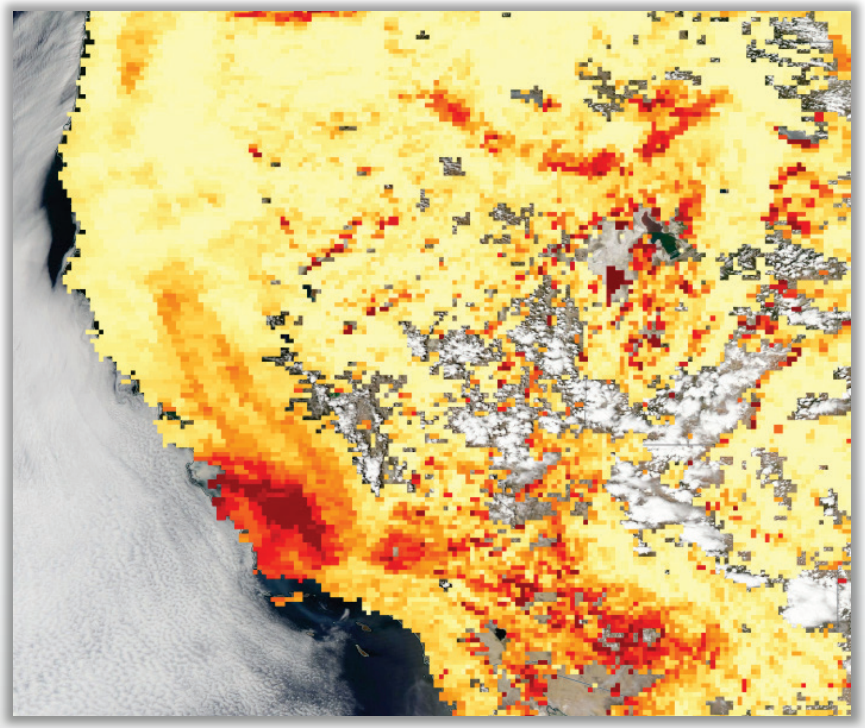
Comparison to AOD
July 29, 2016

Operational NAQFC

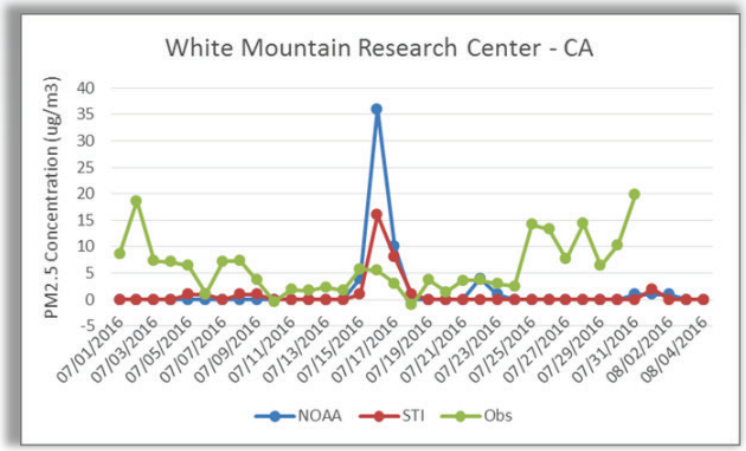
Revised Modeling Pathway

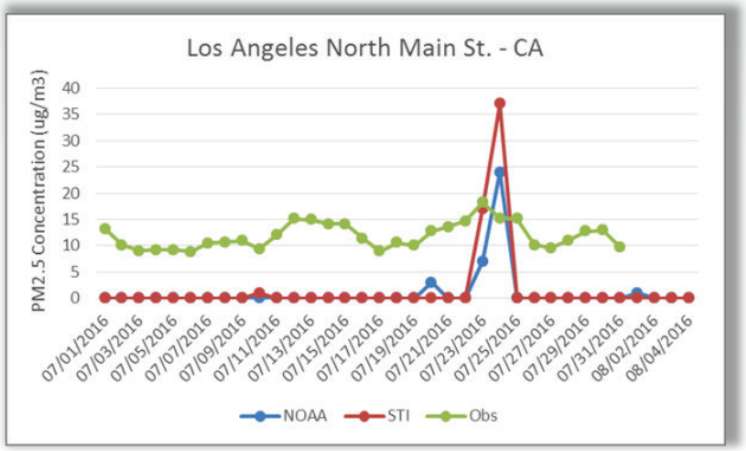


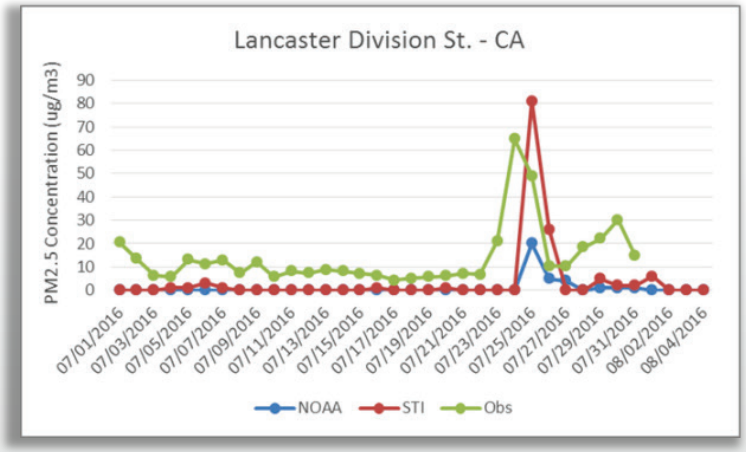
MODIS Deep Blue AOD

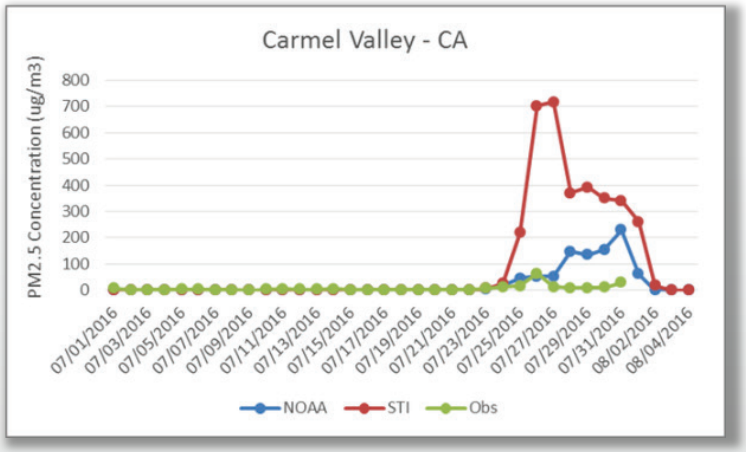


Time Series Comparisons



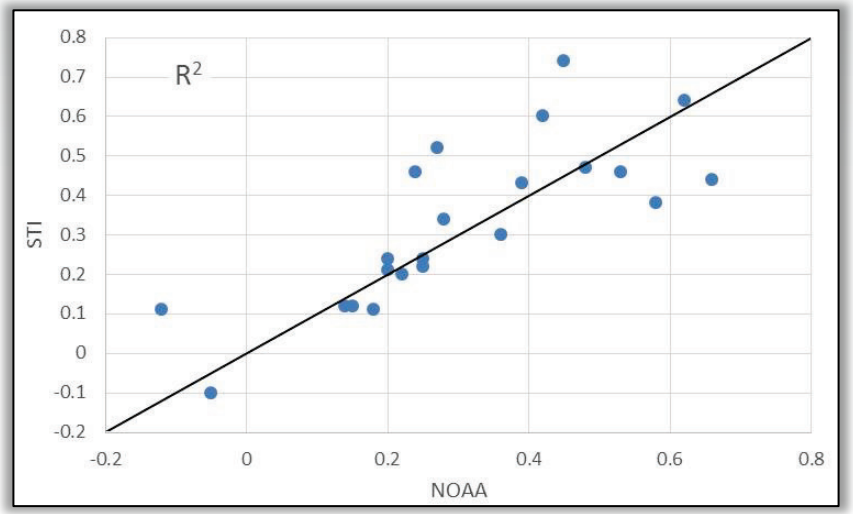


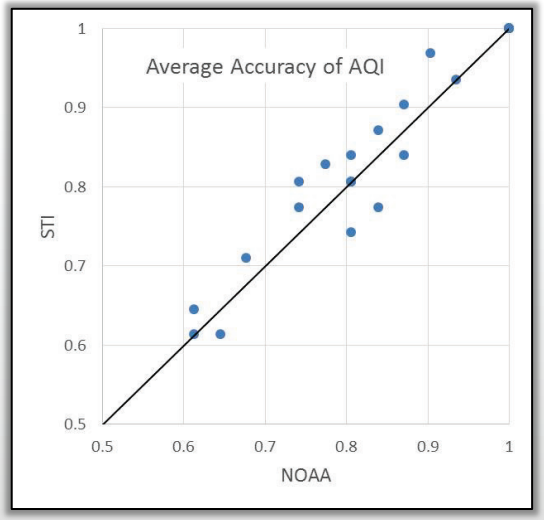


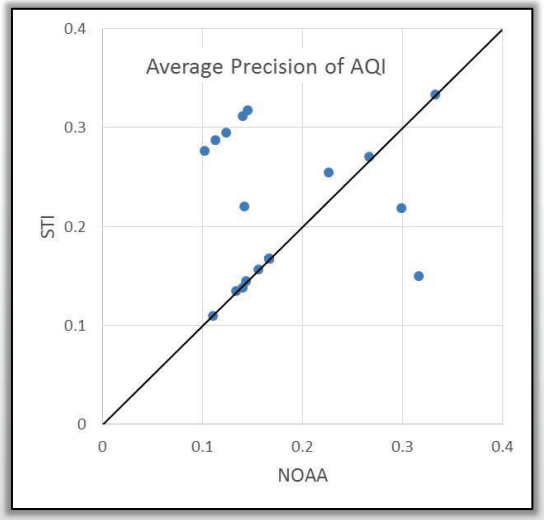


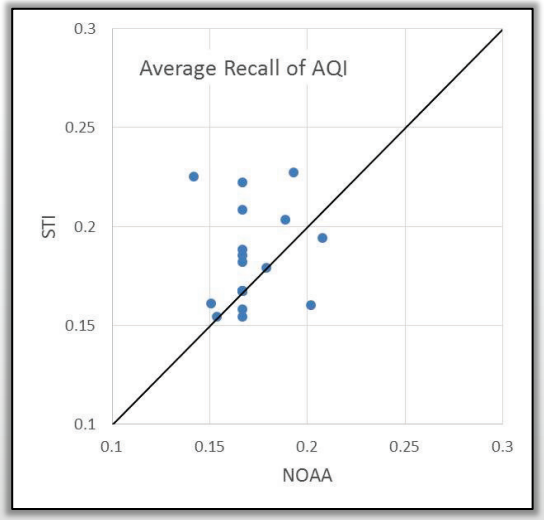
HYSPLIT modeling includes only primary $PM_{2.5}$ emissions from fires, and does not account for other emissions or chemical transformations.

Evaluation Against $PM_{2.5}$ Observations









Conclusions

- GeoMAC can substantially improve fire activity and emission estimates, particularly in the western United States.
- The GeoMAC data stream captures some fires that are missed in the operational NAQFC inventory.
- HYSPLIT simulations predicted similar spatial patterns of surface and column smoke, but subtle differences might be important for forecast end users.
- The revised modeling pathway improved daily $PM_{2.5}$ predictions on both concentration and air quality index (AQI) bases.

Recommendations

- It is worthwhile to pursue expanded testing and evaluation over a longer time period and a wider range of fire and smoke conditions.
- Coordination and synthesis between fire and air quality communities can improve smoke forecasts.
- High spatial-resolution fire footprints may be even more beneficial for higher-resolution systems (e.g., 3-km resolution HRRR-Smoke forecast product).

Contact

Kenneth Craig

Manager, Atmospheric Modeling Group

kcraig@sonomatech.com

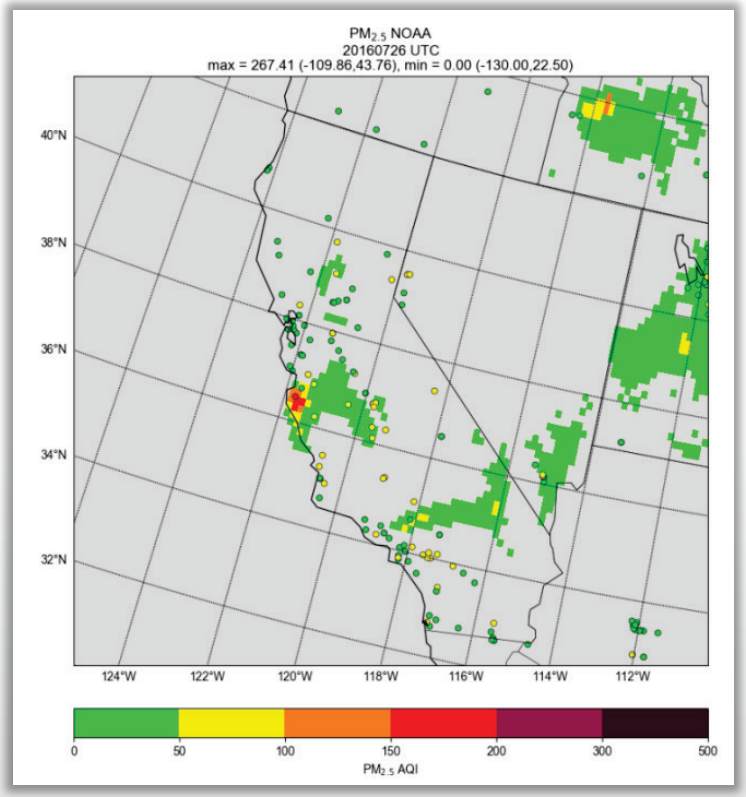
707.665.9900

Acronyms

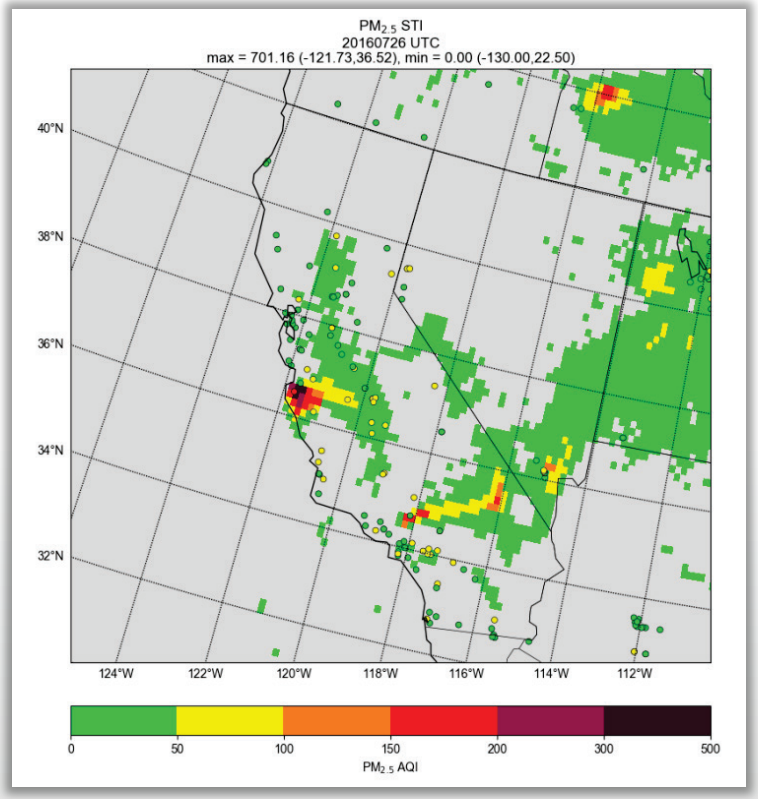
- **AGL:** Above ground level
- **AOD:** Aerosol Optical Depth
- **AQI:** Air quality index
- **FCCS:** Fuel Characteristic Classification System
- **GeoMAC:** Geospatial MultiAgency Coordination
- **HMS:** Hazard Mapping System
- **HRRR:** High Resolution Rapid Refresh
- **HYSPLIT:** Hybrid Single Particle Lagrangian Integrated Trajectory Model
- **MODIS:** Moderate Resolution Imaging Spectroradiometer
- **NAM12:** 12-km resolution North American Mesoscale Modeling System
- **NAQFC:** National Air Quality Forecast Capability
- **$PM_{2.5}$:** Atmospheric particulate matter (PM) with a diameter of less than 2.5 micrometers

Extra Slides

HYSPLIT Smoke Predictions
July 26, 2016



Operational NAQFC



Revised Modeling Pathway

Evaluation Statistics

Site ID	Site Name	R^2		RMSE	
		NAQFC	STI	NAQFC	STI
California					
060270002	White Mountain Research Center	-0.05	-0.10	9.6	8.2
060371103	Los Angeles – North Main St.	0.39	0.43	11.5	12.0
060379033	Lancaster – Division St.	0.48	0.47	17.3	17.4
060530002	Carmel Valley	0.45	0.74	56.5	214.9
060530008	King City 2	0.24	0.46	62.1	11.6
060531003	Salinas 3	0.25	0.22	11.6	6.8
060792006	San Luis Obispo	-0.12	0.11	11.7	9.9
060798002	Atascadero	0.27	0.52	10.4	9.5
061111004	East Ojai Ave	0.62	0.64	10.3	16.0
Idaho					
160050020	Ballard Road	0.18	0.11	9.9	9.7
Nevada					
320030298	Green Valley	0.28	0.34	13.4	12.4
320030540	Jerome Mack-NCore	0.20	0.24	13.3	12.5
320030561	Sunrise Acres	0.15	0.12	15.8	15.8
320032002	JD Smith	0.22	0.20	17.3	16.9
320311005	Sparks	0.53	0.46	10.1	9.1
325100020	Old National Guard Armory	0.20	0.21	5.0	5.0
Wyoming					
560051899	Buckskin Mine North Site	0.42	0.60	3.2	2.9
560130099	South Pass	0.36	0.30	4.2	4.3
560130232	Spring Creek	0.66	0.44	3.2	3.4
560150005	Terrington Mobile	0.14	0.12	3.5	3.5
560210002	Cheyenne Mobile	0.58	0.38	5.6	5.4
560350101	Pinedale Gaseous	0.25	0.24	11.6	10.3

Site ID	Site Name	R^2		RMSE	
		NAQFC	STI	NAQFC	STI
California					
060270002	White Mountain Research Center	-0.18	-0.20	31.0	32.7
060371103	Los Angeles – North Main St.	0.39	0.41	45.8	46.4
060379033	Lancaster – Division St.	0.49	0.47	52.1	49.9
060530002	Carmel Valley	0.70	0.81	64.9	192.8
060530008	King City 2	0.35	0.55	74.6	33.4
060531003	Salinas 3	0.27	0.25	32.9	24.0
060792006	San Luis Obispo	-0.12	0.19	38.7	33.0
060798002	Atascadero	0.32	0.55	32.5	28.8
061111004	East Ojai Ave	0.52	0.53	42.1	43.9
Idaho					
160050020	Ballard Road	0.21	0.13	40.6	40.0
Nevada					
320030298	Green Valley	0.30	0.36	44.6	41.0
320030540	Jerome Mack-NCore	0.22	0.26	44.0	41.0
320030561	Sunrise Acres	0.19	0.19	50.8	49.3
320032002	JD Smith	0.24	0.25	55.2	52.9
320311005	Sparks	0.50	0.43	36.8	33.3
325100020	Old National Guard Armory	0.21	0.23	19.9	19.6
Wyoming					
560051899	Buckskin Mine North Site	0.43	0.60	13.5	12.3
560130099	South Pass	0.37	0.30	17.5	18.0
560130232	Spring Creek	0.65	0.45	13.4	14.3
560150005	Terrington Mobile	0.13	0.11	14.9	14.6
560210002	Cheyenne Mobile	0.58	0.38	23.3	22.4
560350101	Pinedale Gaseous	0.35	0.35	35.7	33.6