

Predicting Weather and Air Quality: from impacts of extreme storms in the Northeast to multi-decadal ozone simulations over the Contiguous United States

Marina Astitha

Assistant Professor

PhD students: Jaemo Yang, Huiying Luo

marina.astitha@uconn.edu

Websites: airmg.uconn.edu, cee-wrf.engr.uconn.edu

Department of Civil & Environmental Engineering, University of Connecticut, Storrs-Mansfield, CT, USA



Seminar at the SIPRAC committee, Jan 12, 2017





RESEARCH TOPICS

- Extreme weather events: forecasting and impacts to the power network
- Air quality: prediction, evaluation and the way forward



Extreme weather events: forecasting and impacts to the power network

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Storm Outage Forecasting



With preparedness at the forefront of ensuring superior customer service, Storm Outage Forecasting delivers actionable information on predicted outage locations and magnitude.

Tree & Forest Management



With 90 percent of power outages during storms caused by trees, our program links forest management and community outreach for creating a sustainable and storm-resistant forest design.

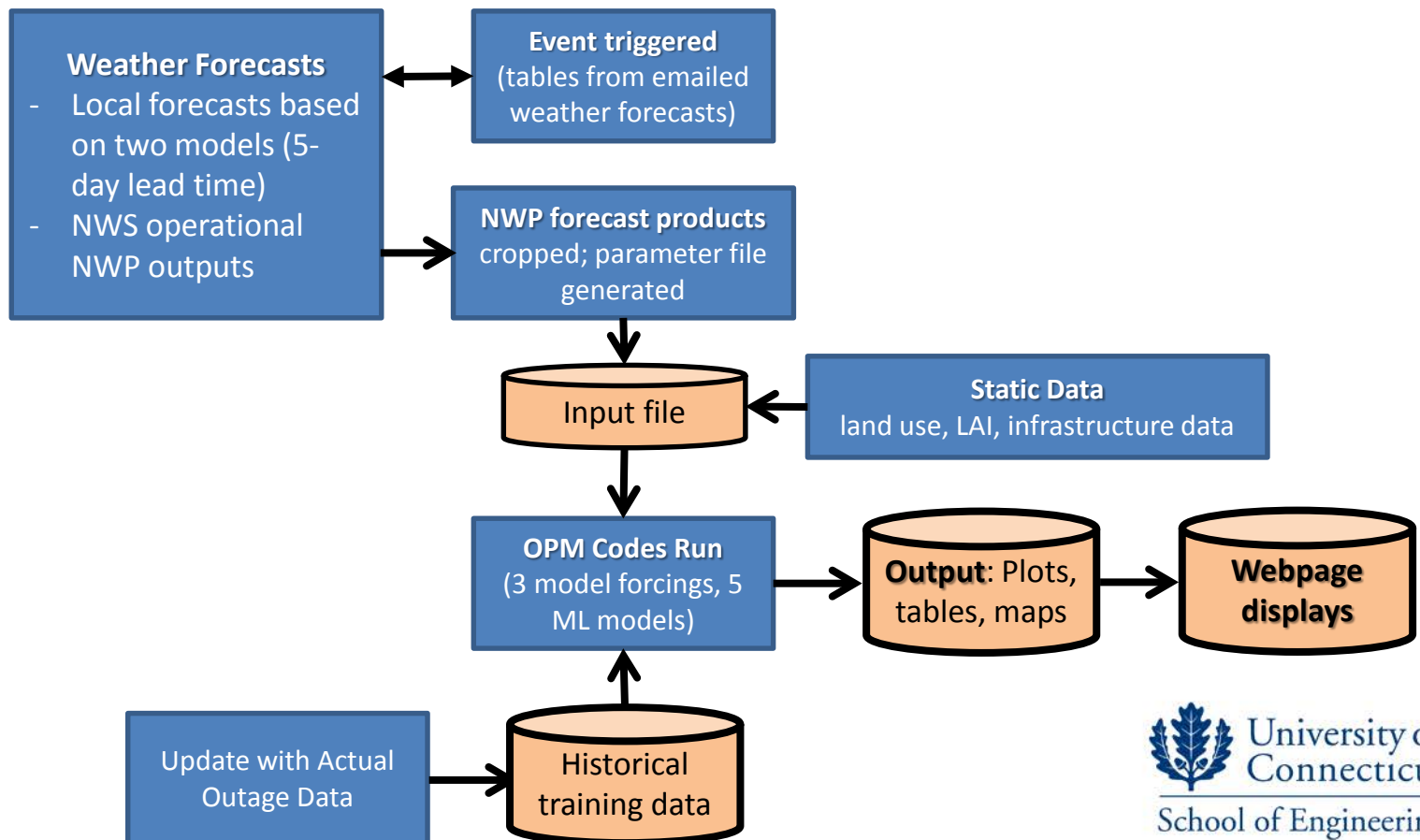
Electric Grid Hardening



Complex system improvements are made with advanced data identifying strategic areas for grid design, efficiency and storm resiliency.

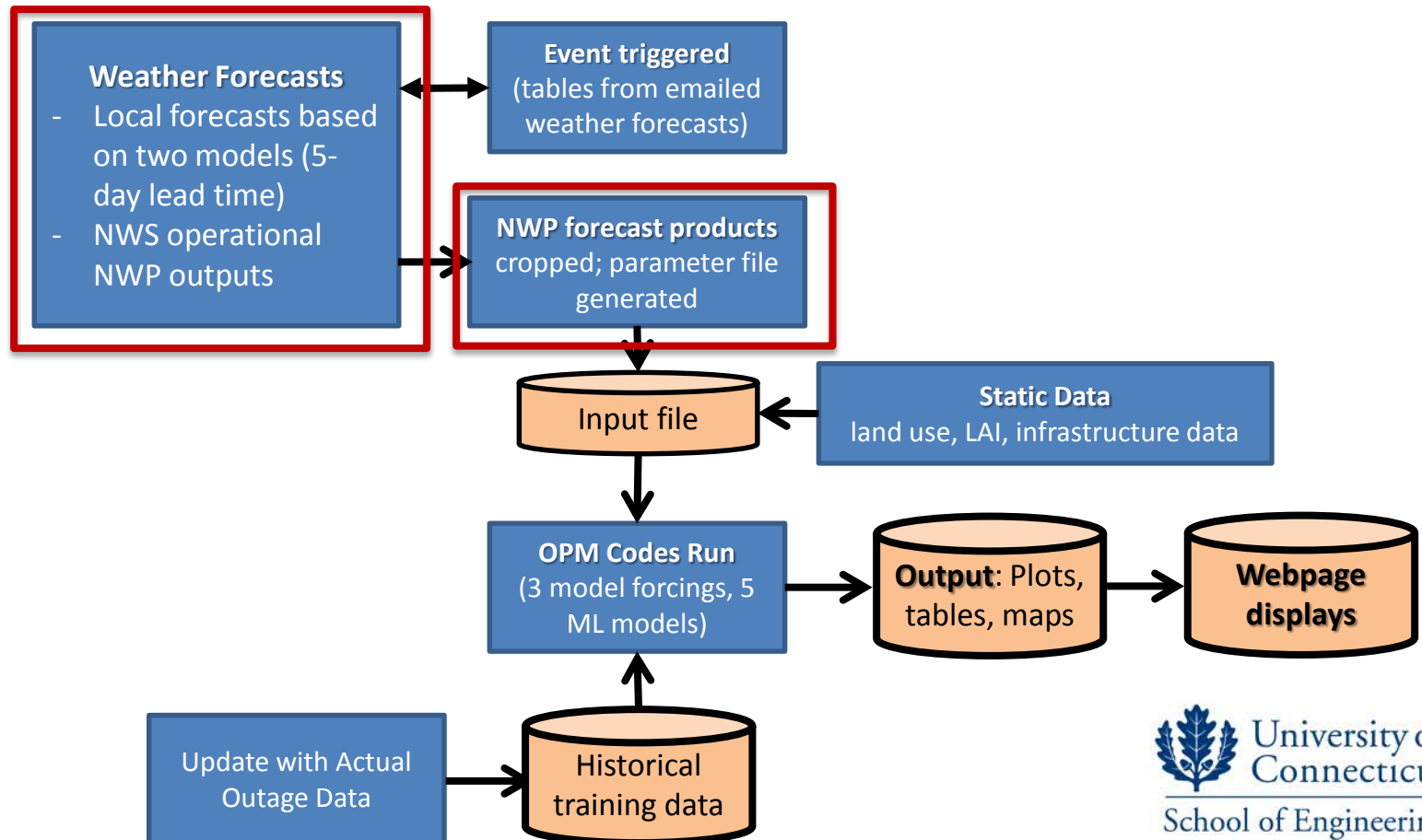
Extreme weather events: forecasting and impacts to the power network

Outage Prediction Model System Architecture



Extreme weather events: forecasting and impacts to the power network

Outage Prediction Model System Architecture





OBJECTIVE: Improve weather forecasting functionality and uncertainty characterization

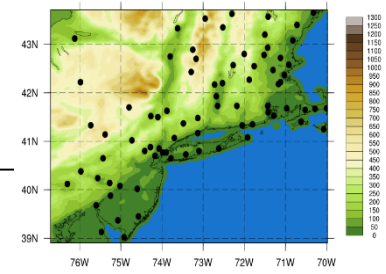
1. *Bayesian regression* peer-review publication in Journal of Applied Meteorology and Climatology ([Yang et al. 2017, minor revision, JAMC](#)).
2. *Analog ensemble forecast*: collaboration with NCAR-RAL (Summer Advance Program Study at NCAR, PhD student Jaemo Yang) ([2 manuscripts in preparation](#)).
3. *Dynamic Ensemble Forecast*; collaboration with NCAR-MMML ([on-going](#)).
4. Real-time weather forecast from two state-of-the-art NWP models.

<http://cee-wrf.engr.uconn.edu/>

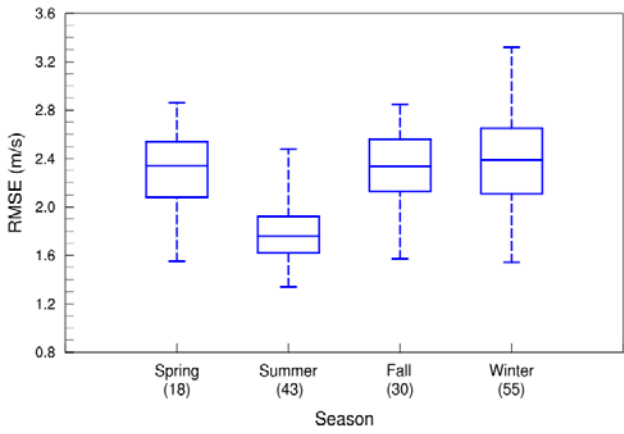


WIND SPEED Error Statistics

146 storms (2004-2016)

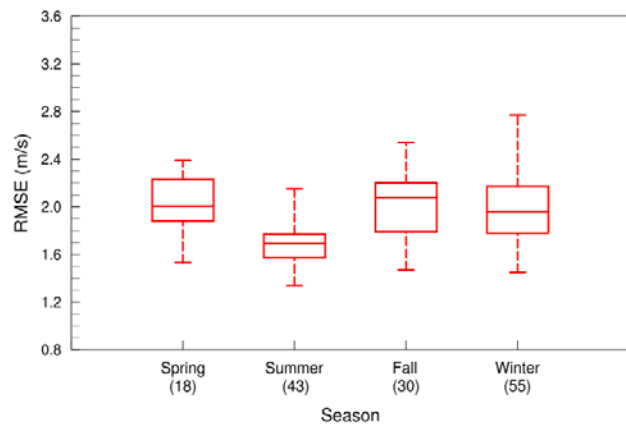


WRF (146 storms)

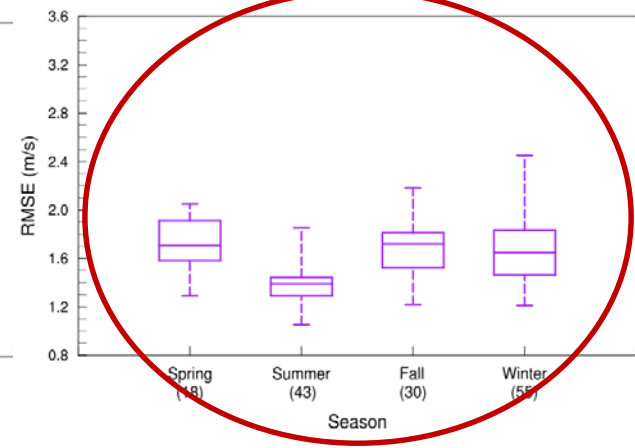


RMSE

ICLAMS (146 storms)



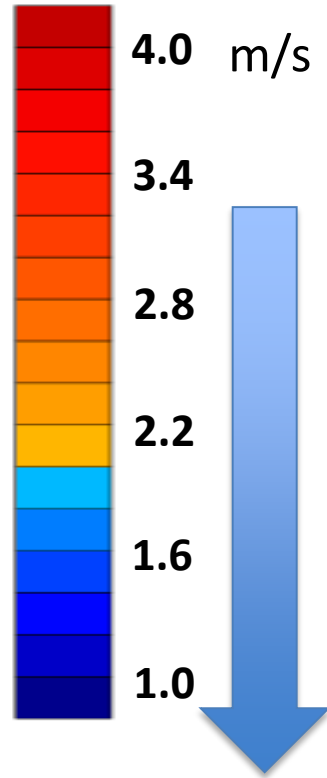
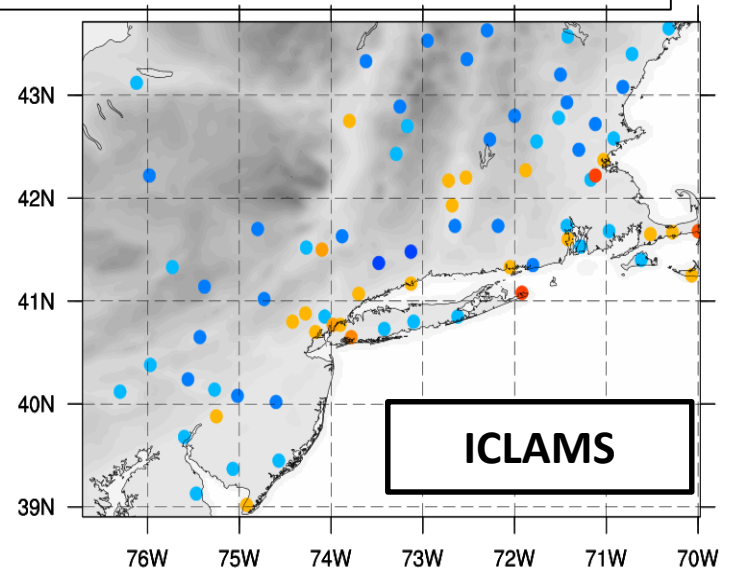
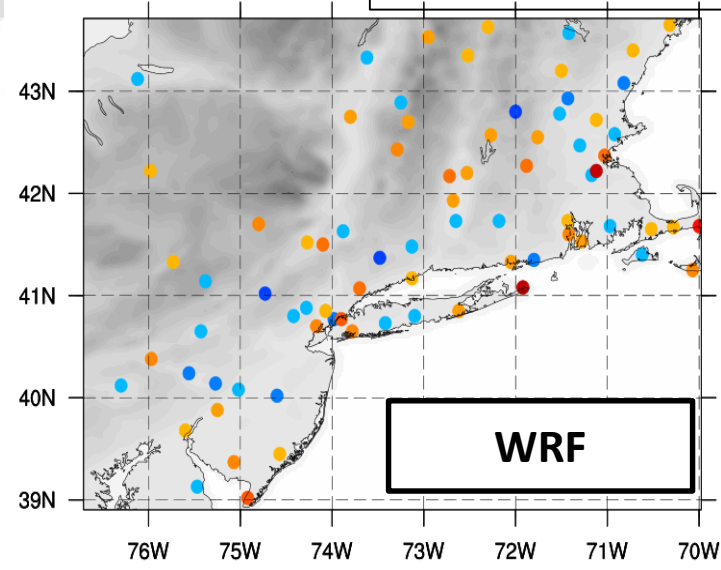
BLR (146 storms)



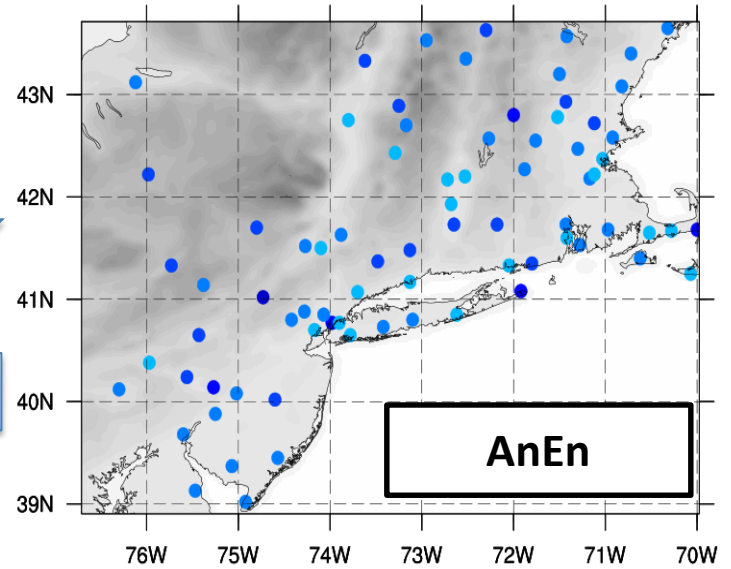
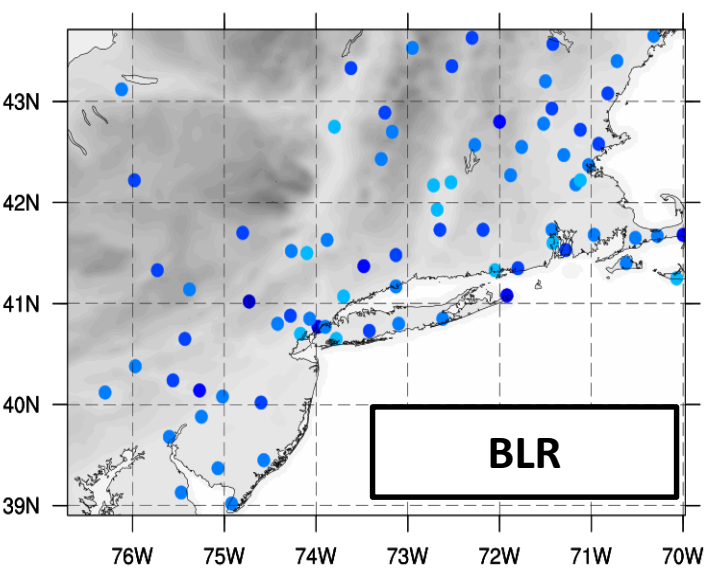


WIND SPEED Spatial Error Statistics

146 storms (2004-2016)

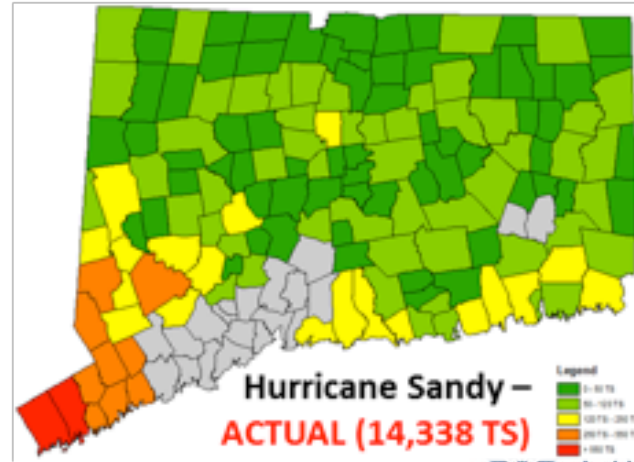
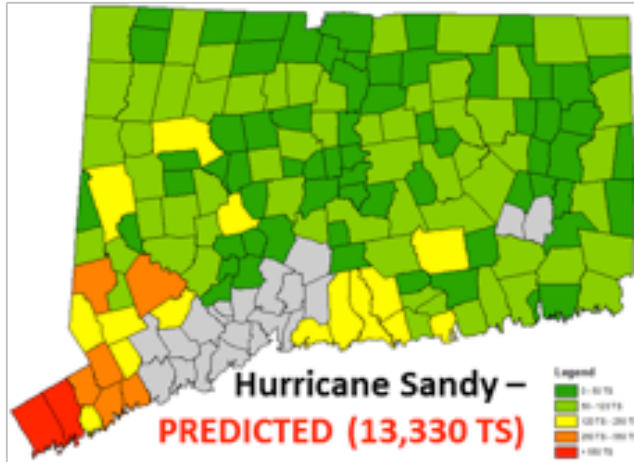
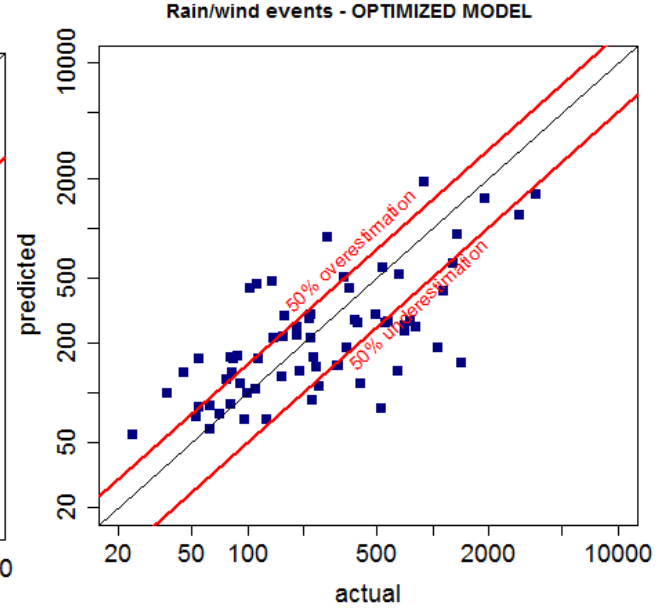
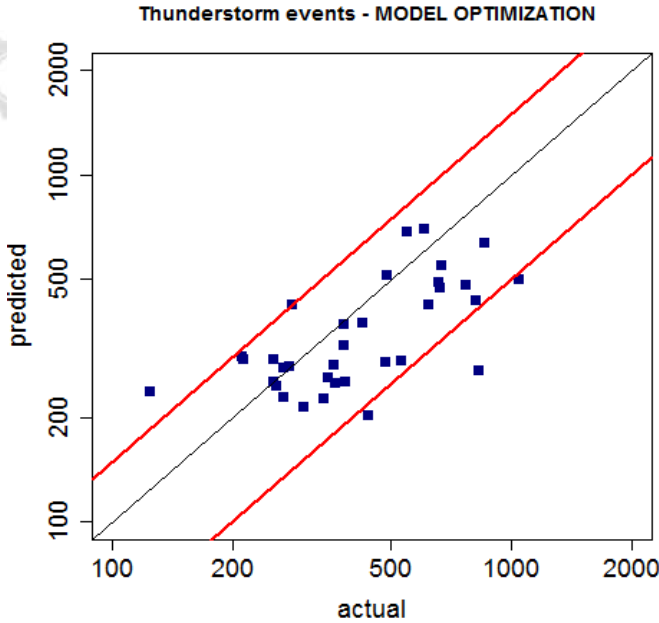


Error reduction





Outage Prediction Modeling






Air quality: prediction, evaluation and the way forward

RESEARCH OBJECTIVES

- ✓ Analyze and interpret features embedded in tropospheric ozone observations and model outputs within a 21-year period (1990-2010)
- ✓ Assess the model's ability to reproduce the O_3 changes as seen in observed concentrations
- ✓ Can we develop confidence intervals for the estimated design value?



Air quality: prediction, evaluation and the way forward

- ✓ On-going collaboration with scientists from the Office of Research and Development (ORD), National Exposure Research Laboratory (NERL) of the EPA: Drs. C. Hogrefe and R. Mathur
- ✓ Project funded by the Electric Power Research Institute (EPRI)

Models and Data

- ✓ 21-years of coupled **WRF-CMAQ** simulations (1990-2010) over the USA driven with internally consistent historic emission inventories and boundary conditions derived from the hemispheric CMAQ model (Gan et al. 2015; Xing et al. 2013)
- ✓ **Observations** of the summertime (May-September) daily maximum 8-hr average (***DM8HR***) ozone concentrations from U.S. EPA's Air Quality System (AQS) for the period 1990-2010

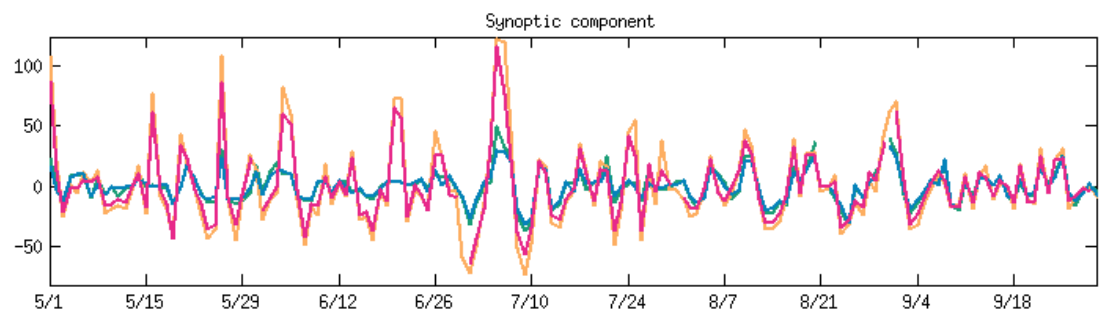
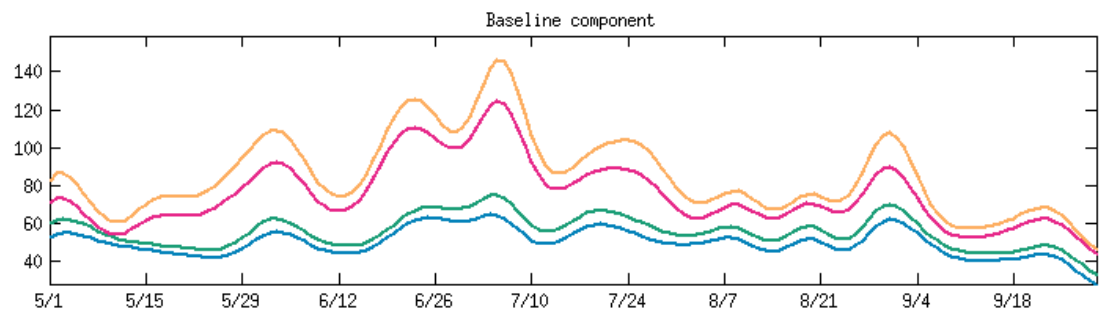
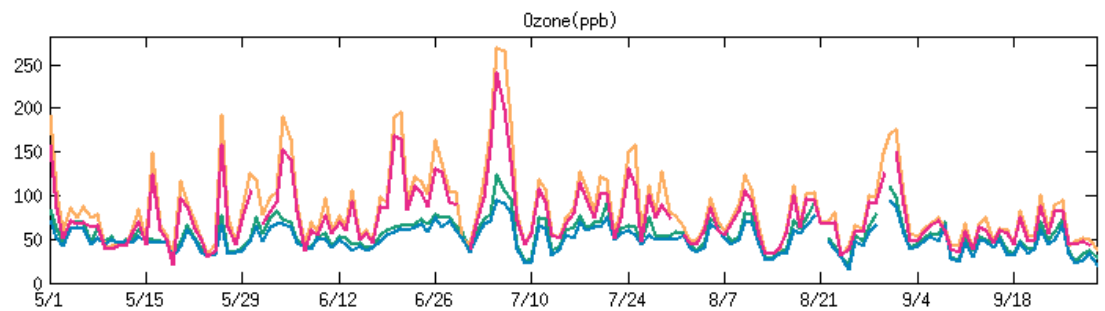


Data Analysis

Spectral decomposition using the **Kolmogorov-Zurbenko (KZ)** filter (Zurbenko 1986; Eskridge et al. 2005). **KZ** is based on an iterative

- DM8HR ozone
- **short-term**
- **long-term**

Baseline (BL)=f
Synoptic Forcing



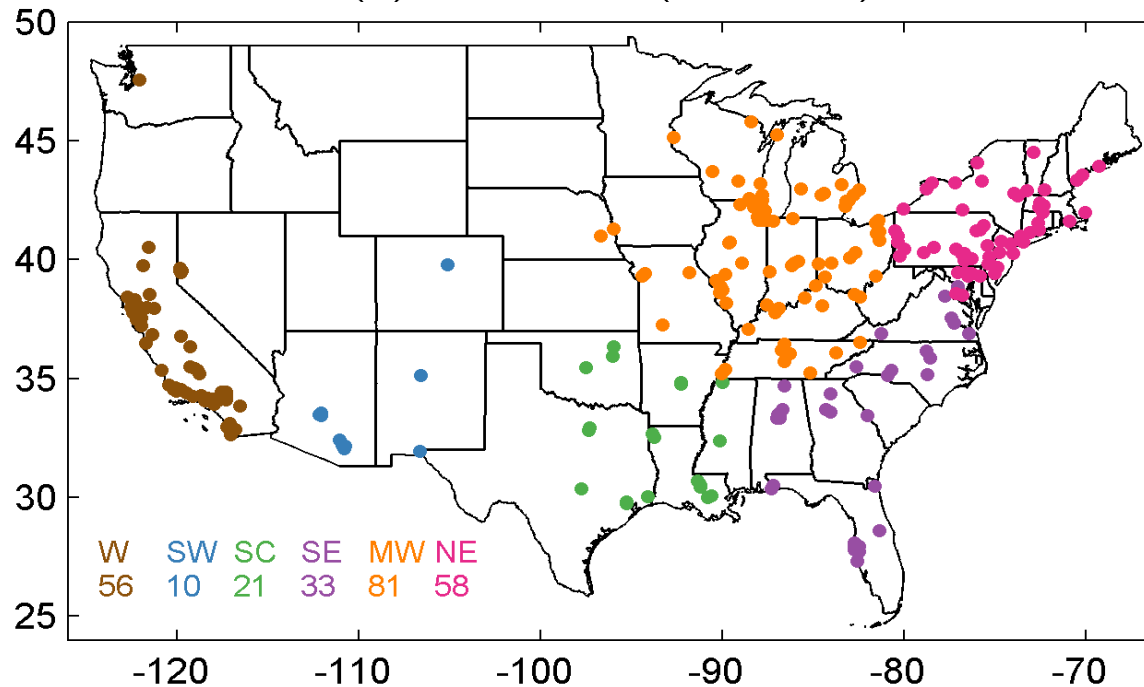
- 1hrMax Obs
- 1hrMax CMAQ
- 8hrMax Obs
- 8hrMax CMAQ

5). **KZ** is based on the data.

and trend: **BL**)

AQS Stations across CONUS (#259)

(a) 1990-2010 (259 sites)

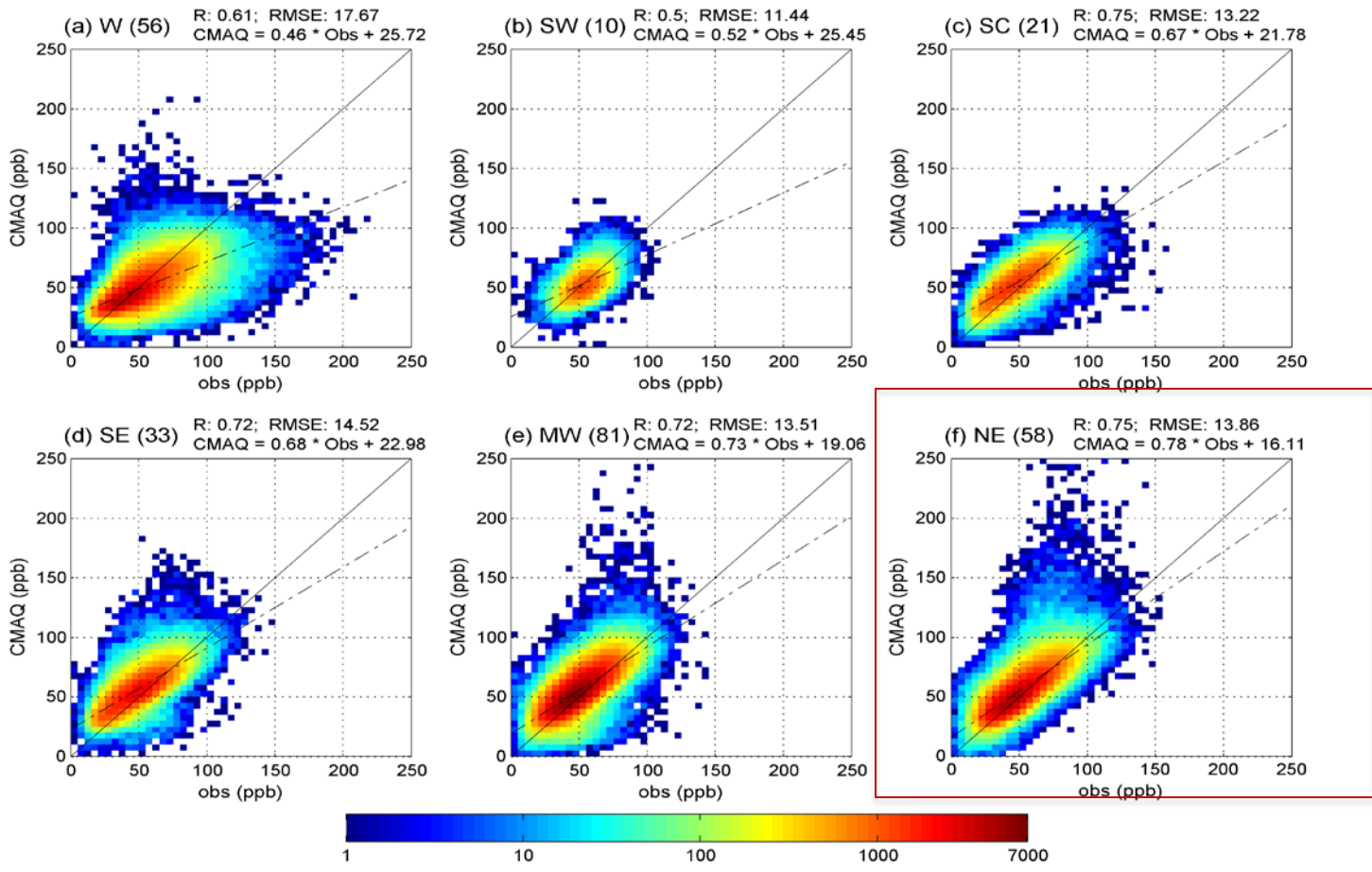


Station selection: >80% coverage for 1990-2010



Operational Evaluation (DM8HR)

1990-2010

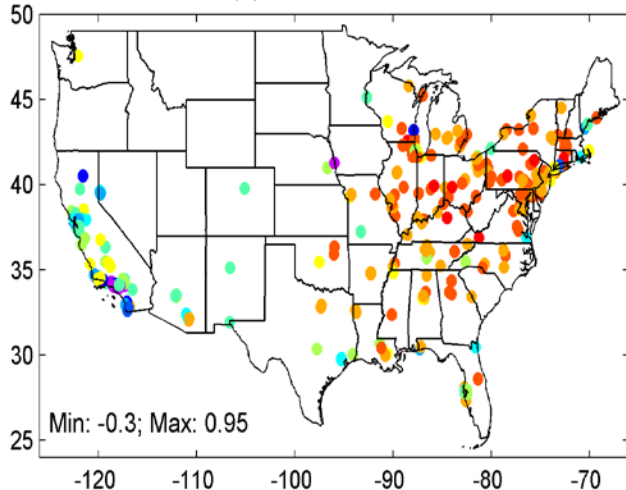


Astitha et al., 2017, in preparation (under review for EPA clearance)

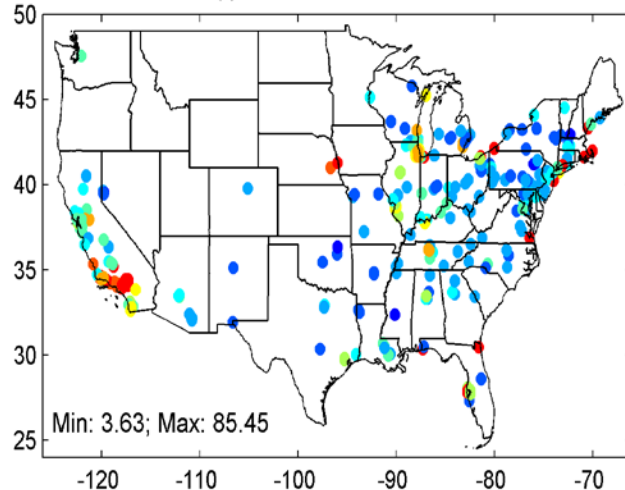
Operational Evaluation



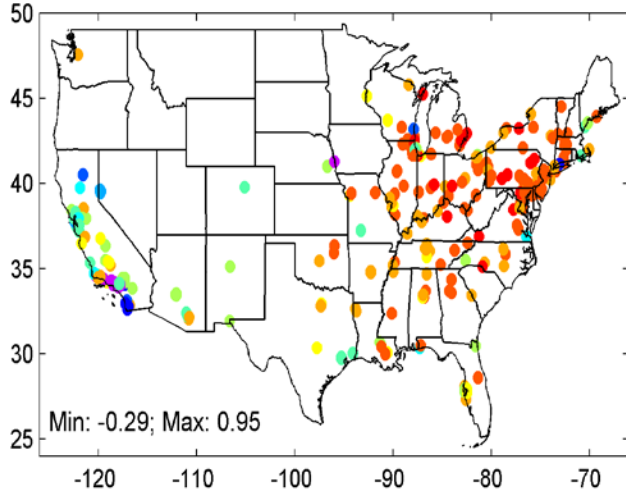
(e) R between 4th



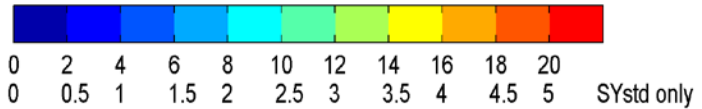
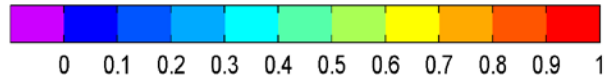
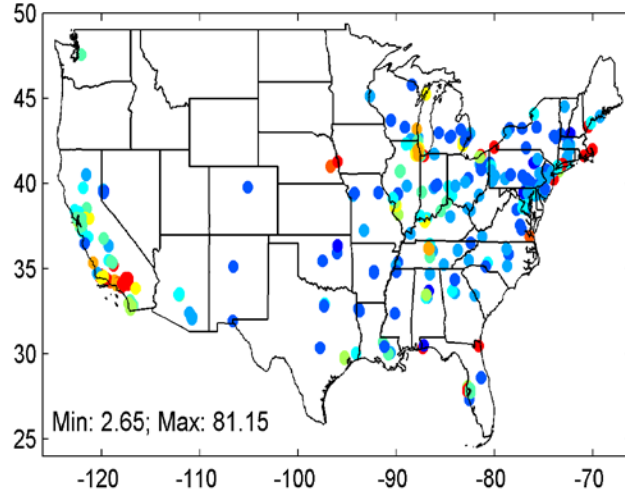
(f) RMSE between 4th



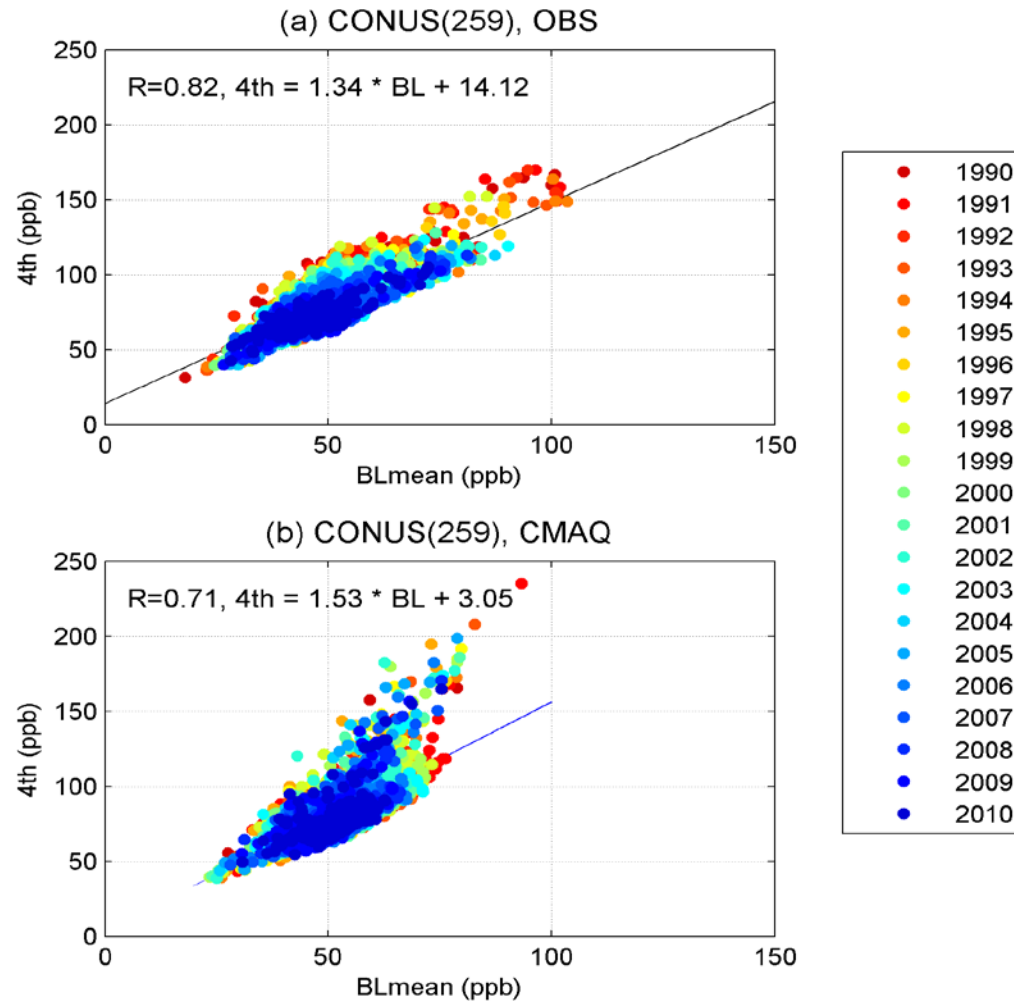
(g) R between top10



(h) RMSE between top10



Relationship between 4th highest O₃ concentration and BLmean



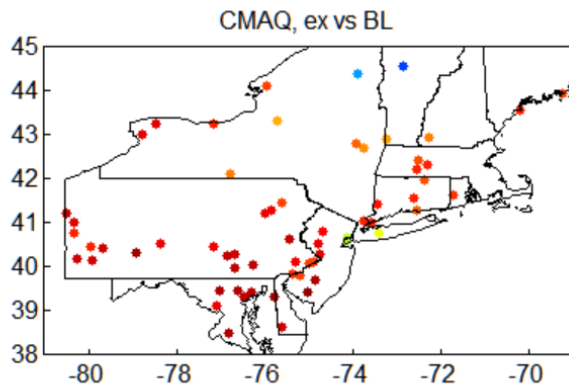
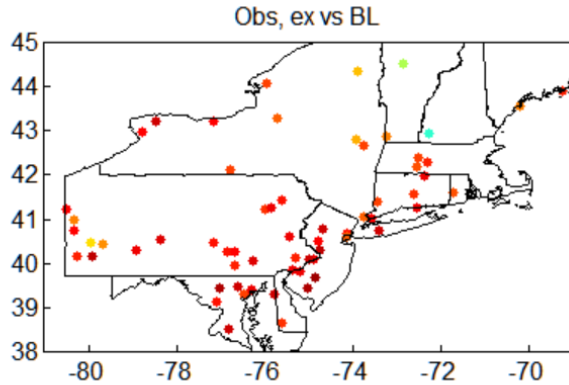
Strong linear correlation between 4th highest and BLmean: suggests that the long-term component controls the exceedances



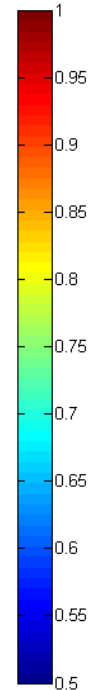
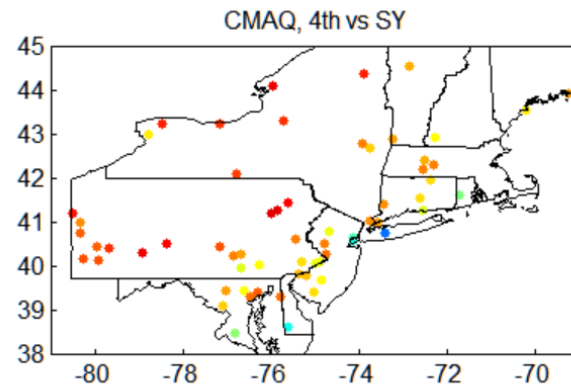
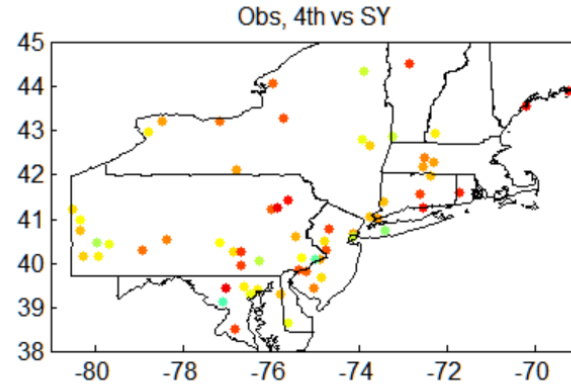
What controls O_3 exceedances?

Correlations; NE U.S. for 1990-2010 (21-y)

BLmean vs. #days>70ppb



SY vs. 4th

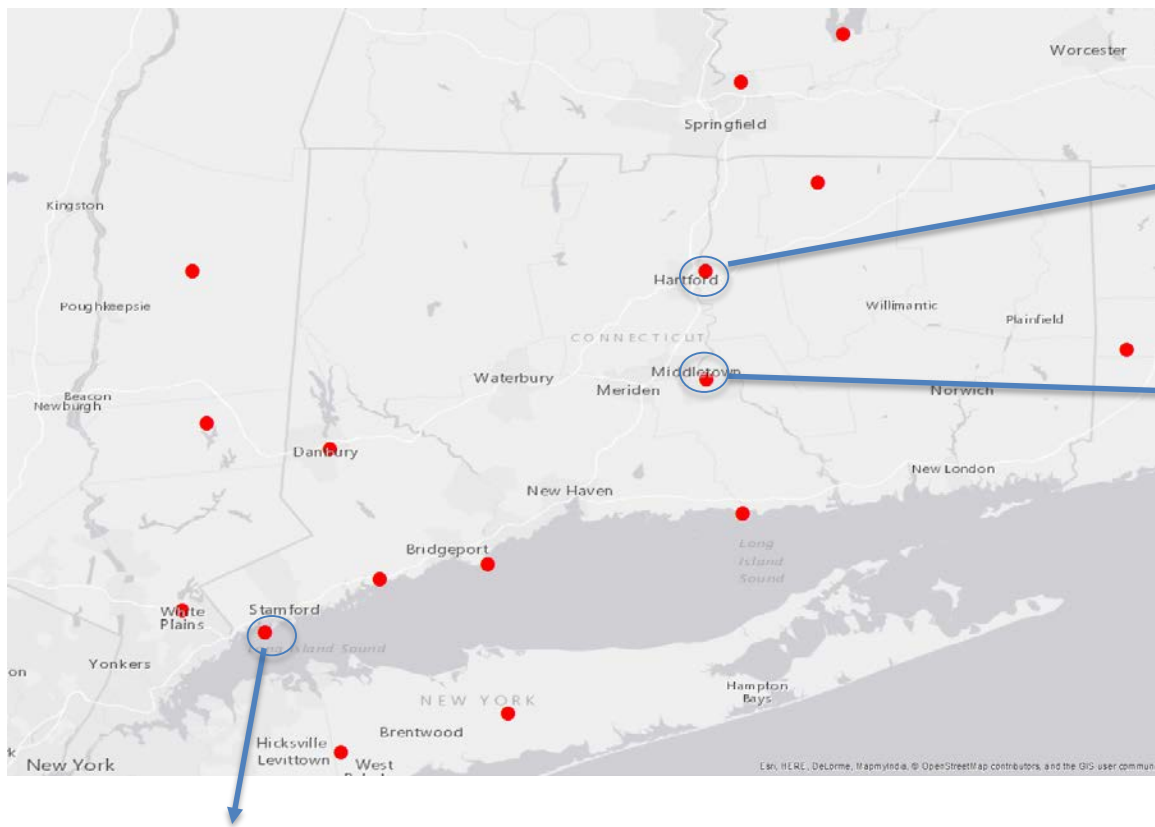


Model and observations show that the Baseline is the main driver for the O_3 exceedances

4th – 4th highest; ex – # of days exceeding 70ppb;
BL – Baseline mean; SY – stdev of SY forcing



AQS stations in CT



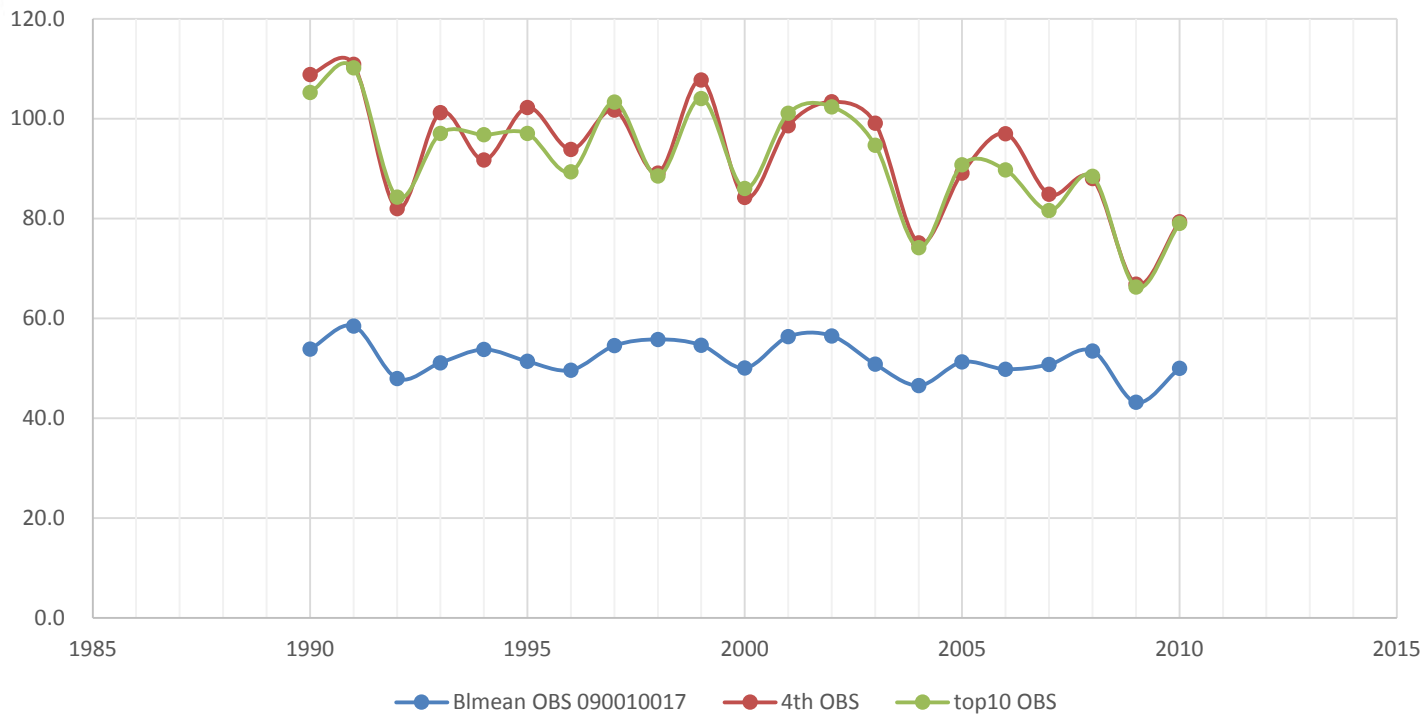
Mcauliffe
Park

Conn. Valley
hosp.,
Middletown

Greenwich

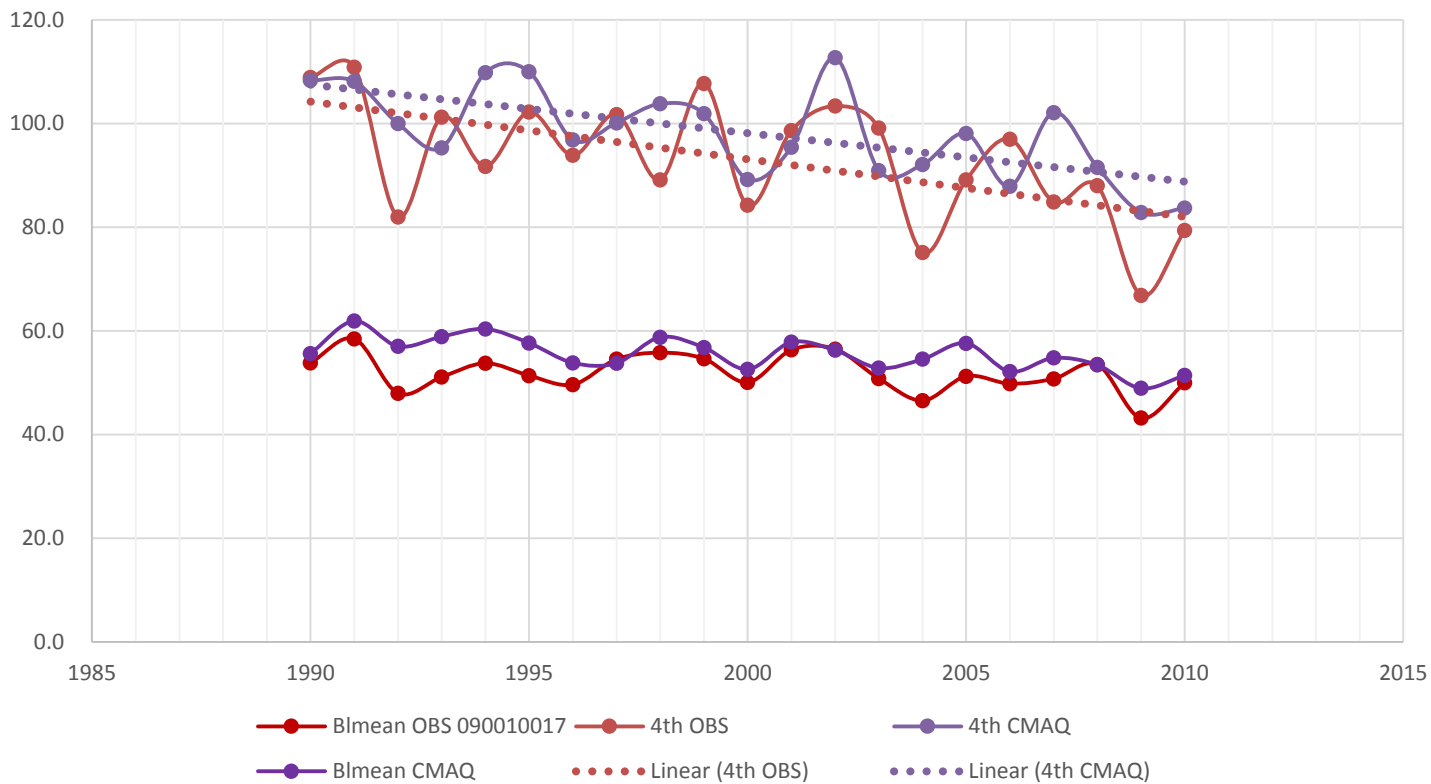


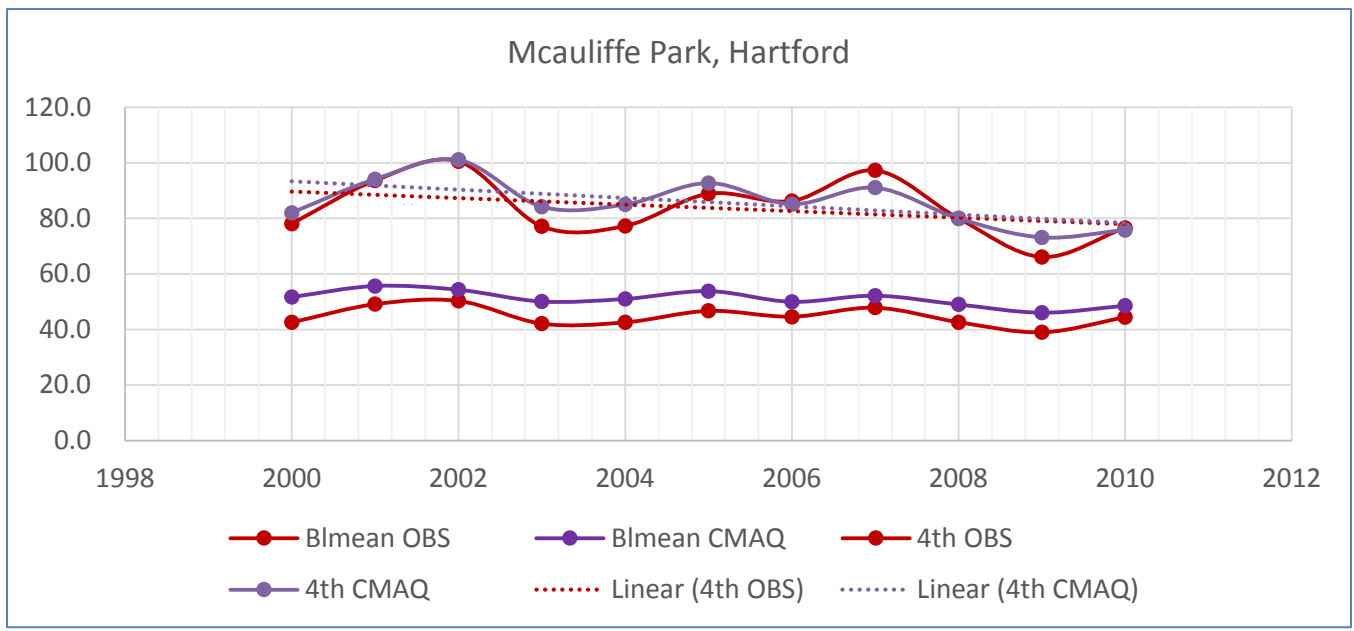
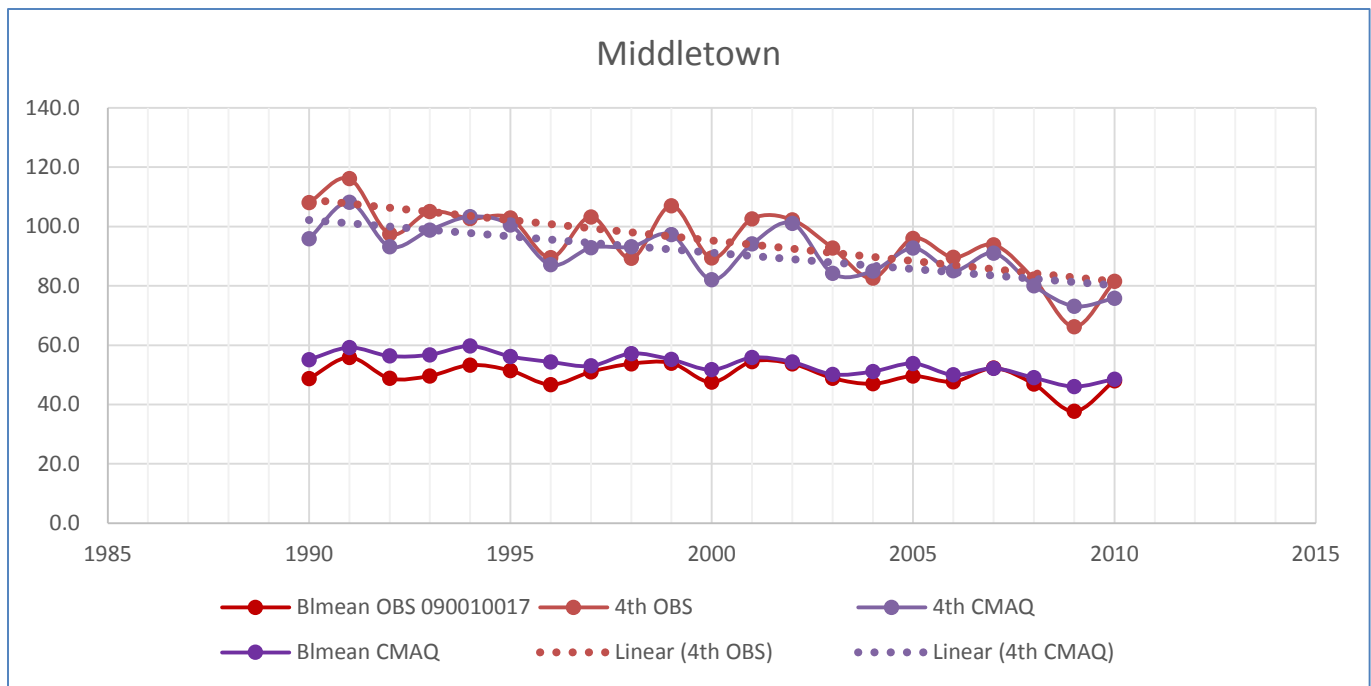
Greenwich





Greenwich







Confidence intervals for Design Values

(preliminary results)

Design Value (3-y average of 4th highest DM8HR)

Mean of 21 DV \pm 2 std. dev. of 21 DV

Example:

Future year = 2010

Base year = 1995

Projected Baseline: $BL_{proj,2010} = BL_{Obs,1995} \cdot \frac{BL_{CMAQ\ 2010}}{BL_{CMAQ\ 1995}}$

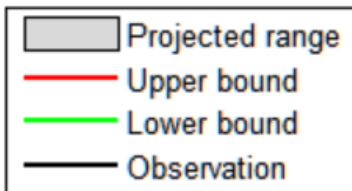
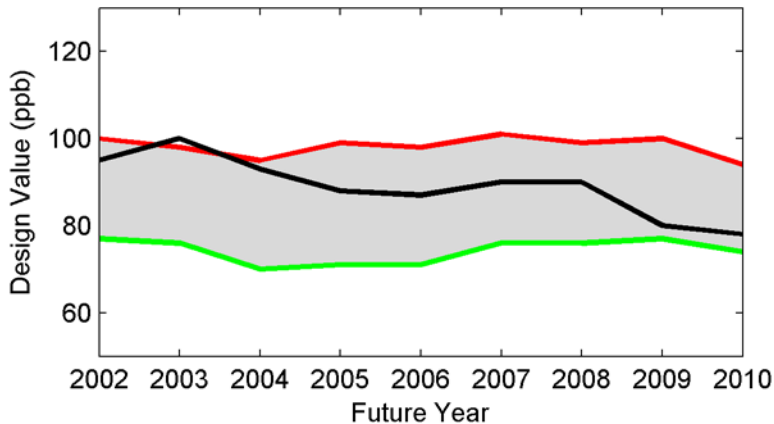
Reconstruction of the ozone time-series:

- $O_3(2010)_1 = BL_{proj}(2010) + SY_{obs}(1990) \longrightarrow 4^{th} (2010),1$
- $O_3(2010)_2 = BL_{proj}(2010) + SY_{obs}(1991) \longrightarrow 4^{th} (2010),2$
- ...
- $O_3(2010)_{21} = BL_{proj}(2010) + SY_{obs}(2010) \longrightarrow 4^{th} (2010),21$

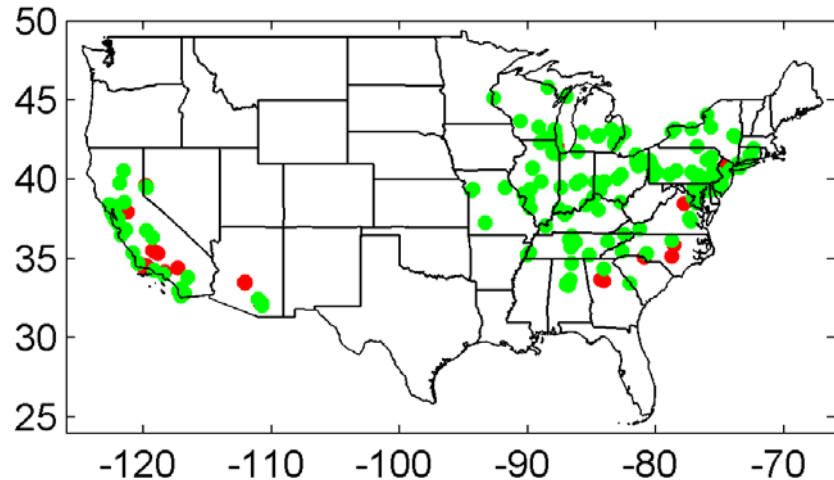
$DV(2010),1 = MEAN4th(2010,2009,2008)$
 $DV(2010),2 = MEAN4th(2010,2009,2008)$
 ...
 $DV(2010),21 = MEAN4th(2010,2009,2008)$

Bounds for the Design Value (3-year average 4th highest ozone conc) 10-year projection interval

Greenwich, CT



Sites showing agreement/disagreement



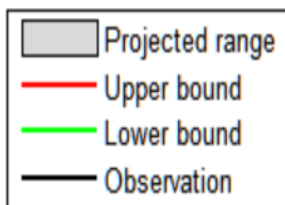
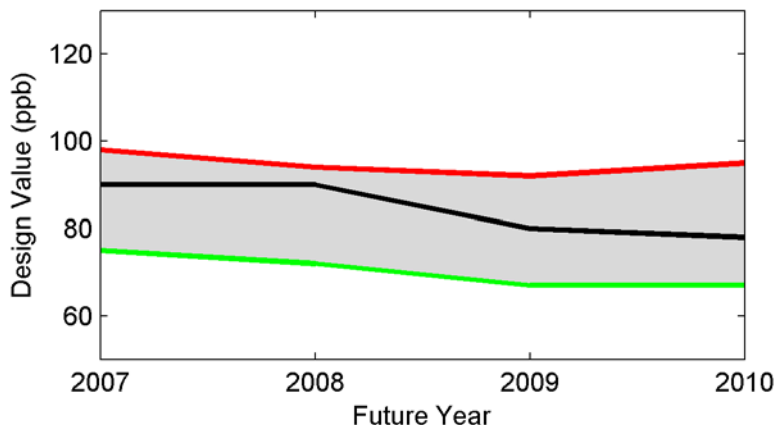
2000-2010 projection

Green: Observed is within the estimated confidence bounds

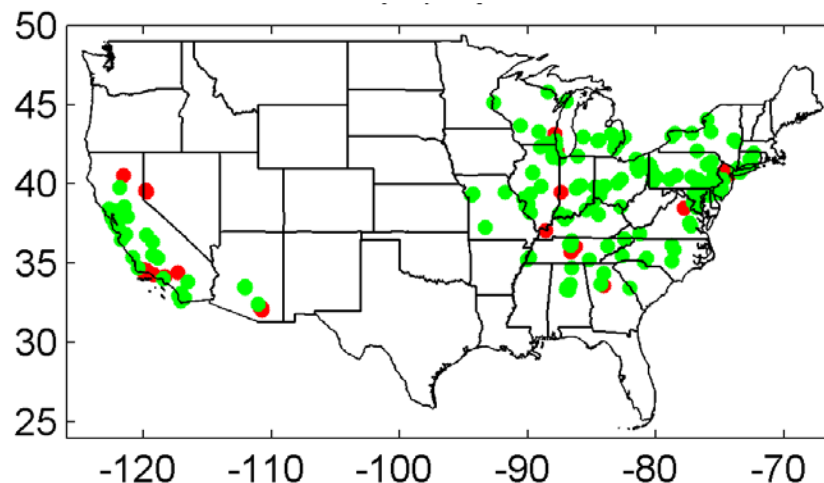
Red: Outside (possible due to 36-Km CMAQ grids)

Bounds for the Design Value (3-year average 4th highest ozone conc) 15-year projection interval

Greenwich, CT



Sites showing agreement/disagreement



1995-2010 projection

Green: Observed is within the estimated confidence bounds

Red: Outside (possibly due to 36-Km CMAQ grids)



Few remarks on the air quality modeling study

- Long-term simulations provide a unique opportunity to assess the changes caused by emission reduction policies
- In general, the model underestimated the observed trends in most regions, denoting a smaller pace in the ozone reduction than what the observations are showing.
- There is a strong relationship between the baseline (long-term forcing) and number of exceedances in both observations and model simulations
- Accurate prediction of changes in baseline O₃ coupled with observed historic SY provide a robust estimate of the impact of emission controls.