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

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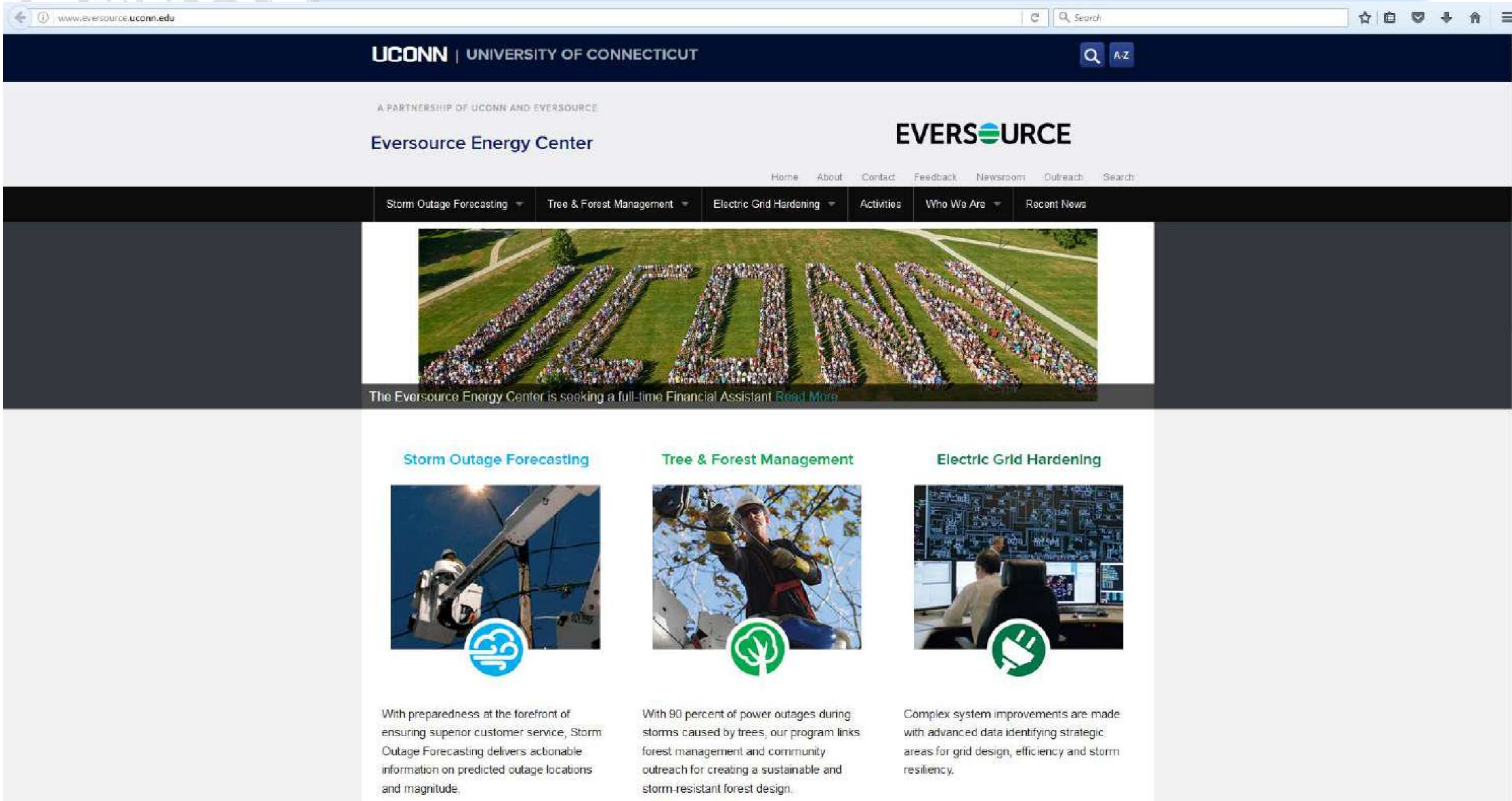
Seminar at the SIPRAC committee, Jan 12, 2017

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



http://www.eversource.uconn.edu/

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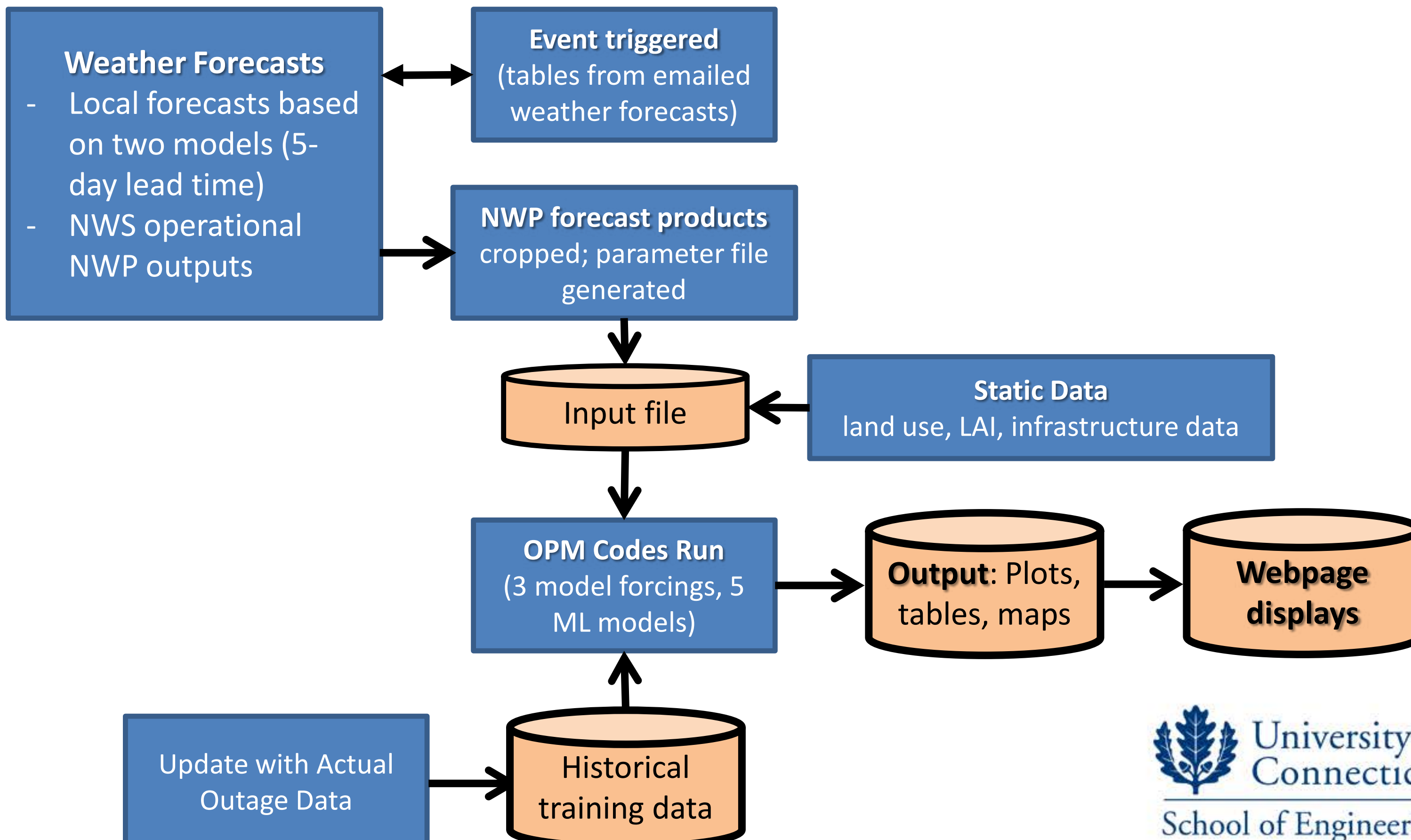
Extreme weather events: forecasting and impacts to the power network

Outage Prediction Model System Architecture



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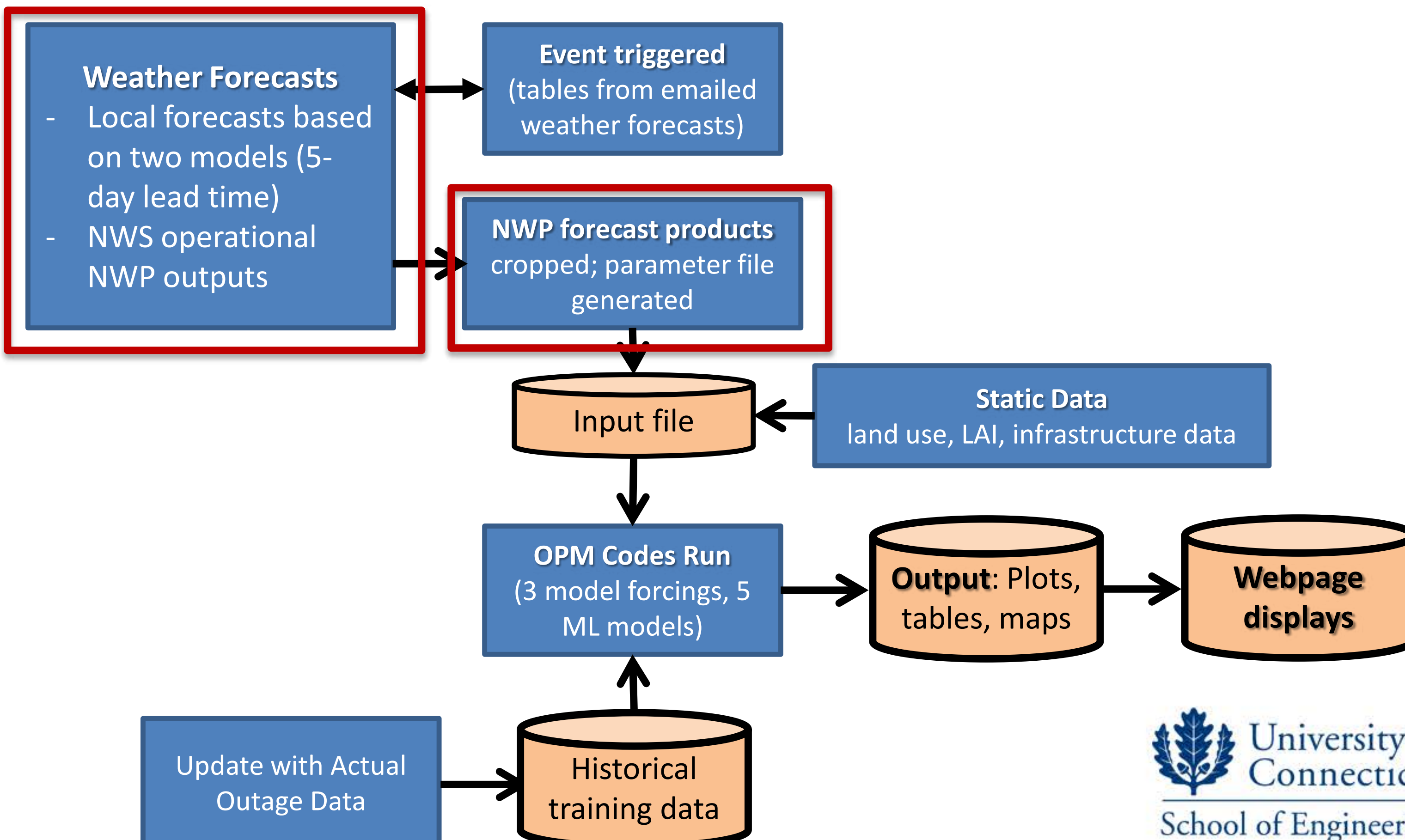
Extreme weather events: forecasting and impacts to the power network

Outage Prediction Model System Architecture



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<u>OBJECTIVE:</u> Improve weather forecasting functionality and uncertainty characterization

1. *Bayesian regression* peer-review publication in Journal of 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.

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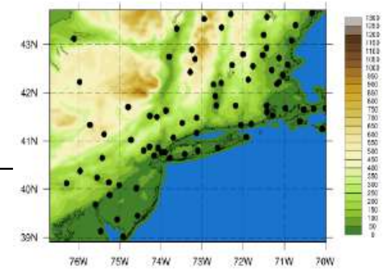
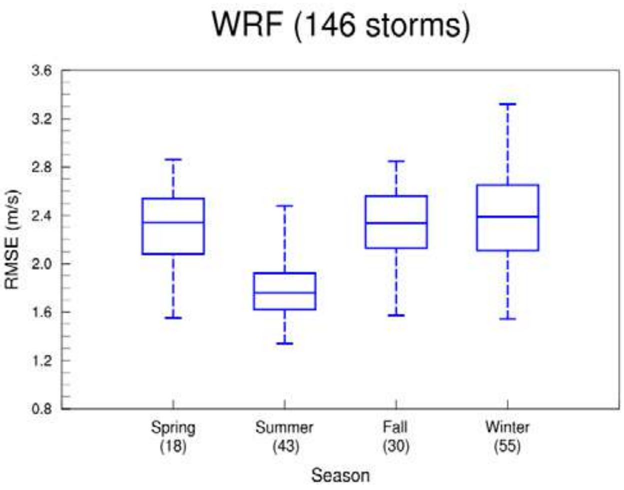
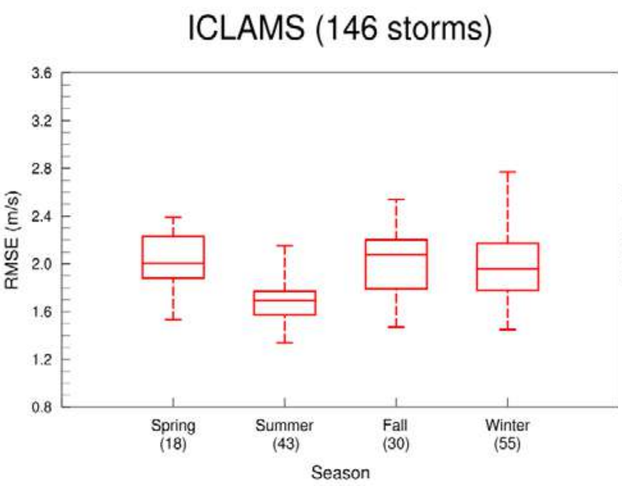
WIND SPEED Error Statistics

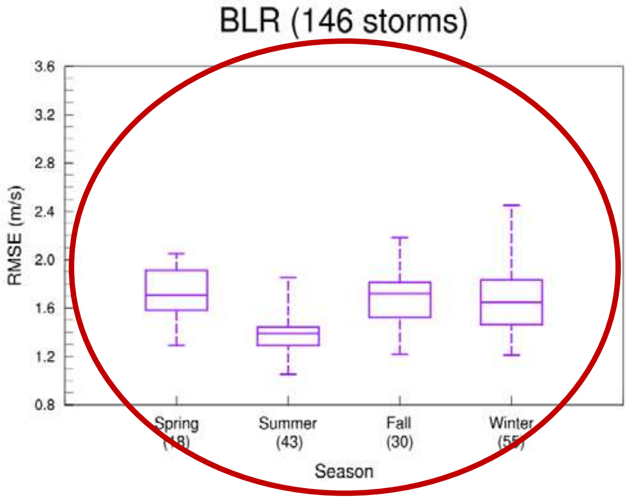
146 storms (2004-2016)



RMSE







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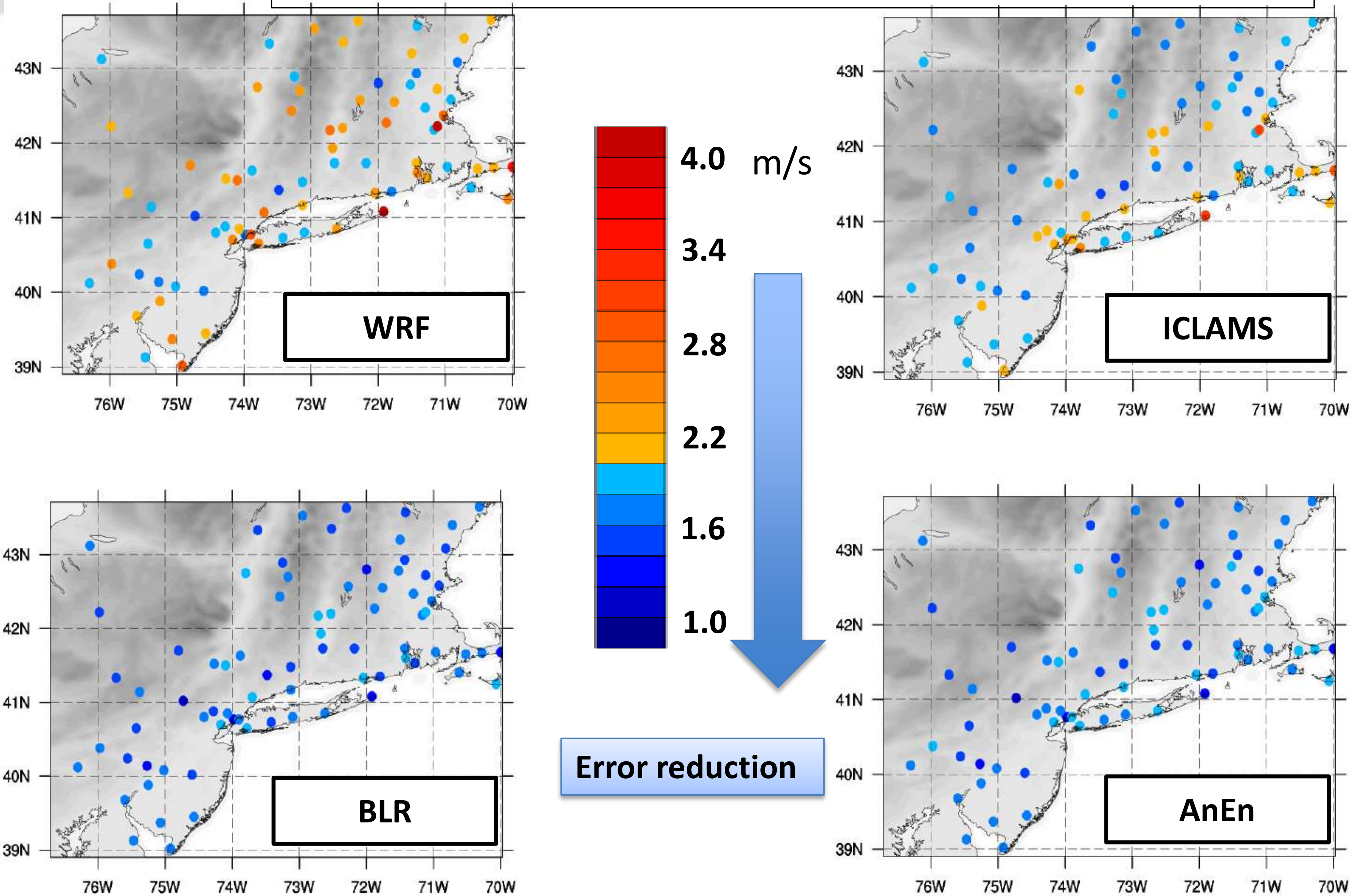
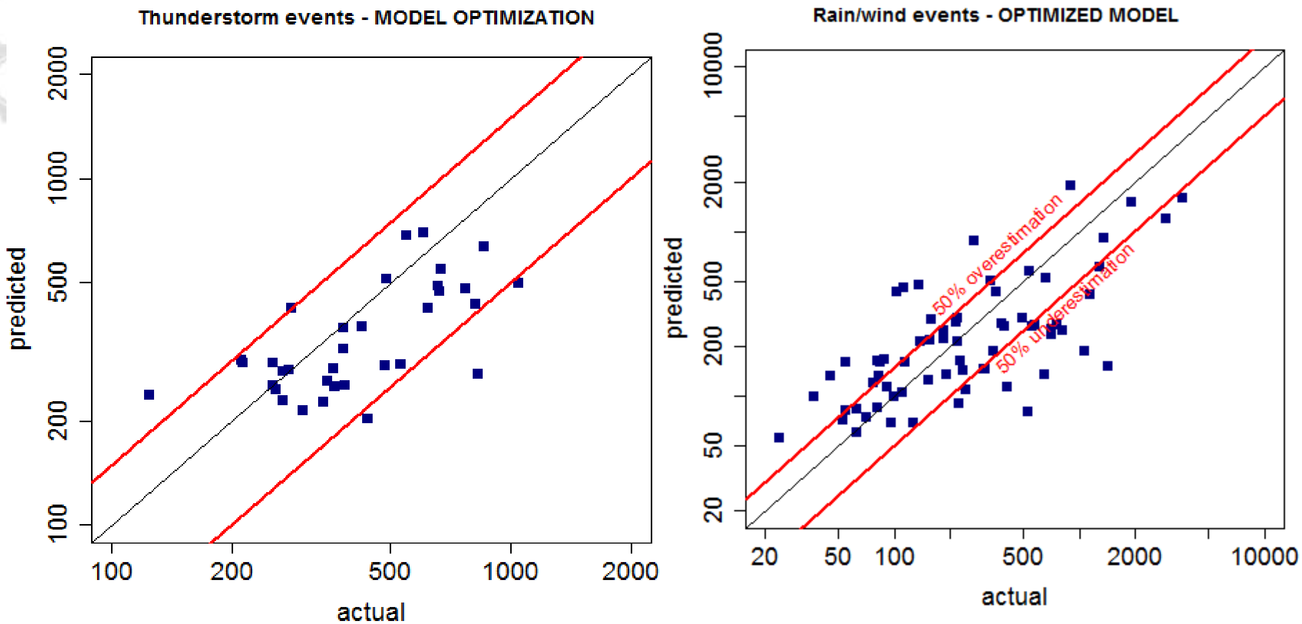
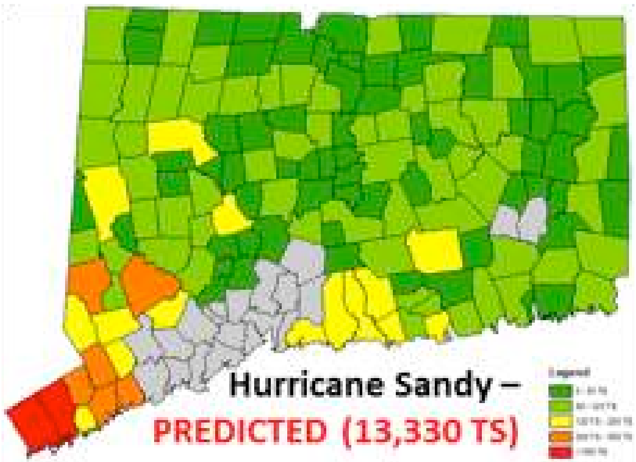
WIND SPEED Spatial Error Statistics

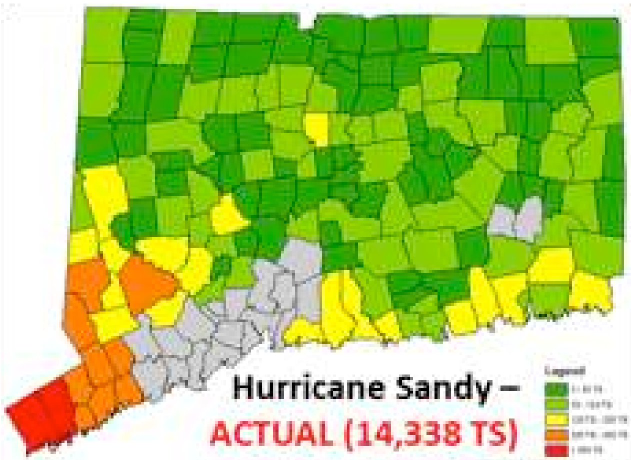
146 storms (2004-2016)



Outage Prediction Modeling







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Wanik et al. 2015, 2017; He et al. 2016

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?

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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

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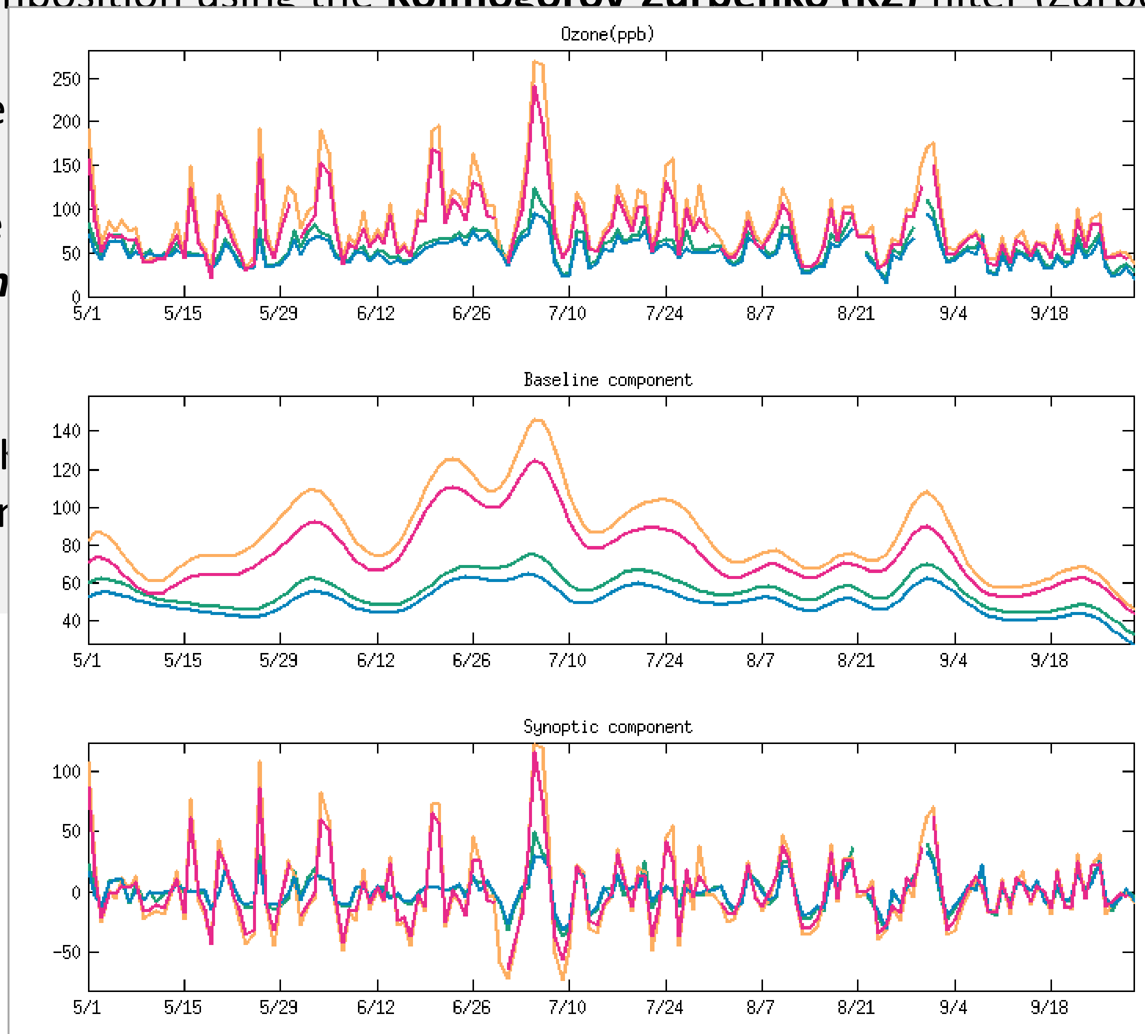
Data Analysis

Spectral decomposition using the **Kolmogorov-Zurbenko (KZ)** filter (Zurbenko 1986; Eskridge et al. … 5). **KZ** is based on an iterative … om the data.

DM8HR ozone …

- ***short-term*** …
- ***long-term*** … nd trend: ***BL***)

Baseline (BL)=…
Synoptic Forci…



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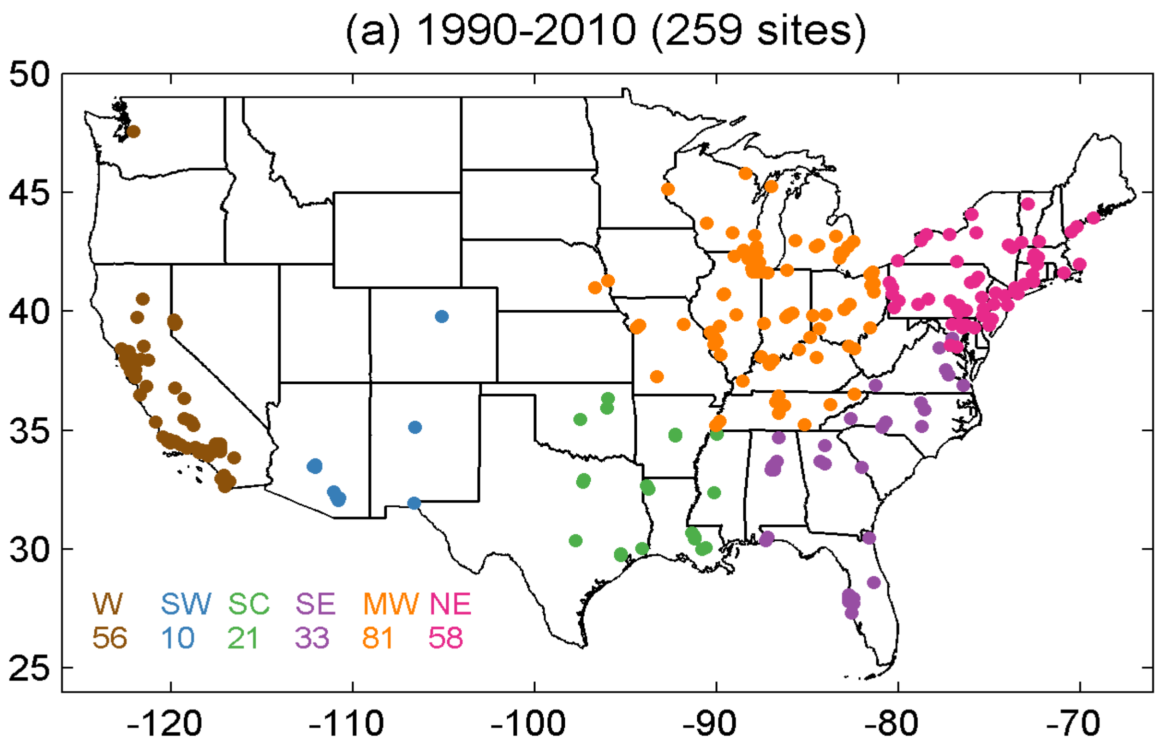
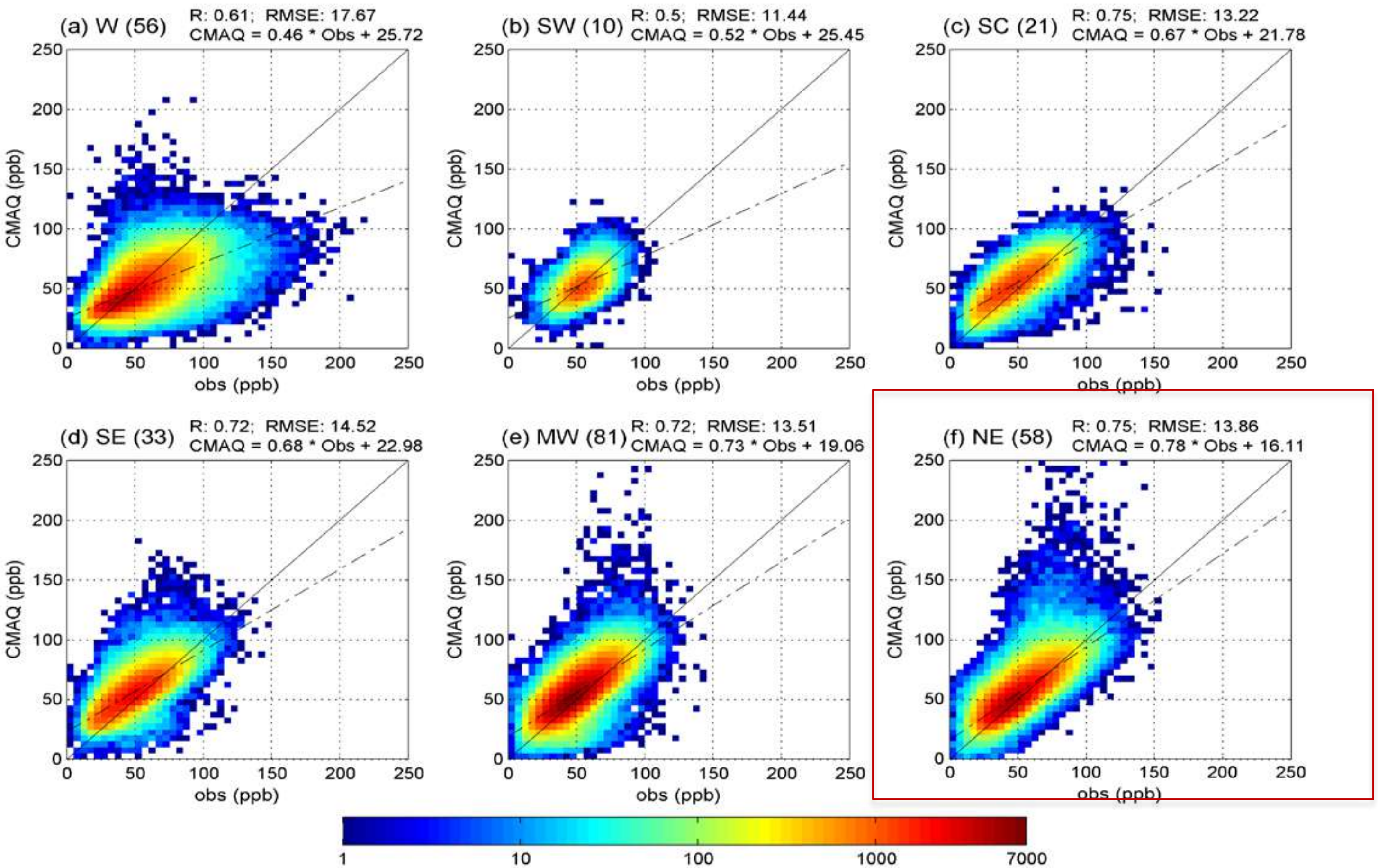
AQS Stations across CONUS (#259)



Station selection: >80% coverage for 1990-2010

Operational Evaluation (DM8HR)

1990-2010



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

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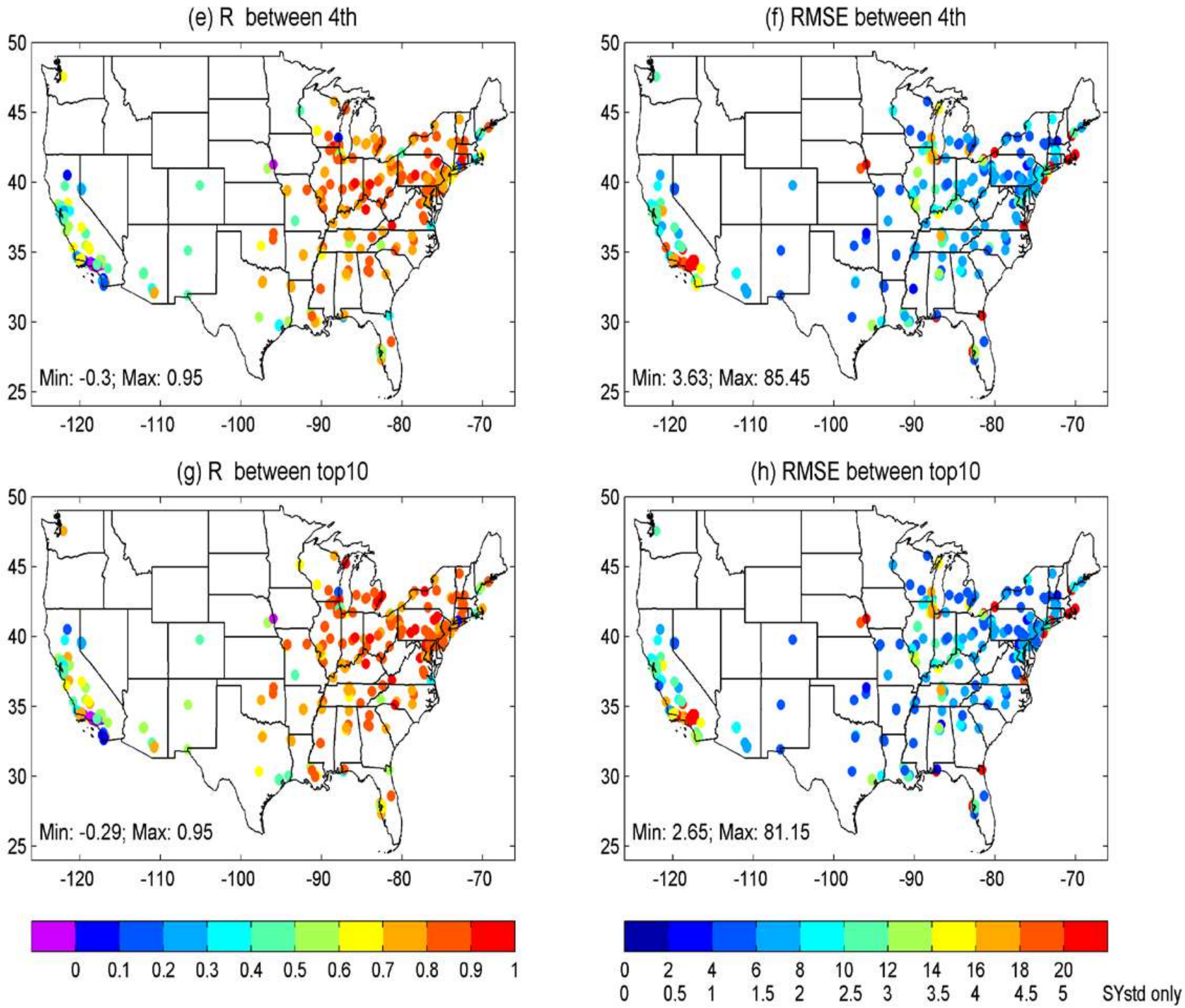
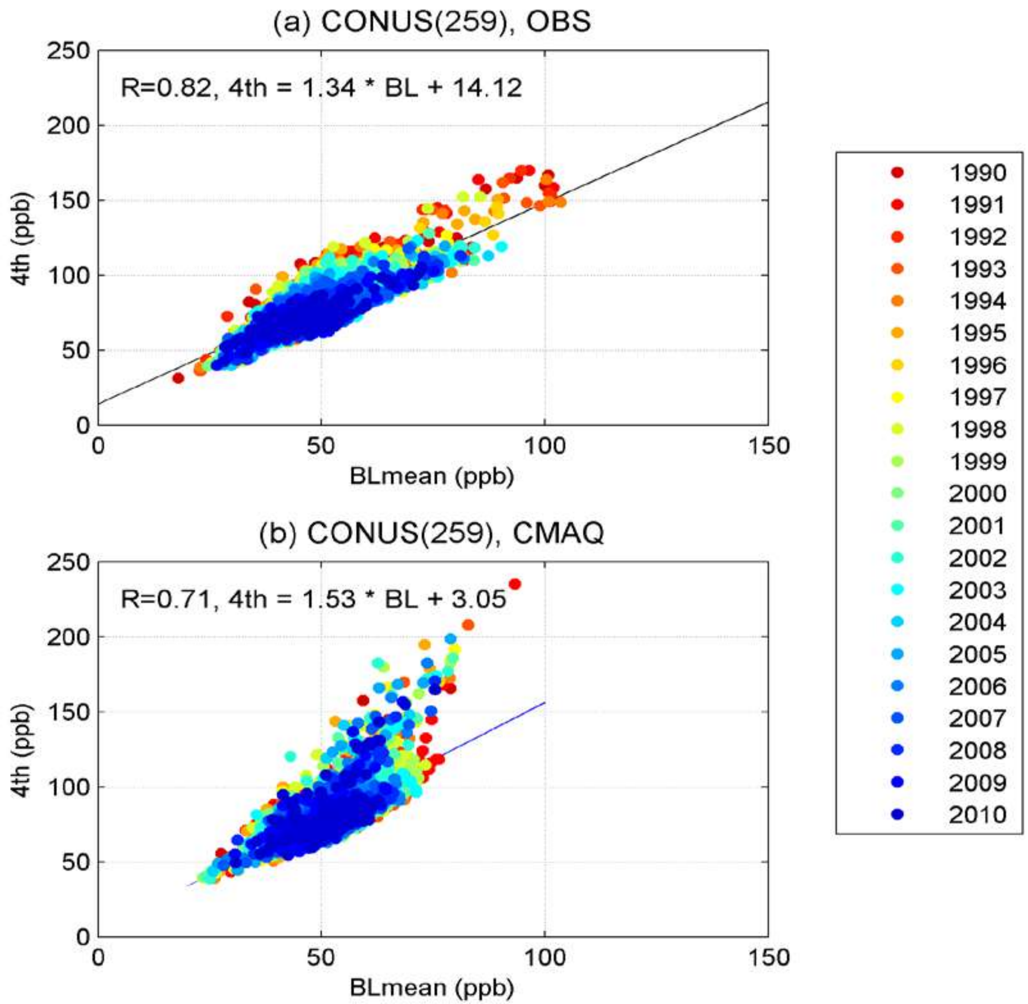
Operational Evaluation



Relationship between 4th highest O_3 concentration and BLmean

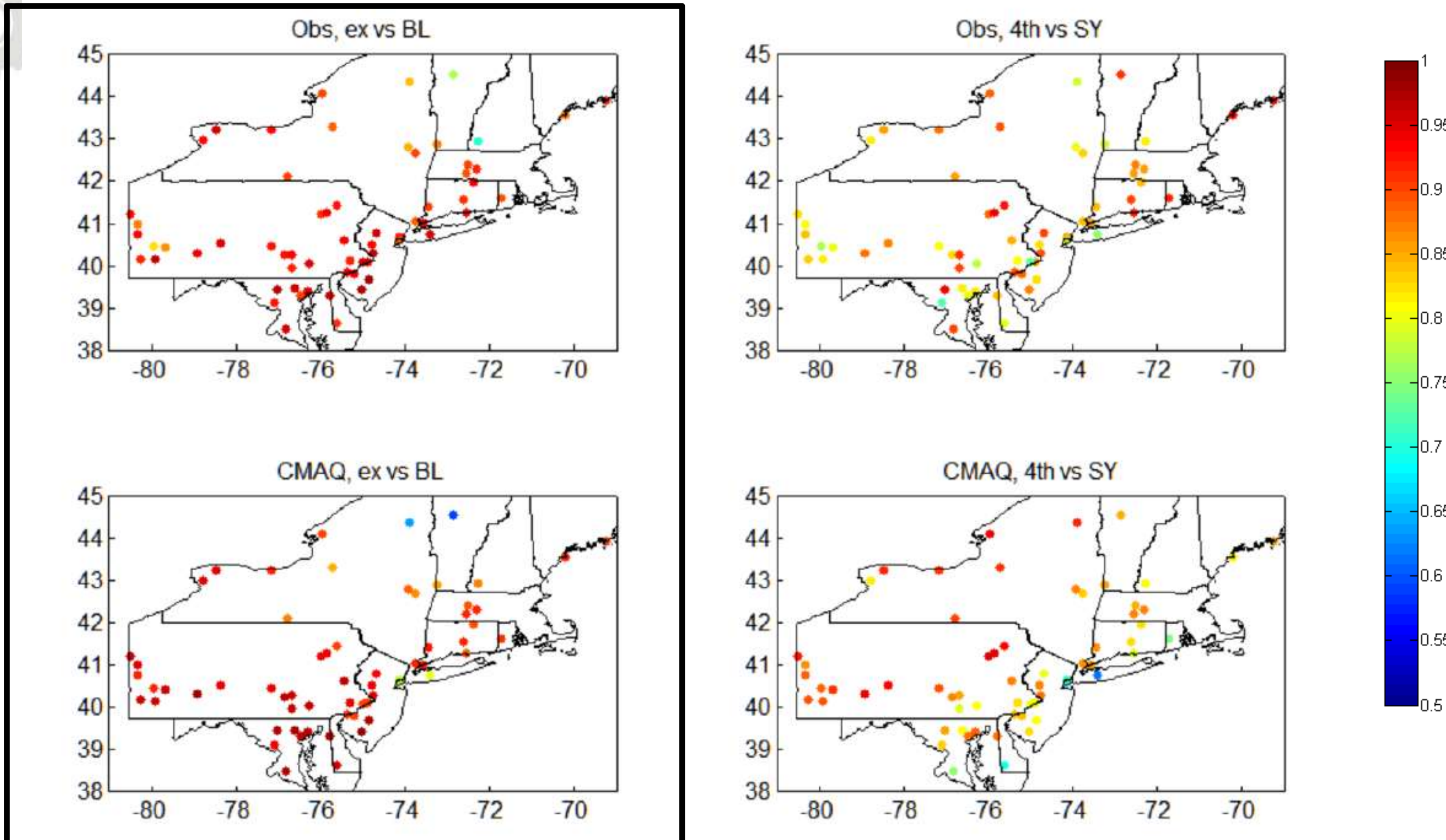


Strong linear correlation between 4th highest and BLmean: suggests that the long-term component controls the exceedances

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

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

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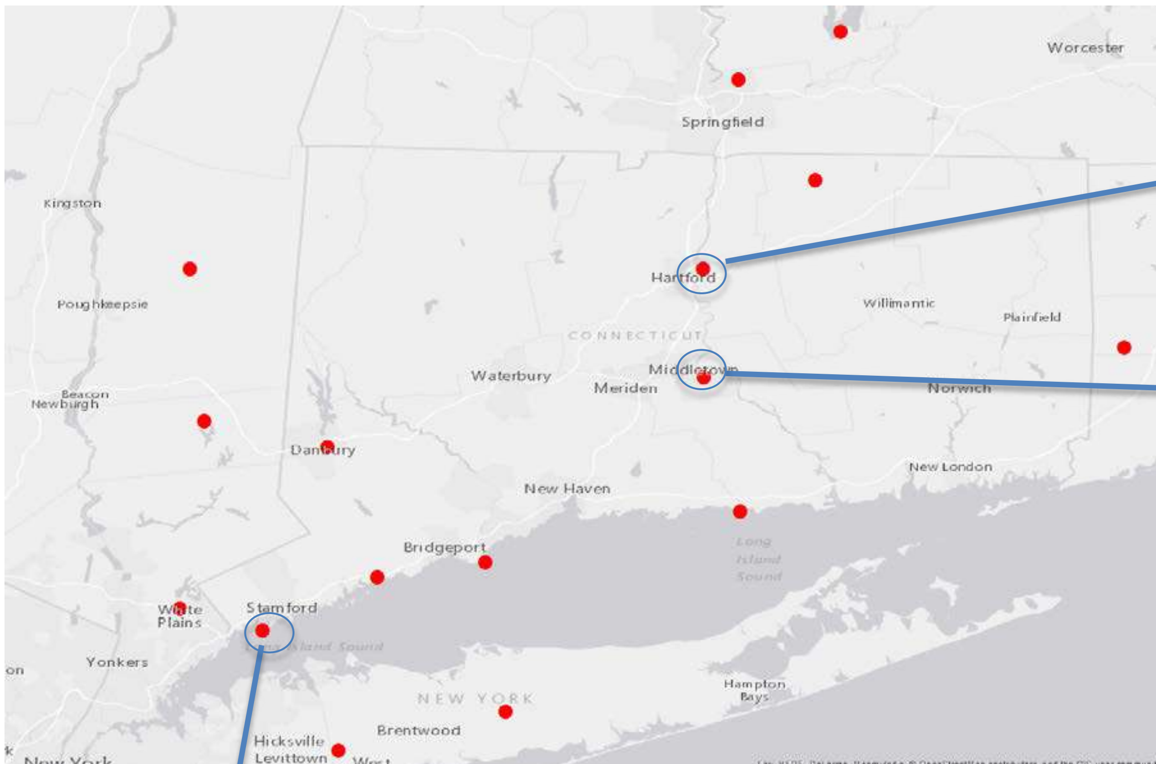
AQS stations in CT



Mcauliffe Park

Conn. Valley hosp., Middletown

Greenwich

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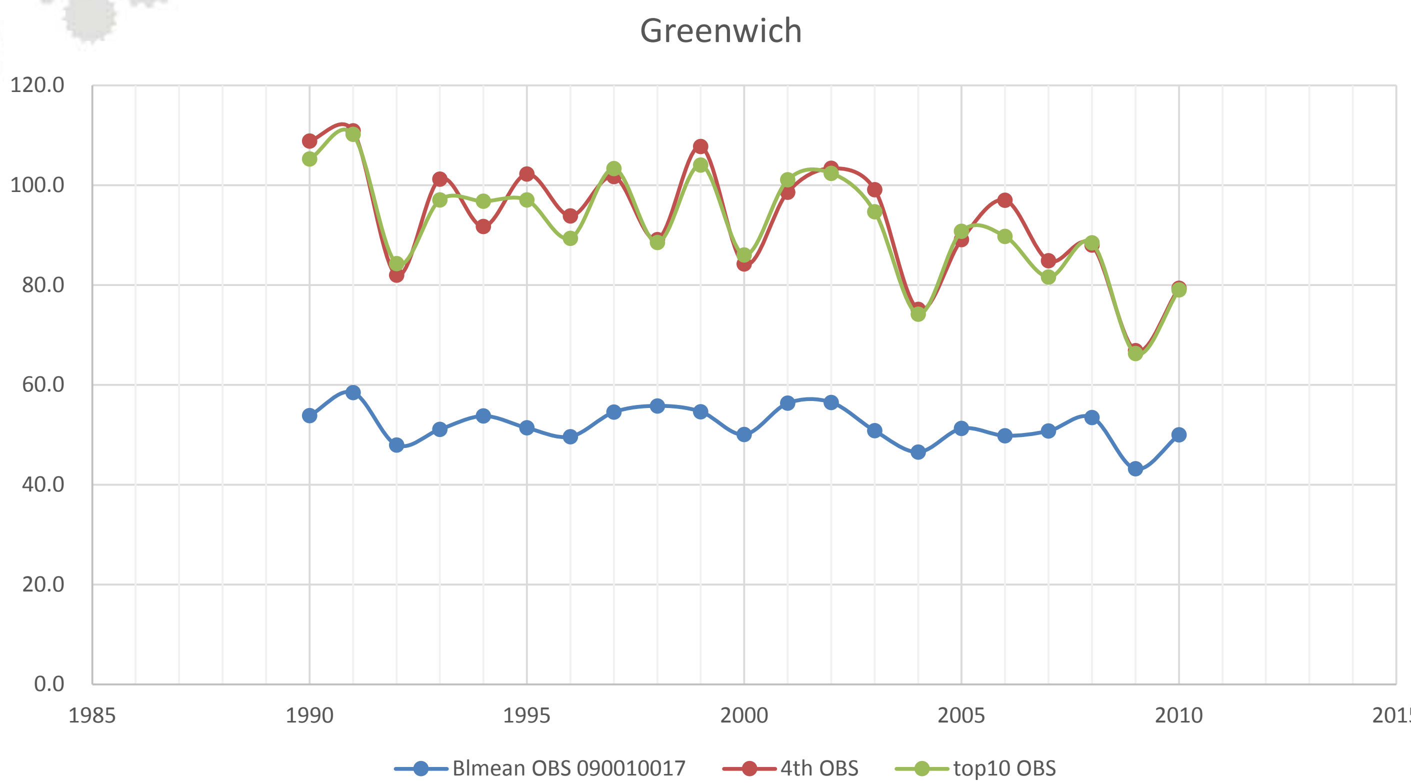
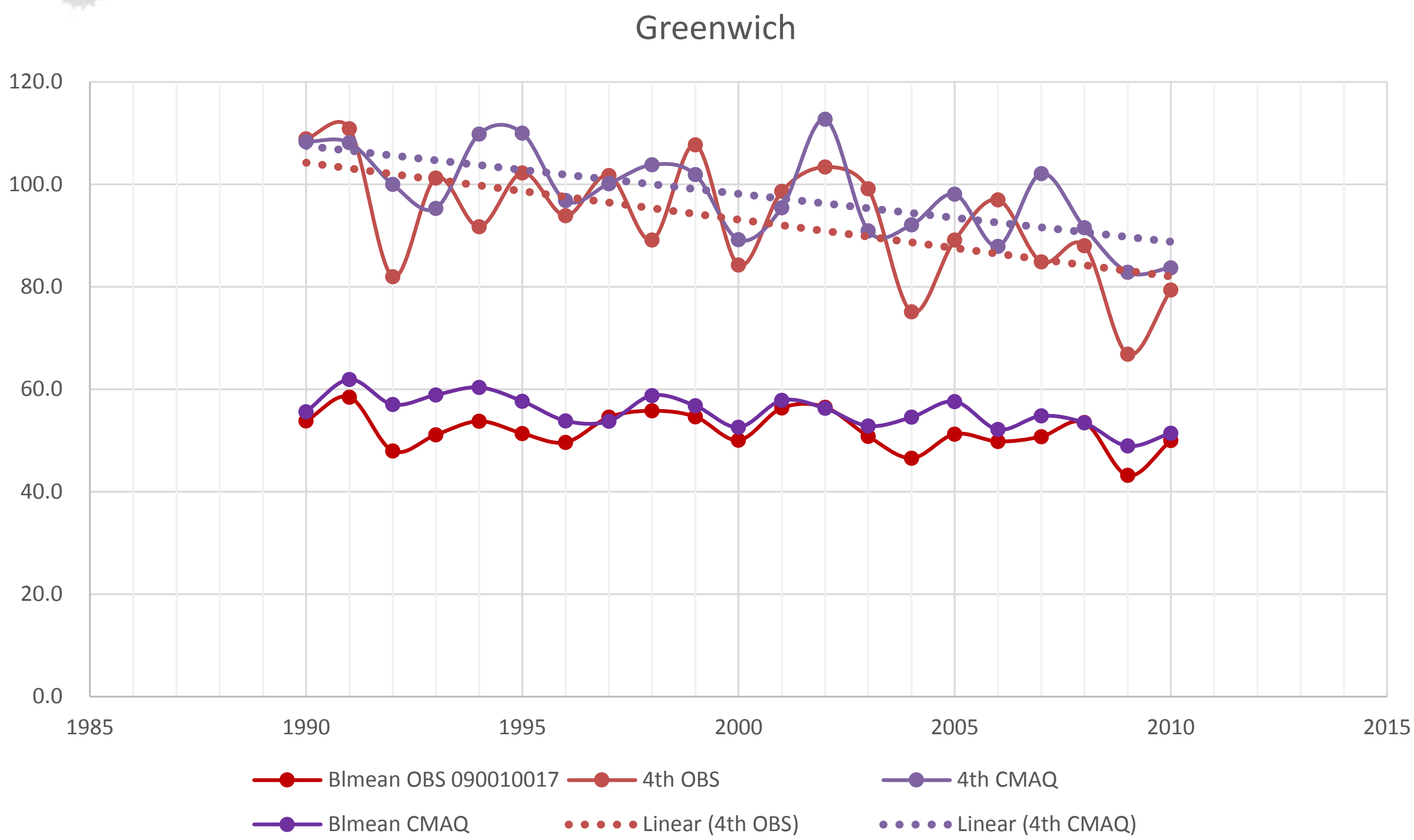

Greenwich
120.0
100.0
80.0
60.0
40.0
20.0
0.0
1985
1990
1995
2000
2005
2010
2015
Blmean OBS 090010017
4th OBS
top10 OBS


Greenwich
120.0
100.0
80.0
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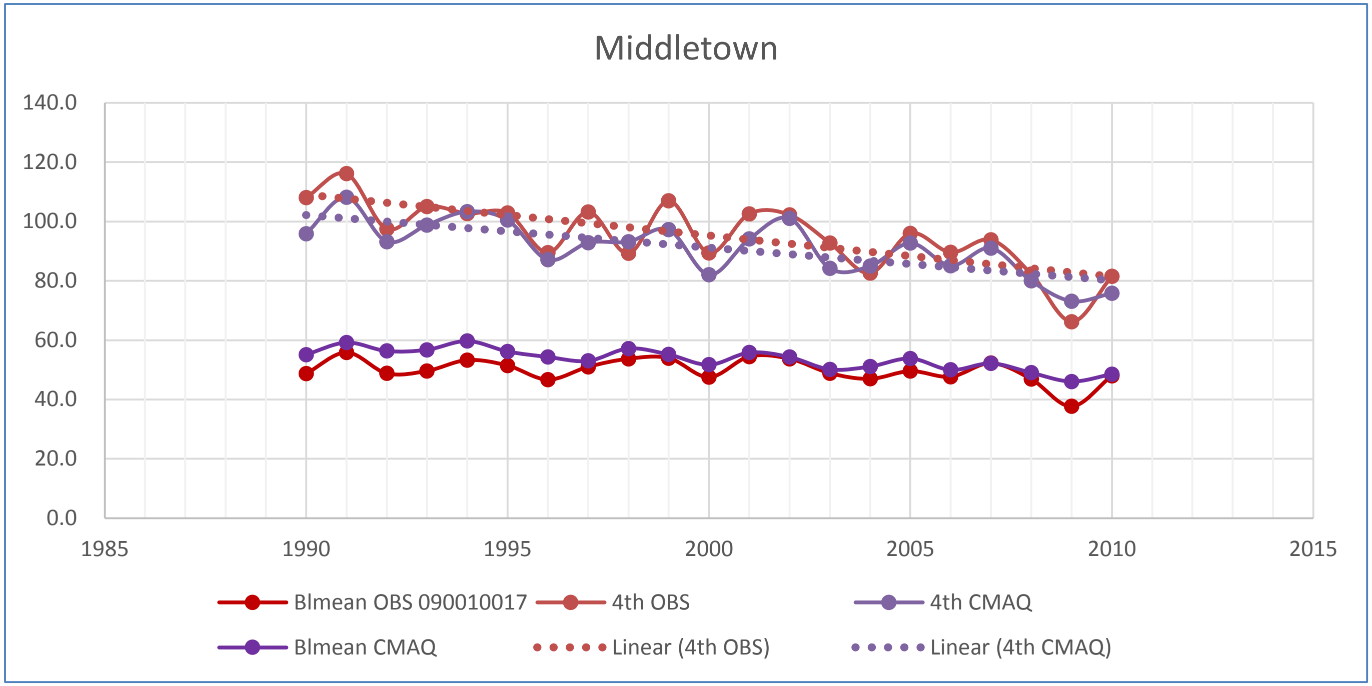
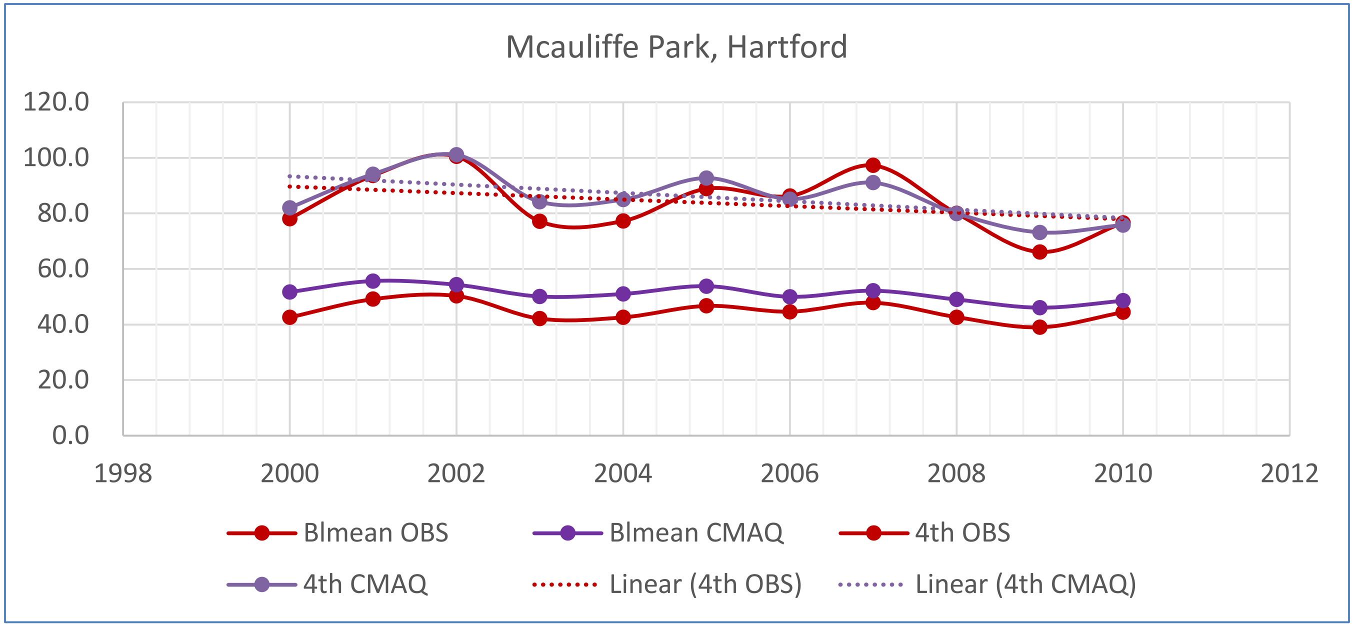
40.0
20.0
0.0
1985
1990
1995
2000
2005
2010
2015
Blmean OBS 090010017
4th OBS
4th CMAQ
Blmean CMAQ
Linear (4th OBS)
Linear (4th CMAQ)





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Confidence intervals for Design Values

(preliminary results)

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

Mean of 21 DV ± 2 std. dev. of 21 DV

Example:
Future year = 2010
Base year = 1995

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

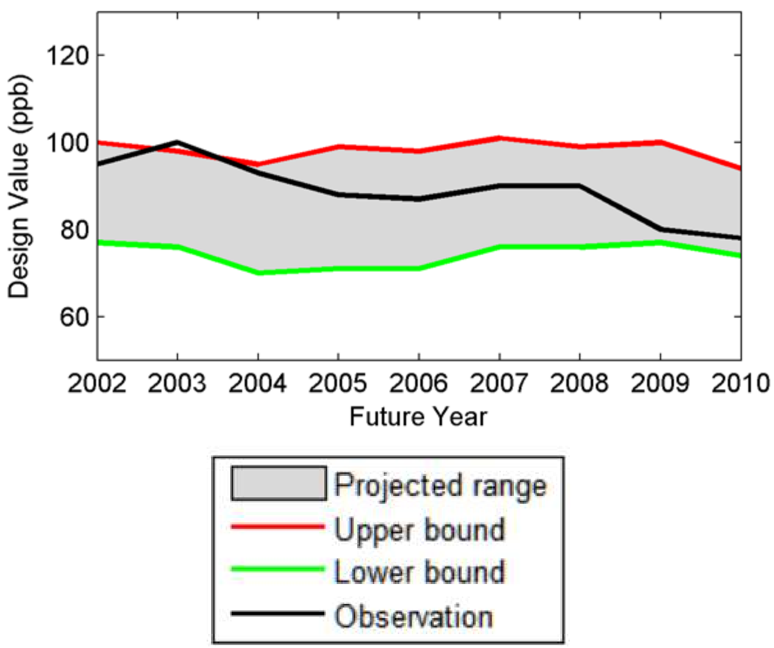
Reconstruction of the ozone time-series:

O_3(2010)_1 = BLproj(2010) + SYobs(1990) → 4^{th} (2010),1
O_3(2010)_2 = BLproj(2010) + SYobs(1991) → 4^{th} (2010),2
... ...
O_3(2010)_21 = BLproj(2010) + SYobs(2010) → 4^{th} (2010),21

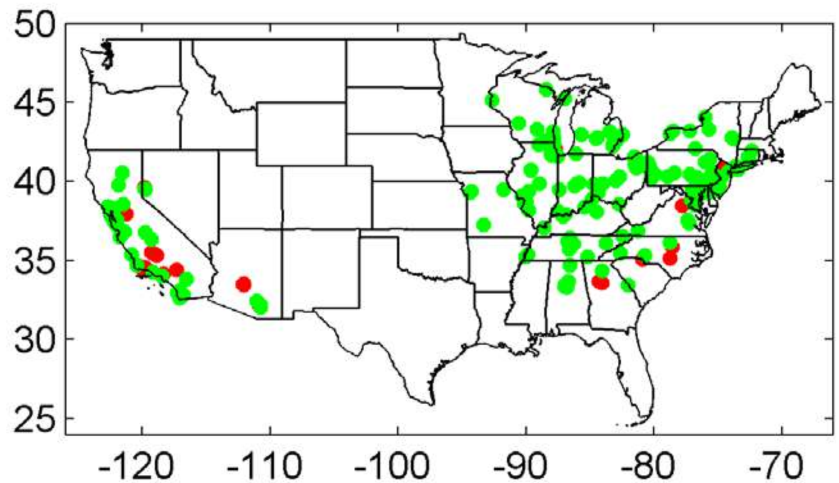
DV(2010),1=MEAN4th(2010,2009,2008)
DV(2010),2=MEAN4th(2010,2009,2008)
...
DV(2010),21=MEAN4th(2010,2009,2008)

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)

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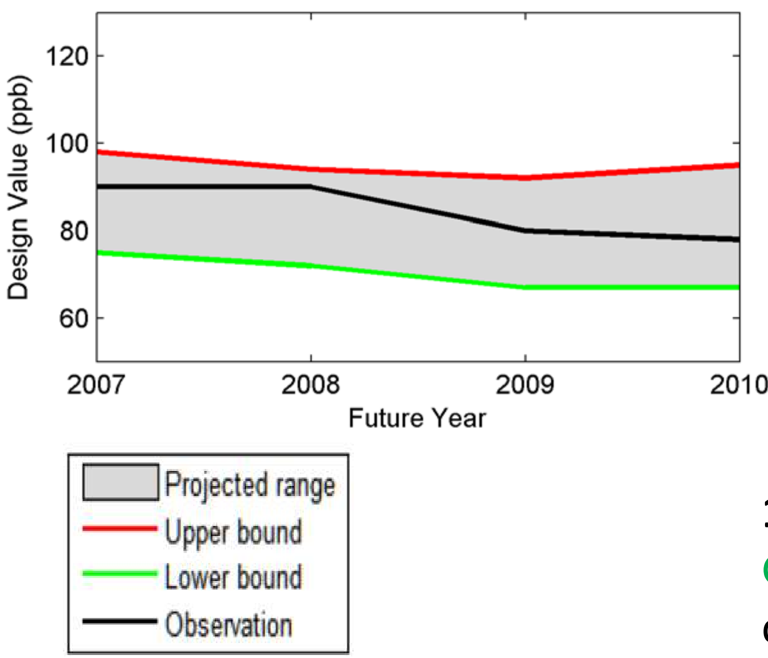
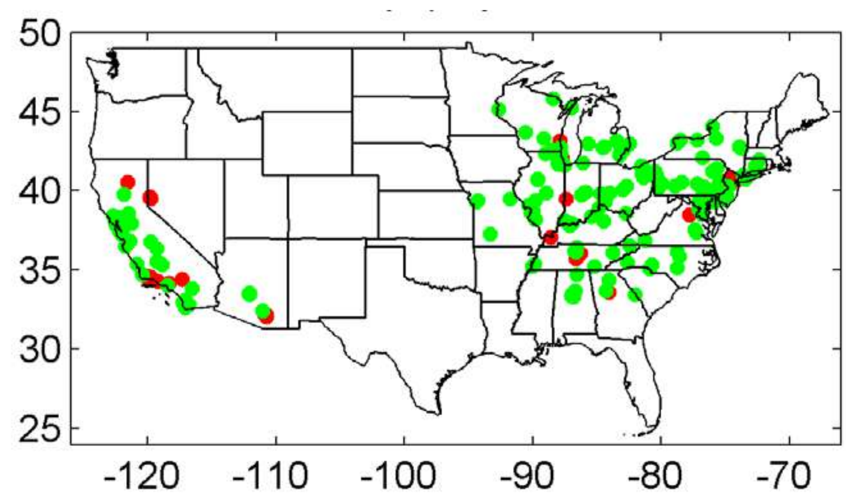
Bounds for the Design Value (3-year average 4^{th} highest ozone conc) 15-year projection interval

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)

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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 O_3 coupled with observed historic SY provide a robust estimate of the impact of emission controls.

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