Testing of AQM V5.1 & Version 8 KFAN bias correction for O$_3$ and PM2.5

July-August 2017

Verification Stats:
http://www.emc.ncep.noaa.gov/mmb/aq/fvs/web/html/regular.html

Spatial Maps:
http://www.emc.ncep.noaa.gov/mmb/aq/cmaqparabc/web/html/index.html

03/09/2018

Team

- Jianping Huang, EMC : code design/transition
- Ho-Chun Huang, EMC: wild fire smoke emission development
- Jeff McQueen, ARL: system evaluation, graphics web page support
- Pius Lee, ARL: OAR/ARL team leader, oil/gas emissions development
- Youhua Tang & Daniel Tang, ARL: Emissions development
- Li Pan, ARL/EMC: research system development and testing
- Jim Wilczak, Irina, Djalalova, Dave Allerud, ESRL/PSD: bias correction development
- Ivanka Stajner, Sikchya Udap, NWS/STI: AQ program management

Summary of work performed

- **Completed EXP AQM V5.1 testing for July-Aug. 2017; Dec-Present**
  - *Oil & gas sector emission update to 2017 from NEI 2011*
  - *Bug correction for Colorado winter VOC emissions*

- **Completed the O_3 and $PM_{2.5}$ V8 EXP bias correction testing for July 2017 – Feb 2018 with unified ESRL KFAN**
  - *Corrected from Operational CMAQ V5.0.2*
  - *V8 w/ Jan. 19 patch for rare events*
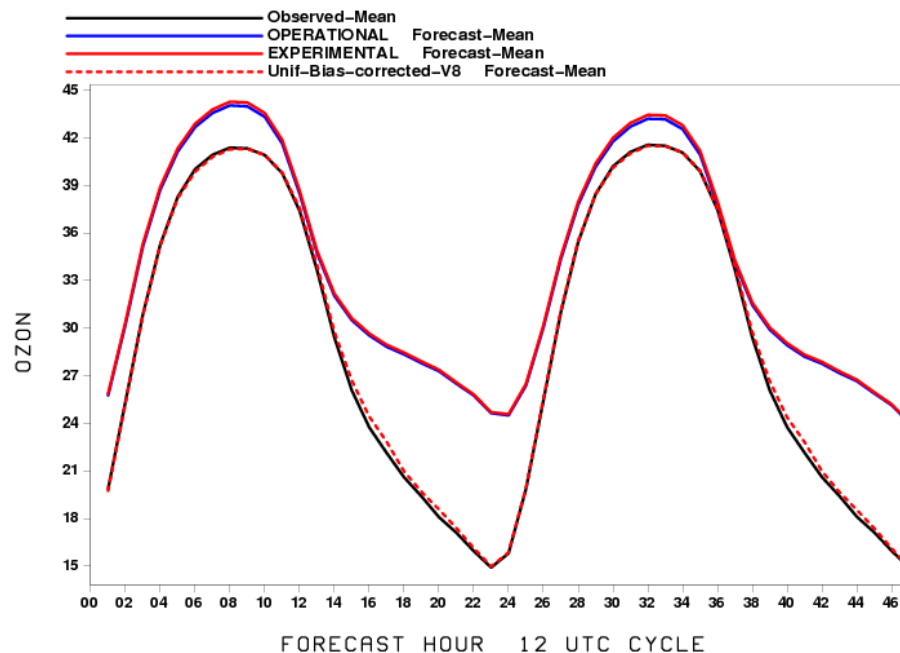 - *900 sites*
  - *V5 training data*
  - *Use of SW rad for analog selection*

Diurnal prod, EXP and *EXP bias corrected* O₃ forecasts: **July 2017**
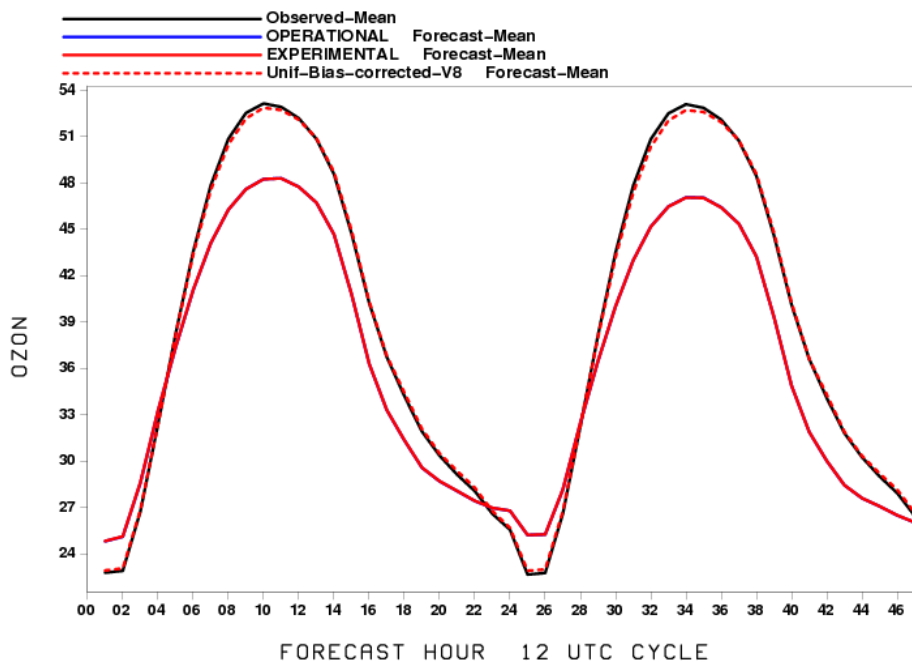
WEST U.S.   EAST U.S.

Exp Unified Bias Correction near perfect
Prod & V5.1: - typical over-prediction East
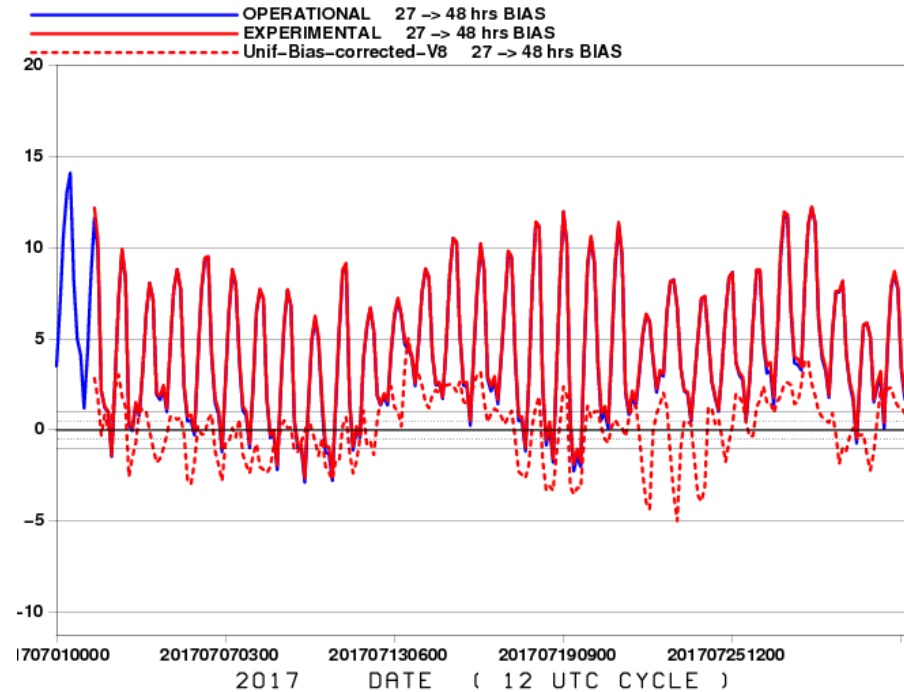   - under-prediction West

Prod, V5.1, *Exp bias corrected* O$_3$
Day 2 Daily Time Series
July 2017
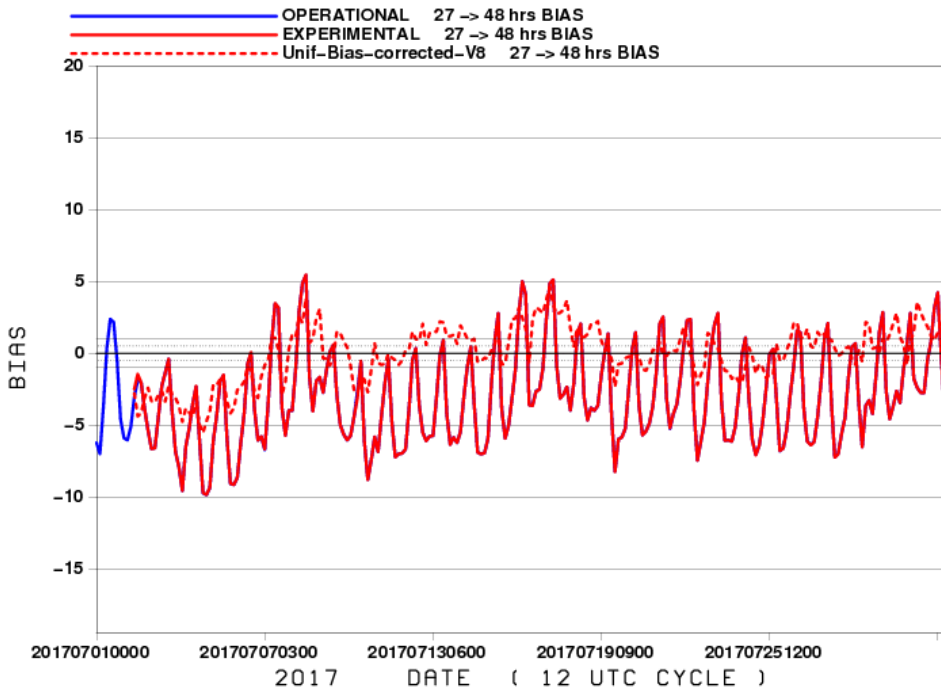
AQM Exp V5.1 raw predictions: small impact
BC: Overpredictions corrected esp over East
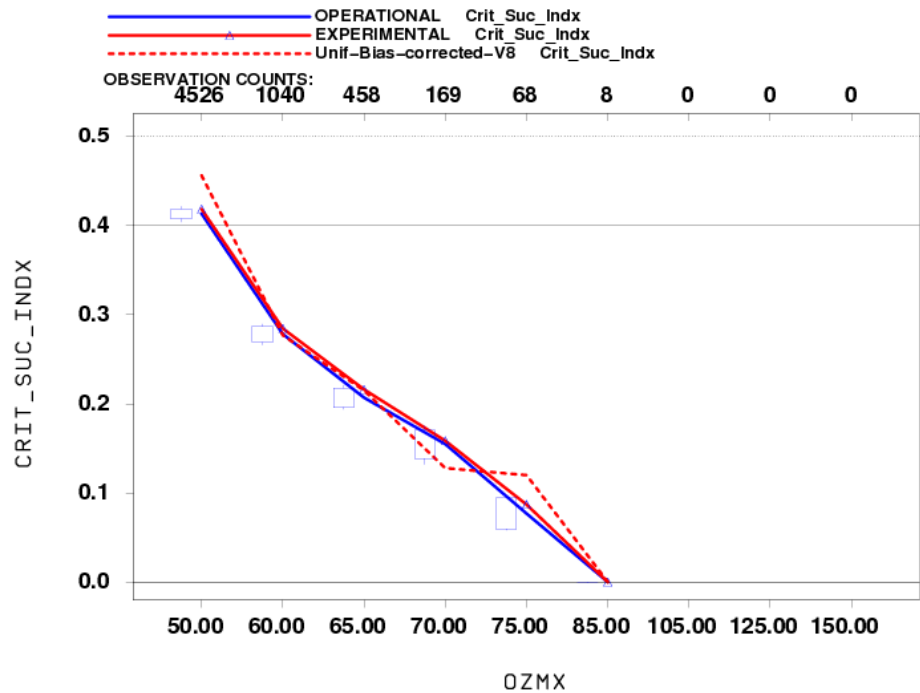
CSI skill score: Day 2 8 hr avg O$_3$
July 2017

WEST

EAST
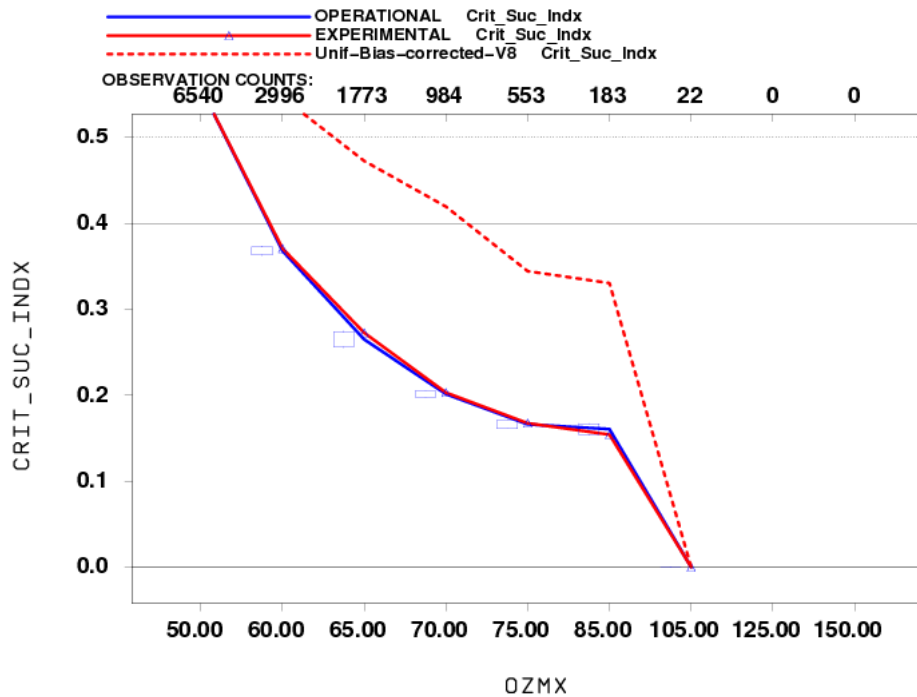
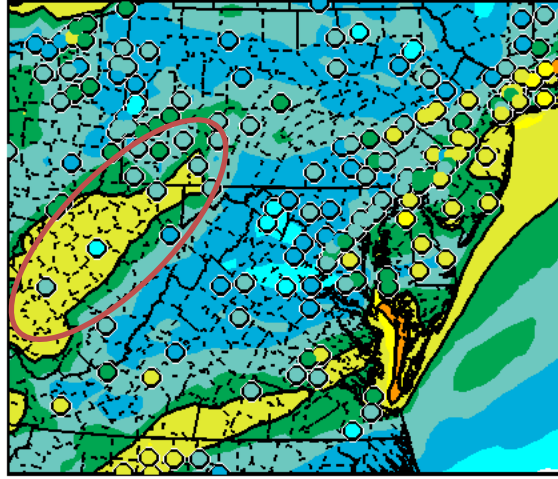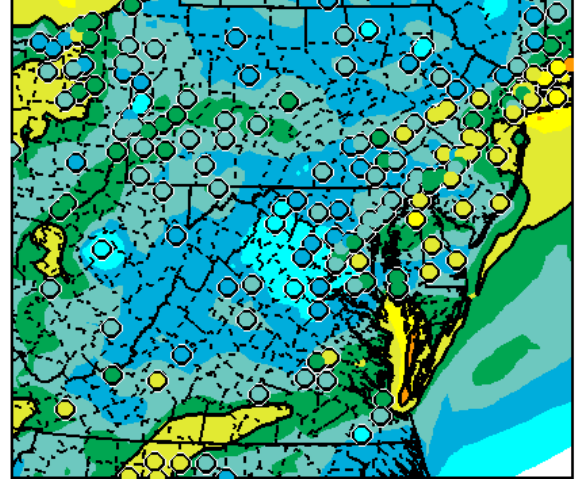Improved Skill mainly over West where many more episodes occurred

July 12 2017 Day 2 8 hr max O3
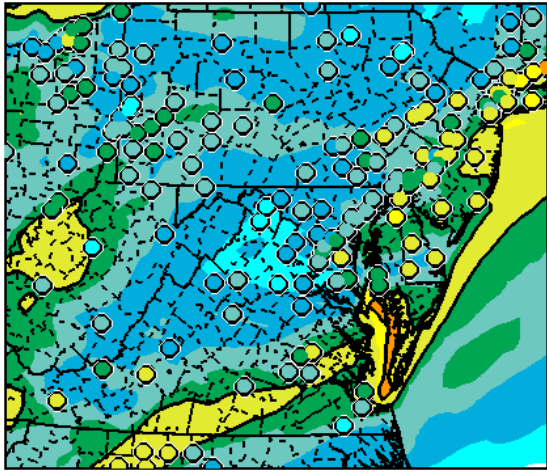
PROD DAY2 OZMXO8 (PPB) 20170711 12Z CYC

PARA5 4X-DAY DAY2 OZMXO8 (PPB) 20170711 12Z C

PARA BIAS COR V8 DAY2 OZMXO8 (PPB) THU 170713/120

PROD
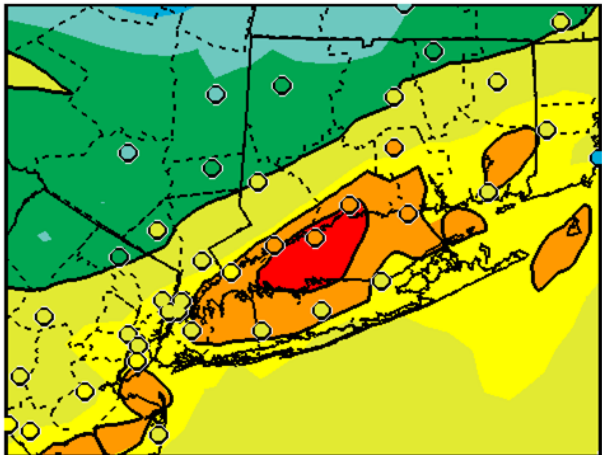
EXP V5.1

EXP Bias Corrected V8

106.0 85.5 70.5 65.0 54.5 50.0 45.0 40.0 30.0

- V5.1: Slightly more ozone in W. VA from oil/gas sector updates

July 19 2017 Day 2 8 hr max O3

PROD   DAY2 OZMXO8 (PPB)   THU 170720/1200V048 ~
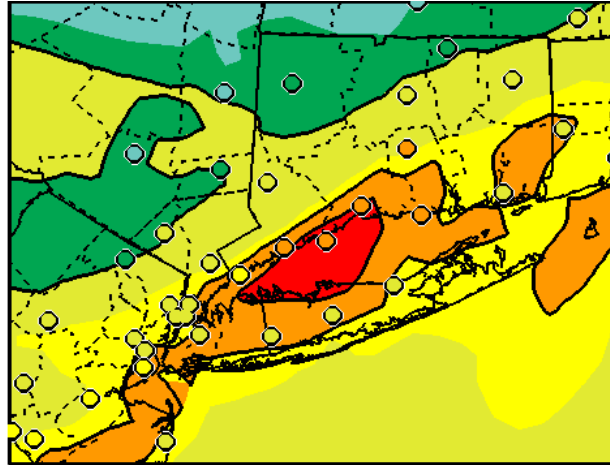
PARA5 4X-DAY DAY2 OZMXO8 (PPB) 20170718 12Z CYC

BIAS COR V8   DAY2 OZMXO8 (PPB)   THU 170720/1200V
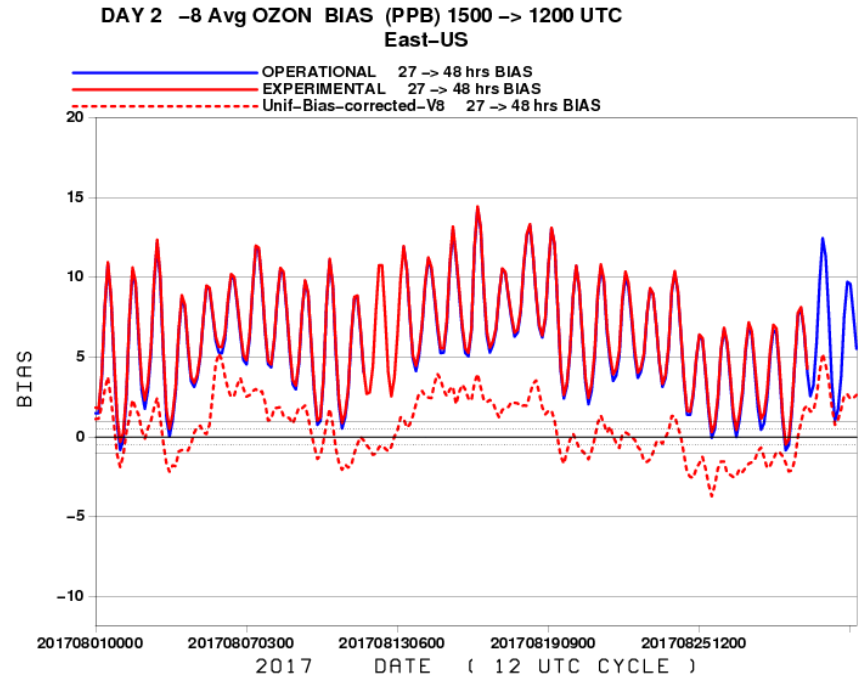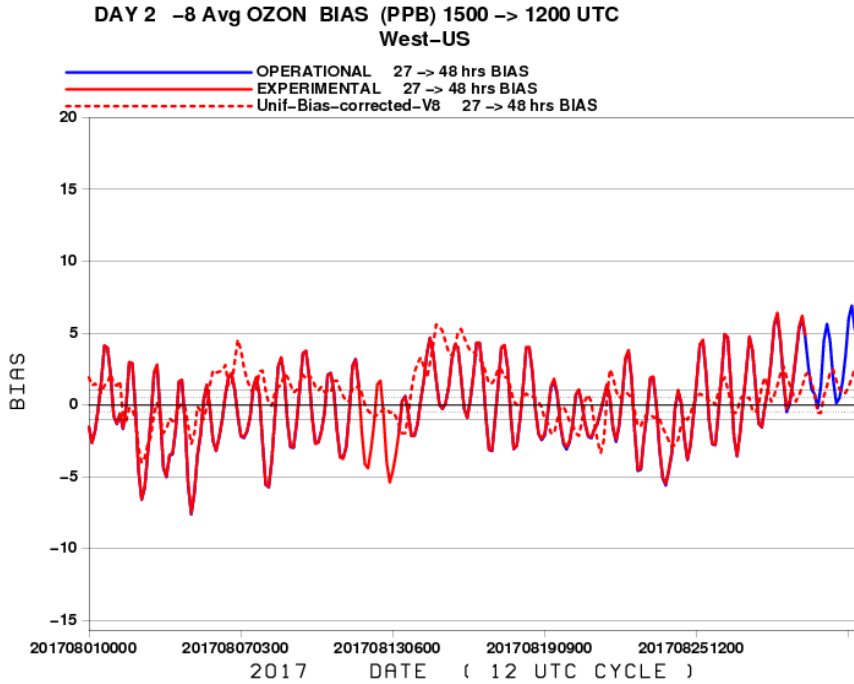
PROD NYC

V5.1
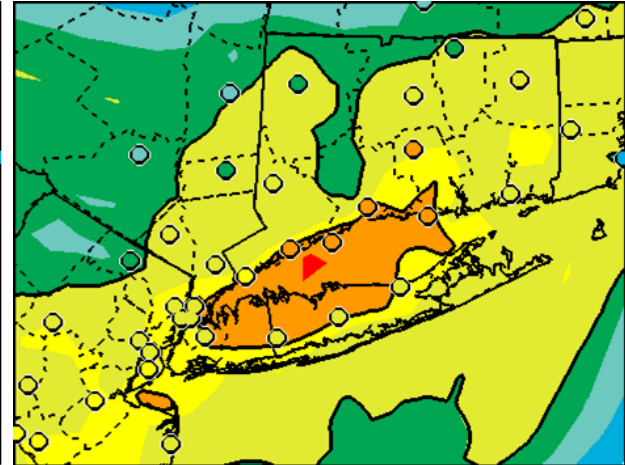
Bias Corrected V8

- BC: no longer overcorrects day 2 max O3

Prod, V5.1, *Exp bias corrected* O_3
Day 2 Daily Time Series
August, 2017

Bias Correction reduces large overpredictions over East

Prod, V5.1, *Exp bias corrected* O$_3$
8h avg Daily Max Day 2 Hit rate
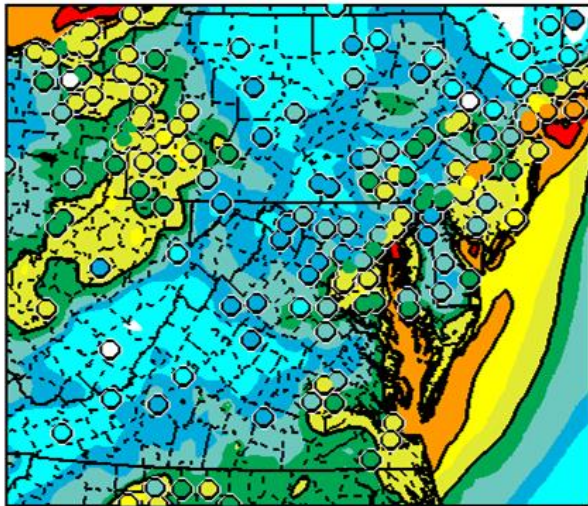## August, 2017

WEST

EAST
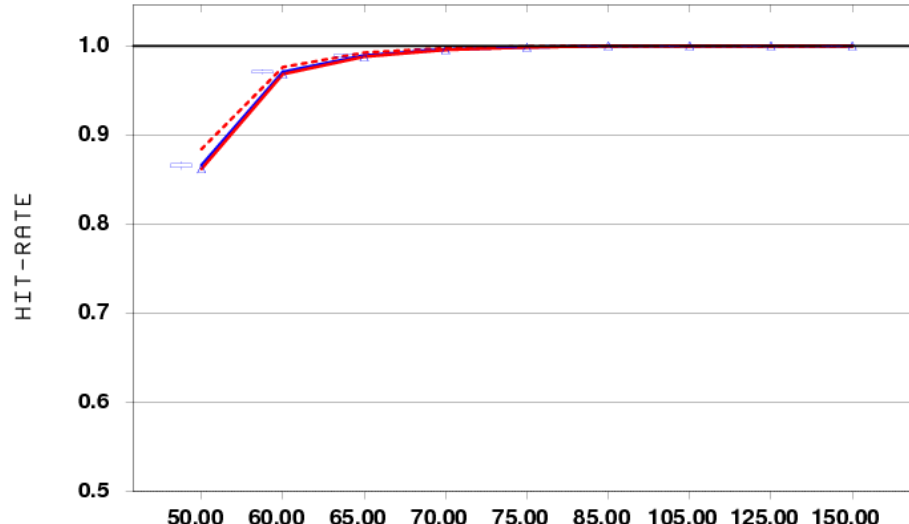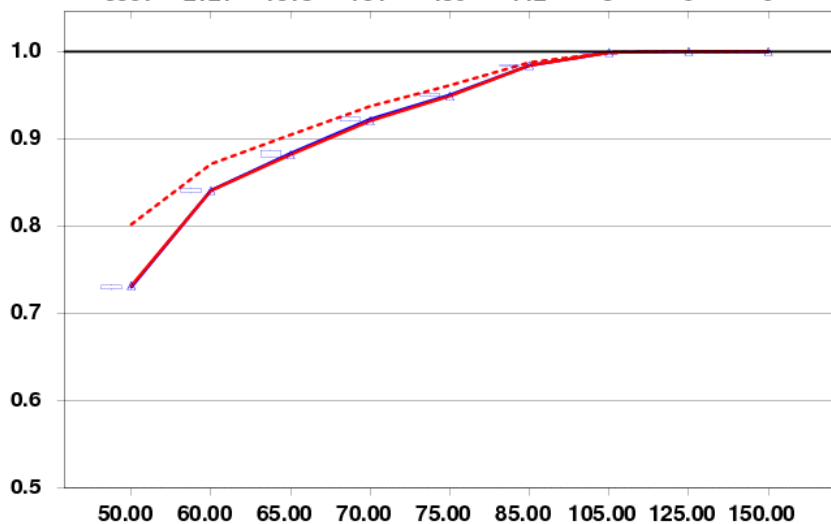
BC: - Improved Skill over West for all thresholds
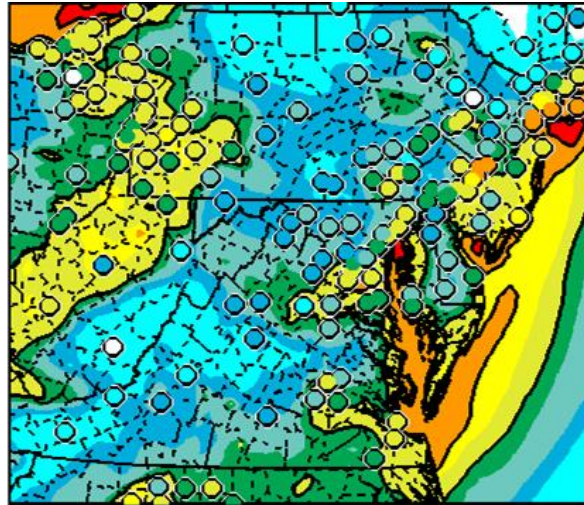- Over East only 35 events for code orange

Aug 1 , 2017 NAM-CMAQ V5
Day 2 8 hr max O_3
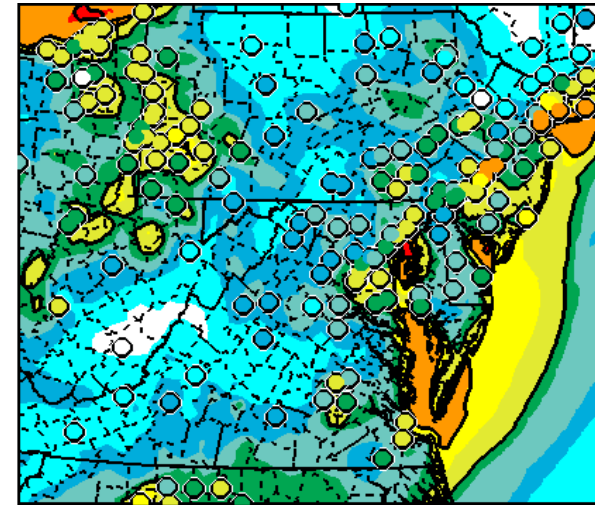

PROD   DAY2 OZMXO8 (PPB) 20170731 12Z CYC~

PROD
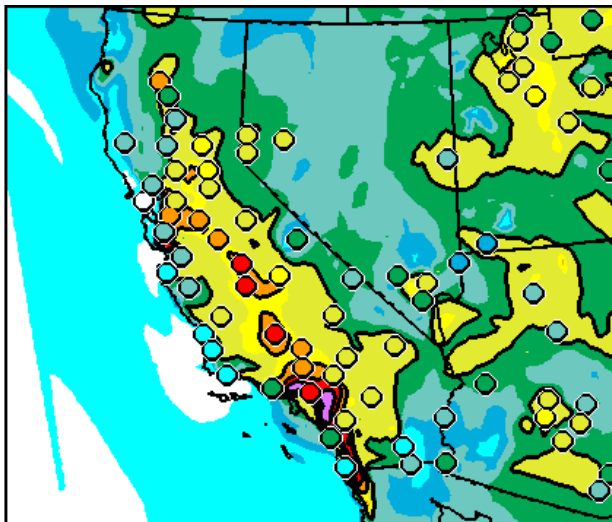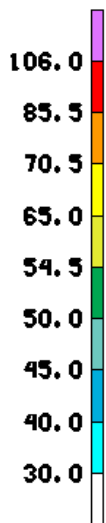
PARA5 4X-DAY   DAY2 OZMXO8 (PPB) 20170731 12Z CY

V5.1

RA BIAS COR V8   DAY2 OZMXO8 (PPB) 20170731 12Z
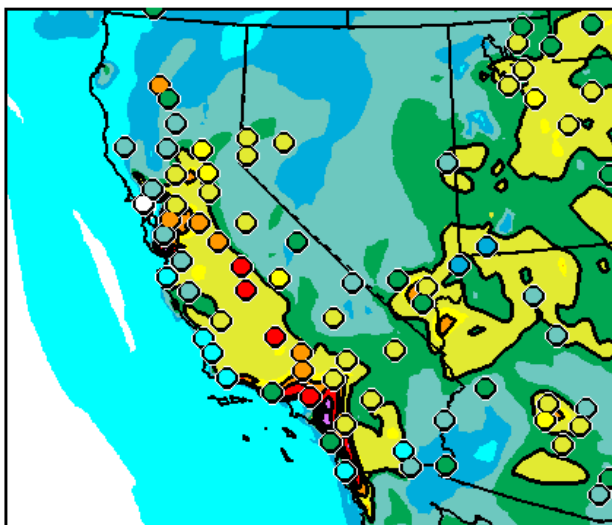
BC V8

- BC: Better Agreement over W. PA & W. VA

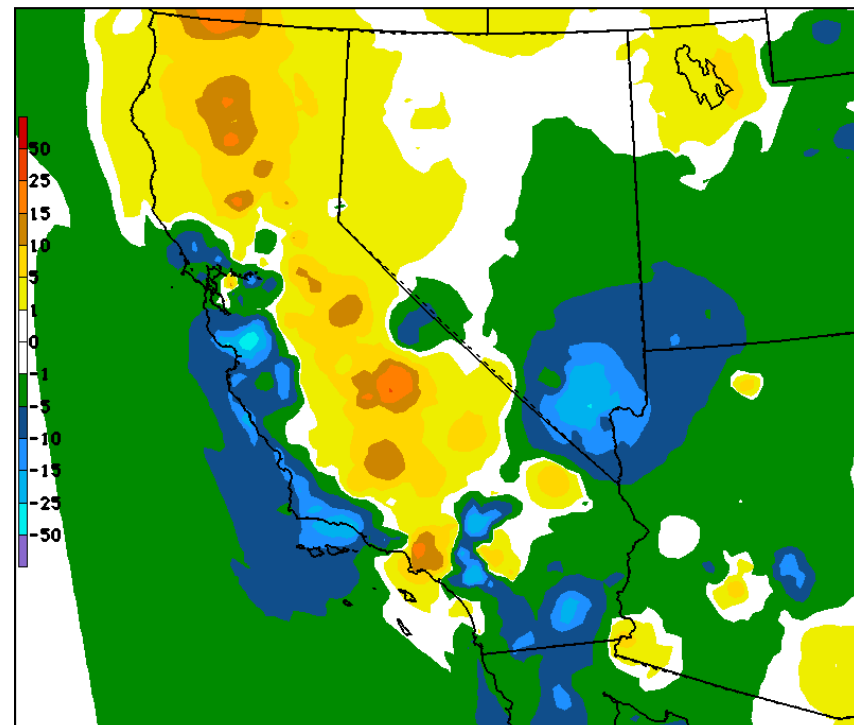# Aug 28 , 2017 Day 2 8 hr daily max O3

EXP BC

PROD

PARA BIAS COR V8   DAY2 OZMXO8 (PPB)   TUE 170829/120

PROD   DAY2 OZMXO8 (PPB)   TUE 170829/1200V048

EXP - OPER BC aqm DAY2 O8 hr avg OZMX from 20170827 12 UTC Run

- BC: helps correct underprediction over California valleys
- Fire influenced O3 production
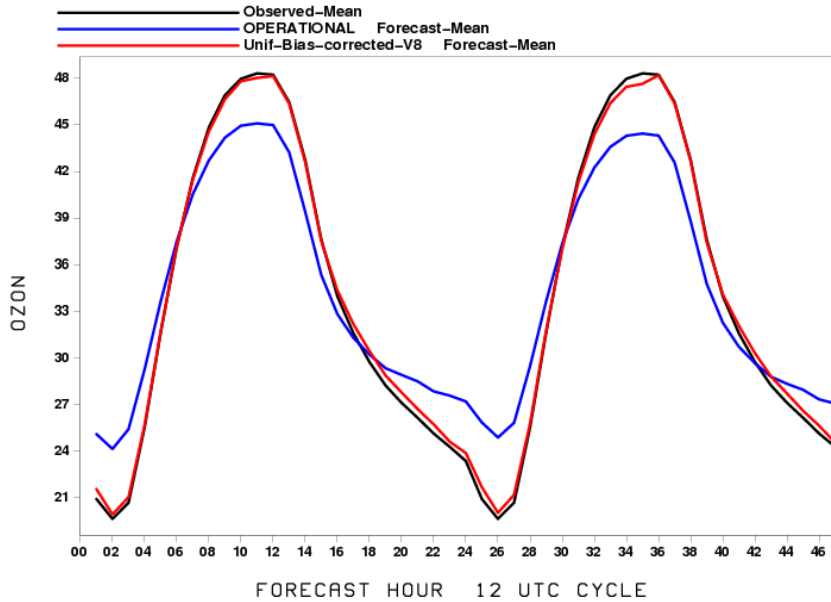
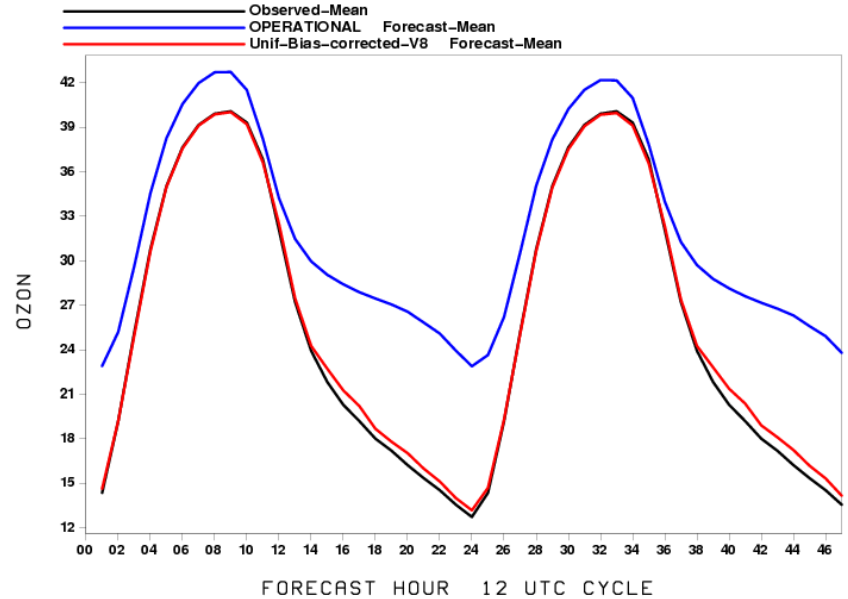# 1h avg O_3 Diurnal Time Series
Prod and EXP bias corrected
September 2017

WEST

1–h Avg OZON obs (PPB) avged by fcst hrs
20170901 to 20170930
West–US

- Observed–Mean
- OPERATIONAL Forecast–Mean
- Unif–Bias–corrected–V8 Forecast–Mean

EAST

1–h Avg OZON obs (PPB) avged by fcst hrs
20170901 to 20170930
East–US

- Observed–Mean
- OPERATIONAL Forecast–Mean
- Unif–Bias–corrected–V8 Forecast–Mean

O3 Bias Correction - Near perfect
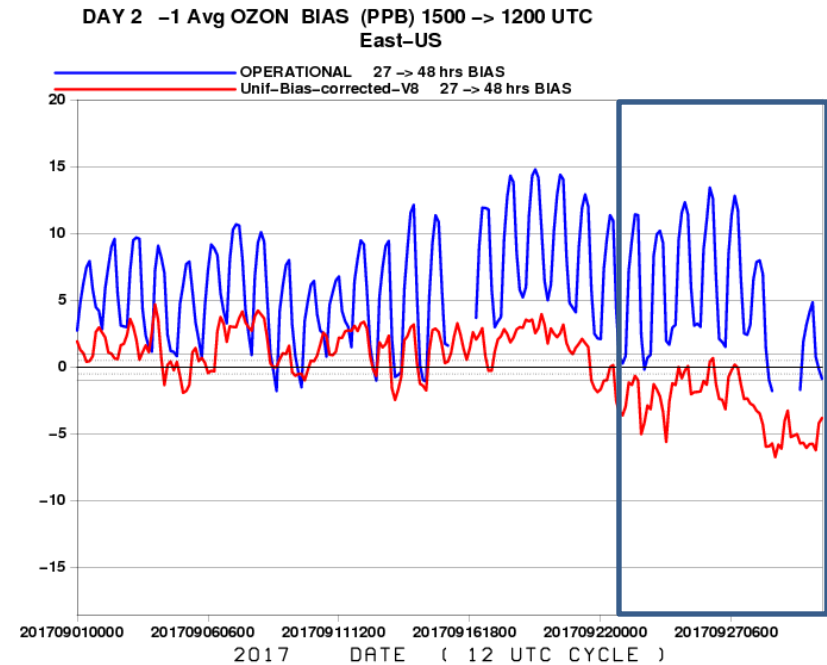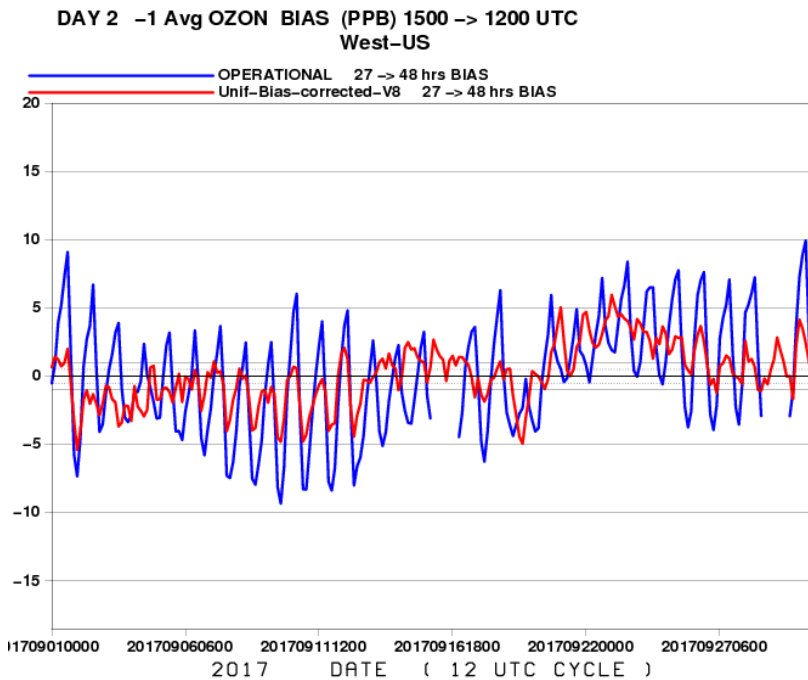
1h avg O$_3$ Day 2 Daily Time Series BIAS
Prod and EXP bias corrected
September 2017

O3 Bias Correction - Improved, similar trend to raw except underprediction in East later in month
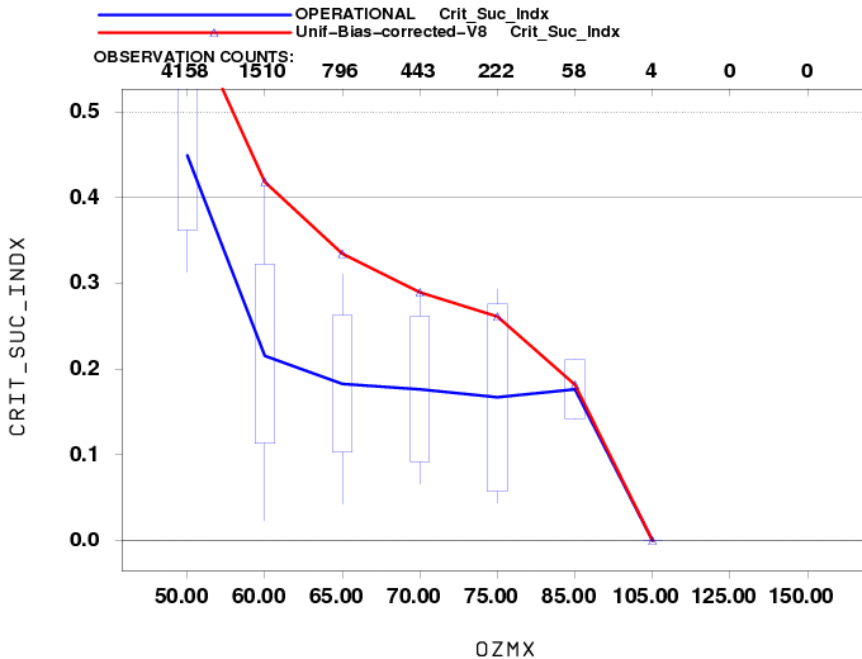
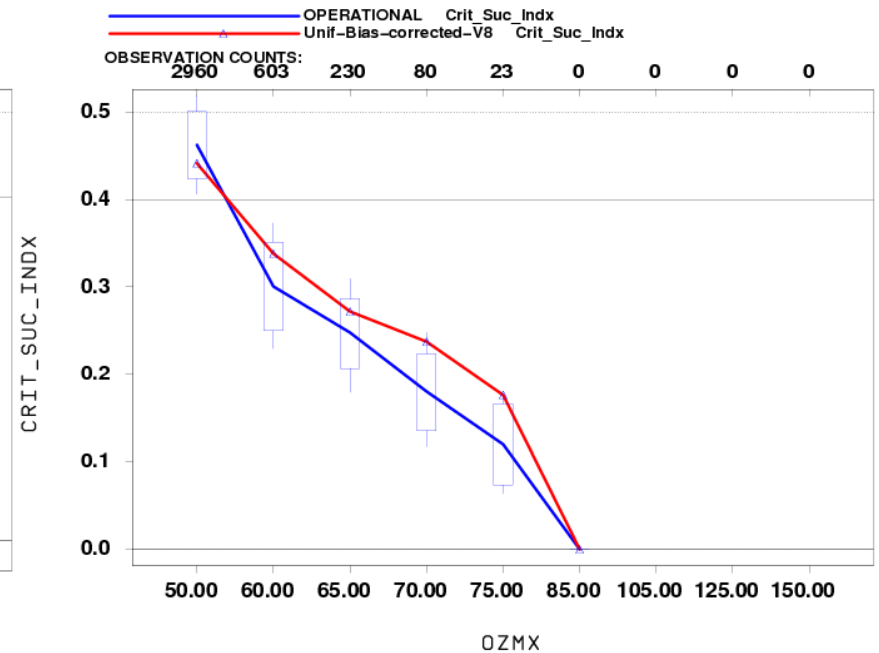# 8 h avg Daily Max O$_3$ Day 2 CSI
Prod and EXP bias corrected
September 2017

WEST

DAY 2 8h-avg OZMX/8 Crit_Suc_Indx avged by Threshold
20170901 to 20170930

— OPERATIONAL   Crit_Suc_Indx
— Unif-Bias-corrected-V8   Crit_Suc_Indx

OBSERVATION COUNTS:
4158   1510   796   443   222   58   4   0   0

EAST

DAY 2 8h-avg OZMX/8 Crit_Suc_Indx avged by Threshold
20170901 to 20170930

— OPERATIONAL   Crit_Suc_Indx
— Unif-Bias-corrected-V8   Crit_Suc_Indx

OBSERVATION COUNTS:
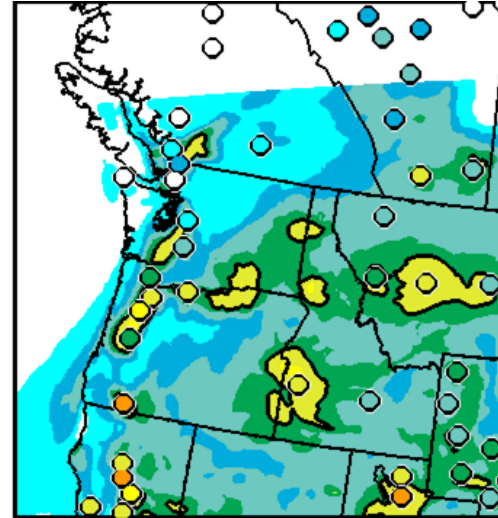2960   603   230   80   23   0   0   0   0

O3 Bias Correction - Larger improvement for all thresholds esp over West
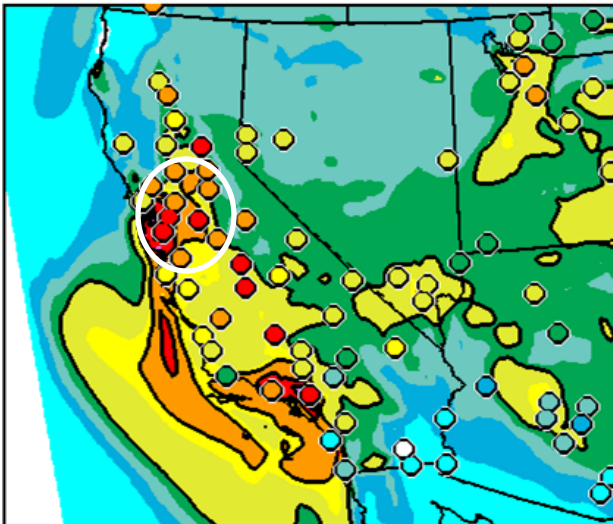
15

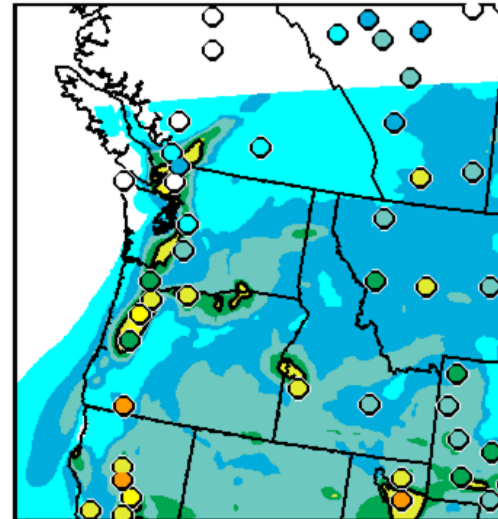# Sept 2, 2017 8hr daily max O3 (Day 1)
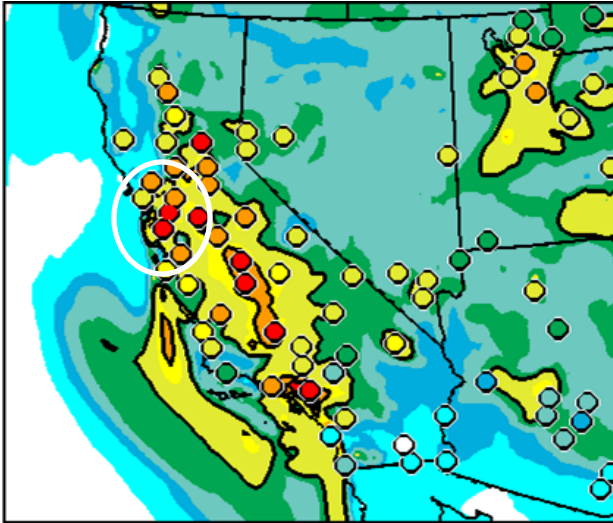
PARA PARABC BIAS COR DAY1 OZMX08   20170902 12Z
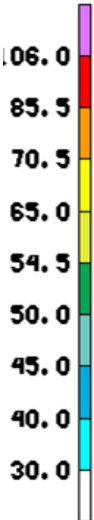
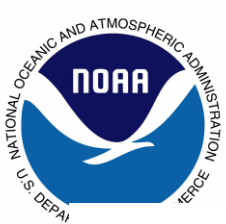PARABC BIAS COR DAY1 OZMX08   20170902 12Z

PARA5 4X-DAY   DAY1 OZMX08   20170902 12Z CYC

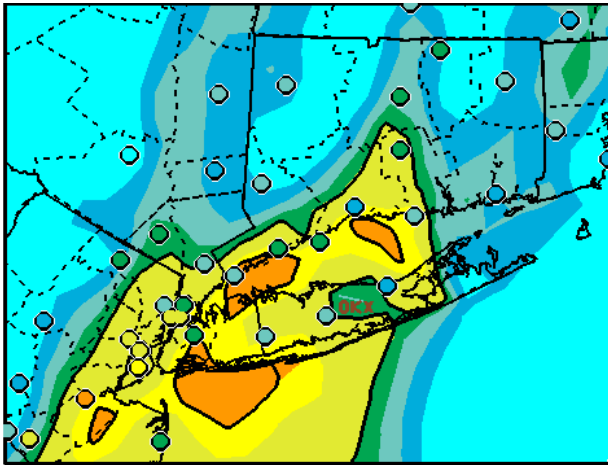IRA5 4X-DAY   DAY1 OZMX08   20170902 12Z CYC
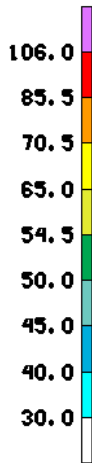
Color scale:
- 106.0
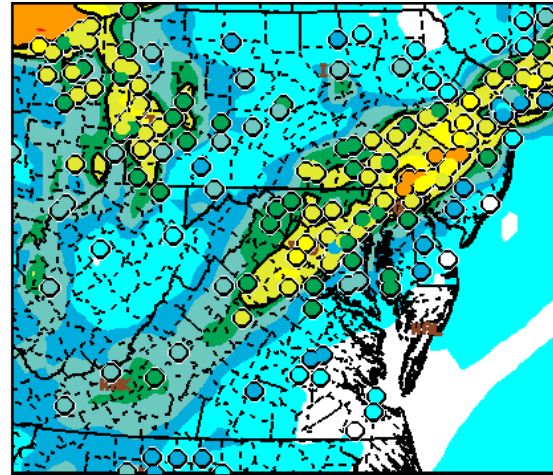- 85.5
- 70.5
- 65.0
- 54.5
- 50.0
- 45.0
- 40.0
- 30.0

- BC: helps correct under-prediction over California valleys
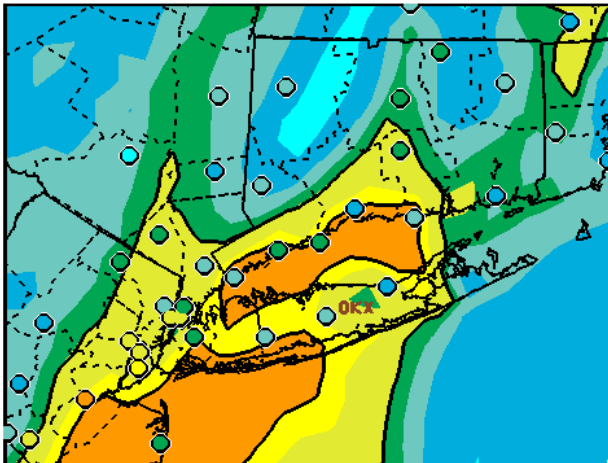- But reduced ozone near fires East of San Francisco
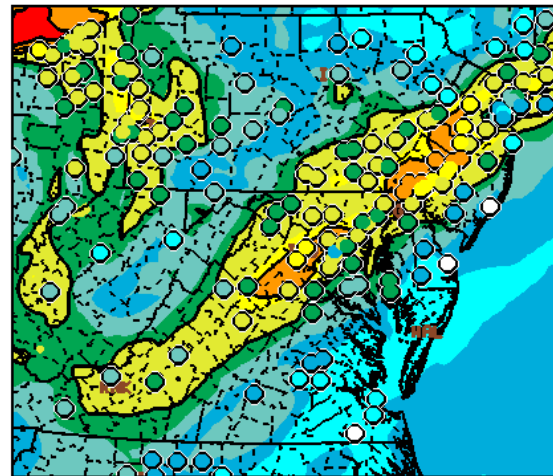
Sept 24/25, 2017 8hr daily max O3 (Day 2)

PARA BIAS COR V8   DAY2 OZMXO8 (PPB) 20170923 12Z CYC

PARA BIAS COR V8   DAY2 OZMXO8 (PPB) 20170924 12Z CYC

PROD DAY2 OZMXO8 (PPB) 20170923 12Z CYC

PROD DAY2 OZMXO8 (PPB) 20170924 12Z CYC

BC: helps correct overprediction over LI and CT coasts and DC area

Raw PM Production vs
PM Operational Bias correction vs
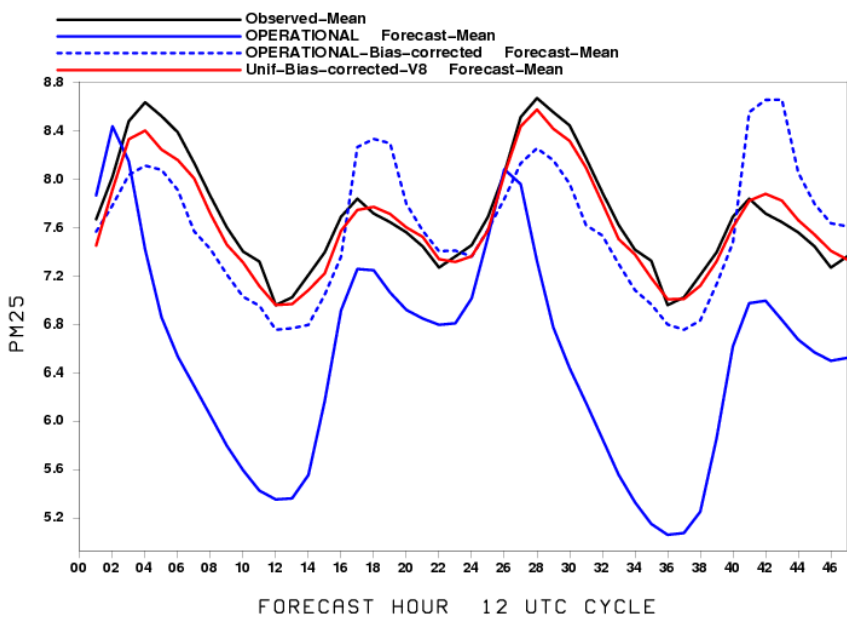*Exp. unified Bias Correction (V8)*
Predictions

1 h avg PM2.5
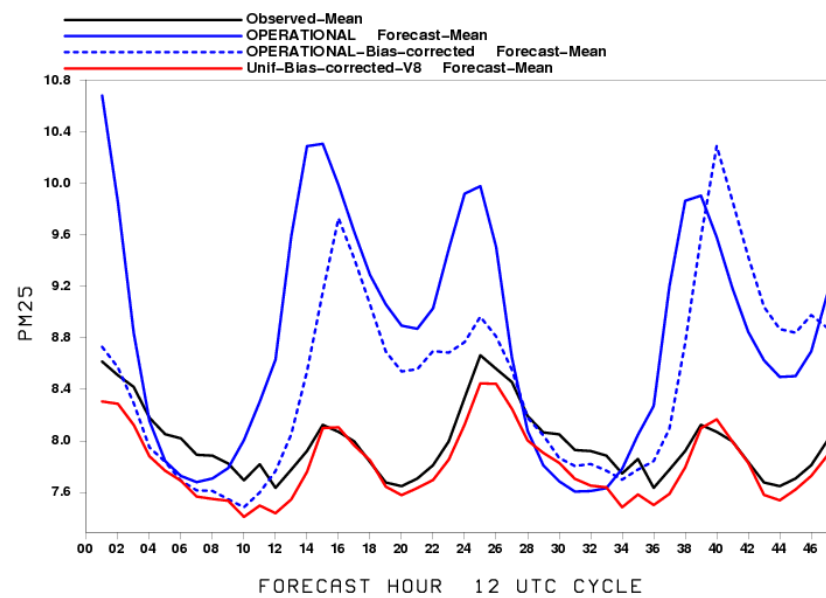## Prod, *Prod bias correction*
vs *Exp bias correction*
July 2017

1-h Avg PM25 obs (ug-m3) avged by fcst hrs
20170701 to 20170731
West-US

1-h Avg PM25 obs (ug-m3) avged by fcst hrs
20170701 to 20170731
East-US

- Large improvement with Exp. Bias correction esp. over East
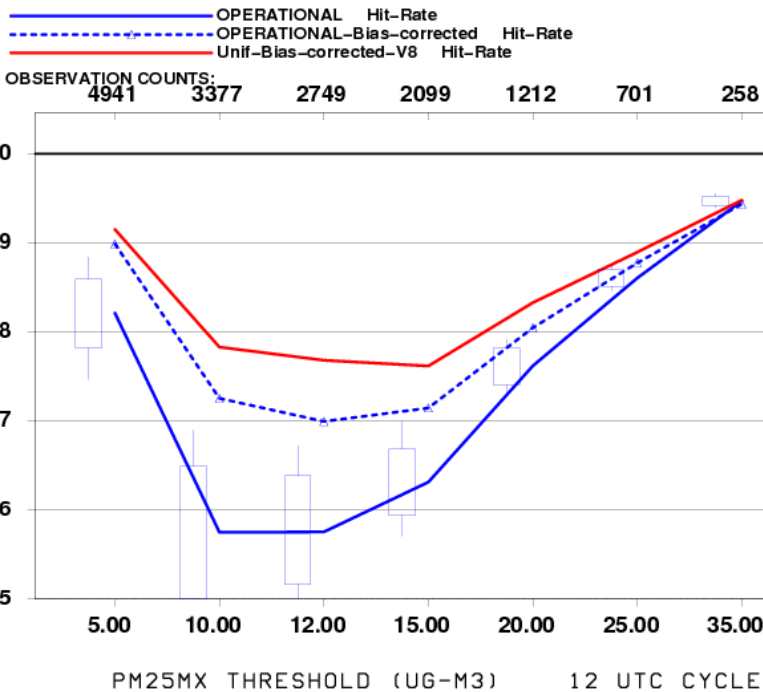- *Note: Operational bias correction still using old V4 training predictions*

1 h max PM2.5 hit rate
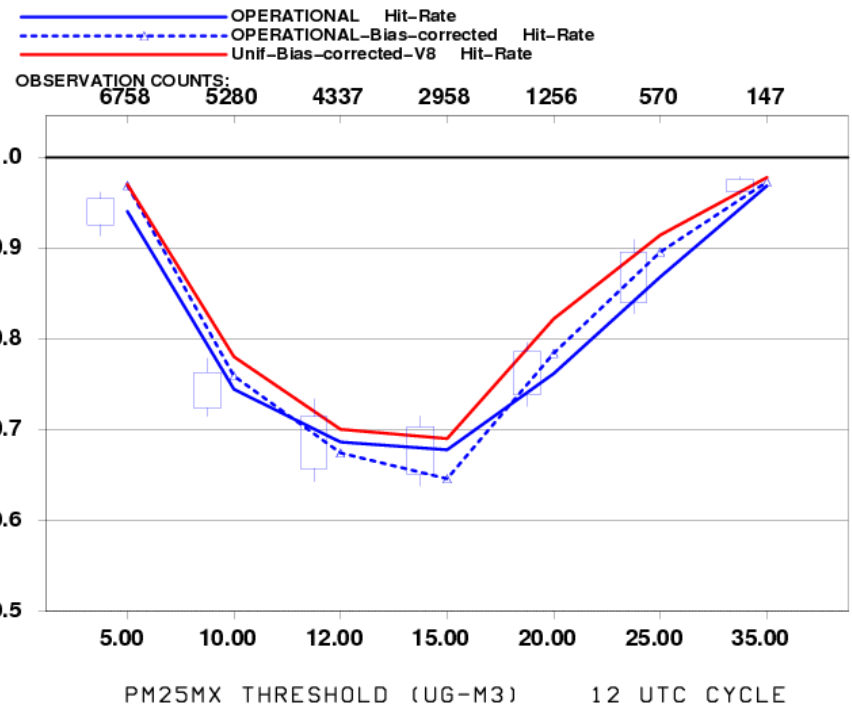## Prod, *Prod bias correction* vs *Exp bias correction*
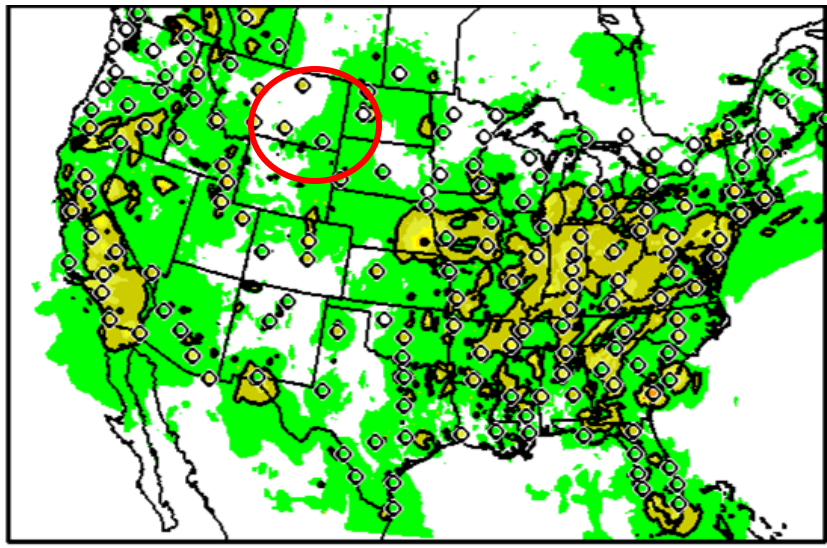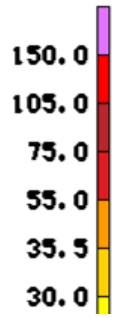## July 2017

DAY 2 01h−avg PM25MX Hit−Rate avged by Threshold
20170701 to 20170731

- Large improvement with Exp. Bias correction esp. over West
- *Note: Operational bias correction still using old V4 training predictions*
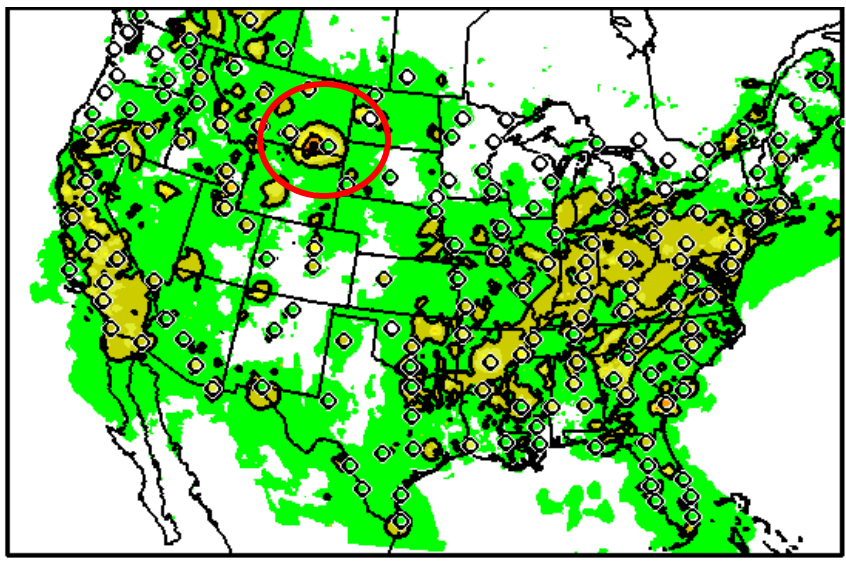
July 13, 2017 Bullseye case (Prod BC vs EXP BC) 1hr daily max PM

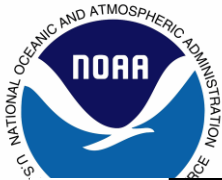PARA PROD BIAS COR DAY1 PMMX01   20170713 12Z CYC
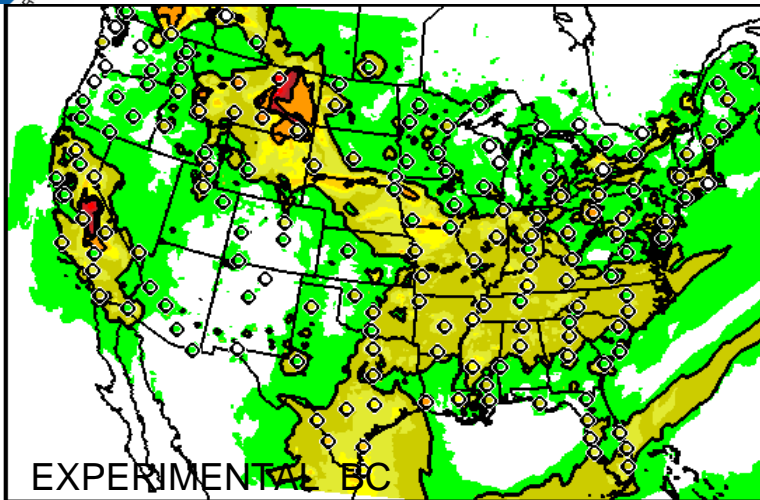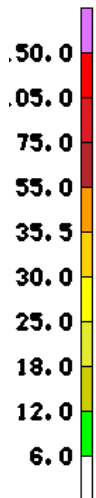
PRODUCTION BC

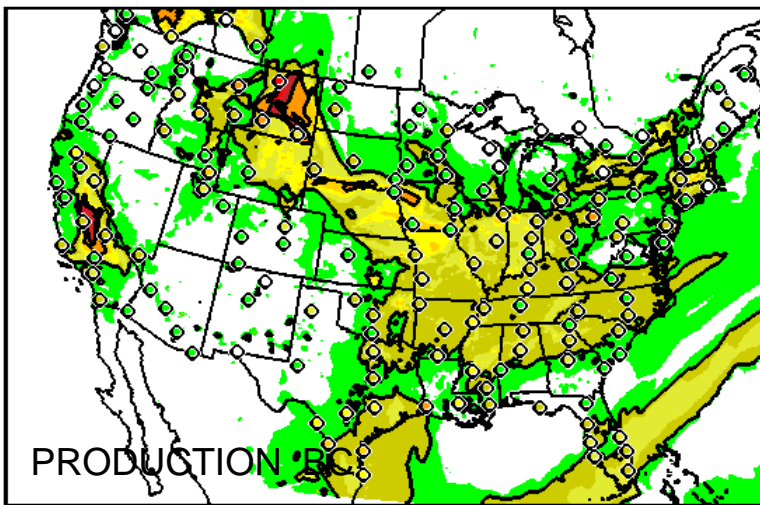PARA BIAS COR DAY1 PMMX01 (UG/M3) 20170713 12Z CYC

EXPERIMENTAL BC

Montana local maxima not seen in production BC outputs
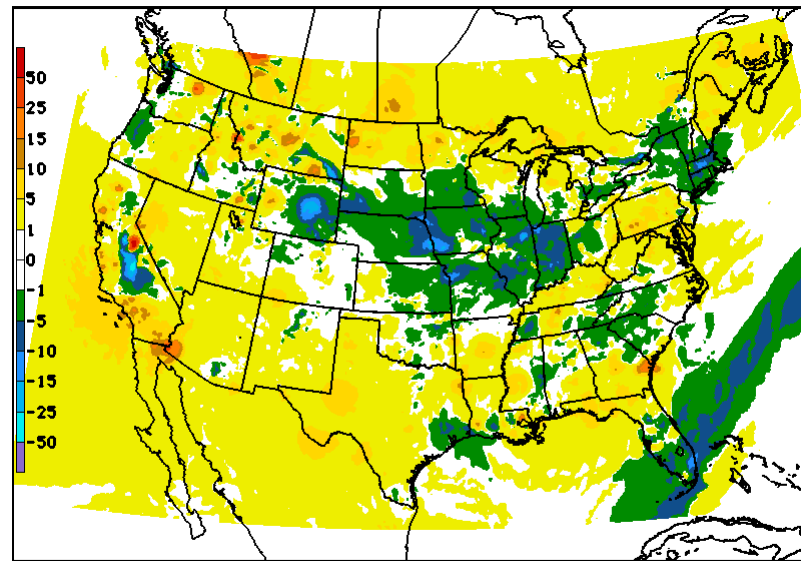but bullseye pattern weakened by August and later

July 23 , 2017 (Prod BC vs EXP BC)
1hr Day 2 daily max PM

PARA BIAS COR V8 DAY2 PMMX01 (UG/M3) 20170722 12Z CYC

PROD DAY2 PMMX01 (UG/M3) 20170722 12Z CYC

EXP - OPER BC agm DAY2 01 hr avg PMMX from 20170722 12 UTC Run

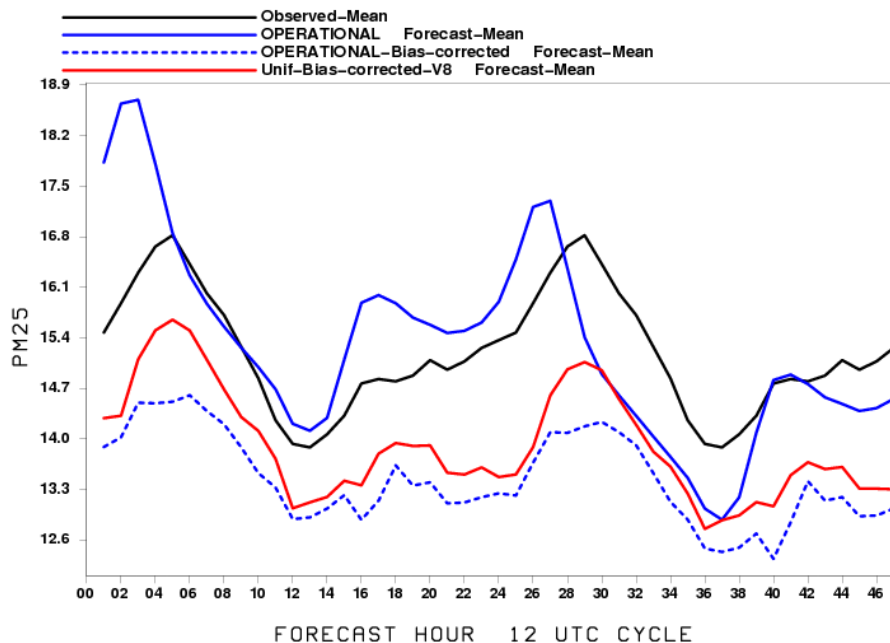PM BC: Less of an impact…reduces overprediction near California fires

1 h avg PM2.5 diurnal time series
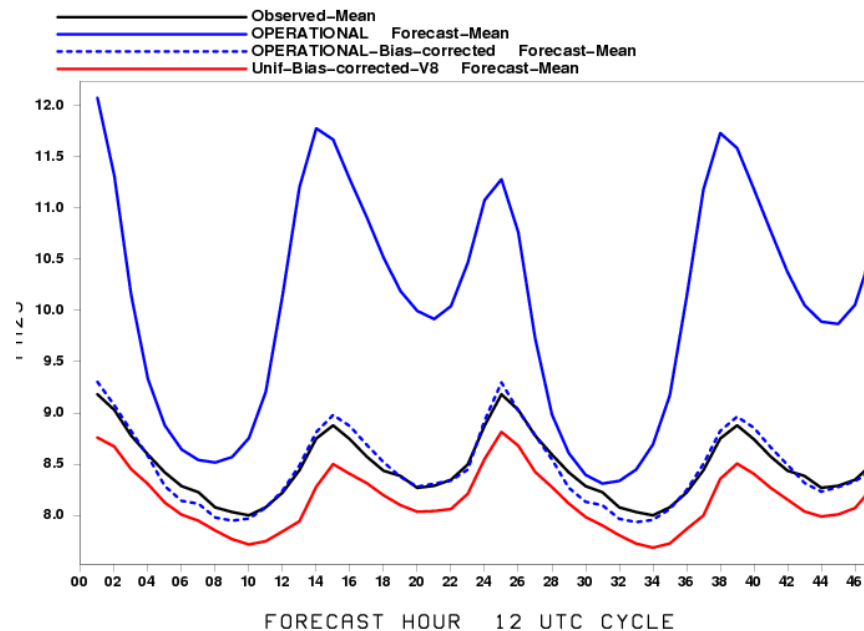
Prod, *Prod bias correction*
vs *Exp bias correction*
August 2017

1−h Avg PM25 obs (ug−m3) avged by fcst hrs
20170801 to 20170831
West−US

1−h Avg PM25 obs (ug−m3) avged by fcst hrs
20170801 to 20170831
East−US

- Improvement with Exp. Bias correction over West compared to prod BC
- All BC results are degraded compared to raw predictions over West
      - Extensive fires over NW US
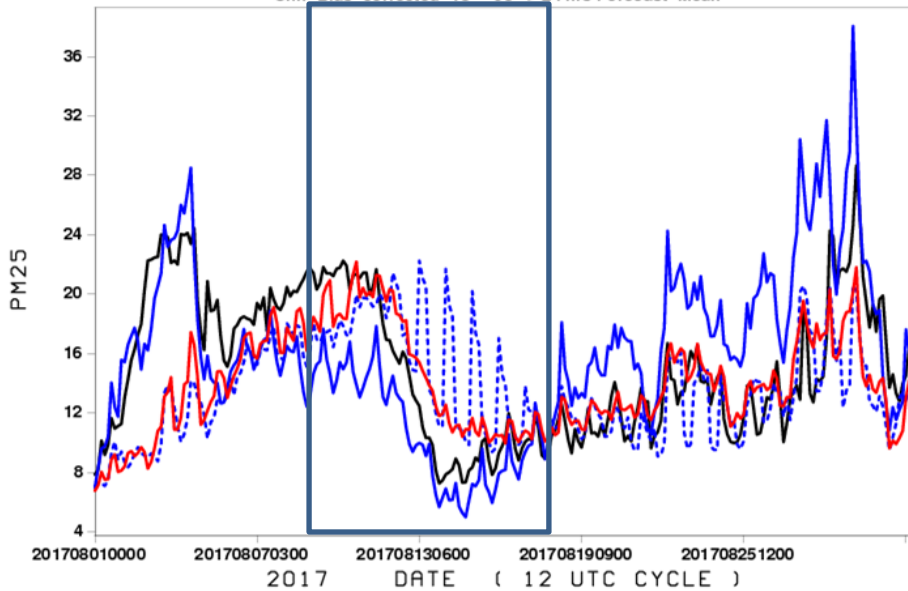- *Note: Operational bias correction still using old V4 training prediction*

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1h PM Day 1 Prod vs Exp BC
Daily Time Series
August 2017
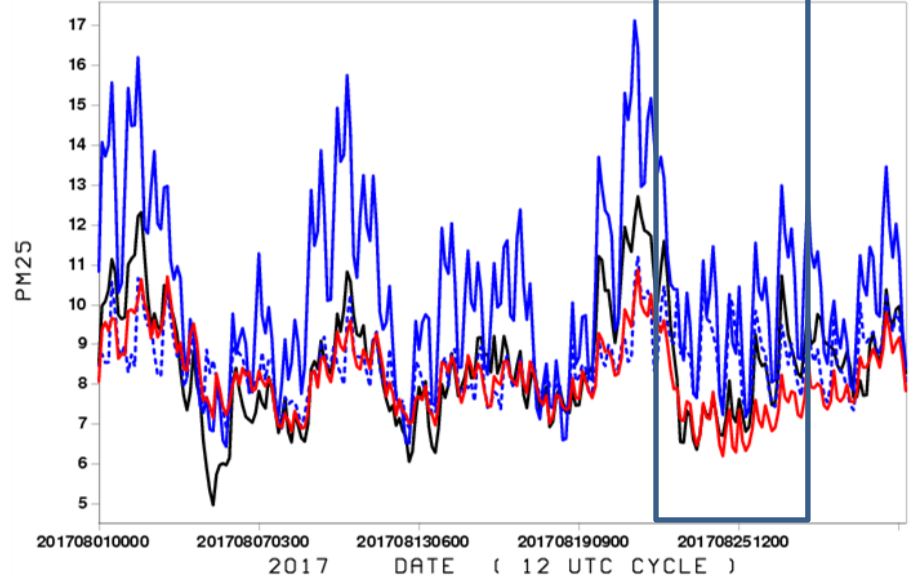
WEST

EAST

Exp Bias correction
- West: - Removes post wild-fire event noise
      - Overcorrects some fire events
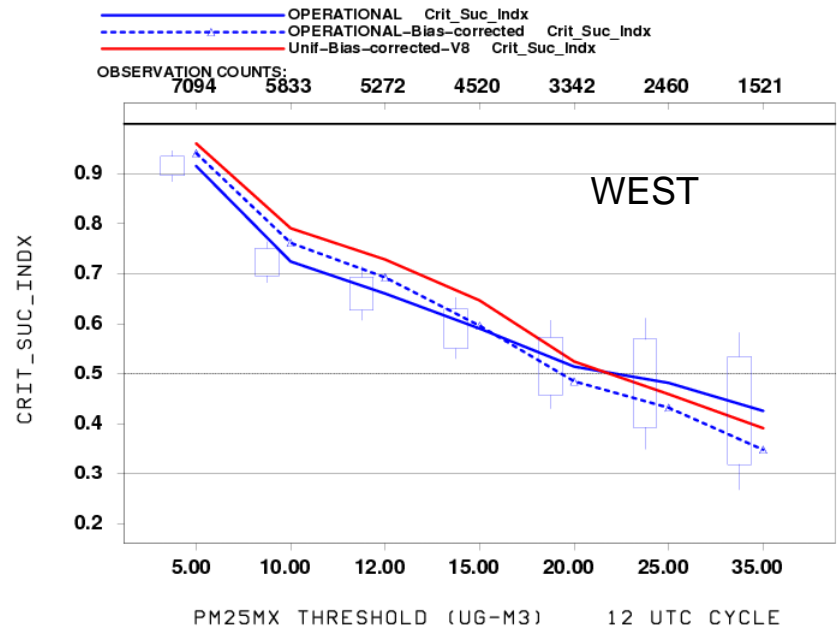- East: Similar to prod BC, some improvement
  around 8/25/17

24

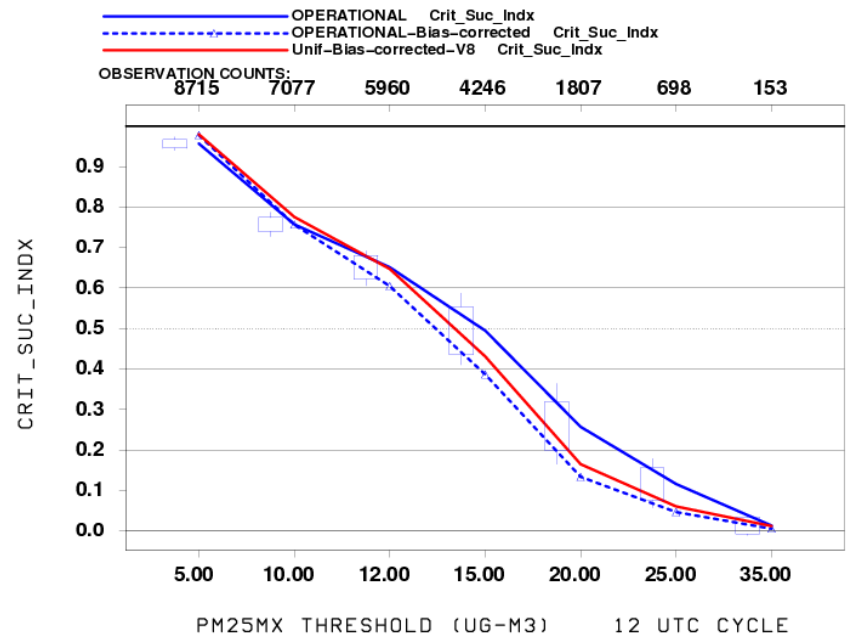# 1 h max PM2.5 Day 2 CSI

Prod, *Prod bias correction*
vs *Exp bias correction*
August 2017

DAY 2 01h–avg PM25MX Crit_Suc_Indx avged by Threshold
20170801 to 20170831

OPERATIONAL   Crit_Suc_Indx
OPERATIONAL–Bias–corrected   Crit_Suc_Indx
Unif–Bias–corrected–V8   Crit_Suc_Indx

OBSERVATION COUNTS:
7094   5833   5272   4520   3342   2460   1521

WEST

DAY 2 01h–avg PM25MX Crit_Suc_Indx avged by Threshold
20170801 to 20170831

OPERATIONAL   Crit_Suc_Indx
OPERATIONAL–Bias–corrected   Crit_Suc_Indx
Unif–Bias–corrected–V8   Crit_Suc_Indx

OBSERVATION COUNTS:
8715   7077   5960   4246   1807   698   153

Exp Bias correction:
- Significant improvement esp. over West except for highest concentrations
- Degradation for higher PM concentrations over East ??
- Reduced POD (not shown)
- *Note: Operational bias correction still using old V4 training predictions*
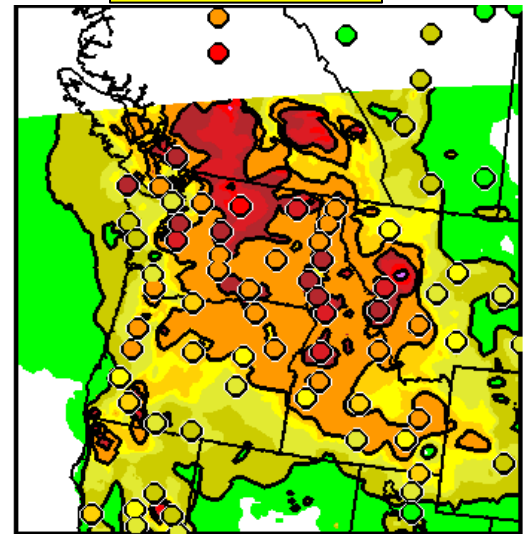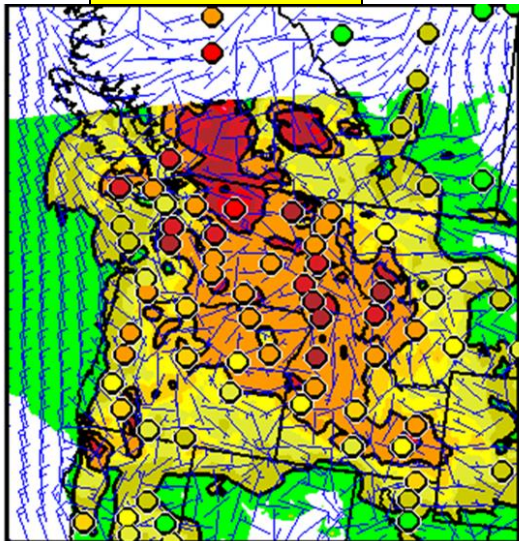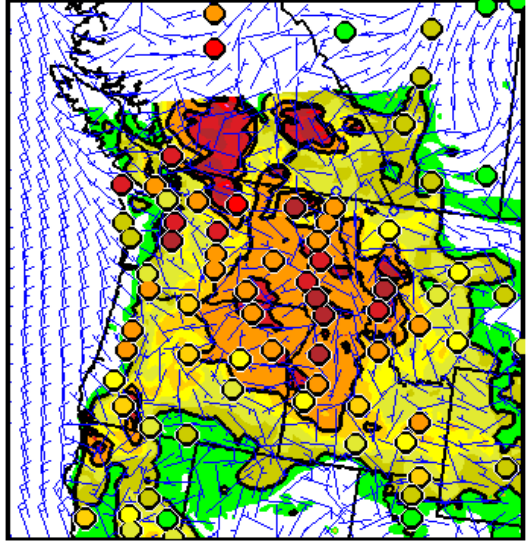
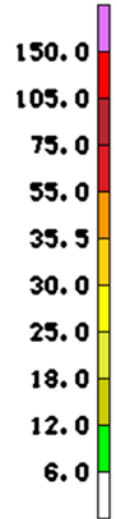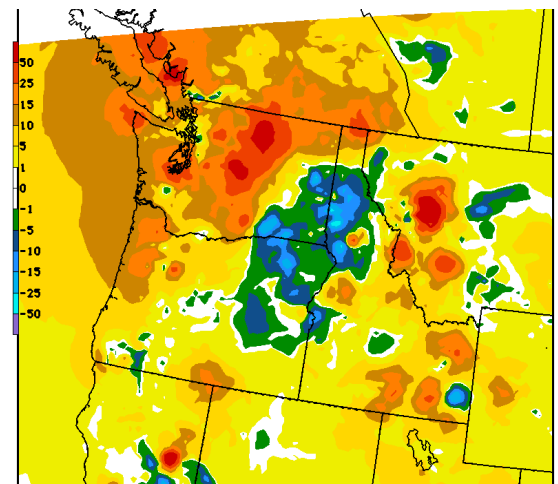# August 9, 2017 Prod vs EXP Bias Correction PM

1 hr day 2 daily MAX PM25

PROD

PROD BC

PARA V8 BC

ARA PROD   DAY2 PMMX01   20170809 12Z CY(

PROD BIAS COR DAY2 PMMX01   20170809 12Z COR V8   DAY2 PMMX01 (UG/M3)   FRI 1708

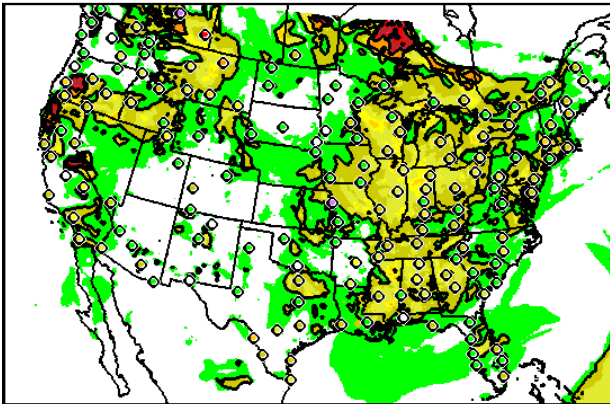Fire case: some improvement over Washington and Western Montana w/ bias correction

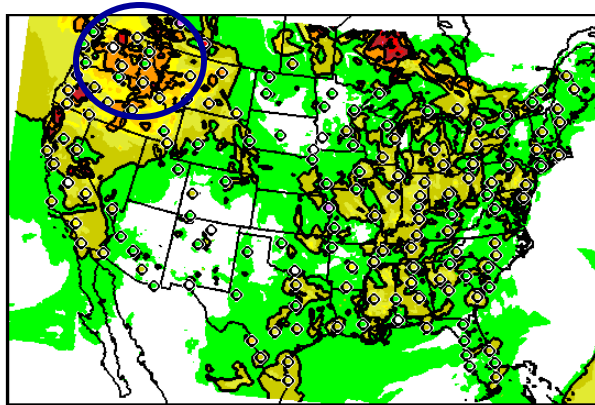EXP - OPER BC aqn DAY2 01 hr avg PMMX from 20170809 12 UTC Run

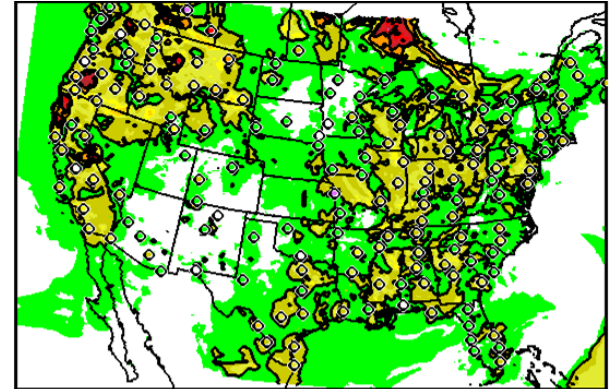# August 14, 2017 Prod vs Bias Correction
1 hr daily MAX PM25 (Day 1)

PARA PROD DAY1 PMMX01 20170814 12Z CYC

PROD

PARA PROD BIAS COR DAY1 PMMX01 20170814 12Z CYC

PROD BC

PARA BIAS COR V8 DAY1 PMMX01 (UG/M3) TUE 170815/0400V016

PARA V8 BC

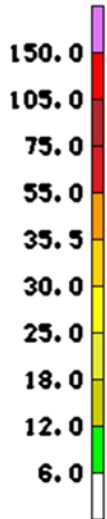150.0 105.0 75.0 55.0 35.5 30.0 25.0 18.0 12.0 6.0

EXP BC: reduces overcorrection after fire events compared to production BC

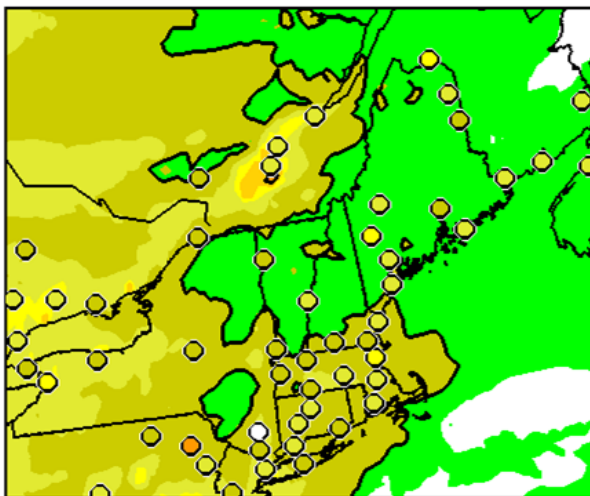# August 22, 27 2017 Prod vs V8 EXP BC

1 hr day 1 daily MAX PM25
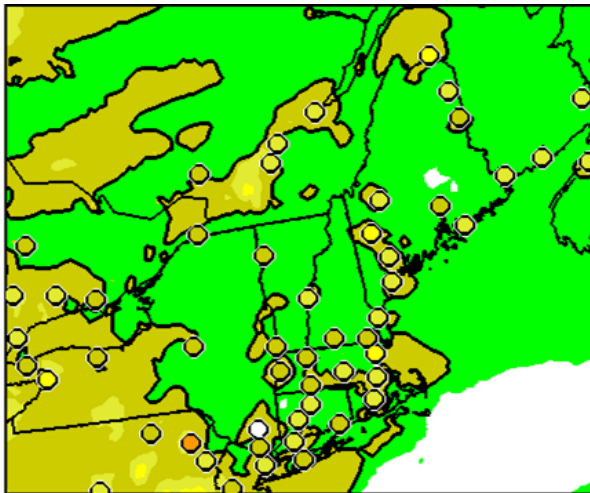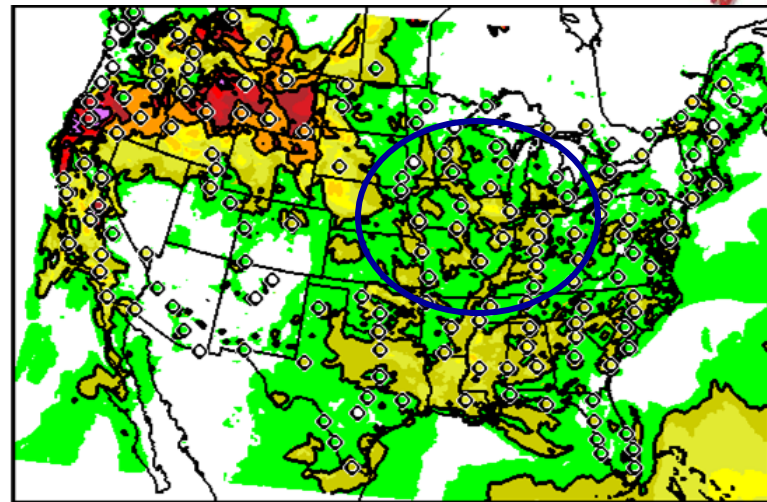
V8 BC

Prod "raw"
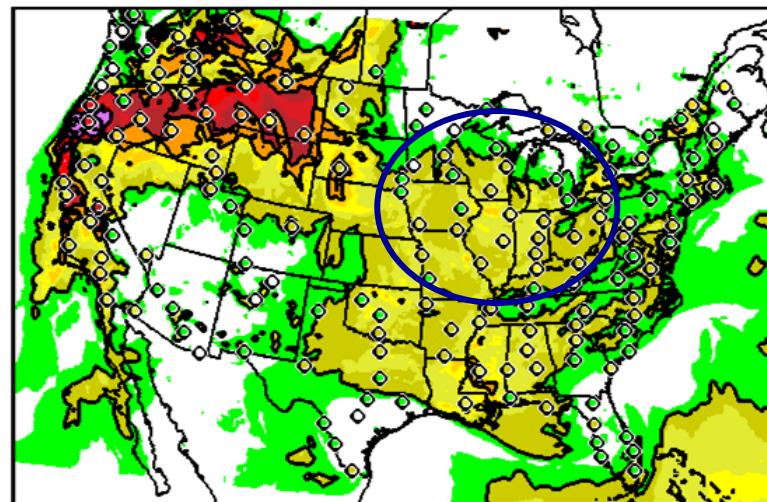
- V8 PM bias correction can still overcorrect raw PM forecasts

1 h avg PM2.5 Diurnal time series

Prod, *Prod bias correction* vs *Exp bias correction*
September 2017
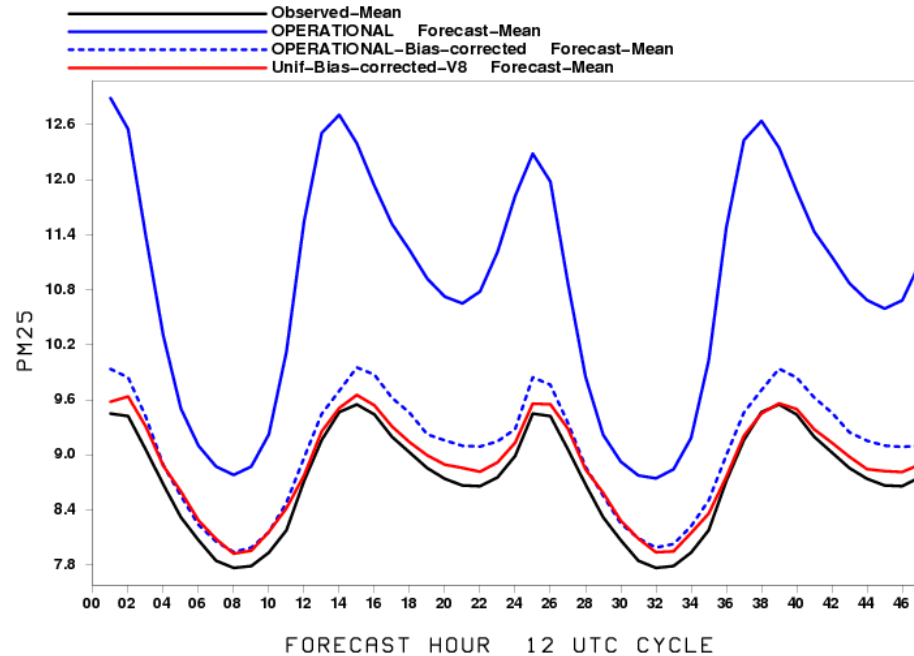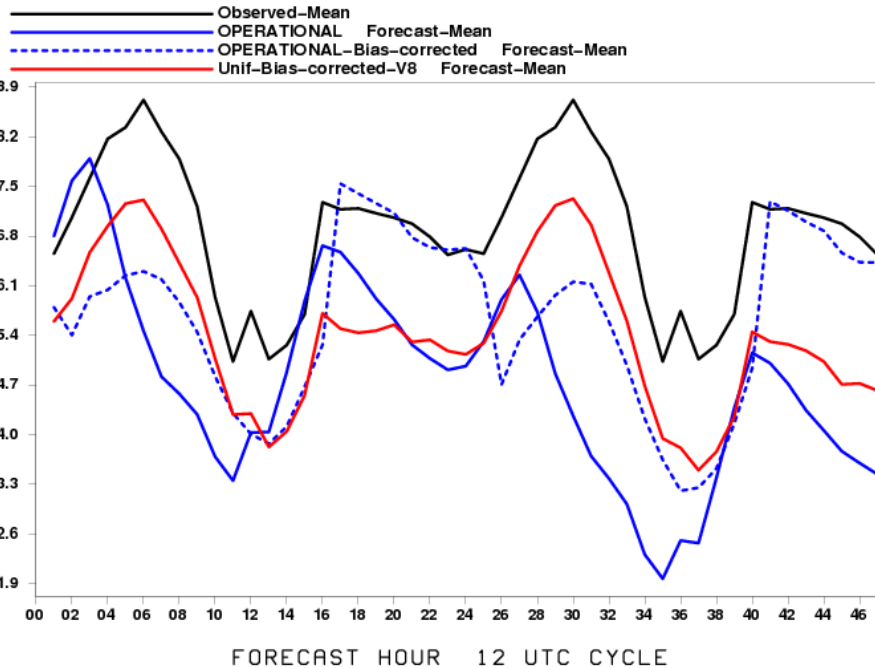
- Improvement with Exp. Bias correction over West during the daytime compared to prod BC
- Best improvement ovoer East with bias correction
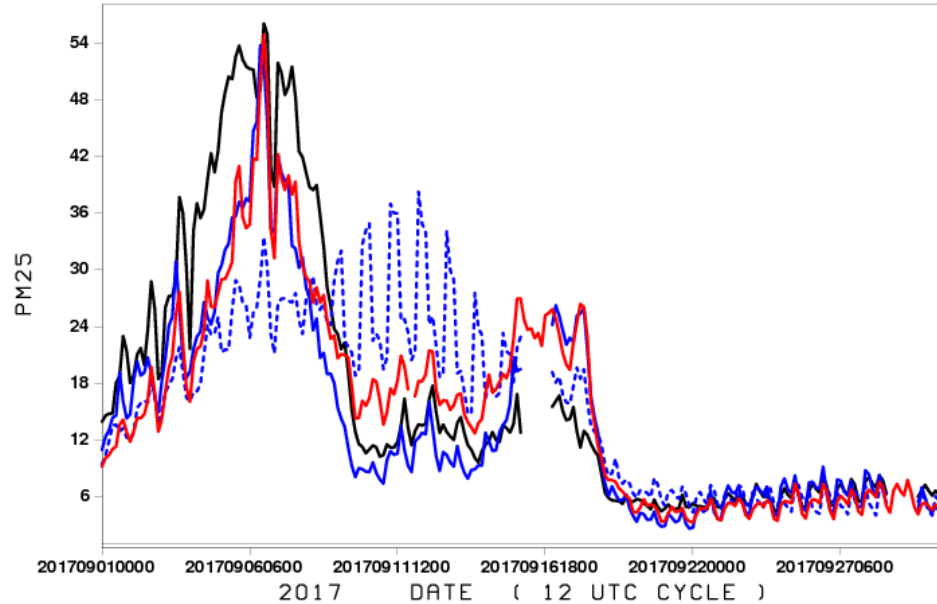- *Note: Operational bias correction using old V4 training prediction ??*

1 h avg PM2.5 Daily time series

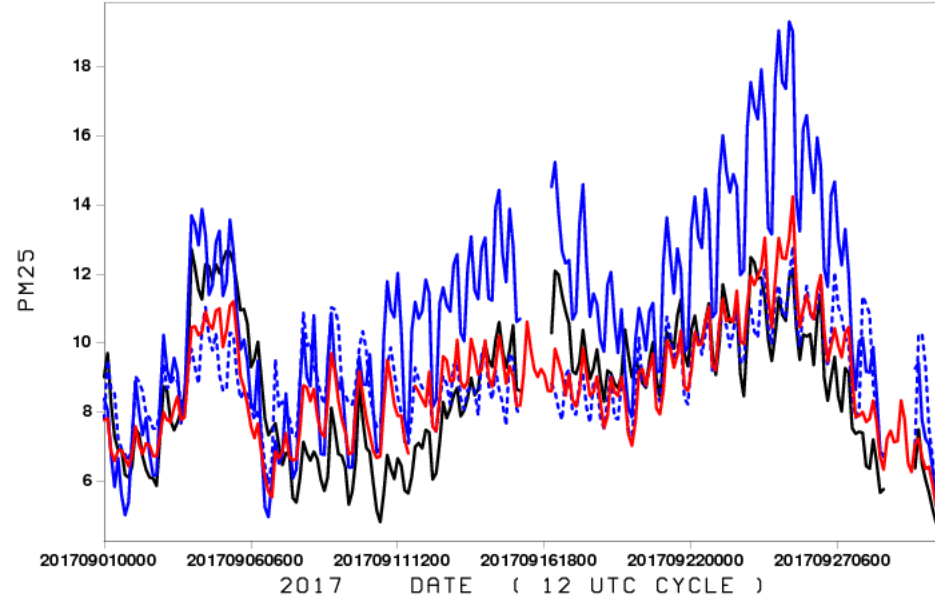## Prod, *Prod bias correction* vs *Exp bias correction*
September 2017

- Improvement with Exp. Bias correction over West compared to prod BC
- Similar results over East
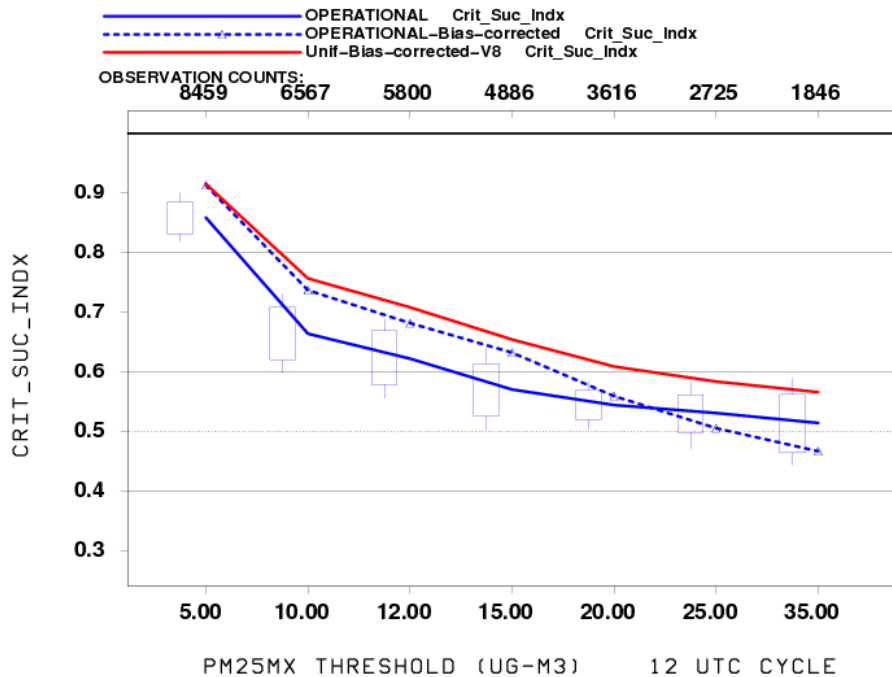- *Note: Operational bias correction using old V4 training prediction ??*
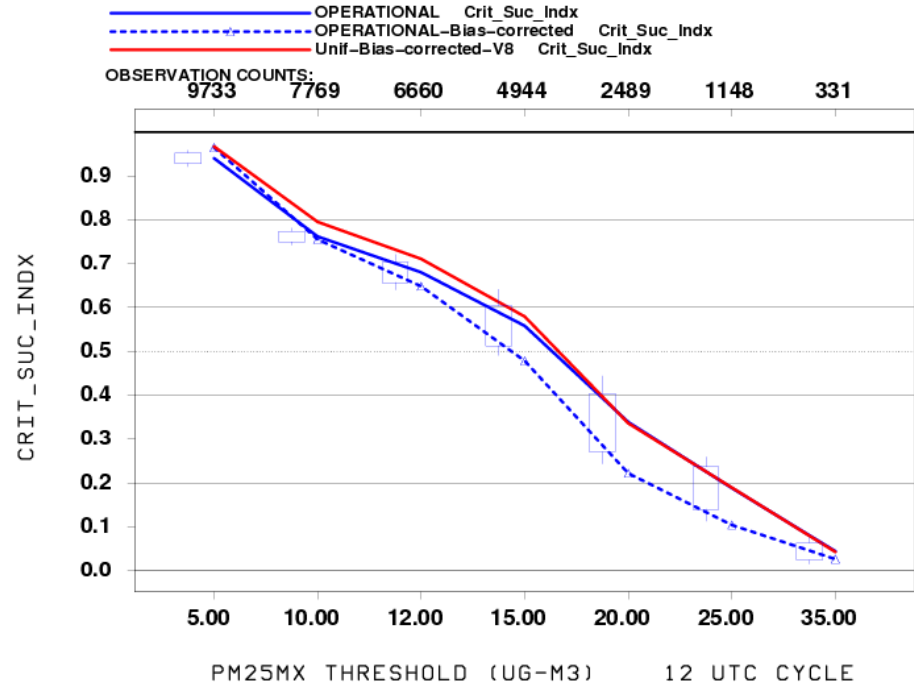
1 h max PM2.5 Day 2 CSI

Prod, *Prod bias correction* vs *Exp bias correction*
September 2017

DAY 1 01h–avg PM25MX Crit_Suc_Indx avged by Threshold
20170901 to 20170930

OBSERVATION COUNTS:
8459 6567 5800 4886 3616 2725 1846

DAY 1 01h–avg PM25MX Crit_Suc_Indx avged by Threshold
20170901 to 20170930

OBSERVATION COUNTS:
9733 7769 6660 4944 2489 1148 331

Exp Bias correction:
- Significant improvement esp. over West except for highest concentrations
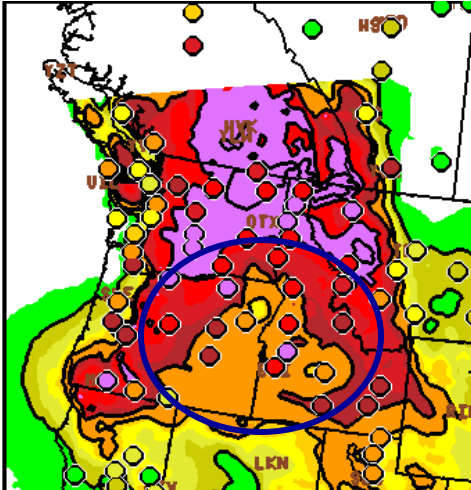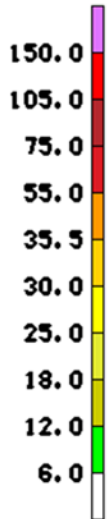- Degradation for higher PM concentrations over East ??
- Reduced POD (not shown)
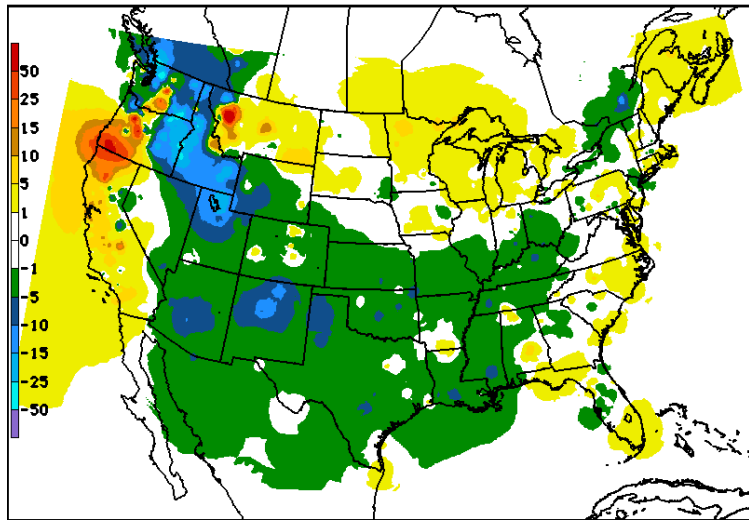- *Note: Operational bias correction still using old V4 training predictions*

31
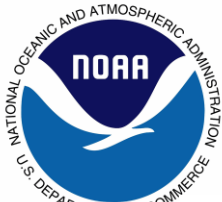
Day 2 daily **_24 hr AVE_** PM25

PARA BIAS COR V8   DAY2 PMAV24 (UG/M3) 20170905 12Z

Exp BC

EXP - OPER BC aqm DAY2 24 hr avg PMAV from 20170905 12 UTC Run
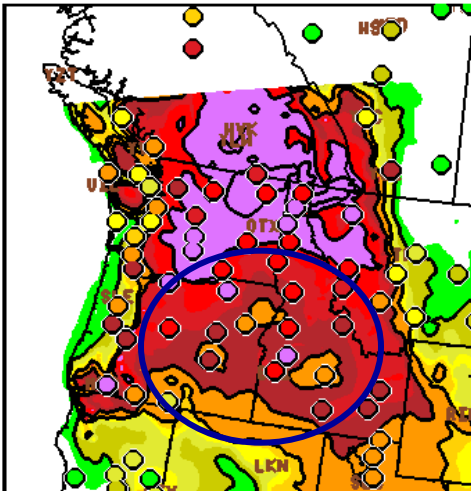
Prod "raw"

PROD   DAY2 PMAV24 (UG/M3) 20170905 12Z CYC

1-h Avg PM25 obs (ug-m3) avged by fcst hrs
20170901 to 20170930
NWEST-Coast

Observed-Mean
OPERATIONAL   Forecast-Mean
OPERATIONAL-Bias-corrected   Forecast-Mean
Unif-Bias-corrected-V8   Forecast-Mean

FORECAST HOUR   12 UTC CYCLE
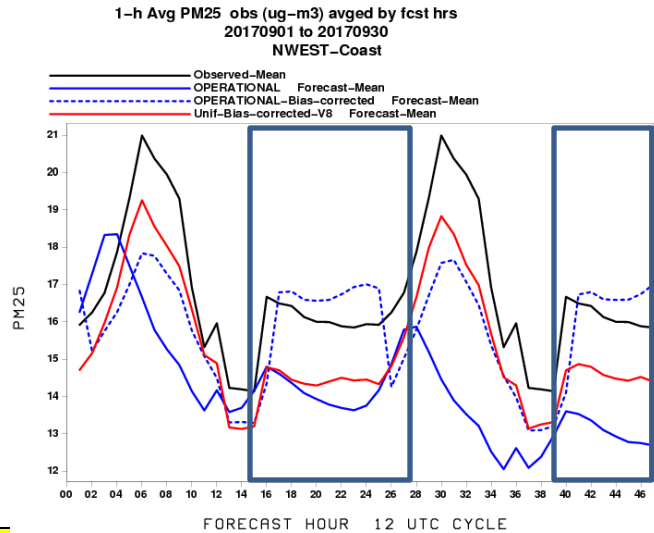
EXP PM bias correction overcorrects raw forecasts over East OR/West ID (due to night-time overcorrection ?)
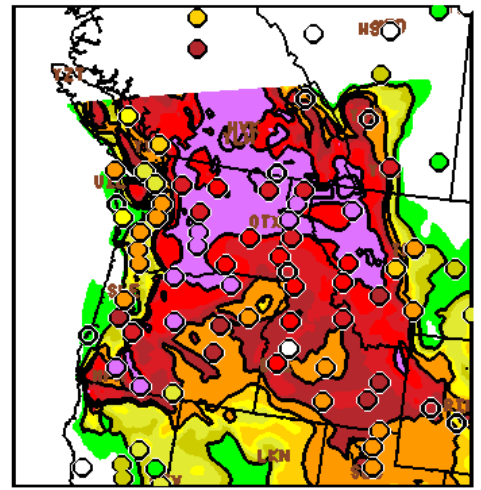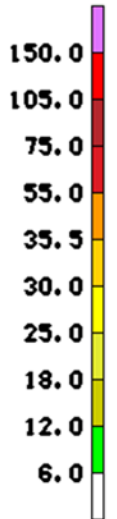
September 5 2017 Prod, Prod BC, V8 EXP BC

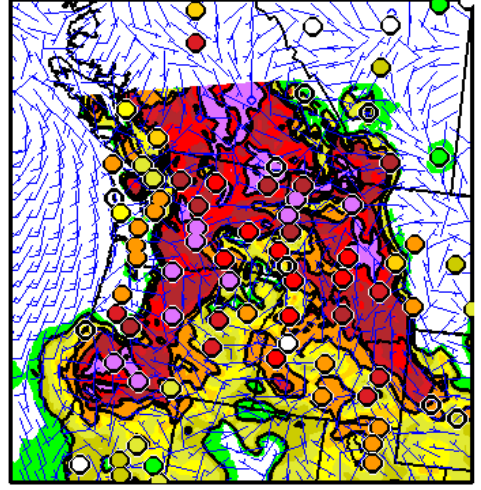## 33 (day) vs 45 hr (night) 1 hr ave PM25 forecast

Prod & EXP BC: worse at night during fire event (too much smoke) but more PM & better during day
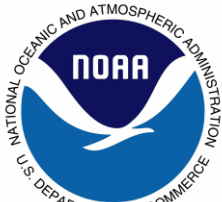
September 16 2017 Prod, Prod BC, V8 EXP BC

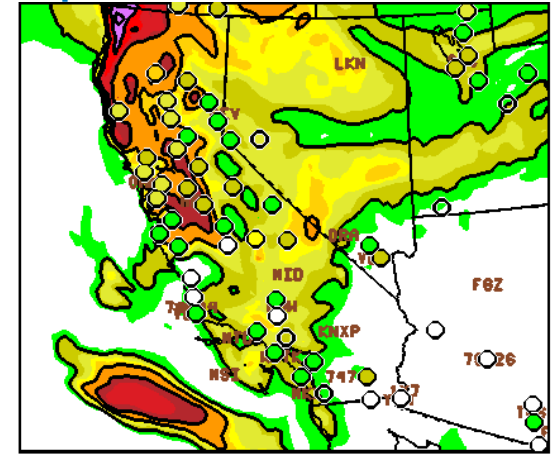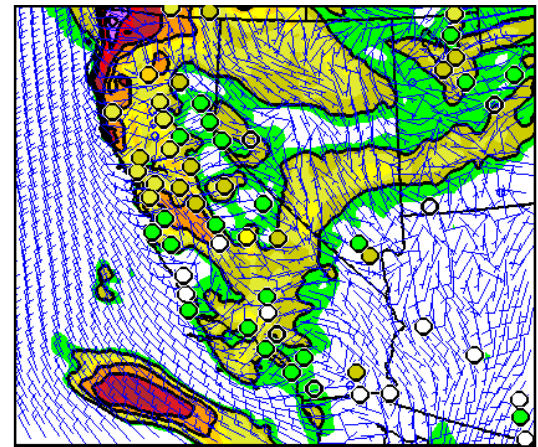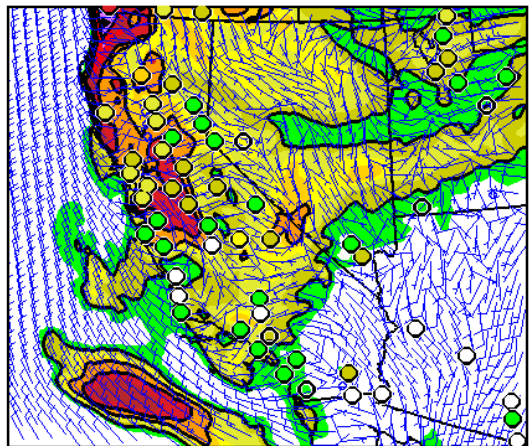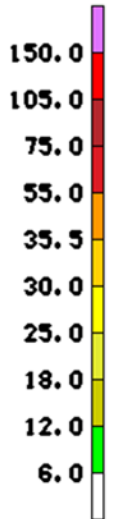## 33 (day) vs 45 hr (night) 1 hr ave PM25 forecast

Prod BC best : less PM during fire event for day and night

January 2018 PM25 Performance
Prod, *Prod BC*, vs EXP BC

1 h avg PM2.5 Diurnal Time series
Prod, *Prod bias correction*
vs *Exp bias correction*
January 2018

1-h Avg PM25 obs (ug-m3) avged by fcst hrs
20180101 to 20180131
West-US

- Observed-Mean
- OPERATIONAL Forecast-Mean
- OPERATIONAL-Bias-corrected Forecast-Mean
- EXPERIMENTAL Forecast-Mean
- Unif-Bias-corrected-V8 Forecast-Mean
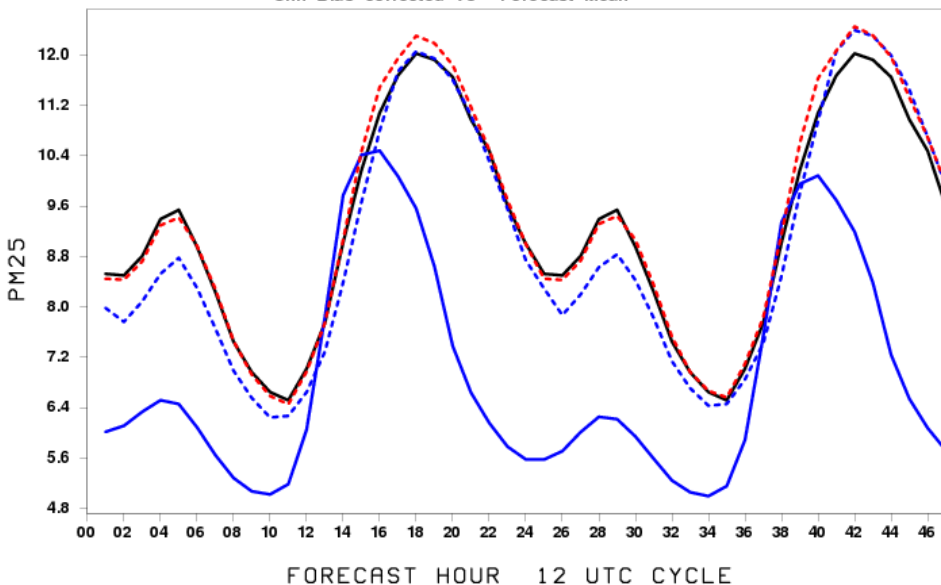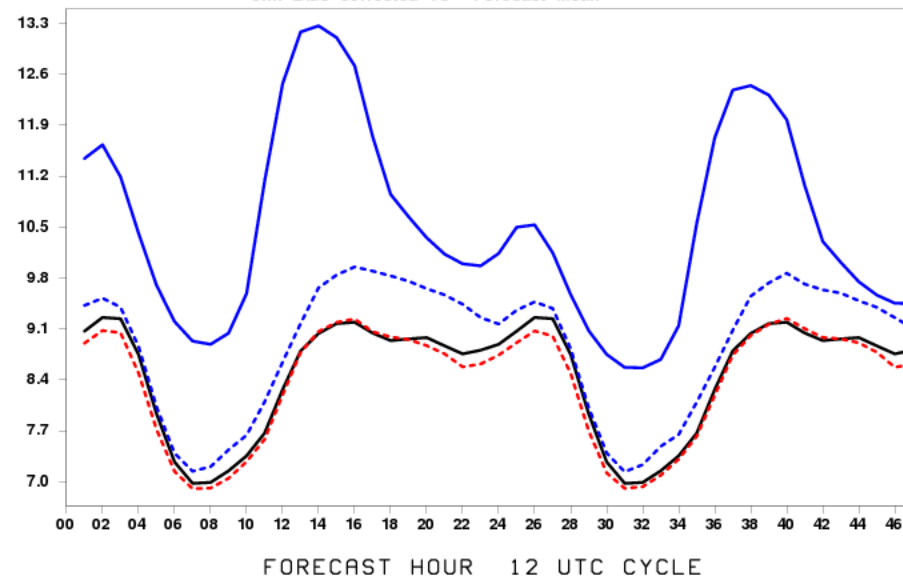
FORECAST HOUR 12 UTC CYCLE

1-h Avg PM25 obs (ug-m3) avged by fcst hrs
20180101 to 20180131
East-US

- Observed-Mean
- OPERATIONAL Forecast-Mean
- OPERATIONAL-Bias-corrected Forecast-Mean
- EXPERIMENTAL Forecast-Mean
- Unif-Bias-corrected-V8 Forecast-Mean

FORECAST HOUR 12 UTC CYCLE

- Less PM (improved) over East with experimental bias correction processing
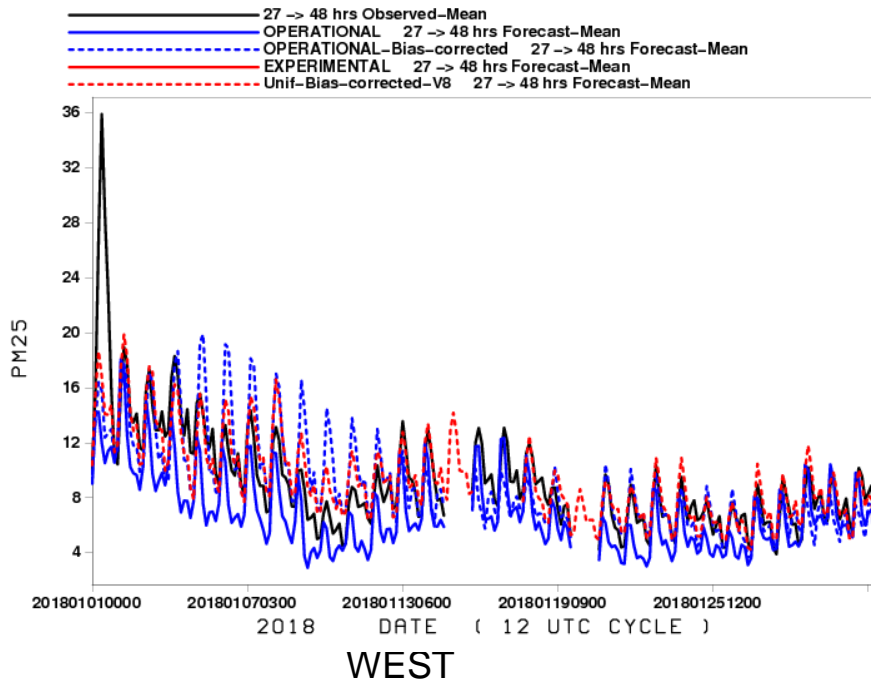*Note: Operational bias correction now using correct V5 training predictions*
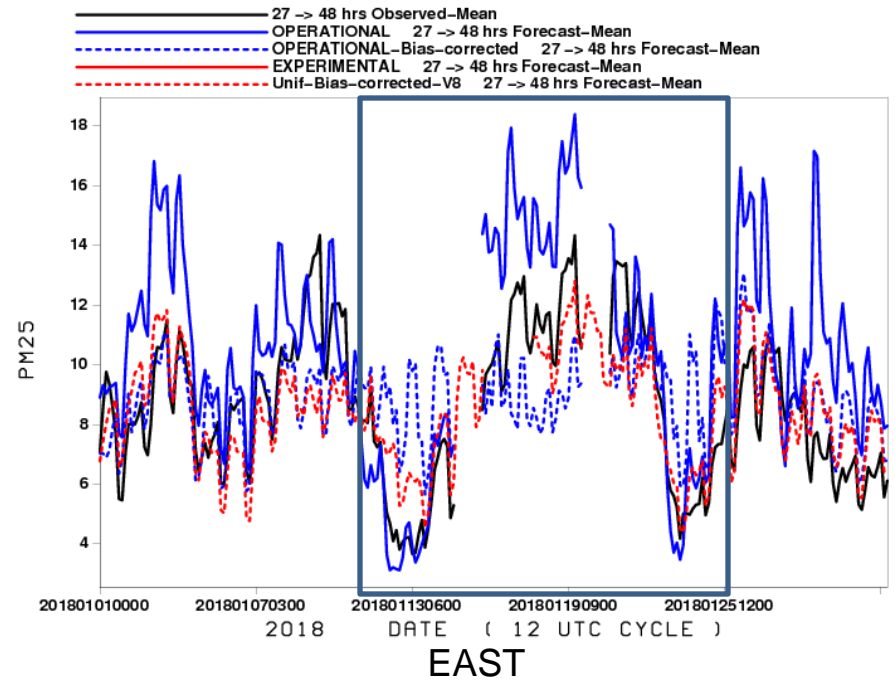
1h PM Prod vs Exp BC
Day 2 Daily Time Series
January 2018

WEST

EAST

Exp: Bias correction
• West: reduces noise seen after high events
• East: Improved over prod BC especially mid- January
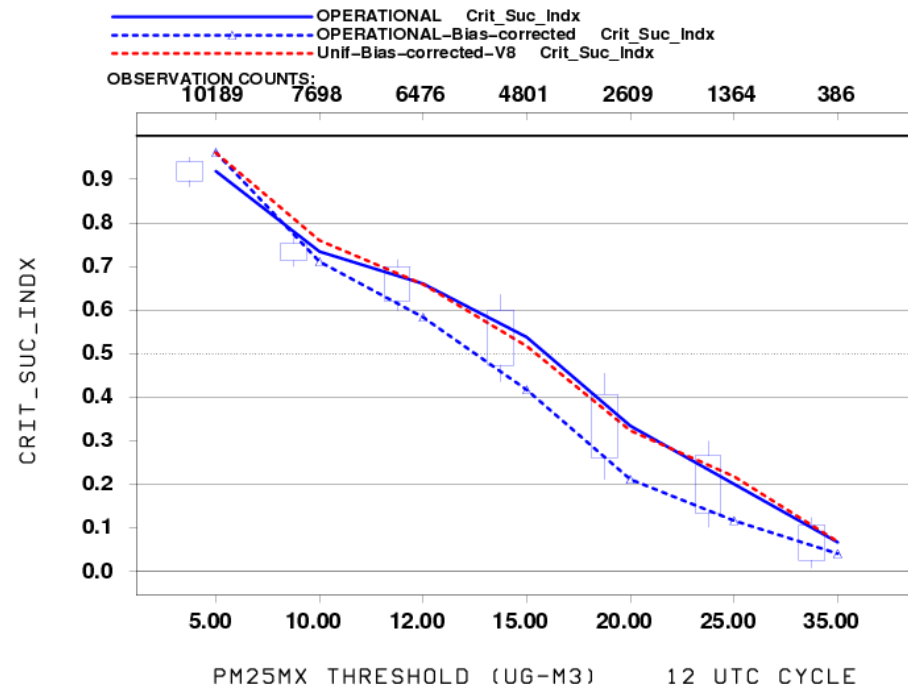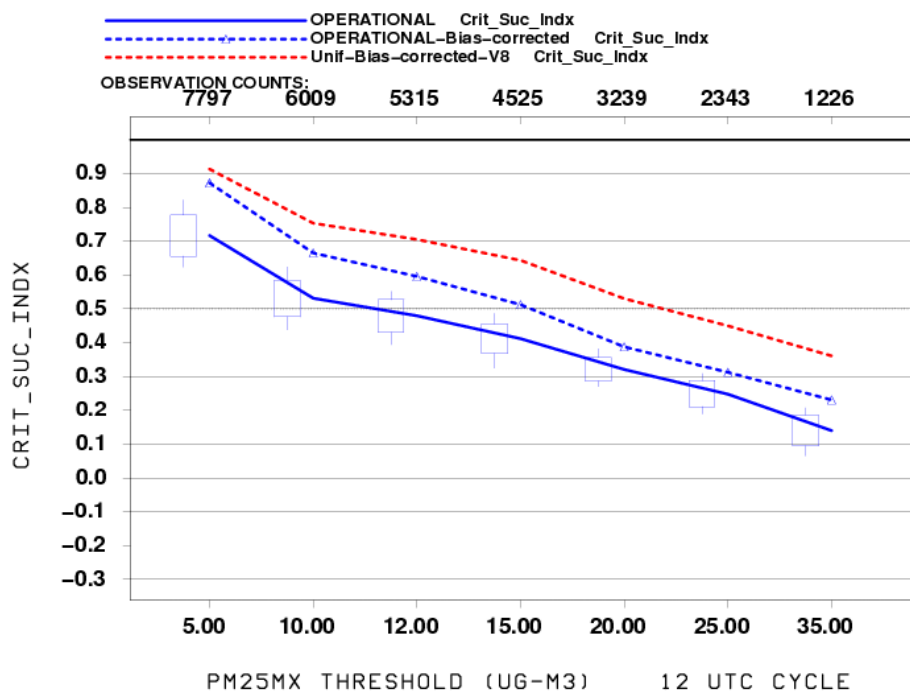
1 h max PM2.5 Day 1 hit rate

Prod, *Prod bias correction*
vs *Exp bias correction*
January 2018

DAY 1 01h-avg PM25MX Crit_Suc_Indx avged by Threshold
20180101 to 20180131

DAY 1 01h-avg PM25MX Crit_Suc_Indx avged by Threshold
20180101 to 20180131
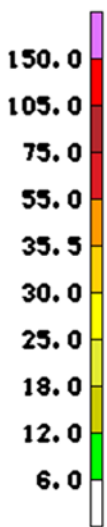
<div style="background-color: yellow;">

•   Large improvement over raw predictions with Exp. Bias correction mainly over West
Note: Operational bias correction using V5 training predictions but less sites, not using SW radiation for analog identification and w/o rare event patch (may explain degradation over East)
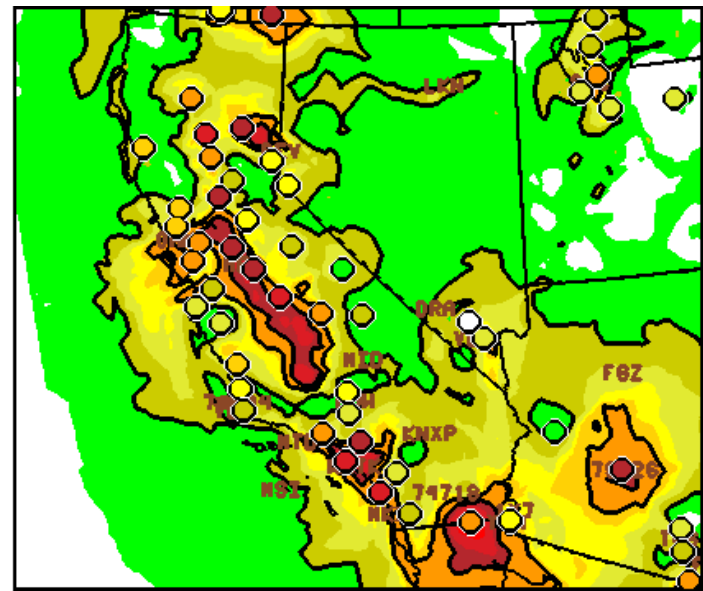
</div>

Raw vs Bias Correction PM

Day 2 daily MAX 1hr PM25
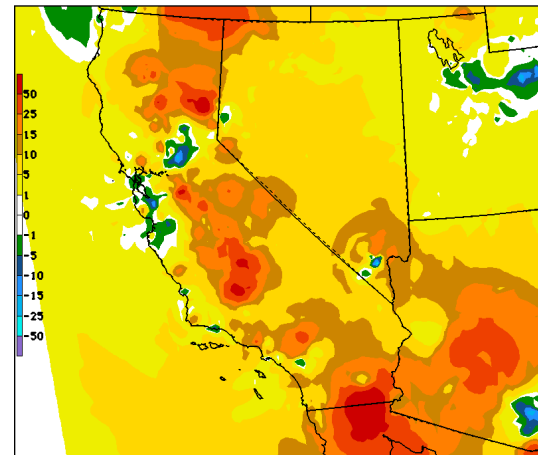
January 1, 2018 West high pm event
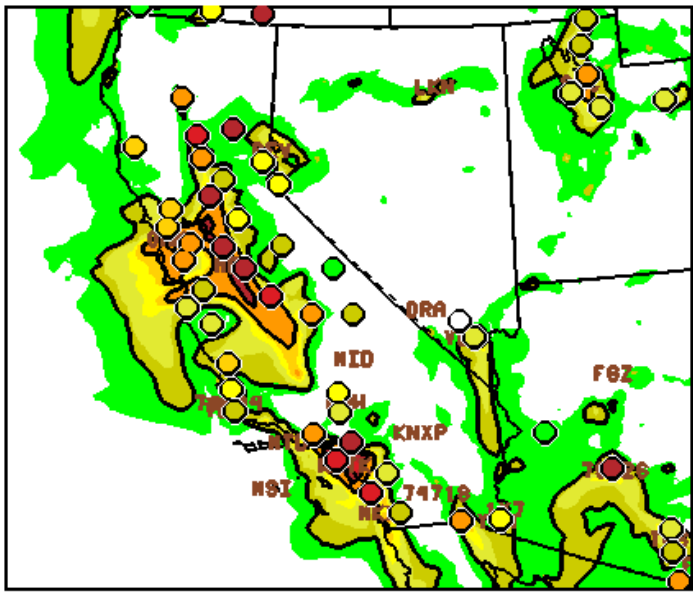
PROD DAY2 PMMX01 (UG/M3) 20180101 12Z CYC-

PARA BIAS COR V8 DAY2 PMMX01 (UG/M3) 20180101 12Z

Bias correction better captures stagnation episode in Central Valley
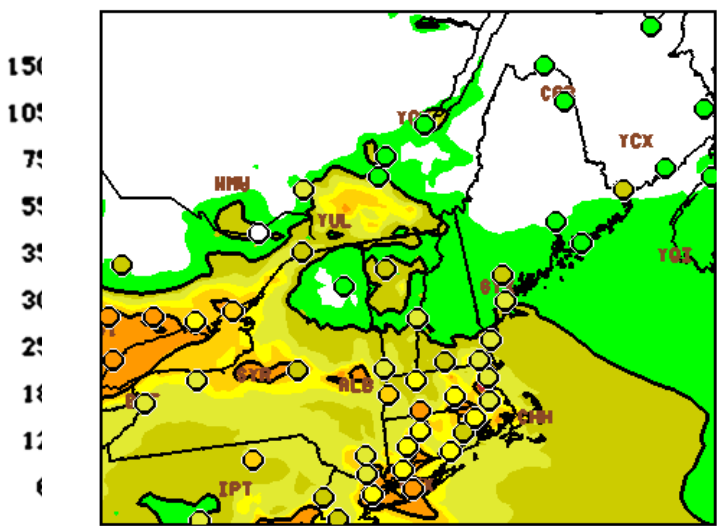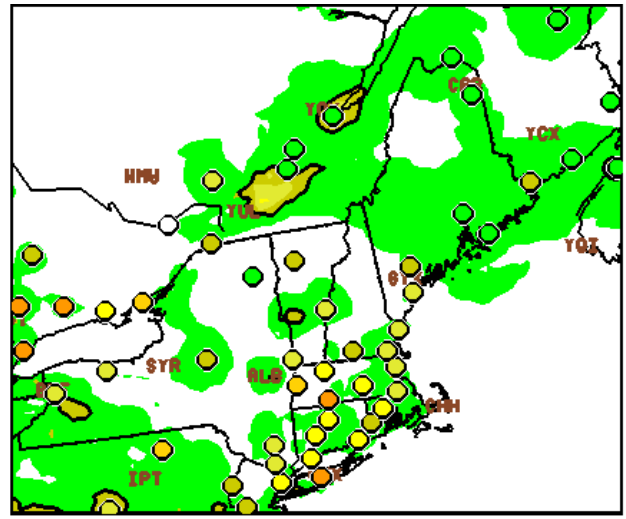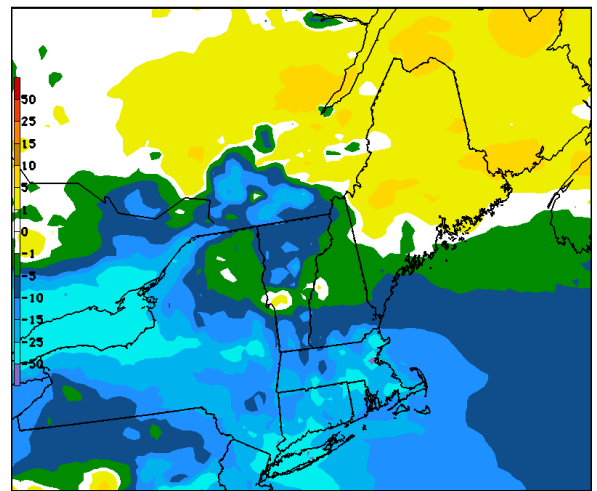
EXP - OPER BC agm DAY2 01 hr avg PMMX from 20180101 12 UTC Run

Raw vs Bias Correction PM
Day 2 daily MAX 1hr PM25
January 21, 2018 NE high pm event

PROD DAY2 PMMX01 (UG/M3) 20180120 12Z CYC

PARA BIAS COR V8 DAY2 PMMX01 (UG/M3) 20180120 12Z

EXP - OPER BC aqm DAY2 01 hr avg PMMX from 20180120 12 UTC Run

Bias correction over-corrects stagnation
episode over NE US
But better prediction for Jan. 22
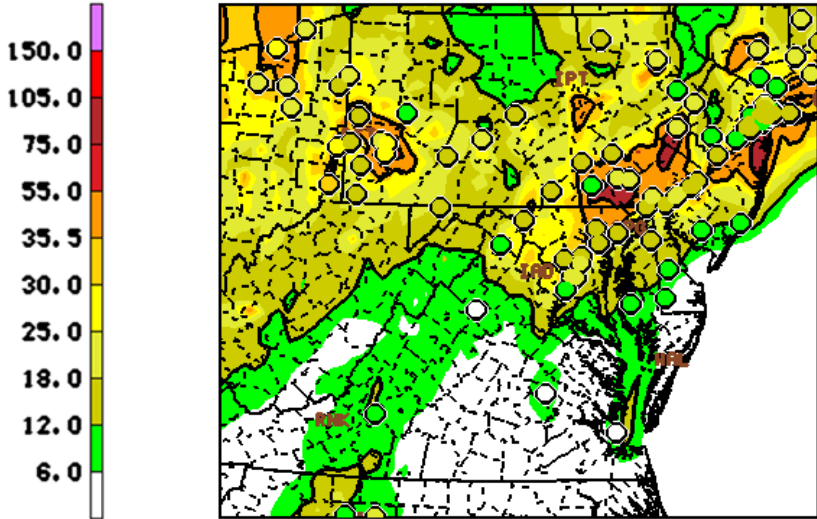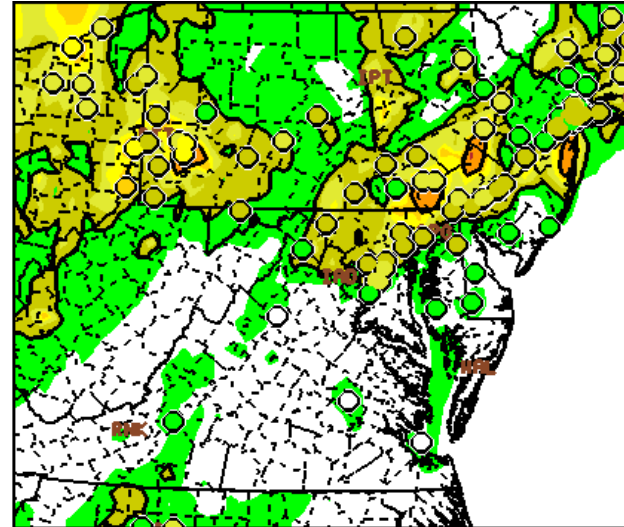Why was this case missed ?

Raw vs Bias Correction PM
Day 2 daily MAX 1hr PM25
January 28, 2018 NE high pm event

PROD DAY2 PMMX01 (UG/M3) 20180127 12Z CYC

PARA BIAS COR V8 DAY2 PMMX01 (UG/M3) 20180127 12Z

EXP - OPER BC a9n DAY2 01 hr av9 PMMX from 20180127 12 UTC Run

Significant improvement with Bias correction

Results

		July	August	September	January
Ozone	East	BC +	BC ++	BC +	
	West	BC ++	BC ++	BC ++	
PM Prod	East	S	BC ++	BC ++	+ / - (cont. sc.)
	West	BC +	BC -	BC +	BC ++
PM Exp	East	BC ++	BC ++	BC ++	BC ++
	West	BC ++	BC -	BC +	BC ++

- Ozone BC: Largest improvement over West where ozone is underpredicted
- PM EXP BC:
    - Largest improvement over East for July/Jan
   - Degradation from raw prod over West Aug (fires)

Summary

- Ozone Bias Correction: Large improvement without degrading exceedence cases in Summer

- Summer PM bias correction :
  - Overall improvement statistically correcting raw model over-predictions (still too much PM near fires at night)
  - Still some overcorrection during fire events but improvements after high PM events
  - Local PM maxima for several cases in July (12th-15th) for one site in Eastern Montana (Not as evident from August onward)

- Winter PM bias correction:
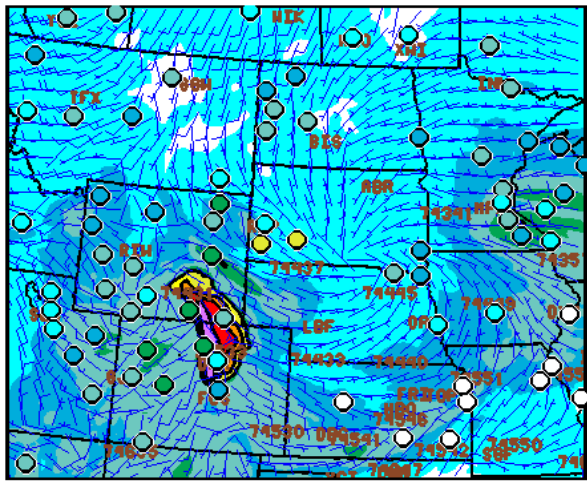 - Improved over west with bias correction but still mixed for some stagnation episodes over North East

Winter Colorado Ozone Plume
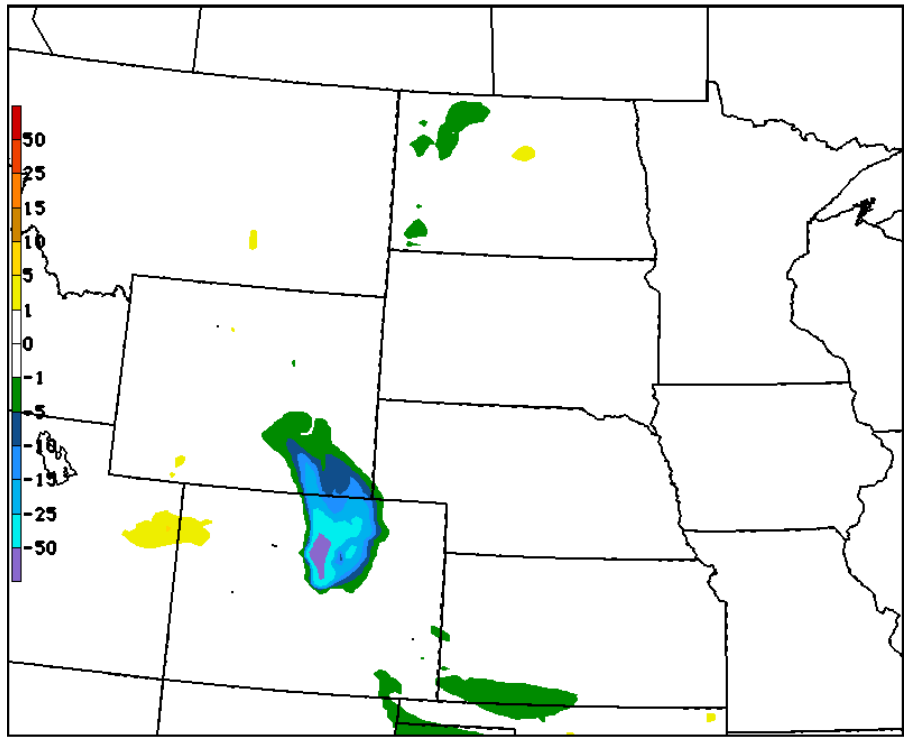## Day 1 daily MAX 8hr Ozone
February 23, 2018
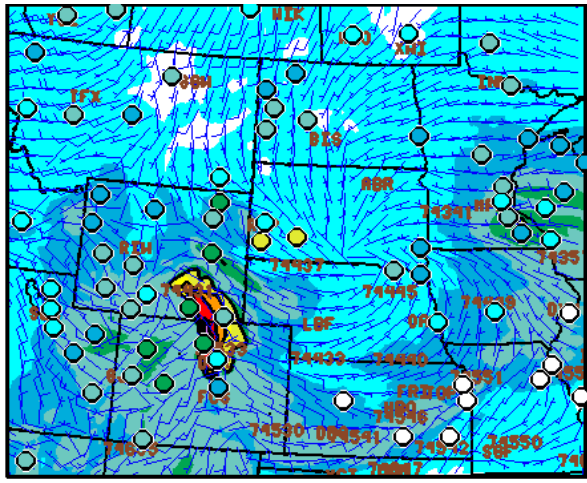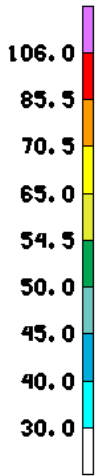
CO ozone plume still too strong but improved with VOC ratio updates to oil/gas sector emissions

Web pages
AQM V5.1

- Real-time prod vs prod BC runs (July 2016-Present)
  - http://www.emc.ncep.noaa.gov/mmb/aq/cmaqbc/web/html/max.html

- Prod vs para pm/ozone BC
  - July, Aug, Sept 2017, Jan. 2018, Mar->present
  - http://www.emc.ncep.noaa.gov/mmb/aq/cmaqparabc/web/html/max.html
- Verification statistics (prod vs parabc for pm/ozone
  - Jul 2017-Feb 2018
  - http://www.emc.ncep.noaa.gov/mmb/aq/fvs/web/html/regular.html
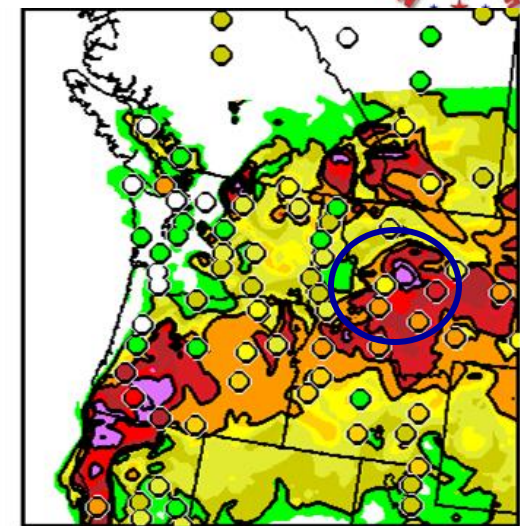
BACKUPS
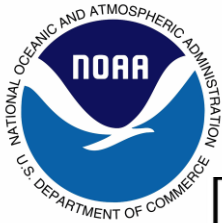
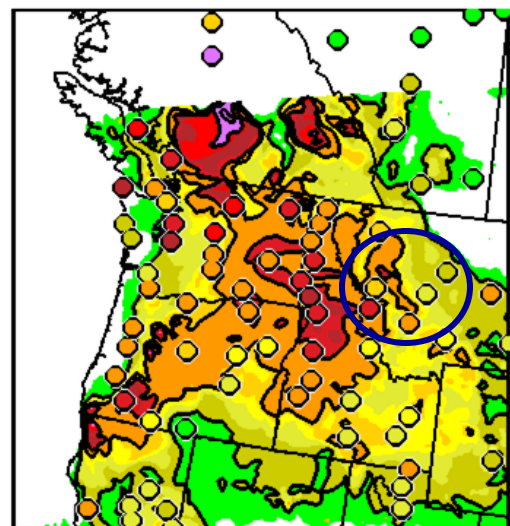# August 2017 Prod vs Bias Correction PM

1 hr day 1 daily MAX PM25
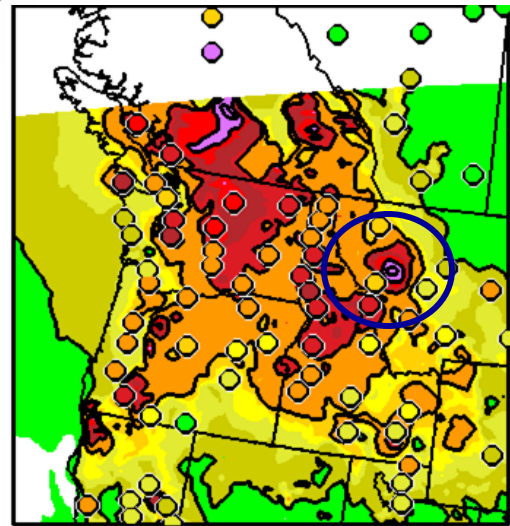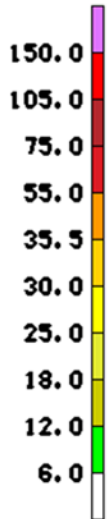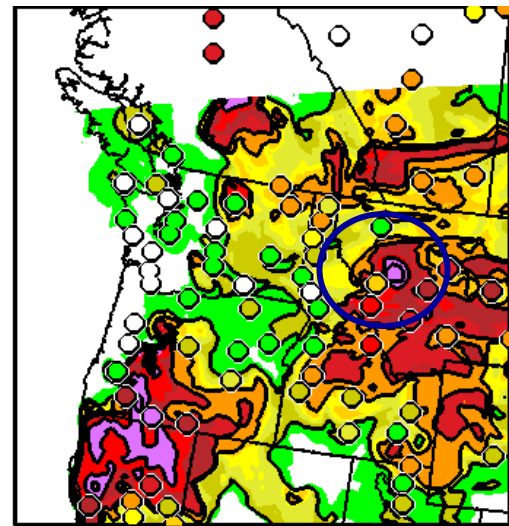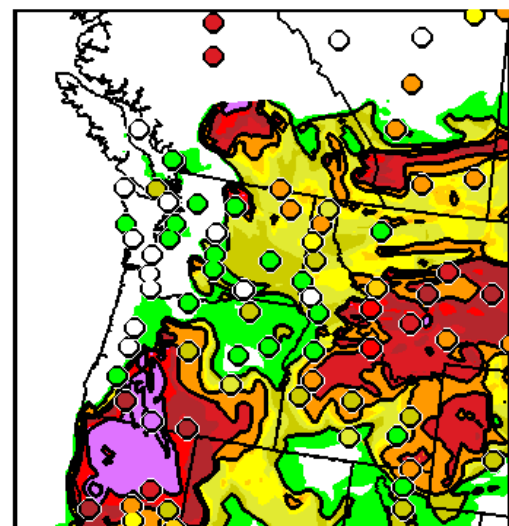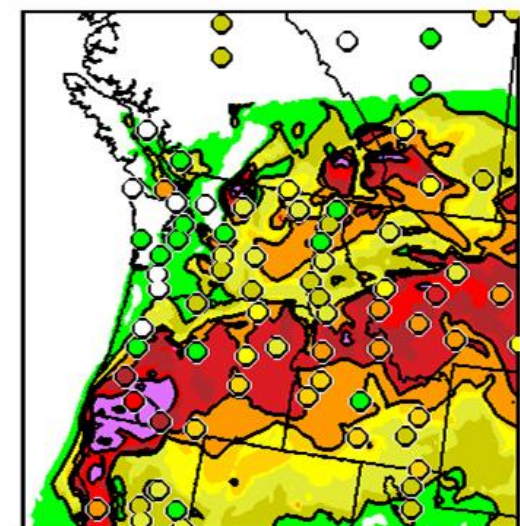
Fire cases: persistent local max in western MT but overall improvements

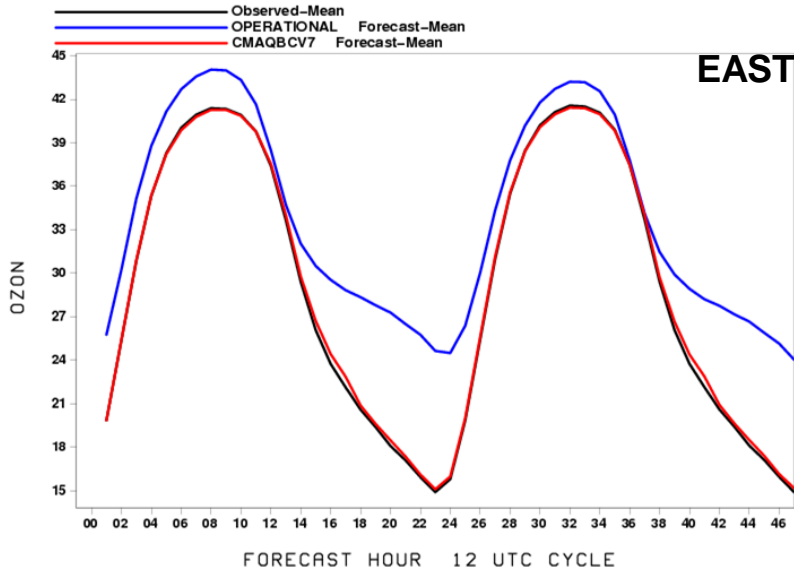# Ozone Errors: July 2017
Obs vs Raw vs Bias Corrected

1-h Avg OZON obs (PPB) avged by fcst hrs
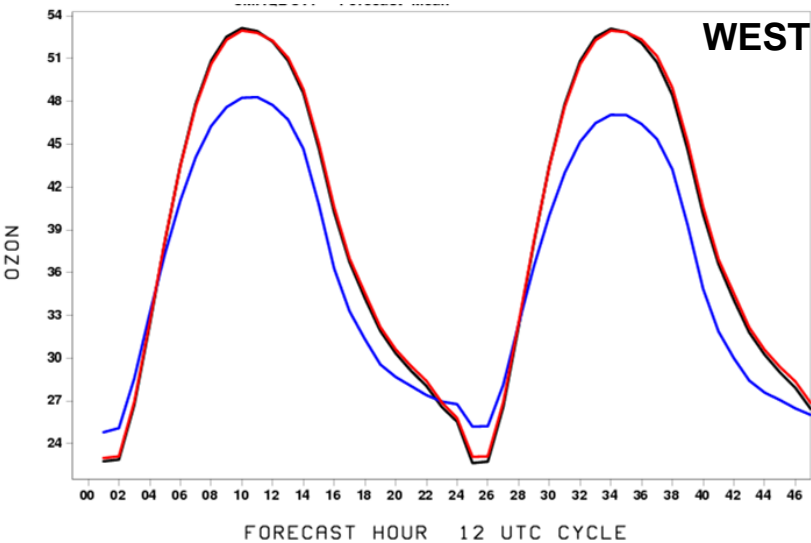20170701 to 20170731
East-US

Observed-Mean
OPERATIONAL   Forecast-Mean
CMAQBCV7   Forecast-Mean

EAST

WEST

DAY 2 1-h Avg OZON obs (PPB)
Northeast

25 -> 48 hrs Observed-Mean
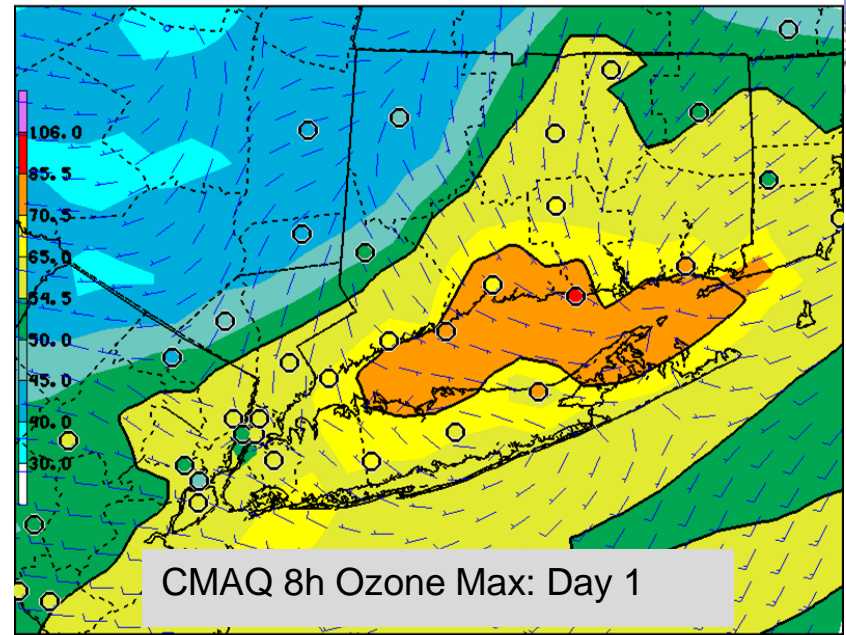OPERATIONAL   25 -> 48 hrs Forecast-Mean
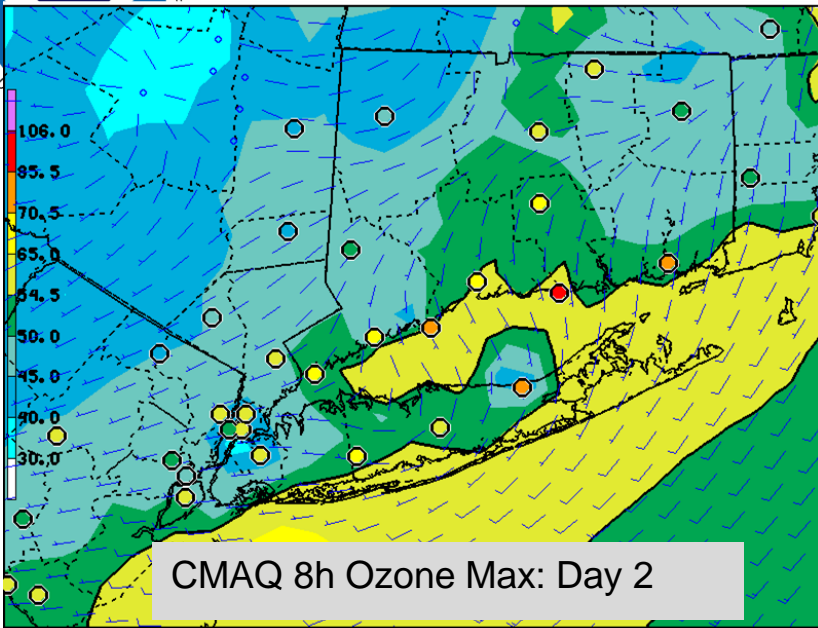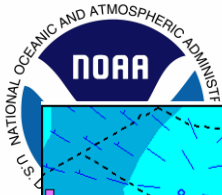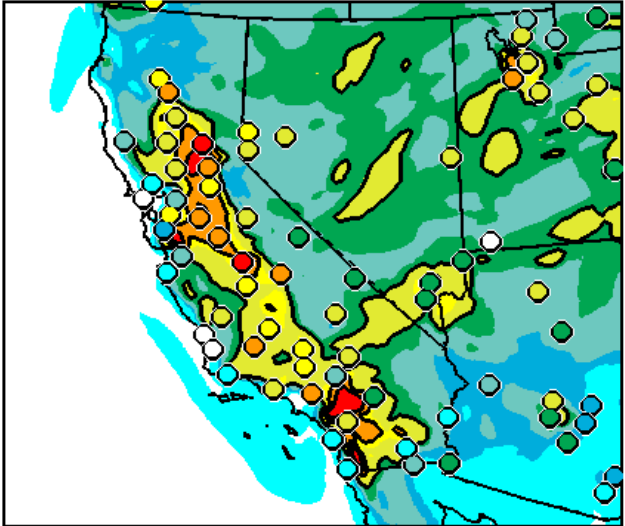CMAQBCV7   25 -> 48 hrs Forecast-Mean
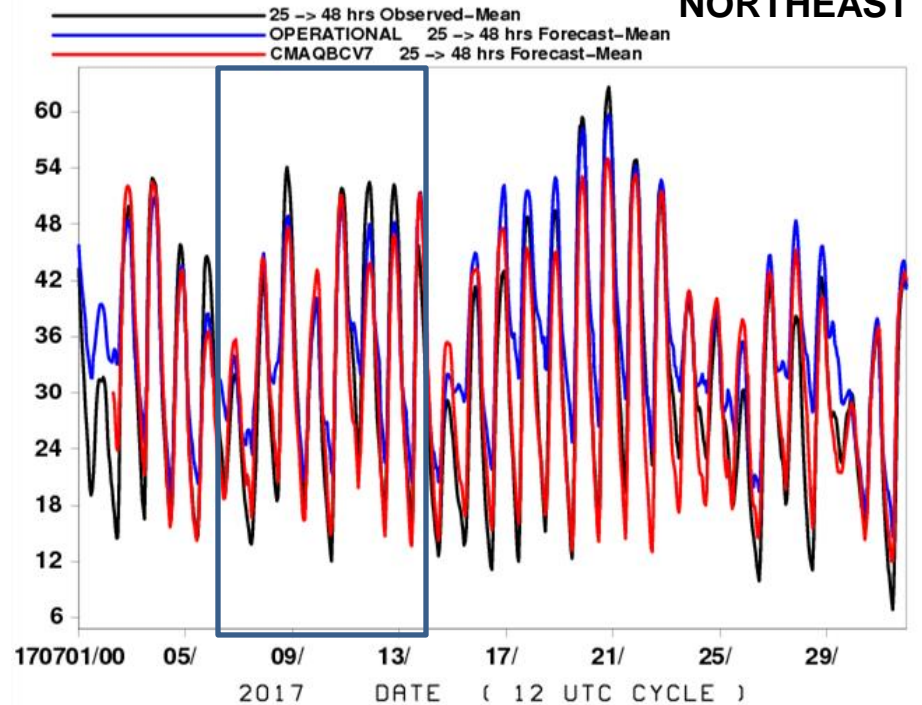
NORTHEAST

East : Overprediction overall but underprediction for July 10-12 exceedences
West: Continued underprediction
O3 BIAS CORRECTION:
→ Diurnal performance good, overcorrects some events (July 10-12, 18-21)
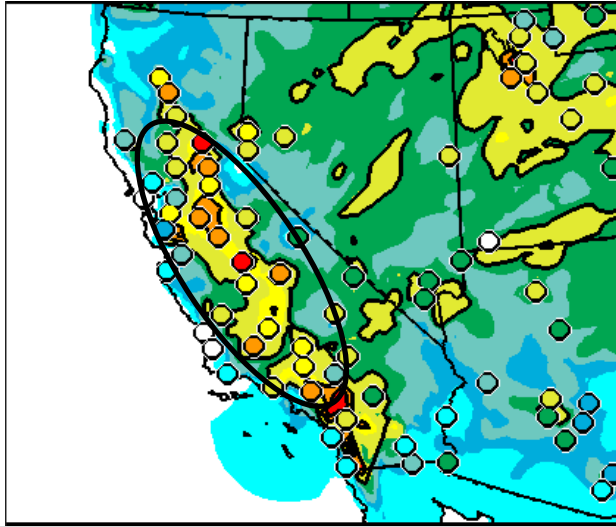
July 12, 2017 NAM-CMAQ V5 Performance

CMAQ 8h Ozone Max: Day 2

CMAQ 8h Ozone Max: Day 1

Bias Corrected 8h Ozone Max: Day 2

8h Ozone Max: Day 1 Mdl-Obs
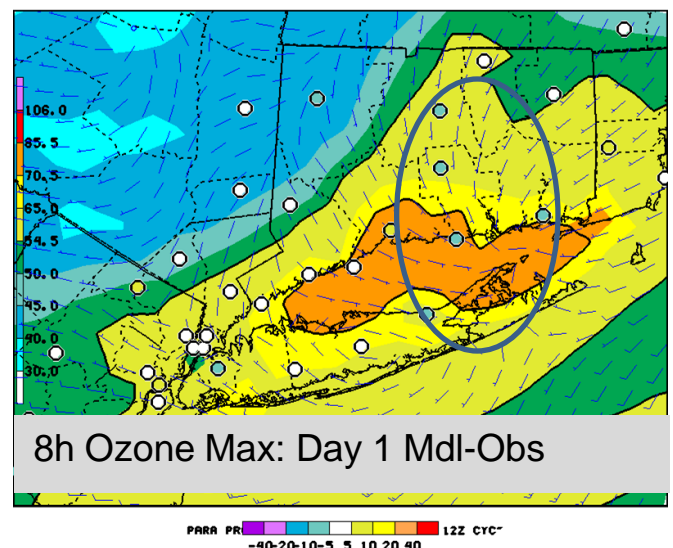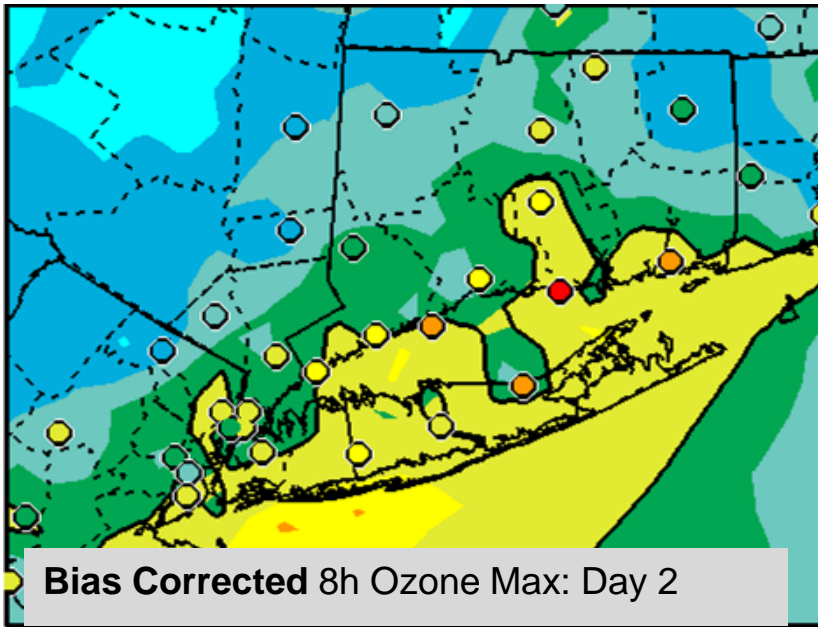
- Continued less ozone predicted for day 2
- O3 Bias correction.improved over LI

July NAM-CMAQ V5 Performance

Southwest
July 31,2017
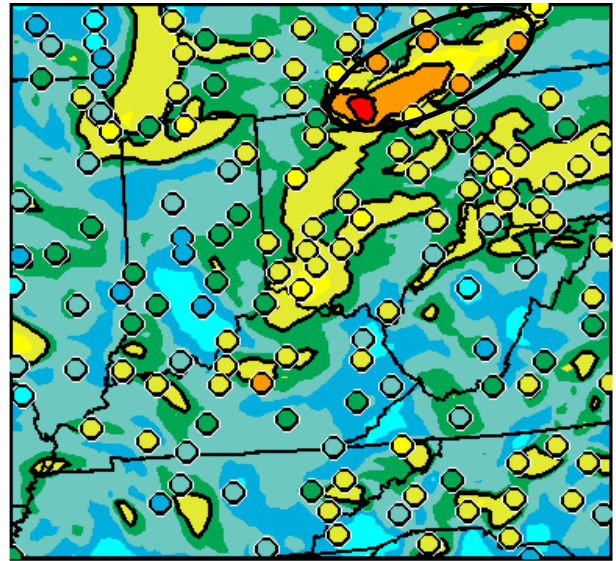
CMAQ 8h Ozone Max: Day 2

Bias Corrected 8h Ozone Max: Day 2

Ohio Valley
July 19, 2017

PROD 4X-DAY   DAY1 OZMXO8   2017Q

PARABC BIAS COR DAY1 OZMXO8   20170719 12Z
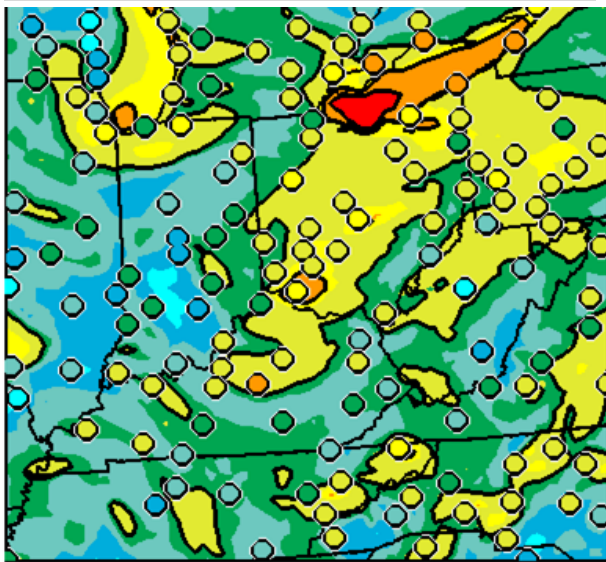
- Continued less ozone predicted for day 2
- BC: Overcorrected in Sacramento & Ohio Valleys