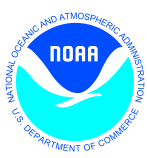


# Improvements to Ozone Forecast Guidance for the National Air Quality Forecast Capability

NWS/NCEP/EMC & NOAA/OAR/ARL - EPA

October 2, 2007



# Acknowledgements

## NCEP/EMC

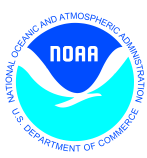
- Pius Lee** – **System design and implementation**
- Marina Tsidulko** – **PBL & Chem Verification**
- Youhua Tang** – **Regional In-line testing & LBC**
- Ho-Chun Huang** – **Global dust/smoke system DT&E (NASA, NESDIS)**
- Sarah Lu** – **Global data assimilation and feedback testing (NASA, NESDIS)**

**Brad Ferrier, Mike Ek** – **WRF retrospective run**

**Eric Rogers, Hui-Ya Chuang** – **NAM products**

**Jeff McQueen** – **EMC AQ model team leader**

**EPA AQ Forecast team (Mathur, Kang, Lin, Yu...)**



# NOAA-EPA AQF system

- **North American Model (NAM)**

- **NAM 3D VAR Data Assimilation** (sat radiances, radar winds, raob, ACARS, surface met)
- **WRF-Non-hydrostatic Mesoscale Model (NMM)**
- **12 km 60 NMM hybrid sigma - pressure levels**
- **June 2007: Changes to landuse & roughness to address moist biases in Pac NW**

- **CMAQ V4.6**

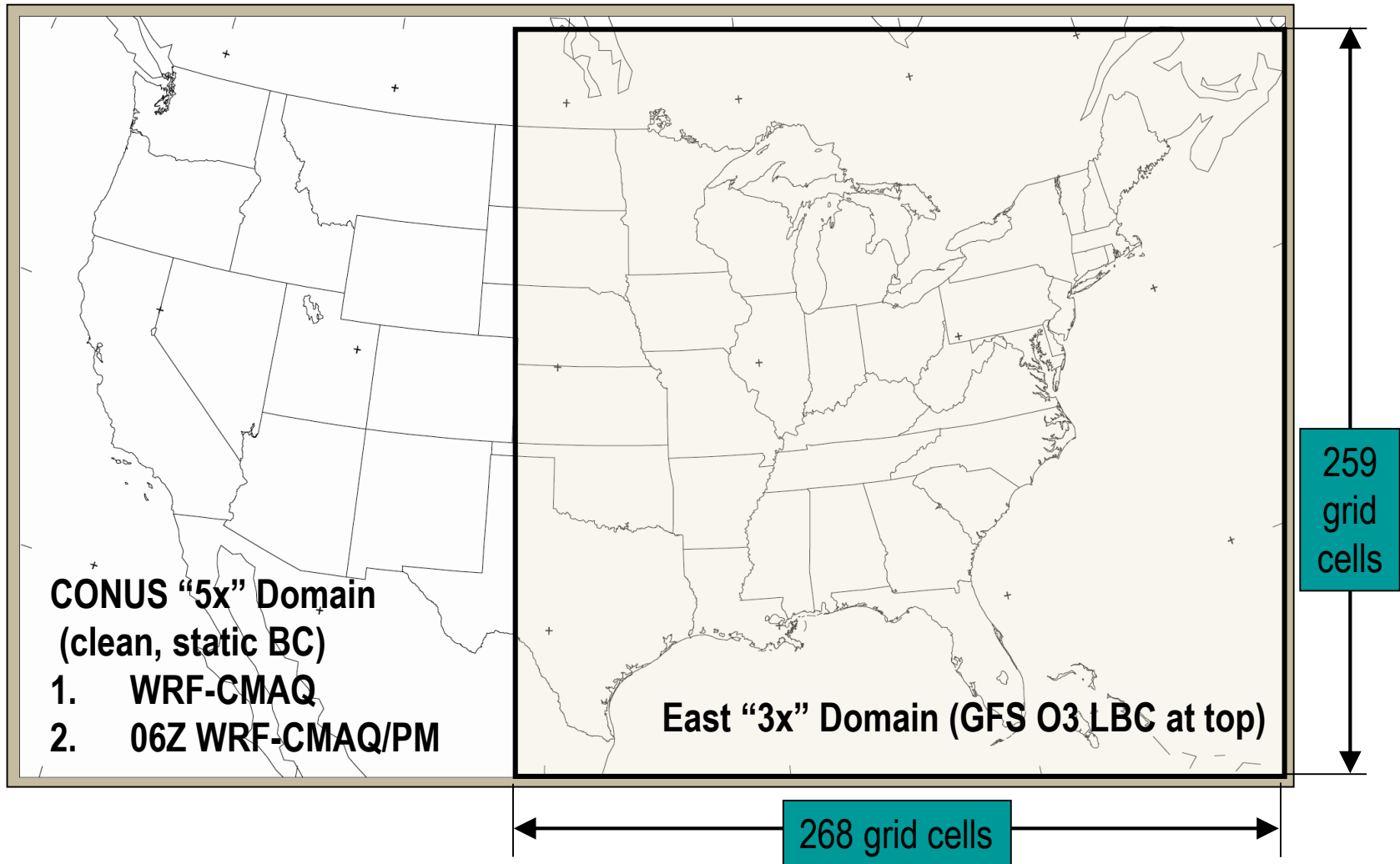
- **CB4** gas-phase chemistry w/ Euler Backward Iteration (EBI) solver
- Simplified aqueous phase chemistry
- **PPM** horizontal advection
- AERO 3 for aerosol developmental run

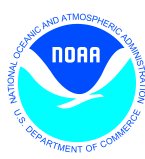
- **Emissions: PREMAQ (SMOKE)**

- **Point, area:** NEI 2001 projected to 2007 with DOE EGU estimates
- **Mobile:** Temperature dependence from MOBILE-6 estimates
- **Biogenic:** PREMAQ BEIS 3
- **Wild Fire Smoke (PM run only):** 2001 inventory

# Forecast Domains (2005-2007)

## 48 h forecasts at 06 and 12Z





# NAM-CMAQ Coupling



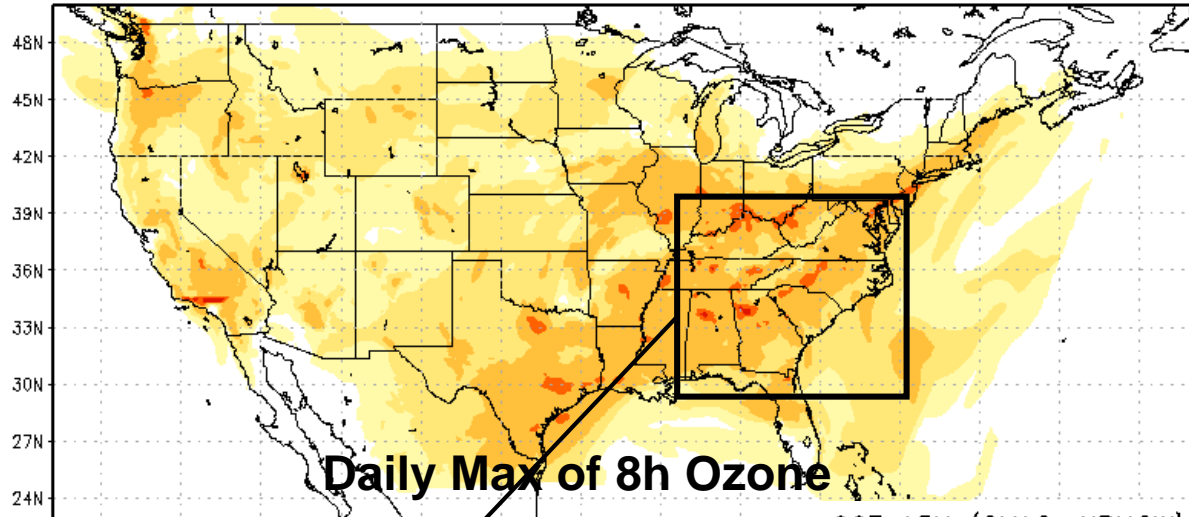
<b>Run</b>	<b>NAM</b>	<b>CMAQ-Op (3X) (retired Sept. 18, 07)</b>	<b>CMAQ-Exp (5X) &amp; CMAQ-Dev (5X PM)</b>
<b>Domain</b>	Rotated Lat-Lon E grid	Interp to Lambert-Conf. C grid	Interp to Lambert-Conf. C grid
<b>Vertical Coordinate</b>	NMM Hybrid (60L)	Interp to Sigma-P (22L)	Common NMM Hybrid coord (22L)
<b>Radiation/ Photolysis</b>	Lacis-Hansen Bulk	Re-compute radiation & clouds from NAM RH	NAM Sfc Radiation for Photolysis Scaling
<b>PBL</b>	Mellor-Yamada-Janjic (MYJ) local TKE	NAM PBL height & RADM Eddy diffusivities	Asymmetric Convective Mixing -2 (1 <sup>st</sup> Order closure for daytime PBL)**
<b>Clouds Aqueous</b>	Ferrier cloud water, graupel/ice	NAM cloud water	NAM cloud water, graupel/ice
<b>Convective Cloud Mixing</b>	Betts-Miller-Janjic Mass Adjustment	RADM-2 Walcek(1980)	Asymmetric Convective Model (ACM) mixing
<b>Land Surface</b>	NOAH LSM	Canopy resistance from NOAH LSM	Canopy resistance from NOAH LSM

\*\* for Exp only

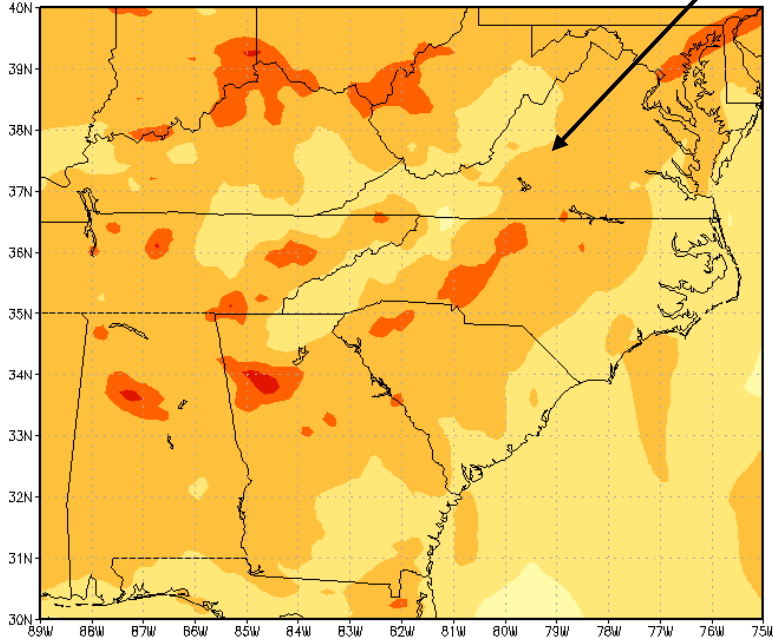
# EMC Products

<http://www.emc.ncep.noaa.gov/mmb/aaq>

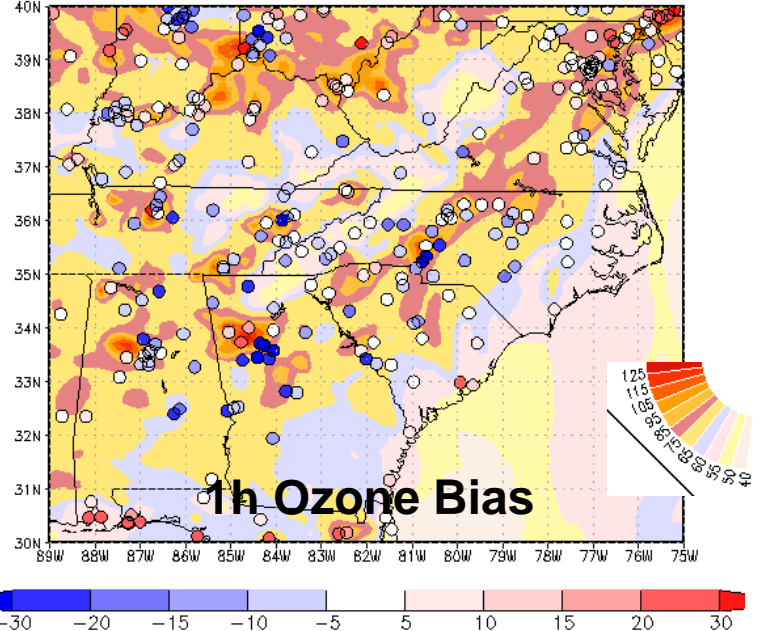
06Z 7H-30H 1st day 8h max sfc O3 (ppb) Valid 16 AUG 2007



7H-30H 1st day 8h max sfc O3 (ppb) Valid 16 AUG 2007



06Z 15H (CMAQ-AIRNOW) O3 (ppb) overlaid on CMAQ O3 at 21Z 15AUG2007

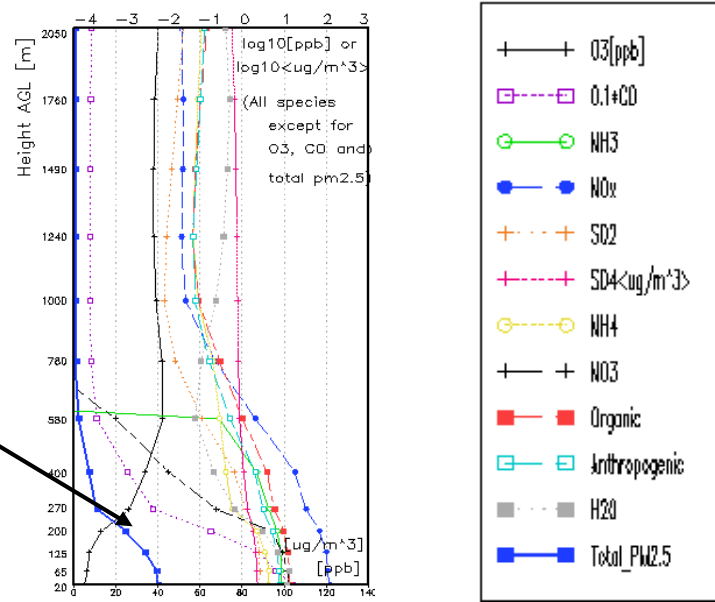
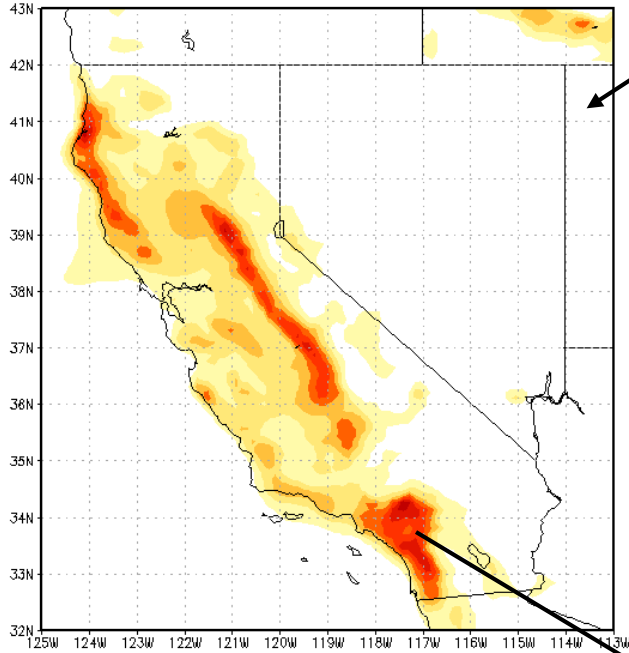
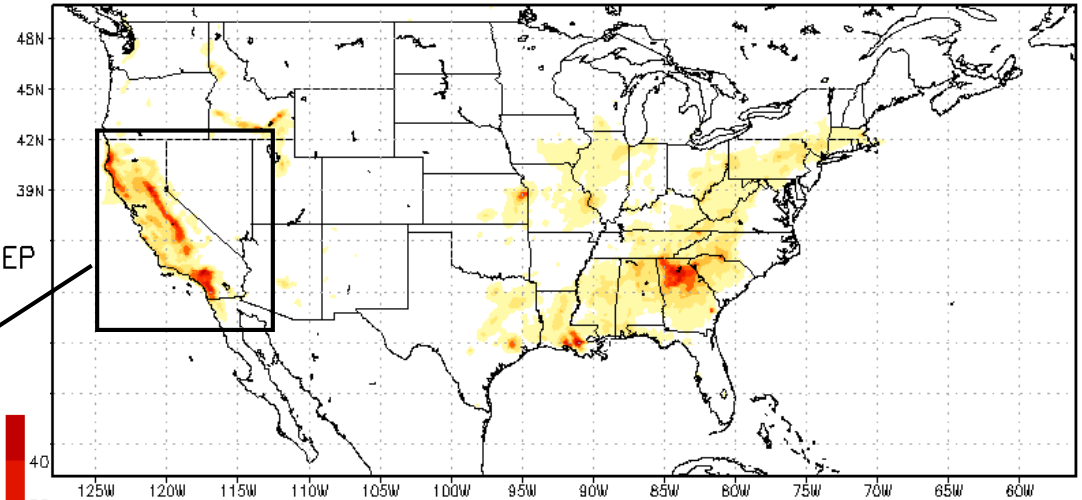


# EMC Web Products

## 1h, 24h avg hrly & Max PM & Profiles (Pius Lee)

0-24h avg sfc pm2.5 (microg m<sup>-3</sup>) Ending 06Z 10 SEP 2007

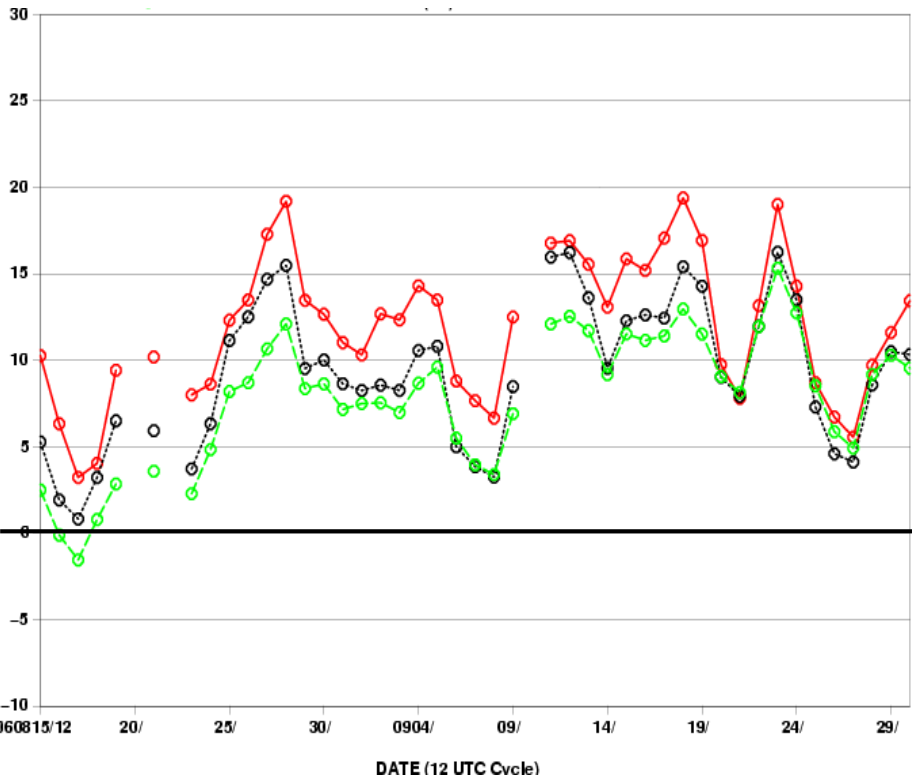
avg sfc pm2.5 (microg m<sup>-3</sup>) Ending 06Z 10 SEP



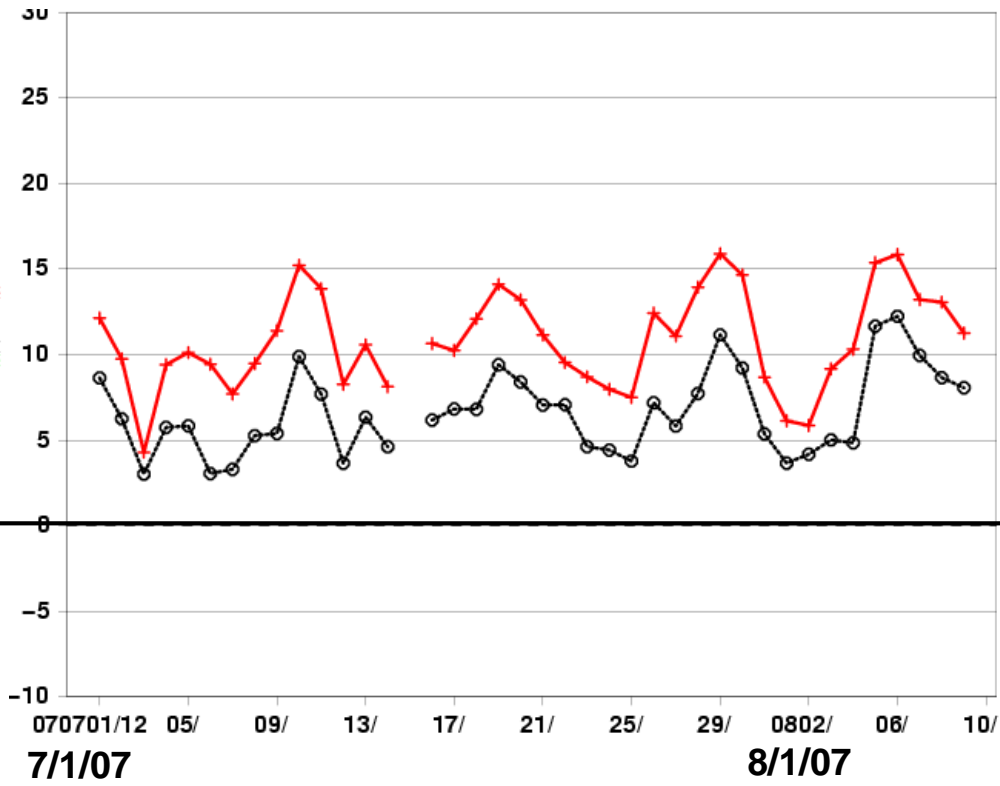
# Daily 8hr max Ozone Biases

## *Op vs Exp over Eastern U.S.*

—○— **CMAQ EAST US DOMAIN (3X) Stats OVER 3X DOMAIN**  
- -○- - **CMAQ CONUS DOMAIN (5X) Stats OVER 3X DOMAIN**  
- -○- - **CMAQ CONUS DOMAIN (5X) Stats OVER 5X DOMAIN**



**Summer 2006**



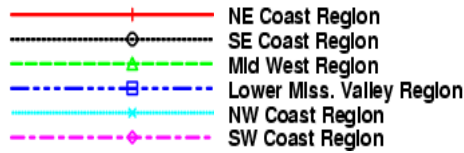
**Summer 2007**

•Both Op and Experimental Runs improved in 2007  
 •For Operational run, NAM improvements partially responsible



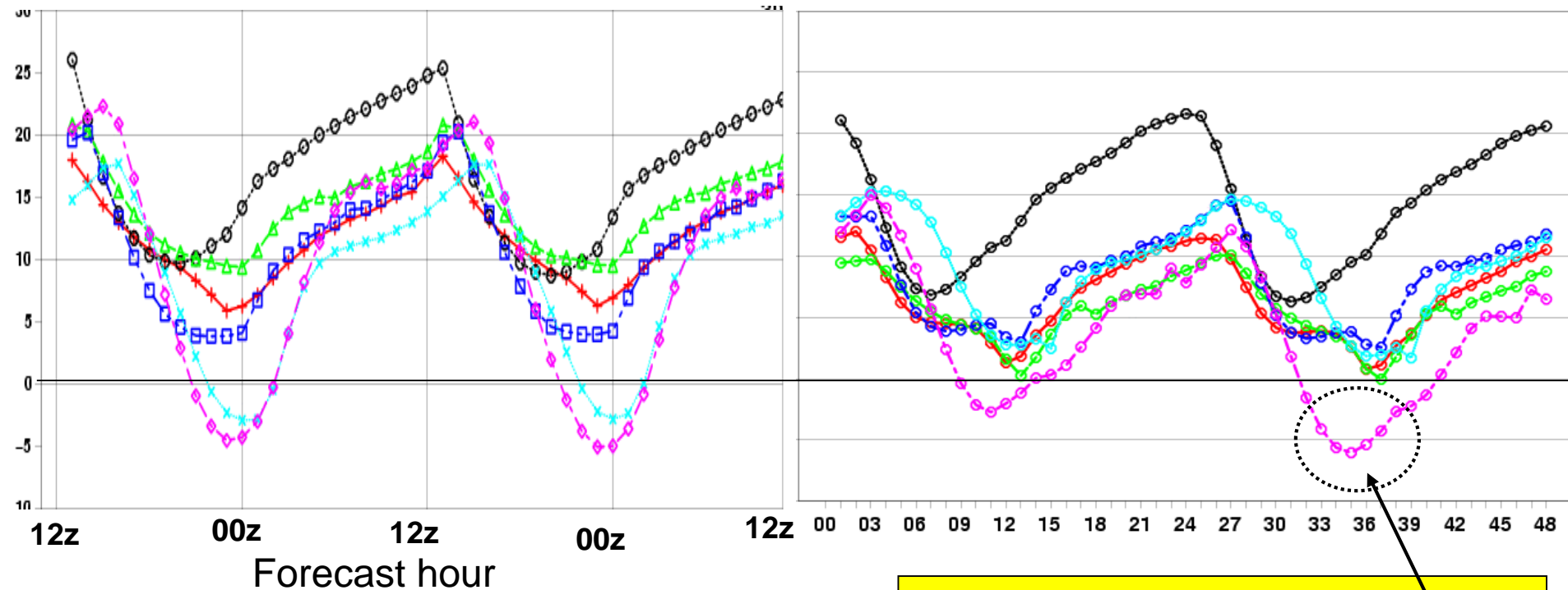
# Regional Performance, 1-h O<sub>3</sub>

## *Experimental Run Bias Reduced in 2007*



2006

2007



2006

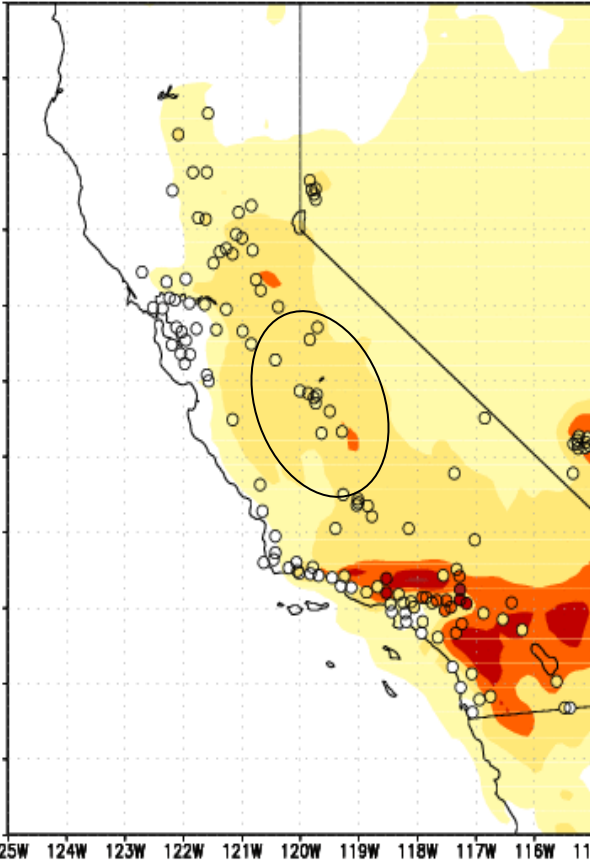
- High bias, up to +25 ppb
- Underprediction SW coast

2007

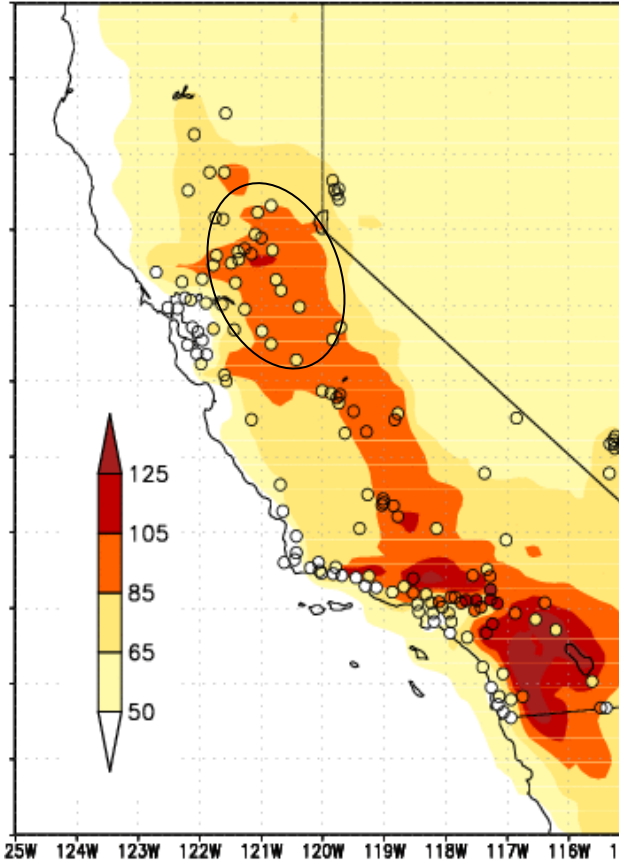
- Bias reduced
- Good forecast for NW coast
- Underprediction SWC (LA basin)

# California Performance 8h Max ozone pred vs obs (M. Tsidulko)

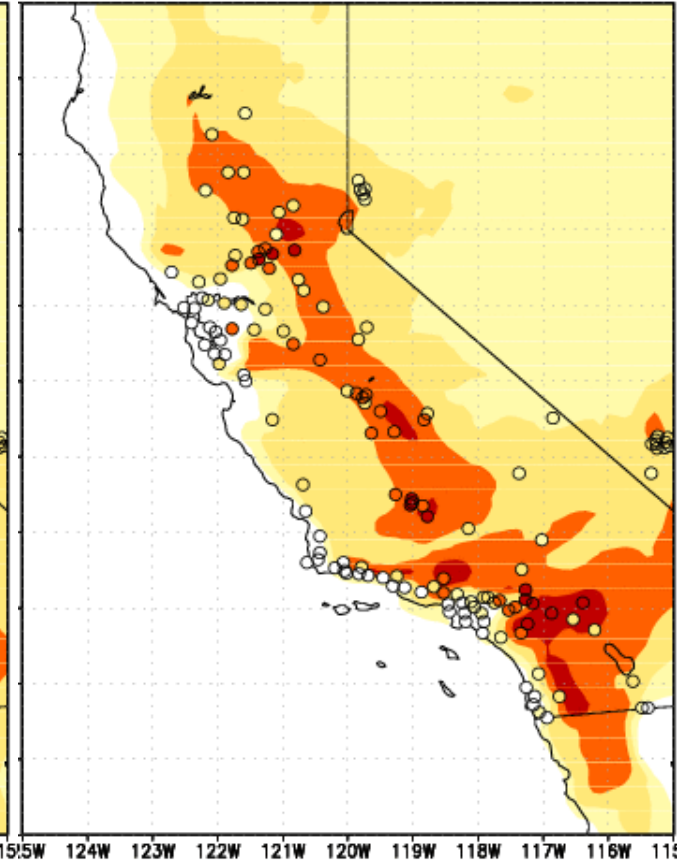
5x 8-hr max 03JUL2007



5x 8-hr max 04JUL2007



5x 8-hr max 05JUL2007



**Good: SAC, SJV**  
**Under: LA urban**  
**Over: East of LA**

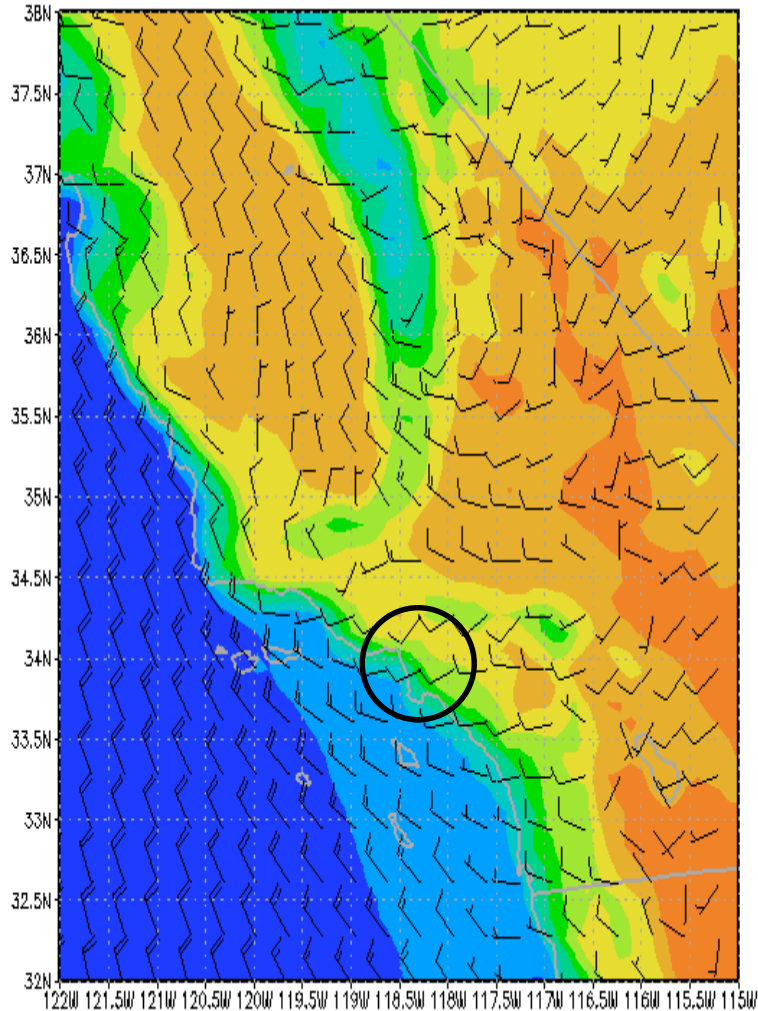
**Good: SJV**  
**Under: LA urban**  
**Over: SAC, East of LA**

**Good: SJV**  
**Under: LA urban**  
**Over: SAC, East of LA**

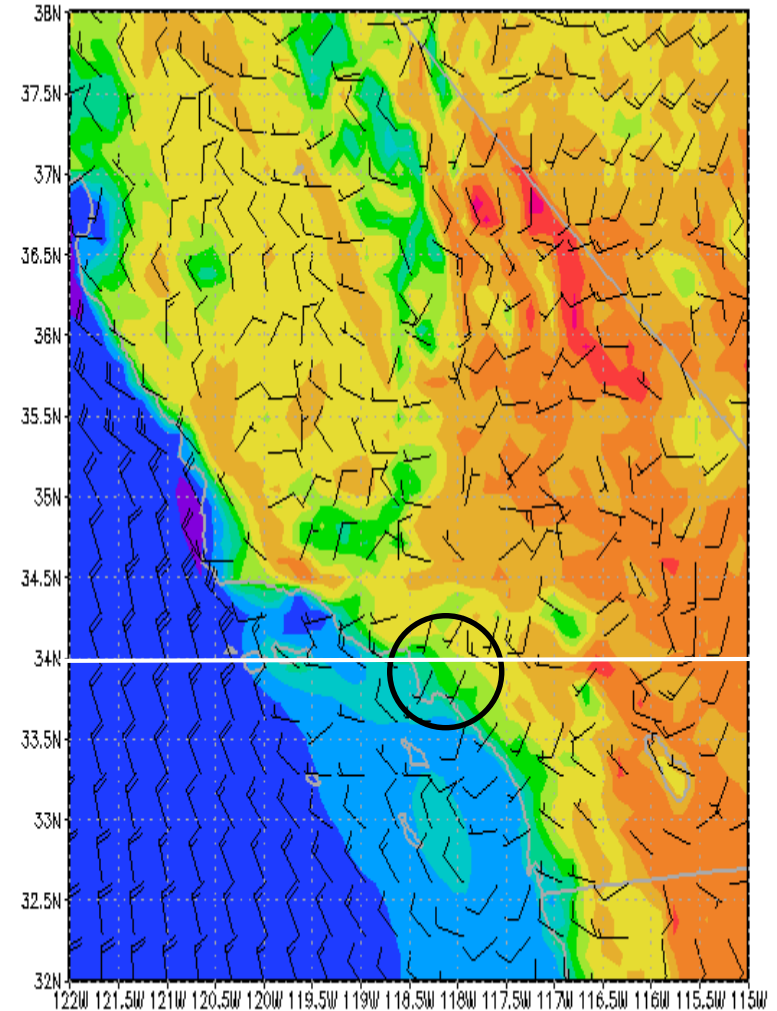
# NAM vs RTMA 10 m Winds

## July 3rd 5 PM, 36 hour Forecasts

### NAM



### RTMA

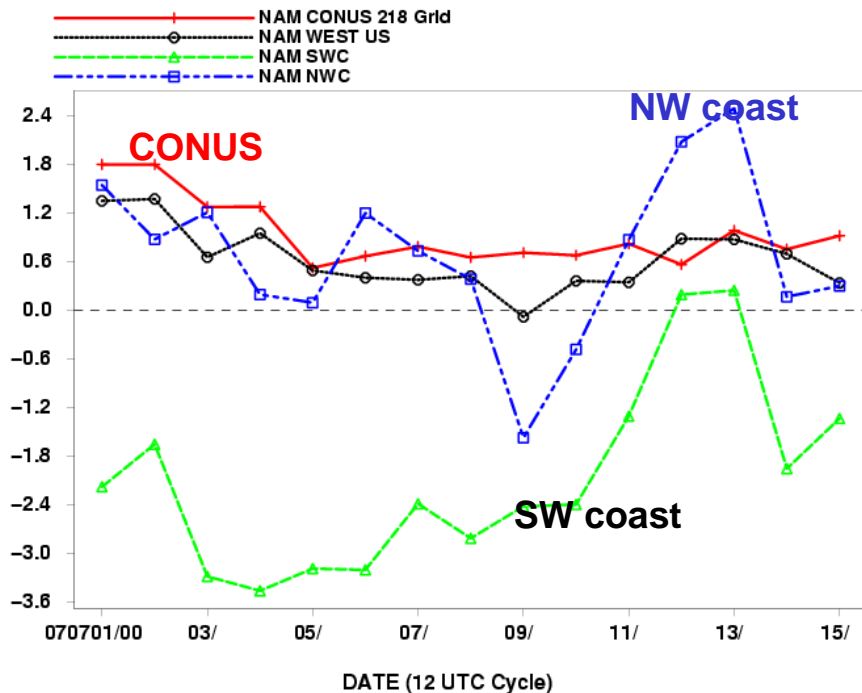


*LA Basin: NAM Temps are warmer; winds are stronger & more westerly*

# NAM 2m Dew point Errors SW Coast (green)

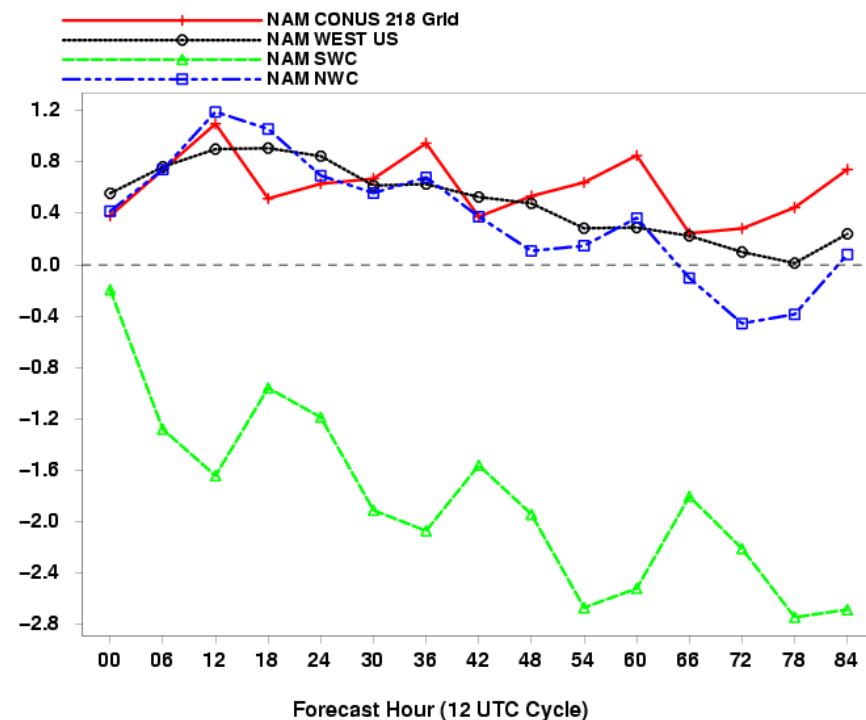
## BIAS for each day

bias SFC DPT Error Daily Time Series from 20070701 to 20070715 for Forecast  
Hr: 36 VALID 0000 GMT



## BIAS by Forecast hour

bias SFC DPT Error averaged by fcst hrs from 20070701 to 20070715

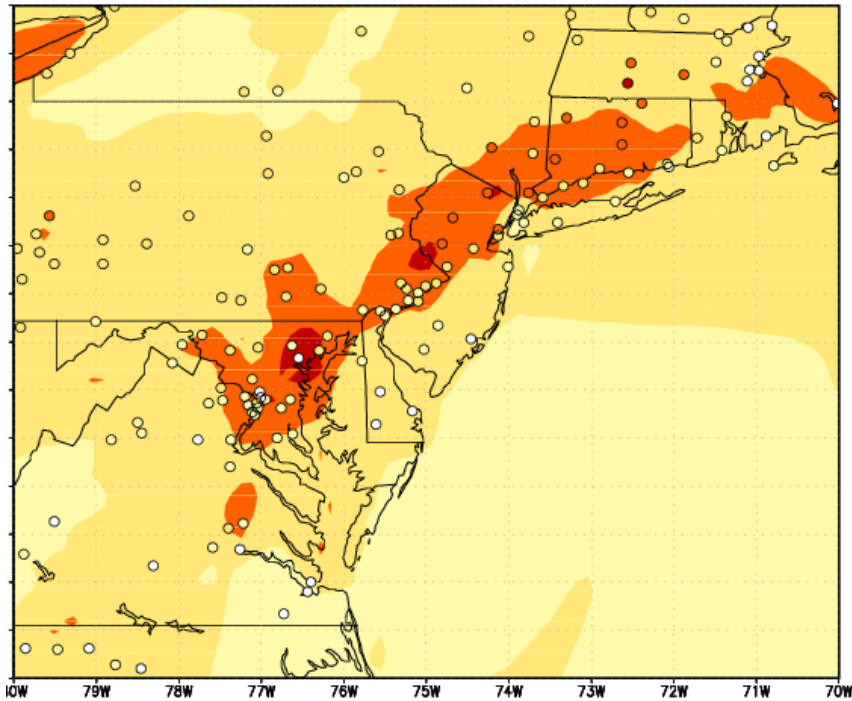


*Dry bias can increase photolysis & ozone production  
can decrease deposition of pollutants over veg*

# Mid-Atlantic 8 h Max Performance July 10, 2007

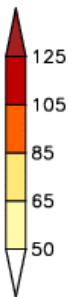
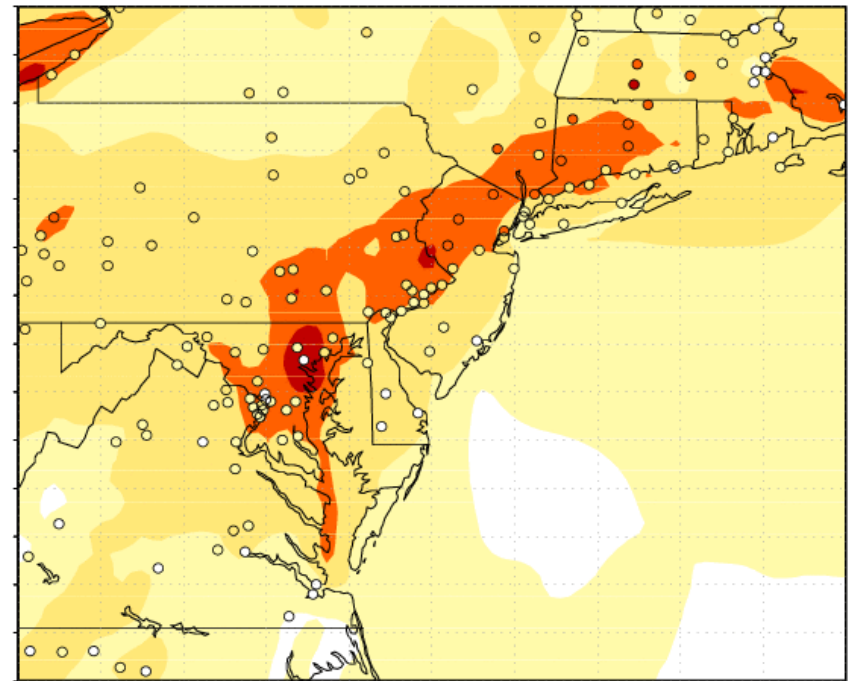
## Operational 3X

3x 8-hr max 10JUL2007



## Experimental 5X

5x 8-hr max 10JUL2007

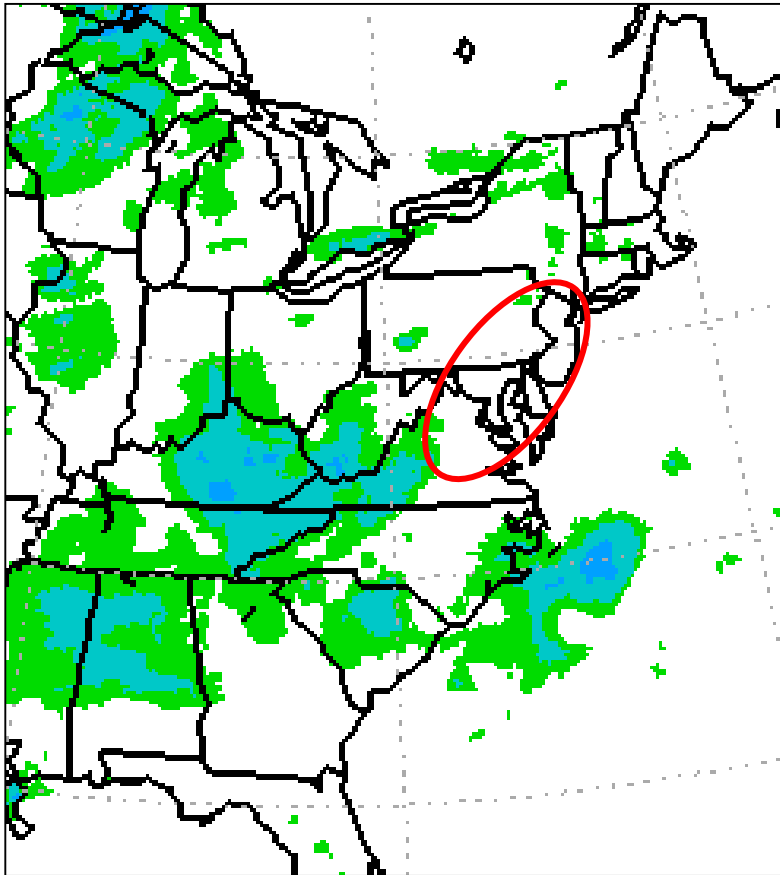


*Very Similar performance between operational and experimental*

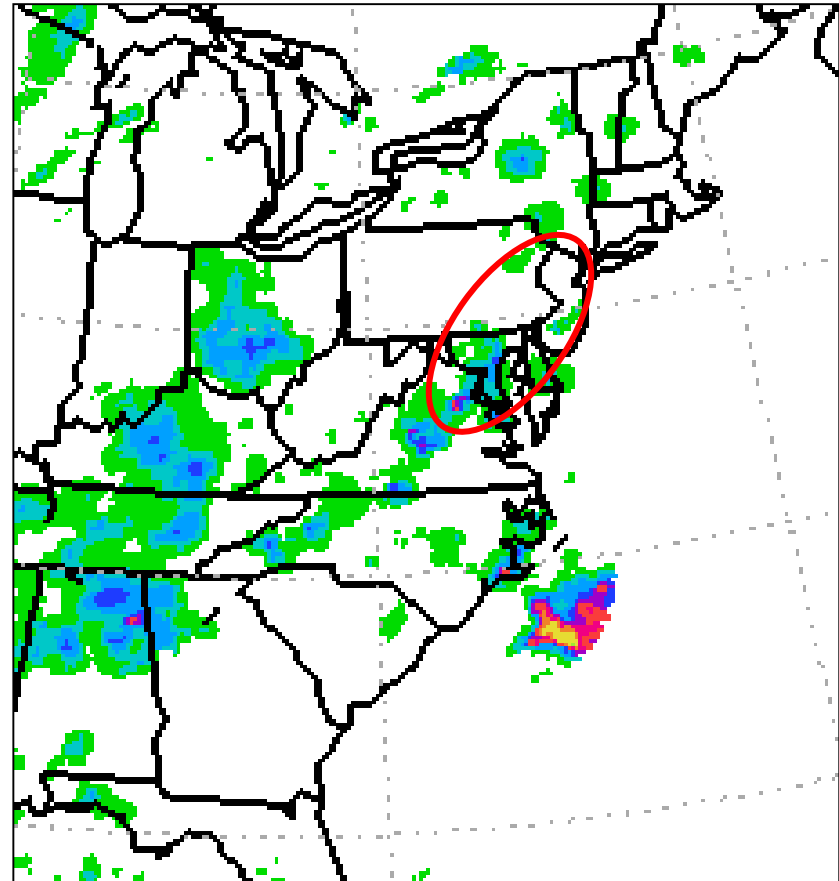
# NAM 30 h Precip Forecast

## July 10, 2007

**NAM Precip Prediction**



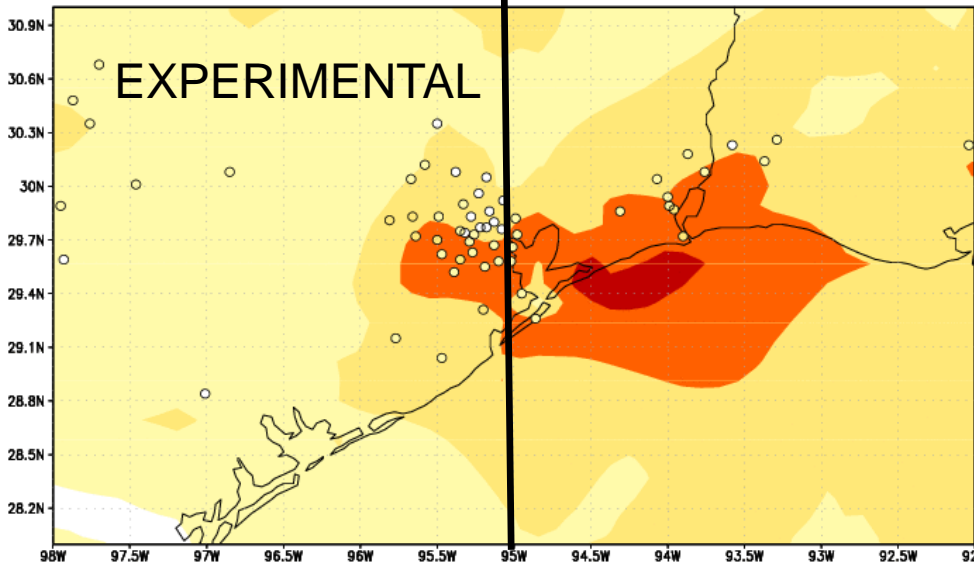
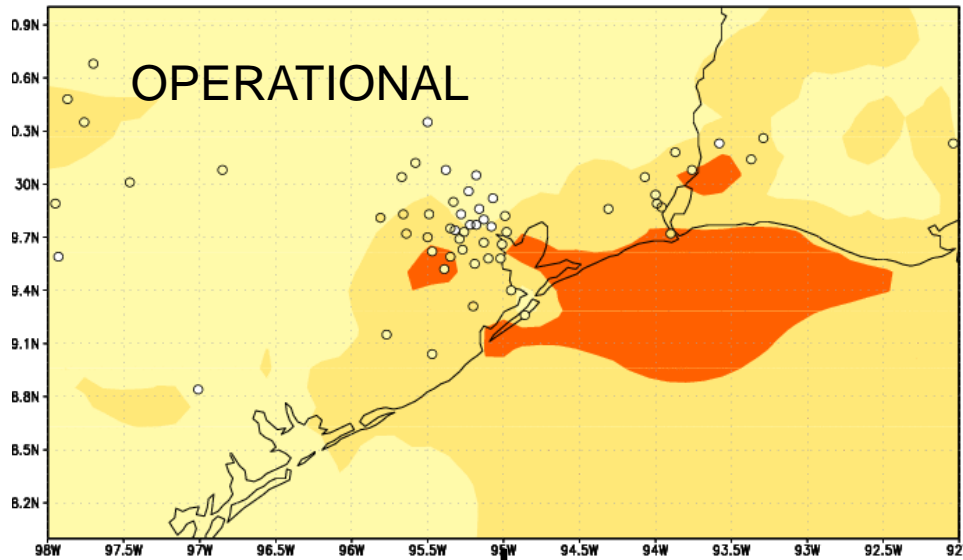
**River Forecast Center  
3 hrly total Precip Analysis**



*NAM convective precip started earlier than predicted in Mid-Atlantic*

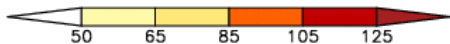


# Exp 8h Max Texas Performance August 11, 2007



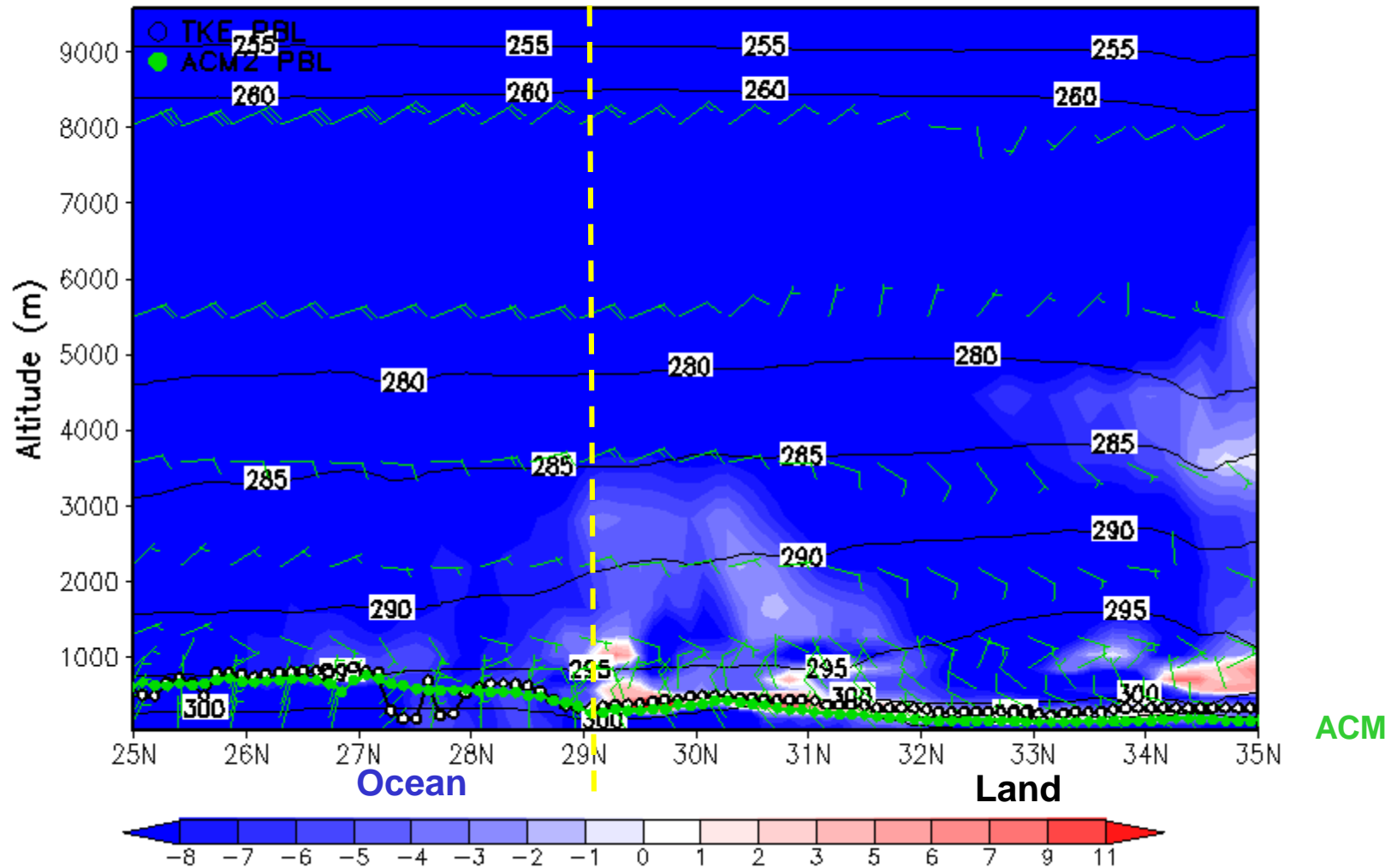
- Ozone buildup over stable marine layer w/ CONUS 5X run.

- This residual layer can recirculate onshore.

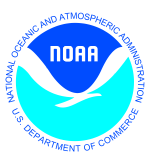


# Exp - Op Ozone Difference 12 Z August 10, 2007 Forecast

Cross-Section O<sub>3</sub> Difference (ppbv) (5X-3X) and Temperature (K)  
over Over\_Lon=-95W at 14UTC, 8/10/2007







# Summary



- **Overall results**

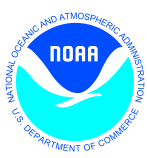
- *Experimental run biases are improved*
  - NAM changes from 2006 to 2007 also have a positive impact (as Operational run biases improved)
- *Skill scores are improved at lower levels and comparable at higher thresholds*
- *Experimental run provides previously unavailable guidance to Western U.S.*

- **California O3 forecasts improved**

- *Better performance in San Joaquin Valley*
- *Underprediction in LA urban area*
- *Some Overprediction in Sacramento Valley & downwind of LA*
  - NAM onshore winds near LA often too strong
  - Upward lofting partially due to inconsistent NAM and CMAQ daytime unstable PBL physics (Vertical resolution may also have an impact)
  - Impact of aerosols & forest fires on ozone production (Stockwell, et al. 2002)

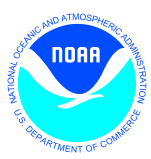
- **5X overprediction along coastal urban areas**

- *ACM-2 stable, marine PBL mixing may be too weak*
  - Produces pollutant reservoir off-shore that can impact coastal urban areas (Houston, Long Island Sound, Lake Michigan...)



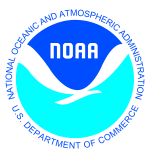
# Recommendations

- **Implement more consistent boundary layer and cloud mixing schemes**
  - *Internal boundary layer processes near coastal regions*
  - *Continue inline testing (WRF-Chem)*
- **Increase focus on chemical data assimilation in Global GSI**
  - *coordination with AQF ESRL/GSD data assimilation, NESDIS, NASA...*
- **LA Basin/ Houston**
  - *NMM high resolution experiments in coordination with ESRL/ PSD NMM study*
  - *Test impact of aerosols/forest fires in California*
- **More complete chemistry**
  - *CB05 more heterogeneous chemistry with aerosols*
- **Improved boundary conditions**
  - *GFS-GOCART, HYSPLIT*
  - *Spatially & Temporally varying Lateral Boundaries (currently static)*
  - *Reduced gas phase chemistry (eg: RAQMS, Goloff & Stockwell, 2002) for ESMF/GFS*



# BACKUPS





# Summer 2007 Evaluations

*(Errors not uncovered w/retro tests)*



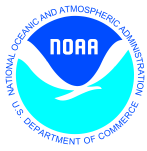
**Experimental/Developmental Runs: Significant under-prediction in upper Mid-West**

## **Deposition Velocity**

- Added Mesophyll component for O<sub>3</sub>, NO, NO<sub>2</sub>
- **STATUS:** Implemented inexper/dev runs on July 22
- Minor impact on forecast → Increased photochemistry in Midwest

## **Plume Rise**

- **STATUS:** Corrected in exper/dev run on July 22
  - minor impact



# 2006-2007 Systems

## NAM/WRF-CMAQ 12 km runs



<b>System</b>	<b>Domain</b>	<b>Vertical coupling</b>	<b>Runs</b>	<b>LBCs</b>
<b><u>Old Operational</u></b> <b>32p, 45 min</b>	<b>Eastern U.S.</b> <b>(3X)</b>	<b>22L Loose:</b> <b>interp from</b> <b>WRF</b>	<b>48 h</b> <b>forecasts at</b> <b>06 and 12 Z</b>	<b>GFS ozone at</b> <b>model top;</b> <b>Same static</b> <b>boundaries</b> <b>below</b>
<b><u>Experimental</u></b> <b>(Current Ops)</b> <b>65p, 70 min</b>	<b>CONUS (5X)</b>	<b>22L Tight:</b> <b>Common</b> <b>hybrid</b>	<b>48 h</b> <b>forecasts at</b> <b>06 and 12 Z</b>	<b>Clean, static</b> <b>profiles</b>
<b><u>Developmental</u></b> <b>127p, 150 min</b>	<b>CONUS w/</b> <b>PM (5X)</b>	<b>22L Tight:</b> <b>Common</b> <b>hybrid</b>	<b>48 h</b> <b>forecasts at</b> <b>06 Z</b>	<b>Clean, static</b> <b>profiles</b>