Status of the NOAA WRF-CMAQ Regional Air Quality Forecast System

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2006 Developments

- **WRF Transition**
  - *Improved vertical coupling*
  - *Continued convective mixing & vertical layering tests*
  - *Continued lateral boundary condition tests*

- **CMAQ Improvements**
  - *Optimized Advection scheme*
  - *Emissions upgraded for 2006*

- **AQF system retrospective & Real-time testing**
  - *July 2005 with experimental CONUS configuration*

- **Real-time Verification**
  - *Spatial map comparisons to observations (03 & PBL hgt)*
  - *Inclusion of AIRNOW PM 2.5 observations*
  - *Use of ACARS, ESRL Profilers for PBL hgt verification*
  - *Inclusion of NESDIS GASP AOD products*

- **Improved Analyses & Visualizations**
  - *Focus group, TEXAQS06 & SHENAIR projects*
  - *Vertical gas-phase and aerosol chemistry profiles*

NAM-WRF Implementation

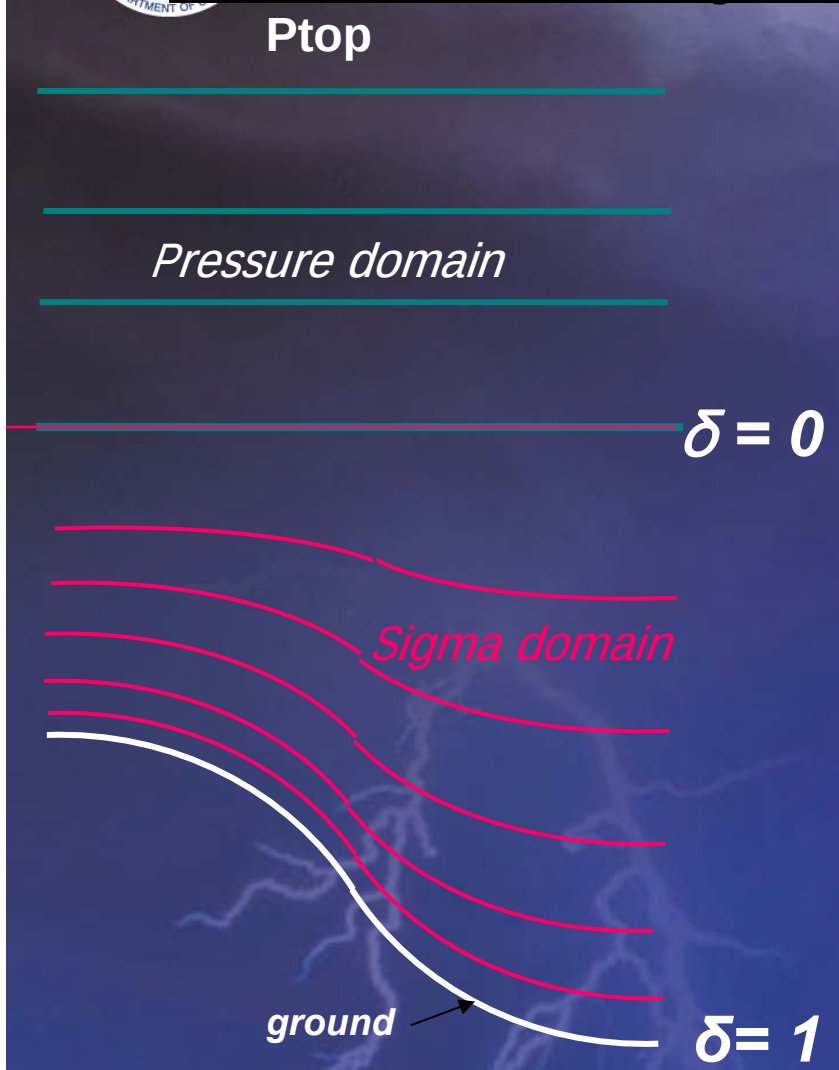
- **Major Components of Upgrade Package for NAM**
  - ***Replace Eta Model with WRF version of NMM (Nonhydrostatic Mesoscale Model)***
    - **WRF Common Modeling Infrastructure**
    - **Non-hydrostatic dynamics**
    - **Use of hybrid sigma-pressure vertical coordinate with top at 2 mb**
    - **Refined advection, diffusion, numerics and physics**
  - ***Replace Eta 3D-Var analysis with Gridpoint Statistical Interpolation (GSI) analysis***
    - **Unified (regional + global) 3D-Variational analysis adapted to WRF**
    - **Begin use of background errors based on WRF-NMM to 2 mb**
    - **Use of new variable for moisture analysis**
    - **Use of tendency in constraint terms**
    - **Use of dynamically retuned observational errors**

NAM-WRF Implementation

- **Model initialization**
  - ***Begin use of:***
    - **high resolution (1/12th degree) SST**
    - **high resolution (4 km) snow**
  - ***Common specification of terrain, land-sea mask***

- **Data assimilation changes**
  - ***Use of bias-corrected observed precipitation analysis values in land-surface physics***
  - ***Start assimilating***
    - **WSR-88D Level II radial wind data**
    - **GPS-Integrated Precipitable Water (IPW)**
    - **NOAA-18 radiances**
  - ***Drop use of***
    - **GOES Precipitable Water retrievals**
    - **SSM/I Total Precipitable Water retrieval**

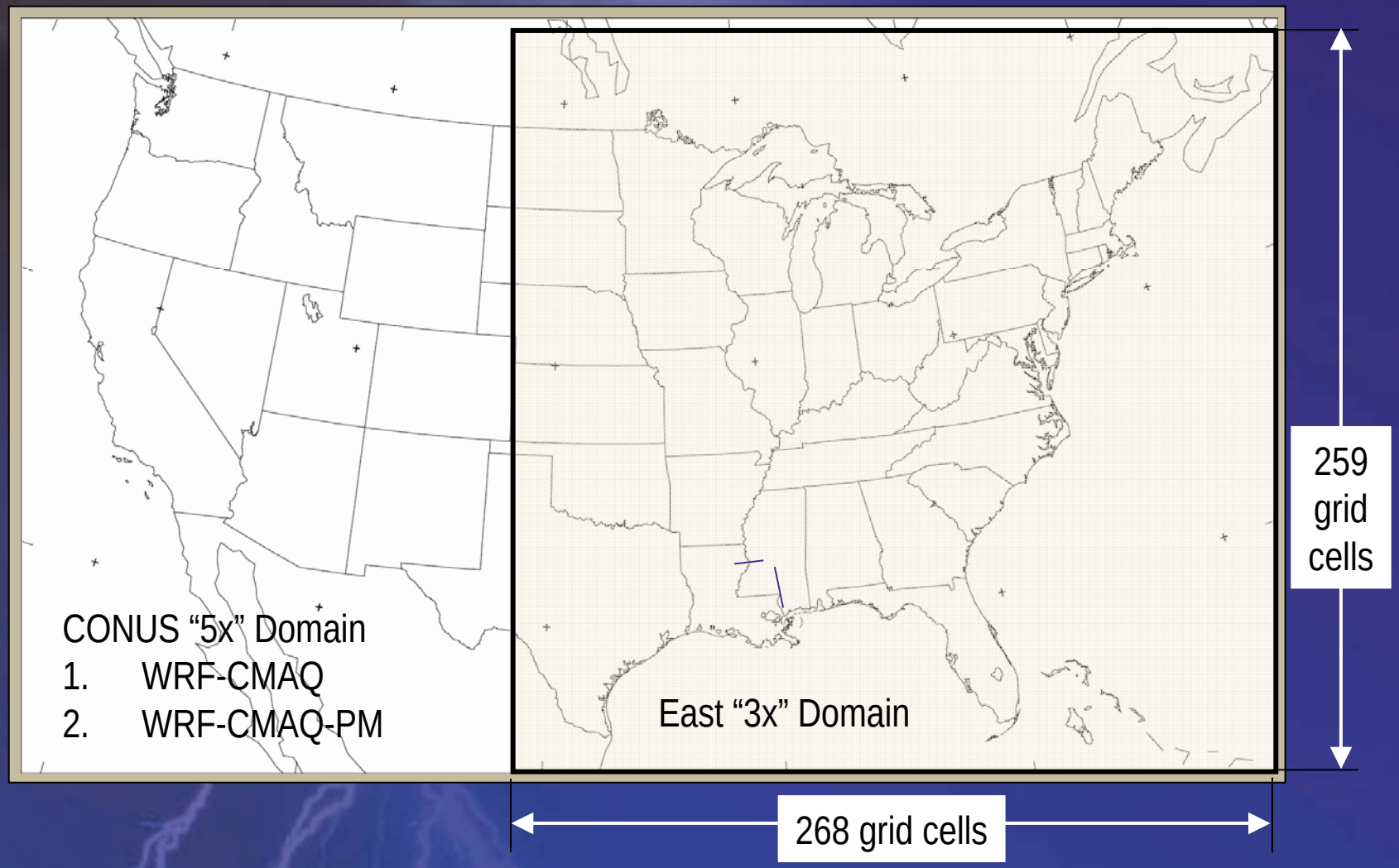
Hybrid vs Step (Eta) Vertical Coordinate Systems



HYBRID

Step (Eta)

Forecast Domains (2006)



2006 Systems
WRF-CMAQ 48 h forecasts

System	Domain	Vertical coupling	Convective mixing	LBCs
<u>Operational</u> Prod: 06/12Z 32p, 45 min	Eastern U.S. (3X)	22L Loose: interp from WRF	Walcek (1980) RADM	GFS ozone at model top: 100mb
<u>Experimental</u> Para: 06/12Z 65p, 70 min	*CONUS (5X)*	22L *Tight: Common hybrid*	Asymetric Convective Model (*ACM-Pleim)*	*Clean, static profiles*
<u>Developmental</u> Blue: 12Z 127p, 150 min	CONUS w/ PM (5X)	22L Tight: Common hybrid	ACM-Pleim	Clean, static profiles

Operational Physics Coupling

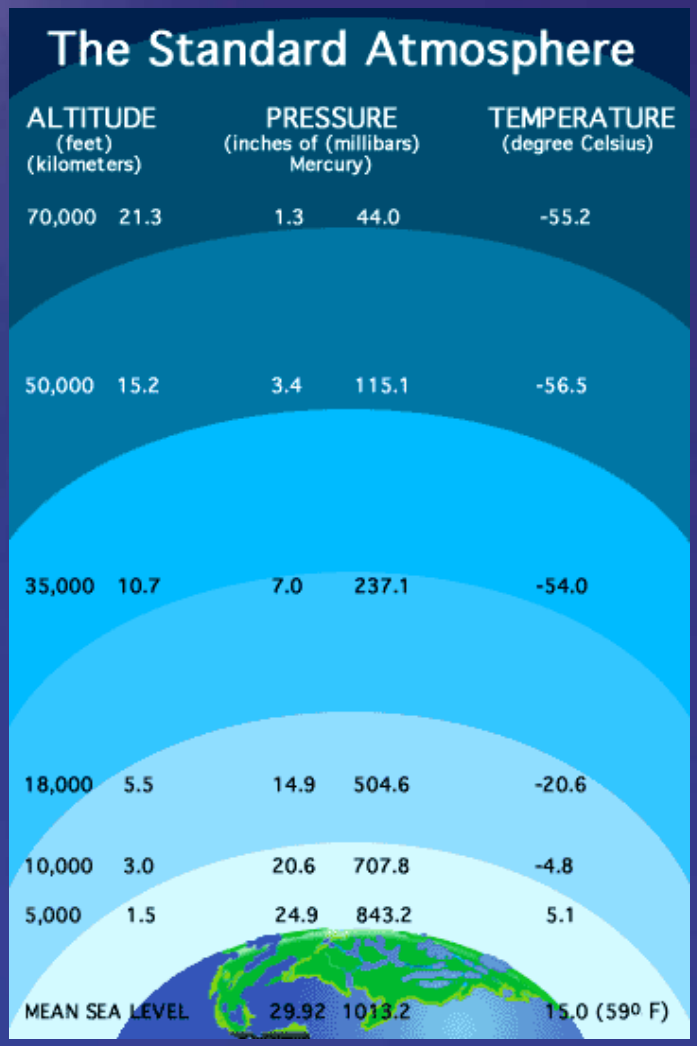
Current Capability	Met Model (WRF/NMM)	AQ Model (CMAQ)
Core/Dynamics	Rotated Lat-Lon E Hybrid sigma-P	Arakawa C Grid Sigma-P
Cloud micro-physics	Full Ferrier Cloud Microphysics	NAM cloud water for aqueous chemistry
Convective mixing	Betts-Miller Janjic	*RADM: Entrainment from top turned off*
Radiation	Lacis-Hansen SW & LW	*CMAQ J Tables for photolysis*
PBL	Mellor-Yamada TKE	NAM PBL hgt for Pleim-Xiu 1st order closure PBL
Land Surface	NOAH common	NAM canopy conductance terms for Pleim-Xiu LSM

Experimental CONUS Coupling

Run	Summer 2006	***Planned***
Domain	Interp to CMAQ Secant Lambert-Conf. C grid	*Common Rotated Lat-Lon E grid*
Vertical Coordinate	*Common NMM Hybrid vertical coordinate*	*Common NMM Hybrid coord.* *Improved vertical resolution*
Photolysis	*NAM Sfc Radiation for Photolosis Scaling*	*3-D Radiative fluxes*
PBL	NAM PBL height into P-X	*NAM TKE/Kh to drive mixing*
Clouds Aqueous Mixing	NAM cloud water *Asymetric Convective Model (ACM) mixing*	*NAM cloud water,graupel & ice* *GFS-RAS mixing into CMAQ*
LBCs	*Clean, Static profiles*	*GFS in strat, static below* *PM from GFS-GOCART*

Improved Vertical Coupling (Hsin-Mu Lin, EPA)

NAM 60L CMAQ 22L



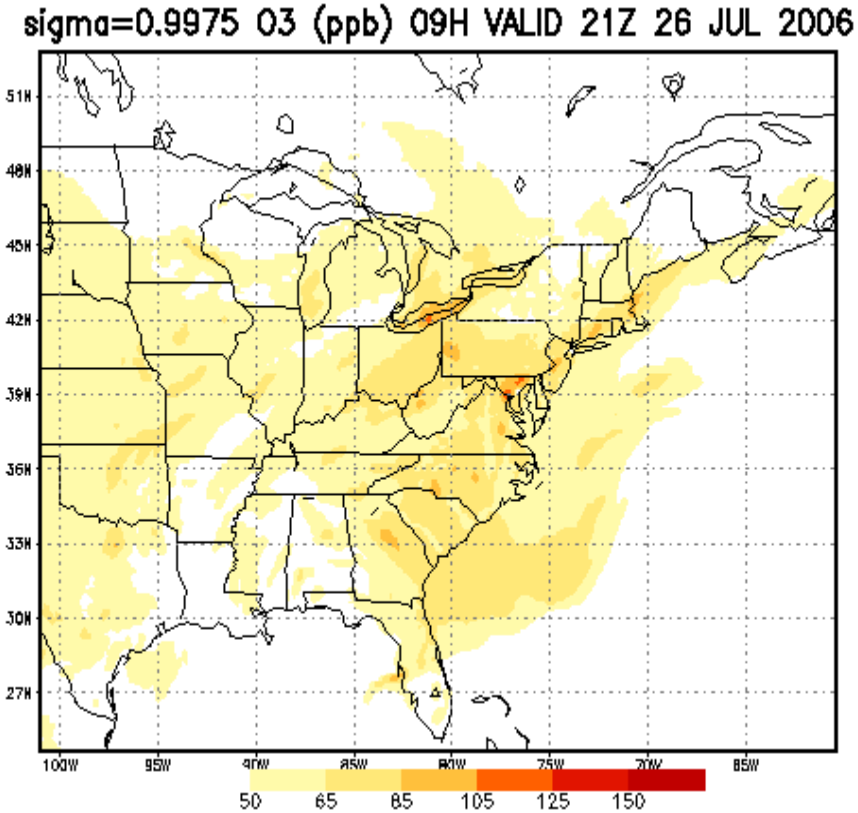
http://virtualskies.arc.nasa.gov/weather/tutorial/tutorial2d.html

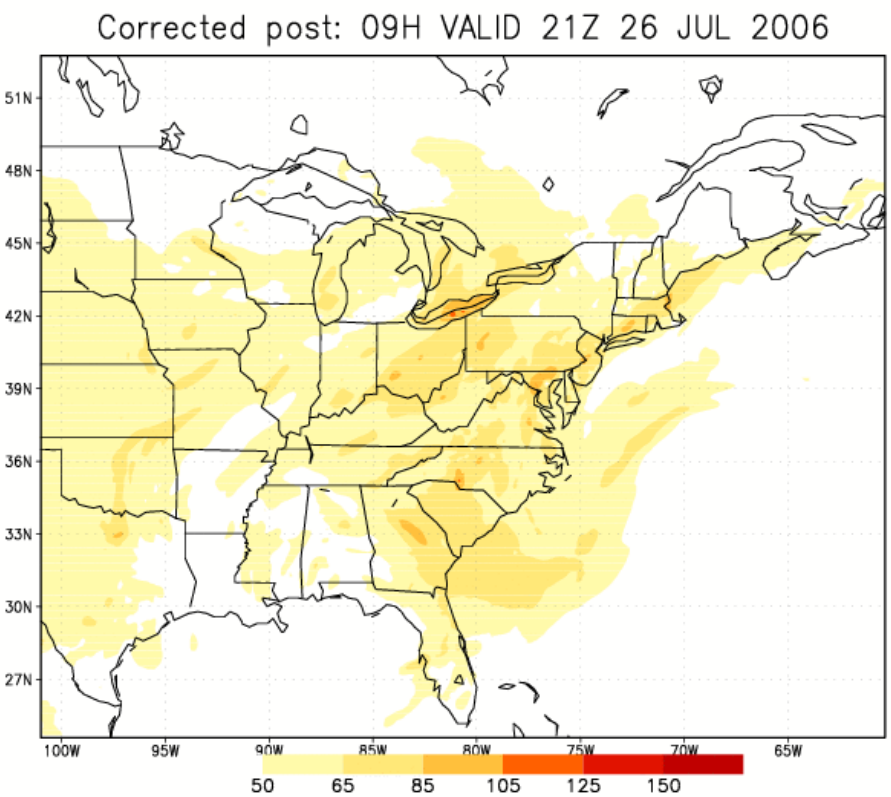
Summer 2006 Evaluations

(Errors not uncovered w/retro tests)

- **Operation Runs: Ozone over-predictions esp. under cool, cloudy conditions**
  - ***WRF-Post temperature interpolation* to CMAQ sigma errors**
    - **Sigma level 1 and 2 temps were too warm for thermally stable conditions (near lakes, water bodies)**
    - **STATUS: Crisis Fix implemented on July 28. 2006**
      - ***Small impact on forecast→ Slightly less ozone produced***
  - ***PREMAQ Emission Processing***
    - **Some arrays for mobile, point, area, biogenic sources were undefined**
    - **Some point and mobile source emission files not upgraded for 2006**
    - **STATUS: Implemented 18Z August 22, 2006**
      - ***Tests show minor impact***

Impact of WRF temperature interpolation error on Oper CMAQ





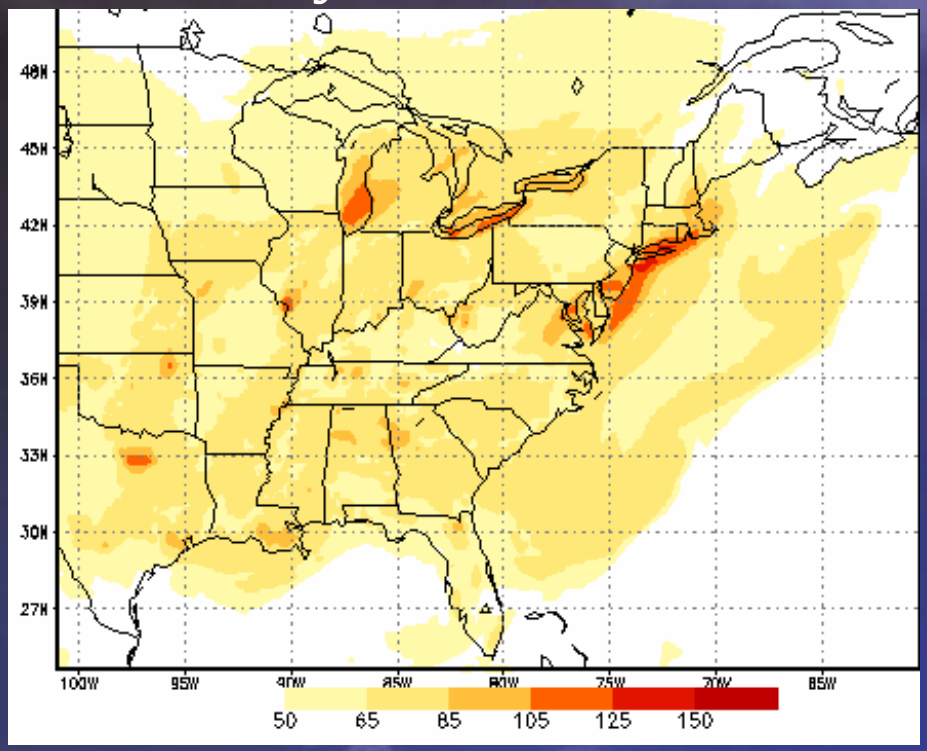
Summer 2006 Evaluations

(Errors not uncovered w/retro tests)

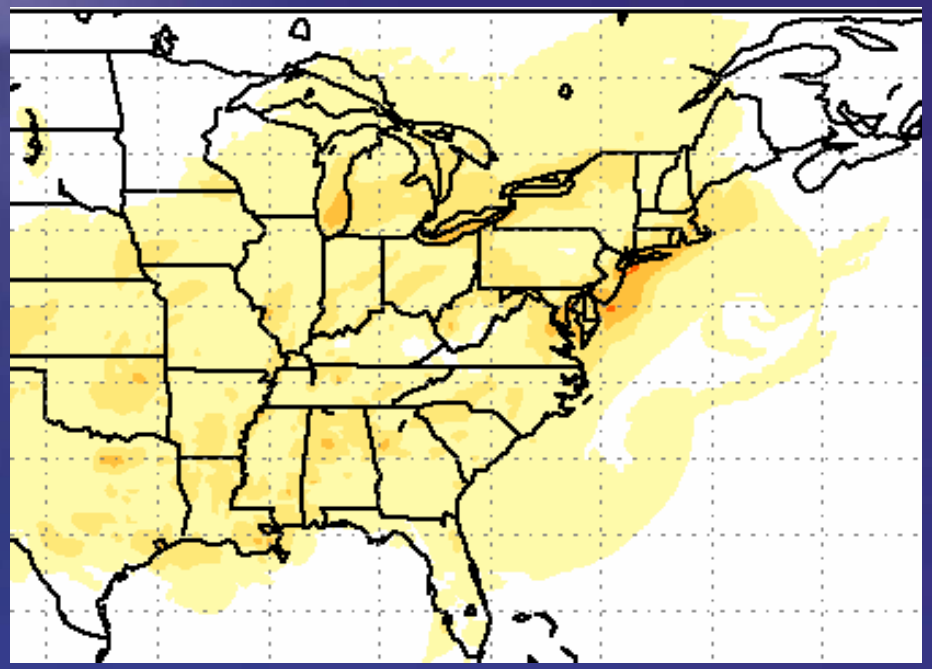
- **Experimental/Developmental Runs: Significant under-prediction esp. near coasts, lakes**
  - ***PREMAQ Biogenic Isoprene emissions***
    - **Turned off for tight vertical coupled codes**
    - **STATUS: Implemented in exper/dev runs on Aug. 5**
      - ***Major impact on forecast→ Increased photochemistry esp. in California***
  - ***PREMAQ Emission Files and Processing***
    - **Some arrays for mobile, point, area, biogenic sources were undefined**
    - **Some point and mobile source emission files not upgraded for 2006**
    - **STATUS: Corrected in exper/dev run on August 5**
      - ***Preliminary tests show minor impact***
  - ***PREMAQ Jacobian Calculations for vertical diffusivity***
    - **Status: Implemented at 18Z on Sept. 5, 2006**

July 17,06 Ozone event (06Z forecast)

1h daily max valid 06z 7/18/06



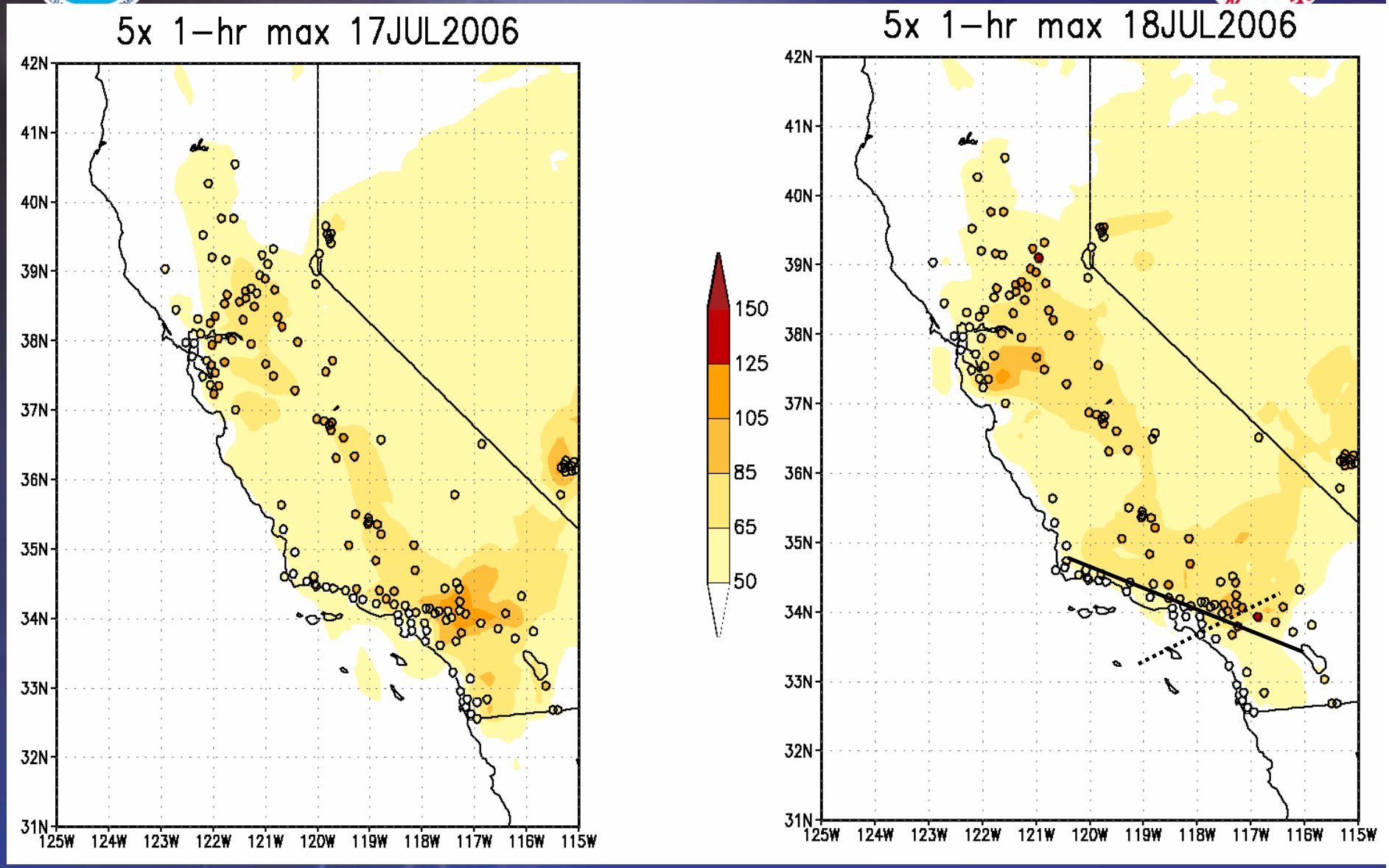
3X loose coupled



5X tight coupled

5X forecasts 1 category less than 3X in general

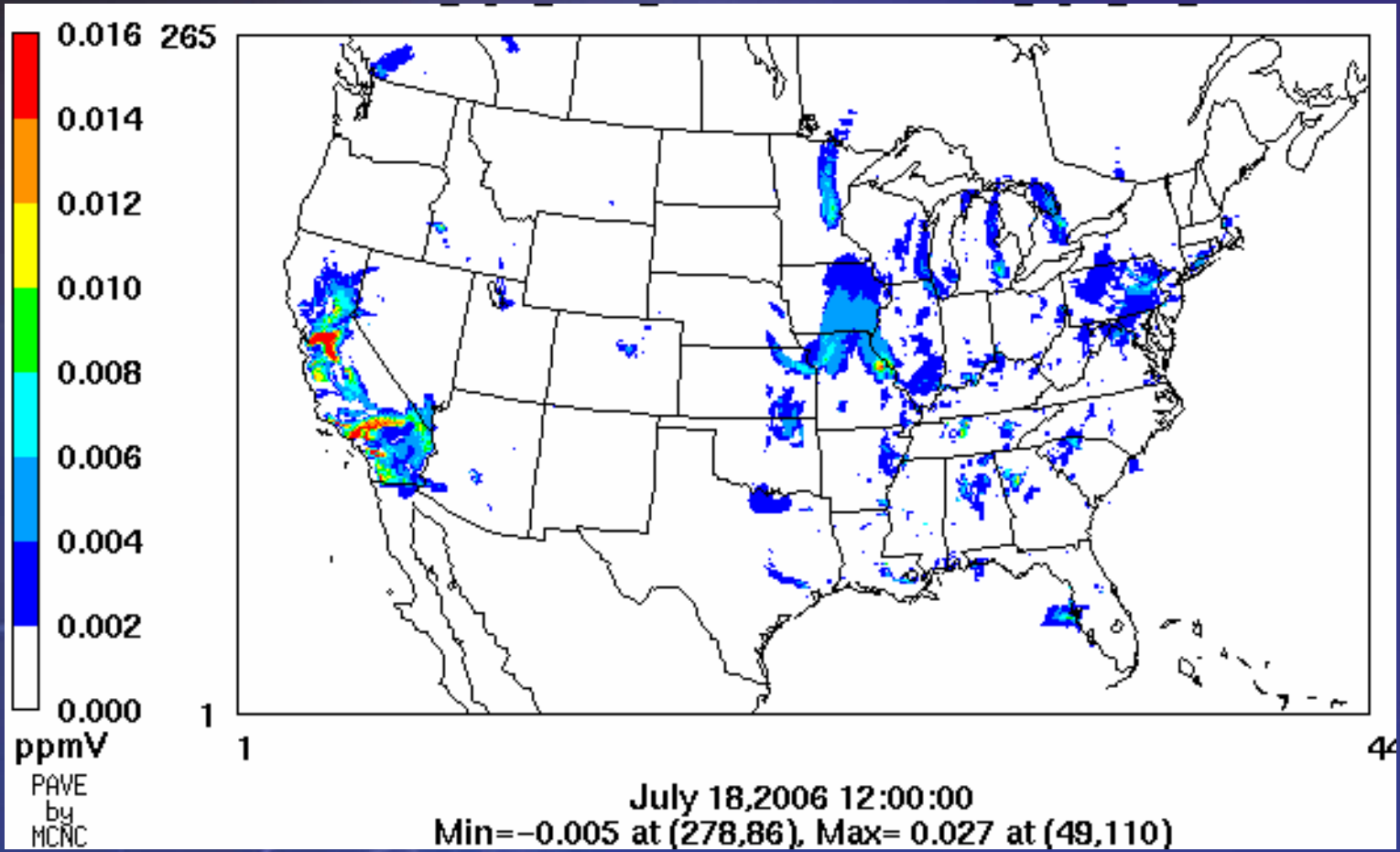
California AQ Forecasts



Impact of Isoprene Emissions Error on Exper. CMAQ

R. Mathur, EPA

MAX Hrly O3 Differences (Corr Tight – Old Tight)



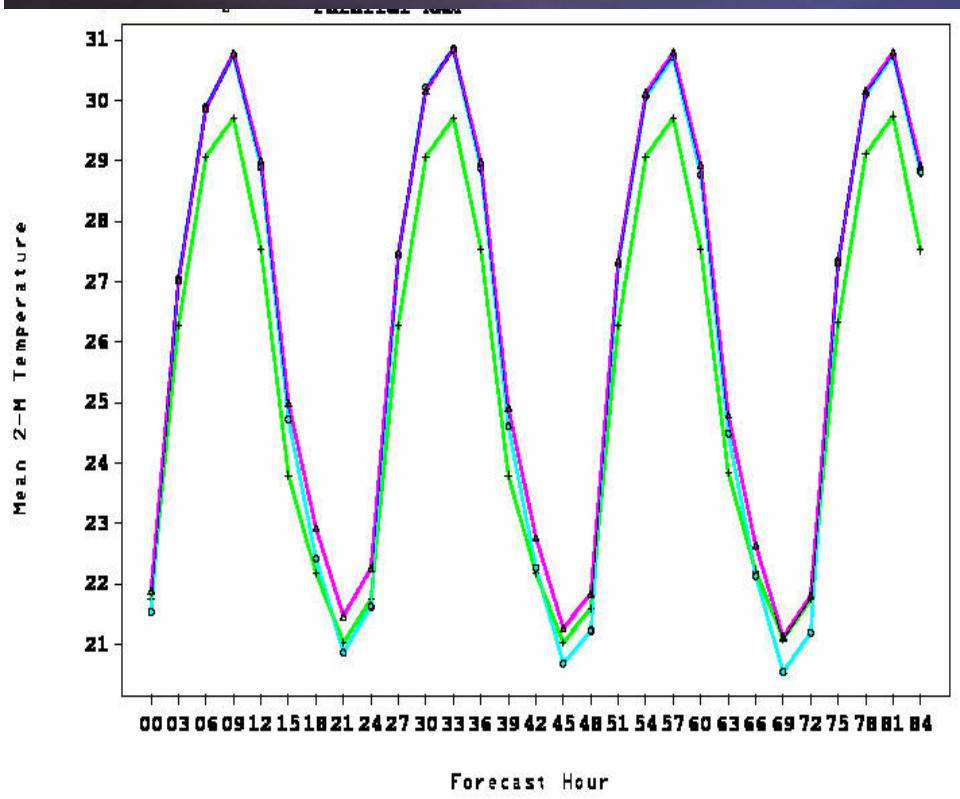
Additional NAM Changes (NAM-Y) Implemented August 15, 2006

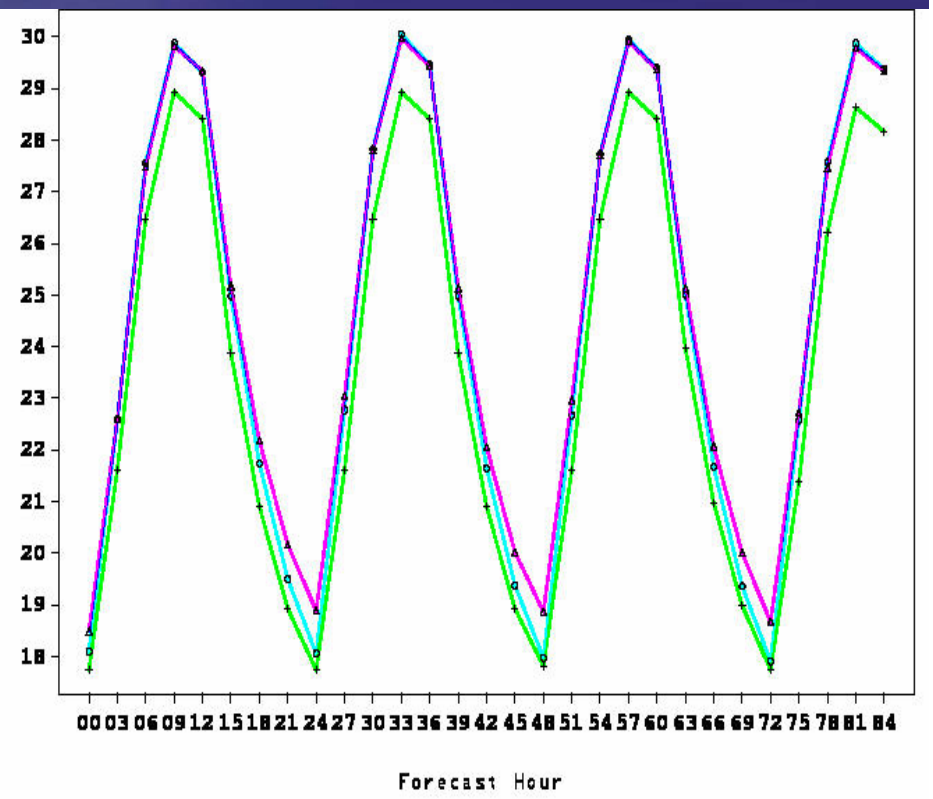
- **WRF-NAM PBL often too cool and moist esp. in complex terrain and over/near water bodies**
- **Over intense storms off West coast**
- **Corrections Made:**
  - ***Increased vertical mixing for stable PBLs***
  - ***Turned on horizontal mixing at and near all coastal points and in complex terrain***
  - ***Fixed SST initializations at Western Lakes***

- **Double horizontal diffusion everywhere: Implemented on Sept. 5, 2006**

NAM vs NAM-Y evaluations

2m Temperature forecast error (12 Z Cycle)





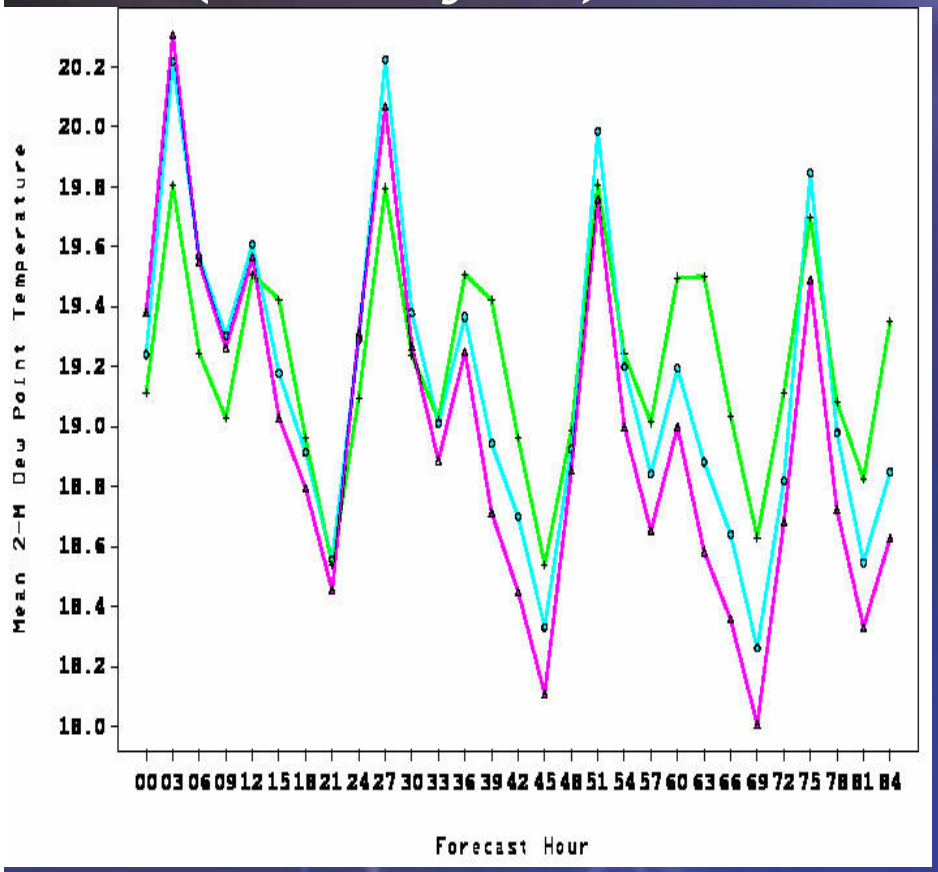
EASTERN U.S.

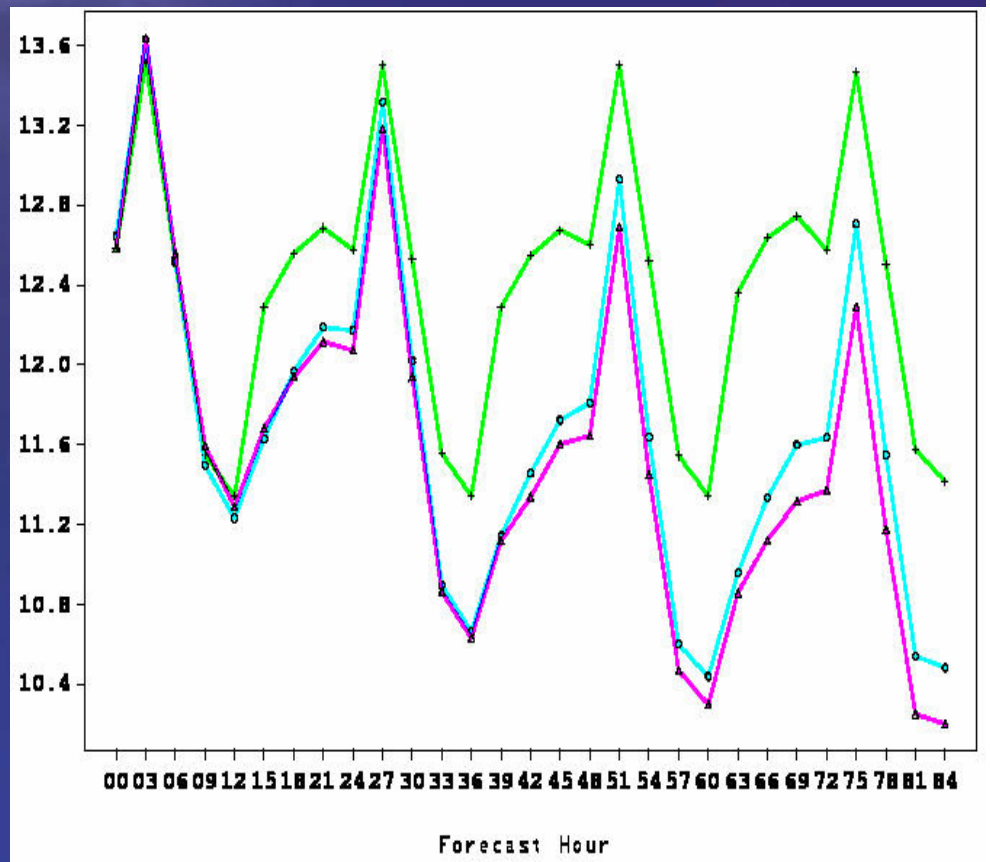
OBS
NAM
NAM-Y

WESTERN U.S.

NAM vs NAM-Y evaluations

2m Dewpoint Temperature forecast error (12 Z Cycle)





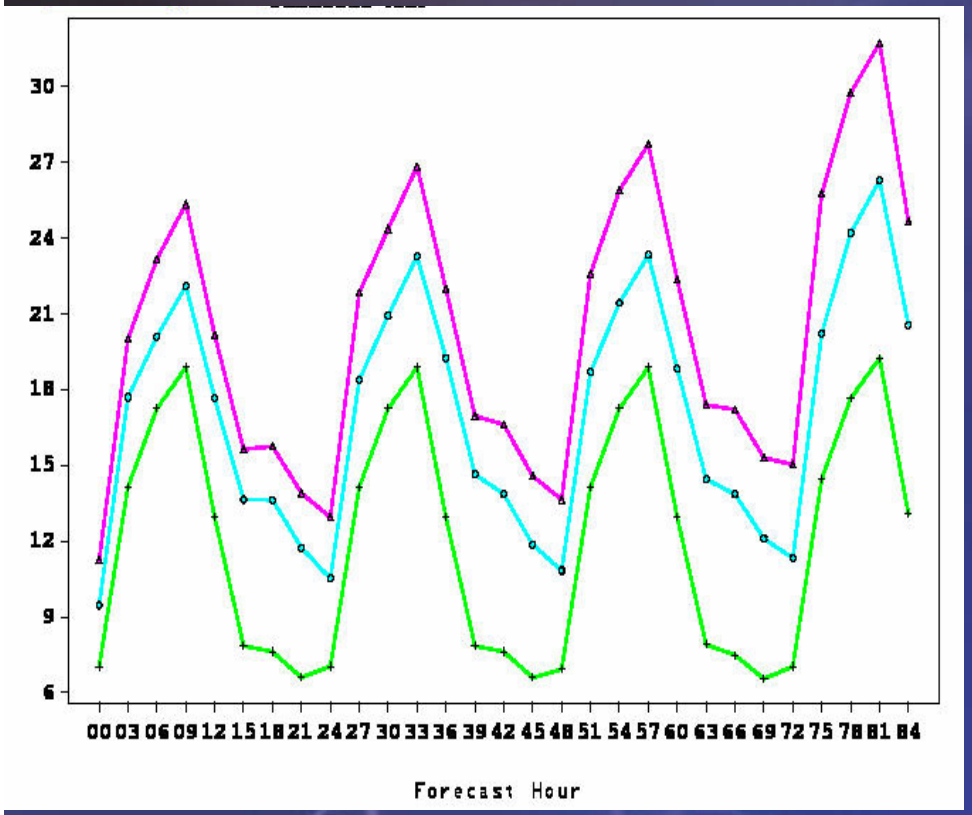
EASTERN U.S.

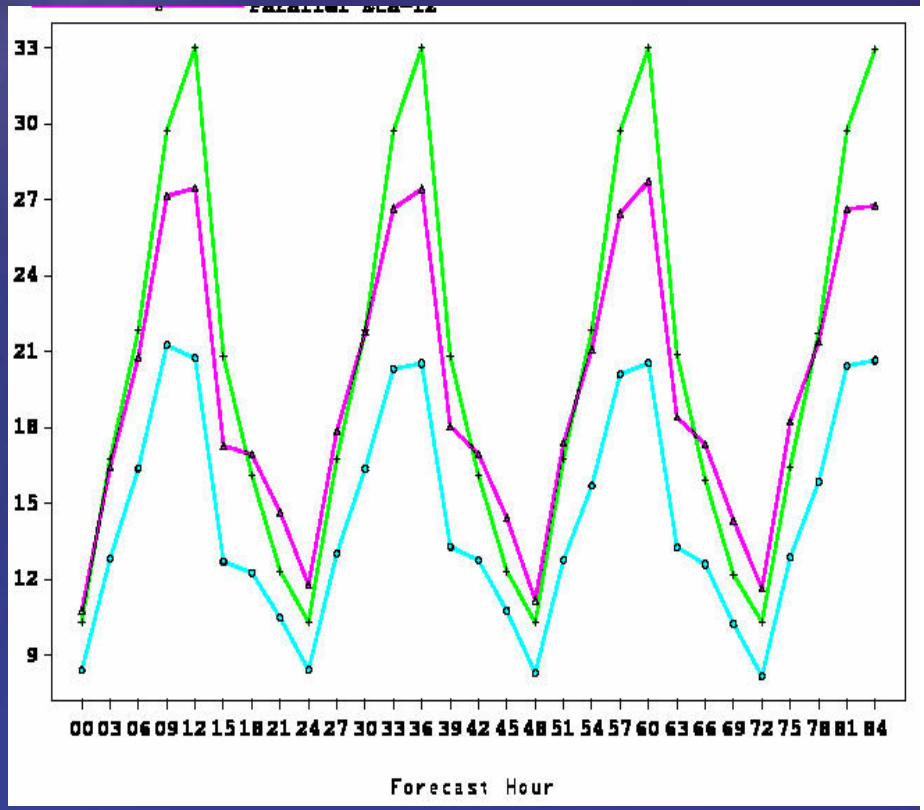
OBS
NAM
NAM-Y

WESTERN U.S.

NAM vs NAM-Y evaluations

10m WIND forecast error (12 Z Cycle)



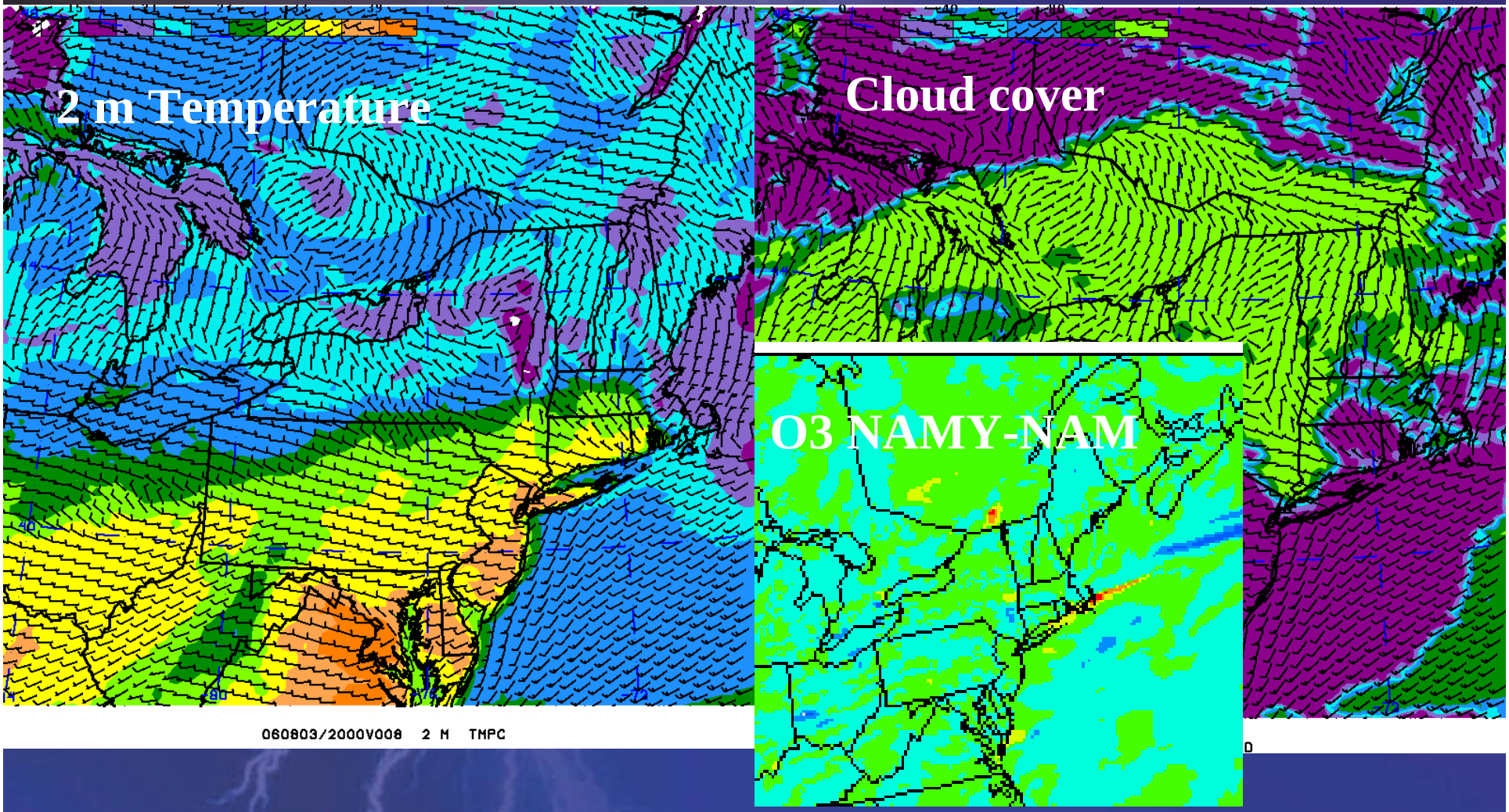


EASTERN U.S.

OBS
NAM
NAM-Y

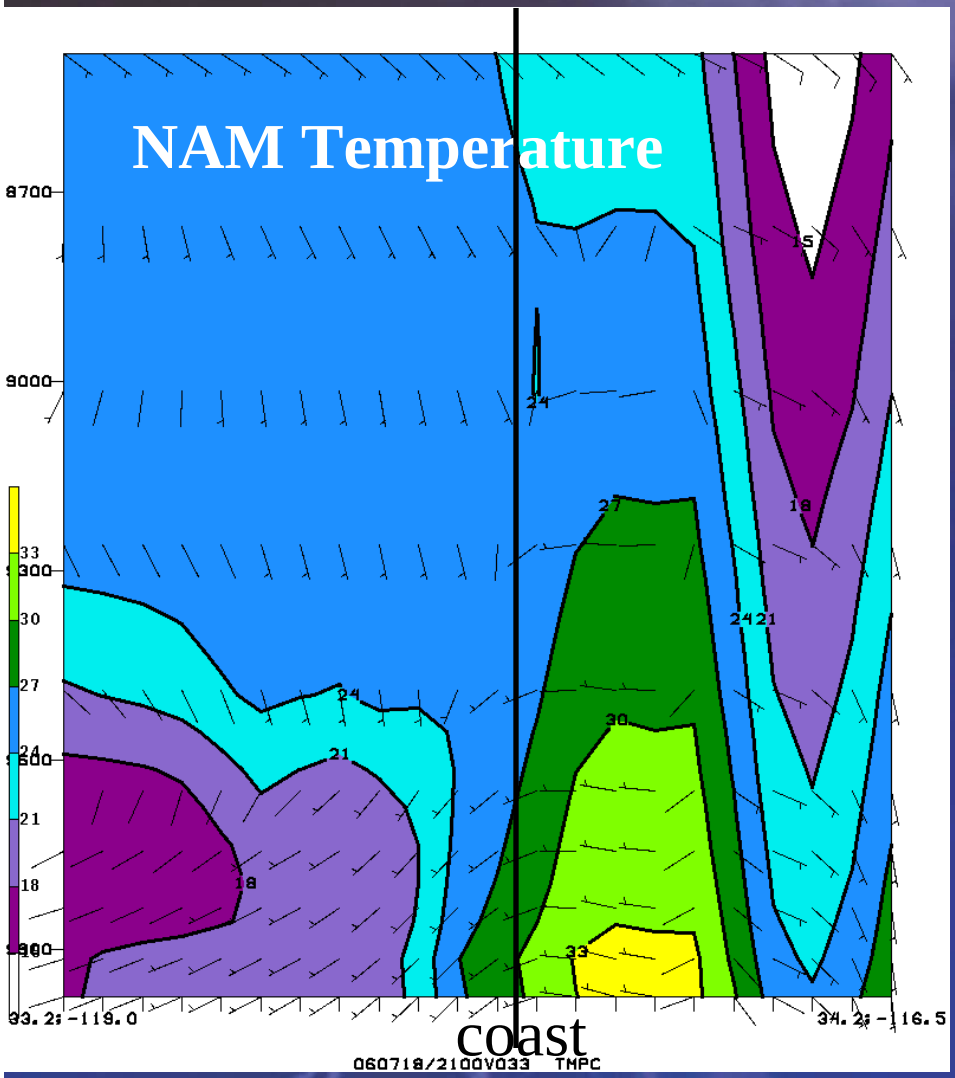
WESTERN U.S.

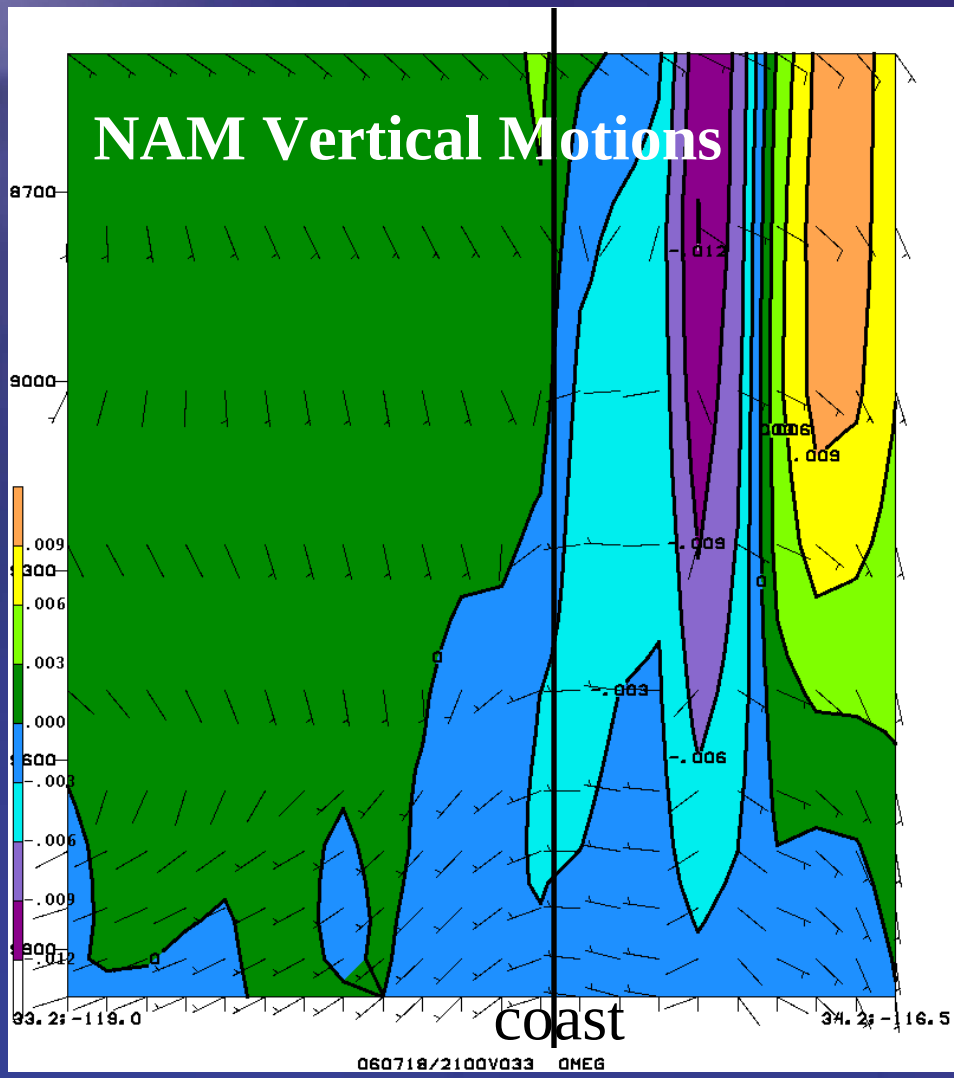
NAM-CMAQ Aug 3 case



The importance of met driver to CMAQ forecasts

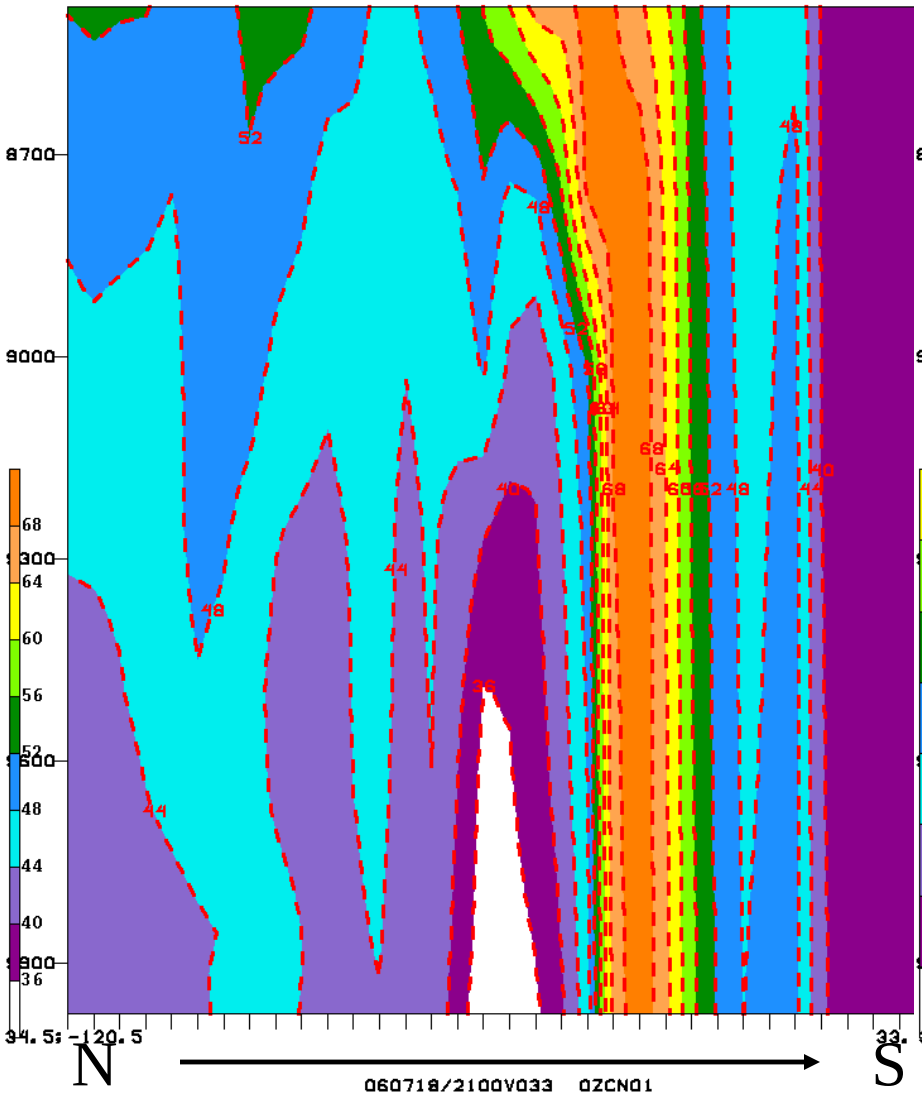
CMAQ under-predictions in California



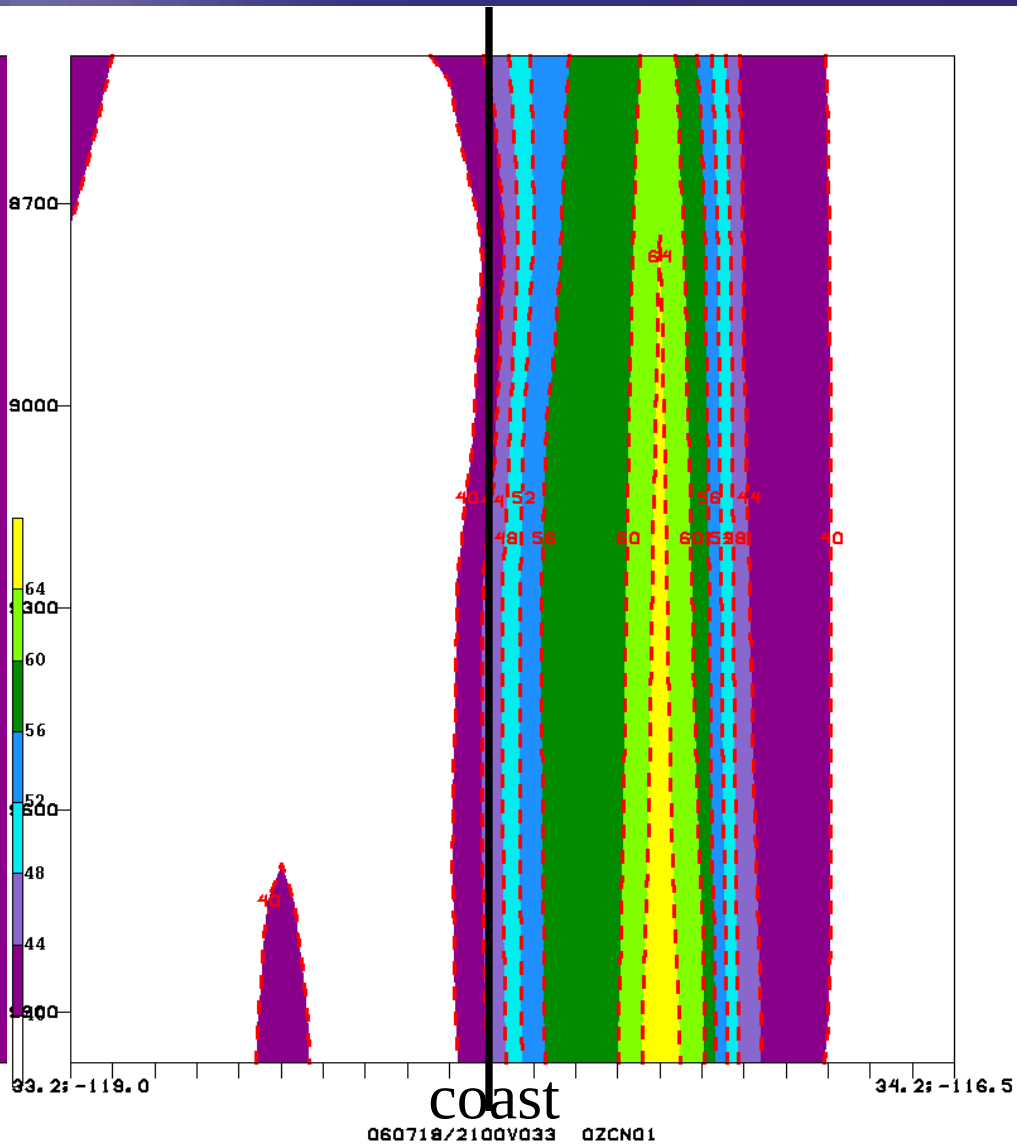


California Ozone Forecast

Inland Along Coast



Across Coast



Impact of Lateral Boundary Conditions

CMAQ 3X (w/ GFS Top LBC) vs
CMAQ 5x (w/ static, clean LBC)

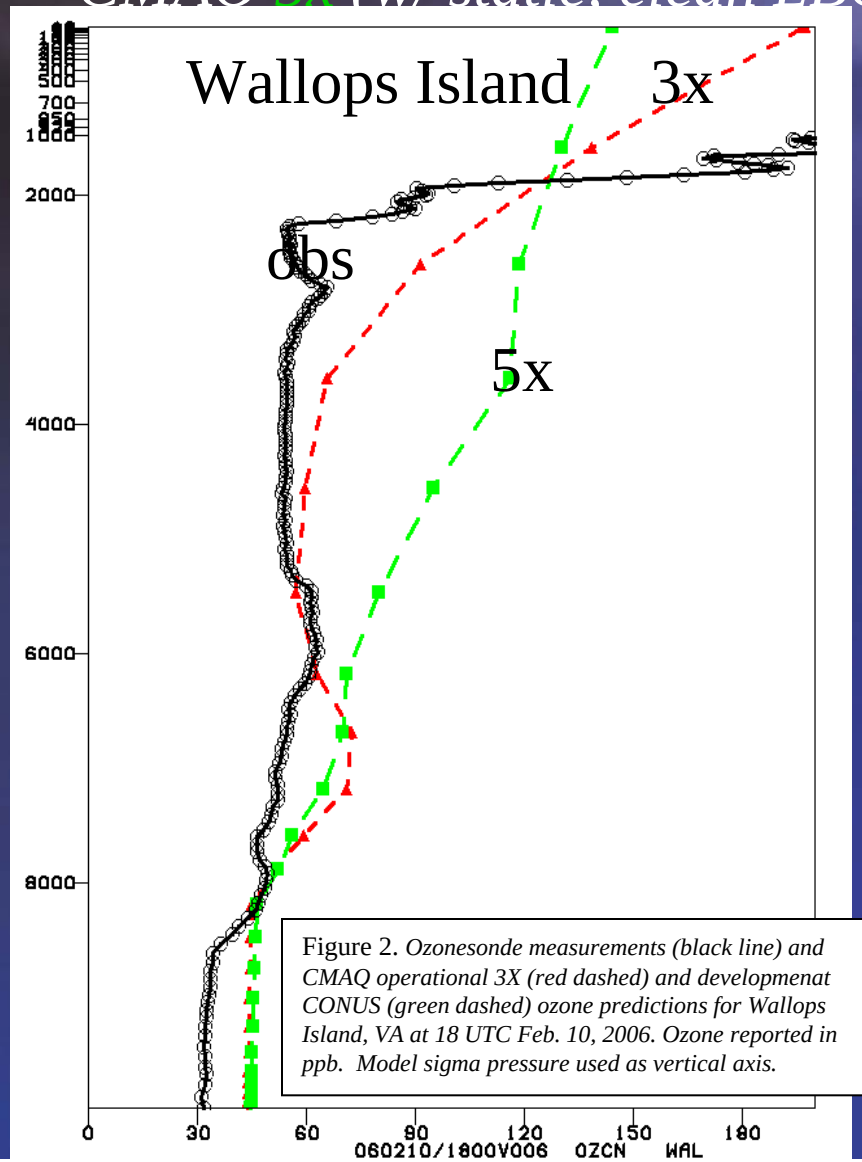
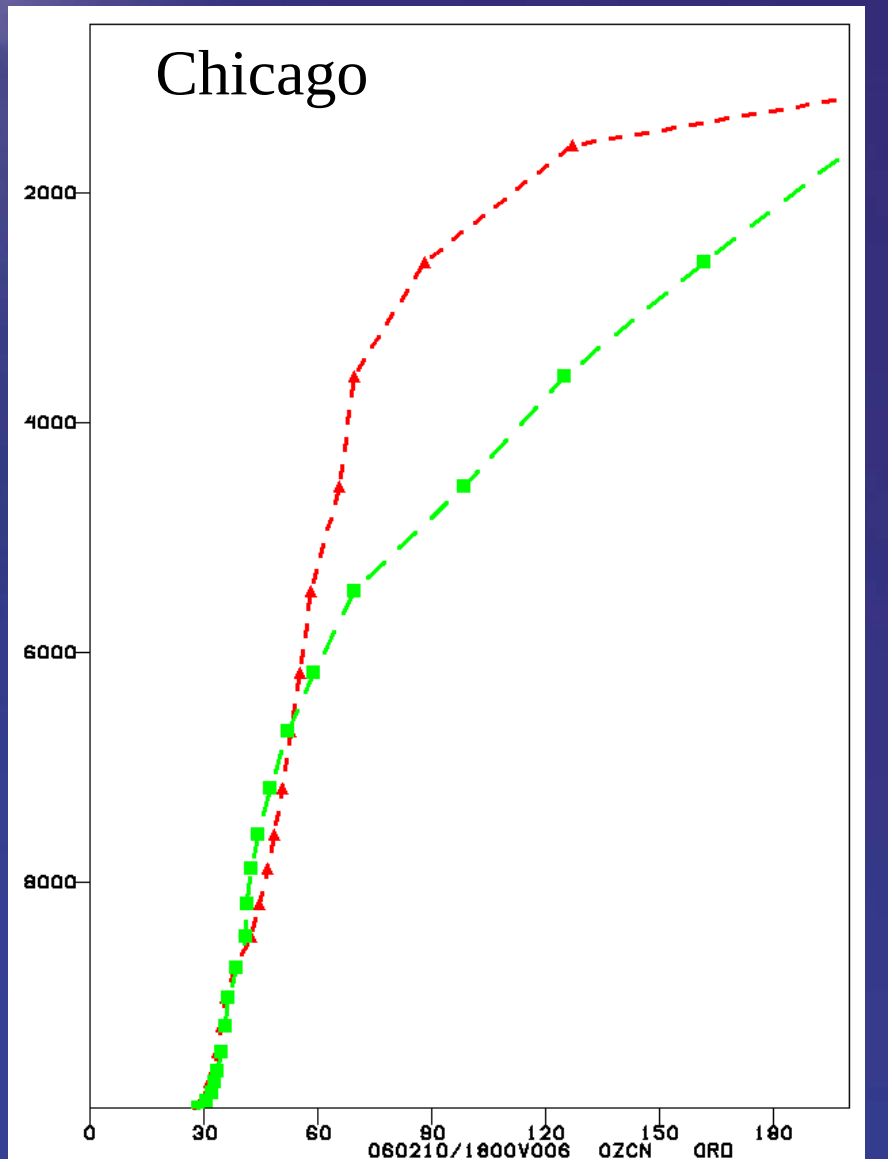


Figure 2. *Ozonesonde measurements (black line) and CMAQ operational 3X (red dashed) and developmenat CONUS (green dashed) ozone predictions for Wallops Island, VA at 18 UTC Feb. 10, 2006. Ozone reported in ppb. Model sigma pressure used as vertical axis.*



Summary

- **Major errors in WRF-Post, biogenic emissions, PREMAQ code and emission files**
  - ***Not found with retrospective testing***
  - ***Encumbered by final WRF retro configurations and Summer 05 retro WRF NDAS runs***

- **True NAM & NAM-Y and vertical structure impact can be assessed on/after August 5 when major isoprene error was corrected**
  - ***Exper CMAQ: genl incr. ozone w/ isoprene corrections***
  - ***NAM-Y-CMAQ: More localized but strong impacts***
    - **Warmer, dryer, well mixed PBL esp. during stable conditions**