Preparation of meteorological inputs to the air quality model for the South Coast Air Basin

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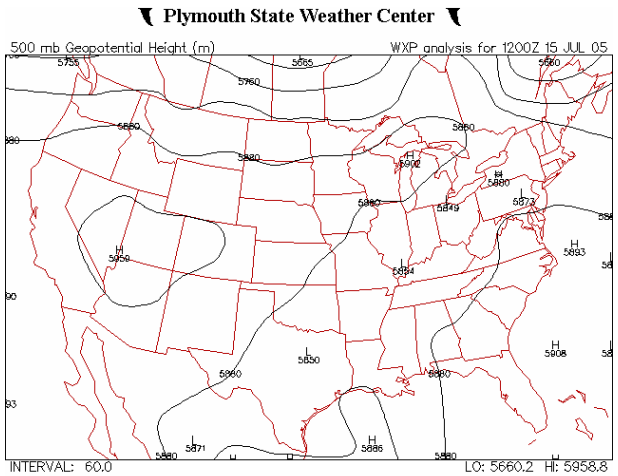
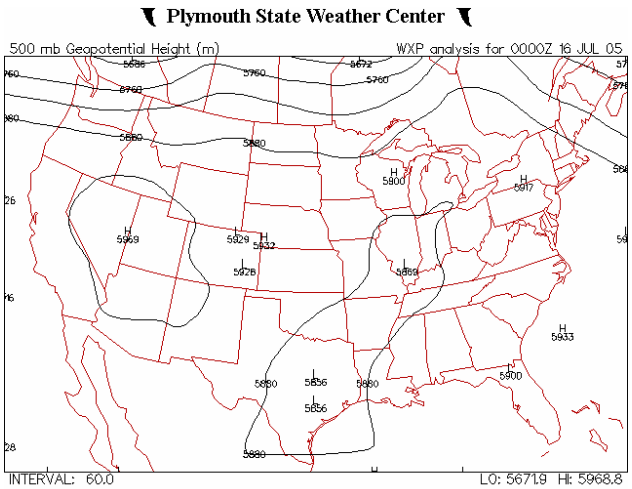
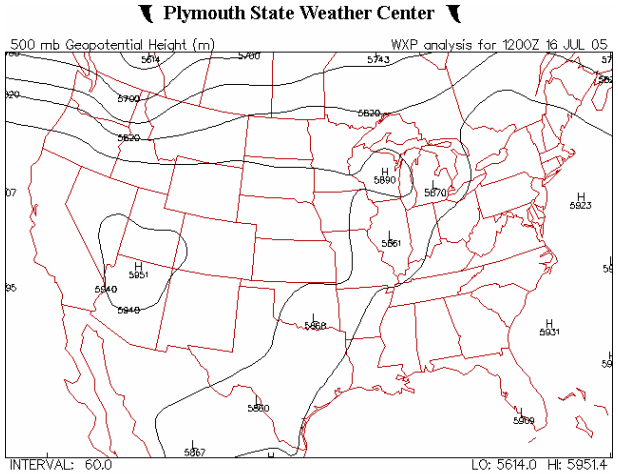
Changes from 2007 to 2010 AQMP

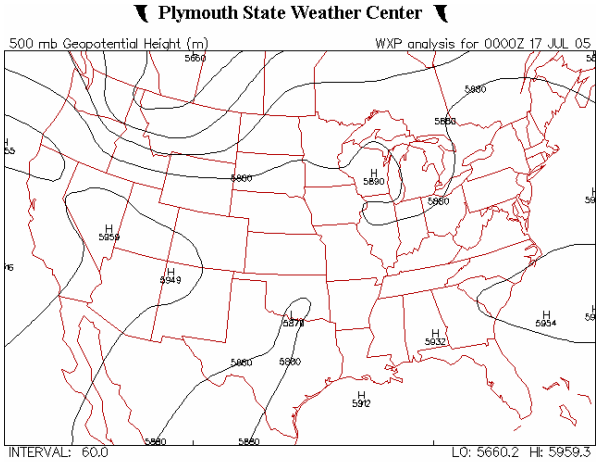
Configuration /Parameters	**2007AQMP**	**2010 AQMP**
Modeling Domain	SCOS 5km Grid size	Statewide 4km Grid size
Meteorological Model	MM5	MM5/ WRF
Air Quality Model	CAMx	CAMx/CMAQ
Chemistry Module	SAPRC99	SAPRC99/SAPRC07/CB05
Pollutant Simulation	PM and Ozone individual run	One Atmosphere ?
Boundary Concentration	- Extracted from WRAP model results - EPA default clean condition	- 2008-2009 AQMD Field Study - 2008 NASA/CARB ARCTAS Fields Study
Emissions	On-Road EMFAC 2007 Area Sources/Off-Road	EMFAC 2010 Surrogates Updates
Simulation Periods	Episodic, Annual	Multi-years

July 14-19, 2005 Ozone Episodes was selected for Meteorological Field Evaluation
The period dominated by high pressure ridge over the west coast
(500 mb Heights > 5,990 m). 1512z1600z1612z1700z

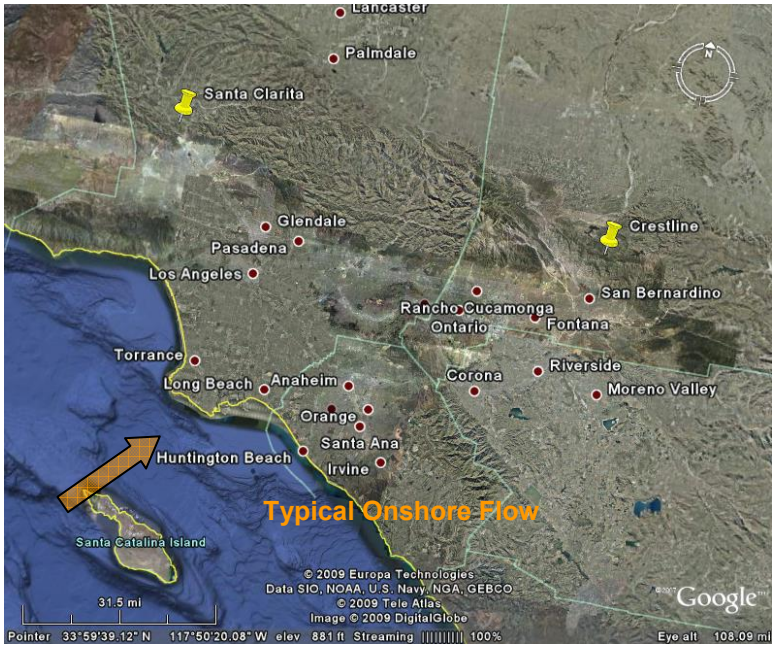


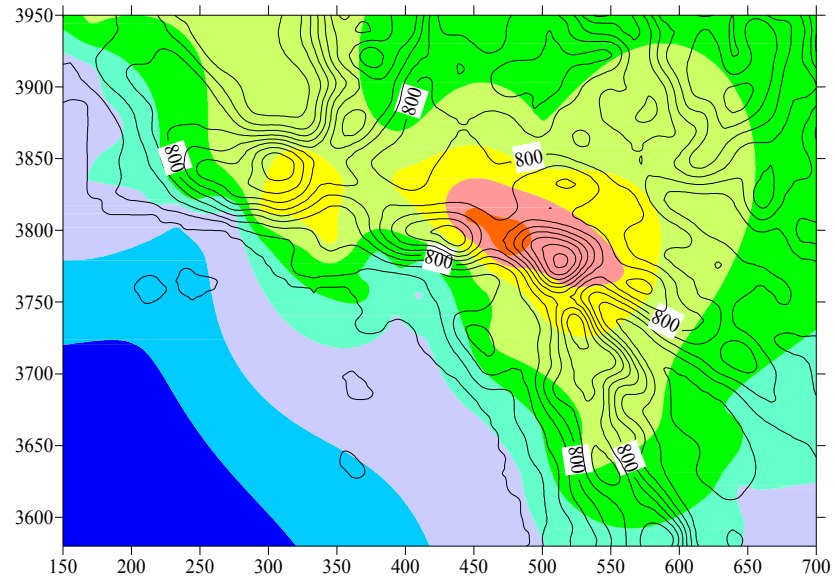


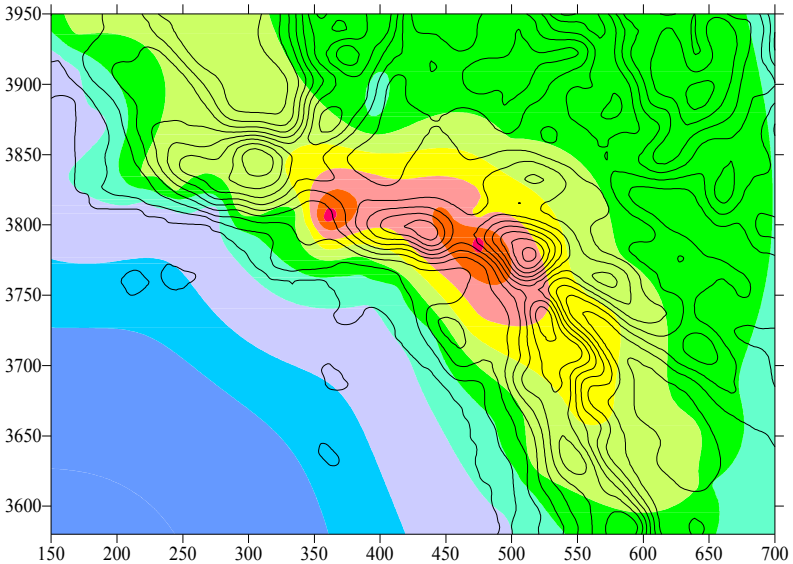


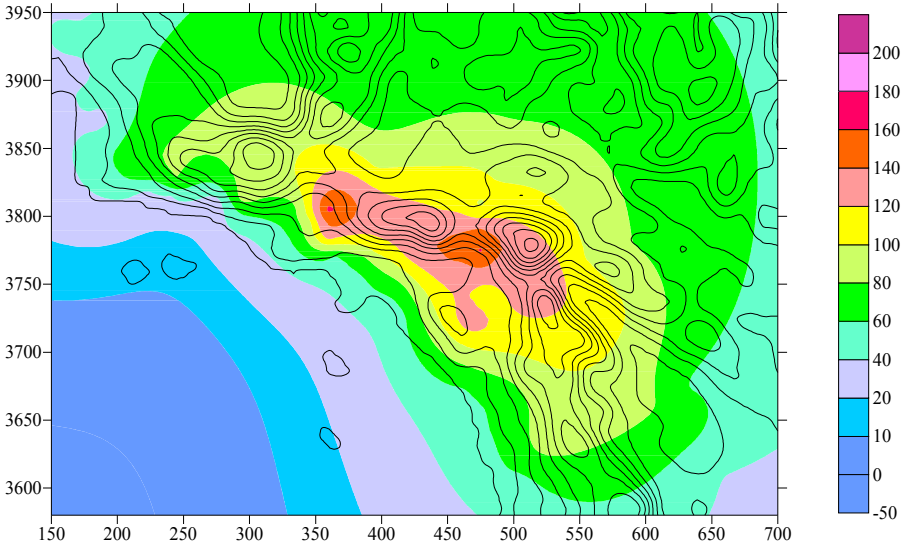


Observed Ozone for July 15Fri(91 ppb,158 ppb), 16Sat (173 ppb,166 ppb) and 17Sun(165 ppb,145 ppb)

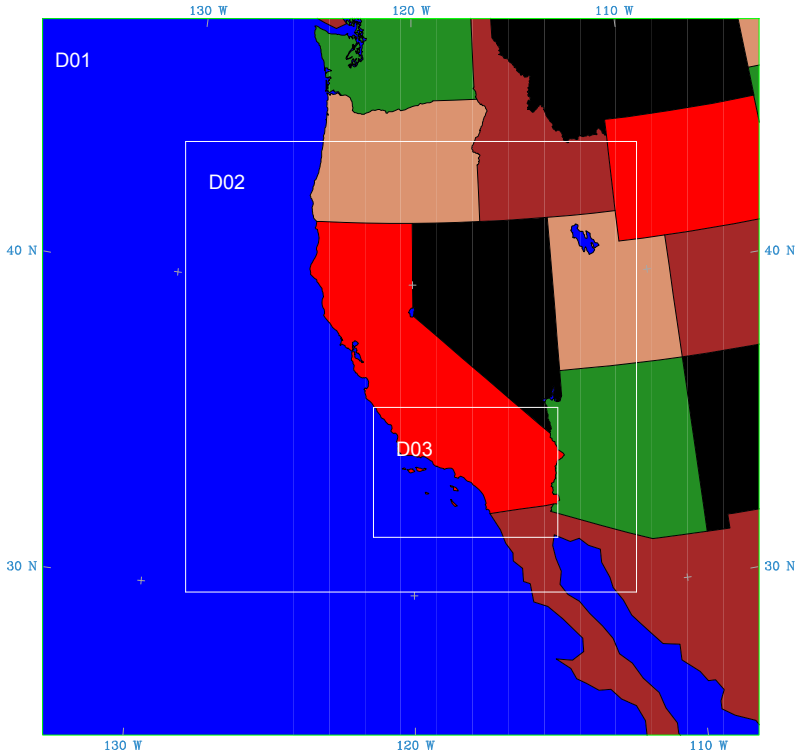






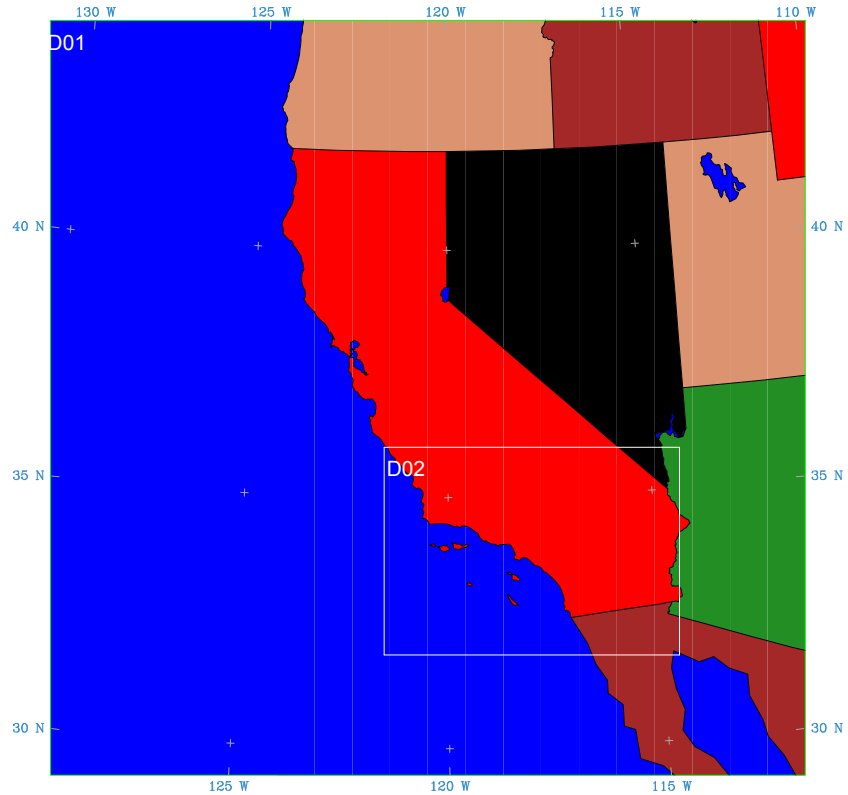


MM5 configuration
Projection: Lambert Conformal Conic
Central Meridian: -120.5W
Latitude of Origin: 37N
Standard Parallel 1: 30N
Standard Parallel 2: 60N
Coordinate System: Sphere 6370 km Radius



3-Domain configuration
Number of Domains: 3
Domain 1: Grid Distance 36 km, Grid Dimensions 70x70, SW Corner (-1260,-1260)
Domain 2: Grid Distance 12 km, Grid Dimensions 132x132, SW Corner (-756,-756)
Domain 3: Grid Distance 04 km, Grid Dimensions 162x114, SW Corner (-96,-564)
Air Quality Modeling Domain 3 cells offsets from MM5 Domain3:
(156x108), SW corner (-84,-552)

MM5 configuration
Projection: Lambert Conformal Conic
Central Meridian: -120.5W
Latitude of Origin: 37N
Standard Parallel 1: 30N
Standard Parallel 2: 60N
Coordinate System: Sphere 6370 km Radius



2-Domain configuration
Domain 1: Grid Distance 12 km, Grid Dimensions 138x138, SW Corner (-828,-828)
Domain 2: Grid Distance 04 km, Grid Dimensions 162x114, SW Corner (-96,-564)

Air Quality Modeling Domain 3 cells offsets from MM5 Domain 2:
(156x108), SW corner (-84,-552)

WRF configuration
Projection: Lambert Conformal Conic
Central Meridian: -120.5W
Latitude of Origin: 37N
Standard Parallel 1: 30N
Standard Parallel 2: 60N
Coordinate System: Sphere 6370 km Radius

3-Domain configuration
Number of Domains: 3
Domain 1: Grid Distance 36 km, Grid Dimensions 70x70, SW Corner (-1260,-1260)
Domain 2: Grid Distance 12 km, Grid Dimensions 132x132, SW Corner (-756,-756)
Domain 3: Grid Distance 04 km, Grid Dimensions 162x114, SW Corner (-96,-564)
Air Quality Modeling Domain 3 cells offsets from MM5 Domain3:
(156x108), SW corner (-84,-552)

MM5 Physics Options

- Grell Cumulus Parameterization
- No Shallow Convection
- MRF PBL
- Simple Ice (Dudhia) Explicit Moisture Scheme
- RRTM longwave Radiation Schemes
- 5 Layer Soil Model
- Vertical Structure 34 levels
- Pressure Top = 10000 Pa

WRF Physics Options

- microphysics option= 3, WSM 3-class simple ice scheme
- longwave radiation option= 1, rrtm scheme
- shortwave radiation option= 1, Dudhia scheme
- boundary-layer option= 1, YSU scheme
- cumulus option = 1, Kain-Fritsch (new Eta) scheme
- land surface model= 5: thermal diffusion scheme (number of soil layers=5)

Vertical Structure for the WRF Meteorological Model

Layer #	Sigma	P_0 (Pa)	Height (m)*	Depth (m)*	Layer #	Sigma	P_0 (Pa)	Height (m)*	Depth (m)*
17	0.8	82000	1657	178	34	0	10000	15674	2004
16	0.82	83800	1478	175	33	0.05	14500	13670	1585
15	0.84	85600	1303	172	32	0.1	19000	12085	1321
14	0.86	87400	1130	169	31	0.15	23500	10764	1139
13	0.88	89200	961	167	30	0.2	28000	9625	1004
12	0.9	91000	794	82	29	0.25	32500	8621	900
11	0.91	91900	712	82	28	0.3	37000	7720	817
10	0.92	92800	631	81	27	0.4	41500	6903	750
9	0.93	93700	550	80	26	0.3	46000	6163	693
8	0.94	94600	469	80	25	0.45	50500	6461	645
7	0.95	95500	389	79	24	0.5	55000	4816	604
6	0.96	96400	310	78	23	0.55	59500	4212	568
5	0.97	97300	232	78	22	0.6	64000	3644	536
4	0.98	98200	154	39	21	0.65	68500	3108	508
3	0.985	98650	115	39	20	0.7	73000	2600	388
2	0.99	99100	77	38	19	0.74	76600	2212	282
1	0.995	99550	38	38	18	0.77	79300	1930	274
0	1	100000	0	0					

Initial/Lateral boundary condition Data Source

ds083.2 NCEP Global Tropospheric Analyses, 1x1 deg
NCEP Global Analyses on 1x1 degree grids covering the entire globe every six hours. (NCEP derives these from the FNL (final) run which they make with observations collected through at least six hours after the synoptic time)

ds609.2
The operational NCEP Eta 212 grid (40km) model output is archived in this dataset

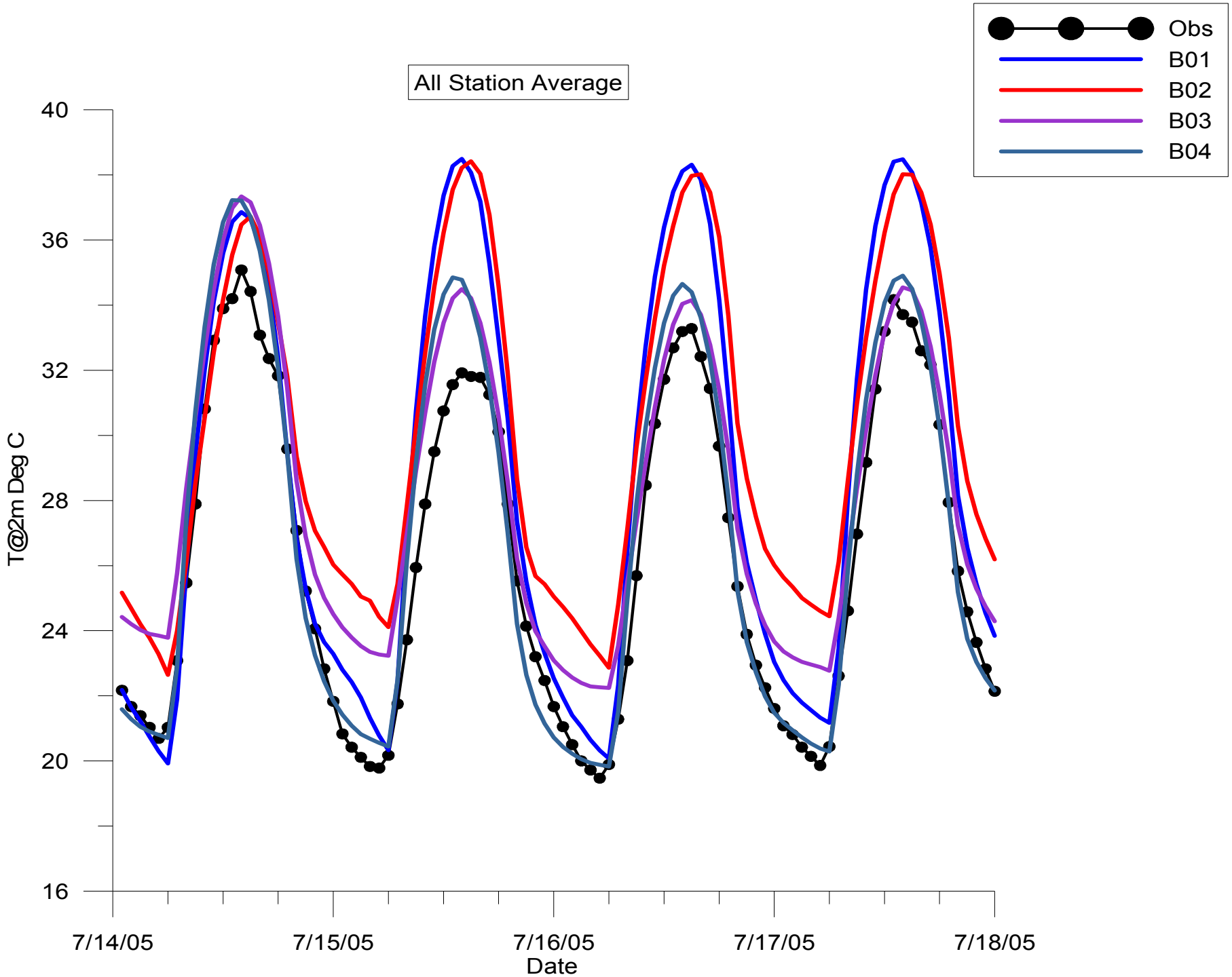
Upper Air Observation Data Source
ds353.4 NCEP ADP Global Upper Air Observation Subsets
ds351.0 NCEP ADP (RAOBS, Aircraft, satellite April 2000-)
Surface Observation Data Source
ds464.0 NCEP ADP Global Surface Observations
ds461.0 NCEP ADP (Surface and Ship data April 2000-)

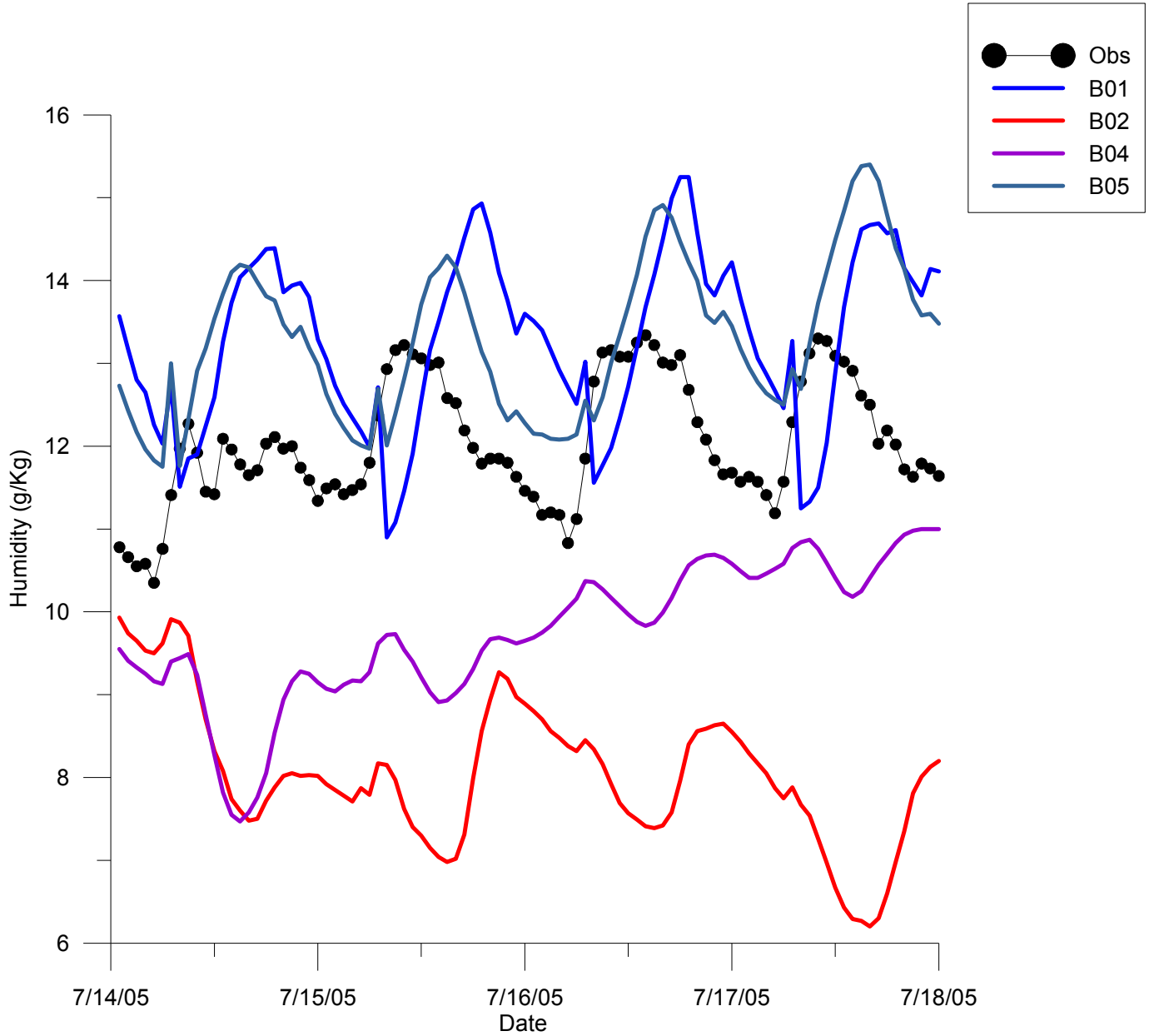
WRF Sensitivity Analysis (1)

Physics	Options	B01	B02	B03	B04	B09	B10	B11	B12	B13	B14	B15
Microphysics	WRF Single-Moment 3-class scheme	X	X	X	X	X	X	X	X	X	X	X
Longwave Radiation	RRTM scheme	X	X	X	X	X	X	X	X	X	X	X
Shortwave Radiation	Dudhia scheme	X	X	X	X	X	X	X	X	X	X	
	CAM scheme											X
Surface Layer	MM5 similarity	X	X	X	X	X	X	X	X	X	X	X
	QNSE surface layer							X	X	X	X	X
Land Surface	5-layer thermal diffusion	X			X	X	X	X				X
	Noah Land Surface Model		X	X					X	X	X	
Planetary Boundary layer	Yonsei University scheme	X	X	X	X	X	X					
	Quasi-Normal Scale Elimination PBL							X	X	X	X	X
Cumulus Parameterization	Kain-Fritsch scheme (except D03)	X	X	X	X	X	X	X	X	X	X	X
Analysis Nudging	Three Dimensional Analysis Nudging			X	X	X	X			X	X	
	met_em			X	X							
OBSGRID												
Objective Analysis techniques	Cressman Scheme											
Upper-Air	metoa_em + wrffdda					X	X			X	X	
Surface	wrfsfdda_d01,02,03					X					X	
Station Observation	OBS_DOMAIN301						X				X	
Datasets	ASOS and RAOBS	X	X	X	X	X	X	X	X	X	X	X
Statististical Analysis	METSTAT (WRF 10m Wind T 2m)	X	X	X	X	X	X	X	X	X	X	X
Datasets	AQMD Surface Observation Stations	X	X	X	X	X	X	X	X	X	X	X

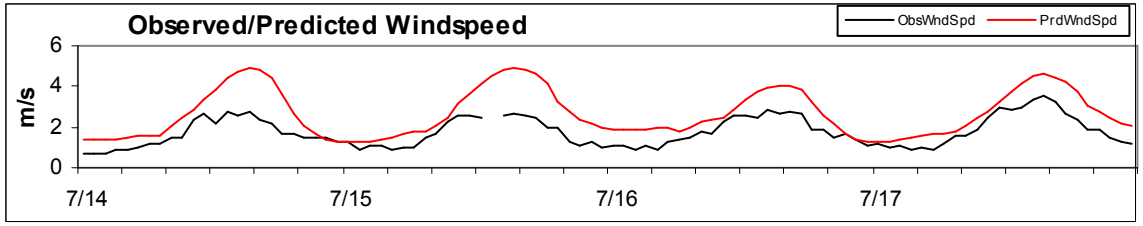
WRF Sensitivity Analysis (2)

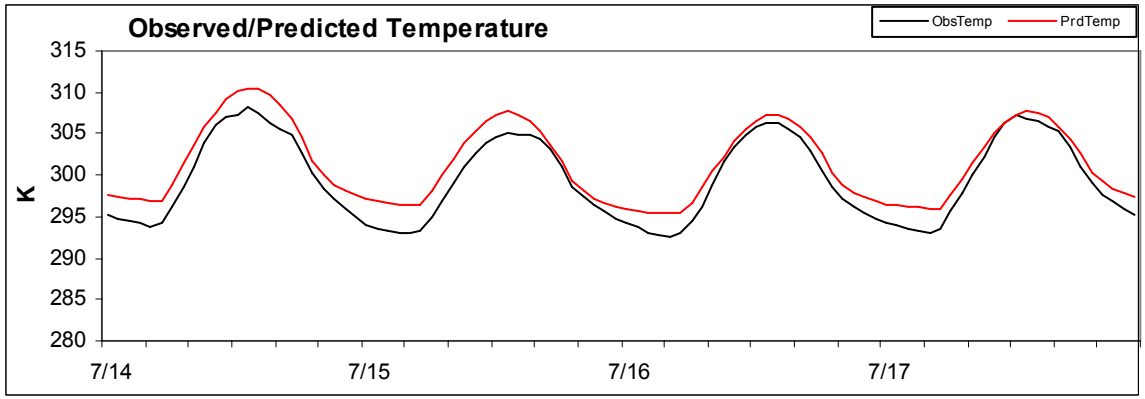
Physicsu	Options	B15	B16	B17
Microphysics	WRF Single-Moment 3-class scheme	X	X	X
Longwave Radiation	RRTM scheme	X	X	X
Shortwave Radiation	Dudhia scheme			
	CAM scheme	X	X	X
Surface Layer	MM5 similarity	X	X	X
	QNSE surface layer	X	X	X
Land Surface	5-layer thermal diffusion	X	X	X
	Noah Land Surface Model			
Planetary Boundary layer	Yonsei University scheme			
	Quasi-Normal Scale Elimination PBL	X	X	X
Cumulus Parameterization	Kain-Fritsch scheme (except D03)	X	X	X
Analysis Nudging	Three Dimensional Analysis Nudging		X	
	met_em			
OBSGRID				
Objective Analysis techniques	Cressman Scheme			
Upper-Air	metoa_em + wrffdda			
Surface	wrfsfdda_d01,02,03			
Station Observation	OBS_DOMAIN301			X
Datasets	ASOS and RAOBS	X	X	X
Statististical Analysis	METSTAT (WRF 10m Wind T 2m)	X	X	X
Datasets	AQMD Surface Observation Stations	X	X	X

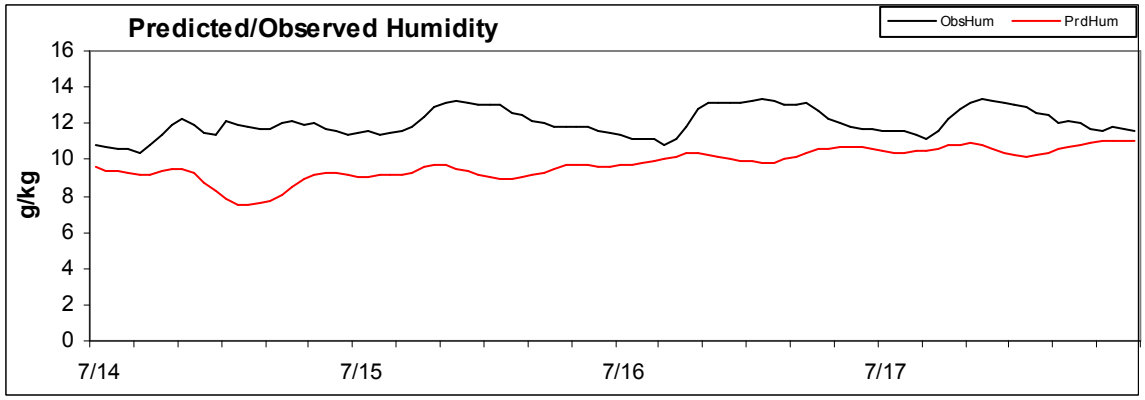

All Station Average
Obs
B01
B02
B03
B04
40
36
32
28
24
20
16
T@2m Deg C
7/14/05
7/15/05
7/16/05
7/17/05
7/18/05
Date


Obs
B01
B02
B04
B05
16
14
12
10
8
6
Humidity (g/Kg)
7/14/05
7/15/05
7/16/05
7/17/05
7/18/05
Date

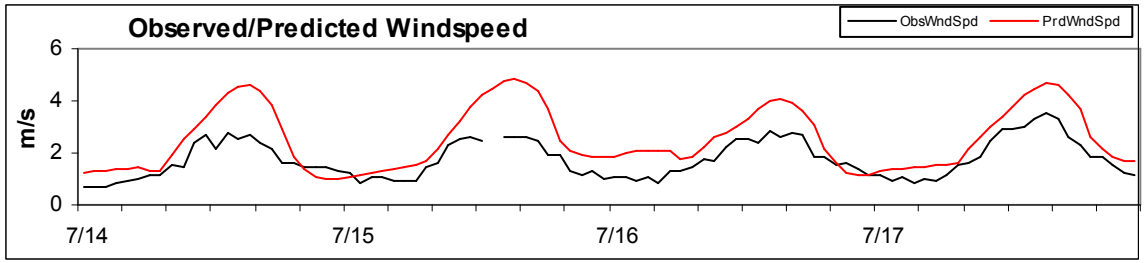
B03

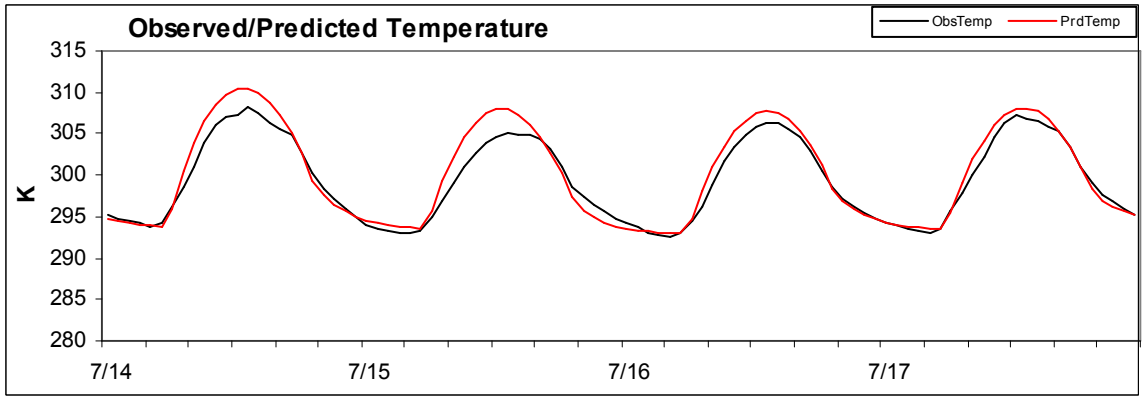

Observed/Predicted Windspeed
ObsWndSpd
PrdWndSpd
m/s
6
4
2
0
7/14
7/15
7/16
7/17

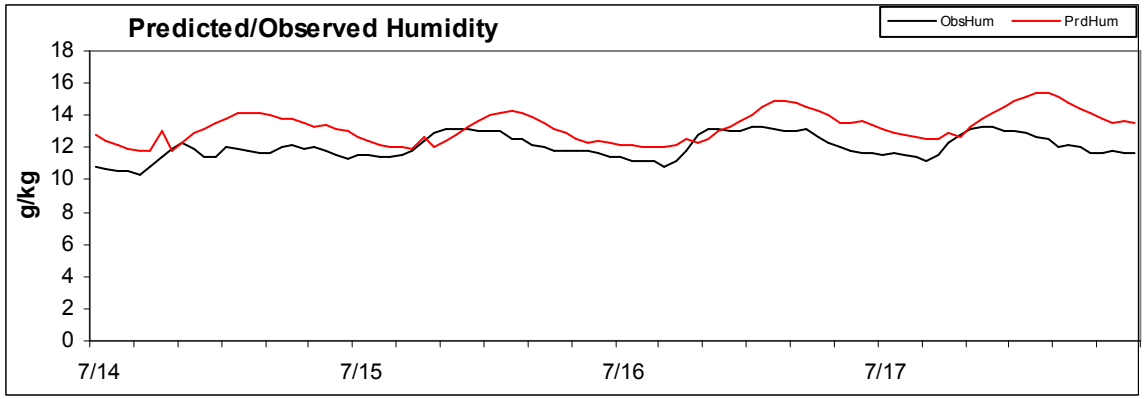

Observed/Predicted Temperature
ObsTemp
PrdTemp
K
315
310
305
300
295
290
285
280
7/14
7/15
7/16
7/17


Predicted/Observed Humidity
ObsHum
PrdHum
g/kg
16
14
12
10
8
6
4
2
0
7/14
7/15
7/16
7/17

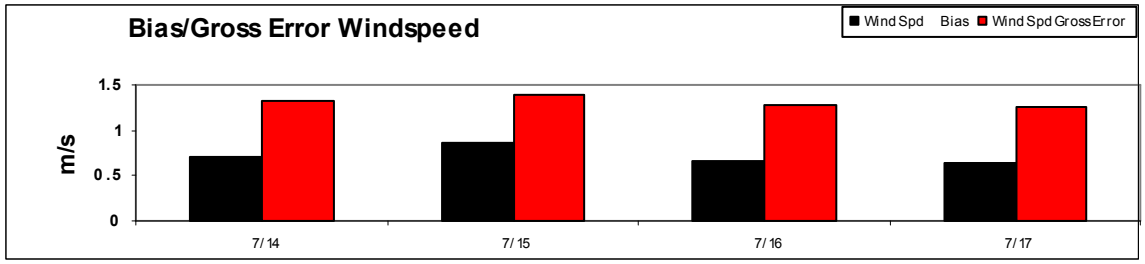
B04

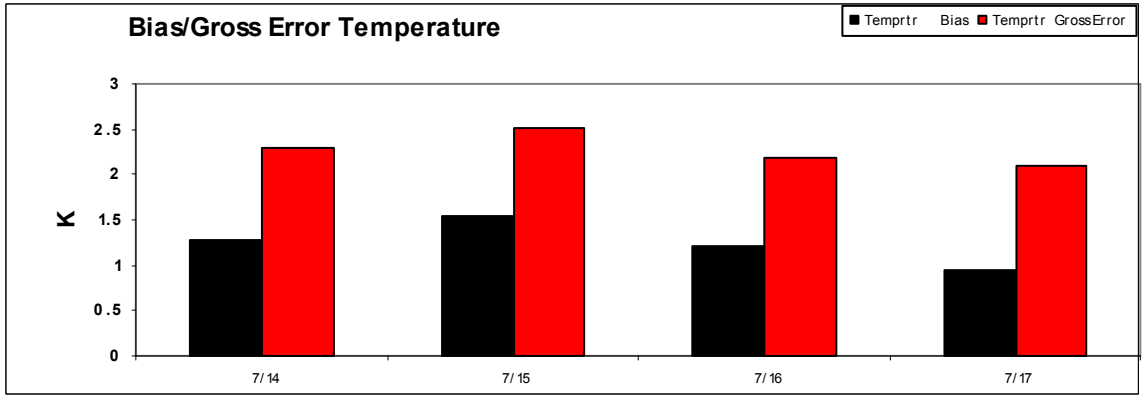

Observed/Predicted Windspeed
ObsWndSpd
PrdWndSpd
m/s
6
4
2
0
7/14
7/15
7/16
7/17

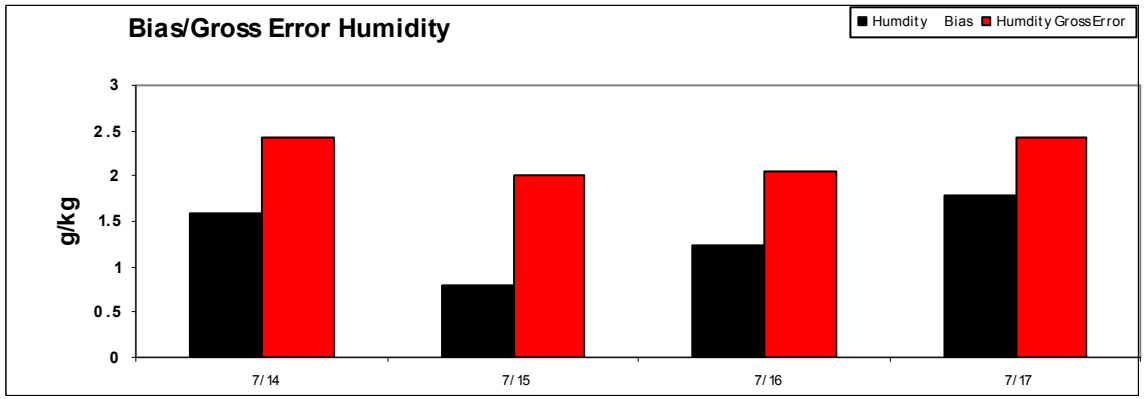

Observed/Predicted Temperature
ObsTemp
PrdTemp
K
315
310
305
300
295
290
285
280
7/14
7/15
7/16
7/17


Predicted/Observed Humidity
ObsHum
PrdHum
g/kg
18
16
14
12
10
8
6
4
2
0
7/14
7/15
7/16
7/17

B04 Daily Statistics

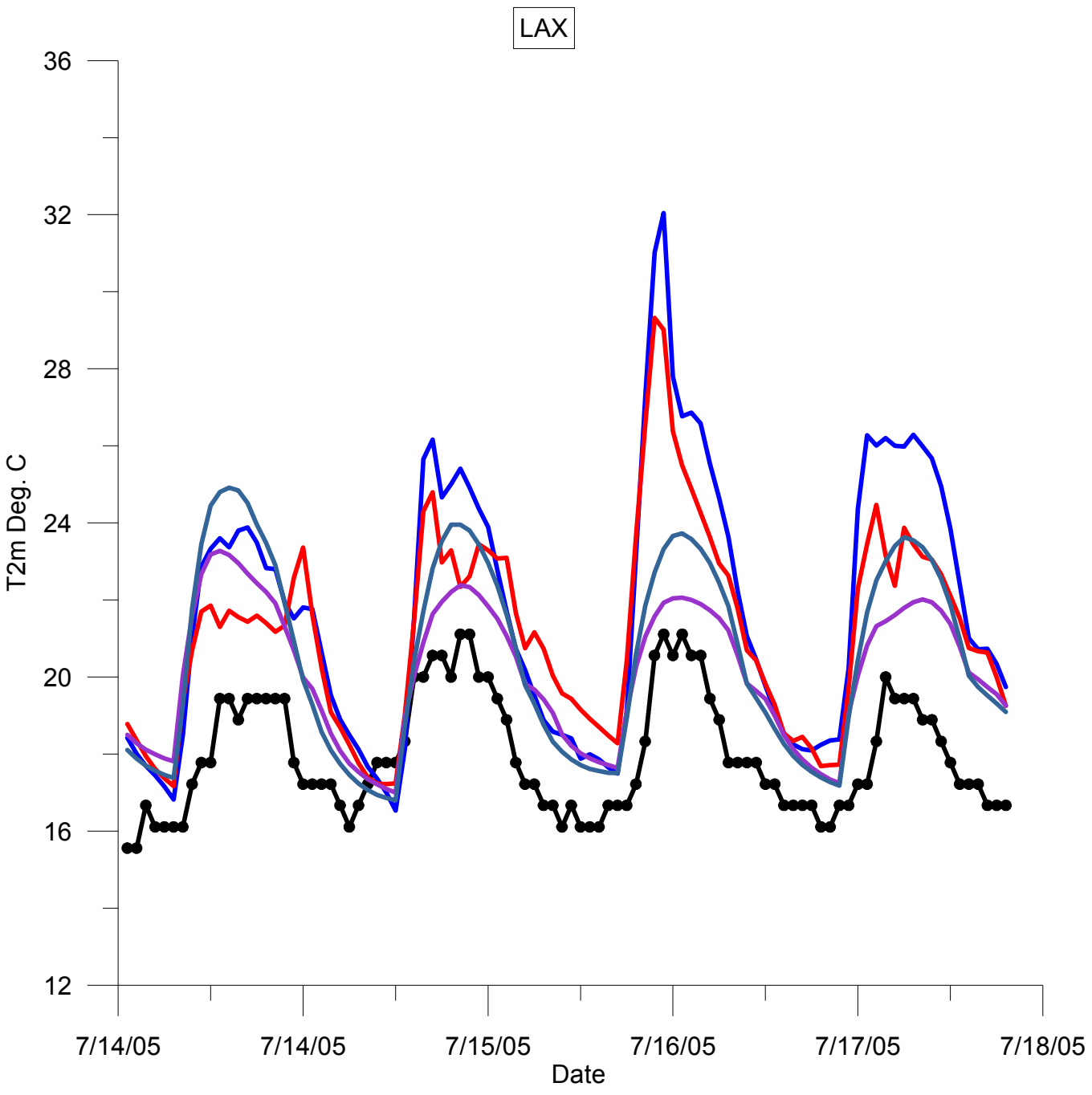


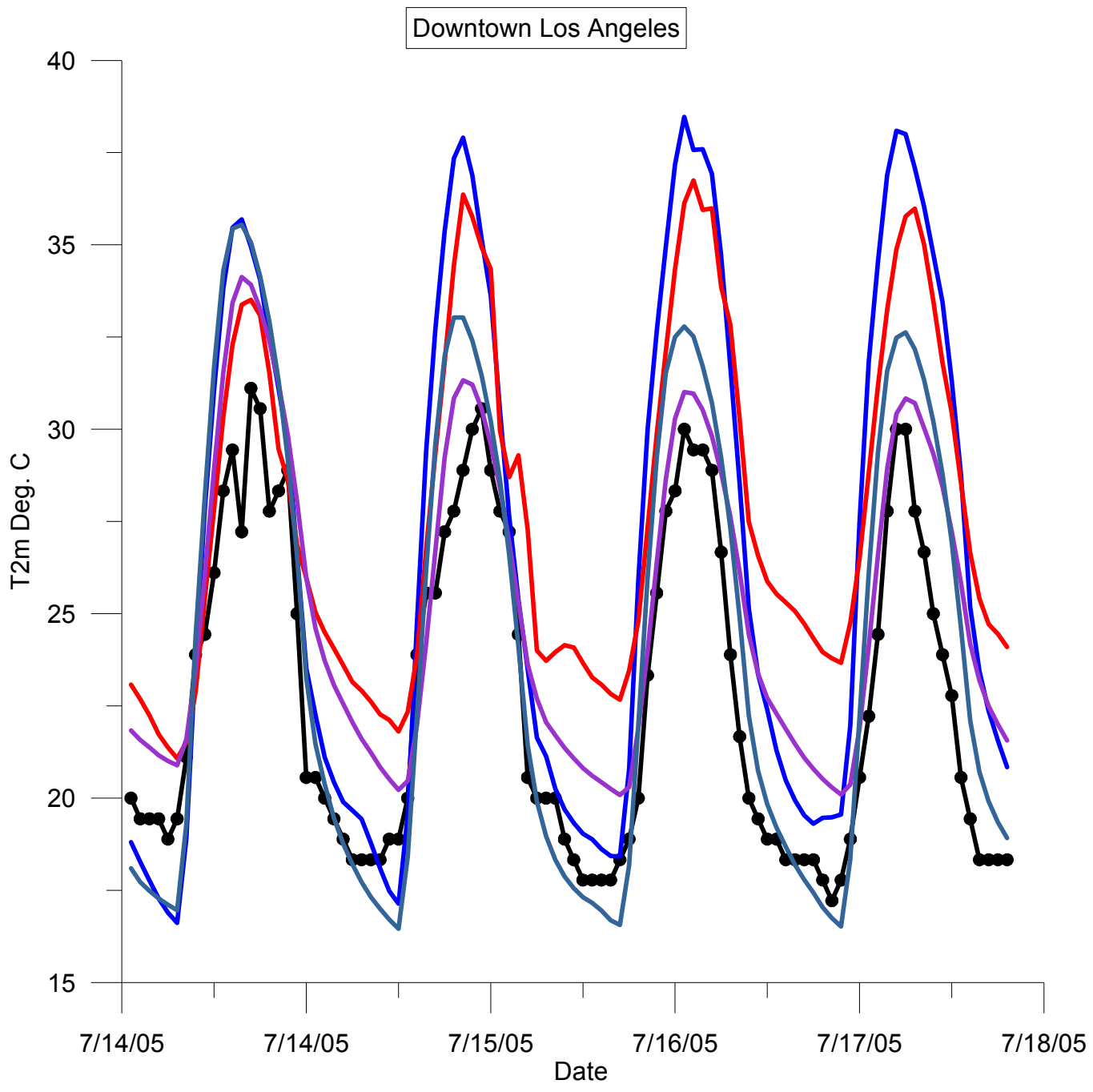


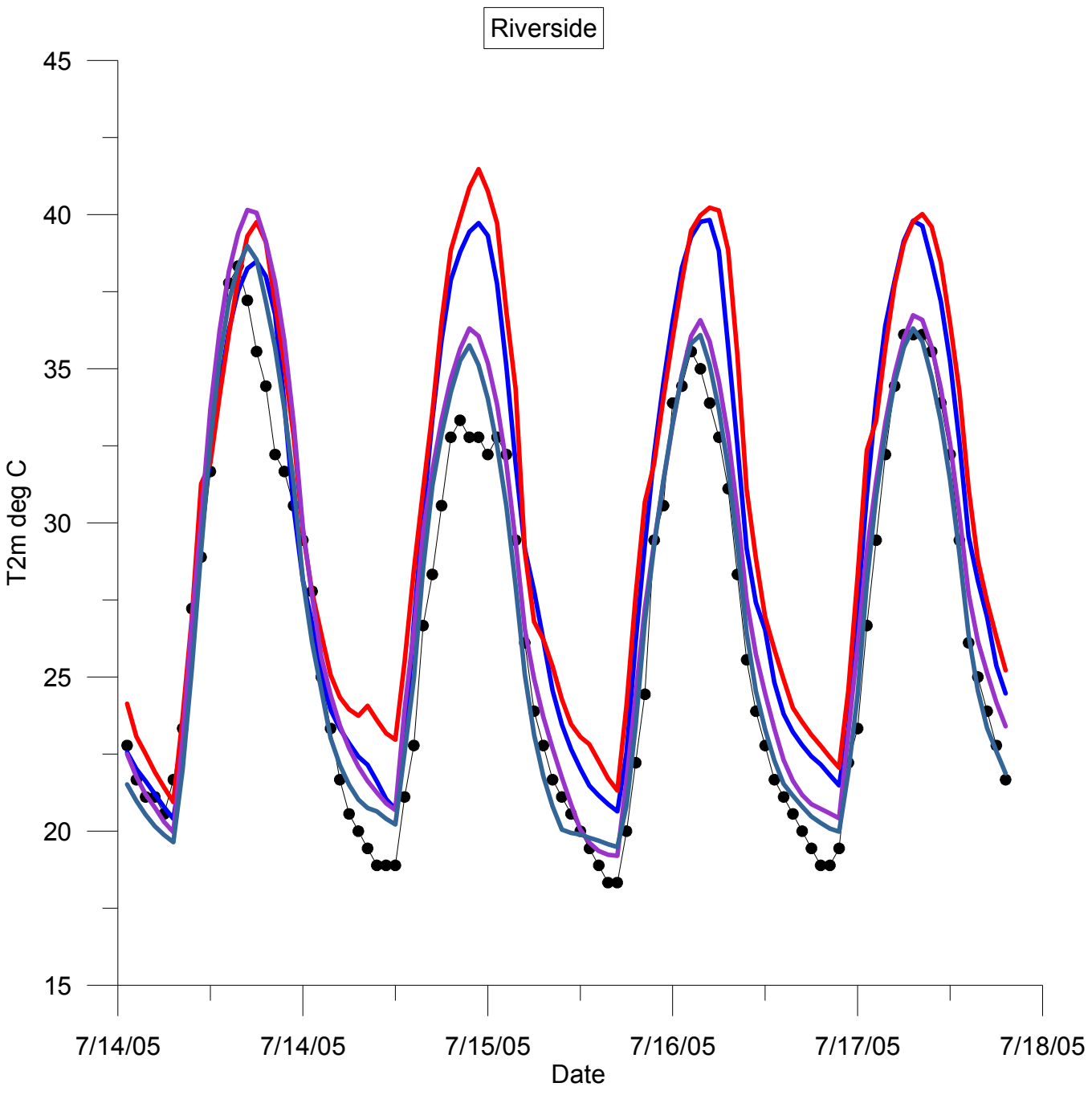


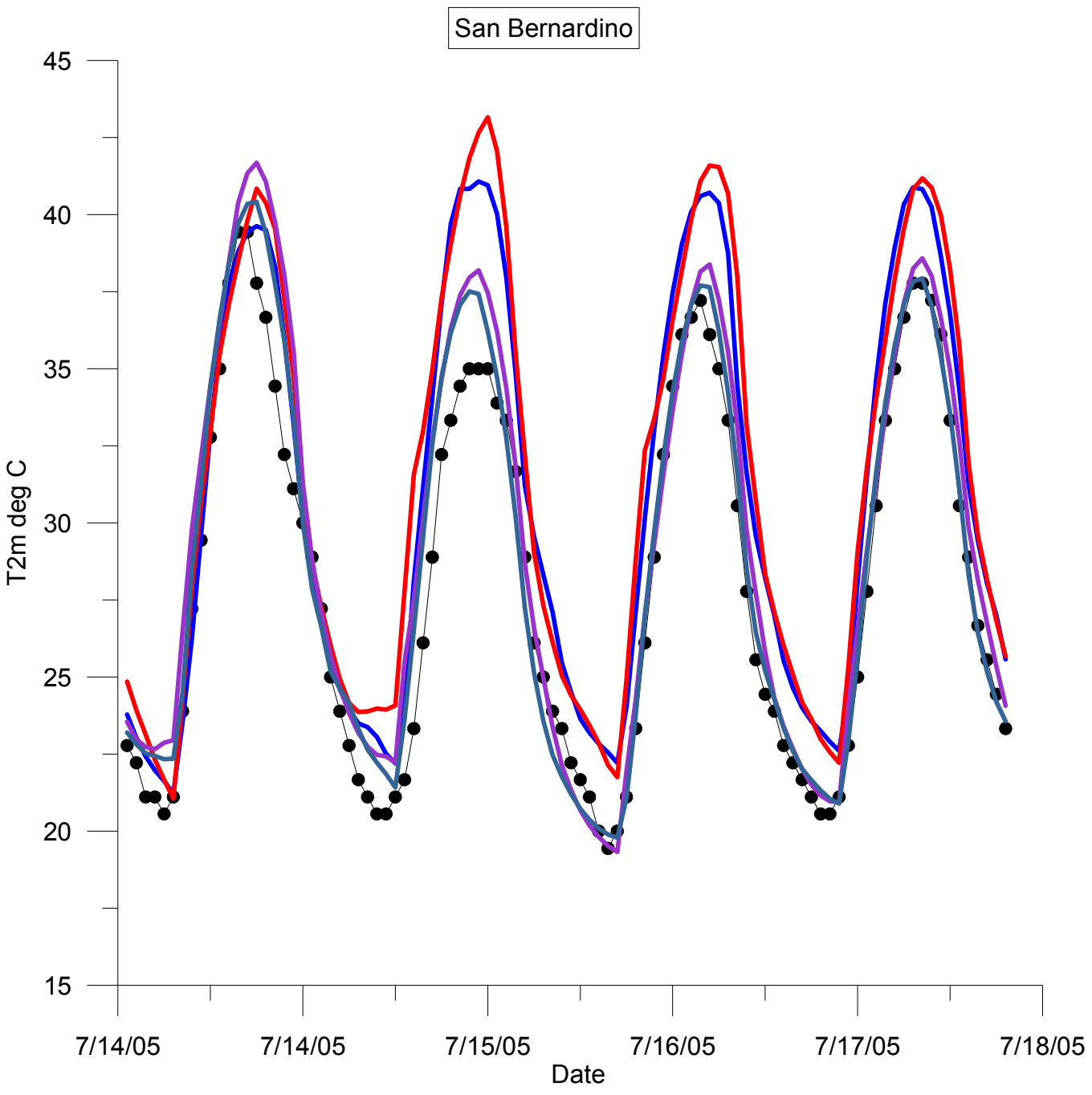
Predicted Temperature by Stations

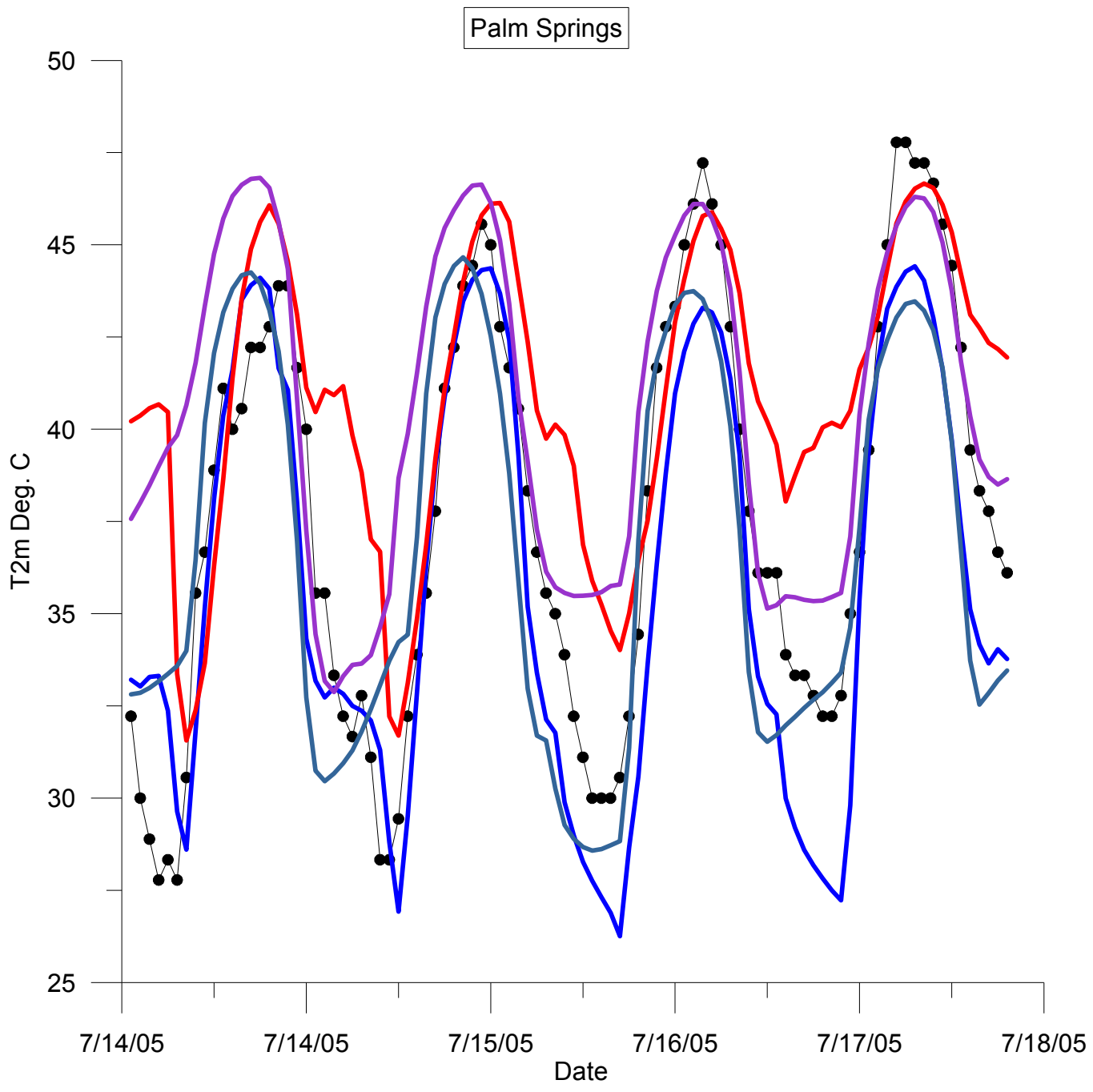
Coastal – LAX
Coastal/Inland - Downtown LA
East Basin - Riverside/San Bernardino
Desert – Palm Springs


LAX
36
32
28
24
20
16
12
T2m Deg. C
7/14/05
7/14/05
7/15/05
7/16/05
7/17/05
7/18/05
Date


Downtown Los Angeles
40
35
30
25
20
15
T2m Deg. C
7/14/05
7/14/05
7/15/05
7/16/05
7/17/05
7/18/05
Date

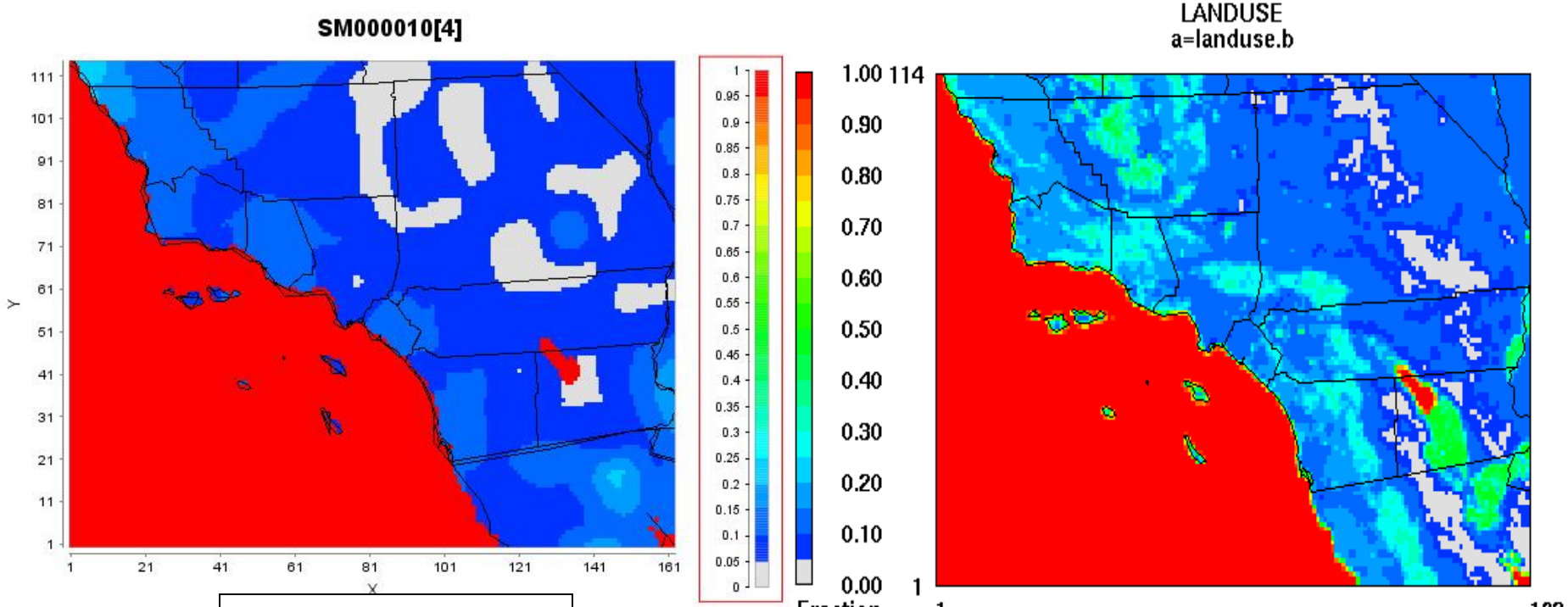

Riverside
45
40
35
30
25
20
15
T2m deg C
7/14/05
7/14/05
7/15/05
7/16/05
7/17/05
7/18/05
Date


San Bernardino
45
40
35
30
25
20
15
T2m deg C
7/14/05
7/14/05
7/15/05
7/16/05
7/17/05
7/18/05
Date


Palm Springs
50
45
40
35
30
25
T2m Deg. C
7/14/05
7/14/05
7/15/05
7/16/05
7/17/05
7/18/05
Date

Land use and Land Cover

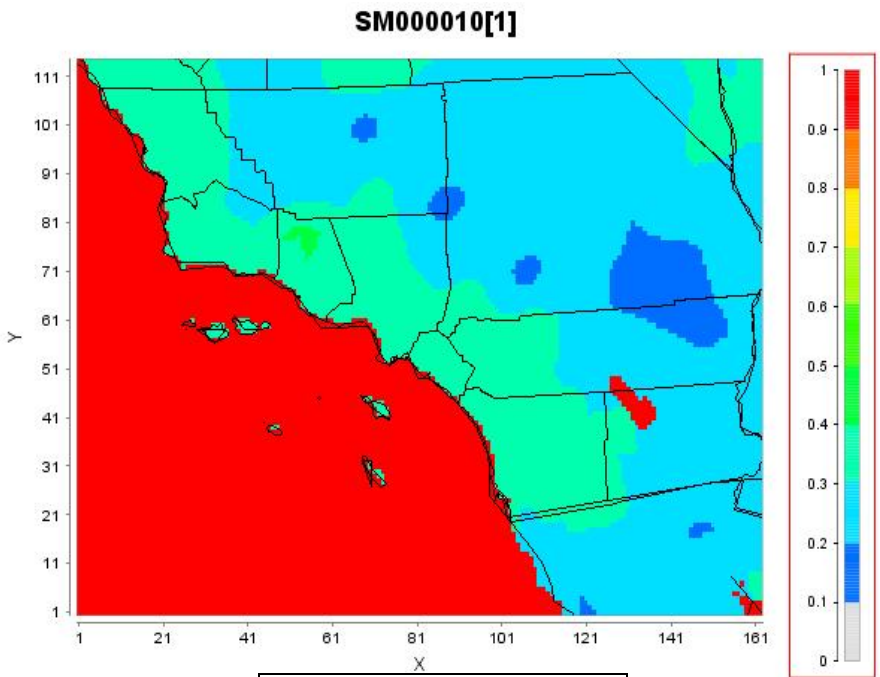
Summer Moisture Availability



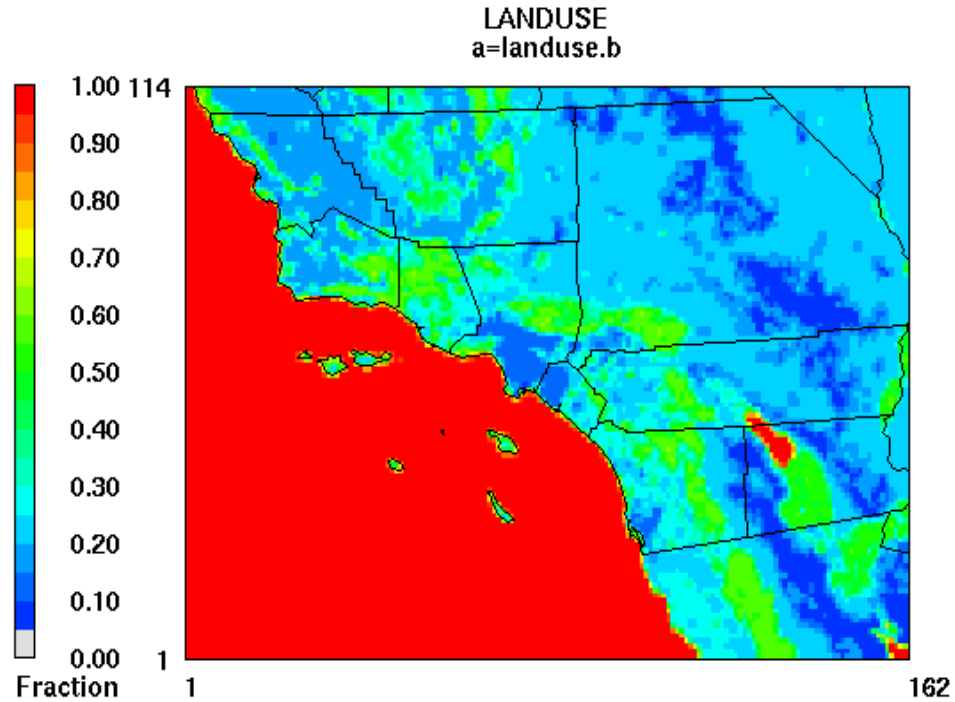
AWIP40

Land use Table

Winter Moisture Availability

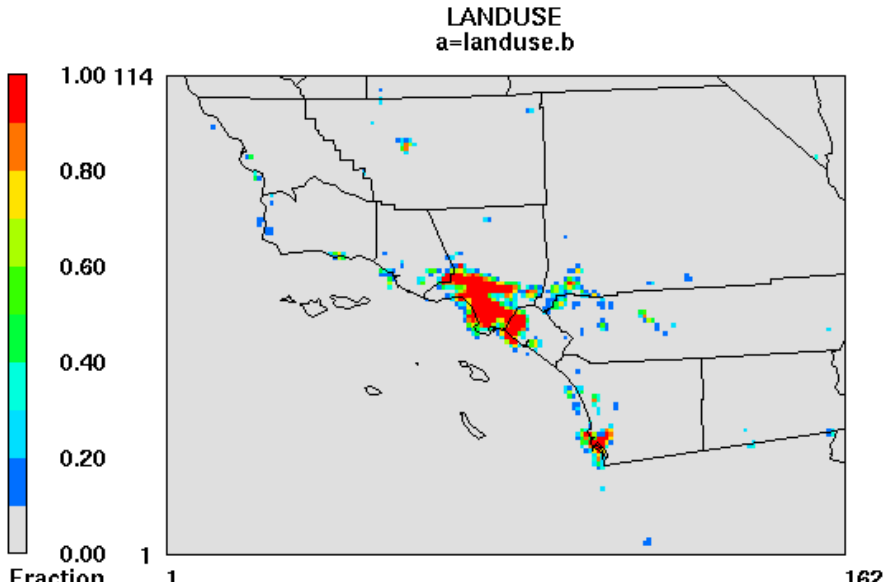


AWIP40

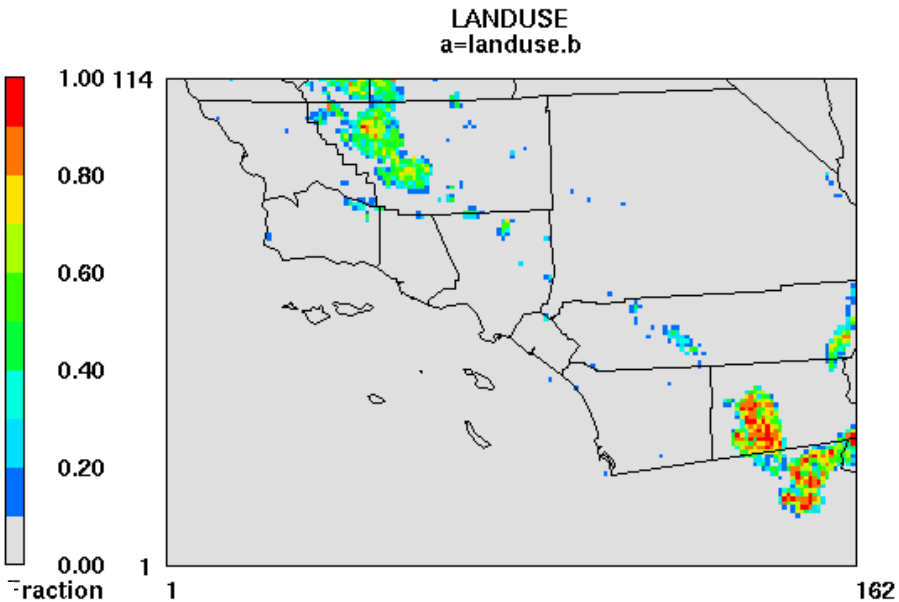


Land use Table

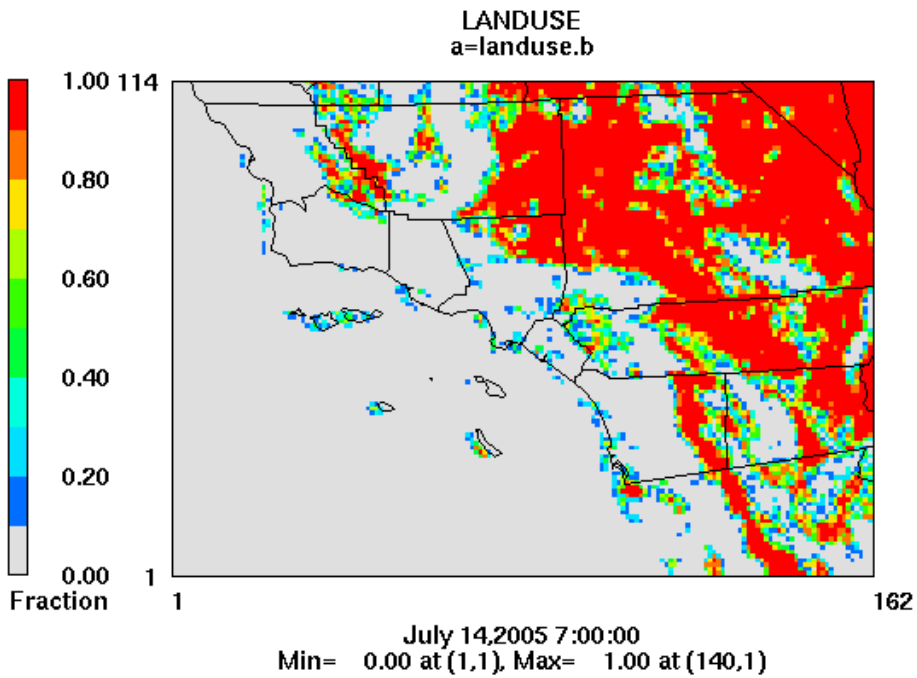
1. Urban and Build-Up Land



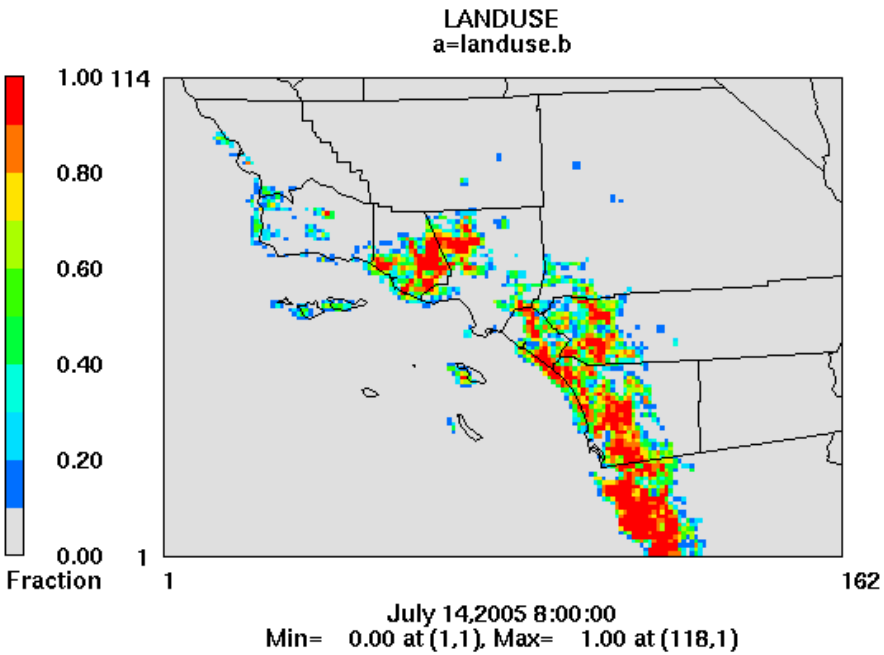
3. Irrigated Cropland and Pasture



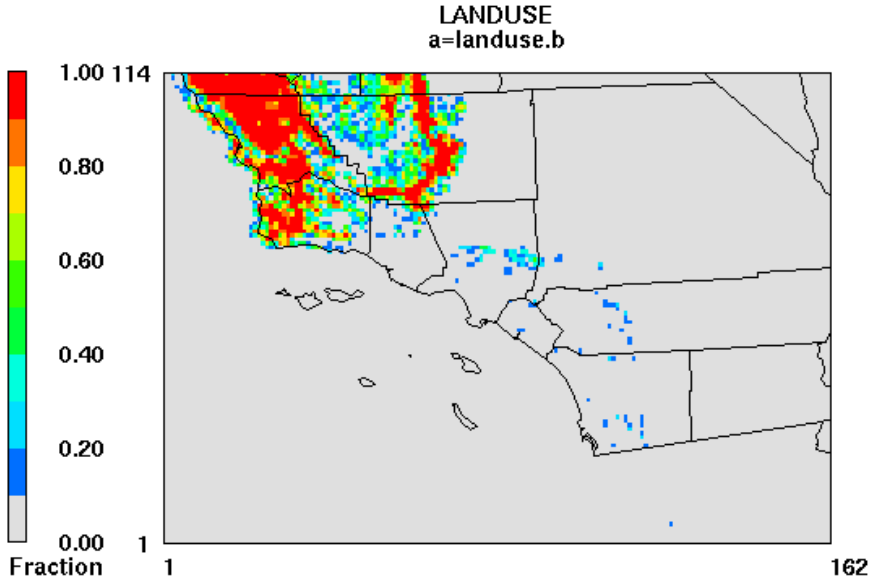
8. Shrubland



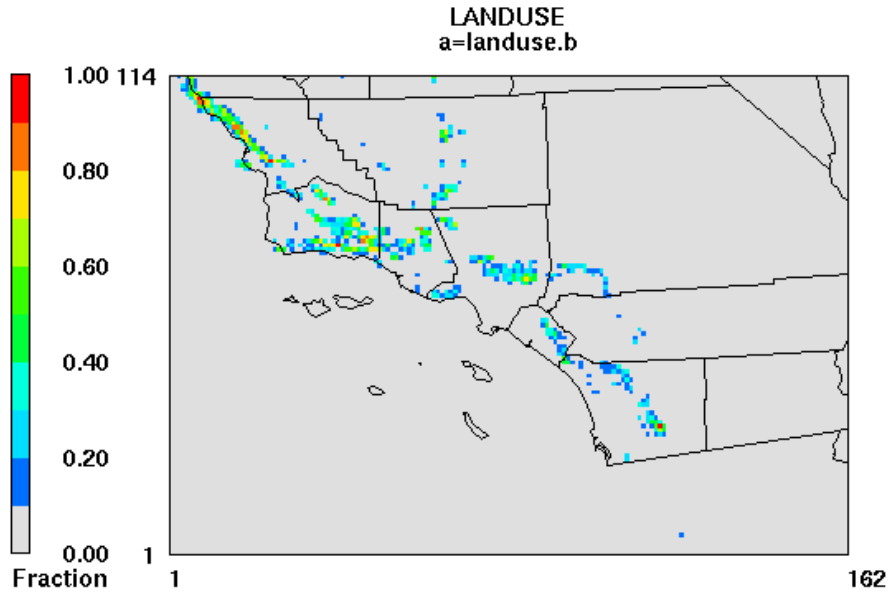
9. Mixed Shrubland/Grassland



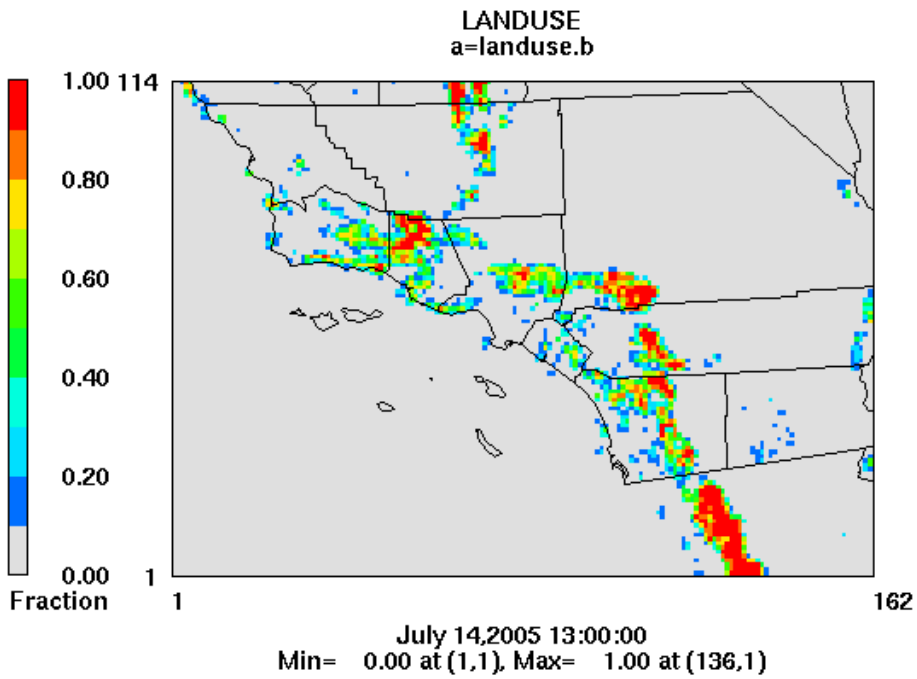
10. Savanna



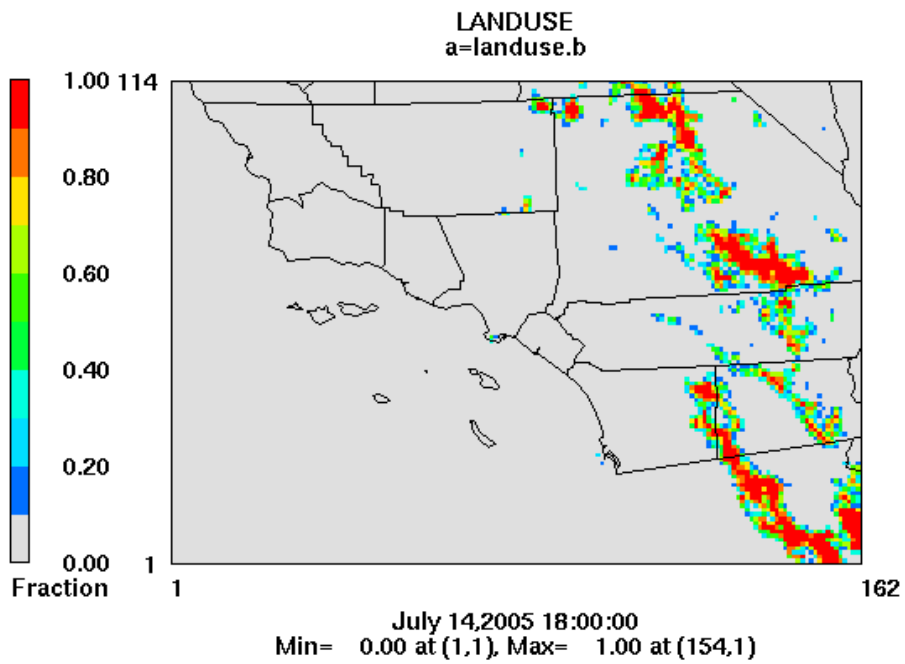
11. Deciduous Broadleaf Forest



14. Evergreen Needleleaf Forest



19. Barren or Sparsely Vegetated



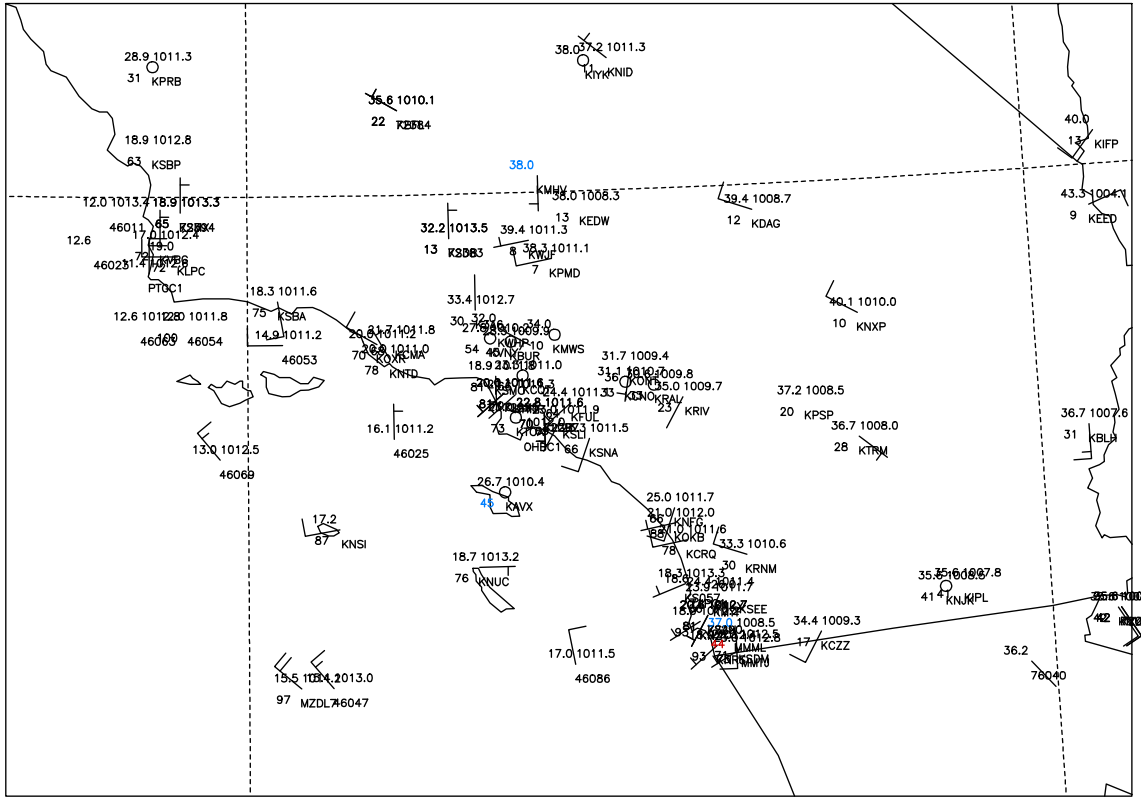
DIGITAL COAST
Land Cover Classes
Developed - High Intensity
Developed - Medium Intensity
Developed - Low Intensity
Developed - Open Space
Cultivated
Pasture / Hay
Grassland
Deciduous Forest
Evergreen Forest
Mixed Forest
Scrub / Shrub
Palustrine Forested Wetland
Palustrine Scrub / Shrub Wetland
Palustrine Emergent Wetland
Estuarine Forested Wetland
Estuarine Scrub / Shrub Wetland
Estuarine Emergent Wetland
Unconsolidated Shore
Bare Land
Water
Palustrine Aquatic Bed
Estuarine Aquatic Bed
Tundra
Snow / Ice
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2009 DigitalGlobe
Image U.S. Geological Survey
Google
Pointer 33°52'34.61" N 118°03'54.89" W elev 138 ft Streaming 100%
Eye alt 79.70 mi

Observation Nudging

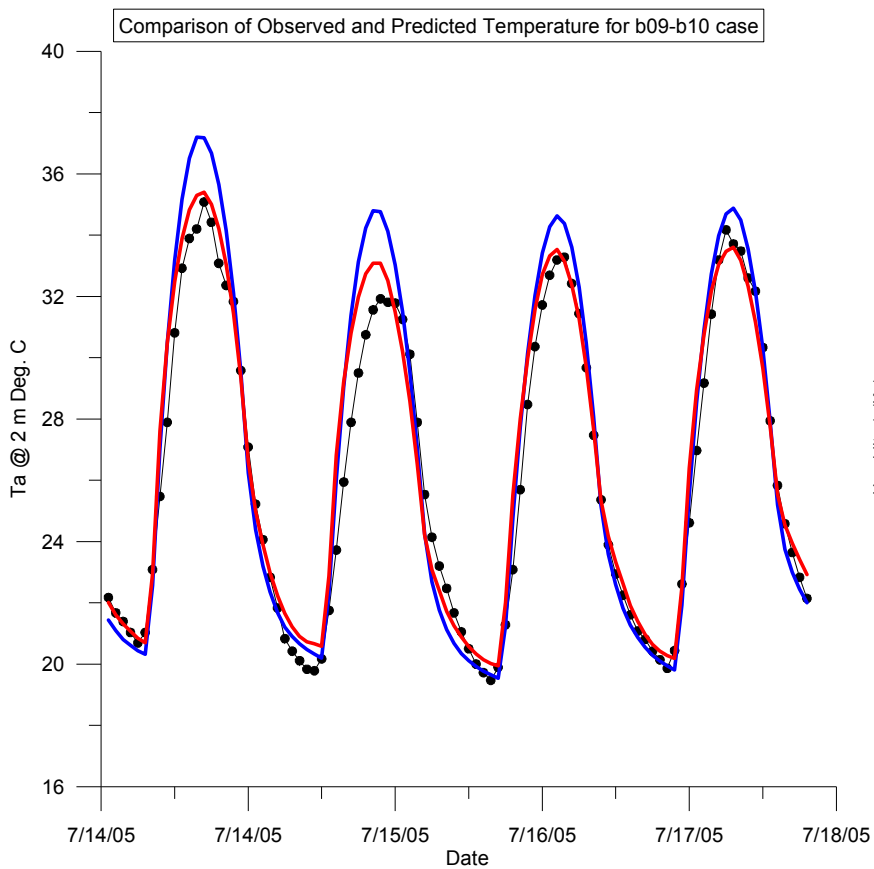
B09 and B10

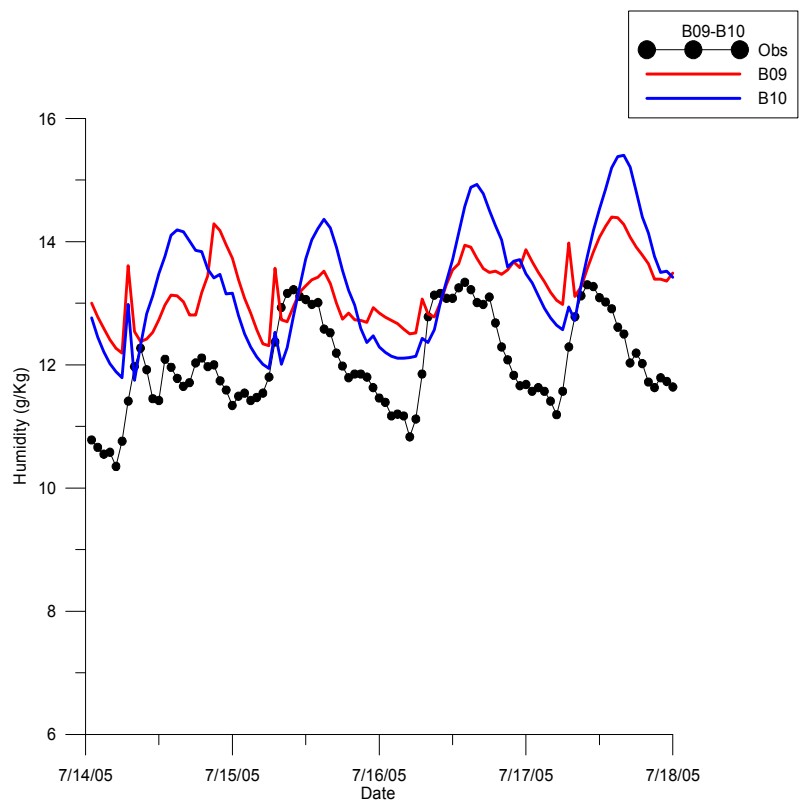
Surface Stations Observation included for the period of July 13-17

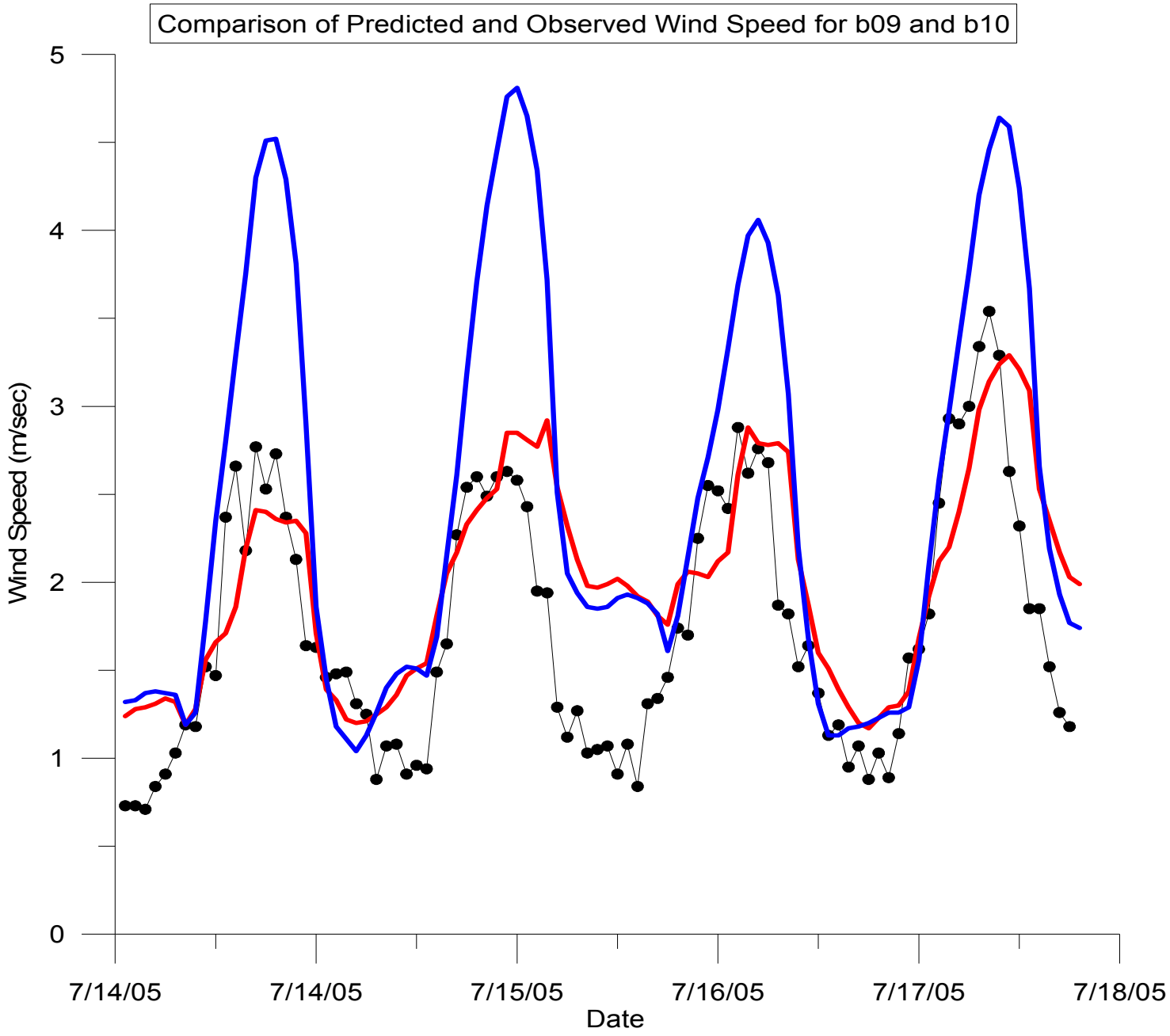
Real-time input observations 2005071418 LEVEL = 1001 NO. OF OBS = 85



Red: Failed errmax test
Orange: Extrapolated from single level
Violet: Vertically interpolated and failed errmax
Green: Vertically interpolated
Gray: Single level interpolated, failed errmax
Cyan: Other errmax failure


Comparison of Observed and Predicted Temperature for b09-b10 case
Ta @ 2 m Deg. C
40
36
32
28
24
20
16
7/14/05
7/14/05
7/15/05
7/16/05
7/17/05
7/18/05
Date

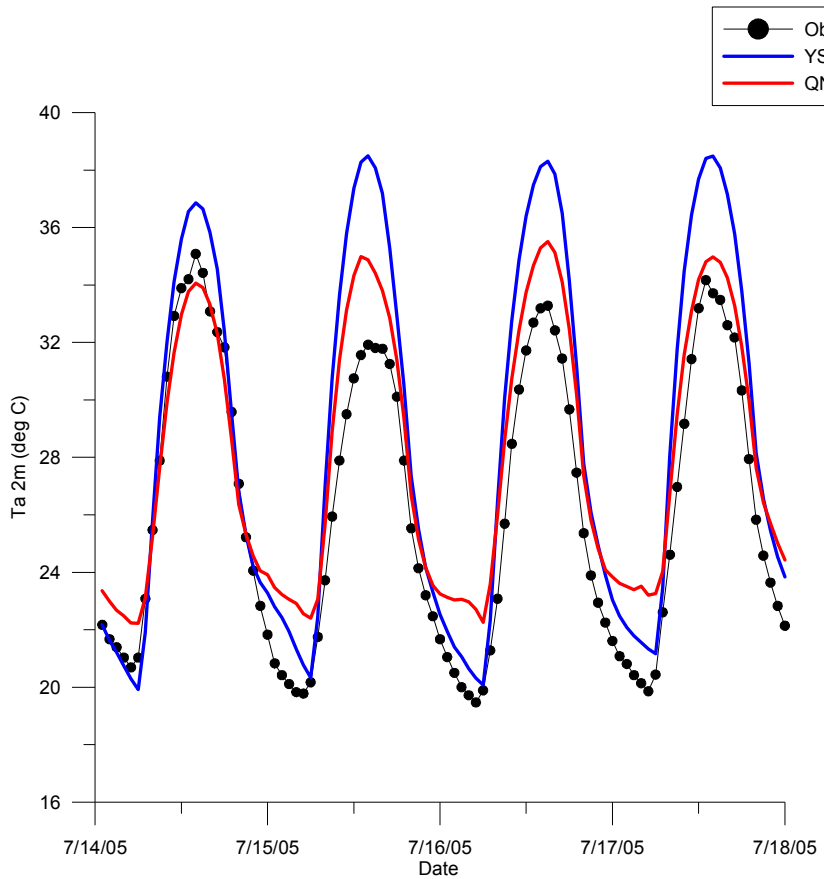

B09-B10
Obs
B09
B10
Humidity (g/Kg)
16
14
12
10
8
6
7/14/05
7/15/05
7/16/05
7/17/05
7/18/05
Date

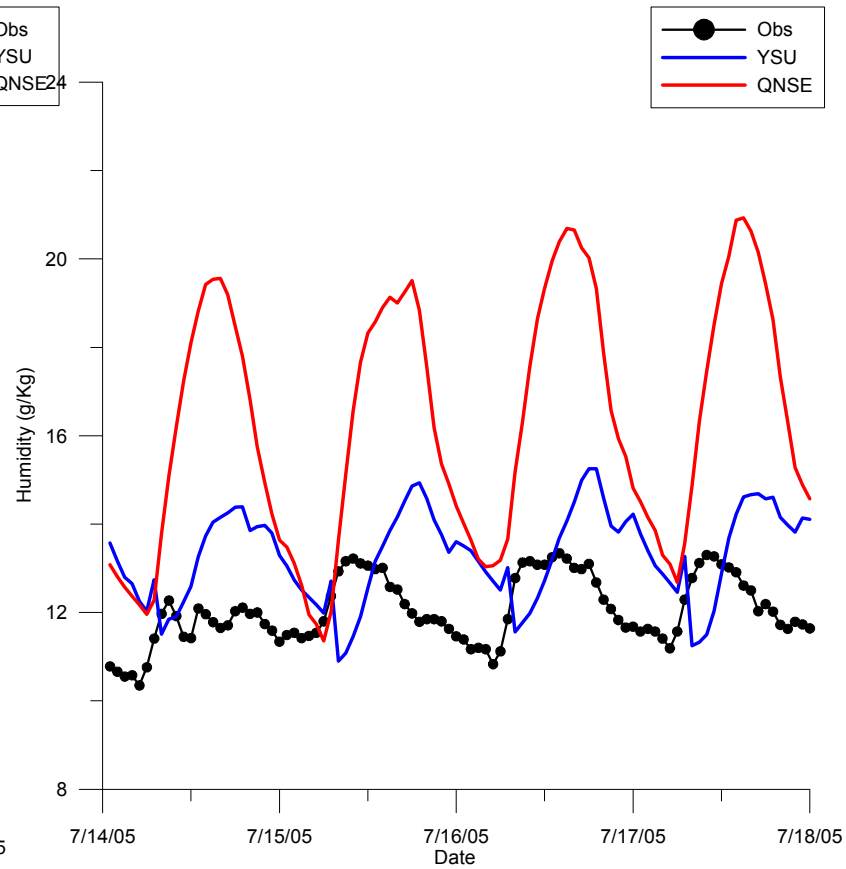

Comparison of Predicted and Observed Wind Speed for b09 and b10
Wind Speed (m/sec)
0
1
2
3
4
5
7/14/05
7/14/05
7/15/05
7/16/05
7/17/05
7/18/05
Date

Sensitivity Run with QNSE

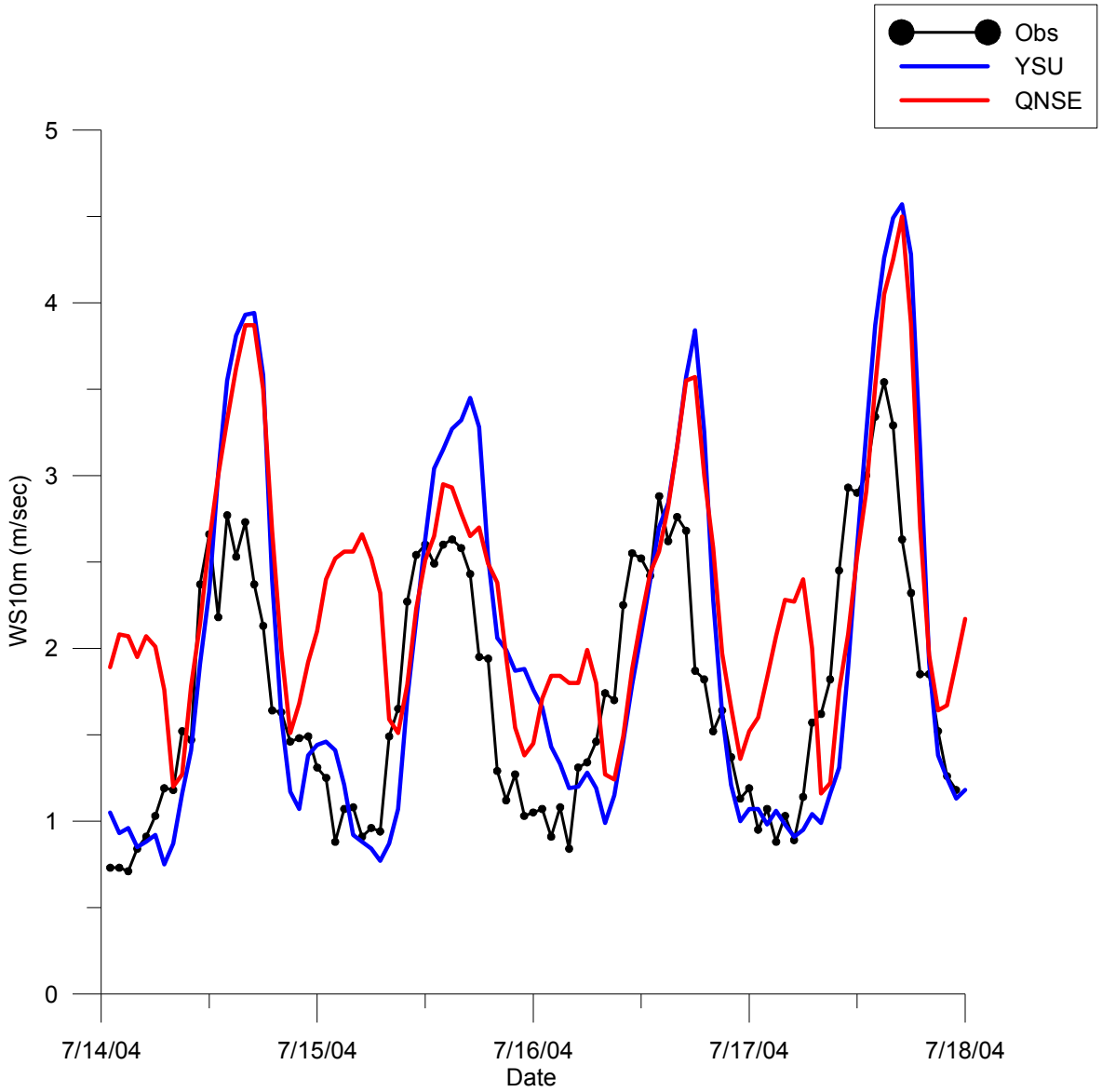
- B11 - 5 layer Soil Model
- B12 - NOAH LSM
- B13 - b12 w/ 3d FDDA
- B14 - 3D, Surface, OBS FDDA
- B15 – B11 w/ CAM
- B16 – B15 3D Nudging
- B17 – B15 Obs Nudging

YSU vs. QNSE

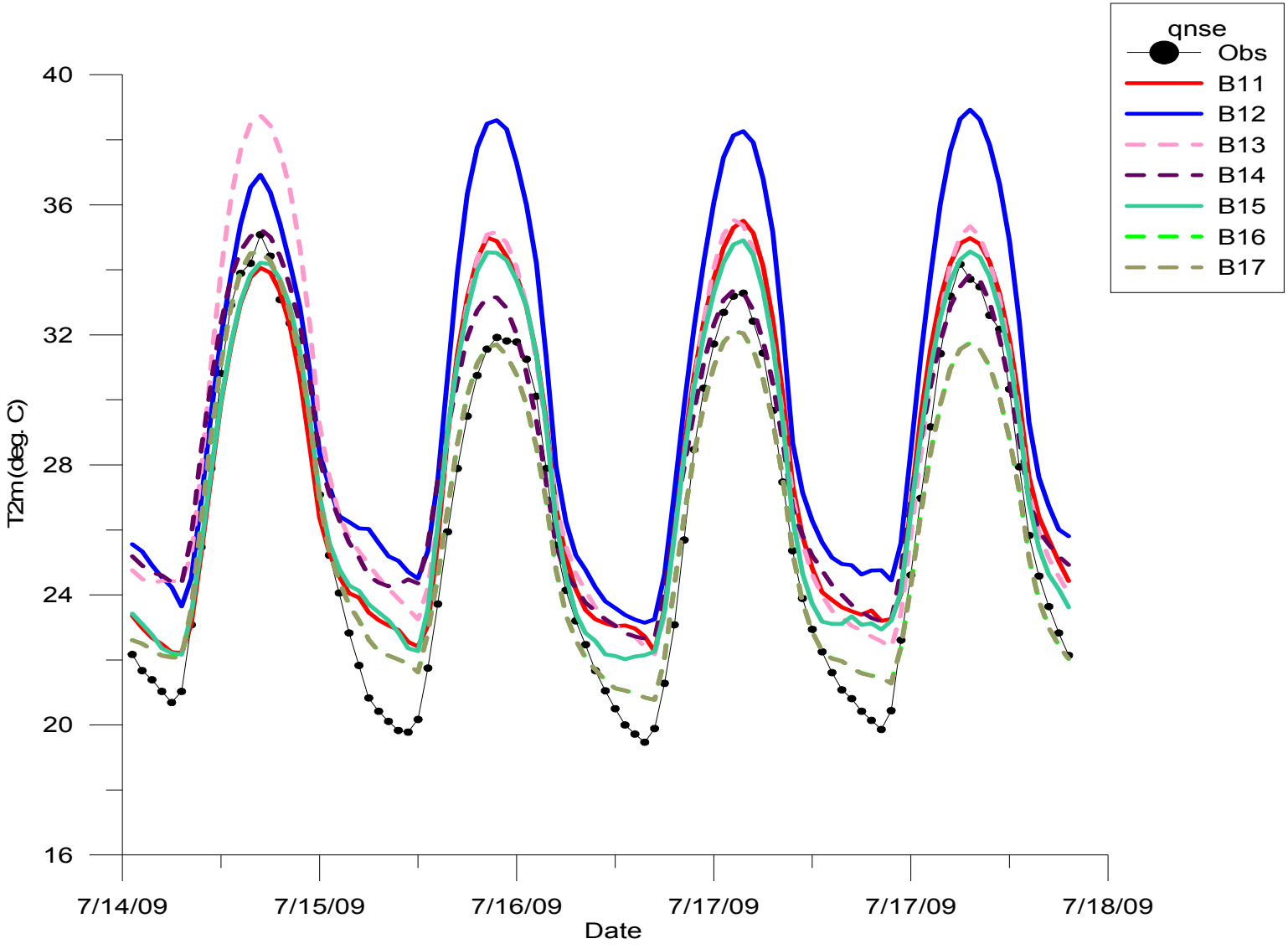

Obs
YSU
QNSE
Ta 2m (deg C)
40
36
32
28
24
20
16
7/14/05
7/15/05
7/16/05
7/17/05
7/18/05
Date


Obs
YSU
QNSE
Humidity (g/Kg)
24
20
16
12
8
7/14/05
7/15/05
7/16/05
7/17/05
7/18/05
Date

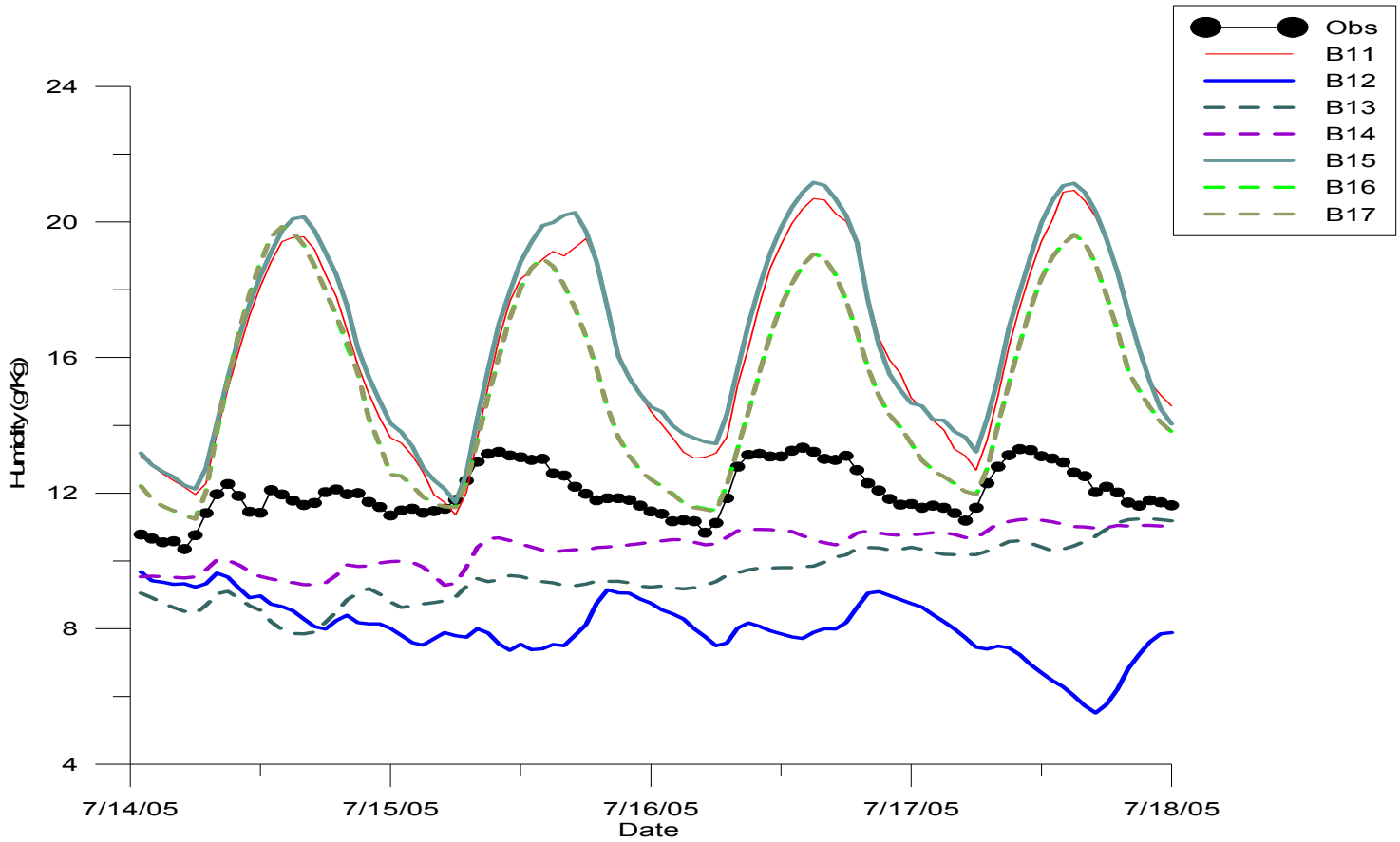
YSU vs. QNSE

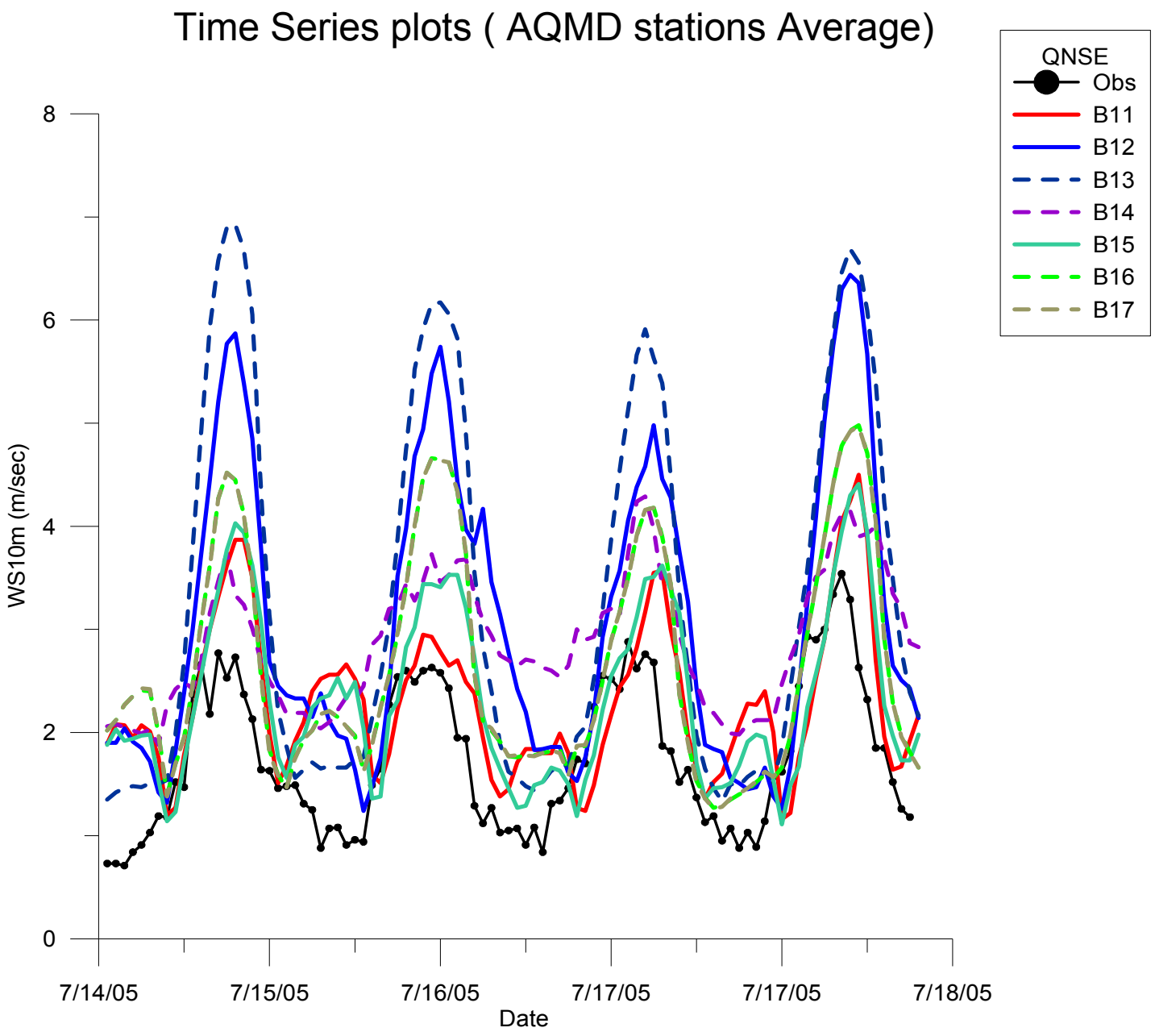

Obs
YSU
QNSE
5
4
3
2
1
0
WS10m (m/sec)
7/14/04
7/15/04
7/16/04
7/17/04
7/18/04
Date

Time Series plots (AQMD stations Average)



Time Series plots (AQMD stations Average)



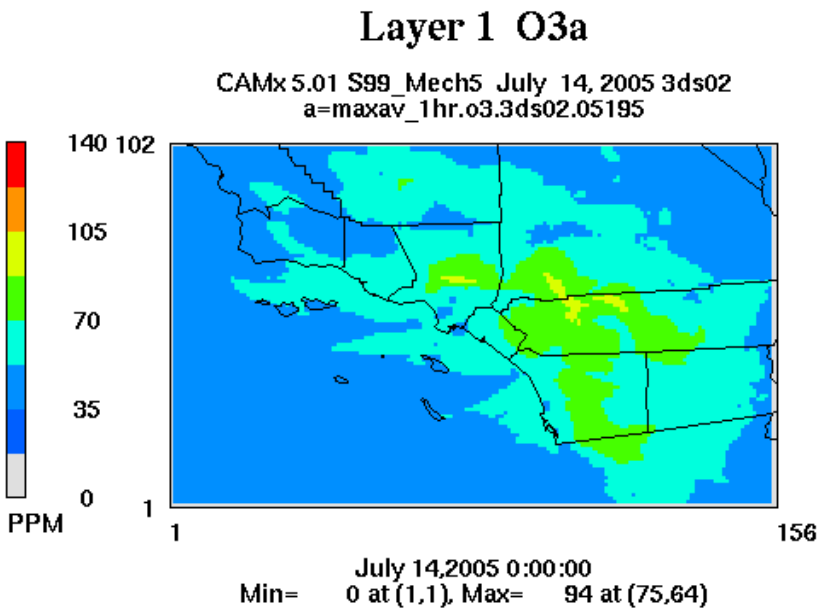

Time Series plots (AQMD stations Average)
QNSE
Obs
B11
B12
B13
B14
B15
B16
B17
WS10m (m/sec)
0
2
4
6
8
7/14/05
7/15/05
7/16/05
7/17/05
7/17/05
7/18/05
Date

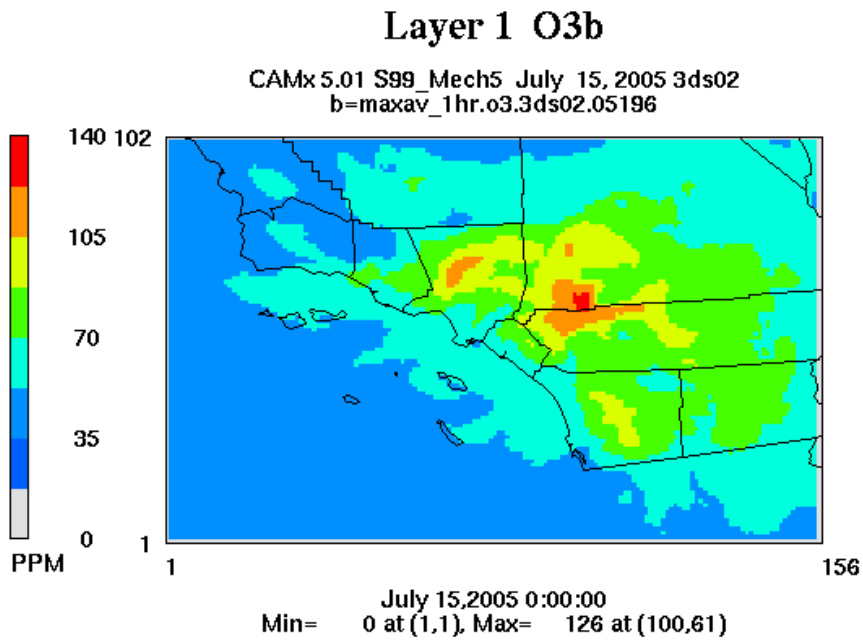
CAMx modeling Results

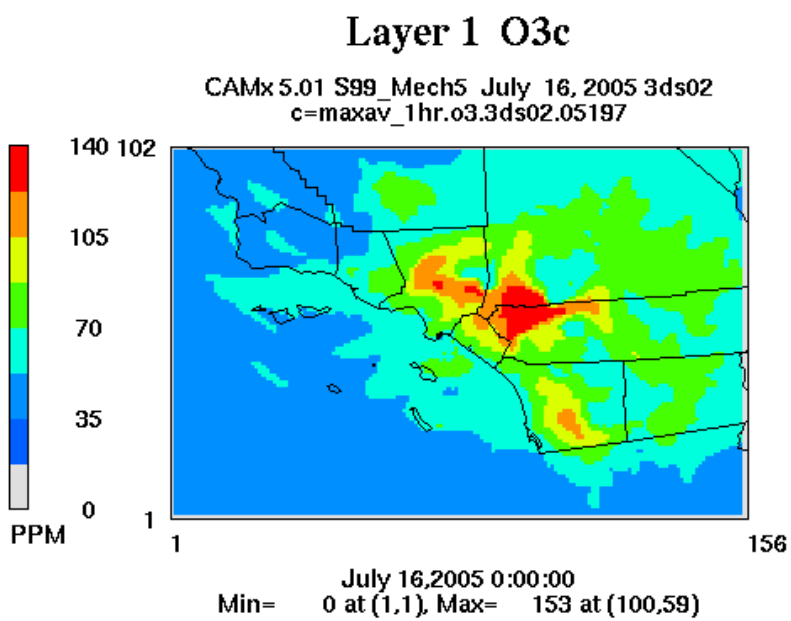
MM5 S02

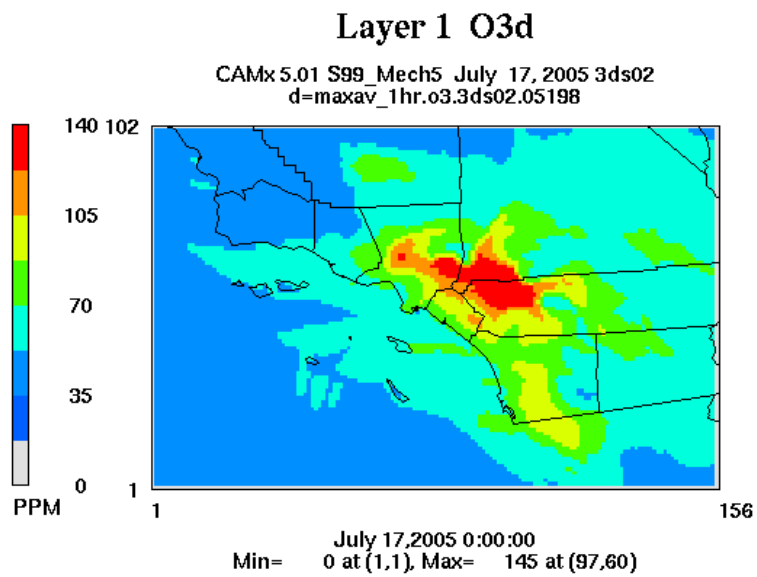
WRF B04 B09 B10 B14 B15 B17

MM5 Case S02


Layer 1 O3a
CAMx 5.01 S99_Mech5 July 14, 2005 3ds02
a=maxav_1hr.o3.3ds02.05195
140 102
105
70
35
0
PPM
1
1
156
July 14,2005 0:00:00
Min= 0 at (1,1), Max= 94 at (75,64)

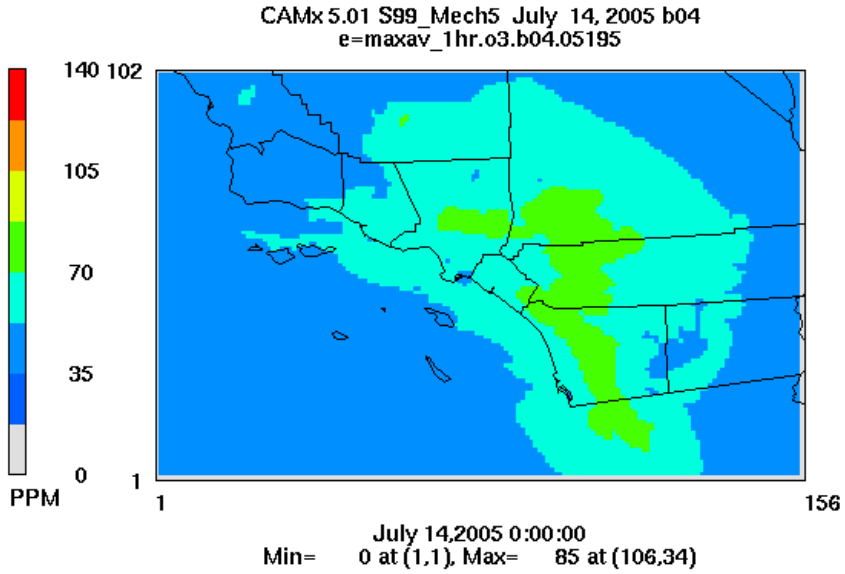

Layer 1 O3b
CAMx 5.01 S99_Mech5 July 15, 2005 3ds02
b=maxav_1hr.o3.3ds02.05196
140 102
105
70
35
0
PPM
1
1
156
July 15,2005 0:00:00
Min= 0 at (1,1), Max= 126 at (100,61)


Layer 1 O3c
CAMx 5.01 S99_Mech5 July 16, 2005 3ds02
c=maxav_1hr.o3.3ds02.05197
140 102
105
70
35
0
PPM
1
1
156
July 16,2005 0:00:00
Min= 0 at (1,1), Max= 153 at (100,59)

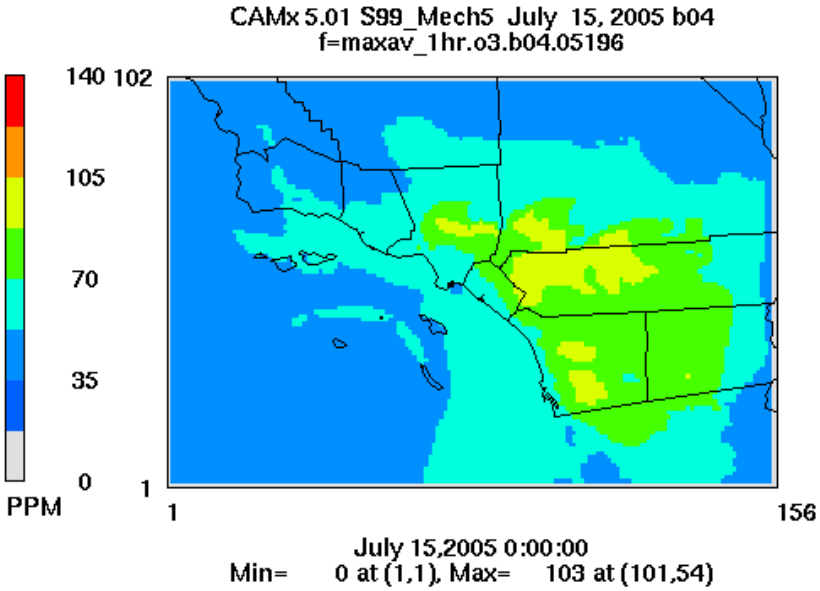

Layer 1 O3d
CAMx 5.01 S99_Mech5 July 17, 2005 3ds02
d=maxav_1hr.o3.3ds02.05198
140 102
105
70
35
0
PPM
1
1
156
July 17,2005 0:00:00
Min= 0 at (1,1), Max= 145 at (97,60)

WRF Case B04

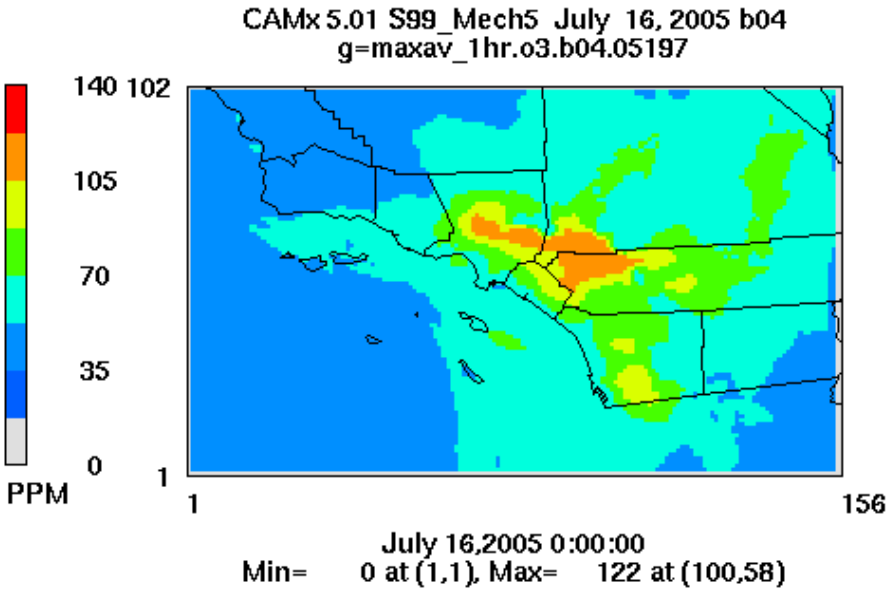
Layer 1 O3e



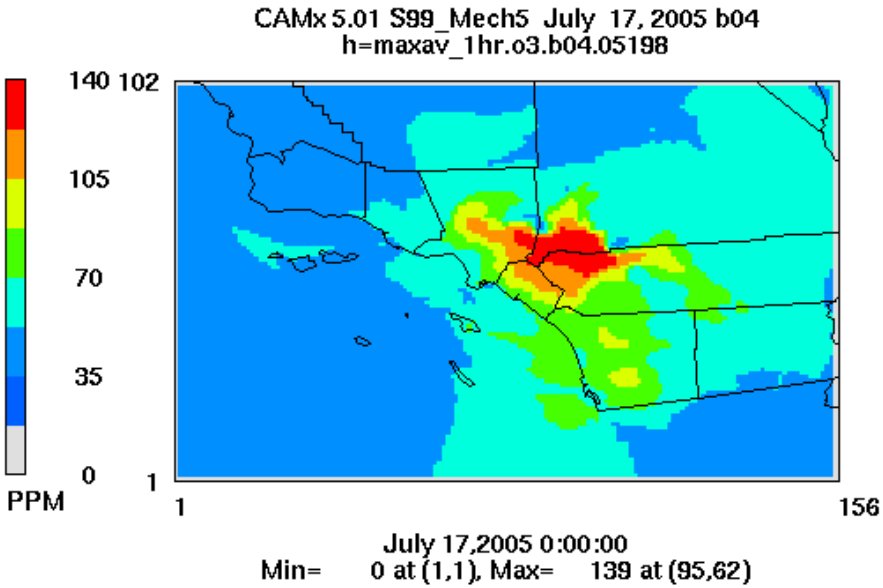
Layer 1 O3f



Layer 1 O3g



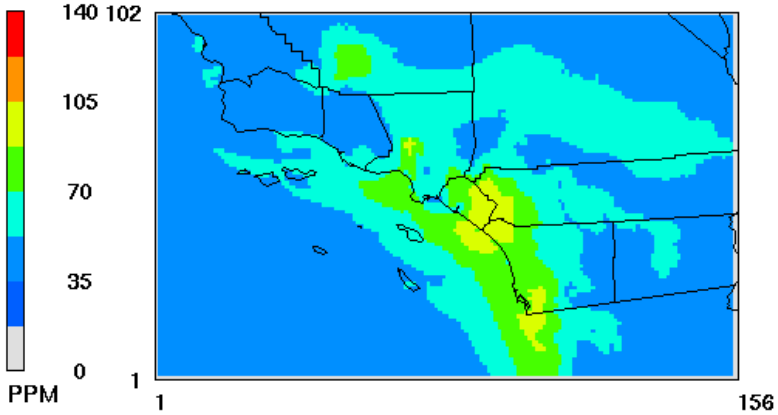
Layer 1 O3h



WRF Case B09

Layer 1 O3i

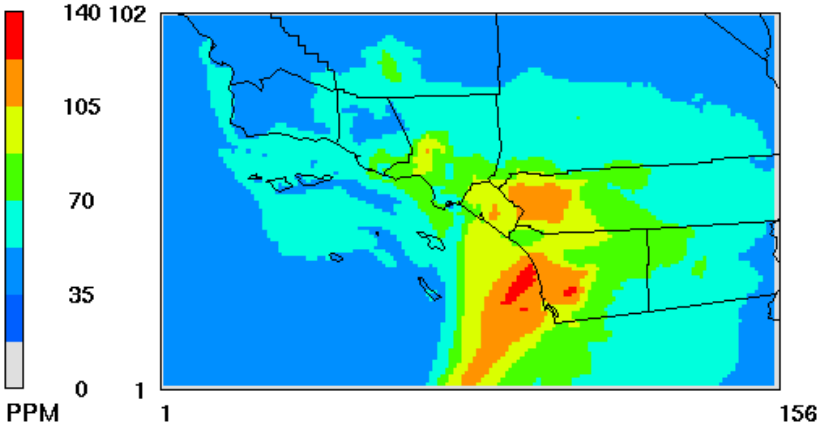
CAMx 5.01 S99_Mech5 July 14, 2005 b09
i=maxav_1hr.o3.b09.05195



July 14,2005 0:00:00
Min= 0 at (1,1), Max= 101 at (91,53)

Layer 1 O3j

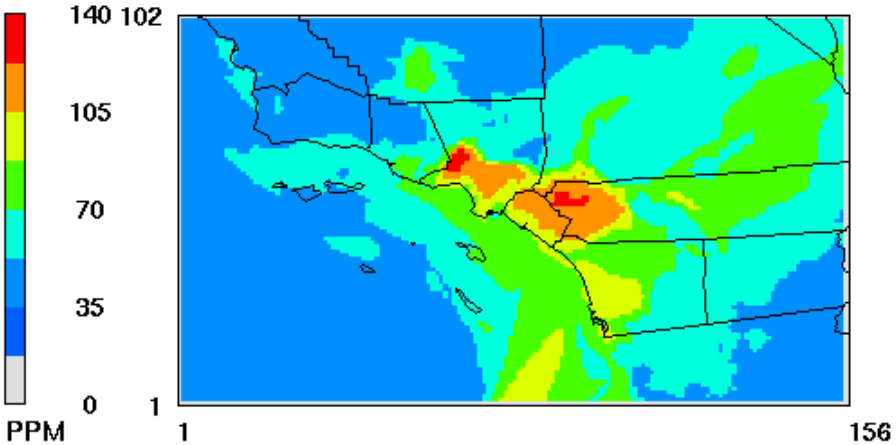
CAMx 5.01 S99_Mech5 July 15, 2005 b09
j=maxav_1hr.o3.b09.05196



July 15,2005 0:00:00
Min= 0 at (1,1), Max= 127 at (93,32)

Layer 1 O3k

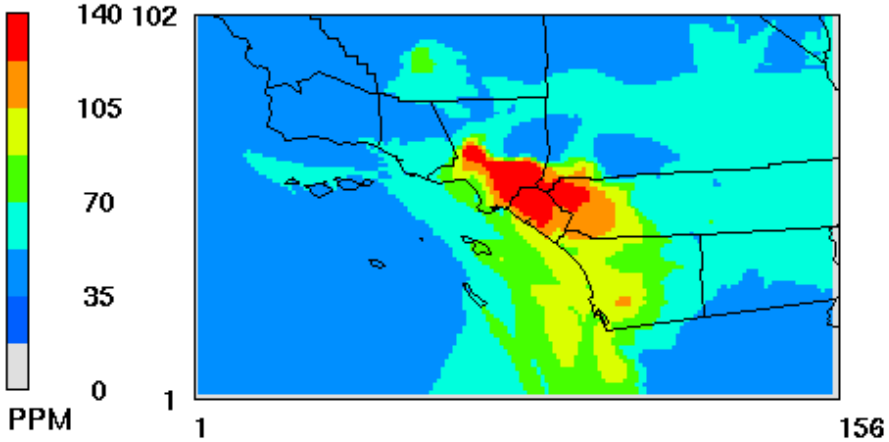
CAMx 5.01 S99_Mech5 July 16, 2005 b09
k=maxav_1hr.o3.b09.05197



July 16,2005 0:00:00
Min= 0 at (1,1), Max= 135 at (66,65)

Layer 1 O3l

CAMx 5.01 S99_Mech5 July 17, 2005 b09
l=maxav_1hr.o3.b09.05198

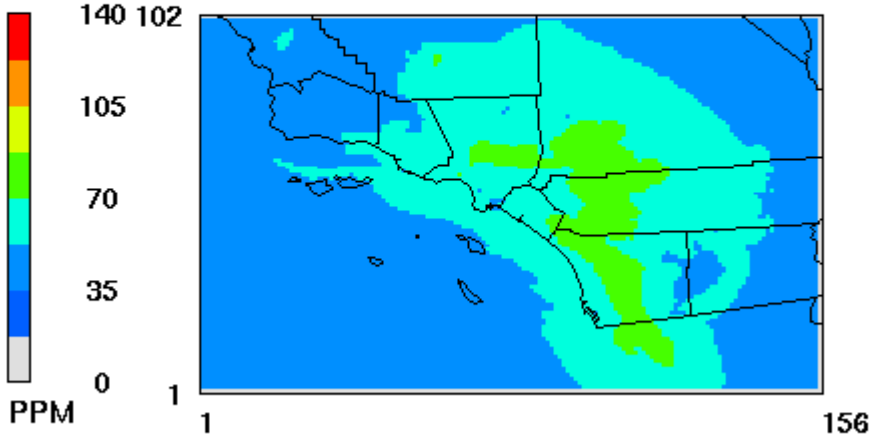


July 17,2005 0:00:00
Min= 0 at (1,1), Max= 156 at (77,61)

WRF Case B10

Layer 1 O3m

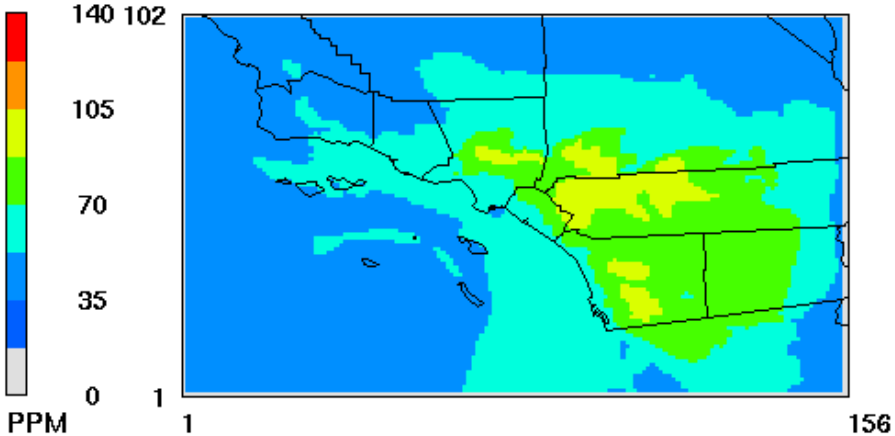
CAMx 5.01 S99_Mech5 July 14, 2005 b10
m=maxav_1hr.o3.b10.05195



July 14,2005 0:00:00
Min= 0 at (1,1), Max= 86 at (101,64)

Layer 1 O3n

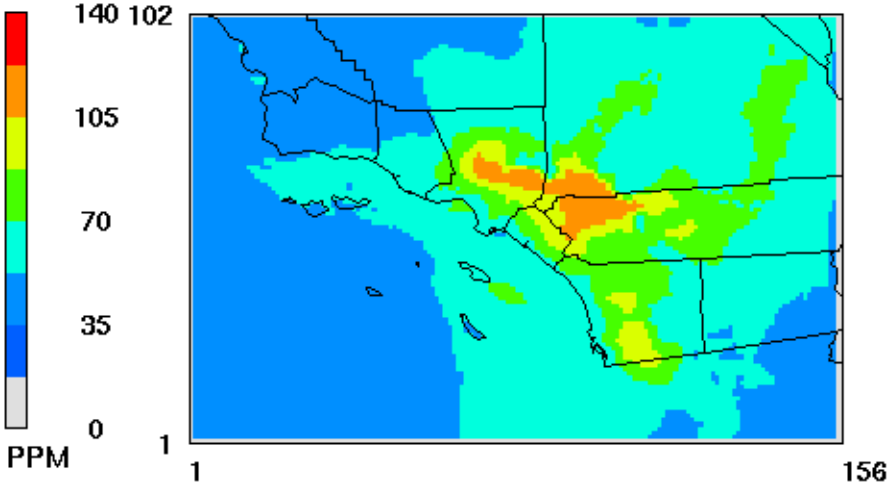
CAMx 5.01 S99_Mech5 July 15, 2005 b10
n=maxav_1hr.o3.b10.05196



July 15,2005 0:00:00
Min= 0 at (1,1), Max= 104 at (101,54)

Layer 1 O3o

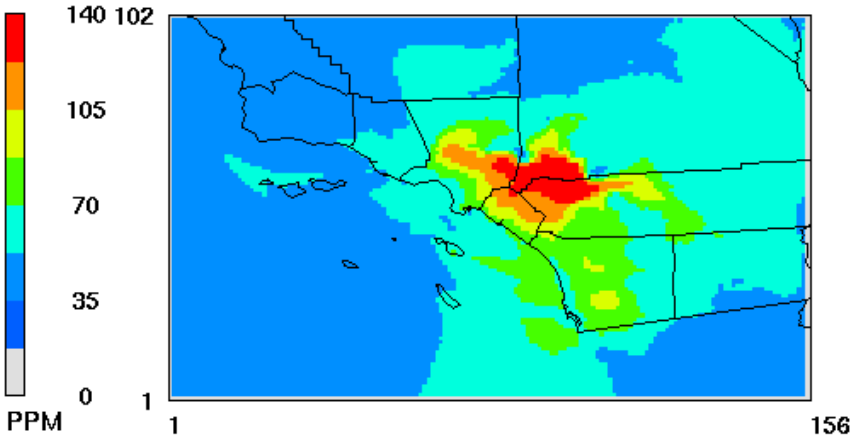
CAMx 5.01 S99_Mech5 July 16, 2005 b10
o=maxav_1hr.o3.b10.05197



July 16,2005 0:00:00
Min= 0 at (1,1), Max= 122 at (100,58)

Layer 1 O3p

CAMx 5.01 S99_Mech5 July 17, 2005 b10
p=maxav_1hr.o3.b10.05198

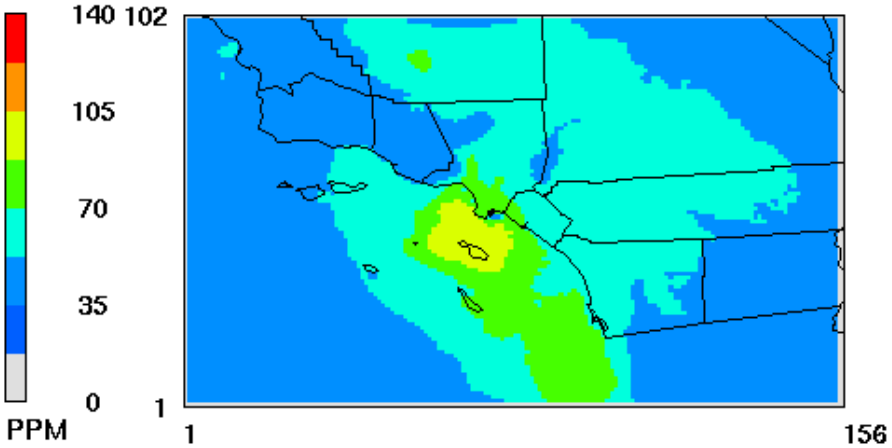


July 17,2005 0:00:00
Min= 0 at (1,1), Max= 141 at (97,61)

WRF Case B14

Layer 1 O3q

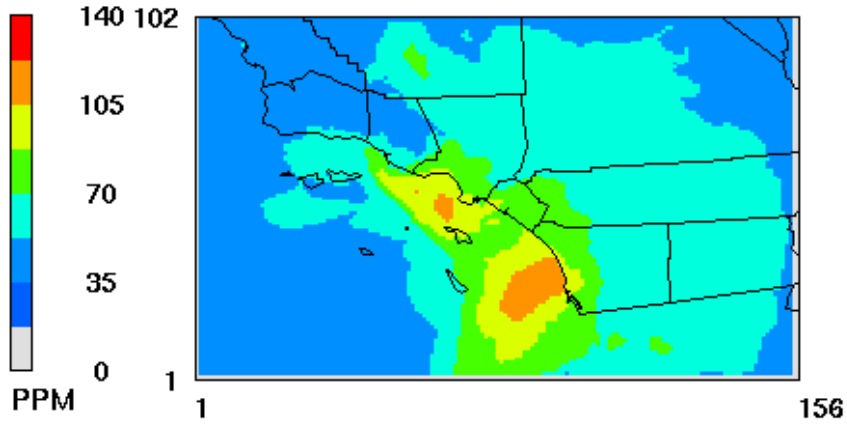
CAMx 5.01 S99_Mech5 July 14, 2005 b14
q=maxav_1hr.o3.b14.05195



July 14,2005 0:00:00
Min= 0 at (1,1), Max= 102 at (69,41)

Layer 1 O3r

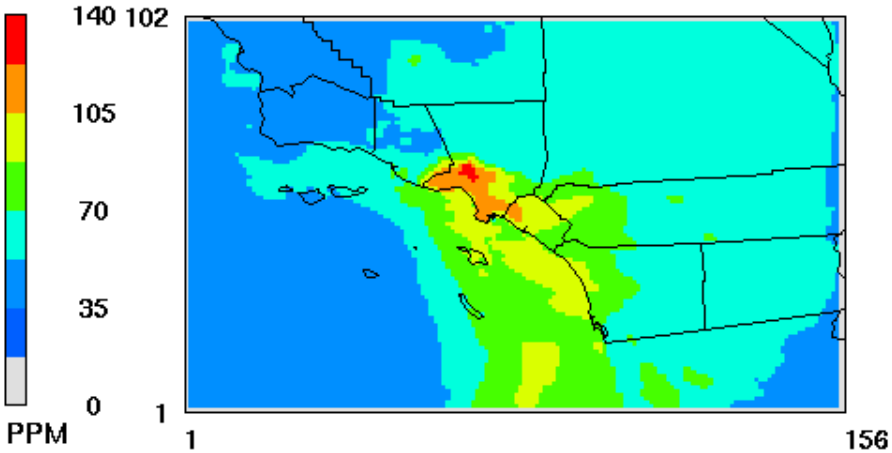
CAMx 5.01 S99_Mech5 July 15, 2005 b14
r=maxav_1hr.o3.b14.05196



July 15,2005 0:00:00
Min= 0 at (1,1), Max= 117 at (87,27)

Layer 1 O3s

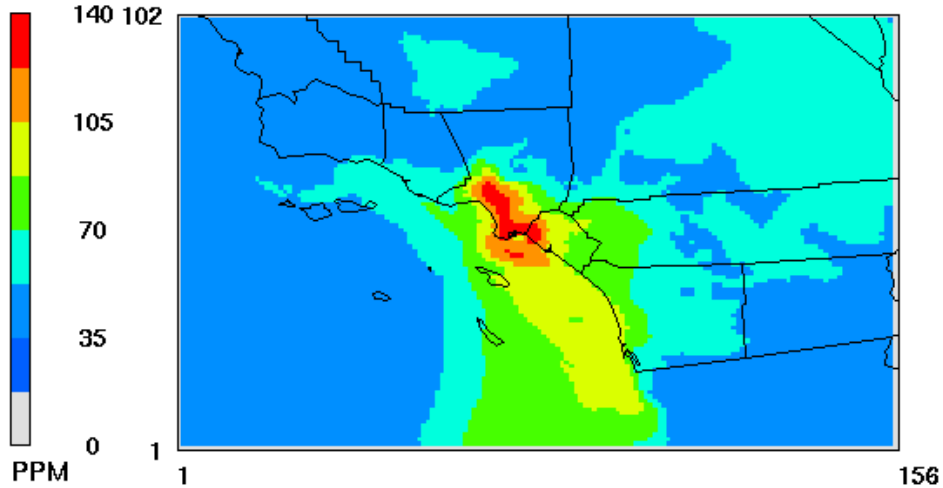
CAMx 5.01 S99_Mech5 July 16, 2005 b14
s=maxav_1hr.o3.b14.05197



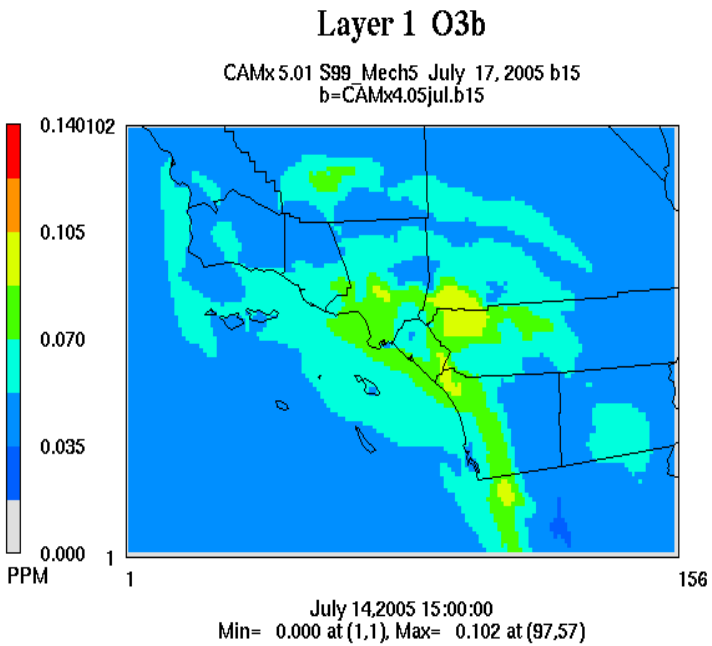
July 16,2005 0:00:00
Min= 0 at (1,1), Max= 128 at (68,63)

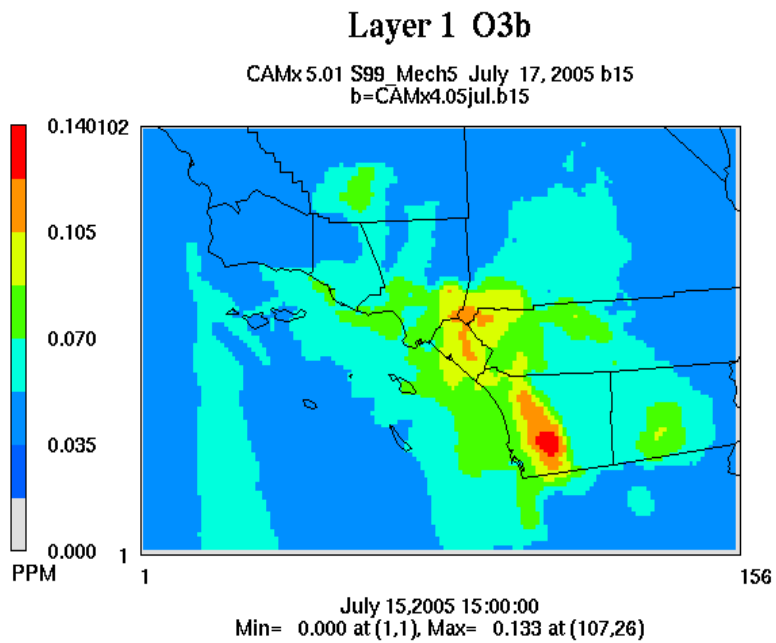
Layer 1 O3t

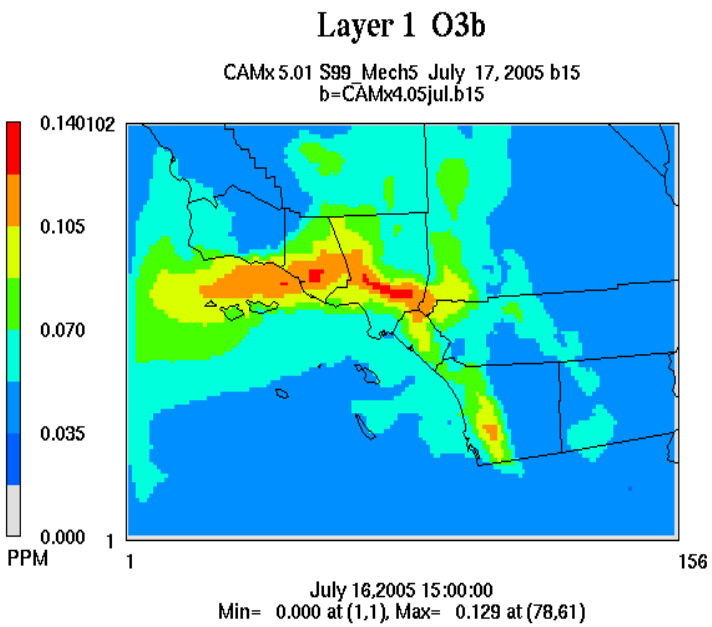
CAMx 5.01 S99_Mech5 July 17, 2005 b14
t=maxav_1hr.o3.b14.05198

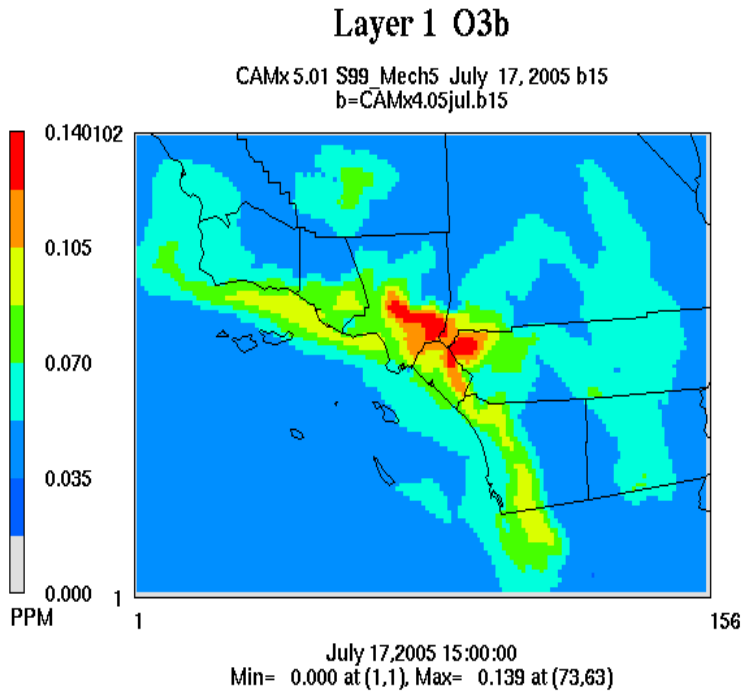


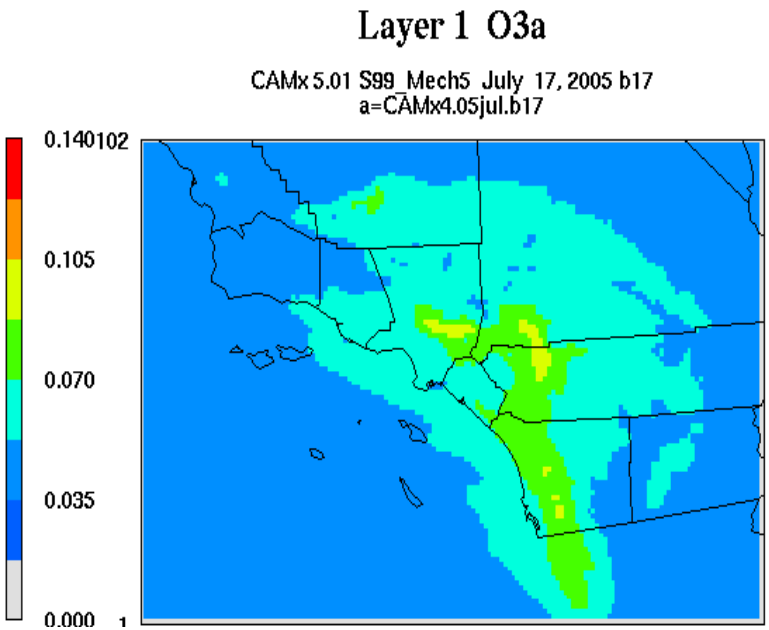
July 17,2005 0:00:00
Min= 0 at (1,1), Max= 140 at (73,51)

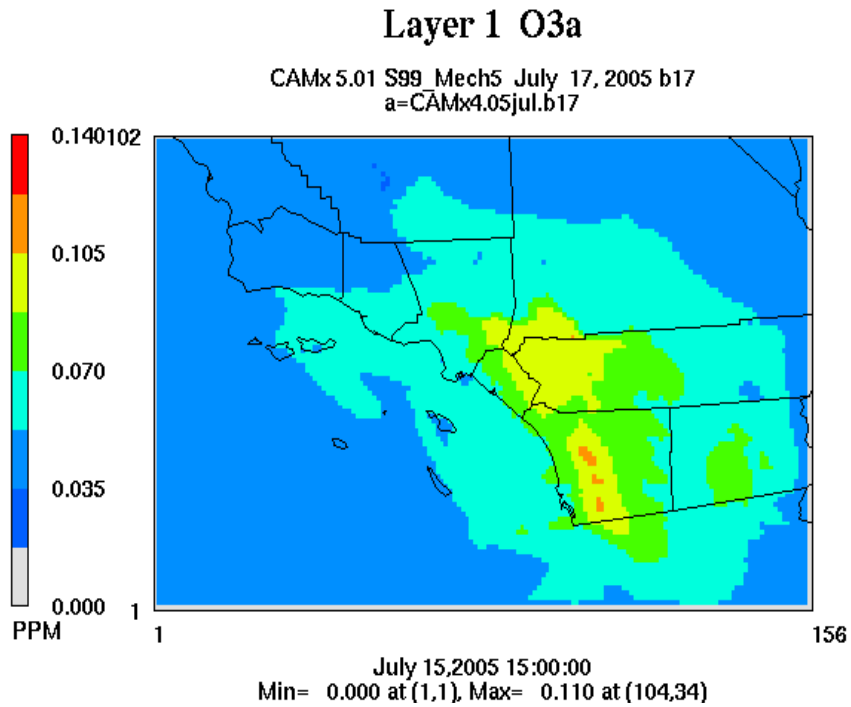

Layer 1 O3b
CAMx 5.01 S99_Mech5 July 17, 2005 b15
b=CAMx4.05jul.b15
0.140102
0.105
0.070
0.035
0.000
PPM
1
1
156
July 14,2005 15:00:00
Min= 0.000 at (1,1), Max= 0.102 at (97,57)

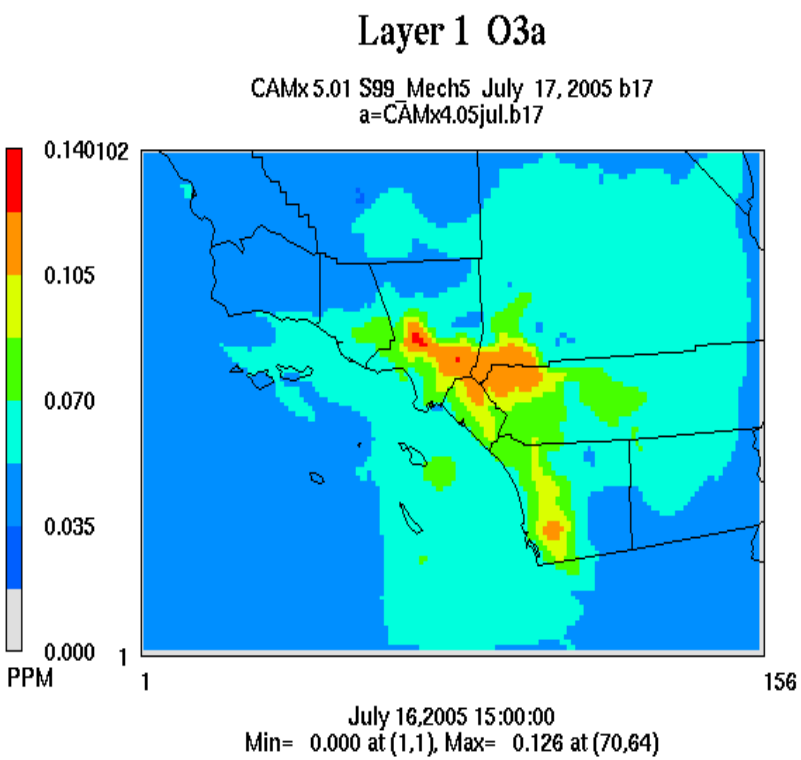

Layer 1 O3b
CAMx 5.01 S99_Mech5 July 17, 2005 b15
b=CAMx4.05jul.b15
0.140102
0.105
0.070
0.035
0.000
PPM
1
1
156
July 15,2005 15:00:00
Min= 0.000 at (1,1), Max= 0.133 at (107,26)

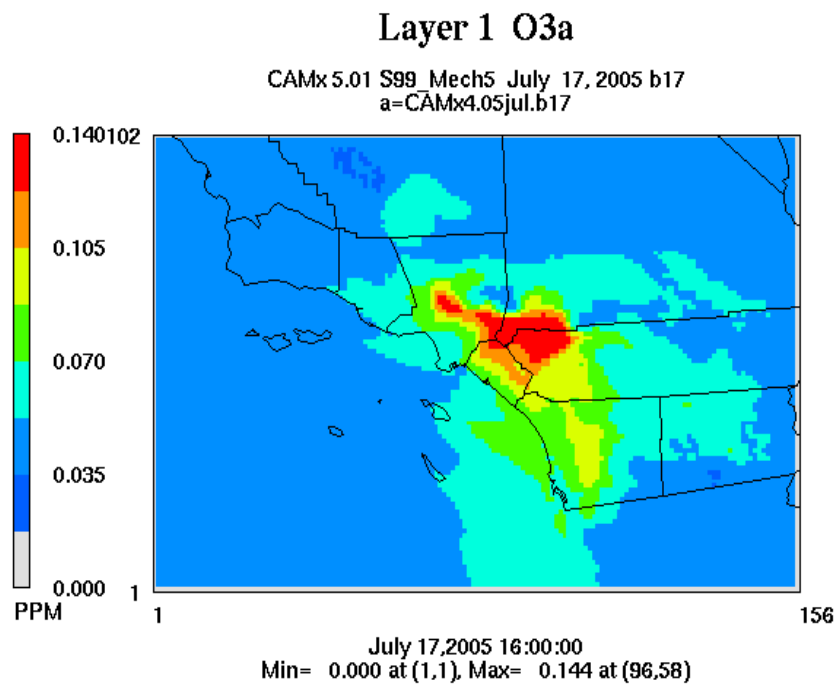

Layer 1 O3b
CAMx 5.01 S99_Mech5 July 17, 2005 b15
b=CAMx4.05jul.b15
0.140102
0.105
0.070
0.035
0.000
PPM
1
1
156
July 16,2005 15:00:00
Min= 0.000 at (1,1), Max= 0.129 at (78,61)


Layer 1 O3b
CAMx 5.01 S99_Mech5 July 17, 2005 b15
b=CAMx4.05jul.b15
0.140102
0.105
0.070
0.035
0.000
PPM
1
1
156
July 17,2005 15:00:00
Min= 0.000 at (1,1), Max= 0.139 at (73,63)


Layer 1 O3a
CAMx 5.01 S99_Mech5 July 17, 2005 b17
a=CAMx4.05jul.b17
0.140102
0.105
0.070
0.035
0.000
1


Layer 1 O3a
CAMx 5.01 S99_Mech5 July 17, 2005 b17
a=CAMx4.05jul.b17
0.140102
0.105
0.070
0.035
0.000
PPM
1
1
156
July 15,2005 15:00:00
Min= 0.000 at (1,1), Max= 0.110 at (104,34)

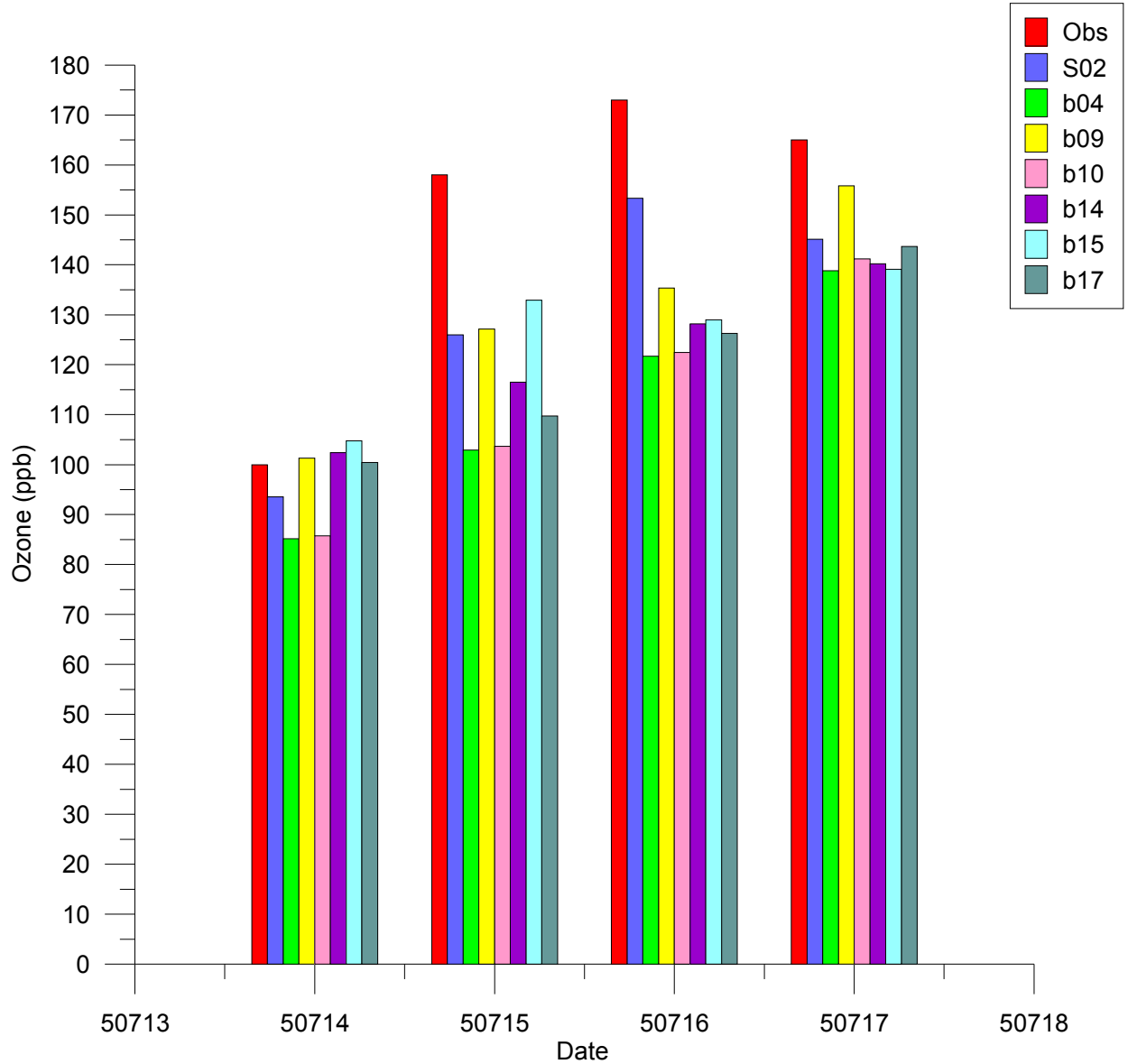

Layer 1 O3a
CAMx 5.01 S99_Mech5 July 17, 2005 b17
a=CAMx4.05jul.b17
0.140102
0.105
0.070
0.035
0.000
PPM
1
1
156
July 16,2005 15:00:00
Min= 0.000 at (1,1), Max= 0.126 at (70,64)


Layer 1 O3a
CAMx 5.01 S99_Mech5 July 17, 2005 b17
a=CAMx4.05jul.b17
0.140102
0.105
0.070
0.035
0.000
PPM
1
1
156
July 17,2005 16:00:00
Min= 0.000 at (1,1), Max= 0.144 at (96,58)

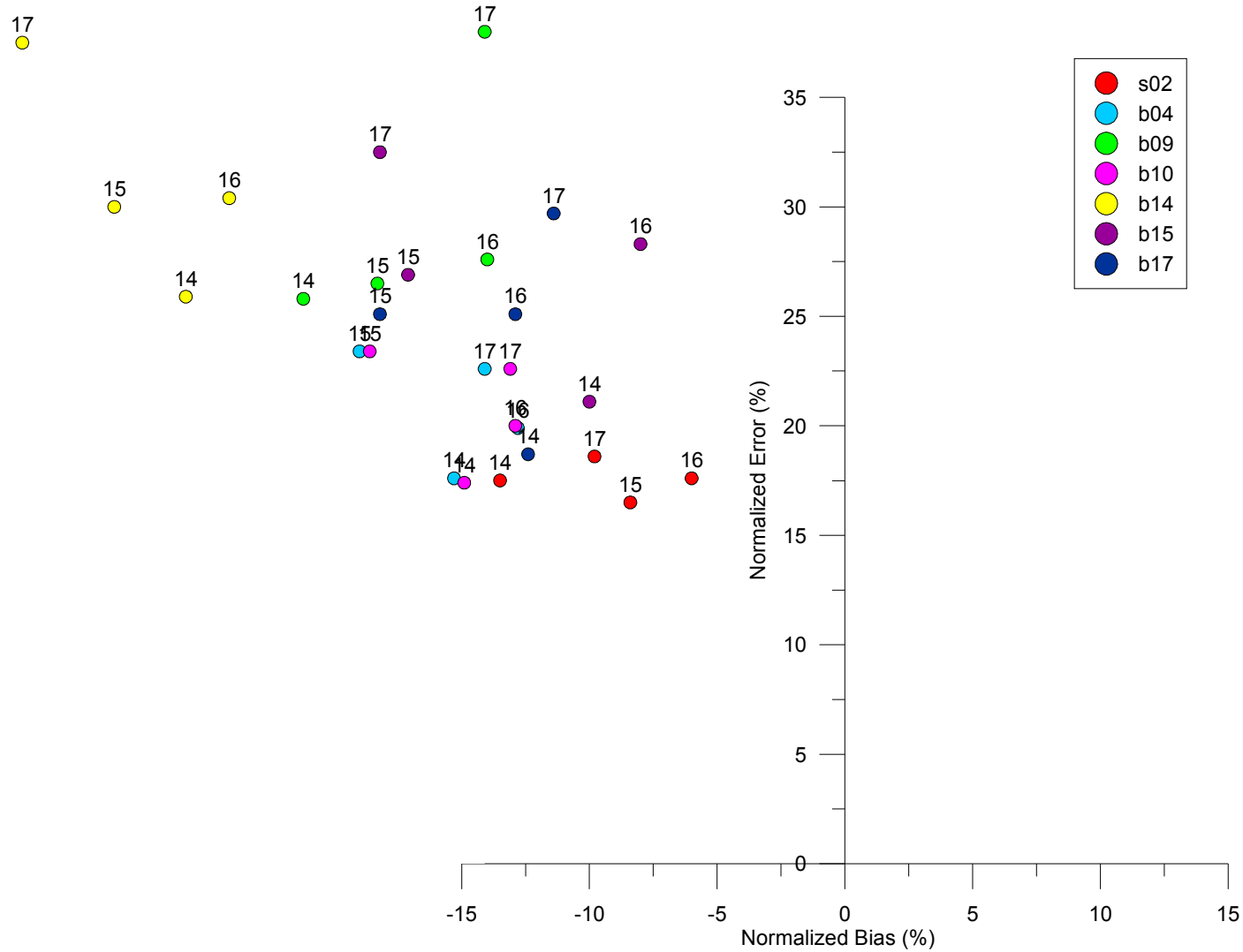
Spatial plots for Ozone

- Poor ---B05, B14 and b15
- Acceptable –B04, B10 and B17

Observed and Predicted Peak



Normalized Bias and Error



Summary and Future Work

- For retrospective runs, 3D FDDA is an effective tool to replicate day to day variability. Surface FDDA reduced the bias of predicted wind speed. However, this needs to be used with caution since it could alter the wind field significantly. The effectiveness of Surface Observational Nudging needs further evaluation.

- While NOAH Land Surface model has an advanced mechanism to address seasonal changes of surface characteristics, the 5 layer soil model appeared to perform reasonably well for the South Coast Air Basin. We will also continue to evaluate the static surface characteristics listed in the default lookup table. Land use and Land cover information require updates to reflect the urbanization of the eastern basin and complex coastal geographic feature.

- We will consider a nested grid with finer resolution to address local meteorological characteristics driven by complex geography

- In all, we will use MM5 as a primary model while we continue to explore an optimum combination of WRF Physics and Parameters options for the South Coast Air Basin.

END

Sensitivity Runs

3db01 - BASE 3 Domain

- ds83.2 for Initial/Lateral boundary condition
- 3D and SRF Analysis Nudging for Domain 1 and 2 (Wind, Temperature, Moisture

2db01 - BASE 2 Domain

- ds609.2 (AWIP40) for Initial/Lateral boundary condition
- 3D and SRF Analysis Nudging for Domain 1 (Wind, Temperature, Moisture)

3ds01 - Sensitivity to boundary condition 3 Domain

ds609.2 (AWIP40) for Initial/Lateral boundary condition

3D and SRF Analysis Nudging for Domain 1 and 2 (Wind, Temperature, Moisture)

3ds02 - Sensitivity to MM5OBS nudging 3 Domain

ds609.2 (AWIP40) for Initial/Lateral boundary condition

3D and SRF Analysis Nudging for Domain 1 and 2 (Wind, Temperature, Moisture)

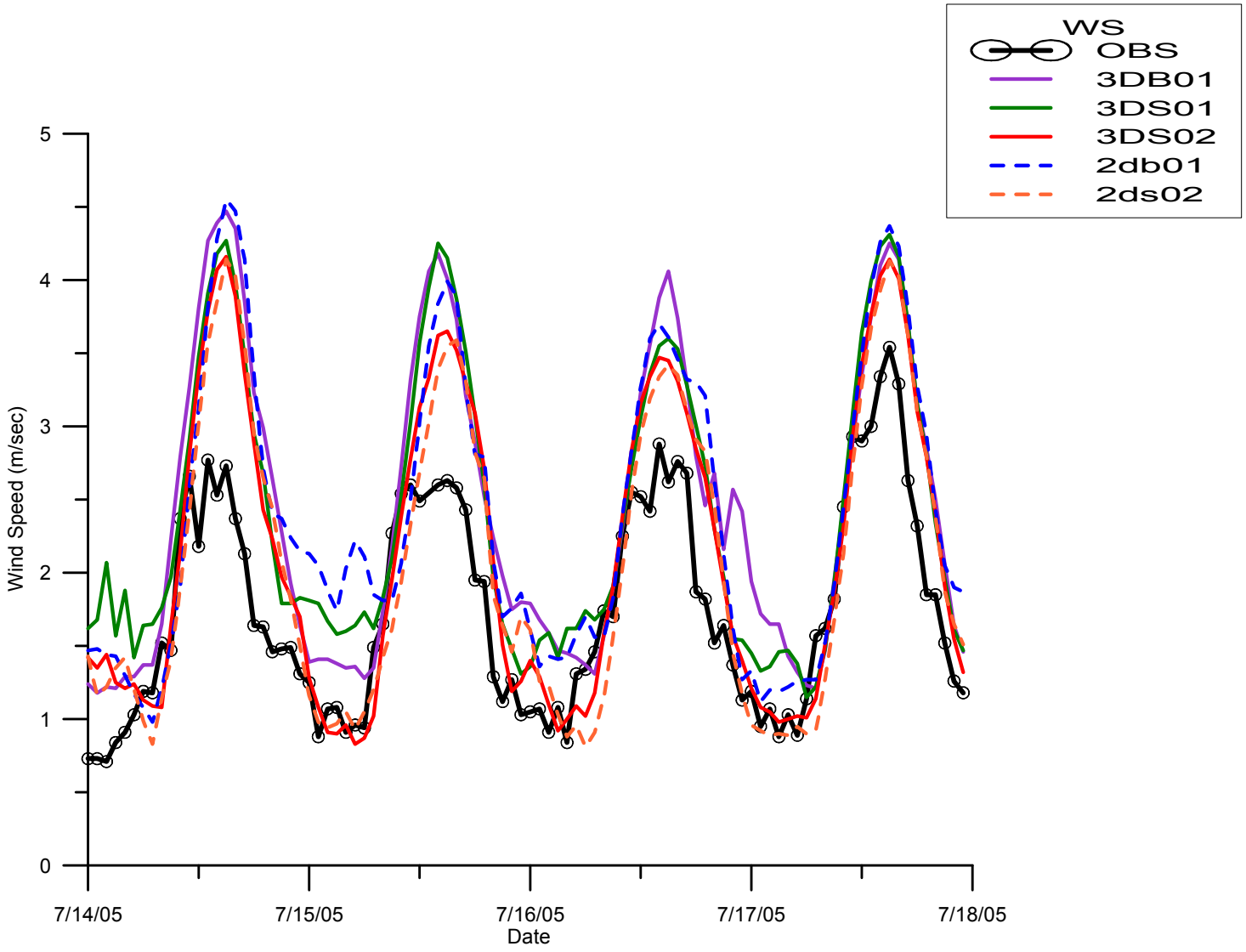
MM5OBS nudging on DOMAIN3

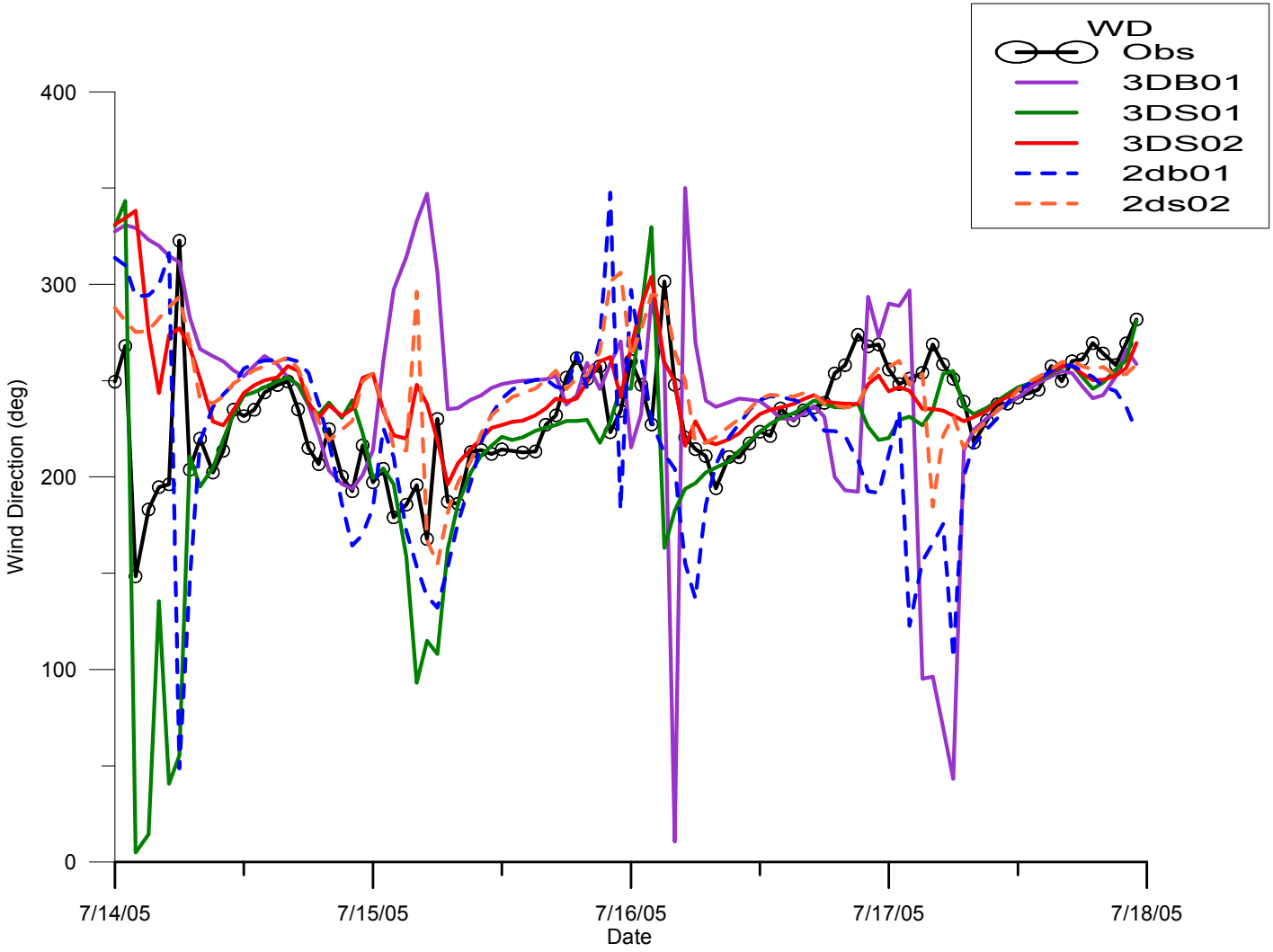
2ds02 - Sensitivity to MM5OBS nudging 2 Domain

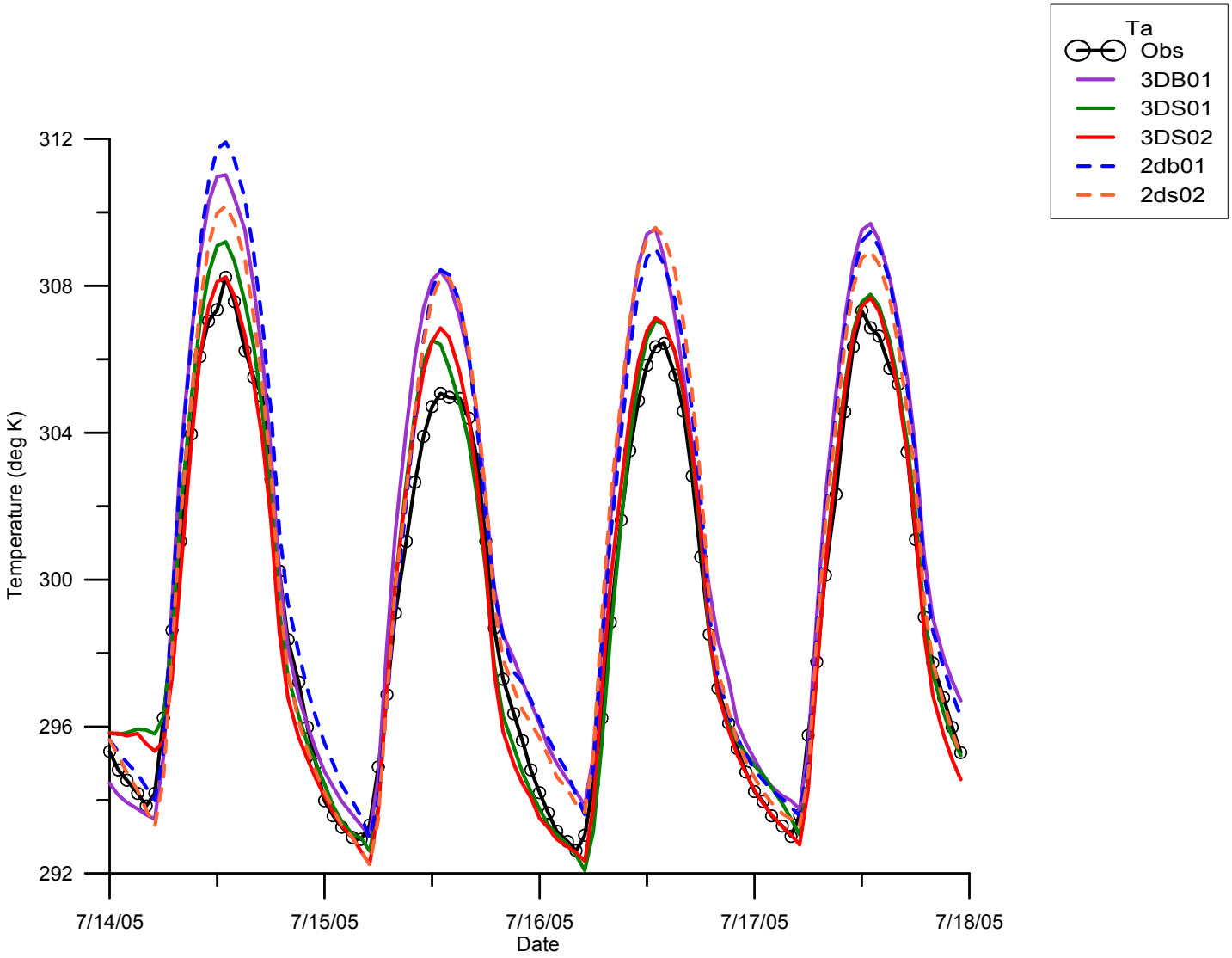
-ds609.2 (AWIP40) for Initial/Lateral boundary condition

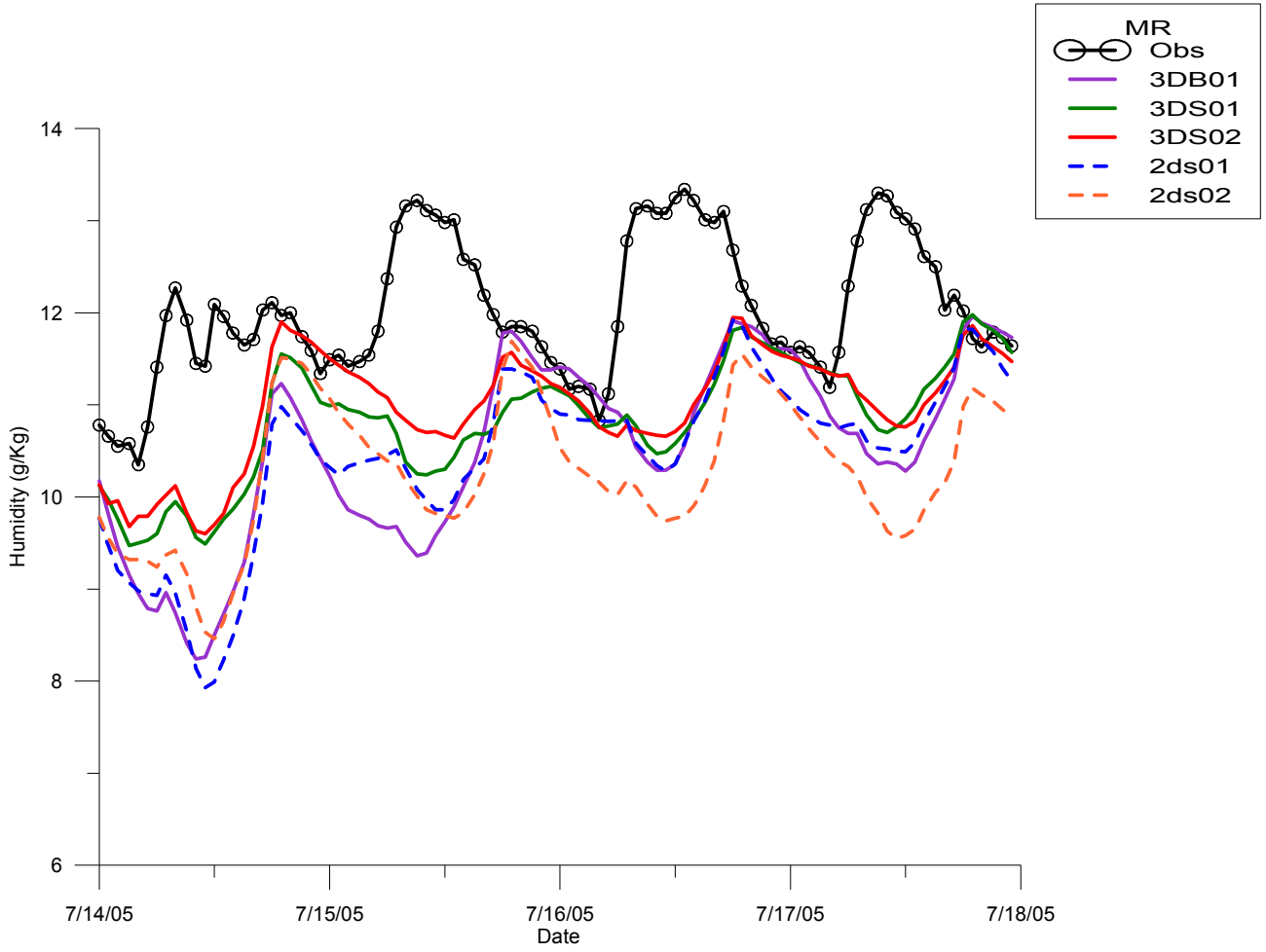
-3D and SRF Analysis Nudging for Domain 1 and 2 (Wind, Temperature, Moisture)

-MM5OBS nudging on DOMAIN2

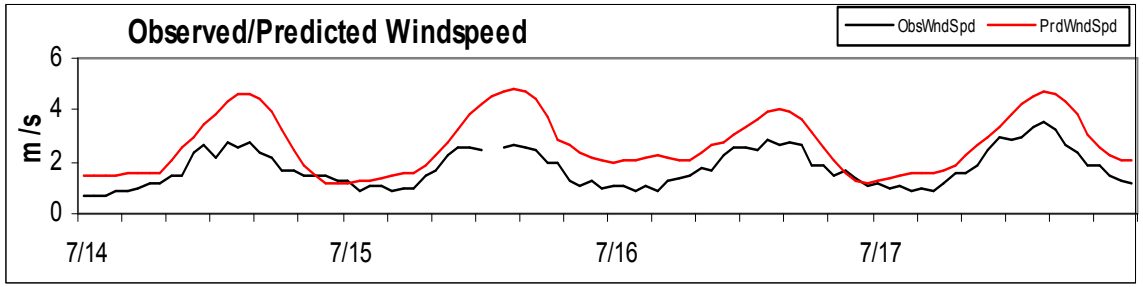

WS
OBS
3DB01
3DS01
3DS02
2db01
2ds02
Wind Speed (m/sec)
0
1
2
3
4
5
7/14/05
7/15/05
7/16/05
7/17/05
7/18/05
Date

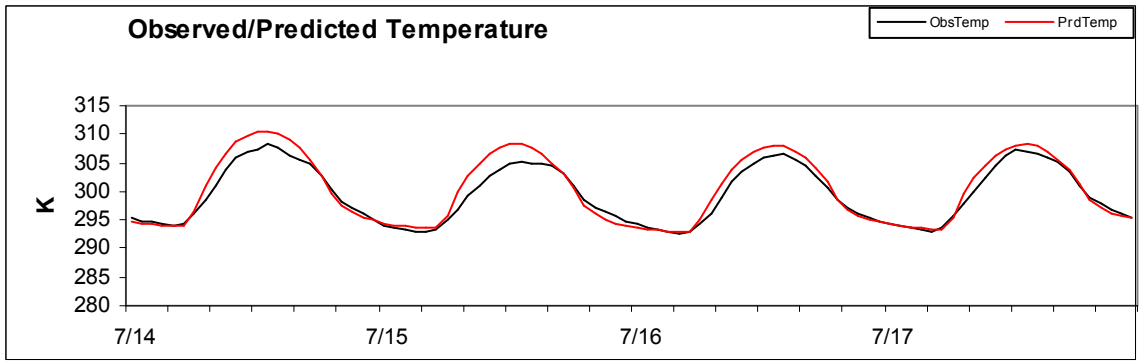

WD
Obs
3DB01
3DS01
3DS02
2db01
2ds02
400
300
200
100
0
Wind Direction (deg)
7/14/05
7/15/05
7/16/05
7/17/05
7/18/05
Date

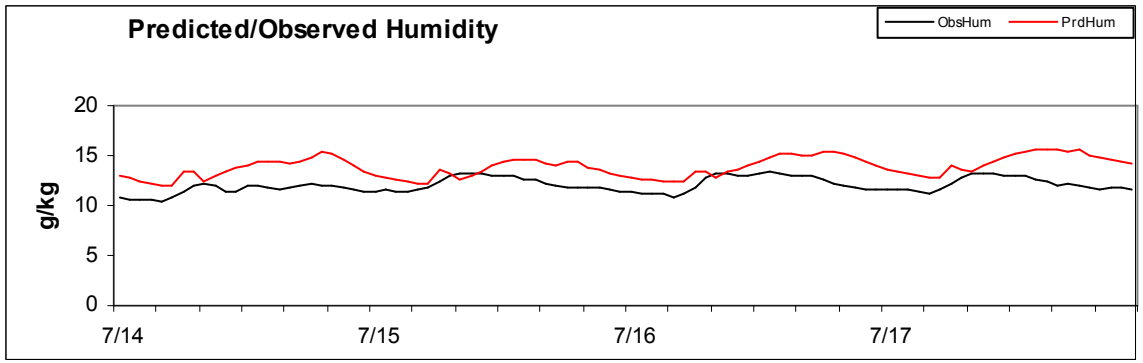

Ta
Obs
3DB01
3DS01
3DS02
2db01
2ds02
312
308
304
300
296
292
Temperature (deg K)
7/14/05
7/15/05
7/16/05
7/17/05
7/18/05
Date


MR
Obs
3DB01
3DS01
3DS02
2ds01
2ds02
14
12
10
8
6
Humidity (g/Kg)
7/14/05
7/15/05
7/16/05
7/17/05
7/18/05
Date

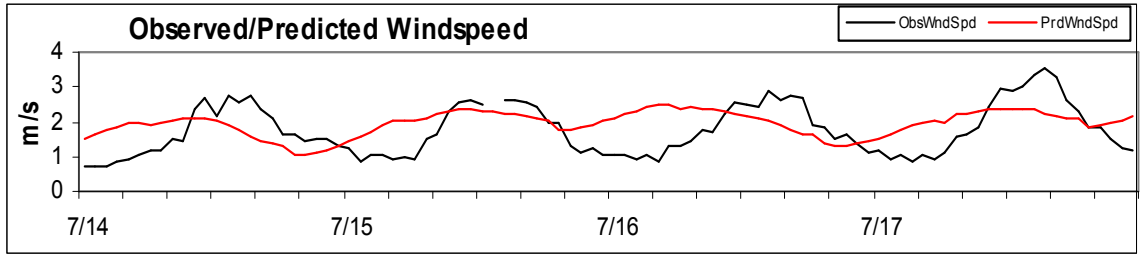
AQMD wrf02 2005 July 14-17

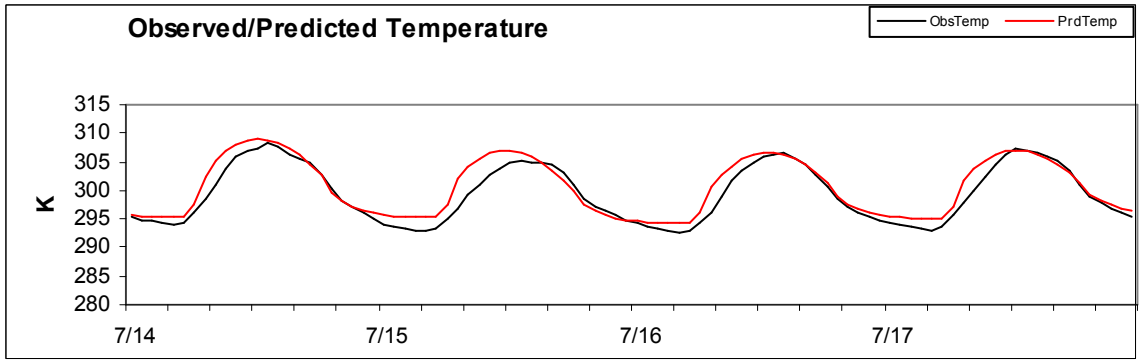


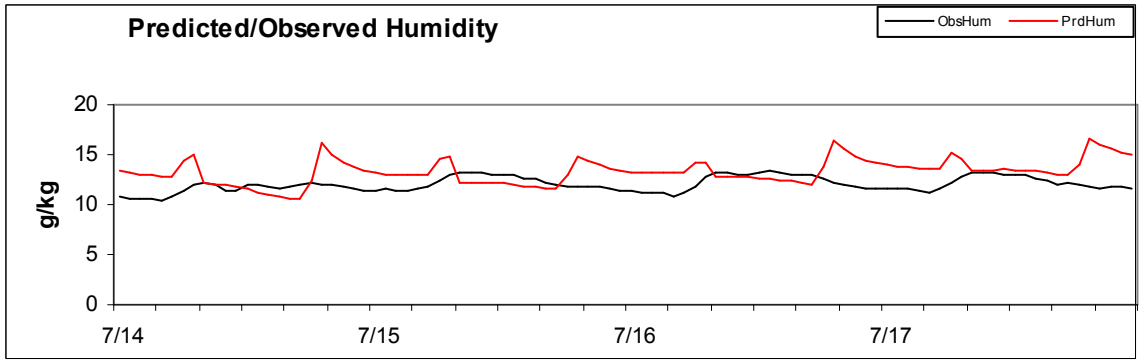




AQMD wrf04 2005 July 14 - 17







Statistical Evaluation

Metstat

Case 3ds02

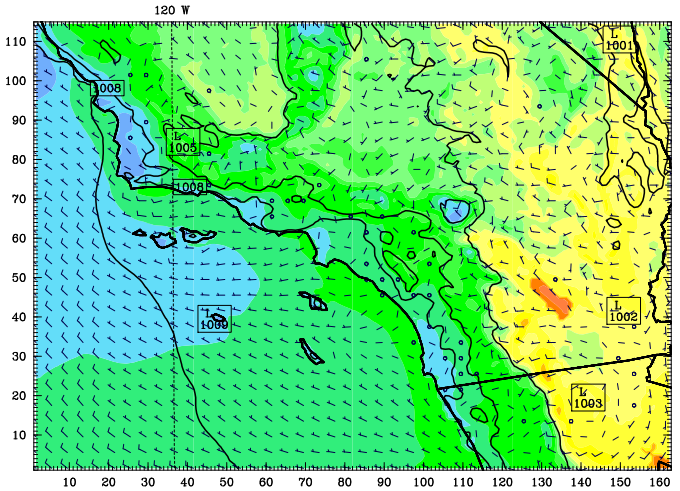
Statistical Evaluation

MM5 case 3ds02	Parameters	7/14/05	7/15/05	7/16/05	7/17/05	Benchmark
Wind Speed (m/s)	Bias	0.60	0.30	0.33	0.29	≤±0.5 m/s
Wind Speed (m/s)	RMSE	1.49	1.34	1.24	1.23	≤2.0 m/s
Wind Speed	IOA	0.69	0.74	0.78	0.84	≥0.6
Wind Direction (deg)	Bias	7.96	8.20	9.19	8.91	≤±10 deg
Wind Direction (deg)	Gross Error	55.32	48.14	47.97	42.84	≤30 degrees
Temperature (K)	Bias	0.46	0.55	0.78	0.40	≤±0.5 K
Temperature (K)	Gross Error	2.18	2.08	2.19	2.21	≤2.0 K
Temperature (K)	IOA	0.95	0.94	0.95	0.94	≥0.8
Humidity/kg)	Bias	-1.44	-1.18	-1.32	-0.96	≤±1.0 g/Kg
Humidity/kg)	Gross Error	2.69	2.4	2.31	2.33	≤2 g/Kg
Humidity	IOA	0.49	0.39	0.47	0.38	≥0.6

Graphical Analysis

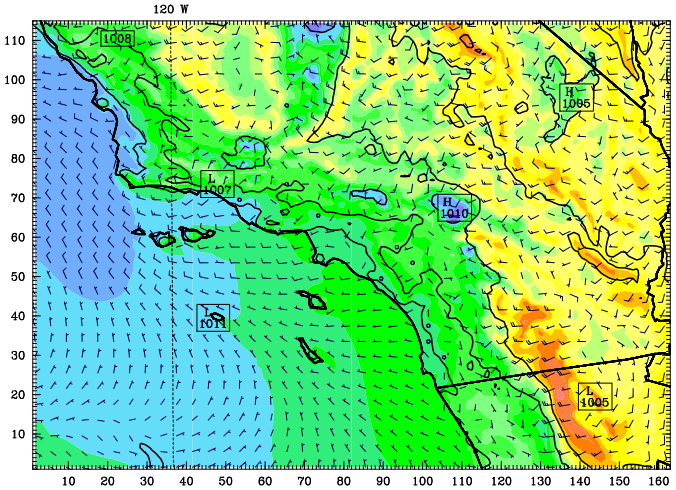
U10,V10,T2 spatial plots for MM5 case 3ds02 and WRF run02 at Hour 04, 08, 12, 16

Dataset: 3ds02 RIP: rip 3ds02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 96.00 h Valid: 1200 UTC Sun 17 Jul 05 (0400 PST Sun 17 Jul 05)
2-meter Temperature
Sea-level pressure
<U10,V10> Vectors



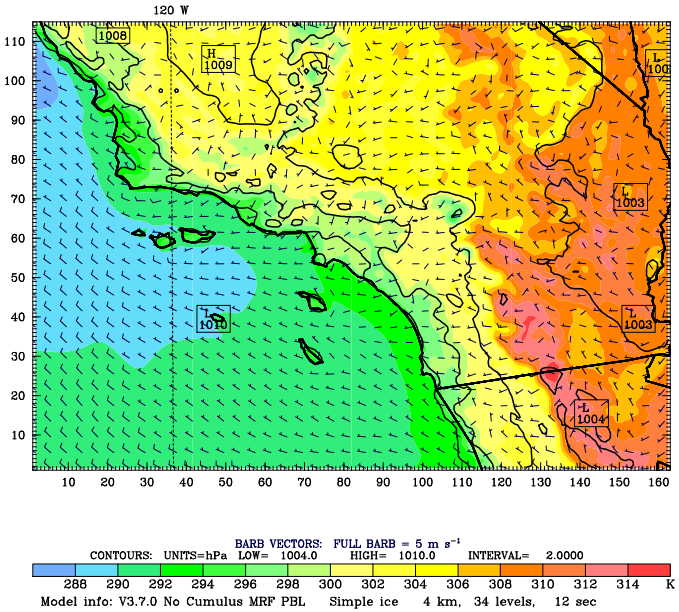
BARB VECTORS: FULL BARB = 5 m s^{-1}
CONTOURS: UNITS=hPa LOW= 1002.0 HIGH= 1010.0 INTERVAL= 2.0000
288 290 292 294 296 298 300 302 304 306 308 310 K
Model info: V3.7.0 No Cumulus MRF PBL Simple ice 4 km, 34 levels, 12 sec

Dataset: wrf02 RIP: rip wrf02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 96.00 h Valid: 1200 UTC Sun 17 Jul 05 (0400 PST Sun 17 Jul 05)
TEMP at 2 M
Sea-level pressure
<U10,V10> Vectors



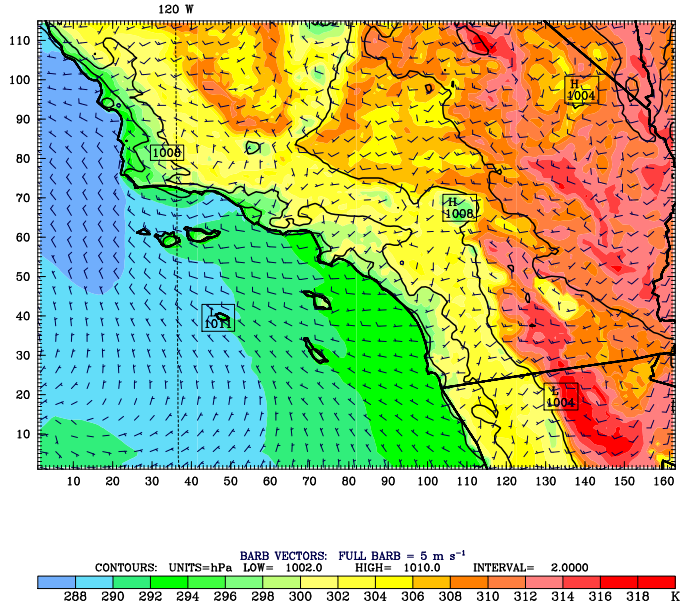
BARB VECTORS: FULL BARB = 5 m s^{-1}
CONTOURS: UNITS=hPa LOW= 1002.0 HIGH= 1012.0 INTERVAL= 2.0000
284 286 288 290 292 294 296 298 300 302 304 306 308 310 312 K

Dataset: 3ds02 RIP: rip 3ds02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 99.99 h Valid: 1559 UTC Sun 17 Jul 05 (0759 PST Sun 17 Jul 05)
2-meter Temperature
Sea-level pressure
<U10,V10> Vectors

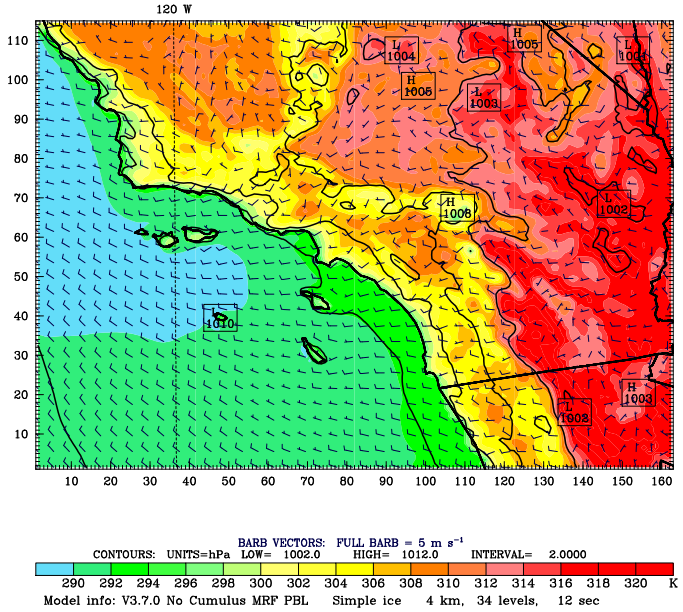


Model info: V3.7.0 No Cumulus MRF PBL Simple ice 4 km, 34 levels, 12 sec

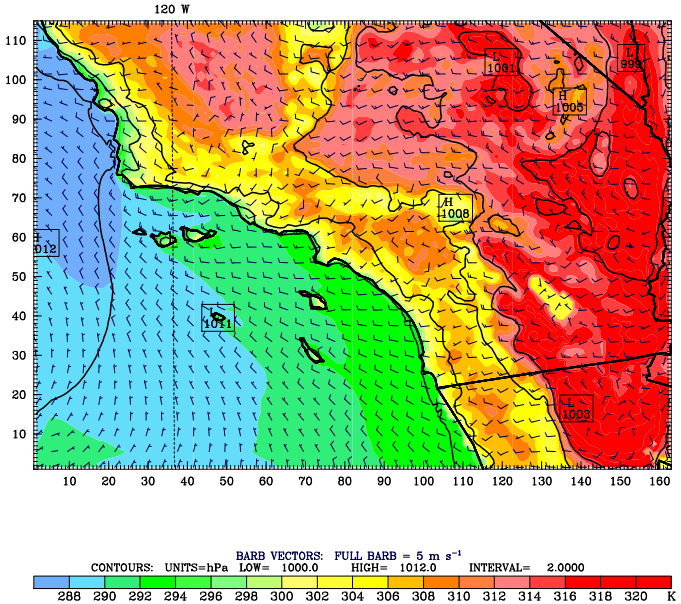
Dataset: wrf02 RIP: rip wrf02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 100.00 h Valid: 1600 UTC Sun 17 Jul 05 (0800 PST Sun 17 Jul 05)
TEMP at 2 M
Sea-level pressure
<U10,V10> Vectors



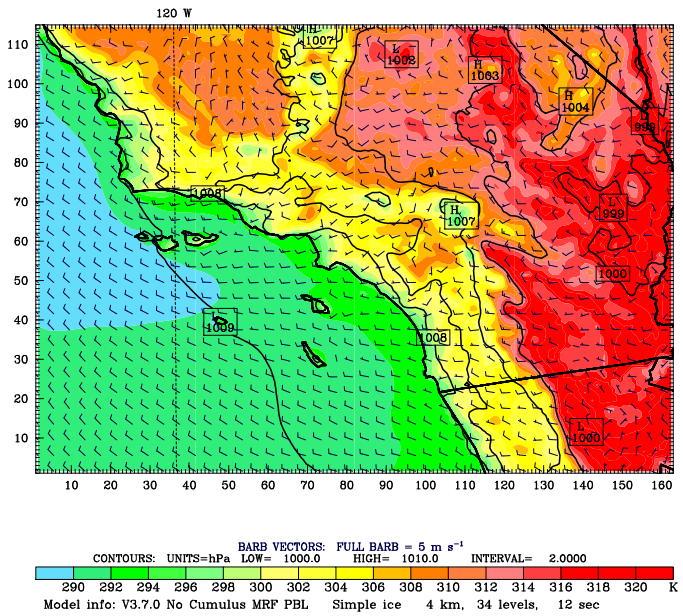
Dataset: 3ds02 RIP: rip 3ds02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 104.01 h Valid: 2000 UTC Sun 17 Jul 05 (1200 PST Sun 17 Jul 05)
2-meter Temperature
Sea-level pressure
<U10,V10> Vectors



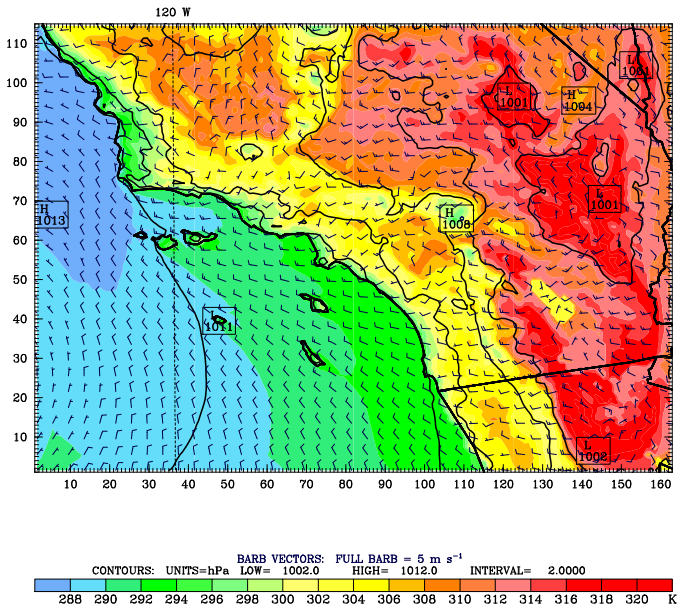
Dataset: wrf02 RIP: rip wrf02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 104.00 h Valid: 2000 UTC Sun 17 Jul 05 (1200 PST Sun 17 Jul 05)
TEMP at 2 M
Sea-level pressure
<U10,V10> Vectors



Dataset: 3ds02 RIP: rip 3ds02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 108.00 h Valid: 0000 UTC Mon 18 Jul 05 (1600 PST Sun 17 Jul 05)
2-meter Temperature
Sea-level pressure
<U10,V10> Vectors



Dataset: wrf02 RIP: rip wrf02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 108.00 h Valid: 0000 UTC Mon 18 Jul 05 (1600 PST Sun 17 Jul 05)
TEMP at 2 M
Sea-level pressure
<U10,V10> Vectors

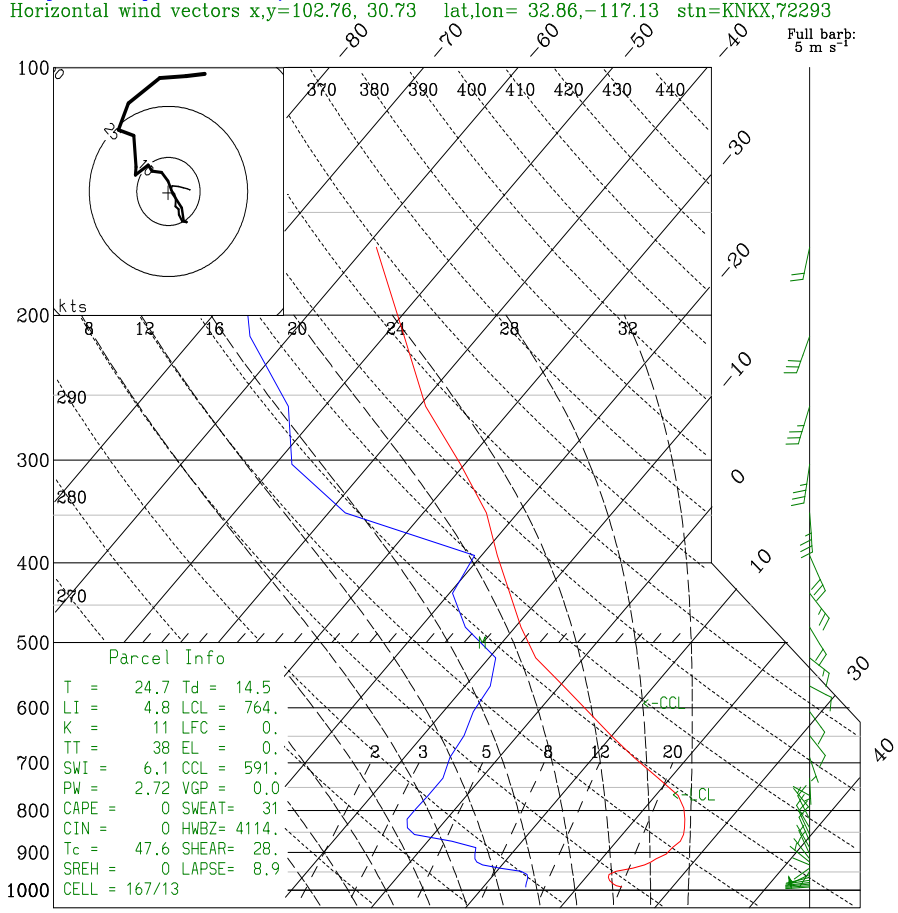


Vertical Wind Profile

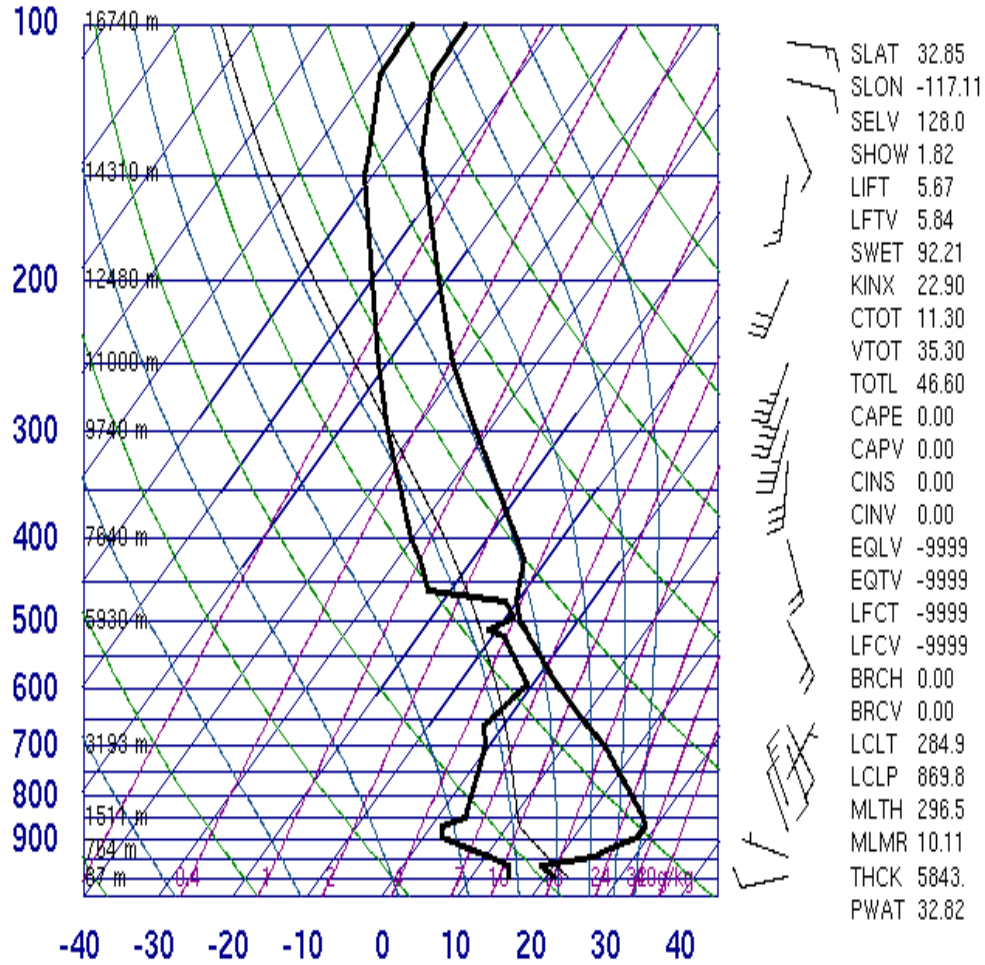
SkewT

NKX JULY 16 00Z	VBG JULY 16 00Z
NKX JULY 16 12Z	VBG JULY 16 12Z
NKX JULY 17 00Z	VBG JULY 17 00Z
NKX JULY 17 12Z	VBG JULY 17 12Z

Dataset: 3ds02 RIP: rip 3ds02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 60.00 h Valid: 0000 UTC Sat 16 Jul 05 (1600 PST Fri 15 Jul 05)
Temperature x,y=102.76, 30.73 lat,lon= 32.86,-117.13 stn=KNKX,72293
Dewpoint temperature x,y=102.76, 30.73 lat,lon= 32.86,-117.13 stn=KNKX,72293
Horizontal wind vectors x,y=102.76, 30.73 lat,lon= 32.86,-117.13 stn=KNKX,72293

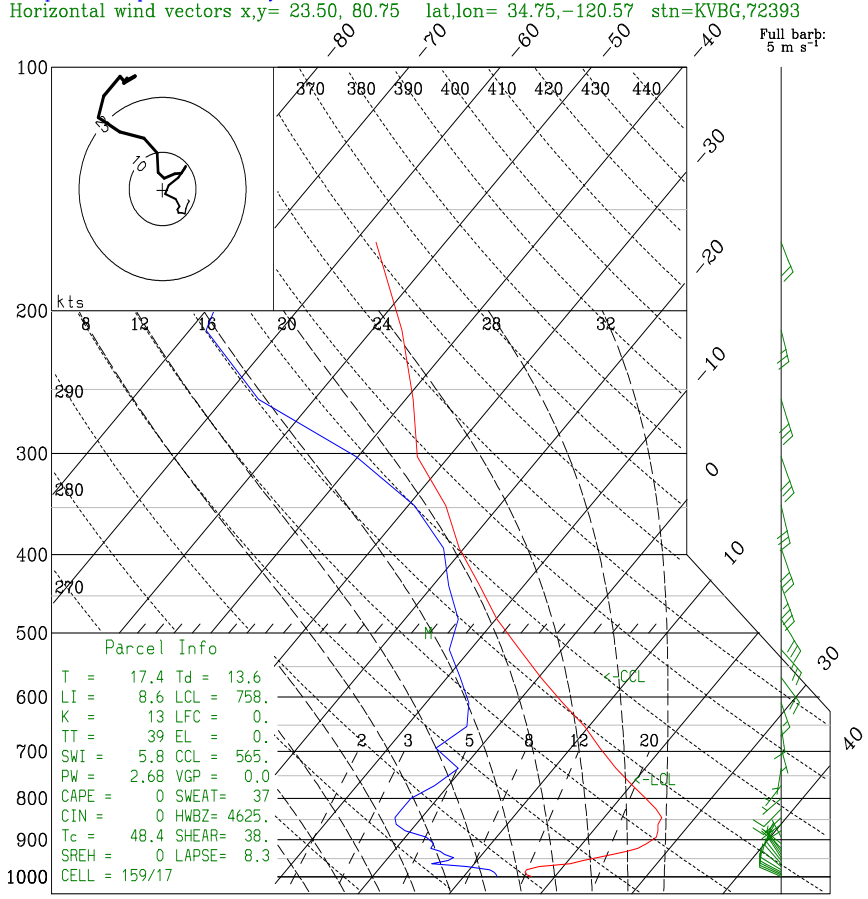


72293 NKX San Diego

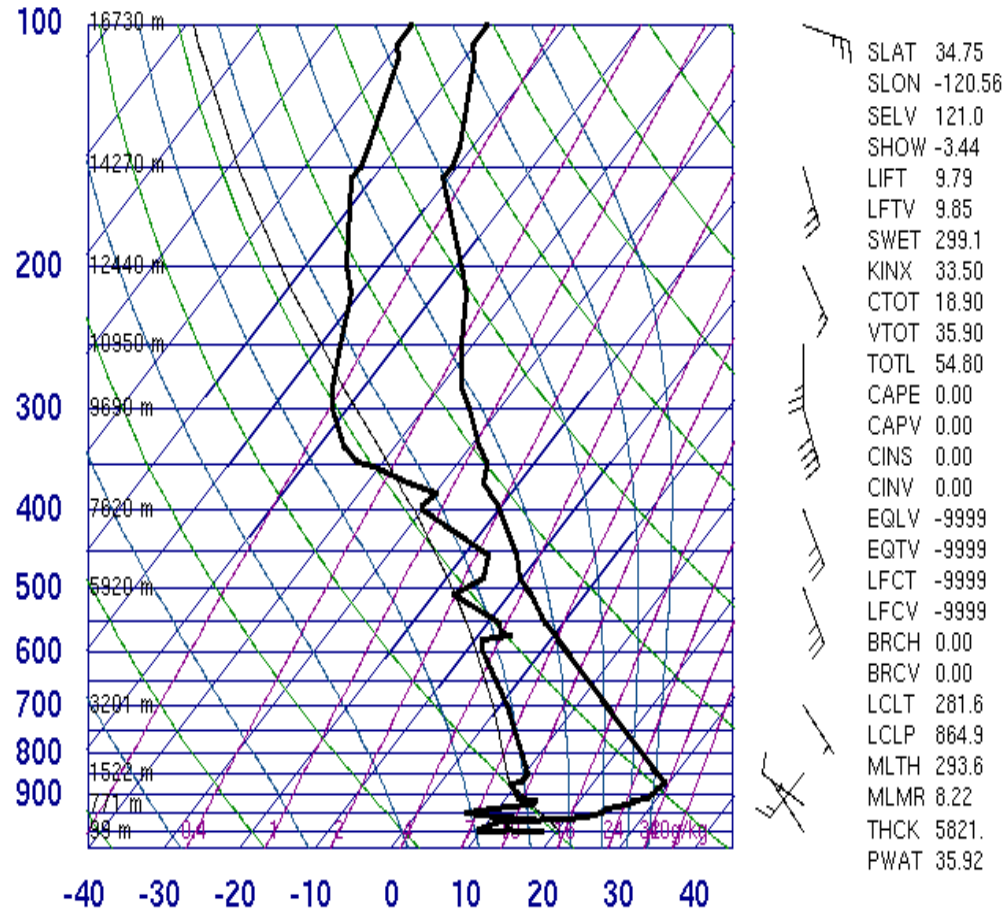


00Z 16 Jul 2005 University of Wyoming

Dataset: 3ds02 RIP: rip 3ds02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 60.00 h Valid: 0000 UTC Sat 16 Jul 05 (1600 PST Fri 15 Jul 05)
Temperature x,y= 23.50, 80.75 lat,lon= 34.75,−120.57 stn=KVBG,72393
Dewpoint temperature x,y= 23.50, 80.75 lat,lon= 34.75,−120.57 stn=KVBG,72393
Horizontal wind vectors x,y= 23.50, 80.75 lat,lon= 34.75,−120.57 stn=KVBG,72393

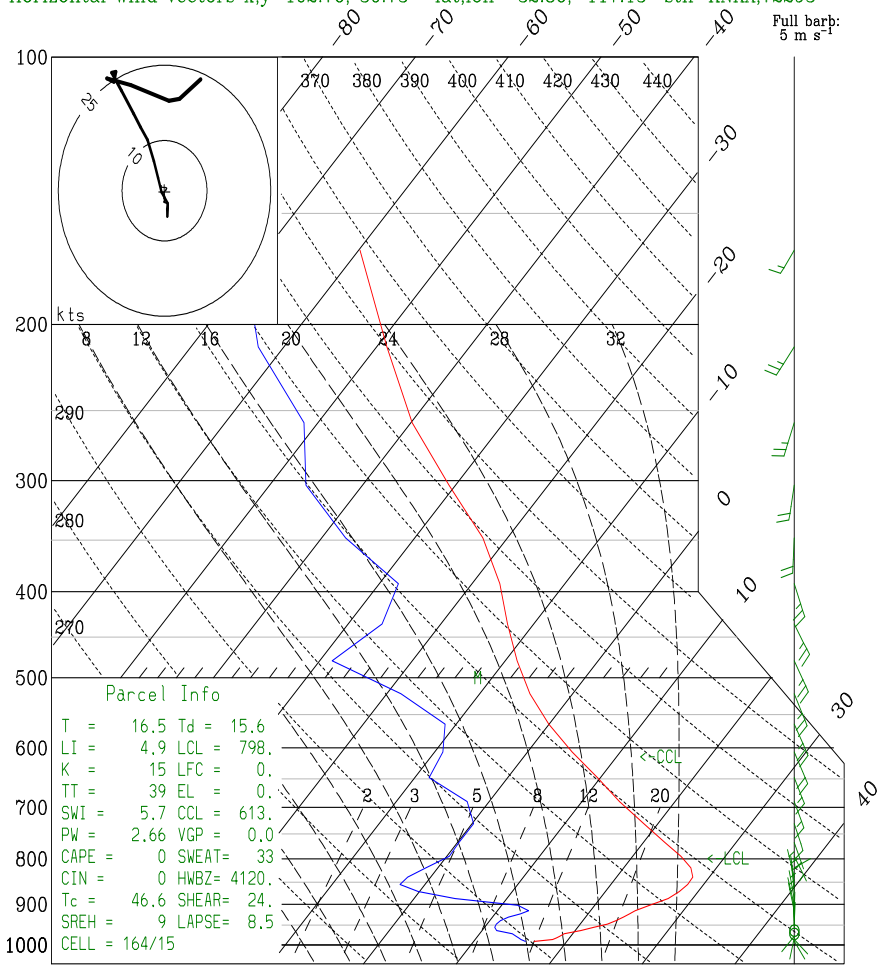


72393 VBG Vandenberg Afb

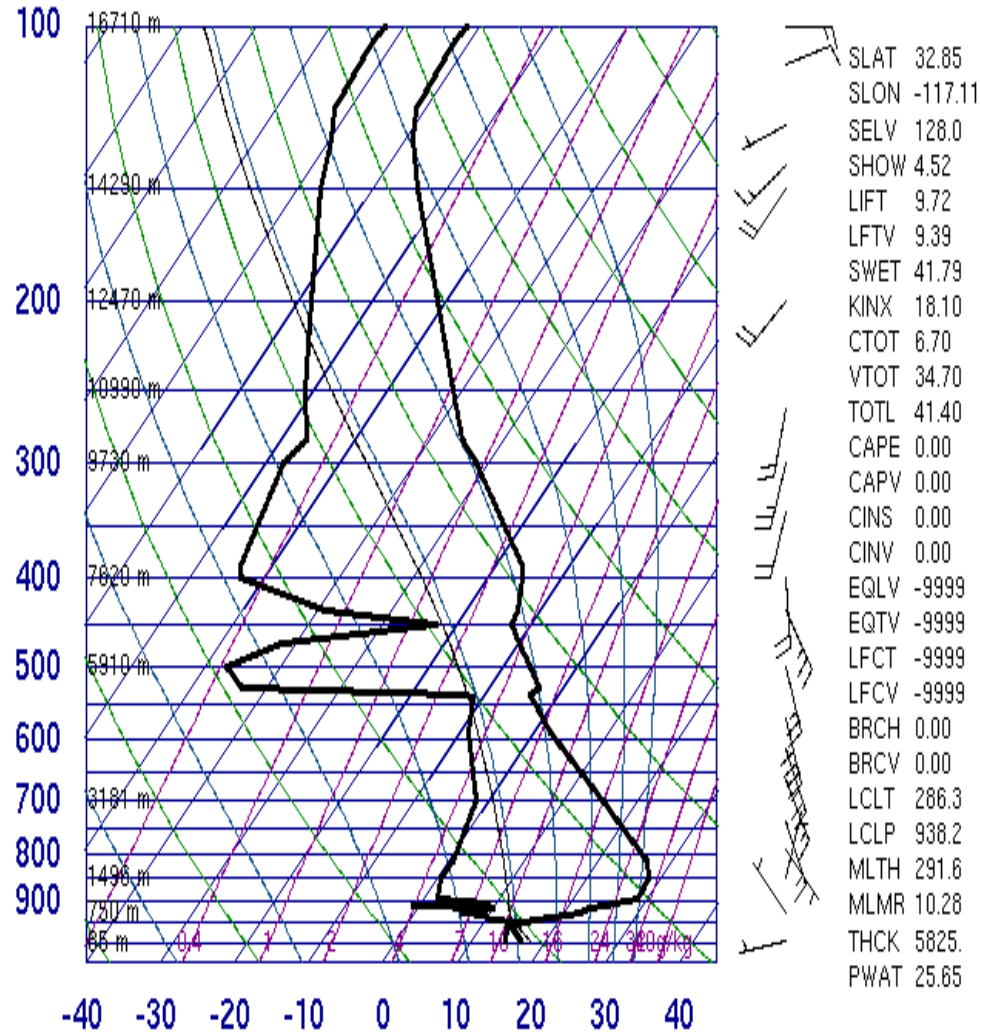


00Z 16 Jul 2005 University of Wyoming

Dataset: 3ds02 RIP: rip 3ds02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 72.00 h Valid: 1200 UTC Sat 16 Jul 05 (0400 PST Sat 16 Jul 05)
Temperature x,y=102.76, 30.73 lat,lon= 32.86,-117.13 stn=KNKX,72293
Dewpoint temperature x,y=102.76, 30.73 lat,lon= 32.86,-117.13 stn=KNKX,72293
Horizontal wind vectors x,y=102.76, 30.73 lat,lon= 32.86,-117.13 stn=KNKX,72293

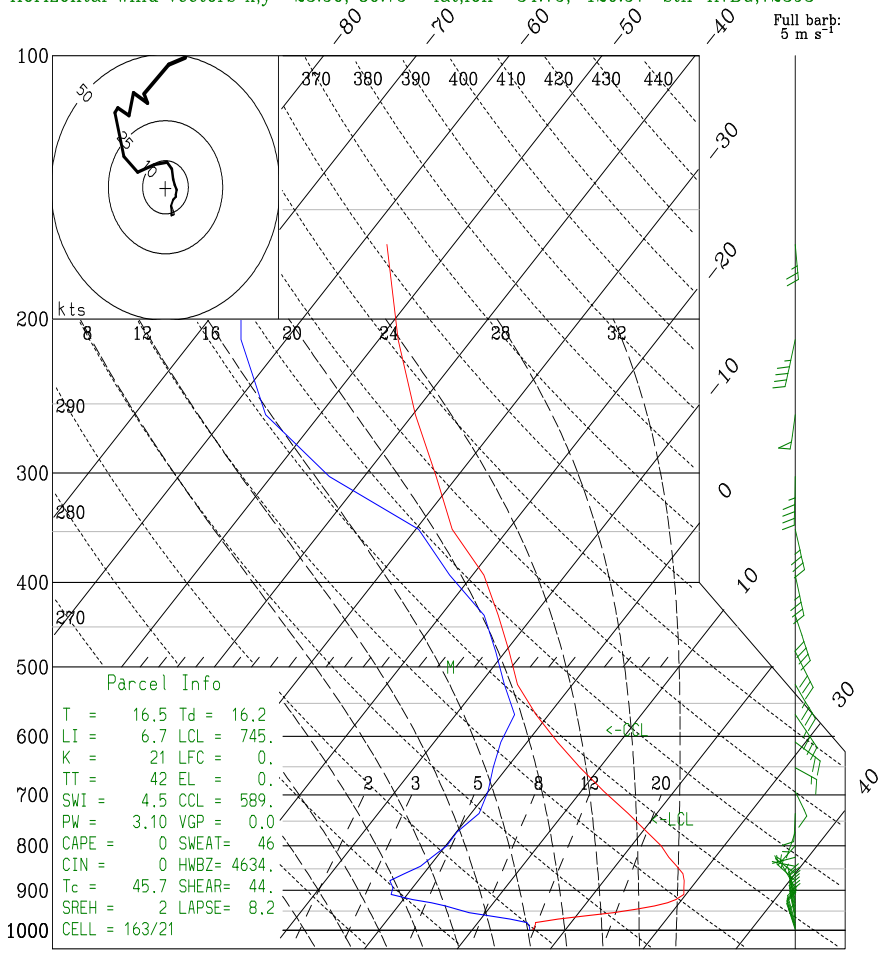


72293 NKX San Diego

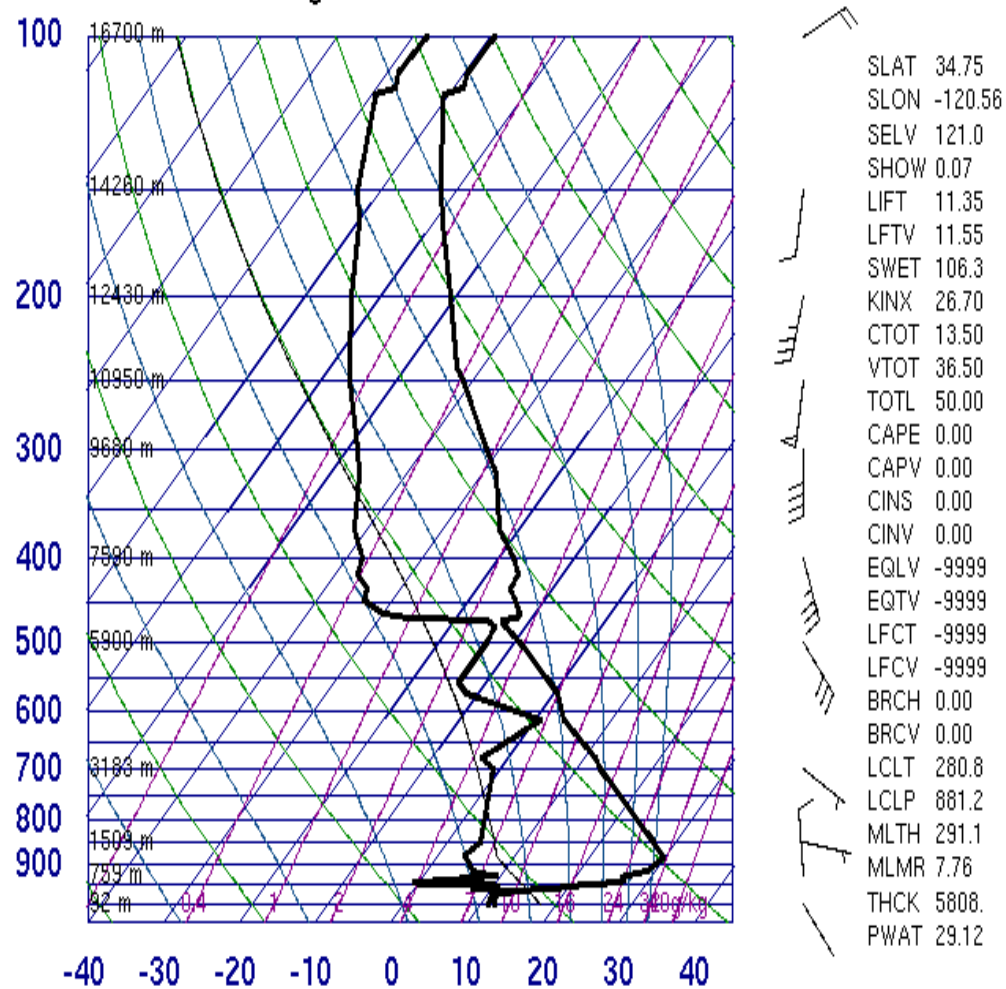


12Z 16 Jul 2005 University of Wyoming

Dataset: 3ds02 RIP: rip 3ds02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 72.00 h Valid: 1200 UTC Sat 16 Jul 05 (0400 PST Sat 16 Jul 05)
Temperature x,y= 23.50, 80.75 lat,lon= 34.75,-120.57 stn=KVBG,72393
Dewpoint temperature x,y= 23.50, 80.75 lat,lon= 34.75,-120.57 stn=KVBG,72393
Horizontal wind vectors x,y= 23.50, 80.75 lat,lon= 34.75,-120.57 stn=KVBG,72393

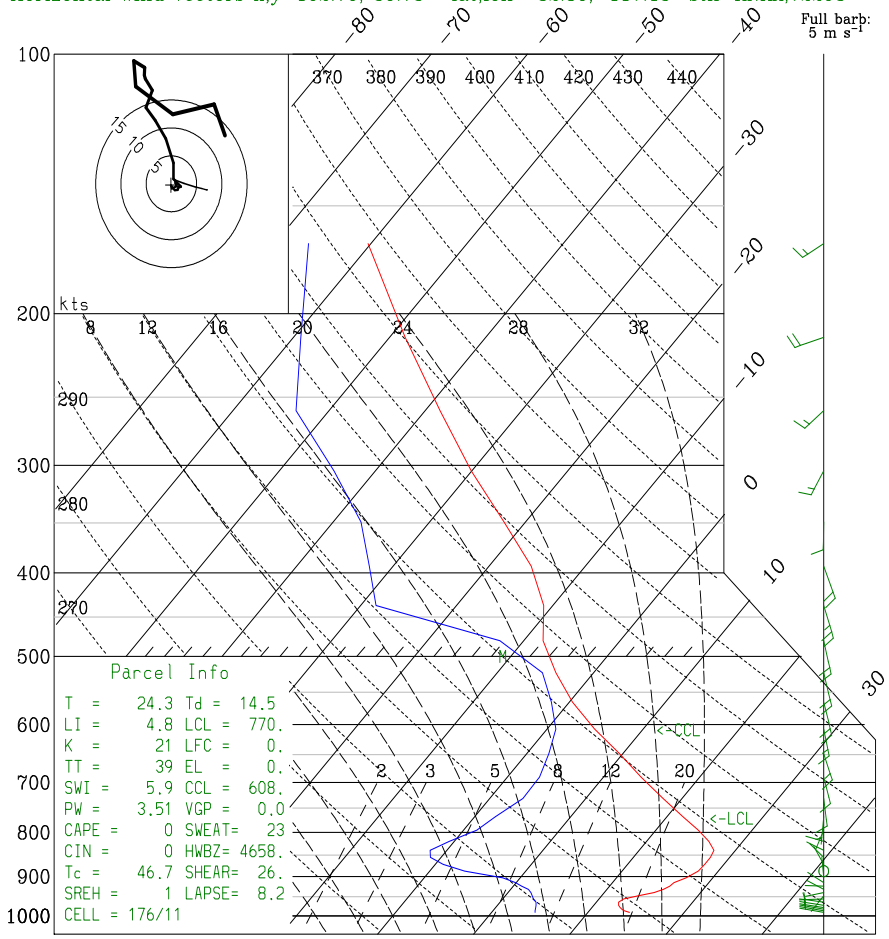


72393 VBG Vandenberg Afb

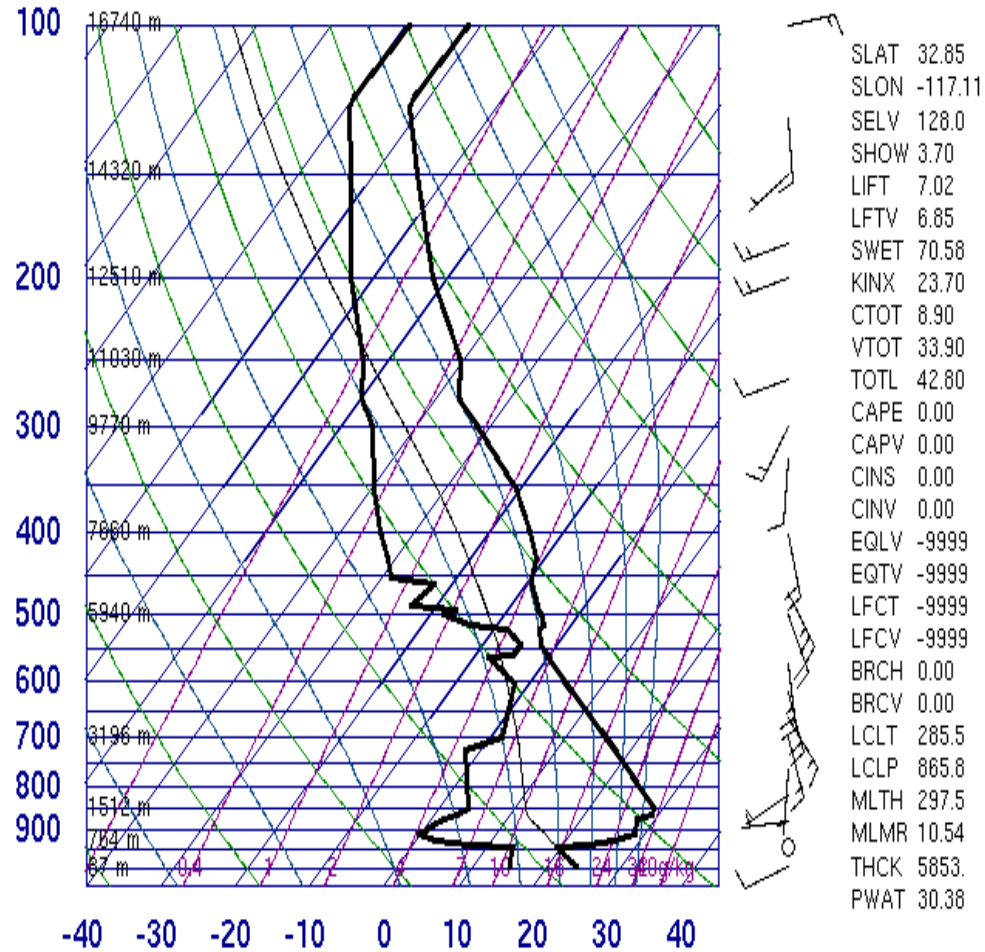


12Z 16 Jul 2005 University of Wyoming

Dataset: 3ds02 RIP: rip 3ds02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 84.00 h Valid: 0000 UTC Sun 17 Jul 05 (1600 PST Sat 16 Jul 05`
Temperature x,y=102.76, 30.73 lat,lon= 32.86,-117.13 stn=KNKX,72293
Dewpoint temperature x,y=102.76, 30.73 lat,lon= 32.86,-117.13 stn=KNKX,72293
Horizontal wind vectors x,y=102.76, 30.73 lat,lon= 32.86,-117.13 stn=KNKX,72293



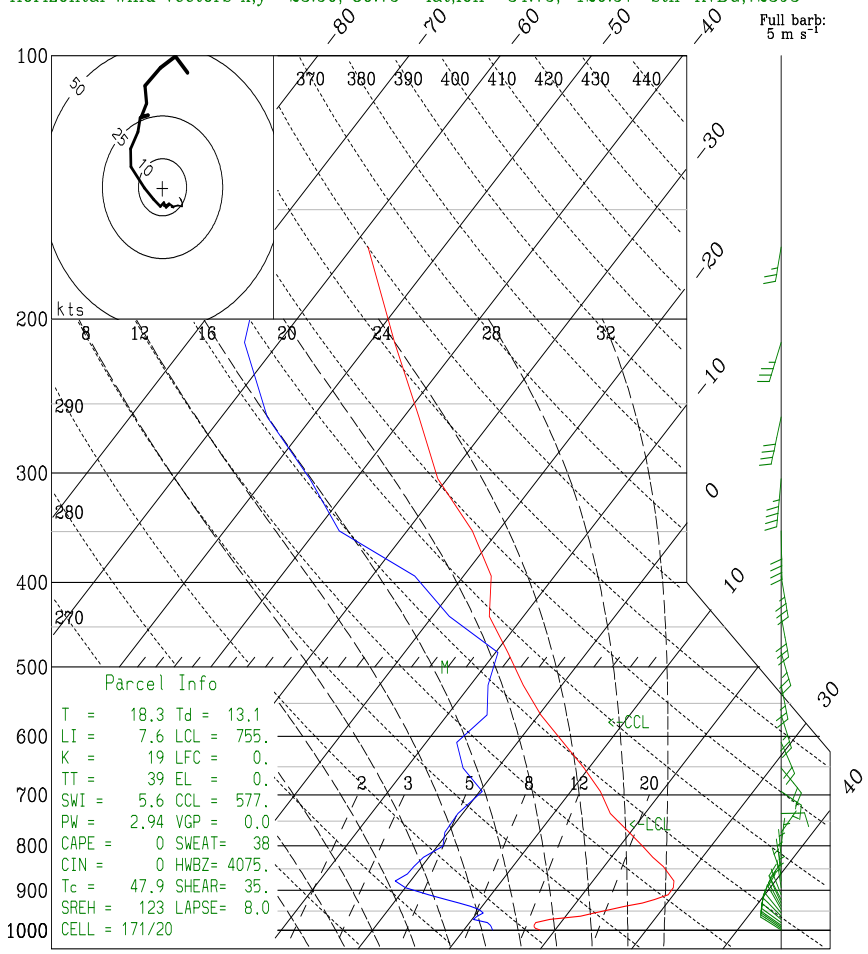
72293 NKX San Diego



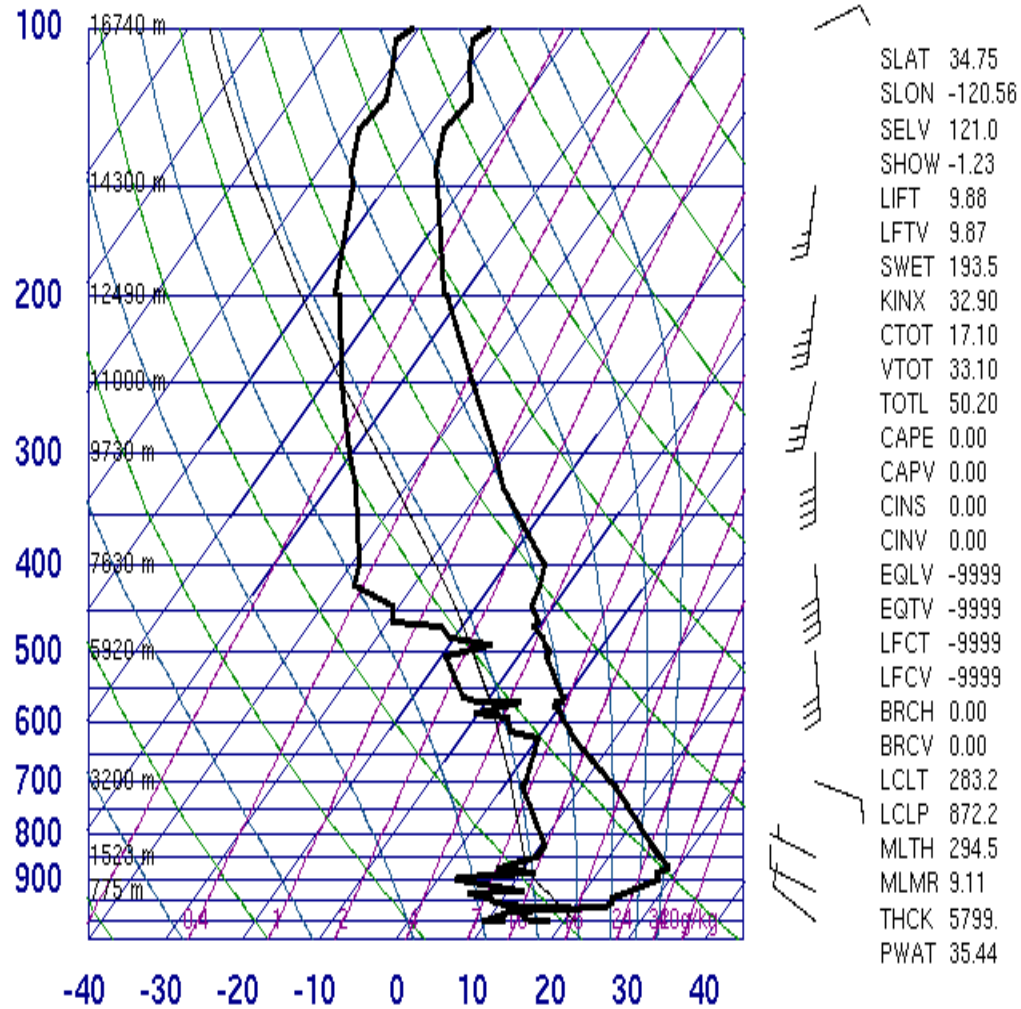
SLAT 32.85
SLON -117.11
SELV 128.0
SHOW 3.70
LIFT 7.02
LFTV 6.85
SWET 70.58
KINX 23.70
CTOT 8.90
VTOT 33.90
TOTL 42.80
CAPE 0.00
CAPV 0.00
CINS 0.00
CINV 0.00
EQLV -9999
EQTV -9999
LFCT -9999
LFCV -9999
BRCH 0.00
BRCV 0.00
LCLT 285.5
LCLP 865.8
MLTH 297.5
MLMR 10.54
THCK 5853.
PWAT 30.38

00Z 17 Jul 2005 University of Wyoming

Dataset: 3ds02 RIP: rip 3ds02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 84.00 h Valid: 0000 UTC Sun 17 Jul 05 (1600 PST Sat 16 Jul 05)
Temperature x,y= 23.50, 80.75 lat,lon= 34.75,-120.57 stn=KVBG,72393
Dewpoint temperature x,y= 23.50, 80.75 lat,lon= 34.75,-120.57 stn=KVBG,72393
Horizontal wind vectors x,y= 23.50, 80.75 lat,lon= 34.75,-120.57 stn=KVBG,72393

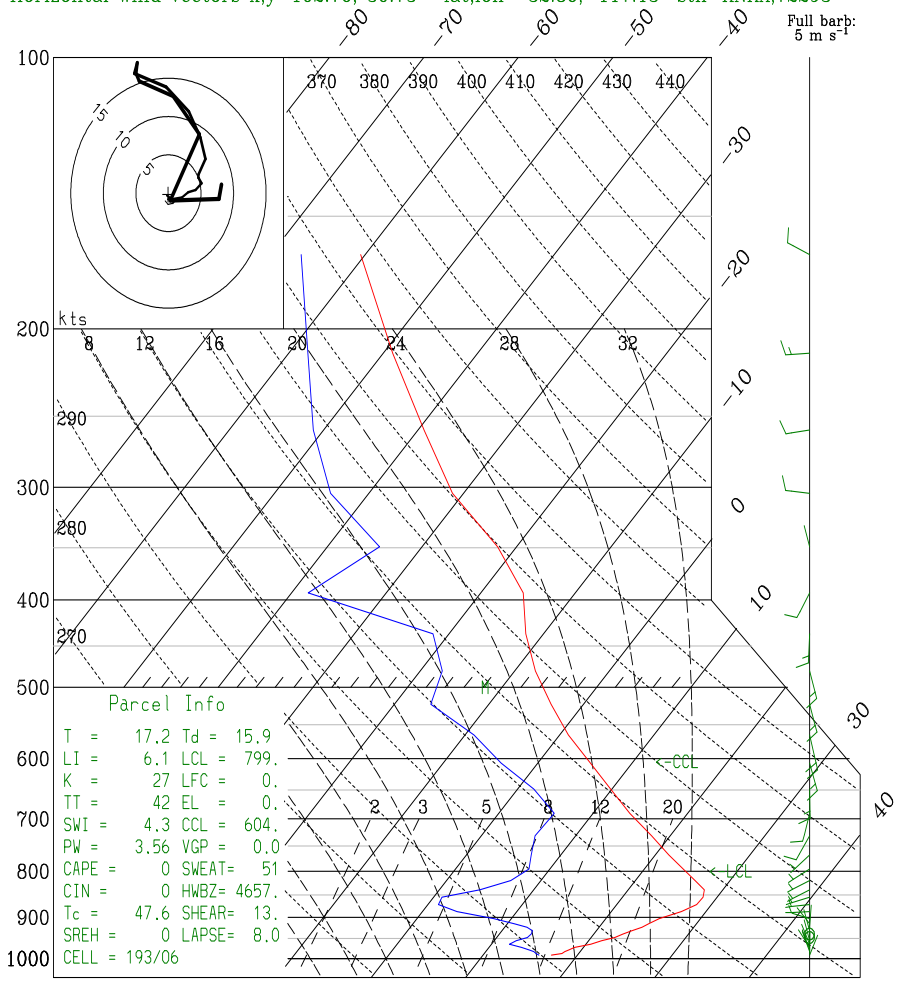


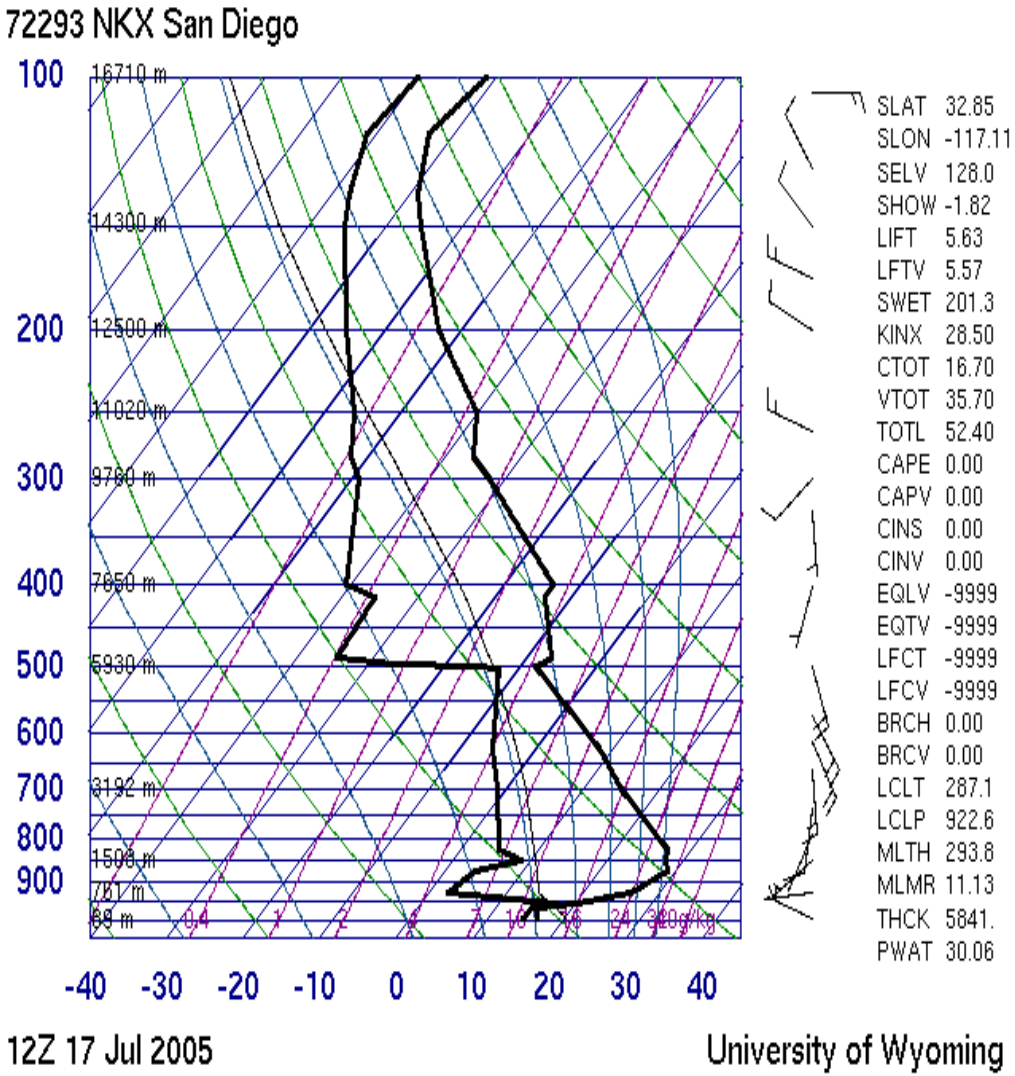
72393 VBG Vandenberg Afb



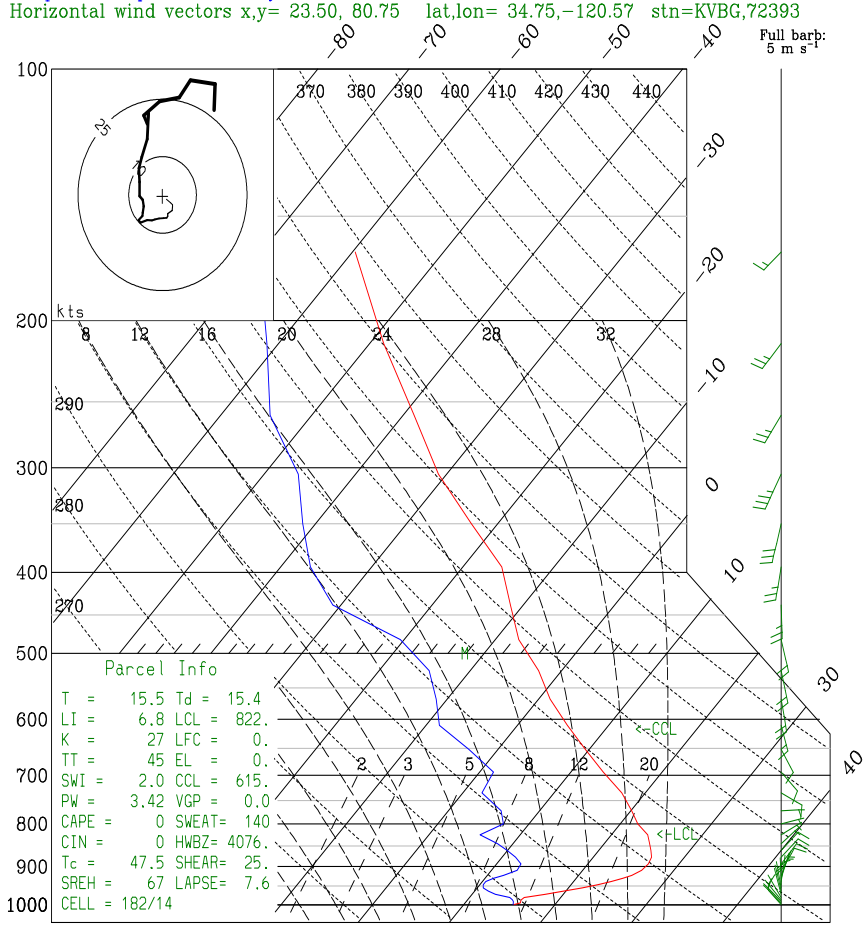
00Z 17 Jul 2005 University of Wyoming

Dataset: 3ds02 RIP: rip 3ds02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 96.00 h Valid: 1200 UTC Sun 17 Jul 05 (0400 PST Sun 17 Jul 05)
Temperature x,y=102.76, 30.73 lat,lon= 32.86,-117.13 stn=KNKX,72293
Dewpoint temperature x,y=102.76, 30.73 lat,lon= 32.86,-117.13 stn=KNKX,72293
Horizontal wind vectors x,y=102.76, 30.73 lat,lon= 32.86,-117.13 stn=KNKX,72293

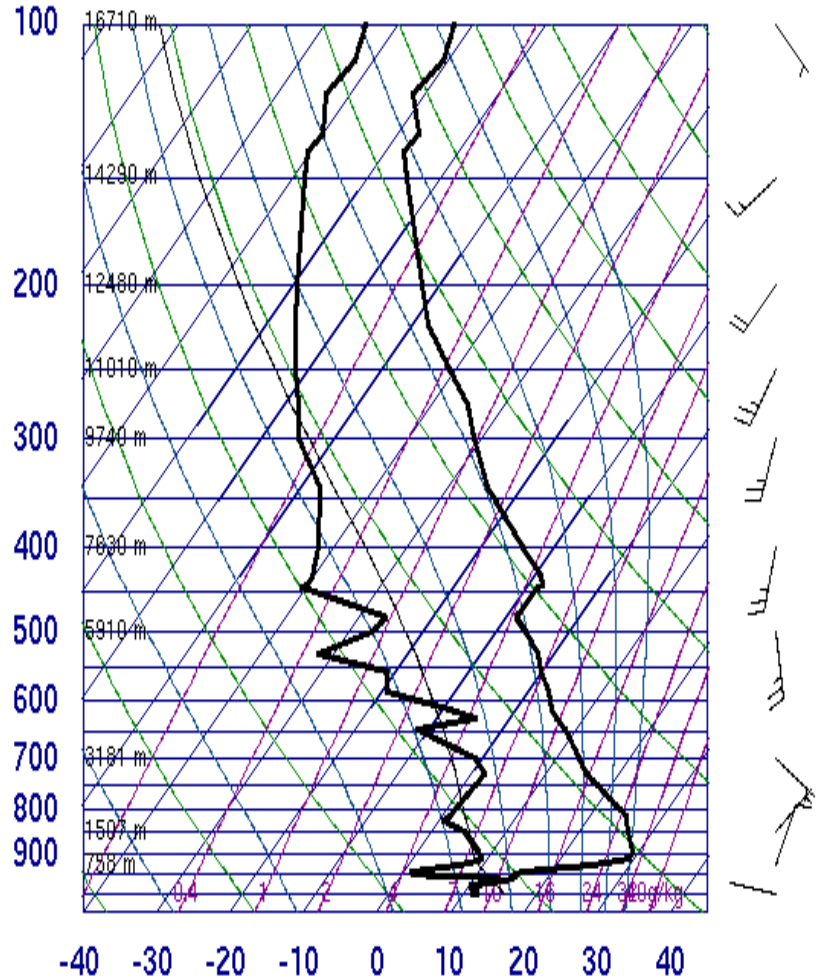




Dataset: 3ds02 RIP: rip 3ds02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 96.00 h Valid: 1200 UTC Sun 17 Jul 05 (0400 PST Sun 17 Jul 05)
Temperature x,y= 23.50, 80.75 lat,lon= 34.75,-120.57 stn=KVBG,72393
Dewpoint temperature x,y= 23.50, 80.75 lat,lon= 34.75,-120.57 stn=KVBG,72393
Horizontal wind vectors x,y= 23.50, 80.75 lat,lon= 34.75,-120.57 stn=KVBG,72393



72393 VBG Vandenberg Afb



SLAT 34.75
SLON -120.56
SELV 121.0
SHOW 3.54
LIFT 16.31
LFTV 16.25
SWET 92.19
KINX 23.10
CTOT 10.50
VTOT 32.50
TOTL 43.00
CAPE 0.00
CAPV 0.00
CINS 0.00
CINV 0.00
EQLV -9999
EQTV -9999
LFCT -9999
LFCV -9999
BRCH 0.00
BRCV 0.00
LCLT 281.2
LCLP 911.4
MLTH 288.8
MLMR 7.75
THCK 5789.
PWAT 25.12

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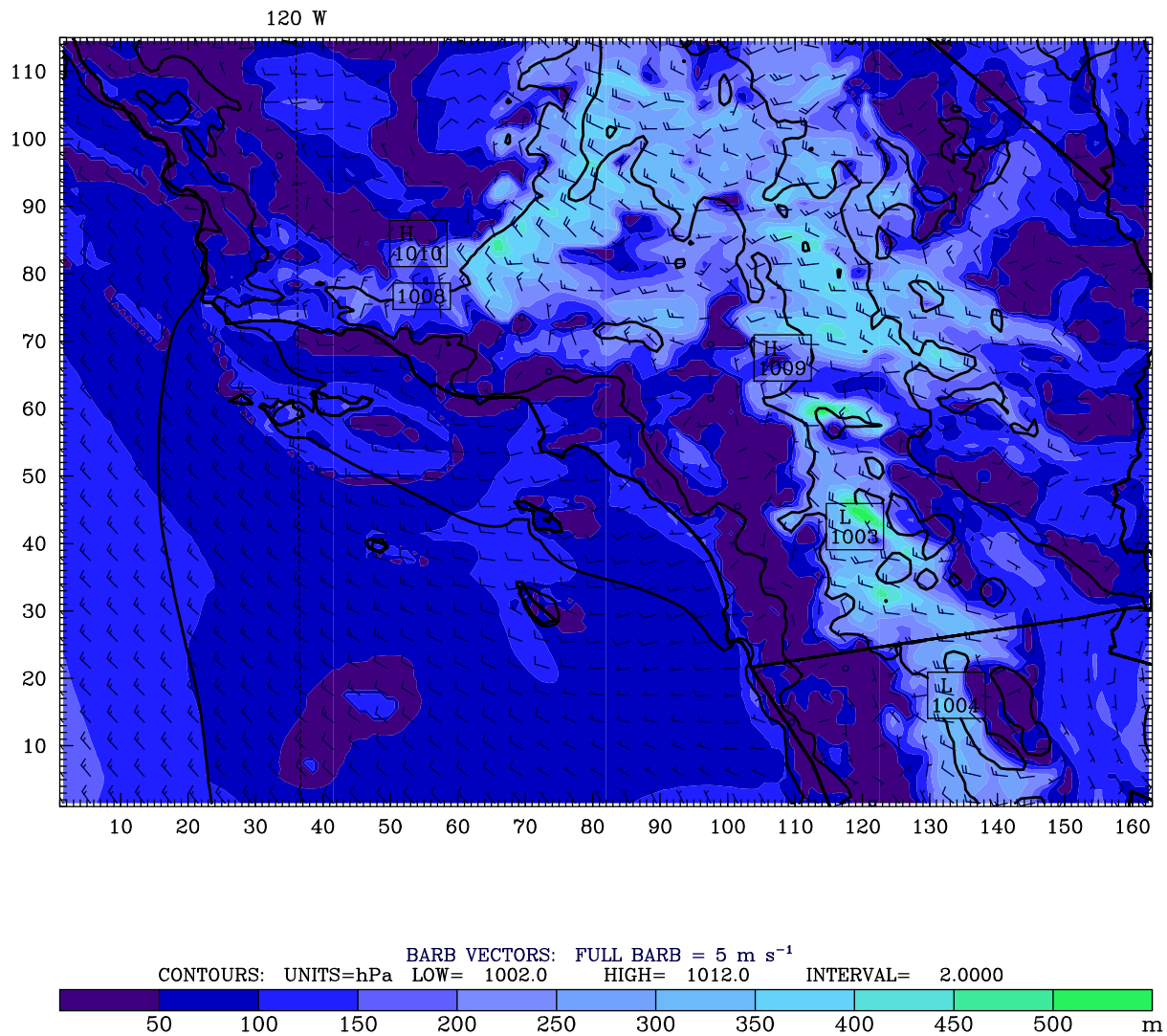
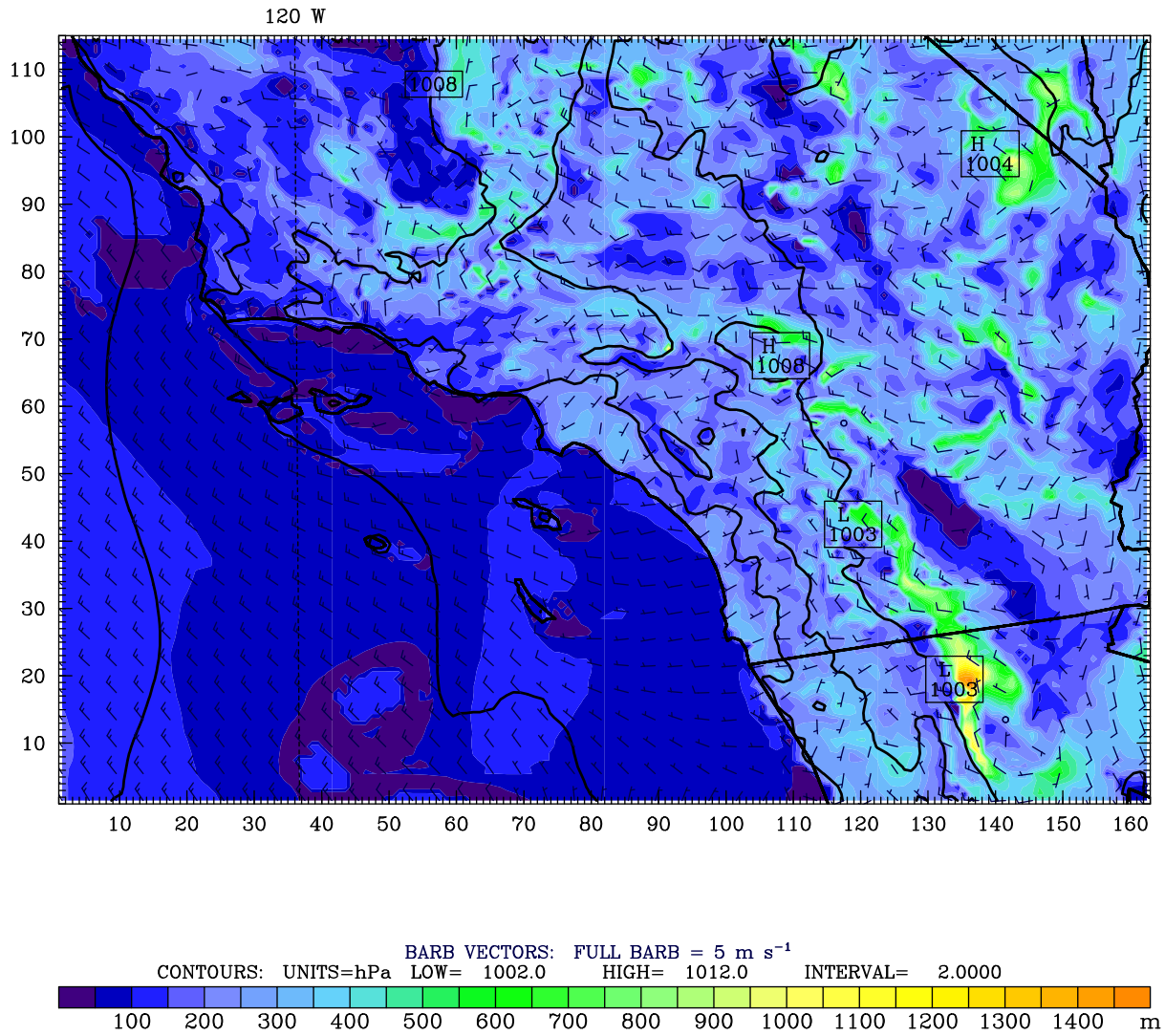
PBL predicted by MM5

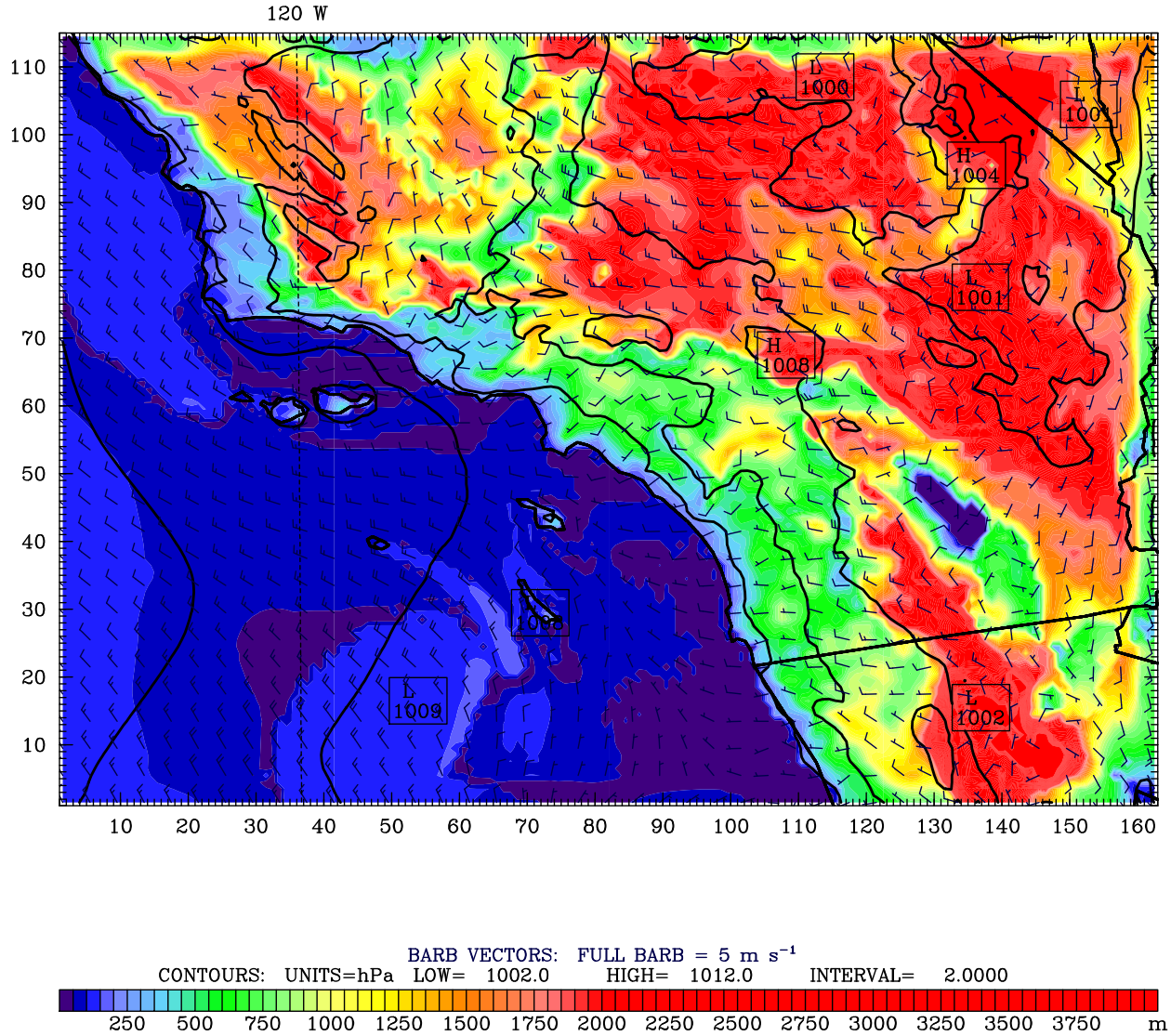
Dataset: wrf02 RIP: rip wrf02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 48.00 h Valid: 1200 UTC Fri 15 Jul 05 (0400 PST Fri 15 Jul 05)
PBL HEIGHT
Sea-level pressure
<U10,V10> Vectors



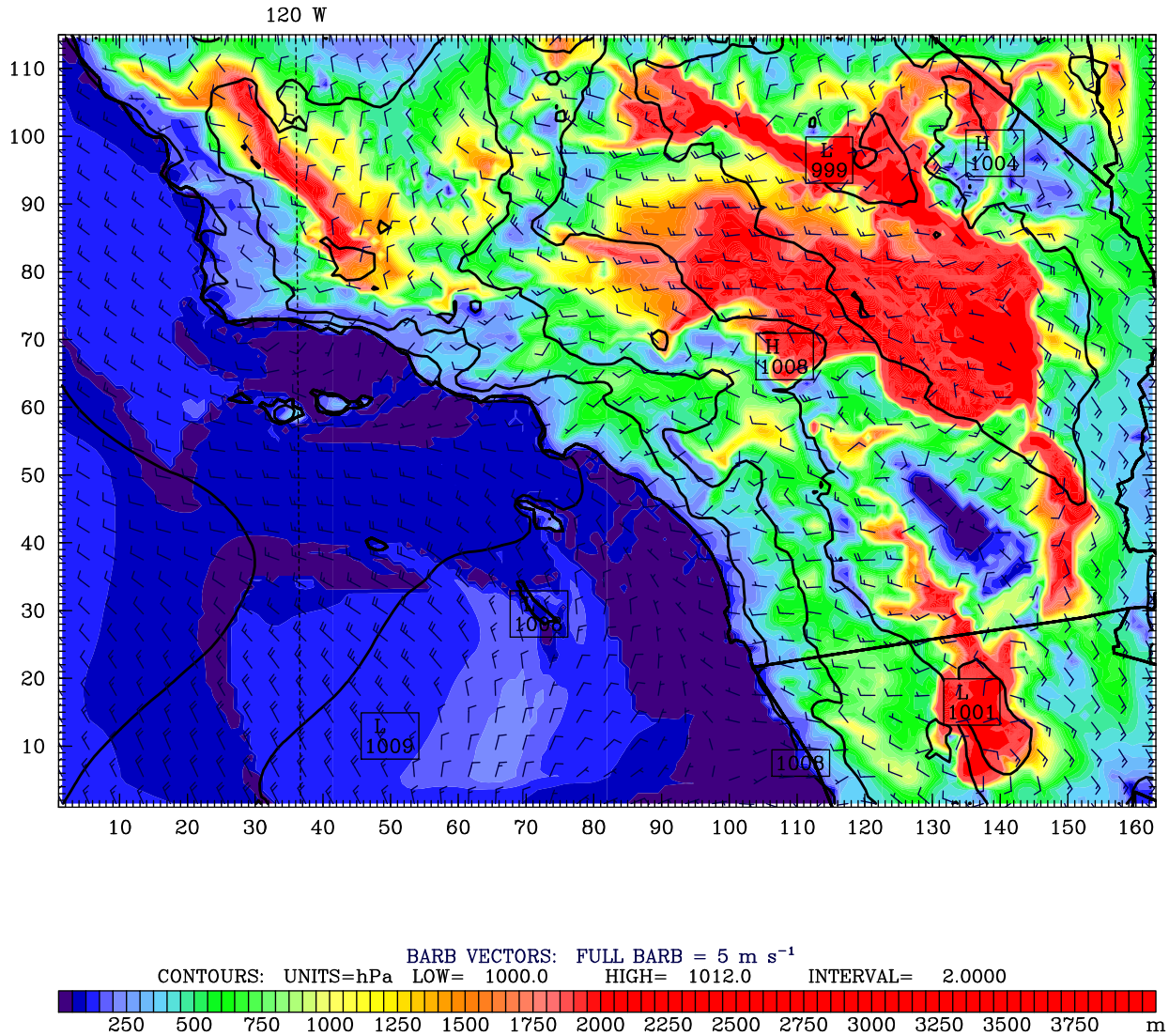
Dataset: wrf02 RIP: rip wrf02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 52.00 h Valid: 1600 UTC Fri 15 Jul 05 (0800 PST Fri 15 Jul 05)
PBL HEIGHT
Sea-level pressure
<U10,V10> Vectors



Dataset: wrf02 RIP: rip wrf02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 56.00 h Valid: 2000 UTC Fri 15 Jul 05 (1200 PST Fri 15 Jul 05)
PBL HEIGHT
Sea-level pressure
<U10,V10> Vectors



Dataset: wrf02 RIP: rip wrf02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 60.00 h Valid: 0000 UTC Sat 16 Jul 05 (1600 PST Fri 15 Jul 05)
PBL HEIGHT
Sea-level pressure
<U10,V10> Vectors



BARB VECTORS: FULL BARB = 5 m s^{-1}
CONTOURS: UNITS=hPa LOW= 1000.0 HIGH= 1012.0 INTERVAL= 2.0000

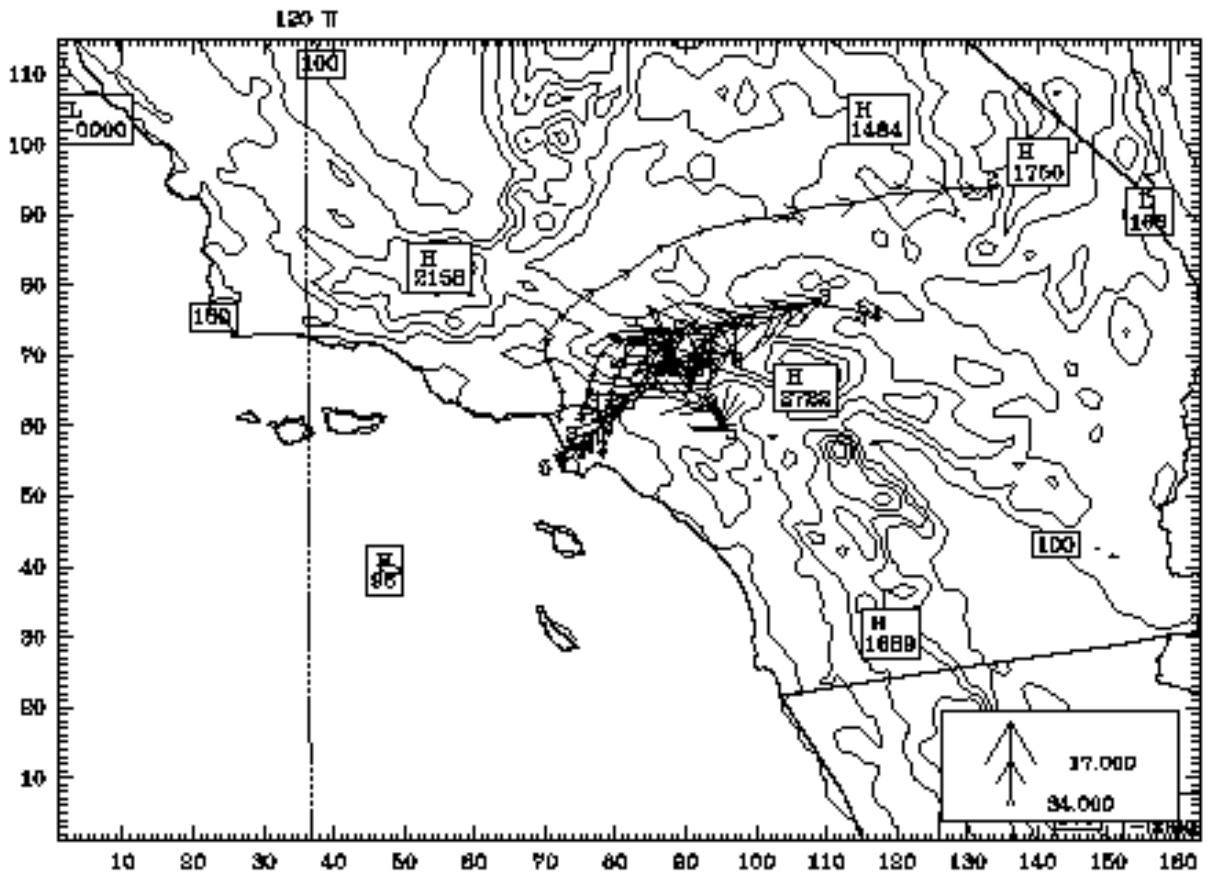
Diagnostic Analysis of Wind Fields

Trajectory Analysis

Forward Trajectory: **July 15 HR 0600 PST-July 16 HR 0000 PST**

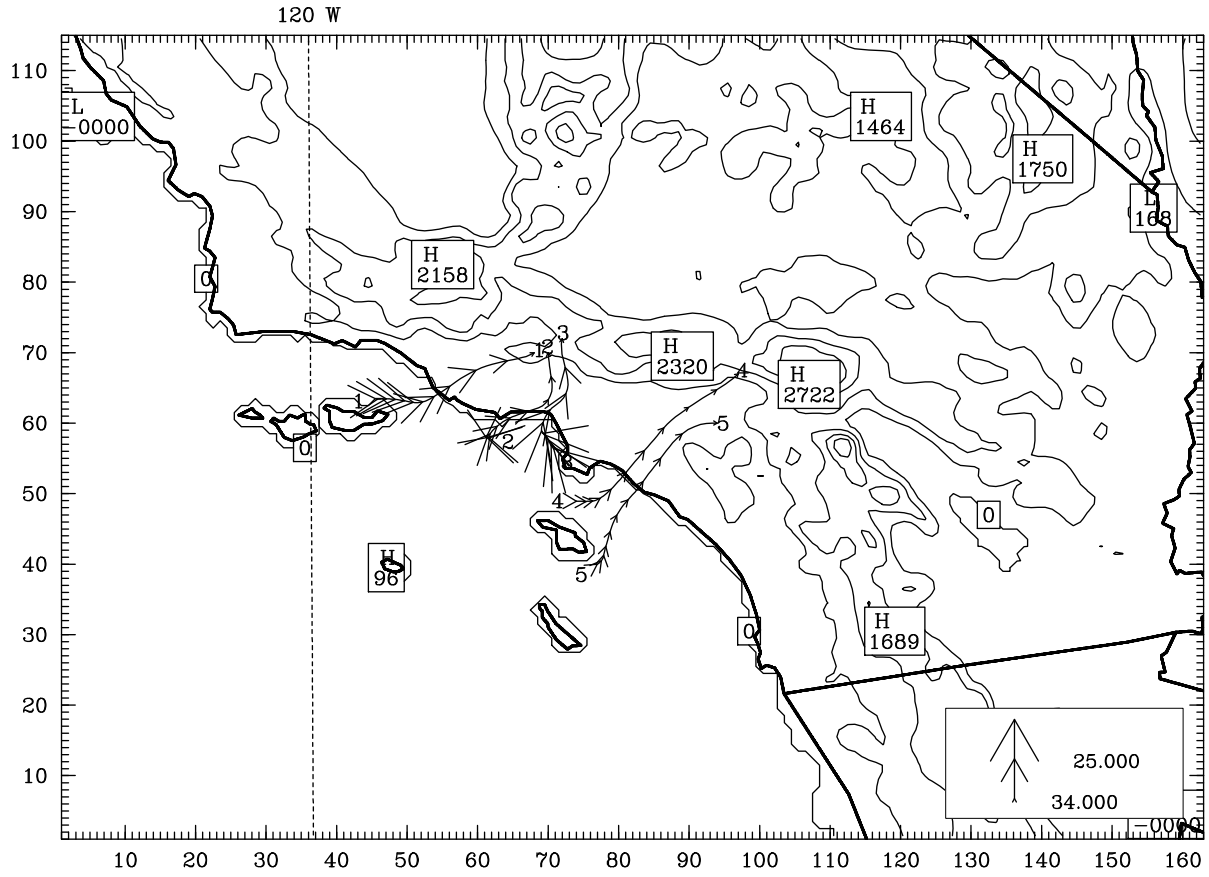
Backward Trajectory : **July 16 HR 1500 PST-July 16 HR 0600 PST**

Dataset: 3ds02 RIP: rip 3ds02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 50.01 h Valid: 1400 UTC Fri 15 Jul 05 (0800 PST Fri 15 Jul 05)
Terrain height AMSL
Trajectories from hour 50.000 to 68.000



CONTOURS: UNITS=m LOW= 100.00 HIGH= 3600.0 INTERVAL= 400.00
Model info: V3.7.0 No Cumulus MRF PBL Simple ice 4 km, 34 levels, 12 sec

Dataset: 3ds02 RIP: rip 3ds02 Init: 1200 UTC Wed 13 Jul 05
Fcst: 83.01 h Valid: 2300 UTC Sat 16 Jul 05 (1500 PST Sat 16 Jul 05)
Terrain height AMSL
Trajectories from hour 50.000 to 60.000

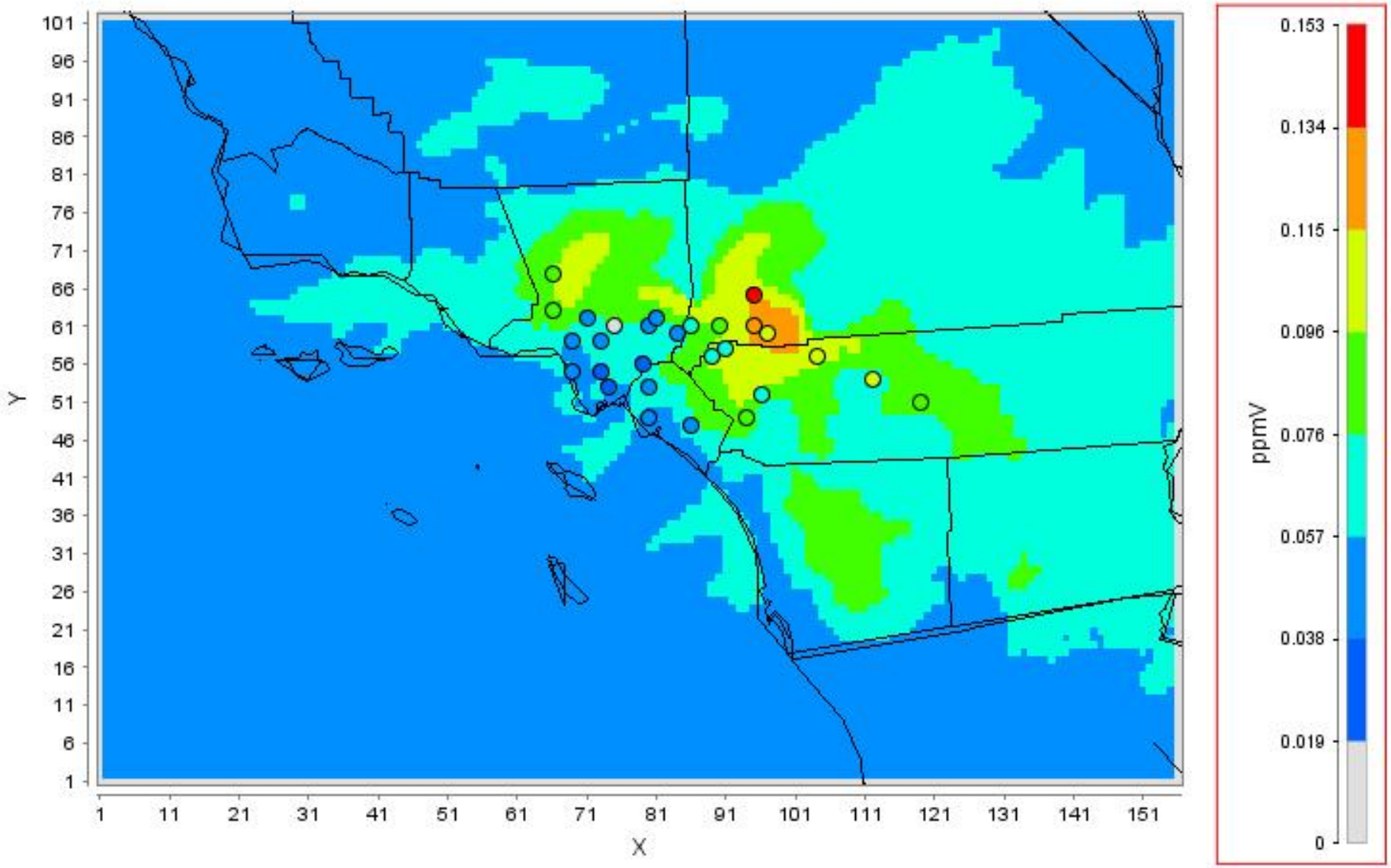


CONTOURS: UNITS=m LOW= 0.0000 HIGH= 2500.0 INTERVAL= 500.00
Model info: V3.7.0 No Cumulus MRF PBL Simple ice 4 km, 34 levels, 12 sec

CAMx simulation

CASE 3ds02
Emissions file: ARB zA04 version

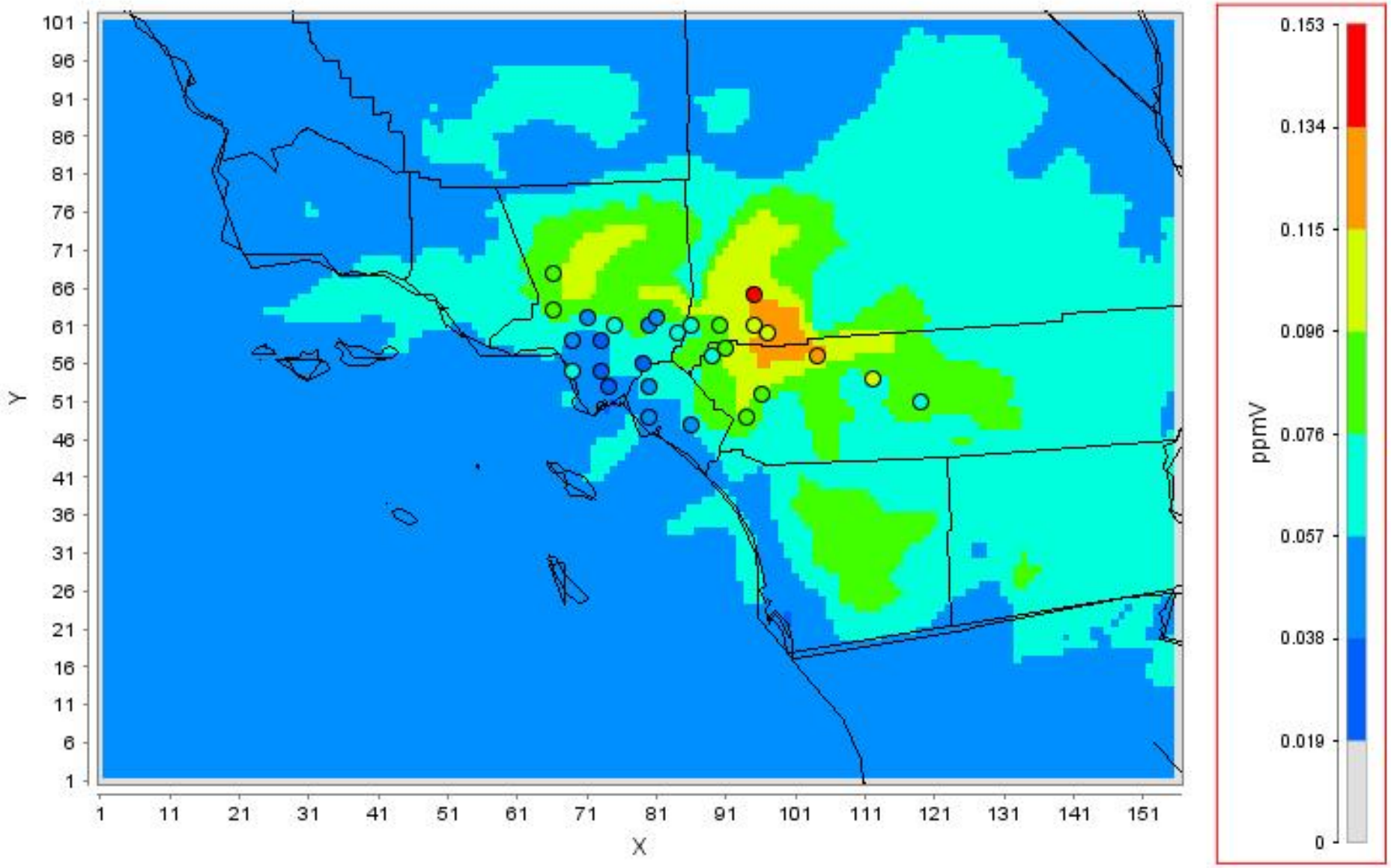
Layer 0 O3[1]



July 15, 2005 22:00:00 UTC

Min (147, 102)... = 0, Max (99, 61) = 0.122

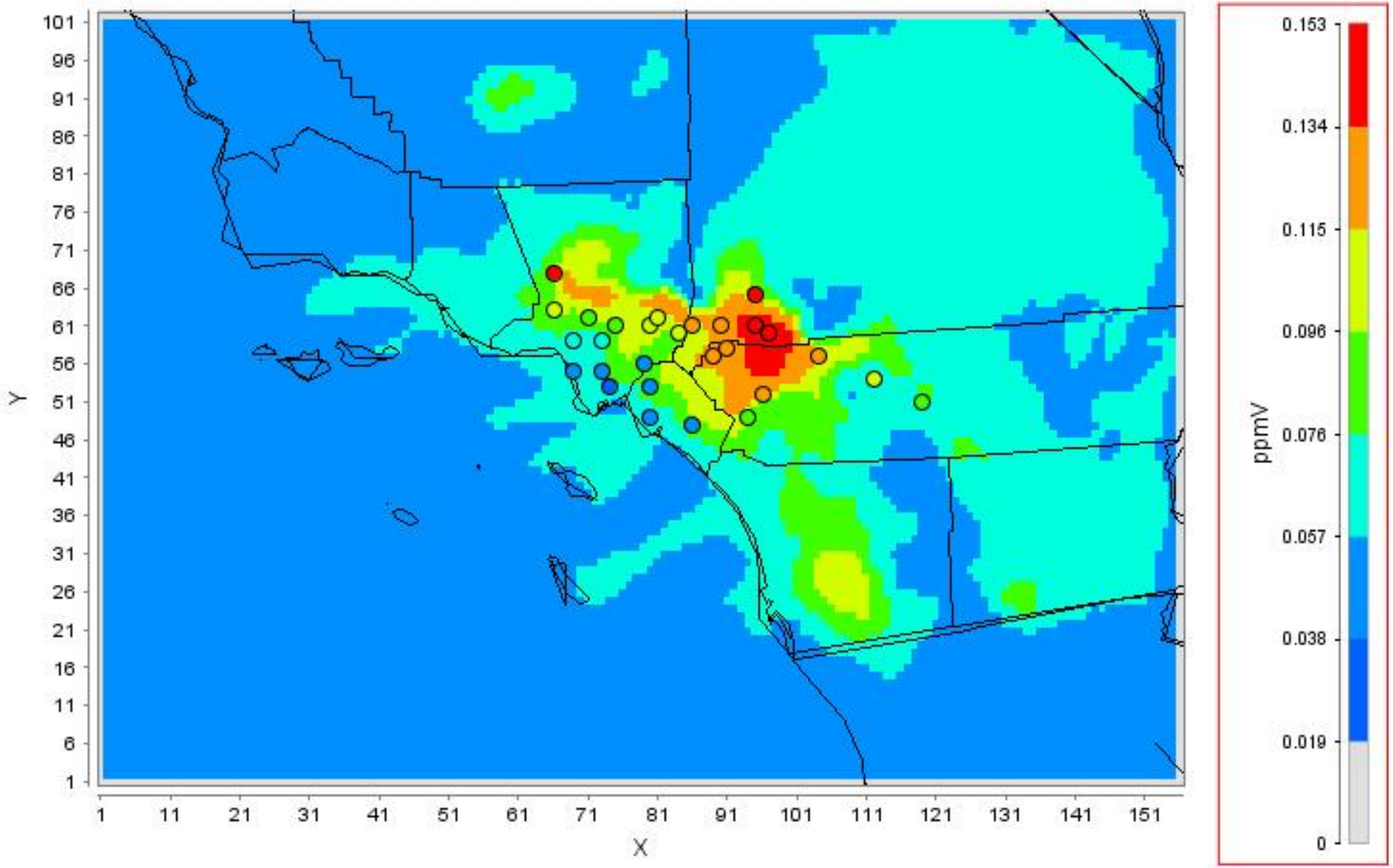
Layer 0 O3[1]



July 15, 2005 23:00:00 UTC

Min (147, 102)... = 0, Max (99, 61) = 0.126

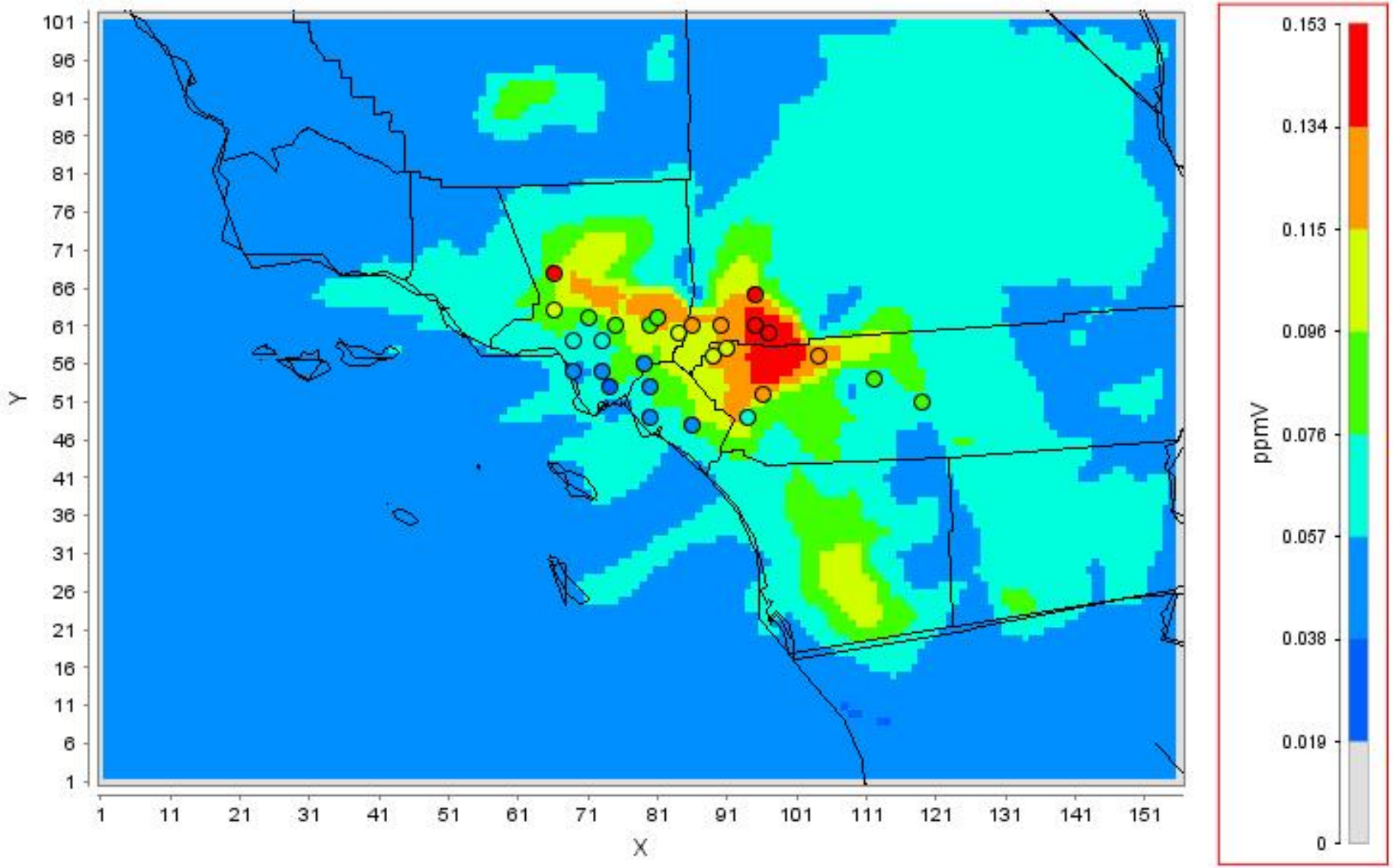
Layer 0 O3[1]



July 16, 2005 22:00:00 UTC

Min (147, 102)... = 0, Max (97, 60) = 0.144

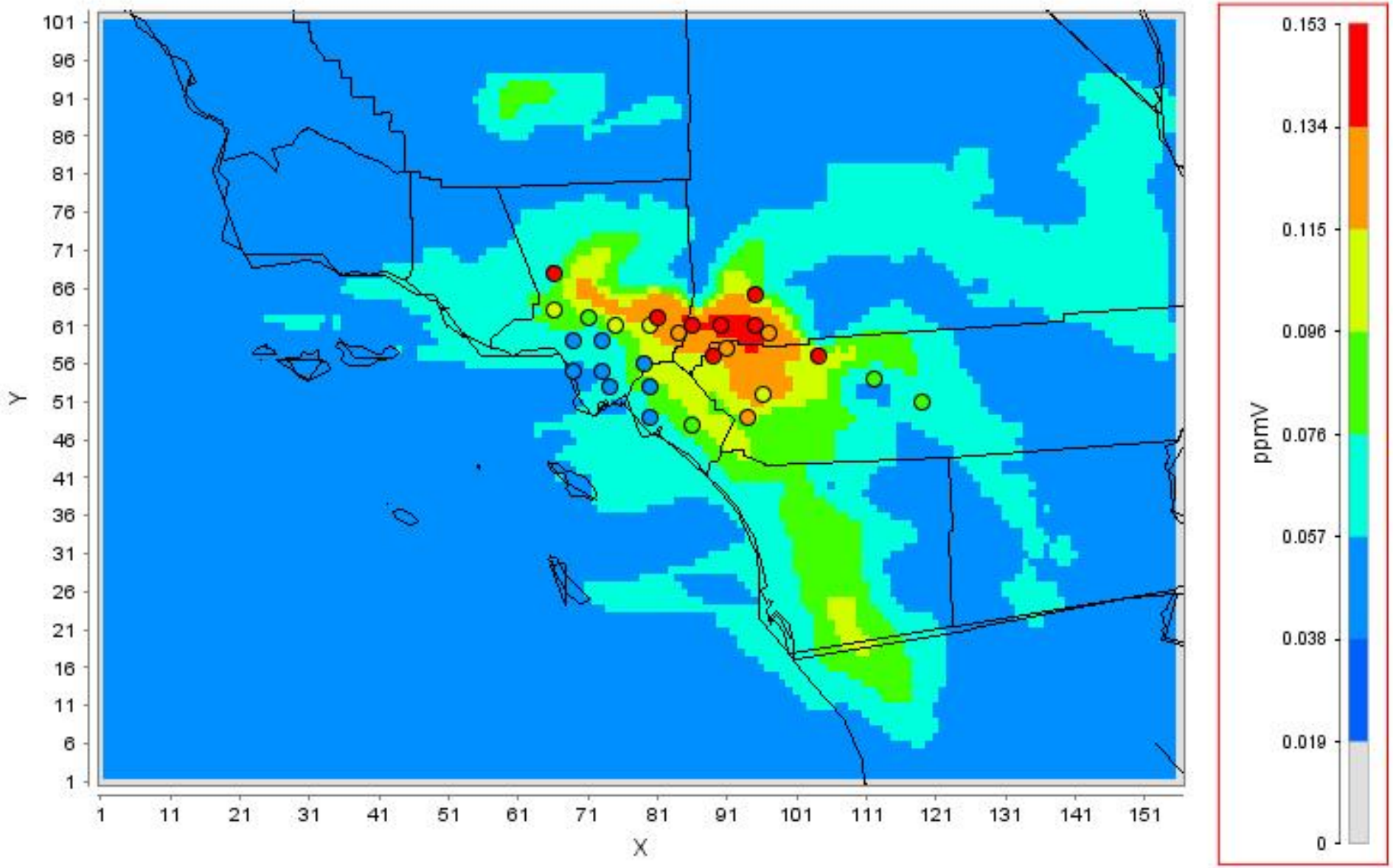
Layer 0 O3[1]



July 16, 2005 23:00:00 UTC

Min (147, 102)... = 0, Max (99, 59) = 0.151

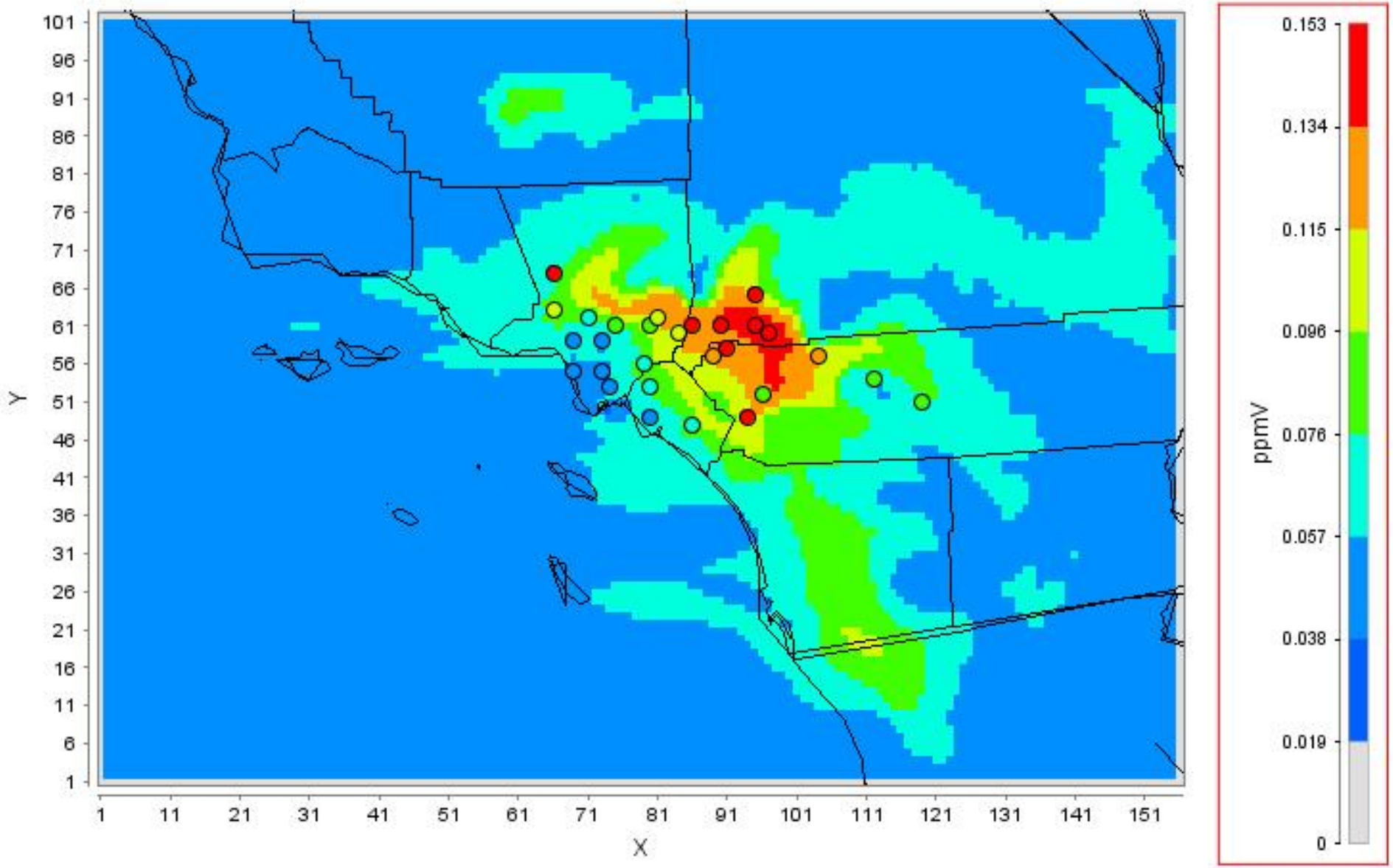
Layer 0 O3[1]



July 17, 2005 22:00:00 UTC

Min (147, 102)... = 0, Max (93, 61) = 0.14

Layer 0 O3[1]

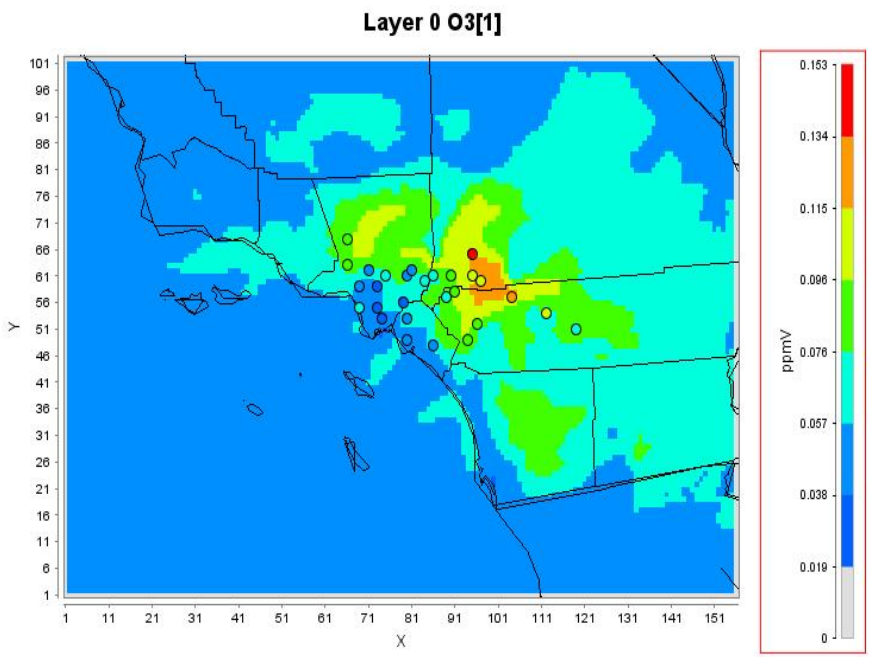


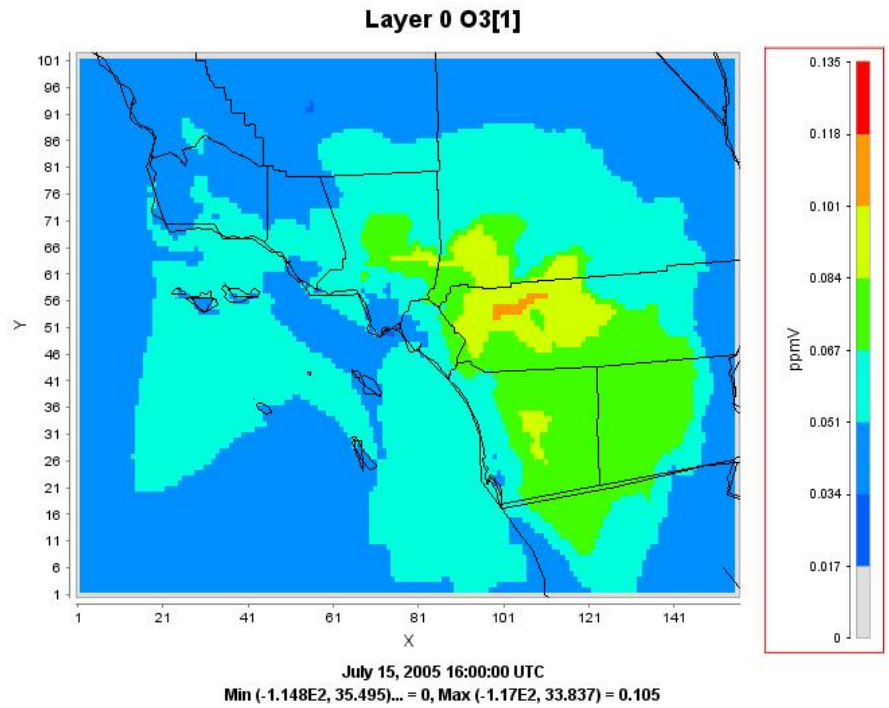
July 17, 2005 23:00:00 UTC

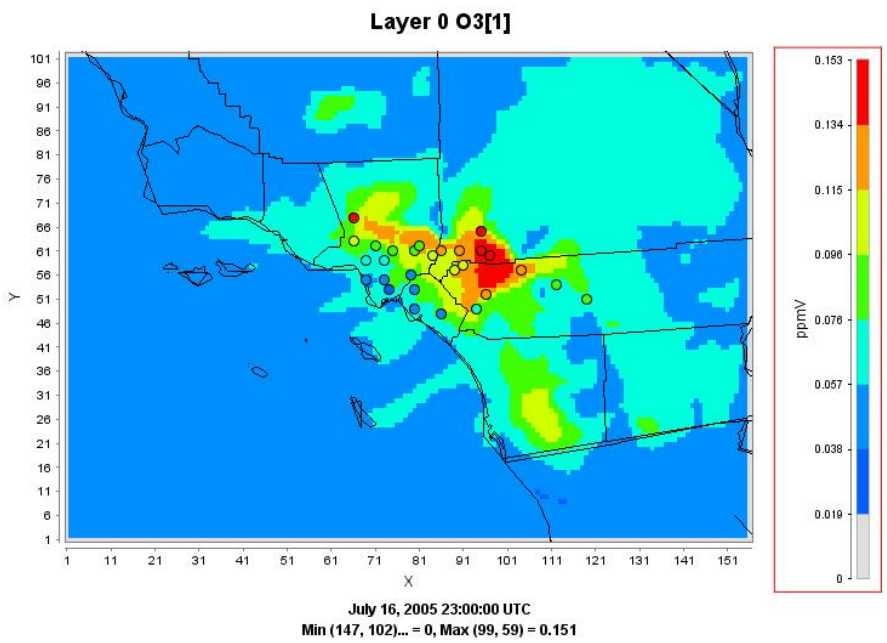
Min (147, 102)... = 0, Max (97, 60) = 0.144

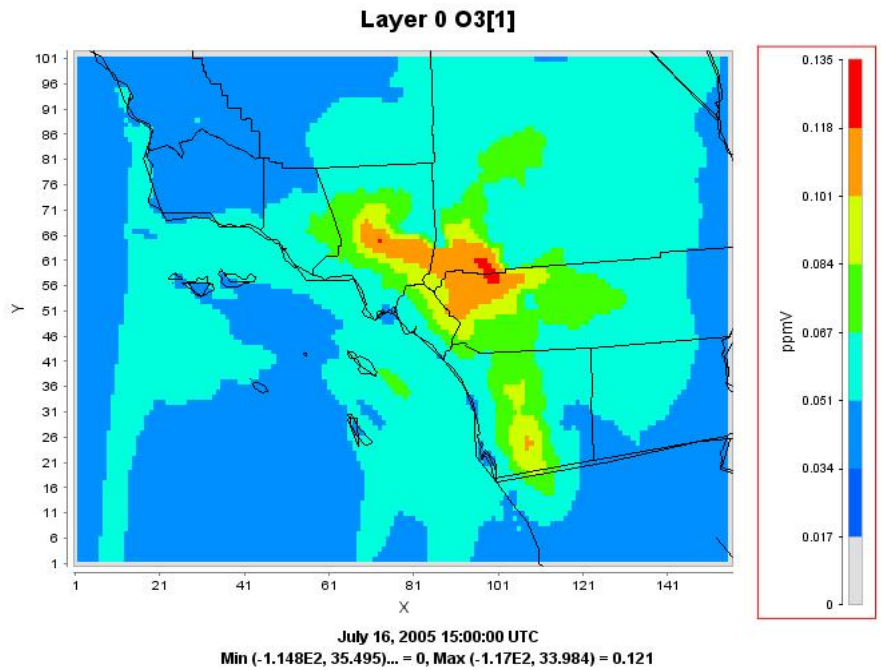
Spatial Distribution of the Predicted Ozone Concentration

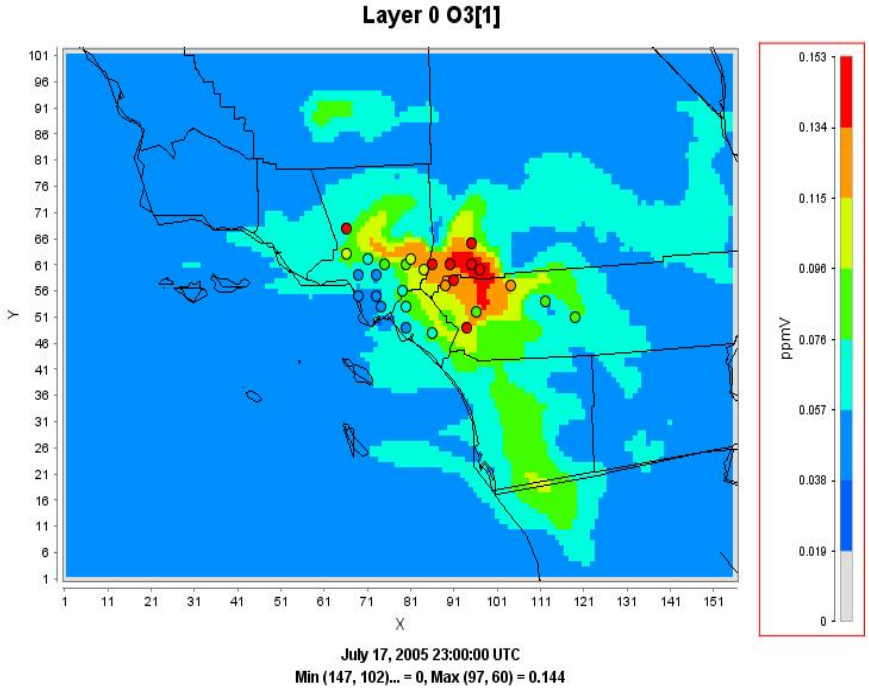
MM5 (3ds02) and WRF (run 02)

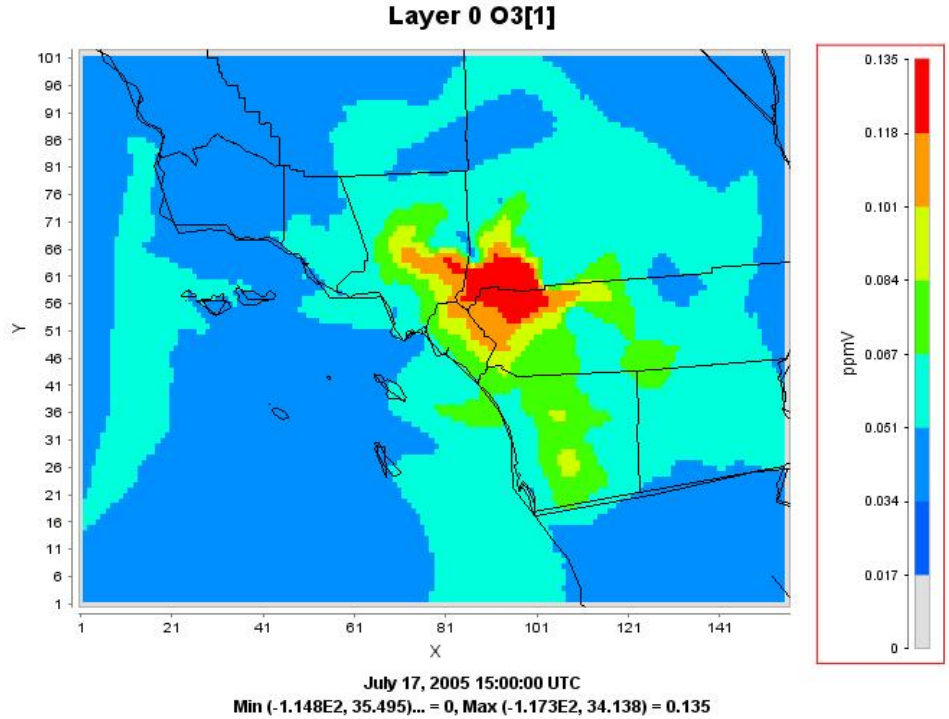

Layer 0 O3[1]
Y
X
ppmV
0.153
0.134
0.115
0.096
0.076
0.057
0.038
0.019
0
July 15, 2005 23:00:00 UTC
Min (147, 102)... = 0, Max (99, 61) = 0.126


Layer 0 O3[1]
Y
X
ppmV
0.135
0.118
0.101
0.084
0.067
0.051
0.034
0.017
0
July 15, 2005 16:00:00 UTC
Min (-1.148E2, 35.495)... = 0, Max (-1.17E2, 33.837) = 0.105


Layer 0 O3[1]
Y
X
ppmV
0.153
0.134
0.115
0.096
0.076
0.057
0.038
0.019
0
July 16, 2005 23:00:00 UTC
Min (147, 102)... = 0, Max (99, 59) = 0.151

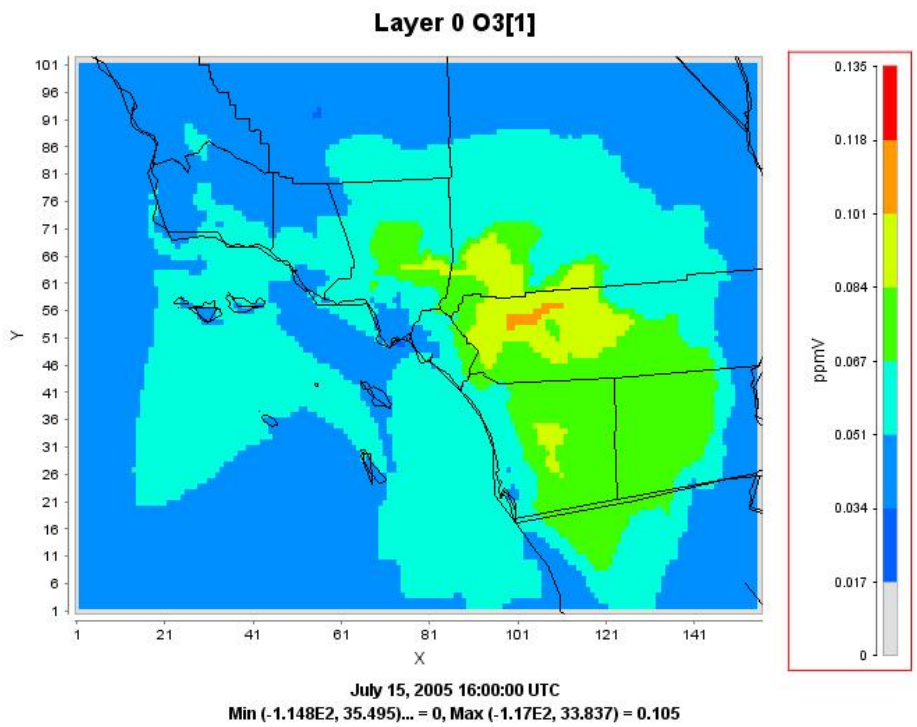

Layer 0 O3[1]
Y
X
ppmV
0.135
0.118
0.101
0.084
0.067
0.051
0.034
0.017
0
July 16, 2005 15:00:00 UTC
Min (-1.148E2, 35.495)... = 0, Max (-1.17E2, 33.984) = 0.121

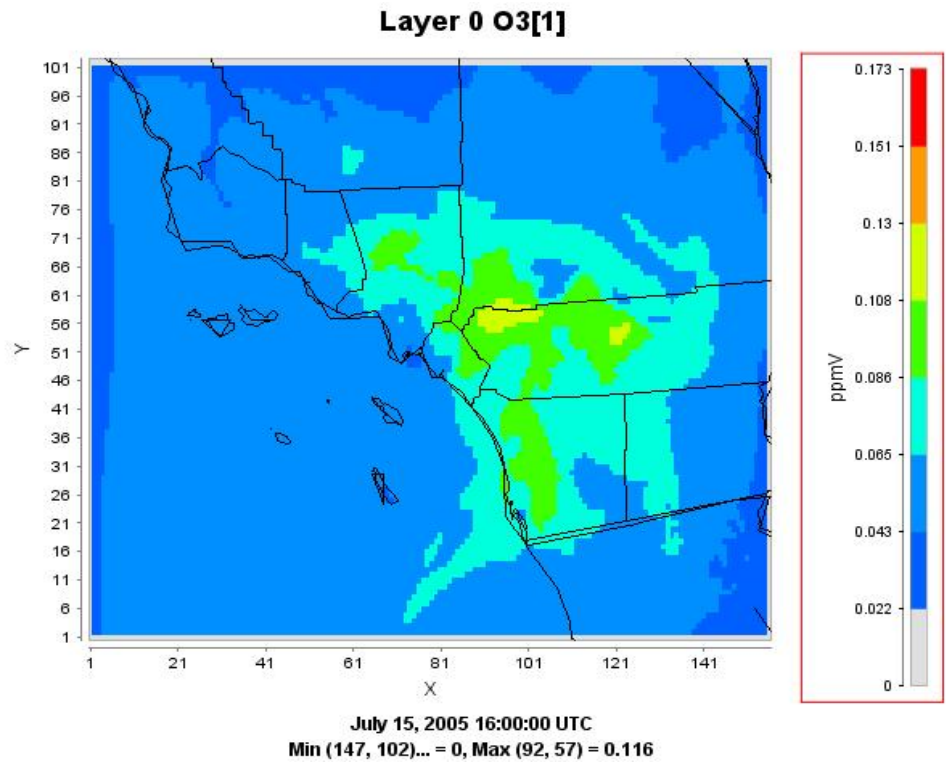

Layer 0 O3[1]
Y
X
ppmV
0.153
0.134
0.115
0.096
0.076
0.057
0.038
0.019
0
July 17, 2005 23:00:00 UTC
Min (147, 102)... = 0, Max (97, 60) = 0.144

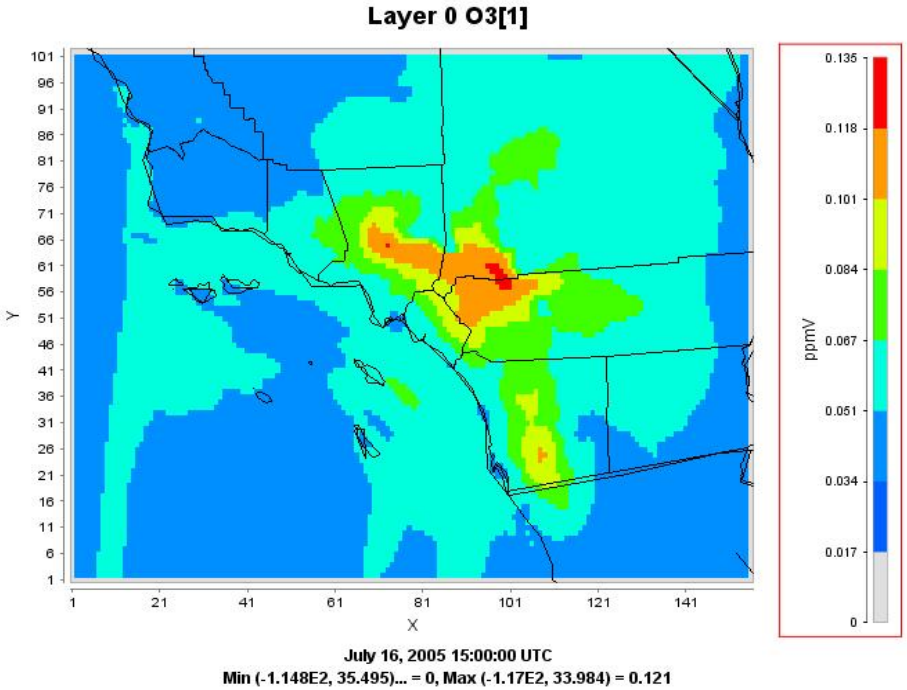

Layer 0 O3[1]
Y
X
ppmV
0.135
0.118
0.101
0.084
0.067
0.051
0.034
0.017
0
July 17, 2005 15:00:00 UTC
Min (-1.148E2, 35.495)... = 0, Max (-1.173E2, 34.138) = 0.135

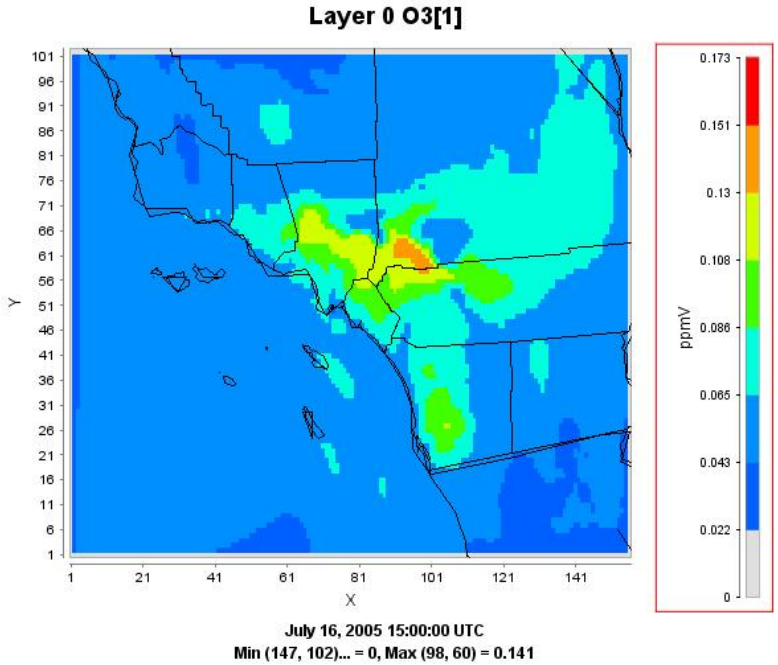
Spatial Distribution of the Predicted Ozone Concentration

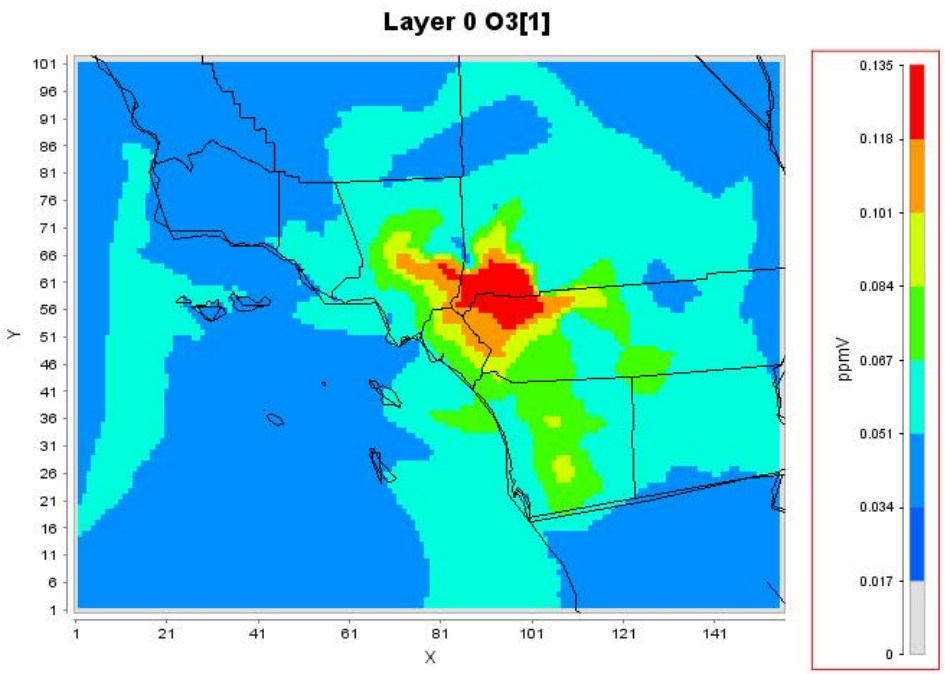
WRF (run 02) and WRF with pseudo Observation Nudging (run 04)

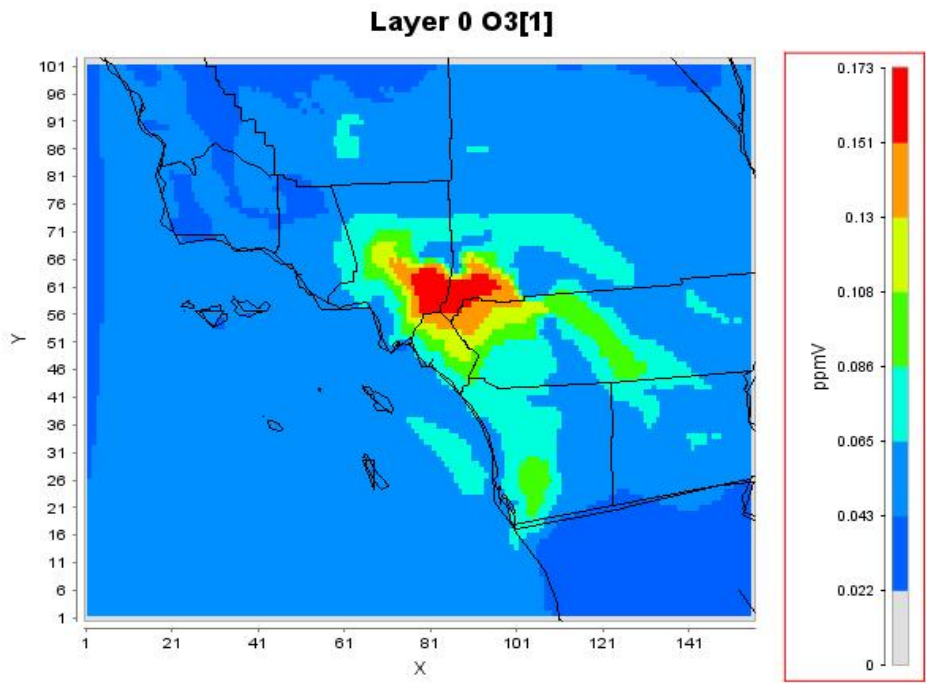

Layer 0 O3[1]
Y
X
ppmV
0.135
0.118
0.101
0.084
0.067
0.051
0.034
0.017
0
July 15, 2005 16:00:00 UTC
Min (-1.148E2, 35.495)... = 0, Max (-1.17E2, 33.837) = 0.105


Layer 0 O3[1]
Y
X
ppmV
0.173
0.151
0.13
0.108
0.086
0.065
0.043
0.022
0
July 15, 2005 16:00:00 UTC
Min (147, 102)... = 0, Max (92, 57) = 0.116


Layer 0 O3[1]
Y
X
ppmV
0.135
0.118
0.101
0.084
0.067
0.051
0.034
0.017
0
July 16, 2005 15:00:00 UTC
Min (-1.148E2, 35.495)... = 0, Max (-1.17E2, 33.984) = 0.121


Layer 0 O3[1]
Y
X
ppmV
0.173
0.151
0.13
0.108
0.086
0.065
0.043
0.022
0
July 16, 2005 15:00:00 UTC
Min (147, 102)... = 0, Max (98, 60) = 0.141


Layer 0 O3[1]
Y
X
ppmV
0.135
0.118
0.101
0.084
0.067
0.051
0.034
0.017
0
July 17, 2005 15:00:00 UTC
Min (-1.148E2, 35.495)... = 0, Max (-1.173E2, 34.138) = 0.135


Layer 0 O3[1]
Y
X
ppmV
0.173
0.151
0.13
0.108
0.086
0.065
0.043
0.022
0
July 17, 2005 16:00:00 UTC
Min (147, 102)... = 0, Max (81, 62) = 0.173

Platform:

HP Proliant DL380 G5 3.00 GHz 2x Quad Core Intel Xeon E5450 ,8x2 GB DIMM RAM
8x HP 146GB Hot Plug 2.5 SAS Dual Port 10krpm Hard Drive
Linux ES 5.0 : PGI CDK 7.2 Fortran

Benchmark Runs:

Statewide 3domain, 34 layers configuration
Single memory option: 15.6 hour user time for 1 day WRF simulation
NCPUS=8 shared memory option: 4.0 hour user time for 1 day WRF simulation