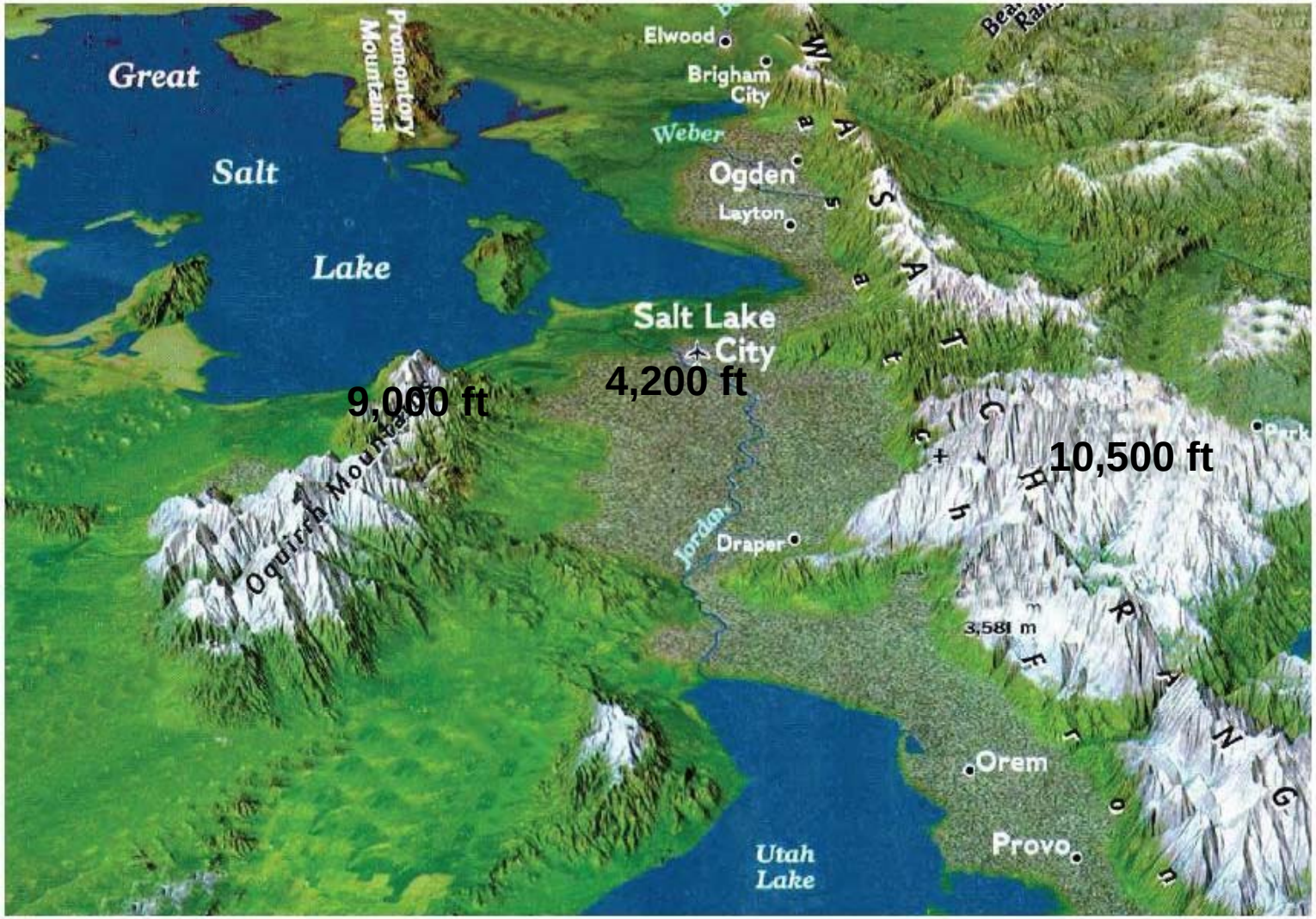
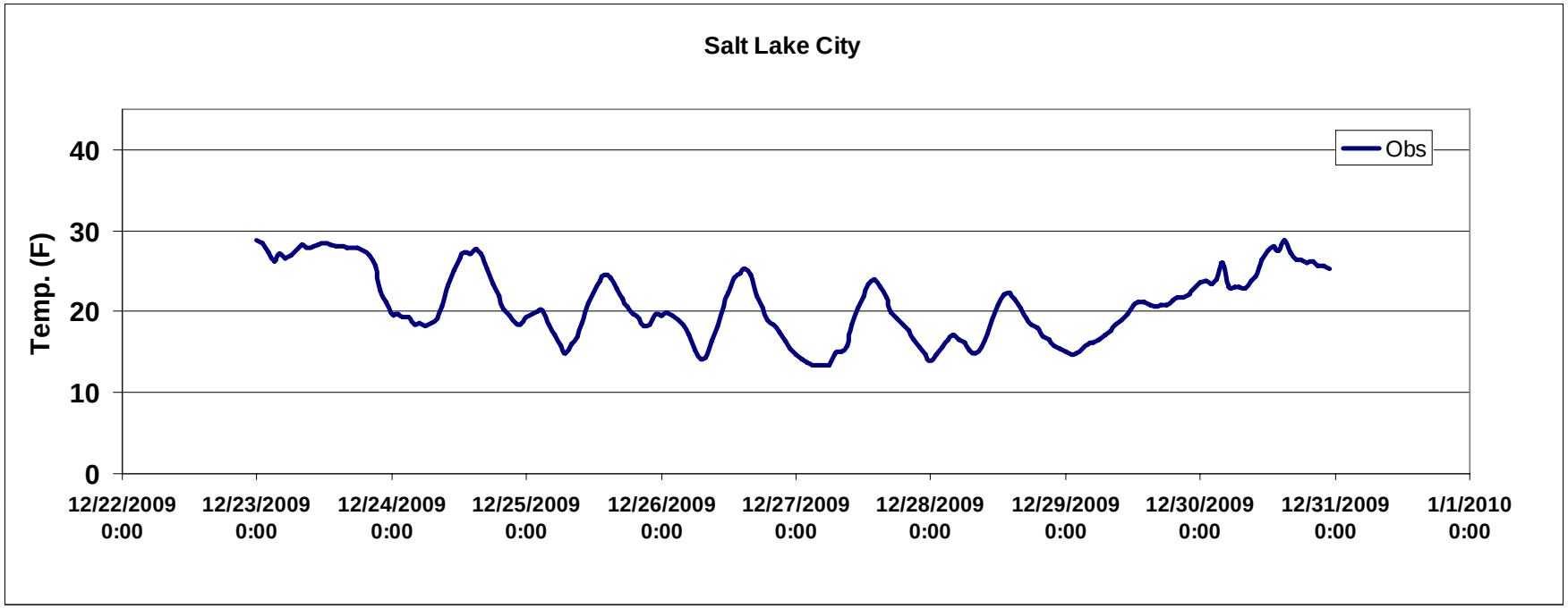
Utah Wintertime Cold Pool Modeling

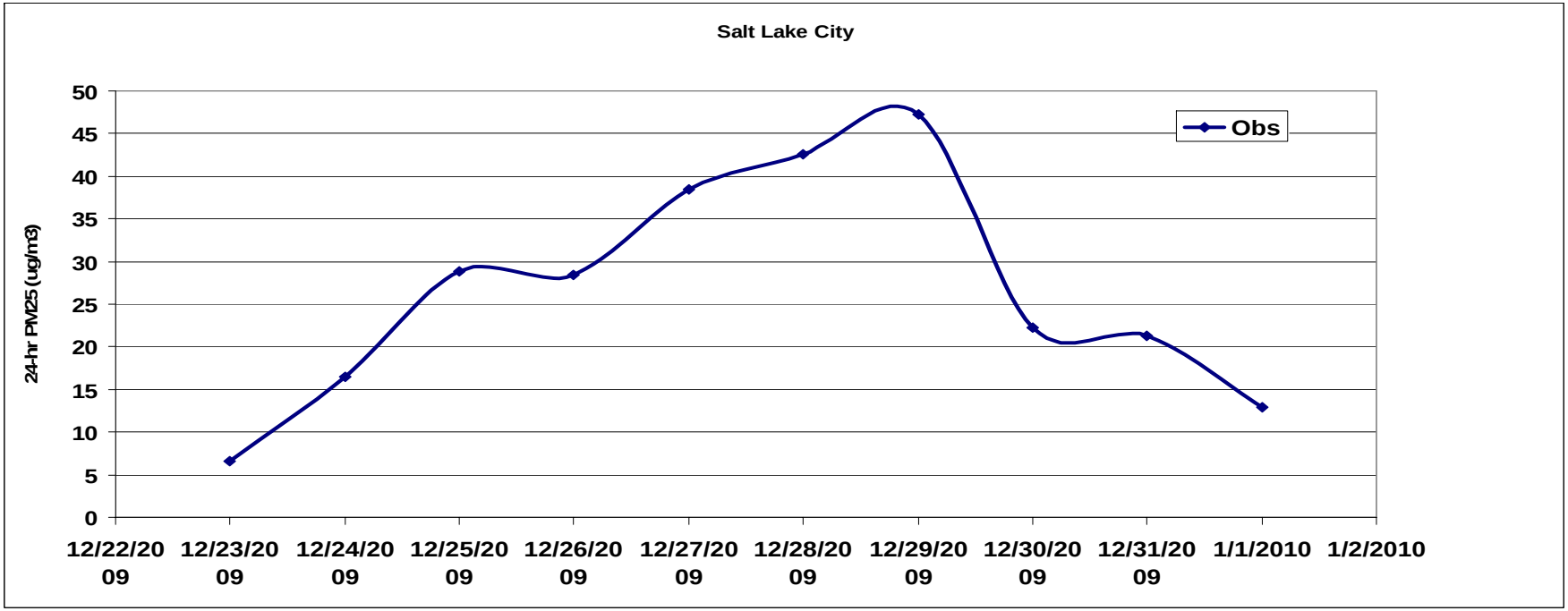
Lance Avey
Utah Division of Air Quality

Salt Lake Basin



Cold Air Pools


Salt Lake City
Temp. (F)
40
30
20
10
0
Obs
12/22/2009 0:00
12/23/2009 0:00
12/24/2009 0:00
12/25/2009 0:00
12/26/2009 0:00
12/27/2009 0:00
12/28/2009 0:00
12/29/2009 0:00
12/30/2009 0:00
12/31/2009 0:00
1/1/2010 0:00


Salt Lake City
24-hr PM25 (ug/m3)
50
45
40
35
30
25
20
15
10
5
0
Obs
12/22/2009
12/23/2009
12/24/2009
12/25/2009
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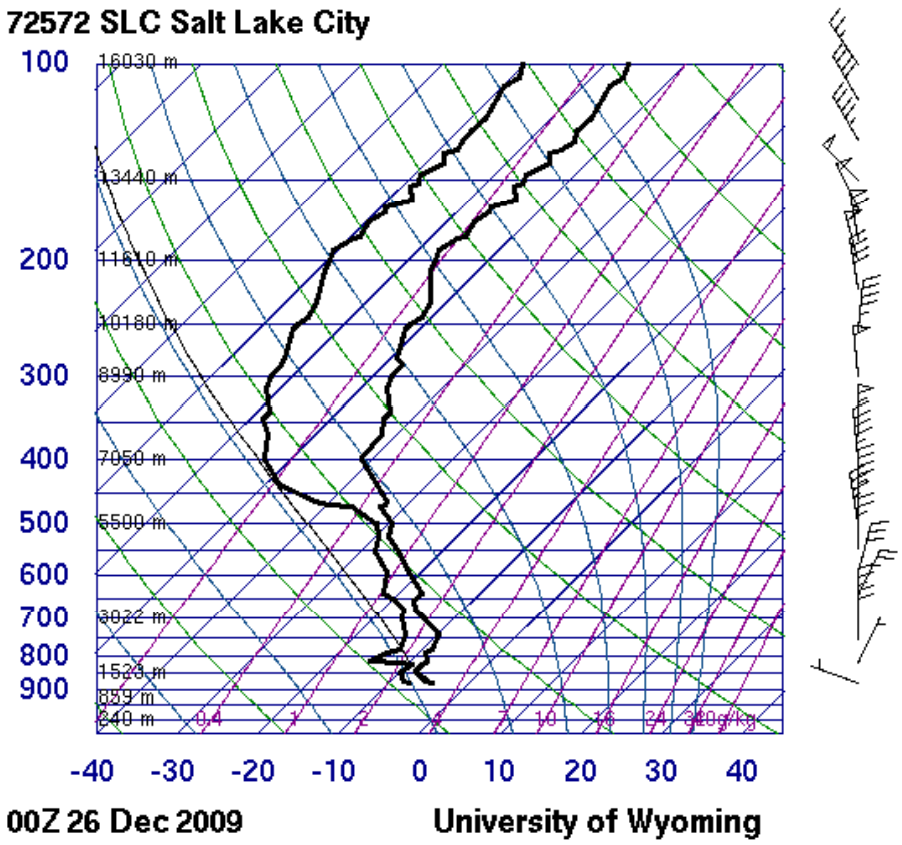
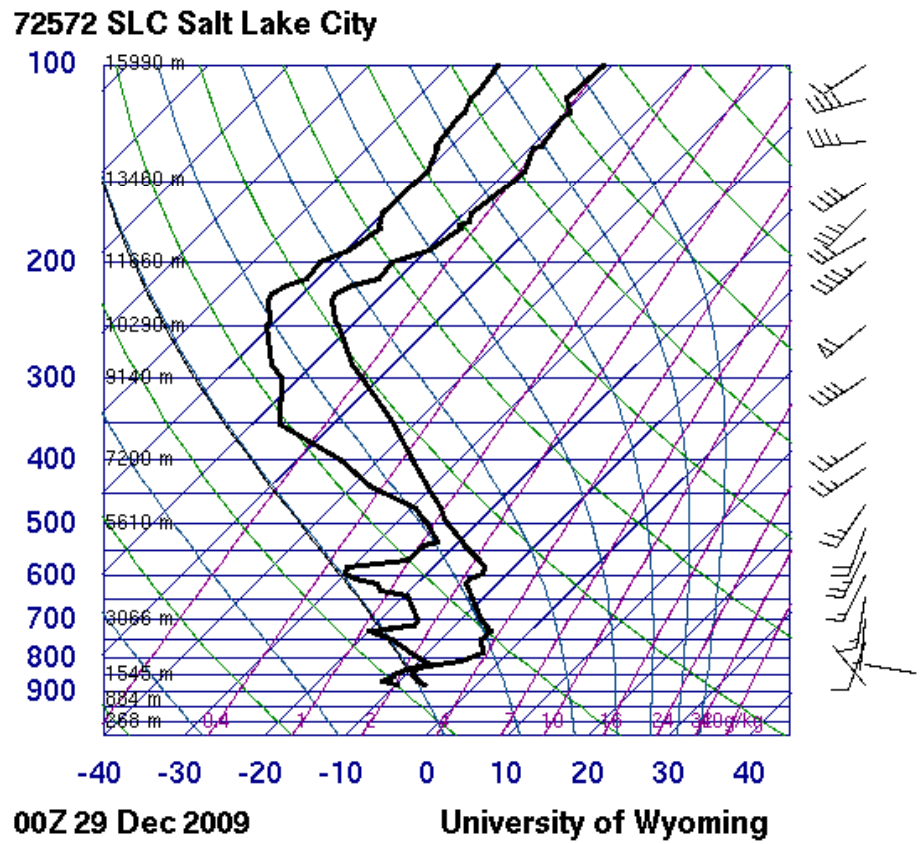
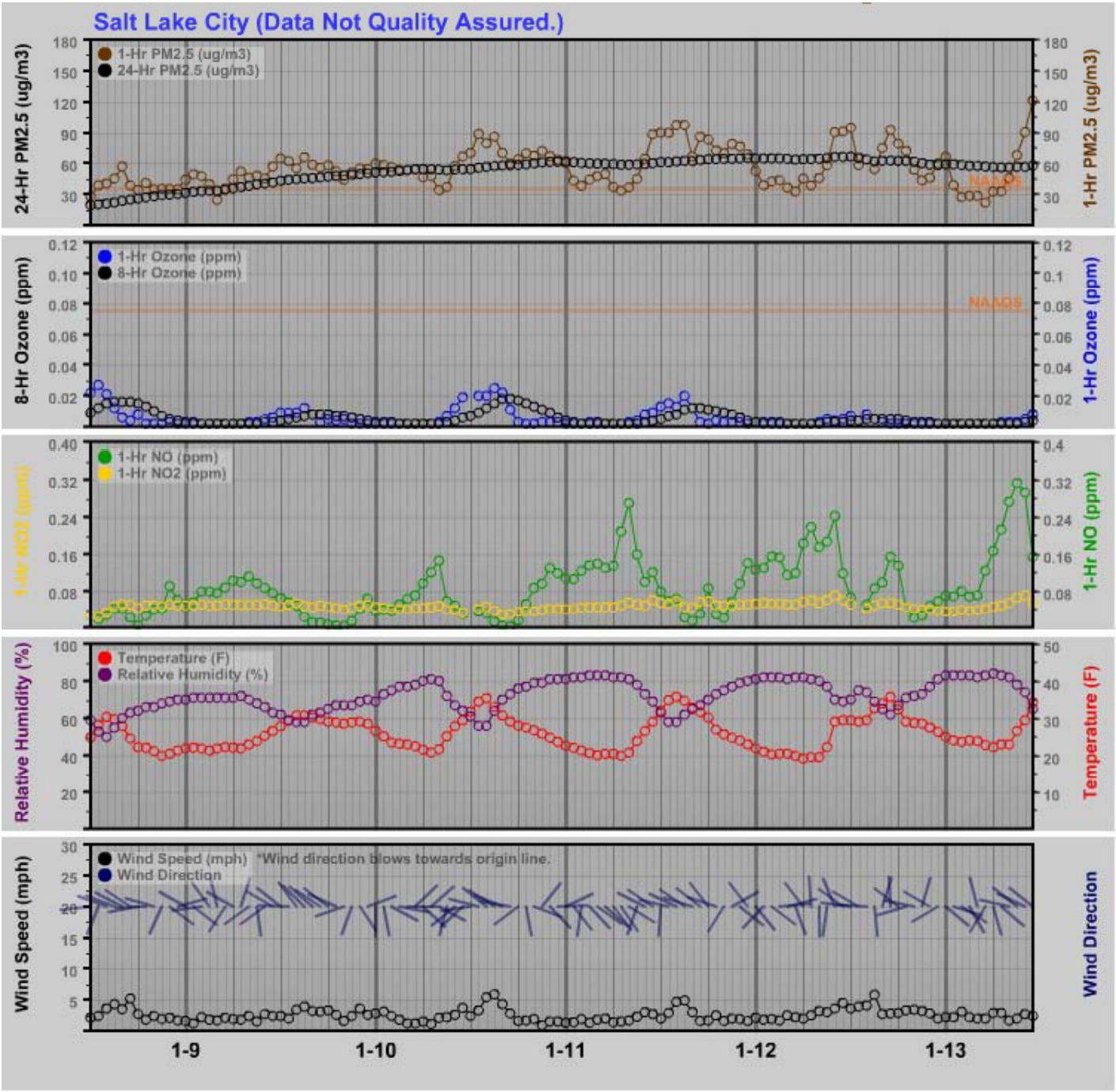
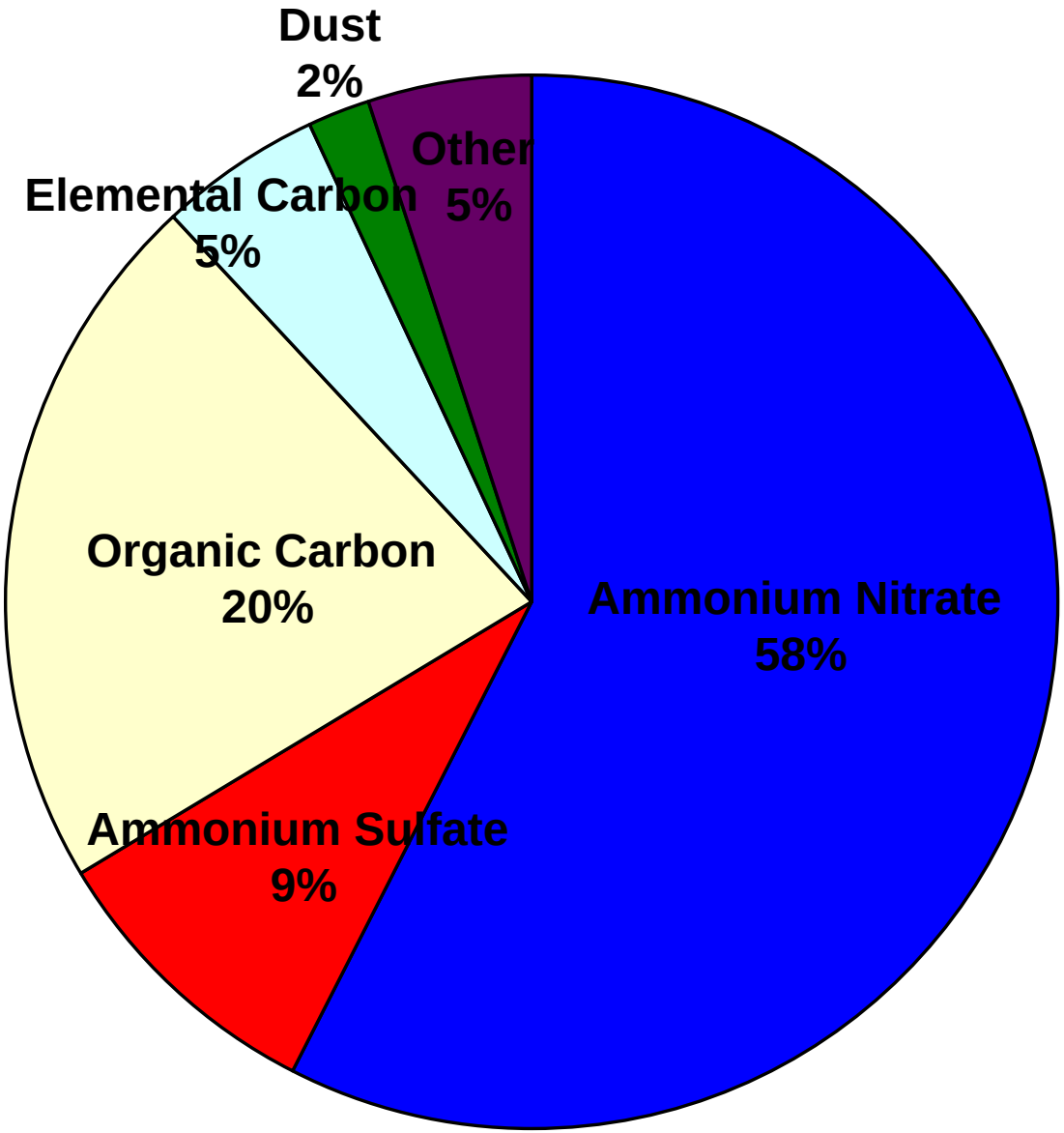
12/31/2009
1/1/2010
1/2/2010

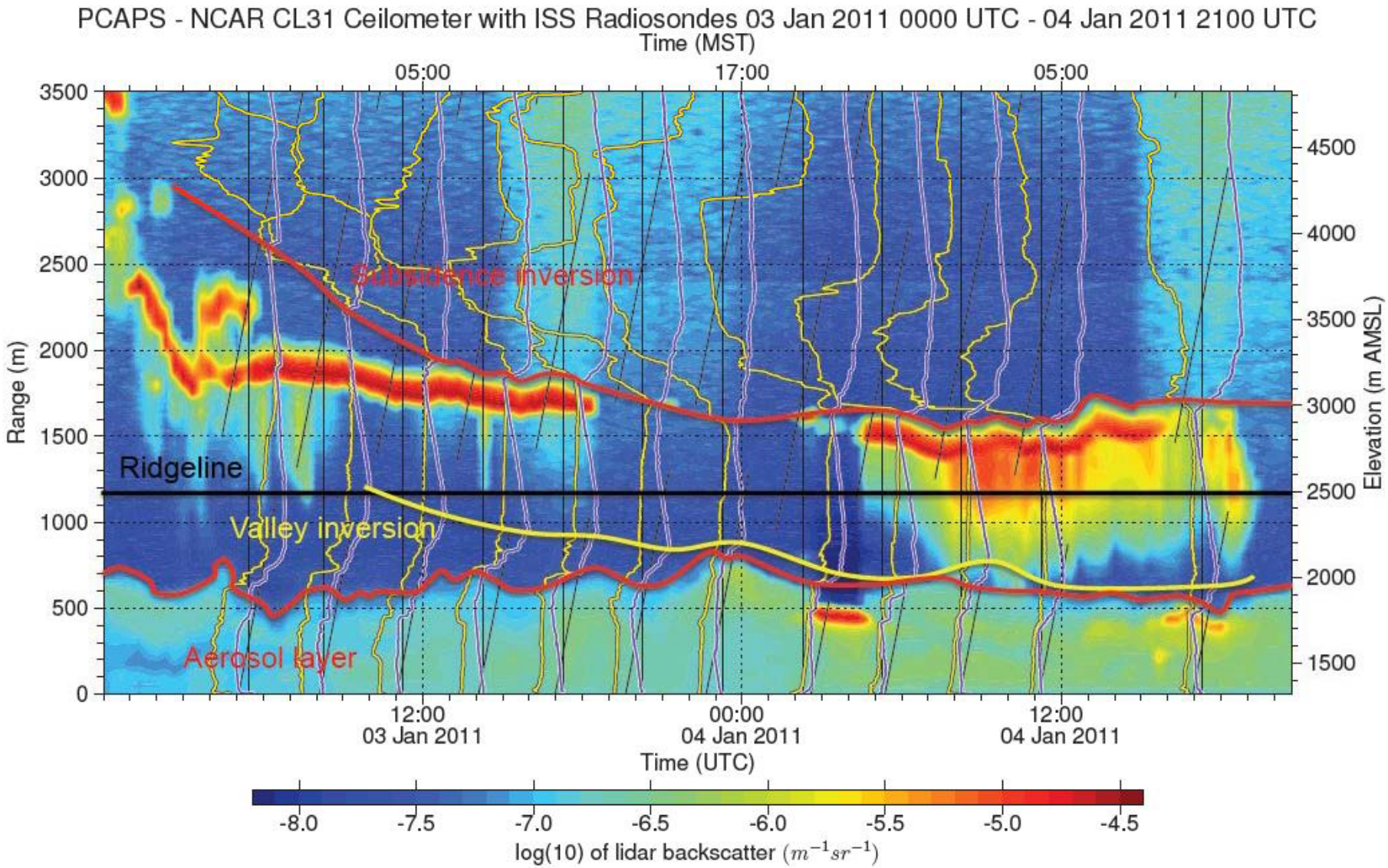

72572 SLC Salt Lake City
100
200
300
400
500
600
700
800
900
16030 m
13440 m
11610 m
10180 m
8990 m
7050 m
5500 m
3022 m
1523 m
829 m
240 m
-40 -30 -20 -10 0 10 20 30 40
00Z 26 Dec 2009
University of Wyoming


72572 SLC Salt Lake City
100
200
300
400
500
600
700
800
900
15990 m
13480 m
11660 m
10290 m
9140 m
7200 m
5610 m
3066 m
1545 m
884 m
268 m
-40 -30 -20 -10 0 10 20 30 40
00Z 29 Dec 2009
University of Wyoming


Salt Lake City (Data Not Quality Assured.)
24-Hr PM2.5 (ug/m3)
1-Hr PM2.5 (ug/m3)
24-Hr PM2.5 (ug/m3)
NAAQS
8-Hr Ozone (ppm)
1-Hr Ozone (ppm)
8-Hr Ozone (ppm)
NAAQS
1-Hr NO2 (ppm)
1-Hr NO (ppm)
1-Hr NO (ppm)
1-Hr NO2 (ppm)
Relative Humidity (%)
Temperature (F)
Temperature (F)
Relative Humidity (%)
Wind Speed (mph)
Wind Speed (mph)
*Wind direction blows towards origin line.
Wind Direction
Wind Direction
1-9
1-10
1-11
1-12
1-13

PM2.5 Speciation

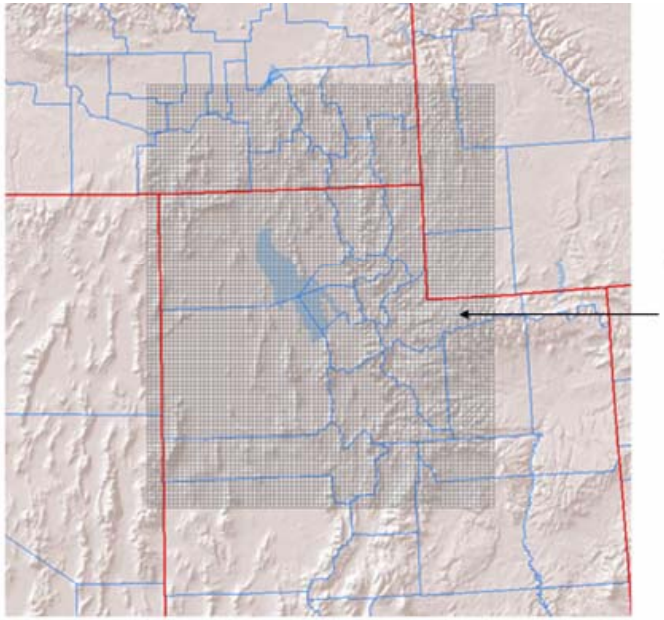




PCAPS
Persistent Cold-Air Pool Study

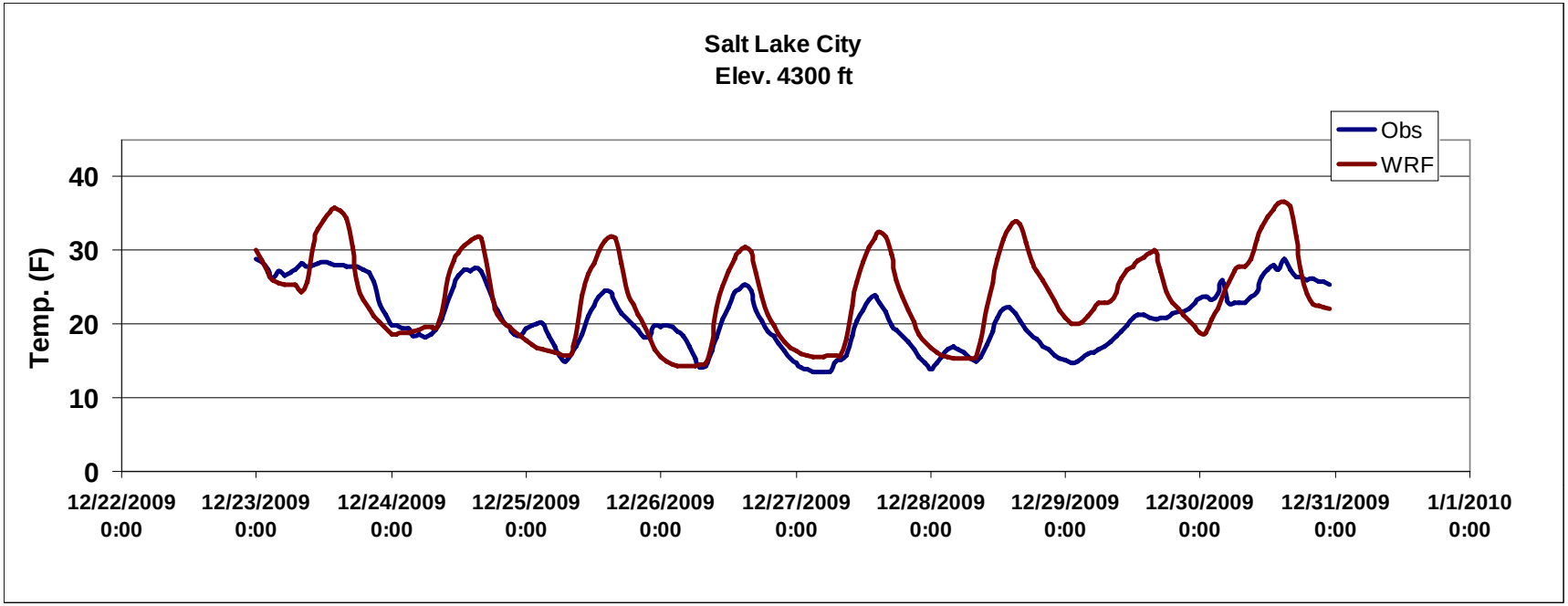
UDAQ WRF

- 36/12/4 km Horizontal Domain
- 37 vertical layers
  - 1st layer at ~ 20 meters
  - 8 layers below 250 meters, 17 below 900 meters
- WPS uses 12km-NAM
- Pleim-Xiu LSM & Surface Layer, ACM2 PBL
- RRTM shortwave/longwave radiation scheme
- Simulations were ran in 5.5 day segments



UDAQ WRF
Nudging Techniques

- Analysis Nudging
  - Applied on all 36 and 12 km domains for temp and winds
- Obs Nudging
  - Applied on 4km Domain in for temp
    - One Sounding from SLC Airport in 4km domain
- Surface Analysis Nudging
  - Applied on all 3 domains for temp and winds
  - 4 km Domain 3 has modified wind speeds in surface analysis grid file (wrfsfdda_d03)
  - wind speeds in wrfsfdda_d03 were modified to 25% of its original value
  - This was done for all grid points where the elevation was less than 1550 m, which takes care of the all the valleys in the domain. For the level from 1550 m to 2500 m, the reduction in wind speed is progressively less so that at 2500 m the original wind is used.


Salt Lake City
Elev. 4300 ft
Obs
WRF
Temp. (F)
40
30
20
10
0
12/22/2009 0:00
12/23/2009 0:00
12/24/2009 0:00
12/25/2009 0:00
12/26/2009 0:00
12/27/2009 0:00
12/28/2009 0:00
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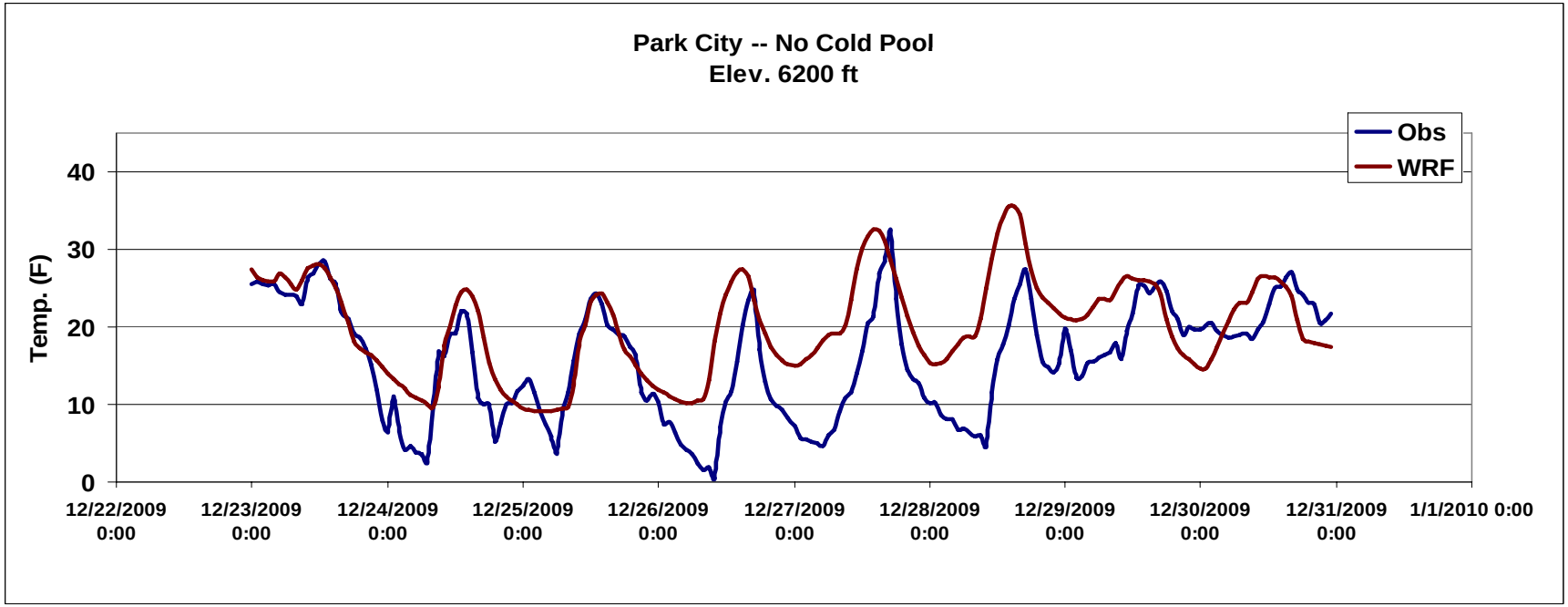
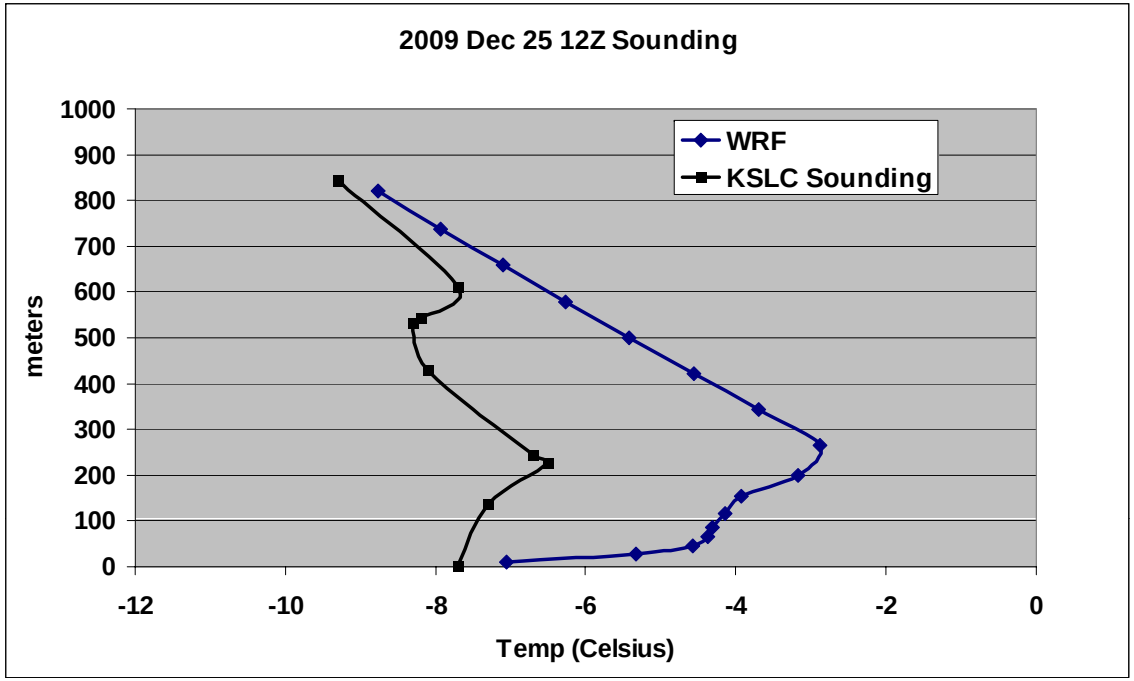
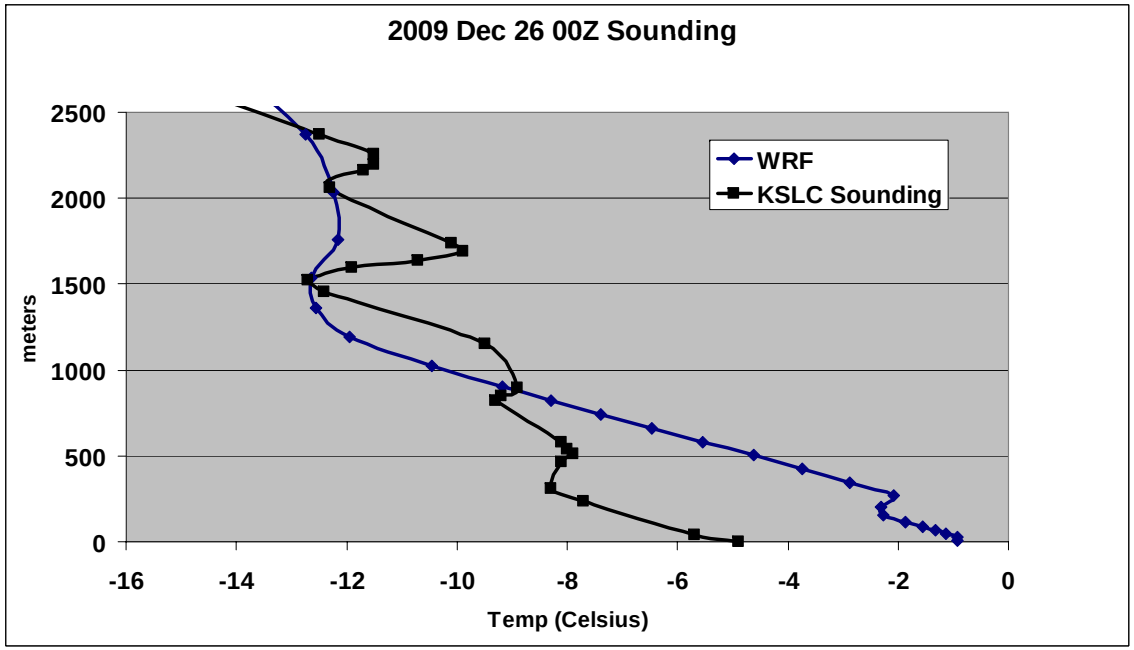
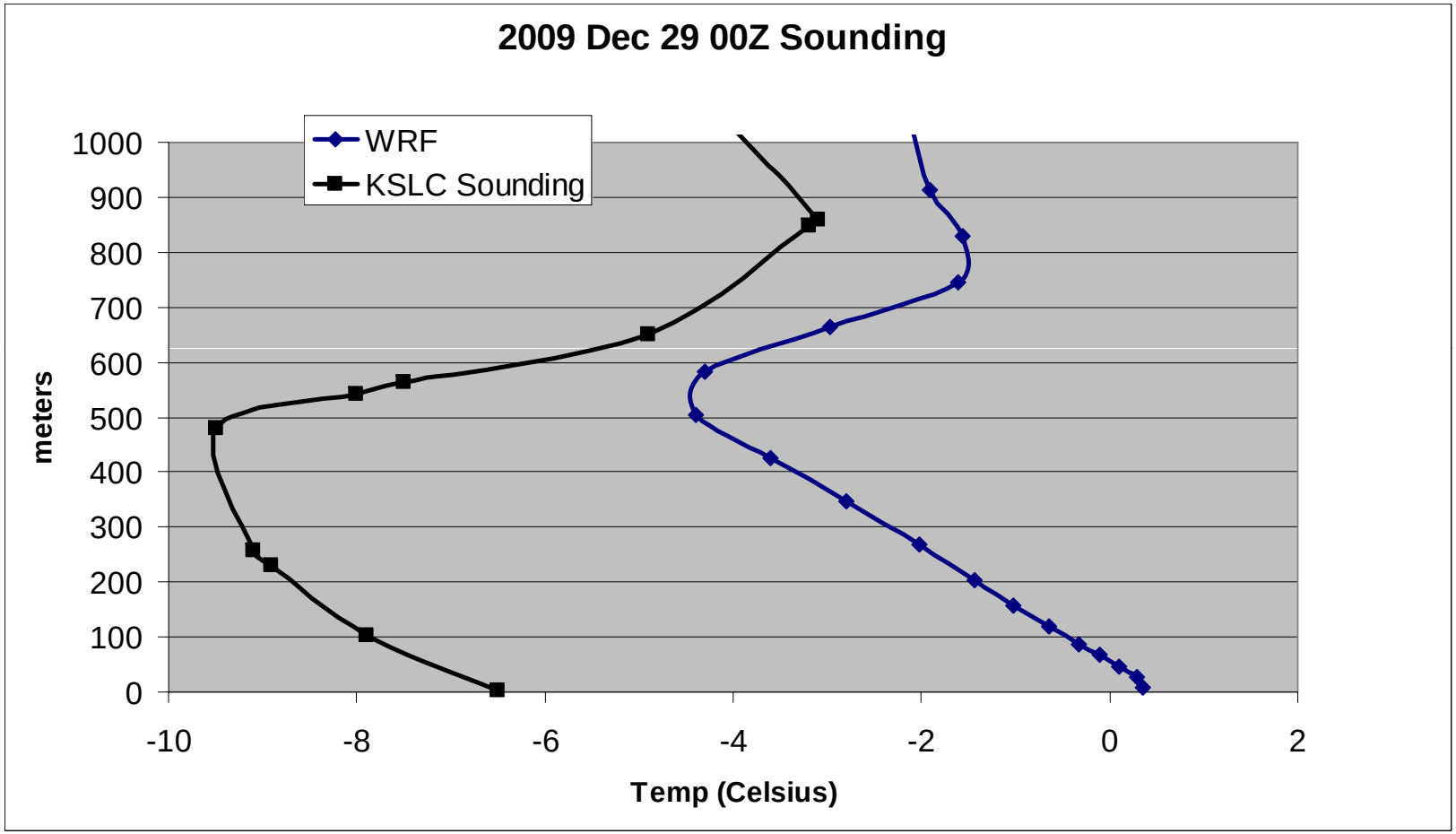
12/30/2009 0:00
12/31/2009 0:00
1/1/2010 0:00


Park City -- No Cold Pool
Elev. 6200 ft
Obs
WRF
Temp. (F)
40
30
20
10
0
12/22/2009 0:00
12/23/2009 0:00
12/24/2009 0:00
12/25/2009 0:00
12/26/2009 0:00
12/27/2009 0:00
12/28/2009 0:00
12/29/2009 0:00
12/30/2009 0:00
12/31/2009 0:00
1/1/2010 0:00

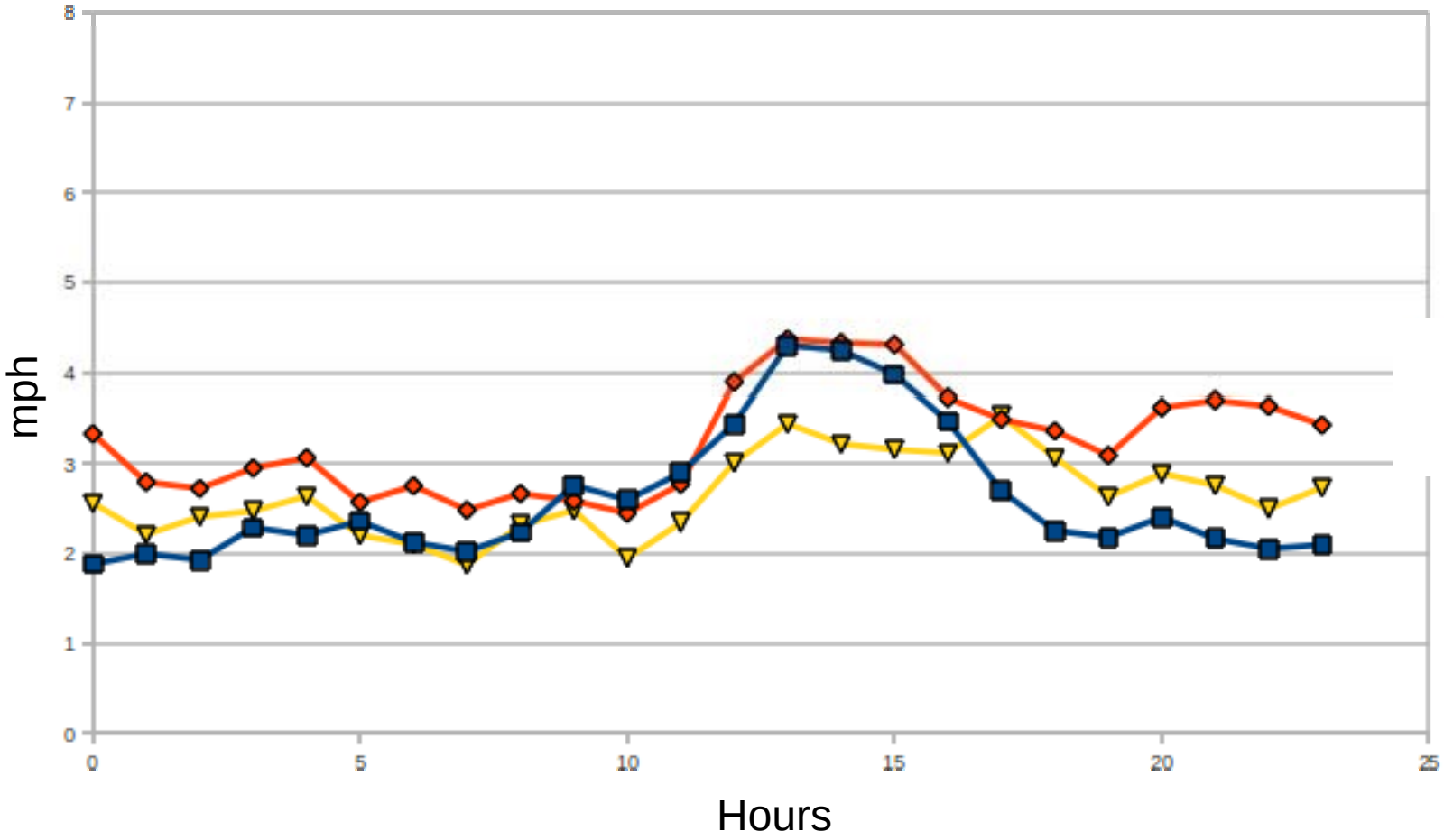
Vertical Profile





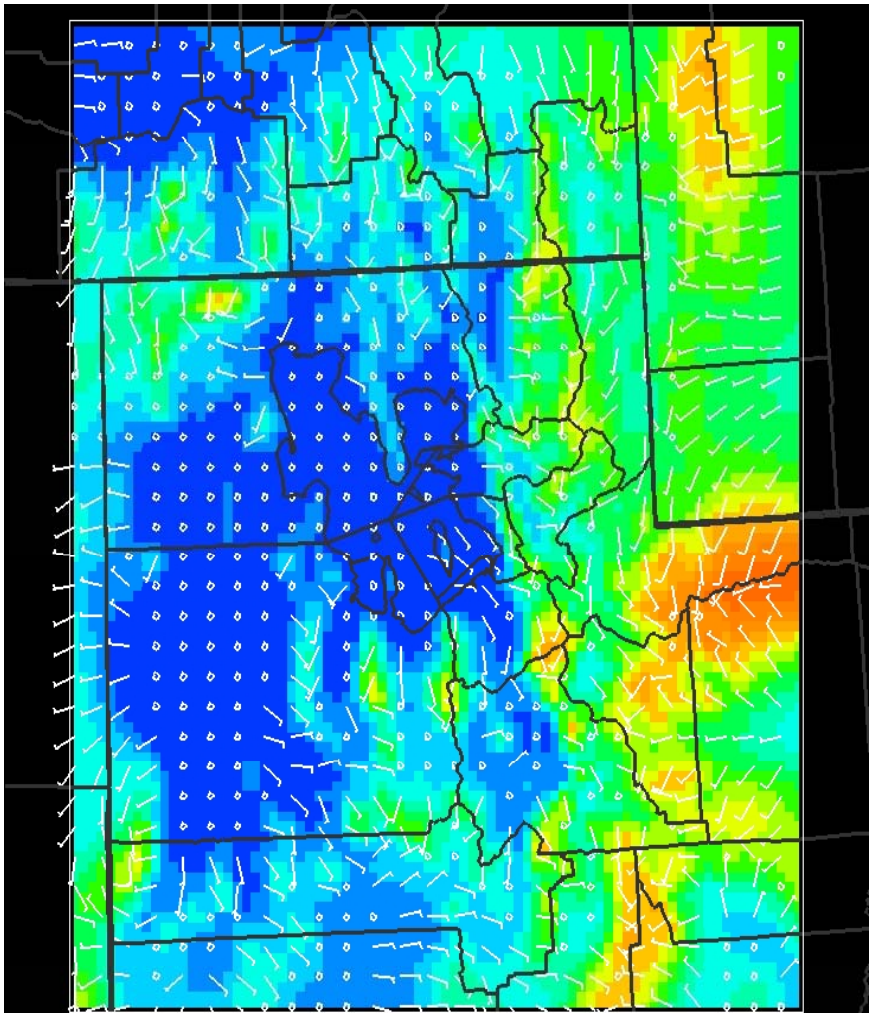

2009 Dec 29 00Z Sounding
WRF
KSLC Sounding
meters
1000
900
800
700
600
500
400
300
200
100
0
-10
-8
-6
-4
-2
0
2
Temp (Celsius)

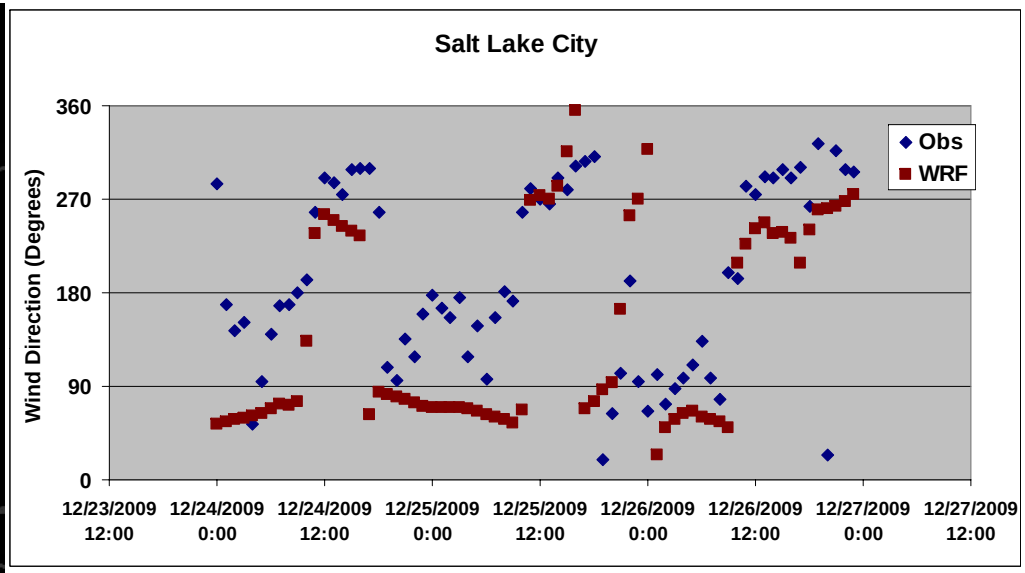
Salt Lake City – Surface Wind Speeds



Blue – obs
Red – WRF
Yellow – WRF with modified surface FDDA

Wind Direction





2009 Dec 26 00 LT

UDAQ experience with cold pool modeling:

Higher Vertical and Horizontal Resolution in WRF

Ensemble WRF and MM5 modeling with NCAR

Adjust eddy diffusivity and vertical diffusion of stable conditions

Influence of the Great Salt Lake

Tested sensitivity to horizontal diffusion, roughness length, friction velocity, PBL height, LSM models, WPS dataset (RUC, NAM)

Strategies that improved photochemical model (CMAQ) performance the best:

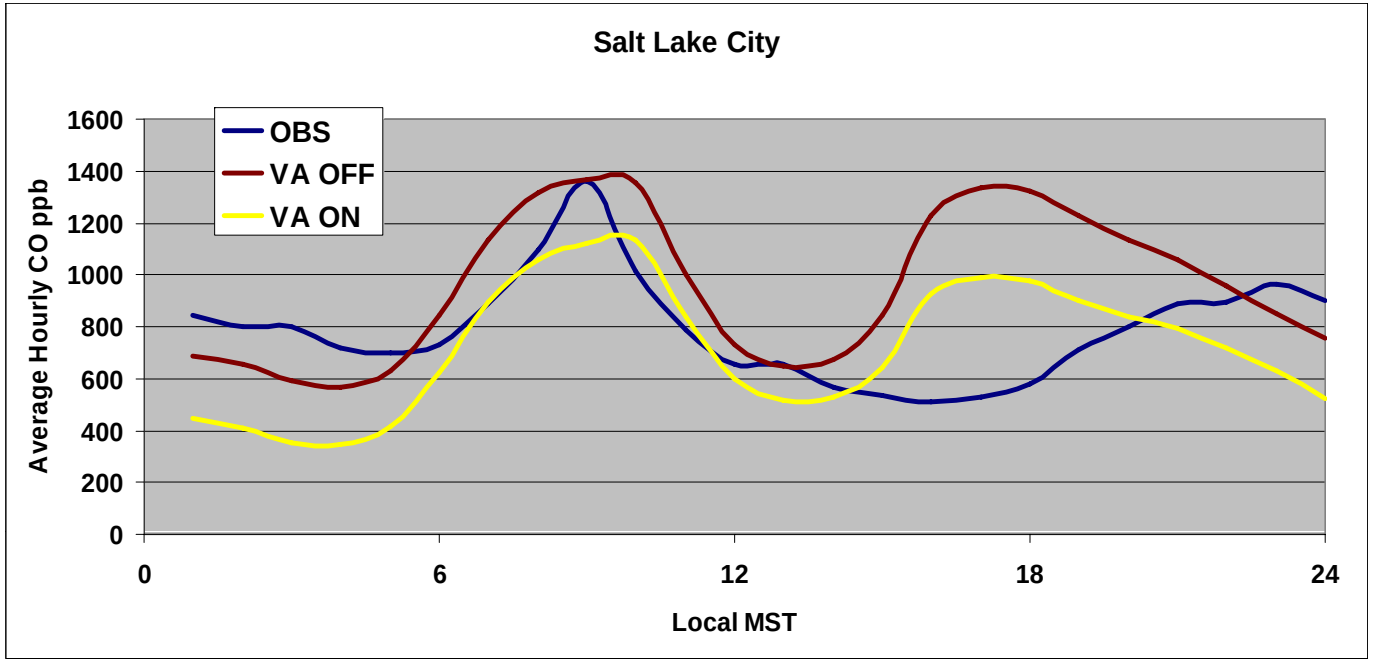
Nudging in WRF to a modified surface analysis (FDDA) grid file to slow surface winds

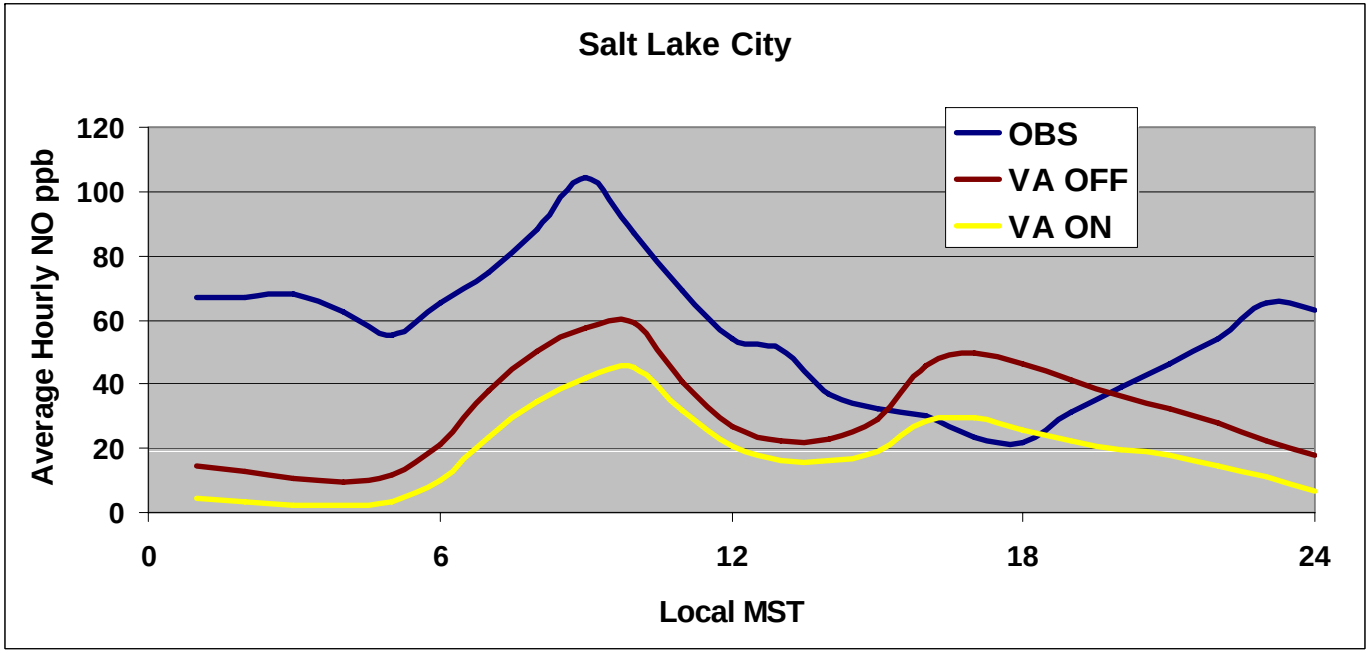
Turning off CMAQ vertical advection

Adding NH3 to emission file

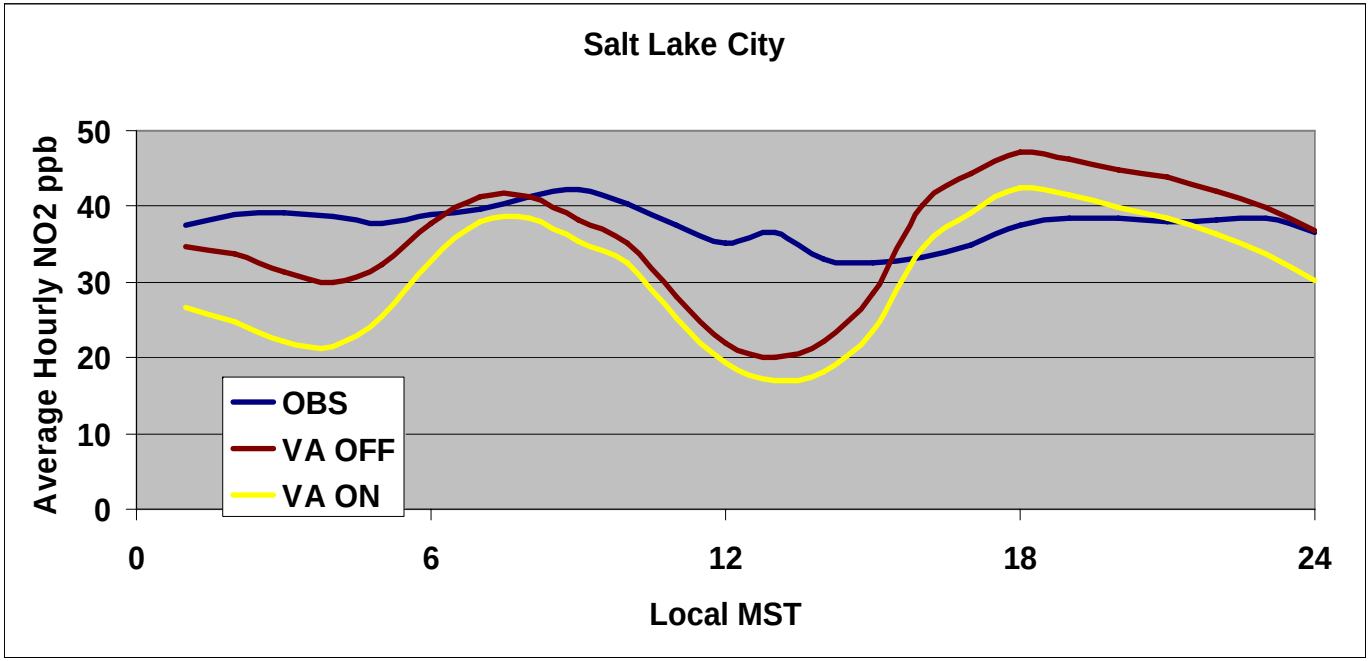
Albedo to adjust for wintertime snow cover

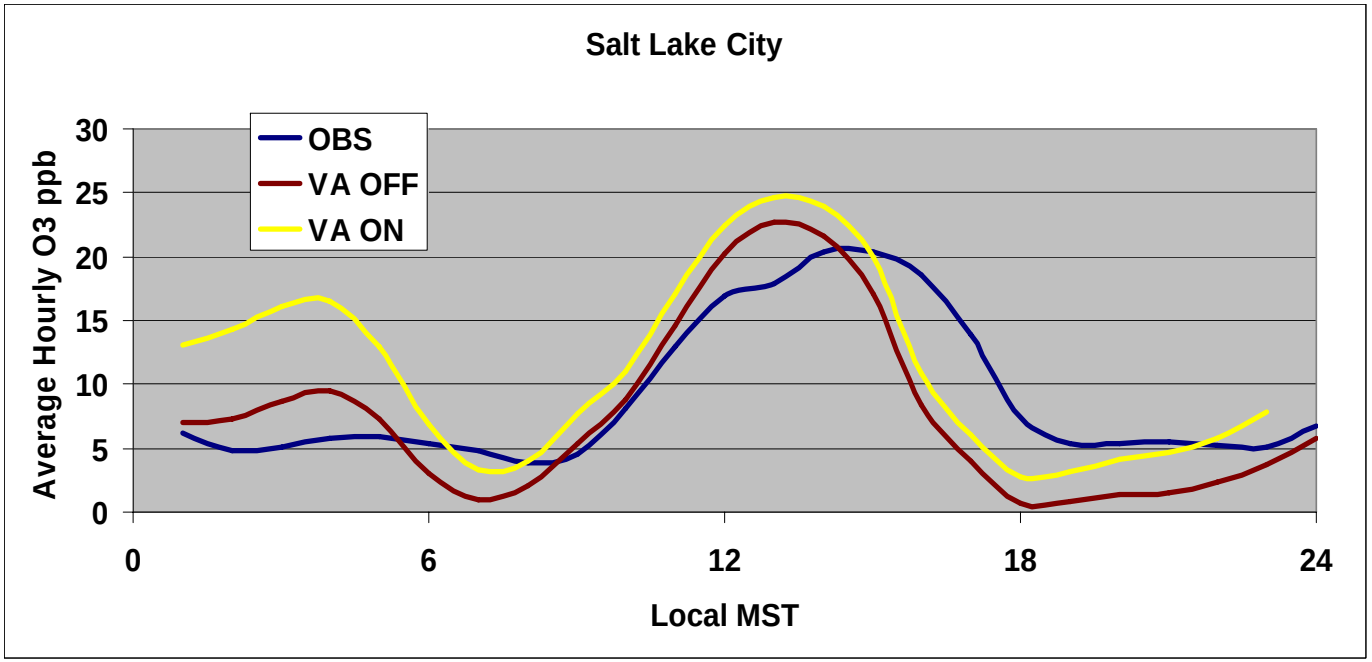
CMAQ


Salt Lake City
OBS
VA OFF
VA ON
Average Hourly CO ppb
1600
1400
1200
1000
800
600
400
200
0
0
6
12
18
24
Local MST

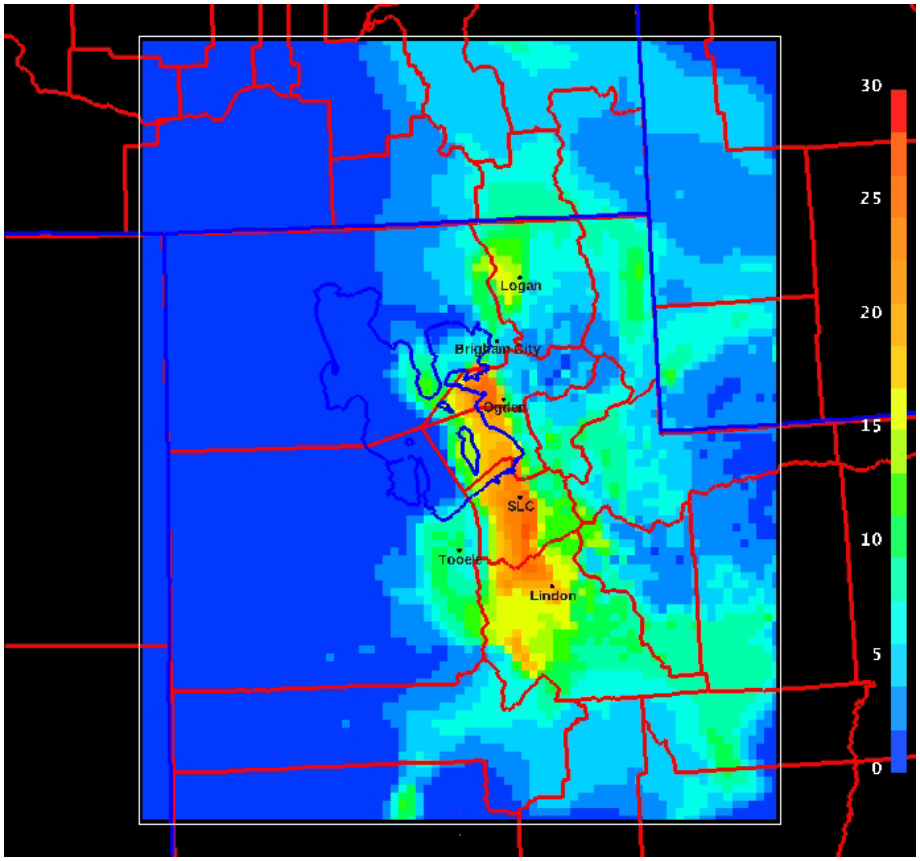

Salt Lake City
OBS
VA OFF
VA ON
Average Hourly NO ppb
120
100
80
60
40
20
0
0
6
12
18
24
Local MST

CMAQ

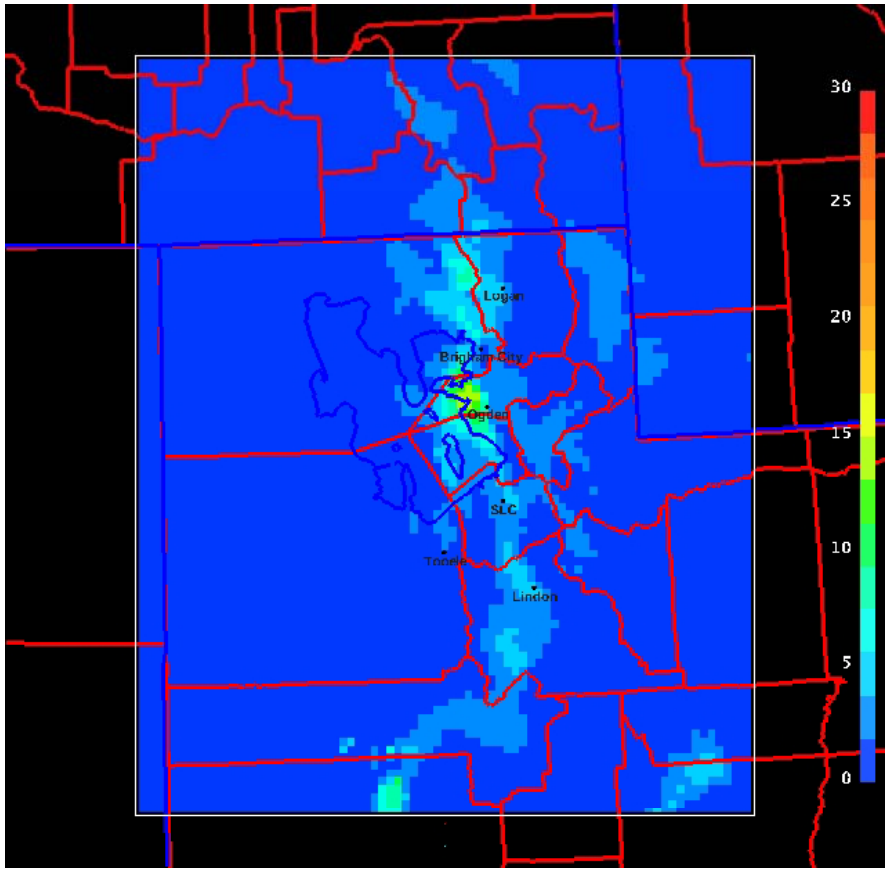

Salt Lake City
Average Hourly NO2 ppb
50
40
30
20
10
0
OBS
VA OFF
VA ON
0
6
12
18
24
Local MST


Salt Lake City
Average Hourly O3 ppb
30
25
20
15
10
5
0
OBS
VA OFF
VA ON
0
6
12
18
24
Local MST

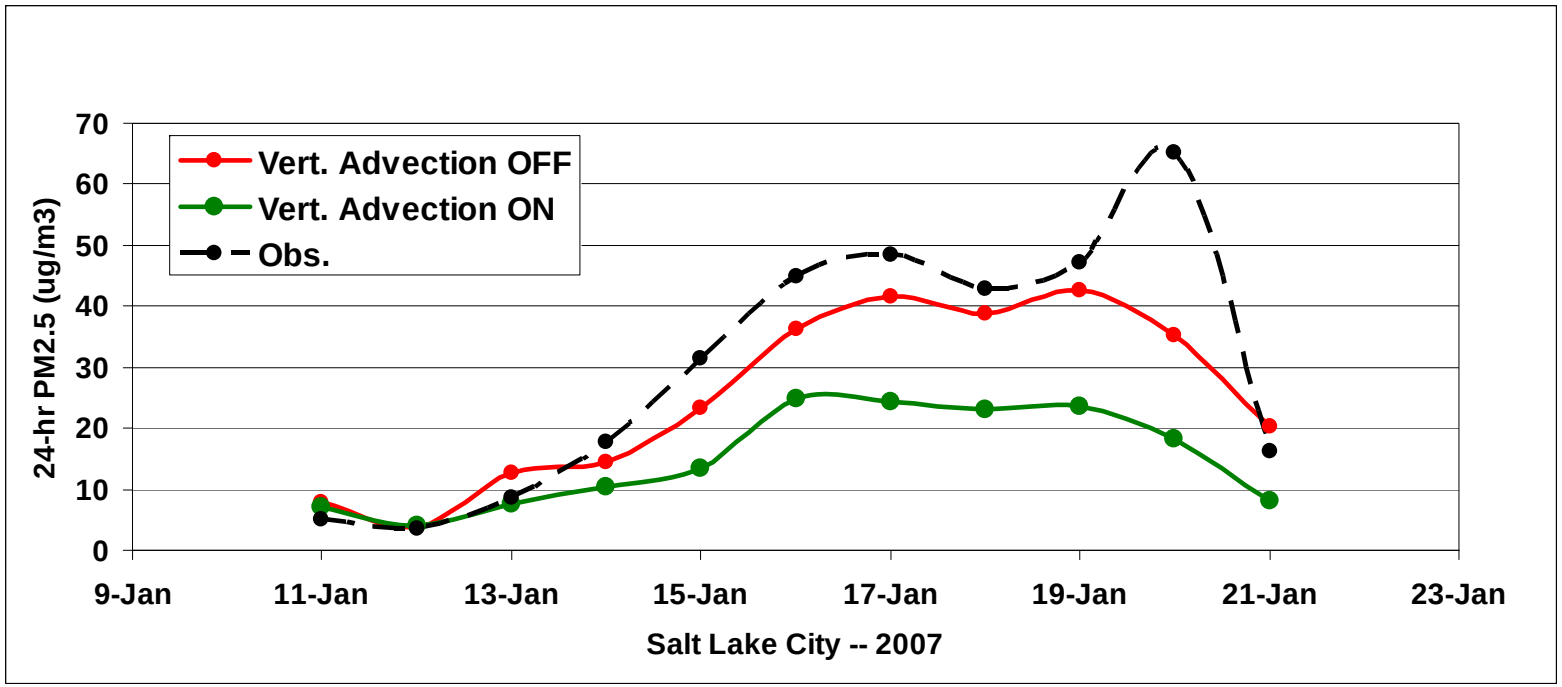
CMAQ Nitrate (ug/m3)

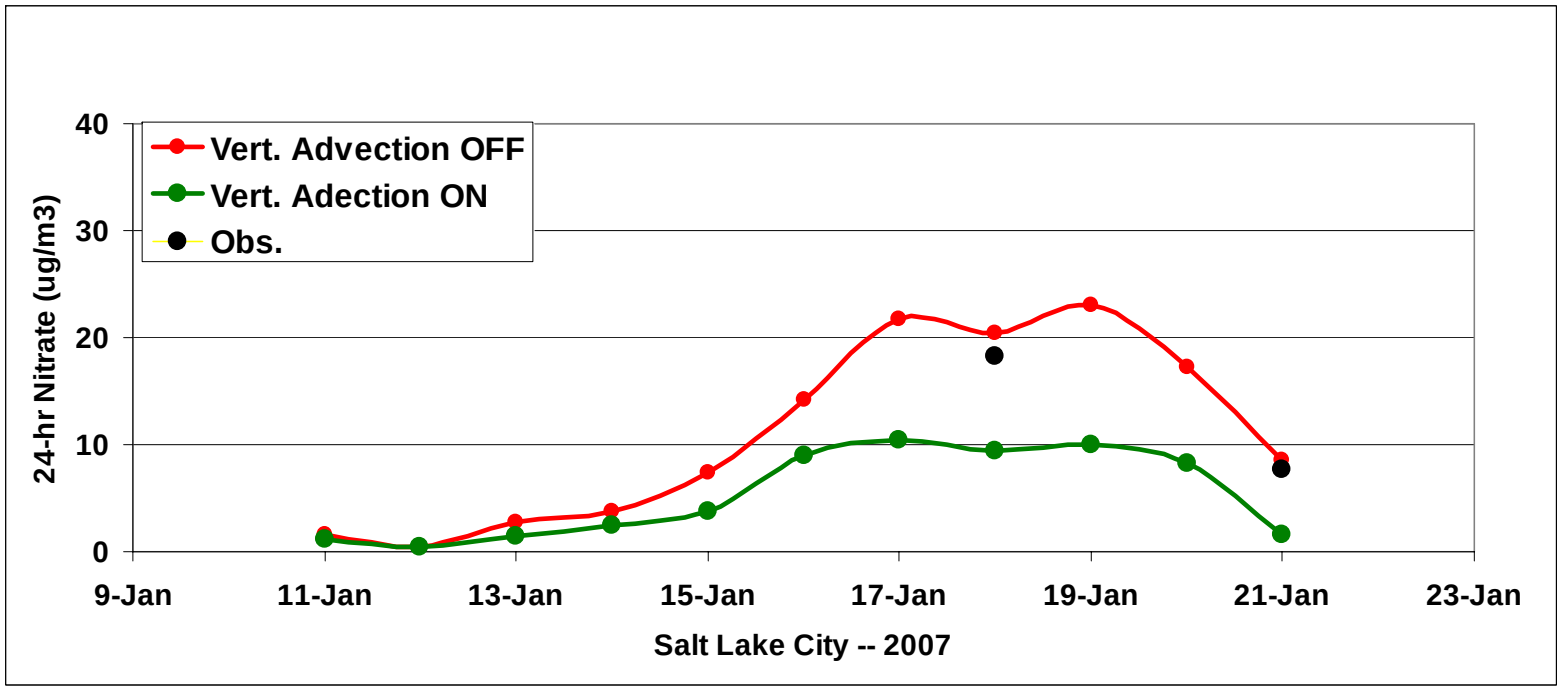


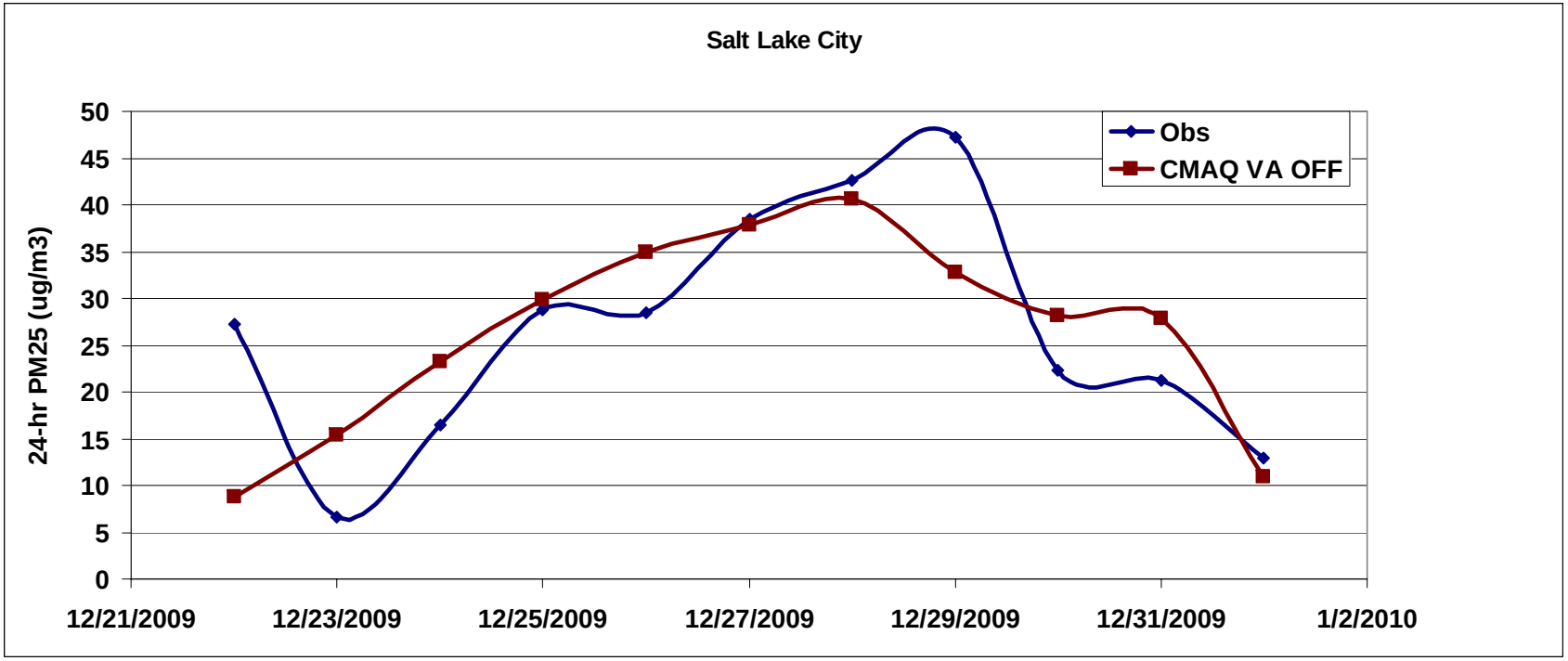
Vertical Advection Off



Vertical Advection On


Vert. Advection OFF
Vert. Advection ON
Obs.
24-hr PM2.5 (ug/m3)
70
60
50
40
30
20
10
0
9-Jan
11-Jan
13-Jan
15-Jan
17-Jan
19-Jan
21-Jan
23-Jan
Salt Lake City -- 2007


Vert. Advection OFF
Vert. Adection ON
Obs.
24-hr Nitrate (ug/m3)
40
30
20
10
0
9-Jan
11-Jan
13-Jan
15-Jan
17-Jan
19-Jan
21-Jan
23-Jan
Salt Lake City -- 2007


Salt Lake City
24-hr PM25 (ug/m3)
50
45
40
35
30
25
20
15
10
5
0
12/21/2009
12/23/2009
12/25/2009
12/27/2009
12/29/2009
12/31/2009
1/2/2010
Obs
CMAQ VA OFF