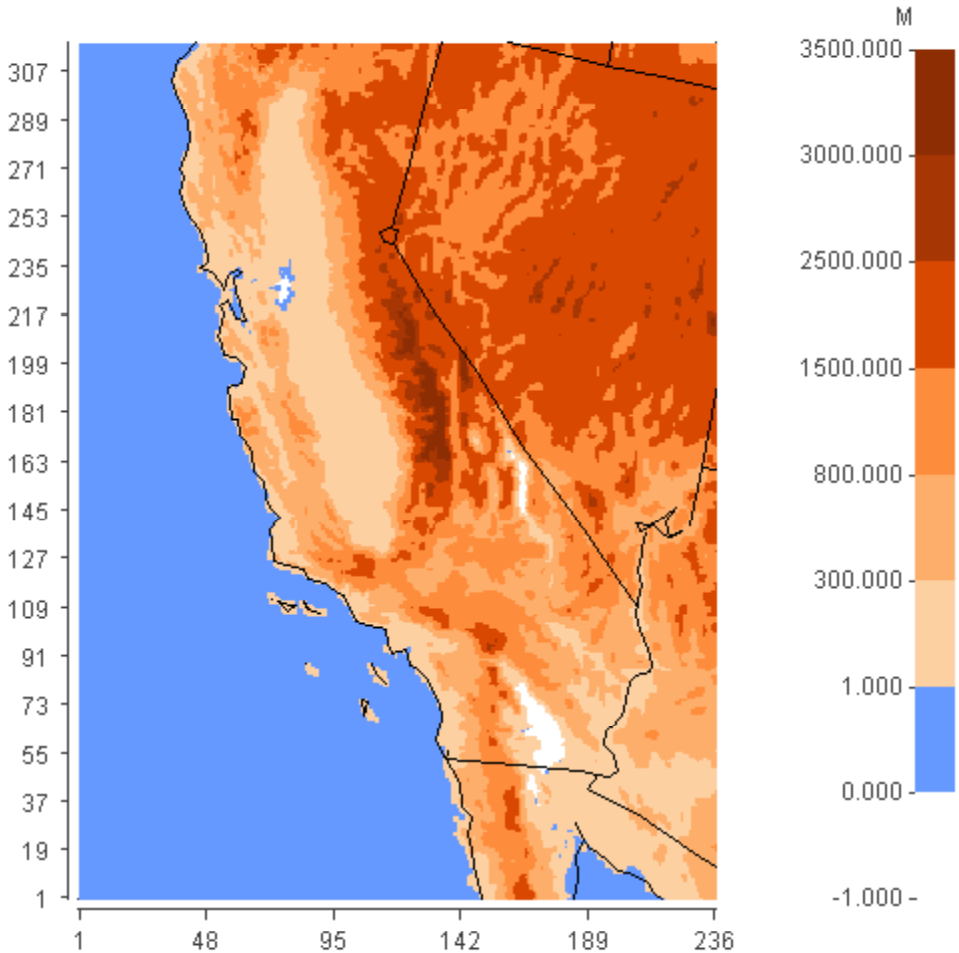
Fine scale (4 km) WRF modeling to support air quality modeling of the 2010 CalNex Field Campaign

Kirk Baker
Chris Misenis
James Kelly

Model Domain (4 km)



Vertical Layers				
k	sigma	press	height	Depth
34	0	100	15,676	2,004
33	0.05	145	13,672	1,585
32	0.1	190	12,087	1,322
31	0.15	235	10,765	1,139
30	0.2	280	9,626	1,004
29	0.25	325	8,622	900
28	0.3	370	7,721	817
27	0.35	415	6,904	750
26	0.4	460	6,154	693
25	0.45	505	5,461	645
24	0.5	550	4,816	604
23	0.55	595	4,213	568
22	0.6	640	3,645	536
21	0.65	685	3,109	508
20	0.7	730	2,601	388
19	0.74	766	2,212	282
18	0.77	793	1,931	274
17	0.8	820	1,657	178
16	0.82	838	1,478	175
15	0.84	856	1,303	172
14	0.86	874	1,131	169
13	0.88	892	961	167
12	0.9	910	795	82
11	0.91	919	712	82
10	0.92	928	631	81
9	0.93	937	550	80
8	0.94	946	469	80
7	0.95	955	390	79
6	0.96	964	310	79
5	0.97	973	232	78
4	0.98	982	154	39
3	0.985	986.5	115	39
2	0.99	991	77	38
1	0.995	995.5	38	38
0	1	1000	0	38

WRF Meteorological Modeling

- NAM-12 analysis; analysis nudging for T, winds, and moisture above PBL only
- OBSGRID for soil nudging (PX application only)
- Soil moisture and temperature continued from one 5 day block to the next
- First 5 day block used average 2m temperature to initialize deep soil temperature

	WRF PX	**WRF MYJ**
Version	3.2*	3.3.1
Longwave radiation	RRTMG	RRTM
Shortwave radiation	RRTMG	Goddard
Surface Layer	Pleim-Xiu	Monin-Obukhov (Janjic)
Land Surface	Pleim-Xiu	NOAH
Boundary Layer	ACM2	Mellor-Yamada-Janjic
Cloud Microphysics	Morrison 2-moment	Thompson
Cumulus	Kain-Fritsch	Grell 3D ensemble

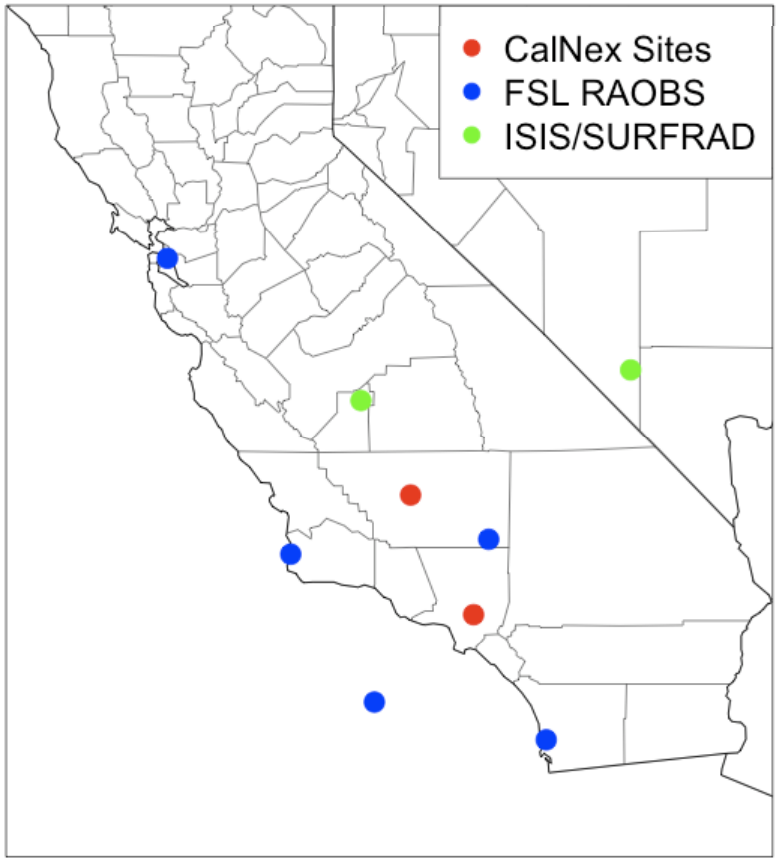
*PX updated from standard release; similar to released form of PX in v3.3

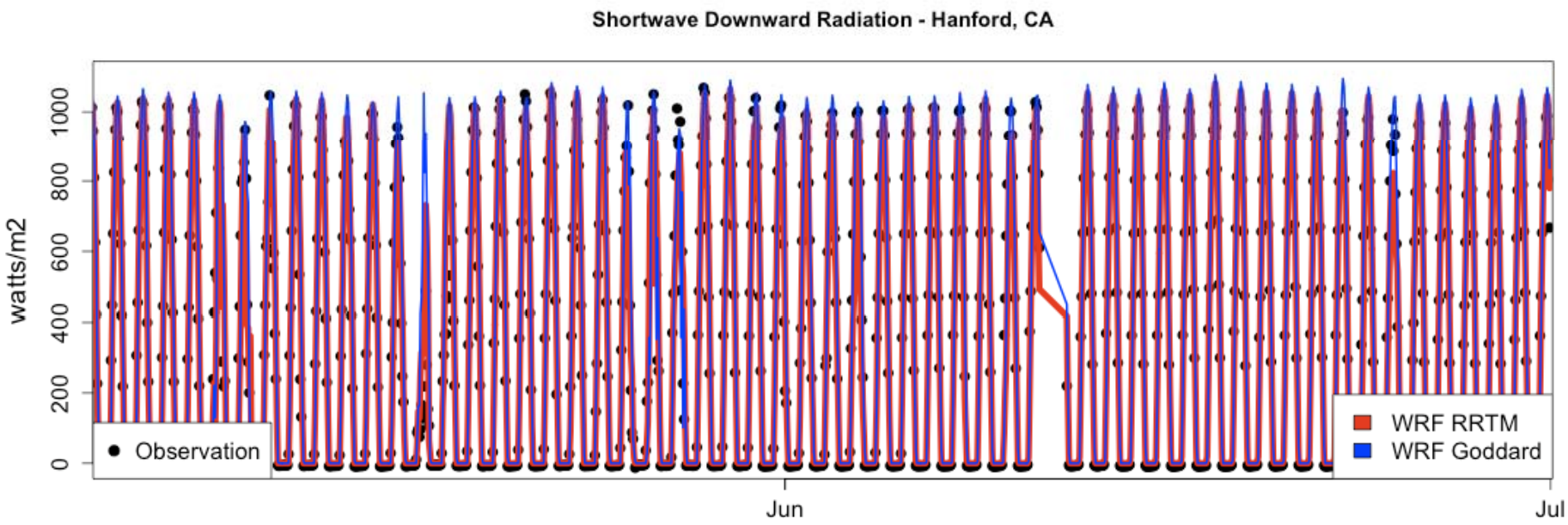
Evaluation

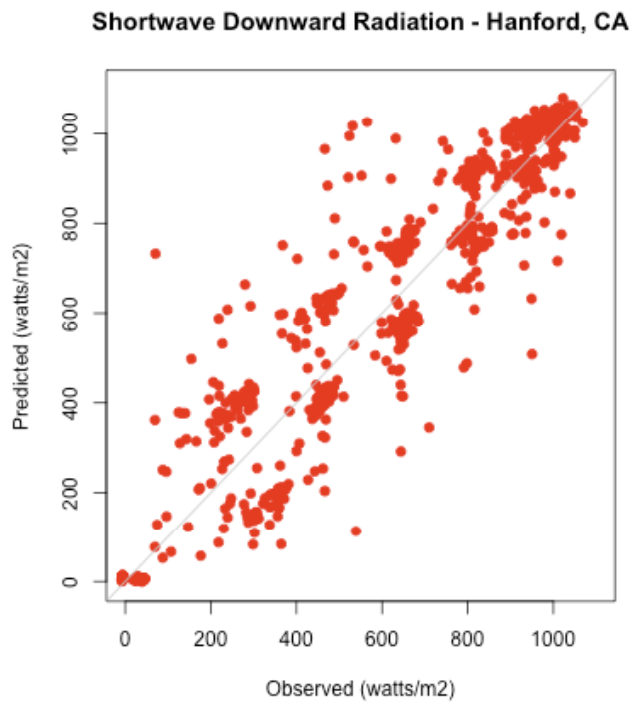
- SURFRAD/ISIS solar radiation
- PRISM precipitation analysis
- HSRL boundary layer height estimates
- U.S. airways meteorological monitors: NCAR ds472 (T, WS, WD, MR)
- NOAA radiosondes: T, WS, WD

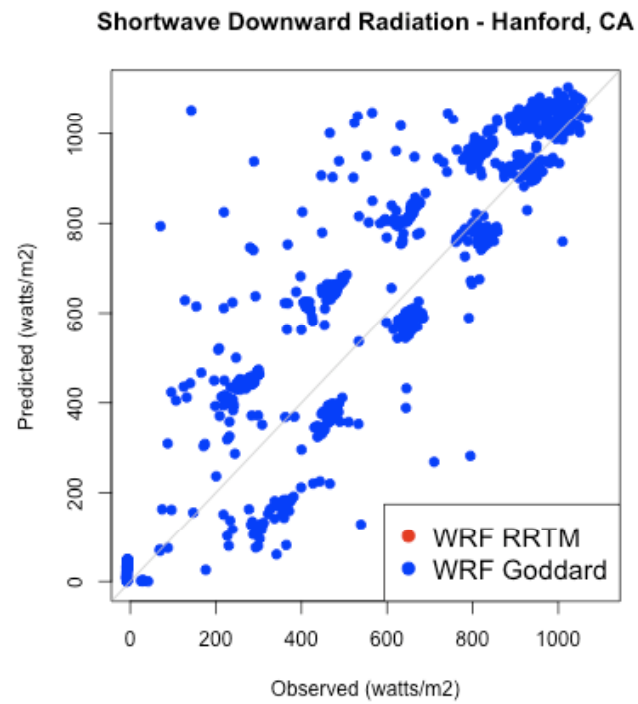
Radiation & Precipitation

- WRF evaluated against hourly shortwave downward radiation at ISIS monitor in Hanford, CA and SURFRAD monitor in Desert Rock, NV (results not shown)
- Monthly total WRF precipitation estimates compared to PRISM analysis estimates



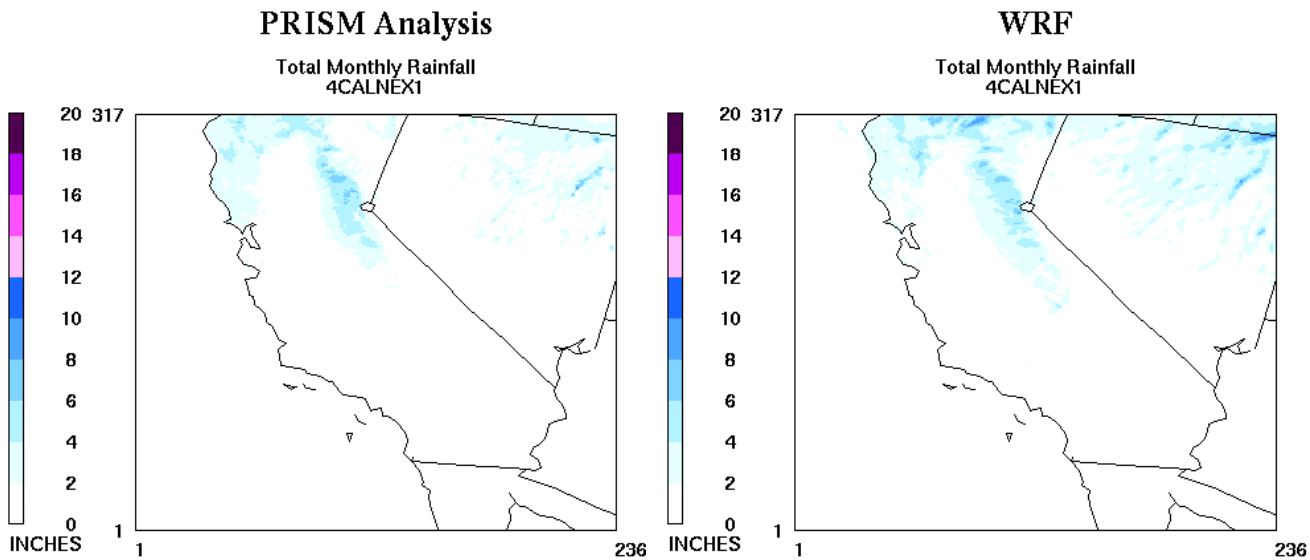

Shortwave Downward Radiation - Hanford, CA
watts/m2
0
200
400
600
800
1000
Observation
WRF RRTM
WRF Goddard
Jun
Jul


Shortwave Downward Radiation - Hanford, CA
Predicted (watts/m2)
Observed (watts/m2)
0
200
400
600
800
1000

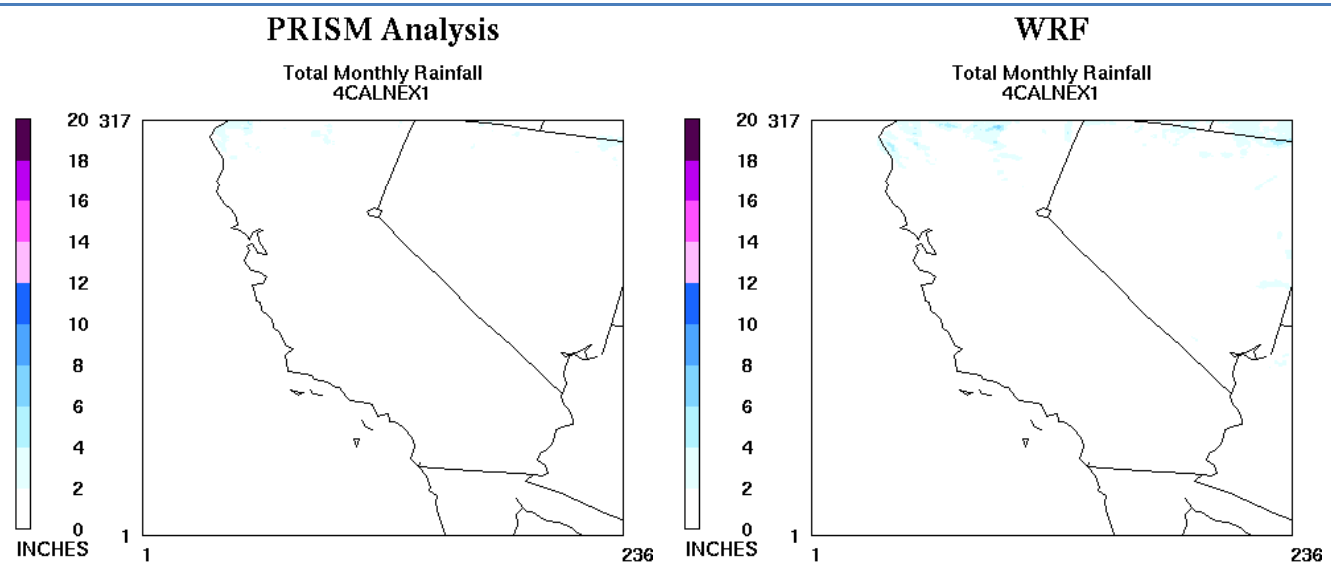

Shortwave Downward Radiation - Hanford, CA
Predicted (watts/m2)
Observed (watts/m2)
0
200
400
600
800
1000
WRF RRTM
WRF Goddard

Monthly Total Precipitation

May 2010

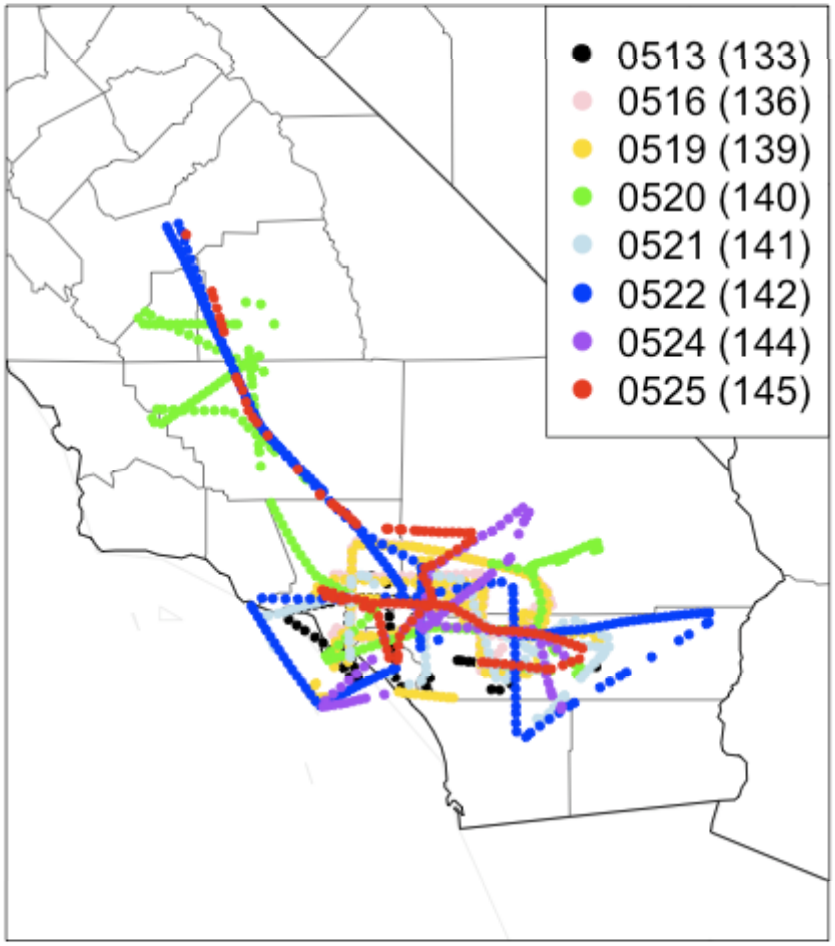


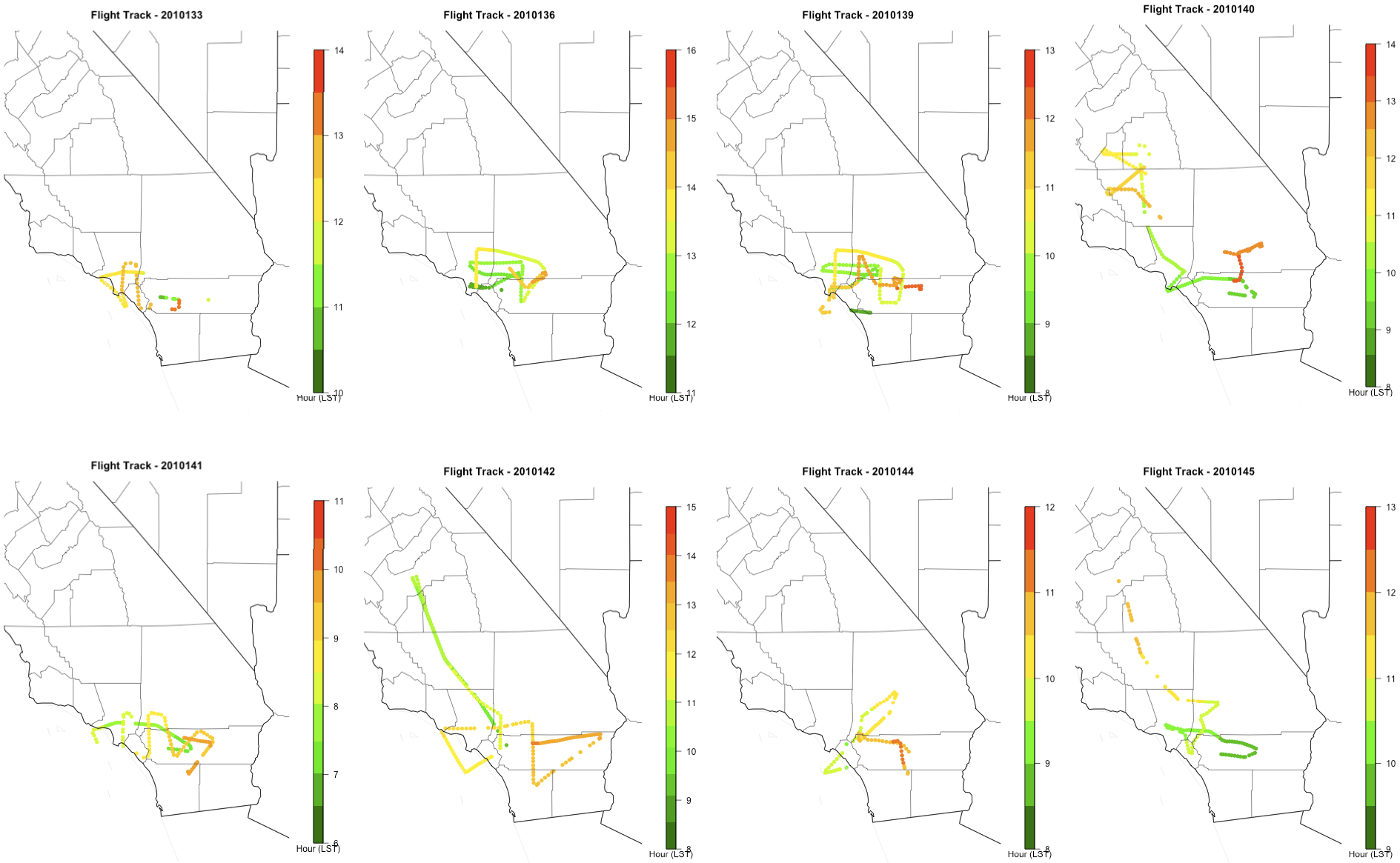
June 2010

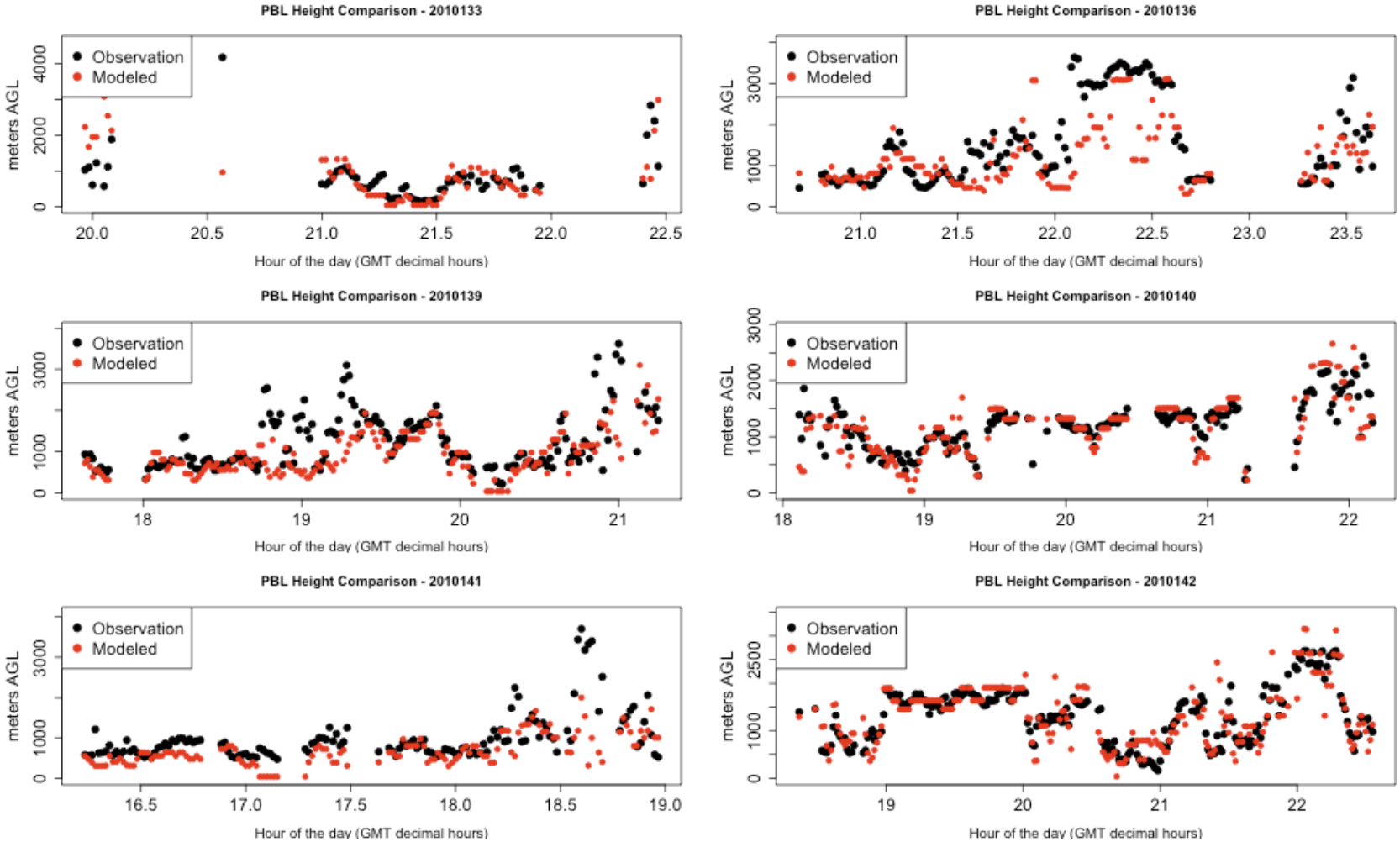


Boundary Layer Height

- Aircraft estimates of boundary layer height
- Measurements made during parts of 6 different flights shown at right

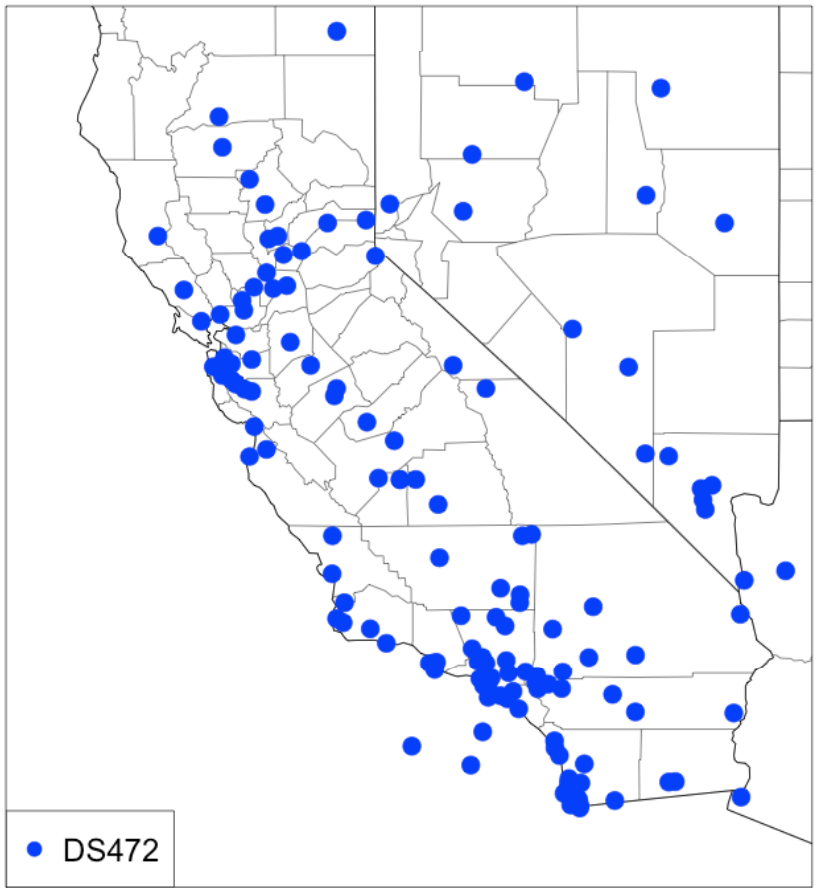


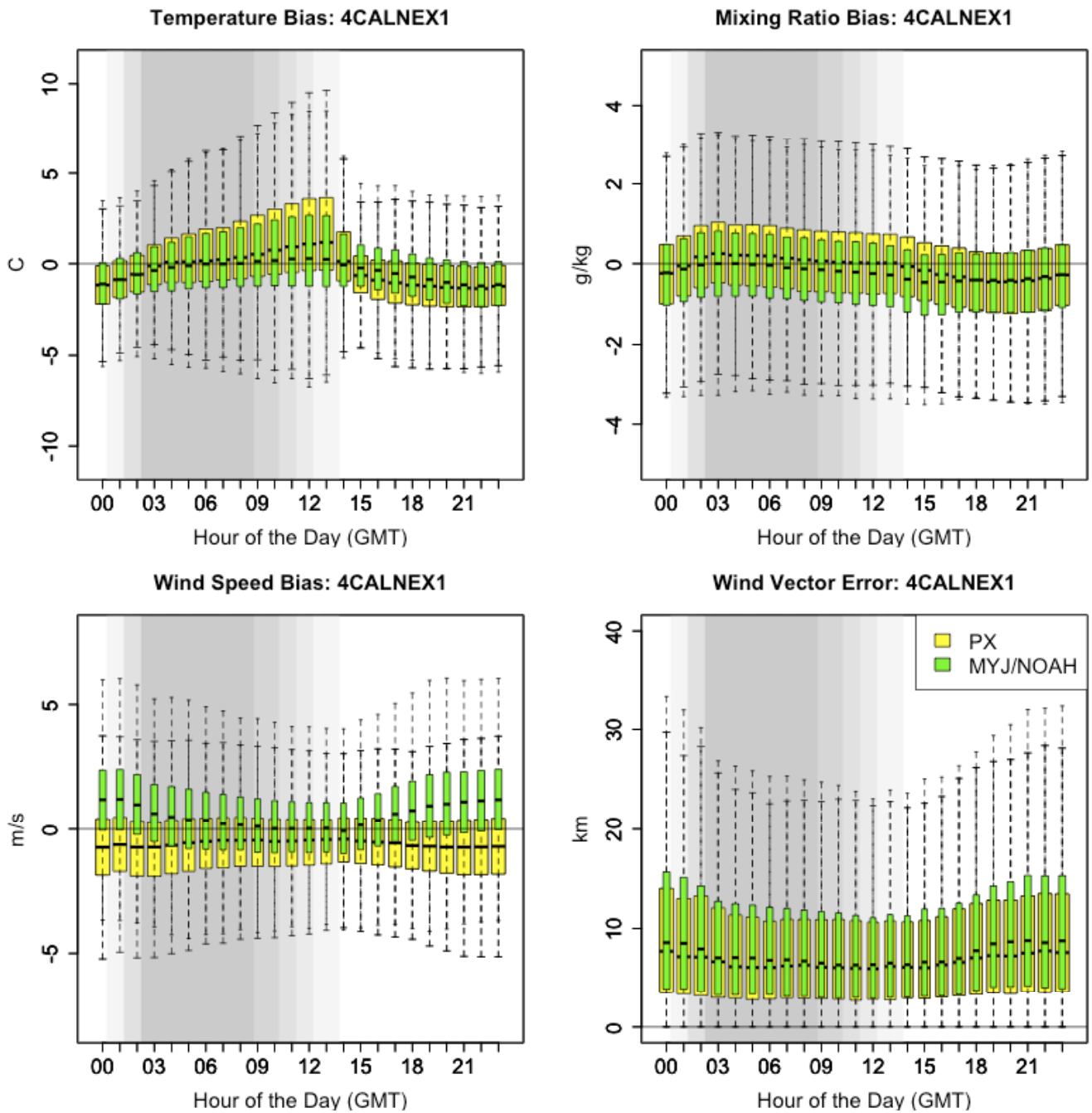

Flight Track - 2010133
Hour (LST)
Flight Track - 2010136
Hour (LST)
Flight Track - 2010139
Hour (LST)
Flight Track - 2010140
Hour (LST)
Flight Track - 2010141
Hour (LST)
Flight Track - 2010142
Hour (LST)
Flight Track - 2010144
Hour (LST)
Flight Track - 2010145
Hour (LST)

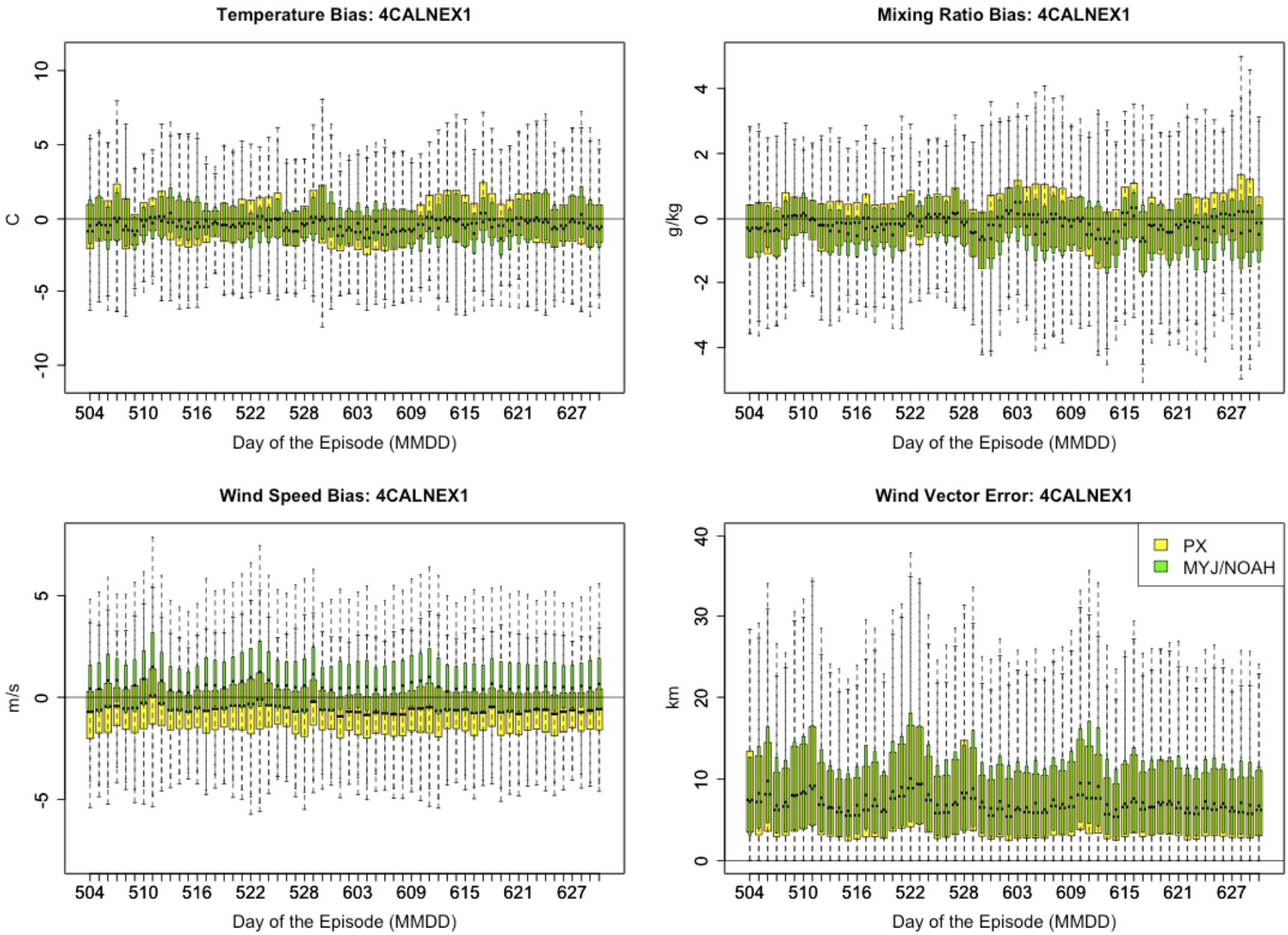

PBL Height Comparison - 2010133
Observation
Modeled
meters AGL
0
2000
4000
20.0
20.5
21.0
21.5
22.0
22.5
Hour of the day (GMT decimal hours)
PBL Height Comparison - 2010136
Observation
Modeled
meters AGL
0
1000
3000
21.0
21.5
22.0
22.5
23.0
23.5
Hour of the day (GMT decimal hours)
PBL Height Comparison - 2010139
Observation
Modeled
meters AGL
0
1000
3000
18
19
20
21
Hour of the day (GMT decimal hours)
PBL Height Comparison - 2010140
Observation
Modeled
meters AGL
0
1000
2000
3000
18
19
20
21
22
Hour of the day (GMT decimal hours)
PBL Height Comparison - 2010141
Observation
Modeled
meters AGL
0
1000
3000
16.5
17.0
17.5
18.0
18.5
19.0
Hour of the day (GMT decimal hours)
PBL Height Comparison - 2010142
Observation
Modeled
meters AGL
0
1000
2500
19
20
21
22
Hour of the day (GMT decimal hours)

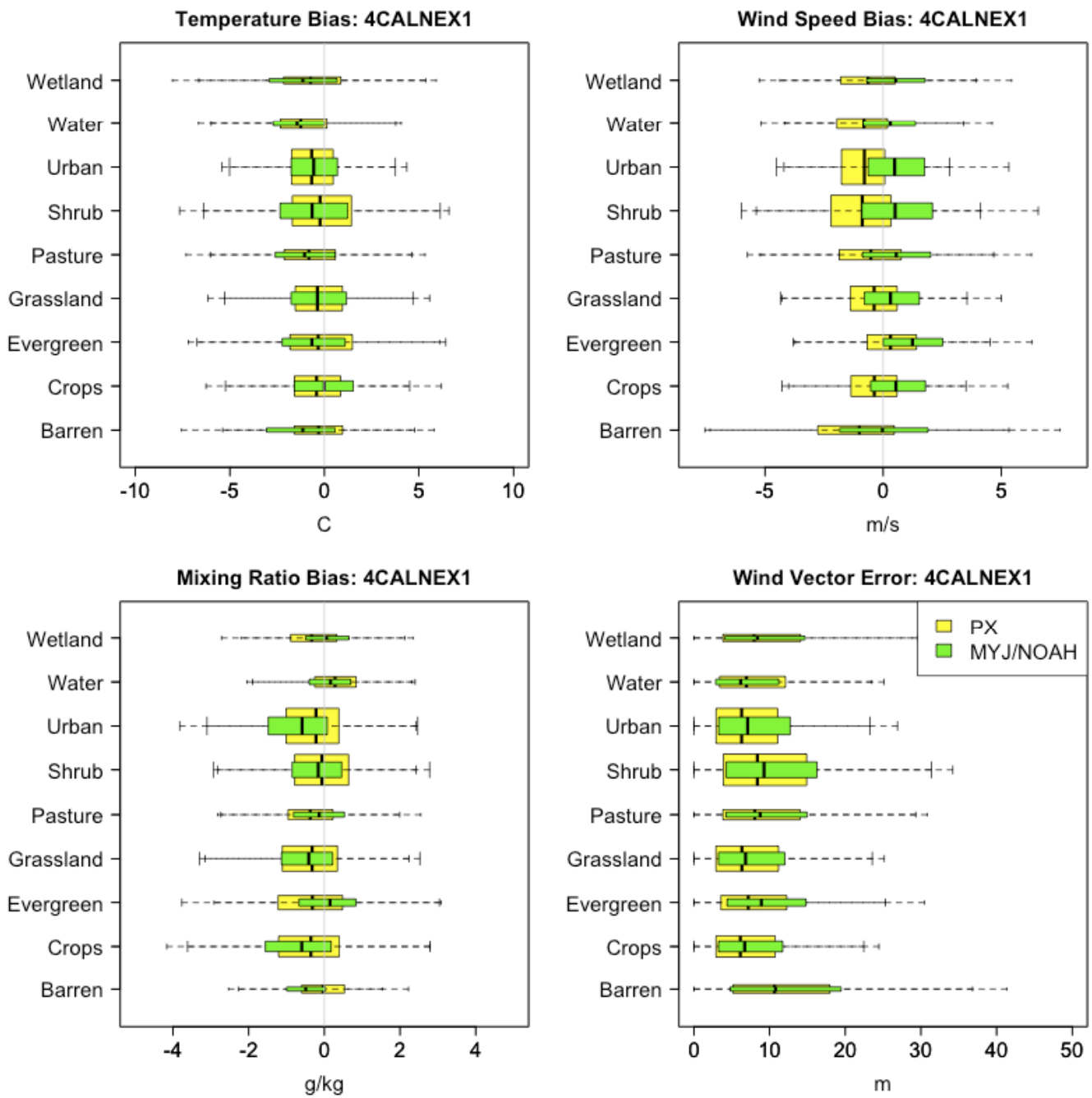
Surface Observations

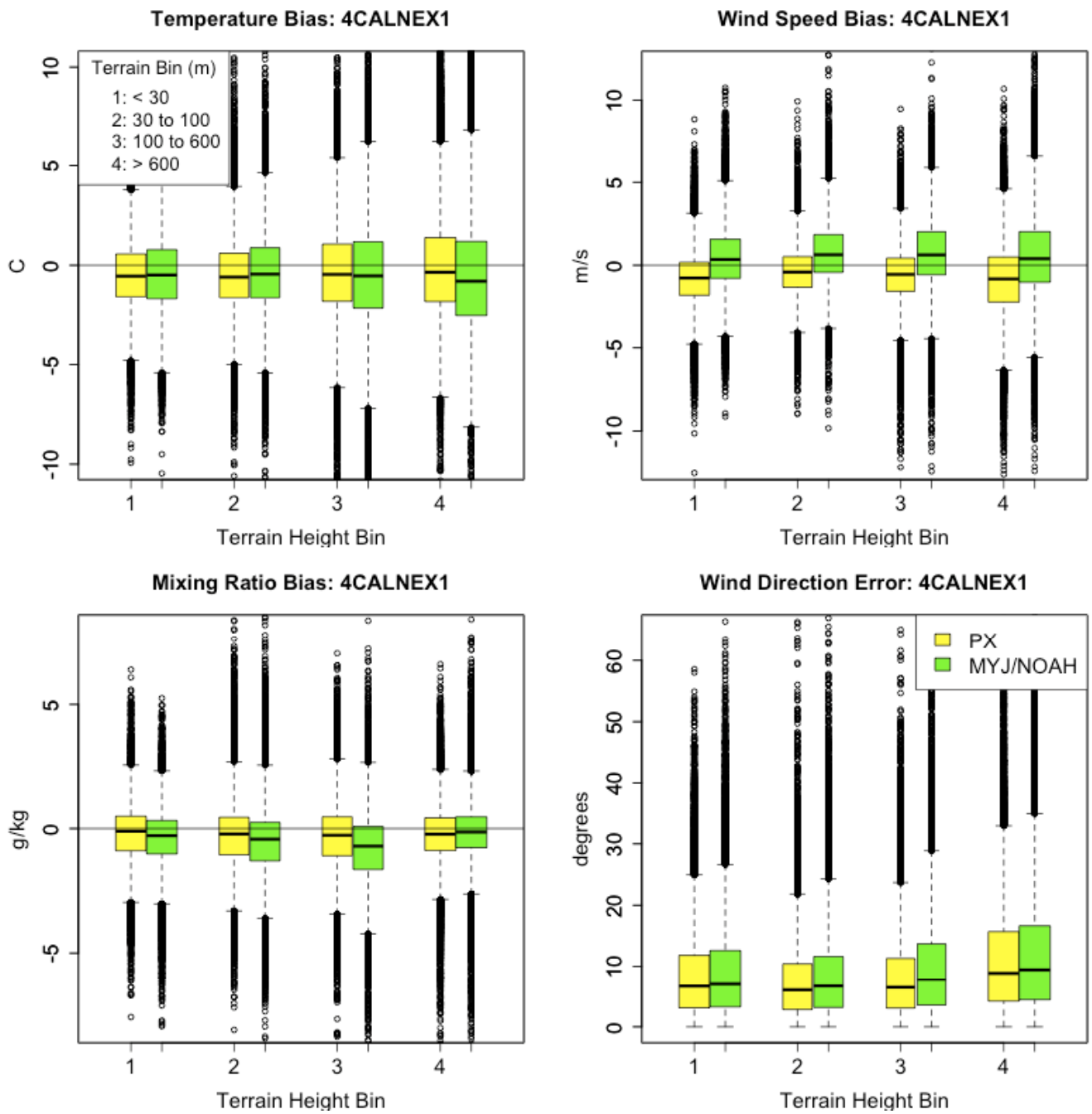
- Evaluate WRF surface estimates of T, MR, WS, and wind vector error against NCAR's ds472 US Airways dataset
- Stations used in the analysis shown at right




Temperature Bias: 4CALNEX1
C
10
5
0
-5
-10
00 03 06 09 12 15 18 21
Hour of the Day (GMT)
Mixing Ratio Bias: 4CALNEX1
g/kg
4
2
0
-2
-4
00 03 06 09 12 15 18 21
Hour of the Day (GMT)
Wind Speed Bias: 4CALNEX1
m/s
5
0
-5
00 03 06 09 12 15 18 21
Hour of the Day (GMT)
Wind Vector Error: 4CALNEX1
km
40
30
20
10
0
PX
MYJ/NOAH
00 03 06 09 12 15 18 21
Hour of the Day (GMT)

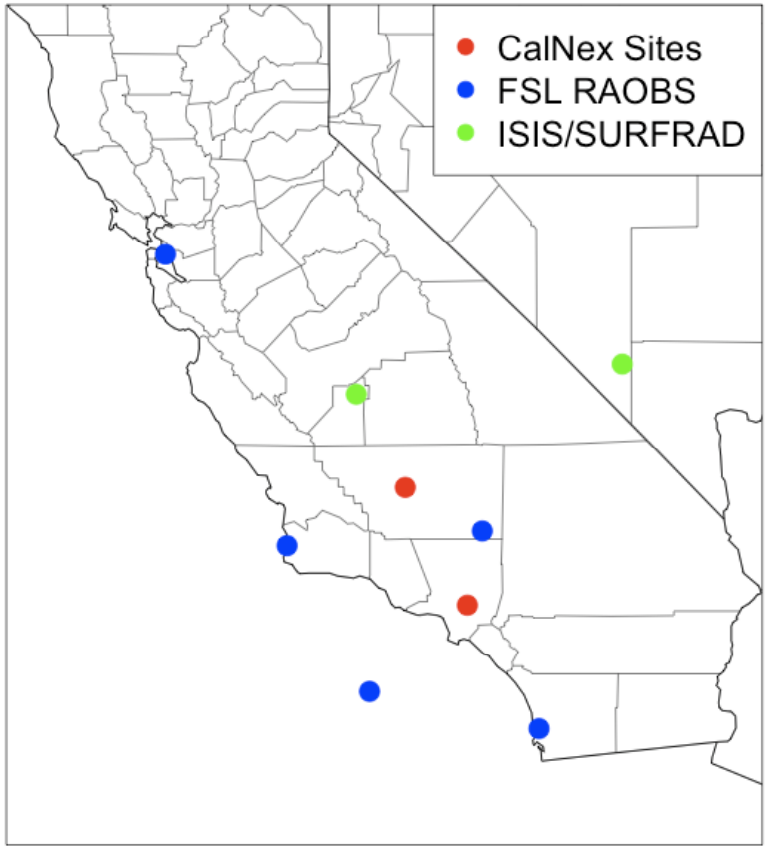

Temperature Bias: 4CALNEX1
C
10
5
0
-5
-10
504 510 516 522 528 603 609 615 621 627
Day of the Episode (MMDD)
Mixing Ratio Bias: 4CALNEX1
g/kg
4
2
0
-2
-4
504 510 516 522 528 603 609 615 621 627
Day of the Episode (MMDD)
Wind Speed Bias: 4CALNEX1
m/s
5
0
-5
504 510 516 522 528 603 609 615 621 627
Day of the Episode (MMDD)
Wind Vector Error: 4CALNEX1
km
40
30
20
10
0
PX
MYJ/NOAH
504 510 516 522 528 603 609 615 621 627
Day of the Episode (MMDD)


Temperature Bias: 4CALNEX1
Wind Speed Bias: 4CALNEX1
Mixing Ratio Bias: 4CALNEX1
Wind Vector Error: 4CALNEX1
Wetland
Water
Urban
Shrub
Pasture
Grassland
Evergreen
Crops
Barren
-10
-5
0
5
10
C
m/s
-4
-2
2
4
g/kg
PX
MYJ/NOAH
20
30
40
50
m

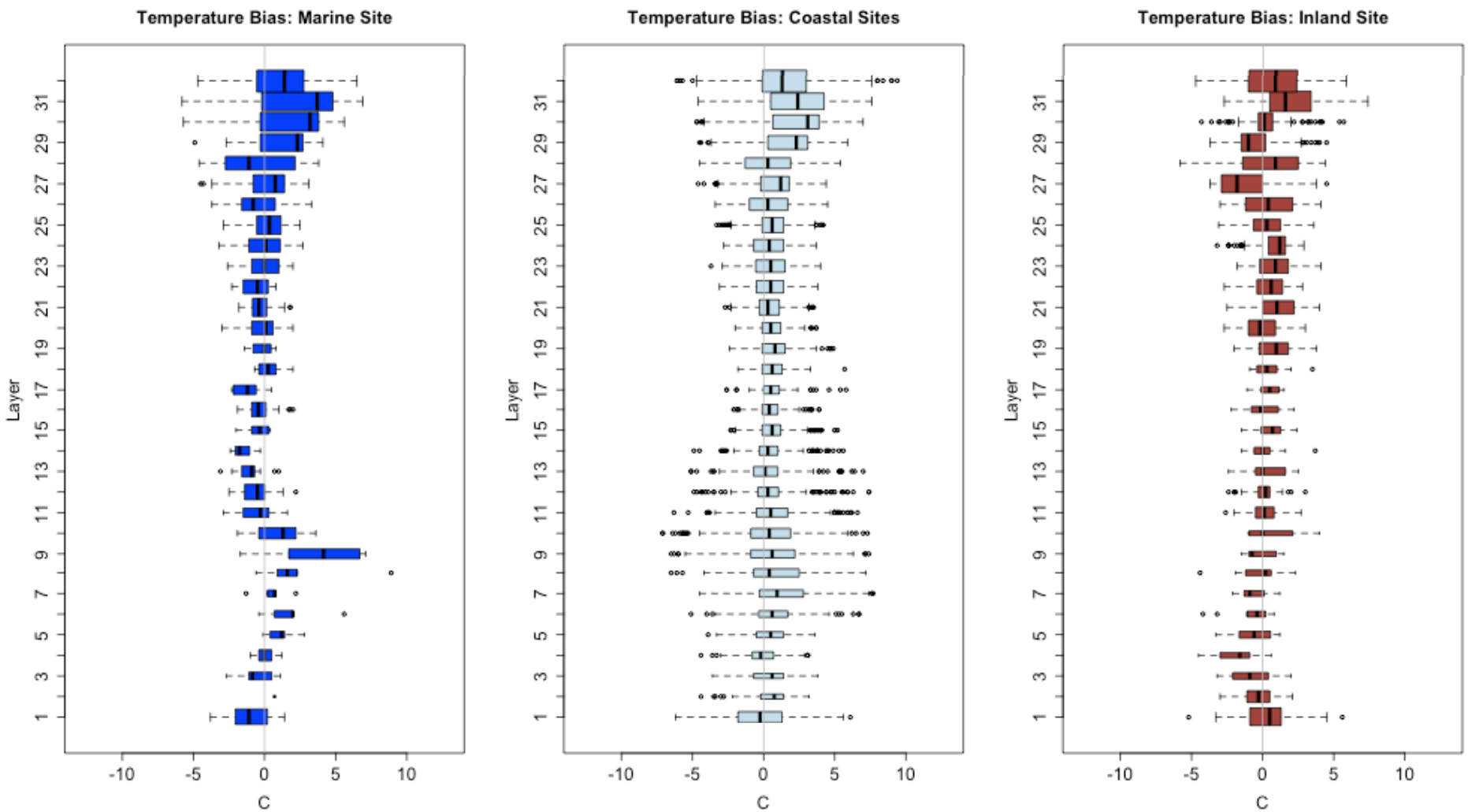

Temperature Bias: 4CALNEX1
Terrain Bin (m)
1: < 30
2: 30 to 100
3: 100 to 600
4: > 600
C
Terrain Height Bin
Wind Speed Bias: 4CALNEX1
m/s
Terrain Height Bin
Mixing Ratio Bias: 4CALNEX1
g/kg
Terrain Height Bin
Wind Direction Error: 4CALNEX1
PX
MYJ/NOAH
degrees
Terrain Height Bin

Routine Soundings

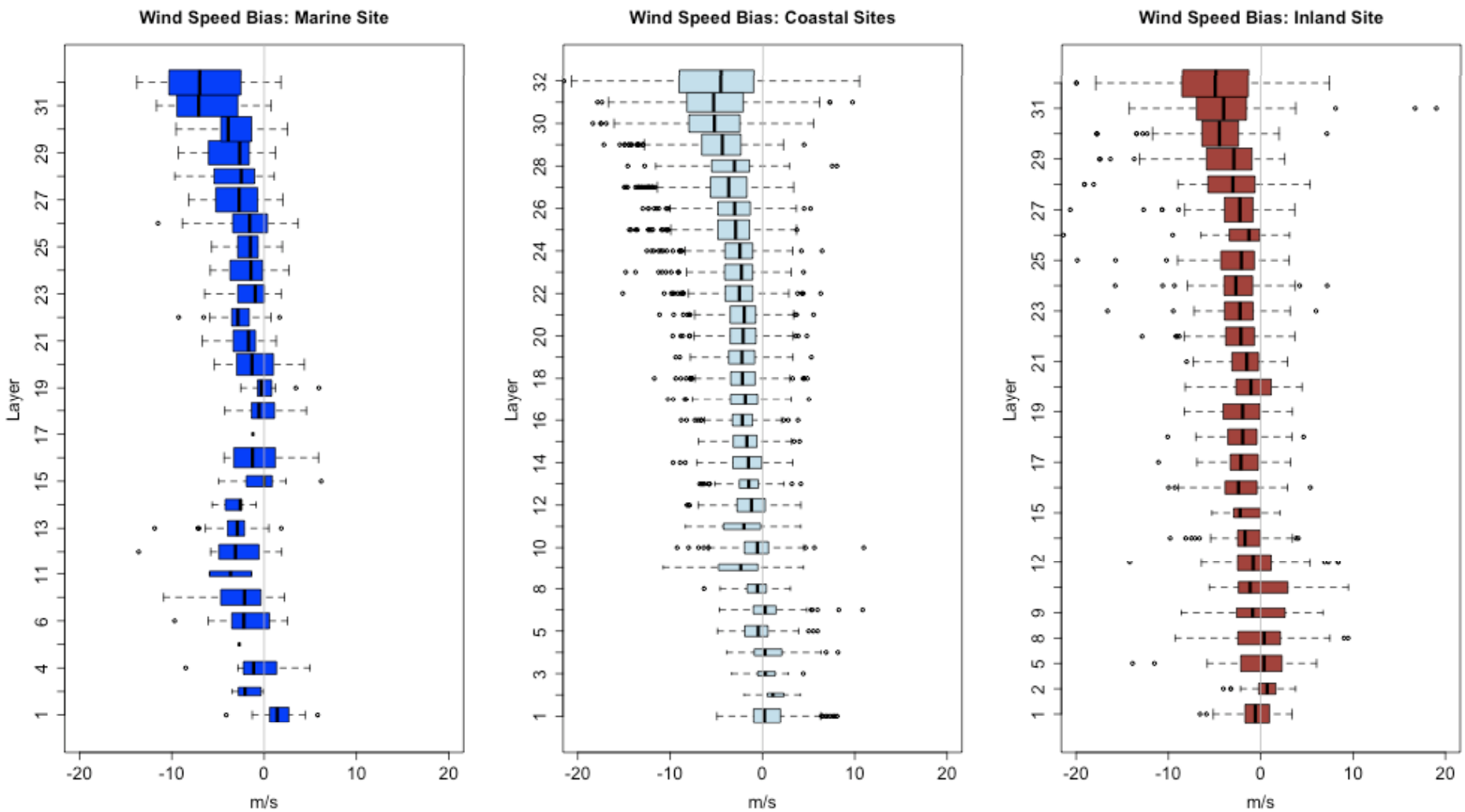
- WRF vertical estimates of T, WS, and wind vector error by altitude
- Radiosonde data provided by NOAA/ESRL
- 5 total sites in California
- http://www.esrl.noaa.gov/raobs/
- Metrics shown by model layer; metric distributions include all soundings in May and June 2010



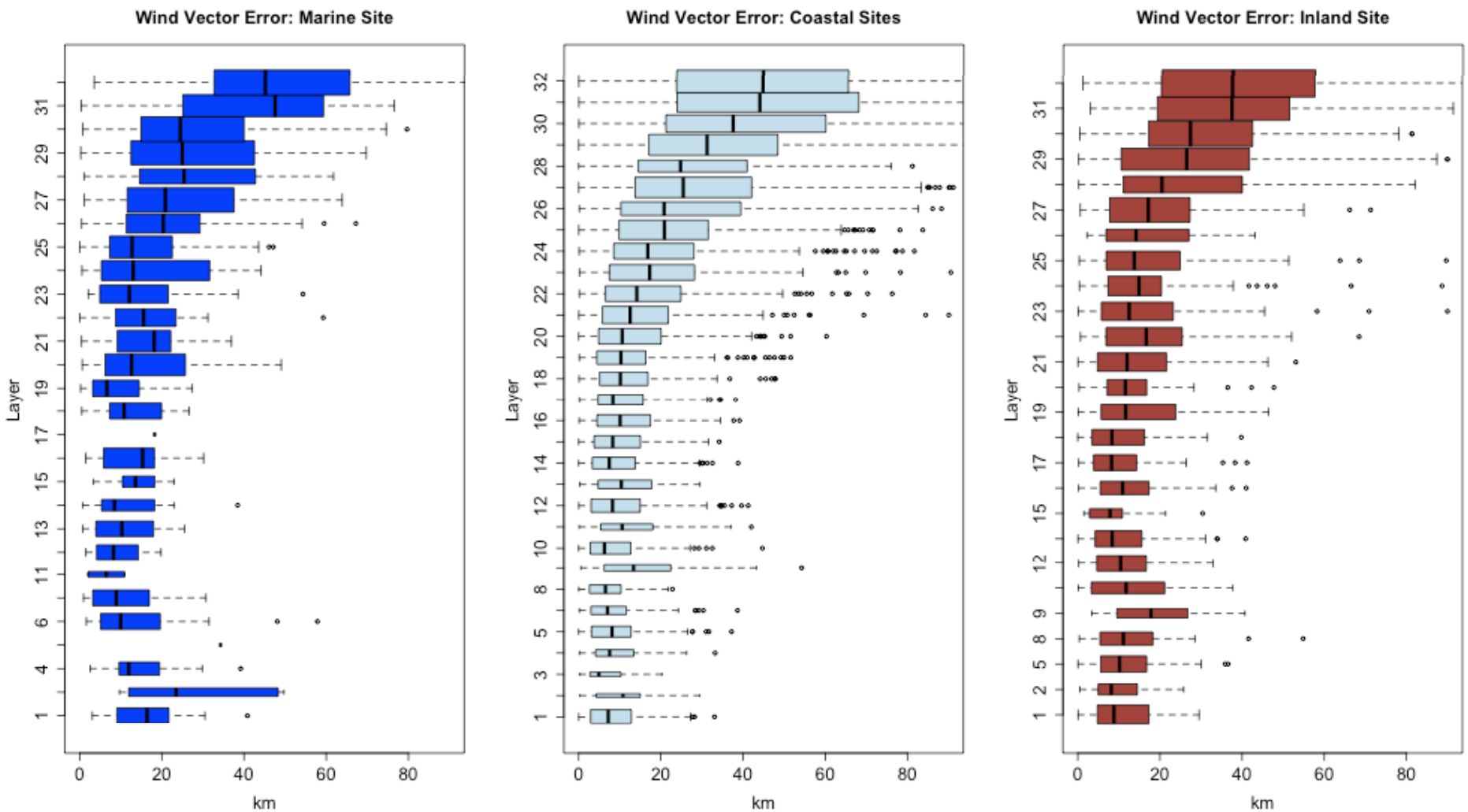
Temperature Bias (WRF-PX)



Wind Speed Bias (WRF-PX)

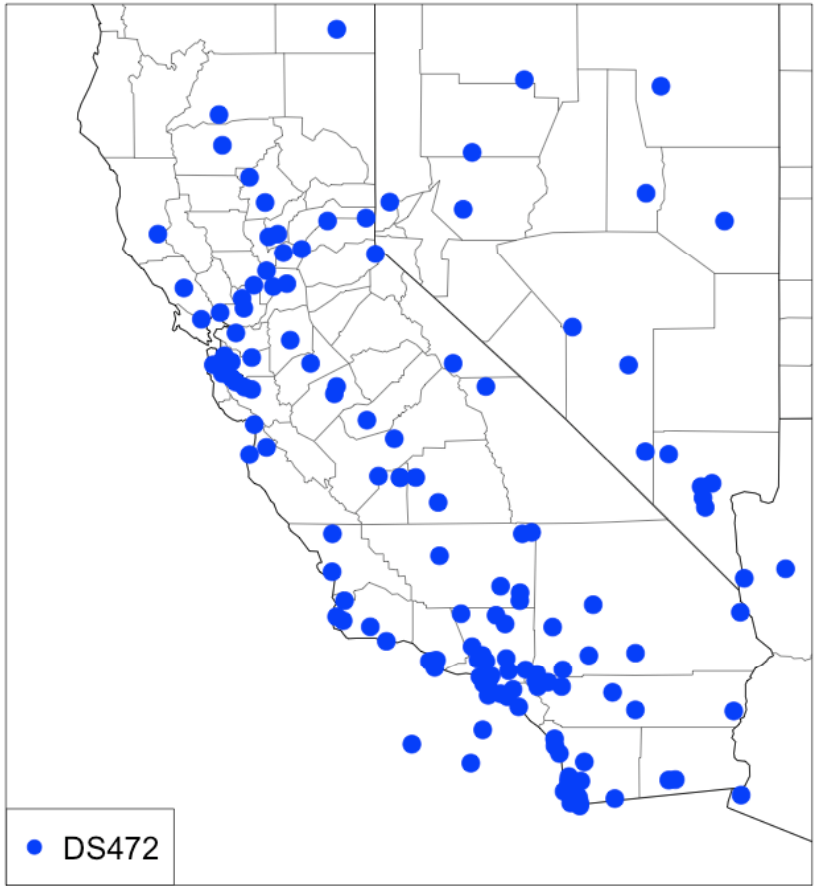


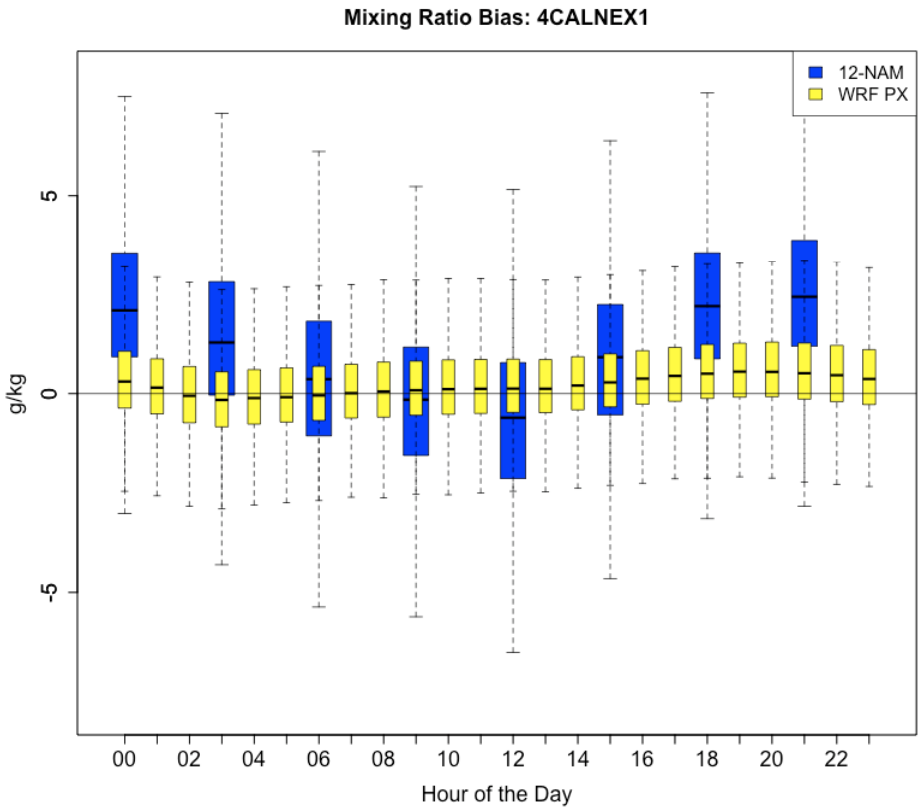
Wind Vector Error (WRF-PX)

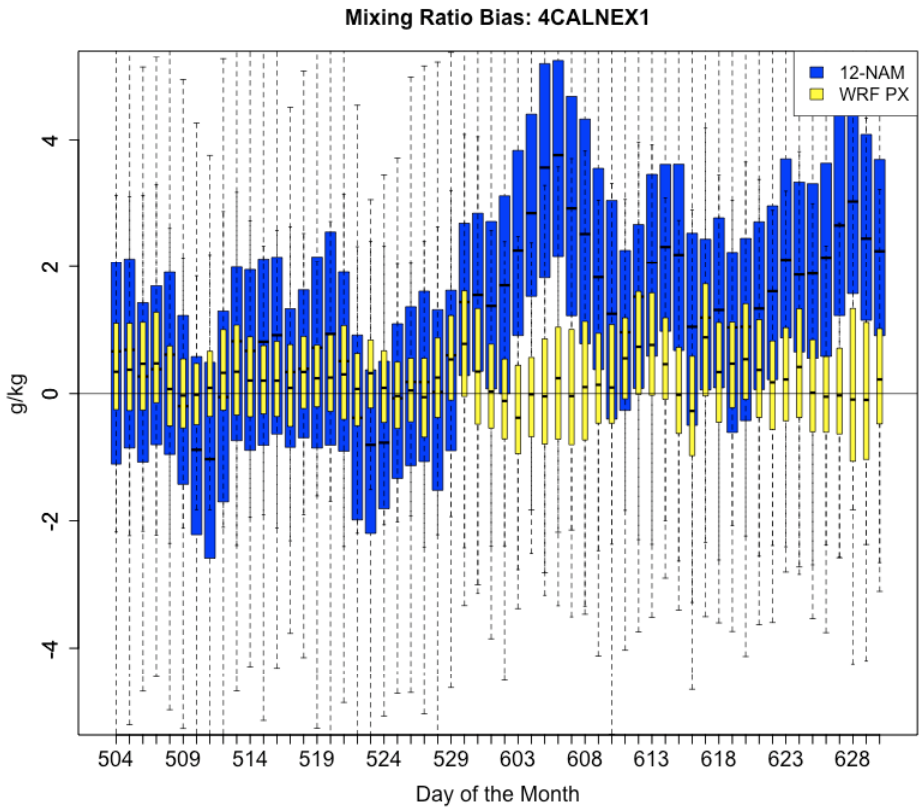


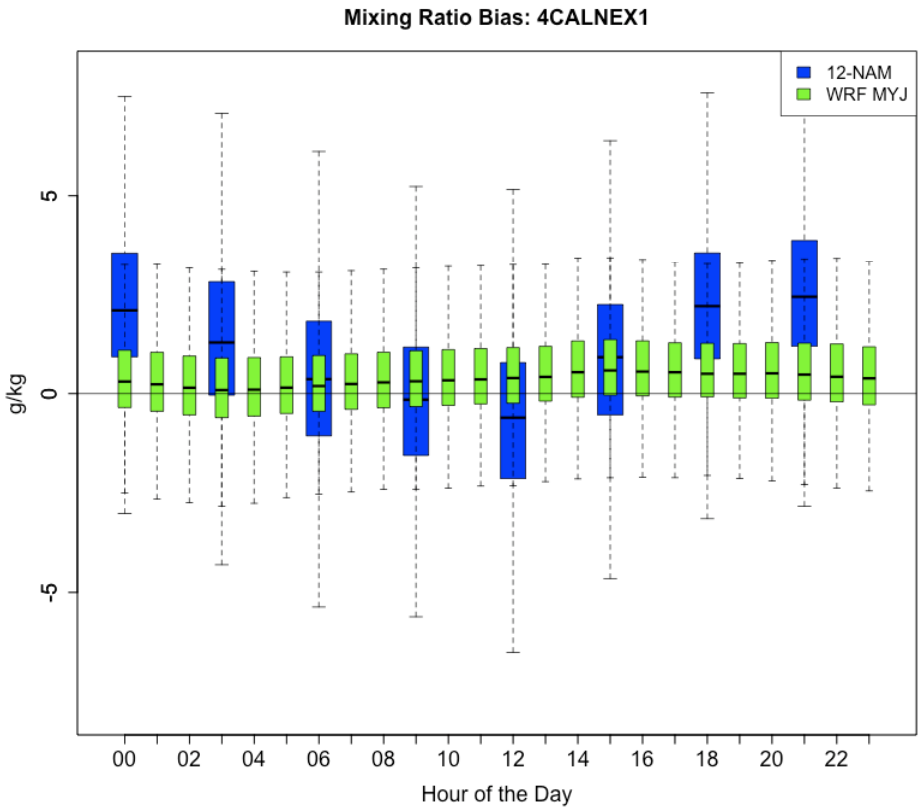
Evaluating WRF Input (12-NAM)

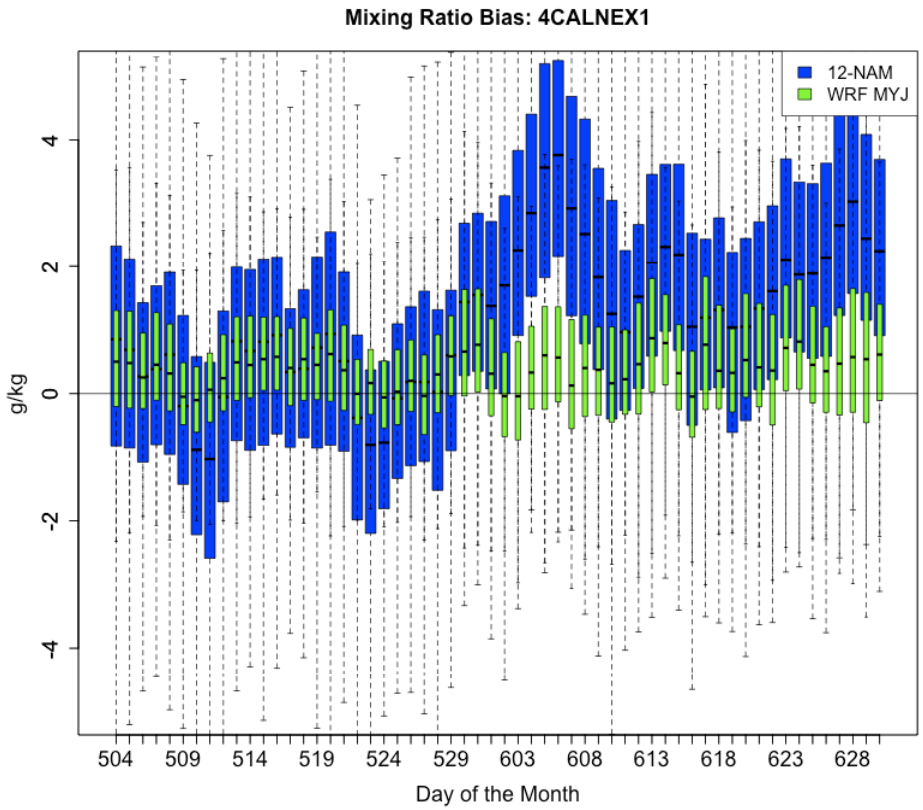
- Evaluate WRF surface estimates of T, MR, WS, and wind vector error against NCAR's ds472 US Airways dataset
- Stations used in the performance evaluation are shown at right
- Metrics shown comparing performance of **WRF output (PX) compared to WRF input (12-NAM**)

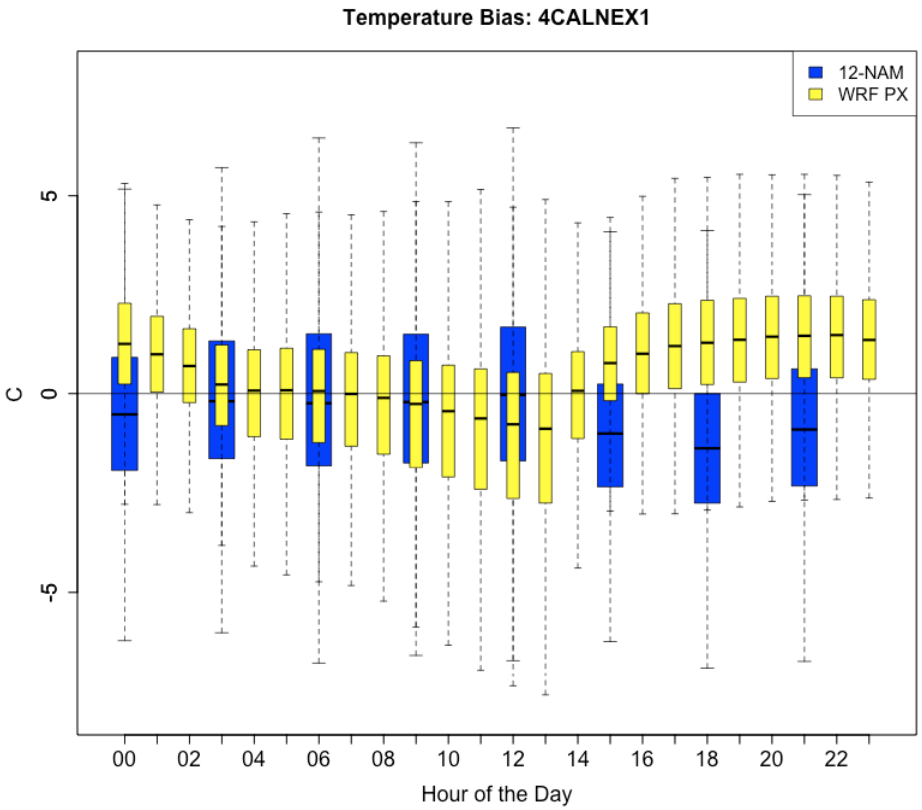


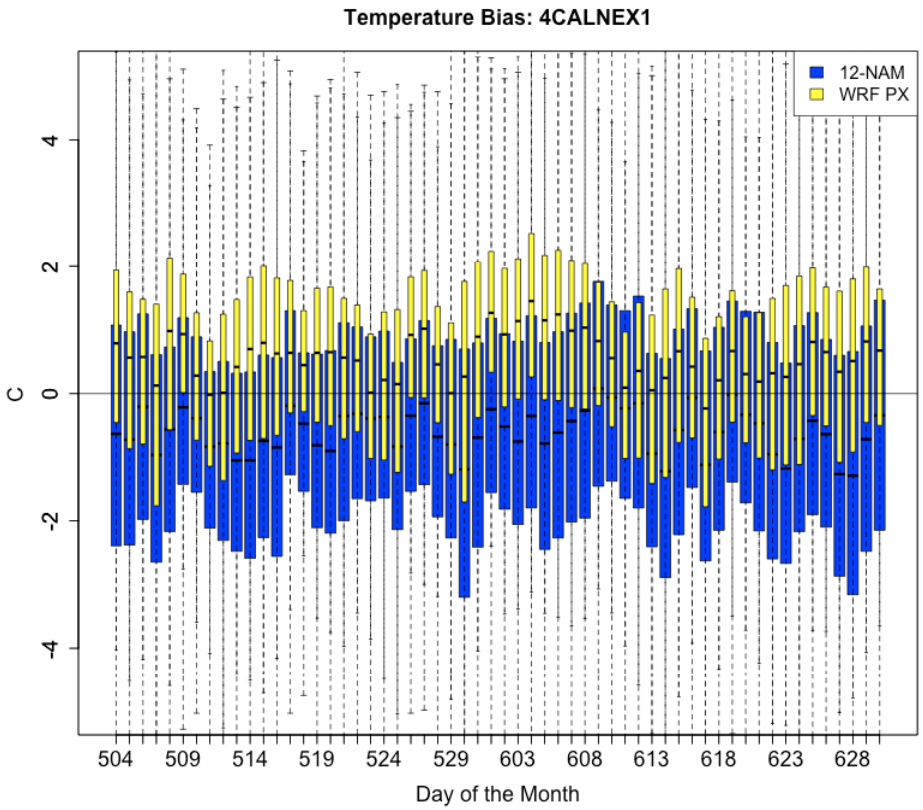

Mixing Ratio Bias: 4CALNEX1
12-NAM
WRF PX
g/kg
5
0
-5
00
02
04
06
08
10
12
14
16
18
20
22
Hour of the Day

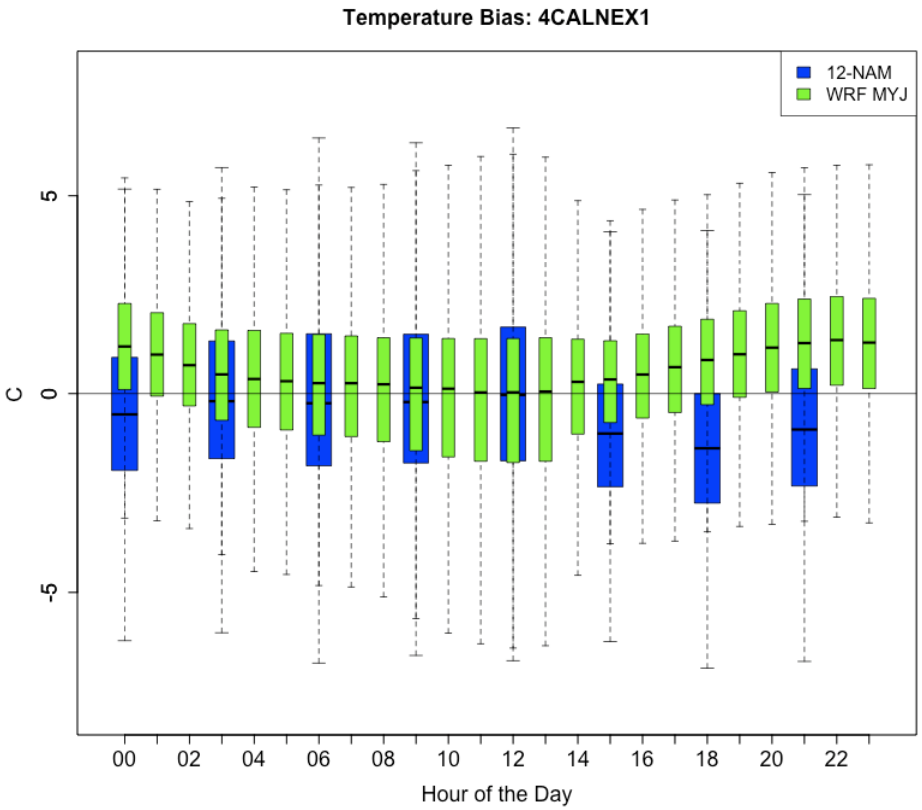

Mixing Ratio Bias: 4CALNEX1
12-NAM
WRF PX
g/kg
4
2
0
-2
-4
504
509
514
519
524
529
603
608
613
618
623
628
Day of the Month

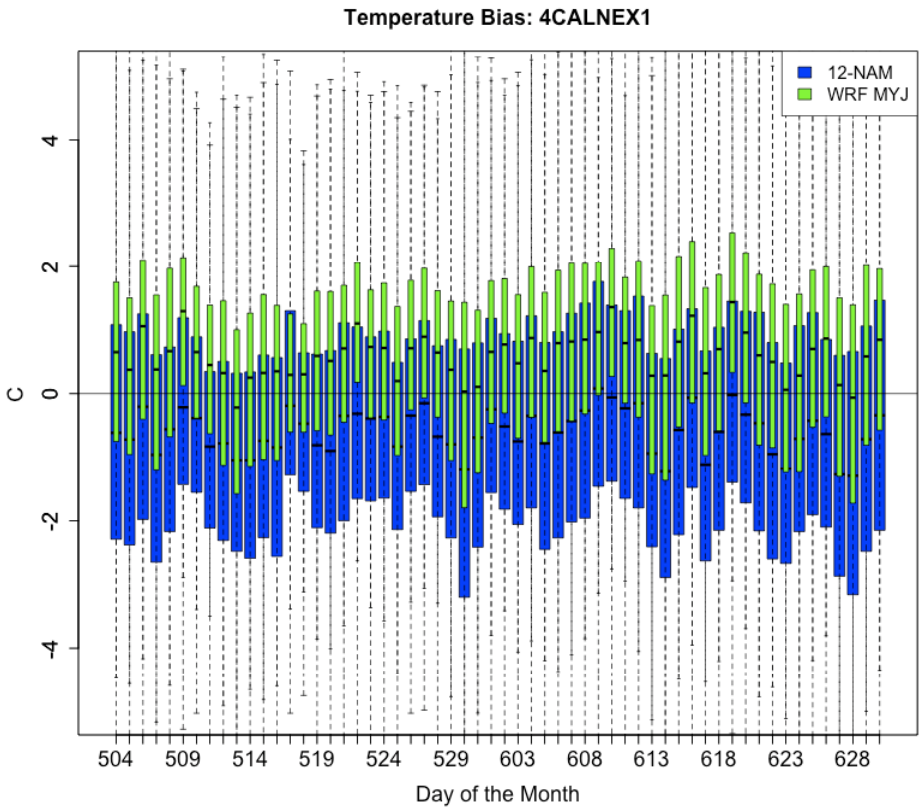

Mixing Ratio Bias: 4CALNEX1
12-NAM
WRF MYJ
g/kg
5
0
-5
00
02
04
06
08
10
12
14
16
18
20
22
Hour of the Day

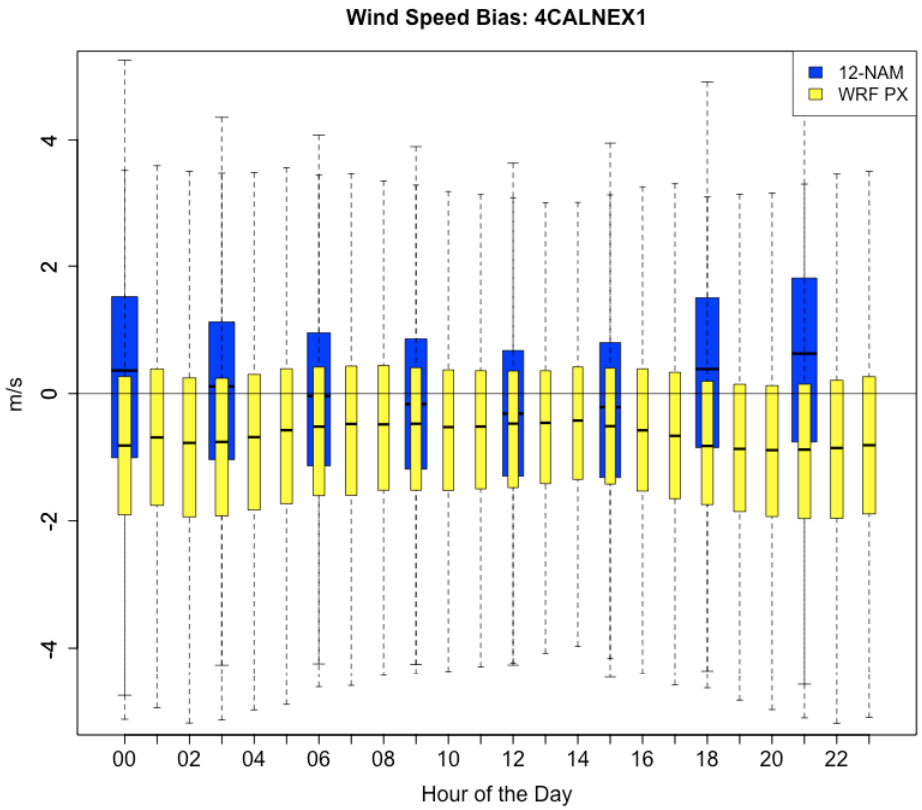

Mixing Ratio Bias: 4CALNEX1
12-NAM
WRF MYJ
g/kg
4
2
0
-2
-4
504
509
514
519
524
529
603
608
613
618
623
628
Day of the Month

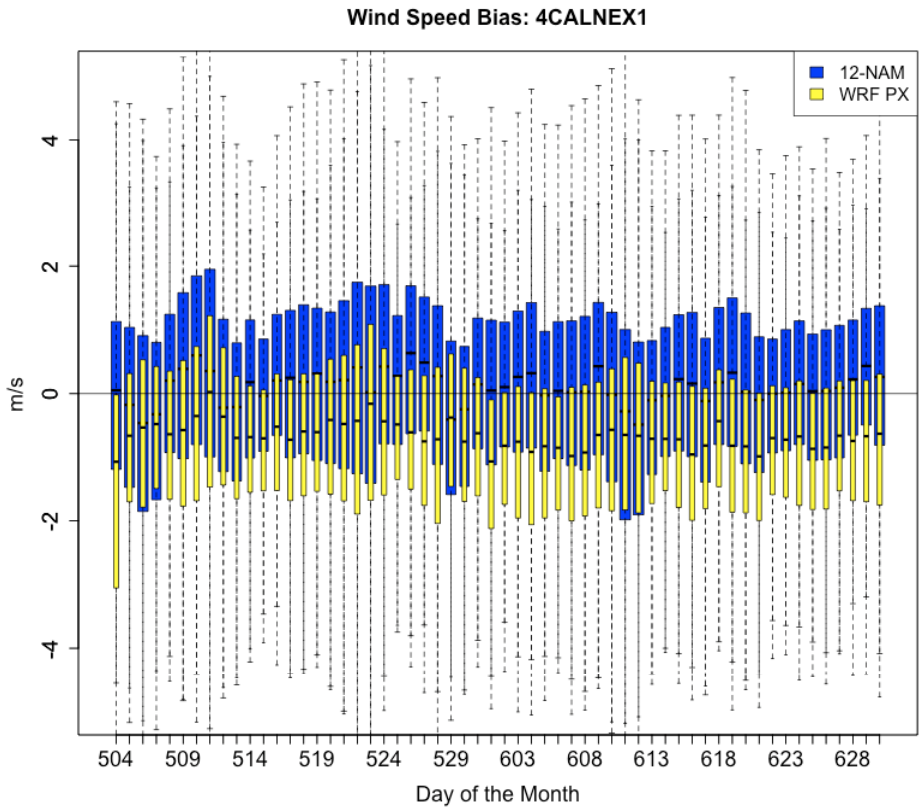

Temperature Bias: 4CALNEX1
12-NAM
WRF PX
C
5
0
-5
00
02
04
06
08
10
12
14
16
18
20
22
Hour of the Day

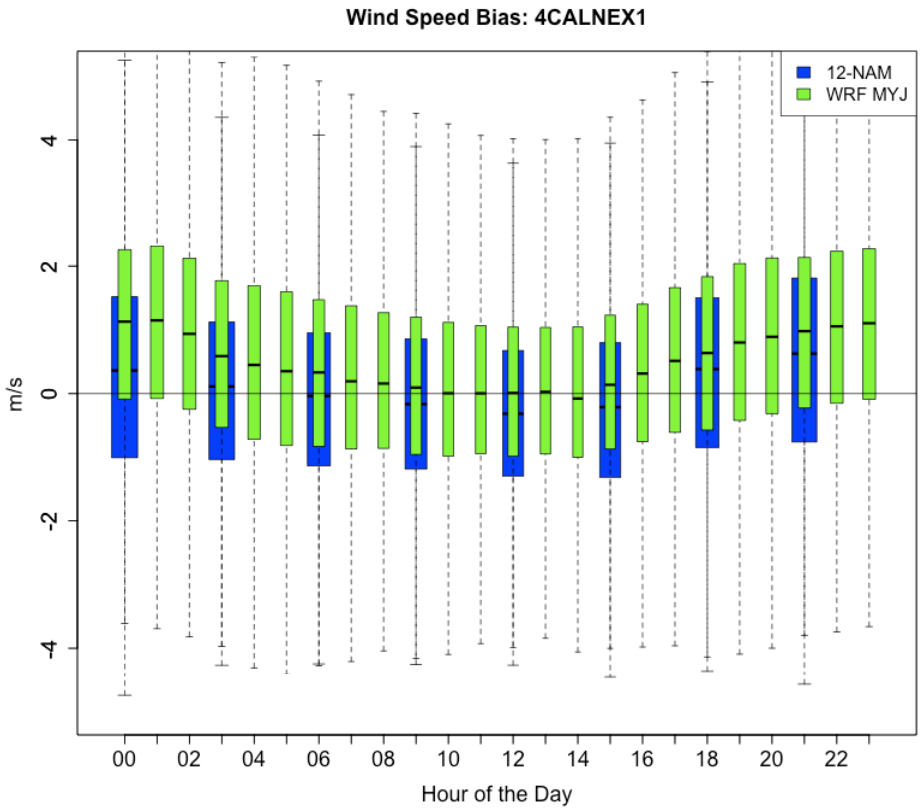

Temperature Bias: 4CALNEX1
12-NAM
WRF PX
C
4
2
0
-2
-4
504
509
514
519
524
529
603
608
613
618
623
628
Day of the Month

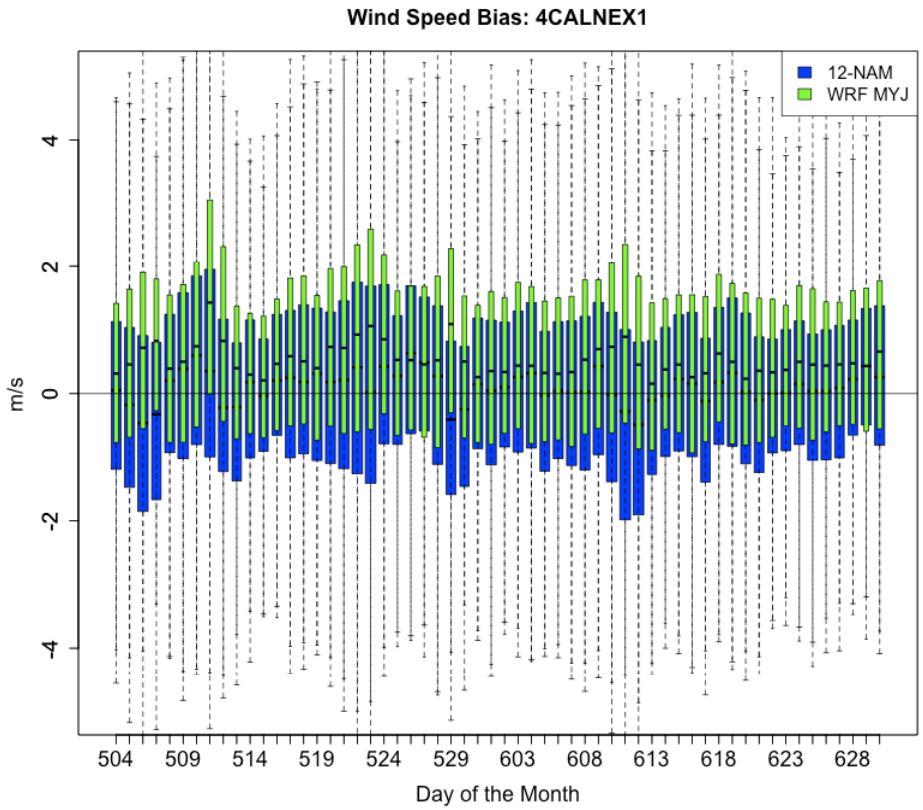

Temperature Bias: 4CALNEX1
12-NAM
WRF MYJ
C
5
0
-5
00
02
04
06
08
10
12
14
16
18
20
22
Hour of the Day

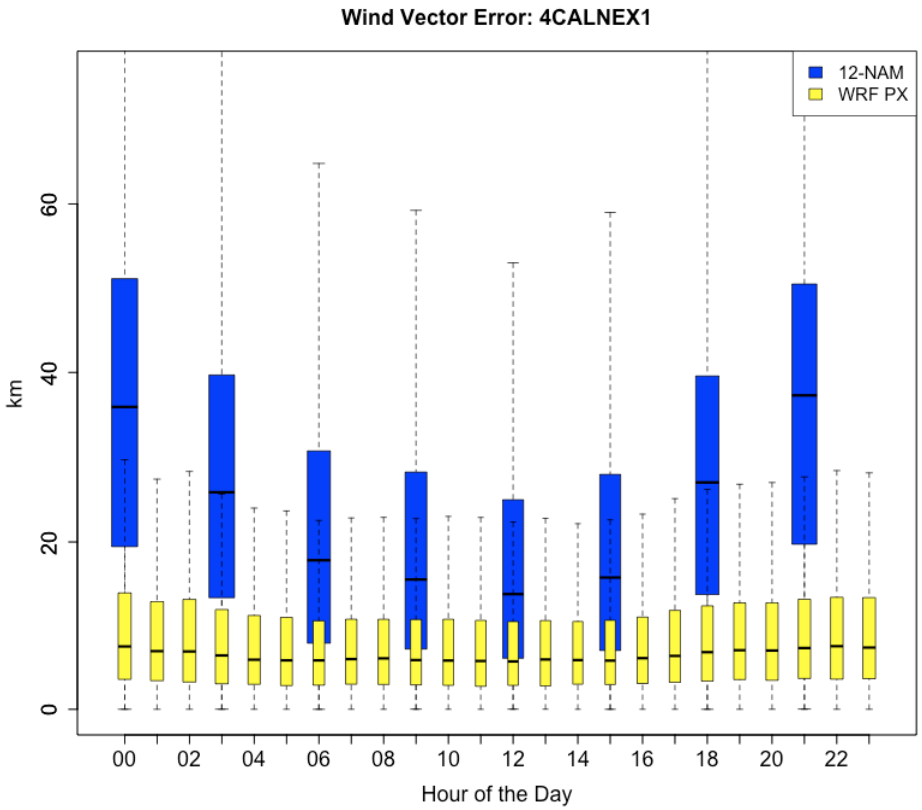

Temperature Bias: 4CALNEX1
12-NAM
WRF MYJ
C
4
2
0
-2
-4
504
509
514
519
524
529
603
608
613
618
623
628
Day of the Month

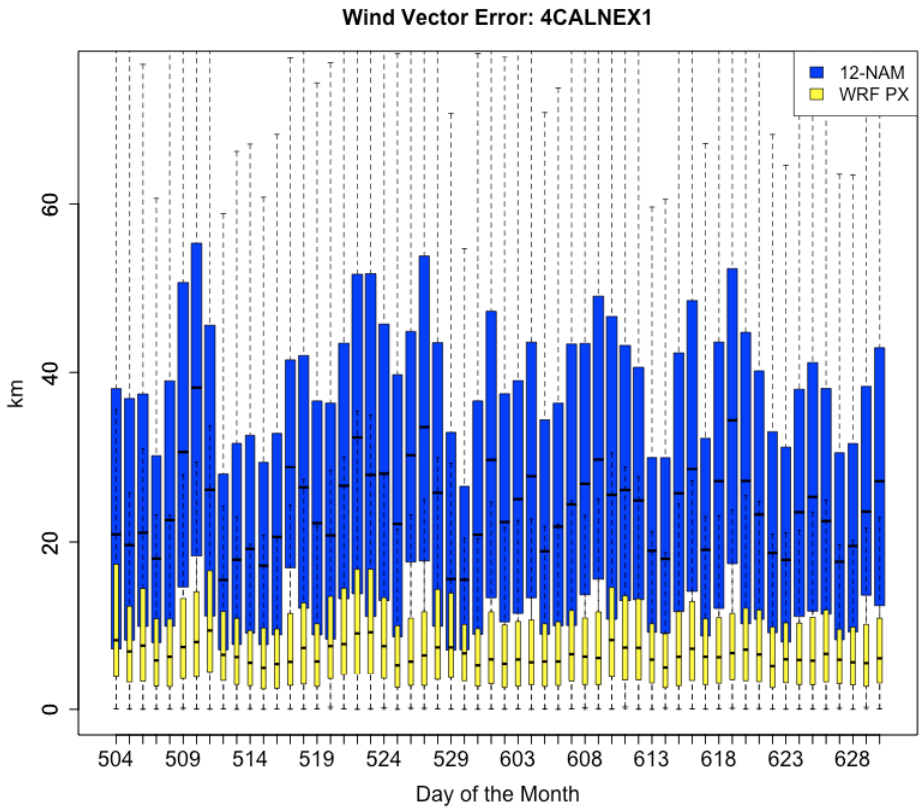

Wind Speed Bias: 4CALNEX1
12-NAM
WRF PX
m/s
4
2
0
-2
-4
00
02
04
06
08
10
12
14
16
18
20
22
Hour of the Day


Wind Speed Bias: 4CALNEX1
12-NAM
WRF PX
m/s
4
2
0
-2
-4
504
509
514
519
524
529
603
608
613
618
623
628
Day of the Month


Wind Speed Bias: 4CALNEX1
12-NAM
WRF MYJ
m/s
4
2
0
-2
-4
00
02
04
06
08
10
12
14
16
18
20
22
Hour of the Day


Wind Speed Bias: 4CALNEX1
12-NAM
WRF MYJ
m/s
4
2
0
-2
-4
504
509
514
519
524
529
603
608
613
618
623
628
Day of the Month


Wind Vector Error: 4CALNEX1
12-NAM
WRF PX
km
0
20
40
60
00
02
04
06
08
10
12
14
16
18
20
22
Hour of the Day


Wind Vector Error: 4CALNEX1
12-NAM
WRF PX
km
0
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40
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504
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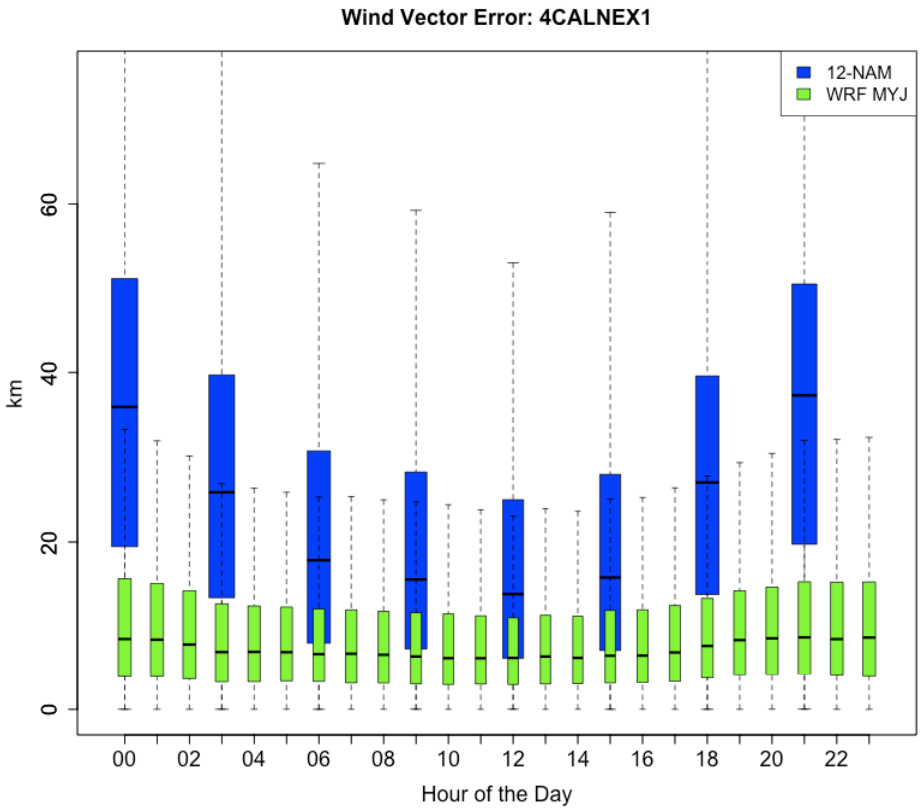
514
519
524
529
603
608
613
618
623
628
Day of the Month


Wind Vector Error: 4CALNEX1
12-NAM
WRF MYJ
km
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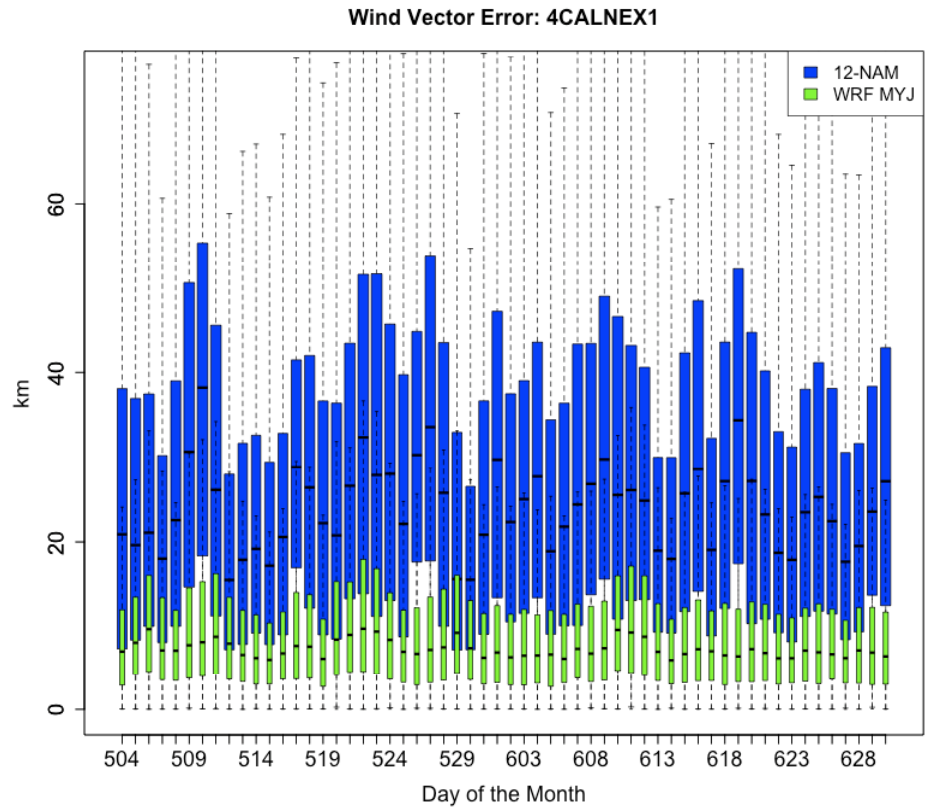
Hour of the Day


Wind Vector Error: 4CALNEX1
12-NAM
WRF MYJ
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Day of the Month

Remarks

- Boundary layer height typically well represented during the CALNEX flight periods and locations; includes marine layer, flat and complex terrain
- PX tends to have slight low wind speed bias and MYJ-NOAH has slight high wind speed bias
- Temperature performance degrades during the morning hours during this time period
- Biases in the input analysis are somewhat noticeable in the WRF simulations, but greatly minimized; WRF compares better to observation data than the input analysis (12-NAM) for this period and these locations
- Solar radiation and rainfall generally well characterized by the WRF modeling applications for this period and location

Acknowledgements

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