

# MM5 Sensitivity Project

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Lake Michigan Air Directors Consortium

<http://www.ladco.org/aqmnew/modeling.html>

# Background

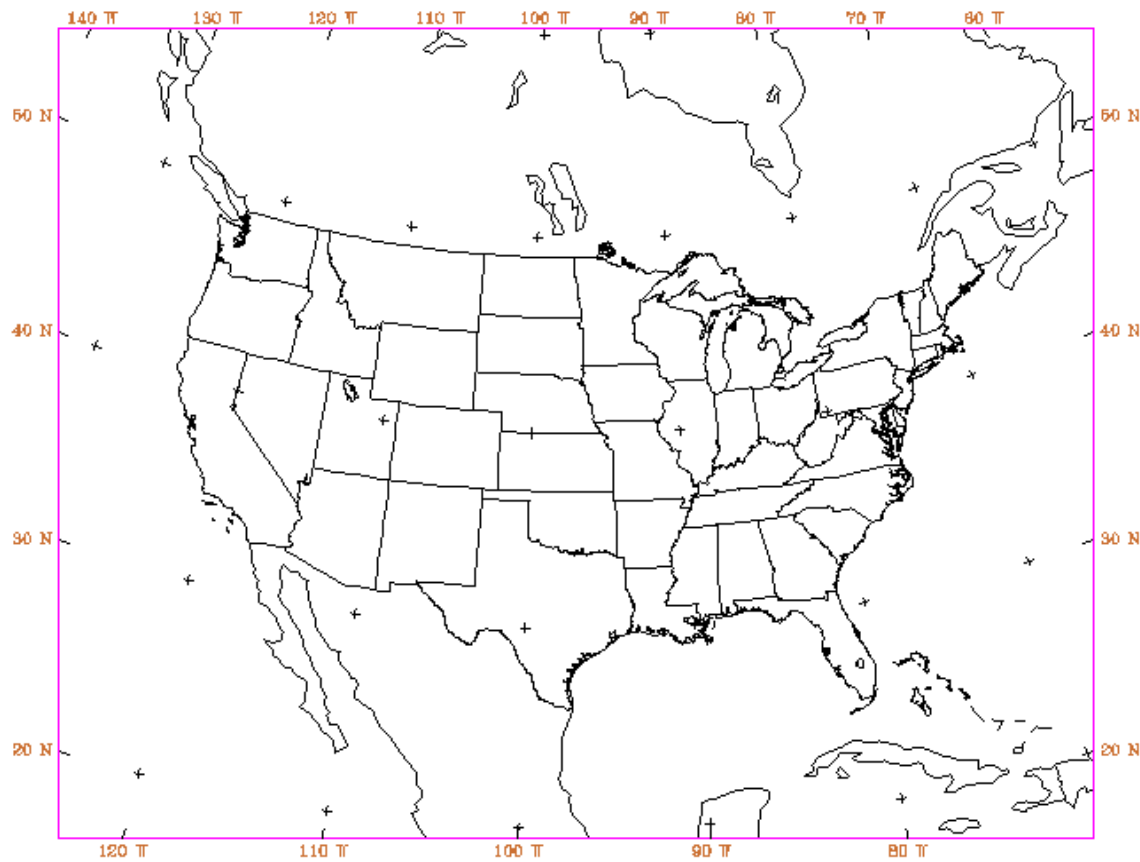
- MM5 version 3.5
- Modeled July 1 - 17, 2001
- Run in 5 day blocks 12Z to 12Z
- The first 12 hours of each run designated spin-up

- Red Hat Linux v7.1 OS
- Single Athlon 1.4 GHz processors (8 total)
- Portland Group Compiler

# Objectives

...in terms of model performance

- Quantify relative differences in physics options
- Quantify resource requirements of selected physics options
- Quantify relative differences in model initialization approach
  
- Identify an optimal group of physics options
- Identify an optimal approach for model initialization



## Lambert Conformal Grid

Center -97,40 & True Latitudes 33,45

$NX = 165, NY = 129, NZ = 35, DX = 36\text{km}$

k(MM5)	sigma	press.(mb)	height(m)	depth(m)
35	0.000	10000	15674	2004
34	0.050	14500	13670	1585
33	0.100	19000	12085	1321
32	0.150	23500	10764	1139
31	0.200	28000	9625	1004
30	0.250	32500	8621	900
29	0.300	37000	7720	817
28	0.350	41500	6903	750
27	0.400	46000	6153	558
26	0.440	49600	5595	527
25	0.480	53200	5068	499
24	0.520	56800	4570	474
23	0.560	60400	4096	451
22	0.600	64000	3644	431
21	0.640	67600	3213	311
20	0.670	70300	2902	302
19	0.700	73000	2600	293
18	0.730	75700	2308	284
17	0.760	78400	2023	231
16	0.785	80650	1793	226
15	0.810	82900	1567	221
14	0.835	85150	1346	173
13	0.855	86950	1173	170
12	0.875	88750	1003	167
11	0.895	90550	836	124
10	0.910	91900	712	122
9	0.925	93250	590	121
8	0.940	94600	469	80
7	0.950	95500	389	79
6	0.960	96400	310	78
5	0.970	97300	232	78
4	0.980	98200	154	46
3	0.986	98740	108	46
2	0.992	99280	61	31
1	0.996	99640	31	31
0	1.000	100000	0	0

# Sensitivity Runs

- Base run
- Z-FAC mod
- Moisture
- Cumulus
- PBL
- ETA v NNRP
- ETA INIT v ETA ANAL
- Inclusion of objective analysis step (RAWINS)
- Land surface modules
- MPP v Serial
- Sea Surface Temp
- Shallow convection

# Starting Set of Options (Base)

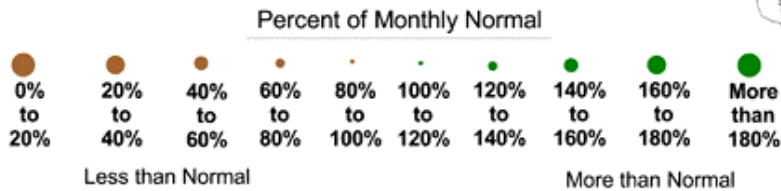
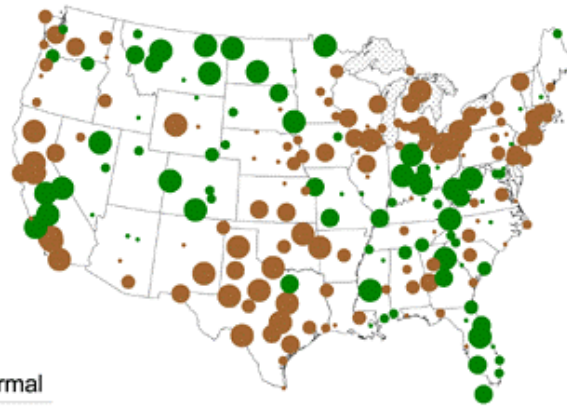
Base Run Configuration	National RPO (Dom 1)
REGRID input	ETA (AWIP grib definitions)
RAWINS input	NONE
LITTLE R input	NONE
Explicit Moisture	Simple ice
Cumulus	Kain-Fritsch
PBL	MRF
Radiation	RRTM
Multi-Layer Soil Model	Yes
Shallow convective option	No
4-D Data Assimilation	Analysis nudging on; only above PBL
Split Model Output	Every 24 hours

# July 2001 Weather

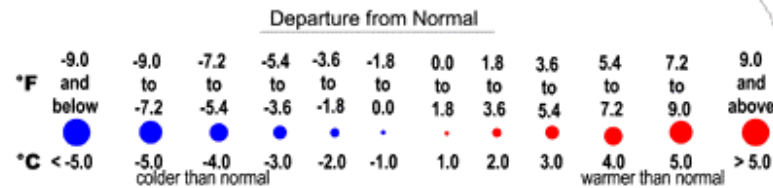
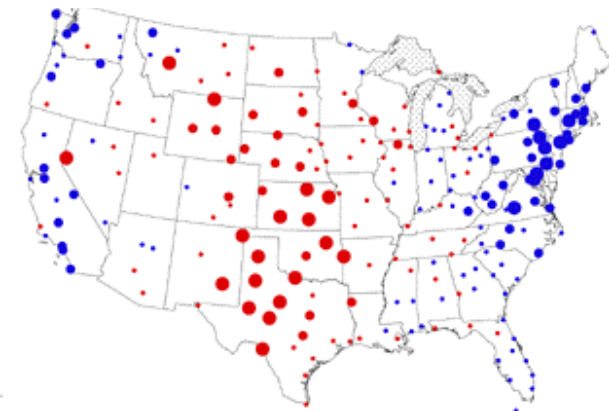


National Climatic Data Center, NOAA

## July 2001 Precipitation Percent of 1961-90 Normal



## July 2001 Mean Temperature Departure from 1961-90 Normal



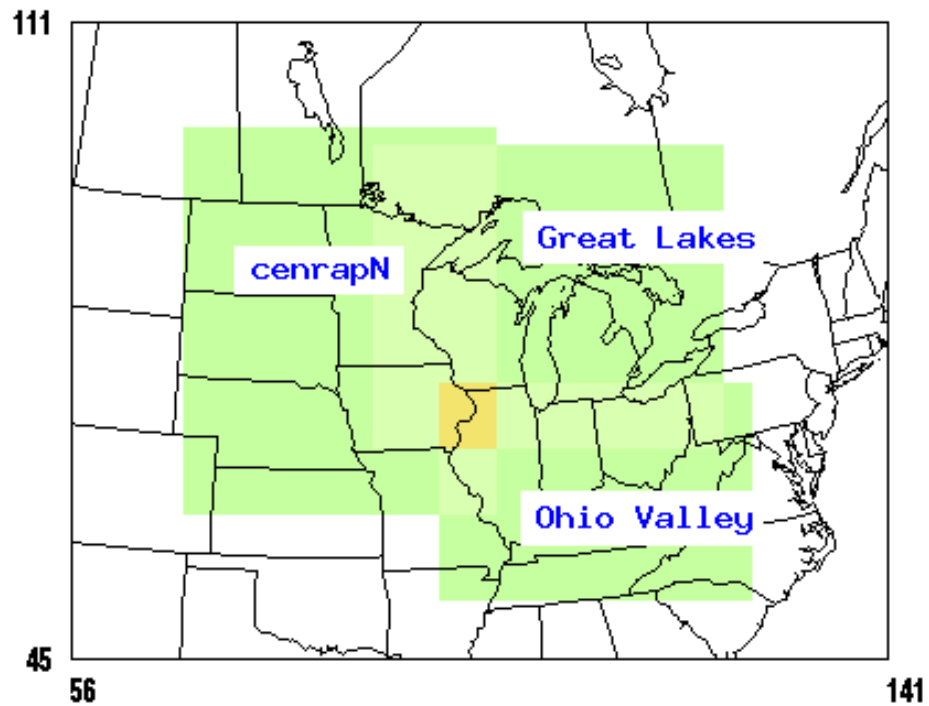
# Model Performance Assessment

- **Qualitative**
  - 12 hourly UNISYS plots
  - 12 hourly infrared satellite photos
  - Sounding plots (0Z and 12Z) for 8 stations
- **Quantitative** (for 3 sub-regions)
  - Daily and hourly statistics: RMSE, IOA, Bias, Gross Error, Prediction Mean, Observation Mean
  - Daily model performance statistics based on 24 hours from 0Z to 23Z

Tools: mm5camx, PAVE, METSTAT, gnuplot



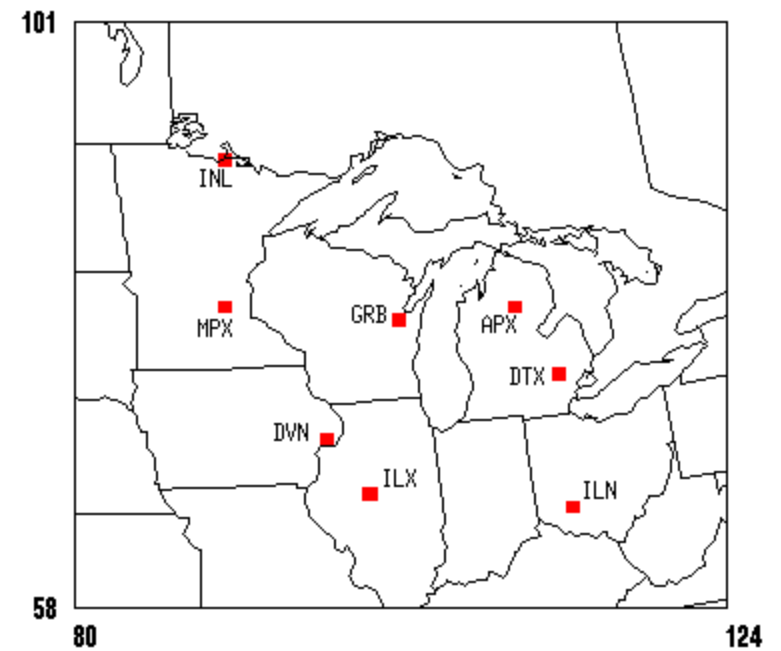
## MM5 Model Performance Regions



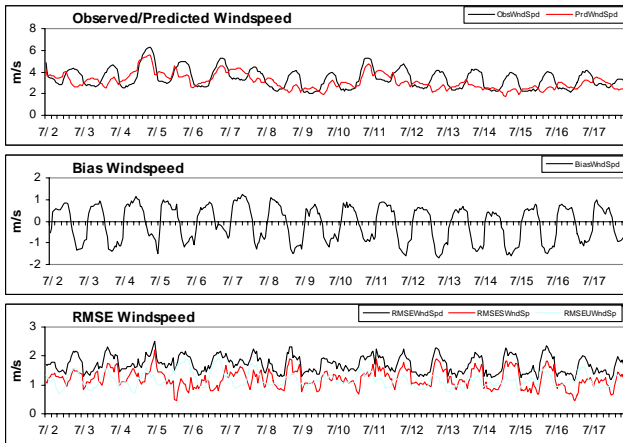
\*Approximate Number of Stations:

Great Lakes (280) Ohio Valley (190) cenrapN (270)

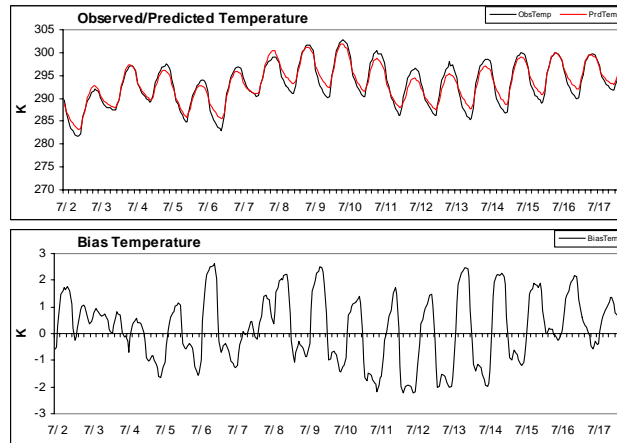
## Upper Air Meteorological Monitors



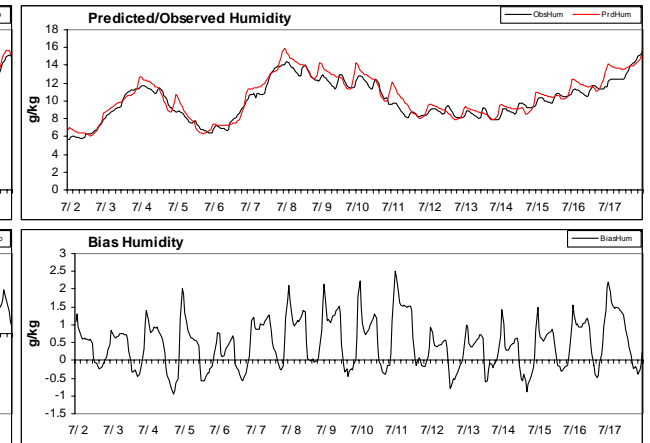
LADCO Natl 36km (gl SikfMRrr)



LADCO Natl 36km (gl SikfMRrr)

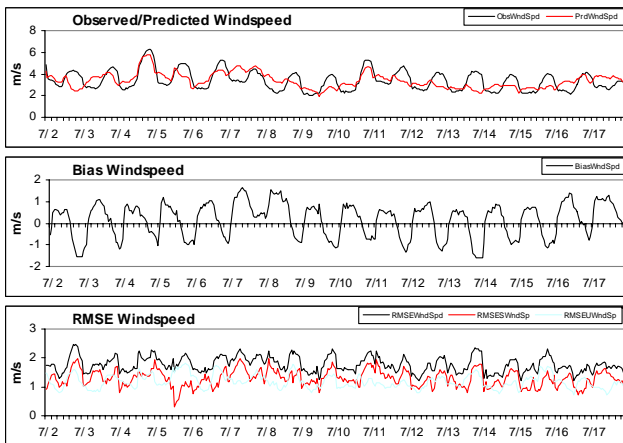


LADCO Natl 36km (gl SikfMRrr)

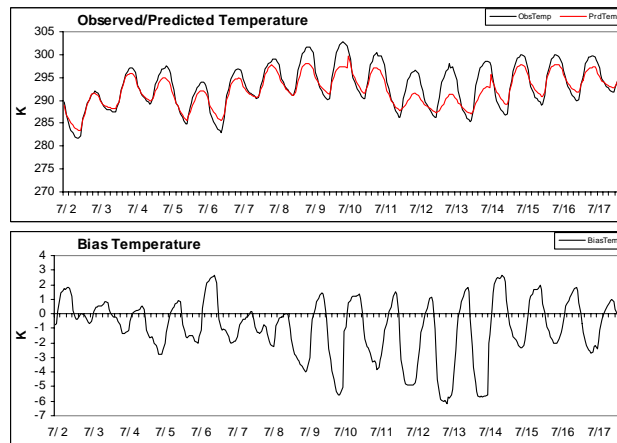


## Great Lakes Region - Base Case (top) and ZFAC (bottom)

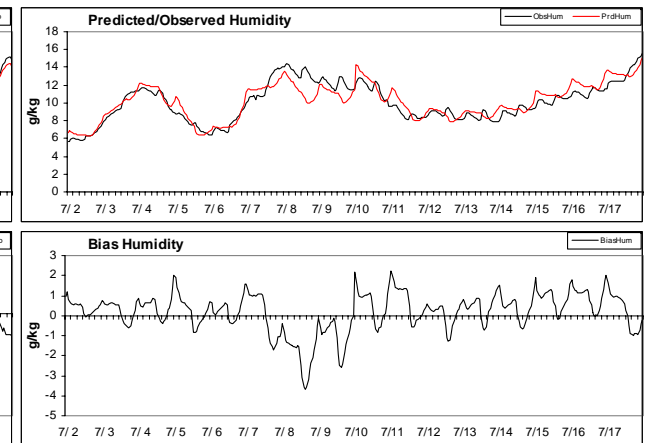
LADCO Natl 36km (gl SikfMRrr\_zfac)



LADCO Natl 36km (gl SikfMRrr\_zfac)

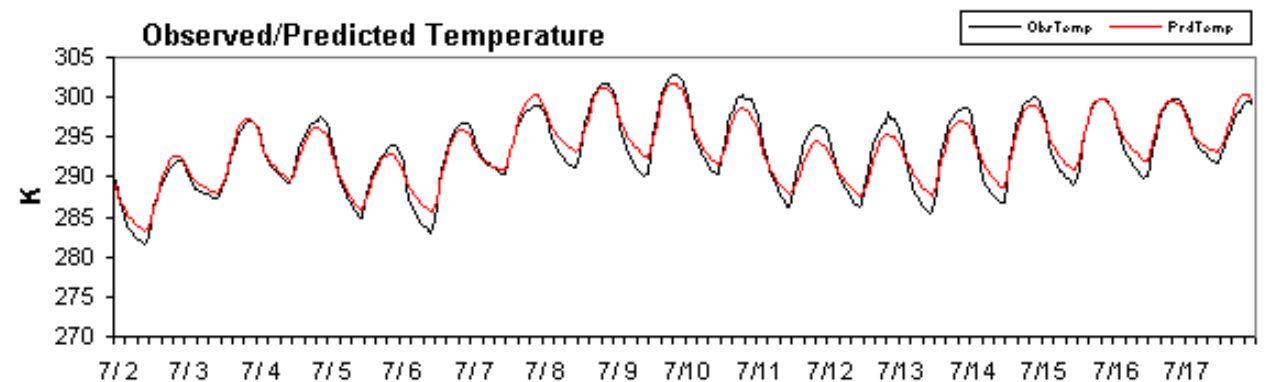
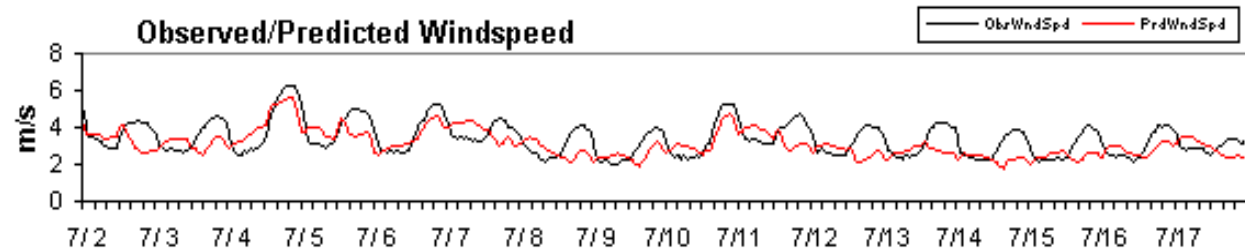
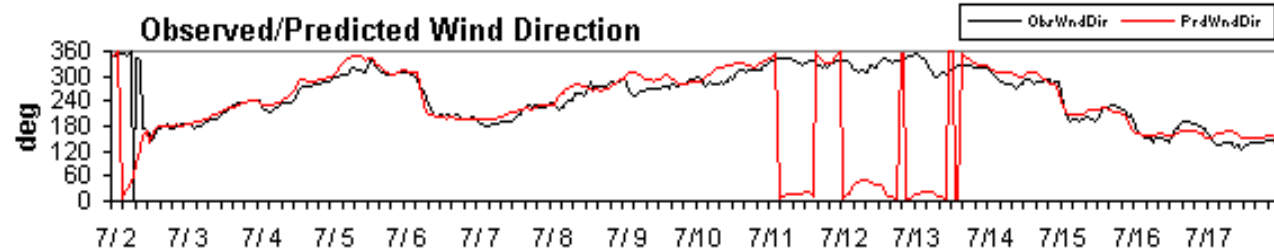
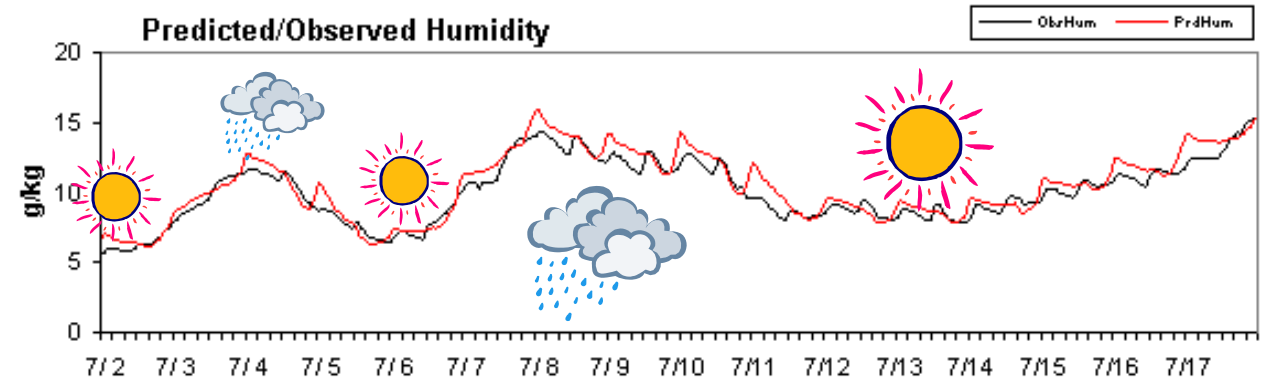


LADCO Natl 36km (gl SikfMRrr\_zfac)



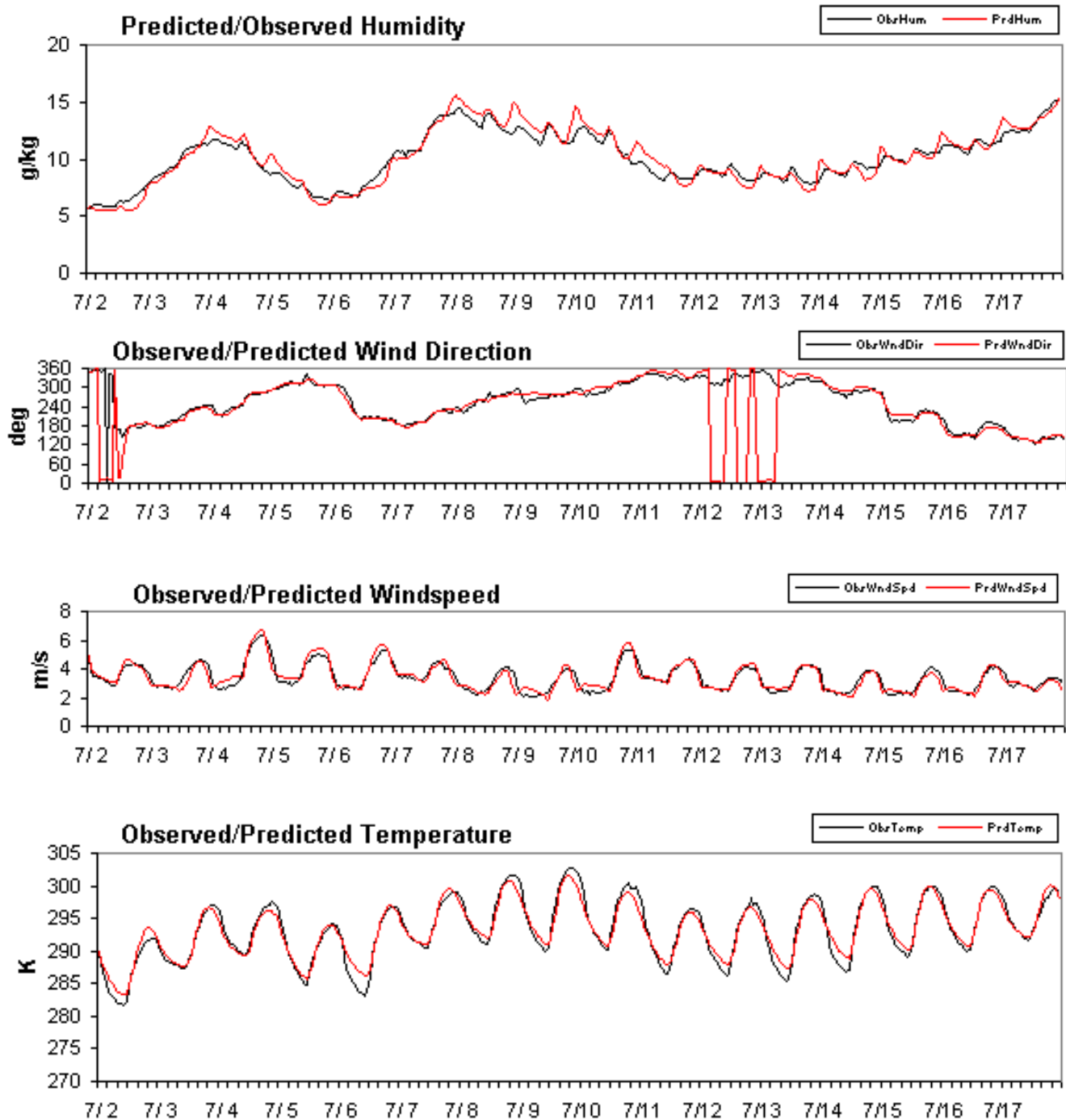
Great Lakes Area -  
Base Run (simple  
ice, kain-fritsh, mrf,  
rrtm)

- Not matching  
observed humidity  
spikes
- Wind speed does not  
seem to match diurnal  
patterns
- Not quite matching  
temperature maximum  
and minimum values
- These charts indicate  
the potential exists for  
pollution to not move  
far enough downwind  
during the daytime  
hours in an air quality  
model



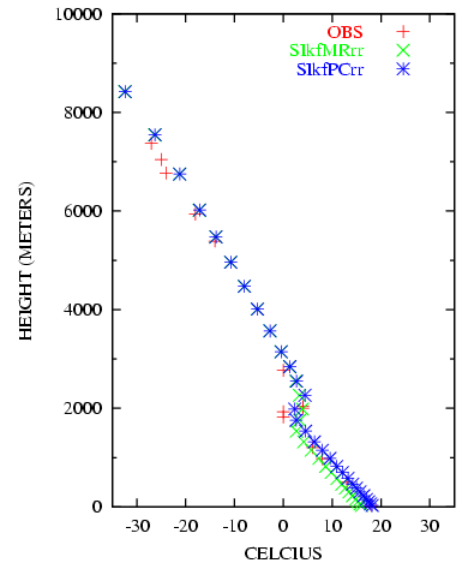
Great Lakes Area -  
(simple ice, kain-  
fritsh, PC, rrtm)

- Improved humidity prediction
- Improved maximum temperature prediction
- Vastly improved wind field prediction
- Should result in more accurate pollution transport

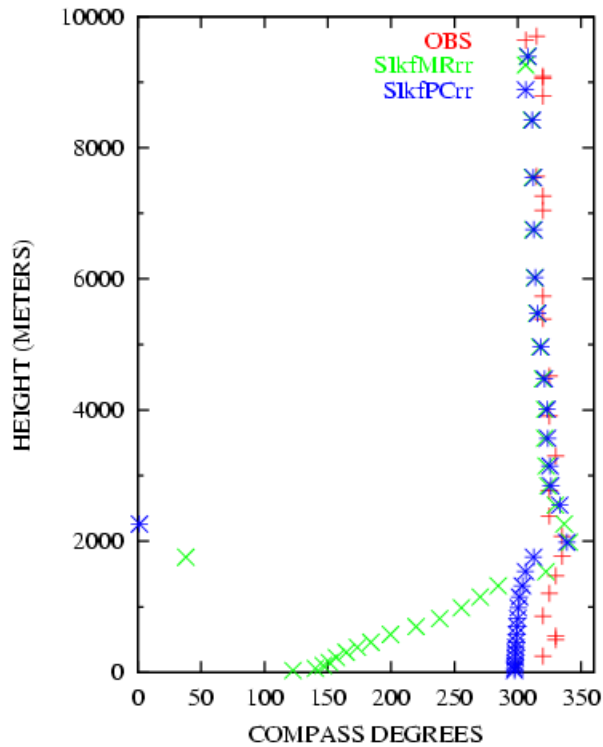


# PX (blue) vs Base Run (green) Observations (red)

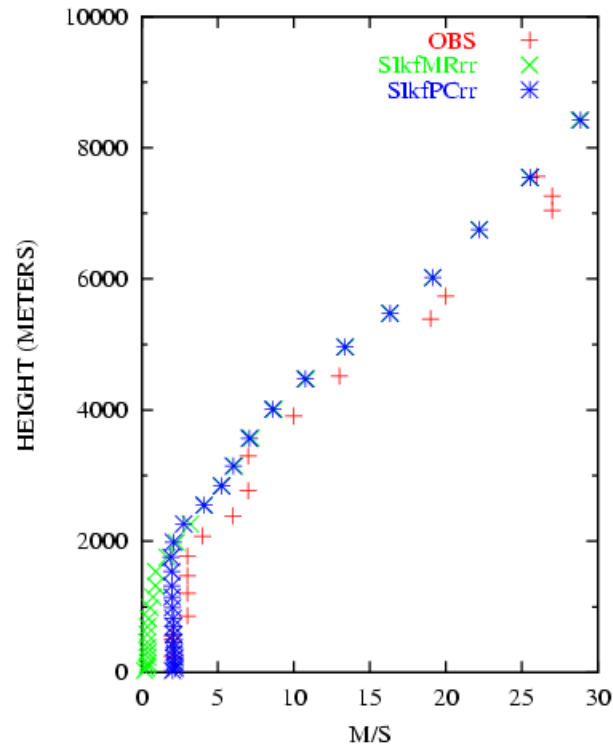
Temperature - INL (010702:0 GMT) LADCO



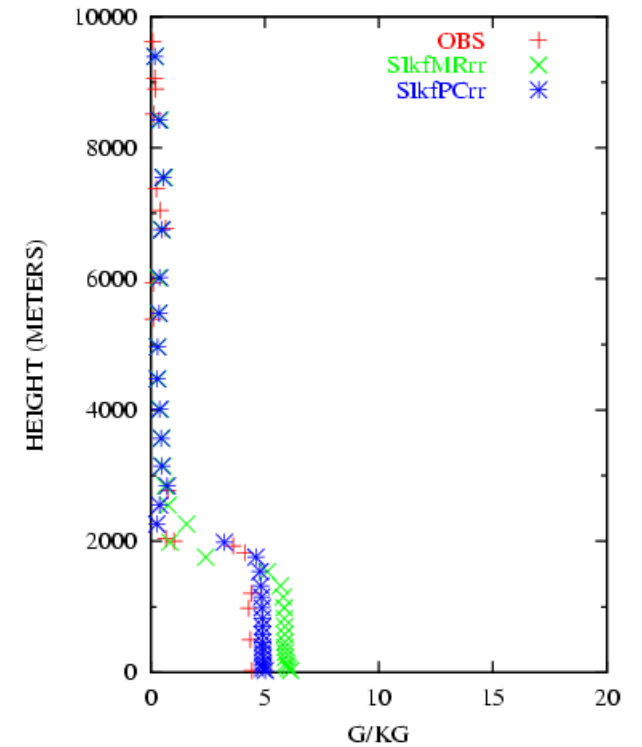
Wind Direction - INL (010702:0 GMT) LADCO



Wind Speed - INL (010702:0 GMT) LADCO

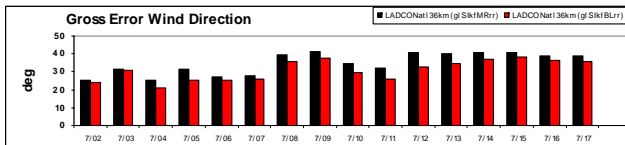
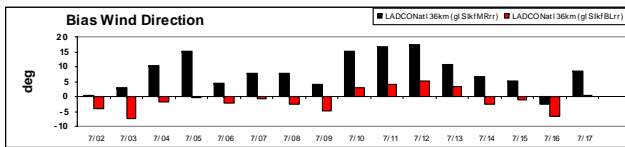
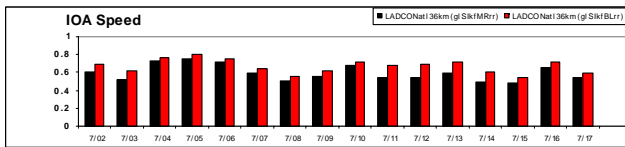
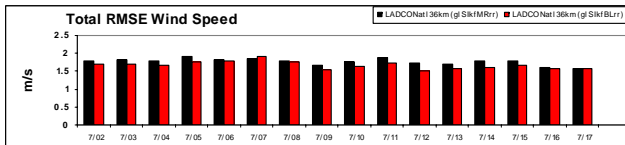
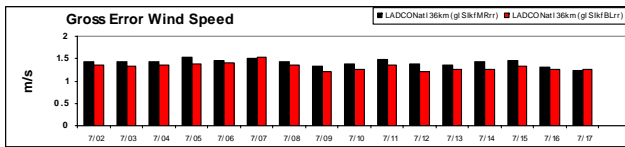
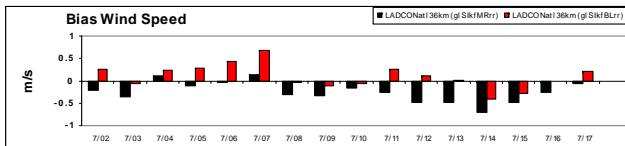


Mixing Ratio - INL (010702:0 GMT) LADCO

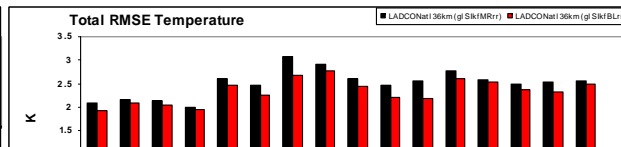
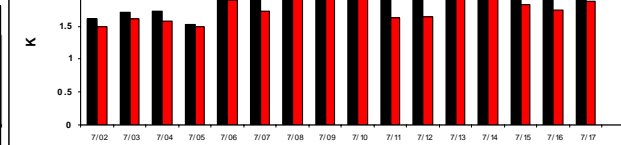
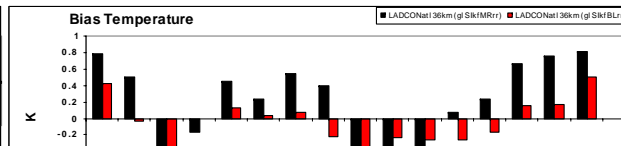


# MRF (black) Blackadar (red)

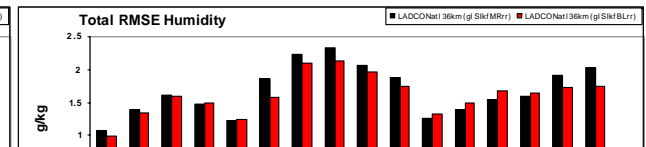
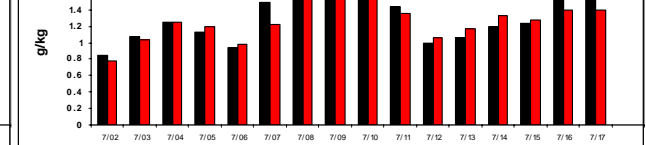
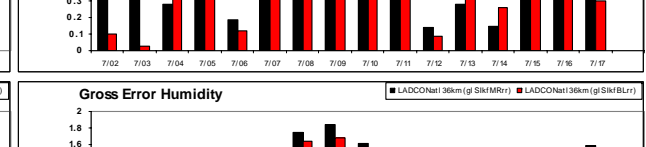
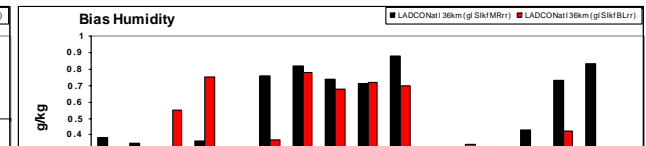
LADCO Natl 36km (gI SIKfMrrr), LADCO Natl 36km (gI SIKfBLrr).



LADCO Natl 36km (gI SIKfMrrr), LADCO Natl 36km (gI SIKfBLrr).



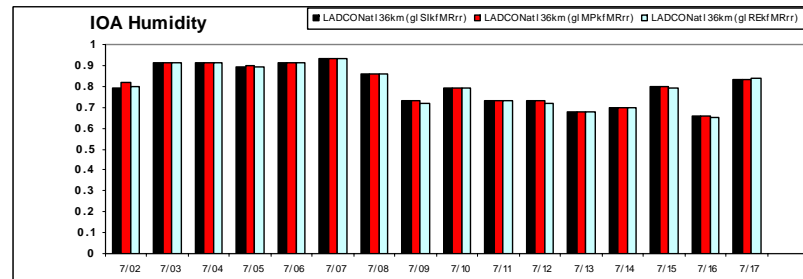
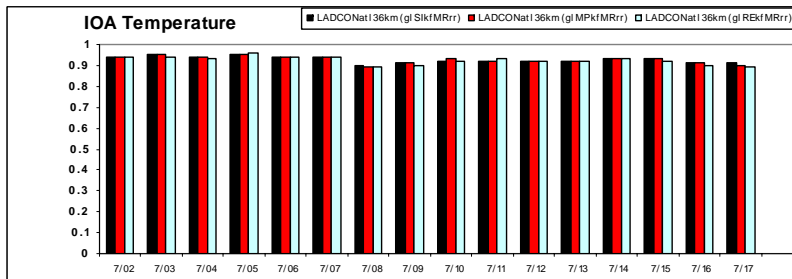
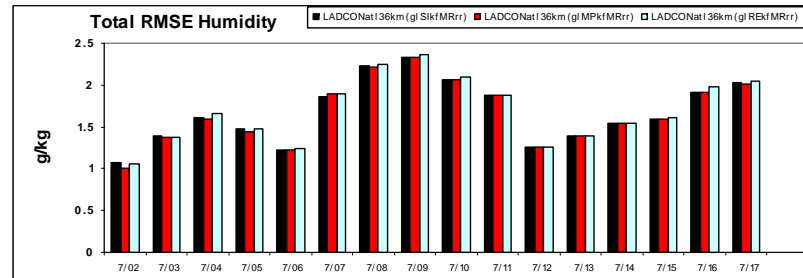
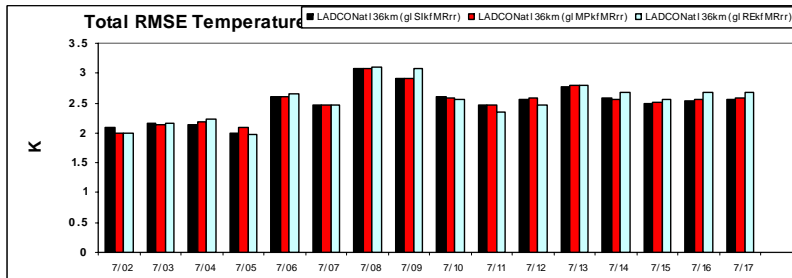
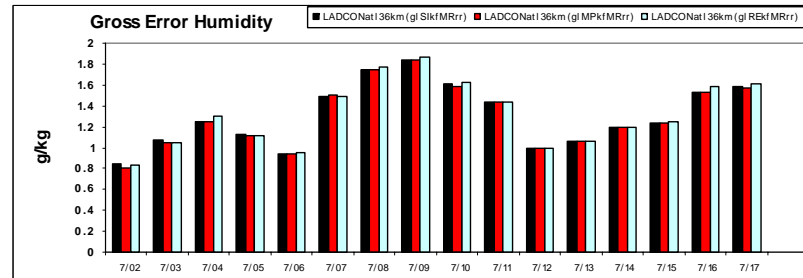
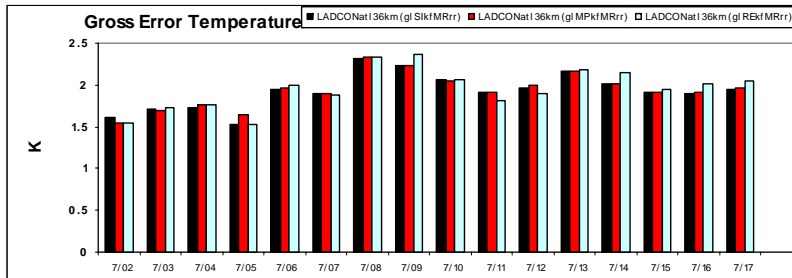
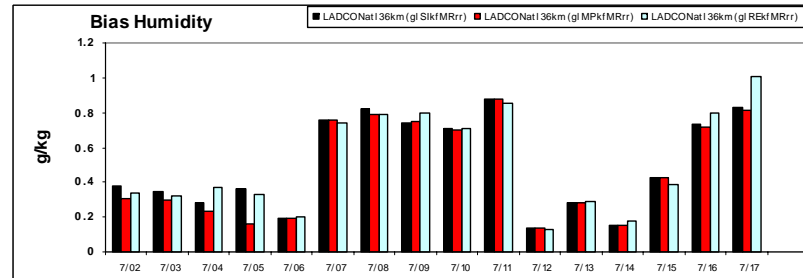
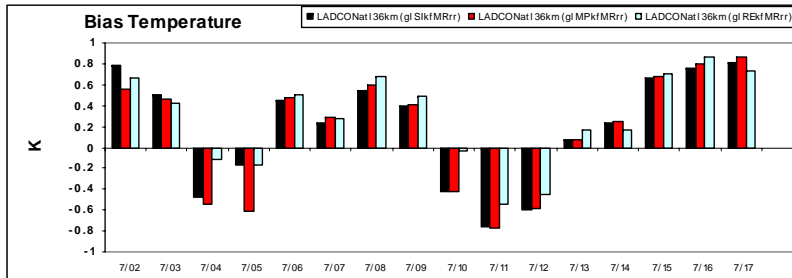
LADCO Natl 36km (gI SIKfMrrr), LADCO Natl 36km (gI SIKfBLrr).



# Simple Ice (black) Mixed Phase (red) Reisner (blue)

LADCO Natl 36km (gl SIKfMRrr), LADCO Natl 36km (gl MPkfMRrr),  
LADCO Natl 36km (gl REkfMRrr).

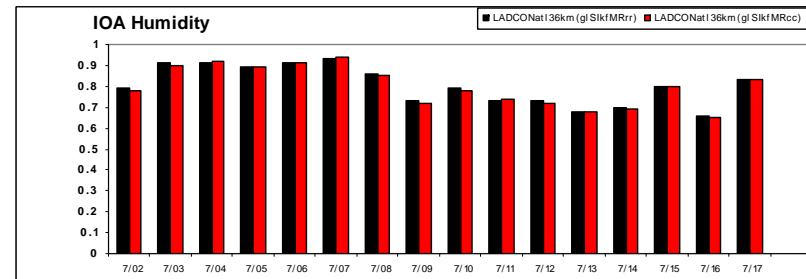
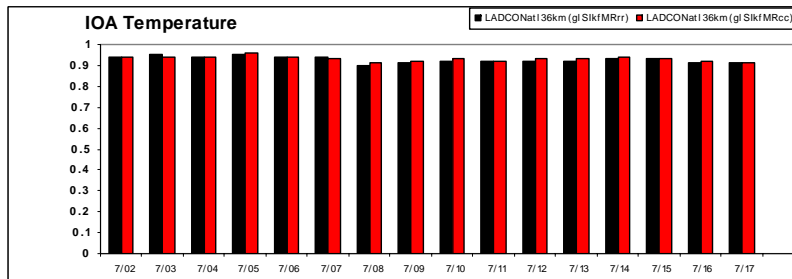
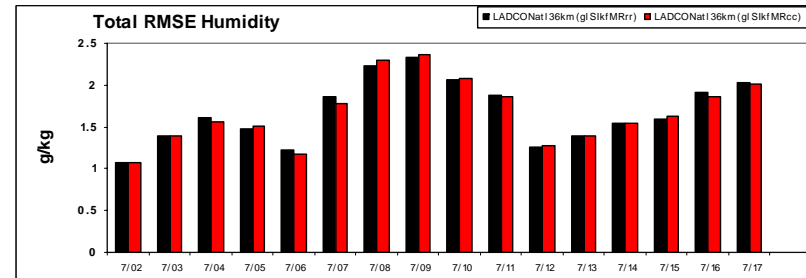
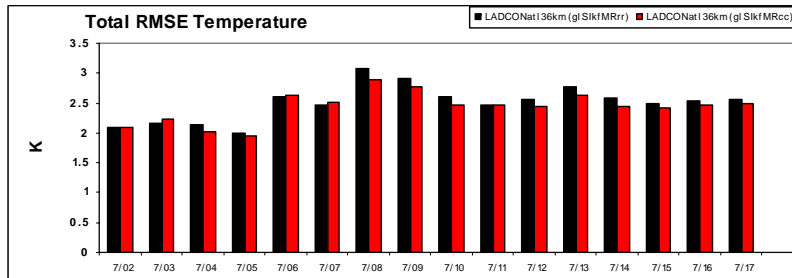
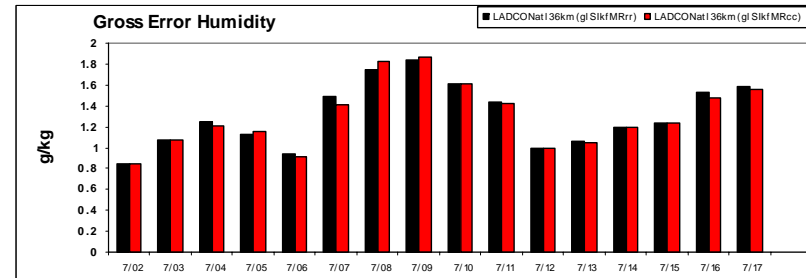
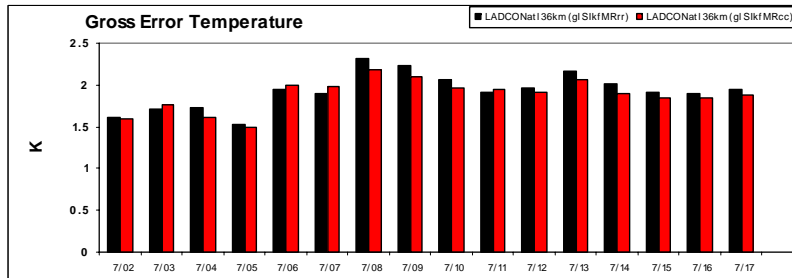
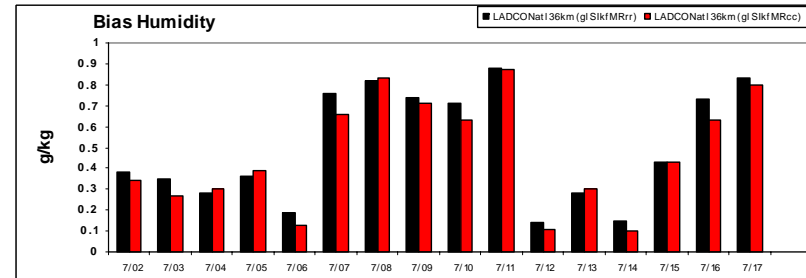
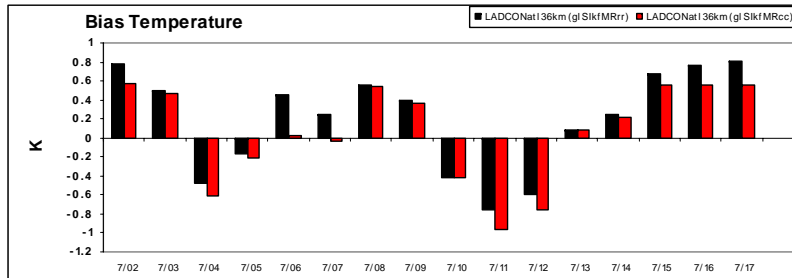
LADCO Natl 36km (gl SIKfMRrr), LADCO Natl 36km (gl MPkfMRrr),  
LADCO Natl 36km (gl REkfMRrr).



# RRTM (black) and CCM2 (red)

LADCO Natl 36km (gl SikfMRrr), LADCO Natl 36km (gl SikfMRcc).

LADCO Natl 36km (gl SikfMRrr), LADCO Natl 36km (gl SikfMRcc).

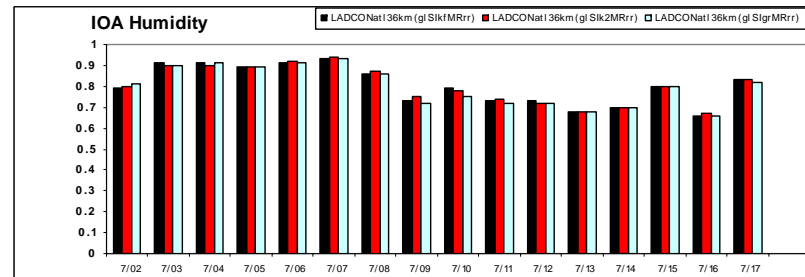
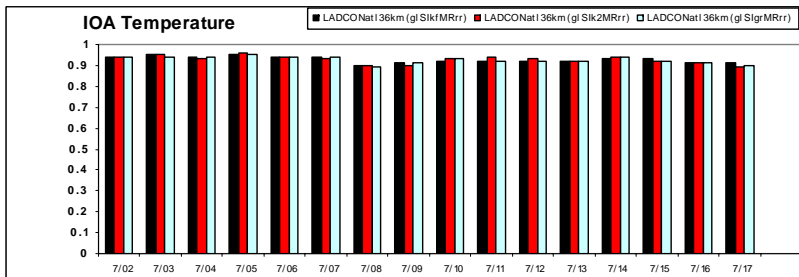
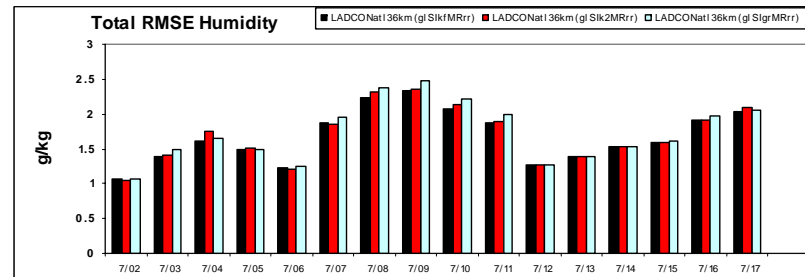
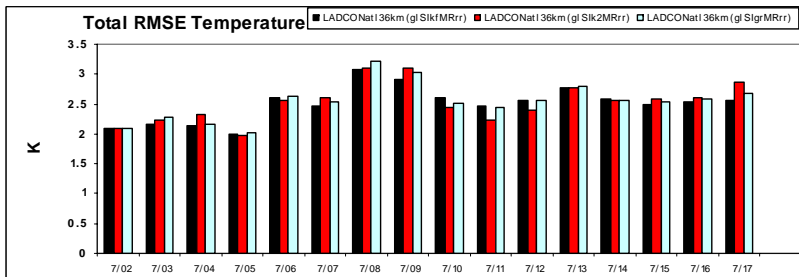
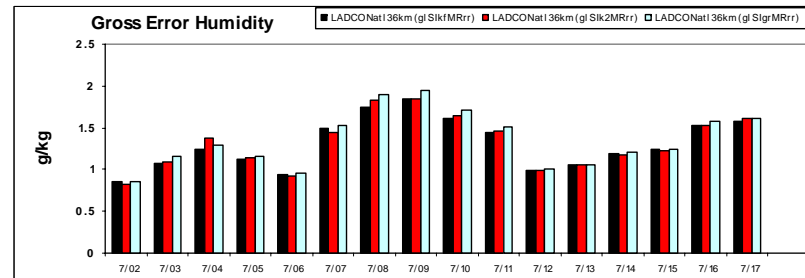
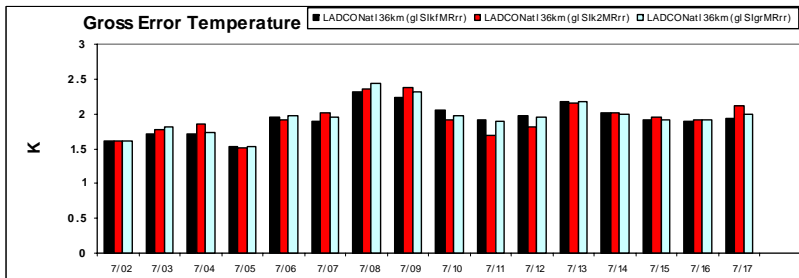
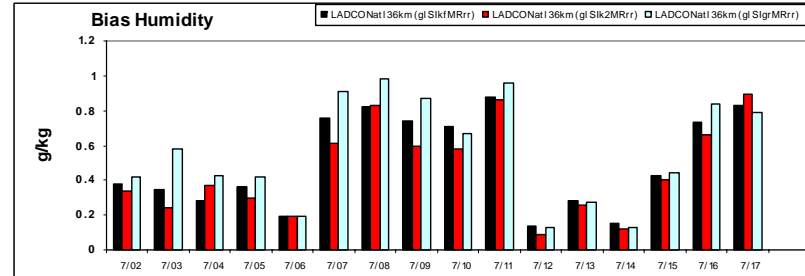
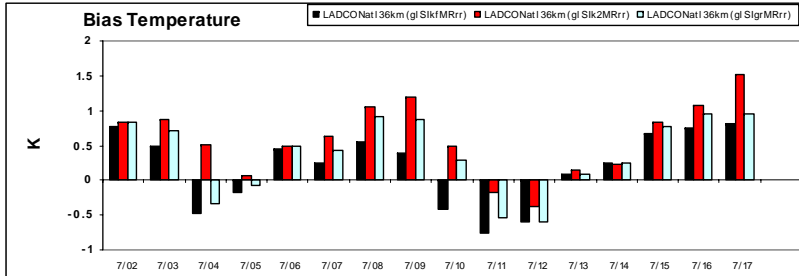




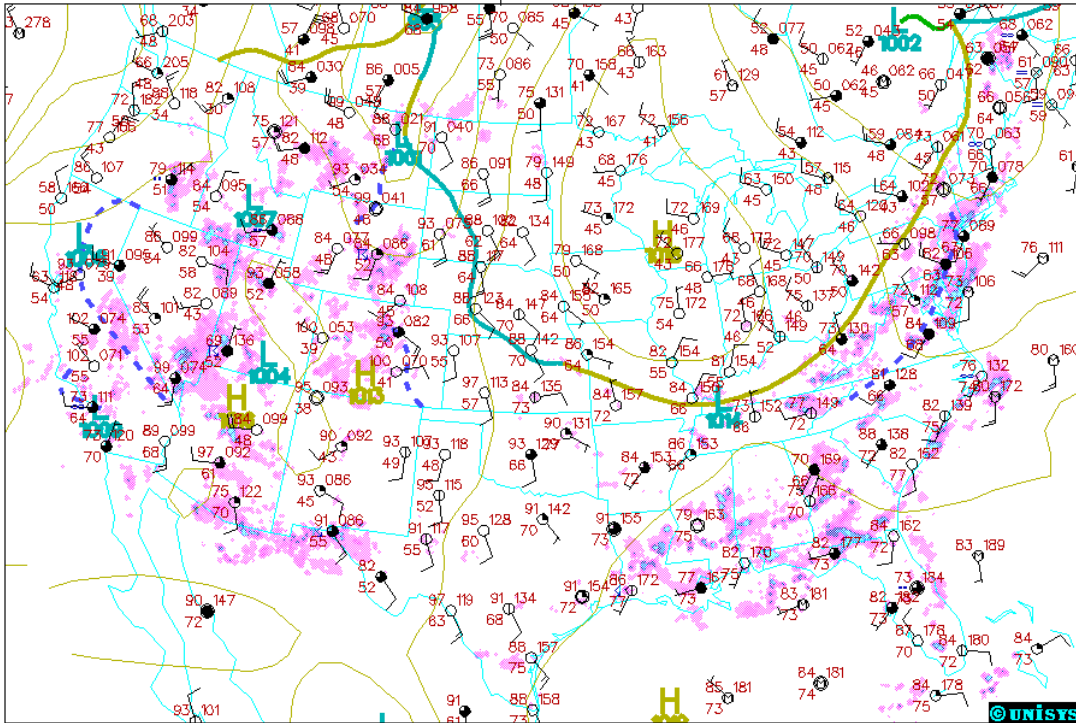
# Kain-Fritsch (black) Kain-Fritsch2 (red) Grell (blue)

LADCO Natl 36km (gl SikfMRrr), LADCO Natl 36km (gl Sik2MRrr),  
LADCO Natl 36km (gl SigrMRrr).

LADCO Natl 36km (gl SikfMRrr), LADCO Natl 36km (gl Sik2MRrr),  
LADCO Natl 36km (gl SigrMRrr).



Surface data plot for 00Z 6 JUL 01



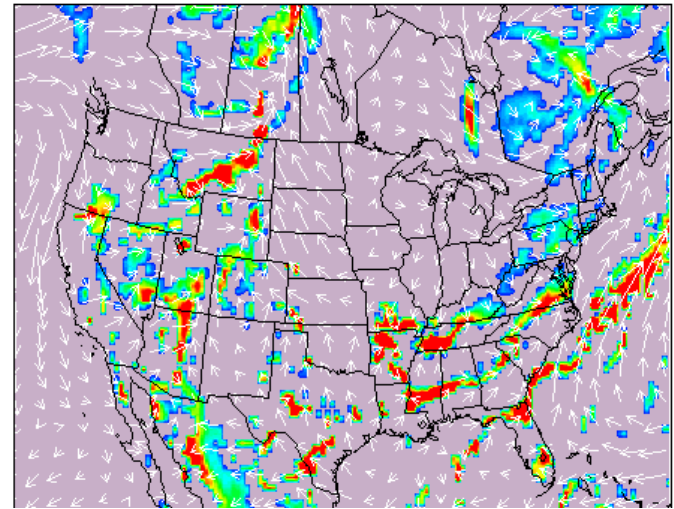
Intensities (Dbz): 20 30 40 45 50 55

Fronts at 00Z

## Rain and Wind Field-20010706 SikfBLrr

natl 36km - LADCO Run  
wind vectors in m2/sec

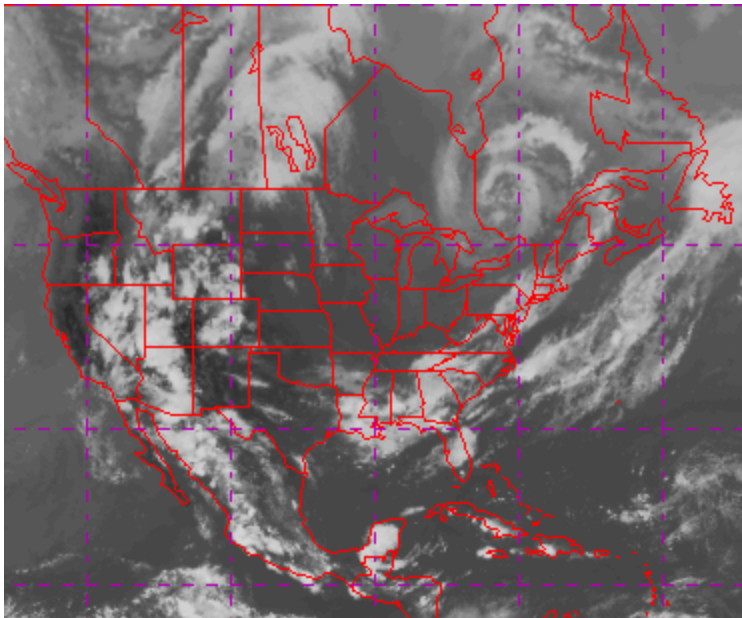
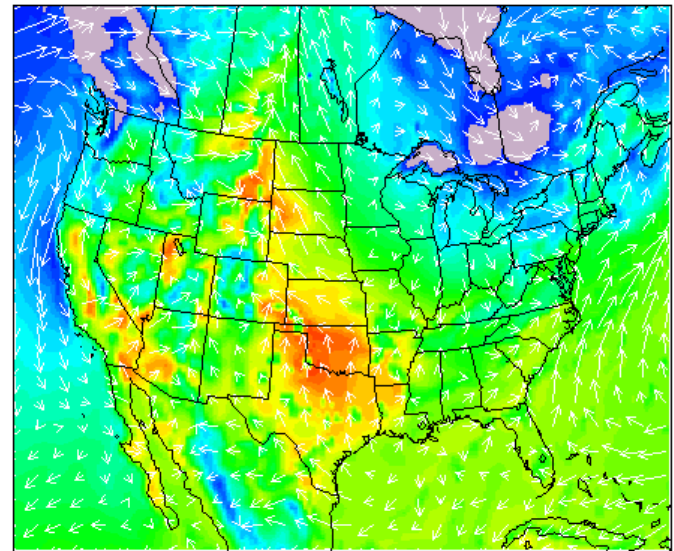
111



## Temperature and Wind Field-20010706 SikfBLrr

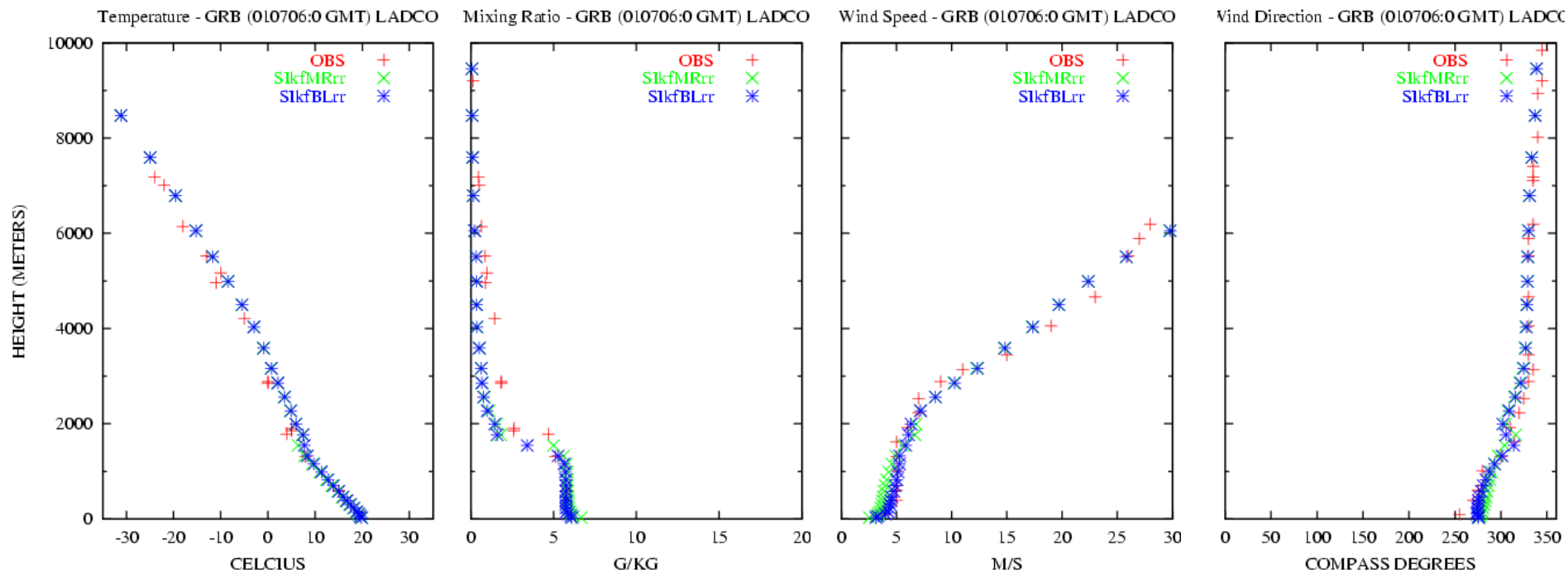
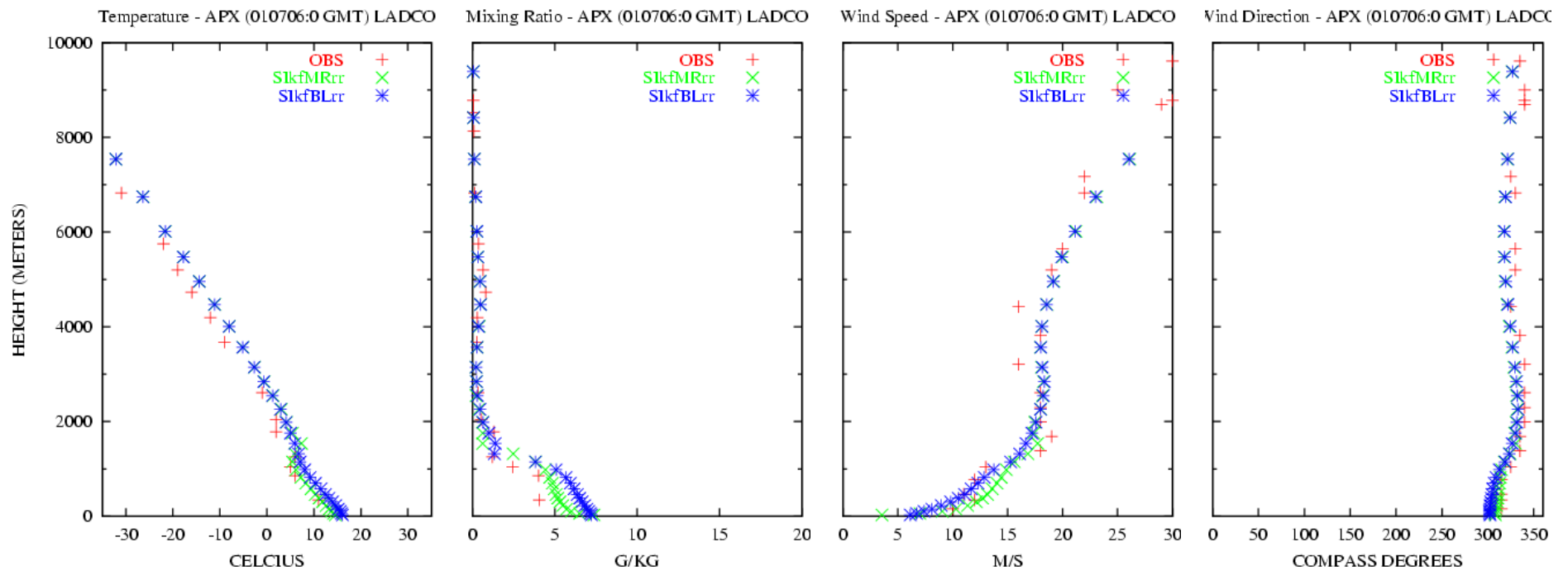
natl 36km - LADCO Run  
wind vectors in m2/sec

111

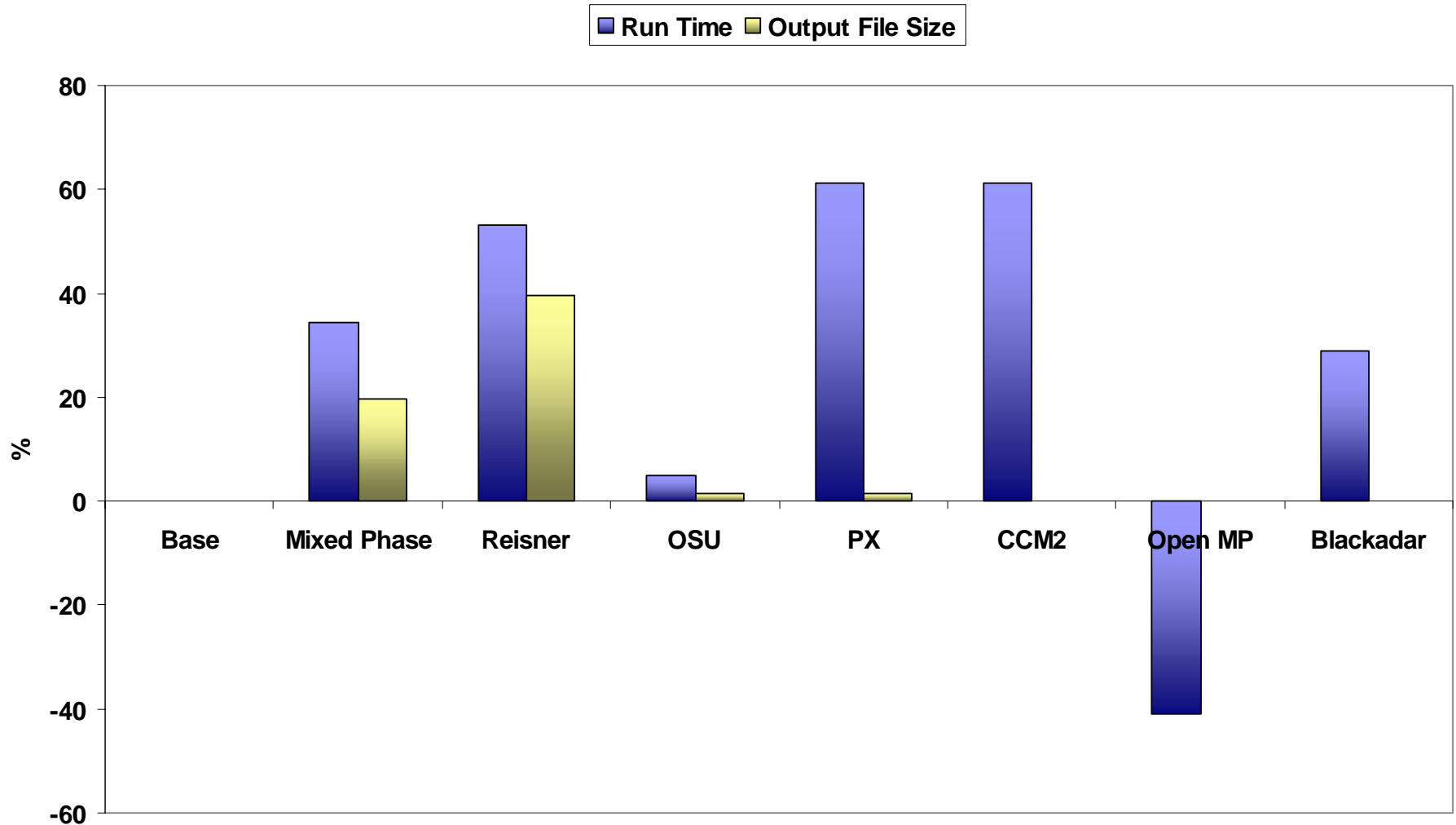


July 6, 2001 0:00:00  
Min= 28 at (92,107), Max= 96 at (68,37)

147  
20.0F



# % Change in Resource Requirements



\*Base run = Simple Ice, Kain-Fritsch, MRF, RRTM

\*\*Open MP used 2 processors

# Great Lakes Model Performance Region

~ 280 stations - Average of daily statistics for 16 day episode

			base	objective analysis	altern. eta	zfac modif.	mixed phase	reisner	blckdr	kf2	grell	ccm2	px	osu	guide
Wind Spd	Mean OBS	(m/s)	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	
Wind Spd	Mean PRD	(m/s)	3.11	3.12	3.11	3.38	3.11	3.14	3.37	3.18	3.12	3.15	3.39	3.17	
Wind Spd	Gross Error	(m/s)	1.41	1.42	1.44	1.45	1.42	1.40	1.32	1.40	1.42	1.42	1.17	1.45	
Wind Spd	RMSE	(m/s)	1.77	1.77	1.80	1.81	1.78	1.75	1.67	1.75	1.78	1.78	1.53	1.80	2
Wind Spd	Sys RMSE	(m/s)	1.17	1.17	1.22	1.25	1.18	1.16	0.97	1.14	1.19	1.17	0.84	1.15	
Wind Spd	Unsys RMSE	(m/s)	1.31	1.32	1.31	1.30	1.32	1.30	1.35	1.31	1.30	1.33	1.27	1.38	
Wind Spd	IOA		0.59	0.59	0.58	0.57	0.59	0.59	0.67	0.60	0.58	0.59	0.72	0.59	0.6
Wind Dir	Mean OBS	(deg)	253.99	253.99	253.99	253.99	253.99	253.99	253.99	253.99	253.99	253.99	253.99	253.99	
Wind Dir	Mean PRD	(deg)	215.96	216.61	219.48	253.87	216.36	215.97	251.43	239.34	216.89	215.66	257.39	237.69	
Wind Dir	Gross Error	(deg)	34.73	34.74	36.66	40.39	35.04	34.77	31.07	34.62	35.15	34.80	30.38	34.11	40*
Temprtr	Mean OBS	(K)	293.27	293.27	293.27	293.27	293.27	293.27	293.27	293.27	293.27	293.27	293.27	293.27	
Temprtr	Mean PRD	(K)	293.46	293.40	293.49	292.27	293.42	293.54	293.21	293.82	293.64	293.32	293.32	293.49	
Temprtr	Gross Error	(K)	1.93	1.93	1.95	2.55	1.94	1.95	1.79	1.94	1.95	1.88	1.82	1.85	2
Temprtr	RMSE	(K)	2.50	2.50	2.53	3.14	2.51	2.53	2.33	2.53	2.54	2.43	2.38	2.43	
Temprtr	Sys RMSE	(K)	1.47	1.45	1.51	2.47	1.46	1.57	1.27	1.48	1.47	1.42	1.42	1.00	
Temprtr	Unsys RMSE	(K)	2.00	2.01	2.00	1.87	2.02	1.95	1.93	2.02	2.04	1.95	1.89	2.19	
Temprtr	IOA		0.93	0.93	0.92	0.86	0.93	0.92	0.94	0.93	0.93	0.93	0.93	0.94	0.7
Humdity	Mean OBS	(g/kg)	10.05	10.05	10.05	10.05	10.05	10.05	10.05	10.05	10.05	10.05	10.05	10.05	
Humdity	Mean PRD	(g/kg)	10.47	10.47	10.44	10.19	10.44	10.48	10.38	10.42	10.53	10.43	10.18	9.56	
Humdity	Gross Error	(g/kg)	1.31	1.30	1.32	1.43	1.30	1.32	1.27	1.32	1.36	1.30	1.22	1.34	2
Humdity	RMSE	(g/kg)	1.68	1.67	1.69	1.84	1.67	1.69	1.61	1.70	1.74	1.68	1.59	1.73	
Humdity	Sys RMSE	(g/kg)	0.99	0.98	1.02	1.23	0.97	0.98	0.94	0.92	1.00	1.00	0.77	0.84	
Humdity	Unsys RMSE	(g/kg)	1.34	1.34	1.32	1.32	1.35	1.37	1.30	1.42	1.41	1.33	1.37	1.49	
Humdity	IOA		0.80	0.80	0.79	0.75	0.81	0.80	0.81	0.81	0.80	0.80	0.84	0.81	0.7

# Summary

- Moisture and Radiation schemes do not show much variation in prediction
- Objective analysis step appears redundant with ETA data
- Using ANAL or INIT output from ETA model has minimal effect on model results
- MPP and serial applications look the same
- Sea surface data vs ETA skin temperature data shows no performance benefit at 36km over the 2 week episode in the Upper Midwest

# Summary

- The Z-FAC modification results in serious model performance degradation
- Blackadar performs better than MRF
- Pleim-Xu land surface module significantly improves wind field prediction
- **Favored physics combination:** PC PBL, RRTM radiation, Kain-Fritsch cumulus, Simple Ice moisture, PX land surface module