MM5 Performance Evaluation (Sensitivity Study) Project

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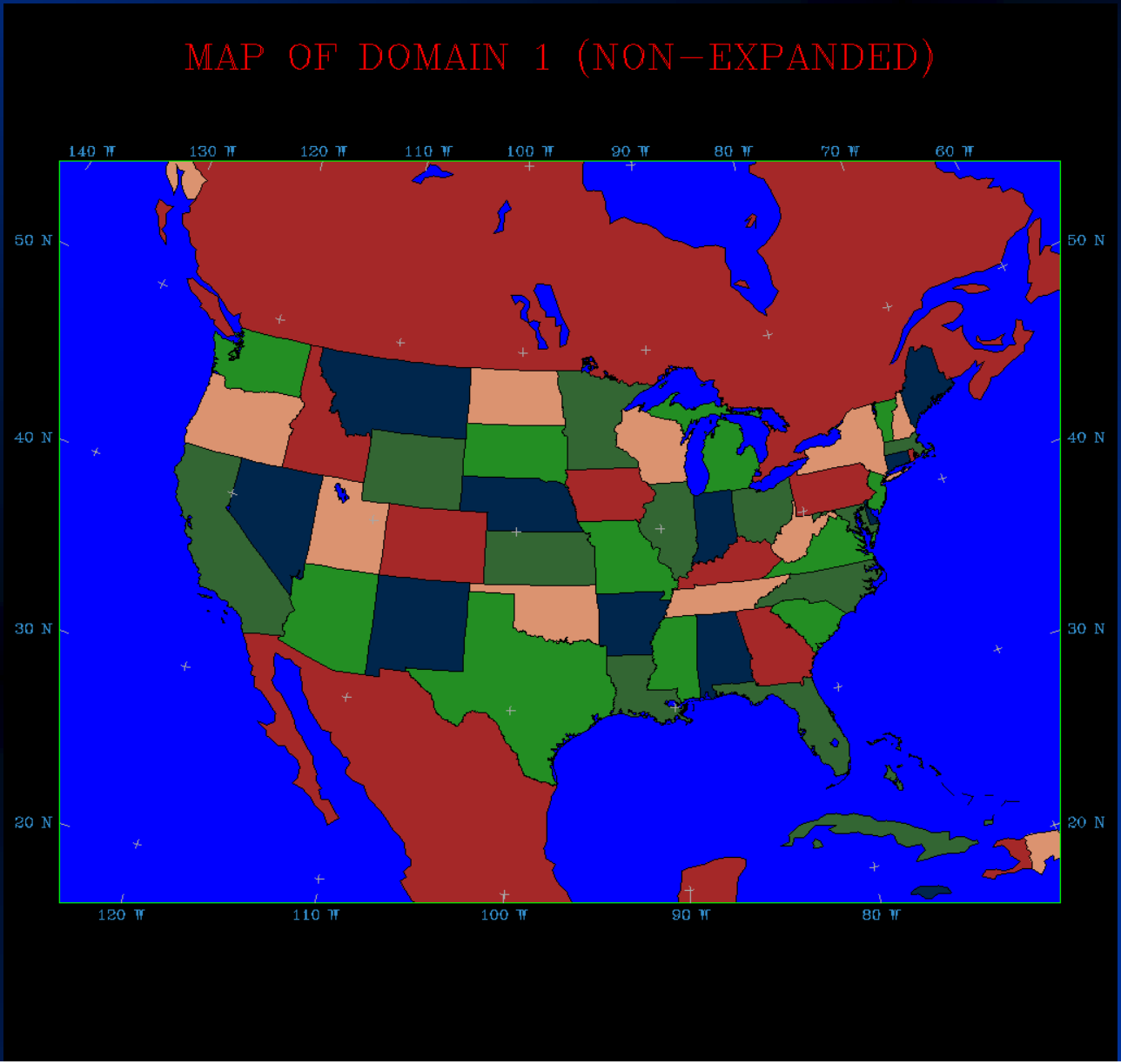
Objectives

- Assess the impacts of logical MM5 configurations upon model performance
- Determine a ‘best approach’ method to MM5 regional meteorological modeling at 36 km
  - Not limited to an absolute configuration
    - May require spatially & temporally dependent configurations
- Practice statistically significant and scientifically sound methods of model evaluation
- Utilize a cooperative approach

Domain

- 36 km res
- Projection
  - -97°, 40°
  - 33°, 45°
- Dimensions
  - E-W 165
  - N-S 129
- Largest grid w/in Eta 212



Basecase Configuration

- MM5 v3-5
  - Simple Ice
  - Kain-Fritsch
  - Simple 5 layer soil model
  - No shallow convection
  - MRF
  - RRTM
  - Analysis nudging (no sfc nudging), default coeffs.
- Eta initialization: Sfc and 3D anal
  - Rawins not incorporated
- 35 layers: Increased resolution in PBL and LLJ
- Episodes: July 2001 & January 2002
  - Initial Focus: July 2001 (7/2-7/17)
    - Supersite data availability

Basecase Configuration

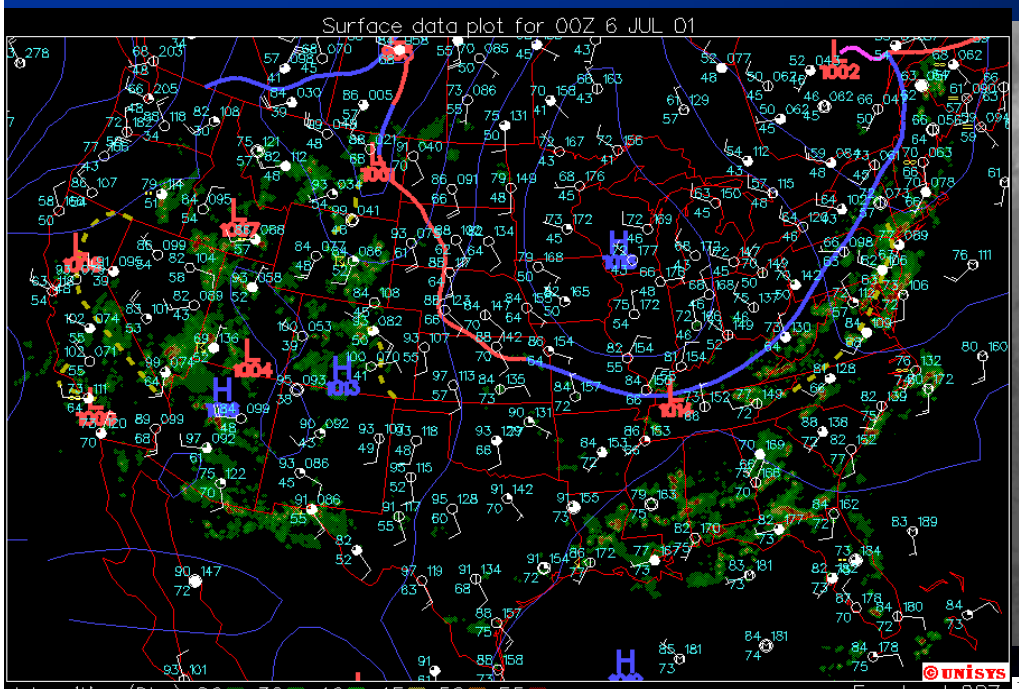
- Model runs conducted in 5 day blocks
  - Initialized at 12Z
  - Examples
    - Run 1: 7/1/01 12Z - 7/6/01 12Z
    - Run 2: 7/5/01 12Z - 7/10/01 12Z
    - …
    - Run 4: 7/13/01 12Z - 7/18/01 12 Z
  - For AQ purposes
    - Allows 17 hours of spin up for modeling midnight-midnight, local time
    - 1 run yields 4 days of data

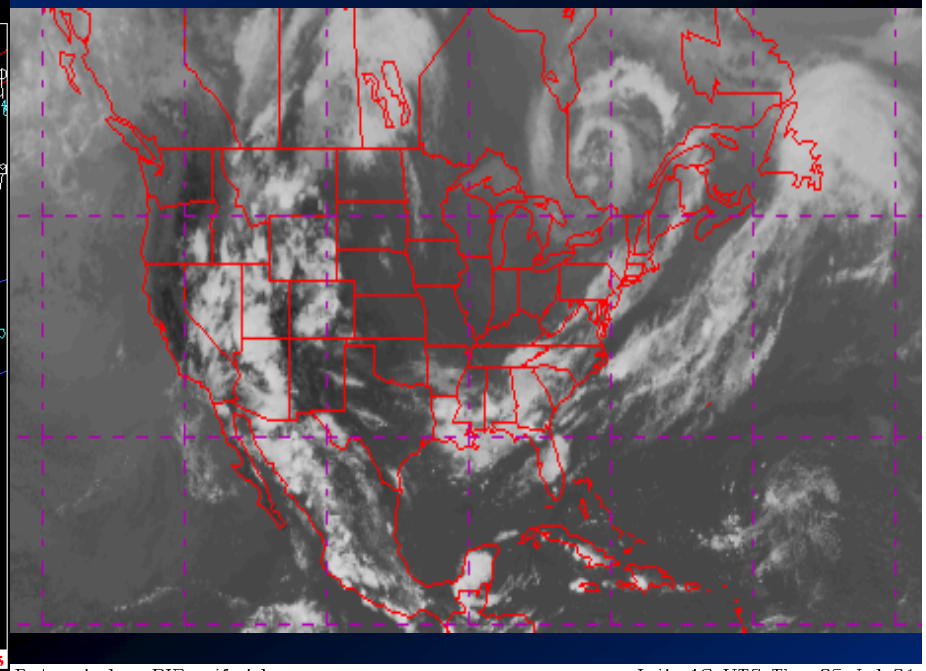
Sensitivity Runs Conducted by Iowa

Descrption	Specific Options	Notes
Basecase		Required
Basecase MPP	MPP configuration	8 node linux cluster
Pleim-Xiu (1)	ismrd = 2	REGRID soil moisture
Pleim-Xiu (2)	ismrd = 0	Landuse.tbl soil moisture
OSU LSM	istlyr =10,40,100,200 ismlyr=10,40,100,200	Specify T,M levels
NCEP SST		
Shallow Convection		
Blackadar		Generate locally for additional eval

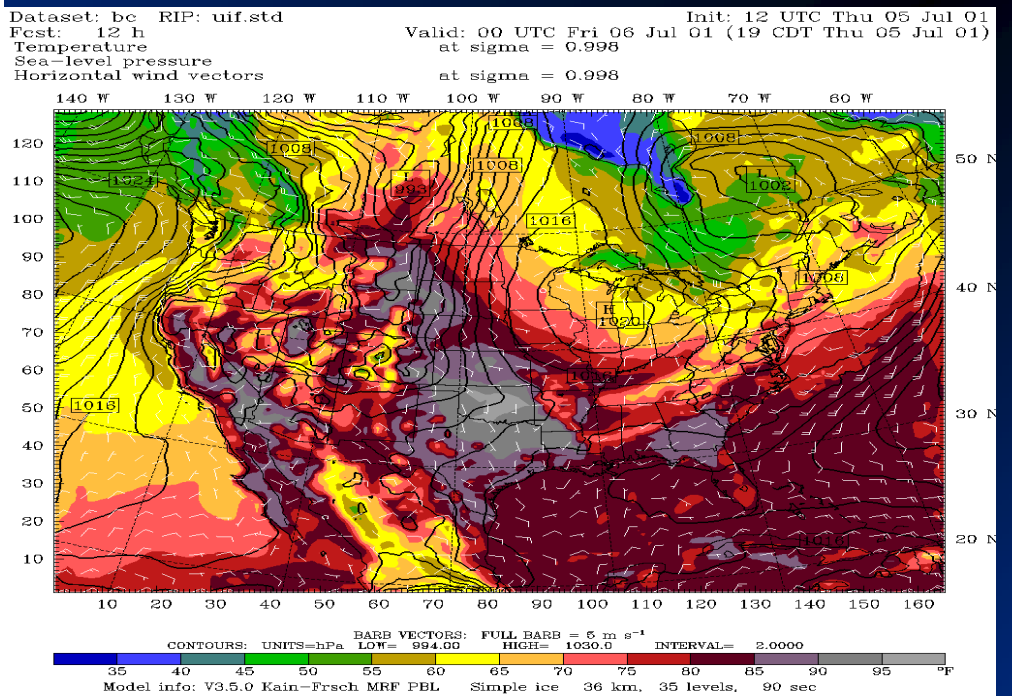
Analysis - Qualitative & Quantitative

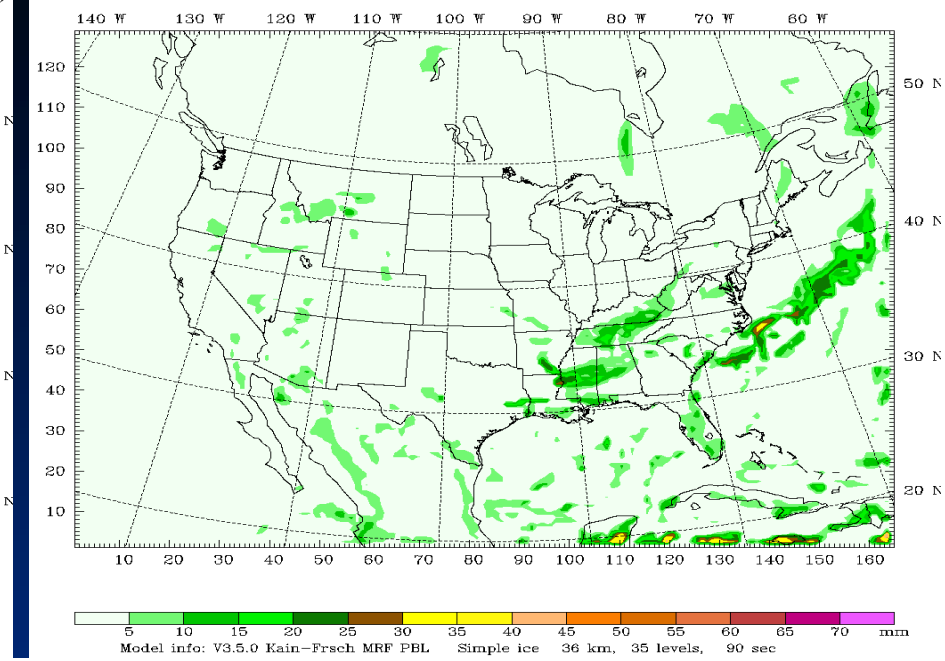
- **Qualitative:** subjective evaluation of synoptic and local scale model performance
  - Methods
    - Synoptic scale assessment
      - Comparison with Unisys data (*e.g.* surface charts, IR satellite images)
    - Local evaluation - Soundings
      - Compare vertical structure of moisture, temperatures, & wind fields
  - Tools
    - RIP, MAPS (Alpine Geophysics)





Dataset: bc RIP: uif.std
Fcst: 12 h
Total precip. in past 6 h
Init: 12 UTC Thu 05 Jul 01
Valid: 00 UTC Fri 06 Jul 01 (19 CDT Thu 05 Jul 01)





Analysis - Qualitative & Quantitative

- **Quantitative** analysis yields objective measures of model performance
  - Tools
    - Metstat (Environ) → hourly & daily statistics of:

	Wind Dir	Wind Speed	Temperature	Humidity
Mean Observed vs Mean Predicted	X	X	X	X
Bias	X	X	X	X
RMSE (Systematic & Unsystematic)		X	X	X
Index of Agreement		X	X	X

Statistical "Benchmarks"

- **Not critical for the sensitivity study evaluations**
  - **Comparison of the sensitivity run statistics key**

Wind Speed	**RMSE**	≤ 2 m/s
	Bias	≤ ±0.5 m/s
	IOA	≥ 0.6
Wind Direction	**Gross Error**	≤ 30 deg
	Bias	≤ ± 10 deg
Temperature	**Gross Error**	≤ 2 K
	Bias	≤ ±0.5 K
	IOA	≥ 0.8
Humidity	**Gross Error**	≤ 2 g/kg
	Bias	≤ ±1 g/kg
	IOA	≥ 0.6

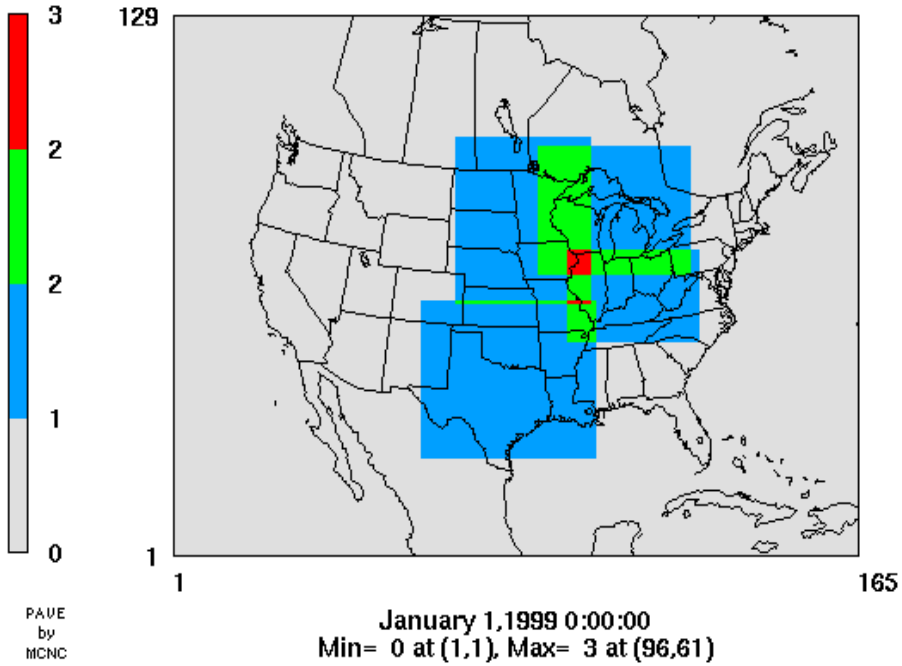
Source: Environ Report: *Meteorological Modeling and Performance Evaluation of September 13-19th Ozone Episode*

Quantitative Analysis

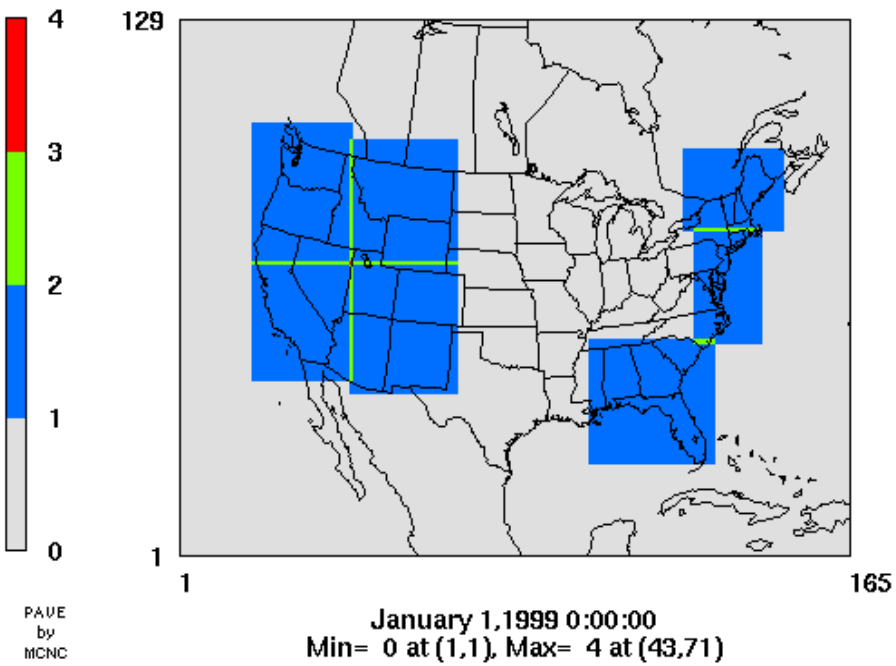
- **Metrics calculated over a national domain of limited use**
  - **Focusing analysis upon four sub-regions**
    - **Northern CenRAP (274)**
    - **Ohio Valley (192)**
    - **Southern CenRAP (213)**
    - **Great Lakes (283)**
  - **CenRAP regions given a higher priority**
  - **A series of 7 additional regions have been developed to blanket the national grid**
    - **Southeast (129)**
    - **Northern (81)**
    - **Mid-Atlantic (128)**
    - **Southwest (118)**
    - **Northeast (115)**
    - **Desert-SW (98)**
    - **Pacific-NW (128)**

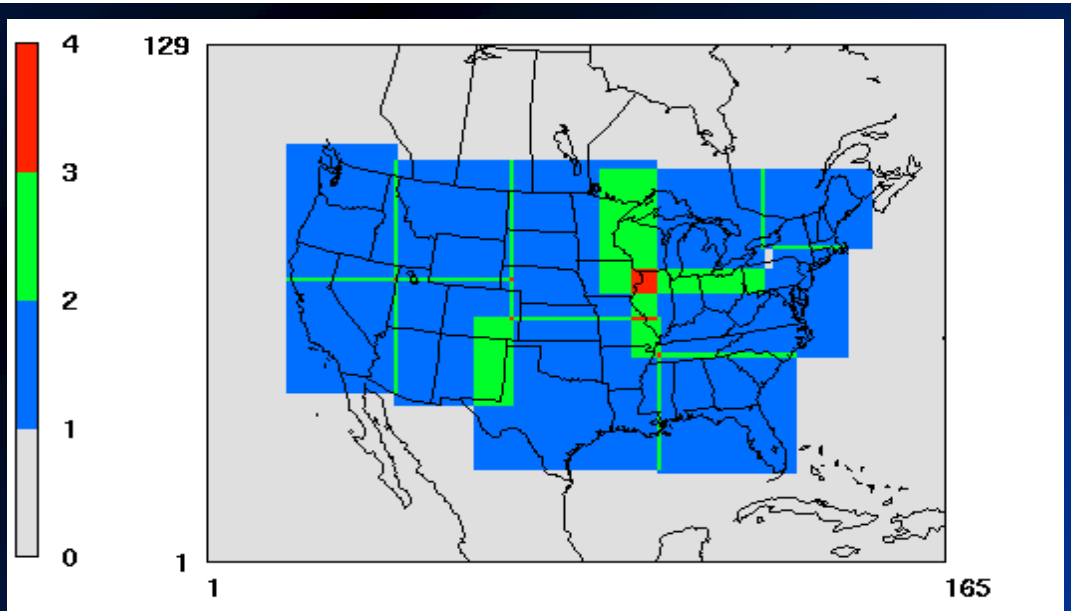
number in parentheses represents the ~number of model vs obs parings within a specific domain

CenrapN, CenrapS, Great Lakes, Ohio Valley



Additional Grids

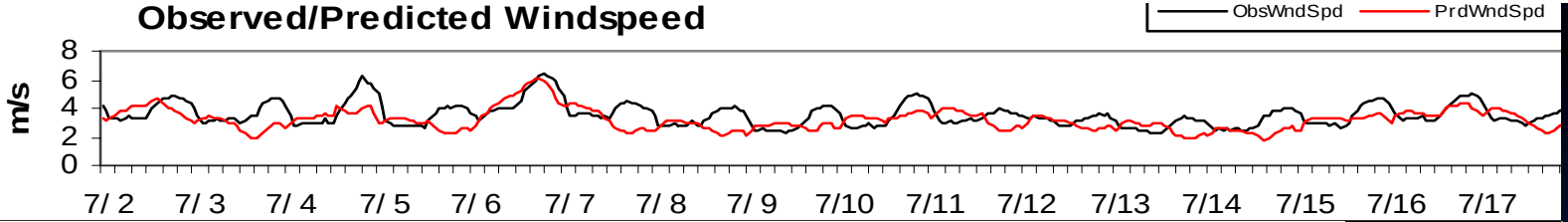




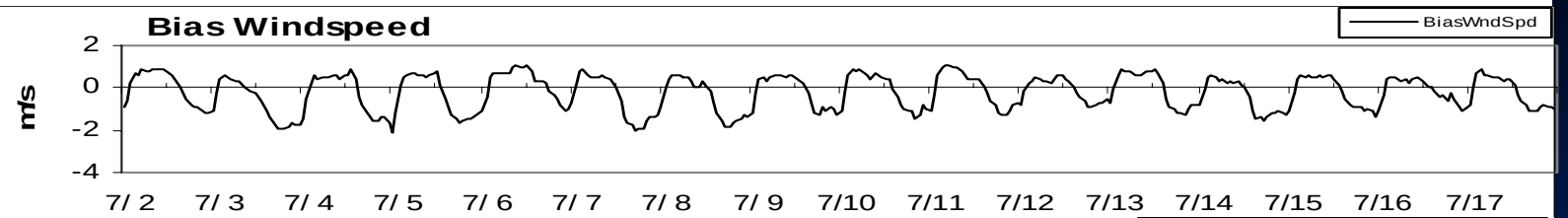
Basecase Summary

- Windspeed
  - Over/under predicted at night/day
    - The day-time low bias more pronounced than nocturnal trends
      - Hourly Avg (-) bias (cenrap N,S) = -0.99, -1.14
      - Hourly Avg (+) bias (cenrap N,S) = 0.51, 0.31
- Wind direction
  - Averaged daily gross error (cenrap N,S) = 36.2, 33.2

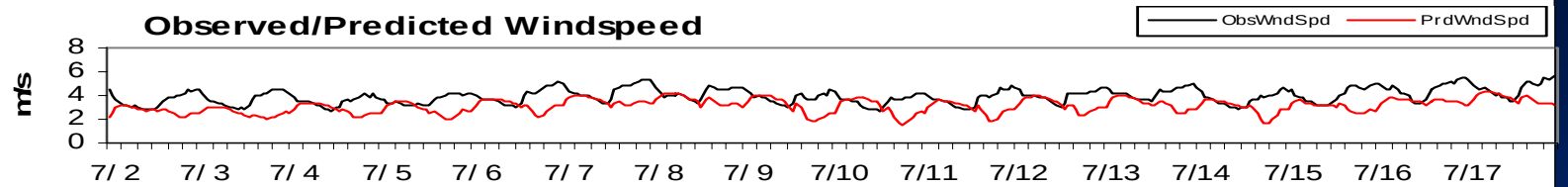
Basecase CenrapN



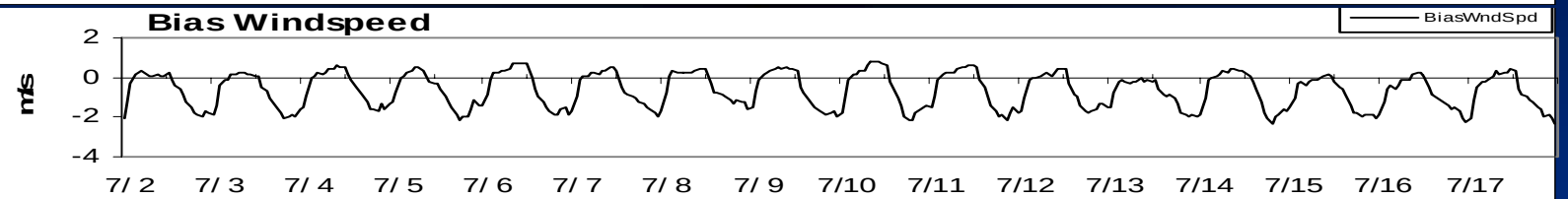
Basecase CenrapN



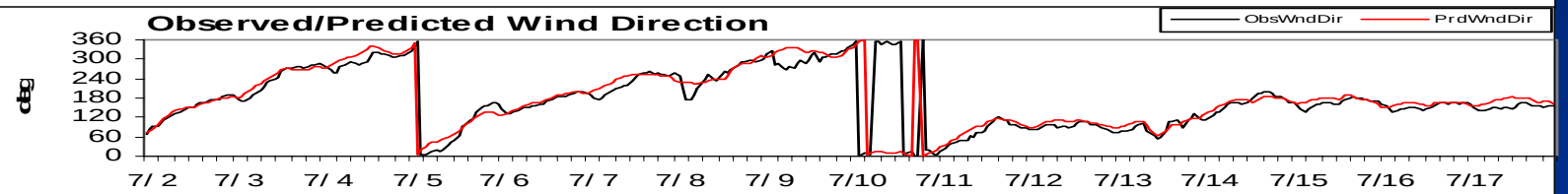
Basecase CenrapS



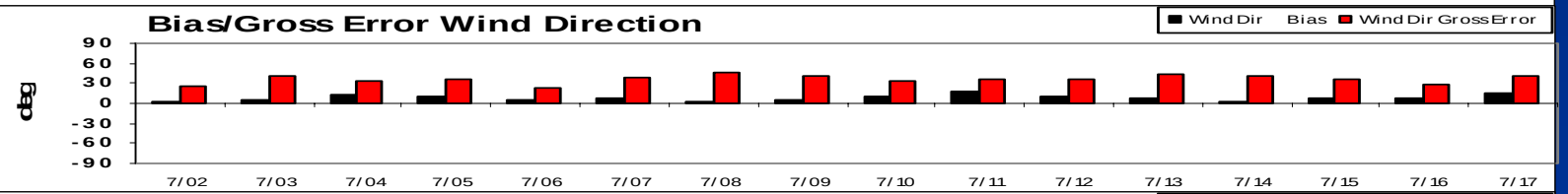
Basecase CenrapS



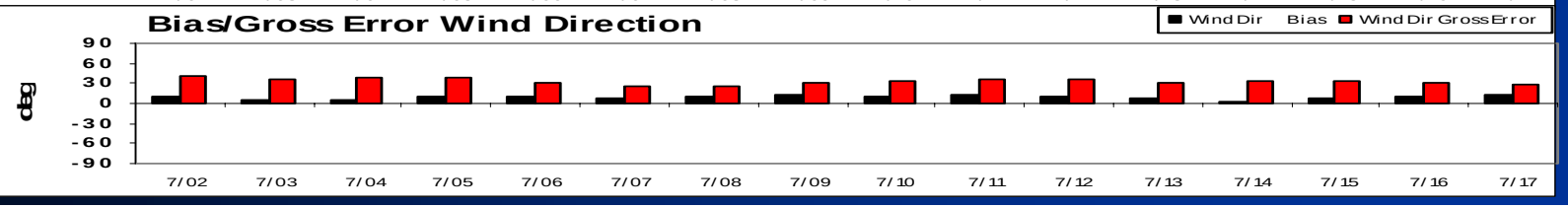
Basecase Cenrap N



Basecase Cenrap N



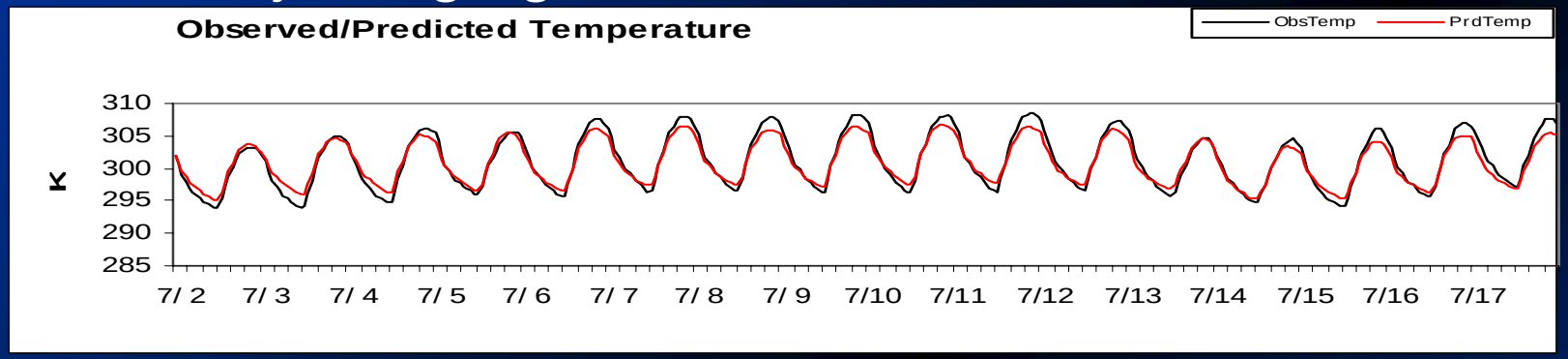
Basecase CenrapS



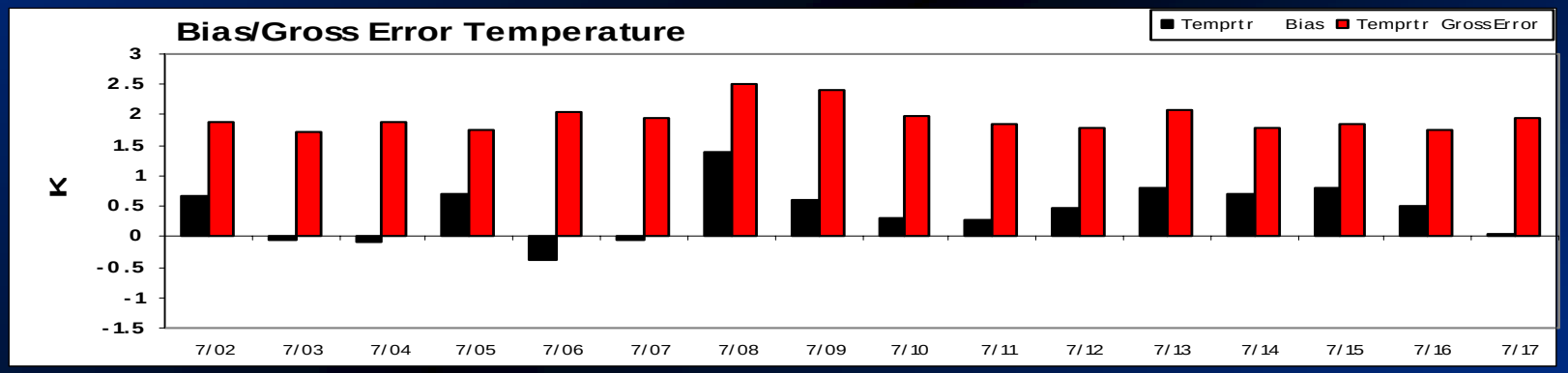
Temperature

- Daily maxima/minima consistently underpredicted
- Daily averaged gross error < 2 K

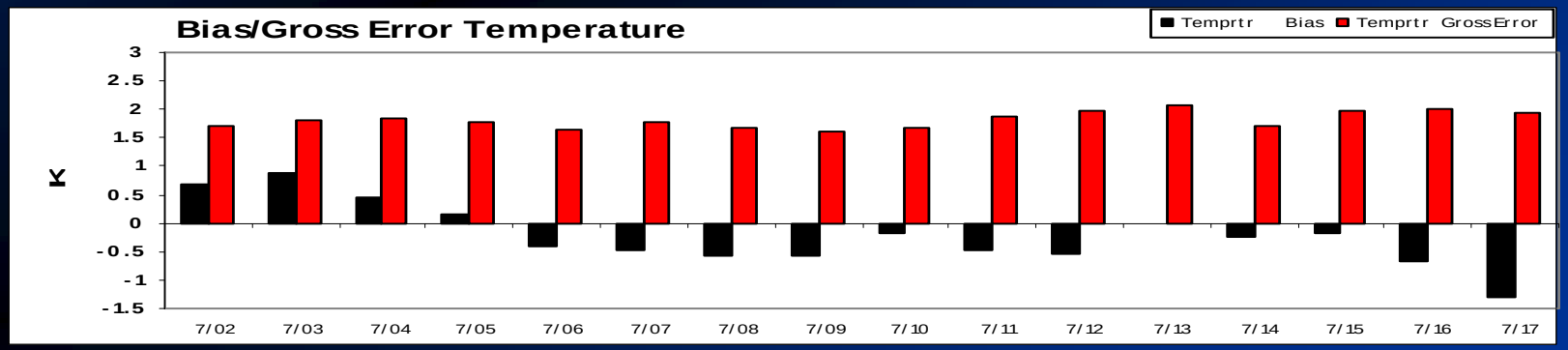
Basecase S-Cenrap



Basecase N-Cenrap



Basecase S-Cenrap



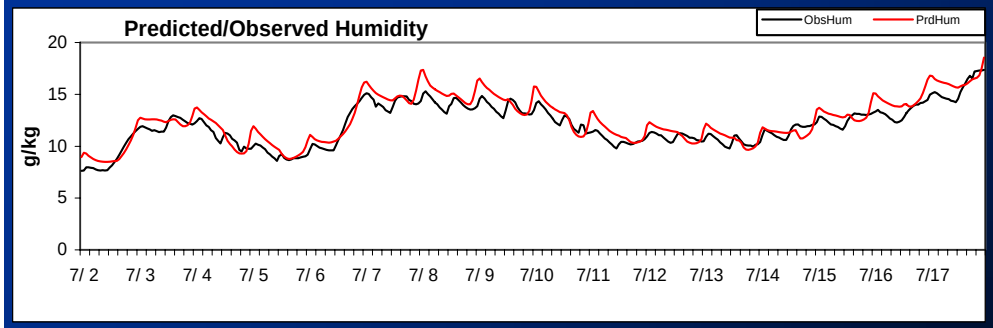
CenrapN avg error = 1.95 K **CenrapS avg error = 1.82 K**

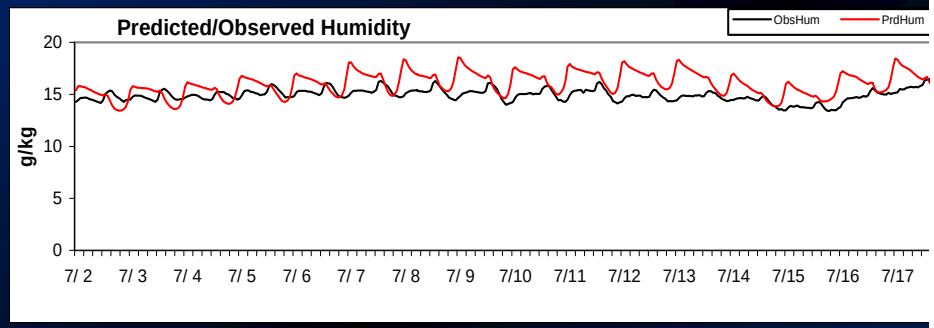
Basecase Summary

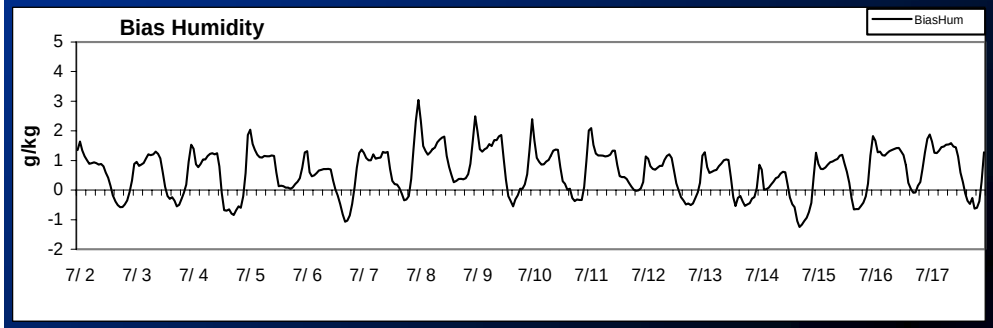
- Moisture
  - Tendency to overpredict moisture levels
  - Sharp spikes in bias occur daily at 0Z
  - Gross error generally < 2 g/kg in cenrapN
  - Gross error > 2/kg in cenrapS 10/16 days

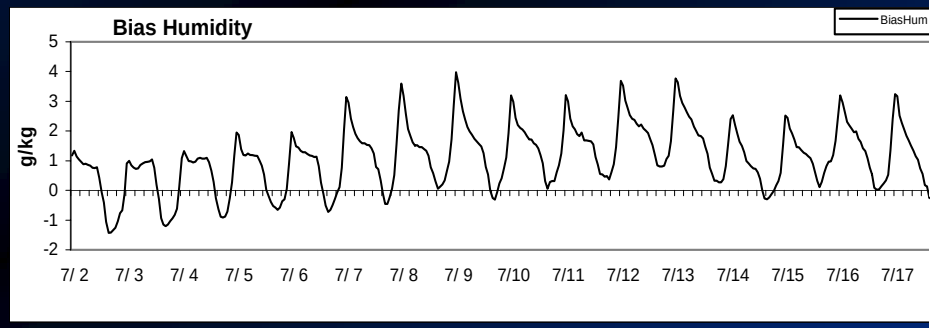
CenrapN

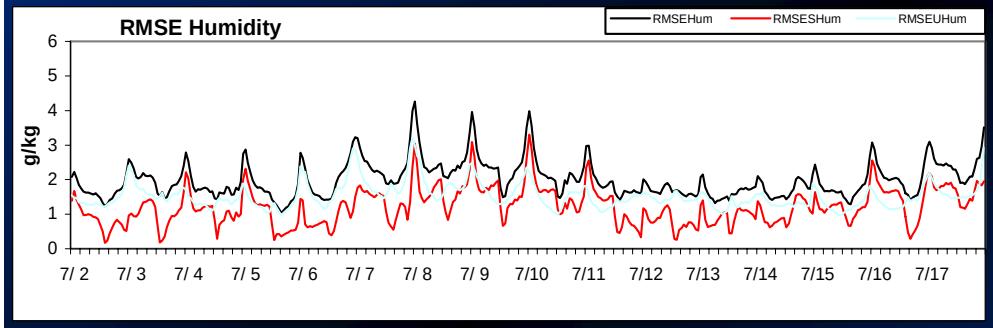
CenrapS

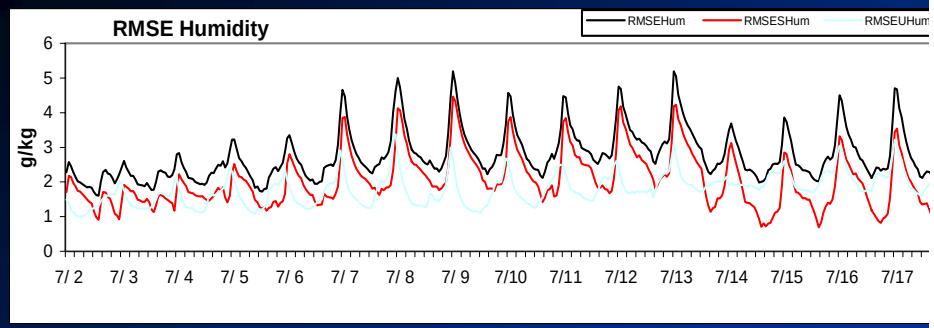


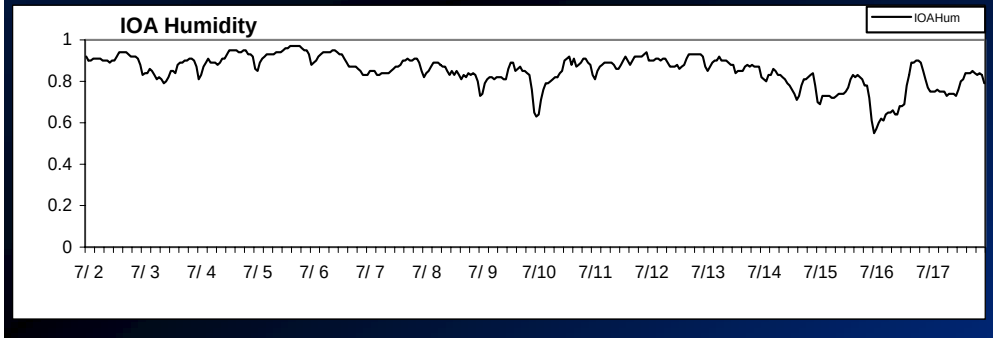


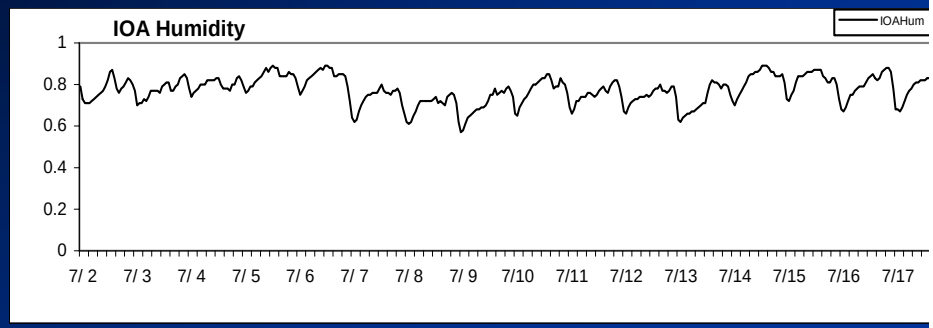






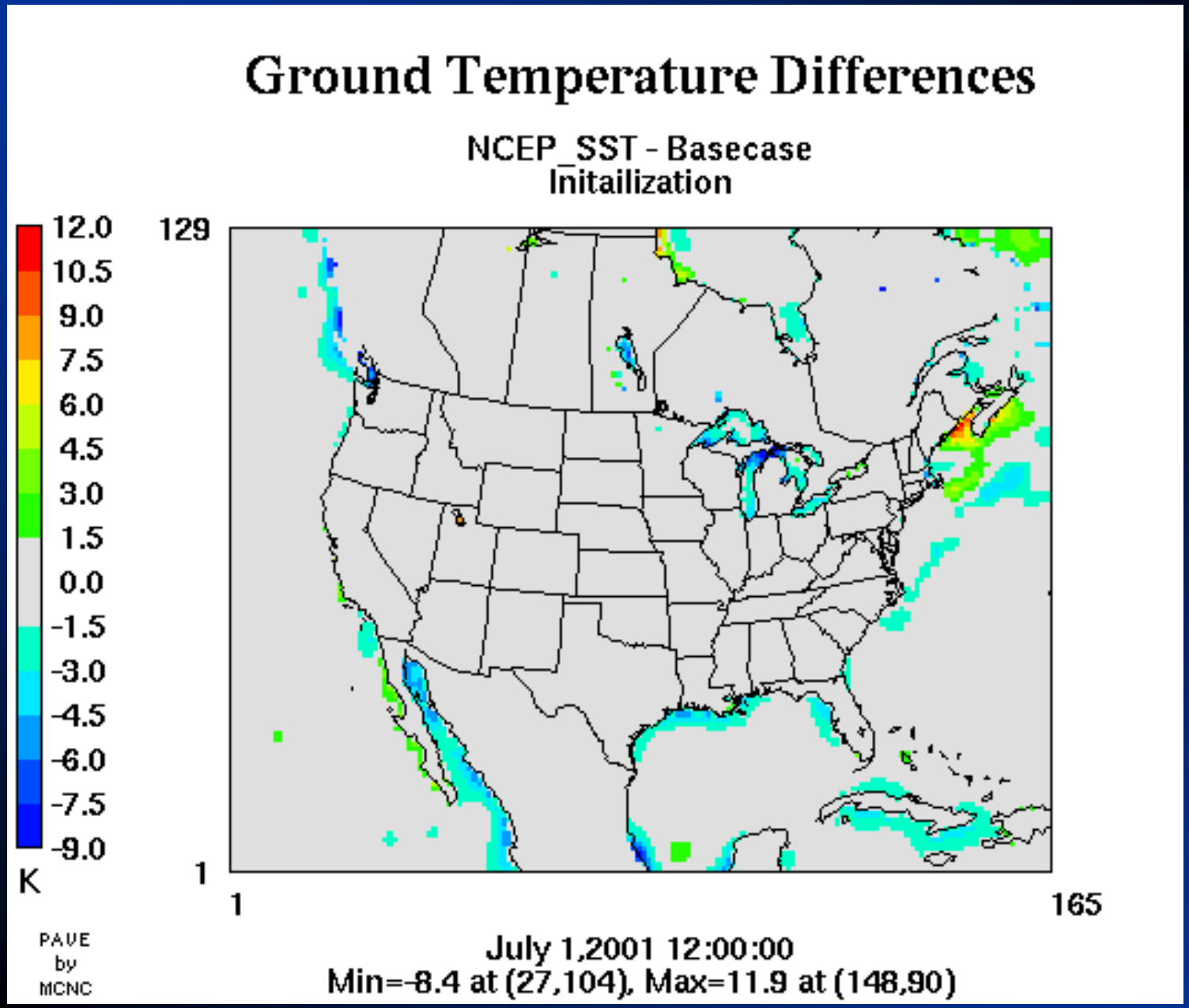




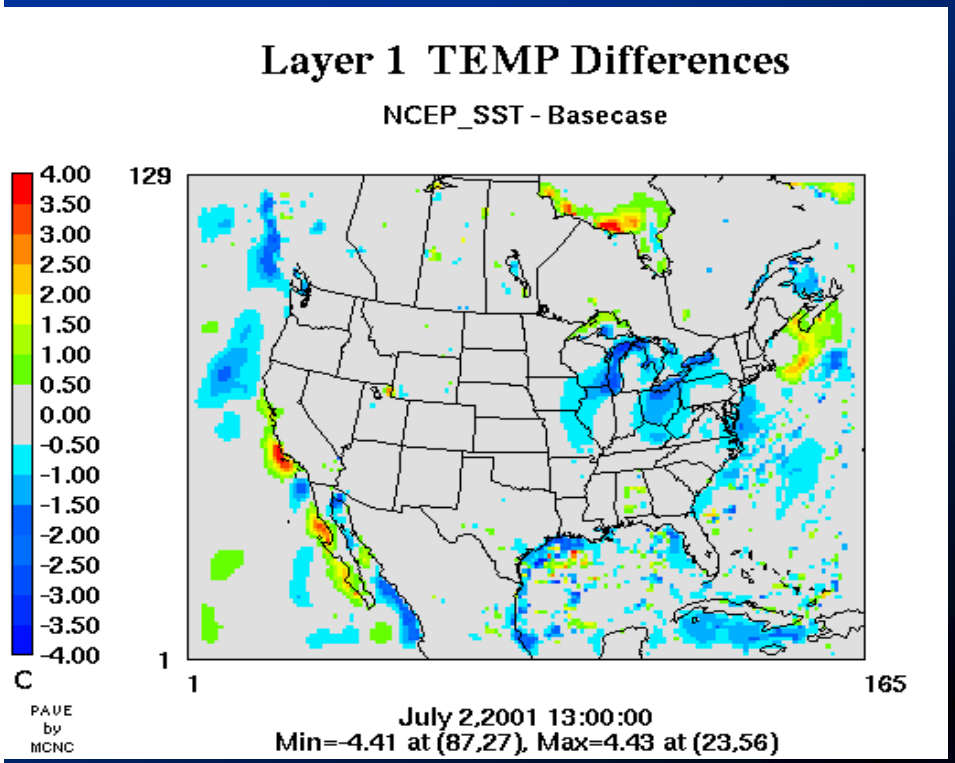


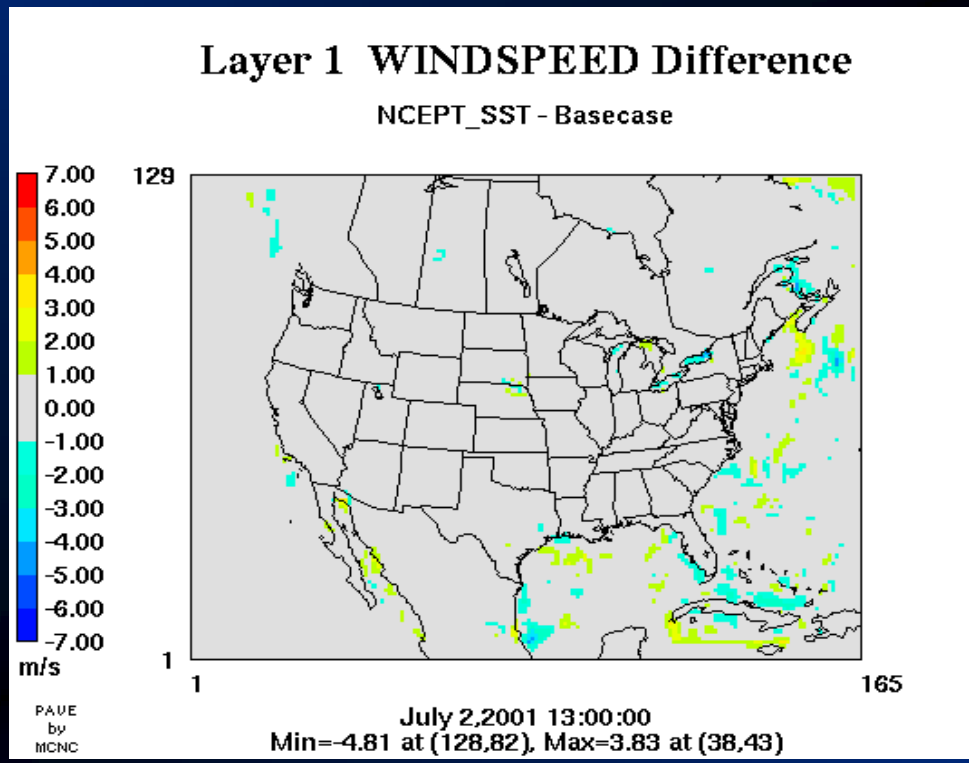
Sensitivity Runs Assessments

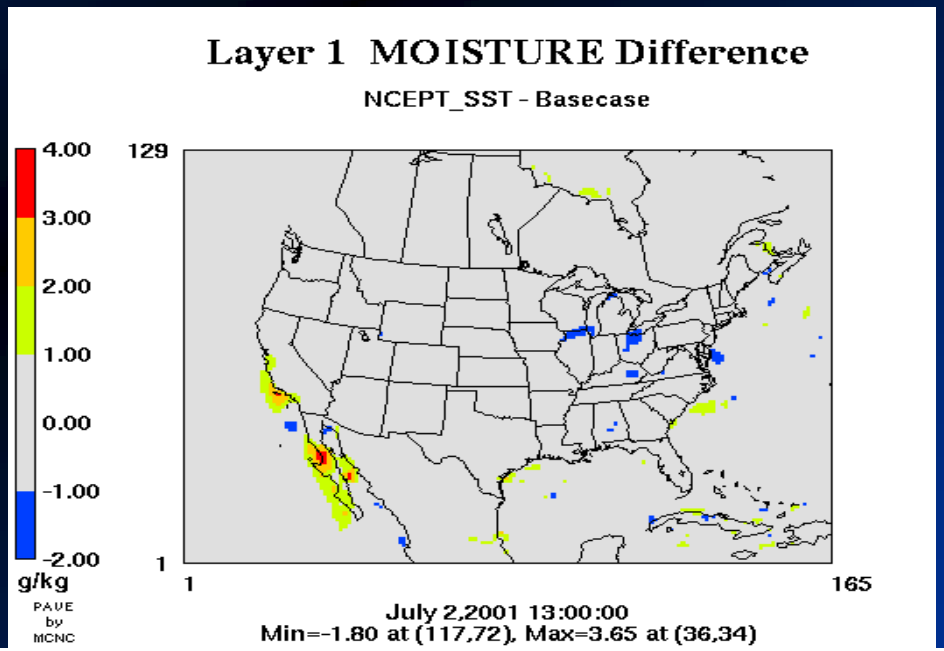
- MPP Basecase
  - Results were identical
- Shallow Convection
  - Differences typically < 1%
- NCEP-SST
  - Little difference found in CenrapN or CenrapS (typically < 1% change)
  - Ohio Valley & Great Lakes show larger variations
    - T and q differences on 7/2 & 7/3
      - NCEP SST cooler and drier on the scale of 0.4^{o} C and 0.3 g/kg
      - Yields little statistical impact over the domain, but locally (i.e. around the shores of the Great Lakes and coastal areas) more pronounced differences occur



Initialization (7/1/2001 12Z) Ground T differences using NCEP SST data vs Eta skin temps


Layer 1 TEMP Differences
NCEP_SST - Basecase
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
-3.00
-3.50
-4.00
C
129
1
1
165
PAVE by MCNC
July 2,2001 13:00:00
Min=-4.41 at (87,27), Max=4.43 at (23,56)

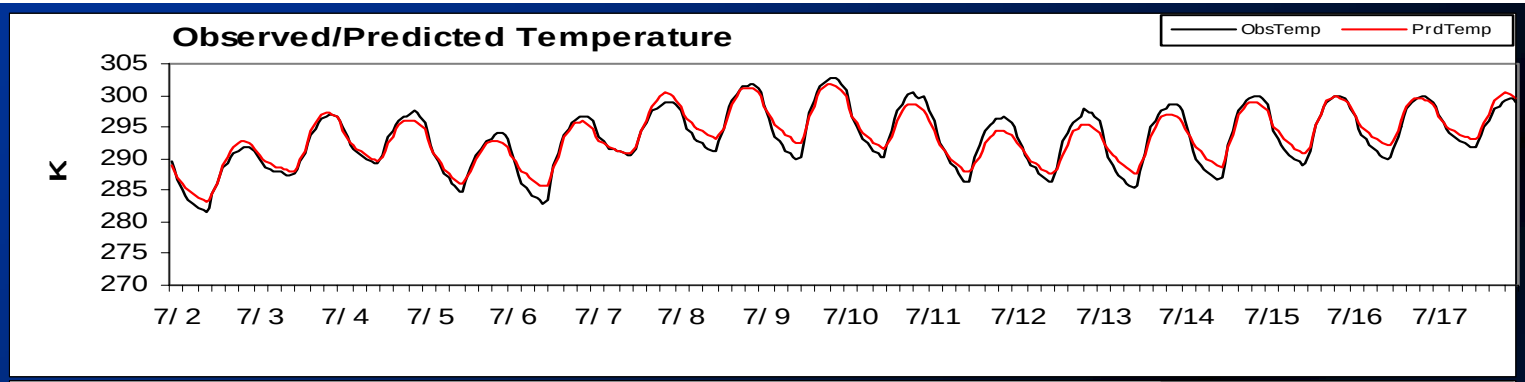

Layer 1 WINDSPEED Difference
NCEPT_SST - Basecase
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
m/s
129
1
1
165
PAVE by MCNC
July 2,2001 13:00:00
Min=-4.81 at (128,82), Max=3.83 at (38,43)


Layer 1 MOISTURE Difference
NCEPT_SST - Basecase
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
g/kg
129
1
1
165
PAVE by MCNC
July 2,2001 13:00:00
Min=-1.80 at (117,72), Max=3.65 at (36,34)

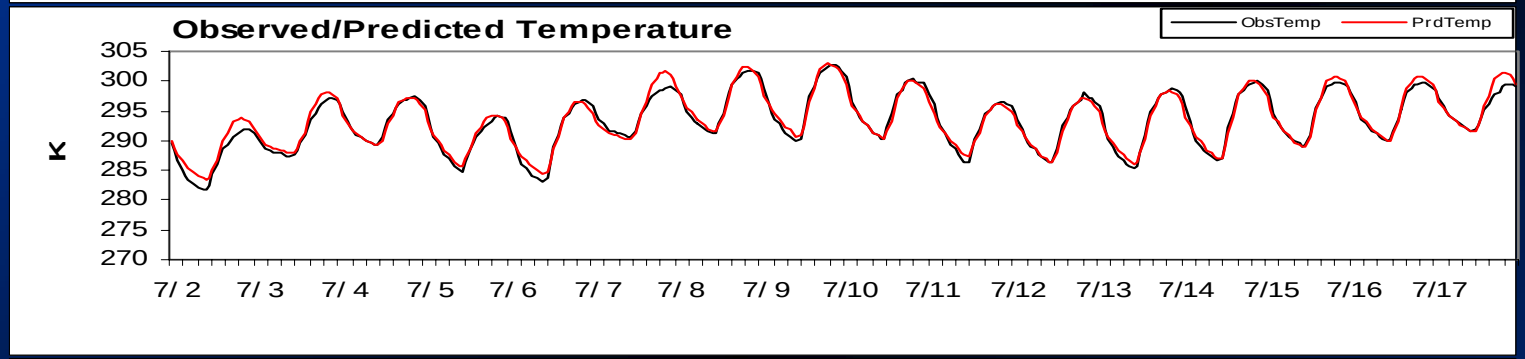
OSU Summary

- Windspeed and Direction
  - Performance similar to Basecase in all 4 grids
- Temperature
  - Slight improvement in Cenrap regions
  - Great Lakes region shows improvements
  - Ohio Valley region produces larger fluctuations in bias and generally greater error vs Basecase
- Moisture
  - In general (4 grids) bias shifts from (+) to (-) and is more evenly distributed about 0 vs the Basecase
  - CenrapS reported the greatest gains
    - Lower RMSE, improved IOA & bias
  - Ohio Valley predictions degraded
    - Averaged daily error increased from 1.4 to 1.7 g/kg

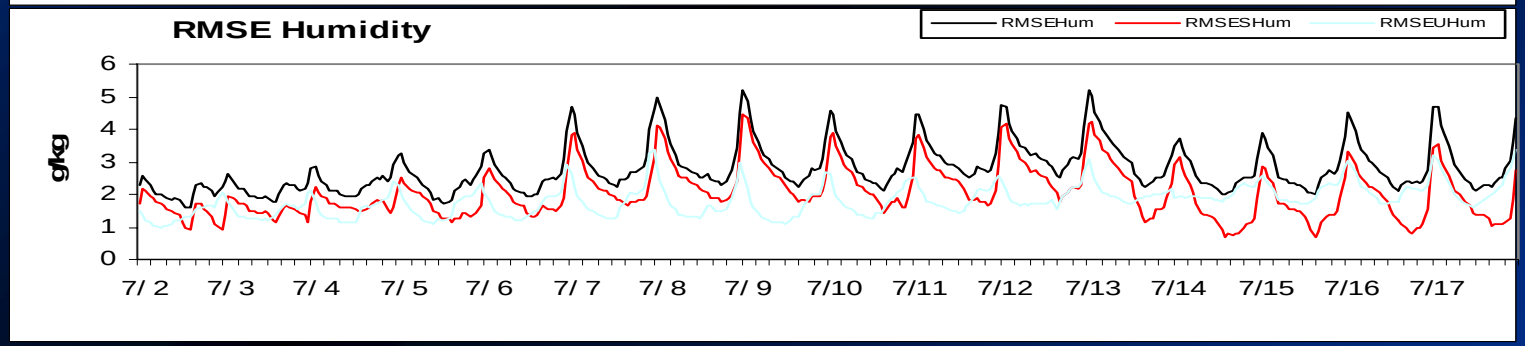
Basecase Great Lakes



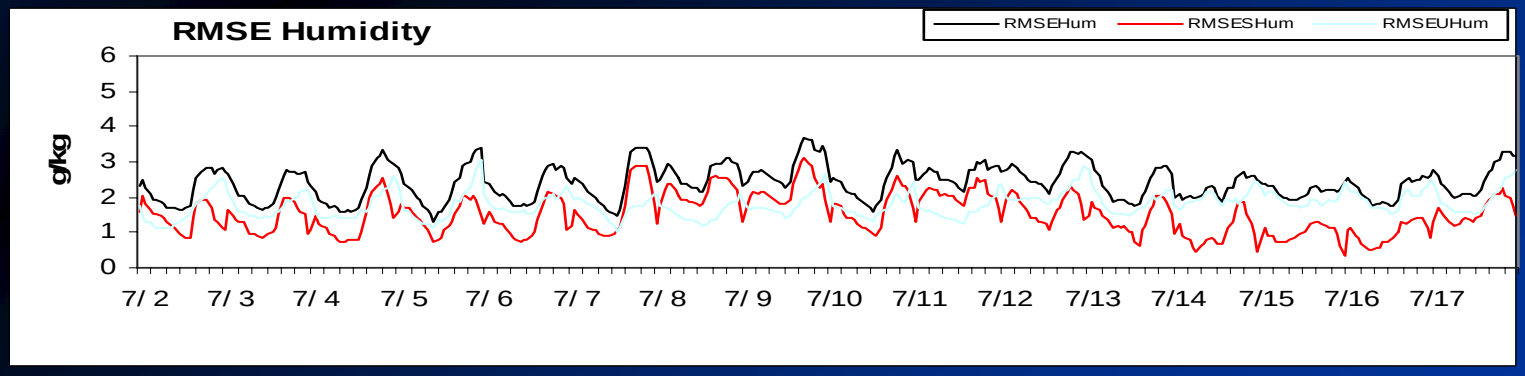
OSU LSM Great Lakes



Basecase CenrapS



OSU LSM CenrapS



Pleim-Xiu

- Numerous options available within PX
  - Soil moisture nudging was not employed
  - LAI and vegetation fraction calculated from estimated emergence dates
    - ifgrow = 2
  - Soil moisture source
    - Sensitivity study conducted using Eta data vs landuse.tbl data
      - Use of the Eta soil moisture data categorically outperformed the landuse.tbl simulations
        - Blackadar outperformed the landuse.tbl option also
      - All subsequent references to the PX simulation imply the Eta soil moisture simulation

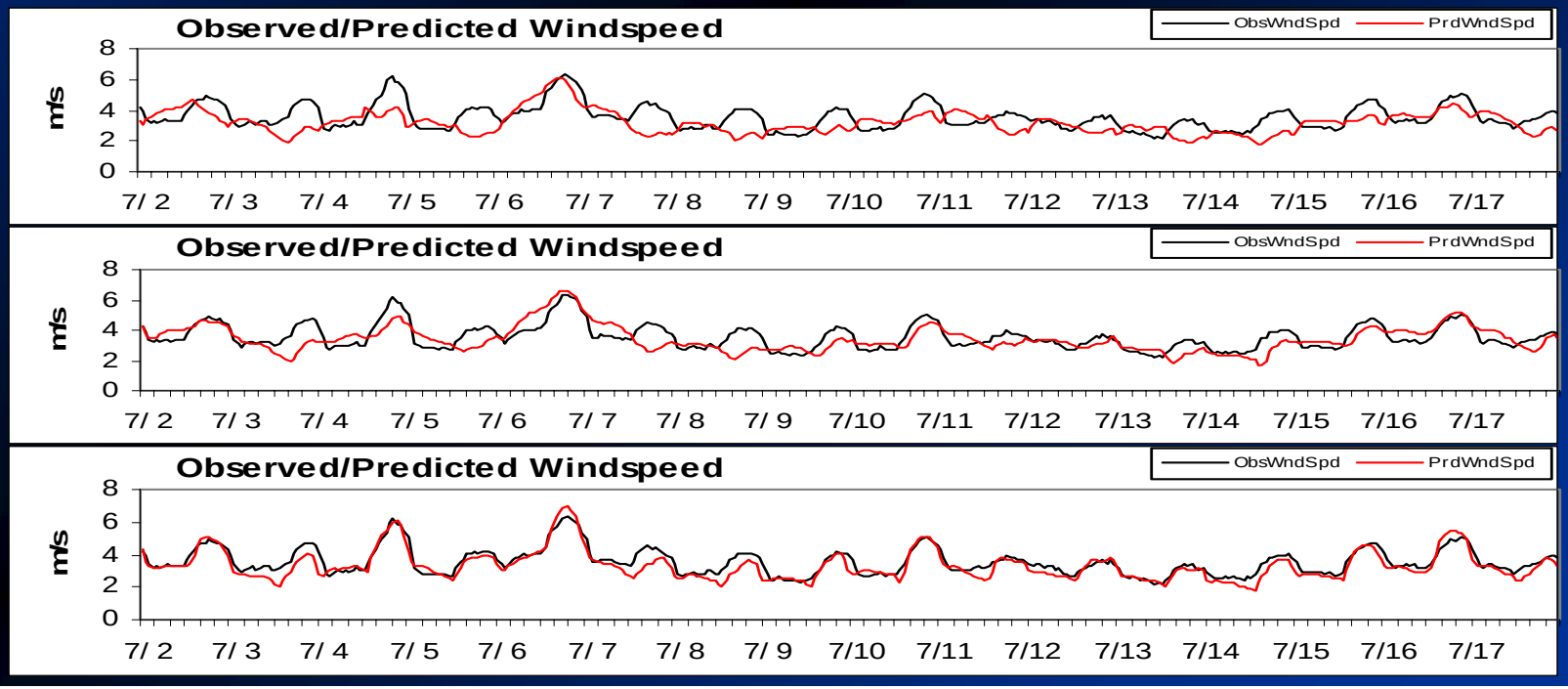
Basecase vs Blackadar vs Pleim-Xiu

- Blackadar and Pleim-Xiu consistently outperform the Basecase
- Pleim-Xiu vs Blackadar
  - PX significantly improves the wind fields
  - Humidity prediction also shows improvement
  - Temperature prediction is *slightly* degraded

Basecase CenrapN

Blackadar CenrapN

PX CenrapN



Blackadar

		CenrapN	CenrapS	Great Lakes
Wind Speed	Bias	0.01	-0.27	0.09
	Error	1.32	1.38	1.33
	RMSE	1.69	1.80	1.67
	IOA	0.68	0.64	0.67
Wind Dir	Bias	-1.34	1.63	-1.27
	Error	32.97	30.74	31.08
Temperature	Bias	0.13	-0.43	-0.05
	Error	1.76	1.72	1.79
	RMSE	2.34	2.38	2.34
	IOA	0.94	0.93	0.94
Humidity	Bias	0.33	0.77	0.41
	Error	1.46	1.91	1.27
	RMSE	1.88	2.54	1.62
	IOA	0.87	0.81	0.81

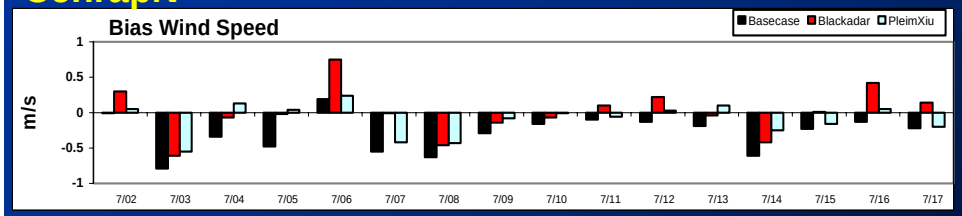
Pleim-Xiu

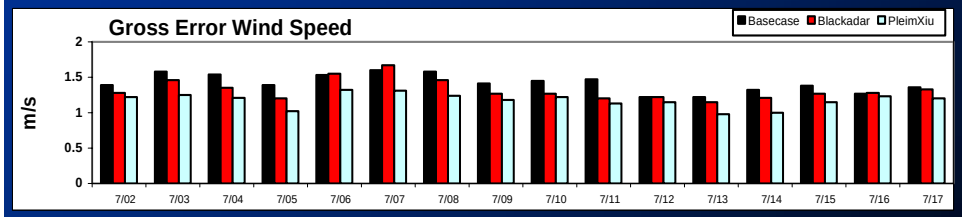
		CenrapN	CenrapS	Great Lakes
Wind Speed	Bias	-0.10	-0.51	0.13
	Error	1.18	1.22	1.17
	RMSE	1.56	1.66	1.53
	IOA	0.71	0.69	0.72
Wind Dir	Bias	-0.49	0.82	0.15
	Error	32.11	30.32	30.38
Temperature	Bias	0.14	-0.20	0.06
	Error	1.83	1.85	1.82
	RMSE	2.44	2.55	2.38
	IOA	0.93	0.93	0.93
Humidity	Bias	0.12	0.07	0.24
	Error	1.44	1.72	1.22
	RMSE	1.89	2.29	1.59
	IOA	0.88	0.86	0.84

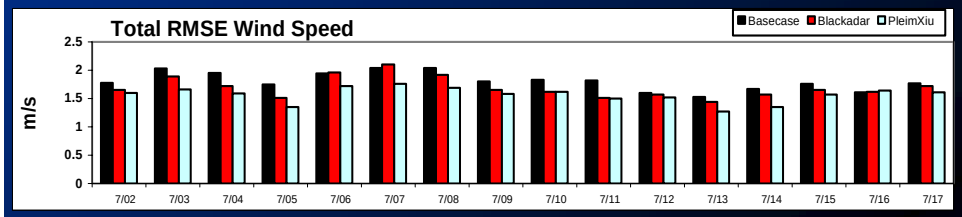
Blue indicates performance improvement

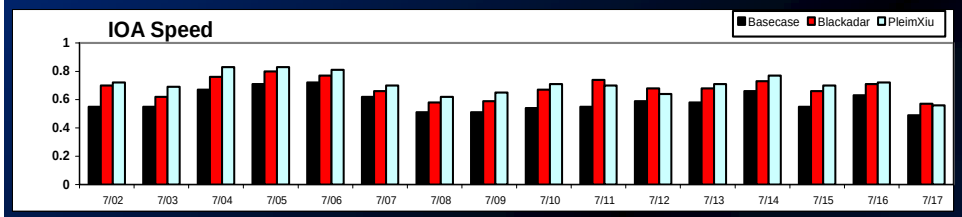
Wind Fields: Basecase vs Blackadar vs Pleim-Xiu

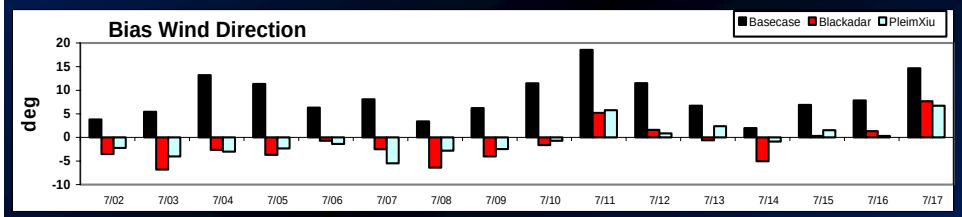
CenrapN

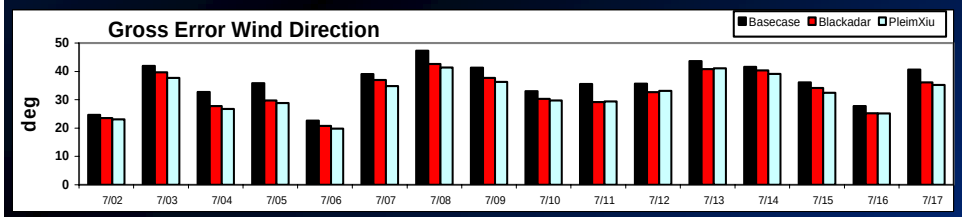




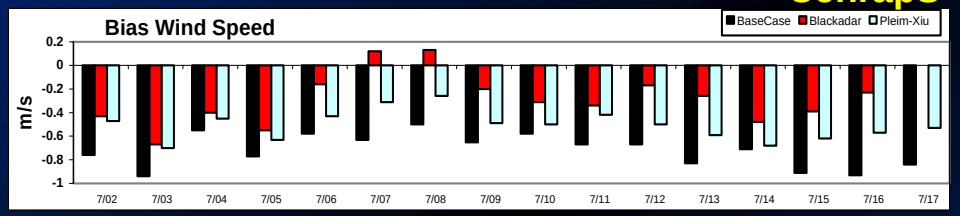


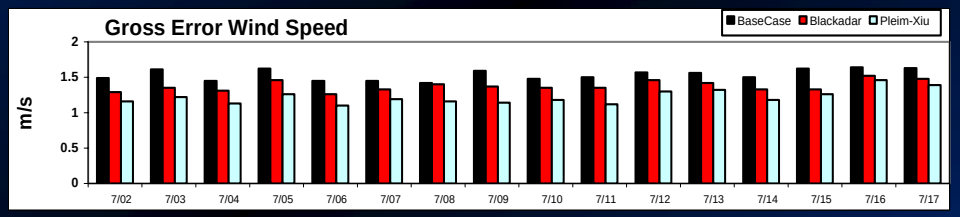


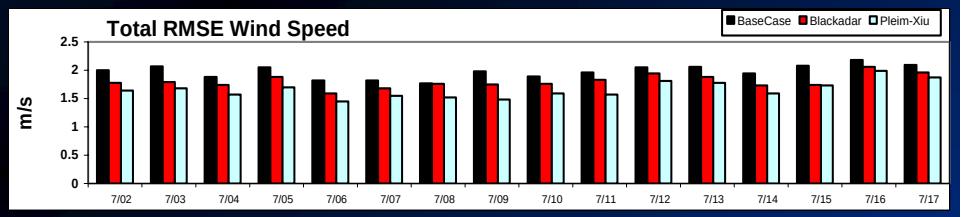


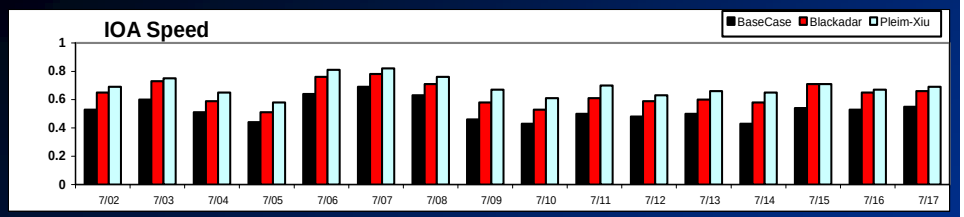


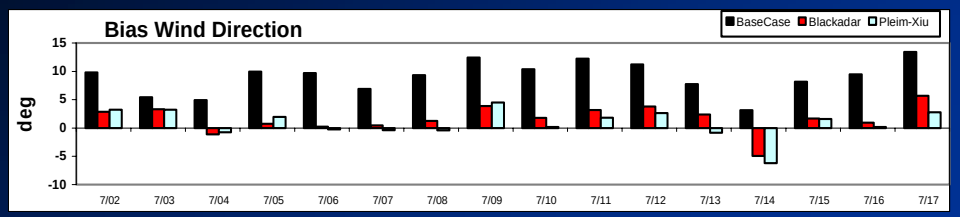
CenrapS

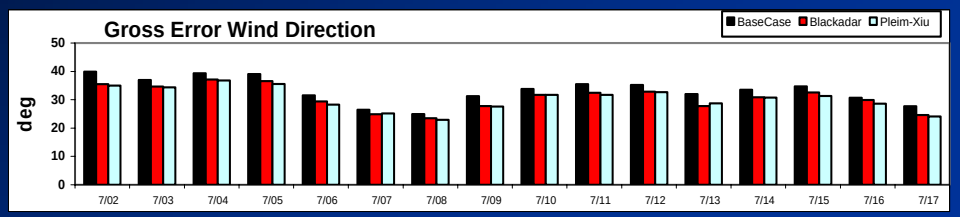








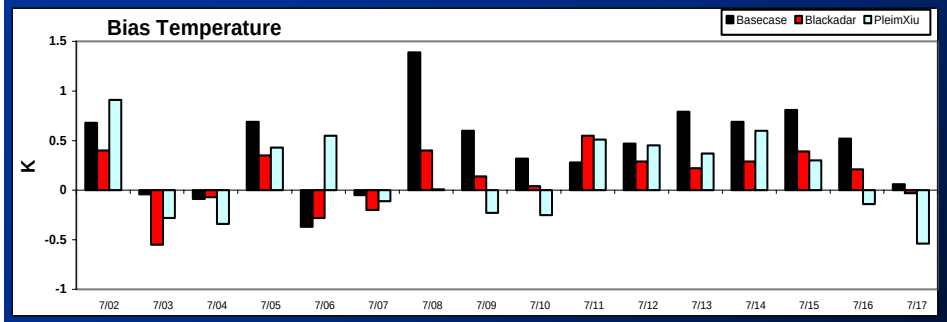


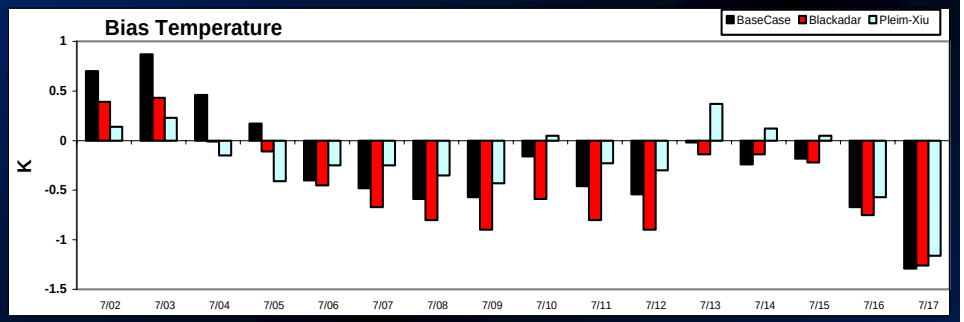


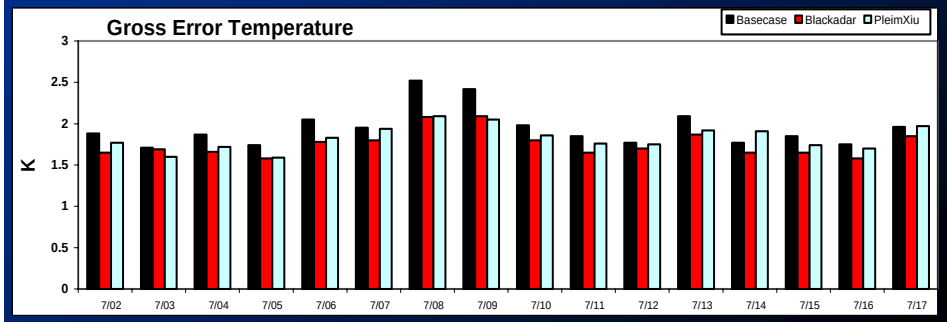
Temperature: Basecase vs Blackadar vs Pleim-Xiu

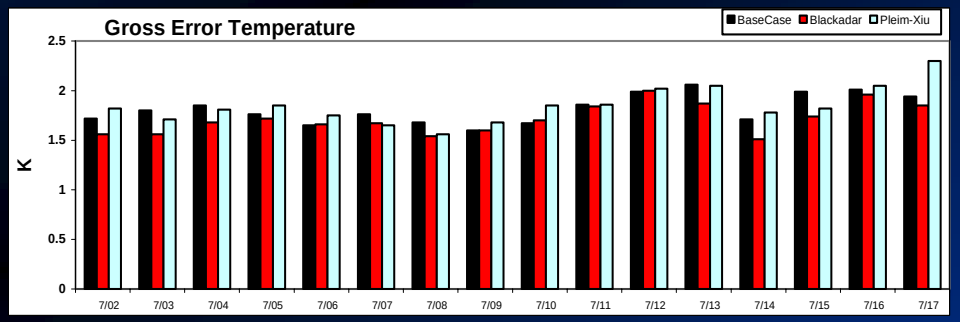
CenrapN

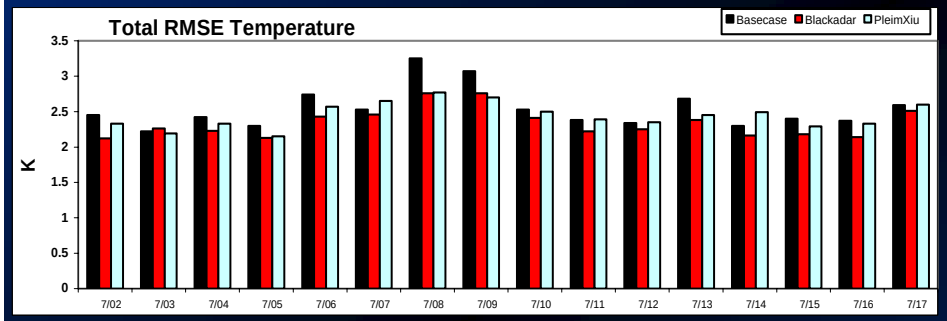
CenrapS

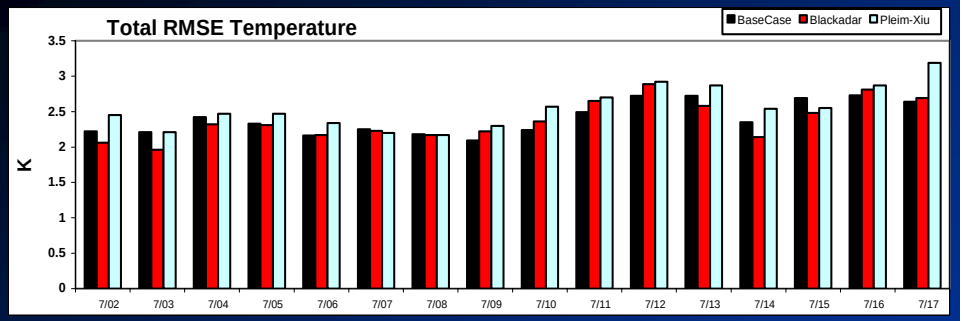


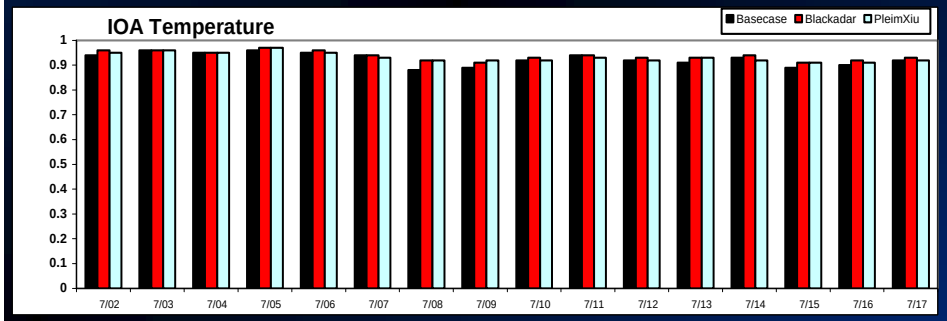


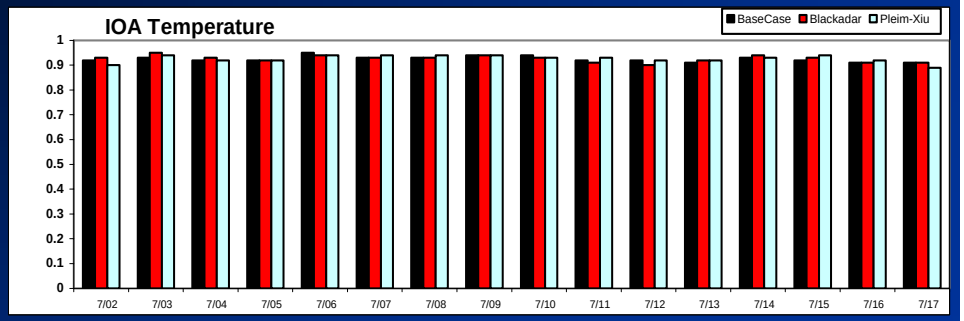






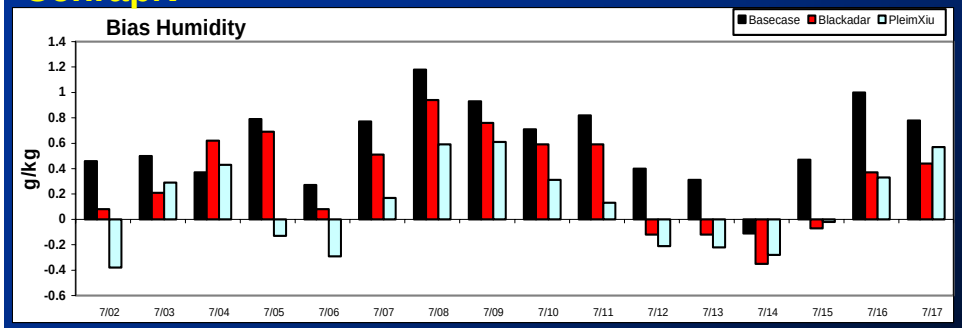


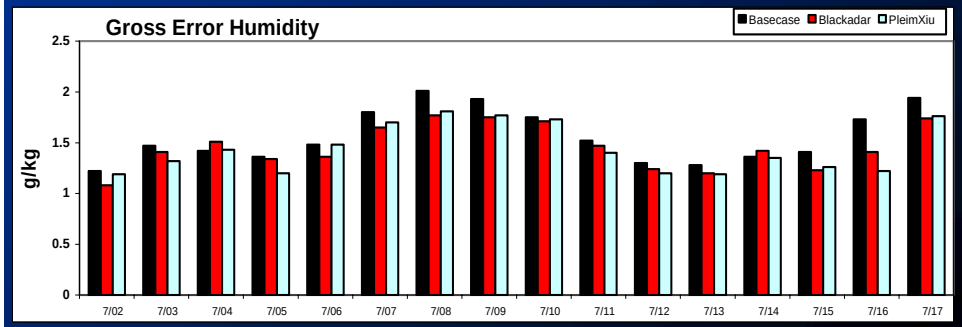


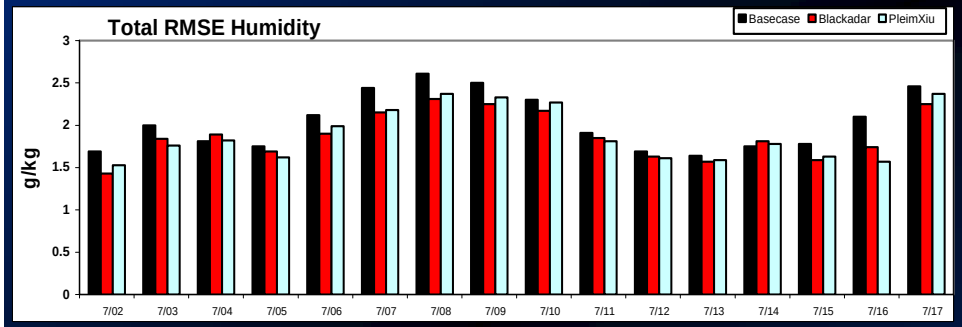


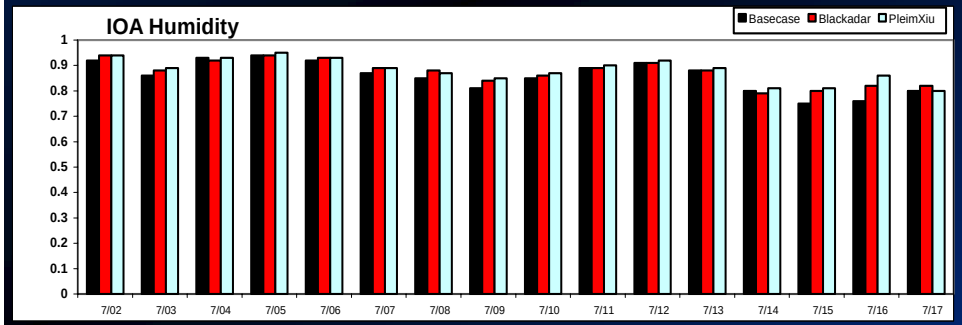
Moisture: Basecase vs Blackadar vs Pleim-Xiu

CenrapN









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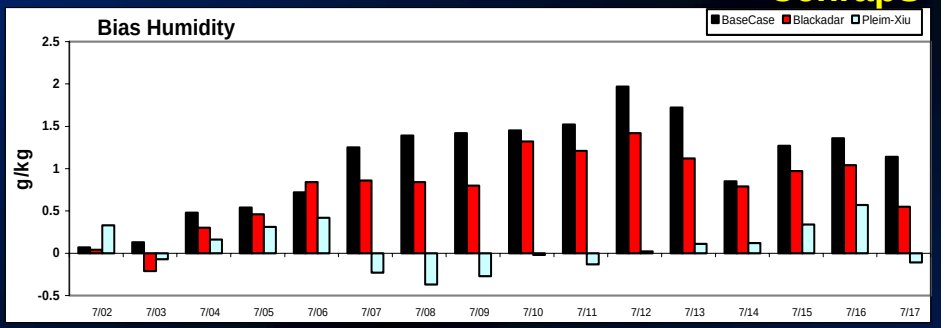
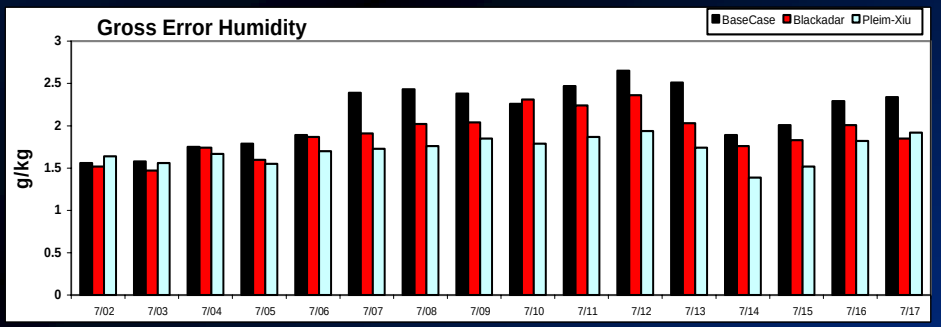
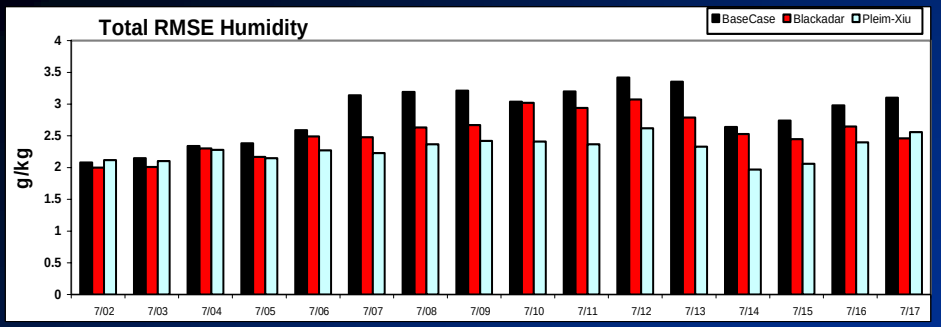
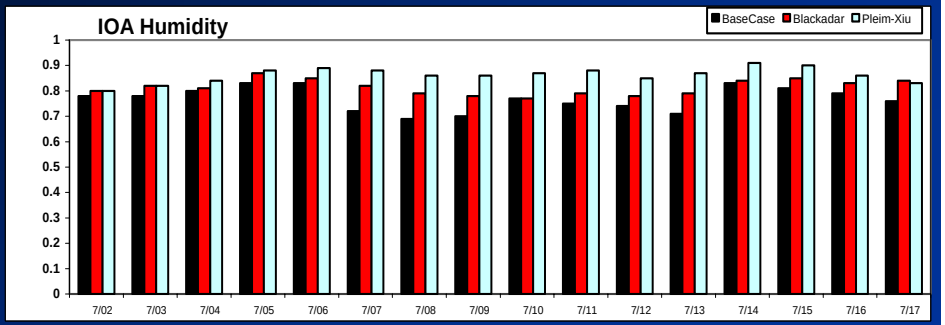




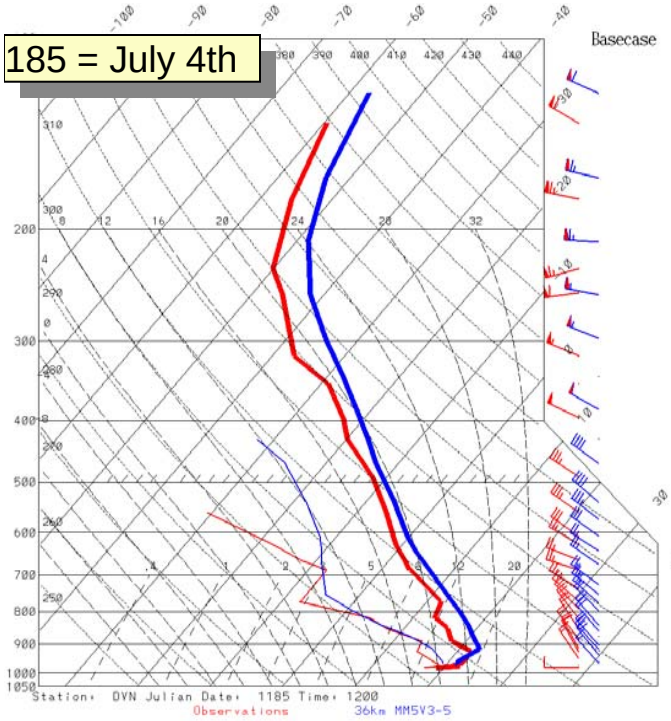


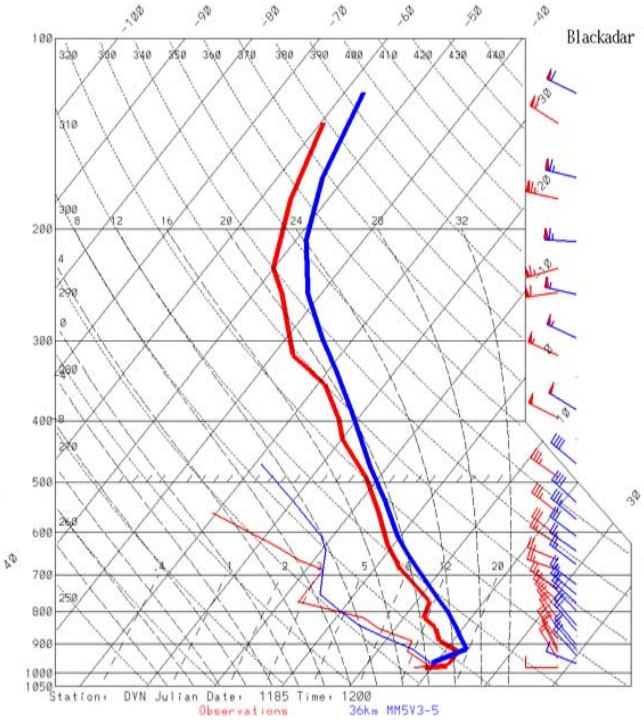


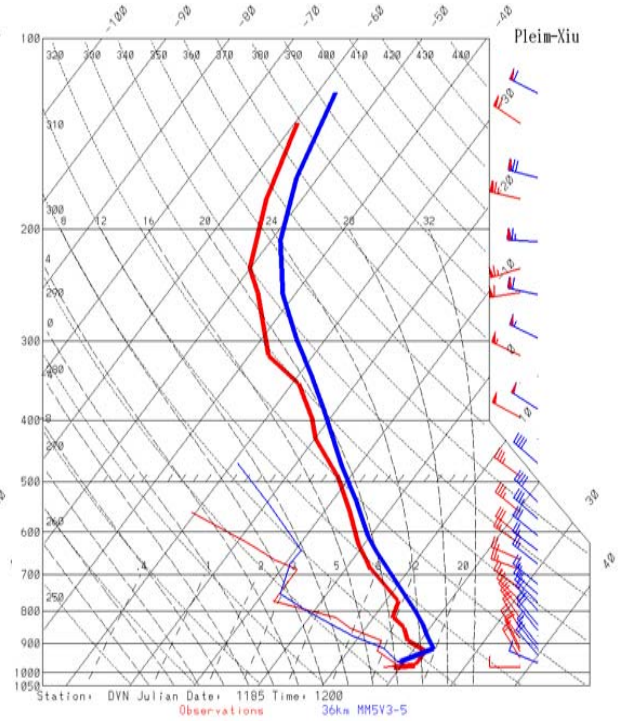
Qualitative Upper Air Assessment

- Soundings: modeled vs observed
  - (~75 sites)(2/day)(16 days) = ~2400 plots/episode
  - We'll look at 6
- General Summary
  - MM5 is typically warmer with higher mixing ratios throughout the depth of the modeled atmosphere, regardless of options
  - Blackadar and PX slightly edge out the Basecase, however, with point assessments each option will occasionally excel
- No evidence found to reject Basecase, Blackadar, or Pleim-Xiu simulations

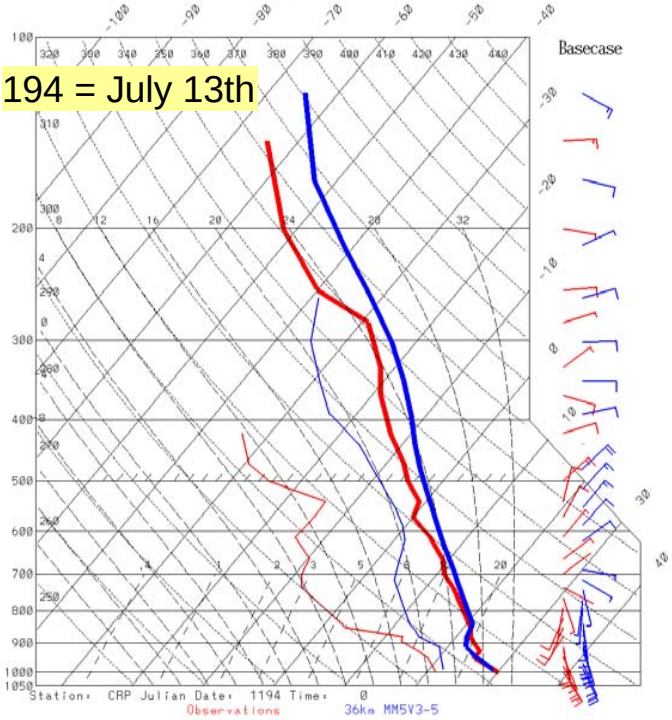
185 = July 4th

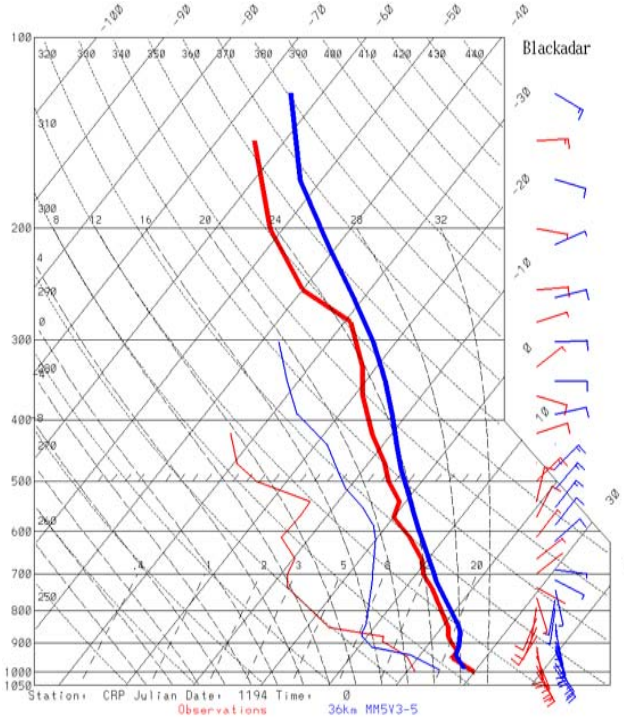


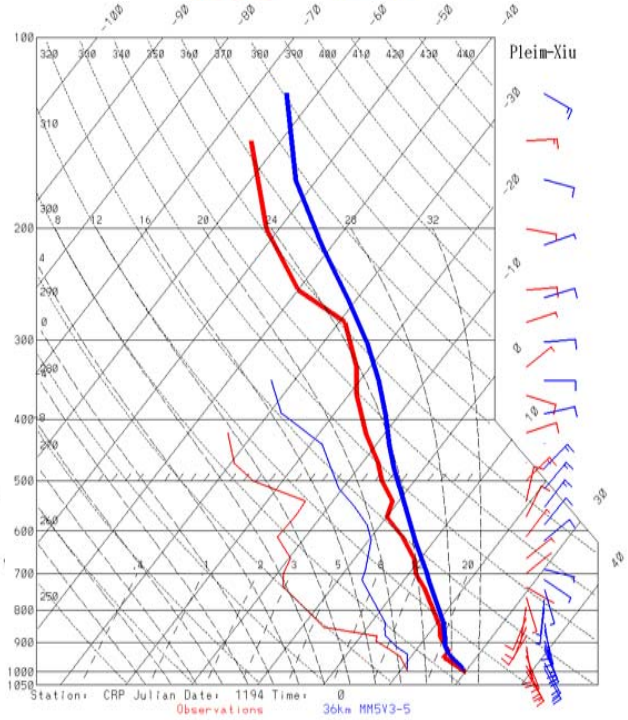




194 = July 13th







Summary

- MPP & single CPU results identical
- Shallow Convection option showed little sfc impacts
- NCEP SST shows significant differences in ground temperatures near coastal areas and larger lakes
  - More evaluation is needed in these areas
- OSU LSM
  - Greatest impacts were on temperature and soil moisture
    - Overall an improvement upon the Basecase, with the exception of the Ohio Valley region

Summary

- Blackadar
  - Preferable over the Basecase
- Pleim-Xiu
  - Use of landuse.tbl soil moisture values not recommended
  - Significant improvements in the wind fields (vs all other options)
  - Moisture prediction improved vs other simulations also
  - Temperature predictions at worst 2nd best
    - Slightly outperformed by Blackadar
- 'Final' Recommendation...

Pleim-Xiu

- What's the catch?
  - 1) Winter analysis will be extremely important
  - 2) Computation resources

Questions?