

# Evaluation of a 2011 WRF v3.5 Simulation

---

David Brown

Iowa Department of Natural Resources

2014 Midwest and Central States Air Quality Workshop

04/23/2014

# Background

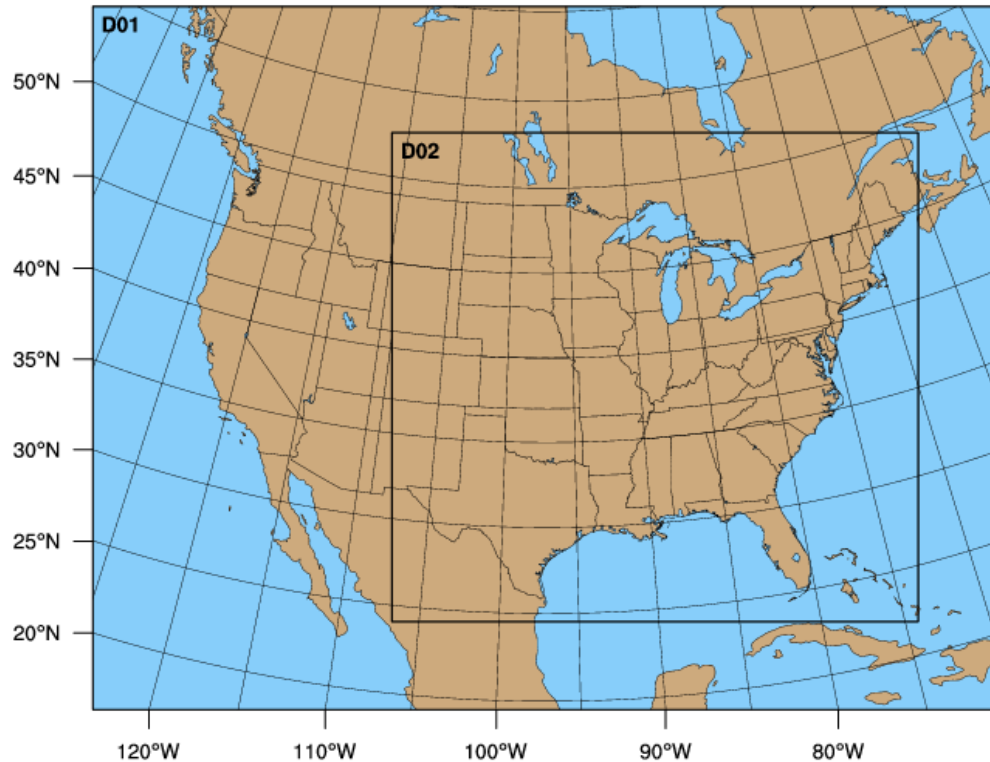
- **Iowa DNR coordinated with LADCO and WI DNR to develop meteorological dataset**
- **Input to photochemical model simulations**
- **Support current and anticipated AQ issues**
  - SIP development
  - Interstate transport
  - Regional haze
- **2011 base year**
  - Process started several years earlier (with 2007 met data)
  - Updated to NEI year

# Configuration

- WRF v3.5 w/ IPXWRF

Physics Scheme	Option Selected
Planetary Boundary Layer	Asymmetric Convective Model 2
Surface Layer	Pleim-Xiu
Land Surface Model	Pleim-Xiu w/ IPXWRF
Microphysics	Morrison et al.
Radiation (Shortwave)	Rapid Radiative Transfer Model for GCMs
Radiation (Longwave)	Rapid Radiative Transfer Model for GCMs
Cumulus	Kain-Fritsch

# Configuration



Domains	Course (1)	Nested (2)
Resolution (km)	36	12
Starting Location (i,j)	1,1	55,17
nx (E-W)	165	286
ny (N-S)	129	268
SW Coordinate (km)	-2952, -2304	-1008, -1728
NE Coordinate (km)	2952, 2304	2412, 1476

# Configuration

- **35 Eta levels**
  - ~20 m first layer depth
  - 50 mb model top
  - Increased resolution near surface and tropopause
- **NLCD 2006 land use**
- **NAM 12 km 6-hrly analyses + 3 hr forecasts**
  - Initial and boundary conditions
  - 3D analysis nudging fields

# Configuration

- **NCEP 1/12<sup>th</sup> degree RTG SST analysis for sea-surface temperatures**
  - Daily-averaged SST
- **3D analysis FDDA**
  - Nudged T, U, V, and Q above PBL at 36 and 12 km
  - No surface nudging
  - 36 km:  $G_t = 5 \times 10^{-4}$ ,  $G_{uv} = 5 \times 10^{-4}$ ,  $G_q = 1 \times 10^{-5}$
  - 12 km:  $G_t = 3 \times 10^{-4}$ ,  $G_{uv} = 3 \times 10^{-4}$ ,  $G_q = 1 \times 10^{-5}$

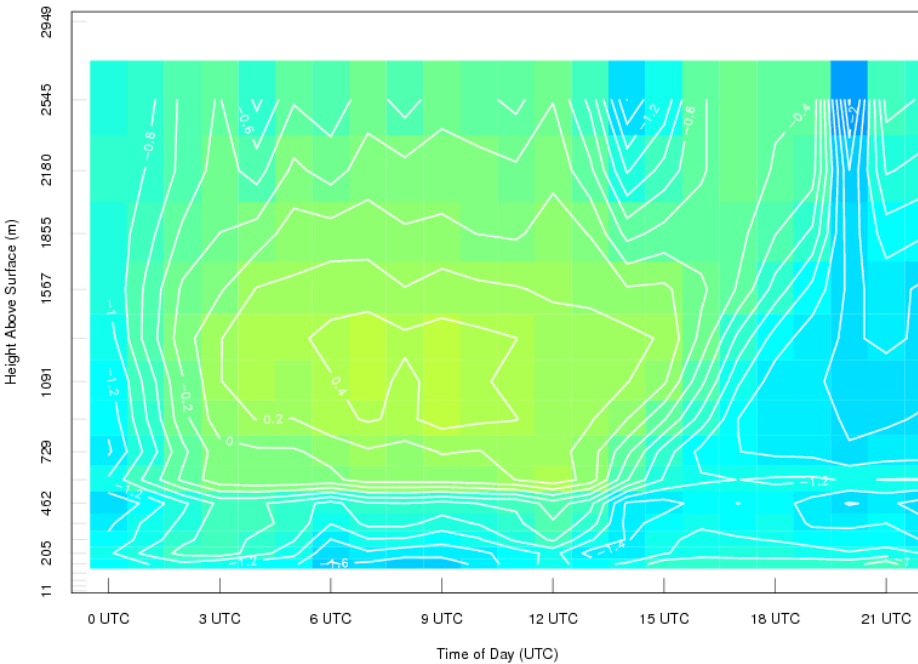
# Configuration

- **WRF annual simulation for 2011**
  - Start date: 2010-12-16 12Z
  - End date: 2012-01-06 00Z
- **Run in 5.5-day blocks**
  - 12 hours of spin-up time for each block
  - Soil temperature and moisture carried over by IPXWRF

# Nudging Sensitivity Analysis

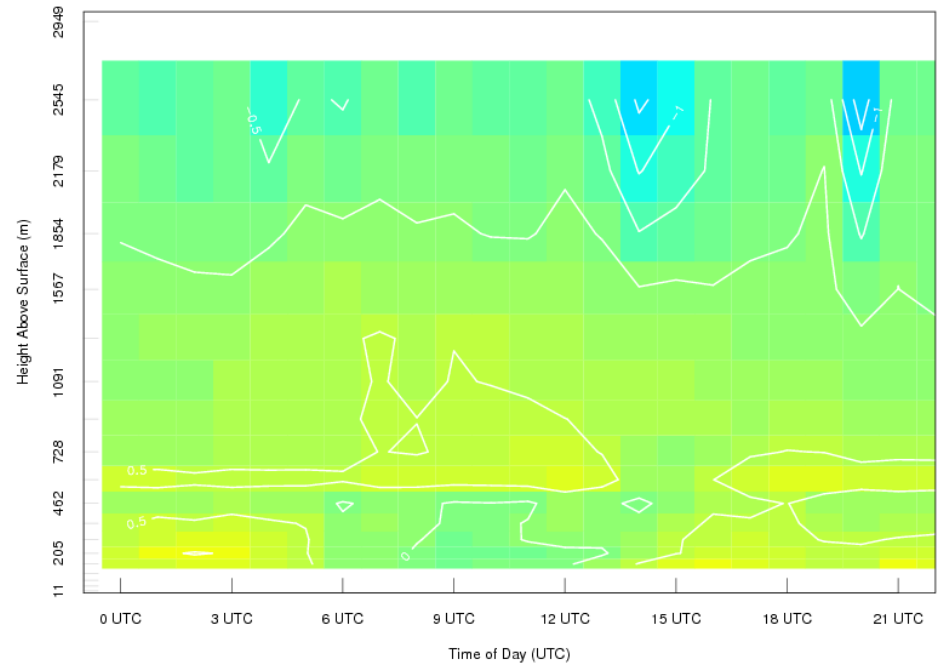
## Wind Speed Bias - June 2011

Time-Height Mean Bias of Wind Speed (m/s)



Old

Time-Height Mean Bias of Wind Speed (m/s)



New

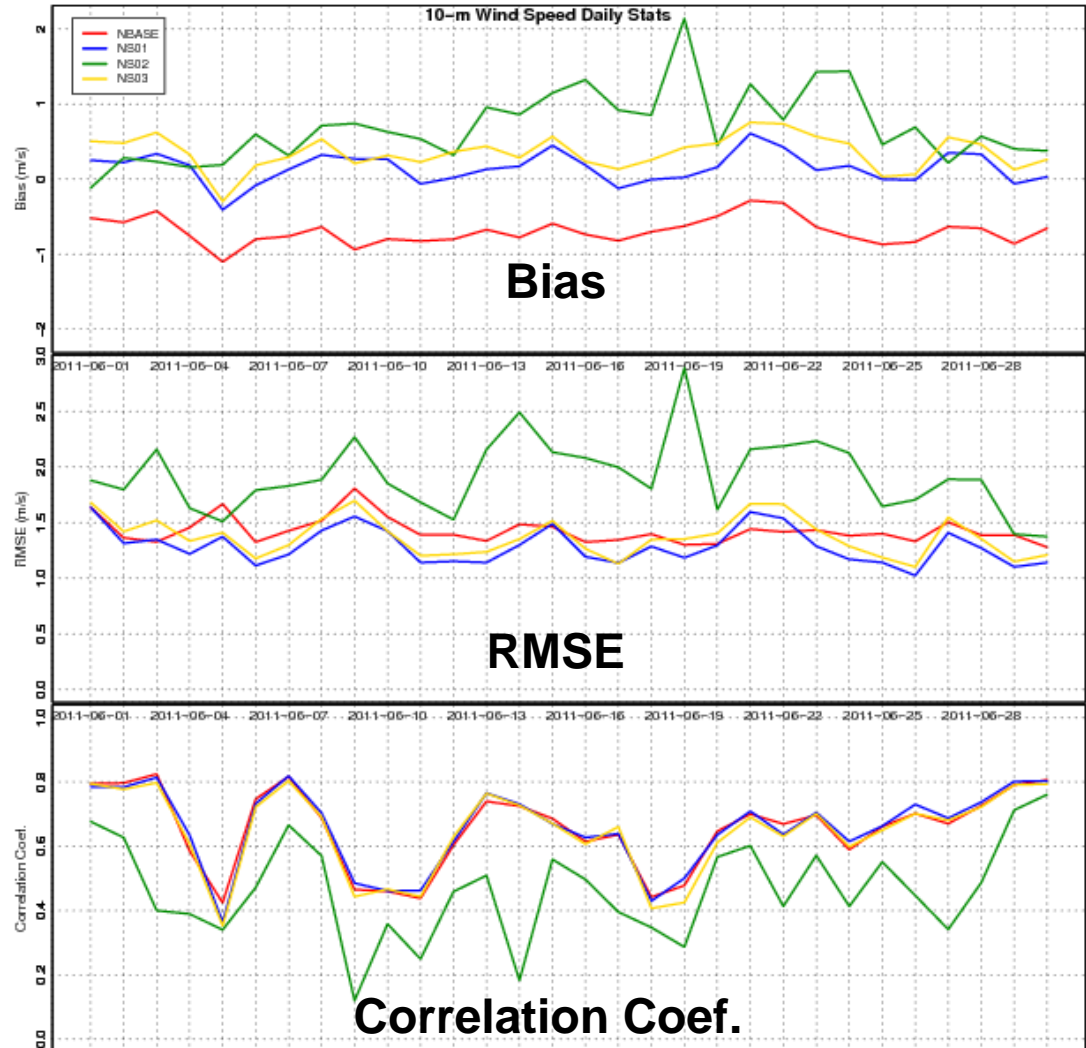


# Nudging Sensitivity Analysis

Daily 10m Wind Speed Statistics

LADCO Region

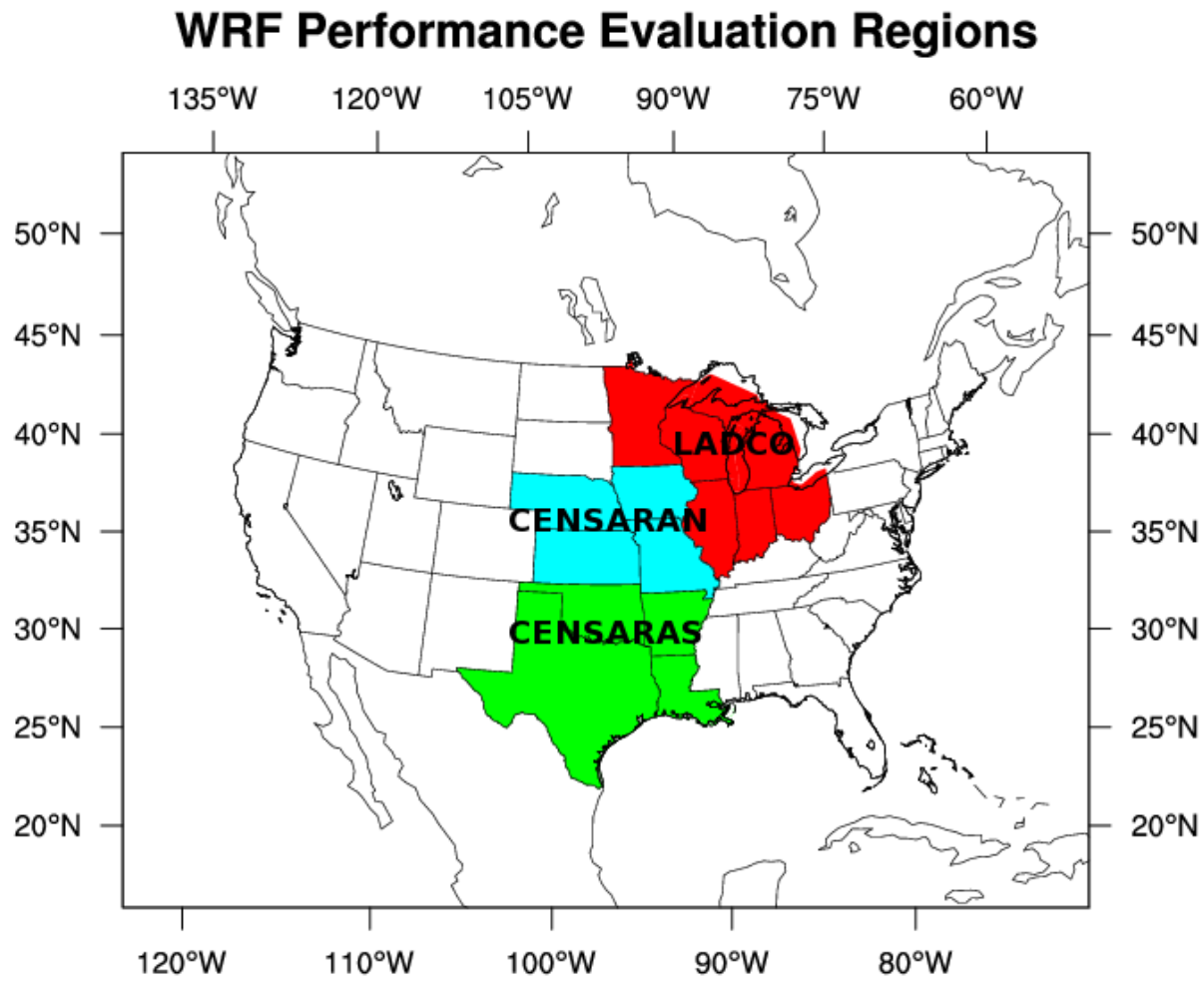
June 2011



# Statistical Evaluation

- **Model Evaluation Tools (MET) v3.0.1 and Atmospheric Model Evaluation Tool (AMET) v1.1**
- **Bias, Mean Absolute Error, Root Mean Square Error, and Correlation Coefficient**
- **2-m Temperature & Mixing Ratio, 10-m Wind Speed (w/o calms presented here)**
- **Hourly, daily, and monthly temporal periods**

# Statistical Evaluation

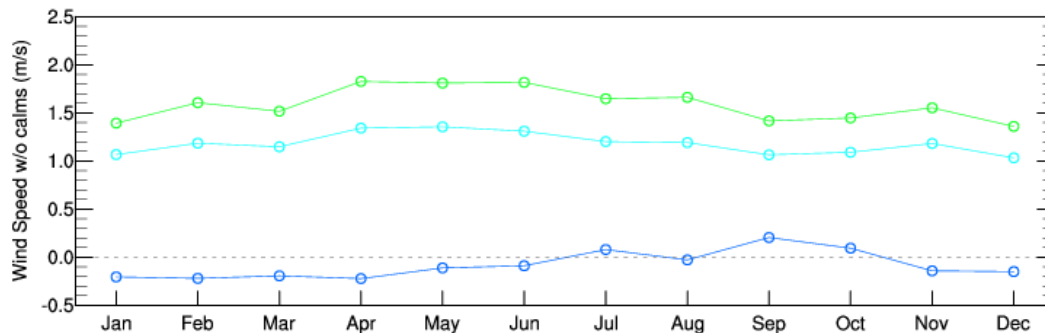


# Monthly Statistics

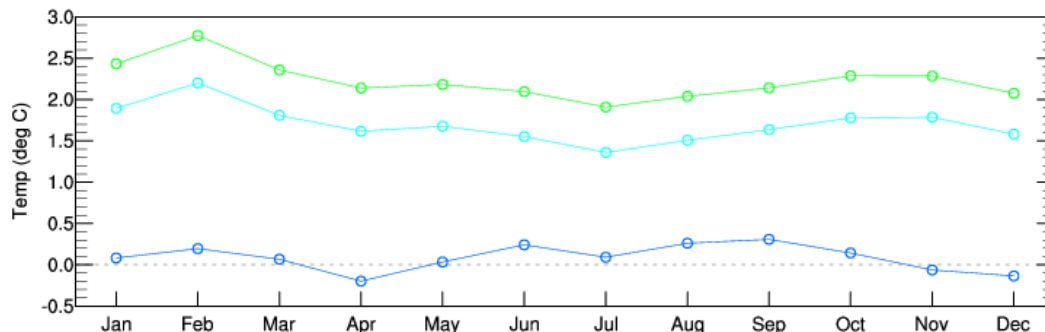
## D02 (12 km)

## CENSARAN

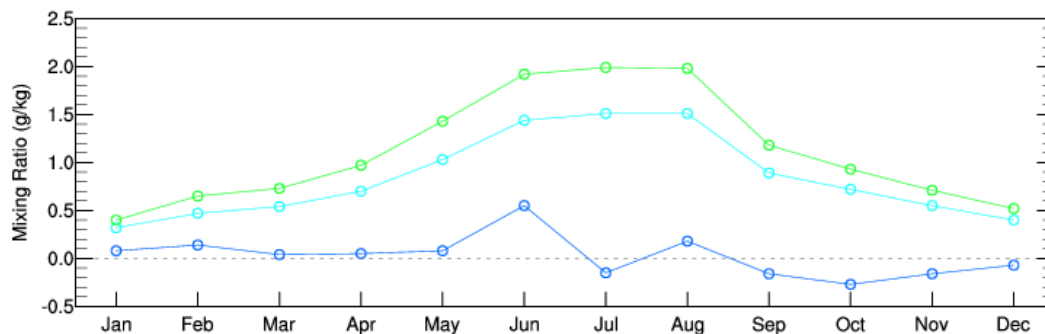
2011 WRF IDNR - D02 - Wind Speed w/o calms Bias (Blue), MAE (Cyan), and RMSE (Green) - CENSARAN



2011 WRF IDNR - D02 - Temp Bias (Blue), MAE (Cyan), and RMSE (Green) - CENSARAN



2011 WRF IDNR - D02 - Mixing Ratio Bias (Blue), MAE (Cyan), and RMSE (Green) - CENSARAN

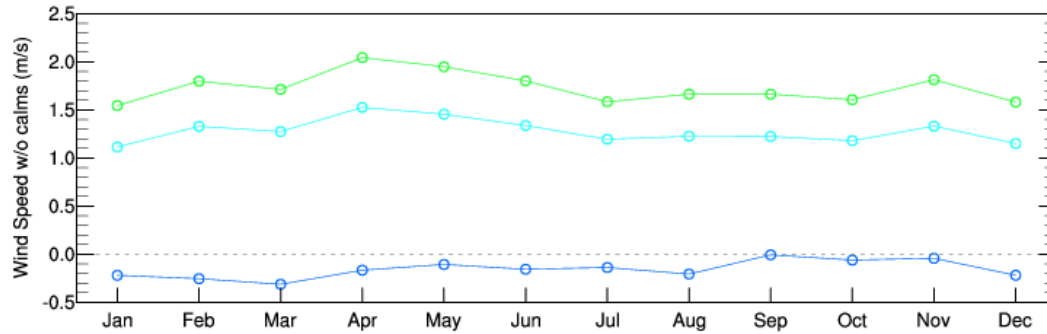


# Monthly Statistics

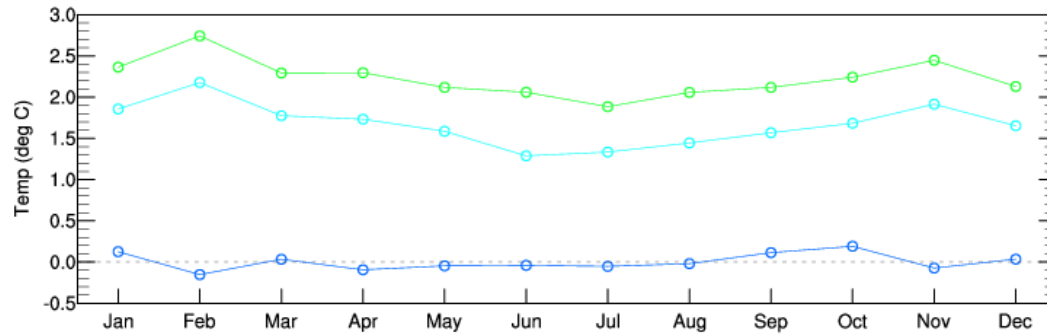
## D02 (12 km)

## CENSARAS

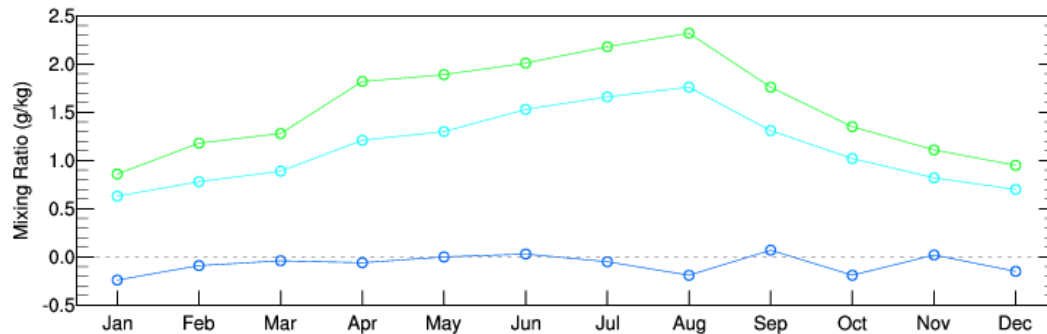
2011 WRF IDNR - D02 - Wind Speed w/o calms Bias (Blue), MAE (Cyan), and RMSE (Green) - CENSARAS



2011 WRF IDNR - D02 - Temp Bias (Blue), MAE (Cyan), and RMSE (Green) - CENSARAS



2011 WRF IDNR - D02 - Mixing Ratio Bias (Blue), MAE (Cyan), and RMSE (Green) - CENSARAS

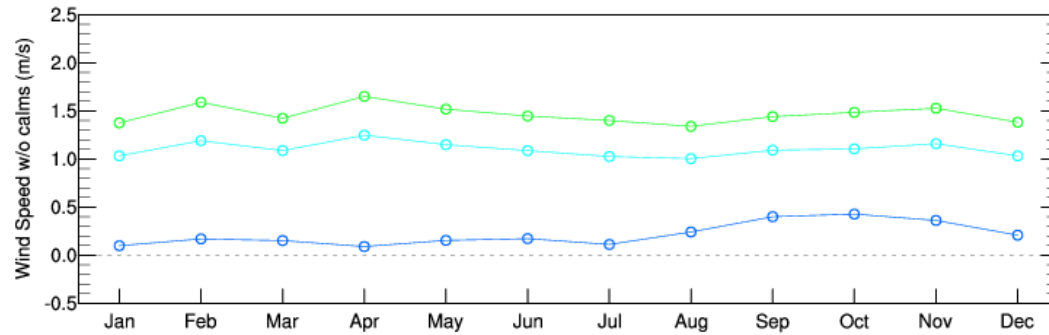


# Monthly Statistics

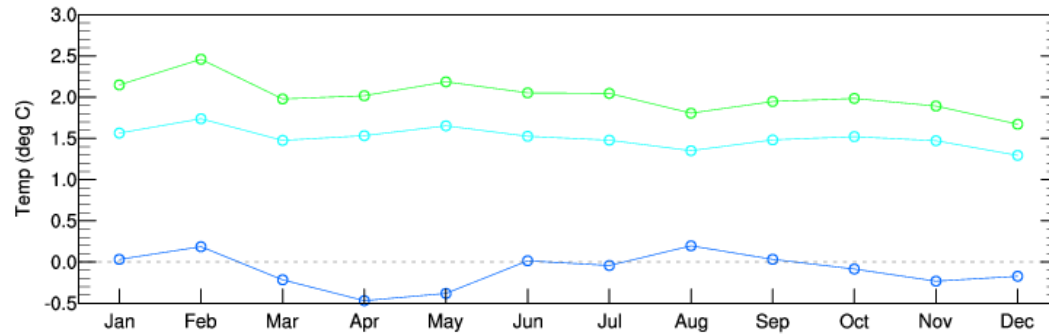
## D02 (12 km)

### LADCO

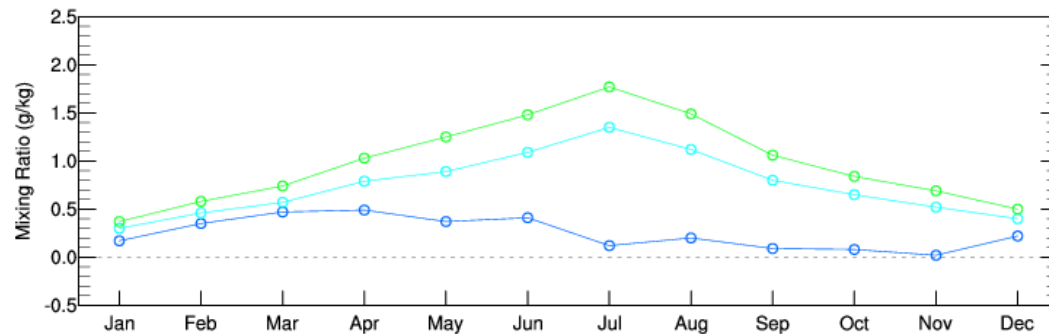
2011 WRF IDNR - D02 - Wind Speed w/o calms Bias (Blue), MAE (Cyan), and RMSE (Green) - LADCO



2011 WRF IDNR - D02 - Temp Bias (Blue), MAE (Cyan), and RMSE (Green) - LADCO

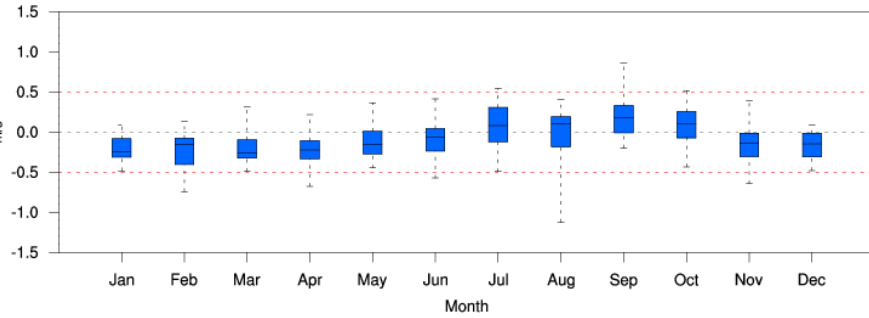


2011 WRF IDNR - D02 - Mixing Ratio Bias (Blue), MAE (Cyan), and RMSE (Green) - LADCO

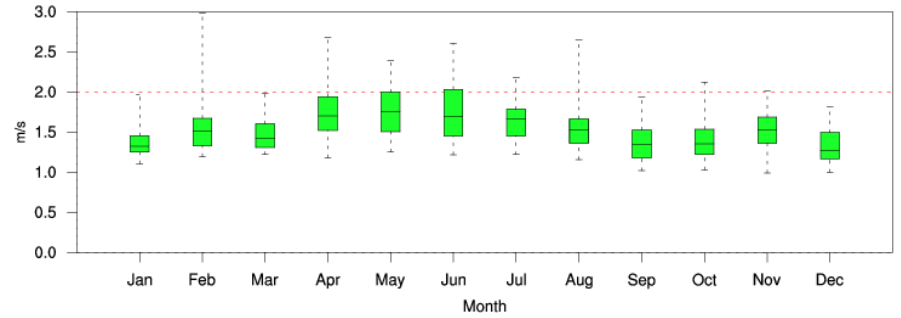


# Daily Statistics – D02 (12 km) – CENSARAN

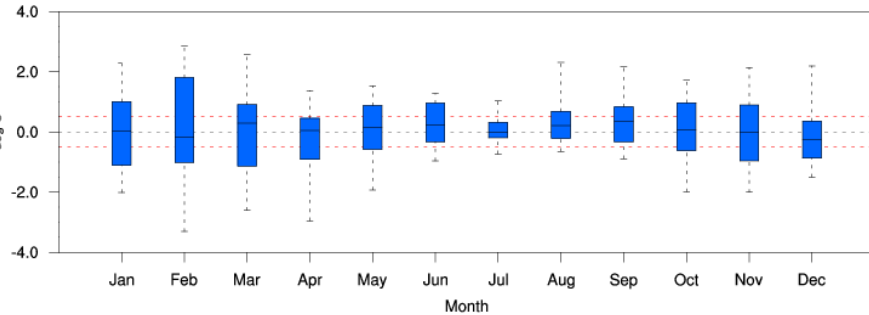
Daily Wind Speed w/o Calms Bias - D02 - CENSARAN - 2011wrfv35v2



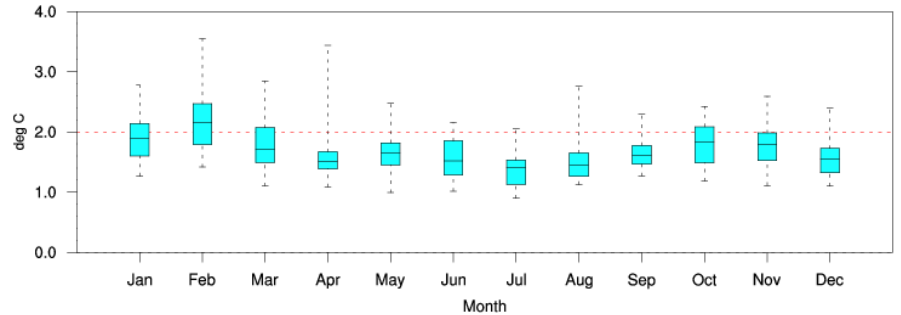
Daily Wind Speed w/o Calms RMSE - D02 - CENSARAN - 2011wrfv35v2



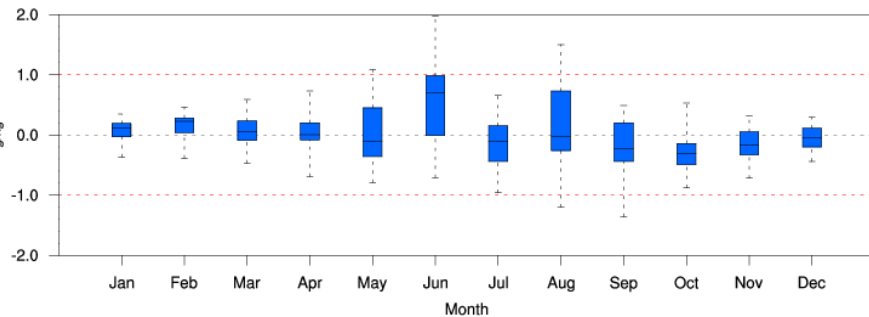
Daily Temperature Bias - D02 - CENSARAN - 2011wrfv35v2



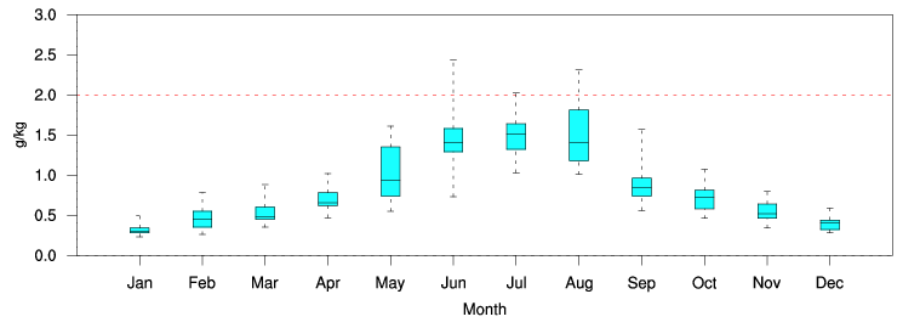
Daily Temperature MAE - D02 - CENSARAN - 2011wrfv35v2



Daily Mixing Ratio Bias - D02 - CENSARAN - 2011wrfv35v2

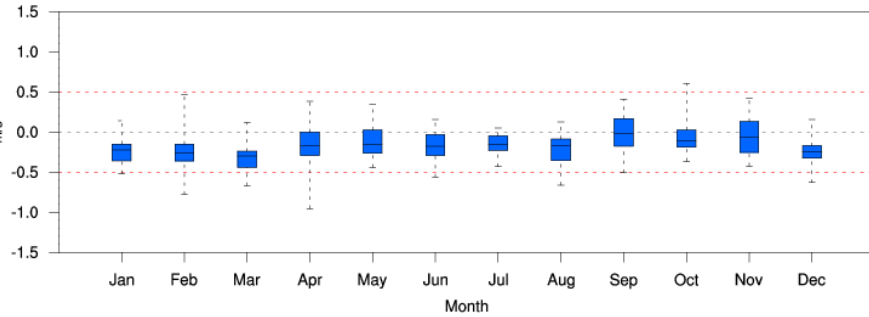


Daily Mixing Ratio MAE - D02 - CENSARAN - 2011wrfv35v2

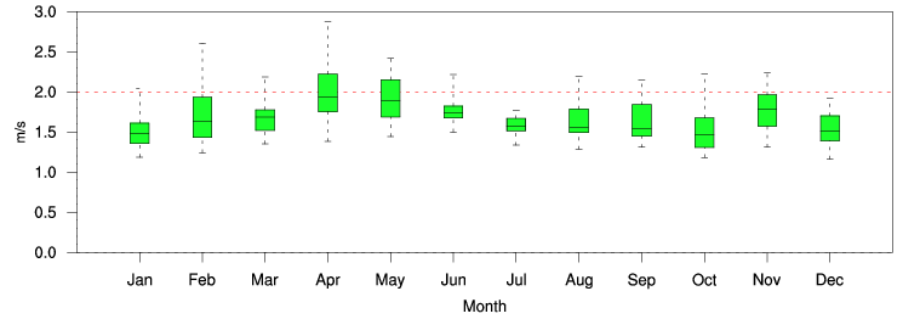


# Daily Statistics – D02 (12 km) – CENSARAS

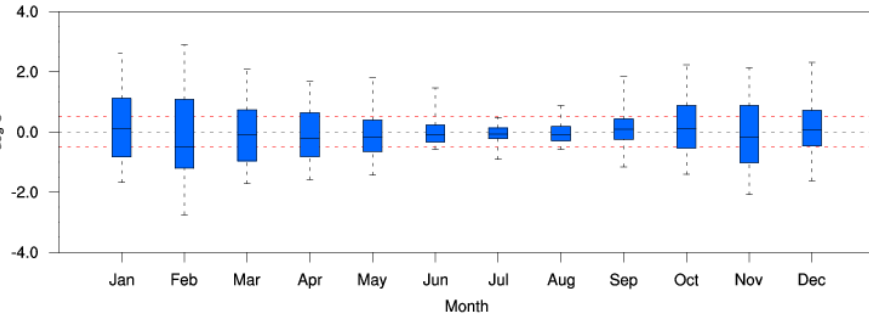
Daily Wind Speed w/o Calms Bias - D02 - CENSARAS - 2011wrfv35v2



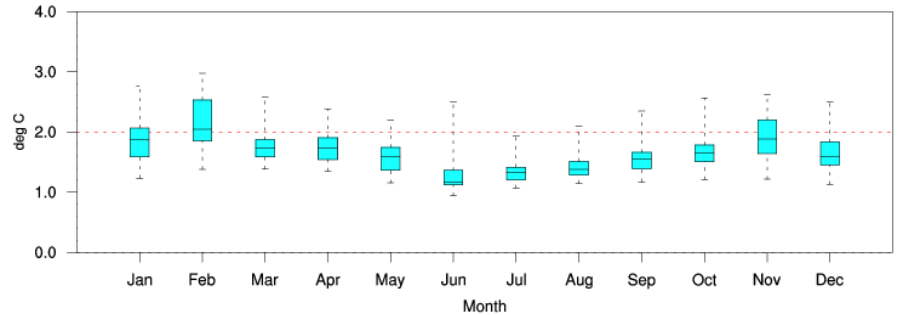
Daily Wind Speed w/o Calms RMSE - D02 - CENSARAS - 2011wrfv35v2



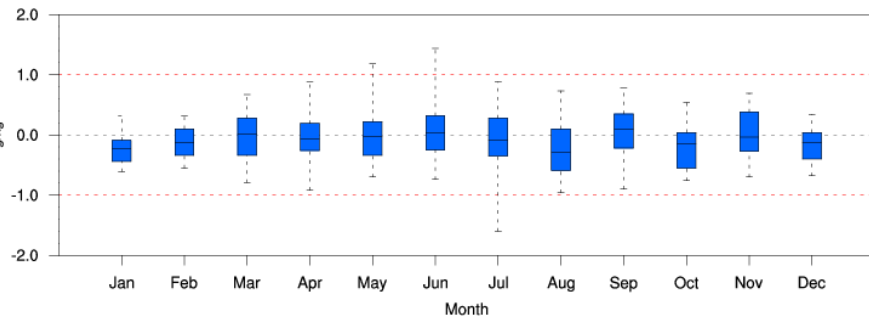
Daily Temperature Bias - D02 - CENSARAS - 2011wrfv35v2



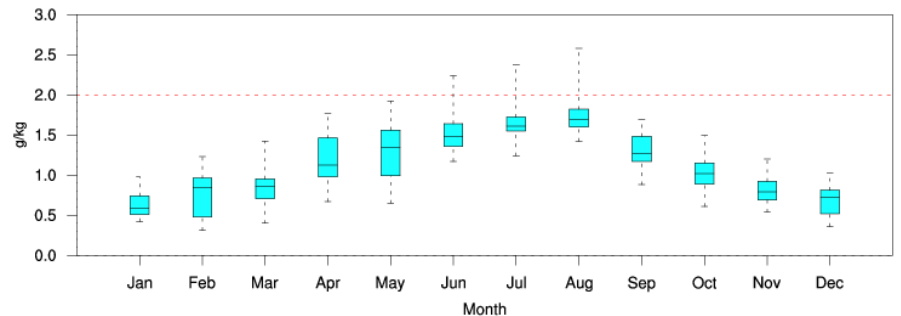
Daily Temperature MAE - D02 - CENSARAS - 2011wrfv35v2



Daily Mixing Ratio Bias - D02 - CENSARAS - 2011wrfv35v2



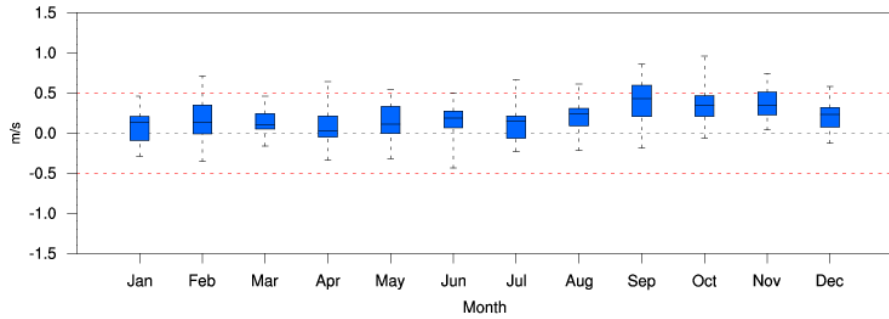
Daily Mixing Ratio MAE - D02 - CENSARAS - 2011wrfv35v2



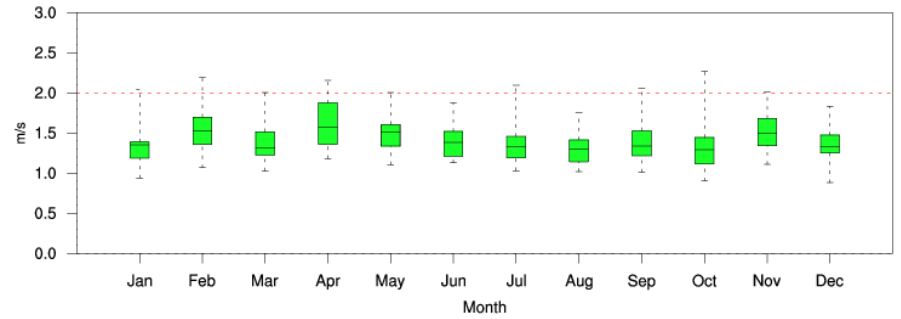


# Daily Statistics – D02 (12 km) – LADCO

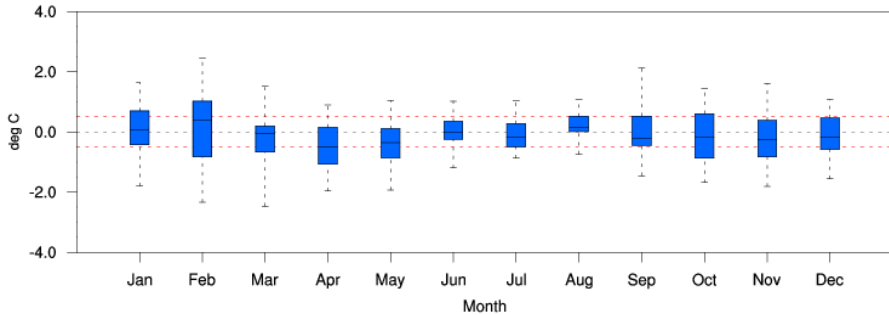
Daily Wind Speed w/o Calms Bias - D02 - LADCO - 2011wrfv35v2



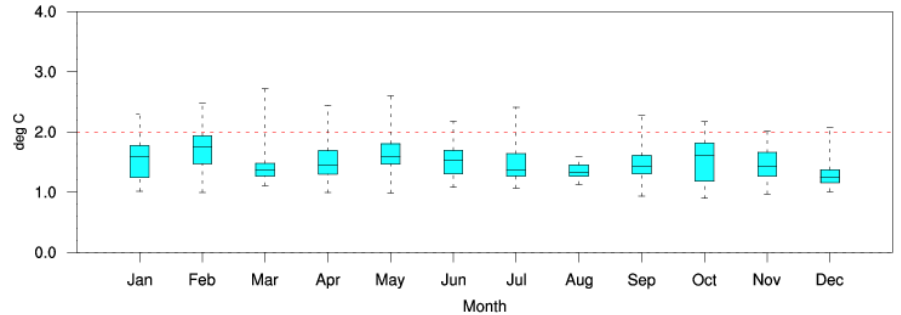
Daily Wind Speed w/o Calms RMSE - D02 - LADCO - 2011wrfv35v2



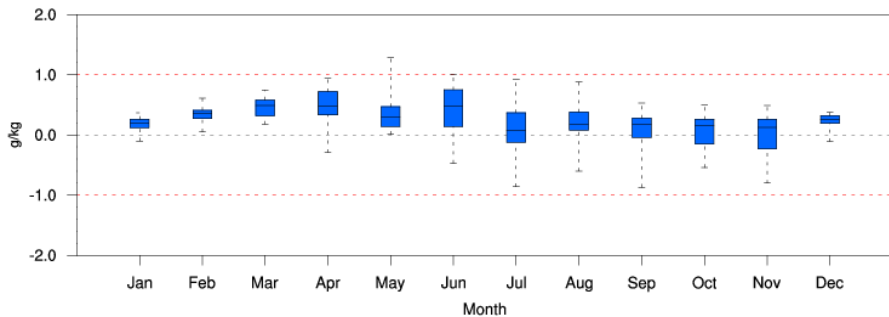
Daily Temperature Bias - D02 - LADCO - 2011wrfv35v2



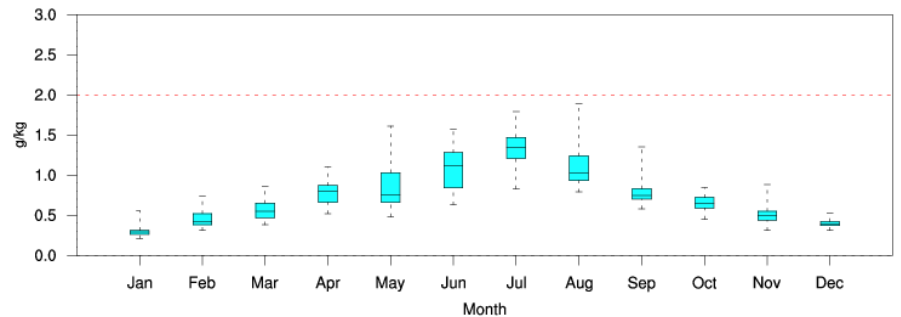
Daily Temperature MAE - D02 - LADCO - 2011wrfv35v2



Daily Mixing Ratio Bias - D02 - LADCO - 2011wrfv35v2



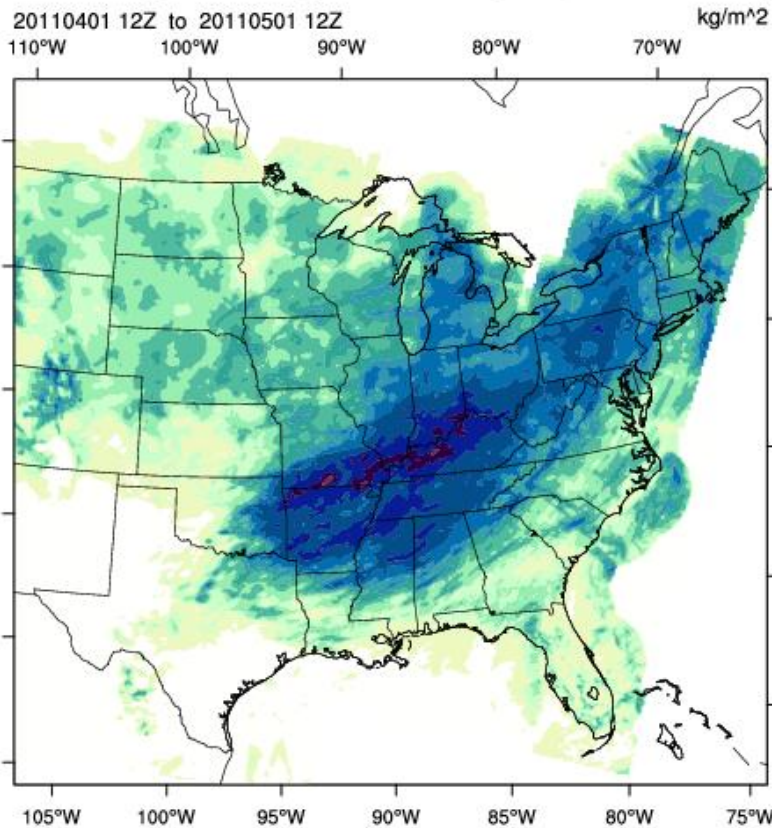
Daily Mixing Ratio MAE - D02 - LADCO - 2011wrfv35v2



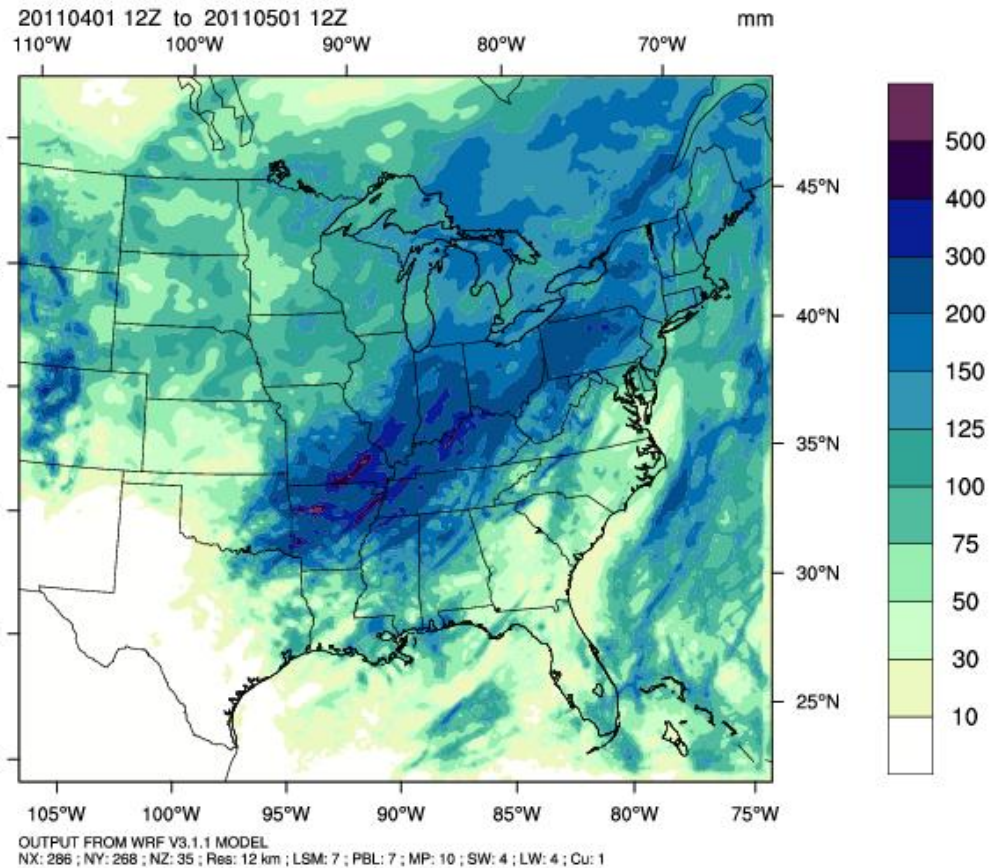
# Precipitation

## April 2011

### NCEP Stage IV Precipitation Analysis (Accumulated)



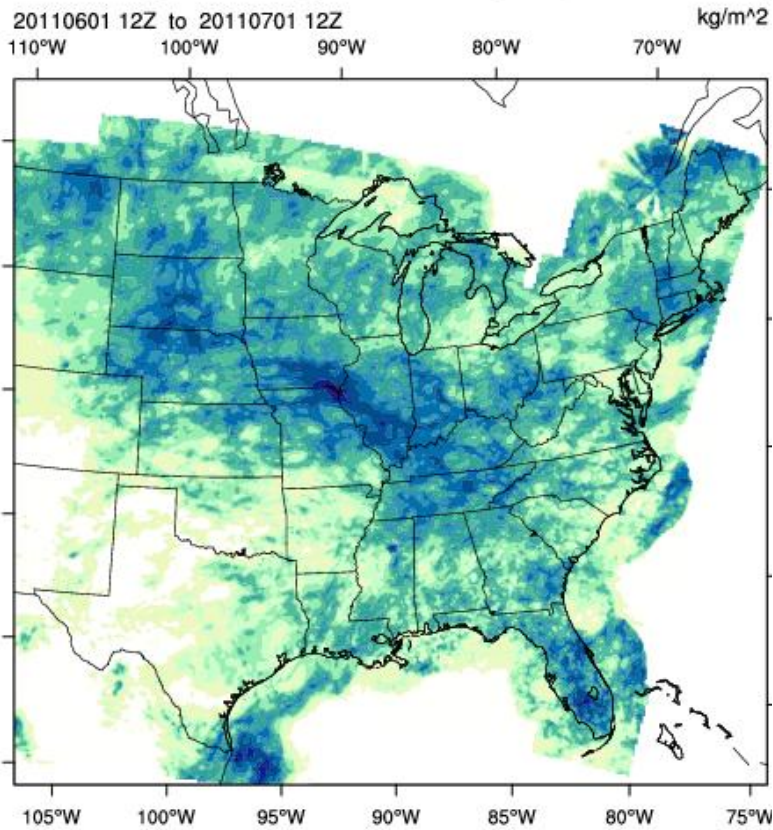
### WRF-ARW Accumulated Precipitation



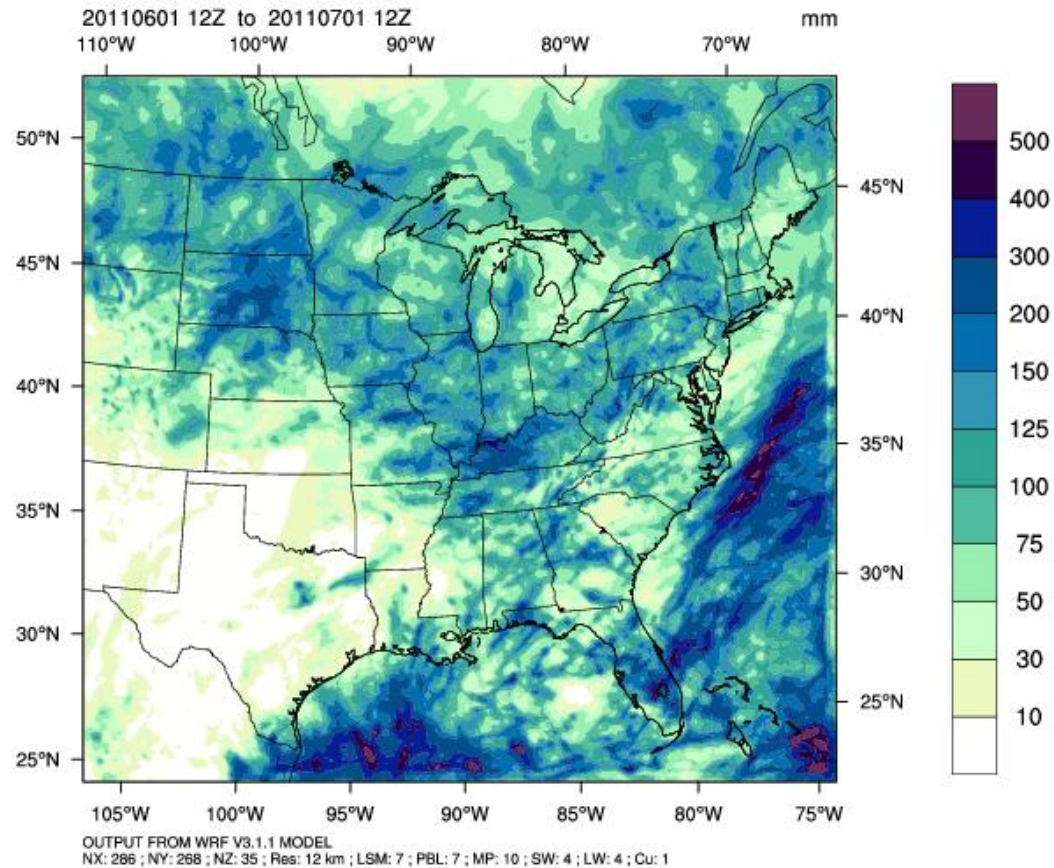
# Precipitation

## June 2011

### NCEP Stage IV Precipitation Analysis (Accumulated)



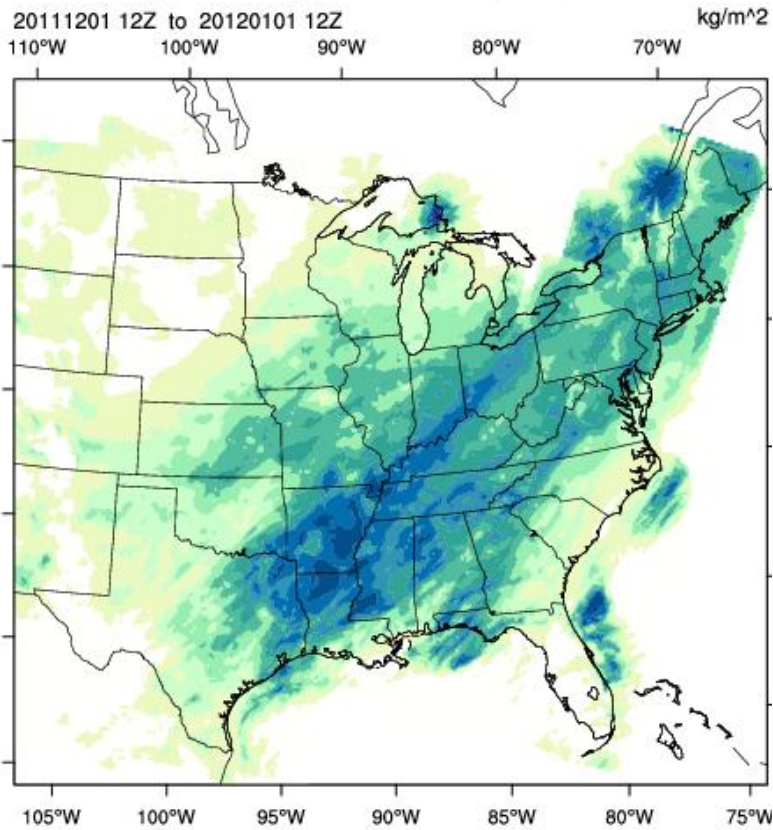
### WRF-ARW Accumulated Precipitation



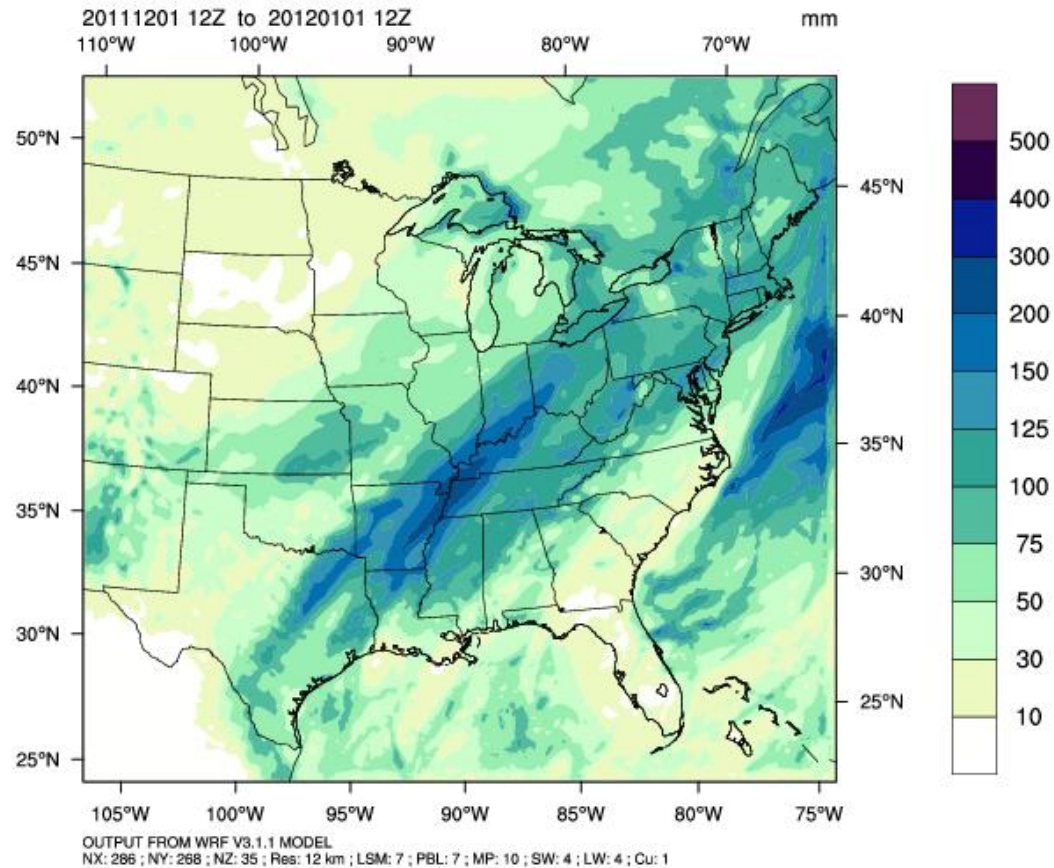
# Precipitation

## December 2011

### NCEP Stage IV Precipitation Analysis (Accumulated)



### WRF-ARW Accumulated Precipitation



# Conclusions

- **10m Wind Speed**
  - Slight negative bias in CENSARAN and CENSARAS regions
  - Slight positive bias in LADCO
  - Errors were highest during spring, but fairly consistent
- **2m Temperature**
  - Warm bias in summer fall in CENSARAN region
  - Cold bias during spring in LADCO region
  - Errors were highest during winter, lowest during summer

# Conclusions

- **2m Mixing Ratio**
  - Over-predicted for the LADCO region, during the summer for the CENSARAN region
  - Errors were lower during the winter (due to low moisture availability; less meaningful)
- **Precipitation**
  - Properly recreated spatial extent
  - Slightly underestimated magnitude over majority of 12 km domain
  - Overestimated convective precipitation over extreme Southeast

# Conclusions

- **Improvement in wind speed bias from 2007**
- **Iowa DNR and EPA WRF configurations are very similar, therefore performance was similar**
- **Acceptable for use in AQ modeling**

**EXTRA SLIDES**  
**Changes from 2007**



# Configuration

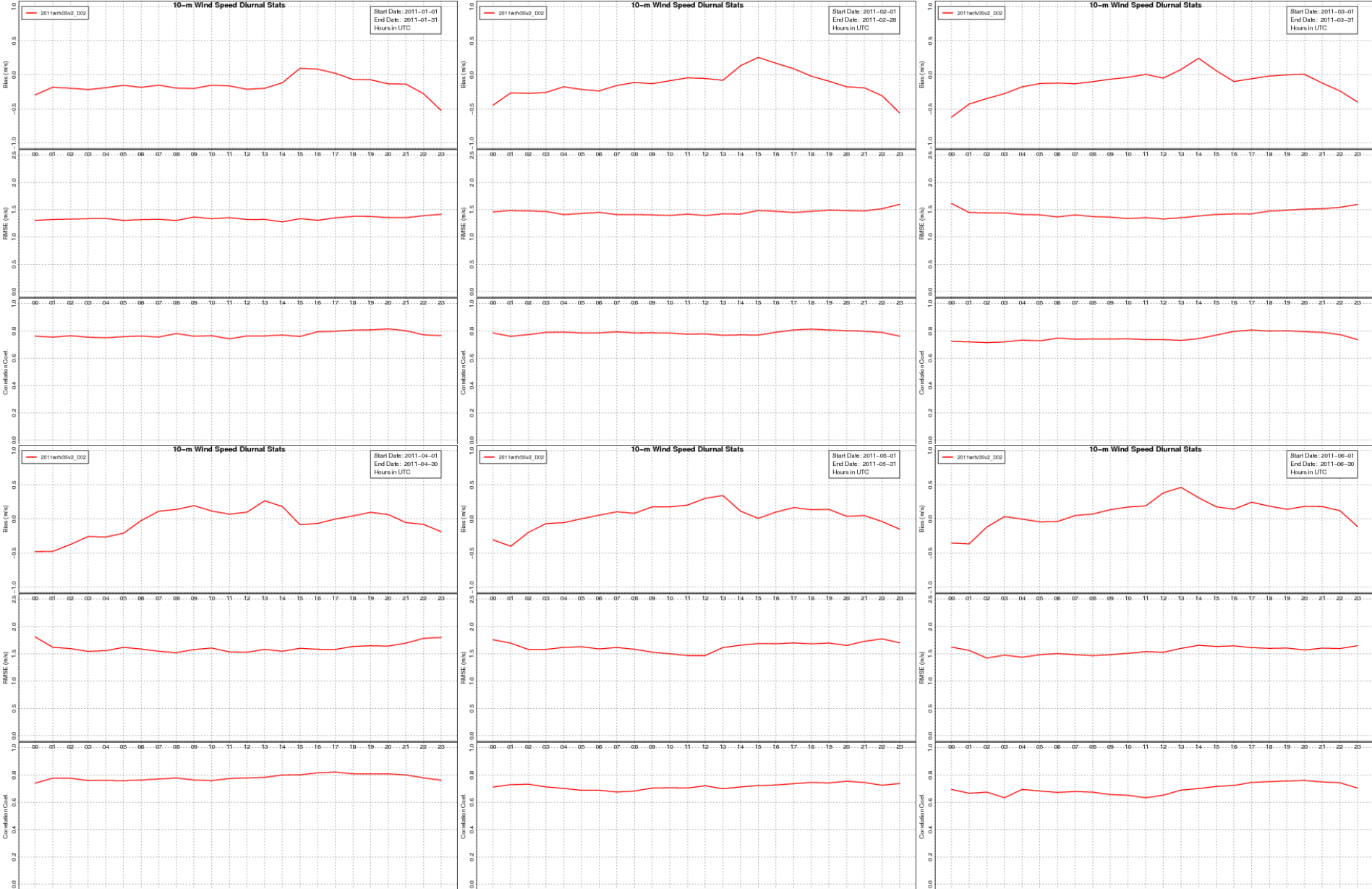
- **Changes from 2007 run:**
  - Expanded 12 km domain
  - Updated nudging configuration
  - NLCD 2006 land-use
  - 12 km NAM 6-hrly analysis for IC/BC
  - NCEP 1/12<sup>th</sup> degree RTG SST analysis for sea-surface temperatures
  - Kain-Fritsch moisture-advection trigger

# EXTRA SLIDES

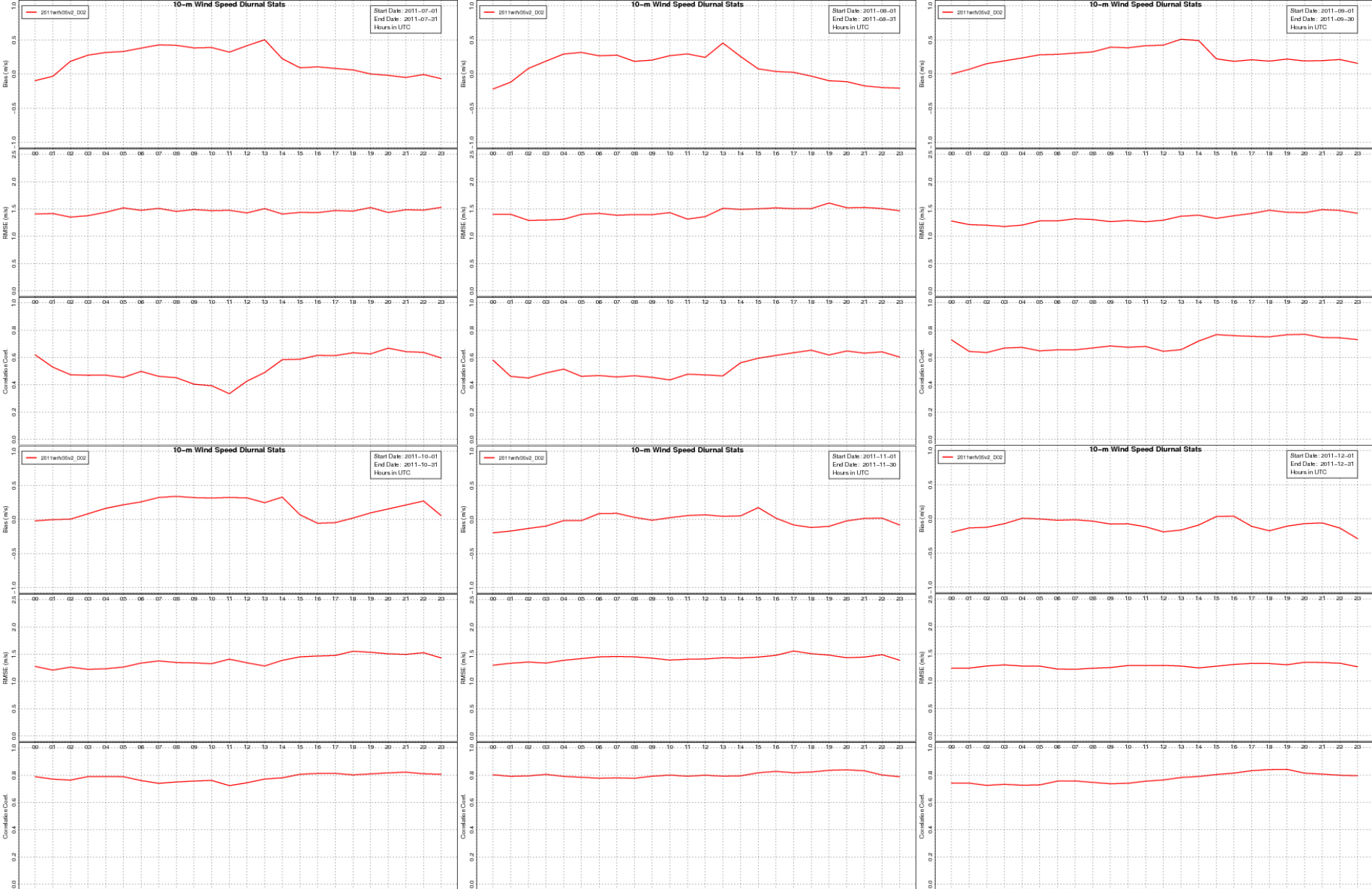
## Vertical Structure

Level	Sigma	Height (m)	Pressure (mb)	Depth (m)	Level	Sigma	Height (m)	Pressure (mb)	Depth (m)
35	0.0000	18663	50	2034	17	0.7828	1924	794	293
34	0.0332	16629	82	1715	16	0.8133	1631	823	259
33	0.0682	14914	115	1515	15	0.8410	1372	849	228
32	0.1056	13399	150	1375	14	0.8659	1144	873	200
31	0.1465	12024	189	1255	13	0.8882	944	894	174
30	0.1907	10769	231	1145	12	0.9079	770	913	150
29	0.2378	9624	276	1045	11	0.9252	620	929	128
28	0.2871	8579	323	955	10	0.9401	492	943	108
27	0.3379	7624	371	870	9	0.9528	384	955	90
26	0.3895	6754	420	790	8	0.9635	294	965	74
25	0.4409	5964	469	715	7	0.9723	220	974	60
24	0.4915	5249	517	645	6	0.9796	160	981	48
23	0.5406	4604	564	580	5	0.9854	112	986	38
22	0.5876	4024	608	520	4	0.9900	74	991	30
21	0.6323	3504	651	465	3	0.9940	44	994	24
20	0.6742	3039	690	415	2	0.9974	20	998	20
19	0.7133	2624	728	370	1	1.0000	0	1000	0
18	0.7494	2254	762	330					

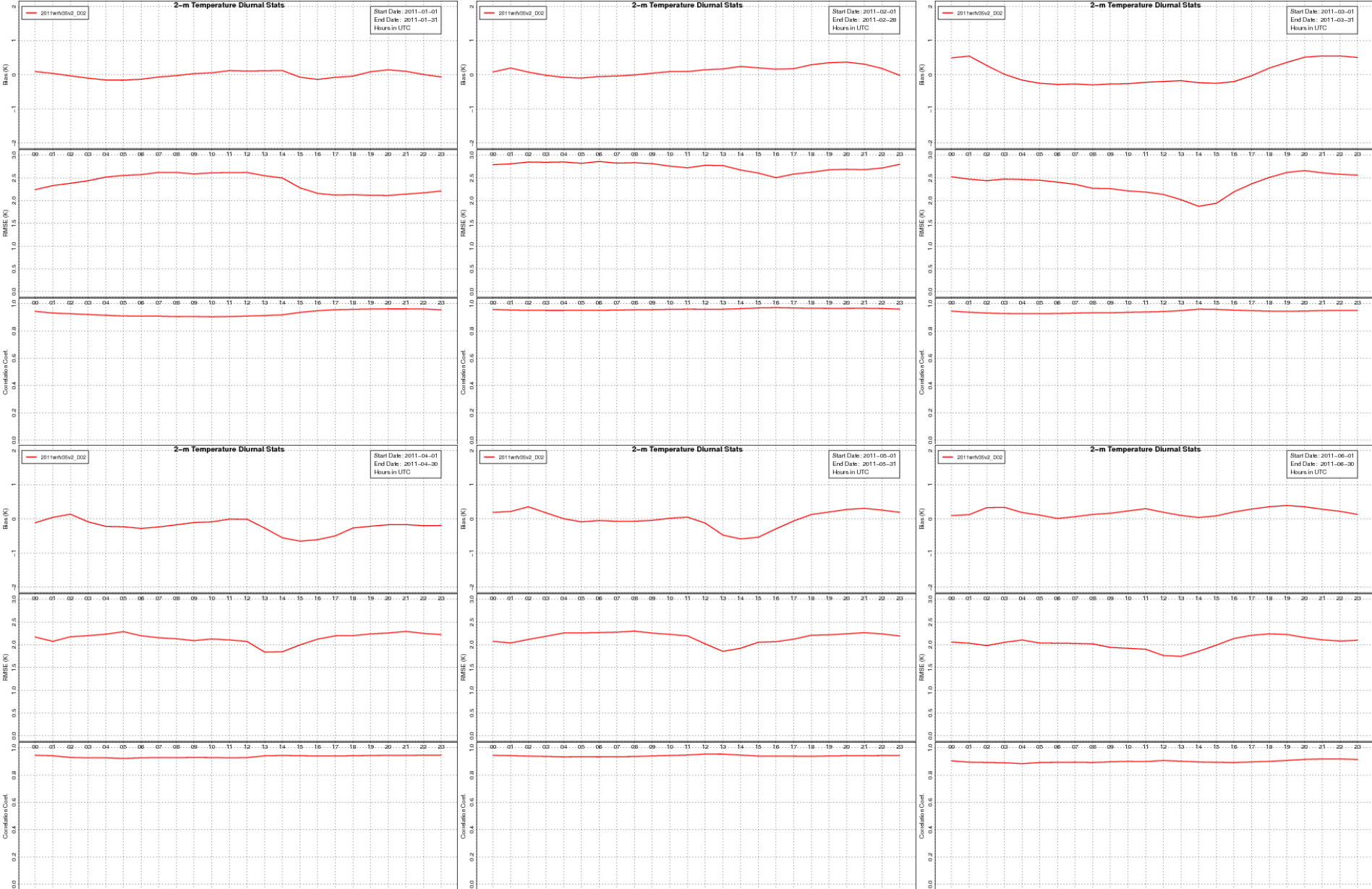
**EXTRA SLIDES**  
**Diurnal Statistics – CENSARAN**



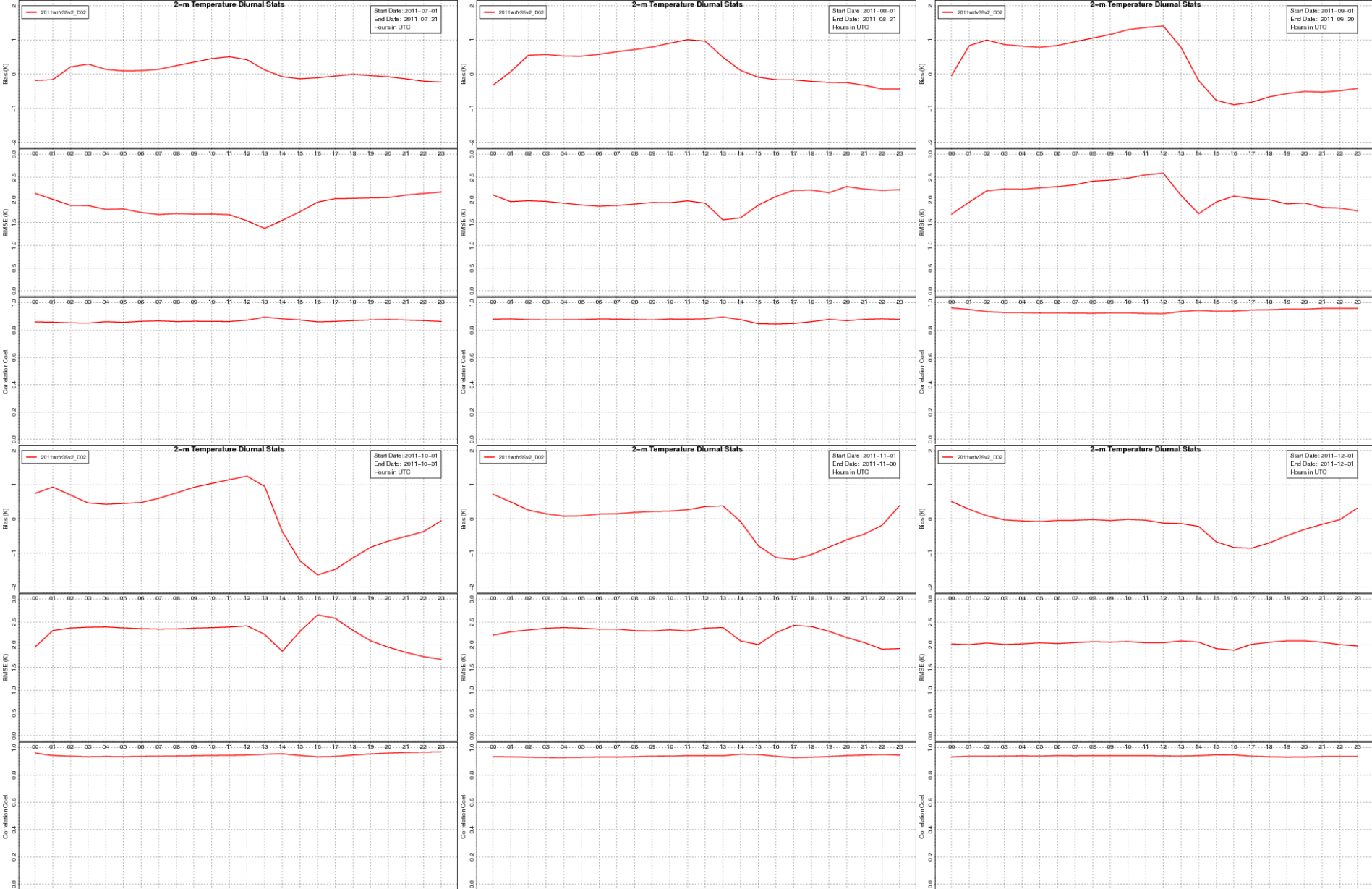
## 10m Wind Speed – Bias, RMSE, and Cor. Coef. – January-June



# 10m Wind Speed – Bias, RMSE, and Cor. Coef. – July-December

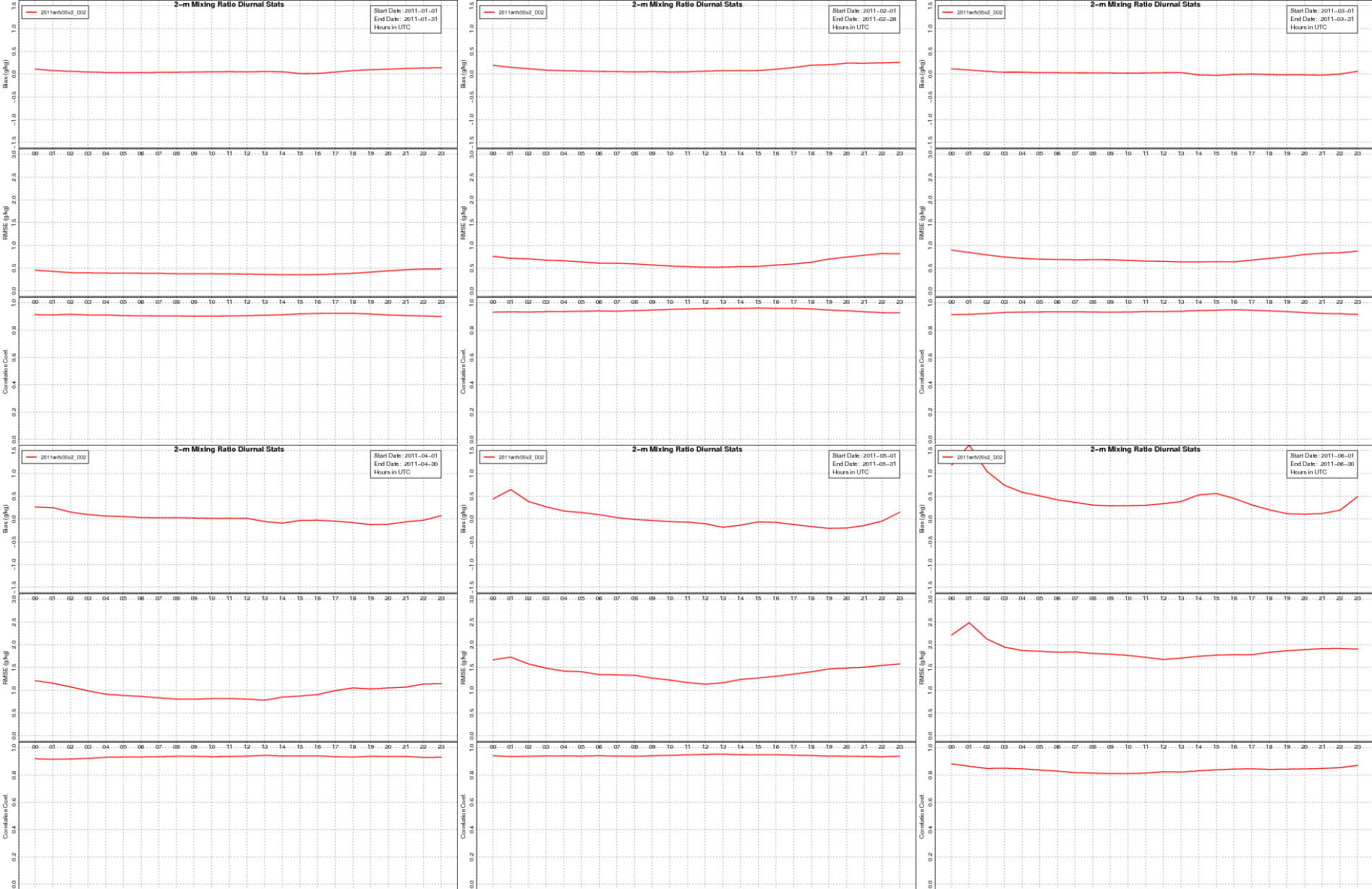


## 2m Temperature – Bias, RMSE, and Cor. Coef. – January-June

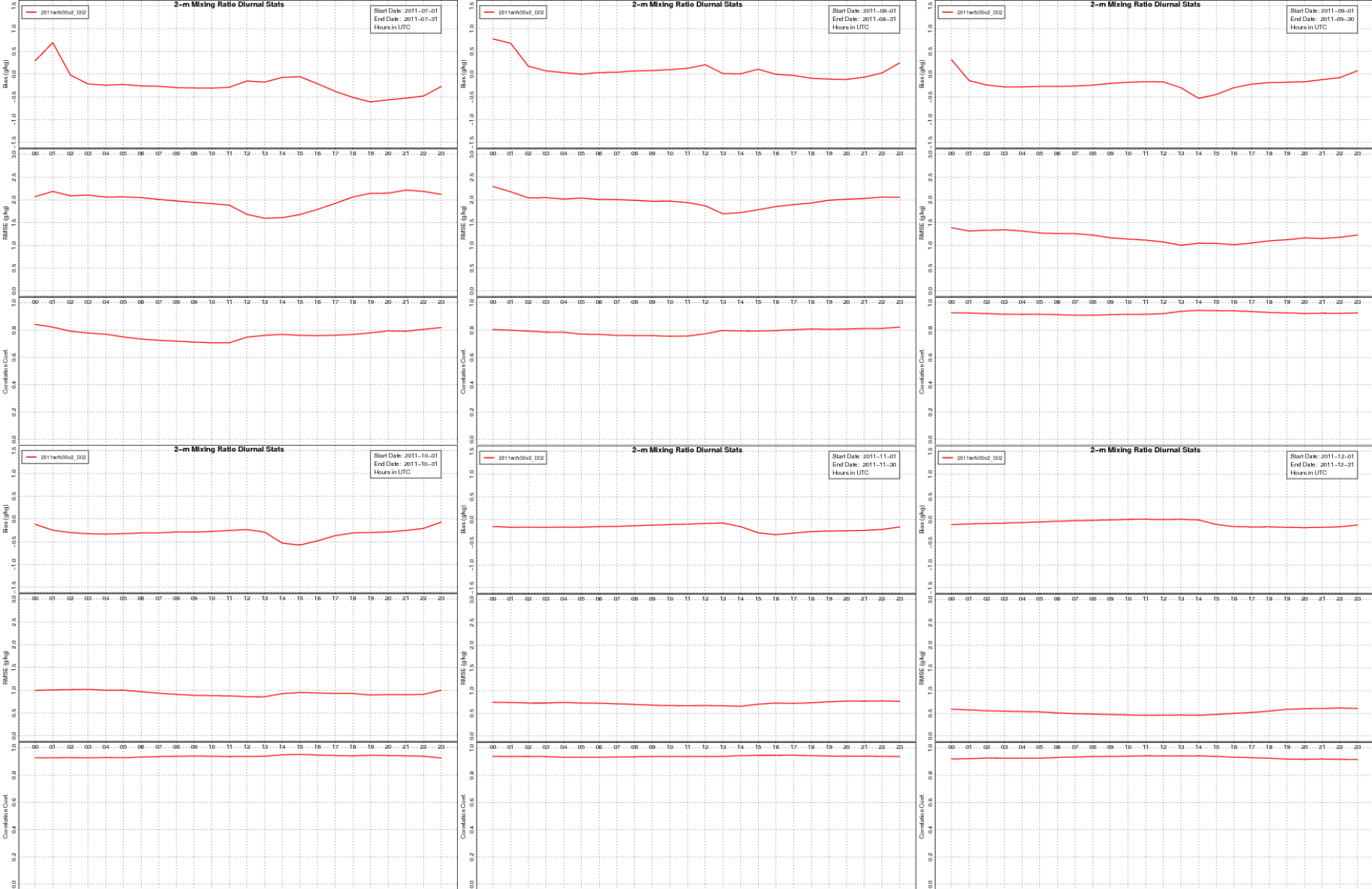


## 2m Temperature – Bias, RMSE, and Cor. Coef. – July-December





## 2m Mixing Ratio – Bias, RMSE, and Cor. Coef. – January-June



## 2m Mixing Ratio – Bias, RMSE, and Cor. Coef. – July-December

**EXTRA SLIDES**  
**Comparison to EPA v2 2011 Run**

# Comparison to EPA v2 2011 WRF Run

CENSARAN			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind Speed	Bias	IDNR	-0.21	-0.22	-0.19	-0.22	-0.11	-0.09	0.08	-0.03	0.20	0.09	-0.14	-0.15
		EPA	-0.20	-0.25	-0.25	-0.28	-0.09	-0.08	0.07	-0.02	0.24	0.08	-0.14	-0.16
	RMSE	IDNR	1.39	1.61	1.52	1.83	1.81	1.82	1.65	1.66	1.42	1.45	1.55	1.36
		EPA	1.40	1.62	1.50	1.80	1.81	1.83	1.65	1.65	1.42	1.45	1.57	1.36
Temperature	Bias	IDNR	0.08	0.20	0.07	-0.20	0.03	0.24	0.09	0.26	0.31	0.14	-0.06	-0.13
		EPA	-0.11	-0.11	0.10	-0.13	0.03	0.29	0.05	0.27	0.24	0.00	-0.12	-0.30
	MAE	IDNR	1.89	2.20	1.81	1.61	1.68	1.55	1.36	1.51	1.64	1.78	1.79	1.58
		EPA	1.89	2.26	1.79	1.59	1.70	1.53	1.32	1.45	1.63	1.79	1.78	1.68
Mixing Ratio	Bias	IDNR	0.08	0.14	0.04	0.05	0.08	0.55	-0.15	0.18	-0.16	-0.27	-0.16	-0.07
		EPA	0.07	0.13	0.05	-0.03	0.03	0.28	-0.42	-0.25	-0.36	-0.43	-0.25	-0.07
	MAE	IDNR	0.32	0.47	0.54	0.70	1.03	1.44	1.51	1.51	0.89	0.72	0.55	0.40
		EPA	0.31	0.44	0.52	0.70	1.02	1.44	1.59	1.50	0.95	0.79	0.59	0.39

CENSARAS			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind Speed	Bias	IDNR	-0.22	-0.25	-0.31	-0.17	-0.11	-0.16	-0.14	-0.21	-0.01	-0.06	-0.04	-0.22
		EPA	-0.23	-0.33	-0.34	-0.19	-0.10	-0.21	-0.13	-0.22	-0.01	-0.06	-0.10	-0.24
	RMSE	IDNR	1.54	1.80	1.71	2.04	1.95	1.80	1.58	1.66	1.66	1.61	1.81	1.58
		EPA	1.56	1.84	1.71	2.02	1.92	1.80	1.60	1.67	1.66	1.61	1.81	1.59
Temperature	Bias	IDNR	0.13	-0.15	0.03	-0.09	-0.05	-0.04	-0.05	-0.02	0.11	0.19	-0.07	0.04
		EPA	0.03	-0.24	0.09	-0.22	-0.12	-0.03	-0.14	-0.03	0.07	0.17	-0.05	-0.10
	MAE	IDNR	1.86	2.18	1.77	1.73	1.59	1.29	1.33	1.44	1.57	1.68	1.91	1.65
		EPA	1.86	2.19	1.77	1.67	1.53	1.23	1.35	1.43	1.56	1.64	1.88	1.70
Mixing Ratio	Bias	IDNR	-0.24	-0.09	-0.04	-0.06	0.00	0.03	-0.05	-0.19	0.07	-0.19	0.02	-0.15
		EPA	-0.11	0.13	0.23	0.21	0.16	-0.07	0.01	-0.16	-0.09	-0.35	-0.05	-0.08
	MAE	IDNR	0.63	0.78	0.89	1.21	1.30	1.53	1.66	1.76	1.31	1.02	0.82	0.70
		EPA	0.58	0.72	0.81	1.06	1.26	1.54	1.71	1.74	1.37	1.08	0.84	0.67

# Comparison to EPA v2 2011 WRF Run

LADCO			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind Speed	Bias	IDNR	0.10	0.17	0.15	0.09	0.15	0.17	0.11	0.24	0.40	0.43	0.36	0.21
		EPA	0.09	0.12	0.17	0.10	0.22	0.23	0.14	0.29	0.45	0.47	0.38	0.23
	RMSE	IDNR	1.38	1.59	1.42	1.65	1.52	1.45	1.40	1.34	1.44	1.48	1.53	1.38
		EPA	1.34	1.53	1.41	1.63	1.54	1.47	1.41	1.36	1.47	1.52	1.55	1.40
Temperature	Bias	IDNR	0.03	0.19	-0.22	-0.47	-0.38	0.02	-0.04	0.20	0.03	-0.08	-0.23	-0.17
		EPA	-0.15	-0.14	-0.24	-0.16	-0.23	0.02	-0.05	0.20	0.03	-0.09	-0.21	-0.22
	MAE	IDNR	1.56	1.74	1.48	1.53	1.65	1.53	1.48	1.35	1.48	1.52	1.47	1.29
		EPA	1.52	1.66	1.43	1.39	1.61	1.50	1.40	1.31	1.46	1.52	1.47	1.34
Mixing Ratio	Bias	IDNR	0.17	0.35	0.47	0.49	0.37	0.41	0.12	0.20	0.09	0.08	0.02	0.22
		EPA	0.12	0.29	0.46	0.13	0.24	0.29	0.00	-0.09	-0.03	-0.05	-0.03	0.28
	MAE	IDNR	0.30	0.46	0.57	0.79	0.89	1.09	1.35	1.12	0.80	0.65	0.52	0.40
		EPA	0.29	0.41	0.55	0.65	0.89	1.09	1.39	1.12	0.82	0.68	0.56	0.45