Implementation of the Pleim-Xiu Land Surface Model and Asymmetric Convective Model in WRF

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Motivation

- Consistent mixing between the meteorological and chemical transport models
- Indirect soil moisture nudging can improve near-surface meteorology in retrospective simulations for air quality applications
- New LSM and PBL options in WRF
- PX LSM fields used to improve dry deposition estimates in AQM

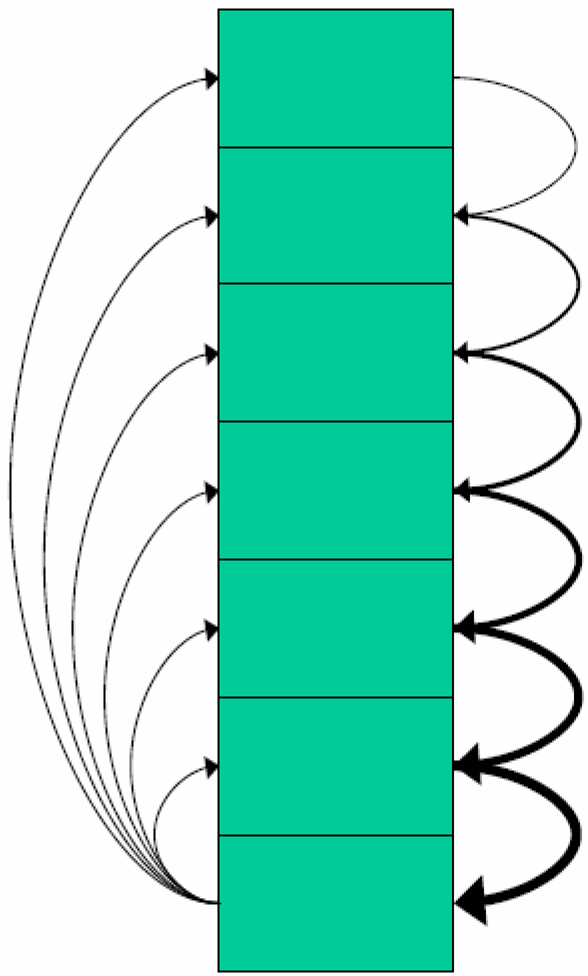
Pleim-Xiu LSM

(Xiu and Pleim, 2001; Pleim and Xiu, 2003)

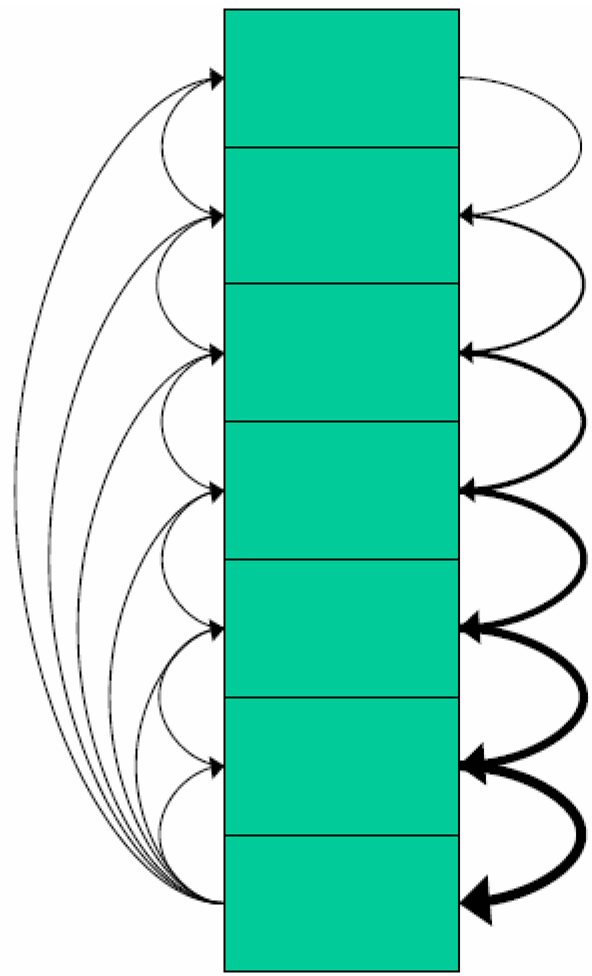
- Based on ISBA (Noilhan and Planton, 1989)
- 2-layer prognostic soil moisture and temperature
  - surface (1 cm), root zone (1 m)
- Grid cell aggregated surface parameters from fractional landuse and soil type
  - Leverage NLCD
- Indirect soil moisture nudging

ACM2
(Pleim, 2006; Pleim, 2007a,b)

- Non-local closure scheme (Stull, 1984; Blackadar, 1976; Pleim and Chang, 1992)
- Simple transilient model for unstable PBL, eddy diffusion for stable PBL.
- Rapid upward transport by buoyant plumes and gradual downward transport by compensatory subsidence
  - asymmetric (ACM) vs. symmetric (e.g., Blackadar)
- ACM2
  - Allows some local mixing at all levels
  - Leads to more continuous profiles in lower layers
  - Smooth transition from stable to unstable



ACM



ACM2

Implementation

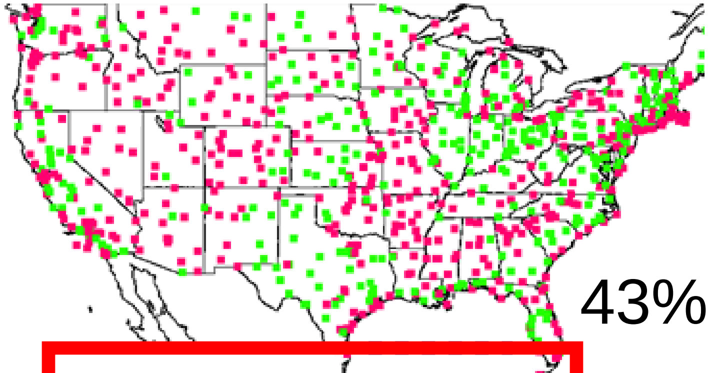
- Parsed into three separate models for WRF
- Options 7 in WRF namelist (as in MM5)
- RA, RS and LAI added to Registry
- 2-m temp, 2-m mixing ratio, and snow water were added to Registry for SM nudging (wrffdda_d01 file)
- Solve, PBL driver, and surface driver modified for new physics calls
- Real.exe modified
  - Initialize PX LSM
  - New analysis nudging file

Initial Evaluation

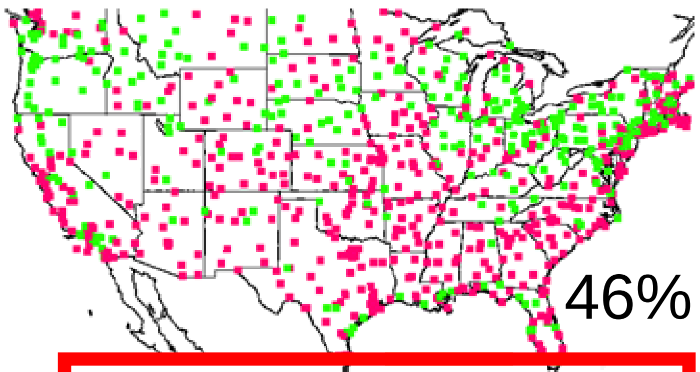
- CONUS domain (36 km), July 2002
  - WRF PX-ACM2-Pleim sfc. lay.
  - MM5 PX-ACM-Pleim sfc. lay.
  - WRF NOAH-YSU-MO sfc. lay.
- All WRF used RRTM, WSM-5, KF2 convective (nearly the same as MM5)
- Analysis nudging (only wind in PBL)
- Simulations compared to NWS hourly surface obs from MADIS

2-m Temperature July 2002

- RMSE of WRF PX less
- RMSE of WRF PX greater



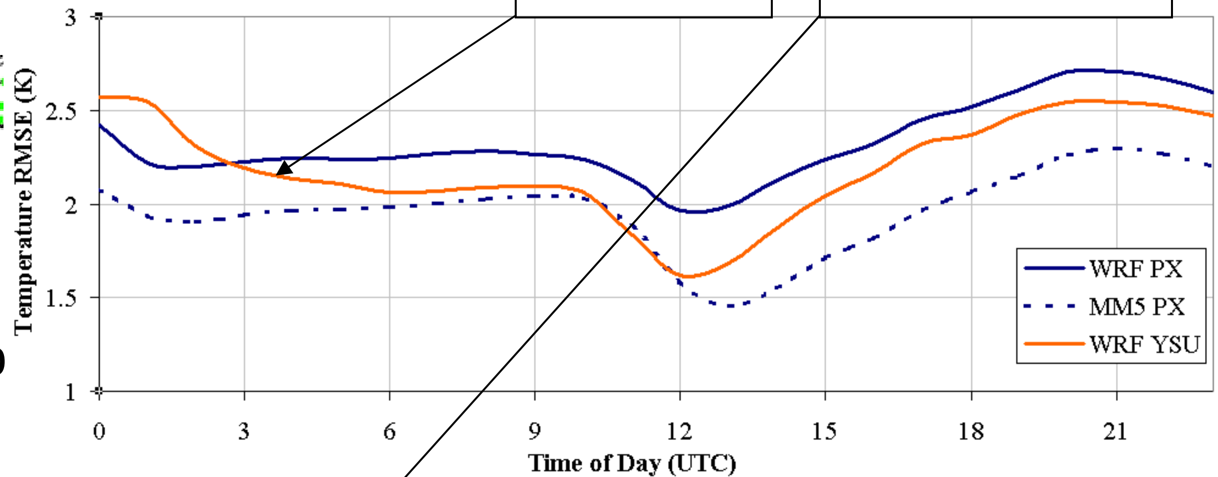
WRF PX vs. MM5 PX

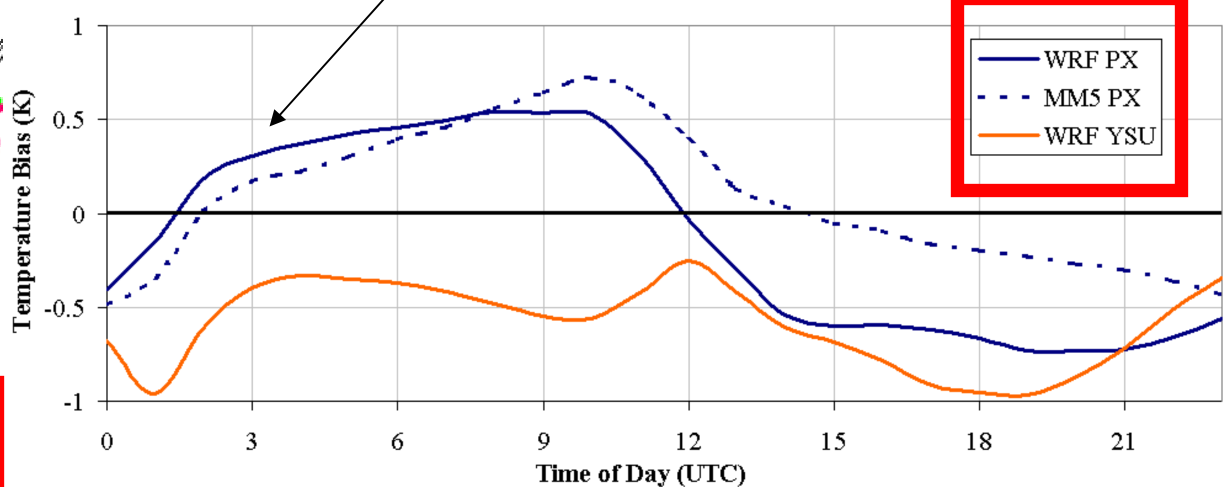


WRF PX vs. WRF YSU

RMSE

Mean Bias

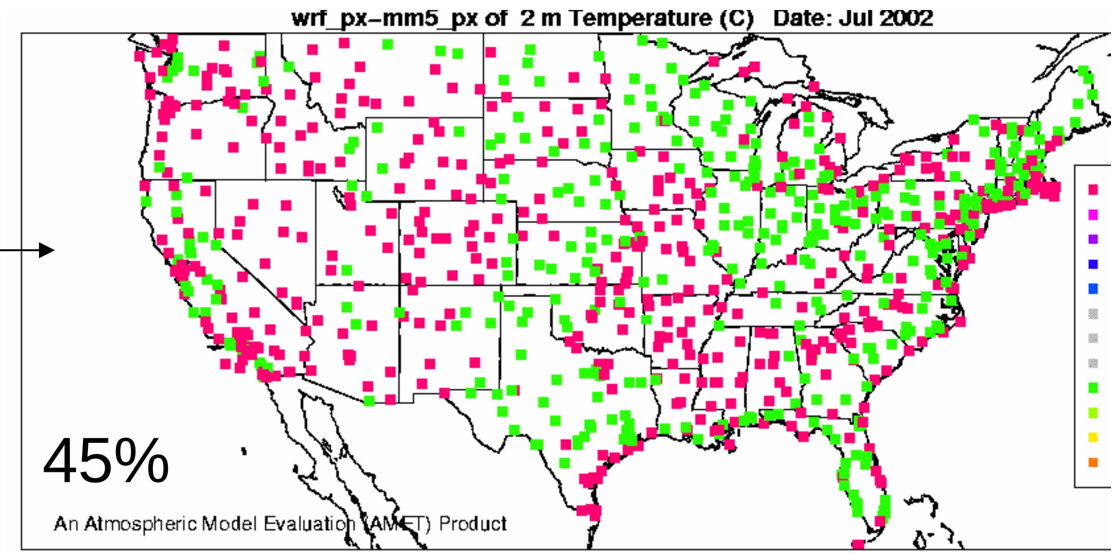




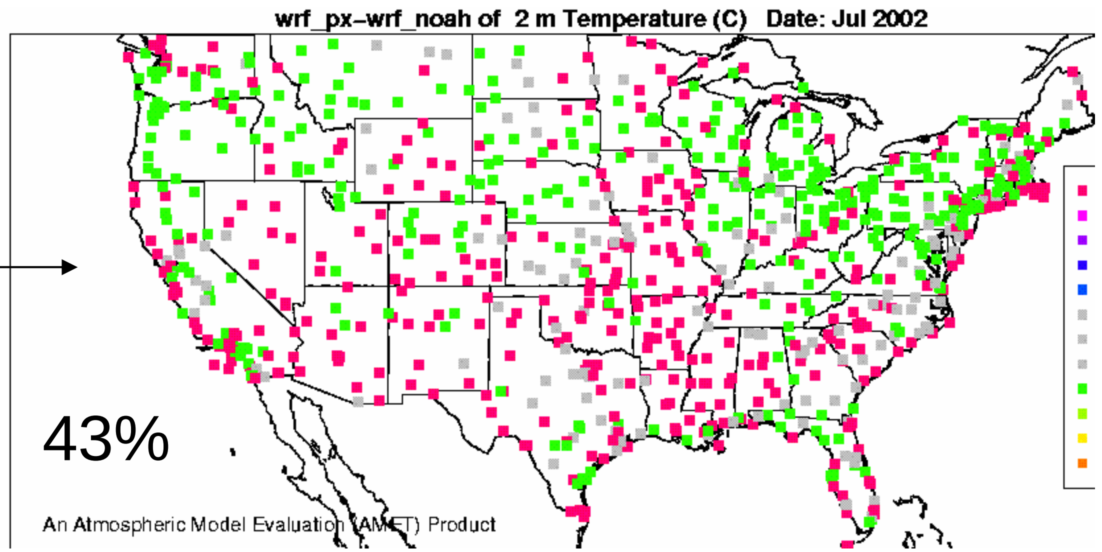
2-m Temperature

- BIAS of WRF PX less
- BIAS of WRF PX greater

WRF PX vs. MM5 PX



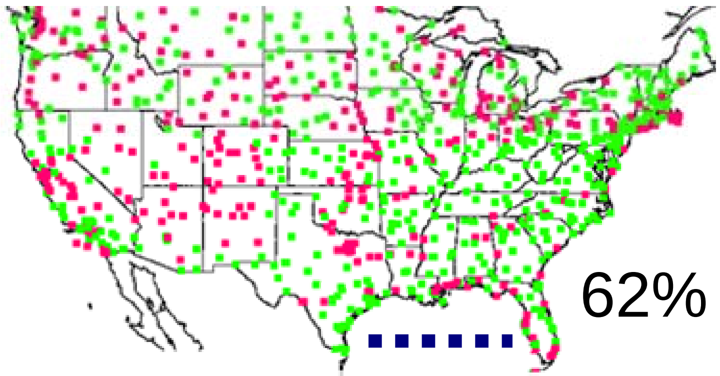
WRF PX vs. WRF YSU



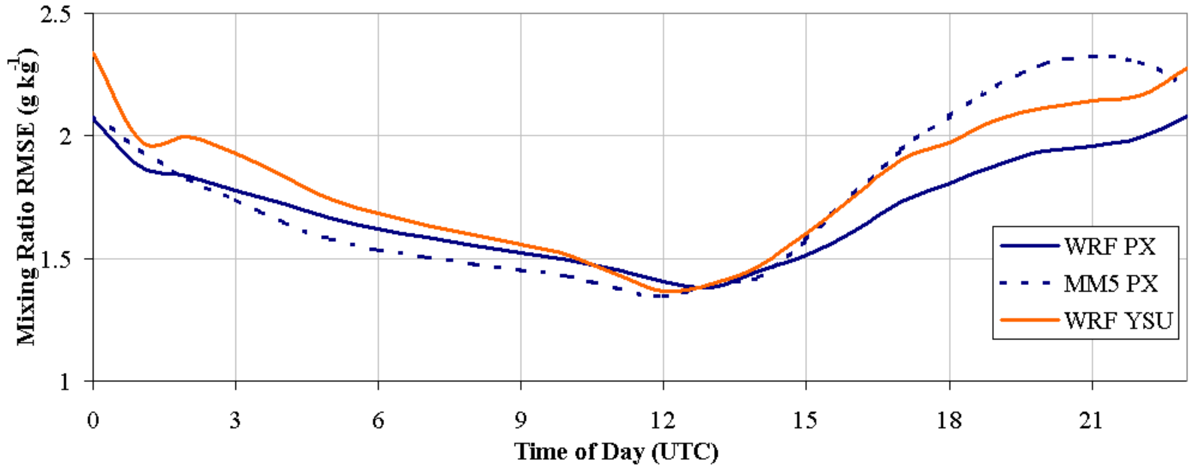
2-m Mixing Ratio
July 2002

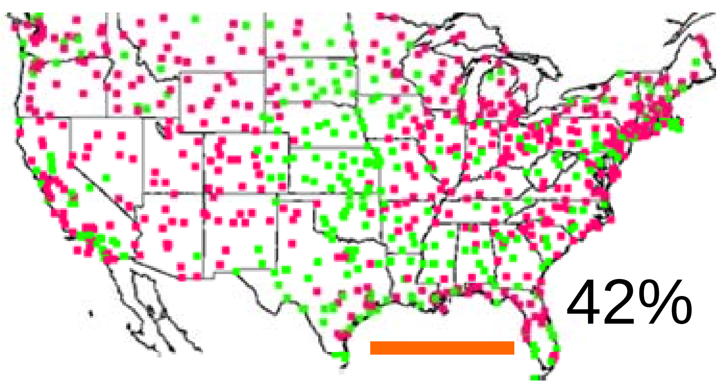
● RMSE of WRF PX less

● RMSE of WRF PX greater

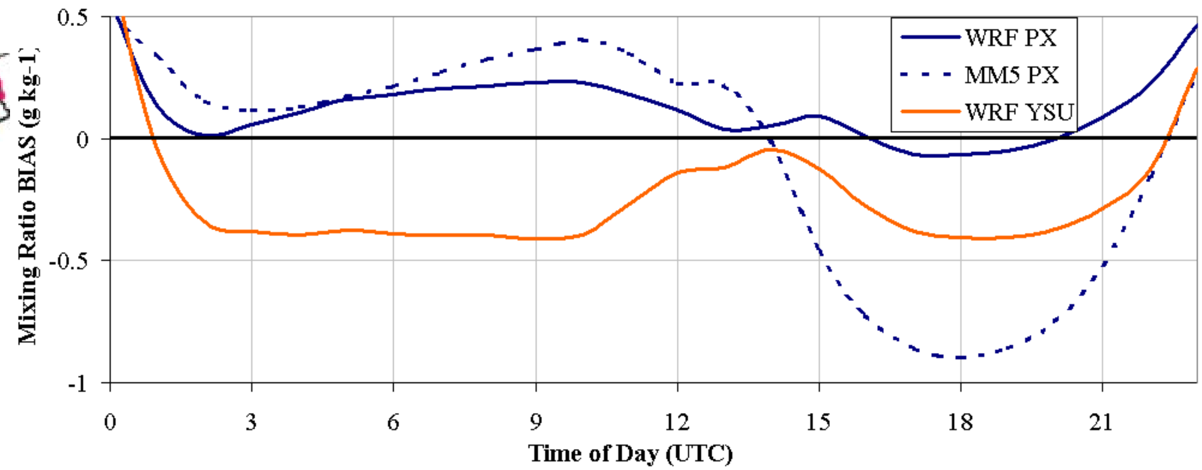


WRF PX vs. MM5 PX





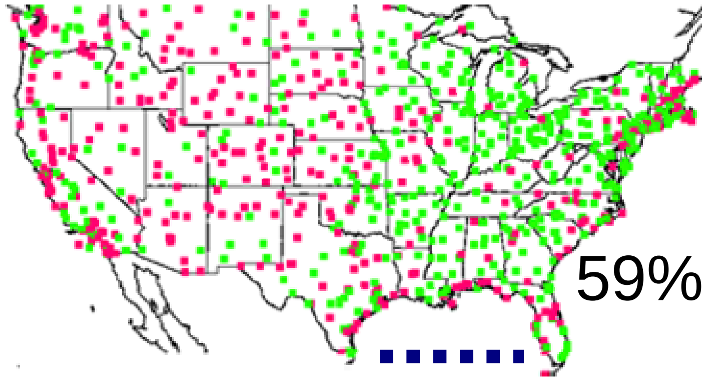
WRF PX vs. WRF YSU



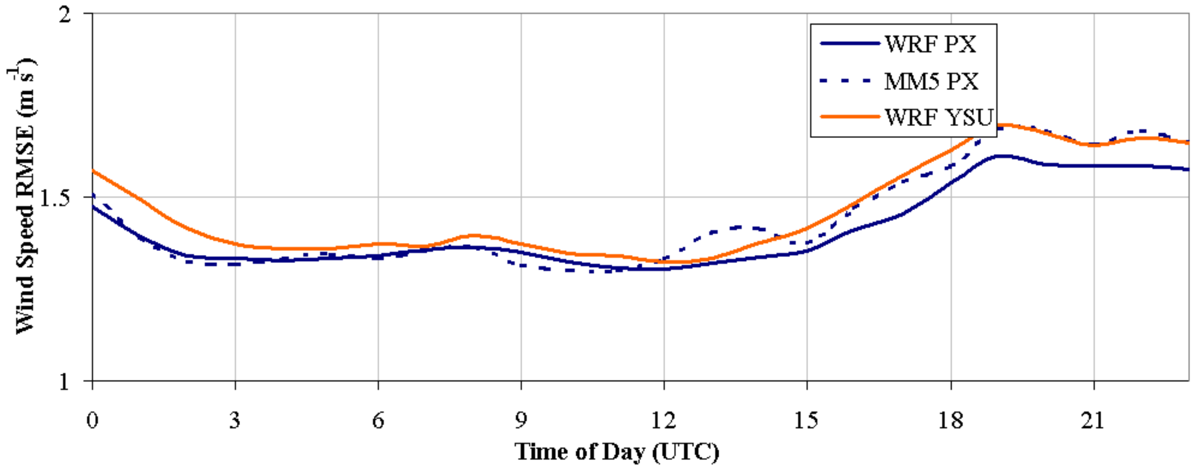
10-m Wind Speed
July 2002

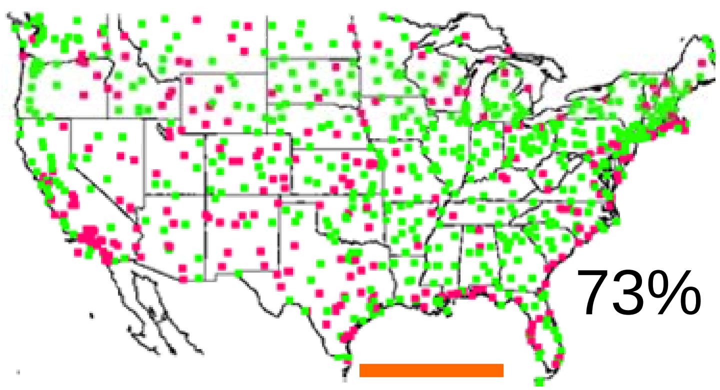
● RMSE of WRF PX less

● RMSE of WRF PX greater

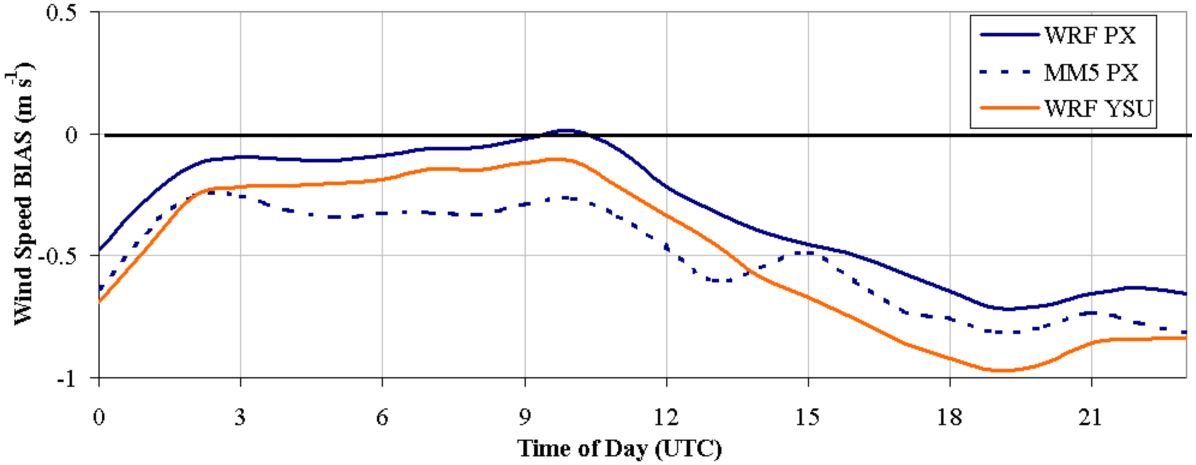


WRF PX vs. MM5 PX





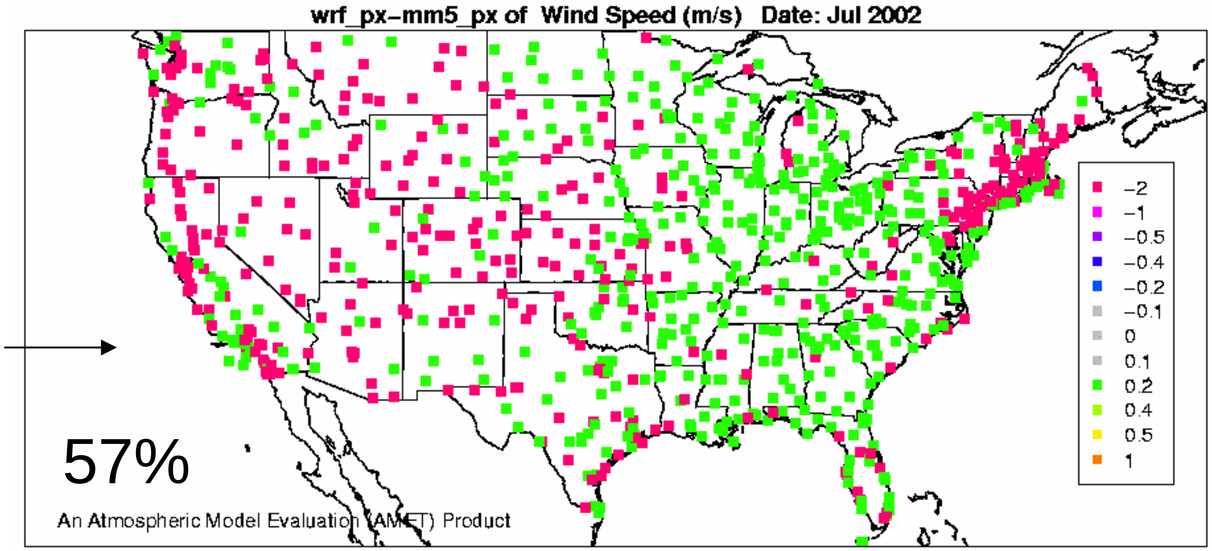
WRF PX vs. WRF YSU



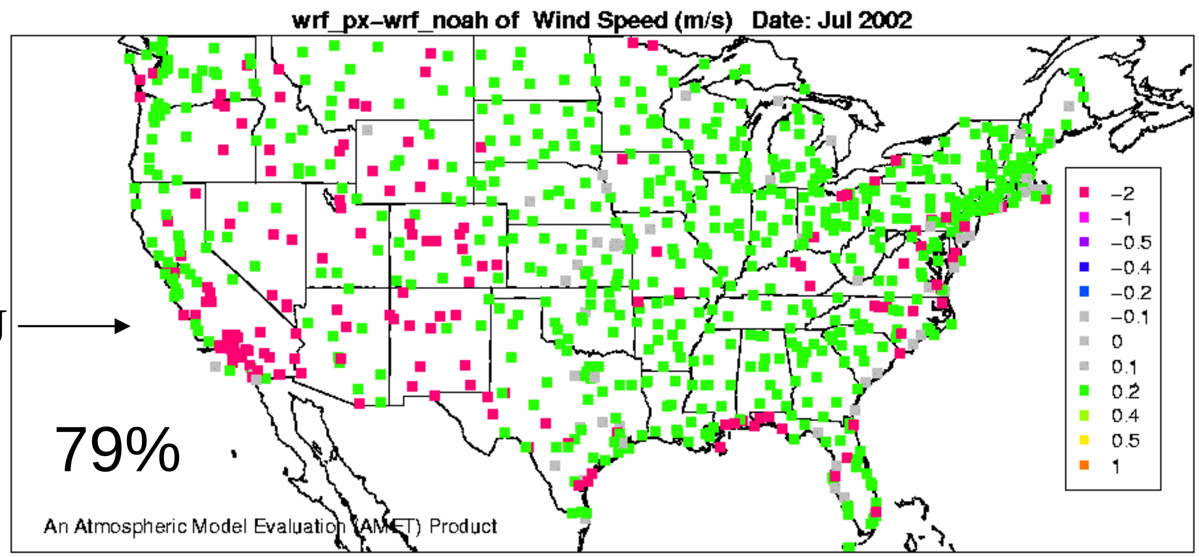
10-m Wind Speed

- BIAS of WRF PX less
- BIAS of WRF PX greater

WRF PX vs. MM5 PX

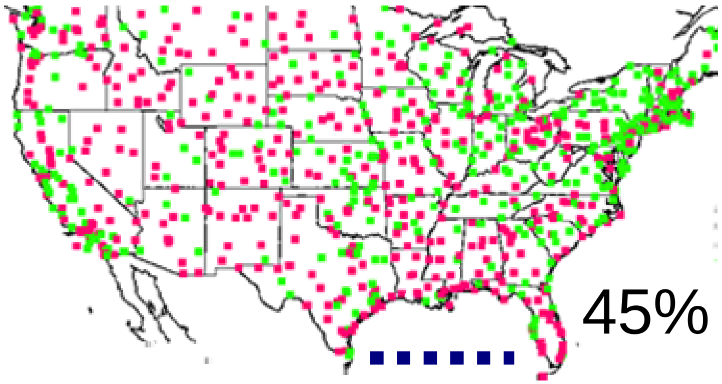


WRF PX vs. WRF YSU

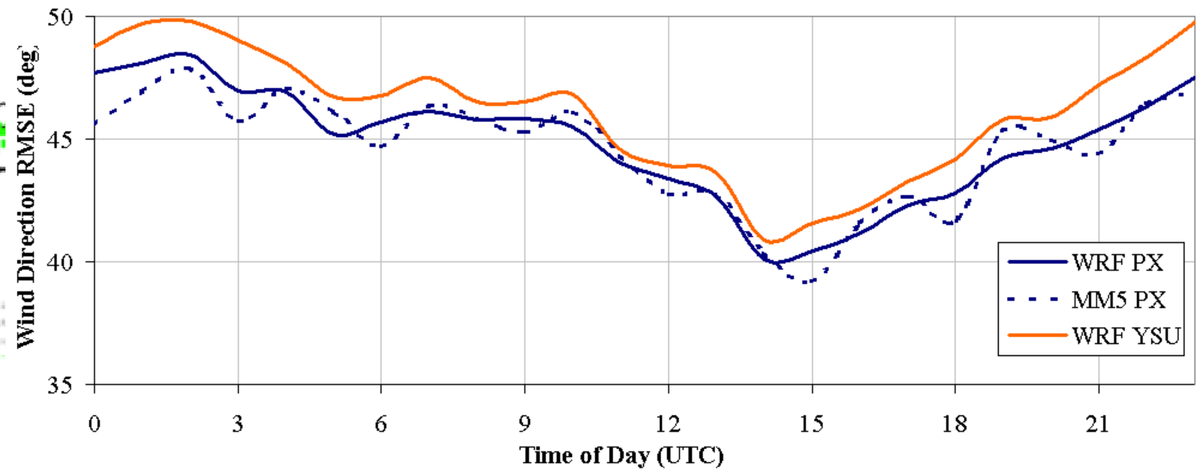


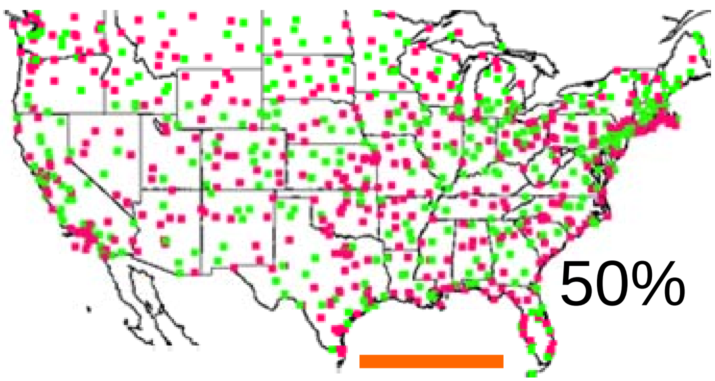
10-m Wind Direction
July 2002

- RMSE of WRF PX less
- RMSE of WRF PX greater

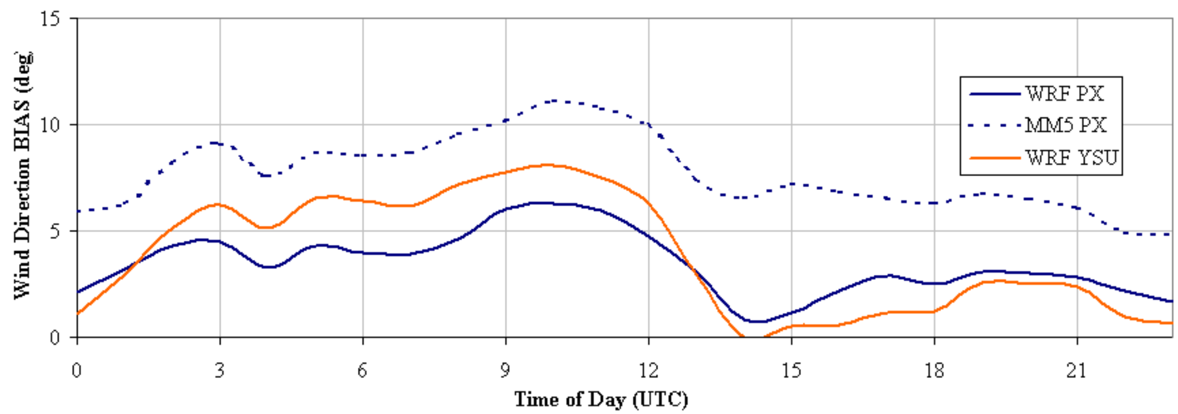


WRF PX vs. MM5 PX





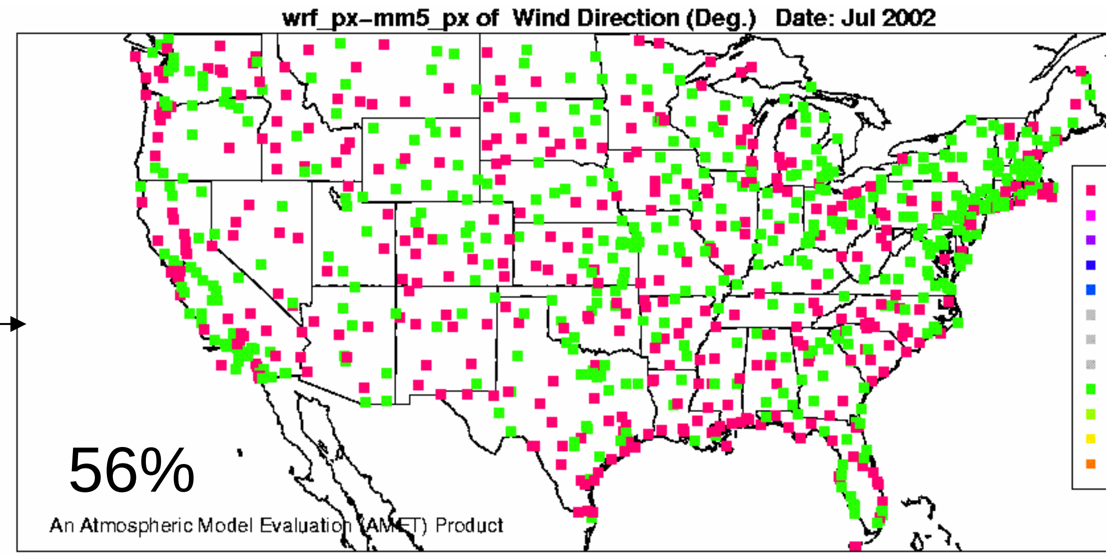
WRF PX vs. WRF YSU



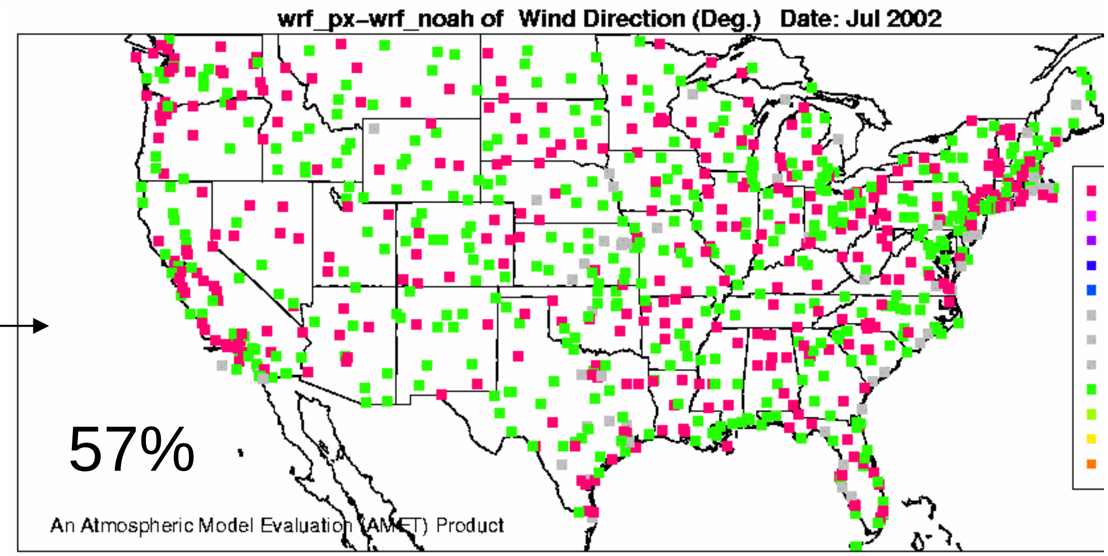
10-m Wind Dir.

- BIAS of WRF PX less
- BIAS of WRF PX greater

WRF PX vs. MM5 PX →



WRF PX vs. WRF YSU →



Initial Assessment

- Reasonable overall performance
- 2-m temperature error greater
  - Further investigation needed
- 2-m mixing ratio error comparable
- 10-m WS error and bias lower
- 10-m WD comparable

Future Efforts

- More evaluation (precip, PBL, etc.)
- Test linkage with other physics options (e.g., ACM2-NOAH, PX LSM-MYJ PBL)
- Refine snow treatment
- Impact on AQM (e.g., CMAQ)
- Work toward release in WRFv3

Disclaimer - **The research presented here was performed under the Memorandum of Understanding between the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) and under agreement number DW 13921548. This work constitutes a contribution to the NOAA Air Quality Program. Although it has been reviewed by EPA and NOAA and approved for publication, it does not necessarily reflect their policies or views.**

The End

Extended Results

Variable	Jul. 2002 Simulation	RMSE	MB	IOA
2-m Temp	MM5 PX	43	45	42
	WRF YSU	46	49	48
2-m Mixing Ratio	MM5 PX	**62**	37	48
	WRF YSU	42	40	40
10-m Wind	MM5 PX	**59**	**57**	48
	WRF YSU	**73**	**79**	**62**
10-m Wind Dir.	MM5 PX	45	**56**	N/A
	WRF YSU	**50**	**55**	N/A

Variable	Jul. 2002	RMSE	MB	IOA
2-m Temp	WRF PX	2.33 / 4.07	-0.13 / -2.19	0.89 / 0.84
	MM5 PX	1.98 / 3.49	0.08 / -1.28	0.92 / 0.88
	WRF YSU	2.19 / 3.96	-0.52 / -2.18	0.91 / 0.85
2-m Mixing Ratio	WRF PX	1.72 / 2.22	0.13 / 0.50	0.84 / 0.63
	MM5 PX	1.80 / 2.15	-0.05 / -0.16	0.85 / 0.71
	WRF YSU	1.85 / 1.84	-0.30 / -0.37	0.82 / 0.70
10-m Wind Speed	WRF PX	1.42 / 2.19	-0.35 / -1.19	0.62 / 0.41
	MM5 PX	1.46 / 2.10	-0.52 / -0.92	0.61 / 0.46
	WRF YSU	1.49 / 2.19	-0.48 / -1.19	0.59 / 0.42
10-m Wind Dir.	WRF PX	45 / 67	03 / 05	N/A
	MM5 PX	45 / 64	08 / 01	N/A
	WRF YSU	45 / 66	04 / 06	N/A

Variable	Jul. 2002 Simulation	MAE	RMSE	MB	IOA
2-m Temp	MM5 PX	**59**	**57**	48	**69**
	WRF YSU	48	47	47	45
	WRF MYJ	42	40	41	43
2-m Mixing Ratio	MM5 PX	**65**	**66**	38	44
	WRF YSU	**67**	**68**	**58**	**61**
	WRF MYJ	**66**	**67**	**50**	**67**
10-m Wind Speed	MM5 PX	47	44	**79**	42
	WRF YSU	**53**	48	**51**	**69**
	WRF MYJ	**75**	**73**	31	37
10-m Wind Dir.	MM5 PX	22	21	42	N/A
	WRF YSU	36	37	46	N/A
	WRF MYJ	**51**	**52**	**53**	N/A

Variable	Jan. 2002 Simulation	MAE	RMSE	MB	IOA
2-m Temp	MM5 PX	**82**	**84**	**77**	**78**
	WRF YSU	13	13	20	13
	WRF MYJ	18	18	26	19
2-m Mixing Ratio	MM5 PX	**50**	49	37	47
	WRF YSU	37	32	**60**	31
	WRF MYJ	46	**43**	**62**	39
10-m Wind Speed	MM5 PX	35	35	**56**	49
	WRF YSU	43	39	41	45
	WRF MYJ	**68**	**66**	38	34
10-m Wind Dir.	MM5 PX	22	22	43	N/A
	WRF YSU	30	30	39	N/A
	WRF MYJ	47	47	48	N/A

Variable	Jul. 2002 Simulation	MAE	RMSE	MB	IOA
2-m Temp	WRF PX	1.86	2.54	-0.23	0.91
	MM5 PX	1.88	2.57	-0.36	0.90
	WRF YSU	1.86	2.55	-0.56	0.91
	WRF MYJ	1.79	2.45	-0.26	0.91
2-m Mixing Ratio	WRF PX	1.38	1.91	-0.16	0.86
	MM5 PX	1.45	1.92	-0.08	0.86
	WRF YSU	1.47	1.94	-0.49	0.84
	WRF MYJ	1.43	1.89	-0.32	0.85
10-m Wind Speed	WRF PX	1.31	1.74	-0.09	0.53
	MM5 PX	1.29	1.71	-0.66	0.55
	WRF YSU	1.35	1.75	-0.09	0.50
	WRF MYJ	1.49	1.93	0.47	0.53
10-m Wind Dir.	WRF PX	40	57	8	N/A
	MM5PX	36	52	5	N/A
	WRF YSU	38	55	5	N/A
	WRF MYJ	40	57	7	N/A

Variable	Jan. 2002 Simulation	MAE	RMSE	MB	IOA
2-m Temp	WRF PX	2.37	3.09	-0.86	0.94
	MM5 PX	2.80	3.63	-1.59	0.91
	WRF YSU	1.98	2.62	-0.31	0.95
	WRF MYJ	1.96	2.62	0.05	0.95
2-m Mixing Ratio	WRF PX	0.62	0.91	0.18	0.90
	MM5 PX	0.60	0.88	-0.30	0.91
	WRF YSU	0.59	0.85	0.27	0.91
	WRF MYJ	0.61	0.87	0.27	0.90
10-m Wind Speed	WRF PX	1.46	1.97	-0.13	0.59
	MM5 PX	1.39	1.84	-0.47	0.61
	WRF YSU	1.44	1.92	0.00	0.59
	WRF MYJ	1.72	2.30	0.86	0.57
10-m Wind Dir.	WRF PX	33	49	8	N/A
	MM5PX	30	46	5	N/A
	WRF YSU	31	47	5	N/A
	WRF MYJ	33	50	9	N/A

Pleim Surface Layer (Pleim 2006, JAMC)

- Accurate and economical estimation of the flux-profile relationships
- For stable, linear functions of Webb (1970) and Dyer (1974) w/ coefficients recommended by Hogstrom (1988)
- For very stable a reduced slope is adopted to avoid decoupling with surface
- Difference between momentum and scalar fluxes by inclusion of quasi-laminar sublayer of resistance for scalar fluxes that is a function of molecular diffusivity