Using WRF Meteorological Data for Dispersion Simulations of Controlled Tracer Experiments

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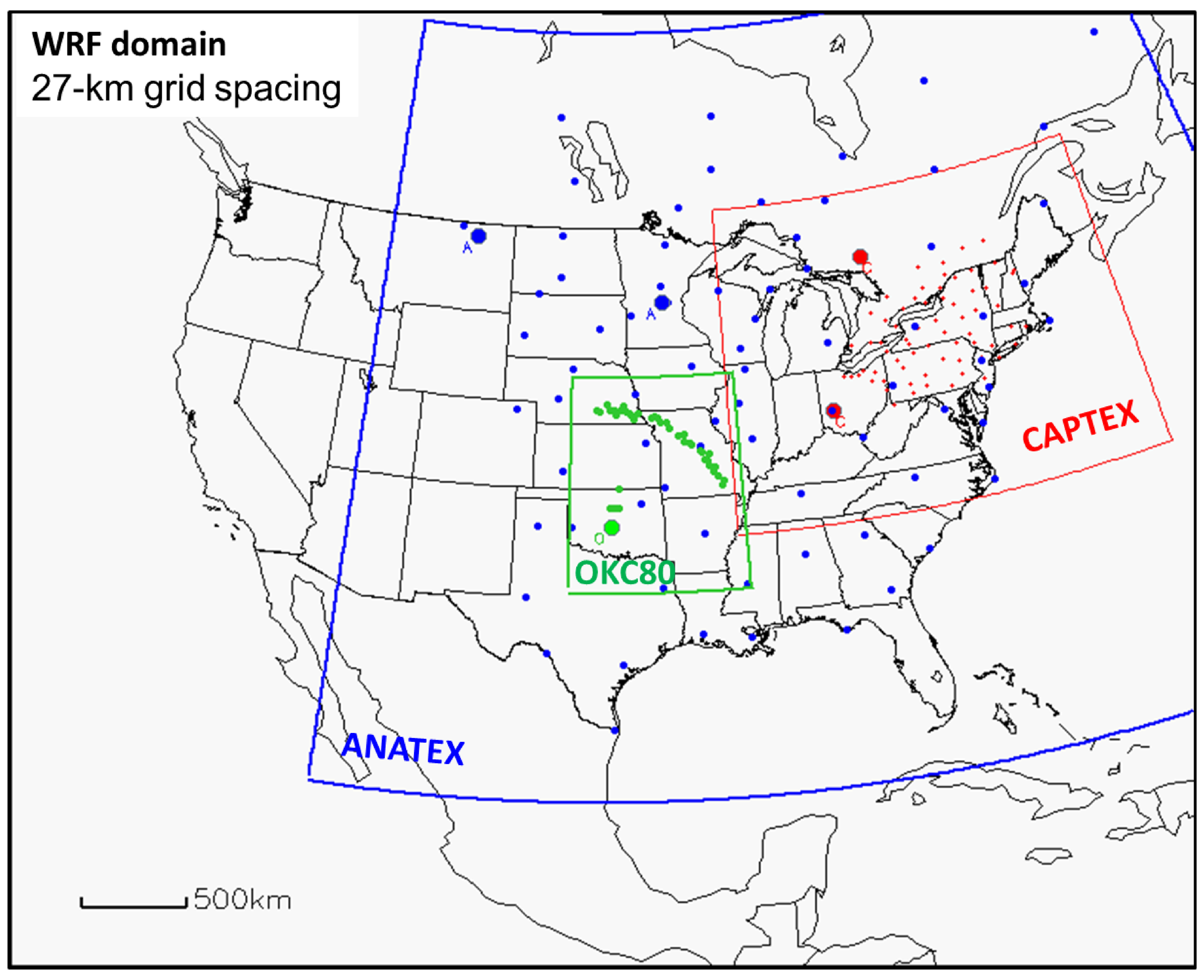
INTRODUCTION

WRF-ARW (v3.5.1) model simulations were conducted to create a long-term archive for driving dispersion applications. The WRF dataset will be available in ARL format to provide meteorological data compatible to the HYSPLIT dispersion model. In addition, this meteorological dataset can be used for dynamic downscale providing initial and boundary conditions for WRF simulations at a finer resolution. A domain with a 27-km horizontal grid spacing and 33 vertical layers was initialized with data from the North American Regional Reanalysis. Different PBL schemes and nudging options were tested to understand the sensitivity of the WRF performance and the subsequent impacts on dispersion calculations. HYSPLIT was set to simulate three controlled tracer experiments focusing on regional scale transport and dispersion; namely, CAPTEX, ANATEX, and OKC80.

WRF physics options

- Longwave radiation – Rapid Radiative Transfer Model
- Shortwave radiation – Dudhia scheme
- Microphysics – WSM3 simple ice
- Sub-grid cloud scheme – Grell-Devenyi Ensemble
- Nudging – grid nudging for U-/V-wind, T and Q
- Land-surface model – Noah LSM (or PX LSM)
- Surface scheme – MM5 MO, Janjic MO, QNSE, MYNN, TEMF
- PBL scheme – MYJ, YSU, ACM2, QNSE, MYNN2, TEMF, BouLac, UW, GBM



Black box: WRF domain, blue box: HYSPLIT domain for ANATEX, green box: HYSPLIT domain for OKC80 and red box: HYSPLIT domain for CAPTEX. Big dots: release locations and small dots: sampling network for different experiments.

EVALUATIONS

Meteorological evaluations

Data – surface and upper level observations for wind and temperature

Taylor Diagram (Taylor, 2001) – indicating model performance in terms of correlation (R) and normalized standard deviation.

Dispersion evaluations

Data – surface tracer concentration taken during the experiments

Rank, a cumulative statistical score ranging between 0 – 4 (Draxler, 2006)

$$Rank = R^2 + 1 - \left|\frac{FB}{2}\right| + \frac{FMS}{100} + \left(1 - \frac{KSP}{100}\right)$$

Correlation coefficient (R) $\quad R = \frac{\sum(M_i - \bar{M})(P_i - \bar{P})}{\sqrt{\sum(M_i - \bar{M})^2 \sum(P_i - \bar{P})^2}}$

Fractional bias (FB) $\quad FB = 2\frac{(\bar{P} - \bar{M})}{(\bar{P} + \bar{M})}$

Figure of merit in space (FMS; %) $\quad FMS = 100\frac{N_P \cap N_M}{N_P \cup N_M}$

Kolmogorov-Smirnov parameter (KSP; %) $\quad KSP = Max|D(M_k) - D(P_k)|$

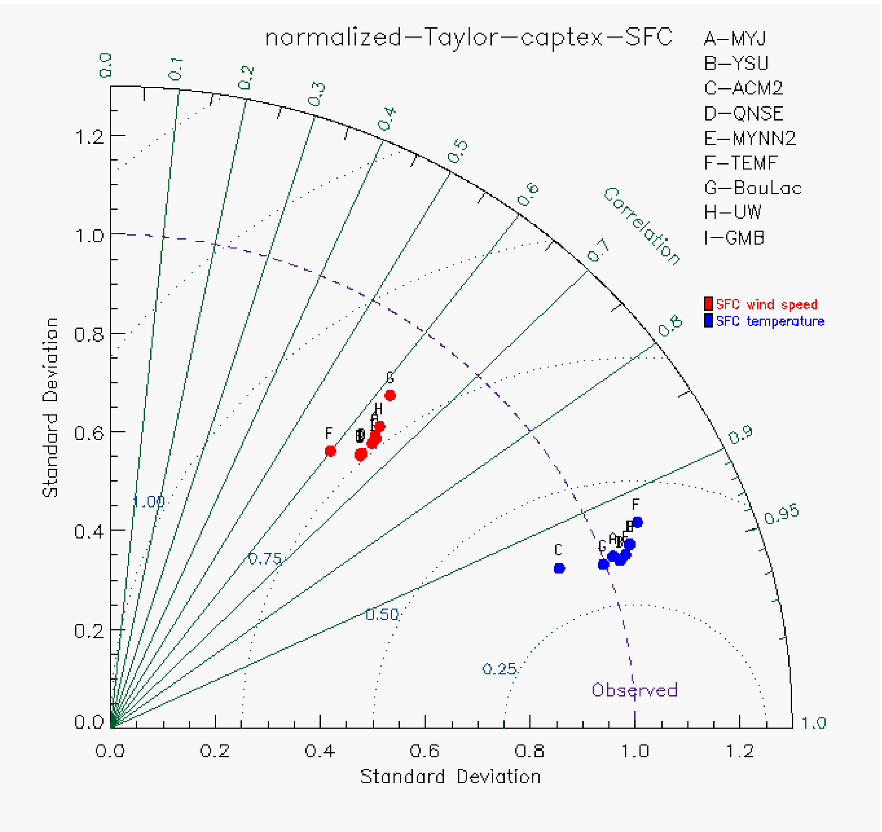
NOTE: "M" & "P" are measured and predicted tracer concentrations

N is number of samples and "D" is the cumulative distribution

RESULTS AND DISCUSSIONS

Cross-Appalachian Tracer Experiment (CAPTEX)

From mid-September to the end of October in 1983; six 3-hr releases from Dayton, Ohio and Sudbury, Ontario, Canada; samples collected at 3-hr and 6-hr averages.



		A	B	C	D	E	F	G	H	I
Rank	NARR	MYJ	YSU	ACM2	QNSE	MYNN2	TEMF	BouLac	UW	GBM
R1	2.12	2.82	2.81	2.72	2.78	2.88	2.77	2.73	3.04	3.03
R2	2.79	2.96	2.95	2.97	2.77	2.74	2.29	3.07	2.97	2.96
R3	1.92	1.95	1.95	1.94	2.02	1.94	1.88	1.87	1.97	1.97
R4	2.18	2.08	2.10	2.02	1.95	2.12	2.06	1.95	2.18	2.12
R5	2.57	2.67	2.56	2.49	2.56	2.60	2.50	2.60	2.49	2.50
R7	2.24	2.15	2.29	2.24	2.17	2.30	2.19	2.26	2.26	2.22
all	**2.43**	**2.52**	**2.52**	**2.66**	**2.39**	**2.44**	**2.33**	**2.58**	**2.61**	**2.62**

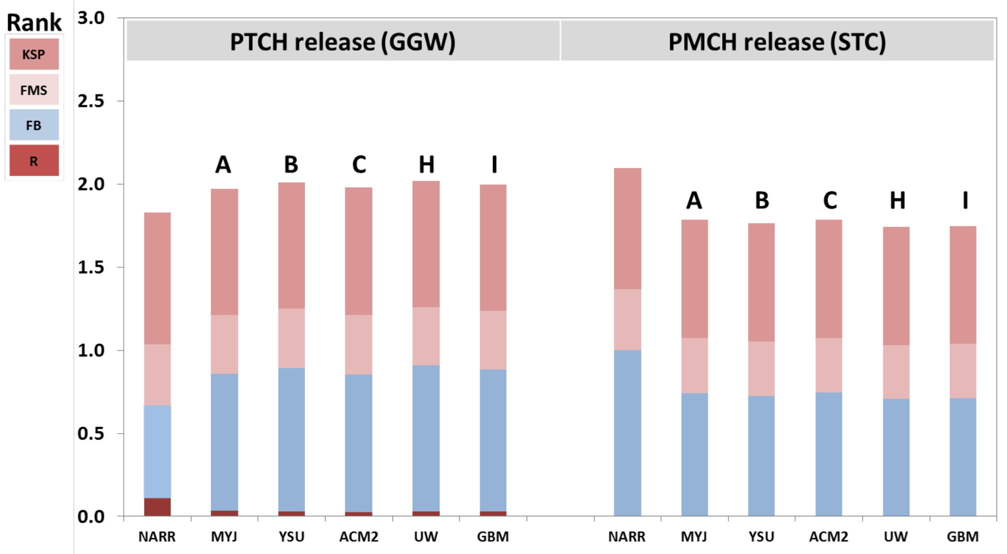
Blue – lowest score *Red – highest scores*

The WRF run using TEMF (F) had the lowest correlation and the largest standard deviation for both surface wind and temperature among all cases while the results using YSU, QNSE and MYNN2 (B, D & E) show relatively good statistics in wind comparisons.

For the dispersion results, the best three rank were those driven by ACM2, UW and GBM PBL schemes. Even though QNSE and MYNN2 had good evaluations in surface wind and temperature, they not necessarily produce good dispersion results.

Across North America Tracer Experiment (ANATEX)

From January to the end of March in 1987; 66 releases at Glasgow (GGW), Montana and St. Cloud (STC), Minnesota every 2.5 days; samples collected over 24-hr average.

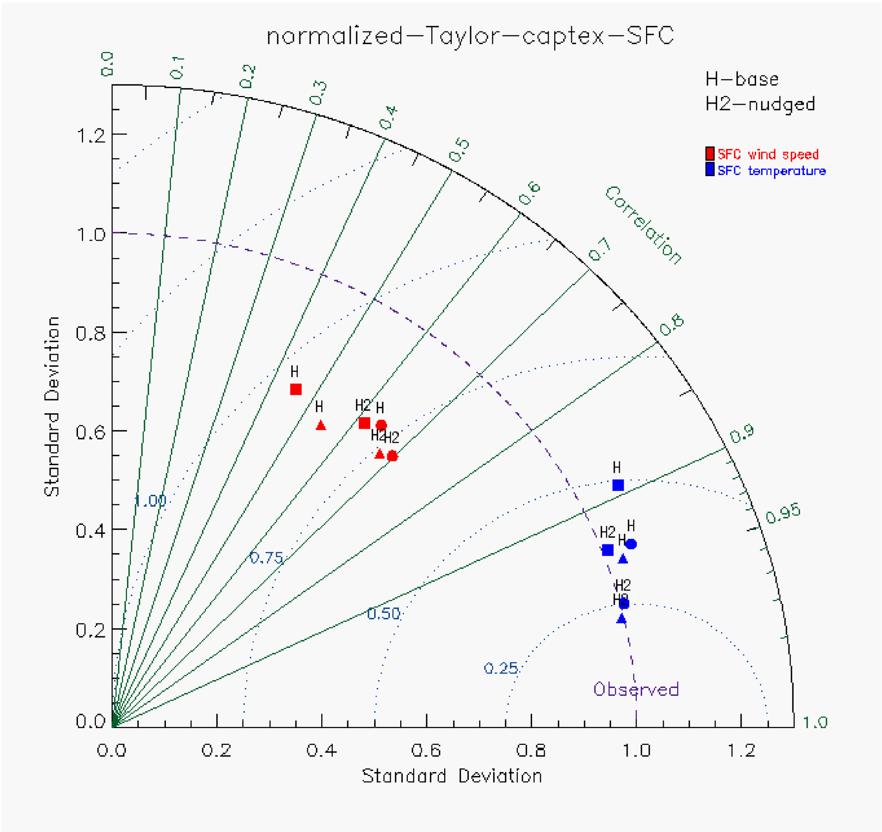


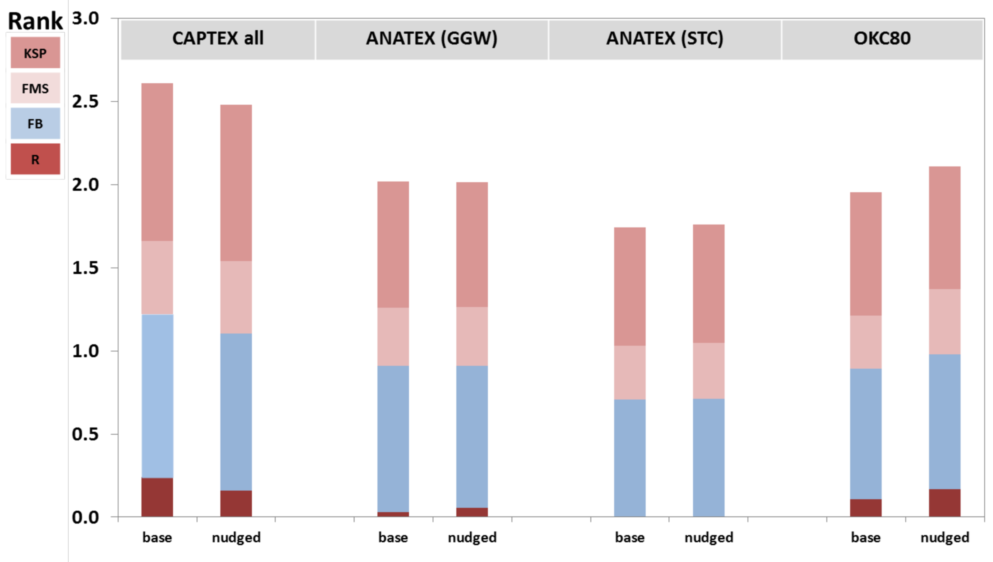
Five WRF simulations with different PBL schemes were selected from the CAPTEX evaluations. Statistical scores were similar for all cases in terms of wind and temperature.

The two releases, at GGW and at STC, during ANATEX were modeled using five WRF data and NARR data. The dispersion simulations using WRF data outperformed the NARR for the GGW release while none of WRF data generated results as good as the NARR for the STC release.

Base case .vs. nudging case

Nudging case uses improved IC/BC files and surface and observational nudging, in addition to the grid nudging included in the base case.



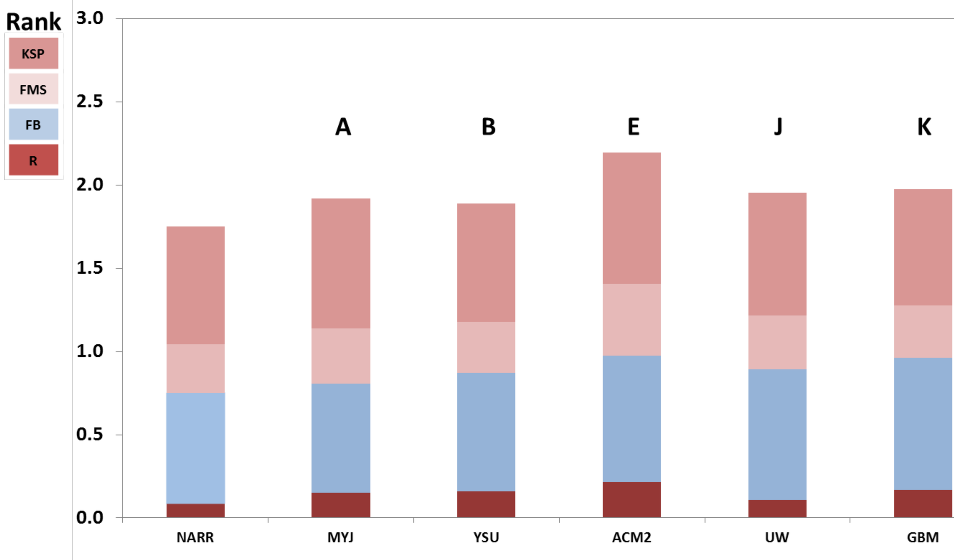


The WRF simulation with UW PBL scheme was selected as a base case for testing how the nudged meteorology impacts the dispersion results. Nudged data had better statistical scores in terms of surface wind and temperature for all three tracer experiments.

CAPTEX and ANATEX dispersion simulations driven by nudged data did not show better performance. Conversely, for OKC80, using nudged data produced a plume with higher correlation coefficient and smaller fractional bias.

Long- range Atmospheric Tracer Experiment in Oklahoma (OKC80)

During July 8th -11th in 1981; one 3-hr release at Oklahoma City; samples collected at 45-min and 3-hr averages.



HYSPLIT simulations for the OKC80 tracer experiment were driven by five WRF and NARR datasets. All cases using WRF meteorological input generated better dispersion results compared to the cases using NARR data. Among all, the ACM2 run had the best rank.

SUMMARY

- We performed WRF-ARW meteorological simulations to create a long-term archive for driving dispersion applications. This WRF output was used to drive the HYSPLIT model. The dispersion simulation results were compared against three controlled tracer experiments.
- The wind comparison shows that the WRF runs using the YSU, QNSE, and MYNN2 PBL schemes had the best statistical performance among all PBL schemes evaluated. HYSPLIT runs driven by WRF data based on the QNSE and MYNN2 PBL schemes show the lowest statistical performances while the top three scores for HYSPLIT results were those using ACM2, UW and GBM PBL schemes. .
- The comparison of the dispersion calculations using non-nudged versus nudged meteorology shows no noticeable improvement for the CAPTEX and ANATEX experiments. But for the OKC80 tracer experiment, using nudged WRF data produced a plume with a higher correlation coefficient and a smaller fractional bias..

Reference

Draxler, R. R., 2006: The use of global and mesoscale meteorological model data to predict the transport and dispersion of tracer plumes over Washington, D.C. Wea. Forecasting, 21, 383–394.

Taylor, K. E.: Summarizing multiple aspects of model performance in a single diagram, J. Geophys. Res., 106, 7183, doi:10.1029/2000JD900719, 2001.

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