A Long-Term WRF Meteorological Archive for Dispersion Simulations: Application to Controlled Tracer Experiments

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Data Archive of Tracer Experiments and Meteorology (DATEM)

❖ What is DATEM?

Consisting of standardized software and uniformly formatted data (emissions, tracer measurements, meteorological inputs and statistical evaluation) for multiple controlled tracer experiments. (*website:* http://www.arl.noaa.gov/DATEM.php)

❖ What is DATEM for?

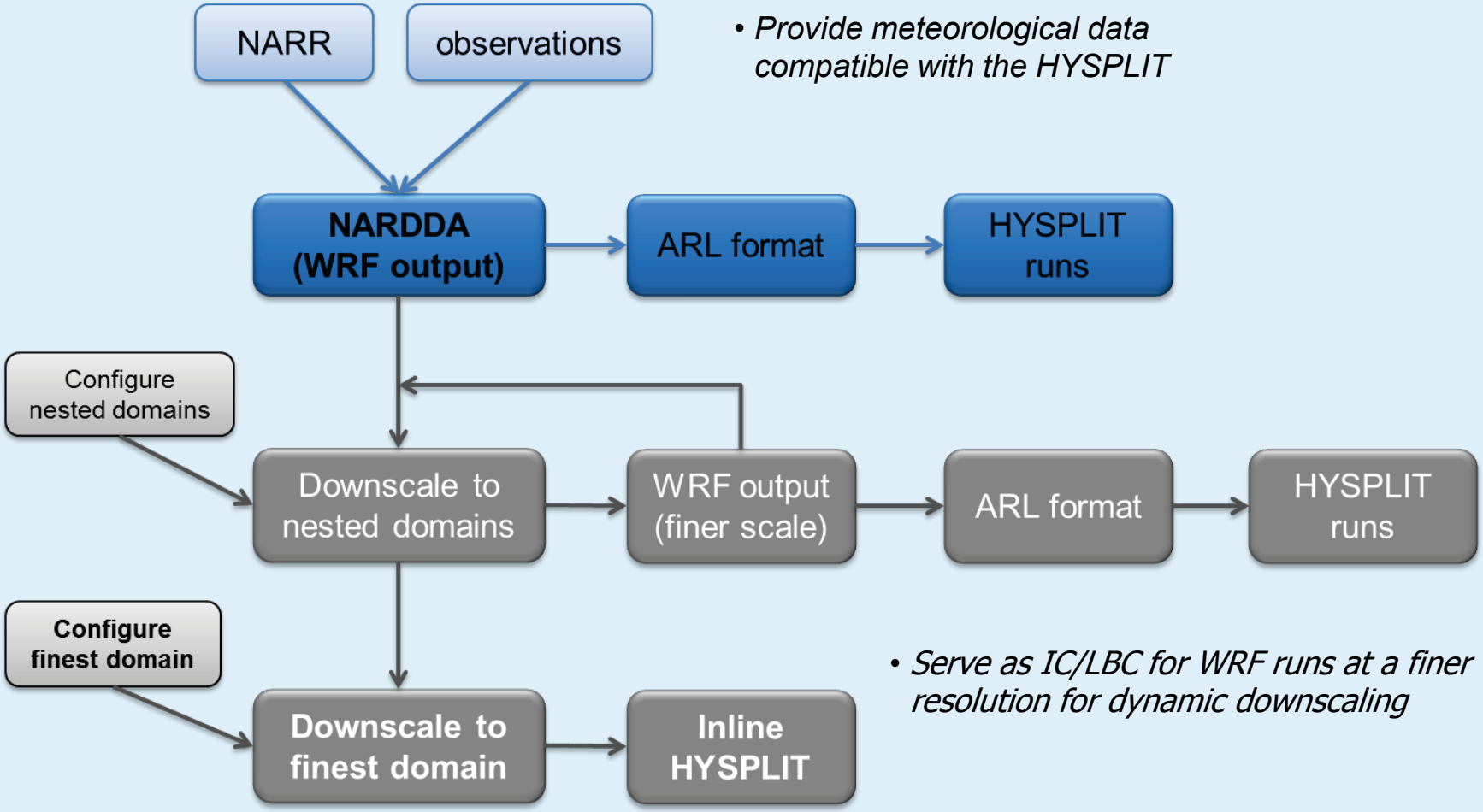
Providing a platform for HYSPLIT's verification and development (various sensitivity studies and results comparisons).

❖ What does DATEM have?

Including 9 tracer experiments ranging from 10s to 1000s of km downwind and 2 meteorological datasets (Global Reanalysis and NARR)

Adding WRF meteorological data

North America Reanalysis Data for Dispersion Application



- *Provide meteorological data compatible with the HYSPLIT*

- *Serve as IC/LBC for WRF runs at a finer resolution for dynamic downscaling*

The Objective

To generate a WRF configuration tailored for dispersion applications based on the statistical evaluation of different controlled tracer experiments.

The end product

A long-term archive of WRF data available for HYSPLIT modeling.

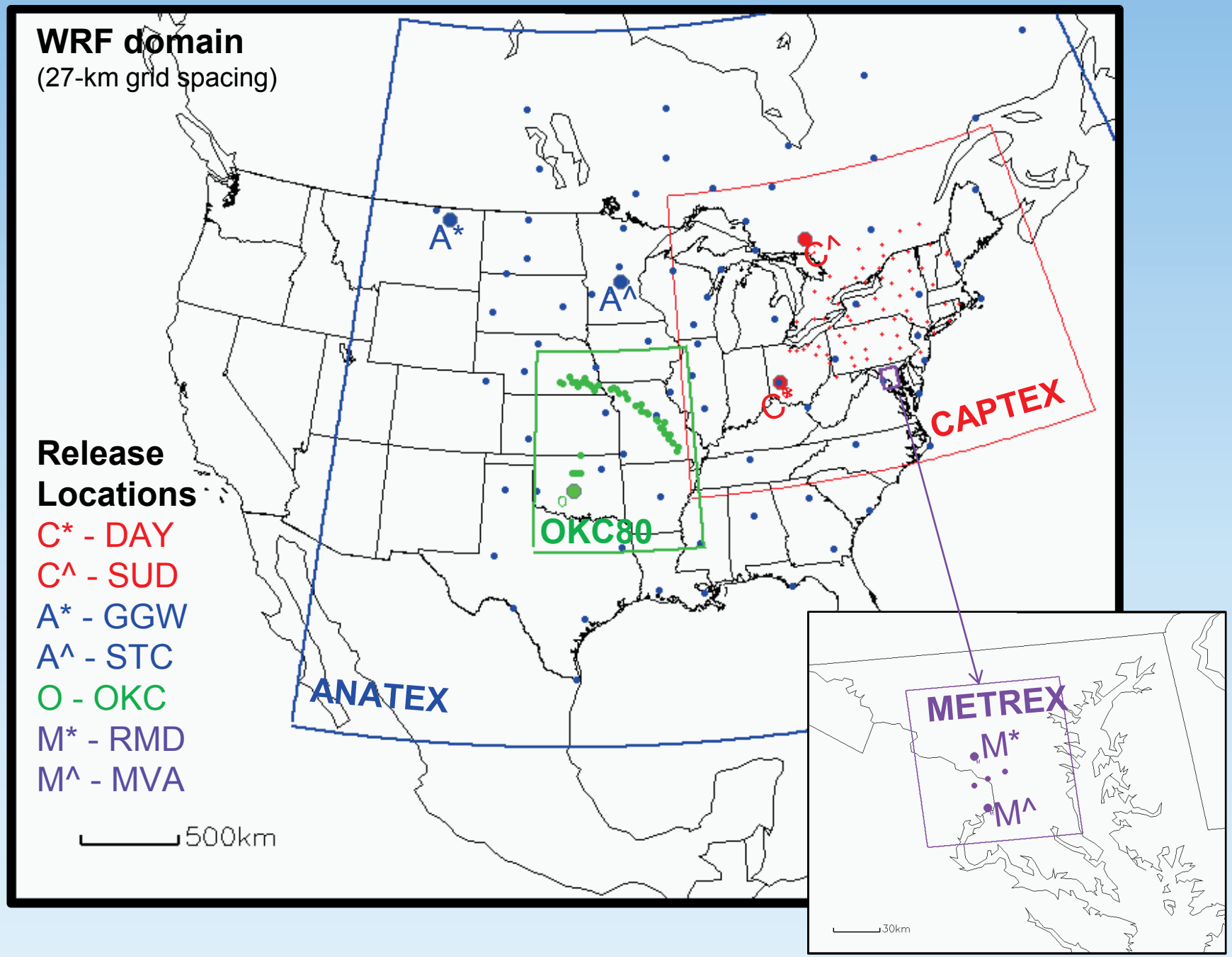
- WRF simulations were set with different PBL schemes and nudging options
- Four tracer experiments – CAPTEX, ANATEX, OCK80 and METREX
- Statistical evaluations for WRF simulations
- Evaluations of the HYSPLIT results against tracer measurements

Tracer Experiments

	Full name	Experiment area	Experiment period	Number of release	Reference
CAPTEX	Cross Appalachian Tracer Experiment	Dayton, OH Sudbury, ONT	Sep. and Oct. 1983 (Single release)	6	Ferber et al., 1986
ANATEX	North America Tracer Experiment	Glasgow, MT St. Cloud, MN	Jan. – Mar. 1987 (every 2.5 days)	2	Draxler and Heffter, 1989
OKC80	Oklahoma Tracer Experiment	Norman, OK	Jul. 8th 1980 (Single release)	1	Ferber et al., 1981
METREX	Metropolitan Tracer Experiment	Washington, DC	Jan. – Dec. 1984 (every 36 hours)	2	Draxler 1987

HYSPLIT grid setup – 25 km horizontal resolution (0.5 km for METREX)
0-100 m vertical grid (0-50 m for METREX)

Modeling domains for WRF and HYSPLIT



WRF configuration

name	PBL scheme	Surface scheme	Land surface model
MYJ	Mellor-Yamada-Janjic scheme[1]	Monin-Obukhov (Janjic) scheme	Unified Noah LSM
YSU	YSU scheme[2]	MM5 Monin-Obukhov scheme	Unified Noah LSM
ACM2	ACM2 PBL scheme[3]	Pleim-Xiu surface layer	Pleim-Xiu LSM
QNSE	Quasi-Normal Scale Elimination PBL[4]	QNSE surface layer	Unified Noah LSM
MYNN2	MYNN 2.5 level TKE scheme[5]	MYNN surface layer	Unified Noah LSM
TEMF	Total Energy Mass Flux scheme[6]	TEMF surface layer	Unified Noah LSM
BouLac	Bougeault and Lacarrere PBL[7]	MM5 Monin-Obukhov scheme	Unified Noah LSM
UW	UW boundary layer scheme[8]	MM5 Monin-Obukhov scheme	Unified Noah LSM
GBM	Grenier-Bretherton-McCaa scheme[9]	MM5 Monin-Obukhov scheme	Unified Noah LSM

[1]Janjic (1994), [2]Hong et al., (2006), [3]Pleim (2007), [4]Pergaud et al., (2009), [5]Nakanishi and Niino (2006), [6]Angevine et al., 2010, [7]Bougeault and Lacarrere (1989), [8]Bretherton and Park (2009), [9]Grenier and Bretherton (2001)

Initial/boundary conditions: NARR 3-hourly

Other physical options: single-moment three class microphysics scheme
RRTM and Dudhia radiation scheme
Grell-Freitas Ensemble sub-grid cloud scheme
Analysis grid nudging (and observational nudging)

Evaluations

- Meteorological evaluations

  Taylor diagram (Taylor 2001)

  The model performance in terms of correlation (R), centered root-mean-square (RMS) difference, and standard deviation.

- Dispersion evaluations

  Rank, a cumulative statistical score (range between 0-4)

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

(Draxler 2006)

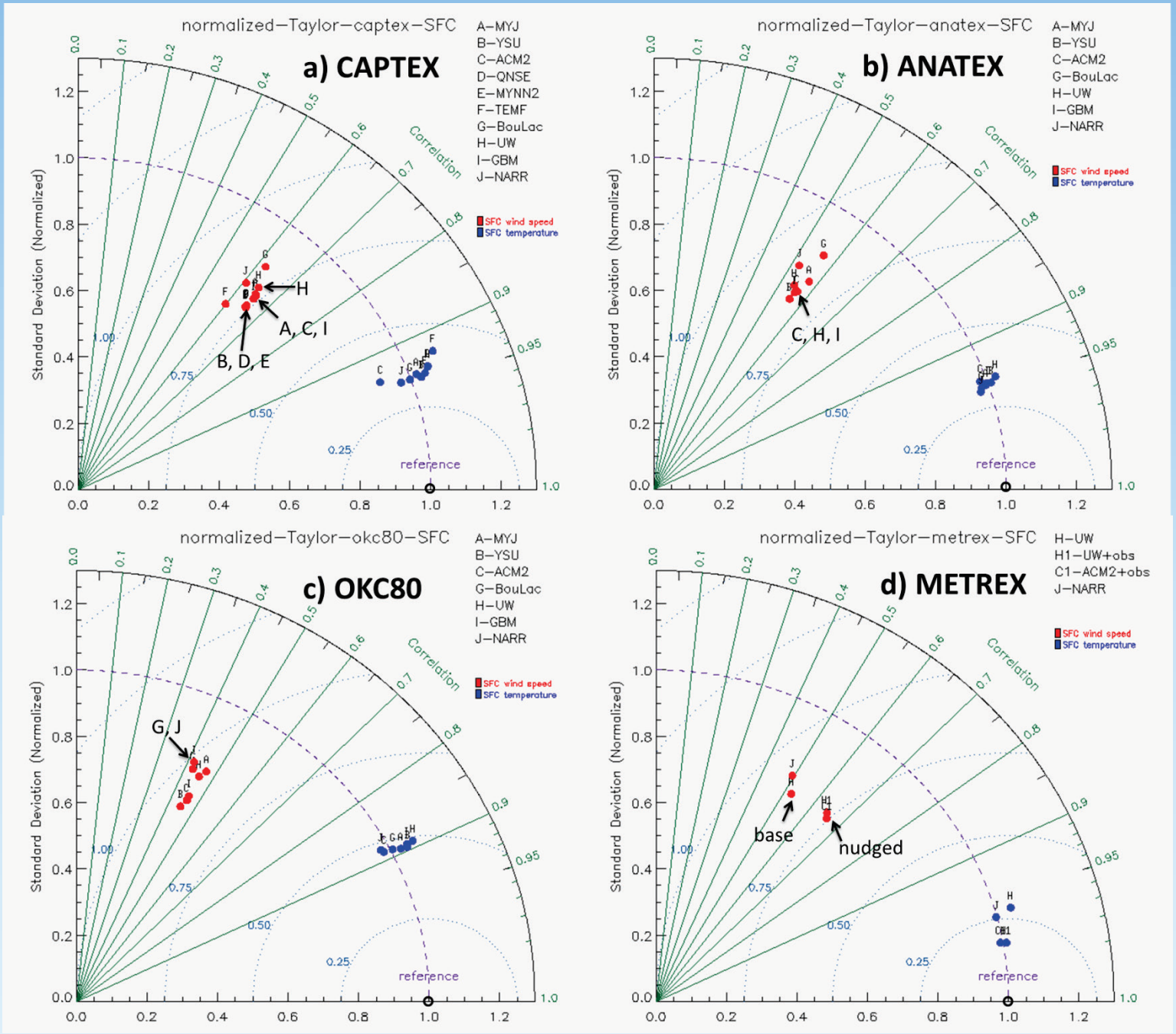
Correlation coefficient (R)

Fractional bias (FB)

Figure of merit in space (FMS)

Kolmogorov-Smirnov parameter (KSP)

Normalized Taylor Diagrams

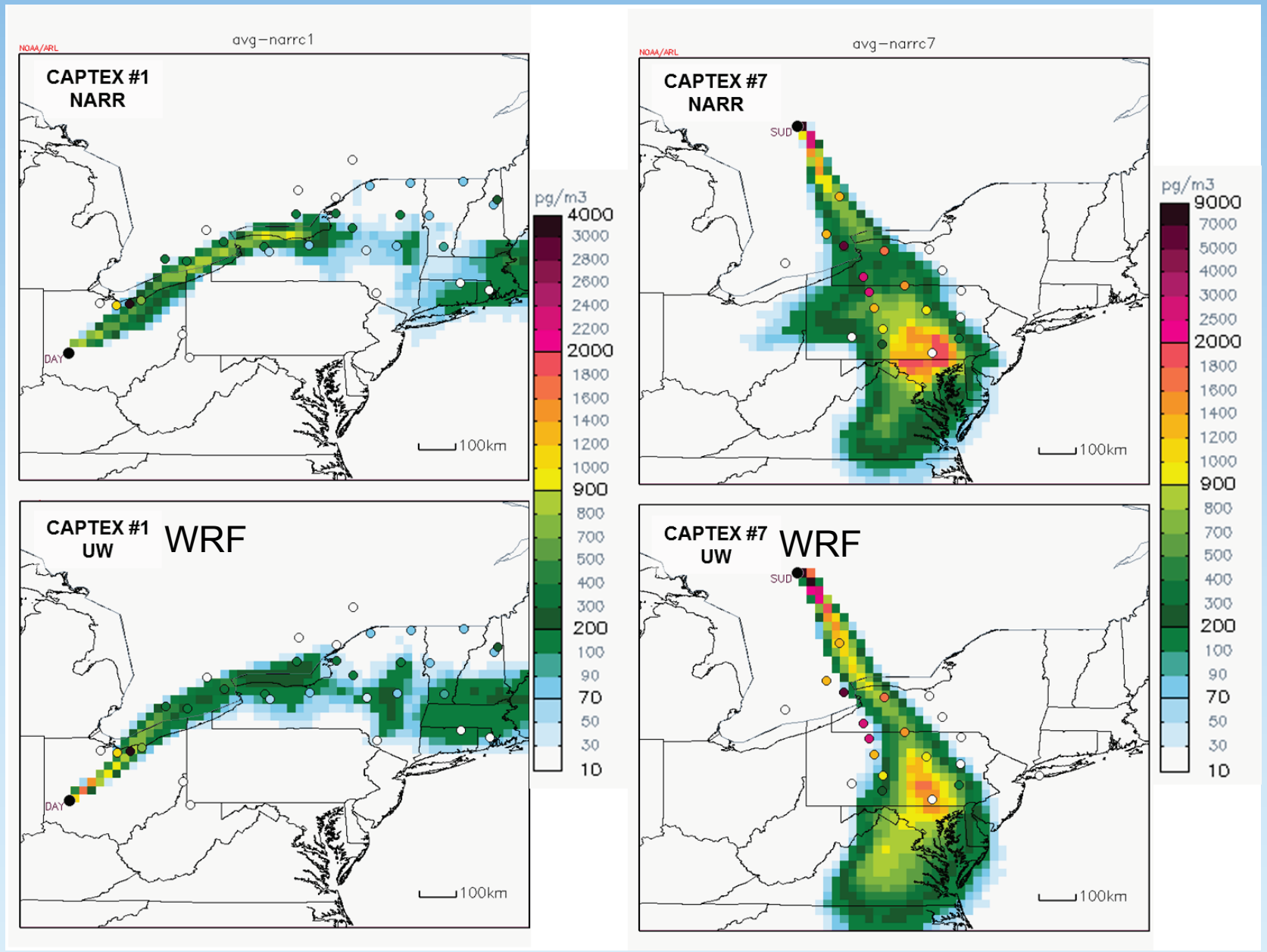


Dispersion results for CAPTEX

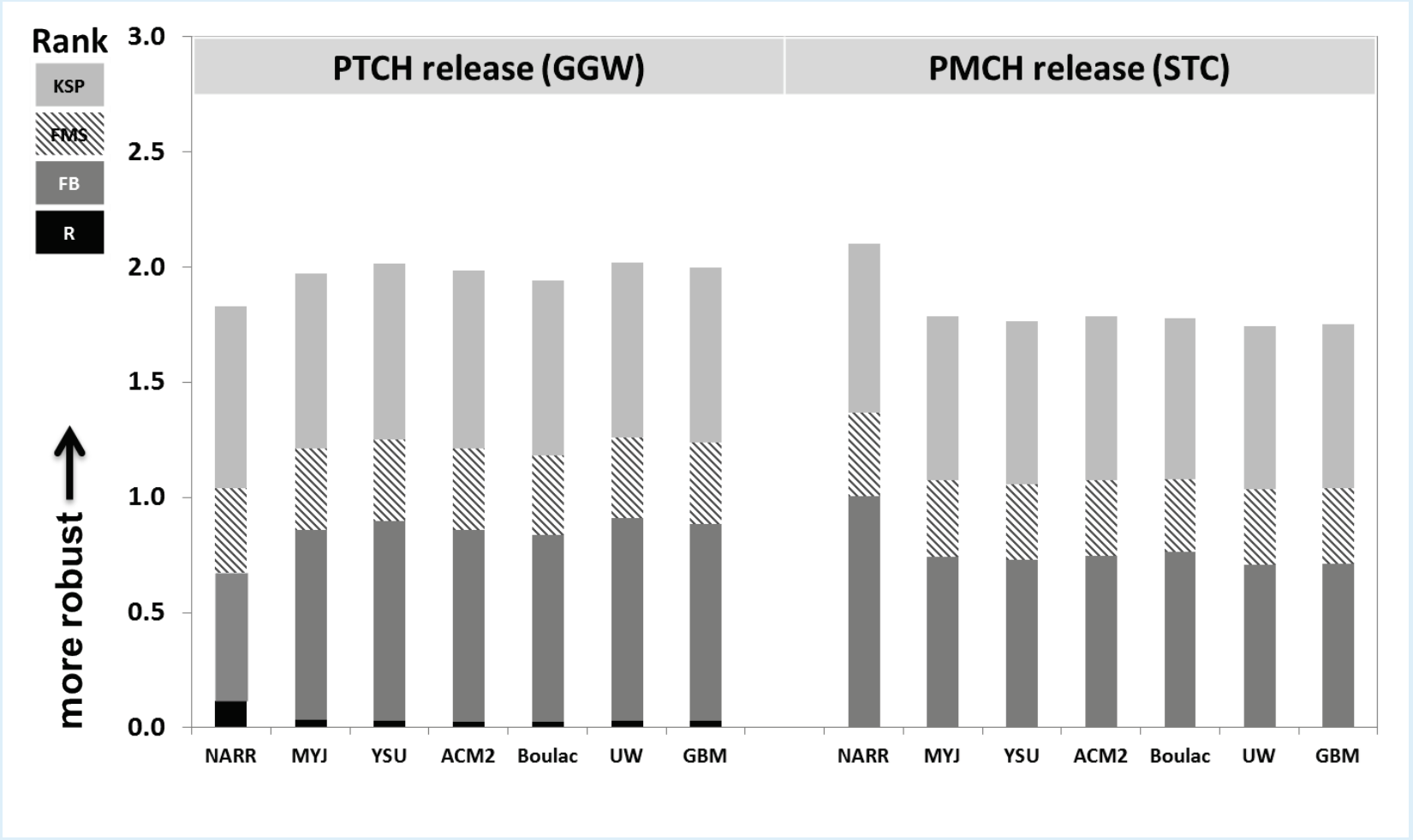
Rank	NARR	MYJ	YSU	ACM2	QNSE	MYNN2	TEMF	BouLac	UW	GBM
R1	2.12	2.82	2.81	2.72	2.78	2.88	2.77	2.73	3.04	3.03
R2	2.79	2.96	2.95	2.97	2.77	2.74	2.29	3.07	2.97	2.96
R3	1.92	1.95	1.95	1.94	2.02	1.94	1.88	1.87	1.97	1.97
R4	2.18	2.08	2.10	2.02	1.95	2.12	2.06	1.95	2.18	2.12
R5	2.57	2.67	2.56	2.49	2.56	2.60	2.50	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**

Note: using all measurements from six episodes

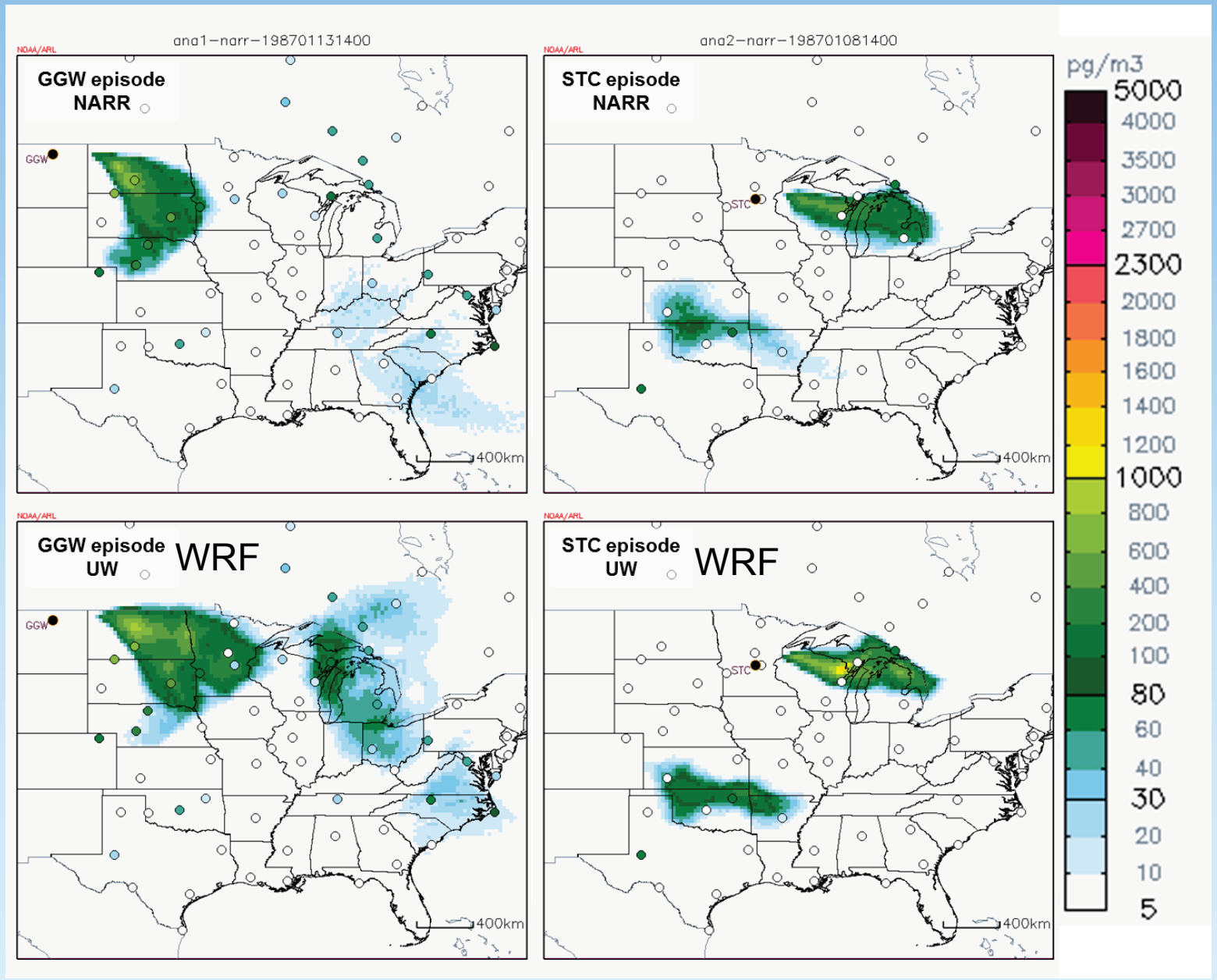
CAPTEX concentration plots



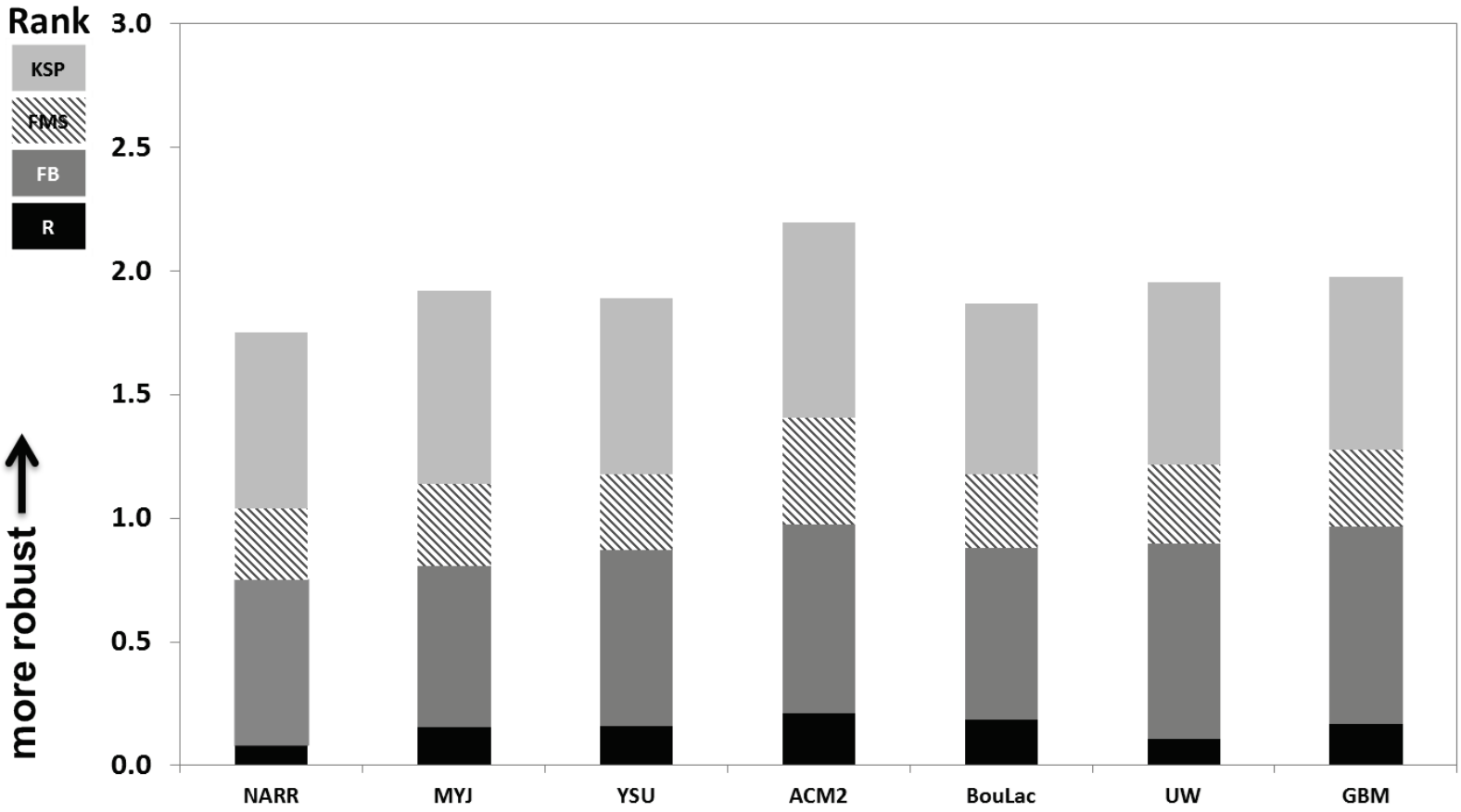
Dispersion results for ANATEX



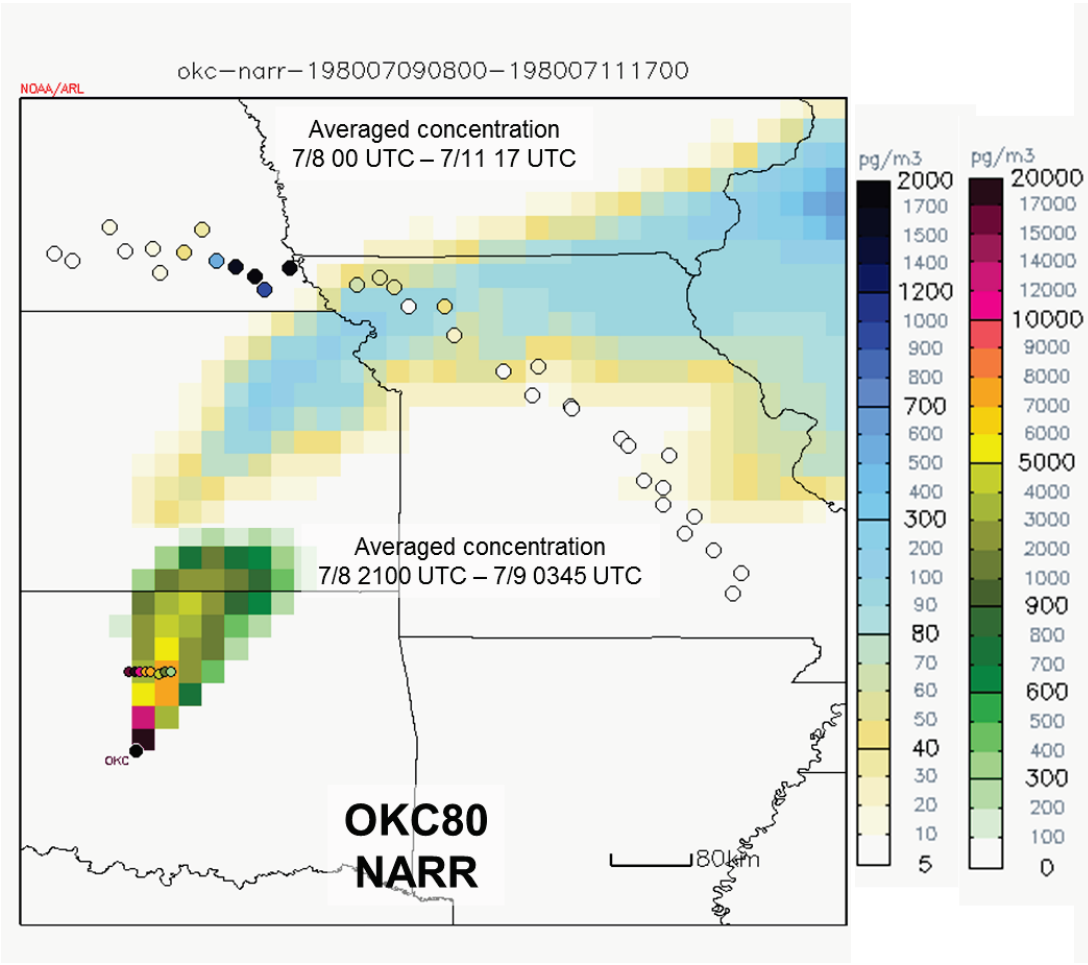
ANATEX concentration plots

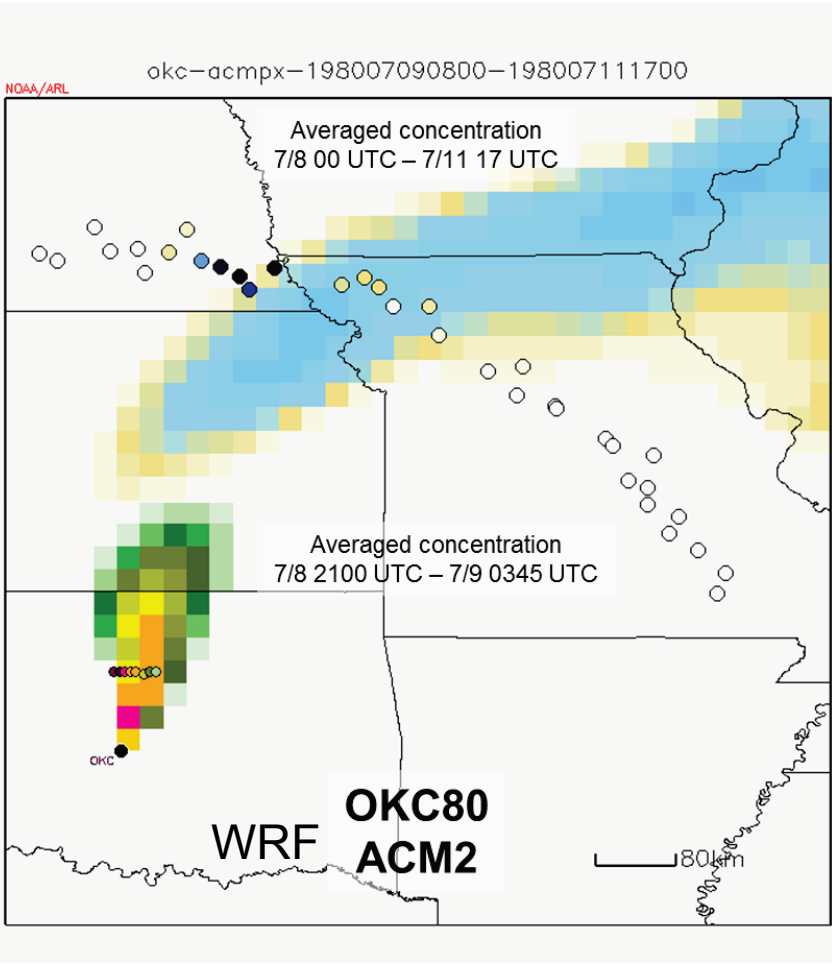


Dispersion results for OKC80

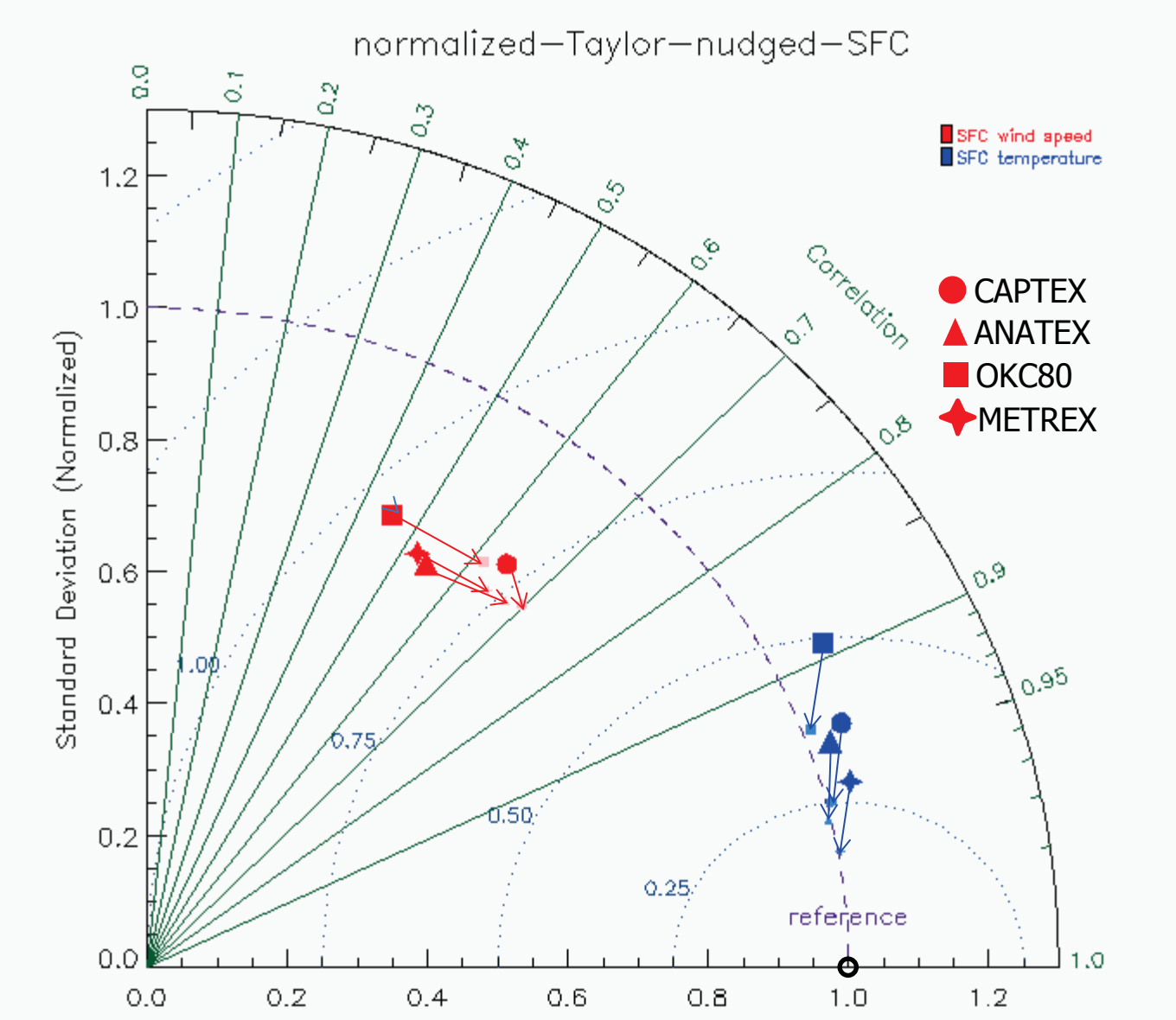


OKC80 composited plots

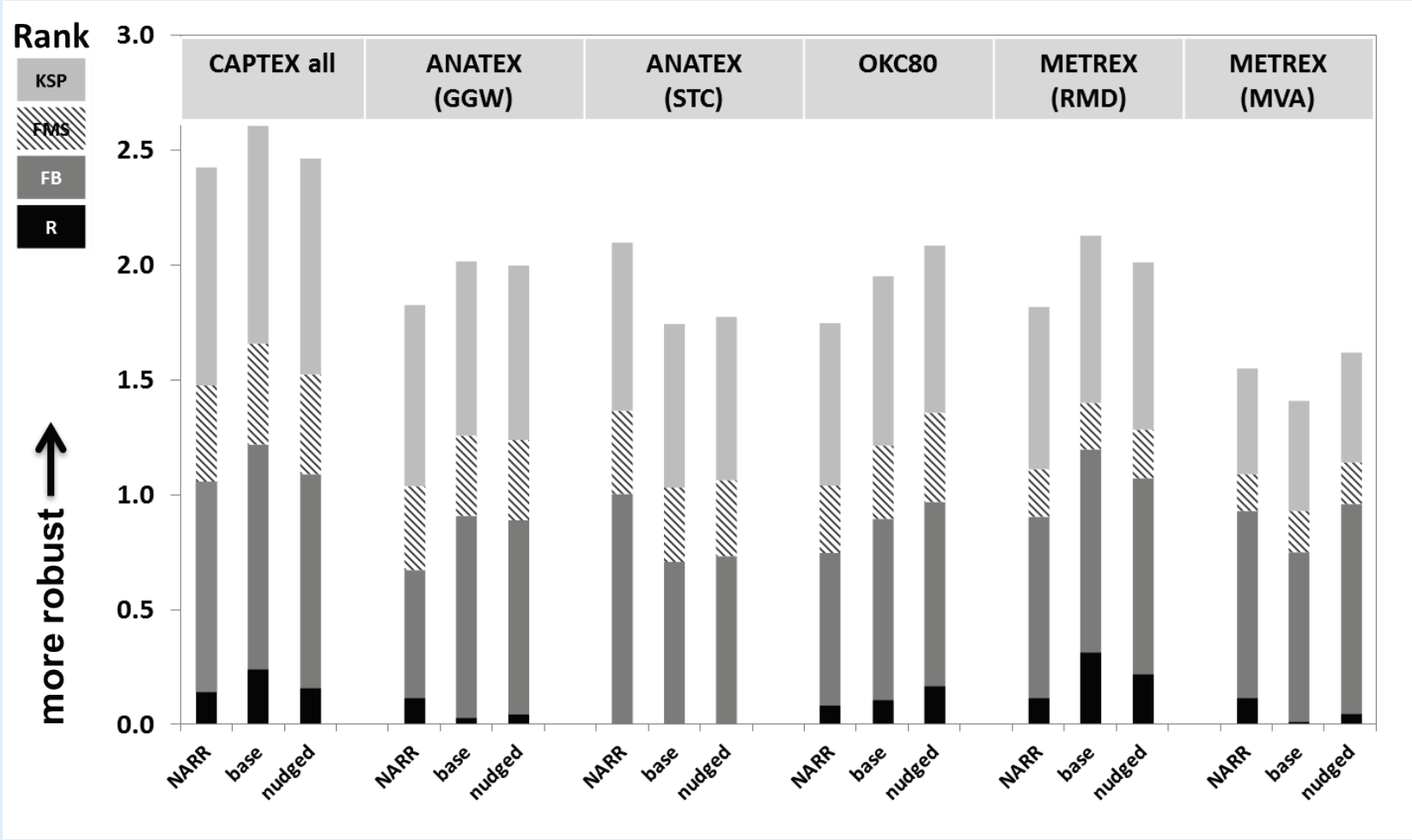




Base WRF .vs. nudged WRF



Dispersion results using NARR, Base WRF, nudged WRF



Summary

- A long-term archive of WRF data in a 27-km horizontal grid spacing was conducted to provide data compatible with the HYSPLIT dispersion model and to serve as initial and boundary conditions for simulations at a finer resolution.
- The evaluation of the WRF results utilizing conventional observations showed a similar statistical performance for the different PBL schemes.
- The dispersion simulations based on WRF data generated equal or slightly better statistical performance than those driven by the NARR dataset. The statistical comparison showed a mixed impact for the dispersion results driven by the non-nudged and nudged WRF data.
- This WRF dataset provides hourly data for HYSPLIT, covering years 1980 – 2016 and including additional variables relevant to atmospheric dispersion.
- The new dataset will available online providing additional capabilities for using different meteorological inputs and a variety of HYSPLIT setups for mixing calculations.

Future Work

- The WRF dataset can be used to generate dispersion ensembles with variations in meteorological inputs and diverse configurations of the dispersion simulations.
- For tracer experiment in a fine scale like METREX, the dispersion calculation can be driven by WRF data nested down to a finer resolution.

HYSPLIT configuration

	Tracer	Particle number	Release date	Emission frequency	Emission rate (g/hr)	Data points
CAPTEX #1	PMCH	50,000	1983/09/18 17z	Single release	69,333	395
CAPTEX #2	PMCH	50,000	1983/09/25 17z	Single release	67,000	400
CAPTEX #3	PMCH	50,000	1983/10/02 19z	Single release	67,000	404
CAPTEX #4	PMCH	50,000	1983/10/14 16z	Single release	66,333	367
CAPTEX #5	PMCH	50,000	1983/10/26 04z	Single release	60,000	357
CAPTEX #7	PMCH	50,000	1983/10/29 06z	Single release	61,000	358
ANATEX GGW	PTCH	300,000	1987/01/05 17z (or 05z) to 1987/ 03/26	every 2.5 days	~ 27,900	5600
ANATEX STC	PDCH	300,000	1987/01/05 17z (or 05z) to 1987/ 03/26	every 2.5 days	~16,700	5482
OKC80	PMCH	150,000	1980/07/08 19z	Single release	~64,000	697
METREX-RMD	PMCH	10,000	1984 01/02 03z (or 15z) to 1985 01/02	every 36 hours	~300	3270
METREX-MVA	PDCH	10,000	1984 01/02 03z (or 15z) to 1985 01/02	every 36 hours	~100	3266

Normalized RSME