



# North America Reanalysis Data for Dispersion Applications And Recent HYSPLIT updates

Fantine Ngan <sup>1,2</sup>, Glenn Rolph <sup>1</sup> and Ariel Stein <sup>1</sup>

<sup>1</sup> NOAA/Air Resource Laboratory, College Park, Maryland

<sup>2</sup> Cooperative Institute for Climate and Satellites, University of Maryland, College Park, Maryland

Email: [Fantine.Ngan@noaa.gov](mailto:Fantine.Ngan@noaa.gov)

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# What is HYSPLIT?



- HYSPLIT is one of the most widely used Lagrangian dispersion models for atmospheric trajectory, dispersion and deposition calculations (www, PC, Mac, LINUX):

[http://www.arl.noaa.gov/HYSPLIT\\_info.php](http://www.arl.noaa.gov/HYSPLIT_info.php)

- Emergency Response Applications

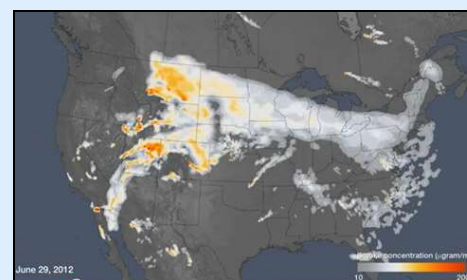
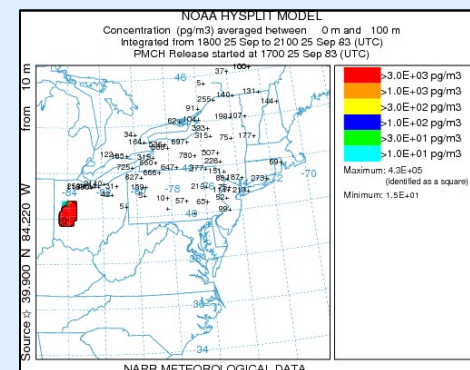
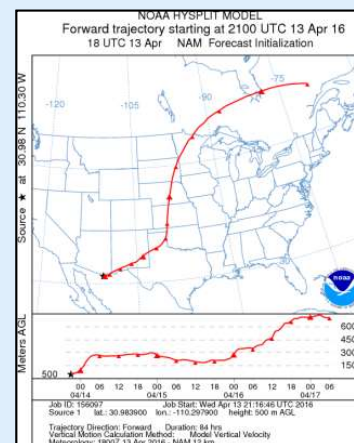
- Volcanic eruptions
- Chemical releases
- Radiological releases

- Air Quality Applications

- Wildfire smoke
- Global pollutant transport
- Wind-blown dust
- Source-receptor analysis

- Model Evaluation

- Data Archive of Tracer Experiments and Meteorology (DATEM)



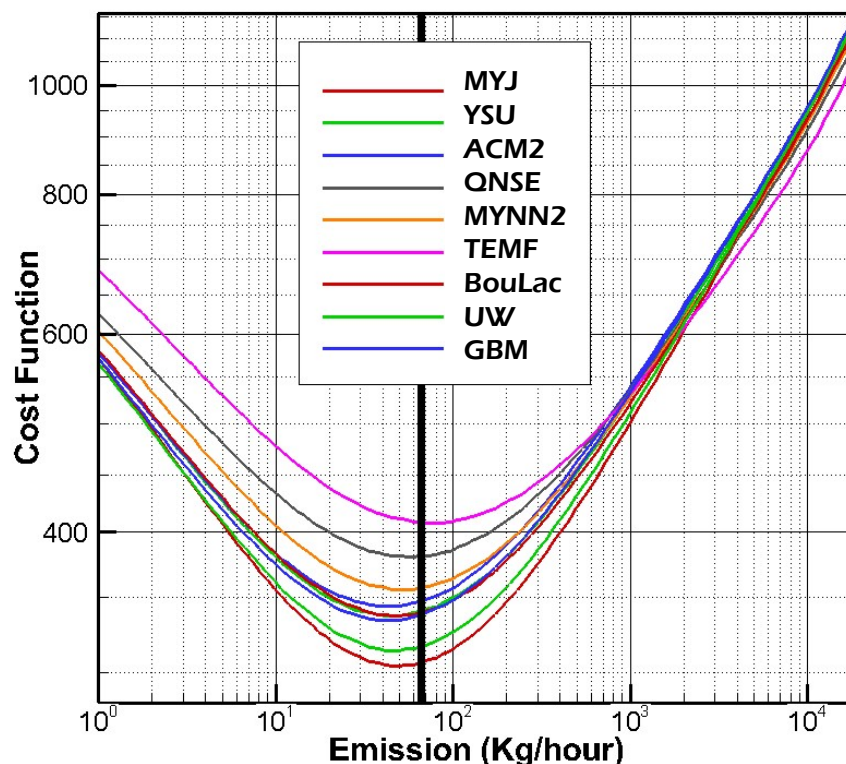
# Recent HYSPLIT Updates

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- Added new HYSPTTEST program to evaluate model inputs (CONTROL and SETUP.CFG) for consistency and suggests appropriate changes.
- Added inverse modeling executable (lbfgsb) that solves the Transfer Coefficient Matrix for the source term vector
- Added new program ecm2arl that converts ECMWF meteorological data to HYSPLIT format (based on grib2arl)
- Added dimensioned CPACK variable so the model can support Cartesian and polar grids within the same run
- Puffs can be converted to multiple 3D particles randomly distributed within the puff (INITD=130/140) at hour defined in CONAGE parameter

## Using tracer experiment data, estimate the source strength with ensemble calculation

Emission inversion based on the assimilation of 4D observations using HYSPLIT model, its Transfer Coefficient Matrix, and a cost function is applied to CAPTEX



### Assumptions:

- Assume release location (Dayton Ohio) is known;
- Exact release starting and ending times (17Z to 20Z on September 25, 1983) are also known.
- An ensemble runs with 9 members with different boundary layer schemes;
- Estimates: 41 – 73 kg/h

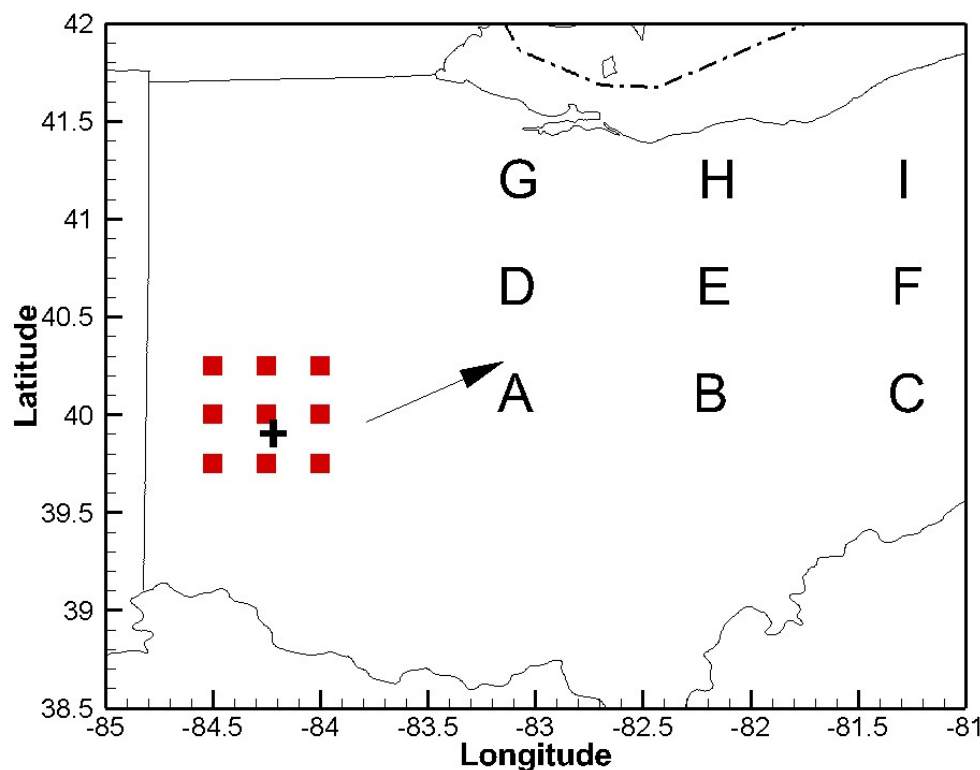
# Recover source location

## Assumptions:

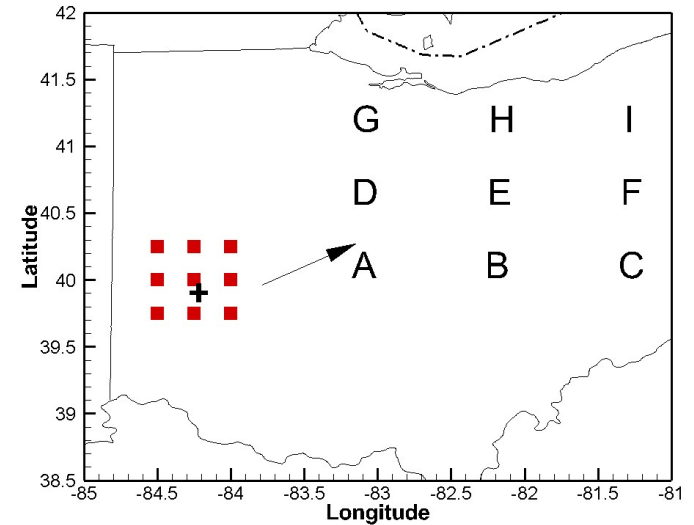
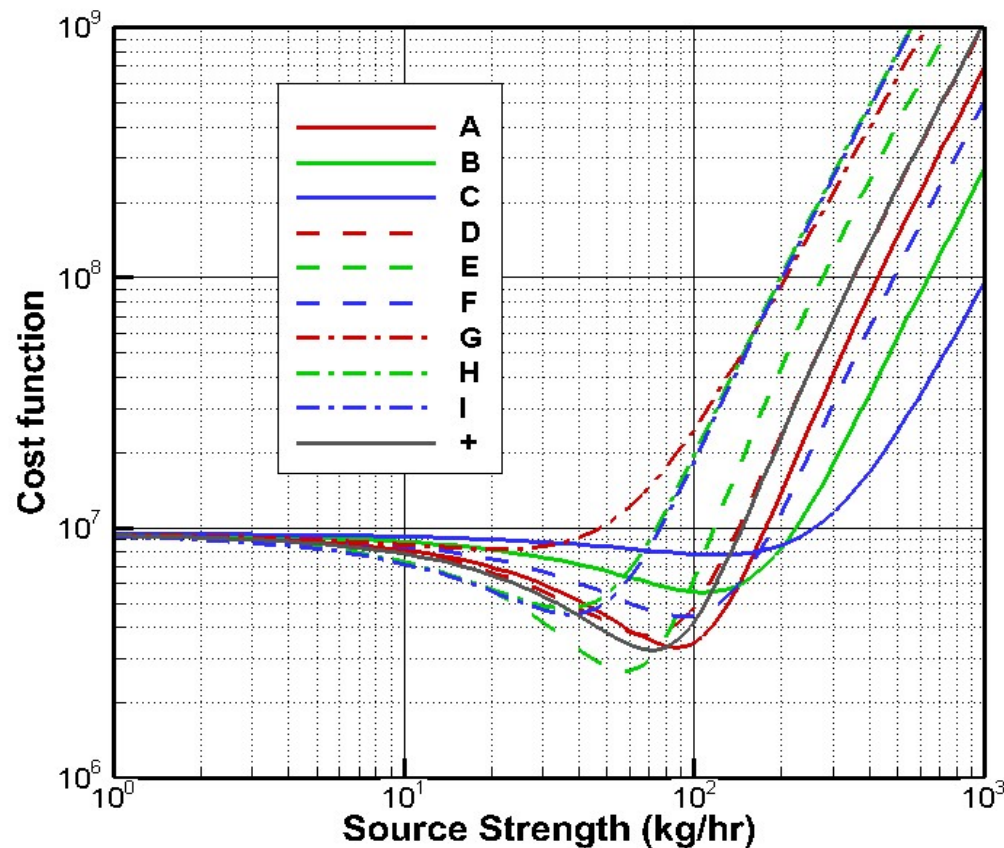
- Exact release time known
- Release strength unknown
- Only one 'true' release location
- 9 candidate locations in a 3x3 grid (0.25 degree resolution)

## Method:

- Each candidate location is solved independently
- Release location that can generate predictions best matching observations (minimal cost function) as the likely source location.



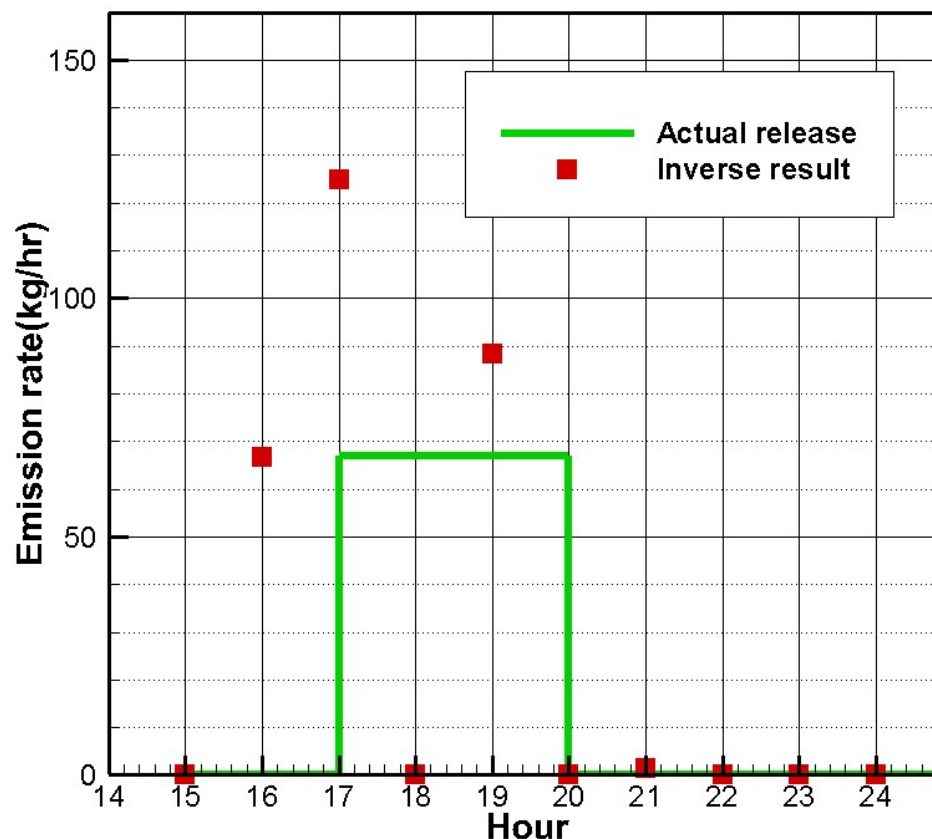
# Identify source location



## Result:

- Out of the 9 candidate locations, location E ( $40.00^\circ$  N,  $84.25^\circ$  W), which is closest to the actual release site ( $39.90^\circ$  N,  $84.22^\circ$  W), has the minimal cost function and is identified as the likely source location.
- The source strength is estimated as 58 kg/hr (-13% from obs).
- Location E actually yields a cost function smaller than that from the actual release site.

# Recover temporal variations of release



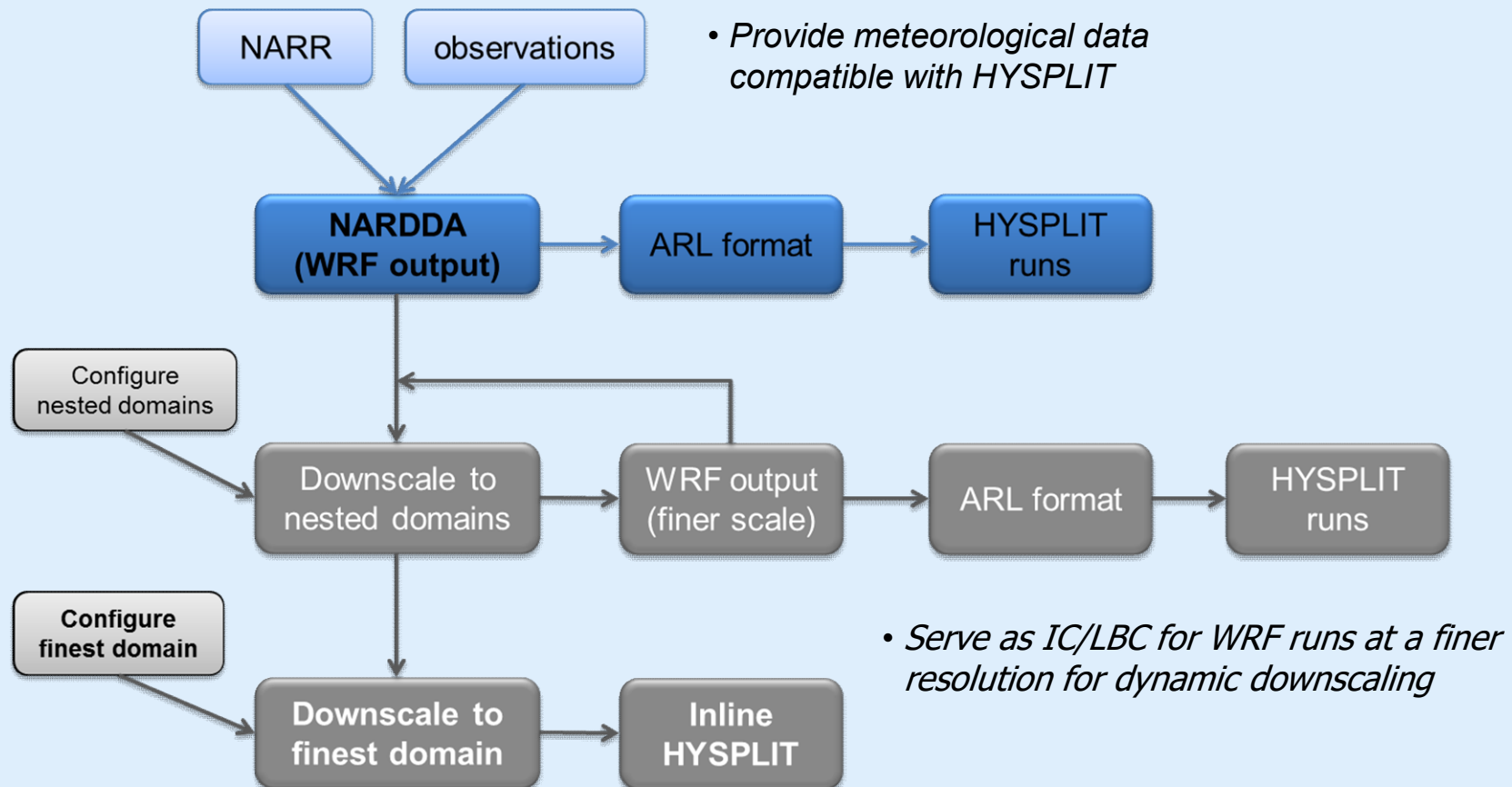
## Assumptions:

- Assume release location (Dayton Ohio) is known;
- Release could vary hourly;
- Possible release starting at 15Z on September 25, 1983 until last measurement.

## Result:

- Releases after 19Z on September 26, 1983 cannot be constrained with available observations;
- Recovered releases after 20Z September 25 are close to 0;
- Temporal variations are different from the actual releases (constant over 3 hours).

# North America Reanalysis Data for Dispersion Applications



## 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 Applications

## 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

Publication: Ngan and Stein (2017): A Long-Term WRF Meteorological Archive for Dispersion Simulations: Application to Controlled Tracer Experiments. J. Appl. Meteor. Climatol., 56, 2203-2220.

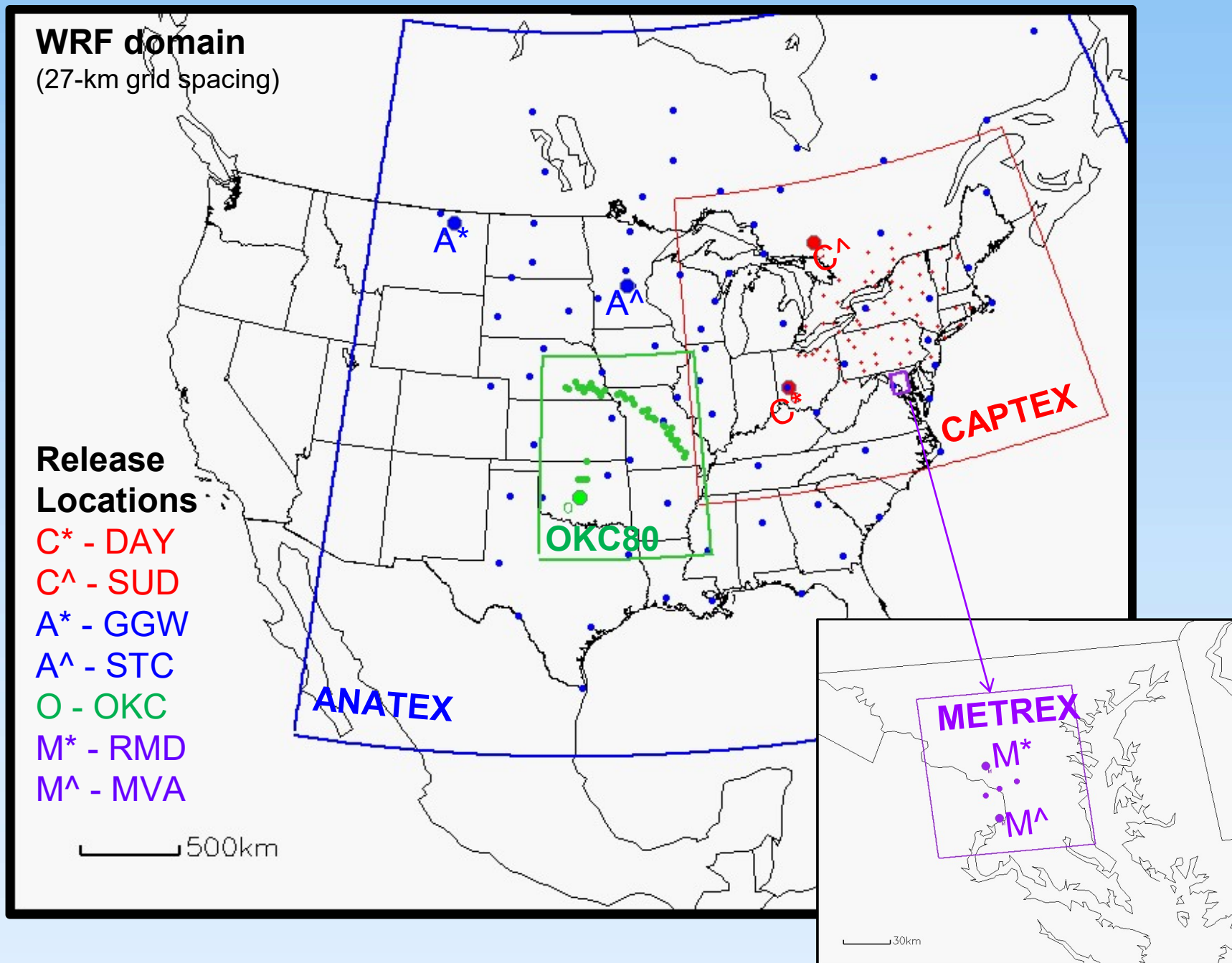
<http://journals.ametsoc.org/doi/full/10.1175/JAMC-D-16-0345.1>

# Tracer Experiments

	Full name	Experiment area	Experiment period	Number of releases	Reference
<b>CAPTEX</b>	Cross Appalachian Tracer Experiment	Dayton, OH Sudbury, ONT	Sep. and Oct. 1983 (Single release)	6	Ferber et al., 1986
<b>ANATEX</b>	North America Tracer Experiment	Glasgow, MT St. Cloud, MN	Jan. – Mar. 1987 (every 2.5 days)	2	Draxler and Heffter, 1989
<b>OKC80</b>	Oklahoma Tracer Experiment	Norman, OK	Jul. 8 <sup>th</sup> 1980 (Single release)	1	Ferber et al., 1981
<b>METREX</b>	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
<b>MYJ</b>	Mellor-Yamada-Janjic scheme <sup>1</sup>	Monin-Obukhov (Janjic) scheme	Unified Noah LSM
<b>YSU</b>	YSU scheme <sup>2</sup>	MM5 Monin-Obukhov scheme	Unified Noah LSM
<b>ACM2</b>	ACM2 PBL scheme <sup>3</sup>	Pleim-Xiu surface layer	Pleim-Xiu LSM
<b>QNSE</b>	Quasi-Normal Scale Elimination PBL <sup>4</sup>	QNSE surface layer	Unified Noah LSM
<b>MYNN2</b>	MYNN 2.5 level TKE scheme <sup>5</sup>	MYNN surface layer	Unified Noah LSM
<b>TEMF</b>	Total Energy Mass Flux scheme <sup>6</sup>	TEMF surface layer	Unified Noah LSM
<b>BouLac</b>	Bougeault and Lacarrere PBL <sup>7</sup>	MM5 Monin-Obukhov scheme	Unified Noah LSM
<b>UW</b>	UW boundary layer scheme <sup>8</sup>	MM5 Monin-Obukhov scheme	Unified Noah LSM
<b>GBM</b>	Grenier-Bretherton-McCaa scheme <sup>9</sup>	MM5 Monin-Obukhov scheme	Unified Noah LSM

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

$$Rank = R^2 + 1 - \left| \frac{FB}{2} \right| + \frac{FMS}{100} + \left( 1 - \frac{KSP}{100} \right) \quad (\text{Draxler 2006})$$

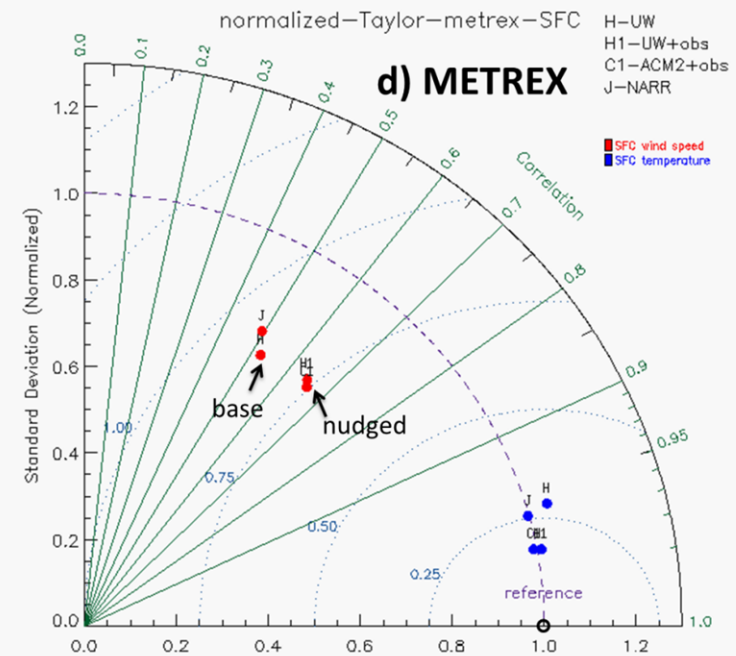
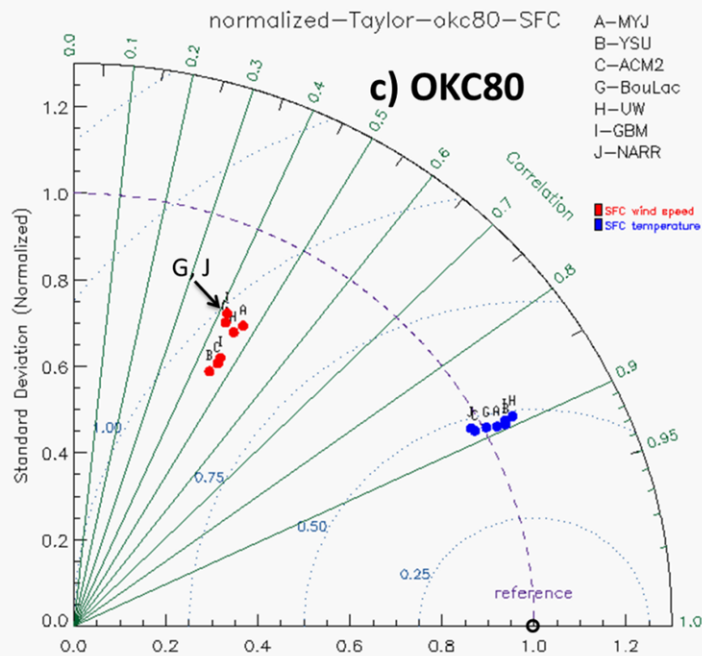
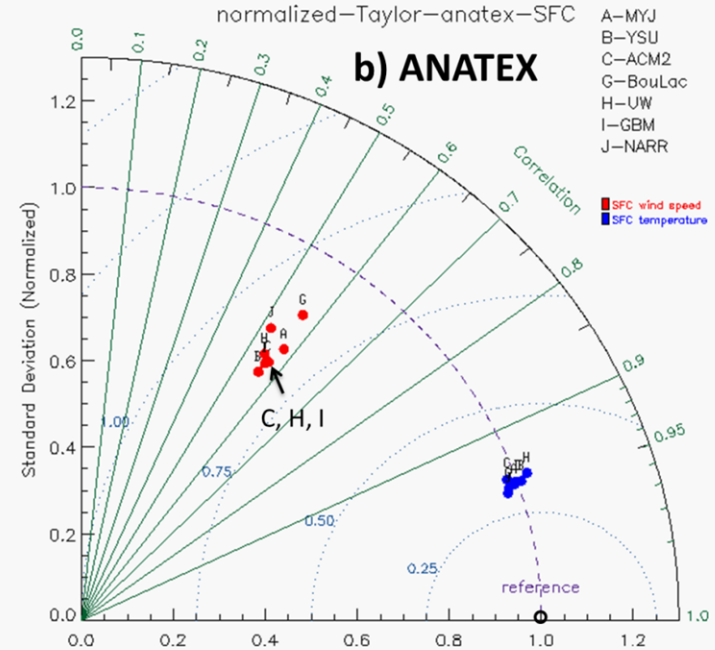
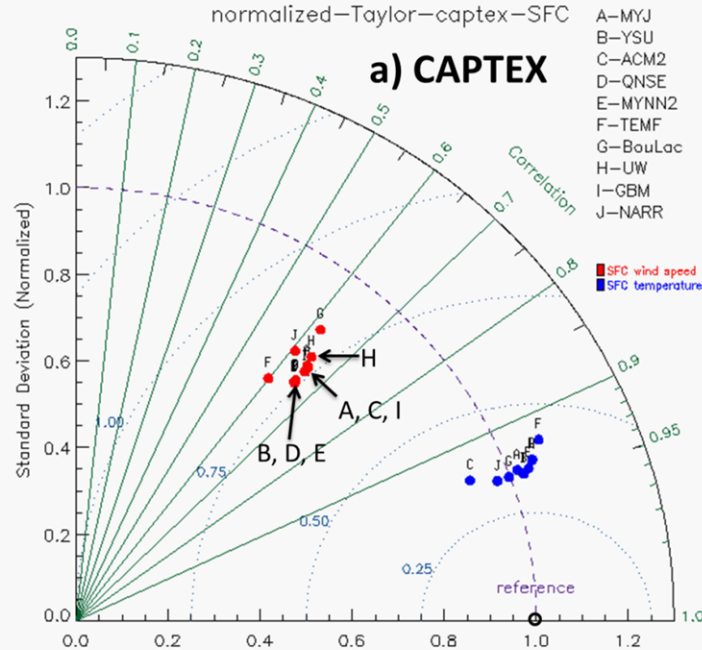
Correlation coefficient (R)

Fractional bias (FB)

Figure of merit in space (FMS)

Kolmogorov-Smirnov parameter (KSP)

# Normalized Taylor Diagrams

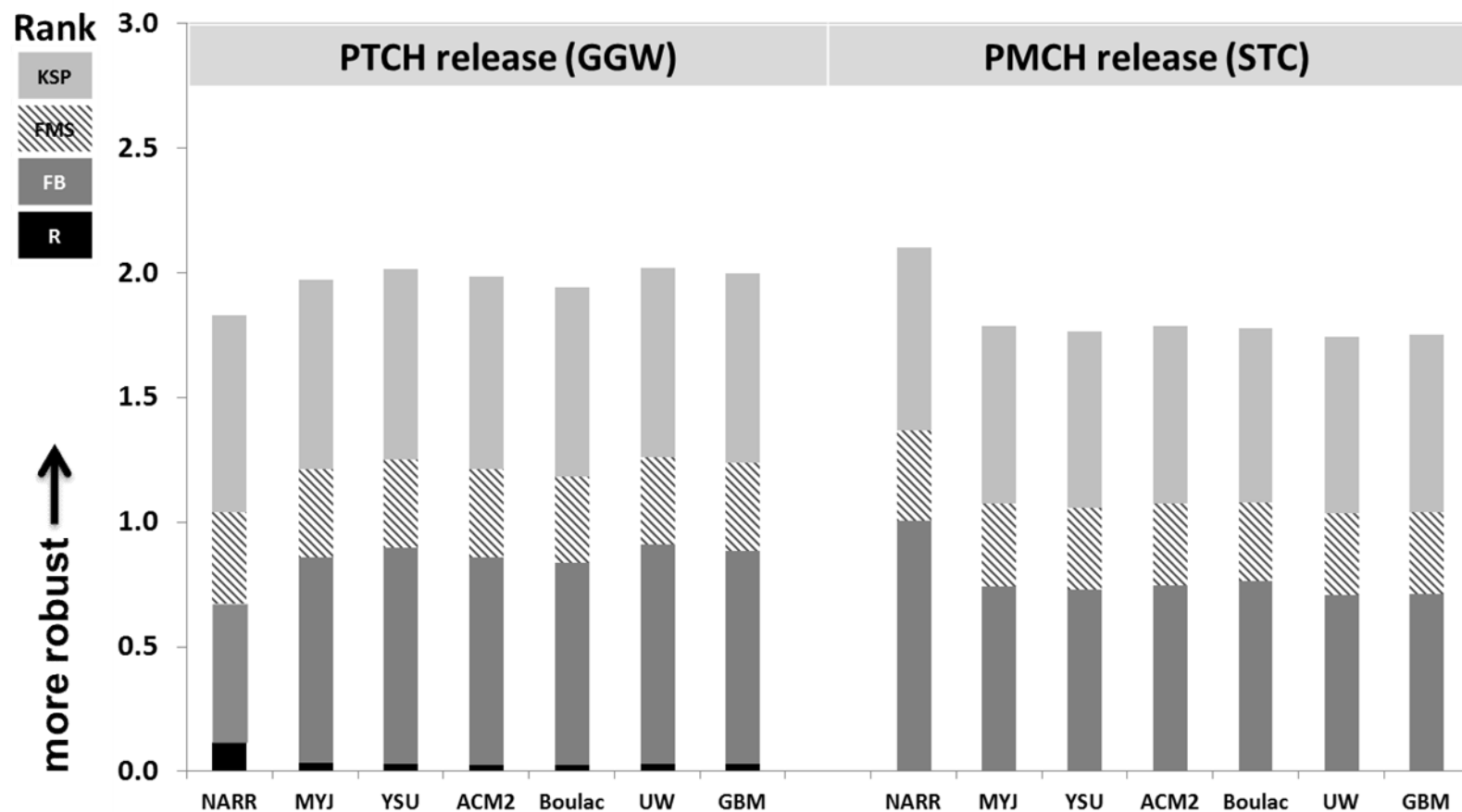


## Dispersion results for CAPTEX

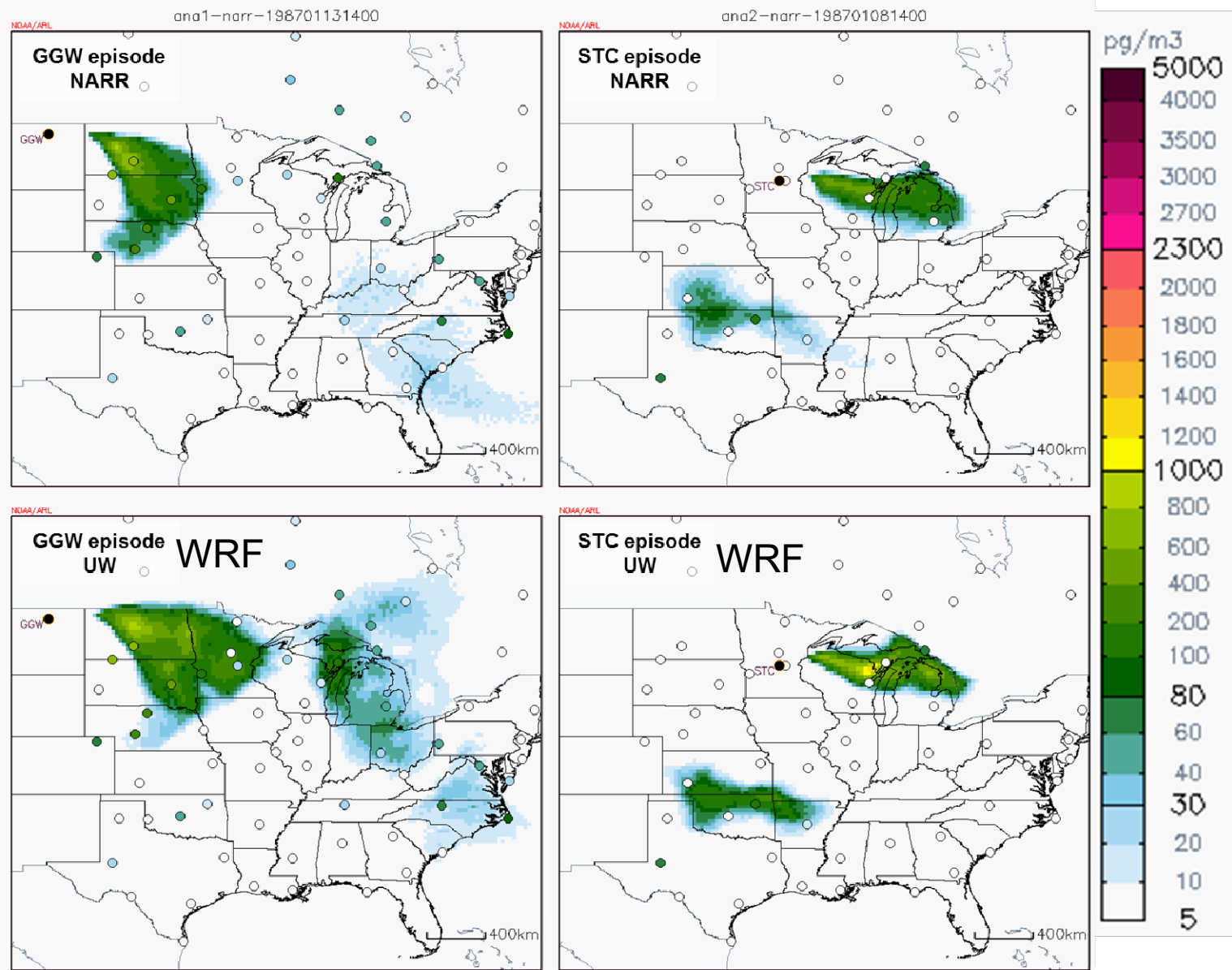
Rank	NARR	MYJ	YSU	ACM2	QNSE	MYNN2	TEMF	BouLac	UW	GBM
R1	2.12	2.82	2.81	2.72	2.78	2.88	2.77	2.73	3.04	3.03
R2	2.79	2.96	2.95	2.97	2.77	2.74	2.29	3.07	2.97	2.96
R3	1.92	1.95	1.95	1.94	2.02	1.94	1.88	1.87	1.97	1.97
R4	2.18	2.08	2.10	2.02	1.95	2.12	2.06	1.95	2.18	2.12
R5	2.57	2.67	2.56	2.49	2.56	2.60	2.50	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
<b>all</b>	<b>2.43</b>	<b>2.52</b>	<b>2.52</b>	<b>2.66</b>	<b>2.39</b>	<b>2.44</b>	<b>2.33</b>	<b>2.58</b>	<b>2.61</b>	<b>2.62</b>

*Note: using all measurements from six episodes*

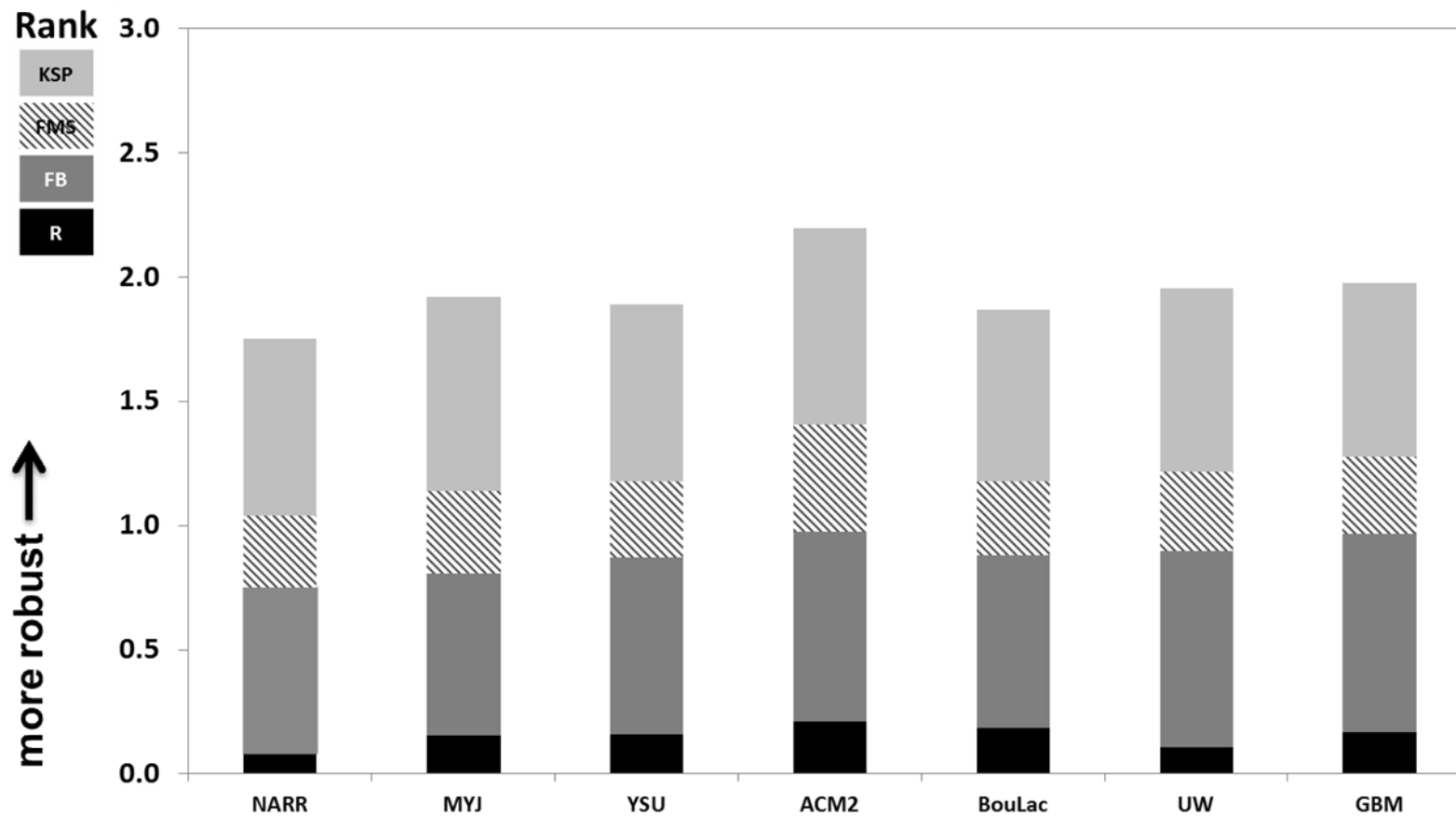
## Dispersion results for ANATEX



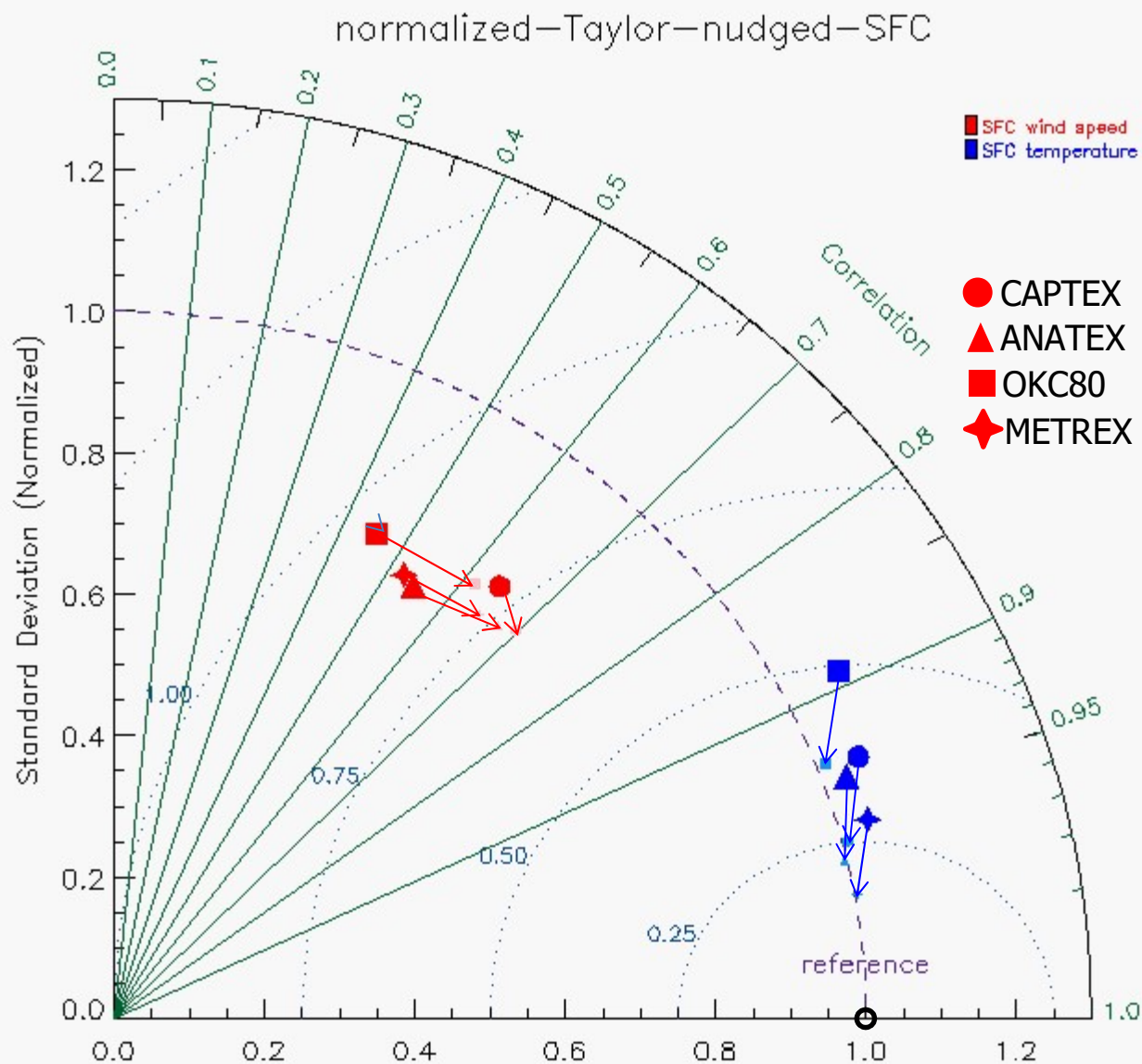
# ANATEX concentration plots



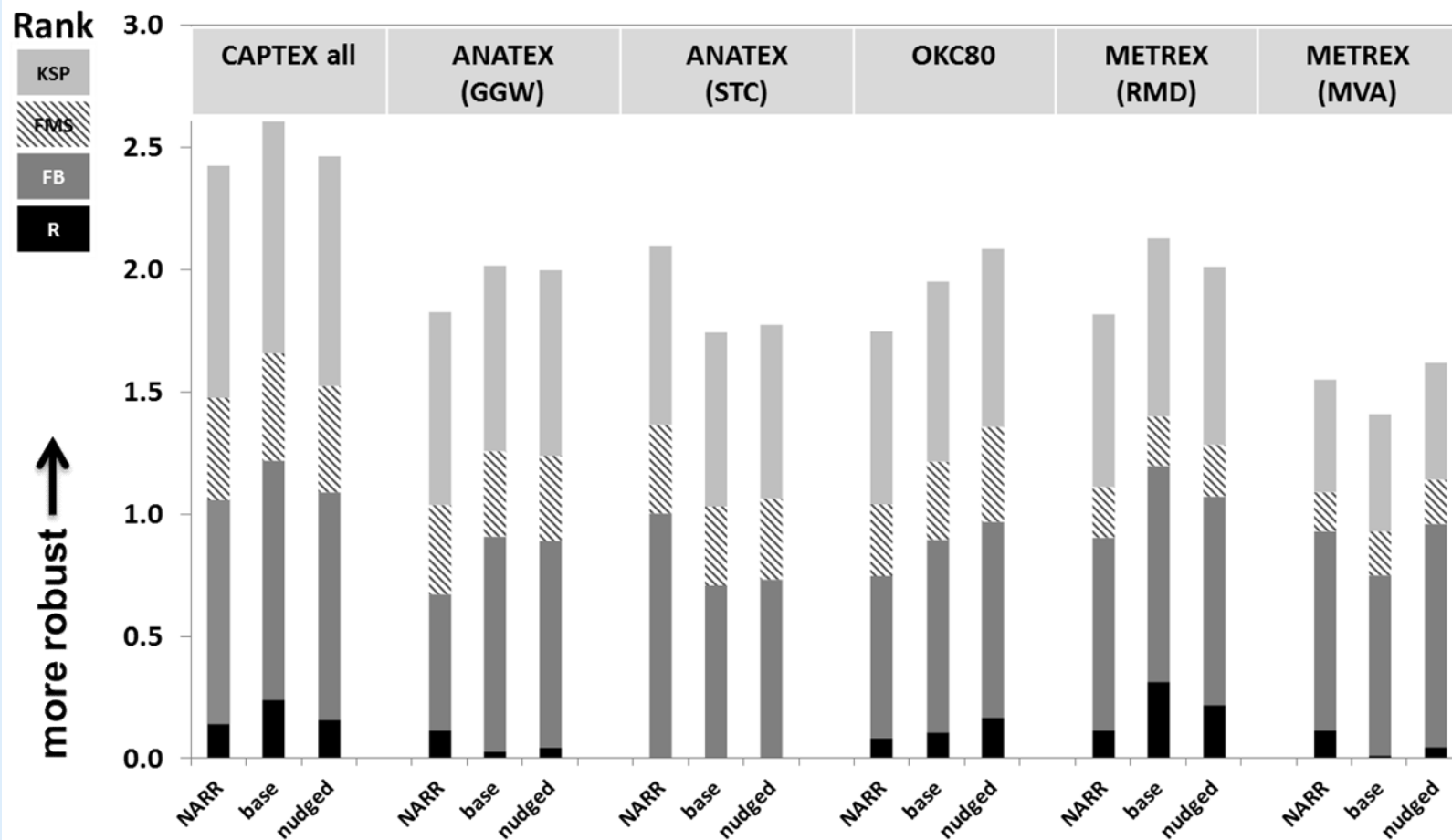
## Dispersion results for OKC80



## Base WRF .vs. nudged WRF



## Dispersion results using NARR, Base WRF, nudged WRF



# Summary

- ❖ Recent HYSPLIT updates include inverse modeling to recover source location, ECMWF converter, converting puffs to 3D particles, supporting cartesian and polar grids within the same run, and checking inputs consistency.
- ❖ A long-term archive of WRF data (27-km resolution) for North America 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.
- ❖ This WRF dataset provides hourly data for HYSPLIT, covering years 1980 – 2016 and including additional variables relevant to atmospheric dispersion.
- ❖ The new dataset will be available online providing additional capabilities for using different meteorological inputs and a variety of HYSPLIT setups for mixing calculations.

## On-going Work

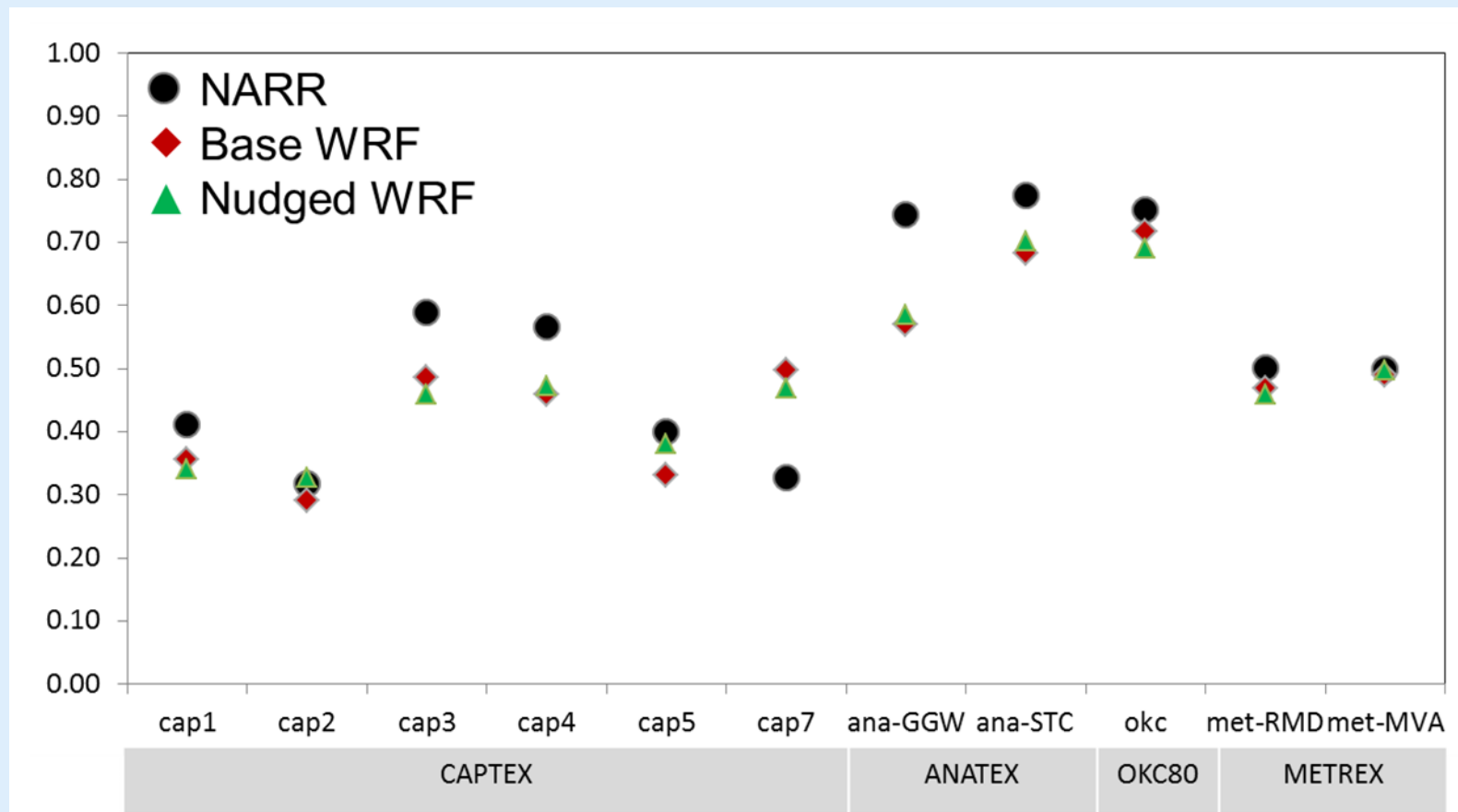
- ❖ Conduct WRF simulations (36-km, 12-km and 4-km resolution) for a 20-day period corresponding to Fukushima incident.
- ❖ Develop a web-based system for registered HYSPLIT users to run WRF simulations for a certain area using the archive WRF dataset as IC/BC.



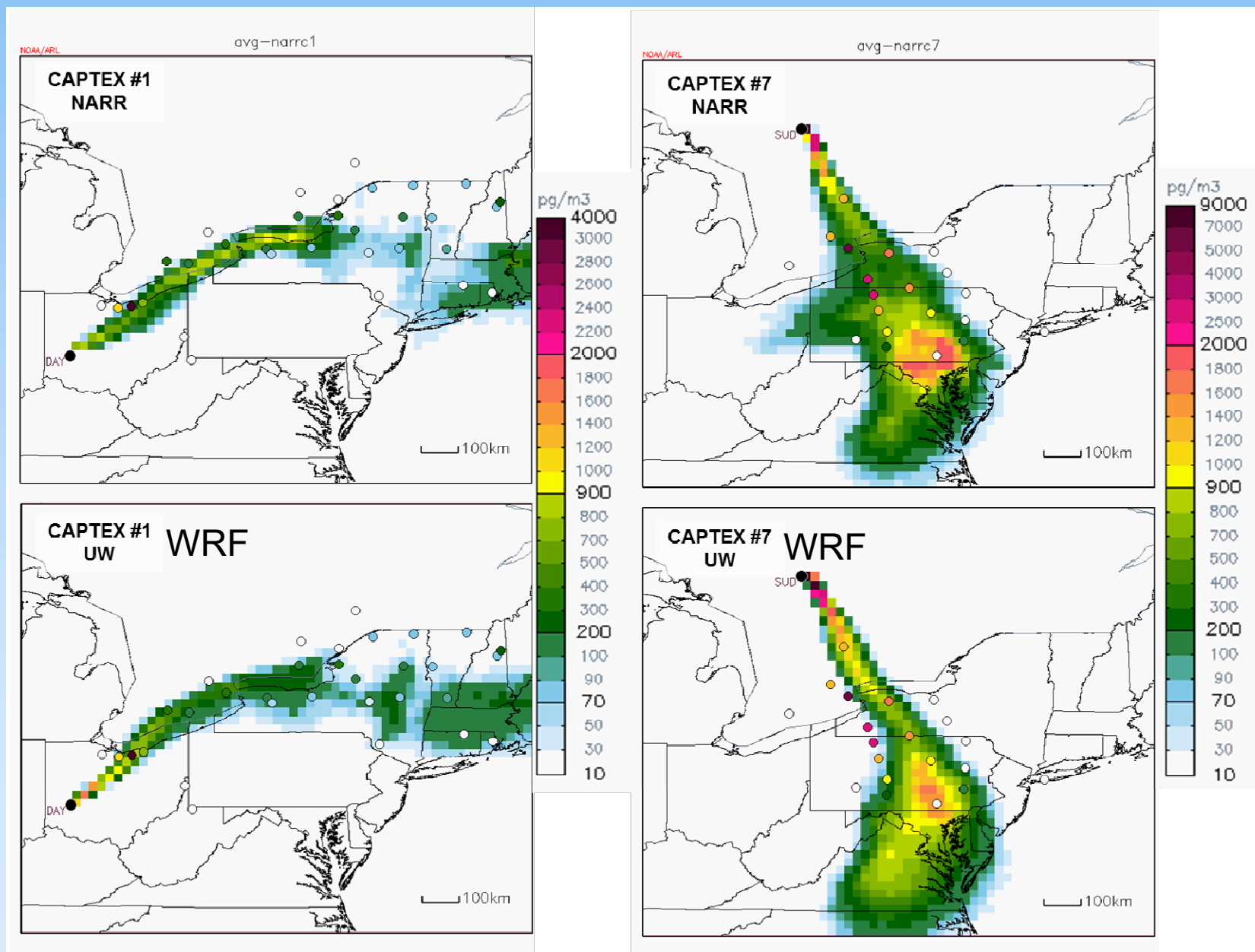
# HYSPLIT configuration

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

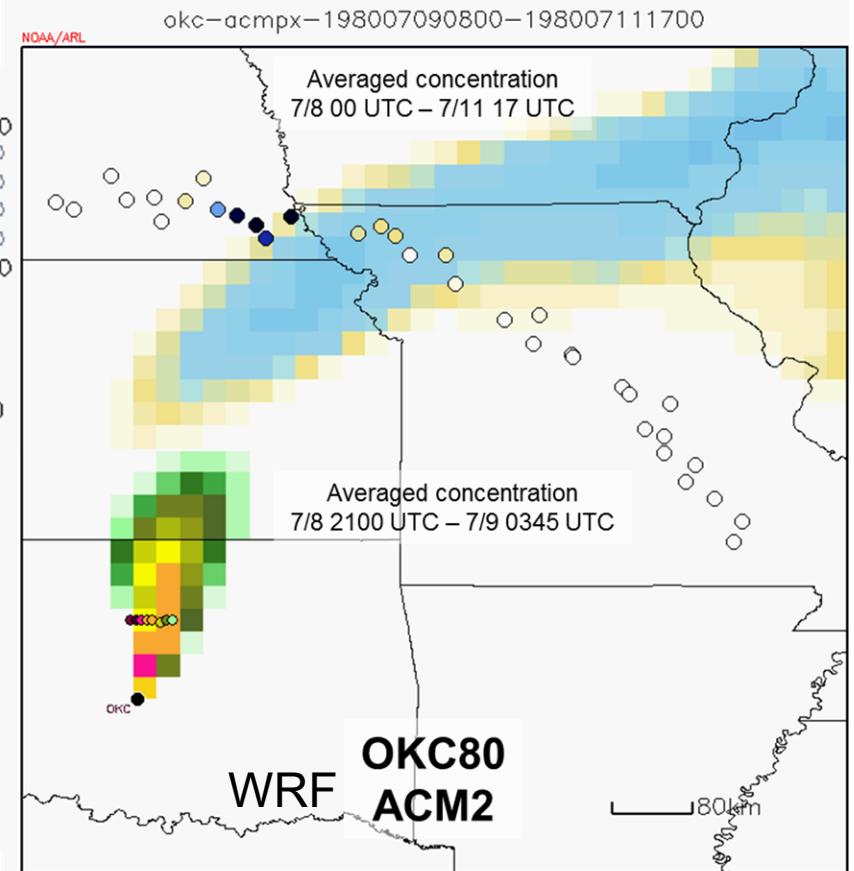
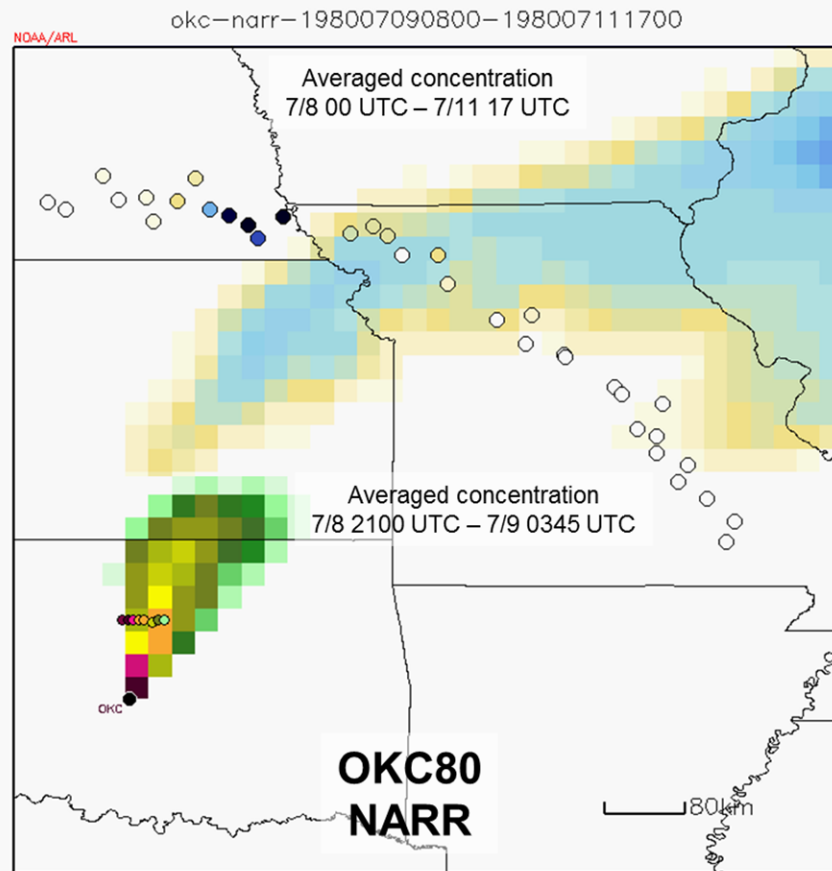
## Normalized RSME



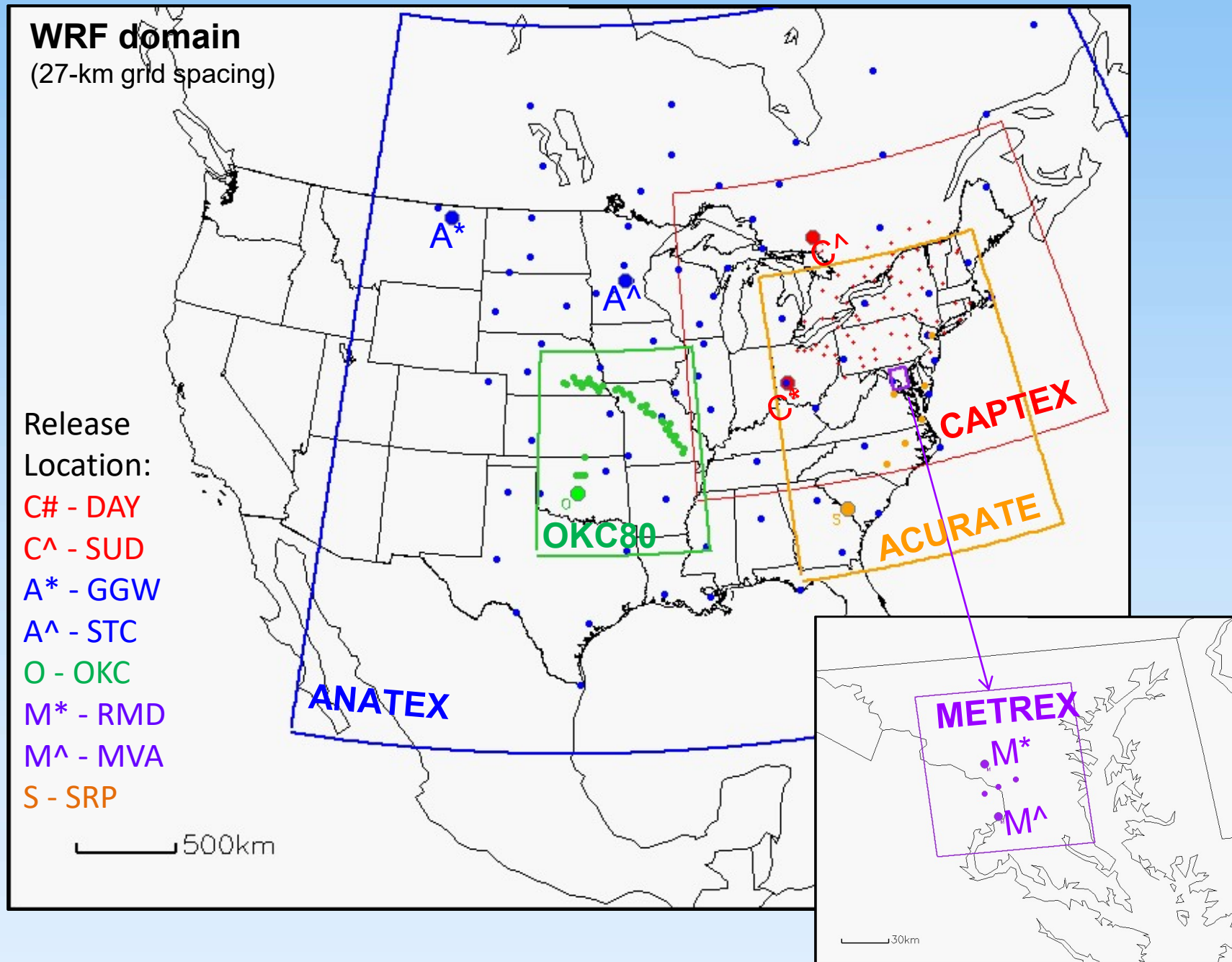
# CAPTEX concentration plots



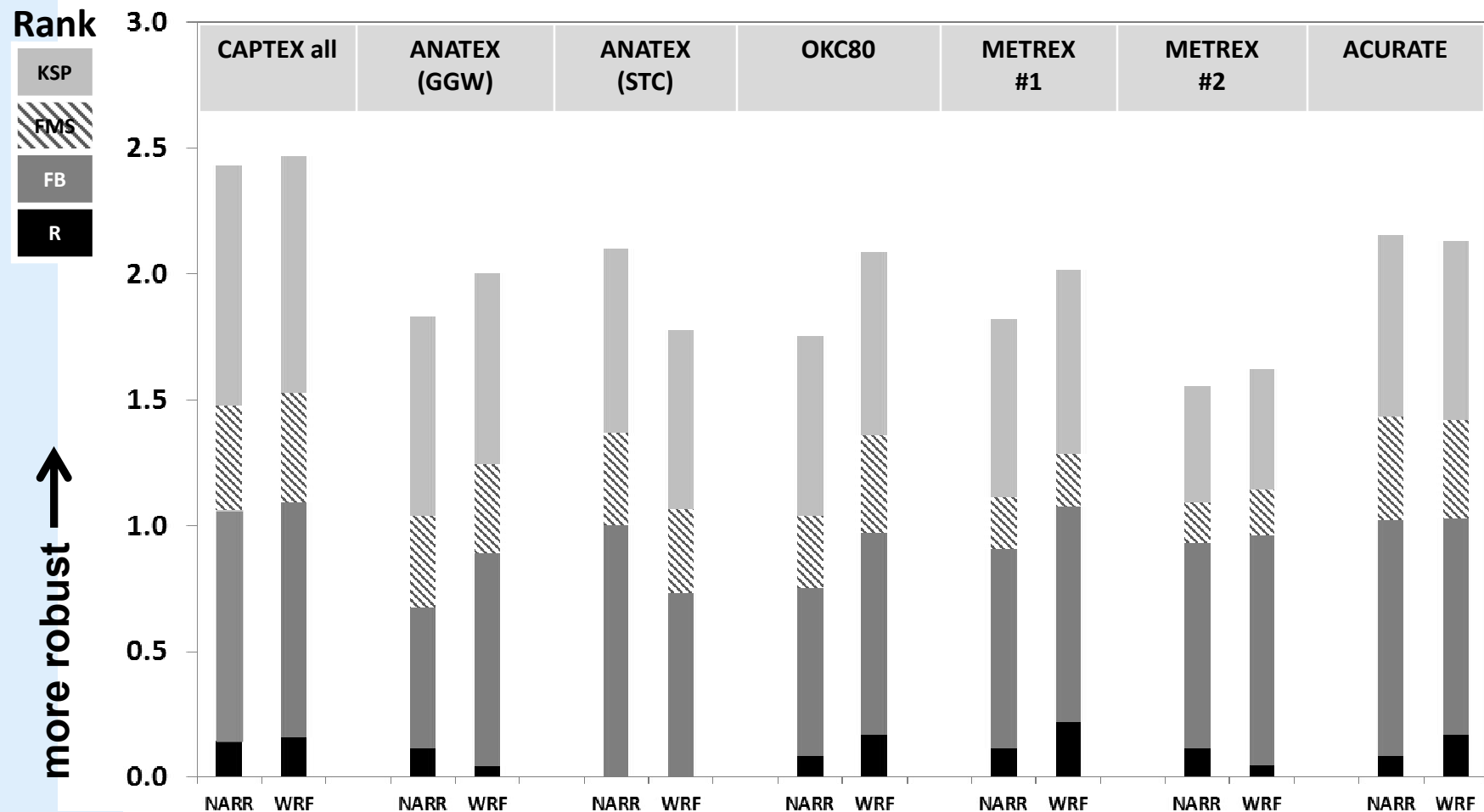
# OKC80 composited plots



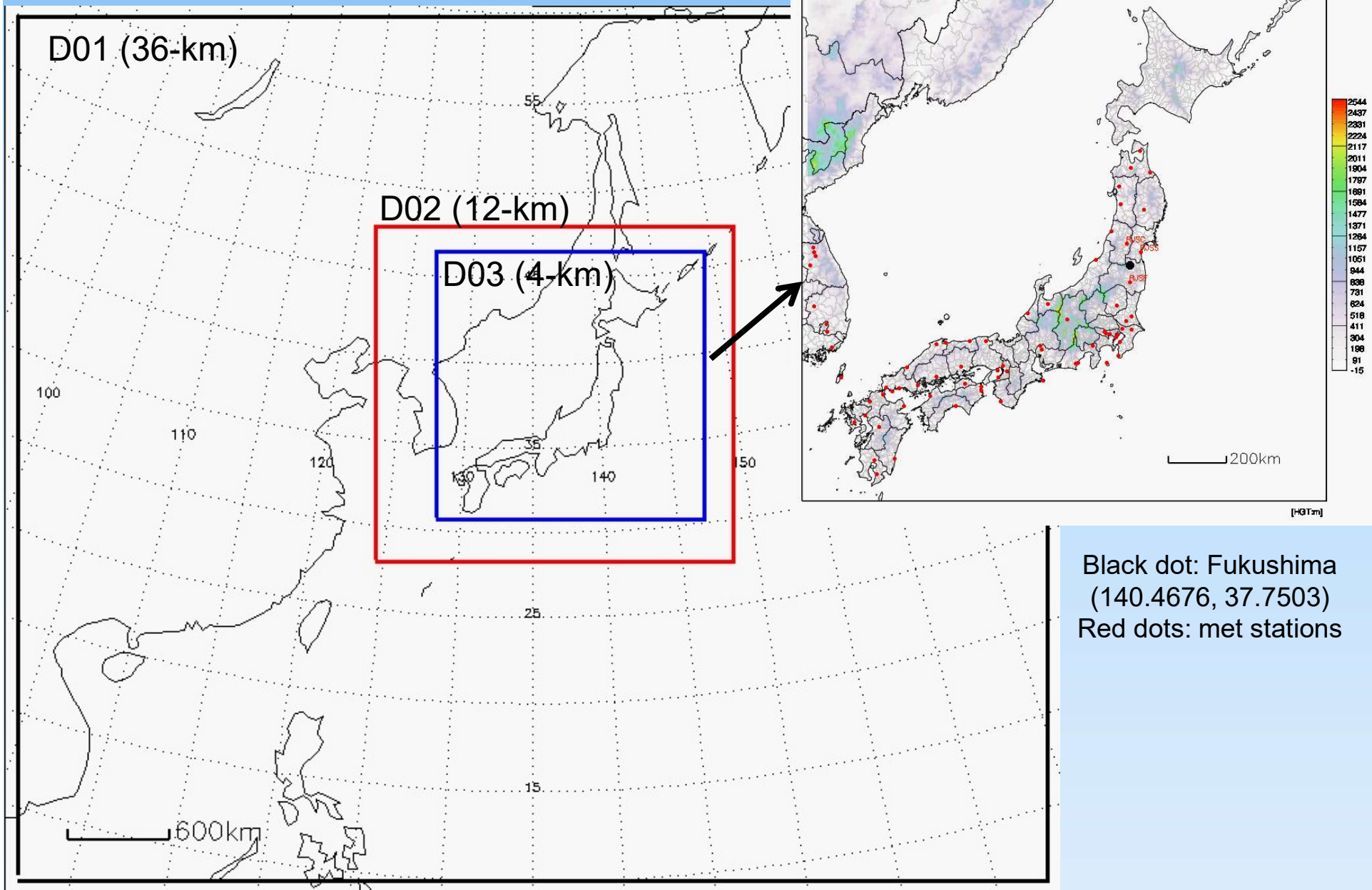
# Modeling domains for WRF and HYSPLIT



## Dispersion results using NARR and WRF (nudged)



## WRF domain for Fukushima



## Domain (4-km) average time series plots

