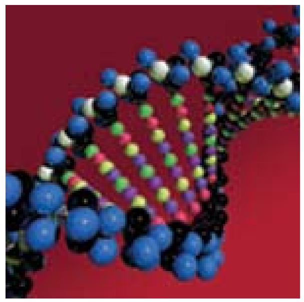
LRT Tracer Model Intercomparison and Evaluation Study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ENVIRON International Corporation

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Evaluate LRT Dispersion Models using Tracer Test Field Experiment Data

- Final Report "Documentation of CALPUFF and Other Long Range Transport Models using Tracer Test Field Experiment Data" (ENVIRON, February 2012)
  - **http://www.epa.gov/ttn/scram/reports/LRT_Tracer_Final_Feb13_2012.pdf**
  - Documents LRT dispersion model simulations and evaluations performed by EPA/USFS during 2008-2011
  - ENVIRON did not do any of the LRT model runs or run evaluation software
    - Just document, QA and display work that EPA performed

Inert Tracer Experiment Evaluation

- LRT transport and dispersion algorithms evaluated using inert tracer field experiments
  - Release known amount of inert tracer
  - Measure at downwind receptor sites
  - Evaluate LRT models ability to predict tracer concentrations
- Examples of past tracer experiment evaluation studies
  - 1986 8-model study
  - 1990 Rocky Mountain Acid Deposition Model Assessment
  - 1998 EPA evaluates CALPUFF using 2 tracer experiments
  - 1998 IWAQM Phase II recommendations
  - 1994 European Tracer Experiment (ETEX)
    - ATMES = real time model evaluation
    - ATMES-II historical model evaluation

EPA 1998 CALPUFF Tracer Test Evaluation

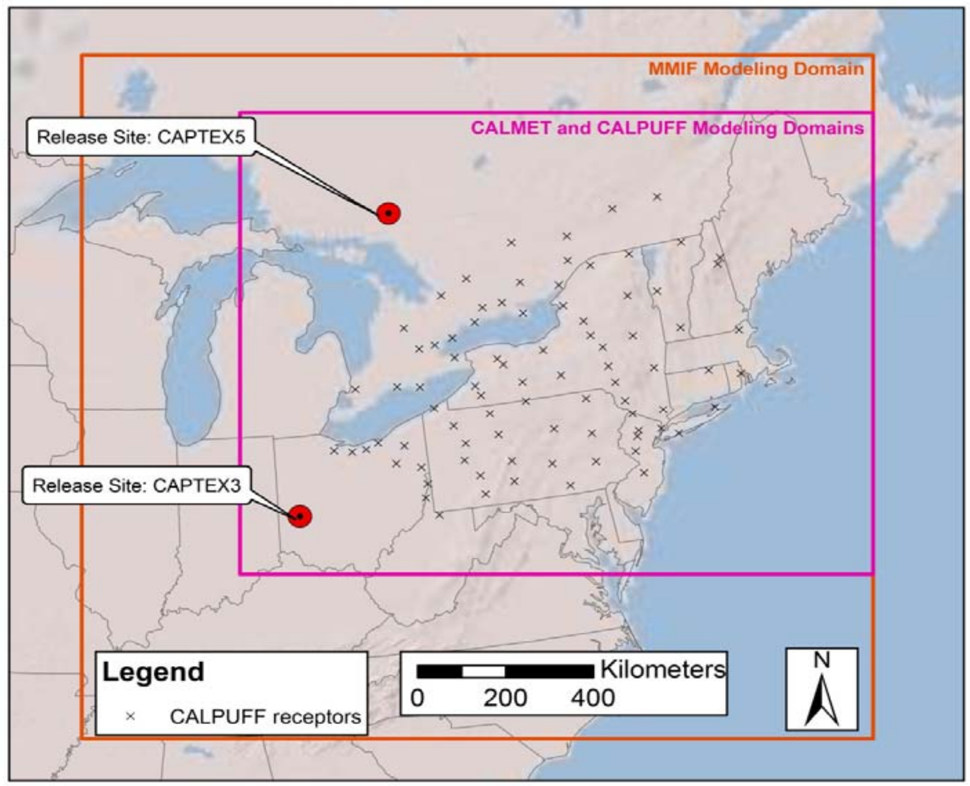
- CALMET using observations only
  - Oklahoma Great Plains 1980 Database (GP80)
  - SRL 1975 Database (SRL75)
- Statistical evaluation using Fitted Gaussian Plume evaluation approach
  - Fit Gaussian plume to observed and predicted concentrations along an arc of receptors at give distance downwind
    - Cmax = maximum centerline concentration
    - Omax = maximum concentration at any receptor
    - σ = plume width; CWIC = Cross Wind Integrated Concentrations
  - Timing statistics
    - Arrival time of tracer to arc
    - Residence time of tracer on arc

Revised LRT Tracer Test Evaluation

- EPA evaluated CALPUFF using five tracer test field study measurements:
  - SRL75
  - GP80
  - 1983 Cross-Appalachia Tracer Experiment (CAPTEX)
  - 1994 European Tracer Experiment (ETEX)
- Compare CALPUFF V5.8 for GP80/SRL76 experiments with 1998 EPA study
- For some experiments compare multiple LRT dispersion models:
  - CALPUFFV5.8/CALMET
  - CALPUFFV5.8/MMIF
  - HYSPLIT
  - FLEXPART
  - SCIPUFF
  - CAMx
  - CALGRID (CAPTEX only)
- This Talk uses CTEX3 as an example

Cross Appalachian Tracer Experiment (CAPTEX)

- 5 tracer releases from either Dayton, OH or Sudbury, Canada were made during Sep-Oct 1983
  - CTEX3 – Oct 2, 1983
  - CTEX5 – Oct 25-26, 1983
- Meteorological Evaluation
  - CTEX3: Evaluate CALMET sensitivity tests
    - Identify best performing CALMET settings
    - Used in EPA-FLM 2009 Clarification Memo
  - CTEX5: Evaluation MM5 and CALMET
- Six LRT Models Evaluated
  - CALPUFF & SCICHEM
  - HYSPLIT & FLEXPART
  - CAMx & CALGRID



CTEX3: CALMET Sensitivity Tests Evaluation

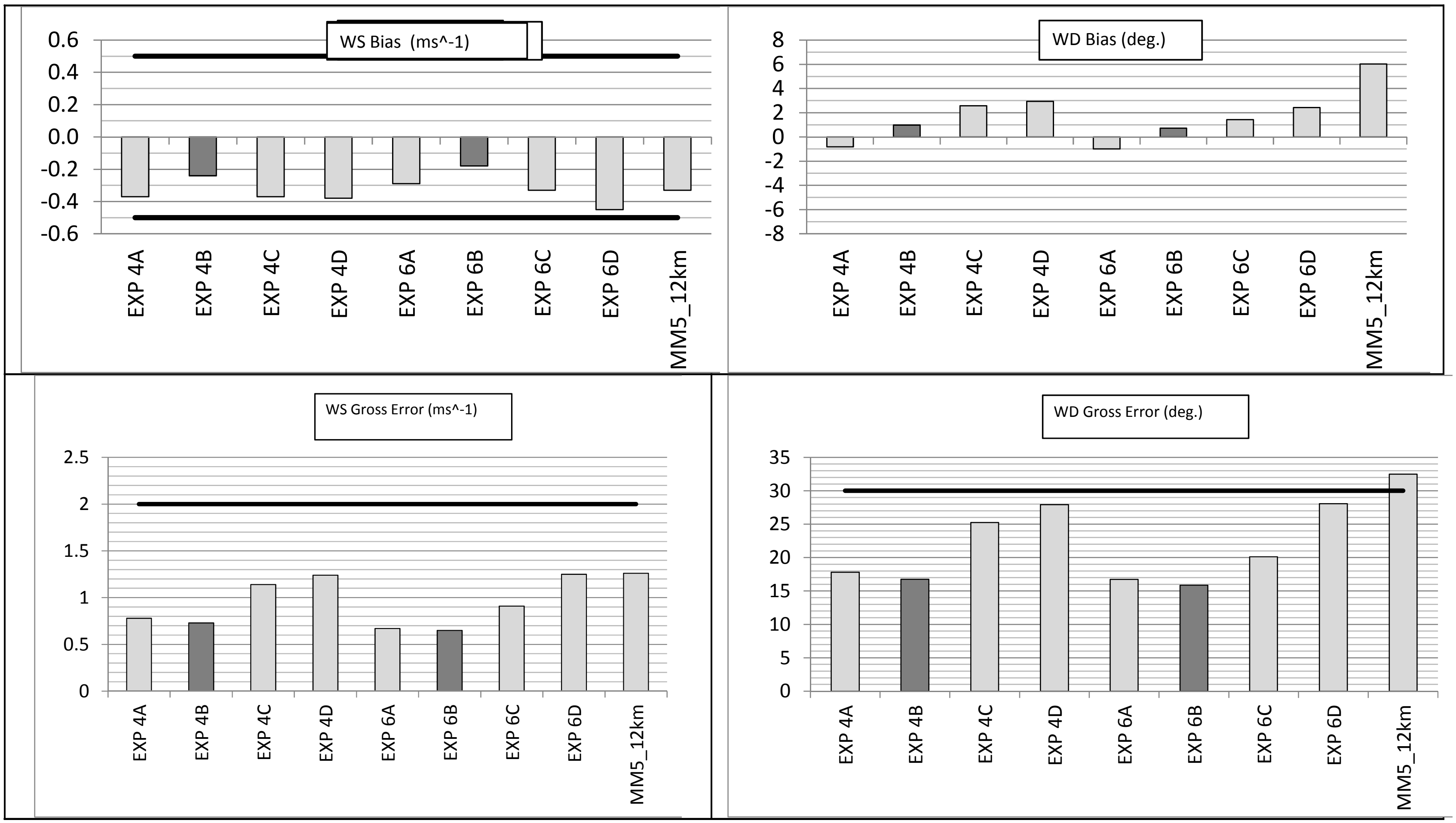
- 31 CALMET Sensitivity Tests :
  - MM5 @ 80, 36 & 12 km
    - How MM5 is used within CALMET
      - First Guess
      - Step 1 Winds
      - None
  - CALMET @ 18, 12 & 4 km
  - RMAX1/RMAX2 (OA)
    - A = 500/1000
    - B = 100/200
    - C = 10/100
    - D = NOOBS
- 3 MMIF Sensitivity Tests:
  - MM5 @ 36, 12 & 4 km
- CALMETSTAT to evaluate wind speed and direction
  - Compare against common benchmarks used to interpret MM5/WRF evaluation

Wind Speed	Root Mean Squared Error (RMSE) Mean Normalized Bias (NMB) Index of Agreement (IOA)	≤ 2.0 m/s ≤ ±0.5 m/s ≥ 0.6
Wind Direction	Mean Normalized Gross Error (MNGE) Mean Normalized Bias (MNB)	≤ 30° ≤ ±10°
Temperature	Mean Normalized Gross Error (MNGE) Mean Normalized Bias (NMB) Index of Agreement (IOA)	≤ 2.0 K ≤ ±0.5 m/s ≥ 0.8
Humidity	Mean Normalized Gross Error (MNGE) Mean Normalized Bias (NMB) Index of Agreement (IOA)	≤ 2.0 g/kg ≤ ±1.0 g/kg ≥ 0.6

WS & WD Bias/Error CALMET w/ 12 km MM5

EXP4 & EXP6 = 12 & 4 km CALMET

A,B,C,D: RMAX1/RMAX2 = 500/1000, 100/200, 10/100, 0/0



Conclusions CTEX3 CALMET Model Performance

- CTEX3 MM5 and CALMET wind model performance:
  - The recommended settings of RMAX1/RMAX2 (100/200, "B" Series) in the EPA 2009 Clarification Memorandum produced best wind model performance.
  - Use of 4 km grid resolution in CALMET tended to produce better wind model performance than 12 or 18 km.
    - Can't say anything about finer grid resolution than 4 km.
  - The CALMET wind model performance was better using the 12 and 36 km MM5 data as input than using the 80 km MM4 data.
- CTEX5 also found RMAX1/RMAX2 = 100/200 best wind performance
- **Note: Not an independent evaluation since WS/WD obs were also used as input to most CALMET tests**

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CTEX3: CALPUFF/CALMET Sens Tests

- CALPUFF evaluation using 25 CALMET sensitivity tests
  - CALPUFF runs for CTEX3 tracer release
  - Evaluate CALPUFF using ATMES-II 12 statistical performance metrics
  - Determine which CALMET configuration results in best CALPUFF performance
- CALPUFF evaluation using 3 MMIF met inputs
- Evaluate using ATMES-II statistical performance metrics:
  - Spatial, Temporal & Global
  - Bias and Error
  - Scatter
  - Correlation
  - Cumulative Distribution

Statistical Metric	Definition	Perfect Score
Spatial Statistics		
Figure of Merit in Space (FMS)	$FMS = \frac{A_M \cap A_P}{A_M \cup A_P} \times 100\%$	100%
Global Statistics		
Normalized Mean Squared Error (NMSE)	$NMSE = \frac{1}{N\,PM} \sum (P_i - M_i)^2$	0%
Pearson's Correlation Coefficient (PCC or R)	$R = \frac{\sum_i (M_i - \overline{M}) \bullet (P_i - \overline{P})}{\left[\sqrt{\sum (M_i - \overline{M})^2}\right]\left[\sqrt{\sum (P_i - \overline{P})^2}\right]}$	1.0
Fractional Bias (FB)	$FB = 2\overline{B} / \left(\overline{P} + \overline{M}\right)$	0%
Kolmogorov-Smirnov (KS) Parameter	$KS = Max\lvert C(M_k) - C(P_k) \rvert$	0%

Two Composite Statistics for Ranking Models

- RANK combines statistics for correlation (R^2), bias (FB), spatial (FMS) and cumulative distribution (KS) with perfect model giving score of 4.0

$$RANK = \left|R^2\right| + \left(1 - \left|FB/2\right|\right) + FMS/100 + \left(1 - KS/100\right) \;\Big|$$

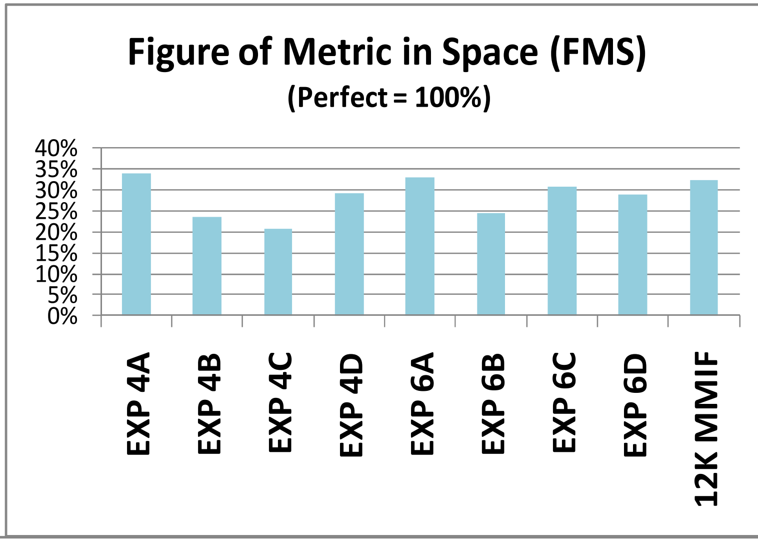
  - RANK statistics needs to be revised, propose replace FB w/ NMSE

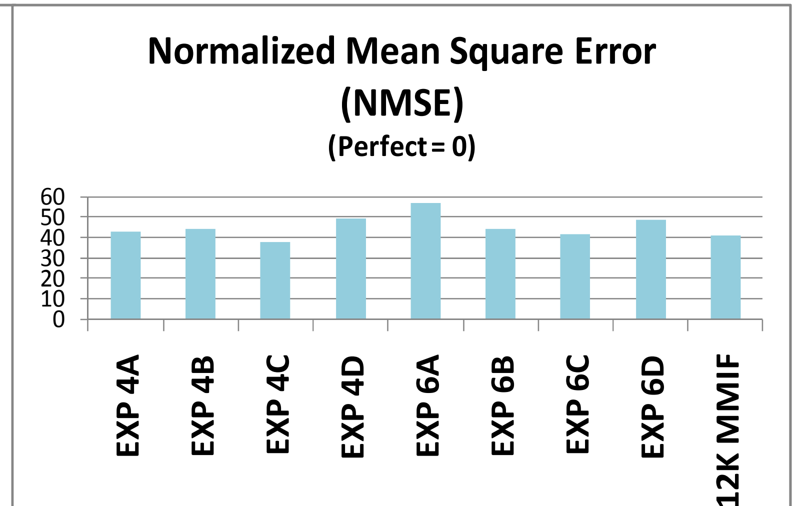
- AVERAGE averages the N model's rankings from 1 to N across the 11 ATMES-II statistics with the best model being model with lowest score closest to 1.0
  - 1.0 = model is highest ranked model across all 11 ATMES-II statistical metrics

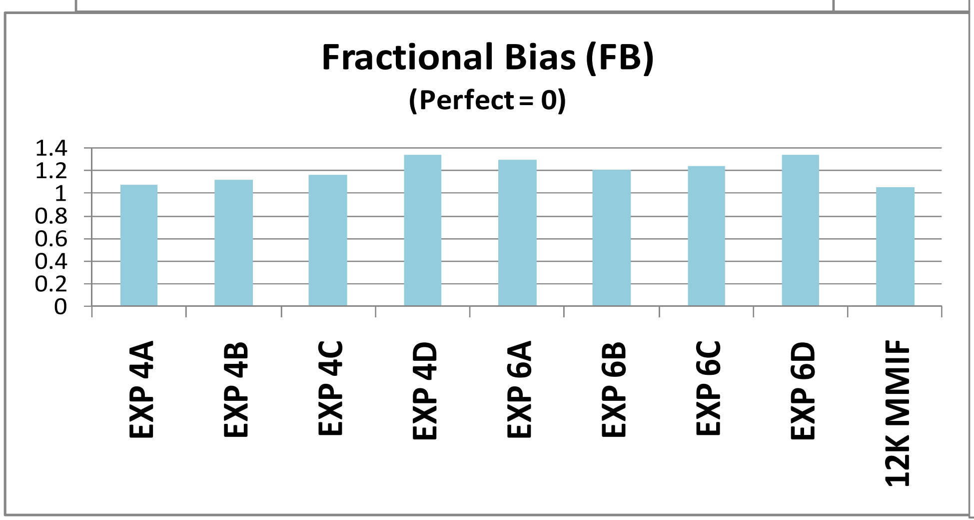
CALPUFF MPE using 12 km MM5

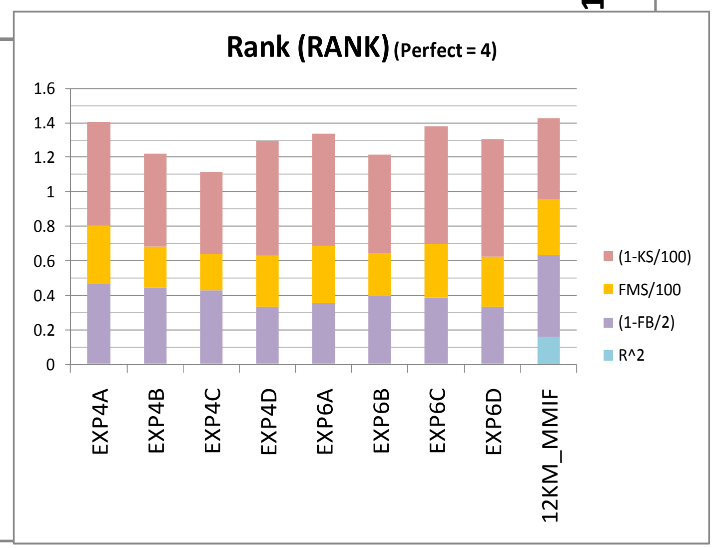
EXP4 & EXP6 = 12 & 4 km CALMET

A,B,C,D: RMAX1/RMAX2 = 500/1000, 100/200, 10/100, 0/0







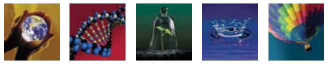


CTEX3 CALPUFF Evaluation Conclusions

- The CALPUFF MMIF sensitivity tests are the best performing configuration for the CTEX3 experiments (worst for CTEX5).
- The CALPUFF/CALMET "B" series (RMAX1/RMAX2 = 100/200) appears to be the worst performing configuration for RMAX1/RMAX2.
  - Contrast to best performing CALMET configuration for WS & WD
- The CALMET/CALPUFF "A" series seems to be the best performing RMAX1/RMAX2 setting (500/1000) followed by the "C" series (10/100) then "D" series (no met observations).
- CALPUFF/CALMET with higher MM5 resolution (36 and 12 km) perform better than using 80 km MM4 data.
- Generally, CALPUFF/CALMET using 4 km resolution performs better than coarser grid resolution.

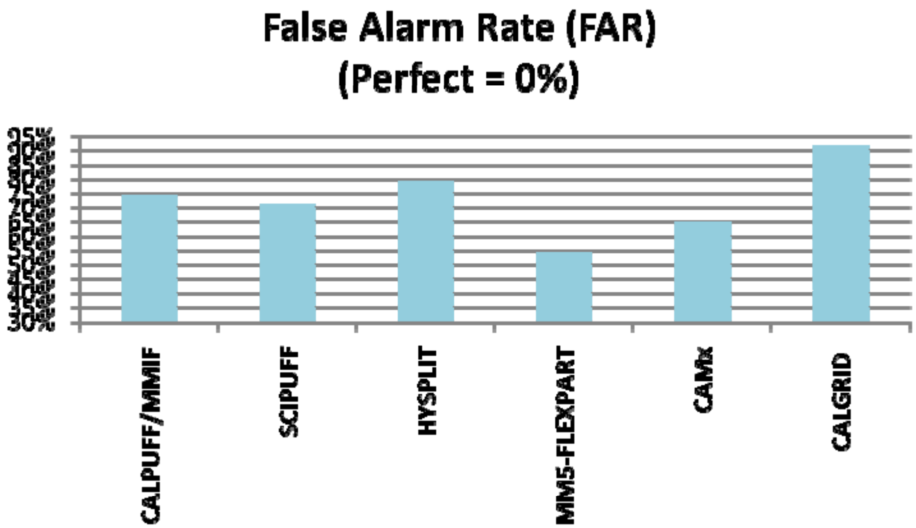
CTEX3 Six LRT Model Evaluation

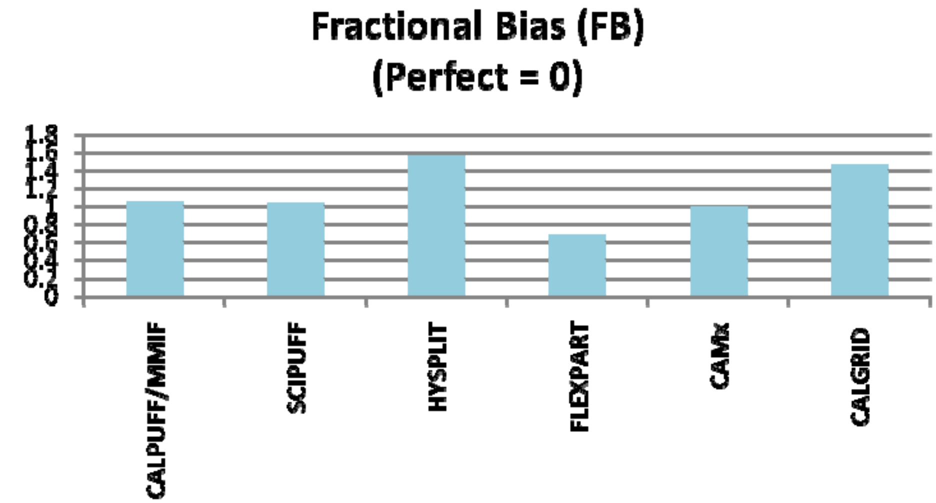
- Use common 36 km MM5 meteorology in all models
- Evaluate using ATMES-II statistical metrics
- 6 LRT dispersion models evaluated:
  - Two Lagrangian Puff Models
    - CALMET (w/ MMIF, best performing for CTEX3)
    - SCIPUFF
  - Two Lagrangian Particle Models
    - FLEXPART
    - HYSPLIT
  - Two Eulerian grid models
    - CAMx
    - CALGRID

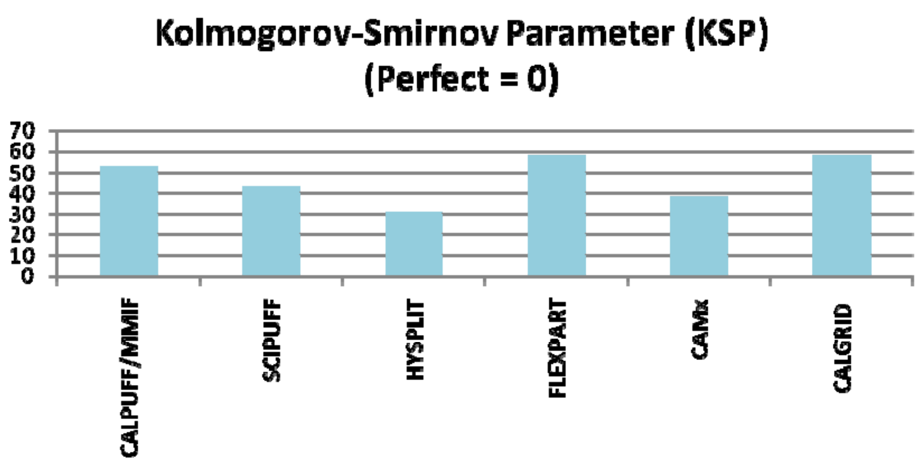


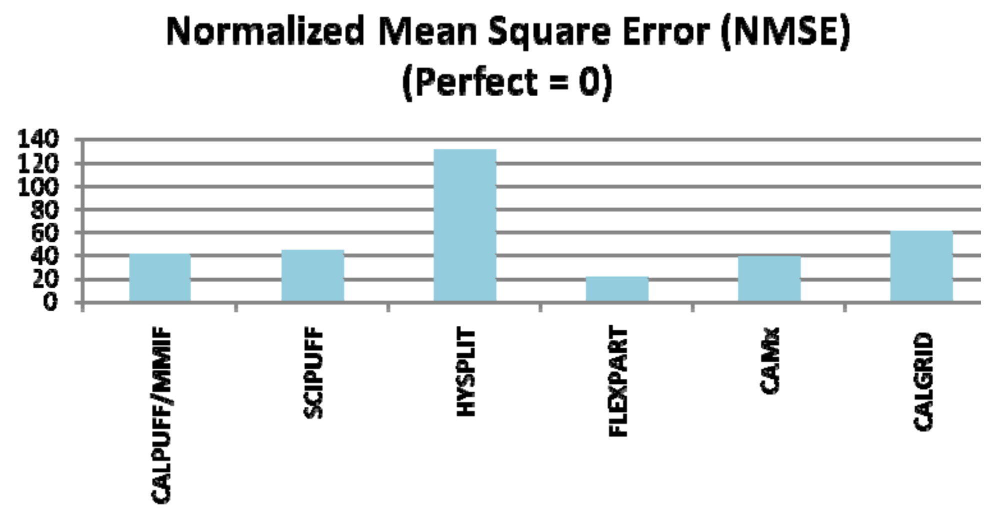
CTEX3 Tracer Test LRT Model Evaluation

(best performing model has lowest value)



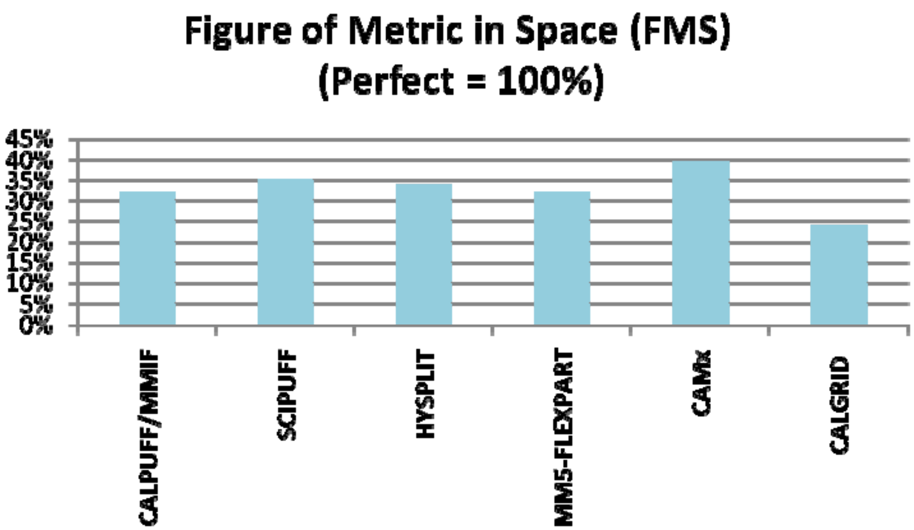


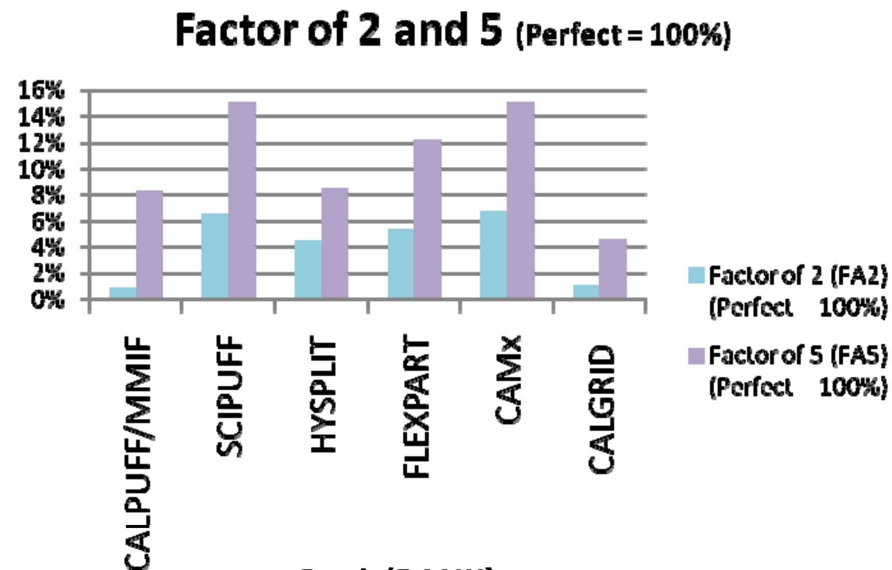


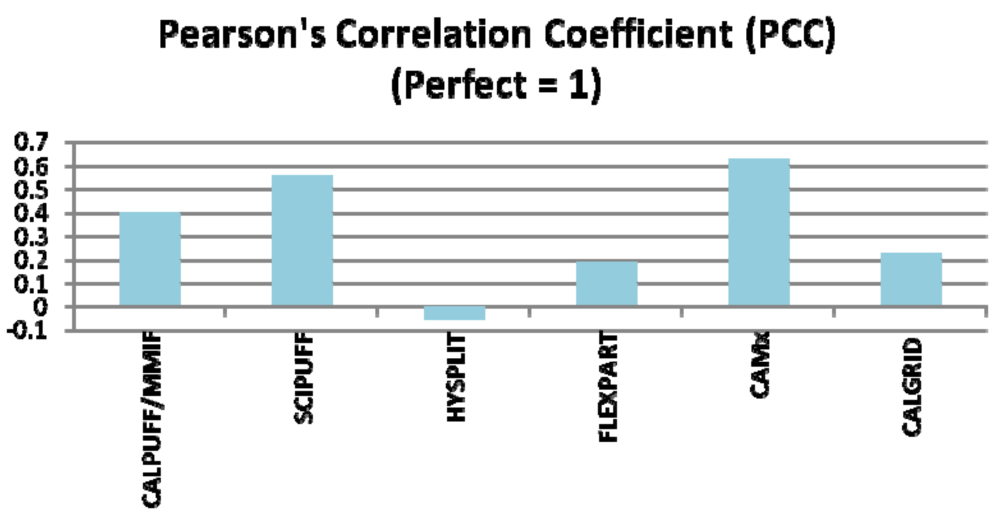


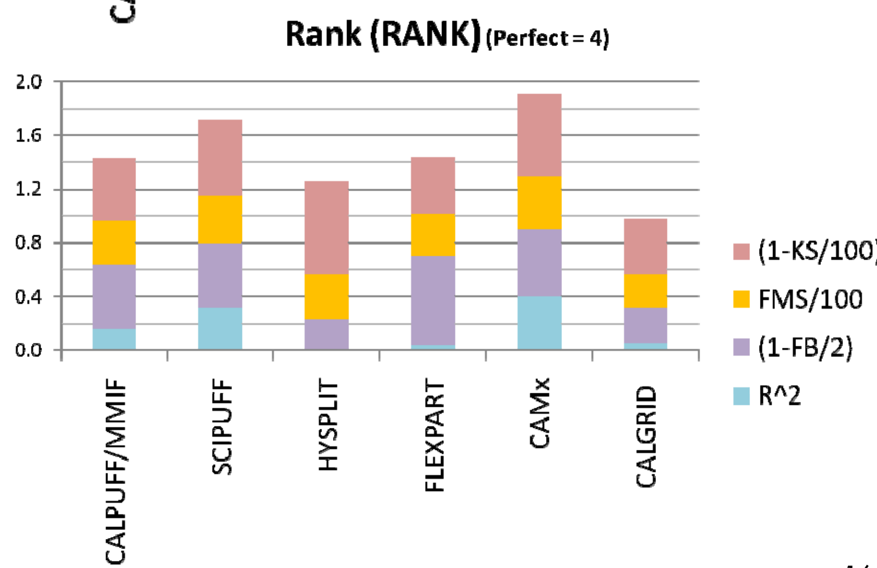
CTEX3 Tracer Test LRT Model Evaluation

(best performing model has highest value)









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Conclusions of LRT Evaluation (1 of 2)

- GP80 Tracer Field Experiment
  - Using different valid CALMET configurations, the maximum CALPUFF concentrations vary by factor of 3
  - Since less option, less variation using MMIF
  - CALPUFF "SLUG" near-field option needed to reproduce "good" model performance on 600 km arc from 1998 EPA study
- SRL75 Tracer Field Experiment
  - Fitted Gaussian plume evaluation approach can be flawed
- CAPTEX Tracer field Experiment
  - RMAX1/RMAX2 = 100/200 (EPA-FLM recommendation) produces best CALMET WS/WD but worst CALPUFF tracer evaluation

Conclusions of LRT Evaluation (2 of 2)

- CAPTEX Tracer Field Experiment (continued)
  - CALPUFF/MMIF performs better than CALPUFF/CALMET for CTEX3 but worst for CTEX5
  - CTEX3: CAMx & SCIPUFF perform best followed by CALPUFF & FLEXPART with HYSPLIT & CALGRID worst
  - CTEX5: CAMx/HYSPLIT performs best followed by SCIPUFF/FLEXPART with CALPUFF/CALGRID worst
- ETEX Tracer Field Experiment
  - CAMx, HYSPLIT & SCIPUFF perform best
  - FLEXPART & CALPUFF perform worst

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Questions?

- Full report available on EPA SCRAM:
  - **http://www.epa.gov/ttn/scram/reports/LRT_Tracer_Final_Feb13_2012.pdf**