Assessment of EPA's ETEX Evaluation Study

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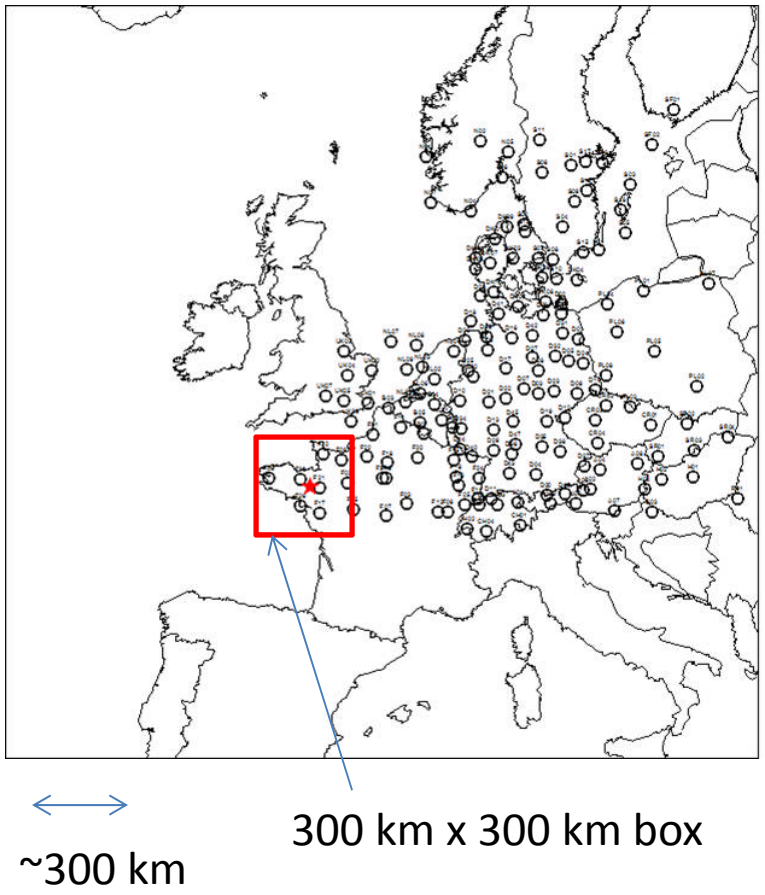
European Tracer Experiment (ETEX)



- Designed for emergency response model evaluation
- PMCH tracer release in Oct and Nov 1994 from northwestern France
- 12-hour release starting on Oct 23, 1994 at 16:00 UTC
- 3-hour average samples at various times over 168 samplers in 17 countries
- Most samplers over 300 km away with tracer measured to over 2000 km from release site

EPA Evaluation Study

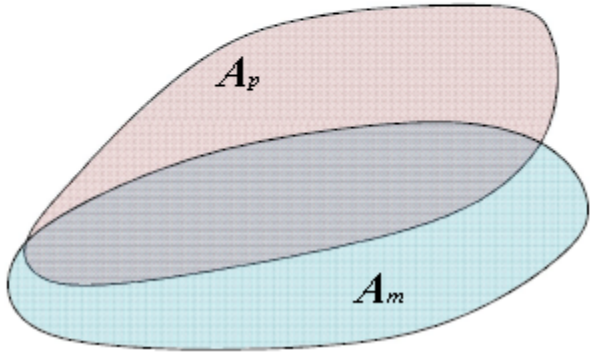
- ETEX-1, Oct 1994
- Models Evaluated
  - CALPUFF
  - SCIPUFF
  - HYSPLIT
  - FLEXPART
  - CAMx
- Papers and presentations on LRT results at numerous conferences and workshops over several years 2008-2012.
- Freedom of Information Act (FOIA) request for data on October 10, 2010. Data received August 2011.
- Used MMIF to drive CALPUFF
- 36-km MM5 data

EPA Statistics

- Figure of Merit in Space (FMS)

$$FMS = \frac{A_M \cap A_P}{A_M \cup A_P}$$

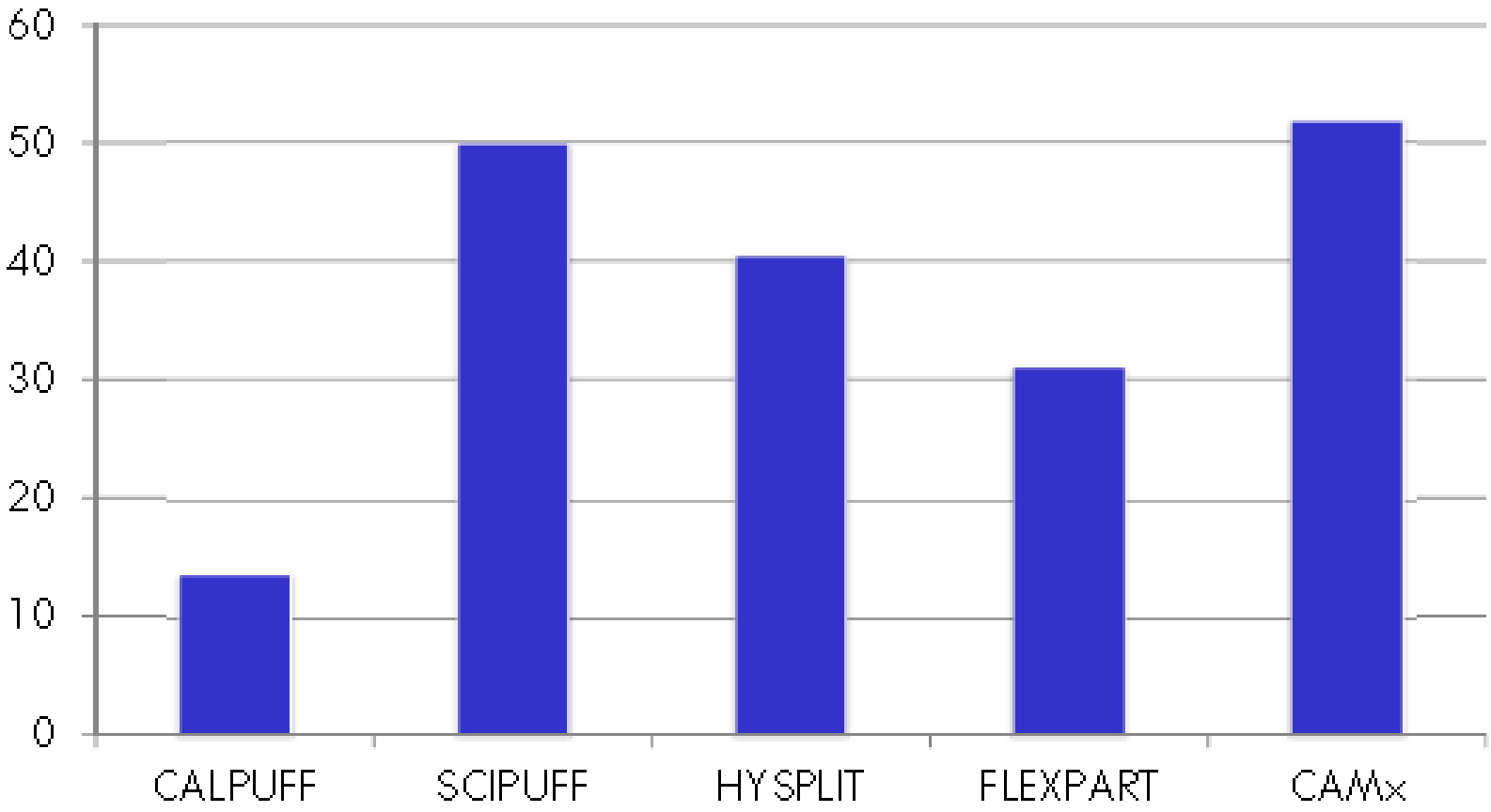
- RANK Statistic
  - Correlation coefficient (R)
  - Fractional Bias
  - Figure of merit in space (FMS)
  - Kolmogorov-Smirnov (KS) parameter



$$RANK = |R| + (1 - |FB/2|) + FMS/100 + (1 - KSP/100)$$

- Measures used emphasis on time-paired weighted statistics

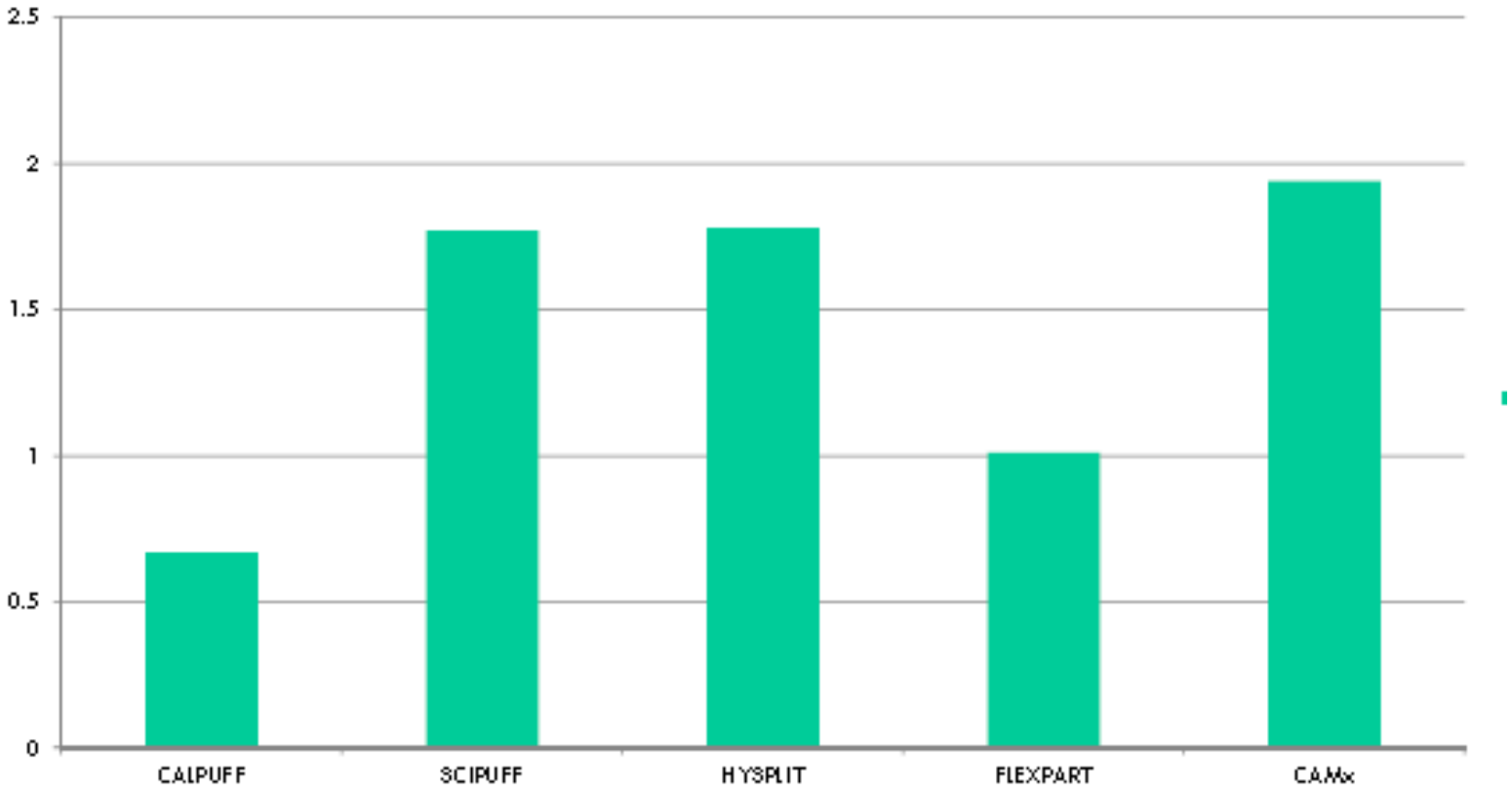
EPA/ENVIRON Results - FMS



ENVIRON Conclusions: CAMx is the best, CALPUFF is the worst, other models between

Source: ENVIRON-EPA (2011)

EPA/ENVIRON Results - RANK



Source: ENVIRON-EPA (2011)

Notes on EPA/ENVIRON Approach

Variable number of configurations tested for each model

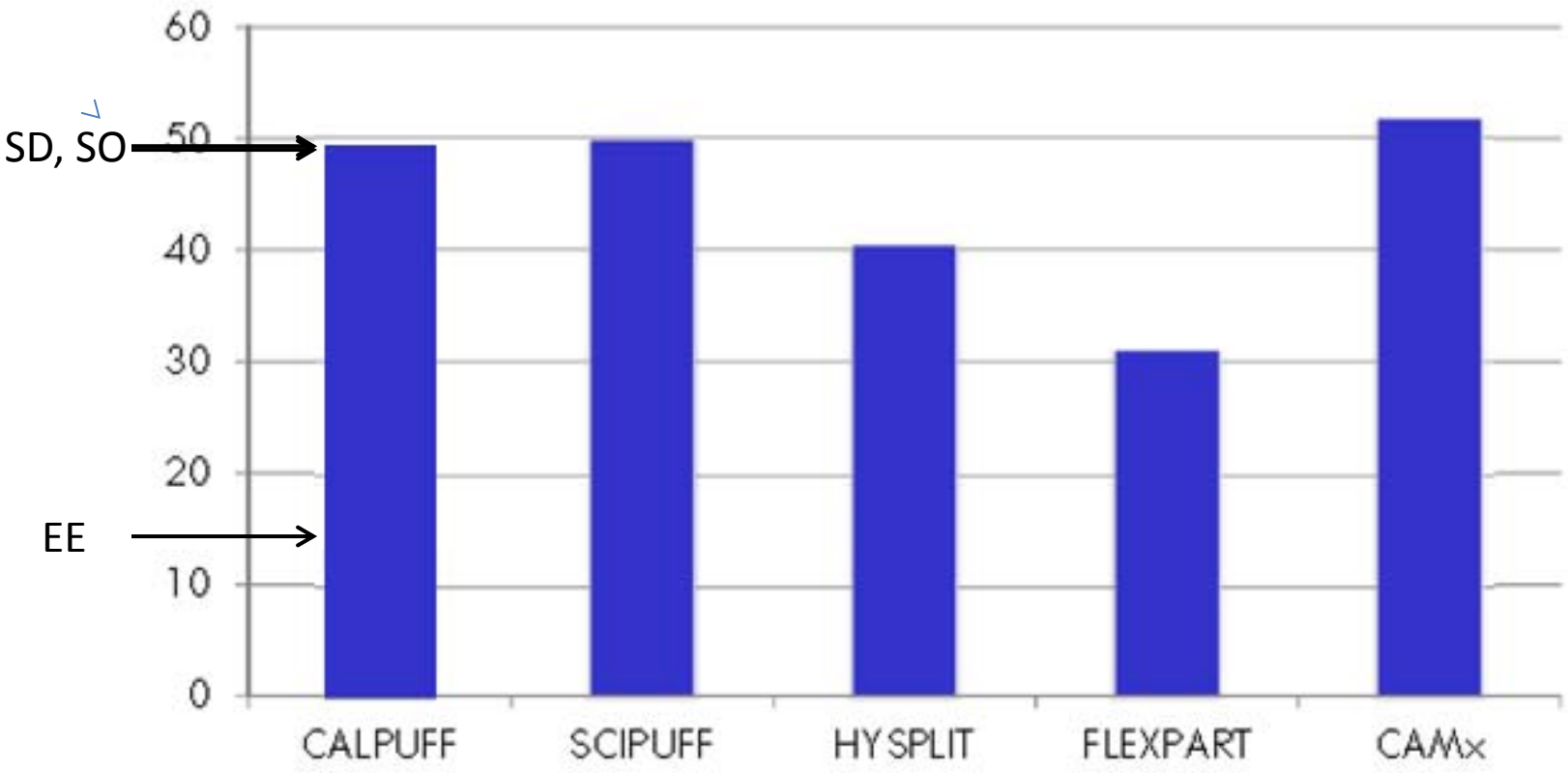
	CAMx	HYSPLIT	SCIPUFF	FLEXPART	CALPUFF
Min# Runs	20	9	1	1	6
RANK	1.9	1.8	1.8	1.0	0.7
Highest	1.9	2.1	-	-	-

CAMx RANKs

- No Pig: 1.5 -1.9 (highest rank selected)
- Pig: 1.5 -1.6
- Pig Var: 1.5 -1.8

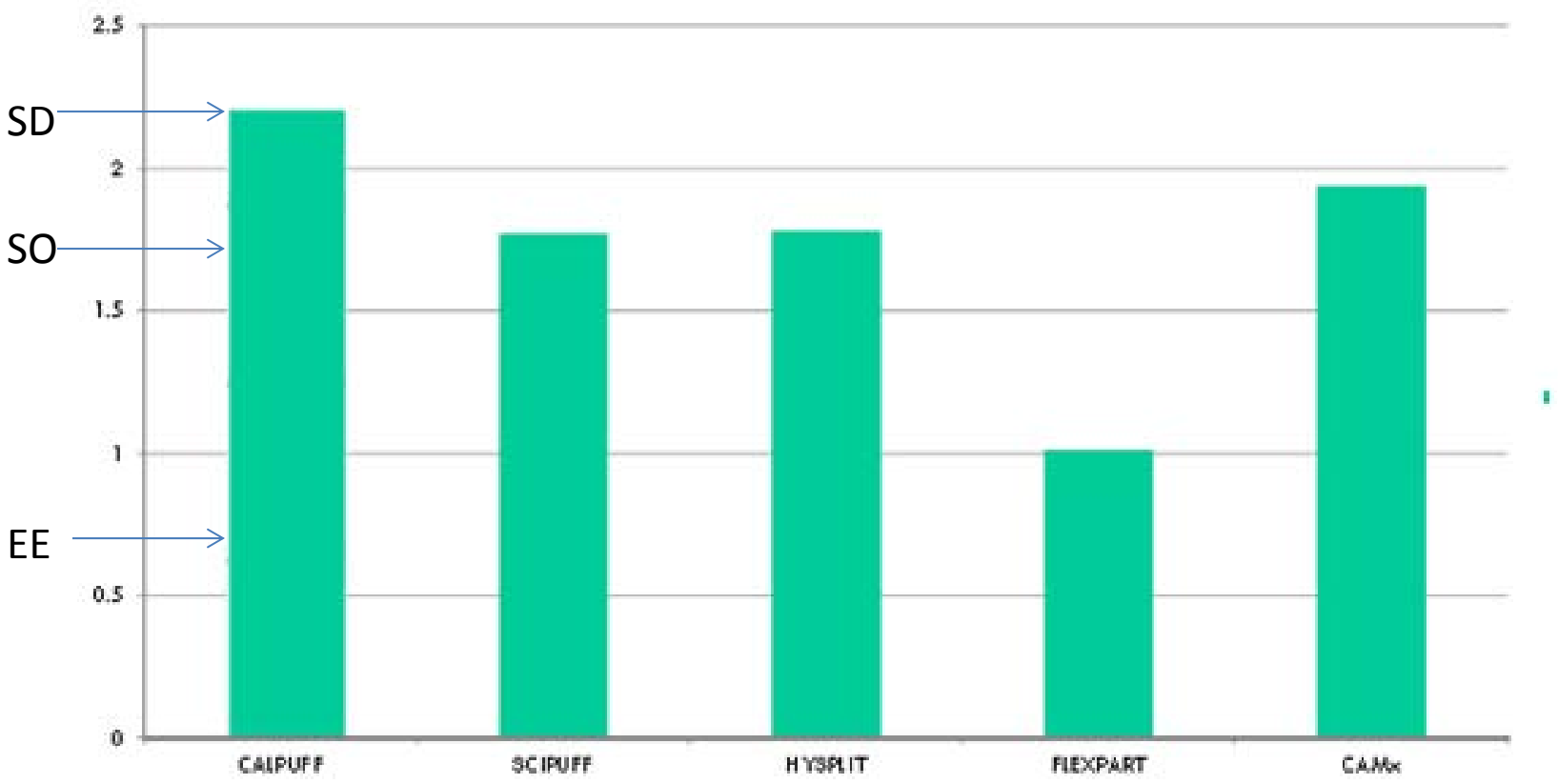
HYSPLIT: 1.0 – 2.1 (highest rank not selected)

CALPUFF Sensitivity Results - FMS



CALPUFF sensitivity tests:
Source dilution (SD), Split optimized (SO), EPA-ENVIRON (EE)

CALPUFF Sensitivity Results - RANK



CALPUFF sensitivity tests:
Source dilution (SD), Split optimized (SO), EPA-ENVIRON (EE)

Factors in CALPUFF Model Performance

- Divergent Flow – ETEX-1 is highly sensitive to proper puff splitting
  - Small changes in trajectory results in puffs moving off to left in branching flow or sheared along NW-SE axis
  - Initial trajectory and early horizontal splits are important
  - Performance measures selected are highly dependent time-space paired puff overlap
  - Problem accentuated by single puff/hour release
- Meteorology
  - MMIF vs. CALMET
  - Resolution of MM5 data is coarse (36-km)
  - Winds at release site are poorly characterized
- Errors in model setup or poor selected of puff parameters

CALPUFF Sensitivity Runs

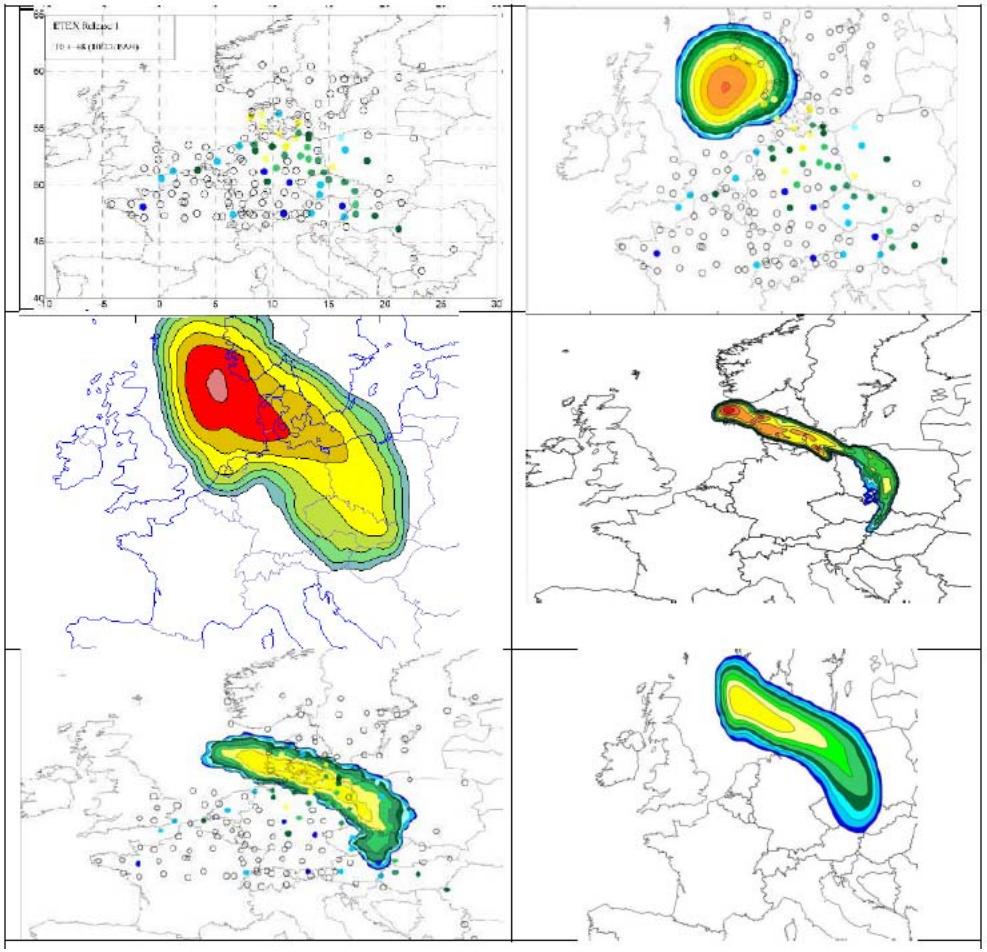
- EPA-ENVIRON Run (Base case)
- Sensitivity Run #1 – CALMET instead of MMIF, 36 km MM5 data, Errors corrected, Gaussian distribution
- Sensitivity Run #2 – Same as #1 except with enhanced puff splitting in near-field
- Sensitivity Run #3 – CALMET, 12 km MM5
- Sensitivity Run #4 – Same as #3 except with enhanced puff splitting in near-field

EPA-ENVIRON Simulation (+48 Hours)

Observations

SCIPUFF

HYSPLIT



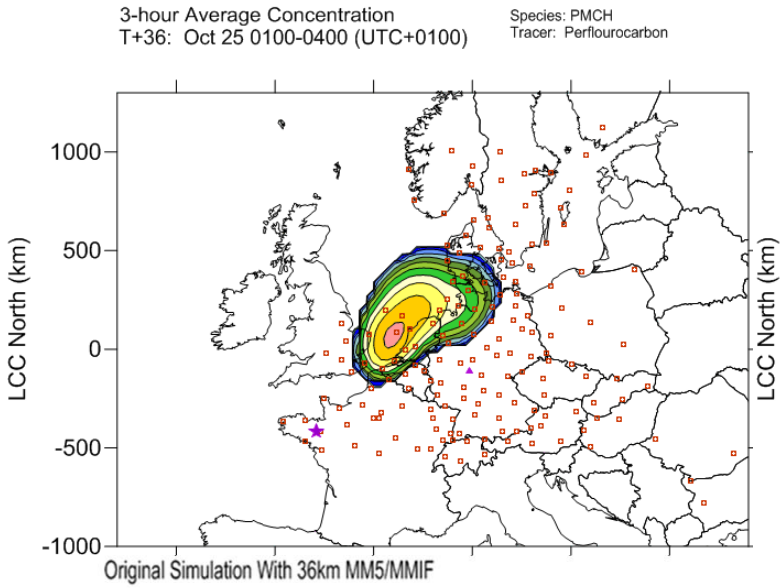
CALPUFF
(EPA-ENVIRON)

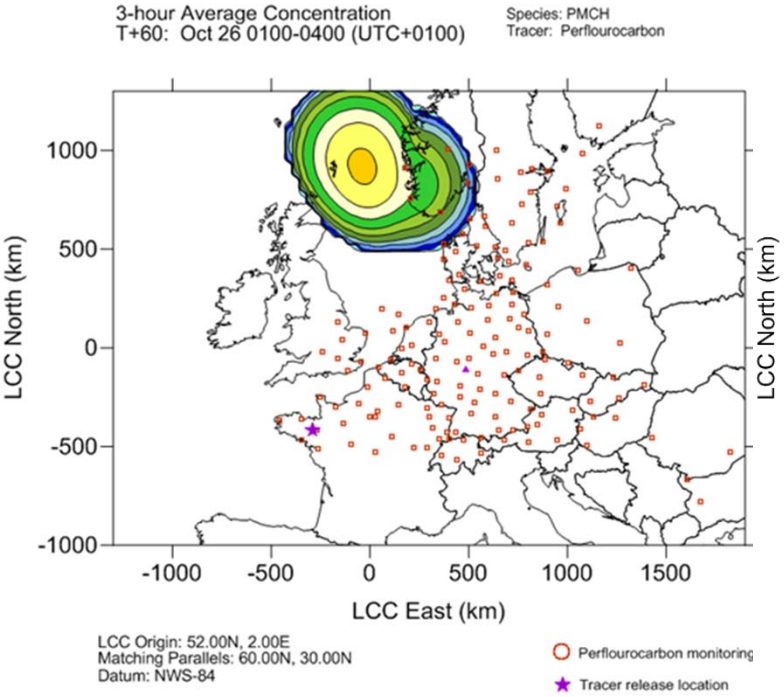
FLEXPART

CAMx

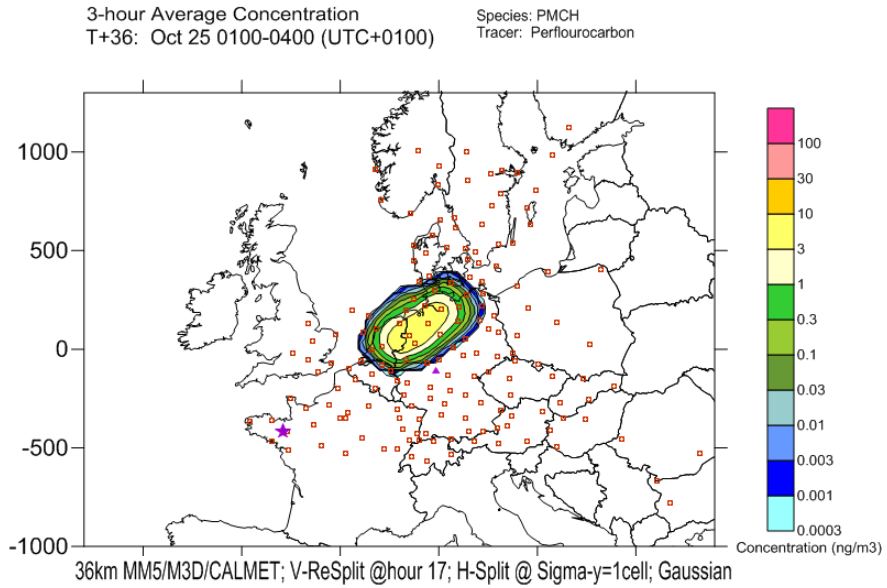
Source: ENVIRON-EPA (2011)

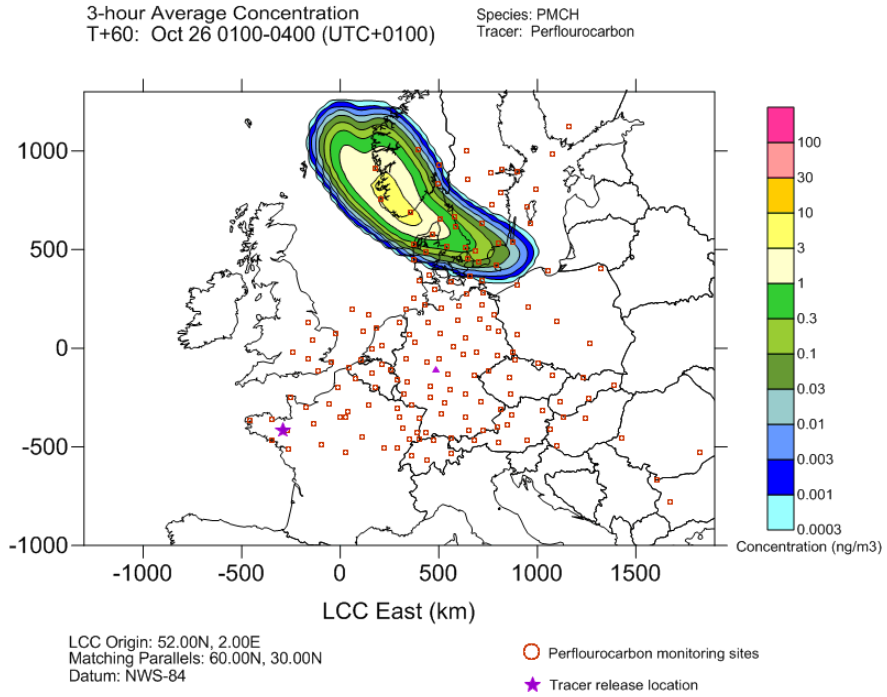
EPA-ENVIRON Run
36-km MM5/MMIF (Gaussian)



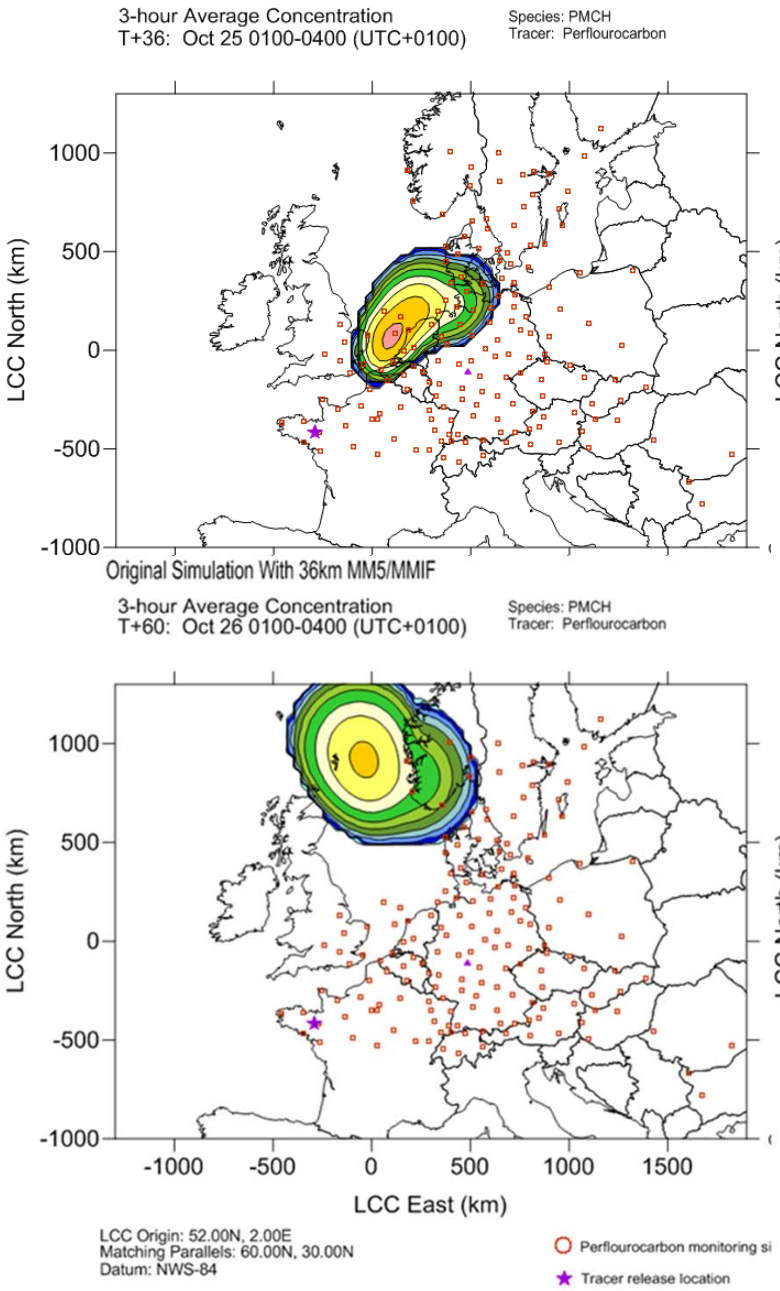


Sensitivity Run #1 (errors fixed)
36-km MM5/M3D/CALMET (Gaussian)

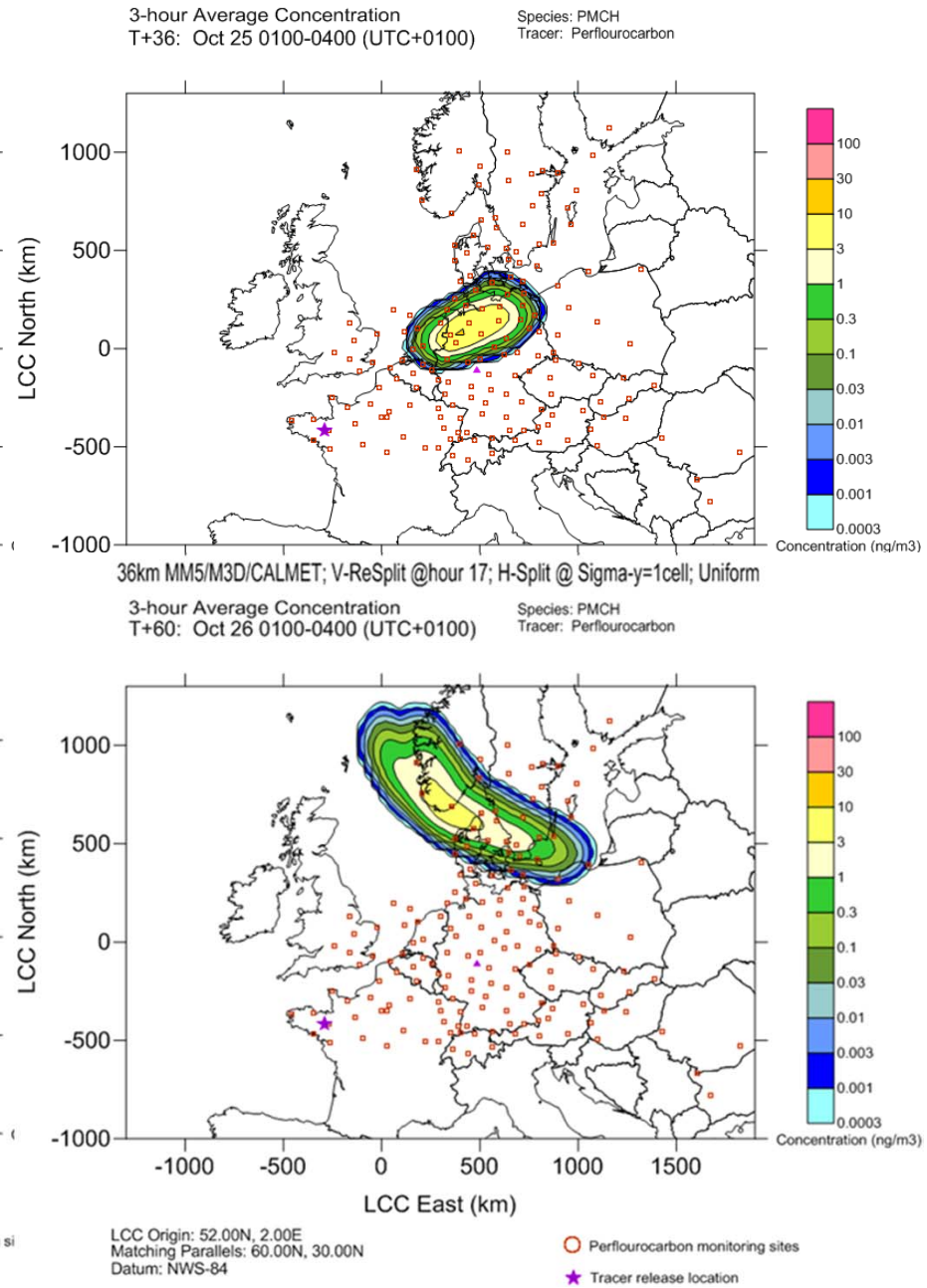




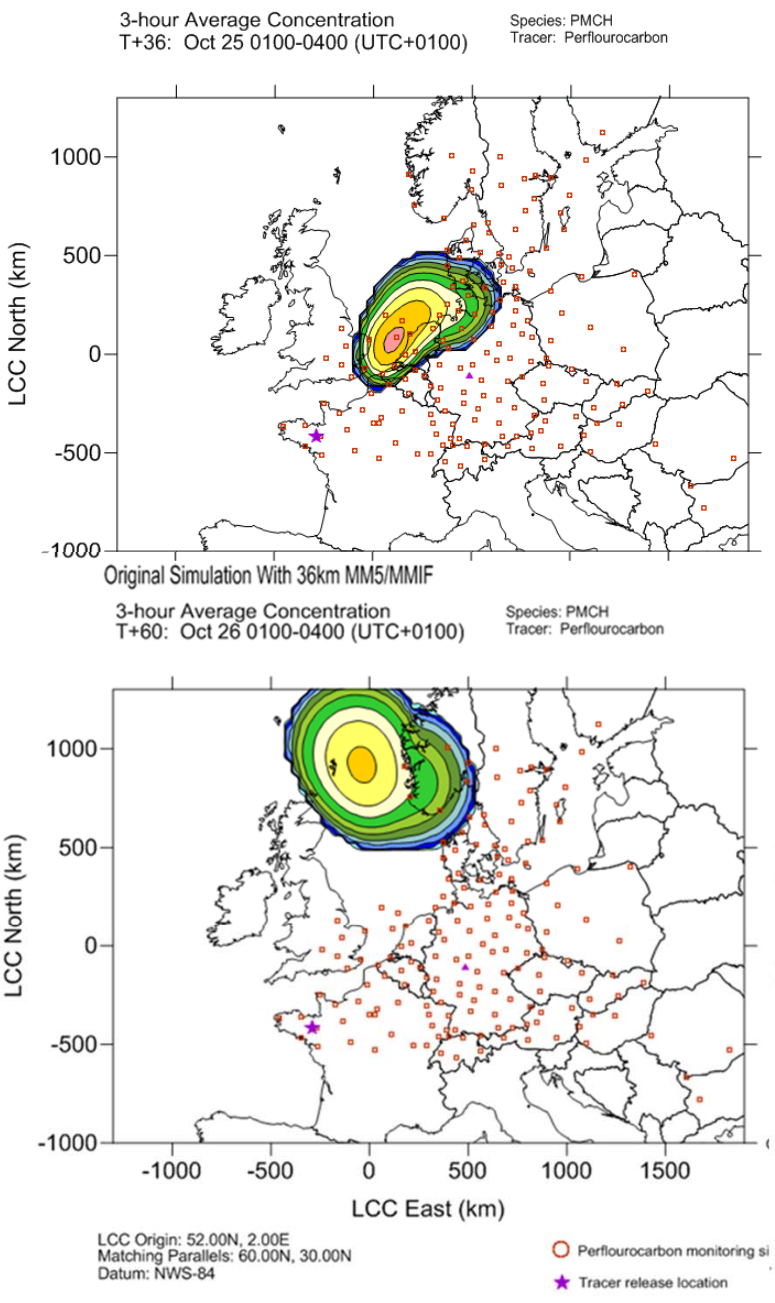
EPA-ENVIRON Run
36-km MM5/MMIF (Gaussian)



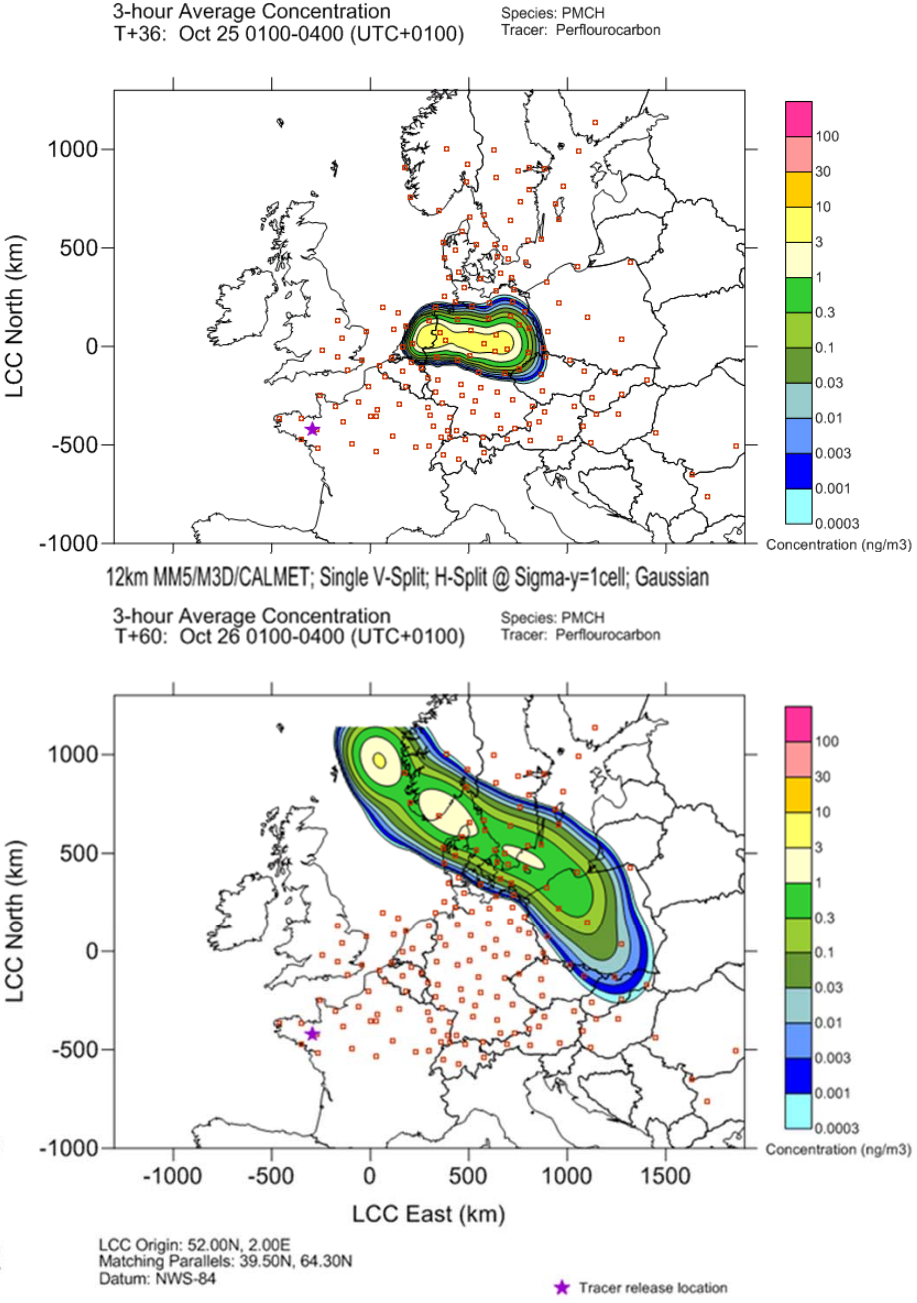
Revised Run #2
36-km MM5/M3D/CALMET (SO)



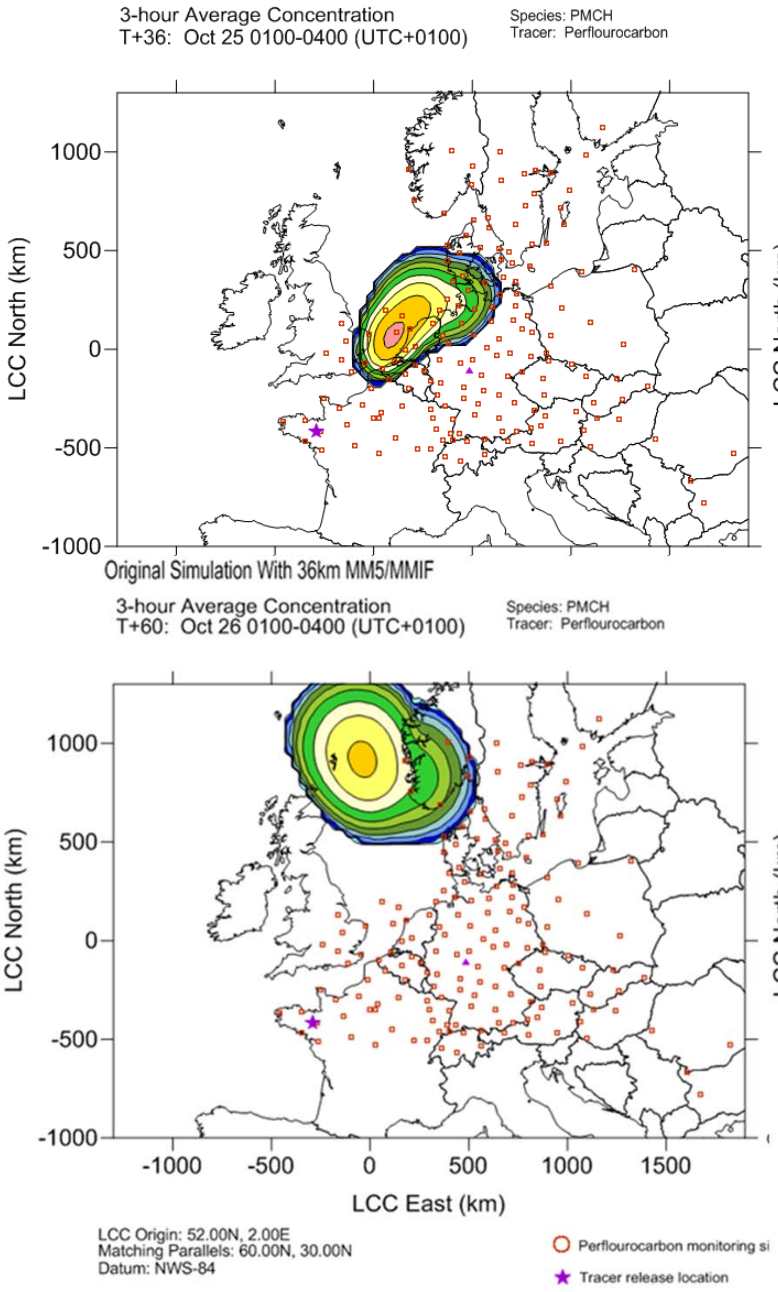
EPA-ENVIRON Run
36-km MM5/MMIF (Gaussian)



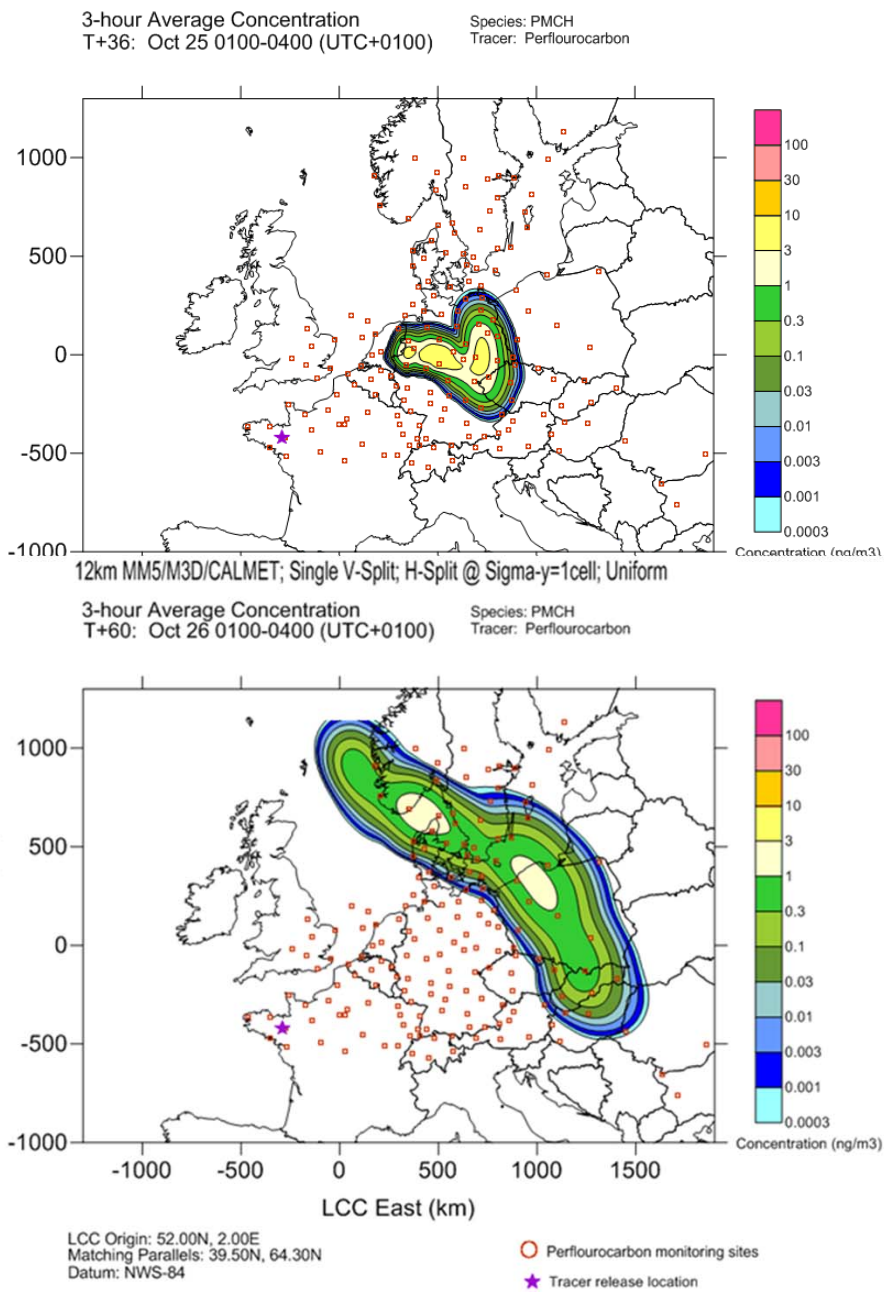
Revised Run #3
12-km MM5/M3D/CALMET (Gaussian)



EPA-ENVIRON Run
36-km MM5/MMIF (Gaussian)



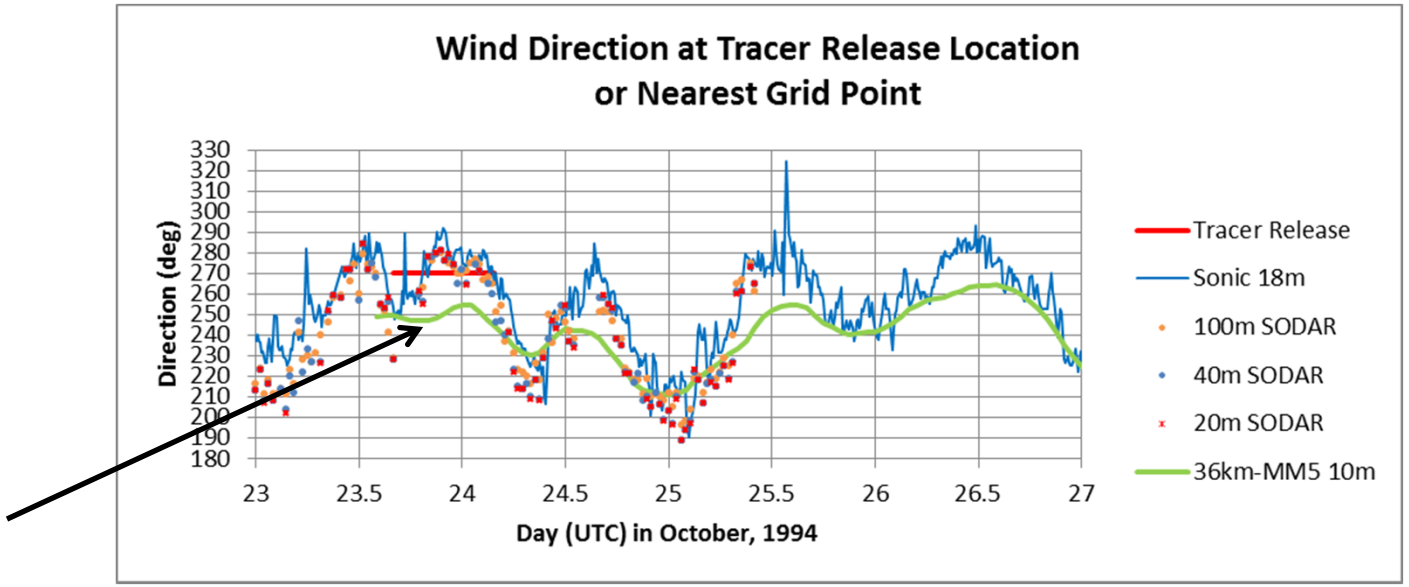
Revised Run #4
12-km MM5/M3D/CALMET (SO)

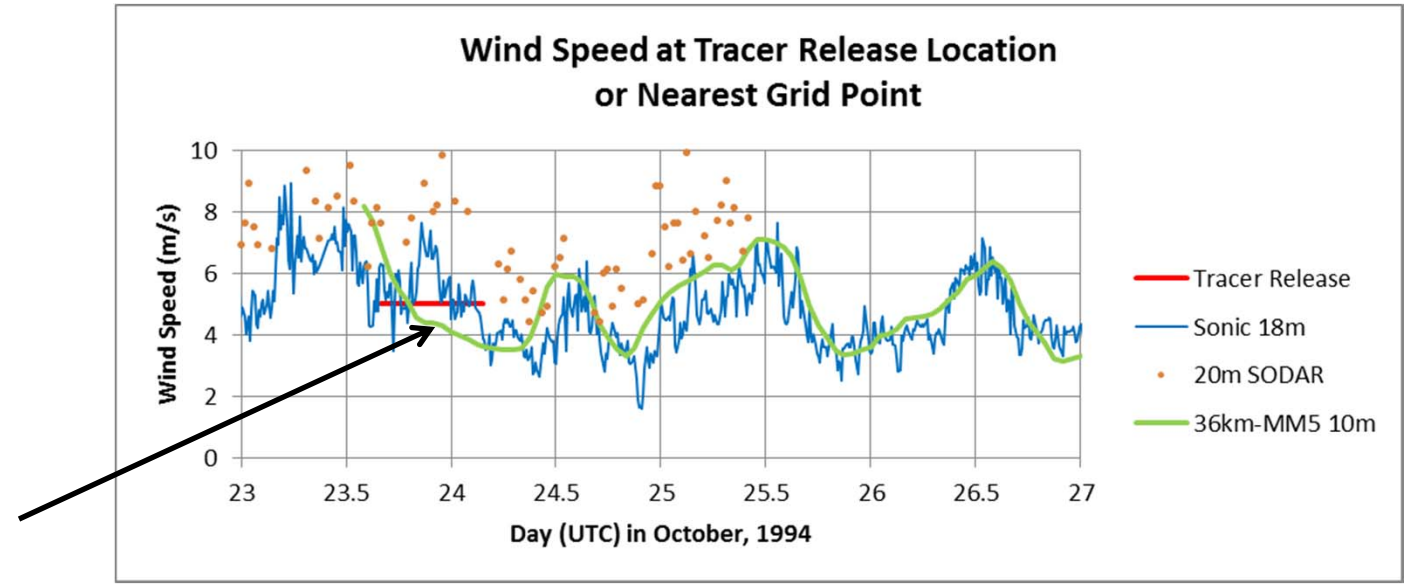


MM5 Data

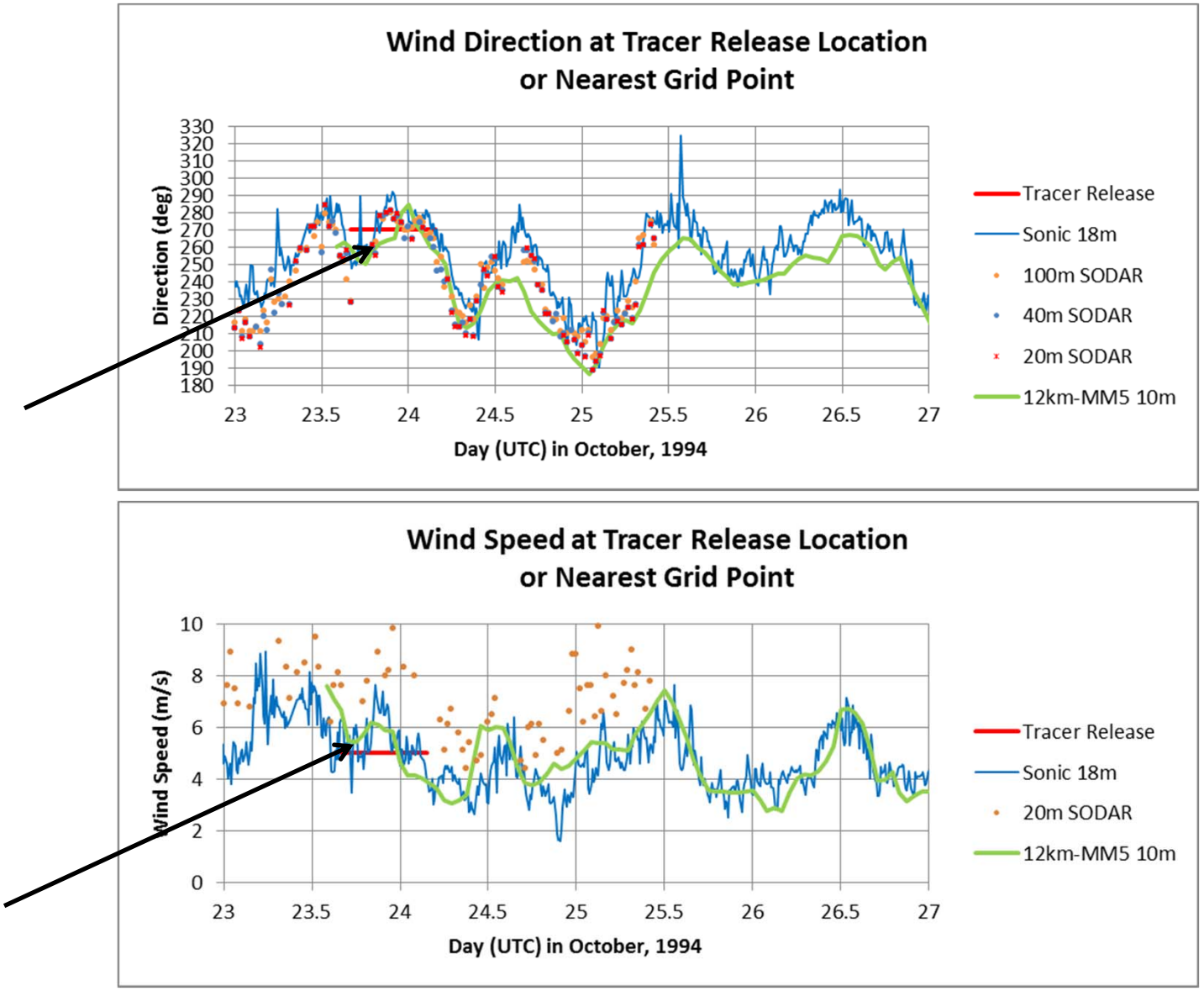
- EPA 36 km MM5 Simulation
  - Coarse representation of terrain and surface characteristics
  - Sub-par representation of observed winds
  - Performance relative to special ETEX meteorological observations not assessed
  - Dispersion models are evaluated with sampler measurements that record event-specific details so unnecessary uncertainties in meteorological modeling only compound interpretation of results
- Alternate 12 km MM5 Simulation
  - Better spatial resolution can be readily simulated and is typical of other applications
  - Same MM5 model options used
  - Better spatial resolution results in better simulation
  - Example: winds measured at the release location during the critical period of the release are simulated better

Wind data from sonic anemometer and SODAR at the release location during the release are not simulated well at 36km resolution during the release





Wind data from sonic anemometer and SODAR at the release location during the release are simulated better at 12km resolution during the release



Comments on Met Data

- Limited quantitative evaluation of 36-km MM5 model failed performance tests for winds
- ENVIRON (2011) incorrectly concluded “meteorological error was not the primary cause of poor performance”
- Sensitivity tests show errors in wind direction near the release site combined with proper puff splitting were critical factors in model performance.
- Specific performance measures used in this study favor diffusive models such as Eulerian models. Little penalty in FMS for highly diluted plumes while high penalty for shifted plume locations.

CALPUFF Application Errors

- Inconsistent Datums for Coordinates
  - Meteorological data are gridded in a Lambert Conformal Conic (LCC) map projection with a spherical Earth Datum (DATUM = NWS-84); CALPUFF grid is in the same projection and Datum
  - Source location and all sampling locations are referenced to the same LCC map projection, but on a non-spherical Earth (DATUM = WGS-84)
- Wrong Tracer Release Period
  - CALPUFF application uses local time, UTC+0100
  - Actual release started at 1600 (UTC) = 1700 (UTC+0100), and lasted 11 hours and 50 minutes (approximately 12 hours)
  - Modeled release was started early at 1600 (UTC+0100) and lasted 13 hours
- Wrong Averaging Periods
  - Measured concentrations are 3-hour averages for 30 sequential time-blocks starting at 1500 (UTC)
  - CALPUFF hourly concentrations are averaged to 3-hour blocks starting 1 hour earlier, so the averages being compared are for different periods

CALPUFF Application Errors

- Wrong stack diameter
  - Stack Diameter = 1.0m in EPA simulation (T=84C, V_e=45m/s)
  - ETEX file release1.txt (http://rem.jrc.ec.europa.eu/etex/) states that "The air stream (67 m3/h) at the top of the chimney (8 m above ground) had an average temperature of 84 degC and a velocity of about 45 m/s."
  - Calculated exit diameter for this air flow is D_e=0.023m (about 0.9 inches), consistent with the photograph:

The tracer release unit

CALPUFF Configuration

- Inappropriate Puff Release Rate
  - 1 instantaneous puff is released at the start of each hour (13 in all) to represent a continuous 12-hour tracer release
  - Tracer mass is artificially concentrated in space and time
  - Will exaggerate sampler hits & misses
  - Will compromise arrival-time assessments
  - Modeled tracer transport will not properly reflect temporal & spatial features in the wind field
- Documentation states that no terrain adjustments were made
  - Application files show that *strain-based terrain adjustment* method was used

EPA-ENVIRON on CALMET

- Rationale for development of MMIF (ENVIRON, 2011)
  - Concerns have been raised regarding CALMET
  - Many options available – multiple answers
  - *CALMET has been shown to degrade meteorological model performance*
  - EPA was not able to achieve pass-through of MM5 winds with CALMET

- EPA developed a Mesoscale Model InterFace (MMIF) tool to map WRF/MM5 model output directly to CALPUFF meteorological inputs
  - *By-passes CALMET and its problems*
  - Includes MMIFSTAT evaluation tool

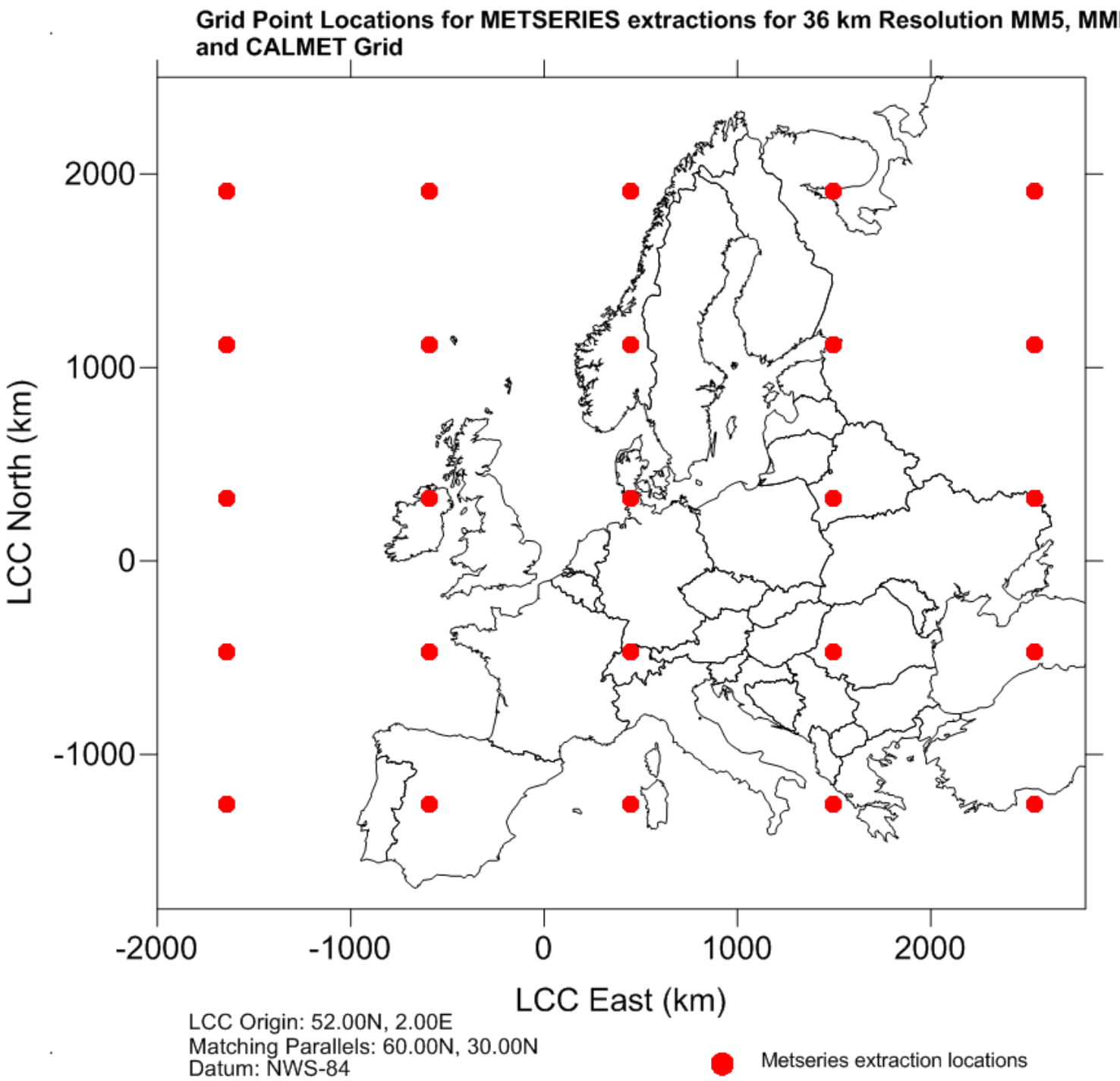
CALMET Comments

- CALMET in its properly configured “pass-through” mode *does not* change the MM5 winds at the MM5 wind points (i.e., dot points)
- MMIF always does spatial interpolation of the MM5 winds even though this interpolation is not necessary
    - Interpolation is done because MMIF places the CALMET grid points on the MM5 cross points, whereas the proper pass-through configuration for CALMET is to place the CALMET grid points at the MM5 dot points
- CALMET pass-through matches MM5 on MM5 grid points
- MMIF pass through does not
- Some vertical interpolation may be done due to differences in the sigma layer structure in MM5 vs the constant thickness layers in CALMET which will introduce differences.

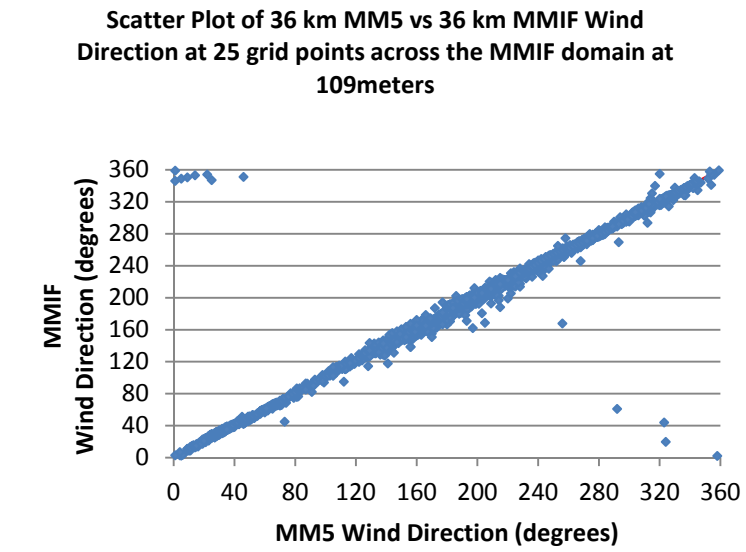
CALMET Pass-Through Configuration

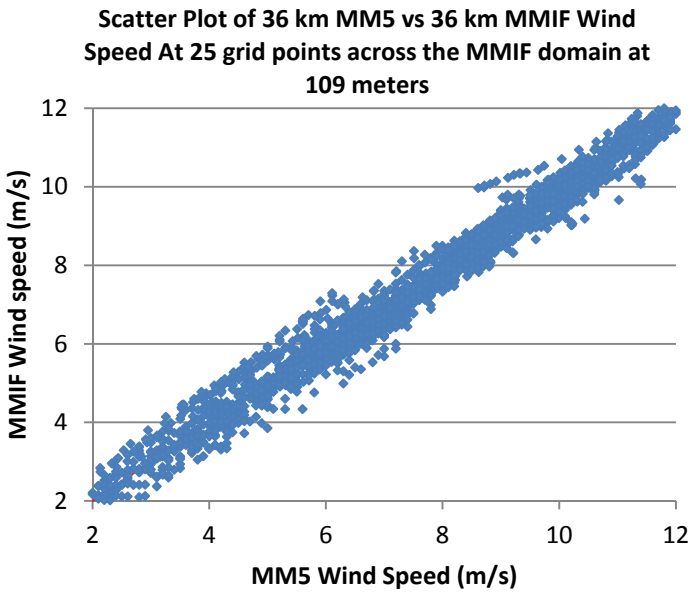
Full NOOBS	Diagnostic Wind Module	No terrain effects	No smoothing or spatial averaging
NOOBS = 2	IWFCOD=1	ISLOPE=0	
IPROG =14	LCALGRD=1	IFRADJ=0	IAVET=0
ITPROG = 2		IKINE=0	NSMTH(NZ)=NZ*0
NPSTA=-1		IOBR=0	
ICLOUD >=3 (*)			
ITWPROG>=1			
IRHPROG=1			
ILUOC3D = 16 (**)			

(*) ICLOUD=3 for V5.8 (ICLOUD=4 is MM5toGRADS option available in MOD6 only)
(**) ILUOC3D must match 3D.DAT water land use category, usually 16 for MM5

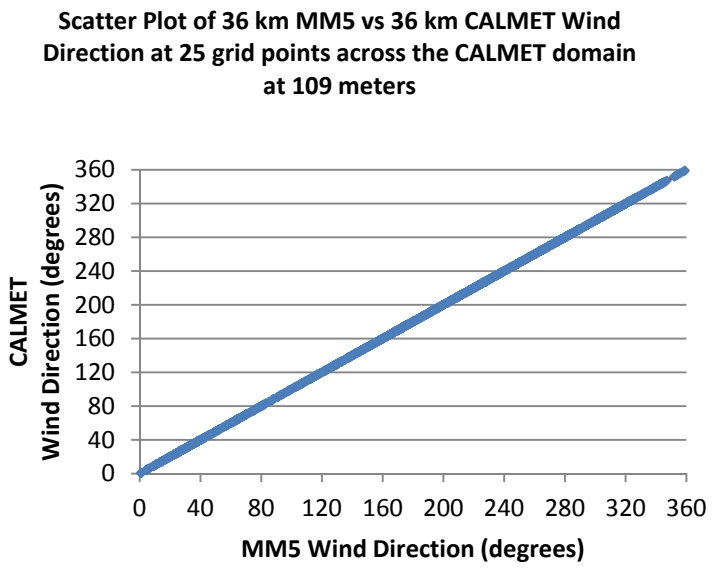

Grid Point Locations for METSERIES extractions for 36 km Resolution MM5, MMIF, and CALMET Grid
2000
1000
0
-1000
LCC North (km)
-2000
-1000
0
1000
2000
LCC East (km)
LCC Origin: 52.00N, 2.00E
Matching Parallels: 60.00N, 30.00N
Datum: NWS-84
Metseries extraction locations

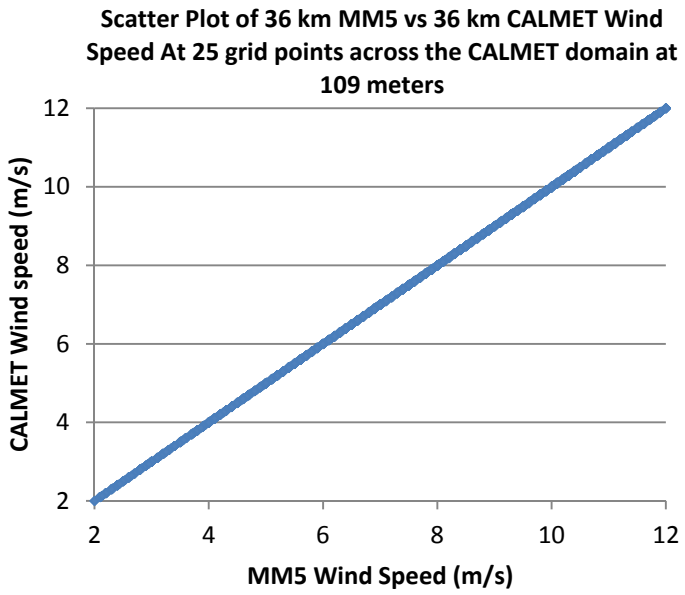
MMIF vs. MM5





CALMET vs. MM5





Conclusions

- EPA-ENVIRON study on the ETEX-1 model evaluation contains flaws which significantly affect model conclusions regarding CALPUFF and which model performs best
  - Errors in model setup
  - Inappropriate model configuration settings
  - Inadequate coarse resolution (36-km) MM5 data
- Alternative CALPUFF configuration with EPA met data significantly improves performance
- Simulation with higher resolution MM5 data produces CALPUFF model performance comparable with the best performing group of models

Recommendations

- Review of modeling conducted by EPA during 2008-2012 is late in the process due to previous lack of access to datasets. *Recommendation: Full and timely access to all model evaluation data be provided to the entire modeling community*
- Evaluation process would benefit from direct involvement of model developers in the evaluation of their models
  - Configuration mistakes and errors more likely to be caught and corrected

Future work

- Independent assessment will continue of other field study results presented in EPA-ENVIRON report
- Assessment of whether current model evaluation measures are adequate for regulatory model

THE END