Long Range Transport Model Evaluations

Reassessment of Interagency Workgroup on Air Quality Modeling (IWAQM) Recommendations

Background

- 8th Modeling Conference – EPA recognizes CALPUFF model science has evolved and discusses intent to update Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2 Guidance
  - Formed CALPUFF Workgroup in 2005 to discuss issues and prioritize tasks
  - Discussed need to perform updated model performance evaluation to examine new science enhancements to model (e.g. puff splitting, P-G v. turbulence, etc.) which are not reflected in current guidance.

LRT Model Evaluation Project

- EPA is performing five tasks for this project:
  - Assemble a tracer and meteorological database for use with LRT model evaluations
  - Develop a comprehensive evaluation framework (methodologies and tools) for both meteorological (prognostic and diagnostic) and LRT models for promotion of more scientifically robust and consistent evaluation of meteorological and LRT models
  - Exercising and testing meteorological and LRT models for the assembled tracer database
  - Provide full documentation of model evaluation measures and results from meteorological and LRT evaluations
  - Updating existing EPA LRT modeling guidance (IWAQM Phase 2) to reflect lessons learned from this project

IWAQM Guidance Goals

- Examine science evolution of CALPUFF modeling system to incorporate recent enhancements to model system in updated guidance. Overarching questions:

1. Can puff-splitting extend the effective range of CALPUFF beyond recommended distance of 200-300 km?
2. Can guidance migrate to recommend turbulence based dispersion (CALPUFF and AERMOD options) over P-G?
3. How best to supply meteorological data to CALPUFF? (Best CALMET Options, MM5CALPUFF, etc.)

Mesoscale Tracer Experiments

- Great Plains Tracer Experiment (GP80) – 1980 (currently evaluating)
- Savannah River Laboratory Tracer Experiment (SRL) – 1975 (underway)
- Cross-Appalachian Tracer Experiment (CAPTEX) – 1983 (TBD)
- European Tracer Experiment (ETEX) – 1994 (completed)

Additional Tracer Studies to Be Included

- Project MOHAVE (Vimont, Koracin)
- VTMX (Urban 2000) (?)
- Dipole Pride 26 (Hanna & Chang)
- Overland Along-Wind Dispersion (OLAD) (Hanna & Chang)

Evaluation of Additional Models

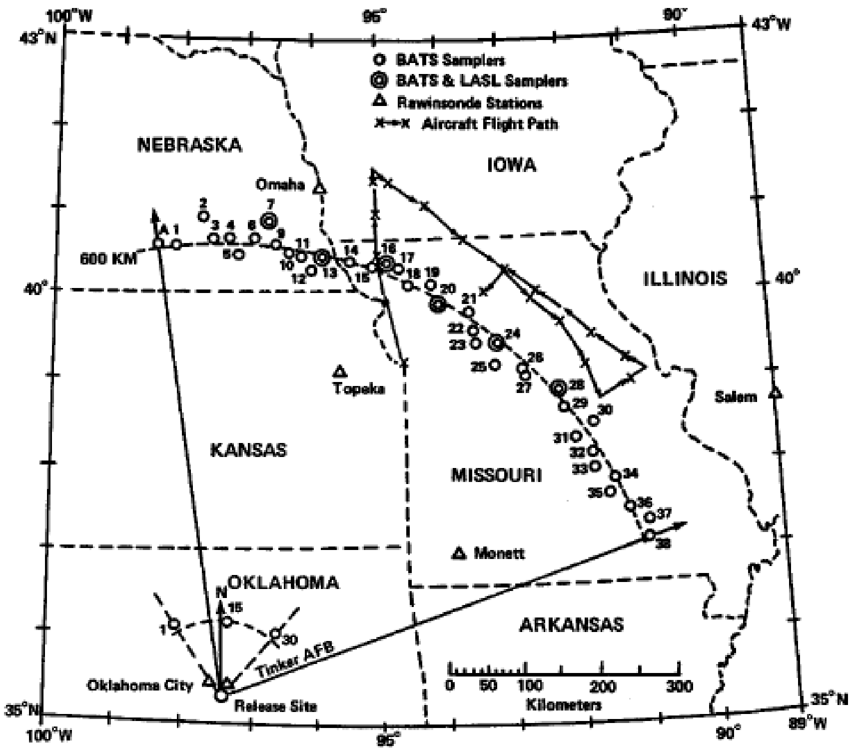
- Evaluation of additional modeling technology to aid understanding of additional LRT modeling and to provide a framework to understand how well can any model reasonably do with these experiments
  - Lagrangian particle models (models routinely available with wide meteorological compatibility)
    - FLEXPART (Norwegian Institute for Air Research)
    - HYSPLIT (Air Resources Laboratory, NOAA)
  - Eulerian grid models
    - Comprehensive Air Quality Model with Extensions (CAMx)

Evaluation Methods

- Irwin Method
  - Plume arrival
  - Arc transit time
  - Fitted maximum
  - Observed maximum
  - Crosswind integrated concentration
  - Plume sigma-y
  - Plume Azimuth

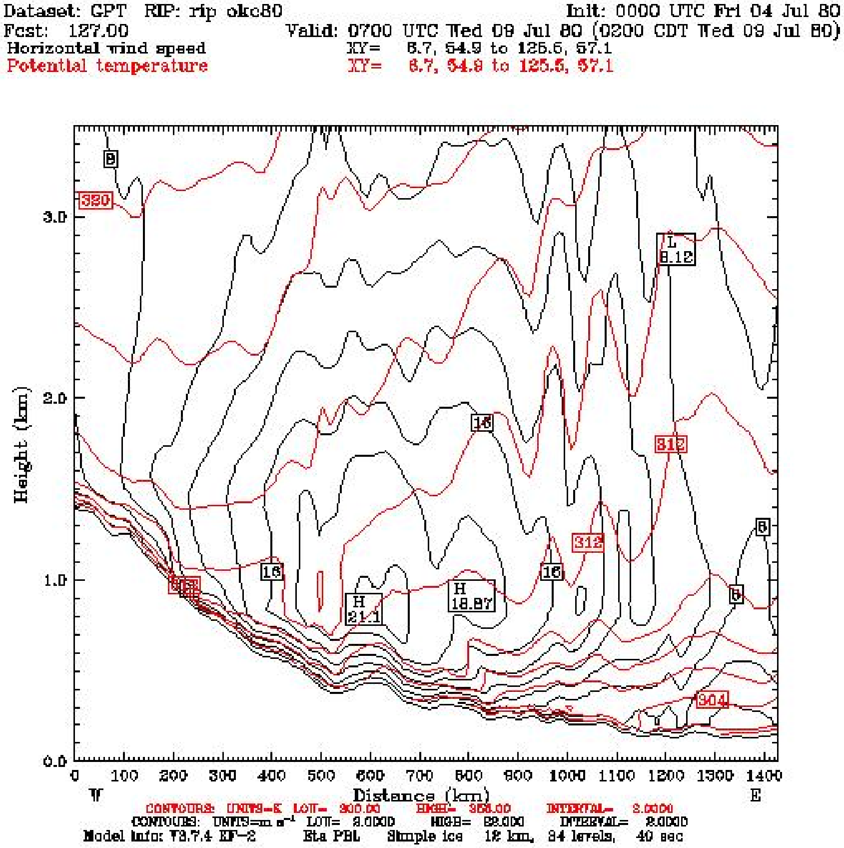
- ATMES-II statistical measures
  - Scatter
    - Normalized Mean Square Error
    - Factor of Exceedance
    - Factor of 2/5
    - Correlation
  - Bias
    - Fractional Bias
    - Mean Bias
  - Spatial
    - Figure of Merit in Space
    - Probability of Detection
    - False Alarm Rate
    - Threat Score
  - Cumulative distribution
    - Kolomogorov-Smirnov Parameter
  - Overall Model Rank

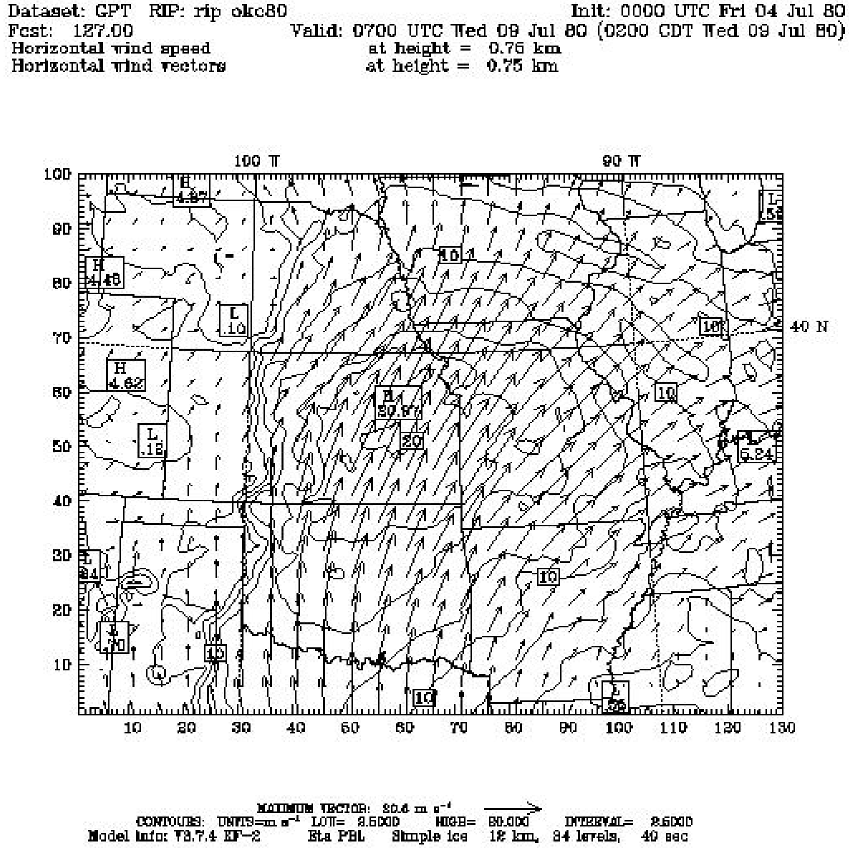
Great Plains Mesoscale Tracer Experiment



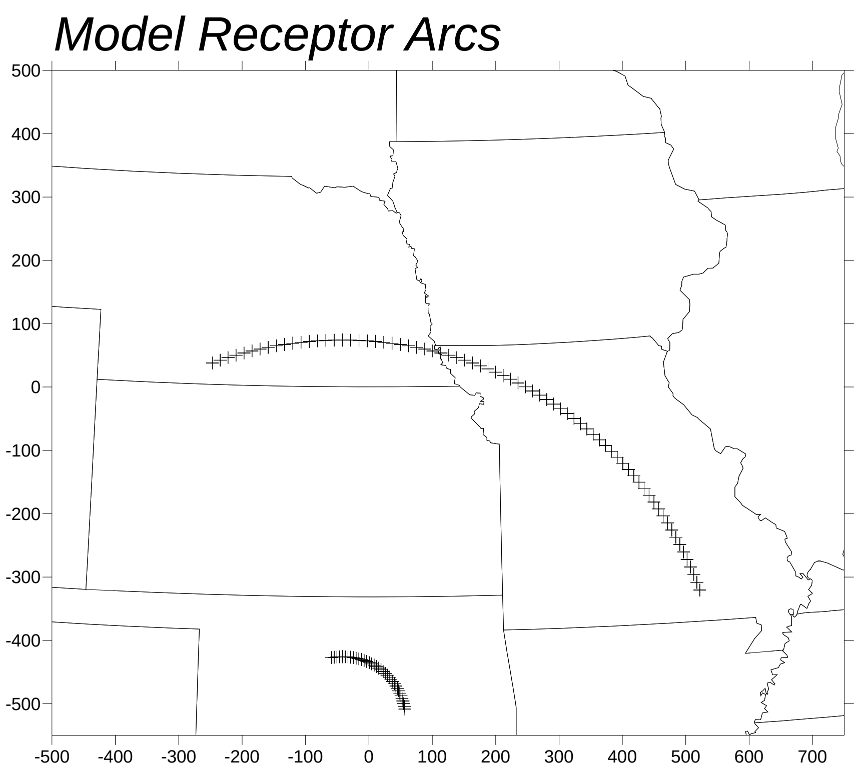
- One of several original EPA tracer study for CALPUFF, documented in EPA-454/R-98-009
- Two perflourocarbaon tracer releases from Norman, OK July 8 and July 11, 1980.

Synoptic Meteorology – July 8-9, 1980





Model Experiment Design



- Three Dispersion Models

1. CALPUFF:
   - CALMET Meteorology
     - Observation only
     - Hybrid (MM5 + Obs)
     - NOOBS=1 (Obs surface, MM5 aloft)
     - NOOBS=2 (No Observations, only MM5)
   - MM5CALPUFF Meteorology
   - All Dispersion Options
     - P-G Turbulence
     - AERMOD Turbulence
     - CALPUFF Turbulence
   - Puff-Splitting on 600 km simulation, none for 100 km
   - 100 km and 600 km arcs of receptors, 0.25° increments, 361 total receptors for each.
   - 2 Domains: 100km, 600 km arcs
   - 20 km CALMET for 600 km
   - 4 km CALMET for 100 km

2. FLEXPART Lagrangian Particle Model
3. HYSPLIT Lagrangian Particle Model

MM5 Configuration

- MM5 Version 3.7.4
- 3 nested domains
  - 108 km
  - 36 km
  - 12 km
- 34 vertical layers
- ICBC: NCEP/NCAR Reanalysis Data available every 6 hours at 2.5° x 2.5°

- Physics:
  - Kain-Fritsch II Cumulus
  - ETA PBL
  - NOAH LSM
  - RRTM Radiation
  - Simple Ice Microphysics

Observed Maximum

Omax (ppt) – actual maximum		CALPUFF Dispersion Option		
	Observed	P-G	CALPUFF	AERMOD
Great Plains, July 8, 100 km, CALMET** Winds	1.05	2.362	1.946	2.014
Great Plains, July 8, 100 km, MM5 Winds**	1.05	1.78	2.27	2.25
Great Plains, July 8, 600 km CALMET Obs Only Winds	0.38	0.867E-1	0.1543	0.1566
Great Plains, July 8, 600 km CALMET Hybrid Winds	0.38	0.1489	0.1331	0.1347
Great Plains, July 8, 600 km CALMET NOOBS=1 Winds	0.38	0.1593	0.1668	0.1648
Great Plains, July 8, 600 km CALMET NOOBS=2 Winds	0.38	0.1647	0.1686	0.1689
Great Plains, July 8, 600 km, MM5 Winds	0.38	0.1561	0.1708	0.1638

*** Round 1 Results – will be updated*

Plume Sigma-y

Cmax (ppt) – fitted maximum		CALPUFF Dispersion Option		
	Observed	P-G	CALPUFF	AERMOD
Great Plains, July 8, 100 km, CALMET Winds	9.1	6.3	6.4	6.4
Great Plains, July 8, 100 km, MM5 Winds	9.1	8.3	6.6	6.6
Great Plains, July 8, 600 km, CALMET Obs Only Winds	19.5	52.2	30.91	30.46
Great Plains, July 8, 600 km CALMET Hybrid Winds	19.5	52.9	35.18	34.59
Great Plains, July 8, 600 km CALMET NOOBS=1 Winds	19.5	36.73	23.67	23.96
Great Plains, July 8, 600 km CALMET NOOBS=2 Winds	19.5	48.66	27.92	28.31
Great Plains, July 8, 600 km, MM5 Winds	19.5	43.85	35.42	33.92

Plume Arrival Time on Arc

Arrival Time at Arc (Julian day: hour LST)		CALPUFF Dispersion Option		
	Observed	P-G	CALPUFF	AERMOD
Great Plains, July 8, 100 km, CALMET Winds	190:1545	190:1600	190:1600	190:1600
Great Plains, July 8, 100 km, MM5 Winds	190:1545	190:1700	190:1700	190:1700
Great Plains, July 8, 600 km CALMET Obs Only Winds	191:0200	191:0200	191:0100	191:0200
Great Plains, July 8, 600 km CALMET Hybrid Winds	191:0200	191:0100	191:0200	191:0200
Great Plains, July 8, 600 km CALMET NOOBS=1 Winds	191:0200	191:0100	191:0200	191:0100
Great Plains, July 8, 600 km CALMET NOOBS=2 Winds	191:0200	191:0200	191:0200	191:0200
Great Plains, July 8, 600 km, MM5 Winds	191:0200	191:0200	191:0300	191:0300

Arc Transit Time

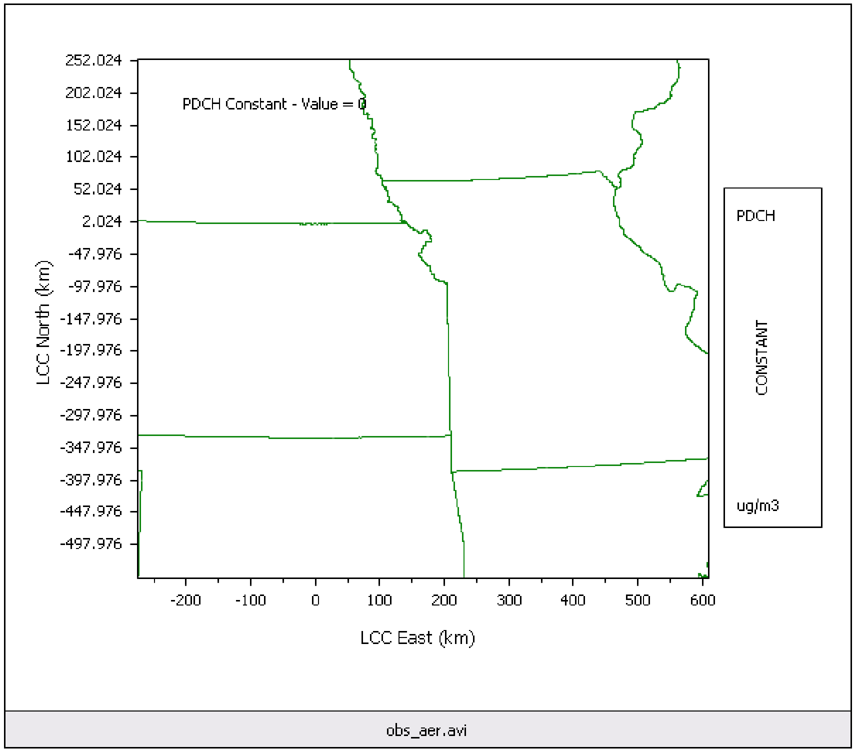
Length of Plume Passage (hours)		CALPUFF Dispersion Option		
	Observed	P-G	CALPUFF	AERMOD
Great Plains, July 8, 100 km, CALMET Winds	5	5	5	5
Great Plains, July 8, 100 km, MM5 Winds	5	4	4	4
Great Plains, July 8, 600 km CALMET Obs Only Winds	15	8	8	8
Great Plains, July 8, 600 km CALMET Hybrid Winds	15	9	8	8
Great Plains, July 8, 600 km CALMET NOOBS=1 Winds	15	6	6	6
Great Plains, July 8, 600 km CALMET NOOBS=2 Winds	15	6	6	6
Great Plains, July 8, 600 km, MM5 Winds	15	15	15	14

Plume Centerline

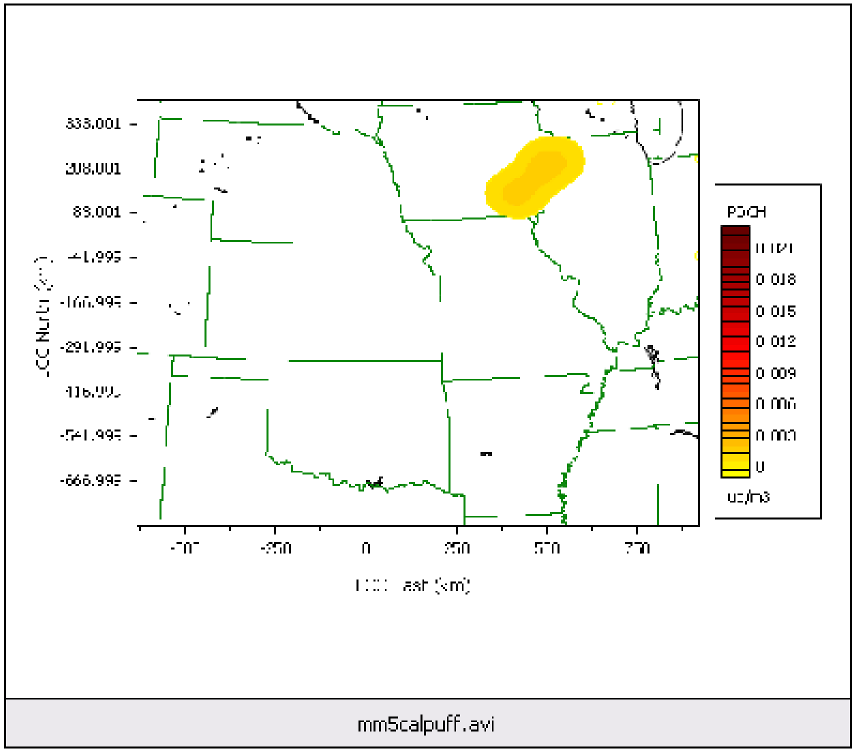
Plume Centerline (degrees from north)		CALPUFF Dispersion Option		
	Observed	P-G	CALPUFF	AERMOD
Great Plains, July 8, 100 km, CALMET Winds	1	28.62	25.04	25.15
Great Plains, July 8, 100 km, MM5 Winds	1	-11.33	-8.78	-8.9
Great Plains, July 8, 600 km CALMET Obs Only Winds	9.8	29.59	26.63	26.57
Great Plains, July 8, 600 km CALMET Hybrid Winds	9.8	25.91	26.52	26.72
Great Plains, July 8, 600 km CALMET NOOBS=1 Winds	9.8	25.03	25.01	25.12
Great Plains, July 8, 600 km CALMET NOOBS=2 Winds	9.8	20.15	28.01	28.31
Great Plains, July 8, 600 km, MM5 Winds	9.8	17.9	17.44	17.80

CALPUFF Simulations

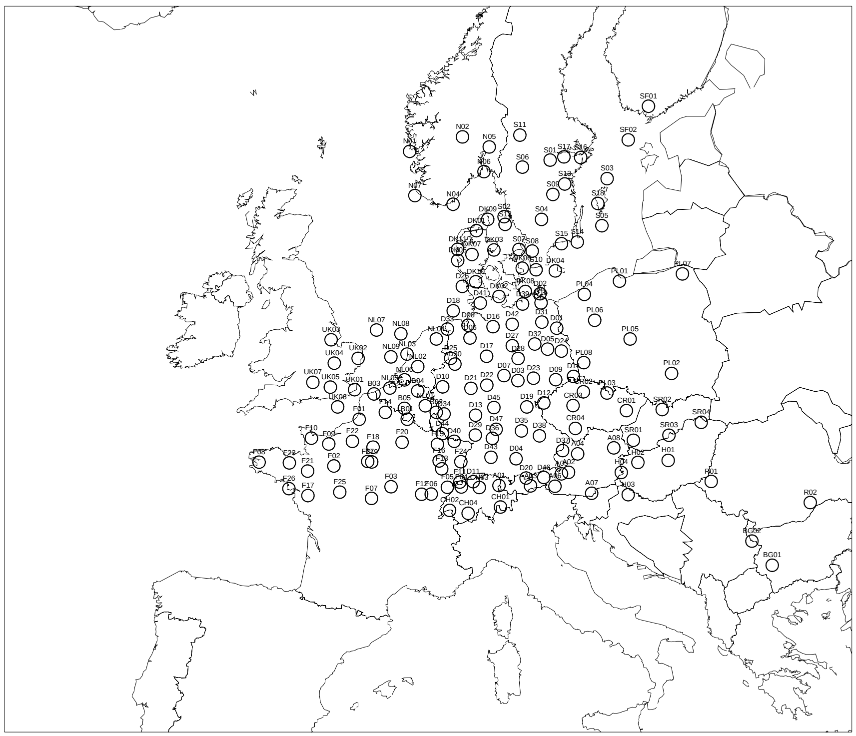
OBS ONLY – AERMOD DISPERSION



MM5 ONLY – AERMOD DISPERSION

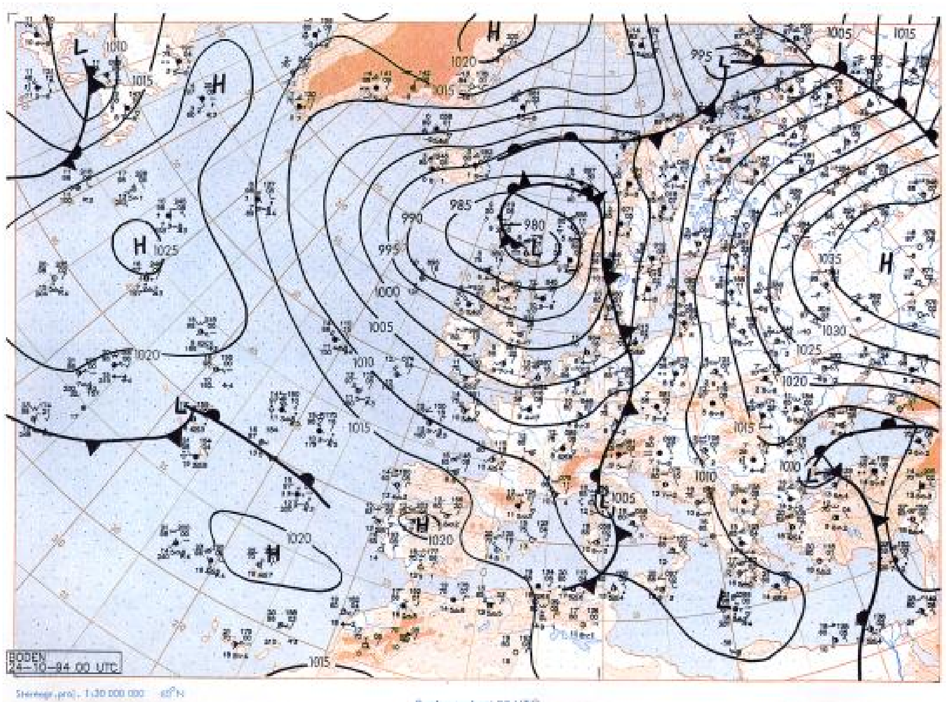


European Tracer Experiment (ETEX)



- ETEX initiated in 1992 by the European Commission (EC), International Atomic Energy Agency (IAEA), and World Meteorological Organization (WMO) to address many of the questions that arose from the 1986 Chernobyl accident regarding the development of LRT models
- ETEX was designed to validate long-range transport models used for emergency response situations and to develop a database which could be used for model evaluation purposes.
- Two releases of perflourocarbon (PFC) tracer were made in October and November 1994 from France.
  - The PFC was released at a constant rate for 12 hours
  - Air concentrations were sampled at 168 monitoring sites in 17 European countries with a sampling frequency of every 3 hours for approximately 90 hours.

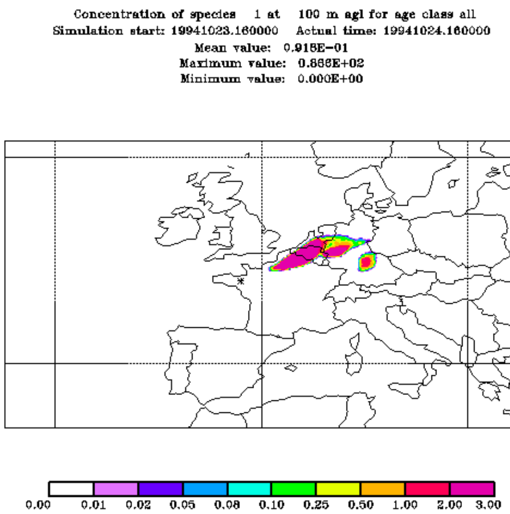
Experiment Design



- Meteorology
  - MM5 Version 3.74
    - Initialized with NCEP Reanalysis Data (available 6-hourly at 2.5 x 2.5 grid)
    - Kain-Fritsch II Cumulus
    - ETA PBL
    - NOAH LSM
    - RRTM Radiation
- LRT Models
  - CALPUFF Version 5.8
  - HYSPLIT Version 4.8
  - FLEXPART Version 6.2 (MM5)
- Each model coupled directly to MM5 to facilitate better intercomparison

FLEXPART Time Series

24 HR



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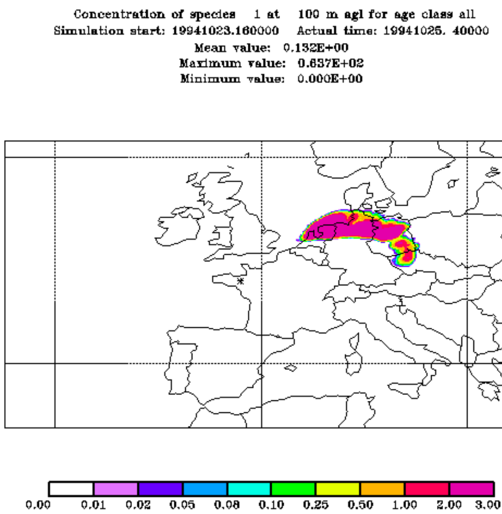

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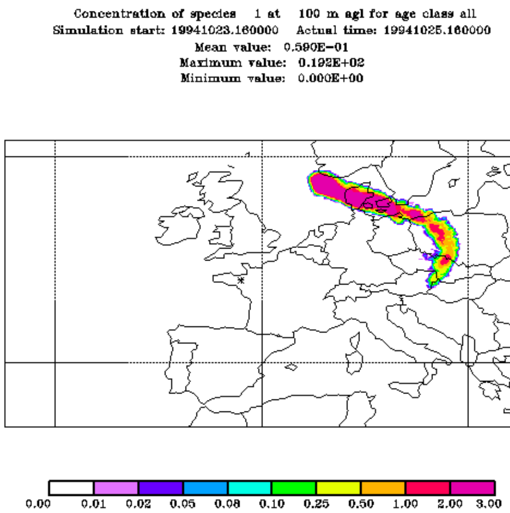

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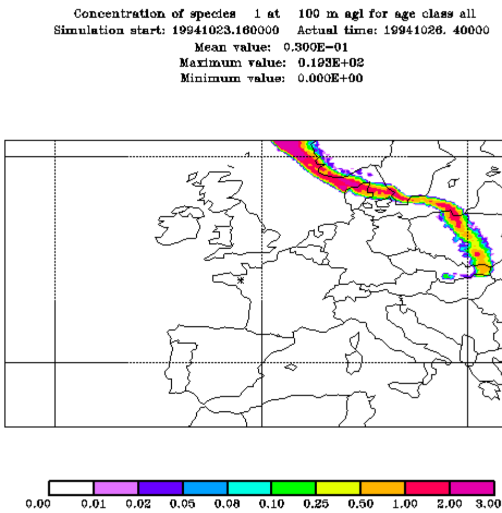
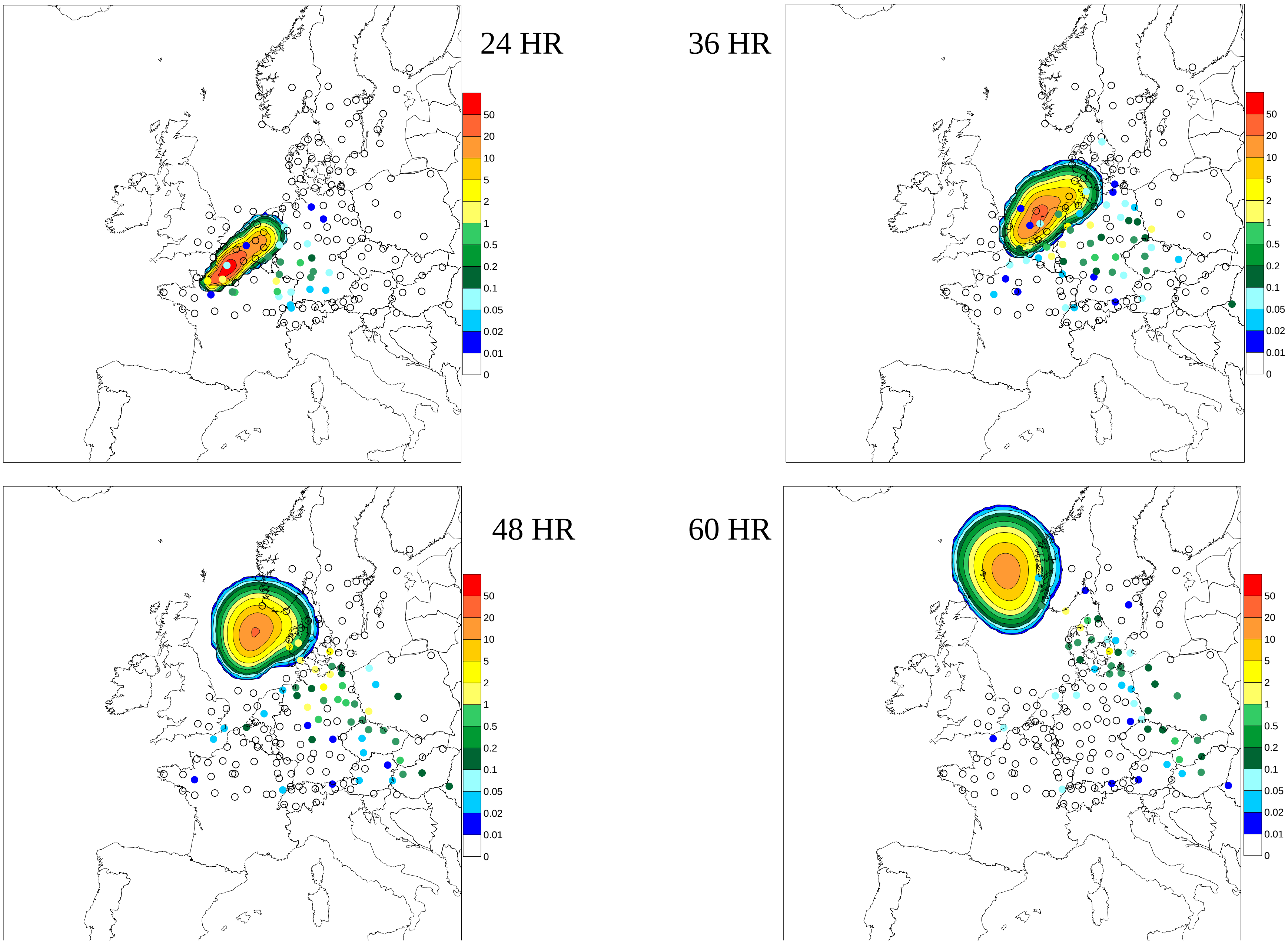


CALPUFF Time Series



HYSPLIT Time Series

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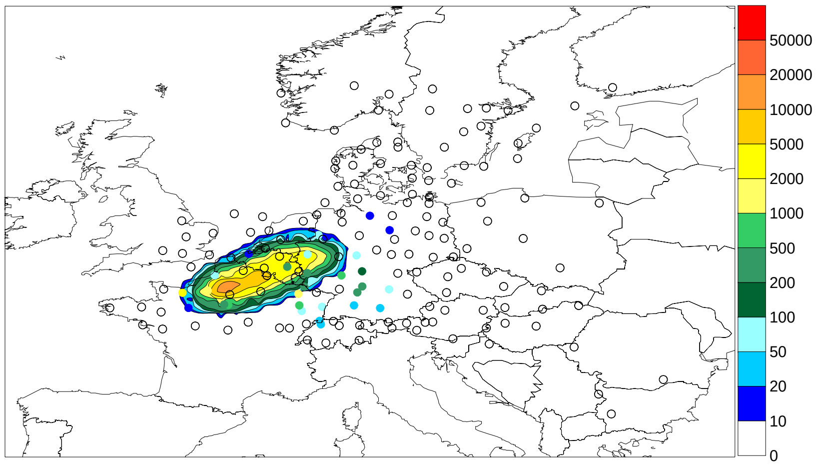

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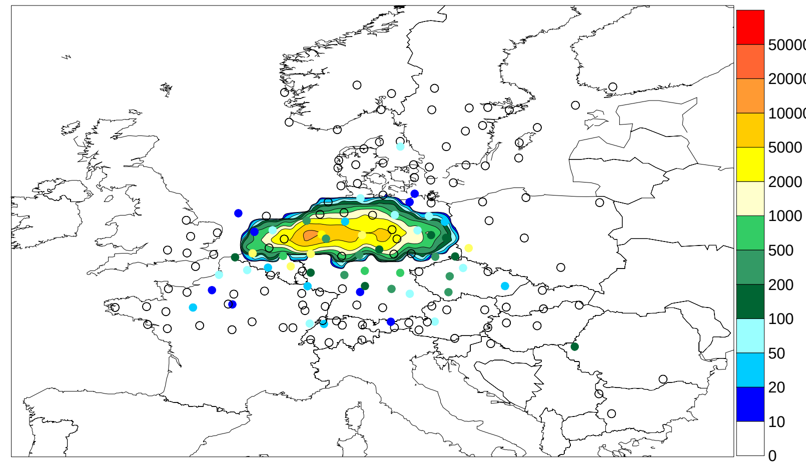

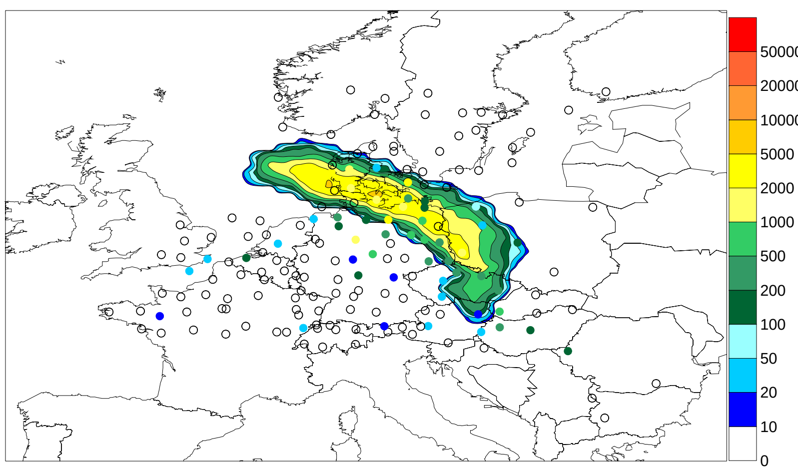

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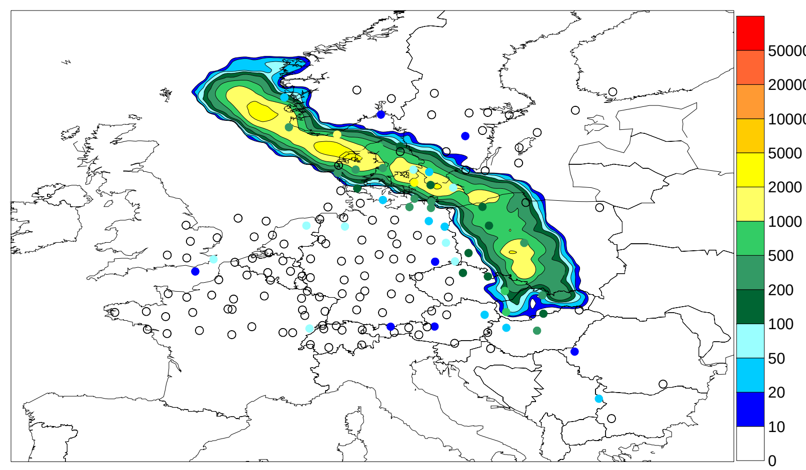

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Spatial Statistics: ETEX

Model	Statistical Measure			
	Figure of Merit in Space (FMS)	Probability of Detection (POD)	False Alarm Rate (FAR)	Threat Score (TS)
CALPUFF	8.35	0.07	0.74	0.06
HYSPLIT	41.4	0.55	0.36	0.42
FLEXPART	30.07	0.27	0.54	0.20

Global Statistics: ETEX

Statistical Measure	CALPUFF	HYSPLIT	FLEXPART
PCC	0.02	0.32	-0.01
FB	1.27	0.69	1.20
NMSE	202.12	18.12	108.06
FA2	0.5	10.05	5.34
FA5	1.99	23.44	11.86
FOEX	-37.48	-10.65	-16.61
KSP	79.00	39.00	49.00
RANK	0.66	1.78	1.24

Initial Observations

- Insufficient number of tracer experiments to draw any conclusions from current data
- Great Plains Tracer Experiment
  - CALPUFF/CALMET 100 km results performed well except for plume azimuth. MM5 results better for azimuth, but worse for time of arrival and duration on 100 km arc.
  - Unable to replicate 600 km arc statistics from original GP80 and SRL studies conducted by EPA in 1997 despite using same raw meteorological data, horizontal, and vertical grid configurations.
    - Two major differences from original EPA study are updated terrain and landuse from old CALPUFF 1.0 distribution and use of lambert conformal projection for GP80 and SRL, all other CALMET options remained constant.
    - CALPUFF performance varied due to variations in CALMET options selected. CALPUFF results appear sensitive to manner in which meteorology is supplied to the model.
- European Tracer Experiment
  - CALPUFF performs reasonably compared to particle models for first 24 hours, has more difficulty further into transport simulation
  - Puff-splitting did not change CALPUFF performance significantly.
    - Additional sensitivities for puff-splitting (eliminating mixing height restrictions) increased number of puffs, but did not augment model performance.

Next Steps

- Project results shown today are work-in-progress
  - Rebuilding database and simulation results after critical hard drive failure in early summer
  - Model evaluation protocol drafted
  - Full documentation and data availability necessary.
  - Need to engage with model developer to help us understand some of our observations
    - Did we go wrong in model setup? What can we do better?
    - Has the model changed since the previous evaluations?