

Enhanced Approach to Model Air Quality Impacts of Aircraft Operations at an Airport for Surface Movement Optimization Research

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Background

- Aircraft emissions from an airport represent a non-negligible source of total emissions that affect air quality in the vicinity of an airport
- 86 airports in counties that are in non-attainment for ozone and PM_{2.5}
- Airport contribution to NO_x emissions vary from 0.7 to 6.1% of total emissions in county
- Capability of EDMS model limited to dispersion of non-reactive air pollutants
- Both comprehensive 3-d models (e.g. CMAQ) and local-scale dispersion models (e.g. AERMOD) have strengths and weaknesses
- Need to assess air quality impacts of projected growth in aviation in the presence of decreasing background emissions
- Assess air quality impacts of aviation in the context of stringent revisions in NAAQS for criteria air pollutants
- Goal: Develop modeling solutions to support analysis of AQ impacts from airport surface operational changes

Motivation

Focus: Meteorological Model

- Hypothesis: Without advancements to the treatment of urban surfaces, “retrospective” meteorological approaches will need to be modified for urban air quality modeling
- See Bowden’s presentation on “High Resolution Meteorological Simulations Over a Metropolitan Area With and Without an Urban Canopy Model” @ CMAS today

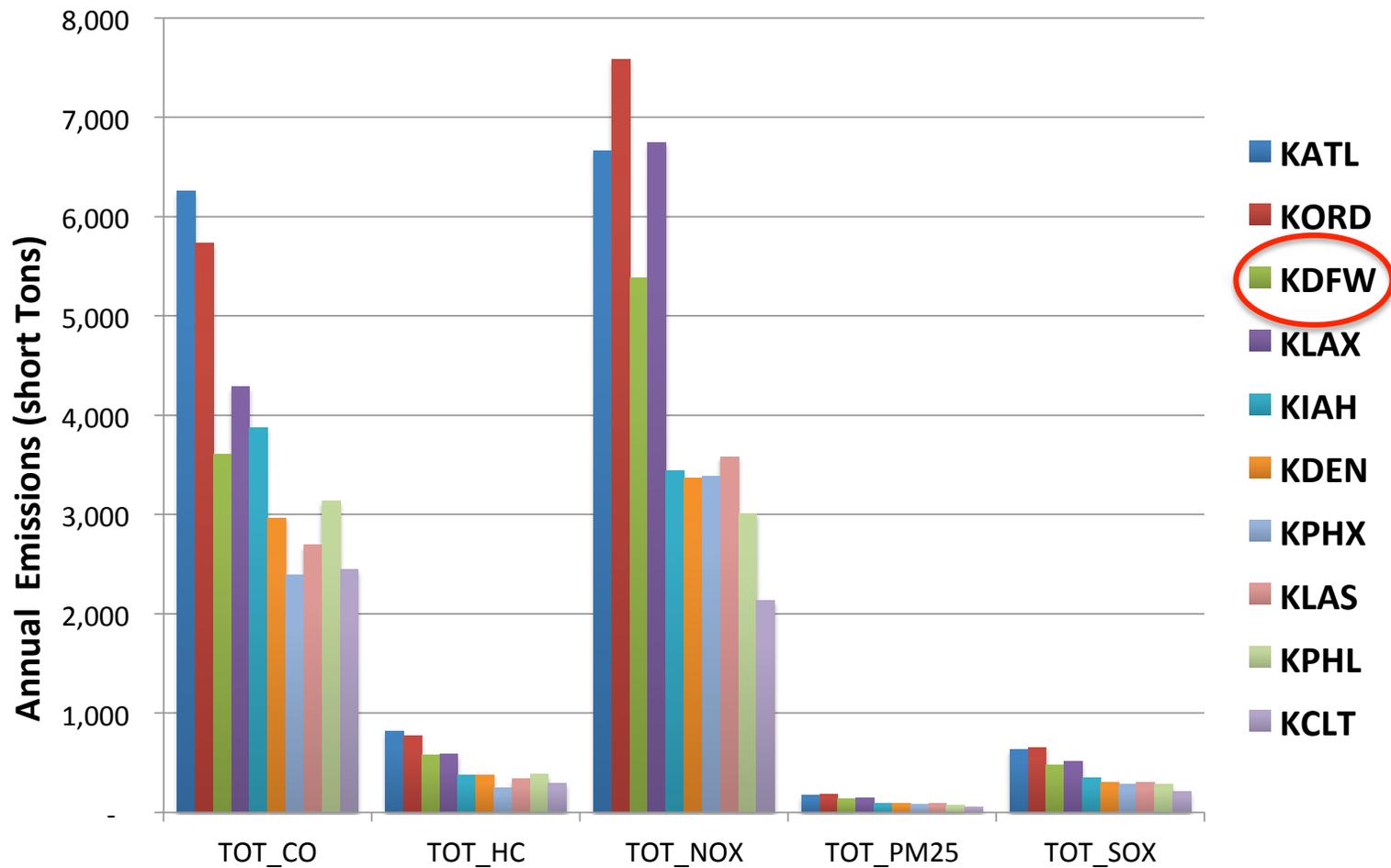
Motivation

Focus: Air Quality Model

- A pressing issue for airport operations is for timely departures and arrivals of aircrafts
- While optimizing for this, environmental impacts of aircraft movement also needs to be minimized
- Air quality models have been used to assess AQ impacts of airport/aircraft emissions at regional and global scales
 - However, local AQ in and around airport is challenging to assess
 - Need to characterize physical and chemical processes adequately in and around the airport, along with accurate representation of aircraft movement and emissions
- Hypothesis: Use of CMAQ with advanced plume treatment (APT) at 4-km resolution will provide enhanced information for assessing AQ impacts at subgrid scales than explicit fine scale modeling (at 1-km)

Airport Selection

Top 10 U.S. Airports by Activity



Modeling Tools and Databases

Models

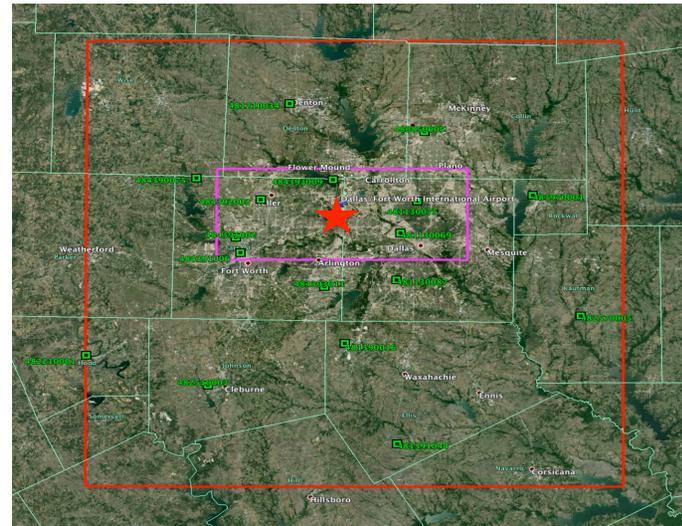
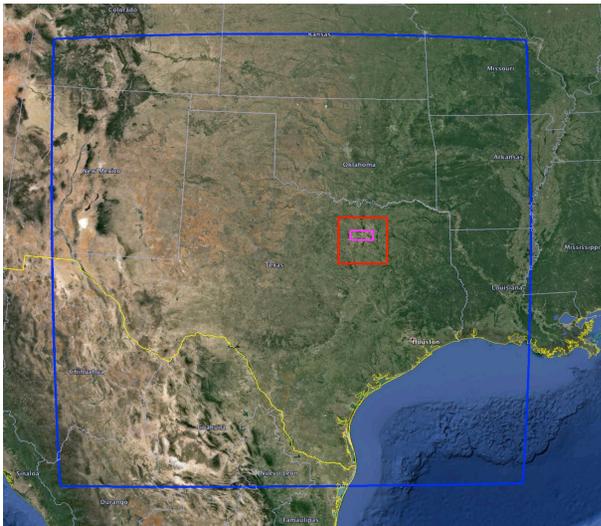
- WRF v3.5
 - “retrospective”, two configurations with changes to LSM and PBL schemes
 - “Urban” uses building effect parameterization (BEP; [Martilli et al. 2002](#))
 - Data from National Urban Database Access Portal Tool (NUDAPT) ([Ching et al, BAMS 2009](#))
- SMOKE v3.0
- CMAQ v5.0.1 CB05 with Aero6
 - Inline processing of elevated point sources
 - Advanced Plume Treatment (APT) ([Karamchandani et al, APR 2010](#); [Rissman et al, ACP 2013](#))

Datasets

- Emissions Dispersion Modeling System (EDMS) V5.1.3 for DFW airport sources
 - Includes jet, onroad and other stationary
 - Inventory developed using aircraft activity during landing and takeoff (LTO) cycles (< 3km) from airport radar data
- National Emissions Inventories (NEI) 2008 for others
 - Both anthropogenic and natural sources

Modeling Domains and Episodes

- Simulations for August 7-13, 2011 and February 5-12, 2012
- 12-4-1km nest for Dallas-Fort Worth airport region
 - WRF-CMAQ with NUDAPT has 50 layers, while others have 35 layers
- CMAQ Simulations
 - Run CMAQ @ 12/4/1 using 2 different LSMs with and without DFW emissions
 - Run CMAQ @ 12/4/1 using WRF-NUDAPT with and without DFW emissions



Dallas-Fort Worth Region

August 2011 Air Quality

O₃

AQS ID	Site Name	8/1/11	8/2/11	8/3/11	8/4/11	8/5/11	8/6/11	8/7/11	8/8/11	8/9/11	8/10/11	8/11/11	8/12/11	8/13/11	8/14/11	8/15/11	8/16/11	8/17/11	8/18/11	8/19/11	8/20/11	8/21/11	8/22/11	8/23/11	8/24/11	8/25/11	8/26/11	8/27/11	8/28/11	8/29/11	8/30/11	8/31/11
48_439_1002	Ft. Worth Northwest C13/AH302	54	65	64	55	50	45	45	36	45	41	41	39	31	39	56	47	53	52	54	61	60	54	50	56	82	81	86	87	73	66	58
48_439_2003	Keller C17	69	80	80	68	63	58	55	48	57	49	50	48	40	76	70	58	67	62	64	73	74	68	63	70	100	97	95	103	88	78	70
48_085_0005	Frisco C31/C680	86	80	92	78	65	61	54	52	62	47	42	45	43	68	77	57	68	67	71	79	65	73	70	71	91	92	78	89	83	76	72
48_139_0016	Midlothian OFW C52/A137	50	63	61	56	50	42	41	40	42	37	43	36	29	74	58	46	49	57	58	66	57	47	54	60	65	72	95	81	80	71	60
48_121_0034	Denton Airport South C56/A163/X157	73	86	86	77	62	62	59	52	54	53	45	48	44	70	74	61	70	60	67	72	74	76	63	66	102	87	81	98	90	76	71
48_439_3011	Arlington Municipal Airport C61	55	66	67	58	50	44	44	39	44	38	43	37	26	74	61	45	49	54	56	63	53	51	53	57	69	73	92	83	77	68	59
48_113_0075	Dallas North No.2 C63/C679	81	78	87	69	53	53	48	46	50	41	41	38	44	68	63	50	59	64	64	75	67	64	64	67	90	98	88	86	82	73	67
48_397_0001	Rockwall Heath C69	80	76	91	69	55	48	46	42	47	42	44	40	57	61	67	36	45	54	54	67	59	49	52	56	65	79	73	65	64	66	56
48_439_3009	Grapevine Fairway C70/A301/X182	71	83	86	73	60	NV	NV	NV	56	44	45	42	37	68	71	53	64	61	64	71	69	68	62	67	98	91	87	97	81	72	64
48_257_0005	Kaufman C71/A304/X071	58	65	65	57	60	54	44	36	40	42	41	41	47	60	60	54	50	56	60	66	65	50	58	52	62	76	81	68	73	74	64
48_221_0001	Granbury C73/C681	45	59	60	55	48	41	41	37	43	39	49	35	37	67	51	44	49	51	52	59	53	48	50	53	61	70	82	80	71	67	56
48_439_0075	Eagle Mountain Lake C75	55	70	67	59	53	49	48	37	45	47	39	38	36	74	59	49	59	52	55	62	65	59	52	56	84	75	79	85	73	63	58
48_367_0081	Parker County C76	52	67	69	63	51	50	50	41	49	47	58	39	45	70	72	55	61	58	59	67	68	59	56	61	84	78	88	93	82	72	63
48_251_0003	Cleburne Airport C77/C682	50	60	60	56	50	43	41	38	43	41	44	38	37	74	60	43	48	54	56	62	52	50	52	57	67	69	90	82	75	67	56
48_113_0069	Dallas Hinton St. C401/C60/AH161	70	75	75	61	52	48	44	41	43	35	41	33	34	68	59	45	40	52	55	67	60	55	55	58	79	88	90	84	76	66	58
48_113_0087	Dallas Executive Airport C402	60	70	69	55	48	41	40	37	42	34	41	32	30	69	58	44	47	55	59	67	58	51	56	57	71	78	96	82	82	73	63
48_231_1006	Greenville C1006/A198	70	67	80	64	52	49	46	38	44	36	41	45	38	67	74	50	54	61	65	71	64	54	58	59	73	83	77	73	66	76	66
48_121_1032	Pilot Point C1032	78	88	91	84	75	68	60	60	64	56	42	51	50	71	91	65	75	67	74	79	64	79	72	67	91	87	79	92	81	83	77
48_139_1044	Italy C1044/A323	43	54	56	52	44	38	33	37	36	35	43	33	34	58	57	47	46	55	57	66	57	49	53	59	62	NV	83	75	79	71	60
48_349_1051	Corsicana Airport C1051	54	64	61	56	58	51	40	37	39	42	43	38	27	64	61	53	57	59	61	67	58	57	59	57	63	69	84	70	76	78	66
AVERAGE		63	71	73	63	56	50	46	42	47	42	44	40	38	69	64	50	56	58	60	68	62	58	58	60	78	81	85	84	78	72	63

PM_{2.5}

AQS ID	Site Name	8/1/11	8/2/11	8/3/11	8/4/11	8/5/11	8/6/11	8/7/11	8/8/11	8/9/11	8/10/11	8/11/11	8/12/11	8/13/11	8/14/11	8/15/11	8/16/11	8/17/11	8/18/11	8/19/11	8/20/11	8/21/11	8/22/11	8/23/11	8/24/11	8/25/11	8/26/11	8/27/11	8/28/11	8/29/11	8/30/11	8/31/11
481130069	Dallas Hinton St. C401/C60/AH161	NA	NA	NA	NA	NA	7.9	NA	6.5	8.7	12.8	10.9	9.3	10.6	9.7	10.5	6.9	8.0	11.5	14.1	14.7	12.9	10.0	10.6	12.7	11.6	12.6	NA	14.3	16.1	14.7	16.9
481391044	Italy C1044/A323	8.8	10.8	9.8	7.4	5.8	5.1	5.0	6.3	7.5	13.1	11.5	8.8	9.0	9.9	8.5	6.7	7.4	11.2	11.5	13.5	10.9	7.4	9.0	9.4	8.5	10.3	13.1	11.0	14.6	13.2	14.0
482570005	Kaufman C71/A304/X071	11.8	11.6	10.5	7.8	6.7	5.6	5.0	5.4	7.5	13.9	11.4	9.0	9.6	7.8	9.7	6.9	10.0	13.4	13.3	14.4	13.2	10.9	12.5	11.5	10.5	12.5	18.8	13.1	16.7	18.2	25.0
483491051	Corsicana Airport C1051	12.9	13.1	11.6	12.1	9.0	7.2	6.8	7.7	11.0	20.9	15.9	12.2	10.6	12.5	13.3	9.2	11.8	17.0	15.7	16.0	11.6	10.7	12.3	12.2	9.9	14.2	14.4	11.9	16.8	16.0	NA
484391006	Greenville C1006/A198	11.0	13.0	12.5	9.3	5.5	5.8	5.6	6.2	9.2	13.1	13.5	11.9	9.7	12.0	11.5	8.3	9.3	13.7	13.0	13.6	13.5	9.5	10.9	11.0	12.5	13.6	15.8	15.1	16.3	13.8	15.0
484393011	Arlington Municipal Airport C61	8.7	11.4	11.5	7.9	4.9	6.3	5.5	5.4	7.8	12.5	13.0	10.1	12.3	11.0	8.4	6.3	8.6	10.9	12.9	15.3	13.3	9.0	10.8	11.5	10.3	9.6	14.7	11.8	15.0	12.3	14.3
AVERAGE		10.6	12.0	11.2	8.9	6.4	6.3	5.6	6.2	8.6	14.4	12.7	10.2	10.3	10.4	10.3	7.4	9.2	13.0	13.4	14.6	12.6	9.6	11.0	11.4	10.6	12.1	15.4	12.9	15.9	14.7	17.0

Not really an Air Quality Episode of Interest... but
 NASA had developed models of surface movement using aircraft activity data at DFW

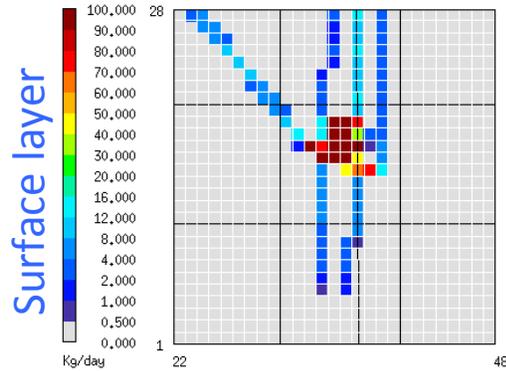
Elevated sources in Modeling Domain

Sector	Description	Number of elevated sources		
		12-km	4-km	1-km
airp_jet	airport aircraft and GSE	5,419	5,149	4,841
airp_st	airport stationary sources	56	56	56
ptcem	point source with CEM data	855	52	6
ptncem	point source without CEM data	26,499	1,319	292
ptseca	Off shore shipping	8,966	0	0
mexpt	Mexico point source	190	0	0

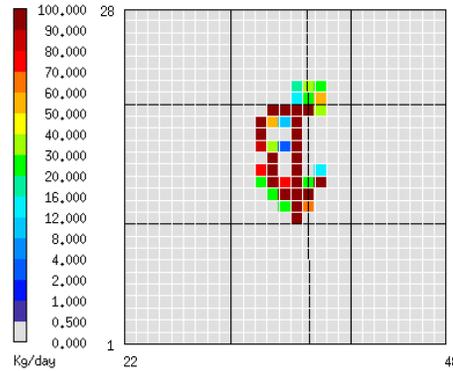
- CMAQ with Advanced Plume Treatment (APT) for subgrid scale treatment is typically applied for 100-200 major elevated point sources
- In this application, we modeled every aircraft from DFW airport as an individual source for subgrid scale processing by APT

Emissions Allocation in 1-km Domain

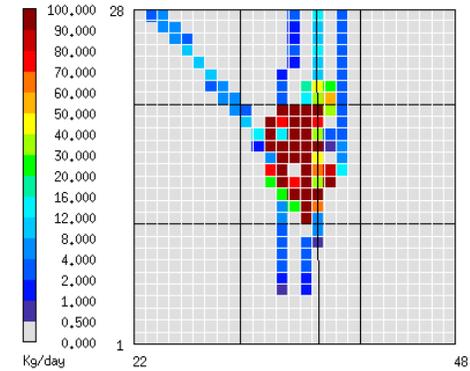
August 9, 2011



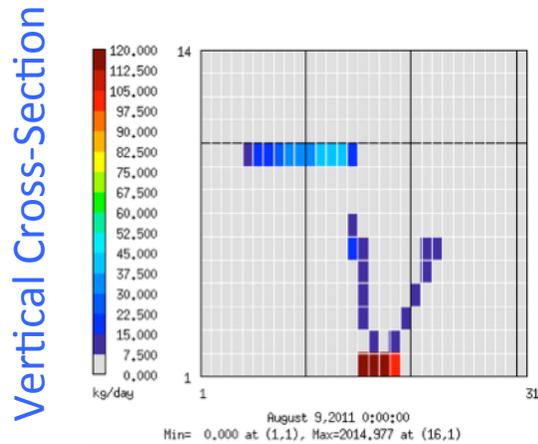
Aircraft Sources



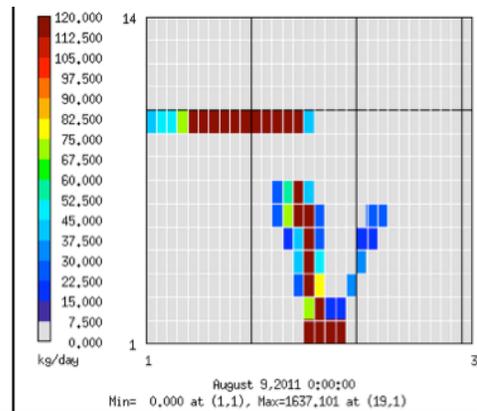
Onroad Sources



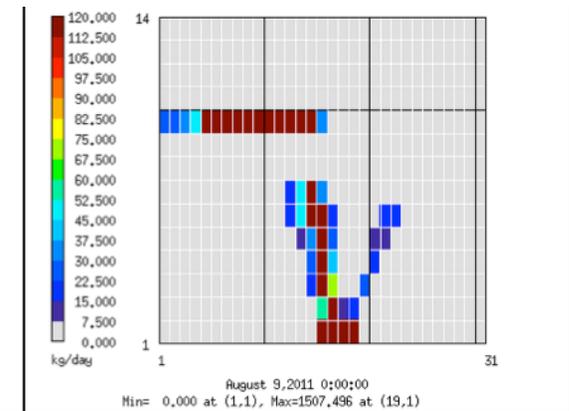
All Airport Sources



Western Runway cross-section (CO)

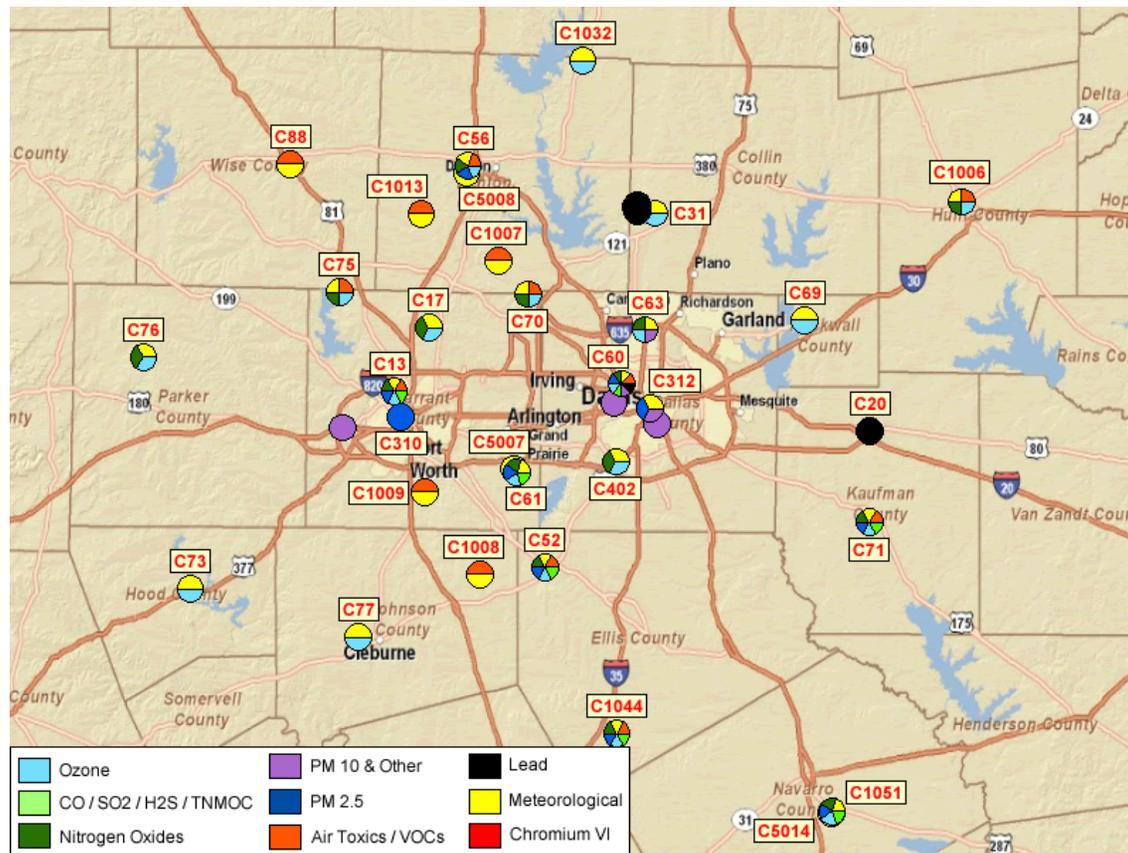


Western Runway cross-section (NOx)



Western Runway cross-section (PM2.5)

Ambient Monitors in DFW Region

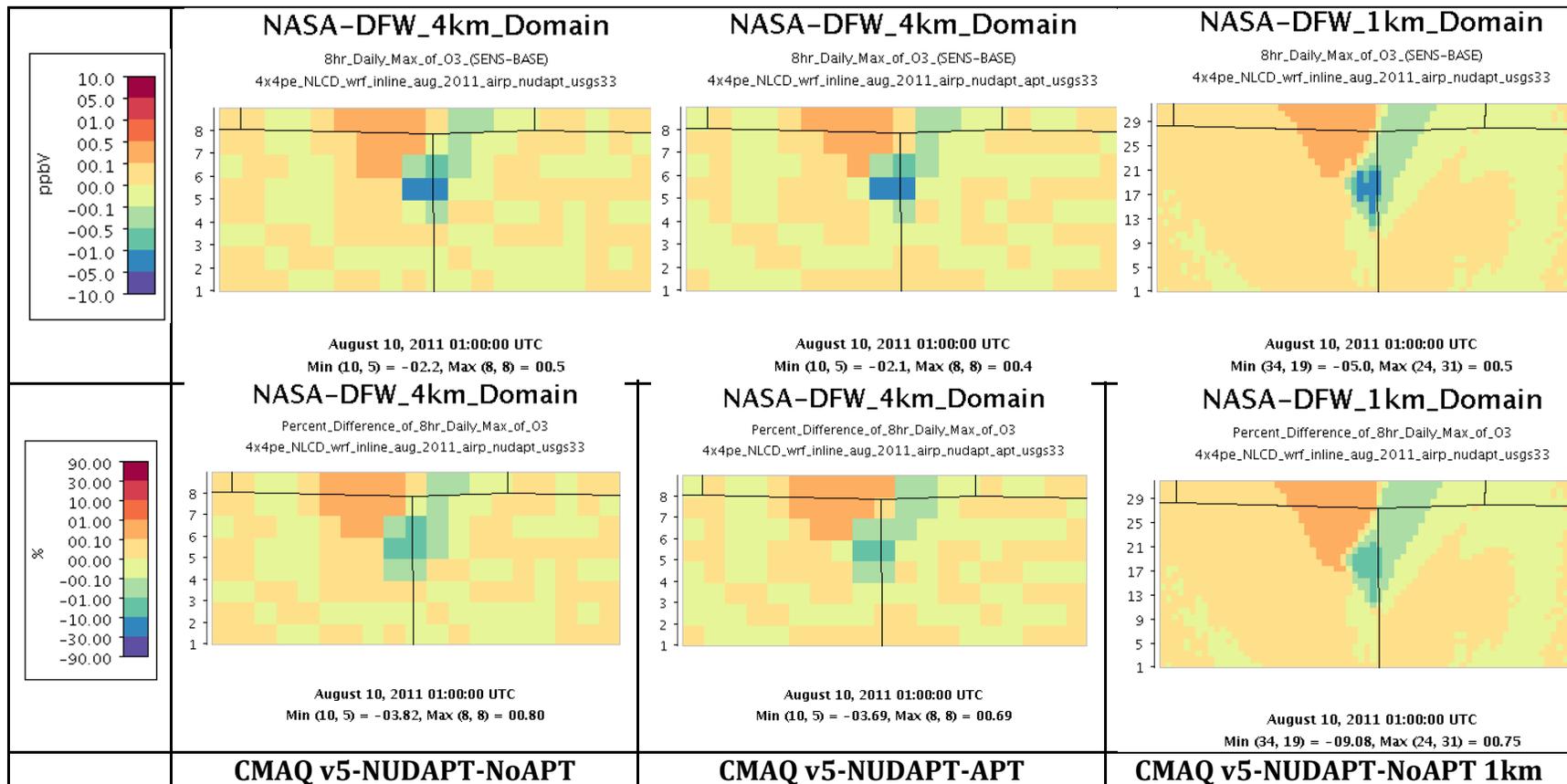


of AQ Monitors

	12-km	4-km	1-km
CO	28	3	2
NOx	64	12	5
NOy	10	2	1
NO2	63	12	5
O3	140	16	5
PM25	70	5	2
NO3	9	1	1
NH4	10	1	1
SO4	10	1	1
Actual Monitors	187	17	6

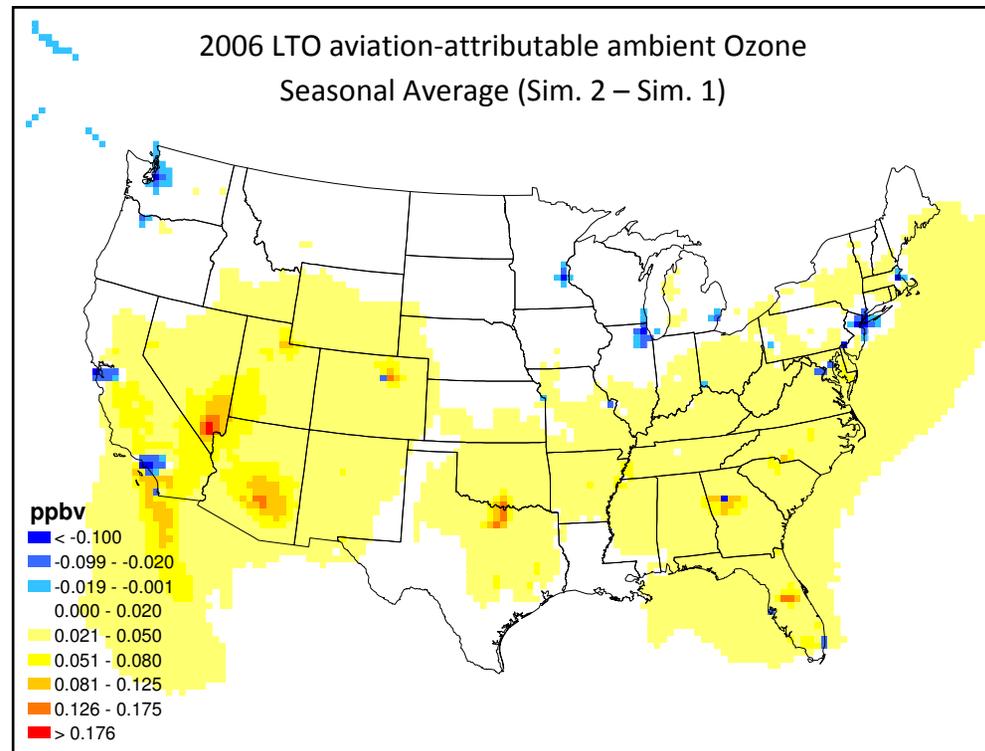
DFW Impacts on Daily Max 8-h O_3

August 10, 2011



NUDAPT @ 1km shows clear depletion of O_3 from DFW airport operations

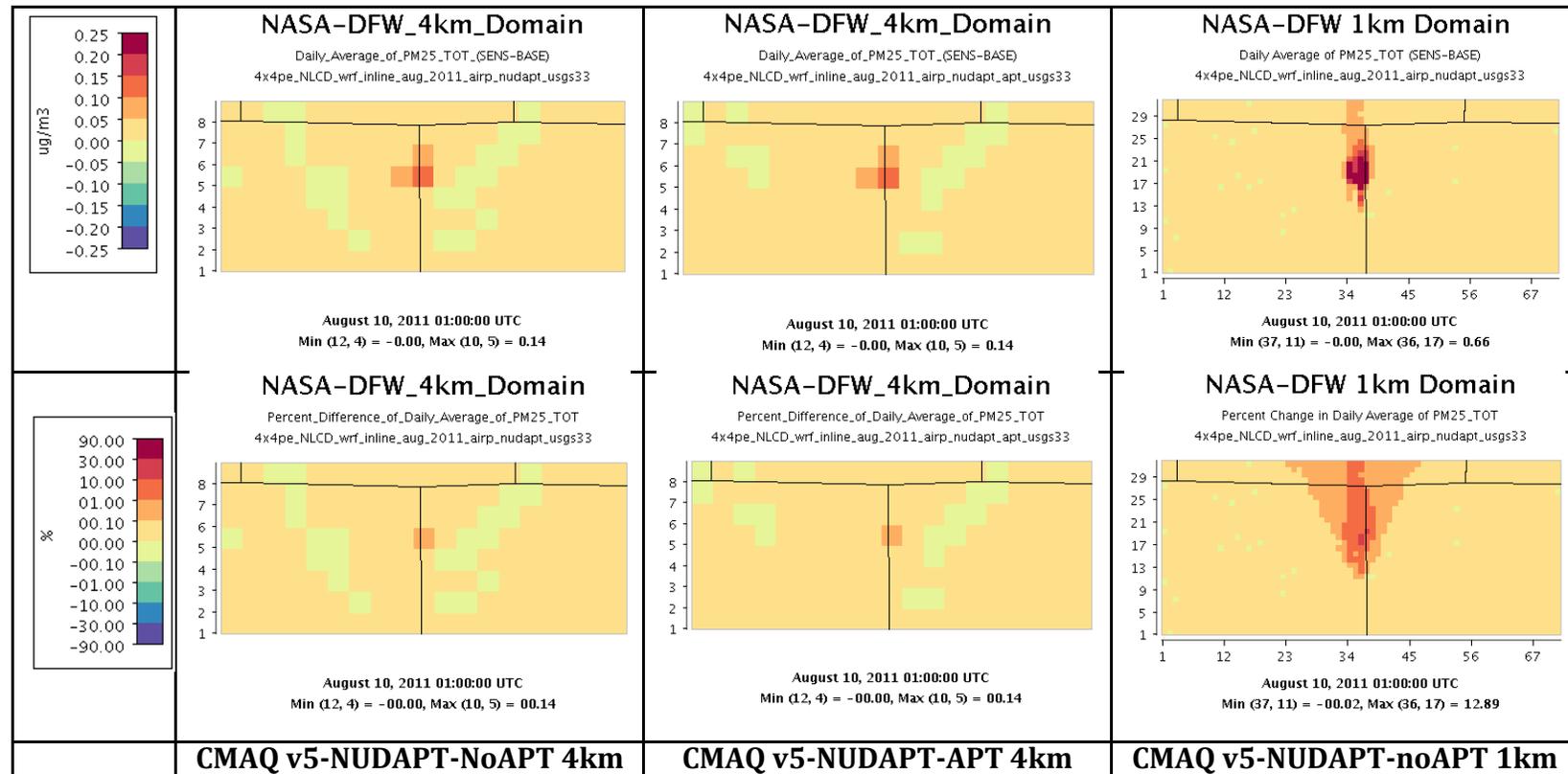
Airport Emissions Impacts on O₃



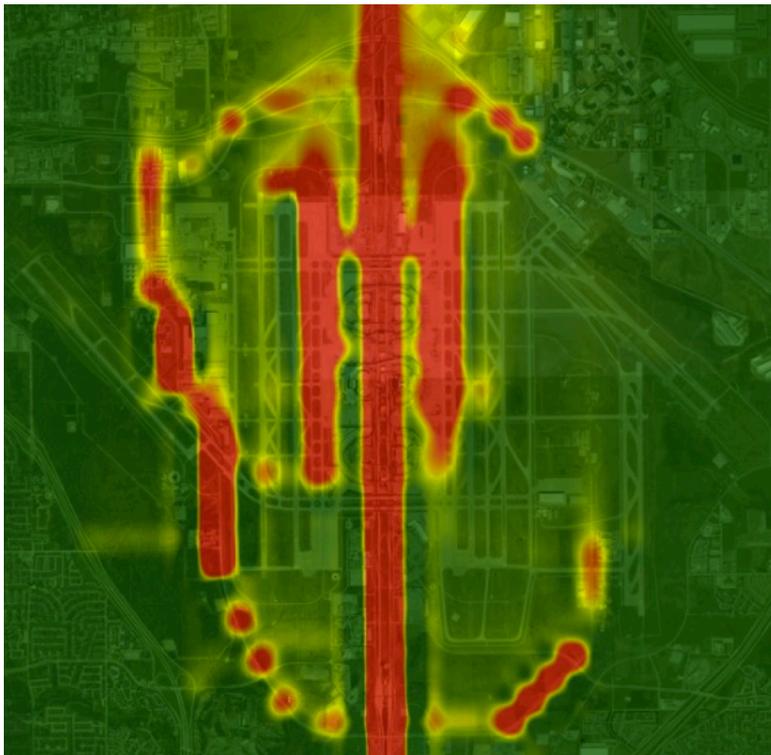
Source: Energy Policy Act Study, 2010

Aircraft NO_x emissions titrate O₃ levels around airports in large urban areas such JFK, LAX, ORD, etc.

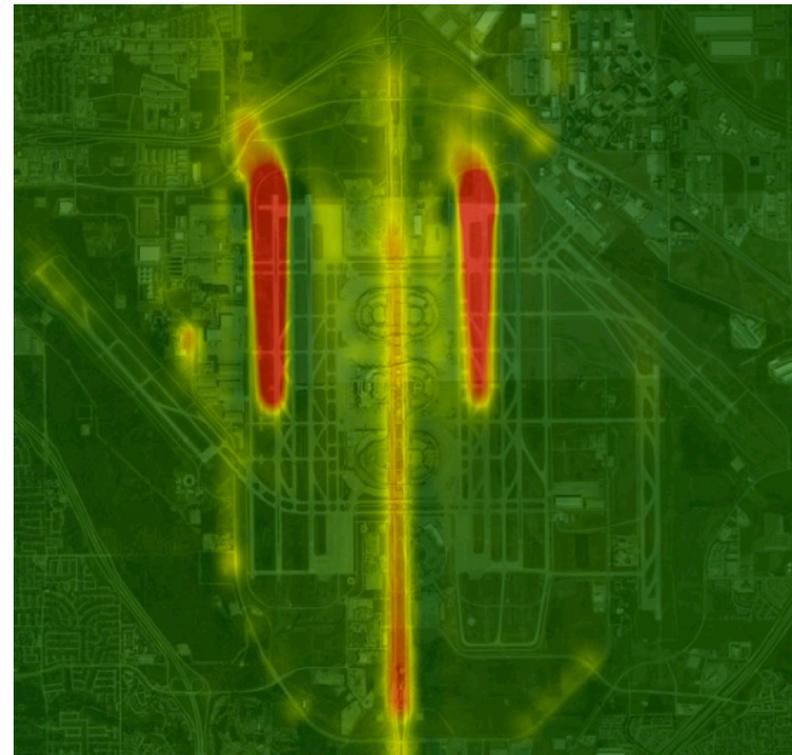
DFW Impacts on Daily Ave PM_{2.5} August 10, 2011



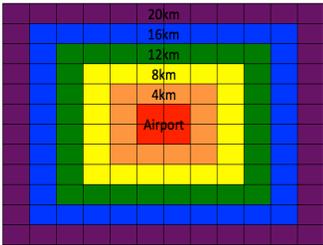
Subgrid Scale Analyses



CO

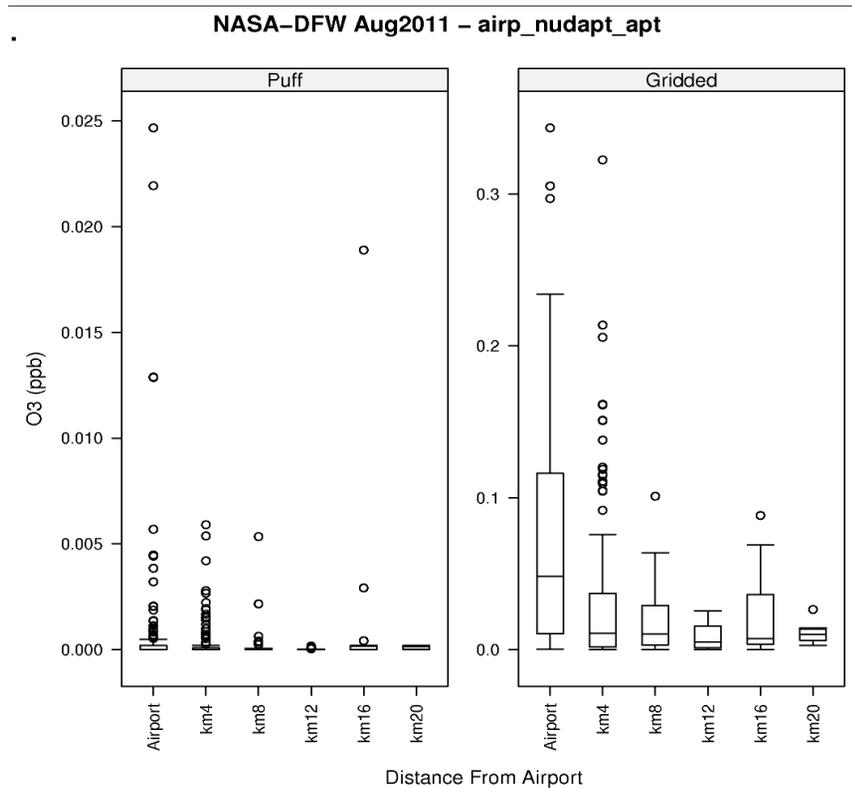


NO₂

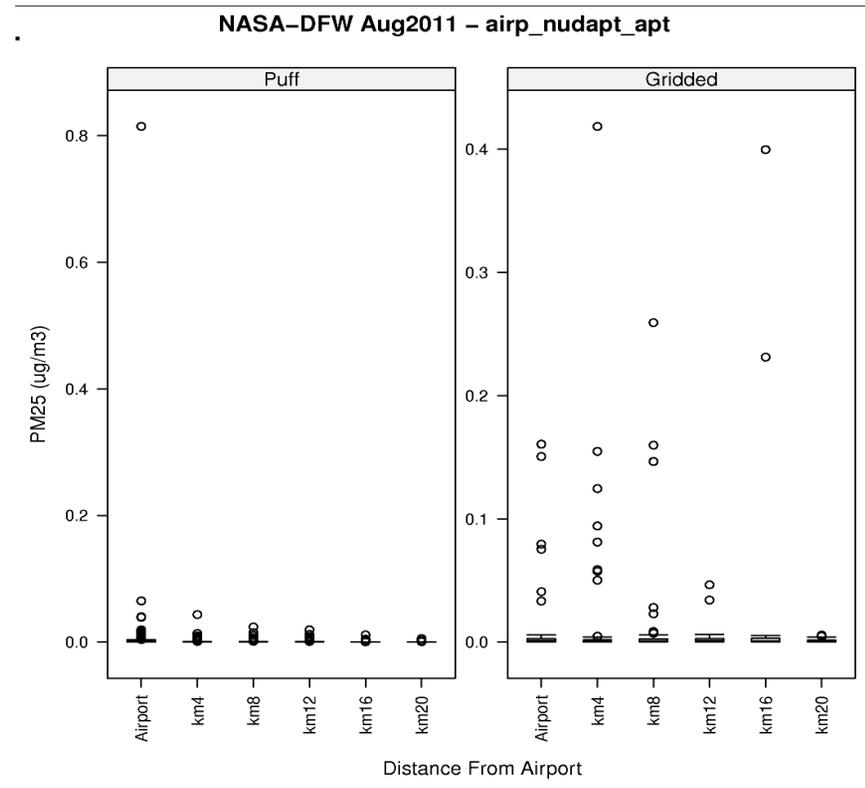


Puff vs. Grid-based Impacts

August 2011



O₃



PM_{2.5}

Max puff concentrations higher than those in grid-scales for PM_{2.5}, by 1-3x, but not for O₃
 Similarly, higher impacts of 1-3x seen in puffs for CO and NO₂ too (not shown)

Summary

- New WRF-NUDAPT modeling system enhances detailed characterization of urban morphology, leading to potentially improved meteorological fields to drive AQ model
- CMAQ using WRF-NUDAPT @1-km showed improved characterization of DFW airport emissions than using CMAQ-APT @ 4km
- Highest impacts of DFW emissions were confined to a radial distance of 4 to 12km from the airport for most pollutants
 - Non-significant impacts seen as far as 50-100 km for secondarily formed pollutants
- Enhanced capability to model air quality at airport – both at gate-level and at downwind distances at 10s and 100s of kms
 - But this comes at a computational cost

Future Work

- Pick different AQ episode with higher observed concentrations for O_3 and $PM_{2.5}$
- Refine WRF-NUDAPT application to improve model performance
- Explore optimizing # of aircraft sources to reduce model runtimes without decreasing fidelity
- Model sensitivity scenarios for alternate flight patterns at airport to study changes in local AQ
- Automate entire suite of modeling tools to enable coupling with NASA's tools

Acknowledgements

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