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An integrated modeled and measurement-based assessment of particle number concentrations from a major US airport

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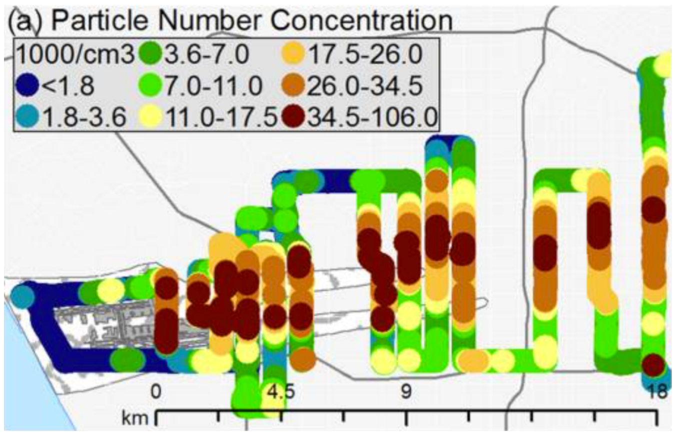
Particle number concentration (PNC) at downwind of airport

PNC at LAX Airport



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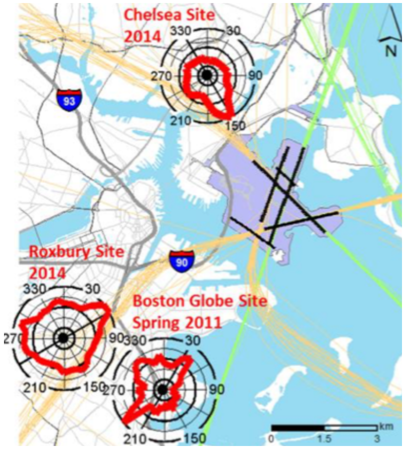
PNC at BOS Airport



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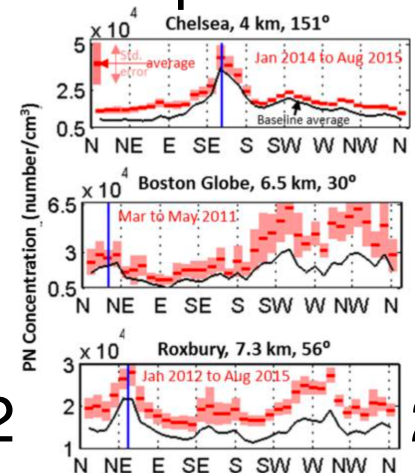

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- Measurements show particle number concentration (PNC) increases 4 to 5 fold at 8-10 km downwind of LAX[1] and 1.33 to 2.33 fold at 4-5 km downwind of BOS[2] airport.
- Dispersion modeling of PNC will be helpful to better quantify LTO attributable PNC increase at nearby spatial locations.
- Dispersion modeling with multi-component chemistry and aerosol microphysics can give aircraft attributable PNC at high resolution spatial locations.

1. Hudda et al., 2014, Environ. Sci. Technol., 48, 6628–6635
2. Hudda et al., 2016, Environ. Sci. Technol., 50, 8514–8521

Motivation and objective

- Estimation of aircraft's landing and take-off (LTO) attributable PNC near surrounding areas of airport is important for health effect study.

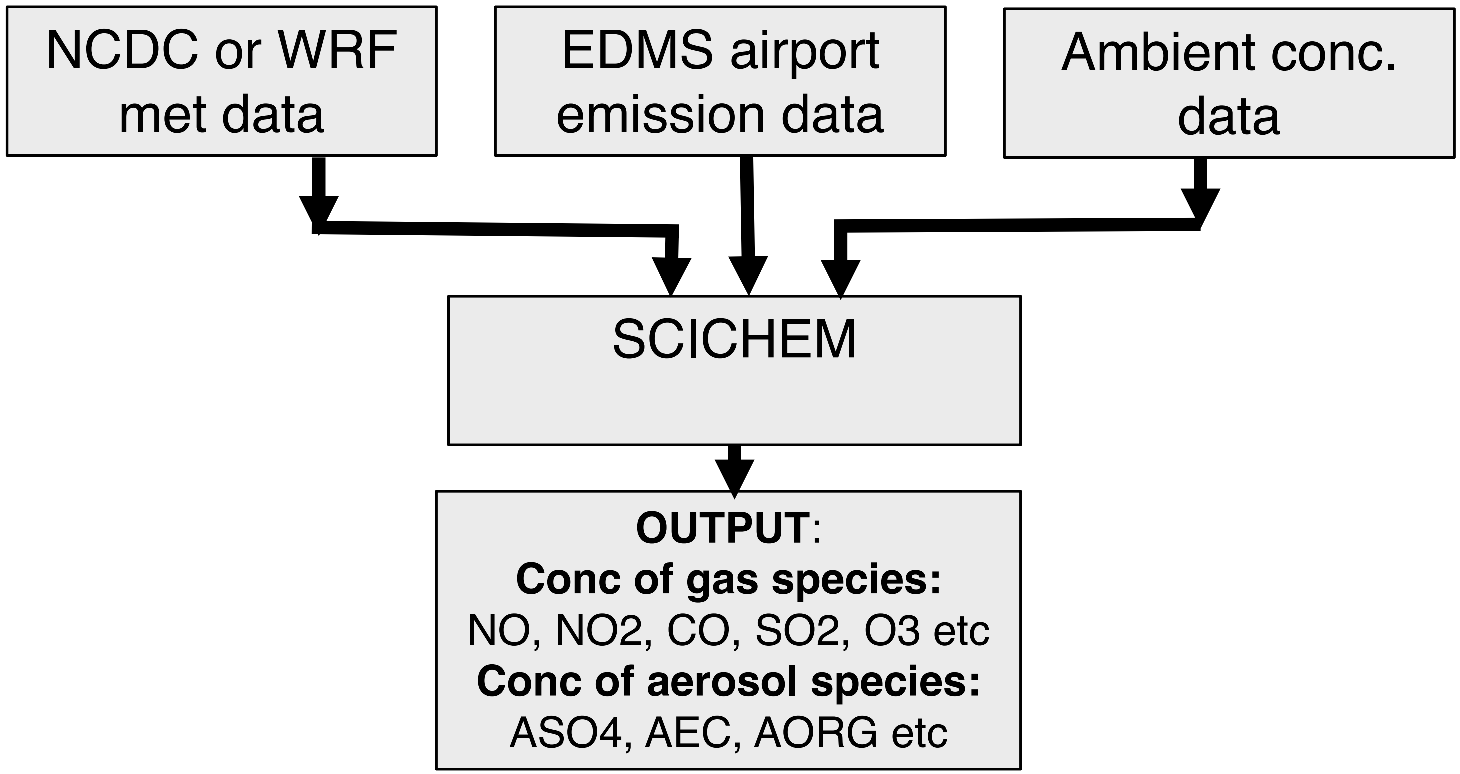
- It is important to know how PNC changes by emission, nucleation, coagulation, deposition and advection by aircraft's LTO emission.

- **Objective:** Estimation of **aircraft's** LTO attributable **PNC** at high resolution spatial locations surrounding Boston Logan International Airport (BOS) **by** the Second-order Closure Integrated Puff model with chemistry (**SCICHEM**[3]) dispersion **model** by:
  - **Single component simulation without chemistry and aerosol microphysics**
  - **Multi-component simulation with chemistry and aerosol microphysics**

  Then compare results with Boston University's PNC measurements.

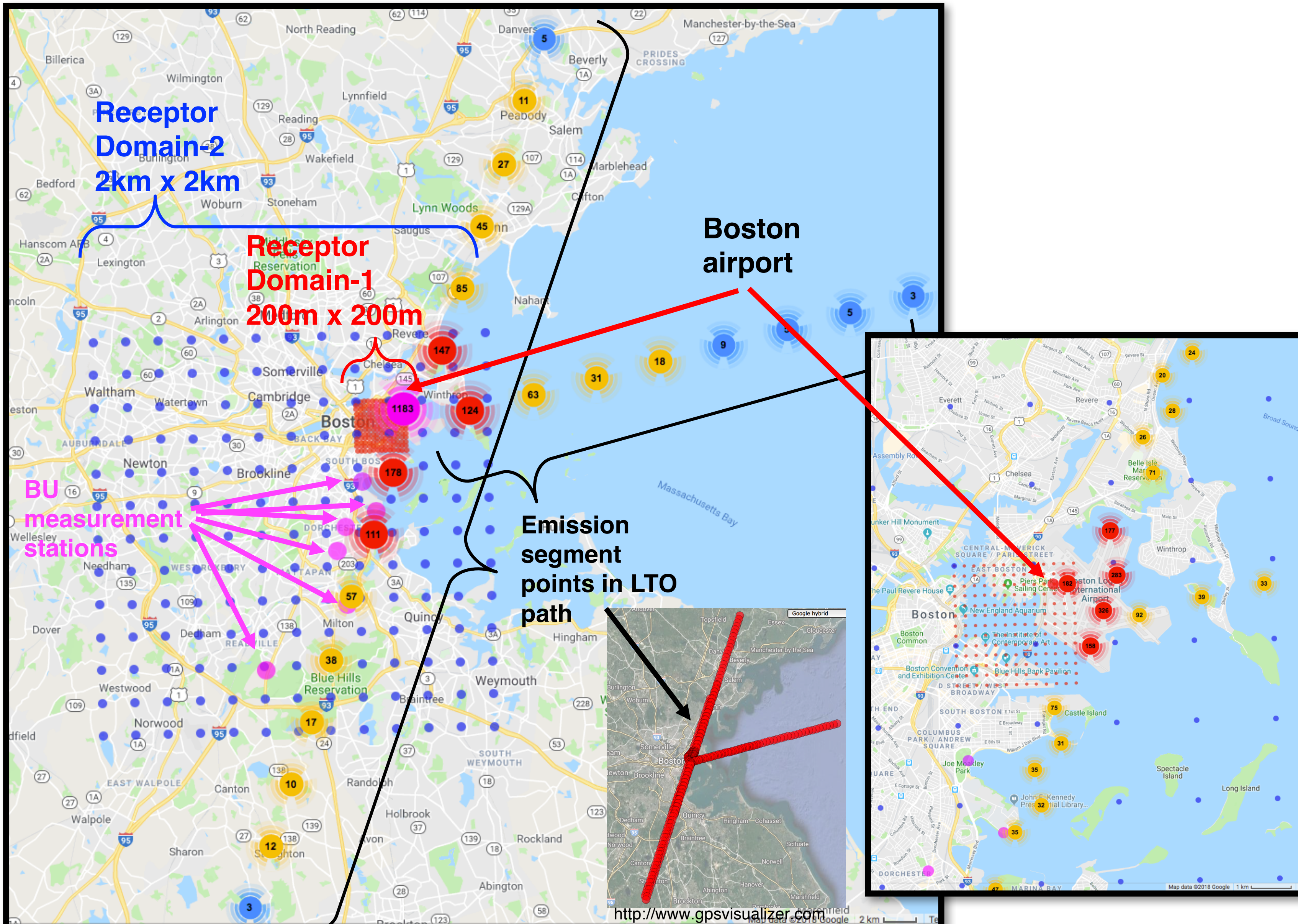
3. Chowdhury et al., 2015, Atmos. Environ., 117, 242–258

Methods: SCICHEM dispersion model



- Model domain :
  - Ymin=300 km, Ymax=420 km, Xmin=4619 km, Xmax=4785 km (UTM)
- Emissions : 959 segmented area emission sources at the ground
- Simulation day and duration : July 13, 2017, 6 hours

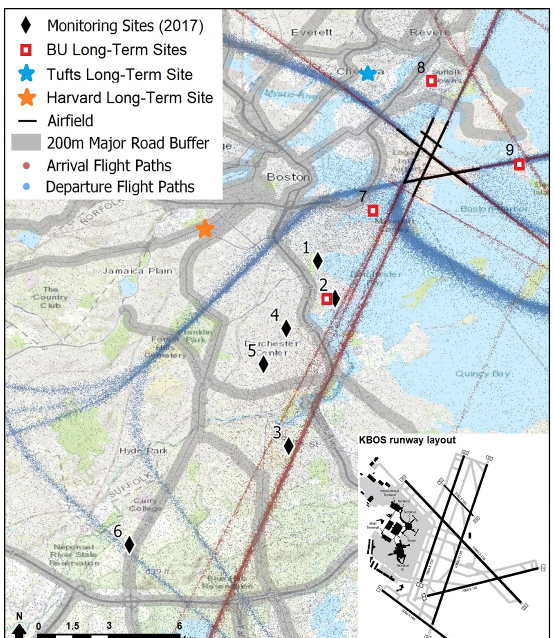
Modeling domain and emission sources



https://mapmakerapp.com

Boston University Measurement Set-up

- 6 Monitor sites along the runway 4R/4L
- Measured High-quality UFP at 1 Hertz
- Measurement period: April- September 2017
- Measured at three sites simultaneously for one week at a time, rotating among six locations



BU measurement stations

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Sample Size (days)	67	71	57	61	57	62
Location	2nd Floor	Ground	2nd Floor	Ground	Ground	Ground
Nearest Runway	4R	4R	4R	4R	4R	4R
Distance to Runway (km)	4.0	4.9	10.8	6.7	8.2	16.6
0.1st PCTL	800	1,100	1,600	2,500	2,000	1,800
1st PCTL	1,000	2,900	2,500	5,100	2,900	2,500
5th PCTL	4,300	5,800	4,300	8,200	5,700	4,300
50th PCTL	14,100	16, 600	11,600	20,600	17,100	12,000
95th PCTL	55,600	63,000	28,000	67,900	47,100	31,400
99th PCTL	116,800	119,200	47,400	103,200	70,700	50,500
99.9th PCTL	180,200	206,600	87,500	150,800	96,500	95,800

PNC (#/cc) distribution at monitor sites at 6 stations

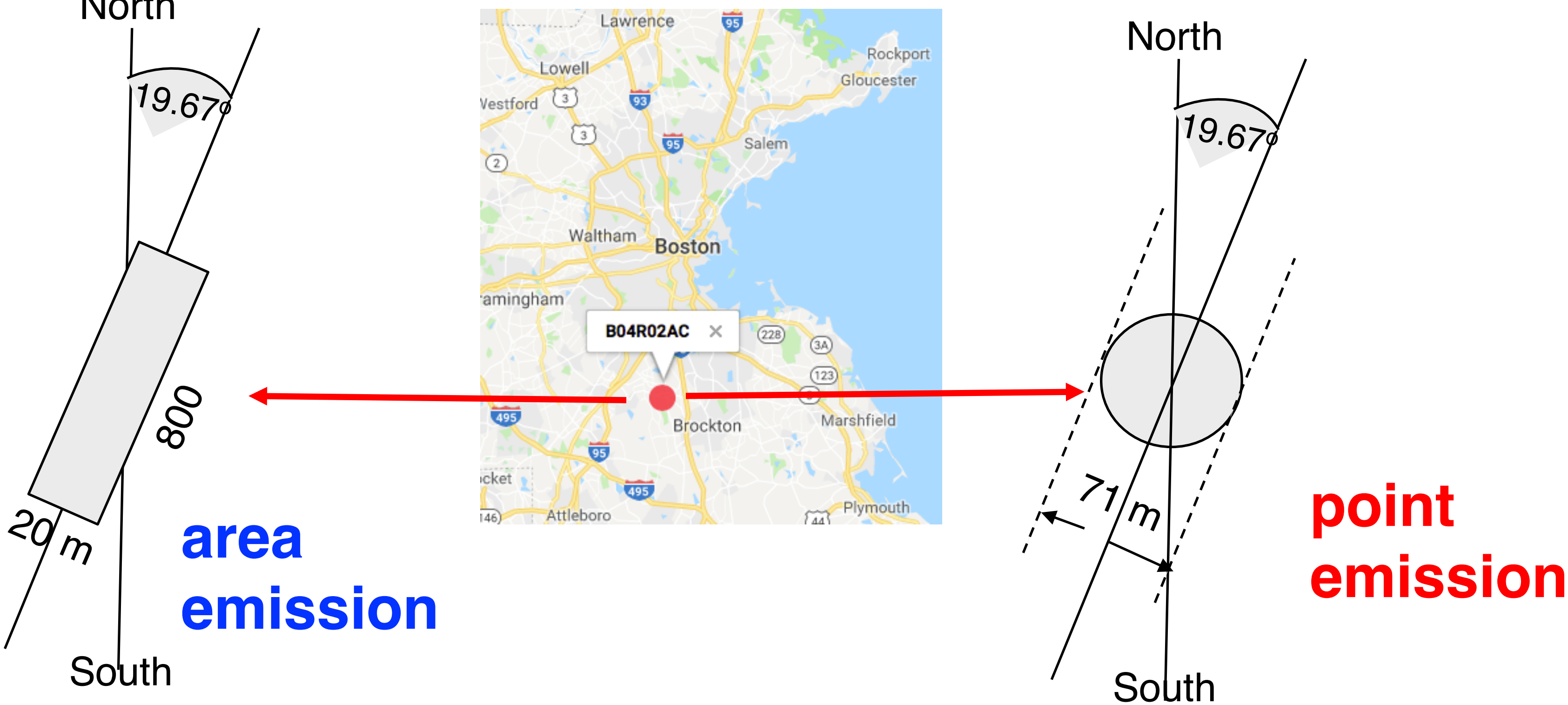
Details of a Single Emission Segment

EDMS area emission segment details:

Segment name = B04R02AC
Release height (m) = 877.45
Length of X side of the area (m) = 20.0
Length of Y side of the area (m) = 800.00
Angle = 19.67 (clockwise from North)
Emission of CO at 01 EST (g/m2-s) = 1.04E-11

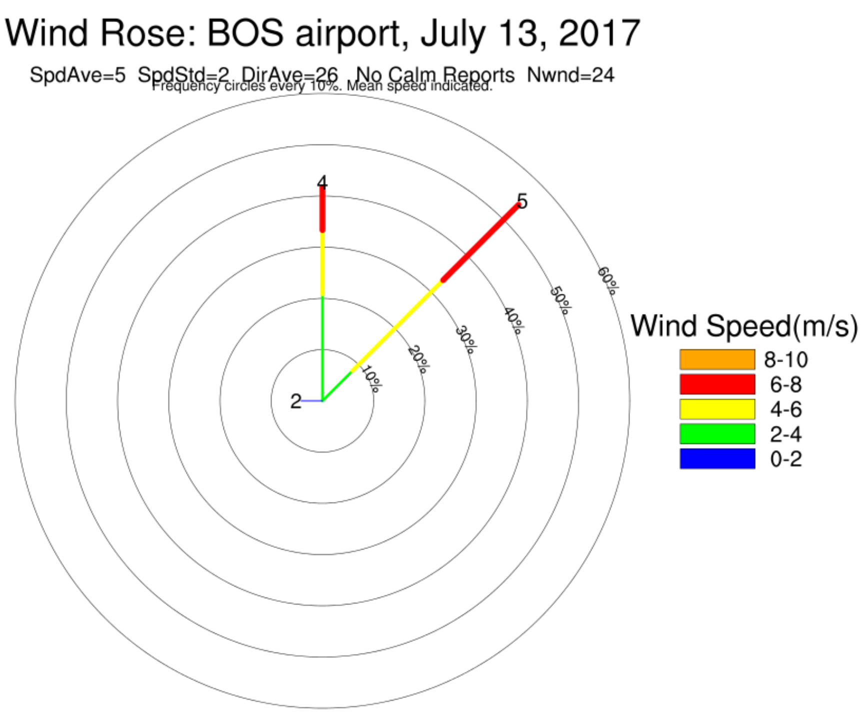
Equivalent point emission details:

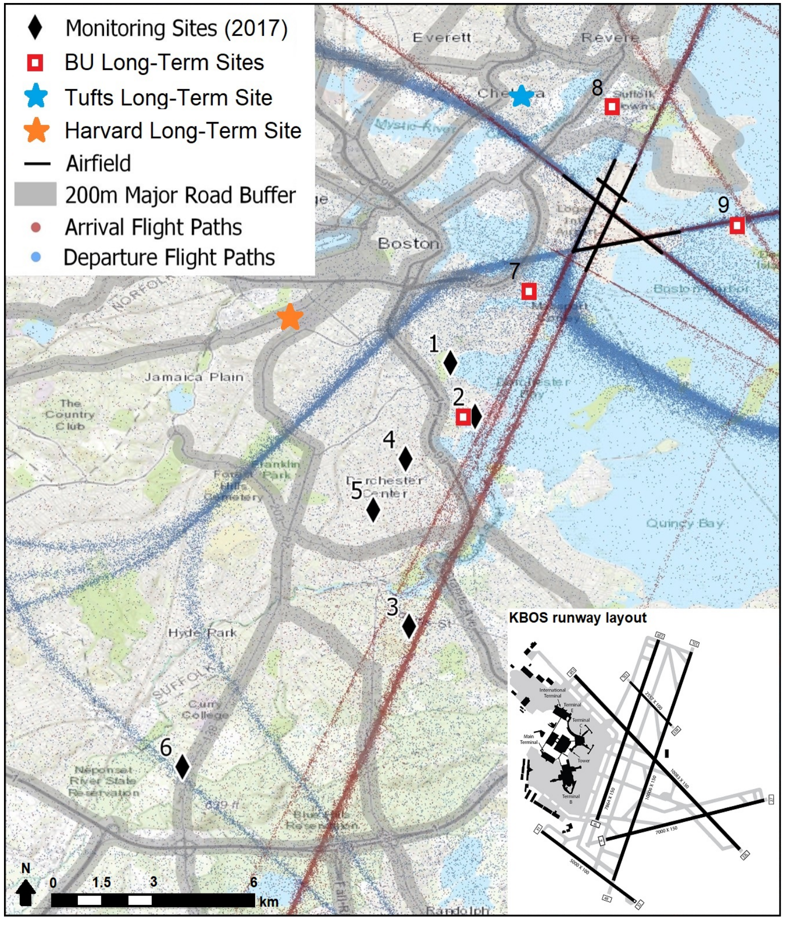
Segment name = B04R02AC
Release height (m) = 877.45
Equivalent Dia (m) = 71.3 (surface area equiv.)
Emission of CO at 01 EST (g/s) = 1.67e-007



- **Area emission has advantages as it does not need stack dia, temp. and velocity**
- **Area emission has been used in single-component run, and point emission will also be explored in multi-component run**

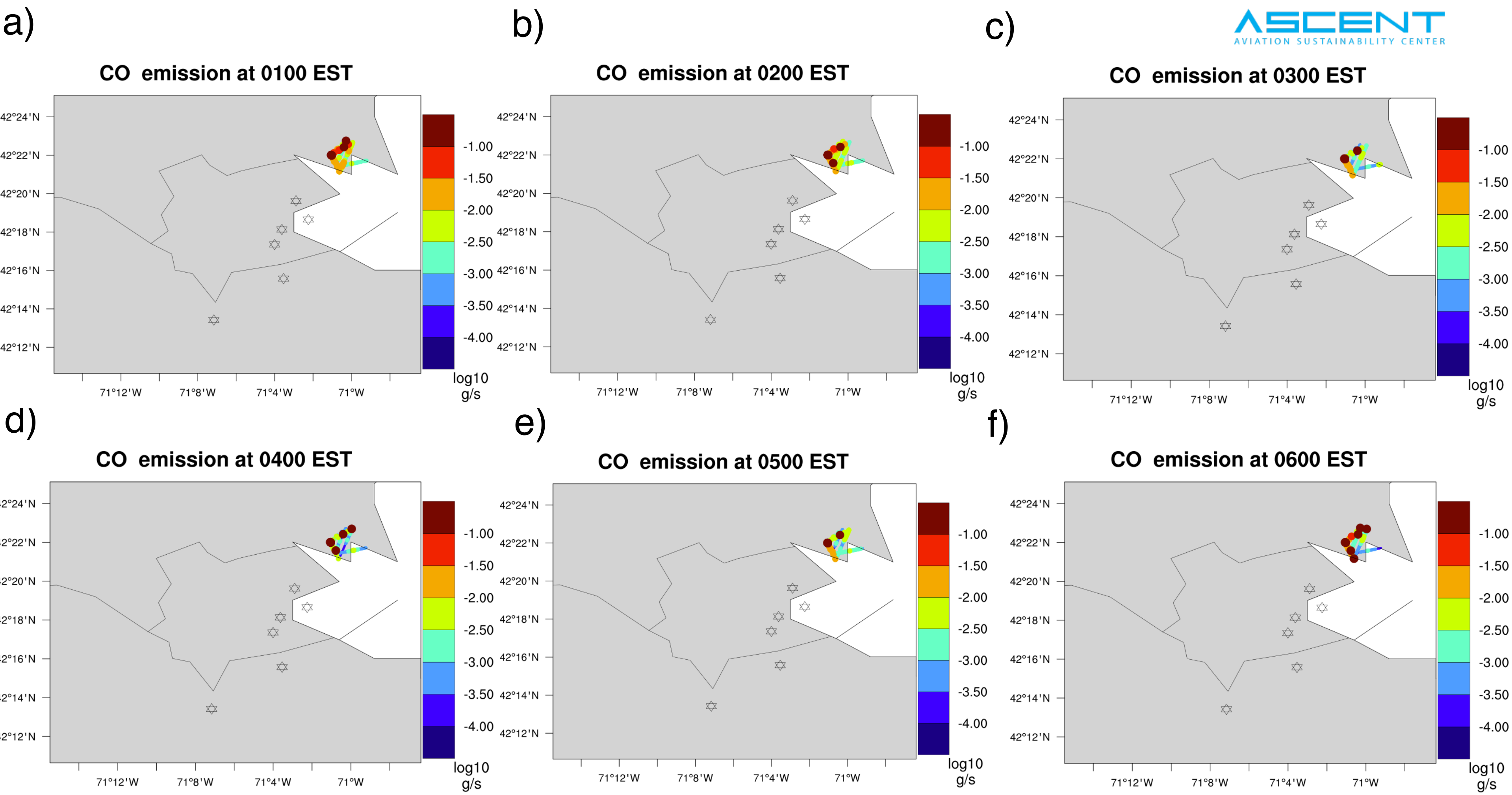
Wind profile on simulation day : July 13, 2017





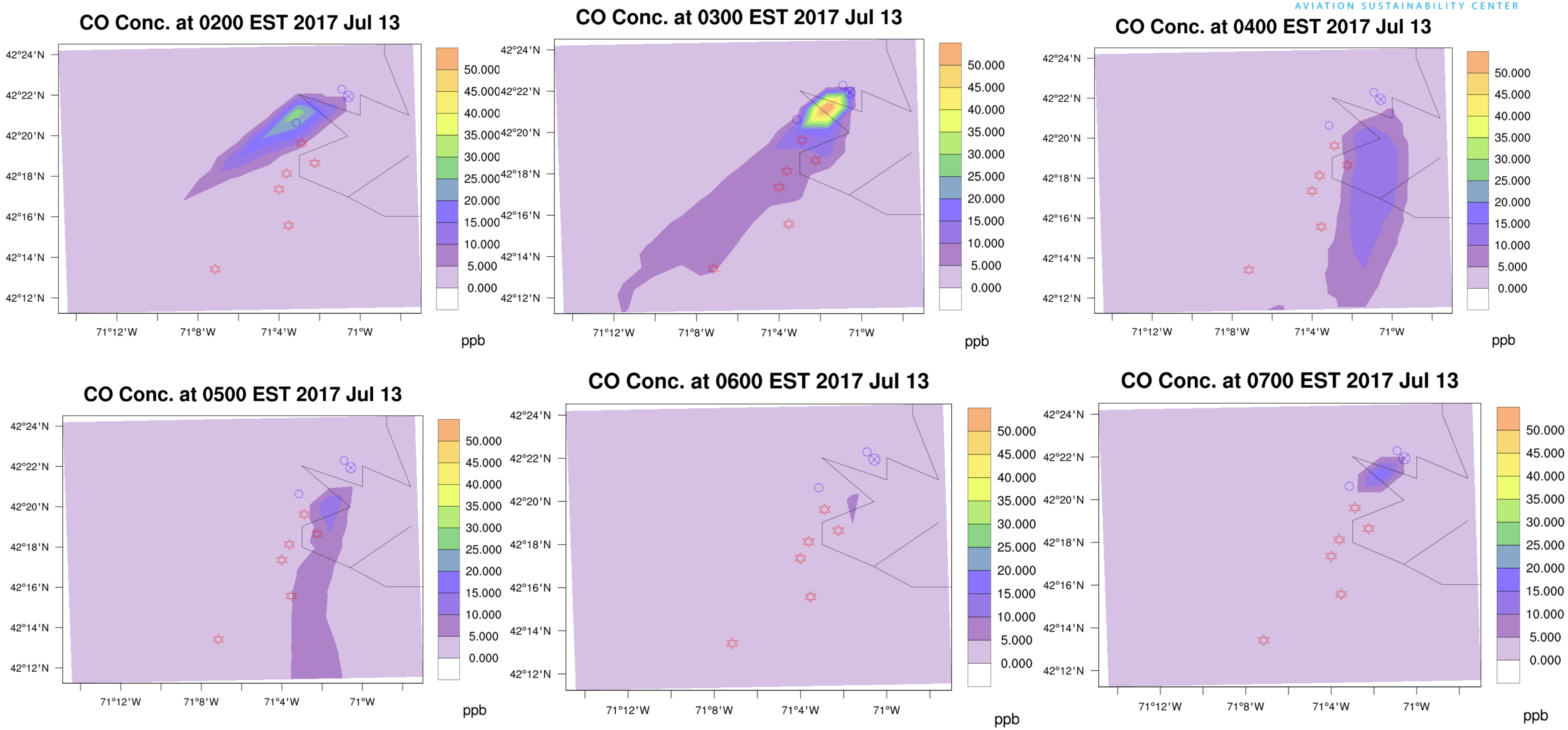
- ❑ **North-easterly wind will bring plume to BU measurement stations**
- ❑ **Hence, simulation day is chosen July 13, 2017 because it has North-easterly and Northerly wind over BOS airport**

Emission of CO from Boston Airport at 6 hours



- Emissions were from EDMS's Feb 19, 2015 emission data which was time shifted to simulation day July 13, 2017
- Each dot represents an area-emission-source segment
- Emissions start increasing 0600 EST

Simulated Airport ground emission attributable CO at 6 hours without chemistry



- ❑ **Aircraft's LTO attributable CO can be seen on the map.**
- ❑ **Plume travels along the wind (North-easterly and Northerly wind)**
- ❑ **The simulation is computationally demanding : 6 hours computation time for 1 hour simulation**
- ❑ **Number of puffs increases ~140k to 386k in 6 hours**

4. Arunachalam et al. 2018, ACRP Report , .

Multicomponent-run : Modeling PNC in SCICHEM: by simple method

- Neglecting nucleation and coagulation, PNC of the i^th mode can be approximated using the volume (mass) concentration of aerosol species in the post process by this equation (Binkowski 2003):

$$N_i = \frac{M_{3,i}}{D_{g,i}^3 \exp\left(\frac{9}{2} ln^2 \sigma_{g,i}\right)} \qquad (1)$$

Where N_i = Particle number concentration of i^th mode (#/cm3)

$M_{3,i}$=3^rd Aerosol moment (Total volume concentration) of i^th mode (cm3/cm3)

$D_{g,i}$=Geometric mean diameter of i^th mode (cm)

$\sigma_{g,i}$=Geometric standard deviation of i^th mode

- $D_{g,i}$ and $\sigma_{g,i}$ will be used in Eq. 1 based on the near source observation (Whitby 1978)[5]

	Aitken	Accumulation	Coarse
$D_{g,i}$ (μm)	0.03	0.3	6
$\sigma_{g,i}$	1.7	2	2.2

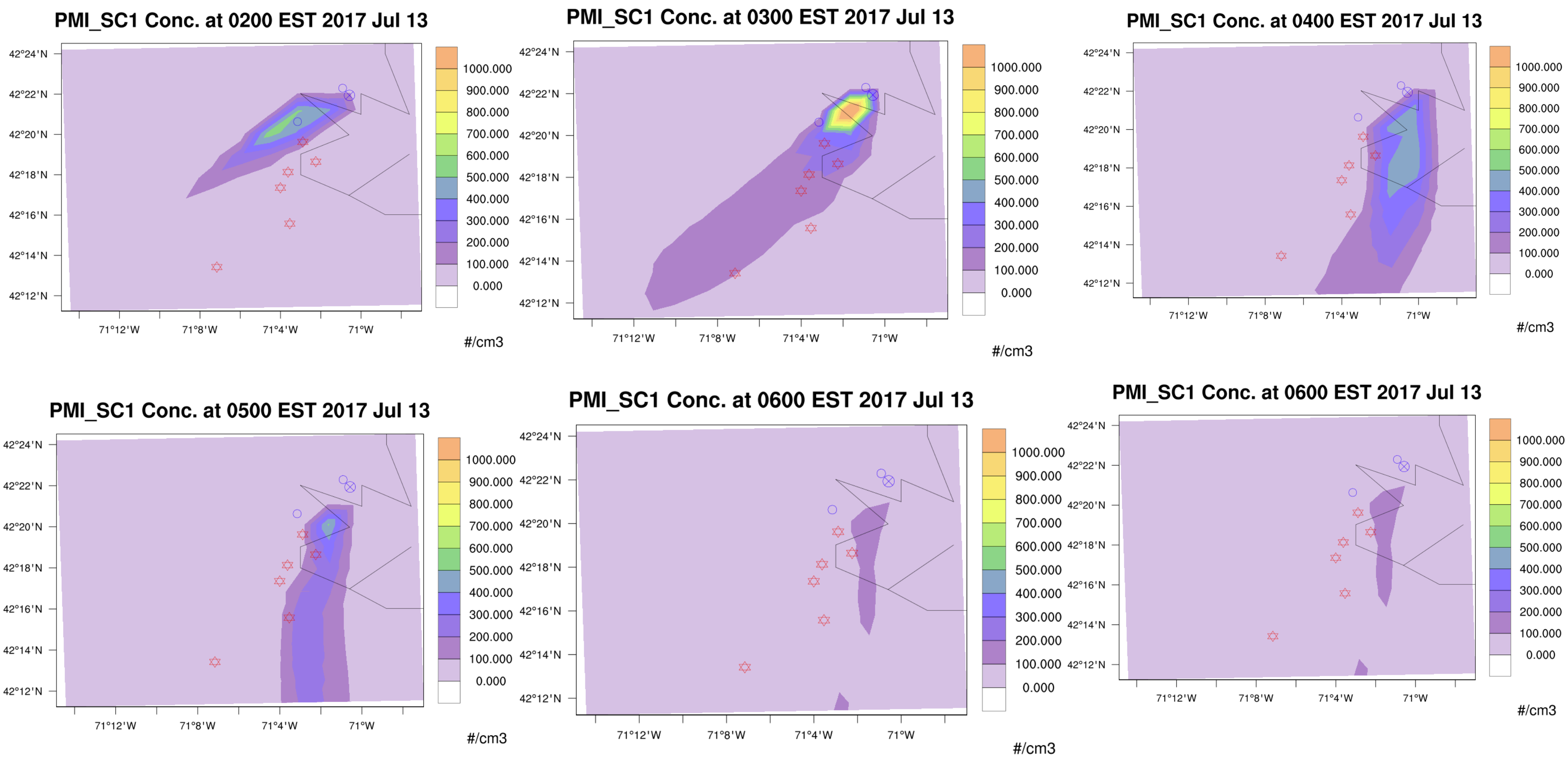
SCICHEM's single component run gives $M_{3,i}$ which will give N_i

4. Binkowski, and Roselle, J. Geophys. Res., 108, 4183–4201, 2003.

5. Whitby, K. T., The physical characteristics of sulfur aerosols, Atmos. En- viron., 12, 135–159, 1978.

Simulated Airport ground emission attributable PNC at 6 hours without chemistry

PNC_I = Aitken mode PNC (ASO4_I + AORG_I + AEC_I which is 91.8% of total PM emission



- Domain maximum PNC in plume were ~1400 #/cm3 at 0300 EST
- Inclusion of nucleation will increase the number

Multicomponent-run : Modeling PNC in SCICHEM: by detailed moment model

- Particles are assumed to follow a log-normal size distribution having 3 modes[4] :
  - Aitken mode : particle diameter from 0 to 0.1 μm
  - Accumulation mode : particle diameter from 0.1 μm to 2.5 μm
  - Coarse mode : particle diameter greater than 2.5 μm
- Moment-based algorithm of Binkowski and Roselle (2003)4 will be used in SCICHEM model to estimate PNC
- SCICHEM will track the 0^{th} (number concentration), 2^{nd} (surface area concentration), and 3^{rd} (volume concentration) moments of all three distinct population modes (Aitken, Accumulation and Coarse modes) [4].

4. Binkowski, and Roselle, J. Geophys. Res., 108, 4183–4201, 2003.

Summary

- ❑ Aircraft's LTO attributable Particle number concentration (PNC) for Aitken model particles and CO have been simulated in a 2 km x 2 km domain around BOS airport by SCICHEM model.

- ❑ PNC and CO concentrations increases along the plume trajectory

- ❑ Most pollutant comes from the terminal at the ground

- ❑ Airport ground emission attributable maximum Aitken mode PNC were found to be ~1400 #/cm3 during a 6 hour period in night time without chemistry and aerosol microphysics at a grid point in a 2x2km domain towards the wind direction.

Future work

❑ Estimation of PNC by detailed aerosol microphysics (nucleation and coagulation) and multi-component chemistry
❑ Compare source-based dispersion model results with BU's regression model that will be developed for PNC at BU for BOS airport
❑ Improve point source treatment

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Thank You

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Reference

1. Hudda et al., 2014, Environ. Sci. Technol., 48, 6628−6635
2. Hudda et al., 2016, Environ. Sci. Technol., 50, 8514−8521
3. Chowdhury et al., 2015, Atmos. Environ., 117, 242−258
4. Binkowski, F. S. and Roselle, S. J.: Models-3 Community Multi- scale Air Quality (CMAQ) model aerosol component. 1. Model description, J. Geophys. Res., 108, 4183–4201, 2003.
5. Whitby, K. T., The physical characteristics of sulfur aerosols, Atmos. Environ., 12, 135–159, 1978.