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Source Attribution of Attainment and Exposure-Based Ozone Metrics

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Outline

- regulatory standards
- sensitivity methods
- adjoint response of policy metrics:
  - attainment
  - exposure

Ozone Standards

threshold-based standards are devised to protect public health

- design value = fourth-highest concentration measured in a year, averaged over 3 years, not to exceed 75 ppb (65 in Canada)
- daily maximum 8-hr average

Attainment

all locations have equal weighting

versus Exposure Metrics

locations are weighted by population

e.g. mortality, health “damages”

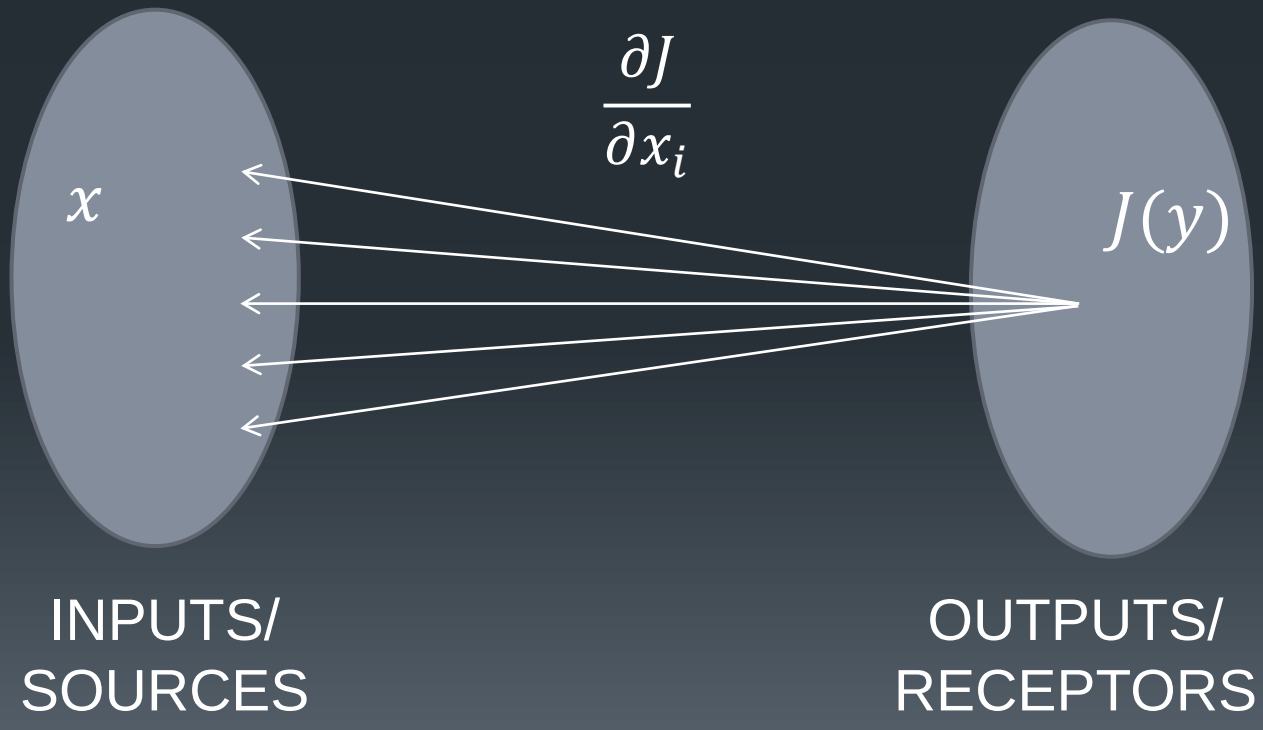
…and thus different responses to emission controls

An ideal regulatory approach would differentiate between source impacts

preferential targeting of the most “damaging” emissions

Adjoint Sensitivity Analysis

where influences come from



Adjoint Cost Functions

1. “probabilistic” attainment metric
2. exposure metric

Possible Cost Functions

- 4th-highest simulated concentration
- probability of non-attainment
- probability-weighted concentrations

Adjoint Cost Function (1)

Attainment

- average design value ($C_{4\text{-highest}}$ > 65 ppb) in Canada & U.S.

$$J = \frac{1}{N_{i,j}} \sum_{i,j} \left(\frac{1}{P} \sum_{t=1}^{92} P_t C_t \right)$$

C_t = simulated max 8-hr avg ozone concentration for day "t"

P_t = probability that C_t is among the fourth-highest simulated concentrations

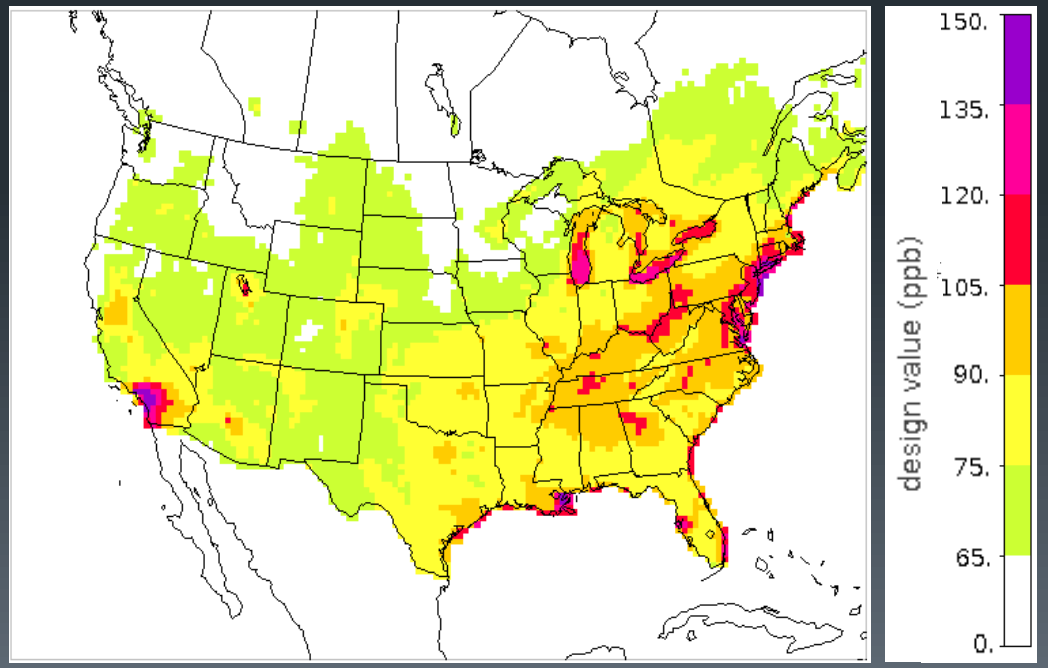
$$P = \sum_{t=1}^{92} P_t$$

Adjoint Cost Function (1)

Attainment

- average design value ($C_{4\text{-highest}}$ > 65 ppb) in Canada & U.S.

$$J = \frac{1}{N_{i,j}} \sum_{i,j} \left(\frac{1}{P} \sum_{t=1}^{92} P_t C_t \right)$$



Adjoint Cost Function (2)

Exposure

- short-term mortality in Canada & U.S.

$$J = \sum_{i,j} M_0 \cdot Pop \cdot e^{\beta \cdot C}$$

$M_0 =$ non-accidental mortality rate

$Pop =$ population

$\beta =$ pollutant response coefficient, 0.0427% per ppb

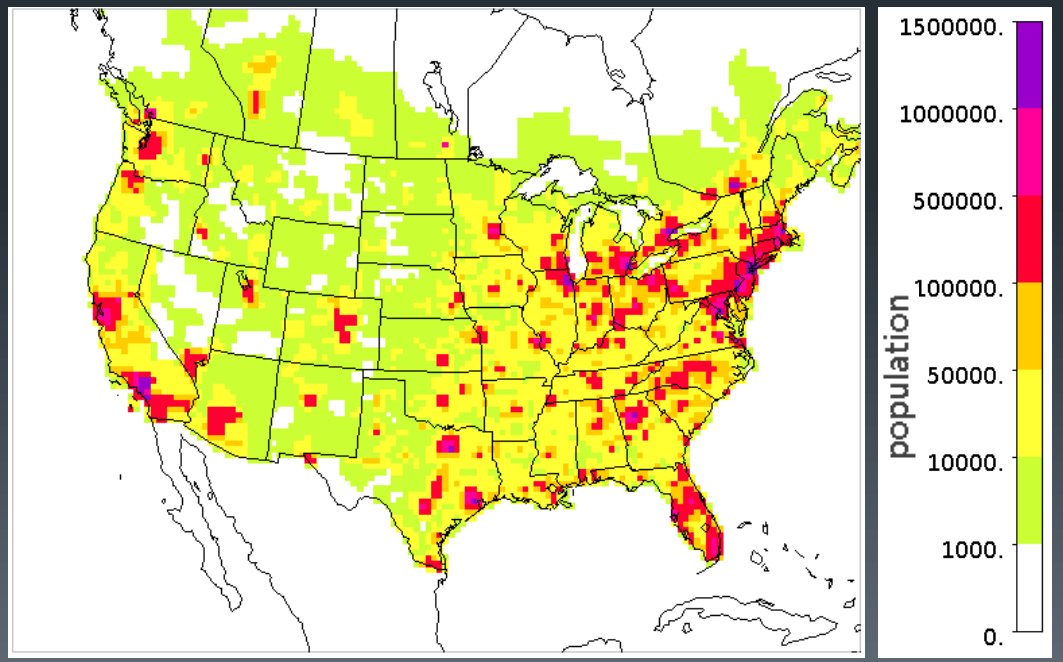
$C =$ max 8-hr avg ozone concentration

Adjoint Cost Function (2)

Exposure

- short-term mortality in Canada & U.S.

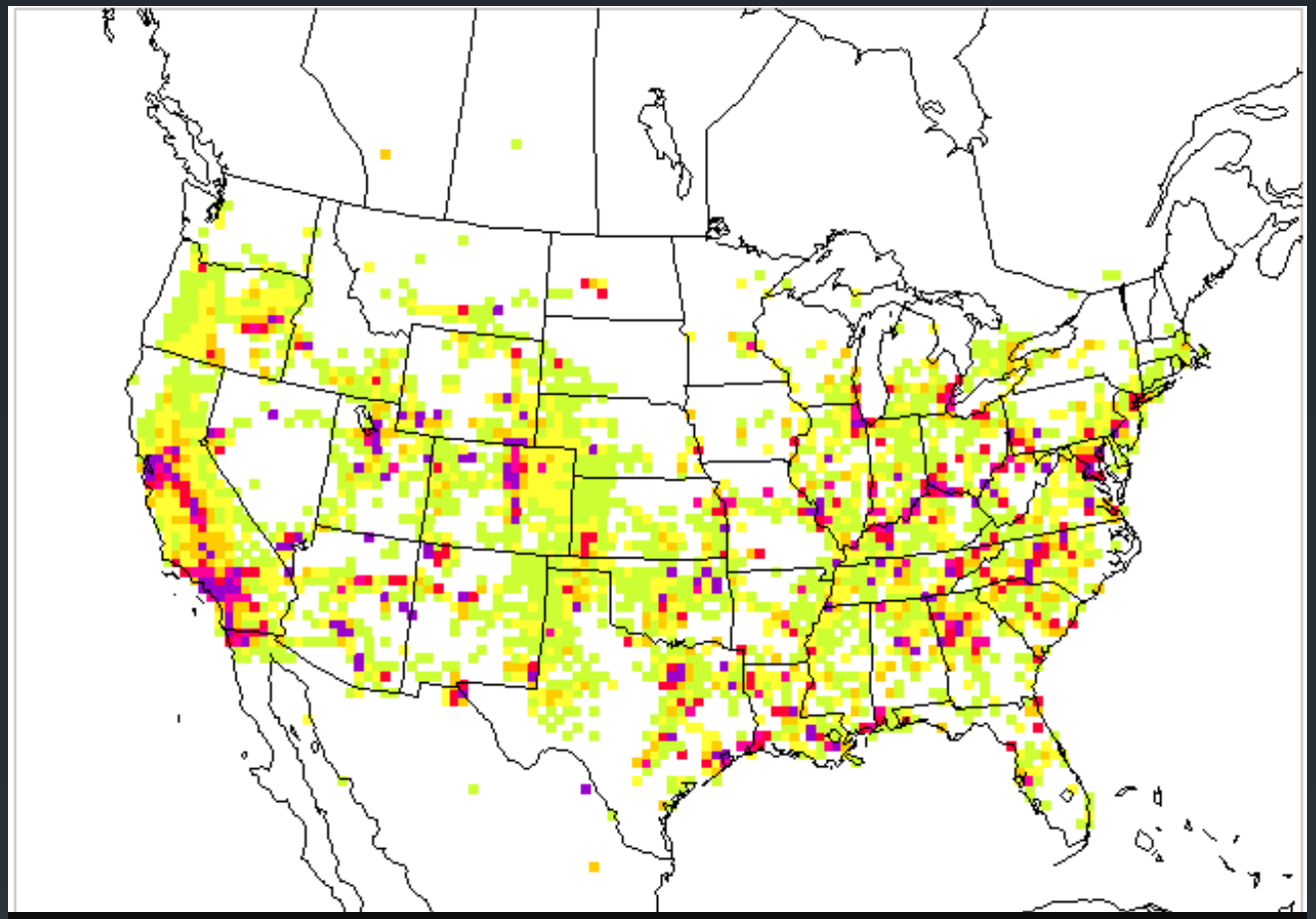
$$J = \sum_{i,j} M_0 \cdot Pop \cdot e^{\beta \cdot C}$$



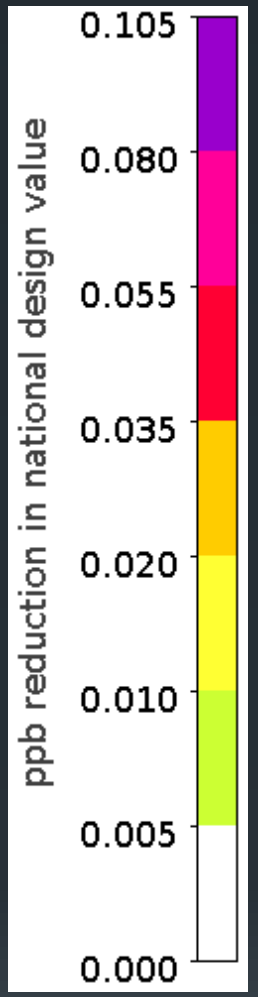
Case Study

- Gas-phase CMAQ adjoint (4.5.1)
- North American domain
- 36 km resolution
- 34 vertical layers
- July-Sept 2007

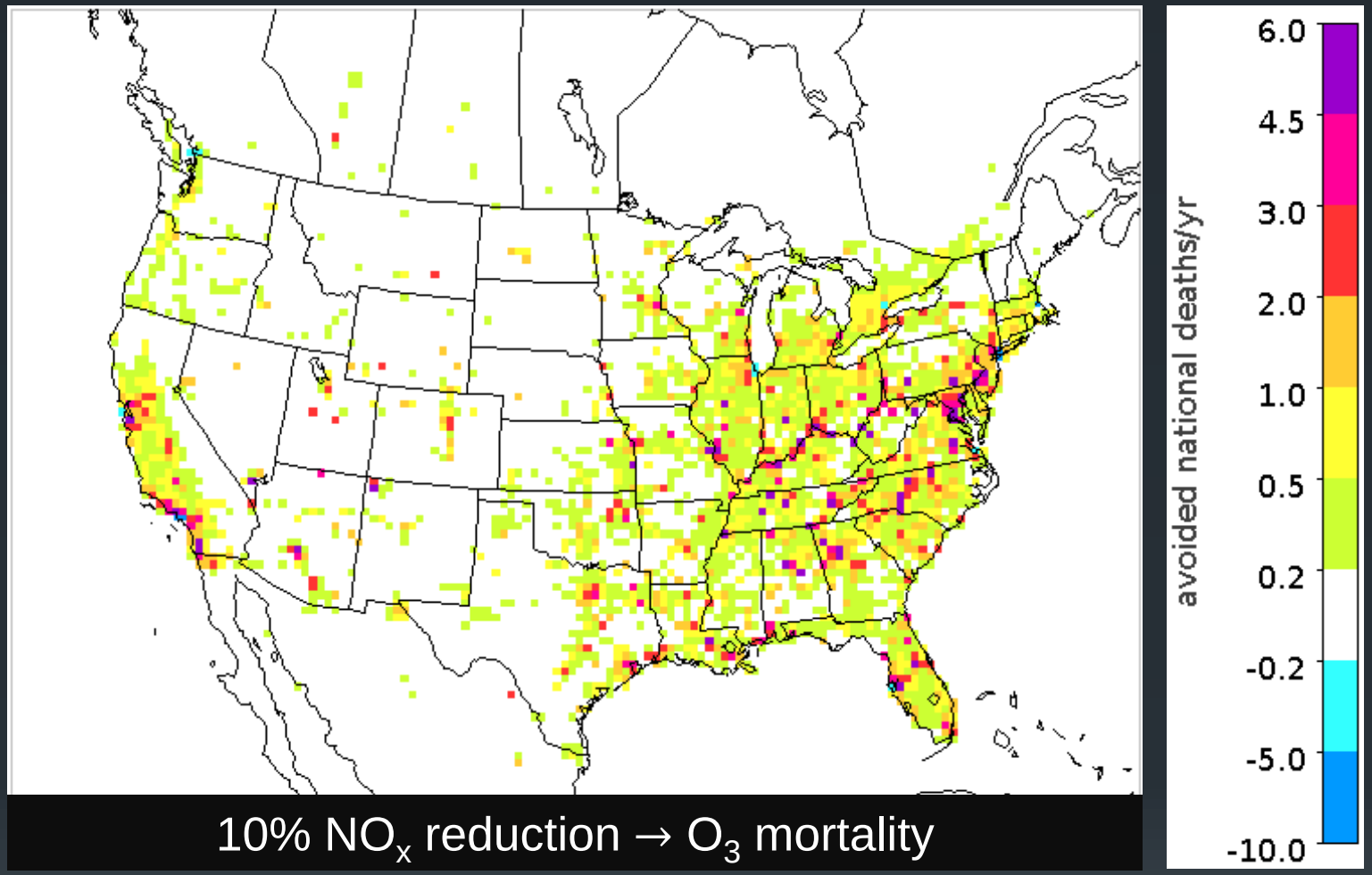
Results



10% NO_x reduction → O_3 design value



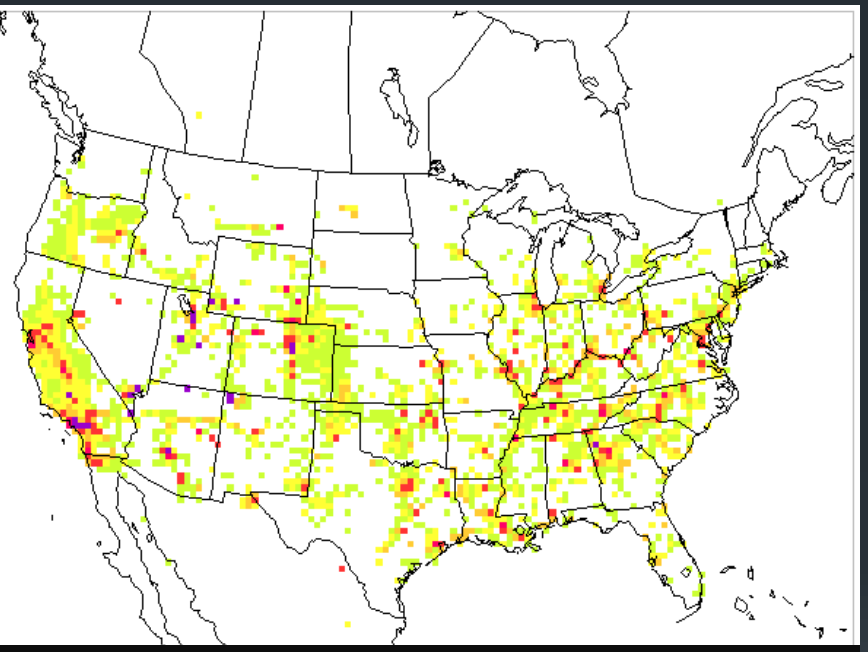
Attainment



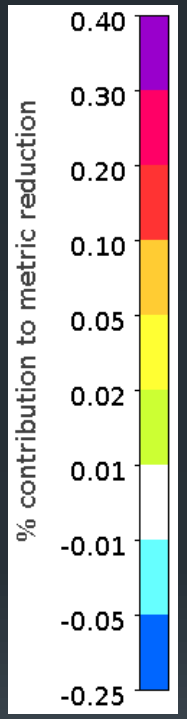
10% NO_x reduction → O_3 mortality

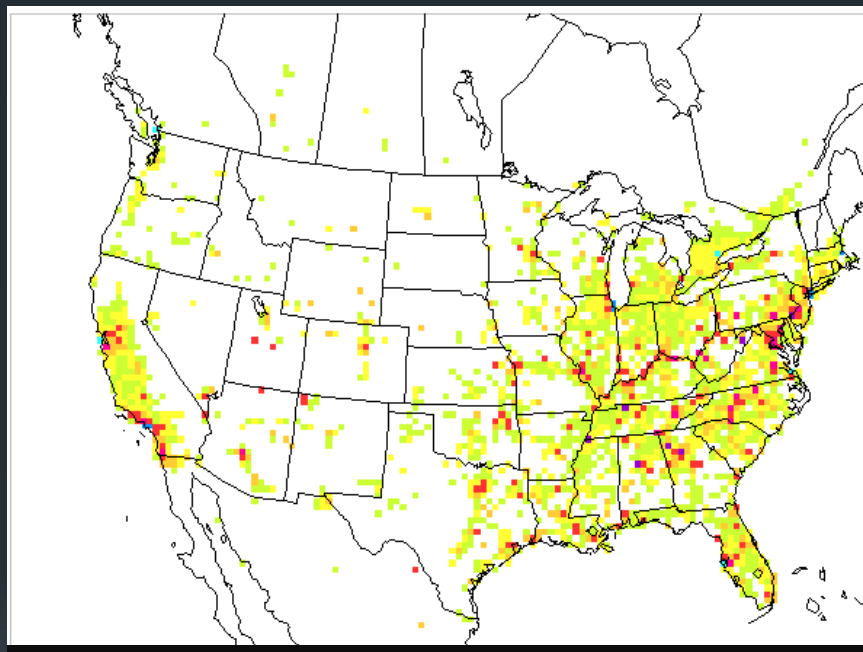
Exposure

Attainment vs. Exposure

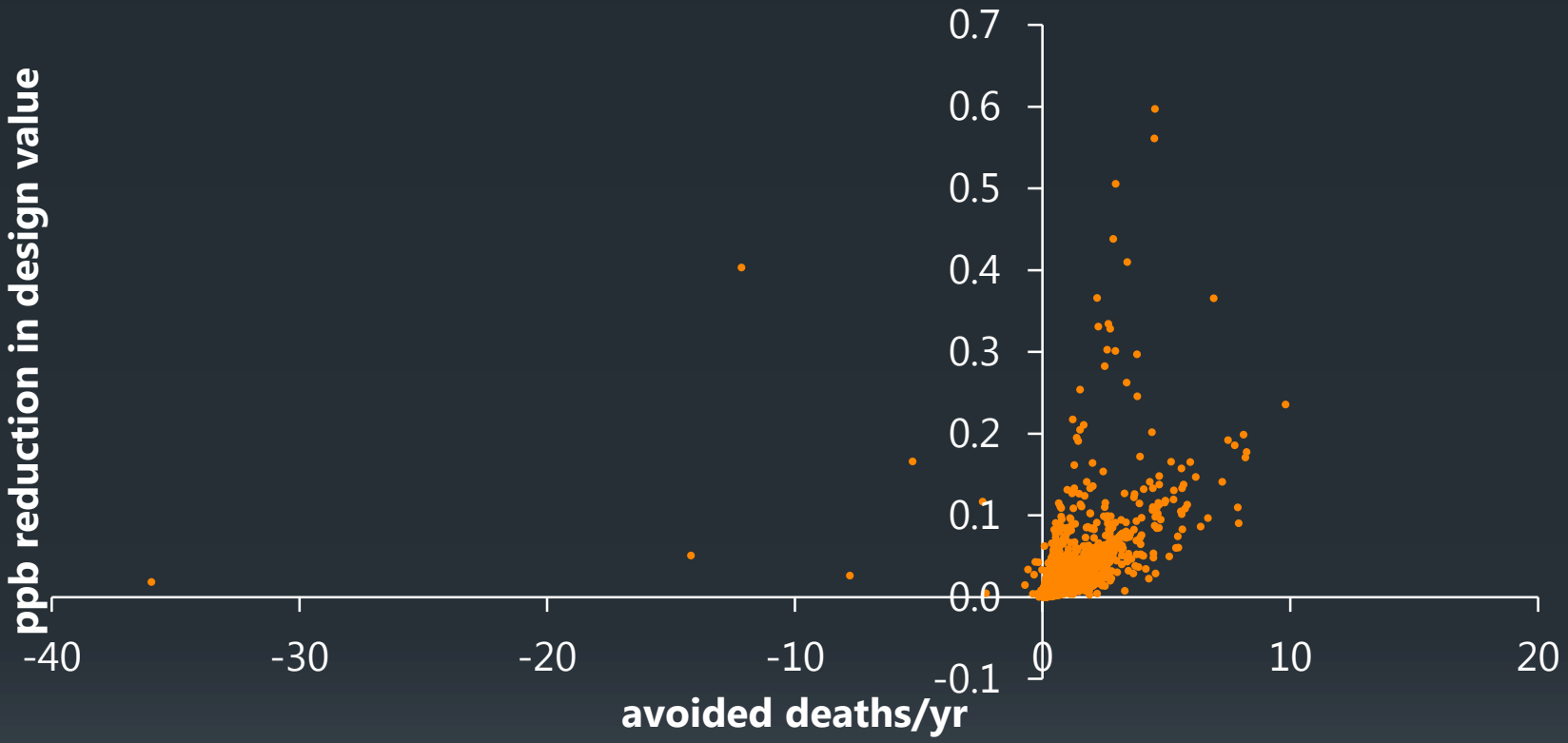


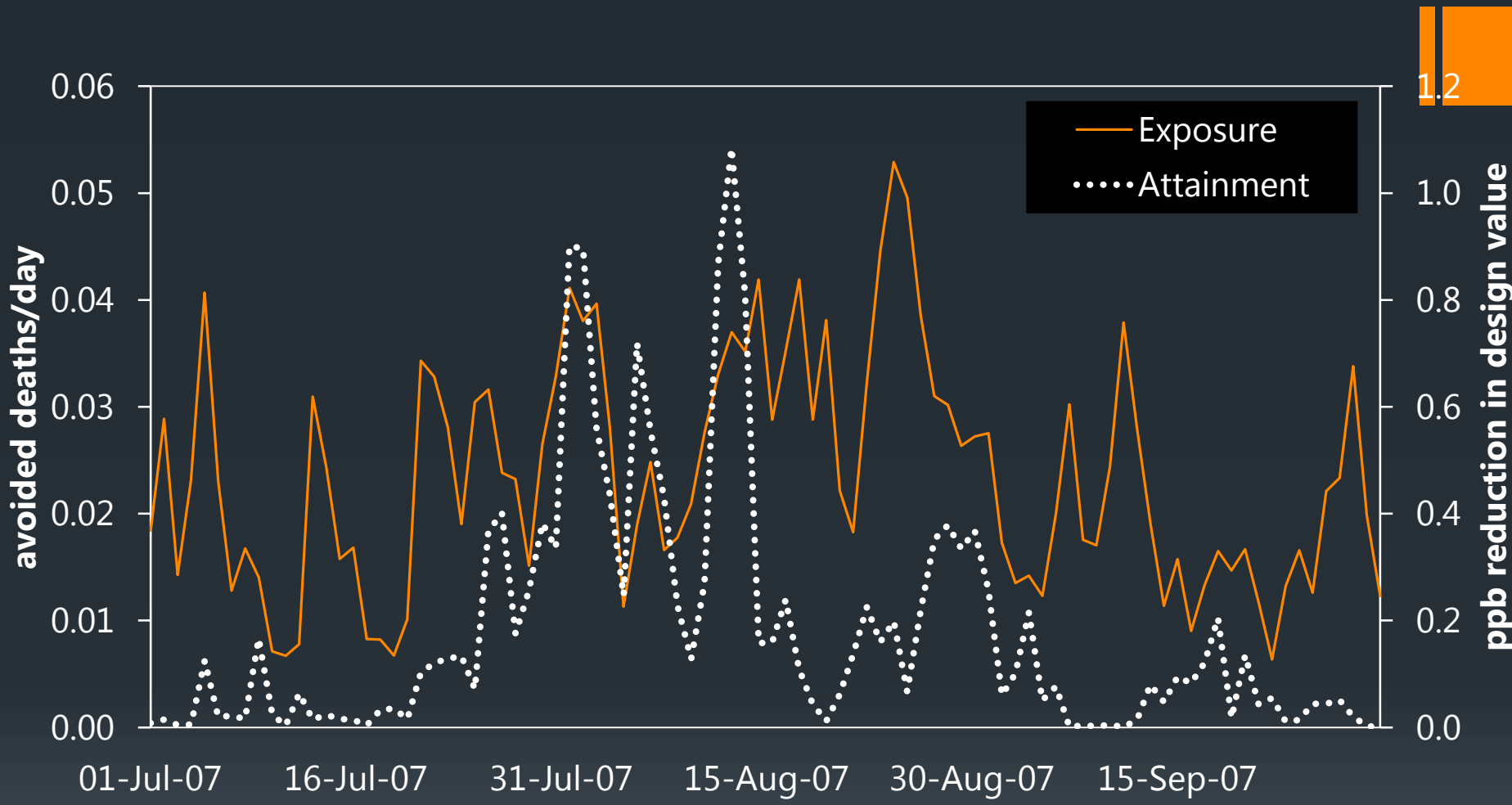
10% NO_x reduction → O_3 design value





10% NO_x reduction → O_3 mortality


ppb reduction in design value
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-40
-30
-20
-10
0
10
20
avoided deaths/yr



Atlanta Time-Series

Combined response of attainment and exposure metrics

Is there a way to directly account for population exposure in regulation?

Interested in CMAQ-adjoint?

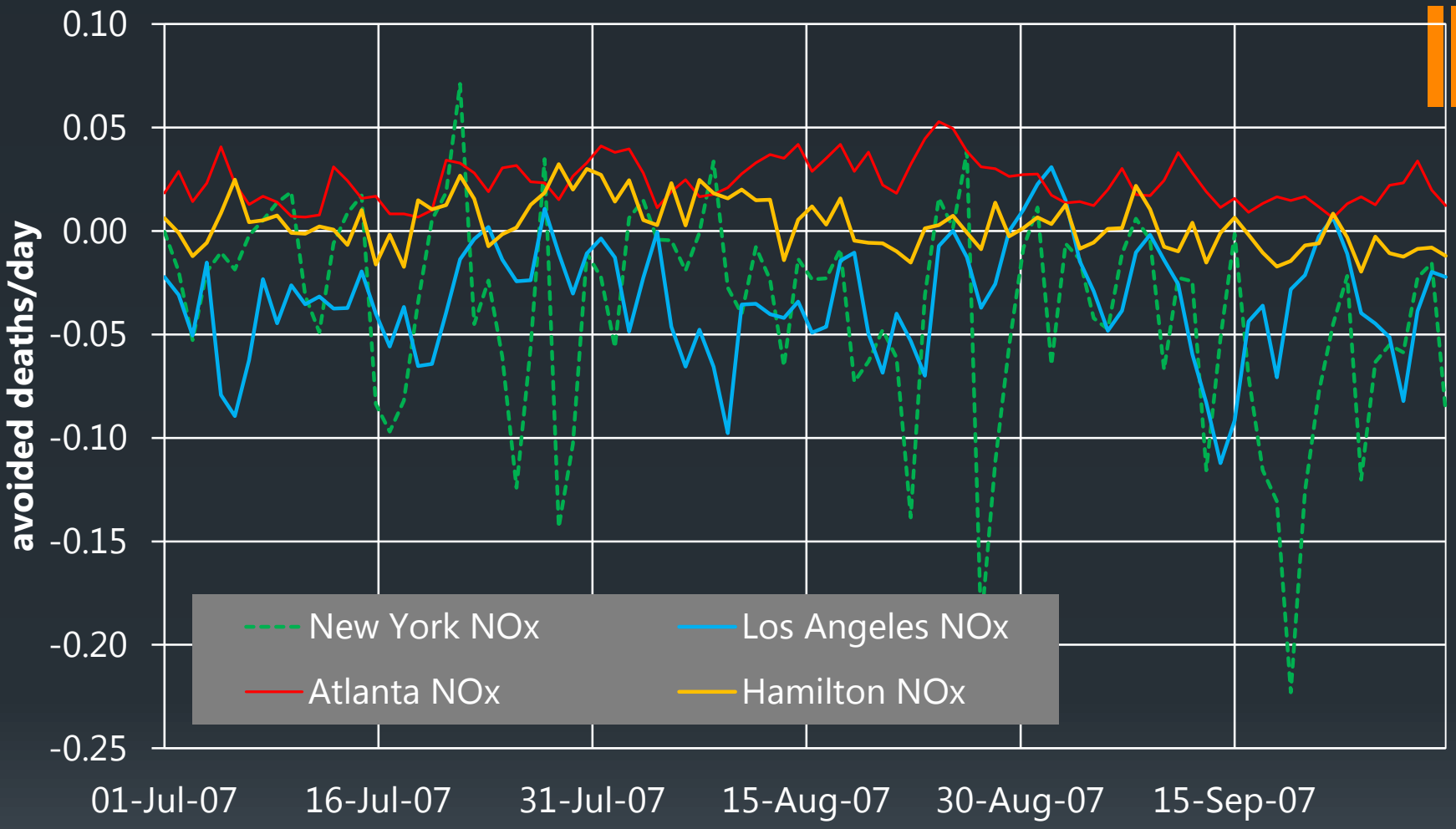
Thank you.

Back-up Slides

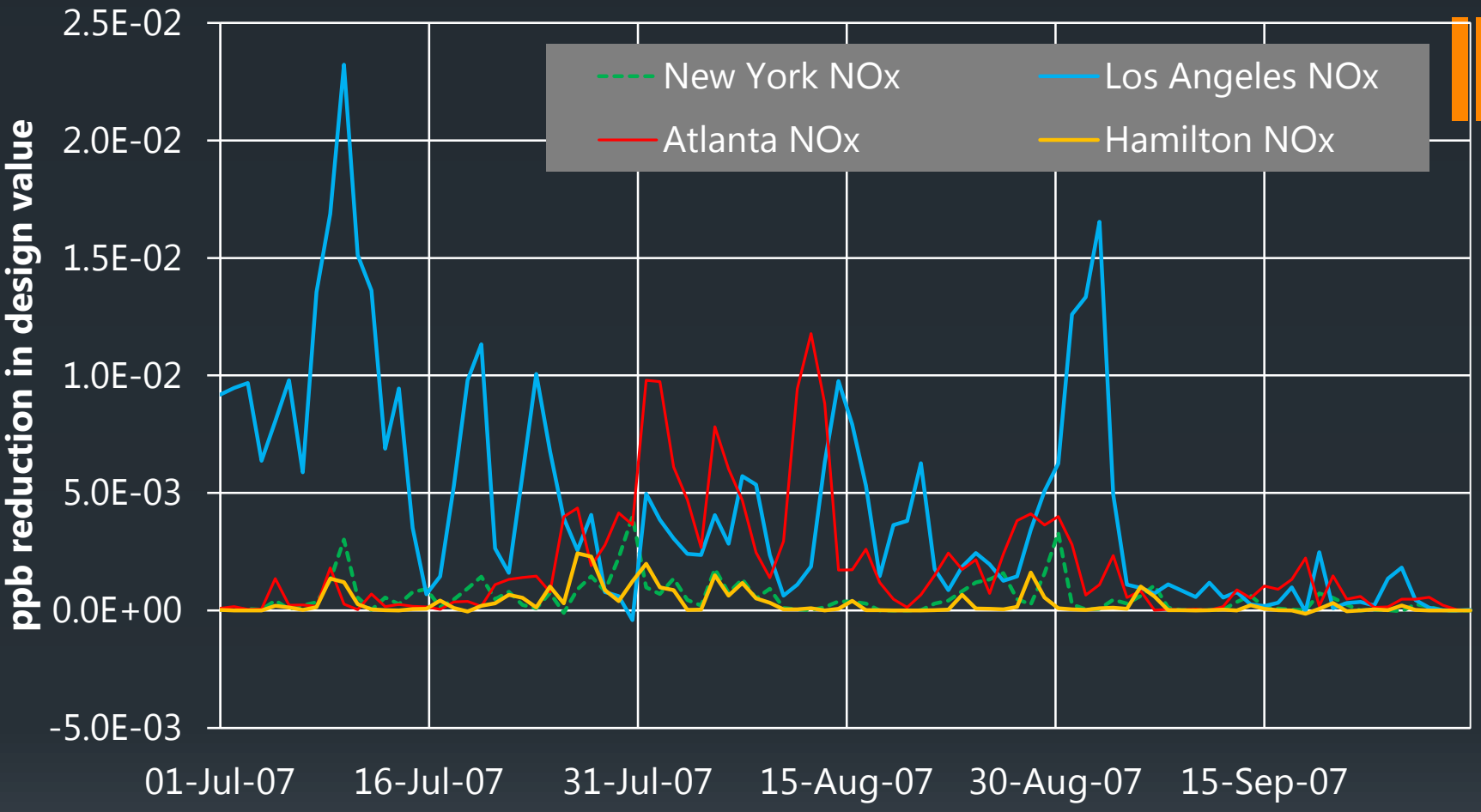
Adjoint Cost Functions

Attainment

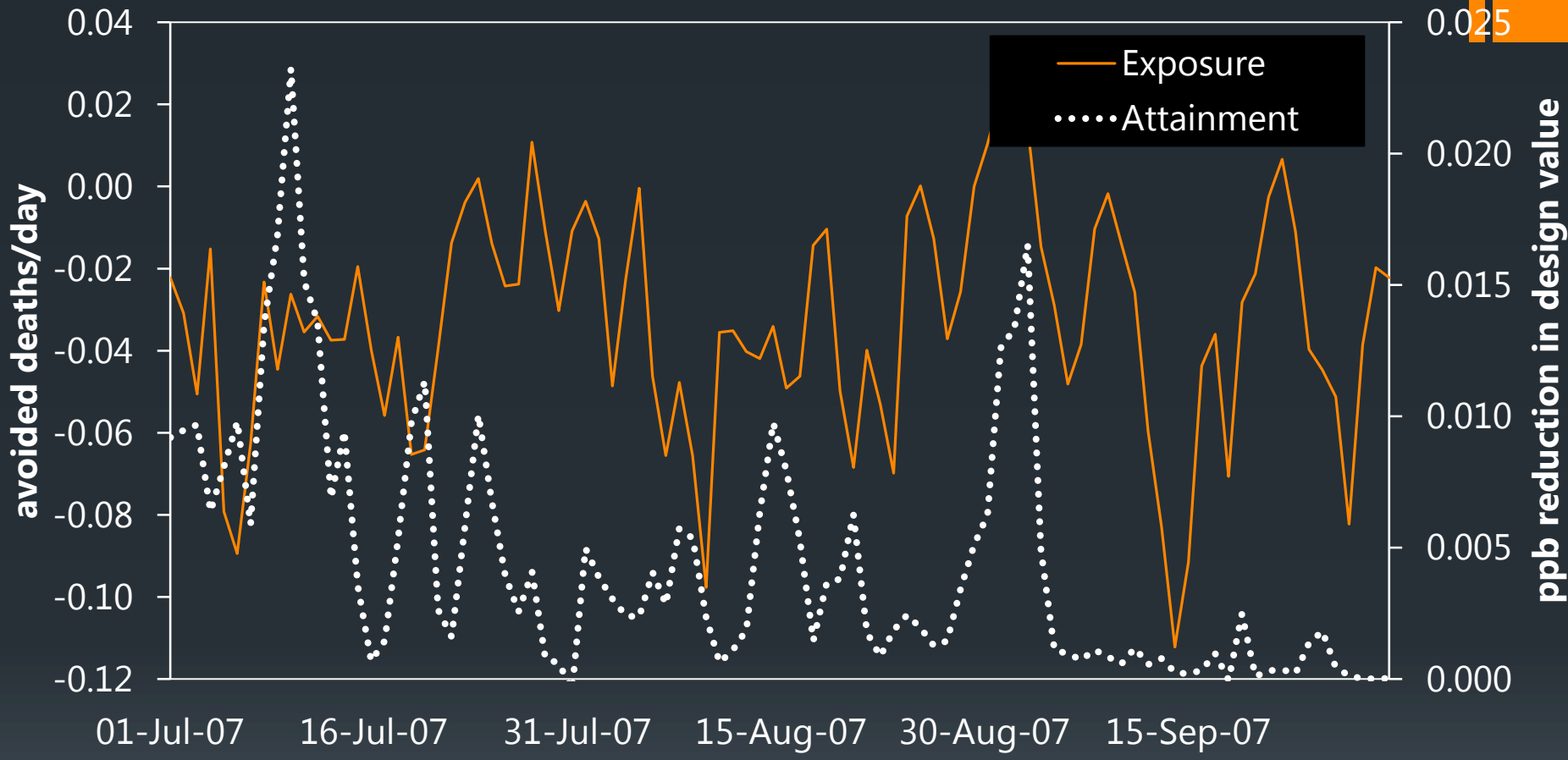
$$P_i = \sum_{j=0}^{3} \binom{n}{j} \cdot \left(P(C \geq C_{O_3,i})\right)^j \cdot \left(P(C \leq C_{O_3,i})\right)^{n-j}$$


0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
avoided deaths/day
New York NOx
Los Angeles NOx
Atlanta NOx
Hamilton NOx
01-Jul-07
16-Jul-07
31-Jul-07
15-Aug-07
30-Aug-07
15-Sep-07

Exposure


2.5E-02
2.0E-02
1.5E-02
1.0E-02
5.0E-03
0.0E+00
-5.0E-03
ppb reduction in design value
New York NOx
Los Angeles NOx
Atlanta NOx
Hamilton NOx
01-Jul-07
16-Jul-07
31-Jul-07
15-Aug-07
30-Aug-07
15-Sep-07

Attainment



LA Time-Series