Projecting Ozone Response to Precursor Emission Changes Using the HDDM Modeling Tool

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Topics

- Review of ozone-precursor relationships
- Modeling techniques
  - Source Apportionment vs. Sensitivity Analysis
- 2006 US modeling with CAMx HDDM
  - Modeling approach
  - Developing a post-modeling analysis tool
- Example of results in the western US
  - Denver
  - Rural areas

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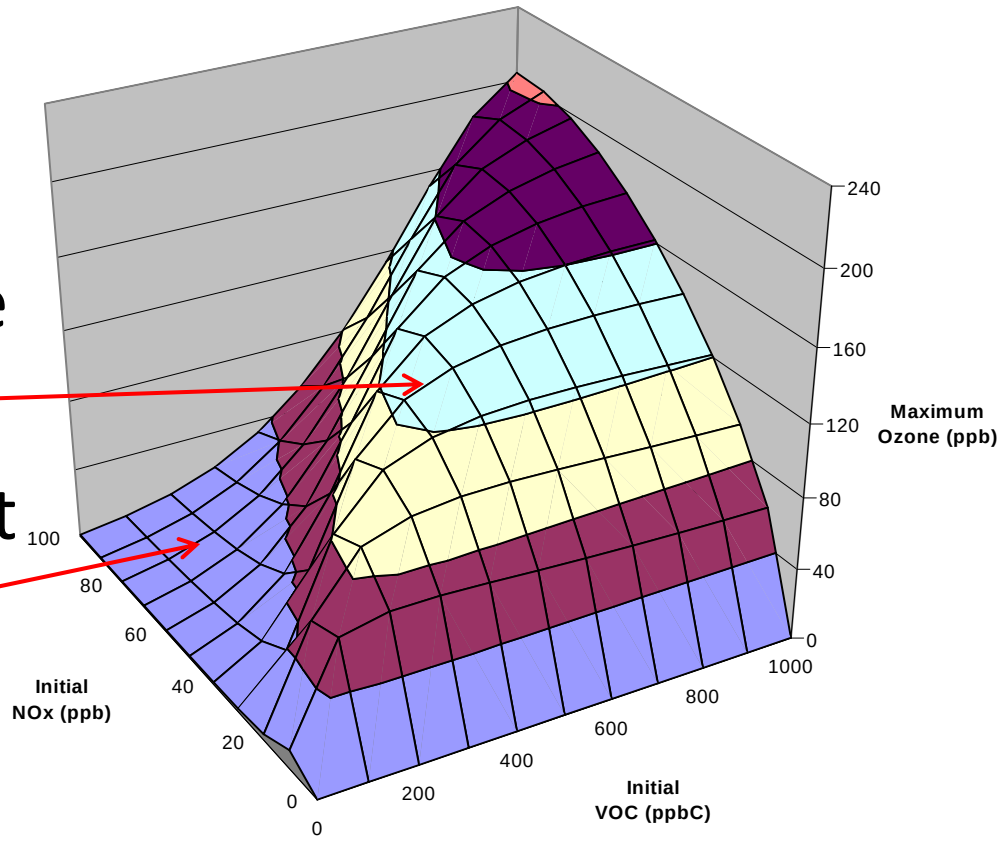
EKMA Diagram: Ozone from VOC and NOx

- **Example** peak O_3 from input VOC and NOx
- Most efficient O_3 production along "ridge line" at VOC:NOx ~10
- Strong NOx inhibition at low VOC:NOx ratios
- Shape/amplitude are site-specific according to numerous factors



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Modeling Techniques

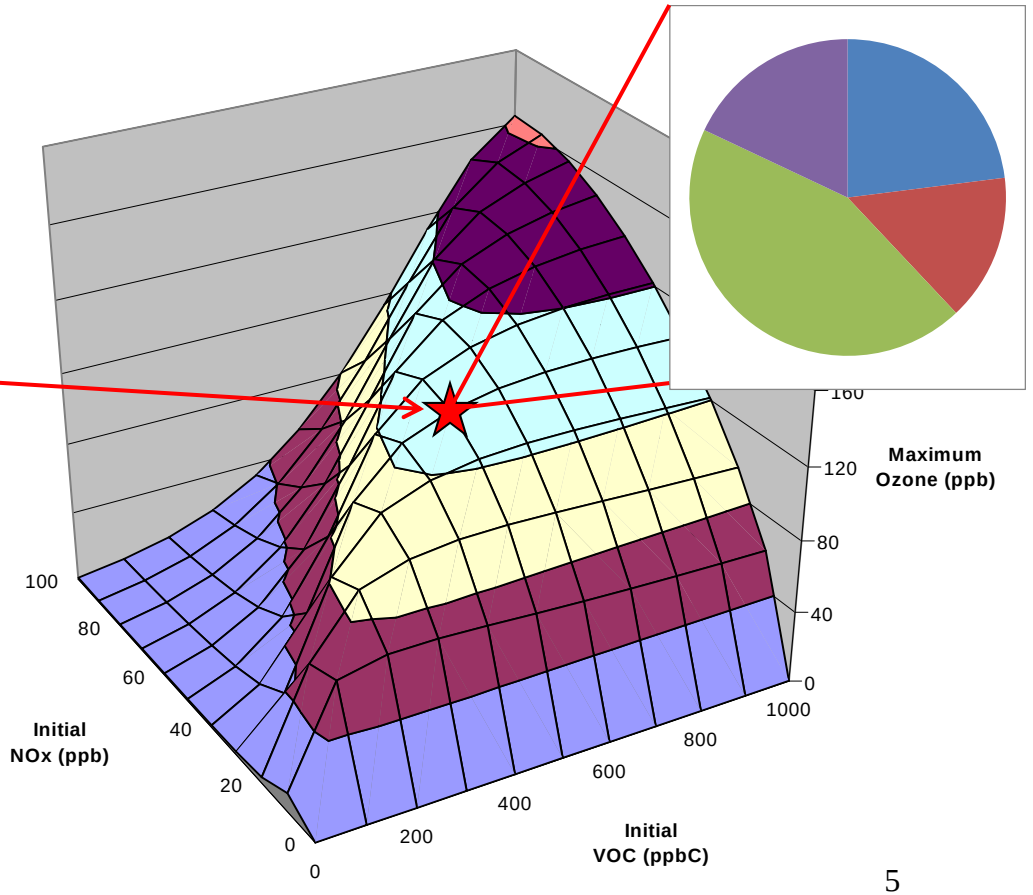
- Source Apportionment
  - Ozone apportioned to NOx and VOC emissions
    - By location and/or source category
  - Distinguishes ozone production as NOx or VOC limited
  - Source Apportionment is NOT Sensitivity
    - ***Can*** identify which precursors participate in ozone production for a given emission scenario
    - ***Is limited*** for sensitivity because ozone response to precursor controls is *non-linear*

Modeling Techniques

- Source Apportionment
  - ***Provides source contributions at a single point on the EKMA diagram***

For example:
Model predicts a day- and site-specific peak value here

SA tells you which sources contribute, and whether ozone chemistry is NOx- or VOC-limited at that point



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Modeling Techniques

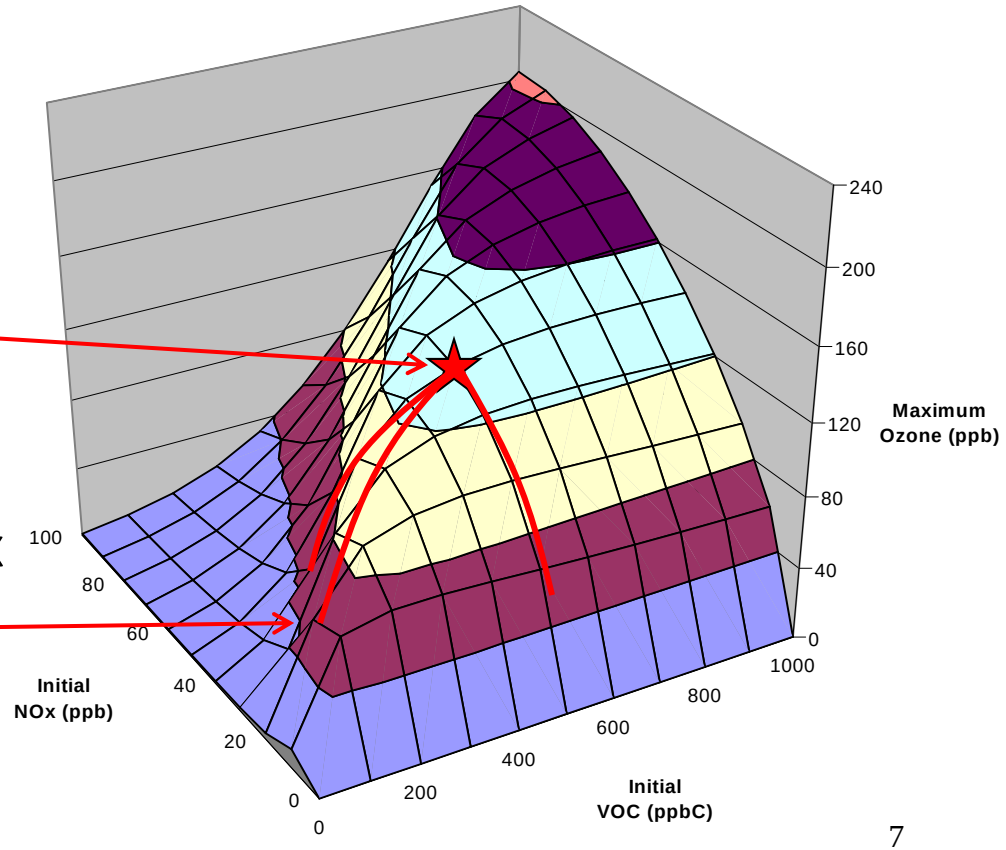
- Sensitivity Analysis
  - High-Order Decoupled Direct Method (HDDM)
  - Ozone sensitivity to NOx and VOC emissions
    - By location and/or source category
    - "Sensitivities" = 1st-order (linear) and 2nd-order (curvature) derivatives
  - Replaces many "brute force" emission scenarios
  - Sensitivity is NOT Source Apportionment
    - ***Can*** predict non-linear ozone response to precursor controls
    - ***Is limited*** for source apportionment because sensitivities can be *positive or negative*, and change as precursors change

Modeling Techniques

- Sensitivity Analysis
  - ***Shows the ozone path between two points on the EKMA diagram***

For example:
Model predicts a day- and site-specific peak value here

HDDM tells you how ozone moves along the surface as NOx and/or VOC change



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2006 HDDM modeling with CAMx

- Approach
  - EPA's 2006 AQMEII-US meteorology and emissions
    - Hourly data at 12 km resolution over North America
  - WRAP Phase III updates to O&G inventory
  - Domain boundary conditions from GEOS-Chem
  - CAMx/HDDM run for two annual emission scenarios:
    - 50% & 90% US-wide NOx/VOC anthro emission reductions
- Post-processing tool
  - Extracts hourly gridded sensitivities at:
    - All 2006 active AQS sites in 22 cities (including 12 EPA/REA cities)
    - All 2006 active CASTNET sites across US
  - Projects 1 & 8-hour ozone for any NOx/VOC level

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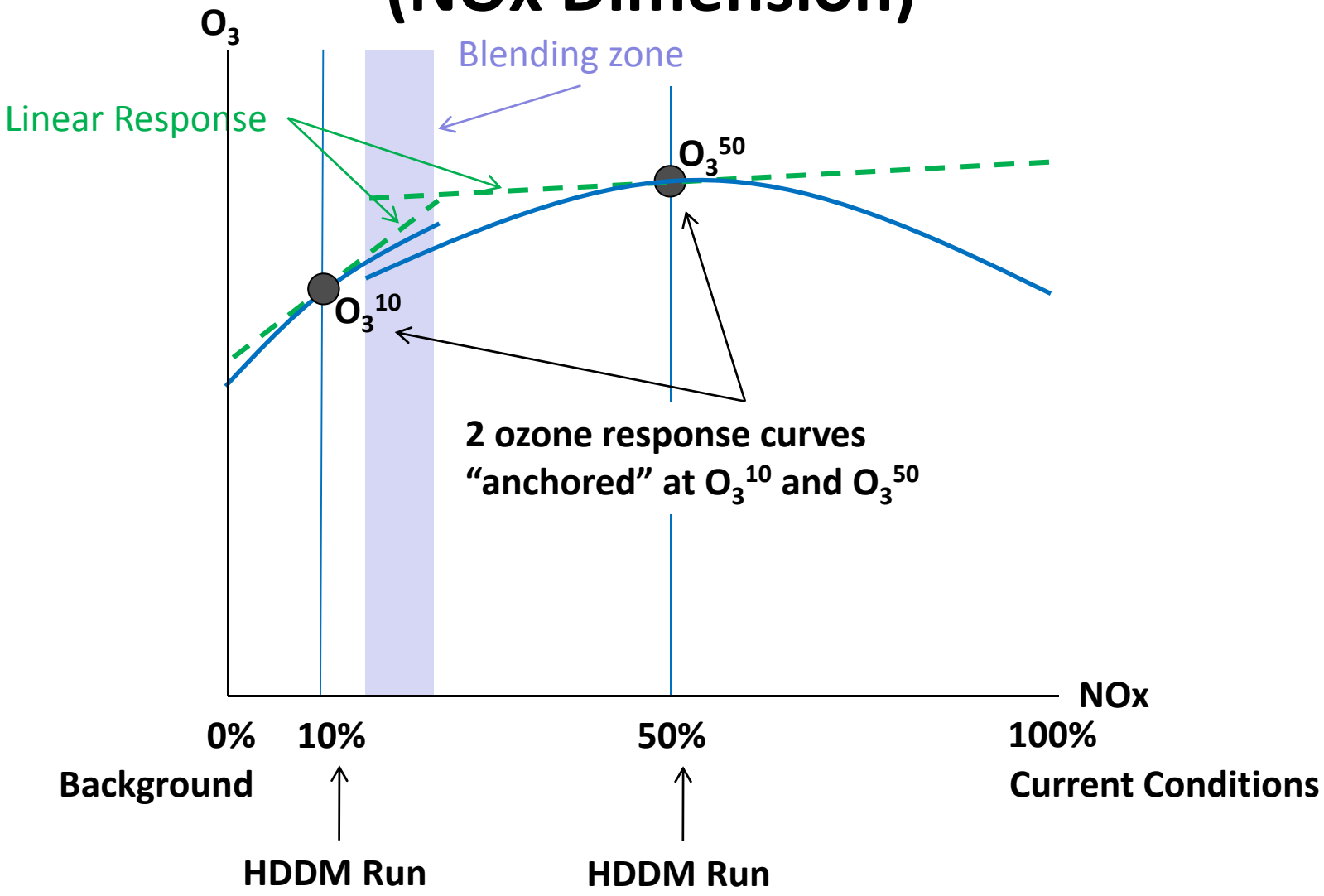
Schematic of HDDM Approach (NOx Dimension)



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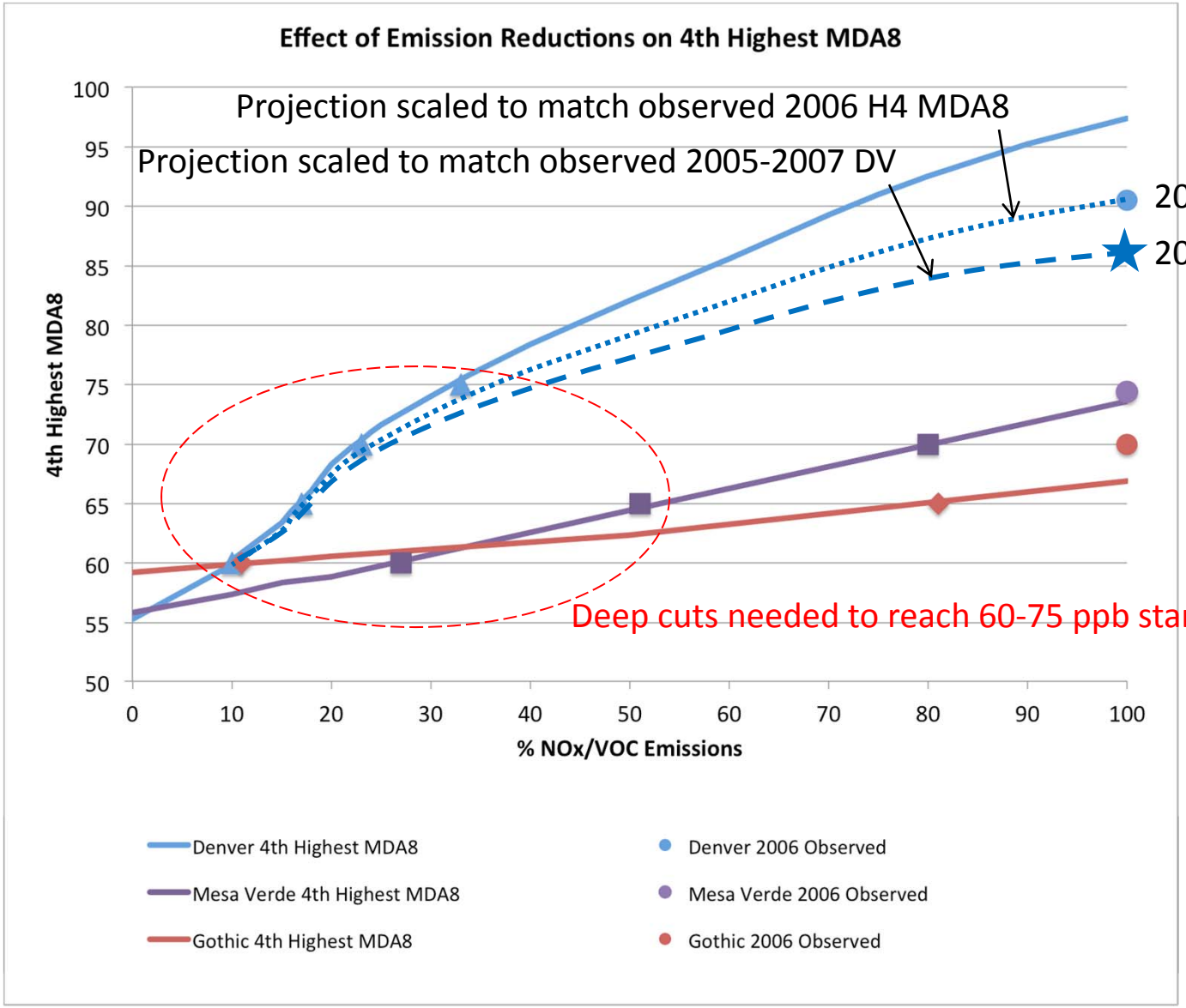
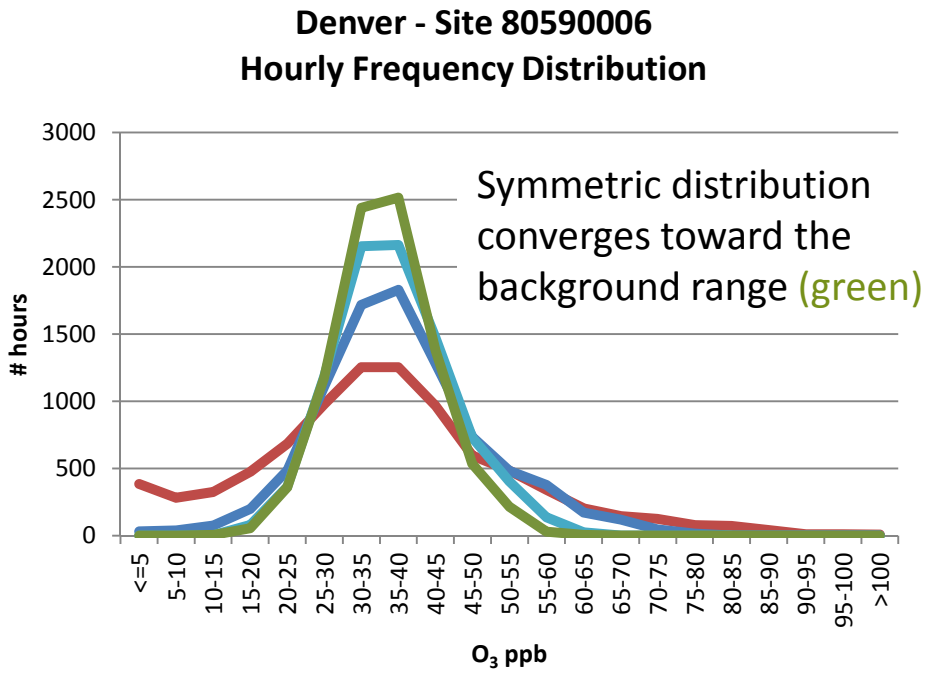
Example Results

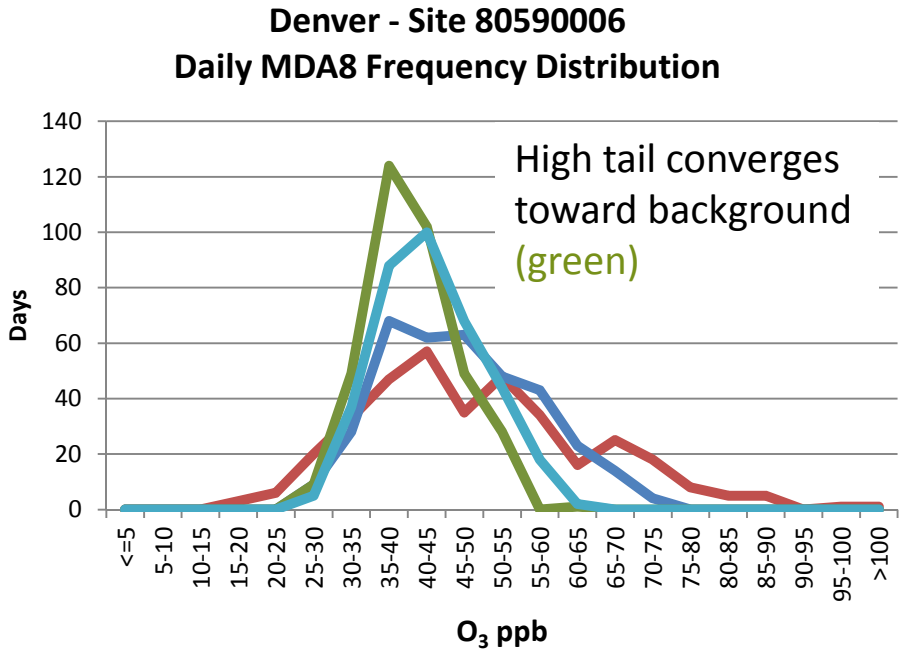
- Urban: Denver
  - 11 AQS sites (excluding Ft. Collins and RMNP)
- Rural: Mesa Verde CASTNET
  - Influenced by local EGUs and O&G fields
- Rural: Gothic CASTNET
  - Highest elevation CASTNET site in US
  - High background ozone
    - Subsidence of upper troposphere/stratosphere ozone intersecting high terrain

Example Results



Example Results
Denver: High Peak Ozone site (Rocky Flats)





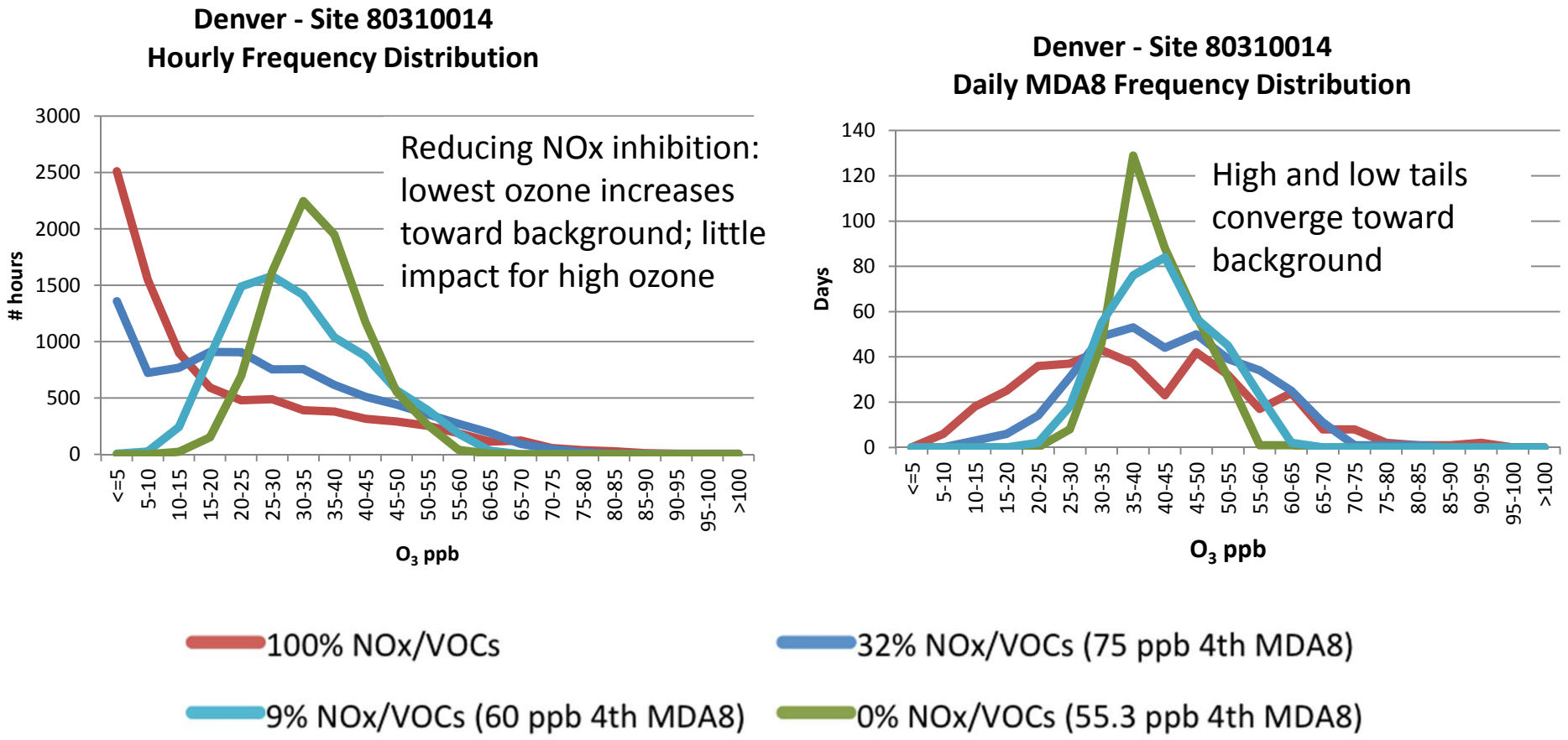
100% NOx/VOCs

32% NOx/VOCs (75 ppb 4th MDA8)

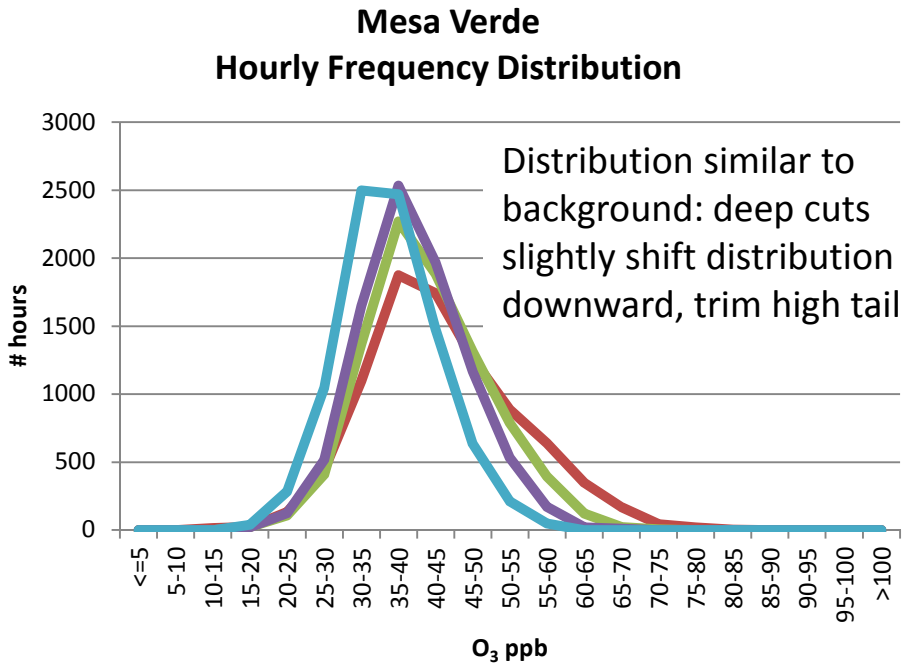
9% NOx/VOCs (60 ppb 4th MDA8)

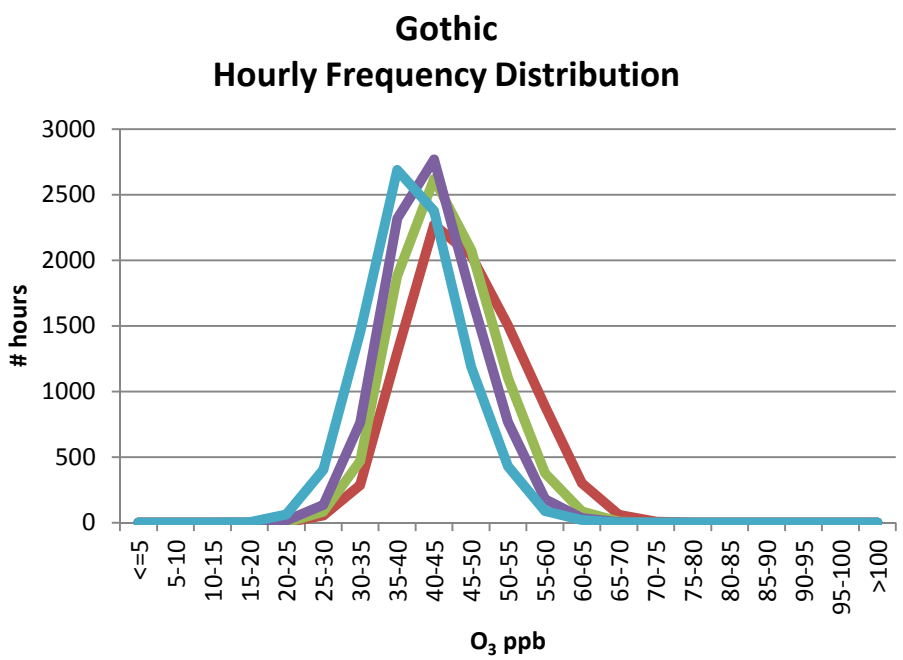
0% NOx/VOCs (55.3 ppb 4th MDA8)

Example Results
Denver: NOx-rich site (Carriage)



Example Results
Rural Sites





O3(HDDM 100%) O3(HDDM 50%) O3(HDDM 25%) O3(HDDM 0%)

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Conclusions (specific to our application)

- Need deep cuts to attain lower ozone standards
  - Urban ozone response steepens for cuts > 50%
  - Some urban sites need to get past NOx-disbenefit effect
  - "Stiff" response at rural sites
    - Dictated by high background that exceed lower standards
- Ozone response is subject to model fidelity
  - 12 km resolution is too coarse for most urban areas
  - Not SIP-quality dataset
  - Single model year (2006)
    - Cannot extrapolate these results to other years
- **BUT** gives strong indication of emission cuts to meet lower standards anywhere across US

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Conclusions (more generally)

- HDDM reduces computing time
  - A few runs replace potentially hundreds
- Screen ozone response over wide range of emissions
  - Carefully consider model configuration to maximize utility
  - Most robust results for good performing cities/sites
    - Need accurate replication of H4 MDA8 (meeting the standard)
    - Need accurate replication of frequency distribution (exposure)
    - Background ozone must be simulated well (fires, STE, etc.)
  - **NEW**: address requirements for secondary standard
- See our HDDM approach/evaluation paper in *Geoscientific Model Development*:

  http://www.geosci-model-dev.net/6/1601/2013/