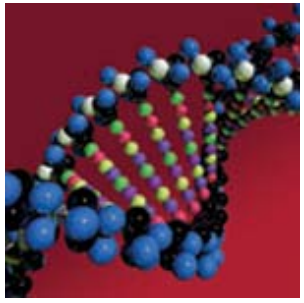
A screening method for ozone impacts of new sources based on high-order sensitivity analysis of CAMx simulations for Sydney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ENVIRON

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  - http://www.environment.nsw.gov.au/

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Outline

- Motivation
- 3-D Modelling of new source ozone impacts
- Screening Tool
- Framework for evaluating ozone impacts
- Summary

Motivation

- The Sydney Greater Metropolitan Region exceeds applicable ozone standards
  - 1-hr average of 100 ppb
  - 4-hr average of 80 ppb
- Need methods to quantify ozone impacts of proposed new sources
  - Photochemical grid modelling is scientifically rigorous but resource intensive
  - Need a technically sound screening tool to efficiently evaluate which new sources require photochemical grid modelling
- Need a framework to evaluate when ozone impacts are significant

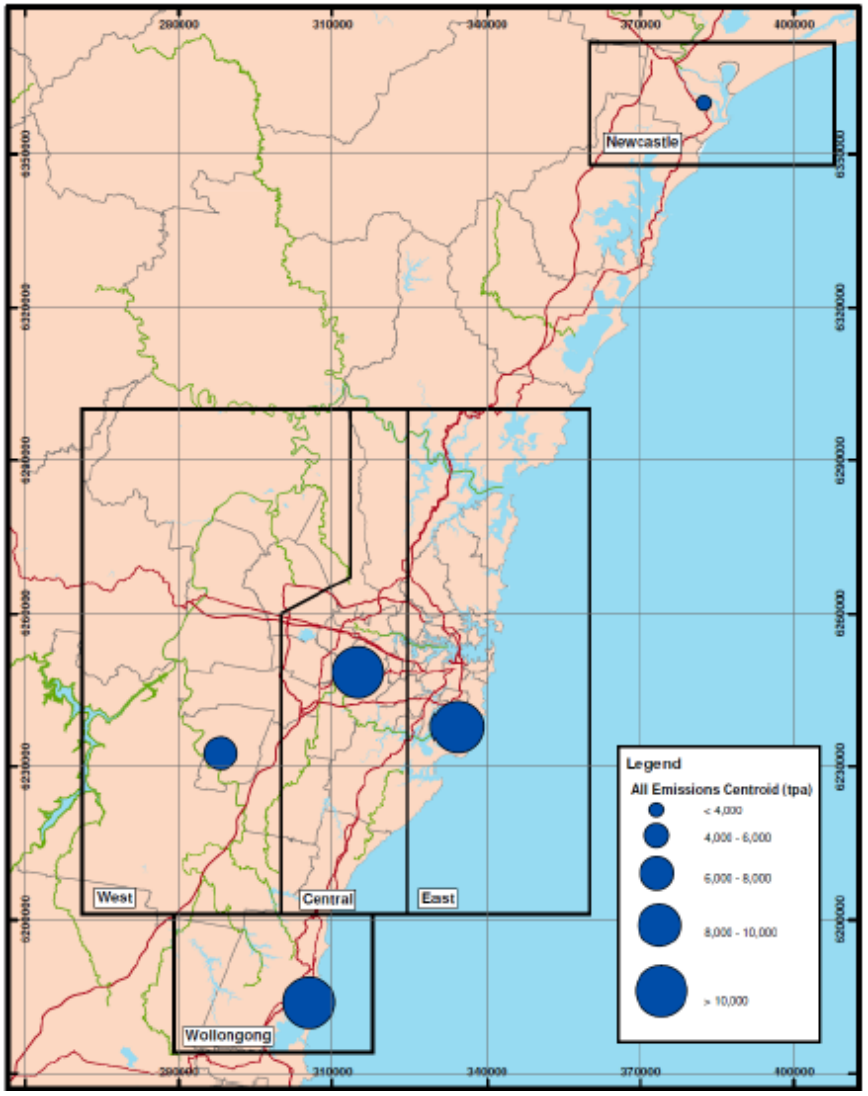
Overview of Methodology

- Reviewed literature to identify defensible methods
  - Photochemical grid modelling
- Model several prototypical new sources using a photochemical grid model (CAMx) for Sydney
- Use a sensitivity method (HDDM) in CAMx to develop a parametric model of the prototypical source impacts
  - O_3 impact = f(NO_X emissions, VOC emissions, source location)
- Implement the parametric model in a screening tool (spreadsheet) that can extend results for prototypical sources to any new source
  - Screening Tool
- Develop criteria to evaluate impacts using a tiered approach
  - Level 1 – screening tool sufficient for sources with “small” impact
  - Level 2 – photochemical modelling required for sources with “large” impact

CAMx Model Application for Sydney GMR

- Domain
  - 3 km grid (70 by 90)
  - 25 levels to 8,000m
- Episodes
  - Two summer periods
    - Dec 2003 / Jan 2004
    - Dec 2004 / Jan 2005
- CAMx version 5.3
  - CB05 chemistry
- Meteorology
  - TAPM prognostic model
- Emissions
  - OEH anthropogenic
  - MEGAN biogenic
- Boundary conditions
  - MOZART4

Prototypical “new sources”



- Locations and magnitude based on analysis of existing sources
- 5 locations selected
  - Newcastle
  - Sydney East, Central, West
  - Wollongong
- Each 500 tonnes/annum
  - VOC + NOx combined
  - VOC/NOx ratio of 1.24
- Stack parameters that produce minimal plume rise for maximum impact

Parametric model using HDDM sensitivity

- The high-order decoupled direct method (HDDM) computes O_3 sensitivity to selected emissions within CAMx
  - Computes first and second order derivatives
- Taylor series describes source impact (ΔO_3)
  - Second order accuracy

$$\Delta O_3 \text{ (ppb)} = X \cdot S^1_{NOx} + Y \cdot S^1_{VOC} + (X^2 \cdot S^2_{NOx} /2) + (Y^2 \cdot S^2_{VOC} /2) + (X \cdot Y \cdot S^2_{NOxVOC} /2)$$

$$\begin{aligned} S^1_{NOx} &= \partial O_3/\partial NO_x \\ S^1_{VOC} &= \partial O_3/\partial VOC \\ S^2_{NOx} &= \partial^2 O_3/\partial NO_x^2 \\ S^2_{VOC} &= \partial^2 O_3/\partial VOC^2 \\ S^2_{NOxVOC} &= \partial^2 O_3/\partial NO_x \cdot \partial VOC \end{aligned}$$

Evaluating the HDDM Parametric Model

- Compare source impacts by the DDM parametric model to brute force differences

  – DDM parametric model impact

$$\Delta O_3 \text{ (ppb)} = X \cdot S^1_{NOx} + Y \cdot S^1_{VOC} + (X^2 \cdot S^2_{NOx} /2) + (Y^2 \cdot S^2_{VOC} /2) + (X \cdot Y \cdot S^2_{NOxVOC} /2)$$

  – Brute force impact

    O_3 with new source – base case O_3 without source

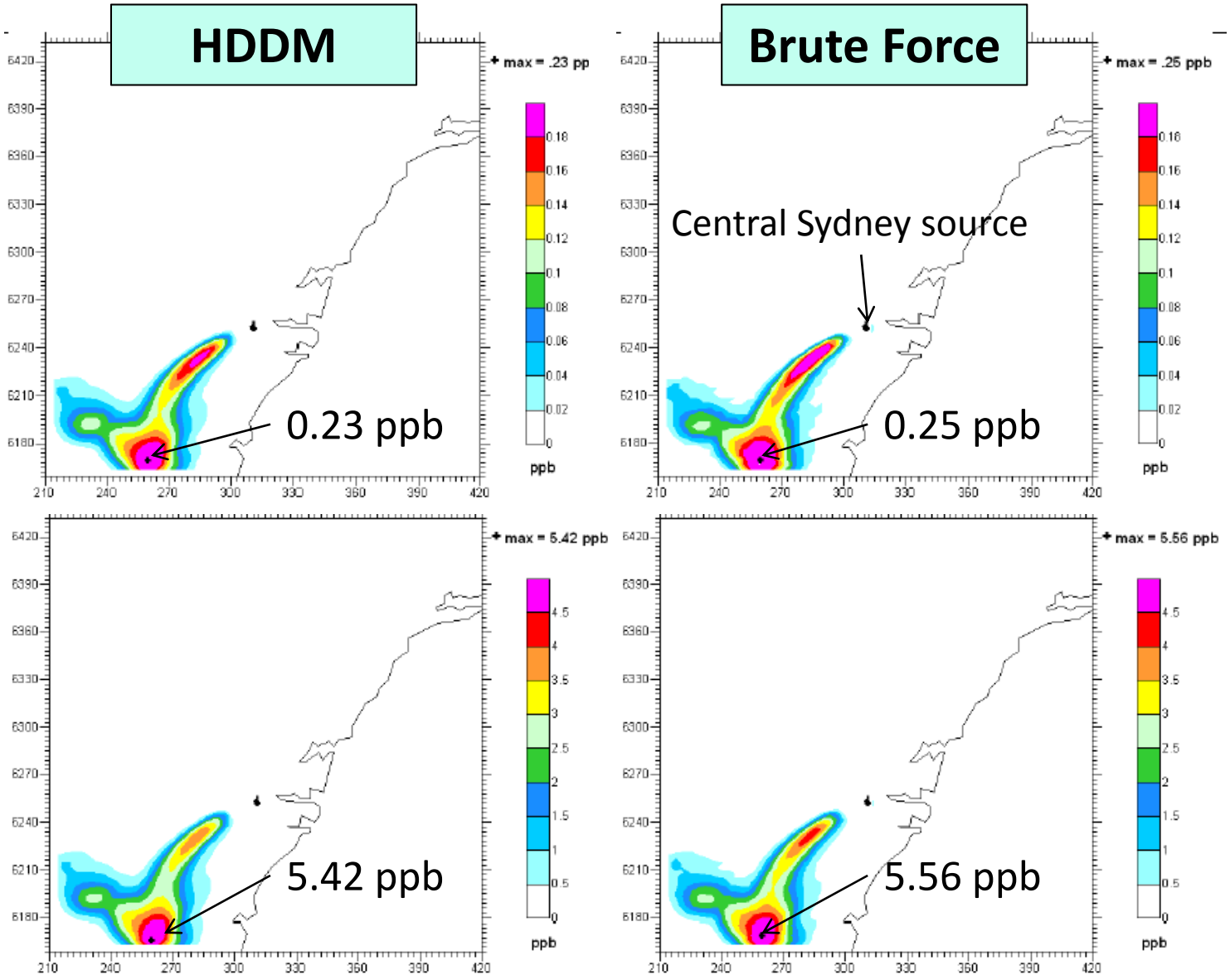
Evaluation: Location of source impacts

500 Tonnes/yr

As used to develop method

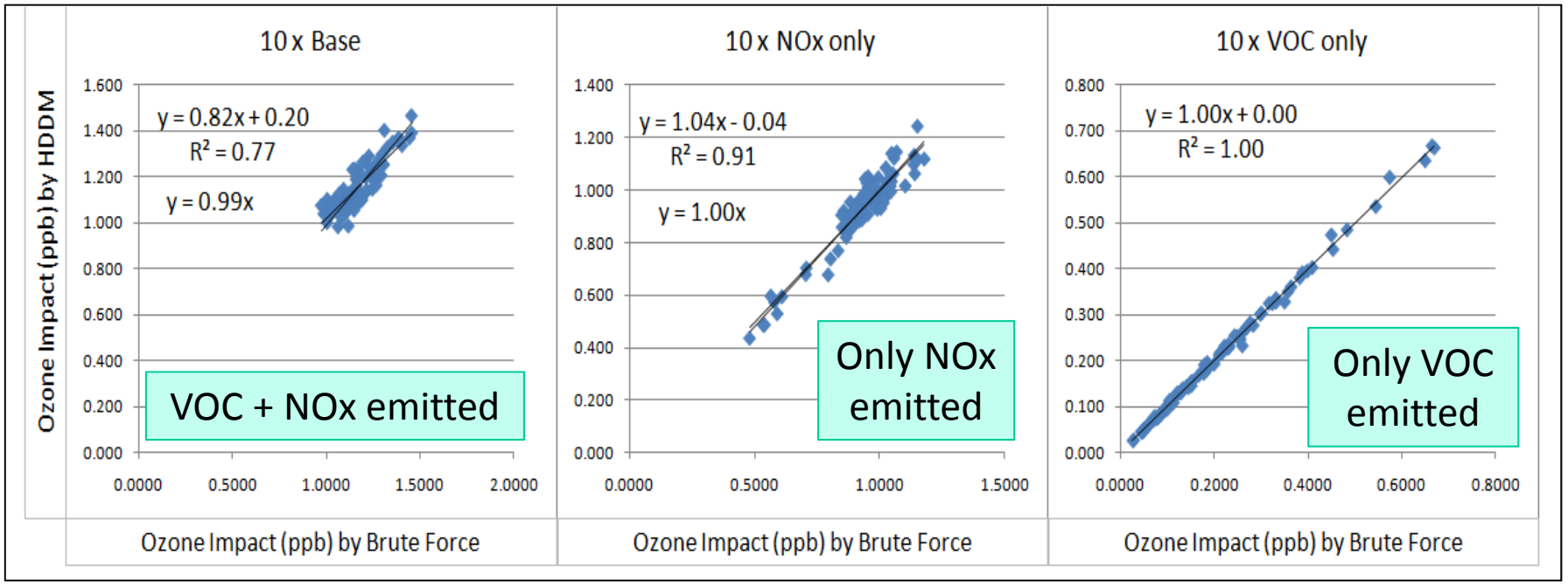
12,500 Tonnes/yr

25 x larger source



Evaluation: Different source VOC/NOx ratios

- Scatter plot the brute force vs. HDDM result for 300 grid cells with the greatest O_3 impact
  - 5000 tonne/yr source in Central Sydney emitting VOC + NOx, VOC only and NOx only
- Very good agreement even when VOC/NOx ratio is changed
  - Screening tool accurately describes non-linearity in O_3 formation
  - Good accuracy for sources 25 x larger used to develop the method
  - Used to set upper bound on range of applicability



Criteria for Evaluating Ozone Impacts

- Factors to consider
  - Magnitude of source impact
  - Located in O_3 attainment or nonattainment area
  - In all cases, sources must satisfy other regulator requirements

- Criteria established (not final)
  - Significant Impact Level (SIL)

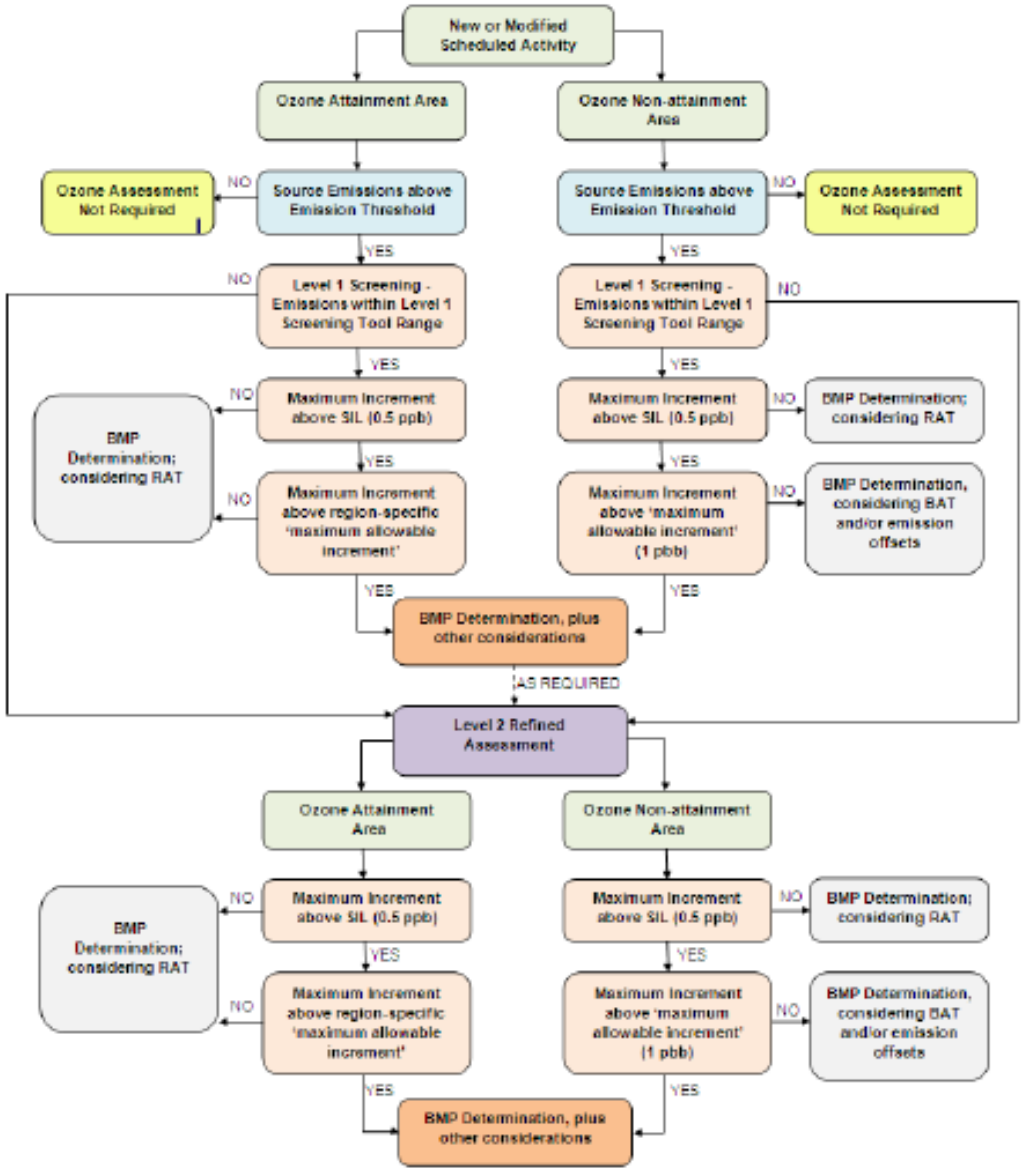
    Source impact below 0.5 ppb measureable ➔ level 1 analysis is sufficient
  - Maximum Allowable Impact (MAI)
    - MAI = 1 ppb for nonattainment areas
    - For attainment areas, MAI = 25% of the difference between measured maximum O_3 and the level of the standard

      e.g. standard = 80 ppb; measured max O_3 = 60 ppb; MAI = 5 ppb

    Source impact below MAI ➔ level 1 analysis is sufficient

Criteria for Evaluating Ozone Impacts

Flow chart to guide source proponents through the evaluation



Level 1: Use Screening Tool

Level 2: Use a model like CAMx

Screening Tool: Spreadsheet Macro

Source data input

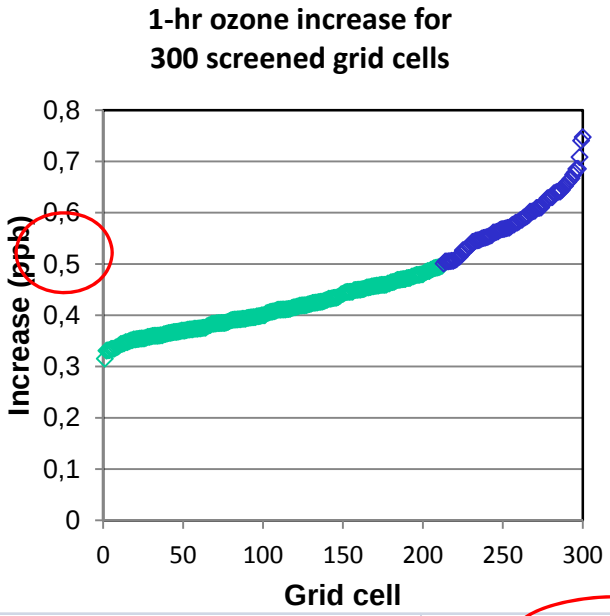
Source Region	Newcastle
VOC Input Option	Default VOC Reactivities
CH4 (tonnes/day)	0.000000
CO (tonnes/day)	0.000000
NOx (tonnes/day)	1.000000
VOC (tonnes/day)	1.000000

Calculate O3 Impacts

MAI for source location

Location		
Source Location	Newcastle	
Baseline Ozone (1-hr)	68.8	ppb
Baseline Ozone (4-hr)	62.4	ppb
Region Classification	Attainment	
Maximum Allowable Increment (1-hr)	7.8	ppb
Maximum Allowable Increment (4-hr)	4.4	ppb
Ozone Standard (1-hr)	100	ppb
Ozone Standard (4-hr)	80	ppb

Ozone impacts compared to SIL



Maximum 1-hr Incremental	0.74735	ppb

Compare maximum impact to the MAI

Summary

- An efficient screening method developed
  - Scientifically defensible and robust
  - Defined range of applicability
  - Suitable for “smaller” sources
  - Use to focus resources on sources that require more detailed evaluation
- This method could be applied in other regions
  - Parameters in the screening tool are location specific
  - Develop parameters for new locations using a photochemical grid model
- Evaluation framework developed
  - In tune with local ozone standards and regulatory practices
    - Not yet finalized
  - Concepts could be adapted for new locations and jurisdictions