DETAILED SCIENCE QUESTIONS FOR NARSTO Ozone ASSESSMENT

Science question 1. *(Addresses Policy question 1.)*

What are the most significant research developments in tropospheric ozone science over the last decade?

- How have these developments confirmed or changed our conceptual picture of tropospheric ozone processes?
- What are the principal remaining scientific uncertainties?
- Are there any scientific breakthroughs on the horizon in the next fewyears?
- Would these breakthroughs/developments alter the way we are managing the ozone problem?

Science question 2. *(Addresses Policy questions 2,3,4,5.)*
How does ozone accumulation on urban (<200 km) and regional (200-2000 km) scales depend on the source dimension and location? How does it depend on the relative contribution from urban and regional sources?

- What are the relationships among point source, urban, regional, and larger scale processes and tropospheric ozone levels?
- What are the regional transport influences on urban-scale ozone and the urban influences on regional tropospheric ozone?
    - How large a region must be considered; do we know how large is large enough?
    - What do modeling analyses and measurements tell us about transport scales of regional, urban, and point source emissions influences?
    - What is the sensitivity of urban ozone to regional transport of ozone, of NO2/PAN, of VOCs/carbonyls?
    - What spatial and temporal resolutions are required for modeling to assess regional transport effects on an urban area experiencing high ozone concentrations?
    - What measurements are needed, where are they needed, and what degree of accuracy is needed to assess regional transport effects on an urban area experiencing high ozone concentrations?
- Can we better understand, further identify, isolate, and explain the fundamental physical, chemical, and meteorological processes responsible for ozone accumulation on urban and regional scales?
    - What are ambient measurement programs revealing about fundamental processes?

    - What are modeling studies revealing about fundamental processes?
    - What are laboratory studies revealing about fundamental processes?

- What is the influence of stratospheric ozone on tropospheric ozone concentrations?

Science question 3. *(Addresses Policy questions 3,4,6.)*
What are the most recent assessments of the relative contributions of VOCs, NOx, and CO to ozone accumulation on urban and regional scales in North America?

- Is the accumulation of ozone limited by the availability of VOCs or NOx?
    - Does this limitation change from day to day for a given area or region, or from area to area on a given day, based on changes in meteorology and emissions?
    - What portion of the ozone precursors are from natural (biogenic) sources, and how will these emissions change with meteorological variability, land-use, and climate change perturbations?

Science question 4. *(Addresses Policy questions 2,3,4,5.)*
What are the strengths and limitations of the current scientific methods and tools in assessing tropospheric ozone issues and developing emissions management strategies?

- How do regional versus urban emissions controls affect urban ozone?
    - What are results of modeling analyses indicating effects of regional versus urban emissions controls?
    - What measurements can be made to assess the adequacy of modeled estimates of emissions control impacts on ozone?

- What are the critical limiting factors (uncertainties) in current models for assessing and managing urban and regional ozone problems?
    - How do strengths and limitations affect the way emissions-based air quality models are best applied?
    - Are emerging multi-scale air quality modeling systems more accurate and more useful than their predecessors in estimating regional/urban ozone, precursor, and other key species concentrations?
    - Can single (urban) scale models be used to assess regional/urban interactions?
    - What is the sensitivity of modeled ozone management strategies to the accuracies of emissions inventories?
    - What confidence do we have in model-predicted changes in ozone given a change in precursor emissions?

- What are the critical limiting factors (uncertainties) in current measurementmethods for assessing and managing urban and regional ozone problems?
    - How do strengths and limitations affect the way measurements are best

used?

- How might an efficient approach toward ozone management be constructed that combines observational analysis and modeling techniques?
    - How might such an approach be made operational?
    - What is needed for a successful modeling study in support of air quality management?
    - How can observational methods and emissions model techniques be combined to reduce uncertainty and risk? How can these risks best be communicated to decision makers?

- What are the scientific implications of assessing ozone and strategies for its control over periods longer than an episode (up to a season or year)?
    - How will emissions control impacts change under a new primary standard, such as an 8-hr averaging period?
    - How many episodes must be analyzed to assess against the new primary standard? Is episodic modeling meaningful?
    - What new measurement and modeling methods might be required to assess a potential secondary (seasonal) ozone standard?
    - Can we characterize the seasonal ozone "baseline" or clean continental concentration for different regions?

Science question 5. *(Addresses Policy questions 3,5,6.)*
What approaches are required to determine historic concentration trends of ozone and its precursors on urban and regional scales? What is required to demonstrate the effectiveness of emissions control strategies over time?

- What measurements are needed, and where, to track the impact of emissions, meteorology, ozone and precursors over time to detect a signal in each component?

- What techniques can be applied to observed concentration trends to minimize the confounding influence of the meteorological signal?

- What do models tell us about the confounding influence of the meteorological signal on pollutant concentration trends?

- Since urban ozone trends are generally downward, is the basic management strategy a sound one but with need for fine-tuning, or are there more fundamental problems?

- What do we know about ozone trends in rural areas? What is the urban ozone influence on rural concentrations?

- What approaches are required to evaluate ozone exposures of humans and ecosystems?

- How can measurements be best utilized?
    - What are the most important additions/improvements in PAMS and similar monitoring to facilitate emissions inventory evaluation and improvement, air quality model evaluation and improvement?
    - What types of method development efforts, field studies, and training are needed to maintain high quality data from PAMS and similar networks?
    - What data analysis techniques are most useful, for scientific or regulatory purposes, in eliciting information from the PAMS and similar data?
    - How can the long-term sustained effort in PAMS or other monitoring be used to establish progress in achieving improved air quality?
    - What improvements are needed in the long-term monitoring effort in rural areas?

Science question 6. *(Addresses Policy question 7.)*
What are the relationships between the control strategies designed to manage tropospheric ozone and those designed to manage other pollutant regimes of interest?

- What are the linkages and feedbacks between other pollutants of concern (especially, fine particles, regional haze, acid deposition, and airborne toxics) and tropospheric ozone?

- Can future operational assessments be performed in an integrated manner across different pollutant regimes?