CHAPTER 6

THE WAY FORWARD

The previous chapters document the significant advances in our scientific understanding of tropospheric O_3 formation and fate that have occurred over the past decade, as well as the potential applications of these advances to air-quality management. From this one may conclude that our ability to quantify tropospheric O_3 behavior is improved but still incomplete, and that future scientific efforts — and management applications — will be necessary to provide the basis required for truly efficient and effective air-quality management. The following paragraphs provide a concluding synopsis of key findings of this Assessment, accompanied by general recommendations for future activities to expedite progress toward this end. These findings and recommendations are intended as helpful input to policy makers, but are expected to be valuable to scientists as well, as they proceed toward their goal of establishing a reliable, definitive, and quantitative scientific basis for efficient and effective management decisions.

CONCENTRATIONS, EMISSIONS, AND TRENDS

Findings:

- O_3 concentrations appear to be decreasing, or at least holding constant in most areas of North America, despite rapid population increases in many of these areas.

- There is very limited information on the trends in O_3 precursor concentrations in North America. The data that are available suggest that NO_x concentrations have decreased during the past ten years in some U.S. and Canadian cities; VOC concentrations appear to be decreasing in some U.S. cities, but are remaining more or less constant in Canadian cities.

- During the past ten years estimated mobile-sector VOC and NO_x emissions have decreased significantly in both the United States and Canada, while total NO_x emissions from all sources have remained nearly constant or slightly increased.

- Decreases in urban O_3 concentrations over the last decade are likely associated, at least in part, with decreases in mobile source emissions.

- Current O_3-measurement networks have sufficient spatial density in most urban areas of Canada and the United States. In Mexico, however, limited monitoring is ongoing in only a few cities. A significantly greater density of measurements throughout rural North America is required for definitive trend analysis.

- Substantial progress has been made in network measurements of NO_x and VOC, owing to the advent of modern networks such as PAMS and NAPS. A significant level of effort and expertise needs to be committed to these networks in order to assure that the resulting data are useful.

- The uncertainty in emissions remains one of the largest sources of our overall uncertainty in understanding source-receptor relationships, despite notable advances in quantifying some emission rates with the use of continuous emission monitors for large point sources and tunnel studies of mobile sources.

Recommendations:

- O_3-monitoring networks should be augmented to increase the spatial density of rural stations in all three countries. O_3-precursor monitoring networks should be reviewed continually to examine opportunities for increased resolution and reliability. Existing NO_x measurement stations using conventional measurement technology should be upgraded to improve NO_x detection limits and to reduce sampling artifacts. Continued attention to acquisition of accurate, speciated VOC measurements is needed to ensure that accurate surveillance of this precursor is maintained with NO_x and O_3 observations.

- Networks in all three countries should actively strive toward harmonized sampling and analysis protocols, as well as techniques for optimized network design, thus assuring comparability of data sets across national boundaries.

- The establishment of a tri-national data center as a central, accessible repository for data produced by networks in all three countries is highly desirable. The quality-assurance and quality-control procedures associated with the network measurements should be embedded within this data center, thus providing standard, consistent quality-assurance protocols.

- Development of improved, more robust, methods for identifying and quantifying meteorologically induced variability is essential for providing refined future analyses of ozone concentration trends. Consistent statistical interpretive techniques should be applied for trend analysis, when analyzing O_3 and precursor trends for comparison among the three countries.

- Innovative testing and validation procedures based on ambient measurements should be used to augment current, standard methods of emission assessment.

ATMOSPHERIC PHYSICS AND CHEMISTRY ADVANCEMENTS

Findings:

- Natural VOC emissions are now known to influence O_3 production over a significant fraction of the North American continent.

- O_3 production can be limited by either NO_x or VOC availability, and these limitations vary as functions of space and time. Extensive evaluation is usually required to determine optimal emission-reduction conditions.

- Although subject to ongoing analysis, recent studies suggest that O_3 production efficiency (OPE, the number of O_3 molecules produced per molecule of NO_x emitted to the atmosphere) is lower than previously believed (values of 1-3 as opposed to 4-8). This is particularly significant from an ozone-management standpoint because it implies less benefit from NO_x emission control than would otherwise be expected.

- Extended modeling studies such as OTAG have contributed to our appreciation of the relative contribution of upwind sources by long-range transport to local O_3 concentrations. Such studies, however, remain fraught with key uncertainties. Moreover, because they are typically limited to a small number of meteorological case studies, they provide little of the long-term, chemical climatology information that is desirable for extensive policy analysis.

- It is now evident that strong physicochemical linkages exist between O_3 and other criteria pollutants such as CO, NO_2, SO_2 and fine particulate matter. Thus, evaluation of potential emission control strategies could provide for the collective and interactive assessment of all pollutant regimes together.

Recommendations:

- The results of policy-driven air quality studies such as OTAG should be published in comprehensive, publicly available, and preferably peer-reviewed technical reports

- There is a need for additional studies on the spatial scale of O_3 transport in different regions of North America, and on improved methods of meteorological characterization under stagnation conditions.

- Several existing NARSTO field-data sets should be subjected to further analysis – in conjunction with models of several varieties – to gain further insights regarding OPE, VOC/NO_x limitations, and multiple pollutant interactions.

- Because reaction rates, reaction intermediates, and product distributions have been determined for only about 20% of VOC species of interest — primarily for shorter chain paraffins and some olefins — additional laboratory research is needed to characterize reactions of more complex VOC's, including aromatics and aldehydes.

- There is a need to better understand and characterize the dynamics of fumigation and vertical mixing and dispersion of plumes over longer transport distances. There is now considerable uncertainty about the contribution to ozone formation of NO_x from plumes at these distances. Improved understanding would be most helpful in assessing the potential benefits of NO_x reductions from power plants and tall stacks.

- Future field studies and network design should place increased emphasis on characterizing the vertical distributions of chemical and meteorological variables.

- Additional field studies are needed to verify and explain findings of reduced OPEs, and to further elucidate aerosol interactions with gas-phase photochemistry.

MODELS AND MODELING

Findings:

- Substantial advances have been made during the past decade in developing comprehensive emission modeling systems describing both anthropogenic and natural emissions, but they do not a priori improve our ability to quantify real-world emissions.

- Photochemical air quality modeling systems (AQMS) have incorporated numerous improvements during the past ten years, including multi-scale and multi-pollutant ("one-atmosphere") capabilities, closer coupling with advanced meteorological models, and improved diagnostics, such as process analysis and sensitivity/uncertainty analyses.

- The ability of air quality models to simulate observed surface O_3 concentrations has not improved substantially over the past ten years when measured by traditional metrics of operational model performance, despite the improvements made in the model formulations. In general, the reliability of air quality models remains ill-defined.

- During the past ten years, a new class of observation-based models (OBMs) has emerged that apply key mechanistic knowledge in conjunction with field observations to elucidate pertinent aspects of present or past pollution behavior, including OPE and the potential for VOC/NO_x-limiting conditions. As of yet, a rigorous evaluation of these techniques has yet to be carried out.

Recommendations:

- More extensive application of online and post-processing interpretive tools, such as sensitivity/uncertainty analysis and process analysis, should be encouraged in conjunction with air quality model applications — for applied data analysis, for detailed evaluations of model skill and proficiency and for applied risk analysis in conjunction with comprehensive pollution-management strategies.

- Despite substantial efforts to improve AQMS over the past two decades, significant uncertainties remain in the accuracy of their outputs. As a result AQMS cannot yet resolve all issues of interest to policy makers addressing the O_3 pollution problem. Before future resources are committed to programs designed to broadly test and improve AQMS, careful consideration should be given to whether these programs address the fundamental limitations of present-day AQMS, within the policy-making context, and whether the development and improvement of other scientific tools might better serve the policy-making community.

- The chemical kinetic mechanisms used in AQMS need to be evaluated at ambient-level NO_x and VOC concentrations. These conditions have not been achieved thus far in smog chamber studies.

- Additional insights are needed into the characterization of uncertainties, biases, and reliability in the results of air quality models used for emission control strategy assessments.

- Future analyses of field-study and network data should encourage application of multiple model types, using OBM and receptor-modeling techniques as complements to conventional emission-based air quality modeling approaches.

POLICY-ORIENTED TOOLS AND SCIENTIFIC IMPLICATIONS OF POLICY ACTIONS

Findings:

- As O_3 standards or objectives are set to lower concentrations, they come closer to background concentrations arising from natural sources and/or numerous, distant, and unidentified anthropogenic sources.

- Lower concentrations and longer averaging periods in O_3 standards and objectives will require expansion and improvement in the scientific and technical infrastructure intended to support the policy-making process.

- Some studies suggest that the new 8-hr U.S. O_3 standard will result in widespread non-attainment in rural areas of the United States, implying further departure from the local-emission-reduction strategies of past decades and require the development of a much more regional observation and analysis structure.

- An iterative, progress-driven air quality management system has the potential to improve the efficiency and efficacy of decision-making, with the iterative use of emission-based air quality models and application of diagnostic analyses including OBMs. Such a system fundamentally requires the acquisition of reliable and comprehensive data through network monitoring.

Recommendations:

- To enhance the existing science-policy interface, testing and implementation of an iterative air quality management process is recommended. This process should have at least the following components:

  - State-of-the-art modeling and analysis – to estimate what strategy is particularly attractive.
  - Near-source monitoring of precursors, both in stack and ambient – to determine if planned reductions in emissions are achieved.
  - Downwind monitoring of ozone and precursors – to track progress and

determine if estimated air quality improvements are being realized.

- Diagnostic analysis of discrepancies between estimated and observed air quality – to determine the causes of shortfalls in improvement.
- Reevaluation of strategies through modeling and analysis.
- Adjustment of strategies as needed.

Assessment and potential improvements to existing air quality monitoring networks will be an essential prerequisite to such a process.

- Consideration should be given to migrating future activities associated with O_3 management toward a formal risk-management framework, which encompasses a total sequence of goals, strategies, and evaluation. Uncertainties associated with specific tools for characterizing process elements (e.g., emission models, AQMS, network measurements) should be quantified and related to the risks of not attaining established goals. Further scientific development, and relative emphasis on specific research areas, should be prioritized on this basis. This should be coordinated on a tri-national basis. In addition, strong consideration should be given to structuring future O_3 assessments from a risk-management perspective.

NARSTO has begun to establish the linkages for efficient, tri-national information flow between air-quality scientists and the policy community. This scientific assessment of tropospheric O_3 is considered to be an initial step in this evolving process, which is anticipated to lead to cost-effective air-quality improvements throughout North America.