TF HTAP WORKSHOP ON INTEGRATED OBSERVATION FOR ASSESSING HEMISPHERIC TRANSPORT OF AIR POLUTION– GENEVA 24 TO 26 JANAURY 2007

Summary of the co-chairs: Terry Keating and André Zuber – draft version 7

Introduction

The Task Force on Hemispheric Transport of Air Pollution (TF HTAP) has the objective to provide the Convention on Long-range Transboundary Air Pollution (CLRTAP) with a fuller understanding of hemispheric and intercontinental transport of air pollution in the Northern Hemisphere. The TF HTAP aims at providing an interim report by 2007 and a full assessment report by 2009. To provide input to the reports, a series of workshops and meetings have been set up and new cooperative analyses have been initiated, including intercomparisons of chemical transport models (CTMs) used to describe and quantify intercontinental transport and hemispheric pollution. In these assessment and analysis activities, the TF HTAP aims to bring together experts from across the Northern Hemisphere, including air pollution experts from countries that are not parties to the CLRTAP or outside the UNECE region. The TF HTAP invites experts with relevant expertise from all countries to participate in its meetings and cooperative activities.

The TF-HTAP jointly with the World Meteorological Organization (WMO) and Group on Earth Observations (GEO) held the workshop in Geneva 24 to 26 January 2007 to better coordinate atmospheric observations for assessing hemispheric transport of air pollution. The workshop follows two meetings organized by the TF-HTAP held in 2006, one on modeling and one on emissions inventories needed for such models. This latest workshop completes the picture by focussing on observational evidence of long-range transport and observations needed for model evaluation today and in the future. The objectives of the workshop were:

- To take stock of the current state of surface-based, aircraft and satellite observations relevant to: (i) hemispheric transport studies supporting the 2007 and 2009 assessments being conducted by the TF-HTAP under the UN-ECE LRTAP Convention, (ii) WMO weather, climate and environmental prediction applications and (iii) to the Societal Benefit Areas of GEO.
- To determine the gaps in observations for priority air pollutants, gaps in data management, and make recommendations on how to fill those gaps taking into account ongoing efforts under regional networks such as EMEP, NARSTO and EANET; GAW; IGACO; and the development of the GEOSS.
- To identify ways to produce a common data base of observations suitable for evaluation of models and inventories for priority air pollutants, such as ozone and particulate matter and precursors thereof.
- To recommend steps needed to create co-operative structures between regional observation networks and other sources of data.
- To identify short-term and long-term efforts that will improve the information technology infrastructure for sharing relevant observational data and integrating observational data with modelling for purposes of evaluation and improved data assimilation for air quality forecasting.
- To further encourage the participation of developing countries in long range air pollution observation systems

The Workshop - Welcome and context setting

The workshop was opened by Mr Len Barrie on behalf of WMO Secretary-General Michel Jarraud. In his introduction Mr Barrie highlighted the WMO programmes for global observations of air pollution from space, aircraft, and the ground and the further need of integration, such as through the implementation of the International Global Atmosphere Climate Observations (IGACO) strategy (http://ioc.unesco.org/igospartners/atmosphere.htm).

The co-chairs of the TF HTAP Mr André Zuber and Mr Terry Keating introduced the scope of the Convention and the charge of the TF HTAP to provide an improved understanding of intercontinental transport of air pollution. In particular they stressed the science-policy questions adopted by the TF HTAP at its first participants in 2005.

Mr Brendan Kelly from the Group of Earth Observation (GEO) Secretariat presented the objectives of the GEO Systems of Systems that integrate all relevant Earth observations. He emphasized the potential of GEOSS to contribute to the aims of the TF HTAP through efforts in the “societal benefit area” of human health. The participants also took note that an international organization such as the CLRTAP could become a member of GEO and could constitute a "community of practice." As a member or recognized community of practice, CLRTAP may be able to receive greater benefits of investments related to the development of GEOSS.

Session 1 -Observational evidence of intercontinental transport and hemispheric pollution (chair David Parrish)

The main purpose of this session was to summarize the state of science concerning observational evidence of hemispheric or intercontinental scale pollution transport.

Mr Oystein Hov presented evidence of intercontinental transport of air pollution and estimates of how much of the emissions in one continent may influence air pollution in another continent. Mr Hov also identified possible causes for the observed changes in air pollution globally, including changes emissions, climate, and land-use. The participants noted how lessons could be learned from regional and global weather observation and prediction, which have resolved similar problems as those faced by the TF HTAP.

The presentation by Mr Hajime Akimoto showed how regional air pollution monitoring networks in East Asia, such as EANET (Acid Deposition Monitoring Network in East Asia), can clearly demonstrate the influence of European and Eurasian emissions on air pollution in East Asia. The participants took note that existing monitoring networks are located in the Asian outflow region, but there is a lack of monitoring in the inflow region or interior of Asia to meet the needs of evaluation of intercontinental transport of air pollution. The participants took note also of some initial results of monitoring in the North China Plain.

Mr Stuart Penkett showed how combinations of observations from the ground, satellites and aircraft can be used to improve the observational basis for the study of chemical and physical processes that determine the levels of tropospheric ozone, stressing the need for better observations of volatile organic compounds and reactive nitrogen species. The participants took note of the observations of increasing background levels of tropospheric ozone in wintertime and the value and future need of observations on isolated islands, such as Mt. Pico in the Azores (PT).

Ten years of air pollution observations from long haul commercial flights obtained in the MOZAIC program was presented by Mr Andreas Volz-Thomas. The vertical profiles and observations over remote regions and the oceans show clear evidence of . Long range transport of air pollution from forest fires and urban plumes and air exchange processes in the upper troposphere and lower stratosphere. The participants took note of high concentrations of CO and NOy observed in the upper troposphere that are not captured by current models. The participants also took note of the plans to continue and extend the observation programme under a new initiative (IAGOS).

Mr Owen Cooper summarized observed ozone trends noting significant ozone increases in Europe and Japan in the 1970s and 1980s, with smaller increases in North America. More recent observations suggest a leveling off or decline in some locations, while other locations, such as remote sites in the North Atlantic, experience a continued increase. The participants took note of the increase of springtime ozone in the middle atmosphere and at ground level observed at many places and that the observations of very low ozone concentrations in the background have become rarer.

Mr Paul Monks presented how airborne observations of air parcel polluted by forest fire emissions or regional urban pollution could be traced over long distances through trajectory analysis and chemical "finger printing." Such studies give an insight in the chemical processes leading to increased levels of

key radical species and ozone. The participants took note that a substantial part of the reactive chemistry in these plumes took place in the lower free troposphere below 4 km altitude.

Mr Gufran Beig presented studies of the impact of Indian emissions on the tropospheric distribution of ozone and its precursors over the South Asian region, and the dependence of ozone on the seasonal monsoon cycle. The participants took note of estimates that the impact of air pollution emissions in neighboring countries on India are larger than the estimated impact of Indian emissions on the neighboring regions.

Ms Lorraine Remer showed the participants how satellite observations are used to constrain model estimates of pollution transport and emission sources. The participants took note of the need to benchmark models against a database of observations from multiple sources, including satellites, and to compare many different parameters.

The workshop presentations and discussions showed that:

- Numerous examples exist of observational evidence of intercontinental transport of air pollution. The evidence comes from observations from ground based measurements, aircraft in situ experiments, and satellite observations, often in combination with chemical transport models. Plumes of polluted air with elevated levels of fine particles, ozone, and ozone precursors, including CO, may be tracked over long distances. The pollution originates from urban regions, forests fires, dust storms, and other sources. Air from the stratosphere may be tracked through its chemical composition and physical properties. Transported air pollution may impact air quality in distant locations, often in the form of elevated CO, ozone, and PM concentrations and other trace components such as Hg and POPs.
- Increased intercontinental transport of air pollution may follow from increased emissions in the source regions. Hemispheric air pollution is also affected by long term (climatic) changes in the atmosphere, such as changing oxidizing capacity, temperature, and transport patterns, overlaid with natural atmospheric variability (NAO, ENSO, monsoon).
- Observation of ozone background concentrations show increases in some regions such as on the western rim of Europe and North America, most clearly indicated in wintertime. This increase in background ozone is not detected consistently in all places globally. In some regions where emission reductions have taken place the ozone background levels are decreasing.
- National and WMO GAW monitoring programs, supplemented by satellites and aircraft observations, achieve some coverage of key air pollutants (PM, ozone, and some precursors), locations, and parameters relevant for the assessment of intercontinental transport and hemispheric air pollution. However, there are substantial gaps in the observation systems.

The workshop recommended that:

- *The TF HTAP should work towards making multiple types of observational data of known quality available in common formats for the purpose of evaluating models used in the assessment of hemispheric transport of air pollutants.*
- *The TF HTAP, EMEP, WMO, and GEO should work to maintain and expand the observation of air pollution concentrations and composition, through routine networks, intensive field campaigns, and satellite observation, to better understand the sources and transport of air pollution.*
- *The TF HTAP's assessments of hemispheric transport should address concepts complementary to model-derived source-receptor relationships, including source contribution analysis from observations and models and objective assimilation techniques (including source information*
- *Observed trends, such as ozone time series from remote sites, should be compared to modeling of long-term changes in emissions and chemical and atmospheric processes.*

- *International organizations and national administrations should make information available for assessments of large-scale changes of air pollution and hemispheric transport of air pollution. The WMO and the GEO could play key roles as focal points for such coordination.*
- *The TF HTAP, EMEP, WMO, and GEO should aim to ensure the establishment and maintenance of air pollution monitoring in areas that are poorly covered by current systems, including the Artic, central Asia, and remote oceans, as well as for observing vertical profiles.*
- *Further efforts should be made to better understand process relevant for long range transport of air pollution, such as the processes leading to the transport of air pollutants from the middle troposphere into the boundary layer and to the surface.*

Session 2 The use of integrated observations for evaluation of models and emission inventories (Chair Michael Schulz)

The main purpose of this session was to discuss how observations can and should be used for the evaluation of models and emissions inventories and to highlight what observations and what forms of integration are useful to the modeling and emissions communities.

Ms Arlene Fiore presented the first preliminary results from the TF HTAP model intercomparison for ozone. To date, 12 modeling groups have provided results for the sensitivity of ozone concentrations to a 20 percent reduction in precursor emissions in four source regions. Most models respond similarly, predicting a small but clear influence of source regions on one another. The response of emission reductions varies between the continents but appears narrower than seen in the literature. The models appear to be more sensitive to emission changes in NO_x and methane than to NMVOC and CO. Reductions in individual ozone precursors appear to be fairly additive. The participants took note of that the first results are promising but need to be carefully analyzed before any conclusions on the size of intercontinental transport can be drawn.

Mr Greg Carmichael showed how estimates of source/receptor estimates may be improved through the closer integration of observations and models. In particular, he stressed the value of using advanced assimilation techniques that explicitly allow for "errors" in the observations, model descriptions, and emissions to generate an optimal description of the state of the atmosphere. He showed North American examples where assimilation, direct sensitivity, and adjoint analysis techniqueshave been successfully applied to better describe air quality and the impacts of emission changes . The participants took note of the potential value of data assimilation and adjoint analysis techniques for the assessment of hemispheric transport.

Ms Kathy Law discussed how Lagrangian observations from aircraft and surface stations may be used for model evaluation by following the evolution of polluted plumes travelling over large distances. The participants took note of the potential to use observations of episodic events such as forest fires and of urban plumes during which the pollution signal is clearly defined. The participants also took note of the further experiments planned for 2007 and 2008 in the POLARCAT experiment.

Mr Qinbin Li showed various observations from satellites, aircraft, and remote ground stations can be used to evaluate or improve model predictions of the outflow of air pollution from a source region. The participants took note on how models combined with observations can be used to improve our understanding of key processes such as deep convection, dilution of continental outflows, and biomass burning plume injection heights. The participants also took note of how models and observations can be used in adjoint analysis and used to constrain emission estimates.

Mr Andreas Richter demonstrated how information from theGOME and SCIAMACHY satellite-based instruments can be used to constrain emission inventories. He identified a number of strengths and limitations of satellite observations of NO_2 and described applications of the data to estimate shipping, lightning, and soil emissions and to quantify anthropogenic emission trends in east Asia and the eastern United States. The participants took note of the large potential of these observations to obtain global coverage for some key species and to track changes over time through a series of observations from various satellite instruments.

Mr Andreas Stohl highlighted the specific issues of the Arctic, a region with very few emission sources, few observations, and unique characteristics that affect transport and photochemistry. He showed several examples of episodes of high concentrations of fine particles, black carbon, CO, and ozone in the Arctic due to transport from urban and industrial air pollution and forest fires in Europe and Asia. Such episodes of air pollution can also be transported across the pole to North America. The participants took note of the further efforts planned for the POLARCAT experiments in 2007 and 2008 that would improve our understanding of Arctic air pollution.

Mr Martin Schultz discussed how CO observations can be used to evaluate the ability of models to describe the transport processes relevant for long range transport. Although a lot of CO observational data exists, there is no "one stop shop" to obtain such data. He concluded that some models can reproduce observed trends and variability of observed surface concentrations of CO, but question remain about the ability to simulate CO concentrations aloft and to constrain emissions. The participants took note of the plans to conduct further work on passive tracers such as CO in phase 2 of the TF HTAP model intercomparison.

Mr Sandy Sillman used model results to explore what ratios of pollutants such as Hg, CO, ozone and HNO3 can tell us about long-range transport and the origin of air masses. He concluded that the ratio of reactive mercury gaseous (RGM) to elementary mercury is an important tracer of local/regional air pollution and slopes of ozone to CO can be used to indicate regional and episodic production of ozone as compared to global background ozone. The participants noted that "fingerprinting" of air pollution provides an additional tool for assessing long-range air pollution and for model evaluation.

Mr Hiroshi Tanimoto presented analyses of the interannual variation and recent trends of surface ozone in East Asia. He emphasized the need to ensure comparability of observations (including traceability of QA/QC) from different networks to be able to track small changes over regions and over time. Comparisons with CTMs over Asia indicate that the emissions in the region are underestimated. The participants took note of the need to improve observations of air pollution in the Asian region.

Mr Sunling Gong described the interannual variation and recent trends of Asian dust storms and the correlation of dust transport with climatic indices. These storms may transport substantial amount of dust across the continents and between the continents. The participants took note of that there is a long term trend in Asian sand storms with an apparent decrease between 1960 and 1995, and a slight increase the last decade. Mr Gong described the proposed structure of a global operational WMO sand and dust storm warning system, which will build on a number of existing observational and operational forecasting systems around the world.

The workshop presentations and discussions showed that:

- Observations collected at the surface or by aircraft or satellite have different strengths and weaknesses. Using multiple types of observational data in coordination with models can help diagnose strengths and weaknesses in the models and together, through assimilation, generate the most complete descriptions of air quality and its sensitivity to changes in emissions and other conditions.
- Comparability and traceability of QA/QC schemes for data from surface site networks is important for detecting spatial and temporal trends.
- Observations from coordinated, intensive field, aircraft, and satellite campaigns, including Lagrangian observations of air masses, can provide information about atmospheric processes that are important for controlling intercontinental transport and hemispheric pollution.
- Observations of vertical profiles, from intensive or routine aircraft campaigns, sondes, or ground-based and satellite-based remote sensors, provide essential information for evaluating models used in assessing long-range transport.
- Satellite observations provide a variety of information that is useful for evaluating models and emissions inventories, but the limitations and assumptions inherent in the data must be well understood.

- The techniques for evaluating models range from "ocular" comparisons to observations to detailed estimates of performance statistics.
- Advanced data assimilation techniques can be used to improve model predictions as well as identify major uncertainties in emission inventories and in key transport and chemical processes in the models.
- The processes leading to the outflow of air pollution from source regions and the transport across large distances has been studied in some detail in field experiments and from long term observations from the ground and space. Chemical tracer experiments (Lagrangian experiment) have given insight in key chemical process governing the ozone production in the middle and upper troposphere. To a lesser extent has the processes governing the deposition of air pollution from the middle atmosphere been studied.

The workshop recommended that:

- *The TF HTAP should design benchmarking criteria for the evaluation of models and characterization of uncertainty in the assessment of intercontinental transport and hemispheric pollution. The benchmarking should use an integrated set of observational data drawn from different platforms with different time and geographical scales and coverage.*
- *The TF HTAP jointly with the EMEP centers, WMO, GEO, and others should continue efforts to improve the observational basis for HTAP and improve the interoperability of data.*
- *The TF HTAP should revisit the observational evidence of intercontinental transport of air pollution at later meetings. Given the focus of this meeting on ozone and ozone precursors, attention should also be paid to the role of long range transport of PM, Hg and POPs.*

Session 3 - – Improving the integration of observational systems and interoperability of observations and models (chair Terry Keating)

The main purpose of this session was to identify what steps can be taken by TF HTAP, WMO, and/or GEO to facilitate the integration of observations and models and improve interoperability.

Mr Len Barrie presented the essential components of an integrated global atmospheric observations system and the challenges to put such a system in place. Several global observational networks are presently operated but there is a need for better coordination of efforts. Key challenges include long-term financing, balancing the interests of different scientific communities (e.g., short-term v. long-term observations, observations v. modeling, forecasting v. assessment), and enabling near-real-time data exchange and long-term data archiving, The participants took note of the major efforts by the WMO to implement the IGACO strategy, to reinforce coordination efforts made by national authorities, and to ensure the continuity and accessibility of long term observations. The participants also took note of the gaps in the observational system with respect to the needs of the TF HTAP.

In his presentation on in-situ observations, Mr Kjetil Thorseth showed that there are a large number of observational networks globally but they are poorly coordinated and only cover adequately some regions. Several new projects are now addressing the data gaps, in particular for regional air pollution in Europe and in North America. The participants noted that there are major issues of comparability, interoperability, and accessibility of data to be addressed in the future.

Mr Rudy Husar presented how information technology can be used to improve the interoperability of observations and other data, following the "system of systems" concept of GEOSS. Mr. Husar demonstrated that shared web-tools for access to "federated" data bases already exist and are being used, but more effort is needed to make other data sets available. The participants took note of the potential to use such technologies in TF HTAP's model intercomparison and evaluation efforts, the potential role of WMO/GAW as a facilitator for global data integration, and the challenges in achieving the vision of GEOSS.

Mr Tony Hollingsworth gave a progress report on the EU contribution to the GEOSS: the Global Monitoring of Environment and Security (GMES) and the project Global and regional Earth-System

(atmosphere) Monitoring using Satellite and in-situ data (GEMS). The prime objective of this project is to create a operational system near-real-time and retrospective analyses and medium- and short-range forecasts of air pollution and greenhouse gases on European and global scales by 2009. The system will use satellite data assimilated into global and regional models that can then be compared to ground-based observations. The participants took note of the close links between the TF HTAP efforts and one of the GEMS subprojects on global reactive gases and between the timing of TF HTAP 2009 assessment and the completion of the GEMS operational system.

Mr Julian Wilson he showed how an integrated database of observation of aerosol physical and chemical properties has been created under the GAW program. This data has been used for model evaluation and closure studies. The participants noted the usefulness of such data for the model evaluation efforts of TF HTAP and the need to continue the observations and data archiving.

Mr Hideaki Nakane presented the recent development of a dust lidar network in Asia and the assimilation of the observations into models to produce dust forecasts and trend analyses. In a network such ground based instruments can track dust transport aloft up to altitudes of 6 km. The participants noted the usefulness of the network for the assessment of long range transport of dust.

The workshop presentations and discussions showed that:

- Several attempts are going on to make observational data more accessible and progress has been made in standardizing formats for data exchange. Still there is more to do to further improve the interoperability of observational and data management systems.
- State of the art information technology can help address some of the challenges associated with data access and exchange, but investments will be needed to take advantage of that technology.
- There is a need for dialogue between major stakeholders in the observations and research communities and policy-makers to improve the long term continuity and utility of integrated observations.

The workshop recommended that :

- *The TF HTAP develop a system for model-observation benchmarking, including a virtual data center that would allow access to key observations and model data.*
- *Particular efforts should be made to fill any data gaps. For the benchmarking there is also a need to further develop tools for model and data comparisons.*
- *The TF HTAP, jointly with EMEP activities and in coordination with other efforts such as WMO, GEO, and the IGBP-WCRP Atmospheric Chemistry and Climate Initiative, should work to develop and promote standards and conventions to improve interoperability and data comparability. In addition, transparent and complete documentation of data (QA/QC) has to be promoted so that the comparison can be made with know quantities and quality.*
- *The community should make efforts to maintain financing of long term monitoring, relevant for assessing intercontinental transport and hemispheric pollution. Such monitoring includes ground-based sites on remote islands (such as the Pico Island and Cap Verde,), at high elevations (such as Mt Bachelor), or in regions with few observations (such as the interior of Asia). The continuity of monitoring from satellites and aircraft must also be supported.*
- *Further efforts should be made to support observations of vertical profiles from sondes, ground based remote sensors, satellites, and aircraft.*
- *WMO/GAW, EMEP, and national administrations should work to create and extend the interoperability of regional and national monitoring networks and to improve the links to the various user communities of atmospheric composition information.*