

Questions to organize Part D: Synthesis

- 1. Observations:** What is the observational evidence for the intercontinental transport of mercury, and persistent organic pollutants in the Northern Hemisphere?
 - Events/Plumes
 - Experimental data show long-range transport across the Pacific and suggest a significant underestimate of Asian mercury emissions.
 - Satellite Observations
 - Not available yet.
 - Trends in Remote Locations (and comparison to emission trends)
 - Mercury concentration measurements in ambient air of documented and accepted quality are available since the mid 1970 and concentration data are available for both hemispheres.
 - Long-term monitoring of atmospheric mercury with high time resolution has been started at Alert, Canada (January 1995) and Mace Head, Ireland (September 1995), followed by numerous other sites since then.
 - Current global TGM background concentration has been observed to be in the range of 1.5 to 1.7 ng m⁻³ in the Northern Hemisphere and 1.1 to 1.3 ng m⁻³ in the Southern Hemisphere (at sea level).
 - All over-water measurements performed during oceanographic cruises crossing the Atlantic and Pacific Oceans show a pronounced concentration gradient between the hemispheres with a ratio NH/SH: 1.45.
 - The inter-hemispherical gradient with 30 % higher TGM concentrations in the northern hemisphere remained nearly constant since mid 1970.
 - Decreasing trends of ambient concentrations of TGM have been observed at regional background sites in Europe and North America as a result of emissions reductions achieved in those regions. However, potentially increased Asian emissions are not yet reflected in the long-term measurement of TGM and mercury in precipitation at ground-based remote locations in Europe and North American.
- 2. Source Attribution:** What do current models tell us about the contribution of intercontinental or global flows to concentrations and deposition in the different regions of the Northern Hemisphere?
 - The models provide consistent estimates of the importance of intercontinental mercury transport and its contribution to local deposition.
 - The contribution of extra-regional anthropogenic sources to annual local deposition fluxes varies from 10% to 30%, on average. However, it is important to point out that 35 to 70% of local deposition is contributed by global natural and secondary emissions; it is believed that oceans account for an important fraction of this.

- East Asia is the most dominant source region contributing to 10-14% of Hg deposition in other regions, followed by contributions from Europe (2-5%), South Asia (2-3%) and North America (1-2%).

O3	PM	Hg	POPs
Inside Region NO _x /VOC/CO	Inside Region Anthro PM & Precursors	Inside Region New Anthro	Inside Region New
Outside Region NO _x /VOC/CO	Outside Region Anthro PM & Precursors	Outside Region New Anthro	Outside Region New
Methane	Vegetation Burning	Re-Emission	Re-Emission
Natural	Dust/Sea Salt/Volcanoes	Natural	

- ✓ Each fraction has different implications for controllability, sensitivity to emission changes, seasonality, spatial variability, ...
 - Changes in emissions in one region affect mercury concentrations and depositions in other regions proportionally to the magnitude of the source region's contribution to the receptor region. For example, a 20% emission reduction in East Asia, Europe, South Asia, and North America separately resulted in 0.6-5.5%, 0.2-3.5%, 0.1-1.5% and 0.1-1.5% decrease of Hg deposition in other regions, respectively.
 - The large contribution of natural sources and secondary emissions to deposition reduces the relative response of Hg deposition to any reduction in anthropogenic emissions. However, the response could be greater in the long term due to a slower response for Hg recycling from surface reservoirs.
- ✓ **Are these the right fractions to describe?** Yes to the best of knowledge currently.
- ✓ **For what conditions?**
 - Global Average v. Specific Region
 - Annual Average v. Peak Concentrations
 - Past, Present, Future Conditions
 - Surface Concentrations, Deposition, Column Loadings

Within the HTAP regions analyzed.

- ✓ Do we have the data?

Yes, we do to support our current conclusions, but not enough for a full validation of models' performance.

3. Source-Receptor Relationships: How will changes in current emissions in one region affect air pollution concentrations or deposition in another region?
 - ✓ Import Sensitivity (combined effect of outside region on inside region)
 - ✓ Variability within regions and across seasons
 - ✓ Relative Strength of S/R Pairs

Jerry, Oleg and Ashu will evaluate the feasibility of providing this assessment by end of July.

4. Impacts: What is the contribution of these intercontinental or global flows to impacts on human health, natural and agricultural ecosystems, and near-term climate change?
 - ✓ By pollutant? Separate section for Arctic?
 - ✓ Different types of information for different pollutants
 - ✓ Emphasize multiple benefits, shared benefits

FROM B-5:

FINDING: Fish are the main source of human exposure to mercury. In regions that have not been contaminated by large local sources of mercury, the majority of population-wide human exposure is from marine fish consumption. Concentrations of mercury in commonly consumed migratory marine fish such as tuna and swordfish are affected by intercontinental transport and deposition of mercury to marine ecosystems.

RECOMMENDATION: Reductions in global anthropogenic mercury sources are recommended as a method for reducing the mercury burden in pelagic marine fish and associated human exposures.

5. **Future Scenarios:** How may the source-receptor relationships change over the next 20 to 50 years due to changes in emissions and climate change?
 - ✓ Impacts of expected emission changes.
 - ✓ Potential for mitigation.
 - ✓ Impacts of expected climate change.
 - Three future anthropogenic emission scenarios for 2020 representing the status quo conditions (SQ), global emission controls similar to the present-day European controls (EXEC) and advanced global emissions control (MFTR) show significant changes in emissions in East and South Asia and smaller changes in European and North American emissions. Depending on the applied emission scenario the change of Hg deposition between 2005 and 2020 will increase by 2-25% for SQ (to verify if SQ = BAU) and decrease by 25-35% for EXEC and MFTR in different HTAP regions.
 - In remote regions, such as the Arctic, the changes are expected to be smaller – from 1.5-5% increase (SQ) to 15-20% decrease (EXEC, MFTR).
 - The models' estimates agreed fairly well (less than 10% inter-model variation) in assessing the impact of future emission scenarios on mercury deposition.

- Based on available projections, mercury source-receptor relationships are not expected to change significantly in the next 20 years.
6. **Processes:** How well can we represent the processes that affect these intercontinental or global flows of air pollutants in quantitative models?
- ✓ Ability to represent overall patterns based on existing models, emissions, and observations.
 - ✓ Challenges for quantifying intercontinental transport.
 - ✓ Pollutant differences in complexity, data availability
 - ✓ Need consistency about what constitutes agreement between models and observations
- Numerous studies using mercury transport models have been conducted in the past two decades on both global and regional scales for a variety of tasks including understanding of Hg processes in the atmosphere, evaluation of Hg levels, and assessment of source-receptor relationships. In many cases the models demonstrate satisfactory agreement with observations; however considerable variability of the model results indicates essential gaps in knowledge of Hg atmospheric chemistry and exchange processes of mercury between the atmosphere and terrestrial and aquatic environments.
 - Ambient concentrations of elemental gaseous mercury, species responsible for long-range atmospheric transport, are reliably simulated by contemporary models. Model results are consistent with observations that show similar concentration gradients from the Southern Hemisphere to the Northern Hemisphere. However, spatial coverage of available long-term observations is not sufficient for constraining the models adequately.
 - Yes, we do have observations to support our conclusions to date, but not yet enough for a full validation of models' performance.
7. **Future Science Directions:** What efforts are needed to develop an integrated system of observation data, emissions, and models to better understand and track these flows?
- Can't include all recommendations
 - Focus on common themes and recommendations that cut across disciplines?

Major effort is needed to build a coordinated observation system on global scale able to provide ground-based, over-water, and free troposphere observations. However a first step has been taken recently by the European Commission which has approved a new project "Global Mercury Observation System – GMOS" (<http://www.gmos.eu>) that involves 24 partners globally and a number of regional networks/sites in Canada, USA, Japan and Korea. GMOS will develop a ground-based observation system that will include nearly 40 monitoring sites worldwide, oceanographic cruise campaigns over the Pacific and Atlantic Oceans and Mediterranean Sea, and aircraft measurements at UTLS. GMOS is part of the GEO Task HE-09-02d "Global Monitoring Plan for Atmospheric Mercury" as contribution to GEOSS work plan 2009-2011.

- Try to highlight cost effective investments?
- Role for TF HTAP?
 - a. To continue to act as synthesizing party and help facilitate the dialog between scientists and policy makers as well as with other programs i.e., UNEP, GEO/GEOSS.

8. **International Cooperation:** What are the potential benefits of further international cooperation to address these pollutant flows?

- Inability to meet some policy goals if intercontinental flows are not mitigated.
- Shared benefits of emission control:
 - Direct: Health, Ecosystem, Climate
 - Indirect: Avoided Costs of Control
- Costs and availability of controls needs to be investigated further.
- Control Decisions need to be understood in terms of their local, regional, and global impacts.

There is an on-going initiative within the UNEP Mercury program to develop a legally-binding instrument aiming to reduce the impact of mercury emissions on ecosystems and human health. Currently the mercury atmospheric models are capable to simulate the effectiveness of emissions reduction scenarios in terms of ambient concentrations and deposition fluxes reductions. These capabilities will be improved with data that GMOS will provide to the modeling community.

The costs related to emission reductions strategies are primarily the focus of the UNEP Mercury program and its partnership areas such Coal Combustion, Fate and Transport, etc. This information can be included in the development of the emission scenarios as soon as the legally-binding instrument establishes targets in terms industrial priority sectors and emission reductions.

Other Questions for Lead Authors:

- Does the content of the chapter provide answers to the synthesis questions? **YES**
- What gaps exist and what further work needs to be done? **See findings and recommendations in each chapter as well as the text reported above.**
- What can be accomplished in 2 weeks? **Scientists will be on vacation.**
- What can be accomplished by August? **Chapter B6 – restructured.**
- What can be accomplished by September?
- What can be accomplished by October?