Schedule to Complete Drafts

Milestone	Weeks to Complete	
2-Mar		**Today**
	3	Draft Findings and Recommendations
23-Mar		**Submit Draft Findings and Recommendations**
	4	Further Revise/Complete Chapters/Summaries
19-Apr		**Revised Drafts Submitted**
	1	Review Draft Production (Formatting)
26-Apr		**Review Draft Circulated**
	3	External Review
17-May		**Comments Due**
	2	Respond to Comments
31-May		**Review Draft Circulated**
	2	TF Review
14-Jun		**ES Acceptance Meeting**

13-15 Sep	EMEP Steering Body Meeting
13-17 Dec	LRTAP Executive Body Meeting

Q1. Process Understanding?

- **What are the processes that affect the intercontinental or global flows of air pollutants and how well do we understand them? How well can we represent them in predictive models?**

Q1. What are the processes that affect the intercontinental or global flows of air pollutants and how well do we understand them?

A2: Satellites clearly observe transport of CO and possibly O3

A2: Plumes are observed over downwind continents

A2: Satellites clearly observe transport events of aerosols

A2: Lagrangian measurement campaigns provide very useful information on ozone production and loss during long range transport

A2: Focused intensive campaigns like ICART/TRACE-P etc provided a wealth information on long-range transport

A2: Chemical tracers (e.g. species ratios, isotopic composition, inert tracers) provide useful indicators of sources, and chemical processing during transport from emissions regions to measurement location.

A3 Continental scale emissions are of same order of magnitude

A4 Representation of Mid-lat circulation (horizontal transport) in model looks fine –models can represent interannual variation in pathways

A4 Models have issues to represent vertical transport – convection, frontal lifting, subsidence; lack of understanding and effective representation at the model resolution

A4 There are large uncertainties in understanding processes – chemistry, scavenging, microphysics, as well as the implementation in models; importance different for O3, aerosol; Uncertainty in deposition and scavenging – how can we evaluate these? Plume and layer structures can’t be resolved.

What are the processes that affect the intercontinental or global flows of air pollutants and how well do we understand them:

Intercontinental transport of mercury can occur through direct transport of emitted mercury plume from one continent to another, through a pathway that typically involves the lifting of mercury plumes to above the planetary boundary layer, followed by the rapid atmospheric transport in the free troposphere. The mercury emission from a source region into the global mercury pool involves the release of Hg(0) into air and dispersion in the atmosphere. Following oxidation/reduction processes, mercury is deposited by various removal mechanisms and recycled between the atmosphere and other environmental compartments.

Q1. Process Understanding: POPs

- **Emissions (amount and location) and residence time ultimately determine the extent of intercontinental LRT.**
- **Wide range of pollutants with different physical and chemical properties & persistence**
- **Physical and chemical atmospheric processes modify the dispersion on a wider scale**
  - **Wind patterns (high level of understanding)**
  - **OH decay (high level of understanding)**
  - **Air-particle interaction (medium level of understanding)**
  - **Surface/air exchange (medium to low level of understanding)**
  - **Emission inventories (low level of understanding)**

Q2. Source Attribution

- **What is the contribution of these intercontinental or global flows of air pollutants to concentrations, deposition, and impacts to health, welfare, ecosystems, and climate?**

Q2. What is the contribution of these intercontinental or global flows to concentrations, deposition, and health and environmental impacts?

A2: Strong evidence for increasing trop O3 at some surface sites and in FT over NA – cause is uncertain – evidence for HTAP? – some alternative data sets (e.g. sondes) give generally smaller trends. Differences are related to measurement techniques and need to be resolved.
A2: Onshore marine air flow carries O3 concentrations that are above some standards of concern for ecosystem and human health
A2: Onshore marine air flow aloft can carry O3 concentrations that approach urban air quality standards, and that air can mix to the surface and contribute substantially to AQS violations – particularly noticeable in low emission regions. Interaction with boundary layer mixing, complex topography.
A2: Decreasing sulfate trends in the Arctic, marine trends (?) MORE INFORMATION TO BE ADDED; reliable info on trends in Europe, N. Am.; no trend info on sulfate other components elsewhere.
A2: BB plumes and dust plumes episodically make substantial contributions to AQS exceedances (particles)
A2: Will say something about CO trends
A4: Models can provide numbers for source attribution –
A4: Understanding of linearity is more reliable for aerosol than for ozone

Q2 (II). What is the contribution of these intercontinental or global flows to concentrations, deposition, and health and environmental impacts?

A5 HEALTH There is strong evidence that ozone and PM adversely affect human health, including relationships with premature mortality. Current evidence suggests that PM is the most important pollutant for health.Emissions from one continent affect human health on other continents, by affecting ozone and PM concentrations.

A5: ECOSYSTEMS: There is evidence of substantial damage by ozone to a variety of different ecosystems including crops, forests and grasslands. More recent experimental studies have found impacts associated with fumigation that simulates rising background ozone concentrations. For PM the evidence is more limited.

Q2 (II). What is the contribution of these intercontinental or global flows to concentrations, deposition, and health and environmental impacts?

A5 :CLIMATE Intercontinental transport of ozone and PM cause significant climate forcing. Ozone is a greenhouse gas that causes a warming, PM is a mixture containing mainly cooling components (including sulfate and organic aerosols) and black carbon that causes a warming. Any change in emissions that influences ozone and PM concentrations also influences global climate.

A5: Long-lived GHGs will accumulate and dominate over next century, but there is an opportunity to slow rate of climate change by reducing ozone and black carbon, which are transported on an intercontinental scale.

A5: There are opportunities to improve air quality while slowing climate change, by reducing emissions of black carbon, methane, carbon monoxide, and NMVOCs. Among ozone precursors, widespread reductions in emissions of CH4, CO, and NMVOCs better reduce net climate forcing than NOx, which may increase forcing.

A5: Reductions in concentrations most aerosols would exacerbate global warming, but there is an opportunity to reduce BC with benefits for air quality and climate. The forcings resulting from changes in emissions of these components depend on location, and this is not fully quantified.

What is the contribution of these intercontinental or global flows to concentrations, deposition, and health and environmental impacts:

Contribution of Hg intercontinental transport is significant, particularly in regions with few local emission sources and sensitive ecosystems. The contribution to annual deposition fluxes varies from ??% to ??%, on average and can be up to ??. More than half of total deposition fluxes to most regions consists of contributions from natural sources and re-emission processes. East Asia is the most important source region followed by Europe, South Asia and North America.

Q2. Source Attribution - POPs

- **Varies strongly depending on properties of the substance - ranging from a minor fraction to complete dominance**
- **For a given substance, strong dependence on emission location and pattern**
- **Impacts vary strongly depending on toxicity**
  - **Most important for remote areas like polar regions and cold alpine areas – effects seen on, eg, polar bears, Inuits**
  - **Arctic ecosystem is particularly sensitive due to nature of food chain**

Q3. Source-Receptor Relationships

- **How have emissions and associated impacts changed over time and How will further changes in emissions in one region affect air pollution and its impacts in another region?**

Q3. How will ?HAVE?changes in emissions in one region affect air pollution and its impacts in another region?

A2: Past observed trends may provide guide to future?

A3: There are several sources of information (country reported, scientifically based) that provide information on current emissions for all major species, by sector and world region; going back to 1850, but more reliable for 1970-2010. More information on spatial distribution of emissions (gridded) is gradually becoming available

A3: The reliability of the emissions data varies by region and species, quantification of uncertainties still problematic.

A3: Progress is made towards reconciliation/harmonization of different emission data sets through international exchange of information by emission experts. (e.g. Asian Case Study and incorporation of regional inventories in global inventory EDGAR-HTAP; RAPIDC)

A3: Emission “events” biomass burning (mainly), mineral dust, and volcanoes are visible in observations.

A4 Models can quantify S-R relationships – detailed numbers available monthly mean continental scales

> **A4** Literature studies provide some information spatial variability (but uncertainty higher…)

A4 Long-term responses through CH_4 (of O_3 or aerosol…) can be quantified, not all feedback have been assessed.

Q3. How will ?HAVE?changes in emissions in one region affect air pollution and its

A5 HEALTH: Emissions of ozone precursors cause greater health impacts outside of some source regions than within, due to larger populations outside of those source regions. (NOTE: Check PM)

A5 While contributions of emissions within a region to ozone and PM are generally most important for human mortality, intercontinental transport make significant contributions (Percent of total impacts?)
Comparison of the magnitude of ozone and PM long-range impacts…?

A5 ECOSYSTEMS Provisional results using AOT40 give some indication that emissions from one continent have the potential to influence crop productivity on other continents by affecting ozone concentrations.

How will changes in emissions in one region affect air pollution and its impacts in another region ?

Any changes in emissions in one region affect mercury concentration and deposition in another region proportional to the magnitude of source region contributions to the receptor region. The proportionality is defined by the rate of change in emissions. For example, East Asian emissions contribute to 30 % of Arctic Hg deposition. Reduction of 20% East Asian emissions will lead to a 6 % of decrease in the Arctic deposition.

Q3 & Q4POPs

3. How will changes in emissions in one region affect air pollution and its impacts in another region?

4. How may the source-receptor relationship change over the next 20 to 50 years due to changes in emissions?

- **Quantitative information on SR from the HTAP SR experiments – to be documented in Part C**

- **Policy actions reducing emissions changes intercontinental flows, but the response in changing load and exposure to the environment and humans may be long due to component's persistence.**
- **Several examples of policy action exist: technical HCH, PCB, etc**

Q4. Future Emission Scenarios

- **How may the source-receptor relationships change due to changes in emissions?**

Q4. How may the source-receptor relationships change over the next 20 to 50 years due to changes in emissions?

A2: Past (observational) trends may provide guide to future?

A3: Future emissions of AP are driven by socioeconomic and regulatory/technology factors, but also influenced by climate policies, especially methane, but implicitly also other reactive components.

A3: There are several sources of information (country reported, scientifically based) that provide information on future emissions for all major species, by sector and world region;

A3: A major activity is the RCP emission scenario work, as well as selected other scenario (GAINS, SRES)

A3: Also important are related issues of future land use changes that will affect emissions (e.g., CH_4) and climate change feedbacks that will affect emissions (e.g., increased droughts → more dust, biomass burning; soil NO_x; lightning NO_x; biogenic VOCs ...)

A4 Models can quantify future contributions from changing emissions.

- **A4** Models in present analysis do not yet consider changing geographical patterns of emissions.
- **A4** Model asssesment of SR relationships, haven’t included natural emissions changes, vegetation-deposition impacts

How may the source-receptor relationships change over the next 20 to 50 years due to changes in emissions?

The source-receptor relationship in the next 20-50 years will strongly depend on the relative changes of emissions in each source region. Based on available mercury emission projections, the source-receptor relationships of anthropogenic emissions should not change greatly, the direction of changes will depend on the assumptions of emission scenarios.

Q3 & Q4POPs

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Q5. Future Climate Scenarios

- **How may the source-receptor relationships change due to changes in climate and concentrations of other pollutants (atmospheric conditions)?**

Q5. How may the source-receptor relationships change due to climate change?

A2: How have emissions changed in the past (natural or biogenic in response to climate change?)

A3: climate change feedbacks will affect emissions (e.g., increased droughts → more dust, biomass burning; soil NOx; lightning NOx; biogenic VOCs ...)

A4 Models can quantify impact of future climate change on SR relationships.
Initial results: O3: Source region impacts increased, remote contributions decreased

> **A4** Model Assesments have not yet included full Earth-system responses (dust source changes, biogenic emissions). Impacts on SR relationships expected to berelatively small (placeholder)

How may the source-receptor relationships change due to Climate Change ?

Climate Change will certainly influence the atmospheric transport, transformations and fate of mercury globally. Although there is no modeling evidence, it is foreseen that the concentration and deposition flux may change due to changes in atmospheric composition and dynamics and ocean and terrestrial processes and therefore will affect the source/receptor relationships.

5. How may the source-receptor relationships change due to climate change?

- **Climate change (temperature) will mainly influence emissions from POPs in products, stockpiles (primary volatilisation) and from POPs already in the environment (secondary volatilisation).**
  - **Could cause a reversal of direction of net flux – from sink to source. eg, remobilize inventories in glaciers & permafrost**
- **Other changes in environmental cycling and transport pathways may also occur**
- **Alteration of food webs could change exposure levels & patterns**
- **The role of extreme events in total transport could become more important**
  - **Net effect of climate change is not easy to quantify**

Q6. Research Needs

- **What efforts are needed to develop an integrated system of observation data, emissions, and models to better understand and track these intercontinental or global flows of air pollutants?**

Q6. What efforts are needed to develop an integrated system of observation data, emissions, and models to better understand and track these flows?

A2: Current satellites are reaching the end of their missions, future capabilities may be reduced.
A2: Development of geostationary satellites would provide much improved temporal coverage
A2: Combined use of surface sites and vertical profiling capability needs to be expanded (e.g. IAGOS)
A2: Optimize location and number of surface sites to assess LRT
A2: Optimize species to be measured (key species are VOCs, aerosol species as well as CO, O3, and perhaps SO2)
A2: Focused intensive campaigns need to continue – Lagrangian experiments, inert tracer experiments – evaluate emissions, processing, transport, removal of gaseous and aerosol species – *investigate import of transported species into BL*
A2: Need for development of high resolution or plume-in-grid models for LRT
A3: Satellite retrievals and field observations (ground/aircraft campaigns) can be used to improve/constrain emission estimates, with forward and inverse modeling, there exist case studies to guide the design of an integrated system.

Q6 (II). What efforts are needed to develop an integrated system of observation data emissions, and models to better understand and track these flows?

A4 Models should reduce uncertainty through better evaluation vs. observations: Coherent plans for observation/model studies. May effect attribution…

A4 Model needs for Observations: focus on poorly-characterised processes

e.g., deposition processes; PBL mixing close to surface; vertical transport processes

A4 Reduction in scale biases w.r.t. threshold values for health impacts

e.g., urban regions, O3 titration effects, etc.

A4 Assimilation studies can better ingest information from measurement in models: important for impact, and improving process representation

Q6. What efforts are needed to develop an integrated system of observation data, emissions, and models to better understand and track these flows?

A5 Current observations of air pollutants limit the ability to understand effects on health, ecosystems and climate in large regions of the world. Improvements to observations through ground-based and satellite measurements, and in emissions and models, can be important for improving understanding of the health, ecosystem and climate effects of air pollutants. Improvements to these systems should be made with health, ecosystem and climate effects in mind.

A5 Ecosystem Existing indices to assess the importance of LRT are constrained by regional [O3] exposure profiles and receptor growing seasons. The development of flux based methods is one way in which impacts associated with LRT could incorporate regional differences that determine impacts. This also forms an important component of O3 deposition and hence is relevant to understanding transport processes.

A5 There is a need to better understand the impacts of ozone and aerosols on vulnerable and important ecosystems (important agricultural regions, biodiversity hotspots etc...) across the N hemisphere, particularly in Asia given that most of the existing experimental data comes from NAmerica and Europe.

A5 There is a need for improved understanding of the interactions of O3 and aerosols with other pollutants (e.g. nitrogen, methane, acidifying pollutants) to assess vulnerability of ecosystems to LRT using additional experimental and modelling simulation studies.

A5 There is a need for a hemispheric ozone dry deposition (flux) network.

Other Key Findings, not in 6 questions

- Estimates of health impacts are uncertain and can be improved through research on
  - improving the resolution of global atmospheric models to better represent concentration gradients near urban areas
  - concentration-response relationships in less industrialized nations and over a range of concentrations
  - possible changes in toxicity of PM and pollutant mixtures as they are transported and age
  - possible differential toxicity of different PM components.

What efforts are needed to develop an integrated system of observation data, emissions, and models to better understand and track these flows?

There is a need for a more comprehensive measurement network and interoperable systems for mercury to constrain models and track mercury trends. This is particularly true for the measurement of dry deposition and speciated mercury concentration, especially in southern hemisphere. The development of analytical techniques for accurately quantifying dry deposition fluxes is critical. Better understanding of mercury chemistry in the atmosphere at different altitudes (particularly the gaseous phase oxidation mechanism and kinetics) and the mechanism of the evasion and deposition processes at the earth's surfaces are important. More accurate estimates of anthropogenic sources, globally, as well as primary natural emissions are critical to fully understanding mercury dynamic processes.

6. What efforts are needed to develop an integrated system of observation data, emissions and models to better understand and track these flows?

- Identify the policy drive - Clearly define what the policy relevant science questions are.
- Resources to do the necessary analysis
- Integrated monitoring
  - Should include monitoring data in soils & oceans to support estimation of secondary emissions
- Better communication between scientists to ensure transferability of data
  - Emission inventories should/could be reported in a way that can be used directly in models
- Official emission estimates made in different countries should be harmonized and collected into a single inventory
  - Particular problem for dioxins (TEQ versus congeners)
  - Official emission inventories are not assembled with modeling in mind
- Coverage of monitoring networks (spatial and temporal) can be improved to allow better evaluation of models and emissions
  - Need for co-ordinated monitoring

Other Issues Identified

- **Length of chapters – Possibility to synthesise and/or have extensive supplementary material on web only**
- **Writing style – the audience (academic but not experts)**
- **Writing process**
  - **The role of editors/leadauthors**
  - **When to deliver what**

Focusing Findings

- What does this mean for emission control in LRTAP domain?
- What does this mean for emission control outside the LRTAP domain?

Focusing Recommendations

- Future TF HTAP efforts
  - Emissions Inventory Development
  - Observations Analysis
  - Multi-Model Experiments?
  - Impact Assessment
  - Integrative Analyses
- Other LRTAP Bodies (e.g., TFEIP, TFMM, WGE…)
- Other Global Modeling Efforts (e.g., AC&C)
- Other Regional Modeling (e.g., MICS-Asia)
- Observational Networks & WMO/GAW
- Field Campaigns
- CEOS (Space Agencies)
- Emission Inventory Efforts
- GEOSS

Process Issues

- **Page Limits, Will be clarified**
  - **Consider use of appendices (to be printed or not)**
- **EC/R now working on Cataloging Citations**
- **Formatting, Notify Terry when Chapter is Stable**
- **Post to Wiki: Early and Often**
- **Identify Figures Early, Need to Get Permissions**
- **Editors need to focus on Chapter 6**
- **Voice/Audience**