Task Force on Hemispheric Transport of Air Pollution

Key messages from HTAP coordinated research activities

Co-Chairs

Frank Dentener, PhD — EC JRC

Terry Keating, PhD — U.S. EPA

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Quantification of Global Influences on Regional Air Quality

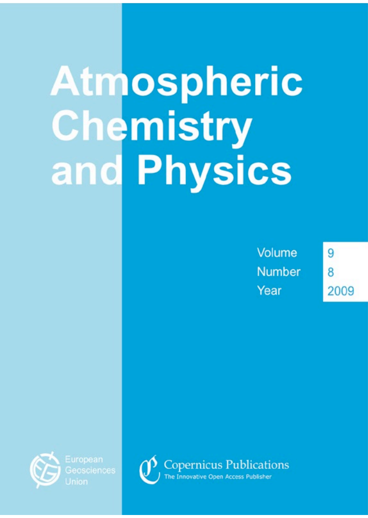
TF HTAP has coordinated joint regional-global model experiments and a special issue in the open access journal *Atmospheric Chemistry & Physics* guided by the **science questions**:

- What **fraction of air pollution** concentrations or deposition can be **attributed** to sources of contemporary anthropogenic emissions **within the region** as compared to **extra-regional**, non-anthropogenic or legacy sources of pollution?
- How do these fractions **impact on human health, ecosystems and climate change**?
- How **sensitive** are regional pollution levels and related impacts **to changes in the sources** of the various fractions?
- How will the various fractions and sensitivities defined above change as a result of **expected air pollution abatement efforts** or climate change?
- How do the **availability, costs and impacts of additional emission abatement options** compare across different regions?

Special Issue in Atmospheric Chemistry and Physics

Title: Global and regional assessment of intercontinental transport of air pollution: results from HTAP, AQMEII and MICS.

- The special issue collected submissions from 15.03.2015 to 31.01.2018.
- 37 articles are published in ACP
- 11 articles in open review in *ACPD*
- Open to all analyses relevant to quantifying extra-regional influences.
- Unprecedented scale in terms of collaborative effort.



Wide regional and global coverage:
- Global (13); Europe(17); North America (9); Asia (12); Arctic (3).

Wide range of thematic topics:
- Emission inventories & evaluation and scenarios (8)
- Global and Regional Modelling & Evaluation (11), processes (21)
- Impacts on health (4); crops & deposition (5); climate (9)
- Ozone (28); aerosol(29)

Not covered in special issue Hg/POPs, Hg POPs.

Some HTAP (relevant) results were published elsewhere.

Highlights and key messages

Order of Highlights

- Global and Regional Emissions
- Processes and Evaluation for Global and Regional Models
- Impacts and Scenarios Analysis

Discussion Points

- What is new/what changed compared to HTAP1?
- What did we learn by including regional models?
- Are answers regarding the role of hemispheric transport more robust?

Need to Know:

- RERER: “Response to Extra-Regional Emission reductions”

  If = 1: concentration changes come entirely from emission reductions outside the region

  If = 0: concentration response is entirely due to changes within the region

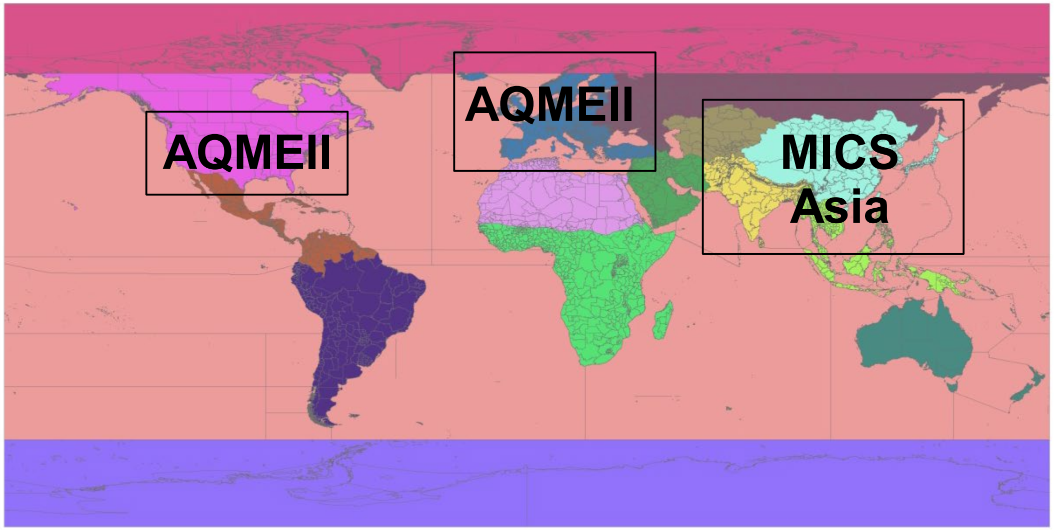
Coordinated modelling experiments

"Ensuring comparability between regional and global model studies"

Overall Approach: Use **global** and **regional** simulations of 2008-2010, to evaluate against observations, and to contribute to the quantification of parameterized S/R relationships. Use these parameterized S/R relationships to estimate impacts of future strategies.

World divided into 16 Regions (60 sub-regions):

Priority source regions: North America, Europe, East Asia, South Asia, Russia/Belarus/Ukraine, Middle East



Nested Regional simulations from **AQMEII** and MICS-Asia

Emission (8 papers)

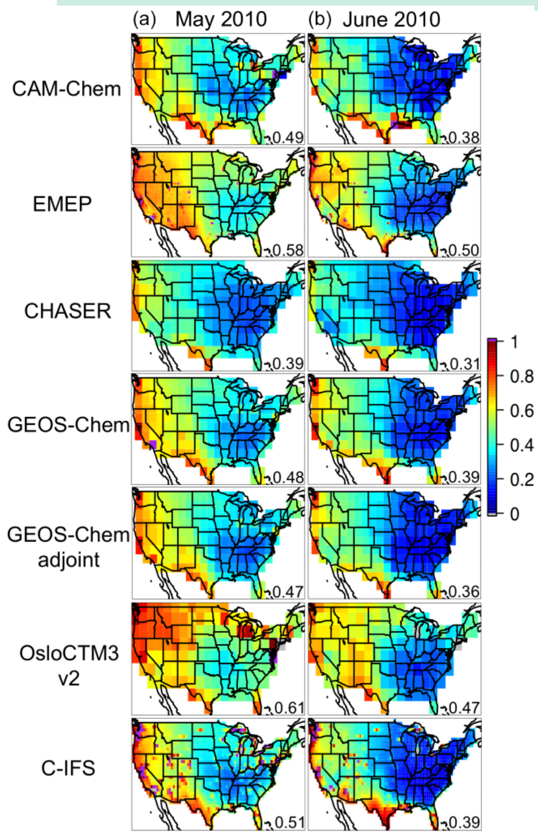
- HTAP2 emission inventory (2008-2010), based on regionally developed data, was input to coordinated modelling. Special paper on the MIX Asian contribution.
- New VOC inventory (EDGAR) => towards HTAP3 inventory
- Over 1990-2010, PM emissions in Europe/North Amercia declined by 30%, but increased in Asia by 50%.
- Newer inventories of BC are higher due to inclusion of new sources.
- 3 papers evaluated emissions for China, finding large differences: 67 $\mu g/m^3$ difference for PM2.5 in central China; different NOx-VOC regimes; SO_2 consistent; NOx emissions biased low by 20-30 % compared to satellite data. Continued community work to better understand inventories in China
- Large uncertainties in India. PM is high everywhere in India, but sources differ (north: residential burning and dust, south: industrial sources).
- Scenarios were based on ECLIPSEv5a; but also on the SSP framework used in the climate community.

Progress compared to HTAP1:

- TF HTAP played a role in advancing knowledge and evaluation of emission inventories, leading to a consistent inventories for regional and global modeling under HTAP2/AQMEII3/MICS, and possibilities to update into HTAP3.
- A common basis to assess mitigation options.

O_3 and PM2.5 annual response in North America to 20 % emission changes in anthropogenic precursors (9 papers)

Perturbation simulation	O_3 [ppb]	$PM_{2.5}$ (ugm^{-3})
GLOBAL	-1.39	-1.52
N. America	-0.65	-1.47
East Asia	-0.62	-0.02
RERER regional models	0.77 [0.54-0.93]	0.12 [0.11-0.12]
RERER global models	0.34 (health weighted)	0.10



Key messages:

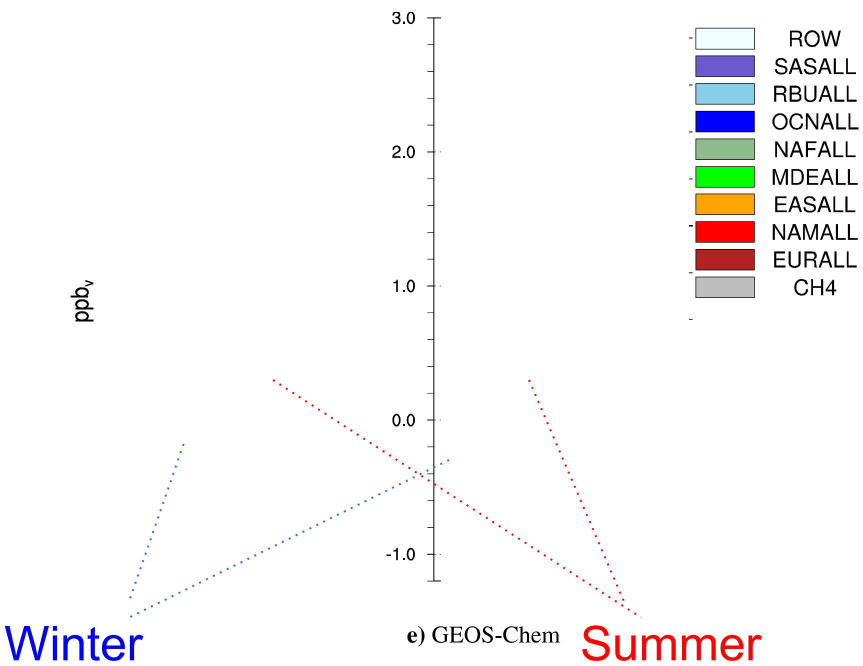
- Intercontinental influence largest in western USA, background (transport + biogenics) can be 4-12 ppb higher on high days than average days
- Transport has strong seasonal variation; 2010 was a high transport year (compared to 2008-2009)
- East Asia is a major contributor- especially NO_x
- In regional models- the combination of the global model boundary conditions, and the vertical mixing in the model is determining the impact.
- Highest O3 days are associated with regional anthropogenic & biogenic emissions in most regions.

Sources: Im et al; Huang et al , Guo et al, Liang et al.

O_3 and PM2.5 annual response in Europe to 20 % emission changes in anthropogenic precursors (17 papers)

Perturbation simulation	O_3 [ppb]	$PM_{2.5}$ (ugm^{-3})
GLOB	-0.82	-1.82
EUR	-0.22	-1.58
NAM	-0.07	-0.02
RERER regional models	0.81[0.44-0.92]	0.23 [0.01-0.34]
RERER global models	0.89 [0.71-1.59]	0.22 (population weighted)

Regional contribution to global signal



- Large seasonal differences in responses
- The ‘chemistry’ of the models is important- especially in winter
- Regional differences, especially North West Europe vs other parts of Europe.
- Contributions from abroad are larger in annual average (e.g. EMEP model 85 %) vs summer (60 %).
- Methane can, in the long-term, have impacts similar to air pollution precursors on ozone.

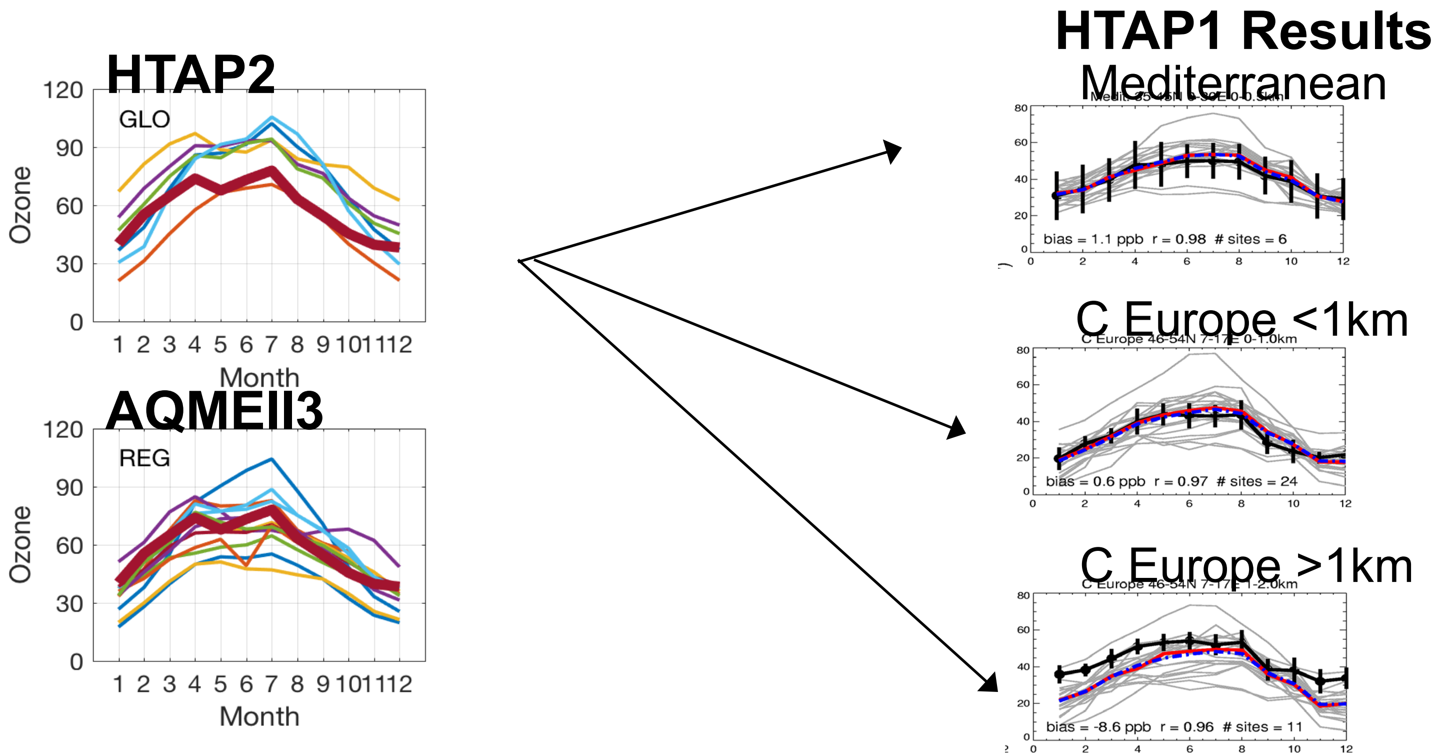
Sources: Im et al; Liang et al., Jonson et al.

Progress in understanding Source-Receptor relationships

- The more confined definition of model regions, harmonized and recent emissions, and harmonized emission perturbation experiments in HTAP2 allow more consistent comparison of regional/global model sensitivity studies.
- The contributions from foreign regions to annual O_3 in the USA and Europe (based on ensemble estimates) are quite similar to HTAP1, but the impact of domestic emission reductions changed.
- New results allow better quantification of the *relative importance* of foreign emission reductions.
- Global and regional models give qualitatively similar answers with regard to long-range impacts on O_3 and $PM_{2.5}$. Regional models have generally better performance statistics–especially for peak values.
- Foreign contributions depend on region, seasons, component and metrics.
- Impact of methane S/R virtually unchanged compared to HTAP1.

Model evaluation

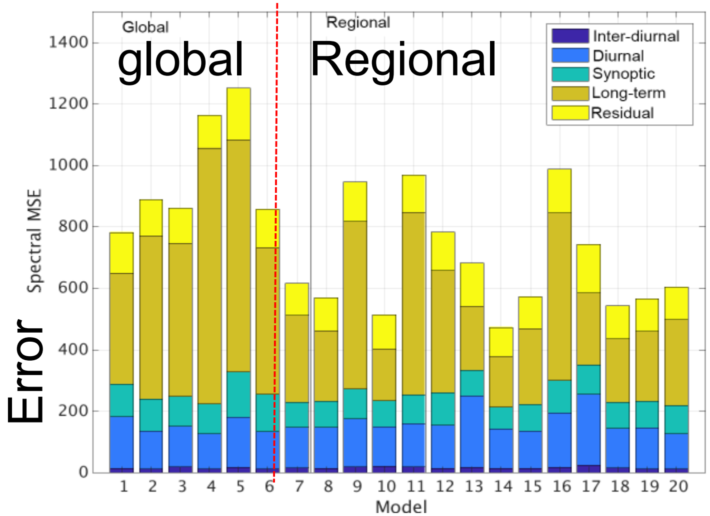
Regional and global models have been systematically compared for O_3 and $PM_{2.5}$ in the US, and North America, using the ENSEMBLES system at JRC and AEROCOM/EBAS at Met.No



- Similar model spread in Europe between global and regional models
- Ensemble of regional models overall less biased than HTAP2 global models
- HTAP2 global models seem to be somewhat more biased than during HTAP1
- This is mainly of importance for threshold based metrics like AOT40
- Where do errors come from and what to do about it?

Source: Galmarini (2018)

Characterisation of model errors



In AQMEII and HTAP2 several novel methods were proposed for understanding sources of errors:

- Decomposition of time series
- Tracers of boundary conditions
- Tracers of longer lived components
- Emission error propagation

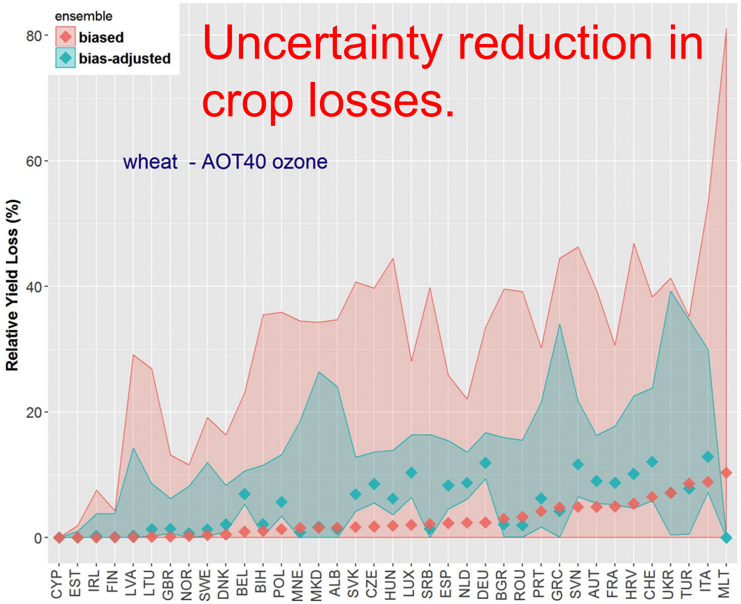
- Global models have a larger long term error component – pointing to issues in emissions/chemistry and transport/inflow processes.
- It is hard to pinpoint errors in long-range transport models with available observations.

In global air quality modeling, there is no preferred method yet for model evaluation and error characterization. Methods need to be shared across communities.

AQMEII has launched a new phase focused on evaluating deposition processes. => Next scientific focus for TF HTAP?

Ensemble modelling

- It is a common practice to use the mean/median of multiple model ensembles to reduce model errors for impact modelling.
- Uncertainty may be artificially inflated: if all models are biased in the same way, the ensemble will be biased. Adding more models doesn't help.
  - Adding global models to a regional model ensemble (which already included boundary conditions from global models) provides limited new information to improve ensemble performance.



We need realistic estimates of model uncertainty.

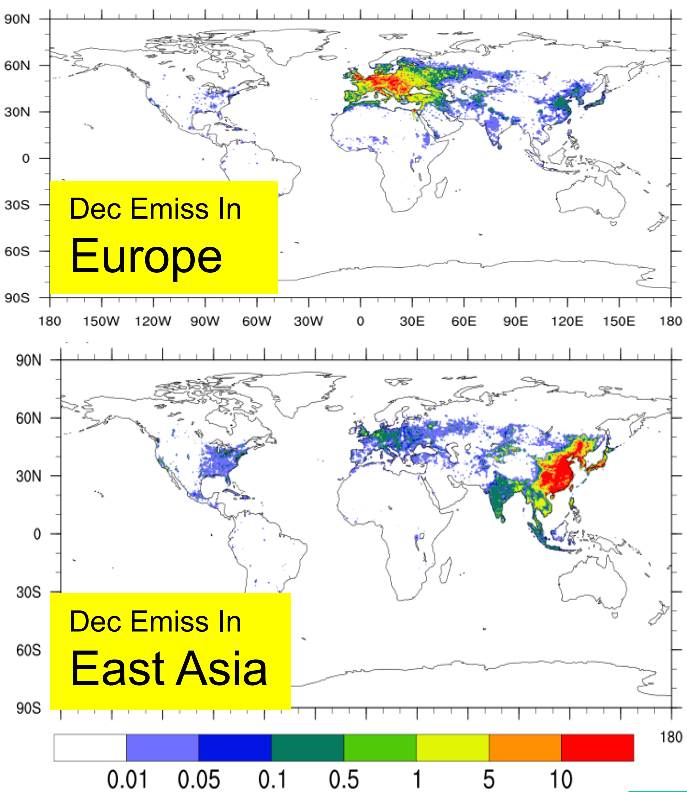
- Careful choice of model ensembles provides more robust estimates for impact estimates.
- Using observations to adjust for systematic long-term bias in models increases reliability of impact estimates, and provides more realistic uncertainty impact range for current conditions.

- Global models suffer from a lack of resolution; while regional models are struggling with boundary conditions. In HTAP1 and AQMEII we have seen global models on 0.5 degree resolution and regional (10-20 km) model going hemispheric. In the next years we'll see convergence of these approaches.

Source: Solazzo et al., 2018

Avoided $PM_{2.5}$ premature deaths by 20 % regional emission reductions

Avoided PM2.5 deaths/yr/1000 km^2

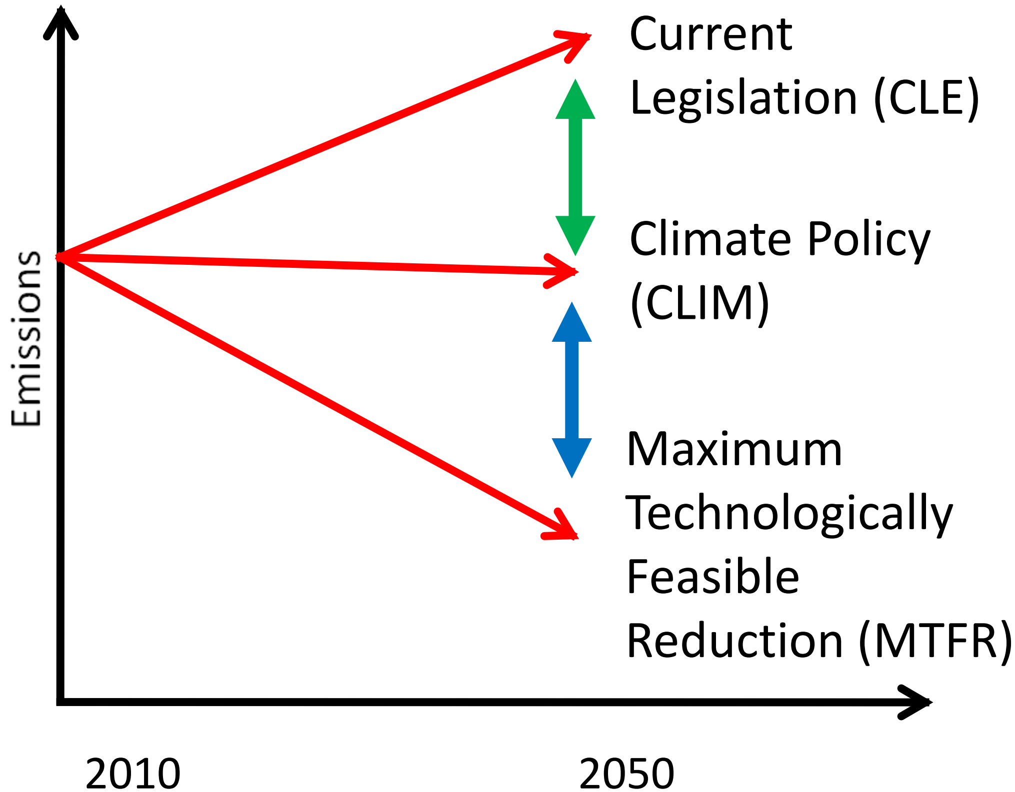


- HTAP Estimated $PM_{2.5}$-related mortality worldwide 2.8 million annually
  - Reducing global emissions by 20 % saves 290,000 deaths, 40 % in East and South Asia.
  - 42,000 deaths by inter-regional atmospheric transport of $PM_{2.5}$- this is more than from O_3 as $PM_{2.5}$ influence mortality more strongly
- Reducing all O_3-precursor emissions by 20 % (ex methane) would save 47,000 lives (half South Asia). 10.000 due to intercontinental transport.
- **Global models health impact estimates lower than regional models- especially in the US.**

O_3+PM deaths/year avoided by 20 % global emissions decrease	Regional models Im et al, ACP, 2018		Global models Liang et al, ACP, 2018	
	In region	Long-range	In region	Long-range
US	27500	2000	19500	570
Europe	54000	1000	33000	670

Source: Im et al, 2018; Liang et al.; 2018

HTAP Air Pollution Benchmark Scenarios



Policy Relevant Questions

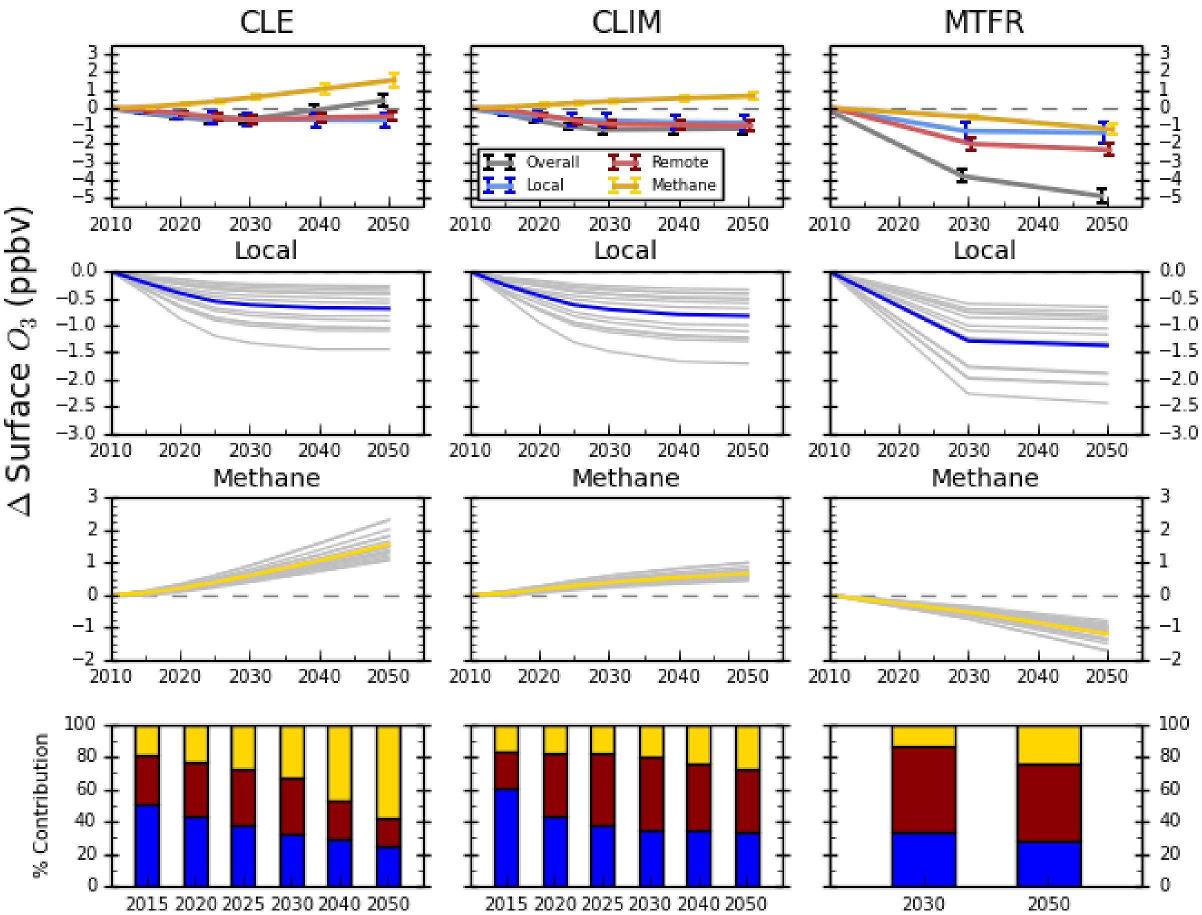
CLE: Given current policies, what are emissions likely to be in the future?

CLE-CLIM: What is the benefit of implementing climate policies for air pollution?

CLE-MTFR: What technology and policy options will be available (at a reasonable cost) to further mitigate pollution problems in the future?

IIASA International Institute for Applied Systems Analysis GAINS

What are expected ozone changes in Europe in the next 4 decades? 3 HTAP/ECLIPSE scenarios.



CLE: O_3 in Europe will be reduced as a result of European and (mainly) North American air pollution legislation. However, increasing CH_4 will more than offset other emissions decreases after 2030.

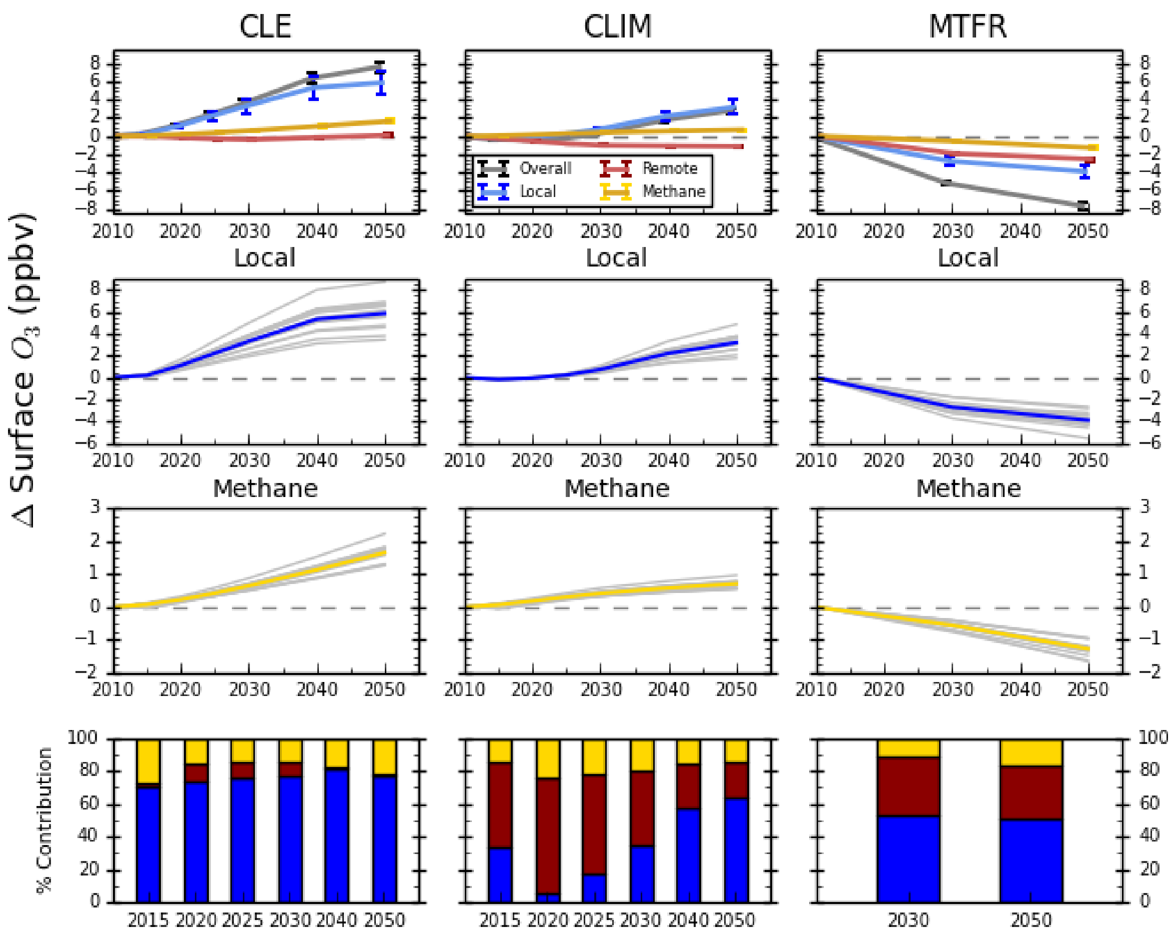
CLIM: Decreased CH_4 emissions+cobenefits from the energy sector will help to stabilize the O_3 concentrations after 2030.

MTFR: Enhanced technologies inside and outside Europe will decrease emissions of O_3 precursors, including CH_4, and have strong benefits for air quality.

- New HTAP2 analysis of benchmark scenarios confirms HTAP1 with respect to role of regional, extra-regional emissions and CH_4 for Europe for annual ozone.

Source: Turnock et al., (2018)

What are expected ozone changes in South Asia?



CLE: O_3 in South Asia will strongly grow as a function of local air pollutant emissions.

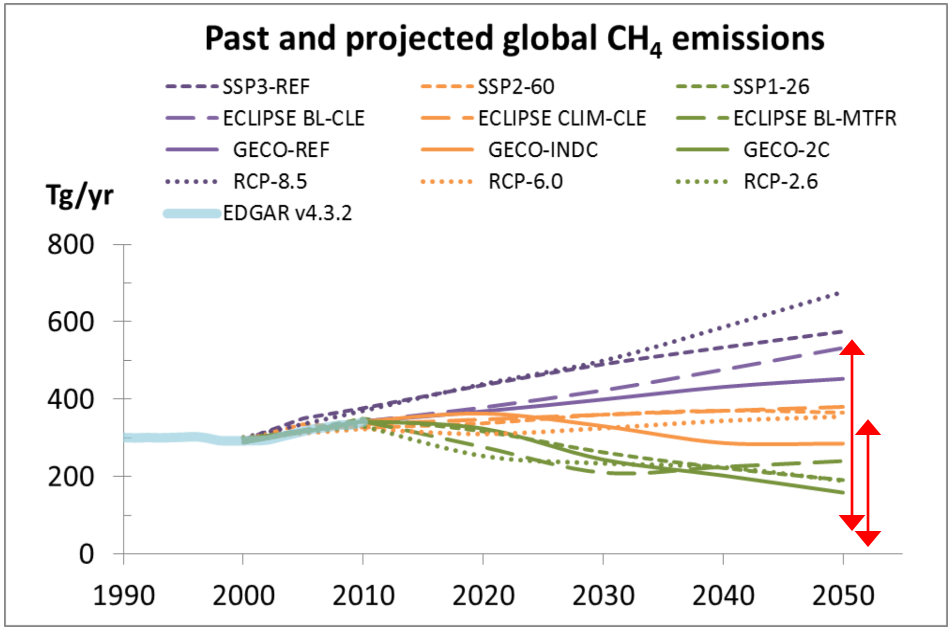
CLIM: Climate policies will decrease O_3 through co-benefits on local AP emissions and decreasing CH_4 emissions.

MTFR: Clean technologies and emission reductions in South Asia and elsewhere, and global decreases in CH_4 emissions all contribute substantially to decreased O_3, with large benefits for health and crop production.

- More analysis than in HTAP1 is now available in other world regions
- A weakness remains the focus on annual ozone.

Source: Turnock et al., (2018)

The mitigation potential of CH4 emissions



Literature analysis of 12 scenarios: low-middle-high mitigation scenario families

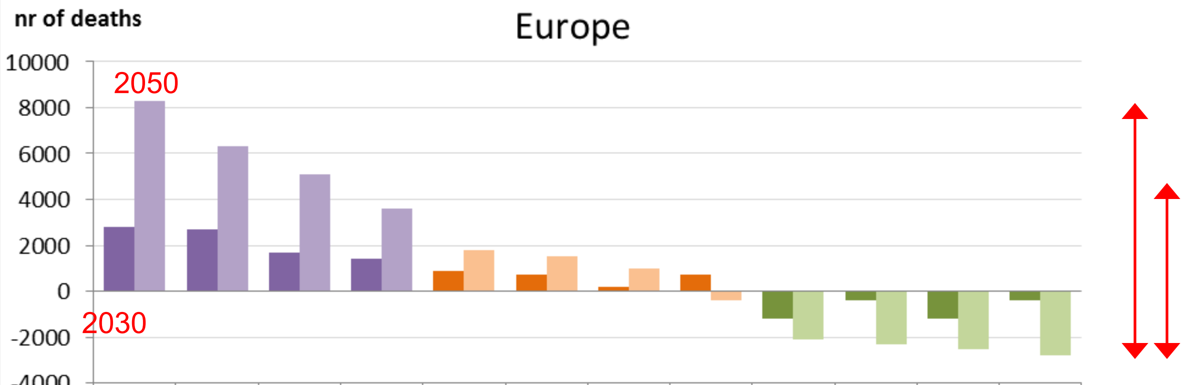
Mitigation range

- Europe's contribution to global anthropogenic CH_4 emissions is currently about 6 %
- Unabated, global anthropogenic CH_4 emissions could increase by 35 to 100 %- from 330 Tg in 2010 to 450-650 Tg CH_4 yr^{-1} in 2050.
- Current commitments to the climate convention (DNCs) are roughly stabilizing CH_4 emissions
- Optimistic sustainability scenarios, such as the Paris Agreement goals, project reductions up to 50%, reaching 180-220 Tg CH_4 yr^{-1} CH_4 by 2050
- Global Mitigation range is ca. 230-480 CH_4 yr^{-1} by 2050.
- Waste and energy sectors seen as most promising- some potential also in agriculture.

Source: JRC science-for-policy report in preparation, 2018 (building on HTAP results) do not cite/quote

The mitigation potential of scenarios in the literature

Premature Death Change compared to 2010



	RCP-8.5	SSP3-REF	ECL-BL-CLE	GECO-REF	ECL-CLIM-CLE	SSP2-60	RCP-6.0	GECO-INDC	ECL-BL-MTFR	SSP1-26	RCP-2.6	GECO-2C
2030	2800	2700	1700	1400	900	700	200	700	-1200	-400	-1200	-400
2050	8300	6300	5100	3600	1800	1500	1000	-400	-2100	-2300	-2500	-2800

Mitigation opportunity for health impacts

- The mitigation opportunity- the difference between pessimistic and optimistic scenarios- is 5-8 ppb for Europe (MDA8) and 4-6 ppb globally.
- 6,000-11,000 annual premature deaths avoided in the EU28 and 70,000-130,000 globally
- Relatively small contribution of Europe's contribution: reducing CH_4 by 10 or 50 % would save 50 to 250 premature deaths per year in Europe, and 540 to 2700 worldwide
- Global cooperation to reduce CH_4 in countries and regions in- and outside of the EU, will also be essential to reduce related O_3 effects in Europe and the world.
- Strengthens HTAP1 arguments for global cooperation.

Source: JRC science-for-policy report in preparation, 2018, do not cite/quote

openFASST: Based on TM5-FASST

OpenFASST

Not secure | openfasst.com

Apps Inbox (24) - terryjkea Space Edits Web of Science [v.5.2 Renewable Portfolio Awards - Federal-Wic ITF Transport Outlool New Tab Other bookmarks

LRTAP Long-range Transboundary Air Pollution

Task Force on Hemispheric Transport of Air Pollution

openFASST

HTAP 2017/09/01

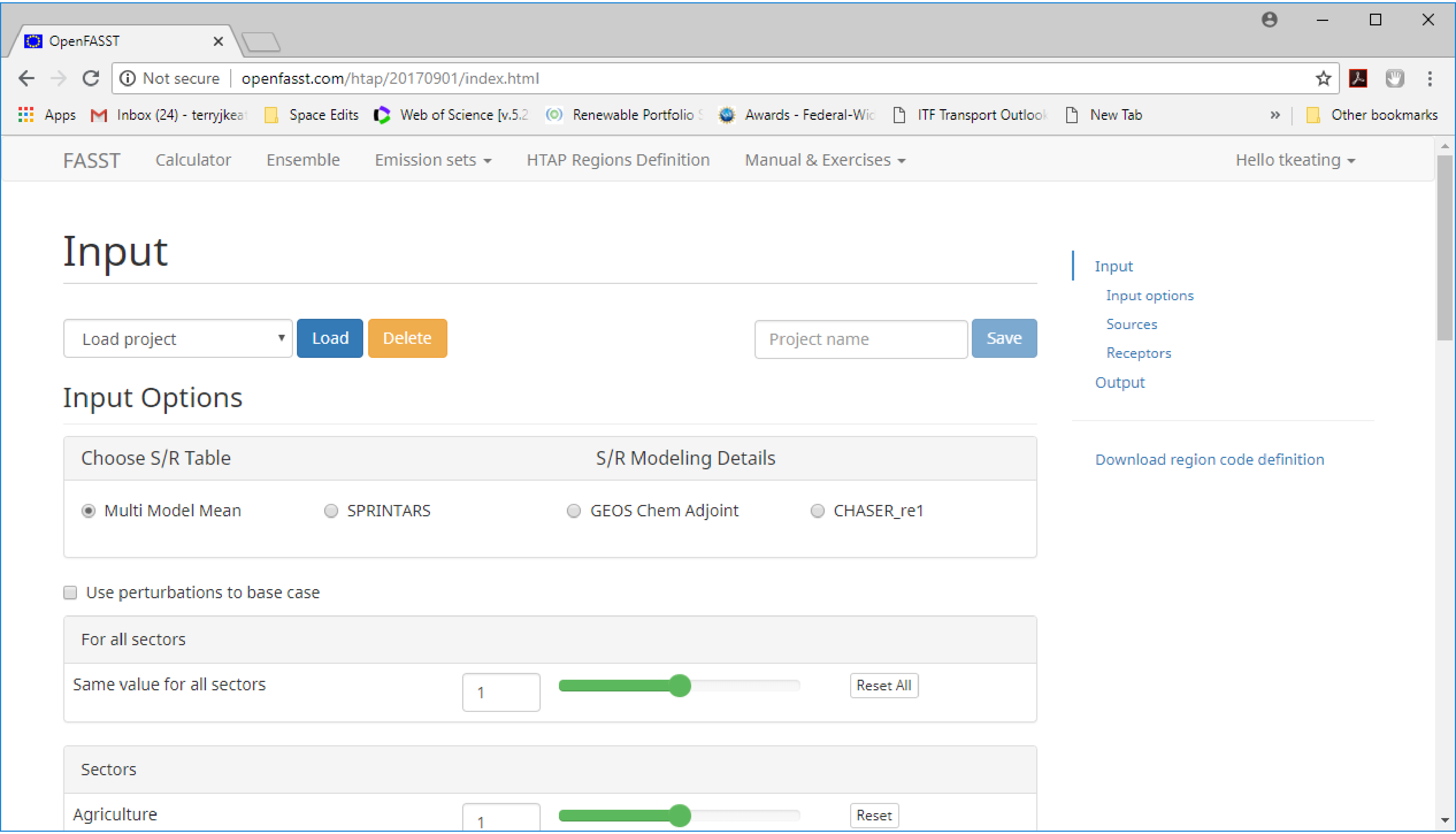
Contact

openFASST: an Open-source Fast Air pollution Scenario Screening Tool

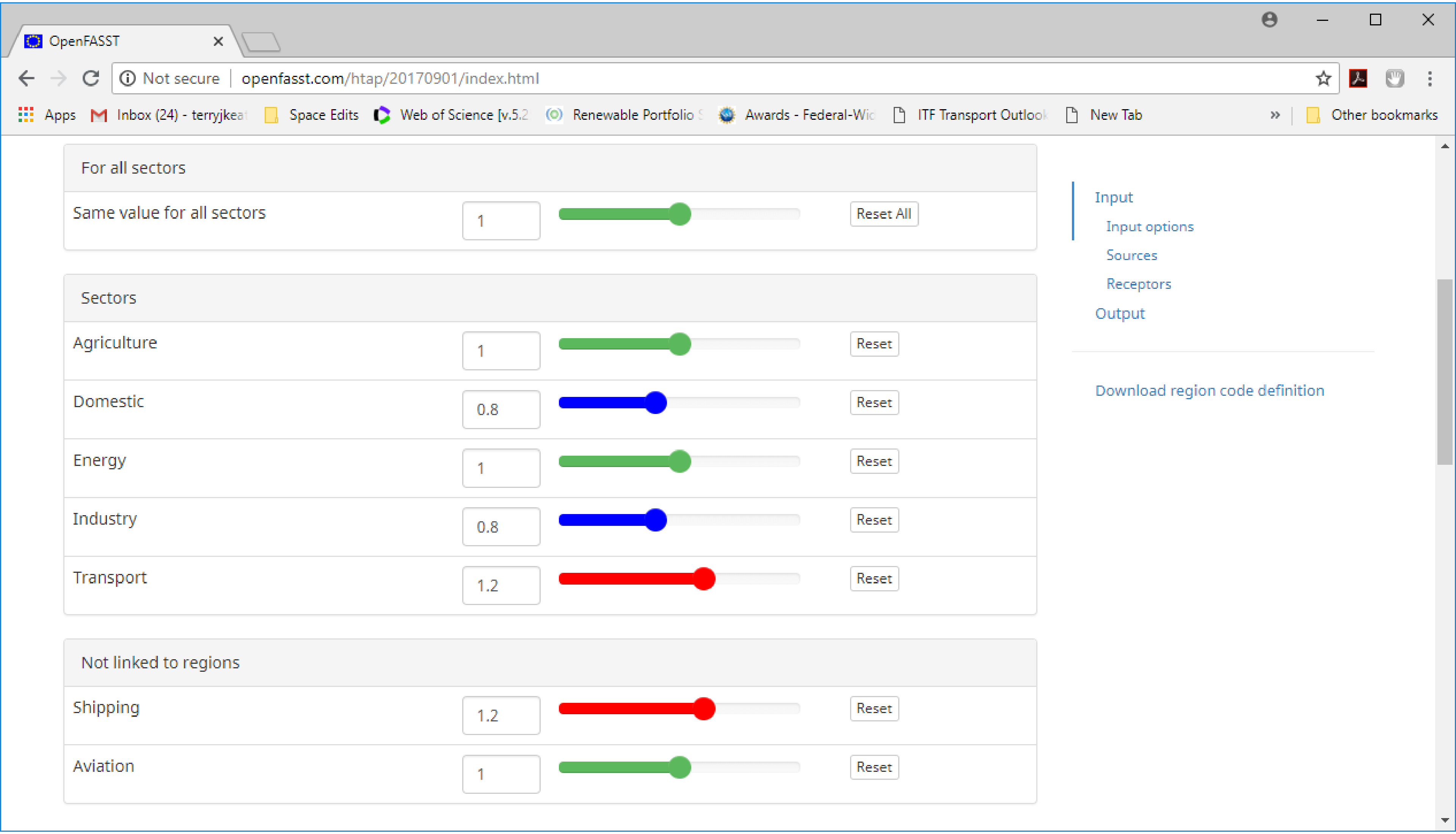
openFASST is a screening tool for the evaluation of global air emissions scenarios and the associated impacts on human health, ecosystems, and climate. It is based on the TM5-FASST tool developed by the European Commission's Joint Research Centre Ispra (Van Dingenen et al. 2018). Under the auspices of the Task Force on Hemispheric Transport of Air Pollution and with funding from the U.S. Environmental Protection Agency and NASA Applied Sciences. The original tool is being modified to become open-source and to allow flexibility in defining source-receptor relationships, baseline emissions scenarios, and impact-response functions. openFASST is hosted by the University of Colorado, Boulder and managed by Daven Henze and Yanko Davila.

The user-friendly, web-based tool is specifically designed to

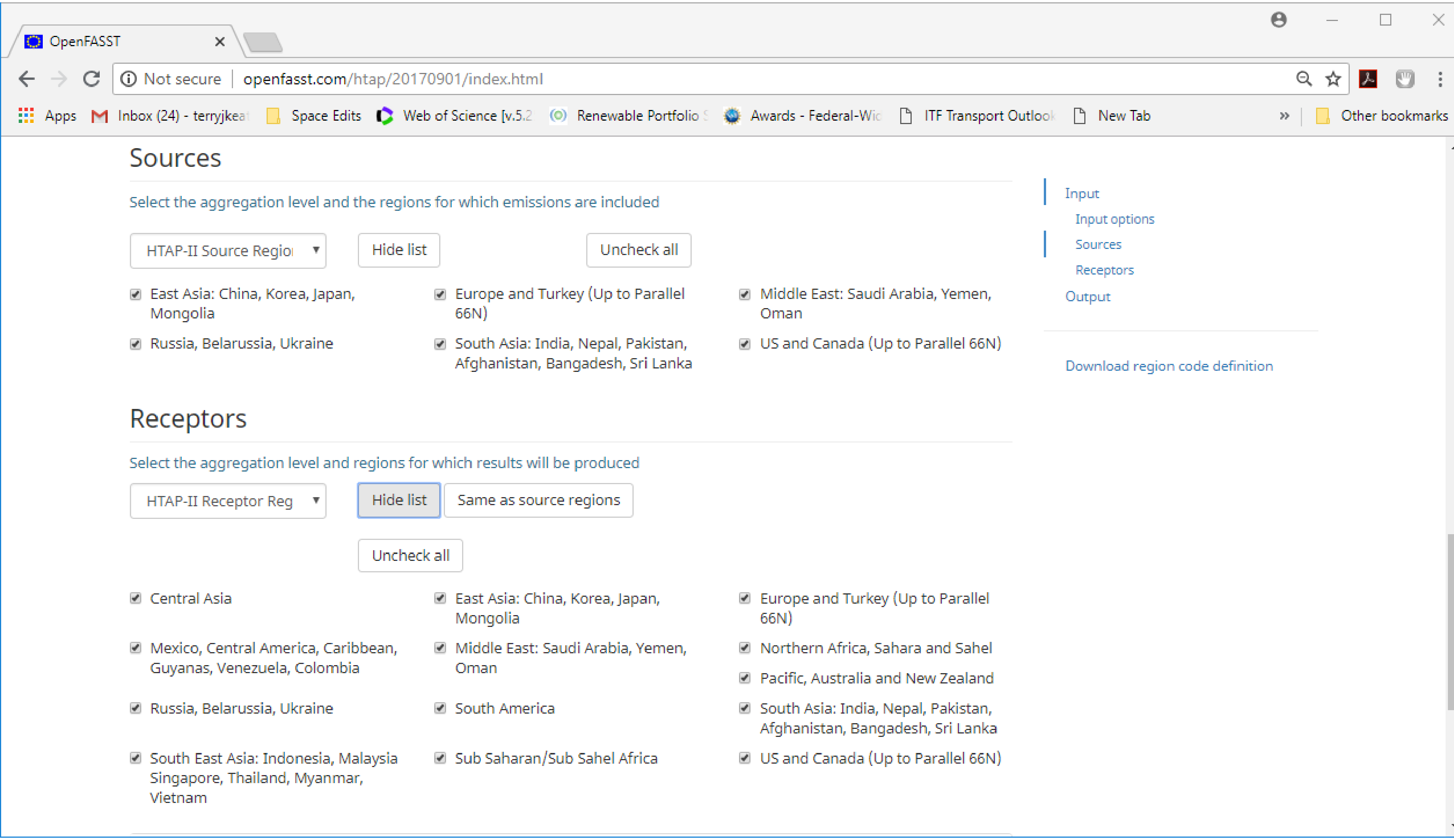
User Selects S/R Matrix from HTAP2 Models



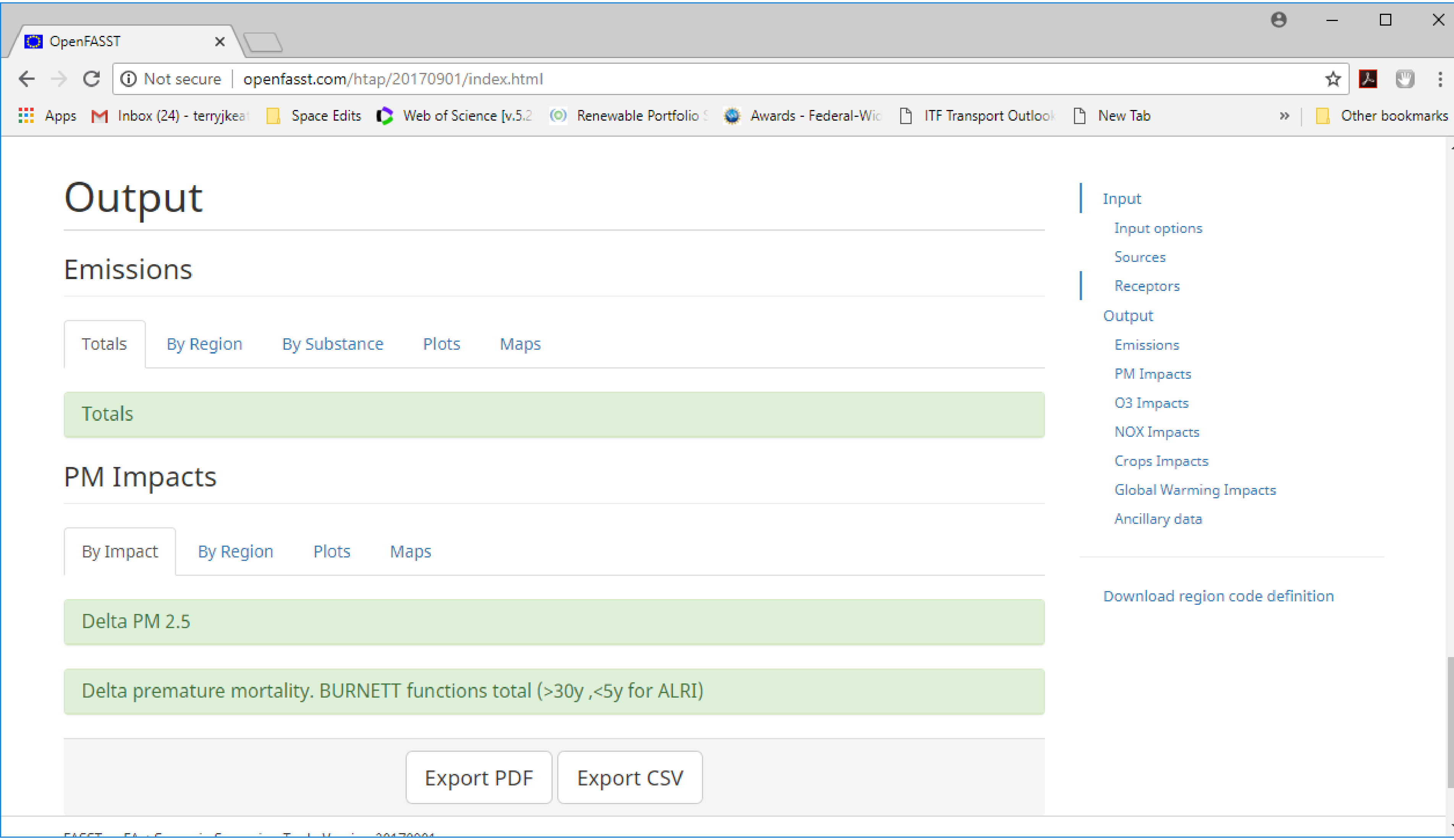
User defines emission perturbations (as in TM5-FASST)



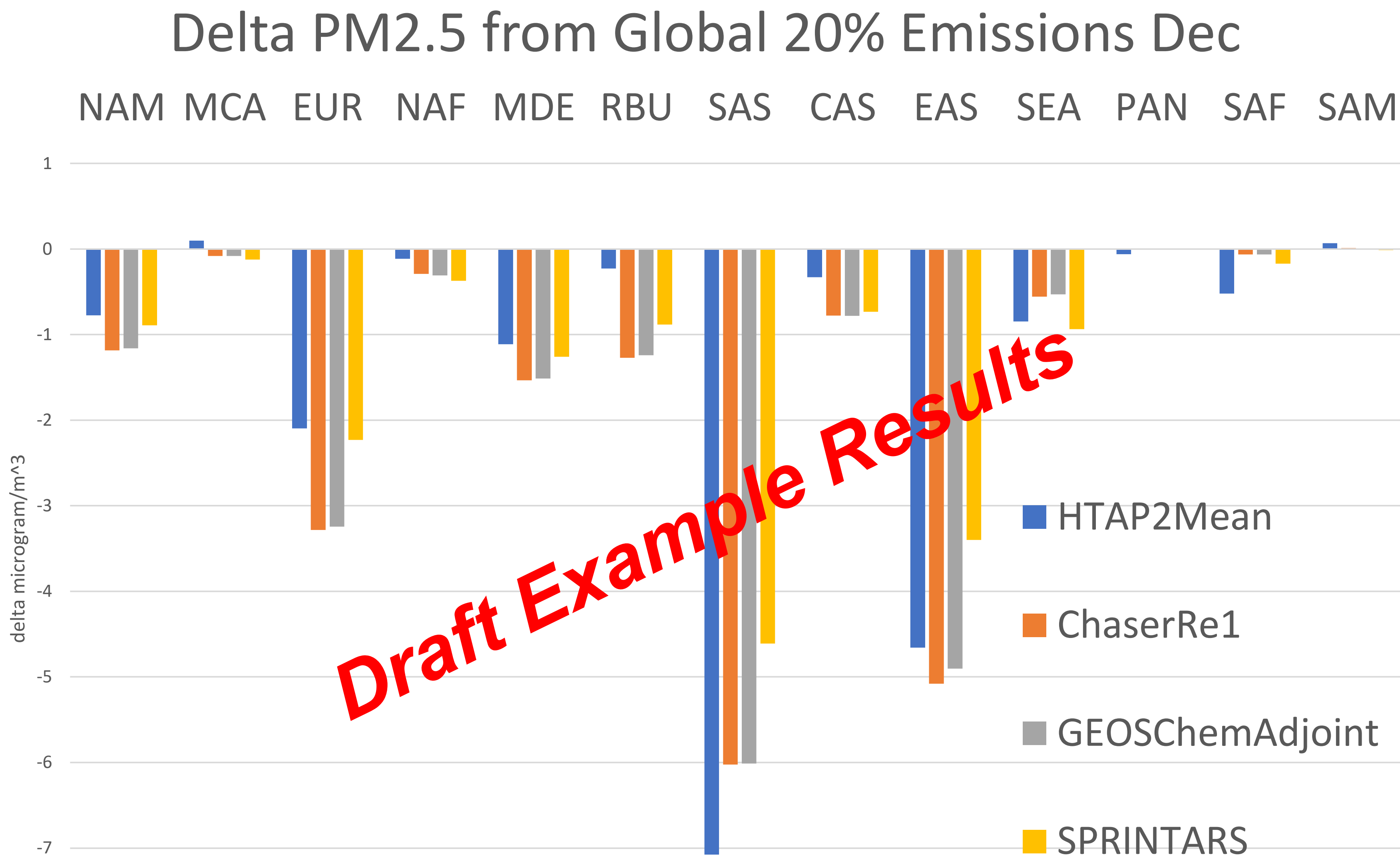
Sensitivities for 6 Source Regions in HTAP2



Graphic and Tabular Outputs (as in TM5-FASST)



Preliminary outputs allow exploration of the implications of using different models.



2018-2019 Work Plan Elements

1.1.4 Tools to account for global-scale issues in air quality assessment

	Activity	*Product*	*Year*	*Partners*	*Status*
1.1.4.1	Global-Regional Modeling and Evaluation	O3 and PM Report: ACP Synthesis	2018		Ongoing
		Deposition Workshop (all pollutants)	2019	TFMM WGE WMO	No plan yet
1.1.4.2	Intercontinental transport of Hg and POPs	Next Steps Workshop	2019	MSCE UNEP AMAP	No plan yet
1.1.4.3	Sectoral opportunities to mitigate intercontinental transport	openFASST: incorporation of HTAP2 results	2018	TFIAM?	Ongoing
		Scoping Workshop (Building on Shipping Report)	2018	TFIAM AMAP CCAC	No plan yet
		Sectors Report	2019	TFIAM AMAP CCAC	Delayed

Need to confirm priorities and reset expectations.

Next steps