Multiple impacts of global air pollution: Tools, Methods and Applications

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Global Assessments of Air pollution –climate linkages need to cover a variety of spatial and temporal scales

CTMs and GCMs are frequently used to evaluate scenarios, but suffer from:

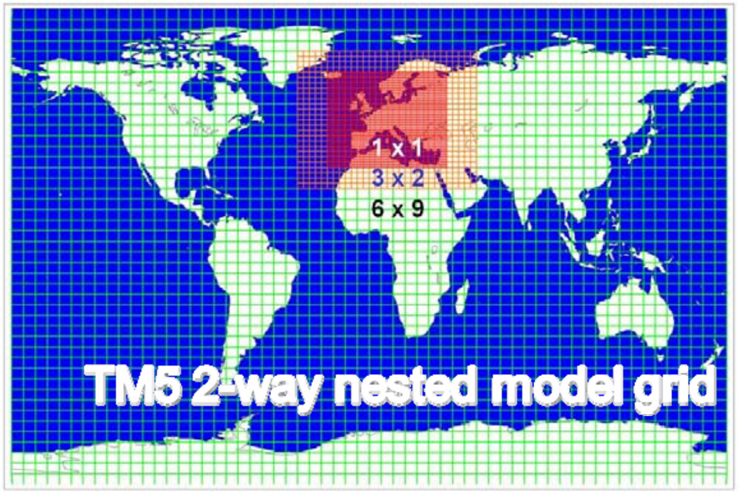
- relatively poor resolution (with regard to impacts)
- flexibility to explore scenario ‘parameter’ space
- give the answers for a particular model, but little insight in uncertainties

New tools and methods are emerging that can more flexibly evaluate impacts- more closely connected to the detail provided by IAMs.

In this talk

- TM5-FASST: 1 model and a lot of impacts
- LIMITS project =>more scenario models
- Work of Task Force Hemispheric Transport: multiple atmospheric models =>impacts

From **emissions** to **impacts:** the FAst Scenario Screening Tool: **TM5-FASST**



•Global Source - Receptor model for air pollutants, radiative forcing and deposition

•Simplified linear emission-concentration/forcing/deposition relations between regions

•Uses TM5-CTM output (2-way nested model, 1°x1° over multiple zoom regions)

•Emissions considered:

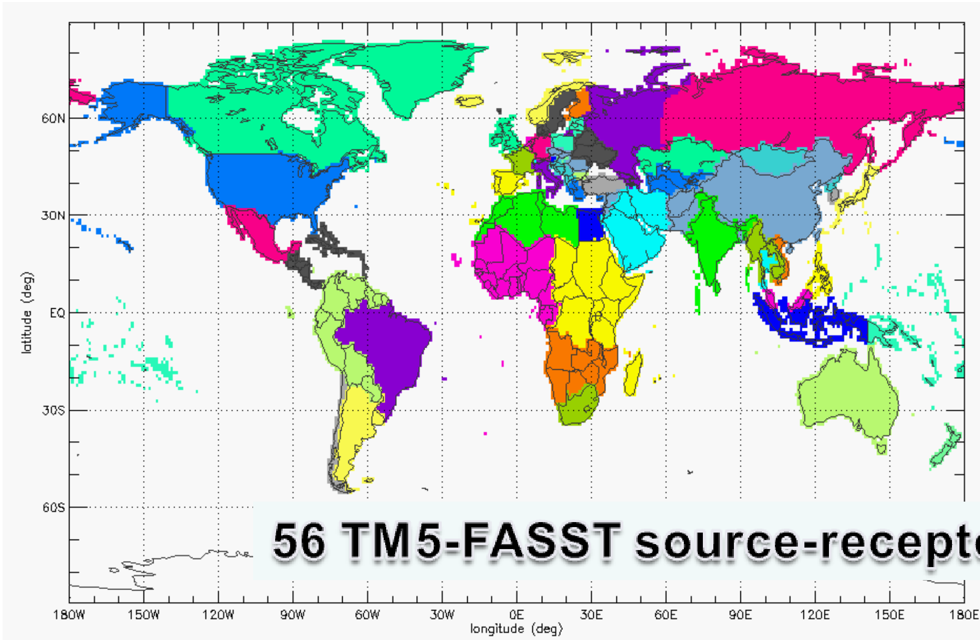
- SO_2, NO_x, NMVOC, NH_3, CO (CH4 concentrations prescribed)
- Elemental Carbon, Primary Organic Matter, other primary PM

•Examples of impacts considered:

- $PM_{2.5}$ and O_3 surface concentration and population exposure
- O_3 metrics for crops and vegetation exposure + impact on yield loss
- Radiative forcing and CO_{2eq} of SLCFs (GWP and GTP based)
- Temperature trend for selected time horizons and emission trajectories of pollutants and CO_2
- Deposition of BC to the Arctic /Himalayas
- Deposition of nitrogen and impacts on sensitive ecosystems

Dentener, Utrecht 2012

TM5-FASST



56 TM5-FASST source-receptor regions

Overlaps with a ranges of IAMs (e.g. IMAGE-MESSAGE-POLES)

How does this work?

Used global chemical transport model

1. Run full model for base emission set (e.g. RCP year 2000 emissions)
2. For each of 56 regions and for each emitted pollutant: run TM5 model again on [base run emissions -20%]
3. Calculate 56x56 matrix of slopes $dCONC_{receptor}/dEMIS_{source}$ from base & perturbation run between all SR regions, for all pollutant precursors and pollutant endpoints (e.g. dNO_3/dNO_x, dO_3/dNO_x, dSO_4/dSO_2, dSO_4/dNO_x,…)

- ➢ SOURCE-RECEPTOR MATRIX LIBRARY AVAILABLE FOR ALL FURTHER CALCULATIONS
- ➢ Note: no separate SR relations for different sectors

4. Apply Source-Receptor matrix to any dEMIS to calculate dCONC (x,y,t)
   For example:
   - UNEP O_3-BC assessment
   - Revision of Gothenburg Protocol
   - RCP scenarios
   - ….

5. Apply appropriate exposure – response functions for health & ecosystem impacts on each grid point (typically on annual basis, but using finer time resolution information).

Methodology Emissions → Concentrations:

$$PM_i = PM_i^b + 5\sum_k \sum_j \Delta PM_{j,k}^i \frac{E_{j,k} - E_{j,k}^b}{E_{j,k}^b}$$

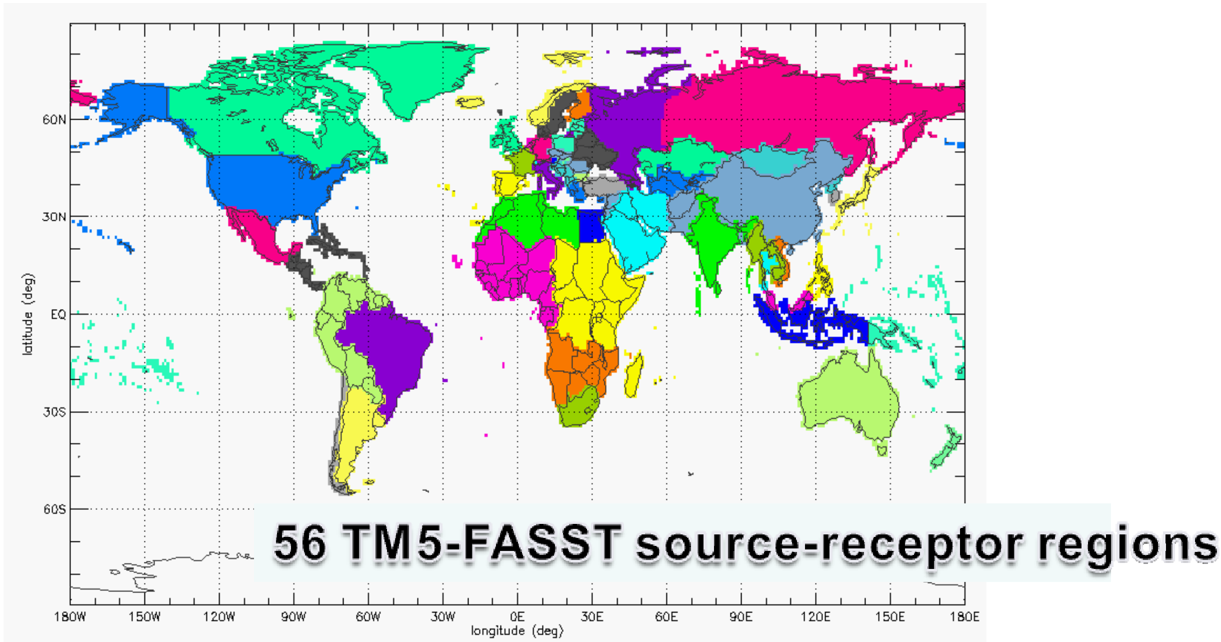
PM_i^b = the total PM base concentration in receptor country *i*

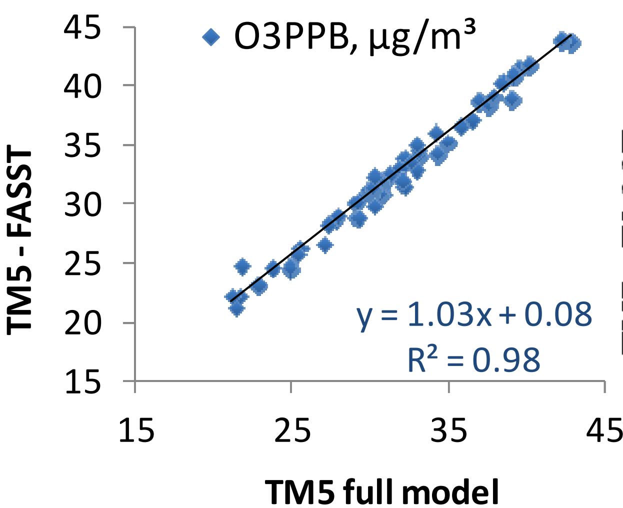
$E_{j,k}^b$ = the base case emission of component (precursor) *k* in source country *j*

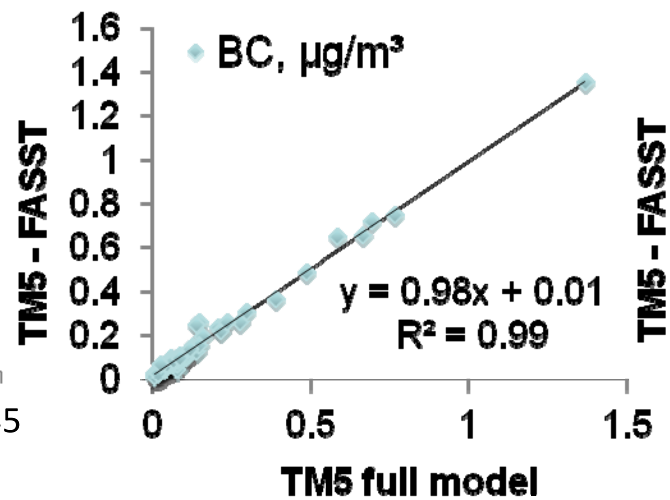
$E_{j,k}$ = the scenario emission of component (precursor) *k* in source country *j*

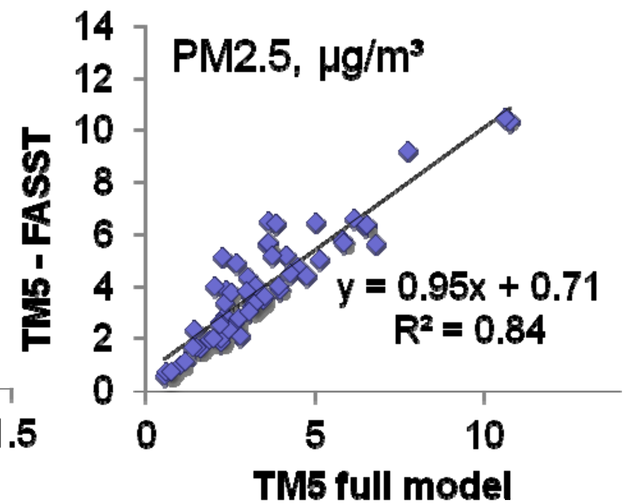
$\Delta PM_{j,k}^i$ = the SR coefficient for component *k*, source country *i* and receptor country *j*

TM5-FASST:









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TM5-FASST is strong in

- Global coverage and global consistency in calculating impacts
- Speed of calculation: ideal for assessments requiring many scenario evaluations (optimization, impact attribution by region or sector,…)
- Internal consistency between various impact categories (health, vegetation, deposition, climate)

FASST is weak in

•Describing non-linear processes

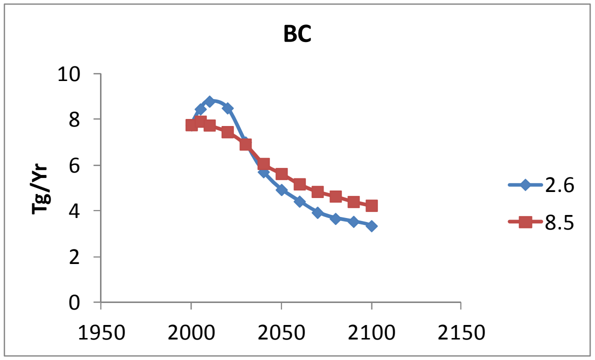
O3 chemistry, NO3-NH4 system, Secondary Organic Aerosol

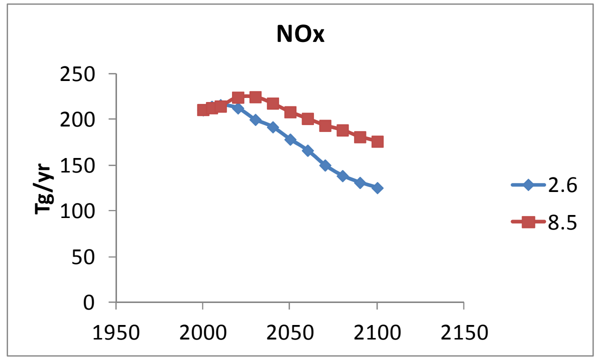
•Role of inter-annual variability/climate change:

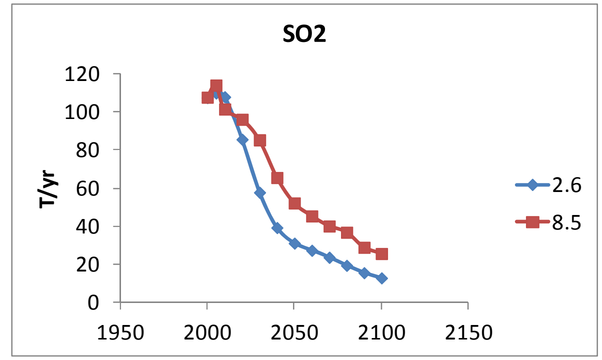
current SR only based on one meteorological year (2001)

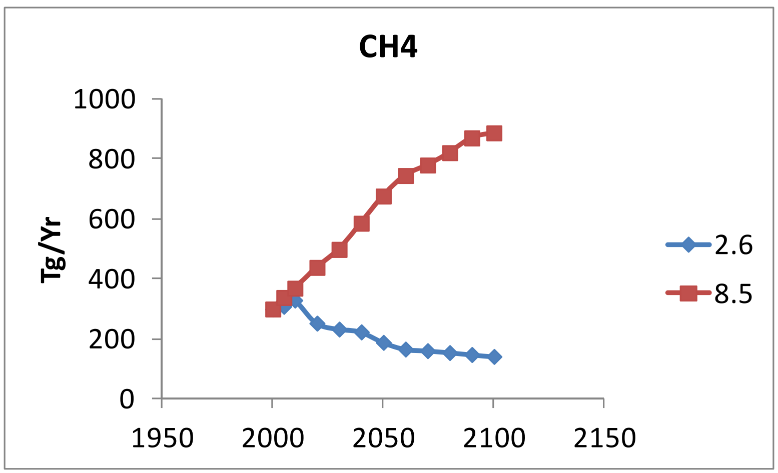
•Uncertainties due to model specific processes

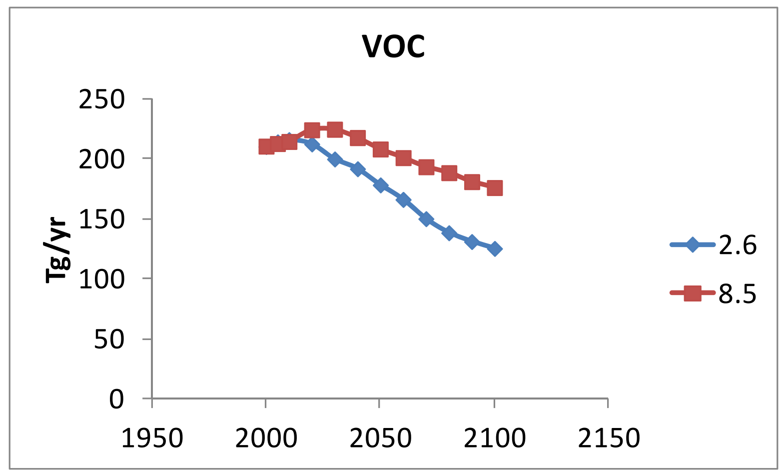
Example of TM5-FASST scenario analysis: RCPs pollutant emissions from 2000 to 2050











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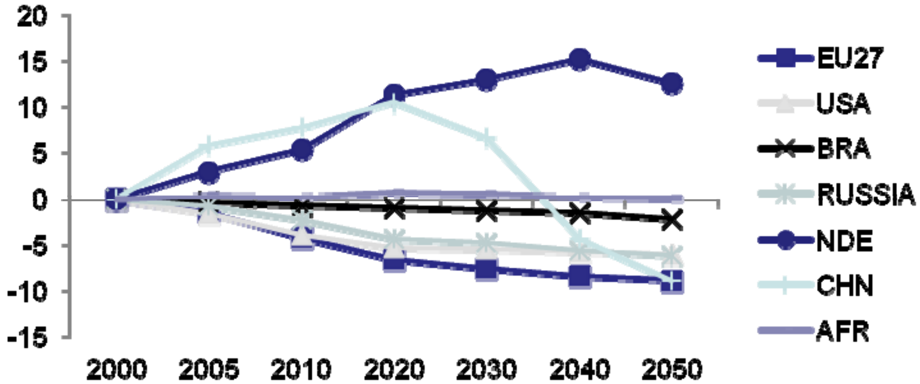
Example of results: RCPs air quality & ecosystem in

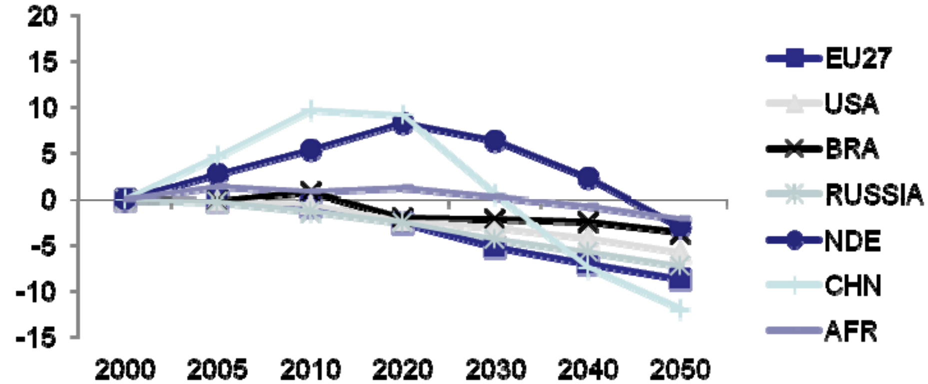
RCP 8.5

PM2.5, µg/m³

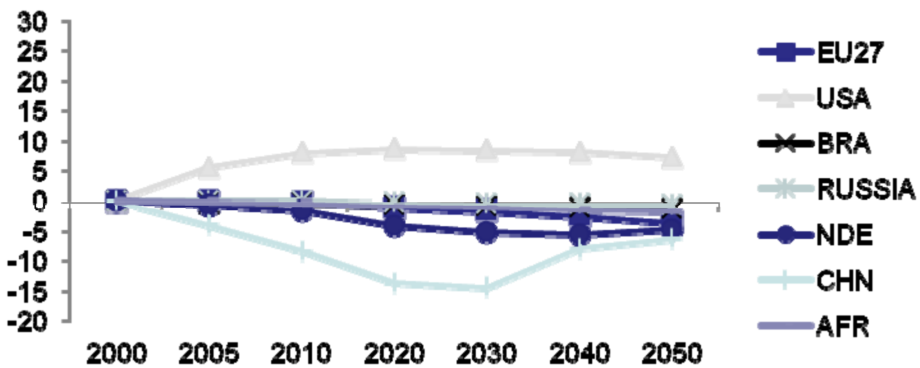


RCP 2.6

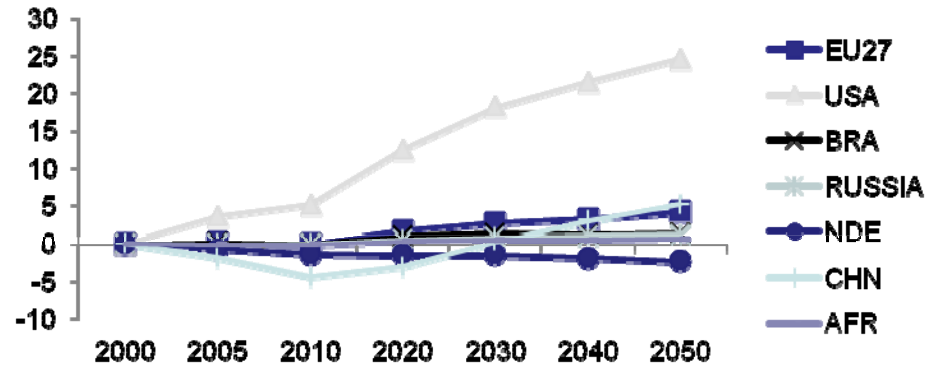
PM2.5 (µg/m³)



Crop yield (MTonnes/yr)



Crop yield (Mtonnes/yr)



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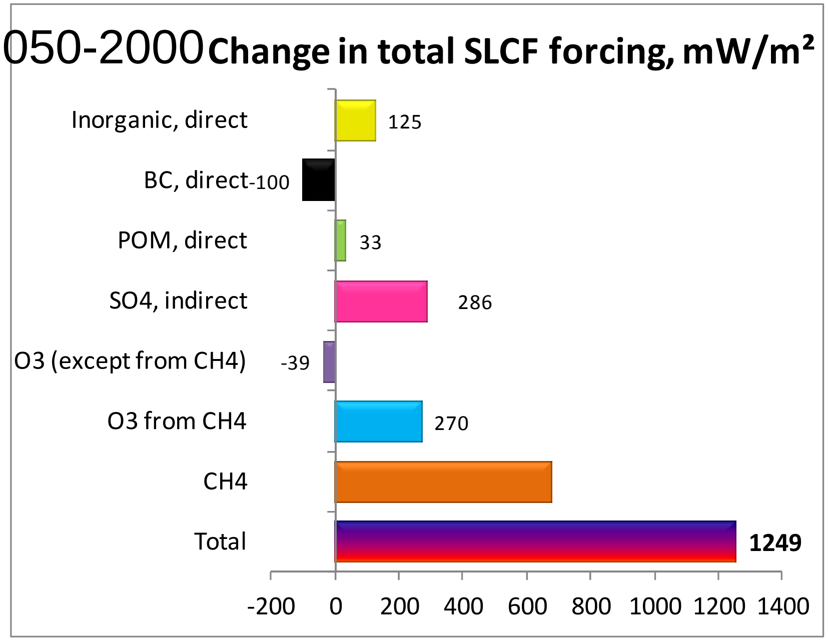
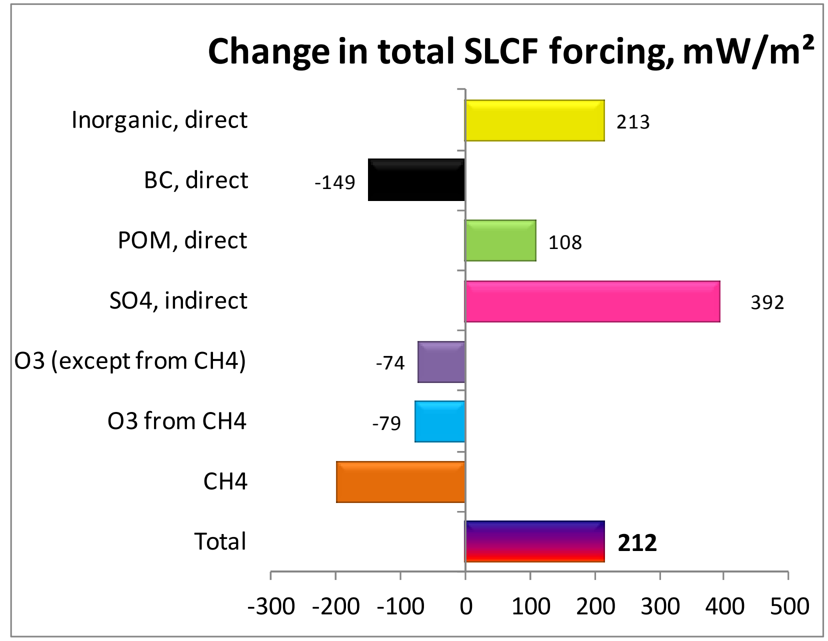
Example of results: RCPs SLCF Climate metrics

RCP 8.5

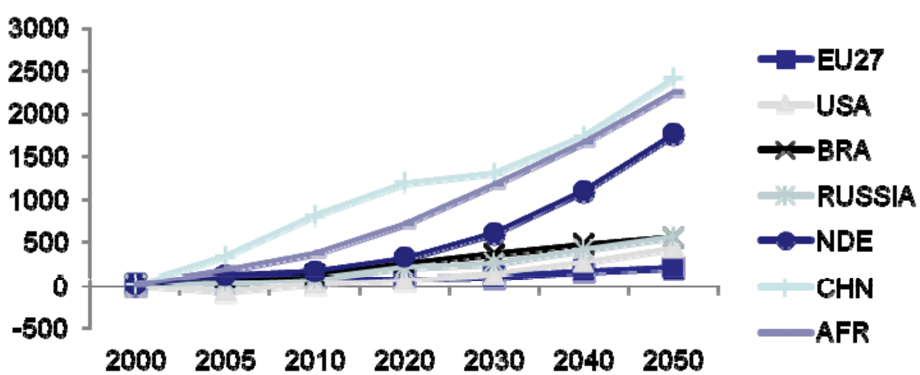
RF: 2050-2000



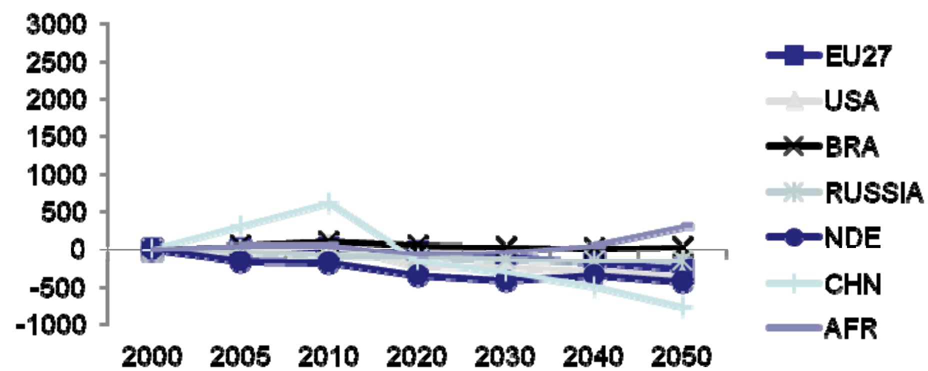
RCP 2.6



'transient' **SLCF CO2e, Tg/yr**



SLCF CO2e (Tg/Yr)



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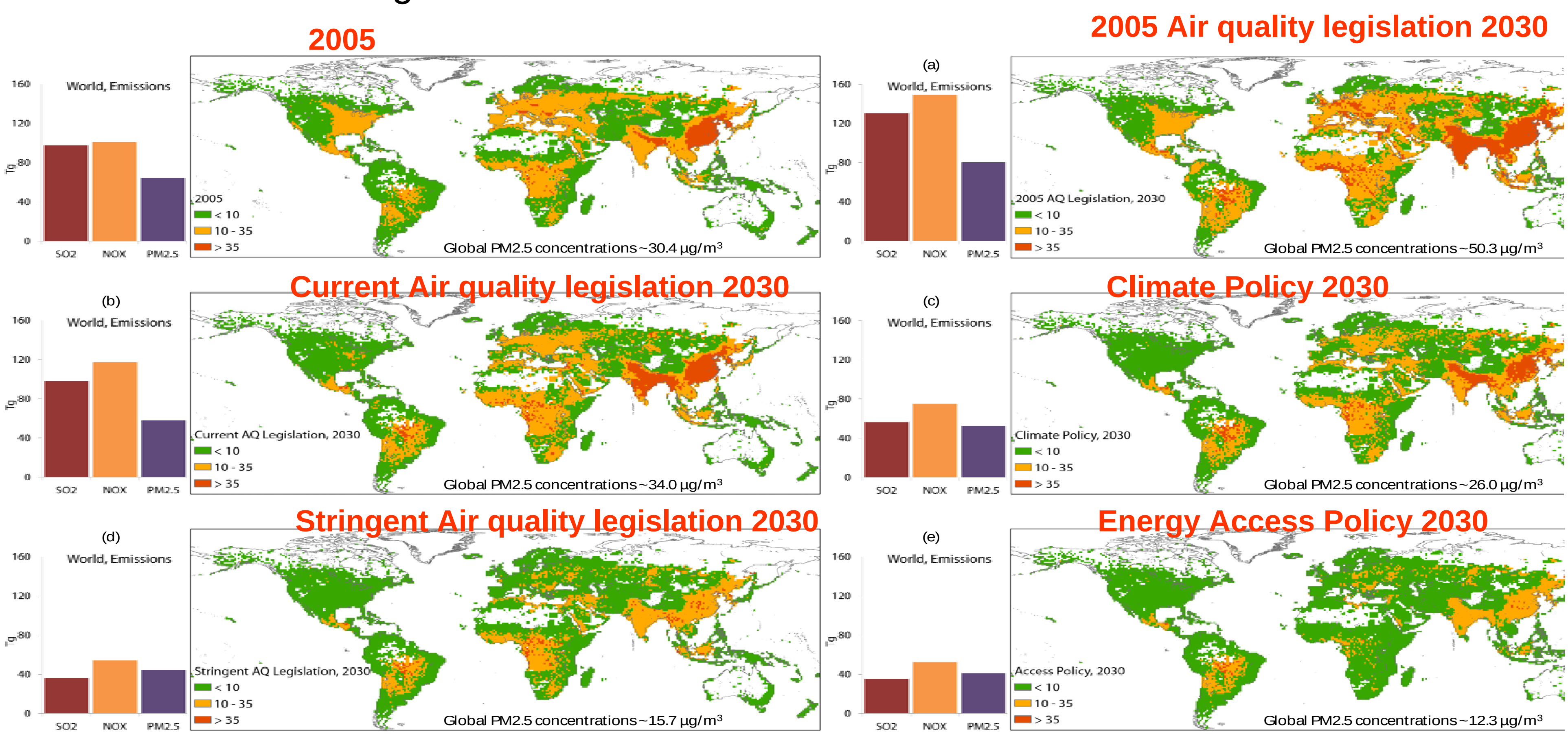
Recent Applications with IAMS:Global Energy Assessment

- •A range of air quality and energy use/access assumptions
- •Anthropogenic PM2.5
- •Colored regions indicate exceedance of WHO treshold



Rao et al., 2012 forthcoming

Dentener, Utrecht 2012

Recent Applications with IAMS:LIMITS project

•5 IAMS participating as well as regional partners from India and China
•Focus on co-benefits of climate policy, also for air pollution
•Application of FASST for the first time for a range global scenarios by different models.
•Testing ground, learning process

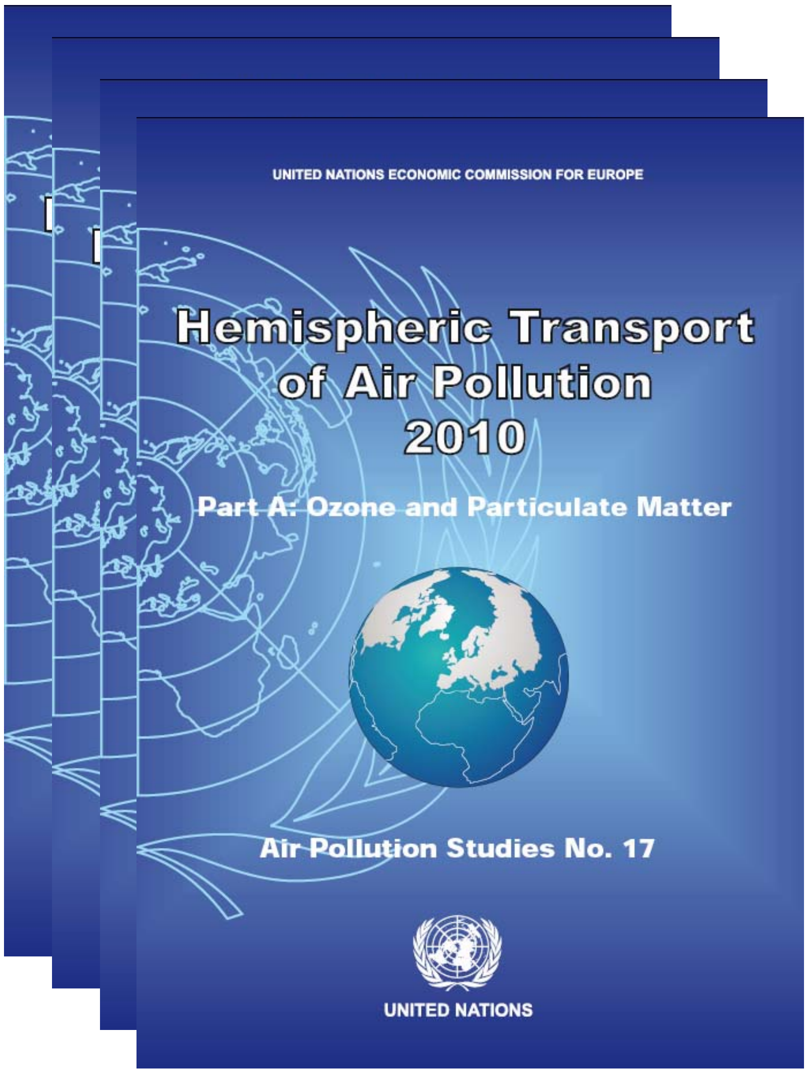
•Many IAMs now include global estimates of air pollution emissions

•Better representation of air quality legislations, expected trends in air pollution will enhance credibility of impact assessments.

•Important to understand the drivers, assumptions and completeness of assumptions

Task Force on Hemispheric Transport of Air Pollution

•**Examine the transport of air pollution across the Northern Hemisphere**
•**Emission mitigation options available in- and outside the UNECE region**
•**Assess their impacts on regional and global air quality, public health, ecosystems, near-term climate change**
•**Outreach**

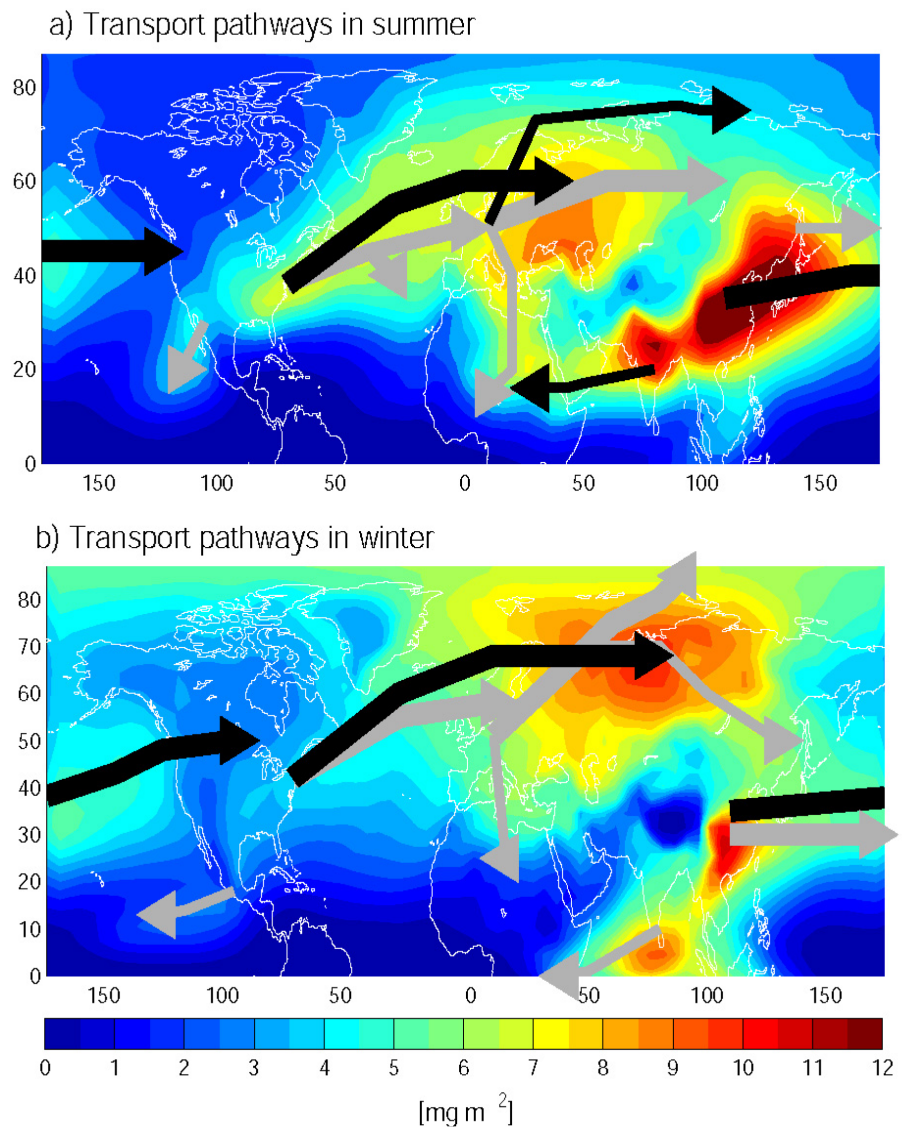


Covers O_3, PM, Hg, POPs:

- Conceptual Models
- Observed Spatial & Temporal Trends
- Emissions Inventories & Projections
- Global & Regional Modeling of Pollution Transport
- Impacts to Health, Ecosystems,Climate

- Available electronically at www.htap.org

Pathways of hemispheric pollution transport



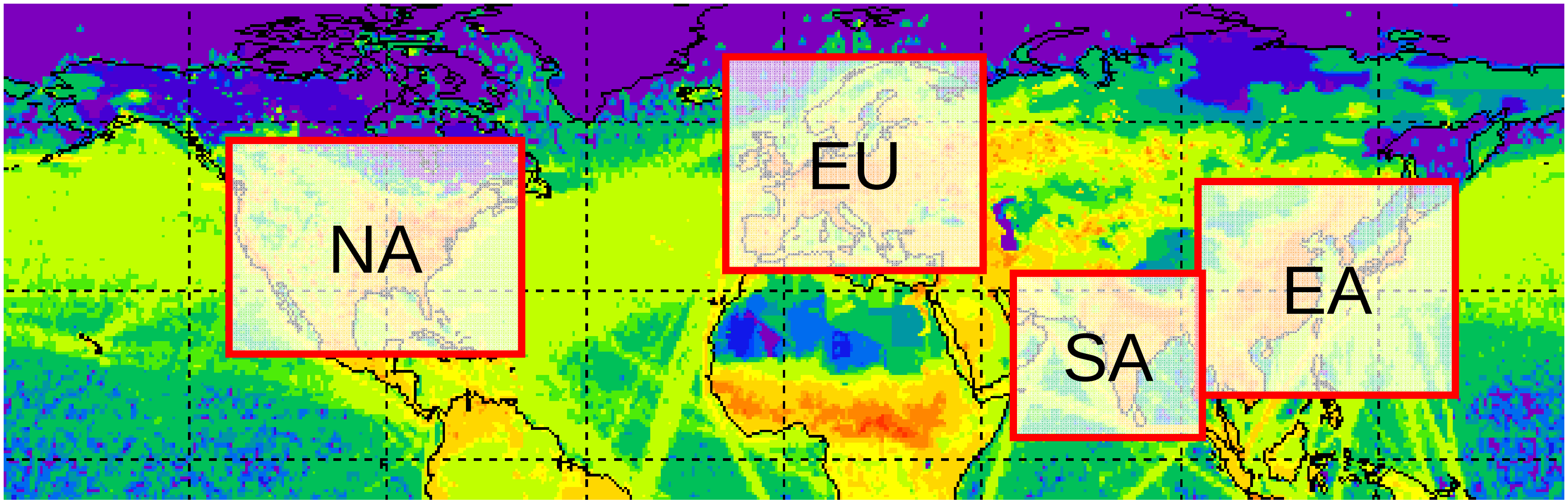
CO passive tracer

Lower troposphere

Mid-upper troposphere

Flexpart, A. Stohl et al, 2004

Design of Multi-Model Experiments



Source-Receptor Sensitivity Simulations

- **23 models**
- Base Year 2001
- Decrease emissions of precursors in each region by 20%
- Precursors emission include

    NO_X, VOC, CO, NO_X+VOC+CO,

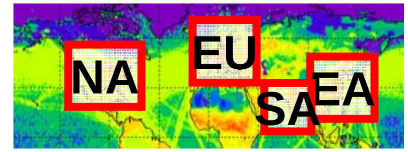
    NO_X+VOC+CO+PM

    Hg, POPs

    CH_4 concentration

Dentener, Utrecht 2012

HTAP reconstruction of O3 changes in Europe: attribution of drivers.

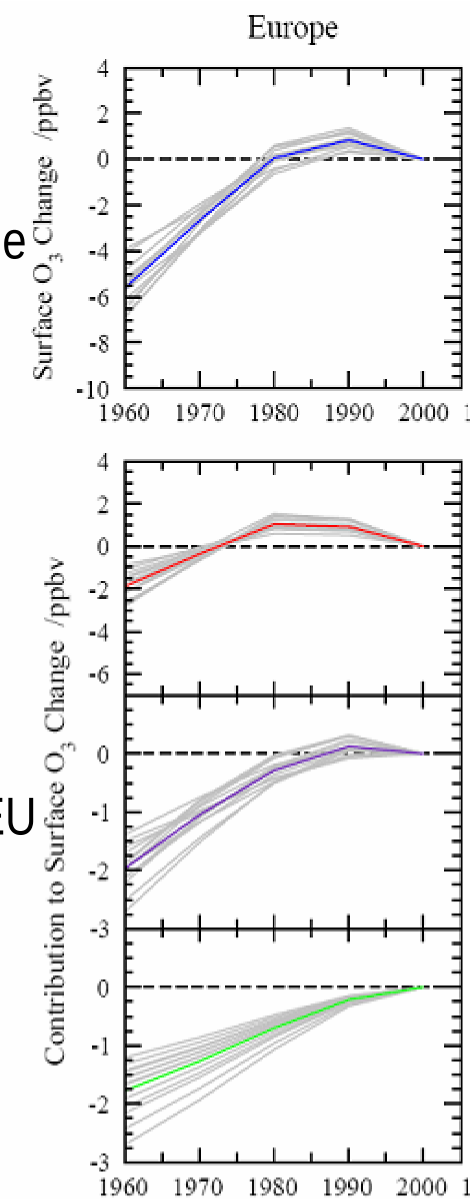


Total change

Within EU

Outside of EU

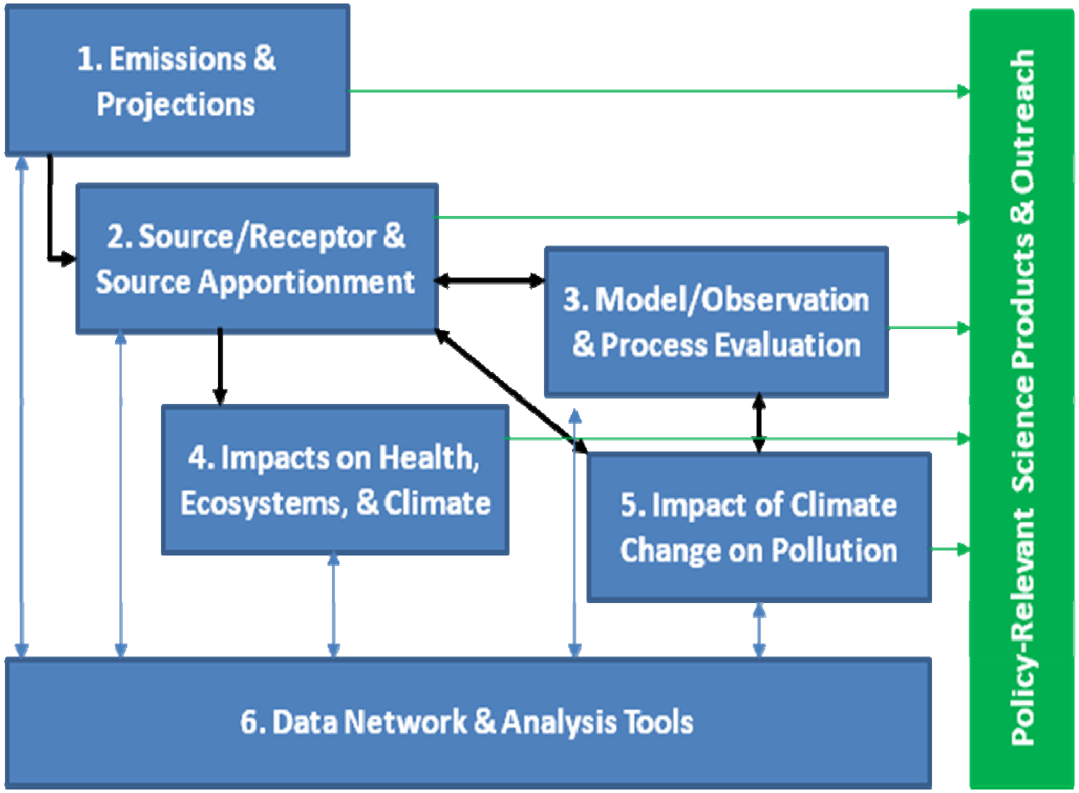
Methane

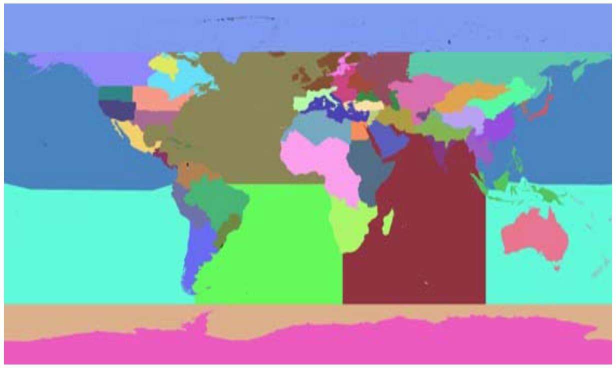


- Annual average - large region
- Small reductions in O_3 during 1980-2000, largest changes (6 ppb) happened before.
- O_3 reductions attributable to EU emissions partly compensated by increasing emissions elsewhere
- Important role for (global) CH_4 (30-50 %)
- Taken together changes in O3 from outside EU and CH4 are larger than within EU (60-70 %)
- External O3 becomes more important when 'local' sources are more regulated.
- More important at 'lower' concentrations

Wild et al., ACP, 2012

TF HTAP Workplan 2012-2016 Themes of Cooperative Activities





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Outlook

•Further development of FASST Toolbox

•TF HTAP Community effort to account for full range of model sensitivities
  - More regions- including coupled regional/global models

•Improved calculation of impacts

•Web distribution of results for scenario assessment

•Can be used also in IAMs =>more realistic air pollution assessments