Chapter A3
Emissions and Projections

(van Aardenne, Streets, Lamarque, Klimont, Smith, Schultz, Ohara, Parrish...)

Interim report emissions chapter was more a methodology chapter explaining available datasets and methodologies.

The current chapter attempts to be more explicit in emission trends in order to address possible future changes in budget and distribution of emissions.

Contents:

Main recommendations of interim report have been addressed in 2010 chapter

- incorporation of other emission inventories with local knowledge into global emission inventories

  Section 3.2.3: JRC-HTAP emission inventory

- accounting for other efforts to develop future emission projections and to identify the magnitudes and distributions (e.g., spatial/temporal) of expected future emissions

  Section 3.2.1 and 3.2.2: RCP harmonized emission inventory and emission scenarios

- improvement of emission inventories and development of projections is of special importance for Asia

  Section 3.4: Case study of Asian emissions

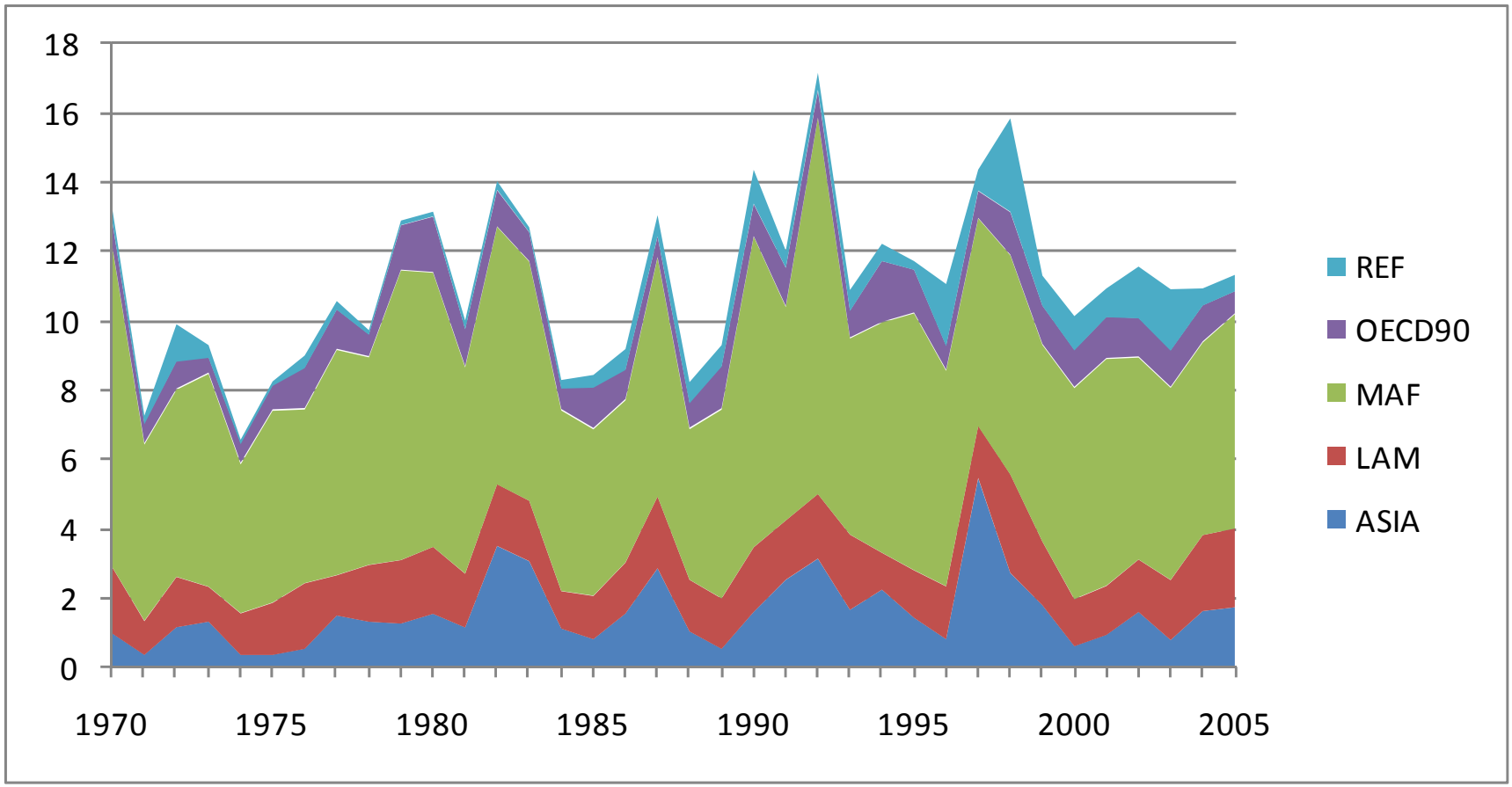
- identification of those emission estimates and uncertainties that are most important for understanding intercontinental transport of air pollution as part of an iterative process between model, measurement and inventory community

  Section 3.5: Iteration between inventory, modeling and observation community

Overview of data sources used to compile the JRC-HTAP emission inventory

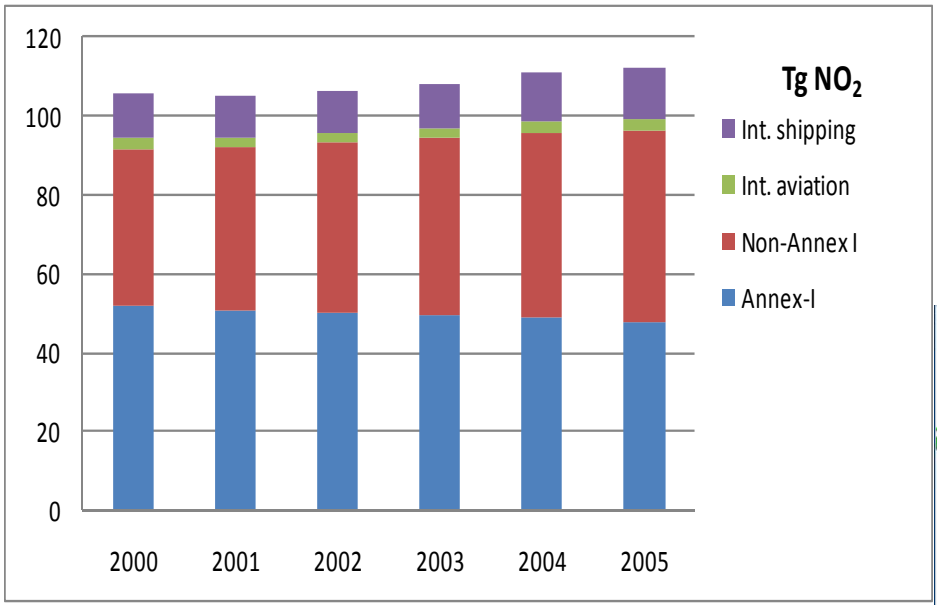
Priority	Inventory	Compounds	Reference/source
1st	US EPA	CO, NOx, SO_2, NMVOC, NH_3, $PM_{2.5}$ and PM_{10}	US EPA (2009)
	Environment Canada	CO, NOx, SO_2, NMVOC, NH_3, $PM_{2.5}$ and PM_{10}	EMEP (2009)/ENV. Canada (2009)
	EMEP	CO, NOx, SO_2, NMVOC, NH_3, $PM_{2.5}$ and PM_{10}	EMEP (2009)
	UNFCCC	CO, NOx, SO_2, NMVOC, CH_4	UNFCCC (2009)
2nd	REAS	CO, NOx, SO_2, NH_3, CH_4, BC, OC	Ohara et al. (2007)
	GAINS-China	CO, NOx, SO_2, NMVOC, NH_3, CH_4, $PM_{2.5}$ and PM_{10} , BC and OC	Klimont (2009)
3rd	EDGAR	CO, NOx, SO_2, NMVOC, NH_3, CH_4, and , BC and OC	JRC/PBL (2009), Van Aardenne et al. (2009).
	IMO (2009)	CO, NOx, SO_2, NMVOC, NH_3, CH_4, $PM_{2.5}$ and PM_{10} , BC and OC	IMO (2009), supplemented with JRC/PBL (unpublished)

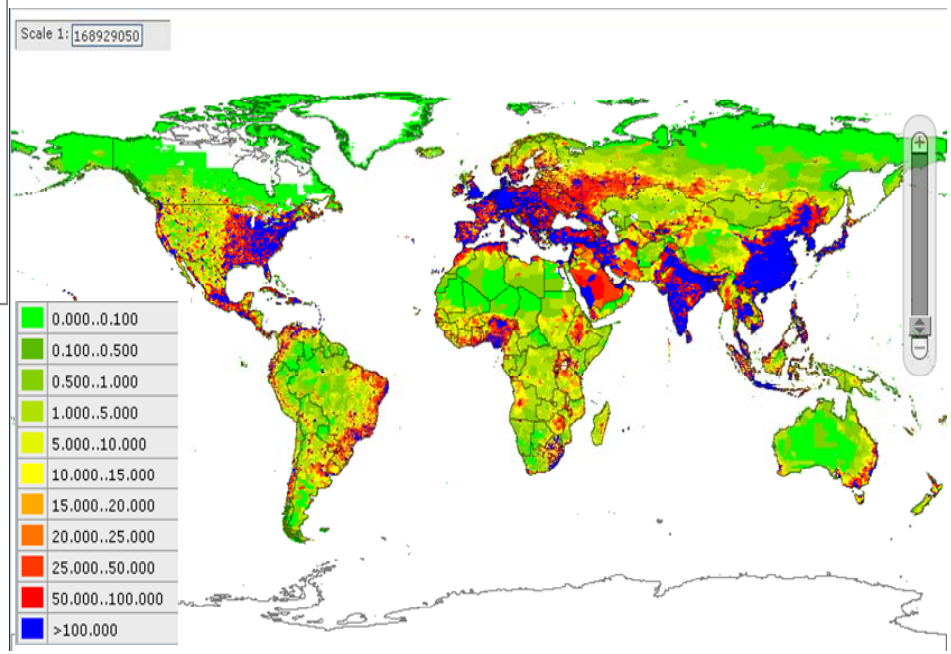
The actual inter-annual variation of biomass burning emissions (forests, savannah, grassland) is obtained by combining the RETRO biomass burning dataset (Schultz et al.) with the GFED dataset (van der Werf et al.); figure shows NOx emissions by main world regions for 1970-2005



What are the major emission sources affecting intercontinental transport?

Information on major emission source strengths and spatial distributions are presented using the new JRC-HTAP inventory: combination of official inventory data, regional and global datasets (2000-2005)





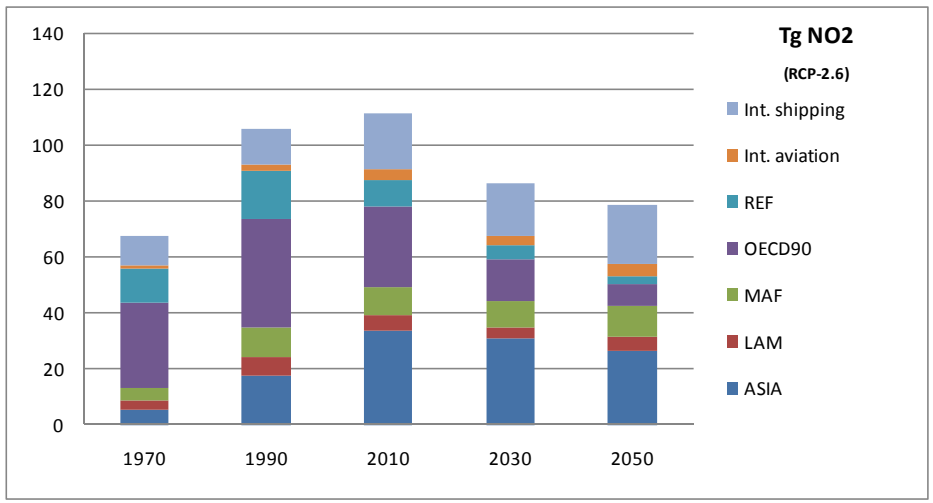
Examples: NOx emission trends for 2000-2005 (above) and global 2005 emissions distributed on a $0.1^{o} \times 0.1^{o}$ grid (right)

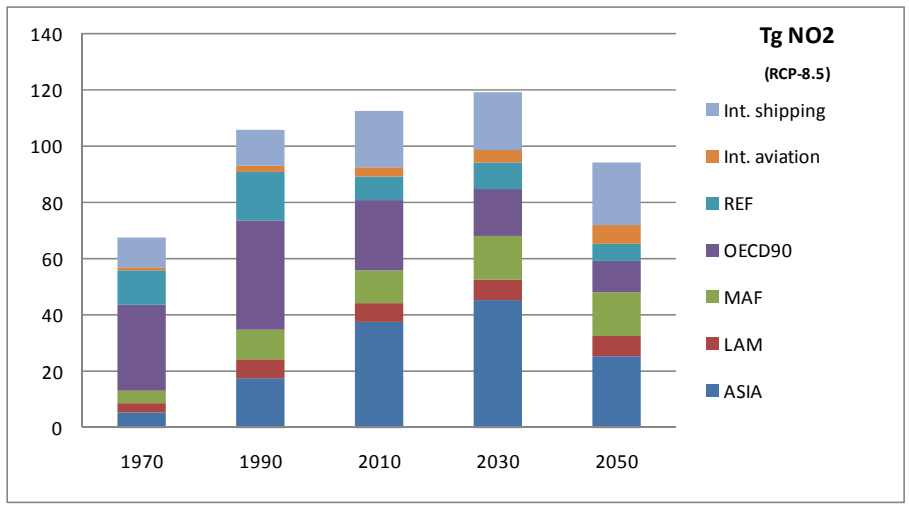
How might emission amounts and spatial distributions change over the next 20-50 years?

Storyline No. 1: **NOx emissions**

o Under the RCP2.6 scenario, NOx emissions return to 1970 levels by ~2050. Strong reductions in OECD countries, reductions in Asia after 2010, strong increases in Africa/Middle East.

o Under RCP8.5 scenario, NOx emissions return to just below 1990 levels by 2050. Strong reductions in OECD, other world regions show reductions after 2030, increasing importance of Africa/Middle East.





	1990/1970	2010/1990	2030/2010	2050/2030
ASIA	3.2	1.9	0.9	0.9
LAM	2.1	0.9	0.8	1.1
MAF	2.4	1.0	0.9	1.2
OECD90	1.3	0.7	0.5	0.6
REF	1.4	0.6	0.5	0.6
Int. aviatic	2.3	1.7	1.0	1.1
Int. shippi	1.2	1.6	0.9	1.1

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ASIA	3.2	2.1	1.2	0.6
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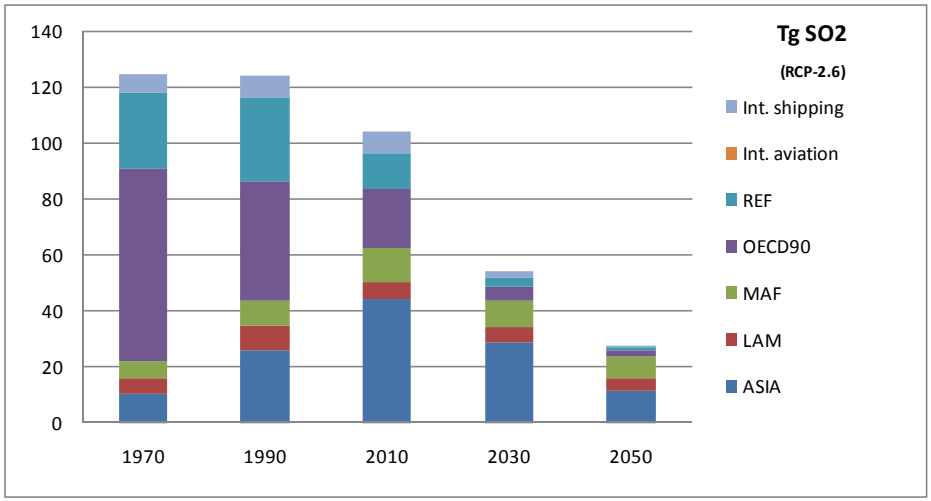
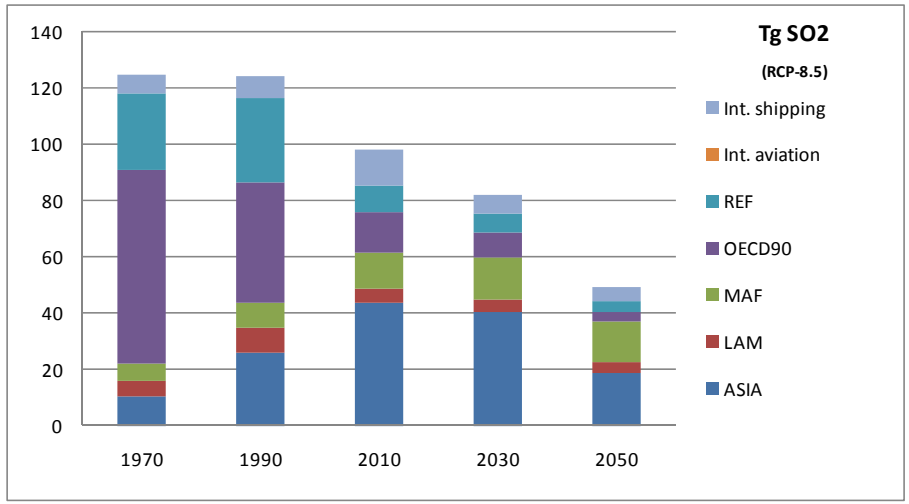
How might emission amounts and spatial distributions change over the next 20-50 years?

Storyline No. 2: **SO_2 emissions**

o Under the RCP2.6 scenario, SO_2 emissions decrease in all world regions after 2010, reaching ~1900 levels by 2050.

o Under RCP8.5 scenario, SO_2 emissions decrease in most world regions after 2010, Africa/Middle East becoming an important source of SO_2.





	1990/1970	2010/1990	2030/2010	2050/2030
ASIA	2.5	1.7	0.7	0.4
LAM	1.6	0.7	0.9	0.8
MAF	1.4	1.3	0.8	0.9
OECD90	0.6	0.5	0.2	0.3
REF	1.1	0.4	0.3	0.4
Int. aviatic	-	-	-	-
Int. shippi	1.2	1.0	0.3	0.3

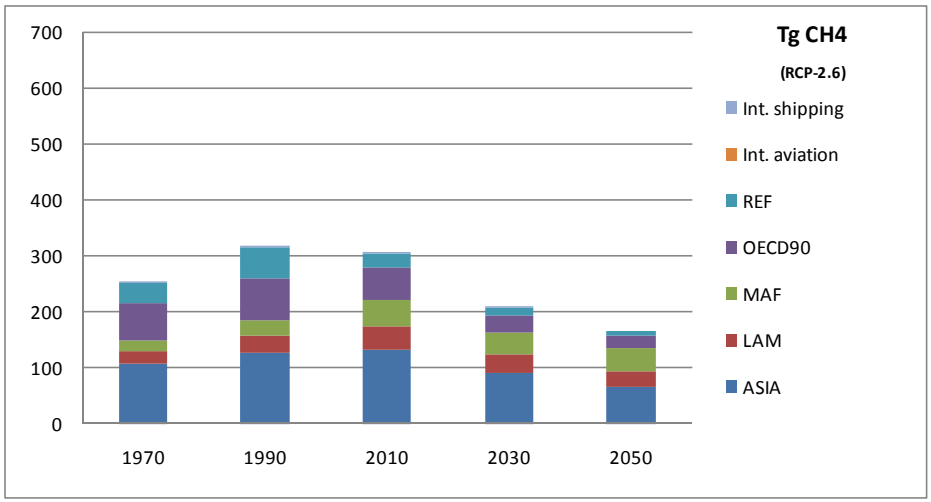
)	1990/1970	2010/1990	2030/2010	2050/2030
ASIA	2.5	1.7	0.9	0.5
LAM	1.6	0.6	0.9	0.8
MAF	1.4	1.4	1.1	1.0
OECD90	0.6	0.3	0.6	0.4
REF	1.1	0.3	0.7	0.6
Int. aviatic	-	-	-	-
Int. shippi	1.2	1.6	0.5	0.8

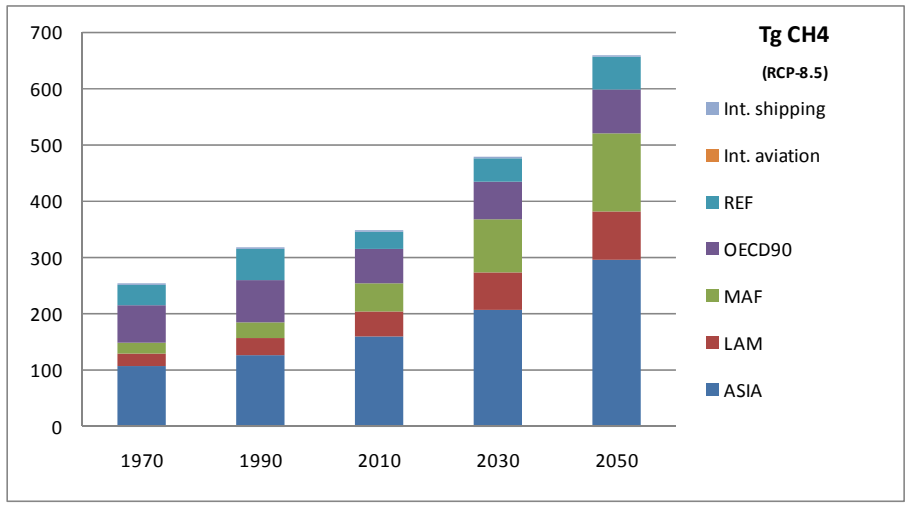
How might emission amounts and spatial distributions change over the next 20-50 years?

Storyline No. 3: **CH_4 emissions (CH_4 scenarios still need to be verified!)**

o Under the RCP2.6 scenario, CH_4 emissions are moderately lower, with similar spatial distribution as in the present day.

o Under RCP8.5 scenario, CH_4 emissions more than double by 2050. Important spatial shifts, with increasing importance of Asia, Latin America, and Africa/Middle East.





	1990/1970	2010/1990	2030/2010	2050/2030
ASIA	1.2	1.1	0.7	0.7
LAM	1.4	1.3	0.8	0.9
MAF	1.4	1.7	0.9	1.0
OECD90	1.1	0.8	0.5	0.7
REF	1.6	0.4	0.6	0.7
Int. aviatic	-	-	-	-
Int. shippi	1.2	1.5	1.1	0.0

)	1990/1970	2010/1990	2030/2010	2050/2030
ASIA	1.2	1.3	1.3	1.4
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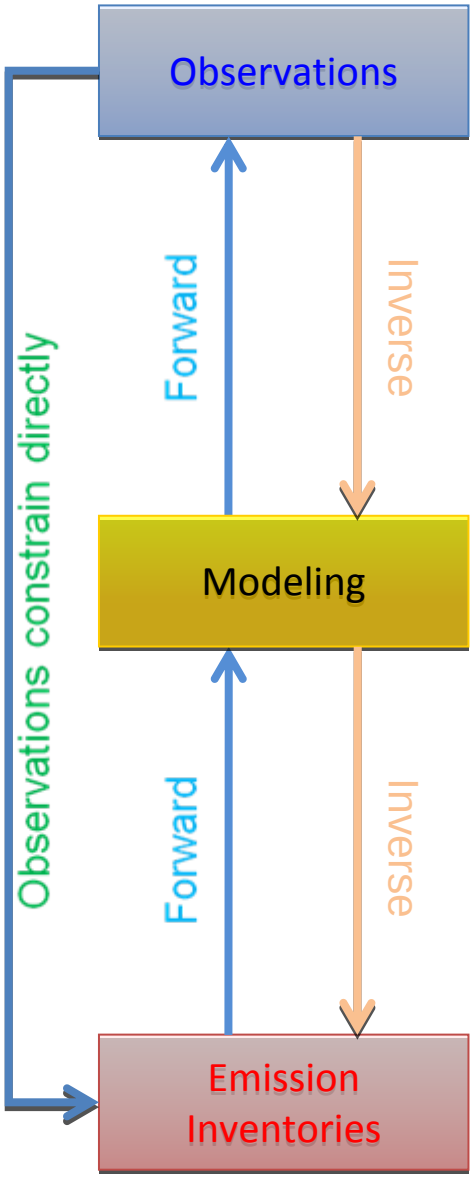
MAF	1.4	1.8	1.8	1.5
OECD90	1.1	0.8	1.1	1.2
REF	1.6	0.5	1.4	1.4
Int. aviatic	-	-	-	-
Int. shippi	1.2	1.6	1.1	1.0

How have observations and modeling been used to improve emission estimates?



"Top-down" approaches to evaluate, constrain, and improve the emission inventories:

Emission of short-lived species (e.g. NO_x, HCHO, HC) sometimes can be constrained directly by observations

Forward modeling

Model output vs. observations

Inverse modeling

An a priori emission inventory used in a CTM is optimized to derive an a posterior emission estimate by systematically reducing the differences between simulations and observations.

Species:	inert	long-lived	reactive
e.g.	CO_2	CH_4	NO_x, CO, HCHO

Uncertainties are associated with activity data from statistics, emission factors, allocation factors, etc.

How have observations and modeling been used to improve emission estimates?

	NO_x	CO	SO_2	CH_4	NMVOC	PM
Observations constrained directly	√		√		√	
Forward modeling	√	√	√			√
Inverse modeling	√	√		√	√	√

	NO_x	CO	SO_2	CH_4	NMVOC	PM
Satellite Data	GOME SCIAMACHY OMI GOME-2	MOPITT SCIAMACHY TES	TOMS GOME SCIAMACHY OMI GOME-2 MODIS, MISR	SCIAMACHY	GOME SCIAMACHY OMI GOME-2	SCIAMACHY MODIS, MISR

Some Discussion Topics

- Estimation of uncertainty in HTAP emission data sets [Sec. 3.2].
- Do we have sufficient data on driving forces needed for making reasonable future emission scenarios [Sec. 3.3]? Different types of data needed lead to different levels of confidence for each species.
- How should future emission scenarios be constructed [Sec. 3.3]?
- Is it necessary or desirable to try to reconcile/harmonize different bottom-up emission data sets for the same regions/time periods [Sec. 3.4]?
- Is it necessary or desirable to try to reconcile/harmonize bottom-up and top-down emission data sets for the same regions/time periods [Sec. 3.5]?
- …….