Model sensitivity to MACC anthropogenic and biogenic emissions: Global simulations and evaluation for reactive gases

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Outline

1. MACC Overview
2. MACC global simulations and emissions
3. Results from the MACC reanalysis
4. MOZART sensitivity simulations
5. Conclusions

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GMES atmospheric environmental services

GMES
Observing our planet for a safer world

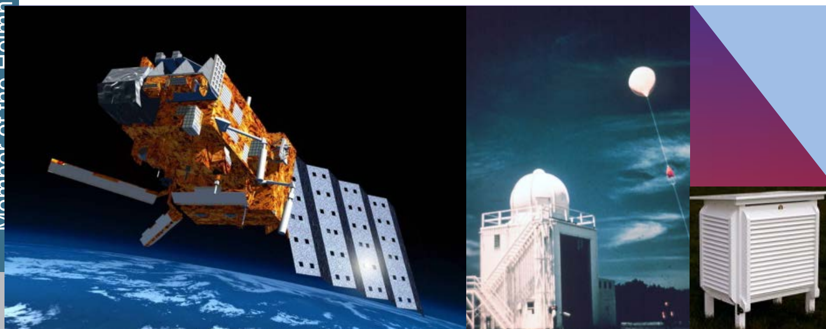
- **A component of Europe's Global Monitoring for Environment and Security intiative**
  - which also provides services for land and ocean

- **The atmospheric programme comprises**
  - developing operational space-based observation of constituents
  - strengthening the provision of complementary *in-situ* observations
  - developing and operating associated data and information services

- **A 48-partner EC-funded project called MACC (2009-2014)**
  - is implementing the core monitoring and forecasting services
  - supports downstream services for specific sectors

macc
Monitoring atmospheric
composition & climate

The underlying computational approach

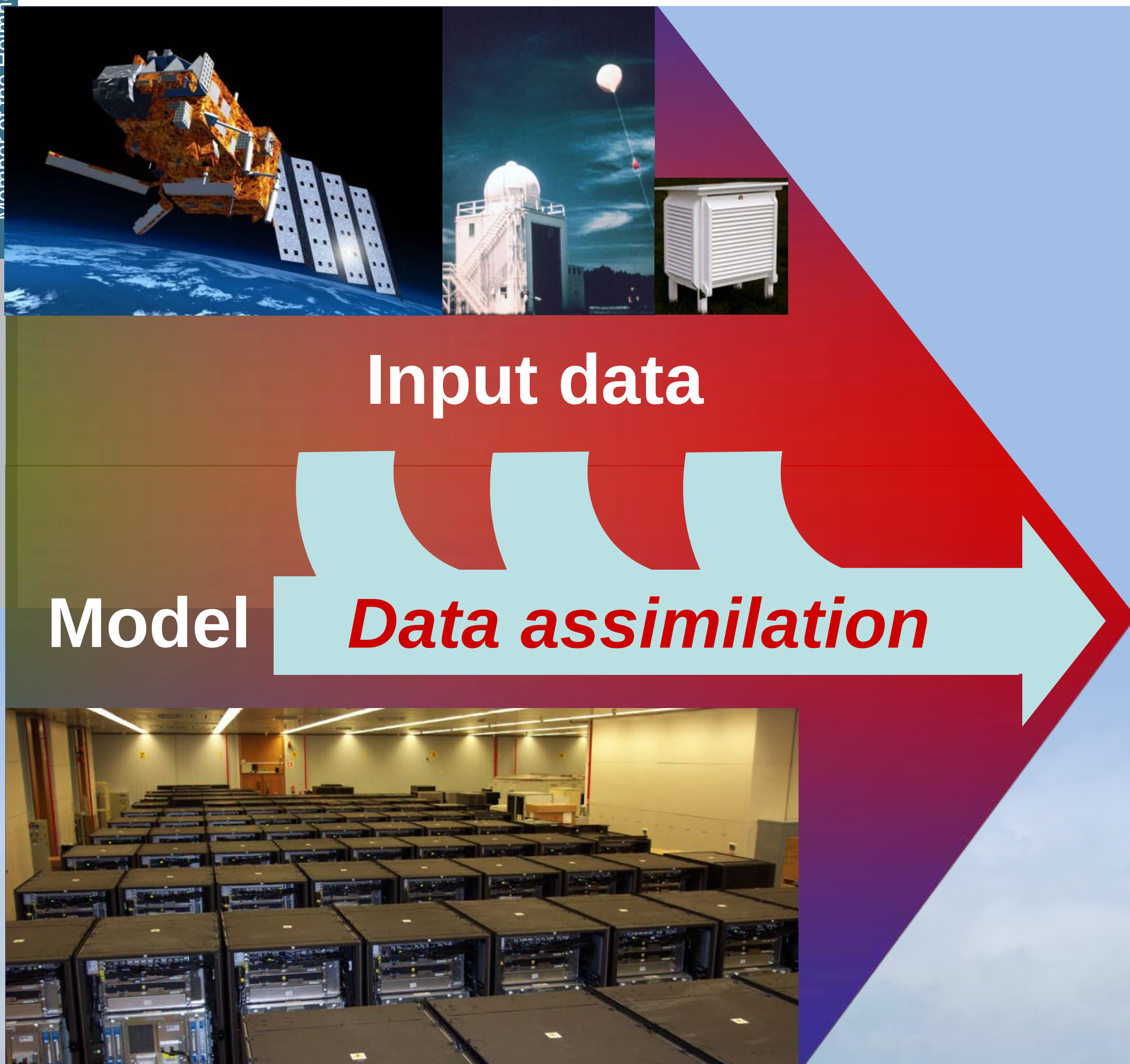


Input data

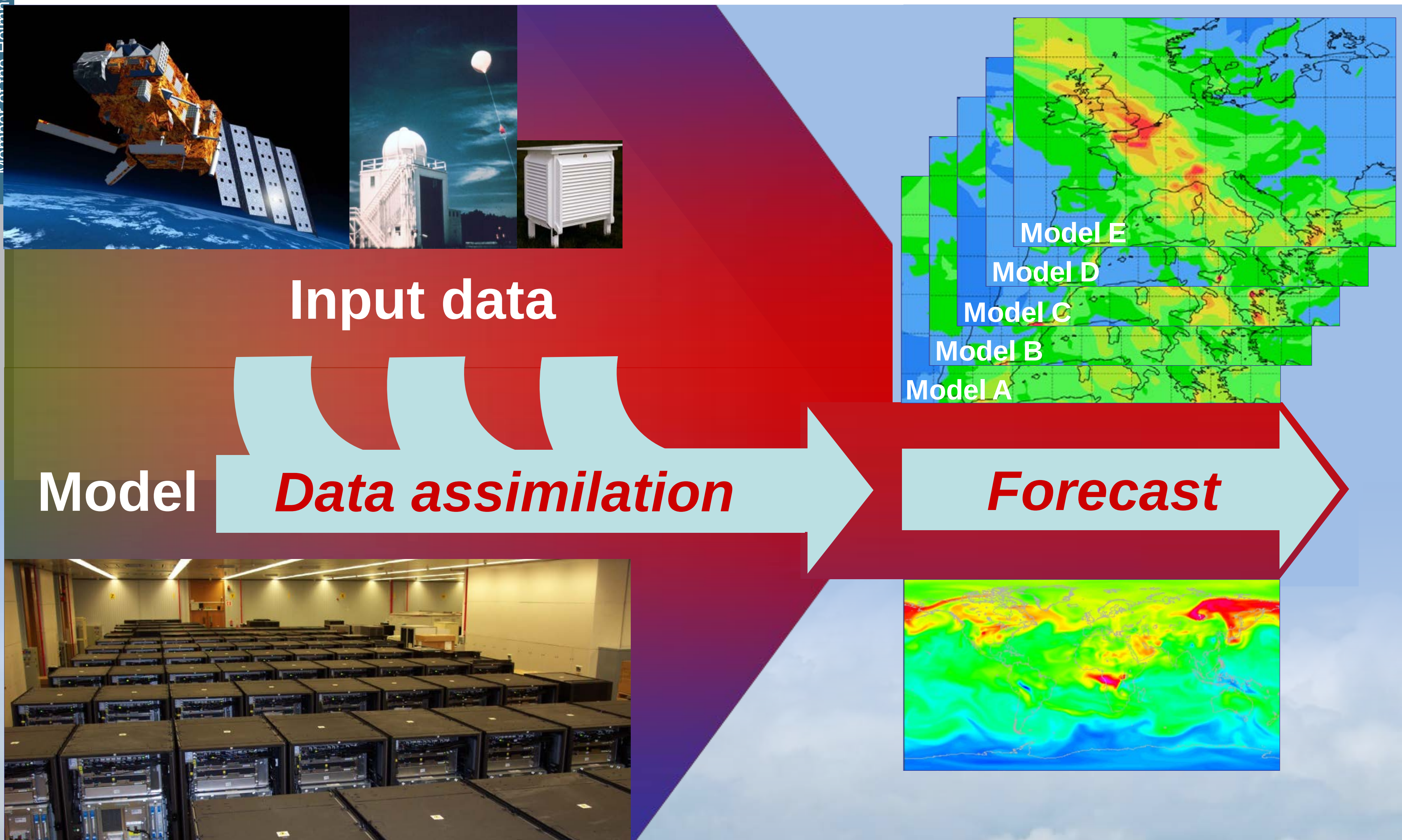
Weather,
constituents, emissions,
land and ocean conditions

Model

The underlying computational approach



The underlying computational approach



From GEMS to GMES: Global model simulations

PROMOTE

GEMS | macc | macc-II | GMES Atmosphere Service

2005 2009 2011 2014

NRT Forecast
Reanalysis 2003-2009

NRT Forecast
Reanalysis 2003-2010 (-2014)

Operational Forecast
Monitoring

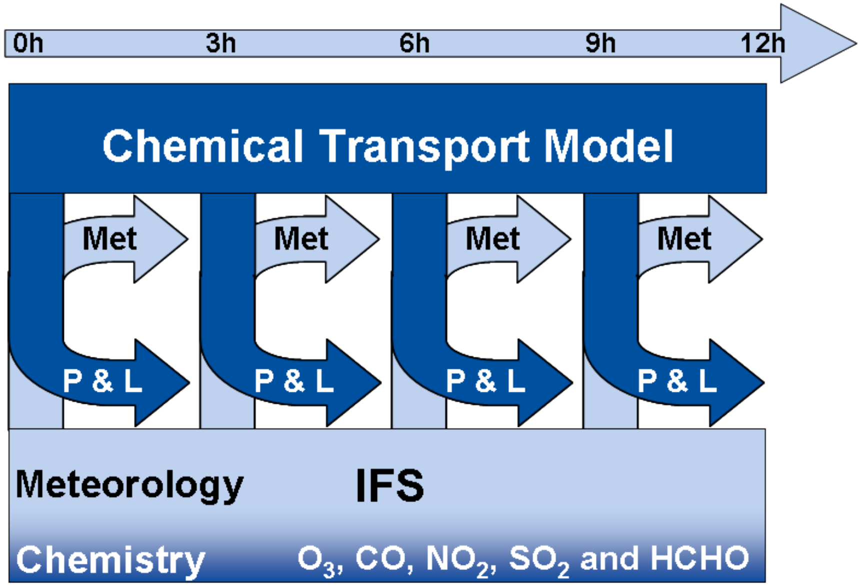
Reactive Gas Species: O3 CO NO2 HCHO SO2
+ Aerosols + GHGs

Boundary conditions for regional AQ models

MACC global data assimilation system

- **Based on ECMWF's "Integrated Forecasting System" - IFS**
- **CO2 , CH4 and aerosols have been incorporated in the IFS**
  - data assimilation has been developed for AIRS and IASI radiances, SCIAMACHY retrievals, MODIS aerosol optical depth, GOSAT …
- **IFS also carries O_3, CO, NO_2, SO_2 and HCHO**

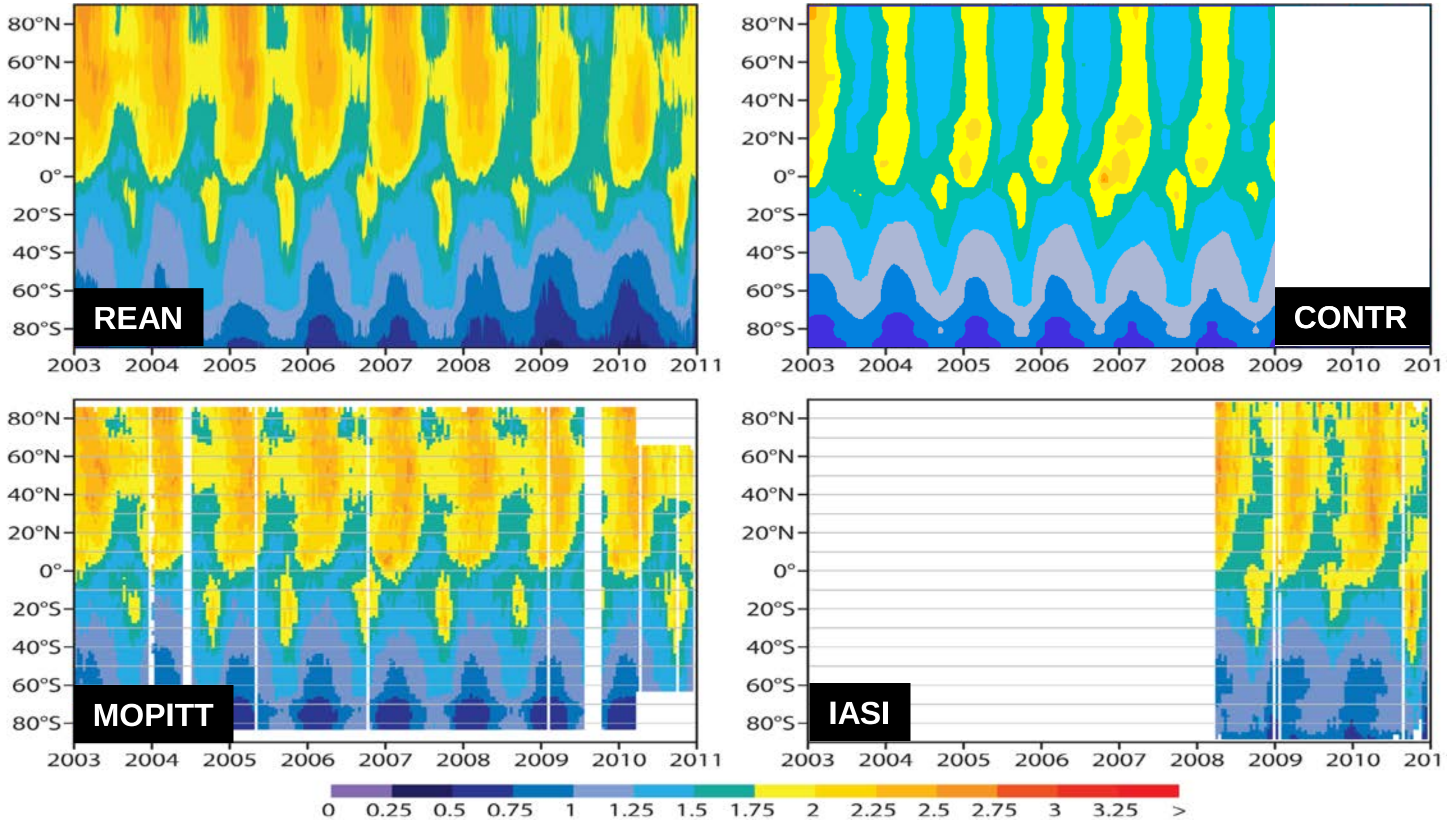
- **Chemical production and loss come from a coupled CTM (MOZART or TM5)**
- **The CTMs calculate detailed chemistry, emissions, deposition for about 100 trace gas species**
- **Satellite data assimilation currently active for O_3 CO NO_2**
- **Chemistry modules are being built fully into IFS to build an integrated model C-IFS by the end of MACC**



MACC global emissions

- Global anthropogenic emissions 2000-2012 are extrapolated from ACCMIP 2000 (Lamarque et al. 2010) using the IPCC RCP8.5 scenario (van Vuuren et al. 2011) → MACCity inventory (Granier et al. 2011)
- seasonal variation from RETRO project (Schultz et al. 2007)
- biogenic emissions from MEGANv2 (Guenther et al. 2006)
- other natural emissions from GEIA and the POET project
- biomass burning emissions from GFASv1 (Kaiser et al. 2012)
- all emission data available from the ECCAD-GEIA database http://eccad.sedoo.fr/

Results from the MACC reanalysis



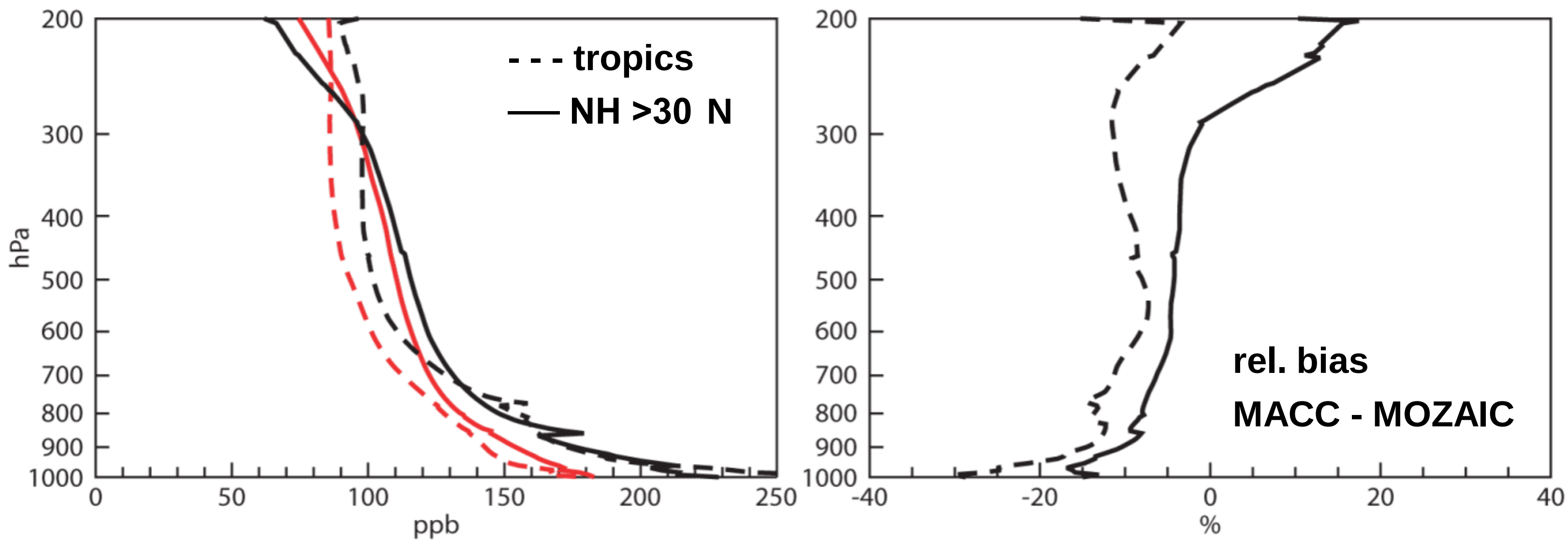
Total column CO [10^{18} molec cm^{-2}]

The MACC reanalysis has a realistic seasonal cycle and interhemispheric differences for CO, while a MOZ standalone simulation run in parallel has too low CO concentrations, particularly in the NH. *(Inness et al. 2012, in preparation)*

→ deficit in MACCity CO emissions
→ data assimilation highly benefitial

Results from the MACC reanalysis

mean MOZAIC and MACC reanalysis CO profiles 2003-2010



→ Tropospheric CO 10-20% lower than MOZAIC profiles
→ surface CO has even larger low bias

Discrepancy between observed and modelled CO is a typical problem of global CTMs using different kinds of bottom-up inventories (e.g. *Stevenson et al. 2006 or Kopacz et al. 2010*)

MOZART sensitivity studies

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MOZART simulations for the year 2008 with varying emissions:

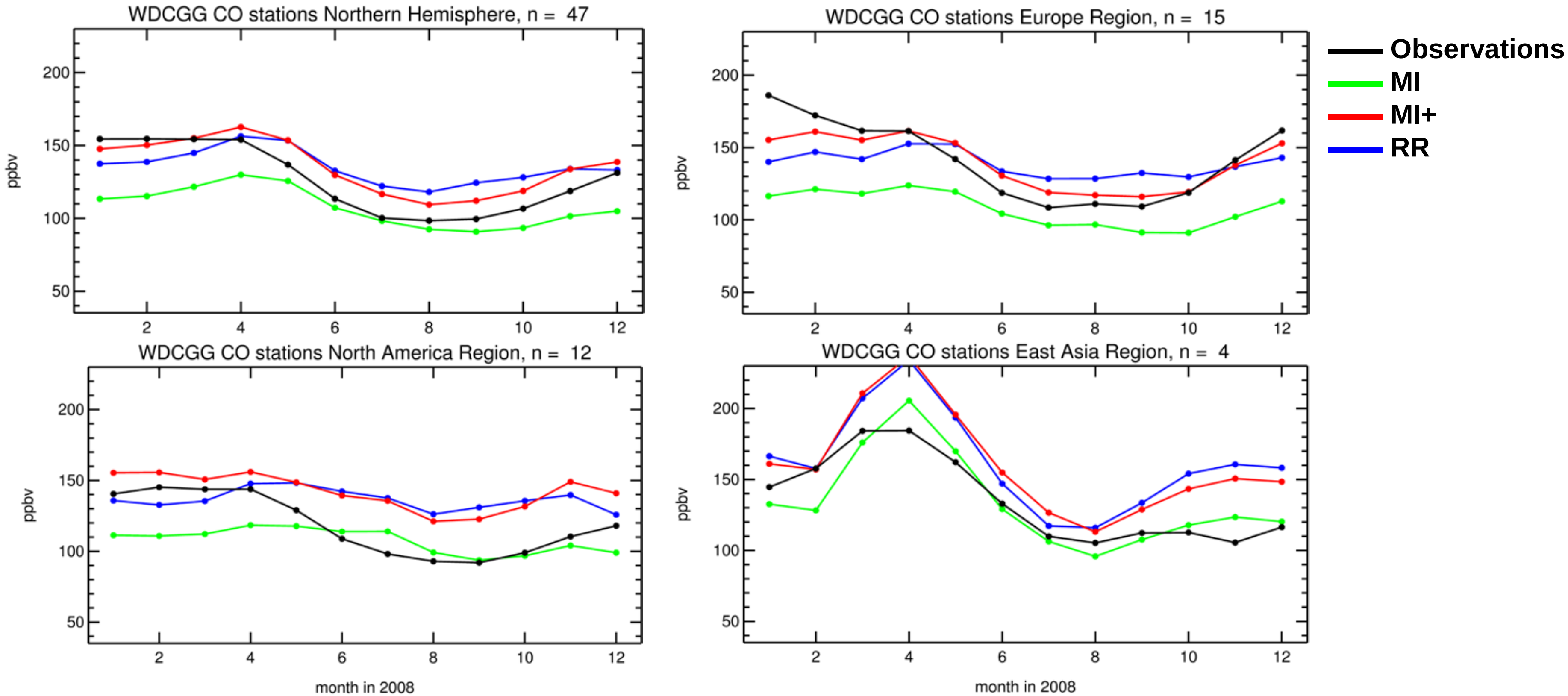
simulation	Anthropogenic emissions	Biogenic emissions
RR	RETRO/REAS	Lathiere et al. (2005)
MI	MACCity	MEGANv2.0
MI+	MACCity, CO traffic emissions scaled by a factor of 2.5	MEGANv2.0
MI+NA_EU	MACCity, CO traffic emissions scaled for Europe and North America	MEGANv2.0
MI+VOC	MACCity, VOC anthropogenic emissions doubled	MEGANv2.0
MI+BIO	MACCity, CO and VOC biogenic emissions doubled	MEGANv2.0, CO and VOC emissions doubled

- **All simulations use GFASv1 biomass burning emissions**
- **resolution: T63 (1.875°x1.875°), 60 levels up to 0.1 hPa**
- **meteorology from ERA INTERIM**

The scaling factor is meant to account for missing emissions from motor vehicles under cold-start conditions (see *Parrish, Atm. Env., 2006* and *Kopacz et al. , ACP, 2010*).

MOZART sensitivity studies

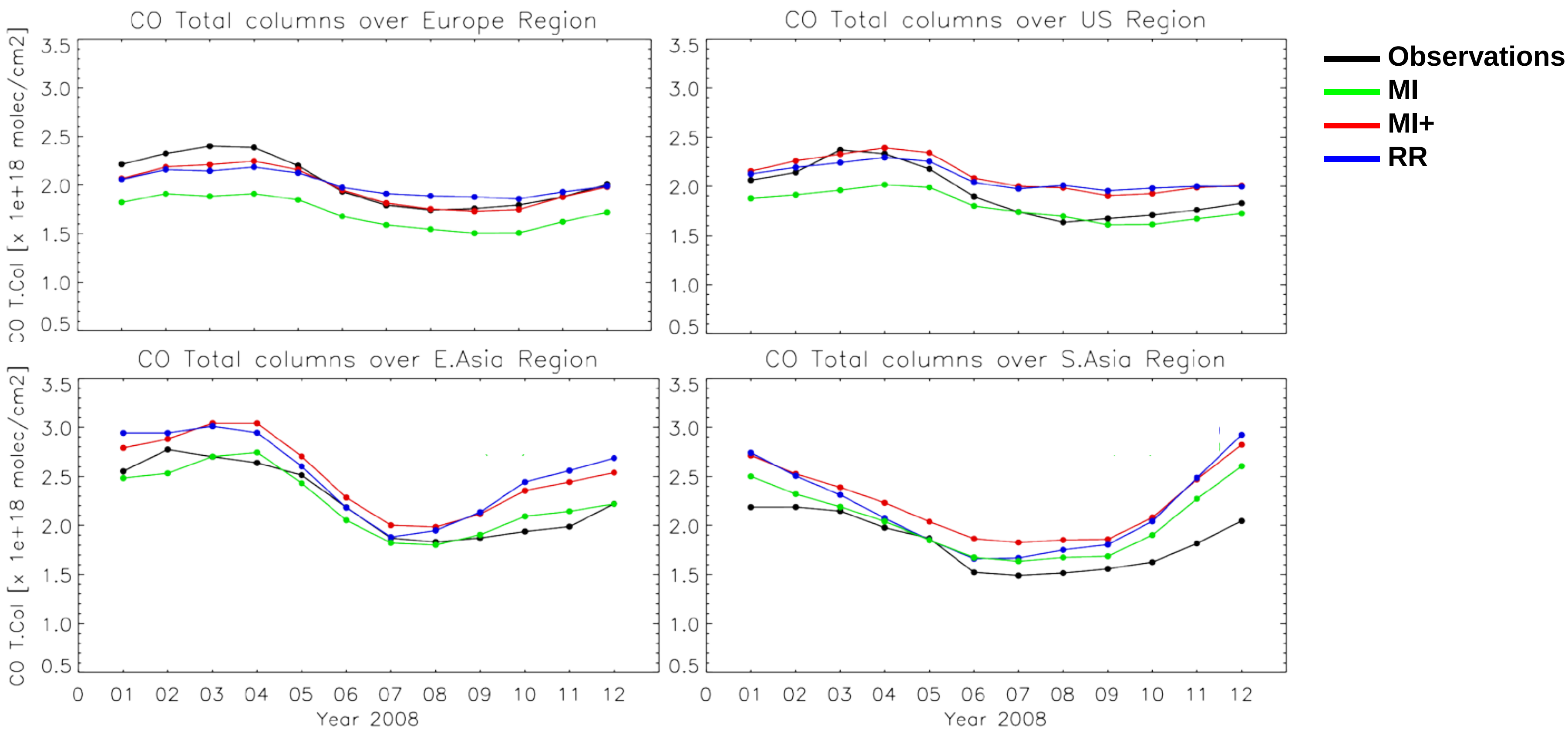
Surface CO compared to WDCGG station data



→ RR generally higher than MI (base year 2003 for RR emissions)
→ MI significantly lower than observations, largest bias in winter and spring
→ East Asia well simulated with MI (updated emission information)
→ MI+ matches observations in Europe, but not other regions

MOZART sensitivity studies

CO Total columns compared to MOPITT



MOZART sensitivity studies

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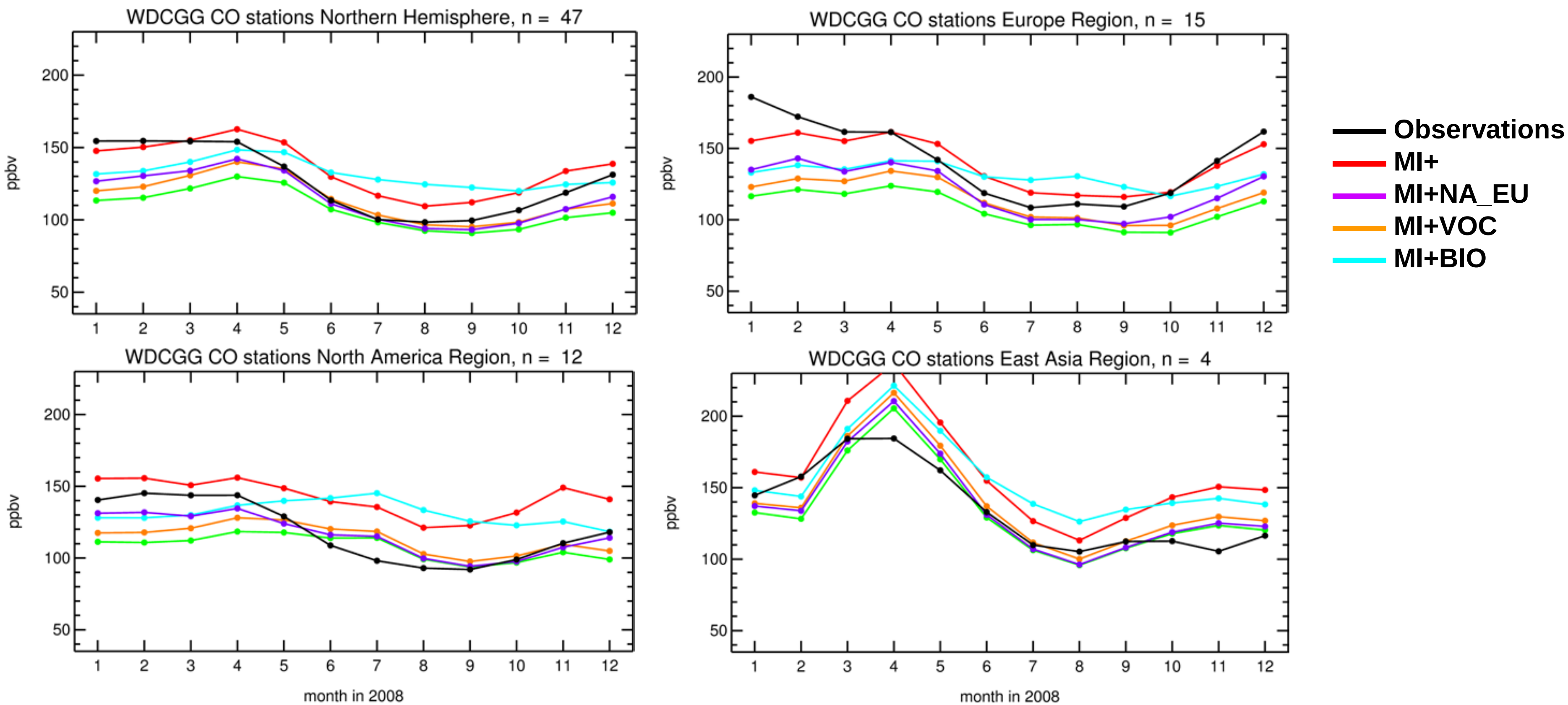
Surface CO compared to WDCGG station data



→ refined scaling MI+NA_EU shifts wintertime CO concentrations to higher values for Europe and North America only

→ doubling VOC anthropogenic emissions (MI+VOC) enhances wintertime CO by up to 10 ppb

→ doubling biogenic CO & VOC emissions (MI+BIO) leads to unrealistically high concentrations in summer

The IPCC RCP8.5 scenario

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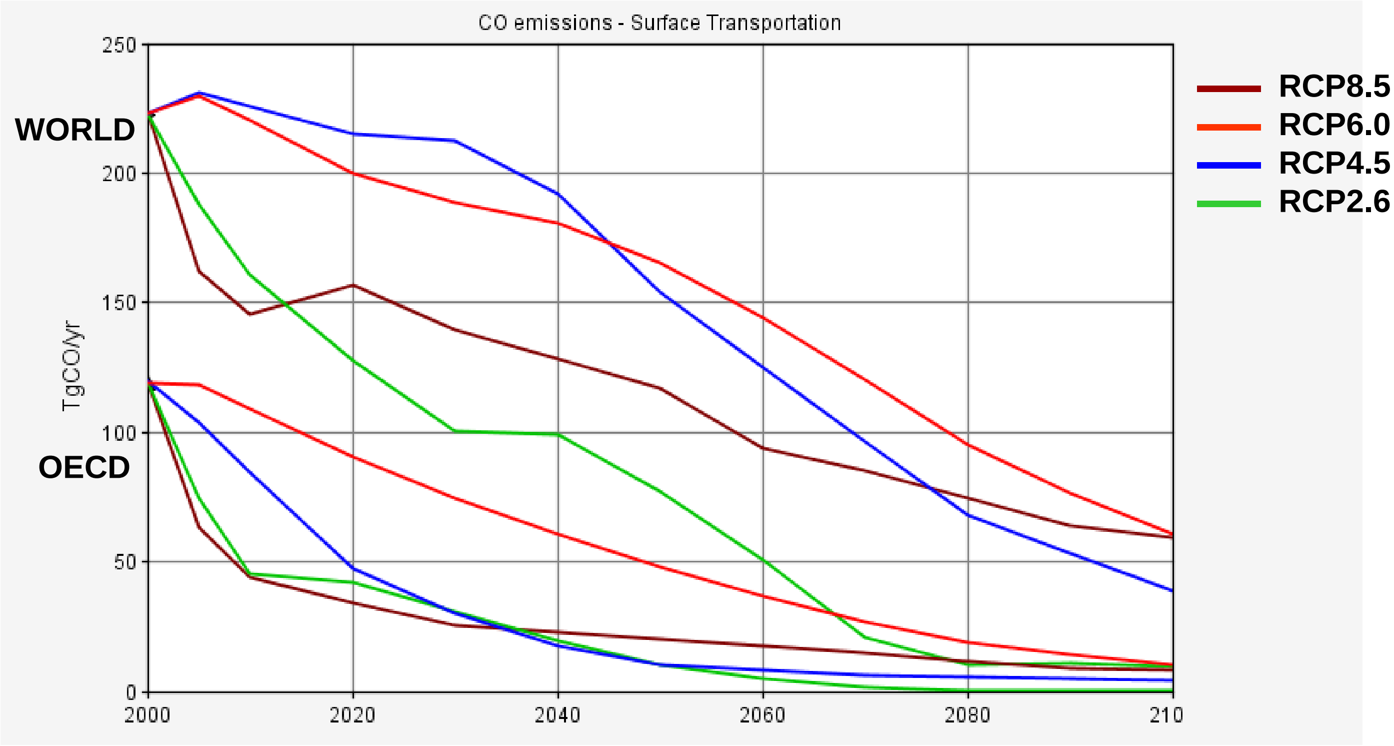
CO surface traffic emissions 2000-2100 for the RCP emission scenarios



Although RCP8.5 is a scenario with relatively high greenhouse gas emissions, the CO anthropogenic emissions decrease rapidly in the first decade, mostly driven by the emission reduction in the OECD countries.

Traffic emissions, which build the majority of anthropogenic CO emissions from these countries decrease from 120 Tg/y in 2000 to 40 Tg/y in 2010).

MOZART sensitivity studies

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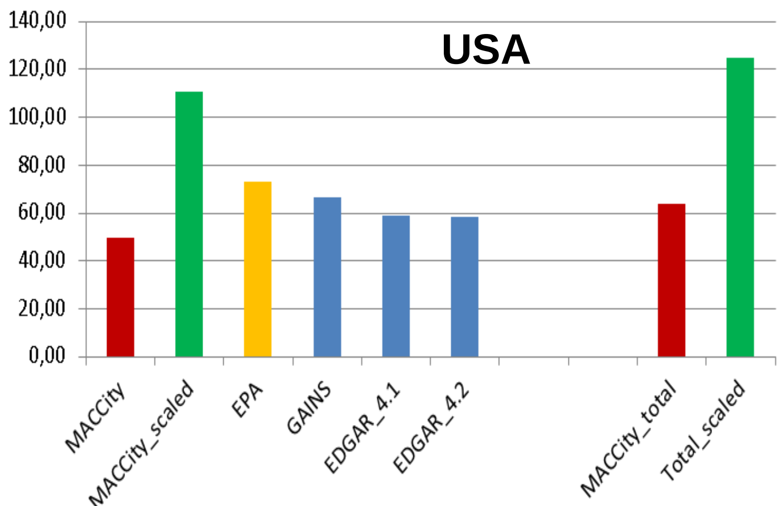
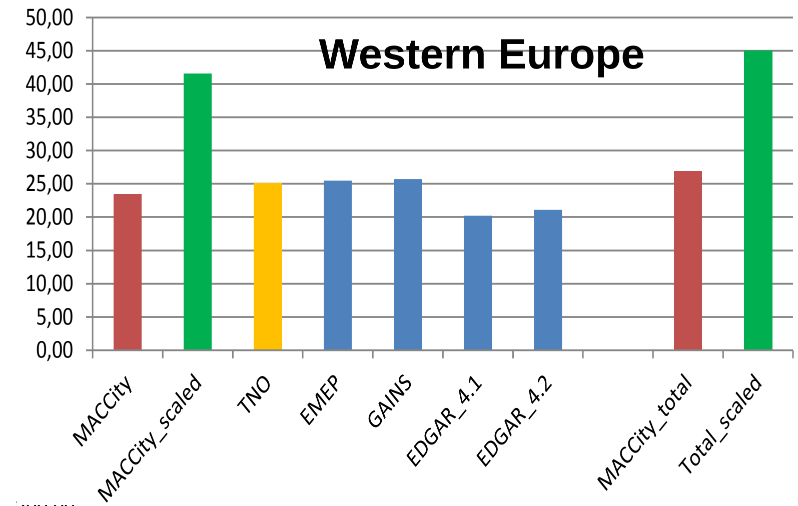
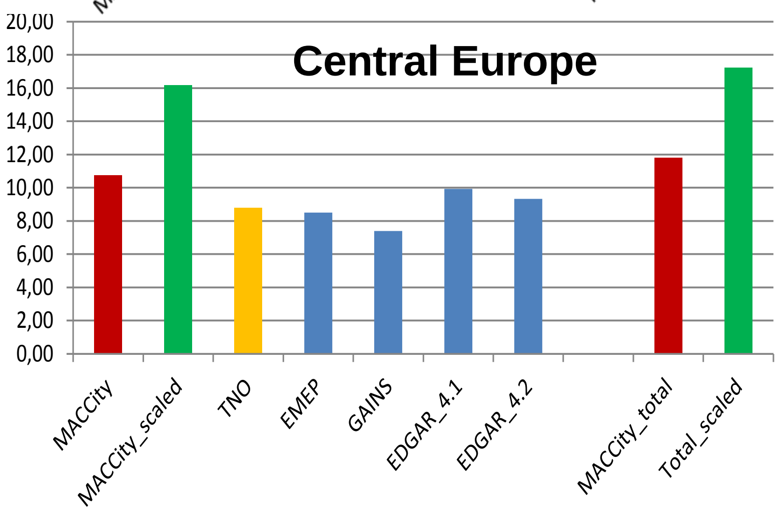
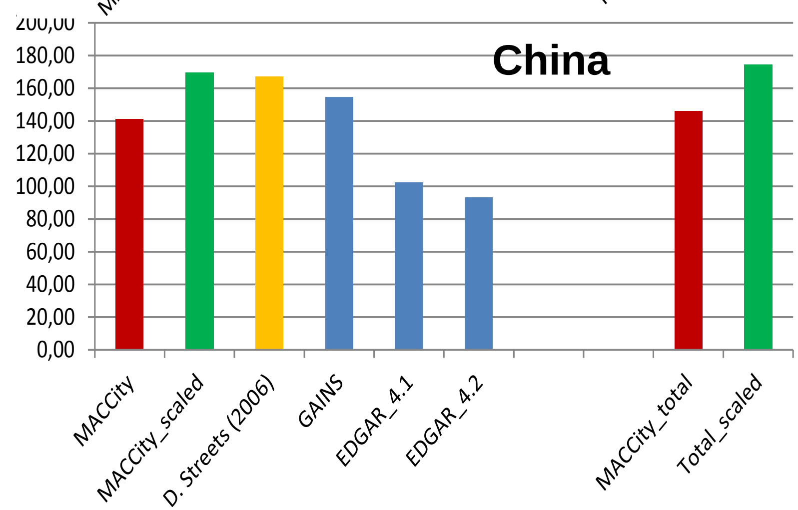
CO anthropogenic total emissions in Tg/y from 2005 global and regional inventories









→ MACCity totals are in the range of other emission estimates
→ uncertainty among inventories is still high

Conclusions

- Global anthropogenic CO emissions are likely to be underestimated by MACCity
- This holds true also for other bottom-up emission inventories and also in combination with other CTMs (see e.g. *Stevenson et al., JGR, 2006*)
- Increasing CO traffic emissions helps reducing the Northern Hemisphere wintertime bias
- A scaling factor of 2.5 is a good estimate to optimize European emissions, but seems to be too high for North America and Asia.
- East Asian emissions are well represented by MACCity.
- The influence of the CO scaling on other tracers is low.
- Southern Hemisphere concentrations are more influenced by fire and biogenic emissions and chemistry, all simulations overestimate CO there.

Suspects:

- missing vehicle emissions during cold start conditions
- inappropriate representation of the annual cycle of emissions
- too optimistic emission reduction in RCP8.5 scenario
- missing anthropogenic VOC emissions