Current status of MEGAPOLI:
Megacities: Emissions, urban, regional and Global Atmospheric POLlution and climate effects, and Integrated tools for assessment and mitigation

(EC FP7 Project)

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MEGAPOLI/CityZen/MILAGRO Splinter Meeting
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Megacities: Emissions, Impact on Air Quality and Climate, and Improved Tools for Mitigation Assessments (MEGAPOLI)

EC 7FP project for: ENV.2007.1.1.2.1. Megacities and regional hot-spots air quality and climate

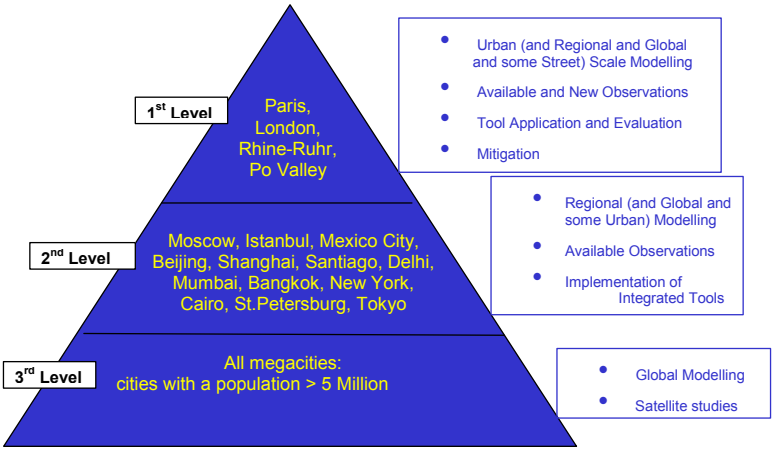
Project duration: 2008 – 2011; Budget: 5,1 mln. Euro
27 European research organisations from 11 countries are involved
Coordinator: A. Baklanov (DMI)
Vice-coordinators: M. Lawrence (MPIC) and S. Pandis (FORTH)

(Project web-site: http://megapoli.info)

The main aim of the project is

(i) to assess impacts of growing megacities and large air-pollution "hot-spots" on air pollution and feedbacks between air quality, climate and climate change on different scales, and

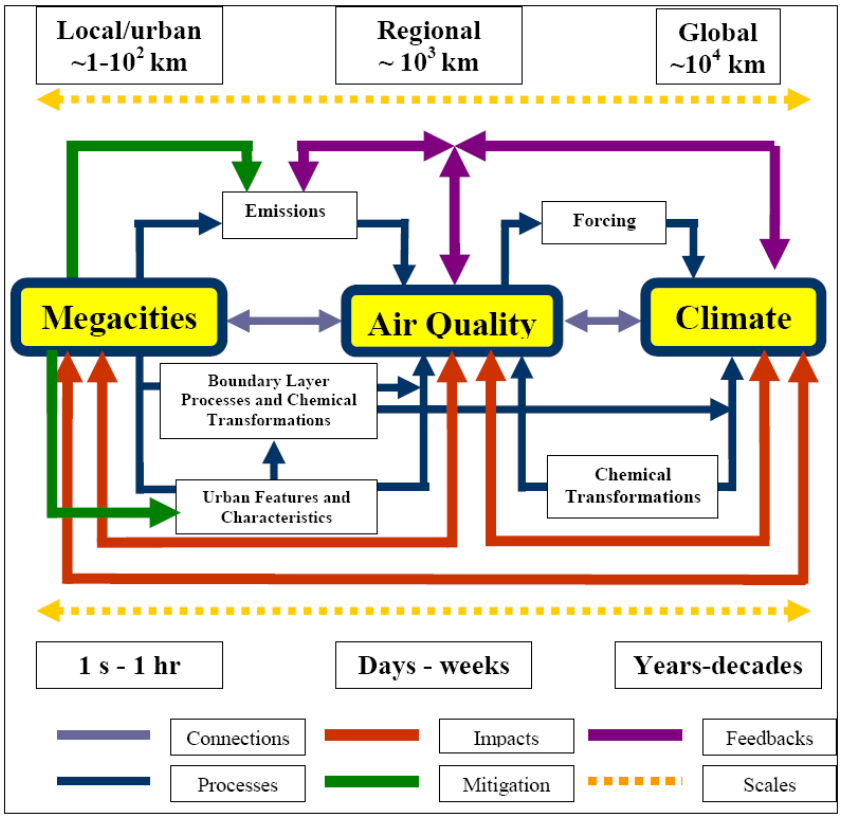
(ii) to develop improved integrated tools for prediction of air pollution in cities.



Connections between Megacities, Air Quality and Climate

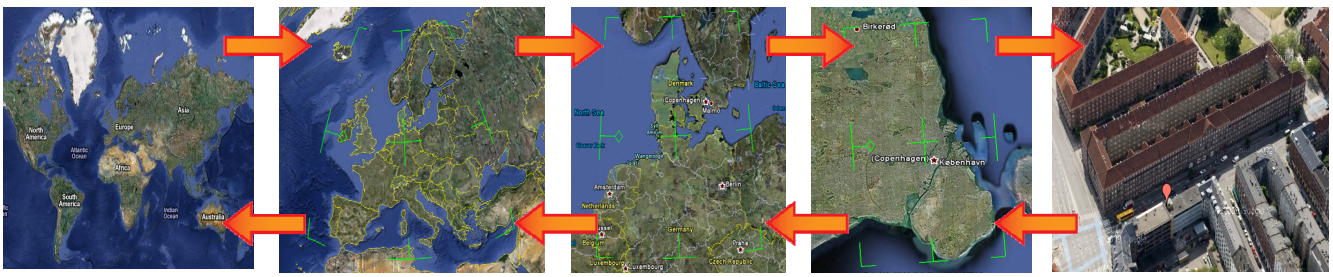
- Science - nonlinear interactions and feedbacks between urban land cover, emissions, chemistry, meteorology and climate
- Multiple spatial and temporal scales
- Complex mixture of pollutants from large sources
- Scales from urban to global
- Interacting effects of urban features and emissions
- FUMAPEX Integrated UAQIFS: in 6 EU cities

see: Nature, 455, 142-143 (2008)



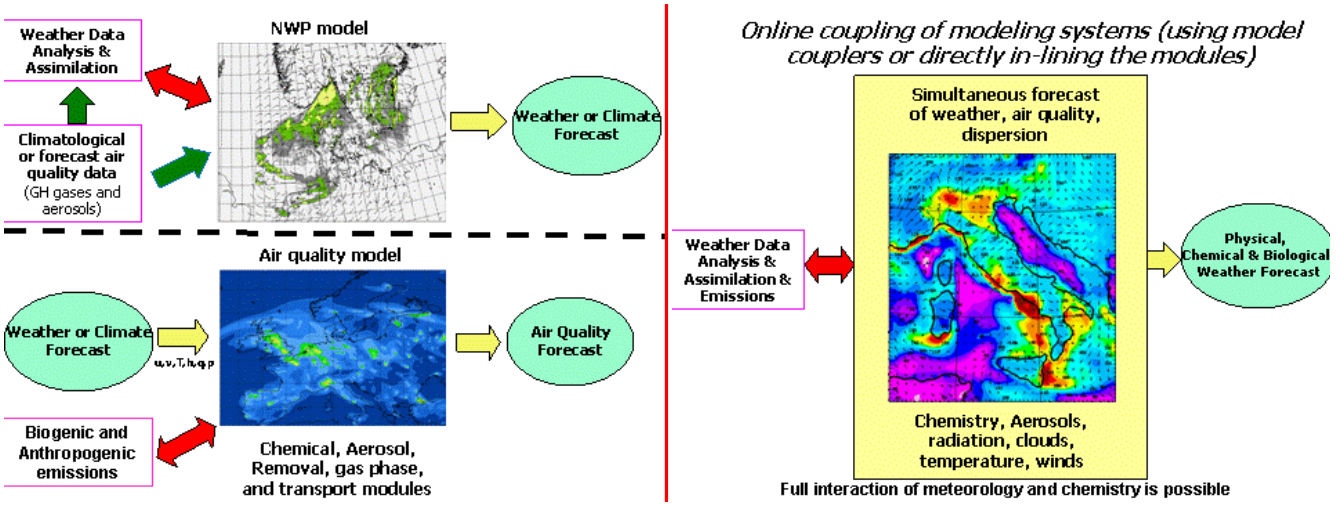
Multi-scale modelling Chain / Framework: from street to global

- Land-use characteristics and scenarios
- Anthropogenic heat fluxes
- Emission inventories and scenarios
- Down- and up-scaling



Two-way Nesting, Zooming, Nudging, Parameterizations, Urban increment methodology (AUTH)

Schematic diagram of the offline and online coupled modelling approaches

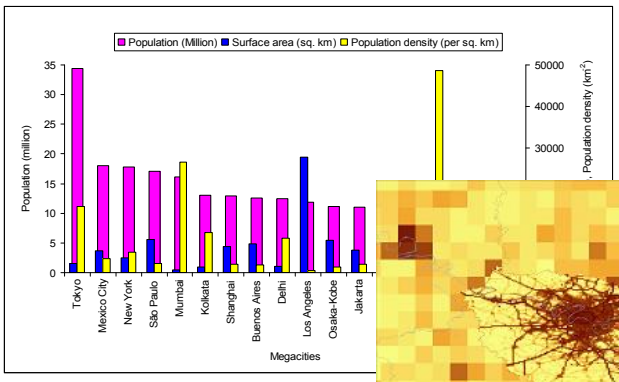


Online coupling can be archived through the use of various available coupling tools or through directly inlining the chemical and aerosol modules into the NWP models.

Level 1 – One way (Global -> regional -> urban), Models: All
Level 2 – Two way (Global <-> regional <-> urban), Models: ECHAM5/MESSy, MATCH-MPIC, UM-WRF-CMAQ, SILAM, M-SYS, FARM .
Order A – off-line, meteorology / emissions -> chemistry, Models: All
Order B – partly online, meteorology -> chemistry & emissions, Models: UKCA, DMAT, M-SYS, UM-WRF-Chem, SILAM
Order C – fully online, meteorology <-> chemistry & emissions, Models: UKCA, WRF-Chem, Enviro-HIRLAM, ECHAM5/MESSv

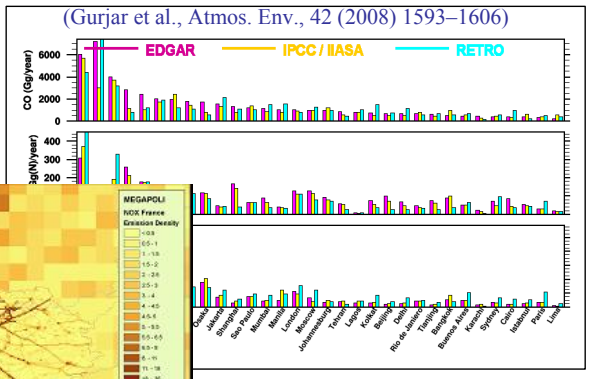
WP1: Megacity Characteristics, Pollution & Emission

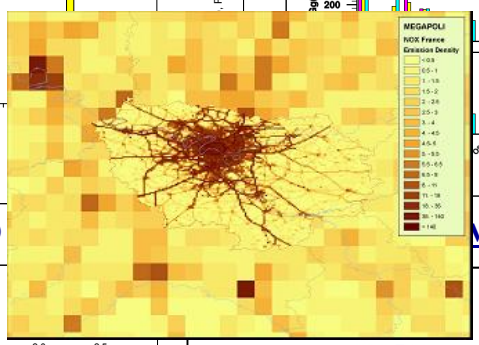
Lead by TNO Team: H. Denier van der Gone et al.



(Butler et al., Atmos. Env., 42 (2008)

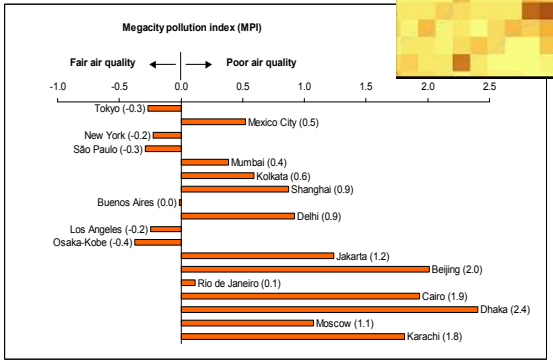
(Gurjar et al., Atmos. Env., 42 (2008) 1593–1606)

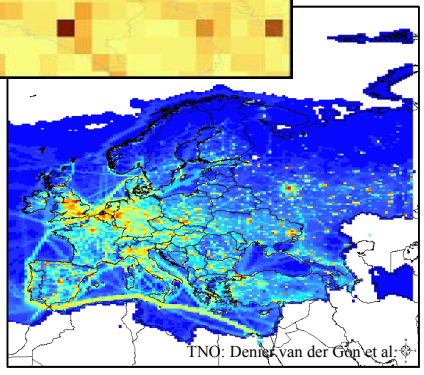




MEGAPOLI:

- **Complete Pan-European inventory at ~ 6x6 km for 200**
- **Nesting local inventories for 5 megacities at the highest resolution:**
  - **London:** Detailed inventory available at 1x1 km
  - **Paris, Po Valley, Ruhr Region, Istanbul**
- **Improved Global emission inventory for 2005**
- **Future emission and mitigation scenario**

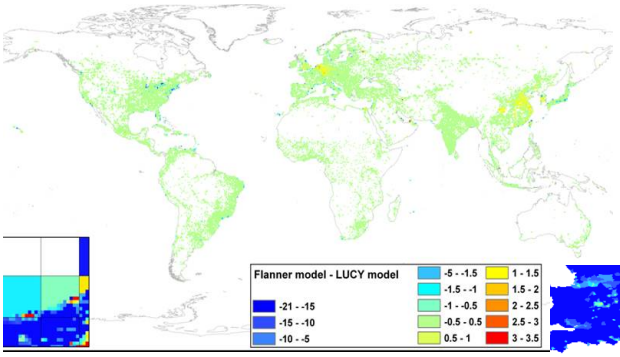




TNO: Denier van der Gon et al.

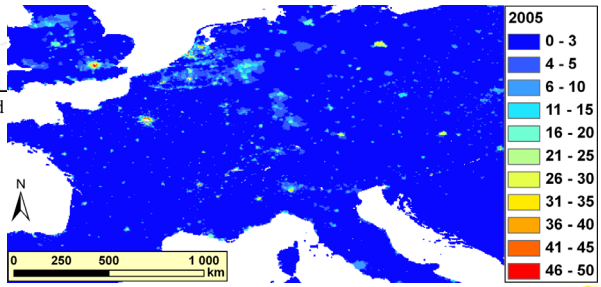
Global to City Scale Urban Anthropogenic Heat Flux

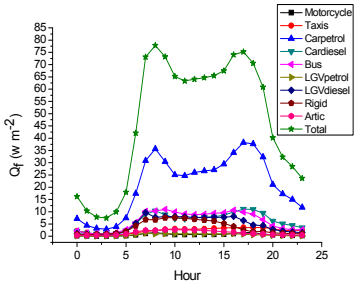
MEGAPOLI rep. D1.4: *L Allen* et al., KCL, 2010



Difference in annual average QF (W m-2) between the model presented by Flanner (2009) and LUCY (spatial resolution = 0.5°) for global urban areas.

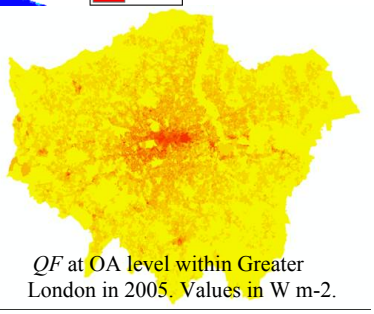
An anthropogenic heat flux (AHF) model (0.25 x 0.25 arc-minute resolution) was developed and used to compute the AHF inventories for Europe and London.





Average daily profiles of QF (w m-2) by vehicle type in London

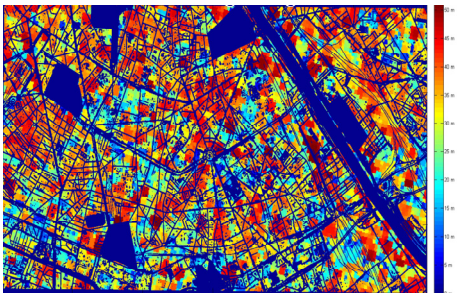
- Multi-scale inventories/models for AHF are available for megacity, regional and global scale modelling
- Results are used in Enviro-HIRLAM for urban (Paris, etc.) and regional scale studies



QF at OA level within Greater London in 2005. Values in W m-2.

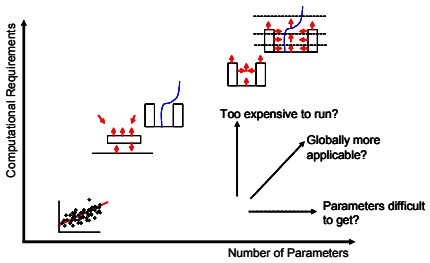
WP2: Megacity Features

(Lead by S. Grimmond, KCL and I. Esau, NERSC)

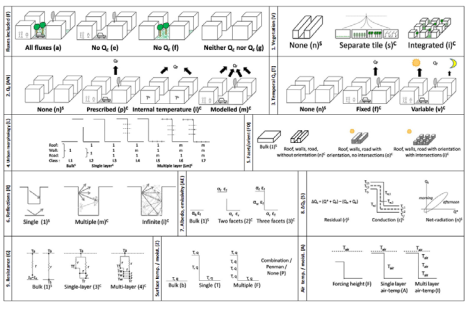


Paris Morphology database (use satellite observations and digital maps) *Sievinen et al., D2.1, 2009*

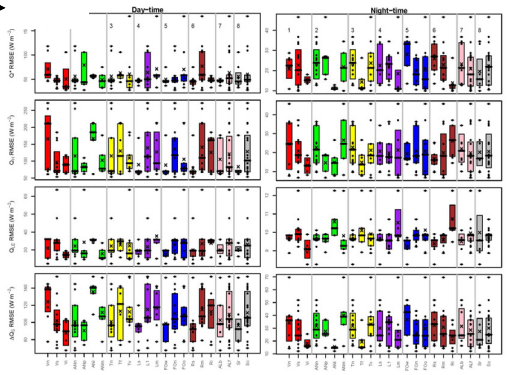
A morphology database for Paris has been developed, along with a hierarchy of urban canopy and energy budget models/ parameterisations for different scale models, which are being used to evaluate the surface flux balance modelling and urban features needed for climate and air quality models.



Hierarchy of urban canopy models/parameterisations for different scale models
Mahura & Baklanov, D2.2, 2010; Esau, D2.4.1, 2010

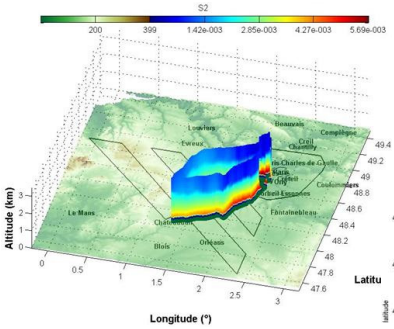


Evaluation of surface flux balance modelling and urban features needed for climate and AQ models
Grimmond et al., D2.3, 2010

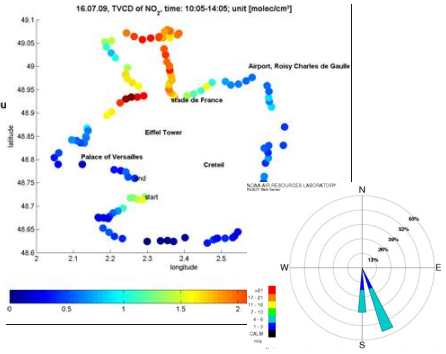


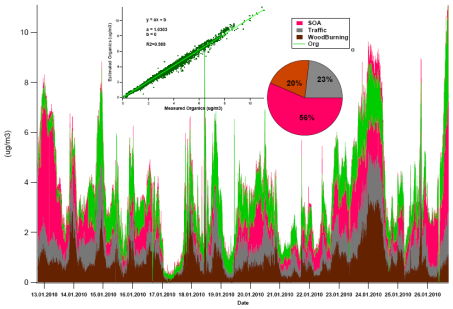
WP3: Paris Measurement Campaigns

Lead by M. Beekmann, CNRS & U. Baltensperger, PSI



- Aim: Provide new experimental data to better quantify sources of primary and secondary carbonaceous aerosol in a megacity and its plume
- Summer – 1-31 Jul 2009, Winter – 15Jan-15Feb 2010
- 30 research institutions from France and other European conutries, both MEGAPOLI Teams and Collaborators





(Courtesy of Monica Crippa et al.; PSI Team)

First achievements:

• The pollution plume was still well defined at more than 100 km downwind from the agglomeration, which gives a clear framework for later studying SOA build-up in the plume.

• Significant new particle formation events were frequently observed during the campaigns.

• During the winter campaign, large PM levels were observed both due to a strong local wood burning source and due to continental advection.

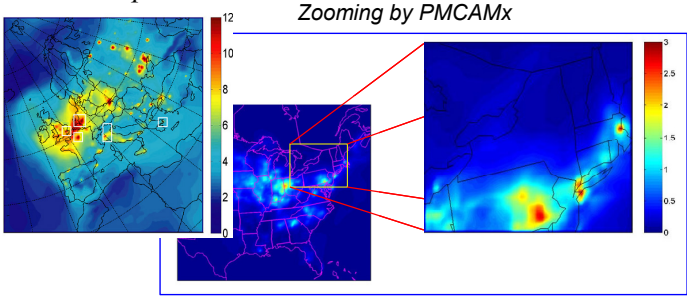
• Database for model studies and validation is available

WP4: Megacity Air Quality and Climate

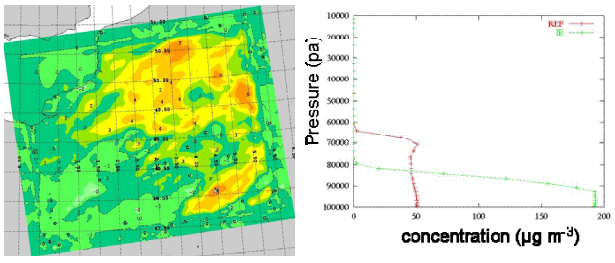
Lead by AUTH, N. Moussiopoulos

New physical and chemical parameterisations and zooming approaches have been implemented and are being tested for several megacities (e.g. Paris, Mexico City, and Po Valley) => relative importance of the various parameterisations.

Zooming by PMCAMx



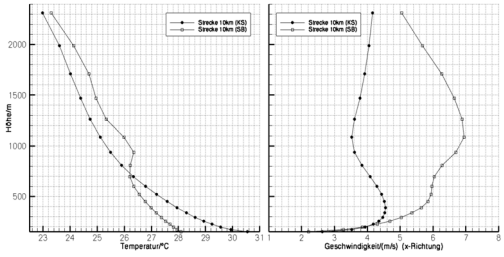
Indirect urban aerosol effects – Enviro-HIRLAM



Urban aerosols were found to significantly affect several meteorological variables (temperature, inversion layers, radiation budget, cloud processes, precipitation, fog, etc.) in and far from the megacities due to the direct and indirect effects.

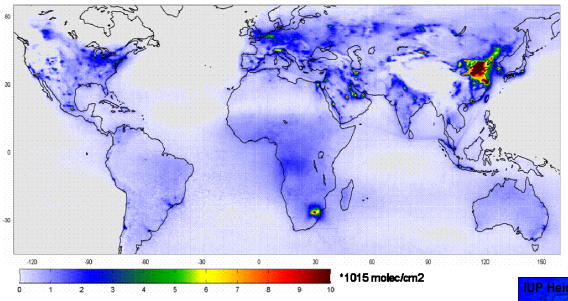
Coupled ACT-NWP models with two-way feedbacks were used to study effects of megacity emissions on meteorological processes and to classify meteorological patterns favouring development of urban air pollution episodes in European megacities.

Direct urban aerosol effects – MEMO/MARS



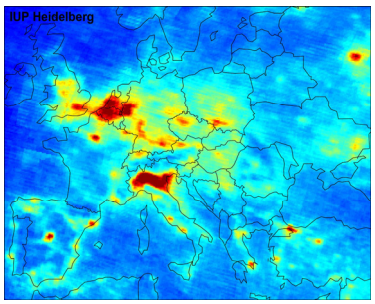
WP5: Regional & Global Atmospheric Composition: Satellite Methods

(Contribution MPIC: Thomas Wagner et al., satellite group).



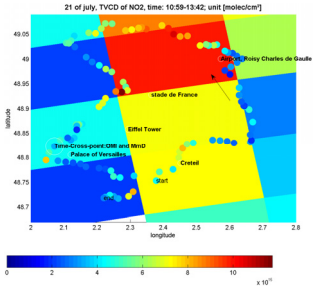
Mean tropospheric NO2 column density
(Sep 2007-Aug 2008) derived from GOME-2 spectra

Substantial progress was made in developing and evaluating the satellite-based methods for the measurement of tropospheric gases and aerosols, especially NO2, in and around megacities. For construction of a regional model ensemble the harmonization of European domain parameters, input data and other modelling details was realized.



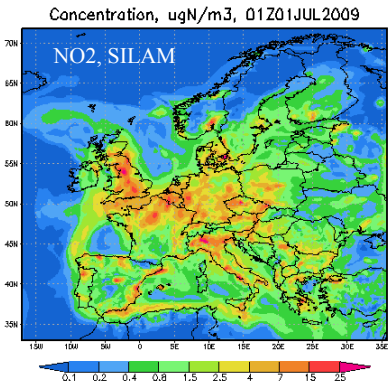
Mean NO2 vertical column density
for Jan 2003 - Jun 2004
(SCIAMACHY on ESA's Envisat)

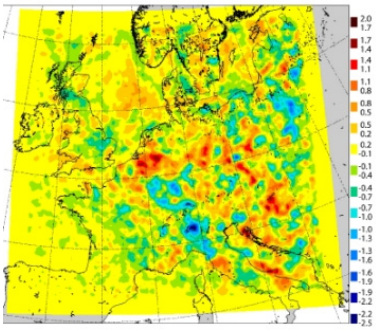
Validation of Satellite Observations over Paris Using Mobile MAXDOAS Observations



WP5: Regional and Global Atmospheric Composition: Modelling

Lead by J. Kukkonen, FMI and A. Stohl, NILU

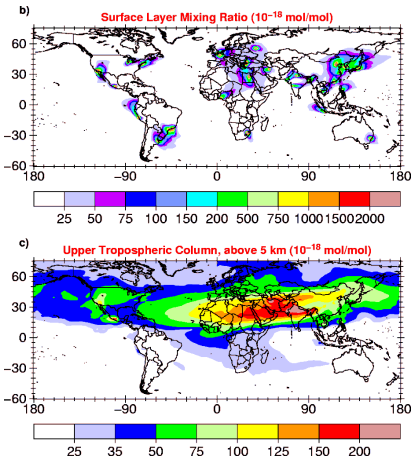




Aerosol effects by Enviro_HIRLAM: Difference (calculated as BASELINE minus 12IE) in cloud top temperature (°C)

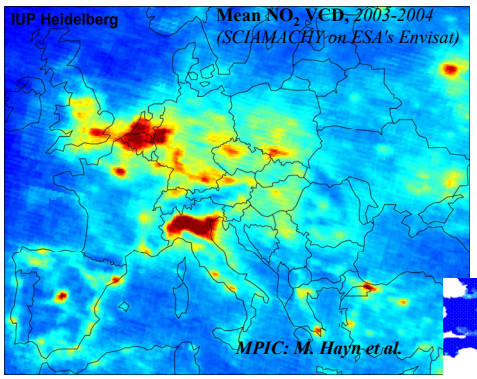
- **Global scale megacity effects simulations**
- **Ensemble regional scale modelling**
- **BC from global CWFs: MATCH-MPIC and MACC**
- **European domain:** *(res – up to10 km)*
- ***Using European 6x6km & megacity 1x1km TNO Emissions***
- ***Online/Off-line Models used in WP5:***
  - ***MEMO/MARS***
  - ***Enviro-HIRLAM***
  - ***PMCAMx***
  - ***WRF-CMAQ***
  - ***WRF-Chem***
  - ***OSCAR***
  - ***SILAM***
  - **...**

D5.2: Provision of Global and Regional Concentrations Fields from Initial Baseline Runs



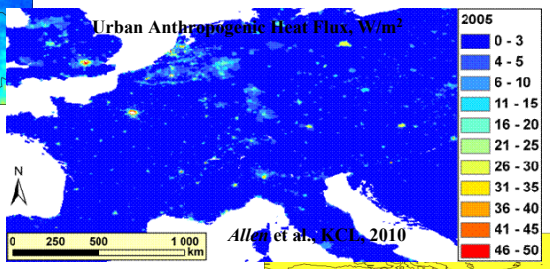
Megacity Regional Pollution Potentials: Aerosol Tracers (MPIC team: Daniel Kunkel et al.)

Megacities: environment and climate change



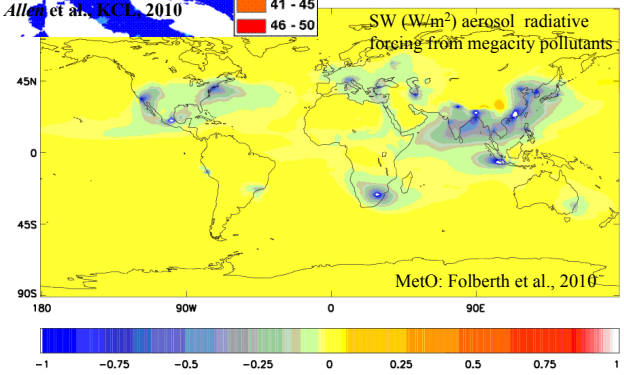
Are the cities to blame for climate change/global warming ?

- On city- and meso-scales definitely 'Yes' (both via UHI and emissions),
- On regional and continental scale: UP extends up to thousands km, so it could effect CC,
- On global scale: probably 'No' due to UHI, but 'Yes' due to GHG emissions (anthropogenic CO_2, CFC, CH_4, N_2O and tropospheric ozone)
- Source of aerosols which have both direct and indirect cloud radiative effects (cooling or warming)
- Too early to make conclusions: new multi-scale studies are necessary!

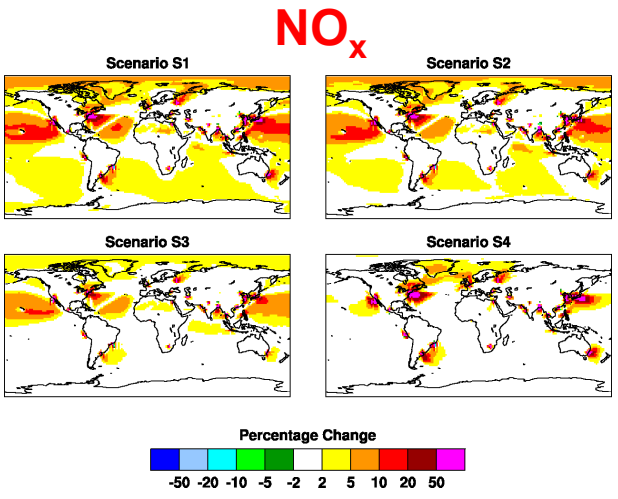


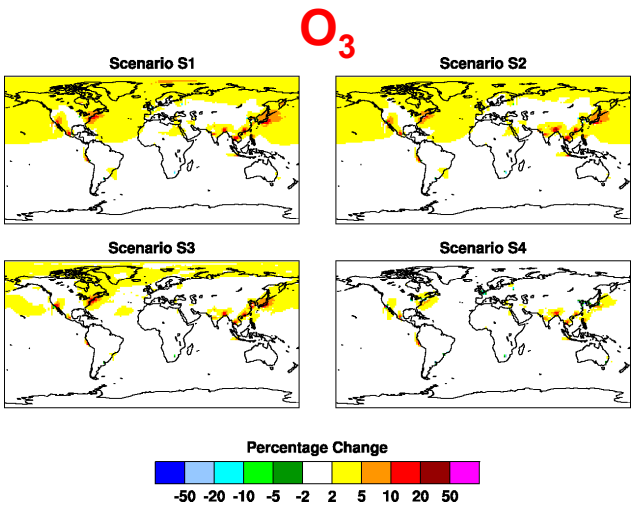
Measures to reduce urban drivers of climate change, e.g.:

- Reducing GHG and aerosol emissions
- Reducing traffic congestion
- Switch to fuels with less GHG side effects
- Conserving energy and water
- Greater use of passive heating and cooling technology
- More compact city design and greater use of mass transportation
- Intelligent use of trees to shelter or shade
- Increased use of light colored surfaces in hot cities.



Global Atmospheric Chemistry Effects



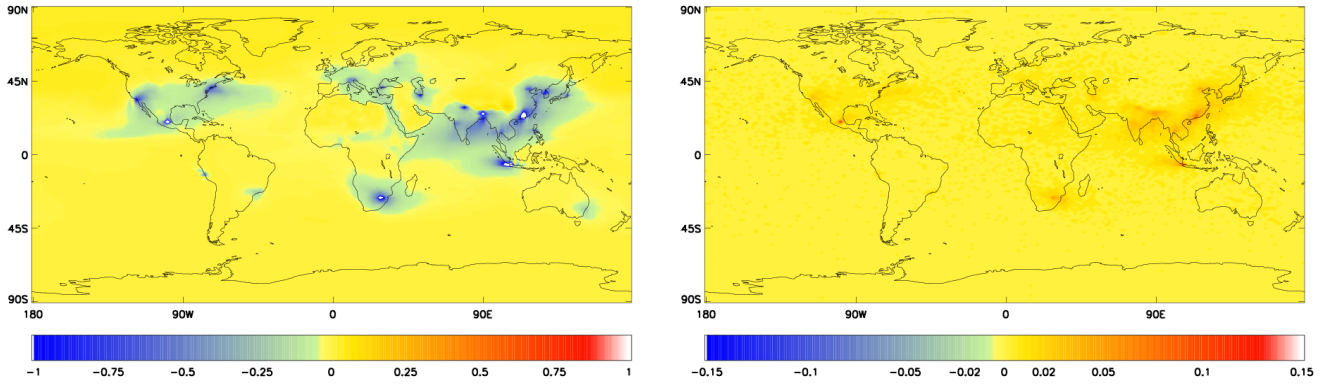


- Simulations with MATCH-MPIC (T62L28)
- Emissions from Megacities (1°x1° cells) set to zero
- Four Scenarios (same as in Dentener et al., ACP, 2005):
  - S1: EDGAR+, Year 2000
  - S2: CLE (current legislation), Year 2030
  - S3: MFR (maximum feasible reduction), Year 2030
  - S4: IPCC SRES A2p (pessimistic), Year 2030

- Net effects on O_3, NO_x and CO ~ 10% (comparable to emissions fraction), more locally concentrated in future scenarios, especially S4
- *Environ. Chem., 2010*

(Courtesy of T. Butler & M. Lawrence, MPIC team)

WP6: Effect of megacity emissions of short-lived species on global climate



(a) *(b)*

Global distribution of - (a) short-wave, SW all-sky and (b) long-wave, LW clear sky - top-of-atmosphere (TOA) radiative forcing due to aerosols from megacities /Forcing is denoted in W/m^2

First conclusions: The radiative forcing from short-lived species emitted from megacities on the global scale was examined. Generally, megacities contribute about 2% to 5% of the total global annual anthropogenic emission fluxes for various compounds. Megacity pollutants were found to contribute a radiative forcing of +6.3±0.4 mW/m2 from an increase in the ozone burden due to pollutant photochemical oxidation. The change in methane lifetime and consequently the change in the CH4 abundance in the atmosphere contributes a forcing of -1.0±0.5mW/m2. The aerosol forcing from megacity pollutants amounts to -15.3±0.6mW/m2 in the short-wave spectrum and +2.0±0.1 mW/m2 in the long-wave spectrum. The combined effect of all of these individual terms is a slightly negative forcing, that is a cooling, of -8.0±1.6 mW/m2 of the climate at present-day conditions.

(Courtesy of UK MetOffice: G. Folberth)

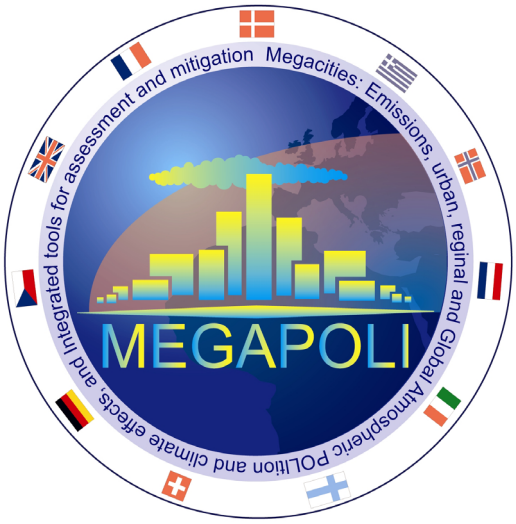
Conclusions

1. Urban effects and effects of urban emissions / air pollution are non-linearly interacting with each other, and to model correctly the effects of megacities online coupled/integrated models with two-way interaction of meteorological and chemical/aerosol processes are considered:
   - Online integrated NWP-ACTM system Enviro-HIRLAM is suggested for such studies.
   - Hierarchy of 3 different levels of models urbanization are suggested and tested.
   - Aerosol feedback mechanisms are implemented and tested.
2. Depending on temporal and spatial scales, the key-processes and types of their interaction are different:
   - For micro-scale (up to 1 km) the obstacle-resolved approach is recommended, and the only pollutant gas density feedbacks are of importance.
   - For the city scale (1-100 km) it includes statistical description of urban characteristics, and semi-direct and second indirect aerosol feedbacks are dominated.
   - For regional scale (more than 100 km) all the above mentioned gas and aerosol feedbacks represent the highest interest, and the urban effects could be simply parameterized.
3. Urban vs. aerosol feedbacks: the same order of magnitude effects on MH, strong sensitivity of chemistry, strong non-linearity, fist indirect effect is much smaller than second one, indirect effects induce large changes in NO2, urban effects – on T2m.
4. Is climate change due to urban/megacity effect as well?
   - On city- and meso-scales definitely ‘Yes’ (both via UHI and emissions),
   - On regional and continental scale: UP extends up to thousands km, so it could effect CC,
   - On global scale: probably ‘No’ due to UHI, but ‘Yes’ due to emissions (GHGs and aerosols),
   - **Too early to make conclusions: new multi-scale studies are necessary !!!**

MEGAPOLI Dissemination

- Web-site: http://megapoli.info
- MEGAPOLI Newsletter (10)
- MEGAPOLI Reports
- Several Books published by Springer
- 3 Journal Special Issues
- A number of scientific papers

Thank You !



MEGAPOLI web-site: http://megapoli.info
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