

European framework for online integrated air quality and meteorology modelling – *EuMetChem* COST Action ES1004 (03.2011 – 02.2015)

P. Suppan (1), A. Baklanov (2), S. Joffre (3), H. Schlünzen (4),
M. Gauss (5), Ch. Seigneur (6), D. Brunner (7)

(1) Karlsruhe Institute of Technology (KIT), Institute for Meteorology and Climate Research

(2) Danish Meteorological Institute, Meteorological Research, Copenhagen, Denmark

(3) Finnish Meteorological Institute

(4) Meteorologisches Institut, KlimaCampus, Universität Hamburg

(5) Norwegian Meteorological Institute

(6) CEREAs, École des Ponts ParisTech

(7) EMPA, Swiss Federal Laboratories for Materials Science and Technology

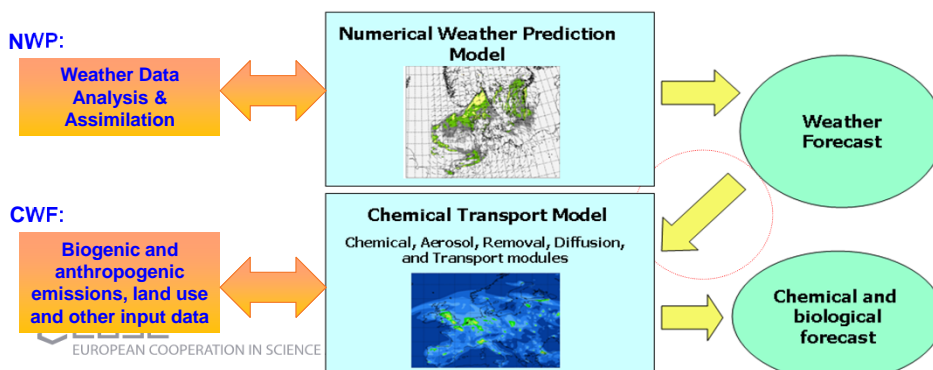
and the COST ES1004 team:

Aksoyoglu S., Baldasano J.M., Douros J., Flemming J., Forkel R., Galmarini S., Grell G., Hirtl M., Kaas E.,
Kaasik M., Kallos G., Korsholm U., Lohmann U., Manders A., Maurizi A., Moussiopoulos N., Orba O., Savage
N., Sørensen B., Vignati E., Vogel B., Zakey A., Zhang Y.

Motivation:

Physical and Chemical Weather → Off-line coupling

- Meteorological (Numerical Weather Prediction – NWP) and Air Quality Modeling – two independent problems and research communities
- Chemical weather forecasting (CWF) - is a new, quickly developing and growing area of atmospheric modeling
- Simplified concept of CWF includes only operational air quality forecast for the main pollutants by using numerical atmospheric chemical transport (ACT) models driven by NWP



Motivation: Aerosol Effects on Atmospheric Processes

Direct effect → decrease solar/ thermal-IR radiation and visibility;
warming: GHGs, BC, OC, Fe, Al, polycyclic/nitrated aromatic compounds
cooling: water, sulfate, nitrate, most OC
(scattering, absorption, refraction, etc.)

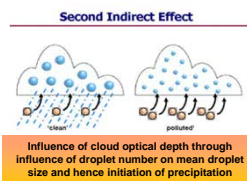
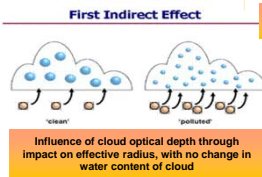
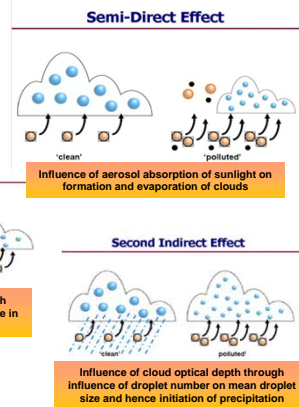
Semi-direct effects → affect planetary boundary layer (PBL),
meteorology and photochemistry;

First indirect effect → affect cloud,
drop size, number, reflectivity, and
optical depth via CCN;

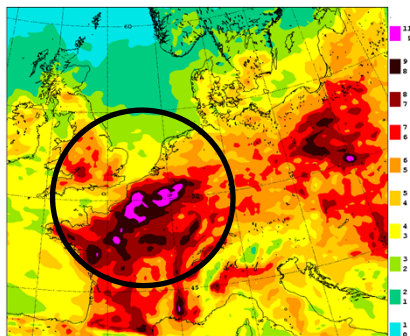
Second indirect effect → affect cloud,
liquid water content, lifetime, and
precipitation;

Chain of all aerosol effects → strong nonlinear interaction

- ➔ High-resolution on-line models with a detailed description of the PBL structure are necessary to simulate such effects
- ➔ On-line integrated models are necessary to simulate (exact as possible) effects which considers secondary feedbacks

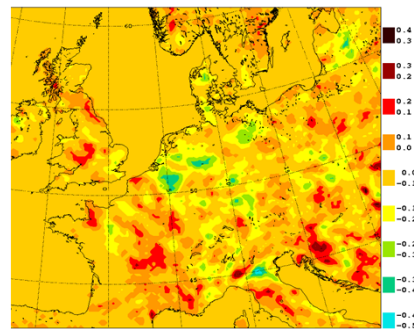


MEGAPOLI study: Comparing simulations with and without aerosol indirect effects for June 2009



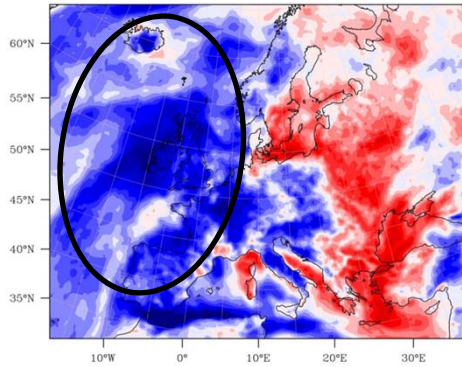
Monthly averaged CCN number concentration (x10⁷ m⁻³) at 850 hPa

Monthly averaged difference in Ts (°C) (RUN - BASELINE)

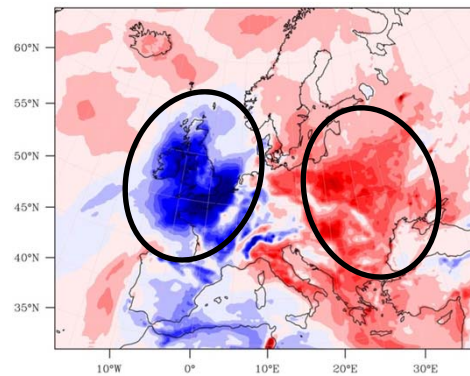


WRF/Chem: Aerosol Effects on Meteorology and Chemical Composition

RFBC- BASE



RFBC- BASE



Differences in ozone (left) and PM10 (right) concentrations in July 2006 between two WRF/CHEM simulations. Simulation BASE does not consider interactions between aerosols and meteorology. Simulation RFBC considers both direct and indirect effects (RFBC).

Motivation: Needed European actions

No European community approach on modelling → large number of model development programmes

Besides Air Quality and Meteorological (Numerical Weather Prediction) communities worked independently

- **Strategic framework** is needed to provide a common goal and direction to European research → multiple models.
- **On-line coupling** between meteorology and chemistry will be a strong research area → 5-10 years.
- **Require enhanced dialogue** and knowledge from several scientific areas → mathematics, physics, chemistry, computer programming, etc.
- Best approach **to integrate, streamline and harmonize** the interaction between atmospheric chemistry modellers, weather modellers and end users → COST Action

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Scientific context and objectives

Action aims on a new generation of online models, using integrated Atmospheric Chemical Transport (*ACT*) and Meteorology (*Numerical Weather Prediction (NWP) and Climate*) modelling with two-way interactions

Overall objective

- multi-disciplinary forum for online integrated air quality/meteorology modeling
- elaboration of the European strategy for a new generation integrated ACT/NWP-CLIM modeling capability/framework

Main application areas of the integrated modeling

- improved NWP and CWF with short-term feedbacks of aerosols and chemistry on meteorological variables, and
- two-way interactions between atmospheric pollution/composition and climate variability/change.



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Key Scientific Questions

- What are the **effects of climate/meteorology on** the abundance and properties (chemical, microphysical, and radiative) of **aerosols on urban/regional** scales?
- What are the **effects of aerosols on urban/regional climate/meteorology** and their relative importance (e.g., anthropogenic vs. natural)?
- How important are the **two-way/chain feedbacks** among meteorology, climate, and air quality in the estimated effects?
- What are the **key uncertainties** associated with model predictions of mentioned effects?
- How to realize **chemical data assimilation** in integrated models for improving NWP and CWF?
- How can simulated **feedbacks** be **verified** with available observations/datasets?



COST Action ES1004 Benefits for Society

- Contribute to **better forecasting of severe weather events** and their consequences (forest fires, dust storms, flooding, volcano eruption, etc.)
- Contribute to **reduction of adverse health effects**
- Contribute to **better predict climate change**
- **Cost-effective measures** to manage transport and energy production
- Improved **management and protection** of terrestrial, coastal, and marine ecosystems
- Enhanced **quality of life** especially in urban areas,
- **Decreased overlap and redundancy** of national, regional or local activities and arrangements



Cost Action ES1004 Working Groups

- **WG1:** Strategy and framework for online integrated modeling
to develop model frameworks and effective code implementation and management strategies for online-coupled meteorology and chemistry models and to identify the model development priorities and milestones
- **WG2:** Interactions, parameterizations and feedback mechanisms
to establish the state of the science in meteorology-chemistry interactions and to provide a framework for the development of efficient techniques for the coupling of NWP and CTM via process-oriented parameterizations and feedback algorithms
- **WG3:** Chemical data assimilation in integrated models
to establish the current state-of-the-science in this area and to provide a framework for the development of efficient techniques for chemical data assimilation in integrated models
- **WG4:** Evaluation, validation and applications
to develop tools and methodologies that can be applied to validate and evaluate integrated meteorology-chemistry models, as well as recommendations on applications of online integrated modeling system

Cost Action ES1004 First Results

- **Review paper (draft version; anticipated submission next weeks)**
Online Coupled Regional Meteorology-Chemistry Models in Europe
- **Survey on existing online coupled models (~ 19 models)**

Model/Country/References	Gas phase chemistry and aerosol component	Feedback of pollutants to meteorology	Applications	Scale
BOLCHEM, Italy http://bolchem.isac.cnr.it/	SAPRC90 gas phase chemistry, AER03 aerosol module	Direct aerosol effect on radiation	CWF; climate; Episodes	Continental to regional
COSMO-ART, Germany Vogel et al., 2009; Stanelle et al., 2009; Bangert et al., 2011a, Bangert et al., 2011b	Extended RADM gas phase chemistry, modal aerosol, soot, pollen, mineral dust, volcanic ash?	Direct aerosol effect on radiation, indirect effects	Episodes, Climate mode	Continental to regional

- **Participation on “Air Quality Model Evaluation International Initiative (AQMEII)”**



Advancing approaches to the evaluation of regional scale photochemical air quality modeling systems (Phase II)

→ *Ensemble modeling exercise for European and North-American modeling communities*



Conclusion

- **On-line integration** of NWP and ACTMs enables:
 - utilisation of all meteorological 3D fields in ACTMs at each time step;
 - consideration of feedbacks of air pollution on meteo-processes & climate forcing.
- **New generation** of integrated models
- Main **advantages** of on-line coupling:
 - only one grid for NWP and ACTM, no interpolation in space and time;
 - physical parameterizations are the same, no inconsistencies;
 - all 3D meteorological variables are available at each time step;
 - no restriction in variability of meteorological fields;
 - possibility to consider two-way feedback mechanisms;
- **Feedback mechanisms** - important in CWF modeling and quantifying direct and indirect effects of aerosols (and probably GHGs); full chain is needed, strong non-linearity

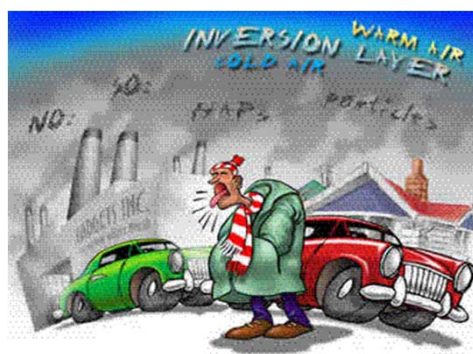
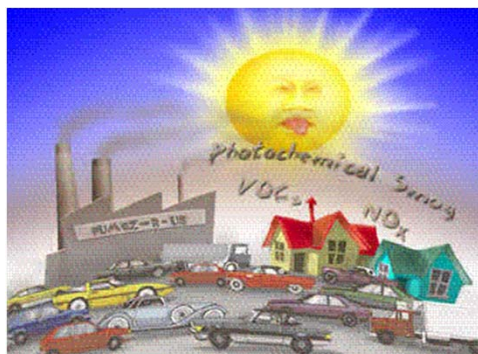


Thank You !

COST ES1004 EuMetChem: <http://eumetchem.info>

Alexander Baklanov (alb@dmi.dk)

Peter Suppan (peter.suppan@kit.edu)



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