European framework for online integrated air quality and meteorology modelling: Methodology and plans of COST Action ES1004

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New EU COST Action ES1004 EuMetChem: 'European framework for online integrated air quality and meteorology modelling' (2011-2015)

- The COST Action will focus on a new generation online integrated ACT and Meteorology modelling with two-way interactions between atmospheric chemistry (including gas-phase and aerosols), clouds, radiation, boundary layer and other meteorological and climate processes.
- At least two application areas of the integrated modelling are planned to be considered:

  (i) improved NWP and CWF with short-term feedbacks of aerosols and chemistry on meteorological variables, and

  (ii) two-way interactions between atmospheric pollution/ composition and climate variability/change.
- 40 teams from 17 COST countries, ECMWF, WMO, US EPA, NOAA, etc.
- Working Groups:

WG1: Strategy and framework for online integrated modelling,

WG2: Interactions, parameterisations and feedback mechanisms,

WG3: Chemical data assimilation in integrated models,

WG4: Evaluation, validation and applications.

- New EGU-2011 Section AS4.25: 'Integrated physical and chemical weather modelling with two-way interactions', Vienna, Austria, 3-8 April 2011, see: http://meetingorganizer.copernicus.org/EGU2011/session/7498

Motivation:
Needed actions and relation to COST

- Historically Europe has not adopted a community approach to modelling and this has led to a large number of model development programmes, usually working independently.
- Besides AQ and NWP communities worked independently.

Needed: A strategic framework will help to provide a common goal and direction to European research in this field while having multiple models.

- The on-line coupling between meteorology and chemistry and the further feedback effects will be a strong research area for the next 5-10 years.

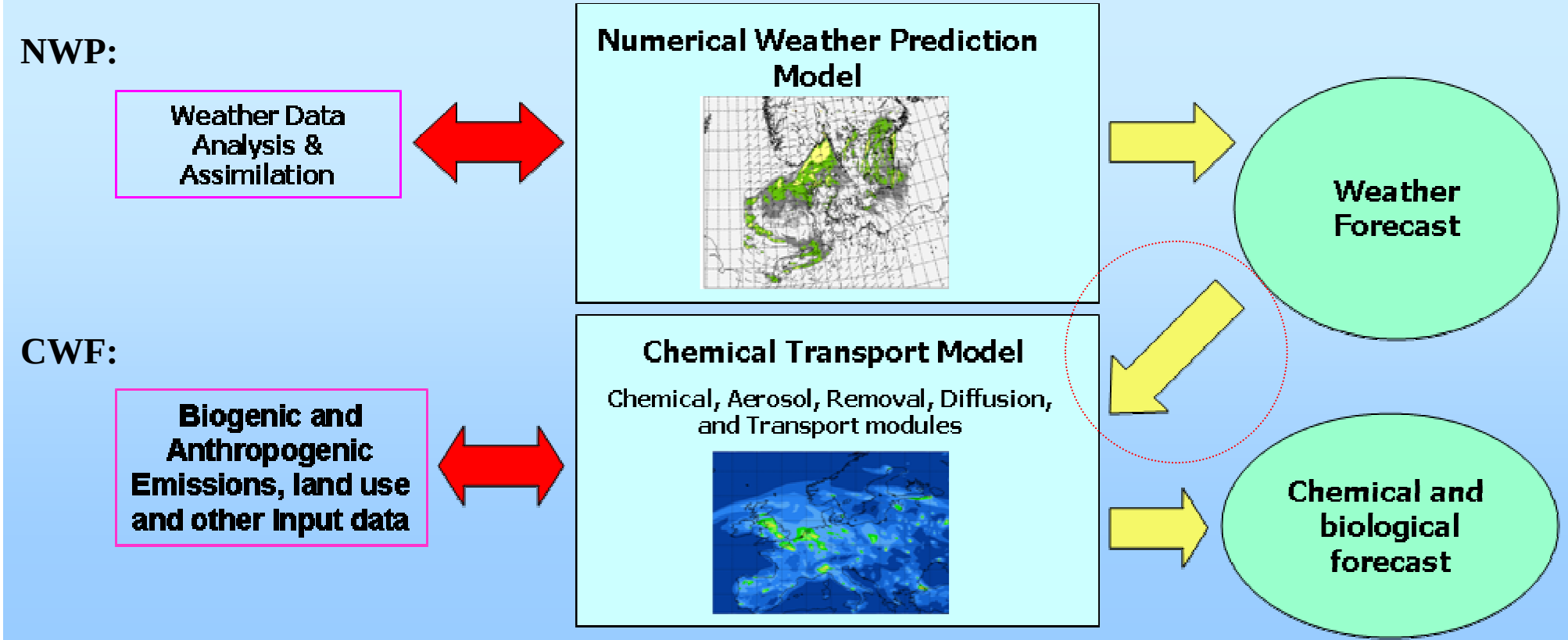
This will require enhanced dialogue and knowledge from several scientific and technological areas such numerics, physics, computer programming, chemistry, etc.

- The COST Action seems to be the best approach to integrate, streamline and harmonize the interaction between atmospheric chemistry modellers, weather modellers and end users. It will lead to strongly integrated and unified tools for a wide community of scientists and users.

Motivation:
Physical and Chemical Weather: Off-line coupling

- Numerical Weather Prediction (Meteorological) and Air Quality Modelling – two independent problems and research communities.
- Chemical weather forecasting (CWF) - is a new, quickly developing and growing area of atmospheric modelling.

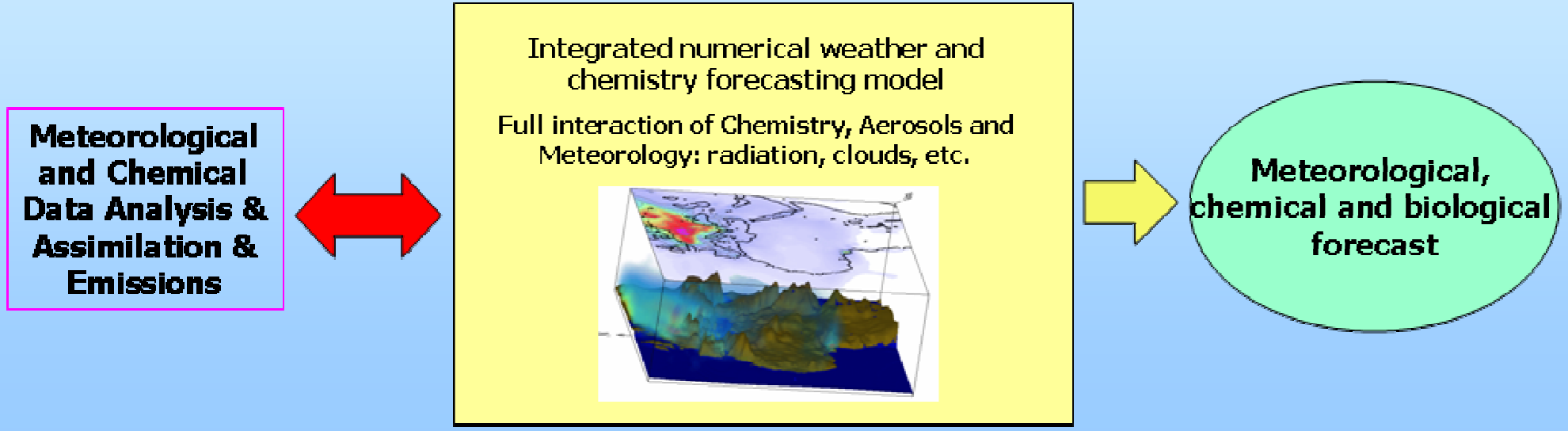
The most common simplified concept of CWF includes only operational air quality forecast for the main pollutants significant for health effects and uses numerical ACTMs with operational NWP data as a driver (no feedbacks).



Motivation:
Physical and Chemical Weather Forecast: New concept

- Many experimental studies and research simulations show that atmospheric processes (meteorological weather, incl. precipitation, thunderstorms, radiation, clouds, fog, visibility and PBL structure) depend on concentrations of chemical components (especially aerosols) in the atmosphere.
- Meteorological data assimilation (in particular assimilation of radiances) depends on the chemical composition.
- Studies also show that air quality forecasts loose accuracy when CTM's are run offline.

New generation of online integrated meteorology and chemistry modelling systems for predicting atmospheric composition, meteorology and climate change is really needed.



Advantages of On-line & Off-line modeling

On-line coupling

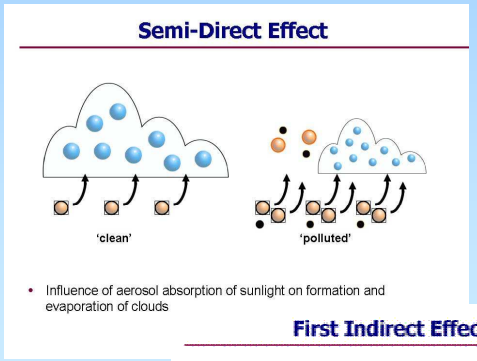
- Only one grid;
- No interpolation in space
- No time interpolation
- Possibility to consider aerosol forcing mechanisms
- All 3D met. variables are available No restriction in variability, no mass consistency concerns
- Possibility of feedbacks from meteorology to emission and chemical composition
- Does not need meteo- pre/post-processors
- Physical parameterizations are the same; No inconsistencies
- Harmonised advection schemes for all variables (meteo and chemical)
- Maybe more suitable for ensembles

Off-line

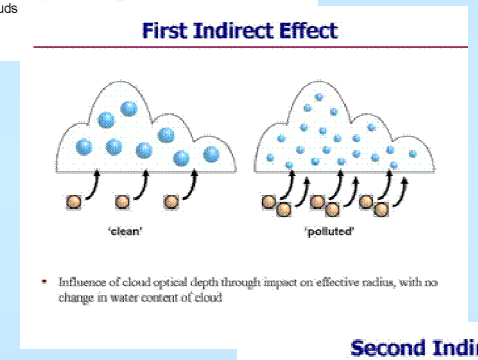
- Easier to use for the inverse modelling and adjoint problem;
- Independence of atmospheric pollution model runs (interpretation of results independent of meteorological model computations);
- More flexible grid construction and generation for ACT models,
- Suitable for emission scenarios analysis and air quality management.
- Possibility of independent parameterizations;
- Low computational cost (if NWP data are already available and no need to run meteorological model);
- Maybe more suitable for ensembles and operational activities;

Motivation: Aerosol Effects on Atmospheric Processes

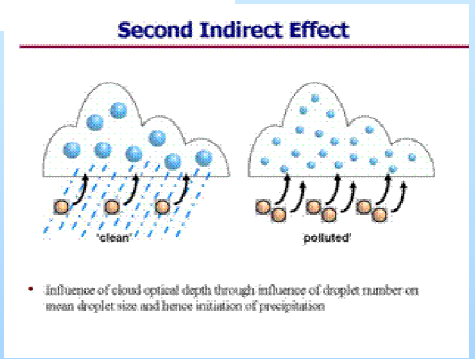
- **Direct effect → decrease solar/ thermal-IR radiation and visibility;**
  warming: GHGs, BC, OC, Fe, Al, polycyclic/nitrated aromatic compounds
  cooling: water, sulfate, nitrate, most OC
  (scattering, absorption, refraction, etc.)



- **Semi-direct effects → affect 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 (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 correctly the effects involved 2nd feedbacks**

Actions Aim and Objectives

Action aims on a new generation of online models, using integrated Atmospheric Chemical Transport (ACT) and Meteorology (Numerical Weather Prediction and Climate) modelling with two-way interactions between different atmospheric processes including chemistry (both gases and aerosol), clouds, radiation, boundary layer, emissions, meteorology and climate.

Overall objective is to set up a multi-disciplinary forum for online integrated air quality/meteorology modelling and elaboration of the European strategy for a new generation integrated ACT/NWP-CLIM modelling capability/framework.

Main topics are:

1. Online versus offline modelling: advantages and disadvantages,
2. Analysis of priorities, particularly focusing on interaction/feedback mechanisms,
3. Chemical data assimilation in integrated models,
4. European strategy/framework/centre for online integrated modelling,
5. Evaluation and validation framework of online ACT/NWP-CLIM models,
6. Collection of suitable datasets for model development and evaluation.

Key science 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 is the relative importance of aerosol direct and indirect effects as well as of gas-aerosol interactions in the estimates on different spatial and temporal scales?
- 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?

Online coupled or online access Atmospheric Chemistry-Meteorology models developed or applied in Europe (1)

Model/Country/References	Online coupled gas phase chemistry and aerosol	Feedback of pollutants to meteorology	Applications	Scale
BOLCHEM, Italy http://bolchem.isac.cnr.it/	SAPRC90 gas phase chemistry, AERO3 aerosol module	Direct aerosol effect on radiation	CWF; climate; Episodes	Continental to regional
COSMO-ART, Germany Vogel et al., 2009	Extended RADM gas phase chemistry, modal aerosol, soot, pollen, mineral dust	Direct aerosol effect on radiation	Episodes	Continental to regional
COSMO-LM-MUSCAT, Germany Wolke et al., 2004; Heinold et al., 2007	RACM gas phase chemistry, 2 modal aerosol models, mineral dust module	Direct aerosol effect on radiation for mineral dust	Episodes	Continental to regional
ECHAM5/6-HAMMOZ, Germany Pozzoli et al., 2008	MOZART gas phase chemistry, HAM aerosol scheme	Direct aerosol effect, indirect aerosol effect	Episodes, long term	Global
ENVIRO-HIRLAM, Denmark and HIRLAM countries Baklanov et al, 2008; Korsholm et al., 2008	NWP gas phase chemistry, modal and sectional aerosol modules, liquid phase chemistry	Direct and indirect aerosol effects	Episodes, chemical weather forecast	Hemispheric to regional and urban
IFS-MOZART (MACC/ECMWF) Flemming et al., 2009, Kinnison et al., 2007, http://www.gmes-atmosphere.eu	MOZART gas phase chemistry with updates to JPL-06, MACC aerosol scheme	Direct aerosol effect, indirect aerosol effect	Forecasts, Re-analysis, Episodes	Global
MC2-AQ, Canada (used in Polen) Kaminski et al., 2007	ADOM gas phase chemistry	none, but possible	Episodes	Regional to urban
Meso-NH, France http://mesonh.aero.obs-mip.fr/mesonh/	RACM or ReLACS gas phase chemistry, modal aerosol module	Direct aerosol effect	Episodes	Continental to regional
MESSy(-ECHAM5) , Germany Jöckel et al., 2005; http://www.messy-interface.org/	Various gas phase chemistry modules, modal aerosol module	Direct aerosol effect, indirect aerosol effect	Episodes, long term	Global

Online coupled or online access Atmospheric Chemistry-Meteorology models developed or applied in Europe (2)

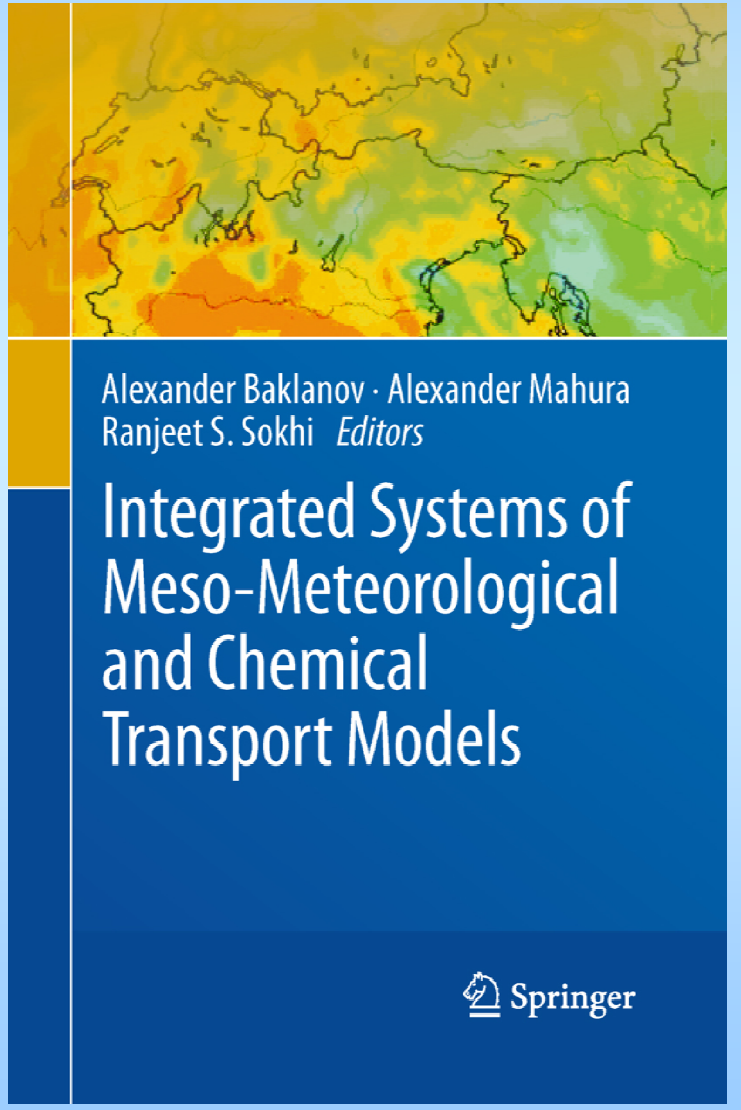
Model/Country/References	Online coupled gas phase chemistry and aerosol	Feedback of pollutants to meteorology	Applications	Scale
MCCM, Germany Grell et al., 2000; Forkel & Knoche, 2006	RADM, RACM or RACM-MIM with modal aerosol module	Direct aerosol effect	Episodes, climate-chemistry	Regional
MetUM (Met Office Unified Model), UK Morgernstern et al, 2009; O' Connor et al 2010	2 tropospheric chemistry schemes, 1 stratospheric chemistry scheme. 2 alternative aerosol schemes.	Direct and indirect effects of aerosols, radiative impacts of N_2O, O_3, CH_4	Episodes, CWF, climate-chem. studies, long-range transport	Regional to Global
M-SYS (online version), Germany von Salzen and Schlünzen, 1999	RADM Gas phase chemistry, sectional aerosol module	none, but possible	Episodes	Regional to local
RegCM-Chem, Italy Zakey et al., 2006, Solmon et al., 2006	Updated GEOS-CHEM RACM, CBMZ, unimodal aerosol, sectional mineral dust, sulfur chemistry	Direct aerosol effect	Climate-chemistry	Continental to regional
RAMS/ICLAMS, USA/Greece http://forecast.uoa.gr/ICLAMS/index.php, Kallos et al. 2009, Solomos et al. 2010	Online photolysis rates. Coupled SAPRC99 gas phase, modal aerosol, ISORROPIA equilibrium and SOA, cloud chemistry.	Direct and indirect aerosol effect	Episodes, CWF, meteo-chemistry interactions	Continental to urban
WRF/Chem, US (used in UK, Spain, etc.) Grell et al., 2005; Fast et al., 2006, further references see Zhang, 2008	RADM, RACM, RACM-MIM with modal aerosol module or CBM-Z with sectional aerosol module, liquid phase chemistry	Direct aerosol effect, indirect aerosol effect	Episodes, chemical weather forecast, climate-chemistry	Continental to regional
WRF-CMAQ Coupled System, USA (used in UK) Pleim et al., 2008; Mathur et al., 2010	Gas-phase mechanisms: CB05, SAPRC-99; Modal aerosols based on the AERO5 CMAQ module	Direct aerosol effects on radiation and photolysis, indirect effect under development	Episodes to annual	Urban to Hemispheric

Courtesy of COST Action ES1004

European operational CWF models

- ***European CWF portal***: http://www.chemicalweather.eu/Domains

- ***Kukkonen et al, ACPD, 2011***: overview of 18 selected regional CWF models used in Europe: ALADIN-CAMx (Austria), CAMx-AMWFG (Greece), EURAD-RIU (Germany), Enviro-HIRLAM (Denmark and others), FARM (Italy), LOTOS-EUROS (The Netherlands), MATCH (Sweden), MM5-CAMx (Greece), MM5-CHIMERE (France and Portugal), MM5/WRF-CMAQ (Spain, UK), MOCAGE (France, Spain, Romania), NAME (United Kingdom), OPANA (Spain and others), RCG (Germany), SILAM (Finland, Estonia, Russia, Lithuania and Spain), SKIRON/Dust (Greece), THOR (Denmark), WRF-Chem (Spain and others)
- Only two of them (Enviro-HIRLAM and WRF-Chem) are online coupled
- Recently published Springer book (***Baklanov et al., 2011***) with description of main coupled ACT-MM models => 15 online =>



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Thank You !

COST Action ES1004 Web-site:
http://eumetchem.info