ECLIPSE project – WP3: Reality Check

Objectives

The overall goal of this work package is to quantify uncertainties in model representations of key processes for estimations of SLCF impacts on air quality and climate, and to evaluate model performance against observations.
In order to accurately simulate the impacts of SLCFs (aerosols, ozone and their precursors) on air quality (including long-range transport) and climate, as measured by indicators such as AOT40, or GWP/GTP for example, global chemistry-aerosol models are required which can reproduce key processes over both source and receptor regions. This knowledge is important for assessing the uncertainty of project end results in WP 7. This WP will evaluate several key processes and model performance in selected key regions (Europe, China, Arctic) as well as during long-range transport in a series of case studies. The objectives are:
O3.1 – Evaluation of aerosol and ozone processing within key source regions (Europe and China)
O3.2 – Evaluation of BC distributions and deposition over Arctic receptor region
O3.3 – Assessment of long-range transport events and source-receptor relationships related to quantification of direct radiative forcing and inter-continental pollutant transport
O3.4 – Quantification of model errors related to plume dilution during long-range transport

Description of work

Global model results from runs for the years 2008-2009 (output of WP 2) using emissions developed in WP 1 will be analysed and evaluated through comparison against a variety of measurement data (ground-based, aircraft and satellite) and against the results from regional models with a variety of treatments of particular processes available. Data from intensive aircraft measurement campaigns as well as monitoring data from surface sites (e.g. ACTRICE) and the free troposphere (MOZAIC, ozone/aerosol lidar data) will be used. Meteorological parameters, also relevant to radiative calculations, such as water vapour, cloud distributions and albedo will also be evaluated.
Firstly, estimates of direct aerosol radiative heating rates based on data analysis as well as data based estimates of ozone and aerosol formation will be estimated and used to evaluate global model results provided from WP 2 and using emissions from WP 1. Global models will be evaluated by comparing to data, to high-resolution simulations with regional models (WRF-Chem and WRF-CMAQ) run at different resolutions and to models run with different chemical/aerosol schemes and treatments of soot deposition. A Lagrangian dispersion model will also be used to evaluate transport and scavenging. The skill of the global models will be evaluated and biases against the observations will be identified in order to better quantify model uncertainties. The results will be fed back to WP 2 and WP 4 periodically to allow correction of biases where possible and will contribute to the analysis of radiative forcing calculations in terms of understanding

about global model performance. They will also be passed to WP 7 where the metrics obtained from the different models will be weighted according to their skill and uncertainty.

Description of work
Global model results from runs for the years 2008-2009 (output of WP 2) using emissions developed in WP 1 will be analysed and evaluated through comparison against a variety of measurement data (ground-based, aircraft and satellite) and against the results from specialized regional models with a variety of treatments of particular processes available. Data from intensive aircraft measurement campaigns as well as monitoring data from surface sites (e.g. ACTRICE) and the free troposphere (MOZAIC, ozone/aerosol lidar data) will be used. Meteorological parameters, also relevant to radiative calculations, such as water vapour, cloud distributions and albedo will also be evaluated.
Firstly, estimates of direct aerosol radiative heating rates based on data analysis as well as data based estimates of ozone and aerosol formation will be estimated and used to evaluate global model results provided from WP 2 and using emissions from WP 1. Global models will be evaluated by comparing to data, to high-resolution simulations with regional models (WRF-Chem and WRF-CMAQ) run at different resolutions and to models run with different chemical/aerosol schemes and treatments of soot deposition. A Lagrangian dispersion model will also be used to evaluate transport and scavenging. The skill of the global models will be evaluated and biases against the observations will be identified in order to better quantify model uncertainties. The results will be fed back to WP 2 and WP 4 periodically to allow correction of biases where possible and will contribute to the analysis of radiative forcing calculations in terms of understanding about global model performance. They will also be passed to WP 7 where the metrics obtained from the different models will be weighted according to their skill and uncertainty.

T3.1 – Evaluation of modelled aerosol and ozone processing over key source regions (Europe and China) (responsible FORTH, UPMC, PKU)
Global model results over Europe and China will be evaluated using available field campaign and regular monitoring data for specific case studies to assess their ability to model aerosol formation and ageing and photochemical ozone production and loss processes such as wet and dry deposition. Assessment of emission uncertainties (WP 1, WP 2) will feed into these analyses.
Ozone formation and loss rates (titration) over source regions will be examined under different VOC:NOx regimes. Possible cases will be selected where plumes from different emission regions have been sampled including both anthropogenic (e.g. residential, traffic, ships) and natural sources (e.g. forest fires, biogenic VOC emissions). The ability of models, which are known to have problems in simulating OVOCs and NOx reservoirs such as PAN and HNO3 will be examined.
Aerosol ageing and oxidant interactions over source regions will be examined and results compared to the other global models. The importance of the following aspects will be evaluated: (i) chemical interactions between natural and anthropogenic emissions (e.g. marine DMS and pollution nitrate radical reactions); ii) interactions between the major pollution components of aerosols BC/OC/SO4 and NO3, iii) interactions between

natural aerosols (e.g. dust) and pollution components (e.g. coating by SO4, NO3, OC). Detailed evaluation in TM4 of aerosol-oxidant interactions and runs using WRF-CMAQ over source regions will be used as a basis to evaluate performance of the other global models over source regions (FORTH). At the regional scale, a coupling between CALIOP lidar products and in-situ measurements will be performed to retrieve the aerosol optical properties included in the different layers over the atmospheric column (UPMC). Aerosol extinction coefficients, aerosol single-scattering albedo, and aerosol depolarization ratio values will be provided to estimate aerosol radiative heating rates over the selected regions and compared to higher resolution simulations using WRF-Chem.

a) Europe - data from campaigns conducted as part of, for example EU projects EUCAARI or MEGAPOLI will be used to examine aerosol processing in polluted air masses. There will also be a focus on the eastern Mediterranean making use of data collected on aerosol parameters and pollutant concentrations as part of the EU CITYZEN project

b) China – data collected as part of the CAREBEIJING campaign in August 2008, and regular data will be used to evaluate model performance over and downwind from Beijing (PKU). Data collected downwind over Korea on aerosol properties/composition as part of CAPMEX and at, for example, the Gosan Observatory will also be used to determine direct radiative forcing (collab. Kim/Yoon Seoul Nat. Univ., see section 2.4 – description of UPMC)

T3.2 – Validation of modelled Arctic black carbon distributions and deposition on snow/ice (responsible CICERO, NILU, collaborators from NOAA – Doherty, Warren)

Koch et al. (2009) and Shindell et al. (2008) have shown that large uncertainties surround model distributions of black carbon over a key receptor region, the Arctic, where it can impact the radiative budget through atmospheric heating or via deposition of soot on snow. In addition, recent measurement campaigns during the International Polar Year provide for the first time a circumpolar dataset on concentrations of black carbon in Arctic snow (Doherty et al., 2010; Forsstrøm et al., 2009; McConnell et al. 2007), as well as information about sources of these aerosols based on chemical “finger-print” analysis (Hegg et al., 2010). These new datasets will be used to evaluate the modelled deposition of BC on snow in the Arctic and impacts on snow albedo (NILU, CICERO). The data will be used to evaluate model performance of the models participating in task 2.1 using the OsloCTM2 to study the role of specific scavenging processes (CICERO). FLEXPART run with simplified treatments of scavenging processes for BC aerosols will also be used to examine scavenging and transport of BC to the Arctic and its loss by deposition (NILU). Results will also be used in WP 5 in the investigation of climate feedbacks.

T3.3 – Validation of long-range transport processes and source-receptor relationships (responsible: UPMC, NILU)

The ability to calculate accurate source-receptor relationships is an extremely important precondition to calculate sector- and region-specific radiative forcing in a model, as the forcing depends critically on how the SLCFs from a specific source are distributed in the model atmosphere. Long-range transport of pollutants between source and receptor regions is governed by chemical/aerosol processing, loss processes such as scavenging as well as mixing with cleaner so-called “background” air masses. For the various

source (south-eastern Europe, China) and receptor (Arctic) regions, we will select cases of long-range transport that occurred during periods when intensive observations were made, for instance during POLARCAT in spring and summer 2008.
UPMC will investigate cases of long-range pollutant plume transport from source regions (anthropogenic and boreal/agricultural fires) to receptor regions making use of a combination of data analysis (satellite – CALIPSO, IASI: aircraft campaign data (e.g. POLARCAT)) and high-resolution chemical-aerosol and tracer modelling to evaluate global model performance. The chemical-aerosol model (WRF-Chem) will be run at different horizontal resolutions and domains ranging from hemispheric to a few kms (for specific periods/regions) and in some cases with different aerosol or chemical schemes which are available (collab. PNNL – Rasch, Fast, Zaveri). These runs will be used to further constrain uncertainties in global model simulations. A particular aspect to be addressed will be the lifetime and scavenging of aerosols in plumes as well as their potential in terms of photochemical ozone production. Model abilities to simulate plume concentrations of OVOCs and NOy components, especially PAN, will be assessed. A particular focus will be on long-range transport of pollutants from mid-latitudes to the Arctic making use of data collected during POLARCAT. Lagrangian cases of plume transport (determined from aircraft-aircraft or satellite-aircraft matches) will be used to evaluate global model performance. For example, a temporal evolution of aerosol optical properties can also suggest a potential removal of the largest particles in the accumulation mode, hence suggesting particle removal.

T3.4 – Dilution of SLCF plumes in models and reality (responsible: NILU)
The Lagrangian particle dispersion model FLEXPART will be used with both passive (e.g., carbon monoxide) and “aerosol-like” (e.g., black carbon with detailed scavenging but simplified ageing treatment) tracers to simulate the long-range transport of SLCFs from the respective source regions. Episodes of strong SLCF export will be identified and used to assess how realistic the global models can simulate these episodic long-range transport processes. Vertical as well as horizontal plume positions will be compared and statistical measures of dispersion (e.g. maximum simulated concentration as a function of transport time) will be compared against the FLEXPART simulations as well as against available data, in particular from the POLARCAT campaigns in 2008. Efforts will concentrate on the Arctic, where model problems will be most pronounced but will also include other regions. Effects of an expected too-quick dilution of pollution plumes on simulated BC and ozone concentrations will be quantified from first-principle process understanding and the resulting uncertainty in global model results will be estimated.