International Conference on Transport, Atmosphere and Climate

26 - 29 June 2006

Book of abstracts

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Engine emissions, emission inventories and scenarios

Light Duty Vehicle Emissions

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Global warming is an important issue facing the automotive industry. Society's assessment of global warming may change in the future as the science develops, but the present risk is clear. The climate appears to be changing, the changes appear to be outside natural variation, and the likely consequences will be serious. This talk will provide a business perspective on vehicle emissions and their contribution to air pollution and climate forcing. Estimates of current and future emissions of CO2, HCs, CO, NOx, PM, R-134a, N2O, and CH4 by the global vehicle fleet will be presented and discussed. Vehicle miles traveled are expected to double over the 2000-2050 time period. However, the absolute magnitude of emissions of \"criteria\" pollutants (HCs, CO, NOx, PM) is projected to decline substantially (by a factor of approximately 5-10). Associated benefits for local air quality and climate forcing will be discussed.

Physico-Chemical Characterization of Soot Emitted by a Commercial Aircraft Engine : Morphology, Size, Structure, and Elemental Composition.

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Nowadays, understanding the aviation's impact on radiative forcing, climate change, air quality and human health is a challenging task. In spite of many efforts undertaken to date by the scientific community, there is still a lack of knowledge about the structure, the morphology, the composition, and the physico-chemical properties of aircraft engine soot that is directly released in the atmosphere. We present here various experimental studies performed on soot particles emitted by a commercial aircraft engine.

Soot sampling is made on a civil aero-engine bench at SNECMA Villaroche center (France) during Landing/Take-Off cycles. Particles are collected by direct impaction on porous polycarbonate membranes (Nucleopore®Isopore), silicon windows, and electron microscope grids (Holey carbon film) that are located at 27 m behind the commercial aircraft engine. The particles size, morphology, structure and elemental composition are studied by using a Scanning Electron Microscope (SEM) and a Transmission Electron Microscope (TEM) that are both equipped with an Energy Dispersive X-ray Spectrometer (EDXS). Functional groups are also characterized by Fourier Transform InfraRed spectroscopy (FTIR).

The collected soot primary particles are spherical and made of concentric graphene layers arranged in an "onion-like" structure. Electron diffraction patterns allow us to determine both the lateral extension and the distances between these graphene layers. We also determine and compare the primary particles size distributions obtained from TEM and SEM analyses and show that they exhibit different behaviours and maxima positions. We then conclude from several sets of measurements that TEM is a more suitable technique for determining the primary particle's size, which follows a log-normal law, since unlike SEM it does not require a sample preparation that strongly affects the particles size distribution by shifting its maximum towards higher values. EDXS analyses performed during SEM and TEM measurements show that soot particles are mainly made out of carbon, oxygen and some traces of sulfur. This elemental composition is correlated to the FTIR spectra that evidence various functional groups present at the surface of soot particles.

Engine emissions, emission inventories and scenarios

Development of an Emissions Database to Inform Comparisons of Various Transportation Modes

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While comparison of emissions within a transportation mode (i.e. comparing Car A to Car B) is fairly straightforward using existing data sources, comparison across modes (i.e. comparing Car A to Aircraft B) is more difficult. Appropriate comparisons are challenging because duty cycles, emissions metrics, measurement instrumentation, and other factors differ among transportation modes. In response, a comparative emissions database (CEDB) is being designed and implemented to inform comparisons of various transportation modes in terms of potential impact on global climate change. The transportation modes being considered are commercial aircraft, light-duty cars, heavy-duty diesel trucks/buses, locomotives, and marine vessels. Emissions data are being drawn from regulatory certification measurements and research-grade measurements, both from literature and our own studies. Certification data include CO, NOX, total hydrocarbons (THC), CO2 (from fuel consumption), smoke number (for aircraft), and particulate matter (for diesel-powered vehicles). Research-grade data generally offer finer speciation of the above measurements for NOX, THC, and particles. While these data may be less complete than the certification data, they significantly enhance the granularity of the dataset and steps are being taken to integrate them into the database. Two common bases of comparison are being considered; grams per passenger-mile for passenger travel and grams per tonne-mile for freight transport. Ancillary data, such as passenger capacity and load factors, are also being included to allow conversion to these comparative emission metrics. A relational database structure is being used to organize the data in order to make the CEDB more compact and less prone to data-entry errors. The focus of this project is compiling and organizing measured emissions data rather than inventory development or policy analysis, yet in order to insure that the CEDB is a useful tool for enabling those types of analyses, its design and scope need to consider the range of queries that may be posed. Thus basic examples of the modal comparisons facilitated by the CEDB have been developed and will be presented.

MODELLING OF PARTICULATE MATTER MASS EMISSIONS FROM A LIGHT-DUTY DIESEL VEHICLE

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Emissions from motor vehicles are a major source of air pollution and studies have shown that exposure to the particulate matter (PM) in fresh diesel exhaust is a significant risk to health. Short term peak exposures are thought to have the greatest impact. Despite the development of several vehicle power-based models to estimate the second-by-second mass emission rates of gaseous pollutant species such as carbon monoxide (CO), carbon dioxide (CO2), Hydrocarbons (HC) and nitrogen oxides (NOx), none of these models predicts PM emissions. This paper presents a new technique for modelling the second-by-second PM mass emission rate of a light duty diesel vehicle. Here, PM emission rates are modelled as a function of both vehicle kinematic parameters (i.e. speed or acceleration) and the mass emission rates of the gaseous co-pollutants (CO, CO2, and NOx). The importance of time alignment in the calibration data is evaluated and a technique for deriving an appropriate lag structure is devised. Four regression models are estimated with an autoregressive error structure (AR1) to account for serial correlation in the emissions data. Accounting for the lag structure and inclusion of the gaseous co-pollutant emission rates as an emissions "fingerprint" both greatly improve model fit. The model overestimates the aggregate PM mass emitted over the cycle by 19.9%, with an R2 of 0.718. This is comparable accuracy to similar estimates of aggregate gaseous mass emissions from existing microscopic emissions models.

Engine emissions, emission inventories and scenarios

An Overview of the Aircraft Particle Emissions Experiment (APEX) Series

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NASA in collaboration with other federal (FAA, DOD, USEPA) and state (California Air Resource Board) agencies, engine/airframe manufacturers (GE, Pratt and Whitney, Rolls Royce, and Boeing), airlines (Southwest, Continental, ExpressJet, FedEx), and airport authorities (Oakland, Cleveland) recently sponsored three broadly-scoped, ground-based field investigations to examine the particle and gas emissions from a variety of in-use commercial aircraft. These Aircraft Particle Emission Experiments (APEX-1, JETS/APEX-2 and APEX-3) brought together researchers from federal laboratories, academic institutions, and private industry to: 1) evaluate new measurement and sampling techniques; 2) examine the impact of fuel composition on soot and secondary particle formation; 3) follow the evolution of particle concentrations and characteristics within engine exhaust plumes as the plumes cool and mix with background air; and 4) obtain detailed data sets for validating models and assessing the impact of aircraft emissions on air quality and climate. Instruments deployed during the tests included standard gas-phase sensors (THC, NOx, CO, and CO2); FTIR-type multi-gas analyzers (speciated HC's, SO2); tunable diode laser spectrometers (NOy, CH2O, HONO); canister and sorbent-type collectors (HC's and air toxics); a Proton-Transfer Reaction Mass Spectrometer (real-time speciated HC's); an aerosol mass spectrometer (aerodynamic size and composition); particle counters and scanning mobility particle size analyzers with and without thermal denuders (total and nonvolatile number and size); filter-type aerosol sample collectors (ions and EC/OC mass); aerosol absorption photometers (black carbon mass); tapered element oscillating microbalances (particle mass); electrical low-pressure impactors (aerodynamic size and number density); and a laser incandescence spectrometer (black carbon mass). Experiment plans typically included placing inlet probes 1, ~10, and ~30 m downstream of the engine exhaust plane and collecting exhaust samples at multiple engine power settings ranging from ground-idle to full takeoff thrust. Fuel samples were collected from each aircraft and carefully analyzed for hydrocarbon and sulfur content. Ambient conditions as well as engine temperatures, fuel flow rates, fan speeds, etc., were documented for each of the more than 1000 test points examined during the experiments. Particular emphasis was placed on evaluating the effects of transport lines and inlet probes the particle and gas-phase measurements. About 80 total hours of particle and gas-phase emission data were collected behind 1 turbojet and 17 turbofan engines mounted on 12 different aircraft during the three field deployments. This talk will further describe the experiments and summarize important results.

In-Situ Microphysical Measurements In Rocket Plumes With The Cloud And Aerosol Spectrometer (CAS)

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High resolution, single particle measurements have been made in rocket plumes using an optical particle spectrometer that measures diameters from 0.5 to 44 um. The Cloud and Aerosol Spectrometer (CAS) measures the light scattered in two directions from individual particles that pass through a focused, 680 nm laser beam and we derive the diameter, shape and composition from this information. The CAS was mounted on the NASA WB-57F aircraft as part of the Plume Ultrafast Measurements Acquisition (PUMA) project, an experiment funded by NSF and NASA to study the chemistry and microphysics of rocket plumes.

Measurements were first made in a plume generated by an Atlas IIAS rocket in May, 2004 and again in July, 2005 in the plume formed from the exhaust of the solid state boosters used to launch the space shuttle Discovery into orbit. The microstructure of the two plumes and the characteristics of their particles were distinctly different. The two cases had similar maximum concentrations of 300 cm-3, but the space shuttle particles were on average larger and a greater percentage of them were irregular in shape. An analysis of the distance between particles suggests clustering because of the non-Poisson shape of the frequency distribution of inter-arrival times.

Engine emissions, emission inventories and scenarios

Historical and future development of air transport fuel efficiency

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A recent study on the development of energy efficiency of individual new civil air aircraft and for the US fleet shows that the IPCC efficiency assumptions yield too optimistic fuel reductions in the future. Like IPCC, most air transport greenhouse gas emission scenarios assume a constant energy efficiency increase leading to a near-zero fuel consumption in the long term. The IPCC special Report on aviation and the global atmosphere assumes values between 1.2% and 2.2% efficiency increase per annum. However, the historical data gathered in the study show clearly that the reduction percentage is not a constant, but reduces itself with time. Implicitly, when using this approach, these scenarios neglect several technology limits. Amongst others, these concern the limited energy content property of the fuel, minimum obtainable levels of drag and weight.

This study also proved that fuel efficiency is just one of the drivers for aviation. For civil airliners, history learns that fuel efficiency figures showed a large discontinuity at the transition from piston powered aircraft to jet power. It is shown that the last piston powered airliners like the Lockheed Super Constellations were almost as fuel efficient as the new jet aircraft entering service in the nineties of the last century. However, the Constellations emissions differ much from those of the modern jet. The historically observed developments clearly illustrates that overall aircraft economy efficiency optimization is preferred over fuel efficiency. The validity of comparing jet- and piston-powered aircraft fuel efficiency can be questioned and will be discussed. Attention will be given to the performance differences – i.e. range, speed and cruise levels –, fuel properties (emissions) as well as second order impacts like energy consumption of production of kerosene compared to high grade gasoline.

Contracting UK carbon emissions: implications for UK aviation

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Stabilising atmospheric carbon dioxide concentrations at or below 550ppmv is widely believed to be necessary to avoid ‘dangerous climate change’. Achieving such levels demands industrialised nations make significant emissions cuts, whilst emerging economies adopt low-carbon pathways. This paper demonstrates the severe consequences for the UK in meeting its obligations to reduce carbon emissions under the apportionment rules informing both RCEP’s 22nd report, Energy the Changing Climate, and the 2003 Energy White, if the UK Government continues to permit the current high levels of growth within its aviation sector.

The paper reveals the enormous disparity between the UK’s position on carbon reduction and the Government’s reluctance to recognise and adequately respond to the rapidly escalating emissions from aviation. A comparison of forecasts and scenarios reflecting growing aviation emissions with a contracting UK emissions profile clearly illustrates this point. Results show that at an annual growth rate of only half of that experienced by UK aviation emissions in 2004, this sector will account for 90% of permissible emissions in 2050 under the 550ppmv regime, and consume the entire carbon budget under the 450ppmv level. The paper goes on to illustrate the serious and significant implications for other sectors of the UK’s economy. The paper concludes that aviation growth must be curbed until sufficient steps are taken to ensure fuel efficiency gains balance growth in activity, or until there is widespread use of alternative fuels that significantly reduce the industry’s carbon emissions.

Engine emissions, emission inventories and scenarios

Calculating UK CO2 Emissions Using Real Air Traffic Data

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This paper recommends a possible methodology for calculating air transport CO2 emissions, using real air traffic data. The basis for the calculations is an air traffic sample which represents one full day traffic for the UK. In order to analyse aircraft fuel burn use and hence CO2 emissions, the Reorganized Air Traffic Control Mathematical Simulator (RAMS) and the Advanced Emission Model (AEM III) are used. The results from these detailed simulations are compared with two of the most widely used aviation CO2 emission estimates which have been done for the UK. These estimates for UK aviation related emissions are the SERAS study and NETCEN estimate. Their figures for the year 2000 are 26.1 Mt and 31.4 Mt, respectively. In addition, the most recent NETCEN estimate for the year 2003 is 34.1 Mt of CO2. Our estimate of total CO2 emissions, using detailed simulations and real air traffic data, are 34.7 Mt for the year 2004. Different methodologies and their implications are also discussed.

First validation of a global road transport emission inventory for the year 2000

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In Activity 1 of QUANTIFY, an emission inventory is produced for road transport in the year 2000. The inventory covers the whole globe with a resolution of 1° longitude by 1° latitude, and gives emissions of CO2, NOx, PM, SO2, CO, CH4 and NMHC. The emissions are calculated in a bottom-up approach, using emission factors estimated by the Institute for Transport Sciences Budapest (KTI), transport volumes compiled and estimated by Transport & Mobility Leuven (TML) and fuel sales data of the International Energy Agency (IEA). For the first time, these emissions are calculated globally on the level of different fuels and vehicles.

The emissions and fuel consumption are calculated as the product of transport volumes and emission factors. They are then scaled so that the fuel consumption in each world region matches the sales figures given by the IEA.

Emissions of CO2, CO, CH4 and NMHC are dominated in nearly all regions by passenger transport, the notable exception being North America. Emissions of NOx and PM are dominated by freight transport in most regions, while the main origin of emissions of SO2 is different in different regions.

The highest emissions of CO2, CO and SO2 occur in North America, the highest emissions of NOx and PM in the European Union and the highest emissions of CH4 and NMHC in Southeast Asia. This can be explained by the high overall transport volume in North America, the higher bus transport volume and much lower emission control standards for NOx and PM in the European Union compared to North America and the high transport volume of motorized two-wheelers combined with often low emission control standards in Southeast Asia.

When comparing our results to data from EDGAR FT32, we find very good agreement for CO2 emissions in most regions. The remaining discrepancies can be explained by the fact that EDGAR used an earlier version of IEA fuel data, extrapolated to 2000, while we use the actual sales statistics for 2000. As we assume much lower emission factors for the other substances than EDGAR, we also calculate much lower emissions, e.g. 20-75% less CO, depending on the region. These lower emission factors reflect the technological changes in the vehicle fleet in the late 90's.

We think that with this inventory it is possible to model the global climate impact of transport more accurately, and we are still in the process of improving it further.

Engine emissions, emission inventories and scenarios

Forecasted maritime shipping emissions for Belgium with an activity based emission model.

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As in many other countries, the current emission estimation methodology for sea-going vessels in Belgium is based on bunker fuels allocated to the country. VITO developed an alternative approach based on traffic related data. The activity based emission model for sea-going vessels calculates the CO2, SO2, NOX, CO, HC and PM emissions from sea-going vessels within Belgian jurisdiction.

We take into account activity data and the specific geometry of each of the Belgian harbours (Antwerp, Ghent, Oostende and Zeebrugge) in the model and we integrate vessel activities from the Belgian/Dutch Vessel Traffic System for the Belgian jurisdiction of the North Sea. We determine the emissions through the energy use (power and fuel consumption), taking into account the length, building year and other technical aspects (e.g. engine type, RPM, fuel type, …) of the sea-going vessels, and the power use during each stage of navigation. Technology-related emission factors were used to compute the NOX, CO, HC and PM emissions. The emission factors depend on the building year of the vessel and the percentage of the maximum continuous rate. The emission factors for CO2 correspond with the IPCC CO2 emission factors for the different maritime fuels. Regulations for the sulphur content of maritime fuels were taken into account. A distinction is made between the exhaust emissions of auxiliaries (e.g for on board electricity production) and the main propulsion engines. For the latter, we distinguish 3 types of main engines, namely 2-stroke engines, 4-stroke engines and steam turbines.

The activity based emission model made it possible to forecast the emissions from sea-going vessels for the near future. To compute the effect of the existing IMO and EU legislation, we defined on the one hand an autonomous growth scenario and on the other hand a current legislation scenario. In the autonomous growth scenario, we only take into account the traffic and fleet evolution, based on activity growth rates per harbour and natural technological improvements (fuel, ship size, engine management). We implemented extra measures to meet the IMO and EU regulations, like technological improvements for the engines and restriction on the sulphur content in the maritime fuels, in the current legislation scenario. The IMO regulation will result in a reduction of merely 1 % of the NOX emissions of main engines in the year 2010 in Belgium. Both the IMO and EU regulations will realize a total reduction of 56 % in SO2 emissions.

Measurement method for emissions from inland navigation

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Transport over water is more efficient and cleaner than transport over land. But the standards for exhaust gas emissions from diesel engines from inland vessels lag 5 to 10 years behind the standards for emissions from road transport. With unchanged policy, this will result in more nitrogen oxides and particle matter to the transport performance (in kilometers) for inland vessels than for trucks.

However, the emissions from the inland navigation are based on only a few experiments with a few vessels whereas the emissions from road transport are much better known.

This measurement method is based on remote measurement of the exhaust plumes from vessels that pass by on a canal/river. In a two-day campaign, 20 km east of Rotterdam, emissions from about 150 ships were obtained. The gasses, which are measured are CO2, NO, NO2. For particulate matter, total particle numbers and particle size distribution were determined. High time resolution made it possible to see the different ship passages. The observed plumes for NOx and particles were linked to those observed for CO2. The latter is linked to the amount of diesel used and to the engine power. In this way we obtained an emission factor for NOx per ship in g/kWh. An average level of 11 +/- 4 g NOx/kWh was obtained (n=132 vessels).

The same procedure worked for particle numbers. For particle mass the uncertainty is significantly larger but the measurements seem to indicate that ships are slightly cleaner than expected. The average emission factor was in the range of 0.1-0.3 g/kWh.

These experiments can give a better understanding of the ship emissions and may facilitate effective policy on reduction of emissions from inland shipping.

Near field and plume processes, effective emissions

Particle Emissions from Ship Engines: Emission Properties and Transformation in the Marine Boundary Layer

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Gaseous and particulate matter emissions from ship engines currently gain increasing attention regarding a possible environmental impact. Black carbon (BC) is the most efficient particulate absorber of atmospheric solar radiation and has therefore a strong impact on the atmospheric radiation balance. Furthermore, combustion particles coated with sulphate can act as nuclei for the formation of cloud droplets and affect by that means the life cycle and radiative properties of stratus clouds at the top of the marine boundary layer. In particular the emission of particles and their fate in the marine environment are, however, widely unknown.

In the framework of a combined effort ship emission studies were conducted in 2004 as part of the European Integrated Project HERCULES (High Efficiency R&D on Combustion with Ultra Low Emissions for Ships). Detailed aerosol microphysics and chemistry was measured in the exhaust gas of a single-cylinder test bed engine, which was operated at various load conditions, running on fuel with a sulphur content of 3.45 wt.-%. The emission studies were complemented by airborne aerosol transformation studies in the marine boundary layer as part of the ICARTT-ITOP (Intercontinental Transport of Ozone and Precursors) experiment in 2004. Research flights using the DLR aircraft Falcon 20 E-5 were conducted in the English channel and in a single plume of a large container ship.

On board of the research aircraft, an extensive set of instruments was operated for measuring aerosol microphysical properties of both the secondary volatile aerosol, the primary combustion aerosol and trace gases H2O, NO, NOx, O3, CO, CO2, and SO2. The plume age during the Single Plume Study was calculated from trajectory analyses of the ship plume with respect to the aircraft flight track and from the geometrical distance from the probing aircraft to the source ship at the time of emission. CO2 data measured during the Single Plume Study were then used for the determination of plume diffusion coefficients according to a plume dispersion model.

The plume dispersion model in combination with the observations from emission studies and plume studies yields a consistent picture of particle transformation processes from emission from a ship engine to atmospheric processing in the marine boundary layer during plume expansion. The results are used for the determination of emission indices of particulate matter from ships and for the estimation of life times of ship exhaust particles in the marine boundary layer.

Aircraft measurements in primary European ship corridors

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Emissions from seagoing ships are released along the major ocean trade routes. European ship traffic occurs mainly in corridors located along the continental coasts, thus affecting also the coastal regions. We report on aircraft measurements in most travelled ship corridors of Europe off the coast of north-western France and the English Channel performed in July 2004 and April 2006. A total of four flights were conducted in preparation and as part of the EC project QUANTIFY. Chemical species and particles were measured during survey flights in the marine boundary layer and in the exhaust trail of individual source ships. The measured parameters to be presented here include CO2, CO, NO, HNO3, NOy, O3, SO2, hydrocarbons and condensation nuclei.

The survey flights in the ship corridors clearly revealed signatures of corridor effects, namely the observation of a multitude of ship exhaust plumes of varying ages and also regional enhancements of the abundance of trace species related to emissions from shipping. The data are used to determine the horizontal and vertical distribution of trace species in the corridors and the peak concentrations, widths and ages of plumes observed in the corridors. In addition we present calculated median emission ratios and infer emission indices using measured CO2 enhancements as reference.

Near field and plume processes, effective emissions

Airport Emission Studies of Gaseous and Particulate Emissions

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Dedicated tests to measure the emissions from aircraft engines are costly due to high fuel and equipment costs, require specialized probes and support structures, and are generally logistically complex to arrange and carry out. On the other hand, in-service aircraft are routinely being operated using normal procedures at any active airport, and they release their emissions into the generally open environment surrounding airport runways. Several recent studies have used the transport of prevailing winds to carry the airplane emissions to a suite of sensitive, fast time response measurement instruments. By coordinating the emissions measurements with notation of aircraft identification numbers, the measured emissions can be tied to the specific engines being operated, and thus these engines can be quantified during routine operation without interfering with airport operations.

Results of these advected plume studies will be presented from a suite of measurement instruments. The measured emissions include NOx, CO, several hydrocarbon species, and a variety of particle parameters. Particle measurements include black carbon (using Multi-Angle Absorption Photometry), particle number (using a Condensation Particle Counter), and non-refractory aerosol composition and size (using an Aerosol Mass Spectrometer). Distinct differences in emission quantities can be discerned for differing aircraft types, especially notable in particle property signatures of older versus newer airplanes.

PM Emissions from advected aircraft plumes at the Oakland International Airport

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With the current state of commercial air traffic and projections for the future of commercial aviation, air quality around airports and the surrounding communities is of growing concern. The most efficient way to quantify the impact of boundary layer jet engine exhaust is through the use of aerosol transport and evolution models which need to be validated with relevant data. At an airport study conducted at the Oakland International Airport (OAK) in August 2005, PM emissions data was gathered during a twelve hour period of normal daylight aircraft operations. The prevailing wind was from the W/NW and the sampling location was situated downwind on the eastern end of the runway at OAK. The location selected for sampling the advected plumes was unique in the sense that it provided an opportunity to measure emissions as aircraft taxied to departure, departed, and landed on the single runway. Real-time PM and emission gas measurements, recorded as a function of ambient atmospheric conditions, provided immediate feedback in terms of emission factors, size distributions and chemistry for over 300 aircraft under normal operating conditions. Aircraft tail numbers were also recorded for identification of the airframe and engine. This paper will discuss the physical characteristics of the PM detected for the following classes of aircraft: B727, B737, B757, DC10, MD-80, A300 and A320.

Water-H2SO4-soot interaction in aircraft plume

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The phenomenon of aircraft contrail formation attracts much attention as a visible and direct anthropogenic impact upon the atmosphere. Analysis of ice residuals in contrails and aerosols from aircraft plumes proves that soot aerosols facilitate contrail ice nucleation. Other studies suggest that the soot aerosols from evaporated contrails make their way into natural cirrus clouds and may affect their microphysical properties. Nevertheless, sparse documentation exists on hygroscopic properties of soot particles measured at contrail level. The lack of experimental data on actual soot from aircraft engines led some investigators to assume that exhaust soot is hydrophobic. Various activation pathways were assumed to facilitate the ice particle formation on hydrophobic

soot particle surface. Numerical modeling showed that coagulation of homogeneously nucleated sulfate aerosols with soot particles as well as binary H2SO4/H2O heterogeneous nucleation, and direct deposition of sulfuric acid vapor may have a pronounced effect on the activation of soot particles by creating a liquid solution coating. However, no visible difference in the appearance of contrail in the aircraft plume has been found at low and normal fuel sulfur content (FSC).

This report presents the review of results obtained from comprehensive study of

- water uptake by original aircraft –generated soot at the conditions of cooling and saturating plume: laboratory studies
- H2SO4 accumulation on exhaust soot due to coagulation with sulfate aerosols and H2SO4/H2O heterogeneous nucleation: Q1D model
- H2SO4 chemical processing of soot particles toward their hygroscopicity: laboratory studies.
- Original soot produced by burning TC1 aviation kerosene in the combustor of a modern gas turbine engine D30-KU were sampling and analyzed by numerous techniques.
- The main findings:

1. Engine-generated soot is highly hydrophilic due to the existence of fraction of impurities; it contains 13.5 wt% water soluble compounds including 3.5 wt% organic and inorganic sulfates.
2. water uptake by engine soot increases with the temperature decrease in the plume and reaches 18 wt% at threshold contrail formation conditions.
3. fraction of impurities does not needed in additional activation behind the engine; it will produce CCN in the normal condensation process.
4. coagulation with sulfate aerosols and H2SO4/H2O heterogeneous nucleation leads to small H2SO4 coverage (~0.1 ML) at high FSC; it may result in hydrophilization only of the hydrophobic main fraction of engine-generated soot particles.
5. fraction of impurities of engine soot plays a key role in the CCN/IN formation at small water supersaturation in the plume.

Numerical Simulations of aircraft plumes using a meso scale code

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Condensation trails or “contrails” are the thin clouds that are commonly visible as white streaks behind aircrafts in otherwise clear sky. Due to the rapid growth of the commercial aircraft traffic, they became an important subject of academic research and practical interest because of their potential environmental impact as mentioned by the Intergovernmental Panel on Climate Change (IPCC) [Penner et al. (1999)]. Indeed, for suitable atmospheric conditions contrails trigger the formation of cirrus clouds, thus altering the radiative balance of the atmosphere. The subject of this study, which is part of the QUANTIFY project within the EU 6th framework program, is to analyze the contrail evolution from a few seconds up to some hours after the release of aircraft exhausts. The final goal is to simulate the contrail evolution at meso-scales (~100-200 km) so as to provide parameterizations to Global Climate Models.

The numerical code Meso-NH used for these simulations was jointly developed by the Laboratoire d’Aérologie (LA) and the Centre National de Recherches Météorologiques (CNRM). It is a non-hydrostatic meso-scale atmospheric model with a horizontal resolution ranging from 1 m to 1 km, allowing simultaneously up to 8 nested models to run. The basic prognostic variables are the velocity field and the potential temperature. In the present simulations, the code is run in a LES mode meaning that the transported turbulent kinetic energy (TKE) is used to model the sub-grid scale fluxes.

The modeling and simulation of the whole lifetime of a contrail represents a difficult task because of the wide range of spatial and time scales there involved. The proposed computational strategy is based on an integrated process of successive simulations, each one adapted to the scales and the relevant physical processes occurring at a given contrail age. In particular, we present here a dynamical study of the vortex and early dissipation regime of the contrail evolution in a stratified environment. The simulations start at an age of 20 s and end at 300 s. A 1 m resolution in the cross sectional plan is initially used; this is gradually reduced (and the computational domain enlarged) so as to deal with larger and larger scales as long as the contrail age increases. Interpolation and filtering are applied at each swap from one domain to the larger one. Validations are presented against the data provided in the work by Holzapfel et al. [Aerospace Science and Technology, 5 (2001) 95-108] and Holzapfel et al. [Aerospace Science and Technology 7 (2003) 263-275].

Near field and plume processes, effective emissions

Aerosol Evolution from a busy Road in North-West England

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Motor vehicle emissions are the most significant source of particulate matter (PM) in urban environments. This study was undertaken to observe the evolution of aerosols from a busy road, concentrating specifically of the aerosol total number maximum and number size distribution. A Grimm Aerosol Technik (5.400) CPC and DMA 5.5-900 classifier was used to measure ultra-fine particles from 9.8 nm to 1 µm at varying distances up to 100 m from the kerbside.

Using a busy main road in north-west England with a prevailing wind direction originating from the nearby Irish Sea measurements were collected downwind at varying distance from the roadside during crosswinds. Temperature, wind speed and traffic flow were also monitored during sampling. Under stable atmospheric conditions the highest particles number density was found to occur at 40 m from the road. The aerosol size distribution data showed an increase in the number of ultra fine particle (<100nm) some distance from the kerbside.

These findings are in agreement with similar findings presented by Gramotnev and Ristovski (2004). They are not easily explained by conventional aerosol dynamic and dispersion models which tend to consider aerosols to behave in a simplified standard manner at ambient temperatures. The releases from vehicle exhausts are at elevated temperatures. These findings suggest an alternative mechanisms may be necessary to explain aerosol evolution from traffic sources. These findings will be discussed with reference to this and results from other studies.

References

Gramotnev, G. and Z. Ristovski, Experimental investigation of ultra-fine particle size distribution near a busy road. Atmospheric Environment, 2004. 38(12): p. 1767-1776.

Investigations of road traffic emissions in Switzerland using a mobile laboratory

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For the assessment and understanding of the atmospheric processes that involve aerosols, it is necessary to study more aerosol properties than just the particulate mass. The combination of chasing experiments and dynamometric tests allows to determine real-world and quantitative emission measurements of vehicles at various driving conditions (e.g. different speeds, different road gradients). The goal is to investigate the relevance of the nucleation mode coming from vehicles for ambient conditions.

The mobile laboratory of the Paul Scherrer Instiute was redesigned to allow for controlled chasing experiments, implementing a bag sampler. Individual vehicles were tested both by the chasing and the dynamometric test method. Emissions plumes of a larger number of randomly chosen vehicles in regular traffic as well as particle concentrations in villages were investigated in a measurement campaign in South of Switzerland.

Results show that there is a quite good repeatability for measurements on test bench and dynamometer. For velocities up to 80 km/h no nucleation mode is seen for EURO 3 diesel passenger cars using low sulphur fuel. Whereas high number concentrations for particle diameters smaller than 30 nm were measured on the highway in Southern Switzerland for cold ambient temperatures using the Fast Mobility Particle Sizer (FMPS) from TSI, Inc. While overall the highway traffic is the main source of nanoparticles (often dominating the total particle number concentration), the wood burning in the villages are more important for the aerosol mass emissions in these valleys. The latter result is confirmed by 14C analysis and FMPS data.

Impact on atmospheric composition

Results of the SCENIC project : impacts of supersonic aircraft emissions upon the atmosphere.

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The SCENIC project has been funded by the European Union from 2002 to 2005. Its aims were to study the atmospheric impacts of possible future fleets of supersonic aircraft. In a unique partnership between relevant European industry representatives and atmospheric scientists, the project has used the most realistic aviation emissions scenarios to date within state-of-the-art numerical models of the atmosphere. The study has made an important contribution to a continuing European effort in supersonic civil transport.

The following questions have been assessed within the project:

a) How large are the impacts of a mixed fleet containing high-speed supersonic passenger aircraft on atmospheric composition and climate likely to be?
b) How can we reduce the possible environmental impacts generated by a supersonic fleet?

Changes in Ozone and Methane due to Aircraft NOx: Sensitivity to Cruise Altitude

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The LEEA (Low Emissions Effect Aircraft) project aims to develop a method of estimating the global climate effect of aircraft engine emissions as a function of cruise altitude. For this purpose we use a systematic approach to investigate the effects of small emission changes on CH4-NOx-O3 chemistry with the ultimate objective to develop a parametric relationship between the amount / altitude / location of emissions and their effect on the climate system. We have carried out a large number of sensitivity experiments with the global 3D chemistry transport model p-TOMCAT. Aircraft NOx emission data was used from the European AERO2k Global Aviation Emissions Inventory for 2002. In the experiments the standard emissions profile was altered such that for each experiment a local emissions increase of 5-20% was applied globally in a 2000 ft (610 m) cruise altitude band. In this way aircraft emissions were stepwise altered between 5-15 km altitude and the response in the concentrations of ozone precursor species, changes in ozone production efficiency and methane lifetime were investigated. Preliminary results for ozone suggest both linear and additive behaviour in the atmospheric response to the emission perturbations within the troposphere. Ozone production efficiency was diagnosed to be highly sensitive to the altitude of the emission perturbation. In addition to the effects of cruise altitude further experiments with regional emission perturbations in latitude bands were carried out. Whilst this paper presents the atmospheric chemistry aspects of the results, the radiative aspects together with the effects of contrail cover changes and the resulting overall climate impact will be presented in a companion paper by Rädel and Shine: \"Sensitivity of radiative forcing due to aircraft altitude\". The LEEA project is funded by Airbus UK and the UK Department of Trade and Industry.

Ship emissions impact on atmospheric composition - case study

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The impact of emission from transportation on climate change is being quantified in EC FP6 Integrated Project QUANTIFY. In Activity 2 the analysis of the dilution and transformation of the emission from microscale at exhausts and plumes till mesoscale distribution will be provided from all modes of transportation. In this

contribution the mesoscale simulation of ship emission impact on atmospheric pollution in selected region is studied with emphasis to test the sensitivity to ship emissions.
The couple MM5-CAMx is used for this purpose, covering the domain of campaign planned for the project, i.e. the Channel, with outer domain with resolution 36x36 km, first inner one with resolution 12x12 km and the second nested domain with resolution 4x4 km placed with respect to the location of ship for individual ship plumes experiments. At this stage emissions from EMEP 50 km x 50 km database are interpolated and represent average ship emissions in the Channel, other emissions are combination of EMEP and UAEI (United Kingdom Atmospheric Emission Inventory).
CB-IV chemistry mechanism is used in CAMx for this study in default settings, some changes are tested with regard to the ship emission in marine boundary layer to find and adopt proper setting in model chemistry applicable for campaign simulations and for study of the mesoscale impact of ship emissions on atmospheric composition.

Multi-model simulations of the impact of international shipping on atmospheric chemistry and climate in 2030

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Seagoing ships emit exhaust gases and particles into the marine boundary layer and significantly contribute to the total budget of anthropogenic emissions. The impact of shipping on air quality and climate is quantified from an ensemble of 10 state-of-the-art atmospheric chemistry models for present-day conditions and two future ship emission scenarios for the year 2030. In one of the 2030 scenarios ship emissions remain constant at 2000 levels whereas the other scenario is a non-proliferation scenario in which emission factors are unchanged and emissions increase with an annual growth rate of 2.5 % p/y between 2000 and 2030. The change of tropospheric ozone distributions and corresponding radiative forcings for the different scenarios are investigated. Results from individual models and the multi-model mean show significant changes in surface ozone and surface NO2.
The study addresses how the influence of ship emissions on ozone in 2030 could be if they were unabated. It is also discussed if an ensemble of models gives approximately the same answer than individual models regarding this.

Impact on atmospheric composition

The impact of increasing ship emissions on air quality and deposition over Europe

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While SO2 and NOx anthropogenic emissions from land-based sources have decreased dramatically over the last decade, and are predicted to decrease further over the coming decades, emissions from shipping have increased and are expected to increase further. Estimates of future growth in shipping traffic range from 1.5%/yr to 2.5%/yr. This paper presents investigation of the impact of the effect of the growth in shipping traffic over the next 30 years on particulate air quality and deposition of eutrophying and acidifying compounds (SO4--,NH4+,NO3-) over Europe. This investigation with the Met Office STOCHEM/HadGEM model, uses results from runs we submitted to the ACCENT multi-model intercomparsion on shipping effects.

Simulation of future road and ship traffic impact on air pollution

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Ship and road traffic is assumed to increase in the future. Current emission cataster for future emissions (2050) do not provide detailed data for single sources. Therefore we created our own emission data following simple assumputions on the future increase of road and ship traffic. The simulation with the CTM MOZART4 provided new insightes into changing air pollution characteristics in most regions of the world, e.g. in such diverse regions as South East Asia or in the Arctic.

Impact on clouds

Analysis of Missing Contrail Effects During USA Air Traffic Shutdown

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Separating natural clouds from those formed by contrails in high traffic areas is a complex task because contrails and cirrus tend to form in similar conditions. However, persistent contrails can also form in drier air than natural cirrus, thus providing a means for forming additional cloudiness in certain conditions. To better assess the contrail-induced impact on cirrus cloud cover and temperature, the relationships between upper tropospheric humidity (UTH) and temperature (UTT) from numerical weather analyses and cirrus from satellite data are examined during the periods before, during, and after the air traffic shutdown in the United States of America (USA) following the terrorist attack of September 11, 2001. Hourly, 40-km Rapid Update Cycle (RUC) analyses provide the UTT/UTH fields, analyses of Terra Moderate Resolution Imaging Spectroradiometer (MODIS) data provide estimates of contrail and cirrus coverage twice per day, and hourly analyses of the GOES-8 and 10 imager data provide a more detailed assessment of the upper-level cloud cover. Correlations between cirrus coverage and UTT/UTH are developed for the days during the air traffic shutdown to establish a contrail-free baseline relationship between cirrus and the atmospheric state. Military contrails are screened out as much as possible and used to estimate the contrail-state parameter relationships. Similar correlations are developed at night during the lull in air traffic and during the regular air traffic conditions to estimate the combined contrail-cirrus dependence on the model parameters. These relationships are used to estimate the extent of cirrus that should have occurred during the air traffic shutdown in normal conditions. The results are compared to estimates of cirrus and contrail coverage that are simulated using the baseline relationships and the average air traffic. The results provide an estimate of the missed contrail coverage and its uncertainty. Impacts on surface temperature are also evaluated.

Natural versus man-made trends in cirrus clouds

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Long–term changes in cirrus cloud cover (CCC) from ISCCP updated to the year 2005 are correlated with aviation flown distance in 2000 by the QUANTIFY emission datasets and compared with corresponding changes in natural parameters (i.e. vertical velocities and relative humidity at 300 hPa from NCEP) at altitude levels with high air traffic. Results presented in this study generally confirm earlier findings on possible effects of aviation on cirrus cloud positive trends over congested air traffic regions (Zerefos et al., 2003). More specifically, long–term changes in CCC from 1984 to 2005 continue to be positively correlated (+0.6) with aviation travelled distance over the northern middle latitudes but not over the tropics. This could be explained by the fact that in the tropics the observed changes in cirrus clouds continue to be correlated with corresponding changes in vertical velocities and relative humidity at 300 hPa (–0.4 and +0.8, respectively), confirming the correlations found in Zerefos et al. (2003) when the records are updated for six more years. Results from recent studies on the increases of cirrus clouds due to air traffic (Minnis et al., 2004; Mannstein and Schumann, 2005; Stordal et al., 2005; Stubenrauch and Schumann, 2005) are also confirmed. The long–term trends in CCC are decreasing over the globe and therefore the significance of the upward trends over areas congested by air traffic is augmenting the significance of the positive statistical trends.

Impact on clouds

Contrail cirrus coverage and radiative forcing derived from satellite data

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Air-traffic has an impact on cirrus cloud cover and consequently the radiation budget of the earth-atmosphere system. This work examines the impact of air-traffic on cirrus coverage as well as the first time direct on outgoing flux density on top of the atmosphere (TOA) using simultaneous observations from Meteosat Second Generation (MSG) SEVIRI instrument and high spatial and temporal resolution air-traffic data from EUROCONTROL (European Organisation for the Safety of Air Navigation). The study shows significant correlations between air-traffic density on the one side and cirrus coverage, outgoing long and short wave radiant flux densities on the other side. The relation between air traffic and radiant fluxes depends strongly on daytime and season

Sensitivity Study on Contrail Evolution

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It has become increasingly clear in recent years that under certain conditions, aircraft contrails will persist and grow into significant cloud cover that might otherwise be confused with natural cirrus. The projected large increases in air traffic in the coming decades and potential impact of increased cloud cover on global climate change has led to a growing realization of the importance of understanding the formation, properties, and effects of persistent contrails. A preliminary sensitivity analysis on contrail evolution out to 1000 seconds has been performed using 3-D high-resolution large-eddy simulations to solve the wake and plume development, coupled with a binned ice microphysics model. Parameters of the study include atmospheric pressure, temperature and relative humidity (with respect to ice), as well as two different aircraft, the Boeing 767and 747. Variations in the turbulent realizations and the effective ice crystal number engine emission index have also been performed. The results of the sensitivity analysis shed light on the relative importance of ambient and aircraft parameters on contrail growth. The aircraft wake dynamics in the first few minutes can have profound effects on the properties of the resulting persistent contrails. This occurs both through its governing of the initial plume dispersion and through the loss of a significant fraction of the ice crystals due to adiabatic heating in the falling wake plume, even for large ambient supersaturation levels. The relative humidity and temperature can have a significant impact on the contrail evolution as expected, while pressure only has a weak effect. Differences in the type of aircraft illustrate the effects of the fuel flow rate and the engine placement for different platforms.

DEVELOPMENT OF METHODS TO RESEARCH ATMOSPHERE CONTAMINATIONS, CONDITIONS OF FORMATION AND COMPOSITION OF AIRPLANES` CONDENSATION TRAILS

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Present-day evaluations of anthropogenic impact on environment confirm the importance of better understanding the role of atmospheric contaminations (particles, aerosols and gases) in direct and indirect influence on climate changing. The influence of these contaminations appears in increasing the atmosphere radiation properties, i.e. \"greenhouse\" effect. Cirrus clouds play a very substantial role in that process, therefore increase of their area, as a result of anthropogenic impacts, may in the future be a cause of noticeable growth of terrestrial surface temperature.

The most substantial factor of aviation influence on formation and development of cirrus clouds are condensation trails, which are created as a result of condensation and freezing of water vapour, contained in the aircraft engine exhaust jet. The condensation trails are created at the same altitudes as the cirrus clouds, they have a structure similar to them and they are even called as artificial cirrus clouds (Cirrus tractus). Its optical

properties depend on quantities and sizes of the particles, emitted by the aircraft engine or created in exhaust jet and on ambient atmosphere conditions also.
The complex consideration of problems, associated with environmental conservation and with searching the ways for their solution has permitted to come to conclusion about possibility and expediency of aircraft using, and using the special equipment to aviation monitoring the contamination of air medium, including quantitative investigations of aircraft engines emissions influence on atmosphere contamination and contrails formation in airports areas and in the cruise flight conditions.
The following will be outlined in the presentation:
- development of the methods and the experimental means to investigate contrails formation conditions and their characteristics and the relation with cirrus clouds parameters;
- development of the methods to perform solo and paired flights of aircraft-gas generator and aircraft-prober taking into account the contrails formation conditions prediction and flight experiment carrying-out;
- development of the method to investigate the contrails formation in loaded routes areas for civil airplanes;
- identification of the calculation model basing on flight experiment results on estimation of the contrails formation conditions and their characteristics and basing on results of the contrails parameters measurements in areas of loaded routes for civil airplanes.

Effects of soot aerosols from aircraft on cirrus clouds

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Anthropogenic aerosols may alter clouds by acting as cloud condensation nuclei (CCN) or as ice nuclei (IN). In warm (liquid phase clouds) and increase in CCN is known to cool the climate, but in cirrus clouds, since the absorption of long-wave radiation is larger than the reflection of solar radiation, the increase in IN may act to warm the climate. Here, we examine the possible effect of anthropogenic aerosols on cirrus clouds. The effect of aerosols on cirrus clouds depends on the aerosols present in the upper troposphere as well as the relative humidity distribution and updraft velocity distribution. We apply two different parameterizations for the impact of aerosols on cirrus clouds using the NCAR CAM3 model and compare the resulting ice particle sizes and number concentrations with observations. The forcing by anthropogenic aerosols may be as large as 0.4 to 0.7 Wm-2, with the effect of soot from aircraft as large as 0.13 Wm-2.

Detection and quantification of impact of traffic emissions on clouds

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Ship emission continue to grow globally, even though land based emissions are decreasing in most of the regions. Ship emission affect the cloud properties and thus play significant role in Earth's radiation budget. We judge possibility of using long-term satellite measurements (mainly from AVHRRs onboard NOAA satellites, along with other new sensors like MODIS,MOPITT) to detect and quantify indirect aerosol effects on regional scales. We show changes in cloud physical properties due to ship emissions and how significant they could be. Possibility of using these data sets to detect influence of road traffic on clouds will also be discussed.

Impact on clouds

Global Distribution of ship tracks from one year of AATSR data

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Emissions from ships are influencing an otherwise very clean environment, the maritime boundary layer. One important aspect is that under certain meteorological conditions aerosol emissions from ships modify existing marine stratocumulus clouds by an increase of cloud condensation nuclei and a decrease in droplet size resulting in a change in cloud reflectivity. These so-called ship tracks can be detected with the help of remote sensing techniques and can be seen as long curves of increased cloud reflectivity in satellite images. Ship tracks can spread over several kilometres and the kind of modification is ranging from new formation of clouds over an almost cloud free ocean to cloud modifications of already existing maritime stratiform clouds. This change in the optical structure of clouds has an impact on the local radiation budget below and above the cloud and earlier studies suggested an influence on the energy budget of the earth due to increased global backscattering.

The Helmholtz Junior Research Group SeaKLIM is interested in the impact of international shipping on the chemical composition of the atmosphere and on climate. In this particular study we are using satellite data for the year 2004 from the AATSR instrument onboard Envisat, and derive a statistic for low cloud distributions in the offshore maritime boundary layer. Further analysis of the low clouds allows an estimation of the global radiative forcing due to ship tracks. A high spatial and temporal variability is observed. The majority of ship tracks occur in the NE Pacific and the North Atlantic, where strong ship traffic meets a high probability of maritime stratus clouds, i.e. in oceanic upwelling regions at the continental west coasts. Estimations of the radiative impact are presented by calculating cloud properties of the ship tracks. Based on these calculations, we also point out the high uncertainty of estimating the influence of ship tracks on the atmospheric radiation budget, because ship tracks show a high variability in shape and radiative properties.

Assessment of a Global Contrail Modeling Method

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Estimates of radiative forcing contributions from aircraft have raised concerns about the impacts of contrails and aviation-induced cirrus on climate. Increasing demand for aviation will further increase contrail formation. This paper provides a model to assess operational options for reducing contrail coverage. Unlike previous studies, the model couples realistic flight performance with hourly meteorological data and makes a direct comparison of contrail estimates to satellite imagery. Key areas for future research are identified through assessment of contrail estimates using NASA satellite images.

Comparisons were made between contrails identified from satellite images and contrail persistence estimates from flight data for 53,844 U.S. continental flights performed during the week of November 12-18, 2001. The satellite data were processed by NASA Langley Research Center using methods for identifying contrails adapted from Mannstein (1999). Given detailed knowledge of the aircraft types and radar-based trajectory data, simulated contrails did not match contrails observed in the satellite images. First, cloud and ground formations were misidentified as contrail pixels. This resulted in most linear image features aligning N-S, while most aircraft routes in the region were aligned E-W. We estimate that 40-50% of the linear features present in the satellite data were misidentified as contrails. Second, a total of 60-90% of the pixels that were either identified as contrails or misidentified as contrails but related to regions of striated cloud formations, occurred in areas where the assimilated meteorological fields of Rapid Update Cycle Data (40km x 40km) showed RHi less than the threshold needed for contrail formation. This demonstrates that the RHi fields, although similar in character to the cloud formations sensed by the satellite, did not accurately portray the true RHi fields for the days we examined in 2001. Finally, the typical length of the estimated contrails was larger than 100km, (several degrees in length), while the typical length of the observed contrails was about 50km. This length is much larger than the meteorological grid scale resolution, so is not a reflection of subscale RHi gradients. Rather, this occurs because the SAGE Aviation Model used for this study compresses the radar tracks for storage purposes by concatenating several chords into a single chord. The discrepancy between the long predicted contrails and the short observed contrails implies that the chord lengths used within SAGE need to be shortened - at least to the extent that they are consistent with length-scales observed in the RHi data.

Impact on clouds

Probabilistic Forecast of Contrails within Cirrus Coverage

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Contrails and cirrus tend to form in similar atmospheric conditions, and thus it is difficult to determine how much persistent contrail coverage affects cirrus coverage. It is clear, however, that contrails that form imbedded in thick cirrus clouds will have little or no impact on climate, while persistent contrails that form in otherwise clear skies will have a greater direct effect on climate. To determine the atmospheric conditions when contrails form within cirrus (and when they form in the absence of cirrus), meteorological variables derived from high-resolution numerical weather analysis models are compared with cirrus and contrail cloud occurrence deduced from multi-spectral satellite measurements. Multi-spectral radiances measured by the Advanced Very High Resolution Radiometer (AVHRR) onboard the NOAA-16 polar-orbiting satellite are collected during afternoon overpasses of a 4 by 6 degree area centered over the states of Ohio, western Pennsylvania and West Virginia (from 38N to 42N, and 84W to 78W) between April 2004 and April 2006. For each 1 by 1 degree grid box within the sample area, persistent contrails and cirrus are detected from the satellite radiances. Using meteorological data from the Rapid Update Cycle (RUC) and the Advanced Regional Prediction System (ARPS), the occurrence or non-occurrence of contrail and cirrus formation within the sample area are related to several atmospheric variables (including upper tropospheric temperature, humidity, wind and atmospheric stability) through logistic regression techniques. A probabilistic forecast model is developed in a manner similar to the Model Output Statistics (MOS) forecasts produced by the US National Weather Service (NWS). Forecast models are developed for the occurrence of persistent linear contrails forming both with and without surrounding cirrus clouds. The atmospheric variables that are selected as the most valuable predictors for both models will be compared, and may provide insight into which atmospheric conditions are most susceptible to the formation of possible climate-altering contrails.

Radiative forcing and impact on climate

The importance of the diurnal and annual cycle of air traffic for contrail radiative forcing

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We used a state of the art radiative transfer model to calculate radiative forcing by contrails over south east England. For background atmospheric conditions we used MetOffice radiosonde profiles for 2003 for the station Herstmonceux. Applying the Schmidt/Appleman thermodynamic criterion for contrail formation we decided if conditions were favourable for forming a contrail. Contrail coverage was based on the AERO2k data base. The contrail coverage has a daily as well as annual variation. As a consequence the contrail induced radiative forcing is influenced by atmospheric conditions and the annual and daily variation of solar insolation as well as the variation of air traffic with time of day and season. Analysing the annual cycle of contrail radiative forcing for south east England we find that winter (DJF) flights contribute 50% to the annual mean forcing even though they account for only 22% of the annual total of air traffic. An analysis of the diurnal cycle of contrail radiative forcing reveals that the daily mean forcing is dominated by night-time air traffic: 82% of the diurnal mean forcing is due to night time flights. This is especially remarkable as flight restrictions result in far less flights during the night. Radiative forcing due to daytime flights can even be slightly negative. In short, winter-time night flights are responsible for most of the contrail radiative forcing over south east England. Analysing the global mean contrail radiative forcing we find only a small seasonal variation in the net forcing. Local night time flights account for only 37% of the global daily total of flights. However, they contribute a disproportionate 60 to 76% to the annual, diurnal mean forcing.

Climate impact of supersonic air traffic: An approach to optimize a potential future supersonic fleet – Results from the SCENIC EU-project

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The demand for intercontinental transportation is steadily increasing and people are requesting short travelling time, which supersonic air transportation would enable. However, besides noise and sonic boom issues, which we are not referring to in this investigation, emissions from supersonic aircraft are known to alter the atmospheric composition and therefore climate significantly more than subsonic aircraft. Here, we propose a measure to quantitatively assess different options for supersonic transport with regard to the potential destruction of the ozone layer and climate impacts. Options for fleet size, engine technology (nitrogen oxide emission level), cruising altitude, range, and cruising height, are analyzed, based on SCENIC emissions scenarios for 2050, which underlay the requirements to be as realistic as possible in terms of e.g., economic markets and profitable market penetration. This methodology is based on a number of atmosphere-chemistry and climate models to reduce model dependencies. The model results differ significantly in terms of the response to a replacement of subsonic aircraft by supersonic aircraft. However, model differences are smaller when comparing the different options for a supersonic fleet. The base scenario, where supersonic aircraft get in service in 2015, a first fleet fully operational in 2025 and a second in 2050, lead in our simulations to a near surface temperature increase in 2050 of around 8 mK and with constant emissions afterwards to around 35 mK in 2100. The related total radiative forcing amounts to 16 mW/m2 in 2050, with an uncertainty between 9 and 29 mW/m2. The scenario with a reduced supersonic cruising altitude or speed (from Mach 2 to Mach 1.6) reduces both the climate impact and the ozone destruction in the order of 40%. The scenario with increased ranges leads to more emissions at lower latitudes since the more routes to SE Asia are taken into account, which increases the ozone depletion, but reduces the climate impact compared to the base case.

Radiative forcing and impact on climate

Climate Impacts of Transport Systems: Chemical responses and radiative forcing

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The impacts of historical and current emissions from all major transport sectors (road, rail, marine, and air traffic) on the global climate are assessed in terms of current and future radiative forcing. Particular emphasis is given to the effects of short-lived species, such as tropospheric ozone (through emissions of precursors) and aerosols, in addition to the long-lived greenhouse gases (mainly CO2). Since current atmospheric levels of the long-lived gases are determined by emission histories, we estimate historical emissions for each of the four transport sectors to calculate their specific contributions to radiative forcing from pre-industrial times. For the short-lived species we use a global 3-D chemical transport model (Oslo CTM2), which includes a comprehensive photochemical scheme and modules for sulphate, soot and organic carbon aerosols. A radiative transfer model is used to calculate the radiative forcing from the changes in gases and aerosols. The transport sector causes radiative forcing of both signs (i.e. warming and cooling) and we find large differences in magnitude of forcing between the various gases/aerosols as well as between the different transport sectors. The dominating current forcing is due to CO2 and tropospheric O3, while sulphate and reductions in CH4 lifetime cause significant negative forcing. Road transport is the sector with the largest net forcing, while marine transport causes a significant negative net forcing, mainly due to increased sulphate levels and reduced atmospheric lifetime of methane. In addition to using radiative forcing from pre-industrial times up to present as the metric for comparisons (i.e. a backward looking perspective), we also compare, using different time horizons, the future radiative forcing from the current transport emissions. This provides a more relevant metric for policy-making.

Sensitivity of radiative forcing due to aircraft altitude

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Emissions by aircraft are one possible contributor to human induced climate change. They are attracting considerable attention because, with the predicted growth of aviation, they could contribute significantly to future climate change.
Besides aircraft emissions of greenhouse gases such as CO_2, water vapour, and ozone and methane via NO_x, the formation of contrails, which can persist for several hours and spread out to eventually become cirrus clouds, is another factor changing the radiation budget of the Earth, which is still subject to large uncertainties.
The objective of the LEEA (Low Emissions Effect Aircraft) project, funded by Airbus Industries and the UK Department of Trade and Industry, is to develop a method of estimating the global climate effect of various aircraft engine pollutants as a function of the cruise altitude.
We will present first results of this project, concentrating mainly on the radiative impact of persistent contrails, and of ozone changes due to aircraft NO_x emissions. In order to determine the radiative effect of aviation on climate, different sophisticated radiation codes have been used together with the AERO2k flight database, providing realistic information on air traffic in 2002.
Perturbation experiments have been performed increasing the air traffic in certain atmospheric layers and thus allowing an assessment of the sensitivity of the radiative forcing to the aircraft cruise altitude. Part of our results are based on ozone changes calculated by the p-TOMCAT chemistry transport model within the LEEA project. The experiment design and the corresponding chemistry aspects are presented in a companion paper by Koehler et al. \"Changes in Ozone and Methane due to

Aircraft No_x: Sensitivity to Cruise Altitude\".

Radiative forcing and impact on climate

Climate Sensitivity of Radiative Impacts from Transport Systems

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Radiative Forcing and Global Warming Potential have been the most common metrics to quantify and to intercompare indvidual contributions to the total anthropogenic climate impact. However, this implicitly assumes Radiative Forcing to be a reliable predictor for the expected global mean temperature change. There is increasing evidence that this assumption is not really valid for spatially and temporally varying radiative perturbations of the climate system, such as contrails or ozone change patterns arising from surface or aircraft NO$_x$ emissions.

As long as no superior metric to assess individual impact contributions has been found, the determination of individual climate sensitivity parameters for each effect offers a way out of the dilemma. Beyond its radiative forcing each effect is thus attributed with an climate impact efficacy that may serve as a weighting factor for that effect.

Examples for some transport related effects are presented and discussed on the basis of equilibrium climate change simulations conducted with the ECHAM climate model. Contrails seem to have a comparatively small efficacy, casting some doubt on recent estimates that have suggested a strong impact of aviation on temperature trends over the U.S.A. The efficacy of non-homogeneous ozone change patterns may also deviate from the reference value for homogeneous CO2 changes, but a considerable level of respective model-dependency continues to exist at this stage.

Results from pulse scenario experiments with the CNRM-CM3 global coupled model

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Climate simulations have been performed with the global coupled ocean/ice/atmosphere model CNRM-CM3. Upon pre-industrial background conditions, perturbations in the solar constant or the carbon dioxide concentration were applied. The perturbations consist of a sudden increase followed by an exponential decay.

These simulations reveal in a clear way the response time of the climate system to sudden changes in the radiative forcing. The CNRM-CM3 model shows a fast adaptation of the atmosphere within 10 years. However, the reaction of the ocean is much slower, and adaptation happens on a timescale of 50 years. The results also seem to suggest that the release of the extra heat stored in the ocean due to the temporarily increased radiative forcing, is released on time scales of more than 250 years. Comparisons with simulations with sustained perturbations show the usefulness of these simulations.

These experiments have been done in the framework of the QUANTIFY project, and identical experiments have been performed at the University of Reading. The results of these simulations can be used to improve metrics and to validate simple climate models

A climate response model for calculating aviation effects

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Simplified climate models can calculate temperature response from small forcings without the need for considerable computer resources. Therefore, these models can be used to provide an initial assessment of the impacts of engine and aircraft technology developments over the long-term.

A linear climate response model using Green's functions has been formulated to calculate radiative forcing (RF) and the temperature response for aviation's effects on the global atmosphere. The model – LinClim – includes CO2, a parameterized methodology for O3 from aviation NOx, a reduction in the CH4 RF from aviation NOx,

contrails, sulphate and black carbon aerosols. From these RFs, temperature responses may be calculated from individual effects in order to determine their relative importance by applying preliminary values for efficacies for the individual effects. The model is tuned to a parent GCM, ECHAM4 and its coupled ocean model. In addition, parameterized methods developed by the IPCC are used to calculate background O3, CH4, sulphate and black carbon forcings.
The model shows good agreement with other simplified models and is able to reproduce IPCC (1999) 2050 aviation-related forcings.
The model is shown through some example application analyses to be a useful tool for exploring the effects of aviation on RF and temperature response, and the potential technological and atmospheric tradeoffs between controlling different emissions.

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Valuing the Impact of Aviation on Climate

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We present an assessment of the marginal future climate costs of new aviation activities. Three features of the work, when taken together, present a new approach with respect to prior considerations of aviation's impact. First, to remove the confounding effects of different assumptions of future aviation growth, we consider the marginal impacts of a unit of aviation emissions (one year) against various background CO_2 growth scenarios. Second, we assess the impacts in terms of marginal changes in surface temperature and value these in terms of health, welfare and ecological costs under different assumptions for discount rates, since monetary estimates are ultimately required for making policy decisions. Third, and most importantly, since uncertainty is high regarding many aviation effects, we explicitly capture the uncertainty by representing most model parameters as probabilistic distributions. The uncertainties are then propagated using Monte Carlo analysis to derive estimates for the impact of these uncertainties on the marginal future climate costs of various aviation impacts (CO_2, NO_x on methane, NO_x on ozone, and contrails/induced cirrus).
To determine the change in atmospheric CO_2 due to one year of aviation emissions and the subsequent change in surface temperature, we employ non-linear impulse response functions derived from a coupled carbon-cycle and climate model (*Hooss, Voss, Hasselmann, Maier-Reimer, and Joos,* 2001). Following (*Sausen and Schumann*, 2000) and (*Lee and Sausen,* 2003), aviation short-lived effects are represented by scaling the normalized radiative forcing for a different climate responses relative to CO_2. For all short-lived effects except for that of NO_x on methane, we assume the radiative forcing is only active in the year of the emissions. For methane we consider a radiative forcing impact for ten years after emission (*Prather*, 1996). The estimated surface temperature changes are valued using results from the Regional Dynamic Integrated Model of Climate Change and the Economy, (*Nordhaus and Boyer*, 2000).
We present results to describe the influence of parametric uncertainties on the expected marginal future costs of aviation impacts. We show that under most scenarios, CO_2 is the dominant contributor to expected future damage costs, followed by NO_x. Shorter-lived effects are less important.

Radiative forcing and impact on climate

Radiative forcing and temperature response from global shipping emissions

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The climate impact of shipping emissions has recently been under discussion as a significant and growing source of emissions in a similar manner to aviation. Initial estimations of effects has quantified both positive and negative radiative forcings from CO2, NOx effects on O3, black carbon, and direct and indirect effects of sulphate particles. In this work, we take recent estimations of historical and future scenarios of shipping CO2, NOx and and S emissions (Eyring et al., 2005a, b) to make initial calculations of radiative forcings and potential temperature responses using a linear climate response model specifically adapted to calculate sectoral emissions (Lim et al., 2006).
It is shown that CO2 emissions and forcing are potentially larger than those from aviation (a sector with a similar history and range of future projections): NOx emissions are much greater than those from aviation but have a similar radiative forcing. Preliminary calculations of the effects of sulphate are made but these are much more uncertain than the CO2 and NOx calculations.

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Aerodynamically induced condensation trails

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Current contrail research focusses on jet engine exhaust contrails. However, there is evidence that a different type of contrails can additionally form as consequence of extremely rapid air cooling in the aerodynamic air flow over the wings. These aerodynamic contrails could in principle form above the formation threshold for jet contrails. However, little is known about their properties and atmospheric relevance. In the presentation we will discuss representative examples and present first results of calculations of the aerodynamics, microphysics, and optical properties of aerodynamic contrails.

Mitigation by technical and operational means

Alternative Fuels Well To Wing Analysis of Aviation Transport CO2 Emissions

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The study which is described is focused on CO2 emissions of aviation transport which contributes among other sources, to the climate change concern. It is motivated by the air-traffic increase, estimated around 4,1% per year in average until 2020, and by the potential interest of alternative fuels solutions in order to mitigate the aviation green house impact.

In this frame, a Well to Wing analysis, close to what is already currently performed for car transport (and called Well to Wheel analysis), is applied to aviation transport. This analysis provides comparisons between the three fuel options, kerosene, cryogenic CH4, cryogenic H2, with different assumptions on the way these three fuels are produced, going from fossil to renewable solutions.

The basis of previous studies applied to car transport, are exploited for the Well to Tank part of the analysis. The complementary Tank to Wing part of the analysis includes current representative values of fuel efficiency for kerosene and estimations for methane and hydrogen using simple models. These values are also extrapolated to take into account aircrafts and engines technology improvements targets in 2020. In addition to CO2 emissions assessments and comparisons, some engine technological features and uncertainties, corresponding to the type of fuel used, are summarised.

The study may be interpreted too in term of fossil energy use, as the Well to Wing CO2 emissions are directly proportional to the fossil fuel Well to Wing consumption. The paper recalls existing studies such as the European Cryoplane project concerning H2 fuel; the indirect green house effect of NOx and particulates from aviation is recalled but not considered in the study.

Alternative fuels perspectives are one of the major topics of the Aeronet III european forum in which Snecma is involved.

Clean Exhaust Engine Concept

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Water vapor, soot and aerosol emissions into the upper atmosphere affect the Earth's energy budget in particularly as it relates to the formation of persistent contrails and the formation and modification of cirrus clouds. The need for green transport aircraft has been identified as there is growing evidence that contrails and aviation induced cirrus clouds contribute to global warming. For this reason, a novel engine concept for commercial aircraft has been invented in order to avoid the formation of contrails and cirrus clouds with significantly reduced CO2 and NOx emissions. This novel engine concept is based on a modified intercooled and recuperated cycle driving fans for propulsion.

Liquid water, as a result of burning hydrocarbon based fuel, is removed from the exhaust gas and can be either retained onboard the aircraft until a flight mission is completed, or released into the atmosphere in liquid phase for precipitation. So far, sensitivity analysis indicate the feasibility of the concept considering ambient conditions at typical cruise altitudes in a highly ice-supersaturated atmosphere. The actual mixing line slope is reduced significantly compared to the theoretical mixing line slope.

The paper will discuss the feasibility of the novel concept including performance predictions and a system level analysis for a weight and volume assessment. An engine/aircraft integration analysis is carried out using advanced performance prediction tools combined with evolutionary optimisation algorithms to outline the benefits of the optimised engine/aircraft configuration and investigate installation issues.

On how to consider the Earth's atmosphere in aircraft design

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The continuously increasing knowledge in atmospheric sciences and atmospheric modelling has started to enable the environmental assessment of aircraft emissions. Aeronautical engineering will thus require such to be considered in future aircraft design.

Mitigation by technical and operational means

Until now, aviation's atmospheric emissions and potential contribution to climate change have been minimised by improving engine technology, refining operational procedures and by adapting the aircraft design, for example by lower weights and less aerodynamic drag. But civil aviation also includes operations, airlines, passengers, air traffic management and economy – domains that generate often contradictory requirements for aircraft design. The consideration of the environmental impact of aviation adds a very complex and interlinked aspect to current basic design requirements.

We are developing a methodology that enables preliminary sensitivity studies to be conducted to determine the repercussion of technological advances in aircraft design on the atmospheric impact of aviation.

As the quantity and location of aircraft emissions are strongly related to operations, an aircraft design based on new technologies is to be embedded in the worldwide traffic. With the help of a market forecast and aircraft performance data, a global emission scenario is created. This process enables the assessment of the respective operational adaptations such as new flight altitudes or speeds, which will result from the new aircraft concept. For the subsequent evaluation of the impact on the atmosphere, some atmospheric metrics and modelling will be included in the process as soon as these are available. A sufficient reliability of the metrics is a prerequisite for their confident integration into the design process. Varying aircraft parameters of the investigated aircraft concept enables a comparative study between the resulting emission scenarios and their respective atmospheric impacts.

Some technology variations are modelled and first findings are described in the paper. The paper will explore the interdependencies of the different aviation stakeholders. Concrete examples such as multistage operations and air-to-air refuelling will illustrate the difficulties in moving from theoretical advances to application in real operations. The complexities associated with the consideration of the environmental impact in aircraft design will be highlighted.

The Reduction of Transport Emissions in Jamaica through the Manipulation of Road Network Condition

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Matters such as the Kyoto protocol have raised the profile of environmental issues and there is now an ever-increasing awareness of how human activity contributes to environmental degradation. Motorised transport has received particular attention primarily because of the characteristics and quantities of emissions derived from the consumption of non-renewable energies. This assumes further significance when consideration is given to the fact that energy used for road transportation constitutes a significant component of the total energy consumption in most countries.

The appraisal of investment in road transport infrastructure usually involves a comparison of (the savings in) road agency costs and road user costs, which leads to the identification of the most economically feasible alternative. However, appraisal procedures have been extended to include other considerations such as technical requirements and environmental concerns. The Highway Development and Management (HDM-4) software package, developed by the World Bank, is one such tool that employs this multi-criteria approach towards the assessment of investment in transport infrastructure.

Policies and practices in developing countries have come under increasing scrutiny because of their polluting nature. The almost complete reliance on road networks for transport requirements in Jamaica and the poor condition of a significant proportion of its road network has contributed its transport sector being identified as one of its largest sources of atmospheric pollutants. Hence, the drive towards sustainability necessitates that any ongoing and future investment in Jamaica's transport infrastructure is also evaluated in environmental terms.

This paper explores the inter-relationships between Jamaica's inadequate public transport system, the poor road network condition and the resulting volumes of atmospheric pollutants that are produced. The underlying models of the HDM-4 software package which identify alternatives that minimise emissions and total life-cycle energy consumption are discussed. The application of these models to the Jamaican situation is explained and further illustrated through the use of a case study.

Mitigation by technical and operational means

Operational impacts of trajectory adjustments to avoid ice-supersaturated regions

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Contrails and the cirrus clouds they form may have a climate impact as large as that of the CO2 emitted by aircraft. One opportunity for reducing the climate impact of aviation could be offered by in-flight adjustments to the flight profile to avoid regions of ice super-saturated air, to prevent the formation of contrails.

This paper explores the potential operational impacts of such a policy, including the consequences for air traffic management and the impact on emissions. Fast time air traffic simulations are used to assess the feasibility of such an approach in areas with high air traffic density. The simulations use a 1-day traffic sample for the UK and test the possible disruption associated with an imposed contrail avoidance zone with a radius of 40nm and thickness of 2000ft situated in the South East region.

CONCENTRATIONS AND CHARACTERISTICS OF PARTICLES WITHIN COMMERCIAL AIRCRAFT EXHAUST PLUMES

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To quantify and better understand the factors that control the generation of particles and pollutants by commercial aircraft during ground-based operation, NASA and other U.S. federal and state agencies have recently sponsored four collaborative field investigations, including: 1) the January 2002 Experiment to Characterize Aircraft Volatile Aerosol and Trace Species Emissions (EXCAVATE), which sampled emissions from NASA's B-757 (RB-211-535 engines); 2) the May 2004, Aircraft Particle Emission Experiment (APEX-1), which sampled exhaust from NASA's DC-8 (CFM-56-2); 3) the August 2005 APEX-2, which measured exhaust emissions from four separate Southwest Airlines B-737s (CFM-56-3,7); and 4) the November 2006 APEX-3, which sampled emissions from NASA's Learjet-25 (CJ610 engine), a Federal Express A300 (PW4158), and Continental Airlines B-757s (RB-211-535-E4B), ERJ145s (AE3007-A1P, -A1E), and B-737-300s (CFM-56-3). Objectives of these experiments included determining the concentration, composition, and microphysical properties of particles emitted by the aircraft as functions of engine power, fuel composition and plume age. Instruments were deployed to measure particle concentration, size, fractional volatility, and black carbon content. Results indicate that at the 1-m sampling location, black carbon (BC) dominated particle mass emissions from all aircraft. Median BC emission indices (EI) were ~20 mg/kg fuel burned at idle and increased to ~150 mg/kg at takeoff thrust. However, takeoff values ranged from ~60 mg/kg (new AE3007-A1P) to over 500 mg/kg (older RB-211) and appeared to vary as a function of the age of the engine technology. The BC size distributions were mono-modal and exhibited geometric mean diameters (GMD) that increased from ~15 nm at idle to ~35 nm at high engine powers. BC Number EIs typically ranged from 0.5 to 5 x 1E15/kg and appeared to be more dependent on engine technology/operating temperature and ambient conditions than on fuel composition within the narrow range available under the Jet-A specification. Aerosol number EI values derived from 30-meter samples were typically 2 to 10 times greater than 1-meter values, indicating that significant numbers of new particles form as the exhaust gases cool and dilute with ambient air. The number and mass of secondary aerosols formed in the plumes were highly dependent upon the concentration of sulfur within the fuel.

The effect of temporal resolution of PAH emission data on transport and deposition patterns simulated with the Community Multiscale Air Quality Model (CMAQ)

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Polycyclic aromatic hydrocarbons (PAHs) are organic pollutants that emerge primarily from combustion of organic matter. A number of PAHs are known to have severe effects on human health and ecosystems and are listed in international pollution reduction conventions. The most important sources are residential heating and traffic which both show significant temporal variations, but on different time scales. While resendential heating strongly depends on season, traffic shows pronounced diurnal and weekly cycles. As meteorological conditions that drive the atmospheric transport model change with time it would be desirable to have also temporally variable emissions of the modelled compounds as input into the model. Unfortunately, official emission data of PAHs are currently only available as yearly bulk emissions.

As a first approach to generate time-resolved Benzo(a)Pyrene (BaP – as example PAH) emissions to feed into our Eulerian air quality model we derived temporal scaling factors from NO-emissions in hourly resolution and applied these factors to the BaP emissions originating from traffic. This approach was based on the assumption that NO has more or less the same emission sources than PAHs from traffic. The seasonal dependence of residential heating was derived from BaP measurements in Kosetice, Czech Republic, which is in an area where residential heating dominates the emssions. We carried out simulations for some selected months in 2001 both with the official time-invariant and the derived time-variant BaP emissions and compared the simulated air concentrations with ground measurements. Also, the results of both model runs were tested for differences in concentration and deposition patterns.

Model process studies of aircraft plume dilution using simplified chemistry

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Usually, emissions from local sources, such as aircraft, ships or large industrial complexes, are implemented in global chemistry transport models (CTMs) simply by homogenously distributing the emissions in the large scale grid box of the CTM. This method neglects non-linear chemical processes occurring during the dilution of the emissions from the local exhaust to the regional scale of the CTM grid box. Petry et al. (1998) introduced the concept of effective emission in order to parameterise the local processes during dilution. However, like other similar approaches, their procedure requires detailed modeling of the full chemistry inside the diluting aircraft plume. This presentation will show results from a model using simplified chemistry, allowing for a wide range of process study applications without requiring any significant computer resources.

Ship emissions in the marine boundary layer: Ozone production and effective emissions

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International shipping is one of the major transport sectors expecting to increase in the future. The Helmholtz Junior Research Group SeaKLIM is investigating the impact of gaseous and particulate emission on climate. One important aspect is the chemical dilution of emissions in the near-field of the ship. Though ships emit their exhaust on a spacial scale of a few meters, current global models have grid sizes of many kilometers and are currently not capable to simulate the complex processes occurring during subgrid-scale plume dispersion. The error made in models when neglecting the chemistry during plume dispersion is often not quantified.
In this study two photochemical box models are applied to investigate the resulting discrepancies. One approach instantaneously disperses the emissions on a large scale like a global model would do. The other starts with a small plume which is then continuously expanded while photochemistry already running. Comparison between these two approaches shows that the neglect of plume expansion overestimates the ozone production up to a factor of 2, depending on emission strength and time. This indicates the necessity of correcting the way ship emissions are taken into account in global models. A possible solution is to introduce effective emissions which are added to or subtracted from the actual exhaust to compensate the neglected effects of subgrid-scale plume dispersion. Here a technique calculating effective emissions is tested for one particular situation and first sensitivity studies are conducted.

Aerodynamically induced condensation trails

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Current contrail research focusses on jet engine exhaust contrails. However, there is evidence that a different type of contrails can additionally form as consequence of extremely rapid air cooling in the aerodynamic air flow over the wings. These aerodynamic contrails could in principle form above the formation threshold for jet contrails. However, little is known about their properties and atmospheric relevance. In the presentation we will discuss representative examples and present first results of calculations of the aerodynamics, microphysics, and optical properties of aerodynamic contrails.

Contrails in a global climate model - effect of reducing systematic errors

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The contrail parameterization of Ponater et al. (2001) is implemented in the global climate model IFSHAM. The global mean net radiative forcing due to contrails is in this model positive, but small and in areas over Europe and the United States the net forcing is negative. The explanation for this needs to be found.
In order to investigate this a series of experiments have been performed modifying contrail optical properties and results from these experiments will be shown.
The climate model exhibits certain systematic errors and the impact of these systematic errors is analysed. The model is run in nudged mode, where the model is relaxed towards observed data thereby reducing the systematic errors of the model substantially. Comparing runs with the model in standard mode and in nudged mode gives the possibility for analysing the impact of model systematic errors on contrail properties and contrail raditive forcing. Results from these experiments will be shown as well.

Physical Characterization of PM emissions from In-service Commercial Gas Turbine Engines – Projects APEX and JETS APEX2

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The University of Missouri – Rolla (UMR) Center of Excellence was involved in two recent ground-based aircraft emissions measurement campaigns – Project APEX (NASA Dryden Flight Research Center, April 2004) and JETS APEX2 (Oakland International Airport, August 2005). The goal of these studies was to advance the understanding of particle emissions and their evolution in the atmosphere from in-service commercial gas turbine engines. On-wing measurements were made on GE CFM56 class engines at the exhaust nozzle exit (~1m) and at several locations downstream (30m and 50m) in the near field plume. A mobile gas and particulate sampling system including a state-of-the-art fast particulate spectrometer, Cambustion DMS500, was used in these measurements for real-time analysis of size distributions, number density, mass concentration and number- and mass-based emission indices (EIn and EIm, respectively) of exhaust particulates.
At the engine exit plane, size distributions were generally lognormal and both geometric mean diameter and geometric standard deviation were generally found to increase with increasing thrust, over the range 12-35nm and 1.2-2.0 respectively. EIn was a minimum at mid-level thrusts (0.14E+15/kg fuel burnt) compared to the idle and high thrust settings (5E+15/kg fuel burnt and 3x1015/kg fuel burnt, respectively). EIm also increased with thrust, exhibiting a trend similar to that of EIn.
For measurements made at downstream locations in the near-field plume, the onset of gas-to-particle conversion was apparent for low to medium thrusts. Non-lognormal size distributions were often observed where the mean sizes (~12-15nm) were found to be smaller than the 1m case. EIn also decreased with increasing thrust, and was an order of magnitude higher than that for the engine exit cases at low thrusts. EIm was found to increase with thrust, ranging from 0.001-0.37 g/kg fuel burnt.

PEDESTRIAN EXPOSURE TO VEHICLE EMISSIONS: THE ROLE OF TRAFFIC SIGNAL TIMINGS

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Most research on vehicle emissions in the field of transport and traffic engineering has focused on measuring or estimating average vehicle emissions with the objective of reducing total emissions from road traffic. This approach has resulted in overlooking hot spots arising from traffic management policies. These hot spots might be of insignificant importance in the gross traffic emissions in a large area but for the persons directly exposed they are a very real problem. One of these emission hot spots is a traffic signal in an urban environment. At a traffic signal, with pedestrian crossings, pedestrians are in the immediate vicinity of a large number of accelerating vehicles. The signal timings, the geometry of the junction plan, the type of pedestrian crossings, all are policy parameters that are not designed with any consideration for traffic emissions. One reason is that the precise nature of how these different parameters affect vehicle emissions is not clearly known. This paper

analyses pedestrian exposure to vehicle emissions and the role played by signal timings. A simple junction is coded in a micro-simulation model and the time series data on vehicle performance, i.e., speed and acceleration is generated for various signal time settings. This data is then used to calculate vehicle emissions through a modal emissions model. The effects of these emissions on the pedestrian paths and crossings adjacent to the traffic junction are then estimated using an air dispersion model. The suitability of various traffic signal plans in terms of pedestrian exposure to harmful vehicular emissions is discussed.

Potential methods to include the full climate impact of aviation emissions into the European Emissions Trading Scheme and their scientific integrity

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The European Commission has stated a preference for including the full climate impacts of aviation into the European Emissions Trading Scheme (EETS). In this work, we examine three potential scenarios by which this might be achieved and consider the scientific plausibility, the ease with which this might be achieved and data and/or operational constraints. The three scenarios are: utilizing a 'multiplier'; an individual 'effects-based' approach; and lastly a CO2 approach with so-called 'flanking instruments' to cover other effects (Wit et al., 2005).

We find that a multiplier approach via the Radiative Forcing Index is not scientifically robust. However, it may be possible at some time in the future to utilize a temperature-based analogous metric as there is a linear relationship between emissions of CO2 and a temperature index. This would need more work but would still result in a lack of incentive to further reduce emissions such as NOx.

An effects-by-effect approach for NOx/O3 and contrails/cirrus has the disadvantage of relatively immature science for policy purposes. Moreover, the effects on a route basis would be non-linear and potentially very difficult to calculate robustly. Lastly, neither basic effect can be satisfactorily quantified using Global Warming Potentials.

Flanking instruments may represent a more practical way forward. We consider cruise NOx certification, NOx en route charges, regulation of cruise altitudes for contrails and NOx airport landing charges. These instruments are evaluated on the basis of scientific plausibility and ease of implementation. Of these, the NOx airport landing charge is the easiest to implement on a regional scale as long as a relationship between LTO NOx certification emissions and cruise NOx emissions remains robust.

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Comparison of cirrus cloud coverage from ECMWF and NCEP data compared with GRAPE data

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The IPCC 'Aviation and the Global Atmosphere' report (1999) identified contrails and cirrus clouds as having potentially the largest effects of aviation on climate. This work forms part of a wider investigation to identify the sources of uncertainties in estimating radiative forcing (RF) from contrails.

A method to calculate contrail coverage has previously been published by Sausen et al. (1998). The first stage of this work uses the aforementioned methodology to produce an offline model that calculates the cirrus cloud coverage from different sources of meteorological data. In order to calculate contrail coverage, it is necessary to have access to sufficiently resolved meteorological data in time and space. Both the ECMWF ERA-40 and NCEP-II reanalysis data sets fulfil these criteria. From these data sets, potential fractional cirrus cloud coverage is calculated from specific humidity and temperature data using a parameterisation similar to that adopted for the general circulation model, ECHAM (Chen and Roeckner, 1997).

In this paper, the resulting cirrus cloud coverage is compared with observed global cloud data (GRAPE v1 data and ISSCP).

This comparison study highlights the sensitivity of meteorological data used in calculating global contrail coverage.

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How to avoid contrail cirrus

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Aircraft induced cirrus clouds have a major effect on climate. These clouds are triggered by air-traffic, if the ambient air is super-saturated with respect to ice. Operational radiosonde data with high vertical resolution is used to estimate the effect of small changes in flight altitudes on contrail and cirrus formation. It is demonstrated that a substantial fraction of contrails and contrail induced cirrus could be avoided by relatively small changes in flight level,if the actual atmospheric conditions are known. Due to the shallowness of ice-super-saturation layers in most cases only small deviations from optimal flight profiles and routes are necessary, to avoid the formation of persistent contrails and contrail cirrus.

The importance of wet deposition for the different transport modes

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All reactive nitrogen in the atmosphere is ultimately removed by either dry or wet deposition. The latter is generally regarded to be the most uncertain process. As road transport, aviation, and ship emissions of NOx occur at different regions with their own specific circumstances, it can be expected that the removal pathways of reactive nitrogen for each transport mode will also be very different.
In this study we used the Tracer Model version 4 (TM4) to investigate the importance of wet removal for the different transport modes relative to dry deposition. The study includes a comparison with observations of wet and dry deposition from EMEP stations. Also the sensitivity of the dry and wet removal budgets to the source strength of each transport model and the most important parameters of the scavenging process will be presented.

Aviation and the Belgian Climate Policy : Integration Options and Impacts - ABC Impacts

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The ABC impacts project aims at providing Belgian stakeholders with a detailed and integrated analysis of issues related to the inclusion of international aviation and shipping into European and/or international climate policy.
Significant climate impacts due to aviation emissions other than CO2 (NOx emissions, condensation trails and cirrus cloud formation) have already been highlighted but emissions from international aviation and shipping are neither included in the Kyoto Protocol commitments, nor in any international climate policy, despite considerable growth in both sectors during the past decades.
Nevertheless, the possibility of integrating these sectors is increasingly considered both at the European (EU-ETS 2013) and UNFCCC levels (post-2012 negotiations).
Consideration of different options for the inclusion of international aviation and shipping into climate policy is of particular interest in Belgium, given the socio-economic importance of these sectors, and also the high concentration of flight paths, as well as transit via sea, rail and road, across this region.
In this context, the ABC impacts project will provide, in two successive phases, a multi-criteria analysis (according to diverse priorities of civil society) aimed at comparing the options for integrating air and maritime transport into climate policy, from a political, technical, socio-economic and environmental viewpoint. To assist this, an interactive tool will also be developed to help stakeholders to explore the effects of various mitigation options and their sensitivity to scientific uncertainties.
This multi-criteria analysis will be based on previous existing studies and on work packages to analyse:

- scenarios describing the potential evolution of the aviation sector (market analysis and traffic projections);
- available technical improvements (e.g. propulsion technologies, air routes, etc.);
- emissions from international air transport transiting through Belgium/EU in comparison with emissions from other transport modes;
- climate impacts of aviation emissions compared with all other greenhouse gases and methods for spatial and temporal aggregation of these impacts using existing simple / intermediate-complexity climate models;
- options for integrating both international aviation and shipping into international climate policy;
- regional climate impacts, with particular focus on effects concentrated over Belgian territory, such as cirrus cloud formation;
- other potential political measures aimed at reducing environmental damage of air and maritime transport.

As this project has recently begun, we welcome suggestions for collaboration. Some illustrative experiments towards these ends may also be presented.

Aircraft Engine Emissions Characterization in APEX-series Measurement Studies

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Recent engine exhaust measurements have been performed to better characterize the gaseous and particle emissions from aircraft engines as a function of engine power and distance downstream in the exhaust plume. Speciation of NOx (using chemiluminescence and Tunable Infrared Laser Differential Absorption Spectroscopy, TILDAS) and hydrocarbon emissions (using TILDAS and Proton Transfer Reaction Mass Spectroscopy), and their dependence on engine power, have been quantified for engines that are used extensively in the commercial fleet. In addition to these gaseous species, non-volatile and volatile contributions to aerosol emissions have also been quantified (using Aerosol Mass Spectroscopy), identifying sulfate and organic contributions to the volatile condensed mass at downstream plume locations. Sulfate mass emission indices (g/kg fuel), due to sulfur contained in the fuel, do not have a strong dependence on engine power, while organic mass emission indices are highest at low powers. Non-volatile particle mass emission indices (measured using Multi-Angle Absorption Photometry) increase strongly from low to high powers.

Quantification of Constrained Scenarios on Aviation and Emissions (CONSAVE 2050)

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CONSAVE 2050 partners are DLR (Germany), QinetiQ, MVA (both from UK), NLR (Netherlands), IIASA (Austria) with support form Lufthansa and Airbus Industries.
CONSAVE 2050 has developed quantified long-term scenarios to contribute to ensuring sustainable growth of air transportation with regard to environmental issues. These scenario quantifications go a step beyond existing scenarios on aviation and emissions (IPCC/SRES), and help to develop a common European understanding on constrained aviation scenarios and emissions.
Four different, constrained scenarios have been developed and analysed for 2020 and 2050. The scenarios include constrained conditions and newest "background" data, which are setting the frame for the long term development in aviation. The scenarios are:

• "Unlimited Skies" featuring a dominant and global, demand driven market

• "Regulatory Push and Pull" having a global market with a strong regulatory impact

• "Fractured World" where the world has been broken up into a few isolated, regional markets

• "Down to Earth" featuring a society that has a limited need for air travel

For each scenario an underlying storyline has been set up. Key descriptors include population, economical and technical developments, energy supplies, political fragmentation and societal values. Each of these scenarios has been explored and tested for consistency. Aviation specific sub-scenarios have been further detailed including constraints on e.g. the number of runways. The behaviour of, and consequences for the various air transport stakeholders (aircraft and engine manufacturers, airlines, airports, air traffic suppliers, governments, consumers) have been explored using the Netherlands' AERO (Aviation Emissions and Evaluation of Reduction Options) model. The key quantified parameters concern infrastructure (runways), local air quality, airport noise, global emissions, airline costs and revenues, aircraft production size and fleet composition, air transport demand and supply volumes, consumer surplus and tax revenues. The results allow identification of the challenges of (future) air transport in several areas.
The scenario building processes and results have been discussed and distributed within an external committee of stakeholders and scientific community for review.

Ship plume chemistry – a model study

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Multiphase chemical reactions in an expanding ship plume were simulated using an extended version of box Model Of Chemistry Considering Aerosols (MOCCA, http://www.mpch-mainz.mpg.de/~sander/mocca/), MOCCA-1D. The chemical mechanism considers reactions in the gas phase, in deliquesced sea-salt and sulphate aerosols and on soot particles. Photochemical reaction rates vary as a function of solar declination. In addition to the standard tropospheric HOx, CH4, and NOx chemistry, the reaction mechanism includes CB-IV mechanism for reactions of hydrocarbons, S, Cl, Br, and I compounds. The plume expansion is described by the Gaussian approximation.

Importance of the heterogeneous reactions in the ship plume was investigated simulating a case study where the plume emissions were available from on-board measurements. Results were compared with measurements performed in a ship plume from the Falcon research aircraft.

New aviation scenarios for 2050

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Aviation scenarios of CO2 and NOx emissions have been constructed for 2050 using the FAST model (Lee et al., 2005). Emissions have been calculated from a base year inventory of 2000, using scheduled traffic from OAG. In order to provide future forecast and scenario years of 2005, 2010, 2015, 2020, 2030, 2040 and 2050, the FAST model has been used in forecast mode, by which real aircraft types are interpreted as hypothetical seat-band categories. In this way, use is made of ICAO traffic forecasts to 2020 of revenue passenger kilometres (RPK). Technological improvements in engine efficiency and NOx performance are accounted for using historical and projected rates of change according to IPCC (1999). For dates after 2020, an alternative approach is used, similar to the IPCC (1999) methodology, whereby a global relationship between RPK and GDP is used according to a non-linear regression model (Verhulst) and predicting RPK from SRES A1 and B2 GDP data. A range of SRES scenarios of RPK to 2050 are presented and emissions calculated for A1 and B2 for 2030, 2040 and 2050.

The CO2 emissions resulting from SRES B2 and A1 FAST 2050 scenarios are greater than the IPCC's Fa1 and Fe1 scenarios, respectively. FAST-A1 predicts a global emission of 2,971Tg CO2 and FAST-B2 predicts 1,996 Tg CO2.

From the scenario data, appropriate scaling factors are applied – as was done for IPCC – to account for systematic underestimation of fuel usage and the radiative forcing response calculated.

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Diurnal and Inter-annual variability of Contrail Coverage derived from AVHRR data over continental United States of America and surrounding areas.

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To study the diurnal and inter-annual variability of contrail coverage and microphysical properties, Advanced Very High Resolution Radiometer (AVHRR) data from NOAA-15 and NOAA16 over the CONUS and surrounding areas are analyzed for selected months during 2004 for each season and compared with the results of our previous study based on 2001 AVHRR data. The 2001 morning NOAA-15 results yielded nearly twice the contrail coverage found from the analyses of afternoon NOAA-16 data. This difference may be due to spreading and saturation of contrails formed during the morning in areas of heavy air traffic that could mask the contrails formed during the afternoon or suppress their formation to some extent. Or, it may be a result of differences in sensitivity of AVHRR infrared channels on the two satellites. We will examine if this holds true for 2004 dataset. Contrail formation requires both air traffic and suitable atmospheric conditions. Air traffic over the domain during 2004 is comparable to that in 2001. However, the upper troposheric humidity (UTH) in numerical weather analyses is considerably greater in 2004 than during 2001, which had one of the lowest values during the past 35 years. This study will explore how the increase in UTH relates of contrail coverage. Preliminary contrail results from the AVHRR sensor on the NOAA-17 and NOAA-18 satellite along with linear contrail coverage, optical depth and longwave radiative forcing derived from NOAA-15, 16,17 18 daytime overpasses will be presented.

Large-eddy simulation of a turbulent jet and wake vortex interaction: particle formation and evolution in the near-field of an aircraft

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Aircraft are prolific sources of particles (soot, aerosols and contrails) that can impact cloudiness and may affect the Earth's radiative budget balance. In order to study the formation and evolution of these particles, a numerical approach has been developed combining large-eddy simulation (LES) and a detailed microphysical model.

In this study, temperature and dilution factor at sample particle positions are obtained from a high-resolution large-eddy simulation of an exhaust jet blowing into the boundary layer of a model-scale wing platform (representative of a large civil transport aircraft). These fluid particles (or clusters of particles) are initially randomly placed at the jet exit section; afterwards their trajectories -including the local thermodynamic properties- are tracked in the flow-field using a dedicated Lagrangian particle solver. This allows a full description of particle formation and evolution using an "off-line" coupling between LES results and a detailed microphysical model. Indeed, the turbulent dispersion as well as the 3D spatial distribution of supersaturation are automatically taken into account, and their impact on the evolution of aerosols and ice particles in the aircraft wake can be accurately evaluated. Approximately half a million clusters are tracked to get a good statistical representation of turbulent dispersion. The computational domain for the LES covers half of the wing span (symmetry conditions can be used on one side) and is large enough to let the wing boundary layer vortical structures merge into a well-formed trailing vortex. The initial temperature at the jet exit section follows a tanh profile, ranging between Tj=440K at the center of the jet to Ta=220K at background level; pressure is constant and equal to 24000 Pa. These values are representative of a typical cruise flight at an altitude of 11 Km.

The detailed microphysical model simulates both the formation of submicron volatile aerosols and the formation of contrails. The formation of aerosols, which depends strongly on the concentration of sulfur in the fuel, is described in terms of coagulation processes in the sulphuric acid-water binary mixture, taking into account both charged (ions or charged clusters) and neutral species (molecules or clusters), the presence of charges having a stabilizing effect on clusters and enhances growth and coagulation. The formation of contrails that nucleate on soot particles when the water saturation ratio (with respect to liquid water) is larger than one is also described in terms of coagulation between the molecules or clusters and the soot particles. Finally, this model considers all the interactions between neutral molecules and clusters, charged molecules and clusters, aerosols and soot particles, aerosols and contrails etc.

Transportation and the Carbon Cycle

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The amount of carbon dioxide released in the atmosphere by anthropogenic activities has increased from 5PgC/year (10e15) in the early 1980s to over 7 PgC/year today. Climate studies have shown that models cannot reproduce the observed increase in temperature since the 1960s if the anthropogenic source of CO2 is not taken into account. Half of the anthropogenic CO2 is absorbed by the biosphere over land or at the ocean surface and half stays in the atmosphere. Transportation is responsible for close to 1/5 of the global CO2 sources due to fossil fuel burning while power generation and the industrial sector are responsible for 1/3 and 1/6 respectively. We have derived a new CO2 and CO transportation emissions inventory for the USA based on the Federal Highway Administration statistics on gasoline and diesel sales by state and allocated with 4-km spatial resolution using the EPA's National Emission Inventory. We present this inventory and compare it with other available bottom-up estimates of transportation CO2 and CO sources for the USA. The sensitivity of the simulated CO2 to this source at a set of in situ stations is analyzed. The need for better anthropogenic CO2 emissions databases will be emphasized in the context of CO2 inverse modeling studies.

Homogeneous freezing of ice particles, including effects of aerosol size distribution in the University of L'Aquila CCM.

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A low resolution climate-chemistry coupled model, including a microphysics code for aerosols formation and growth, is used to study ice particles formation in cirrus clouds, including the effects of the aerosol size distribution. The parameterization used is that for homogeneous freezing of supercooled aerosols of Kärcher and Lohmann (JGR, 2001), extended to include the effects of aerosol size on the freezing process in adiabatically rising air particles (Kärcher and Lohmann, JGR 2002).
Changes of the aerosol size distribution can modify the homogeneous freezing process when the timescale of the freezing event is fast (low temperatures and high vertical velocity).
We present the results of the ULAQ-CCM about the feedback of the aerosol size distribution on the mechanism of formation and growth of ice particles in the UT/LS region. Preliminary numerical simulations are made considering subsonic aircraft emissions, which may greatly perturb the amount of ultrafine aerosol particles. We further evaluate denitrification and dehydration produced by ice cloud particles and their impact on ozone.

Climate Impact Reduction due to Cryoplane Introduction: A state-of-the-art assessment

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Aircraft fuelled with liquid hydrogen (cryoplanes) offer a number of advantages over conventional aircraft as far as climate impact is concerned. CO2 emissions are avoided during cryoplane operation, whereas for the fuel production process this only holds if renewable energies are utilized. The NOx emission index can be reduced more efficiently for liquid hydrogen engines than for kerosene engines. Larger but much less ice particles are expected in cryoplane contrails, making them optically thinner than conventional contrails. There are also counteracting effects, e.g. a higher contrail formation probability and higher emission rates of of water vapour to the lower stratosphere, if cryoplanes replace conventional aircraft while current flight levels are left unchanged.
A synthesis of available knowledge on aircraft climate impact is made to produce a state-of-the-art assessment of the potential environmental gain of a hypothetical transition from conventional aircraft to cryoplanes between 2015 and 2050. The best estimate suggests a climate impact reduction in 2050 of between 15% and 50% in terms of radiative forcing and of between 5% and 15% in terms of surface temperature change. The limits of the assessment and perspectives for longer time horizons will also be considered.

Calculating contrail RF with the Edwards-Slingo radiative transfer code (POSTER)

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The representation of the radiative properties of air traffic induced clouds is assessed in a two-stream radiative transfer code (Edwards and Slingo, 1996) and contrasted with a natural cirrus case. Our parametrization is based on a hexagonal geometry for the ice crystals and in-situ measurements of their concentration and size. A bimodal gamma function is also used to represent the particle concentrations, allowing us to separate the contribution by small and large particles, which represents an important source of uncertainty in ice-cloud modelling.
The effect on the radiation flux and temperature profile of an atmospheric column due to an increase in the cirrus and contrail cover is compared.

Seasonal and spatial variation in contrail cover over the UK (2001-2006)

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Observations of cloud cover from aircraft condensation trails have been carried out by the UK National Contrail Network, which has been set up as an informal adjunct to the UK Meteorological Office Climatological observing network and is administered by Lancaster University. The contrail network has volunteers at 15 stations across the UK. The observations show seasonal cycles for persistent contrail occurrence, with maxima in spring and autumn, but interannual variability is high. Approximately one contrail is counted per observation as an annual average at Lancaster over the six years of study. The average contrail coverage translates roughly into an annual contrail radiative forcing of 100 mW m-2 for Lancaster, which is a factor of 30 higher than the global annual average calculated in other studies and reflects the position of Lancaster below the North Atlantic air traffic corridor.
With radiosonde data from Lancaster's Hazelrigg Fieldstation, research specific to upper-tropospheric ice supersaturation is being undertaken. The radiosonde data are daily launches spanning a seventeen month period between November 2003 and April 2005, supplemented by several one-day "intensives" with multiple launches, and provides detailed information on the state of the upper troposphere associated with high contrail occurrence.

West African Weather Systems in the Development of Tropical Cyclones

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Tropical cyclones have their origins from areas of low atmospheric pressure over warm waters in the tropics or subtropics. We have carefully studied the interconnection between the West African Weather Systems (WAWS) and their subsequent development into Tropical Cyclones.
Between 2004 and 2005, we studied the interconnection and the teleconnection between the WAWS and the various occurrences of Tropical Cyclones and their eventual development into Hurricanes. We noted that critical synoptic characteristic and the environmental properties of the Systems; the thermodynamic conditions of the storms trajectory and the conditions of the ocean are all closely linked. It is therefore believed that proper understanding and monitoring of these systems will play a very vital role in early detection of potential WAWS that may develop into Tropical Cyclones and even Hurricanes. More practical issues will be presented.
It was recorded that over the period 1992-2001, weather and climate-related disasters especially those of Tropical Cyclones origin killed about 622 000 people, affected more than two billion, left millions more homeless, devastated arable land and spread diseases.

On the coupling of the MOCAGE-Climat CTM with the CNRM climatic system

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We present the strategy and some results of the coupling between MOCAGE-Climat and the CNRM climatic system. This coupling might allow progress in understanding the two-way interactions between reactive gases and the climate system, and will be a useful tool for the future study of climate scenarios.
MOCAGE-Climat is the climate version of the Météo-France multi-scale Chemistry and Transport Model MOCAGE, that covers a wide range of scientific applications, and includes both tropospheric and stratospheric chemistry.
The CNRM-CM3 global coupled system is the third version of the ocean-atmosphere climate model. CNRM-CM3 consists of ARPEGE-Climat version 3 AGCM and the ocean model OPA8.1, and includes the land surface scheme ISBA, a snow scheme, a parameterisation of the homogeneous and heterogeneous chemistry of ozone, the sea ice model GELATO2, and a river routing module TRIP.
In a first step towards the coupling, for the validation of MOCAGE-Climat meteorological fields from the European Centre for Medium-Range Weather Forecasts model have been used as thermodynamical forcing for MOCAGE-Climat. The results of these simulations allow a comparison with tropospheric and stratospheric observations.
In a second step, the sensitivity of MOCAGE-Climat to the specification of the meteorological parameters is investigated in an off-line mode applying meteorological forcing from the ARPEGE-Climat model which is the atmospheric component of the CNRM ocean-atmosphere climate model. We will show results from these simulations.
In a future step, an on-line coupling between MOCAGE-Climat and ARPEGE-Climat will be implemented. With a six-hourly frequency ARPEGE-Climat will exchange meteorological fields to MOCAGE-Climat, and with the same frequency MOCAGE-Climat will give distributions of radiative active gases to ARPEGE-Climat.
This new system should allow a significant number of interactions and feedbacks from chemistry on the climate which are essential for climate scenario studies.

Initial conditions for contrail-to-cirrus transition

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It is known that the number of contrail ice crystals that survive the vortex phase depends critically on ambient humidity. In the present work we investigate the sensitivity of the number of surviving ice crystals as a function of humidity, temperature (i.e. flight level), vortex decay (depending in turn on stability and atmospheric turbulence), and aircraft parameters. The study is done using 2-D simulations of the vortex phase including ice microphysics.

Measurements of ozone and Black Carbon along a Mediterranean cruise track during the winter season 2005-2006 ; comparison with TM5 model

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Local emissions as well as long range transport influence the atmosphere of the Mediterranean Basin. Combined with the particular climatic conditions of this area with high insolation and frequent occurrence of sea breeze circulation this may cause elevated levels of air pollutants. In fact, high levels of ozone as well as particles, including Black Carbon, have been observed at sites around the Mediterranean Sea, however systematical, long term observations are limited to relatively few sites, and observations over the sea surface are particularly scarce. A collaboration has been established between the JRC and the Italian company 'Costa Crociere' to assess the effect of air pollution on Mediterranean climate. This has allowed to install a monitoring station on board the

cruise liner 'Costa Fortuna' that regularly performs cruises on the Mediterranean, with regular weekly tracks in the Western Mediterranean during spring, summer and autumn, and in the Eastern Mediterranean during winter. Measurements of ozone, Black Carbon (aethalometer) and particle size distributions (optical particle sizer) have been performed, starting from the autumn of 2005; this activity will continue for several years.
The analysis of the measurements for the period autumn-winter 2005-2006 collected during the Costa Fortuna cruise routes in the Eastern Mediterranean is presented. Observed data of ozone and black carbon are compared to modeled values, obtained by the TM5 global atmospheric chemistry-transport zoom model.