1st International Workshop of EULAG Users

Bad Tölz, Germany

6-10 October 2008

Program

Abstracts

List of Participants

Practical Information

DLR

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

UCAR

NCAR

Deutsche Forschungsgemeinschaft DFG

MetStröm

PROGRAM

Monday, 6 October 2008

Convener: A. Dörnbrack

14:00 – 14:10 A. Dörnbrack: Welcome

14:10 – 15:30 P. K. Smolarkiewicz: EULAG: high-resolution computational model for research of multi-scale geophysical fluid dynamics

15:30 – 16:00 Tea Time

16:00 – 16:30 R. Klein: A Godunov-type projection scheme for sound-proof models

16:30 – 17:00 O. Knoth and S. Jebens: Time splitting methods for the compressible Euler equation using peer methods

17:00 – 17:30 U. Achatz: Gravity-wave breaking beyond traditional instability concepts

17:30 – 18:00 D. Reinert and V. Wirth: Analysis of banner cloud dynamics using a newly developed LES model

18:00 – 18:30 T. von Larcher and R. Klein: Multiple Scales in Fluid Dynamics and Meteorology: The DFG Priority Programme MetStröm

Tuesday, 7 October 2008

Convener: R. Klein

09:00 – 10:30 J. M. Prusa: Adaptive Grid Transformations and Generalized Coordinates in EULAG

10:30 – 11:00 Coffee Break

11:00 – 11:30 W. J. Gutowski, Jr., B. J. Abiodun, and J. M. Prusa: Implementation of a Non-Hydrostatic, Adaptive-Grid Dynamics Core in the NCAR Community Atmospheric Model

11:30 – 12:00 P. Ortiz and P. K. Smolarkiewicz: Numerical simulation of landform/atmosphere coupled evolution

12:00 – 12:30 C. Kühnlein and A. Dörnbrack: Scalar advection with adaptive moving meshes

12:30 – 13:00 J. Szmelter and P. K. Smolarkiewicz: On forward in time differencing: an unstructured mesh framework

13:00 – 14:00 Lunch Break

Convener: A. A. Wyszogrodzki

14:00 – 15:30 N. P. Wedi: Some Reference Simulations from Laboratory to Planetary Scale

15:30 – 16:00 Tea Time

16:00 – 16:30 U. Harlander, K. Alexandrov, Y. Wang, Ch. Egbers: Multi-Scale flow in a heated rotating annulus

16:30 – 17:00 A. Warn-Varnas, S. Piaczek and J. Hawkins: Issues in predicting solitary waves in Luzon Strait and South China Sea region

17:00 – 17:30 A. M. Gadian, S.-J. Lock, N. S. Dixon, P. K. Smolarkiewicz, and A. Tomlin: Application of a non-hydrostatic meteorological model to flow and dispersion of tracers in a street canyon

17:30 – 18:00 J.-F. Cossette and P. K. Smolarkiewicz: The Monge-Ampère differential equation and semi-Lagrangian advection schemes

18:00 – 18:30 T. Misaka, S. Obayashi, I. Yamada, and Y. Okuno: Lidar-Measurement-Integrated Simulation of Wake Turbulence

Wednesday, 8 October 2008

09:00 – 14:00 Walking Trip to the nearby mountains (optional)

Convener: N. P. Wedi

14:00 – 15:30 A. A. Wyszogrodzki: Parallelization and Data Structure of EULAG

15:30 – 16:00 Tea Time

16:00 – 16:30 Z. Piotrowski: Parallel NETCDF output and visualization of EULAG simulations

16:30 – 18:00 Discussion and Exchange of Information about Tools developed for EULAG analysis (visualization, budgets, …..)

Confirmed contributions:

A. A. Wyszogrodzki: VIS-5D
A. Dörnbrack: Simple Interface to IDL and other tools

19:00 Workshop Dinner/Banquet

Thursday, 9 October 2008

Convener: P. Spichtinger

09:00 – 10:30 W. W. Grabowski: Moist Processes

10:30 – 11:00 Coffee Break

11:00 – 11:30 J. Slawinska, W. W. Grabowski, H. Pawlowska, H. Morrison: EULAG simulation of shallow cumulus clouds with two-moment warm-rain scheme and prescribed entrainment-mixing scenarios

11:30 – 12:00 D. Jarecka and W. W. Grabowski: Modeling of subgrid-scale mixing in large-eddy simulation of shallow convection

12:00 – 12:30 M. Kurowski, S. P. Malinowski and W. W. Grabowski: LES Simulations of Entrainment and mixing on the Stratocumulus Top

12:30 – 14:00 Lunch Break

Convener: W. W. Grabowski

14:00 – 15:00 P. Spichtinger: Impact of mesoscale dynamics and aerosols on the life cycle of cirrus clouds

15:00 – 15:30 Tea Time

15:30 – 16:00 Z. Piotrowski, P. K. Smolarkiewicz and S. P. Malinowski: Sensitivity of modeled atmospheric convection to effective viscosity

16:00 – 16:30 G. C. Craig and A. Dörnbrack: Entrainment in Cumulus Clouds: Which resolution is cloud-resolving?

16:30 – 17:00 F. Fusina: Cirrus clouds triggered by radiative cooling and small eddies - a multiscale problem

Friday, 10 October 2008

Convener: J. M. Prusa

09:00 – 12:00 Discussion about EULAG development, master code, …

12:00 End of the Workshop

A Godunov-type projection scheme for sound-proof models

Rupert Klein

FU Berlin
Institut für Mathematik
Arnimallee 6
14195 Berlin
Germany

There is a close structural similarity between Bannon's anelastic, Durran's pseudo-incompressible, and the full compressible Euler equations when all are written in conservation form for mass, momentum, and potential temperature. Working from this observation, I am currently developing a second-order finite volume scheme that addresses these equation systems through an uniform approach. The scheme uses Godunov-type / MUSCL upwind techniques for advection and a projection approach to handle the stiff pressure terms. The current implementation also employs directional operator splitting.

Besides the overall design of the scheme we will discuss in particular

- an advection scheme that avoids the clipping of extrema induced by standard slope limiters but nevertheless maintains constant plateaus of the advected scalars well,
- the temporal discretization using ideas from auxiliary variable projection methods, and

an inf-sup-stable projection and its derivative as employed here.

Time splitting methods for the compressible Euler equation using peer methods

Oswald Knoth und Stefan Jebens

IFU Leipzig
Institut für Troposphärenforschung
Permoserstr. 15
04303 Leipzig
Germany

A new time-splitting method for the integration of elastic equations is presented. It is based on a three-step peer method which is a general linear method with second-order accuracy in every stage. The scheme uses a computationally very efficient forward-backward scheme for the integration of the high-frequency acoustic modes. With this splitting ansatz it is possible to integrate stably elastic equations without any damping. The peer method is tested with the dry Euler equations and a comparison with the common split-explicit second-order three-stage Runge-Kutta method by Wicker and Skamarock shows the potential of the class of peer methods with respect to computational efficiency, stability and accuracy. Different density based formulations of the Euler equation are compared within this splitting ansatz.

Gravity-wave breaking beyond traditional instability concepts

Ulrich Achatz

Institut für Atmosphäre und Umwelt
Goethe-Universität Frankfurt
Altenhöferallee 1
60438 Frankfurt am Main
Germany

In a summary of recent work on the breaking of gravity waves (GWs) and the corresponding onset of turbulence the question of critical thresholds is given a systematic discussion. Contrary to a widespread belief static and dynamic stability do not indicate a GW's stability against breaking. Low-frequency inertia-gravity waves can be destabilized by singular vectors even if their amplitude is too weak to produce local Richardson numbers less than a quarter. High-frequency gravity waves have horizontal gradients strong enough so that even at statically and dynamically stable amplitudes they are destabilized by normal modes. The dynamics of the processes can be discussed within a framework which takes a careful path from linear stability analyses to direct numerical simulations. The latter show that subcritical GW breaking can lead to turbulence of a strength as observed in the middle atmosphere. In many cases the GW amplitude is reduced way below the conventional thresholds of static or dynamic instability.

References:

1. **Achatz, U., 2005:** On the role of optimal perturbations in the instability of monochromatic gravity waves. *Phys. of Fluids*, **17**, 094107, [DOI: 10.1063/1.2046709].
2. **Achatz, U., and G. Schmitz, 2006a:** Shear and static instability of inertia-gravity wave packets: Short-term modal and nonmodal growth. *J Atmos. Sci*., **63**, 397-413
3. **Achatz, U., and G. Schmitz, 2006b:** Optimal growth in inertia-gravity wave packets: Energetics, long-term development, and three-dimensional structure. *J. Atmos. Sci.*, **63**, 414-434
4. **Achatz, U., 2007a:** The primary nonlinear dynamics of modal and nonmodal perturbations of monochromatic inertia-gravity waves. *J. Atmos. Sci.*, **64**, 74-95
5. **Achatz, U., 2007b:** Modal and nonmodal perturbations of monochromatic high-frequency gravity waves: Primary nonlinear dynamics, *J. Atmos. Sci.*, **64**, 1977- 1994
6. **Achatz, U., 2007c:** Gravity-wave breaking: Linear and primary nonlinear dynamics. *Adv. Space Res.*, **40**, 719-733

.

Analysis of banner cloud dynamics using a newly developed LES model

Daniel Reinert and Volkmar Wirth

Institute for Atmospheric Physics
Johannes Gutenberg-University
Mainz
Germany
dreinert@uni-mainz.de

Banner clouds belong to the class of orographic clouds. They are known to occur when sufficiently moist air flows across steep mountain peaks or quasi 2D ridges. The cloud is confined to the immediate lee of the mountain, whereas the windward side remains cloud-free. Preferred places of occurrence are e.g. the Matterhorn in the Swiss Alps or Mount Zugspitze in the Bavarian Alps. The cloud has a banner-like appearance with a characteristic (horizontal) scale of 1 km. It is attached to the mountain, while its downwind end flickers in the wind like a flag. The cloud is quasi-stationary and can often be observed for several hours. The underlying mechanisms of formation as well as the relative importance of dynamics versus thermodynamics for its formation and maintenance are not yet fully understood.

As a tool to investigate this phenomenon we developed a new Large Eddy Simulation (LES) model which can handle moist atmospheric flow above highly complex terrain. The model is able to treat orography with slopes up to 90◦ by applying the method of viscous topography. Furthermore, turbulent inflow conditions can be generated by using a modified perturbation recycling method. The model has been tested in detail and was validated against wind tunnel data.

Here we shortly present the new LES model including non-standard technical features like the new turbulence generator and the treatment of complex orography. We then focus on the dynamics of banner clouds as a typical area of application. Both dry and moist flow across an idealized pyramidal shaped obstacle is investigated, because observations suggest that pyramidal shaped mountain peaks are preferred places for banner cloud occurrence (e.g. Matterhorn).

The dry simulations reveal that the flow field is highly asymmetric regarding the Lagrangian vertical displacement: air parcels which are lifted in the upward branch of the induced lee vortex originate at lower levels than air parcels which are lifted on the windward side. As we will show, the upward displacement in the lee is sufficient to explain the occurrence of banner clouds. Due to the strong asymmetry of the flow field this is even true for horizontally homogenous initial conditions regarding both moisture and temperature. Simulations with moist physics switched on show that our model is able to simulate realistically shaped banner clouds downwind of a pyramidal shaped mountain peak. A comparison of model runs with the cloud model switched on and off indicates that thermodynamics (i.e. latent heat release) do not have a significant impact on the mean flow, even though they do increase the intensity of leeward turbulence. We conclude that banner clouds are primarily a dynamical phenomenon, with their dynamics only slightly modulated by thermodynamical processes.

Multiple Scales in Fluid Dynamics and Meteorology: The DFG Priority Programme MetStröm

Thomas von Larcher and Rupert Klein

FU Berlin
Institut für Mathematik
Arnimallee 6
14195 Berlin
Germany

One of the most important challenges in meteorological modelling is the simulation of local disasters with high attention to detail. Examples are the development and growth of severe weather storms like cyclones, or extreme weather events with high flooding potential. Such events are most often associated with processes on multiple spatio-temporal scales representing such multiscale interactions accurately and efficiently given limited computational resources is one of the major arising difficulties.

A promising approach in this context in Meteorology and Fluid Dynamics is the use of variable, dynamically adaptive spatio-temporal grid resolution. While adaptive dynamic kernels for meteorological models and adaptive flow solvers exist today, some severe open issues remain. For example:

a) Systematic formulations of closure models or parameterizations for small scale, non-solved processes applicable on dynamically adaptive grids are practically non-existent today, although there are promising developments in the area of Large Eddy Simulation.

b) Parameterizations will have to depend on the type of numerical scheme adopted in the dynamic kernel, i.e., they will differ for finite difference, finite volume, finite element, and spectral schemes. How do flow solvers and subgrid-scale closures interact, and how do numerical and subgrid-scale modelling errors conspire to perturb the accuracy of a simulation?

MetStröm covers the expertise of Meteorology, Fluid Dynamics, and Applied Mathematics to develop model- as well as grid-adaptive numerical simulation concepts in multi-disciplinary projects. The goal is to provide simulation models which combine scale-dependent (mathematical) descriptions of key physical processes with adaptive flow discretization schemes. Deterministic continuous approaches and discrete and/or stochastic closures and their possible interplay are taken into consideration. Research focuses on the theory and methodology of multiscale meteorological-fluid mechanics modelling. Accompanying reference experiments support model validation.

Here, we provide an overview of the overall targets of the priority programme, which became operational in Fall of 2007.

Implementation of a Non-Hydrostatic, Adaptive-Grid Dynamics Core in the NCAR Community Atmospheric Model

William J. Gutowski, Jr.[1], Babatunde J. Abiodun[1,2,3], and Joseph M. Prusa[4]

[1]Dept. of Geological and Atmospheric Sciences, Iowa State University, Ames, Iowa USA
[2]Dept. of Meteorology, Federal University of Technology, Akure, Nigeria
[3]Dept. of Env. & Geographical Sci., University of Cape Town, Cape Town, South Africa
[4]Teraflux Corporation, Boca Raton, Florida, USA

We report on our implementation of EULAG as a dynamical core in the NCAR Community Atmospheric Model (CAM). Compared to existing dynamics cores in CAM, EULAG has novel advantages. Specifically, it is non-hydrostatic, and it combines non-oscillatory forward-in-time (NFT) numerical algorithms with a robust elliptic Krylov solver. A signature feature of EULAG is that it is formulated in generalized coordinates, which enables grid adaptivity.

A series of aqua-planet simulations are used to demonstrate that CAM–EULAG results compare favorably with those from CAM simulations at standard CAM resolution that use current finite volume or Eulerian-spectral dynamical core options. In further analysis, we exploit EULAG's grid adaptivity to show how horizontal grid resolution in CAM-EULAG strongly affects Inter-Tropical Convergence Zone (ITCZ) morphology as well as the amount of tropical precipitation through its influence on resolved dynamics. The grid adaptation capability of our global model enables simulations that separate the influence of tropical and extra-tropical dynamics on both the ITCZ and tropical precipitation.

The presence of single versus double ITCZs in our aqua-planet simulations depends on the resolution of convectively coupled equatorial waves. When the tropical resolution is sufficiently high to resolve prominent equatorial waves a double ITCZ occurs, otherwise a single ITCZ occurs. In contrast, tropical resolution does not affect the magnitude of tropical precipitation in our aqua-planet simulations. Instead the precipitation is sensitive to extra-tropical resolution, through its influence on the strength of baroclinic eddies and their forcing of the Hadley circulation.

Numerical simulation of landform/atmosphere coupled evolution

Pablo Ortiz[1] and Piotr K. Smolarkiewicz[2]

[1] University of Granada
Ed. Politecnico.
Granada 18071
Spain

[2] NCAR, MMM
PO Box 3000
Boulder, CO 80307
USA

Predicting sediment transport and bed evolution in severe wind conditions depends on accurate computations of flows past complex boundaries, evolving with the flow itself. We employ a variant of the nonhydrostatic atmospheric numerical model EULAG that couples the internal flow with a lower boundary developing in response to the sand saltation and/or dust storms.

The key prerequisite facilitating this development is the use of time-dependent curvilinear coordinate transformation that accommodates rapid changes of the boundary shape. In consequence of the adopted severe wind scenario, the geometric difficulty of the two-phase coupling is enhanced by the ubiquity of the turbulence and separating surface planetary boundary layers, requiring an adequate modelling of the details of the local surface stress field.

The flux-form PDE for the interface profile — accounting for saltation, sand avalanches and mobilised sediment fluxes from and to the ground — is formulated as a forced advection-diffusion equation. This novel formulation not only facilitates finite-difference integrations, but it also aids understanding of landform propagation. Theoretical considerations are illustrated with numerical experiments that explore the landform/atmosphere system. In particular, we investigate the dune/flow response to the character of the underlying surface, the development of dunes via instability of sand ripples and the associated dust phenomena.

Scalar advection with adaptive moving meshes

Christian Kühnlein and Andreas Dörnbrack

DLR Oberpfaffenhofen
Institut für Physik der Atmosphäre
D-82234 OBERPFAFFENHOFEN
Germany

Geophysical flows cover an enormous range of spatial and temporal scales. For instance, flows in the Earth's atmosphere involve energy scales that span at least ten orders of magnitude. Given today's computational resources, the presence of the many different scales together with their nonlinear interactions makes numerical simulation of such flows an exceptionally challenging task. While local phenomena like density interfaces and strong shear layers require spatially high numerical resolution, other regions, where the flow is characterised by smooth varying fields, could be treated with less numerical effort.

The all-scale anelastic geophysical flow solver EULAG enables continuous dynamic grid adaptation (CDGA) by a time-dependent coordinate transformation (Prusa and Smolarkiewicz, 2003). The basic idea of CDGA is to redistribute grid points, fixed in number, in order to reduce the errors resulting from the spatial discretisation. We aim to extend the recent work of Prusa and Smolarkiewicz (2003) by coupling moving mesh partial differential equations (MMPDEs) to EULAG. The parabolic MMPDEs describe the movement of the mesh points in physical space. So-called monitor functions establish the link of the MMPDEs to the numerical solution of the physical equations. They are designed to provide a measure of the local error, numerically or physically motivated, and are also used to control the geometric properties of the generated mesh.

Here, we present a model of two-dimensional scalar advection. It couples MMPDEs for mesh adaption with the flow solver MPDATA of EULAG. Results from experiments with simple choices of the monitor function for this model are presented. Also we point to consequences for further developments.

Prusa J. M. and Smolarkiewicz P. K., An all-scale anelastic model for geophysical flows: dynamic grid deformation. J. Comp. Phys., 190 (2003) 601–622.

On forward in time differencing: an unstructured mesh framework

Joanna Szmelter[1] and Piotr K. Smolarkiewicz[2]

[1] Loughborough University
Leicestershire LE11 3TU
UK

[2]NCAR, MMM
PO Box 3000
Boulder, CO 80307
U.S.A.

A rigid connectivity of Cartesian grid routinely used in the simulation of stratified rotating flows imposes severe limitations on mesh adaptivity to flow features and/or the complex geometry of physical domains. In contrast, for many problems, a wide range of scales in atmospheric flows, heterogeneous distribution of regions of interest, and/or complex geometry can be accommodated efficiently with fully-unstructured mesh technology. The realization of limitations of structured-grids, and of a need for flexible mesh adaptivity, has stimulated recent interest within the atmospheric/oceanic science community in the development of unstructured-mesh solvers. However, such solvers are still in their infancy compared to both established structured-grid codes and state-of-the-art engineering advancements with unstructured meshes. In order to prove the competence and competitiveness of unstructured-mesh technology for simulating all-scale flows in the atmosphere and oceans, there is a need for developing an advanced fully non-hydrostatic model for simulating accurately rotating stratified flows in a broad range of the Rossby-, Froude-, and Reynolds-number regimes. The presentation will report on recent developments towards an unstructured mesh ”clone” of EULAG, aiming at this goal.

The key of the present development is the derivation of an approach which provides an equivalence between the structured grid methodologies used in EULAG and the edge-based framework. Consequently, the proven elements of the EULAGs non-hydrostatic model are adopted to unstructured meshes. This not only provides a particularly efficient numerical development path, but also facilitates a meaningful comparison between the performance of structured and unstructured meshes. The essential steps leading towards a fully non-hydrostatic model such as a development of an accurate advection scheme and a class of non-oscillatory forward in time solvers will be described. A generalization to algorithms operating on a sphere will follow.

The resulting, non-oscillatory forward in time solvers are applicable to both incompressible and compressible flows including problems with complex geometries for which unstructured meshes and mesh adaptivity are desirable. Theoretical considerations will be supported with numerical examples from standard benchmarks, idealized atmospheric flows and multidisciplinary applications illustrating flexibility and robustness of the approach.

Multi-Scale Flow in a heated rotating annulus

Uwe Harlander, Konstatin Alexandrov, Y. Wang, Christoph Egbers

Department of Aerodynamics and Fluid Mechanics
BTU-Cottbus, Siemens-Halske-Ring 14
D-03046 Cottbus
Germany

In the fifties, Fultz and Hide designed an elegant laboratory experiment to study baroclinic waves. It consists of a cooled inner and heated outer cylinder mounted on a rotating platform, mimicking the heated tropical and cooled polar regions of the earth's atmosphere. The gap between the two cylinders is filled with water. Depending on the strength of the heating and the rate of rotation, different flow regimes can be identified: wave-regimes that can be classified by prograde propagating waves of different wavenumbers, and quasi-chaotic regimes where waves and small scale vortices coexist. The former regimes are well studied, the latter, however, still raise fundamental questions.

More recently, these classical experiments have been reconsidered. The reason for this revival is manifold. First, the experiments observed by modern laser techniques and analyzed by modern statistical methods give reliable quantitative information on the flow field. Such data can thus be used to verify numerical models of turbulent flows. In fact, this is the main motivation for our experiment that is part of the priority program of German Science Foundation (DFG) 'MetStröm', an initiative to link numerical techniques of engineering computational fluid dynamics with methods of numerical weather prediction. Second, like numerical models, the experiments can be seen as data generators that produce data ensembles appropriate to investigate flow features statistically.

Goal of our study is to provide a velocity and temperature data base to numerical modelers (e.g. from the EULAG community) for comparative numerical simulations of complex multi-scale flow.

Issues in predicting solitary waves in Luzon Strait and South China Sea region

A.Warn-Varnas[1], S. Piacsek[1] and J. Hawkins[2]

[1]Naval Research Laboratory
Stennis Space Center
MS 39529, USA

[2]Planning Systems Inc.,
Slidell, LA 70458
USA

Studies of solitary wave generation and propagation are conducted in Luzon Strait and South China Sea region. The EULAG nonhydrostatic model is used for simulating the generation and propagation of internal solitary waves. The model is initialized from density profiles obtained from the Navy Coastal Ocean Model (NCOM) with tides and is forced with an analytical tidal function derived from data or by assimilating the barotropic tidal forcing predicted by NCOM.

The emphasis of this investigation is on various issues that arise in conducting the model predictions. The domain size is about 600 km along longitude and 444 km along latitude.
Grid resolution is varied from 100 m to 1 km in longitude and 1 km to 25 km in latitude. The effects on solitary wave train structure and horizontal curvature are considered, including decoupling of dynamics along latitude as the resolution becomes coarse. Vertical resolution is varied from 21 to 41 sigma layers. Tidal forcing issues involve variation of analytical forcing function in time and space. Assimilation of barotropic tidal forcing from NCOM can lead to damping of internal bores as they propagate away from Luzon Strait towards China. Various settings of model parameters are considered.

Application of a non-hydrostatic meteorological model to flow and dispersion of tracers in a street canyon

A. M. Gadian[1] S.-J. Lock[1], N. S. Dixon[1], P. K. Smolarkiewicz[2], and A. Tomlin[1]

[1] University of Leeds
Institute of Atmospheric Sciences
Leeds, LS2 9JT
U. K.

[2]NCAR, MMM
PO Box 3000
Boulder, CO 80307
U.S.A.

Flow in a street canyon in a small town in the North of England is modeled using the EULAG model.

Two instrumented lamp-posts were used to measure velocities and concentrations. The street is ~ 15 m wide and 11m high and is subject to significant traffic flow. Preliminary results of the observations are presented.

The modeling of the airflow was carried out using the EULAG. The simulation was attempted using the Gal-Chen and immersed boundary condition, which proved to be more appropriate. Results will be presented of this work. The calculations were carried out in three phases; one to calculate the velocity fields, another to calculate the mean values and finally to calculate the variances.

Completion of a comparison of TKE fields and modeled fields is still to be completed, and the calculation of the helicity component is still to be completed.

The effect of the build up of concentration at street junction is demonstrated.

The Monge-Ampère differential equation and semi-Lagrangian advection schemes

Jean-François Cossette[1] and Piotr K. Smolarkiewicz[2]

[1] Université de Montreal,
Montreal,
Canada

[2] NCAR, MMM
PO Box 3000
Boulder, CO 80307
U.S.A

We discuss a class of semi-Lagrangian advection schemes based on the selection of a contour in a space-time continuum for the integration of a fluid variable PSI. In our numerical examples, the form of the equations resulting from the choice of this specific contour leads to a non-conservative advection technique for PSI. We supplement this technique with a correction based on the satisfaction of the mass continuity equation in which a nonlinear elliptic equation, the Monge-Ampère differential equation, must be solved at each step of the advection process. This approach allows for the selection of larger time steps than those allowed by the Courant-Friedrich-Lewy stability condition (CFL) encountered in Eulerian schemes and provides the overall numerical scheme with an improved set of trajectories satisfying mass continuity equation. A comparative study between Eulerian and semi-Lagrangian methodologies in a variety of flows such as decaying and evolving turbulence as well as a two-dimensional double-layer shear flow will be presented.

Lidar-Measurement-Integrated Simulation of Wake Turbulence

Takashi Misaka[1], Shigeru Obayashi[1], Izumi Yamada[2], Yoshinori Okuno[3]

[1]Institute of Fluid Science, Tohoku University, Japan
[2]Electronic Navigation Research Institute, Japan
[3]Japan Aerospace Exploration Agency, Japan

Wake turbulence is one of the factors which restricts airport's landing and takeoff capacities. Numerical simulation of wake turbulence has been performed using large eddy simulation and direct numerical simulation. Although the numerical simulation could reproduce detailed flow structure of wake vortices, it is difficult to incorporate the effect of actual weather conditions at airport which affects the decay process of the wake vortices. Lidar is an effective tool to measure the wake turbulence of operating aircrafts. For the understanding of flow structure of wake turbulence; however, there are some drawbacks such as the lack of spatial resolution in the line-of-sight direction and the difficulty in tracking wake vortices for long periods due to the disturbance of ambient winds.

For the consideration of actual atmospheric conditions in the numerical simulation, the present study attempts to integrate lidar measurements into the numerical simulation using a data assimilation technique. Specifically, Four-dimensional variational (4D-Var) method was applied to integrate lidar measurements with the three-dimensional computational fluid dynamics simulation, in which actual scanning processes of the lidar was simulated as a measurement operator of the 4D-Var method. And a bogus vortex technique was adopted to ensure the existence of a vortex pair in the flow field. The validation of the method was performed by idealized test cases using the virtual lidar measurement which was produced by the reference simulation of a vortex pair. Then, the method was applied to actual lidar measurements at Sendai Airport in Japan.

EULAG simulation of shallow cumulus clouds with two-moment warm-rain scheme and prescribed entrainment-mixing scenarios

Joanna Slawinska, Wojciech W. Grabowski, Hanna Pawlowska, Hugh Morrison[2]

[1]University of Warsaw
Institute of Geophysics
ul.Pasteura 7,
02-093 Warszawa
Poland

[2] NCAR, MMM
PO Box 3000
Boulder, CO 80307
U.S.A.

We will present results of three-dimensional simulations of shallow cumulus convection using EULAG with two-moment bulk warm-rain microphysics scheme combined with a simple approach to model entire range of subgrid-scale mixing scenarios, from homogeneous to extremely inhomogeneous (Morrison and Grabowski, J. Atmos. Sci. 2007, 2839-2861; 2008, 792-812). A series of simulations was performed using the nonprecipitating (BOMEX) as well as precipitating (RICO) cases and assuming various idealized aerosol characteristics (PRISTINE versus POLLUTED) as well as various mixing scenarios. The focus is on the impact of the entrainment-mixing processes on microphysical properties of clouds, the effective radius in particular. A possibility of in-cloud droplet activation (e.g., due to increasing updraft strength or entrainment) is also investigated. For the RICO case, the impact of entrainment/mixing on rain processes is explored. The results of these investigations will be summarized at the meeting.

Modeling of subgrid-scale mixing in large-eddy simulation of shallow convection

Dorota Jarecka[1] and Wojciech W. Grabowski[2]

[1]University of Warsaw
Institute of Geophysics
ul.Pasteura 7,
02-093 Warszawa
Poland

[2] NCAR, MMM
PO Box 3000
Boulder, CO
80307
U.S.A

This paper will discuss representation of subgrid-scale turbulent mixing in models of warm (ice-free) clouds. For models with bulk representation of cloud microphysics, instantaneous adjustment to grid-scale saturation is assumed. This is a reasonable assumption for condensation of water vapor because supersaturations inside clouds are typically small (except near cloud bases where about order of magnitude larger supersaturations are anticipated). For the cloud evaporation, however, instantaneous adjustment to grid-scale saturation is questionable, especially when evaporation occurs as a result of turbulent mixing between a cloud and its unsaturated environment. This is because turbulent mixing between initially separated volumes of cloudy and cloud-free environmental air proceeds through a gradual filamentation of these volumes, with progressively increasing evaporation of cloud water during the approach to final homogenization. A relatively simple model of this chain of events is included in a bulk model of moist non-precipitating thermodynamics. The model delays adjustment to saturation for cloud evaporation following the turbulent mixing until the volume can be assumed homogeneous. Two additional prognostic variables, the mean width of a cloudy filament and the fraction of the grid-volume occupied by the cloudy air, are added to represent the progress of turbulent mixing and approach to homogenization. An extension of this approach to a two-moment cloud microphysics scheme predicting the supersaturation field is also being developed. Numerical tests presented at the conference will illustrate the impact of these developments on large-eddy simulations of shallow convection.

LES Simulations of Entrainment and mixing on the Stratocumulus Top

Marcin Kurowski[1], Szymon P. Malinowski[1] and Wojciech W. Grabowski[2]

[1]University of Warsaw
Institute of Geophysics
ul.Pasteura 7,
02-093 Warszawa
Poland

[2] NCAR, MMM
PO Box 3000
Boulder, CO
80307
U.S.A.

We discuss here results of LES simulation of entrainment and mixing near the STBL top. Setup of the numerical experiment is based on research flight RF-01 in DYCOMS-II field campaign (geometry 96x96x301, dx=dy=35m, dz=5m). The focal point is the Entrainment Interface Layer (EIL), a few- to a few-tens of meters deep mixing zone that separates the cloudy and cold (in the potential temperature sense) boundary layer air from the dry and warm free-tropospheric air aloft. We investigate stability of the flow in the cloud-top region using the local gradient Richardson number calculated at the surface of maximum static stability near the STBL top and at the material top of STBL, the latter defined using a threshold value of the total water content.

Boundary-layer updrafts, spanning entire depth of the STBL, impinge upon the inversion and produce diverging horizontal flows just below the layer of maximum stability. Ensuing strong vertical shear results in the local gradient Richardson number smaller than one typically associated with onset of flow instabilities. Turbulence, characterized by large local values of enstrophy, causes mixing responsible for the formation of the EIL and for the entrainment of free-tropospheric air into the STBL.

Entrainment processes are further analyzed using a passive scalar introduced after three hours of the simulation above the layer of maximum stability. Mixing fraction of this scalar within the STBL, an indicator of the fraction of entrained free-tropospheric air, falls within the range corresponding to the buoyancy reversal at the cloud top.

Large-eddy simulations of Sc cloud strongly depend on a grid resolution as well as subgrid processes. Switching off the turbulence (an inviscid case) leads to unstable conditions, where liquid water path systematically grows up to unrealistic values - subgrid scheme is necessary to produce credible characteristics of STBL. Finer vertical grid size (with subgrid mixing) suppresses the role of subgrid parameterization and produces more thick cloud. It points a question about the role of subgrid mixing within LES simulations. Another question considers the problem of the numerical estimate of the Critical Richardson number at the top of STBL.

Impact of mesoscale dynamics and aerosols on the life cycle of cirrus clouds

Peter Spichtinger

ETH Zurich
Institute for Atmospheric and Climate Science
CHN P 14, Universitaetsstr. 16
8092 Zurich, Switzerland

The role of clouds is crucial for our understanding of the current and the changing climate (IPCC, 2007). Cirrus clouds modulate the Earth's radiation budget significantly. It is assumed that (thin) cirrus clouds contribute to a net warming of the Earth-Atmosphere system (see e.g. Chen et al., 2000) but the magnitude of this warming has not been quantified yet. Recently, the impact of thin cirrus clouds in the mid latitudes was estimated in idealised framework using vertical profiles from radiosondes (Fusina et al., 2007), but the global effect is still uncertain. The formation and evolution of cirrus clouds depends in a complex way on a variety of environmental conditions (temperature, relative humidity, wind fields) as well as on the impact of background aerosol acting as ice nuclei. The interaction of various processes and their non-linear dependence on ambient conditions renders the understanding of cirrus clouds in general a difficult task.

Although cirrus clouds appear quite homogeneous from a satellite perspective (e.g., a warm-front cirrus), even a casual glance from the ground reveals an inhomogeneous, patchy structure of cirrus, corroborated by in situ measurements: Inside cirrus clouds temperature and vertical velocity flucutations are substantial, thus causing inhomogeneities in ice crystal number concentrations and ice water content. Based on temperature and/or vertical velocity measurements in the upper troposphere (e.g. Gary, 2006; Gierens et al., 2007) an ``ubiquitous'' background of temperature fluctuations is often assumed and superimposed on trajectory calculations for large-scale updraft motion. However, these variations (in temperature and/or vertical velocity) have a deterministic physical origin. In particular, small-scale variations can be related to turbulence generated by breaking internal gravity waves. One main task in our cirrus cloud research is to identify physical sources of these variations inside cirrus clouds and their impact on the life cycle of cirrus clouds.

Using the EULAG model together with a newly developed and validated ice microphysics scheme (Spichtinger and Gierens, 2008) the impact of orographic waves and turbulence generated in critical layers is investigated. Additionally, the impact of heterogeneous ice nuclei competing against homogeneous freezing, the dominant pathway of ice crystal formation in the tropopause region, on the life cycle of cirrus clouds is investigated prescribing the same dynamical setup.

Sensitivity of modeled atmospheric convection to effective viscosity

Zbigniew P. Piotrowski[2], Piotr K. Smolarkiewicz[1] and Szymon P. Malinowski[2]

[1]University of Warsaw
Institute of Geophysics
ul.Pasteura 7,
02-093 Warszawa
Poland
l

[2] NCAR, MMM
PO Box 3000
Boulder, CO 80307
U.S.A

We present idealized dry simulations of the convective boundary layer with the horizontal resolutions of 500 m, 1 km and more. We show that organization of convection within the ABL in such simulations is sensitive to the effective (resolved+subgrid+numerical) heat and momentum transport coefficients. In particular, using the flux corrected of MPDATA advection scheme allowing for the control of transport processes in the simulations, we demonstrate the sensitivity of solutions to the anisotropy of transport coefficients.

Entrainment in Cumulus Clouds: Which resolution is cloud-resolving?

George C. Craig and Andreas Dörnbrack

DLR Oberpfaffenhofen
Institut für Physik der Atmosphäre
D-82234 WESSLING
Germany

Systematic numerical experiments to determine the spatial resolution required to resolve a moist thermal show convergence at a scale proportional to the smaller of the initial thermal diameter D_0 and a buoyancy length scale L_{buoy}. The buoyancy length scale $L_{buoy.} = \Delta T_0/\Delta \Gamma$ (ΔT_0 is the initial buoyancy excess of the thermal and $\Delta \Gamma$ is the ambient stratification) describes the maximum vertical displacement that can be induced against the stratification in the environment by buoyancy-driven pressure perturbations in the cloud, and thus the maximum scale of eddies that cross the cloud boundary. For typical atmospheric conditions where the cloud size D_0 is larger than L_{buoy}, numerical simulations of the mixing processes in cumulus clouds must resolve L_{buoy}.

Cirrus clouds triggered by radiative cooling and small eddies - a multiscale problem

Fabian Fusina

ETH Zurich
Institute for Atmospheric and Climate Science
CHN P 14, Universitaetsstr. 16
8092 Zurich, Switzerland

In this study, the influence of radiative cooling and small eddies on cirrus formation is investigated. For this propose the nonhydrostatic, anelastic model EULAG is used with a recently developed and validated ice microphysic scheme (Spichtinger and Gierens, 2008). Additionally, we implemented a fast radiation transfer code (Fu, 1998).

Using idealized profiles with high supersaturations up to 144% and weak stable stratifications with vertical gradients of the potential temperature down to 0.4 K/km within a layer of about 1km thickness in a height of approx. 10 km, the influence of radiation on the formation of cirrus clouds is remarkable. Due to the radiative cooling at the top of the ISSR with cooling rates down to 2 K/d and heating rates at the bottom of the ISSR up to 0.2 K/d, the stability of the ISSR stratification decreases with time. At a critical point, Gaussian temperature fluctuations turn the layer to an unstable regime and convection starts. The effects of increasing the local relative humidity by cooling due to radiation, convective lifting and small eddies lead to the formation of a cirrus cloud with IWC up to 20mg/m3 and optical depths up to 0.7. In all simulations, only homogeneous nucleation is considered. Our simulations could show that, if one of the two effects (either the radiation or the Gaussian temperature fluctuations) is disabled, no nucleation occurs within the simulation time of 6 h. Only the interaction of a small scale (fluctuations) and a large scale (radiation) effect leads to the formation of a cirrus in these particular cases, i.e. the cirrus only can be formed by a superposition of processes on different scales.

The main goal of this study is to obtain deeper insights in the different environmental conditions (temperature, relative humidity, stratification, strength of temperature fluctuations, insolation), which allow the formation of this type of cirrus clouds. Additionally the radiative properties of theses clouds are investigated.

Participants

Babatunde Abiodun	Iowa State University, USA	babiodun@iastate.edu
Ulrich Achatz	Uni Frankfurt, D	achatz@iau.uni-frankfurt.de
Kiril Alexandrov	TU Cottbus, D	kiril.alexandrov@tu-cottbus.de
Jean-François Cossette	Université de Montréal, CA	jf_astro@hotmail.ca
Andreas Dörnbrack	DLR Oberpfaffenhofen, D	andreas.doernbrack@dlr.de
Fabian Fusina	ETH Zürich, CH	fabian.fusina@env.ethz.ch
Alan Gadian	Uni Leeds, UK	alan@env.leeds.ac.uk
Wojciech W. Grabowski	NCAR Boulder, USA	grabow@ucar.edu
William J. Gutowski	Iowa State University, USA	gutowski@iastate.edu
Uwe Harlander	TU Cottbus, D	uwe.harlander@tu-cottbus.de
Dorota Jarecka	Uni Warszawa, PL	dorota@igf.fuw.edu.pl
Rupert Klein	FU Berlin, D	rupert.klein@zib.de
Oswald Knoth	IfT Leipzig, D	knoth@tropos.de
Marcin Kurowski	Uni Warszawa, PL	mkuro@igf.fuw.edu.pl
Christian Kühnlein	DLR Oberpfaffenhofen, D	christian.kuehnlein@dlr.de
Thomas von Larcher	FU Berlin, D	larcher@math.fu-berlin.de
Lech Lobocki	Uni Warszawa, PL	llobocki@is.pw.edu.pl
Stefan Löbig	TU Darmstadt, D	sloebig@mathematik.tu-darmstadt.de
Szymon Malinowski	Uni Warszawa, PL	malina@igf.fuw.edu.pl
Takashi Misaka	Tohoku Uni, JP	misaka@edge.ifs.tohoku.ac.jp
Pablo Ortiz	Univ. de Granada, ES	portiz@ugr.es
Zbyszek Piotrowski	Uni Warszawa, PL	zbych@igf.fuw.edu.pl
Joseph M. Prusa	Iowa State University, USA	prusaj@bellsouth.net
Daniel Reinert	Universität Mainz, D	dreinert@uni-mainz.de
Joanna Slawinska	Uni Warszawa, PL	pilvi@igf.fuw.edu.pl
Piotr K. Smolarkiewicz	NCAR Boulder, USA	smolar@ucar.edu
Peter Spichtinger	ETH Zürich, CH	peter.spichtinger@env.ethz.ch
Joanna Szmelter	Loughborough University, UK	j.szmelter@lboro.ac.uk
Alex Warn-Varnas	NRL, USA	varnas@nrlssc.navy.mil
Nils P. Wedi	ECMWF Reading, UK	nils.wedi@ecmwf.int
Volkmar Wirth	Universität Mainz, D	vwirth@uni-mainz.de
Andrzej A. Wyszogrodzki	NCAR Boulder, USA	andii@ucar.edu
Michael Ziemianski	IMGW, Gdynia, PL	michael.ziemianski@imgw.pl

Practical Information

Posthotel Kolberbräu
Marktstraße 29
D - 83646 Bad Tölz
Germany

Phone:: ++49 (0)8041/7688-0
Fax: ++49 (0)8041/7688-200

Email: info@kolberbraeu.de
WEB: www.kolberbraeu.de

How to get to Bad Tölz?

We recommend to fly to Munich International Airport or to take a train to Munich Main Station. From both places there is easy public transportation to Bad Tölz.

Connection to Munich City by S-Bahn:

The S1 and S8 go frequently between the airport and Munich City center. On both lines, the journey between the airport and Munich Main Station takes just 40 minutes. For schedule information contact:

http://www.mvv-muenchen.de/en/home/passengeraeinformation

Exit the trains at Donnersberger Brücke (2 stops before or after Munich Main Station). From there, take the

Bayrische Oberlandbahn http://www.bayerische-oberlandbahn.de

directly to Bad Tölz (approximately 50 minutes ride). We recommend using a taxi for the short (5 min) ride to the hotel.

If you plan to rent a car at Munich Airport, ask at the desk for directions to the Bad Tölz. The Posthotel "Kolberbräu" has it own parking spot behind the building.

Alternatively, the hotel offers a shuttle service from Munich Airport to Bad Tölz. As the costs amount to about 140 €, this service makes sense for a group of 4 to 5 people.