# International course of lectures "Geophysical turbulence and boundary layers: nature, theory and role in Earth's systems"

University of Helsinki and Finnish Meteorological Institute
"Dynamicum", Erik Palménin aukio 1, 00561 Helsinki, Finland, 27 May – 1 June 2007

## Supported by

EU Marie Curie Chair Project MEXC-CT-2003-509742 "Planetary boundary layers – Theory, Modelling and Role in Earth Systems" (TMRES), NordForsk (former NorFA) Nordic Network on Fine-scale Atmospheric Modelling (NetFAM); NORDPLUS Neighbour Project 1777039/V11 "Boundary-layer Phenomena over Ice Covered Arctic Seas"; EU TEMPUS JEP 26005 "Development of a Competency-based Two-level Curricula in Meteorology"; and EU Marie Curie Chair Project MEXC-CT-2005-025353 "Fundamental and Conceptual Aspects of Turbulent Flows" (TURBCONG)

## Organising Committee

A. Belotserkovski (RSHU), S. Joffre (FMI), H. Savijarvi (UH), M. Sofiev (FMI; Course Director), S.Zilitinkevich (UH & FMI)

## Summary

The main objective of this course is to summarise current knowledge on the nature, theory and parameterisation of geophysical turbulence, planetary boundary layers (PBLs) and meso-scale boundary-layer type flows relevant to numerical modelling of weather, climate, air-pollution and both terrestrial and marine ecosystems. From the physical point of view, these are the very high Reynolds number, stratified, rotating, turbulent flows. Their improved parameterisation is becoming a challenging problem in view of new demands from operational modelling employing very high resolution general circulation models (GCMs), especially the coupled atmosphere-soil/sea/ice-biosphere model suites needed to realistically predict local consequences of the climate change. The course covers the following main topics:

- Nature and theory of geophysical turbulence and PBLs
- Turbulence closure problem
- Radiation and turbulence PBLs
- Semi-organised structures and fully chaotic turbulence: similarity and difference
- Observation of the turbulent and mean structure of PBLs
- Large-eddy simulation (LES) of PBLs
- Flow-surface interaction and turbulent fluxes at the surface[1]
- Turbulent and mean structure of air flows within vegetated and urban canopies
- Meso-scale and urban turbulent flows
- Weather and climate problems essentially dependent on PBLs
- PBLs and turbulence in ecosystem modelling

At the end of the course we arrange a special session on modern aspects of meteorological education (in the scope of the above EU TEMPUS JEP).

[1] Air-sea interaction has been the subject of a recent summer school (28 August – 1 September 2006, FMI, Helsinki).

## Programme of the course

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| **28.05.2007**<br>**Nature and theory of geophysical turbulence and PBLs** | |
| Introduction to fundamentals of turbulence 9:00 – 10:30 | Prof. Arkady Tsinober, UCL, UK |
| New effects in turbulent aerosol transports: theory, lab and field experiments 10:45 – 12:15 | Dr. Igor Rogachevskii, BGU, IL |
| PBLs in stable, neutral and unstable stratification: scaling, data and analytical models, surface-flux algorithms 13:15 – 14:45<br>15:00 – 16:30 | Prof. Sergej Zilitinkevich, UH / FMI, FI |
| Discussion 16:30 – 17:30 | A. Tsinober, I. Rogachevskii, S. Zilitinkevich |
| **29.05.2007**<br>**Turbulence closure problem for stable stratification:** | |
| Turbulence energetics and critical Richardson number<br>Energy and flux-budget (EFB) turbulence closure model for steady-state, homogeneous and heterogeneous regimes 9:00 – 10:30 | Prof. Sergej Zilitinkevich, UH / FMI, FI |
| **Radiation and turbulence in PBLs** | |
| Radiative heat transfer and its role in stable PBLs 10:45 – 12:15 | Prof. Hannu Savijärvi, UH, FI |
| **Semi-organised structures and fully chaotic turbulence: similarity and difference, LES** | |
| Semi-organised structures in convective BL 13:15 – 14:45 | Dr. Nathan Kleeorin, BGU, IL |
| Large-eddy simulations of PBLs, LES "portraits" of typical semi-organised eddies 15:00 – 16:30 | Dr. Igor Esau, NERSC, NO |
| Discussion 16:30 – 17:30 | S. Zilitinkevich, H. Savijarvi, N. Kleeorin, I. Esau |
| **30.05.2007**<br>**Observation of the turbulent and mean structure of PBLs** | |
| What do we want to measure in turbulence, why and how? 9:00 – 10:30 | Prof. Arkady Tsinober, UCL, UK |

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| **Flow-surface interaction and turbulent fluxes at the surface** | |
| Interaction of air-flow with ice and snow 10:45 – 12:15 | Dr. Timo Vihma, FMI, FI |
| Stability dependence of the roughness length and displacement height 13:15 – 14:00 | Dr. Ivan Mammarella, UH. FI |
| Turbulence and transports in vegetation canopies 14:15 – 15:45 | Prof. Timo Vesala, UH, FI |
| Modelling of turbulence within vegetation canopies 16:00 – 16:45 | Dr. Andrey Sogachev, UH, FI |
| Discussion 16:45 – 17:30 | A. Tsinober, T. Vihma, I. Mammarella, T. Vesala, A. Sogachev |
| **<u>31.05.2007</u>**<br>**Turbulent and mean structure of air flows within vegetated and urban canopies** | |
| Meso-scale meteorological models: correcting model errors and limitations. Characteristics of urban PBLs Urbanized meso-scale meteorological models Global-warming induced reverse-reactions: summer daytime coastal-cooling 9:00 – 10:30<br>10:45 – 12:15 | Prof. Robert Bornstein, SJSU, USA |
| **Meso-scale and urban turbulent flows (cont)** | |
| Boundary-layer aspects in shallow-water approximations 13:15 – 14:00 | Prof. Arakel Petrosyan, IKI RAS, RU |
| Modelling of boundary-layer type flows: sea breezes, katabatic winds and internal boundary layers 14:00 – 15:30 | Prof. Hannu Savijärvi, UH, FI |
| Urban boundary layers: experience of EU-FUMAPEX 15:45 – 16:45 | Dr. Alexander Baklanov, DMI, DK |
| Discussion 16:45 – 17:30 | R. Bornstein, A. Petrosyan, H. Savijarvi, A. Baklanov |
| **<u>1.06.2007</u>**<br>**Weather and climate and ecosystem modelling problems essentially dependent on PBLs** | |
| The role of the PBL parameterization in operational numerical weather prediction: HIRLAM experience 9:00 – 10:30 | Dr. Carl Fortelius, FMI, FI |
| The role of the PBLs parameterization in operational air quality modelling: SILAM experience 10:45 – 12:15 | Dr. Mikhail Sofiev, FMI, FI |
| High resolution atmosphere–sea–water ecosystem model suite: the general architecture and the role of turbulence 13:15 – 14:45 | Dr. Rein Tamsalu, UT, EE |
| Discussion 15:00 – 16:00 | C. Fortelius, M. Sofiev, R. Tamsalu |

## Glossary

BGU = Ben Gurion University of the Negev
DMI = Danish Meteorological Institute
FMI = Finnish Meteorological Institute
GCM = general circulation model
IG RAS = Institute of Geography, Russian Academy of Sciences
IKI RAS = Institute of Space Research, Russian Academy of Sciences
LES = large-eddy simulation
NERSC = Nansen Environmental and Remote Sensing Centre
PBL = planetary boundary layer
SJSU = San Jose State University
UCL = University College, London
UH = University of Helsinki (Division of Atmospheric Sciences)
USF = University of South Florida
UT = University of Tartu