The Afternoon Transition:
Boundary layer structure with decaying turbulence

Issue

Growth of the convective planetary boundary layer (CBL) in the morning and at mid-day is well known and represented by models, but the evolution from mid-afternoon on, and the transition from the mixed layer to a residual layer at the end of the afternoon are still not well understood. The definition of the boundary layer itself at that time of the day is fuzzy, since there is no concensus on what criteria to use and no scaling laws to apply. Yet this transition to the nocturnal boundary layer is important, especially for the transport of species. The residual layer overlying the nocturnal stable layer can be incorporated into the free troposphere, so that water vapour and pollutants emitted at the surface and diluted into the CBL during the day can be introduced in the free atmosphere and transported at larger scale.

After a certain time in the afternoon, the surface buoyancy flux is not large enough to maintain turbulent mixing, especially for a deep CBL. Yet, vertical motion of about 1 m/s extending over several km has been observed, most notably by free-flight pilots (glider, paraglider, hangglider... pilots). The reason for this large-scale uplift is unclear; possibilities include surface processes, orography, or mesoscale forcing.

The scale of updrafts during the transition indeed seem to be larger than the turbulent scales of vertical transfer during the middle of the day. Previous LES studies showed that during that period of the day, a decoupled residual layer, within which turbulence is still active, develops above the stable surface layer. It is characterised by updrafts of larger scale than the mid-day eddies, that persist even when the sensible heat flux at the surface turns negative. These updrafts may generate smaller scale eddies that are able to induce entrainment at the top of the residual layer.

Two time scales are relevant here: an external timescale that control the evolution of the sensible heat flux at the surface and the convective timescale. Dynamical scaling laws do not apply during the transition phase, whereas the scaling law for temperature is still in effect within the mixed layer, but not at the capping inversion. With a pronounced non-stationarity, this period is also associated with non-linear sensible heat flux profiles, that have an 'S' shape due to the decrease of the flux at the surface. Flux at the top remains constant so that the ratio between the two increases.

This topic seems to have been studied previously using numerical simulation to a much greater extent than by observations.

Indeed, if the CBL is rapidly growing, it is easily detected, for example, by the maximum of the refractive index deduced from the radar reflectivity. The refractive index structure is much more complex and variable during the afternoon transition, even in simple meteorological cases. It is also difficult to measure the small turbulent fluxes occurring during the transition with aircraft, especially due to the transitory conditions and large length scales.

In summary, this phenomenon is complex and challenging to study, due to both its transitional aspect and because the forcing variables at that time are weak. However, it is an important regime because of its impact on mesoscale circulations and passive scalar transport.

Questions

- What is the role played by the stratification that sets in during the afternoon on the evolution of the PBL and the future of the residual layer ? And on the growth of the PBL the day after ?
- What is the impact of this transition at mesoscale, especially on transport of pollutants ?

Are the LES results on changing scales, entrainment, heat flux profiles,... are verified in the real world ?

- What is the interaction between waves that develop in the stables layers (above or below the residual of the mixed layer) and the mixed layer ?
- What is the role played played by clouds ?
- Is there really a change in predominant scales ? Is it linked with the scale of the surface heating patterns ? Or mesoscale convergence/divergence patterns ? Orography ?

Strategy

So far, we plan to base our work during 2009 and 2010 on previous dataset that seem appropriate for this issue. The workshop will allow us to coordinate our future works, write a white book and have preliminary thinking of a future field campaign that would be defined based on our preliminary studies. This campaign would potentially involve small aircraft(s), ground-based remote sensing, tethered and radiosounding balloons, surface station and Unmanned Aerial System.

We plan to use the combination of the observations in real world, laboratory experiment, large eddy simulation and mesoscale numerical simulations from the start of the project, in order to connect as much as possible our understanding of the observations to the improvements of the parameterisations of the processes in the bulk models.

Workshop - information

The workshop will be help in **Toulouse** on **13 and 14 May 2009**, at the International Conference Center **(CIC) of Météo-France**, 42 avenue Gaspard Coriolis, 31057 Toulouse.

Organizers: Marie Lothon (Laboratoire d'Aérologie, UMR CNRS, University of Toulouse)

Fleur Couvreux (CNRM, Météo-France, Toulouse).

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Sponsors : CNRS (Centre National de la Recherche Scientifique), INSU (Instituta National des Sciences de l'Univers), UPS (Université Paul Sabatier de Toulouse), Météo-France.

Current list of participants :

(*: still needs confirmation)

Wayne Angevine	CIRES, University of Colorado and NOAA Earth System Research Laboratory, Boulder, Colorado, USA
Patrick Augustin	Laboratoire de Physico-Chimie de l'Atmosphère (LPCA), UMR CNRS, Université du Littoral-Côte d'Opale, Dunkerque, France
Jens Bange	Technische Universitaet Braunschweig, Germany
Bob Beare	School of Engineering, Computing and Mathematics, University of Exeter, UK
Fleur Couvreux	Centre National de la Recherche Météorologique (CNRM), Météo-France, Toulouse, France
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Pierre Durand	Laboratoire d'Aérologie (LA), UMR CNRS, University of Toulouse, France
Pierre Flamant (*)	Laboratoire de Météorologie Dynamique, IPSL/CNRS, Ecole Polyttechnique, Palaiseau, France
Fabien Gibert	Laboratoire de Météorologie Dynamique, IPSL/CNRS, Ecole Polyttechnique, Palaiseau, France
Beniamino Gioli	Ibimet, CNR, Florence, Italia
Françoise Guichard	Centre National de la Recherche Météorologique (CNRM), Météo-France, Toulouse, France
Ronald Hutjes (*)	ALTERRA - Research Institute for the Green World, Center for Water and Climate, Wageningen, the Netherlands
Harm Jonker	Delft University of Technology, Delft, The Netherlands
Madhu C. Kalapureddy	Laboratoire d'Aérologie (LA), UMR CNRS, University of Toulouse, France
Don Lenschow	National Center for Atmospheric Research, Boulder, Colorado, USA
Marie Lothon	Laboratoire d'Aérologie (LA), UMR CNRS, University of Toulouse, France
Sabrina Martin	Technische Universitaet Braunschweig, Germany
David Pino	Technical University of Catalonia, Barcelon, Spain
Frédérique Saïd	Laboratoire d'Aérologie (LA), UMR CNRS, University of Toulouse, France
Zbigniew Sorbjan	Marquette University, Milwaukee, Wisconsin, USA
Jordi Vilà-G. de A.	Meteorology and Air Quality Wageningen University and Research Center, the Netherlands

List of people who are interested in the project but cannot come to the workshop:

Frank Beyrich	Meteorologisches Observatorium Lindenberg, Richard-Aßmann-Observatorium, Deutscher Wetterdienst, Lindenberg, Germany
Bernard Campistron	Laboratoire d'Aérologie (LA), UMR CNRS, University of Toulouse, France
Ulrich Corsmeier	Institute for Meteorology and Climate (IMK), University of Karlsruhe, Karlsruhe, Germany
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Larry Mahrt	Oregon State University, Corvallis, Oregon, USA
Shane Mayor	California State University, Chico, California, USA

Program in brief

Wednesday 13	*morning*	- Introduction: Main issue of the project and objectives of the workshop - Previous works (presentations)
	afternoon	- Previous works (presentations) - continuation - Revision of the main issues and goals and definition of sub-topics and directions - Finding an inventive acronym... - Preparation works and previous campaigns that give an appropriate frame
Thursday 14	*morning*	- Presentations (related/relevant previous/current studies)
	afternoon	- Discussion about a future field campaign - White book writing – Definition of tasks
Friday 15		- Visit of the « Pic du Midi de Bigorre » and its astronomy and atmospheric observatory (if the weather permits !). Lunch at the observatory and visit of the museum. - (if we have time :) Visit of the Centre de Recherche Atmosphérique (Laboratoire d'Aérologie) in Lannemezan

Detailed Program of the workshop :

Wednesday 13

- 8h30-9h00: Welcome
- **9h00** Introduction: Main issue of the project and objectives of the workshop
- **9h15** *Zbigniew Sorbjan:* Daily transitions in the atmospheric boundary layer
- **10h00** *David Pino:* How large-eddy simulations reproduce sunset decaying turbulence over land

10h30-11h00 coffee break

- **11h00** *Jordi Vila:* Role of afternoon transition in transporting and transforming atmospheric compounds
- **11h30** *Bob Beare:* Large-eddy simulation of evening and morning transition boundary layers
- **12h00** *Harm Jonker:* Laboratory experiment and DNS for the study of planetary boundary layer processes

12h30-14h00: lunch break

- **14h00** *Wayne Angevine:* Observations of afternoon transitions of the convective boundary layer during Flatland
- **14h30** *Don Lenschow:* The "Buffer layer"
- **15h00-16h00** Discussion: Revision of the main issues, goals and directions. Definition of associated involvements.

16h00-16h30 coffee break

- **16h30-18h00** Discussion: Preparation works and previous campaigns that give an appropriate frame.

Thursday 14

- **8h30** *Fabien Gibert:* The nocturnal transition phenomenology as observed by Doppler Lidar
- **9h00** *Beniamino Gioli:* Aircraft observations made during the afternoon transition
- **9h30** *Hervé Delbarre:* Sea/land breeze switch in costal areas
- **10h00** *Jens Bange:* 'Airborne measurements in the Early-Morning Shallow Convective Boundary Layer'

10h30-11h00 coffee break

- **11h00-12h30:** Discussion: (1) Observing, modelling and reproducing the decaying PBL, (2) Past and future field campaigns

12h30-14h00: lunch break

- **14h00-16h00:** Discussion: planned field campaign, proposal, funding possibilities

16h00-16h30 coffee break

- **16h30-18h00** White book writing – Definition of structure, content and tasks.