Dynamic and radiative process driving the stratus – fog transition.

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ABSTRACT

This study aims at better understanding the interactions between dynamic and radiative fluxes likely to affect the life cycle of low level clouds and particularly during the stratus-fog transition. We use on the one hand the 1D Mercure_Saturne code and on the other hand the measurements performed at the SIRTA Observatory (25 km South Paris, France). Our study focuses on 10-day period at the end of December 2006. We compare turbulent kinetic energy profiles, vertical gradient of temperature and humidity, infrared radiative cooling and solar radiative heating, horizontal visibility provided by numerical code and observations. Hence, we test the numerical code and we analyse the weight of each factor during the fog event (formation and dissipation) in making sensitivity tests. We also establish probability statistic distribution on dynamic and radiative process during fog event to identify signal responsible of life cycle of fog starting from stratus clouds.

1. INTRODUCTION

Fogs are weather conditions with significant socio-economic impacts, associated with increased hazards in road, maritime and air traffic and subsequent elevated constraints in transport regulation. The life cycle of fogs involves a complex composite of dynamical, microphysical and radiative processes that are still not fully understood ([1]). While current NWP models are able to forecast situations that are favorable to fog events, these forecasts are usually unable to determine the exact location and time of formation or dissipation. On the one hand, critical processes occur at micro scales that are unresolved by forecast models and must hence be correctly parameterized. On the other hand, current models do not take into account some of the key physical processes such as the microphysical and radiative roles of aerosols. A 6-month field experiment, named ParisFog ([2], [3]), was carried out in winter 2006-2007 outside Paris, France, to monitor simultaneously all key processes that drive formation and dissipation of fogs. ParisFog gathered a suite of active and passive remote sensing instruments to measure profiles of wind, turbulence, radiative properties as well in-situ sensors to monitor temperature, humidity, aerosol and fog microphysics and chemistry in the surface layer. All observations are gathered in the ParisFog database. A comprehensive characterization of fog and near-fog events sampled during ParisFog shows the large variability of observed situations, with predominant occurrences of radiation fogs and stratus lowering fog [4]. Key processes involved in the different situations are discussed and comparisons with Mercure_Saturne code developed by the Atmospheric Environment Teaching and Research Center (CEREA; http://cerea.enpc.fr/fich/mercure/mercure_anglais_web.html).

2. OBSERVATIONAL DATA SETS

Data used to evaluate the effect of dynamic process on fog cycle are gathered at SIRTA Observatory [5]. Instruments were deployed on 3 different zones in a 4-km^2 area. Two 30-m masts hosted standard weather sensors to monitor the vertical thermodynamic structure in the surface layer. Measurements were extended vertically by radiosonde profiles performed routinely at 00 and 12 UT 15km West of SIRTA as part of the MF national network. During IOPs, measurements were also extended using weather sensors on a tethered balloon (5 sensors covering the 30-150m altitude range) and radiosondes launched from the site every 3 hours. Thermal and moisture soil conditions were monitored to 50 cm depth. A Bowen station was used to measure sensible and latent heat fluxes. Infrared and solar radiative fluxes were measured in 3 zones. As local dynamic conditions are key in fog processes, wind and turbulence were monitored by several systems distributed in the 4-km^2 domain. Classic and sonic anemometers at 10 and 30-m heights were available to study the state of turbulence. Active remote sensing instruments, namely a sodar and a UHF-radar were deployed to monitor the vertical structure of the wind field. A ceilometer and a 95GHz Doppler radar provided detailed information on the evolution of cloud and fog layers.

3. PRELIMINARY STUDY

3.1 Ground-based measurement

These comparisons focus on 3 days, 23 to 25 December 2006. During this period, stratus base altitude ranges from 100 to 400m (Figure 1). This figure corresponds to the radar reflectivity inside the cloud between 23 and 24 December 2006. Stratus cloud formation is 23 dec. at 12h00 and during the next night, fog appears at 06h00.

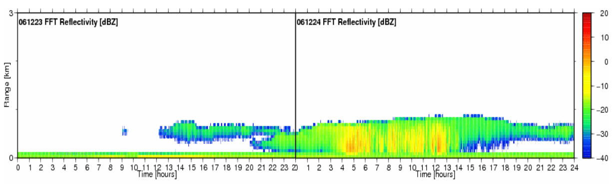

Figure 1. Radar reflectivity between 0 and 3 km for the 23-24 December 2006 period.

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Delft, The Netherlands, October 2009. Editors, A. Apituley, H.W.J. Russchenberg, W.A.A. Monna

Figure 2 presents the stratus base height retrieval provided by the CT25K ceilometer between 23 and 25 December 2006 and the cloud altitude derived from adiabatic and pseudo-adiabatic cooling starting from the ground-level. The two parametric condensation levels show a well agreement with the measurement what suggest a significant impact of the surface fluxes on this stratus cloud life cycle. The main discrepancies are simultaneous with the increase of the kinetic energy near the ground level (Figure 3).

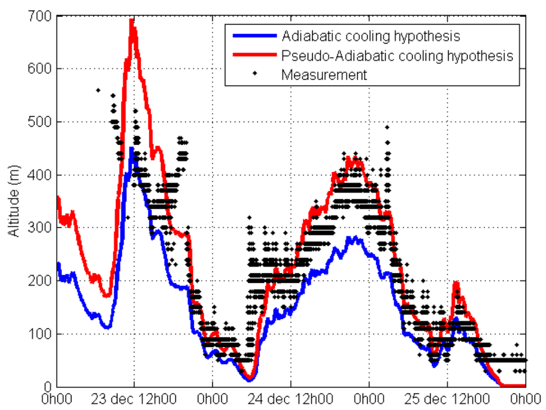

Figure 2. *Cloud altitude provided by CT25K ceilometer and derived from adiabatic and pseudo-adiabatic cooling starting from the surface.*

Figure 3 presents the turbulent kinetic energy between 23 and 25 December 2006 derived from sonic anemometer at 10 and 30 m over zone 1 and zone 4.

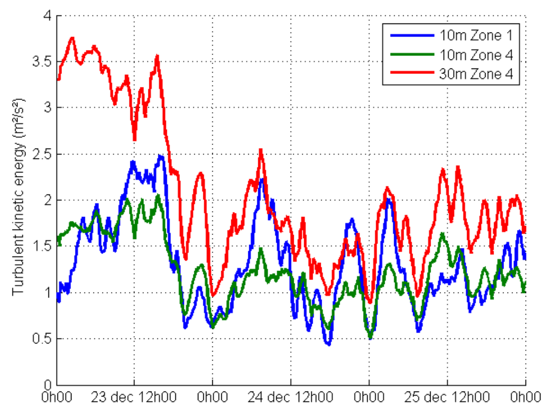

Figure 3. *Turbulent kinetic energy between 23 and 25 December 2006 derived from sonic anemometer at 10 and 30 m over zone 1 and zone 4.*

3.2 Comparisons with Mercure_Saturne simulations

Mecure_Saturne code is here used in single column model which accounts for nucleation, self-condensation, evaporation/condensation and sedimentation processes [6]. Turbulence mixing is considered with the Louis [7] or k-epsilon turbulence closure and solar / infrared interaction between ground and cloud are considered. We apply the 1-D version of Mercure_Saturne with a high-resolution grid (x,y,z=30km, 30km et 2.6km, with 69 levels and z_0=2m). However, the horizontal pressure and advection term are treated as external influences.

The initial and boundary conditions are obtained with atmospheric surface layer (ASL) method and deduced Radiosonde and Mat-Sonic by using Cressman analysis scheme.

Figures 4 and 5 correspond to comparisons between measurement and Mercure_Saturne simulations for 2m-tempertaure and 10m-sensible heat flux.

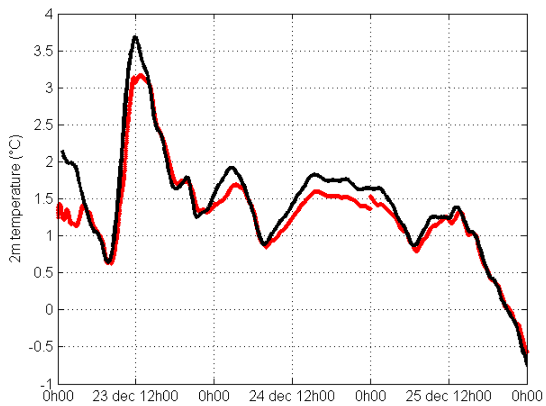

Figure 4. *2m-temperature obtained by Mercure_Saturne run (red line) and measurement (black line) during 23-25 december 2006.*

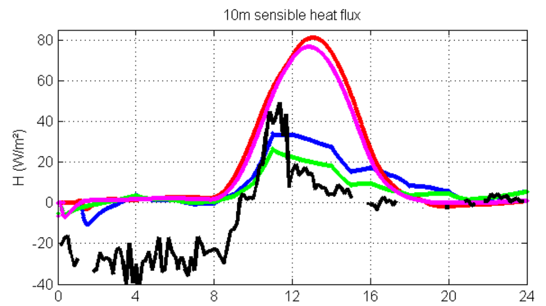

Figure 4. *10m-sensible heat fluxe obtained by Mercure_Saturne run (for k-epsilon in red/pink and Louis in blue/green turbulence closure) and measurement (black line) during 23-25 december 2006.*

The fog evolution depends on the coefficient exchange of turbulence, the chemical composition of the aerosol incorporated in cloud droplets, the activation PDF and the sedimentation velocity. The fog evolution is quite sensitive to the nudging coefficient under the forcing condition.

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