THE PARISFOG FIELD EXPERIMENT: BETTER UNDERSTANDING OF KEY PHYSICAL PROCESSES DRIVING FOG LIFE CYCLE BASED ON BOUNDARY LAYER PROFILING OF TEMPERATURE, HUMIDITY AND AEROSOLS


(1) IPSL; (2) LMD/IPSL; (3) HYGEOS; (4) CNRM/Meteo-France; (5) LATMOS; (6) IPGP; (7) CEREA; (8) LSCE; (9) LISA; (10) LRPC

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ABSTRACT

Fog is a weather phenomenon that produces weather conditions with significant socio-economic impacts, associated with increased hazards and constraints in road, maritime and air traffic. Air quality is also affected by fog occurrence. While current numerical weather prediction models are able to forecast situations that are favourable to fog events, these forecasts are usually unable to determine the exact location and time of formation or dissipation.

Fog is influenced by numerous factors, spanning multiple spatial and temporal scales. Its life cycle is driven by the competing interactions between thermodynamics, dynamics, microphysical and chemical properties of particles, and radiative fluxes, all of which are difficult to model. The ParisFog field campaigns (http://sirta.ipsl.polytechnique.fr/parisfog/), aim at documenting the role of aerosols on radiative processes and the interactions between turbulence and aerosol/droplet microphysical properties during the fog life cycle.

Several ParisFog field campaigns have taken place at the SIRTA site since 2006 with a suite of instrumentation that grows significantly each year. An efficient collaboration between IPSL, IPGP, LRPC, CEREA and CNRM laboratories allows us to sample approximately 200 hours of fog during each six month period (October to March). On the one hand, automated measurements have been specifically deployed to better characterise aerosol and droplet properties (size, concentration) and cloud radar reflectivity/Doppler velocity to estimate liquid water profiles up to fog top;

(2) in-situ measurements at ground level documenting droplet properties (size, concentration) and cloud radar reflectivity/Doppler velocity to estimate liquid water profiles up to fog top;

(3) cup/sonic anemometer, Doppler lidar and sodar to quantify the accuracy of each system and calculate turbulence for clear-sky and stable events and inside the fog layer. This work aims at responding these scientific questions:

Radiative processes

What is the impact of hydrated aerosols on infrared radiative cooling before radiative fog formation and what is the impact of interstitial aerosols on solar radiative warming during fog dissipation?

Dynamical processes

What is the vertical structure of turbulence during the fog life cycle (stable conditions before radiative fog event, entrainment zone near the fog top, heat fluxes close to the surface) and what is the impact on the fog life cycle

Microphysical and chemical processes

What is the impact of dry aerosol microphysical and chemical properties on hydration/condensation process and fog characteristics

1. MOTIVATIONS

A significant work has been conducted to combine:

(1) in-situ measurements at ground level documenting aerosol microphysics on one hand and lidar/ceilometer on the other hand, to characterize vertical profiles of aerosol extinction during radiative cooling before fog formation;

2. OBSERVATIONAL DATASET

2.1 ParisFog field experiment

To provide a dataset suitable to study these processes simultaneously in continental fog, a suite of active and passive remote sensing instruments and in-situ sensors are currently deployed at the SIRTA observatory (http://www.sirta.fr). It is a French national atmospheric observatory dedicated to cloud and aerosol research [1]. SIRTA is located at Palaiseau (49N, 2E), 20 km south of Paris (France) in a semi-urban environment. The observatory gathers and operates a suite of state-of-the-art active and passive remote sensing instruments from a large community to document and monitor an ensemble of radiative and dynamic processes in the atmosphere. The detailed description of the state of the atmospheric column is archived and made accessible to the scientific community.

In the framework of the PreViBOSS (http://hygeos.com/fr/previboss.php) project, the ParisFog field experiment ([2],...
The fog statistics at SIRTA site, Paris fog field experiment 2010-2012

2.2 ParisFog statistics

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2.3 Remote sensing

The new continuous wave cloud-radar, named BASTA, and developed by the LATMOS, takes part in the routine observation at the SIRTA site, with a sampling starting from 20m above the radar, so that it is well-suited for studies of fog and low level clouds (high vertical resolution, coherent averaging). The RPG-HATPRO microwave profiler provides total column on liquid/vapour water and the ALS450 lidar or CL31 telemeter provides backscatter signal along the vertical between surface and 10km. The fog microphysical properties along the vertical will be derived from synergistic observations provided by in-situ sensors but also by active/passive remote sensing. Next, cloud radar, backscatter lidar and microwave radiometer data will be combined and used in variational algorithms dedicated to derive some microphysical properties of cloud layers.

2.4 In-situ sensors

Multiple in-situ instruments are installed (some of them permanently) at the SIRTA site to document particle microphysical and optical properties between 2.5nm and 50µm diameter. Dry aerosols, hydrated aerosols and droplets are documented. The aerosol dry size spectrum is provided permanently by a TSI Scanning Particle Size (SPS) device with a GRIMM optical counter to cover the 5nm-10µm aerosol diameter range. Microbalance (TEOM-FDMS) provided particulate mass concentration (smaller than 1 or 2.5µm). Droplet microphysics is documented by the DMT Fog Monitor sensor (FM-100) giving the droplet size distribution between 2 and 50µm as well as the total amount of liquid water, also provided by the Gerber PVM. Ambient aerosols between 0.4 and 2µm are characterized by the PALAS Welas instrument. The objectives of this complete instrumental set up are to measure the continuous size distribution of ultrafine aerosol particles and the water droplet size distribution around 50µm while humidity conditions vary strongly between less than 0 relative humidity to saturated air.

The visibility is derived from DF20 and DF20+ Degreanne diffusometer installed at 3m and 18m agl. A specific tethered balloon has been deployed during two nights of March 2012 in order to document very precisely the vertical profile of temperature and humidity between surface and 300m agl.

3. RADIATIVE / STRATUS LOWERING FOG

The two main types of fog studied in this project that are the most frequent over the SIRTA site [2] are the radiative and the stratus lowering fogs. The initial conditions several hours before the fog formation are significantly different for each.

3.1 A radiative fog event (10-11 November 2011)

The period just before the radiative fog formation for this specific event is characterized by a clear-sky regime with visibility larger than 5000m, in contrast to hazy and foggy conditions when visibility can reach dramatically smaller values of 50m [3]. We often note two situations during the clear-sky regime. The first situation corresponds to relatively constant visibility and the second to a steady decrease of visibility until a minimum of 5000m is reached. For the first, we will quantify the impact of the atmospheric boundary layer changes coupled with the solar diurnal cycle. For the second, we will analyse the effect of wind speed, wind direction and humidification near the surface. The magnitude of the temperature inversion plays a significant role for the establishment of favourable conditions for fog formation [4].

http://www.parisfog.sirta.fr, monitors profiles of wind, turbulence, temperature, humidity, aerosol and fog microphysics and chemistry in the surface layer for 18 months (October 2010 – March 2013). Moreover fog droplet and aerosol microphysics and chemistry (size distribution between 4 nm and 50µm, liquid water content, black carbon, PM2.5) as well as near surface dynamics (vertical profile between surface and the top of boundary layer height) are measured.
The vertical distributions of aerosols and moisture in the boundary layer have a large influence on the formation and evolution of radiation fog. Hydrophilic aerosols will grow by deliquescence when relative humidity increases (between 16h00 and 16h40) and may act as droplet condensation nuclei (at 17h00 and after). Large and moist aerosols absorb and emit infrared radiation more efficiently than aerosol-free air, leading to cooling of the aerosol layer, hence reducing radiative cooling of the surface. In addition, the depth of the boundary layer across which moisture and aerosols are distributed will also influence the formation process of radiative fog. A deep moist layer is not favorable for condensation at the surface as moisture is too distributed. Cloud formation aloft is more likely than fog formation under these conditions, in particular if vertical mixing occurs. To understand the formation of radiative fog and the activation of fog droplets, it is important to characterize the temporal evolution of aerosol properties from the ground to the top of the boundary layer [5]. Sedimentation of condensed liquid water is measured by the BASTA radar and the droplet diameter drives sedimentation, drizzle and precipitation. During fog development, droplet size increases significantly (between 17h00 and 20h00) with bigger values near the surface due to collection efficiency.

3.2 A stratus lowering fog event (23-24 February 2012)

This stratus lowering fog event is more complex because of the important interactions between turbulence, radiation and thermal processes occurring during the stratus-fog transition [Oliver et al., 1978]. We will focus on the variability of sedimentation and on the intensity of the evaporation rate inside the stratus cloud 3-4 hours before the fog formation (between 00h00 and 04h00). Impact on the vertical gradient of temperature and humidity will be established and compare to previous results [6].

Dry air entrainment at cloud top and the solar absorption effects and the advective flow impact leading to fog dissipation (at 08h00) will be studied. The impact of solar heating on the liquid water content inside fog directly driven by the absorption coefficient of aerosol is a key process, so the extinction, the absorption and the scattering of the visible radiation by the aerosols will be analyzed. Droplet size distribution profiles and liquid fog liquid water are also significantly modified (i.e after 09h30) acting to dissipate fog and forming a stratus cloud (after 10h00).

The magnitude of sedimentation and precipitation of fog droplets will be calculated when fog develops and when stratus lifts or lowers. The cloud droplet sedimentation rate (proportional to the 6th power of the droplet diameter) measured at the surface with the in-situ instrumentation and inside the stratus cloud with the cloud-radar over the SIRTA site and will be validated and related to the liquid water content and to the fog vertical extension.

4. REFERENCE


