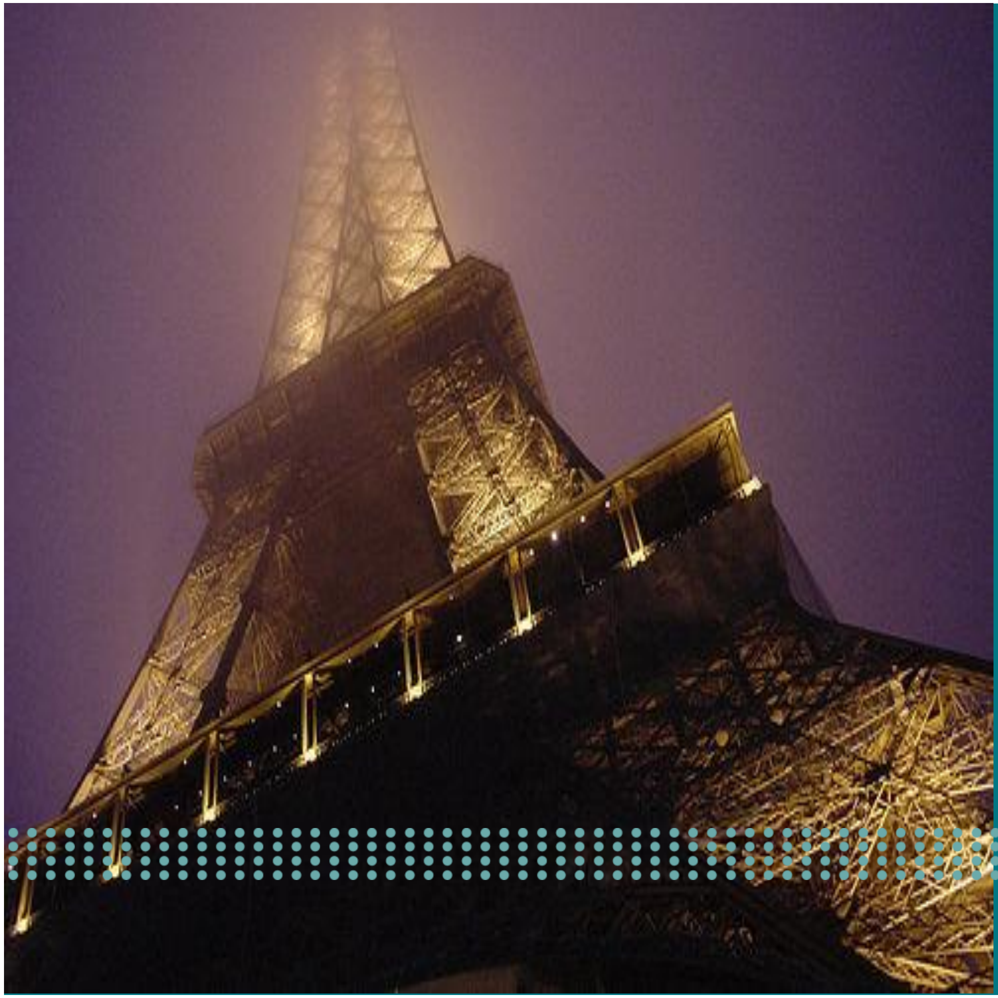

Numerical Simulation of Radiation Fog

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Atmospheric Environment Teaching and Research Centre (CEREA)

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EDF R&D

Outline

1. Introduction
2. Single column model (SCM)
3. 1-D simulation results
4. Conclusion and perspective

Introduction

Fog is an **important** meteorological phenomena

The impact of fog on modes of **transportation** *(Air, Terrestrial, Marine)*

The impact of fog on the **environment** *(Industry, Air pollution, Agriculture, etc.)*

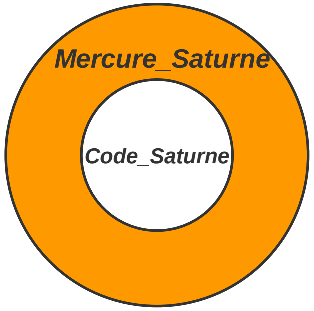
For **CEREA**

Micro-scale modeling of atmosphere - Atmospheric aqueous-phase chemical reactions

- Cooling Tower modeling *(Plumes – Lower clouds)*
- Dispersion under very stable and humid conditions

Single column model (SCM)

General presentation



Mercure_Saturne

- Dedicated modules for atmospheric environment.

- 4 prognostic microphysical parameters (as extra-parameters) : **Liquid Potential Temperature**, **Cloud Water** (the sum of water vapor and liquid water), **Cloud Drop Concentration**, and ***Rain Drop Concentration*** *(rain case ONLY)*.

- Diagnostic scheme for predicting Liquid Water Content and Cloud Fraction.

$$\theta_l = \theta\left(1 - Lq_l / C_p T\right) \text{ with } \theta = T\left(p/p_0\right)^{-R/c_p}$$

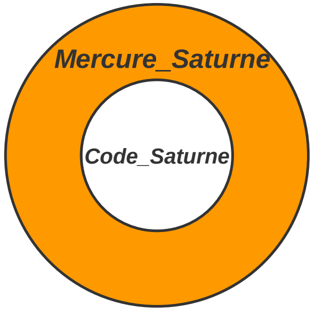
$$q_w = q + q_l \text{ with } q_l = q_c + q_r \text{ (if } q_r : N_r\text{)}$$

$$N_c = \int_0^s n(s)ds$$

→ Prognostic Equations

Single column model (SCM)

General presentation



Mercure_Saturne

Prognostic equations (fog case)

$$\rho \frac{d\theta_l}{dt} = \Delta\theta_l - \frac{\theta}{TC_{pa}}\frac{\partial F_{rad}}{\partial z} - \rho \frac{L}{C_{pa}}\frac{\theta}{T}\left(\frac{\partial q_l}{\partial t}\right)_{SED+DPO}$$

$$\rho \frac{dq_w}{dt} = \Delta q_w + \rho\left(\frac{\partial q_l}{\partial t}\right)_{SED+DPO}$$

$$\rho \frac{dN_c}{dt} = \Delta N_c + \rho\left(\frac{\partial N_c}{\partial t}\right)_{C/E} + \rho\left(\frac{\partial N_c}{\partial t}\right)_{NUC} + \rho\left(\frac{\partial N_c}{\partial t}\right)_{SCC} + \rho\left(\frac{\partial N_c}{\partial t}\right)_{SED+DPO}$$

σ

Single column model (SCM)

Warm cloud microphysics (fog case)

Probability density function (PDF) of cloud droplet

$$n_c(r) = \frac{N_c}{\sqrt{2\pi}(\ln\sigma_c)r}\exp\left[-\frac{(\ln r/r_0)^2}{2(\ln\sigma_c)^2}\right]$$

Where r is the drop radius, $n_c(r)$ is the number of drops in the radius range, N_c is the total number of drops per unit volume (cm^{-3}), σ_c is the standard deviation of the distribution and r_0 is the median radius.

Lognormal distribution with 2 parameters to determine !

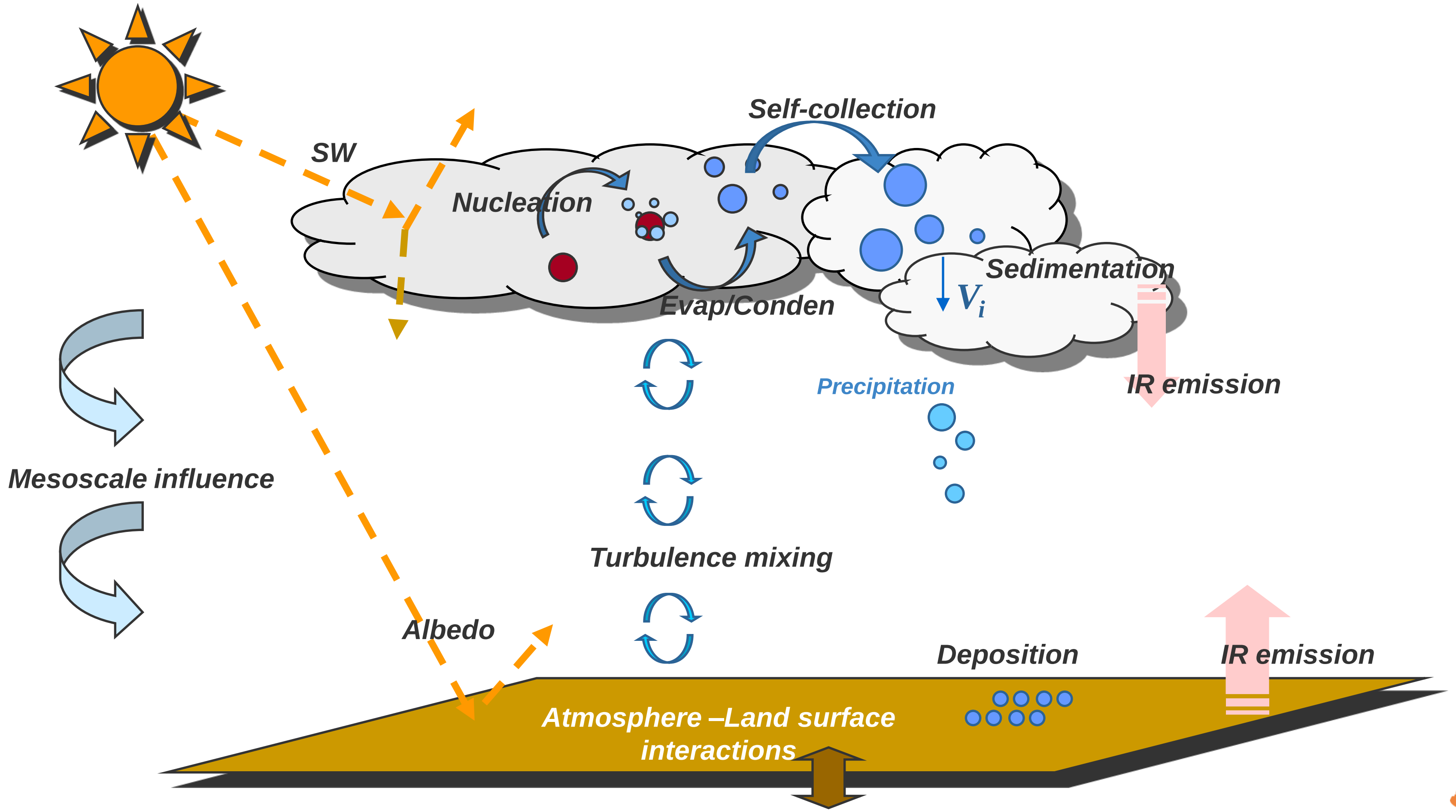
Cloud microphysics-resolving

Process resolved: evaporation/condensation, nucleation, self-collection, sedimentation, and deposition.

$$N_c,\ q_l \Rightarrow \left(\frac{\partial N_c}{\partial t}\right)_{E/C},\ \left(\frac{\partial N_c}{\partial t}\right)_{NUC},\ \left(\frac{\partial N_c}{\partial t}\right)_{SCC},\ \left(\frac{\partial N_c}{\partial t}\right)_{SED+DPO},\ \text{and}\ \left(\frac{\partial q_l}{\partial t}\right)_{SED+DPO}$$

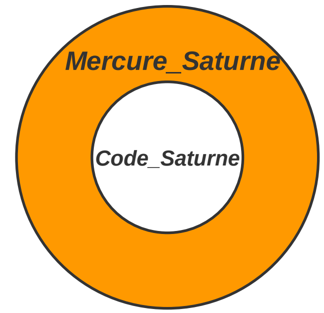
Single column model (SCM)

Summary of model characteristics



Single column model (SCM)

SCM

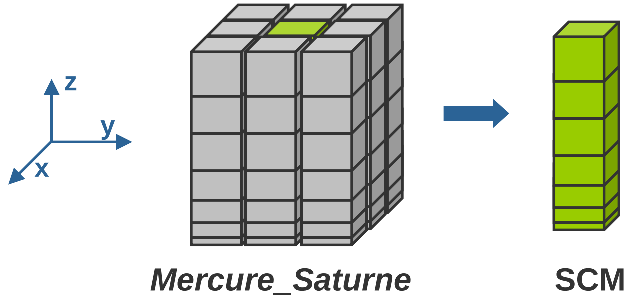


Mercure_Saturne

Dedicated modules for atmospheric environment.

SCM :1-D version of *Mercure_Saturne*

The SCM represents a single *Mercure_Saturne* gridpoint atmospheric column. The treatment of all physical processes occurring within the SCM are identical to *Mercure_Saturne. HOWEVER, the horizontal pressure and advection term are treated as external influences.*



High-resolution grid *(x,y,z = 30km, 30km, 2.6km. 69 levels with z_0 = 2m)* + Detailed physics *(Warm Cloud Microphysics, Radiation, Turbulence)* + Nudge technique

SCM Advantages: (1) very inexpensive; (2) results independent of the rest of the model.

1-D simulation results

Synoptic background

Fog event simulated: *February 18-19, 2007 (ParisFog field campaign, IOP 13*)*

Time of fog formation/dissipation: *2230UTC FEB18 and 0800UTC FEB19.*

Control simulation

Initial and boundary conditions

Ground surface : atmospheric surface layer (ASL) method; initial condition: the data deduced from Radiosonde-Mat-Sonic by using Cressman objective analysis scheme

External forcing data (Mesoscale data)

Cressman objective analysis scheme

Physics

Turbulence closure: k-epsilon; Radiation: SW and LW ; Microphysics: Fog case, PDF cloud fitted with SMPS data.

24h Run with a time-step of 60s (from FEB18 1200UTC to FEB19 1200UTC)

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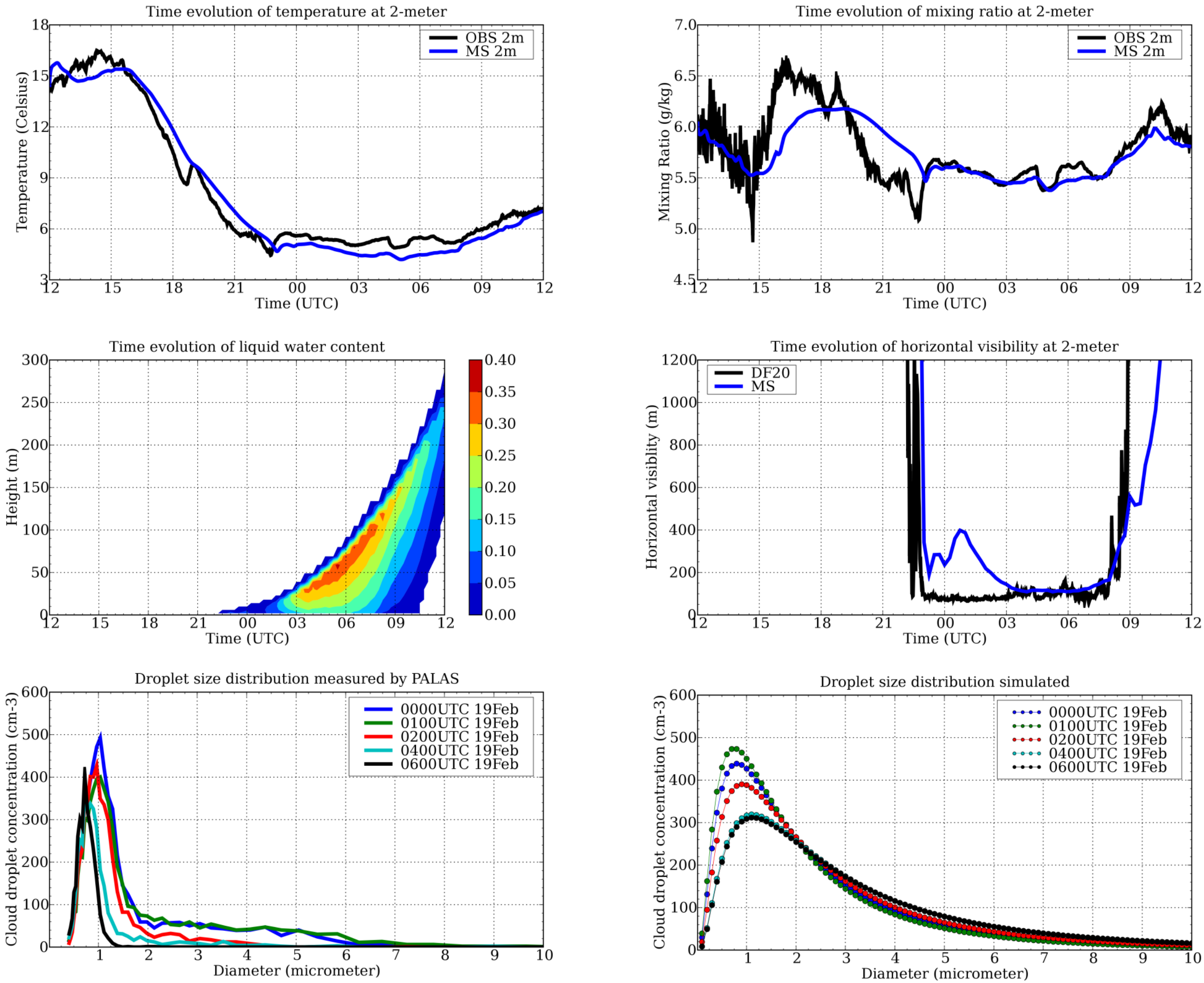
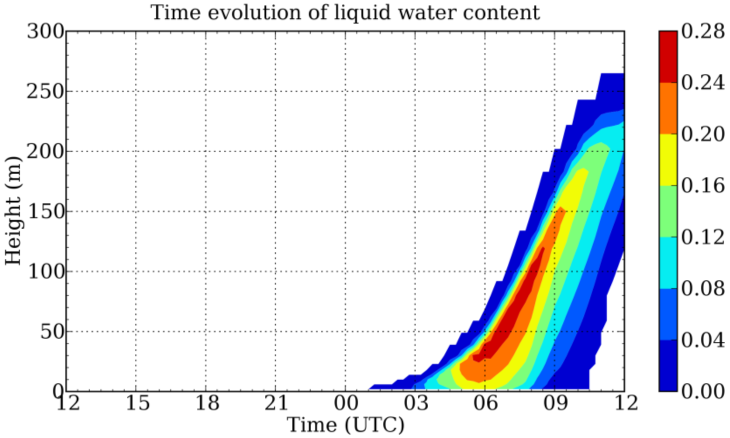
* http://sirta.ipsl.polytechnique.fr/parisfog/

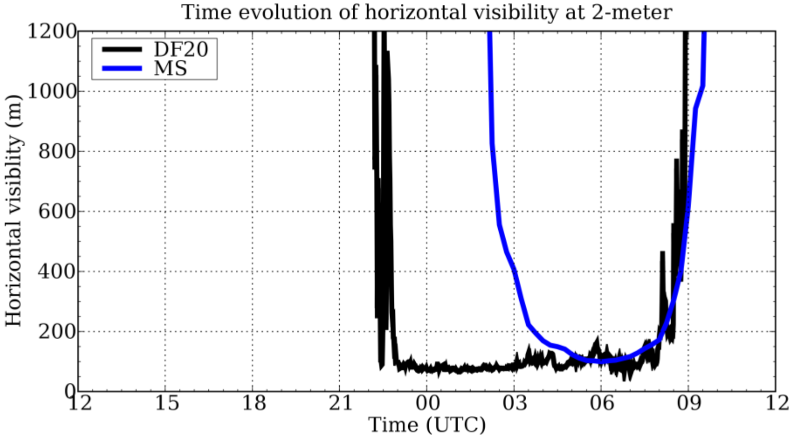

Time evolution of temperature at 2-meter
OBS 2m
MS 2m
Temperature (Celsius)
Time (UTC)
Time evolution of mixing ratio at 2-meter
OBS 2m
MS 2m
Mixing Ratio (g/kg)
Time (UTC)
Time evolution of liquid water content
Height (m)
Time (UTC)
Time evolution of horizontal visibility at 2-meter
DF20
MS
Horizontal visibility (m)
Time (UTC)
Droplet size distribution measured by PALAS
0000UTC 19Feb
0100UTC 19Feb
0200UTC 19Feb
0400UTC 19Feb
0600UTC 19Feb
Cloud droplet concentration (cm-3)
Diameter (micrometer)
Droplet size distribution simulated
0000UTC 19Feb
0100UTC 19Feb
0200UTC 19Feb
0400UTC 19Feb
0600UTC 19Feb
Cloud droplet concentration (cm-3)
Diameter (micrometer)

eDF R&D

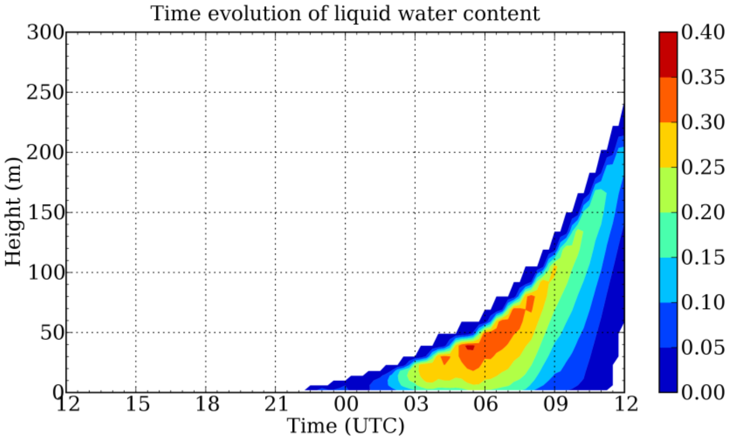
Sensitivity tests

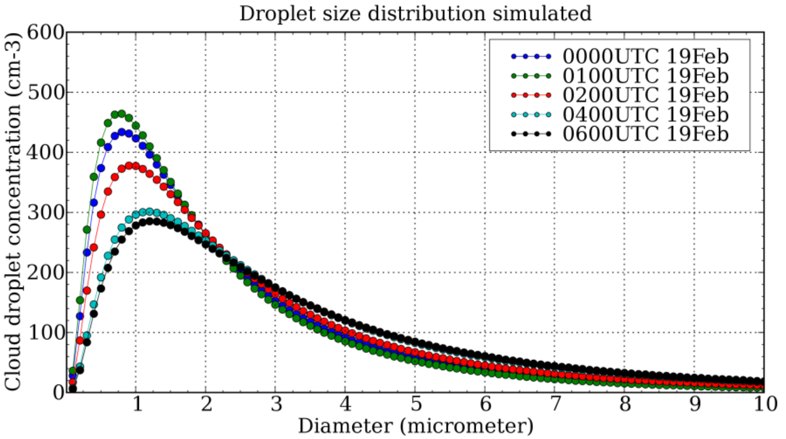
Turbulence closure *Turbulence closure : Louis* [Louis 1979 BLM, Musson-Genon 1995 MWR]*





Microphysics *Sedimentation : Duynkerke and Driedonks [1998 JAS]*





Conclusion and perspective

C1: First test of fog simulation using objective analysis.

C2: The fog evolution depend on the coefficient exchange of turbulence, the cloud SSA (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.

C3: The fog deposition has a small impact on local fog simulation. However, it is an important pathway for atmospheric inputs of pollutants to vegetation, especially to forest ecosystems.

P: 3-D modeling on the SIRTA site (Ecole Polytechnique)


Photo by Stevenvanwel

Thanks & Questions

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