Towards a 3D prediction of fogs on airports with Météo-France operational forecast model AROME

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Overview

- Aeronautical needs for fog forecasts are very demanding.
- Fog is a weather phenomenon particularly difficult to predict.
- New perspectives (models, observation systems).
- Météo-France research project for improved fog forecasts.
Aeronautical needs

Fog perturbs airport operations and is a source of accidents. In Roissy CDG, the airport capacity is divided by ~2. Costs can amount to several tens of million €.

Precise predictions 1hr to 12hrs in advance of formation or dissipation times on airports are needed to mitigate the impact.
The need is very demanding

Simulation exercise conducted in 2011 by a fine resolution (2.5km) version of AROME. The horizontal extent and the timing is rather well predicted. Locally, the time of formation or dissipation can be wrong by several hours...
Real vs. predicted visibility@ CDG

Roissy CDG airport
22 October 2012

Overall prediction rather good, but fog forms 2 hours before the prediction...
Fog: a complex weather phenomenon

Fog is a thin phenomenon... (a few meters to a few hundreds of meters).

Involving several highly non linear processes: radiation, condensation, turbulence, heat and water vapour exchange with the surface.

Night-time
cloud free skies

temperature inversion

moist air cools

$T_{\text{air}} = T_{\text{dew}}$

lwc

IR flux

cold surface

SW flux

mixing

heat transfer

Radiation fog
With a large spatial variability

The buildings induce large spatial variabilities during the fog formation phase and a blocking effect (here, about 1.5 hours before complete cover).

Research model mesoNH in LES mode.

\[ \text{length} = 4.5\text{km} \]
\[ \text{width} = 1.5\text{km} \]
\[ \Delta x = 1.5m \]
\[ \Delta z = 1m \]

See Bergot et al., QJRMS, 141. doi:10.1002/qj.2358
Models

A fine resolution is required:

- Until recently, could not be achieved with 3D forecast models.
  - Use of 1D column models instead. But 1D models cannot account for the spatial variability.
- With the growing capacity of HPCs, the 3D forecast model now seems within reach.
  - Horizontal resolution of several hundreds of meters are envisaged for AROME over domains of several hundred kilometres.
  - Research studies are being conducted to define the model specifications.

Ex: COBEL at Roissy-CDG
Impact of vertical resolution

From Philippe et al., Weather and forecasting, 31, 1655-1671, 2016
New observation systems: MWR

Microwave radiometer (MWR)

Provision of accurate vertical profiles of temperature at high time resolution.

Comparison of MWR, RS and AROME T profiles in a narrow valley in the Alps.

Bias and rms of a 1D-Var retrieval of temperature profiles from MWR brightness temperature (against RS).

New observation systems: W radar

W-band radar (95GHz) → detect fog water drops

Measure the dynamics inside the fog layer.
On-going work to convert reflectivity into liquid water contents.

From Delanoë et al., Journal of Atmospheric and Oceanic Technology, 33, 1023-1038, 2016.
New observation systems: UAV

Exploration of the 3D structure of fog with thermodynamic, radiation, microphysics sensors.

Aerosol inlet + particle size and number.
Research project

• Objectives:
  – assess the capacity of a dedicated AROME version to forecast fogs
    • Size domain of about 100km x 100km
    • Horizontal resolution of several hundreds of meters.
    • Refined microphysics parametrizations (2-moments)
    • Refined parametrization for surface exchanges.
  – Prepare the assimilation of new operational observation systems.

• Methodology
  – Run the model in real time during a field campaign with many sensors
documenting the various processes involved in fog and exploring the 3D
structure.

• Collaboration with research laboratories in France and Europe.
• Campaign in winter 2019-2020 in South-West France.
Number of days/year with high probability of mist or fog (CARIBOU, 2008-2014)

Fog statistics for Auch
Thank you