Récentes campagnes de mesures atmosphériques par drones

Session nº5 : Projets de recherche sur les drones chez les partenaires du GIS Micro-Drones



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Drone Garden Workshop, 7 June 2019

Summary of UAS Flights at CNRM





- 10 different types of platforms (all fixed-wing)
- Weather conditions: winds up to 17 m/s, snow, ice, rain, fog; up to 3350 m.agl

Motivation: atmospheric science

- Sources and transport of aerosols and gases (i.e., sea spray, volcanic eruptions, biomass burning, industrial pollution, dust)
- Aerosol-cloud interactions, fog, visibility, health effects
- In-situ input and validation of numerical models, satellites.





Process studies and spatial/temporal variability



Fire plume flux measurements using UAS

Flux (N.cm



Sea salt emissions – natural aerosol



- Parametrizations in models create uncertainties in assessing the role of sea salt (and consequently anthropogenic aerosol) on Earth's climate
- Aerosol and energy surface flux measurements needed to improve models

Primary marine aerosol in surf zone

- Transects across surf zone (Montalivet, Atlantic coast, France)
- Spiral vertical profiles from ~ 7 to 150 m.asl
- Aerosol size distribution (0.5 < Dp < 10 um; RH < 40%), PTU







Sea salt emissions (surf zone)



- Steep gradient in aerosol concentration < 30 m.asl
- Number concentrations (Dp > 0.5 um; red): ~ 200 / cc in surface layer; ~ 60 /cc in boundary layer
- Aerosol mass (black): ~ 1.5 ug / m³ surface layer; < 0.2 ug / m³ in boundary layer

Flux estimate: F = D (dC / dz):: $\rho \sim 2 g/cm^3$; $D \sim 10^{-2} m^2 / s$

→ F ~ 1 ng / m².s (PMA surf zone)
 (note: not all mass measured
 – see next slide)

Mission specific science payload



Payload for MIRIAD / ReNovRisk



- Designed to measure air-sea interactions: Aerosol concentration and size distribution, 3D winds and turbulence; sea surface temperature, wave height, solar flux, meteorological state, video
- Payload data sent to ground-station in real-time for mission planning.

Platform: BOREAL

Specifications:

- Wingspan: 4.2 m; 25 kg max take-off
- Flight capacity up to 700 km with a 5 kg payload (ca. 7 hrs)
- Two-stroke gas engine
- 95 km/h cruise air speed (26.4 m/s); Range: 60-130 km/h
- Catapult take-off; belly landing





Onboard instrumentation during ReNovRisk):

- Transponder (mode S/ADS-B)
- Strobe
- C2Link RF communication & Iridium satellite with realtime video (up to 50 km from GCS)
- Radar altimeter to measure sea state and for security
- Science payload to measure 3D winds, aerosol, turbulent fluxes

Objectives and field operations

Recent campaigns in February – April 2019 leveraged two research programs:

- **MIRIAD**, with the aim to develop the scientific payload and technical capacity of the Boreal to study air-sea interactions
- **ReNovRisk**, a program to study the impacts of aerosol fluxes on the development of tropical cyclones (in collaboration with the University of La Réunion and LACy).
- Flight corridors established to access international airspace from aerodromes on east and west coasts of Reunion Island (Cambaie and Bras Panon)
- Restricted airspace extended to 250 km from the operations center with a flight ceiling of 3500 ft (1067 m).
- Flight operations conducted by BOREAL (ground-station pilot and a security pilot)
- Coordination of BOREAL flights with ATC and other users of the airspace conducted by DroneXSolution.
- The CNRM team coordonated scientific and logistical operations.





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METEO











http://windy.com

• Flight operations:

- 4 19 February; 21 March 2 April 2019
- ULM Cambaie; ULM Bras Panon (La Réunion)
- 12 research flights; 53.7 hours; 5012 km

Airspace

MIRIAD / ReNovRisk flights

Reunion

Island

[La France metropole shown for scale]

Maur

de Bras Panon

598

- 500 km diameter circle
- Surface to 1000 m.asl (w/ corridor to access international airspace)
- > 25 km from RUN (commercial airport)
- Authorization requested for Reunion Island airspace only.

Flight experience

- Average flight duration : 4.5 hours
- Three flights farther than 200 km from ground operations (202, 222 and 245 km)
- Longest flight lasted 6.3 hours and covered 610 km
- Minimum altitude : 40 m.asl
- Observations on the perimeter of the Cyclone Joaninha (three flights between 23/03 and 25/03)
- Observed gradient in sea state during Southen Swell event

Scientific experiment conducted in relatively difficult conditions :

- Strong wind shear in air flow around Réunion Island
- rapid development of convective clouds / precipitation
- turbulent conditions during take-off and landings





Integration into international airspace



Saint-Denis

Le Tampon

Saint Pierre

Saint-Gilles

La Saline-Les-Bains

Saint-Leu



IR MAURITUS 3B-NBD

RADAR RADAR

0

060014

053977

- Transponder (S/ADS-B) allowed integration into airspace (ca. 200 km range; altitude dependent).
- Real-time updates on: http://www.flightradar24.com http://www.adsbnetwork.com/FMEE

0.0 k

2.5 k

9.0 k

5925 ft

-1000 ft

BOREAL followed by ATC, commercial aircraft, and civilian users of airspace.



- Precipitation and wind vector overlay on flight trajectory for route planning (communication via SatCom PLANET)
- Tracking of marine traffic to avoid flying over vessels (AIS equipped)

Real-time visualization of data



- Data from scientific payload transmitted via RF or SatCOM to the ground station in real time
- Results used to verify performance and assist mission planning

Preliminary results (25.03.2019)



- Strong steady winds over open ocean; confirmation of island wake (not seen in all models)
- Aerosol concentrations relatively high; well-mixed in boundary layer
- Video shows white caps and swell



Produced by Fayçal Lamraoui

MesoNH-LES

NEPHELAE: Network for studying Entrainment and microPHysics of cLouds using Adaptive Exploration

ANR 2017 01/2018 - 06/2021

Atmospheric science driven with focus on cloud microphysical processes

- Identify dominant entrainment mechanism and timescale of cloud development and onset of precipitation
- Assess impact of aerosol on entrainment and precipitation as well as feedback mechanisms

NEPHELAE aims to develop a UAS fleet with decentralized cooperative sampling

- inter-UAV communication
- Adaptively plan and control fleet to maximize utility of gathered data



Balloon and drone operations on Maido

March – April 2019



- CNRM conducted aerosol/cloud flights with balloon and drones within separated restricted airspaces
- Balloon flights consisted of vertical profiles and constant altitude sampling (1000 m.agl)
- Drone flights consisted of spiral climb (radius 100 m) near GCS to 650 m.agl followed by spiral climb (radius 700 m) above forest or continue spiral (100 m) near GCS up to ceiling (2000 m.agl)

NEPHELAE operations





- UAS operations conducted at 1400 m.asl in pasture on the western slope of Maido
- Infrastructure installed / removed daily
- Bungee/ramp take-off; net landing



Backscatter cloud sensor & airspeed



temperature, moisture, pressure

NEPHELAE payloads



data acquisition



PPZ autopilot



optical particle counter



aerosol inlet



NEPHELAE Overview

- flights on five days (2, 3, 4, 6, 7 April); between 9:00 to 18:00; four flights / day
- 17 flights total; 15:16 total flight time; surface to ceiling (6600 ft AGL); within 2 km from GCS
- Flights in convective clouds, precipitation, winds up to 8 m/s at altitude
- Flew circular pattern in/out of clouds to study mixing at cloud interface



An example of flight analysis : flight 4 (3 April 2019)



NEPHELAE operations in airspace



Airspace issues

- VHF radio used to listen to helicopter and ULM traffic. Useful to assess location and direction of helicopters and ULMs during drone operations.
- Most helicopters and ULM flew along north or south perimeter of restricted airspace (ZRT drone)
- Six intrusions within ZRT zone (five helicopters and one ULM); not all were identified, will include some pictures in final report
- Did not need to reposition flight of drone (either clearly at different altitudes, not on same trajectory or drone on the ground).

Using ultra-light (flying wing) for regular tropospheric profiling

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2. Scripps Institution of Oceanography, USA





METEO FRANCE



RPAS and instruments

Ultra-light vector for P, T, U

Autopilot card Paparazzi Apogee Sensor acquisition included

> Sensor conditioning Meteostick 🕅





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Campagne à Cerdagne :

- vols jusqu'à 1000m/sol (tous les 20 min)
- étudier l'évolution de la couche limite





Field Experience Cerdanya 2017: mountain boundary layer (cold air pool)







Intercomparison: T from UAV, MWR, WindRASS, RS



Some results - Fog in Bure

Temp comparison with radiometer, tower, RS, AROME model



RPAS and instruments

Humidity calibration In lab and fields





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Calibration coefficients stored in Meteostick Precision measurement board (ENAC Paparazzi) T, R.H., absolute and differential P



TP ENM : vols et traitement de données

P2OA CRA, Lannemezan

G. Cayez, F. Lohou (ENM et Université de Tarbes)





Instrumentation (pression, température, humidité) d'un drone multicoptère

L'objectif est d'intégrer un capteur de température, d'humidité et de pression avec système d'acquisition sur un drone du commerce

Permet d'effectuer rapidement des profils verticaux et d'étudier précisément des couches de l'atmosphère, dans le brouillard par exemple

Les capteurs seront intégrés dans un abri ventilé imprimé en 3D pour une mesure optimale des conditions atmosphériques

Il est développé par les services 4M et MNPCA du CNRM sur le site de la météopole à Toulouse





UAS flights in EUREC4A

20 January – 20 February 2020



- R/T ferry from Barbados to operation zone (~100 km)
- Remaining 400 to 500 km allowed for BOREAL scientific mission
- NEPHELAE flights near coast
- Science objectives:
 - Role of ocean surface on mesoscale cloud field
 - Cloud development / dissipation
 - Impact of clouds on radiative budget and precipitation

Sandrine Bony (LMD, CNRS); Bjorn Stevens (MPI Meteorology); David Farrell (CIMH)



EUREC4A UAV deployment







Upcoming meetings



WORLD METEOROLOGICAL ORGANIZATION WMO Workshop on Use of Unmanned Aerial Vehicles (UAV) for Operational Meteorology 2 - 4 July; Toulouse, France

https://public.wmo.int/en/events/workshops/wmo-workshopuse-of-unmanned-aerial-vehicles-uav-operational-meteorology



International Society for Atmospheric Research using Remotely piloted Aircraft (ISARRA) 15-23 July; Lugo, Spain <u>http://www.isarra.org</u>



acknowledgements

