Les Drones Instrumentés pour la Météorologie et les Études de l'Atmosphère

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CNRS-GAME

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METEO FRANCE
Toujours un temps d'avance

cnrs
dépasser les frontières

L'AVION JAUNE

Outline

- Overview of Unmanned Aerial Systems (UAS) in atmospheric research
- Miniature *in-situ* instrumentation (modular payloads)
- Demonstration flights (Aérodrome à Condom, Jan. 2012)

UAS in Atmospheric Research

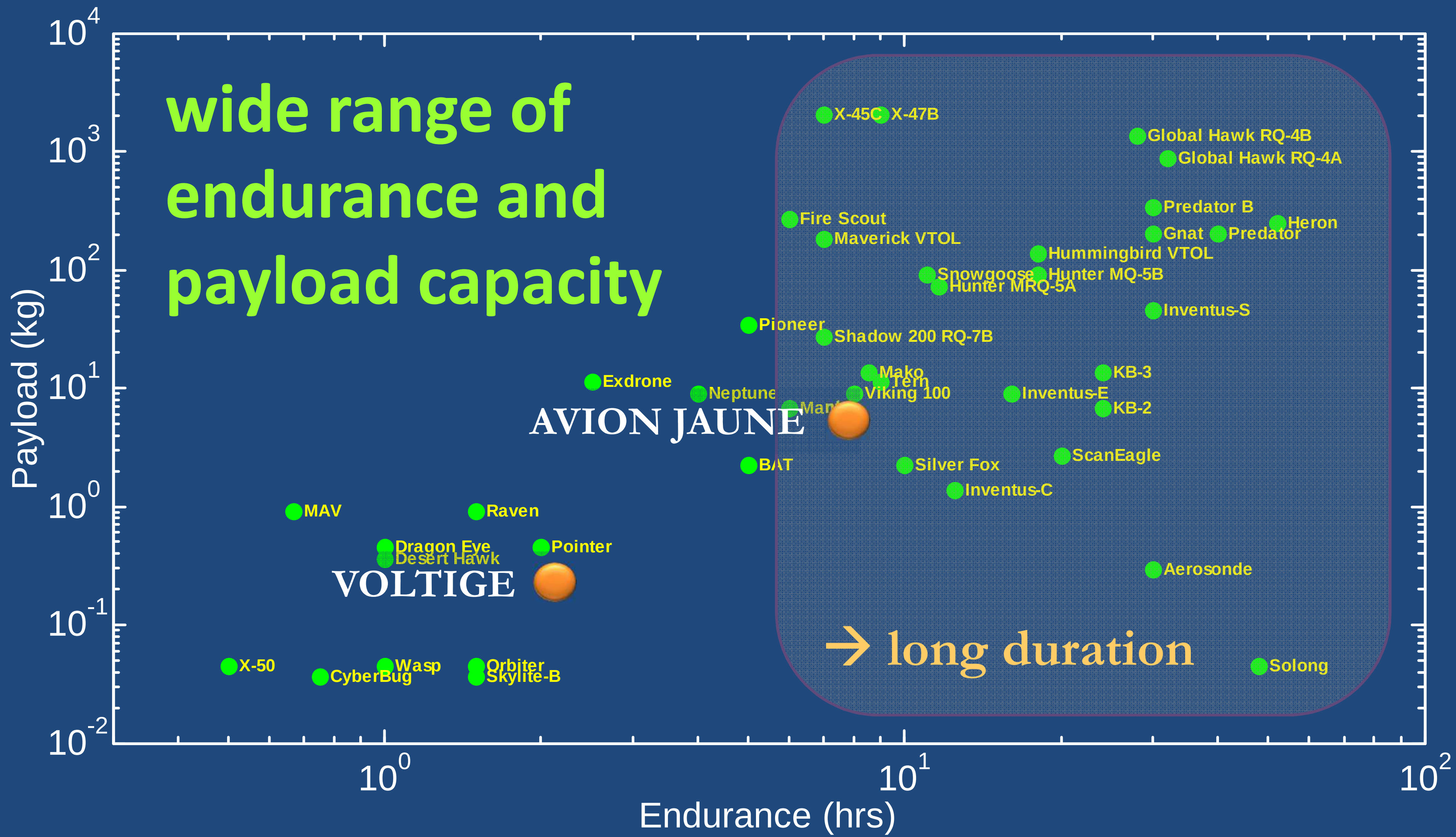
In the last decade:

- improvements in autonomous flight performance → UAS now a major resource for scientific research and civilian applications.
- less infrastructure required → more frequent and longer measurements & lower operational costs.

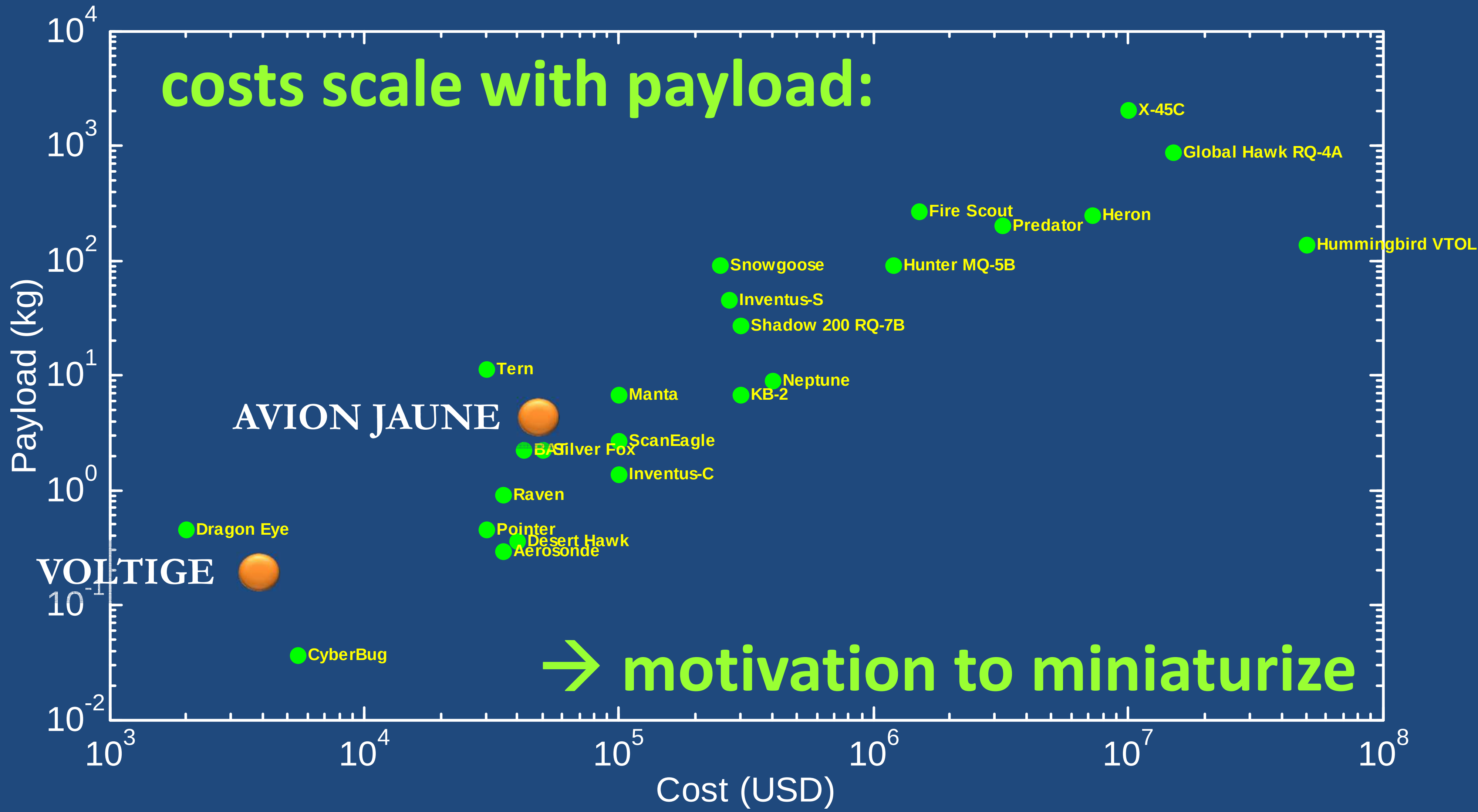
Needed improvements:

- increased reliability (esp. take-off & landing)
- higher altitudes (most UAS < ca. 4 km)
- integration into airspace (limited sites, authorization takes up to several months)

UAS Performance Comparison



UAS Cost Comparison



UAS Observations of Hurricanes

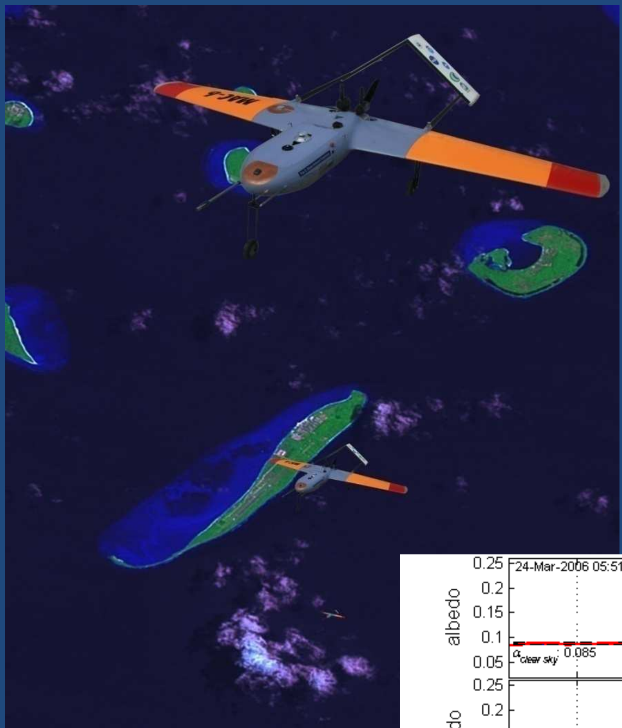
Global Hawk flight over Hurricane Earl
2 September 2010

Global Hawk HDVis Imaging Camera
NASA Ames Research Center

Aerosonde in the eye of a hurricane

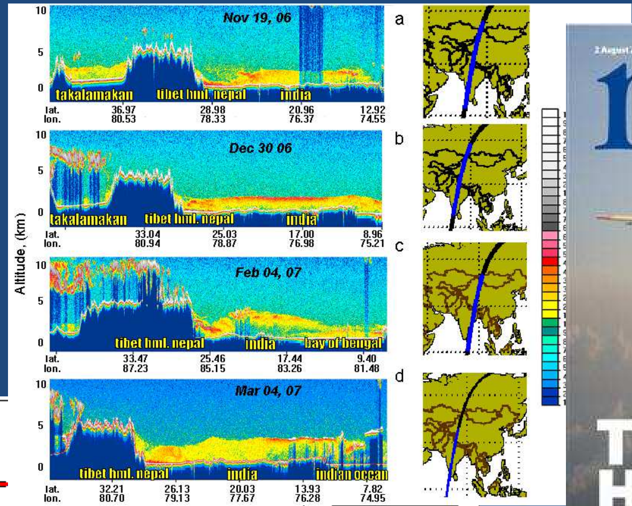
Capable of operating in dirty and dangerous environments.

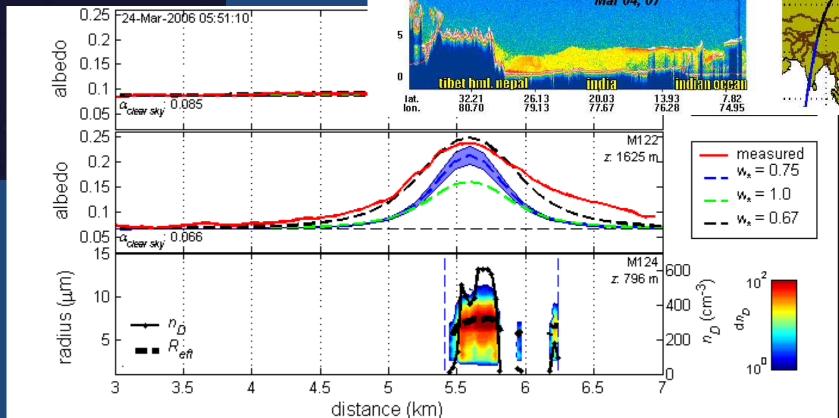
Enhanced Observational Capabilities



Roberts et al., 2008

formation flights





Ramanathan et al., 2007

Simultaneous observations to measure

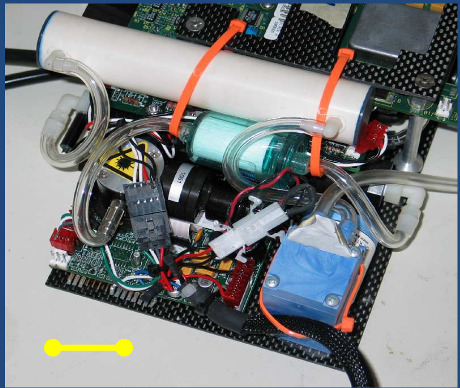
- aerosol-cloud interactions & cloud microphysics
- atmospheric heating of aerosol layers

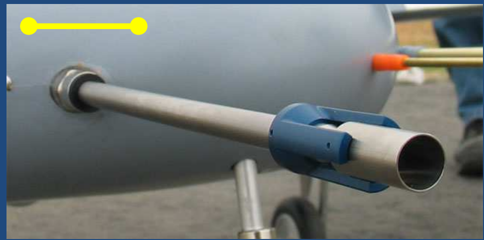
UAS for Boundary Layer Studies

Boundary Layer Late Afternoon and Sunset Turbulence (BLLAST)
http://bllast.sedoo.fr/ – Lannemezan, summer 2011; PI: M. LOTHON

- Observation of boundary layer turbulence at the end of the day.
- United several research groups involved in COST-ES0802 (PI: J. Reuder).

UAS *in-situ* Instrumentation


Particle size & number (580 g)

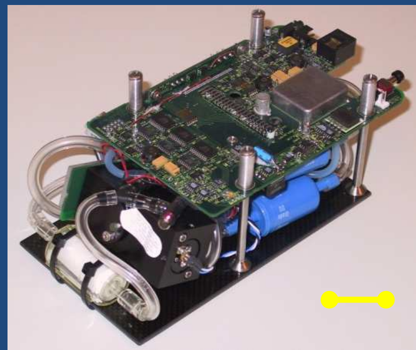

Aerosol sampling (150 g)

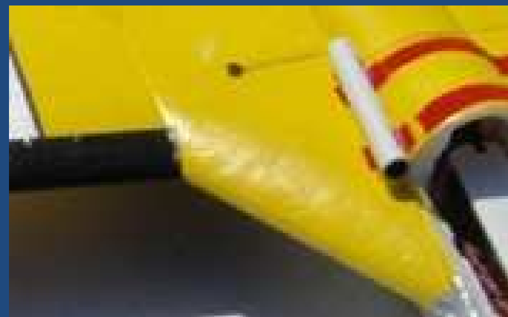

Cloud droplets (1.4 kg)


Electrical field (<30 g)

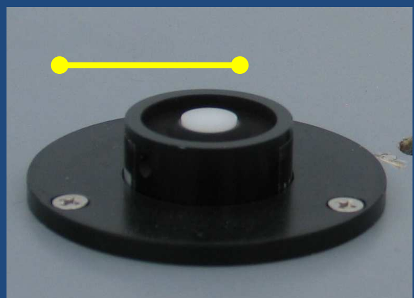

Smoke aerosol (280 g)


CCN aerosol (1.9 kg)


Total particle number (870 g)


Radiometers & Temperature / humidity (<20 g)


Broadband flux (190 g)


Sun energy: visible (45 g)


Ozone (600 g)


Turbulence (100 g)

Modular Payloads (i)

Base instrumentation (T, P, RH, v)

+ modular payload (< 5kg UAS)

- **Aerosol:** number and mass concentration, size distribution ($0.01 < d_p < 10$ um), chemical composition, black carbon (BC)
- **Clouds:** concentration and size distribution ($2 < d_p < 50$ um), liquid water content
- **Gas phase:** concentration (i.e., O_3, SO_2, CO, H_2O)
- **Solar flux:** irradiance, extinction, albedo
- **Turbulence:** *u, v, w*

Modular Payloads (ii)

Choose the measurements according to the *scientific focus* (T, RH, P, v + ….)

- **Volcanic ash:** aerosol size distribution (0.01 to 50 um) + filters → 5kg package
- **Solar absorption of pollution layer:** size distribution + BC + pyranometers → 4kg package
- **Urban pollution / health:** SO2 + ozone + CO + size distribution + BC → 5 kg package
- **Precipitation:** CCN, cloud droplet probe, hot wire probe, turbulence → 7 kg package

→ Payload and data system for each configuration ←

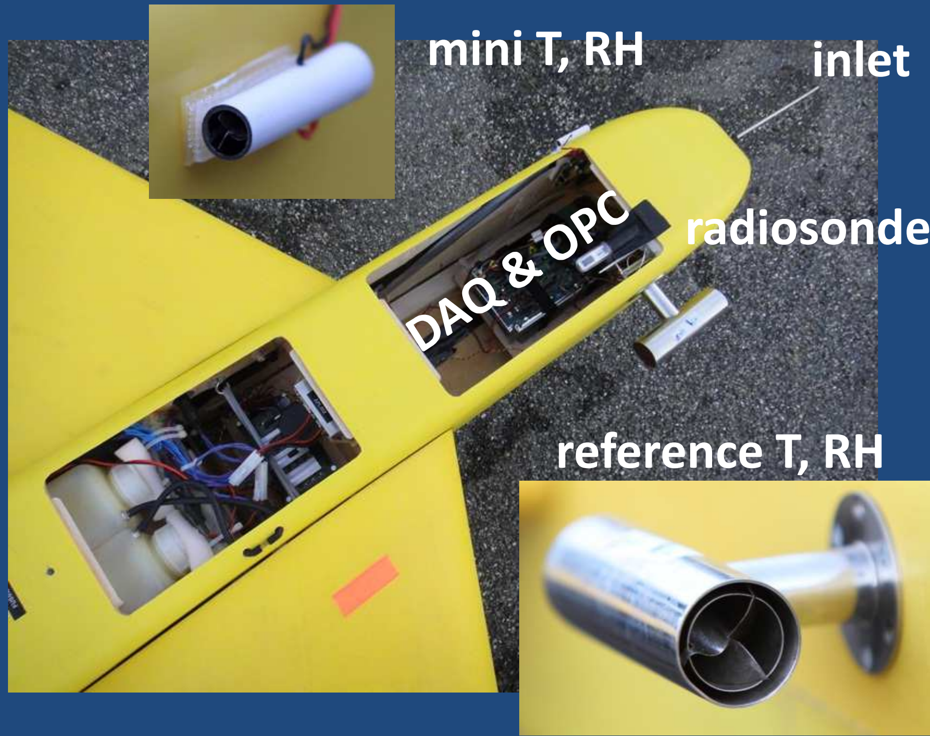
Flight Demonstration

Aérodrome at Condom (Jan 2012)

- Meteorological and aerosol measurements with UAS
- Profiles to 3000 m.asl (authorized in civilian airspace)
- Compare measurements of T, RH, P with balloon sondes

Met / Aerosol Instrumentation

ALTIMUM payload
Data acquisition (T, P)
Reference met probe (T, RH, hot wire)
Miniaturized met probe (T, RH)
Radiosonde Vaisala (T, RH, P, GPS)
Optical Particle Counter (OPC) (aerosol size; dp > 0.3 µm)
Aerosol inlet
Batteries
Total mass (2.2 kg)

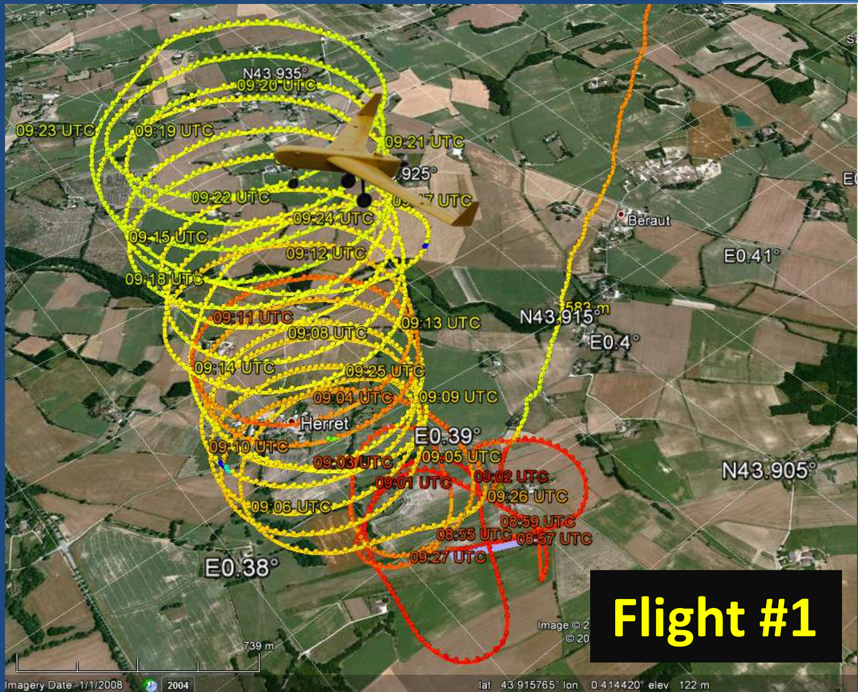


Overview of Operations

Flight	Start time (UTC)	Duration (min)	Objective
AJ_RF1	9:00	28	UAS profile to 1000 m.asl
RS1	9:41	-	Balloon sonde
AJ_RF2	10:18	29	UAS profile to 1150 m.asl
AJ_RF3	11:32	44	UAS profile to 3000 m.asl
RS2	12:16	-	Balloon sonde
AJ_RF4	12:57	47	UAS profile to 3000 m.asl
RS3	14:28	-	Balloon sonde

x4 vertical profiles with UAS; x3 profiles with balloon sonde

Vertical Profiles – UAS & Sondes

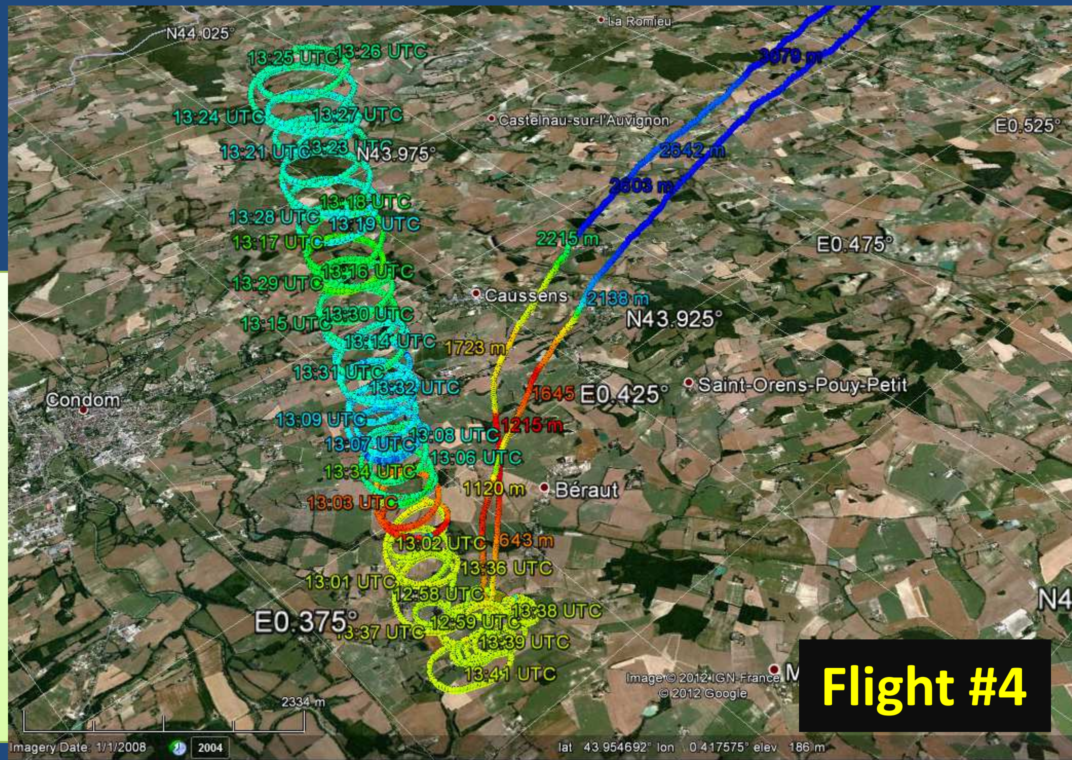


Flight #1 & radiosonde #1

- Profile to 1000 m.asl (spiral w/ 700 m Ø)
- Ascent / descent rates (34 / -268 m.min^{-1})

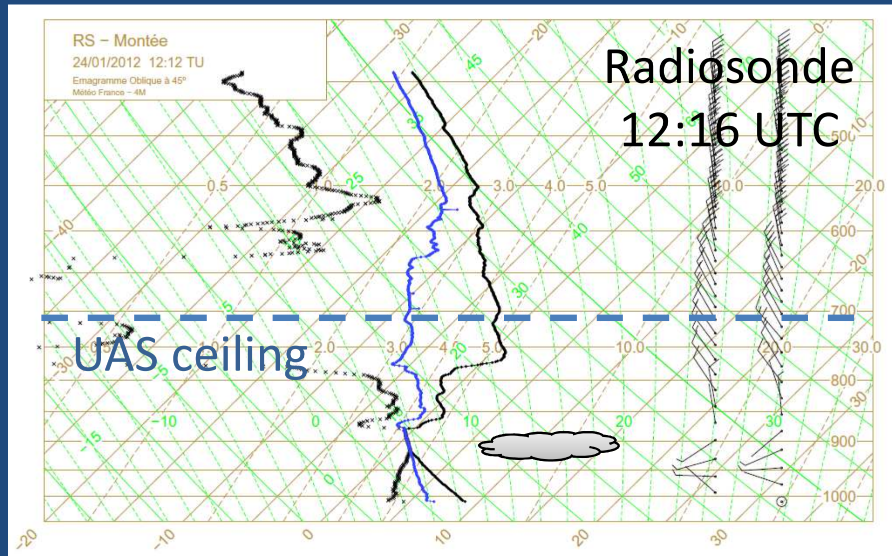
Flight #4 & radiosondes #2,#3

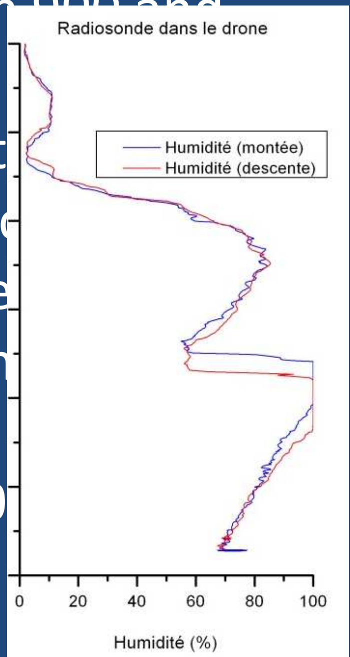
- Profile to 3000 m.asl (spiral w/ 700 m Ø)
- Ascent / descent rates (100 / -230 m.min^{-1})

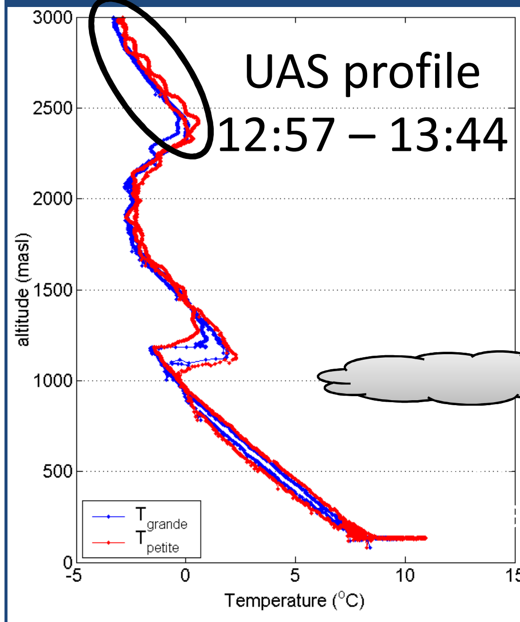


Vertical Profile (Flight #4)

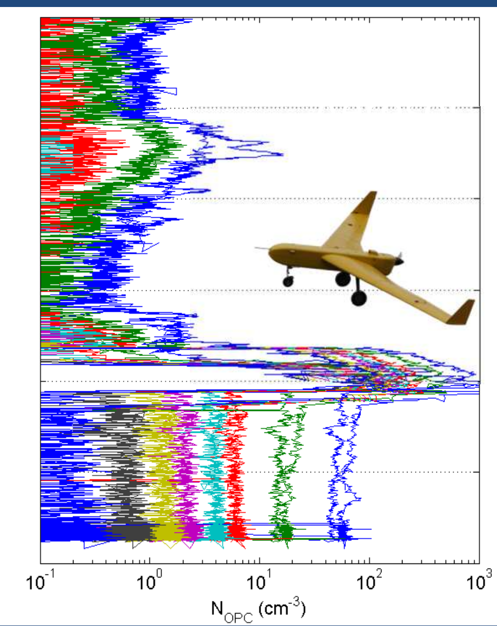
- Take-off: 12:57 UTC
- Flight duration: 47 min
- Profile to 3000 m.asl
- Ascent / descent rates (100 & - 230 m.min^{-1})
- Multiple inversions
- Cloud level between 900 and 1200 m
- Temperature on left cumulative aerosol c on right figure (note
- High aerosol concen boundary layer
- Aerosol layer at 230





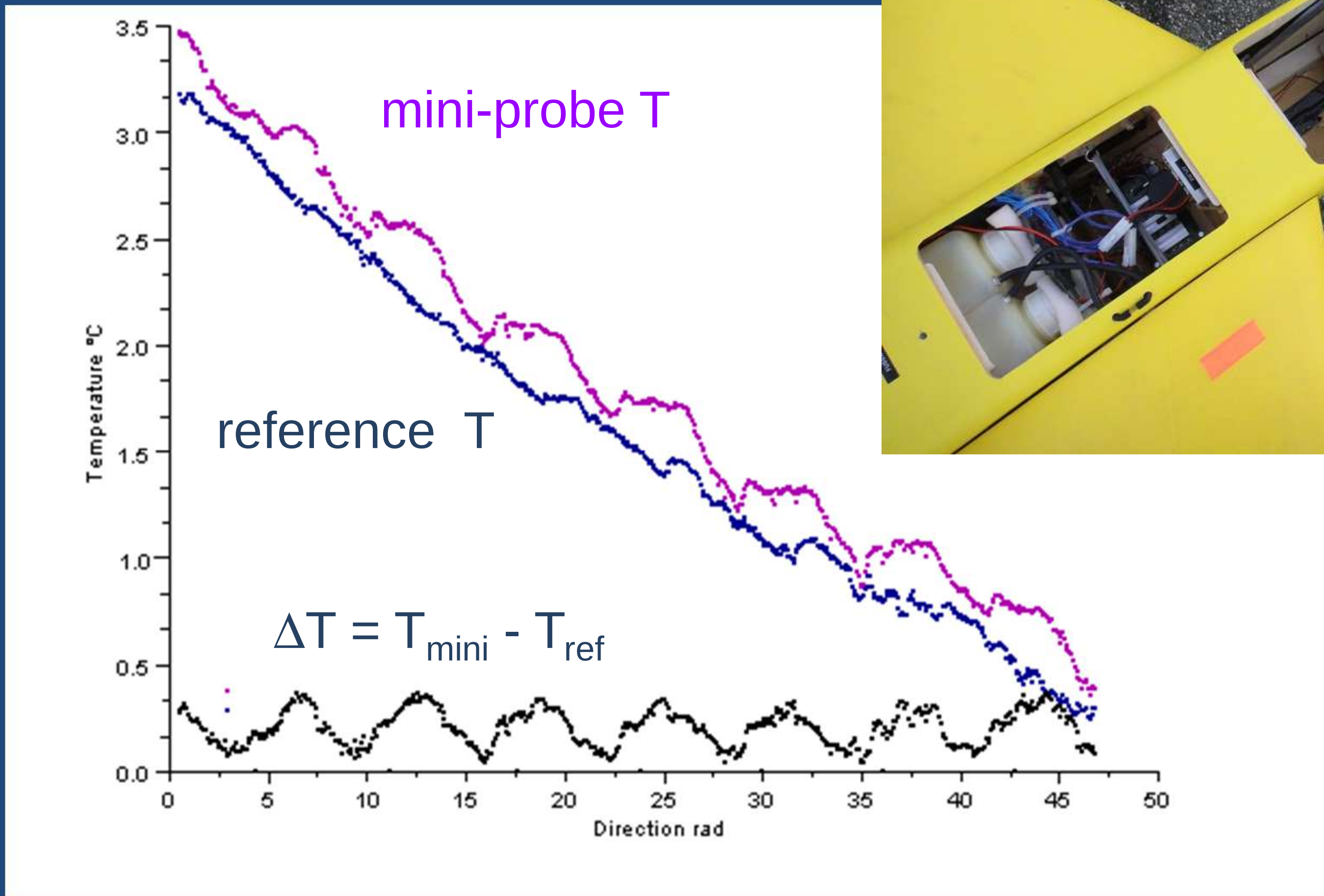


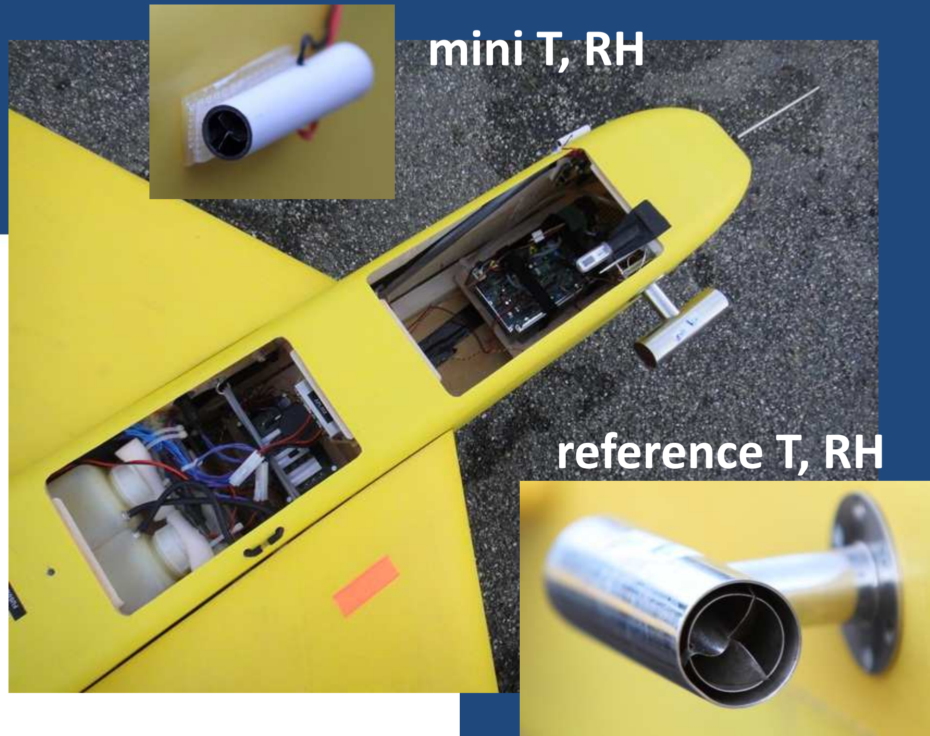
Temperature profile : reference (T_{grande}) and miniature probe (T_{petite})



Cumulative aerosol profile (0.25 < dp < 2.5 μm)

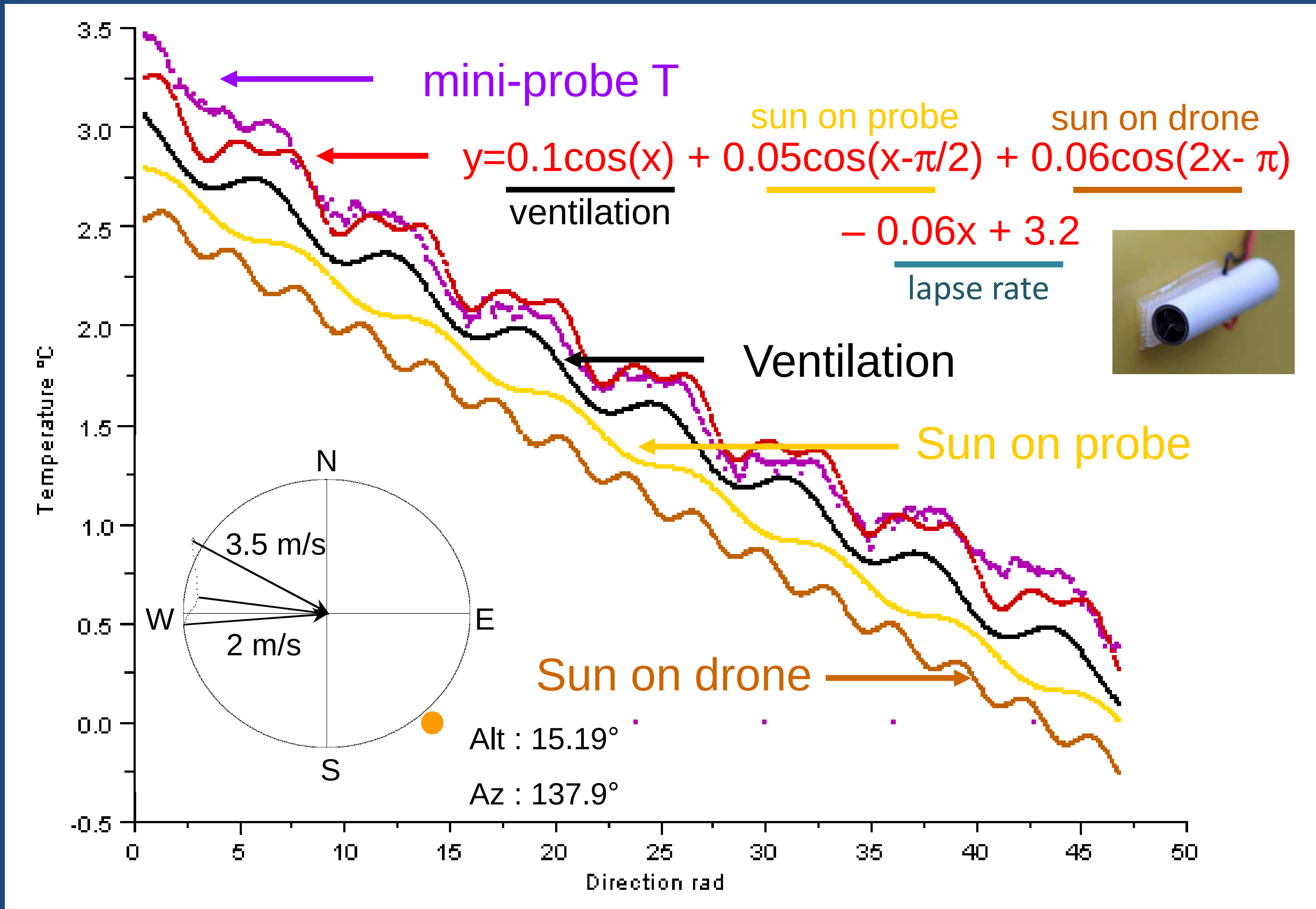
Oscillations in Mini-Temperature Probe





Oscillations correlate with position during spiral profile – sun, airspeed or both?

Components of Biases in Mini-T Probe



Solar heating and ventilation effect temperature sensor

Future Developments

CNRS-GAME &

École Nationale de la Météorologie

(G. Roberts, G. Cayez)

École Nationale de l'Aviation Civile

(C. Ronfle-Nadaud)

1) continue development of viable meteorological sensors on ultra-light UAS (internships in spring/summer 2012)
2) engage university students in atmospheric sciences, instrument development and aeronautics (IUT Toulouse, GEII, ENM, ENAC)

Summary

- Costs scale with payload weight → justification for small platforms and miniaturized instrumentation
- Formation flying, observations in remote locations, monitoring are but a few applications for UASs
- Modular payloads necessary for targeted science missions
- Demonstration flights with meteorological and aerosol sensors (January 2012 near Condom)
- Autonomous flights up to 3000 m.asl in civilian airspace
- Continue development & testing of UAS sensors

Flight team: Gregoire Cayez (ENM), Frank Lavie (CNRM), Diane Tzanos (CNRM), Michel Gavart (AJ), Mikaël Joanne (AJ), Greg Roberts (CNRM-GAME)

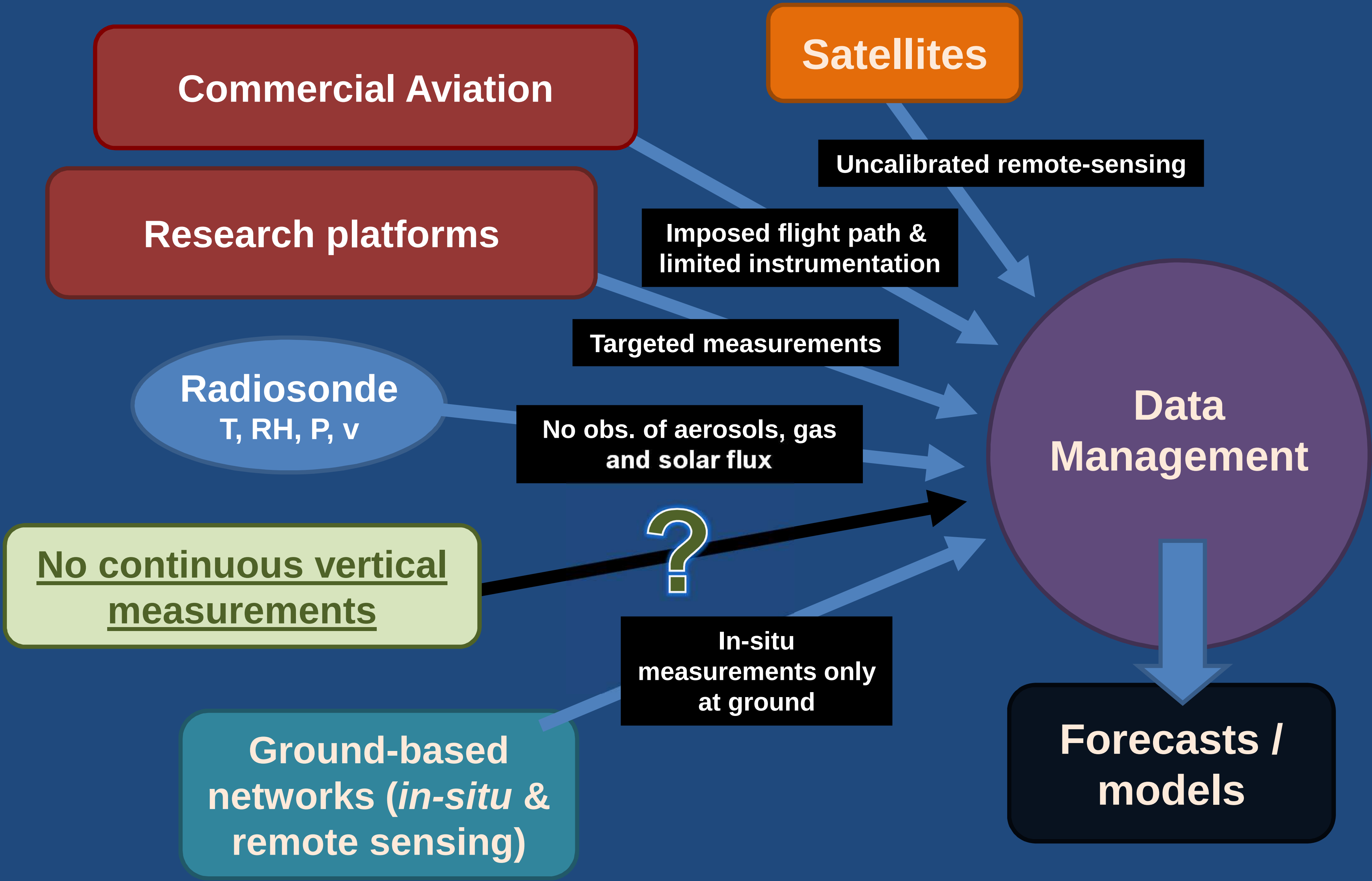
Acknowledgements: Jean-Louis Brenguier (CNRM), Équipe MNPCA, Équipe 4M, Aéroclub Herret

Challenges for UAS Research

Advances needed to exploit the full potential of the light weight UAS:

- Increased reliability of light weight UASs (esp. take-off & landing)
- Ability to launch UASs from remote platforms (ships or buoys)
- Coordinated flying with multiple platforms to determine vertical and horizontal gradients in atmospheric variables
- Long duration flights to track atmospheric phenomenon and diel cycles
- High altitude capability for small, lightweight UAS
- Continued development of miniaturized instrumentation for measuring atmospheric parameters

Current Observational Approach



Observational Approach w/ UAS