

# Flottes de drones pour l'observation de phénomènes atmosphériques

Aperçu de recherches en sciences des systèmes autonomes

Simon Lacroix  
LAAS/CNRS, Toulouse

Gautier Hattenberger  
ENAC, Toulouse

Greg Roberts  
CNRM, Toulouse

(and several interns, PhDs, postDocs...)

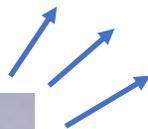
# De l'intérêt des drones pour l'observation de phénomènes atmosphériques locaux

Space



Drones : acquisitions in situ  
contrôlées  
(Cf International Society for  
Atmospheric Research using  
Remotely piloted Aircraft  
<http://isarra.org/> )

Ground

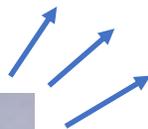
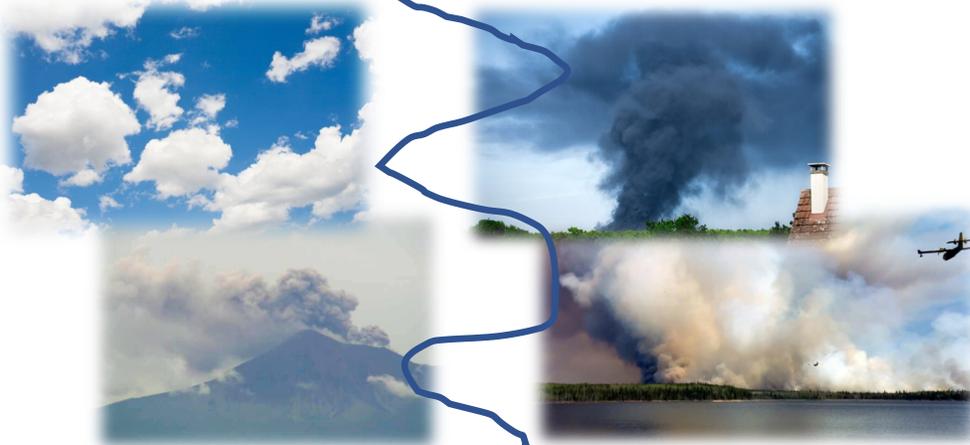


(and manned planes  
– *e.g.* SAFIRE)

# De l'intérêt des drones pour l'observation de phénomènes atmosphériques locaux

Aug. 2007

Space



Ground

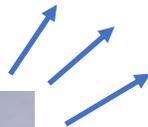


# De l'intérêt des drones pour l'observation de phénomènes atmosphériques locaux

Space



Ground



## Flottes de drones :

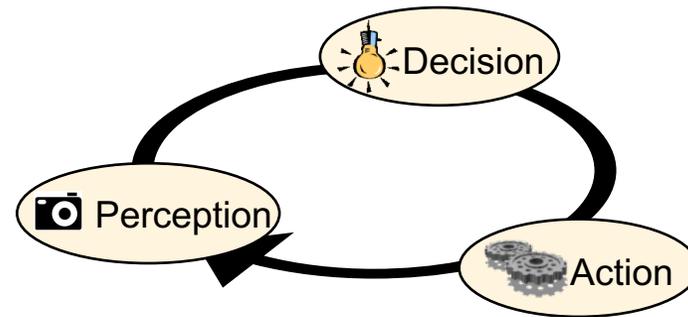
- Acquisitions plus denses
- Synchronisées

## Deux finalités un peu différentes :

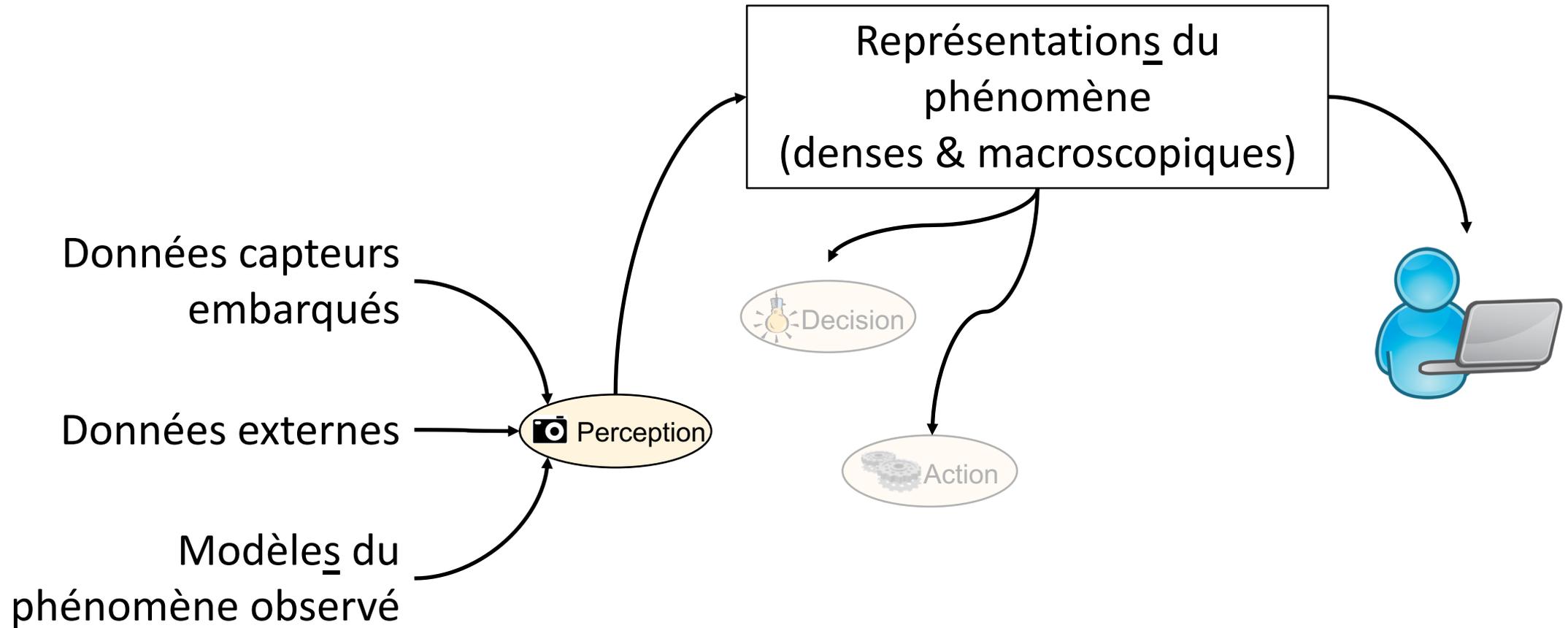
- Scientifique : améliorer les modèles
- Opérationnelle : affiner les prévisions

# Flottes de drones : principes

Les trois processus de base au sein de tout système autonome :



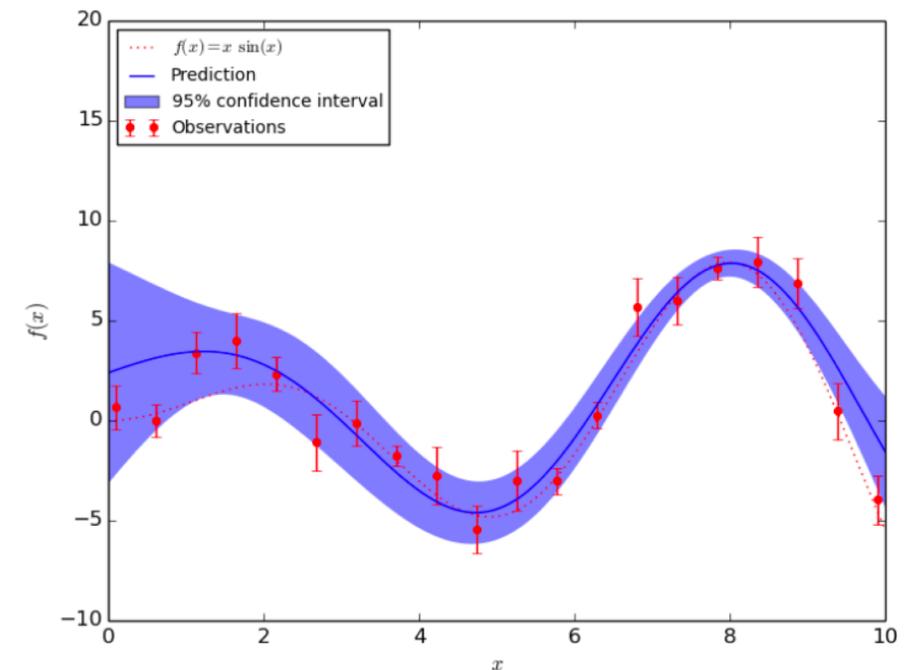
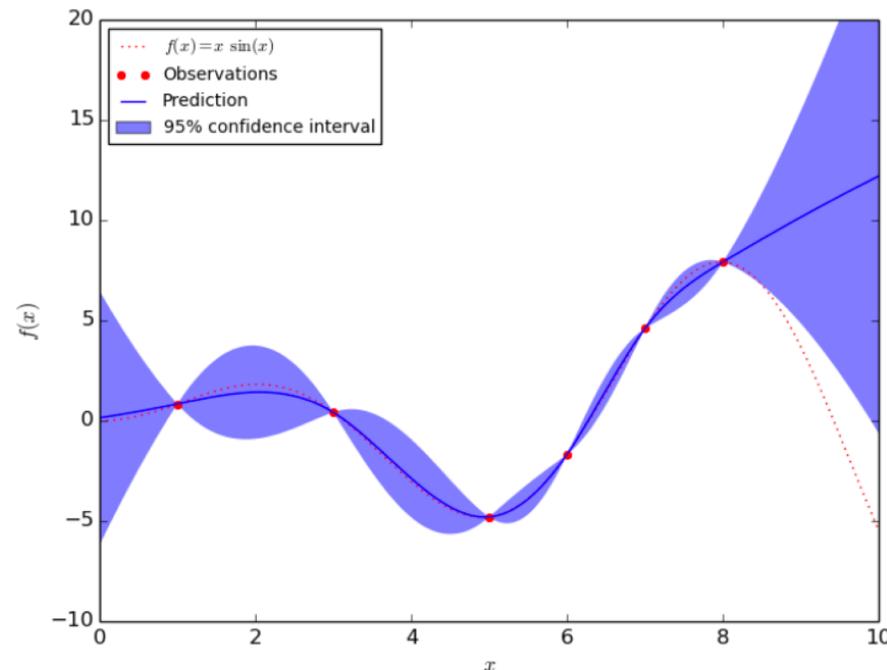
# Flottes de drones : perception



# Flottes de drones : perception “dense”

- Goal: dense map of variables of interest (*e.g.* wind, LWC, pollutant...)
  - Dynamic volumic phenomenon (*i.e.* 4D) probed by pointwise measurements along the UAVs trajectories
- Use Gaussian Processes Regression (= « model-free » regression)

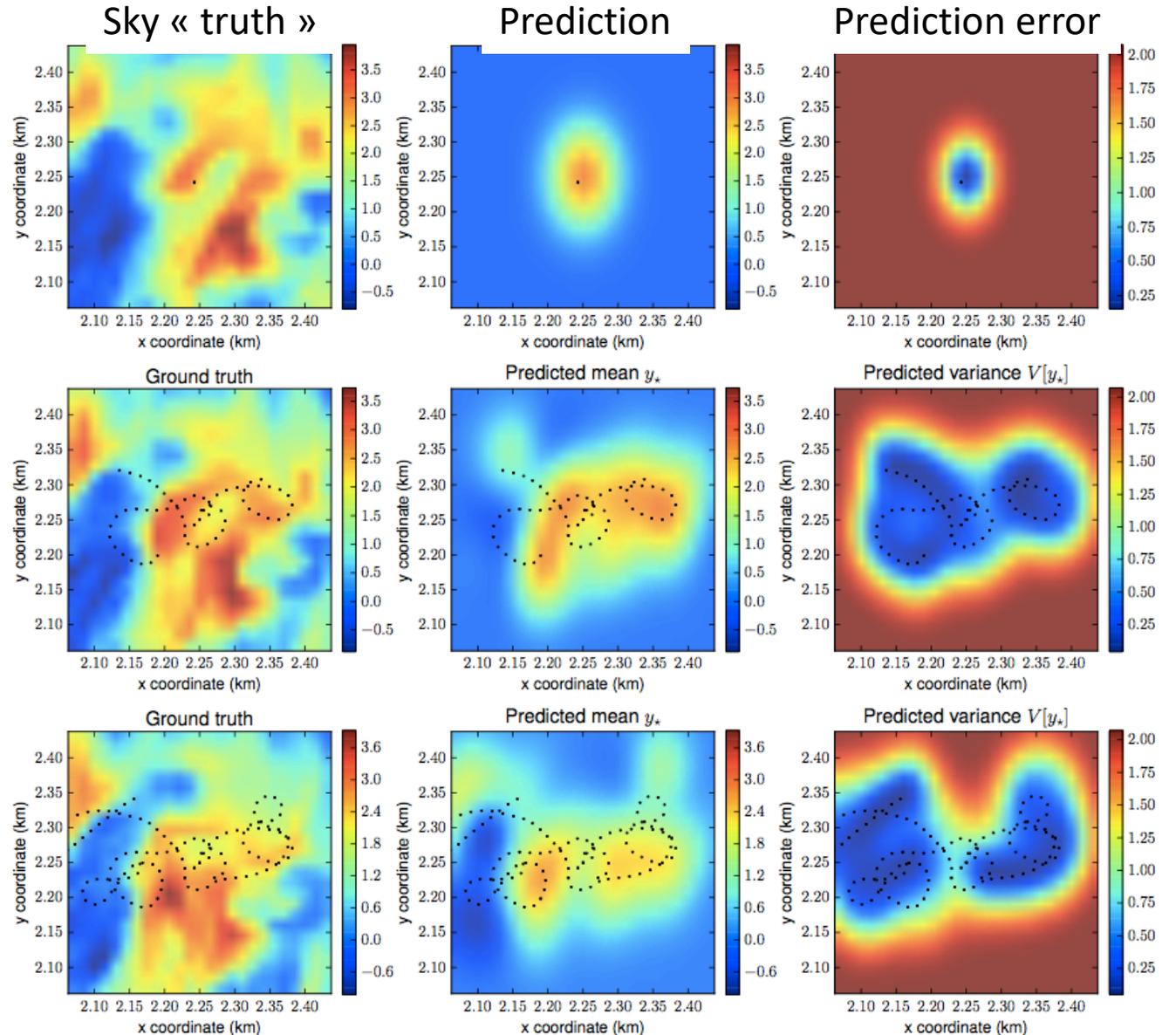
For a 1D signal,  
with and wo.  
noise in the data



# Flottes de drones : perception "dense"

Illustration: LWC dans un nuage simulé

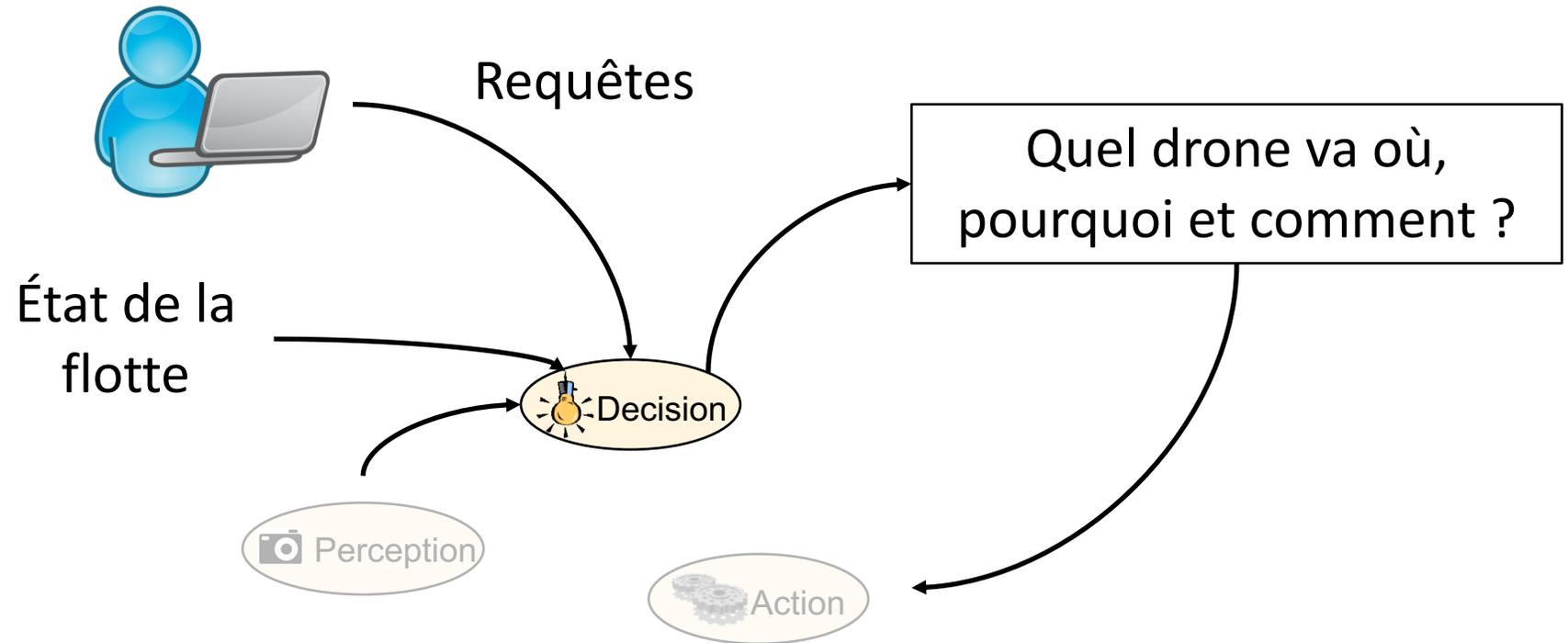
↓  
Temps



# Flottes de drones : perception “macroscopique”

- Goal: estimate global variables (diameter, height, « center », mean advective wind, ...) of the phenomenon
  - Derived from dense maps
  - Resort to dedicated actions (see next slides)
  - Use vision ?

# Flottes de drones : décision



- « Adaptive sampling » ; « optimal (experiment) design » ;  
« optimal sensor placement » ; « active perception »

# Flottes de drones : décision

1. Approche par génération directe de trajectoires, optimisation du gain d'info / de l'énergie dépensée

Two-step optimization scheme:

- Blind random sampling for trajectories initializations
- Constrained stochastic gradient ascent algorithm (SPSA) with local convergence guarantee

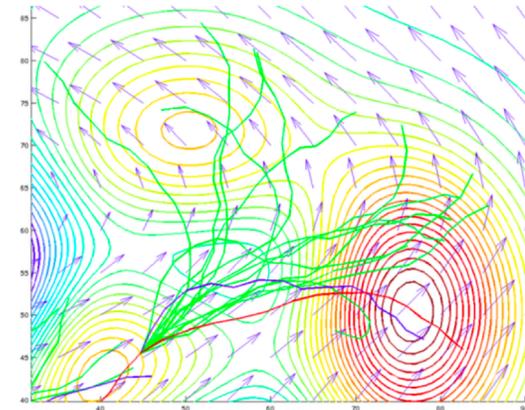
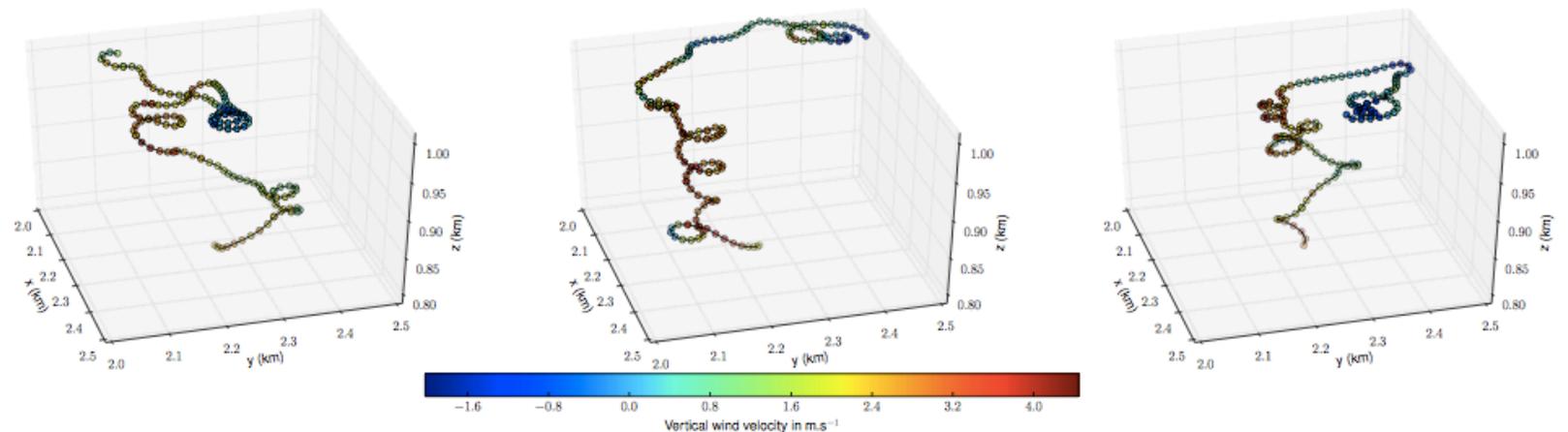
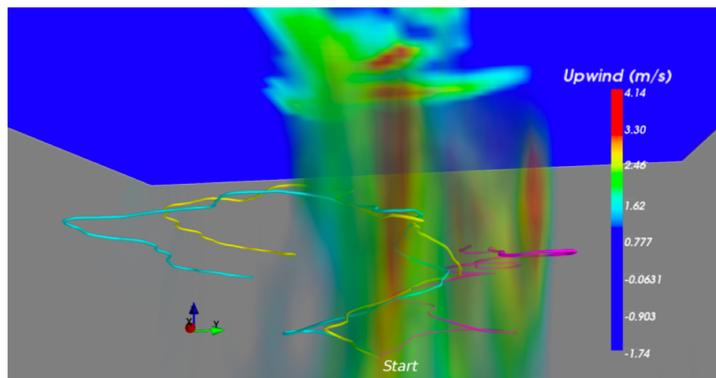
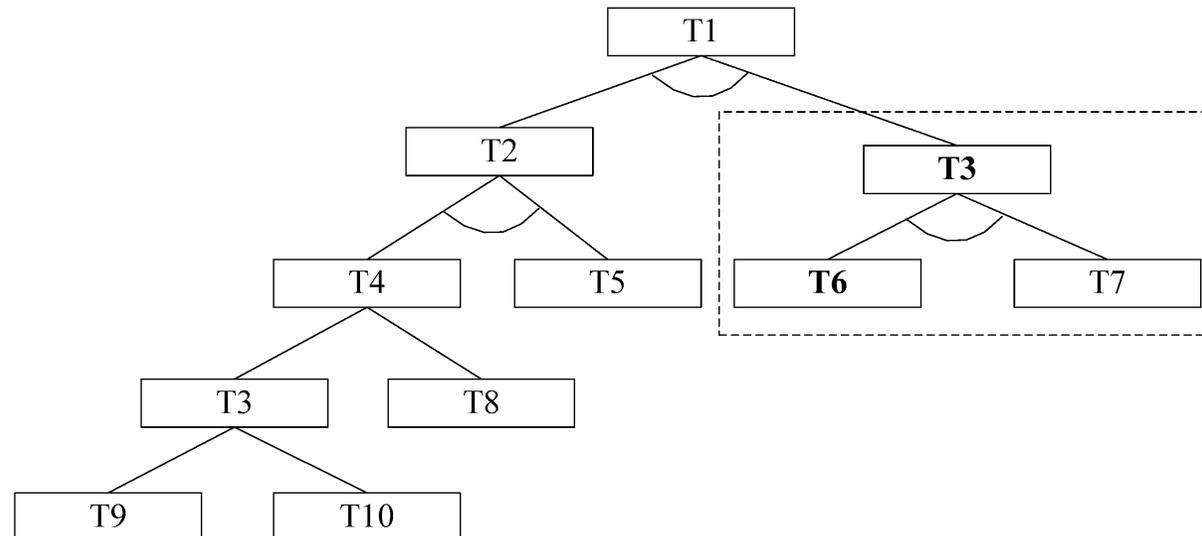


Illustration: « go map a given slice »

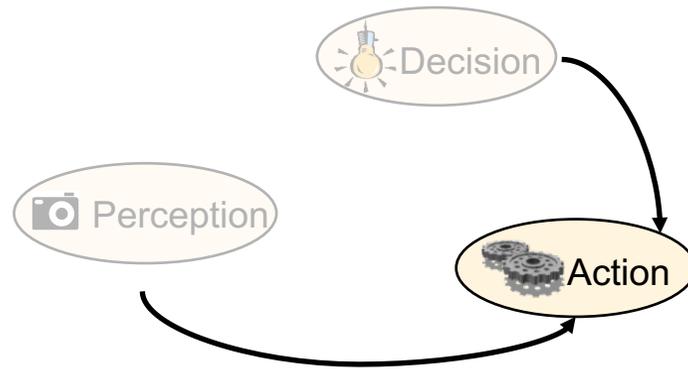


# Flottes de drones : décision

1. Approche par planification d'actions de plus haut niveau
  - Techniques d'allocation de tâches
  - Techniques de planification hiérarchiques→ À entrelacer



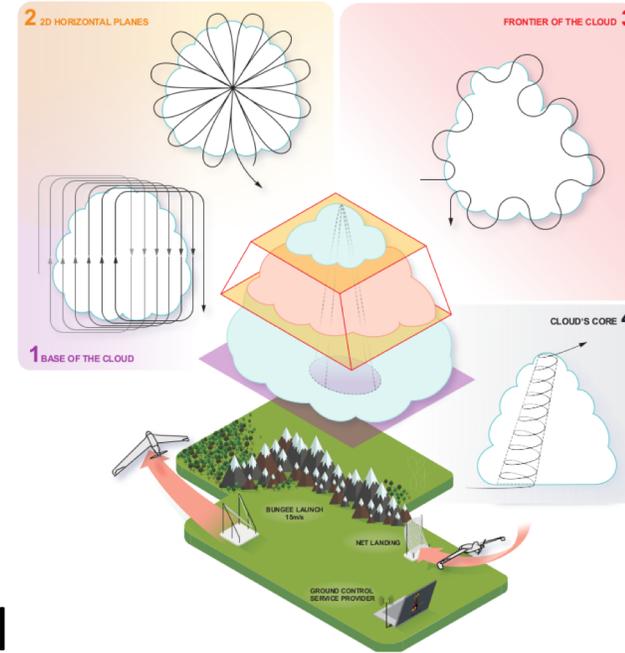
# Flottes de drones : action



# Flottes de drones : action

Sur la base de besoins utilisateurs...

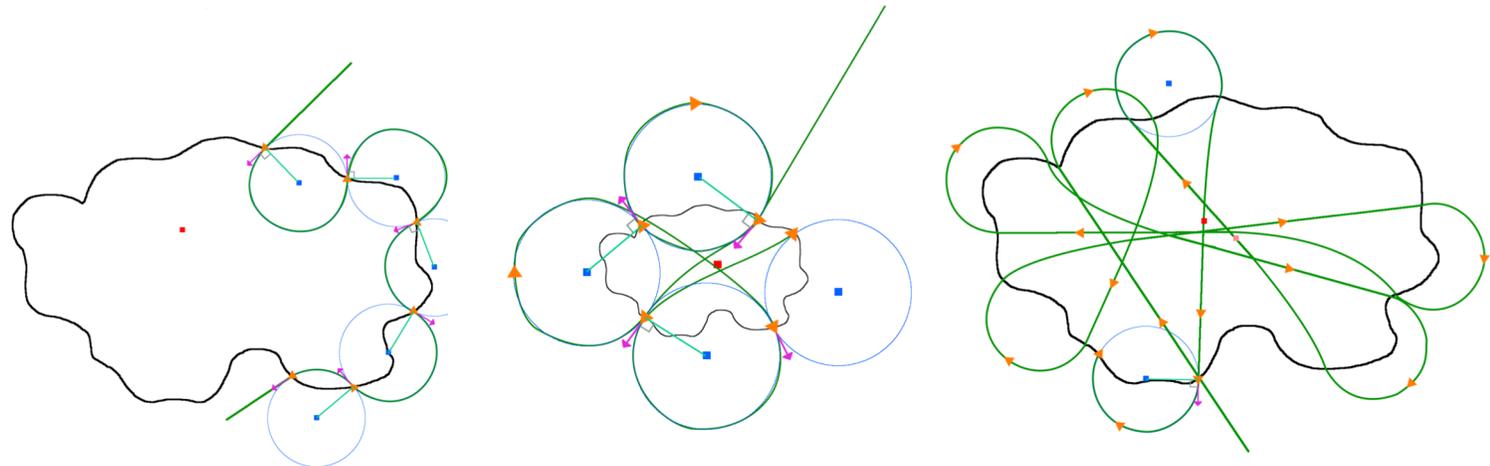
Map  
horizontal  
sections



Track  
cloud  
border

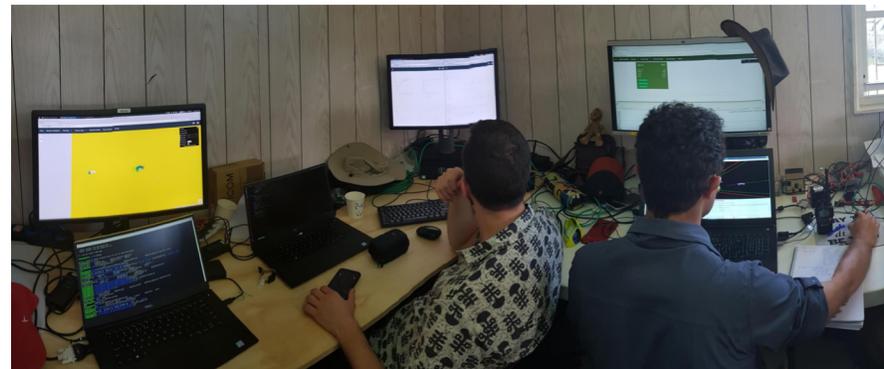
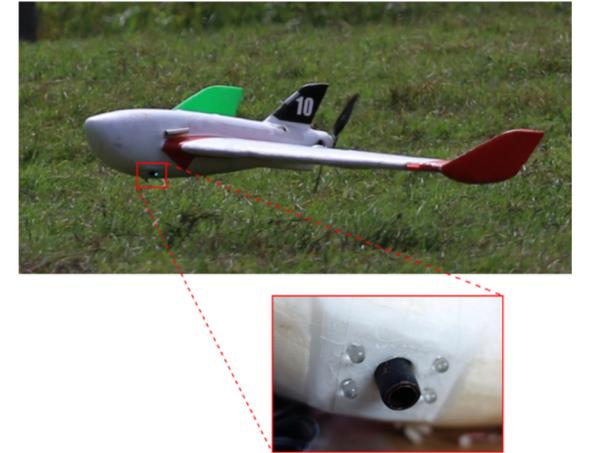
Measure  
cloud  
height

... définition de lois de commande de vol  
*asservies* sur données acquises  
et représentations construites



# Flottes de drones : premiers résultats

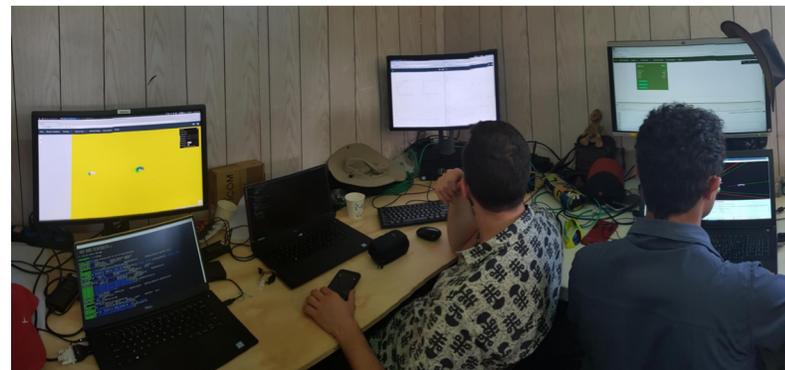
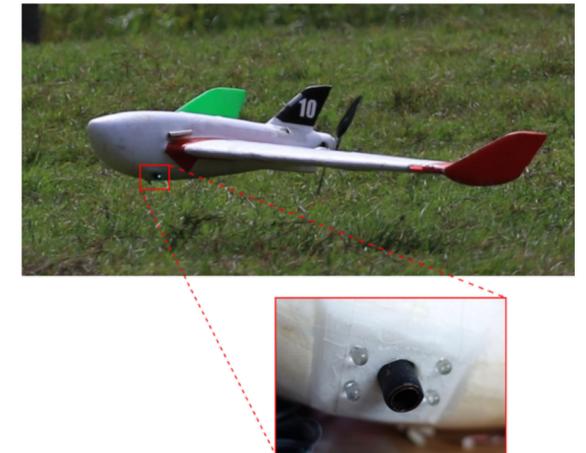
Janvier 2020: campagne de vols à la Barbade  
(en parallèle de la campagne EUREC4A)



Pour une flotte de...  
2 drones !

# Flottes de drones : premiers résultats

Janvier 2020: campagne de vols à la Barbade  
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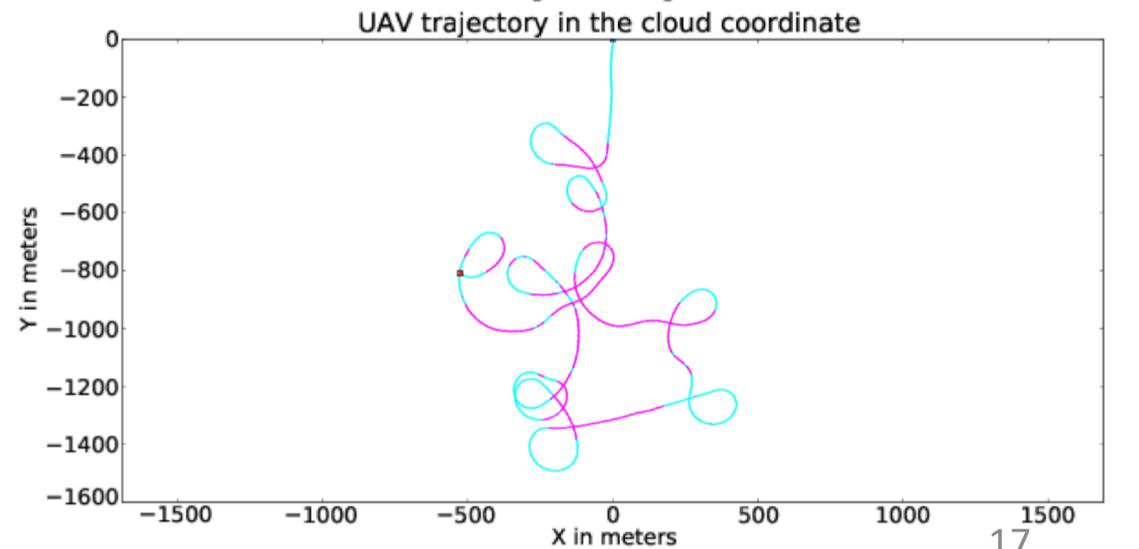
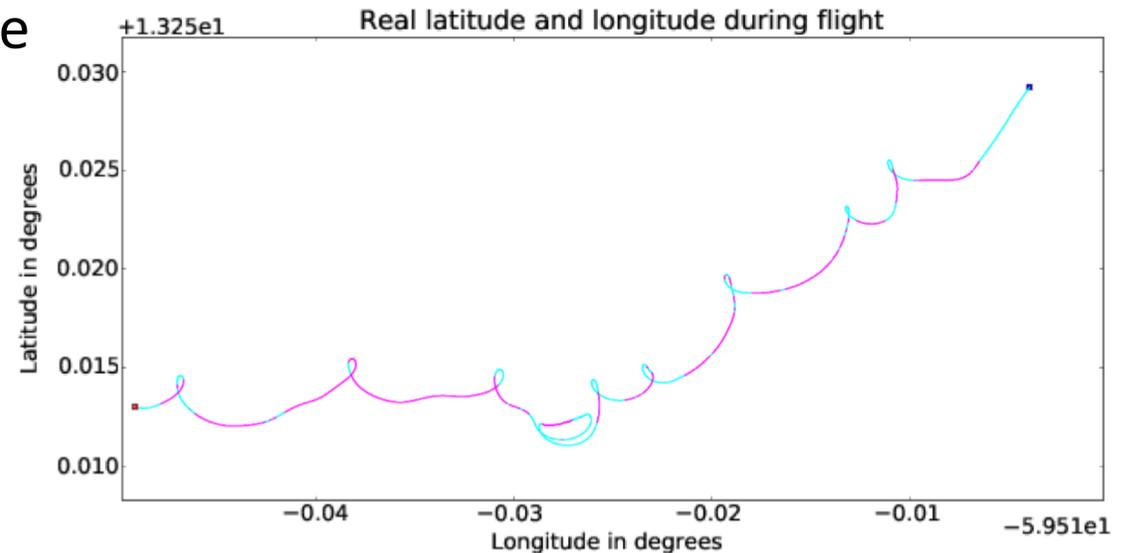


Number of flights	48	22 flights realized with two UAVs
Data recorded	45 hours	Flight time average around 53 minutes per flight
Calibration flights	23	Cloud sensor and UAV calibration, validation of the flight pattern
Measurement flights	25	Vertical profile and cloud tracking mission
Usable flights	18	Tracking of a cloud during more than 2 minutes. Average following time around 5 minutes per tracking.

# Flottes de drones : premiers résultats

Janvier 2020: campagne de vols à la Barbade  
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Env. 8 km, vent d'est env. 8 m/s



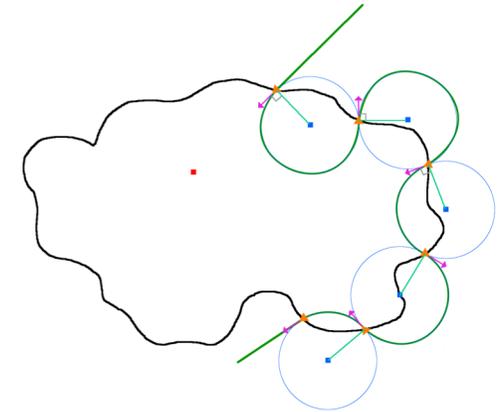
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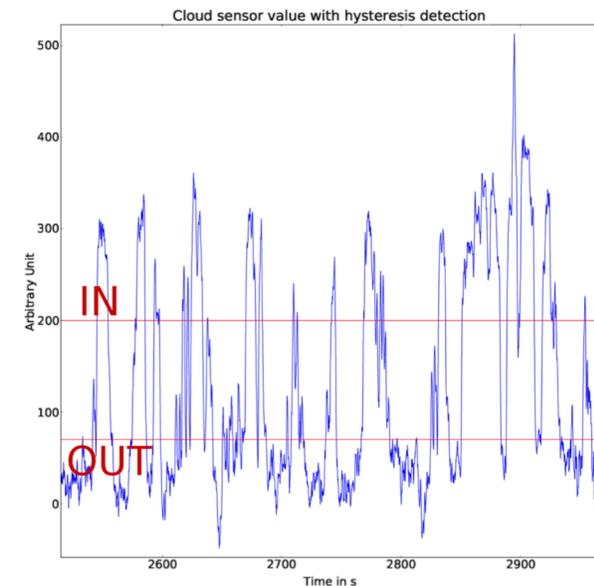
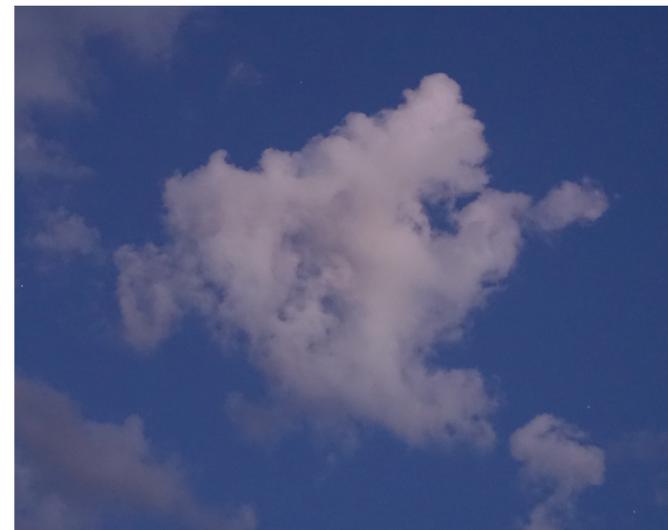
Env. 8 km, vent d'est env. 8 m/s



Du concept...



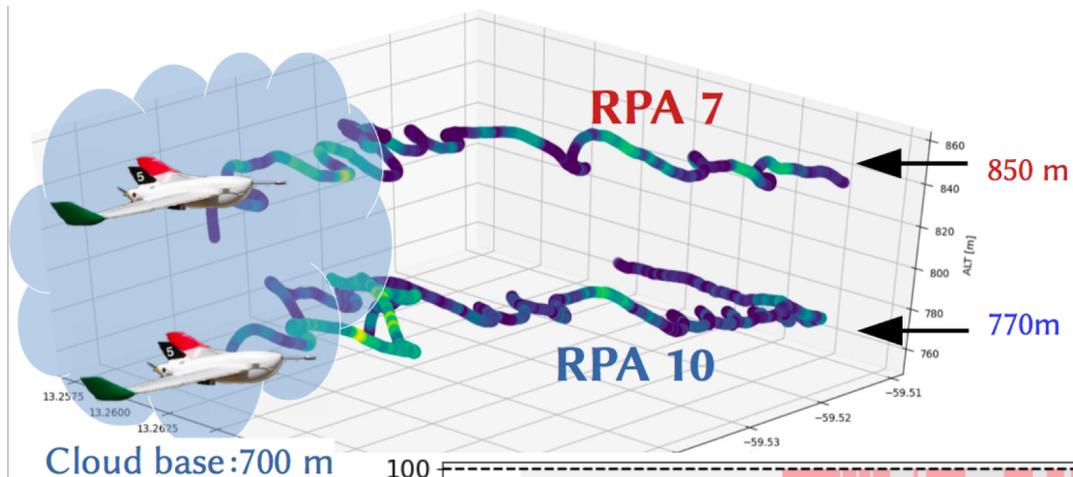
.. au vrai monde



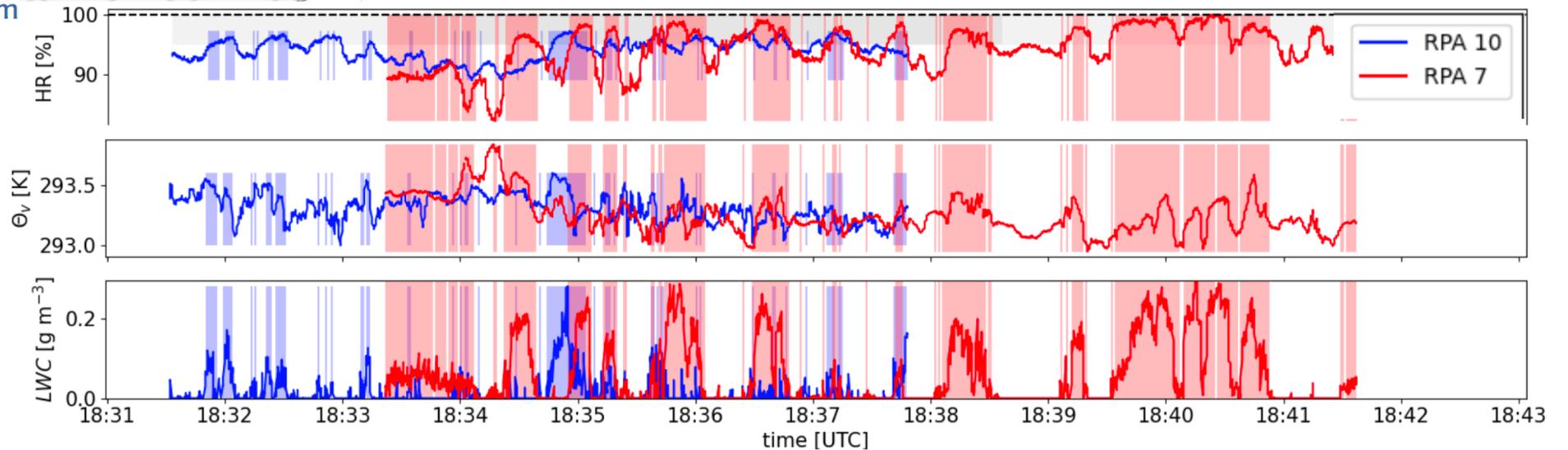
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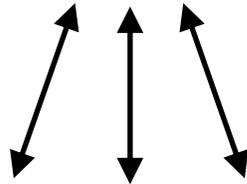
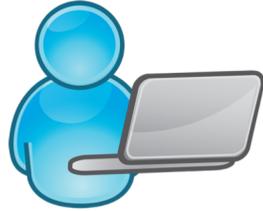
Env. 8 km, vent d'est env. 8 m/s



Cloud base: 700 m



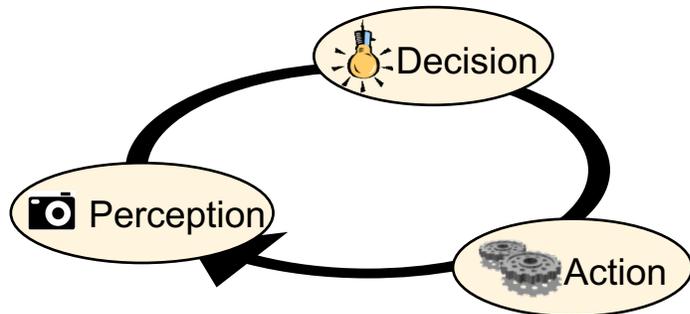
# Overall integration



« Cloud Adaptive Mapping System »

<https://redmine.laas.fr/projects/nephelae-devel/wiki>

(Should be thoroughly re-designed, yet valuable as it is now)



Architecture décisionnelle  
et logicielle

# A whole research program

- Perception : towards better mapping processes
  - How to incorporate models & external data ?
  - Gaussian Process Regressions: from active perception to active learning
  - Data fusion & data assimilation
  - Using on-board vision to detect and estimate macro-parameters of the phenomenon
  - ...
- Decision
  - How to efficiently control the fleet ?
  - How to interleave task planning & task allocation ?
  - ...
- Action
  - Develop robust servoed acquisition schemes (with dedicated supervision schemes)
  - Autonomous energy harvesting ?
  - ...

# A whole research program

- And a few more things:
  - Which UAV ? Impact on the the observed phenomenon ?
  - Definition, development and qualification of the on-board sensors (PTU, liquid water, aerosols, 3D wind, pollutants...)
  - Communication infrastructure
  - Regulatory issues
  - ...

Toujours en collaboration étroite  
avec les utilisateurs  
(scientifiques ou opérationnels)