Synergetic use of field campaign observations and detailed simulations to improve NWP models at Météo-France

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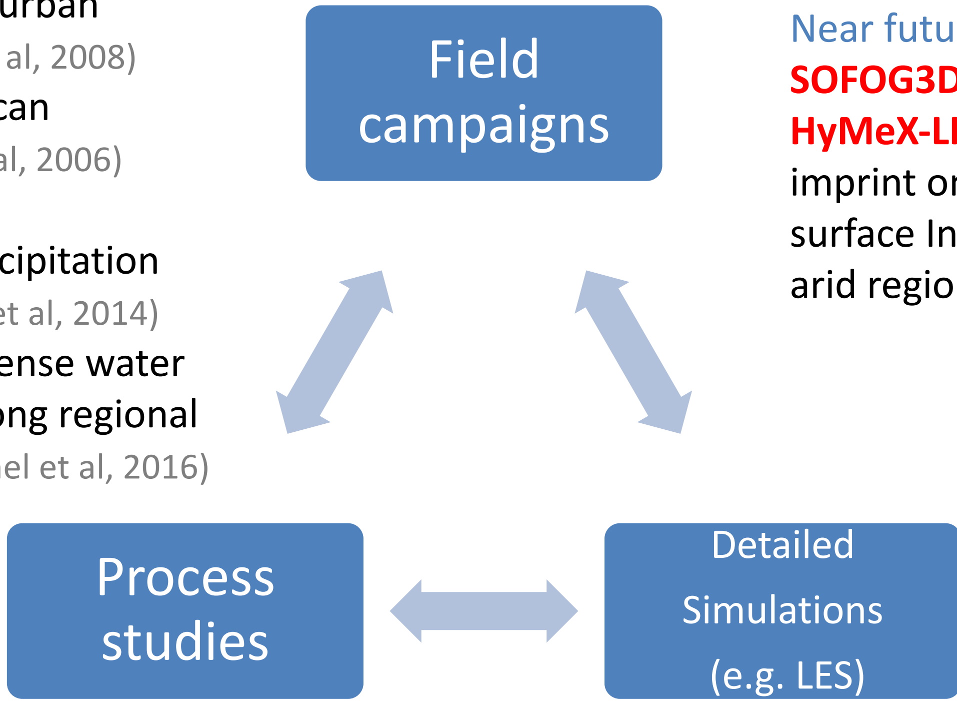
Introduction

Past field campaigns coordinated by CNRM:

CAPITOUL (2004-2005) – urban boundary layer (Masson et al, 2008)
AMMA (SOP 2006) - African Monsoon (Redelsperger et al, 2006)
HyMeX - SOP1 (2012) - Mediterranean heavy precipitation and flash-floods (Ducrocq et al, 2014)
HyMeX - SOP2 (2013) - Dense water formation induced by strong regional winds in NW Med (Estournel et al, 2016)

Near future field campaigns:

SOFOG3D (2019-2020) on fog
HyMeX-LIAISE (2020) - human imprint on atmosphere-land surface Interactions over semi-arid regions.



Our research strategy is based on a « Field campaigns – Process studies – Detailed simulations » nexus for developing and improving physical parameterizations of Météo-France NWP and climate models for atmosphere, continental surfaces and ocean-atmosphere coupled models.

Outline

1. Observations ⇒ Design of new physical parameterizations

2. Model ⟺ Observations comparison

3. Multi- Earth component observations

4. Future field campaigns

5. Final remarks

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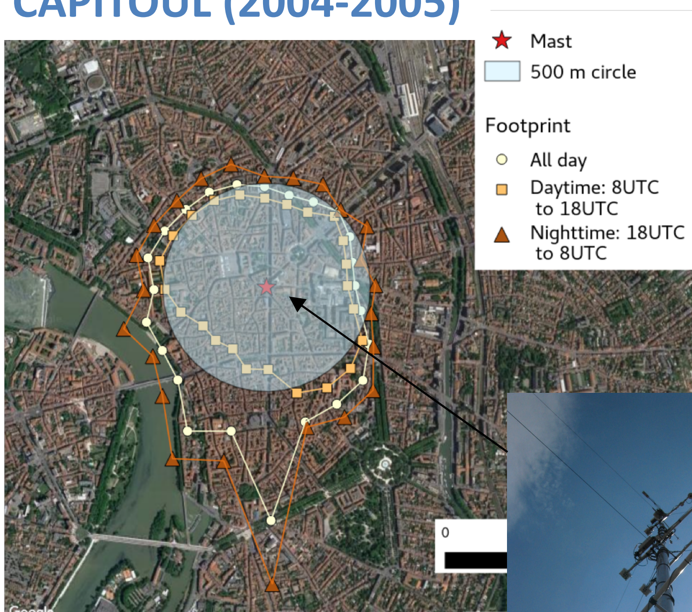
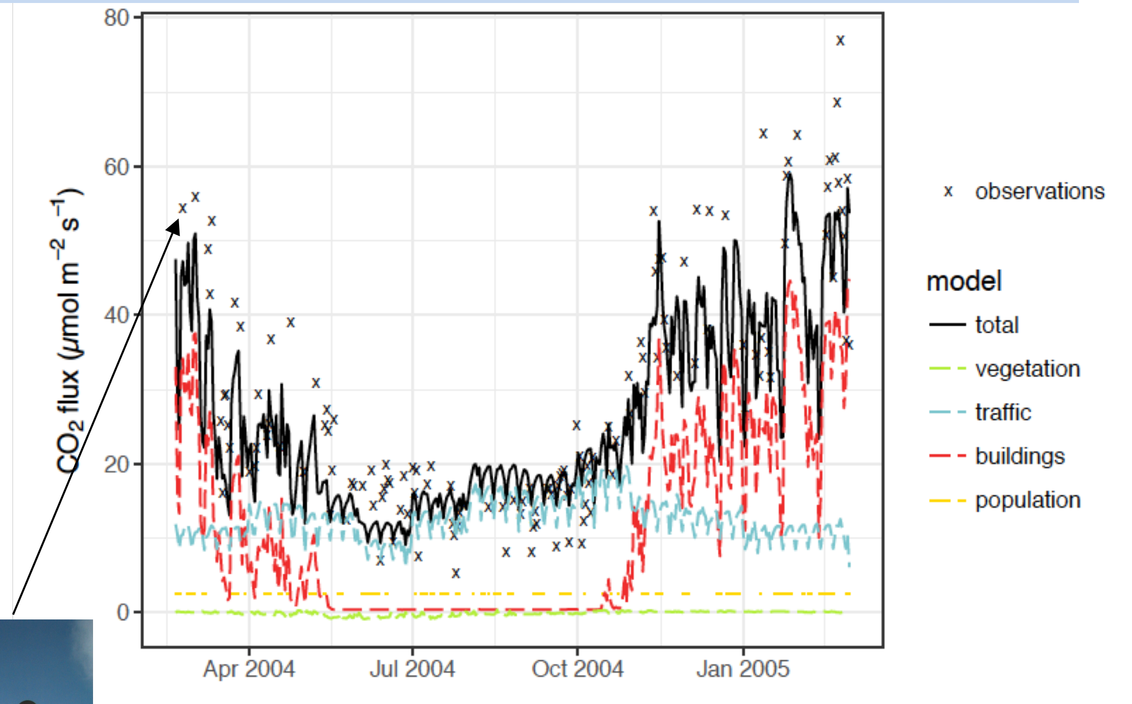
Obs for design of new physical parameterizations

CO_2 fluxes in urban areas

Inclusion of a CO_2 flux modelling in the urban canopy layer model TEB and evaluation over an old European city centre (Toulouse)

CAPITOUL (2004-2005)





The highly weather-dependant contributors (buildings and vegetation) to CO_2 fluxes are explicitely modelled

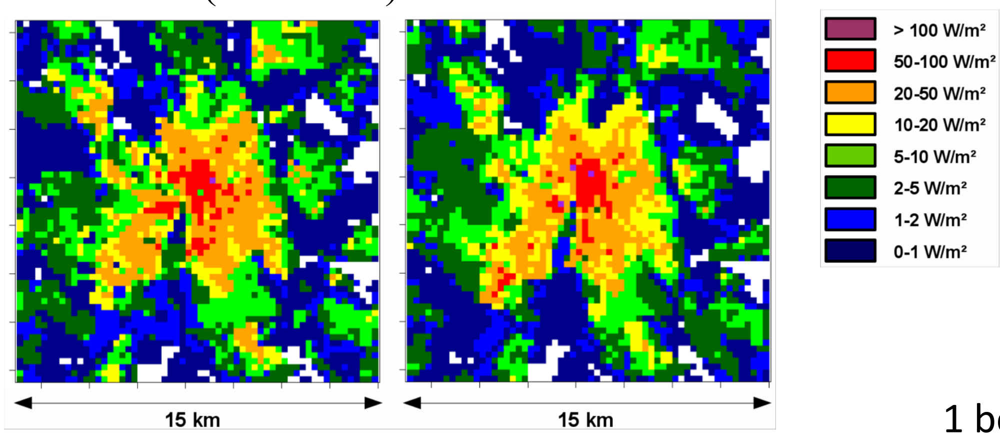
Goret et al., submitted

Obs for design of new physical parameterizations

Parametrisation of the variety of human behaviour related to building energy consumption

1 year-long simulation MesoNH model (Δx=250m)

Inventory from CAPITOUL data



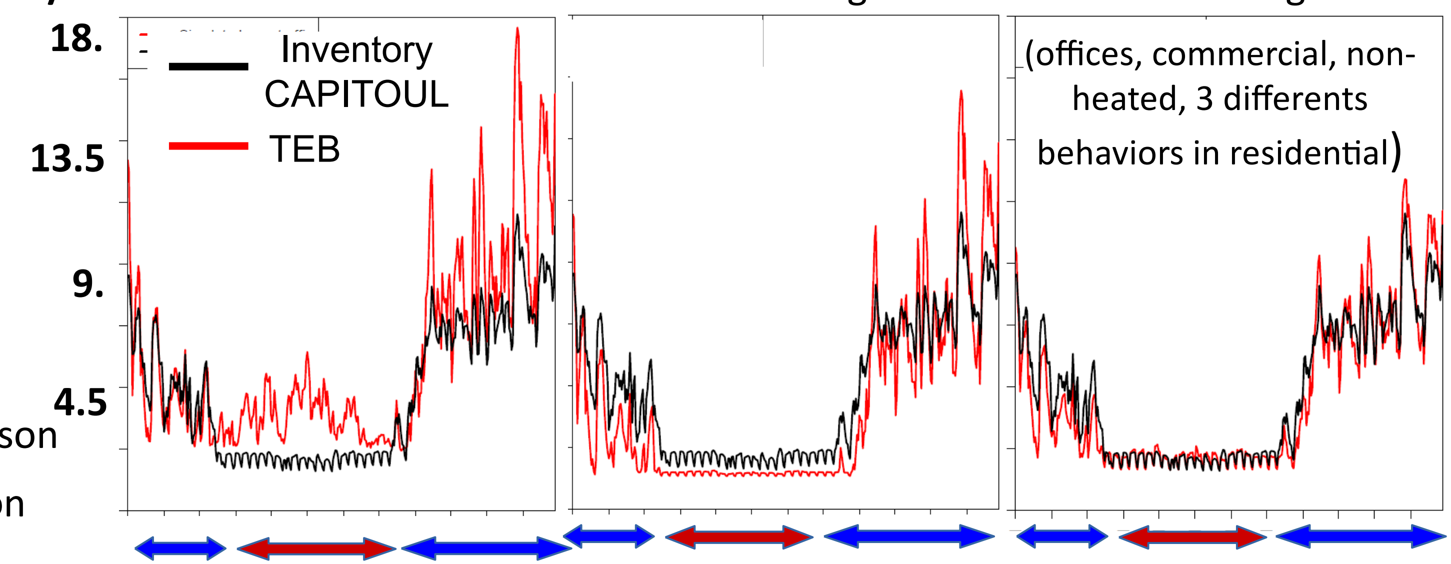
Energy consumption inside buildings depends on building use and human behaviour (heterogeneous in most urban areas) => modify TEB to take fractional building use and human behaviour at the grid point scale into account

Buildings energy consumption due to domestic heating, Toulouse (winter 2004-2005)

Uniform behaviour

1 behaviour for main building use

6 fractional use/behaviour in buildings



Heating season

Warm season

Schoetter et al., GMD 2017

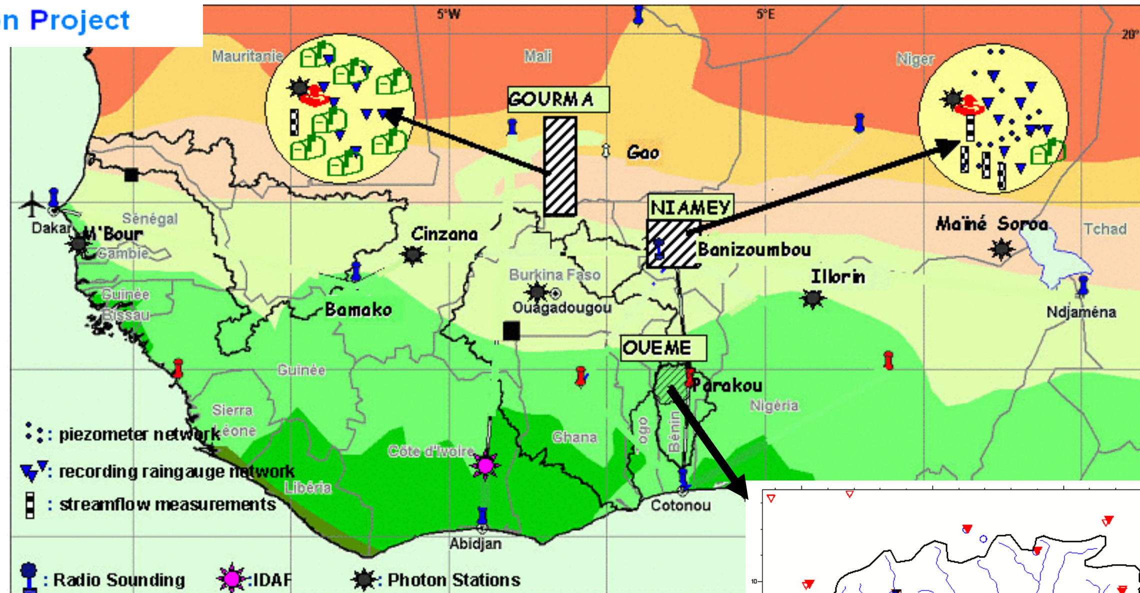
Obs. for international intercomparison model project

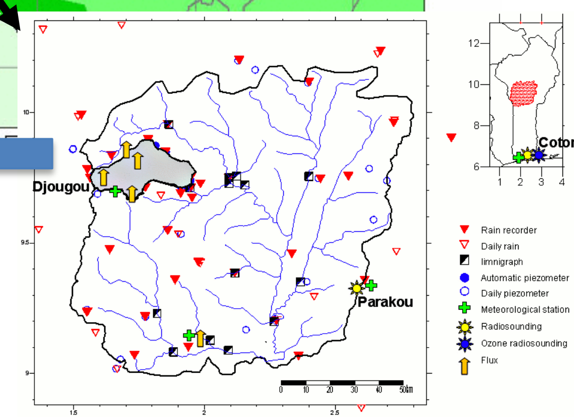
ALMIP AMMA Land Surface Model Intercomparison Project

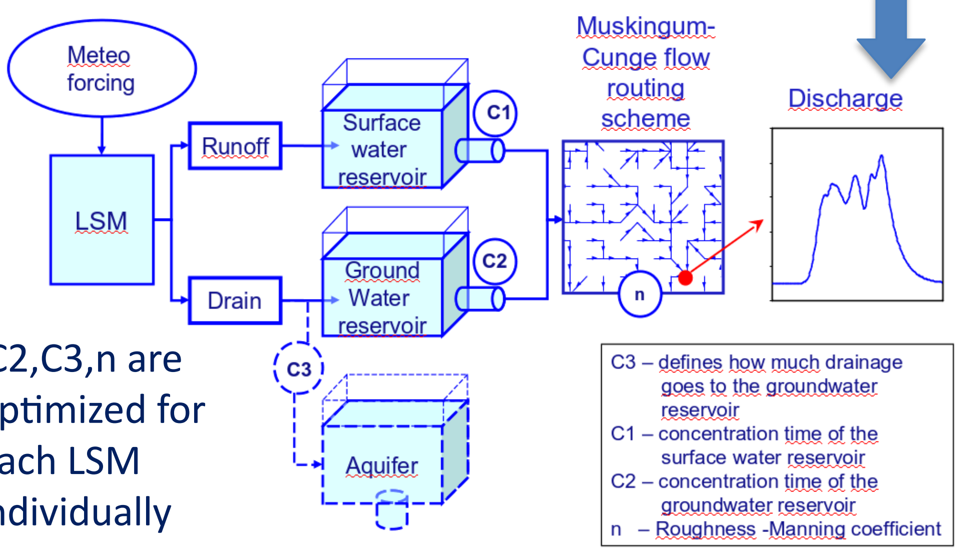
Data for ALMIP
Phase II-Mesoscale

Meso-Super Sites

Model evaluation and Forcing : Local scale data, Turbulent fluxes, Soil moisture, Temp, Discharge, Vegetation (LAI…)







C1,C2,C3,n are optimized for each LSM individually

Evaluation of Land Surface Models (LSM) using observed discharge

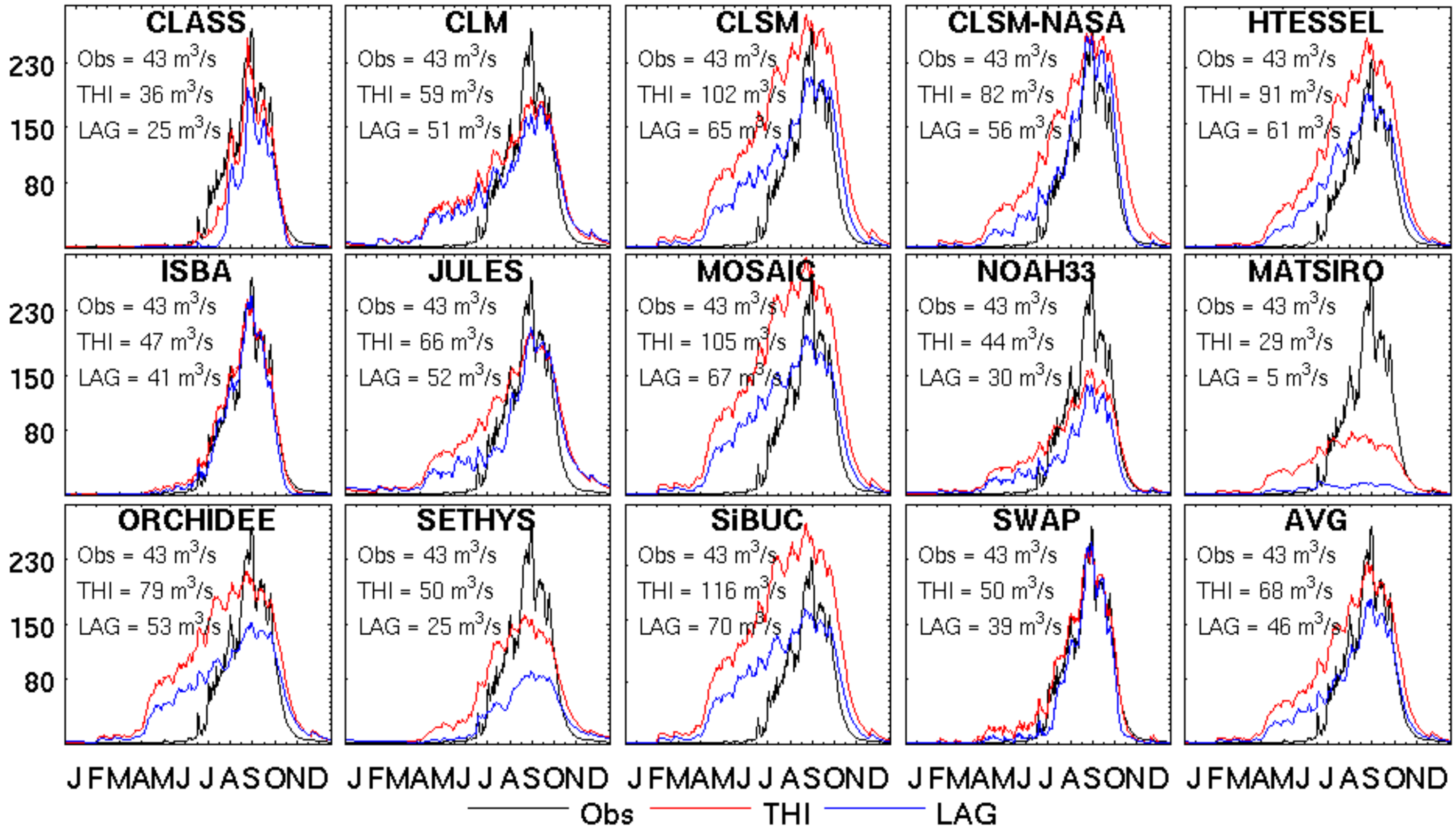
Getirana, Boone et Peugeot et al., J Hydromet, 2017

Obs. for international intercomparison model project

ALMIP AMMA Land Surface Model Intercomparison Project

4 Year-average Seasonal Discharge 2005-2008

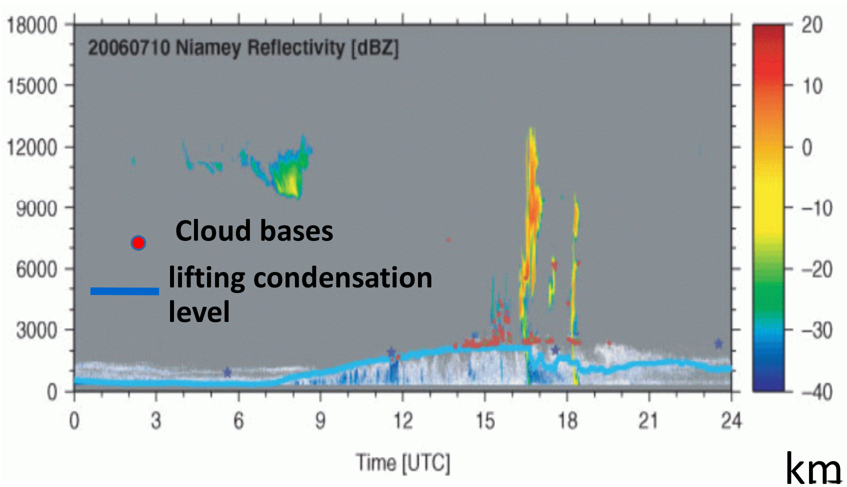
Daily discharge (at Bétérou) for 2 precipitation inputs: LAG and THI for 14 LSMs



Most LSMs tended to simulate runoff at first rainfall owing to sub-grid runoff parameterizations not adapted to local runoff mechanisms: in reality, a lag effect between rain and runoff

Getirana, Boone et Peugeot et al., J Hydromet, 2017

Obs. for LES as a reference for physical parametrisations

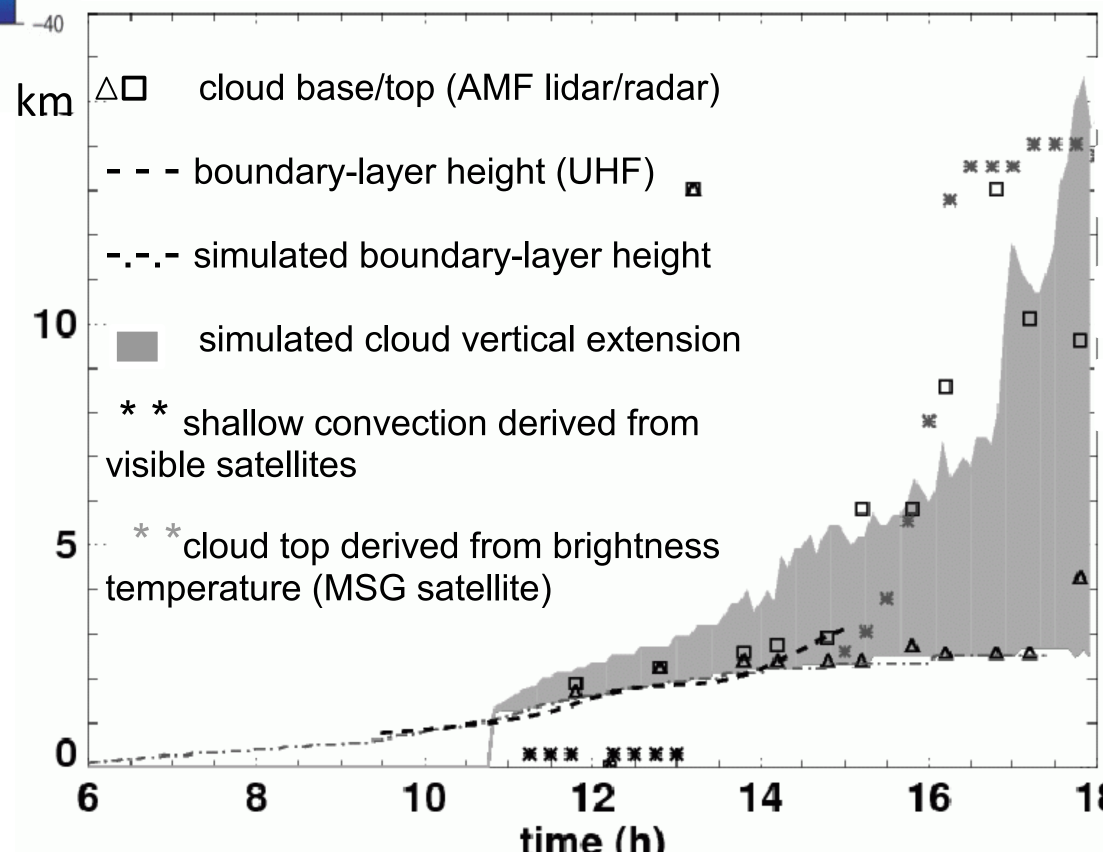


A case from AMMA of local initiation in a semi-arid region (Niamey)

two distinct transition phases:

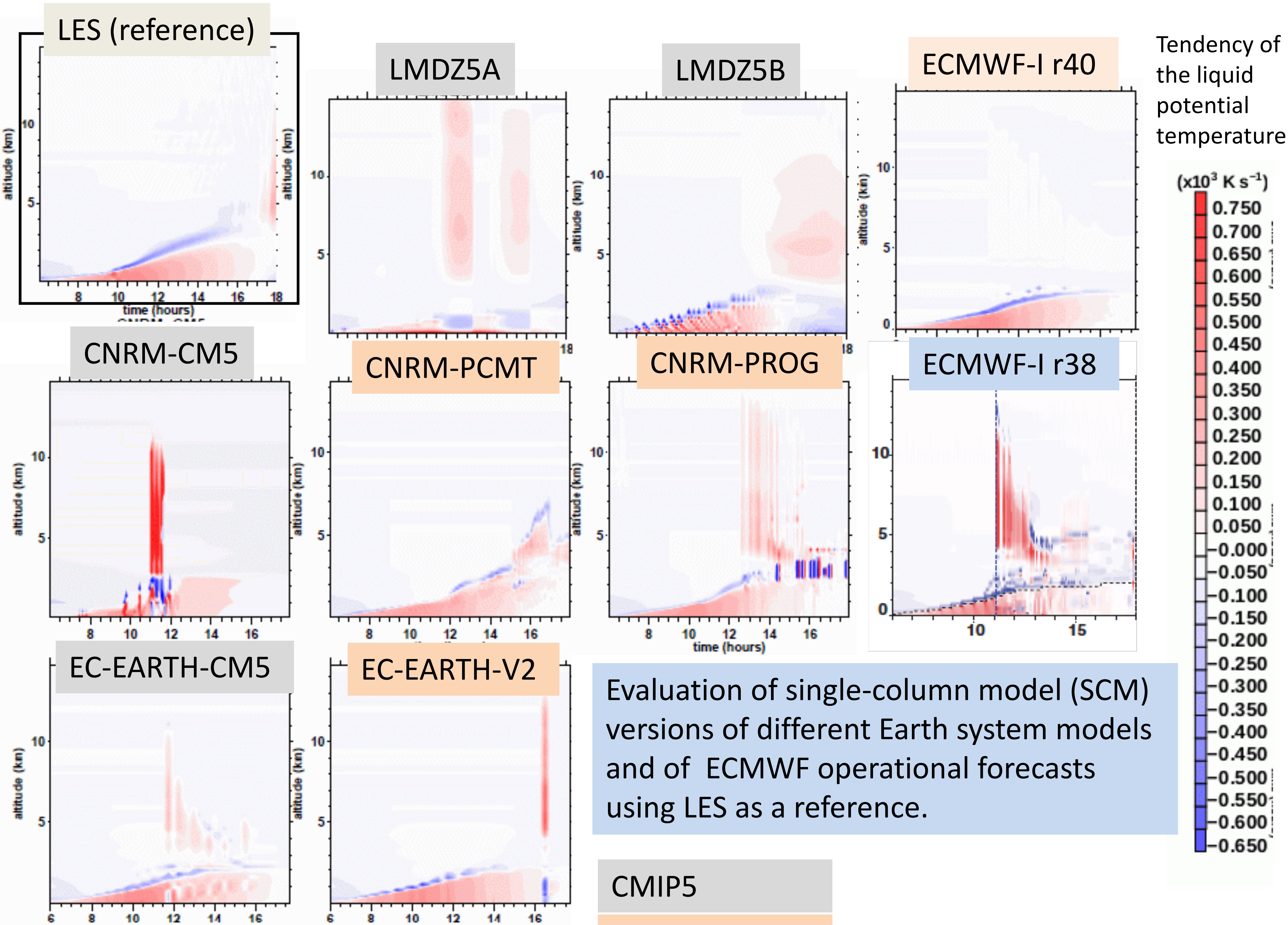
- from clear sky to shallow cumulus
- from cumulus to deep convection

Simulation LES (dx=200m) over a 100x100 km^2 domain



➡ evaluation of the LES using AMMA field campaign observations (soundings, satellites, radar, aircraft)

Couvreux et al, QJRMS, 2015



Evaluation of single-column model (SCM) versions of different Earth system models and of ECMWF operational forecasts using LES as a reference.

CMIP5

Newer versions

Couvreux et al, QJRMS, 2018

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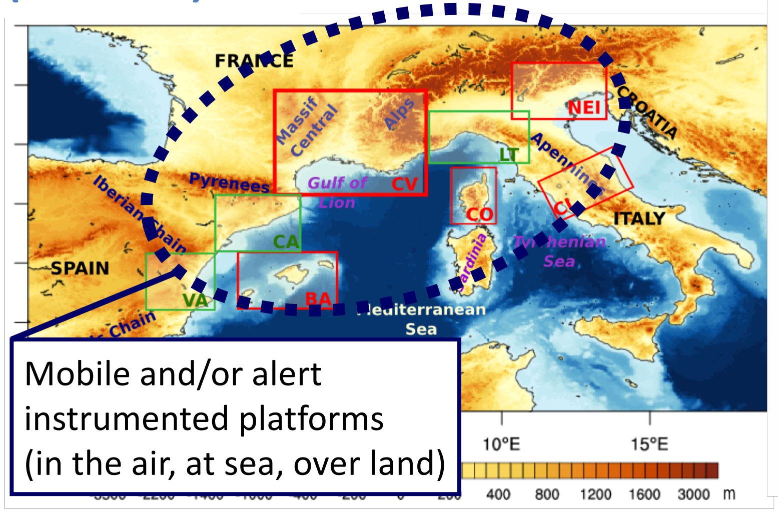
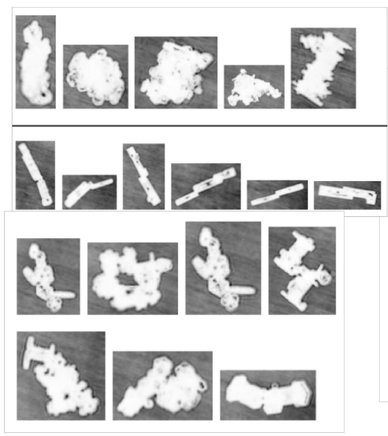
Field campaigns provide many Obs that are not model variables

HYMEX-SOP1 (fall 2012)

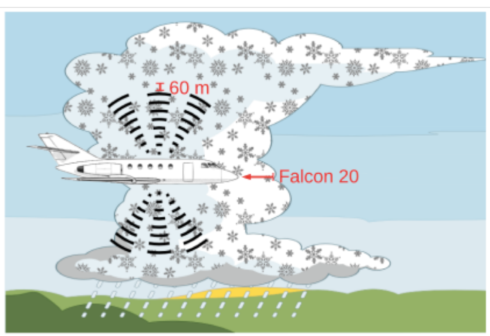
~200 instruments deployed
250 flight hours
(SAFIRE/ATR42 & F20,
KIT/DO128)
16 IOPs dedicated to heavy
precipitation



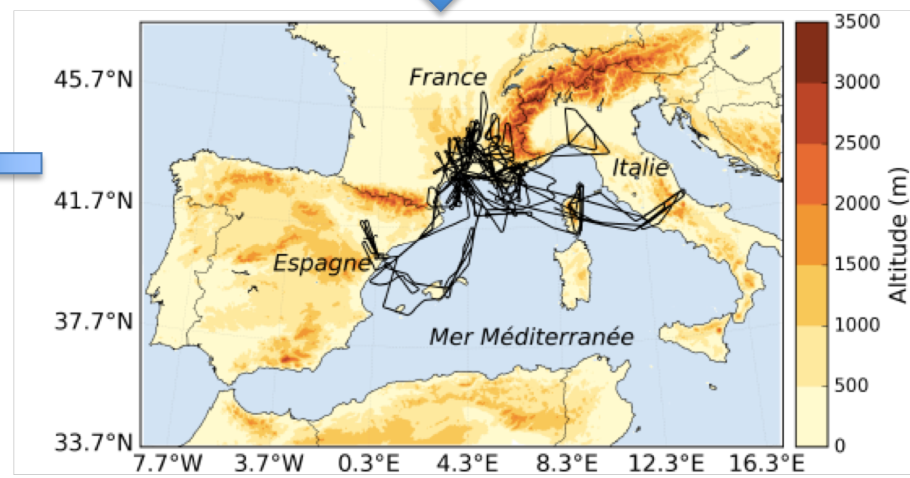
F20 flights inside MCS



Microphysics probes



RASTA Doppler cloud radar
(see J. Delanoë talk)

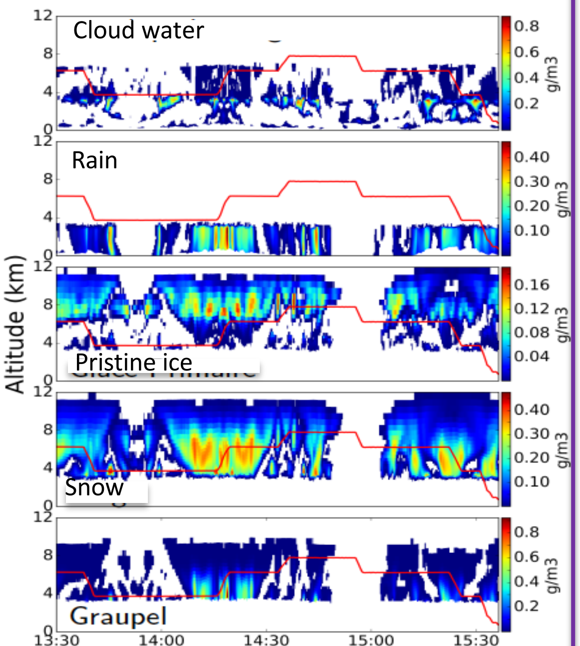


Falcon 20 flight tracks (52h – 18 flights)

Ducrocq et al, BAMS, 2016

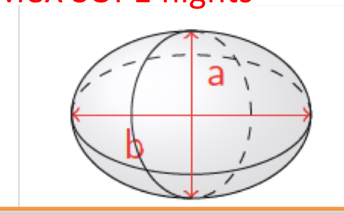
Model-to-observations approaches

Predicted hydrometeor species from AROME



particle size distributions fom the ICE3 one-moment bulk microphysical scheme of AROME

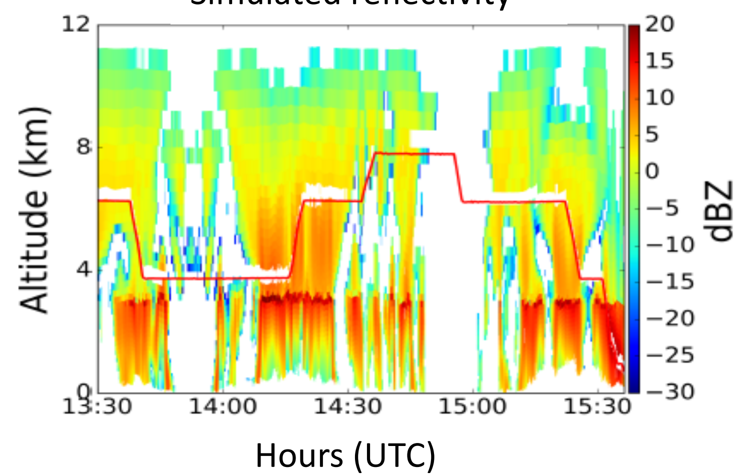
Shapes of the solid hydrometeor species optimized using the 18 HyMeX SOP1 flights

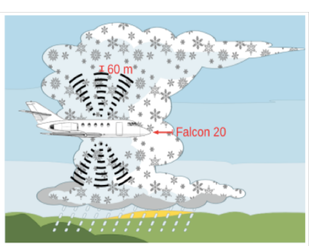


scatttering: T-matrix method
attenuation by hydrometeors and moist air

$$z_e \propto \int_{D_{min}}^{D_{max}} \sigma(D) \cdot N(D)\, dD$$

Simulated reflectivity





Radar characteristics:
Frequency : 95GHz
Sensitivity : -27 dBZ@1km
Geometry: nadir- and zenith-pointing antennae at each range gate

Borderies et al, QJRMS, 2018

Comparison methods to disentangle spatial/temporal forecast model errors to physical parameterization errors

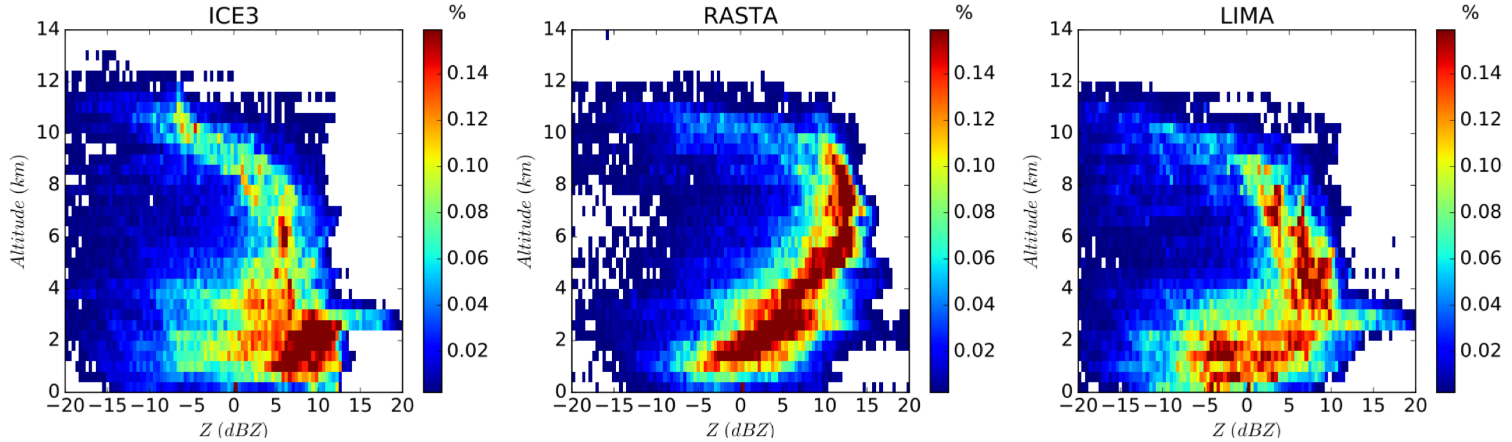
Grid-to-grid or along flight track comparisons require a perfect match between forecasts and observations, which is rarely the case…

A first method: Contoured Frequency by Altitude Diagrams (CFADs) normalized to the total number of points for reflectivities observed by RASTA and simulated by the model. It provides a statistical view of how a model capture cloud vertical structures.

1-moment microphysics scheme ICE3 of AROME

RASTA obs from HyMeX IOPs 6 and 16a

2-moment scheme LIMA prepared for AROME



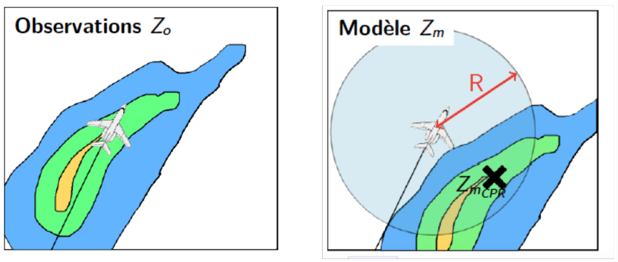
The reflectivity is underestimated with both microphysical schemes
LIMA produces a smoother transition from ice to liquid cloud
ICE3 overestimates the frequency of high clouds (above 10 km)

Taufour et al, QJRMS, 2018

Comparison methods to disentangle spatial/temporal forecast model errors to physical parameterization errors

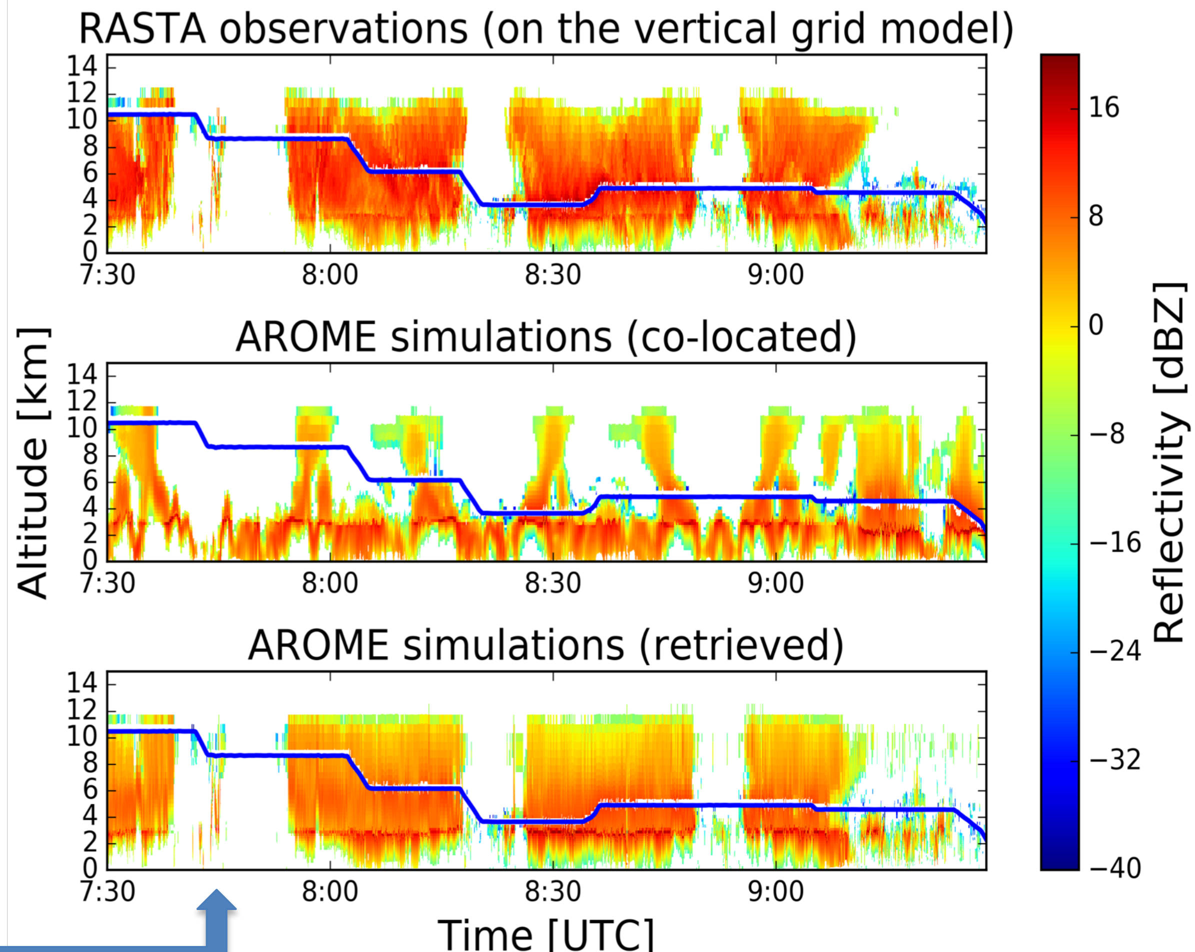
A new neighbourhood validation method for 3D fields: the Most Resembling Column method

The MRC method



$$Z_{m_{CPR}} = \underset{Z_m}{\operatorname{argmin}}\, STD(Z_o - Z_m)$$

derived from the 1D Bayesian retrieval method employed in the first step of the 1D+3DVar assimilation used to assimilate radar reflectivity in the AROME model (Caumont et al., 2010)



Borderies et al, QJRMS, 2018

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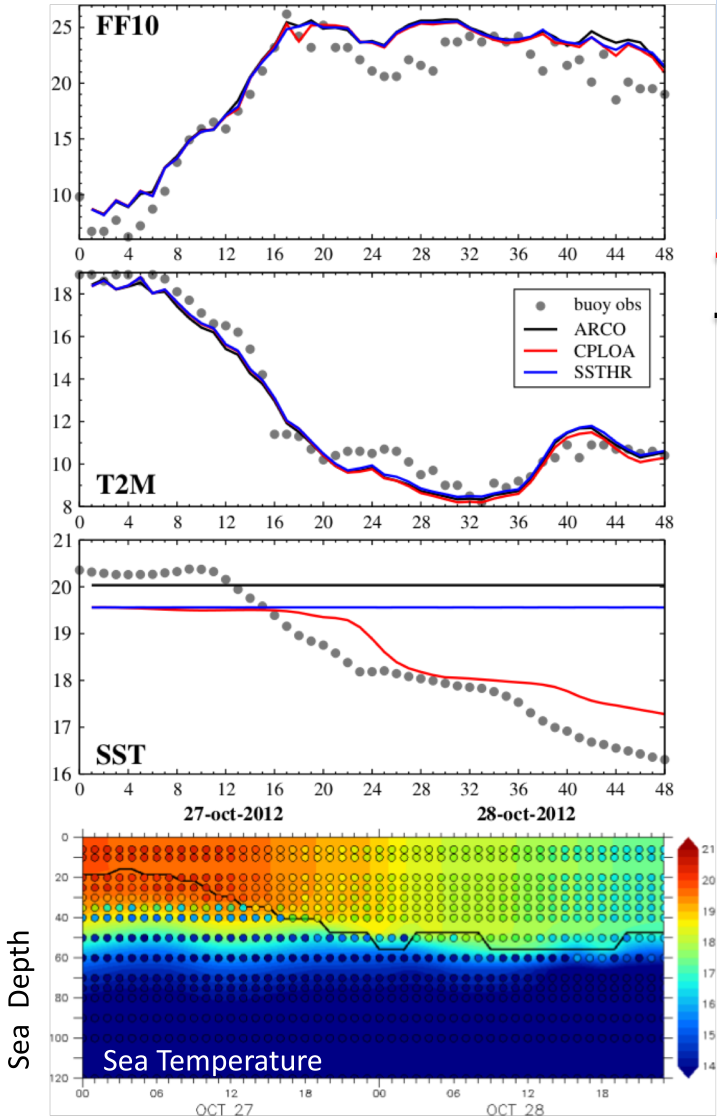
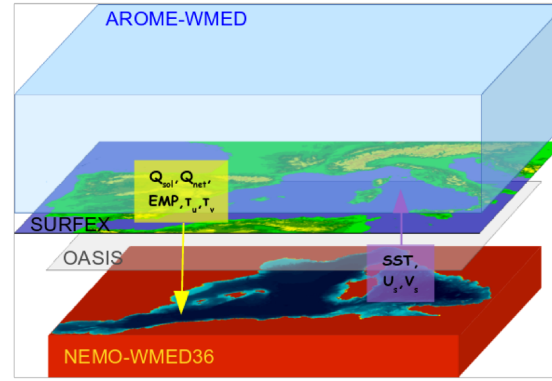
Multi-component evaluation of coupled ocean-atmosphere models

HyMex SOP1 IOP16b (strong mistral)

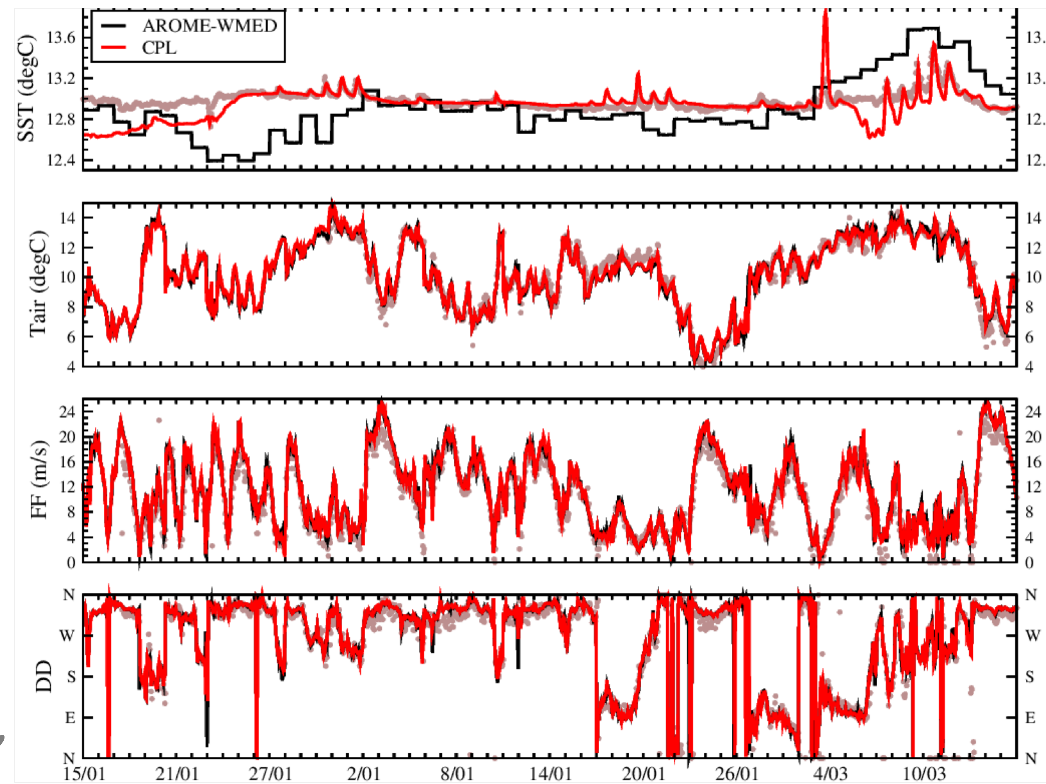


Comparisons of coupled AROME-NEMO WMED forecasts and AROME-WMED uncoupled forecasts to the Gulf of LION buoy air/sea boundary layer observations



- AROME-NEMO (red line)
- AROME only (black line)
- Obs (grey dots)

HyMeX SOP2 (2-month)

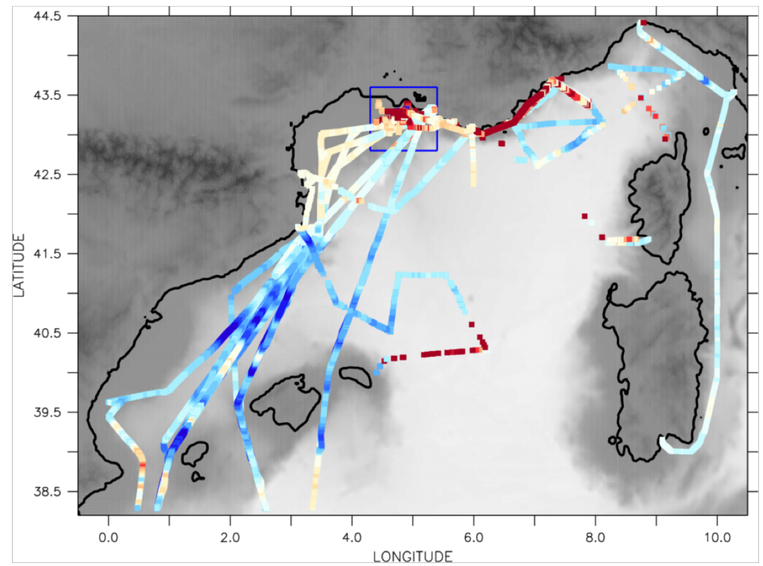


Lebeaupin Brossier et al. 2017, Rainaud et al. 2017, Voldoire et al. 2017

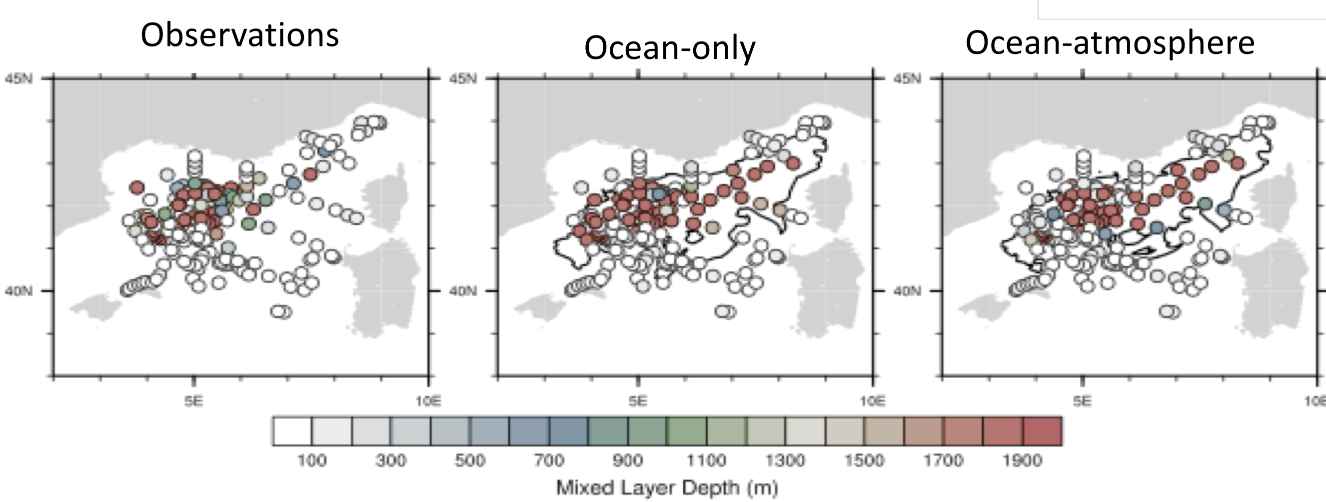
Dense in-situ data for validation of HR ocean-atmosphere models

HyMeX SOP1 &SOP2 provide a particularly dense in-situ data collection in the NW Med Sea area that permits to extensively validate high-resolution models in the marine/coastal zone

Sea Surface Salinity (SSS, psu) bias of NEMO-NWMED72 (1/72°)
against Thermosalinograph data aboard a ship of opportunity during HyMeX SOP1



Mixed Layer Depth from in-situ profiles during HyMeX SOP2 and colocalized simulated in NEMO-WMED36 ocean-only model and AROME-NEMO-WMED36 coupled model



Sauvage et al. 2018
Léger et al. 2016
Lebeaupin Brossier et al. 2017

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SOFOG3D SOuth west FOGs 3D experiment

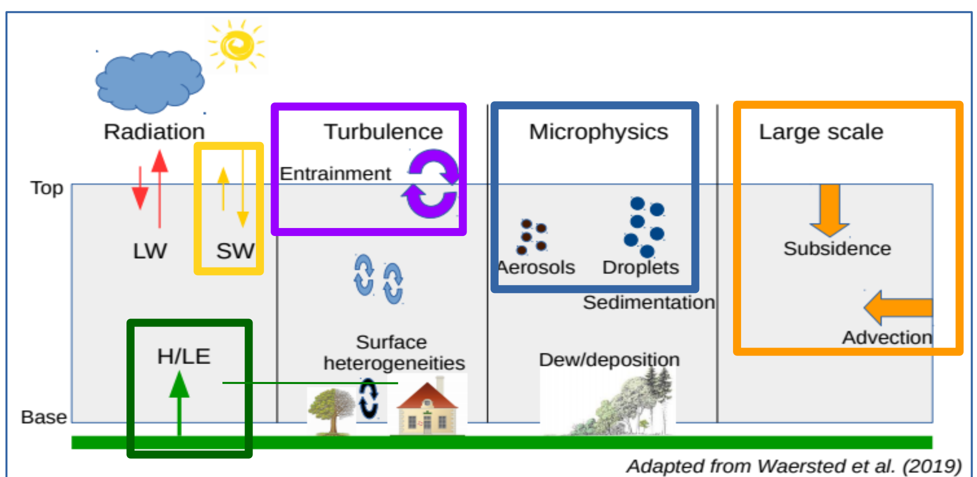
- To provide a **3D characterization of fog layer properties** with detailed observations of dynamics, radiation, microphysics and surface fluxes over heterogeneous vegetation and hilly terrain

- To study processes using **synergy between 3D high-resolution LES and unprecedented detailed observations**

- To better understand **contrasts** leading to radically different fate in fog life cycles:
  - **Shallow stable fog *vs* deep adiabatic fog**
  - **Stratus lowering into fog *vs* stratus persisting aloft**
  - **Daytime fog dissipation or lifting *vs* daytime fog persistence**

- **Data assimilation of new local observations:** MWR network and synergy with ground cloud radar 95 GHz

Processes of fog mainly investigated:

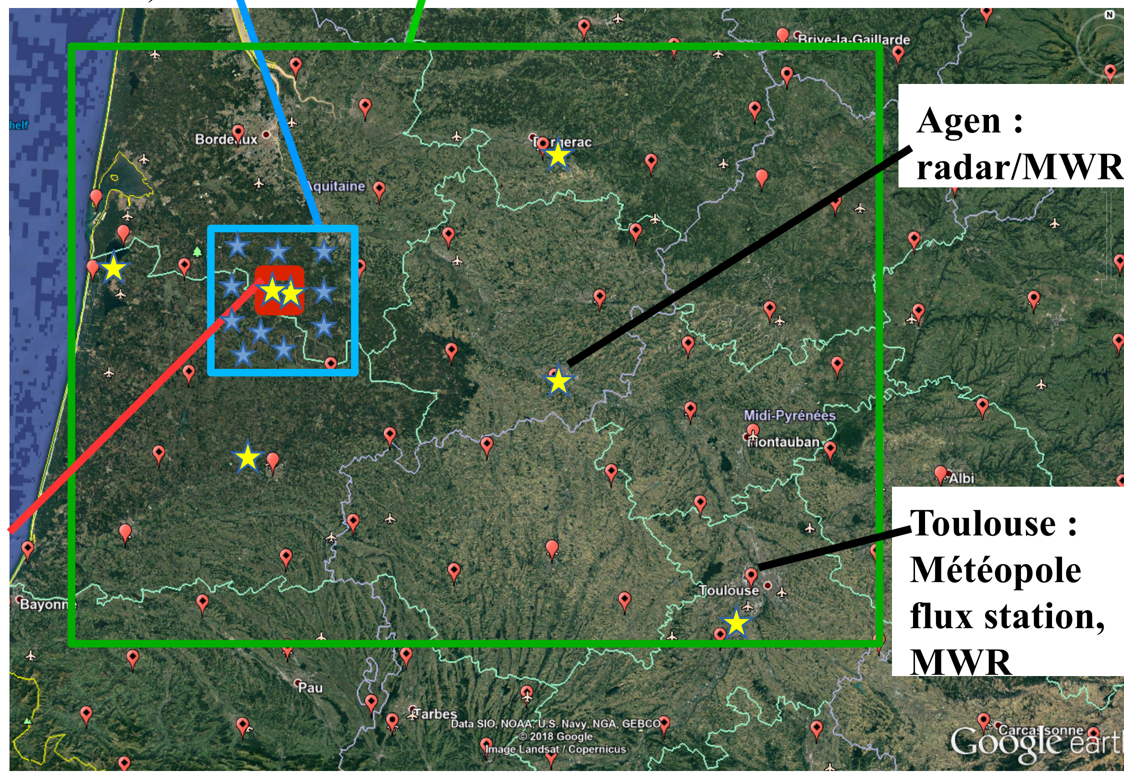


SOFOG3D Experimental strategy – winter 2019-2020

Surrounding domain 50 x 50 km with increased density in-situ sensors network (~ 15 surface met. stations, visibility, ceilometers, turbulence)

Larger domain 300 x 200 km (AROME-500m model) with in-situ sensors (~ 50 surface meteor. stations) and MWR (6) networks ☆

Super-site 10 x 10 km:
- **radar/MWR/lidars**
- **tethered balloon**
- **UAVs fleet**
- 10 meteor. stations
- **50 m mast (2)**
- 3 areas with **different vegetation types**: heat and turbulent fluxes, radiation budget, aerosol and fog microphysics, water deposition, visibility, ceilometers



International collaborations : PI : Frédéric Burnet – CNRM Toulouse

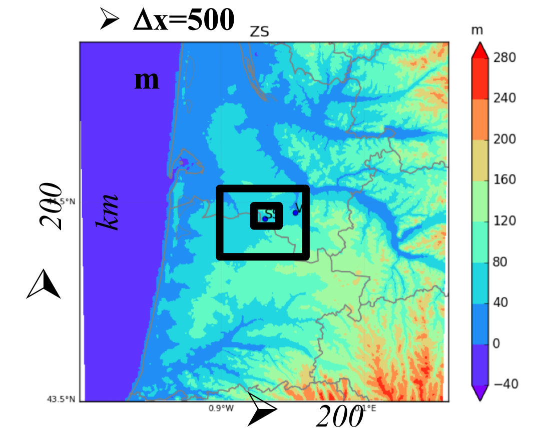
CNRM – IPSL – Met Office (J. Price) - Univ. Cologne - MeteoSwiss - CNR/IMAA

ANR – PROJET FINANCÉ PAR L'ANR – PROJECT FUNDED BY THE ANR

SOFOG3D Large Eddy Simulation strategy

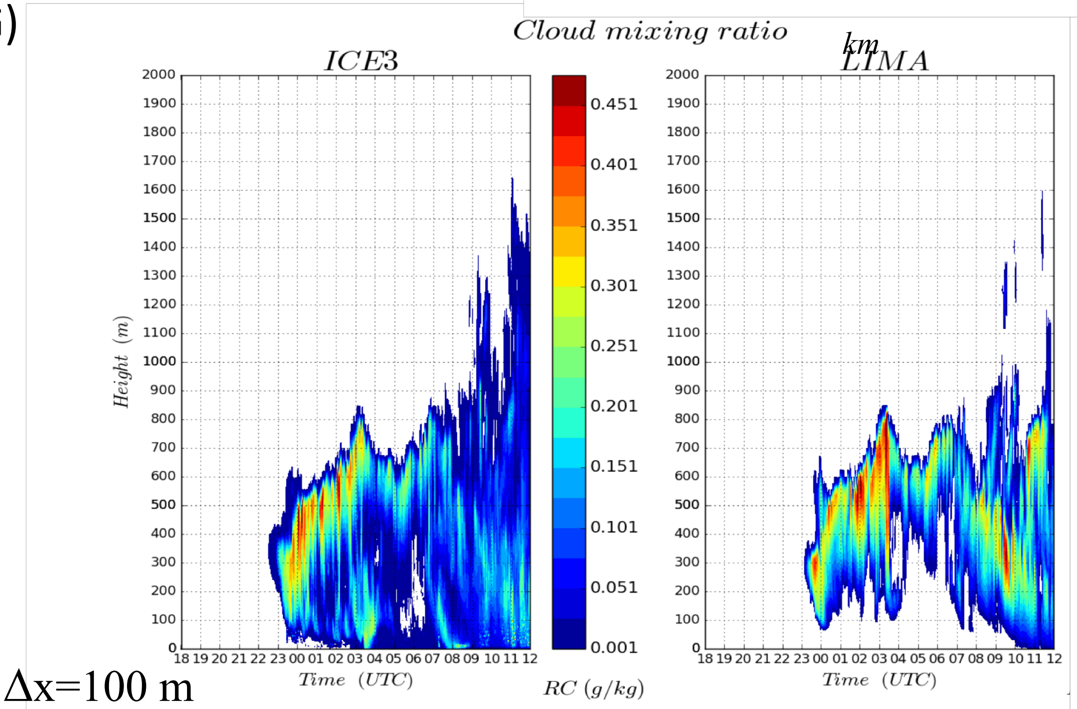
- Run of the most documented cases with **Meso-NH** model (Lac et al., 2018) from **AROME analyses** with **grid-nesting** downscaling up to Dx=**5 m** (Dz=1 m)

- Microphysics : **LIMA** 2-moment scheme (Vié et al., 2016)
Initialization of aerosols from OPC and SMPS microphysics measurements
- Radiation : **ecRad** (Hogan and Bozzo, 2016) with 14 SW bands
- **SURFEX** (Masson et al., 2013) ISBA-Diff vegetation scheme – HR surface data base (ECOCLIMAP-SG)



- A major issue of SOFOG3D is the **validation of LIMA for AROME**

Illustration of the impact of microphysics (1-moment ICE3 vs 2-moment LIMA) on a ***fog stratus lowering***



LIAISE: Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment

Objectives : to better understand and model the **human imprint on the semi-arid energy and water cycles** over a region which has significant anthropization.

Science questions:

1) What are the key natural and anthropogenic semi-arid surface processes that modulate or control infiltration and runoff and govern turbulent fluxes and their spatial heterogeneity?

2. How does the highly heterogeneous (natural and anthropized) surface impact boundary layer development, mesoscale circulations and potentially precipitation recycling over this region via feedbacks with the atmosphere?

3. What is the sustainability of ground water and reservoirs in the face of expanding agricultural and farming activities, especially in light of projected future warming and drying over this region?

HyMeX

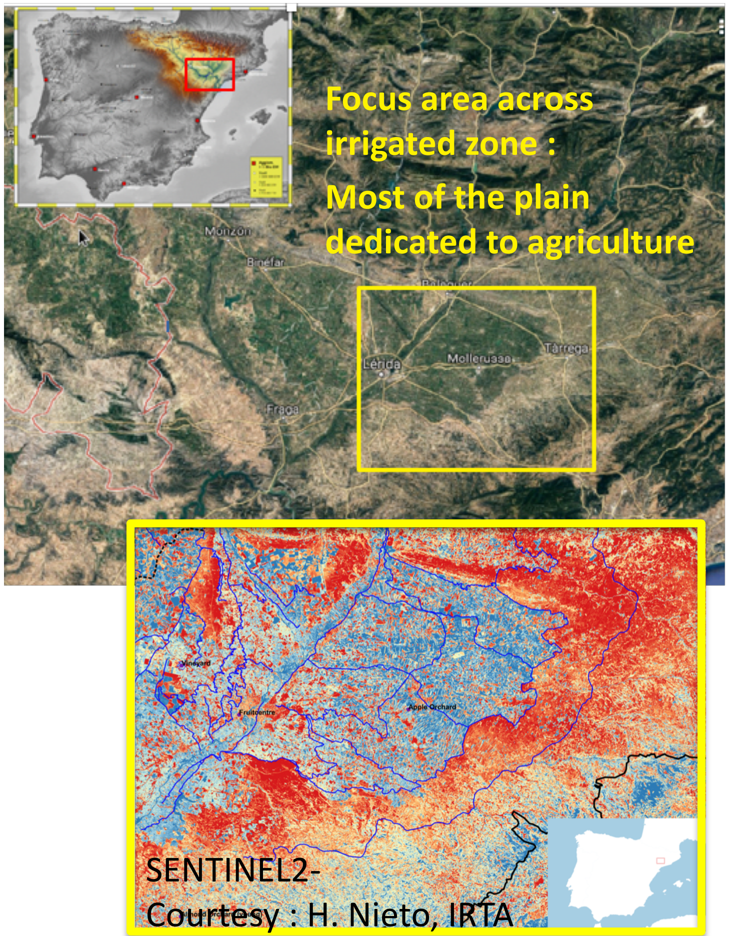
WCRP World Climate Research Programme

GEWEX

For more information: Boone et al, GEWEX Newsletter, 29(1), 2019

LMD · Observatori de l'Ebre · UIB Universitat de les Illes Balears · IRTA · Met Office · Institut Pierre Simon Laplace · CESBIO · LA · HSM · cnrs · CNRM · METEO FRANCE

LIAISE: Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment



Field experiment strategy:

EOP : April-October, 2020
surface flux stations, sfc satellite products (S2/S3), operational NWP (incl. AROME from Météo-France), lysemeters, river discharge...

SOP : mid-Juy 2020 – 15d

SAFIRE/ATR42 flights : along 30km transects of turbulent fluxes of heat, moisture, momentum.

Onboard instruments : GLORI (surface soil moisture), LST

Surface Energy Budget (SEB) sites (EOP)

Turbulent fluxes of heat, moisture, conduction, radiation, LST
Soil moisture and T at 4 (5) levels, Soil and vegetation properties, 2 lysemeters, 2 SEB sites with up-to 50m towers

Lower Atmosphere

2 Tethered balloons, 2 Radiosoundings sites, 2 Wind profilers (UHF), Lidars (Raman/dial doppler, microwave)

Final remarks

« Some lessons learned from my experience as coordinator of a measurement field campaign but with a background in atmospheric modelling researches »

- Field campaign observations can be used **a long time after the data collection** (e.g., 15-y after CAPITOUL), sometimes for uses that were not foreseen in the design of the field campaign, and can gained **in added value by combining with other field campaign data** (e.g. HyMeX, HAIC, T-NAWDEX microphysics data).

- The **expertise of instrumentalists is crucial** to make good use of observations and to exploit their full potential for model improvement and evaluation. In particular, **observation and model experts should work together** to exploit observations that are not straightforward model variables and to develop forward observation operators.

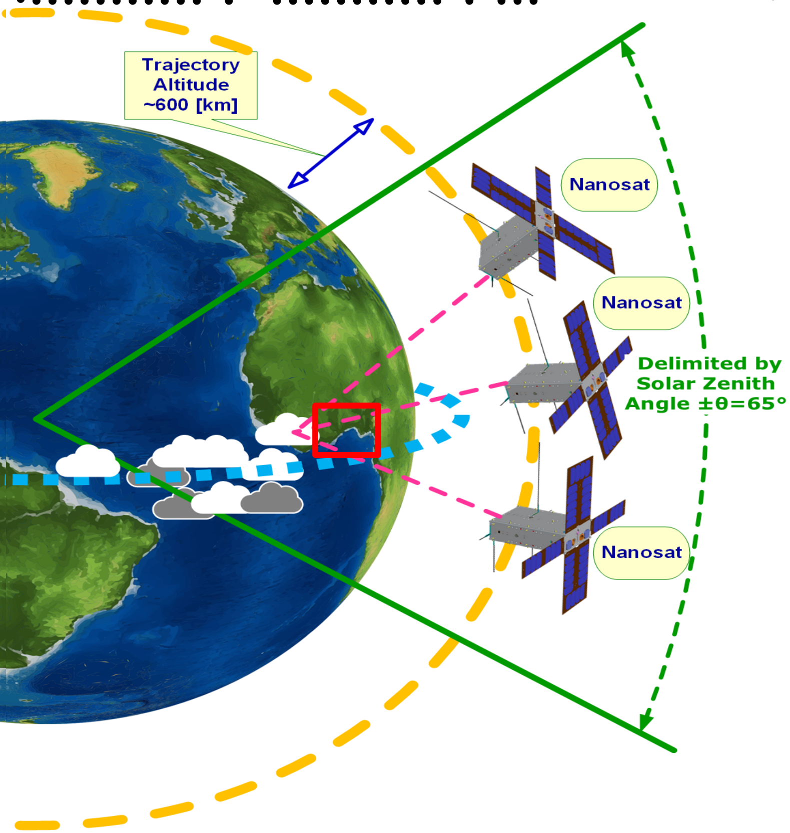
- From HyMeX: short-range km-scale forecast errors in Med Heavy precipitation events are more sensitive to initial conditions than to refinements in physical parameterizations. **Observations of winds and humidity at mesoscale over the Mediterranean sea in the lowest km are missing** and data assimilation systems should still progress **in better making use of observations within cloudy regions**.

- From the point of view of model development at km and hm resolutions: there is still a lack of capabilities of measuring **vertical velocity in convective updrafts** and also of **turbulence observations in convective clouds**.

Thanks for your attention

Fine-scale observations for cloud dynamics

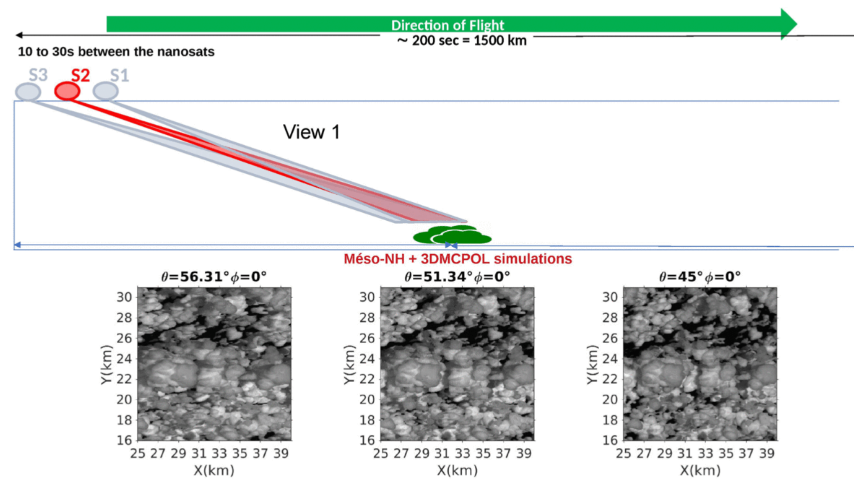
2 to 3 simultaneous observations of the same field of 80 km x 80 km every 20 s during 200 s



Validation of vertical velocity in clouds for NWP models

- Need for fine-scale observations inside convective clouds

  - Doppler radar
  - Mission C³IEL (PI: D. Rosenfeld, C. Cornet)
    - *(University of Jerusalem – LOA)*
    - 2 to 3 nano-satellites with high-resolution (20 m) visible imagers: 3D cloud top evolution (development velocity, divergence, mixing)
    - Synergy with LES (mission preparation with synthetic data, improvement of parameterization)



In-cloud turbulence

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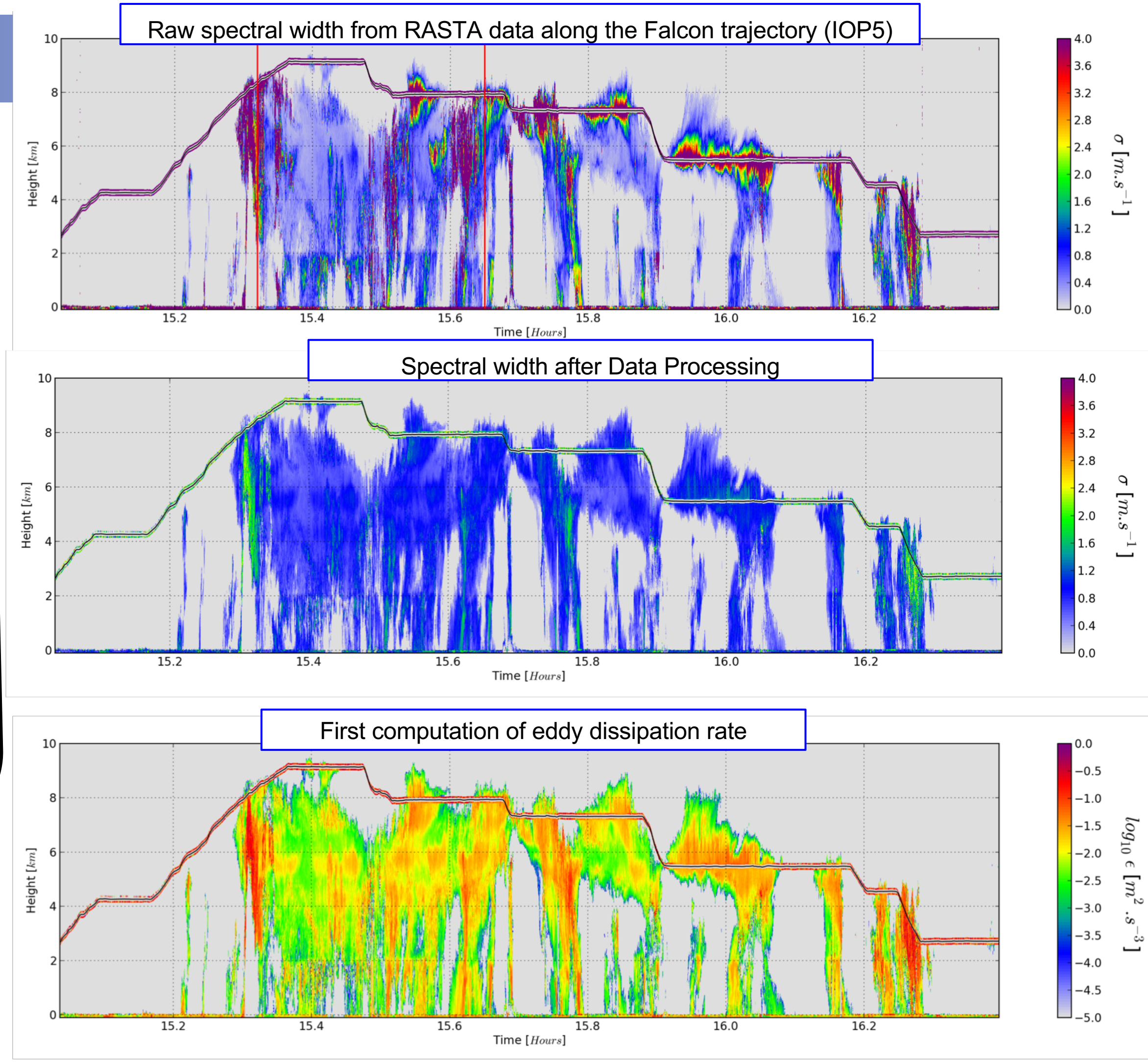
Validation of the turbulence schemes used in CRMs

- Need for fine-scale observations of turbulence inside convective clouds

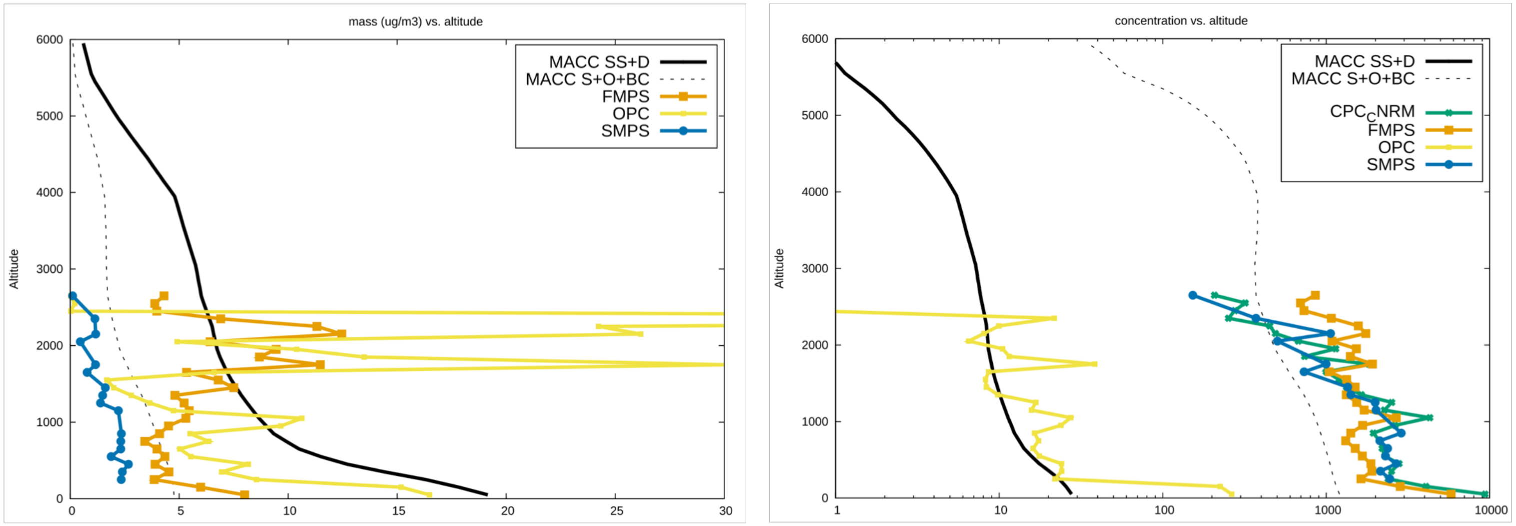
→ EDR estimates from RASTA data for IOP5 (EXAEDRE field campaign)
10 October 2018: convection over the Gulf of Genoa
Comparison with CRMs

R. Houël, D. Ricard, J. Delanoë
(CNRM - LATMOS)



Realistic aerosol population for LIMA

- CAMS analyses provide mass mixing ratios for 5 aerosol species
- Mass to number conversion calibrated using the ATR42 observations
- Good match for both big aerosols (sea-salt and dust from CAMS compared to the OPC) and small aerosols (sulfates, organics, black carbon from CAMS)



Average vertical profiles of aerosol mass mixing ratio (left, µg.m^{-3}) and number concentration (right, m^{-3}), ATR flight 58.
Black lines : CAMS average vertical profiles of aerosol mass mixing ratio, and inferred number concentration.
Colored lines : Observed average vertical profiles of aerosol number concentration, and inferred mass mixing ratio.