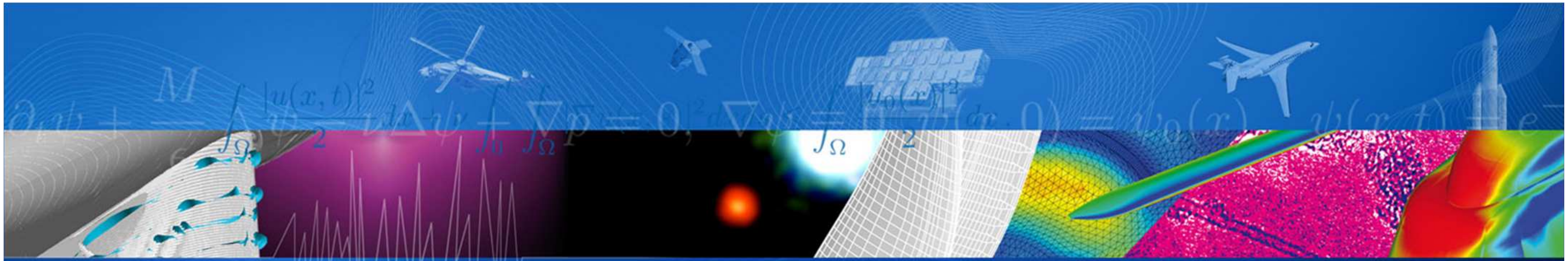


70 ans 2016

ONERA

THE FRENCH AEROSPACE LAB

MODELING AIRPORT AIR QUALITY AT HIGH RESOLUTION

C. Sarrat, S. Aubry, T. Chaboud

ONERA
THE FRENCH AEROSPACE LAB

retour sur innovation

Plan

I. Methodology

II. Models Presentation

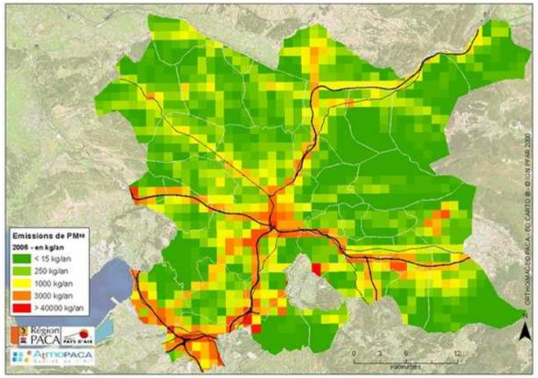
III. First Results

IV. Conclusion and Perspectives

Objective

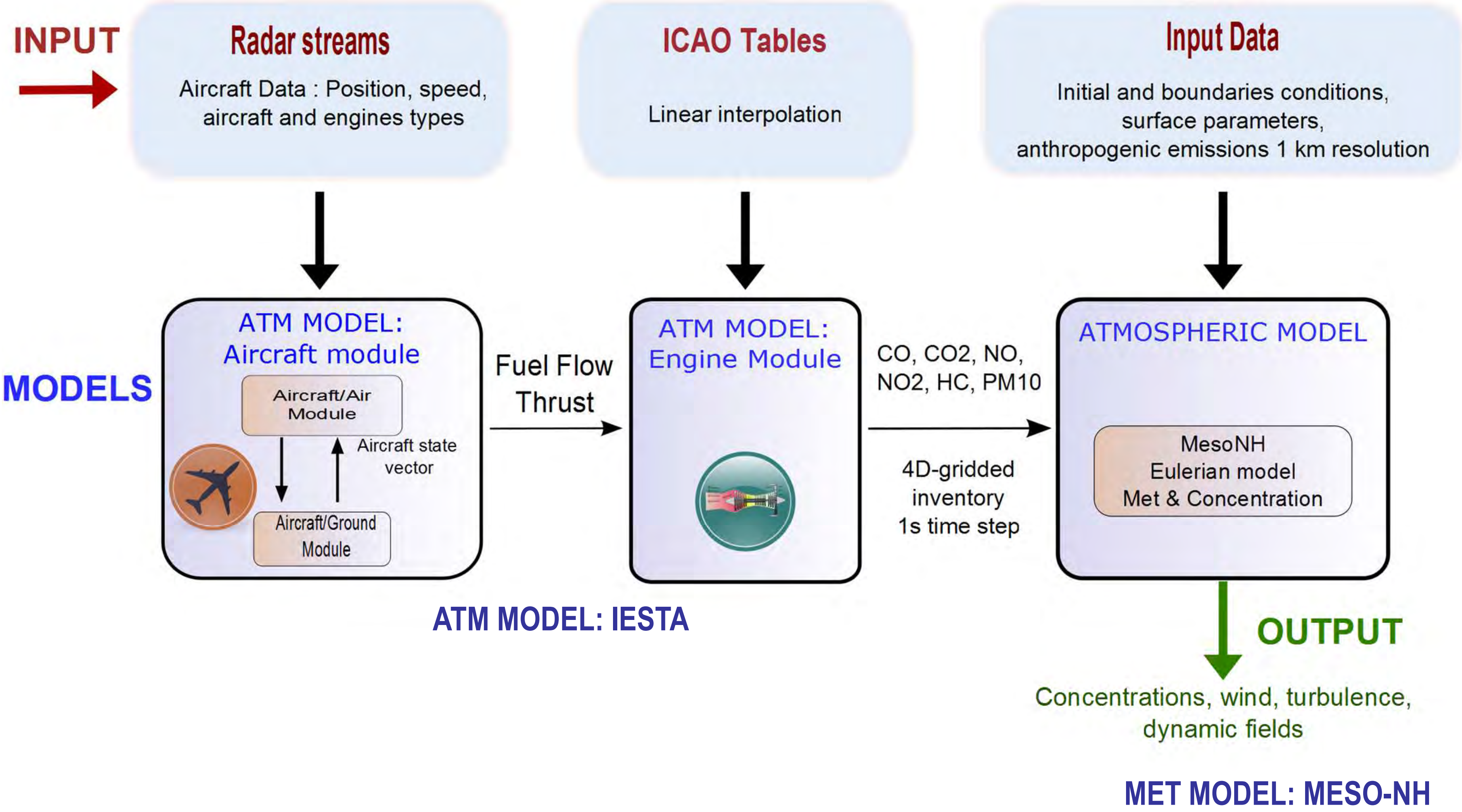
⇒ Airport Air Quality Modeling at **high spatio-temporal resolution** :

- 10 m resolution, 1s time step
- Create an emissions database containing aircraft + road traffic data



- Modeling the local airport meteorology: accurate vertical and horizontal winds, turbulent fluxes, the surface-atmosphere interaction (buildings)

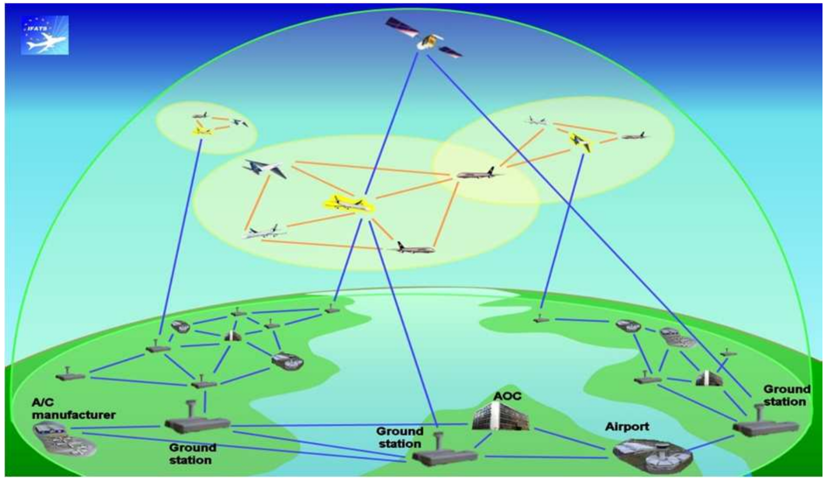
Coupling ATM and meteorological models



ATM Model : IESTA

System scale:

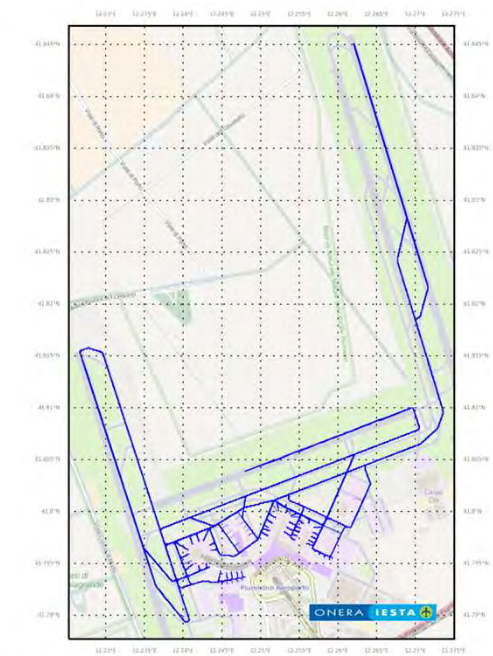
ATM concepts



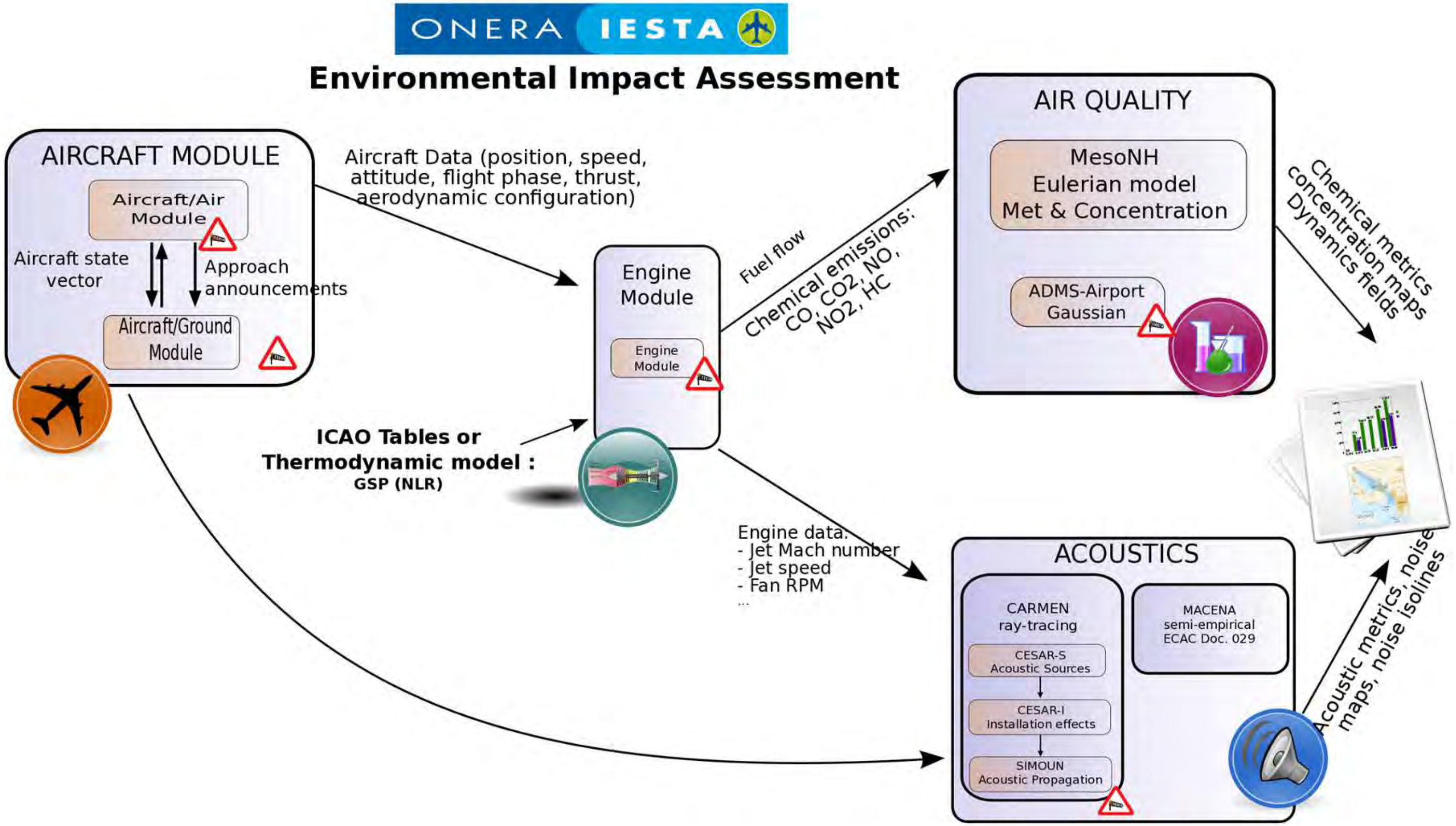
Airport scale:

- Environmental impact,
- air quality,
- noise,
- new procedures assessment
- new technologies assessment

CleanSky_LIRF_2020_CS_ground_tracks

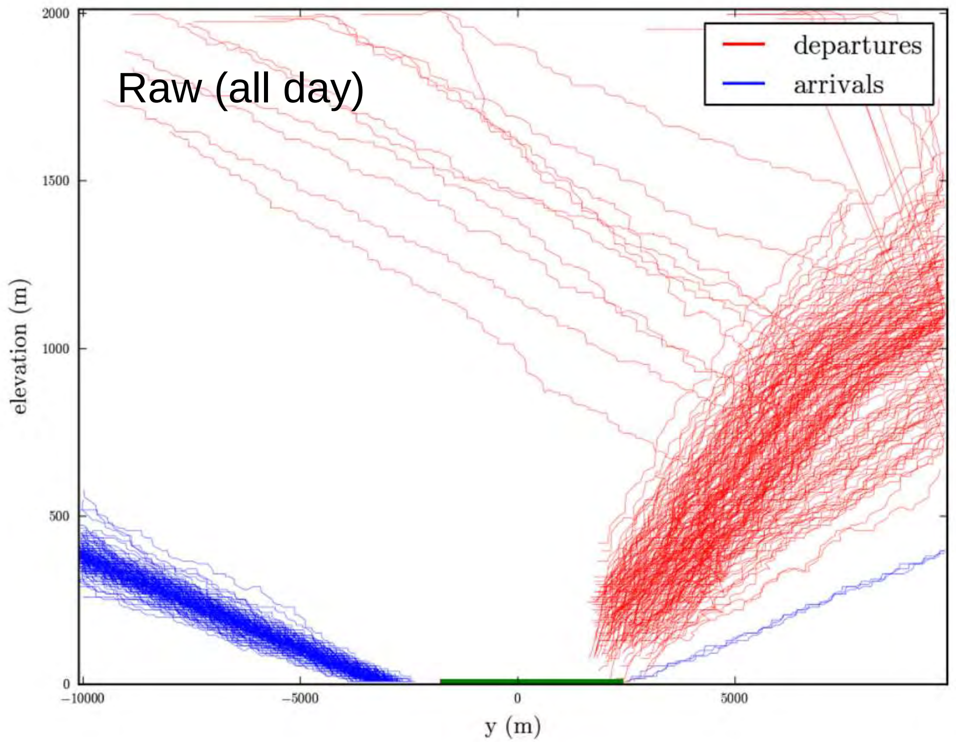


ATM Model : IESTA



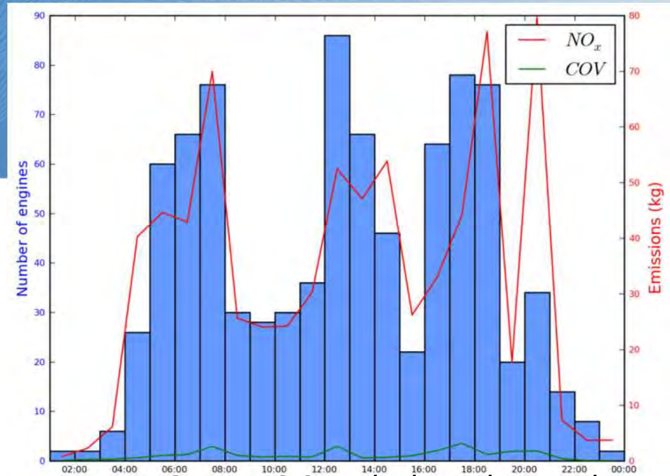
ATM Model : Traffic data pre-treatment

- Case study: One real day with observations at the TWR is simulated over a regional airport, with local data and observations
- Air traffic and taxiing data: Trajectories from radar stream, aircraft mass, engines



Vertical Profiles of aircraft trajectories (raw data)

ATM Model: IESTA Emissions



NOx et VOC emissions time series

Aircraft engines emissions

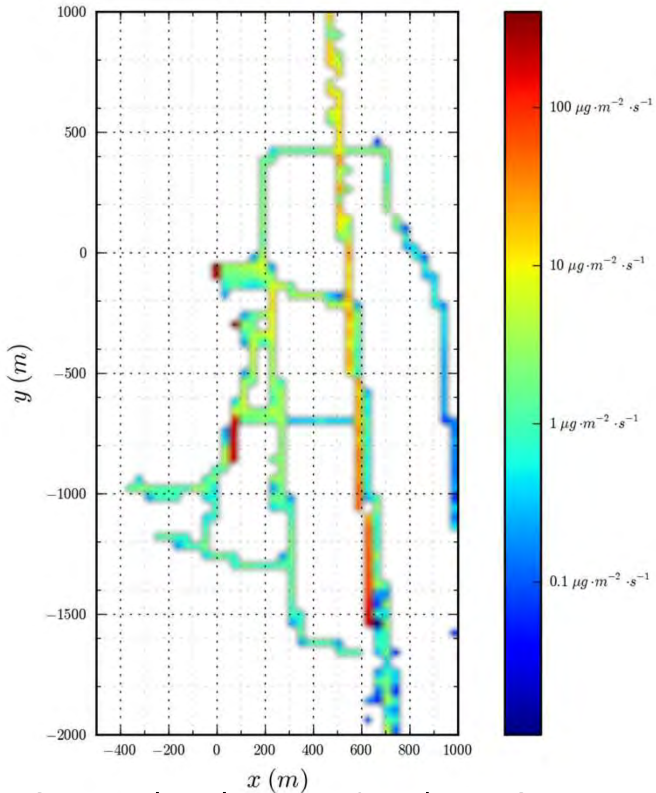
399 A/C trajectories
Type, positions, thrust

↓

IESTA
Engine module → 3 Rejected

↓

824 engine trajectories
NOx, CO, CO2, SO2, S.N.



NOx emssions between 6 and 7 UTC

APU emissions

ICAO/CAEP Airport Air Quality Manual:

- Short-haul aircraft LTO = APU on for 45min
- 700g NOx, 30g UHCs, 310g CO, 25g PM10

Atmospheric Model: Meso-NH physics

Meso-NH
mesoscale non-hydrostatic model

- Meso-NH: non-hydrostatic meteorological research model
- Scales from Δx=50km to 1 meter
- Time scale = a few days to 1 second or less
- Prognostic variables : wind (u,v,w), potential temperature, TKE, mixing ration, reactive or passive tracers

PHYSICS

- **Turbulence**
- **Convection**
- **Surface interactions**: energy and emissions fluxes
- **Chemistry** on-line scheme
- **Microphysical scheme**
- **Radiation**: ECMWF package
- **Drag force** applied to buildings

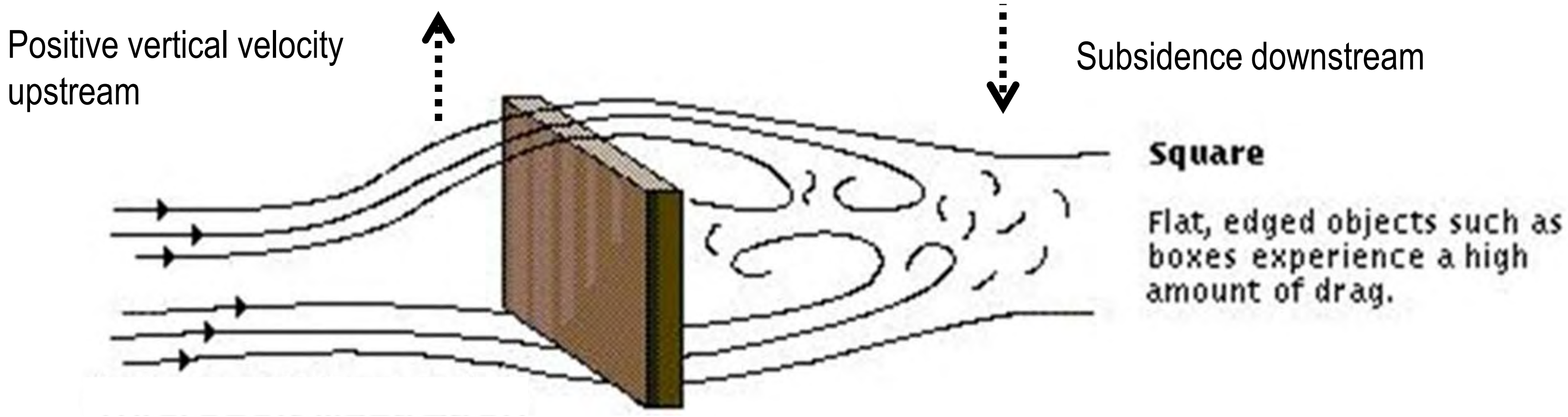
Atmospheric Model: Drag force with buildings or trees

Force opposed to the wind direction : additional term in the momentum and TKE equations:

- $\frac{\partial U}{\partial t}|_{drag} = -C_d A_u \sqrt{U^2 + V^2}$

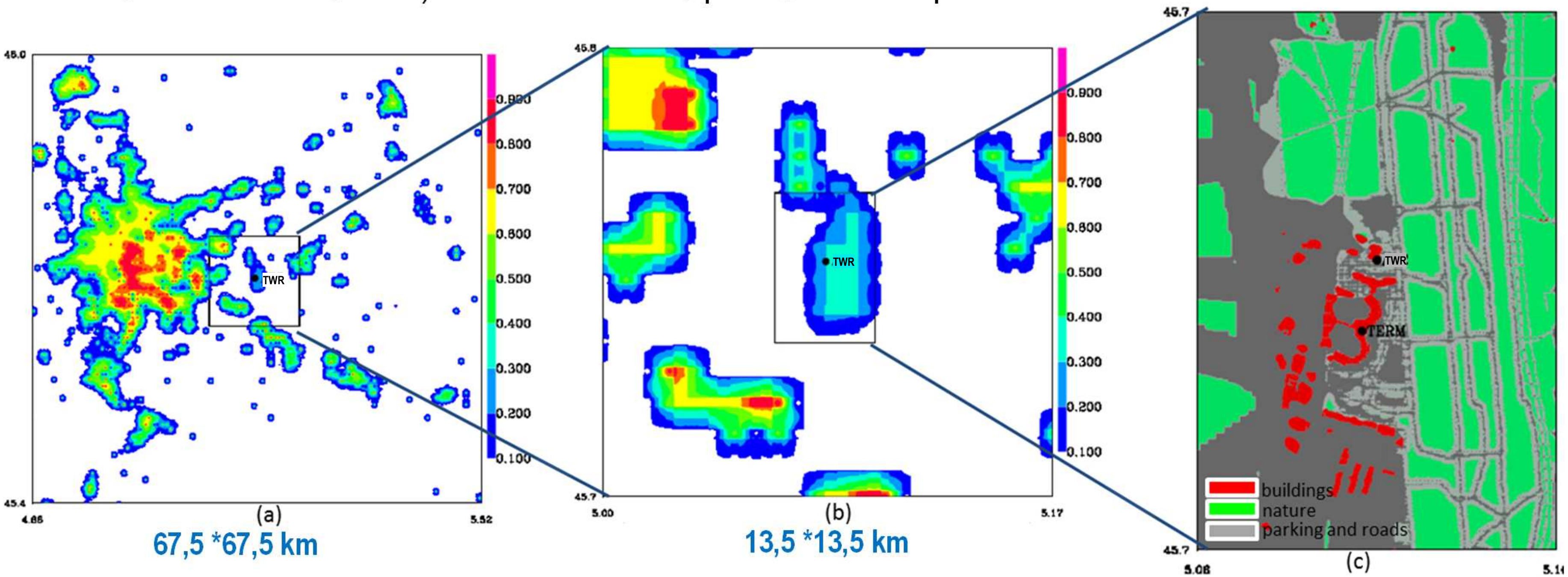
where C_d = drag coefficient and A = Canopy area density, building C_dA = 1000 inside buildings

- $\frac{\partial e}{\partial t}|_{drag} = -C_d A_e \sqrt{U^2 + V^2}$ => Increased turbulence



Atmospheric Model set-up

- Initialization and lateral boundary conditions given by 2 km resolution AROME model (the French NWP)
- 3 domains in grid-nesting two ways
- Surface cover and parameters (albedo, roughness) given by Ecoclimap (derived from Corine Land Cover) database and Open Street Map data



67,5 *67,5 km

13,5 *13,5 km

4,5 *3 km

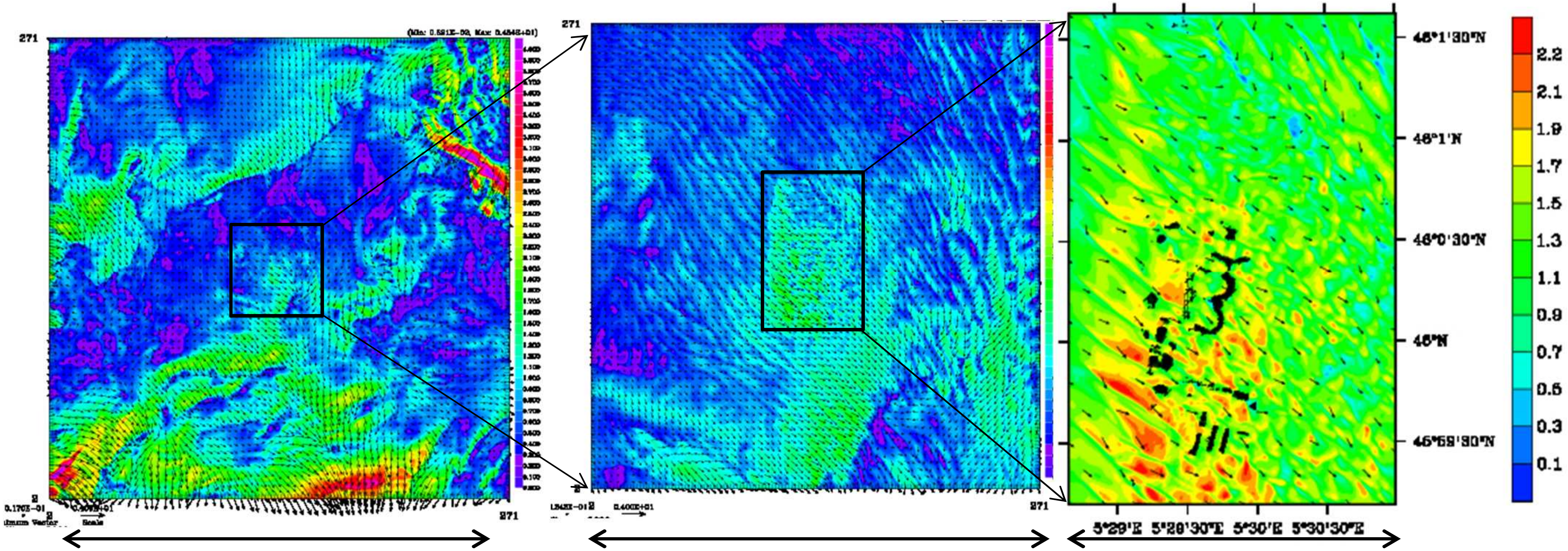
250 m resolution
270*270 cells

50 m resolution
270 * 270 cells

10 m resolution
300*450 cells

Atmospheric Model Results

Wind module and direction -3600s-

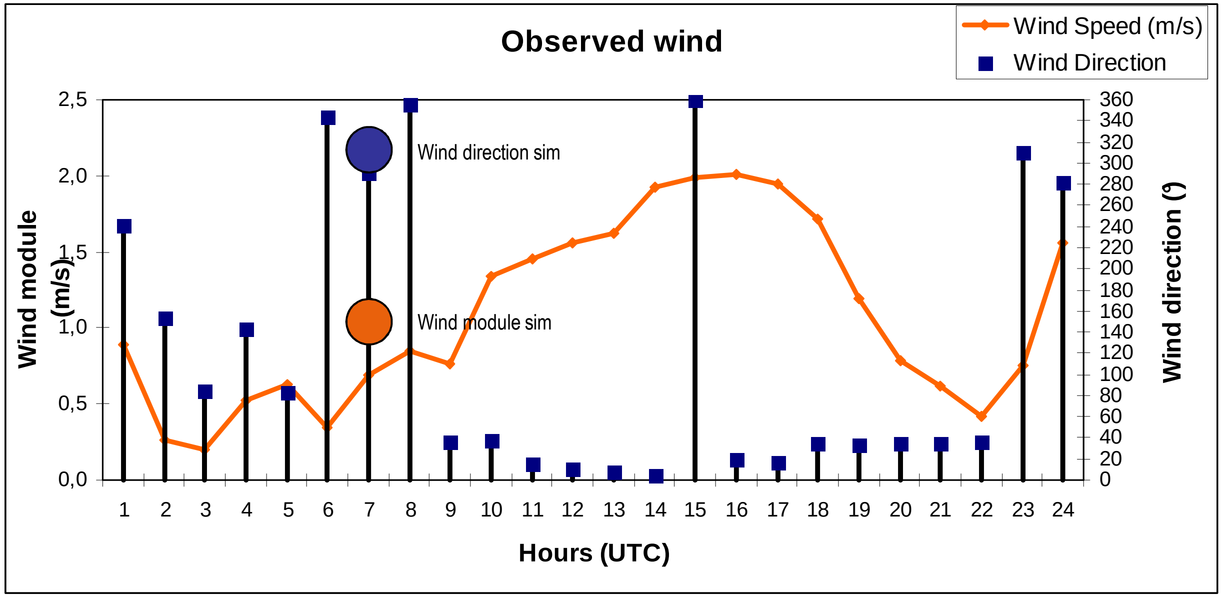


67,5 *67,5 km	13,5 *13,5 km	4,5 *3 km
250 m resolution	**50 m resolution**	**10 m resolution**
270*270 cells	270 * 270 cells	300*450 cells

Observations near the TWR

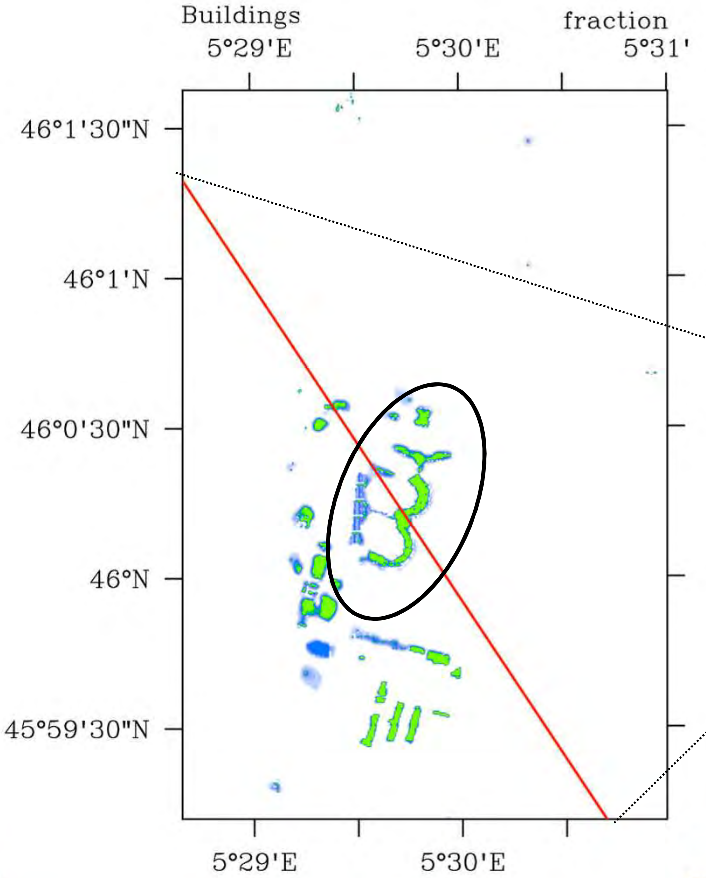
Meteorological characteristics of the day of interest:

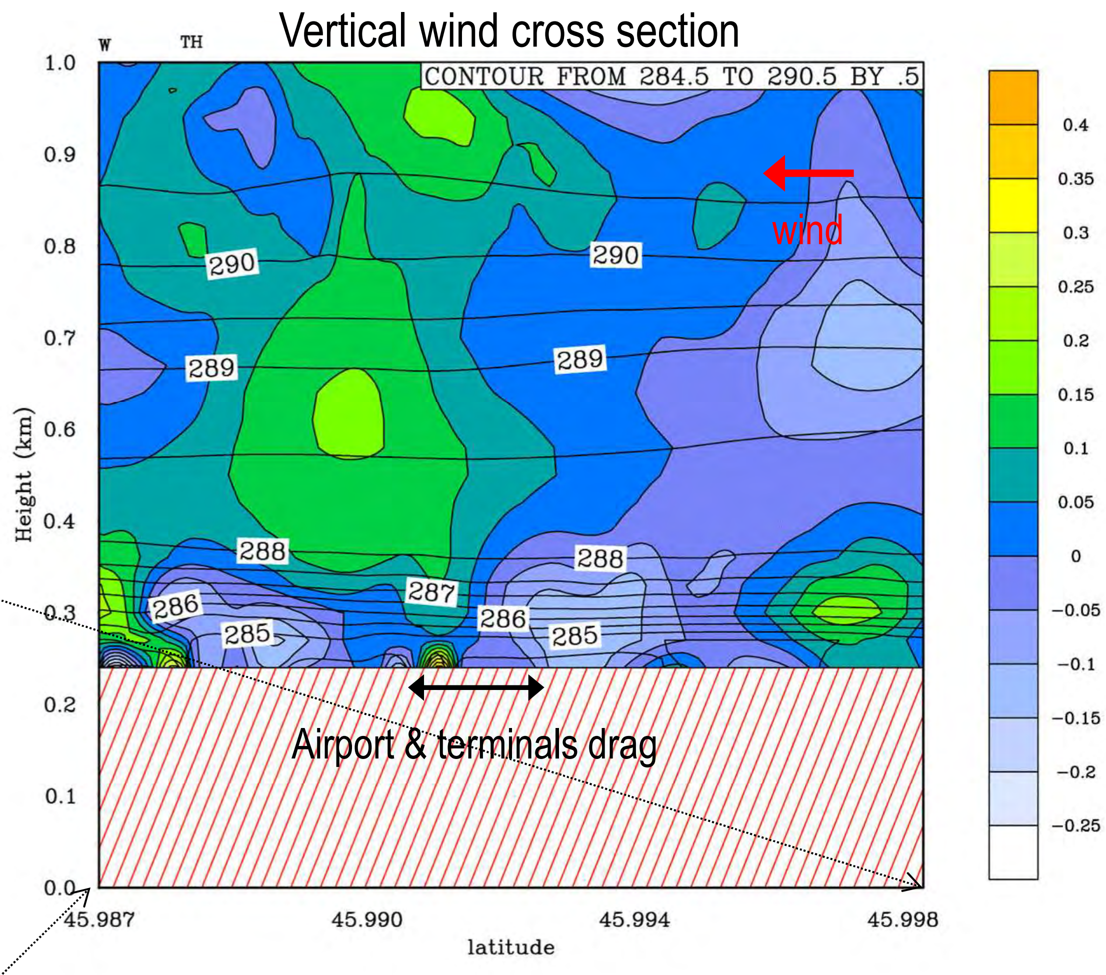
- High temperature
- Clear sky
- Light winds (<2m/s) from North-North-East



Atmospheric Model Results

Vertical velocity due to building drag force

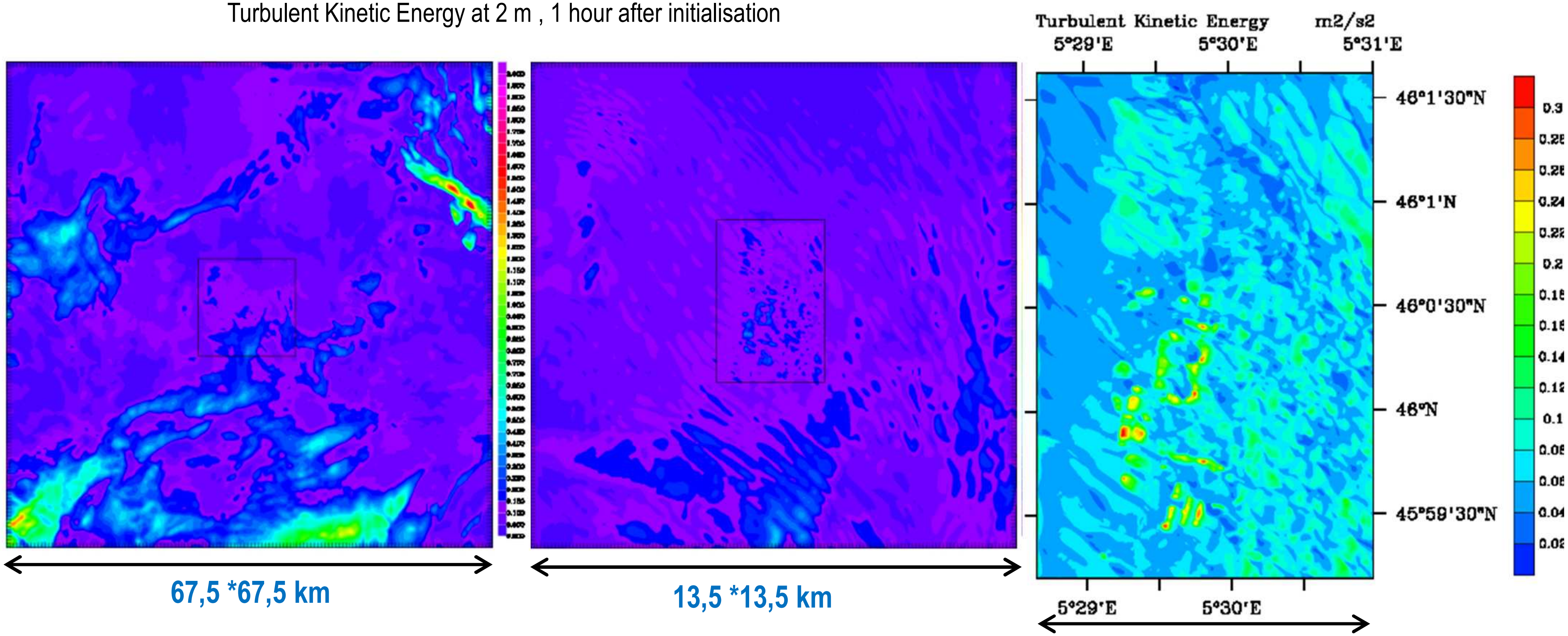




Atmospheric Model Results

Increase of TKE due to buildings near the terminals => dispersion of pollutants increased

Turbulent Kinetic Energy at 2 m , 1 hour after initialisation



250 m resolution

50 m resolution

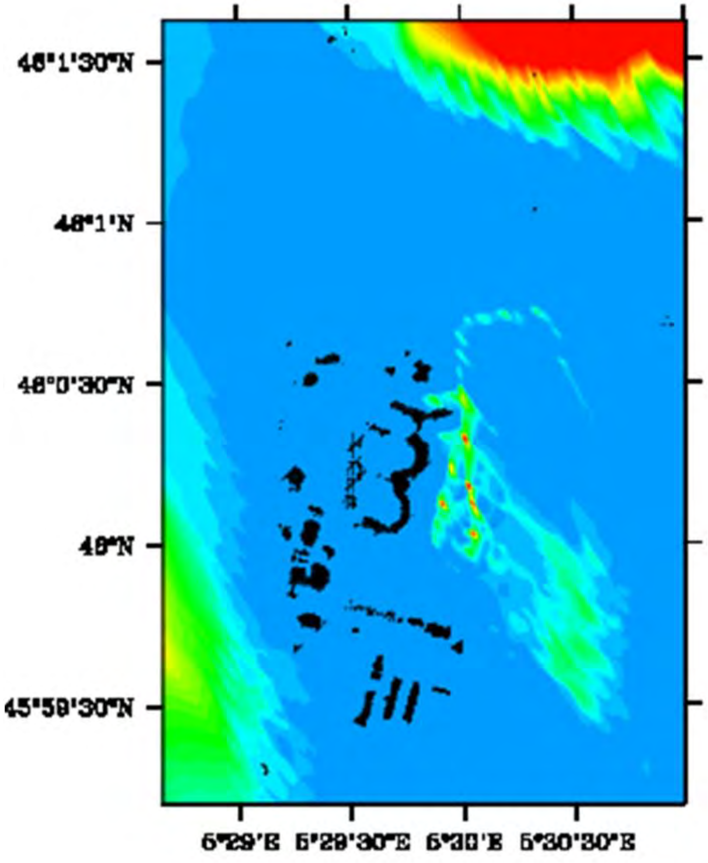
10 m resolution

ONERA
THE FRENCH AEROSPACE LAB

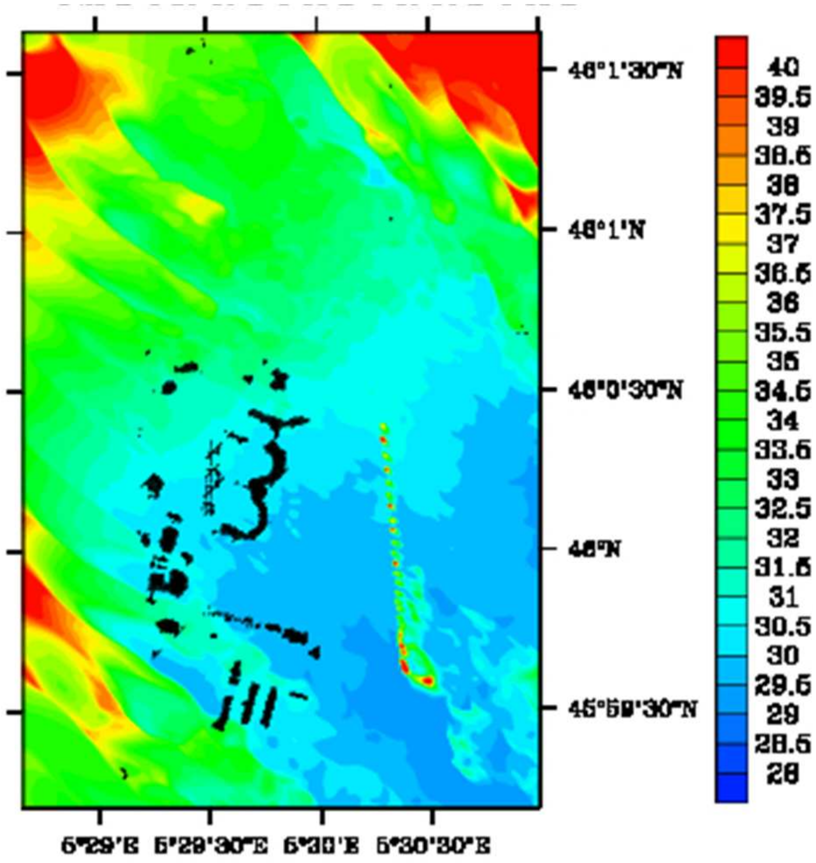
Atmospheric Model Results

Passive scalar for NOx only

Larger scale contribution due to northern winds



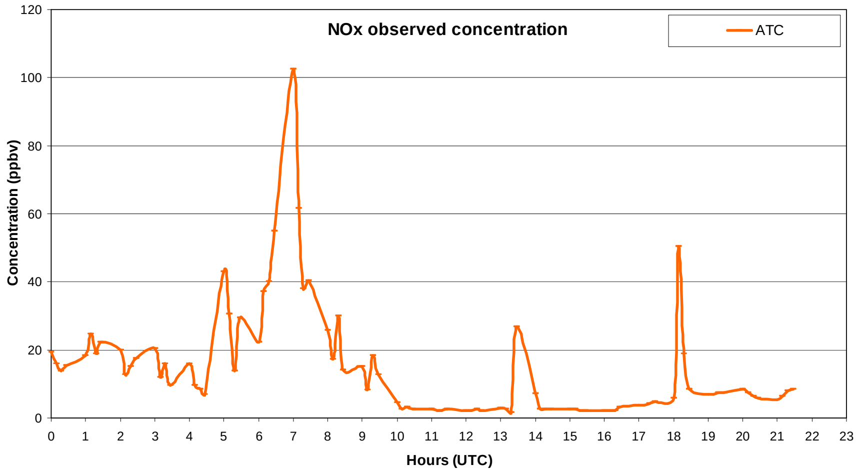
NOx concentration – 1200 s-

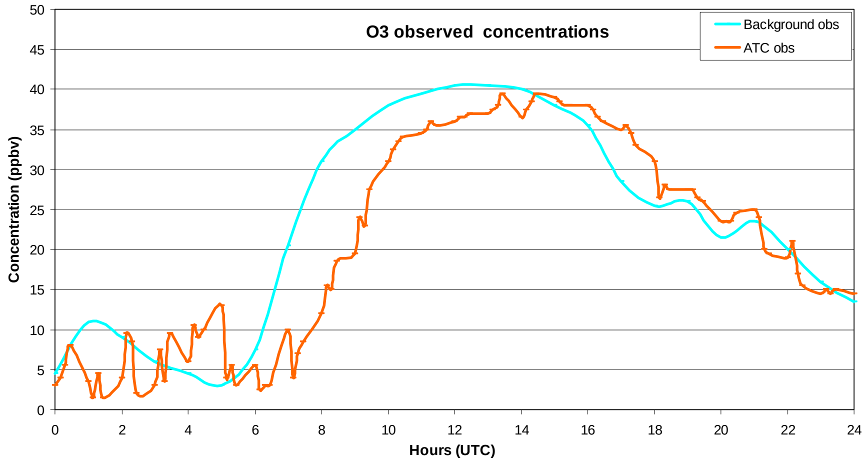


NOx concentration – 3600 s-

Observed NOx at TWR

Highest NOx concentration at 7H UTC > 100 ppbv





Atmospheric Model Results: Computing details

- **High Performance Computer** Occigen (French National Computing Centre for Higher Education): 50,000 cores, 2.1Petaflops
- **Time step for the model very low** due to vertical high resolution : 1s, 1/4s and 1/8 s for the three domains respectively
- 240*240*120 points for the both larger domains, 450*350*120 points for the small scale domain
- **1 hour run = 600 cores, for a total of 38,000 CPU hours**

Conclusion and perspectives

The IESTA-Meso-NH coupling proved able to simulate :

- Air traffic emissions
- Pollutants dispersion
- High spatio-temporal resolution: 10 m & one second
- Using state-of-art physics model

Way Forward:

- Reactive chemistry
- Longer simulation
- Comparisons with observations