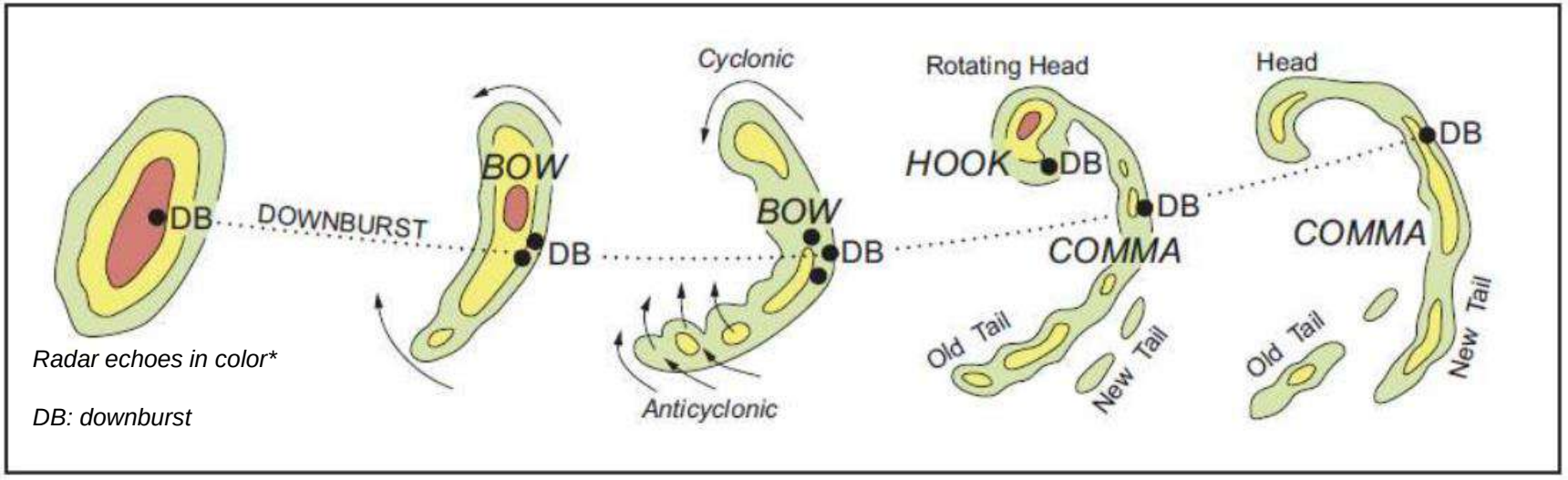
Sensitivity study to physical parameterisations and resolution of the Mediterranean derecho of 18 August 2022

Didier Ricard, Clément Strauss, Marc Mandement, Christine Lac, Benoît Vié, Clotilde Augros

CNRM (Météo-France/CNRS), Toulouse, France

Introduction: derecho definition

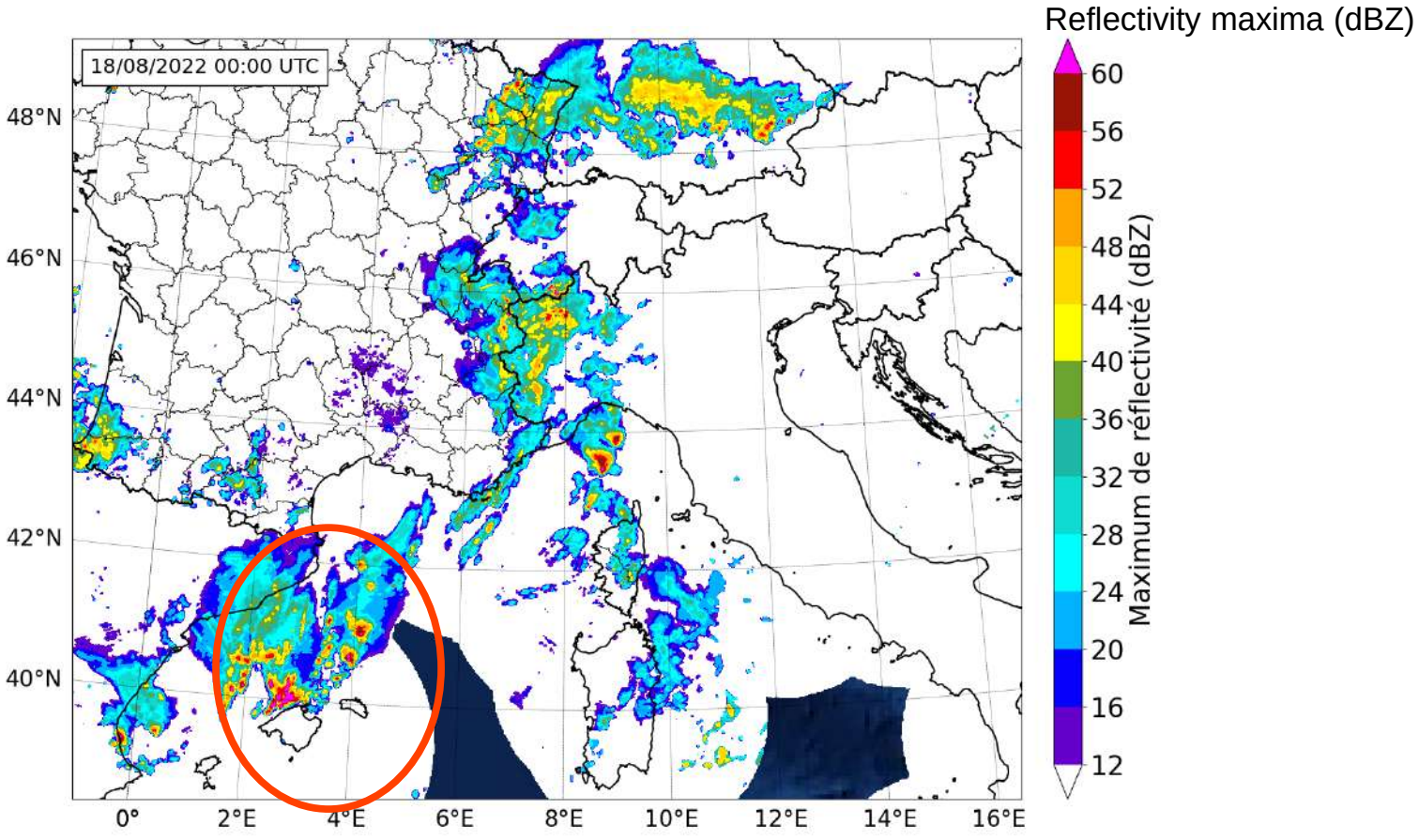
Markowski et Richardson (2013), from Fujita (1978)



bow echo: *zone of downbursts in front of the maximum curvature of the line (DB).*
A second zone at the northern end (in the northern hemisphere) of the storm system when the curved line takes on a comma shape.

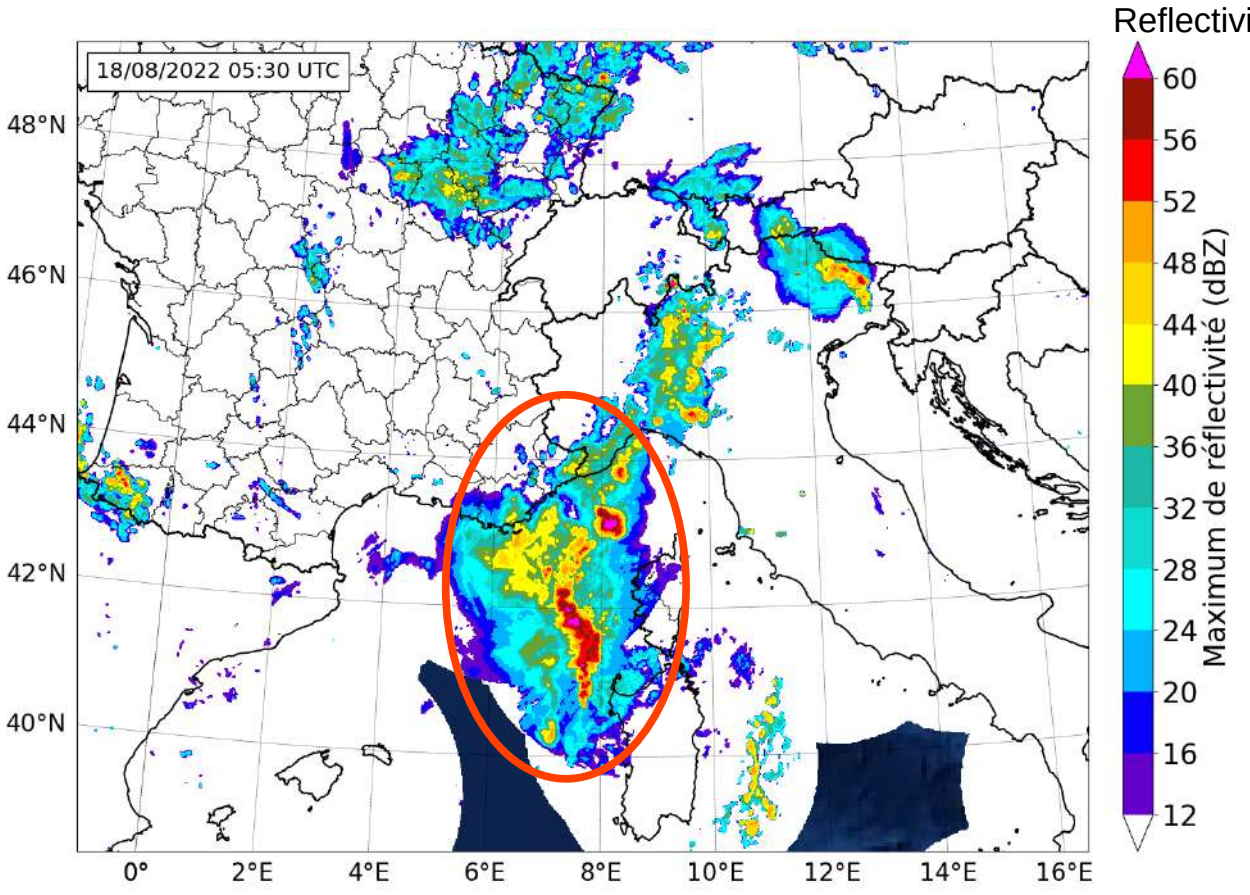
derecho: *convective system producing violent winds over a long distance with the following properties (Johns and Hirt 1987) :*
- at least three gusts greater than 33 m s^{-1} or corresponding F1 damage, separated by 64 km or more
- bands of gusts greater than 26 m s^{-1} or an area of corresponding damage more than 400 km long and more than 100 km wide

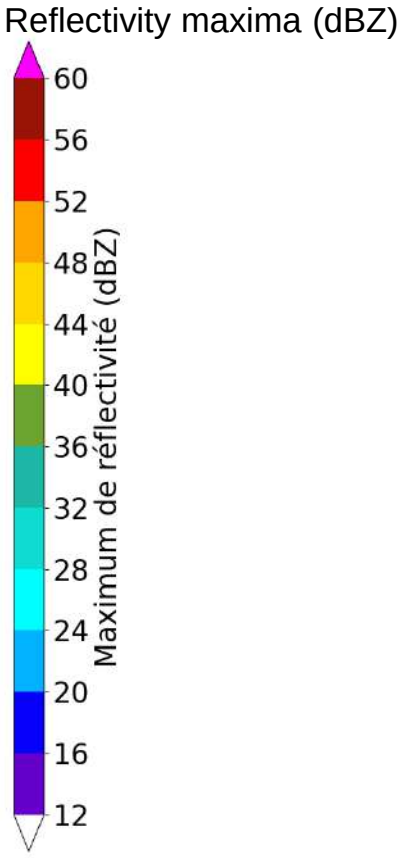
Introduction: overview of the derecho



Chronology: convective activity near the Balearic Islands during the night

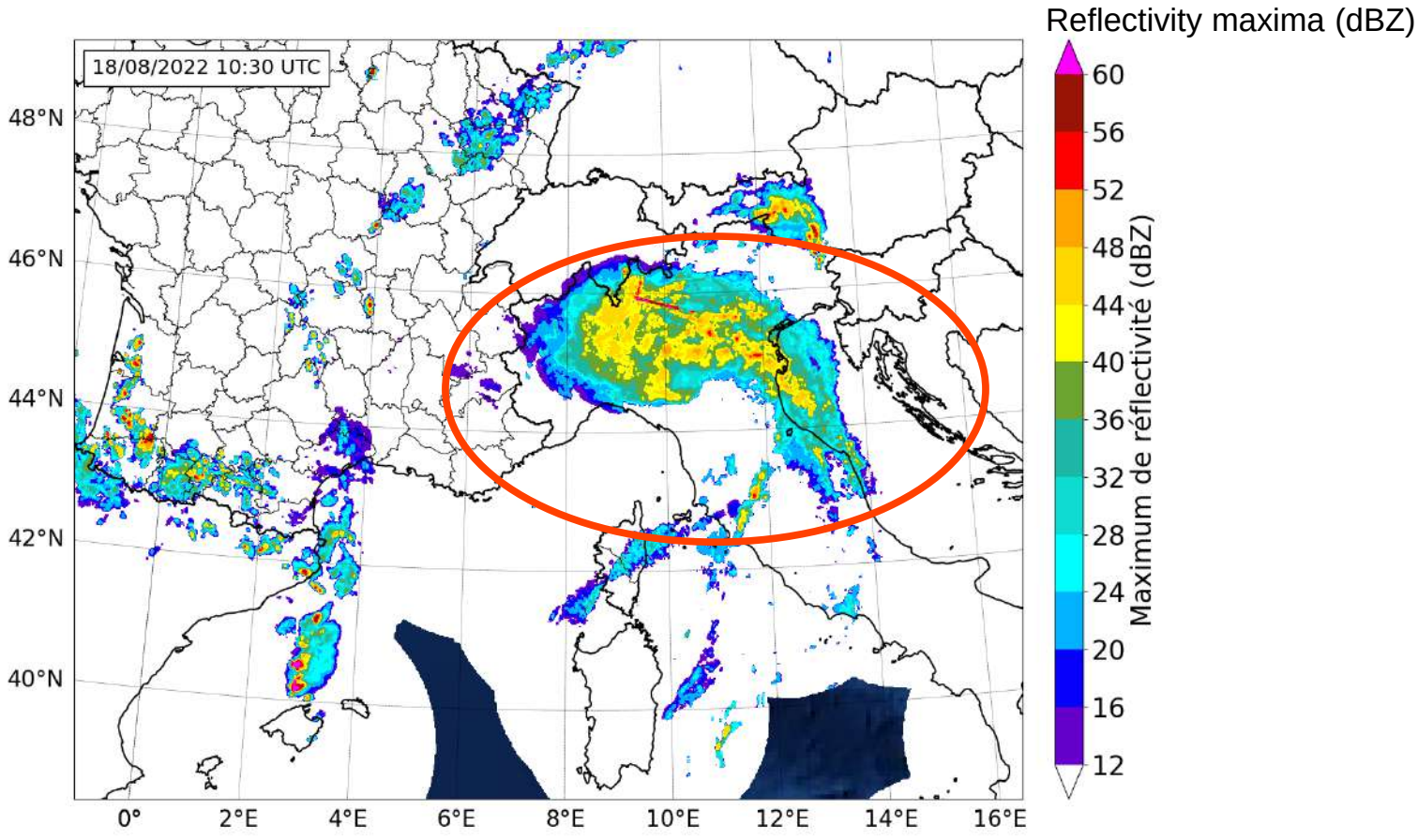
Introduction: overview of the derecho





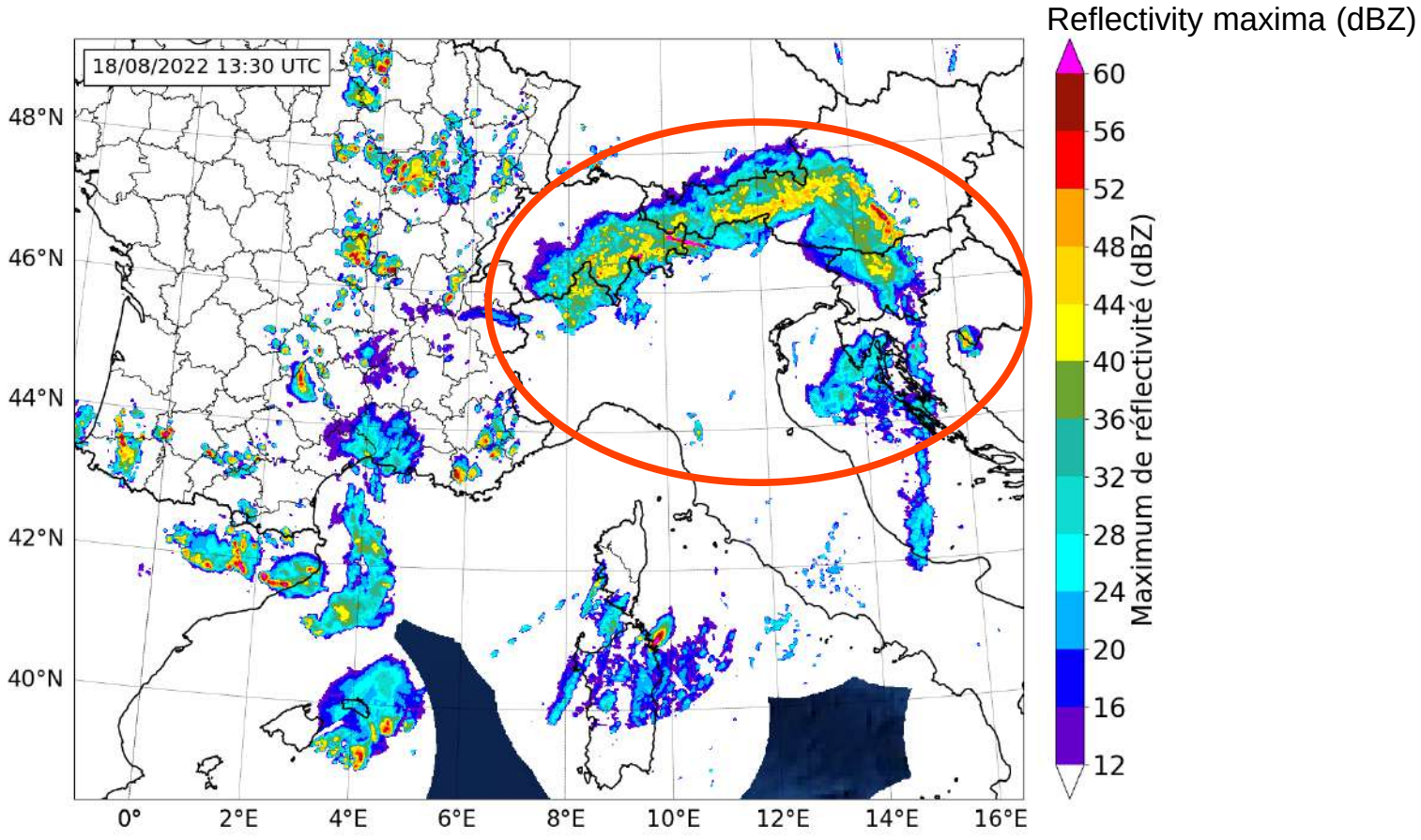
Chronology: organisation in a convective line with a rapid eastward propagation, then it takes an arched shape → bow echo

Introduction: overview of the derecho



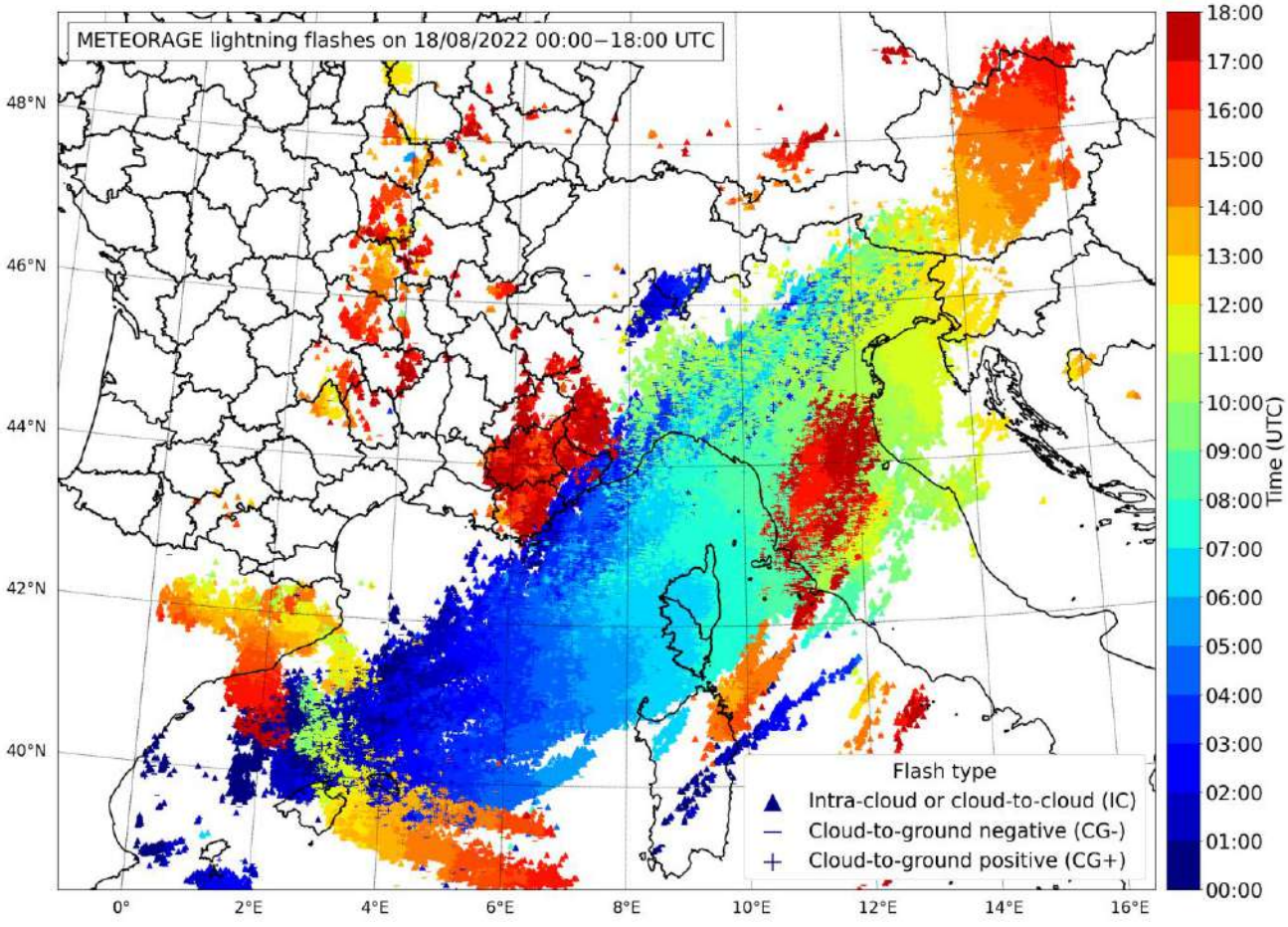
Chronology: winding of the line around a minimum pressure and continuing its route towards Italy

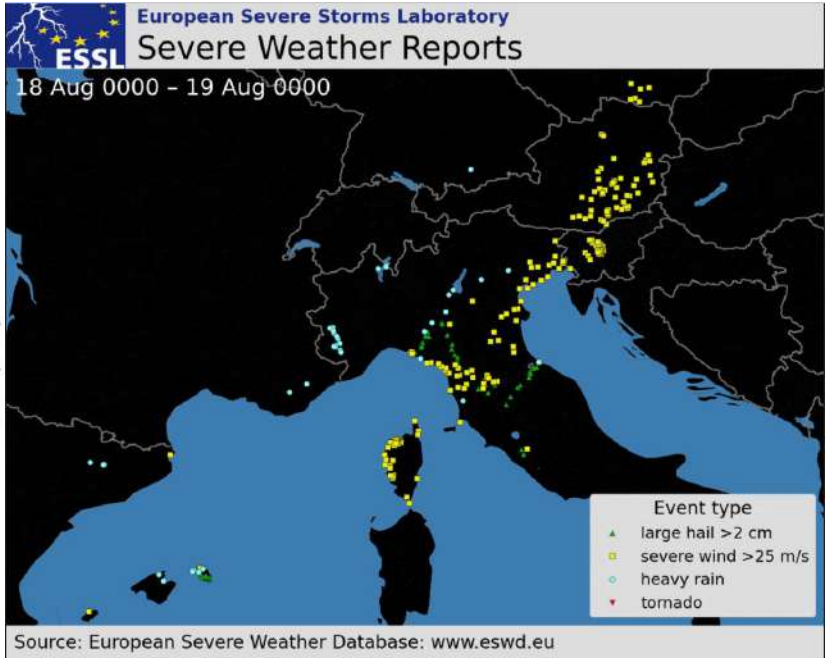
Introduction: overview of the derecho



Chronology: winding of the line around a minimum pressure and continuing its route towards Italy and Eastern Europe

Introduction: overview of the derecho





Impact: intense electrical activity over a long distance (>1400 km), very strong gusts (> 60 ms^{-1}) causing extensive damage and many deaths (12) and injuries (>100)

Introduction

Aims:

- ➔ **Comparison AROME and Meso-NH**
- ➔ **test and evaluate the contribution of new parameterisation and resolution options with the Meso-NH research model**
- ➔ **process study**

Meso-NH
mesoscale non-hydrostatic model

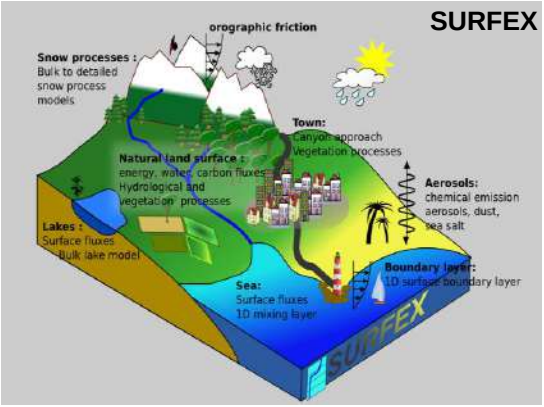
DYNAMICS

- ► Non-hydrostatic
- ► Eulerian, explicit, grid-point
- ► 4^{th} or 5^{th} order advection scheme
- ► Grid-nesting (embedded domains)

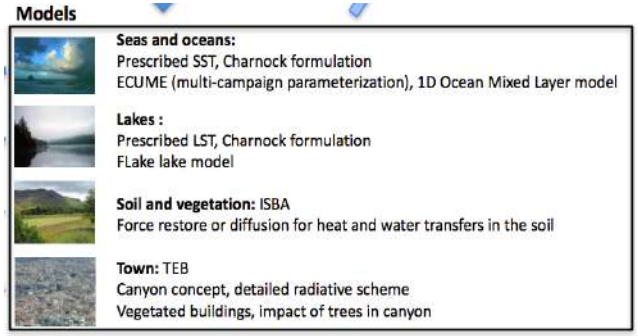
PHYSICS

- ► Turbulence 1D, ou 3D (LES)
- ► 1 or 2 moment microphysics
- ► Deep and Shallow Convection
- ► Radiation
- ► Surface (vegetation, town, sea, lake)
- ► Chemistry
- ► Aerosols
- ► Electricity
- ► Wind farm
- ► Fires

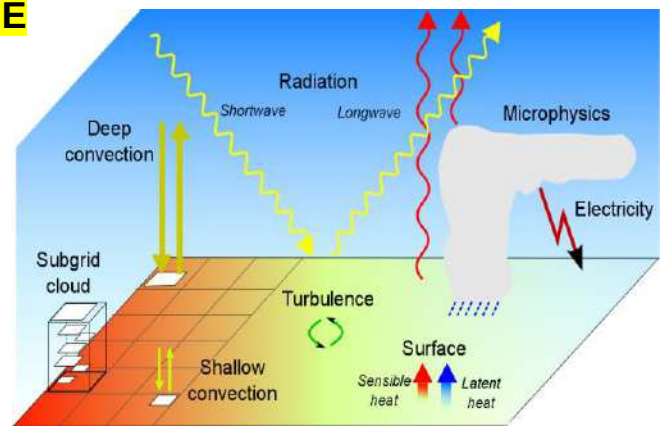
common with AROME



Masson et al., 2013, GMD

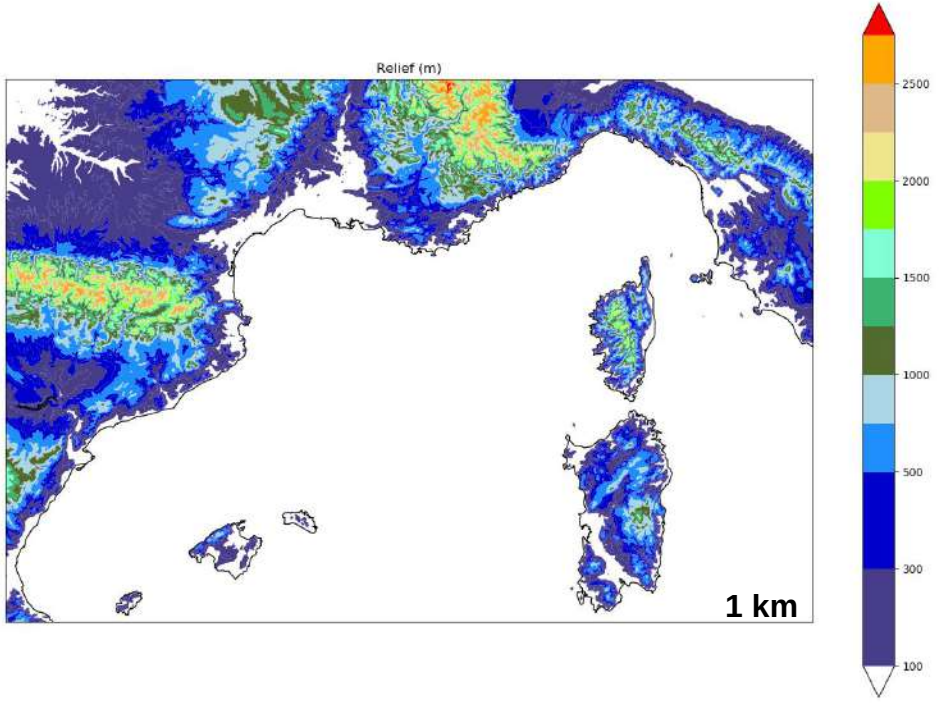


Lafore et al., 1998, Lac et al., 2018



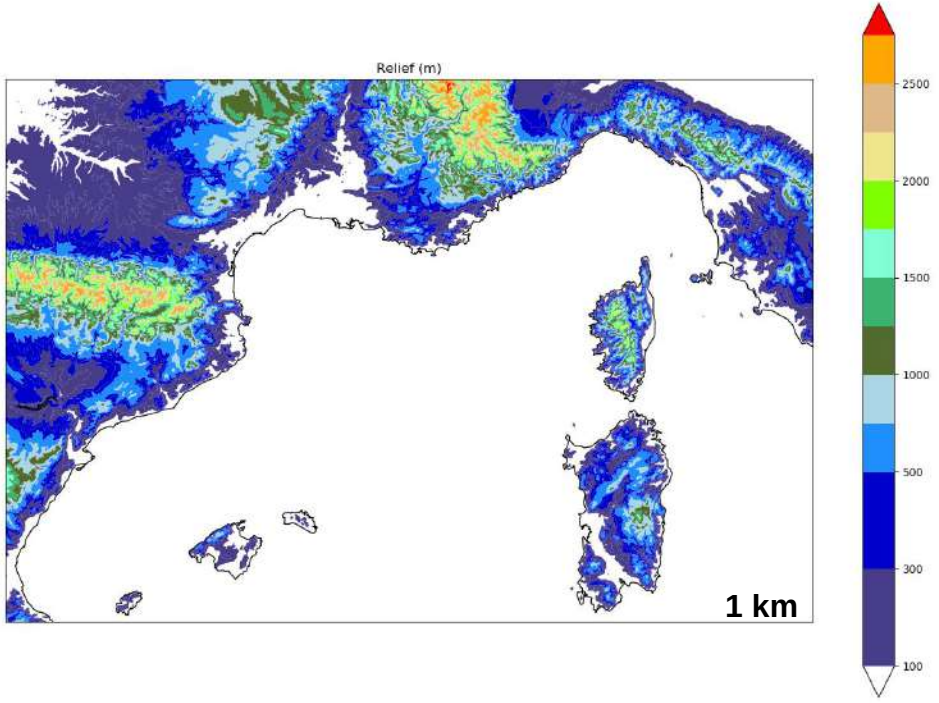
Meso-NH runs

- **Configuration**
  - domain 1080 pts x 750 pts
  - resolution: 1 km
  - vertical grid as AROME
  - initiation: AROME 00 UTC analysis
  - coupling: AROME forecasts
  - duration: 00-12 UTC
- **Simulation MNH REF 1KM**
  - turbulence : 1D, BL89
  - microphysics : ICE3
  - Shallow convection: EDKF
  - radiation : ECMWF
  - numerical schemes: Centered 4th order, RKC4
  - dt = 1,5 s – > **except for dynamics, configuration as close as possible to AROME 00 UTC**



Meso-NH runs

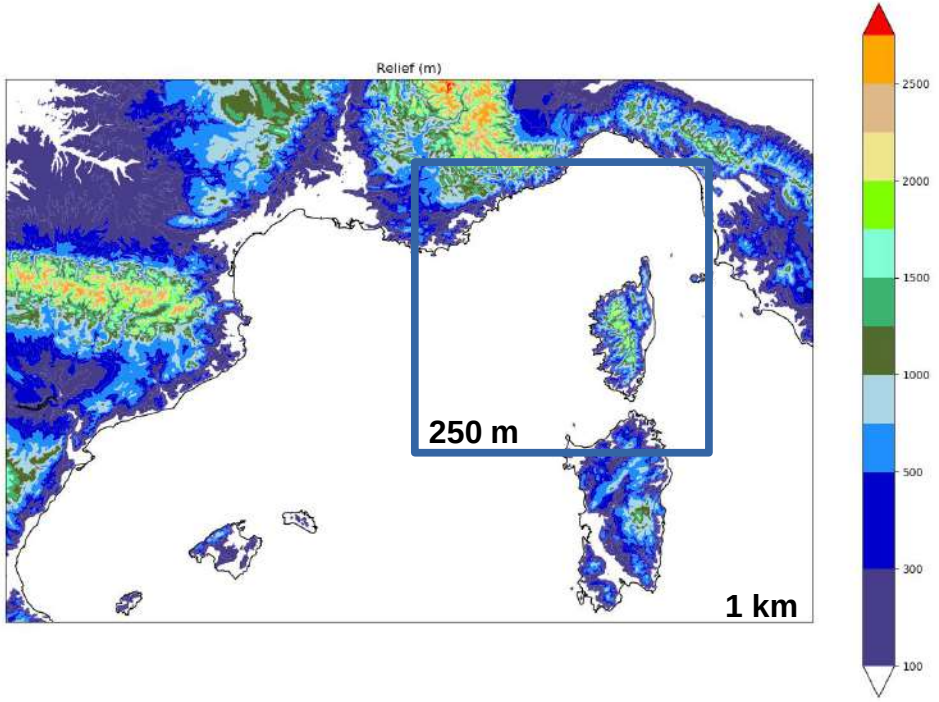
- **Configuration**
  - domain 1080 pts x 750 pts
  - resolution: 1 km
  - vertical grid as AROME
  - initiation: AROME 00 UTC analysis
  - coupling: AROME forecasts
  - duration: 00-12 UTC



- **Simulation MNH REF 1KM**
  - turbulence : 1D, BL89
  - microphysics : ICE3
  - Shallow convection: EDKF
  - radiation : ECMWF
  - numerical schemes: Centered 4th order, RKC4
  - dt = 1,5 s – > **except for dynamics, configuration as close as possible to AROME 00 UTC**
- **Sensitivity test to turbulence and microphysics** ADAPT LIMA

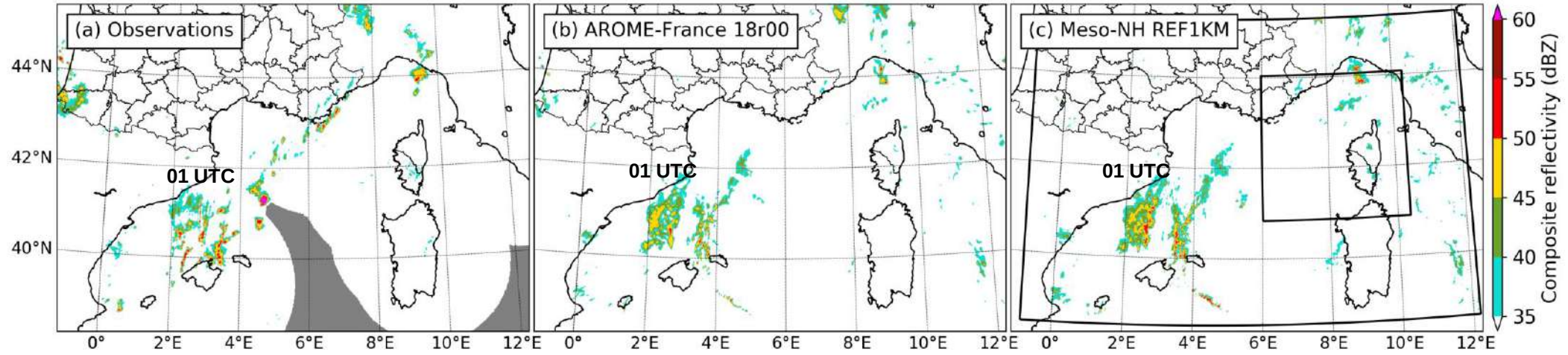
Meso-NH runs

- **Configuration**
  - domain 1080 pts x 750 pts
  - resolution: 1 km
  - vertical grid as AROME
  - initiation: AROME 00 UTC analysis
  - coupling: AROME forecasts
  - duration: 00-12 UTC
- **Simulation MNH REF 1KM**
  - turbulence : 1D, BL89
  - microphysics : ICE3
  - Shallow convection: EDKF
  - radiation : ECMWF
  - numerical schemes: Centered 4th order, RKC4
  - dt = 1,5 s – > **except for dynamics, configuration as close as possible to AROME 00 UTC**



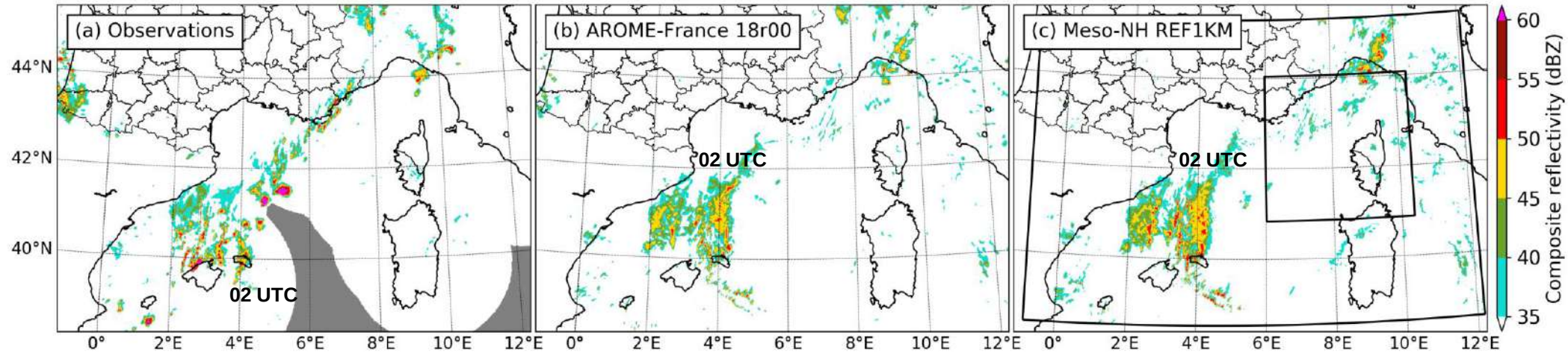
- **Sensitivity test to turbulence and microphysics** ADAPT LIMA
- **Impact of horizontal resolution**: nested domain at 250 m (1440 pts x 1440 pts)

Comparison Observations - AROME - Meso-NH



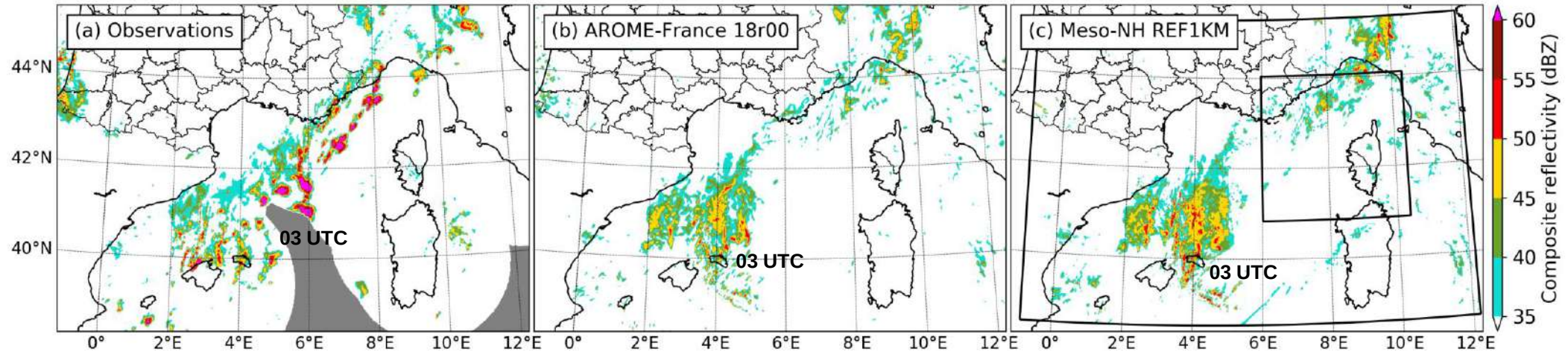
- development of the first convective cells at sea, near the Balearic Islands, progressing eastwards

Comparison Observations - AROME - Meso-NH



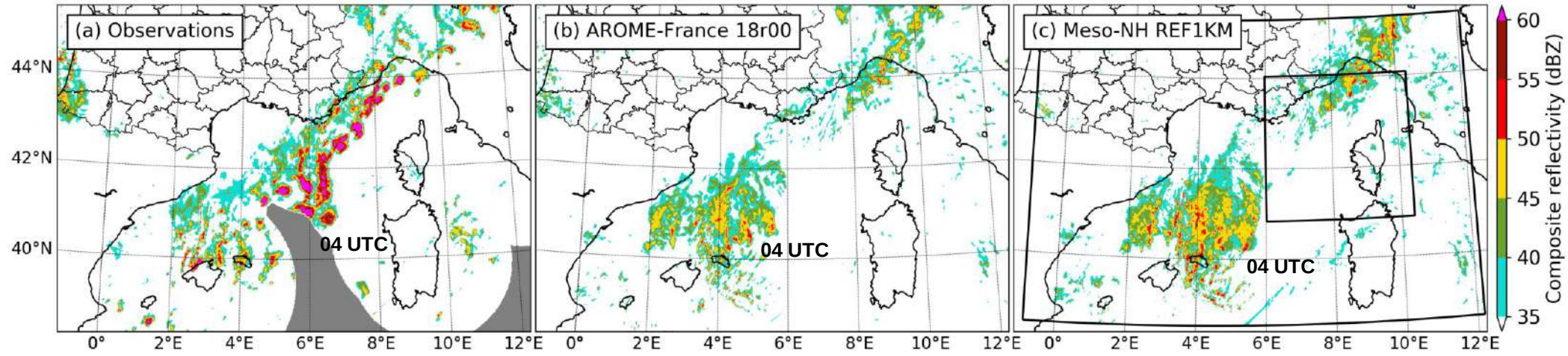
- development of the first convective cells at sea, near the Balearic Islands, progressing eastwards
- lack of development of supercells and cells off the French coast

Comparison Observations - AROME - Meso-NH



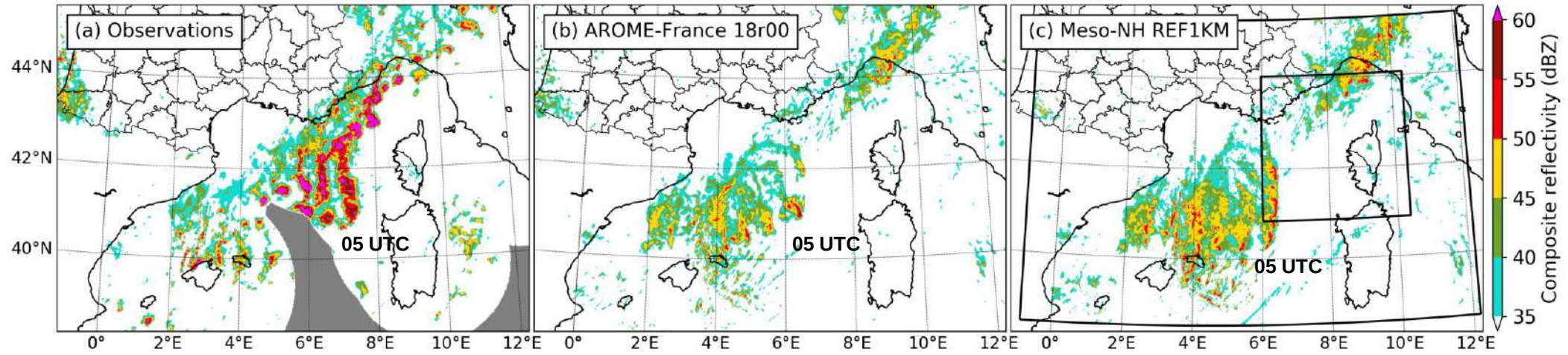
- development of the first convective cells at sea, near the Balearic Islands, progressing eastwards
- lack of development of supercells and cells off the French coast

Comparison Observations - AROME - Meso-NH



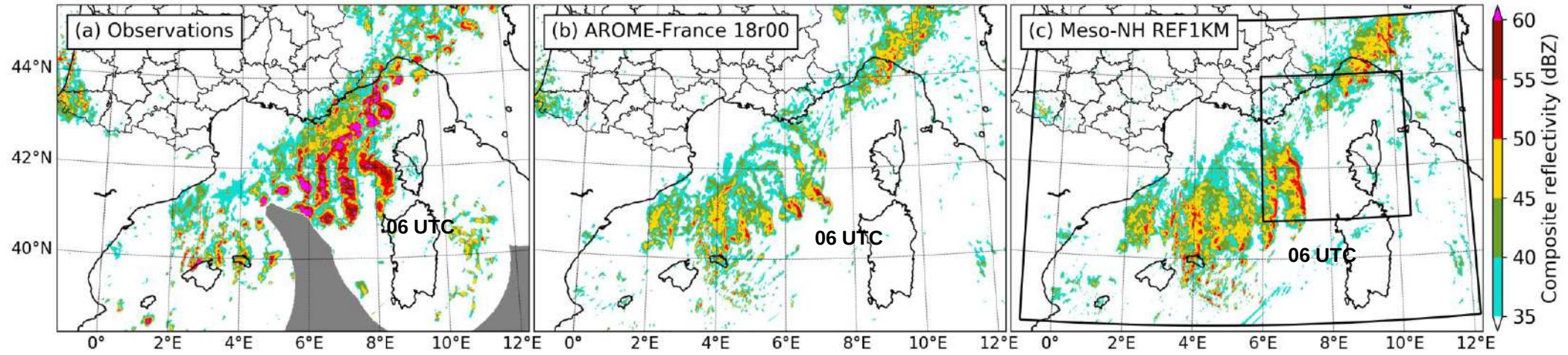
- development of the first convective cells at sea, near the Balearic Islands, progressing eastwards
- lack of development of supercells and cells off the French coast

Comparison Observations - AROME - Meso-NH



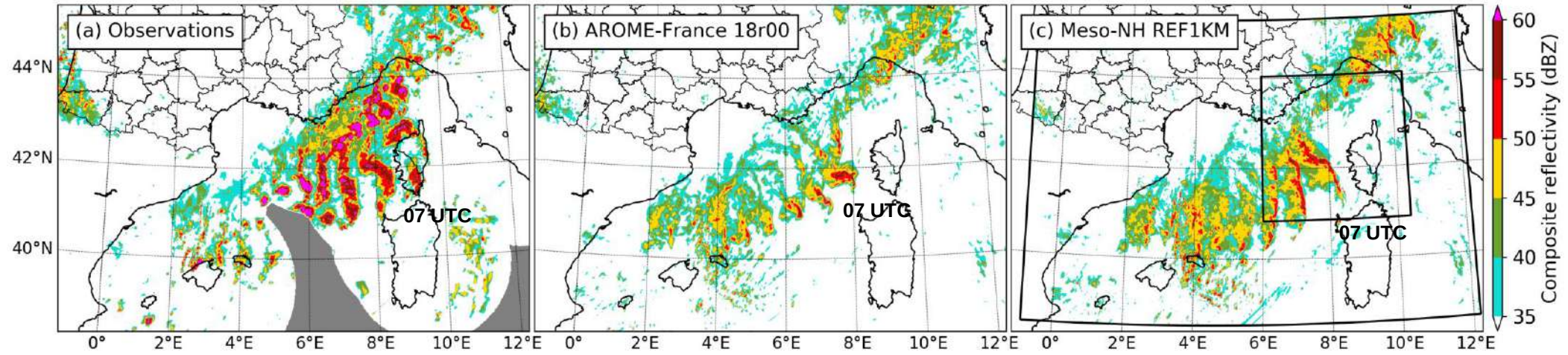
- development of the first convective cells at sea, near the Balearic Islands, progressing eastwards
- lack of development of supercells and cells off the French coast
- convective line structure, more extensive in Meso-NH than in AROME

Comparison Observations - AROME - Meso-NH



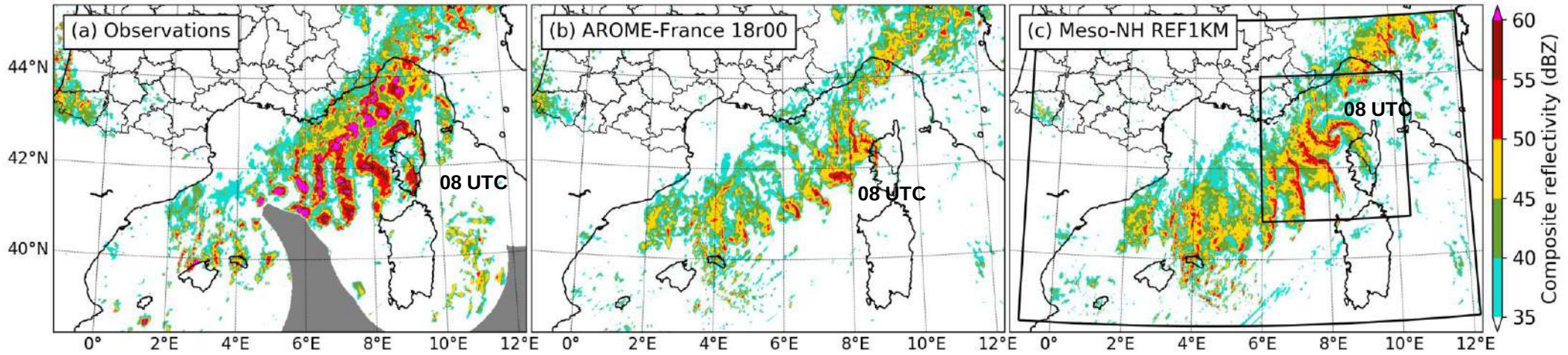
- development of the first convective cells at sea, near the Balearic Islands, progressing eastwards
- lack of development of supercells and cells off the French coast
- convective line structure, more extensive in Meso-NH than in AROME
- delay in simulations (> 1h, 80 km), line curves in observations

Comparison Observations - AROME - Meso-NH



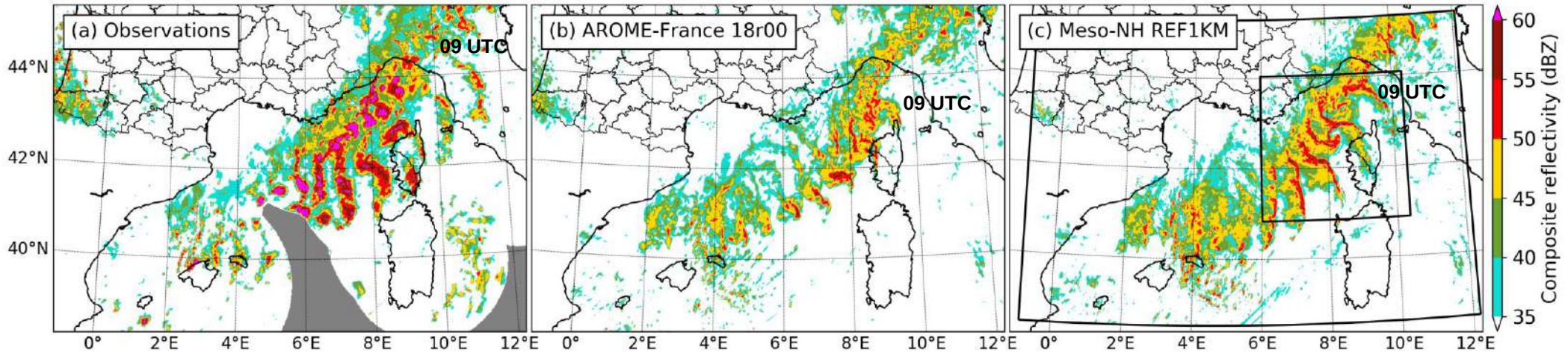
- development of the first convective cells at sea, near the Balearic Islands, progressing eastwards
- lack of development of supercells and cells off the French coast
- convective line structure, more extensive in Meso-NH than in AROME
- delay in simulations (> 1h, 80 km), line curves in observations
- system over Corsica, bow echo in simulations over the sea: delay of 1h30 for AROME, 1h15 for MNH

Comparison Observations - AROME - Meso-NH



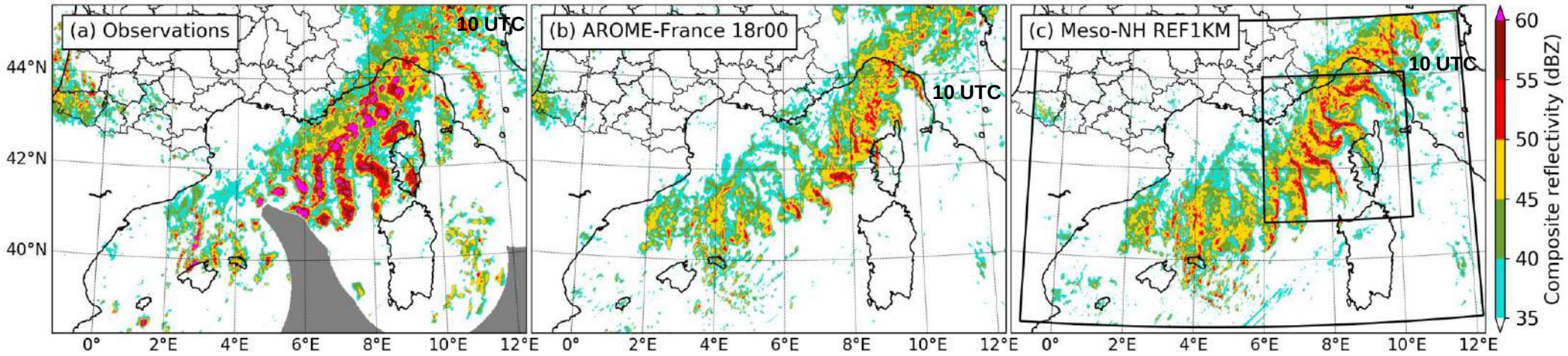
- development of the first convective cells at sea, near the Balearic Islands, progressing eastwards
- lack of development of supercells and cells off the French coast
- convective line structure, more extensive in Meso-NH than in AROME
- delay in simulations (> 1h, 80 km), line curves in observations
- system over Corsica, bow echo in simulations over the sea: delay of 1h30 for AROME, 1h15 for MNH

Comparison Observations - AROME - Meso-NH



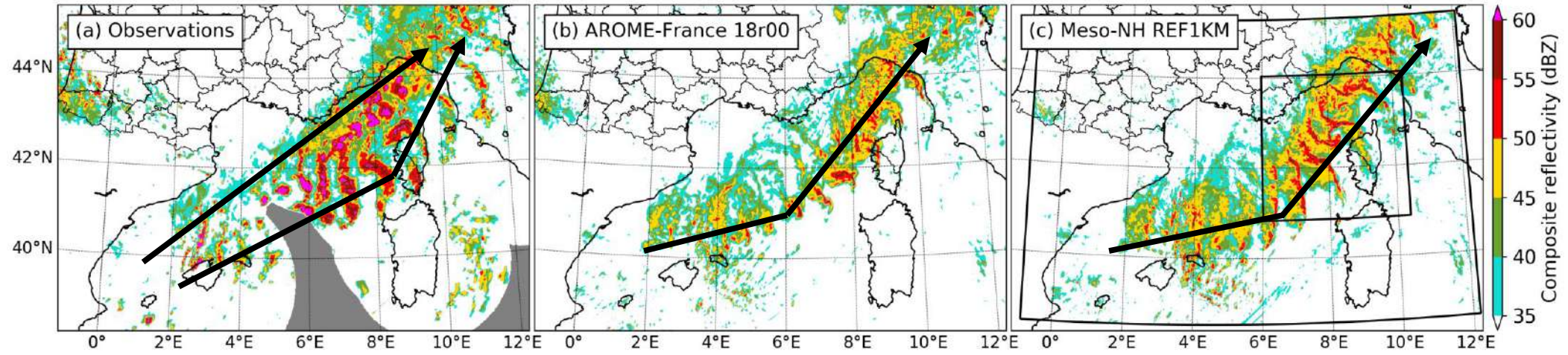
- development of the first convective cells at sea, near the Balearic Islands, progressing eastwards
- lack of development of supercells and cells off the French coast
- convective line structure, more extensive in Meso-NH than in AROME
- delay in simulations (> 1h, 80 km), line curves in observations
- system over Corsica, bow echo in simulations over the sea: delay of 1h30 for AROME, 1h15 for MNH

Comparison Observations - AROME - Meso-NH



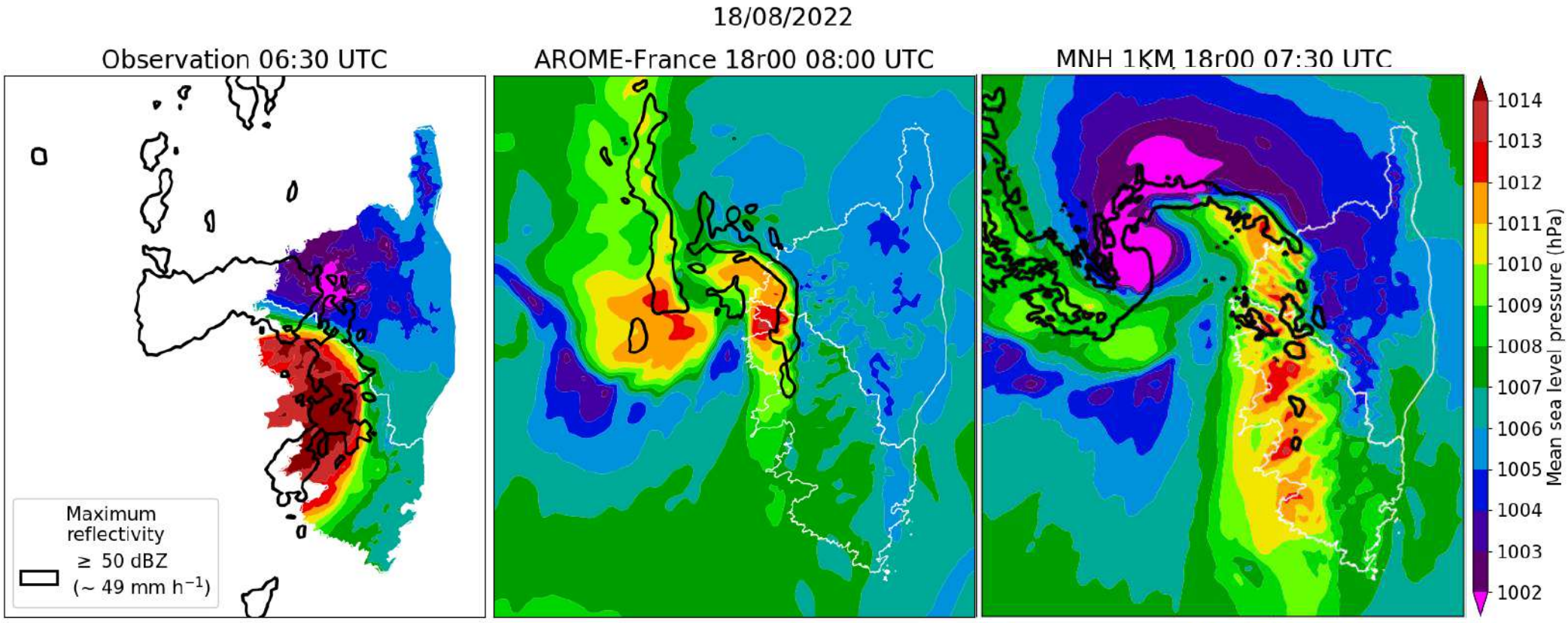
- development of the first convective cells at sea, near the Balearic Islands, progressing eastwards
- lack of development of supercells and cells off the French coast
- convective line structure, more extensive in Meso-NH than in AROME
- delay in simulations (> 1h, 80 km), line curves in observations
- system over Corsica, bow echo in simulations over the sea: delay of 1h30 for AROME, 1h15 for MNH

Comparison Observations - AROME - Meso-NH



- development of the first convective cells at sea, near the Balearic Islands, progressing eastwards
- lack of development of supercells and cells off the French coast
- convective line structure, more extensive in Meso-NH than in AROME
- delay in simulations (> 1h, 80 km), line curves in observations
- system over Corsica, bow echo in simulations over the sea: delay of 1h30 for AROME, 1h15 for MNH
- intense convective activity at sea between Corsica and the mainland in the simulations, while the instability has already been consumed by the supercell in the observations

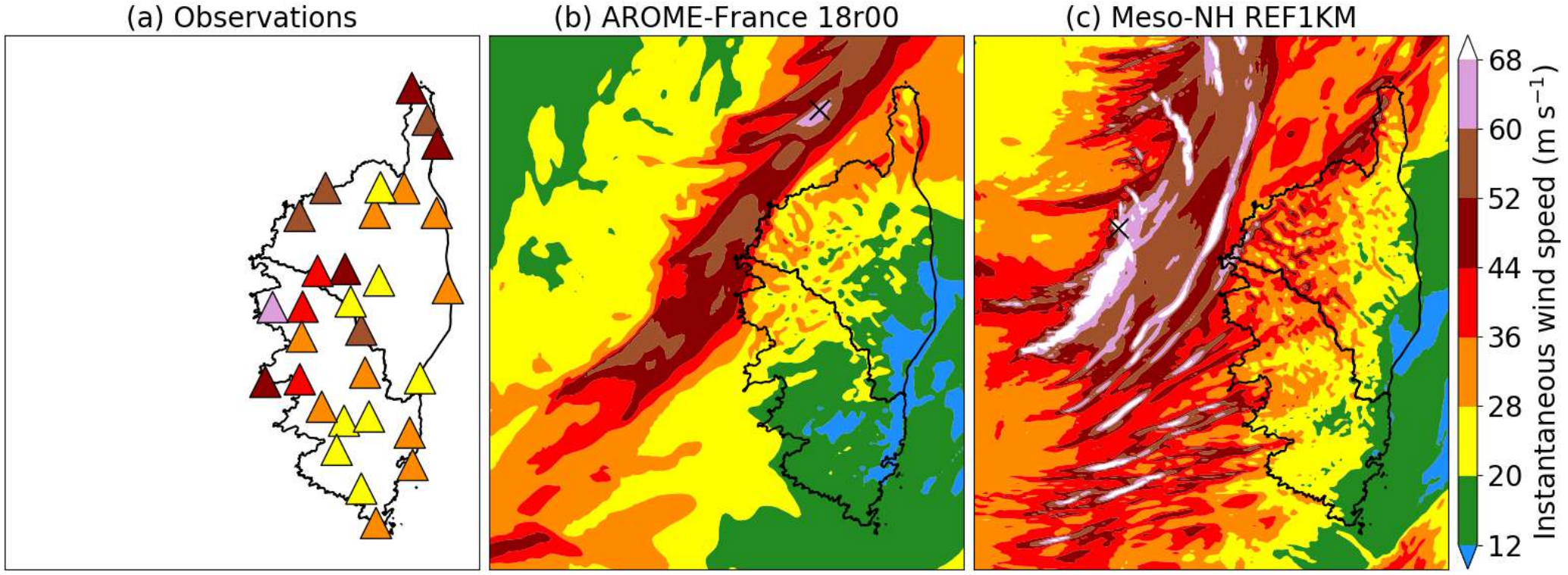
Comparison MSLP Observations - AROME - Meso-NH



- Value of fine-scale observations: strong pressure gradients, difference > 12 hPa
- Pressure tripole more marked in Meso-NH with a slightly more realistic gradient over Corsica
- Strong pressure minimum associated with the development of the northern cyclonic vortex → winding of the convective line

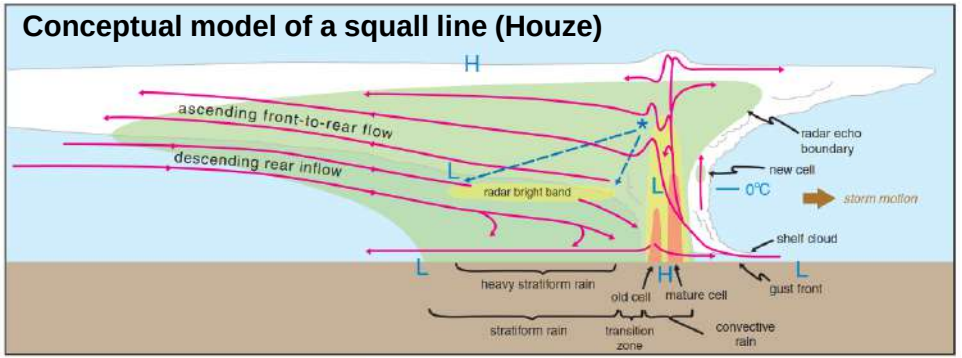
Comparison wind gusts Observations - AROME - Meso-NH

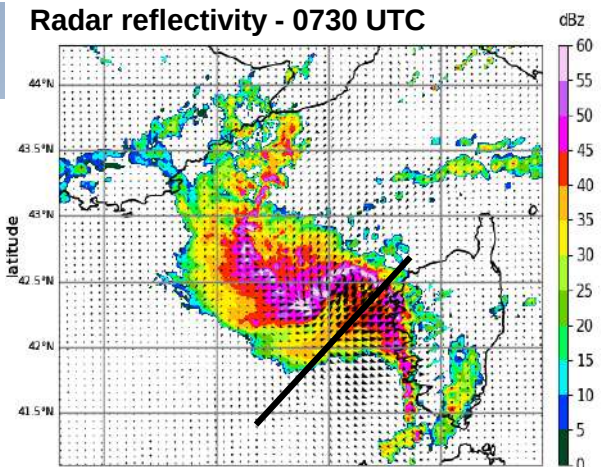
Maxima of wind gusts at 10m (m/s) between 00 and 12 UTC 18 August 2022



- Strong gusts associated with strong pressure gradients along the bow echo, its mesoscale eddies and the bookend cyclonic vortex to the north
- Extended area of strong gusts in Meso-NH with finer-scale structures

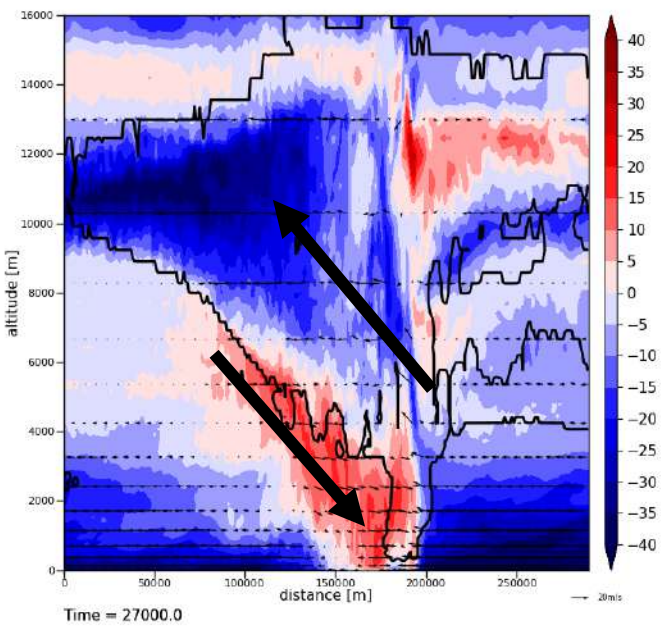
Vertical structure Meso-NH 1km



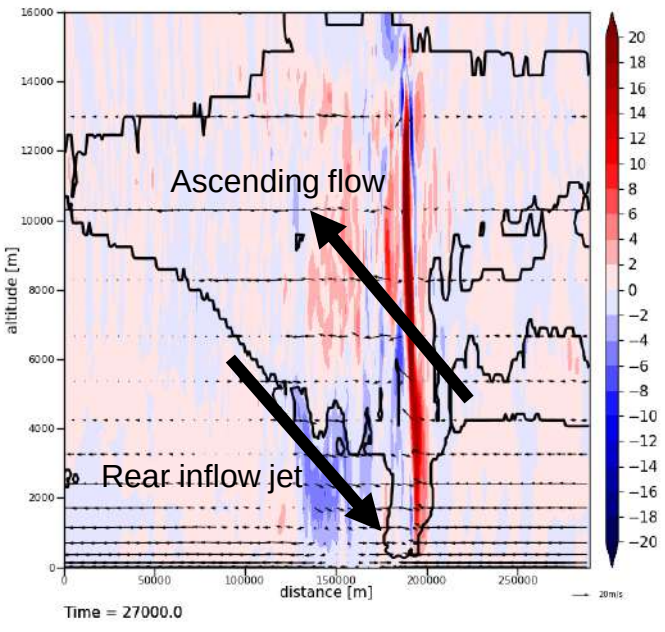


0730 UTC

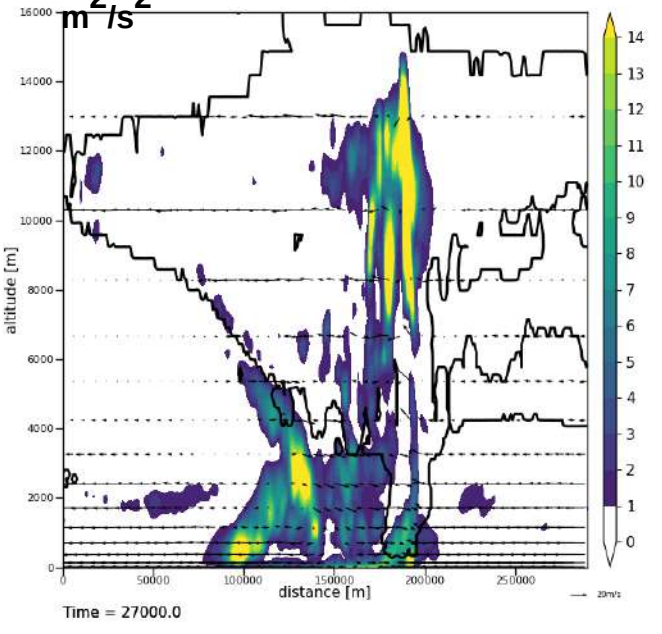
Anomaly of horizontal wind m/s



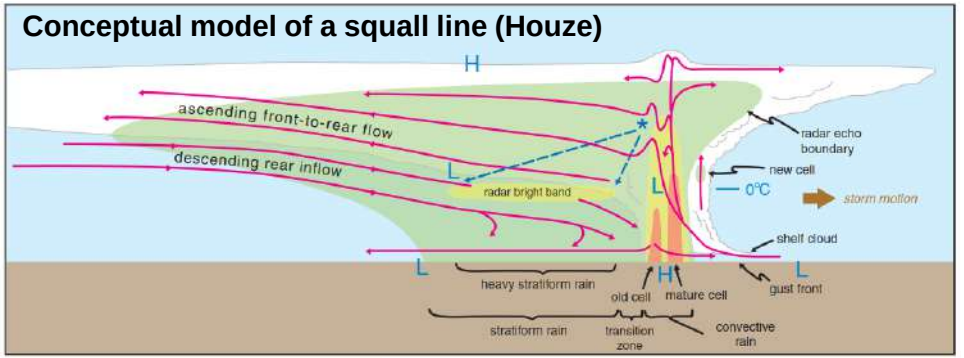
Vertical velocity m/s

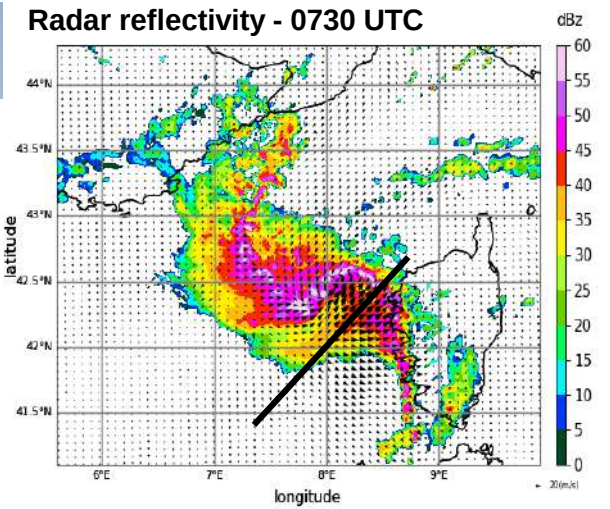


TKE m^2/s^2



Vertical structure Meso-NH 1km

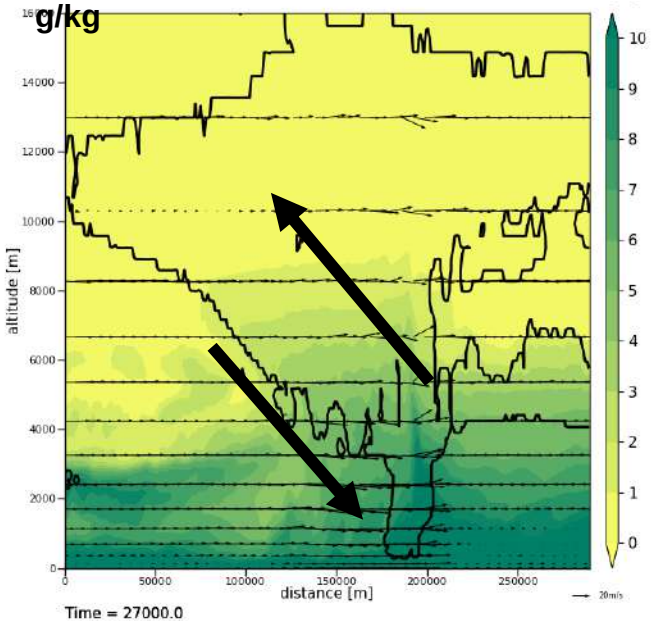




0730 UTC

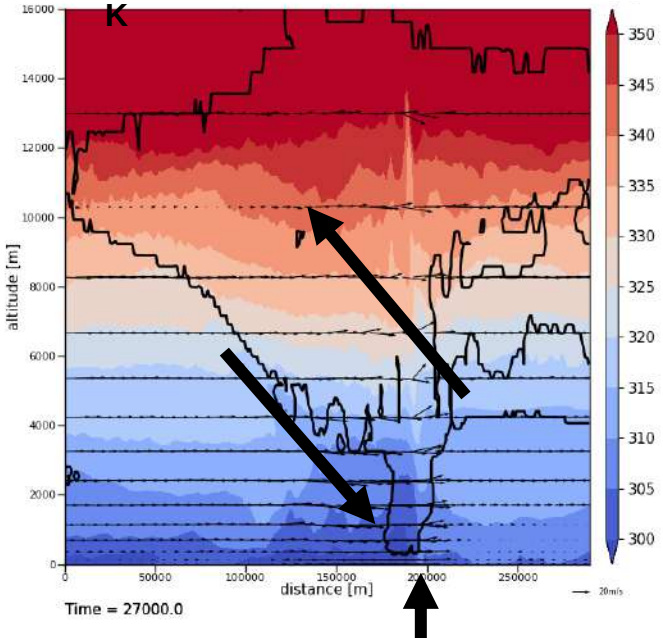
Mixing ratio of water vapor

g/kg



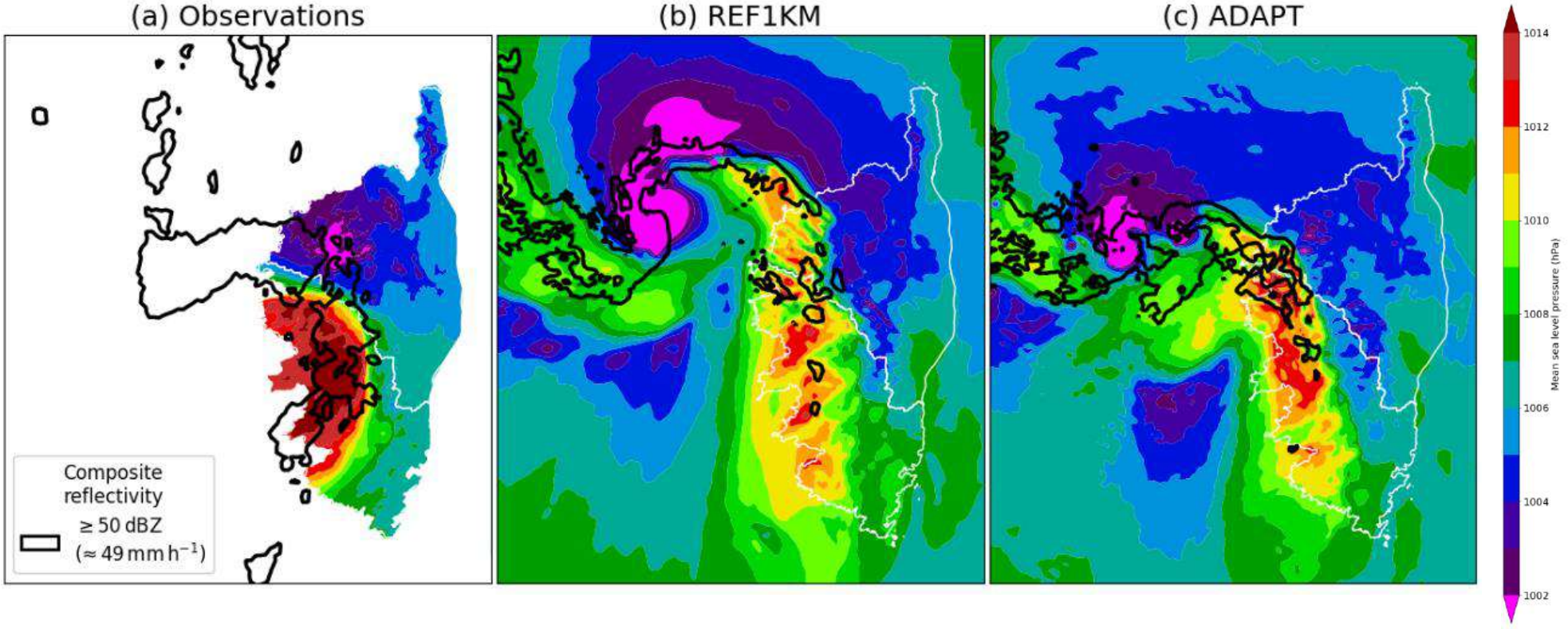
Virtual potential temperature

K



- dry intrusion at the back of the system
- evaporation of part of the precipitation
- cold pool under the convective line (more than 2000m thick)
- gust front ahead of the cold pool

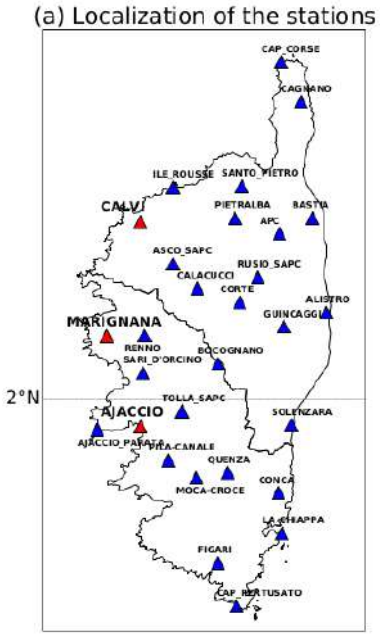
Impact of mixing length Meso-NH 1km



ADAPT = min(RM17, 0.5 * 1 km) *Rodier et al, 2017 Honnert et al, 2021*

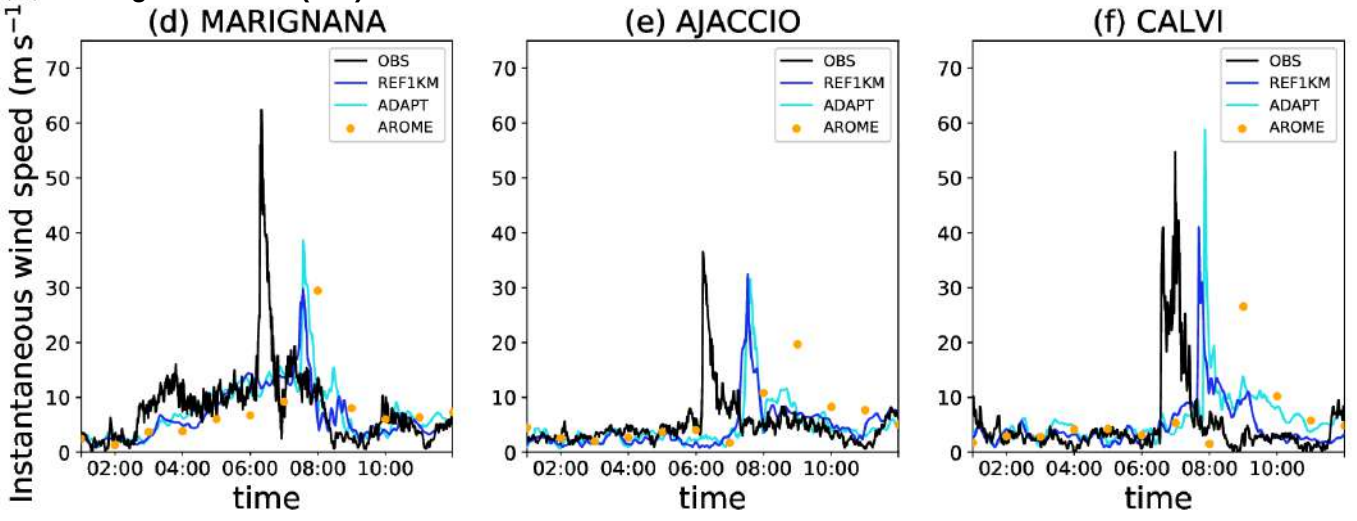
- Smaller mixing length with ADAPT (taking into account vertical wind shear and mesh size):
  - less intense bookend vortex
  - mesohigh a little stronger but a little more delay in the progression of the line

Impact of mixing length Meso-NH 1km

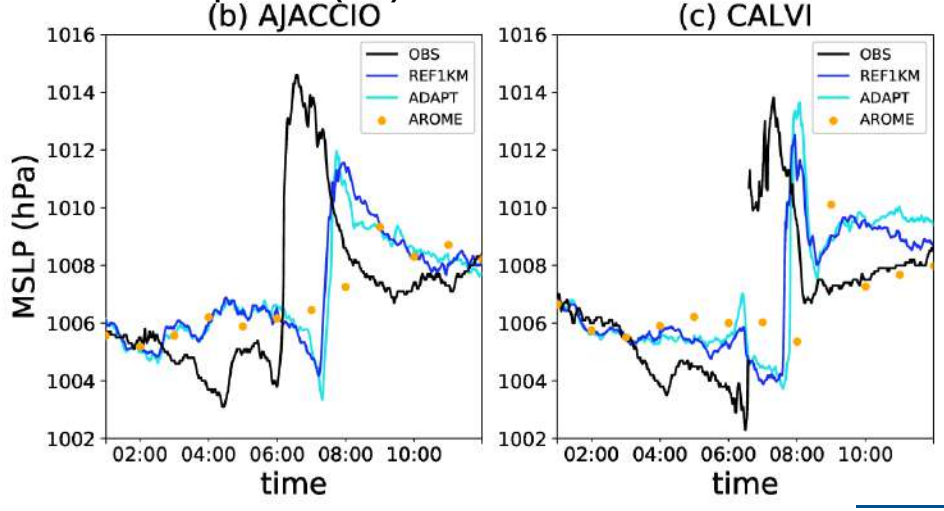


- Simulation of strong gusts (> 30 m/s) but underestimation and time lag
- Higher values for reduced mixing length (ADAPT) due to less turbulent mixing
- Simulation of the overpressure associated with the gust front

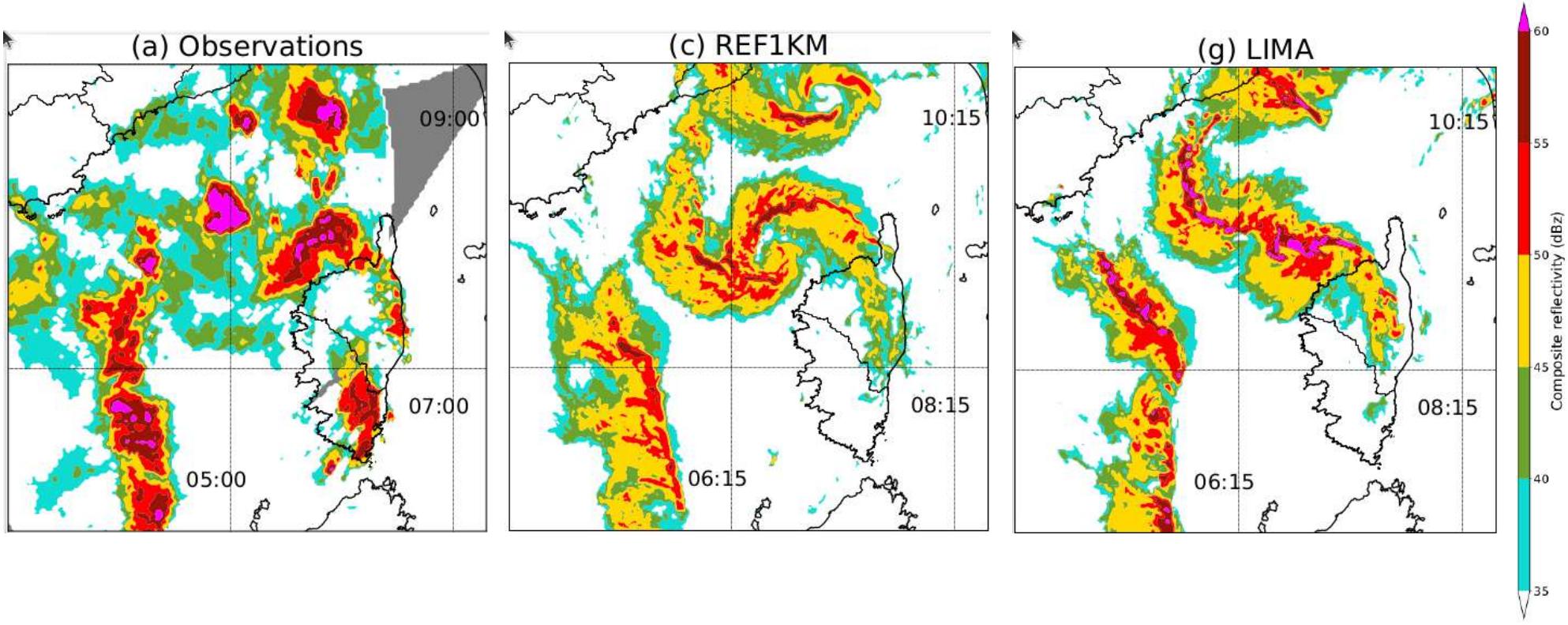
Wind gusts at 10m (m/s)



Surface pressure (hPa)



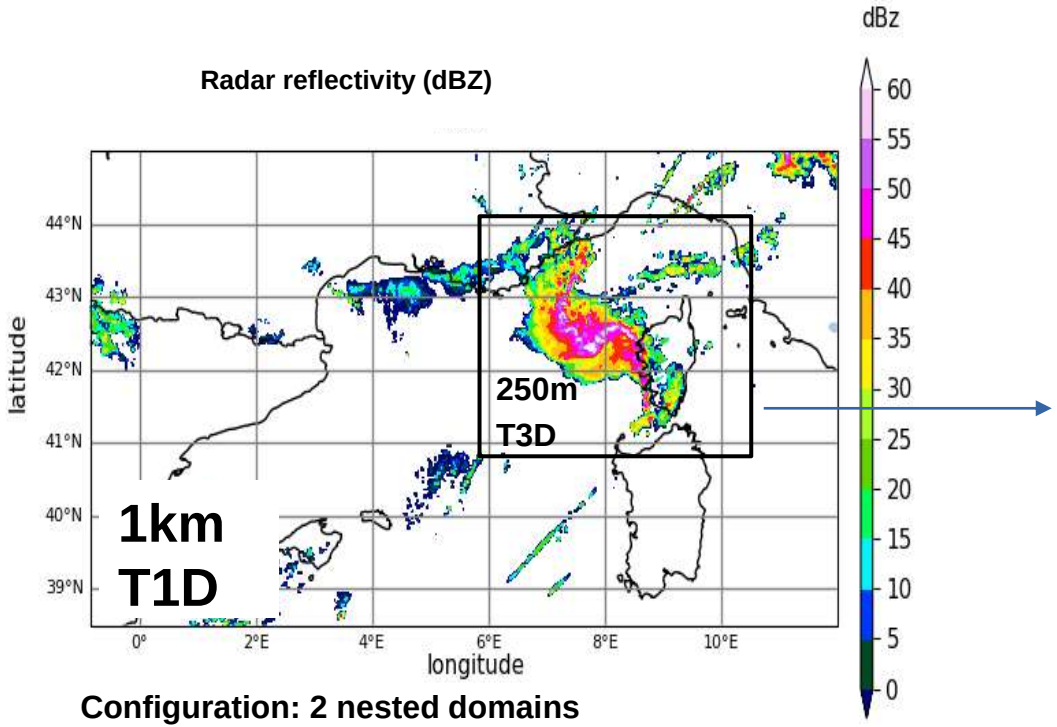
Impact of microphysics: ICE3 versus LIMA

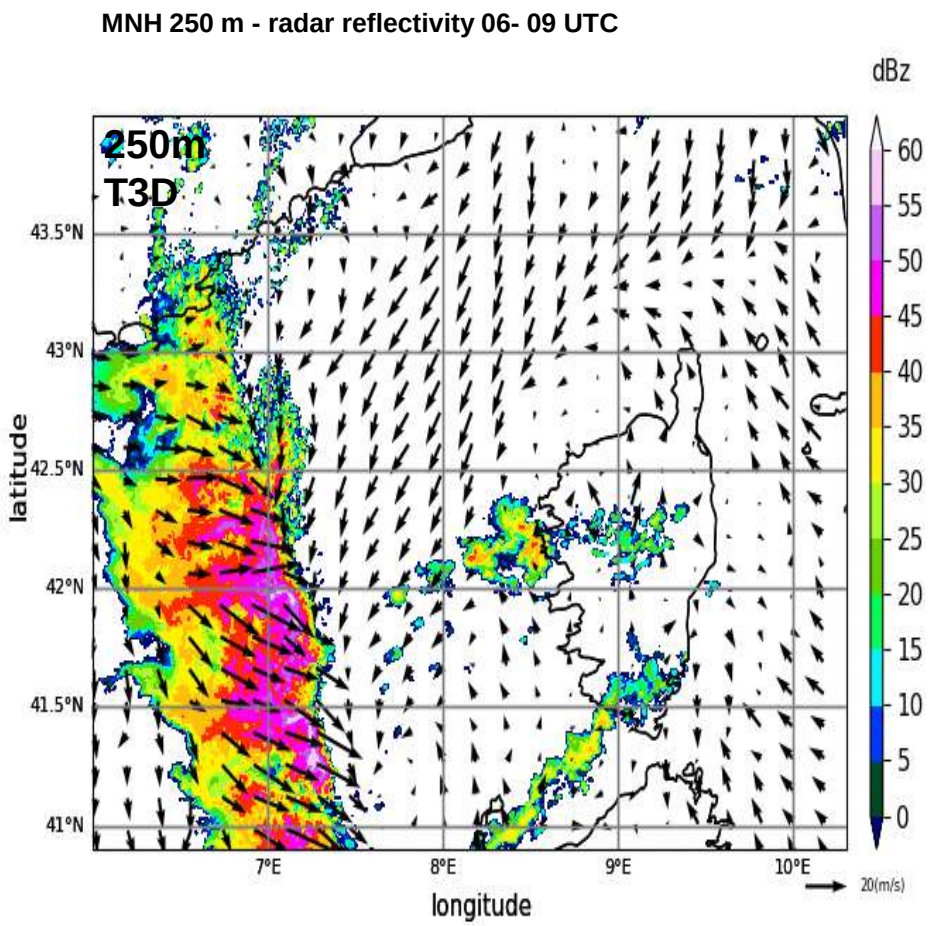


REF1KM ICE3 **1 moment scheme**
LIMA *(Vié et al, 2016)* **2 moment scheme (rain, ice, cloud water, graupel, snow)**

→ Similar convective structures and chronology but more extended in LIMA with more intense reflectivity

Impact of horizontal resolution: 250m versus 1km





Configuration: 2 nested domains

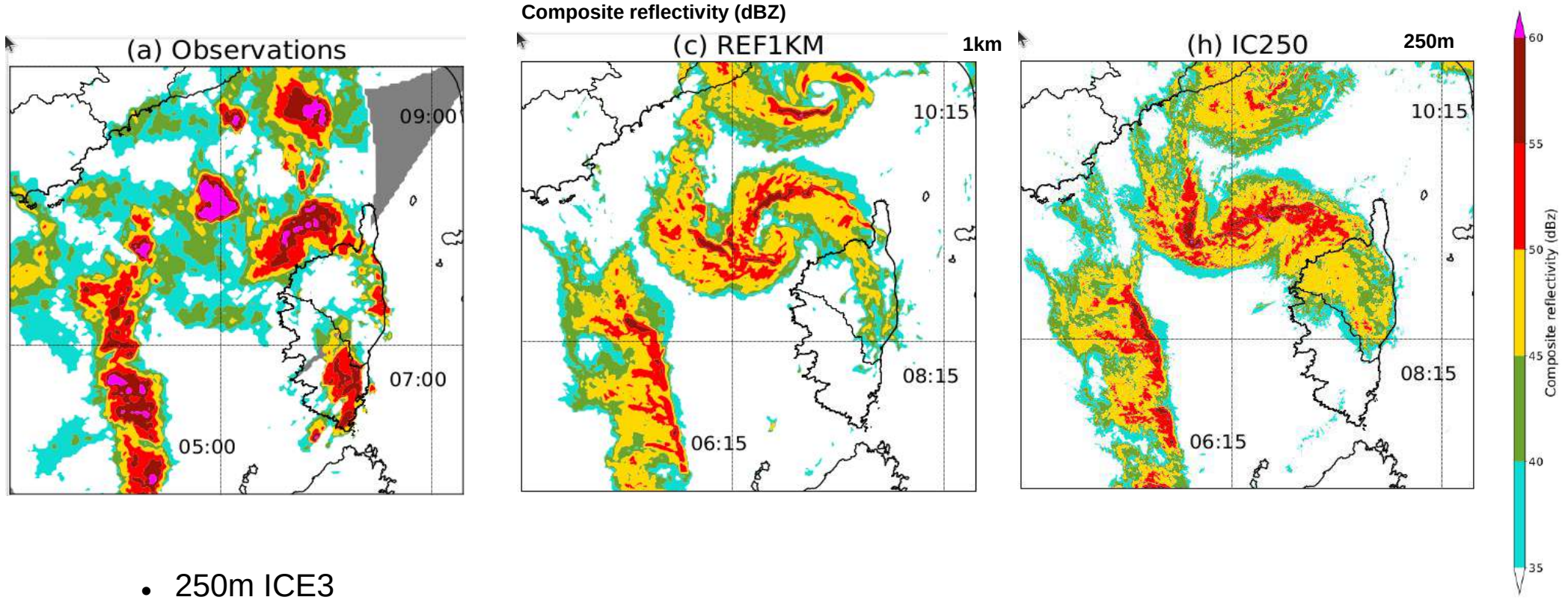
- Domain 1km

  ADAPT
  1D turbulence
  Shallow Convection

- Domain 250m

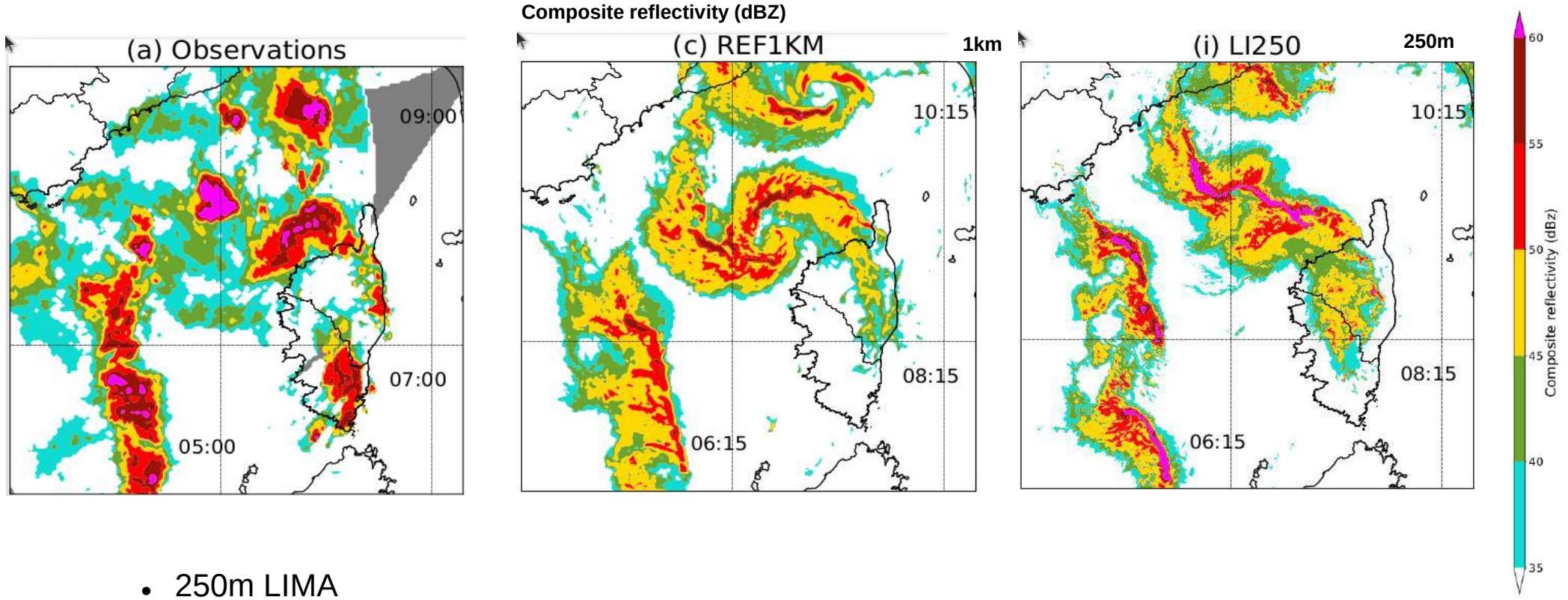
  ADAPT
  3D turbulence
  No shallow convection

Impact of horizontal resolution: Observation - 1km – 250m ICE3



- 250m ICE3
- line comprising more pronounced convective cells
- more extensive line, bookend vortex a little further north, slightly more intense reflectivity, more eddy structures (mesovortices)

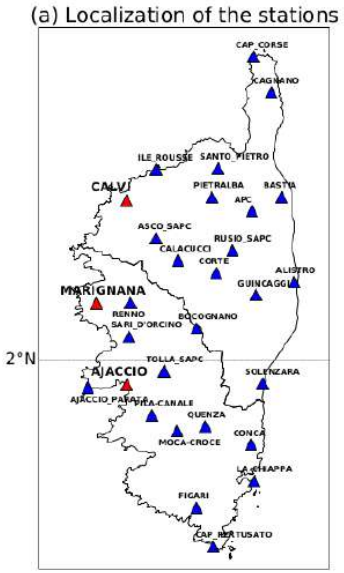
Impact of horizontal resolution: Observation - 1km – 250m LIMA

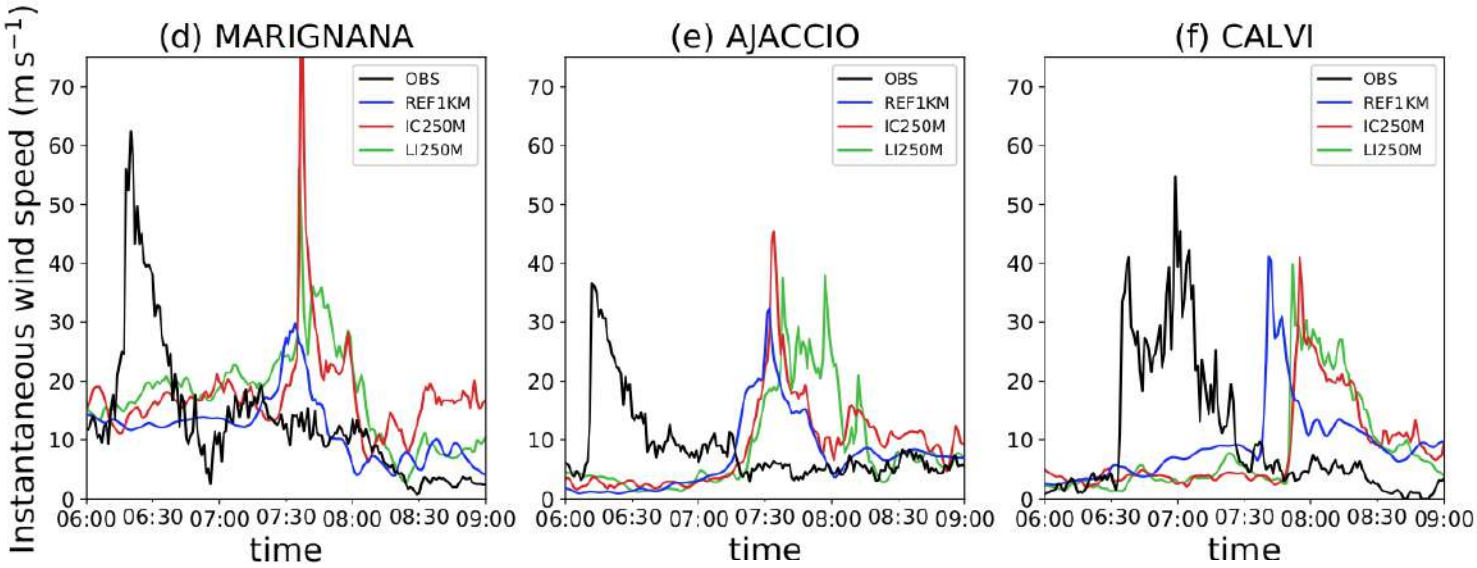


- 250m LIMA
- line comprising more pronounced convective cells
- more extensive line, bookend vortex a little further north, more intense reflectivity, more eddy structures (mesovortices)

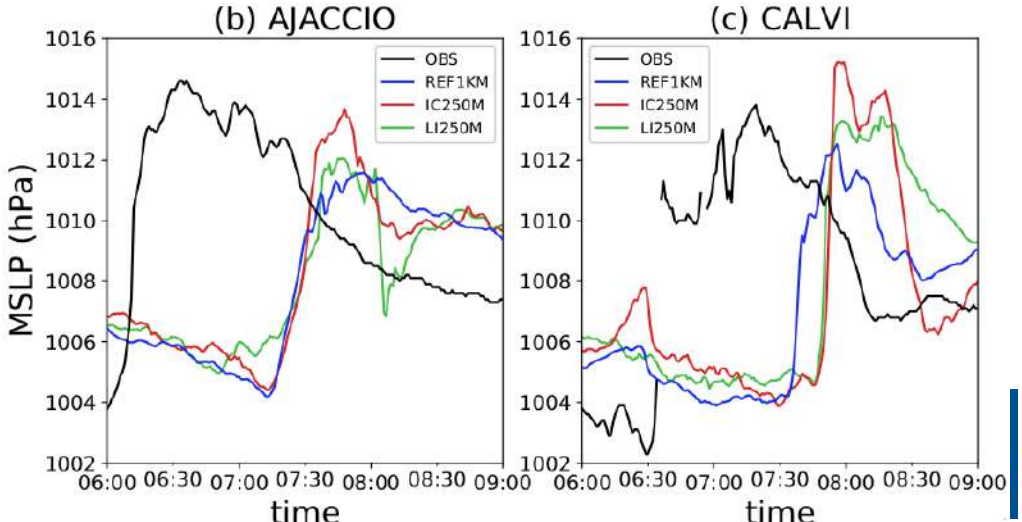
Impact of horizontal resolution: 1km versus 250m

Wind gust at 10m (m/s)





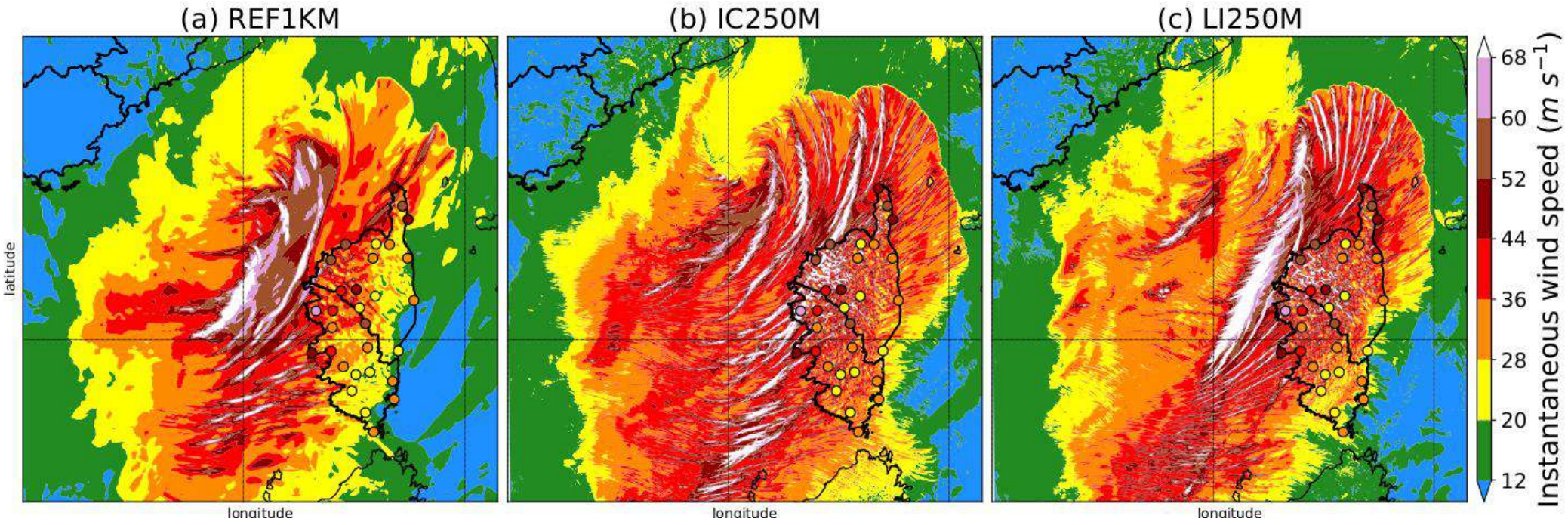
Surface pressure (hPa)



- Very good representation of strong gusts (> 50 ms^{-1}) and better peak pressure, but still with a time lag
- Better fine-scale variability

Impact of horizontal resolution: 1km – 250m

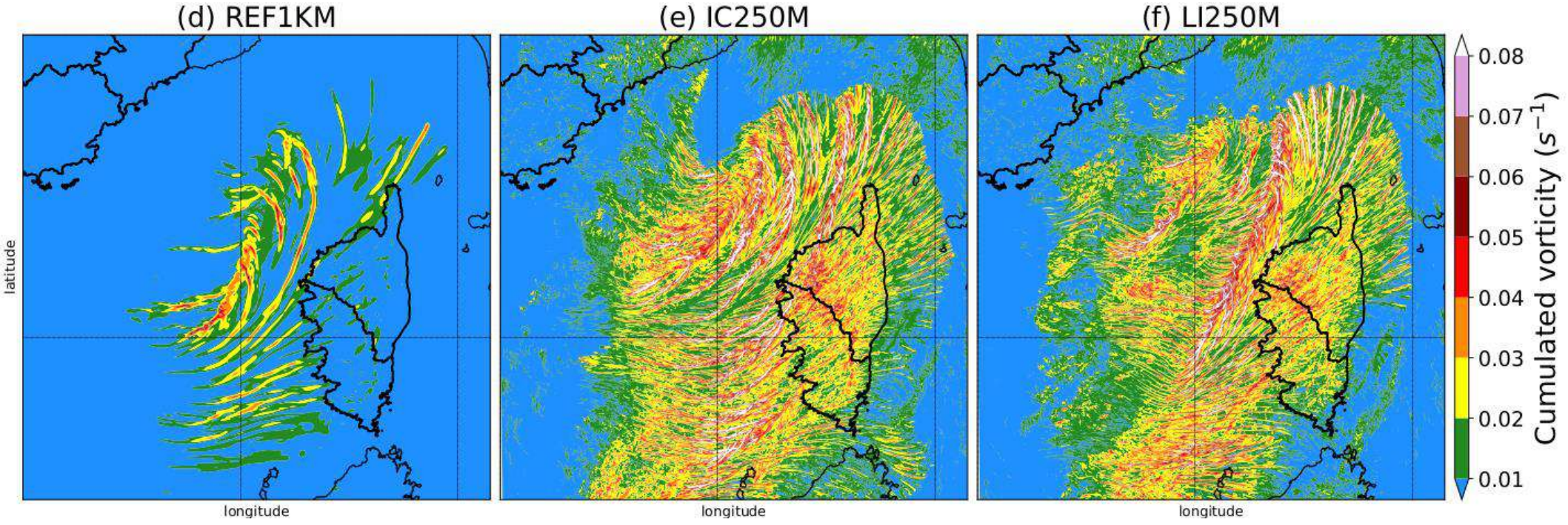
Wind gusts: maxima values between 06 and 09 UTC



- Finer and more intense wind structures over a larger area in Corsica for the 250m resolution runs
- Larger area of strong wind associated with the bookend vortex in LI250m

Impact of horizontal resolution: 1km – 250m

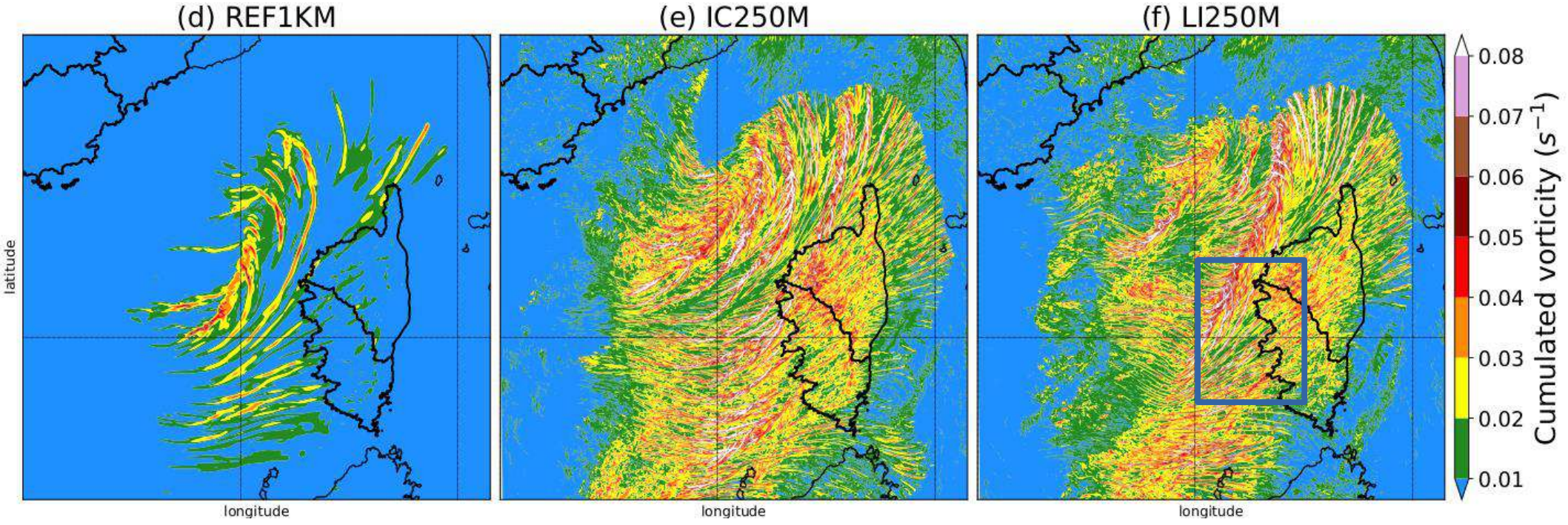
Vorticity: maxima values between 06 and 09 UTC



- Finer and more intense wind structures over a larger area in Corsica for the 250m resolution runs
- Larger area of strong wind associated with the bookend vortex in LI250m
- Strong winds associated with mesovortices, many discernible vortex trajectories

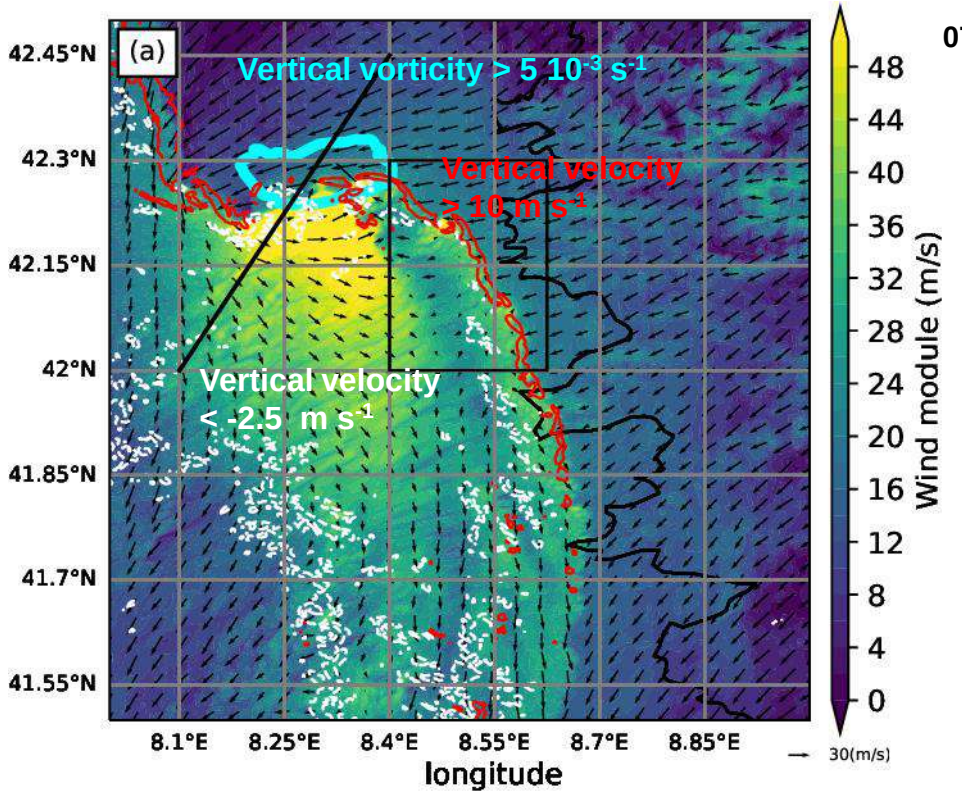
Impact of horizontal resolution: 1km – 250m

Vorticity: maxima values between 06 and 09 UTC

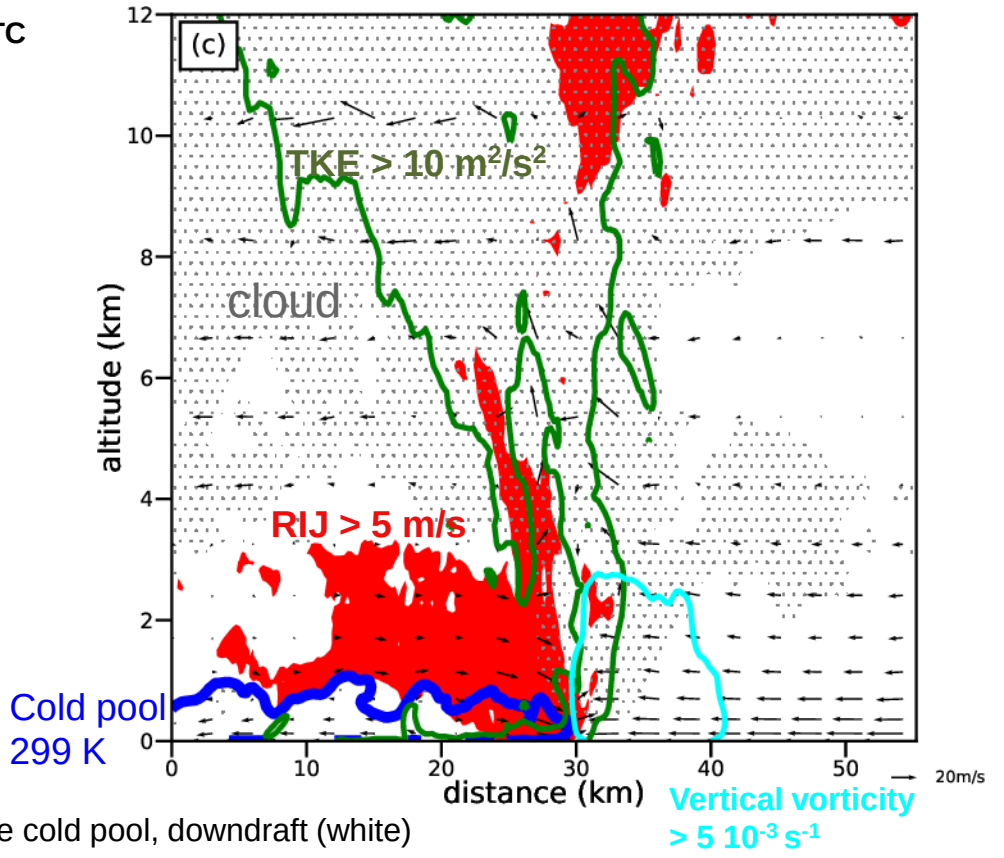


- Finer and more intense wind structures over a larger area in Corsica for the 250m resolution runs
- Larger area of strong wind associated with the bookend vortex in LI250m
- Strong winds associated with mesovortices, many discernible vortex trajectories

Zoom on a mesovortice: LI250m



0730 UTC

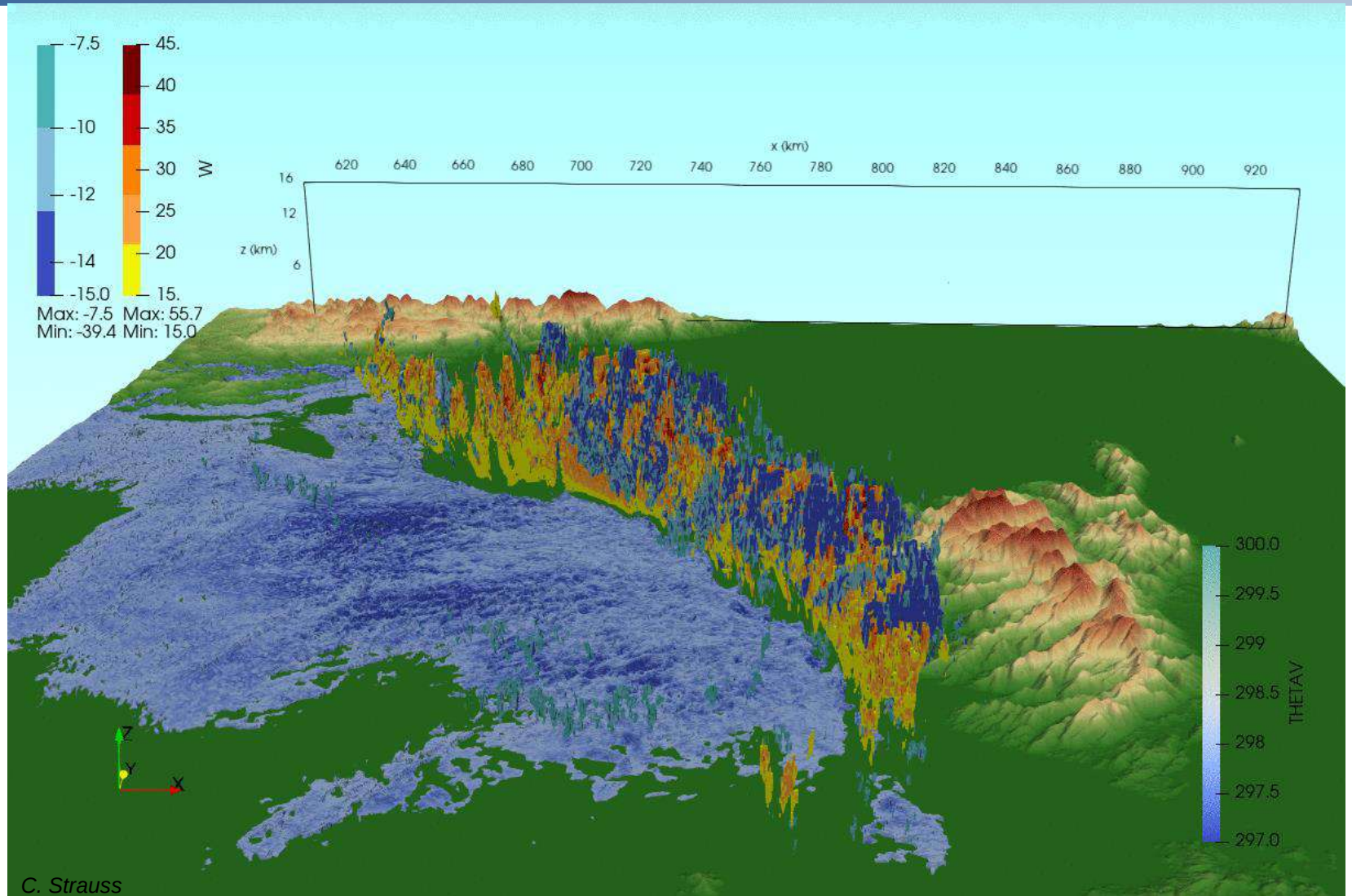


- Updraft (red) along the leading edge of the line, ahead of the cold pool, downdraft (white)
- Strong wind associated with the rear inflow jet
- acceleration to the south of the eddies: contribution of the vortices to the generation of strong winds

Conclusion – Perspectives

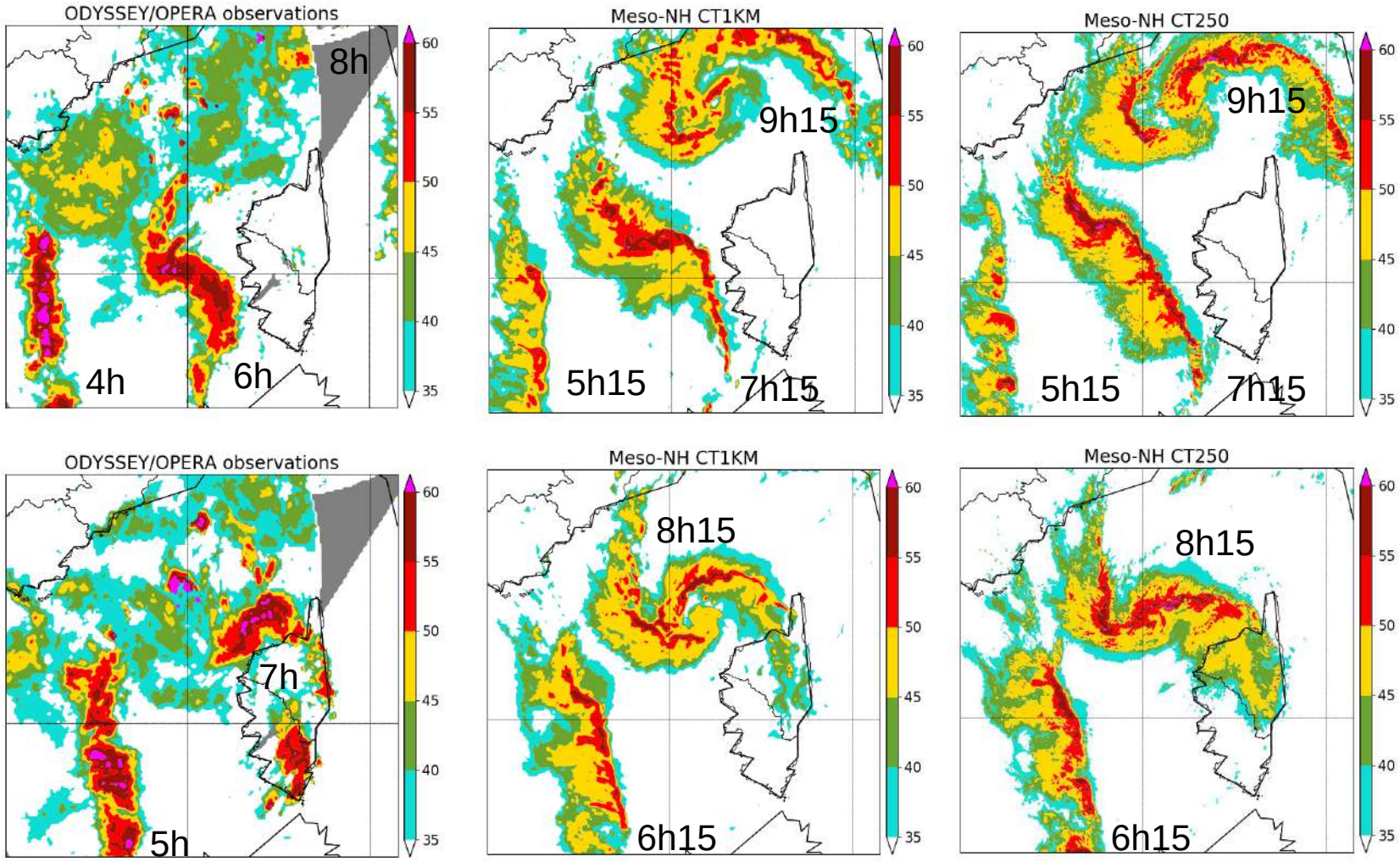
- **Realistic simulations of the Corsican derecho (with good initial conditions from AROME 00UTC)**
  - rapid displacement of the convective line
  - accentuation of the northern vortex, transition to a bow echo and winding
  - but with a delay and lack of the supercell to the north
  - gusts associated with dynamic (eddies) and thermodynamic aspects (cold pool under system)
- **More intense line and better chronology with Meso-NH compared with the more diffusive AROME (effective resolution)**
  - possible contribution from AROME 500 m
- **Meso-NH incubator for new parameterisations**
  - impact of turbulence on wind and gust intensity
  - impact of microphysics on reflectivity intensity and convective system extension
  - strong impact of resolution on line extension and gust intensity
- **Perpectives**
  - assessments to look more closely at the dynamic and thermodynamic aspects
  - tests on other physical parameterisations: marine surface schemes (ECUME, WASP, ….)
  - need of work on predictability issues

Thanks for your attention

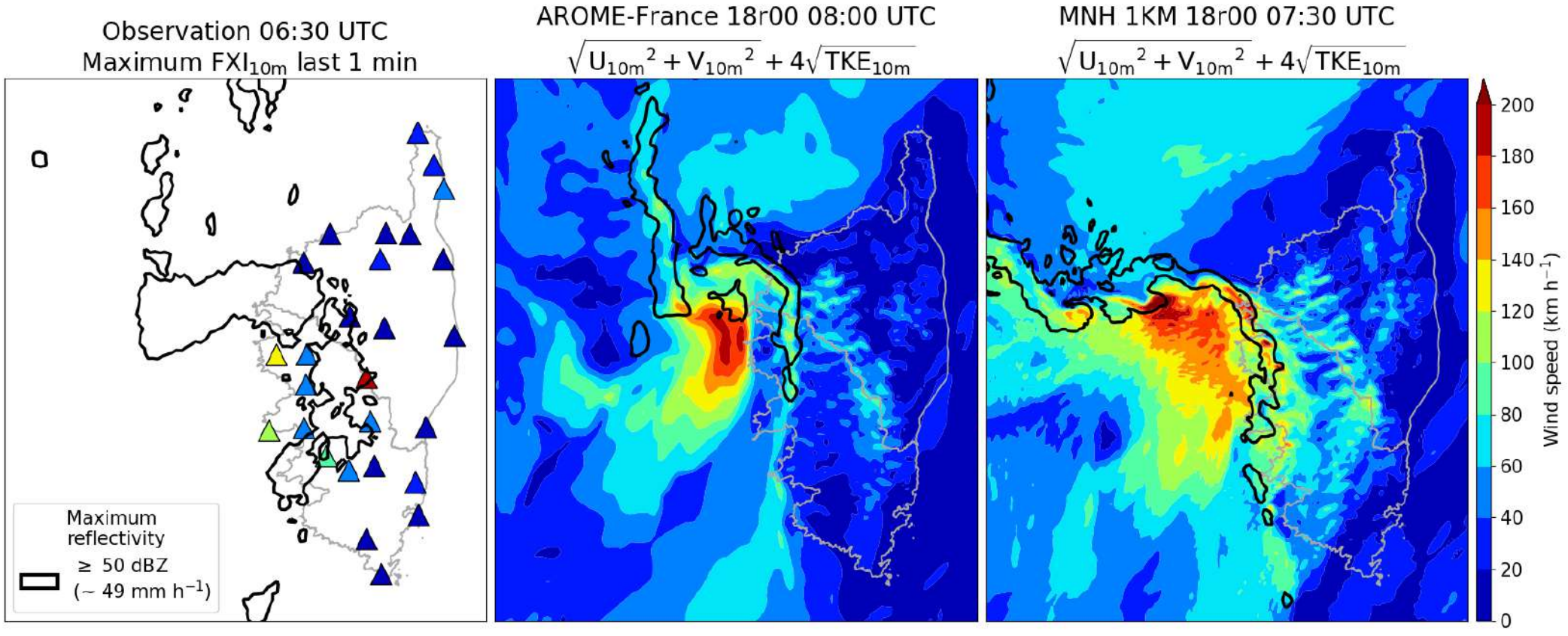


C. Strauss

Impact of horizontal resolution



Comparison Observations - AROME - Meso-NH



- Strong gusts associated with strong pressure gradients along the bow echo, its mesovortices and the northern bookend vortex
- Larger area of strong gusts in Meso-NH