ARPAL
Agenzia regionale per la protezione dell'ambiente ligure

MODELLISTICA ATMOSFERICA ARIANET A suez company

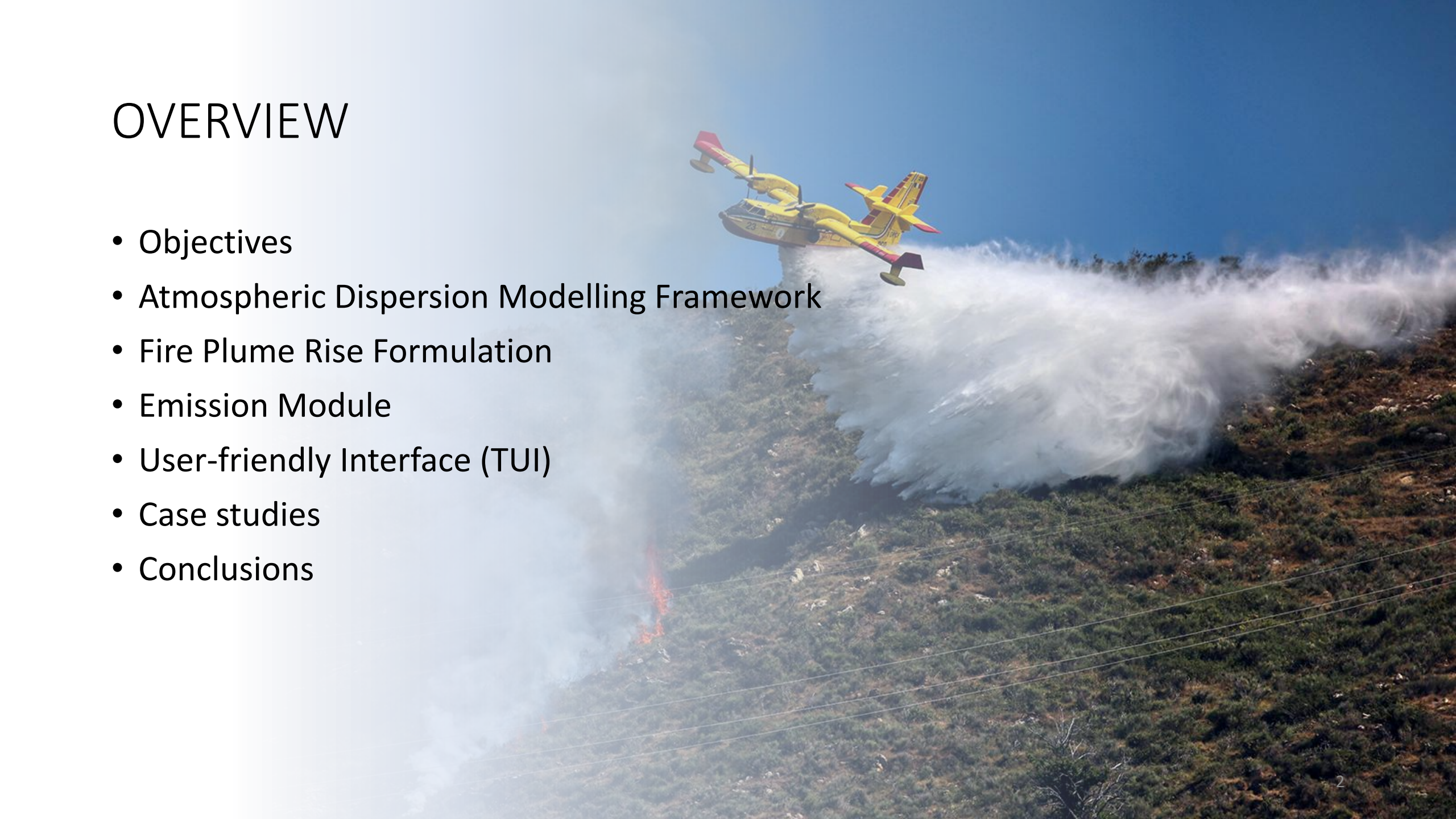
Operational forecast of fire smoke dispersion for emergency response in Liguria region

C. Righi, A. Bisignano, P. Oliveri, D. Barbero, G.L. Tinarelli

XIII Giornata della modellistica in ARIA(NET)

OVERVIEW

- Objectives
- Atmospheric Dispersion Modelling Framework
- Fire Plume Rise Formulation
- Emission Module
- User-friendly Interface (TUI)
- Case studies
- Conclusions



Objectives

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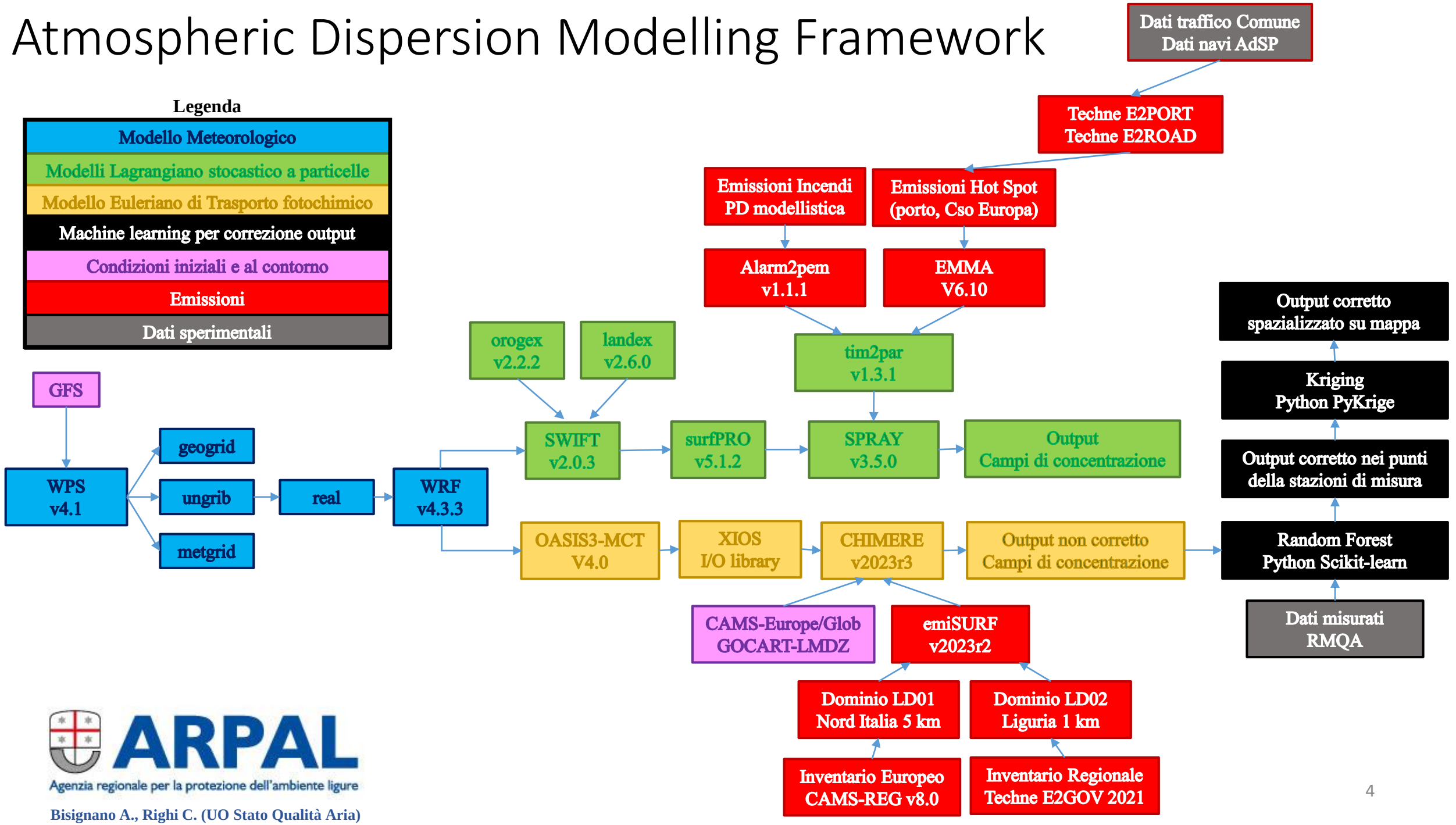
- Fires (industrial, waste, accidental) → high-impact air pollution events
- ARPAL's mandate: provide rapid response and assessment
- Challenge: limited time, data uncertainty, few trained modelers
- Develop an operational, user-friendly tool

Atmospheric Dispersion Modelling Framework



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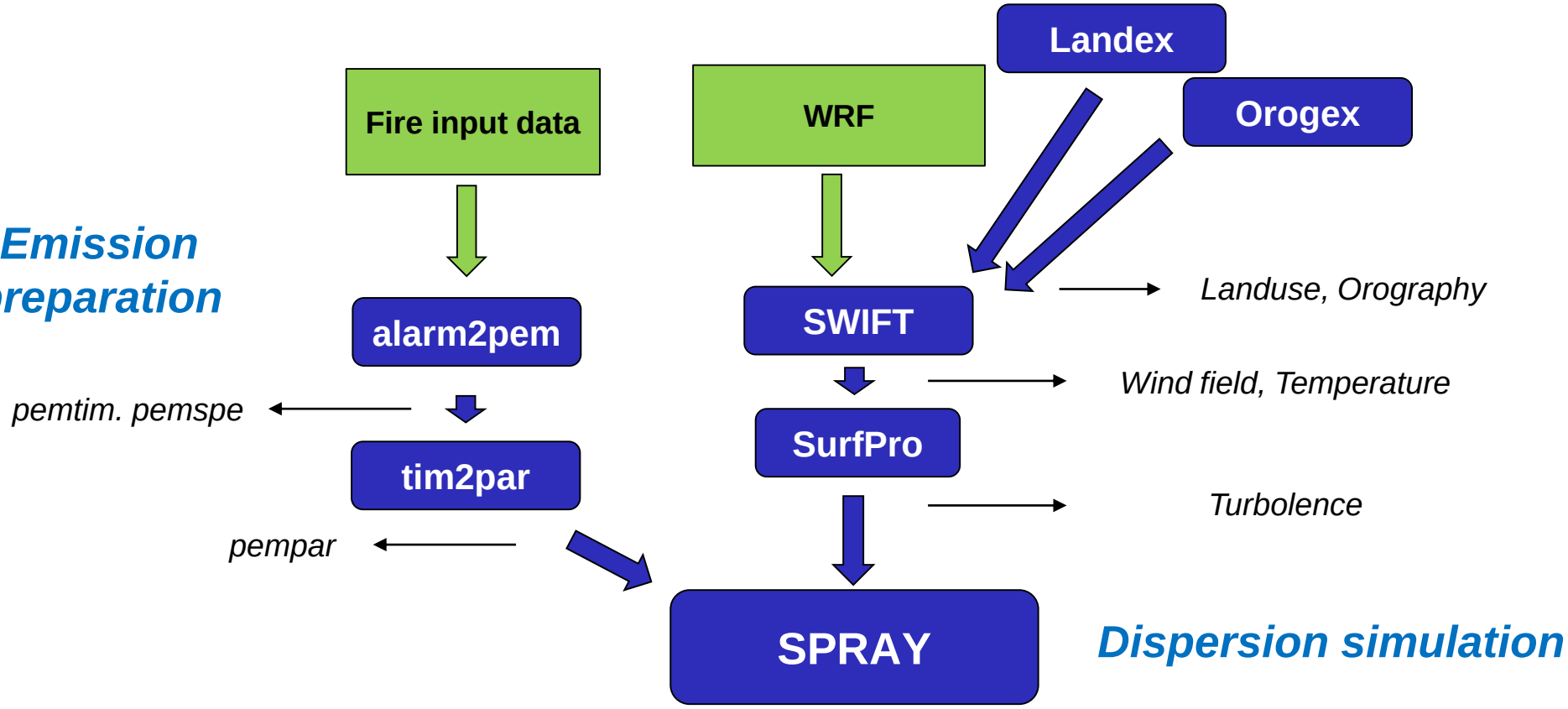
Bisignano A., Righi C. (UO Stato Qualità Aria)

Atmospheric Dispersion Modelling Framework



Fire Plume Rise Formulation

- Based on Mills (1987), extending Briggs
- Inputs: heat release rate (Q_h), radiative fraction, wind, air density
- Includes **smouldering phase** → persistent low plume near the source

$$F_b = g(1-\varepsilon)\, Q_h / \pi\, c_p \rho_a T_a$$

$$H_F = [H_B^3 + (r/\beta)^3]^{1/3} - r/\beta$$

with

$$H_B(x) = (3/(2\beta^2))^{1/3} F_b^{1/3} x^{2/3} U_a^{-1}$$

Buoyancy height

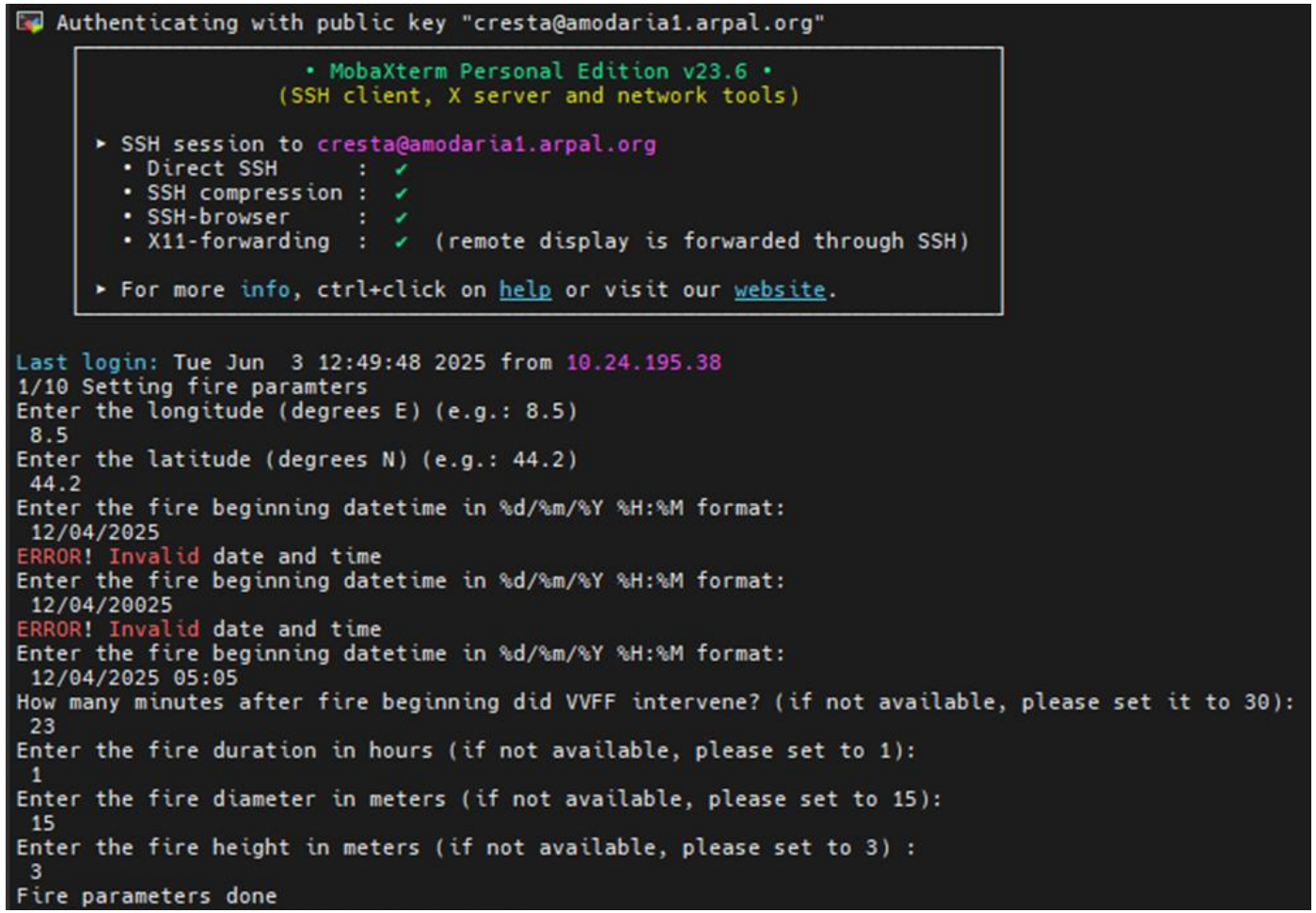
downwind distance

Buoyancy flux

Wind speed

Friendly TUI for the simulations execution

- Minimal text-based interface (TUI)
- SSH access for operators, requires only essential inputs (location, fire size, duration, firefighting time)



Friendly TUI for the simulations execution

- Real-time input validation → automatic launch of modelling chain
- Typical duration of the simulation ~15min

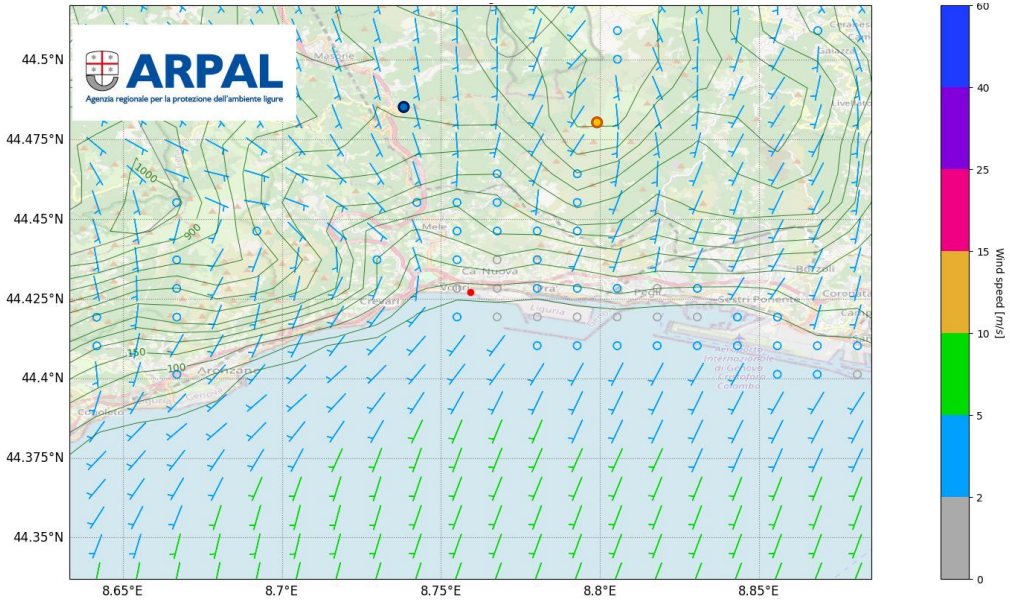
```
Fire parameters done
Simulation started: DON'T PRESS ANY KEY
sbatch -o "/home/fire-test/mylogs/spray_%x_%j.log" /home/fire-test/myscripts/pdrunAI3Dfire.sbatch
Submitted batch job 5929
2/10 Building orography ...
Orography done
3/10 Building landuse ...
Landuse done
4/10 Building WRF meteo input ...
... may take few minutes ...
WRF extraction done
5/10 Running swift (3D mass-consistent wind field model for downscaling)...
... may take few minutes ...
swift done
6/10 Running surfpro (calculation of parameters for turbulence and dry deposition) ...
surfpro done
7/10 Preparing fire emission input ...
Fire emission done
8/10 Executing spray simulation ...
... may take few minutes ...
spray simulation done
9/10 Producing plots ..
Plots done ..
10/10 Sending plot by email ..
Enter the email: andrea.bisignano@gmail.com
Email inviata con successo!
Email sent
End of simulation
Bye bye
```

Case studies

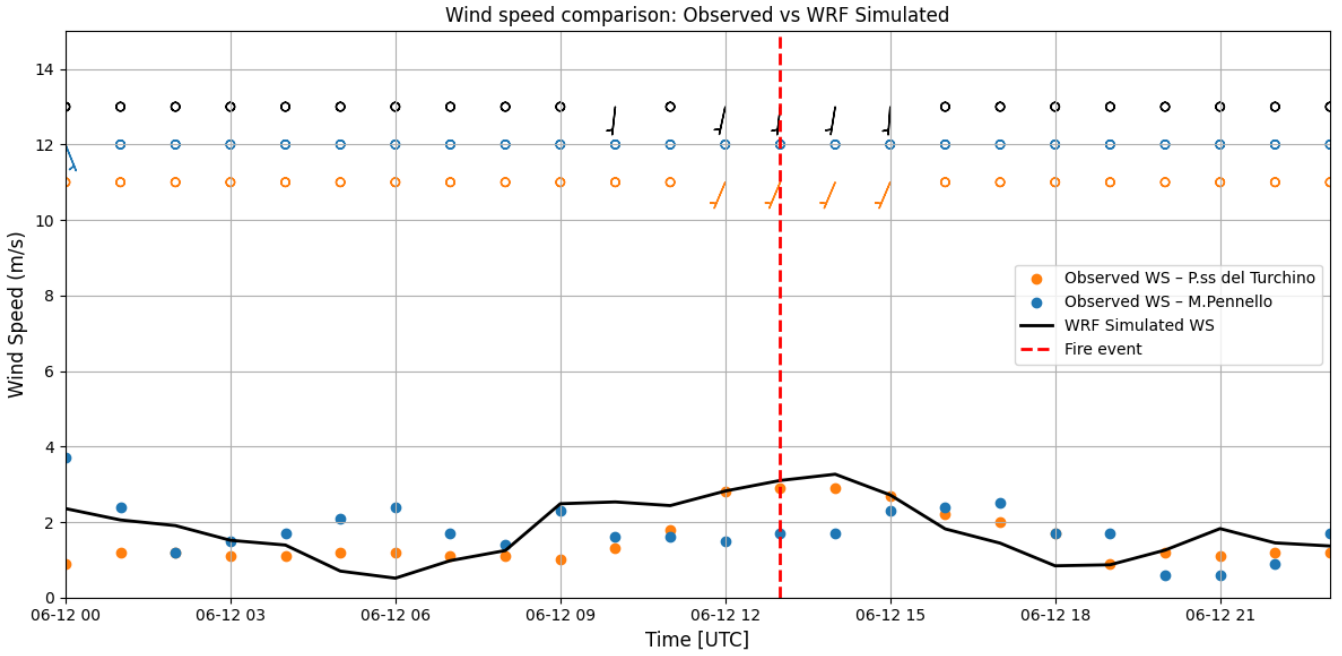
Voltri: 12/06/2025 13:00 UTC

- Fire at former **Costaguta shipyard (Voltri, Genoa)**
- Meteorological conditions: typical **daytime sea-breeze regime**, light winds (< 5 m/s)
- The smoke plume was clearly visible over the urban area and towards the port
- **Estimated plume top height** (from photo analysis): ~100–120 m above ground level

Voltri: 12/06/2025 13:00

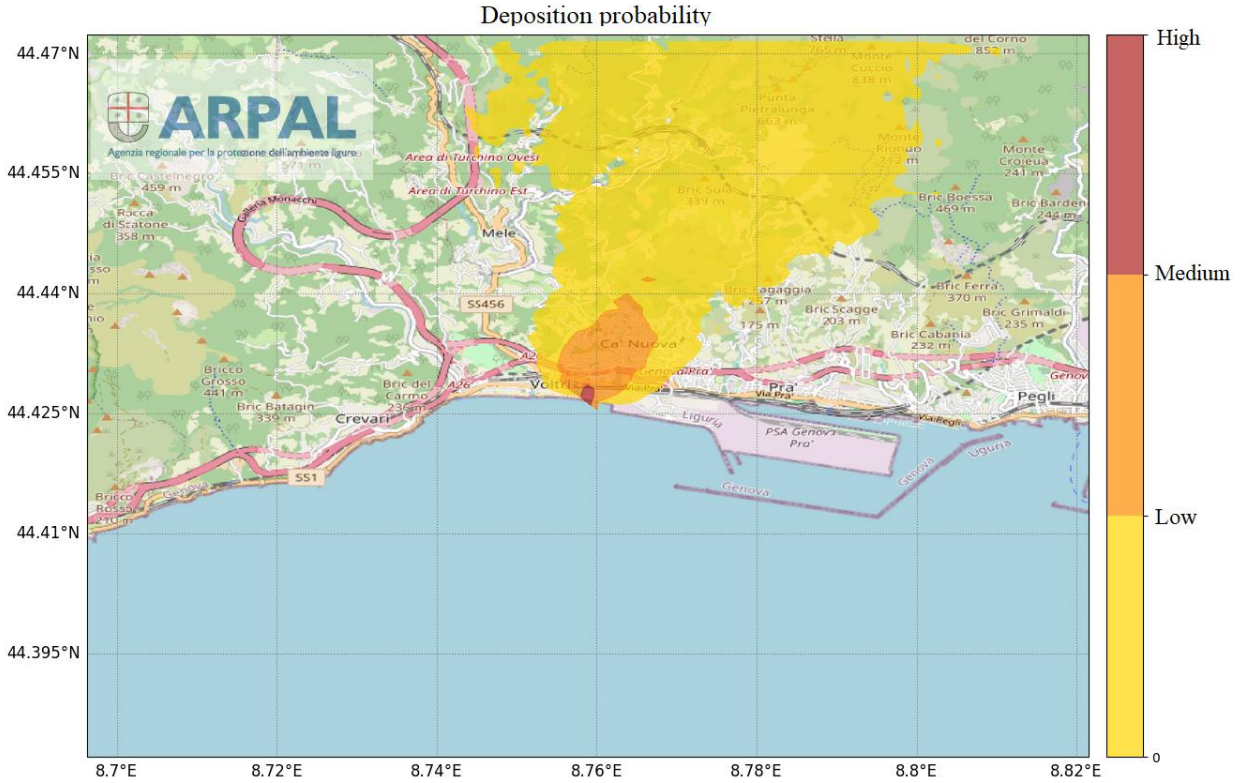


- Simulated meteo condition confirmed the meteorological condition (light wind);
- Closest weather stations compatible with s and observations (photo)



Voltri: 12/06/2025 13:00 UTC

- No increase from closest stations
- Compatible with observations

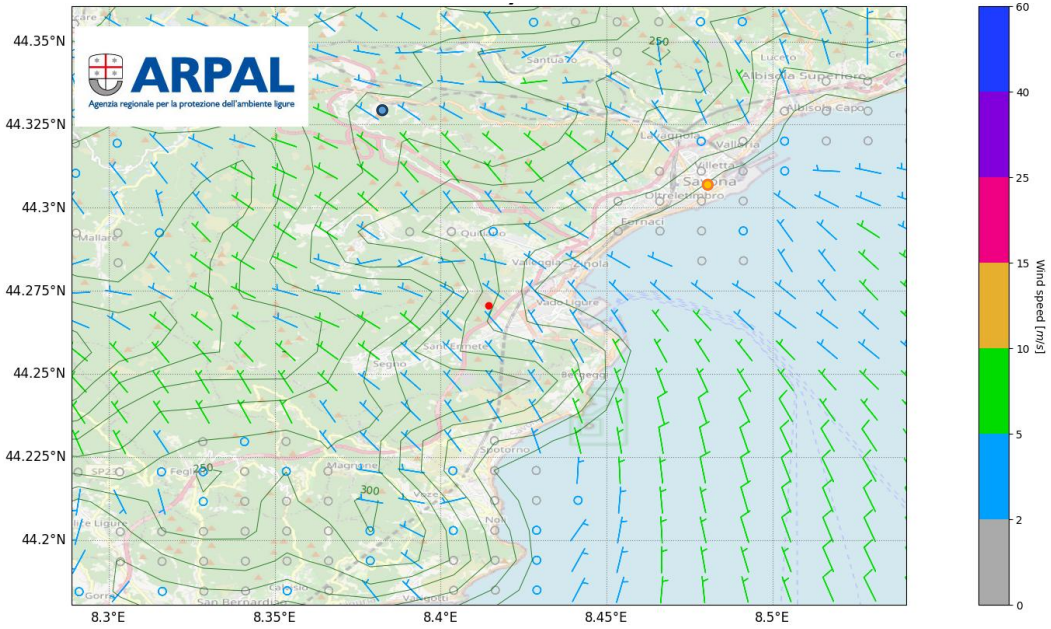


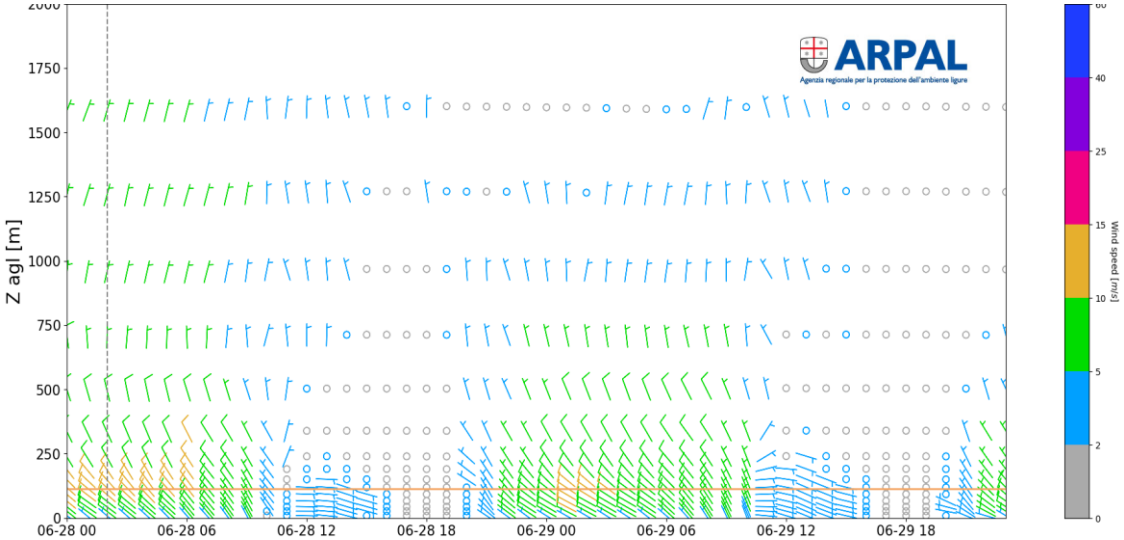
Bossarino: 28/06/2025 2:00 UTC

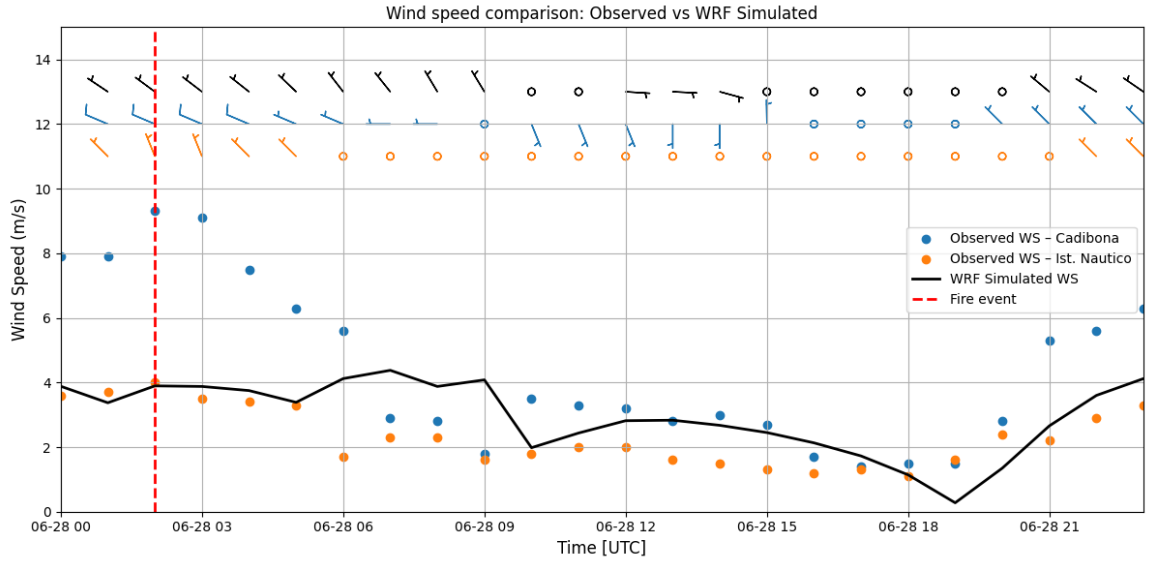
- Fire at **waste management facility (Bossarino site, Vado Ligure)**
- Meteorological conditions: **strong northerly synoptic flow**, wind speeds up to 15 m/s
- **Estimated plume top height** (from photo analysis): ~100–120 m above ground level
- Outputs from modelling: deposition footprint stretched southwards over the coastal area and offshore

Bossarino: 28/06/2025 2:00

- Synoptic flow above







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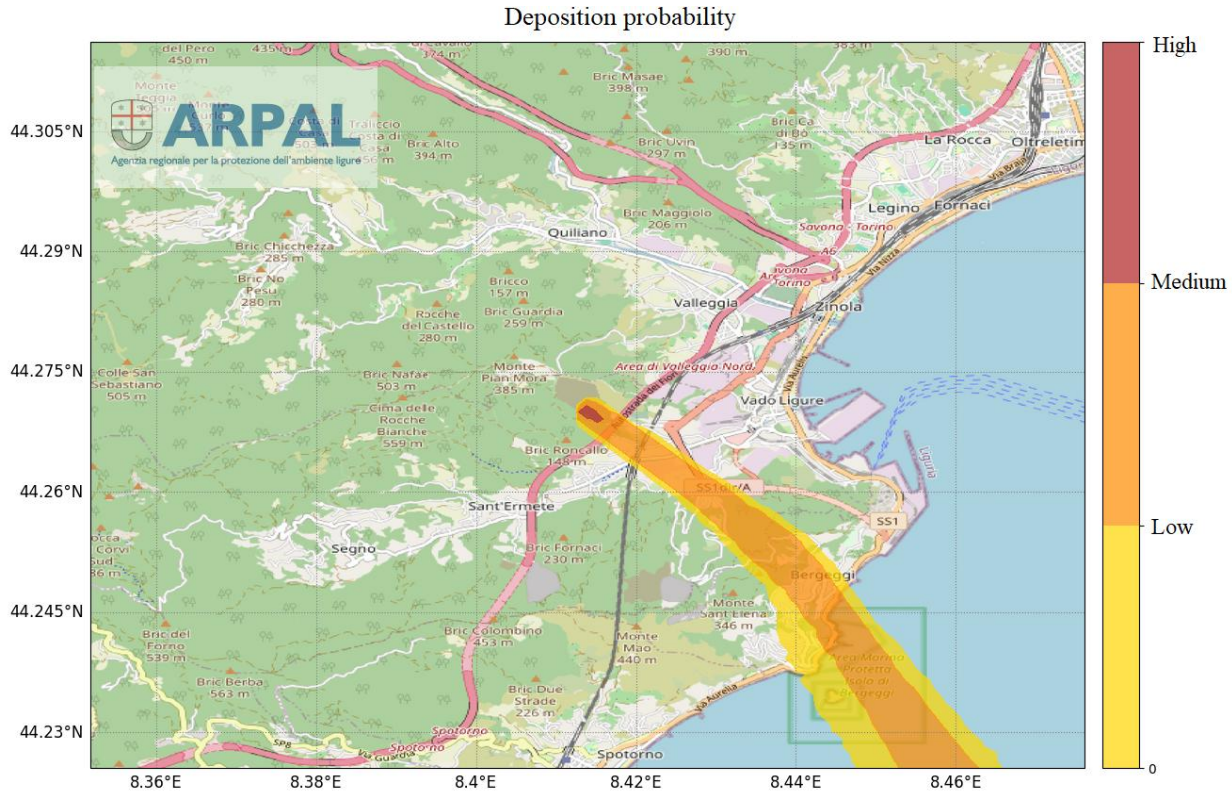
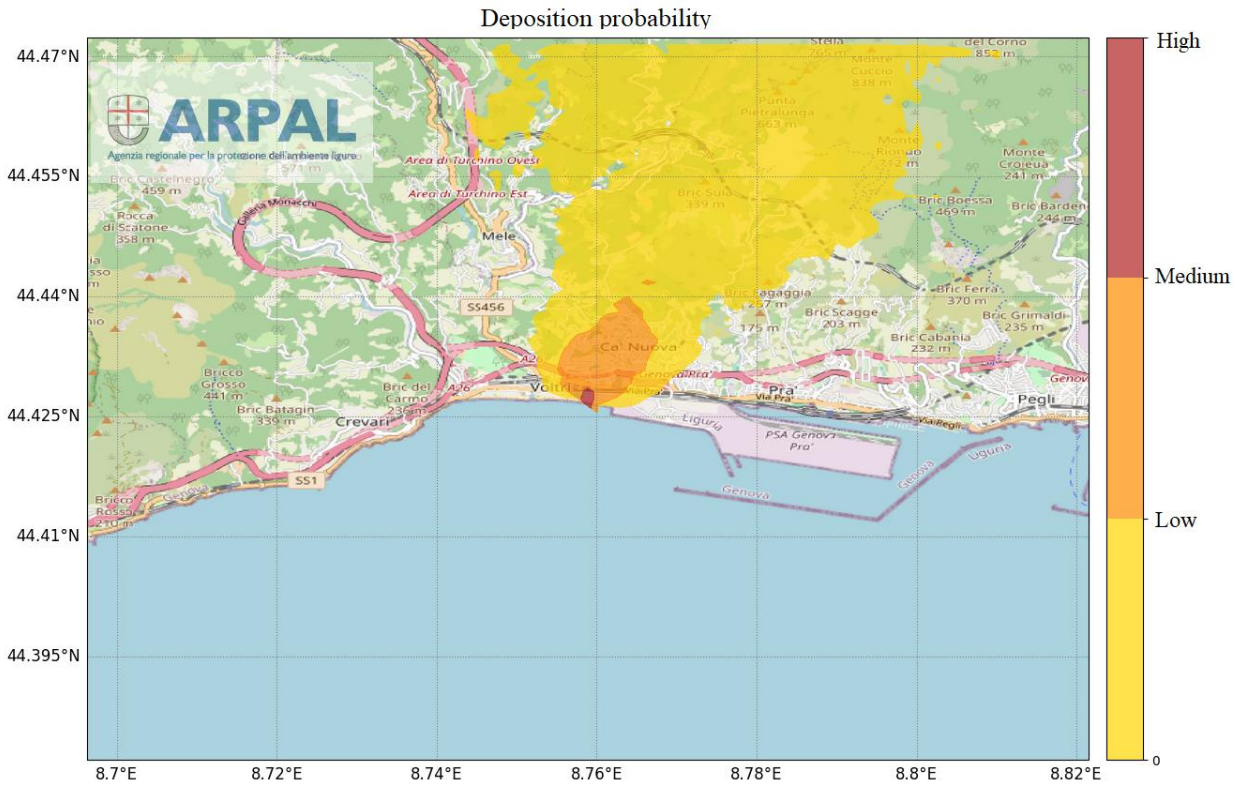
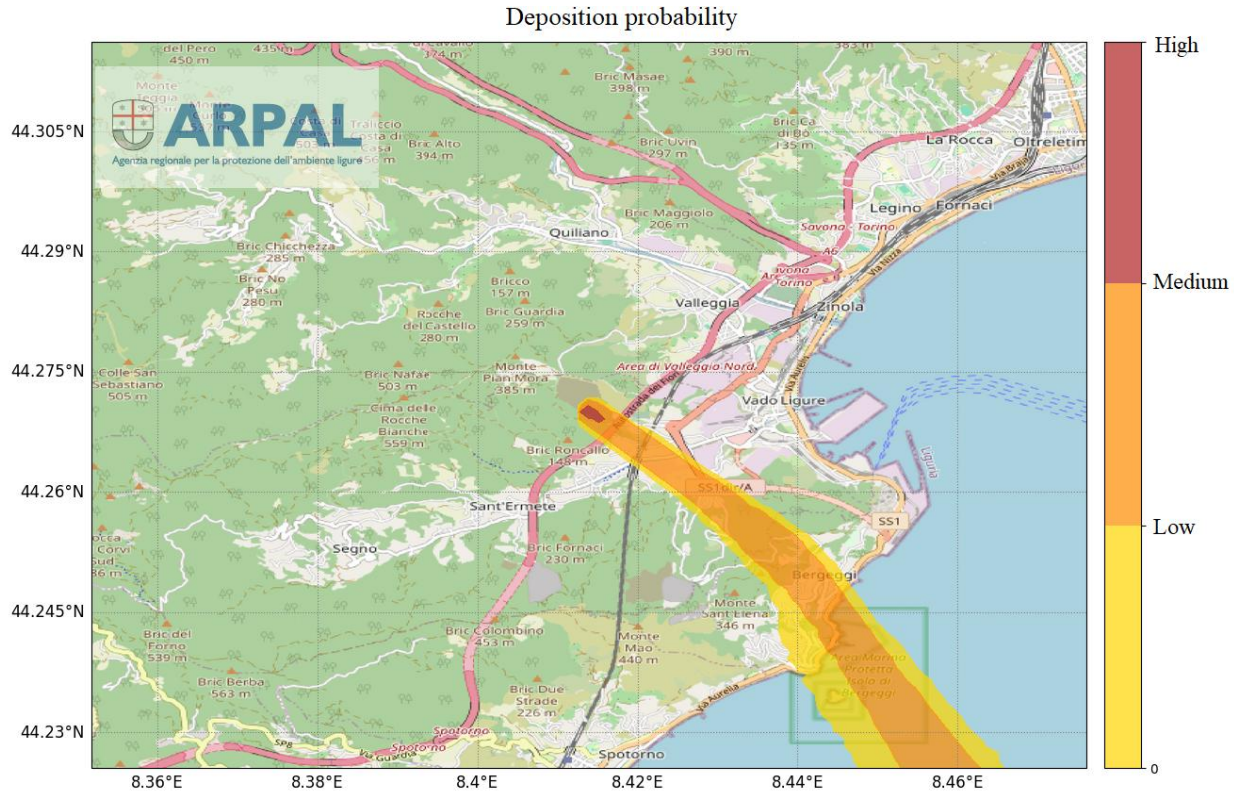


Case studies: models comparison



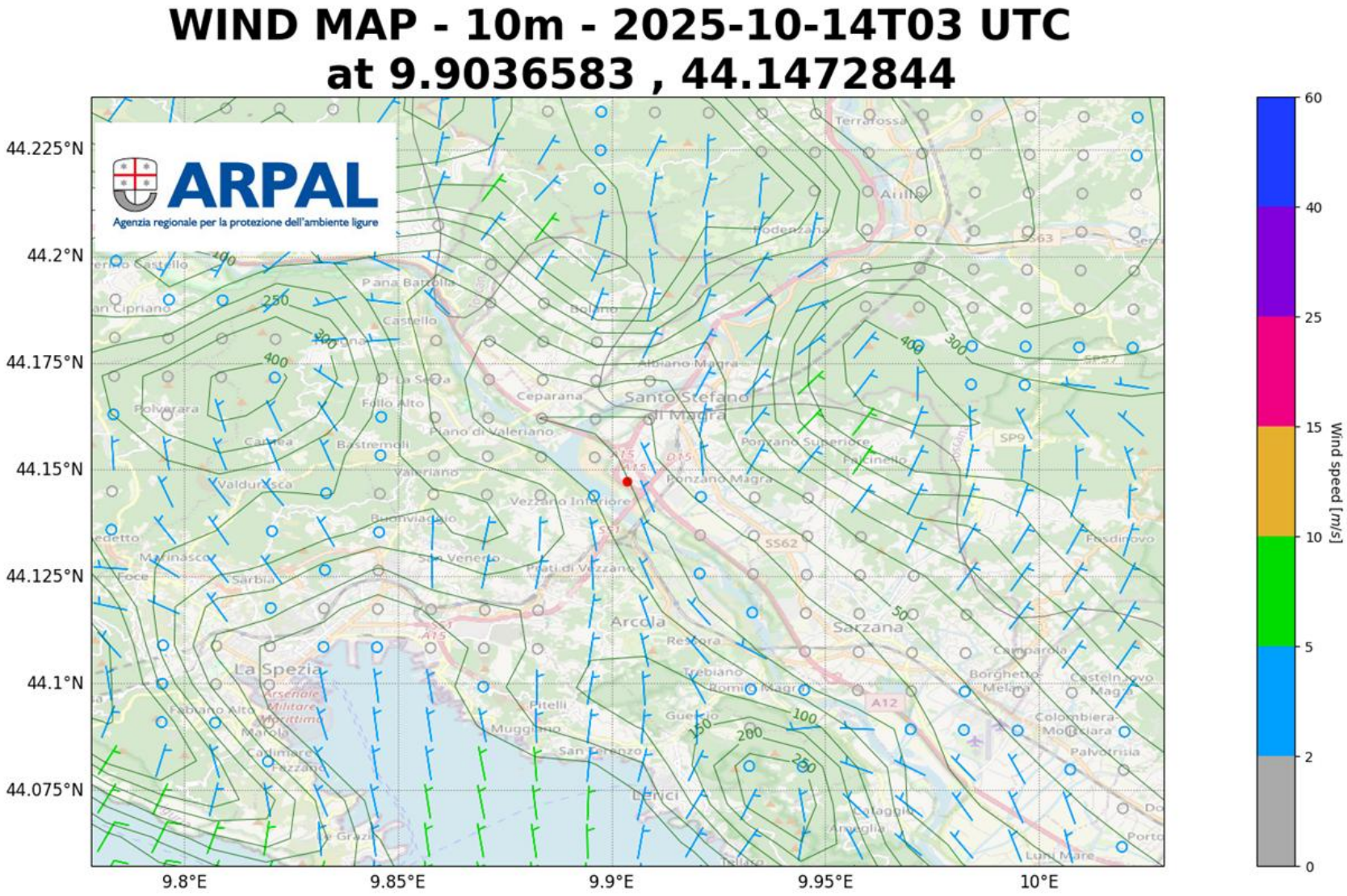


- Weak winds under a **sea-breeze regime**
- Turbulent diffusion (both vertical and horizontal) contributes significantly
- Result: **wider, more dispersed plume**

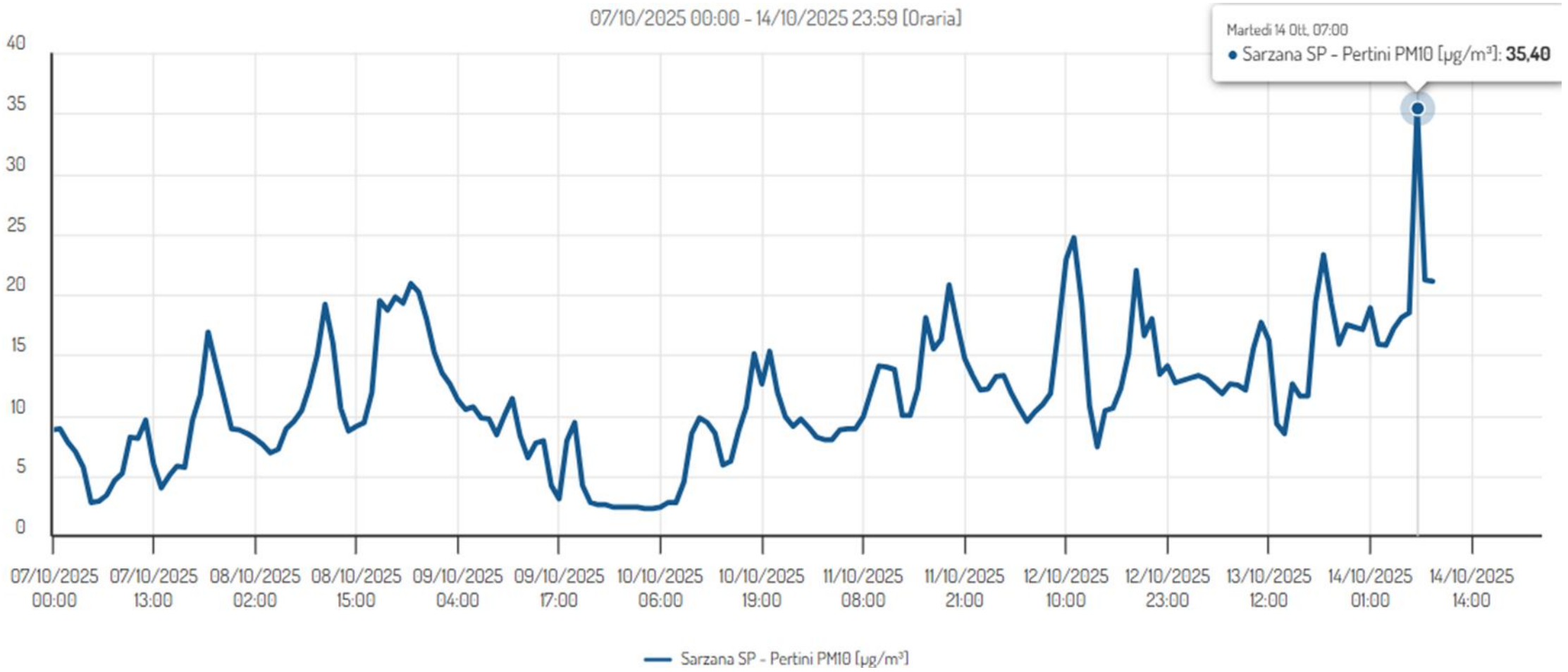
- Stronger **synoptic northerly flow** (> local sea breeze)
- Transport (mean wind) dominates over turbulent diffusion
- Result: **elongated, narrow plume**

Vezzano: 14/10/2025 3:30 UTC

- Fire at waste management facility (Reco spa, Vezzano Ligure)
- Very complex local circulation



Vezzano: 14/10/2025 3:30 UTC



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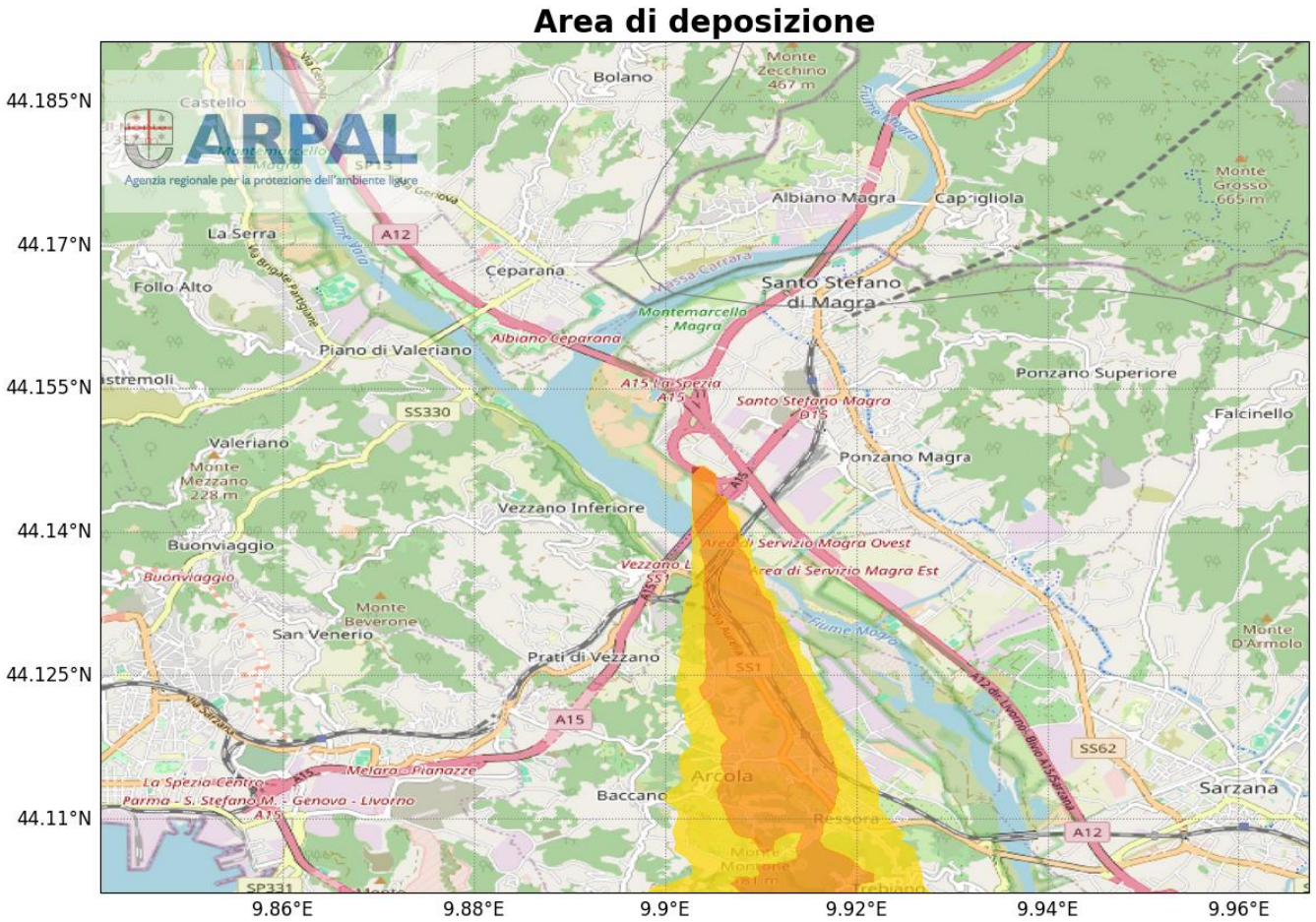
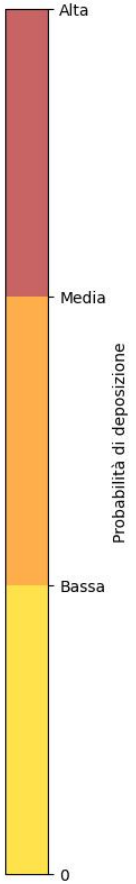
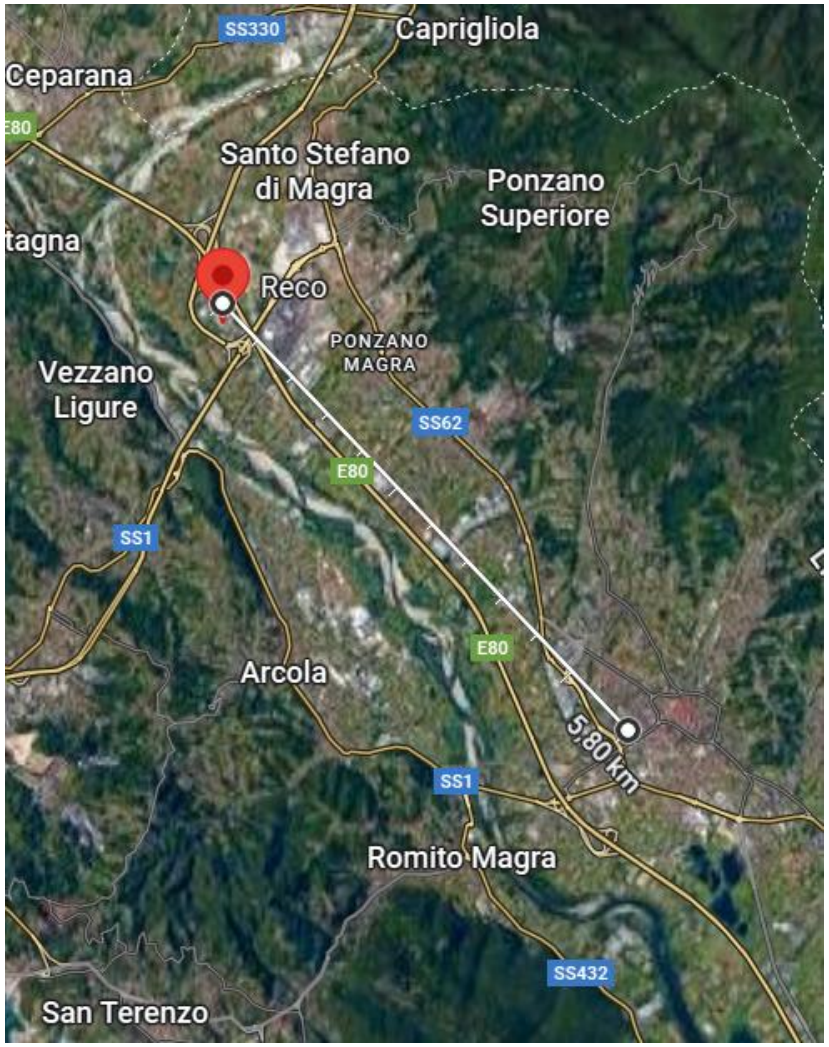




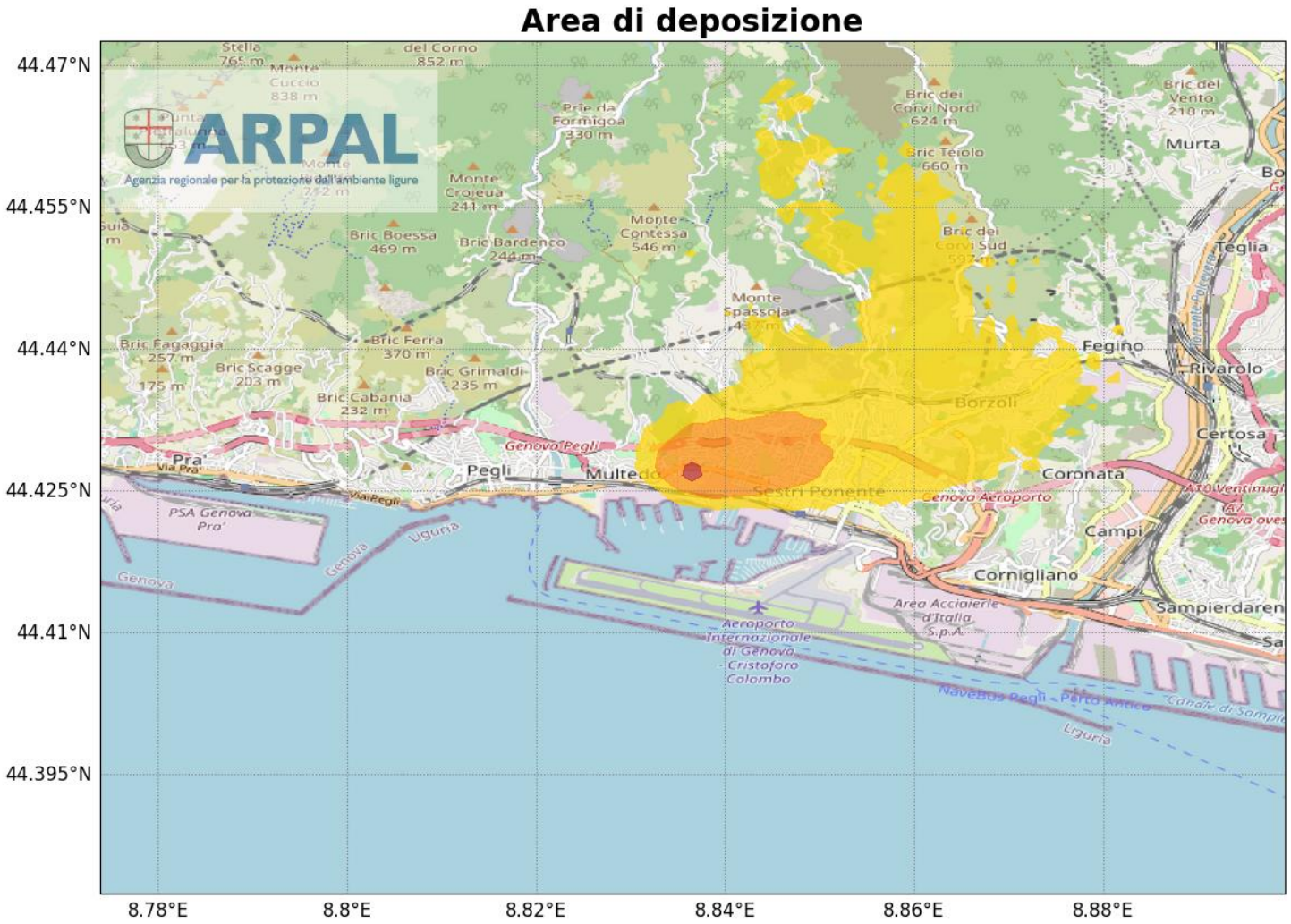
Il risultato della simulazione modellistica WRF-SPRAY consiste in una mappa qualitativa della deposizione al suolo, calcolata come frazione dell unità idealizzata di massa emessa (non è noto il rateo emissivo effettivo) ed espressa come probabilità di deposizione; si tratta della zona in cui è più probabile la ricaduta delle particelle di fuliggine prodotte dall incendio.

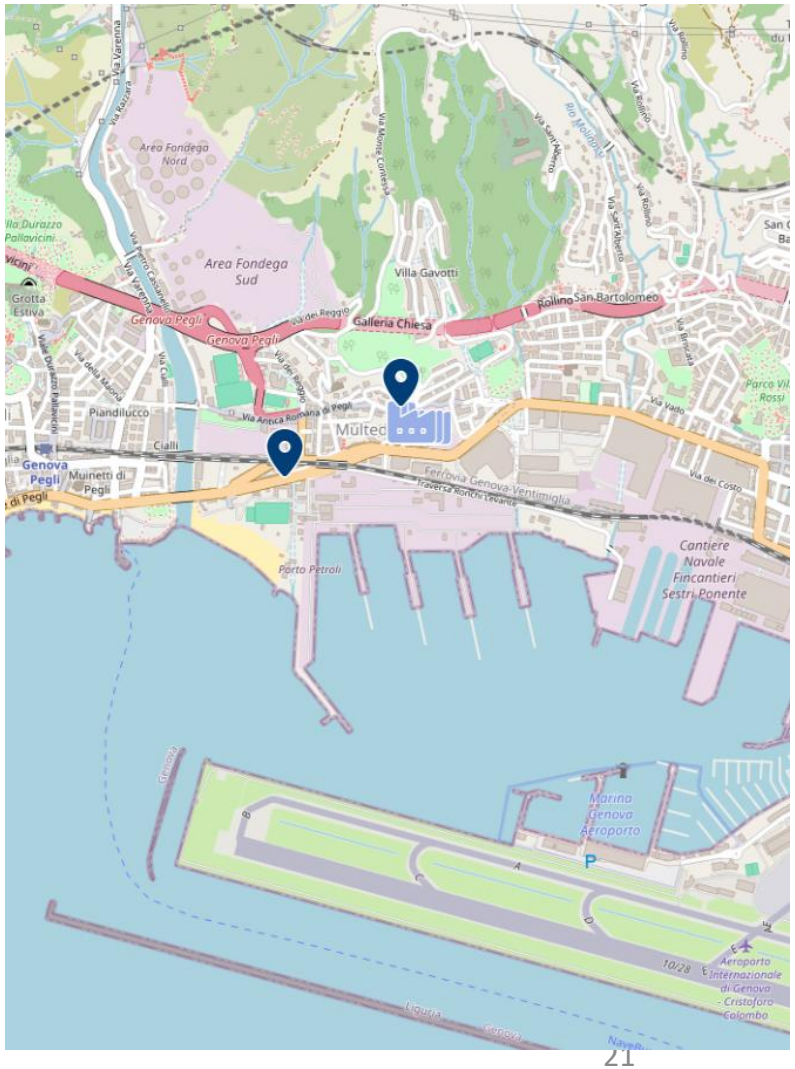


Genova Sestri Ponente: 29/12/2025 13:50 UTC

- Fire at an electrical engineering company
- Urban environment
- Very low wind with varying direction

Genova Sestri Ponente: 29/12/2025 13:50 UTC





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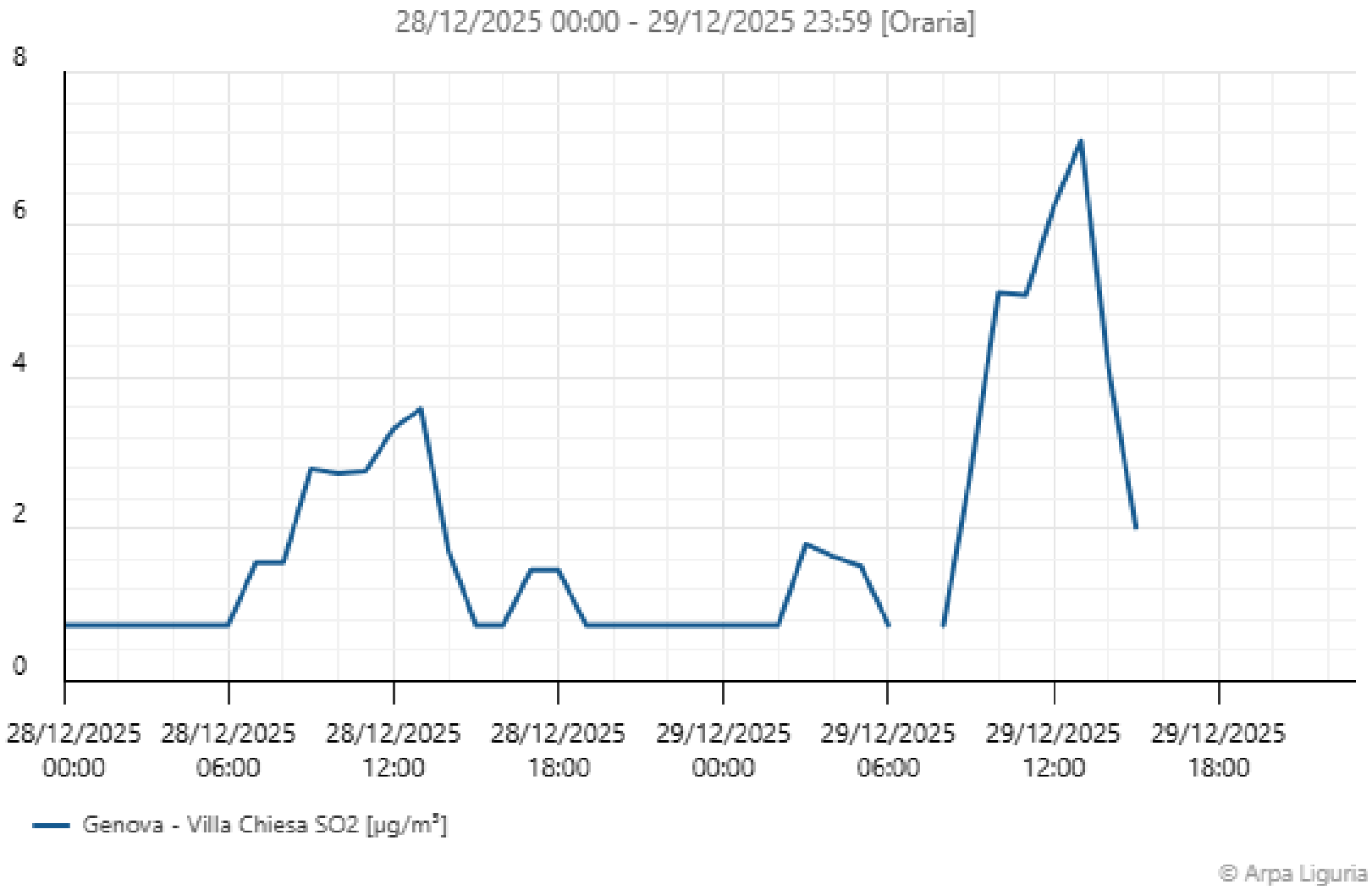

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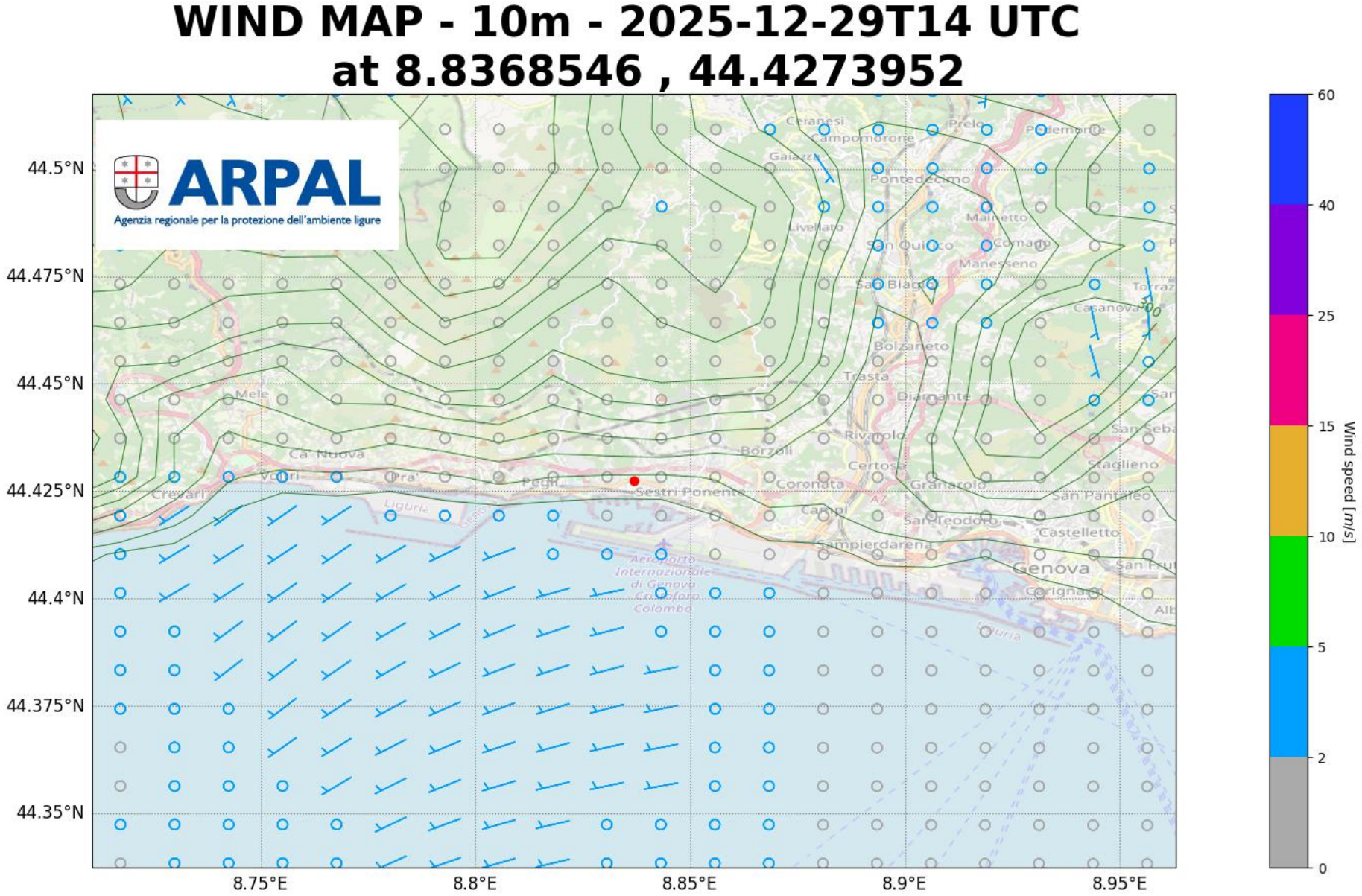
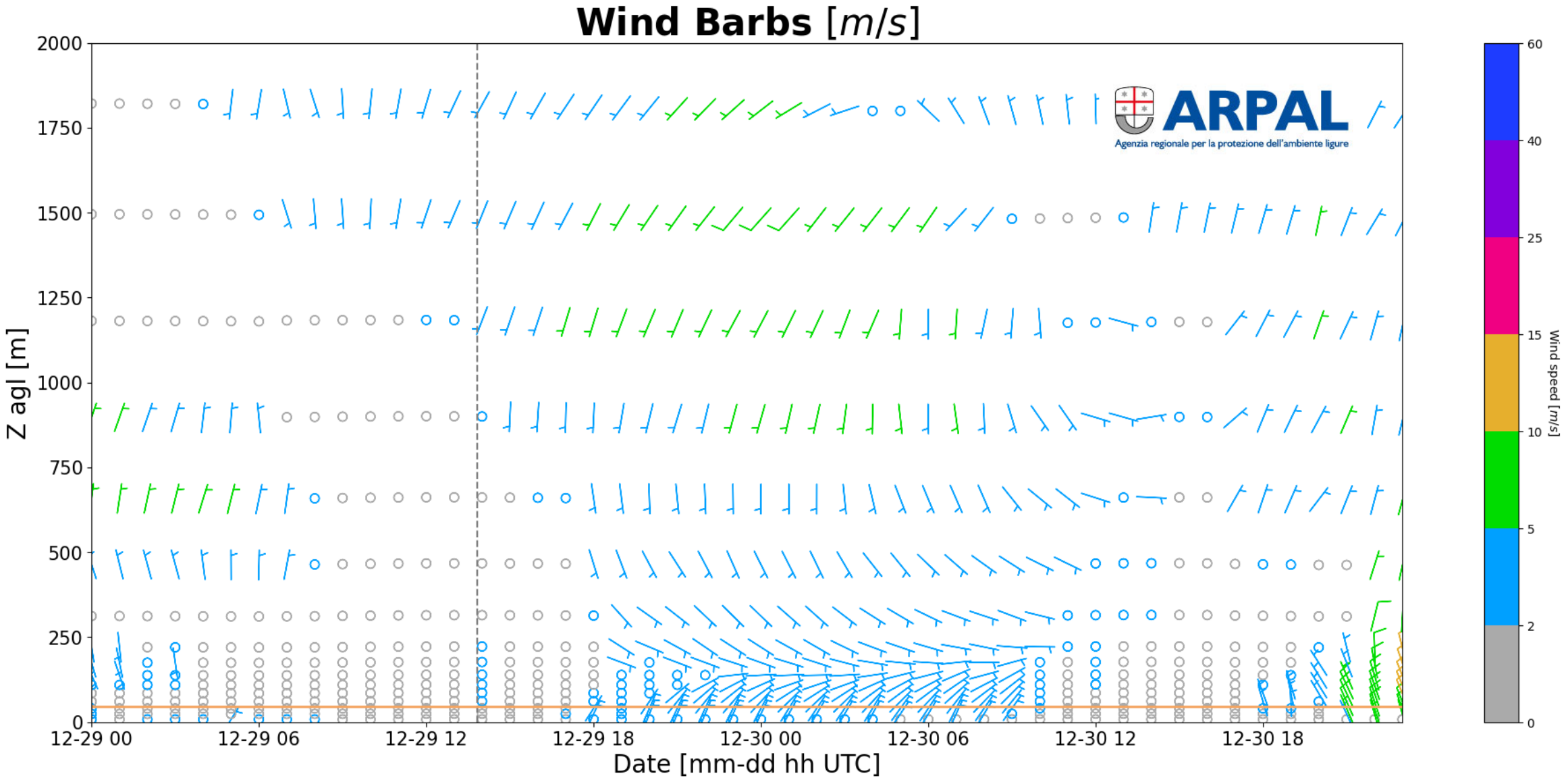


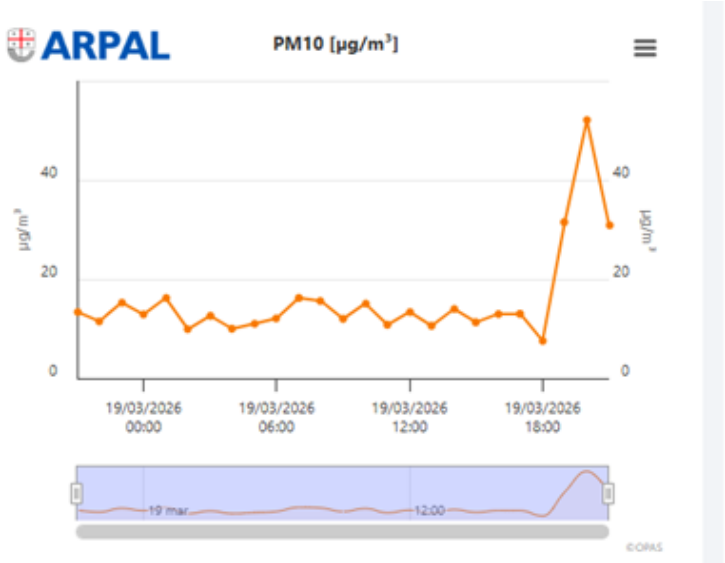
Genova Sestri Ponente: 29/12/2025 13:50 UTC

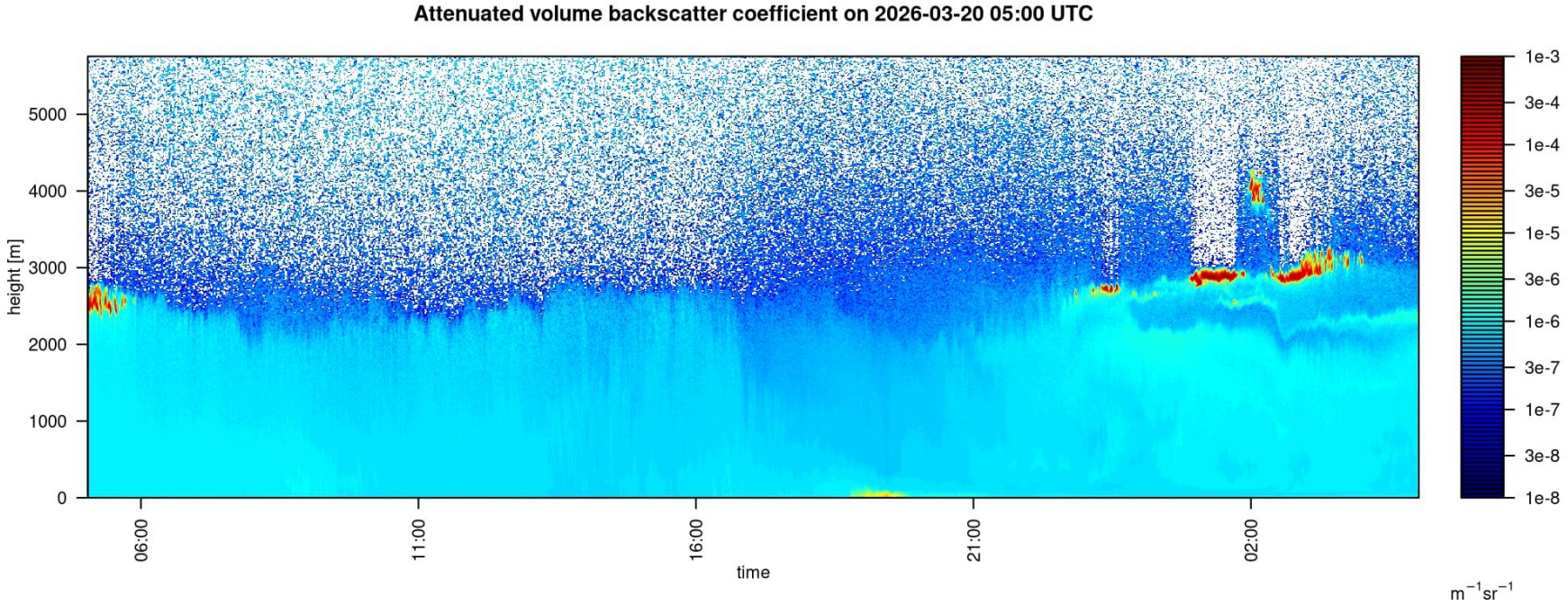


Genova Borzoli: 19/03/2026 19:30 UTC

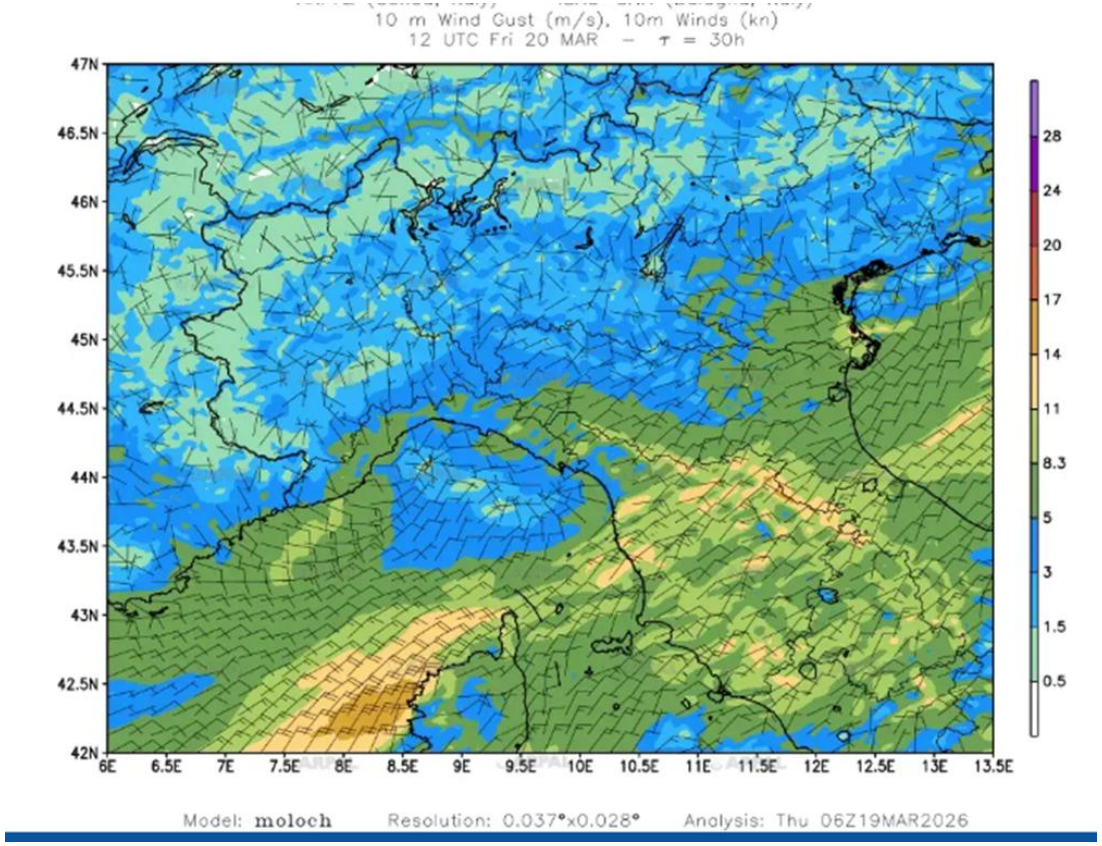
- Landfill fire
- Moist woody material
- Incomplete combustion
- Slight temperature inversion

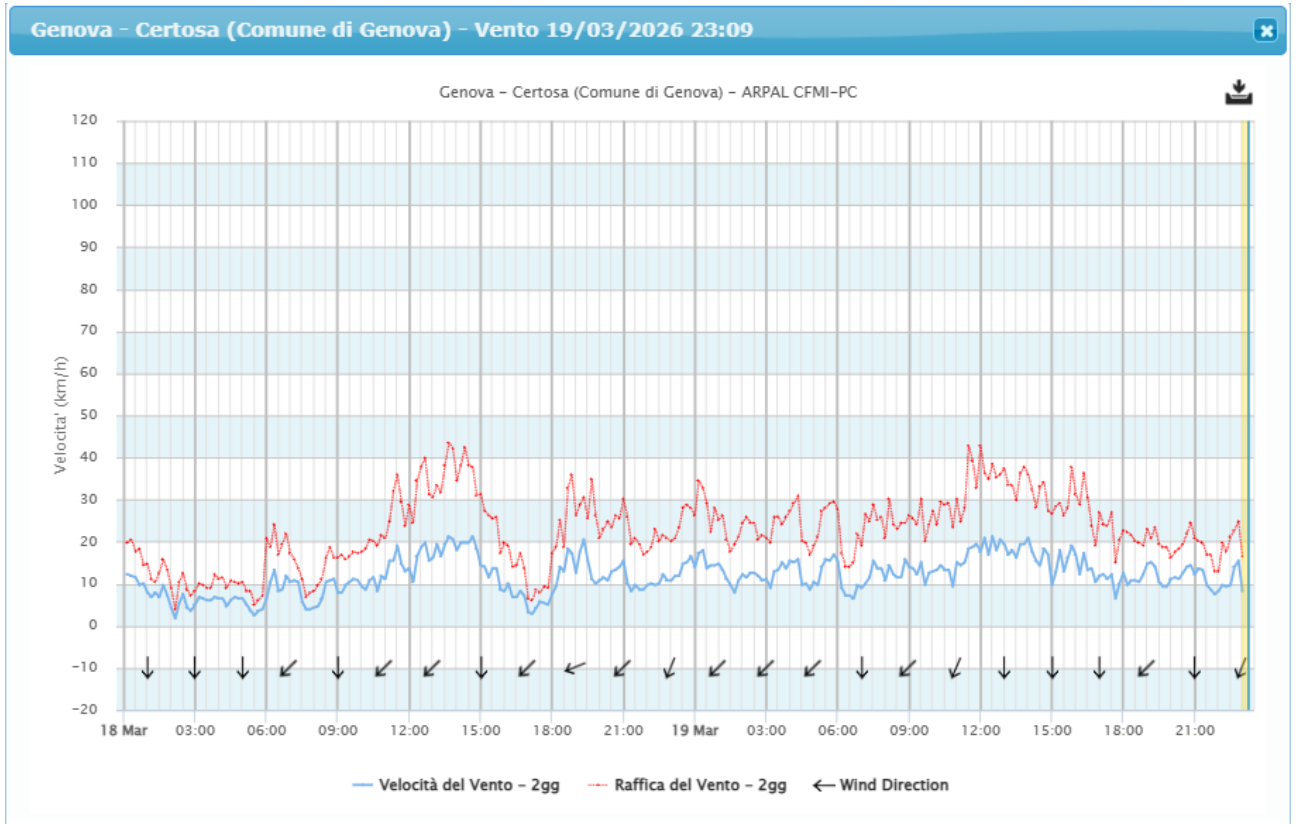
Genova Borzoli: 19/03/2026 19:30 UTC





Genova Borzoli: 19/03/2026 19:30 UTC





Conclusion

- Operational system enables **rapid identification of exposed areas**
- Usable by non-specialist operators
- Limitations: high input uncertainty, need for continuous validation
- Effective tool for emergency response and civil protection
- Next steps:
  - Automated fuel module
  - Photogrammetric validation
  - Extension to multiple case studies