A novel approach for tracing the origin of odour nuisance with SMART meteo-dispersive modelling system

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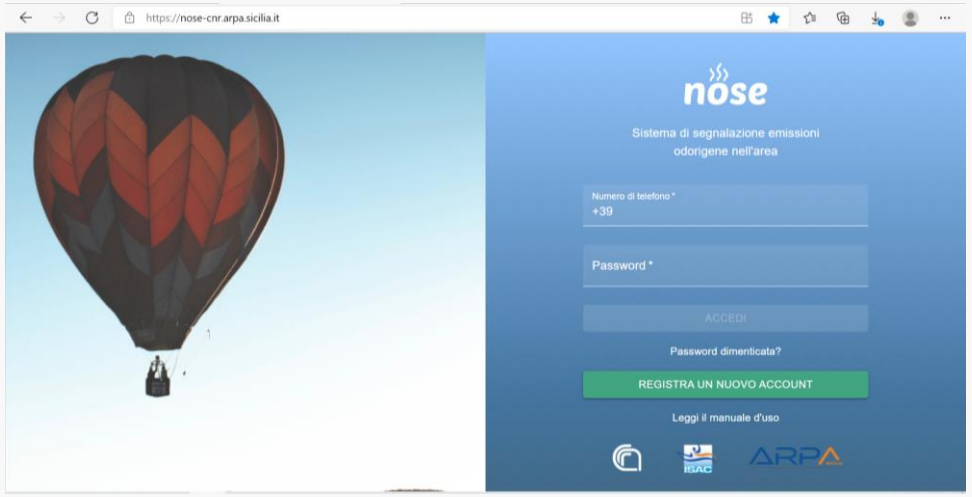
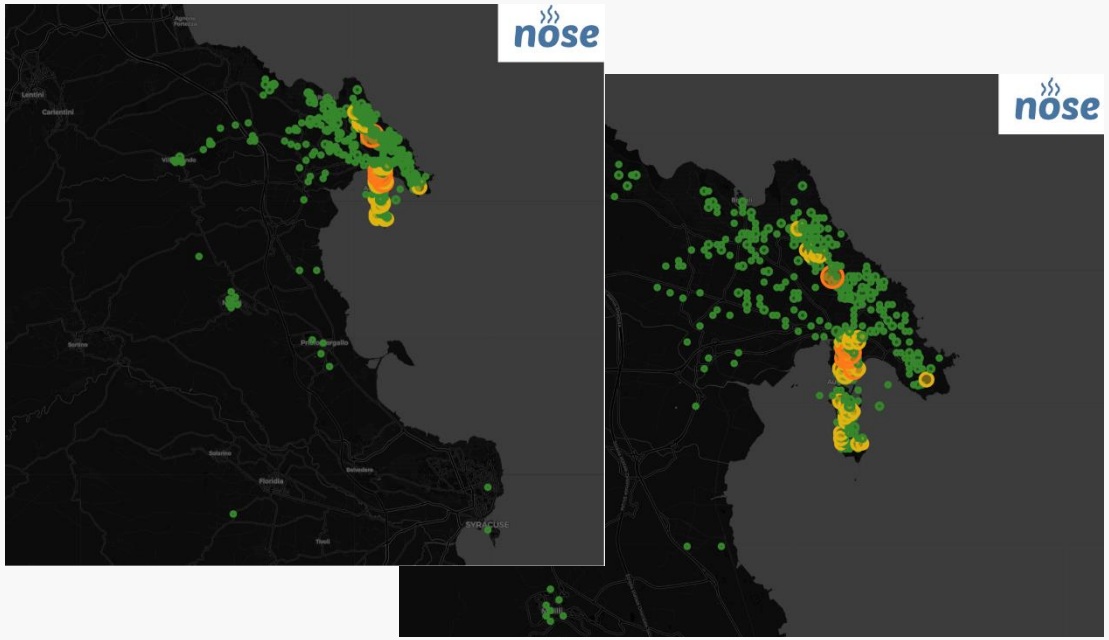
CNR-ISAC *ARIANET* *ARIANET* *CNR-ISAC* *CNR-ISAC* *CNR-ISAC*

Harmo21 – Aveiro, Portugal – 27-30 September 2022

The Web-App and the modelling system

An alert-system, **NOSE - Network for Odours Sensitivity** has been realized by CNR-ISAC and ARPA Sicilia with the aim of tracking episodes of odour nuisance, through a **citizen-science** approach





(https://nose-cnr.arpa.sicilia.it/)

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The Web-App and **the modelling system**

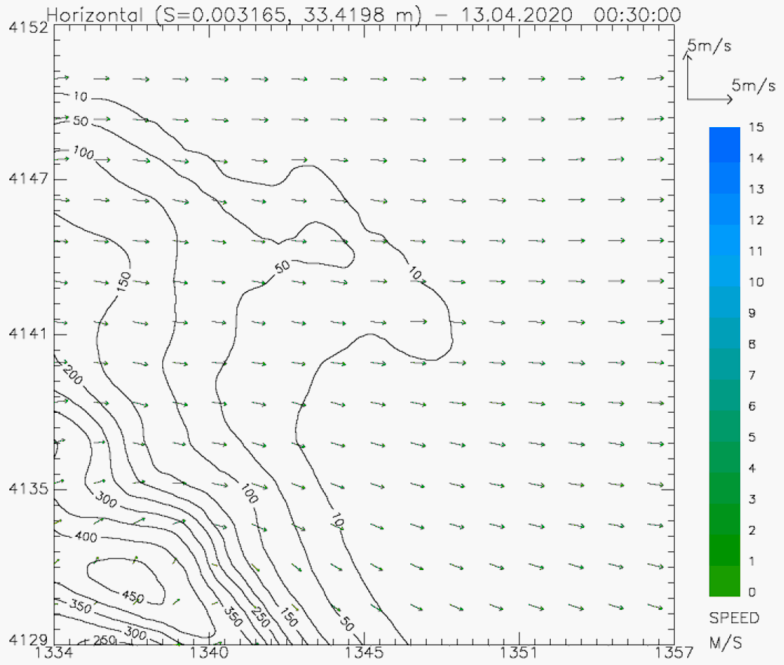
Improvements of the modelling module in NOSE are in process with the integration of the meteo-dispersive modelling suite **SMART** (Spray-Moloch Atmospheric Regional Tool) recently developed.

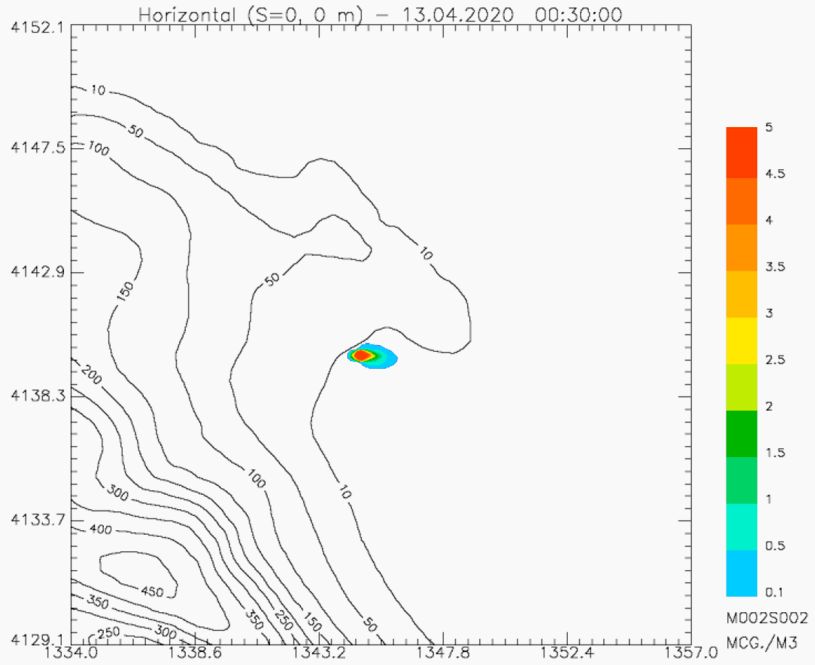
SMART

MOLOCH
MOdello LOCale coordinate H

ARAMIS
Atmospheric Regional Algorithm for Moloch Interfaced to Spray

SPRAY
Lagrangian particle dispersion model





New and original developments are in progress for **SPRAY** Lagrangian particle dispersion model, starting from a version of the model that includes the option for back-trajectories, **RetroSPRAY**

The NOSE Case Study: April 13, 2020

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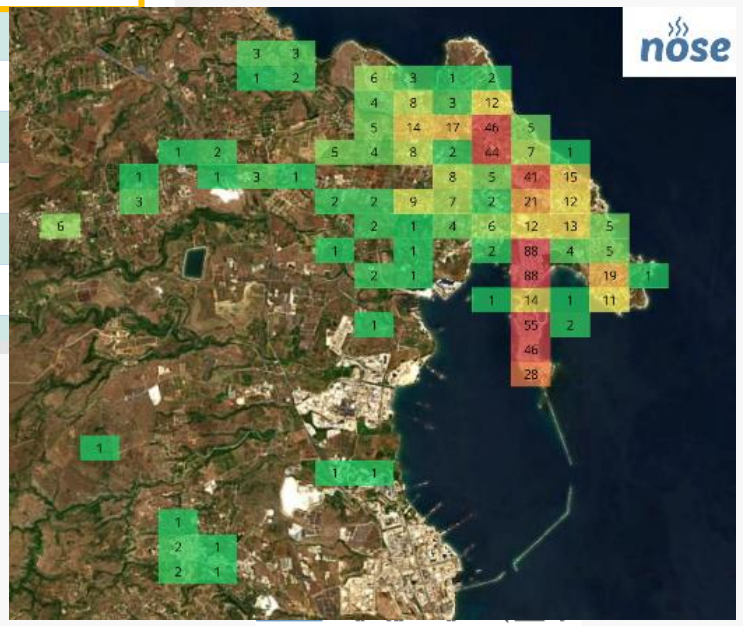
Report giornalieri

Data	Augusta	Floridia	Melilli	Priolo	Siracusa	Solarino
2020-04-17	2	0	2	4	5	0
2020-04-16	1	0	0	0	1	0
2020-04-15	1	1	0	1	1	0
2020-04-14	16	1	1	1	4	0
2020-04-13	801	1	28	8	2	0
2020-04-12	0	0	1	1	11	
2020-04-11	2	0	2	6	25	
2020-04-10	1	1	6	2	19	
2020-04-09	2	1	13	13	21	
2020-04-08	0	0	0	0	6	
2020-04-07	0	0	0	0	4	
2020-04-06	0	0	0	0	2	



8-12 AM on 13/04/2020
The clustering in NOSE Web-App

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RetroSPRAY: the location of an unknown source is generally estimated from **concentration observations** with two approaches:

- ✓ by identifying areas with maximum spatial and temporal consistency among backward trajectories from each sensor;
- ✓ through a variational method to minimize the objective function at each grid-box reached by backward trajectories, providing information on the source location and related uncertainty.

The **new challenge** is using the signals from citizens – that are qualitative and subjective – in place of observed concentrations as input receptors for **RetroSpray**.

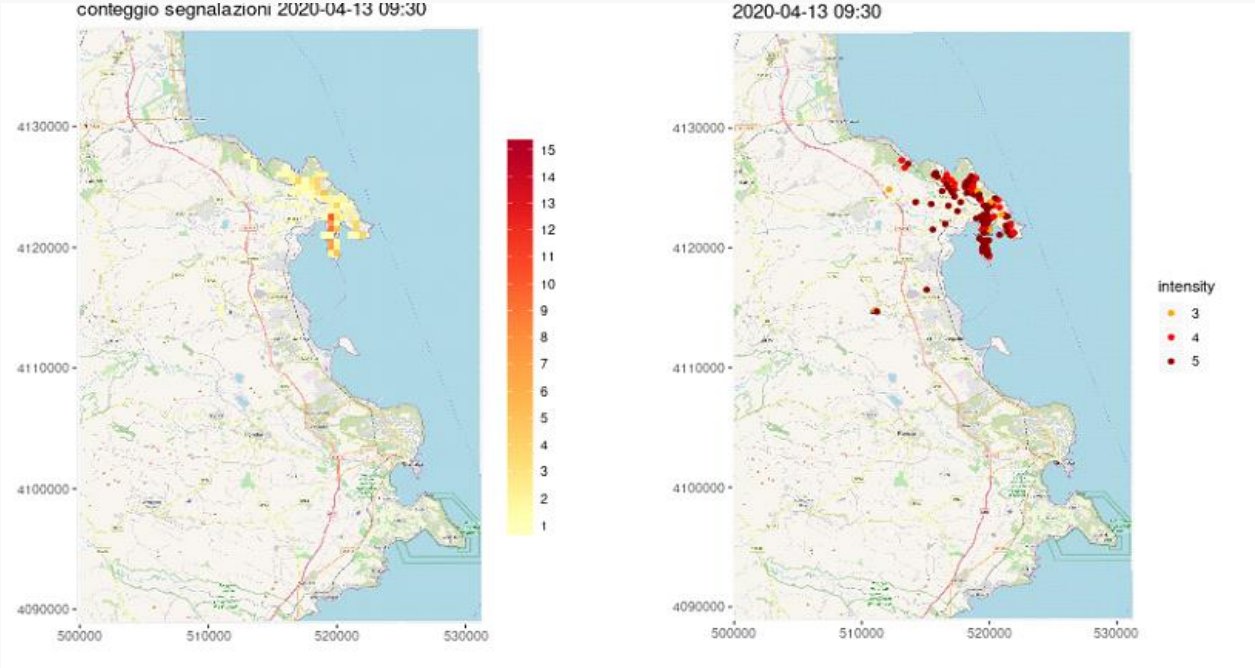
Date	lat	lon	region_name	intensity	perceived_smell_id	perceived_smell_name	disturbs	other	mal_di_testa	bruciore_irritazione_alla_gola	prurito_irritazione_al_naso	bruciore_agli_occhi_occhi_rossi	illness_comment
13/04/2020 23:08	37,2677	15,1783	Augusta	3	2	Idrocarburi	Mal di testa, Bruciore agli occhi/occhi rossi	0	1	0	0	1	
13/04/2020 22:56	37,2553	15,1962	Augusta	5	3	Zolfo	DifficoltÃ di respiro, Bruciore/irritazione alla gola, Mal di testa	1	0	0	1	1	Non si resprira
13/04/2020 21:15	37,2746	15,1879	Augusta	5	2	Idrocarburi	Altro	0	0	0	0	0	
13/04/2020 20:39	37,2471	15,2181	Augusta	4	4	Solventi	Mal di testa	0	0	0	0	1	
13/04/2020 20:31	37,2622	15,1632	Augusta	5	2	Idrocarburi	DifficoltÃ di respiro, Mal di testa	1	0	0	0	1	
13/04/2020 19:53	37,2718	15,1398	Melilli	3	2	Idrocarburi	Bruciore agli occhi/occhi rossi	0	1	0	0	0	
13/04/2020 18:44	37,151	15,1714	Priolo	5	2	Idrocarburi	Mal di testa	0	0	0	0	1	
13/04/2020 18:29	37,2279	15,2236	Augusta	5	1	Bruciato	DifficoltÃ di respiro, Prurito/irritazione al naso, Bruciore/irritazione alla gola, Mal di testa	1	0	1	1	1	Cattivo odore
13/04/2020 18:29	37,1592	15,1907	Priolo	5	5	Fognatura	Bruciore/irritazione alla gola, DifficoltÃ di respiro, Bruciore agli occhi/occhi rossi, Prurito/irritazione al naso, Mal di testa	1	1	1	1	1	Vomito
13/04/2020 17:43	37,1592	15,1907	Priolo	4	2	Idrocarburi	DifficoltÃ di respiro, Prurito/irritazione al naso, Mal di testa	1	0	1	0	1	
13/04/2020 16:45	37,2746	15,2071	Augusta	4	2	Idrocarburi	Mal di testa, Bruciore/irritazione alla gola	0	0	0	1	1	Alle ore 8 del 13/04/2020

The warnings from the NOSE WEB-APP are sparse in space and time, yet they can be considered as a receptor grid moving in space/time.

The NOSE Case Study: April 13, 2020

A clever clustering of the warnings is the first step to generate proper 'pseudo-receptors' for simulations of the back-trajectories with RetroSPRAY model.

Number of alerts ←



→ *Intensity of the nuisance*

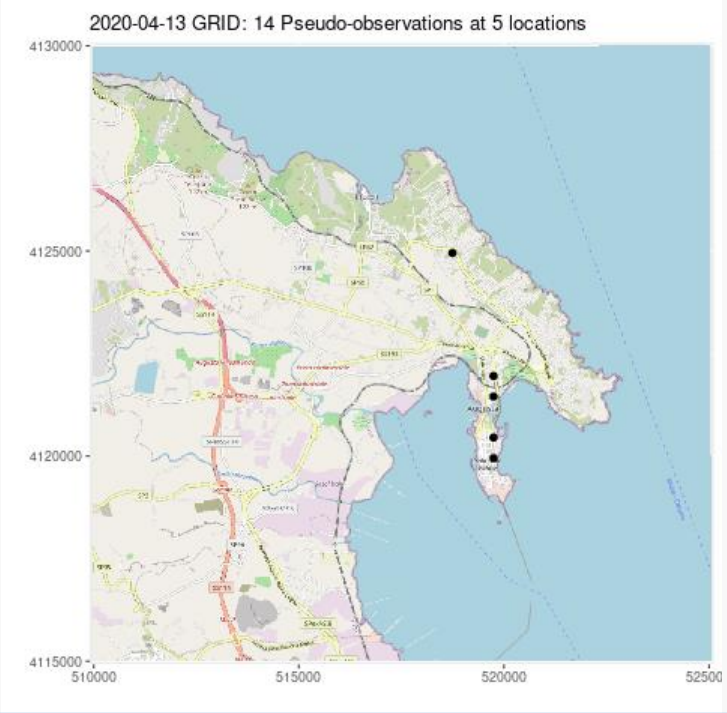
Two methods have been developed:

- a 500-m-spacing **grid** is defined on the domain, alerts exceeding the established odour intensity threshold are counted within each grid cell at each time → to identify the cells that can be considered as sensible pseudo-receptors for the release of backward stochastic trajectories.
- a simple **cluster analysis** based on spatial coordinates is applied at each time interval, a spatial scale of 500 m and a variable* minimum number of alerts are used to choose the clustering level → the cluster centroids are identified as location of "pseudo-receptors" for the "retro-emission" sources

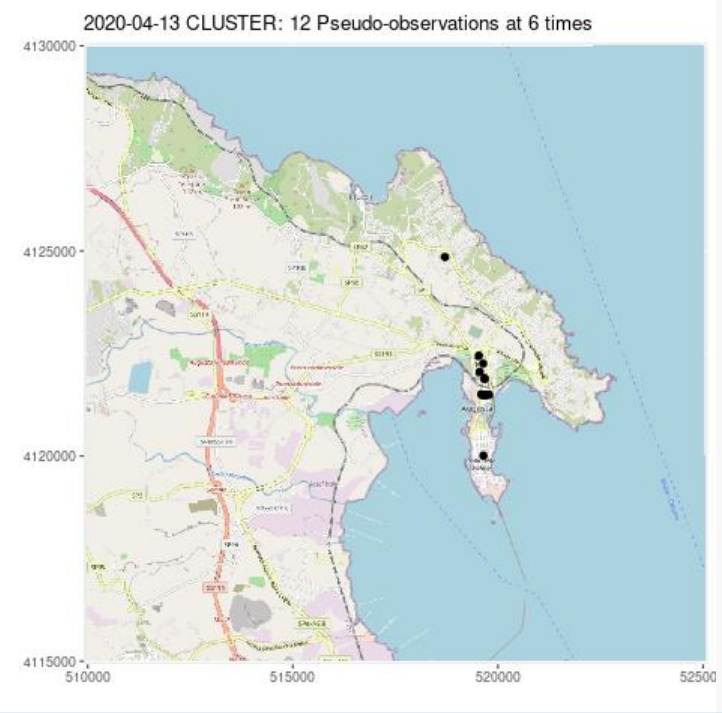
*(*varying depending on the maximum number of citizen notifications received at each time interval*)

The NOSE Case Study: April 13, 2020

A clever clustering of the warnings is the first step to generate proper ‘pseudo-receptors’ for simulations of the back-trajectories with RetroSPRAY model



Spatial locations of pseudo-receptors for the grid method (left) and the cluster analysis (right): pseudo-observations are defined at some times within the event period here considered, from 08:00 to 11:00 on 2020-04-13



GRID: 5 gridbox act as pseudo-receptors, defining a total of 14 pseudo-observations; their locations are the same at all times, so when a sufficient number of alerts falls within a gridbox an observation is defined and this may happen in the same gridbox at several times.

CLUSTER: the centroids are recalculated at each time, thus their location differ at different times *(even if they may happen to be close to each other).* As a result, 12 pseudo-observations are defined within the time period, each at a different location.

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The retro-emissions for RetroSPRAY are defined at the locations and at the time-intervals of such '**pseudo-observations**'

They are independent from each other and each of them generates a '**retro-concentration**' field, as 'retro-puffs', moving *backward*, following the atmospheric flow upstream and dispersing according to the turbulence conditions

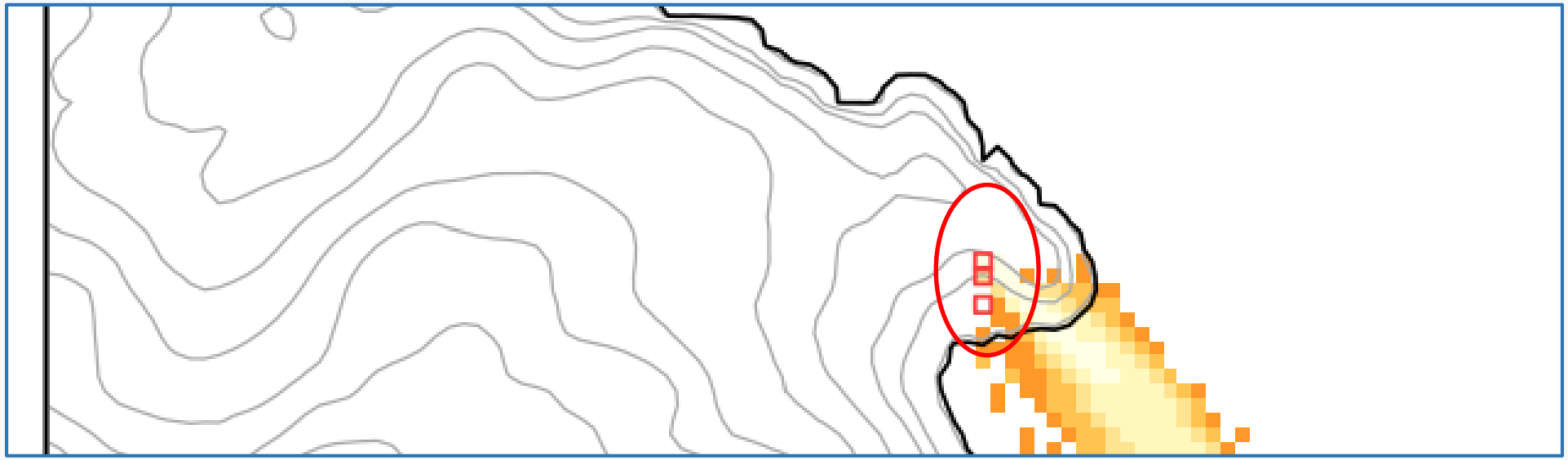
From this case study, an example of the application is given for three 'emitting grid cells', among the different pseudo-observations in the interval 0800-11:00 LT, for a total of 9 retro-puffs moving backward in time

The numerical integration lasts for a reasonable time 'before' the first pseudo-observations, here taken back to 0600 LT

Thinking *forward*: searching for a source area that could start emitting in the interval 0600-0630 LT

The NOSE Case Study: April 13, 2020

The 13.04.2020 case study: **an example** of the puffs simulations considering **three receptor cells**



SMART simulations: the 3D meteorological fields from MOLOCH atmospheric model - 0.5 km horizontal grid space - have been processed by ARAMIS turbulence and boundary-layer parameterization code → preparing the input for RetroSPRAY

RetroSPRAY Simulations: performed by releasing, from the identified receptor cells, a series of retro-puffs **at each time interval** from the selected 'pseudo-receptors', here (and even typically) at a 30' time frequency

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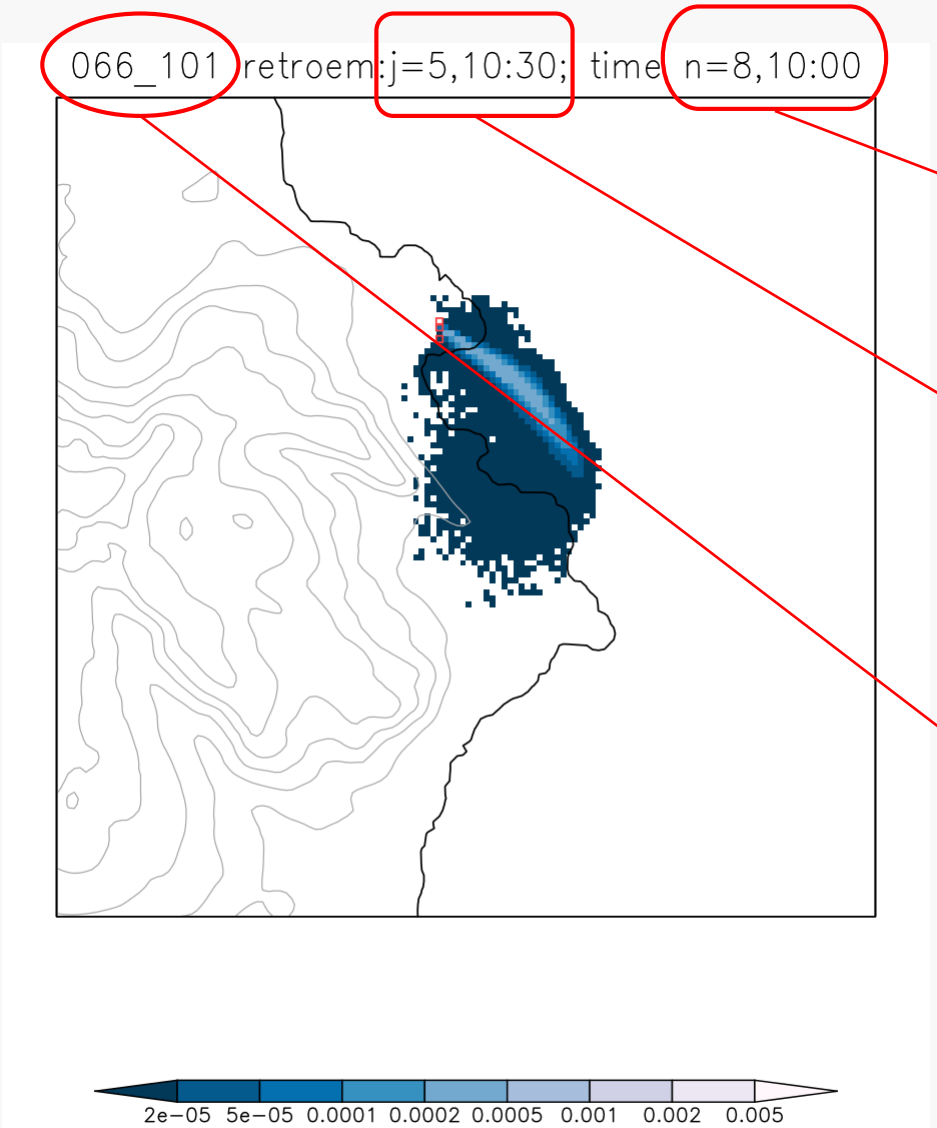
Example….

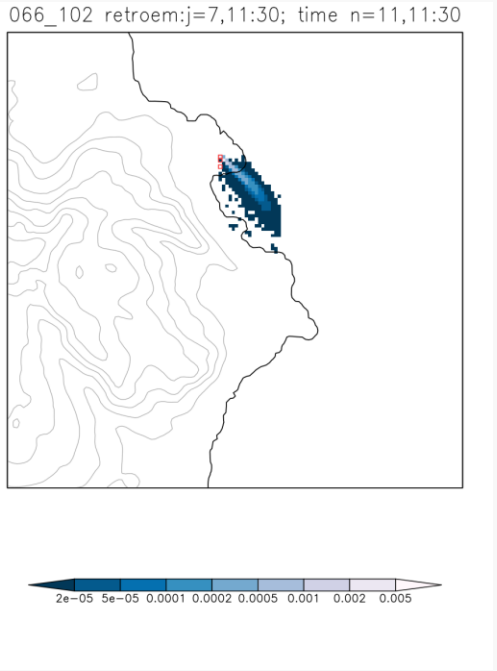
where is at 10:00 forward time *n,* the retro-puff corresponding to the pseudo-observation recorded in the interval 10:30 - 10:00 backward in time in the cell xxx_yyy



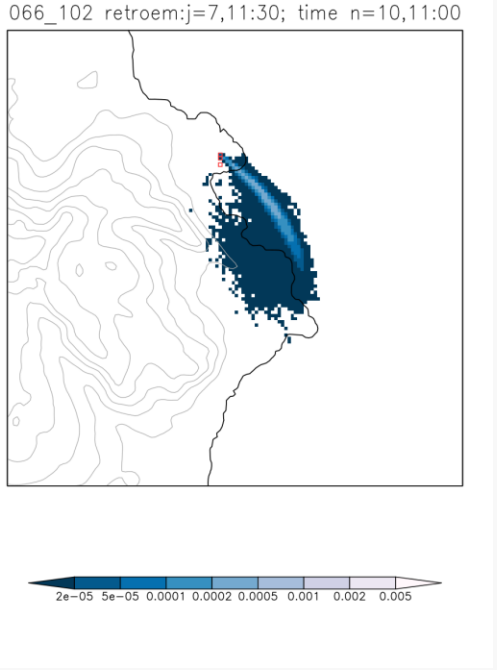
Time of possible forward emis

Time of the pseudo-obs (retro-emis)

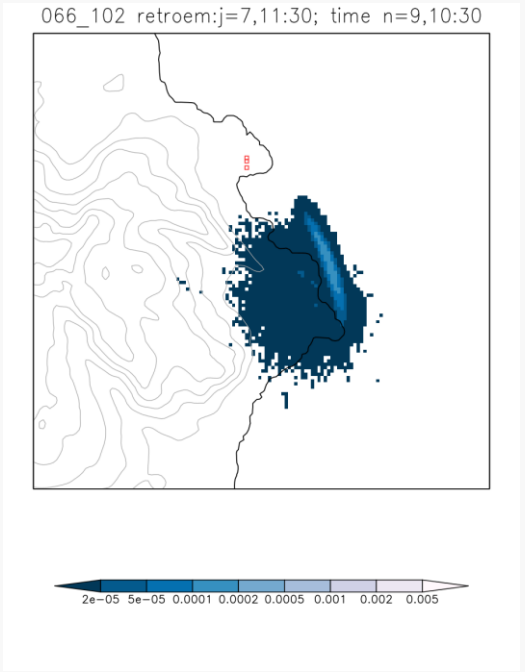
Cell number

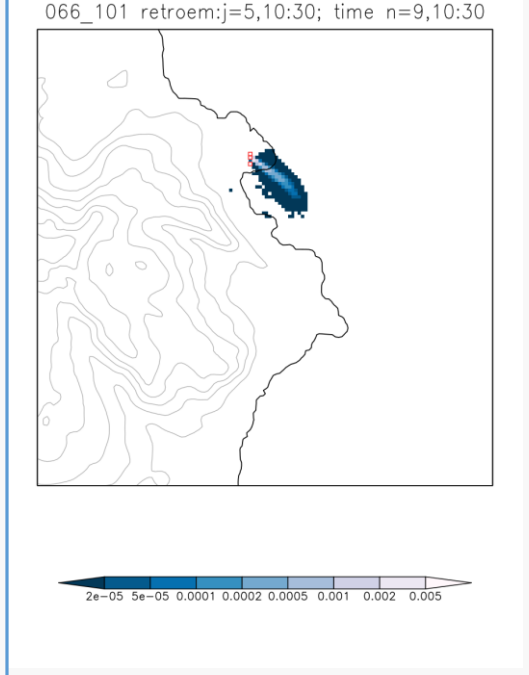


Forward time *n*=11
11:00 – 11:30



Forward time *n*=10
10:30 – 11:00





Forward time *n*=9
10:00 – 10:30

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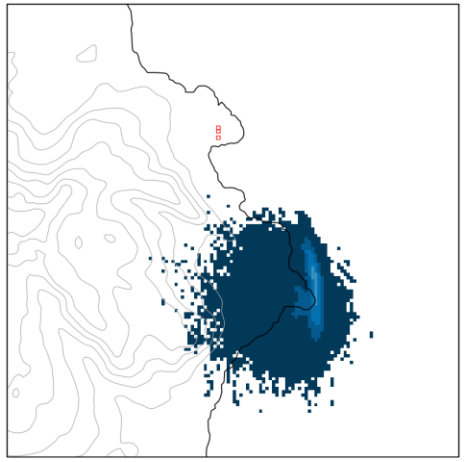

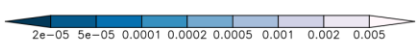

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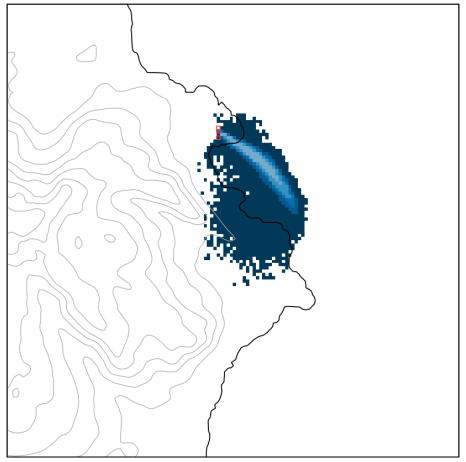

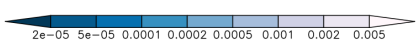

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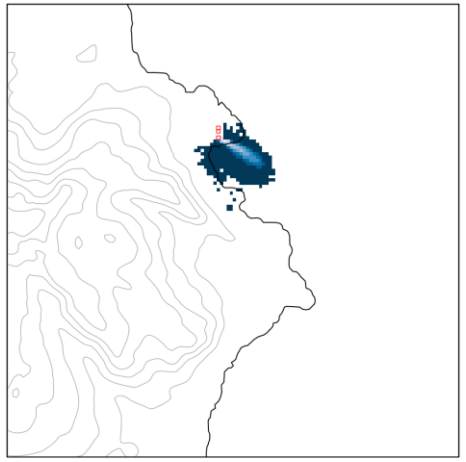

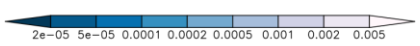

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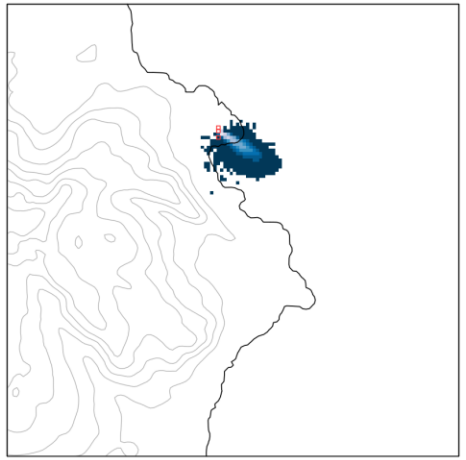
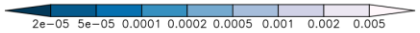
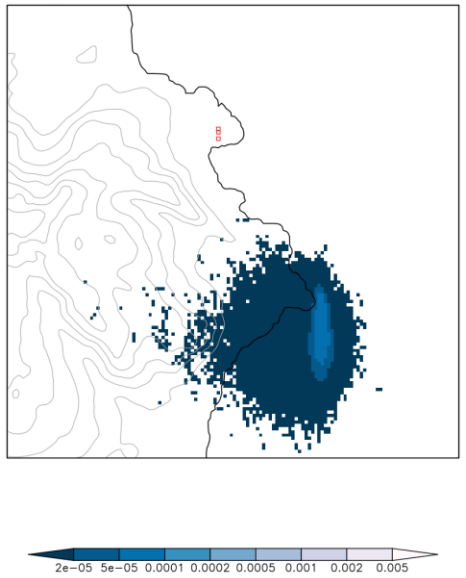




Forward time *n*=8
09:30 – 10:00

066_102 retroem:j=7,11:30; time n=7,09:30



2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

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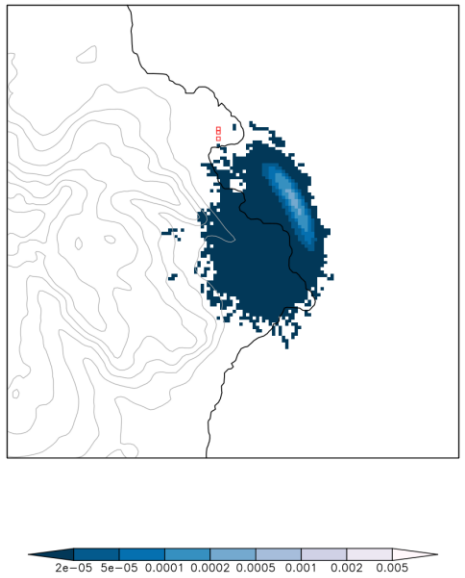

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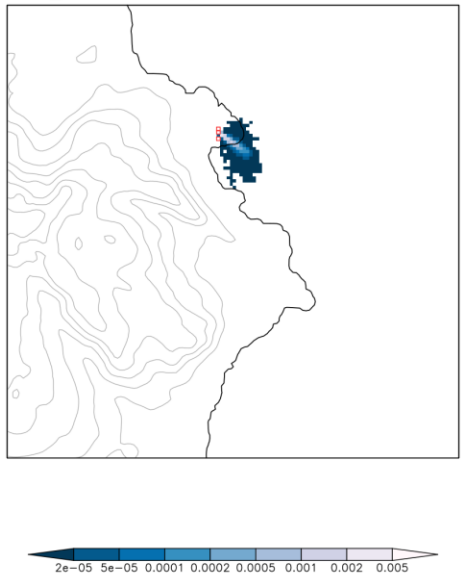

2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

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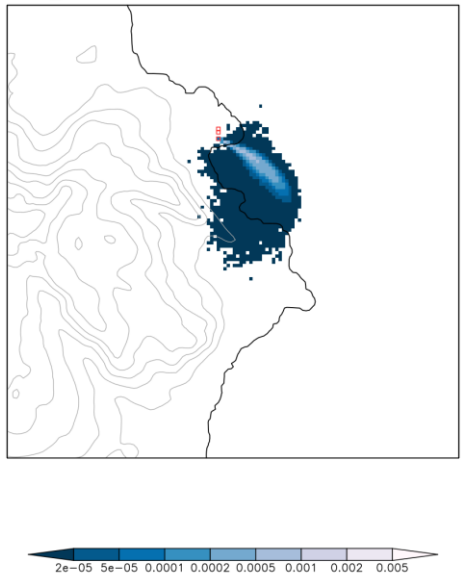

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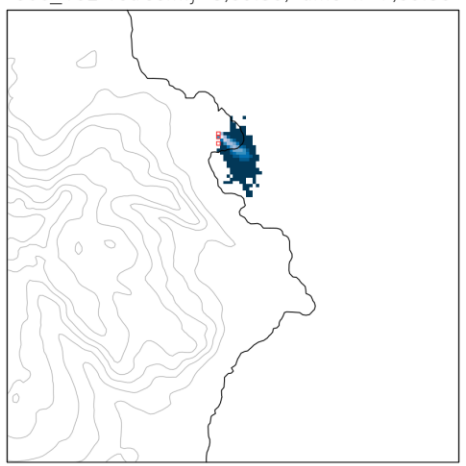

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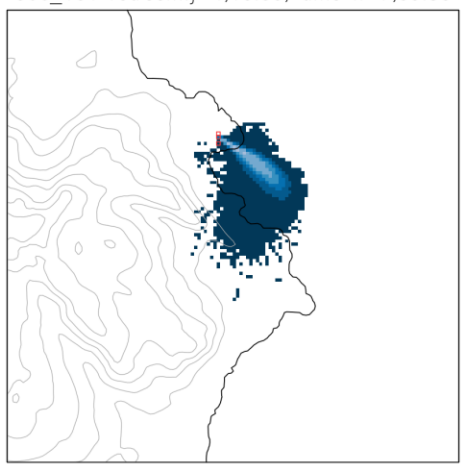

2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

Forward time *n*=7
09:00 – 09:30

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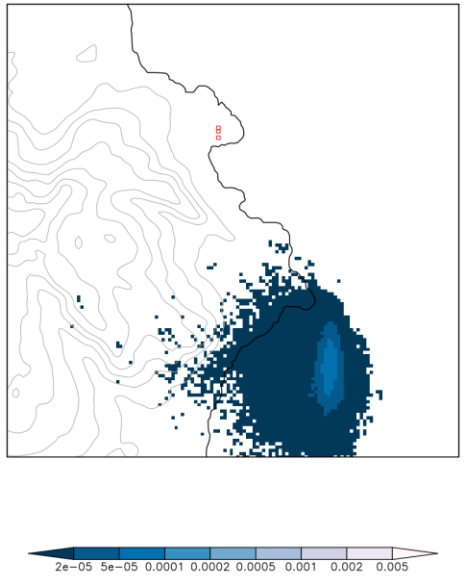

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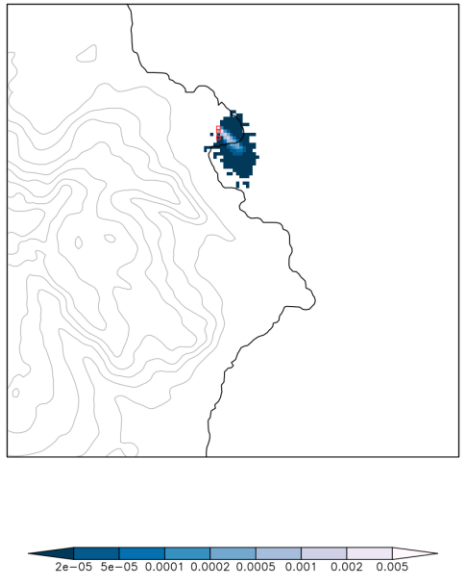

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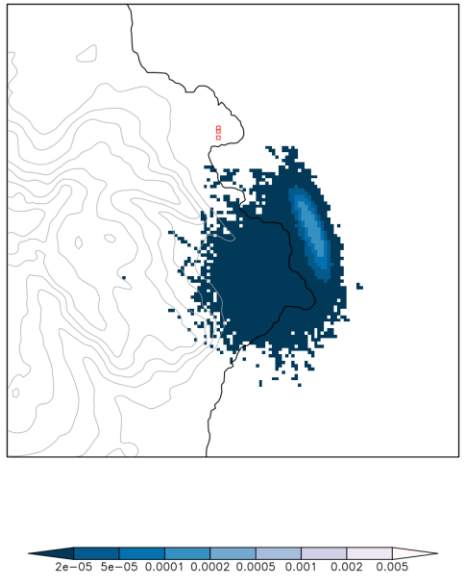

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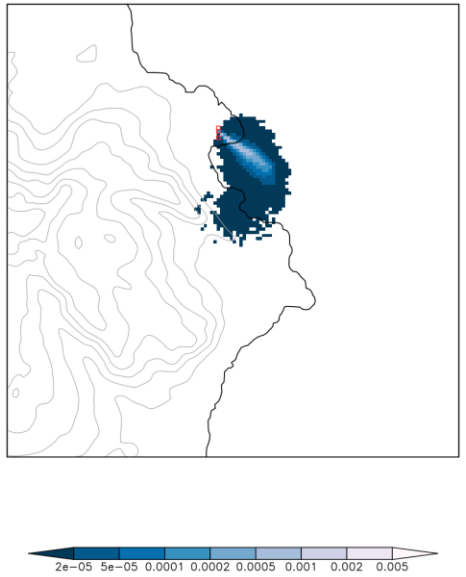

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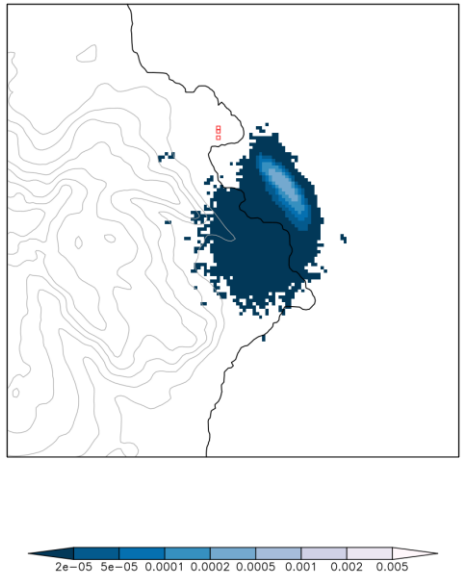

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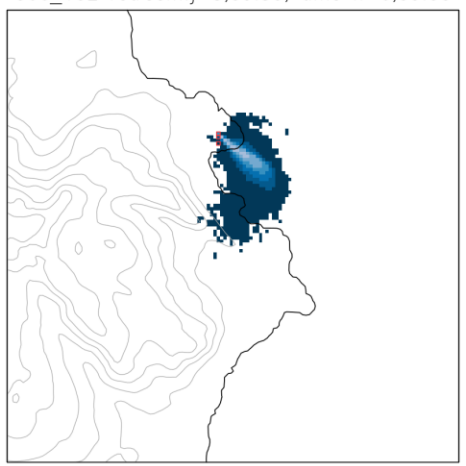

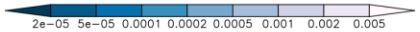

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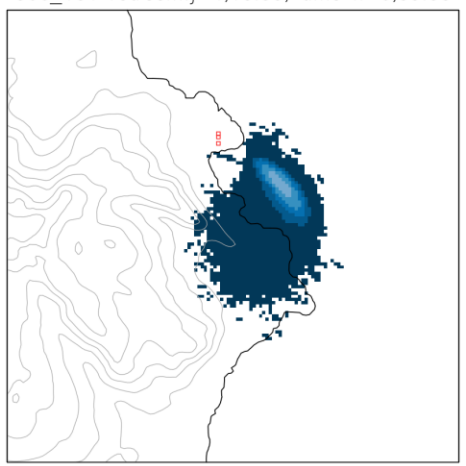

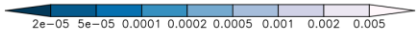

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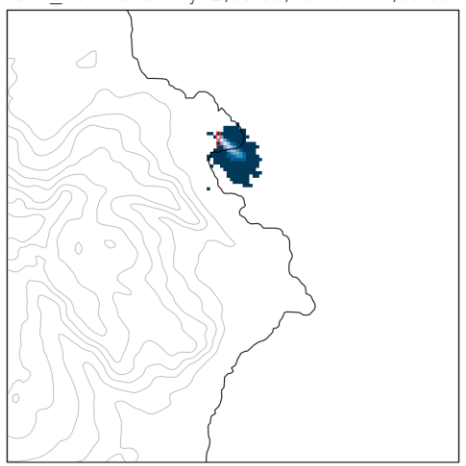
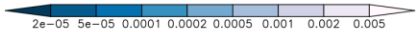
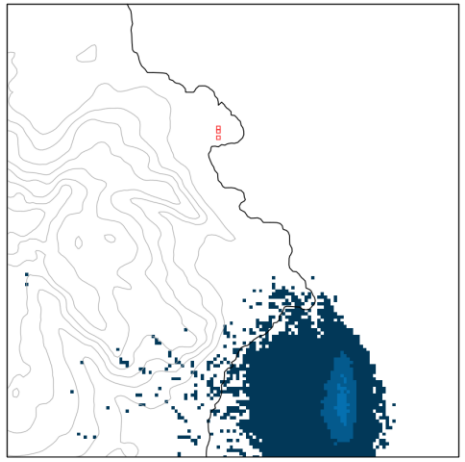




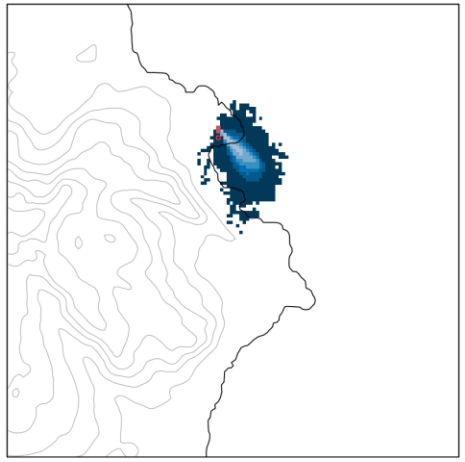
Forward time *n*=6
08:30 – 09:00

066_102 retroem:j=7,11:30; time n=5,08:30



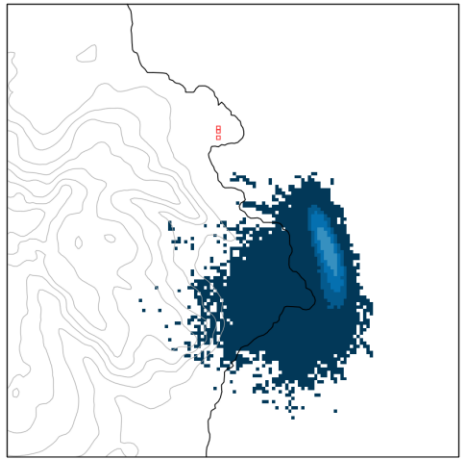
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_102 retroem:j=2,09:00; time n=5,08:30



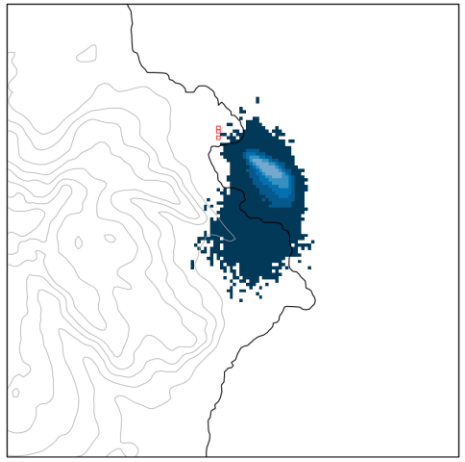
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_101 retroem:j=5,10:30; time n=5,08:30



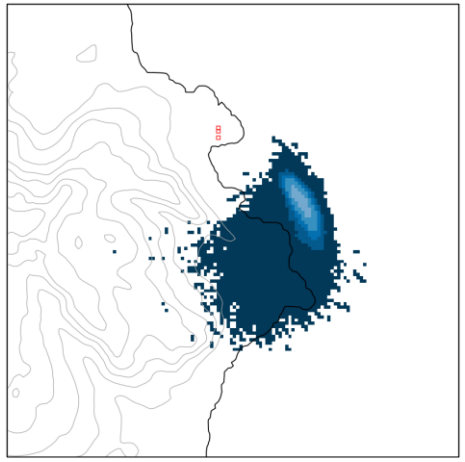
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_101 retroem:j=3,09:30; time n=5,08:30



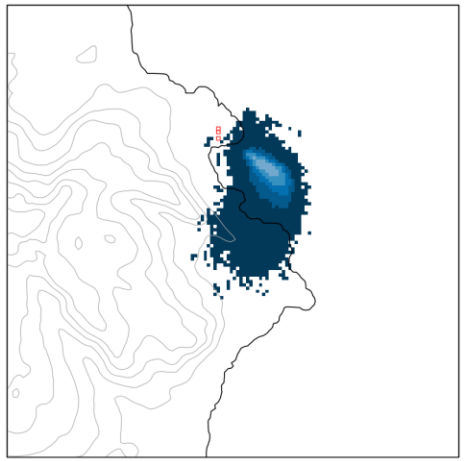
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_099 retroem:j=4,10:00; time n=5,08:30



2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_102 retroem:j=3,09:30; time n=5,08:30

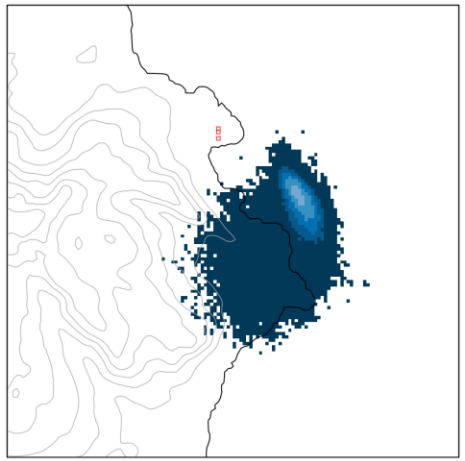


2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_102 retroem:j=1,08:30; time n=5,08:30

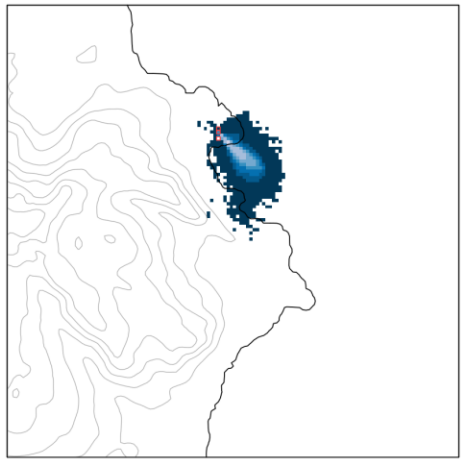
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_101 retroem:j=4,10:00; time n=5,08:30



2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

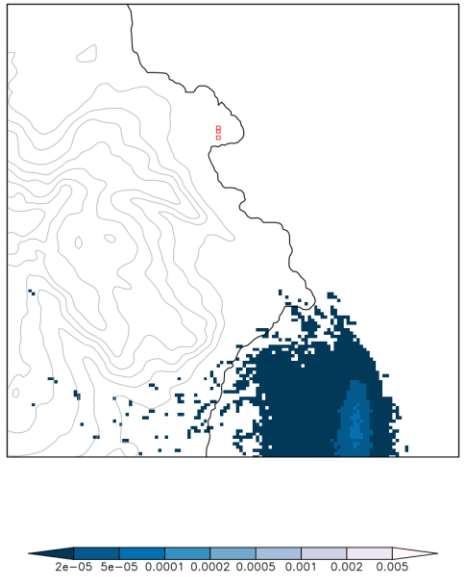
066_101 retroem:j=2,09:00; time n=5,08:30



2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

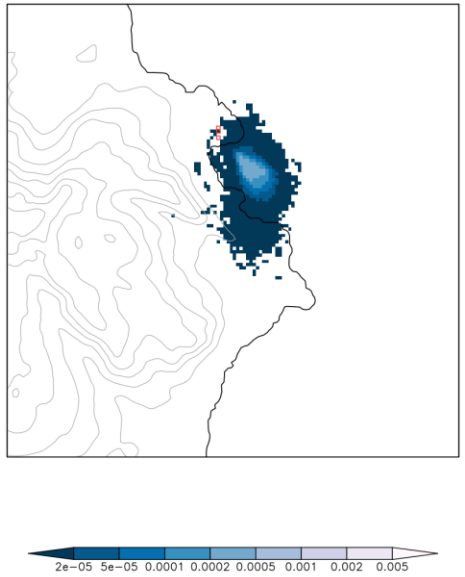
Forward time *n*=5
08:00 – 08:30

066_102 retroem:j=7,11:30; time n=4,08:00



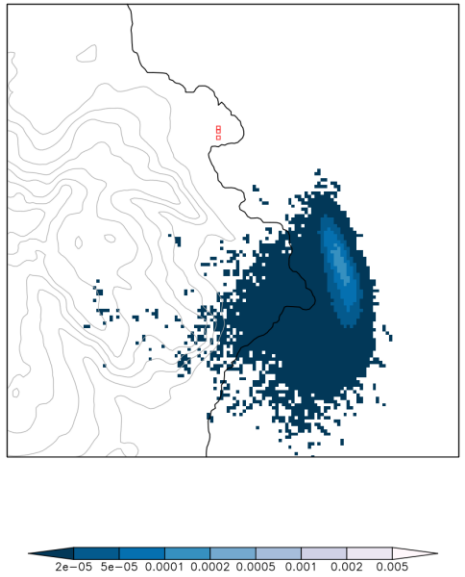
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_102 retroem:j=2,09:00; time n=4,08:00



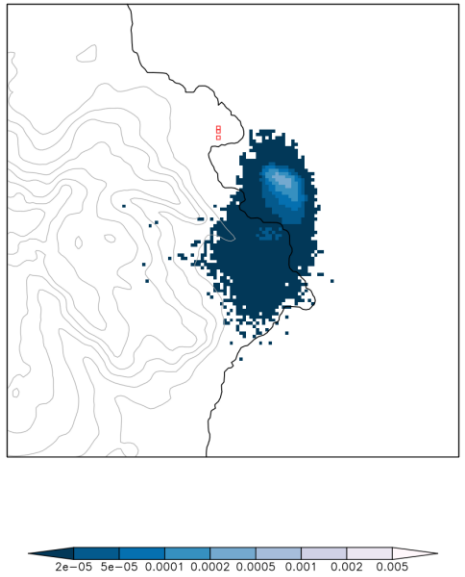
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_101 retroem:j=5,10:30; time n=4,08:00



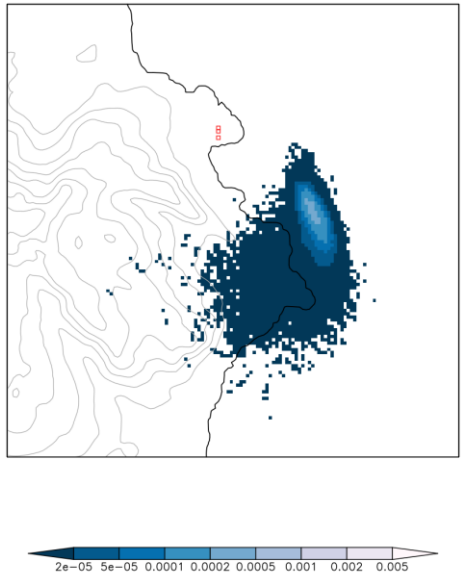
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_101 retroem:j=3,09:30; time n=4,08:00



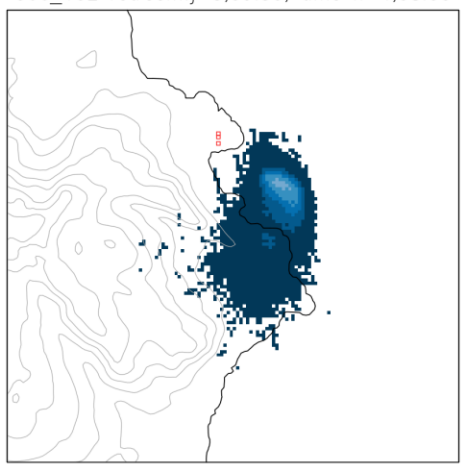
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_099 retroem:j=4,10:00; time n=4,08:00



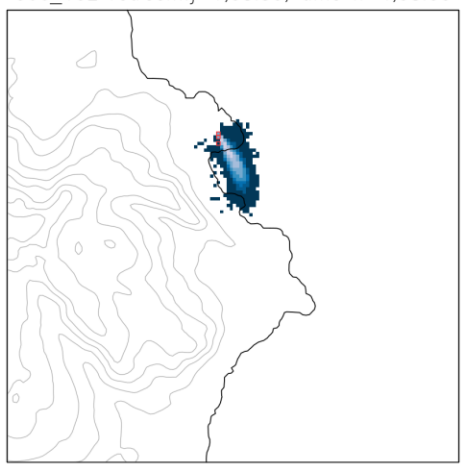
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_102 retroem:j=3,09:30; time n=4,08:00



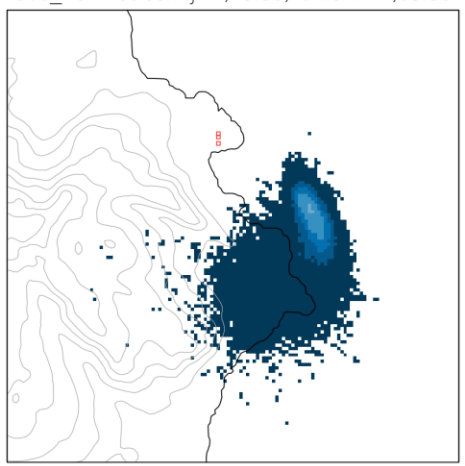
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_102 retroem:j=1,08:30; time n=4,08:00



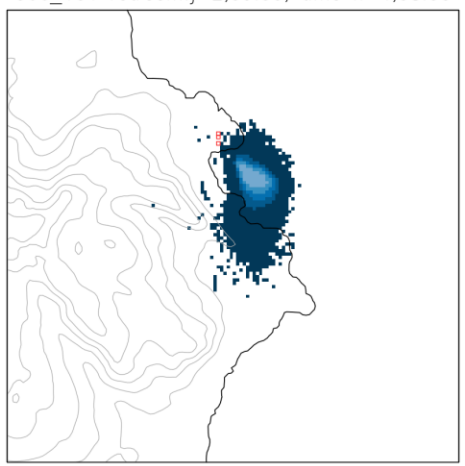
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_101 retroem:j=4,10:00; time n=4,08:00



2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

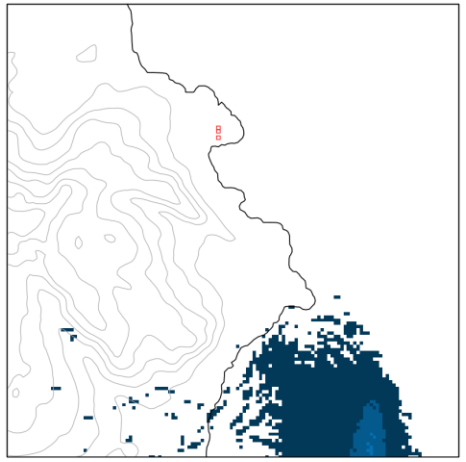
066_101 retroem:j=2,09:00; time n=4,08:00

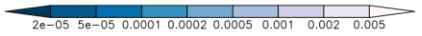


2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

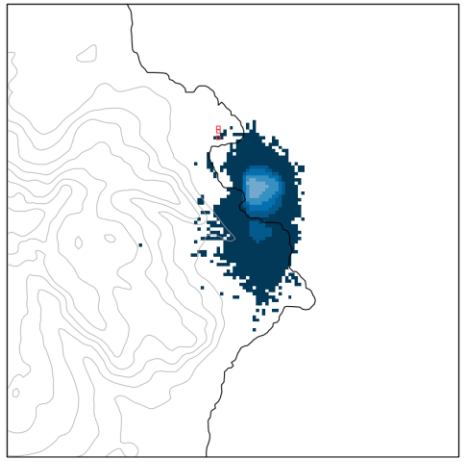
Forward time *n*=4
07:30 – 08:00

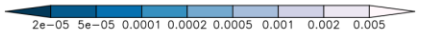
066_102 retroem:j=7,11:30; time n=3,07:30



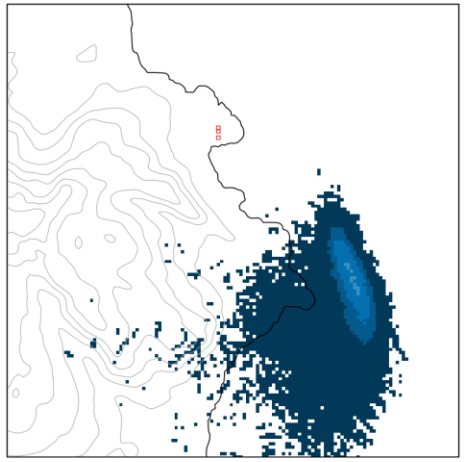


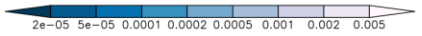
066_102 retroem:j=2,09:00; time n=3,07:30



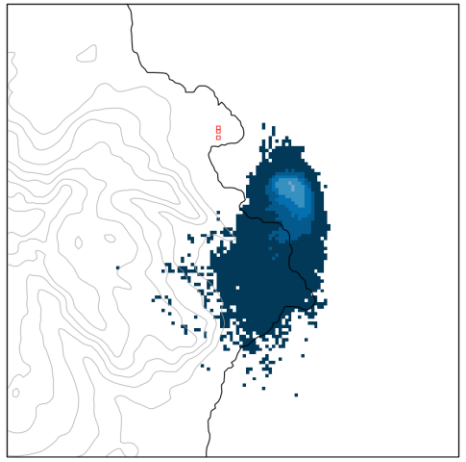


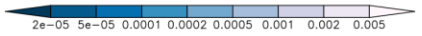
066_101 retroem:j=5,10:30; time n=3,07:30



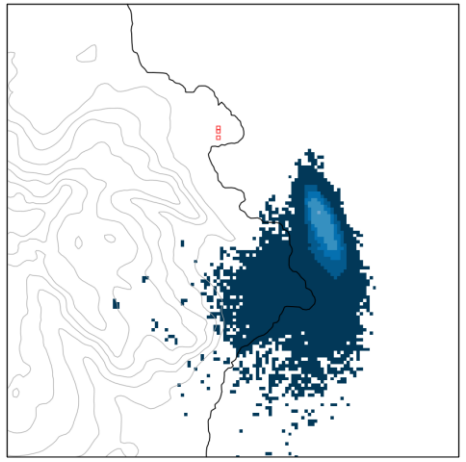


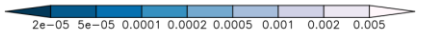
066_101 retroem:j=3,09:30; time n=3,07:30



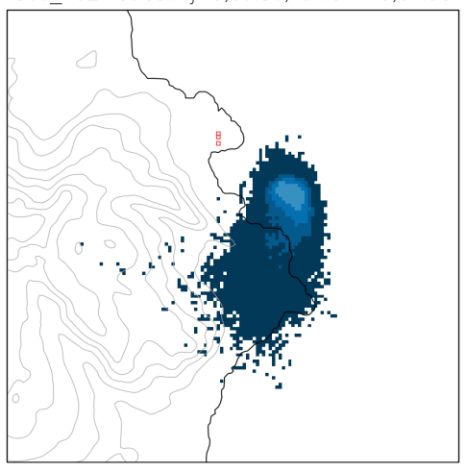


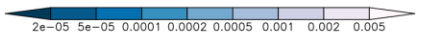
066_099 retroem:j=4,10:00; time n=3,07:30



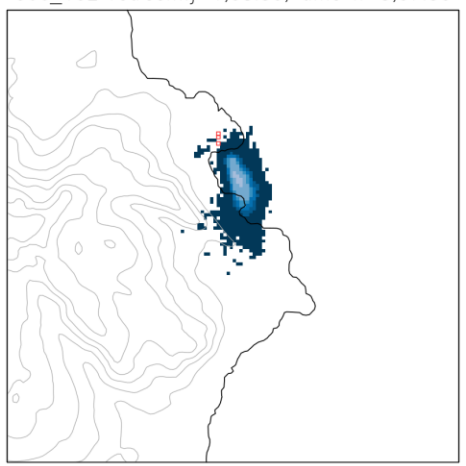


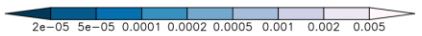
066_102 retroem:j=3,09:30; time n=3,07:30



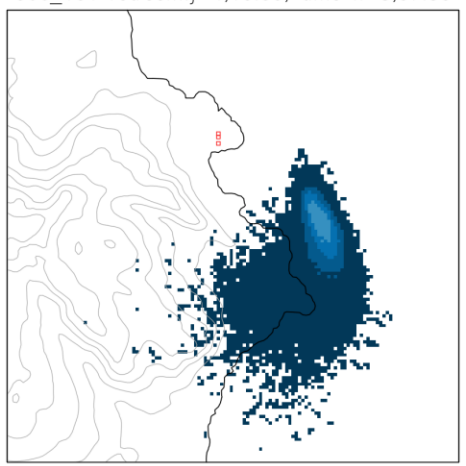


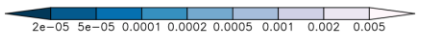
066_102 retroem:j=1,08:30; time n=3,07:30



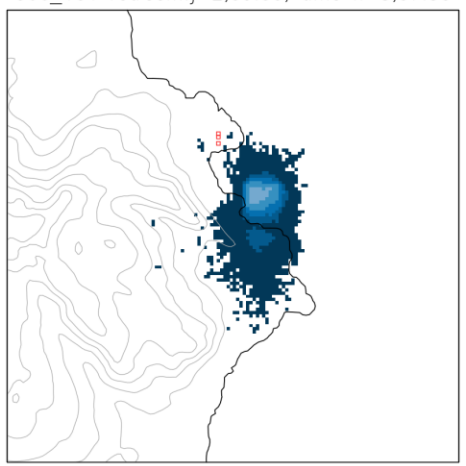


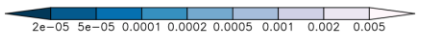
066_101 retroem:j=4,10:00; time n=3,07:30





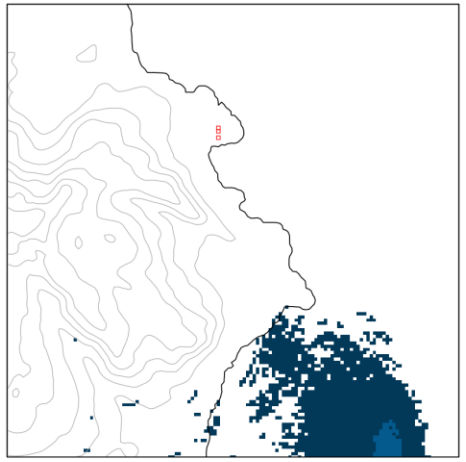
066_101 retroem:j=2,09:00; time n=3,07:30





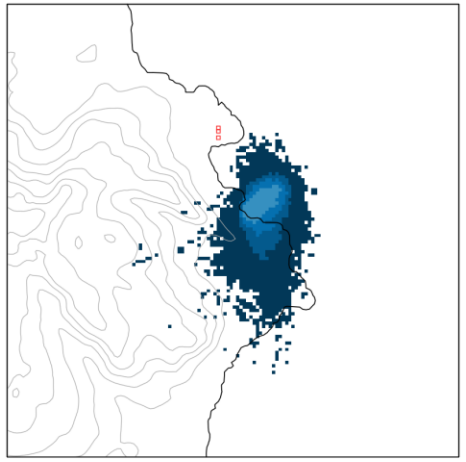
Forward time *n*=3
07:00 – 07:30

066_102 retroem:j=7,11:30; time n=2,07:00



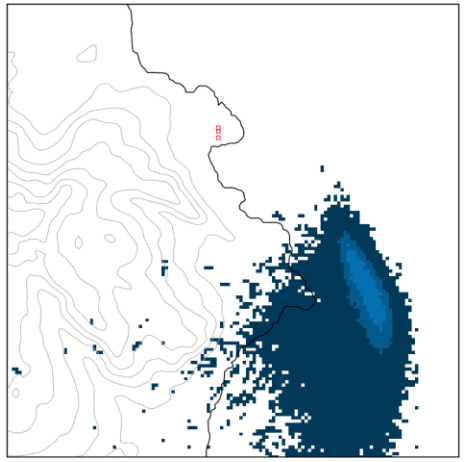
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_102 retroem:j=2,09:00; time n=2,07:00



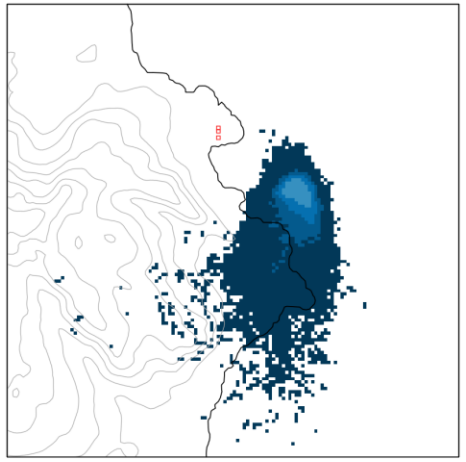
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_101 retroem:j=5,10:30; time n=2,07:00



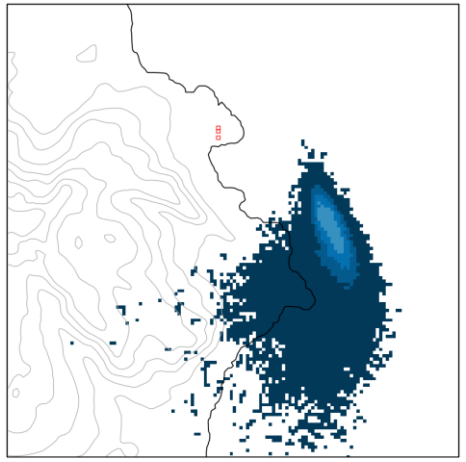
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_101 retroem:j=3,09:30; time n=2,07:00



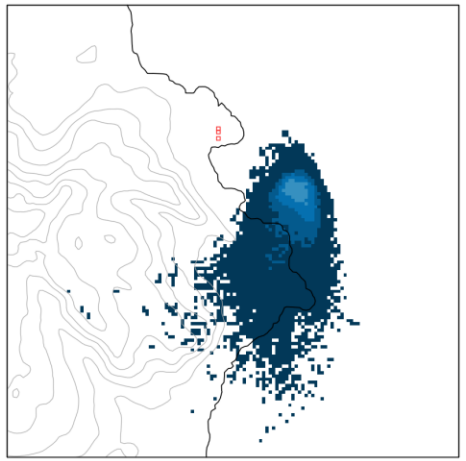
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_099 retroem:j=4,10:00; time n=2,07:00



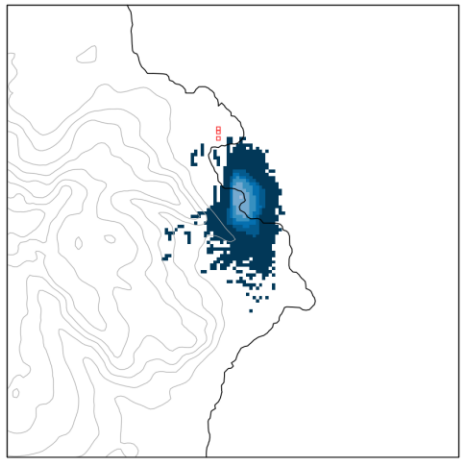
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_102 retroem:j=3,09:30; time n=2,07:00



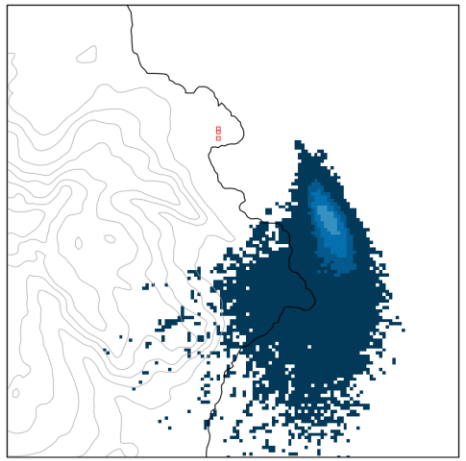
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_102 retroem:j=1,08:30; time n=2,07:00



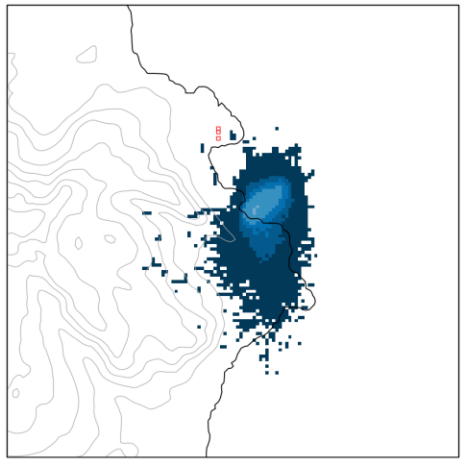
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_101 retroem:j=4,10:00; time n=2,07:00



2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

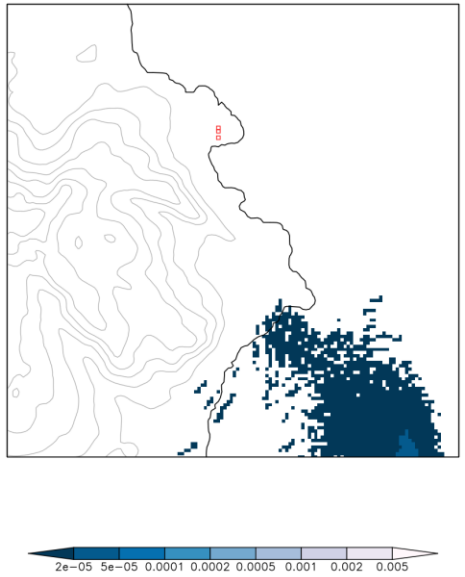
066_101 retroem:j=2,09:00; time n=2,07:00



2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

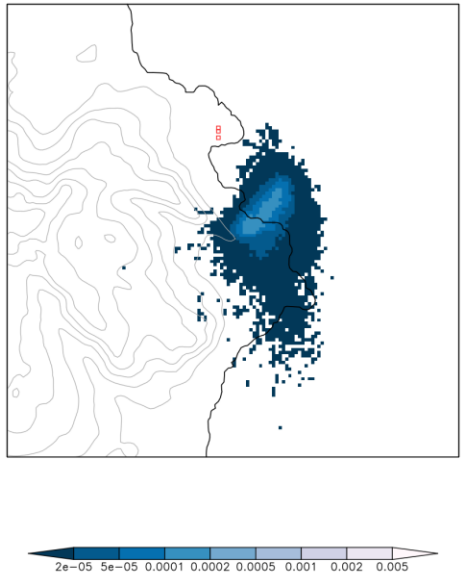
Forward time *n*=2
06:30 – 07:00

066_102 retroem:j=7,11:30; time n=1,06:30



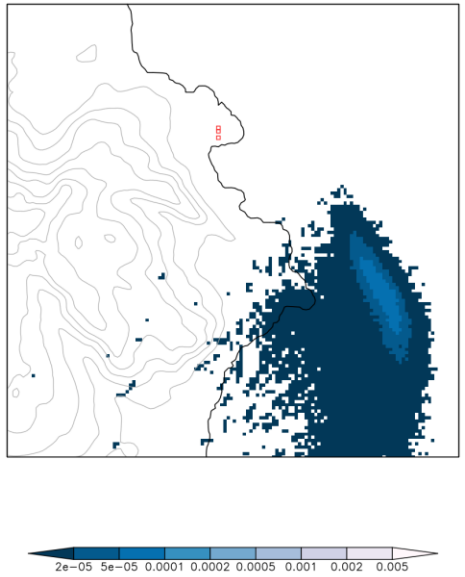
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_102 retroem:j=2,09:00; time n=1,06:30



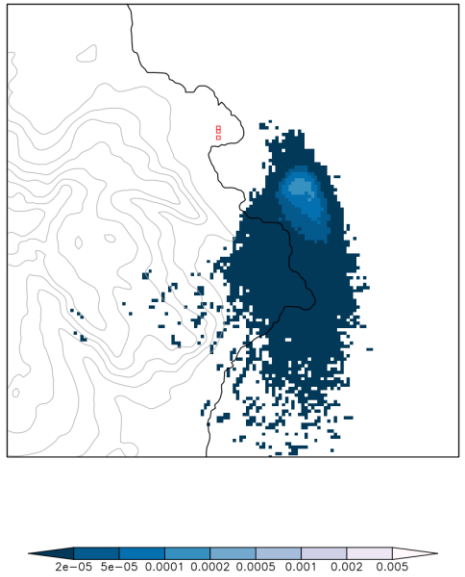
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_101 retroem:j=5,10:30; time n=1,06:30



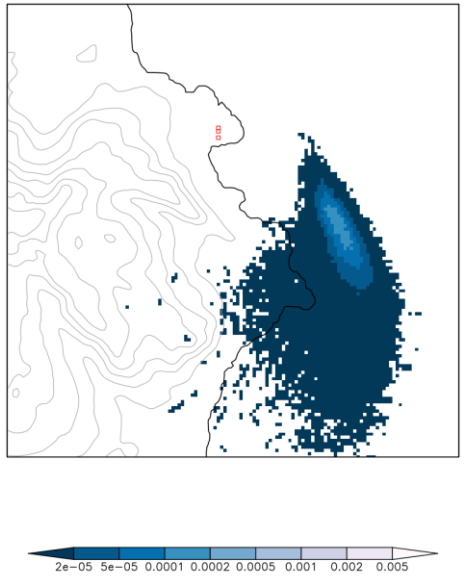
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_101 retroem:j=3,09:30; time n=1,06:30



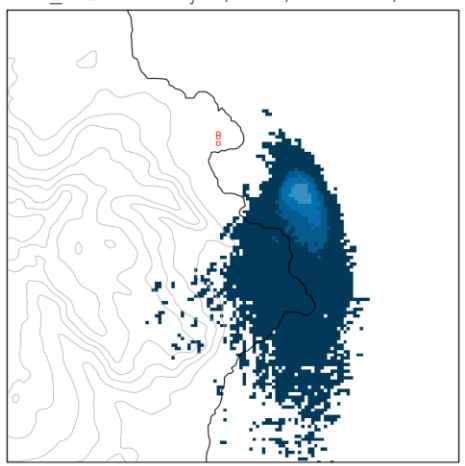
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_099 retroem:j=4,10:00; time n=1,06:30



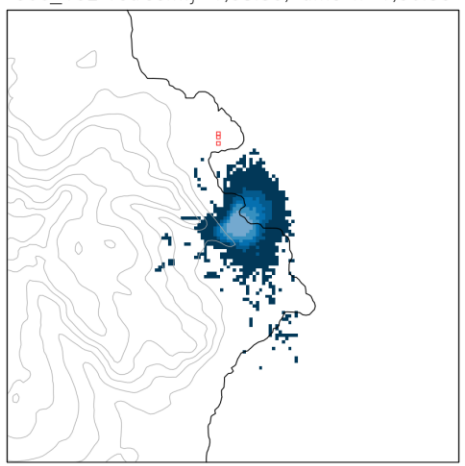
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_102 retroem:j=3,09:30; time n=1,06:30



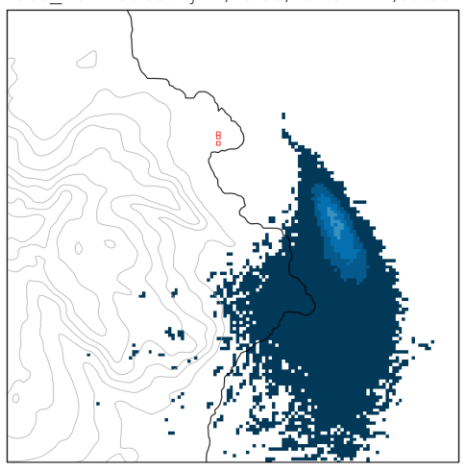
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_102 retroem:j=1,08:30; time n=1,06:30



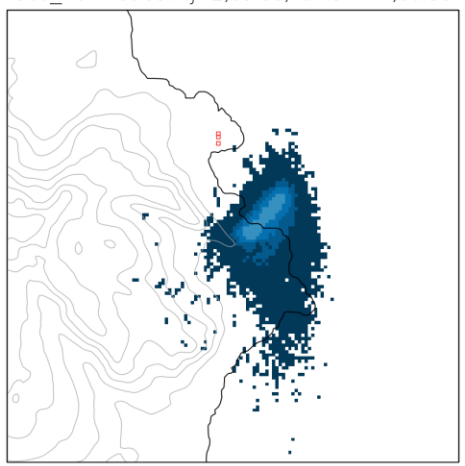
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_101 retroem:j=4,10:00; time n=1,06:30



2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

066_101 retroem:j=2,09:00; time n=1,06:30



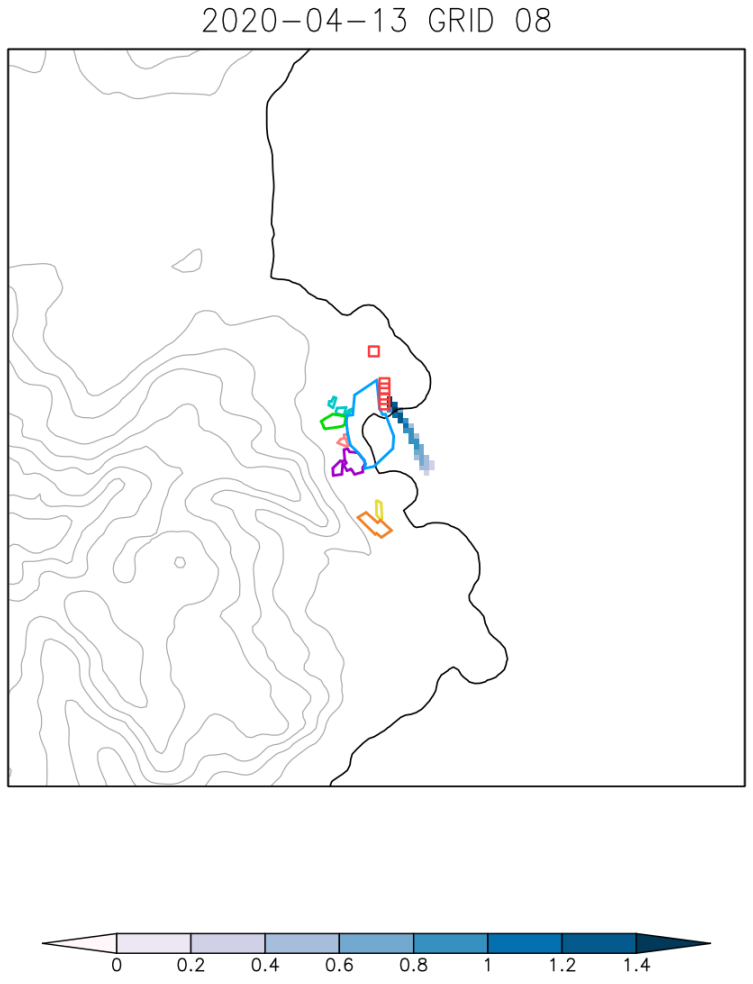
2e−05 5e−05 0.0001 0.0002 0.0005 0.001 0.002 0.005

Forward time *n*=1
06:00 – 06:30

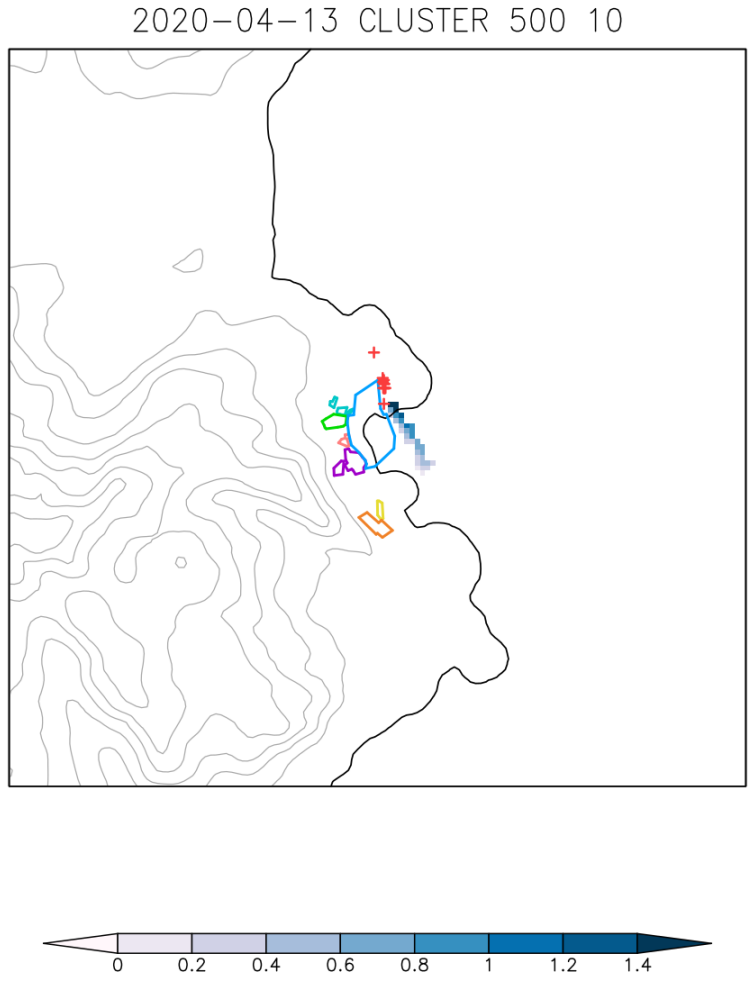
The NOSE Case Study: April 13, 2020

The retro-concentration fields generated by the retro-puffs are then combined both at **emission and receptor times**, through a process that calculates their geometric average (representing a logical AND operation) and their arithmetic average (representing a logical OR operation) in order to build final maps describing the areas where possible sources can be potentially located and their related probability.

The NOSE Case Study: April 13, 2020



Final maps of the area where potential sources may be located, over a simplified topography output by the model run. In the colour scale, lighter colours indicate locations where the emission should be very high to reach the receptors, thus **darker colours indicate areas where emitting sources may be more likely expected**.



GRID

CLUSTER

CONCLUSIONS

The newly developed approach implemented to use, after appropriate processing, citizens' warnings from NOSE WEB-APP as input to RetroSPRAY model, demonstrates to be promising and applicable.

In two rather different case studies, one with a high number of notifications (*here shown, 13/04/2020*), the other with a lower number of notifications (*03/04/2020*) but for which the source was then identified, the simulations provided reliable results.

In the first case, this has been confirmed by performing test simulations in forward mode, where potential releasing sources have been placed in different locations in the areas identified as more or less possible origin of odour nuisance, and also in the region outside them. It was seen that the sources placed in the 'most probable' areas were in fact affecting the receptor locations during the main hours of the recorded warnings. In the second case, the most probable area identified by the simulations and following output elaboration was in fact hosting the plant that produced the odour nuisance after an accidental release.

The new modules, elaborating the citizens' notification and final maps of probability density, are being integrated with the SMART modelling suite and the full package is presently going to be interfaced to NOSE alert system, with the aim of making available an operational system that can respond to a nuisance event in the timeframe of a few hours.

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