



Risk of *Culicoides* dispersal by the wind

CASE STUDY WITH EPIZOOTIC HEMORRHAGIC DISEASE VIRUS IN FRANCE

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INRAE


VetAgro Sup



**Boehringer
Ingelheim**

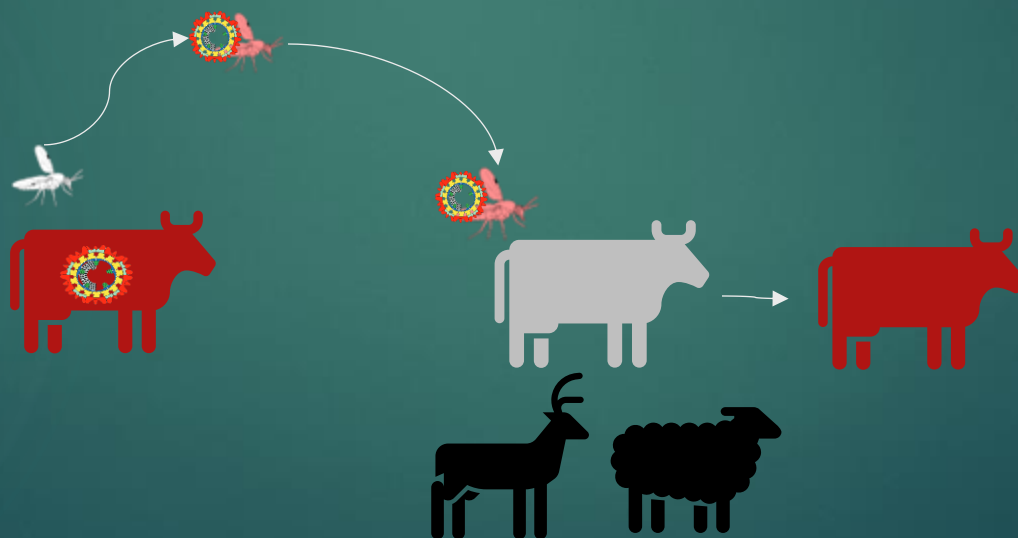


EHDV: an arbovirus transmitted by *Culicoides*

- ▶ Hemorrhagic fever affecting domestic & wild ruminants
- ▶ 90% mortality in deer ; variable in cattle according to serotypes
- ▶ High economical & animal health impacts (WOAH-listed disease)
- ▶ Transmitted by *Culicoides* midges
- ▶ No EU-licensed vaccine available



First animal infected by EHDV-8 in Italy
(Alessio Lorusso, IZST)

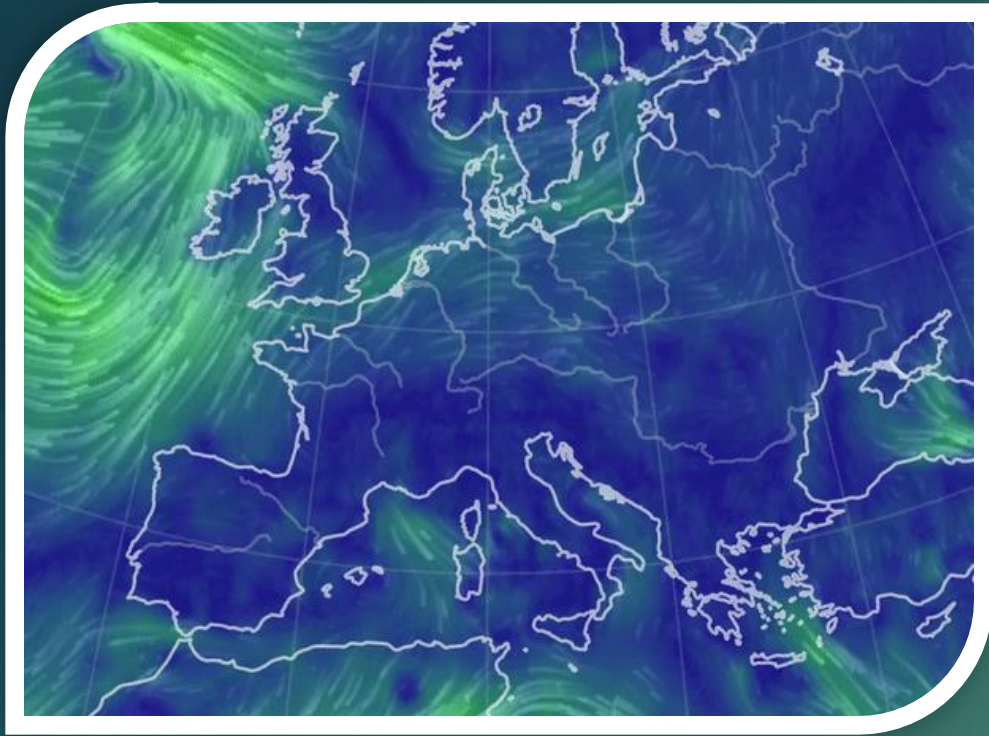


Biting midge (*Culicoides glabrator*), female.
Extracted from Mullen, 2019



Historical emergence EHDV-8 in Europe

- ▶ Tunisia : 2021
- ▶ Sardinia & Sicily: October 2022
- ▶ Southern Spain : November 2022
- ▶ Portugal : July 2023
- ▶ France: September 2023
- ▶ Pathways of introduction : long-distance dispersal by the wind & trade of live animals



How to predict Culicoides wind dispersal in Europe?

Atmospheric Dispersion Model

HYSPLIT Model

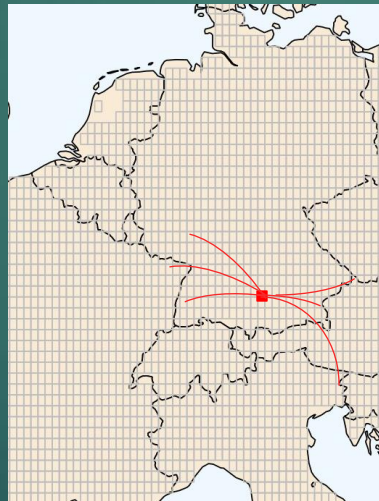


- ▶ HYSPLIT simulates the dispersion and trajectory of particles in our atmosphere, at local and global scales.
- ▶ Originally developed for nuclear explosion and volcano eruption
- ▶ Adapted to the specific biological & ecological limits of *Culicoides* spp.

1 Define the starting point(s)

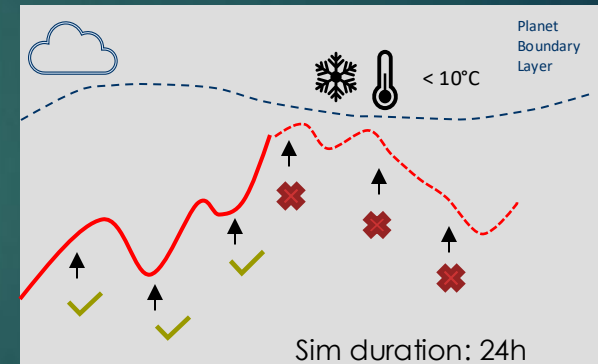


2 Initiate trajectories from it



- **2 starting time** per day (sunset & sunrise)
- **36 weeks** of simulations (mid March – Mid Nov)
- **Historical data of 2020-2021-2022-2023**

3 Filter suitable trajectories according to midges survival conditions



$H_{ij} \sim$ probability to reach destination from starting point

▶ Stein A F, Draxler R R, Rolph G D, Stunder B J B, Cohen M D and Ngan F 2015 NOAA's HYSPLIT Atmospheric Transport and Dispersion Modeling System *B Am Meteorol Soc* **96** 2059–77

Emergence of EHDV-8 in France

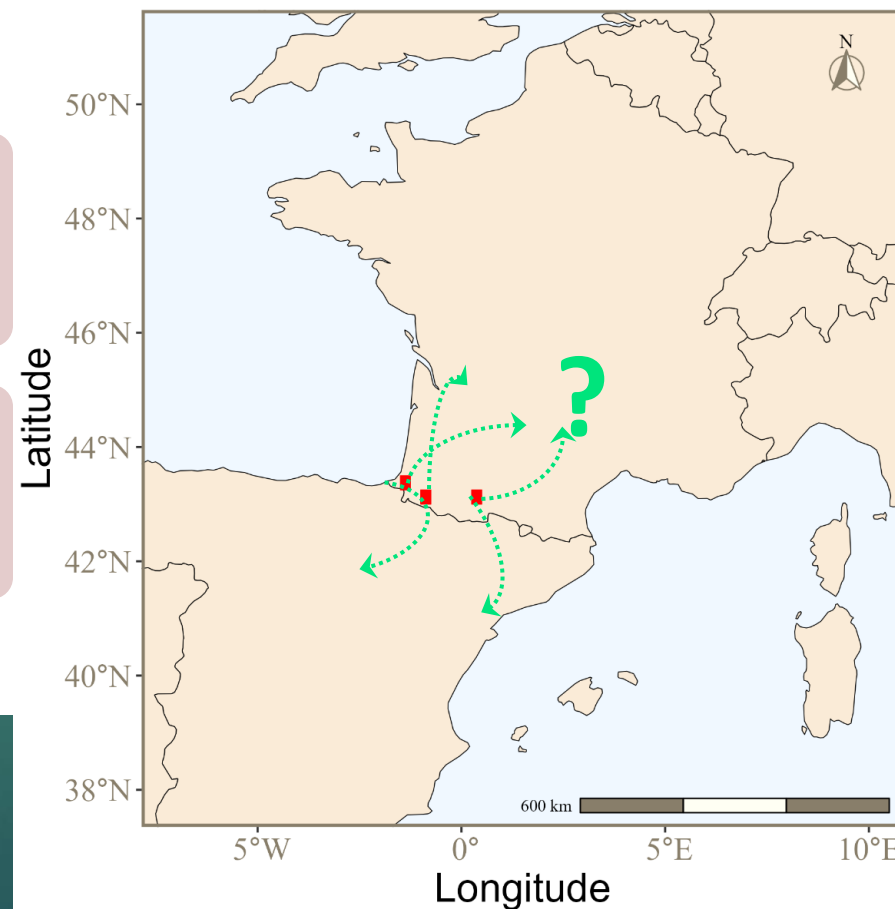
- ▶ First detection in Pyrénées-Atlantiques department early September 2023



What is the magnitude of the long-distance dispersal zone from the first index cases?

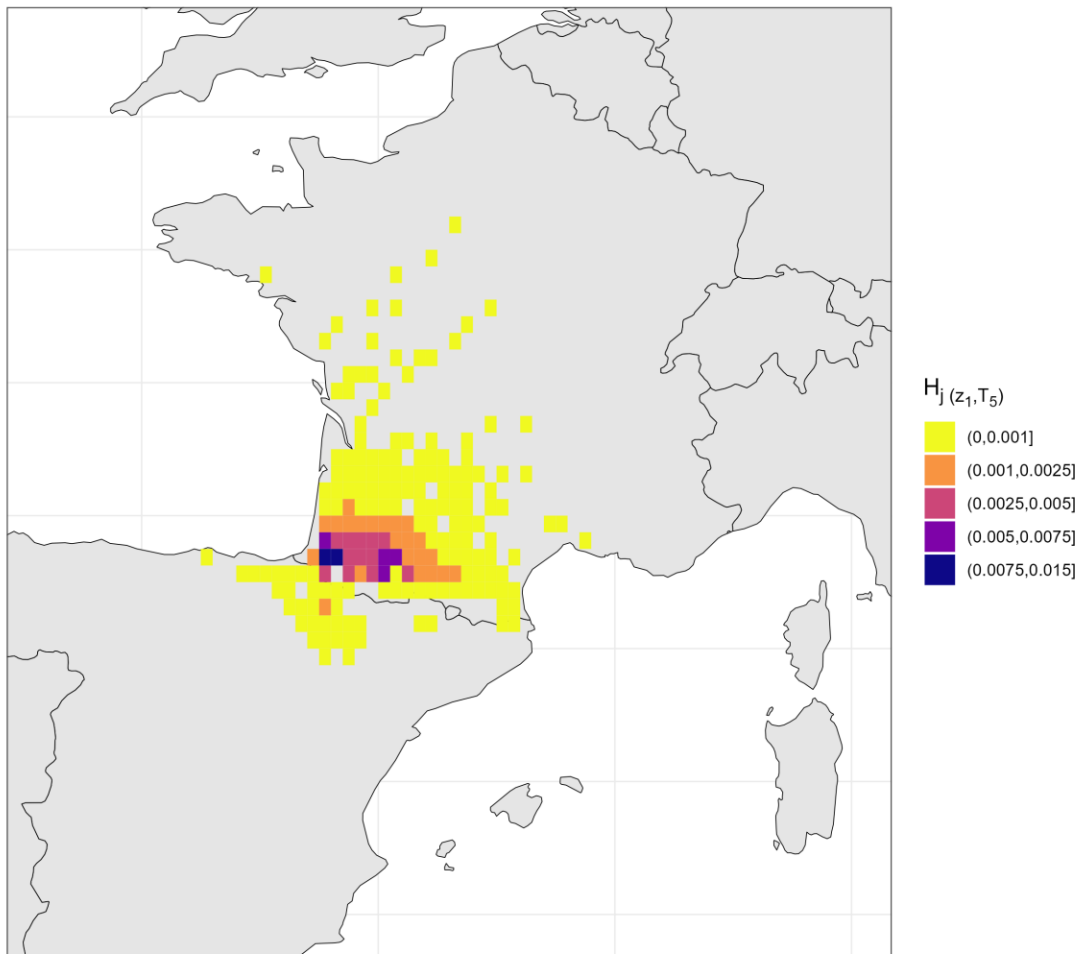


Is this zone predictive for emerging outbreaks?



Predicted risk zone averaged over 5 week-period

Windborne dispersion from index source zone z1

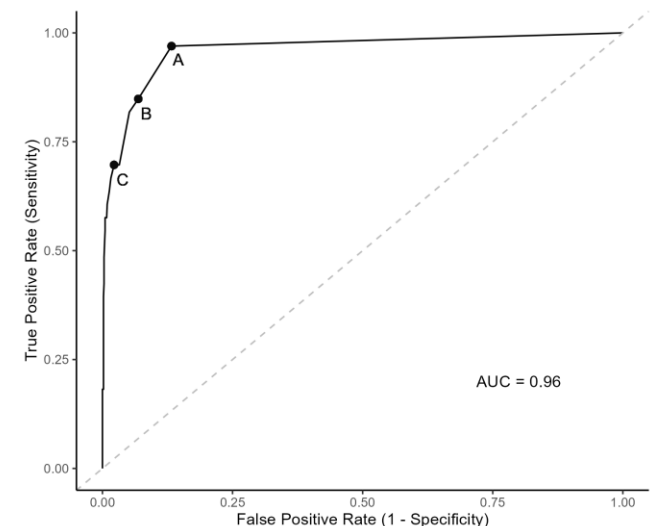
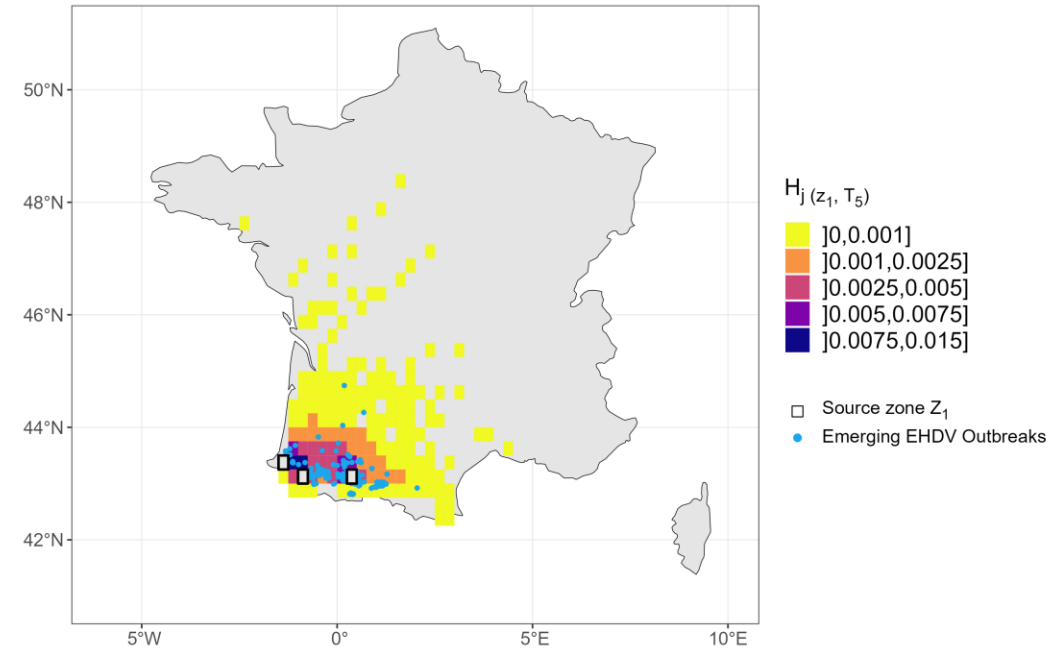


- ▶ Risk averaged from mid September to mid October (2023 only)
- ▶ High-risk zone mostly in the south western region ; (if $H_j > 10^{-3}$ ~25 000 km²)
- ▶ Full risk zone (~103 000 km²)
- ▶ Limited risk of incursion in SP

Very good predictability of the model

- ▶ 99.9% locations with at least 1 outbreak were predicted at risk
- ▶ BUT 26.3% Ob remain within the source zone > under estimation of the short range dispersion
- ▶ ROC curve of 0.96 (Se:97%, Sp:86,7%)
- ▶ Reducing the risk threshold leads to a significant drop in sensitivity

Situation	θ	TPR	FPR	Area (km ²)	Proportion
A	1.10^{-4}	97%	13.3%	103,125	100%
B	3.10^{-4}	84.8%	6.9%	60,625	58.8%
C	9.10^{-4}	69.7%	2.2%	28,750	27.9%

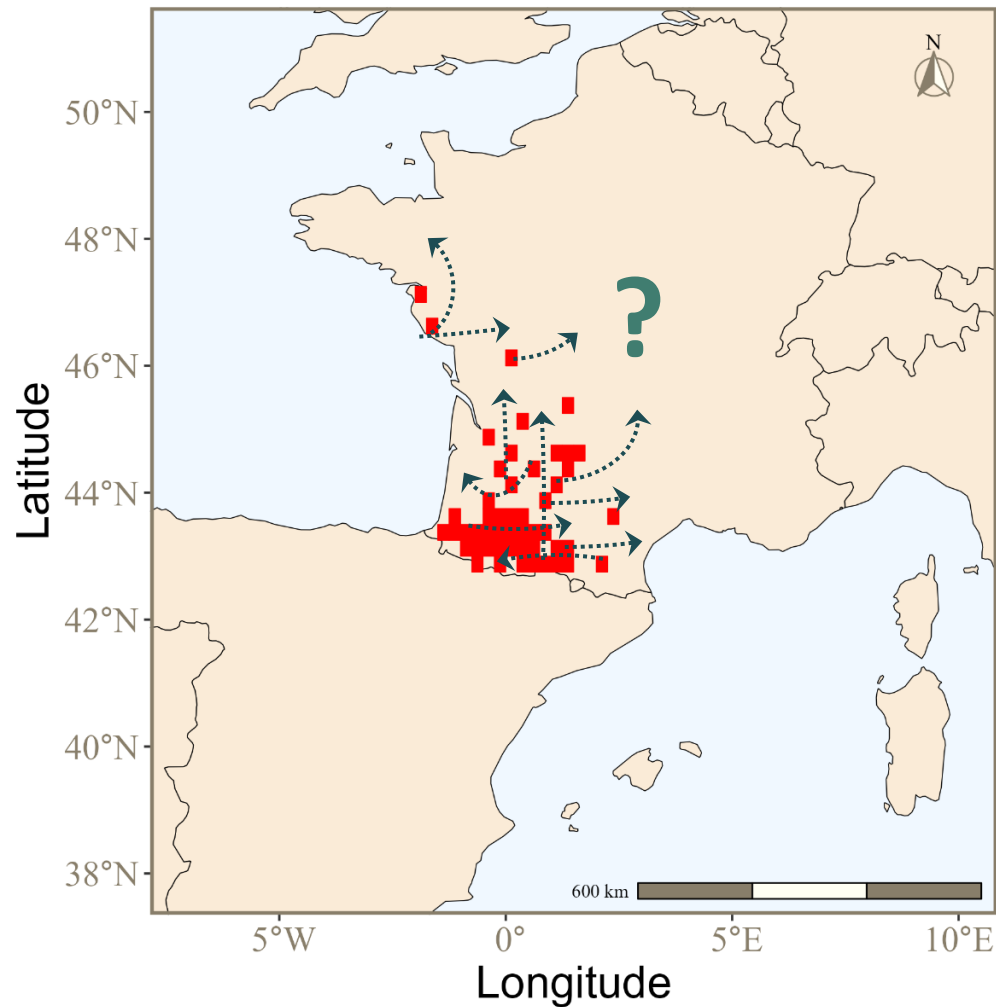


Prospection of future expansion

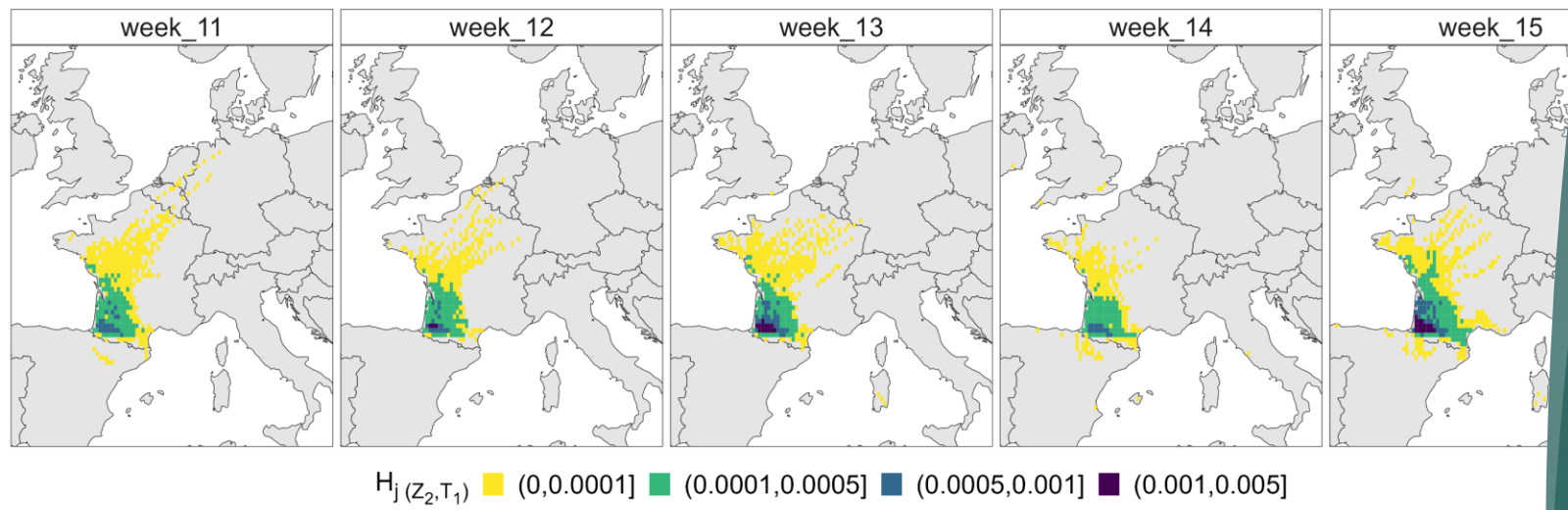
- ▶ Last available infected zone (early December 2023)
- ▶ Assumption of virus overwintering



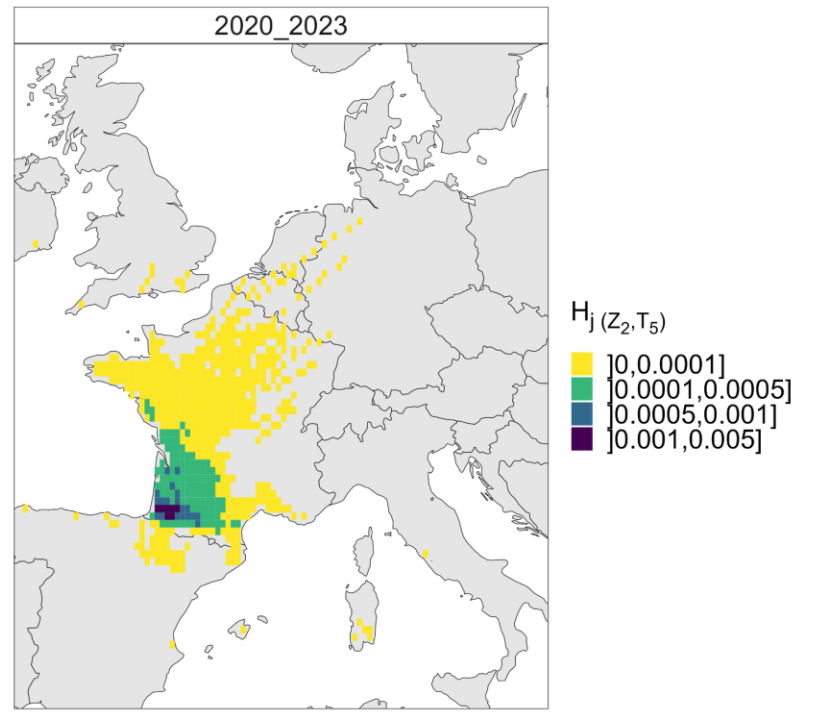
What is the zone at risk of wind-dispersal in 2024, at the re-start of the season?



(A)



(B)



- ▶ Mostly the western half of France

- ▶ Extreme destinations at very low probability (UK, Belgium, Sardinia..)

- ▶ Pyrénées & Massif Central mountains act as orographic barriers

Windi App



RShiny application for rapid assessment of the zone at risk of wind dispersal
https://windiapp.univ-lyon1.fr/windi_app/

Welcome to the WINDi App !

The WINDiApp has been developed to assess the risk of long-distance dispersal of *Culicoides* at the European scale.

By selecting an initiation area of your choice, you will be able to visualize either the potential at-risk destinations (forward mode) or the potential at-risk source locations (backward mode).

Before use you should be aware that:

- Risk maps provided by WindiApp result from HYSPLIT atmospheric simulations, which were specifically adapted to the ecological and survival constraints of *Culicoides* spp. The use of WindiApp for other arbovirosis than *Culicoides*-borne diseases is not advised.
- Users are encouraged to read the related and published articles :
 - 'Assessing the Risk of Windborne Dispersal of *Culicoides* Midges in Emerging Epizootic Hemorrhagic Disease Virus Outbreaks in France' [CR](#)
 - 'Quantitative risk assessment for the introduction of bluetongue virus into mainland Europe by long-distance wind dispersal of *Culicoides* spp.: A case study from Sardinia'
- WindiApp is an open tool designed for Research purpose only. The users are allowed to use, download, distribute and build upon material only so long as attribution is given to the creators.

Ready?



1. Click on «Initiation Area» to define your geographical area of interest
2. Click on «Forward results» or «Backward results» depending on your research question
3. Inside panel, select the desired time period (weeks) and years of meteorological data (2020-2023)



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1 Select your 'Initiation Area' (starting point for atmospheric simulations)

Initiation Area

The «Initiation Area» is the geographical zone of interest where *Culicoides* midges are known to be present. Depending on the Research question, this zone could have been infected by a disease (risk assessor intends to infer potential destinations) or free-of-disease (risk assessor intends to speculate on potential sources).

How does Initiation Area work?

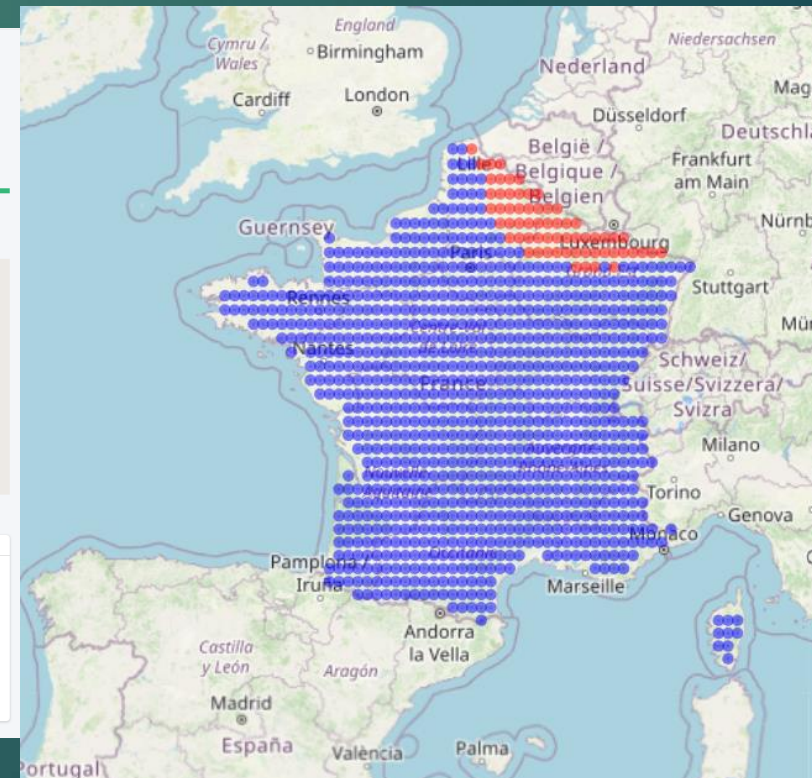
1. Select one or multiple countries in Europe
2. On the map, click on specific blue points or use the lasso to select multiple points at the same time. Once selected the points turn red and are implemented in the «Selected points» panel
3. When all desired points are selected, scroll up and click on «Forward Results» or «Backward results»

Select a country

Selected:

12573	12578	12414	12722	12577	12263	12418	12415	12576	12723	12579	12423	12266	12422	12581
12724	12725	12582	12420	12419	12575	12416	12574	12417	12718	12267	12421	12720	12726	12269
12268	12120	12277	12729	11976	11324	11972	11659	11821	12125	11495	11818	11164	11663	10251
10637	11824	11665	9826	11664										

Clear



Windi App

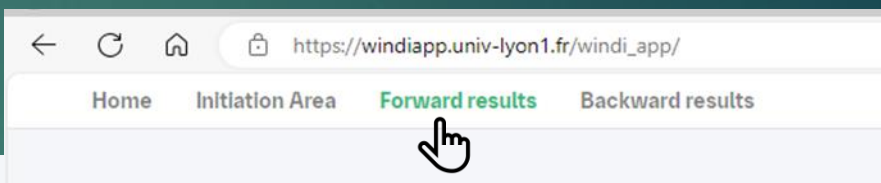


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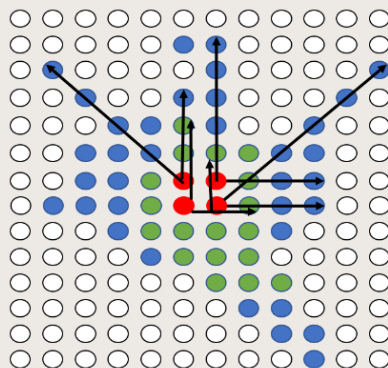
2

Get to the Forward Risk Map



Forward Results

«Forward» probability : inferring destinations from source



The Forward probability of long-distance dispersal (H_j) is the probability for a Culicoides to reach the destination cell j knowing that it started from the source cell i

- (ID_i) : source cell i selected by the risk assessor
- (ID_j) with 1 connection (1 trajectory went through)
- (ID_j) with 2 connections (2 trajectories went through)
- (ID_j) not connected

$$H_j(Z_i, T_y) = \frac{1}{(s_i y_n t_m \alpha)} \sum_{y=1}^{y_n} \sum_{i=1}^{s_i} \sum_{t=1}^{t_m} D_{ijt}$$

D_{ijt} is the number of connections between the source cell i and the destination cell j at day t ;
 s_i is the number of source grid cells i in the source zone Z_i ;
 y_n is the number of historical years of meteorological data considered (between 1 and 4 from 2020 to 2023);
 t_m the total number of days in the period T_y , with T_1 for a period of 1 week ($T_m=7$ days) and T_5 for a period of 5 weeks ($T_m=45$ days); and α is the maximal number of possible destinations reached in a day from a given source cell i , such as $\alpha=48$ (24 potential deposition spots per trajectory, 2 trajectories started per day)

Run

By Year

By Weeks

Specific

Week to consider

11, 12, 13, 14, 15, 16, 17, 18, 19, 20 ▾

Go

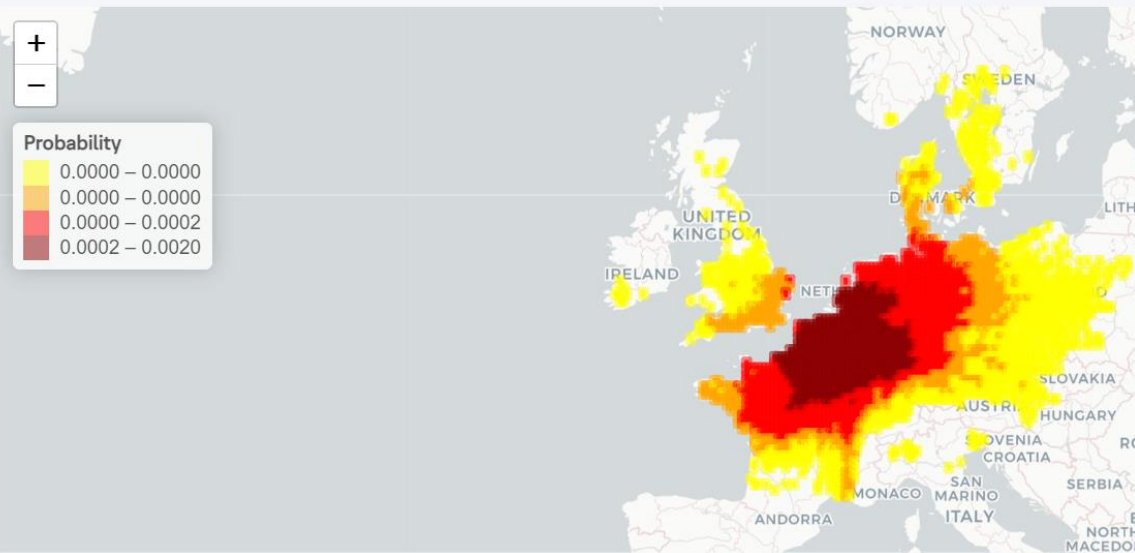
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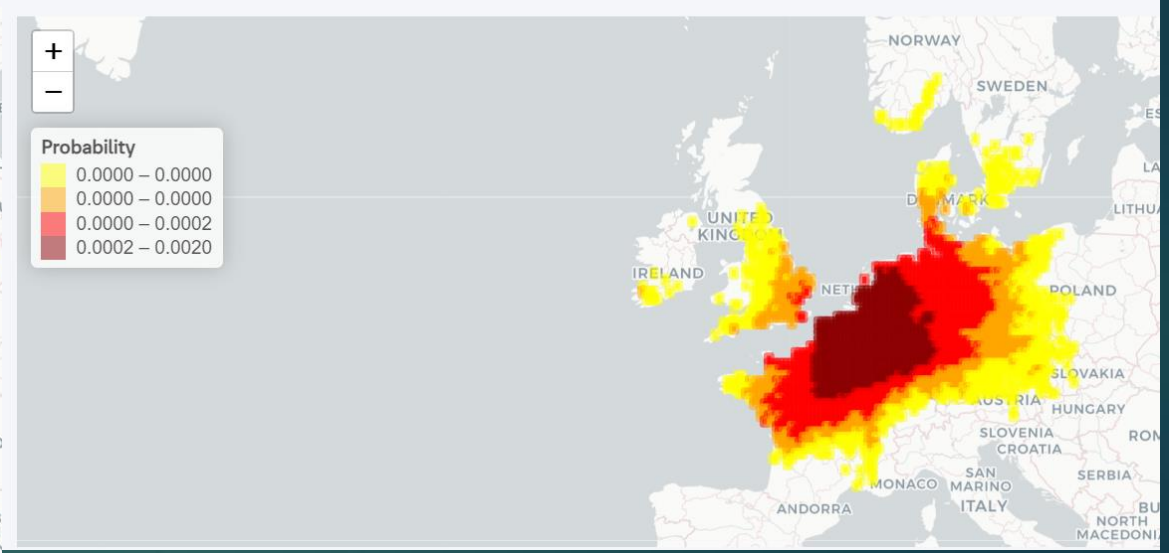
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Display the mean probability per year (mean over mid March to mid of November)

Forward map for year 2020



Forward map for year 2023

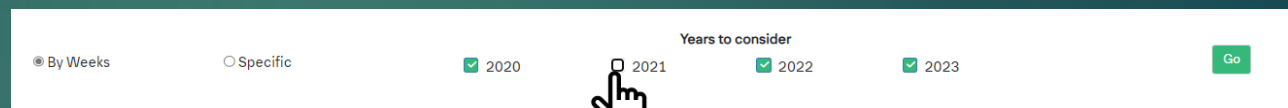


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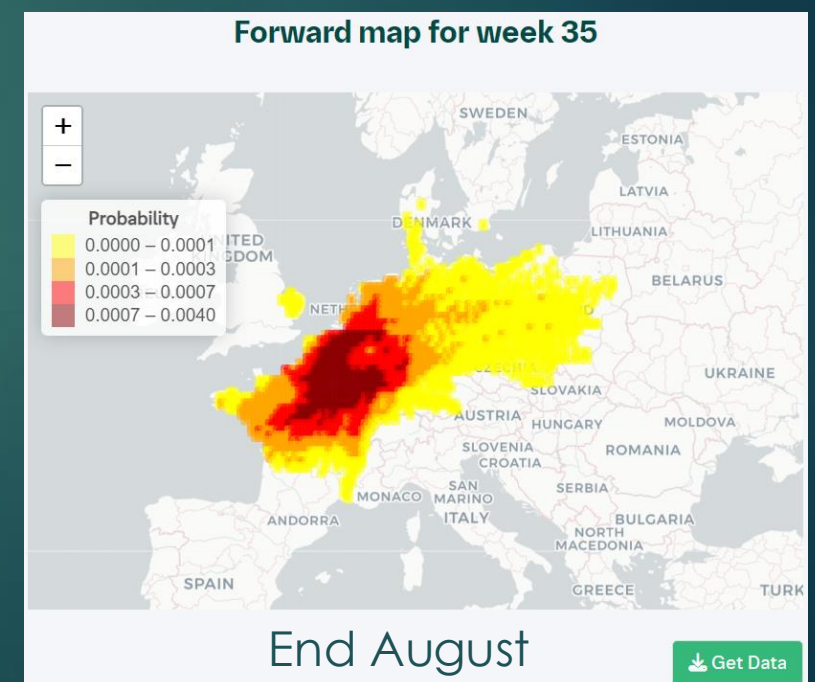
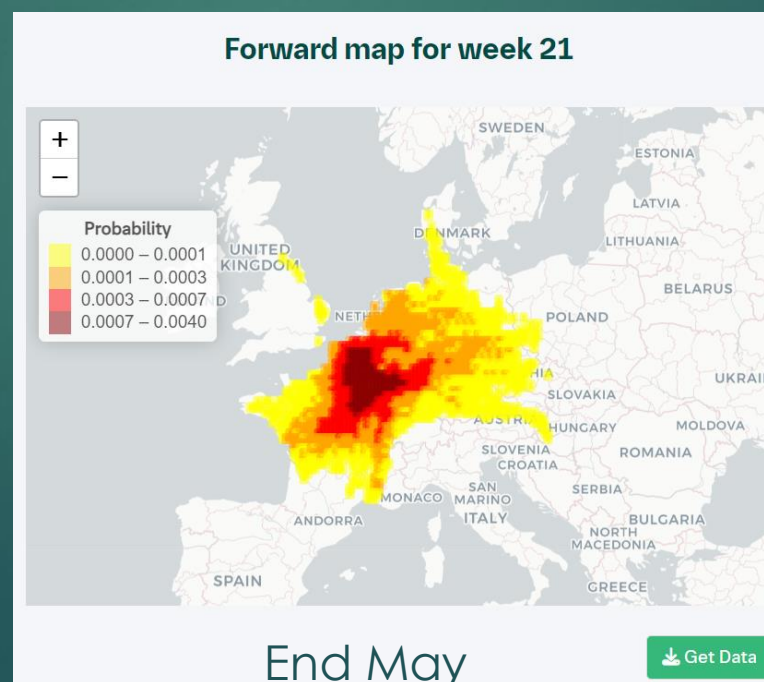
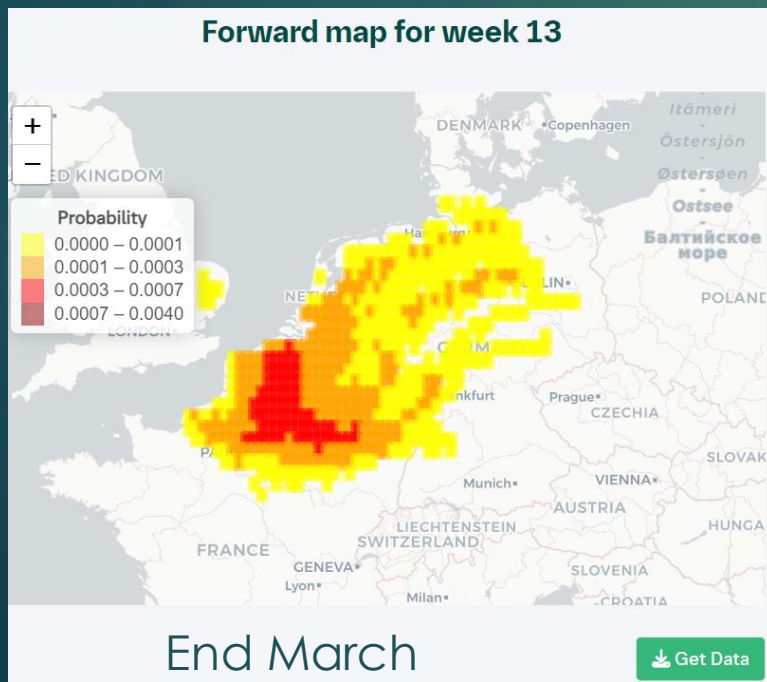


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Select the desired years of meteorological data (2020-2023)



Display the mean probability per week



Conclusions & Perspectives

- ▶ Our model is able to **rapidly assess the risk of *Culicoides* long-range dispersal** by the wind
- ▶ It considers **historical variations** of wind speed, directions at **large scale** of Europe
- ▶ Provides insights to **identify at-risk locations** at risk from a known area with a very **good predictability** (over 5 weeks)
- ▶ **Flexible** tool (source locations / *Culicoides* borne disease /time period...)

However...

- ▶ Model assumes homogenous vector/host presence in source & destinations
- ▶ Under estimates short-range dispersal
- ▶ Source area to be updated according to the disease epidemiology

Thank you for your attention
Thanks to all the contributors

Research Article

Assessing the Risk of Windborne Dispersal of *Culicoides* Midges in Emerging Epizootic Hemorrhagic Disease Virus Outbreaks in France

Amandine Bibard ¹ Davide Martinetti ² Albert Picado ¹ Karine Chalvet-Monfray ³ and Thibaud Porphyre ⁴



Thibaud Porphyre



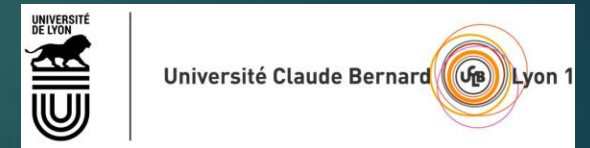
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