Risk of *Culicoides* dispersal by the wind : case study with EHDV in France

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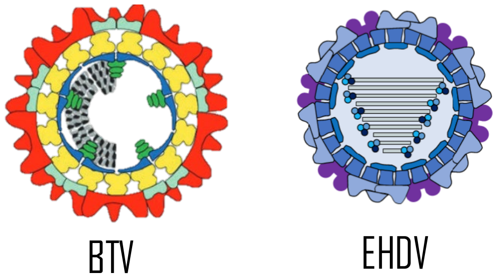
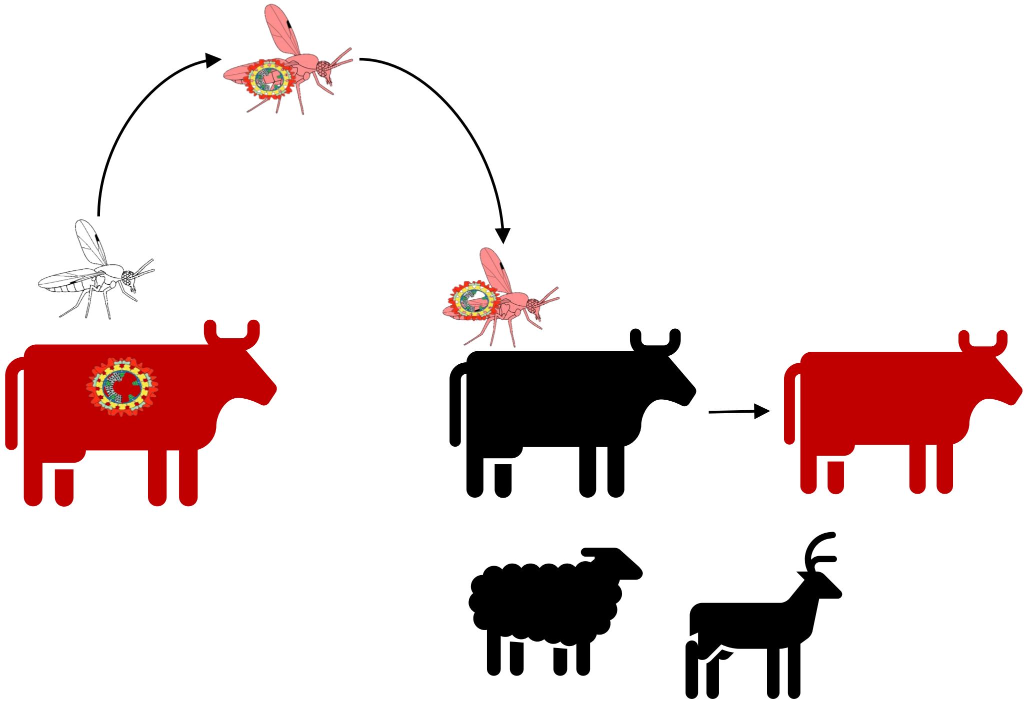
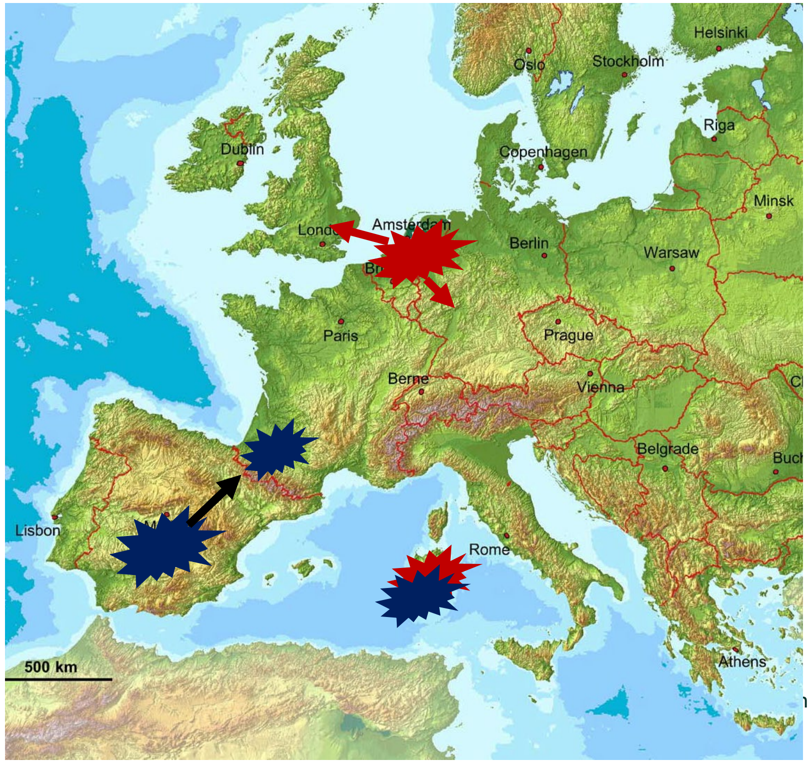
Epizootic Hemorrhagic Disease Virus (EHDV) : an emerging threat in Europe

- Orbivirus like Bluetongue virus
- Morbidity/mortality variable according to serotypes
- High economical & animal health impacts mostly in the cattle farms
- Also transmitted by *Culicoides* midges







BTV-3

Sardinia: 2018
Nl: Sept 2023

EHDV-8

Sardinia: Oct 2022
Spain: Oct 2022
France: Sept 2023

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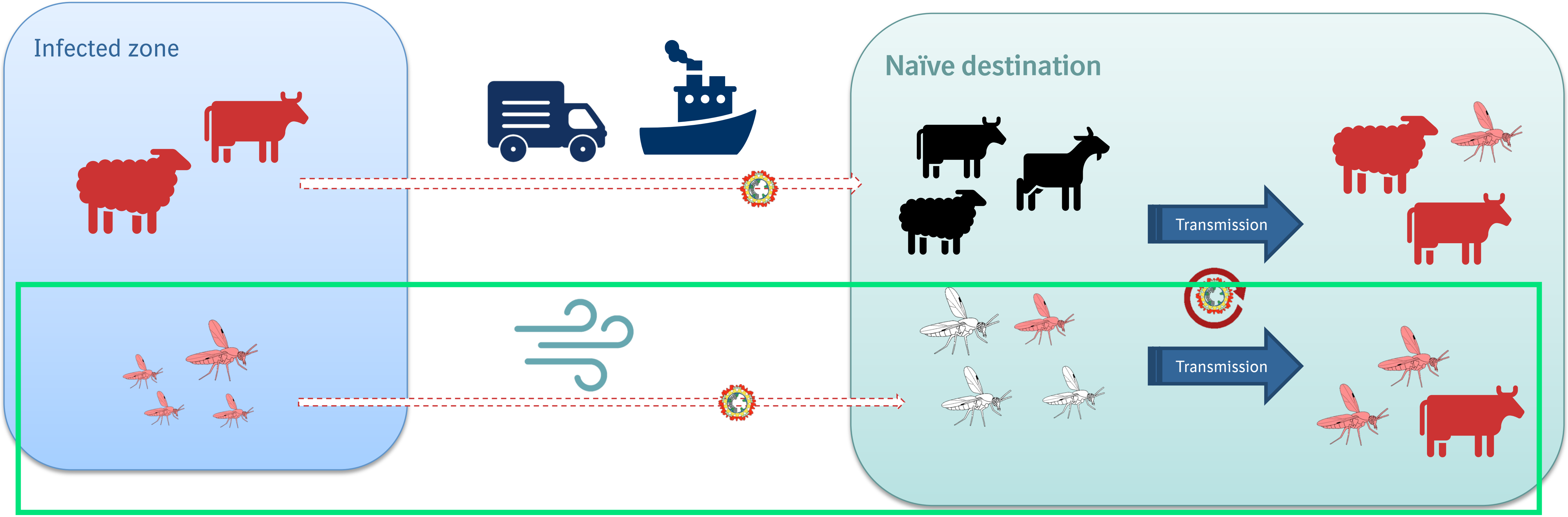
Two main pathways of virus introduction



- Animal movements & *Culicoides* dispersal by the wind
- Dispersal by the wind difficult to control and highly variable due to the high number of parameters to control

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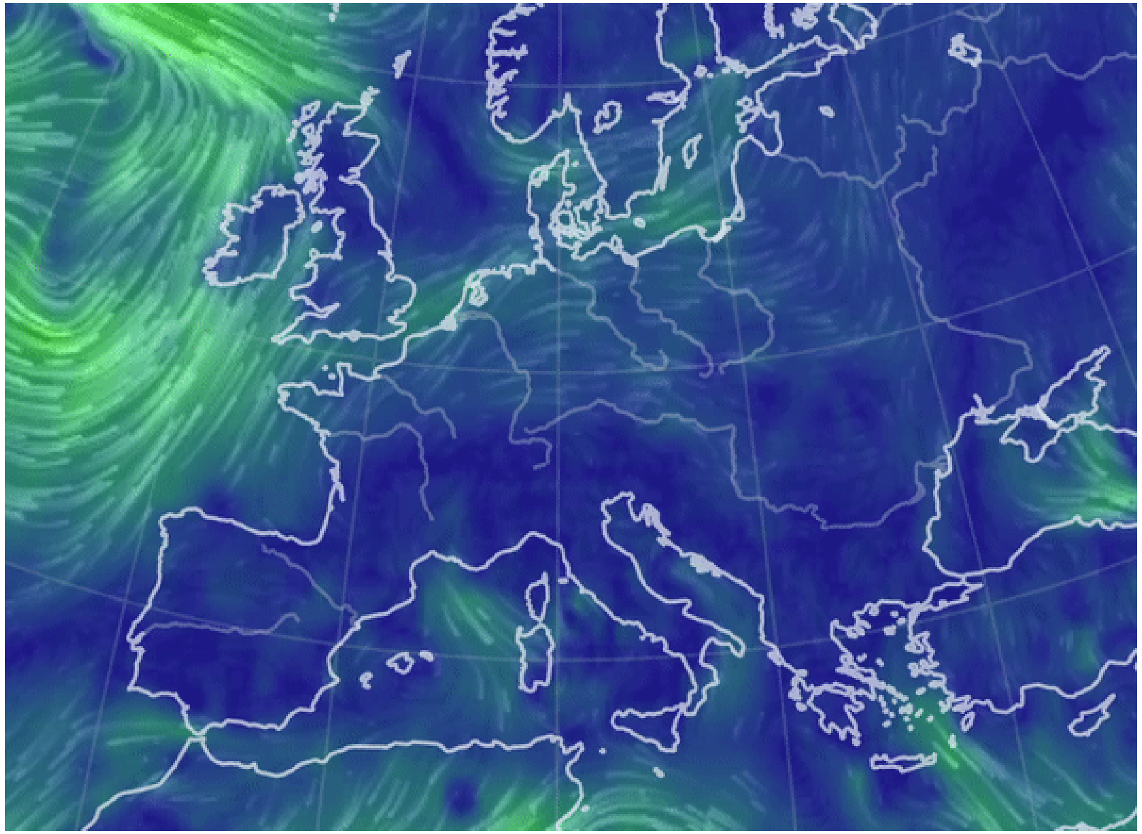
The wind: highly variable parameter

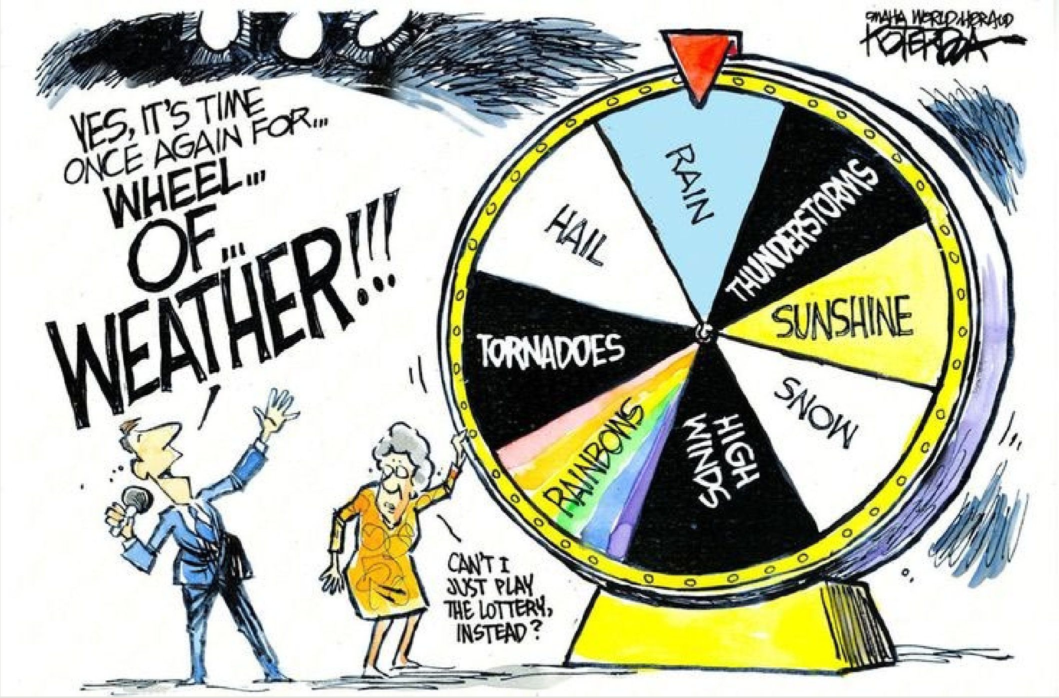


Source: *iweathernet.com*

- Wind direction and speed highly variable
- Influenced by the terrain
- Midge survival depends on temperature

How to predict *Culicoides* wind dispersal in Europe?

Atmospheric Dispersion Model (ADM)



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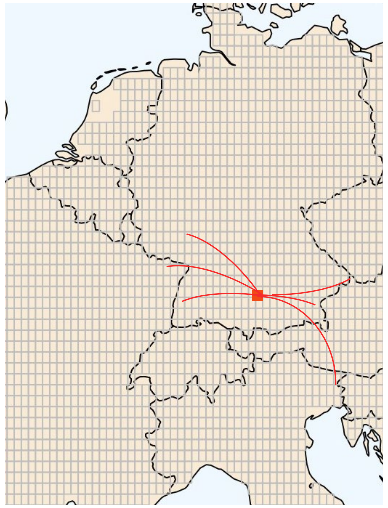
HYSPLIT Model

- Originally developped for nuclear explosion and volcano eruption.
- HYSPLIT **simulates the dispersion** and **trajectory** of substances transported and dispersed through our atmosphere, over **local to global scales**.

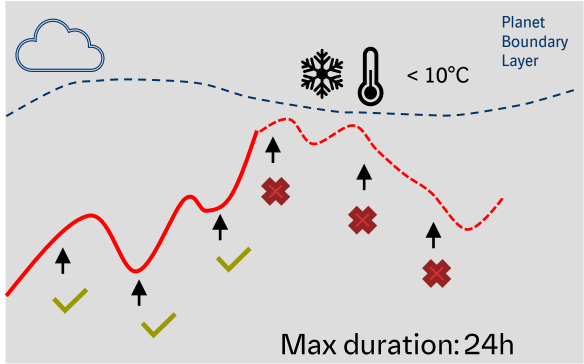
1 Define the starting point(s)

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

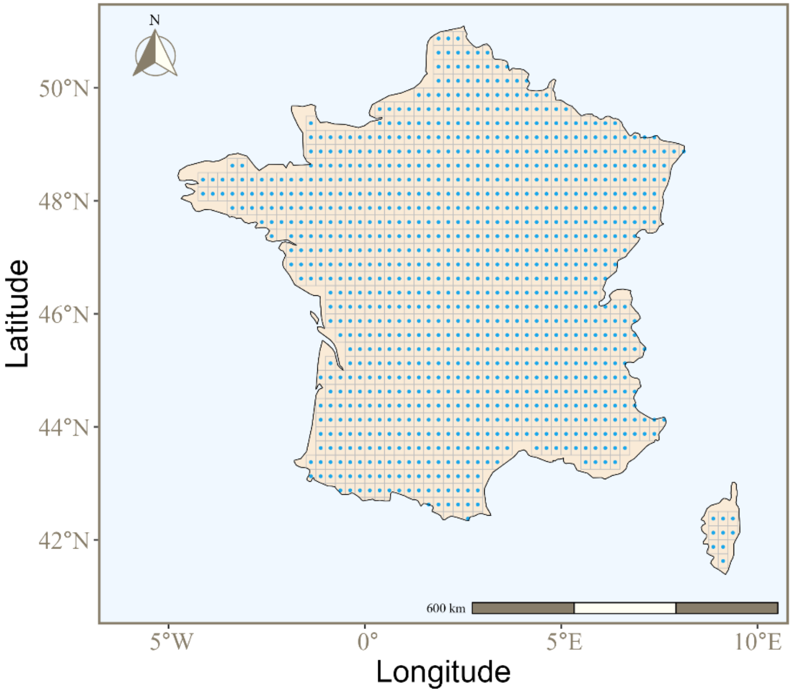


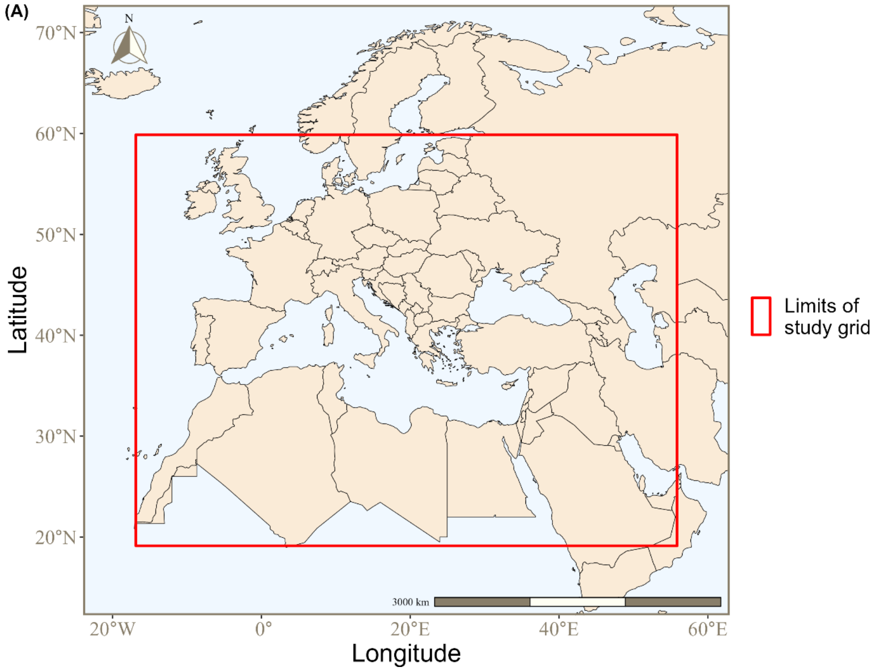
H_{ij} ~ probability to reach destination from starting point

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

A framework developped for the whole EU

- Large study grid
- 32 292 grid cells of ~25x25 km
- 65 100 672 atmospheric simulations performed
- > 10 Go of output data





EHDV-8 in France: zone of vector wind dispersal from index cases

First introduction in EU France (Sept 2023)

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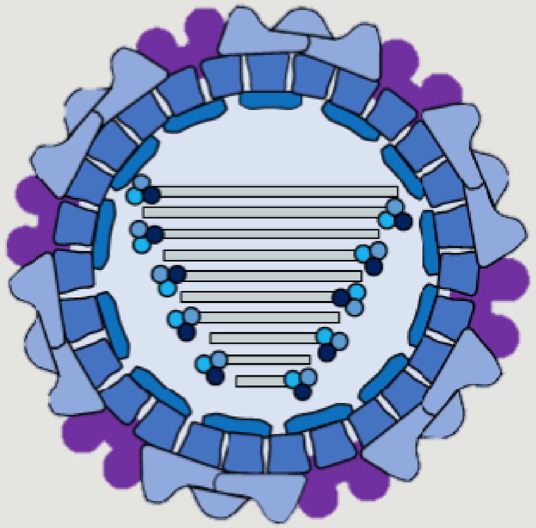
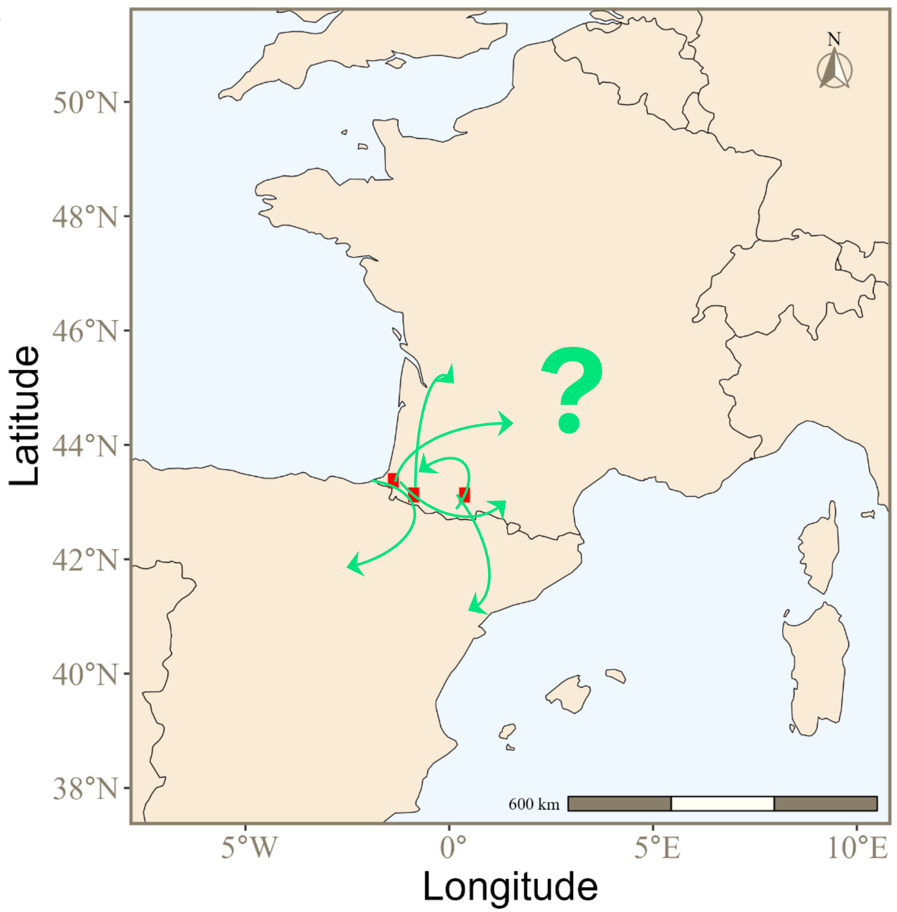


First 3 outbreaks in France (early September 2023)



- 3 first outbreaks reported in France

What could be the magnitude of the long-distance dispersal zone from the first cases?

Is a predictive insight for emerging outbreaks?

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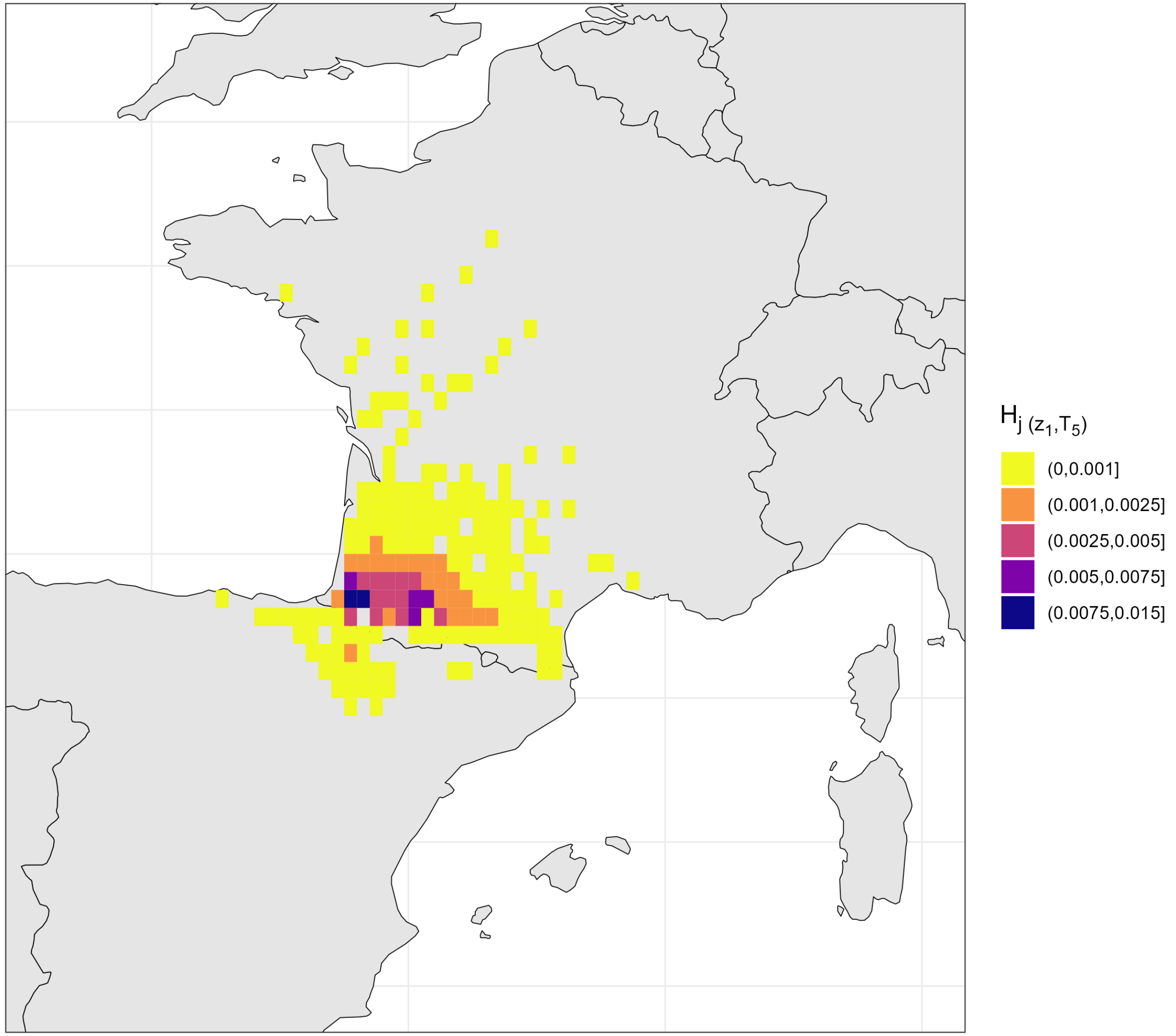
Predicted risk zone averaged over 5 week-period

Windborne dispersion from index source zone *z1*



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

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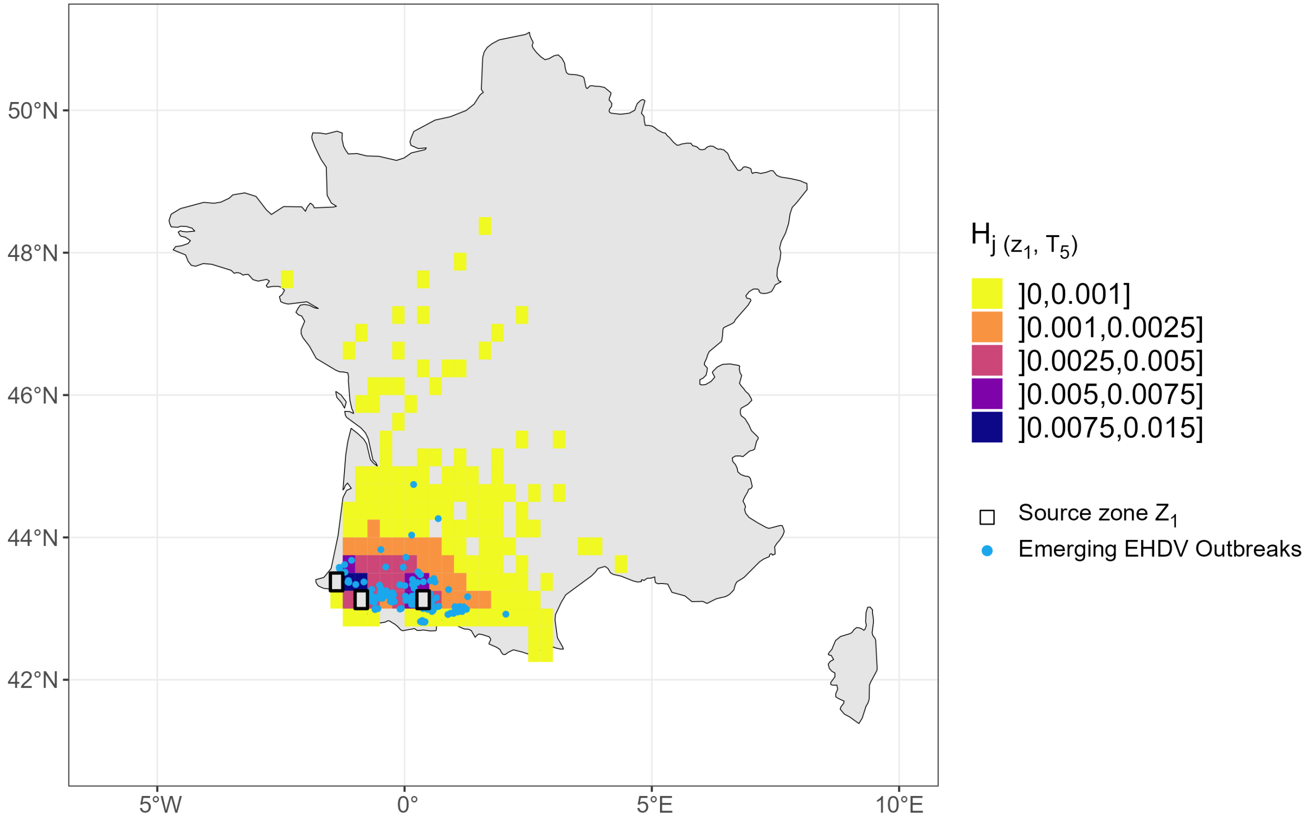
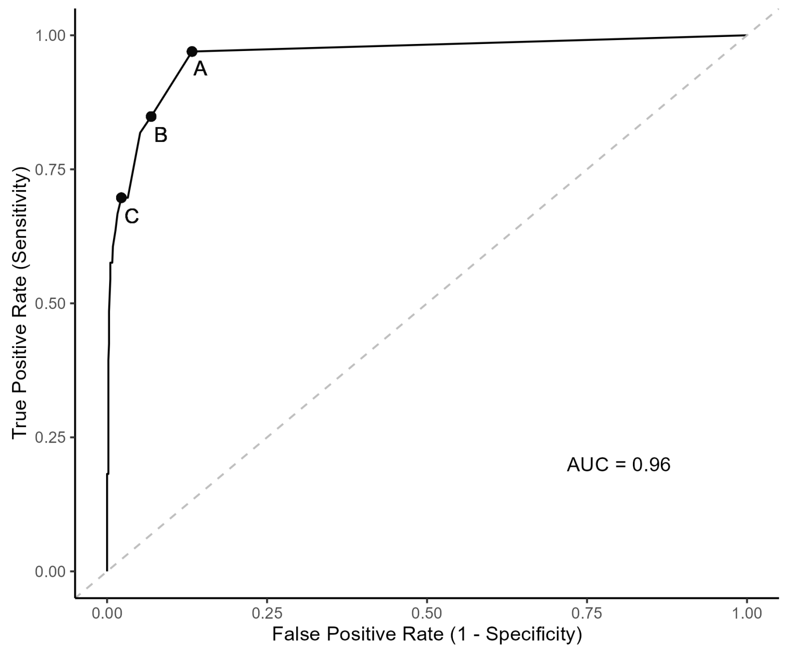
Very good predictability of the model



- 99,9% locations with at least 1 outbreak were predicted at risk
- ROC curve of 0,96 (Se:97%, Sp:86,7%)
- Reducing the risk threshold leads to a significant drop in sensibility



But under estimation of the short range dispersion (26.3% Ob remain within the source zone)

Situation	θ	TPR	FPR	Area (km²)	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%

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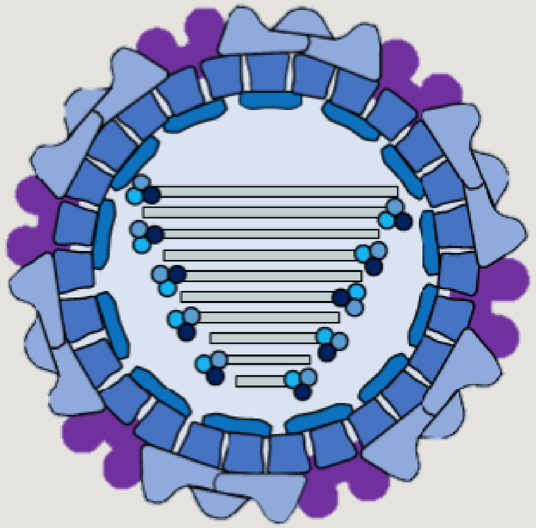
And what about next year ?

What could be the magnitude of the long-distance dispersal zone in early 2024?



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EHDV-infected area (early December 2023)

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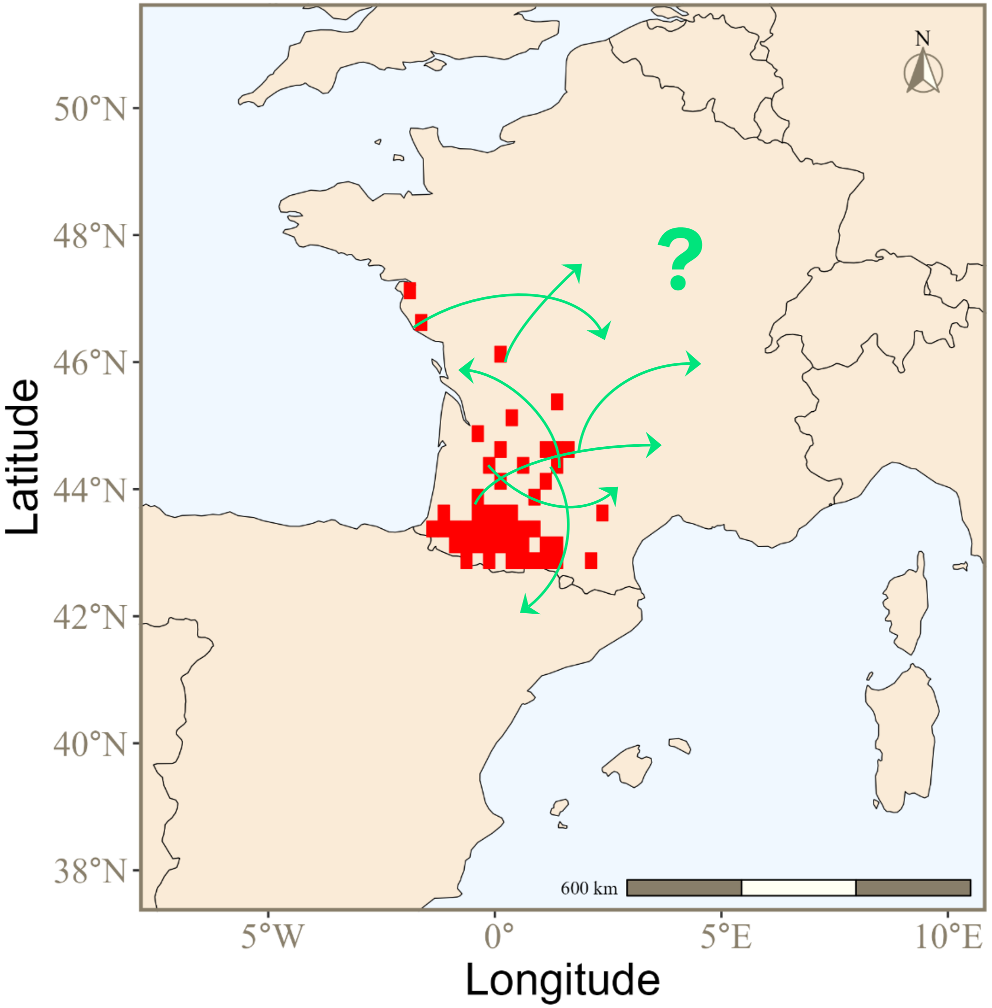

- Areas where at least 1 EHDV outbreak occured in France
- WOAH data at December 1st
- Main assumption: all red locations start to be infectious again all at the same time, mid of March (week 11)

What are the locations at risk of long-distance dispersal by the wind?

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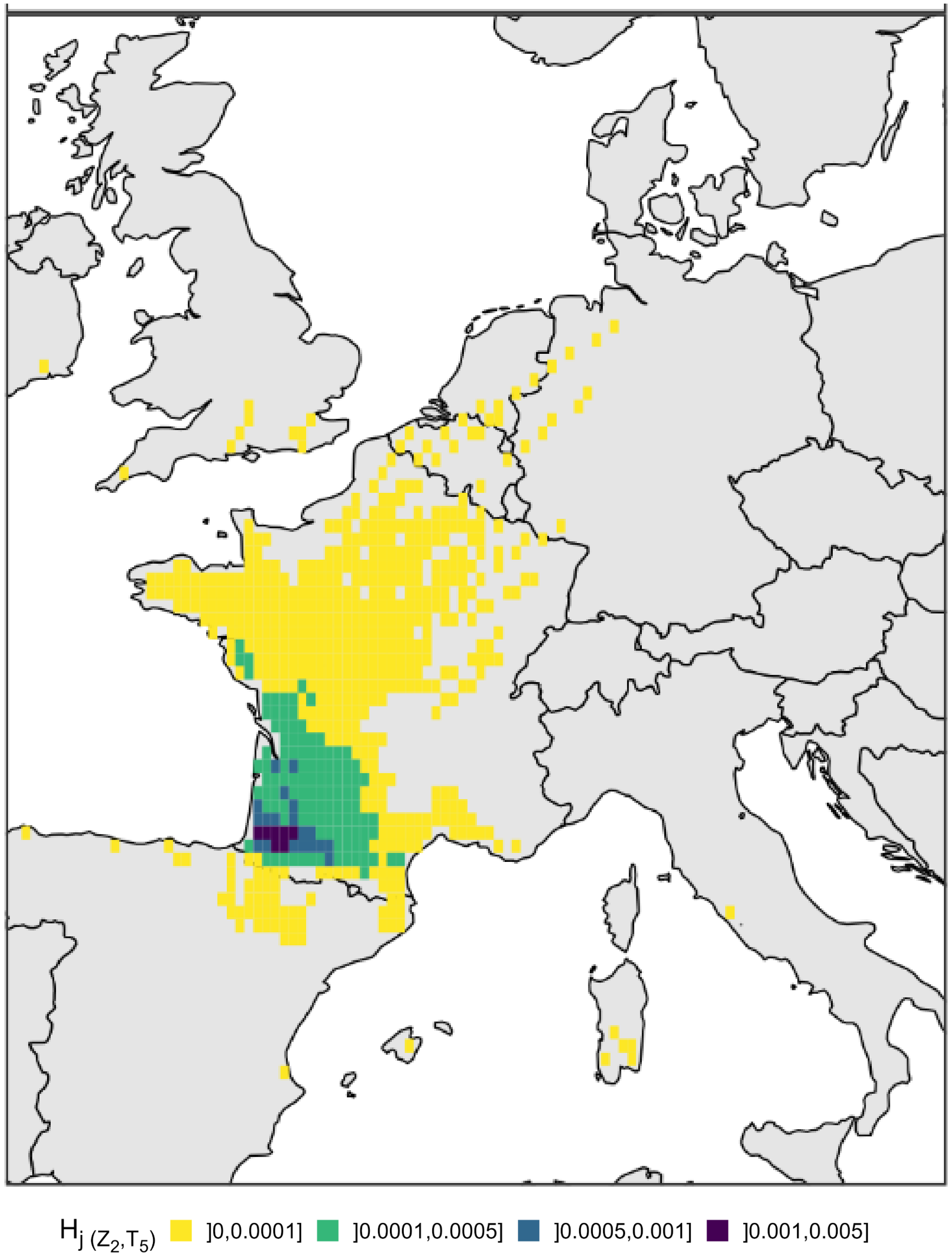
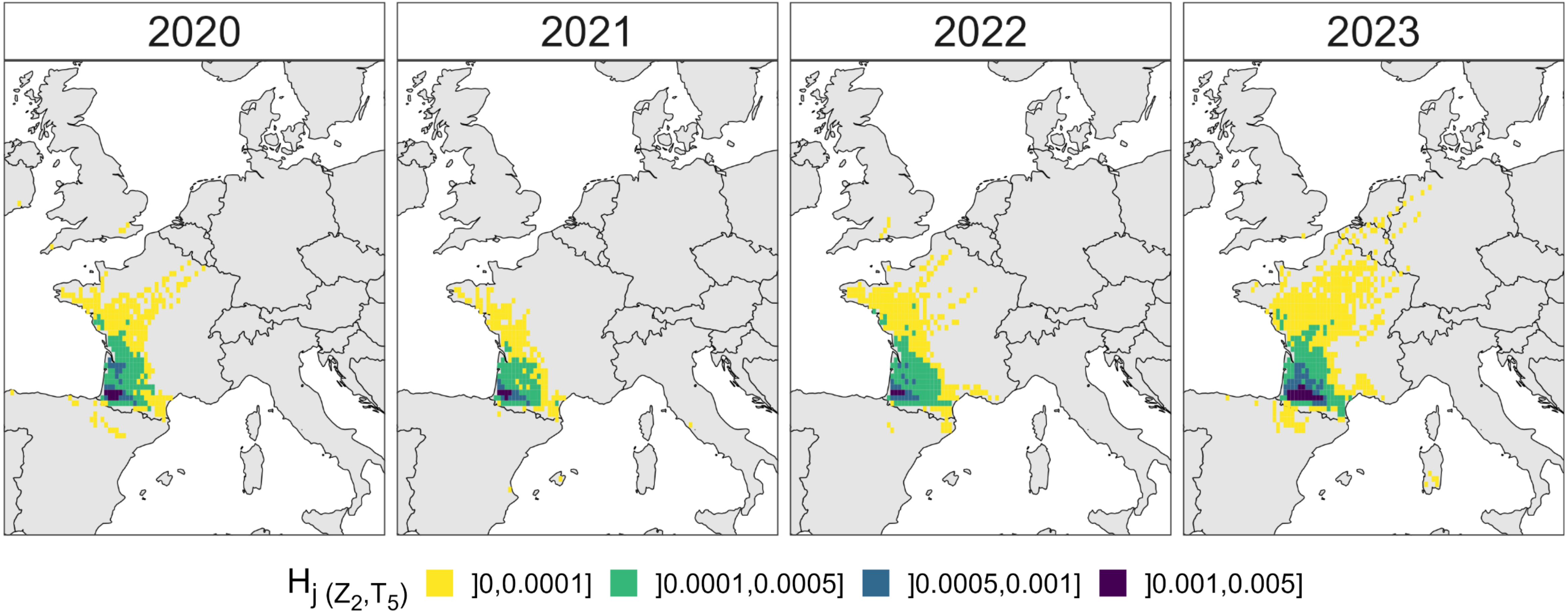


Risk zone averaged over the 2020-2023 period

- Mostly the western half of France
- Extreme destinations in UK, Ireland, Belgium, the Netherlands, Germany, the Balearic Islands, southern Sardinia, and the western border of Italy
- Pyrénées & Massif Central mountains act as orographic barriers

Variability over years



H_j: probability of long-distance dispersal for each destination j over a 5 week period (from W11 to W15; from mid-March to mid-April

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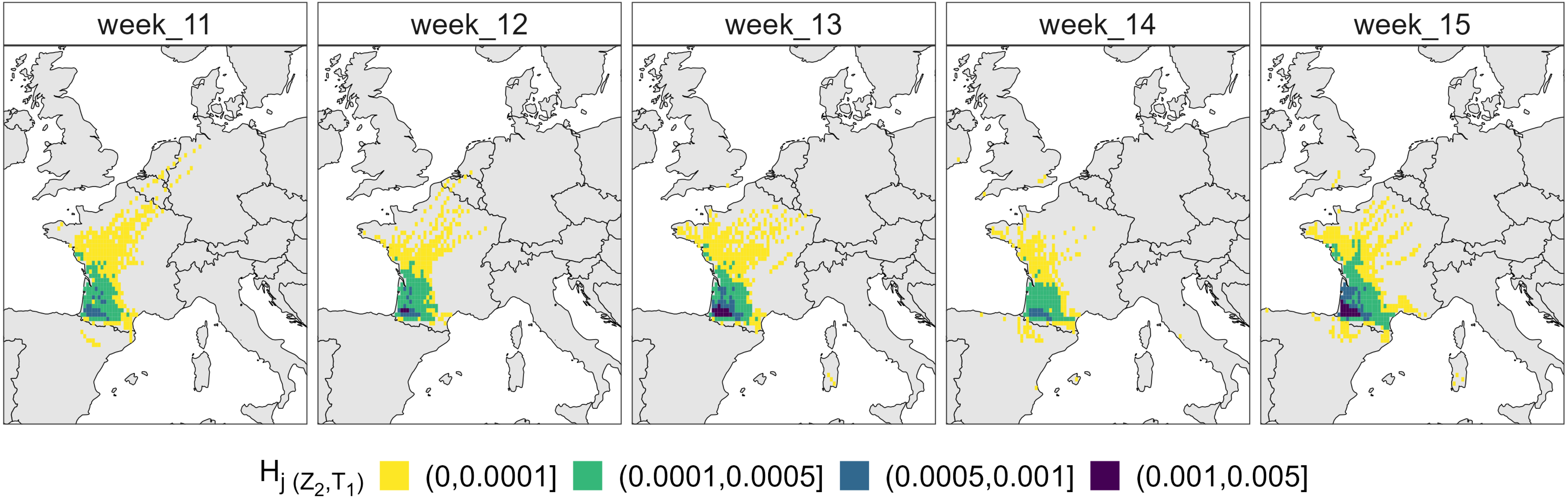
Variability over weeks



H_j: probability of long-distance dispersal for each destination j over a 5 week period (from W11 to W15; from mid-March to mid-April) – averaged over 2020-2023

Conclusions & perspectives

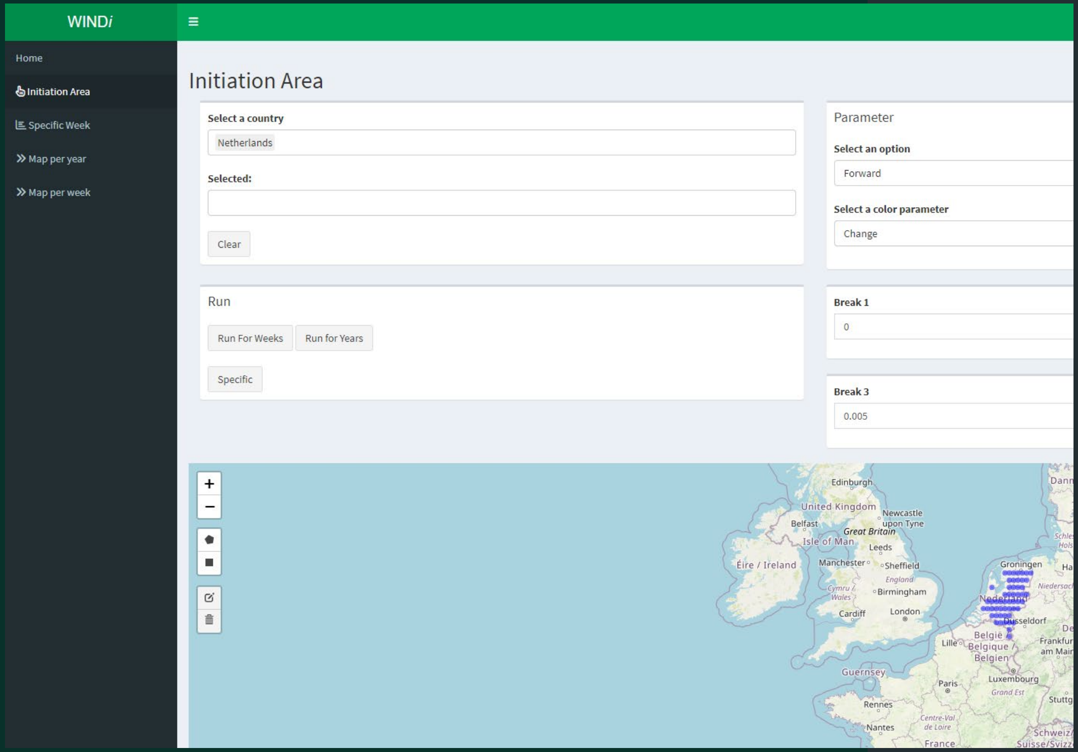
- Our model is able to **rapidly assess the risk of *Culicoides* long-range dispersal** by the wind
- It consider **historical variations** of wind speed, directions at **large scale** of Europe
- Provides insights to **identify at-risk locations** at risk from a known area with a very **good predictability**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

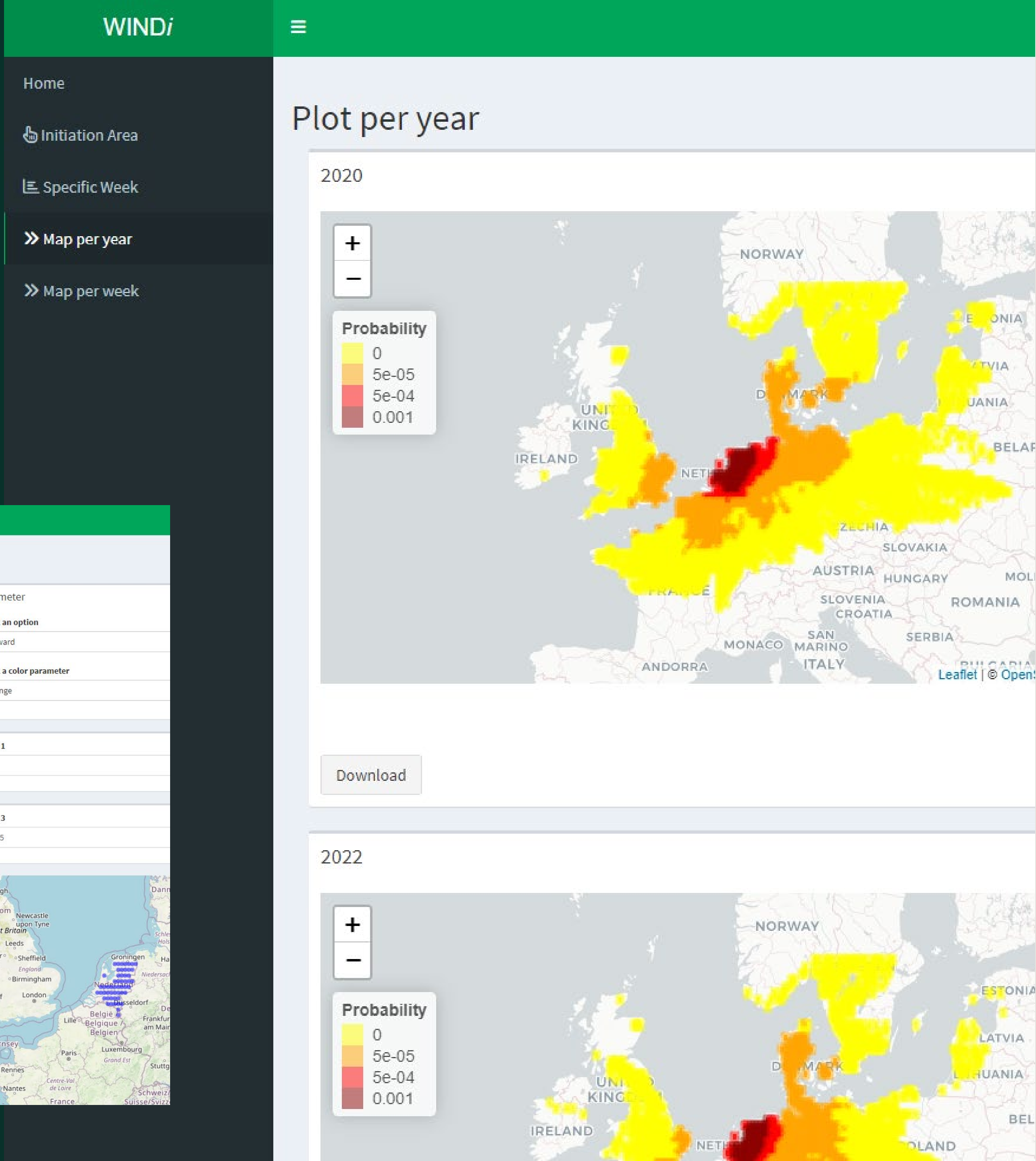
However…,

- Risk of *Culicoides* wind dispersal ≠ disease introduction
- Under estimate short-range dispersal
- Source area to be updated according to the disease epidemiology

Windi App

A web application for data visualisation and analysis





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Thank you for your attention

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