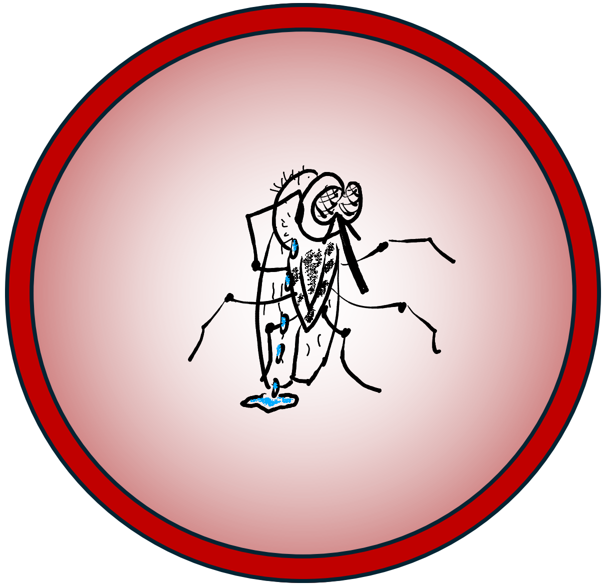
Impact of climate and weather on *Aedes albopictus* in Italy

Open Slides



Miguel Garrido Zornoza

Cyril Caminade &

Adrian M. Tompkins

ICTP 1964–2024

&

UNIVERSITY OF COPENHAGEN

FACULTY OF SCIENCE

Climate-Sensitive Vector Dynamics Modelling Workshop, Bologna (IT) Sep. 19-20 (2024)

Outline

1 Introduction: the VECTRI model
2 Parametrization and calibration of *Aedes albopictus*
3 Objectives
- 3.1 Validate the model against ovitrap data
- 3.2 Asses the geographical distribution and activity in Italy
- 3.3 Study the effect of heatwaves on the population of *Aedes albopictus*

4 Results
5 Conclusion and future perspectives

1 Introduction: the VECTRI model

The **VEC**tor-borne disease community model of ICTP, **TRI**este, is

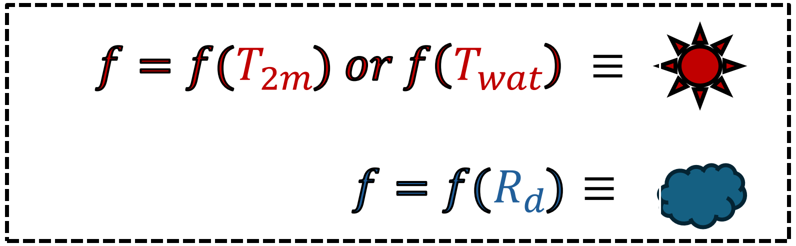
- A **multi-species** dynamical model, currently describing the life cycle of
  - *Anopheles gambiae s.s.* (original, see *e.g.*, Tompkins *et al.* 2013, Asare *et al.* 2016 +15), malaria is parameterized
  - *Anopheles funestus* (in development, not evaluated)
  - *Anopheles sacharovi* (Karypidou *et al.* 2020)
  - *Aedes aegypti* (in development, not evaluated)
  - *Aedes albopictus* (Garrido Zornoza *et al.* 2024, under review), dengue is **not** parameterized

- **Climate-aware**: air temperature at two-metre height, T_{2m}(°C), and daily rainfall, $R_d(mm \cdot day^{-1})$
- **Open source**: http://users.ictp.it/~tompkins/vectri/
  - Install *Aedes* version:

```
git clone https://gitlab.com/tompkins/vectri.git
git checkout tags/v1.11.3
```

  - Run example in OSF repository https://osf.io/3gcfb/

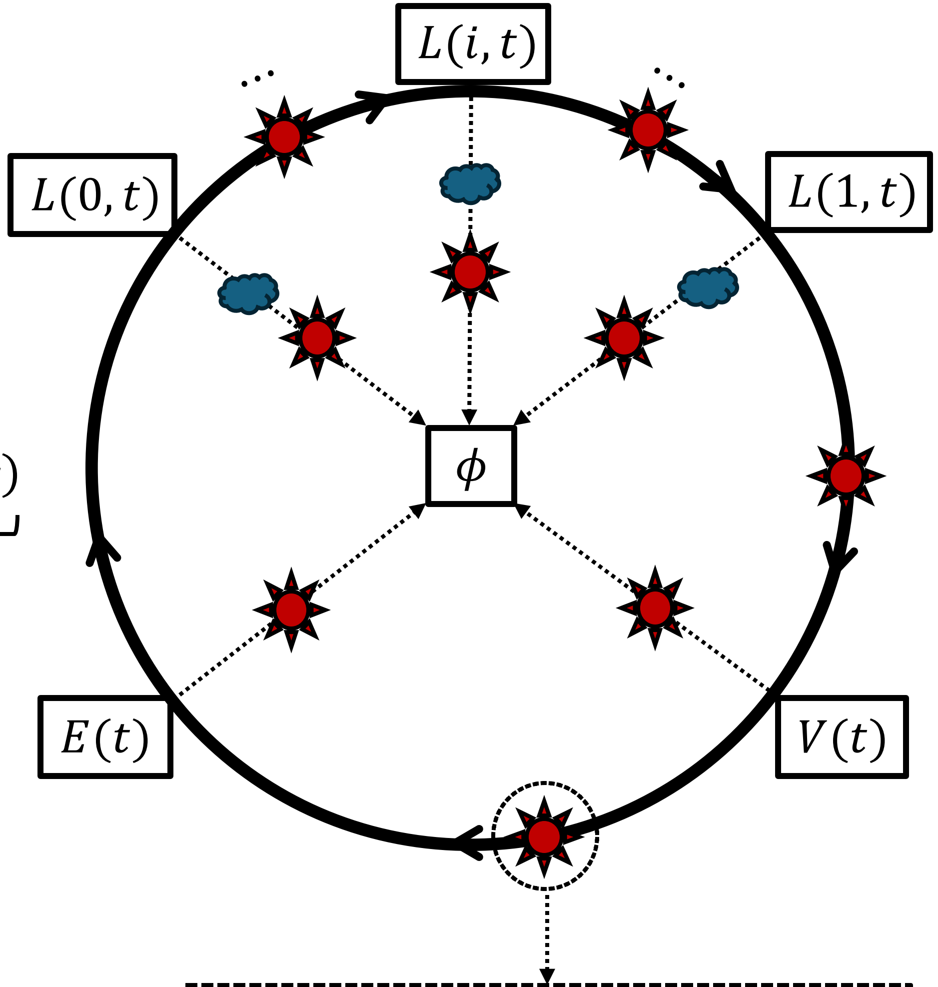
1 Introduction: the VECTRI model



$$\frac{dE(t)}{dt} = \overbrace{N_{egg} \cdot R_{gono}(T_{2m}) \cdot V(t)}^{\text{oviposition}} \overbrace{-\delta_E(T_{wat}) \cdot E(t)}^{\text{mortality}} \overbrace{-g_E \cdot E(t)}^{\text{hatching}}$$

$$\frac{\partial L(f,t)}{\partial t} = \underbrace{[f = 0] \cdot g_E \cdot E(t)}_{\text{hatching}} \underbrace{-R_L(T_{wat}) \cdot \frac{\partial L(f,t)}{\partial f}}_{\text{development (advection)}} \underbrace{-\delta_L(T_{wat}) \cdot L(f,t)}_{\text{mortality}} \underbrace{-\delta_{crowd}(R_d, L) \cdot L(f,t)}_{\text{predation and overcrowding}}$$

$$\frac{dV(t)}{dt} = \underbrace{R_L(T_{wat}) \cdot \left.\frac{\partial L(f,t)}{\partial f}\right|_{f=1}}_{\text{emergence}} \underbrace{-\delta_V(T_{2m}) \cdot V(t)}_{\text{mortality}}$$



$$R_{gono}(T_{2m}) = \frac{T_{2m} - T_{gono}}{K_{gono}} \in [0,1]$$

- Temperature-driven decay rates fitted from lab. and obs. data
- Fixed time step, $\Delta t = 1\ day$
- $T_{wat} = T_{2m} + 2°C$ (when no hydro)
- No vector mobility across grid boxes

2 Parameterization and calibration of *Aedes albopictus*

Parameterization

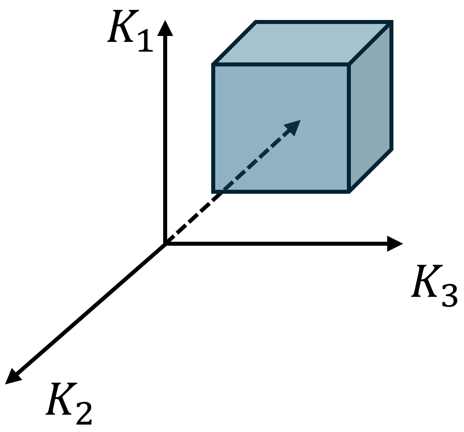
- Temperature mortality scheme for V, E and L, *i.e.*, $\delta_V(T_{2m}), \delta_L(T_{2m}), \delta_E(T_{2m}) \rightarrow$ Metelmann *et al.* 2019
- Life cycle parameters, *e.g.*, T_{gono} or N_{egg} $\rightarrow$ from literature (referenced in the manuscript)

Calibration

- Life cycle **parameters**, $\vec{K}$, are constrained by field and lab. studies but nevertheless **uncertain**
- **Search** within this uncertainty “window” for the best, yet **realistic**, **solution**
- Constrained optimization using the **Genetic Algorithm** (GA) from Tompkins *et al.* 2018

$$\vec{K} \ s.t. \ \ \vec{\sigma}(x,t) - \vec{S}(x,t;\vec{K}) \rightarrow \vec{0}$$

$$\vec{K}_{min} \leq \vec{K} \leq \vec{K}_{max}$$



- **Emilia-Romagna** ovitrap data from Carrieri *et al.* 2011, 2017, 2021

4 Results

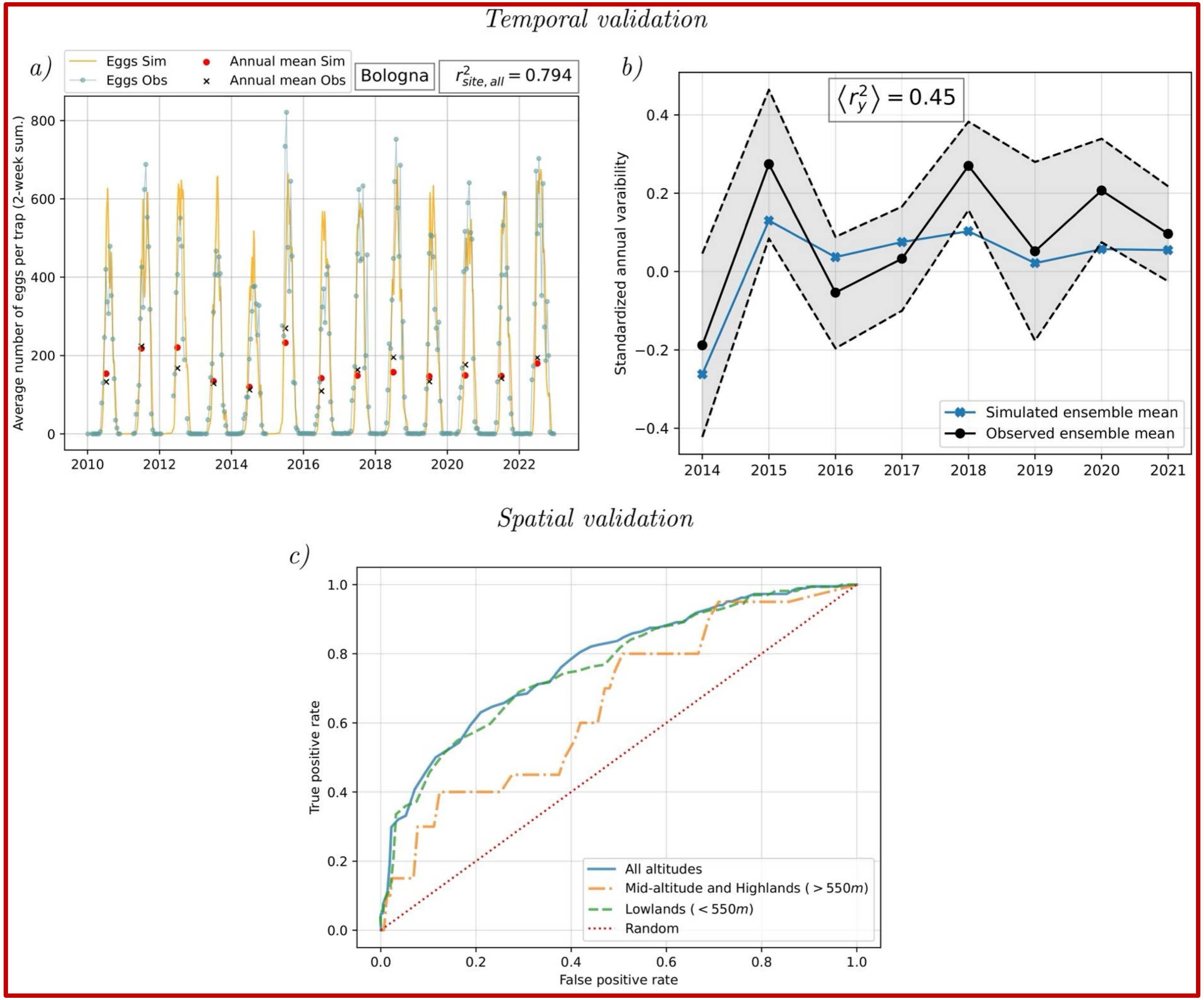
4 Results

4.1 Model validation

a) Seasonality

b) Inter-annual ensemble

c) ROC curves (AUC $\sim 0.65 - 0.85$)



Garrido Zornoza et al. 2024
(in review for JRSI)

4 Results

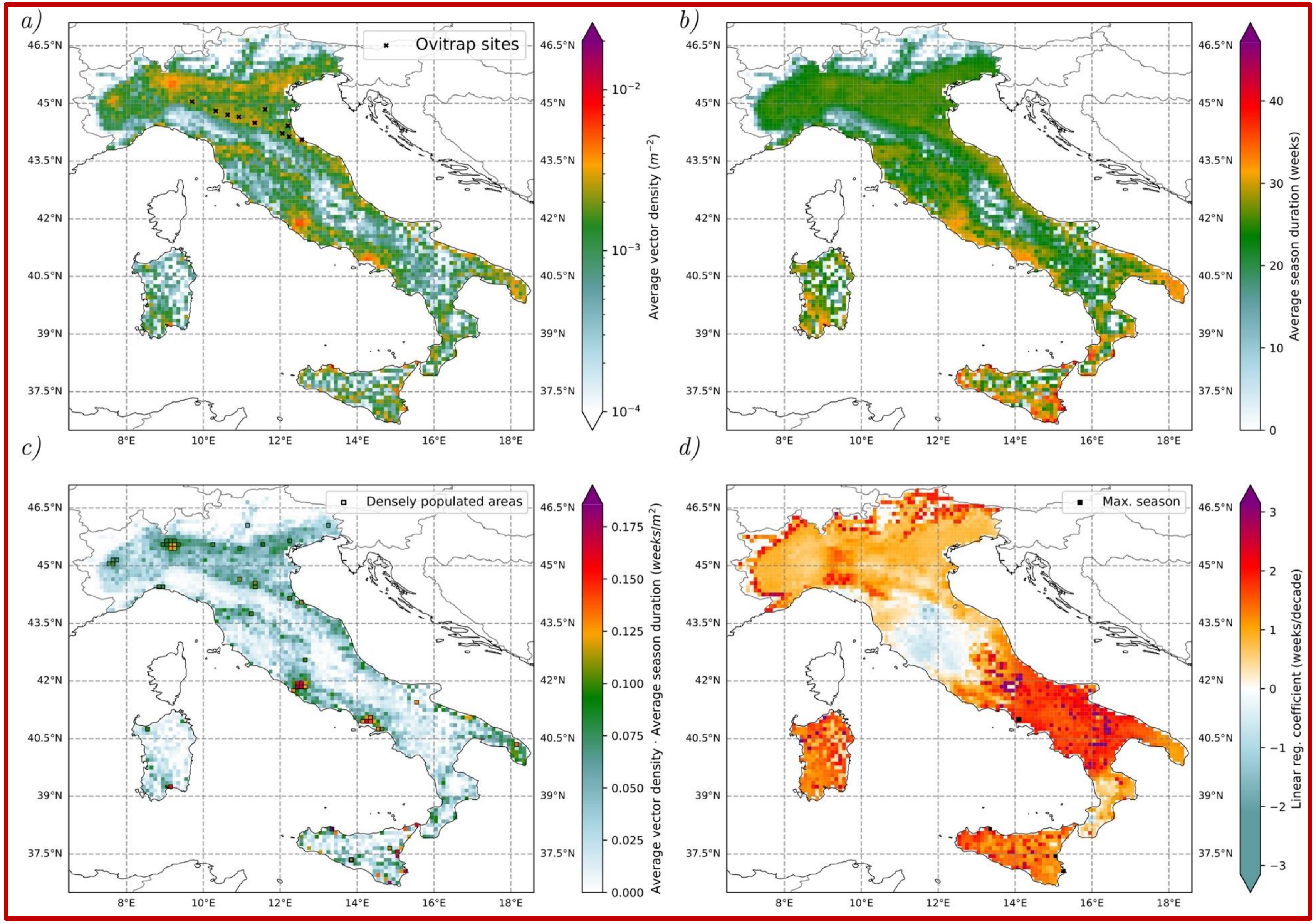
4.2 Geographical distribution and activity in Italy

a) Average density 1980-2022

b) Average sesion duration

c) Risk estimate

d) Increase in season length of $0.5 - 3$ weeks per decade



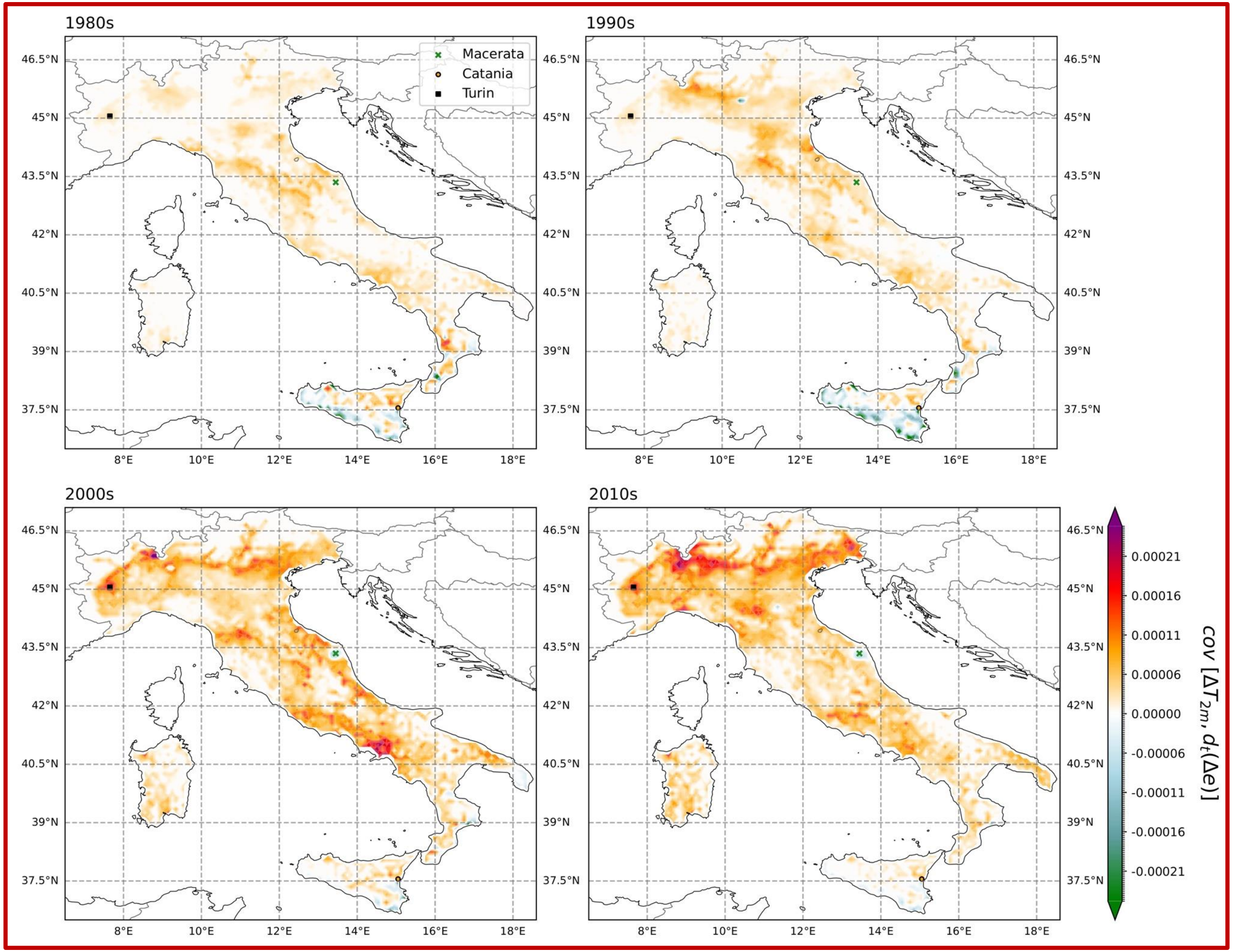
Garrido Zornoza et al. 2024
(in review for JRSI)

4 Results

4.3 Heatwaves

- Decadal increase
  - Mostly positive
  - Can be negative in southern areas

Garrido Zornoza et al. 2024
(in review for JRSI)



4 Results

4.3 Heatwaves

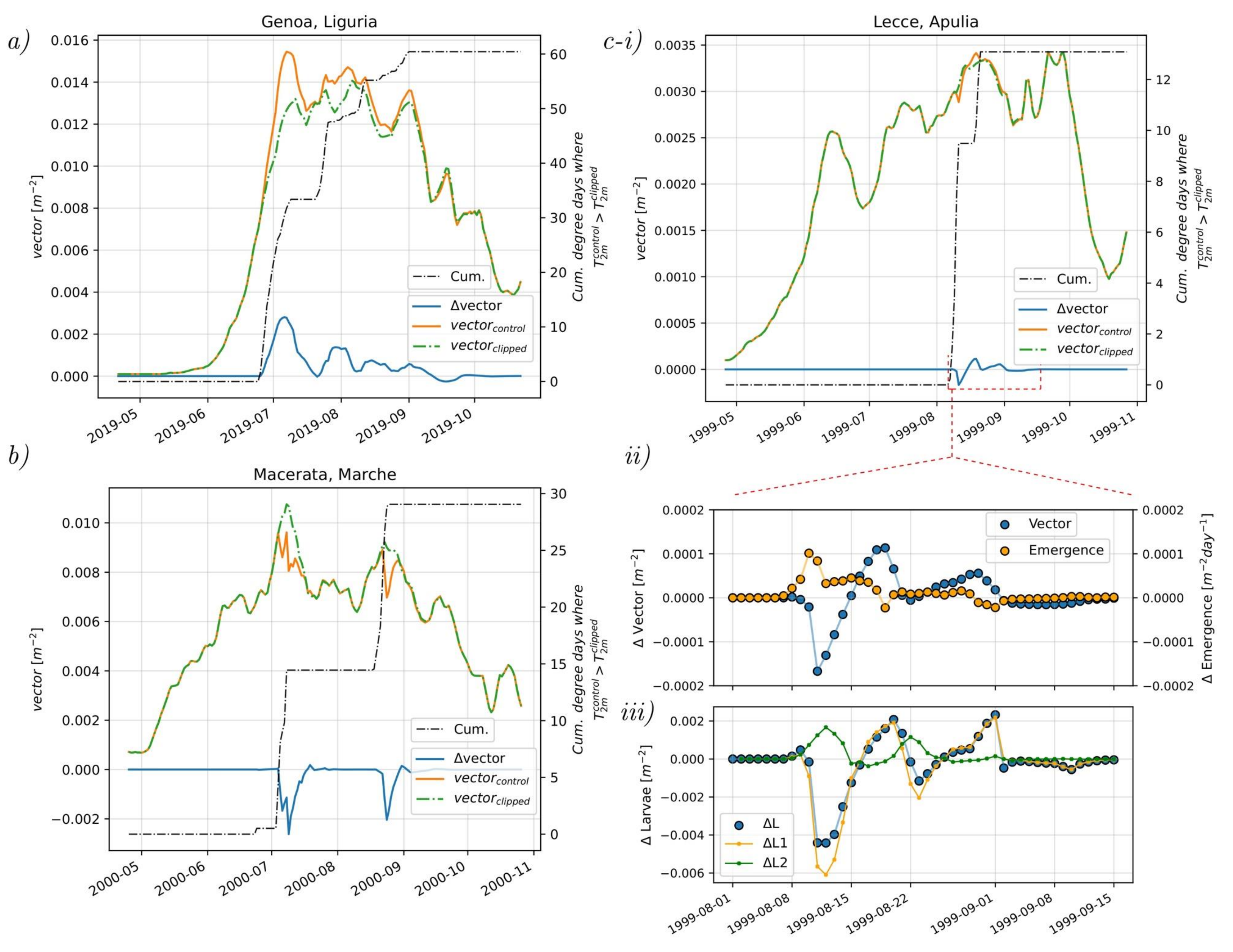
a) Beneficial

b) Detrimental

c-i) Temporarily detrimental

c-ii,iii) Differential impact on larval age structure

Garrido Zornoza et al. 2024
(in review for JRSI)



5 Conclusion and future perspectives

Summary

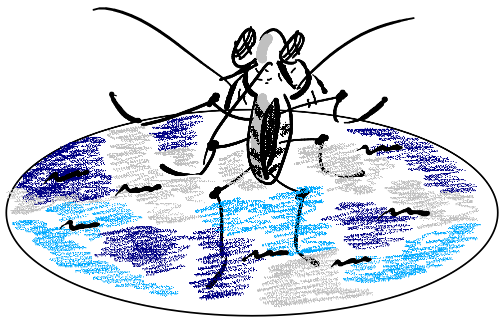
- VECTRI as a multi-species **climate-aware** mechanistic model
- Adapted VECTRI to *Aedes albopictus* → parameterization + calibration
- **Validated** the model for Italy (Emilia-Romagna ovitrap data)
- Model reproduces **seasonality** and **inter-annual** variability of observed ovitrap data
- Densely populated areas are hotspots
  - Rome, Milan, Naples, Foggia, Catania, Palermo, Lecce, …
- Modelled **increase** of vector **activity** of $0.5 - 3$ weeks per decade between 1980-2022
- Heatwave impact on simulated *Ae. albopictus* population can be **detrimental** in warmest regions but is **beneficial** over most areas during summer

Future perspectives

- Include **diapause** parameterization, larval **cannibalism** and **dengue** transmission dynamics

Thank you for the attention

S.1 Introduction: the VECTRI model



Breeding model for larval development

$$\frac{\partial L(f,t)}{\partial t} = \boxed{\text{hatching}} + \boxed{\text{mortality}} + \boxed{\text{predation and overcrowding}} + \boxed{\text{emergence}}$$

$$-\underbrace{\delta_{crowd}(R_d, L)}_{= 1 - \underbrace{P_{L,surv}(R_d, L)}_{= P_{L,surv0} \cdot P_{flush}(R_d) \cdot P_{crowd}(R_d, L)}} \cdot L(f,t)$$

- Logistic → $P_{crowd}(R_d, L) = \left(1 - \frac{\sum M_L}{w(R_d) \cdot M_{max}}\right)$
- Fractional water coverage of potential breeding sites → $w(R_d) = \underbrace{r_{urbn} \cdot w_{urbn}(\rho_h)}_{\text{stationary}} + \underbrace{r_{perm} \cdot w_{perm}}_{\text{stationary}} + \underbrace{r_{pond} \cdot w_{pond}(R_d)}_{\text{dynamic}}$
- r_i are vector-specific **usage coefficients**