The effect of time dependent vaccination protection (SIR-model)

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250070 SE Seminar Applied PDE (2022S)

Master of Computational Science

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Agenda

- Introduction & Motivation
  - Concept SIR-model
- Model design
  - Assumptions, Equations
- Results & Discussion
- Conclusion & Outlook

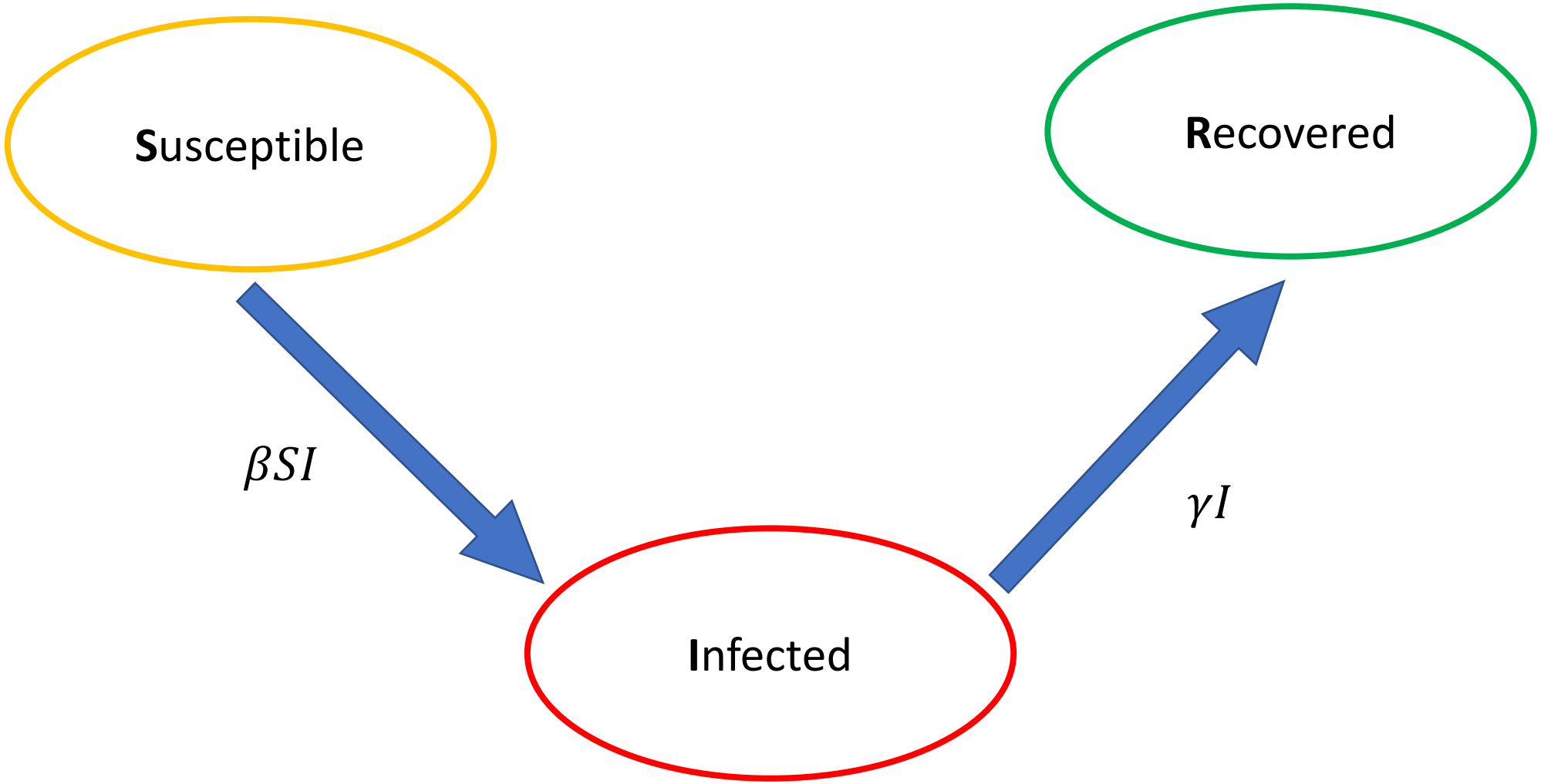
Introduction & Motivation 1

- End of August 2021 the Austrian *COVID Prognose Konsortium* published a policy brief
- Predict the upcoming pandemic development until December 2021
- 1 of the 3 models: SIR-X-model
  - Very simple
  - Prone to input errors
  - One assumption: Covid-19 vaccines would maintain full protection over effective period

Introduction & Motivation 2

- *Problem*: vaccination protection would not decrease, and consumers would become de facto immune (max. level is 80%)
- *Result*: severe misprediction, strong winter wave
- *Question*: In how far does this simple assumption change the model's prediction?

Model design: Simple SIR-model



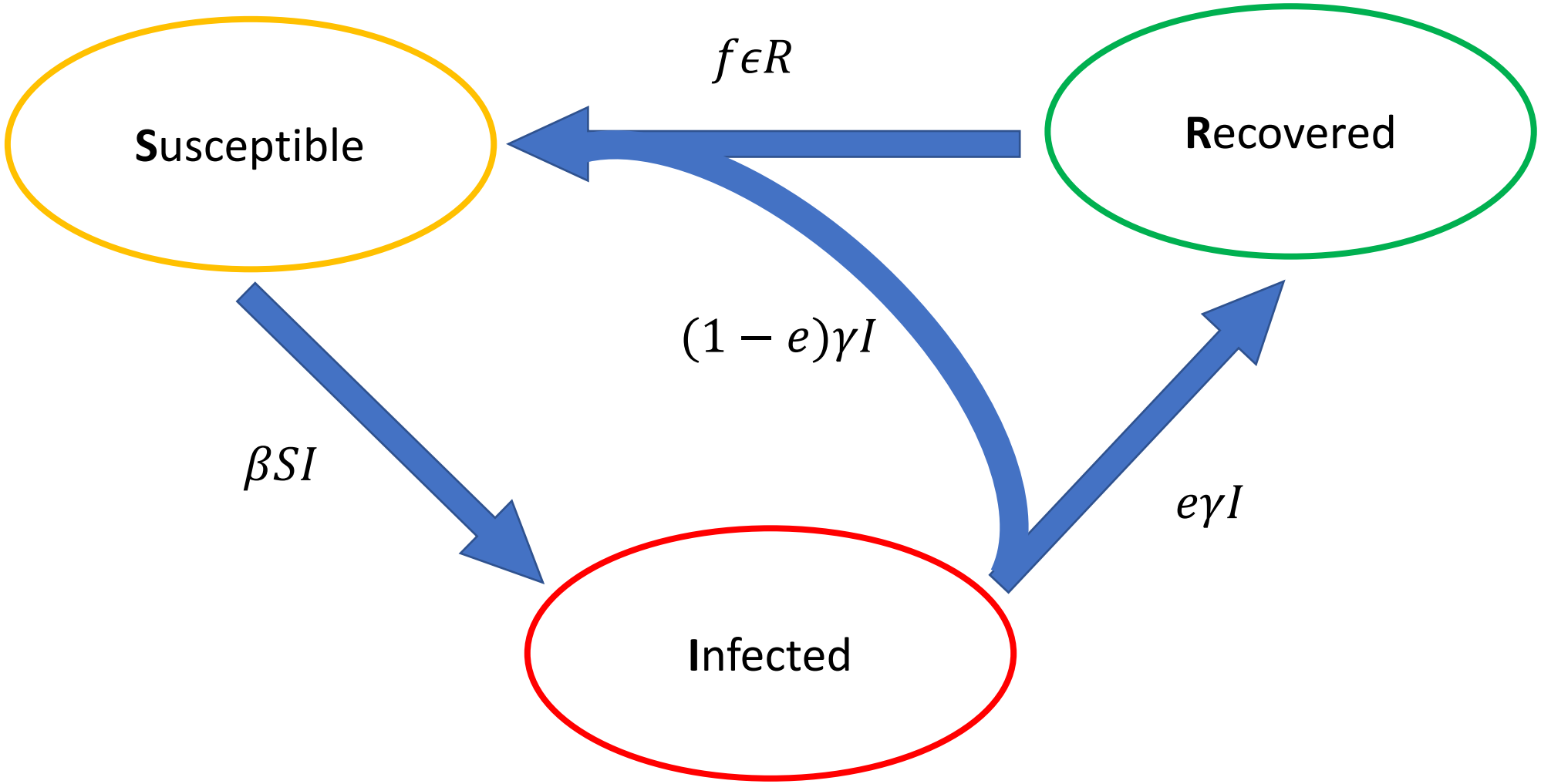
Model design: Assumptions 1

- The average convalescence period of a Covid-19 infection is 10 days
- The maximum level of immunity e = 80% on average
- There are no new vaccinations during the modelled time period
  - Naive approach was tried (bonus slides)

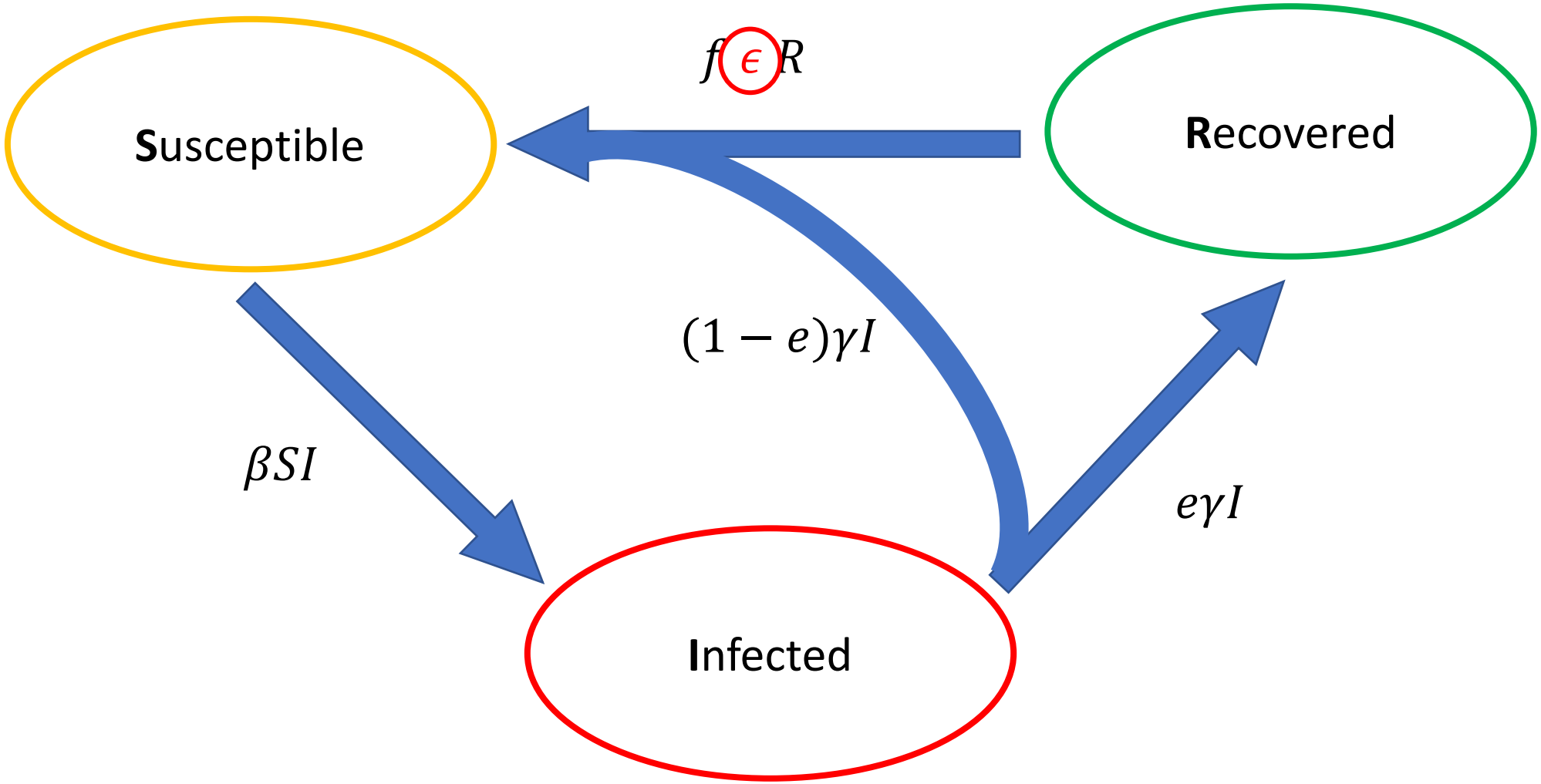
Model design: Assumptions 2

- No data / knowledge from the future, just calibration:
  - R_0 → fully vaccinated 58% + $\sim 30\%$ which are protected by other means
  - Transmission rate $\beta = 1.07$ (initial effective reproduction rate)
  - Damping factor $f = 0.01$ to calibrate the effect of the central model B assumption (decay function ϵ)
- September 1st, 2021 until January 31st, 2022

Model design: Refined SIR-model



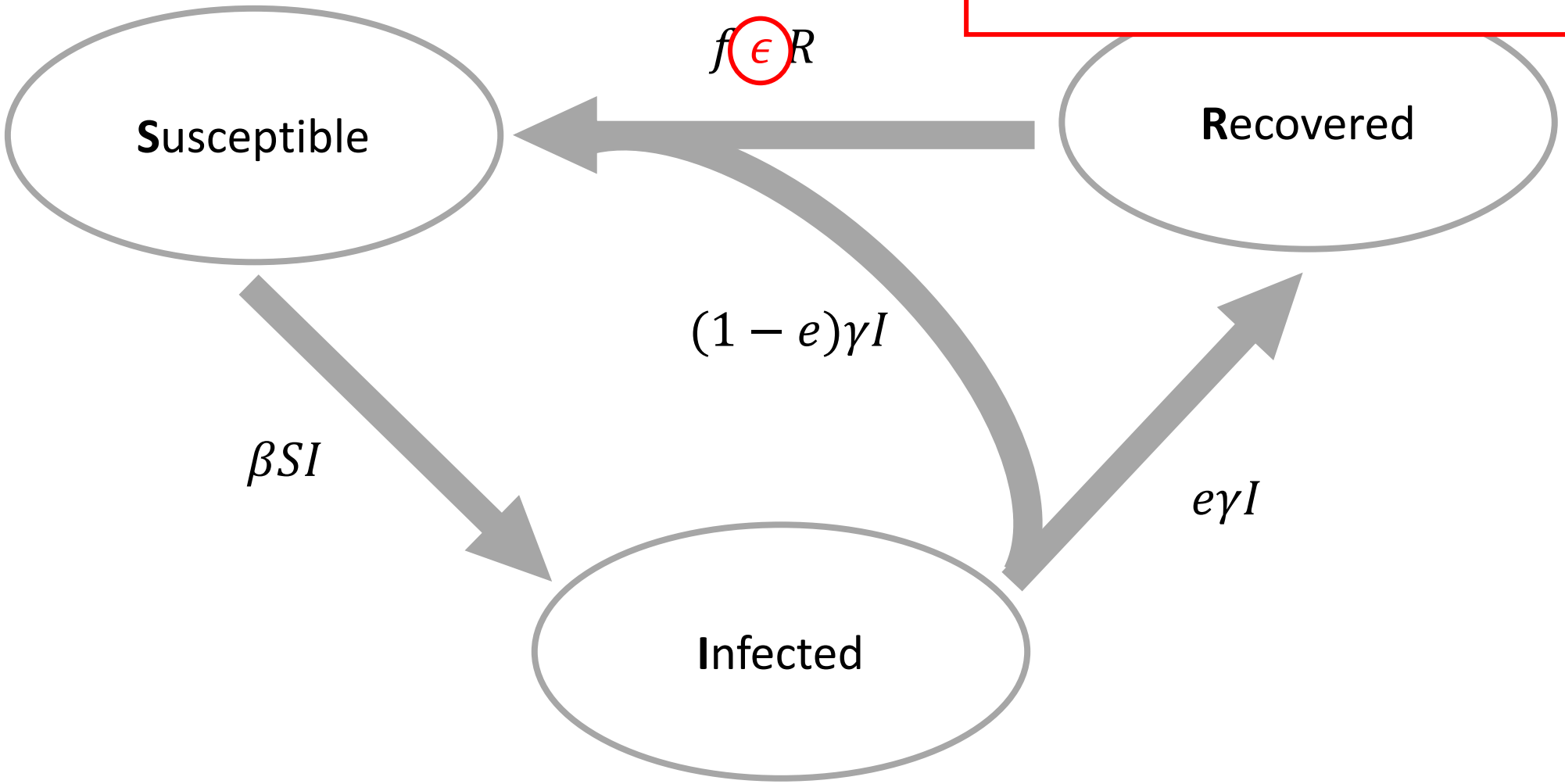
Model design: Refined SIR-model



Model design: Refined SIR-mod

Model A

Model B



Model design: Equations

$$\frac{dS}{dt} = -\beta SI + f\epsilon_{A,B}R + (1-e)\gamma I \quad (1)$$

$$\frac{dI}{dt} = \beta SI - \gamma I \quad (2)$$

$$\frac{dR}{dt} = e\gamma I - f\epsilon_{A,B}R \quad (3)$$

Model design: Equations

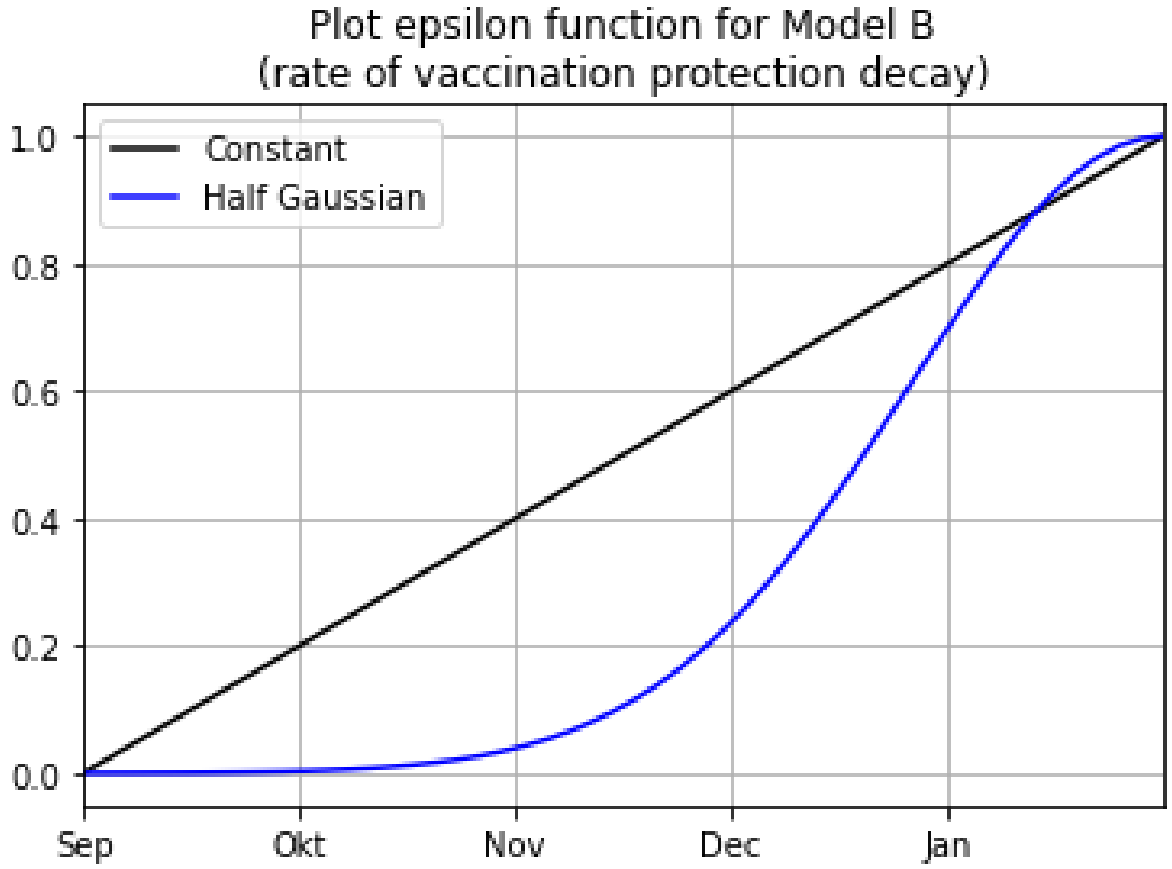
$$\frac{dS}{dt} = -\beta SI + f\boldsymbol{\epsilon_{A,B}}R + (1-e)\gamma I \quad (1)$$

$$\frac{dI}{dt} = \beta SI - \gamma I \quad (2)$$

$$\frac{dR}{dt} = e\gamma I - f\boldsymbol{\epsilon_{A,B}}R \quad (3)$$

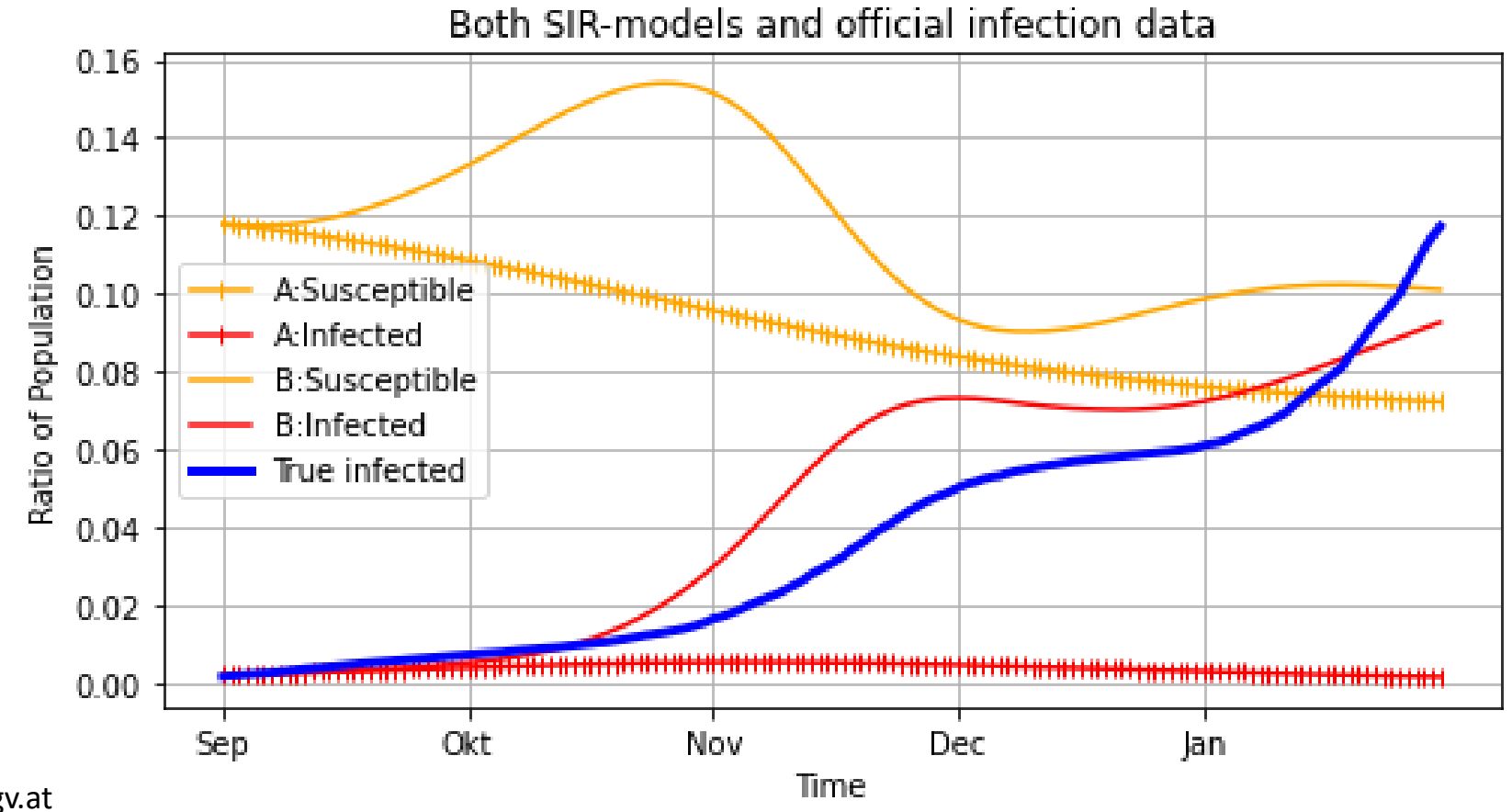
Model design

- Two functions considered for central model assumption ϵ of vaccination protection decay for model B
- Scaled by factor $f = 0.01$



Results & Discussion

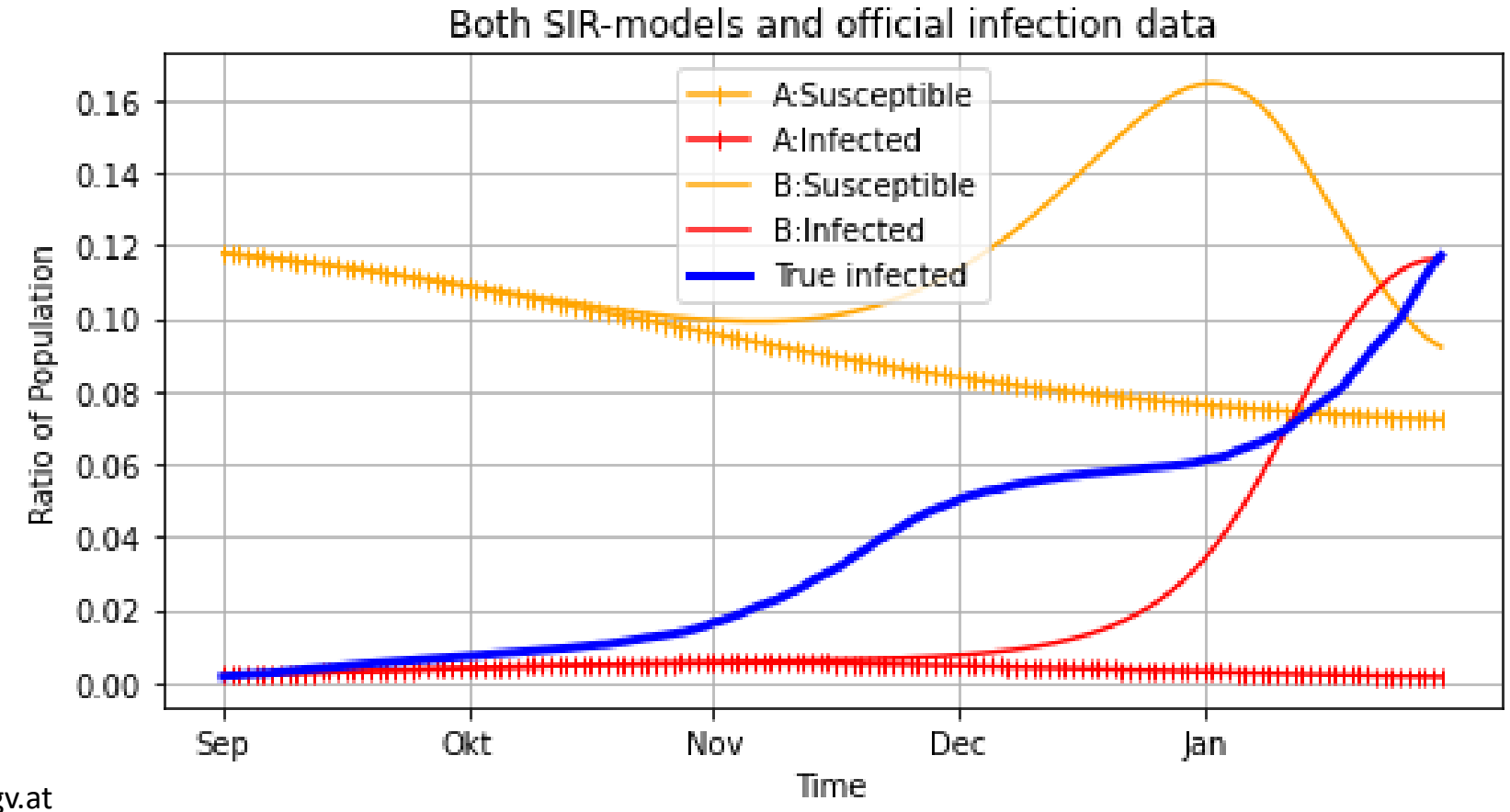
Model A and best model B with constant decay function



Data source: data.gv.at
https://www.data.gv.at/katalog/dataset/zeitverlauf-der-gemeldeten-covid-19-falle-im-ems-morgenmeldung/resource/c47bd305-a21e-40a7-8094-580e040cd27f

Results & Discussion

Model A and B but with half Gaussian distribution function for decay



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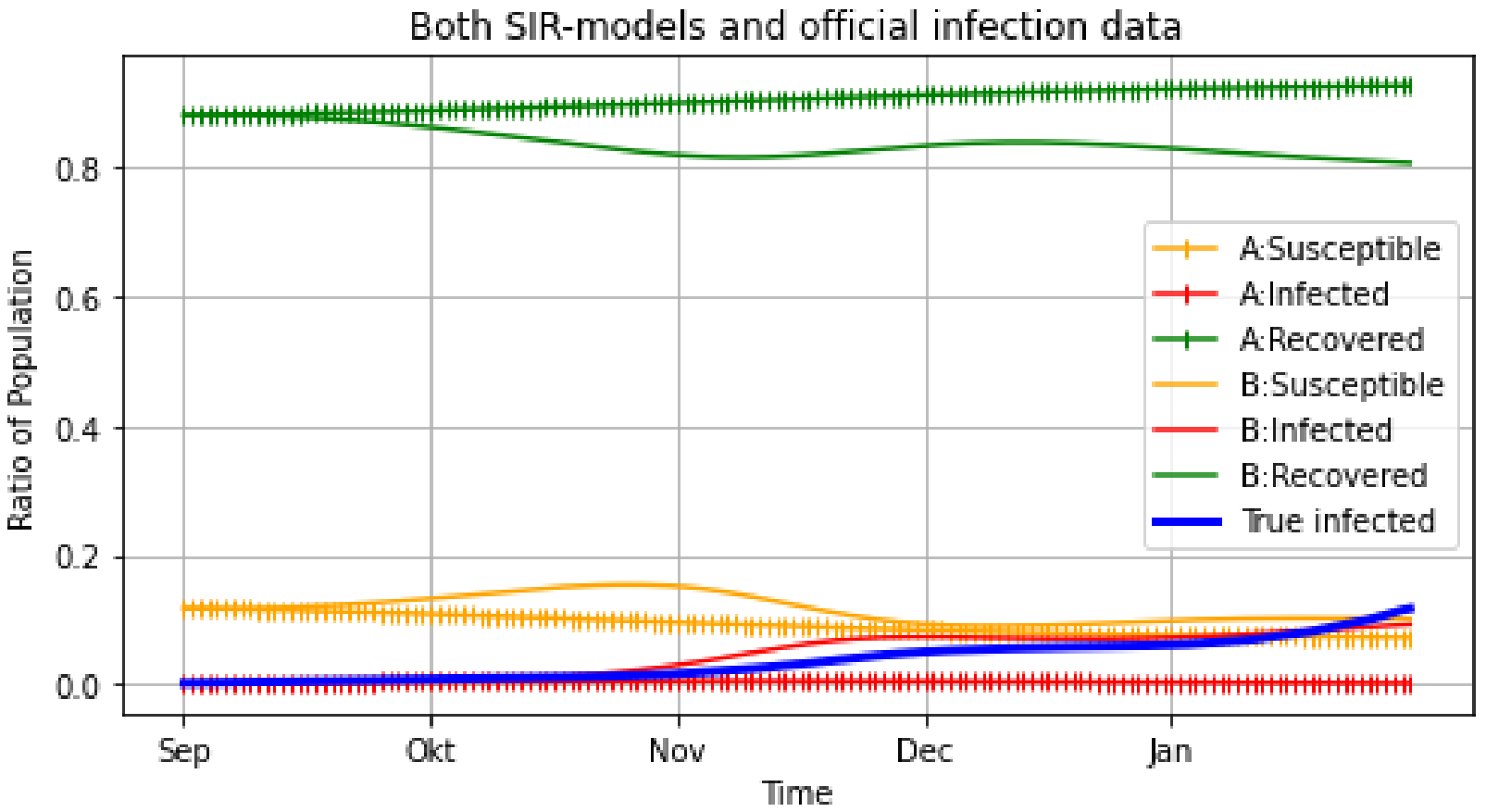
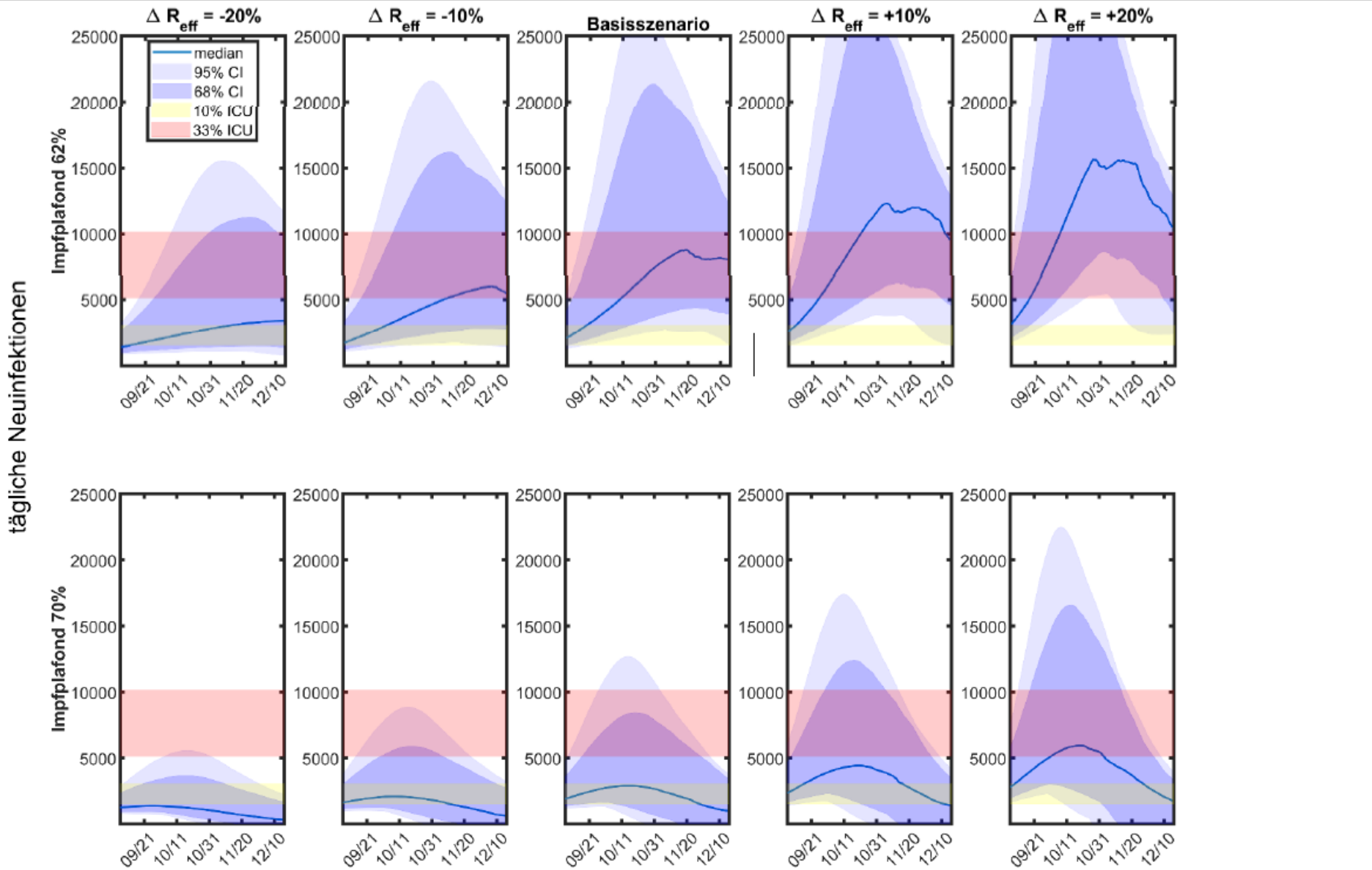
Results & Discussion

Model A and B (constant decay) and all phase lines



How did the model of the COVID Prognose Konsortium perform?

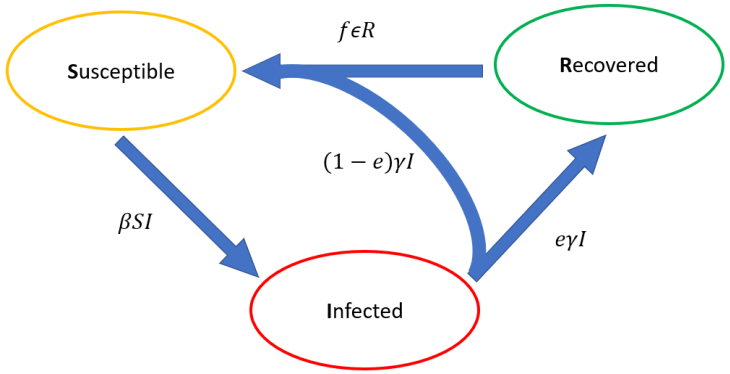
Abbildung 1: Szenarien zur Virusverbreitung und des Systemrisikos Herbst/Winter 2021



Quelle: COVID Prognose Konsortium

Source: Policy_Brief_update_20210831.pdf

Conclusion



- The model presented today is very simple
- Central model assumption of immunity decay has the strongest influence
- No data / knowledge from the future was used, only some calibration
- Predicts second wave, unlike the policy brief

Outlook

- Model expansion
  - More compartments
  - New vaccinations
  - Covid-19 policies

- Note: the number of infected does not reflect on the virulence and the virus' development over 2 years (!)
  - Scaling by number of severe cases deemed reasonable

Sources

- BMSGPK, 2021. www.data.gv.at/katalog/dataset/. [Online] Available at: https://www.data.gv.at/katalog/dataset/9723b0c6-48f4-418a-b301-e717b6d98c92 [Accessed 2022 June 16.].

- COVID_Prognose_Konsortium, 2021. Sozialministerium. [Online] [Download] Available at: https://www.sozialministerium.at/dam/jcr:8847f88c-b314-4d86-9d2b-3f169e047b0e/Policy_Brief_Update_20210831.pdf [Accessed 11. Juni 2022].

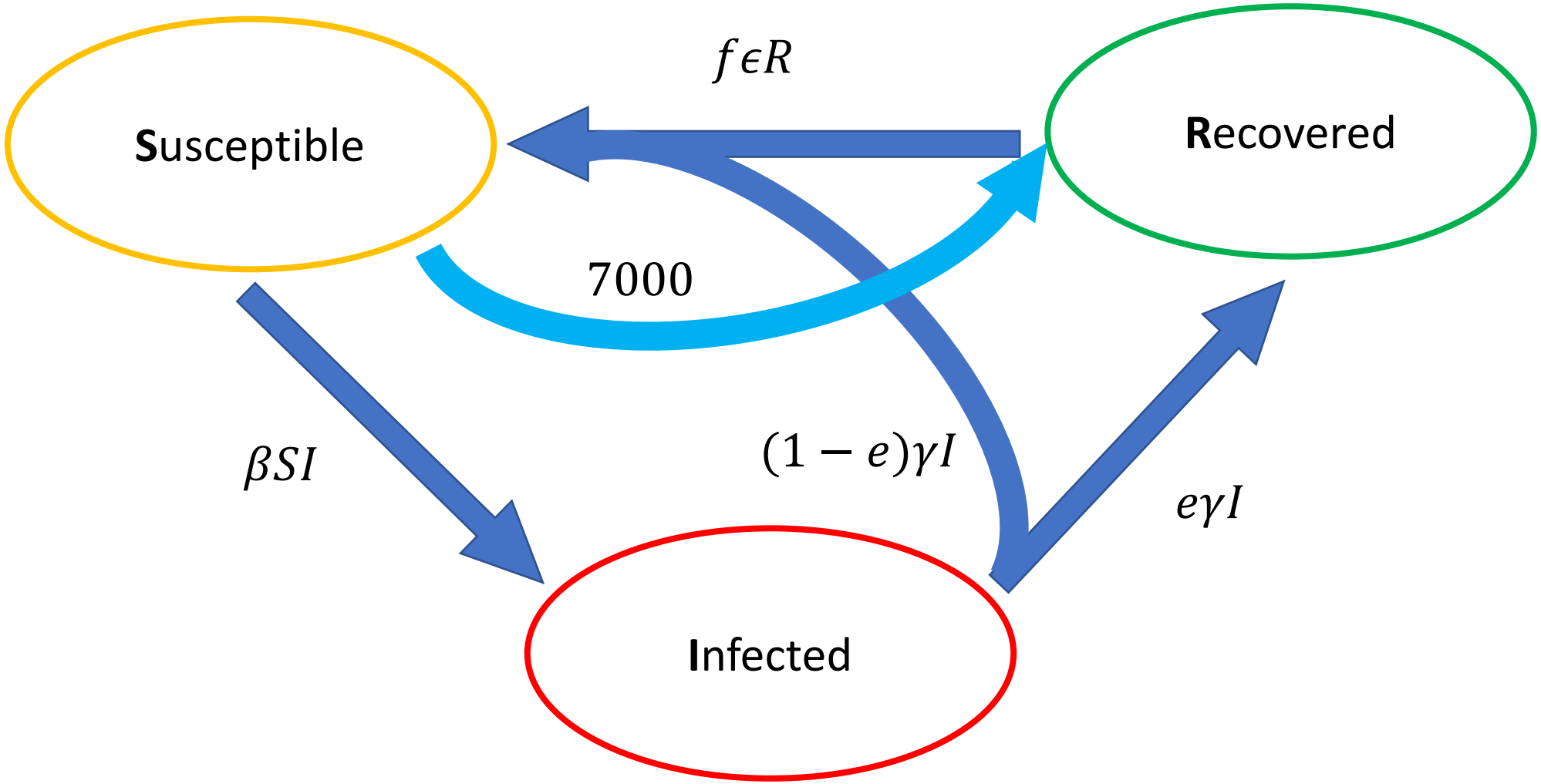
- ORF.at, 2022. ORF.at/Corona/Daten/Österreich. [Online] Available at: https://orf.at/corona/daten/oesterreich [Accessed 07. June 2022].

- *I published the simulation source code on my online repository: https://github.com/wagerc97/SIR-model*

Thank you for your attention

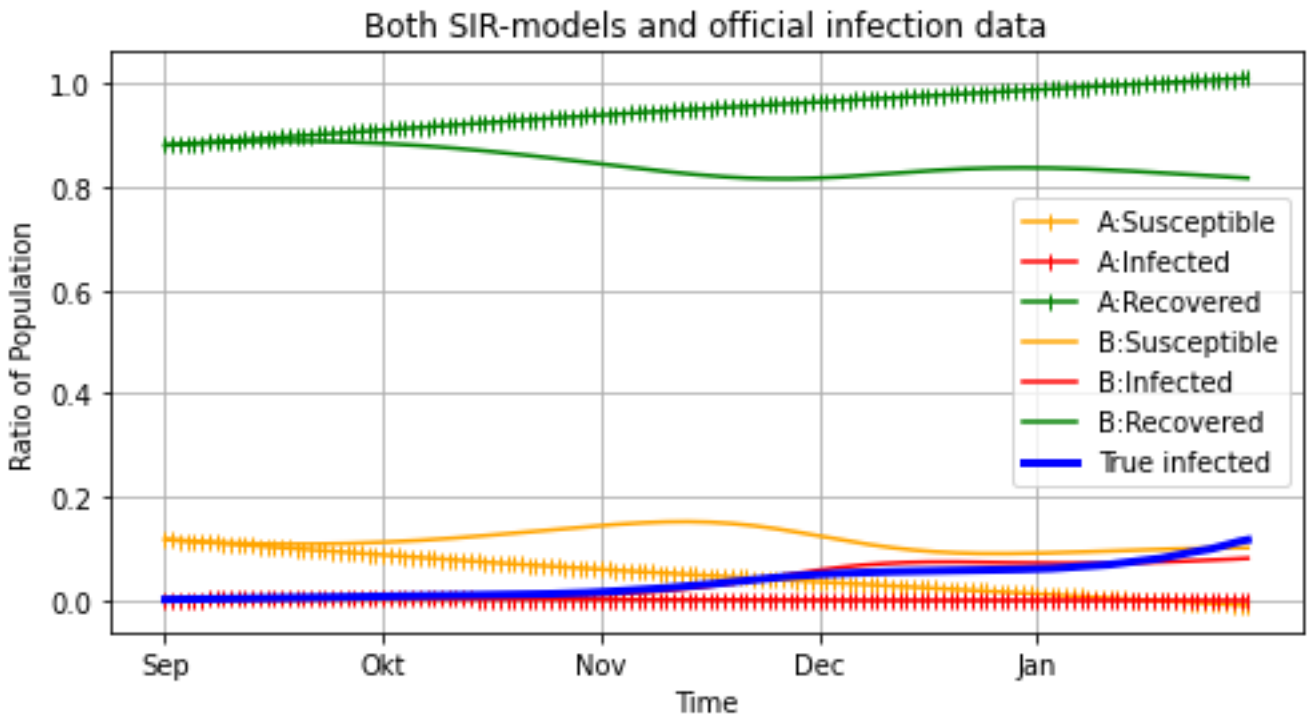
Bonus model design: Refined SIR-model

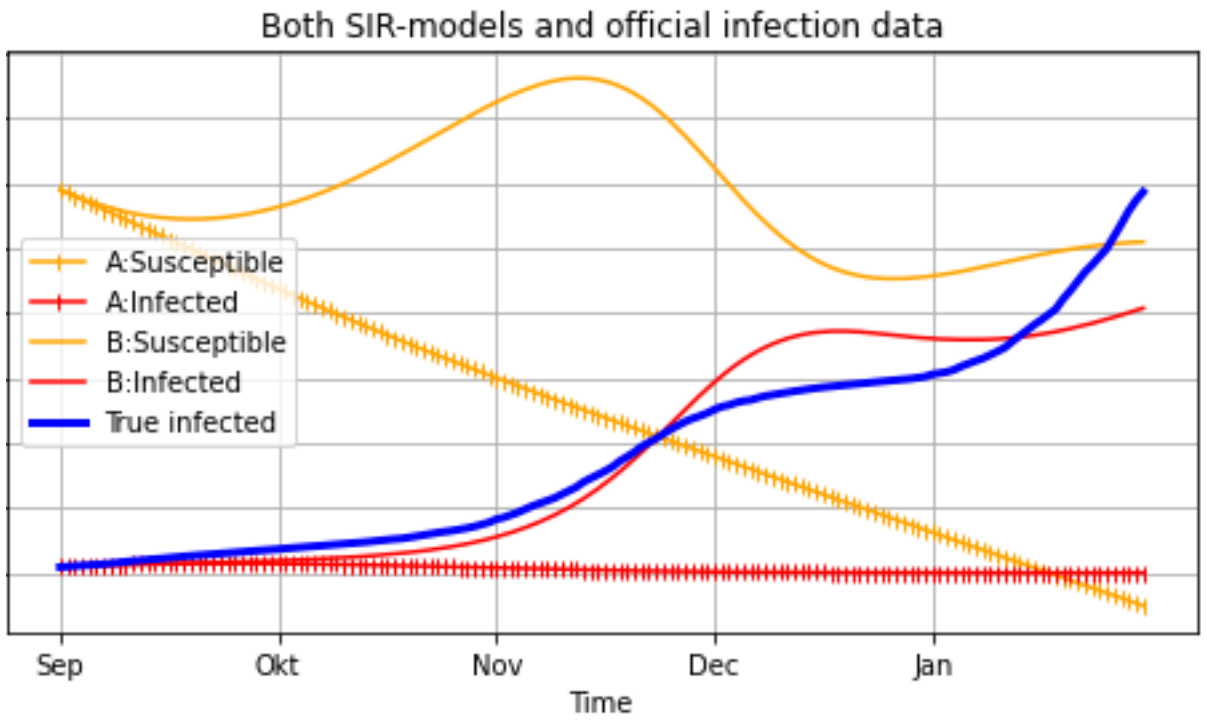
+ constant vaccination rate



Bonus plot 1

Naive attempt with daily new vaccinations and constant epsilon



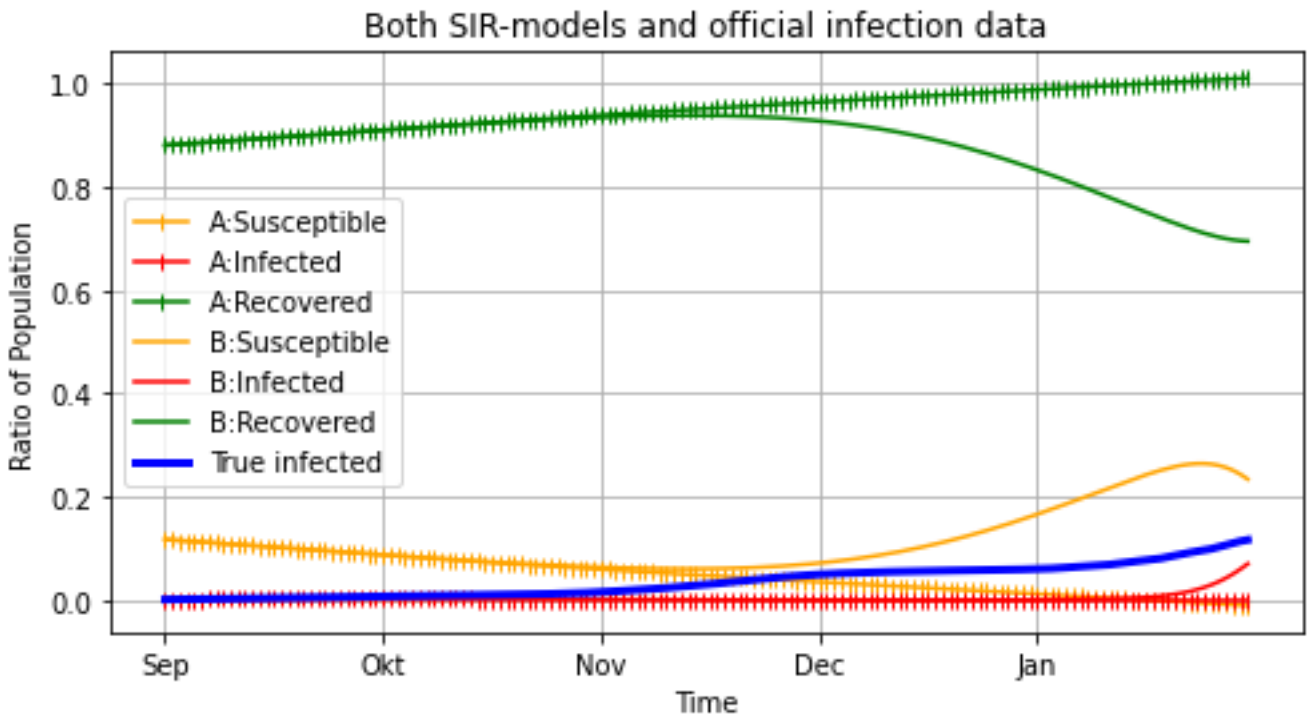


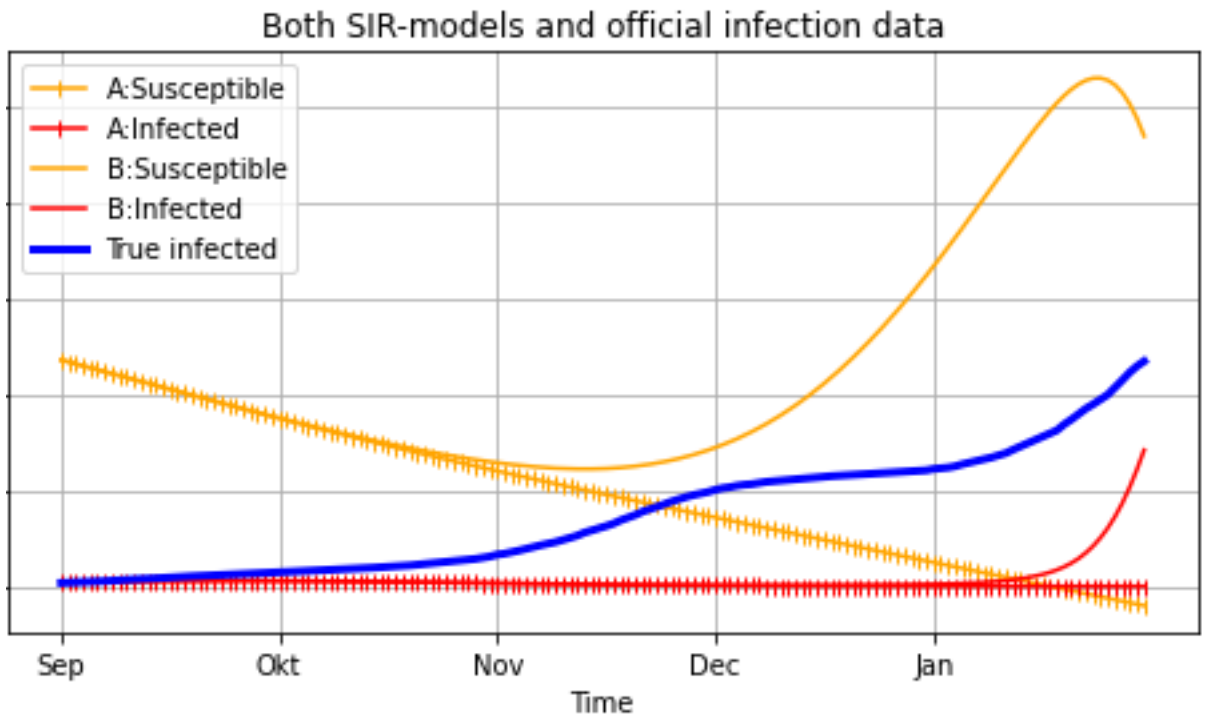
new_vaccinations_per_day = 7000

Note: Susceptibles turn negative if immunity does not decay over time!

Bonus plot 2

Naive attempt with daily new vaccinations and half_Gauss_epsilon





new_vaccinations_per_day = 7000

Note: Susceptibles turn negative if immunity does not decay over time!

End