Forecasting the COVID19 pandemic

Using Ensemble Data Assimilation to Enhance and Guide Models to More Reliable Predictions 📊

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SIParCS Summer Internships in Parallel Computational Science BOULDER • CO

NCAR | NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

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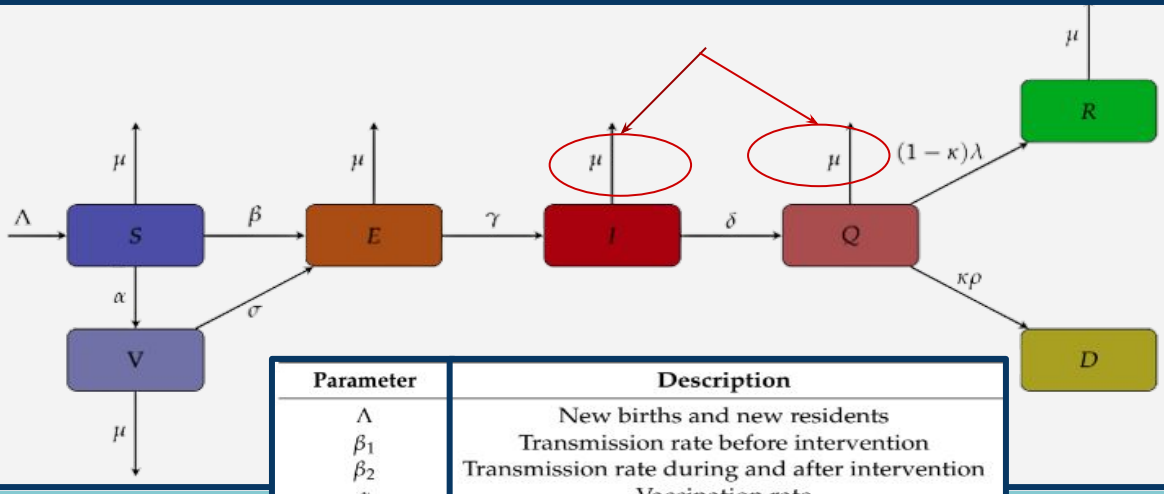
Presentation Outline

- Epidemiological Modeling
- Introducing DART
- Case Study on 4 countries:
  - United States of America 🇺🇸
  - Guyana 🇬🇾
  - Ethiopia 🇪🇹
  - Trinidad 🇹🇹
- Conclusion

Image Source: Stats vector created by storyset - www.freepik.com

EPIDEMIOLOGICAL MODELING

- The SEIR model is a model implemented by epidemiologists to model infectious diseases
- SEIQRDV is an extension of the SEIR model that has been used by scientists to model the spread of the pandemic
- By letter SEIQRDV represents the following state variables:
  - S-Susceptible
  - E-Exposed
  - I-Infected
  - Q-Quarantined
  - R-recovered
  - D-Death
  - V-Vaccinated

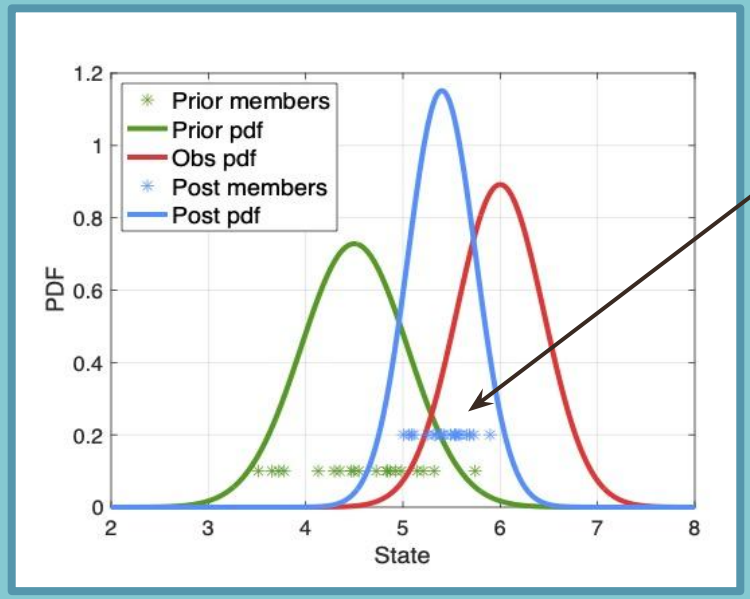


Parameter	Description
Λ	New births and new residents
β_1	Transmission rate before intervention
β_2	Transmission rate during and after intervention
α	Vaccination rate
μ	Natural death rate
γ^{-1}	Incubation period
σ	Vaccine inefficacy
δ^{-1}	Infection time
κ	Case fatality rate
λ^{-1}	Recovery time
ρ^{-1}	Time until death

Citation: Ghostine, R.; Gharamti, M.; Hassrouny, S.; Hoteit, I. An Extended SEIR Model with Vaccination for Forecasting the COVID-19 Pandemic in Saudi Arabia Using an Ensemble Kalman Filter. Mathematics 2021, 9,636.
https://dx.doi.org/10.3390/math9060636

The Data Assimilation Research Testbed (DART)

- Data Assimilation (DA) is a technique used to enhance model predictions using observations
- DA can assimilate both noisy and sparse observations
- DART-LAB: A Matlab-based version of the DART software



Probability Density Function (PDF) is estimated using an ensemble (multiple model instances/realizations to account for nonlinearities)

Here, we use the Ensemble Kalman Filter (EnKF)

Website: https://dart.ucar.edu

NCAR | DART

Data Assimilation case studies

SET UP AND DATA ASSIMILATION CONFIGURATION

	USA	Guyana	Ethiopia	Trinidad
Data Available	Deaths Vaccination	Deaths Vaccination	Deaths Recovered Active	Deaths Vaccination
Frequency	Daily	Weekly	Daily	Daily
Challenge	Stopped tracking Recovered data	Recovery data unreliable	Vaccination started too late	Recovered data unreliable
Assimilation Period	Jan 2020 - June 2022	Jan 2020 - June 2022	Jan 2020 - Jan 2021	Jan 2020 - June 2022

Variables in State:

- Susceptible
- Exposed
- Infected
- Quarantined
- Recovered
- Death
- Vaccinated

Desired Observed Variables: ARDV

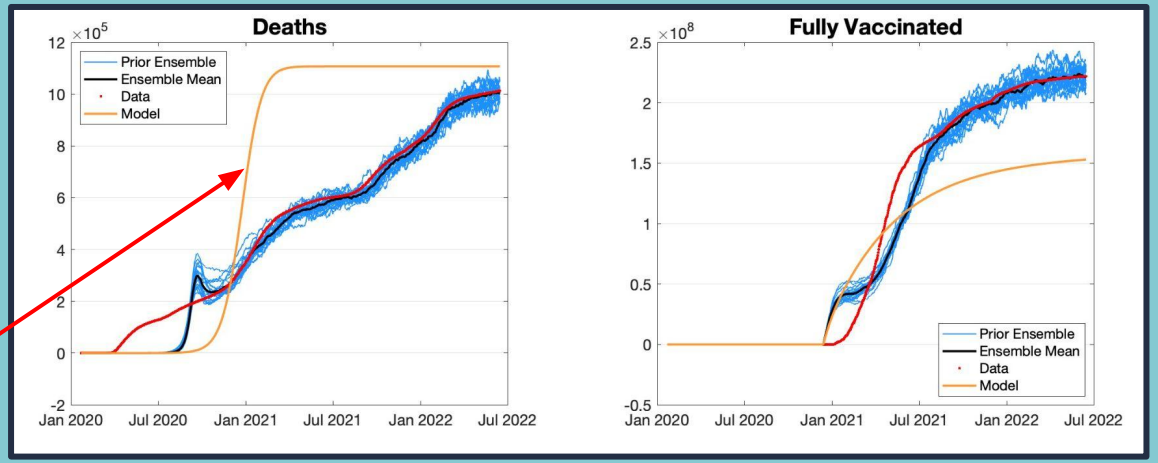
United States

Population: ~330 Million
DA Application: Demonstrate how a properly tuned model can enhance DA forecasts

CASE STUDY : USA 🇺🇸

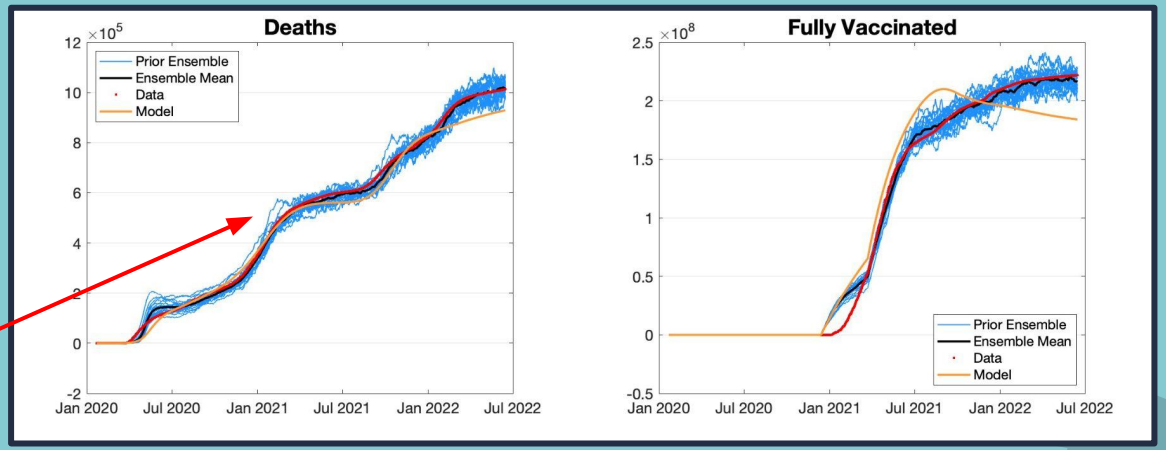
A.Poorly Tuned

Model parameterized with using two transmission rates: before and after lockdowns



B. Properly Tuned

More sophisticated parameterization of beta accounting for waves, variants and lockdowns

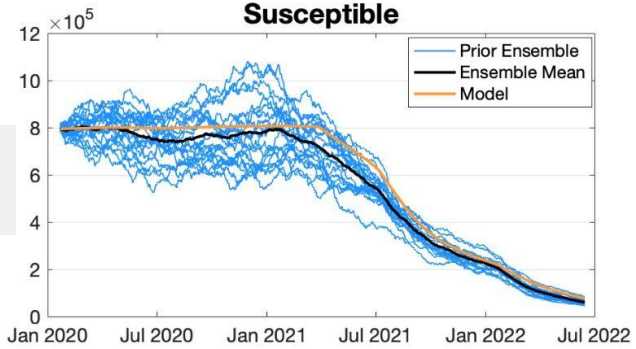


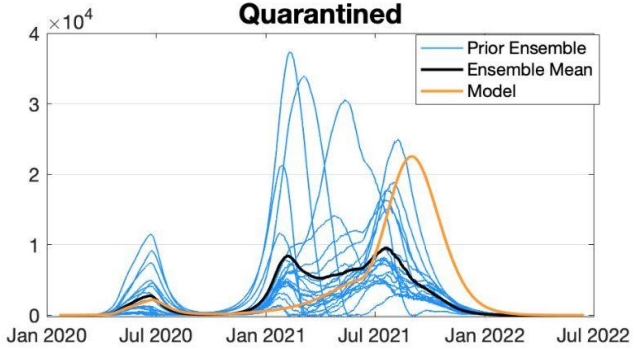
GUYANA

Population: ~790k
DA Application: Demonstrate how Data Assimilation can make model predictions on noisy or sparse data

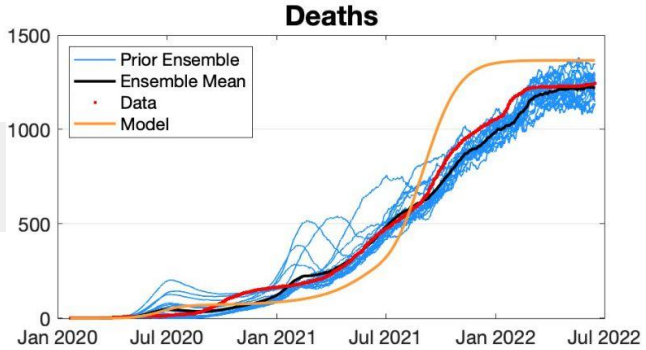
CASE STUDY : GUYANA

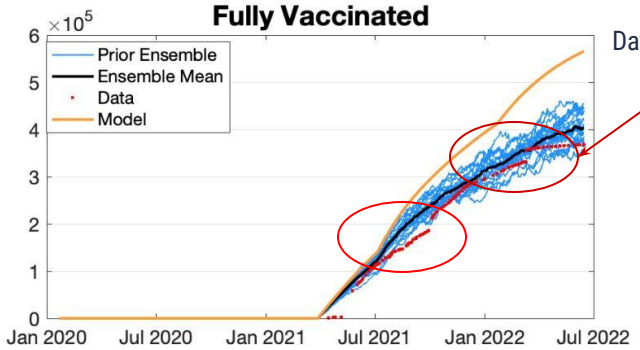
Unobserved Variables





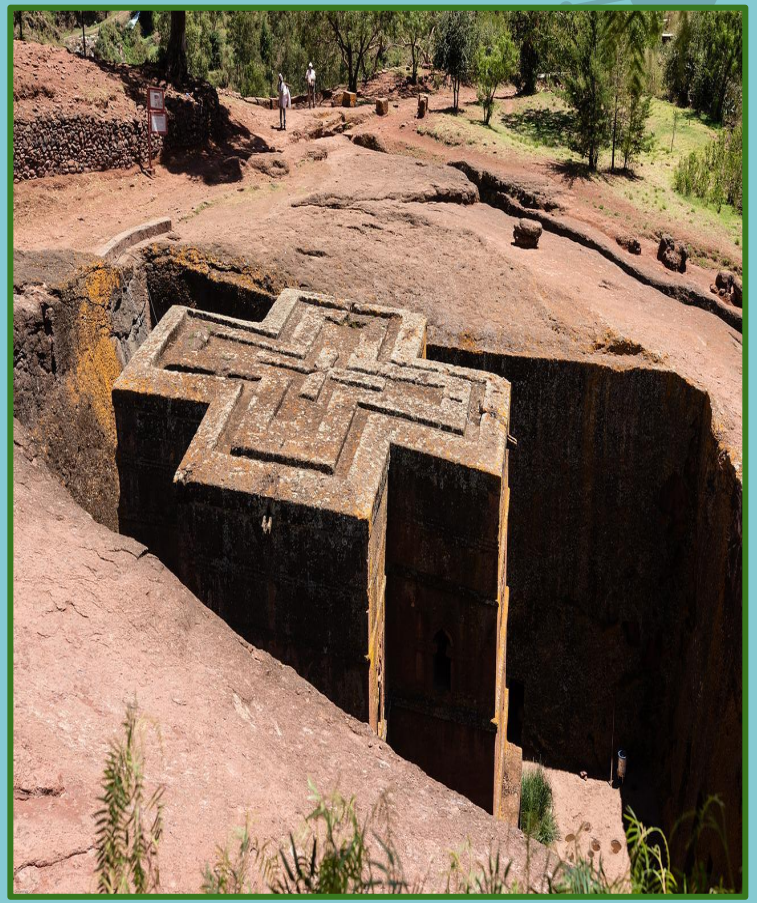
Observed Variables





Data gaps

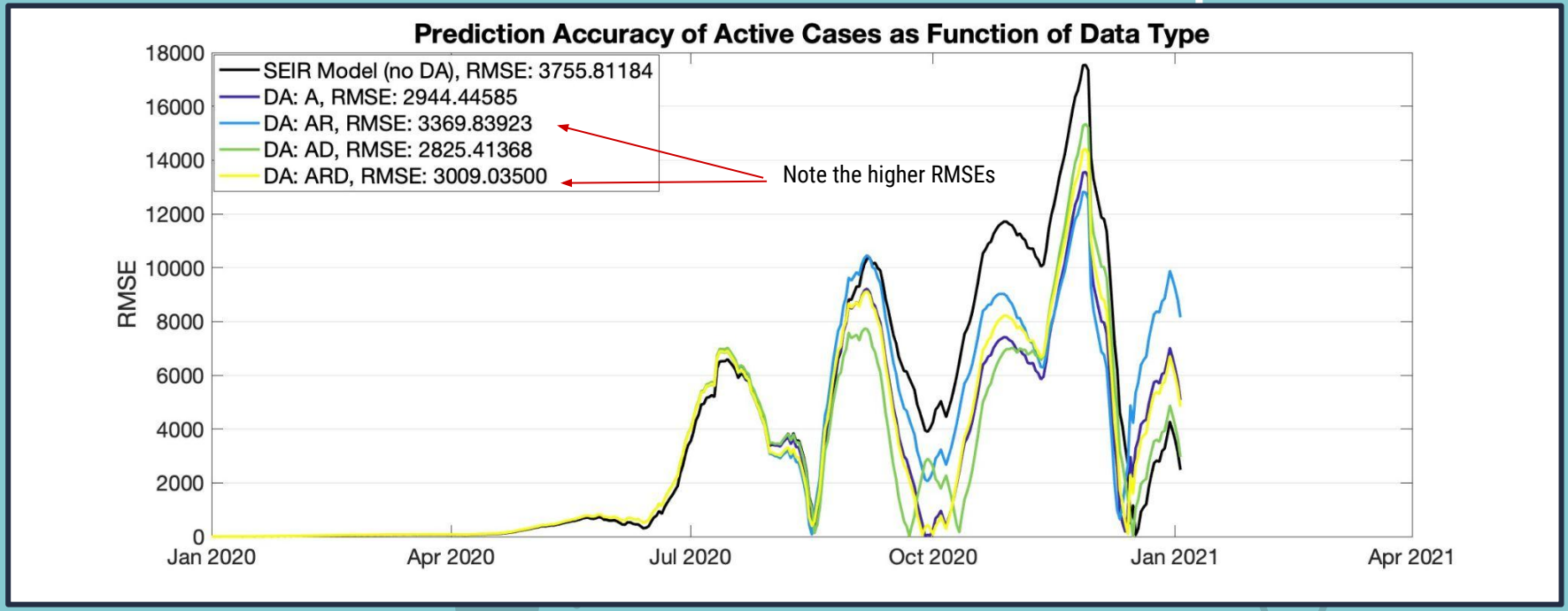
ETHIOPIA



Population: ~115 M
DA Application: (i) How data assimilation RMSE performance improves with the addition of data types and (ii) how ‘bad data’ can impact RMSE values

CASE STUDY : ETHIOPIA 🇪🇹

MODEL DATA ASSIMILATION

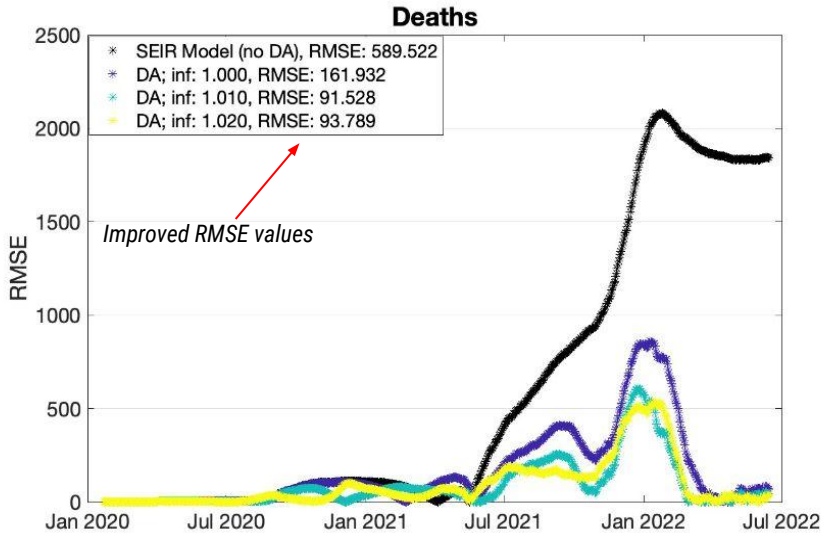


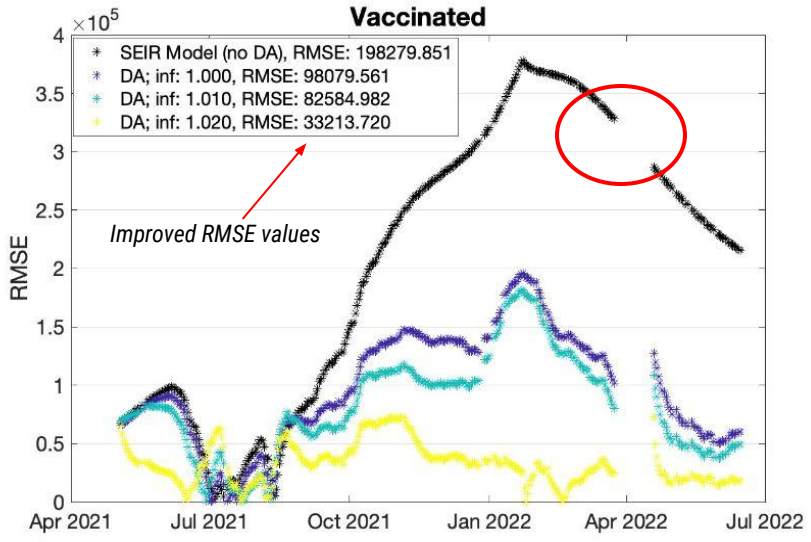
TRINIDAD

Population: ~1.4 M
DA Application: Enhance data assimilation performance using different filtering algorithms

CASE STUDY : TRINIDAD

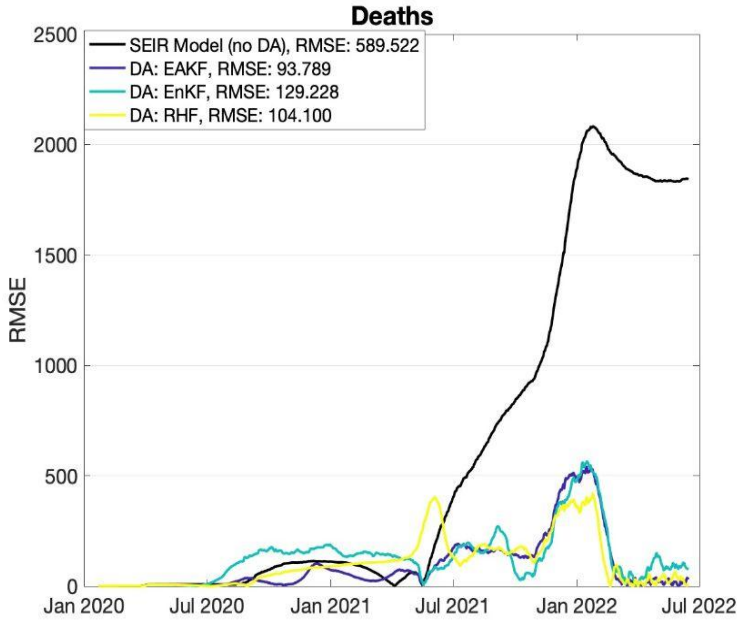
INFLATION SENSITIVITY

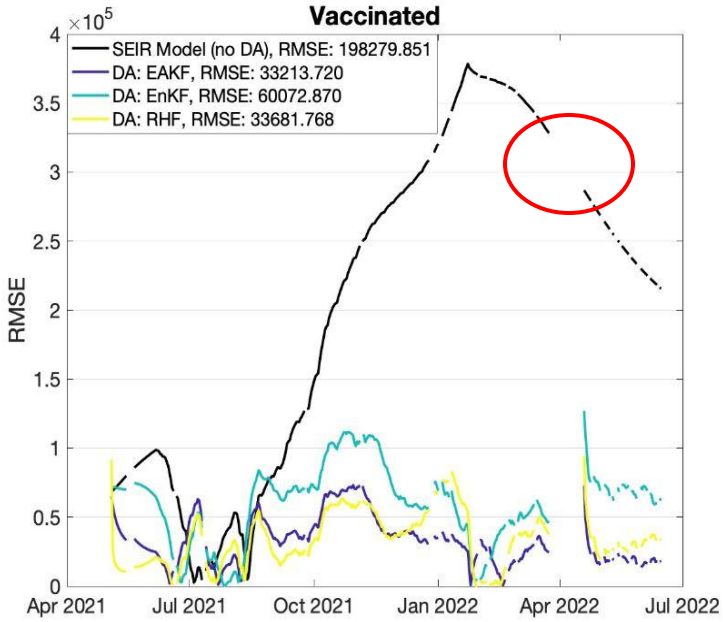




CASE STUDY : TRINIDAD 🇹🇹

FILTER SENSITIVITY





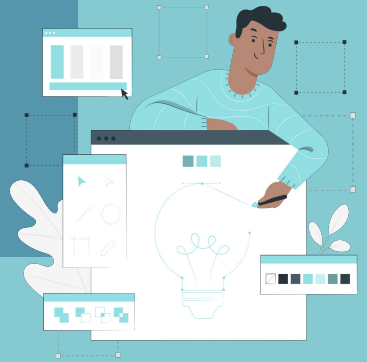
CONCLUSION

Why this is important:

- Numerical models are important for simulating real world systems
- Models can be improved
  - For example, we can evaluate the impact of different vaccination doses on the trajectory of the pandemic
- Data Assimilation can help enhance models

How this can be used in the future:

- The data presented demonstrated the impact the COVID vaccinations had on decreasing active cases during the pandemic
- The use of epidemiological models should not be disregarded should another pandemic arise
- Extended SEIR models coupled with DA can provide very useful information



Technology illustrations by Storyset

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THANK YOU!!!!

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