Economic prediction in real-time?

or an agent-based model with Ensemble Kalman Filter for the US wealth distribution

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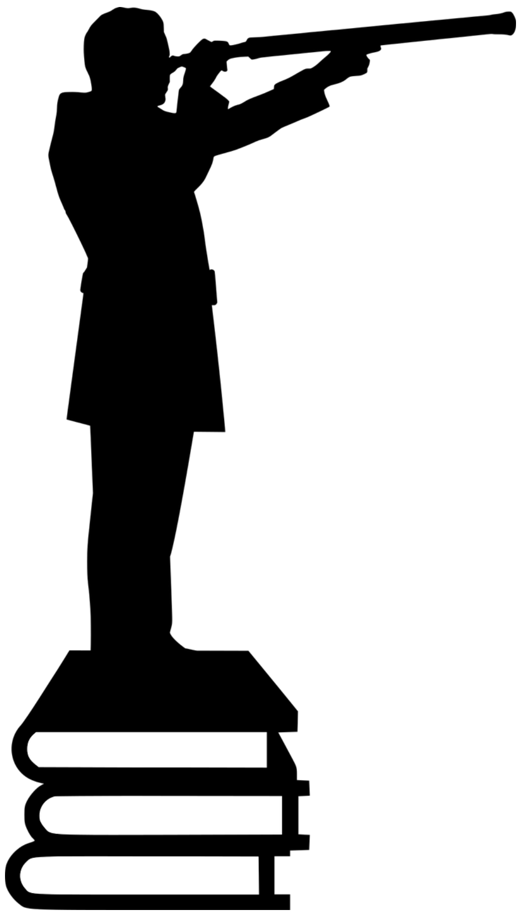
Agenda

- Motivation
- Models
- Ensemble Kalman Filter and Data assimilation
- First results
- Discussion



Background of work – DUST project

- data assimilation for agent-based modelling
- mostly in Urban Analytics
- led by Nick Malleson

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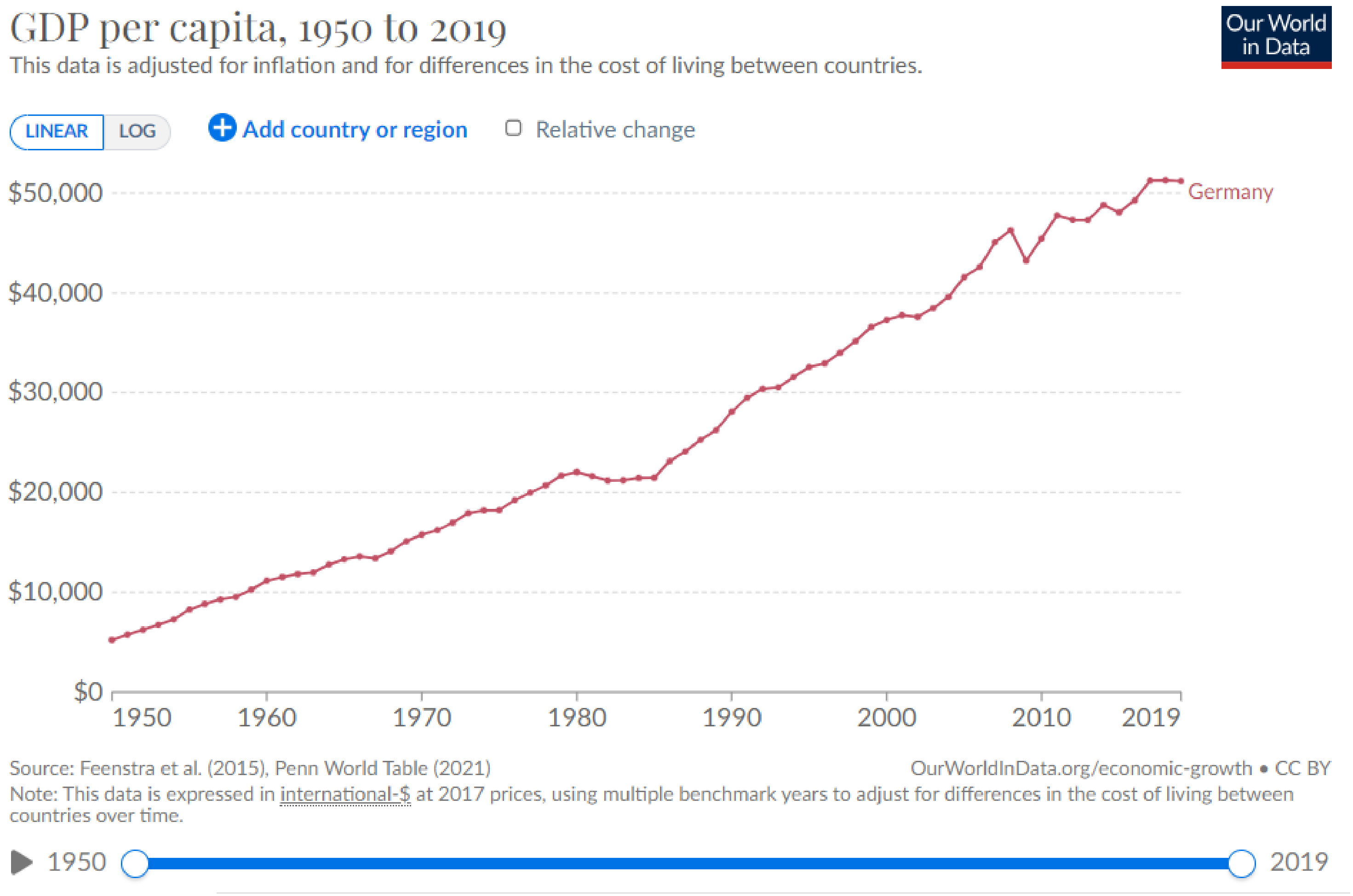
Traditionally economic data is slow

and

Economic models focus on “slow”/long-term processes

Example: Economic growth



Solow-Swan growth model

$$\dot{k}(t) = sk(t)^{\alpha} - (n + g + \delta)k(t)$$

Today the economy is almost monitored in real-time

And models focus also on high-frequency processes

Home > Economy > Economic output and productivity > Output > Economic activity and social change in the UK, real-time indicators

Economic activity and social change in the UK, real-time indicators: 14 September 2023

Early experimental data on the UK economy and society. These faster indicators are created using rapid response surveys, novel data sources and experimental methods.

This is the latest release. View previous releases

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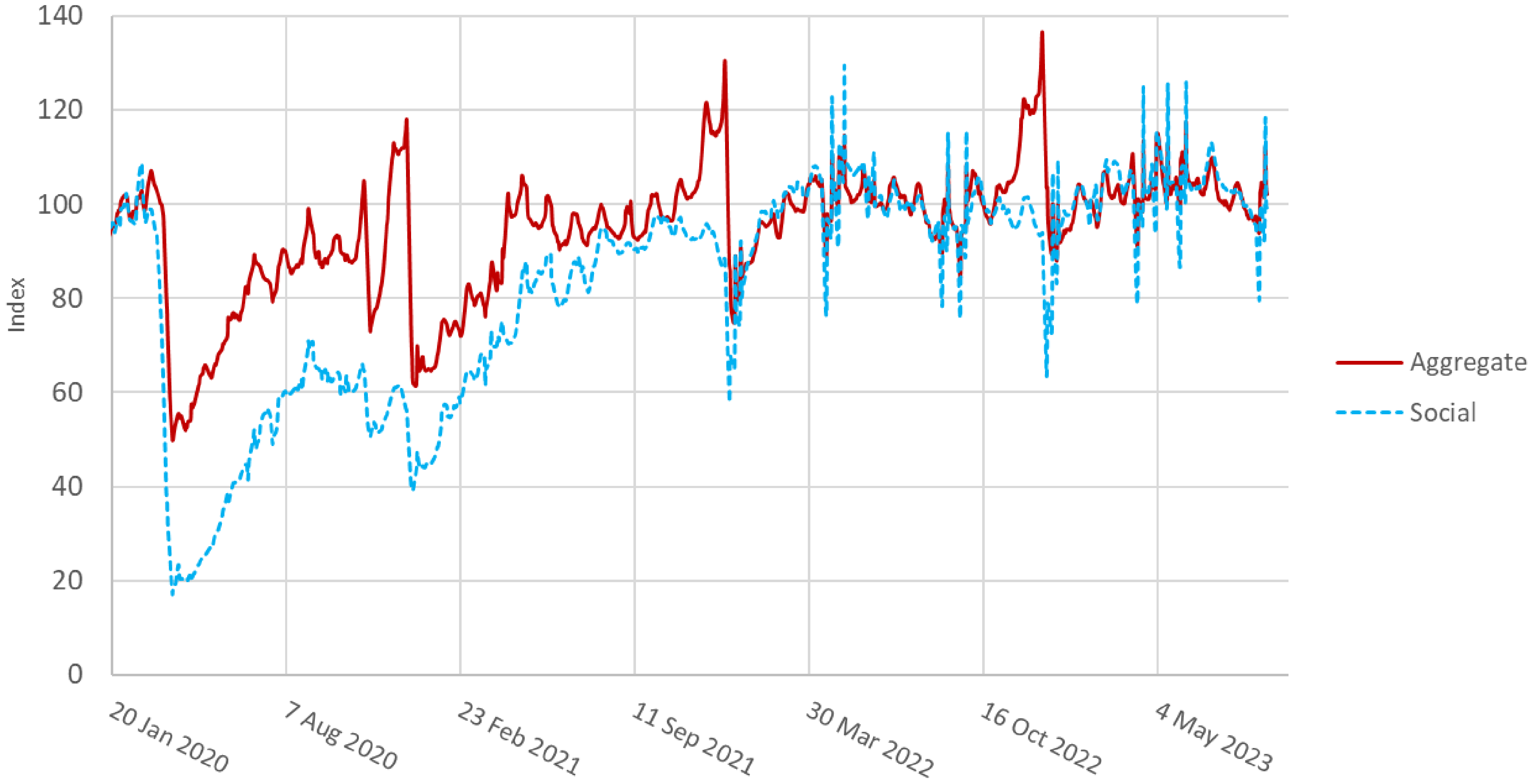
Real Time Economics

Key market moving economic indicators with calendared events updated in real time.

Request details

Example: Daily Credit card spending in the UK



Source: https://www.ons.gov.uk/economy/economicoutputandproductivity/output/datasets/ukspendingoncreditanddebitcards

There is much work in economics, especially in <u>econometrics,</u> focusing on high frequency forecasting already.

Yet overall in theoretical models this is still underdeveloped.. And also…

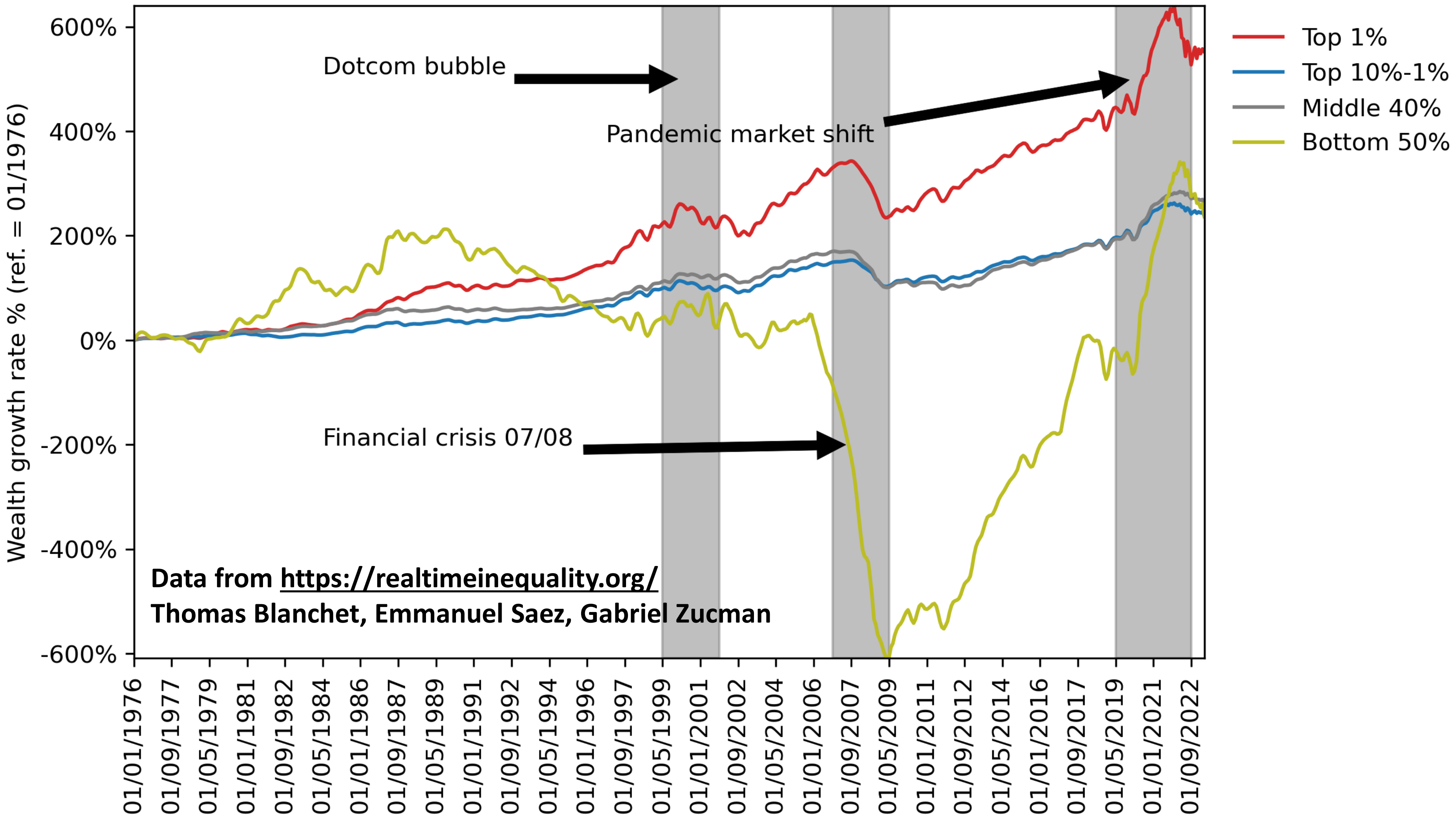
Problem 1:

How do you model such fast-paced processes/data?

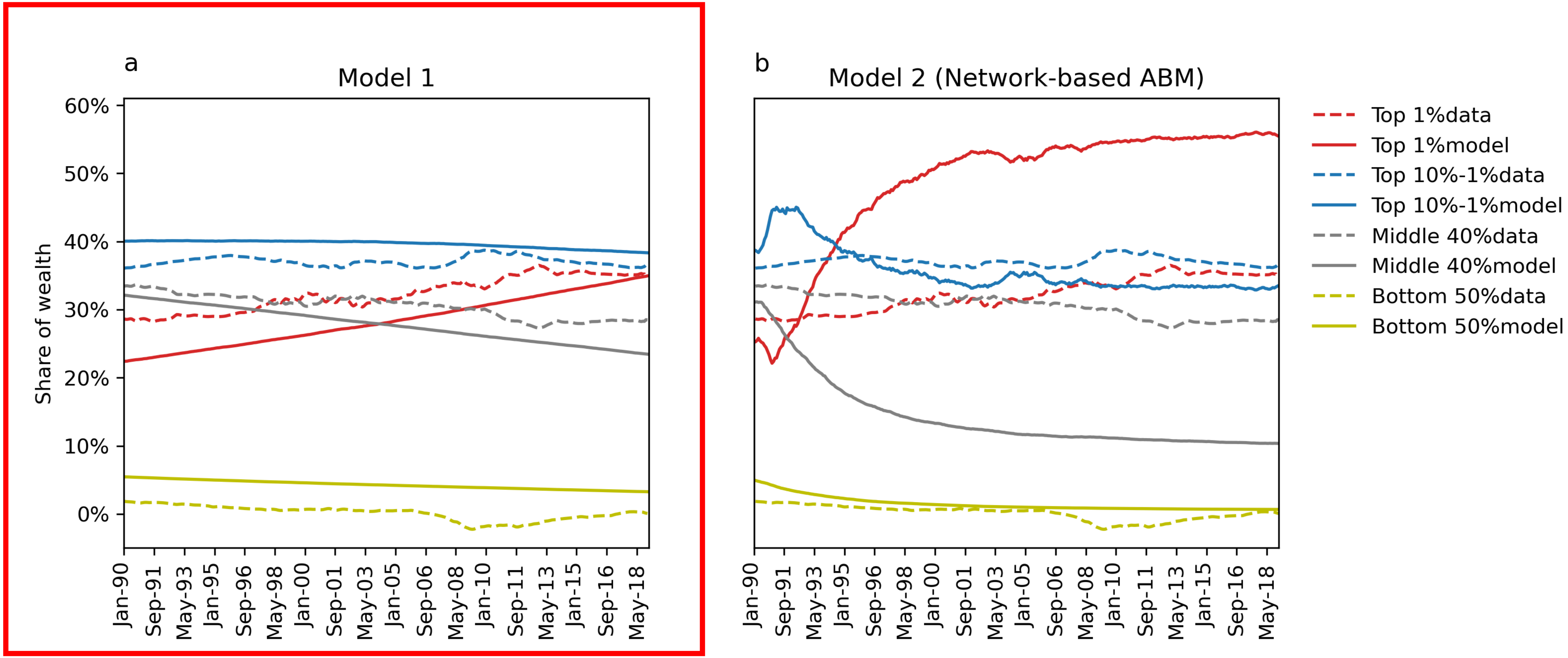
Problem 2:

What if a model quickly diverges from reality?

Our use case: **American Wealth inequality**



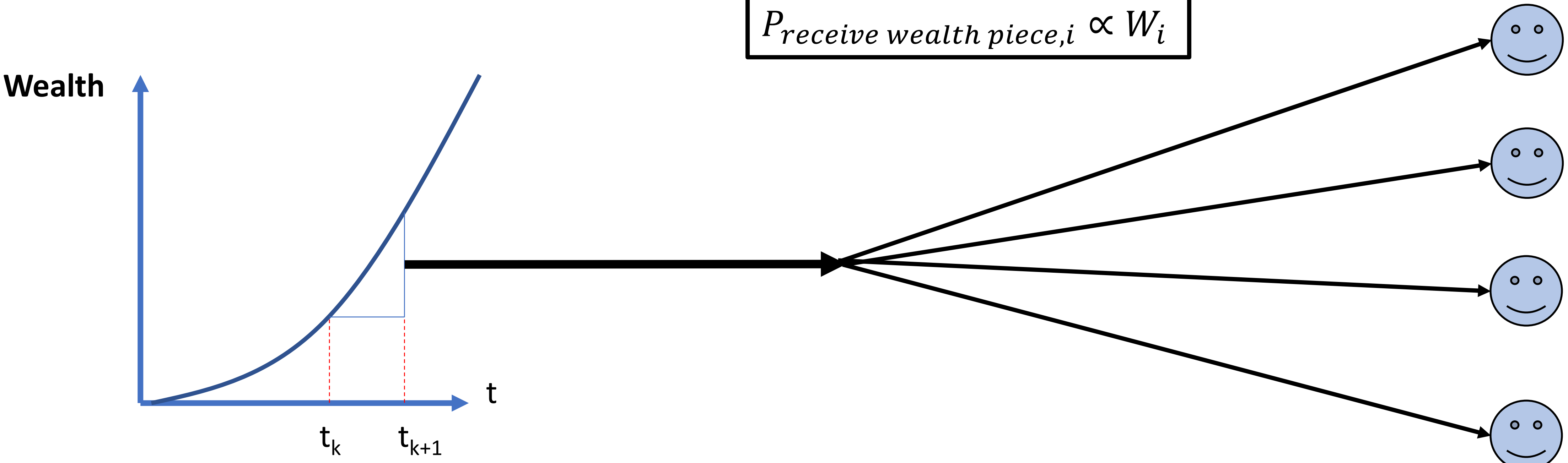
Two agent-based models to explain this



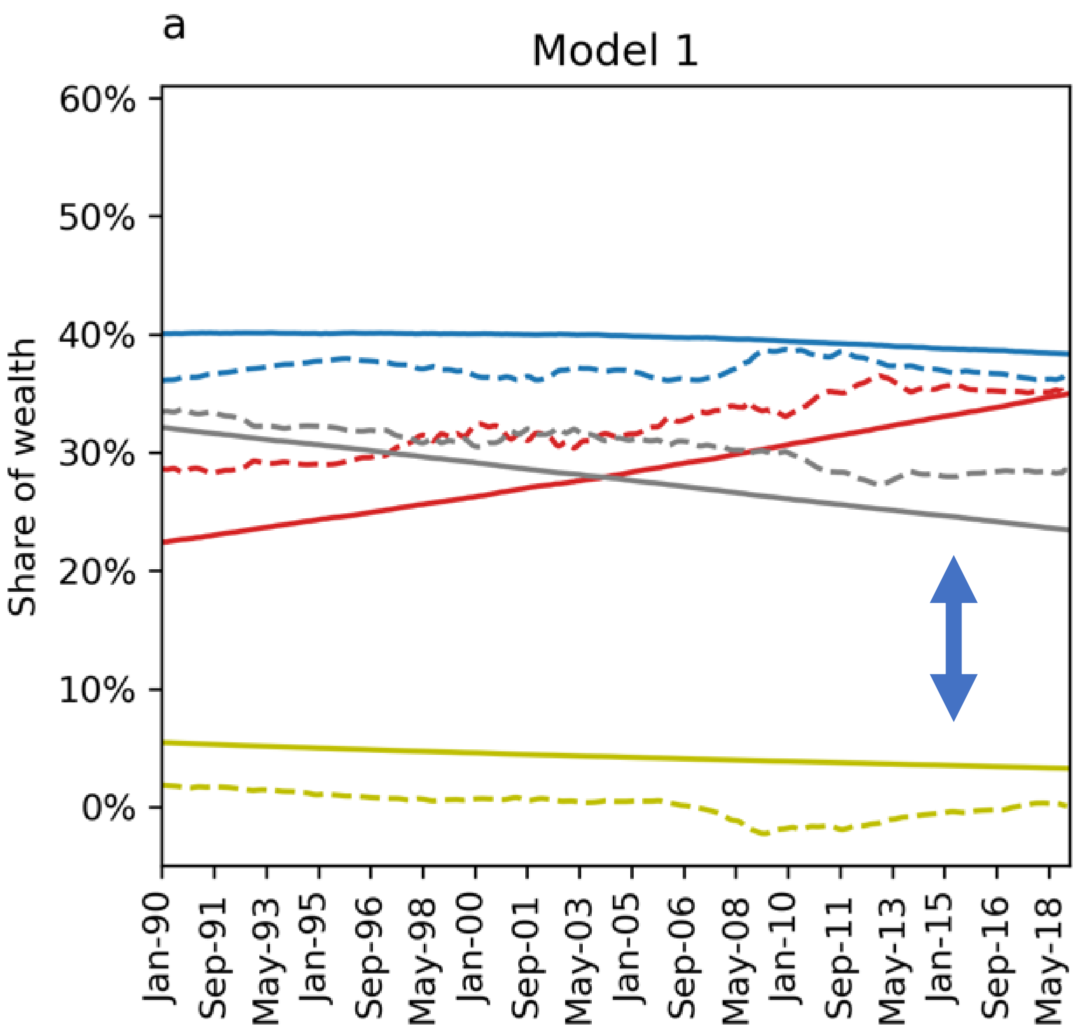
Model 1 – by Vallejos, Nutaro, and Perumalla (2018) Not really an ABM, rather individual-based

Aggregate economic (wealth) growth **Economic pie is distributed** **N agents**

$$P_{receive\ wealth\ piece,i} \propto W_i$$



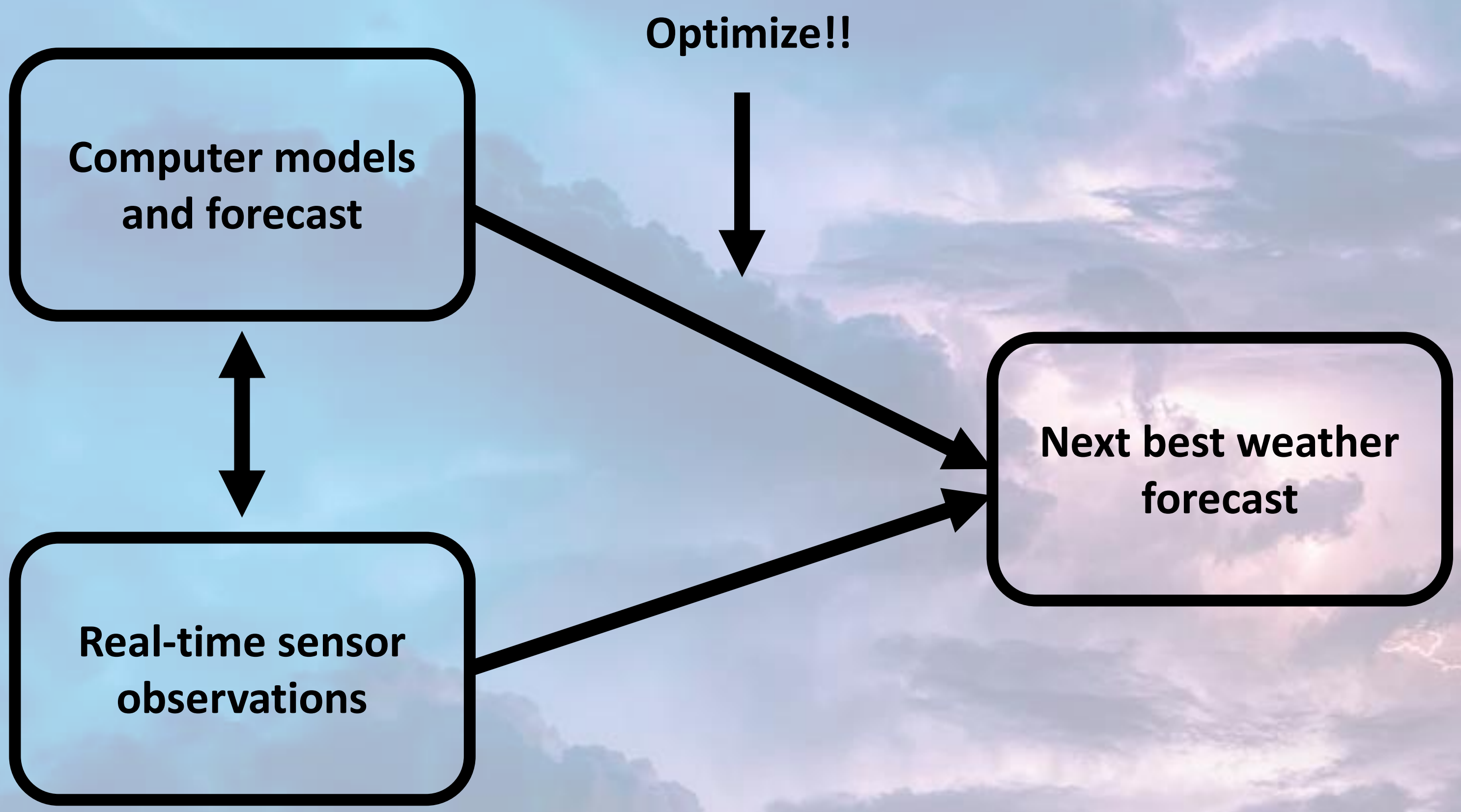
Back to problem #2:
What do we do when a model does not fit the data?



Option 1: Recalibrate

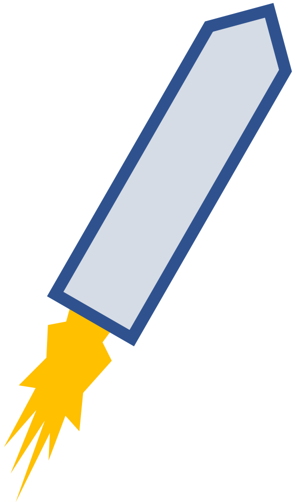
Option 2: Change the model

Option 3: Data assimilation = update the internal model state based on observations



A brief note on data assimilation and weather

The Kalman Filter



Rudolf Emil Kalman 1930 - 2016
Engineer and mathematician

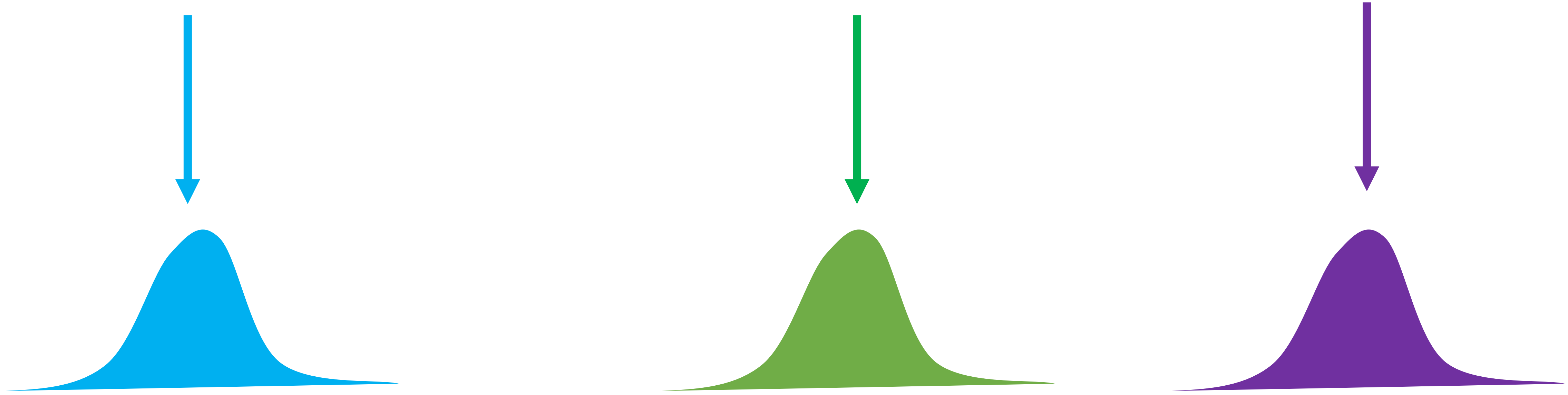
Very general idea

$$X_{estimate,t+1} = (1 - K) * X_{model,t} + K * X_{obs,t}$$

System	$X_{estimate,t+1} =$	$(1 - K) * X_{model,t} +$	$K * X_{obs,t}$
Rocket	**Position**	**Law of motion**	**Position obs.**
Economic growth	**GDP**	**“Law” of growth**	**Economic activity obs.**
Wealth inequality	**Some inequality metric**	**“Law” of distribution /ABM in our case**	**Wealth classes obs.**

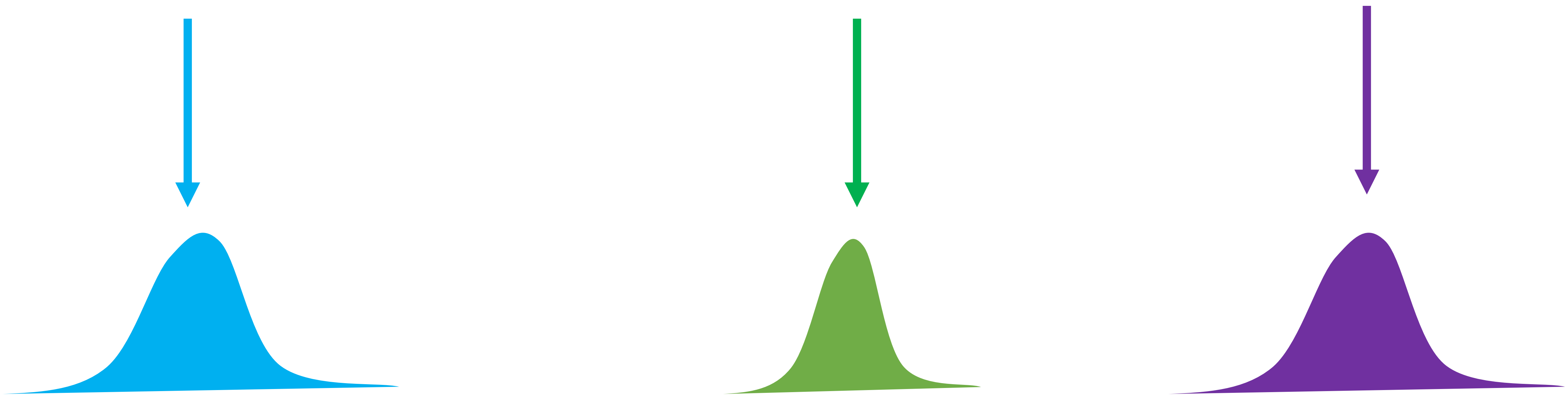
The Kalman Filter considers uncertainty

$$X_{estimate,t+1} = (1 - K) * X_{model,t} + K * X_{obs,t}$$



The Kalman Filter is optimal because weights K minimize uncertainty

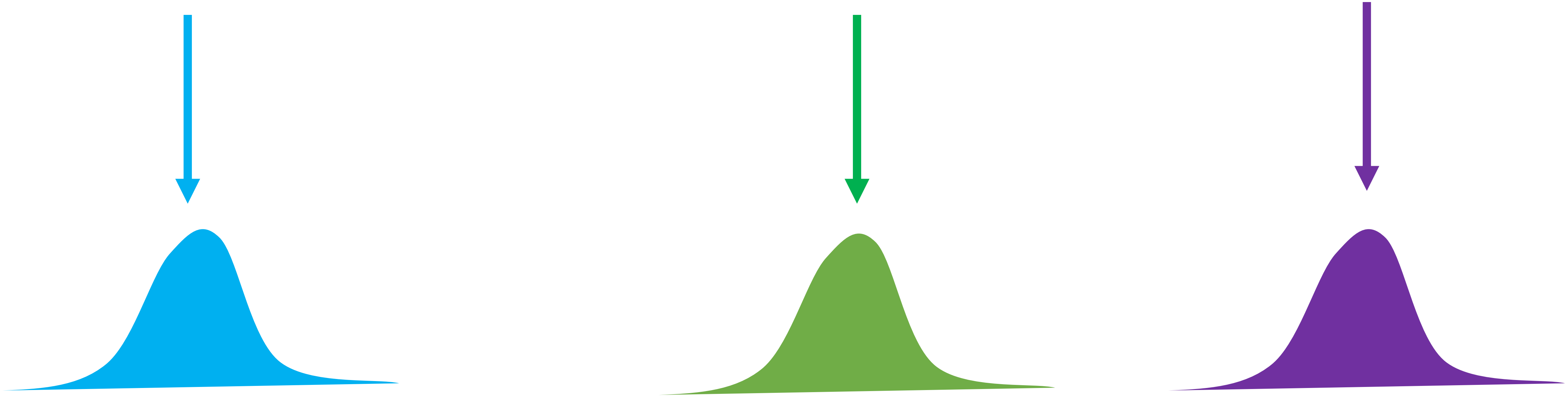
$$X_{estimate,t+1} = (1-K) * X_{model,t} + K * X_{obs,t}$$



If Variance model < Variance Obs then (1-K) > K

The Ensemble Kalman Filter takes uncertainty from an ensemble of models and an ensemble of observations

$$X_{estimate,t+1} = (1 - K) * X_{model,t} + K * X_{obs,t}$$



From Ensemble of ABMs

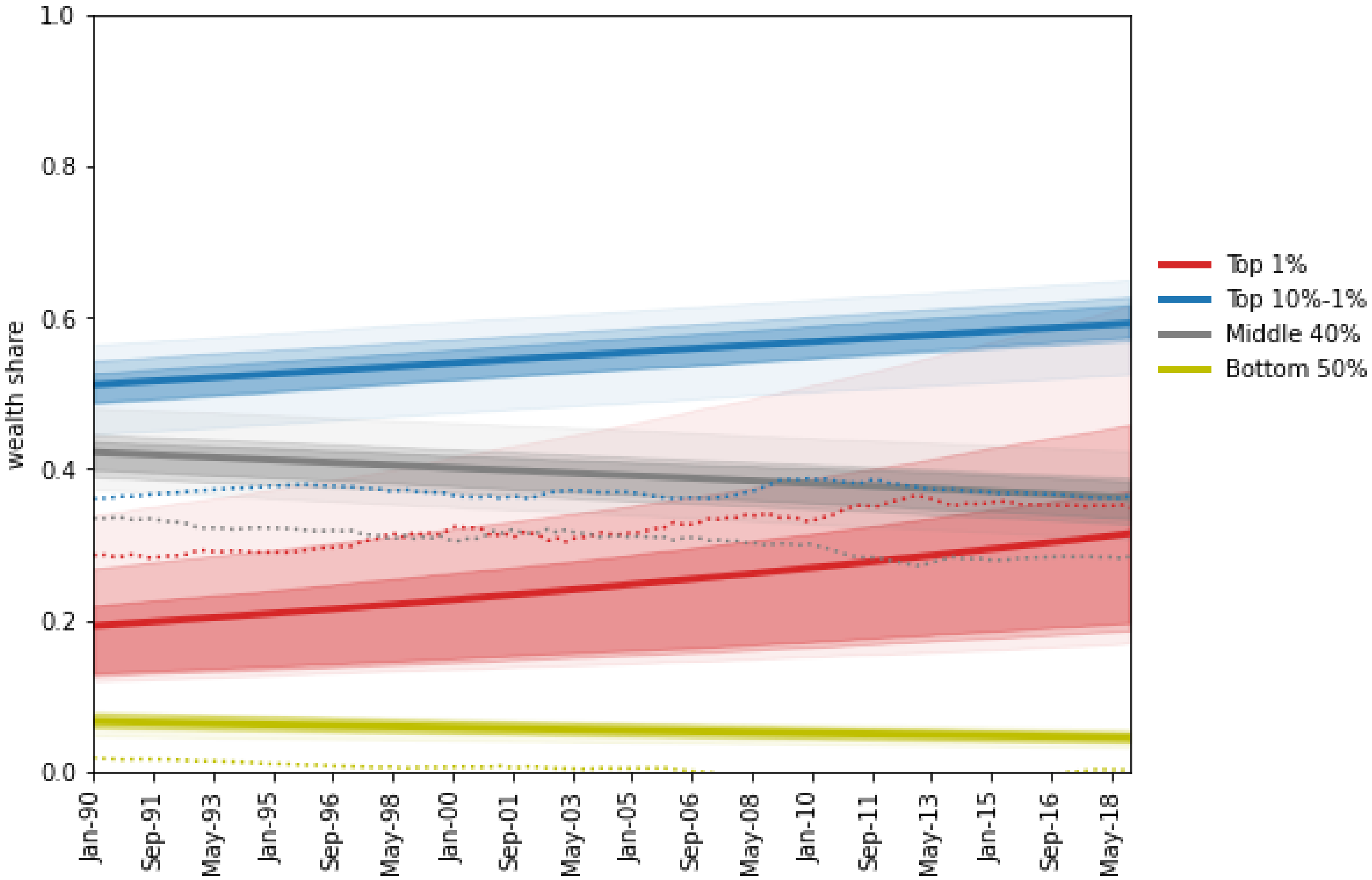
Model and observation are not necessarily of the same dimensionality

$$X_{estimate,t+1} = (1-K) * X_{model,t} + K * X_{obs,t}$$

$$\begin{bmatrix} top\ 1\% \\ middle\ 40\% \\ bottom\ 50\ \% \end{bmatrix} \longleftrightarrow \begin{pmatrix} agent_1 \\ agent_2 \\ \vdots \\ agent_n \end{pmatrix} \longleftrightarrow \begin{bmatrix} top\ 1\% \\ middle\ 40\% \\ bottom\ 50\ \% \end{bmatrix}$$

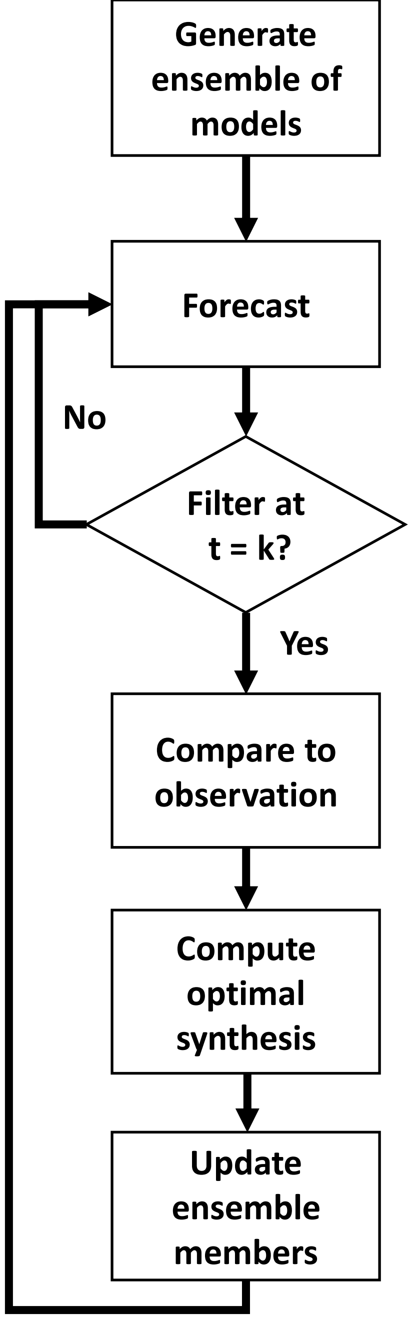
Micro to macro

Ensemble of simulation runs model 1

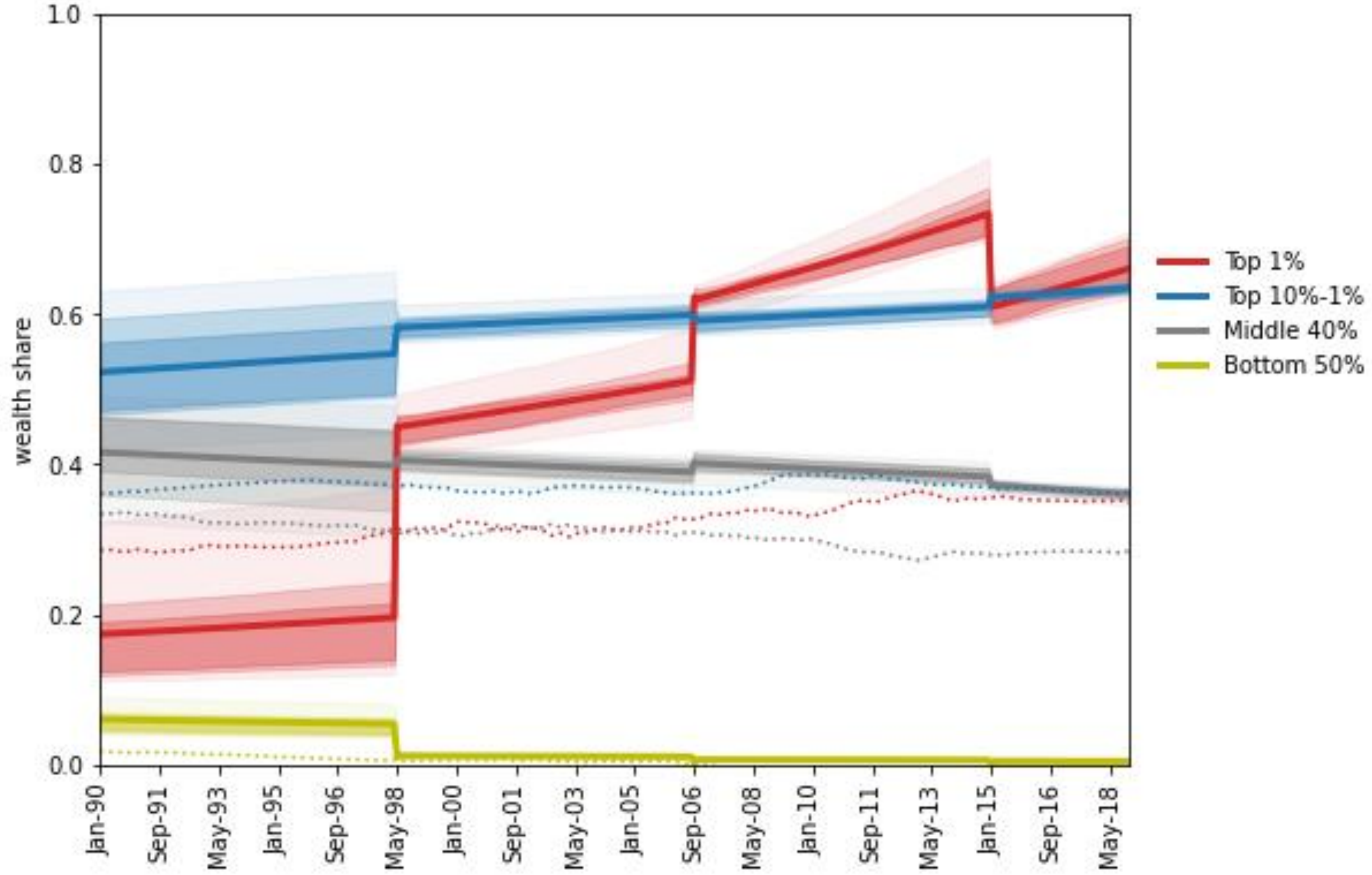


The Ensemble Kalman Filter (ENKF)

Procedural flow



Ensemble of simulation runs with ENKF – unfinished work, not robust yet



Discussion and outlook

- Does the filter work correctly?
  - Is the micro-macro translation correctly?

- We want to test the method during crisis moments like the pandemic 2020

- We hope that this inspires more data-assimilation-based control in economic forecasting