KüNO Online Workshop 'Predictability in Natural and Social Sciences'
3 May, 2022

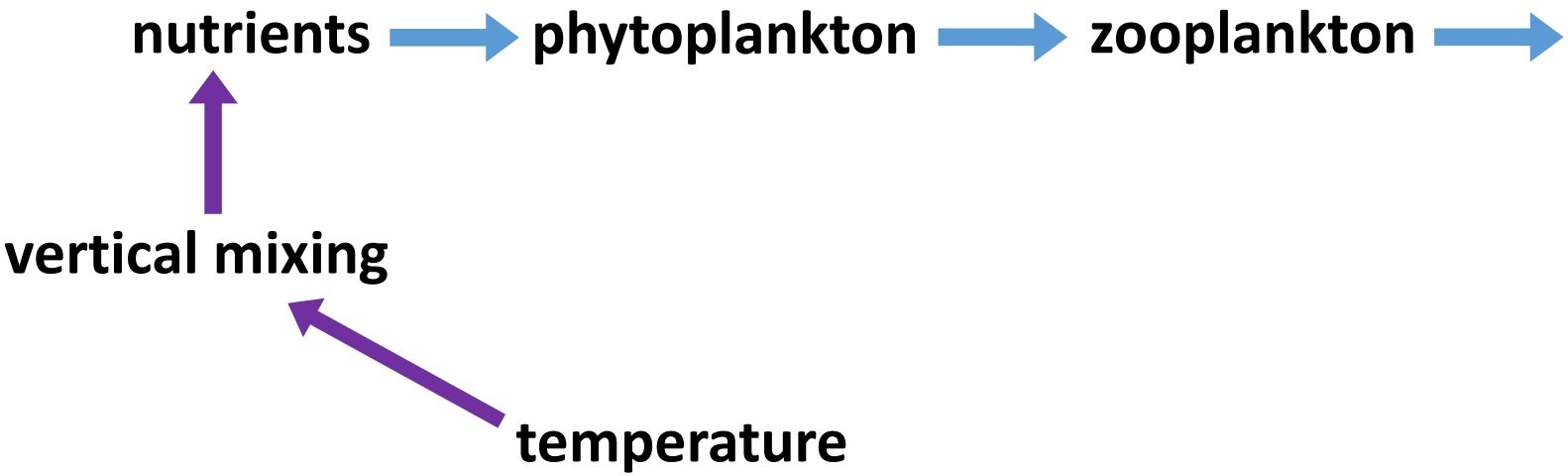
Predictability of ecosystem dynamics:

models misbehave if they miss behavior

Kai Wirtz

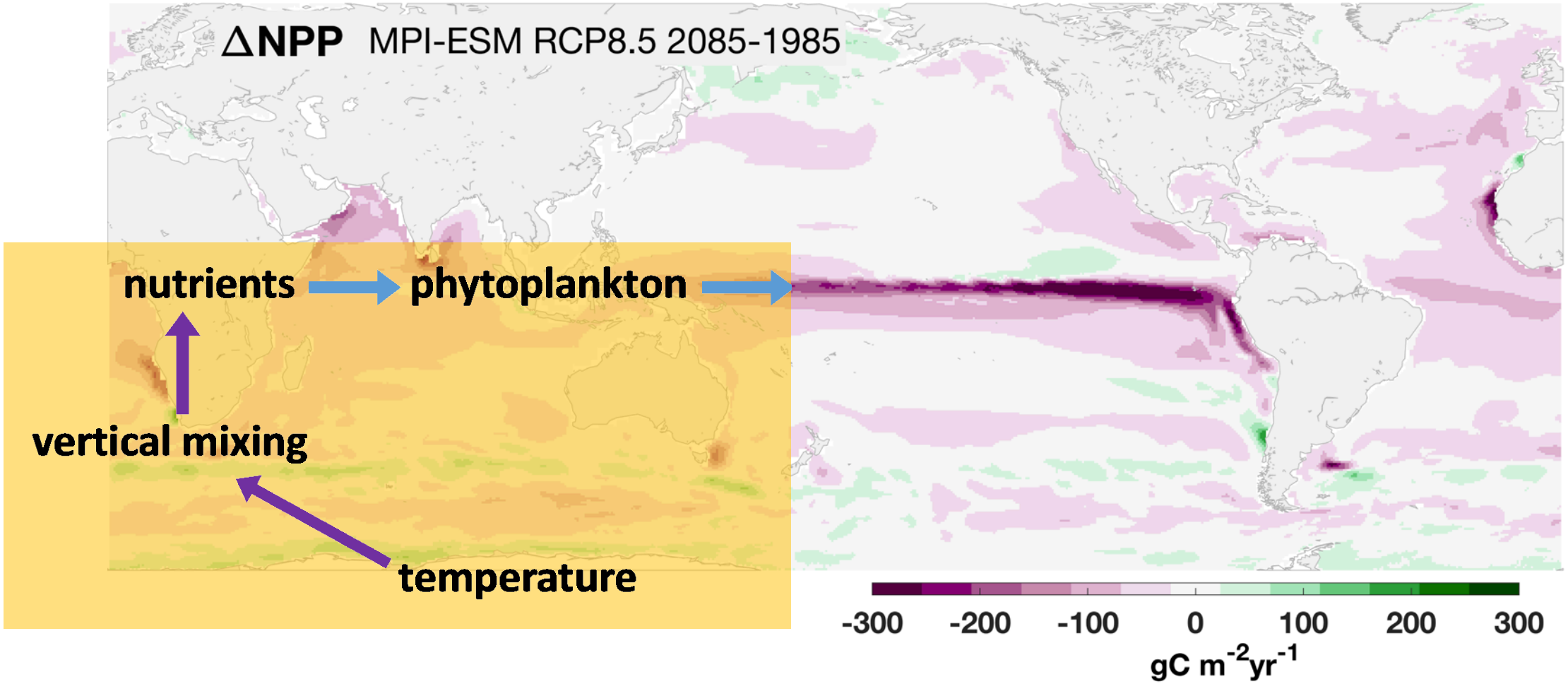
Helmholtz-Zentrum hereon

modeling marine ecosystem response



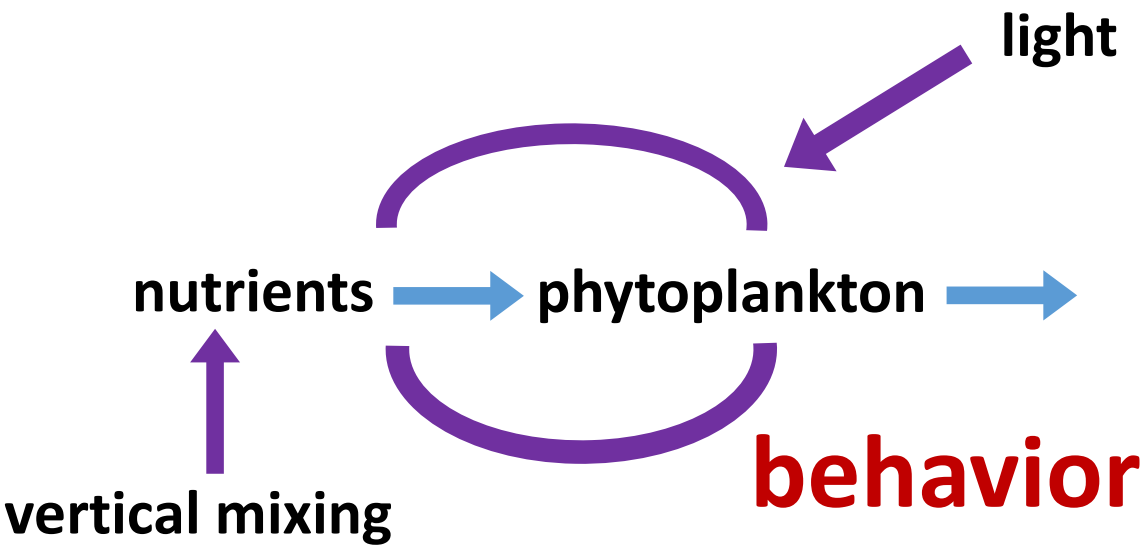
predictability of marine ecosystem response

decrease in Net Primary Productivity (NPP) under climate change



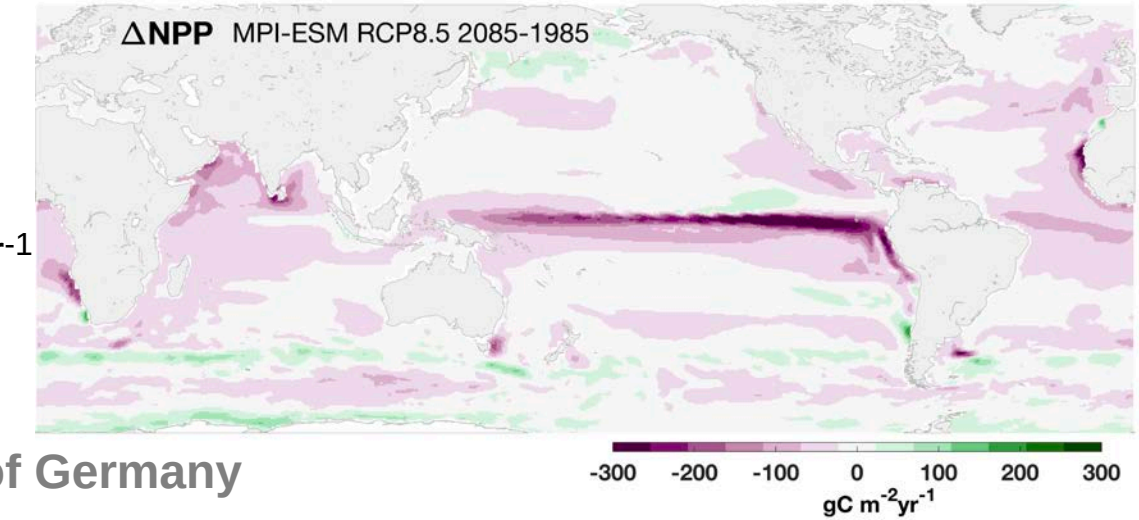
Wirtz, Mathis et al *Nature Clim Change*

phytoplankton vertical migration



Wirtz & Smith *Sci Rep* 2020

global NPP in a warmer future ocean

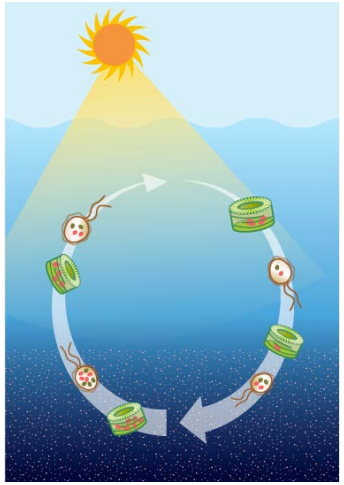


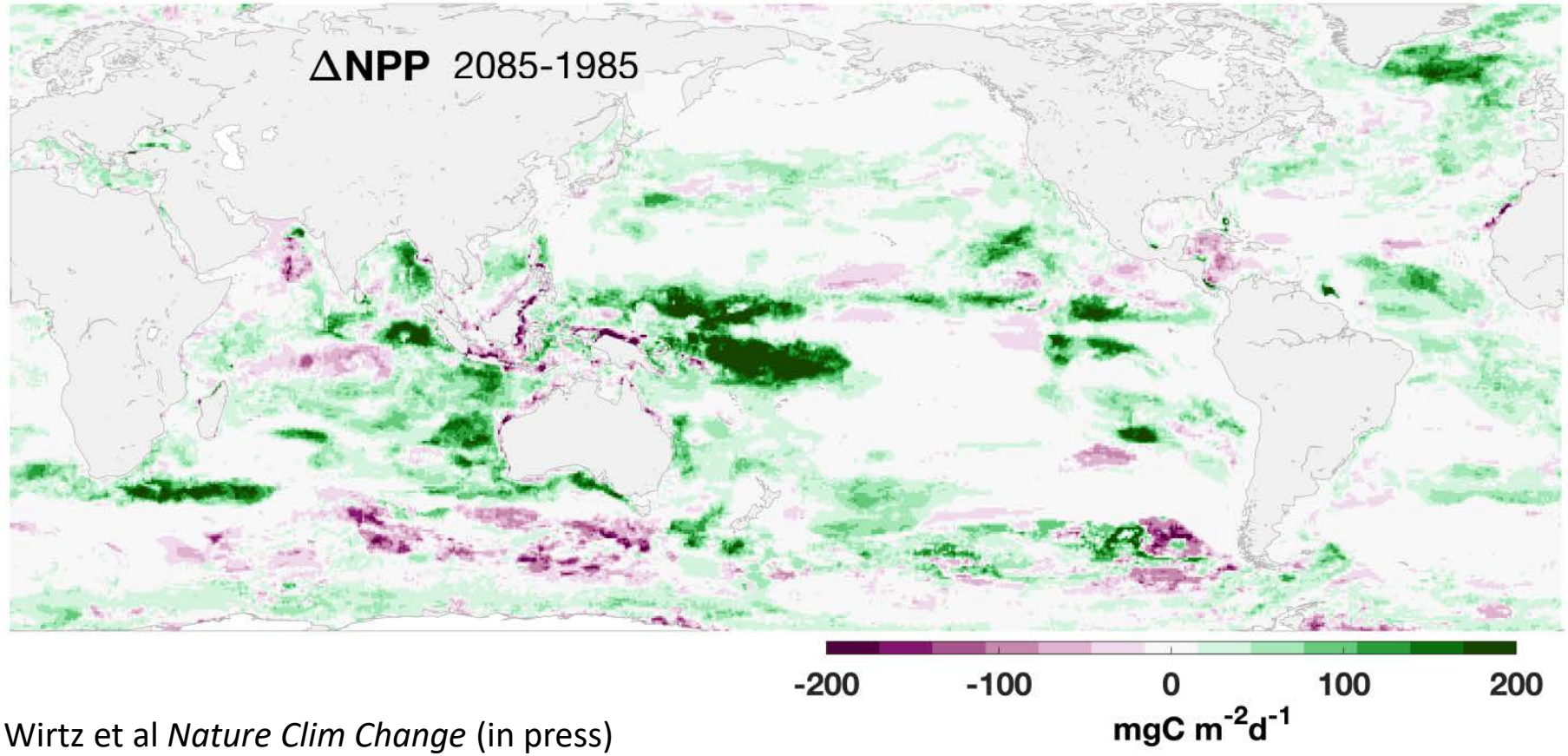
decrease by 8.5 Pg-C yr^{-1}
(classical models)

increase by 2.3 Pg-C yr^{-1}
(to 58.4 Pg-C yr^{-1})

difference: 70 × C-emission of Germany

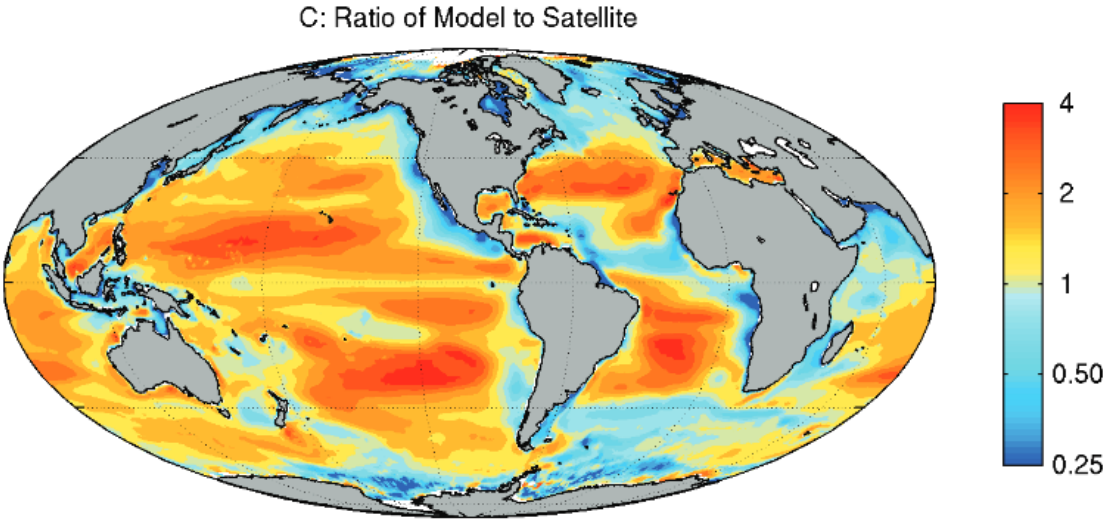
identically forced simulation incl. phytoplankton vertical migration



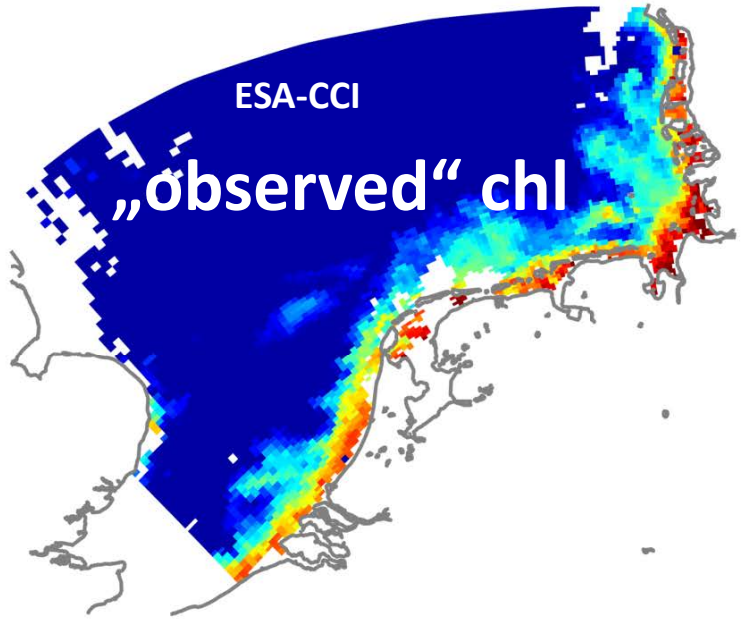


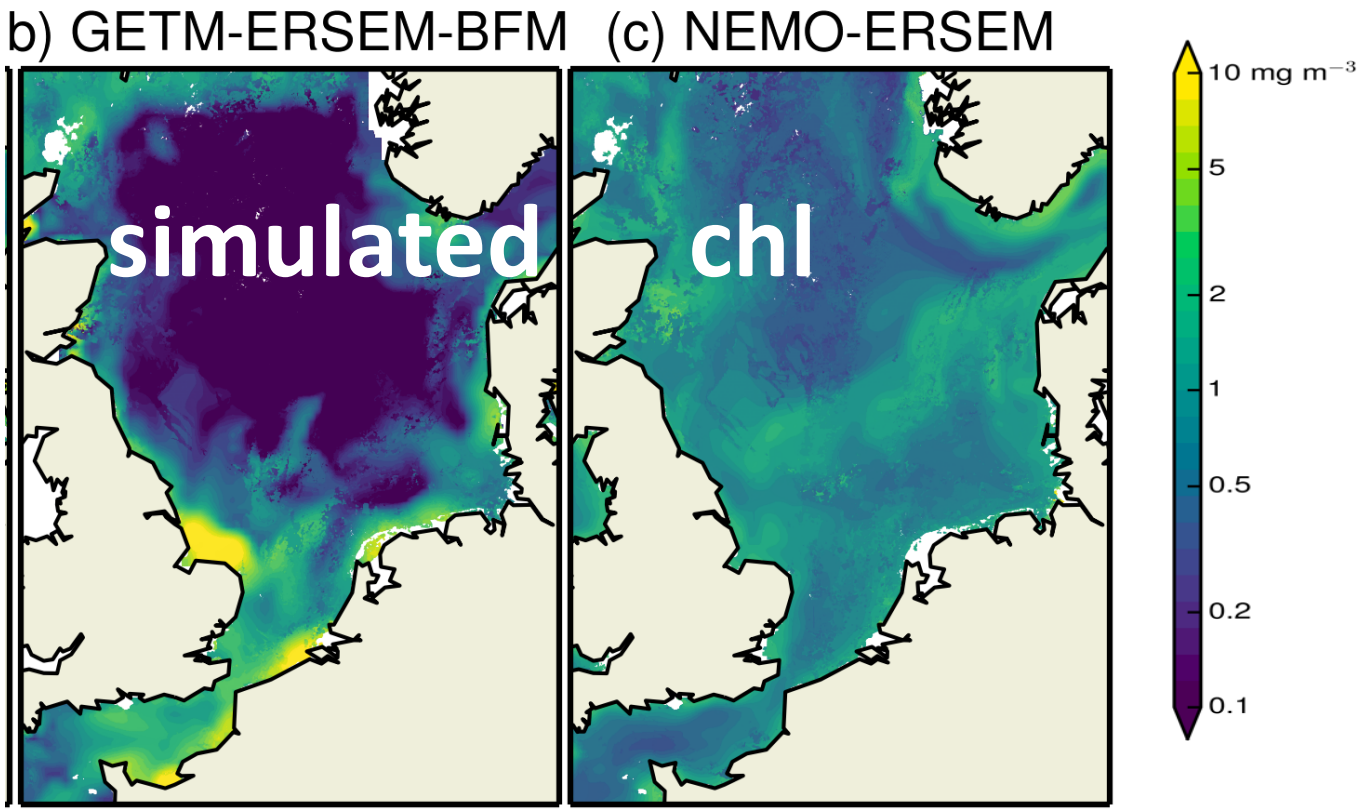
Wirtz et al *Nature Clim Change* (in press)

underestimation of Chlorophyll-a (chl) in shallow waters

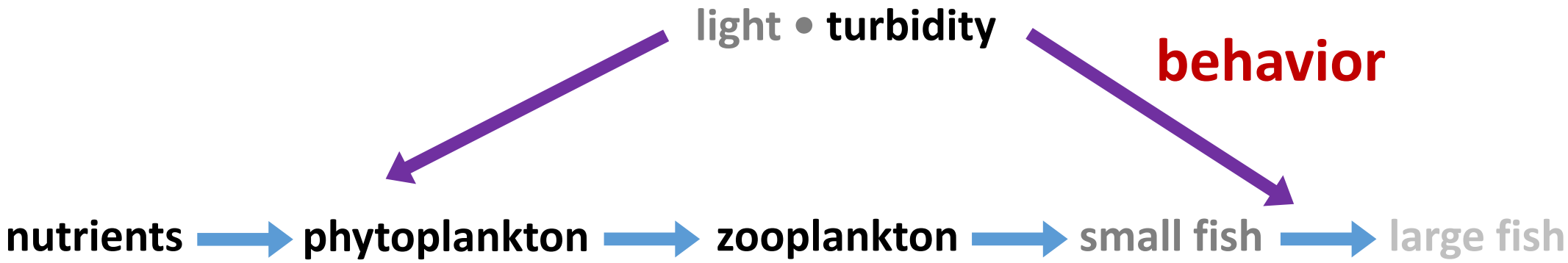


Baird et al *IOCCG* 2020





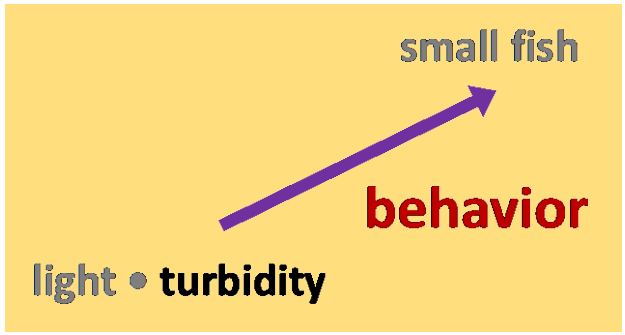
Ford et al., 2017



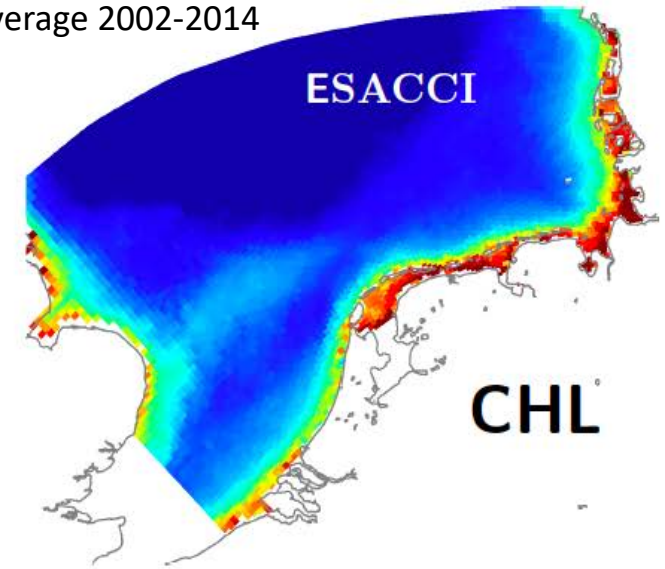
Wirtz *PLOS* 2019

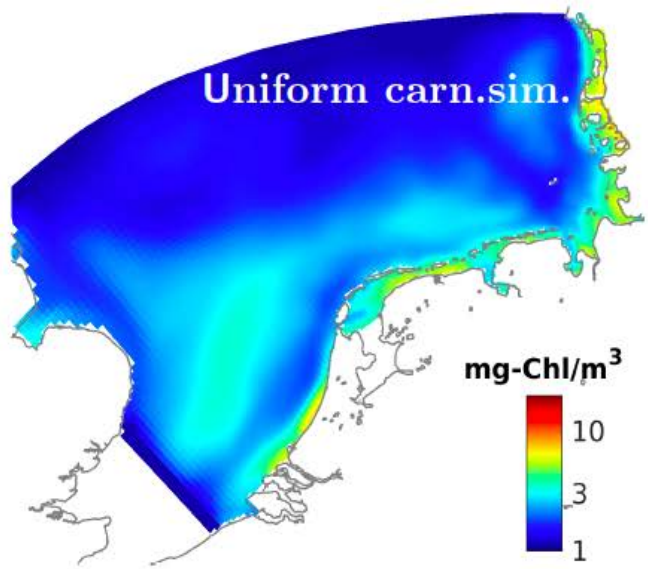
CHL accumulation in shallow coasts

due to behaviorally controlled trophic cascading



average 2002-2014





remote sensing

simulation
without
higher near-shore zooplankton mortality

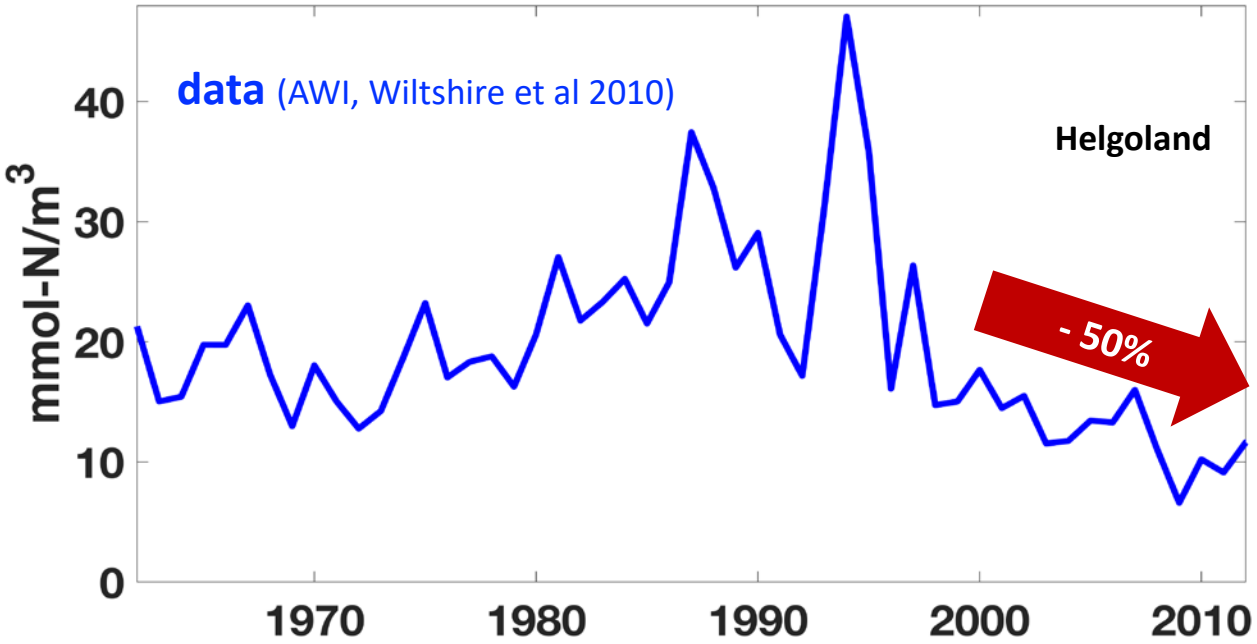
(almost all ecosystem models)

Wirtz *PLOS* 2019

less nutrients, less phytoplankton ?

decrease in nutrients (de-eutrophication after mid 90s)

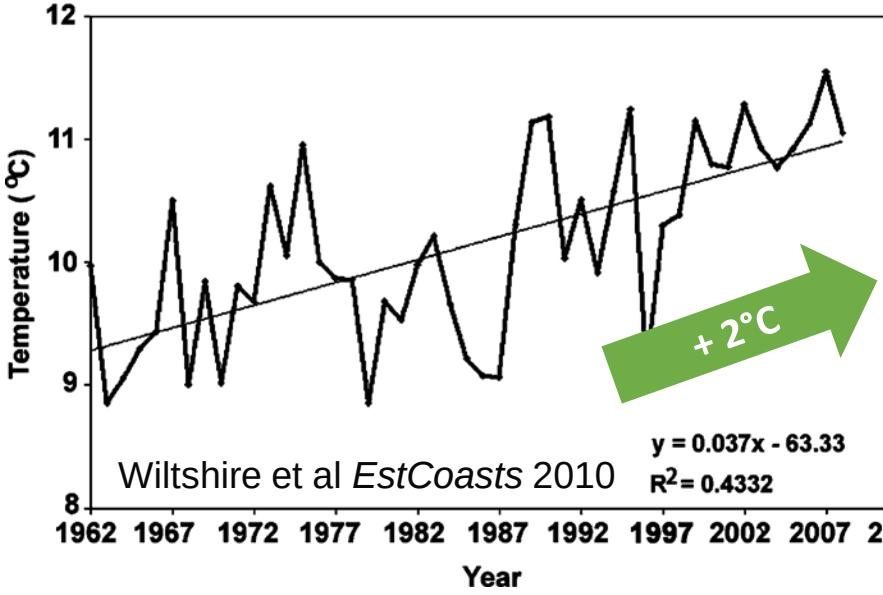
dissolved inorganic nitrogen



classical models hindcast lower NPP after 1996
(e.g. Daewel & Schrum 2013)

NPP & chl

predictability of marine ecosystem response depends on the account of behavior in models



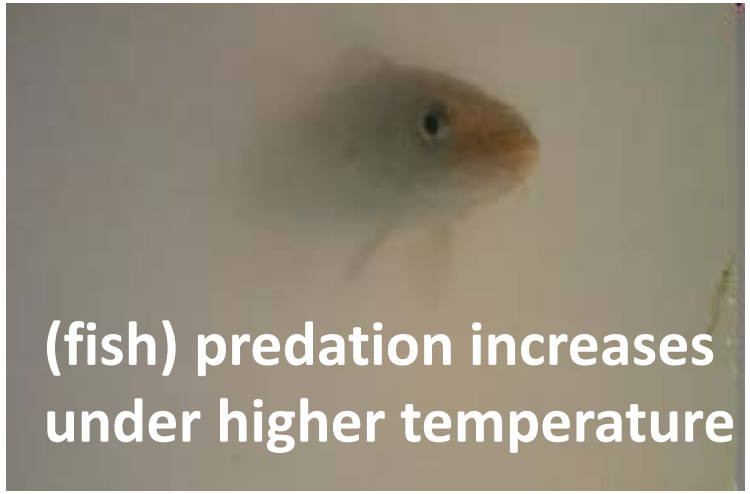
Wiltshire et al *EstCoasts* 2010

nutrients → phytoplankton → zooplankton → small fish → large fish

behavior

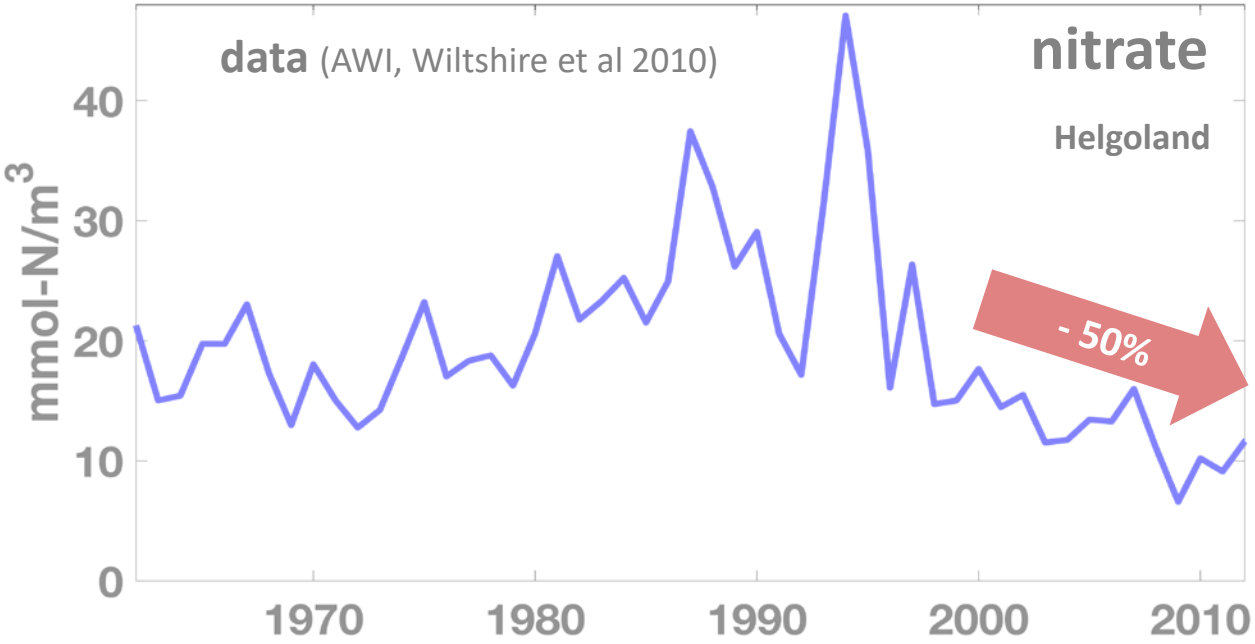
light • turbidity

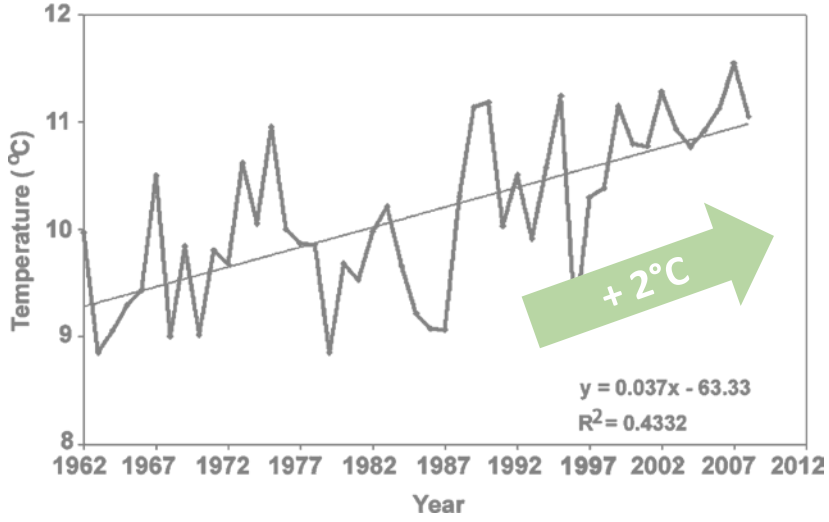
temperature



less nutrients, more phytoplankton …

due to behaviorally controlled trophic cascading



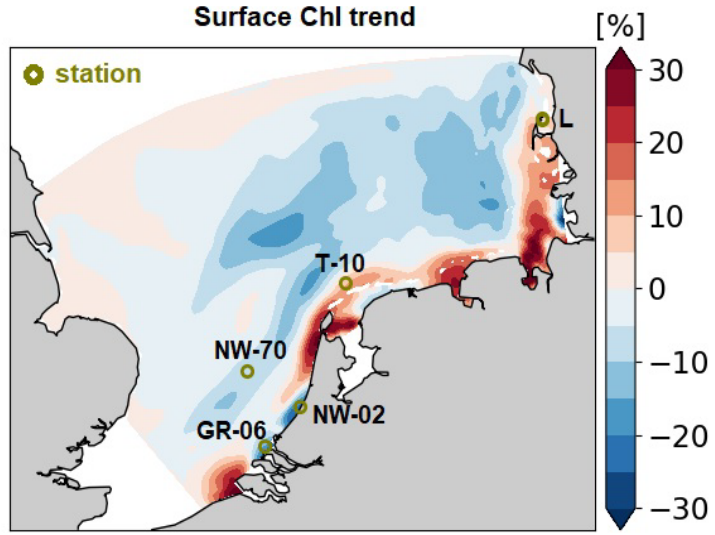


data (CPR, MBA-UK)

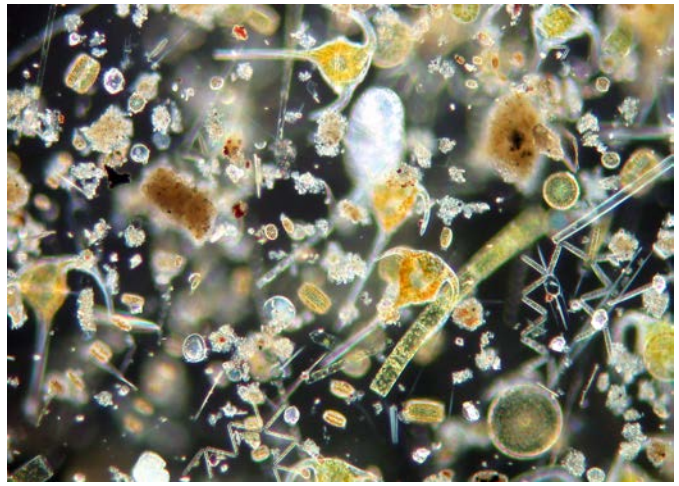
Chl

1961 1971 1981 1991 2001 2011

climate change: **thermally intensified trophic cascading in** (most) **near-shore waters**



Wirtz 2019, Xu et al 2020



Nutrients → Phytoplankton → Zooplankton

light

temperature

Behavior

NPZ→ NPZB models

predictability in epidemiology and social sciences

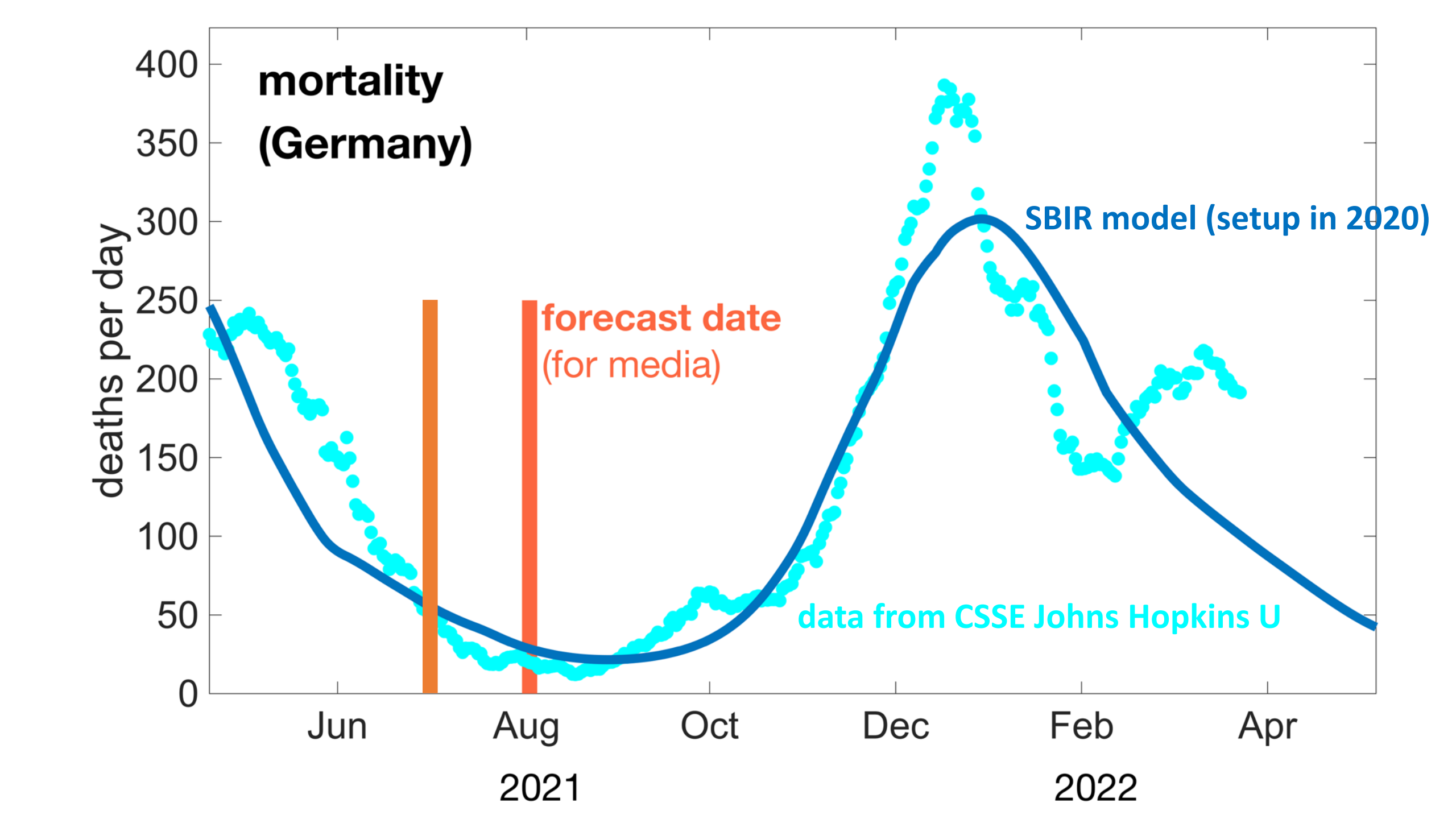
Susceptible → Infected → Recovered

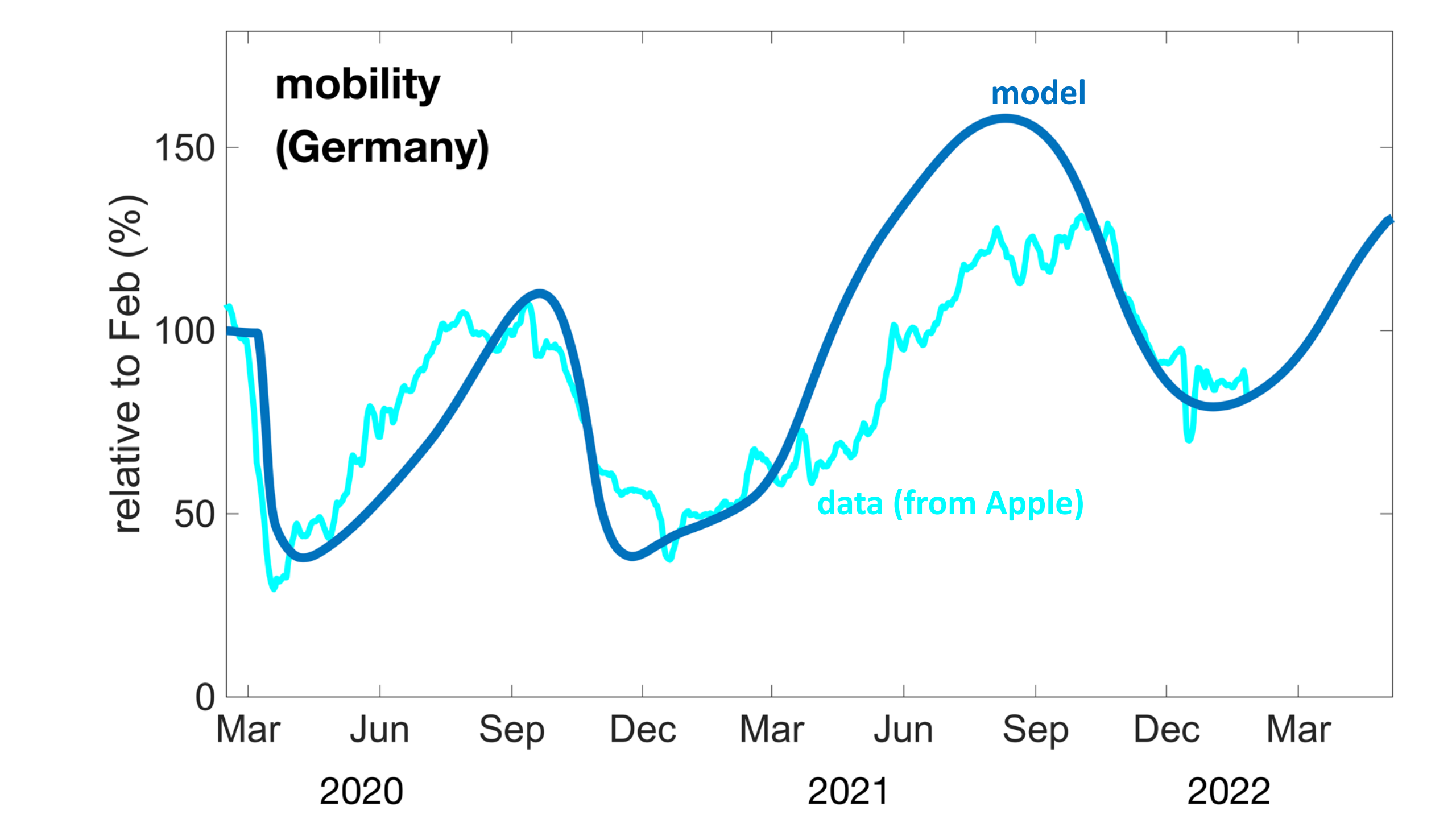
light

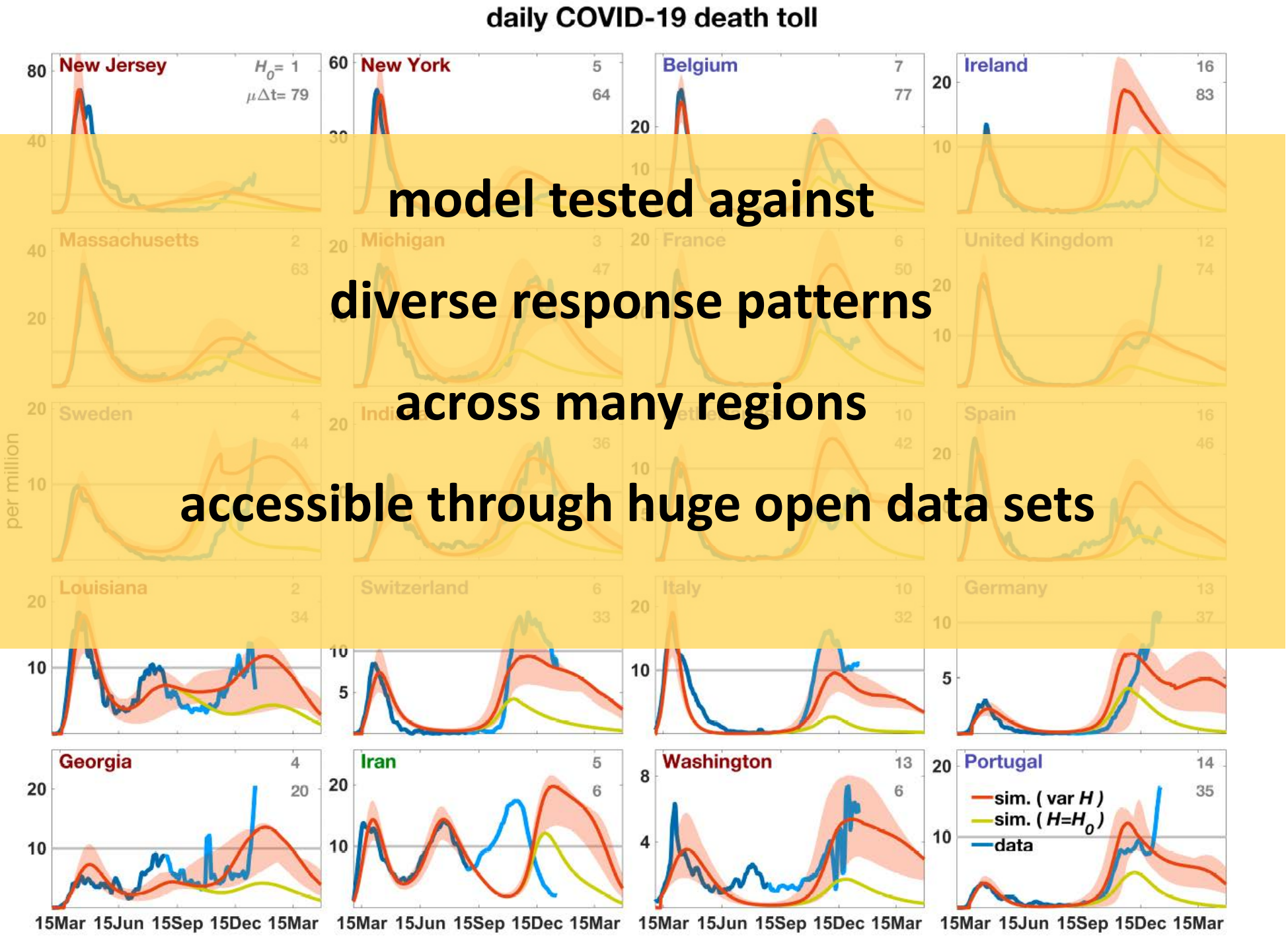
temperature

SIR models
revealed only short forecast horizons
in the SARS-CoV-2 pandemics

SBIR model
resolves changing societal response


mortality
(Germany)
deaths per day
400
350
300
250
200
150
100
50
0
Jun
Aug
Oct
Dec
Feb
Apr
2021
2022
forecast date
(for media)
SBIR model (setup in 2020)
data from CSSE Johns Hopkins U


mobility
(Germany)
model
data (from Apple)
relative to Feb (%)
150
100
50
0
Mar
Jun
Sep
Dec
Mar
Jun
Sep
Dec
Mar
2020
2021
2022



model tested against

diverse response patterns

across many regions

accessible through huge open data sets

Wirtz *Sci Rep* 2021

socio/eco-system responses can be reasonably predicted

when combining

- **mechanistic models**
- **critical processes driving long-term dynamics (e.g., behavior)**
- **data for diverse response patterns from different environments**

models can behave if they are trained and know about behaviour

Thanks

to M. Mathis, L. Smith, X. Xu, C. Lemmen, data contributors (ESA, Apple, …)

and for Your attention !