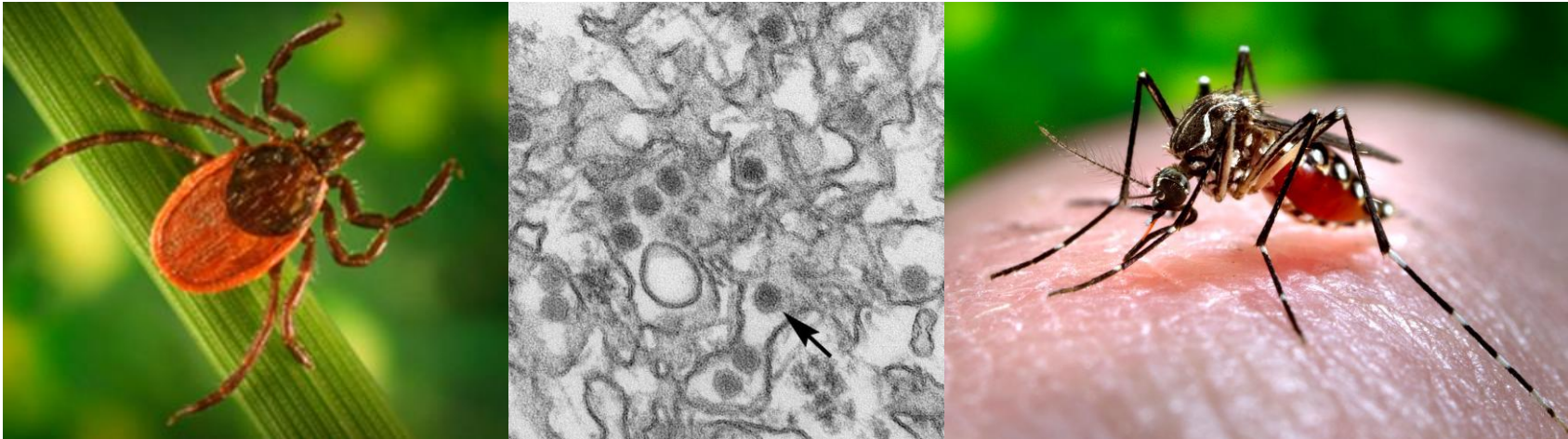


Impact of Climate Change on Infectious Diseases

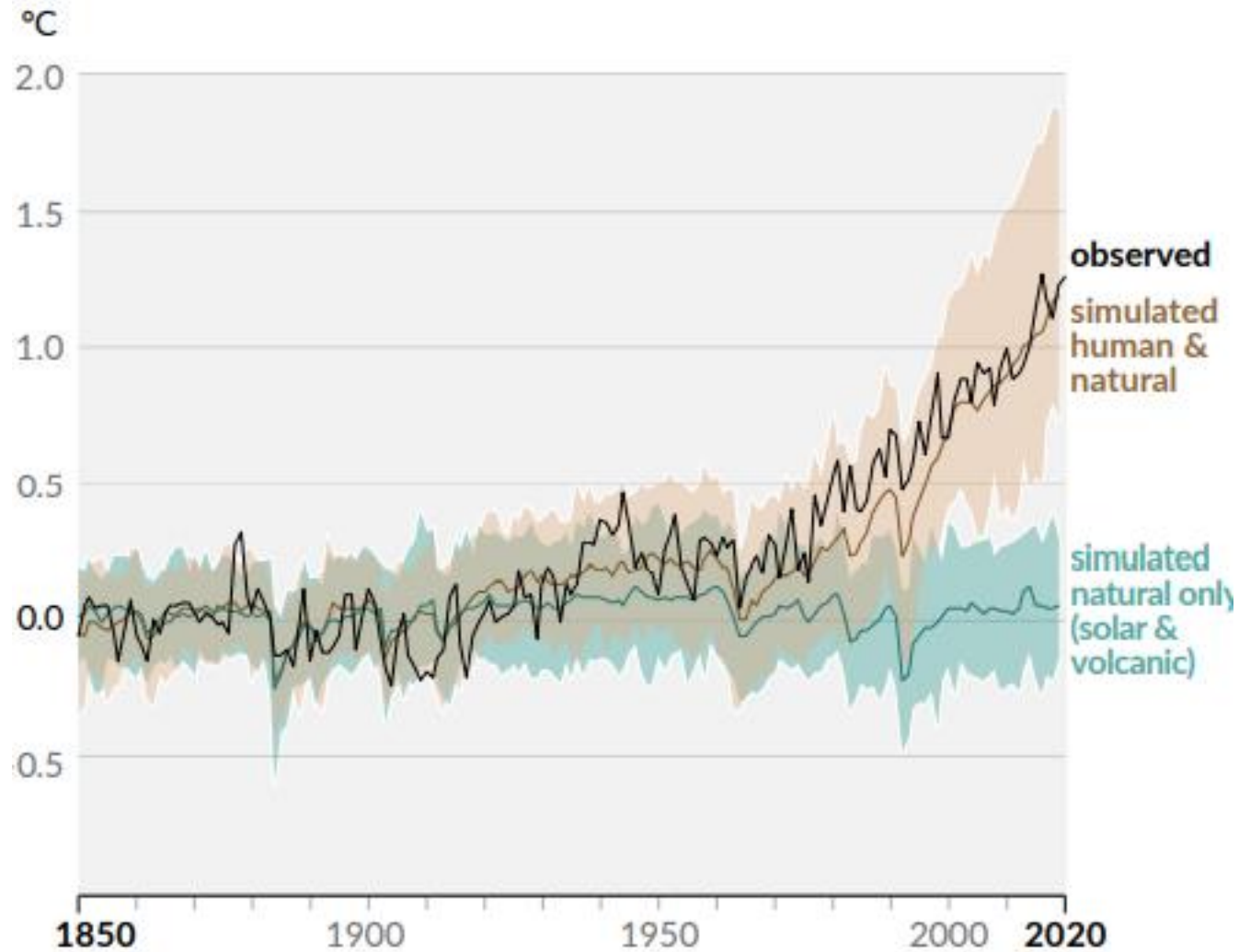


Lyle R. Petersen, MD, MPH

Director

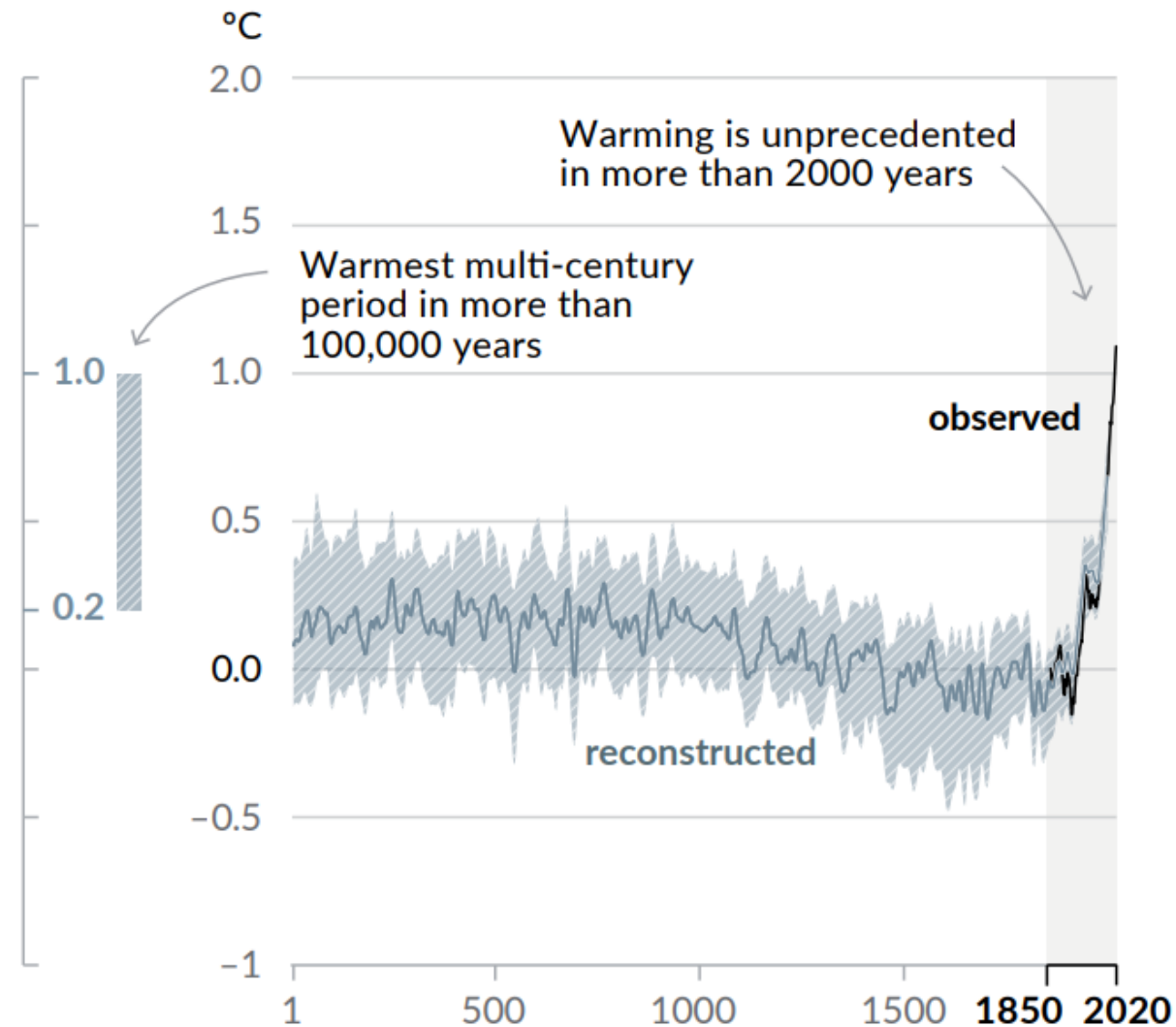
Division of Vector-Borne Diseases, NCEZID, CDC

Change in global surface temperatures as observed and simulated using human and natural and only natural factors (both 1850-2020)



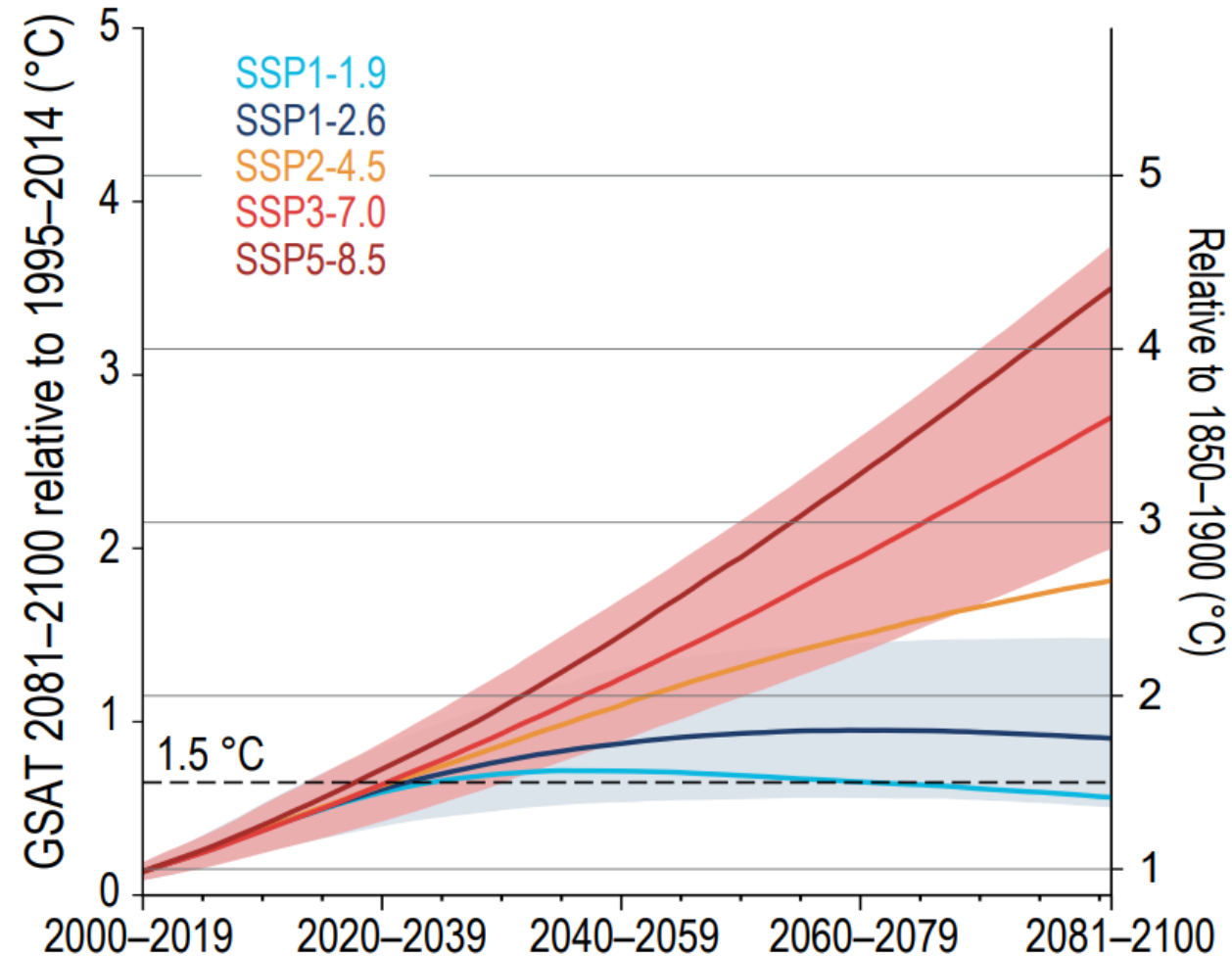
Source: IPCC Climate Change 2021; The Physical Science Basis

The recent change in temperature is unprecedented



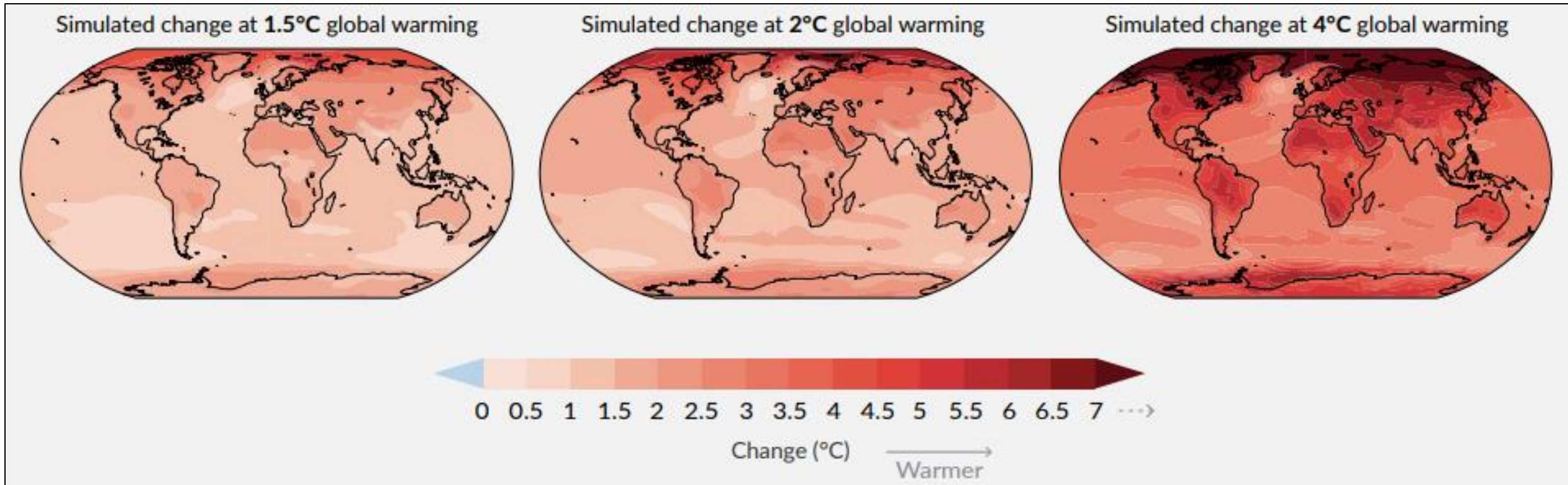
Source: IPCC Climate Change 2021; The Physical Science Basis

Predicted increases in global surface air temperatures, by shared socio-economic pathways (SSPs)



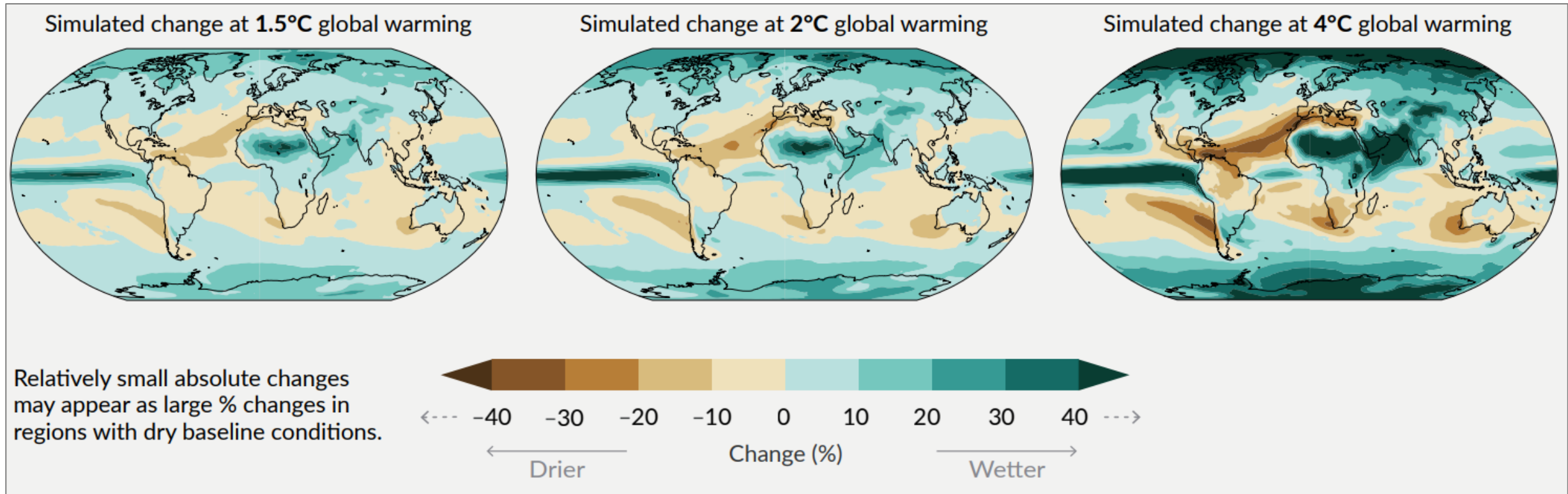
Source: IPCC Climate Change 2021; The Physical Science Basis

Annual mean precipitation change relative to 1850-1900



Source: IPCC Climate Change 2021; The Physical Science Basis

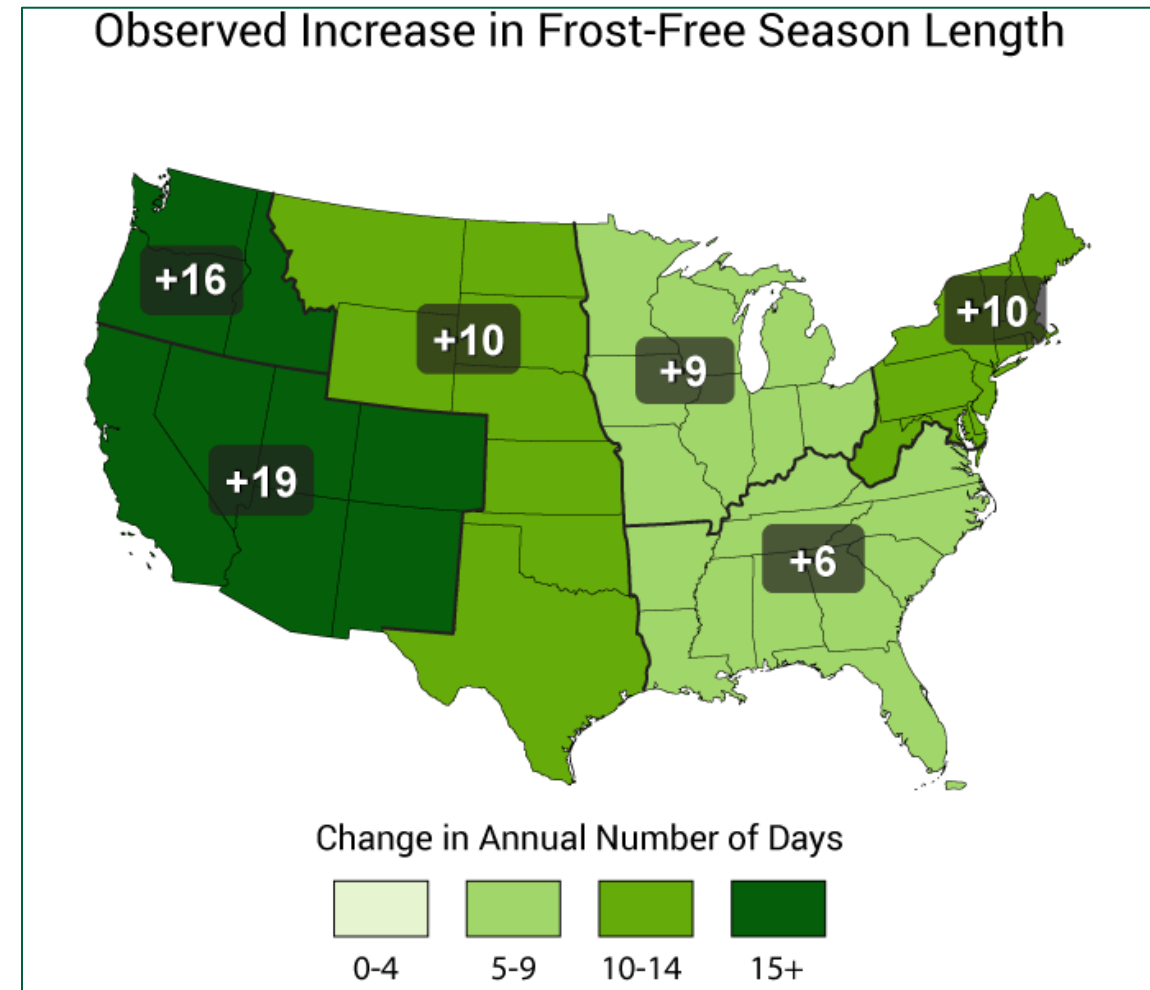
Annual mean precipitation change relative to 1850-1900



Source: IPCC Climate Change 2021; The Physical Science Basis

Climate change – Observations and Trends

- Longer and warmer summers
- Shorter and milder winters
- Increased frequency of severe and unpredictable weather events (e.g., storms, heat waves, droughts)
- Regional variations
- Influence on global weather patterns



Source: The frost-free season length, defined as the period between the last occurrence of 32°F in the spring and the first occurrence of 32°F in the fall, has increased in each U.S. region during 1991-2012 relative to 1901-1960. Increases in frost-free season length correspond to similar increases in growing season length. (Figure source: NOAA NCDC /CICS-NC).

**Climate change influence on
infections disease: Proving
causality in a traditional manner is
impossible**

There is no known control group.



Approaches to assessment of climate change on infectious disease

■ Event-driven observations

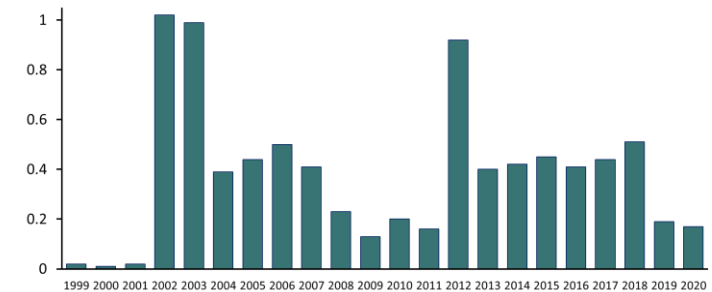
- Health impacts during extreme weather events (e.g., floods, heat waves) that are predicted to be more common with climate change
- Then model scenarios based on long-term changes in weather (climate).
- Examples: floods impacting water treatment plants, heat waves and West Nile, hurricanes and leptospirosis
- Problems:
 - single event doesn't prove that climate change is a factor – it is the increased frequency of events that matters
 - very difficult to develop a validated quantitative model incorporating extreme events



Approaches to assessment of climate change on infectious disease

■ Long-term observational data

- Monitor temporal trends in disease incidence and distribution and relate these trends to weather
- Then develop a predictive model based on expected long-term changes in weather (climate). Variety of modeling techniques.
- Examples: geographic changes in vector-borne diseases; expanded geographic distribution of soil-borne pathogenic organisms; rainfall and hantavirus



■ Problems:

- establishing causality – other factors may influence trends; geographically heterogeneous outcomes
- Modeling
 - Difficult to know all the important parameters, how they interact with each other, and how climate will impact them
 - Uncertainties about future climate
 - Societal impacts and vulnerabilities vary

Case studies: Climatic hazards

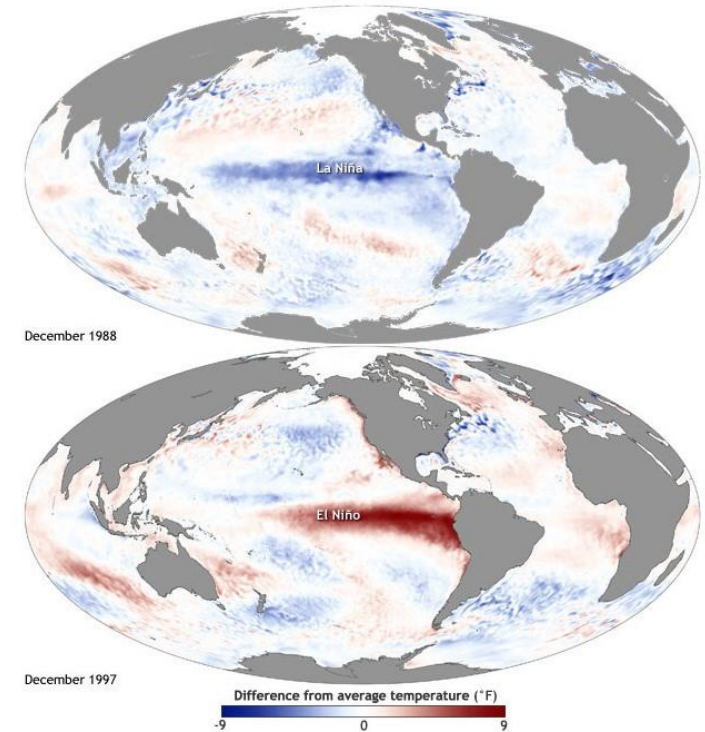
Over half of known human pathogenic diseases can be aggravated by climate change

- Review of >77K manuscripts revealed 830 references with case examples of diseases affected by climatic hazards
- 3,213 case examples related to 286 unique pathogenic diseases (58% of 375 known infectious diseases)
 - 223 aggravated
 - 54 both aggravated and diminished
 - 9 exclusively diminished
- Most common influencing factors
 - Warming (160), precipitation (122), floods (121), drought (81), storms (71)
- Most common pathogens
 - Viruses (76), bacteria (69), fungi (24), protozoans (23)
- Most common transmission pathways
 - Vectors (103), waterborne (78), airborne (60), direct contact (56), foodborne (50)

Source: <https://doi.org/10.1038/s41558-022-01426-1>

Climate Change and El Niño

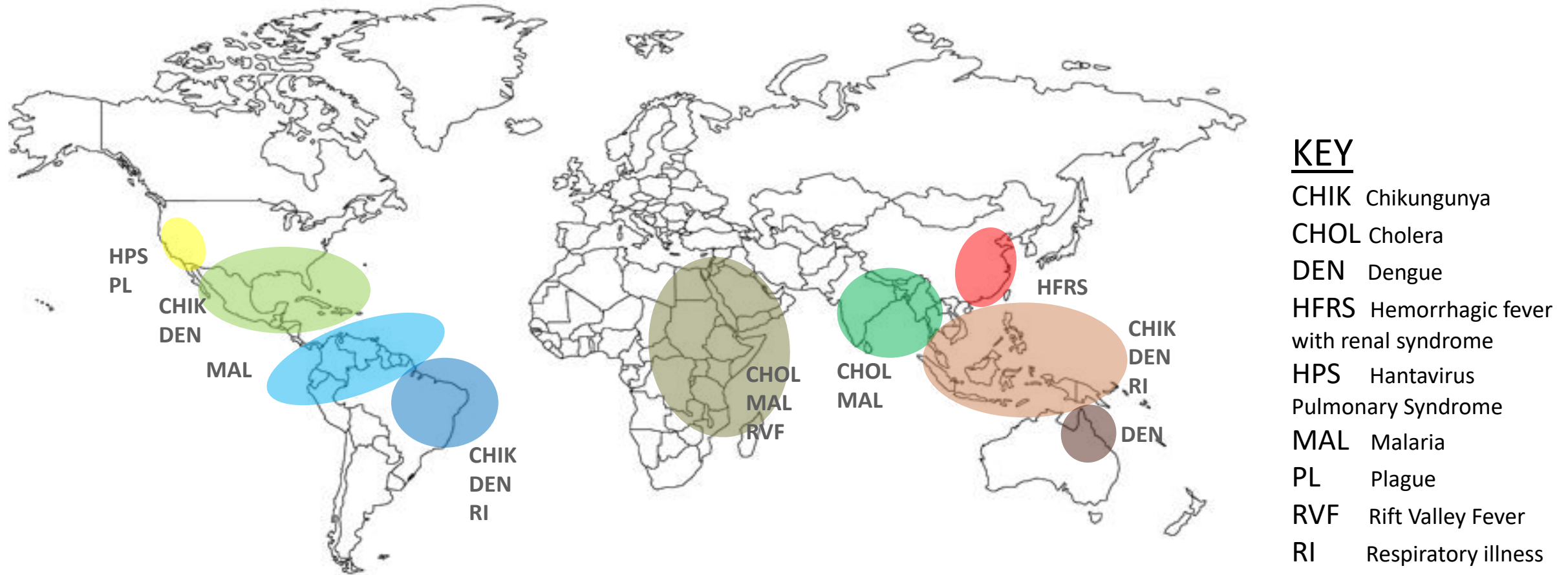
- El Niño events lead to changes in precipitation and temperature patterns across many regions of the world, including the U.S.
- Effects in the U.S. are typically seen in the cooler months of the year and are characterized by cooler and wetter seasonal weather.
- El Niño events are not caused by climate change, nor are they expected to occur at greater frequencies, but climate change may lead to greater El Niño intensity.



<https://www.climate.gov/enso>

Environmentally-sensitive diseases globally:

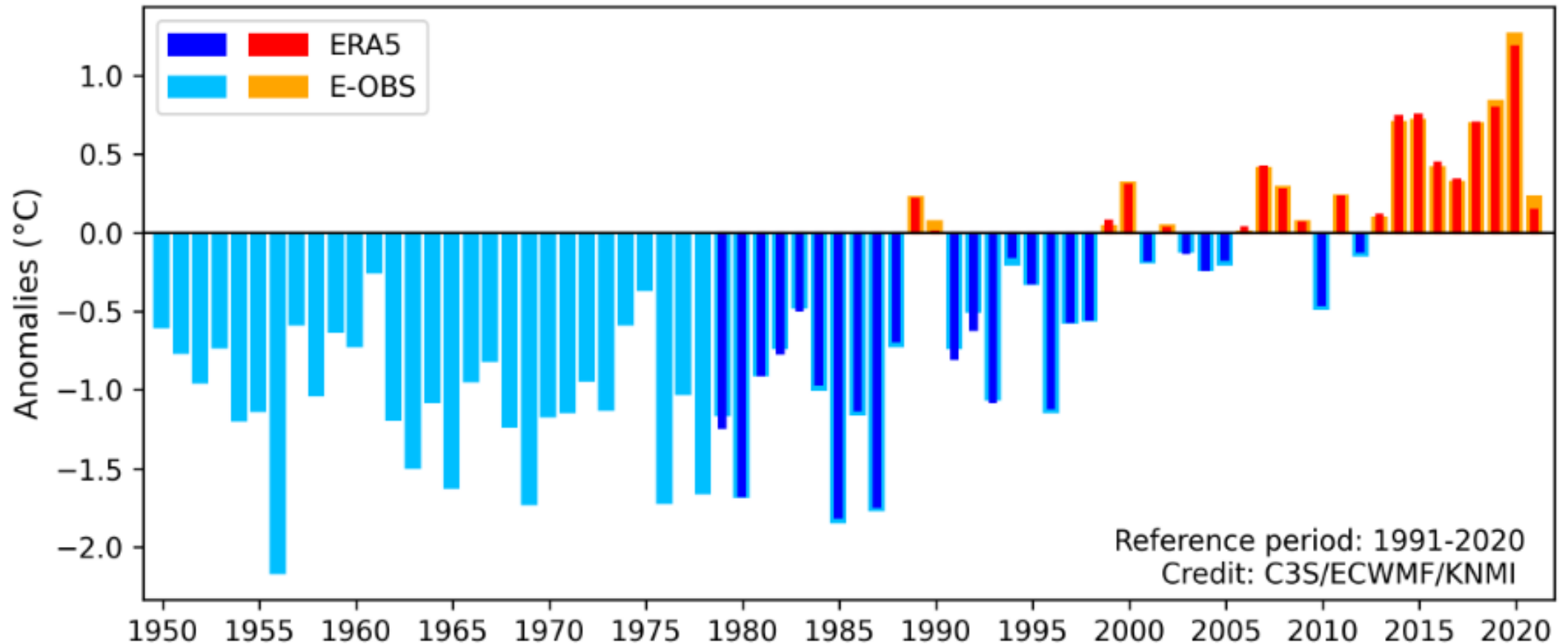
Potential elevated risks associated with El Niño-Southern Oscillation (ENSO)



Source: Chretien J, Anyamba A, Small J, Britch S, Sanchez, JL, Halbach AC, Tucker C, Linthicum KJ. 2015. Global Climate Anomalies and Potential Infectious Disease Risks: 2014-2015. PLOS Currents Outbreaks. 2015 Jan 26. Edition 1. doi: 10.1371/currents.outbreaks.95fbc4a8fb4695e049baabfc2fc8289f.

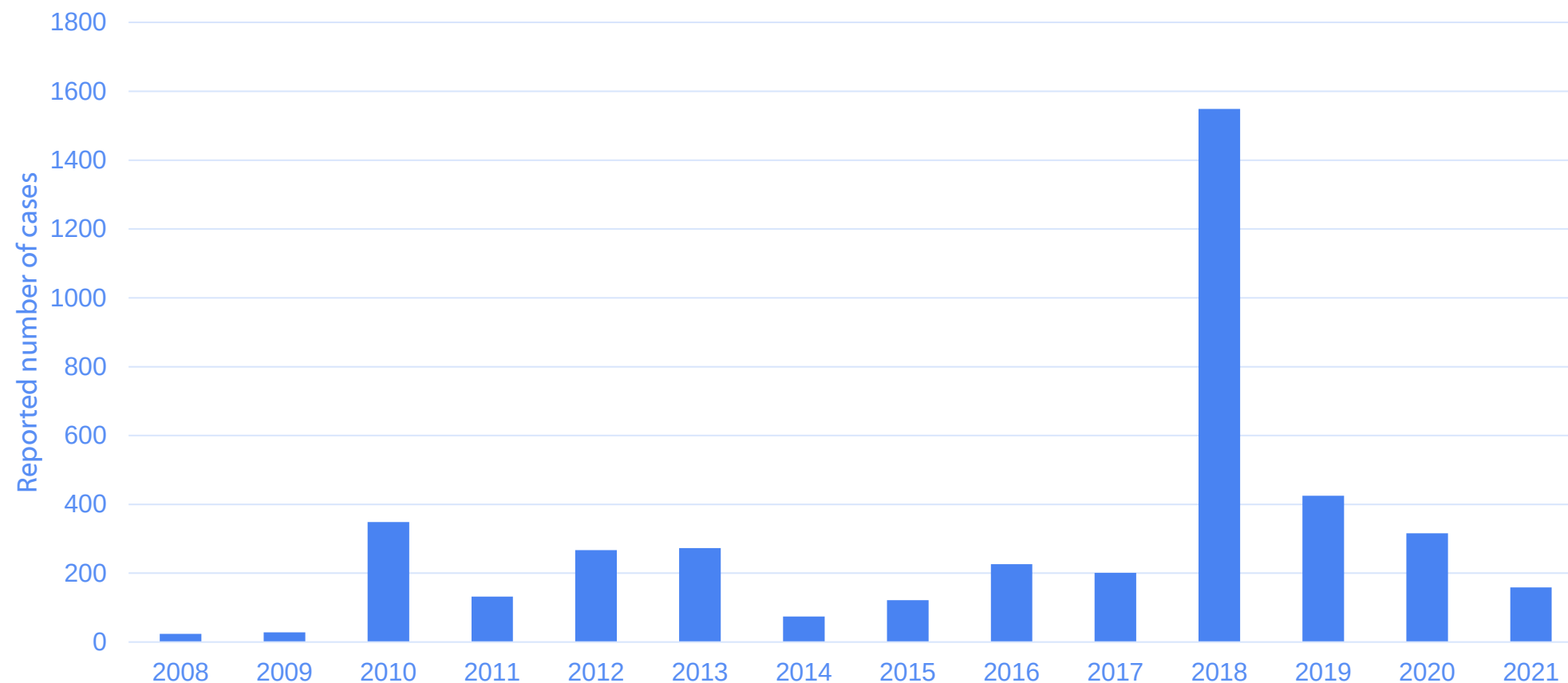
Case study: West Nile virus

European annual surface air temperature anomalies



Source: Copernicus Climate Change Service, European State of the Climate 2021

Reported West Nile virus cases, by year of report, European Union, 2008-2021



Source: ECDC

Human West Nile virus cases began to appear in northern Europe in 2019

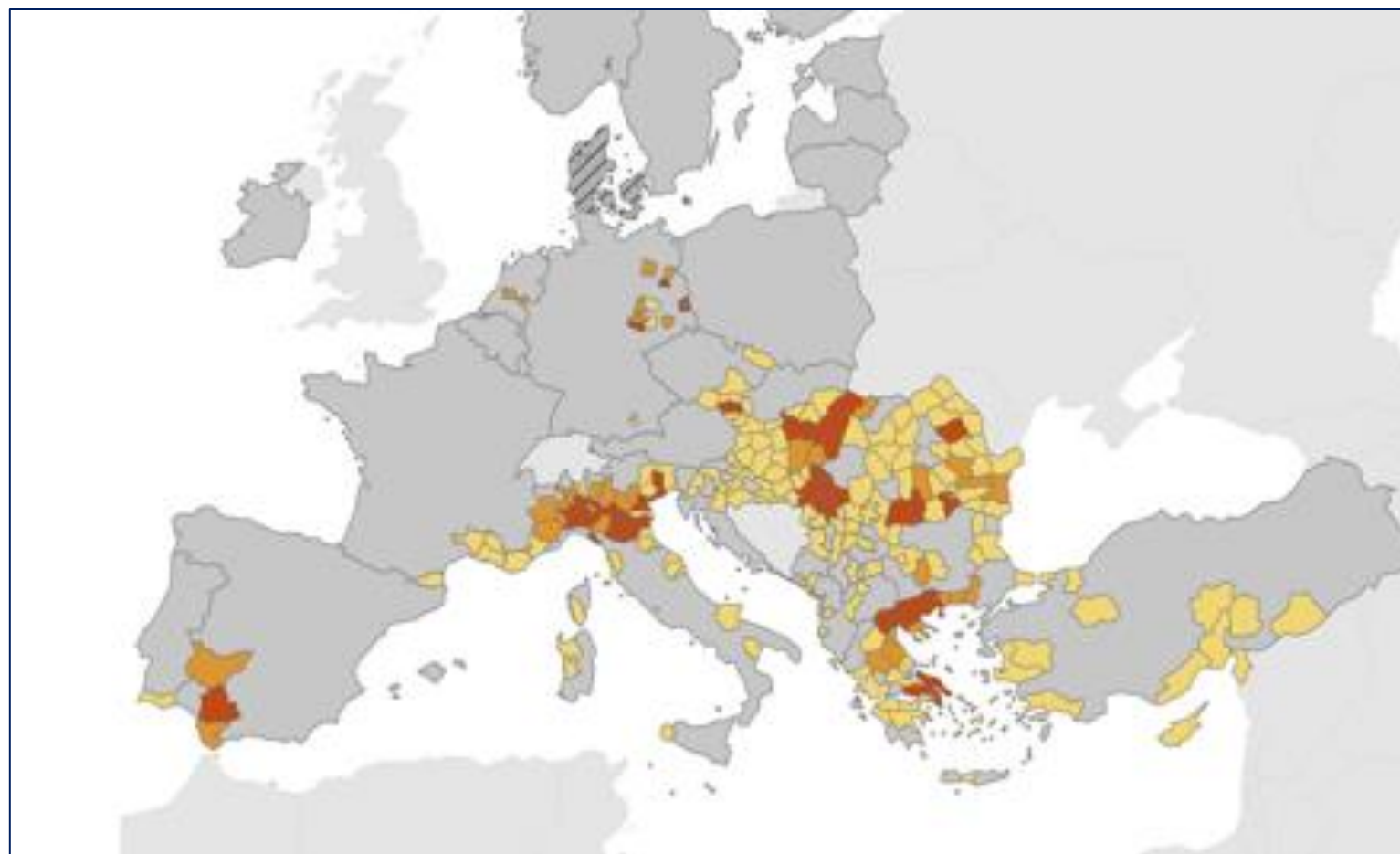


**Distribution of human West Nile virus infections
in NUTS 3 or GAUL 1 regions in the EU/EEA
and neighbouring countries
during 2011–2022, as of 10 February 2022**

-  Human infections reported, current season (2021)
-  Human infections reported, 2020
-  Human infections reported, 2011–2019
-  No data reported
-  No infections reported
-  Not included

Countries not visible
in the main map extent

-  Malta
-  Liechtenstein

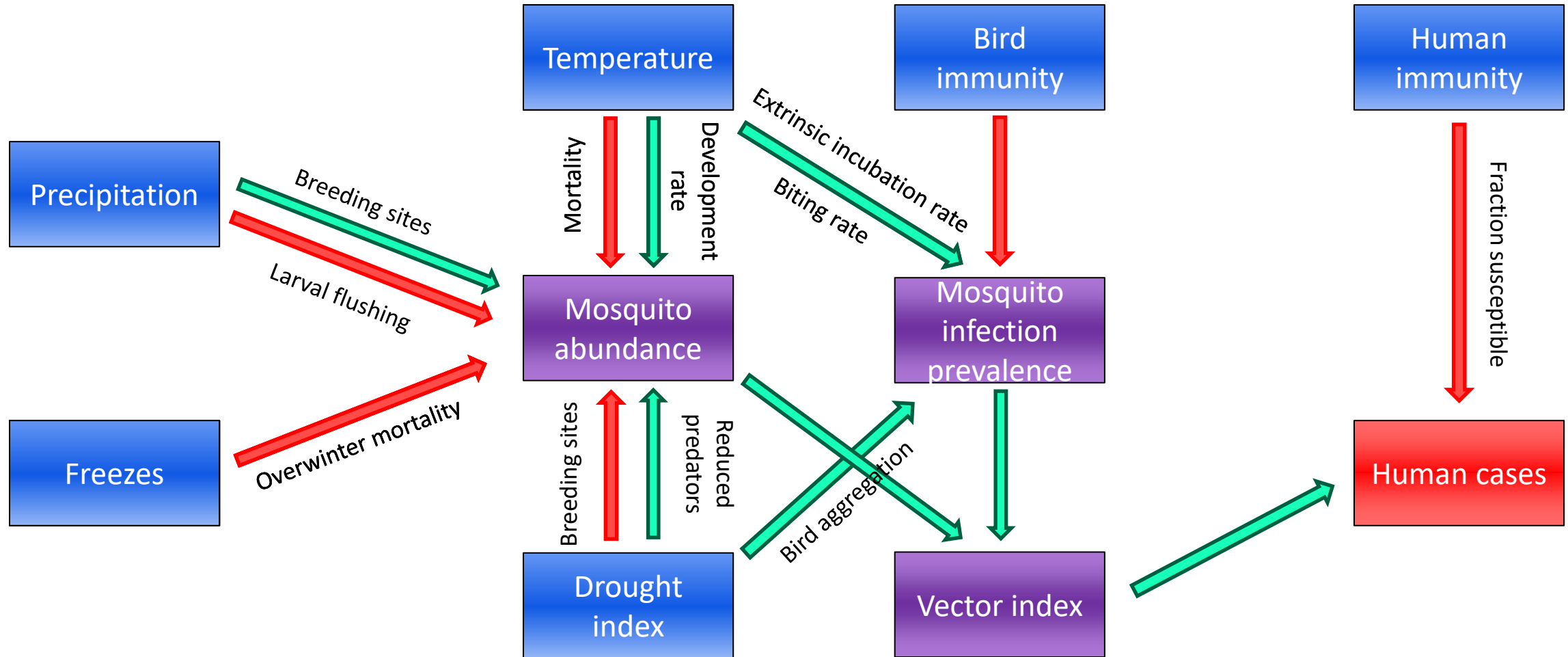


Studies have correlated increased temperature with increased interannual WNV incidence in endemic areas

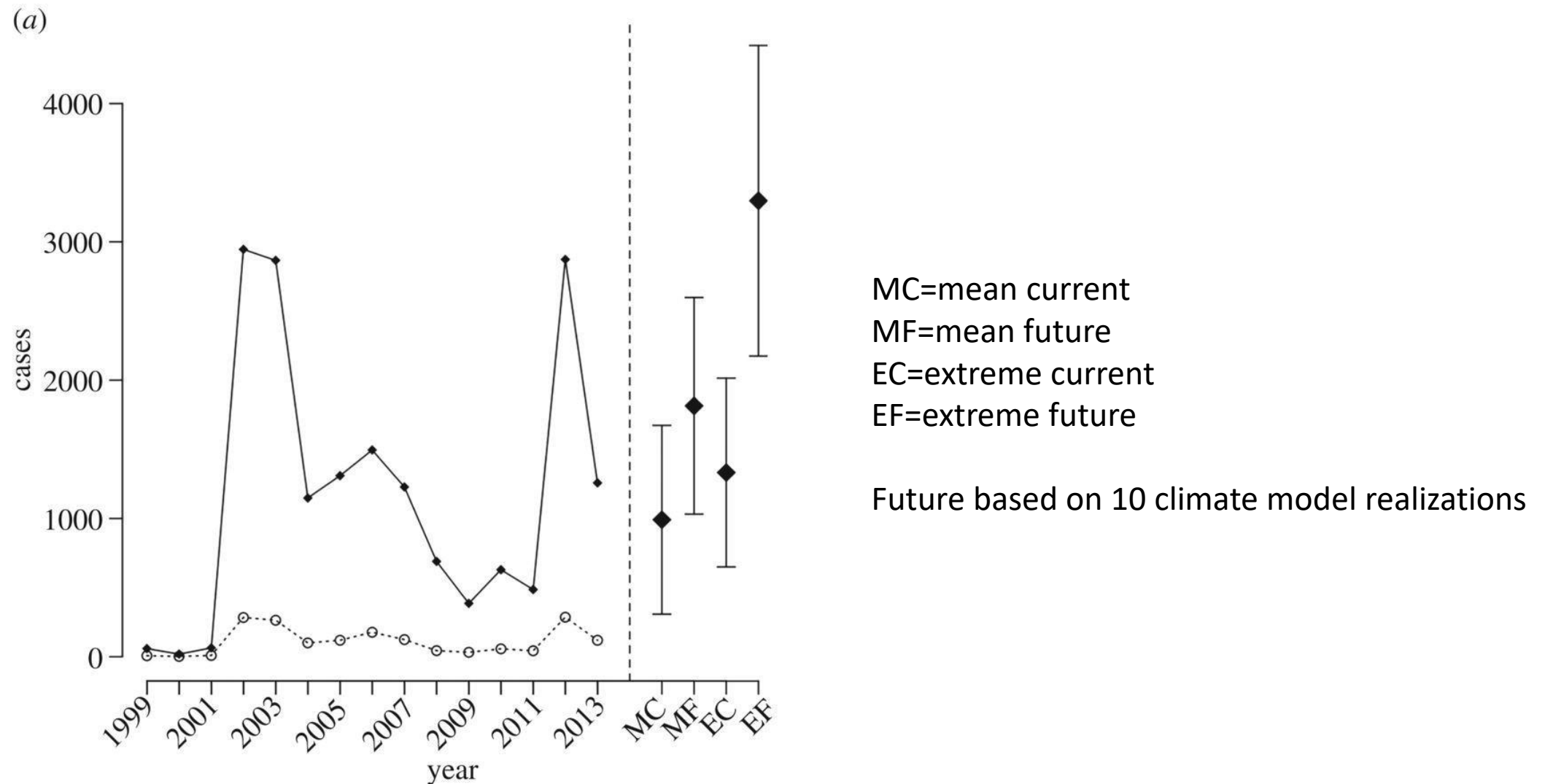
Study	Location	Year	Findings
Chuang	Upper plains states	2004-2010	Land surface temp. in spring and summer. Increased normalized vegetation index in spring. Increased evapotranspiration.
Davis	South Dakota	2004-2017	Increased summer temp. and vapor pressure deficit
Giodano	Ontario, Canada	2002-2013	Increased summer temp.; no relationship to rainfall
Karki	Chicago	2005-2016	Increased summer temp., warm winters

Source: PLoS One 2012;7(10): e46882; Acta Tropica 2018;185: 242-50; PLoS One 2017; 12(8): e0183568; PloS One 2020; 15: e0227160

Influence of temperature and rainfall on West Nile virus transmission



Current and projected (2036-2049) West Nile virus cases, USA



Conclusions

- Earth's temperature has increased 1.2 degrees C in last century
- 0.5-4.5 degree C further increase expected this century
- Most infectious diseases expected to be impacted – almost all increased incidence
- Impacts due to seasonal long-term changes in temperature and rainfall as well as increased extreme weather events
- Proving causality is difficult
- Evidence that climate change has already impacted distribution and incidence of West Nile virus
- Modeling of future impacts of climate change on infectious diseases has many difficulties
 - Environmental systems are complex and climate changes may have opposing impacts
 - Difficult to know all the important parameters to model and some may not be measurable
 - Climate models are uncertain
 - Anthropogenic factors difficult to model
- Bottom line: This is bad

Thank you and questions



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Director

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National Center for Emerging Zoonotic and Infectious Diseases
lxp2@cdc.gov

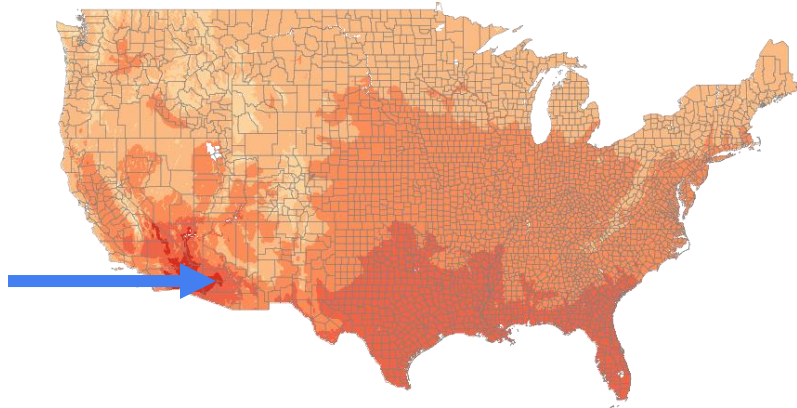
The findings and conclusions in this presentation are those of the author and do not necessarily represent the views of the Centers for Disease Control and Prevention.



In 2021, the largest recognized local WNV outbreak occurred in Arizona.

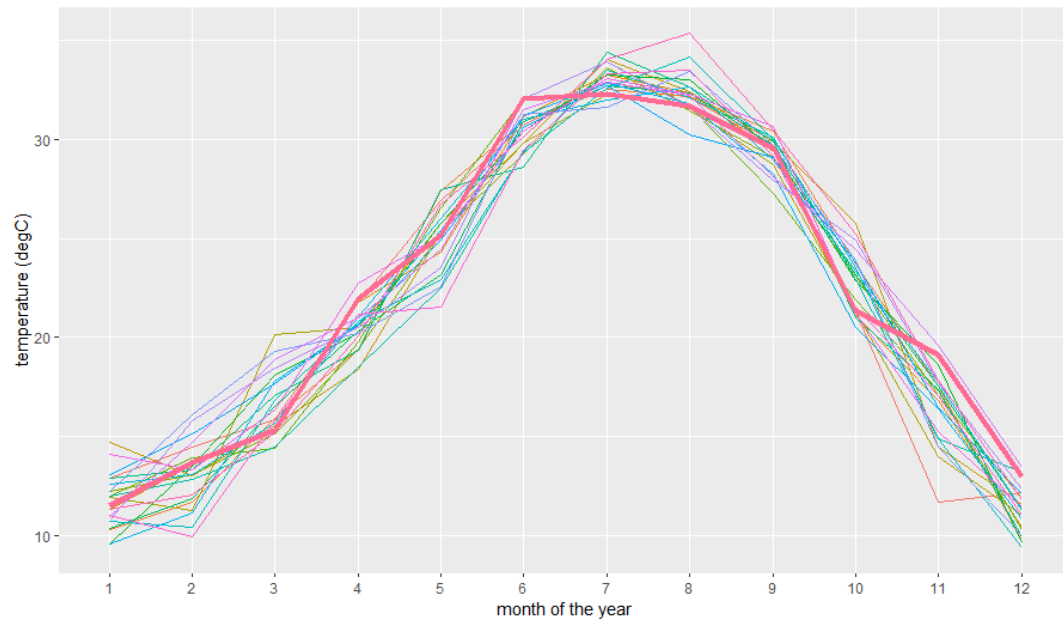
Provisional data (as of 11 Jan 2022)

- 1644 reported total cases
- 1090 neuroinvasive cases
- 113 deaths
- Outbreak occurred in Maricopa County (Phoenix) – 1417 cases
 - About 5% of population infected



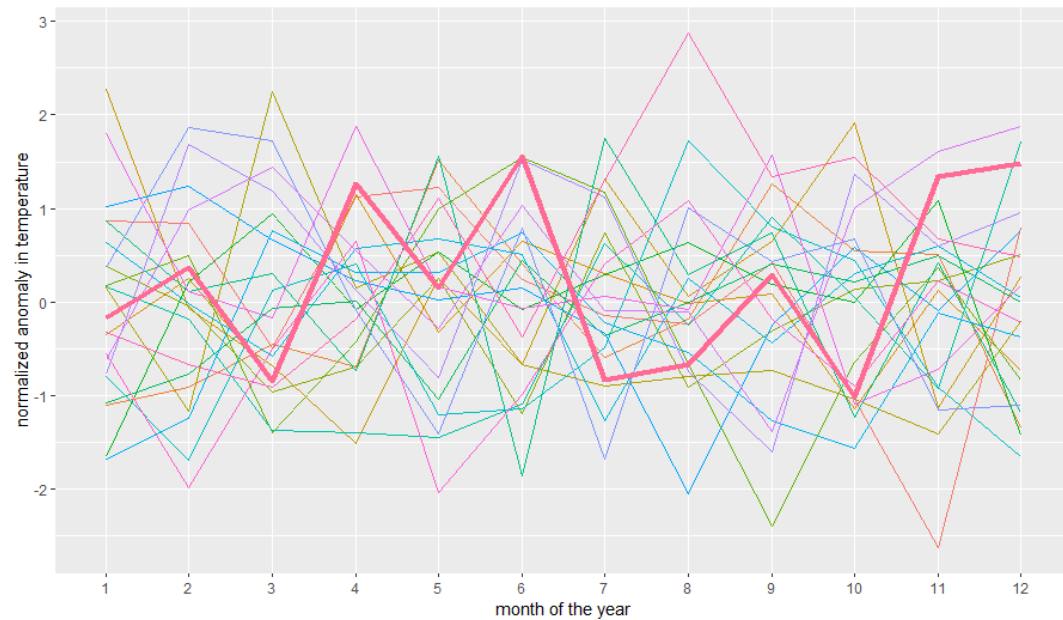
Source: <https://www.azdhs.gov/documents/preparedness/epidemiology-disease-control/mosquito-borne/west-nile/data/west-nile-virus-stats-2021.pdf?v=20220111>

Arizona-Maricopa County (Phoenix)



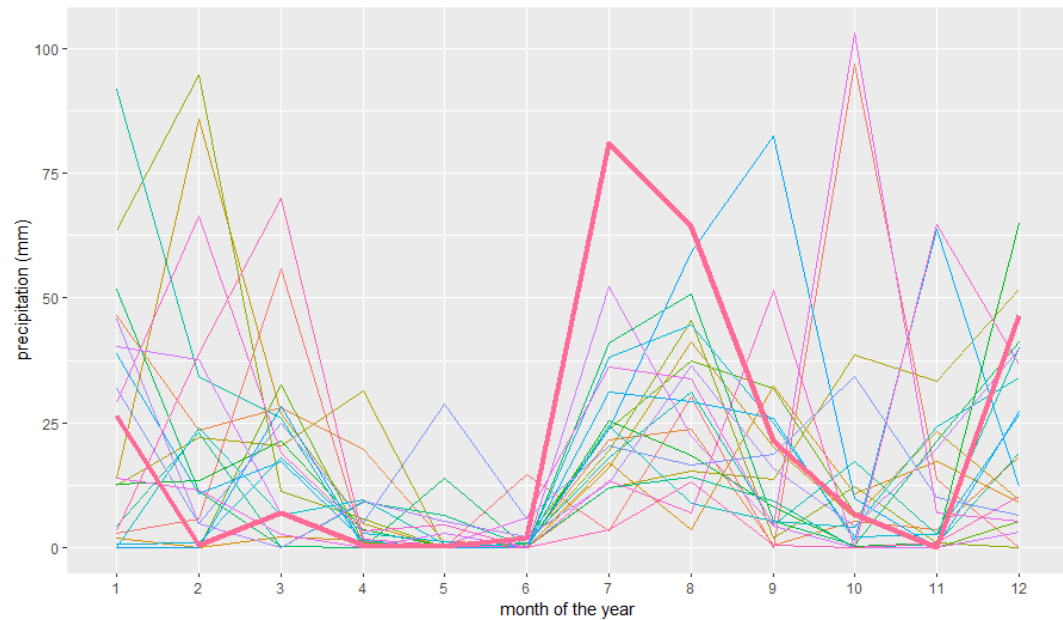
year

2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020
2001	2003	2005	2007	2009	2011	2013	2015	2017	2019	2021



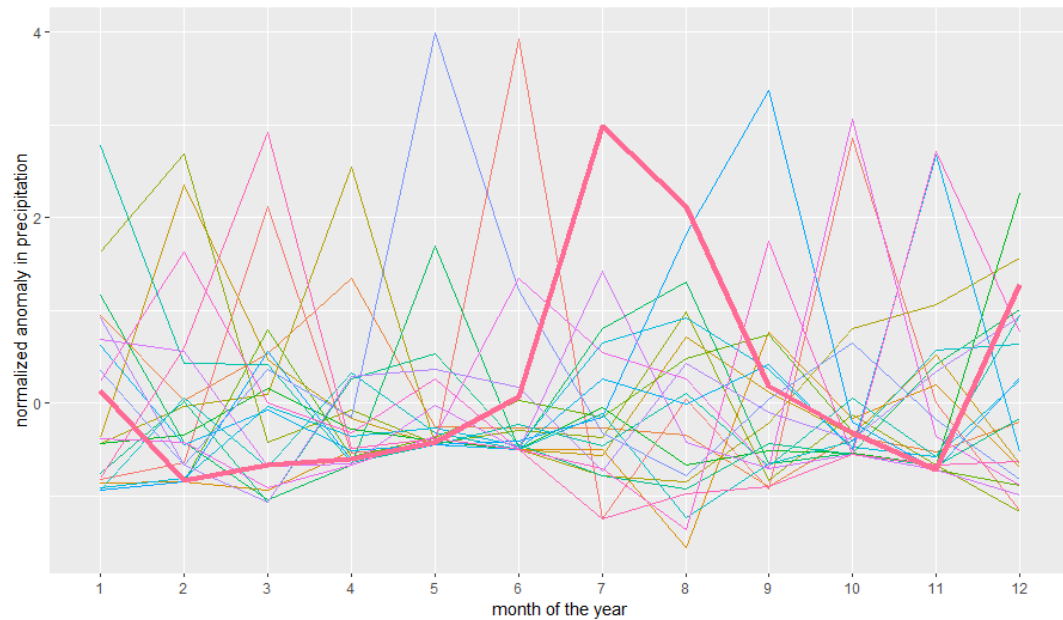
year

2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020
2001	2003	2005	2007	2009	2011	2013	2015	2017	2019	2021



year

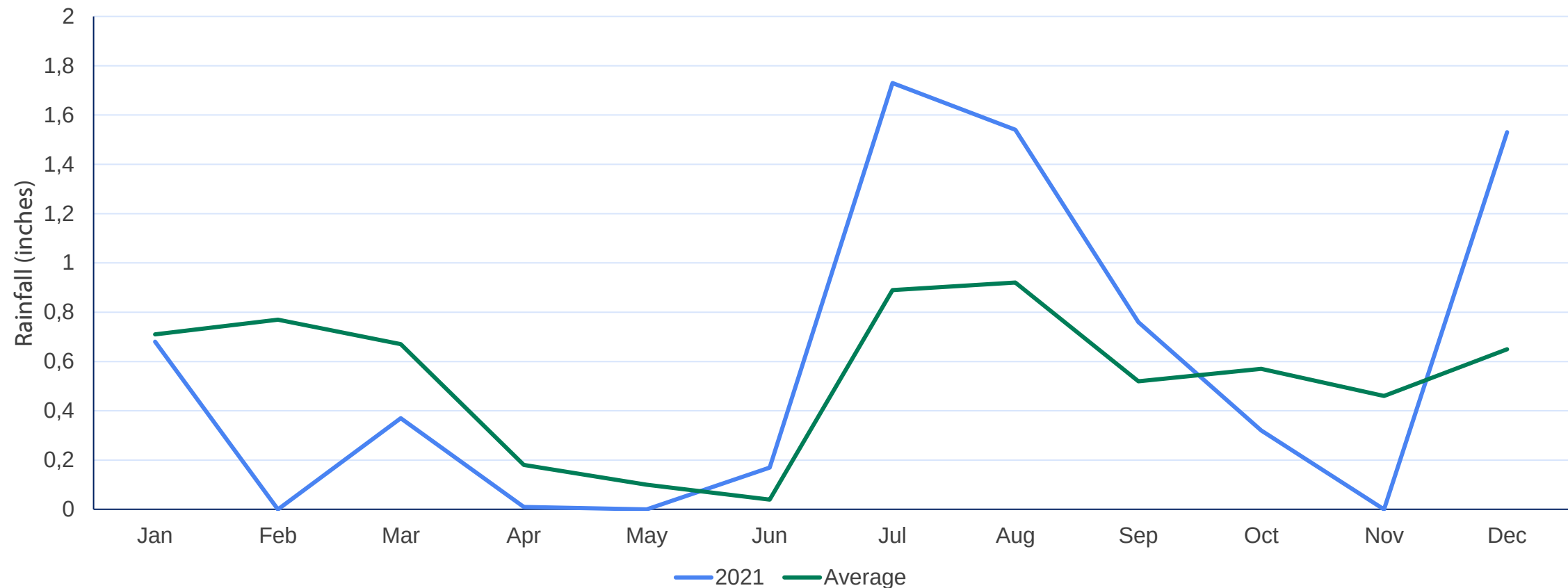
2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020
2001	2003	2005	2007	2009	2011	2013	2015	2017	2019	2021



year

2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020
2001	2003	2005	2007	2009	2011	2013	2015	2017	2019	2021

Monthly Rainfall in Phoenix, 2021 Compared to Average from 2000-2021



Climate, weather, and Lyme disease

- Minimum temperature primarily defines northern distribution of vectors
- Warmer temperatures may increase reproductive capacity of ticks, leading to larger populations and greater risk for disease transmission
- Higher moisture levels allow tick survival in warmer environments
- Temperature and moisture affect tick behavior
- Temperature (cumulative growing degree days) affects disease seasonality



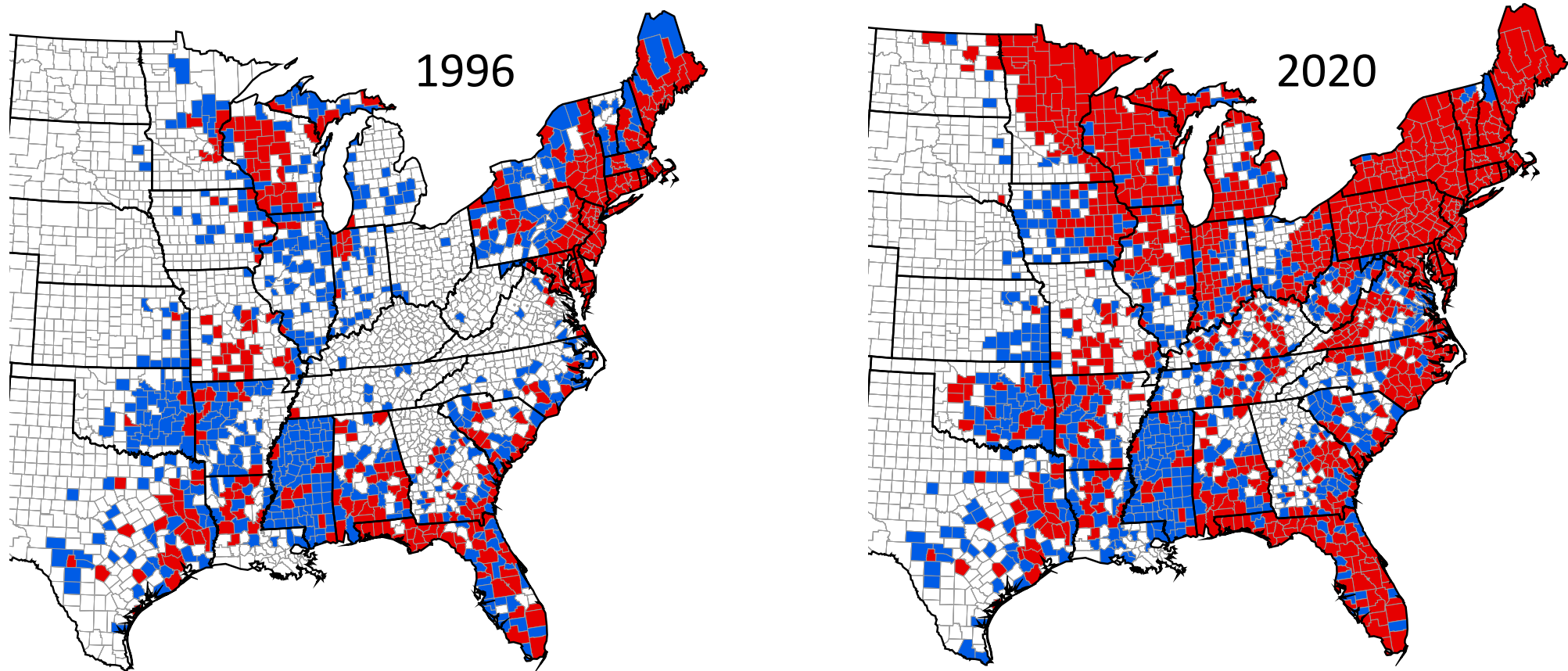
Brownstein, J. S., T. R. Holford, and D. Fish. 2003. Environ Health Persp 111: 1152-1157

Eisen, L., R. J. Eisen, and R. S. Lane. 2002. Med Vet Entomol 16: 235-244

Yuval, B., and A. Spielman. 1990. J Med Entomol 27: 196-201

Moore, S. M., R. J. Eisen, A. Monaghan, and P. Mead. 2014. Am J Trop Med Hyg 90: 486-496

Geographic distribution of *Ixodes scapularis* from 1996 to 2020



- **Established:** ≥ 6 or more ticks or > 1 life stage recorded in a single year
- **Reported:** < 6 individuals of a single life stage recorded in a single year

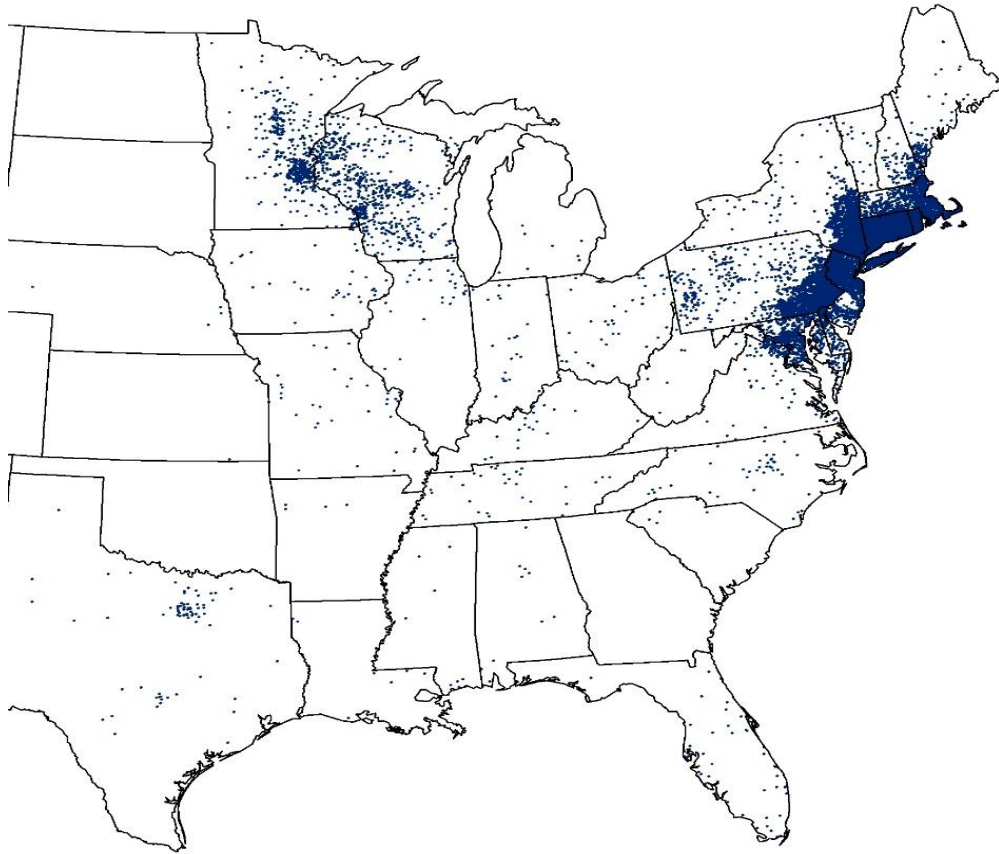
Source:

Dennis DT, Nekomoto TS, Victor JC, et al. J Med Entomol. 1998 Sep;35(5):629-38.

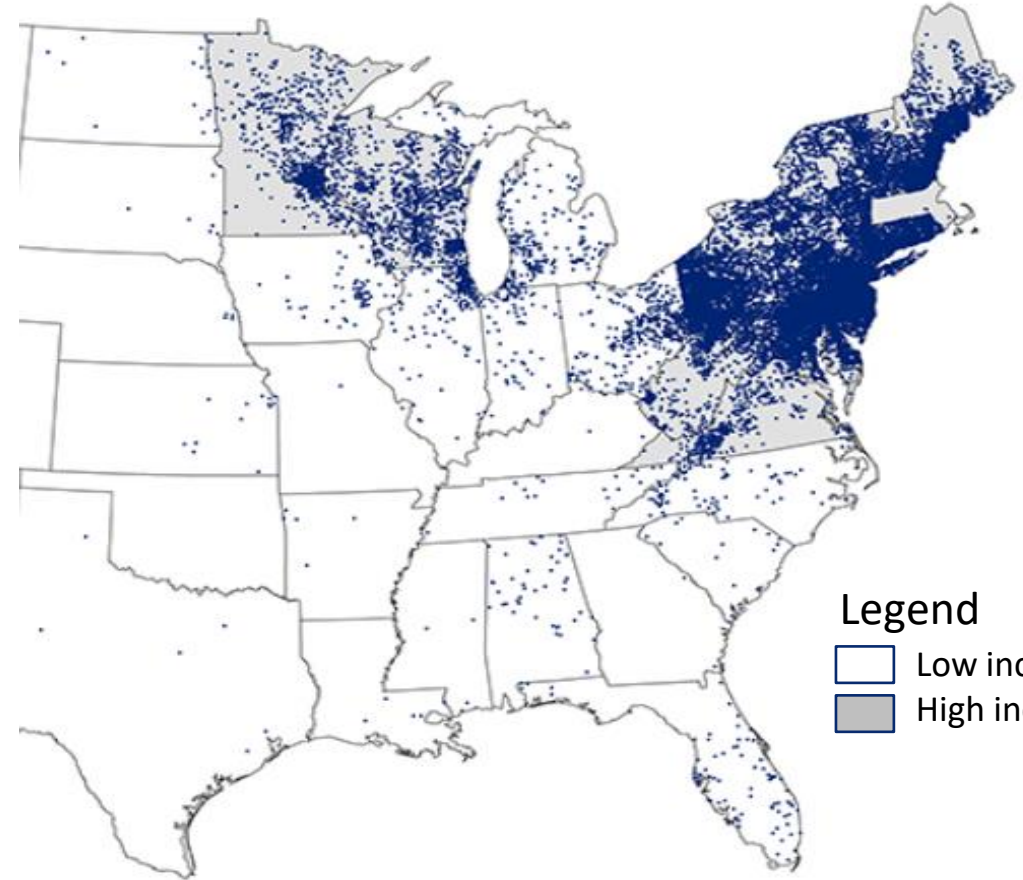
Eisen RJ, Eisen L, Beard CB. J Med Entomol. 2016 Mar;53(2):349-86.

CDC National Tick Surveillance Program, ArboNET, February 2020. URL: <https://www.cdc.gov/ticks/surveillance/index.html>

Expanding geographic range of Lyme disease cases



2001



Legend

- Low incidence state
- High incidence state

2019

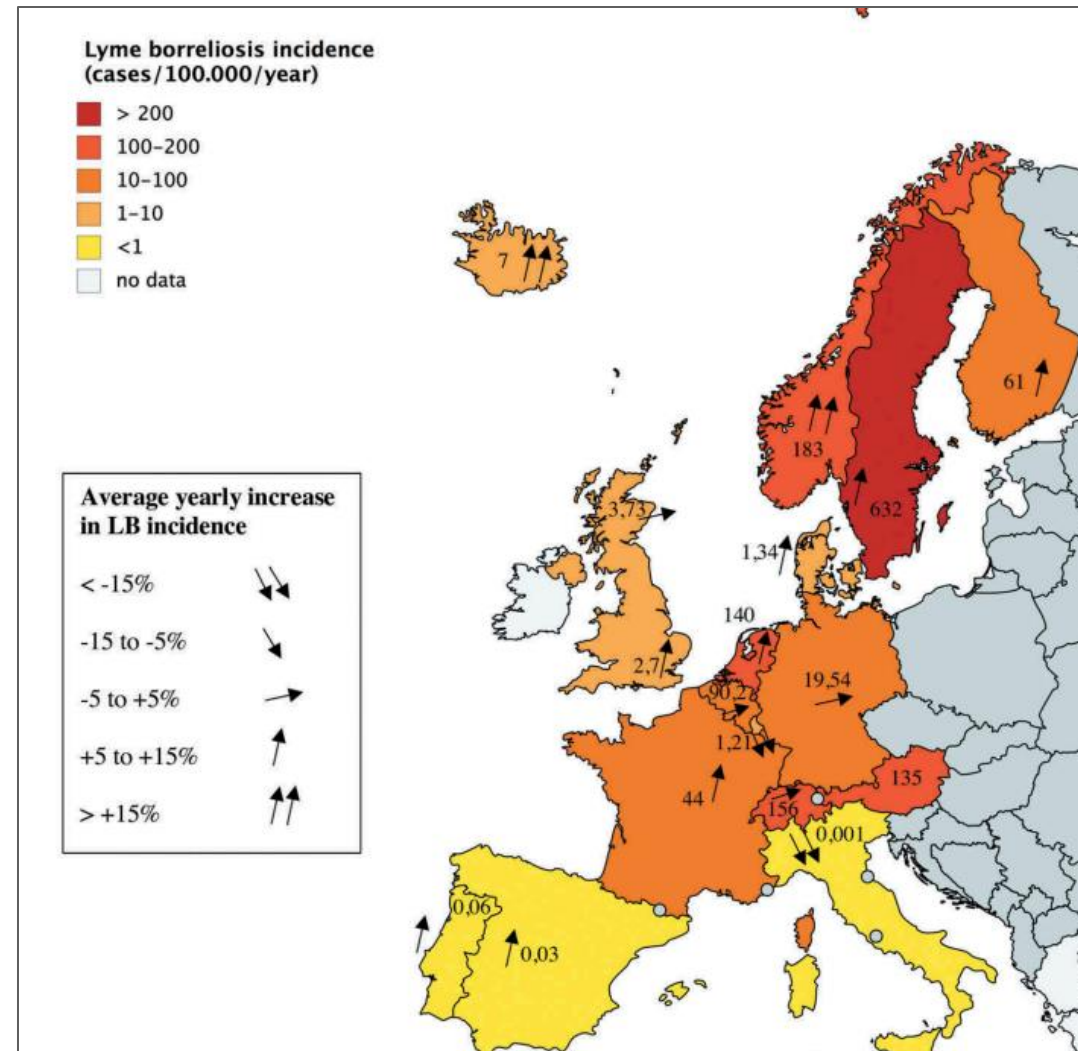
Source: cdc.gov/lyme/stats/index.html

Estimated ranges of *I. ricinus* in Sweden, early 1990s and 2008

- Determined from survey of residents

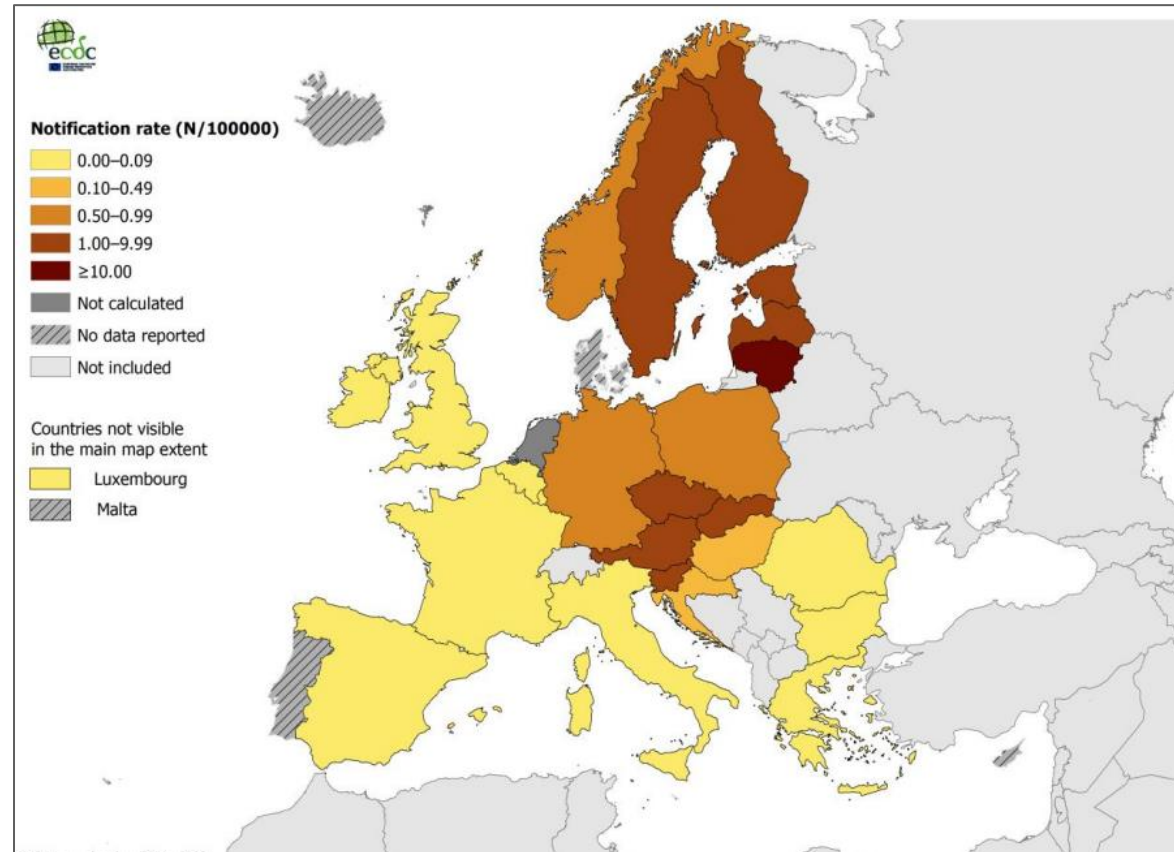


Lyme disease incidence and trends: summary of the literature and surveillance reports



Source: Acta Clinica Belgica 2021;76: 244-252

Tickborne encephalitis, by country, 2019



Source: ECDC