Climate change and impacts on disease vectors

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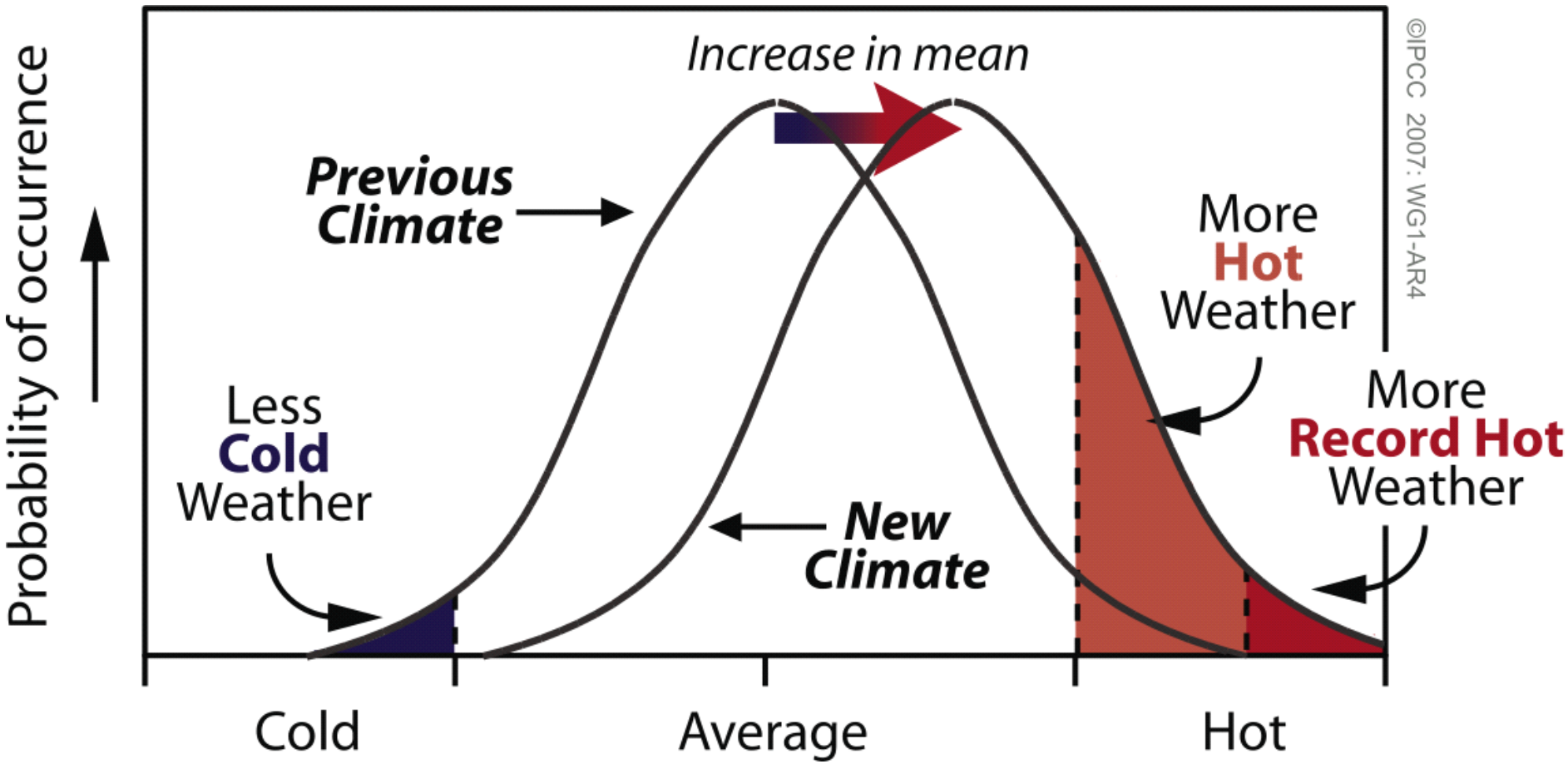
Motivation

- Recent vector borne disease epidemic outbreaks (e.g., DENV, CHIKV, ZIKV) suggest that Climate Change may influence the occurrence rate of such episodes
- Disease vectors such as invasive mosquitoes (*Ae. albopictus*, *Ae. aegypti*), ticks and other vector-insects (sandfly/*Phlebotomus papatasi*) are affected by climate variability
- Interested in spatial-epidemiology of vectors of disease and vector borne disease and how these respond to climate changes
- Employ state-of-the art Climate Models to project/simulate the meteorological conditions in present and future periods
- Utilize the simulated climatic data to drive biological/vector distribution models and population dynamics models to map the habitat suitability of vectors and associated diseases

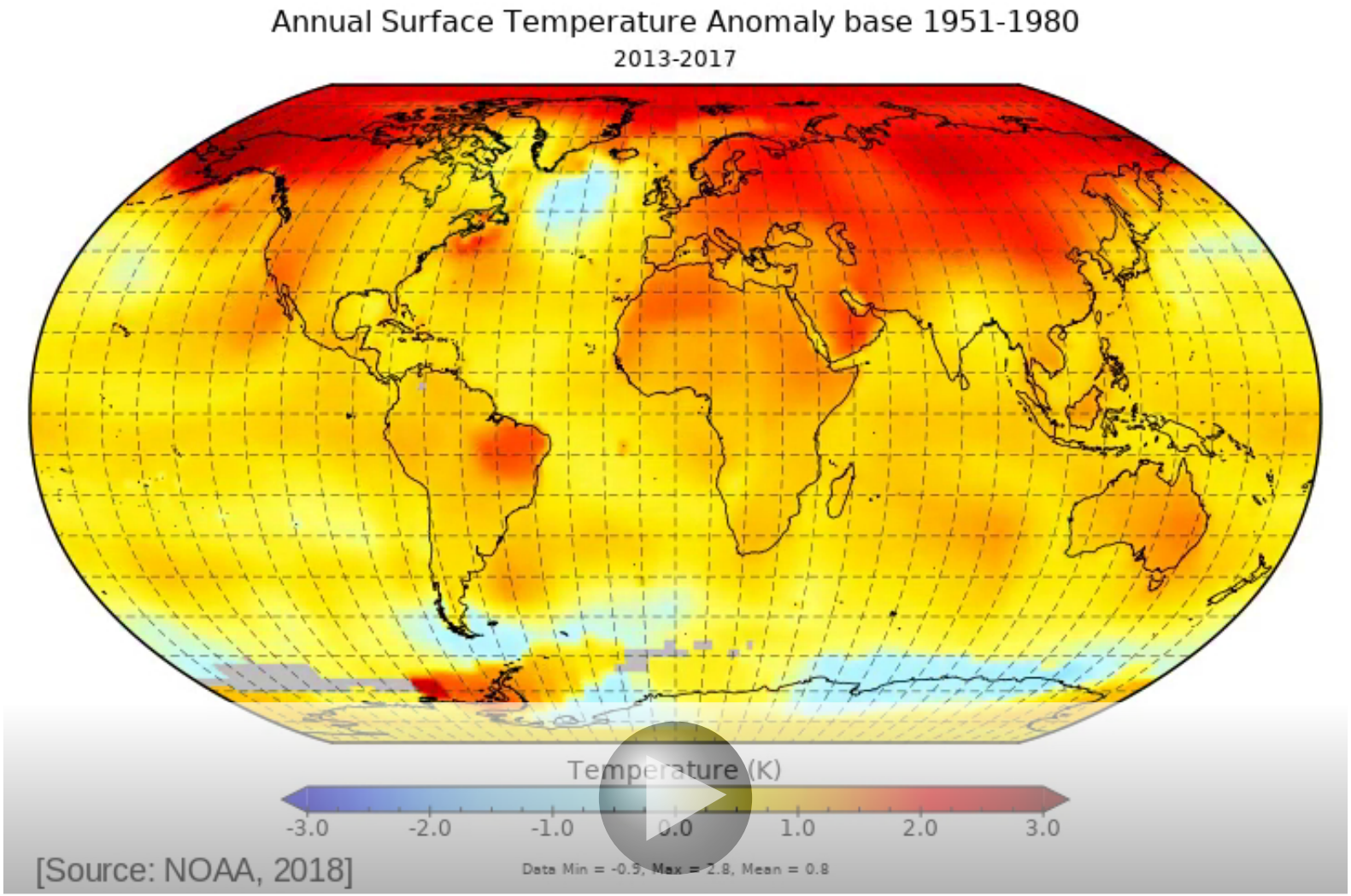
Global climate change

- Observations and Climate research indicate a tendency for a warmer future



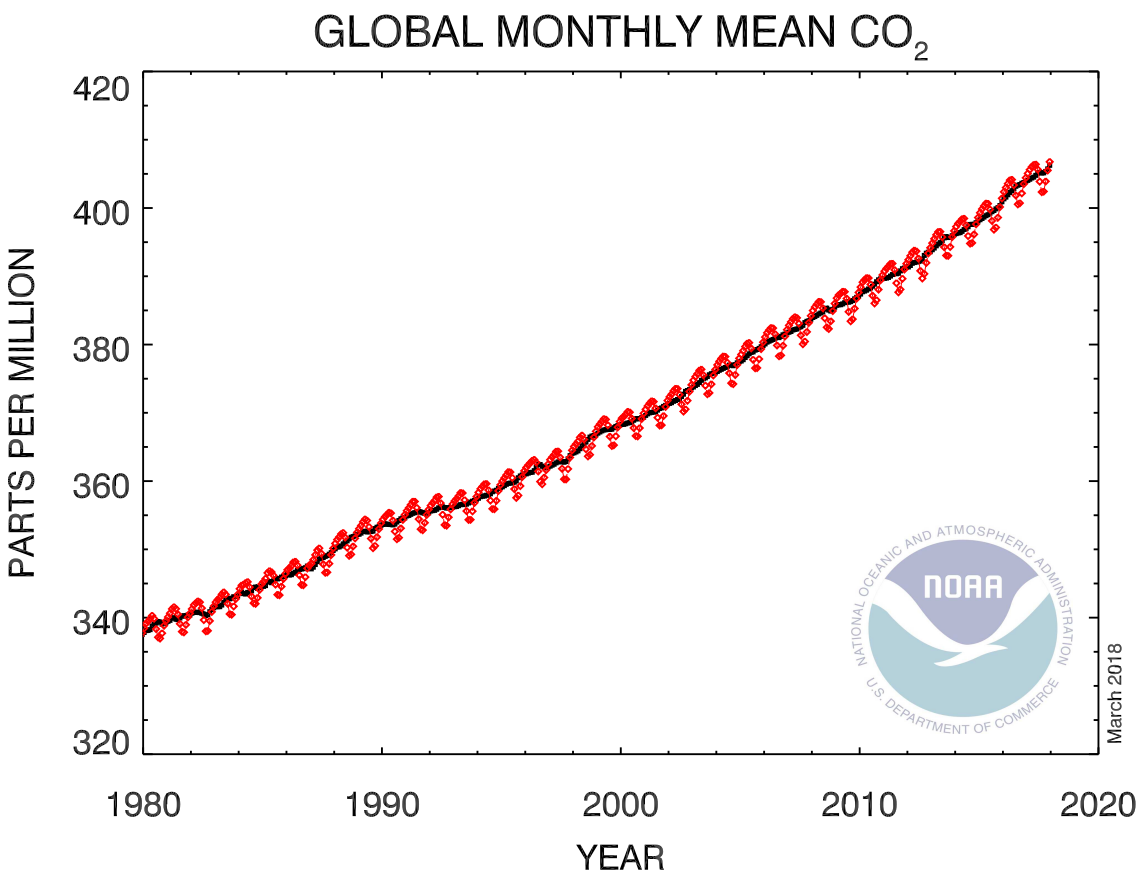
Global climate change: Temperatures show an increasing trend

- Climate may be affected by natural variability (e.g., Solar radiation, El Niño Southern Oscillation) and man-made causes



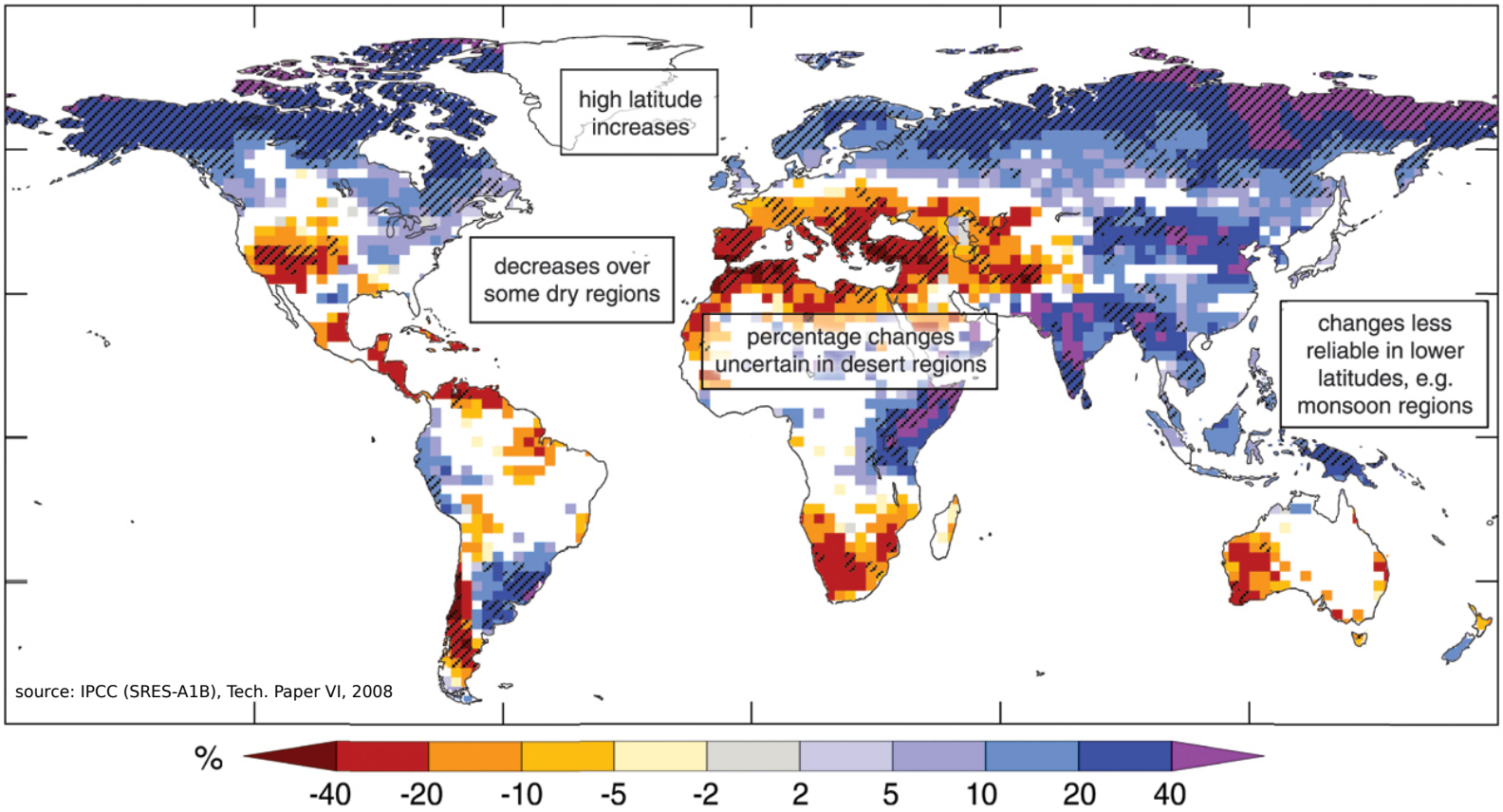
Global climate change: Green house gas emissions on the rise

- The Keeling curve (Charles D. Keeling, 1958) of CO_2 measured at Mauna Loa, Hawai
- The red dots are natural seasonal variations in CO_2 related to plant growth cycle
- Unfortunately, the black trend line is linked to anthropogenic activities... fossil fuel burning is most likely the reason behind this steep trend!



Global climate change

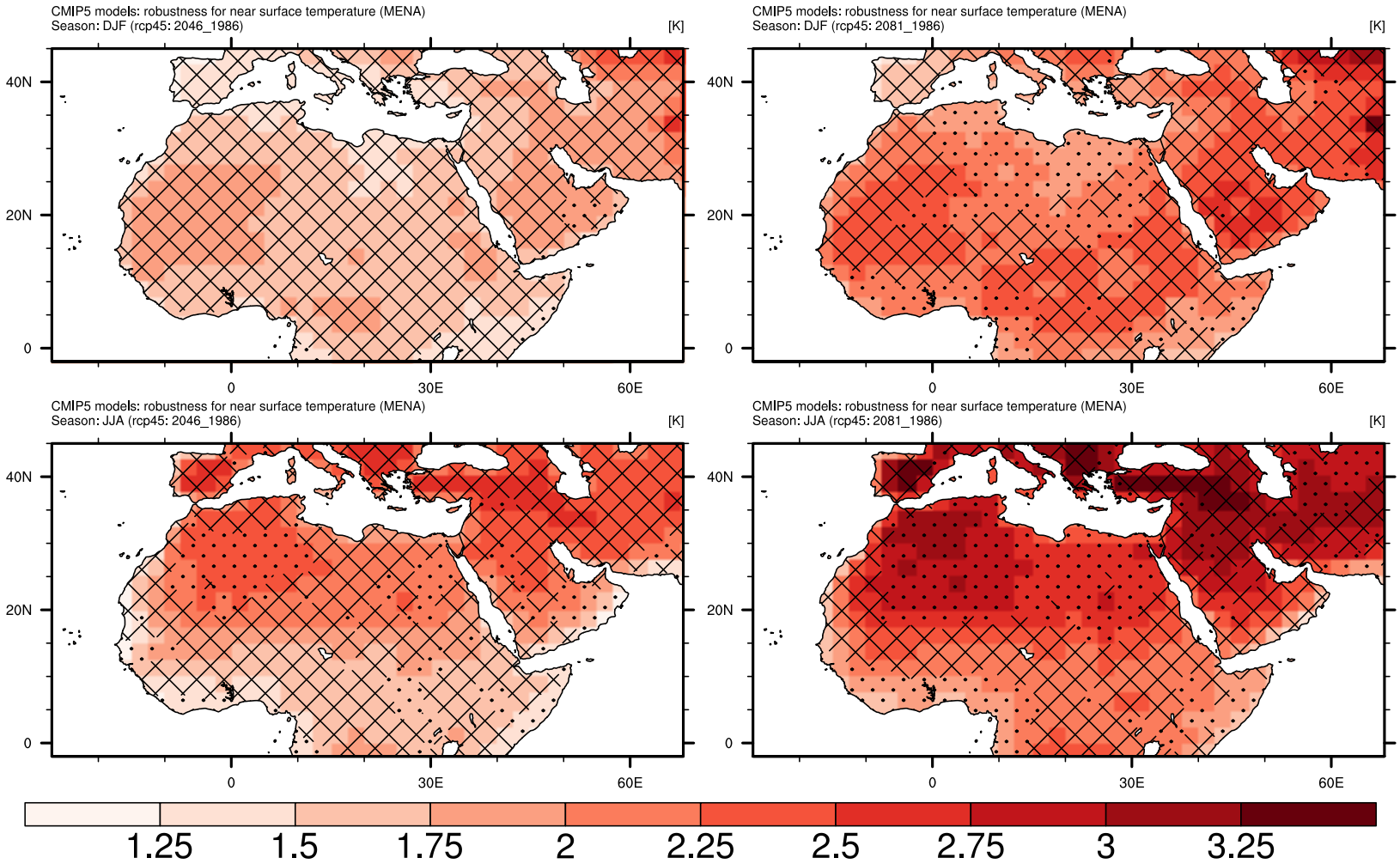
- Will alter the precipitation patterns. Some places may become drier and other wetter



- Climate change (e.g., rainfall, temperature and humidity variations) affects ectothermal species such as disease mosquitoes. As a consequence this may increase the threat of more frequent epidemics of the associated vector borne diseases!

Climate change in the MENA region

- IPCC/CMIP5/*Stabilizing scenario* (RCP4.5 W/m^2)

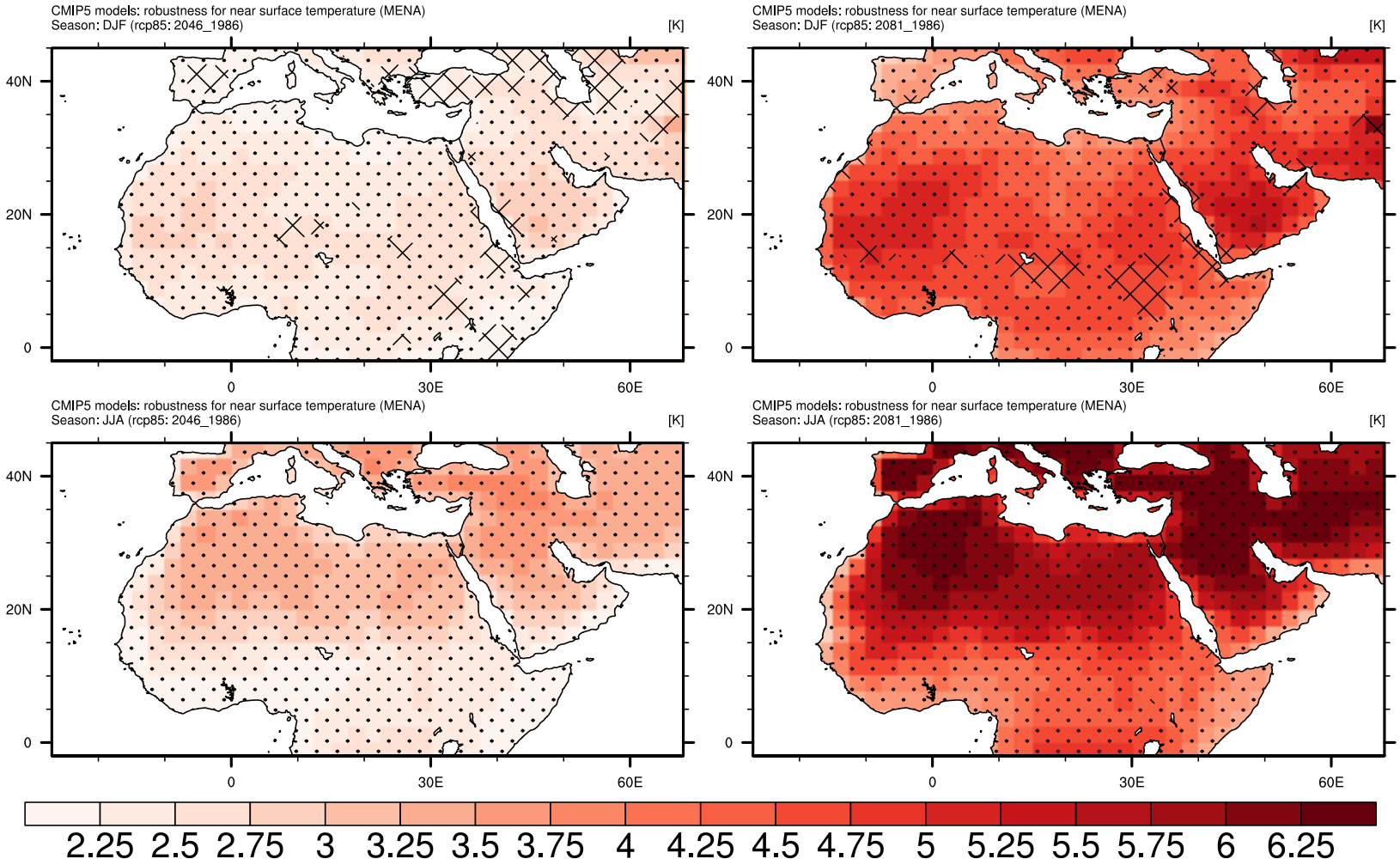


Lelieveld et al., *Clim. Change*, 2016

[***Note***: IPCC = The United Nations **I**ntergovernmental **P**anel on **C**limate **C**hange, CMIP5 = The **C**limate **M**odel **I**ntercomparison **P**roject-5, RCP = **R**adiative **C**oncentration **P**athway]

Climate change in the MENA region

- IPCC/CMIP5/*Business-as-usual scenario* (RCP8.5 W/m^2)



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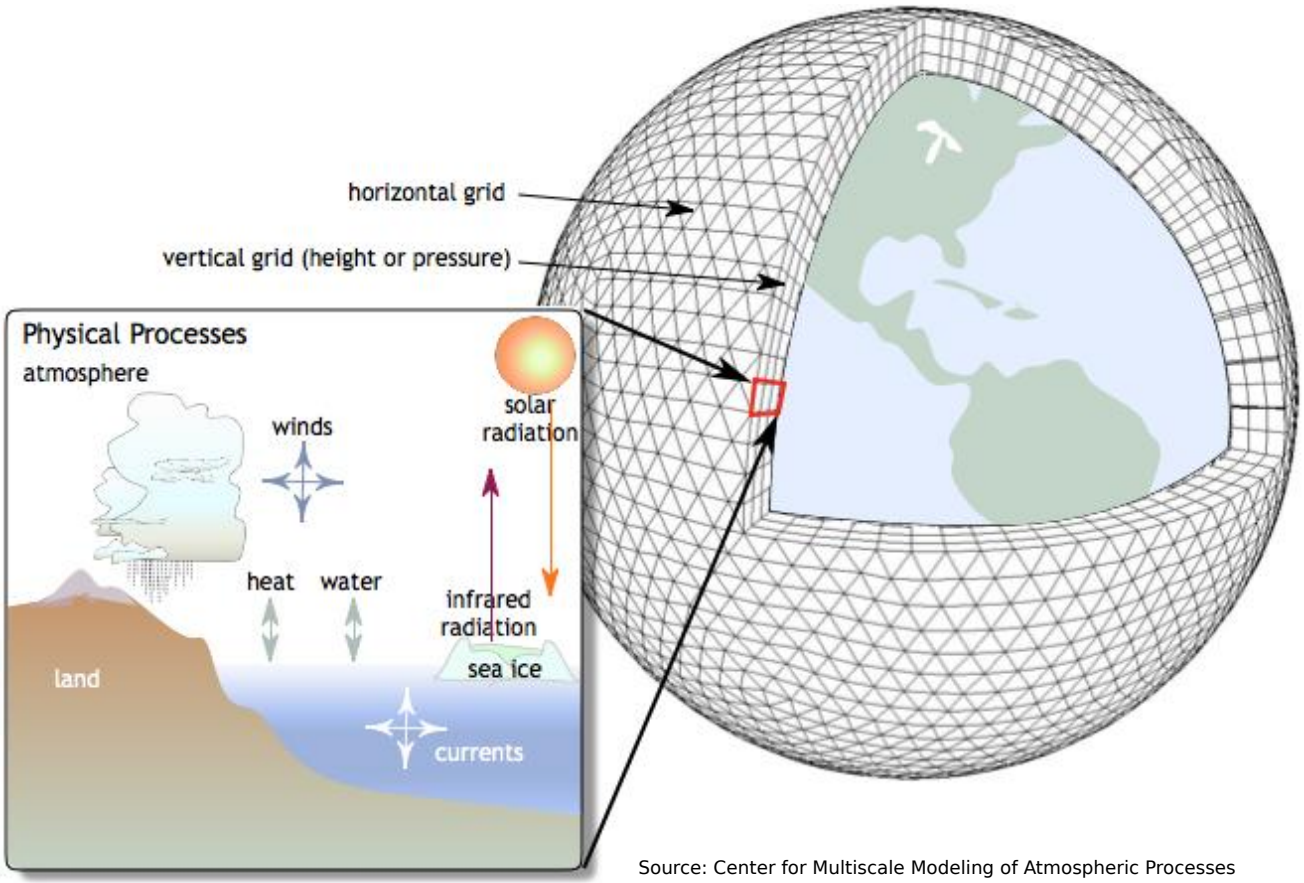
Numerical Climate prediction: General Circulation Models (GCM)

- GCMs are used in climate studies, climate future projections and weather forecasting at global scales. GCMs are specially designed to simulate complex physical atmospheric processes and interactions, with oceans, land and human influences, using state-of-the art numerical methods and algorithms
- Modern day GCMs, equipped with atmospheric chemistry components are used in air-quality studies (e.g., for assessing the impacts of fine particulate matter, $PM_{2.5}$, to premature mortality), in modelling of aerosols (e.g., dust particles), and as radioactive nuclide tracer transport tools (e.g., to study fallouts from nuclear power plant accidents), etc.
- GCM experiments (e.g., future climate projections) often require vast amounts of computational resources. Our Atmosphere and Climate Modelling group at the Cyprus Institute, employs and contributes to the development of the *EMAC-Atmospheric Chemistry general circulation model* in collaboration with the Max Planck Institute for Chemistry (Mainz) and conducts simulation experiments using the CyTERA High Performance Computing Facility at Cyl

Numerical Climate prediction: General Circulation Models (GCM)



Source: Center for Multiscale Modeling of Atmospheric Processes

- We conduct climate model simulations based on emissions scenarios to predict future climatic conditions. The relevant environmental variables (e.g., temperature, humidity, rainfall, etc.) are then used to model the habitat suitability of disease vectors and drive vector borne disease models
- Global models are limited in terms of spatial (horizontal) resolution. We push EMAC to its limits by performing global simulations at 50km resolution

Aedes albopictus (Skuse, 1895) and Climate change

- *Ae. albopictus* (a.k.a. asian tiger mosquito) is a well studied and an epidemiologically important vector of several viral pathogens (DENV, CHICKV, ZIKV, etc.). It's a highly invasive species with robust ecological plasticity-quickly adapts to temperate climates
- It's a container breeder (e.g., used tyres, lucky bamboo). Human activities, due to transportation of goods (ports) contribute to its geographic expansion
- It's eggs show resistance to desiccation of diapause (over-wintering)
- It prefers feeding on humans, animals and birds

- It is a threat to humans/animals due to its proven efficiency of transmitting infectious agents in field and experimental conditions and may pose a risk for the biodiversity when established in a new region

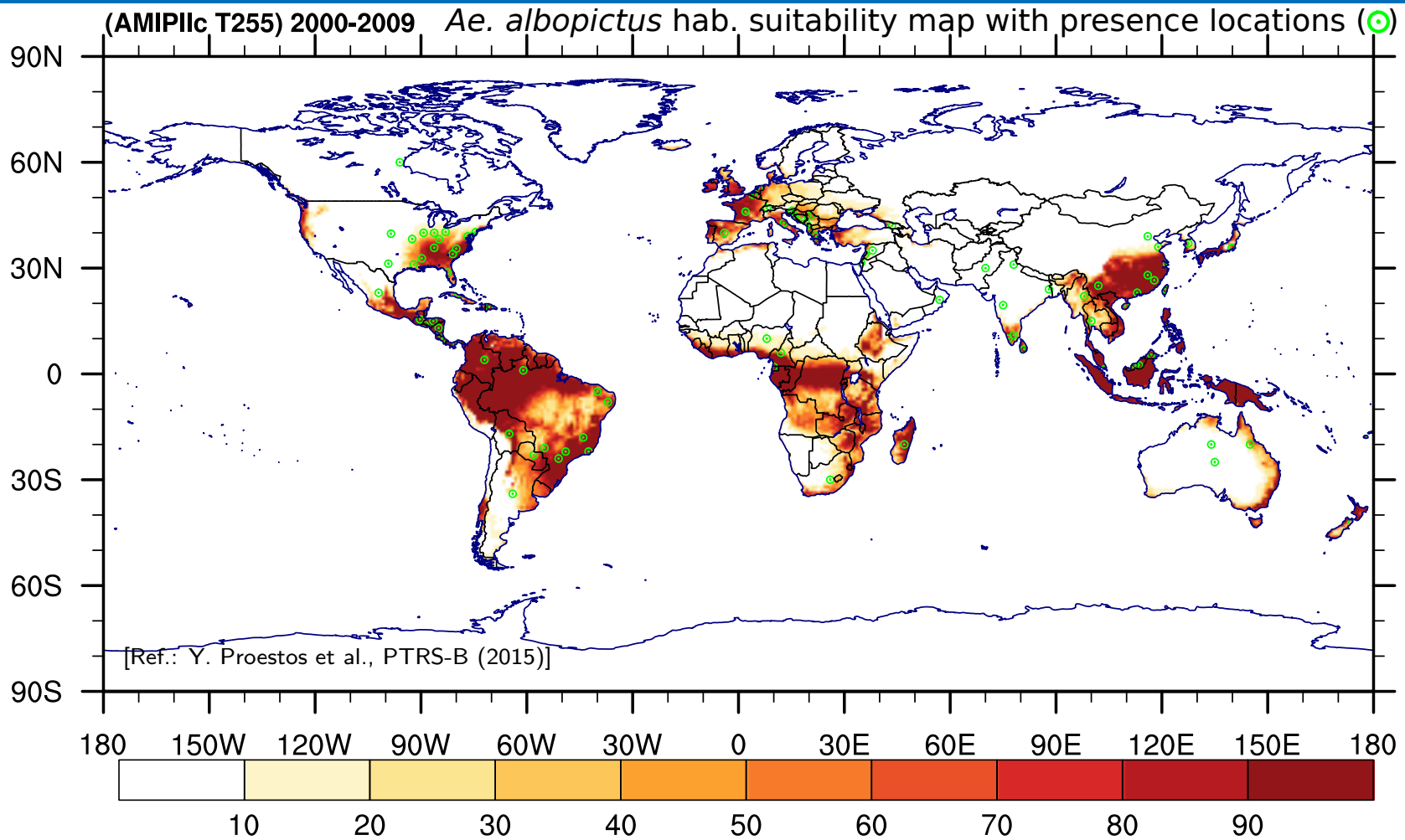
Modelling the habitat suitability index (hsi) of *Ae. albopictus*

- We map hsi using a vector decision support model (VDSM)
- Based on literature review and expert opinion/knowledge, the VDSM is driven by the following set of criteria (with *soft thresholds*) imposed on meteorological variables:

  1. Annual average precipitation $\gtrsim 200 \frac{mm}{yr}$
  2. Annual average temperature $\gtrsim 8.0\ ^{\circ}C$
  3. January average minimum temperature $\gtrsim -4.0\ ^{\circ}C$
  4. Summer average maximum temperature $\lesssim 40\ ^{\circ}C$
  5. Measurable rainfall $(> 1mm) \gtrsim 60 \frac{days}{yr}$
  6. Summer relative humidity $\gtrsim 30\%$
  7. Winter relative humidity $\gtrsim 50\%$

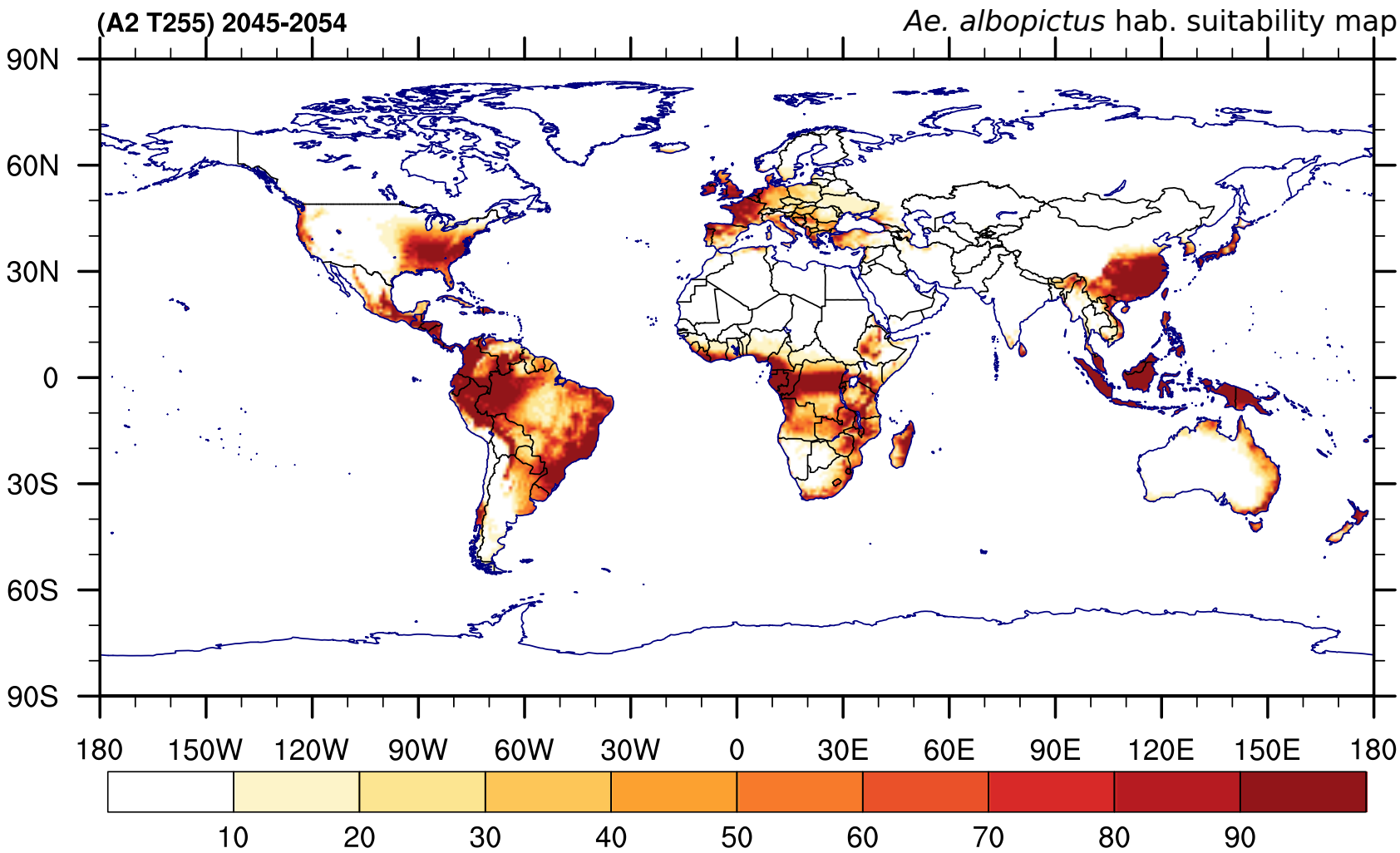
- We have utilized meteorological data from our global climate model simulations for the recent past and future projections

Habitat suitability index - recent past (2000-2009)



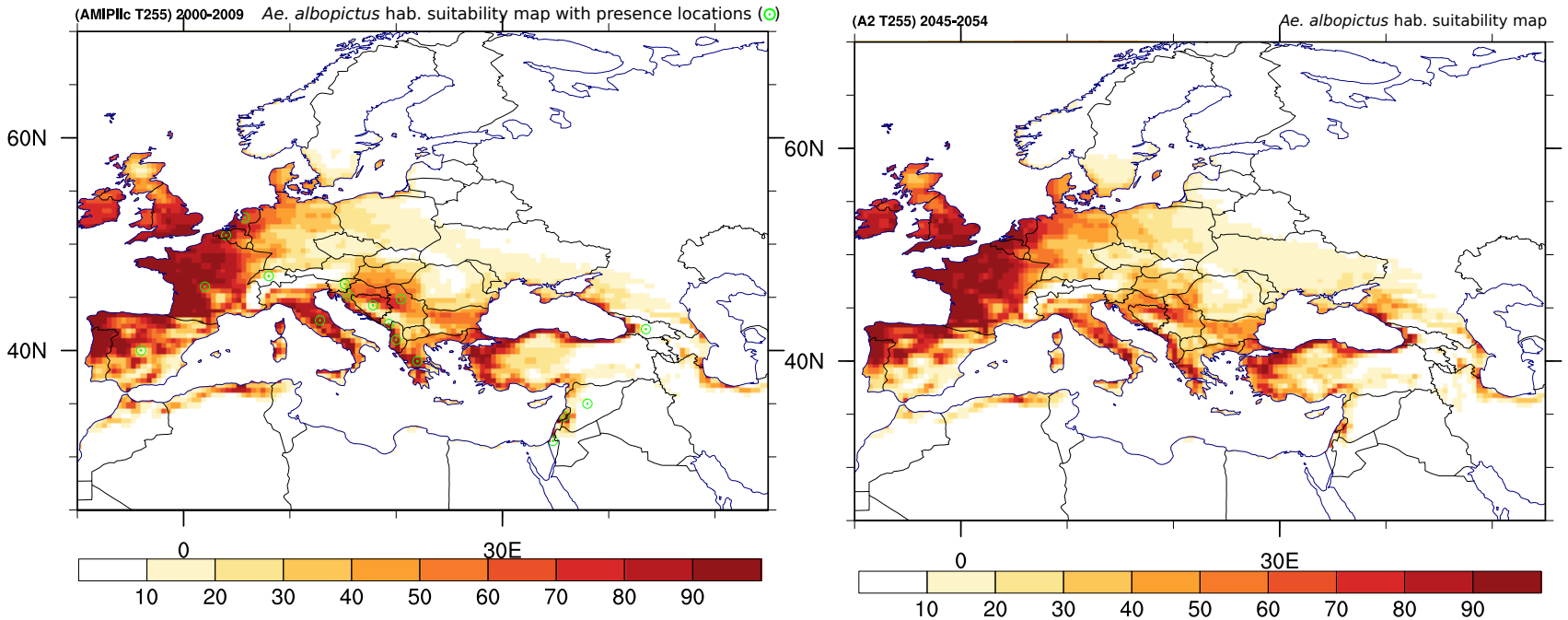
- Global hsi > 10, with presence locations (CABI database, state and/or country level)
- The horizontal resolution is about 50km, based on our climate model simulations

Habitat suitability index - future projection (2045-2055)



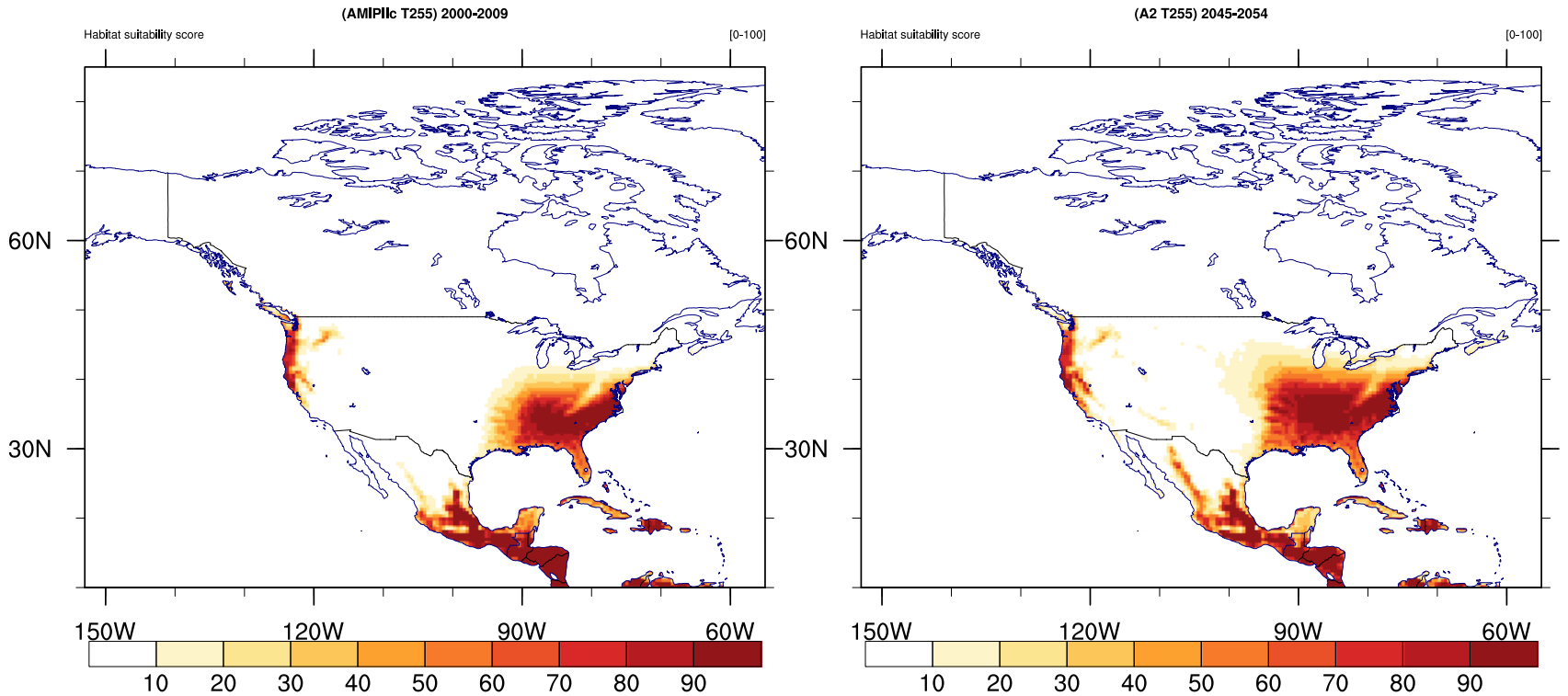
- Global hsi > 10 – Mid-century projection

Habitat suitability index by region - recent past vs. mid-century projections



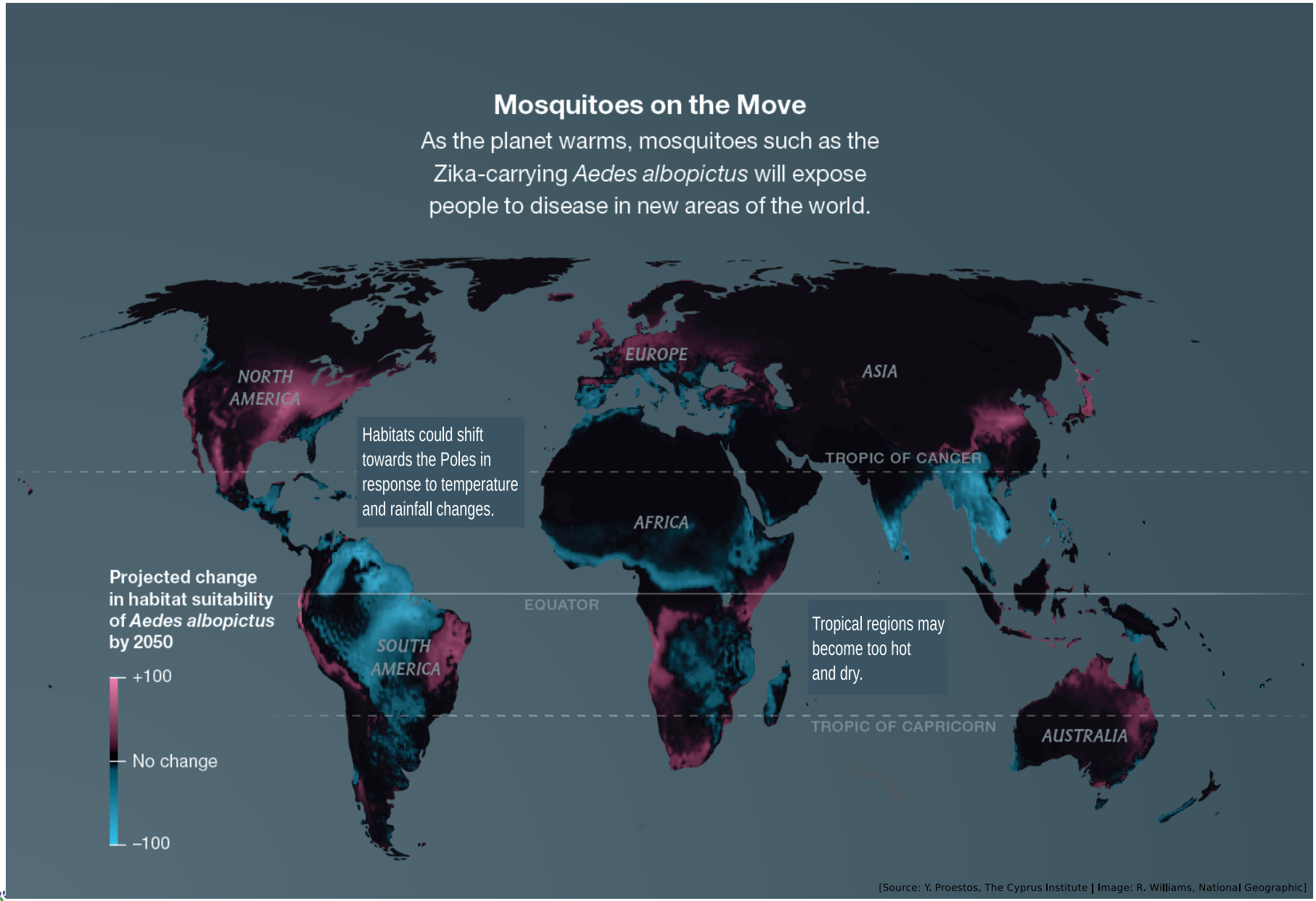
- Europe and Middle East

Habitat suitability index by region - recent past vs. mid-century projections

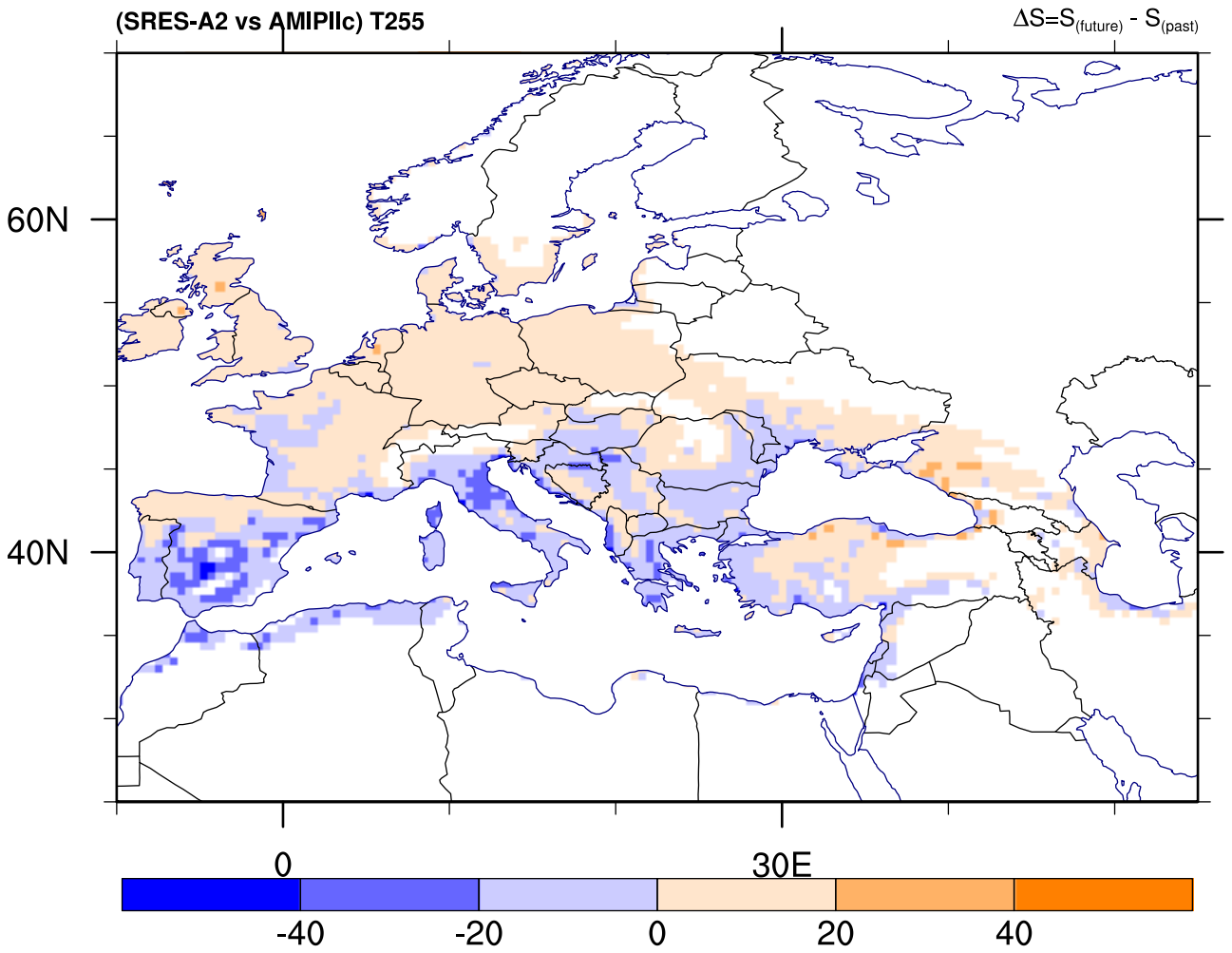


- North America

Habitat suitability index: Global projected change by 2050

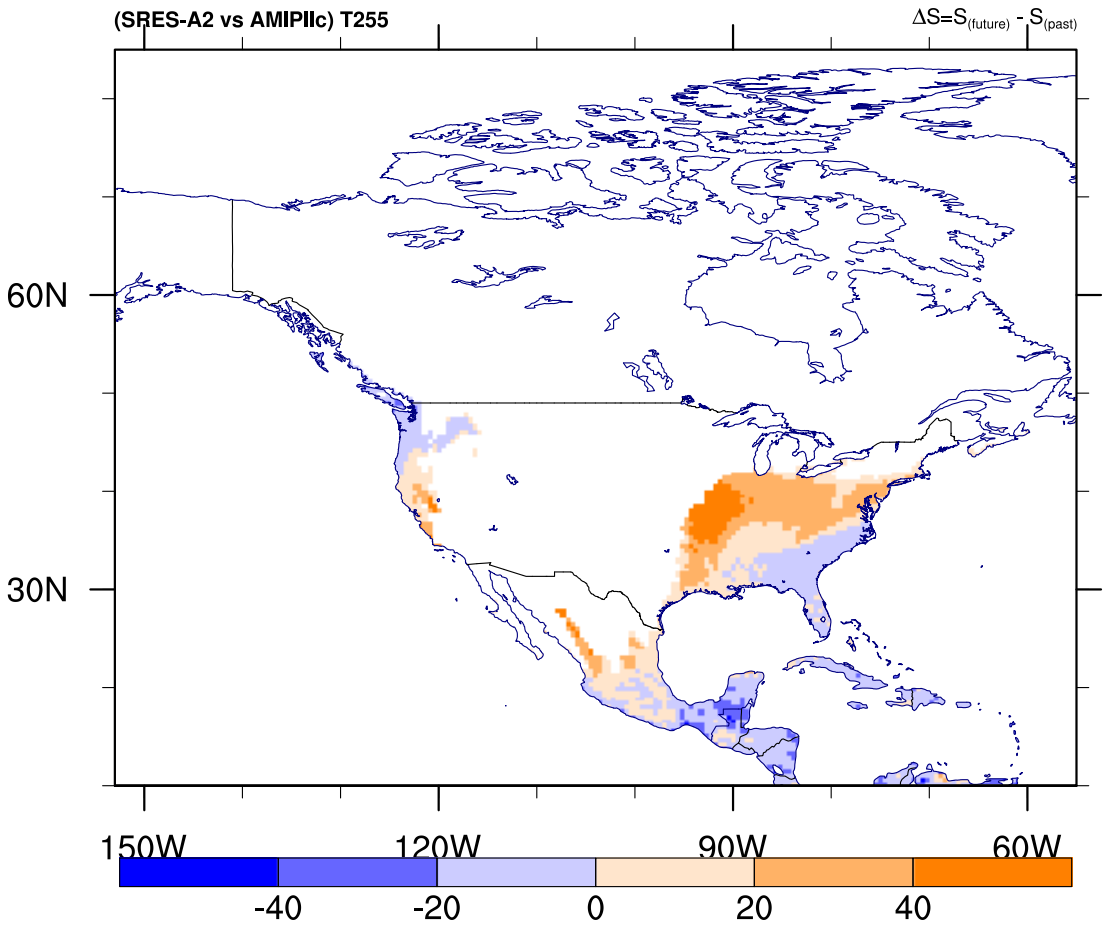


Projected change in habitat suitability index by region



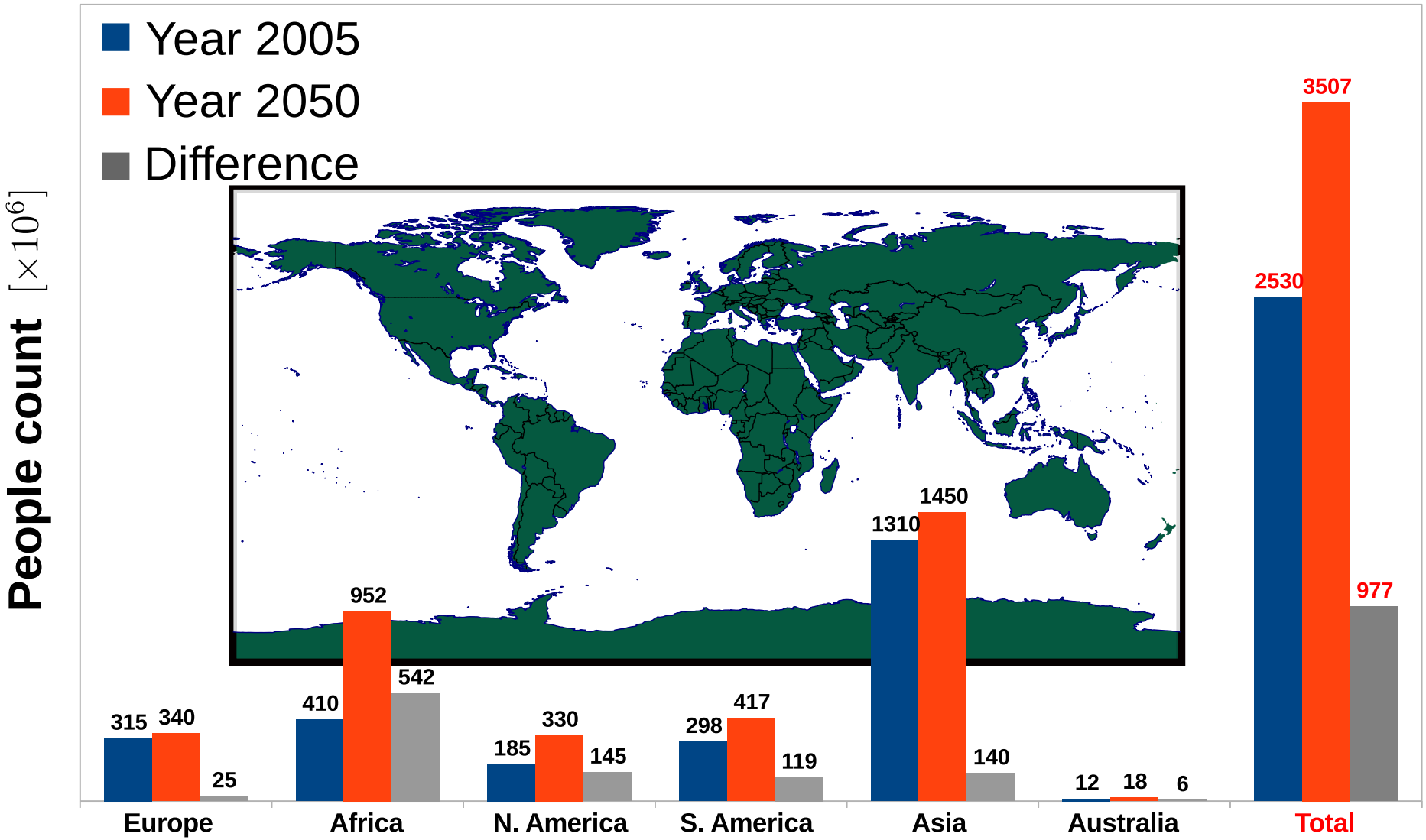
- Europe and Middle East – *Poleward shift* of favouring hsi pattern due to the enforced climate change scenario (i.e., warming, drier summers, wetter winters)

Projected change in habitat suitability index by region

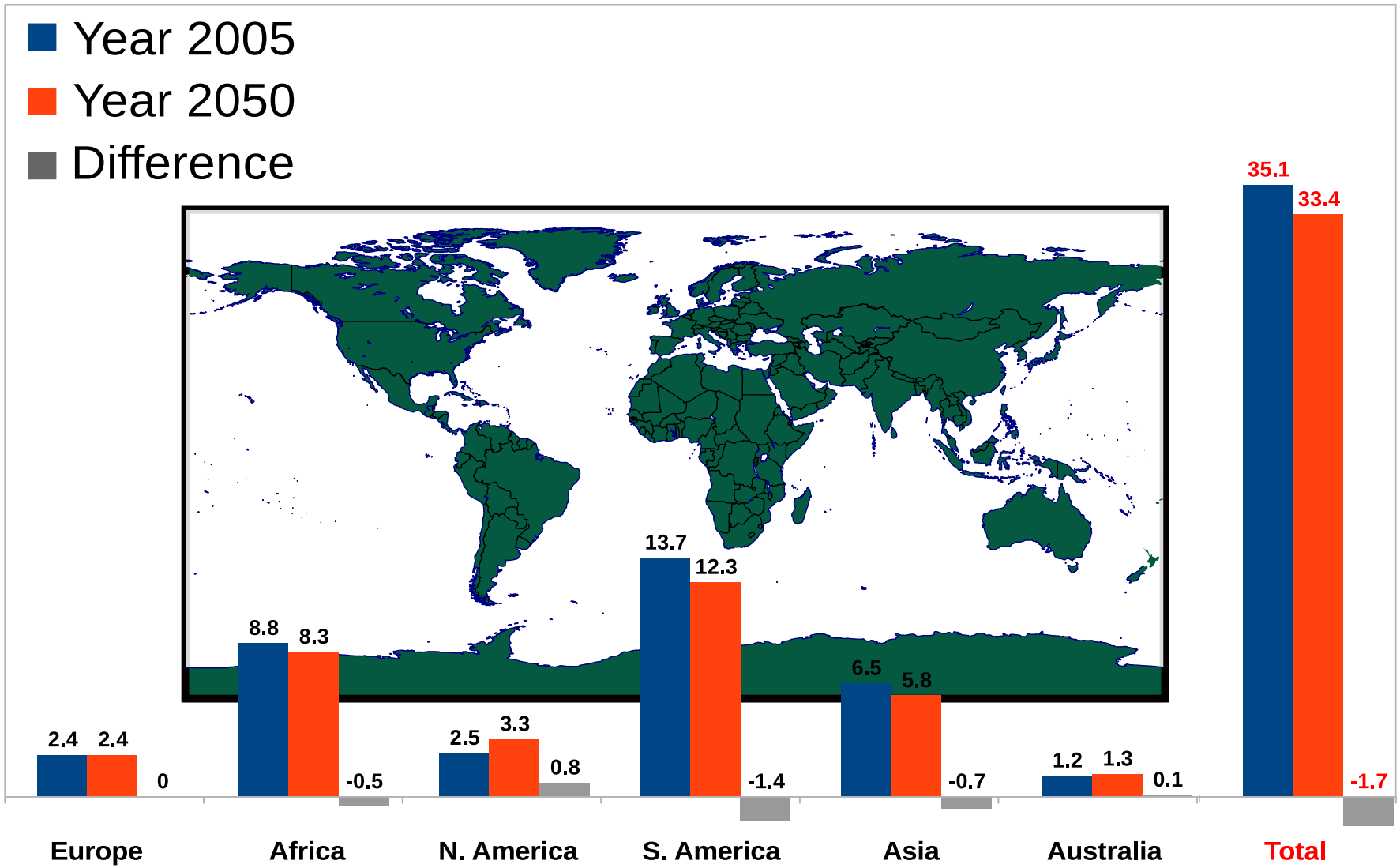


- North America – Expansion in likely suitable geographical range

Estimates: human population counts subject to hsi >35



Estimates: area subject to hsi >35



Outlook

- Some limitations
  - Uncertainties in high resolution climate model simulations are hard to evaluate and control (e.g., computational limitations)
  - The VDSM assumes that all criteria contribute equally
  - Epidemiological and vector occurrence (gridded) data are not always available, especially on global scales
  - The effects of globalization and human population patterns of movement activities are something that needs to be properly parameterized in GCMs
- On-going work
  - Working on higher resolution global climate datasets and future projection scenarios
  - A modified version of the VDSM is currently being tested for the *Ae. aegypti* species

THANK YOU!