Global forecasted scenarios of THI and HLI anomalies

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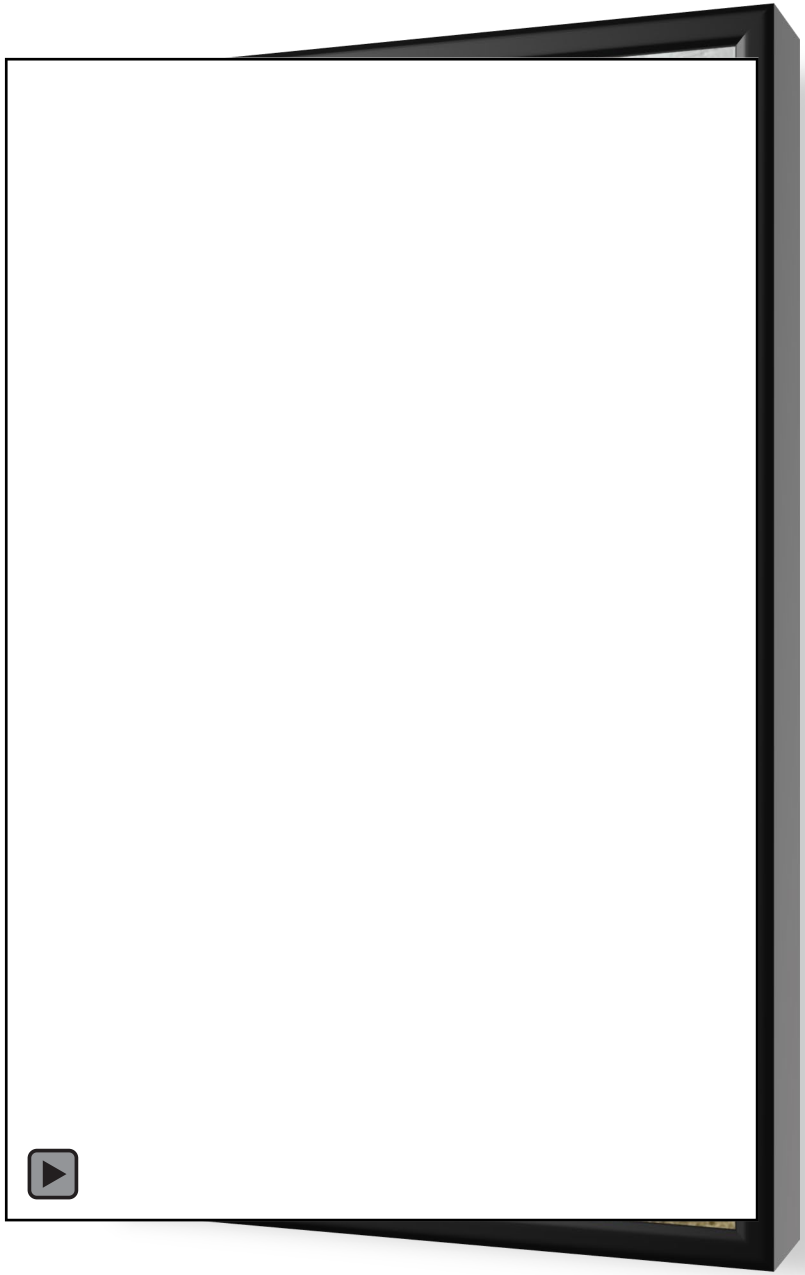
Global risk of heat stress for cattle

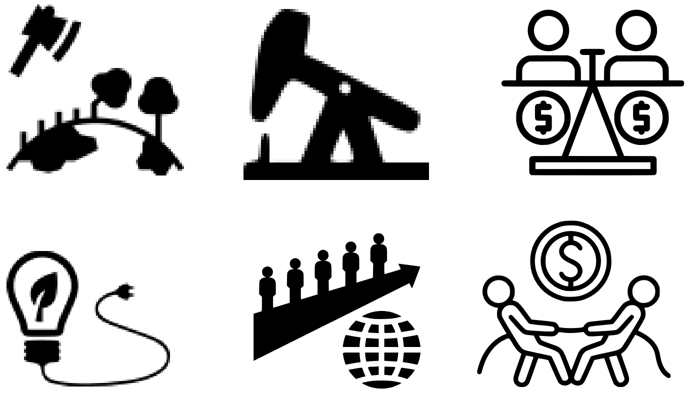
Heat stress in dairy cattle occurs when the animal's **body temperature increases** as a result of heat accumulated **for physiological functions** such as maintenance, production, reproduction **and heat accumulated from the environment**.

Conditions of **heat stress increase risk of death** and **negatively impact** on **health**, **milk yield** and **reproduction efficiency**.

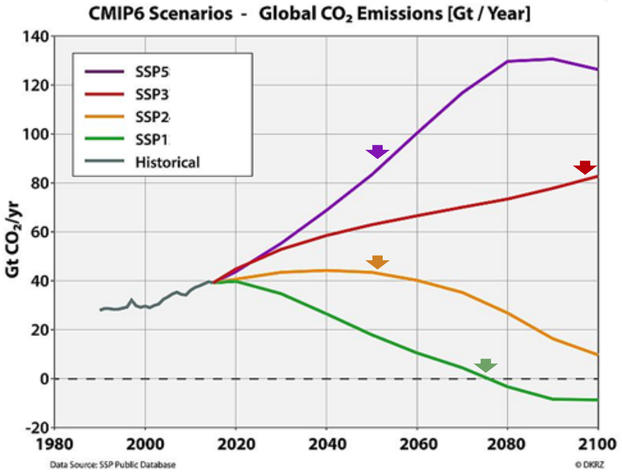


How are climate projections developed?

Different development **paths of society** were designed and **form the basis of** the Shared Socioeconomic Pathways (**SSPs**)

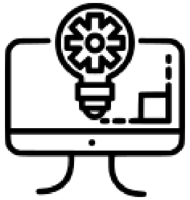


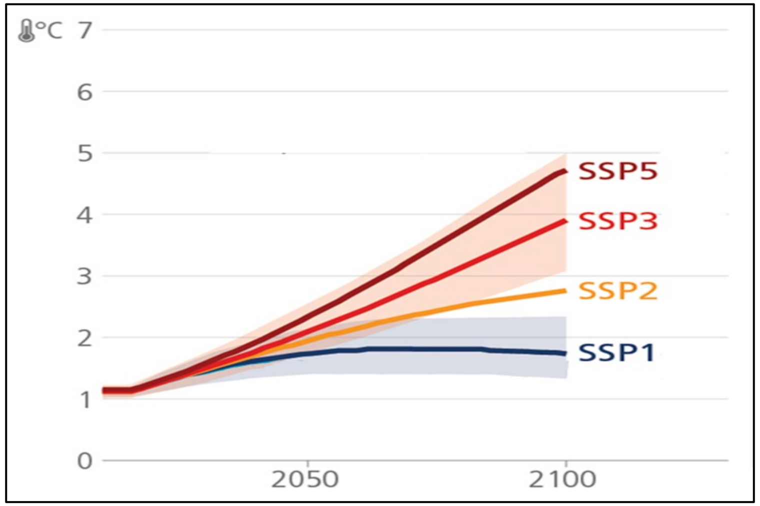
- **SSP1**: The Sustainability Pathway
- **SSP2**: The Middle of the Road
- **SSP3**: Regional Rivalry
- **SSP5**: Fossil-fueled Development



Determining representative CO_2 **concentration scenarios**

Modelled climate projections

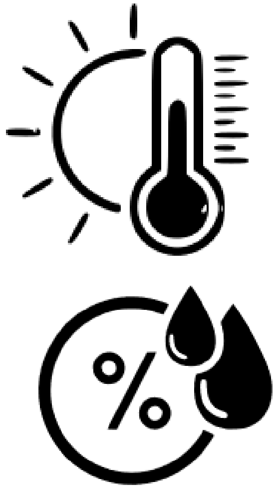




SSP	Scenario	Estimated warming (2041-2060)	Estimated warming (2081-2100)
SSP1	low GHG emissions CO2 emissions cut to **net zero around 2075**	1.7°C	1.8°C
SSP2	intermediate GHG emissions CO2 around **current level until 2050**, then falling but not **reaching net zero by 2100**	2.0°C	2.7°C
SSP3	high GHG emissions CO2 emissions **double by 2100**	2.1°C	3.6°C
SSP5	very high GHG emissions CO2 emissions **triple by 2075**	2.4°C	4.4°C

The Temperature Humidity Index (THI)

The temperature-humidity index (**THI**) **combines** values **of air temperature and humidity**, and it is widely used to **express** the level of **thermal stress**. It is particularly **effective in representing** the **climatic conditions experienced by housed livestock**, making it a key indicator in animal husbandry.



THI equation

$$THI = (1.8 \times tas\_c) + 32 - (0.55 - 0.55 \times hurs) \times [(1.8 \times tas\_c + 32) - 58]$$

Where:

tas_c = near-surface temperature in °C

$hurs$ = near-surface relative humidity (%)

Source: National Oceanic and Atmospheric Administration | NOAA, 1976

The Heat Load Index (HLI)

The Heat Load Index (**HLI**) brings together **all the weather parameters** that impact the environmental load on an animal: **Temperature**, **radiation**, **relative humidity** and **wind speed**. It is particularly **useful for accurately representing the climatic conditions faced by outdoor livestock**.

Where:

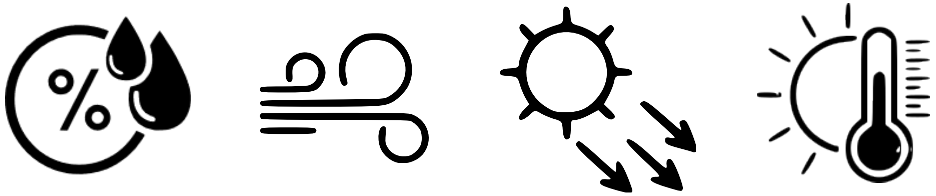
$hurs$ = near-surface relative humidity (%)

T_{bg} = black globe temperature (°C).

$sfcWind$ = daily mean near-surface wind speed (m/s)

tas_c = near-surface air temperature in °C

$rsds$ = surface downwelling shortwave radiation (W/m^2)



HLI equations

For T_{bg}>25°C:

$$HLI_{T_{bg}>25} = 8.62 + (0.38 \times hurs) + \left(1.55 \times T_{bg}\right) - (0.5 \times sfcWind) + [e^{2.4-sfcWind}]$$

For T_{bg}<25°C:

$$HLI_{T_{bg}<25} = 10.66 + (0.28 \times hurs) + \left(1.3 \times T_{bg}\right) - sfcWind$$

Where T_{bg} is calculated as:

$$T_{bg} = 1.33 \times tas\_c - 2.65 \times tas\_c^{0.5} + 3.21 \log(rsds + 1) + 3.5$$

The sigmoid function for Black Globe Temperature (BGT) was determined by:

$$S(BGT) = \frac{1}{\left(1+\exp\left(-\frac{(BGT-25)}{2.25}\right)\right)}$$

and the final HLI was computed as:

$$HLI = S(BGT) \times HLI_{BG_t>25} + \left(1 - S(BGT)\right) \times HLI_{BG_t<25}$$

Source: A new heat load index for feedlot cattle| Gaughan et al., 2008

Research objectives

Assessing the **evolving global spatiotemporal patterns** of **heat stress risk in livestock** by describing the **anomalies** of the Temperature-Humidity Index (**THI**) and Heat Load Index (**HLI**).

Dataset sources

Data were sourced by:

- **N**ASA **E**arth E**x**change **G**lobal **D**aily **D**ownscaled **P**rojections (**NEX-GDDP**) archive

Derived from:

- The latest **C**limate **M**odel **I**ntercomparison **P**roject (**CMIP6**)

WCRP CMIP6
World Climate Research Programme

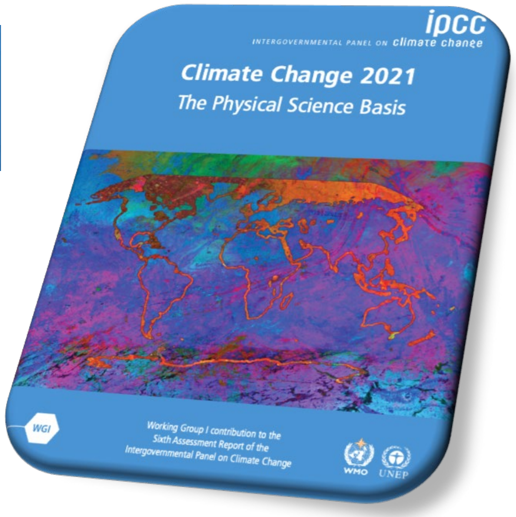
Employing:

- The latest release of the **C**ommunity **E**arth **S**ystem **M**odel (**CESM2**)

NCAR | COMMUNITY EARTH SYSTEM MODEL CESM

nex-gddp-cmip6 / NEX-GDDP-CMIP6 / CESM2

The archive contains downscaled **historical** and **future projections** from **1950** to **2100**



Source: https://nex-gddp-cmip6.s3.us-west-2.amazonaws.com/index.html#NEX-GDDP-CMIP6/CESM2/

Key variables extracted from dataset

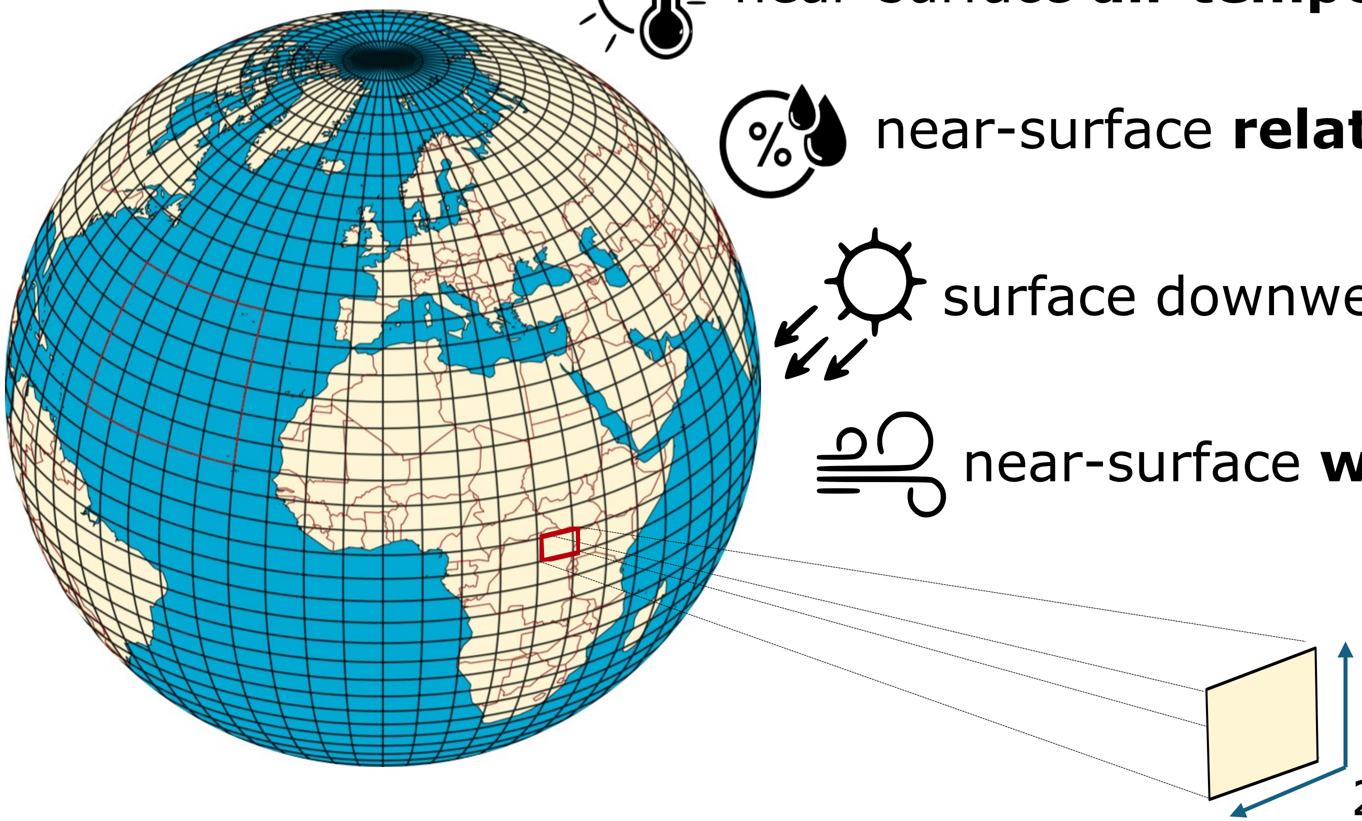
Historical, **SSP1**, **SSP2**, **SSP3**, and **SSP5**, **Daily Mean**:

near-surface **air temperature** (*tas*) in degrees Kelvin

near-surface **relative humidity** (hurs) data

surface downwelling **shortwave radiation** (*rsds*) in W/m^2

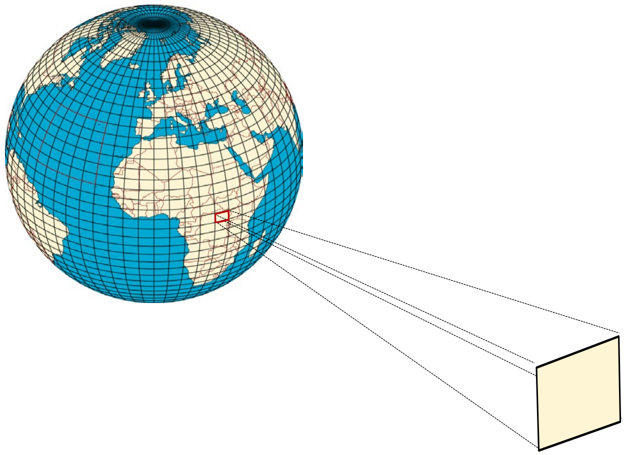
near-surface **wind speed** (*sfcWind*) in m/s.

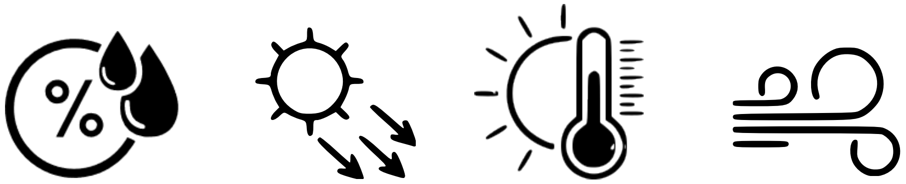


27.7 km x 27.7 km at the equator

spatial resolution of 0.25° latitude by 0.25° longitude

Data modelling



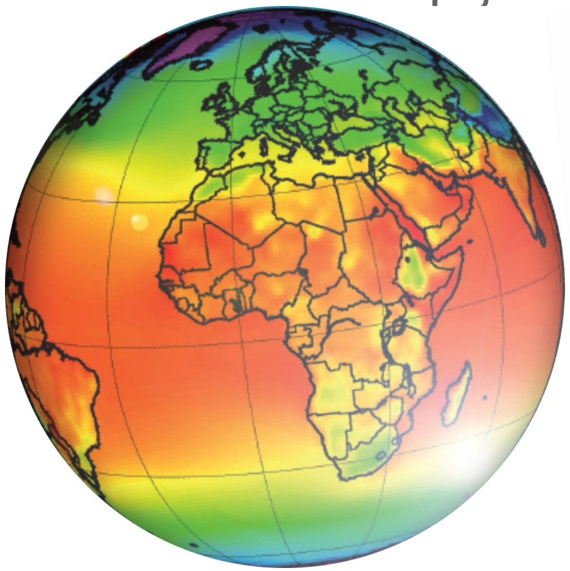


Per grid daily **historical** (1985-2014) and **projected** (2026-2100) **climate data**

THI equation

HLI equation

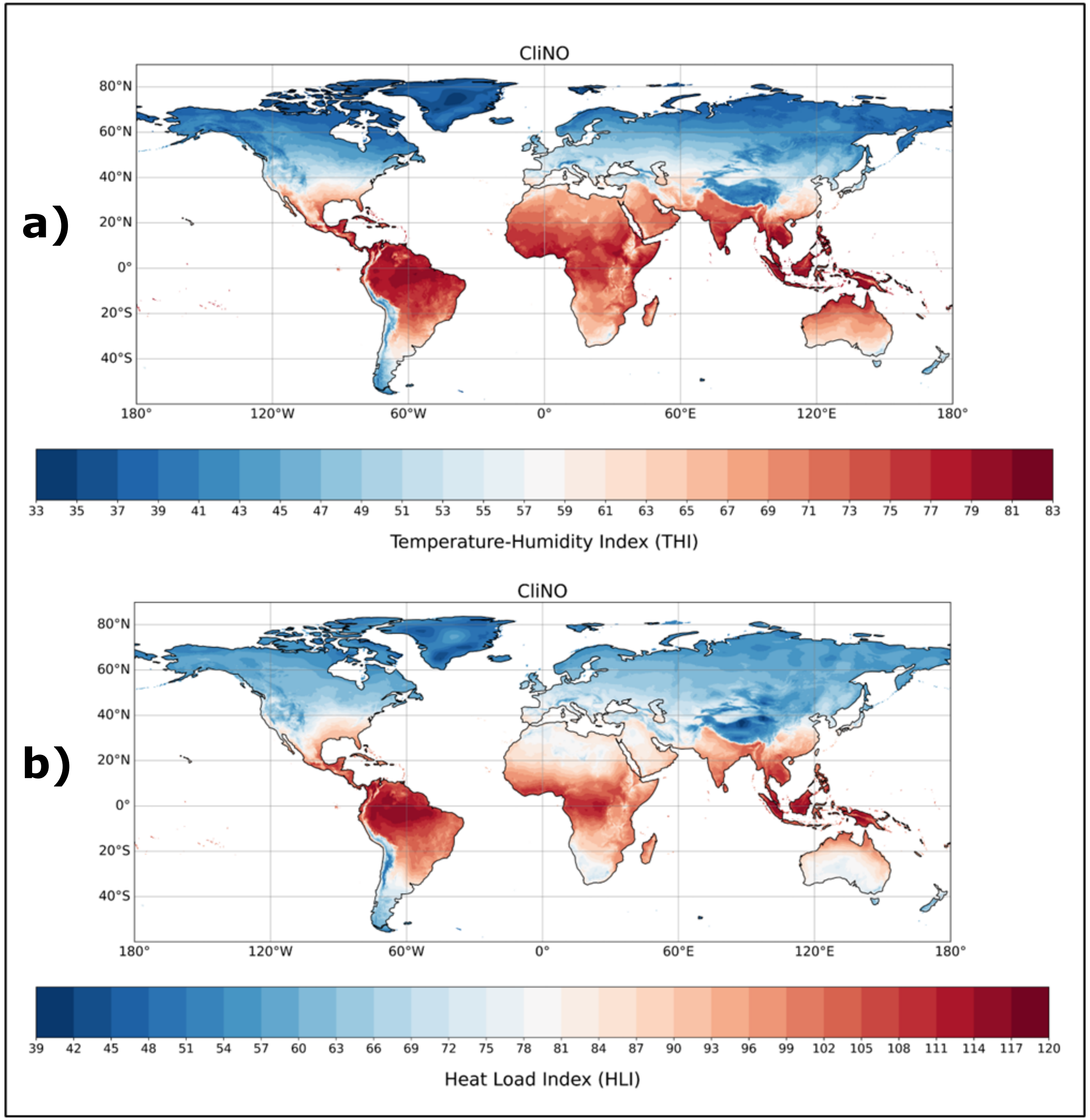
The 30-year (**1985-2014**) **THI** and **HLI averages** were calculated **for each grid to establish** the Climatological Normal (**CliNO**). Thus, maps were used to **compare global THI and HLI** variations **against projected climate** data at 25-year intervals.



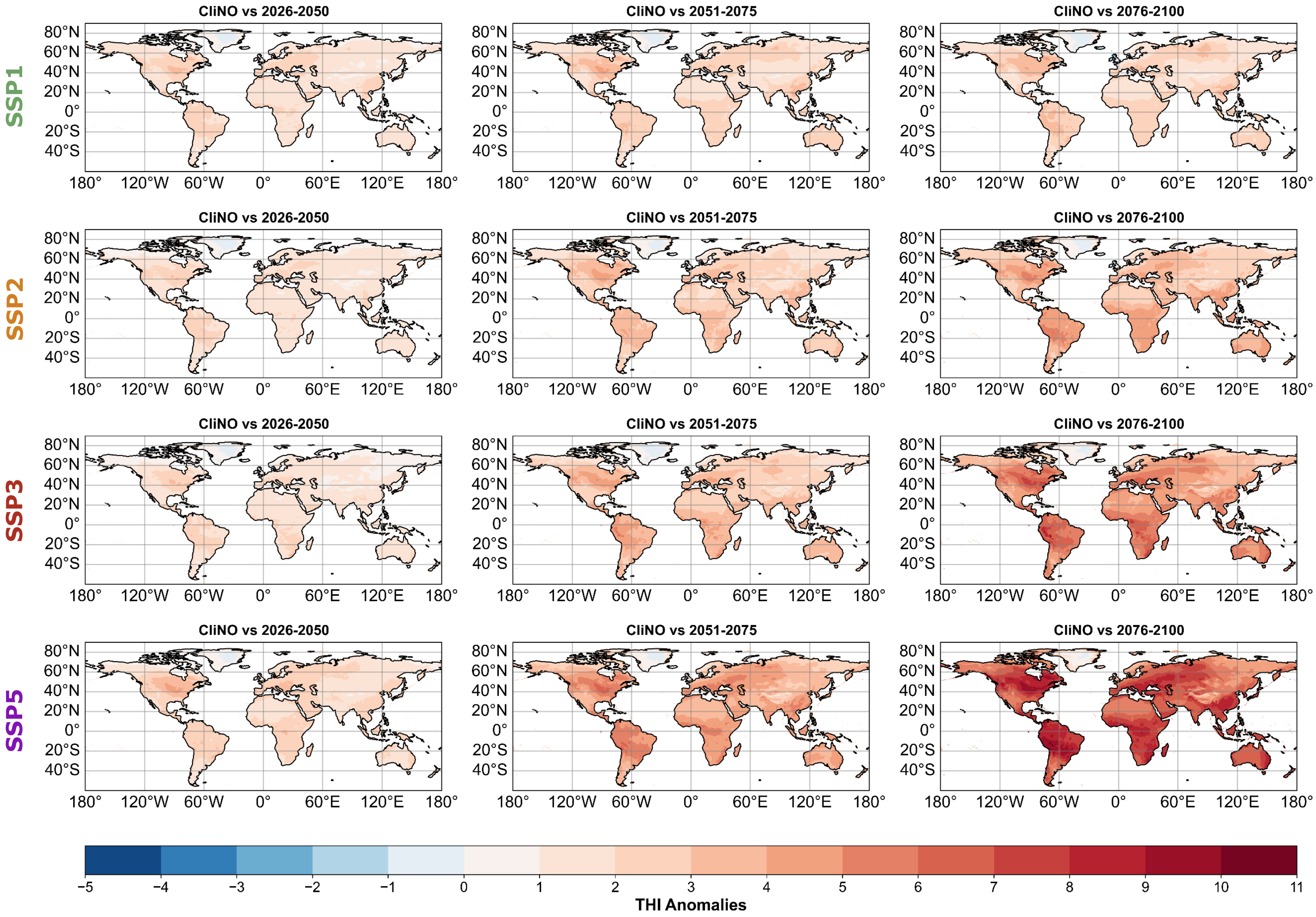
THI and HLI CliNO

a) Average (1985-2014) annual Temperature-Humidity Index (**THI**). Areas with higher values, shown in red, indicate zones of substantial thermal stress, while the blue regions represent more temperate conditions.

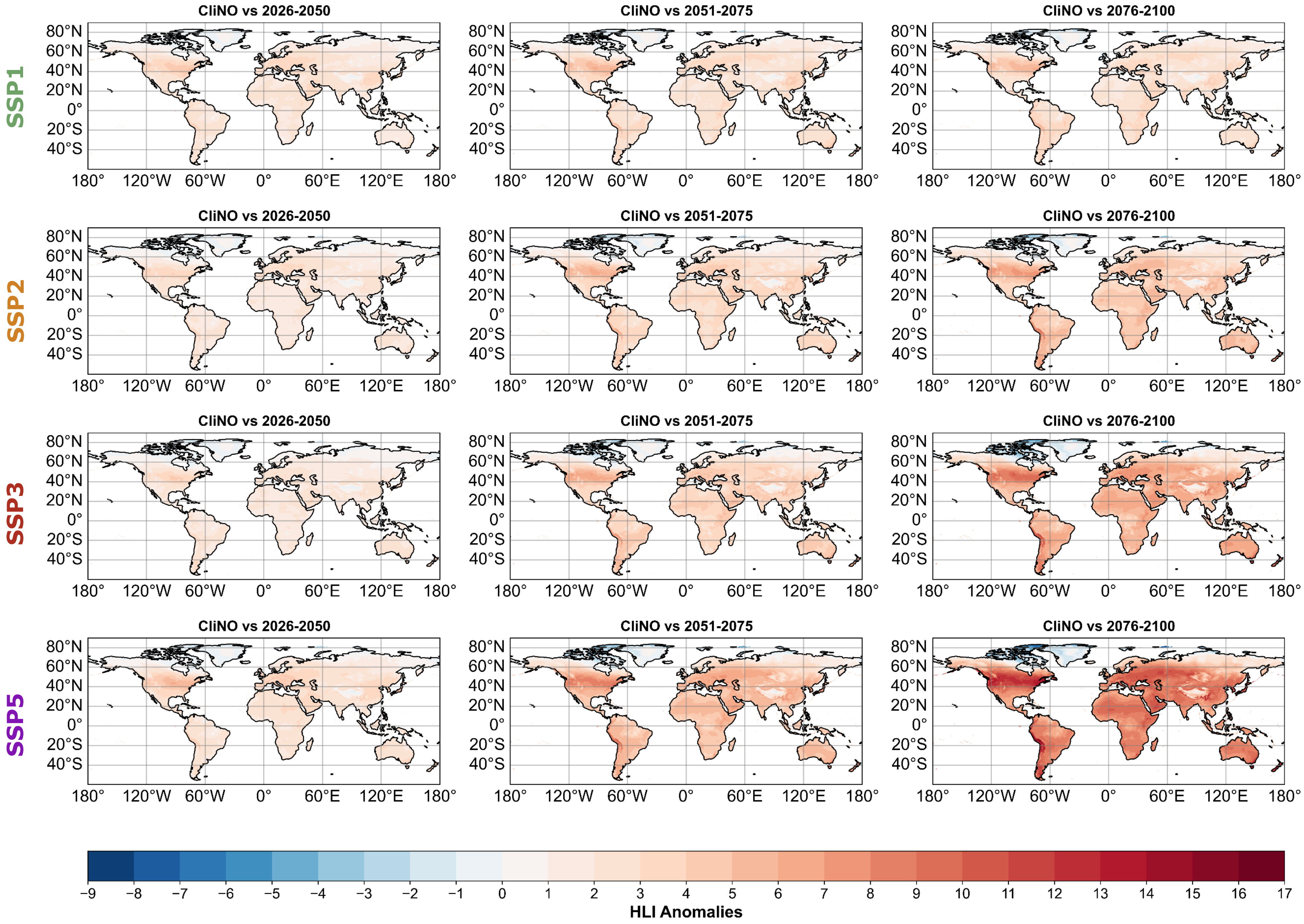
b) Average (1985-2014) annual Heat Load Index (**HLI**). In this visualization, red areas signify regions subjected to significant heat stress, whereas cooler zones, depicted in blue, are less impacted by heat.



THI anomalies maps



HLI anomalies maps



Conclusions

- Climate change is **expected** to **increase risk of thermal stress** for livestock globally

- **Certain regions** are likely to **experience** significantly **higher levels of heat stress** in the coming decades

- **Urgent adaptation strategies are required** to mitigate the effects of rising temperatures on livestock, especially in regions facing the most severe increases in thermal stress

- The **shift of milk production** to warmer regions **to meet growing populations** could **worsen the effects** of heat stress on the dairy industry

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