IMPACT OF GLOBAL WARMING AND GREENLAND ICE SHEET MELTING ON MALARIA IN AFRICA

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2 – MINUTES MADNESS

SCENARIOS
RCP8.5 or
GrIS or
Historical

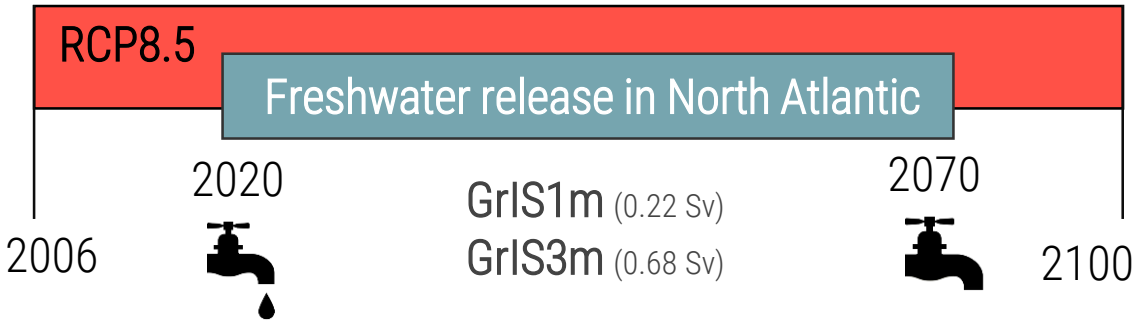
→ **CLIMATE MODEL**
IPSL-CM5A-LR

→ Temperatures
Precipitations

→ **IMPACT MODELS**
5 malaria models

→ Model outputs
Prevalence (in %)
LTS (month/year)

Scenarios with Greenland melting



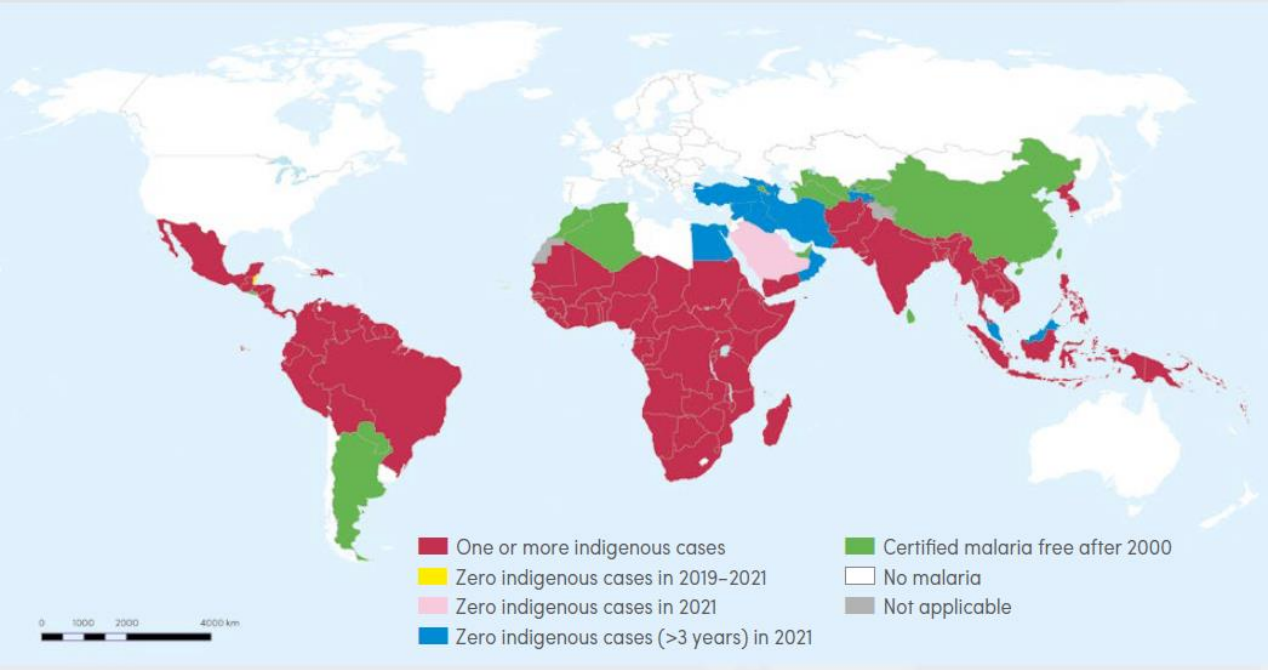
MALARIA

- Vectors: *Anopheles* mosquitoes
- Parasitic disease: *Plasmodium*
- Cases: 247 million
- Deaths: 619,000

Africa:

- Parasite: *P. falciparum*
- Cases: 96 %
- Deaths: 95 %

Countries with malaria indigenous cases in 2000 and their status by 2021



World malaria report (2022)

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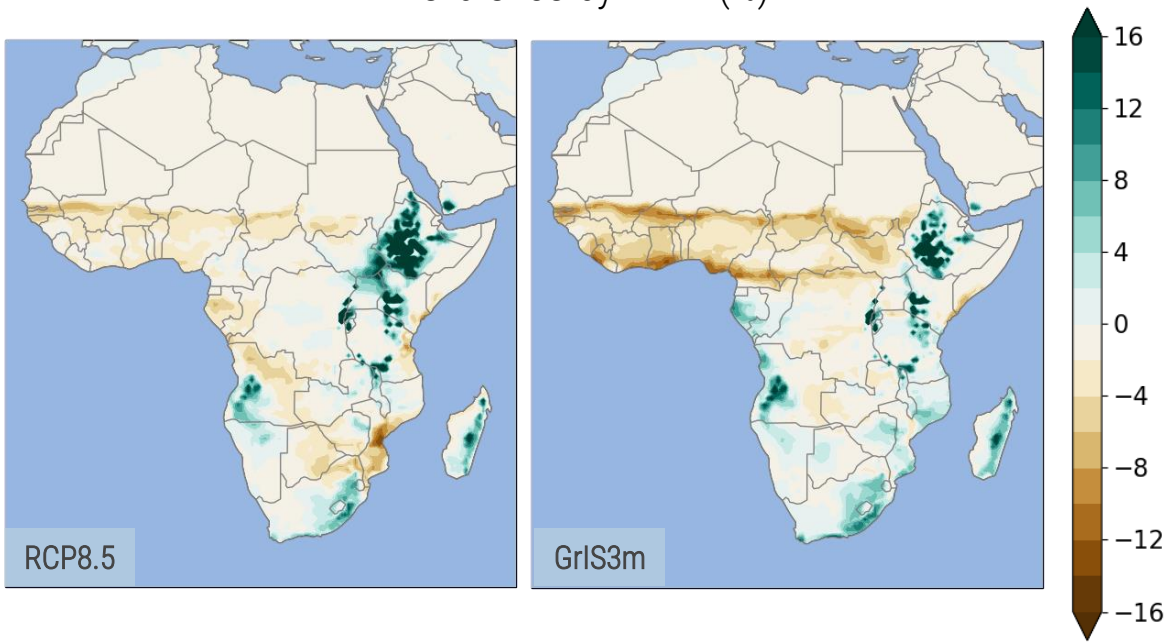
2 – MINUTES MADNESS

Temporal evolution according to the scenarios

[2040-2050] – [2000-2020]
Annual mean

Δ Prevalence by LMM (%)

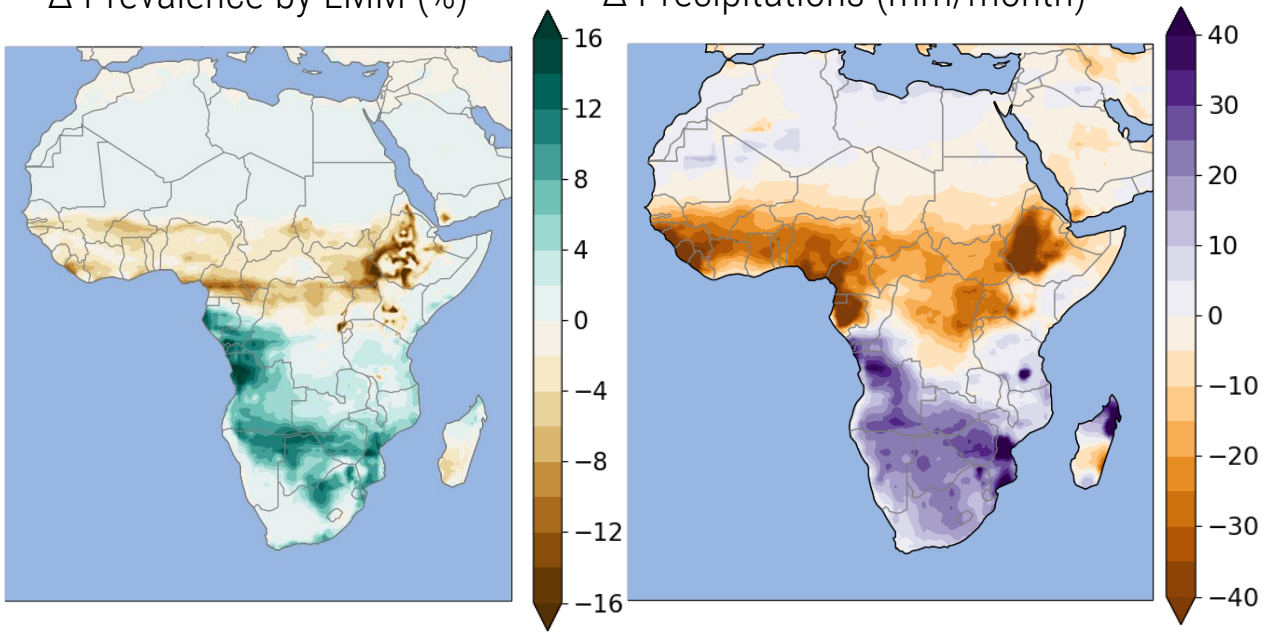


- Decrease in simulated prevalence in the Sahel
- Increase in simulated prevalence in East Africa

Additional effect of Greenland melting

GrIS3m – [RCP8.5]
Annual mean [2040-2050]

Δ Prevalence by LMM (%) Δ Precipitations (mm/month)



- Transmission risk emerges in southern Africa
- Associated with a southward shift in rainfall

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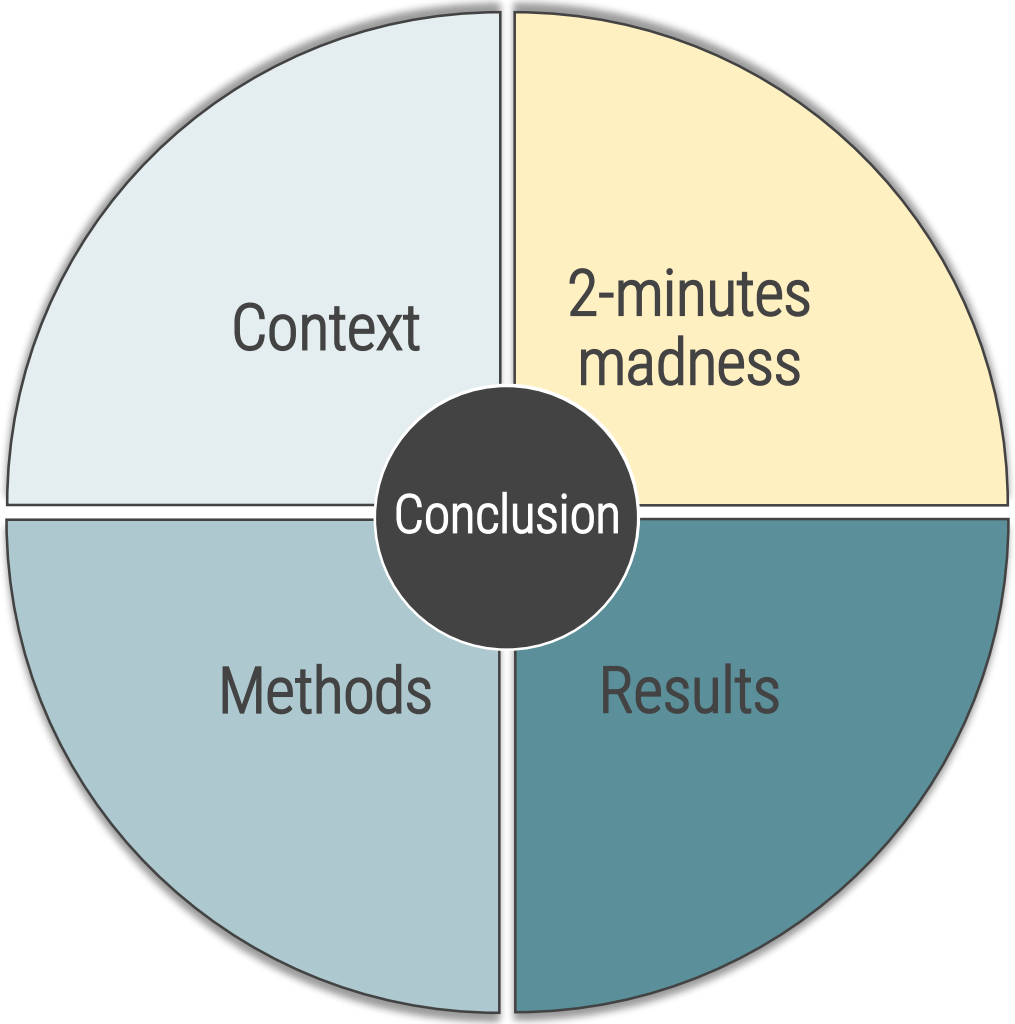

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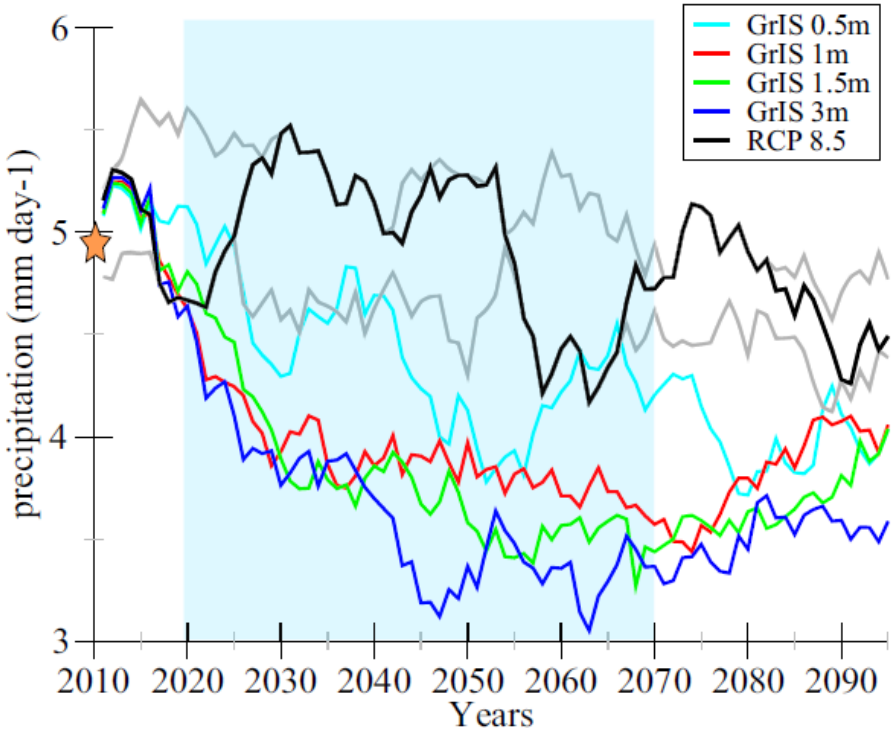
CONTEXT

Defrance et al. (2017)

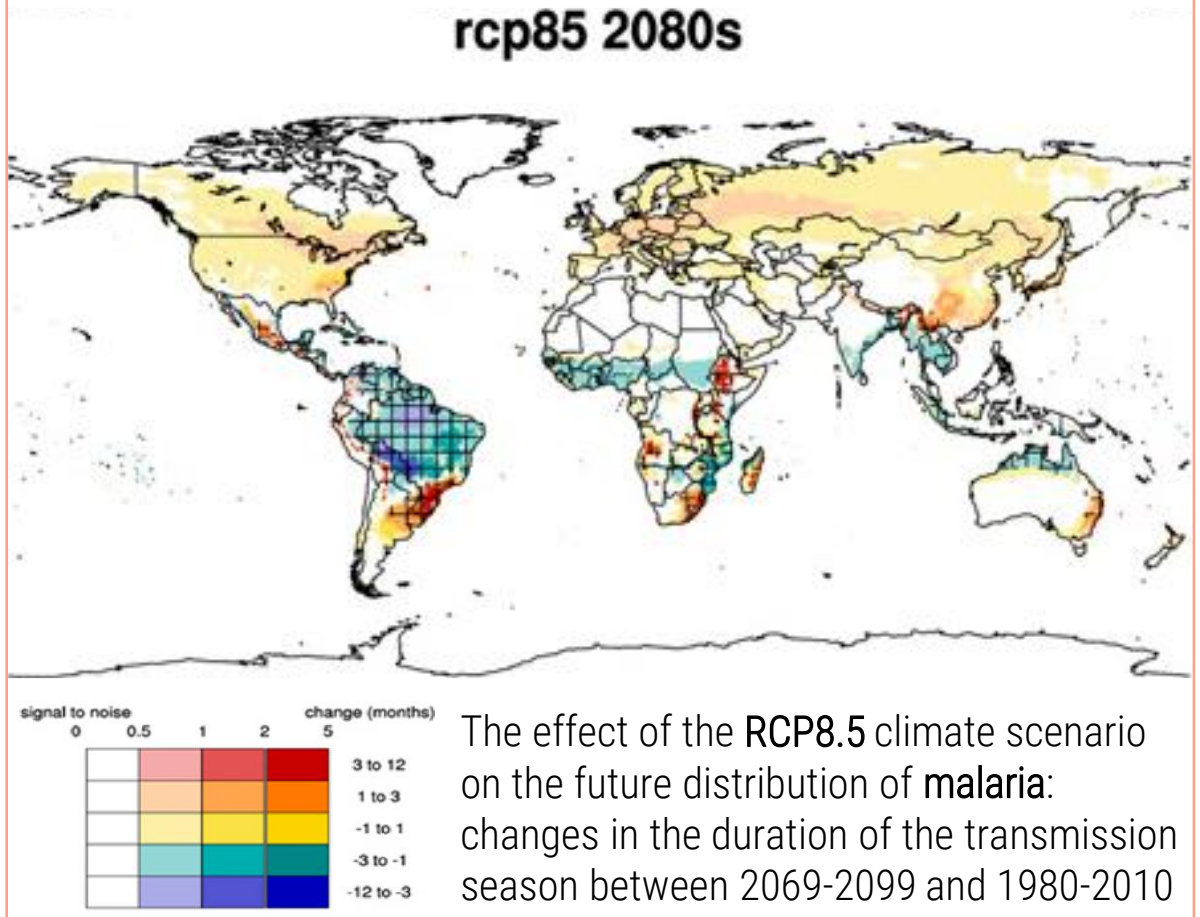
Consequences of rapid ice sheet melting on the Sahelian population vulnerability



Evolution of JJAS **precipitation** during the 21st century averaged over the **Sahel** area for the RCP8.5 and the GrIS scenarios

Caminade et al. (2014)

Impact of climate change on global malaria distribution



The effect of the **RCP8.5** climate scenario on the future distribution of **malaria**: changes in the duration of the transmission season between 2069-2099 and 1980-2010

Two key studies

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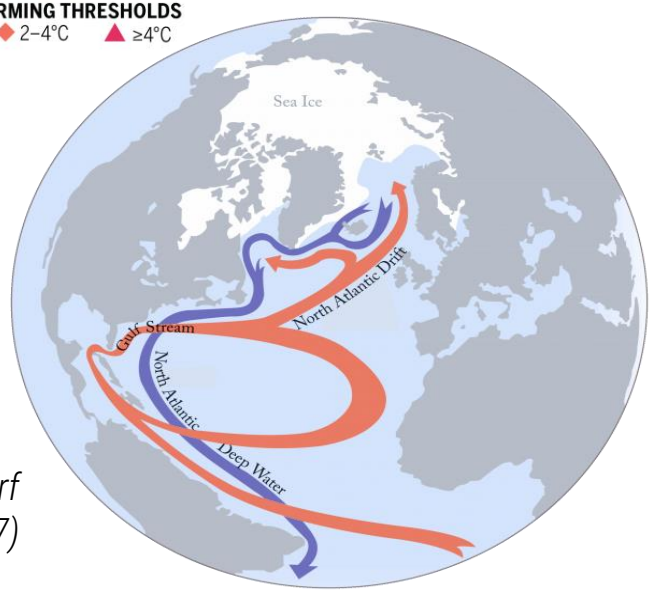
CONTEXT

Armstrong McKay et al. (2022)

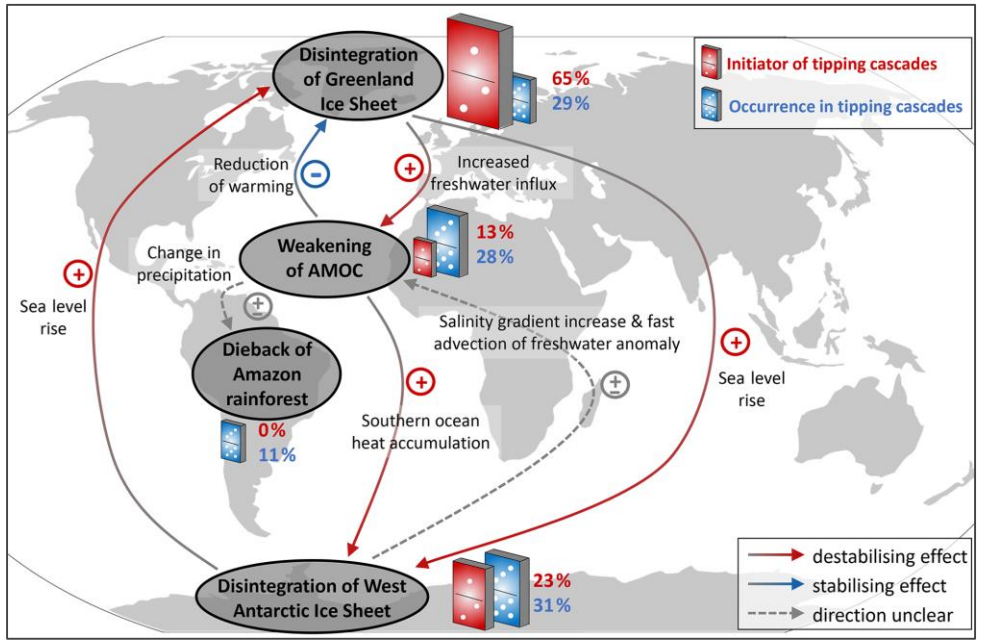


Rahmstorf (1997)

WHY STUDY A RAPID MELTING OF THE GREENLAND ICE-SHEET?

- Past climate:
  - Heinrich events: icebergs discharge in Atlantic ocean
  - Non-linear deglaciation
- A major tipping point in the climate system, with a threshold below +2°C
- Currently, global warming is causing a loss of ice mass
- Location in subpolar region: Direct impact on oceanic circulation
- Important feedbacks at global scale

Wunderling et al (2021)



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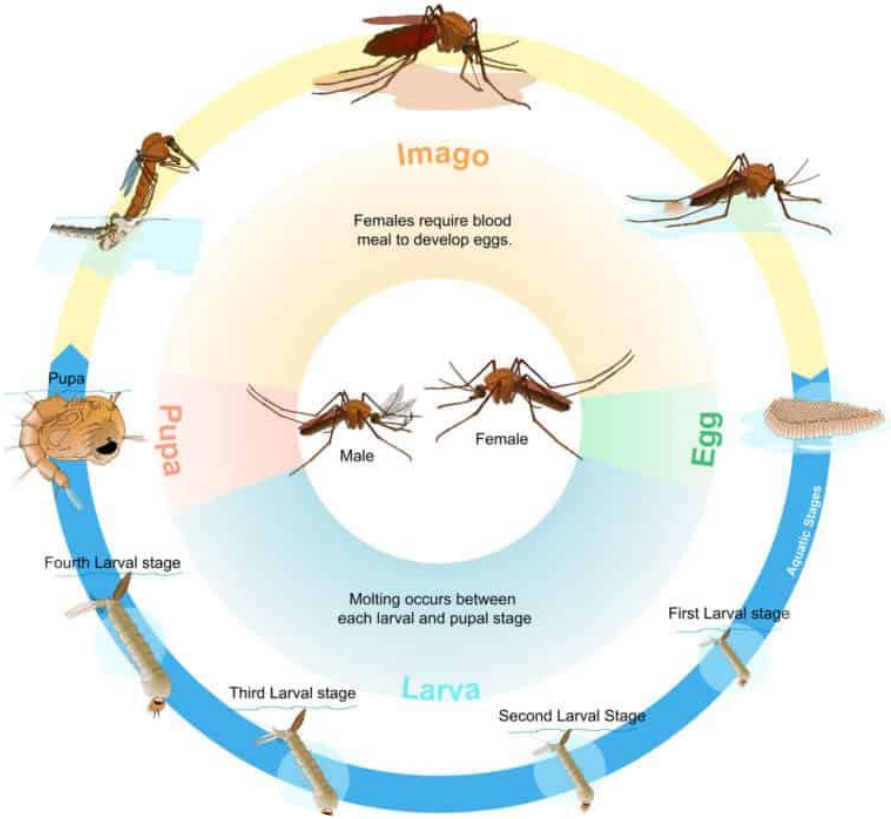
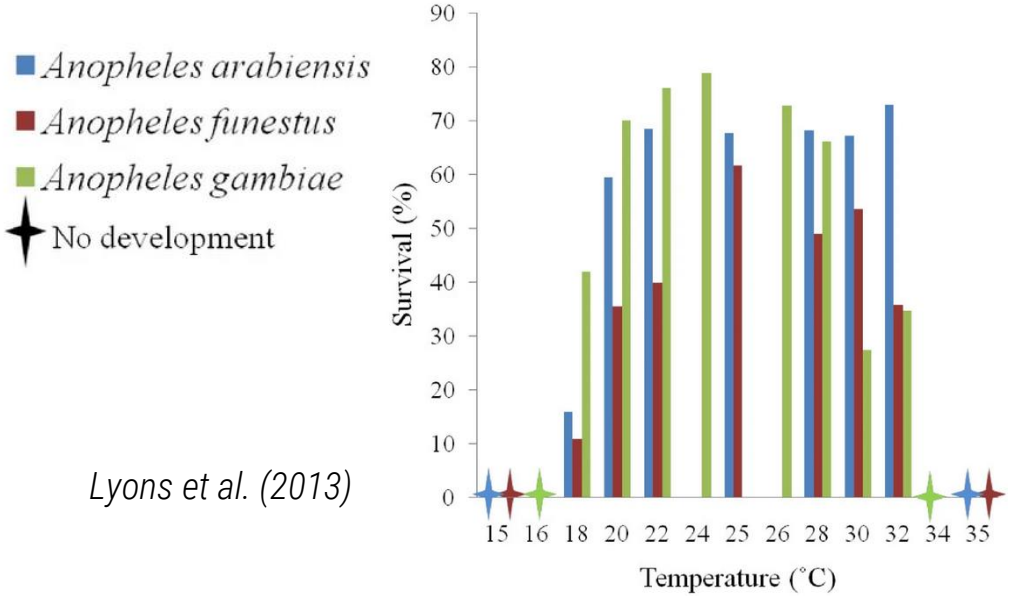
CONTEXT

Malaria is a parasitic vector-borne disease caused by **Plasmodium** transmitted by ***Anopheles*** **mosquitoes**

Mosquito life cycle





Lyons et al. (2013)

WHICH LINK BETWEEN MALARIA AND GLOBAL WARMING?

Mosquito density is dependent on **rainfall** which impacts the presence and maintenance of breeding sites

Mosquito density is dependent on **temperatures** that affect their survival and development time

Parasite transmission is dependent on **temperatures**, which affect the rate of development of the pathogen in the mosquito's body and the rate of bites

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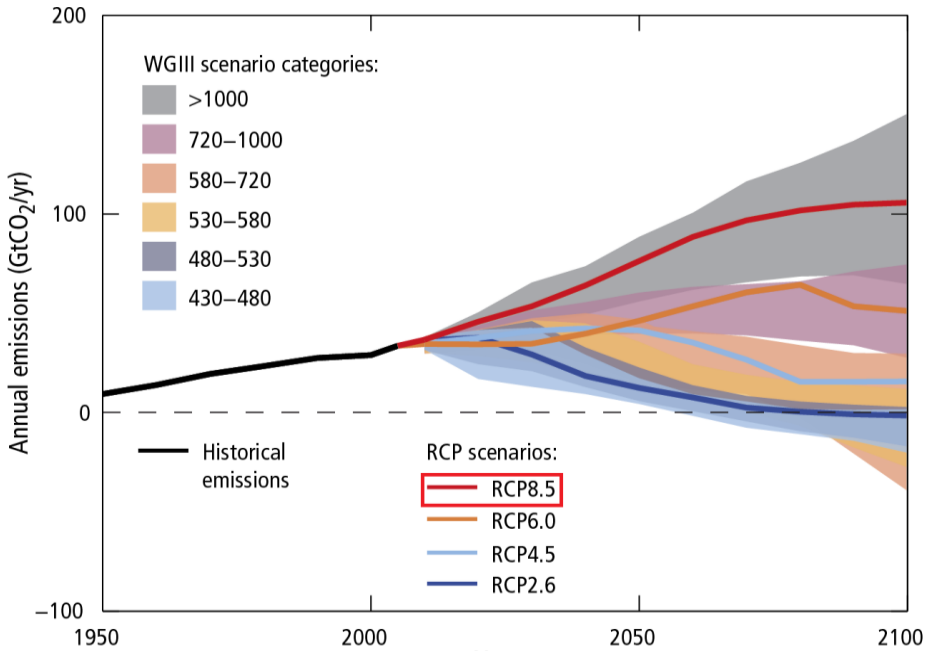
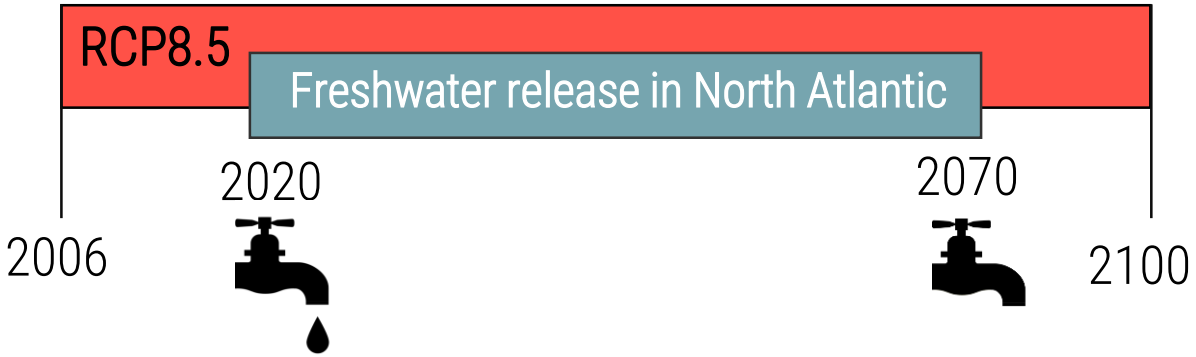
METHODS

RCPs scenario



Climate Change 2014, Synthesis Report Summary for Policymakers.

GrIS Scenarios (with Greenland melting)



2 scenarios of Greenland melting (GrIS), each corresponding to different sea level rises: 1m, 3m

(Defrance et al., 2017)

GrIS1m (0.22 Sv)
GrIS3m (0.68 Sv)

1 Sv = 10^6 $m^3.s^{-1}$

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METHODS

SCENARIOS

- Historical (1976 - 2005)
- RCP8.5 (2006 - 2100)
- GrIS1m
- GrIS3m (2020 - 2100)
- WAIS3m

CLIMATE MODEL

IPSL-CM5A-LR

Global coupled model

Atmospheric resolution:

- Longitude 3.75°
- Latitude 1.875°
- 39 vertical levels

Oceanic resolution:

- Between 0.5 and 2°
- 31 vertical levels

For the study of malaria: bias correction

- Matching the CDF of a simulated climate variable (model output) to the CDF* of an observed climate variable via a mathematical transfer function.
- The CDF-t method retains the trends
- Reference data: EWEMBI
- 0.5°x 0.5° grid
- 1979 – 2013
- Application period: 1950-2099
- * cumulative distribution function

5 Malaria models

❖ 3 monthly :

- MARA
- MIASMA
- LMM R_0

LTS Duration of malaria transmission season (months/year)

❖ 2 daily :

- LMM
- VECTRI

Prevalence (%)

Temperatures
Precipitations

→ Bias correction (CDF-t method)

→ Temperatures and precipitation corrected

→ **IMPACT MODELS**: 5 malaria models

→ Model outputs
Prevalence (in %)
LTS (month/year)

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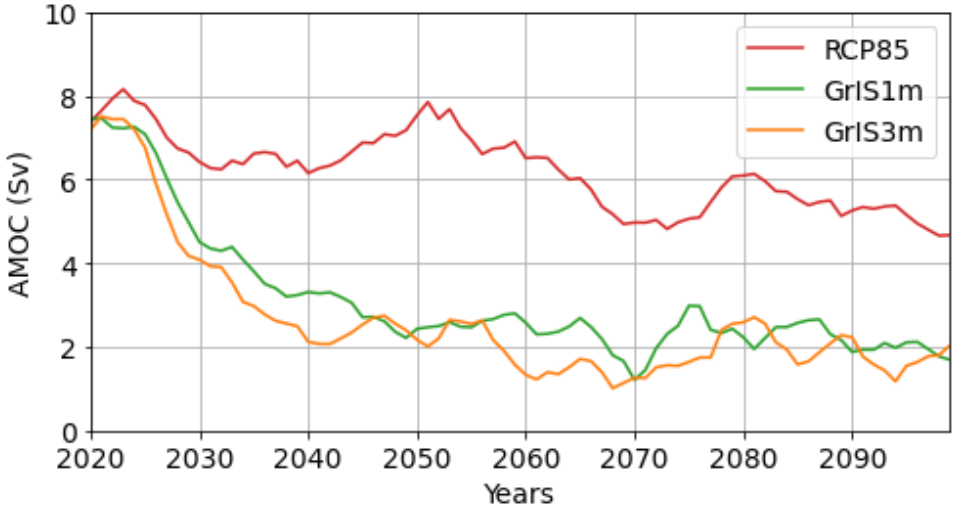
RESULTS

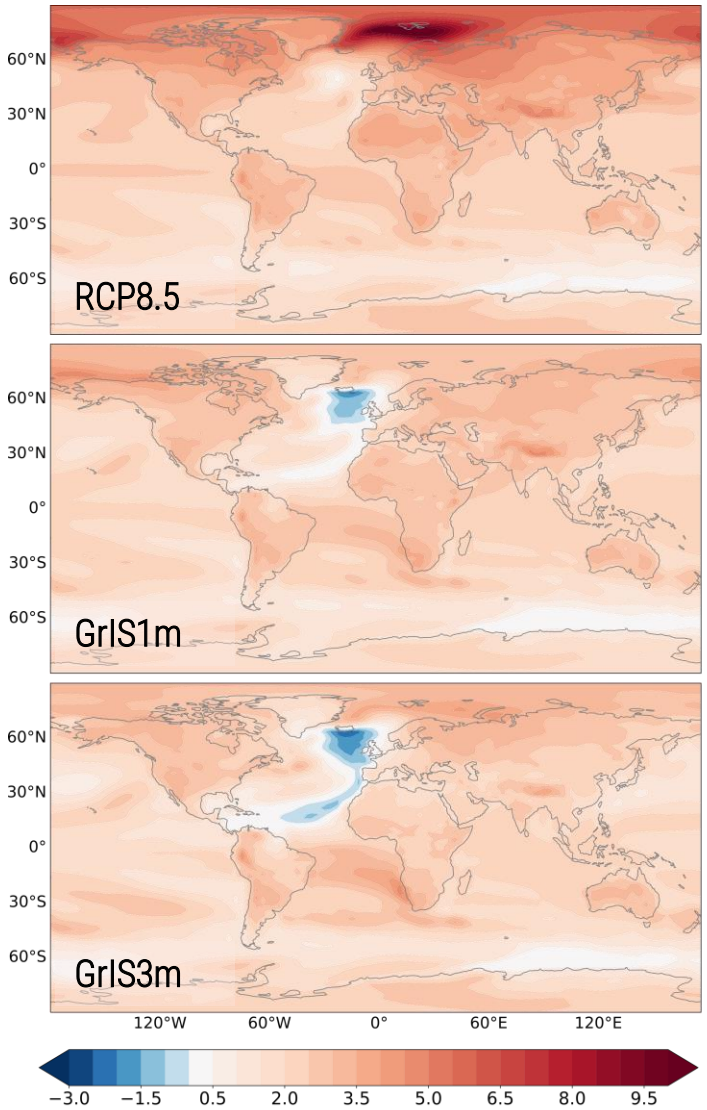
[2041–2070] – [1976–2005]
Annual mean

CLIMATE RESULTS

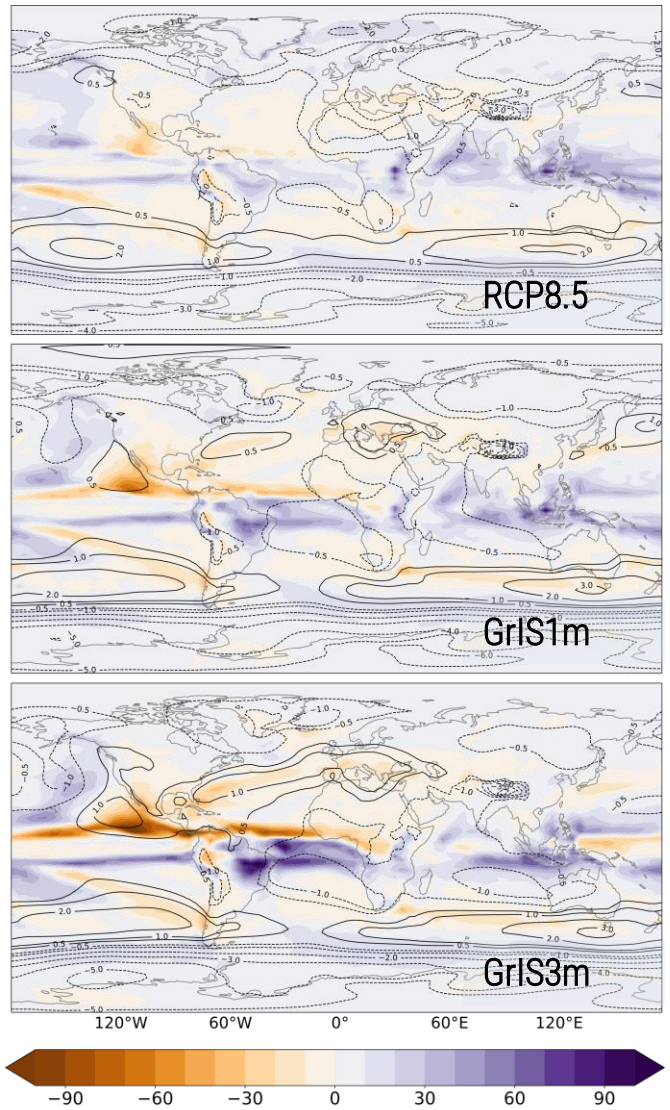
- Slowdown of the AMOC
- Local cooling where freshwater was released
- Temperature increase more moderate in GrIS vs RCP8.5 simulation
- Changes in inter-hemispheric pressure gradients
- Southward shift of the intertropical rain belt (GrIS)



Chemison et al. (2022)



Δ Temperature (°C)



Δ Precipitations (mm/month)

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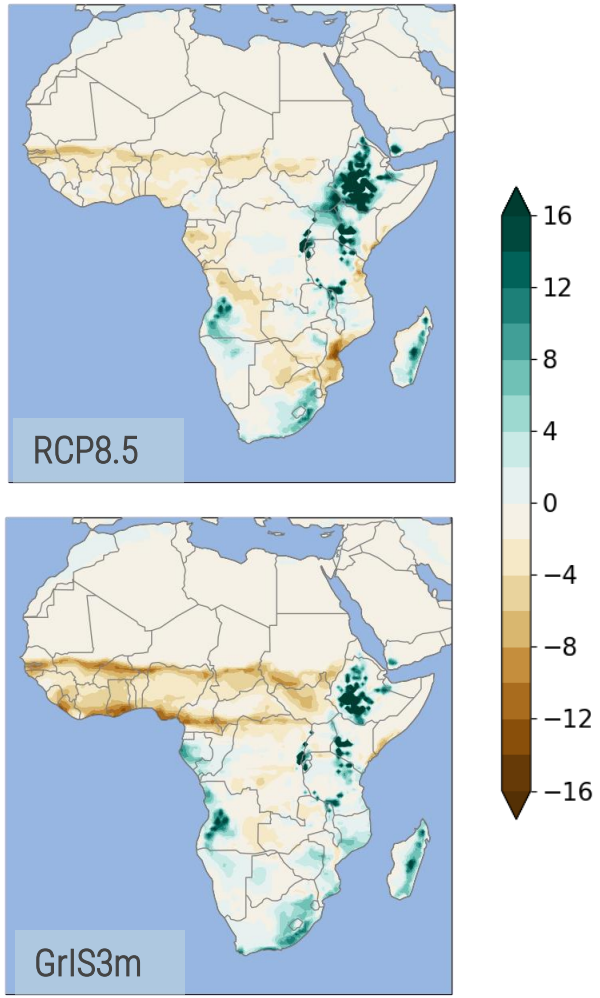
RESULTS

[2040-2050] – [2000-2020]
Annual mean

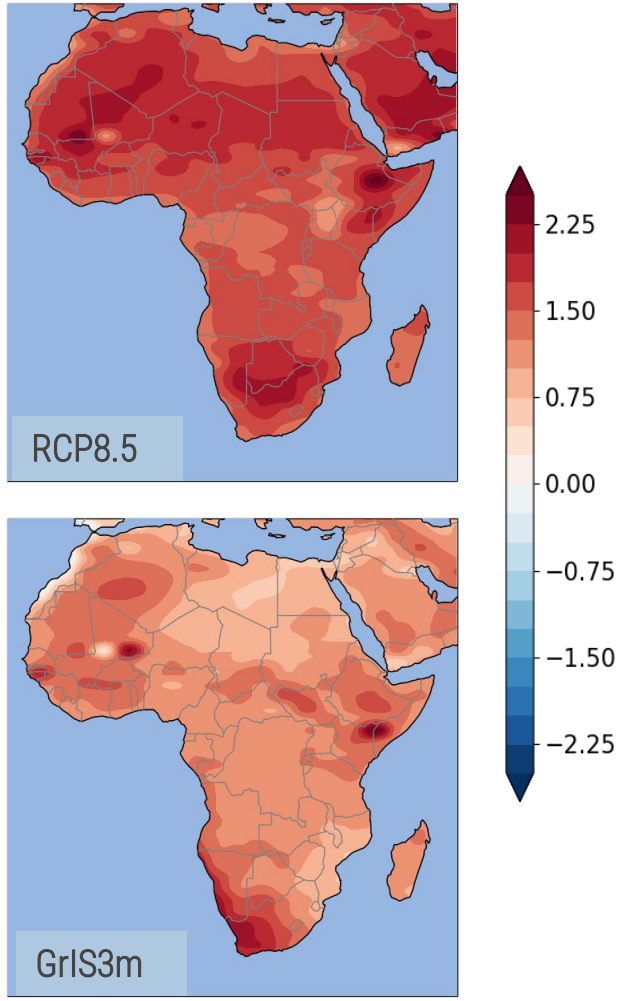
MALARIA RESULTS

- Increase in East Africa with increase of:
  - Temperature
  - Precipitation
- Decrease in West Africa with:
  - Temperature increase
  - Precipitation decrease for GRIS3m

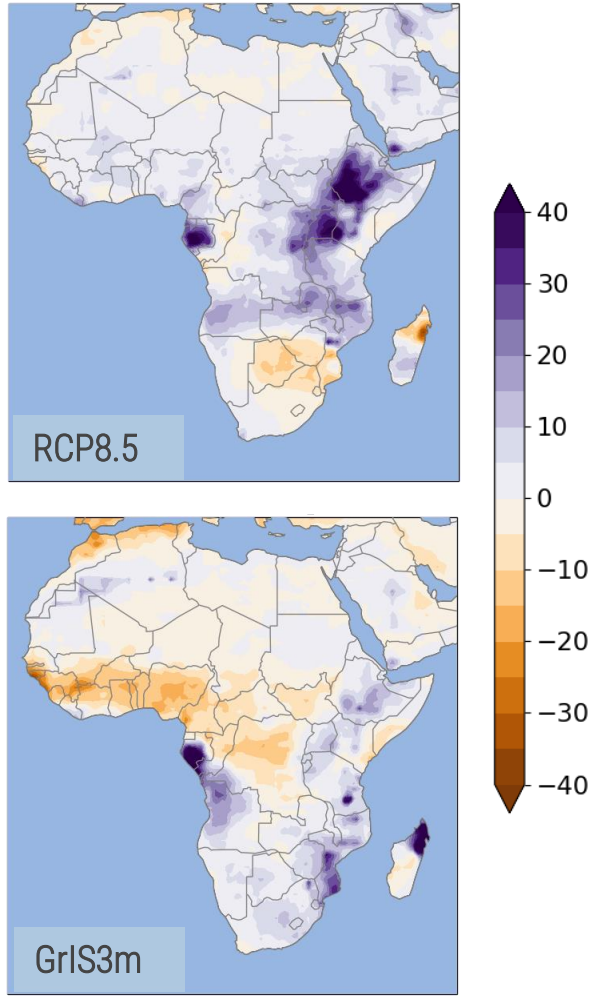
Δ Prevalence by LMM (%)



Δ Temperatures (°C)



Δ Precipitations (mm/month)



Chemison et al. (2021)

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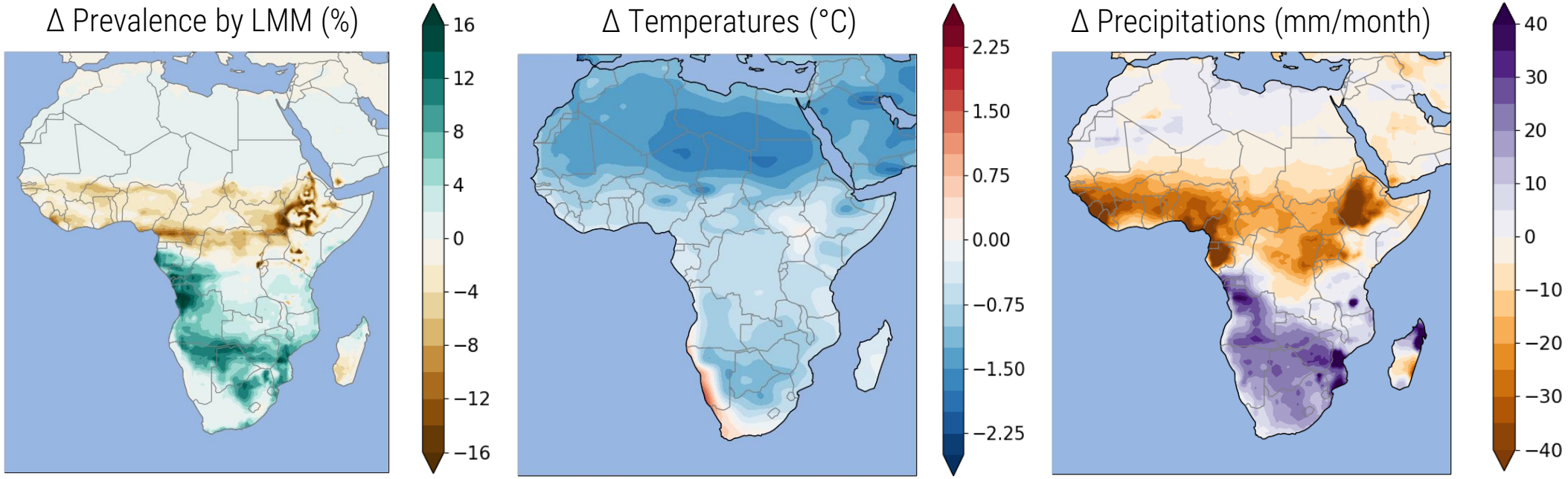
RESULTS

Additional effect of Greenland melting [GrIS3m – RCP8.5]

Annual mean [2040-2050]



❖ **Emerging malaria transmission risk in southern Africa** associated with a large increase in rainfall in this region

Chemison et al. (2021)

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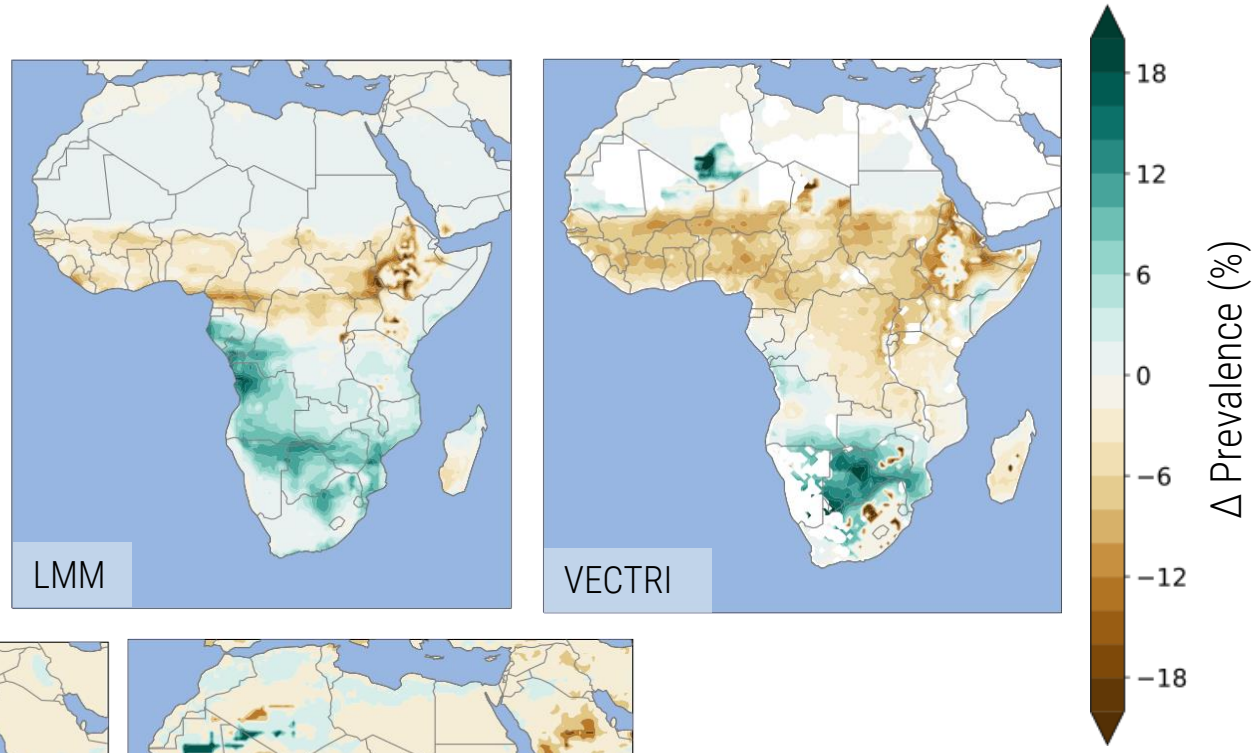
RESULTS

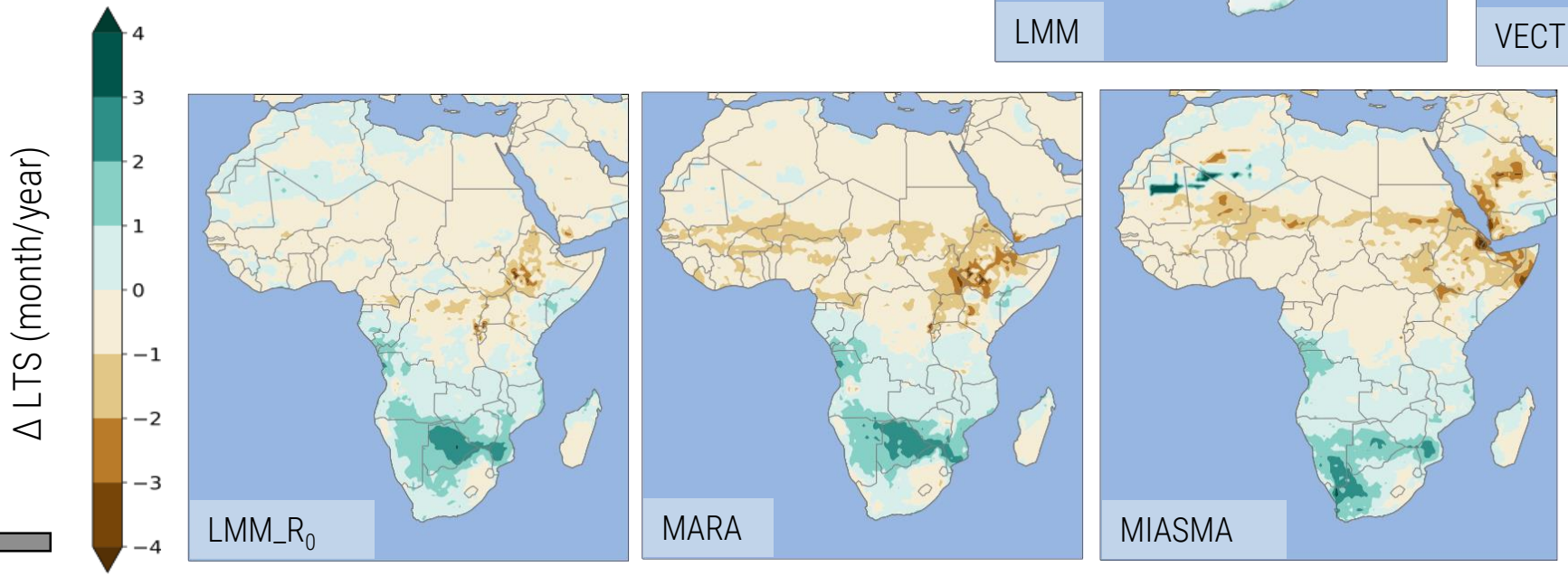
Additional effect of Greenland melting

[GrIS3m – RCP8.5]

Annual mean [2040-2050]

- The **results** are **similar** between the **different models**, especially for the risk increase in the southern of Africa





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CONCLUSION

Greenland melting

Release of fresh water in North Atlantic

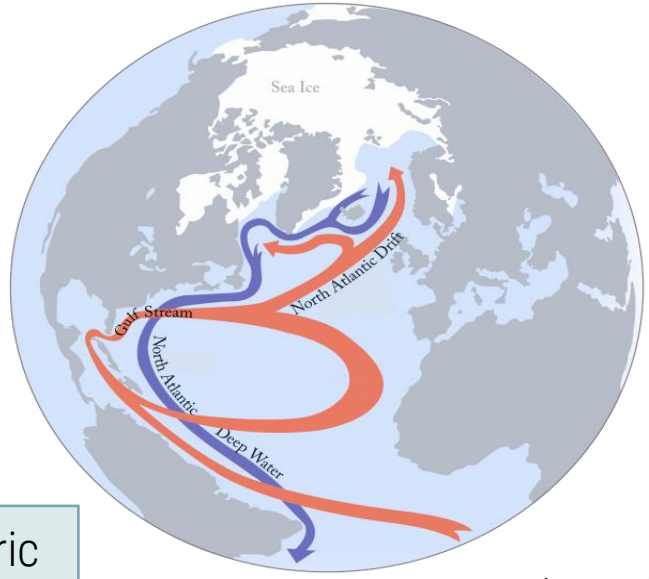
Slowdown of the AMOC*

Changes in atmospheric circulation

Climate change

Impacts on population

**AMOC : Atlantic meridional oceanic circulation*



Rahmstorf (1997)

KEYS RESULTS

With the melting of the Greenland ice sheet:

- Buffer effect of rising temperatures
- Shift of the rain band towards the south
- Changes in monsoon intensity, seasonality and location
- Strong results for Africa

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CONCLUSION

WEST AFRICA

- With RCP8.5: **Decrease in malaria risk**, linked to increased temperature
- With Greenland melting: **Amplified decrease** in malaria transmission risk due to reduced rainfall

EAST AFRICA

- With RCP8.5: **Increase in malaria risk** due to increased rainfall and temperature
- With Greenland melting: **Reduction in increase** due to moderation of temperature and precipitation increase respect to RCP8.5

SOUTHERN AFRICA

- With RCP8.5: no visible change
- With Greenland melting: **Emerging risk of malaria** transmission due to increased rainfall

The results are visible from the GrIS1m scenario and are amplified with GrIS3m

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