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ASSESSING THE IMPACT OF CLIMATE CHANGE ON MALARIA TRANSMISSION IN WEST AFRICA

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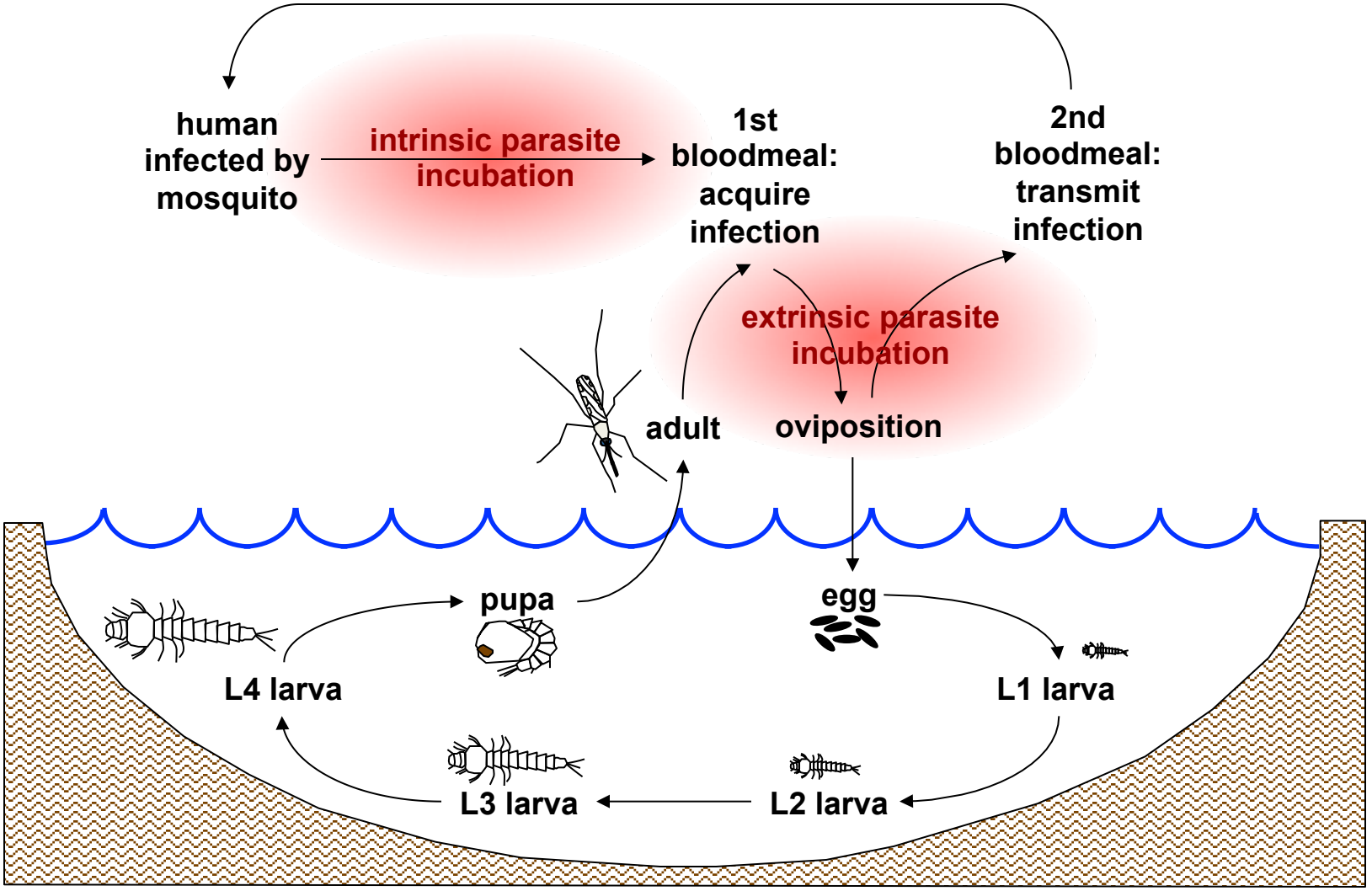
Research Question

- How will environmental suitability for malaria transmission in West Africa respond to climate change scenarios predicted by current GCMs?
- We expect warming alone to decrease transmission. However the combined impacts of warming and changing precipitation is unknown.

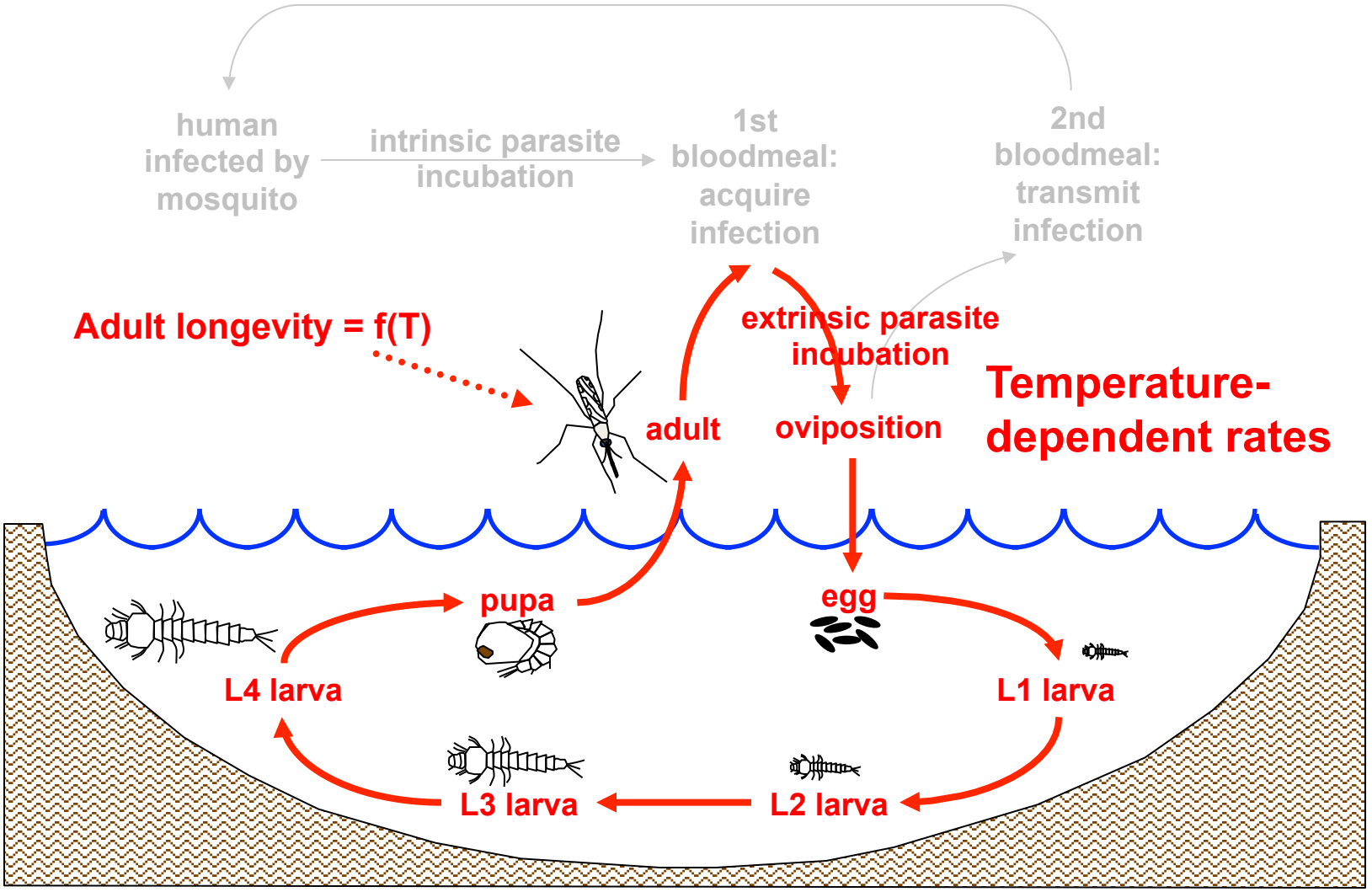
Relationship between climate and malaria

Anopheles gambiae mosquito ecology



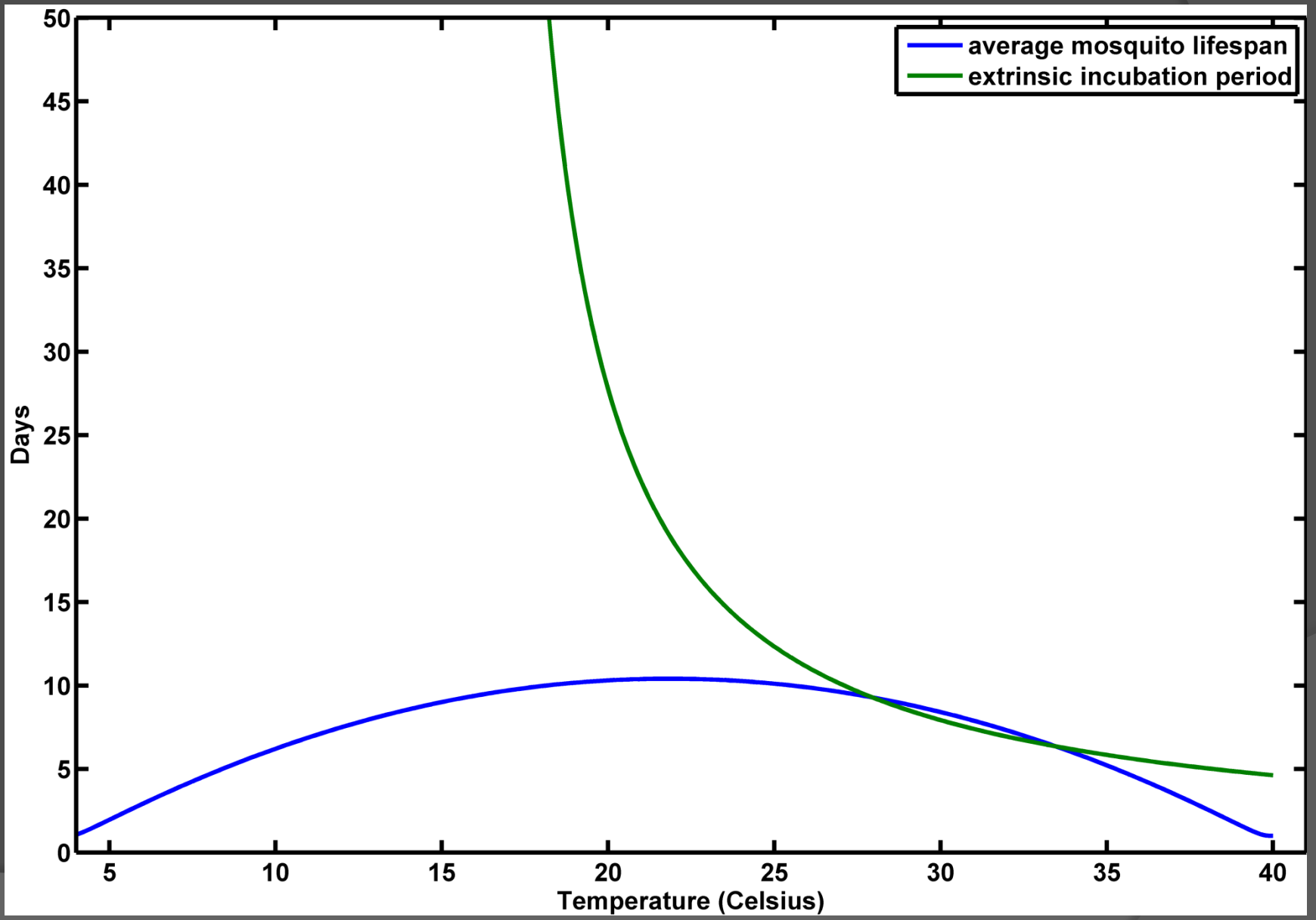
Bomblies, 2008

Anopheles mosquito ecology



Bomblies, 2008

Timescales of mosquito lifespan and malaria development



Measure of climate suitability: Vectorial Capacity

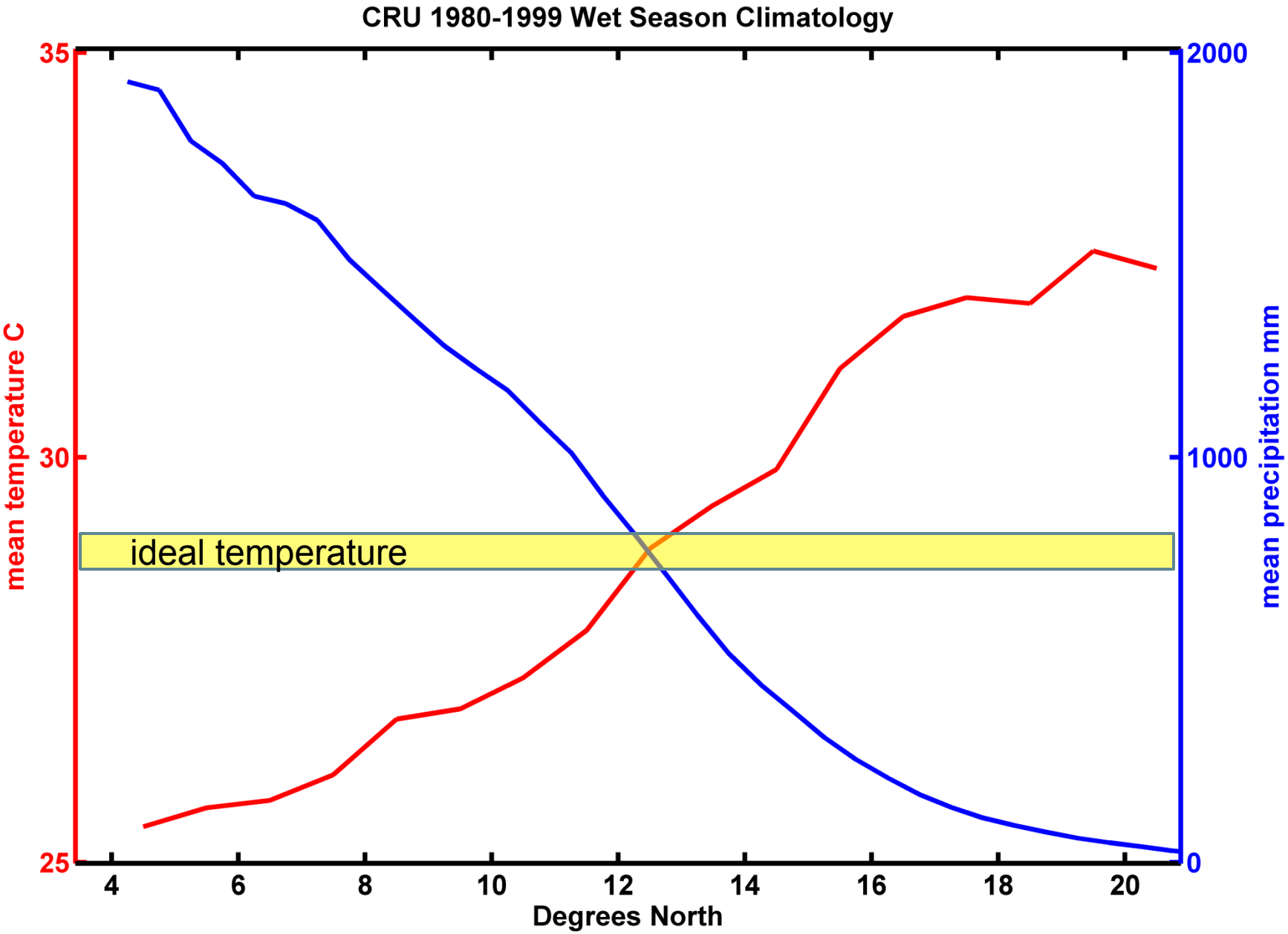
- **Vectorial Capacity: Number of inoculations from a single infected person per day**

$$VC = ma \times p^n \times d \times a$$

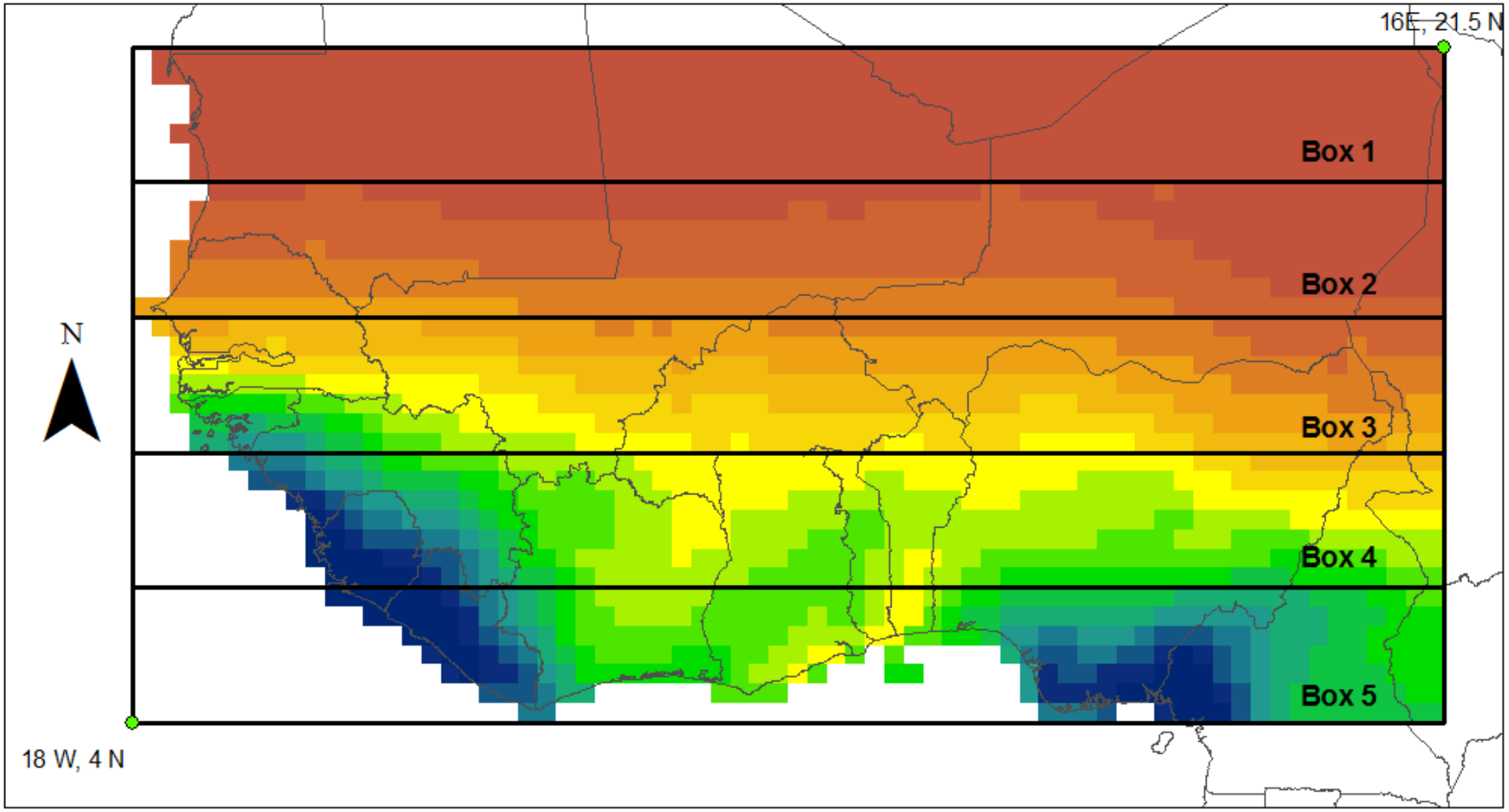
m: mosquitoes per human
a: bites per mosquito per day
p: probability mosquito survives one day
n: parasite development time in mosquito gut
d: average number of days until mosquito dies

p,n and *d* depend on temperature
m and *a* depend on temperature and rainfall

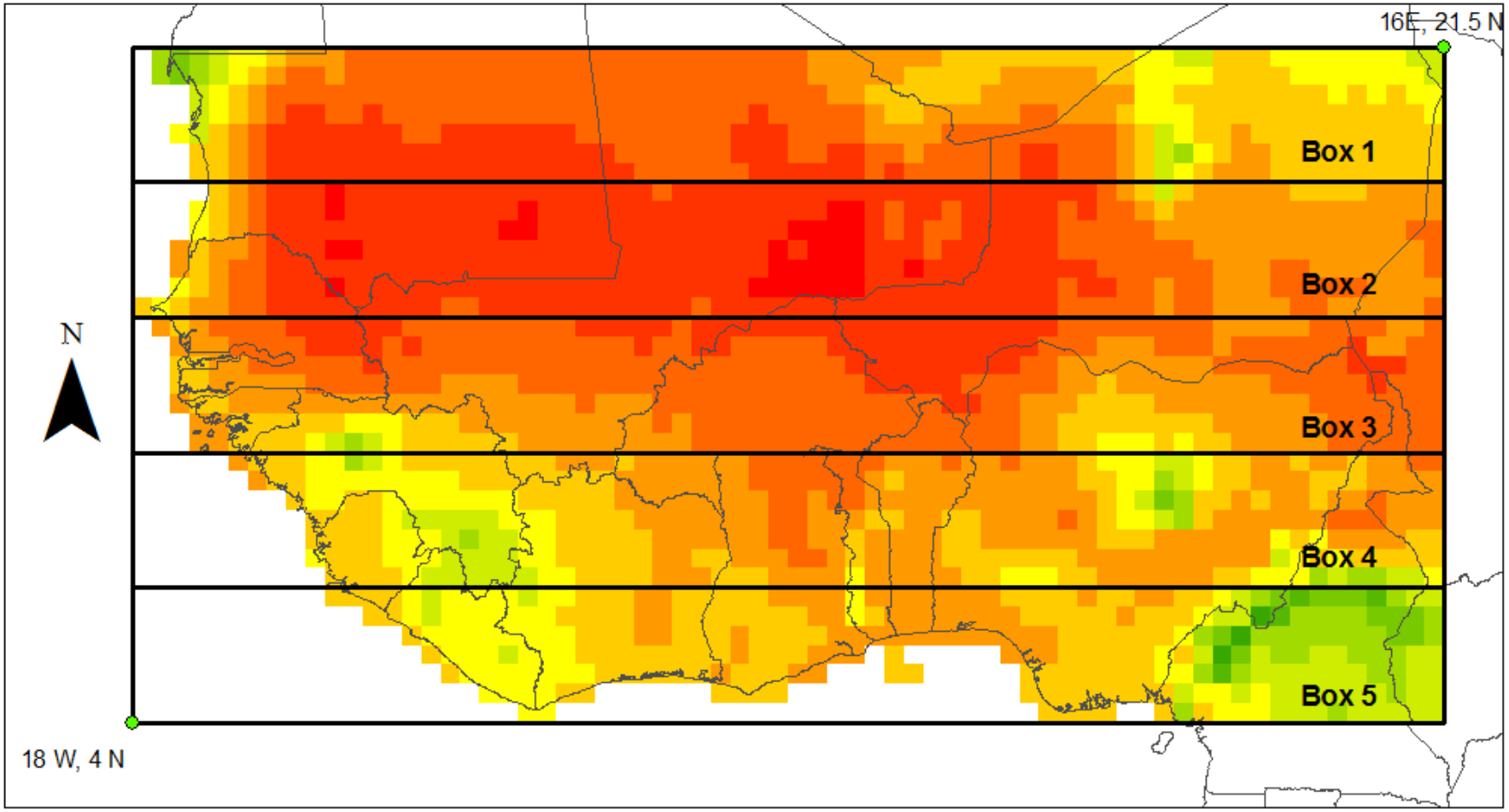
Current climate in West Africa


CRU 1980-1999 Wet Season Climatology
35
30
25
2000
1000
0
mean temperature C
mean precipitation mm
ideal temperature
4
6
8
10
12
14
16
18
20
Degrees North

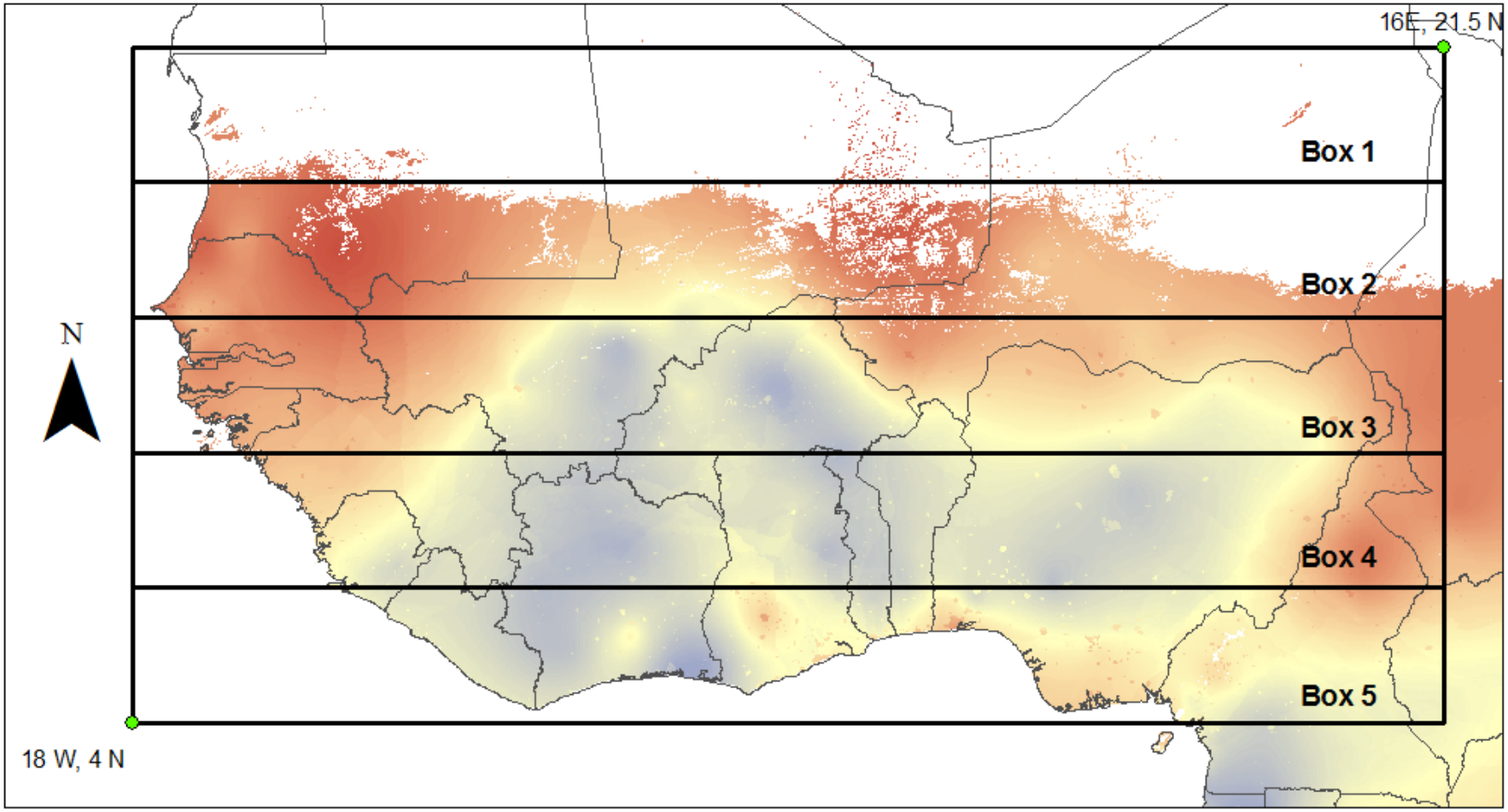
West Africa mean annual rainfall
CRU 1980-1999



West Africa mean annual temperature
CRU 1980-1999



West Africa malaria prevalence
Malaria Atlas Project



Legend

prevalence

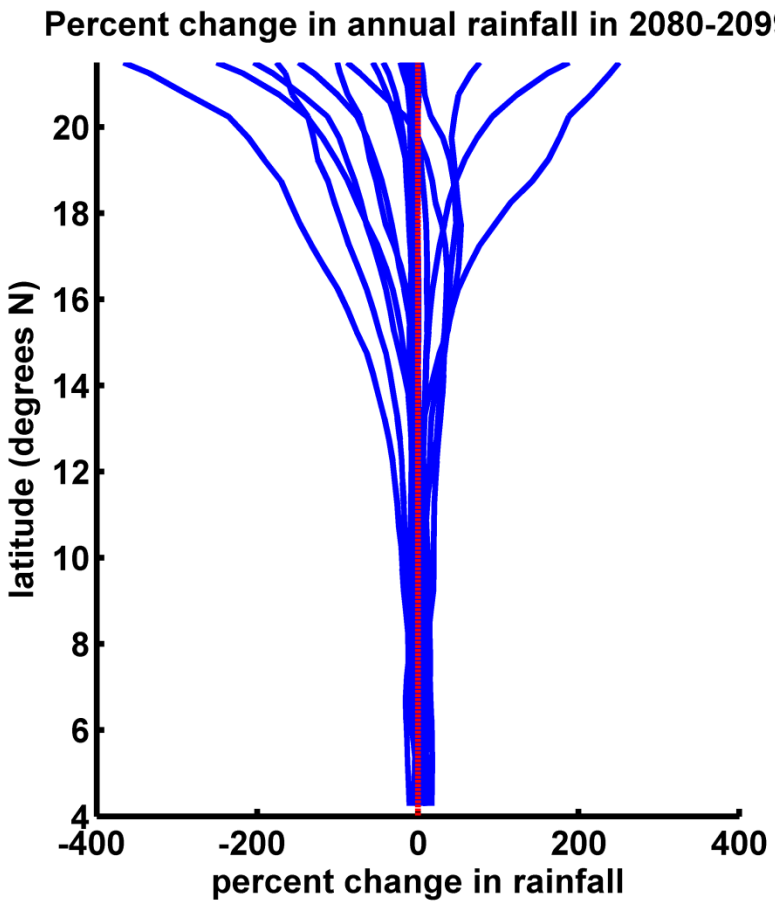
High : 1

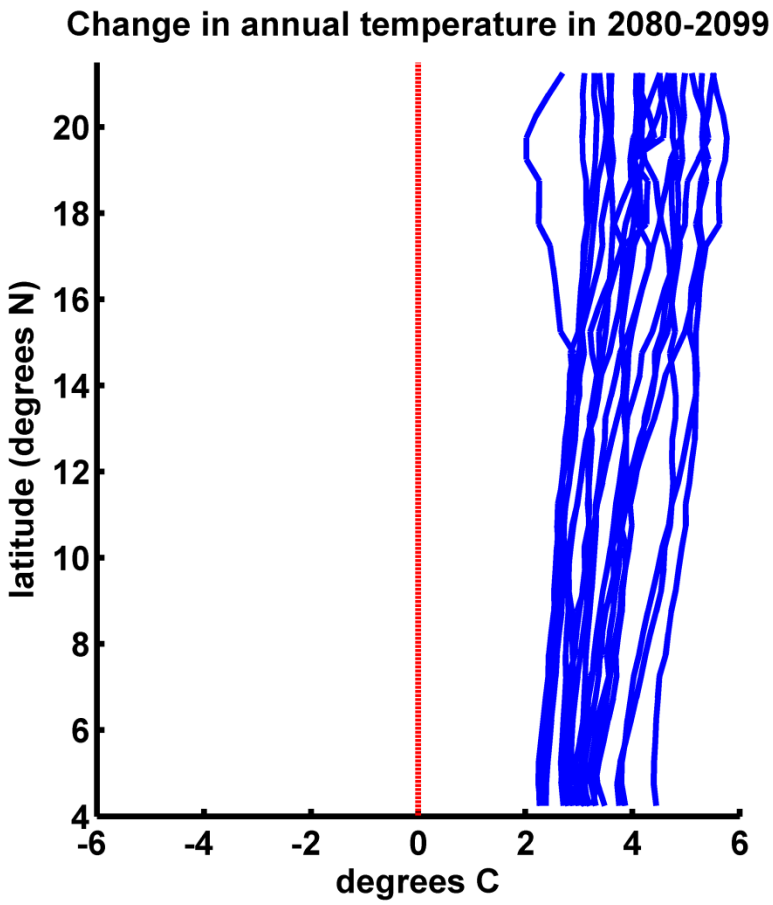
Low : 0

Citation: Hay, S.I. *et al.* (2009). A world malaria map: *Plasmodium falciparum* endemicity in 2007. *PLoS Medicine* **6**(3): e1000048.

Predicted climate in west africa

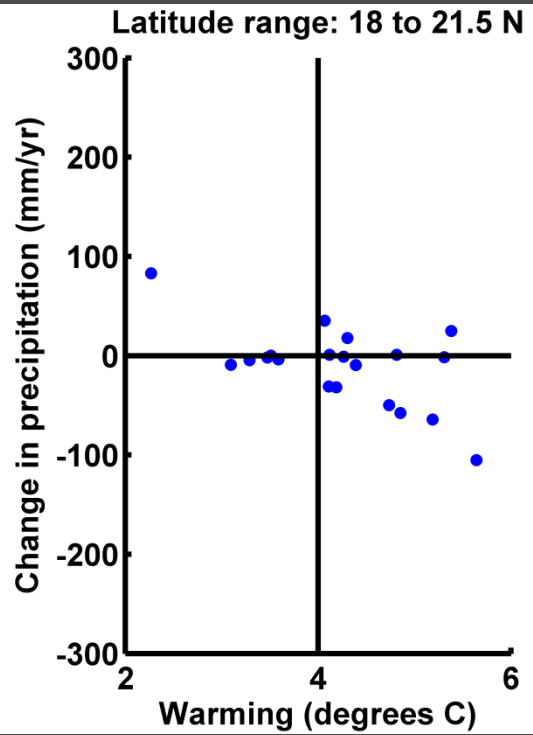
Change in climate predicted by IPCC Assessment Report 4 A1B emissions scenario





Changes predicted by IPCC models

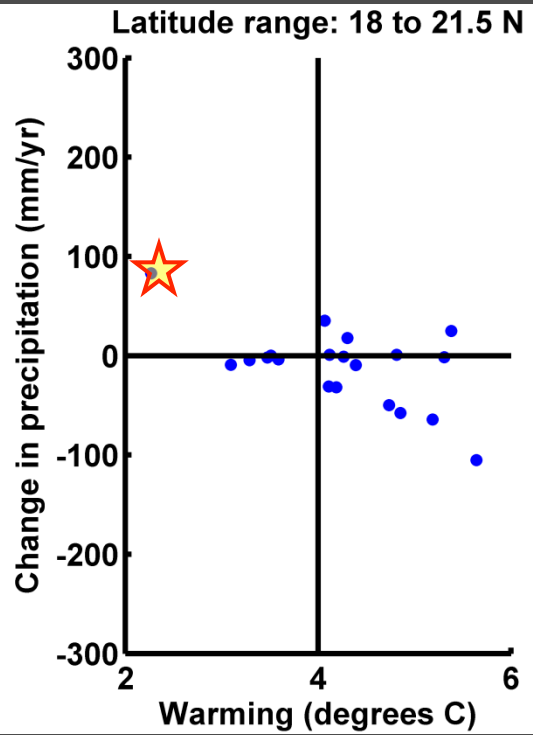
Box 1



Change in climate predicted by a GCM

Changes predicted by IPCC models

Box 1

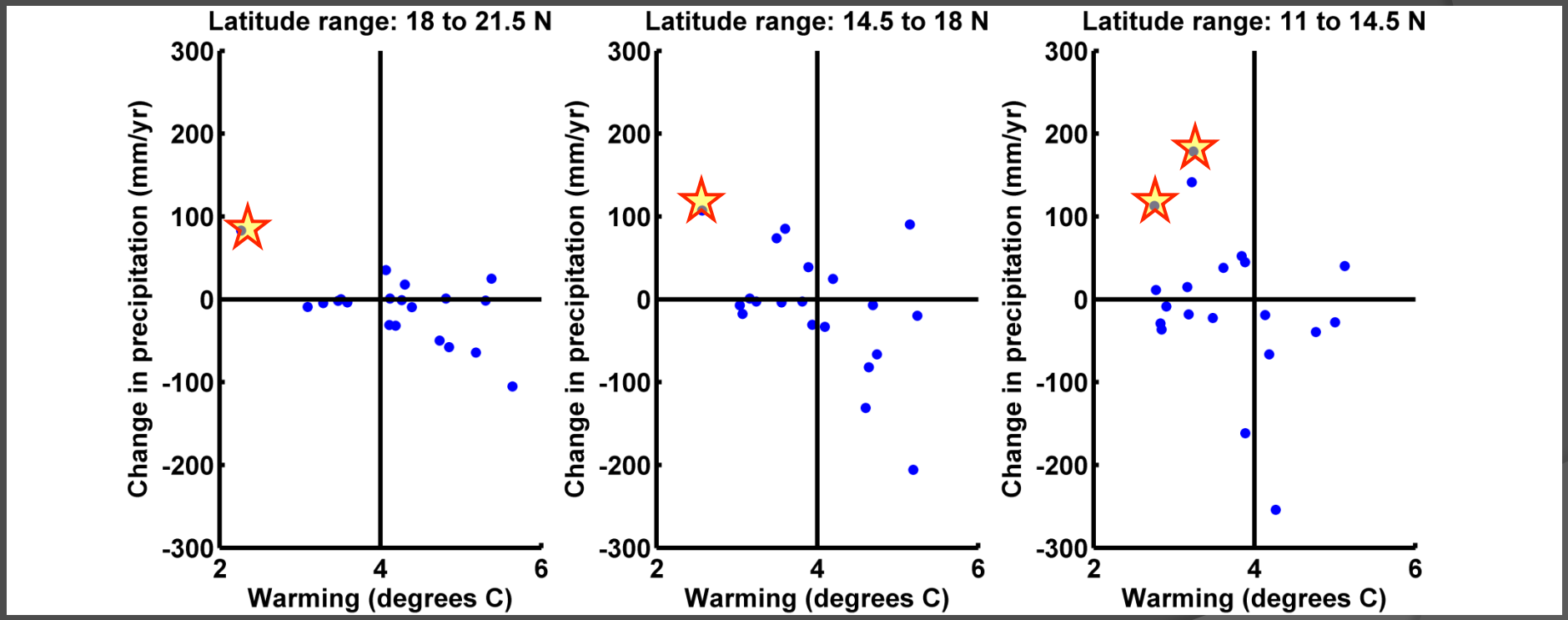


Worst case outcome

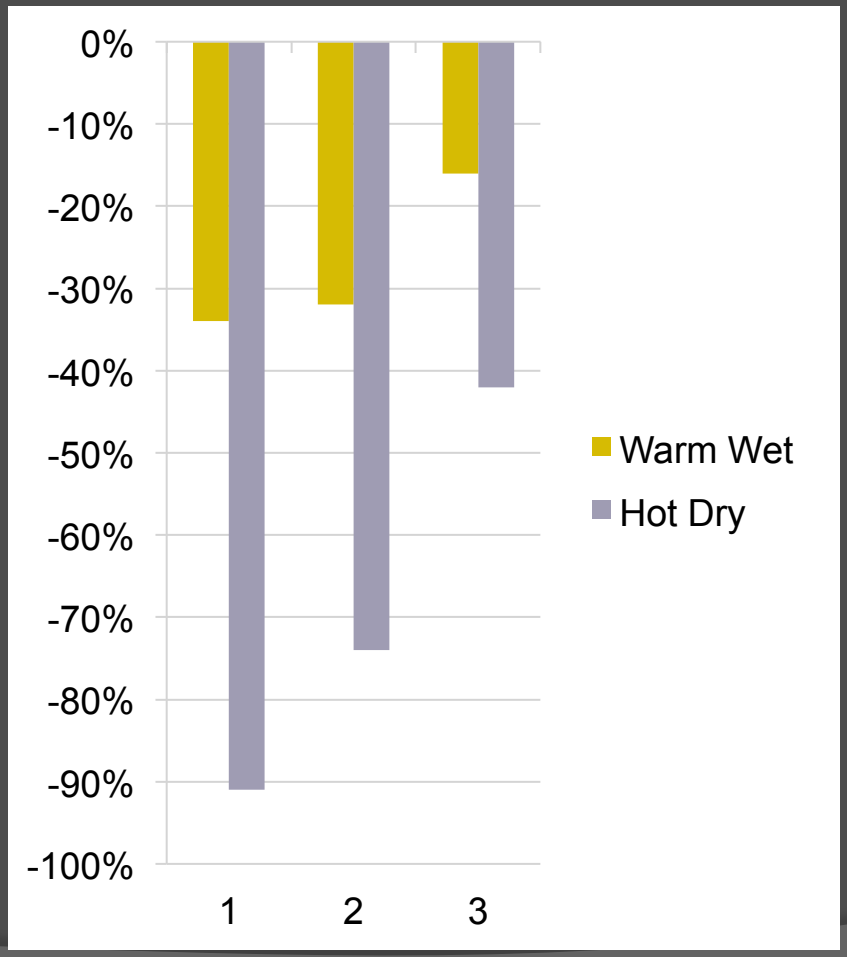
Change in climate predicted by a GCM

Changes predicted by IPCC models

Box 1 Box 2 Box 3



Change in Vectorial Capacity due to temperature alone



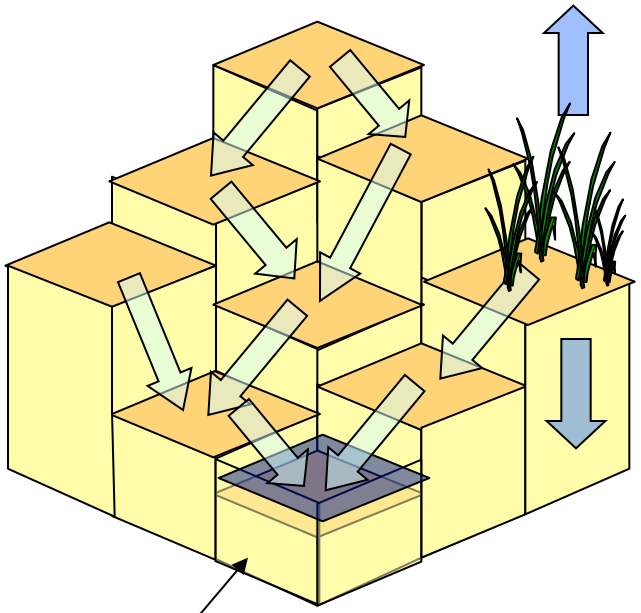
$$VC = ma \times p^n \times d \times a$$

- Warm Wet:
  - Maximum increase in precipitation and minimum increase in temperature
  - "Worst Case Scenario"
- Hot Dry:
  - Minimum Increase in precipitation and maximum increase in temperature
  - "Best Case Scenario"

Hydrology, Entomology and Malaria Transmission Simulator

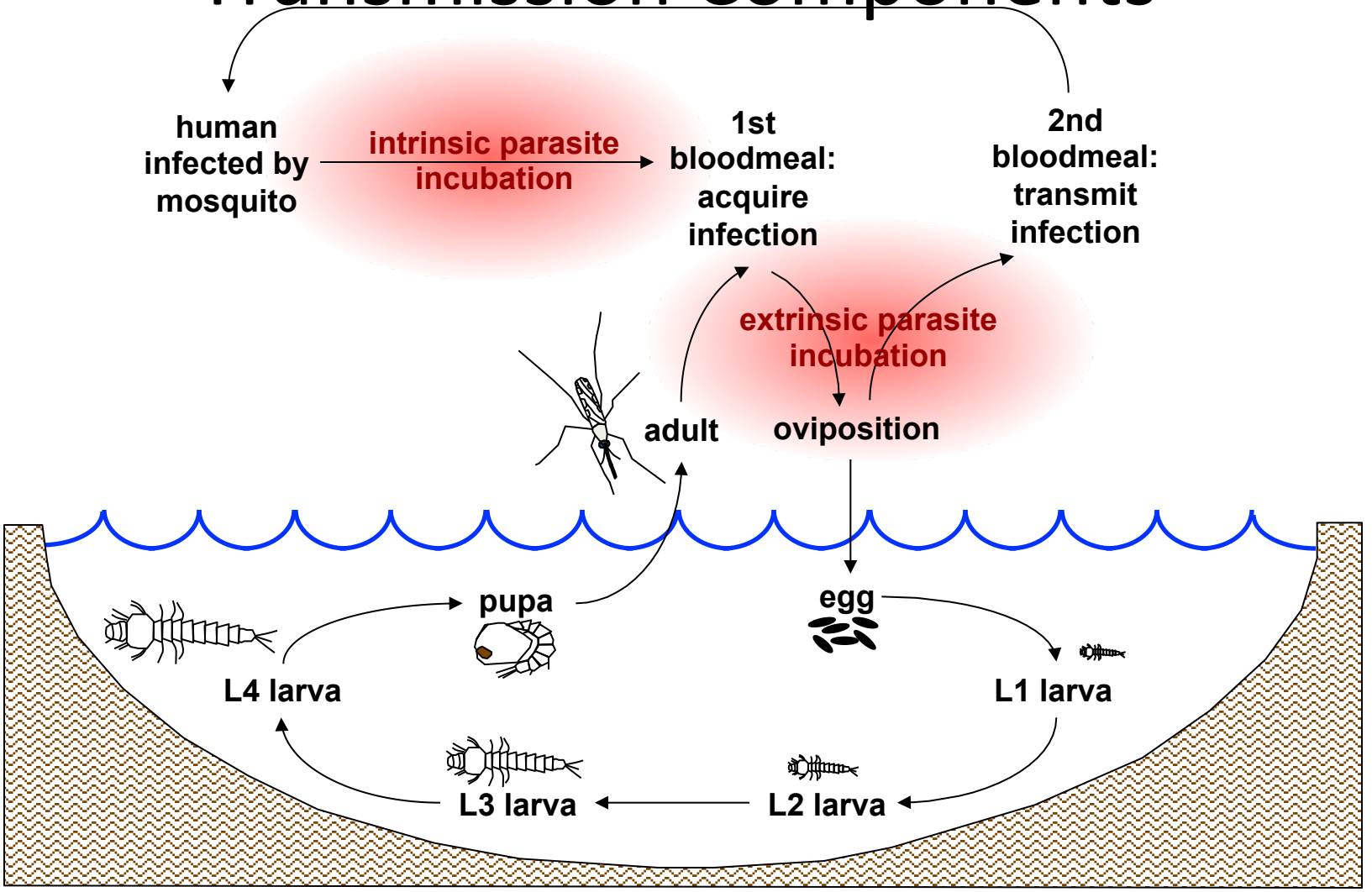
Model Description: HYDREMATS

HYDREMATS: Hydrology component



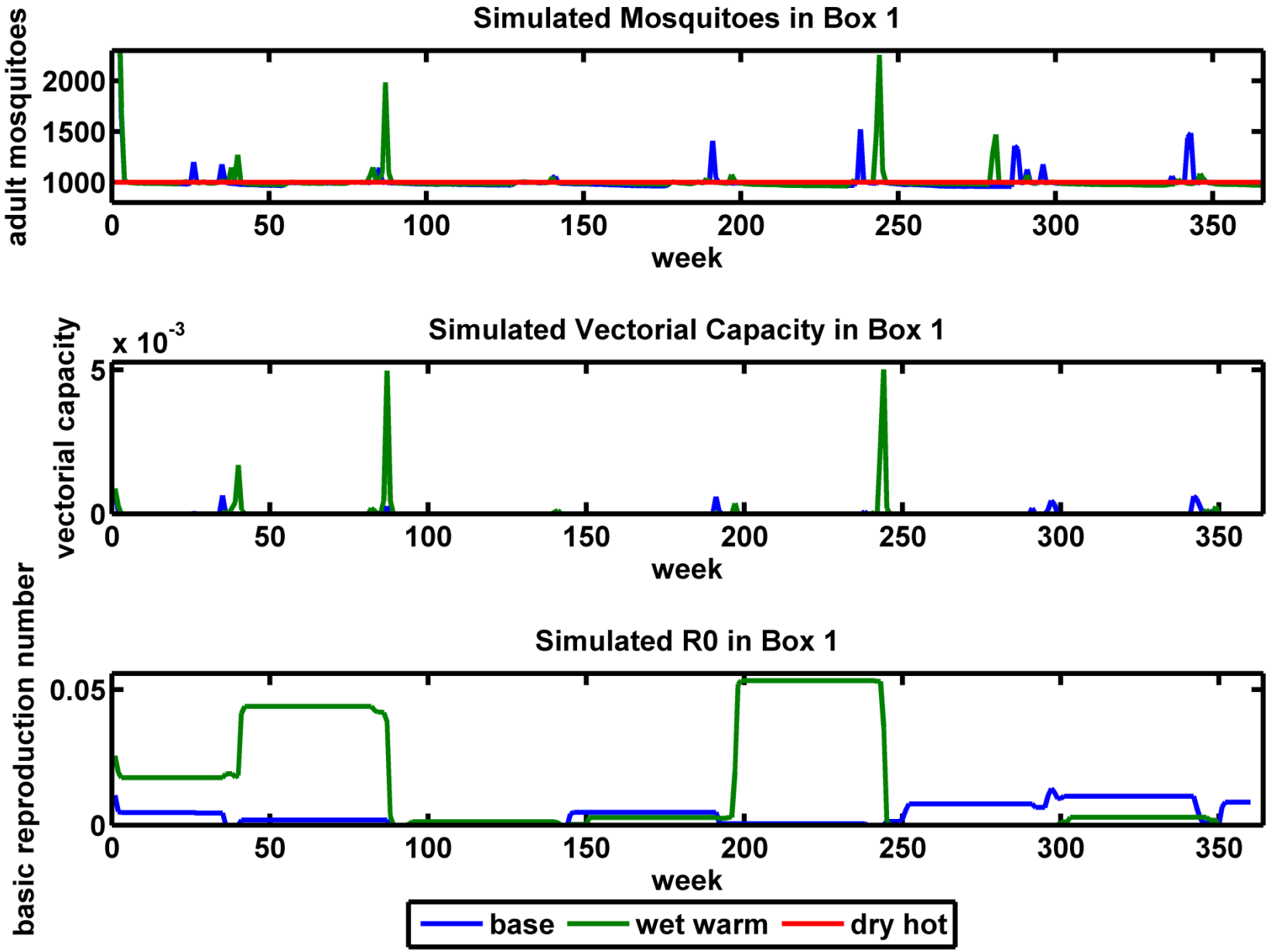
Overland flow model will pool water and simulate pool losses to infiltration/evaporation

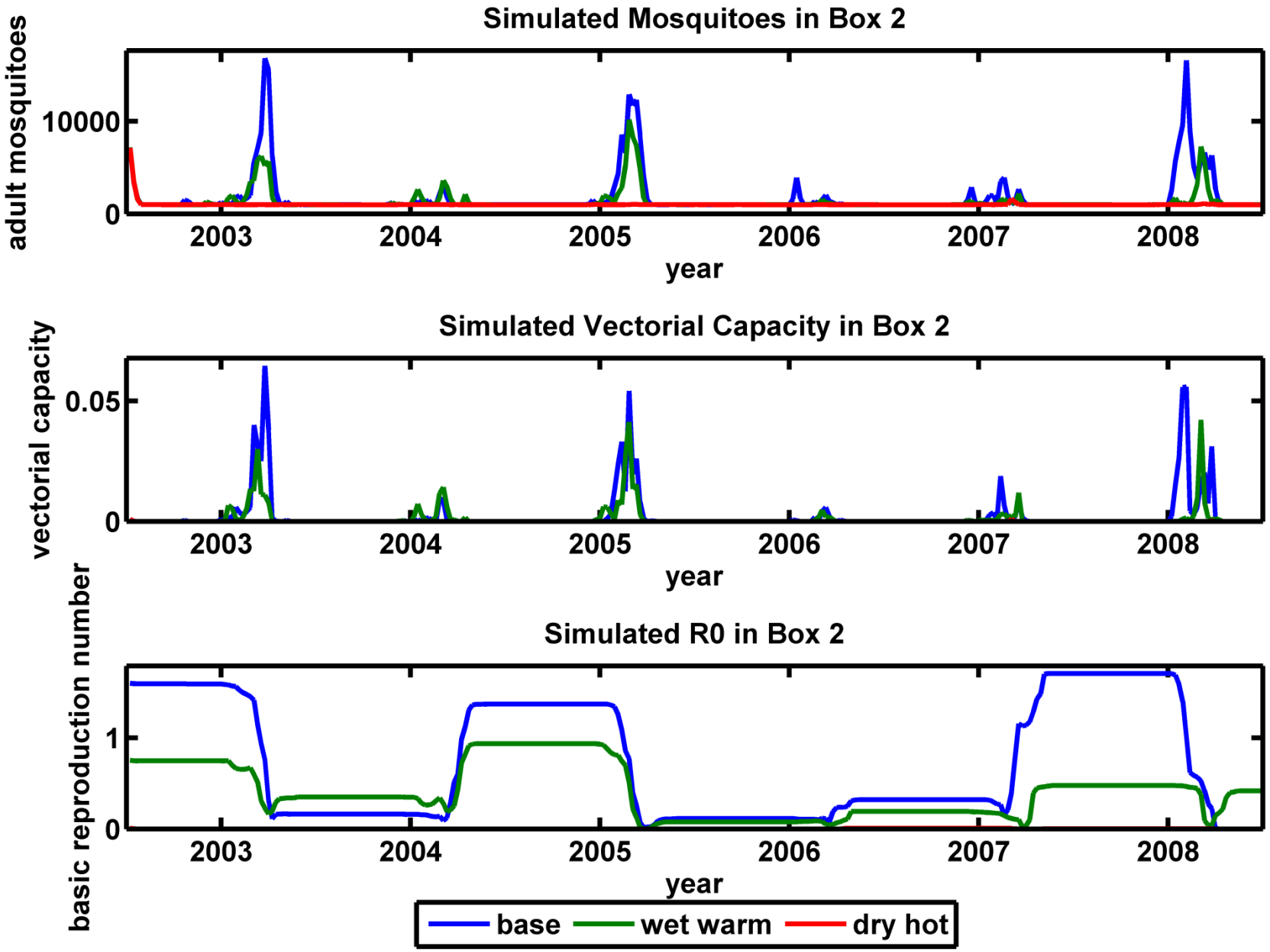
HYDREMATS: Entomology and Malaria Transmission Components

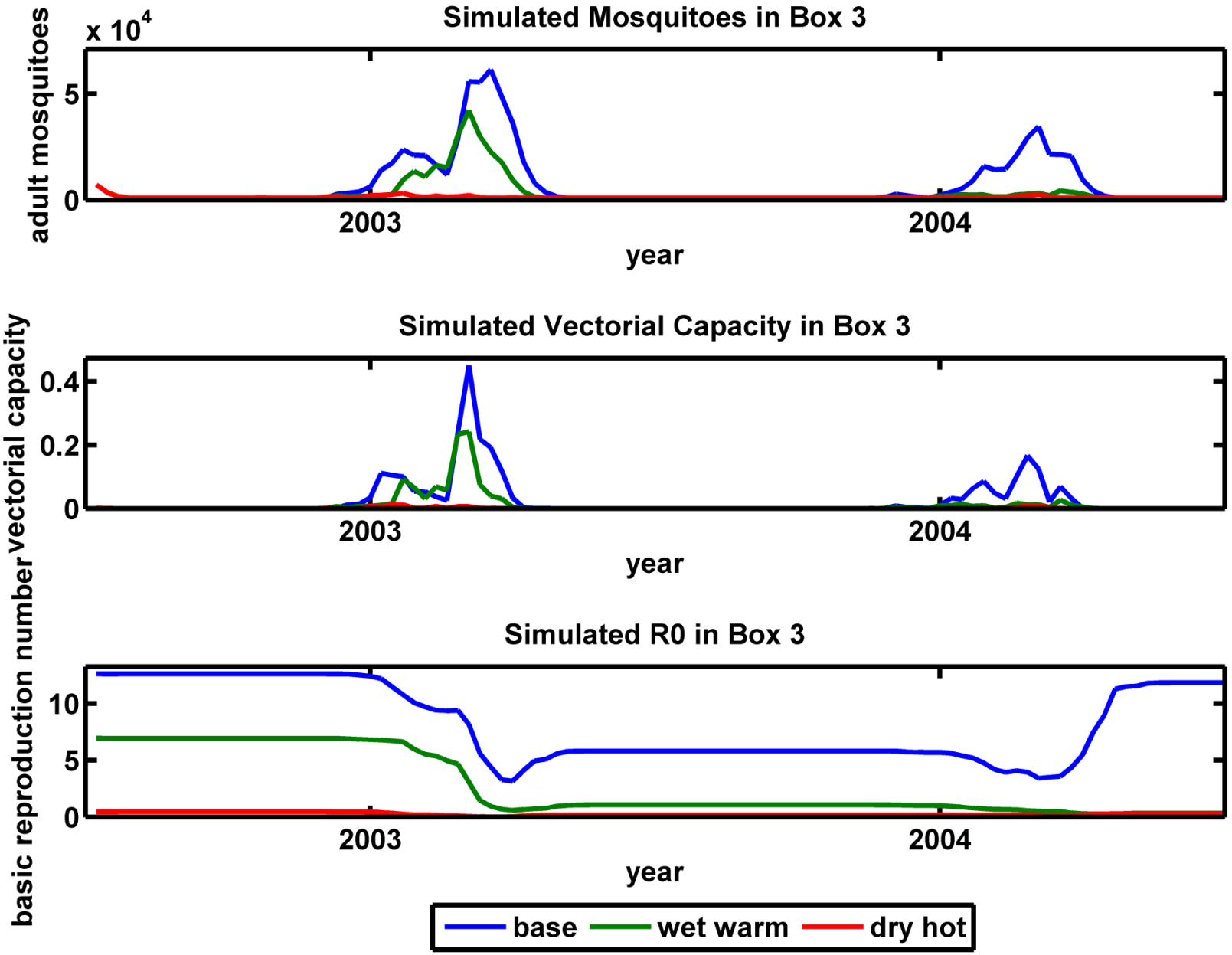


Bomblies, 2008

Preliminary results from HYDREMATS


Simulated Mosquitoes in Box 1
adult mosquitoes
2000
1500
1000
0
50
100
150
200
250
300
350
week
Simulated Vectorial Capacity in Box 1
x 10^-3
vectorial capacity
5
0
week
Simulated R0 in Box 1
basic reproduction number
0.05
0
week
base
wet warm
dry hot


Simulated Mosquitoes in Box 2
adult mosquitoes
10000
0
2003
2004
2005
2006
2007
2008
year
Simulated Vectorial Capacity in Box 2
vectorial capacity
0.05
0
2003
2004
2005
2006
2007
2008
year
Simulated R0 in Box 2
basic reproduction number
1
0
2003
2004
2005
2006
2007
2008
year
base
wet warm
dry hot


Simulated Mosquitoes in Box 3
x 10^4
adult mosquitoes
5
0
2003
2004
year
Simulated Vectorial Capacity in Box 3
vectorial capacity
0.4
0.2
0
2003
2004
year
Simulated R0 in Box 3
basic reproduction number
10
5
0
2003
2004
year
base
wet warm
dry hot

Conclusions

Conclusions

- There is a wide range of climate change predictions in West Africa using current IPCC general circulation models
- Even under the worst case scenario, we do not expect to see a significant increase of malaria transmission in this region

Acknowledgements

- Advisor Elfatih Eltahir
- Arne Bomblies, University of Vermont
- NSF
- Data sources
  - NOAA CPC Morphing technique (CMORPH)
  - University of East Anglia CRU TS 3.1
  - IPCC AR4 SRES scenarios monthly climatologies
  - Malaria Atlas Project

Extra slides

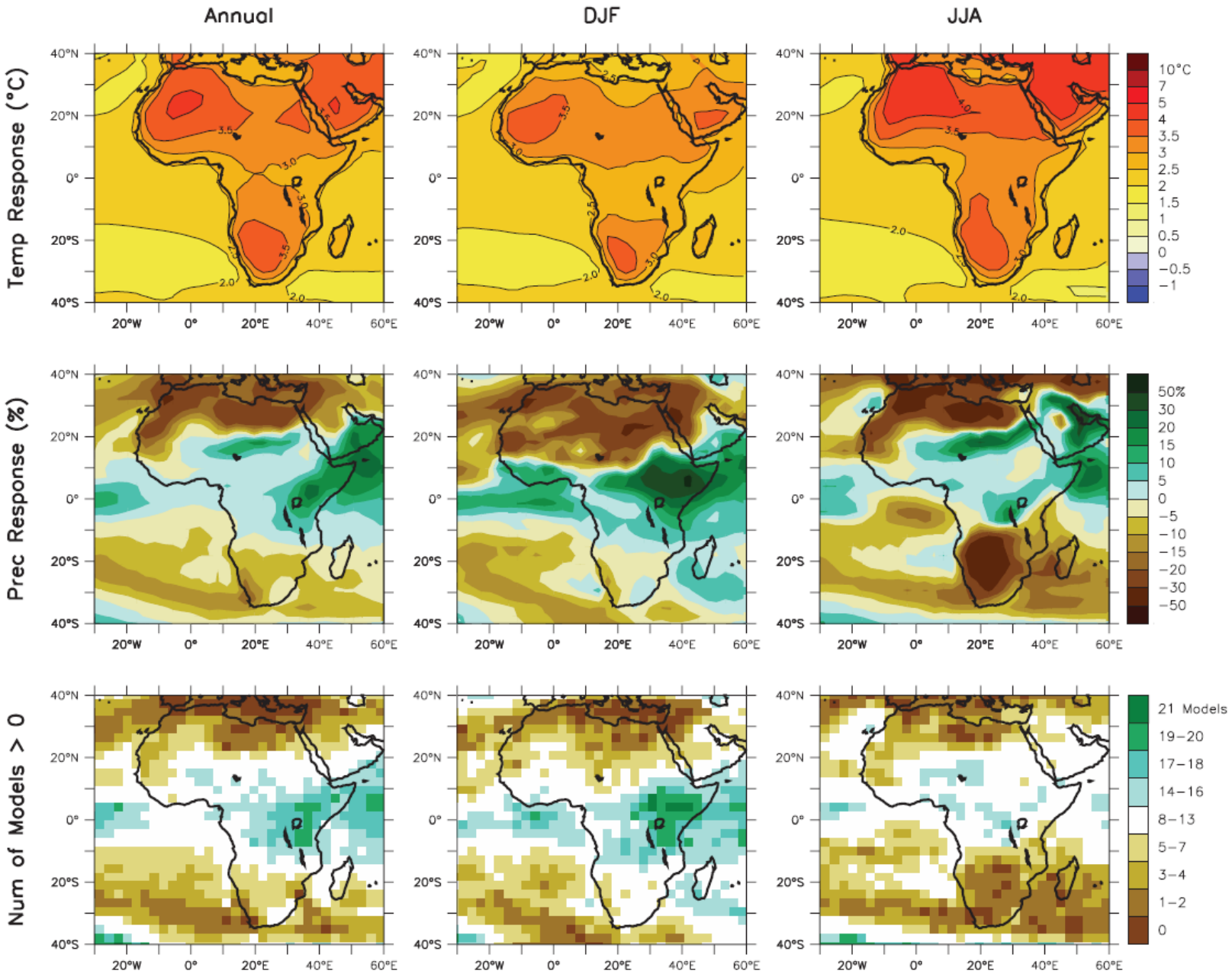


Figure 11.2. *Temperature and precipitation changes over Africa from the MMD-A1B simulations. Top row: Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Middle row: same as top, but for fractional change in precipitation. Bottom row: number of models out of 21 that project increases in precipitation.*

Range of predicted changes in temperature

Box	CRU 1980-1999: temperature in rainy months	Max rainy season increase 2080-2099	Model predicting max increase	Min rainy season increase 2080-2099	Model predicting min increase
1	32.2	5.6	GFDL/NOAA	2.3	NCAR - CCSM
2	31.3	5.2	ECHAM	2.6	NCAR - CCSM
3	28.9	5.1	University of Tokyo – MIROC high-res	2.8	NCAR - CCSM
4	26.8	4.8	University of Tokyo – MIROC high-res	2.6	NASA/GISS - AOM
5	25.7	4.4	University of Tokyo – MIROC high-res	2.3	CSMK3

Range of predicted changes in rainfall

Box	CRU 1980-1999	Max increase 2080-2099	wettest	Max decrease 2080-2099	driest
1	52	83	NCAR	-105	GFDL/NOAA
2	223	107	NCAR	-206	GFDL/NOAA
3	715	178	ECHAM + HOPEG	-254	GFDL/NOAA
4	1286	214	ECHAM + HOPEG	-212	GFDL/NOAA
5	1743	295	NASA/GISS E-H	-227	University of Tokyo – MIROC med-res