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The Response of Environmental Capacity for Malaria Transmission in West Africa to Climate Change

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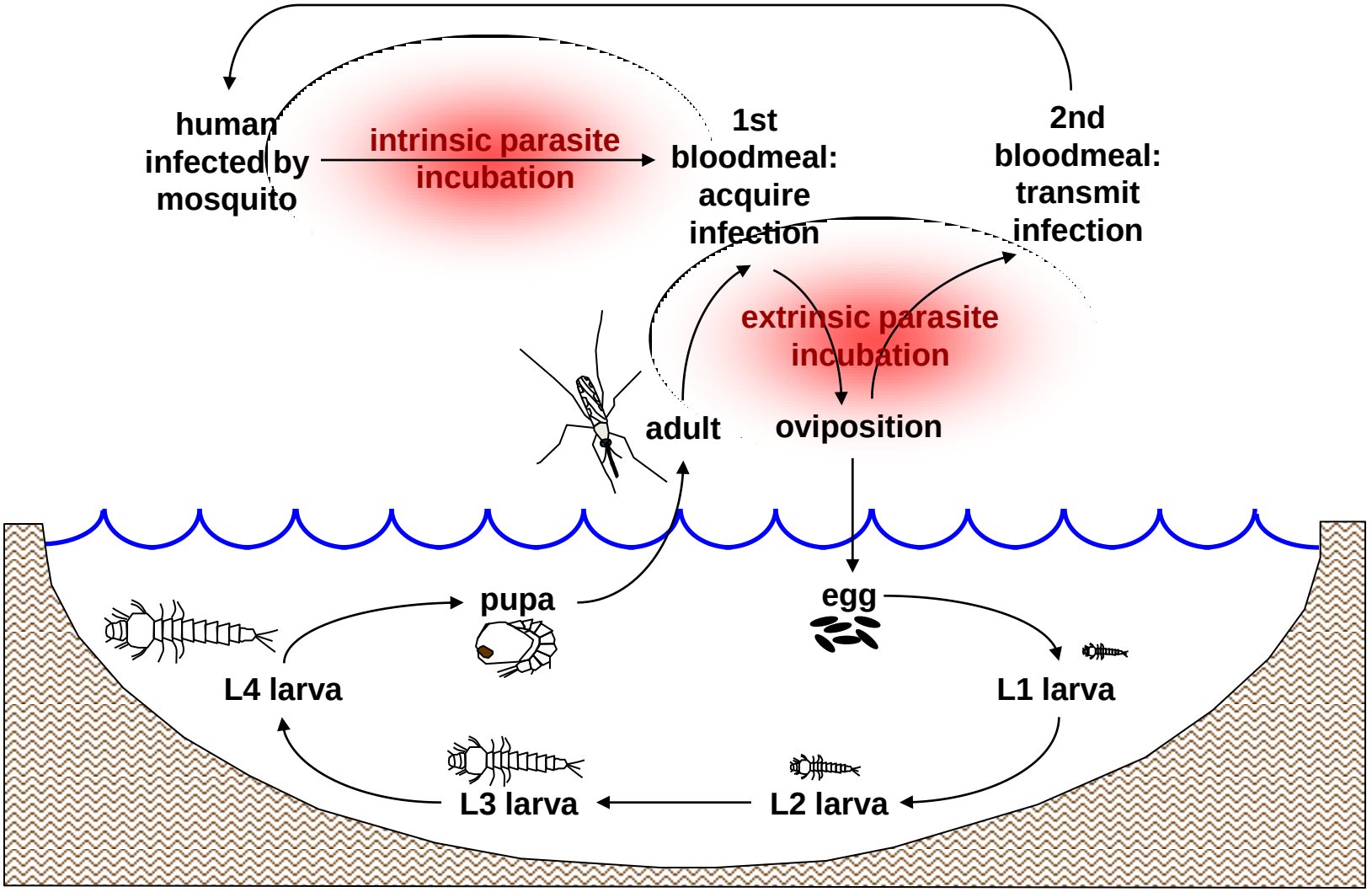
Research Question

- How will environmental suitability for malaria transmission in West Africa respond to climate change scenarios predicted by current GCMs?
- In some scenarios, the effects of warming and changing precipitation act in opposite directions, so the overall effect of malaria transmission is unknown.

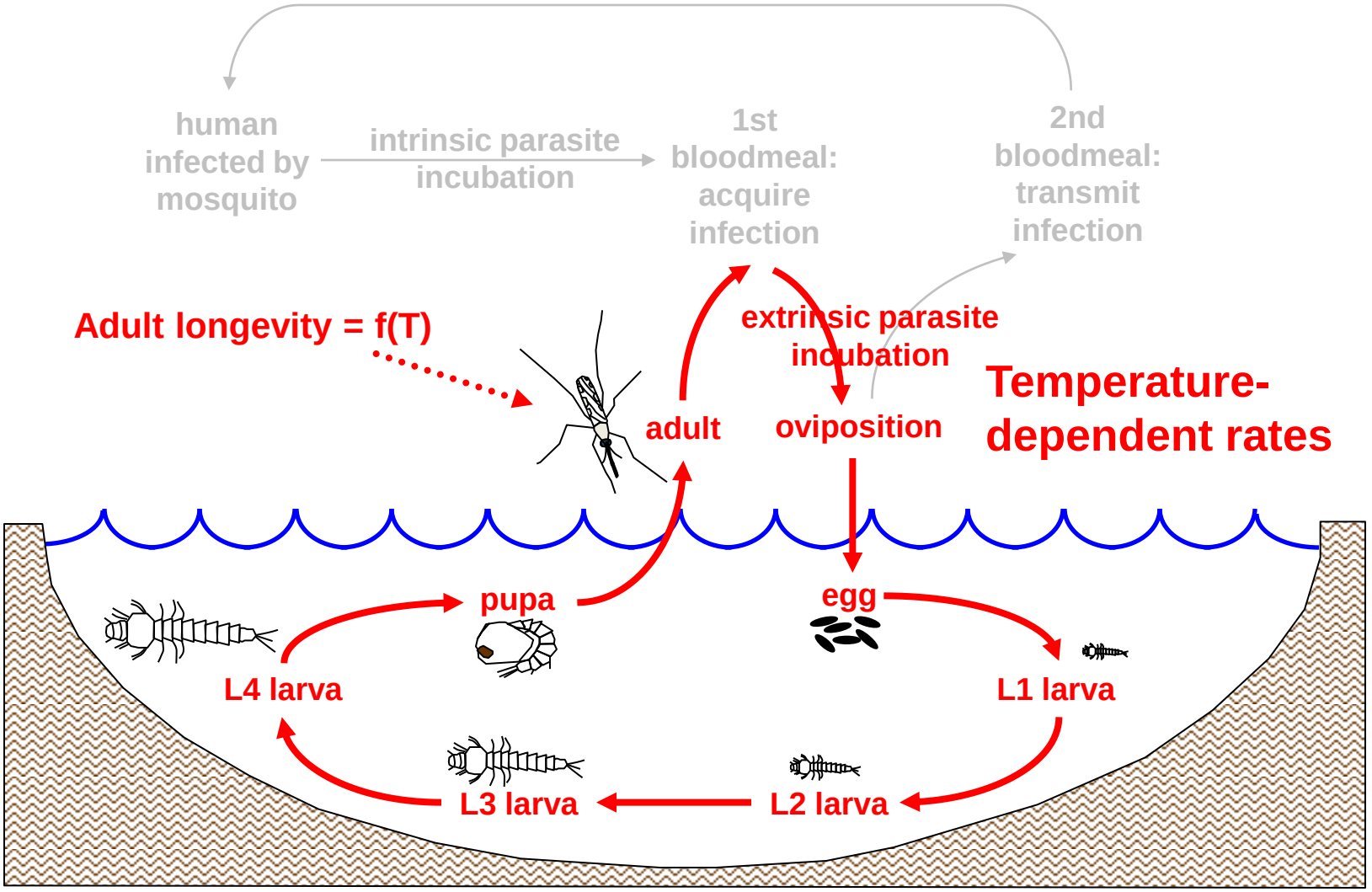
RELATIONSHIP BETWEEN CLIMATE AND MALARIA

Anopheles gambiae mosquito ecology



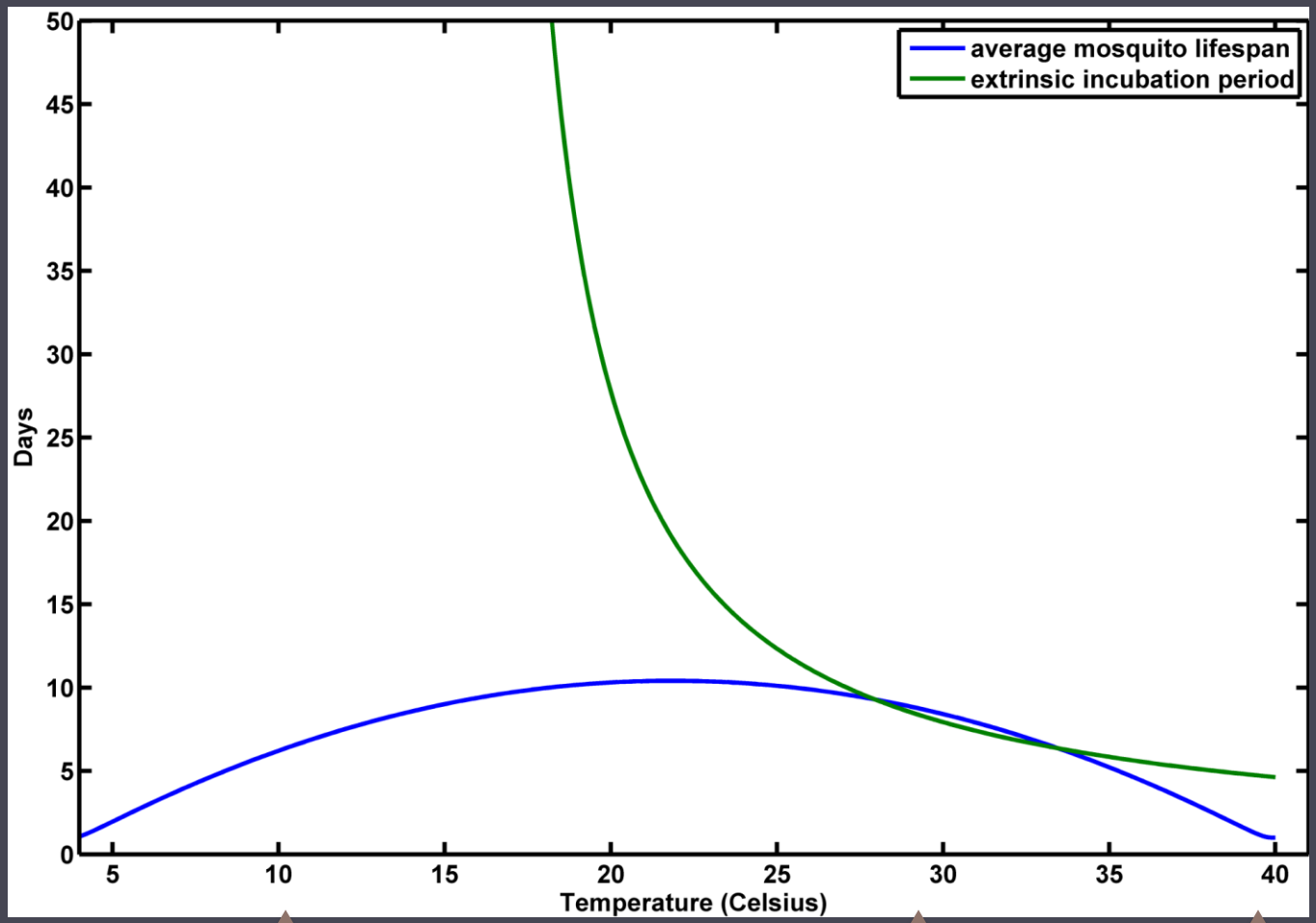
Bomblies, 2008

Anopheles mosquito ecology



Bomblies, 2008

Timescales of mosquito lifespan and malaria development



EIP too long: no transmission

Ideal for transmission

Too hot for mosquito

Measure of climate suitability: Vectorial Capacity

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

$$VC = ma^2 \times p^n \times d$$

m: mosquitoes per human
a: bites per mosquito per day
p: probability mosquito survives one day
n: extrinsic incubation period
d: average number of days until mosquito dies

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

Measure of climate suitability: Vectorial Capacity

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$$VC = ma^2 \times p^n \times d$$

Temperature dependent equations

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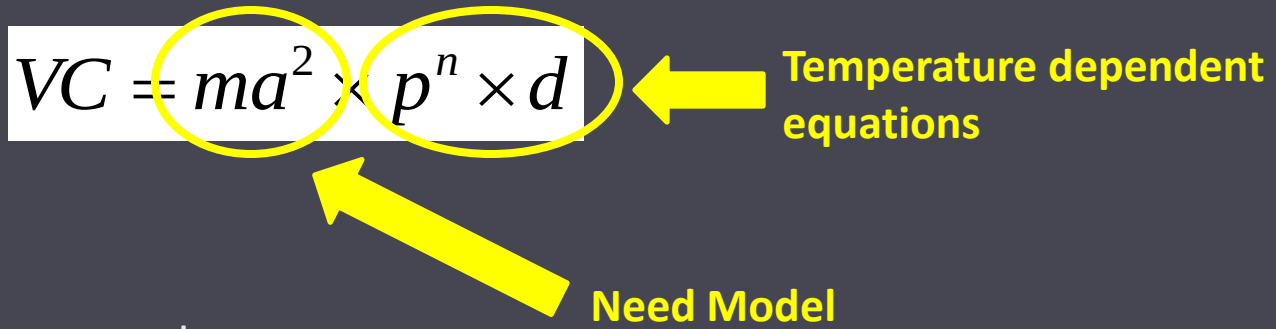

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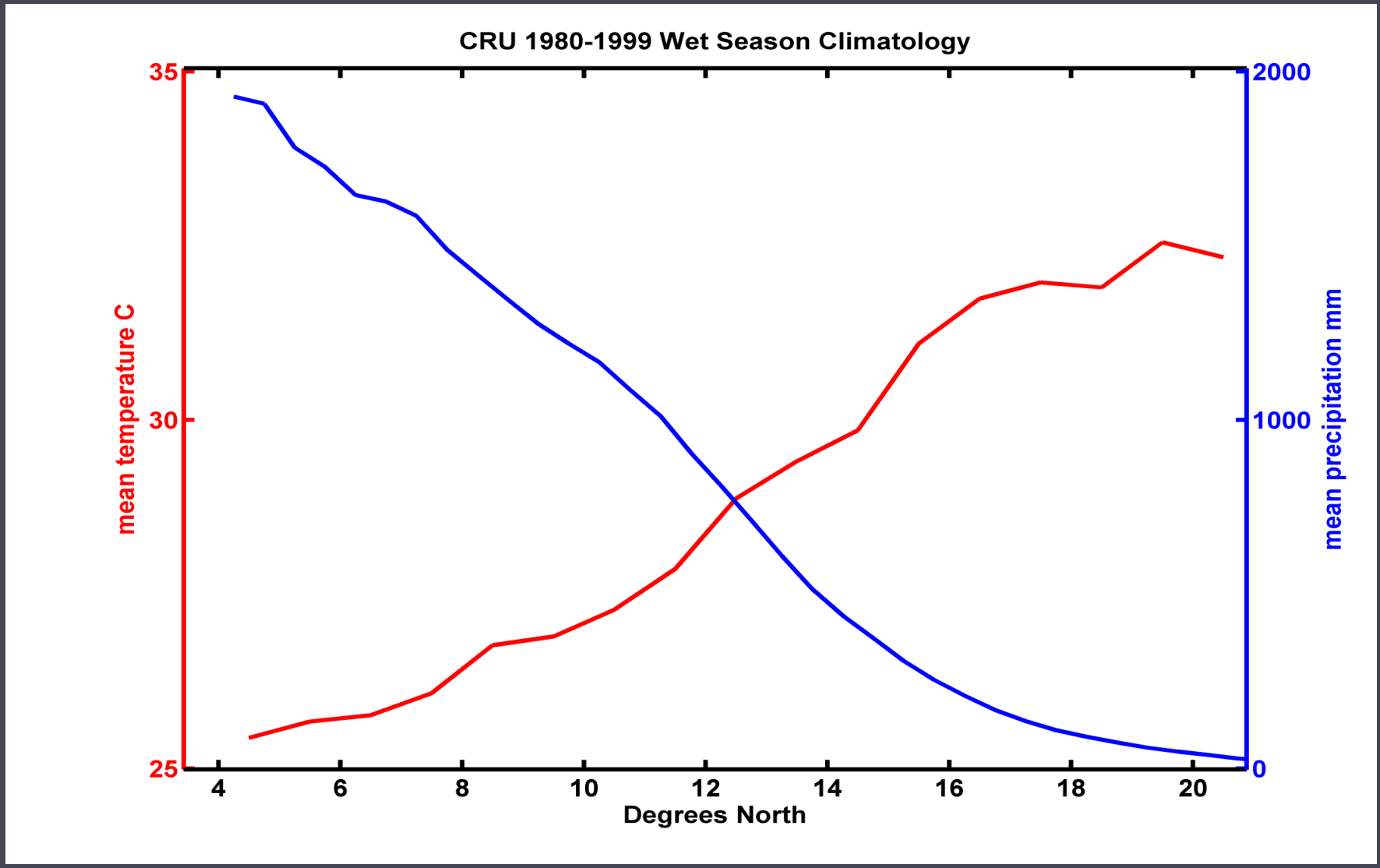
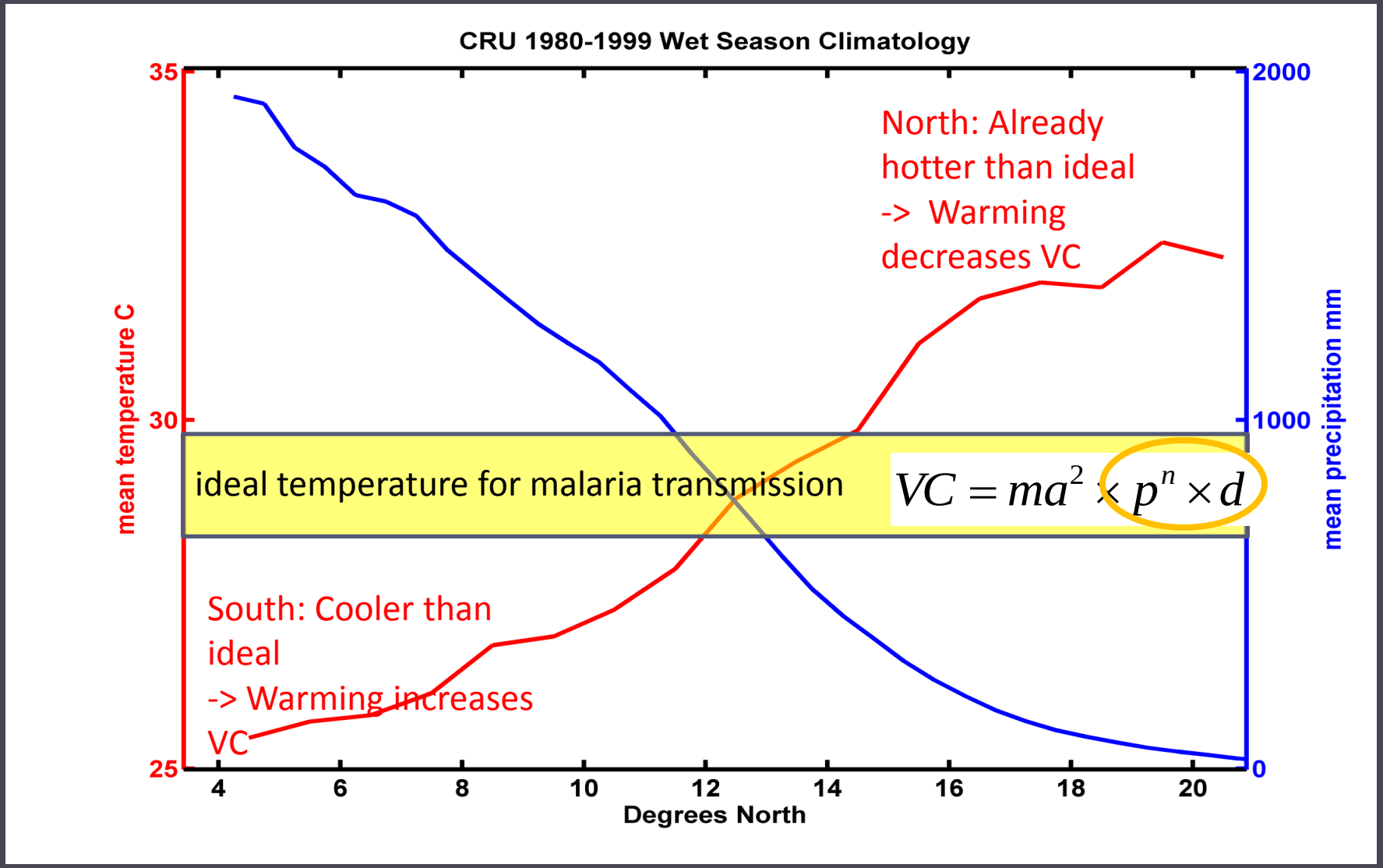
CURRENT CLIMATE IN WEST AFRICA

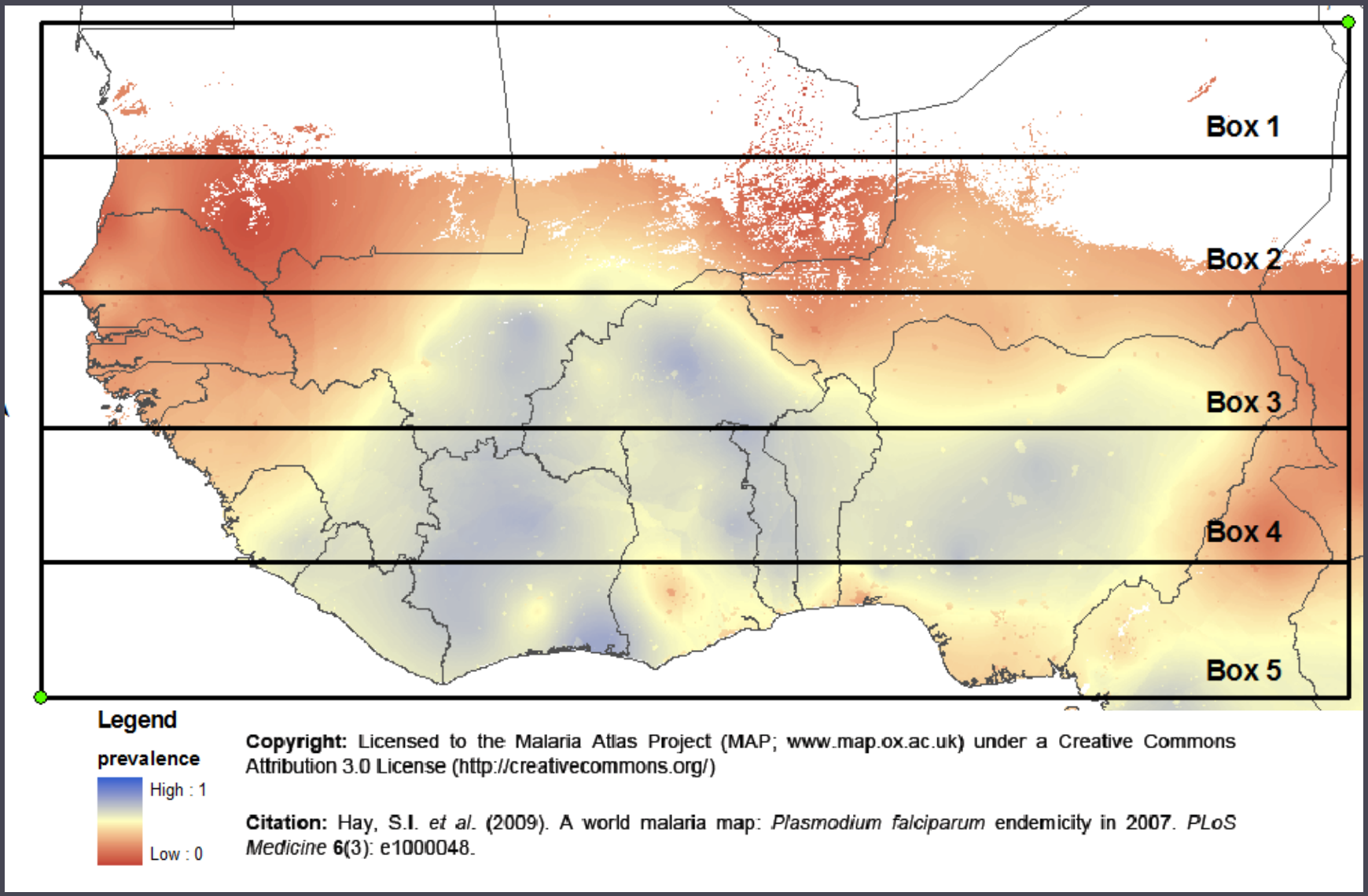
North-South Gradients in Temperature and Rainfall



North-South Gradients in Temperature and Rainfall



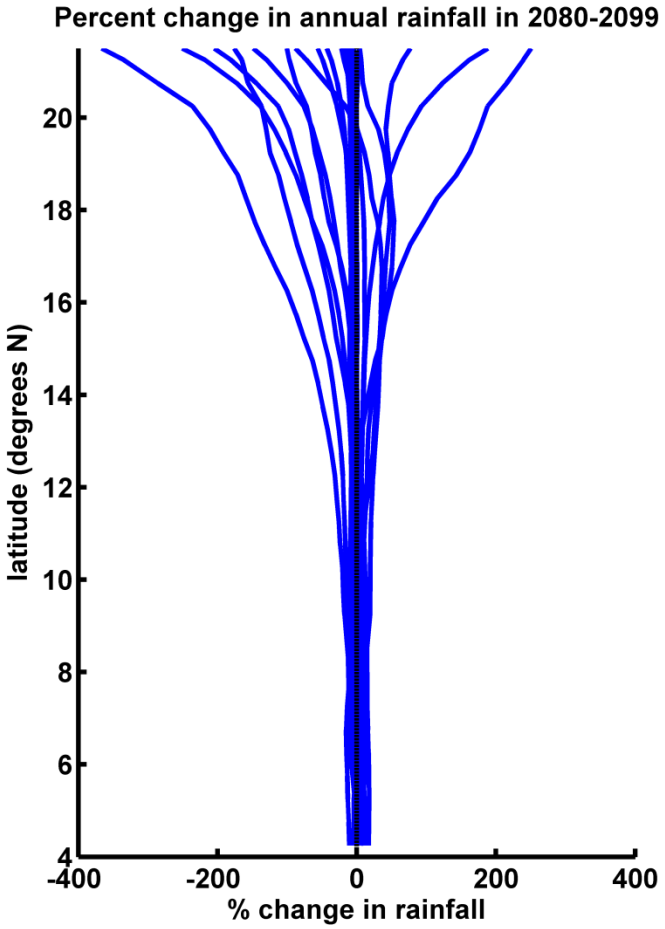
Estimated malaria prevalence

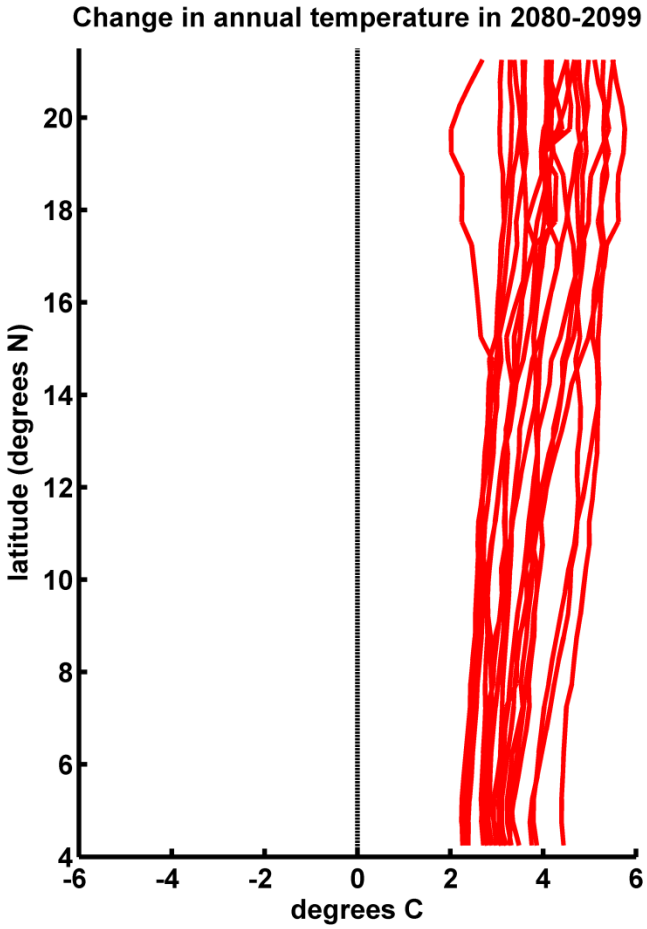


Citation: Hay, S.I. *et al.* (2009). A world malaria map: *Plasmodium falciparum* endemicity in 2007. *PLoS Medicine* **6**(3): e1000048.

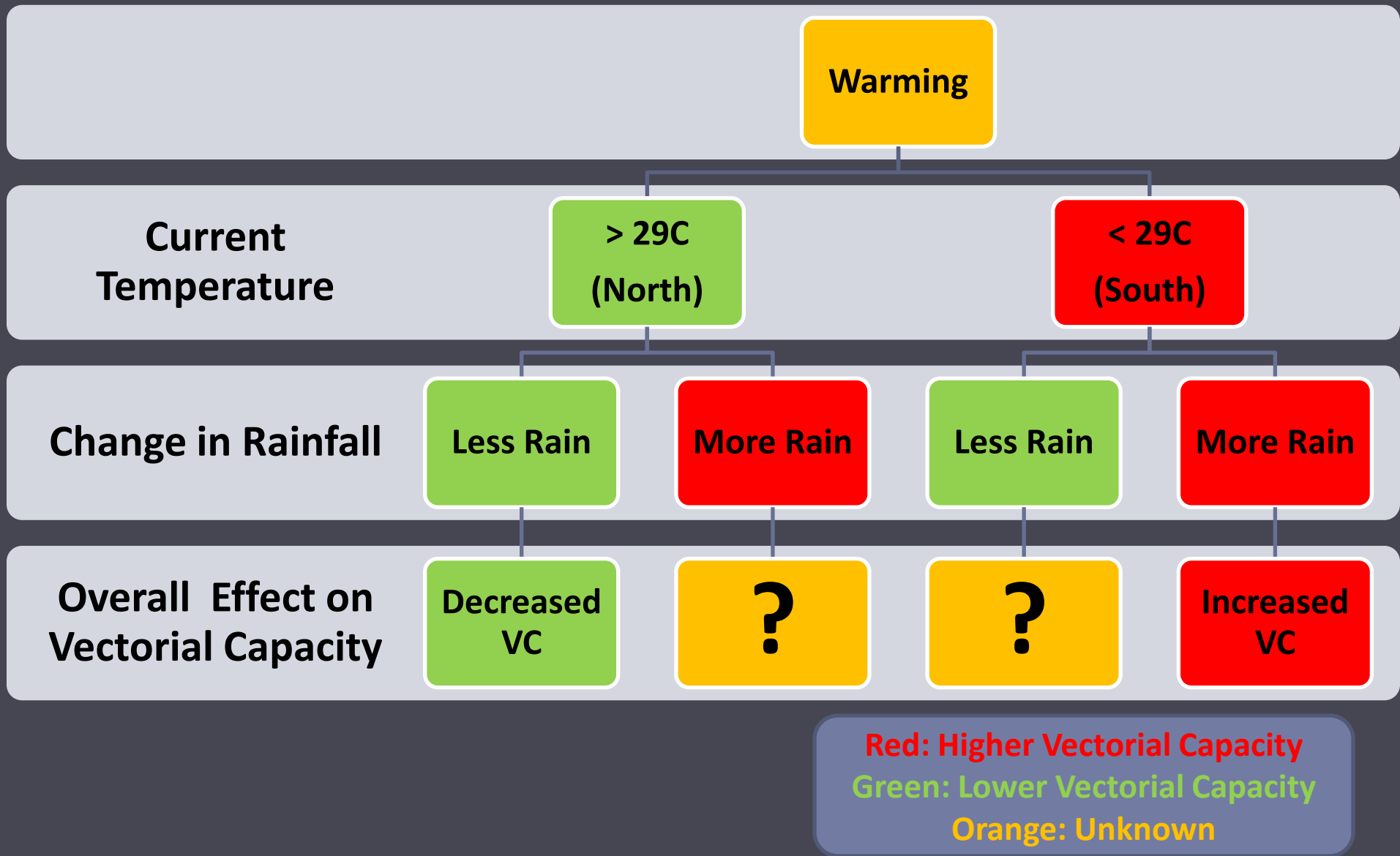
PREDICTED CLIMATE IN WEST AFRICA

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



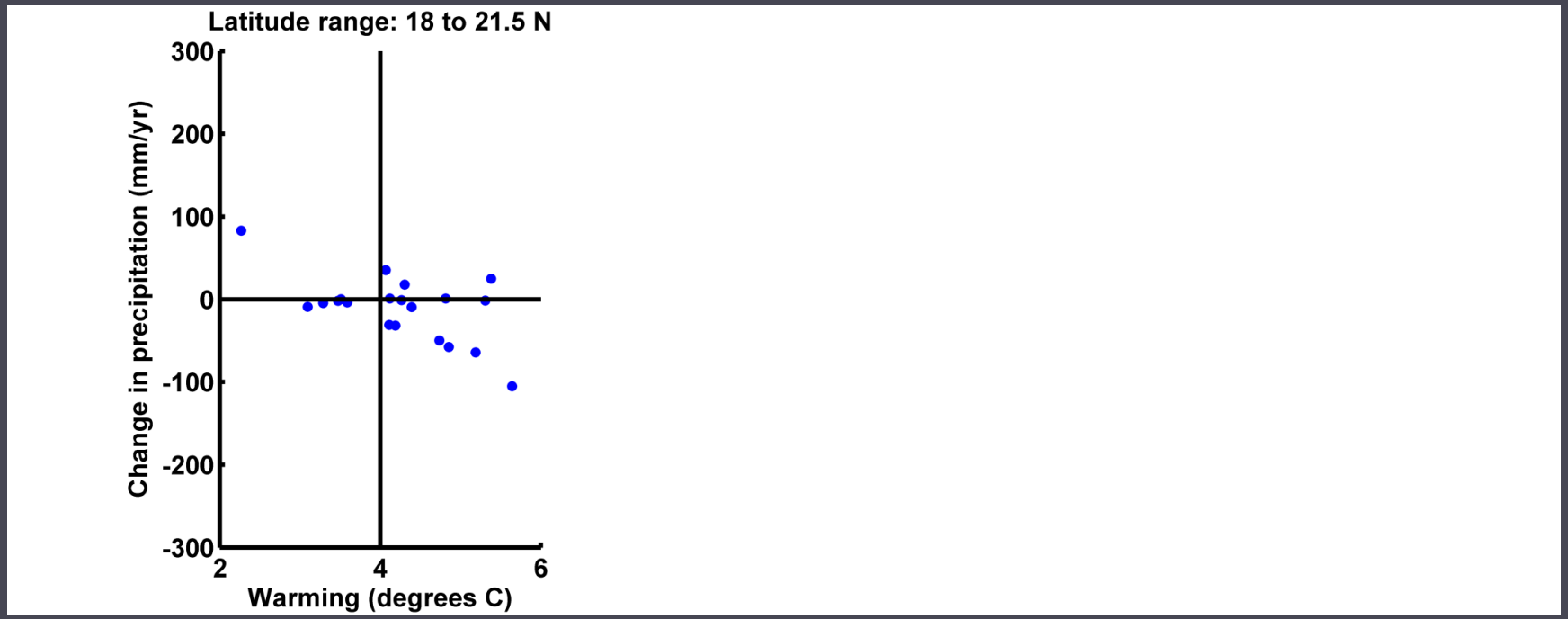


Expected effect of Climate Change



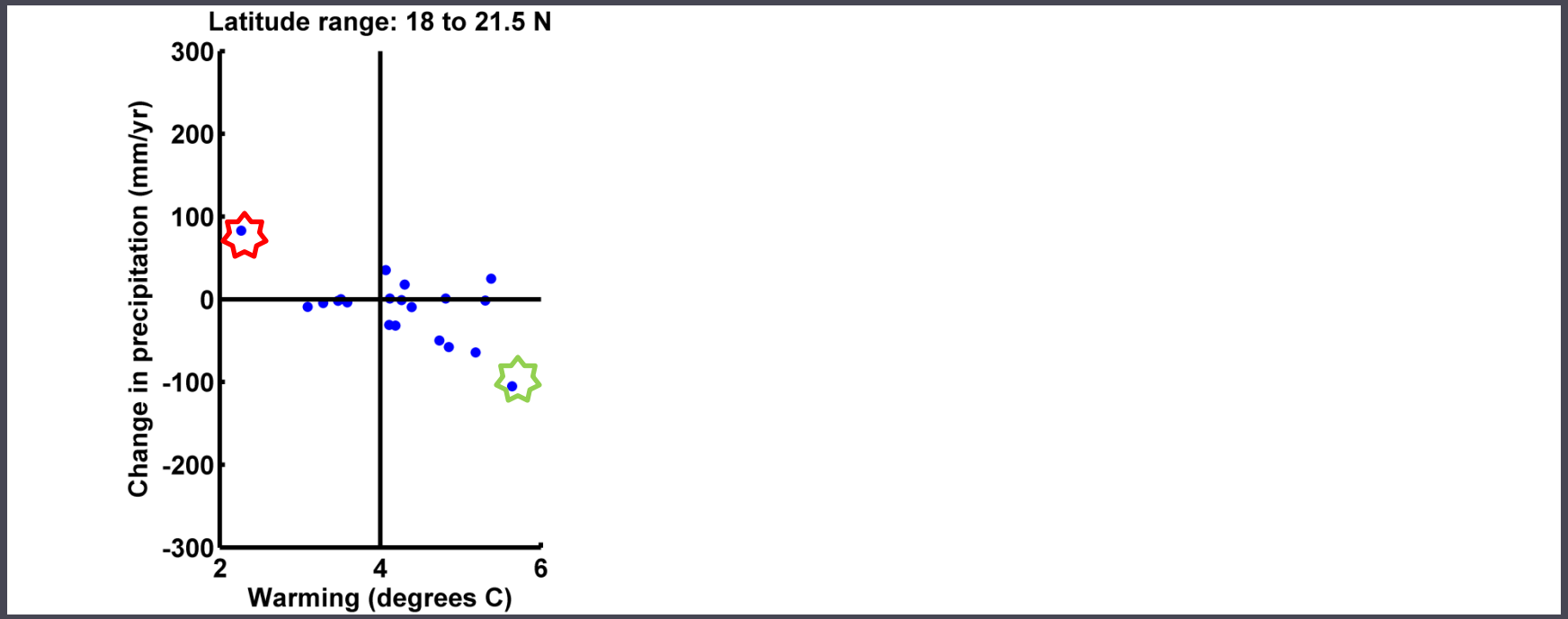
Changes predicted by IPCC models

Box 1



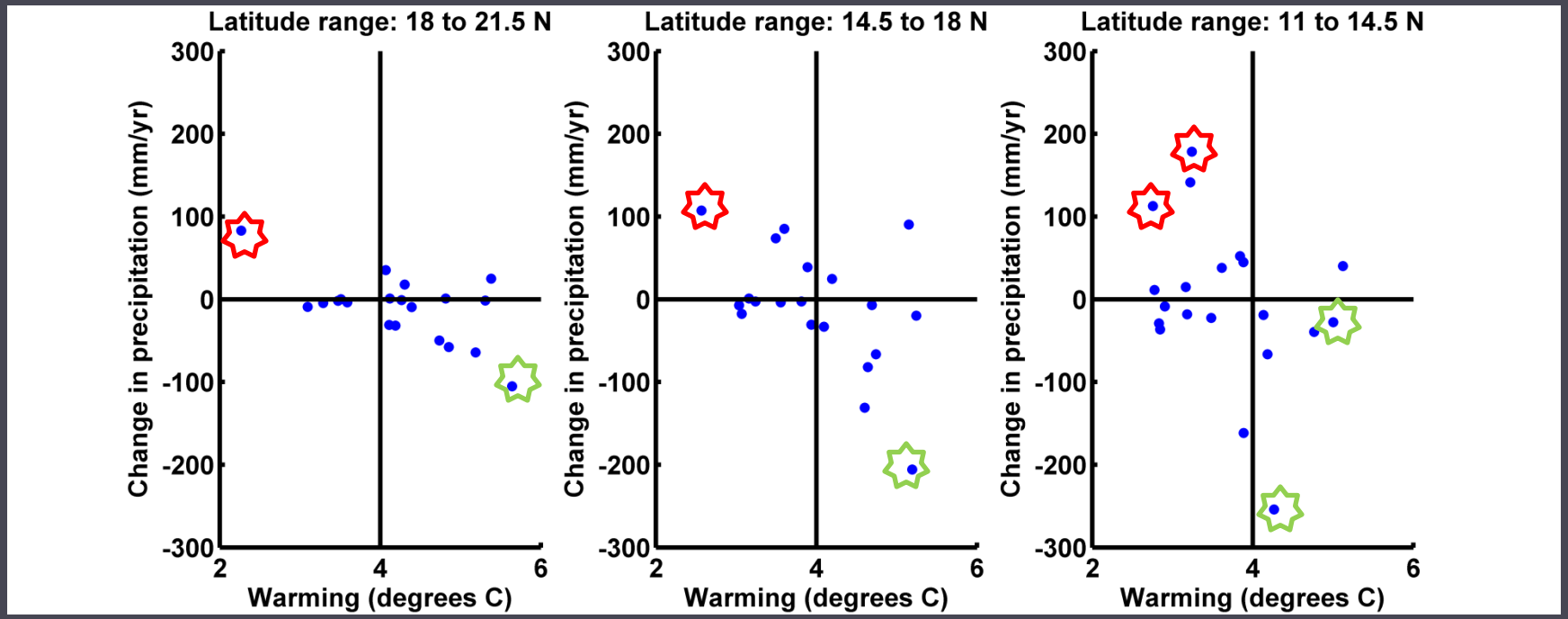
Changes predicted by IPCC models

Box 1

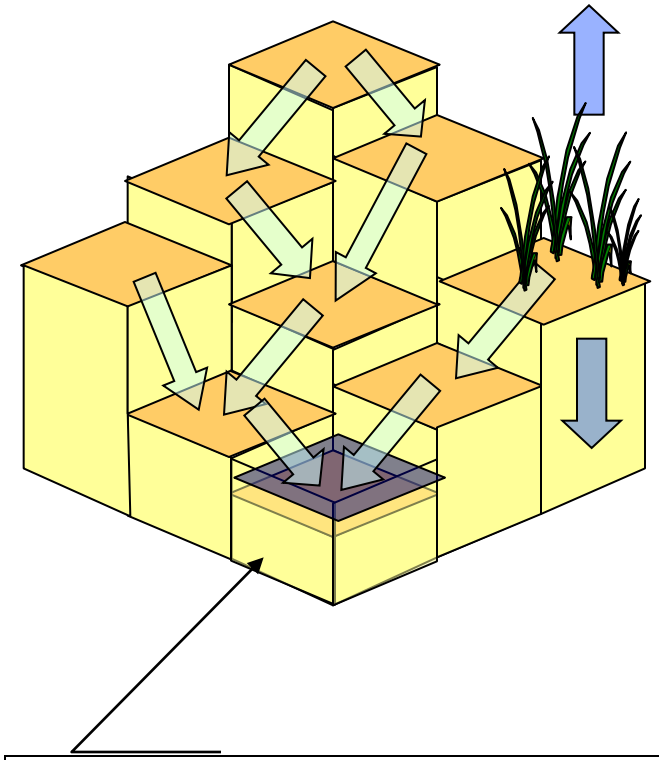


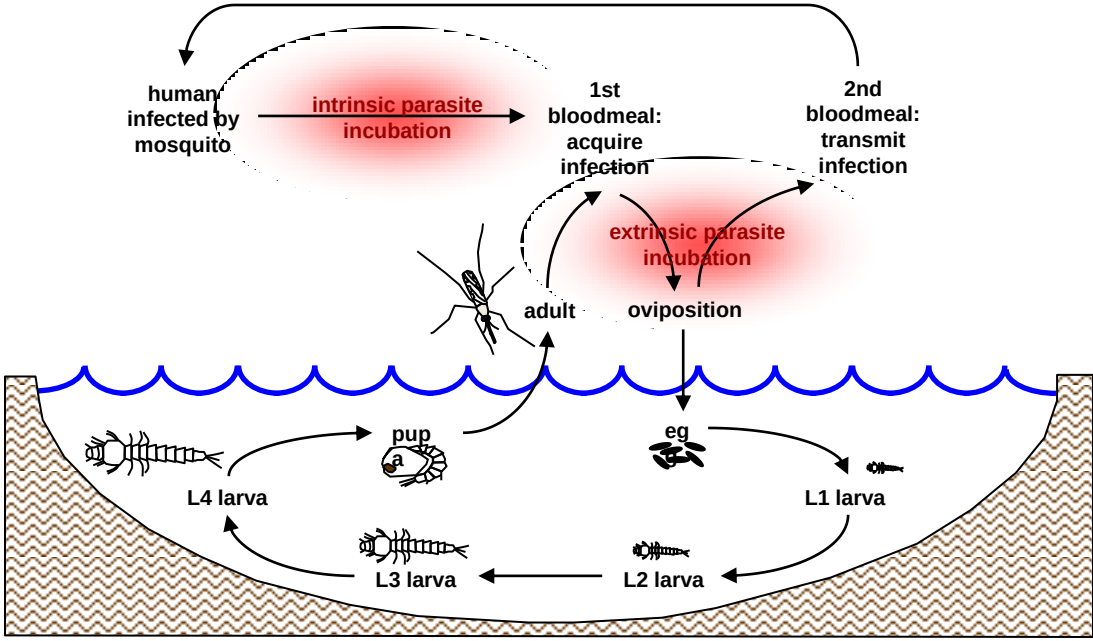
Changes predicted by IPCC models

Box 1 Box 2 Box3



HYDREMATS: Hydrology Entomology & Malaria Transmission Simulator

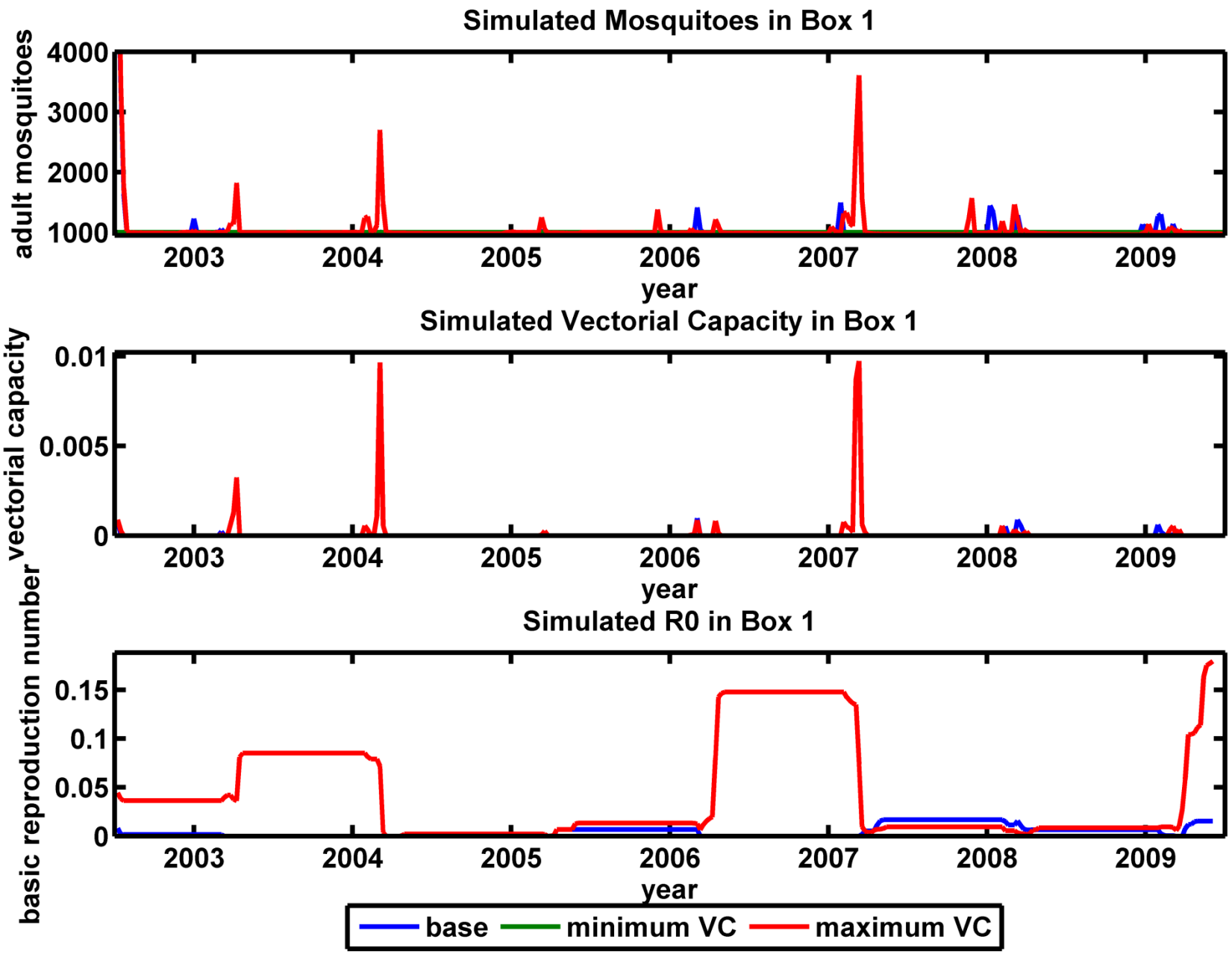


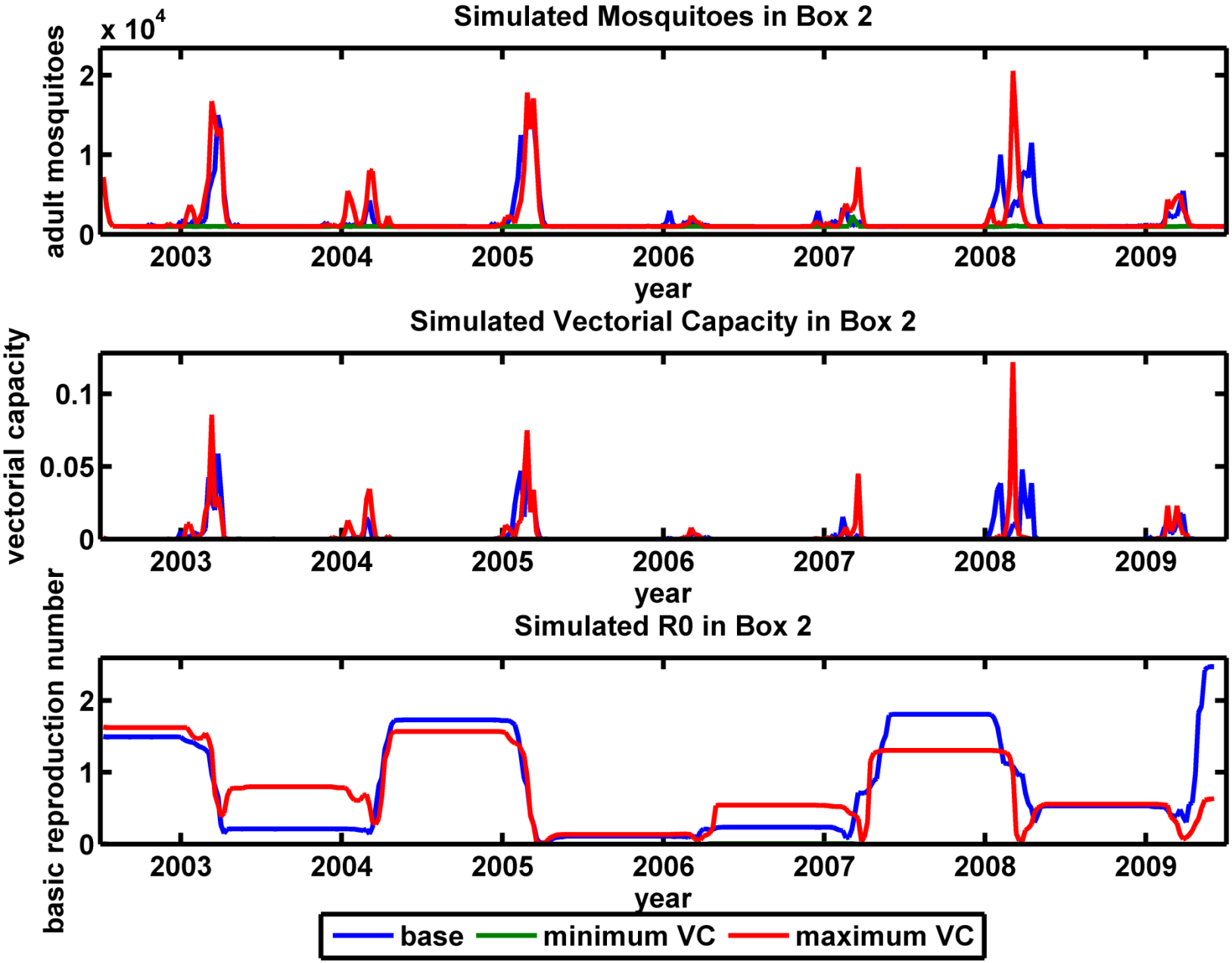


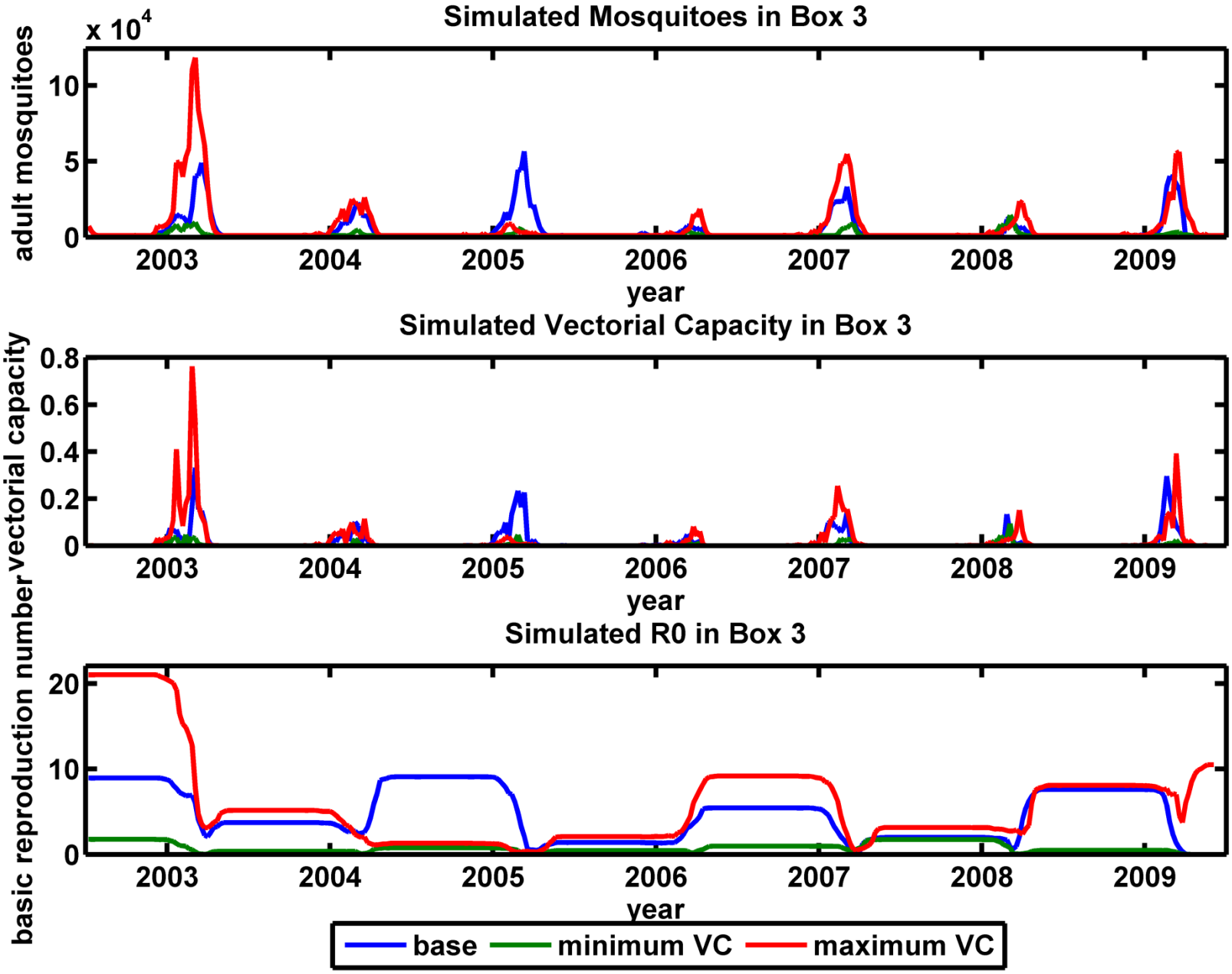
Overland flow model will pool water and simulate pool losses to infiltration/evaporation

Bomblies et al. *Water Resources Research*, 2008

PRELIMINARY RESULTS FROM HYDREMATS


Simulated Mosquitoes in Box 1
adult mosquitoes
4000
3000
2000
1000
2003
2004
2005
2006
2007
2008
2009
year
Simulated Vectorial Capacity in Box 1
vectorial capacity
0.01
0.005
0
2003
2004
2005
2006
2007
2008
2009
year
Simulated R0 in Box 1
basic reproduction number
0.15
0.1
0.05
0
2003
2004
2005
2006
2007
2008
2009
year
base
minimum VC
maximum VC


Simulated Mosquitoes in Box 2
x 10^4
adult mosquitoes
2
1
0
2003
2004
2005
2006
2007
2008
2009
year
Simulated Vectorial Capacity in Box 2
vectorial capacity
0.1
0.05
0
2003
2004
2005
2006
2007
2008
2009
year
Simulated R0 in Box 2
basic reproduction number
2
1
0
2003
2004
2005
2006
2007
2008
2009
year
base
minimum VC
maximum VC


Simulated Mosquitoes in Box 3
x 10^4
adult mosquitoes
10
5
0
2003
2004
2005
2006
2007
2008
2009
year
Simulated Vectorial Capacity in Box 3
vectorial capacity
0.8
0.6
0.4
0.2
0
2003
2004
2005
2006
2007
2008
2009
year
Simulated R0 in Box 3
basic reproduction number
20
10
0
2003
2004
2005
2006
2007
2008
2009
year
base
minimum VC
maximum VC

CONCLUSIONS

Conclusions

- Even under the worst case scenario, we do not expect to see a major increase of malaria transmission in this region
  - Box 1: Higher VC, but still too low for transmission
  - Box 2: Increase in VC due to increased rainfall balances the decrease in VC due to higher temperature
  - Box 3: Small increase in VC over the 9 years
- The hottest and driest scenarios would eliminate transmission in Boxes 1 & 2, and substantially decrease transmission in Box 3

EXTRA SLIDES

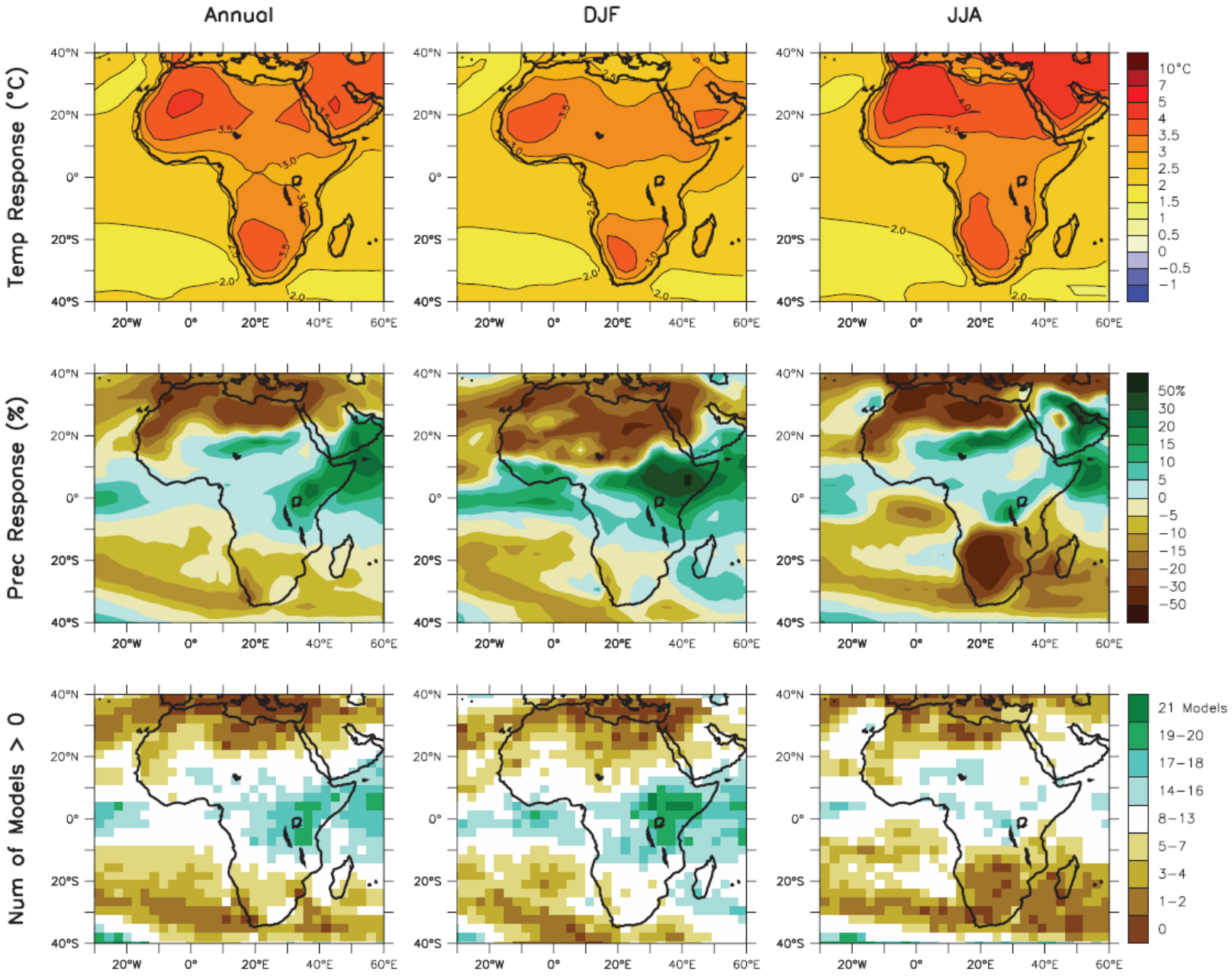


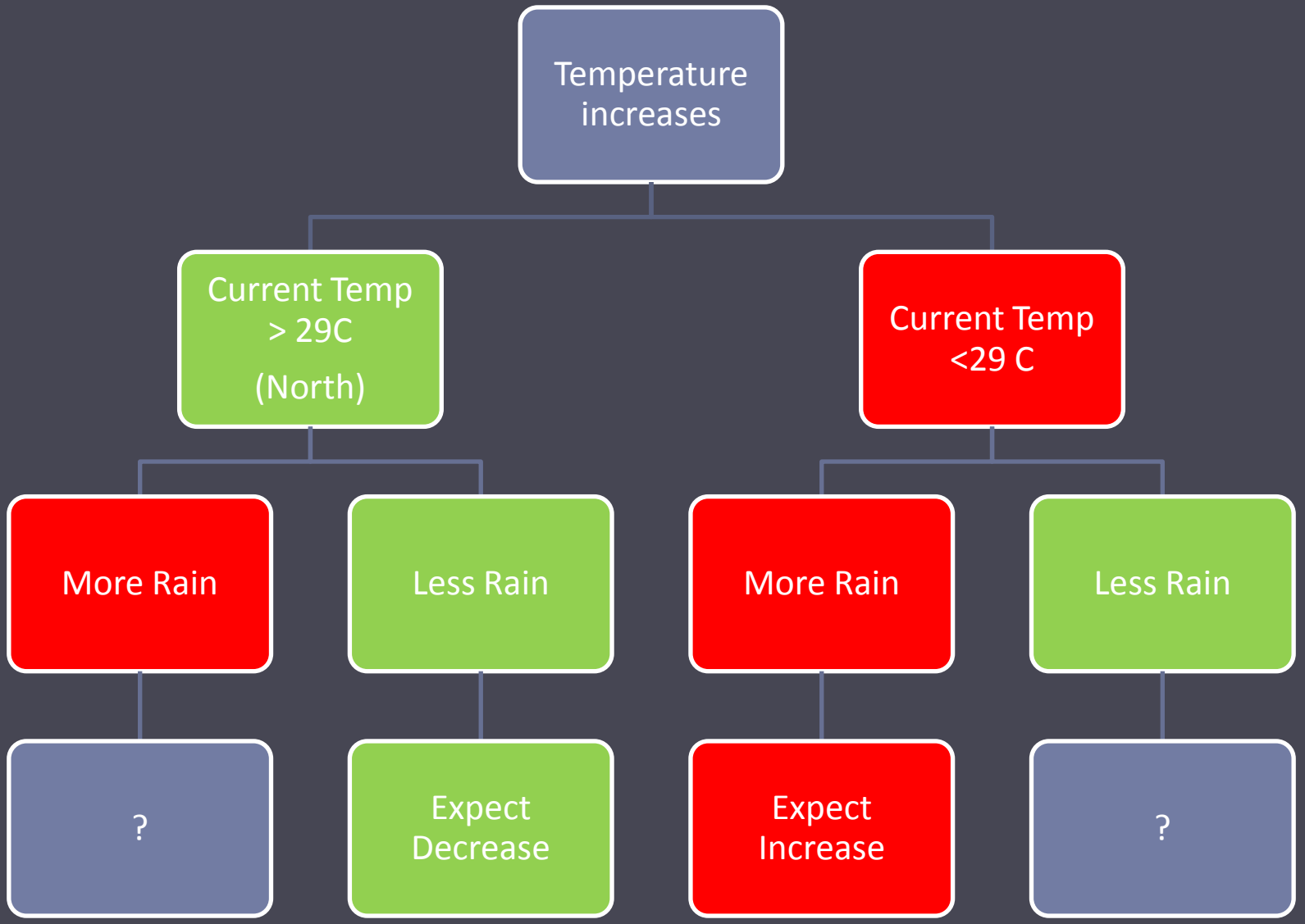
Figure 11.2. *Temperature and precipitation changes over Africa from the MMD-A1B simulations. Top row: Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Middle row: same as top, but for fractional change in precipitation. Bottom row: number of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

Range of predicted changes in temperature

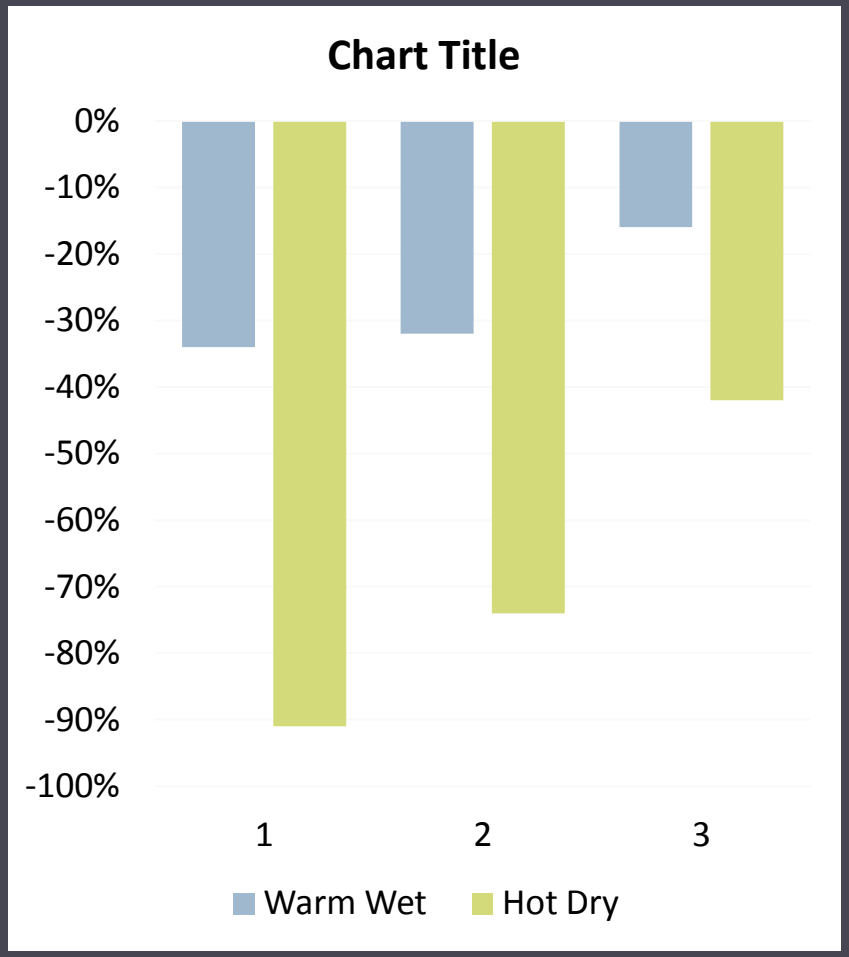
Box	CRU 1980-1999: temperature in rainy months	Max rainy season increase 2080-2099	Model predicting max increase	Min rainy season increase 2080-2099	Model predicting min increase
1	32.2	5.6	GFDL/NOAA	2.3	NCAR - CCSM
2	31.3	5.2	ECHAM	2.6	NCAR - CCSM
3	28.9	5.1	University of Tokyo – MIROC high-res	2.8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


Temperature increases
Current Temp > 29C (North)
Current Temp <29 C
More Rain
Less Rain
More Rain
Less Rain
?
Expect Decrease
Expect Increase
?

Change in Vectorial Capacity due to temperature alone



$$VC = ma^2 \times p^n \times d$$

- 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"