Stochastic simulation of mesoscale convective systems to assess the evolution of hydrological extremes in the West African Sahel

Vischel T.*, Wilcox C.*, Panthou G.*, Quantin G.*, Harris P.▲, Blanchet J.*, Aly C.*, Taylor C. ▲, Berthou S. ♦, Vanderveare J-P.*, Lebel T.*, Stratton R. ♦

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▲ CEH

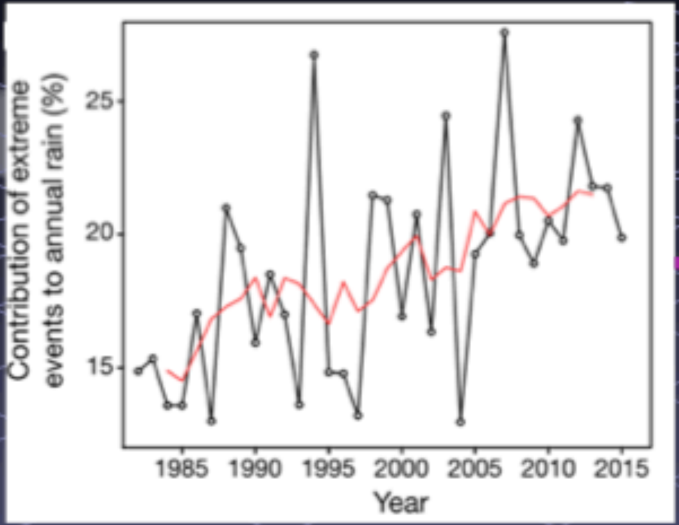
♦ Met Office

8th GEWEX Open Science Conference: Extremes and Water on the Edge, May 6-11, Canmore, Canada


West Africa
Sahel

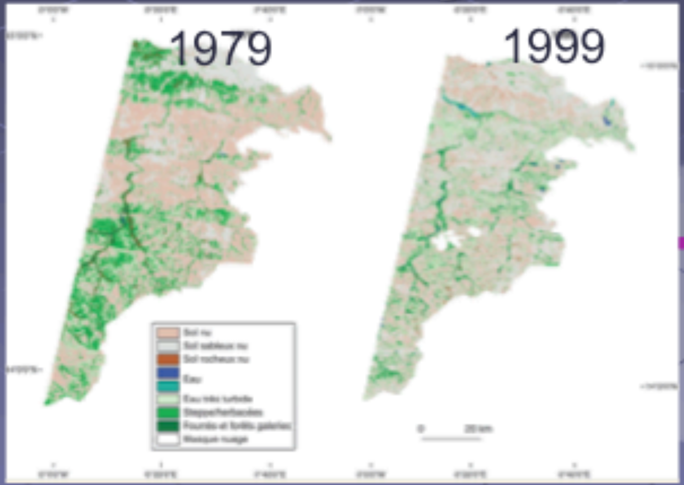
Hydro-climatic intensification in the Sahel

Rainfall intensification



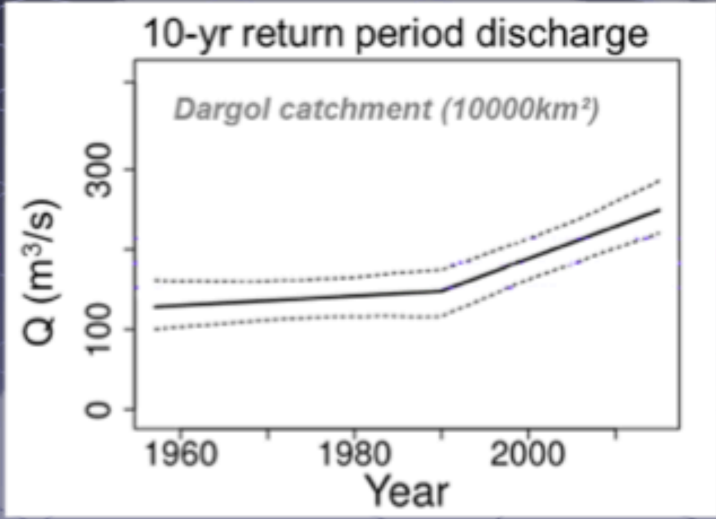
Taylor et al., 2017,Nature → Talk Monday, S1
Panthou et al., accepted, ERL → Poster C38

Land surface degradation



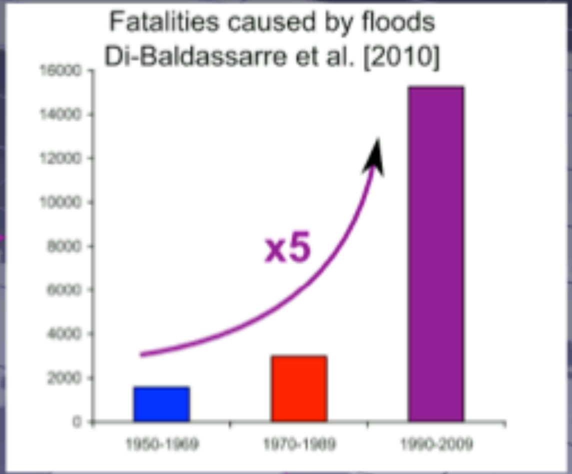
Descroix et al., 2009, J. Hydrol.

Hydrologic intensification



Wilcox et al., in review, J. Hydrol.

Increasing fatalities



Di Baldassare et al., 2010, GRL.

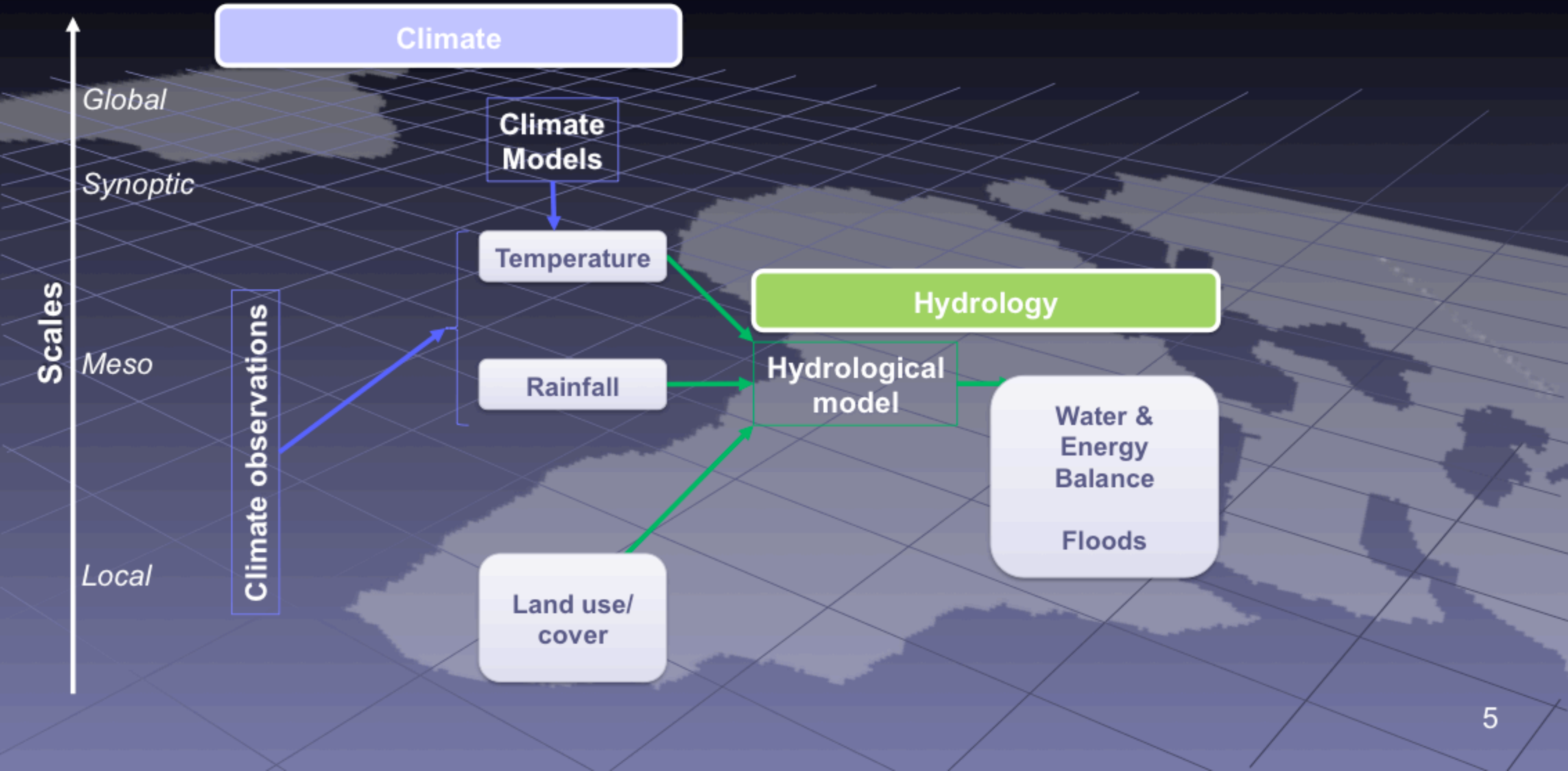
Increasing Human vulnerability

Scientic challenges

- **Over the recent-past : hydrological attribution**
  - ***Climate or Land use/cover changes?***
  - ***Impact of the human footprint?***

- **Over the future: projection issues**
  - ***Will trends in hydrological hazards be significant over the next decades?***

Modeling framework



Modeling framework

Scales

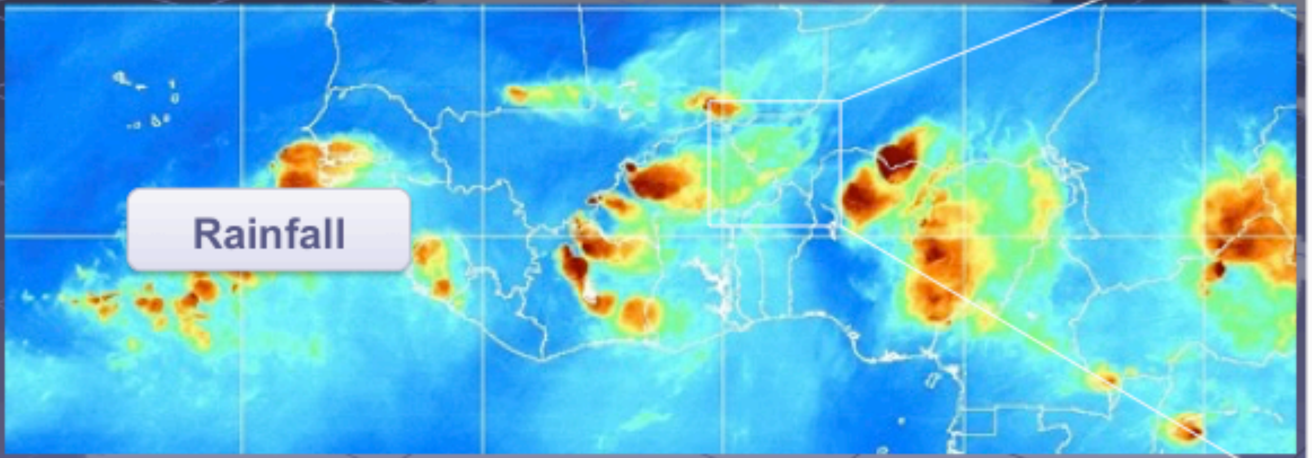
Global

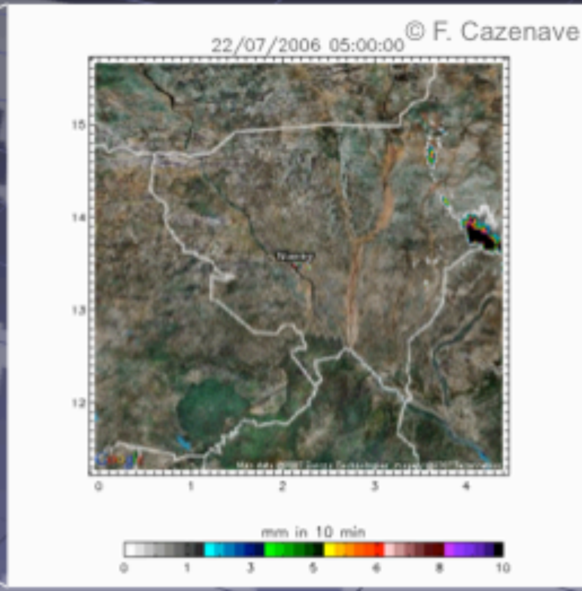
Synoptic

Meso

Local

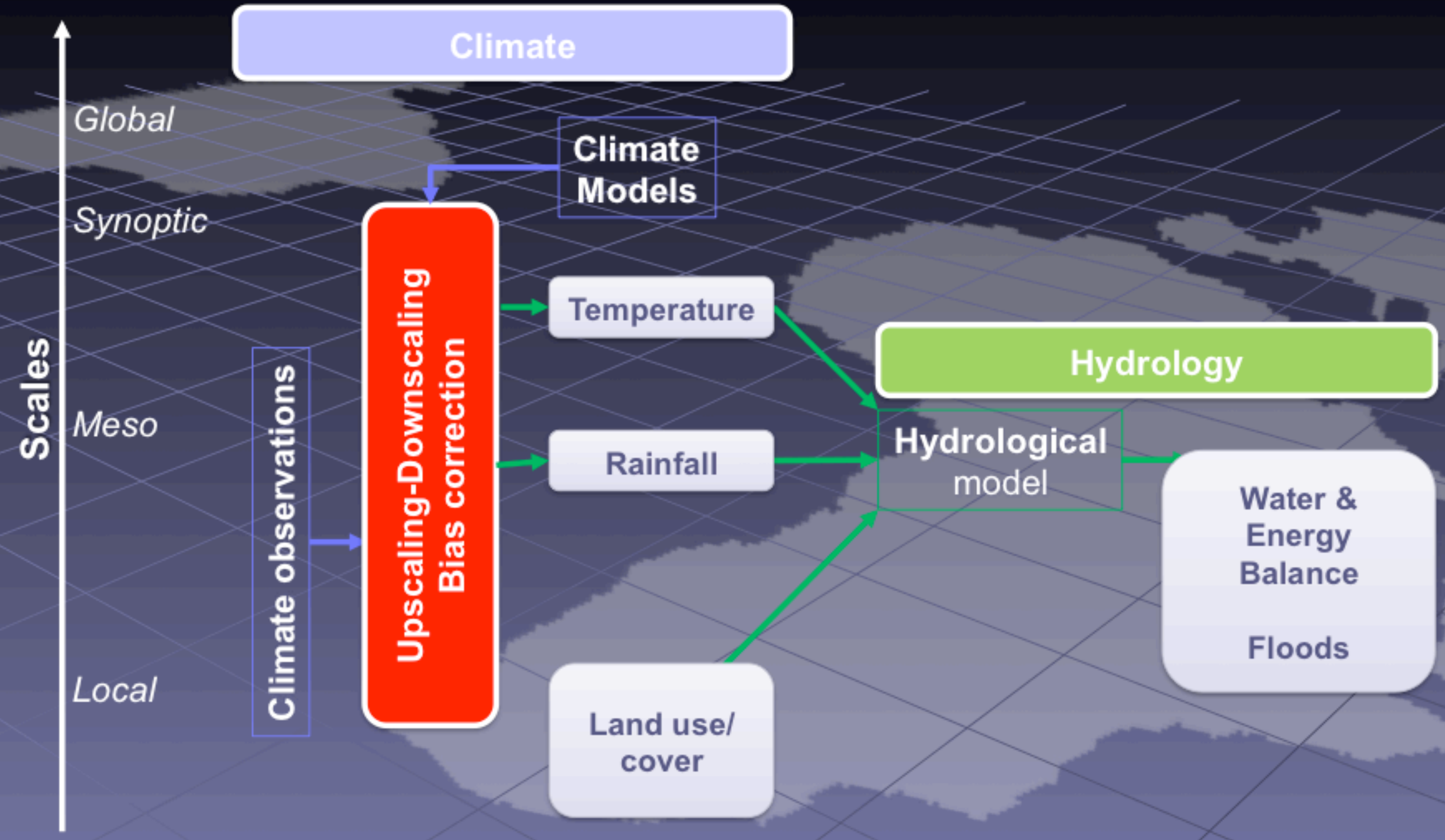
Mesoscale Convective Systems





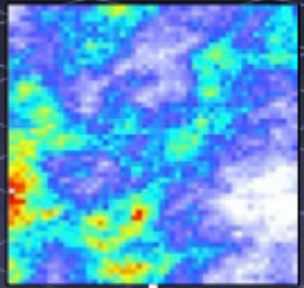
Occurrence, intensity and size/aggregation :
- sensitive to atmospheric processes at synoptic scales
- influence the response of the hydrologic-systems

Scale and bias issues



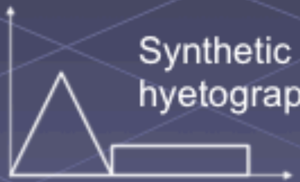
Stochastic Storm generator

Event rainfield

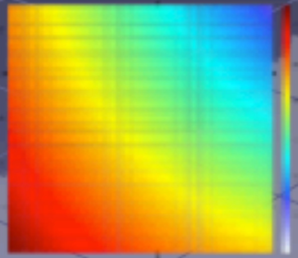


CDF
Spatial covariance

Temporal disaggregation

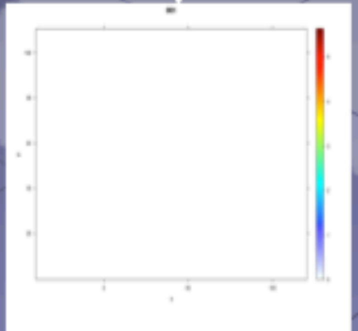


Synthetic hyetograph



Propagation

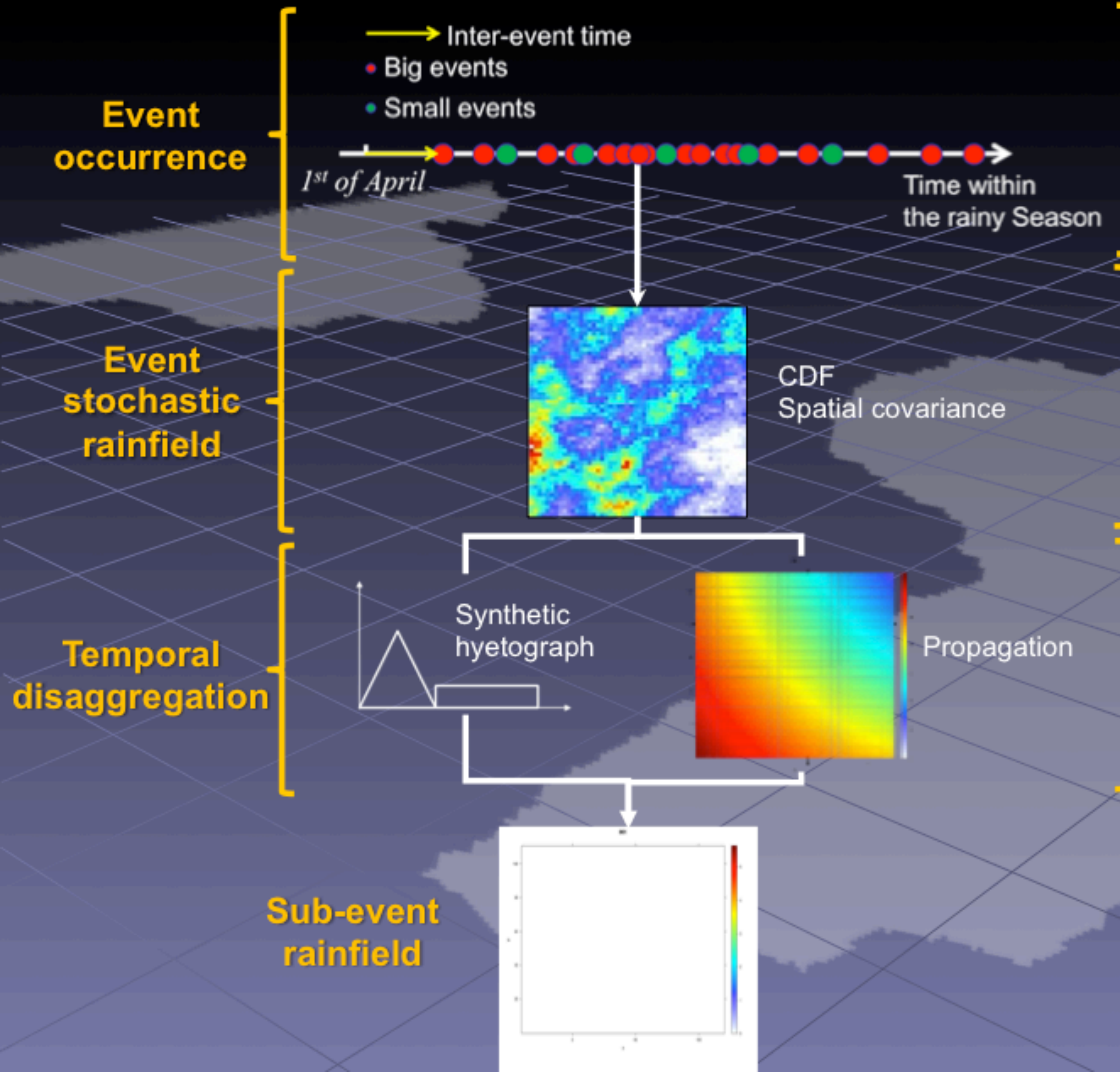
Sub-event rainfield



		Object	Function	parameters		Degree	Fitting method
Event Rain field	Marginal	Big events	F0-Gamma	atom	F_0	-	Moments
				shape	α_B	-	
				rate	β_B	-	
	Variogram	Gaussian fields associated with big events	Double exponential	Range	ϕ_1	-	Gibbs sampler
				Range	ϕ_2	-	
				Anis. Coef.	a_1	-	
				Anis. Coef.	a_2	-	
				variance ratio	v	-	

Sub-event Rain field	Big events	Hyetogram shape	-
		Propagation	Mean speed
			Mean direction

Vischel et al. 2009 J. Hydrol



		Object	Function	Parameters		f(t) degree	Fitting method
Occurrence		Start Date	Gauss	mean	μ_s	-	likelihood
				std	σ_s	-	
		End Date	Gauss	mean	μ_e	-	likelihood
				std	σ_e	-	
		IET	Gamma	shape	α	3	likelihood
				rate	β	2	
		Big vs small	Bernoulli	ratio	κ	-	moment
Event Rain field	Marginal	Big events	F0-Gamma	atom	F_0	3	Censored likelihood
				shape	α_B	1	
				rate	β_B	3	
			GPD	threshold	λ	-	likelihood
				scale	σ_{GPD}	-	
				shape	ξ_{GPD}	-	
		Small events	F0-Gamma	atom	F_0	3	likelihood
				shape	α_S	3	
				rate	β_S	2	
	Variogram	Big events	Double exponential	range	φ_1	-	Censored likelihood
				range	φ_2	-	
				anis. coef.	a_1	-	
				anis. coef.	a_2	-	
				variance ratio	v	-	
		Small events	Exponential	Range	φ	-	Censored likelihood
Sub-event Rain field		Big events	Hyetogram shape	-			
			Propagation	Mean speed			
				Mean direction			
		Small events	Hyetogram shape	-			

StochaStorm

Vischel et al. in prep.

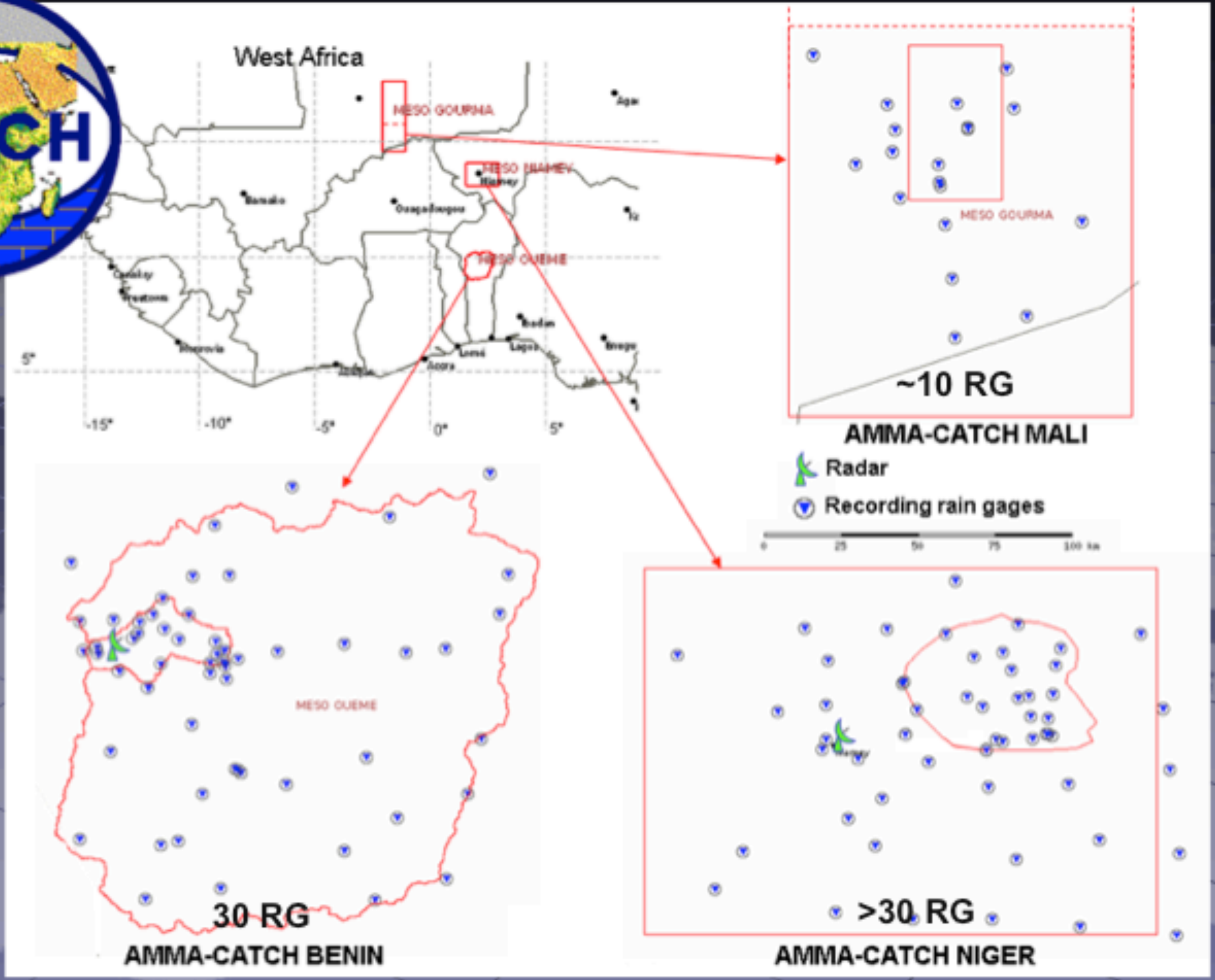
Application to simulate Sahelian storms

AMMA-CATCH Observatory

Eco-hydrological observatory

Data freely available on
www.amma-catch.org

- **High density recording rain gage network**
- **5-min rainfall data**
- **Continuously operating since :**
  - **1990 in the Niger**
  - **2000 in the Benin**
  - **2005 in Mali**



Lebel et al., 2009, J.Hydrol.

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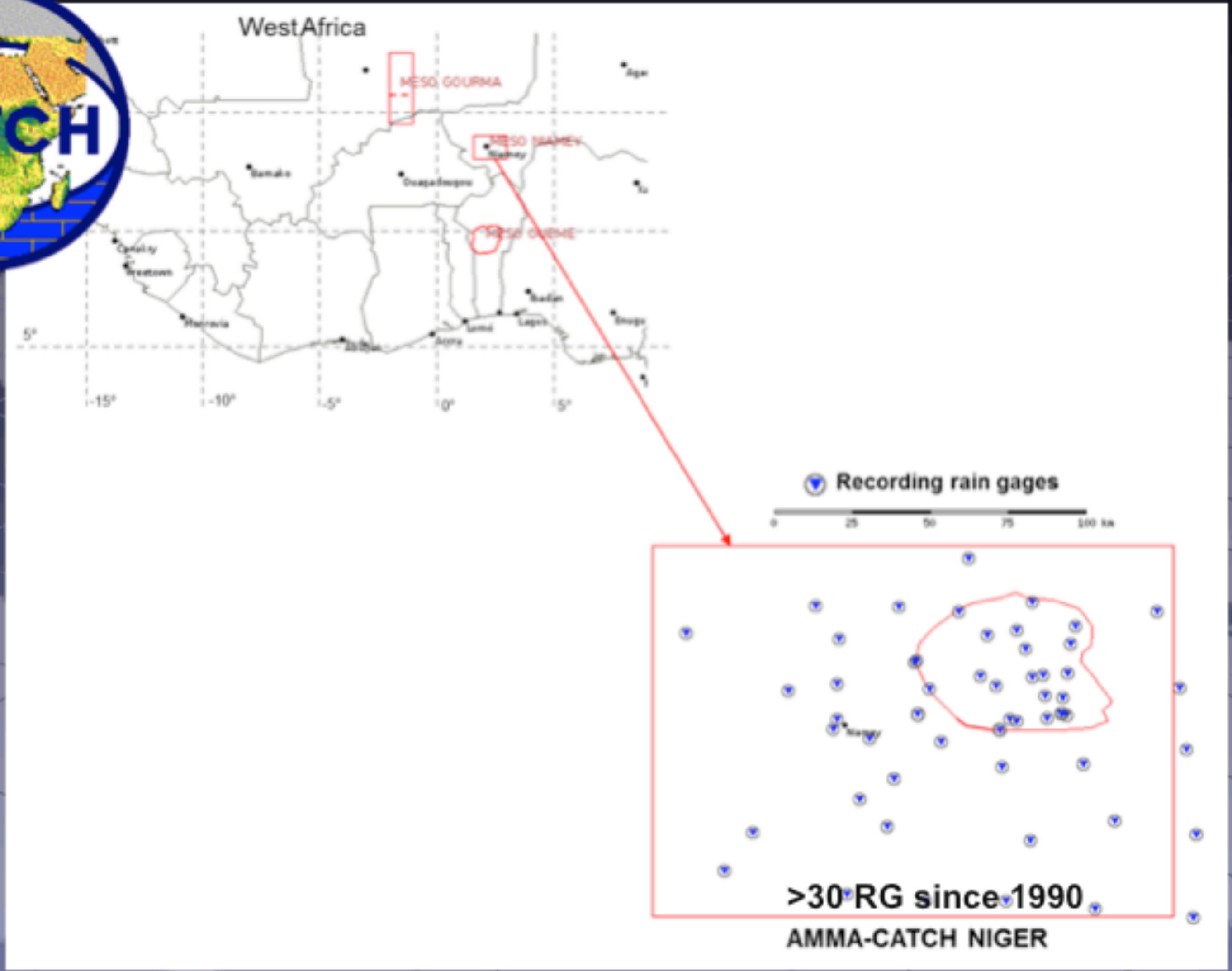
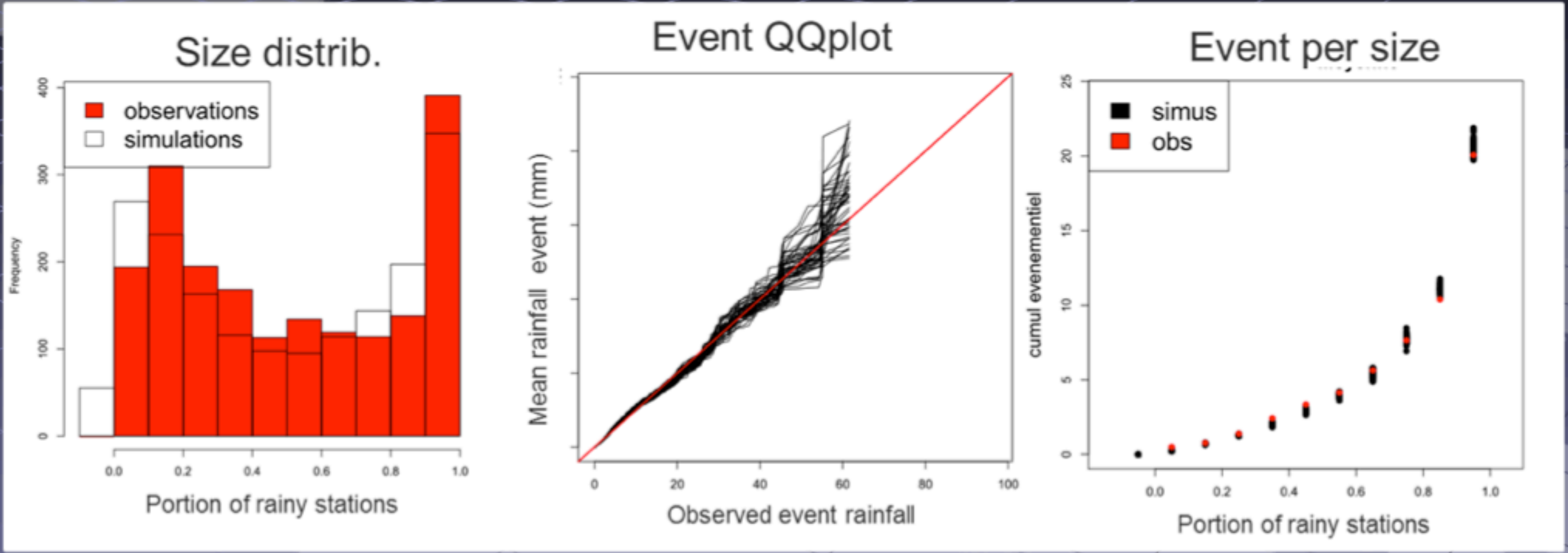
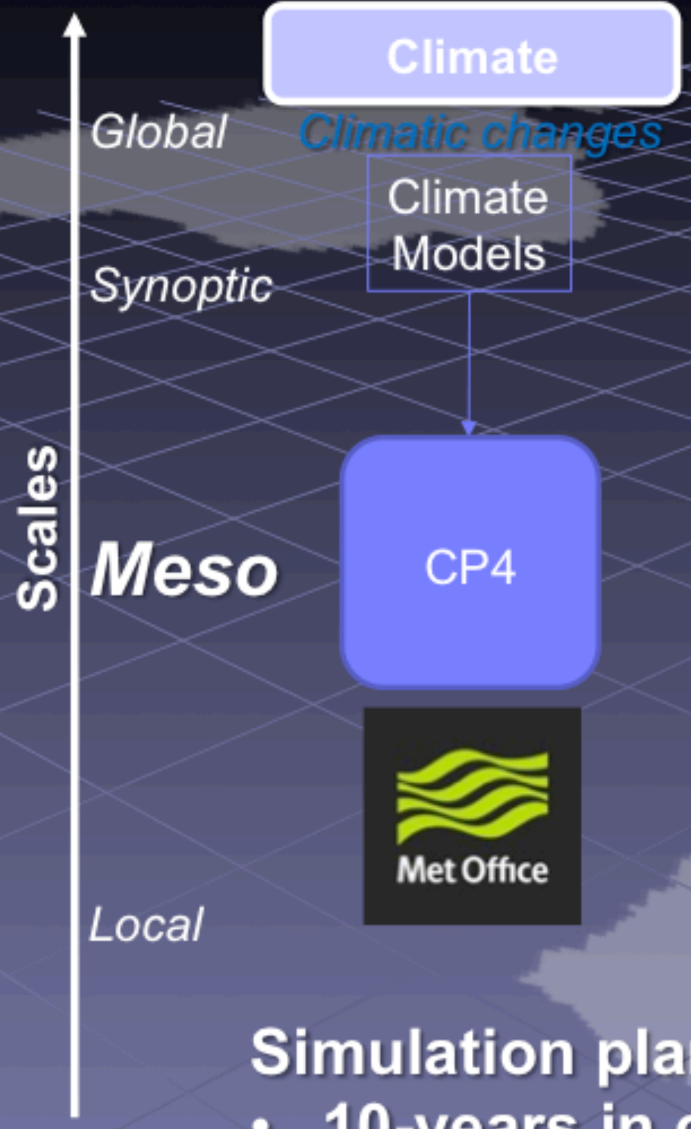
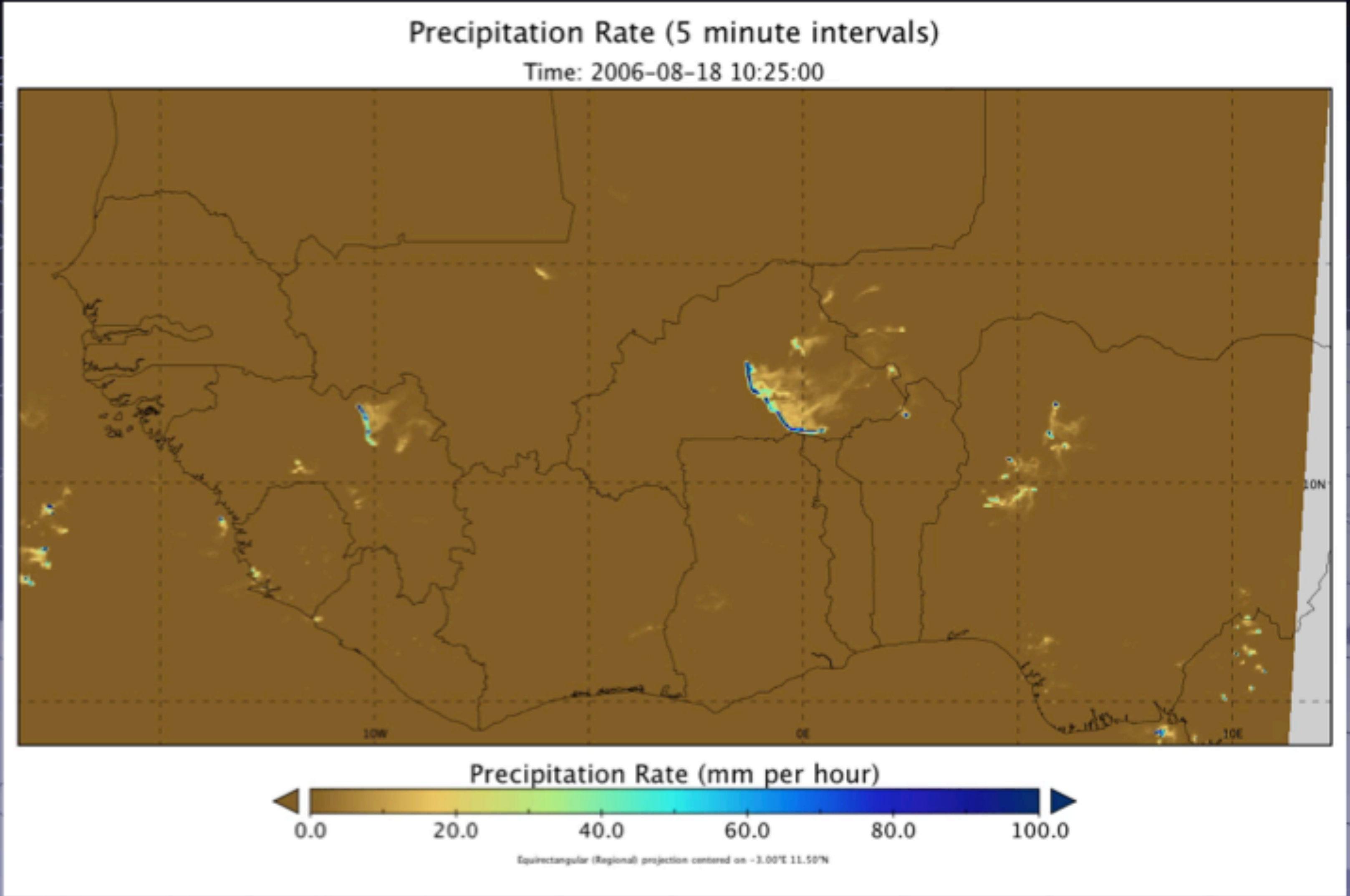


Evaluation of StochaStorm



CP4-Africa: a convection-permitting model for Africa



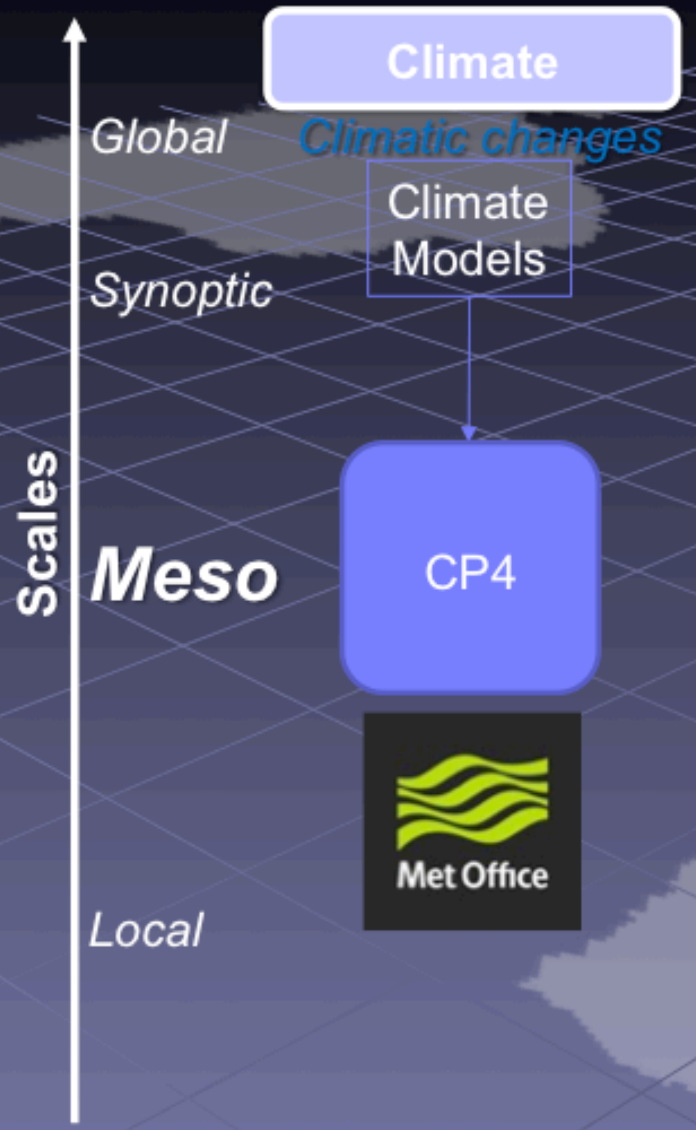


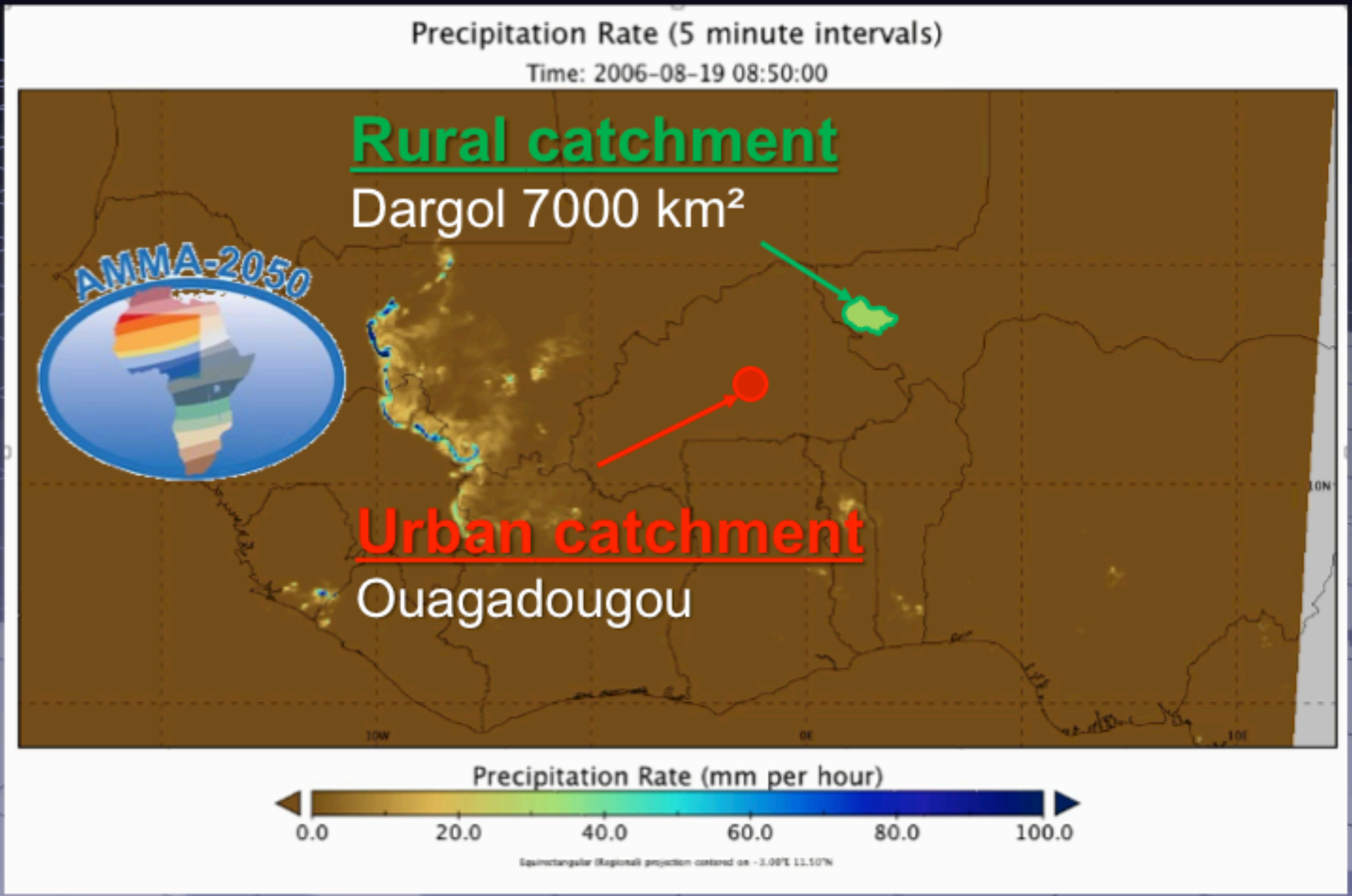
Simulation plan:

- **10-years in control period 1997-2006**
- **10-years future climate ~2080-2100**

Stratton et al, 2018, J. Climate
Lizzie Kendon, talk, Monday S25

CP4-Africa: a convection-permitting model for Africa

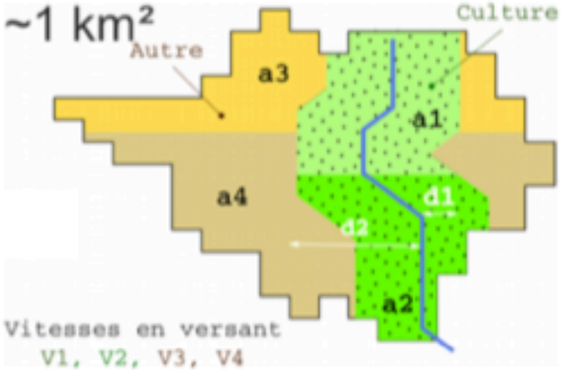




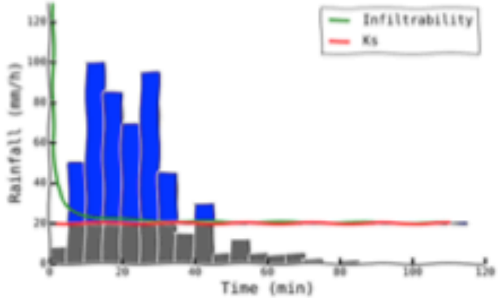
Stratton et al, 2018, J. Climate
Lizzie Kendon, talk, Monday S25

Hydrological application

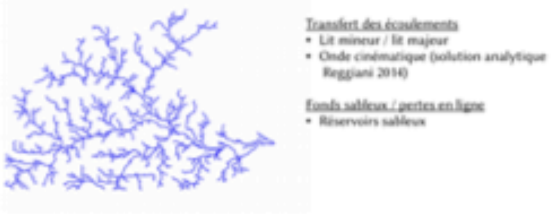
Discretization

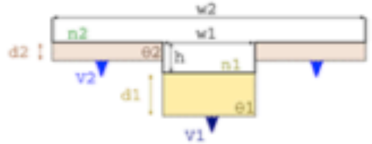


Production



Transfer



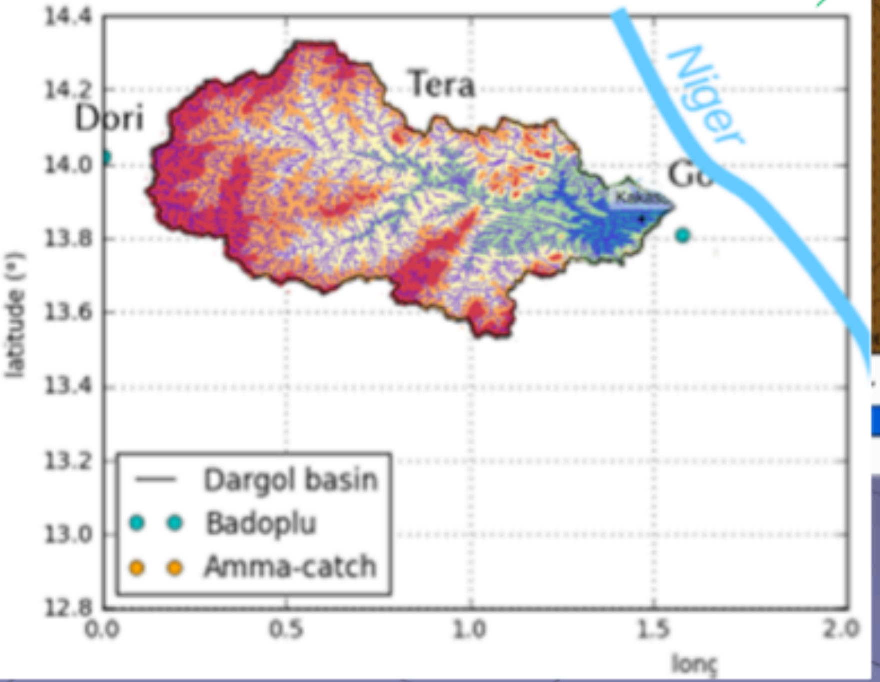


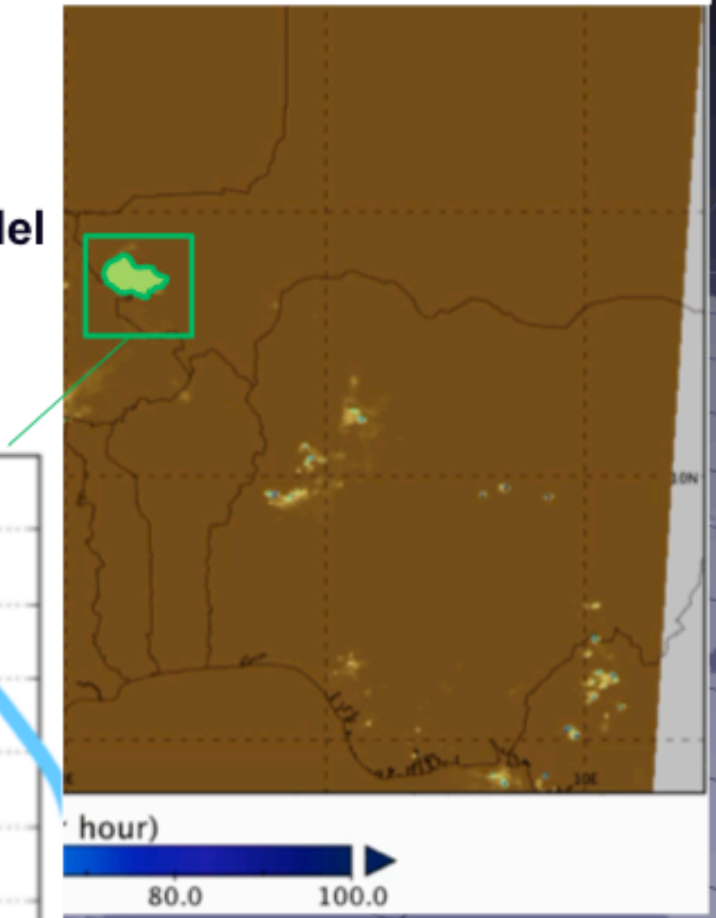
Quantin et al. in prep.

PHORM

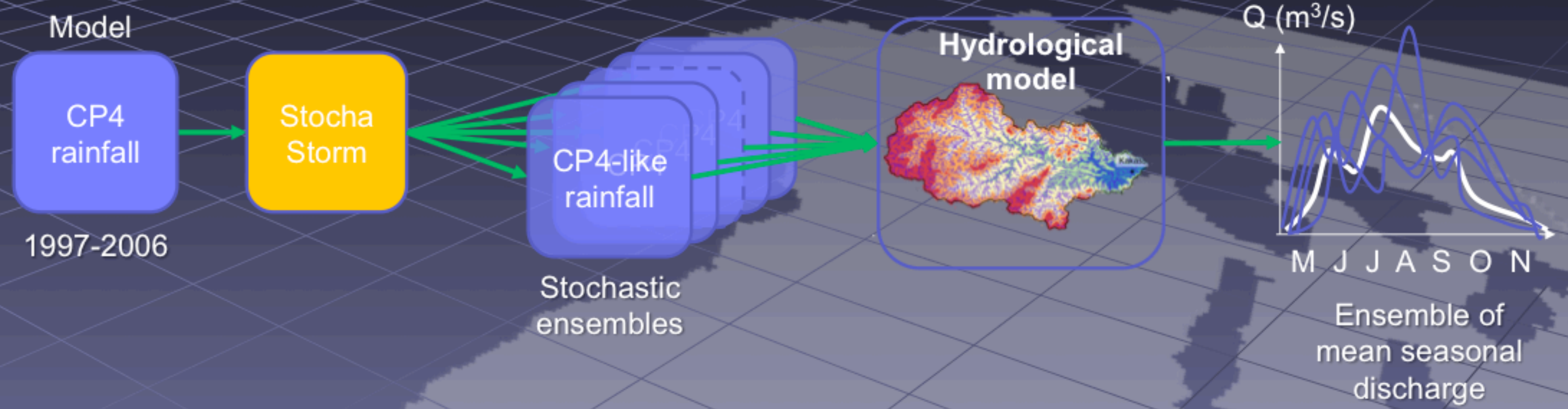
Purely HOrtonian Runoff Model

Process-Based Hydrological Model





Hydrological application

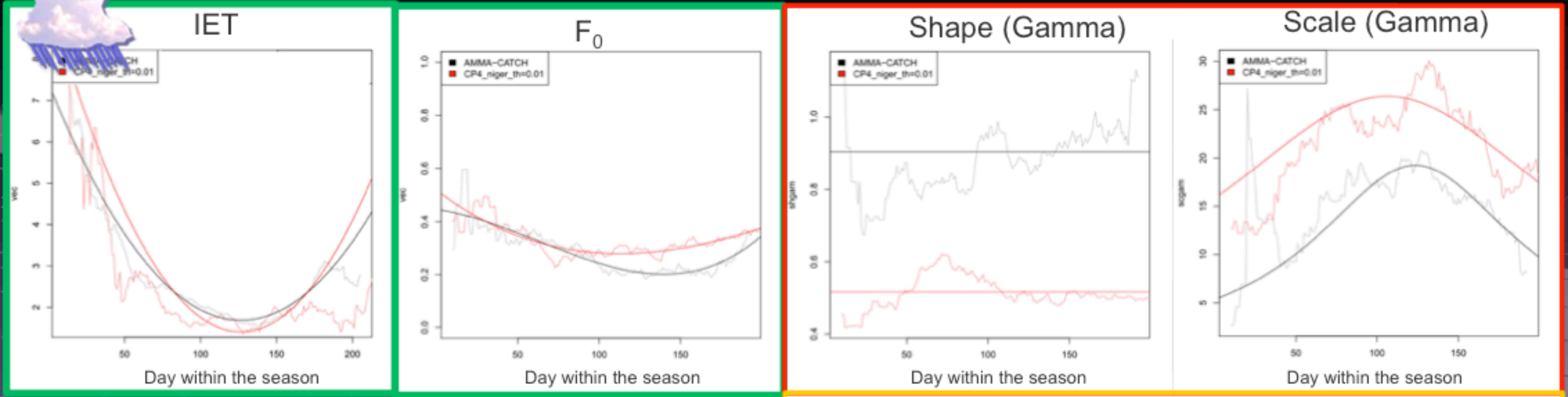


CP4 rainfall vs Observations

Control period 1997-2006

	Mean number of events per year			Mean annual rainfall (mm)		
	Total	Big	Small	Total	Big	Small
AMMA-CATCH Niger	76 (100%)	44 (58.7%)	32 (41.3%)	515 (100%)	486 (94.3%)	29 (5.7%)
CP4	89 (100%)	44 (48.1%)	45 (51.9%)	435 (100%)	375 (87.5%)	60 (12.5%)

CP4 vs Obs: StochaStorm parameters

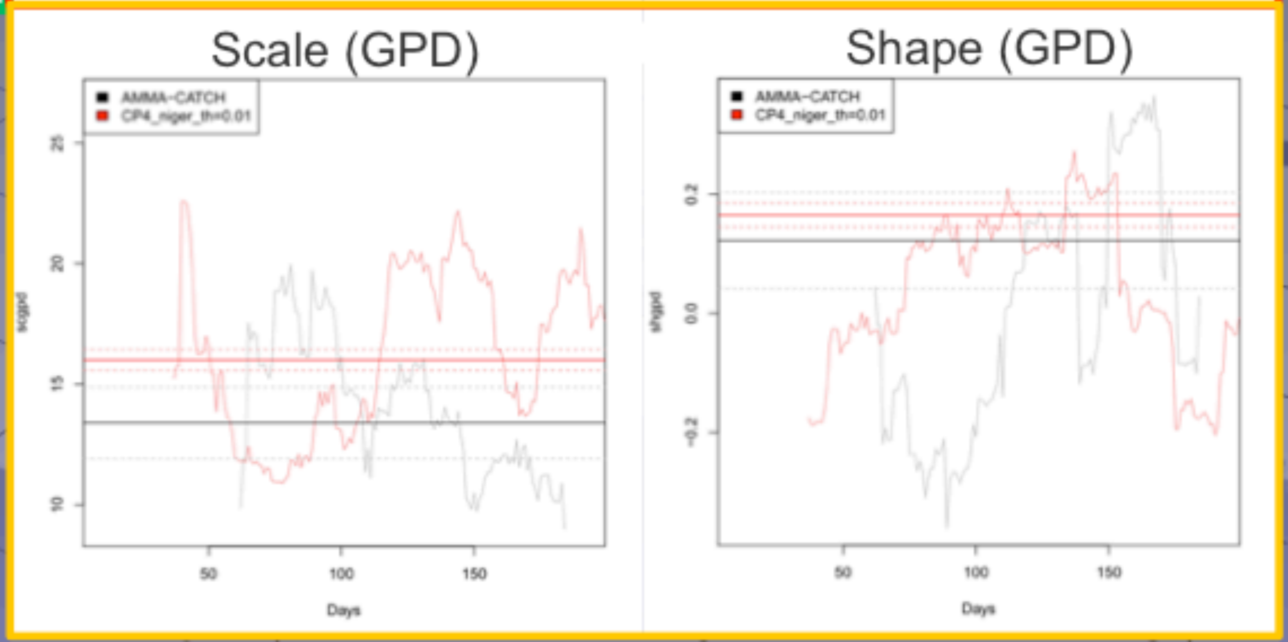


Storm occurrence

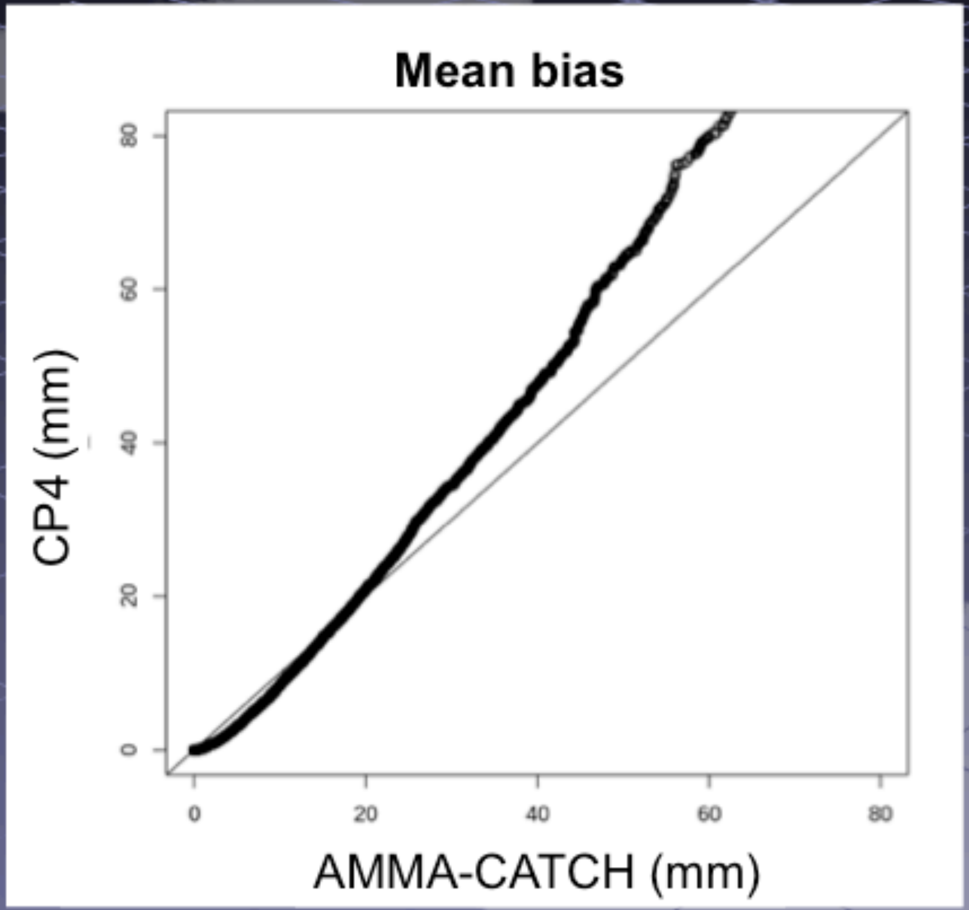
Storm internal intermittency

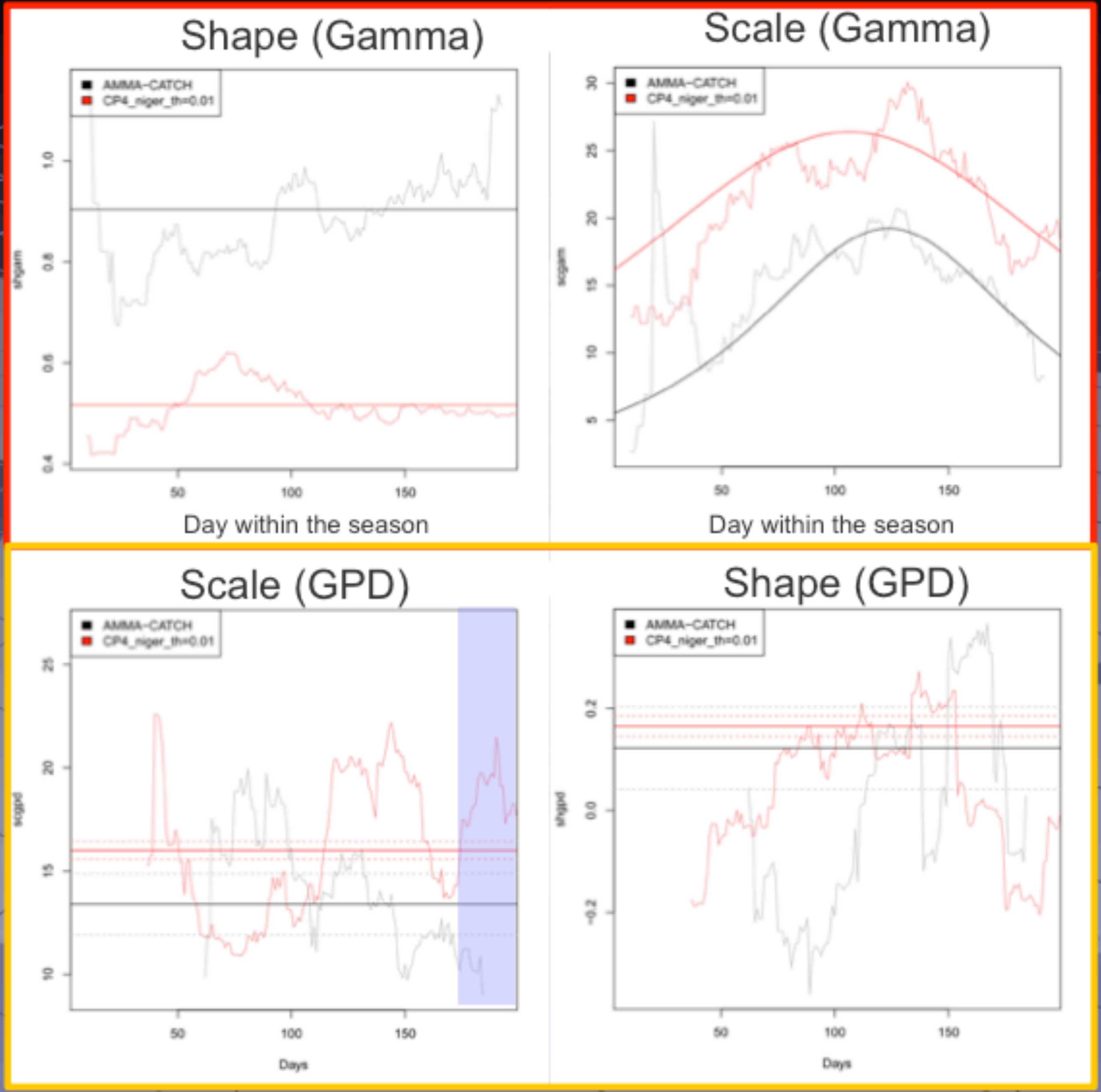
Distribution of event rainfall
0< values <40mm

Distribution of event rainfall
values >40mm

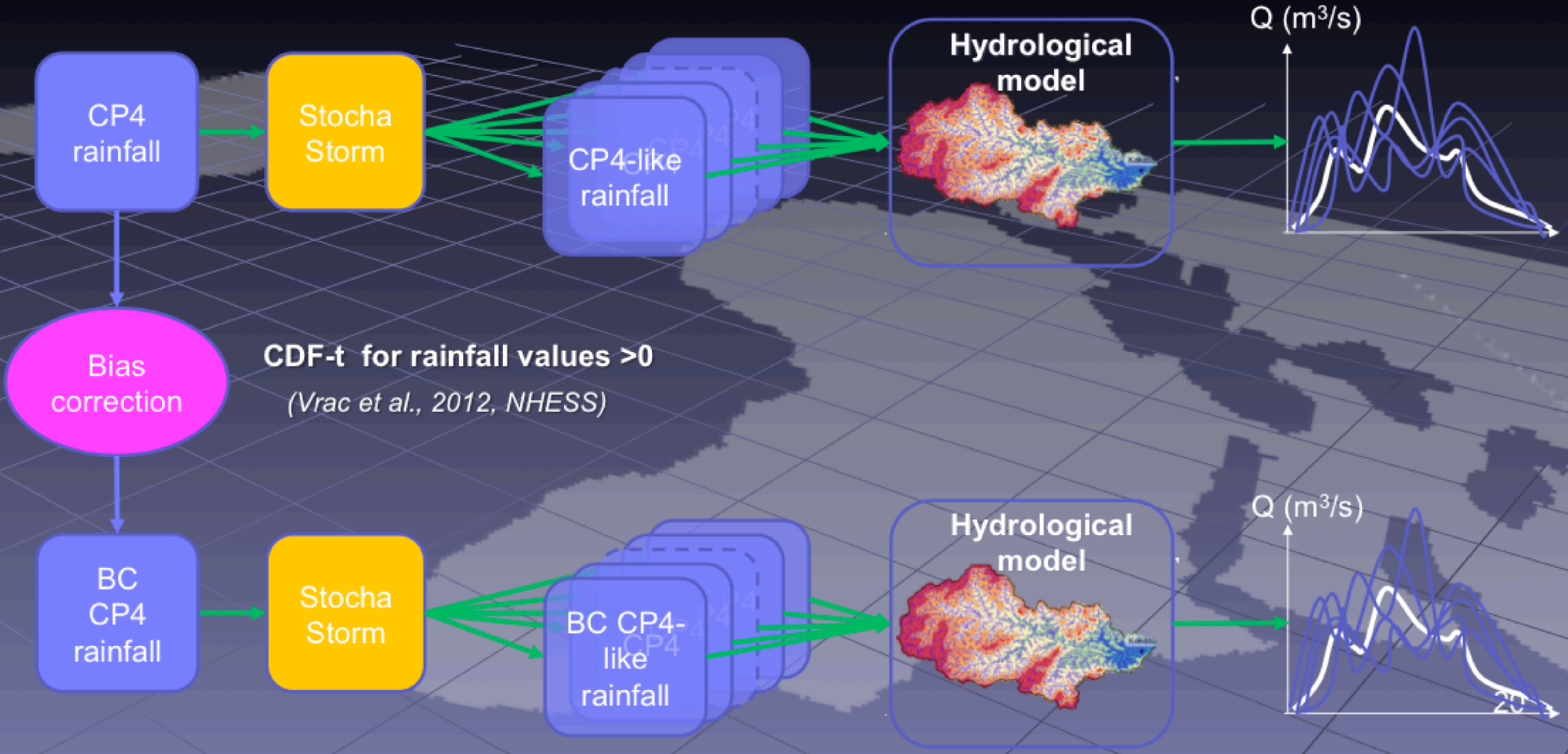


CP4 vs Obs: StochaStorm parameters

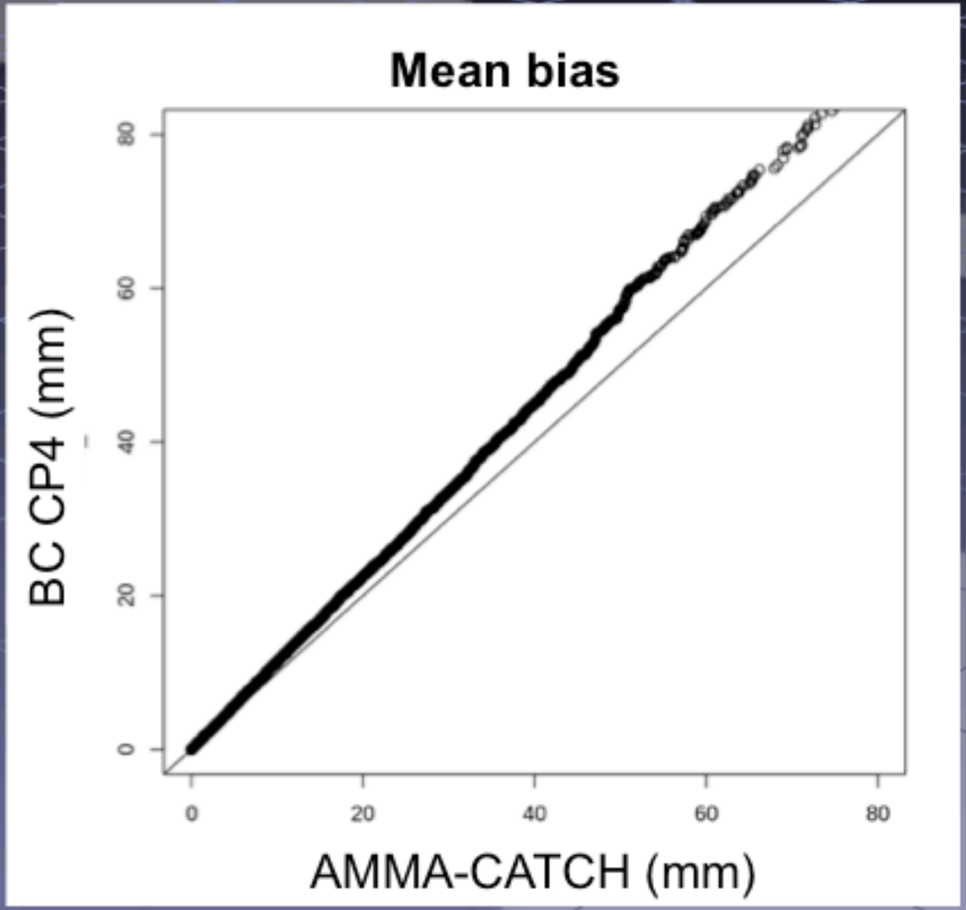


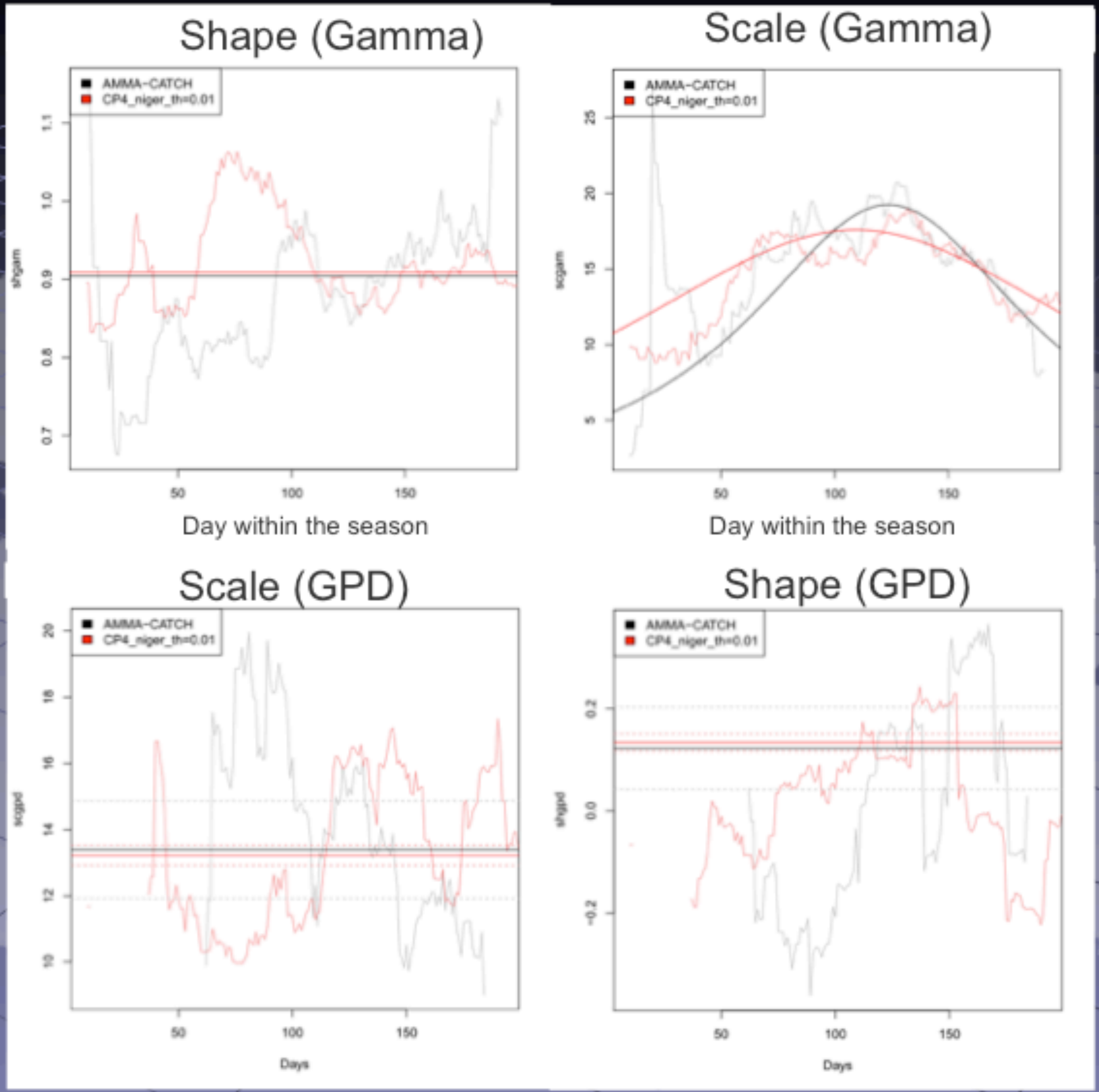


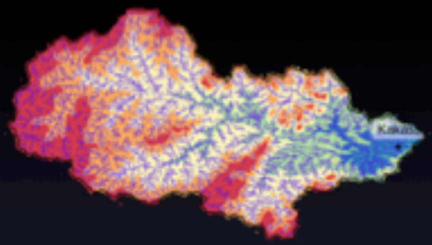
Hydrological application



CB CP4 vs Obs: StochaStorm parameters







100 realizations CP4

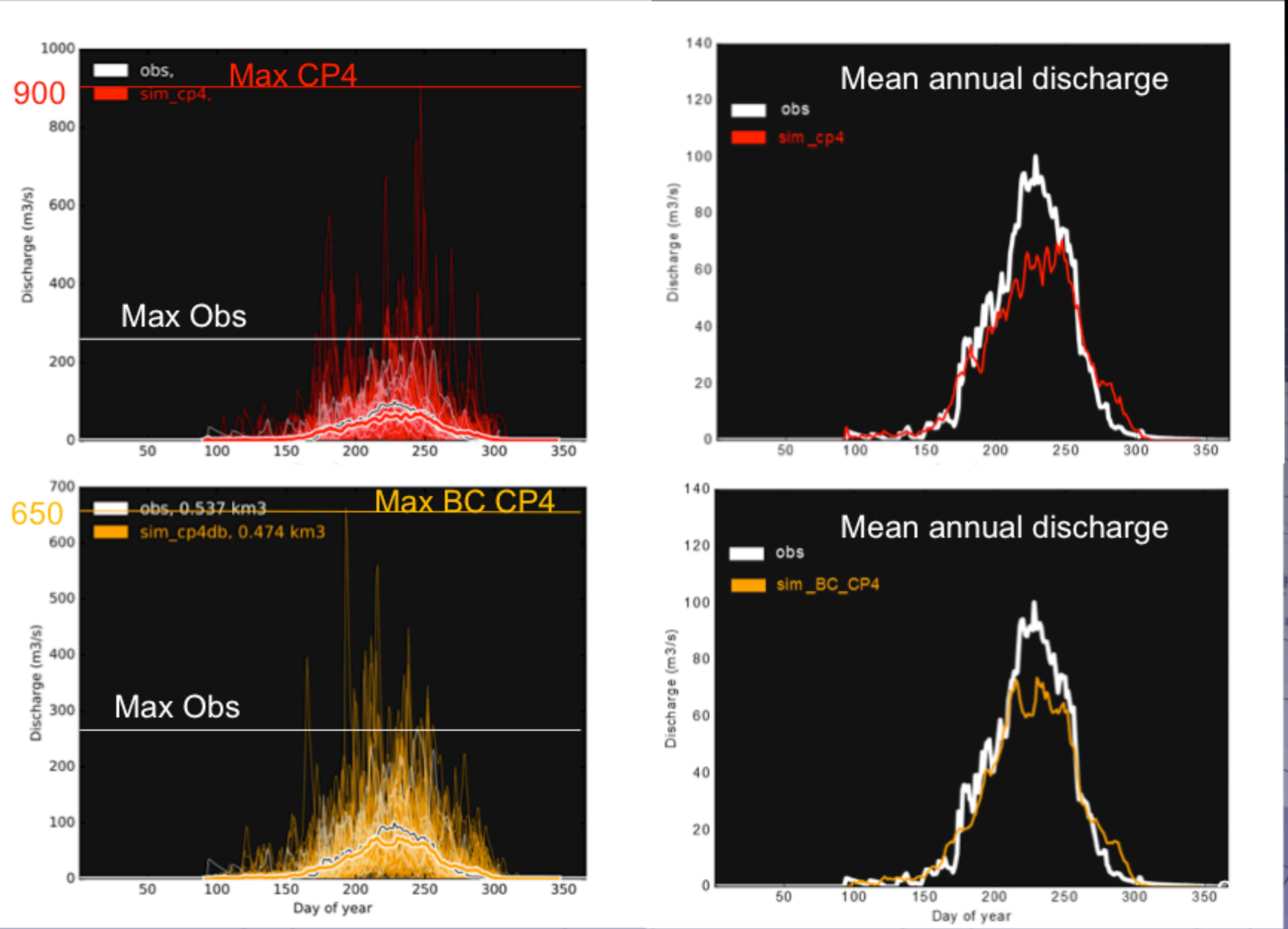
vs

10 years of Qobs

100 realizations of Bias Corrected CP4

vs

10 years of Qobs



Conclusions

- CP4 Rainfall:
  - Very realistic simulation of storm occurrence
  - Some bias in the event cumulative rainfall
    - → Requires bias correction
- CP4 Hydrological applications:
  - Promising potential for hydrological applications
  - Still some residual biases
    - → Requires further analysis
- Next steps:
  - → Improving the bias correction
  - → Using the statistico-dynamic modeling chain for simuation over the future period

They are note here but they made the job!!

Catherine WILCOX, PhD student, UGA

Guillaume QUANTIN, Research Engineer IRD