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Satellite rainfall for food security on the African continent: performance and accuracy of seven products between 2001 and 2016

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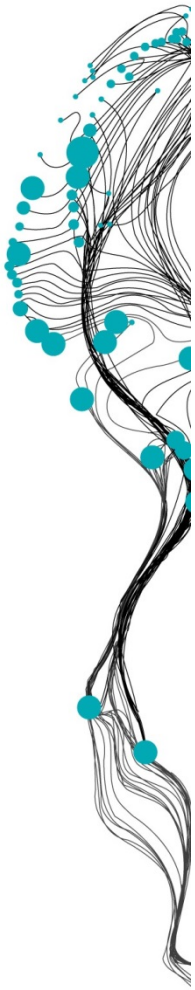
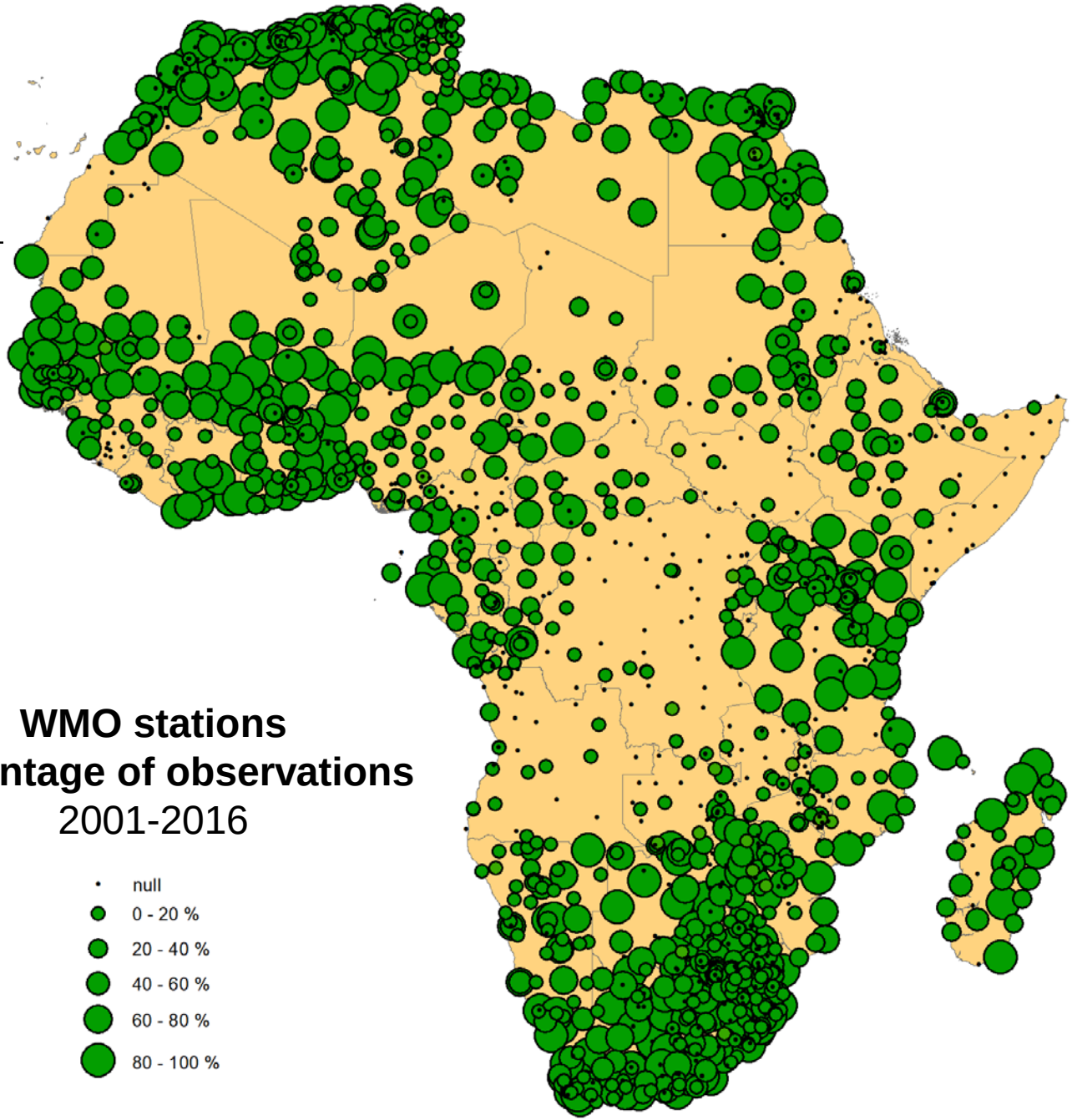
- Where is rainfall measured in Africa? (and where not)
- Where are observation records improving? (and where not)
- Comparing 7 satellite products
- Evaluating with WMO stations, and non-WMO stations
- What can we conclude (and what not)

low station density in Africa

	# WMO stations	sq km per station
Asia	5,718	7,700
Africa	1,643	17,340
Australia	1,231	4,208
Europe	5,304	1,465
North America	8,320	2,802
South America	1,581	9,829




WMO stations
percentage of observations
2001-2016
null
0 - 20 %
20 - 40 %
40 - 60 %
60 - 80 %
80 - 100 %

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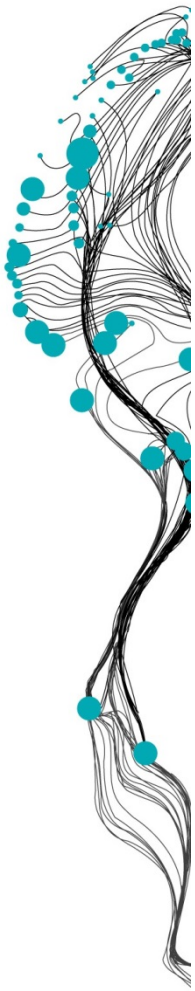

Sahel desert
Low rainfall
Low population density

Horn of Africa
Low rainfall
Frequent droughts

Central Africa
High rainfall
Low population density

WMO stations
percentage of observations
2001-2016

- null
- 0 - 20 %
- 20 - 40 %
- 40 - 60 %
- 60 - 80 %
- 80 - 100 %

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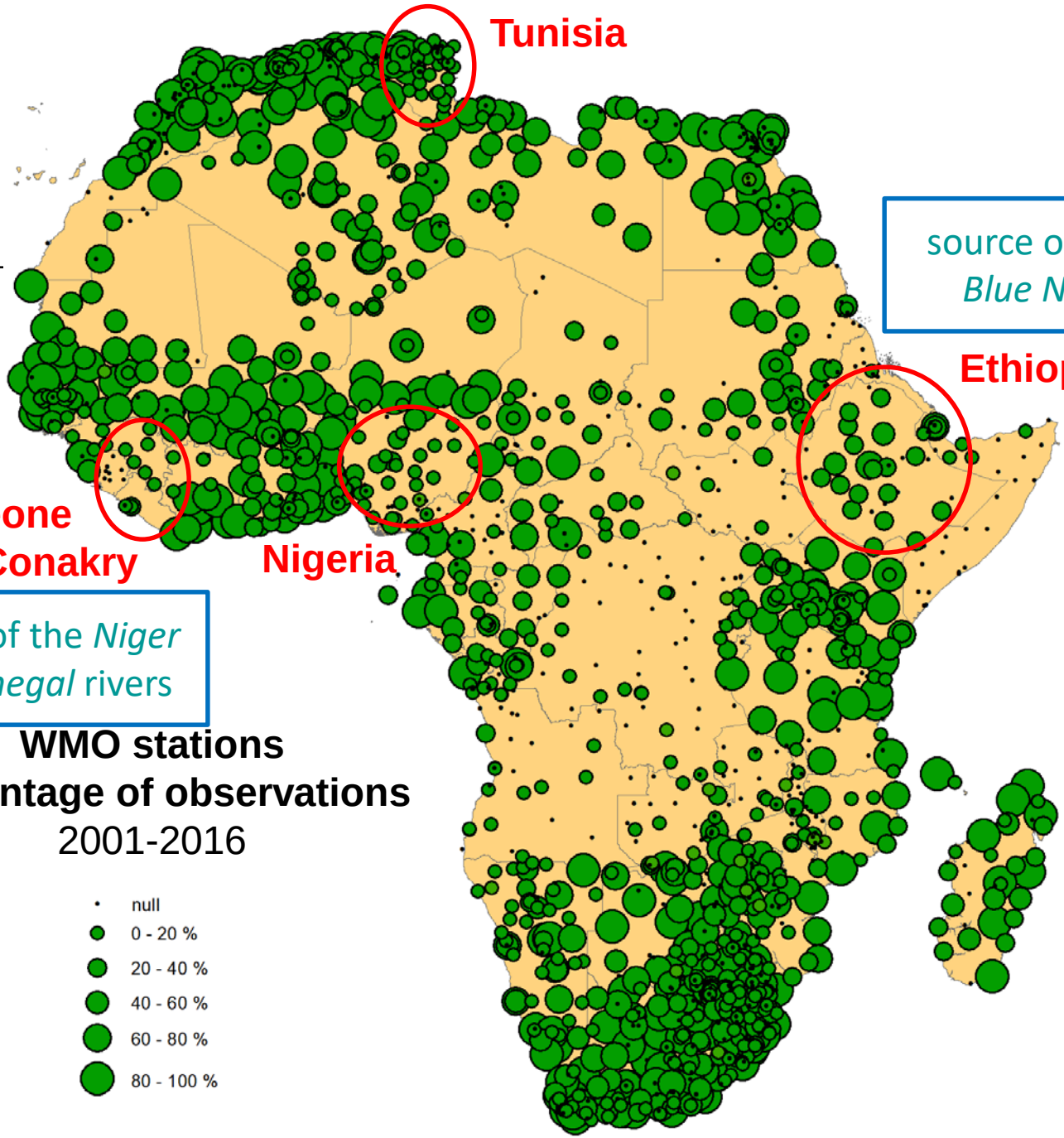
Tunisia
source of the
Blue Nile
Ethiopia
Liberia
Sierra Leone
Guinea-Conakry
Nigeria
source of the Niger
and Senegal rivers
WMO stations
percentage of observations
2001-2016
null
0 - 20 %
20 - 40 %
40 - 60 %
60 - 80 %
80 - 100 %

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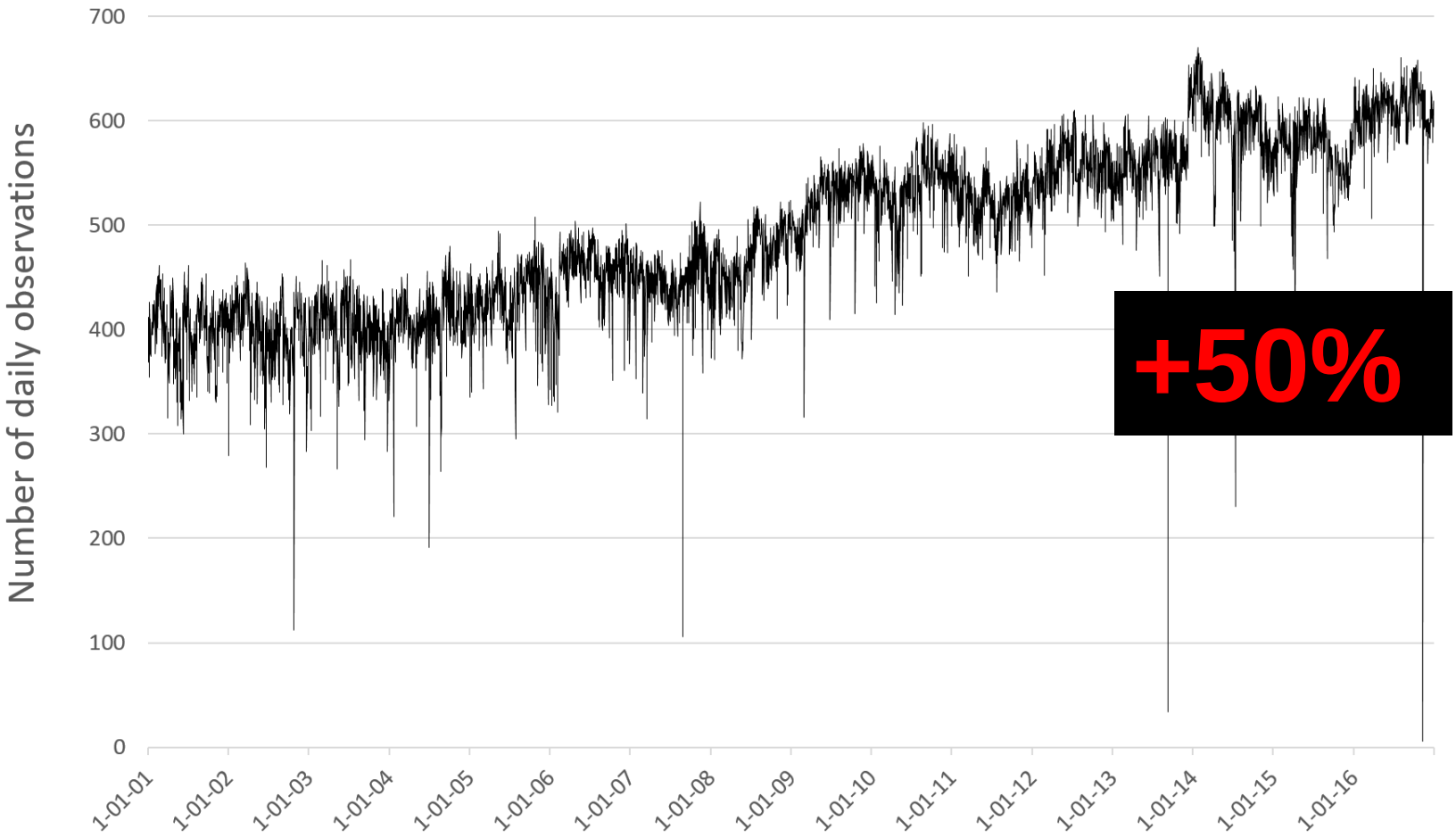
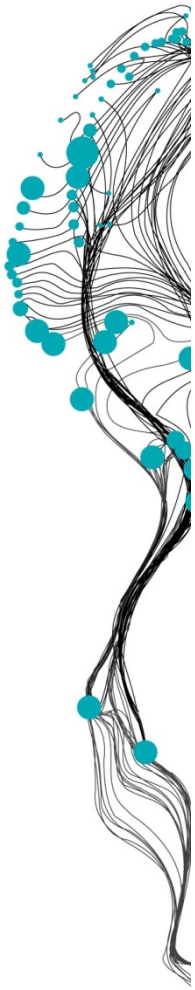
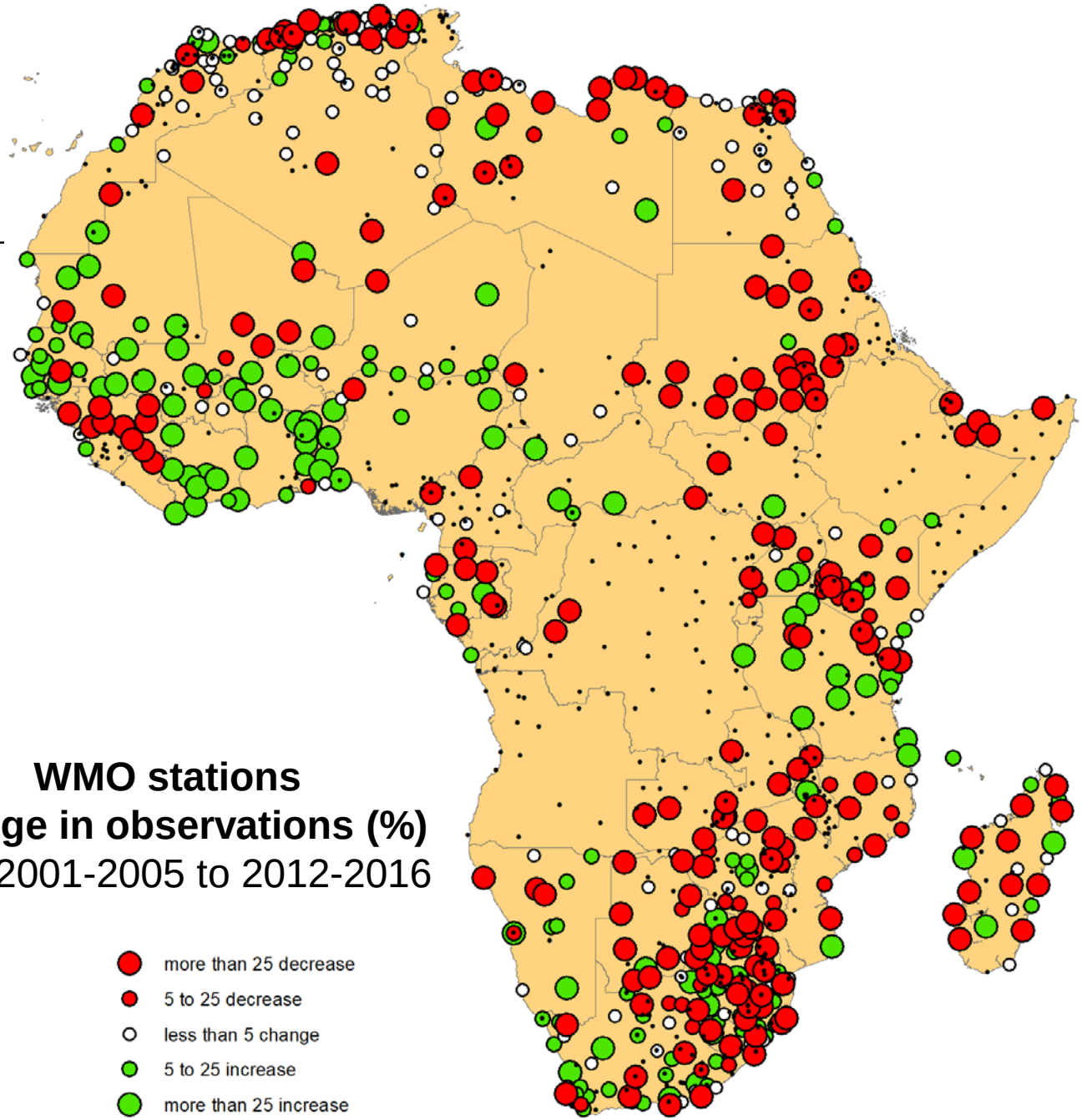
Reported daily rainfall observations (2001-16)







WMO stations
change in observations (%)
from 2001-2005 to 2012-2016

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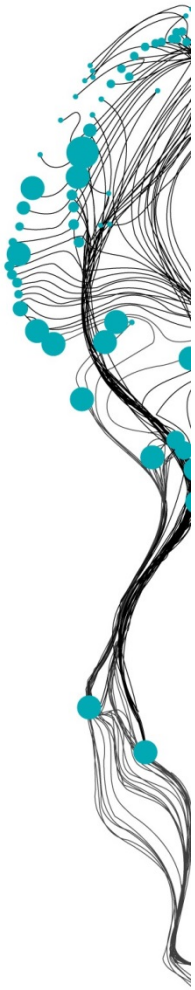

West-Africa

major improvements

Tanzania

WMO stations
change in observations (%)
from 2001-2005 to 2012-2016

- more than 25 decrease
- 5 to 25 decrease
- less than 5 change
- 5 to 25 increase
- more than 25 increase

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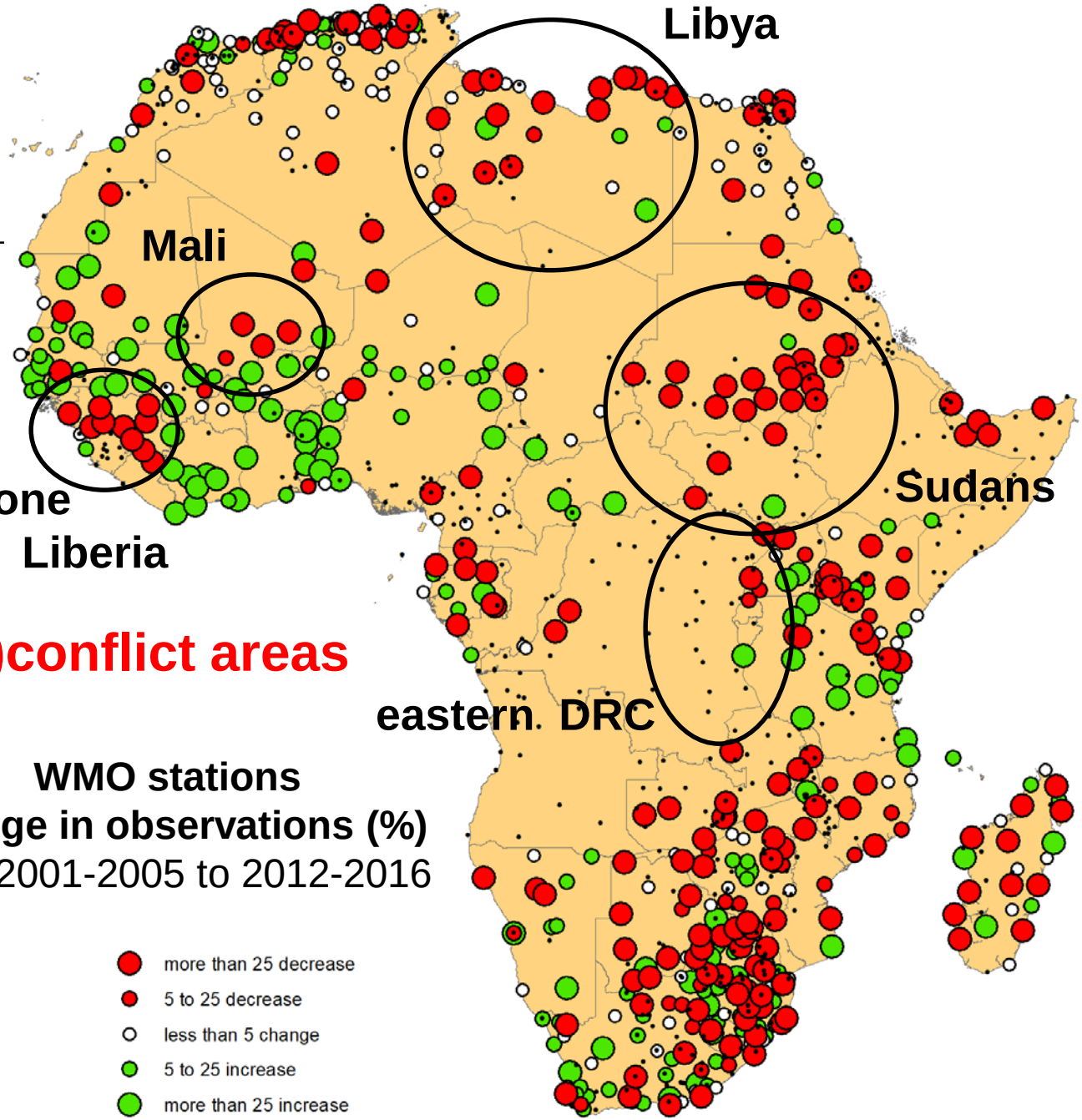
Libya
Mali
Sierra Leone
Liberia
Sudans
eastern DRC
(post-)conflict areas
WMO stations
change in observations (%)
from 2001-2005 to 2012-2016
more than 25 decrease
5 to 25 decrease
less than 5 change
5 to 25 increase
more than 25 increase

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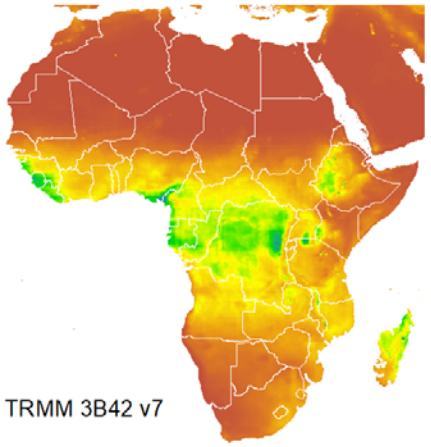
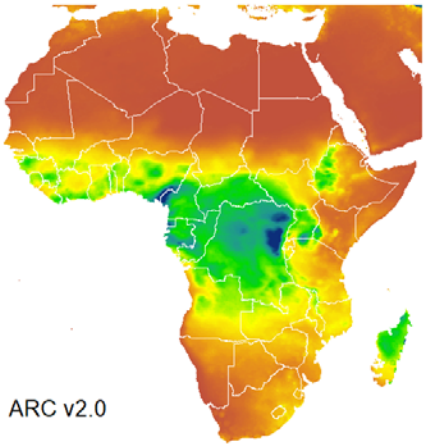
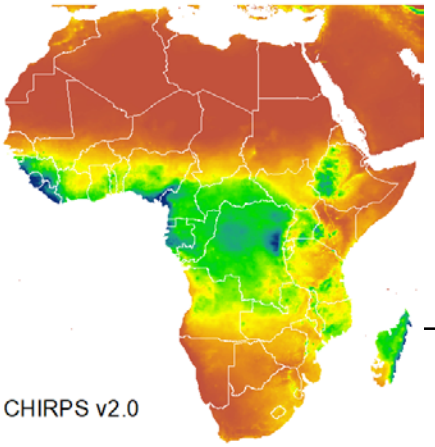
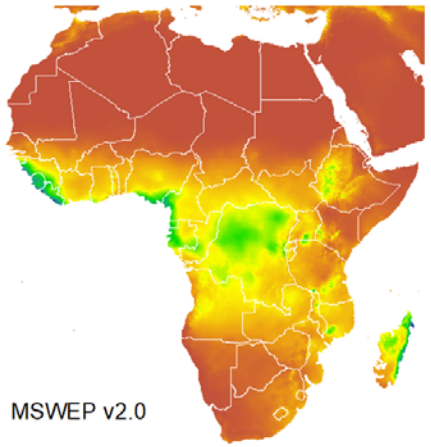
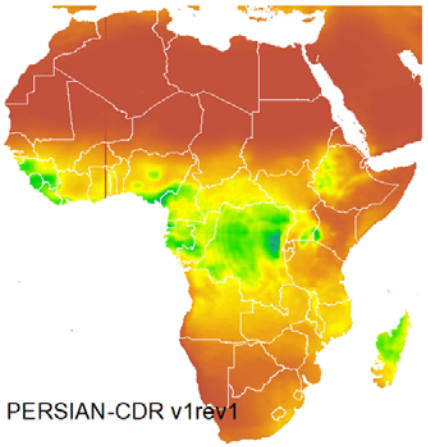
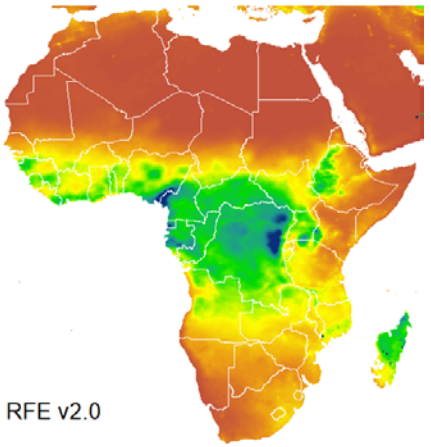


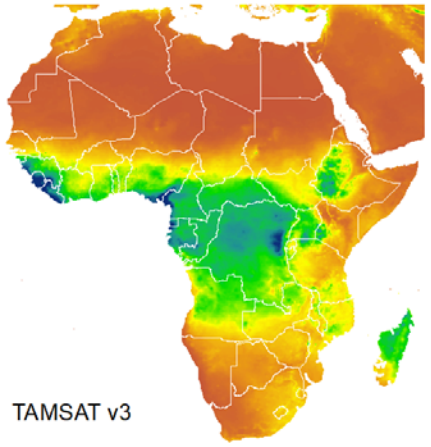


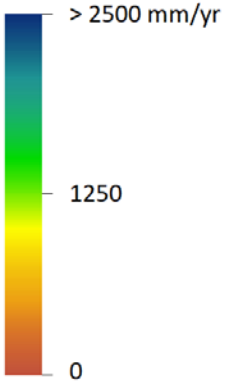




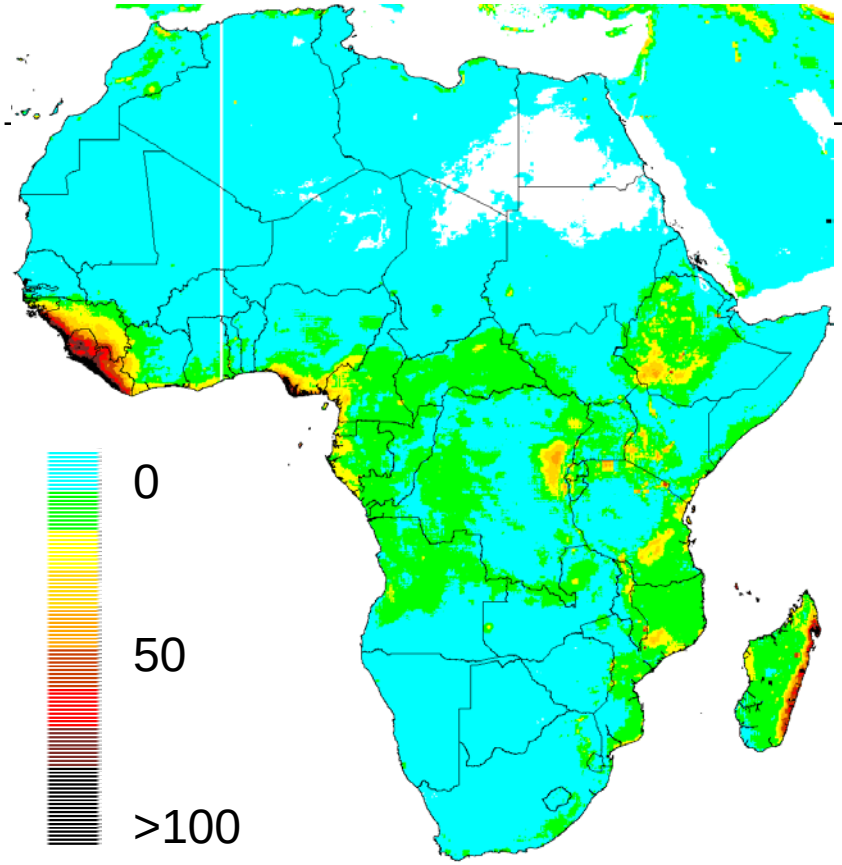




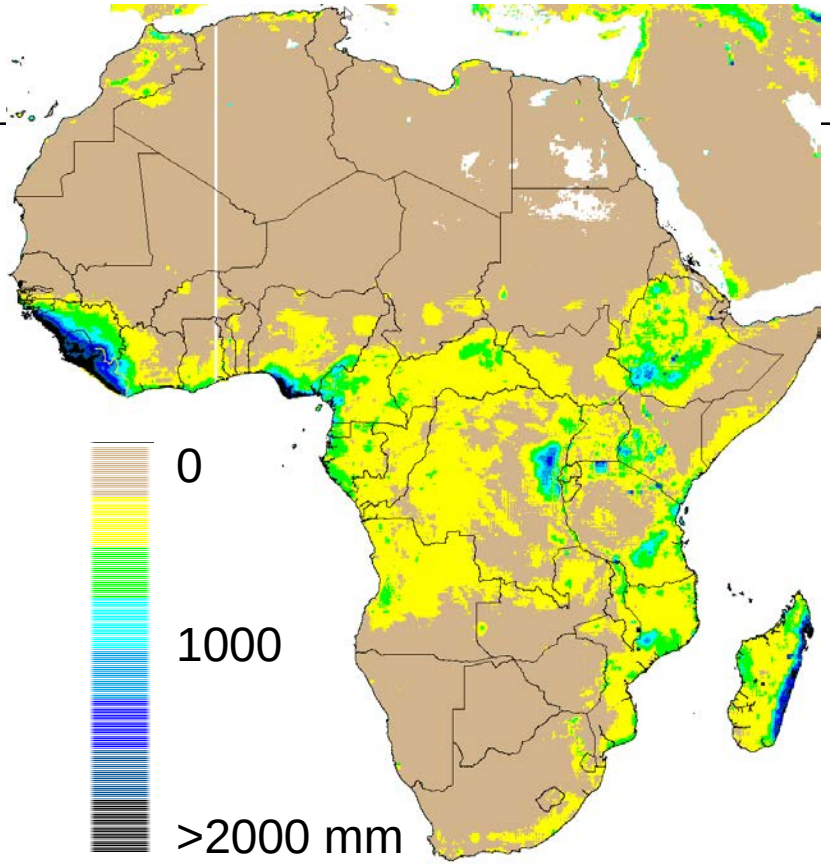




Annual average rainfall
2001-2016
for 7 satellite precipitation products



Standard deviation (n = 7)



Maximum difference between two products

Evaluation with WMO observations

- Evaluation approach published in **Dembélé and Zwart (2017)** in International Journal of Remote Sensing:

- **Continuous statistics** to assess rainfall quantity
- **Categorical statistics** to assess capability to detect rainfall

- **Time steps**: dekads, months, years (not daily!)

- **Pixel-to-point** comparison

- Only stations with **more than 50 % completeness** in observations

CONTINUOUS STATISTICS		VALUES RANGE	PERFECT SCORE
Pearson correlation coefficient	$r = \frac{\sum_{i=1}^{n}(G_i-\bar{G})(S_i-\bar{S})}{\sqrt{\sum_{i=1}^{n}(G_i-\bar{G})^2}\sqrt{\sum_{i=1}^{n}(S_i-\bar{S})^2}}$	–1 to 1	1
Mean Error	$ME = \frac{1}{n}\sum_{i=1}^{n}(S_i - G_i)$	–∞ to ∞	0
Bias	$Bias = \frac{\sum_{i=1}^{n} S_i}{\sum_{i=1}^{n} G_i}$	0 to ∞	1
Root Mean Square Error	$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(S_i - G_i)^2}$	0 to ∞	0
Nash–Suthcliffe efficiency coefficient	$E = 1 - \frac{\sum_{i=1}^{n}(S_i-G_i)^2}{\sum_{i=1}^{n}(G_i-\bar{G})^2}$	–∞ to 1	1
CATEGORICAL STATISTICS		**VALUES RANGE**	**PERFECT SCORE**
Probability of detection	$POD = H/(H+M)$	0 to 1	1
False alarm ratio	$FAR = F/(H+F)$	0 to 1	0

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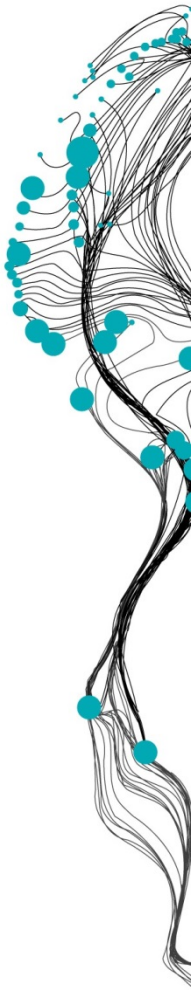

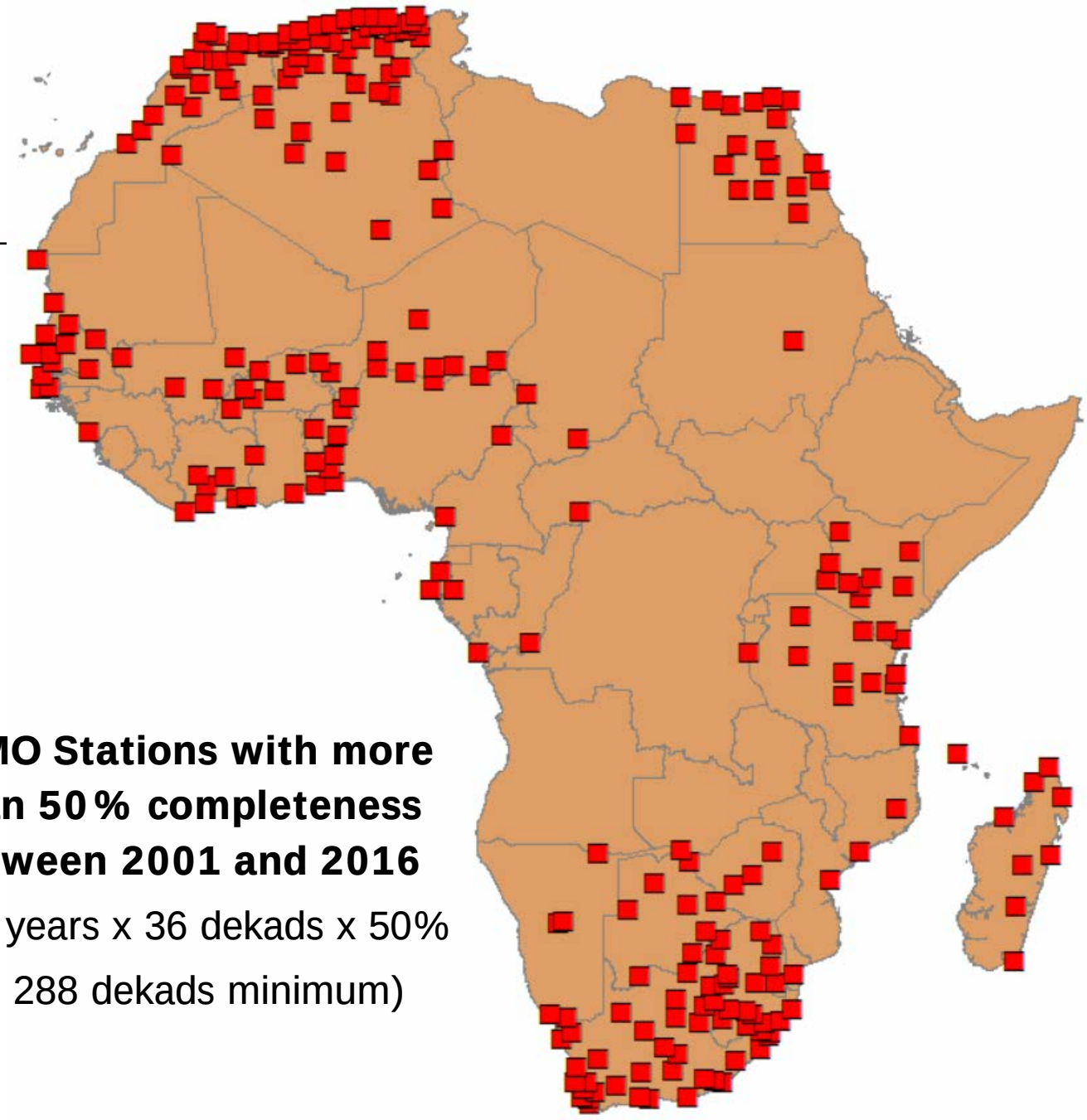

WMO Stations with more than 50 % completeness between 2001 and 2016

(16 years x 36 dekads x 50% = 288 dekads minimum)

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Statistical comparison for dekads (2001–16)

	PCE	ME	RMSE	Bias	NSE	POD	FAR
ARC	0,74	-0,09	15,54	1,33	-0,41	0,90	0,16
CHIRPS	0,61	0,39	19,02	1,01	0,32	0,75	0,29
MSWEP	0,85	0,00	12,52	1,04	0,34	0,95	0,26
PERSIAN	0,56	0,41	21,31	1,36	0,03	0,90	0,37
RFE	0,73	-0,49	15,85	1,20	0,15	0,92	0,19
TAMSAT	0,46	0,41	22,72	1,59	-0,55	0,76	0,33
TRMM	0,60	0,23	21,02	1,38	-0,10	0,84	0,33

Averages of all stations in Africa that report minimal 50% completeness

- Pearson's correlation coefficient
- Mean Error
- Root Mean Squared Error
- Bias
- Nash-Suthcliffe efficiency coefficient
- Probability of Detection
- False Alarm Ratio

ITC

Statistical comparison for dekads (2001–16)

	PCE	ME	RMSE	Bias	NSE	POD	FAR
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TAMSAT	0,46	0,41	22,72	1,59	-0,55	0,76	0,33
TRMM	0,60	0,23	21,02	1,38	-0,10	0,84	0,33

RELATIVE RANKING							
ARC	0,7	0,8	0,7	0,4	0,2	0,8	1,0
CHIRPS	0,4	0,2	0,4	1,0	1,0	0,0	0,4
MSWEP	1,0	1,0	1,0	0,9	1,0	1,0	0,6
PERSIAN	0,3	0,2	0,1	0,4	0,7	0,8	0,0
RFE	0,7	0,0	0,7	0,7	0,8	0,9	0,9
TAMSAT	0,0	0,2	0,0	0,0	0,0	0,0	0,2
TRMM	0,4	0,5	0,2	0,4	0,5	0,4	0,2

ITC

Statistical comparison for dekads (2001–16)

	PCE	ME	RMSE	Bias	NSE	POD	FAR	
ARC	0,74	-0,09	15,54	1,33	-0,41	0,90	0,16	2
CHIRPS	0,61	0,39	19,02	1,01	0,32	0,75	0,29	4
MSWEP	0,85	0,00	12,52	1,04	0,34	0,95	0,26	1
PERSIAN	0,56	0,41	21,31	1,36	0,03	0,90	0,37	5
RFE	0,73	-0,49	15,85	1,20	0,15	0,92	0,19	2
TAMSAT	0,46	0,41	22,72	1,59	-0,55	0,76	0,33	7
TRMM	0,60	0,23	21,02	1,38	-0,10	0,84	0,33	5

RELATIVE RANKING

ARC	0,7	0,8	0,7	0,4	0,2	0,8	1,0	4,6
CHIRPS	0,4	0,2	0,4	1,0	1,0	0,0	0,4	3,3
MSWEP	1,0	1,0	1,0	0,9	1,0	1,0	0,6	6,5
PERSIAN	0,3	0,2	0,1	0,4	0,7	0,8	0,0	2,4
RFE	0,7	0,0	0,7	0,7	0,8	0,9	0,9	4,6
TAMSAT	0,0	0,2	0,0	0,0	0,0	0,0	0,2	0,4
TRMM	0,4	0,5	0,2	0,4	0,5	0,4	0,2	2,6

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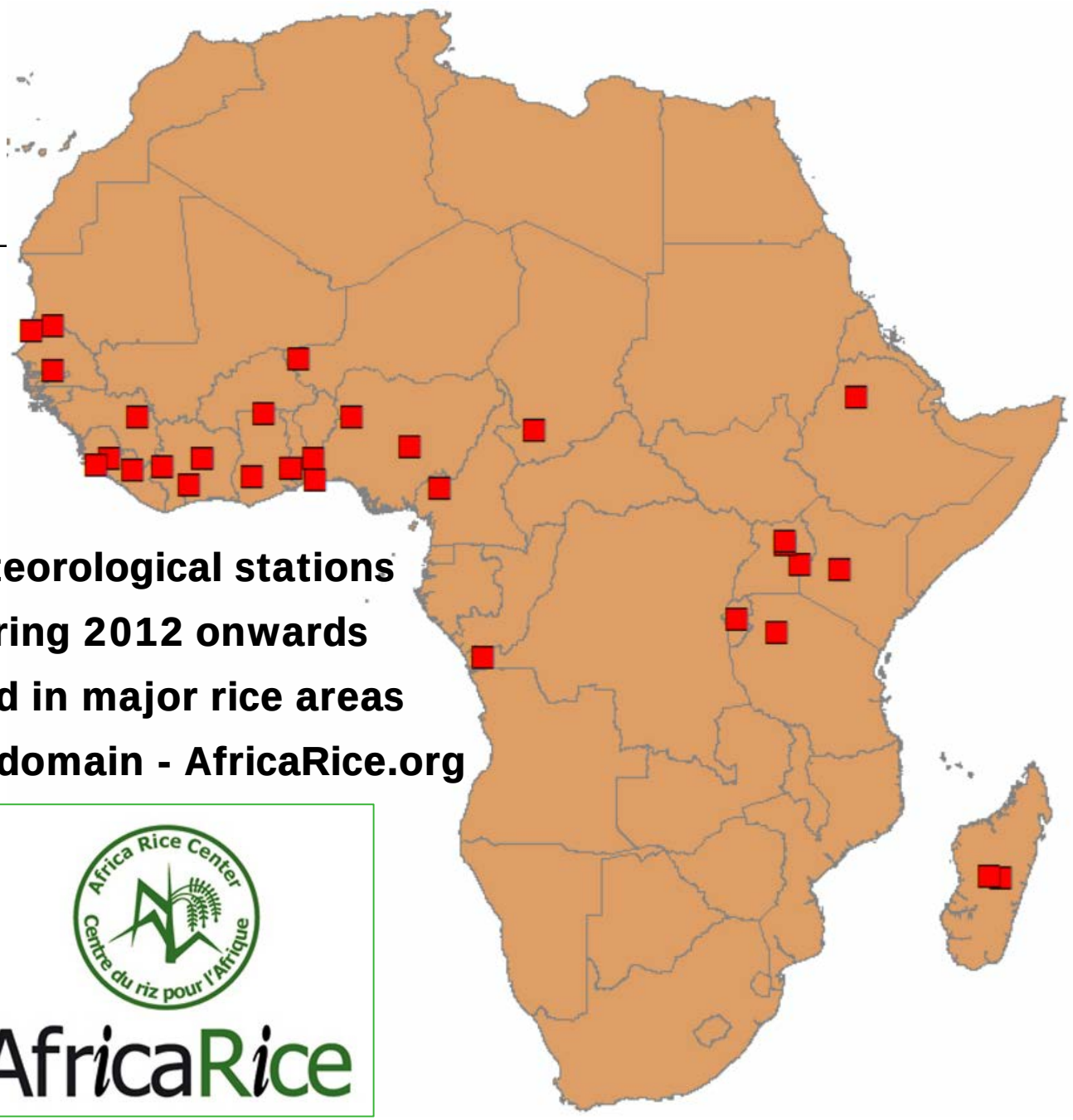

- **32 meteorological stations**
- **Measuring 2012 onwards**
- **Located in major rice areas**
- **Public domain - AfricaRice.org**

Africa Rice Center
Centre du riz pour l'Afrique
AfricaRice

ITC

Statistical comparison for dekads (2001–16)

	PCE	ME	RMSE	Bias	NSE	POD	FAR	
ARC	0,59	-3,24	30,76	1,01	0,15	0,89	0,23	5
CHIRPS	0,63	0,58	29,56	1,12	0,21	0,88	0,24	2
MSWEP	0,63	-1,44	28,47	1,00	0,31	0,95	0,22	1
PERSIAN	0,63	-0,52	29,17	1,10	0,22	0,98	0,34	2
RFE	0,61	-2,09	29,67	1,02	0,22	0,93	0,26	4
TAMSAT	0,63	1,23	28,56	1,16	0,27	0,90	0,26	5
TRMM	-0,03	-17,03	45,77	0,46	-0,70	0,60	0,39	7

RELATIVE RANKING

ARC	0,9	0,8	0,9	1,0	0,8	0,8	0,9	**6,2**
CHIRPS	1,0	1,0	0,9	0,8	0,9	0,7	0,9	**6,2**
MSWEP	1,0	0,9	1,0	1,0	1,0	0,9	1,0	**6,9**
PERSIAN	1,0	1,0	1,0	0,8	0,9	1,0	0,3	**6,0**
RFE	1,0	0,9	0,9	1,0	0,9	0,9	0,8	**6,3**
TAMSAT	1,0	1,0	1,0	0,7	1,0	0,8	0,8	**6,2**
TRMM	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**0,0**

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Statistical comparison for dekads (2001–16)

	PCE	ME	RMSE	Bias	NSE	POD	FAR	
ARC	0,59	-3,24	30,76	1,01	0,15	0,89	0,23	6
CHIRPS	0,63	0,58	29,56	1,12	0,21	0,88	0,24	4
MSWEP	0,63	-1,44	28,47	1,00	0,31	0,95	0,22	1
PERSIAN	0,63	-0,52	29,17	1,10	0,22	0,98	0,34	2
RFE	0,61	-2,09	29,67	1,02	0,22	0,93	0,26	4
TAMSAT	0,63	1,23	28,56	1,16	0,27	0,90	0,26	3
TRMM								7

RELATIVE RANKING

ARC	0,0	0,0	0,0	0,9	0,0	0,1	0,9	2,0
CHIRPS	1,0	1,0	0,5	0,3	0,4	0,0	0,8	4,0
MSWEP	1,0	0,7	1,0	1,0	1,0	0,7	1,0	6,4
PERSIAN	1,0	1,0	0,7	0,4	0,4	1,0	0,0	4,5
RFE	0,5	0,4	0,5	0,9	0,4	0,5	0,7	3,9
TAMSAT	1,0	0,7	1,0	0,0	0,8	0,2	0,7	4,3
TRMM								

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Statistical comparison for dekads (2001–16)

WMO stations

MSWEP	1
ARC	2
RFE	2
CHIRPS	4
PERSIAN	5
TRMM	5
TAMSAT	7

AfricaRice stations

MSWEP	1
PERSIAN	2
TAMSAT	3
CHIRPS	4
RFE	4
ARC	6
TRMM	7

Take-home messages

- **Daily estimations** of precipitation **should not be used** in hydrological modelling, food security assessments, etc.
- **Best performing** products (in general) in continental Africa is **MSWEP**
  Least performing is **TRMM**
- Local studies should **always evaluate** products beforehand and then decide **for a specific region** and **specific purpose**

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Evaluation and comparison of satellite-based rainfall products in Burkina Faso, West Africa

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ABSTRACT

The performance of seven operational high-resolution satellite-based rainfall products – Africa Rainfall Estimate Climatology (ARC 2.0), Climate Hazards Group InfraRed Precipitation with Stations (CHIRPS), Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN), African Rainfall Estimation (RFE 2.0), Tropical Applications of Meteorology using SATellite (TAMSAT), African Rainfall Climatology and Time-

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