School of Earth and Environment
INSTITUTE FOR CLIMATE AND ATMOSPHERIC SCIENCE

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From Extreme Weather to Climate Change in Africa

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22nd October 2019

Michael Sadler Rupert Beckett Lecture Theatre

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GCRF African SWIFT

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

GRATITUDE

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I thank Peter and Susan Cheney for funding my fellowship

I acknowledge all the different people and sources from which I got various materials used.

Intergovernmental Panel on Climate Change (IPCC)

The role of the IPCC is to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information, relevant to:

- understanding the scientific basis of risk of human-induced climate change
- Its potential impacts
- And options for adaptation and mitigation

IPCC outreach on Climate Change

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Climate change Evangelist

- https://youtu.be/T1eGJLqxxKQ

Some statements

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1) Most of Africa’s natural disasters are hydrometeorological in origin
2) **Natural disasters are challenging to predict, but we can plan for impending disasters and prepare for risks**
3) Africa’s contribution to the greenhouse gas (GHG) emissions is negligible compared to developed countries (about 4% of global GHG emissions)
4) Africa is the most vulnerable to the impacts of climate change and disasters
5) Climate change will affect the weather systems differently in different regions of Africa
6) **IPCC projects an increase in the intensity and frequency of extreme events (e.g. Floods, heatwaves, droughts and storms)**
7) **Climate is what you expect, Weather is what you get**
8) **Inferences about weather systems in a changing climate have been made from climate models (and not weather prediction models)**

Extreme Event Prediction: The Case of Cyclone Idai

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1) The IPCC projects an increase in frequency and intensity of extreme events
2) The predictability of hurricanes/cyclones is relatively better compared to other extreme events
3) This is illustrated by model agreement from different centres
4) Yet the impact of one hurricane in one country is devasting enough
5) What preparation is being put into the other common extreme events in Africa whose predictability is relatively more challenging than the hurricanes?
6) Take home message: As resources are being put into climate change policies and strategies, there is the need to develop weather infrastructure along side. As the impact of climate change will still be felt if emissions were reduced to zero even in 2020. We all know we are very far from that even by 2050
7) More needs to be done to reduce the impact of extreme events. For example, early warning must be coupled with early action

CYCLONE IDAI

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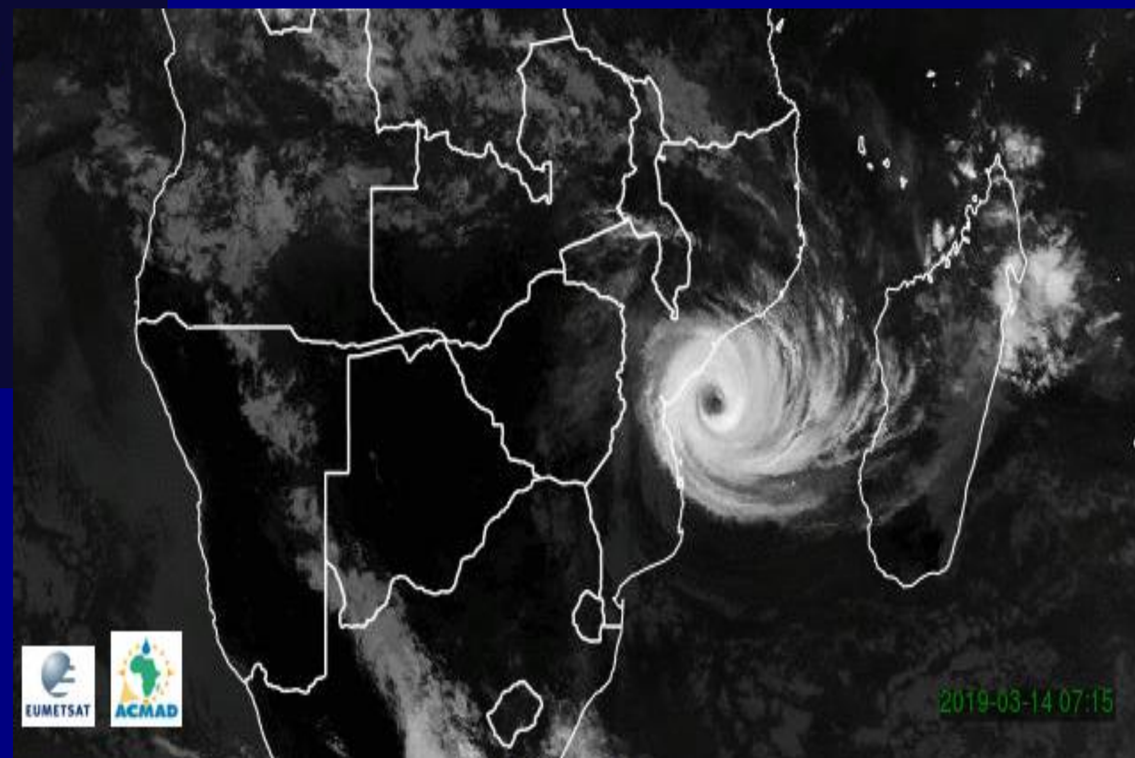

Zimbabwe

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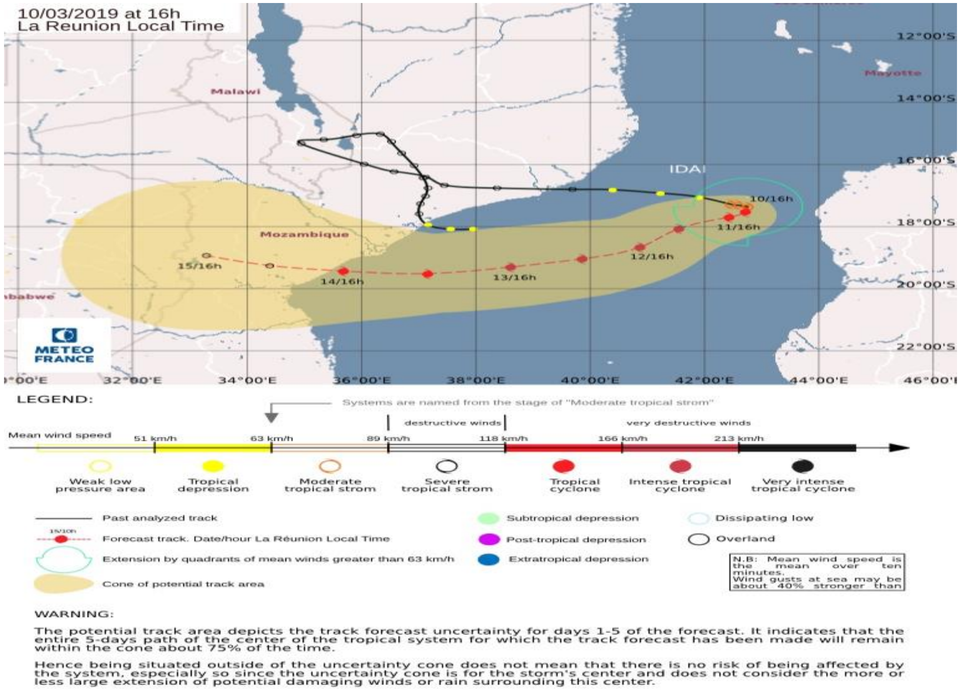
Storm Track


10/03/2019 at 16h
La Reunion Local Time
Malawi
Mozambique
Mayotte
IDAI
10/16h
11/16h
12/16h
13/16h
14/16h
15/16h
12°00'S
14°00'S
16°00'S
18°00'S
20°00'S
22°00'S
32°00'E
34°00'E
36°00'E
38°00'E
40°00'E
42°00'E
44°00'E
METEO FRANCE
LEGEND:
Systems are named from the stage of "Moderate tropical strom"
destructive winds
very destructive winds
Mean wind speed
51 km/h
63 km/h
89 km/h
118 km/h
166 km/h
213 km/h
Weak low pressure area
Tropical depression
Moderate tropical strom
Severe tropical strom
Tropical cyclone
Intense tropical cyclone
Very intense tropical cyclone
Past analyzed track
Forecast track. Date/hour La Réunion Local Time
Extension by quadrants of mean winds greater than 63 km/h
Cone of potential track area
Subtropical depression
Post-tropical depression
Extratropical depression
Dissipating low
Overland
N.B: Mean wind speed is the mean over ten minutes.
Wind gusts at sea may be about 40% stronger than
WARNING:
The potential track area depicts the track forecast uncertainty for days 1-5 of the forecast. It indicates that the entire 5-days path of the center of the tropical system for which the track forecast has been made will remain within the cone about 75% of the time.
Hence being situated outside of the uncertainty cone does not mean that there is no risk of being affected by the system, especially so since the uncertainty cone is for the storm's center and does not consider the more or less large extension of potential damaging winds or rain surrounding this center.

Model Agreement – Cyclone Idai: 24hr lead time 13th to 16th March 2019

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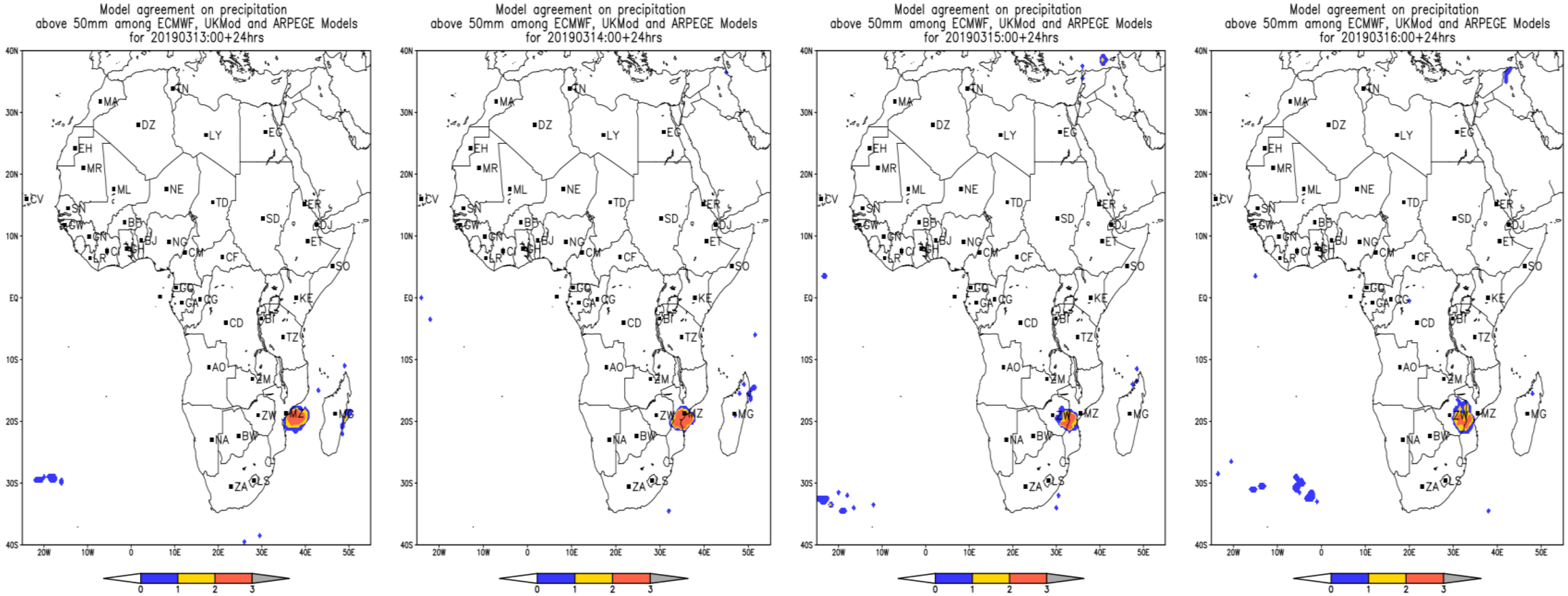

Model Agreement – Cyclone Idai: 24hr lead time
17th to 21st March 2019

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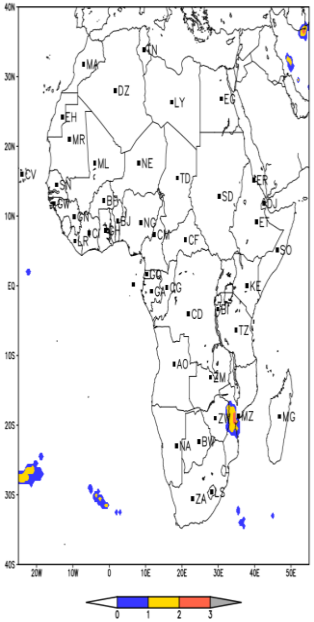
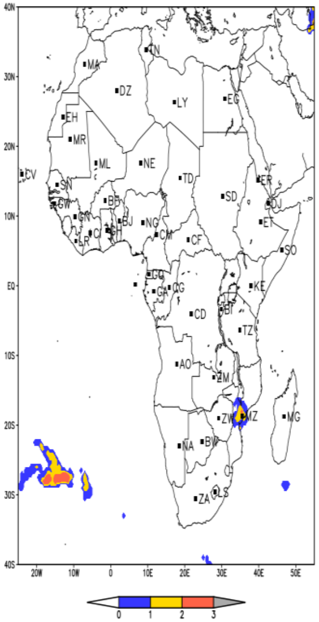
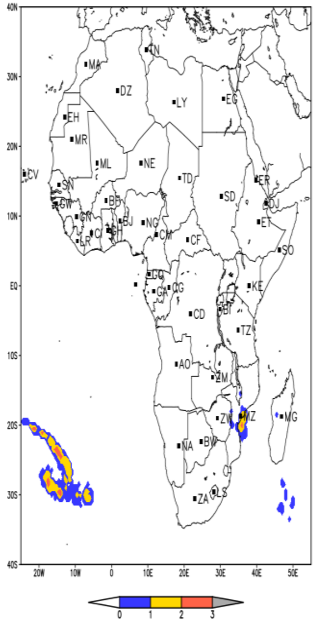
Model agreement on precipitation
above 50mm among ECMWF, UKMod and ARPEGE Models
for 20190317:00+24hrs



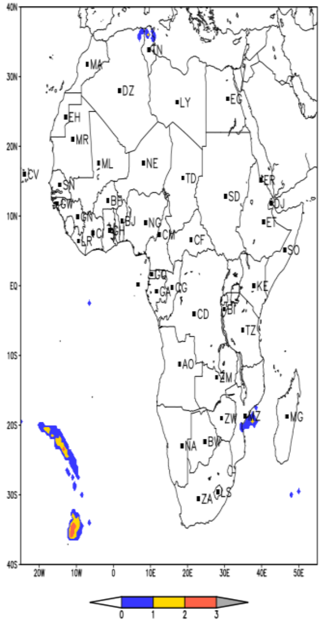
Model agreement on precipitation
above 50mm among ECMWF, UKMod and ARPEGE Models
for 20190318:00+24hrs



Model agreement on precipitation
above 50mm among ECMWF, UKMod and ARPEGE Models
for 20190319:00+24hrs



Model agreement on precipitation
above 50mm among ECMWF, UKMod and ARPEGE Models
for 20190320:00+24hrs



Model agreement on precipitation
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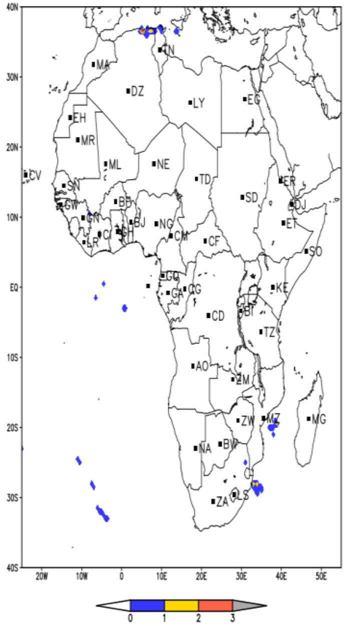

Respective updates from Mozambique, Malawi and Zimbabwe on Impacts of Cyclone IDAI

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Mozambique

Deaths	Houses (partially or totally destroyed)	Schools affected	Classrooms affected	Health facilities partially destroyed	Health facilities completely destroyed
603	240 000	137	4219	91	3

Malawi

Deaths	Houses (partially or totally destroyed)	Schools affected	Injured people	Affected people	Displaced people
60	288,371	154	672	975,000	86, 976

Zimbabwe

Deaths	Houses (partially or totally destroyed)	Schools affected	Injured people	People requiring humanitarian assistance	Health facilities damaged
344	17, 000	971	192	270,000	294

Summary

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1. Models agree in their forecast with different lead times (e.g. 24, 48 hrs.) – only 24 hr. lead time is shown
2. March 14, 2019 cyclone reached peak intensity with maximum winds of 195 km/h (120 mph) and minimum central pressure of 940mb in Mozambique
3. During the event, satellite picture showed the cyclone enter Mozambique and later retreated. The models in agreement captured this movement
4. **There is growing confidence in the science of attribution - To quantify the link between some extreme weather events and climate change**

Food for thought

1. Are we ready with the weather infrastructure to be able to predict these extreme events when the projections of the Intergovernmental Panel on Climate Change manifests?
2. Note the events will be weather events at the time of occurrence.
3. Studies in recent past, made projections for 2020. The year 2020 starts in a few months. How prepared are we to manage the projected events, should they occur? Examples of such studies:
   a) Theobald, 2005: Landscape Patterns of Exurban Growth in the USA from 1980 to 2020
   b) Hanaoka and Kainuma, 2012: Low carbon transitions in world regions: comparison of technological mitigation potential and costs in 2020 and 2030 through bottom-up analyses

Value of economic outcome

Could be increased:

1. By improving the forecast
2. By improving communication
3. By improving decision-making process

So what do we want?

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1. A reliable, modern, and real-time weather, water and climate information services, supporting communities and countries towards meeting their **climate resilience** and economic development goals
2. To deliver daily weather forecasts and advise policy makers about climate variability and change
   - In doing so, support actions that protects lives and property from extreme weather and builds long-term climate resilience
3. An improved weather forecasting system will reduce loss of property and lives. Early Warning coupled with Early Action contributes to resilience

Meteorology and Natural Disasters

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1. Although, strategies for coping with weather disasters are essentially of national concern, they involve international considerations for the following reasons
   a) Science and practice of meteorology requires an international approach, and national storm warning systems are dependent upon international exchange of information
   b) In many developing countries, technical assistance is needed in developing the NMHS, so as to improve the internal storm warning systems (SWIFT and Nowcasting, etc.)
   c) In some cases, devastation calls for international relief measures.

2. Basic International arrangements – WWW, GARP
3. Tropical cyclones most devastating, however, tornadoes, floods, blizzards, droughts are other examples of the manifestation of natural disasters.

Resilience

1. The best response strategy is one that improves the resilience of

   Economies, Environment and societies

2. Requires an overall **development approach** which seeks

   a) To Mitigate the risks posed by climate change and variability to the attainment of the Sustainable Development Goals at the global level

   b) Ambitious and urgent global commitments required to tackle climate change and variability, **else most African countries will not be able to implement 2030 Agenda for Sustainable Development and the AU Agenda 2063**

   c) Resilience building requires decision making across time scales (weather prediction, seasonal climate prediction, climate change projections)

Decision-making across timescales

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Begin monitoring mid-range And short-range forecasts	Continue monitoring Short-time-scale forecasts	Deploy assessment teams
Update contingency plans	Mobilize assessment teams	Activate volunteers
Train volunteers	Alert volunteers	Instruction to communities to evacuate, if needed
Sensitize communities	Warn communities	
Enable early-warning systems	Local preparation activities	

Weather-climate interface

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1. Resilience to present day climate is necessary for resilience to the future
2. Impact-based weather forecasting is somehow necessary for climate resilience
3. Management –
   a) Emergency – Weather time scale
   b) Operational – Weather and Seasonal time scale
   c) Policy/Planning – Climate Change time scale
4. Decision
   - Tactical – Weather information
   - Strategic – Climate information

Seasonal Prediction (1)

1) Seasonal prediction and its use is a potential entry point for addressing issues about climate change (near and future)
2) Coping strategy will inform adaptation measures
3) Seasonal Decisions in Agriculture
    a) Shall I Sow?
    b) Which cultivar?
    c) Shall I sell stock while the price is high?
    d) Shall I buy more stock while they are cheap?
    e) Shall I now invest off-farm?
    f) Shall I prepare for disaster

Seasonal Prediction (2)

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1) Deterministic skill of North American Multi-Model Ensemble

a) To predict Sahel rainfall with respect to lead time

- **Skill for regionally averaged rainfall for the JAS target season is essentially the same whether the forecast is made in February/March or it is made in June**
- The two dominant influences on Sahel rainfall, North Atlantic and global tropical oceans, shape predictability
- MME skill hinges on the combination of skillful predictions of ENSO made with one model (CMC2-CanCM4) with those of North Atlantic SST made with another model (NASA-GEOSS2S)

b) An earlier prediction (2-3 months ahead) has consequences for decisions such as purchasing, stocking and distributing adapted seed varieties or preventing regional food insecurity

2) National Scale: Ongoing research for dynamical seasonal forecast in Ghana (e.g. Agyeman et al., 2017)

Climate Change

Half a degree matters for reducing & delaying global land exposure to combined daytime-nighttime extremes

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A 0.5degC reduction in global warming will shelter about 20% of global lands from strong increases and prevalence of combined hot extremes

Compared to 2degC, the 1.5degC target helps avoid a new heat regime with unprecedented combined hot extremes becoming the norm in the tropics

Previous univariate-based analyses underestimate both spatial scale and emergence rate of 0.5degC - added hotspots to hot extremes

Chen_et_al_EF_2019

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Simulation of relative impact of land cover and carbon dioxide to climate change from 1700 to 2100

Lamptey_et_al_JGR_2005

Experiment 1 (GCM)

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Simulation	CO_2 (ppmv)	Vegetation
P_{17}	280	natural
P_{21}	690	natural
A_{21}	690	Natural plus agriculture

Lamptey et al., 2005 JGR

Formula

$$\frac{|A_{21}-P_{21}|}{|A_{21}-P_{21}|+|P_{21}-P_{17}|}\times 100$$

Mean DJF 2m temp. difference due to (a) Increased CO_2 (b) agriculture

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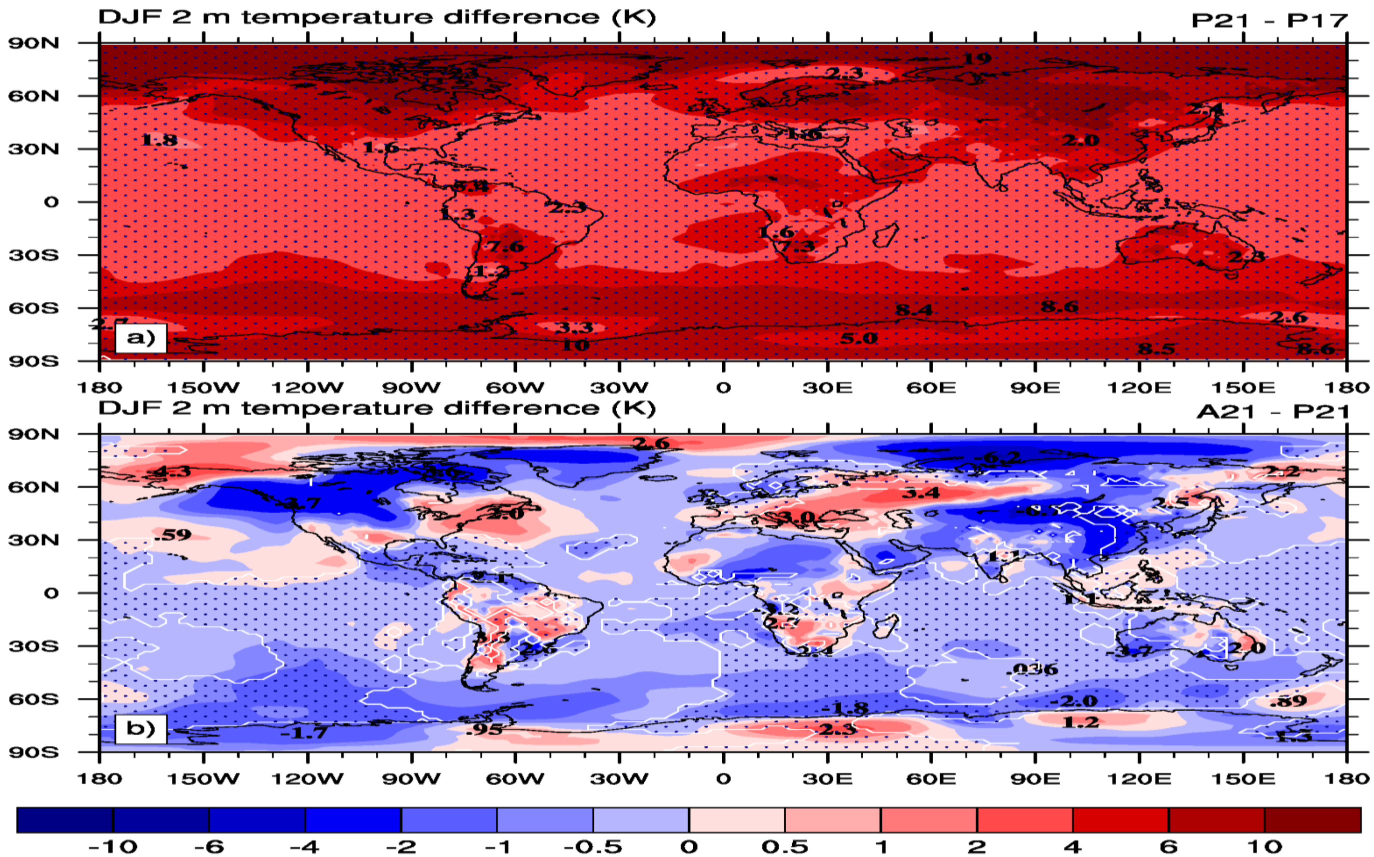

Lamptey et al., 2005 JGR

2m temperature change (% explained by LCC)

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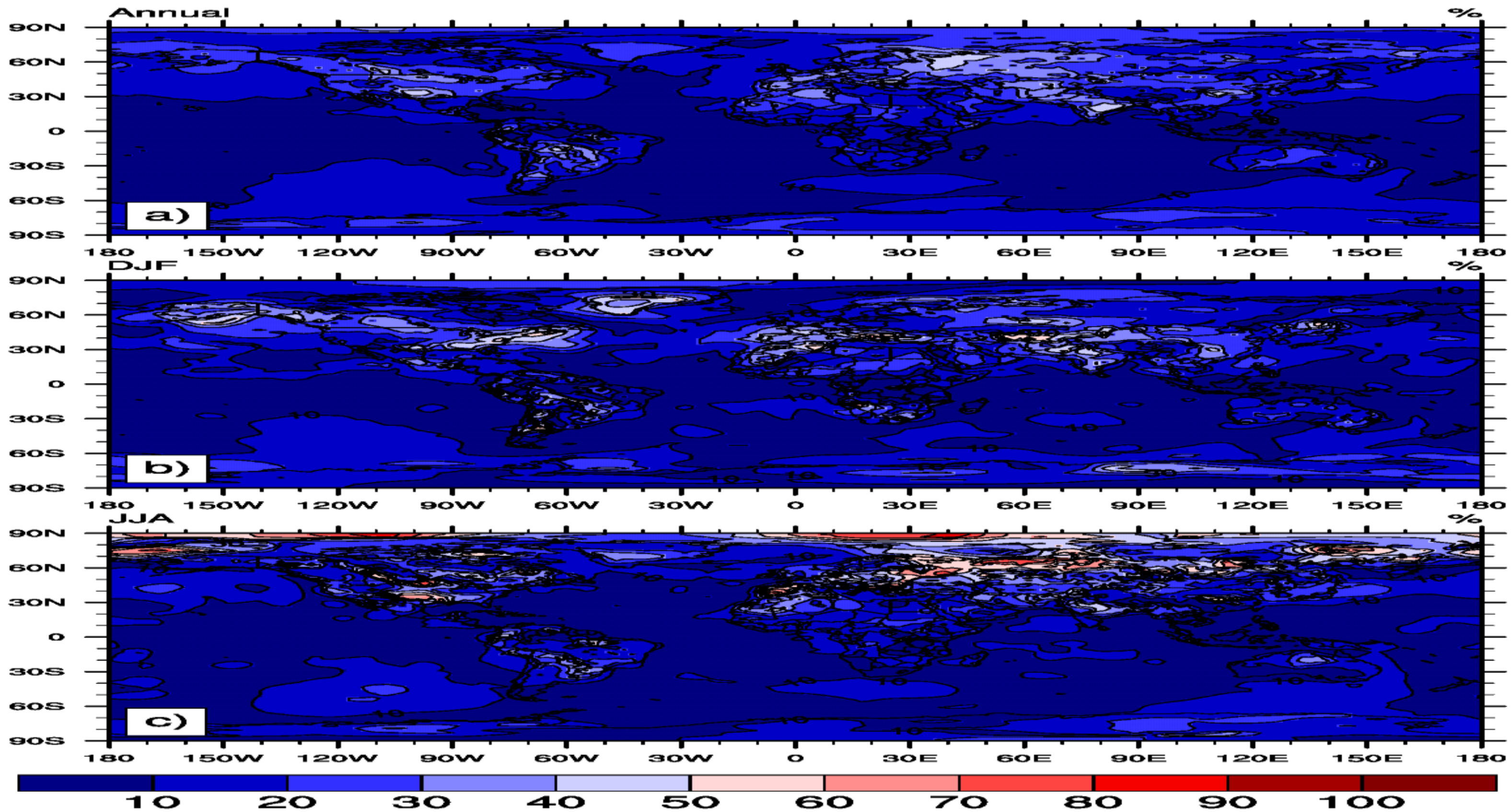

Lamptey et al., 2005 JGR

Mean JJA rainfall difference due to (a) Increased CO_2 (b) agriculture

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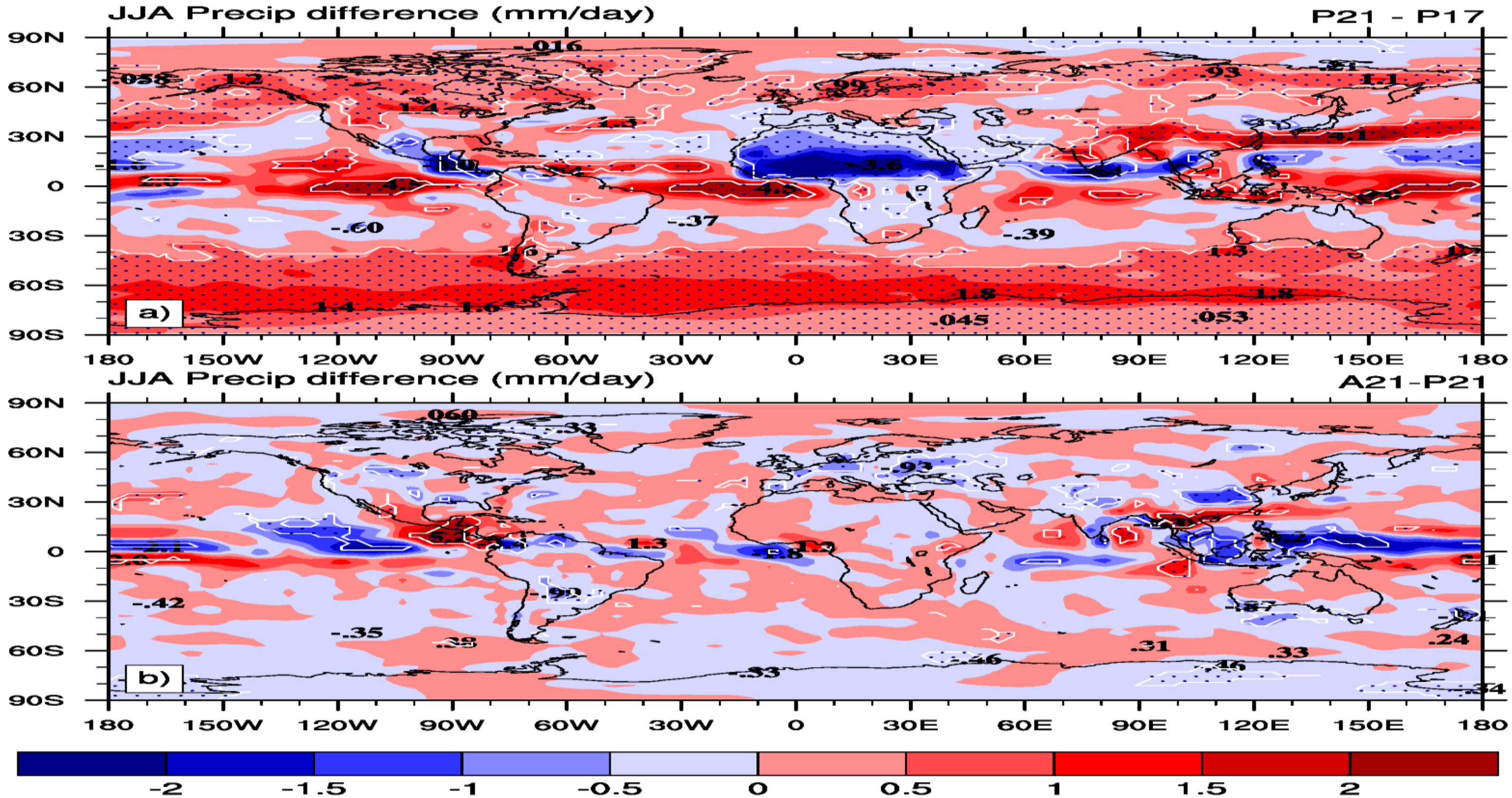

Lamptey et al., 2005 JGR

Change in rainfall (%age explained by LCC)

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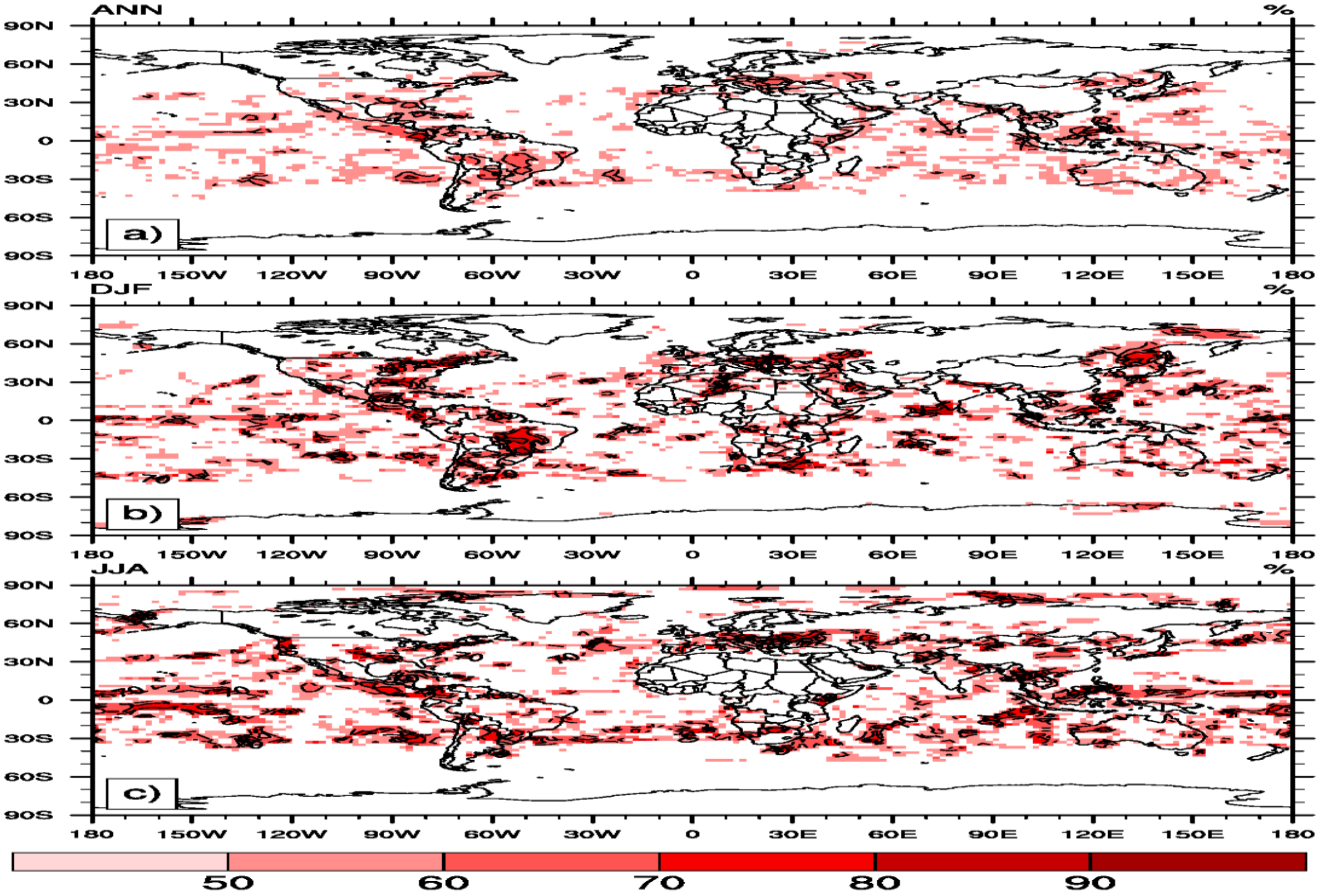

Lamptey et al., 2005 JGR

DJF regional (WA) climate from GCM

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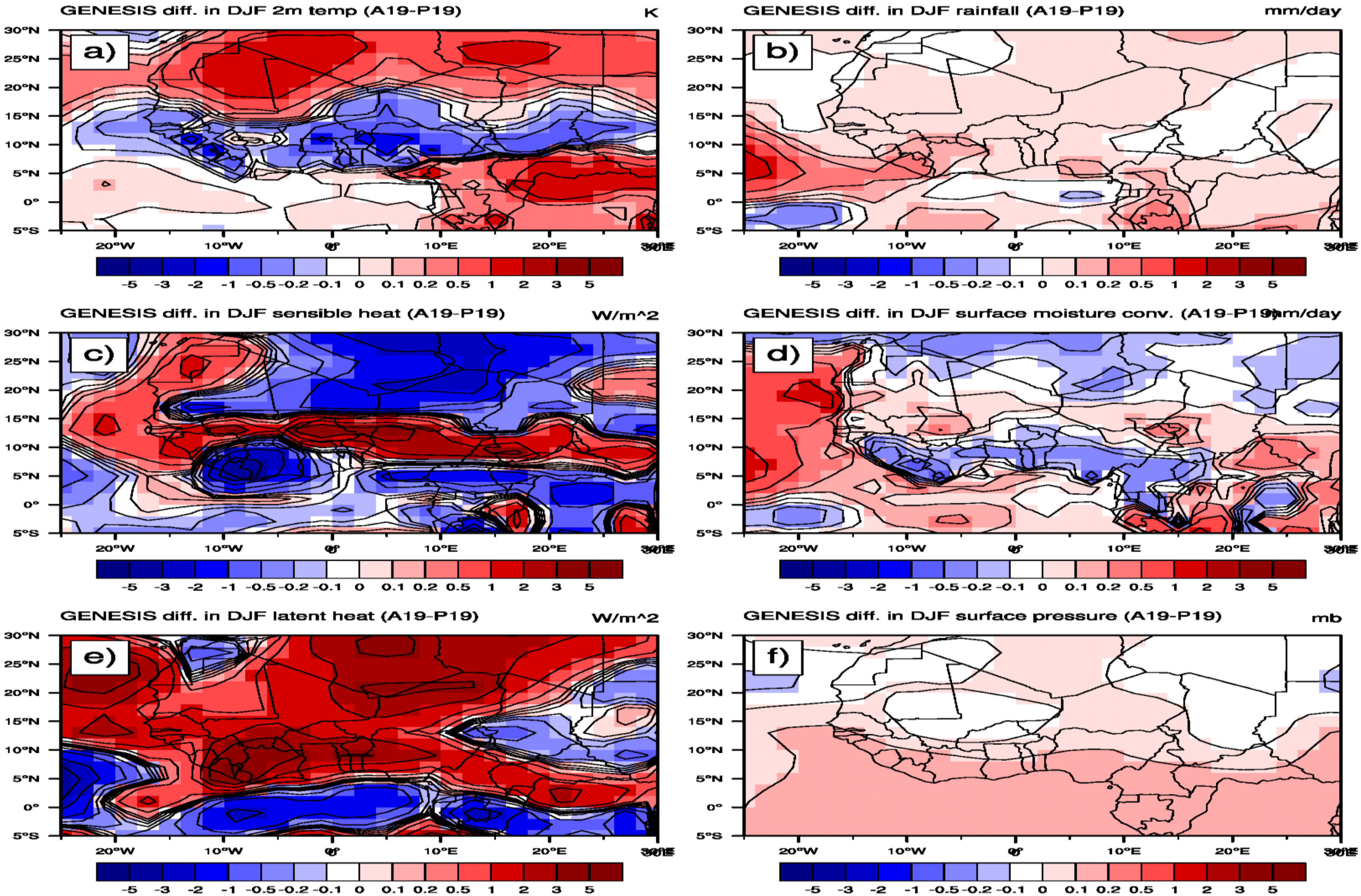

Summary

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1) LCC greatly modifies magnitude and spatial extent of climate due to increased Carbon dioxide

2) Urbanization and regional agriculture produced a decrease in diurnal temperature range

Summary from another regional study (middle latitude)

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1) Impacts of both agriculture and urban land cover are more pronounced during summer
2) Urbanization increased mean temperature but decreased diurnal temperature range
3) Urbanization effect was widespread

Lamptey et al., 2005 GPC

Urban Land Cover

1) Effect of urbanization at global scale is minimal due to relatively small fraction of earth covered by urbanization
2) How important will the urban effect become globally with the expected increase in urbanization (will increase ground heat flux term) and population density (will increase anthropogenic term in the SEB equation)?
3) Possibility of a critical threshold of influence (in terms of modeling)
   - Can arise from convergence of increasing spatial resolution of GCM and expected growth in urban areas.
4) Influence of a land cover type varies with the percent land cover area

Lamptey, 2010 IJOC

Impact of land cover characterization over West Africa (RCM) -domain

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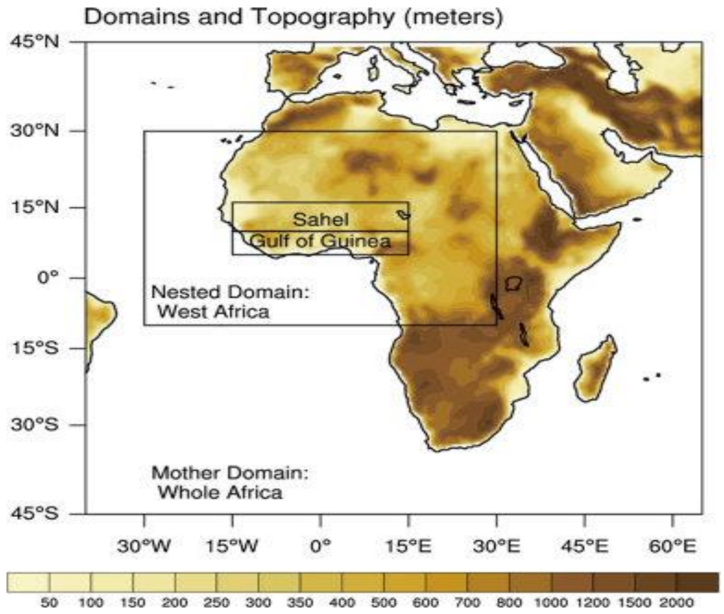

Sylla et al, 2016 Clim Dyn

Impact of land cover characterization over West Africa (RCM) - simulation

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1) Model: RegCM4.3
2) Resolution: 50km - Africa, 25km – West Africa
3) Coupled with NCAR CLM3.5
4) Simulation period: 1998 - 2010
5) Simulation 1 uses Coarse Resolution Vegetation
6) Simulation 2 uses Newer High Resolution improved Land Cover
7) **Replacement of C4 and C3 grasses with corn and Tropical broadleaf evergreen trees in parts of West and Central Africa**

Sylla et al, 2016 Clim Dyn

Temperature changes due to improved LC distribution

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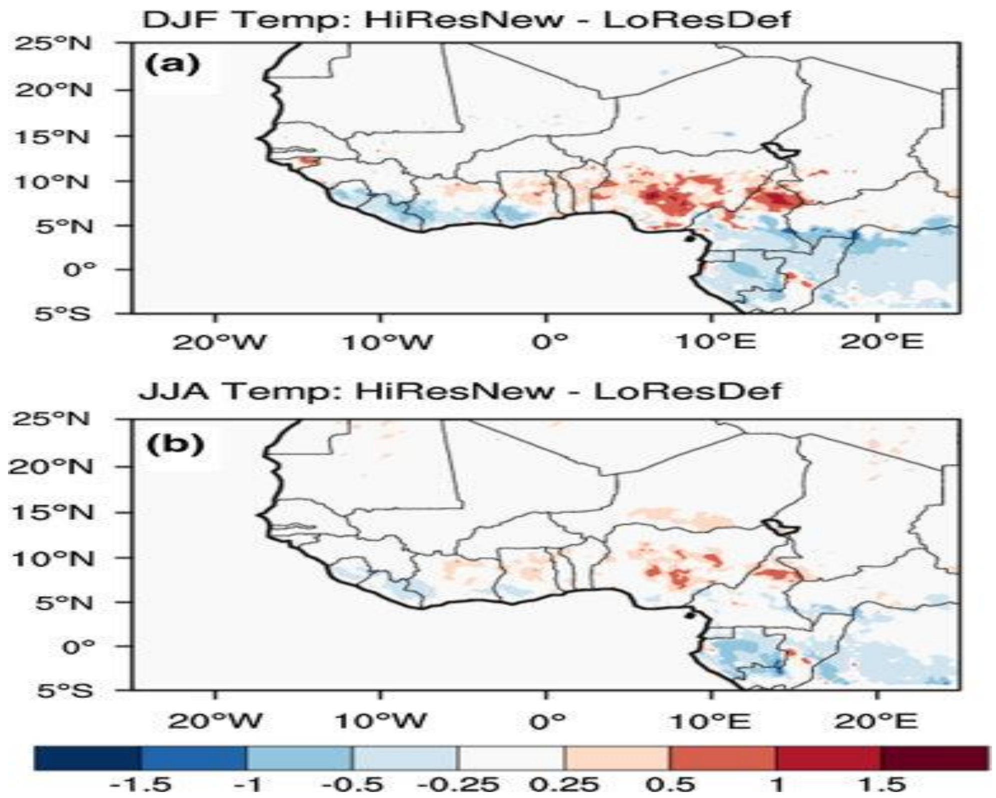

Changes in temperature greater in DJF than In JJA

Sylla et al, 2016 Clim Dyn

Precipitation changes due to improved LC distribution

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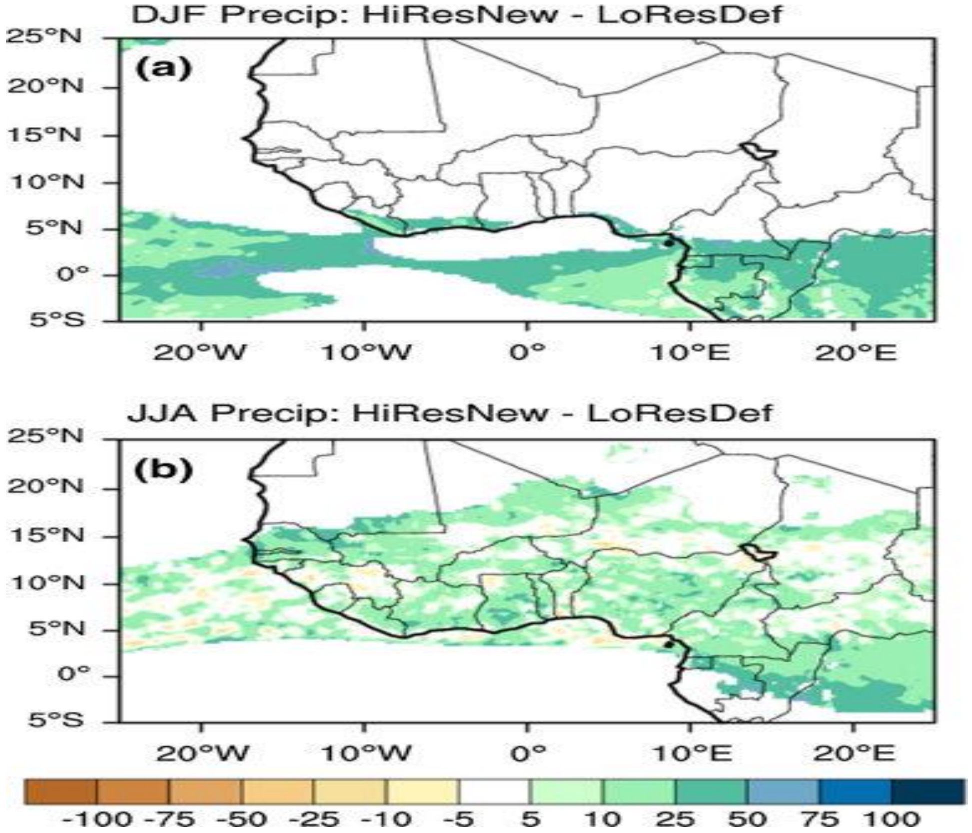

Increase in precipitation during both DJF and JJA

Increase is via a stronger soil moisture feedback

Sylla et al, 2016 Clim Dyn

Summary from study

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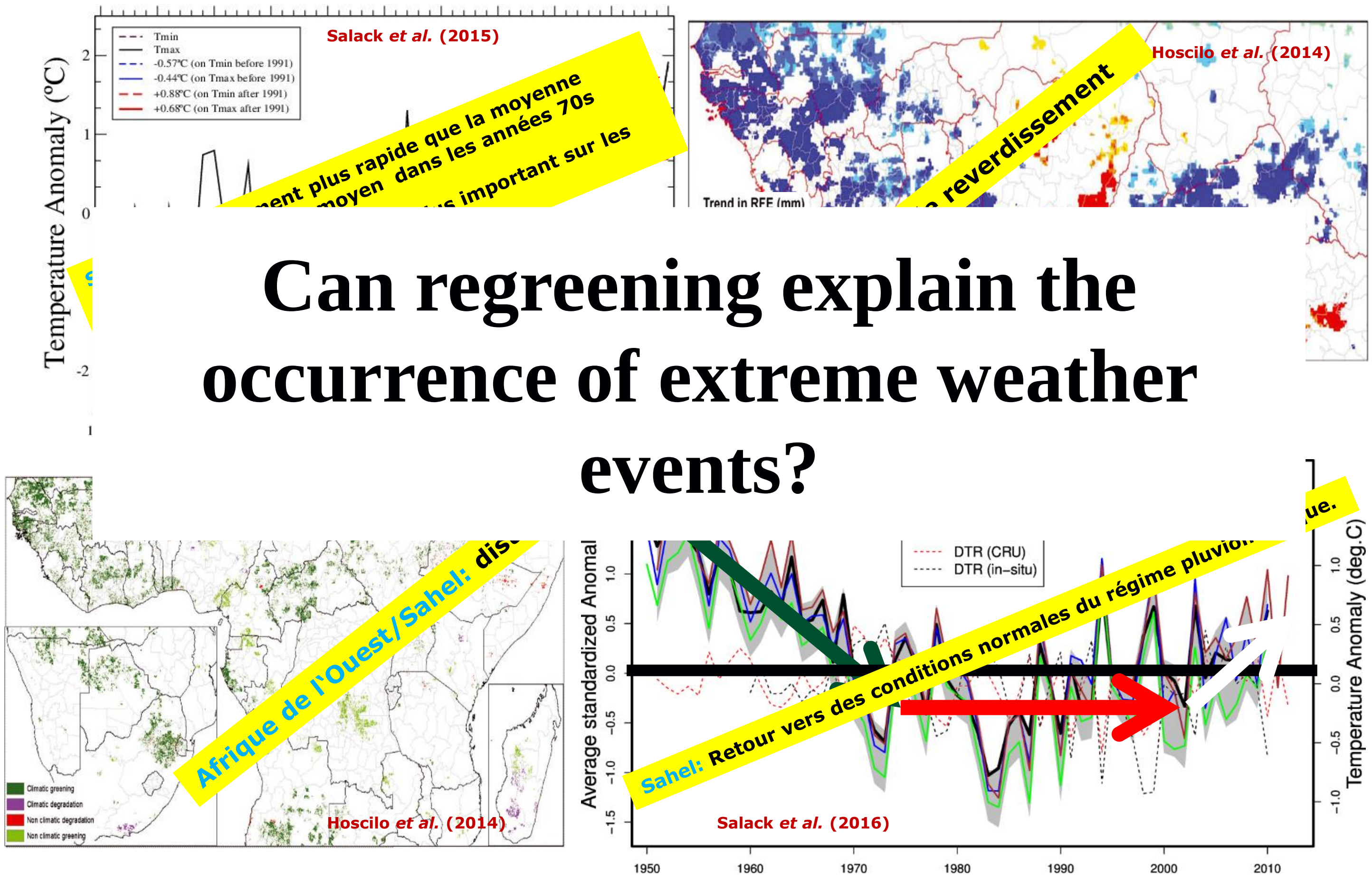
1) In DJF, increases in the frequency and intensity of precipitation events occur mainly over the Gulf of Guinea coastlines and Central Africa
2) In JJA, changes are more heterogeneous
3) The increased precipitation is caused by increased low level convergence and enhanced soil moisture feedback
4) Wetter conditions are simulated over most part of the domain, even in regions where land cover changes are negligible.
5) Replacement of C4 grass with corn produces warming while replacement of C3 grass with tropical broadleaf evergreen trees produces cooling over over areas of change
6) Results indicate land cover distribution should be accounted for in climate change experiments over West Africa.

Sylla et al, 2016 Clim Dyn

Potential Impacts of the Great Green Wall (GGW) on Climate Extremes in the Sahel

Saley et al., 2017 Atmos Sci Lett

Observed changes



Can regreening explain the occurrence of extreme weather events?

The Great Green Wall (GGW)

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- Project: CEN-SAD and African Union
- Length: Dakar to Djibouti (> 7000km)
- Width: 15km
- 11 states involved
- Endogenous species

(Dia and Dupponois, 2010)

Regrowth Scenario (GGW) (1)

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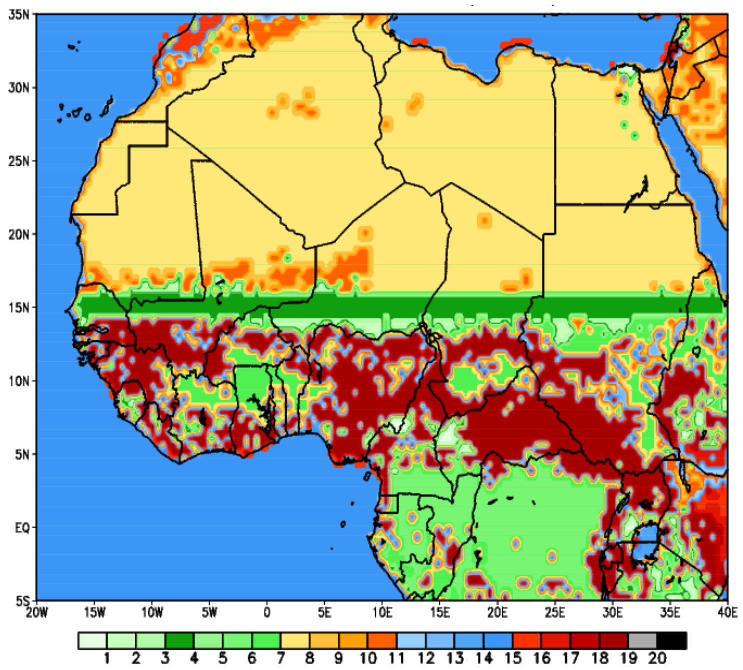

- Model: RegCM4
- Resolution: 50kmx50kmx18pres. level
- Period 1988-2012.
- Initial and Boundary Conditions: Re-analyzes ERA-Interim, Optimum Interpolation Sea Surface Temperature (OISST).
- A strip of vegetation on 14.08-15.84 ° N wide.

Scenario de reverdissement (GGW) (2)

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Model Biophysical Parameters	Vegetations Types	
	Short gras	Deciduous Needleleaf trees
Vegetation albedo for wavelengths < 0.7µm	0.1	0.05
Vegetation albedo for wavelengths > 0.7µm	0.3	0.23
Soil color type	3	4
Roughness length (m)	0.05	1
Displacement height	0	9
Maximum leaf area index	2	6
Minimum leaf area index	0.5	1
Minimum stomatal resistance (s/m)	60	80
STEM (dead matter area index)	4	2
Root zone soil layer depth (mm)	1000	1500

Control Experience (Ref) Default Continental Surface Settings.

GGW scenario:

Disturbance of the Biosphere-Atmosphere-Transfer Scheme (BATS)

Regrowth Scenario (GGW) (3)

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Indices of extreme rainfall and temperatures

INDICES	DEFINITION	UNIT
CDD	Maximum number of Consecutive Days with precipitation < 1mm	Day
CWD	Maximum number of Consecutive Days with precipitation > 1mm	Day
RR1	Maximum number of Days with precipitation > 1mm	Day
R99P	Annual cumulative rainfall (rain exceeds 99th percentile)	mm
TNx	Monthly maximum of the minimum temperature	°C
TNn	Minimum monthly minimum temperature	°C
TXx	Maximum monthly maximum temperature	°C
TXn	Minimum monthly maximum temperature	°C
DTR	Mean diurnal temperature difference (Tmax - Tmin)	°C

Effects of GGW on extreme rainfall

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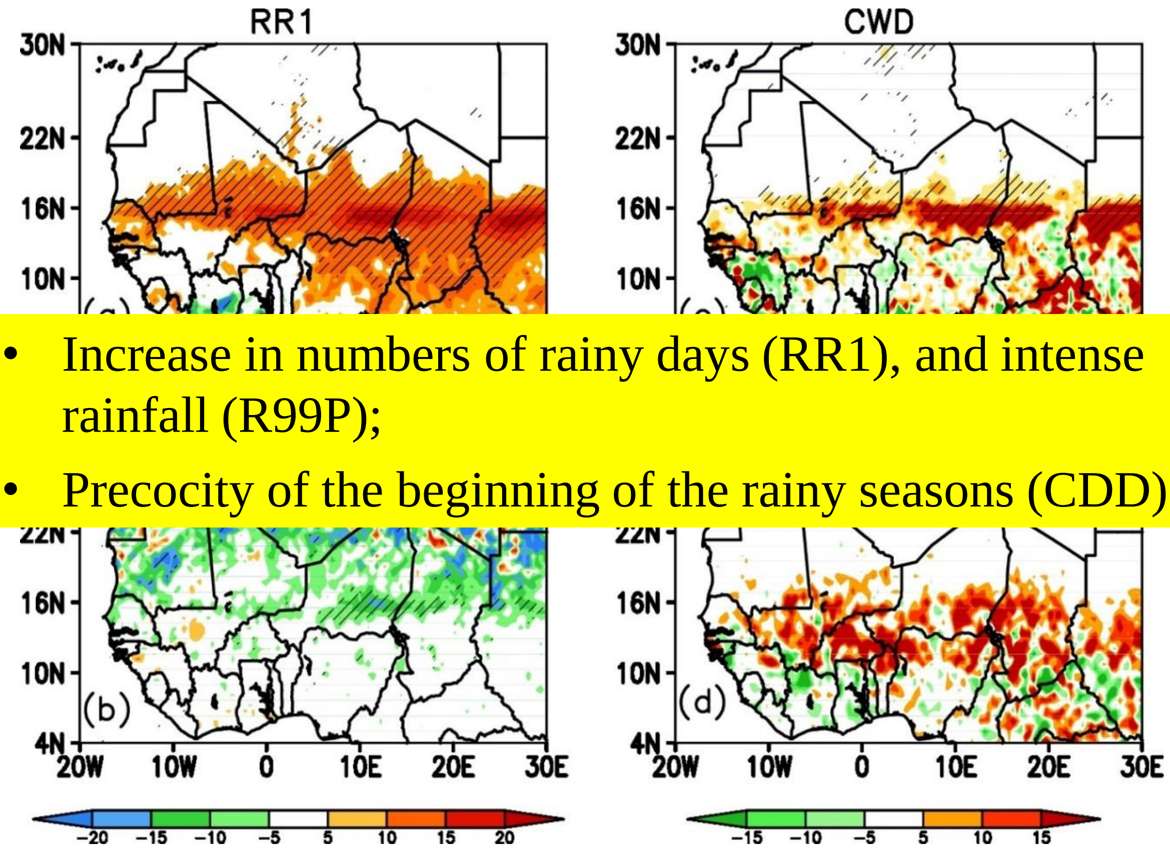
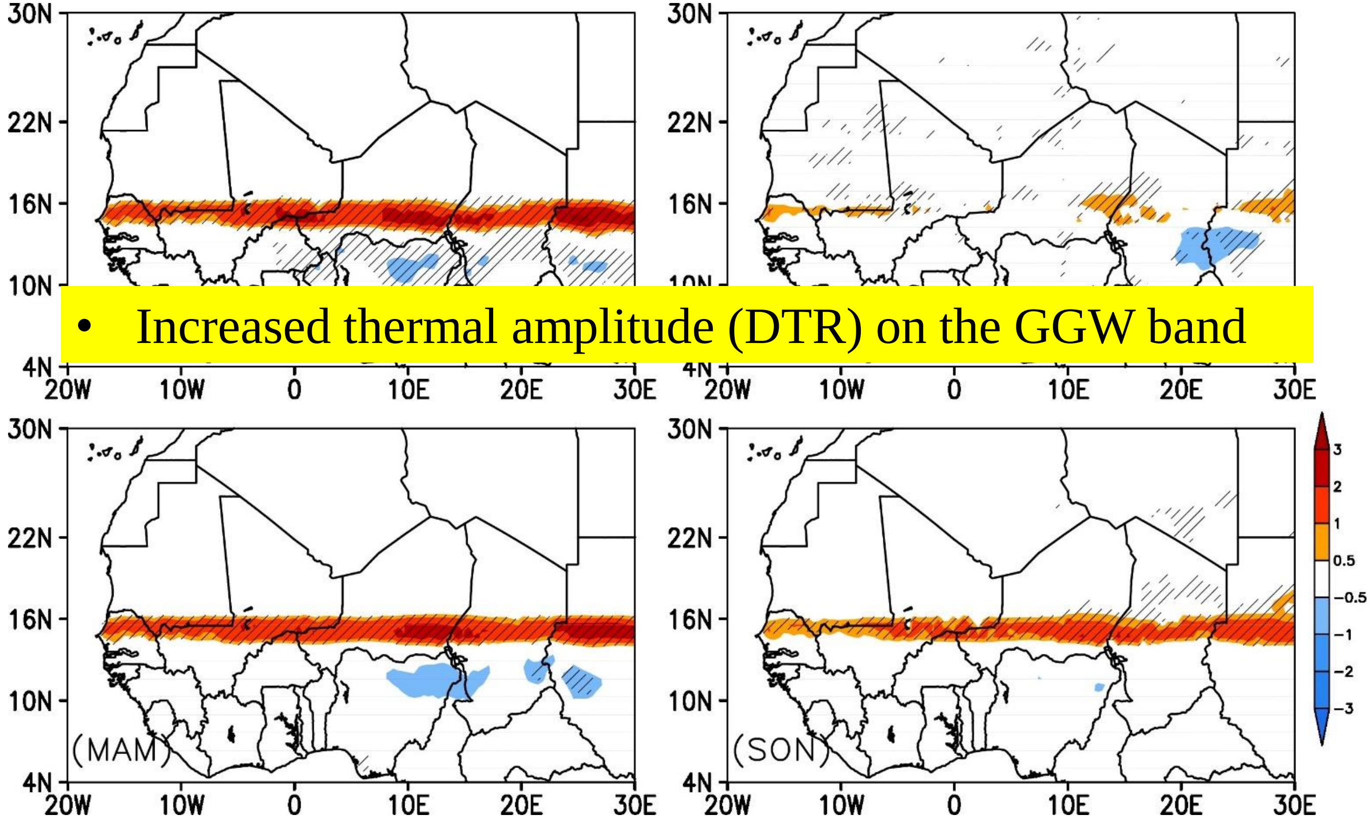


- Increase in numbers of rainy days (RR1), and intense rainfall (R99P);
- Precocity of the beginning of the rainy seasons (CDD)

Effects of GGW on temperature extremes



- Increased thermal amplitude (DTR) on the GGW band

Summary

The recent regreening and the implementation of the GMV would lead to:

An increase in rainy days;

An increase in the frequency and amplitude of intense rainfall;

A precocity of the beginnings of the rainy seasons.

An increase in the daily thermal amplitude

The (hypothetical) Sahelian re-greening strengthens the Land-Atmosphere feedback, which in turn alters the frequency and magnitude of climatic extremes in the subregion.

Concluding Food for thought

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1. **Weather Prediction**: To what extent are we paying attention to building or improving infrastructure for weather prediction, as the projected increase in frequency and intensity of Extreme Events will occur on weather time scales, when the time comes?
2. **Climate Resilience**: To what extent are we paying attention to weather and seasonal time scales, in addition to formulating climate change policies and strategies, recognizing that resilience building requires decisions and action across time scales?
3. **LULCC vs GHG Emissions**: While preparing for the impact of climate change in Africa, is it worth considering the role of Land Use Land Cover Change as well?

Global Targets and implementation in Africa

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1) UN Agenda 2030 – Sustainable Development Goals (SDGs)
2) 2015 Paris Climate Agreement
3) Sendai framework for Disaster Risk Reduction 2015-2030
4) Global Framework for Climate Services (GFCS) – For example National, EU funded Intra- ACP
5) AU Agenda 2063 https://au.int/en/agenda2063
6) African Ministerial Conference of Ministers on Meteorology (AMCOMET) Integrated African Strategy on Meteorology (Weather and Climate Services)(Investing in Weather and Climate Services for Development) https://www.wmo.int/amcomet/sites/default/files/field/doc/pages/amcomet-integrated-african-strategy-meteorology-13677_en.pdf
7) African Space Policy (meteorological input)
8) Climate Research for Development in Africa (CR4D-Africa)
9) Africa Hydromet Programme

AU 2063 – implementation will involve high level sector documents on other

IASM – STRATEGIC PILLARS

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1) SP1: Increase Political Support and Recognition of NMHSs and related WMO Regional Climate Centres
2) SP2: Enhance the Production and Delivery of Weather and Climate Services for Sustainable Development
3) SP3: Improve Access to Meteorological Services in particular for the Marine and Aviation Sectors
4) SP4: Support the Provision of Weather and Climate Services for Climate Change Adaptation and Mitigation
5) SP5: Strengthen Partnerships with Relevant Institutions and Funding Mechanisms

THANK YOU