Regional-scale climate change projections of annual, seasonal and monthly near-surface temperatures and rainfall in Uganda

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21 August 2014

CDKN Climate & Development Knowledge Network

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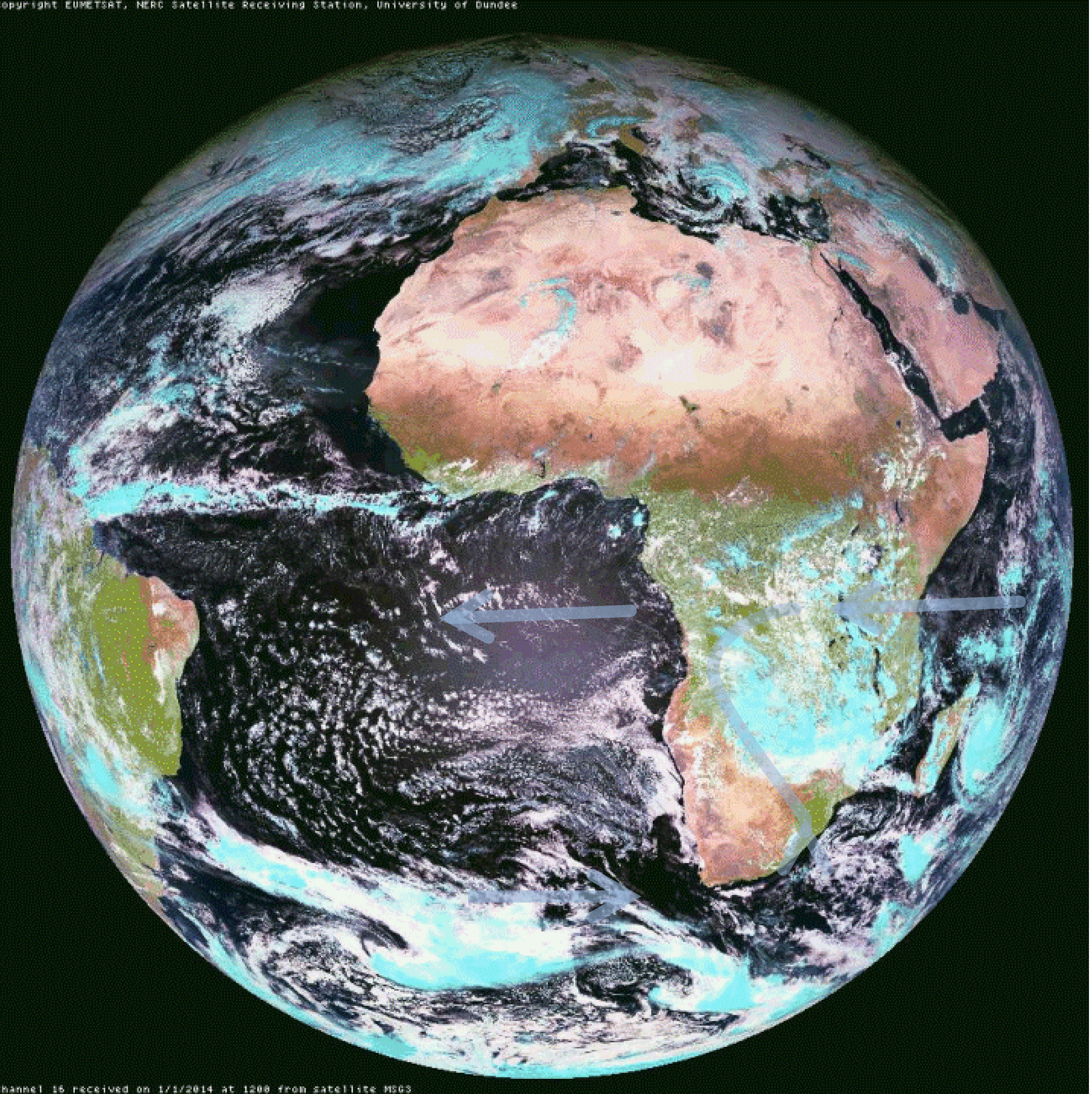
Content

- Major forces that modulate Earth's climate system – heat as a driver for atmospheric flow;
- Uganda climate within a global atmospheric circulation system;
- Earth's radiation budget and Representative Concentration Pathways for greenhouse gasses;
- Modelling of the atmospheric system and experimental design of the regional dynamical downscaling simulations;
- Future projections of near-surface temperature and rainfall in Uganda;
- "Correcting" model results according to observations – regional statistical downscaling



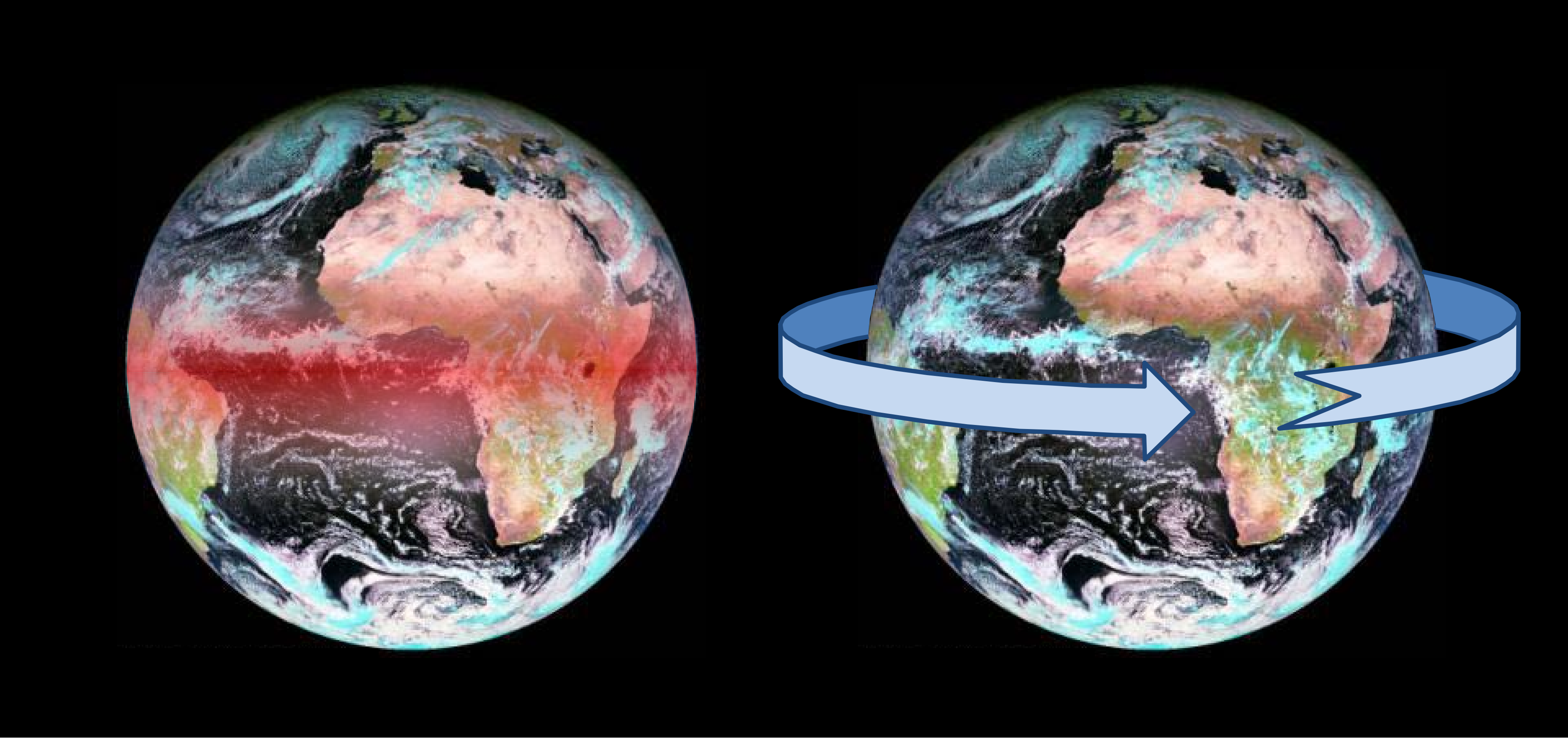
Satellite images: January 2014, 12:00

University of Dundee – Satellite Receiving Station
www.sat.dundee.ac.za

The atmosphere behaves like a fluid with components of chaos in its propagation.

However, atmospheric mass (and therefore flow) is partially modulated by forces:
- Gravitation
- T_{emp} & P_{res} gradients
- Rotation
- Friction and others

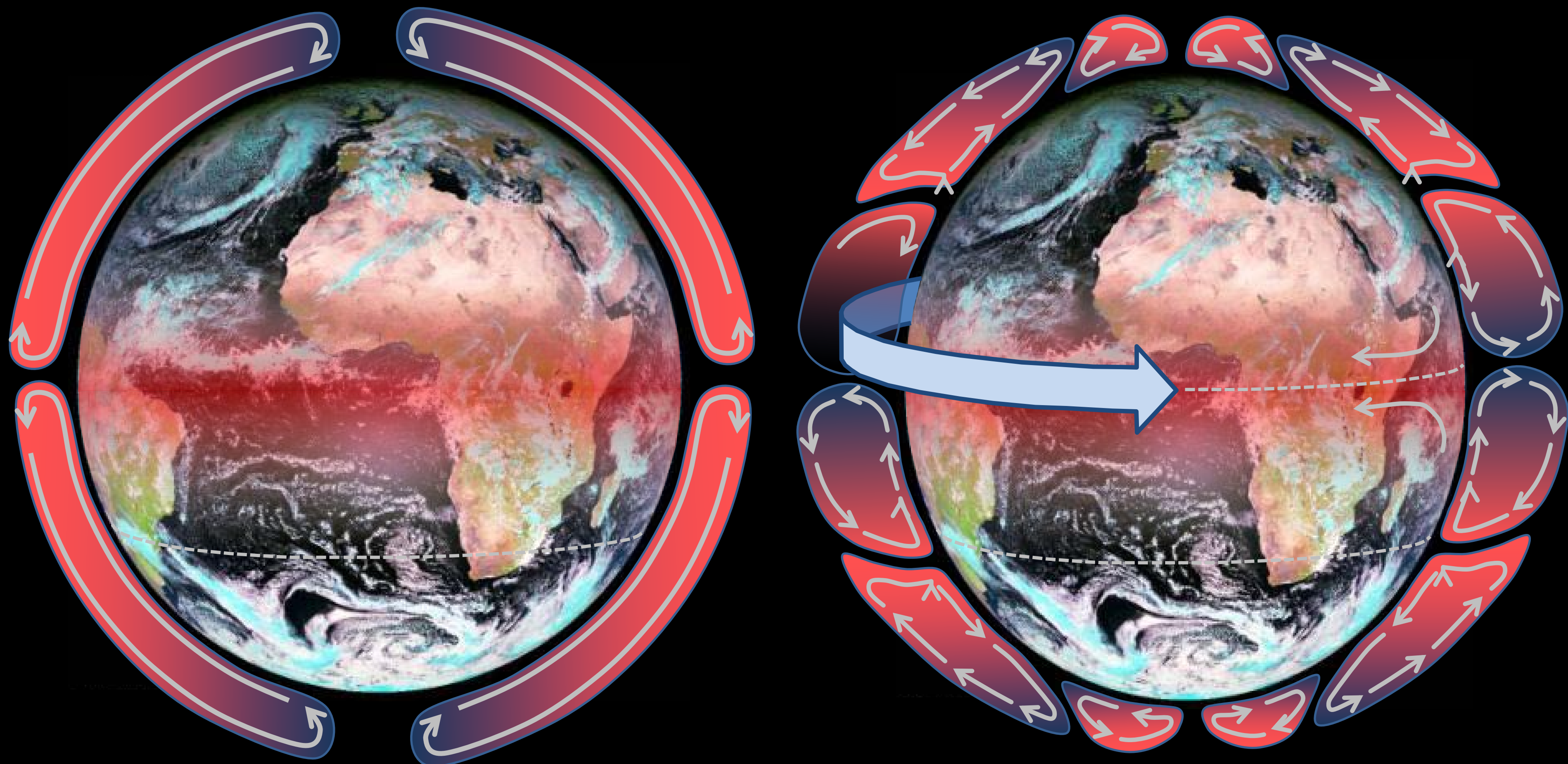
The influence of such forces results in some identifiable flow patterns or distinct rainfall zones



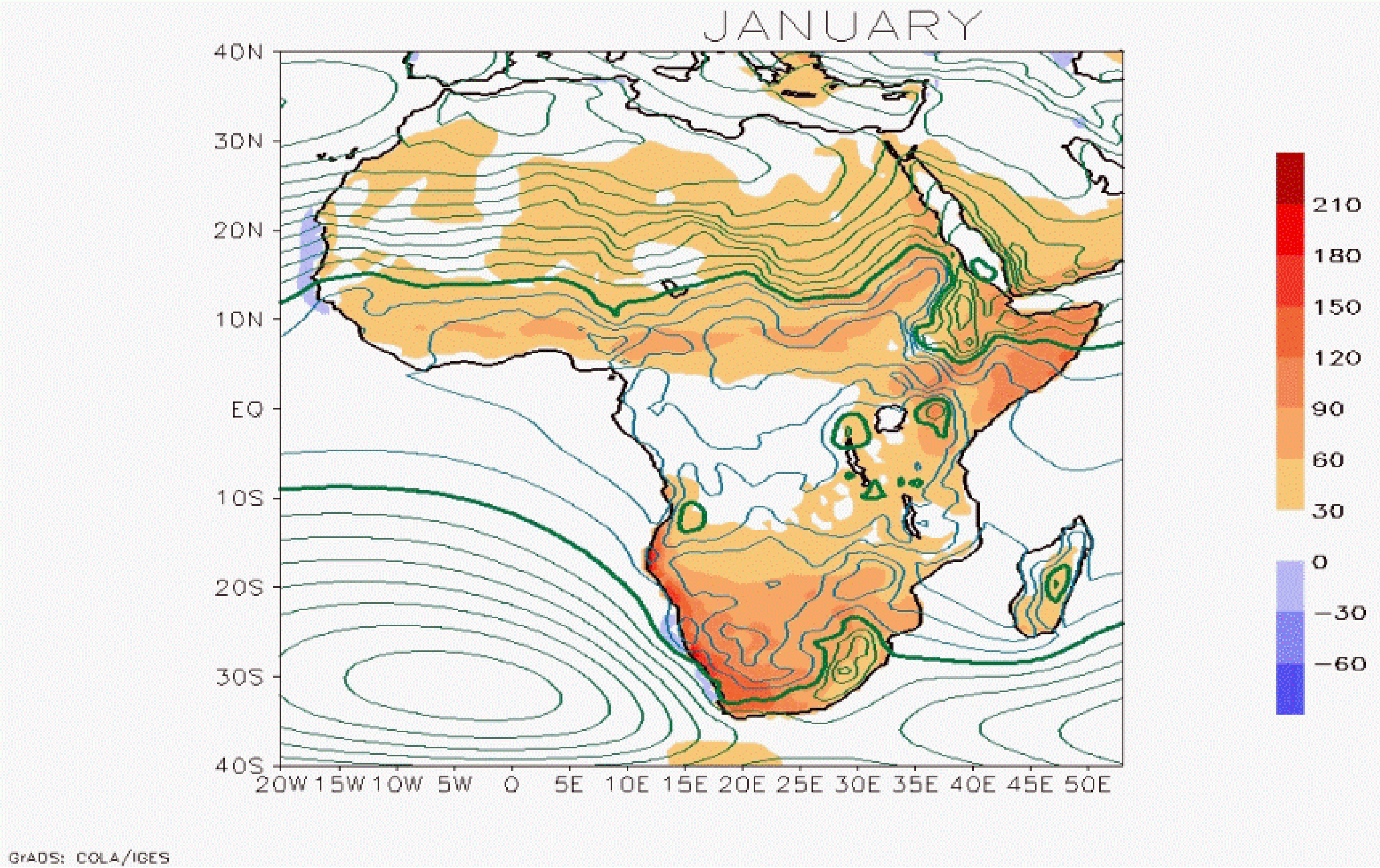
PLANETARY-SCALE atmospheric flow is considerably modulated by two drivers or forces:

- Temperature gradients between the equator (higher T) towards the poles (lower T), as a result of surface HEAT radiation gradients. More heat radiation at the equator results in lower surface pressures which initiate surface flow from higher pressures regions (convergence). This leads to convection at the equator and subsidence at the poles (Hadley Circulation).

- The rotation of the Earth, at one revolution in 24-hours, results in a surface velocity gradients from the equator (higher surface velocities) towards the poles (lower surface velocities).



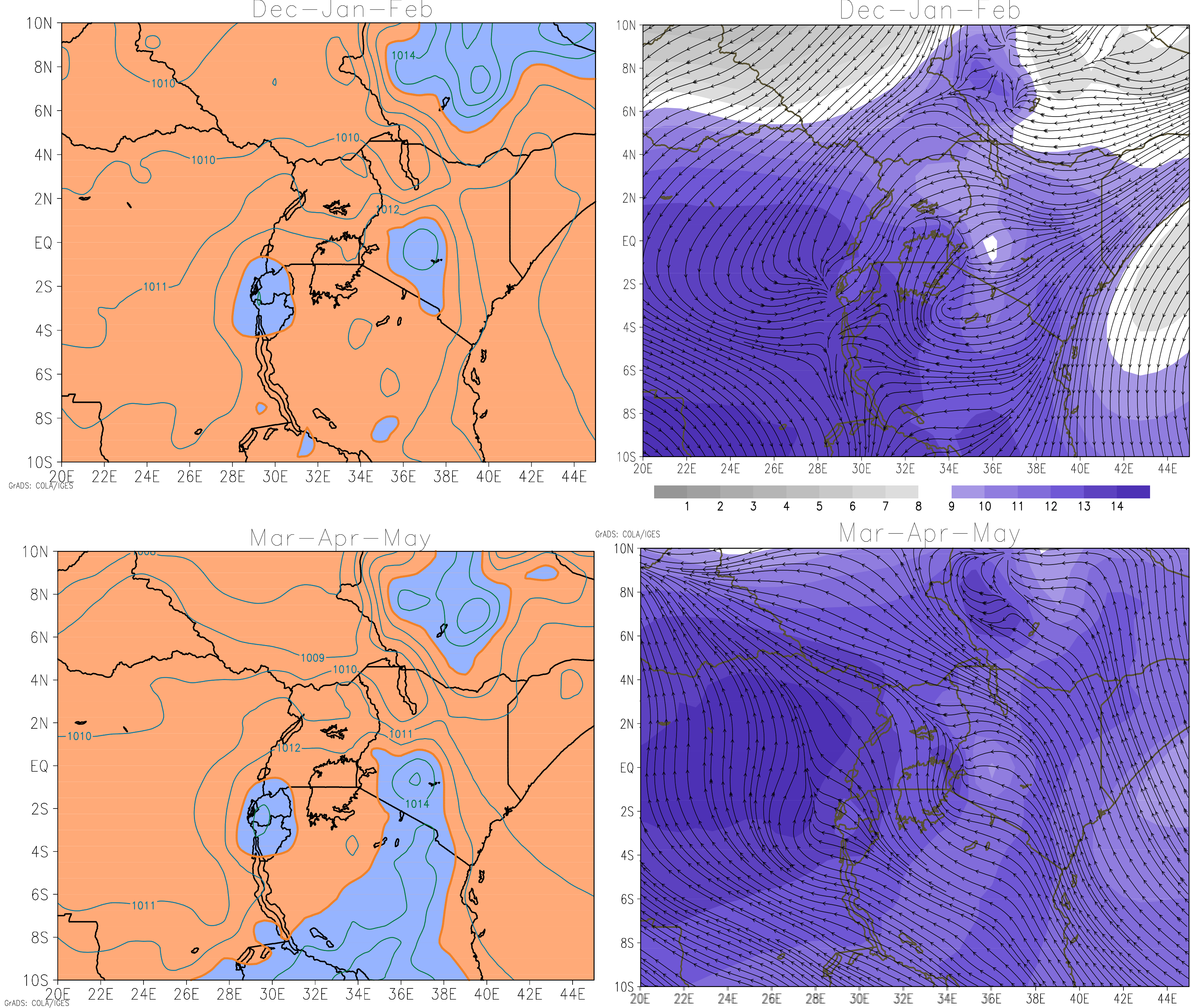
- PLANETARY-SCALE atmospheric flow is characterised by convection (lift of air mass) at equatorial regions (in reality above the HEAT equator) associated with easterly flow.
- As a result, Uganda is located in an area of convection, with easterly surface flow (trade winds) which results in moisture advection from the Indian Ocean.



Continental HEAT (**Sensible Heat Flux** – shaded in W.m^{-2}) has a noticeable influence on surface pressure patterns (**Mean Sea Level Pressure** – contours in hPa). Note how troughs develop during summer months over areas of high continental HEAT radiation.

ERA-Interim Reanalyses data: monthly sensible heat flux (W.m^{-2}) and mean sea-level pressure (hPa) as calculated over the 20-year period 1986-2005.

Averaged (1986 to 2005) seasonal mean sea level pressure (hPa) and 850 hPa streamlines with specific humidity from ERA Interim Reanalysis data.



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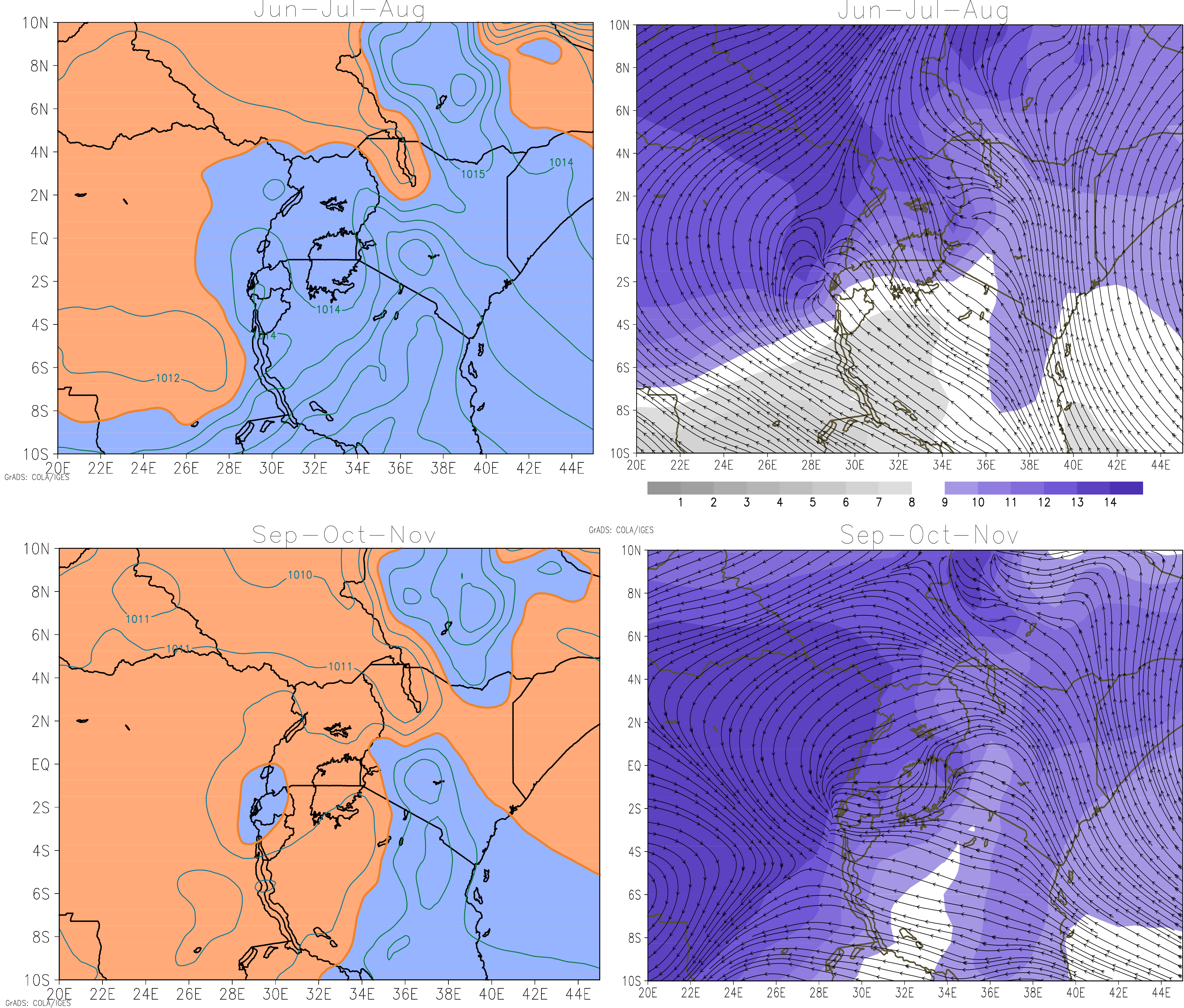
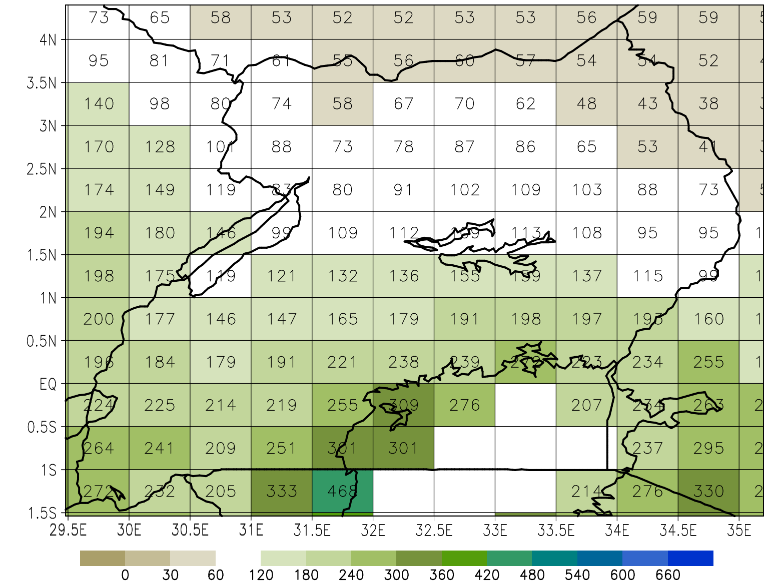
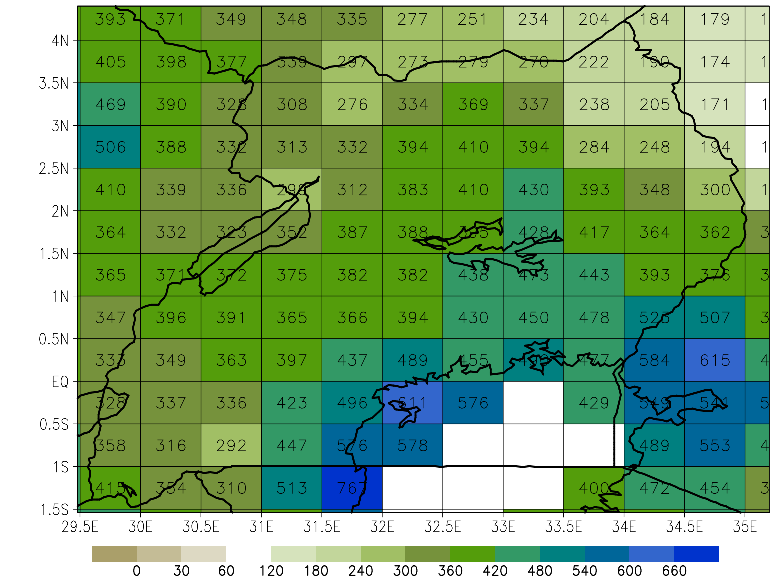


Estimated average (1981 to 2010) seasonal rainfall totals ($mm.season^{-1}$) as derived by the Global Precipitation Climatology Centre (GPCC).

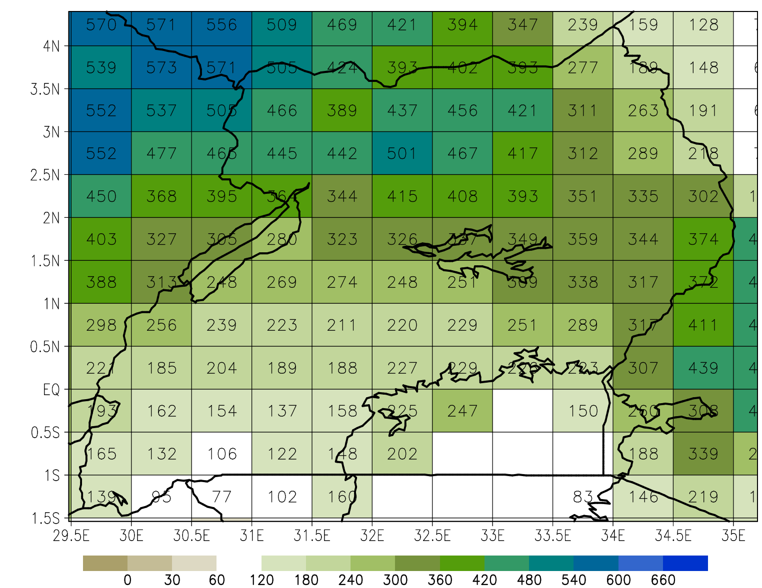
DJF



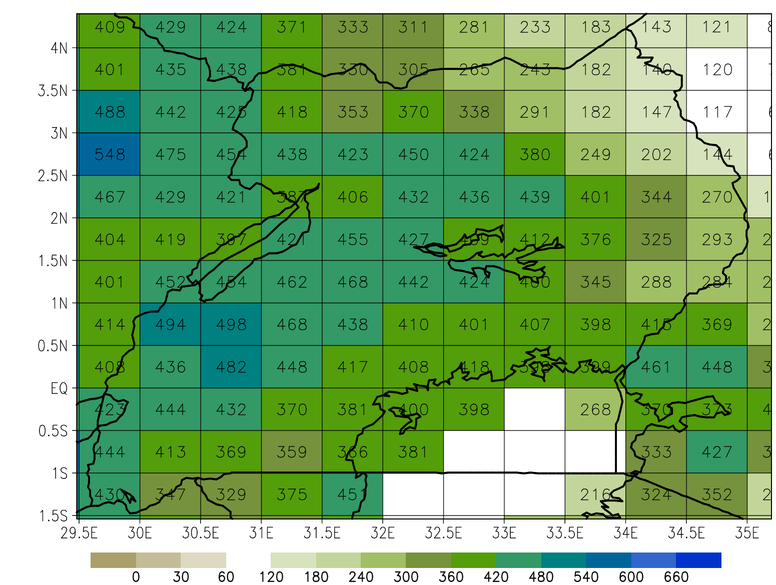
MAM



JJA

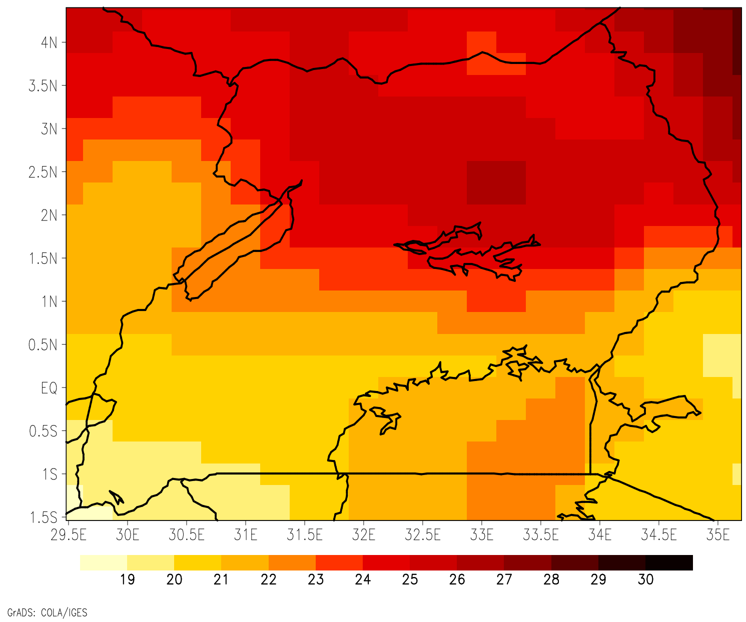


SON



Averaged (1986 to 2005) seasonal near-surface (2m above surface) temperatures (°C) as captured by ERA Interim Reanalysis data.

DJF



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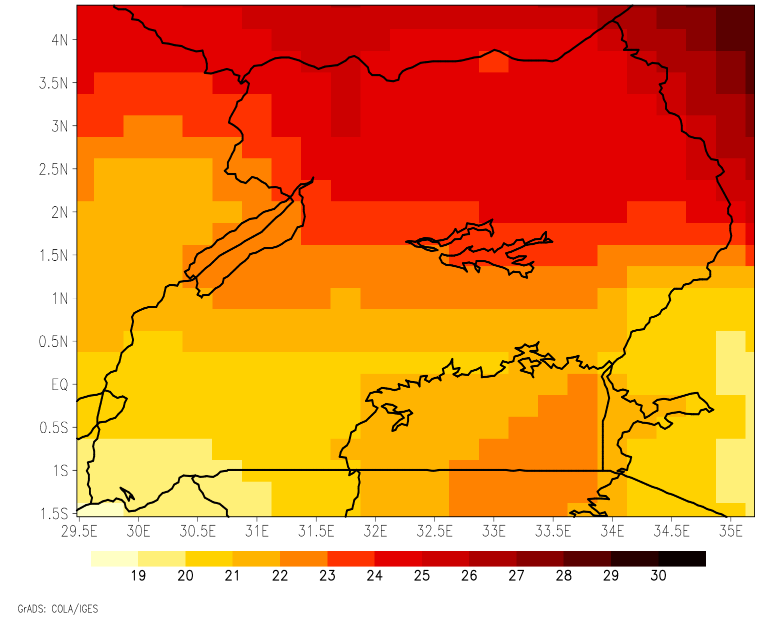

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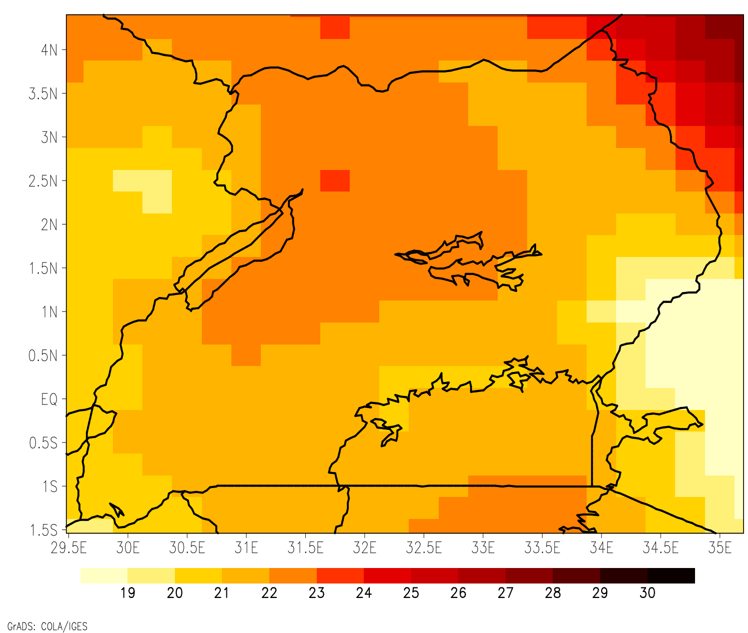

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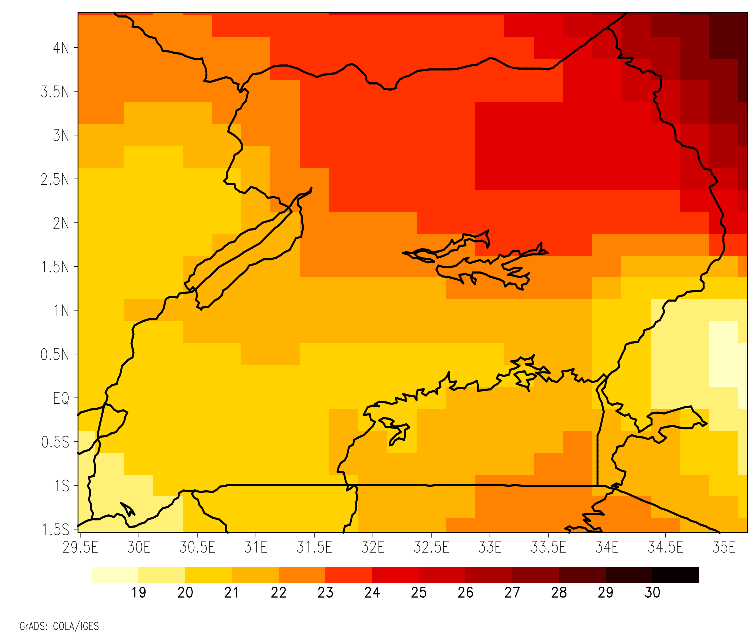
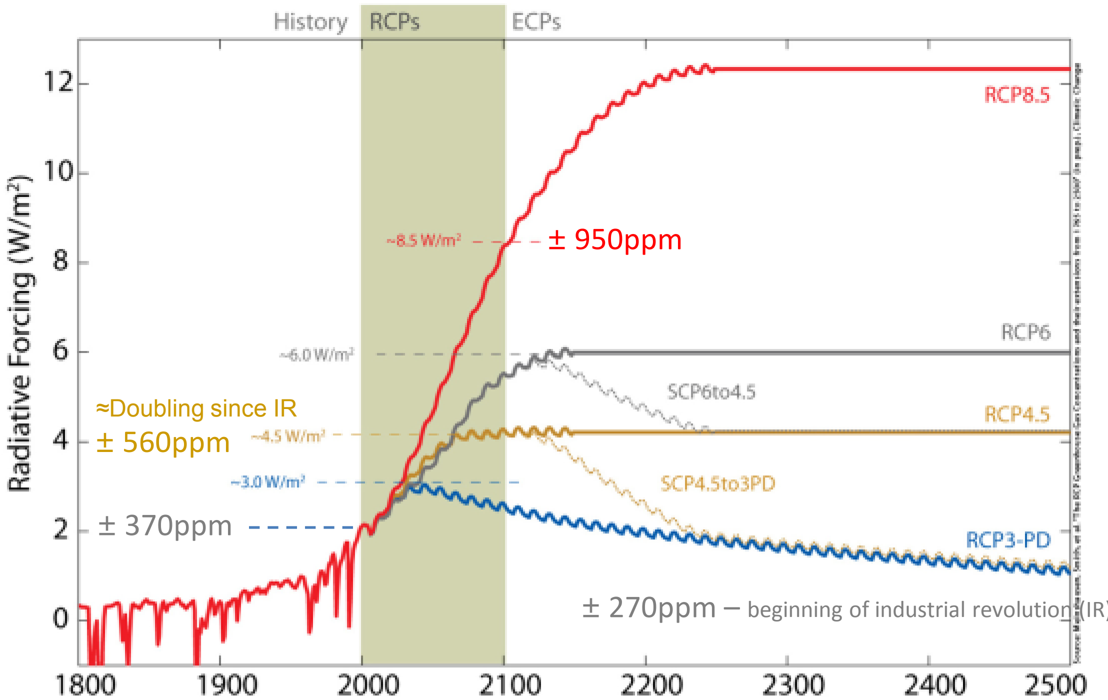


It is all about HEAT (W.m-2) = Energy



Global Anthropogenic Radiative Forcing for the high RCP8.5, the medium-high RCP6, the medium-low RCP4.5 and the low RCP3-PD.

In addition, two supplementary extensions are
shown, connecting RCP6.0 levels to RCP4.5 levels by 2250 (SCP6TO45) or RCP45 levels to RCP3PD concentrations and forcings (SCP45to3PD).

Reference:

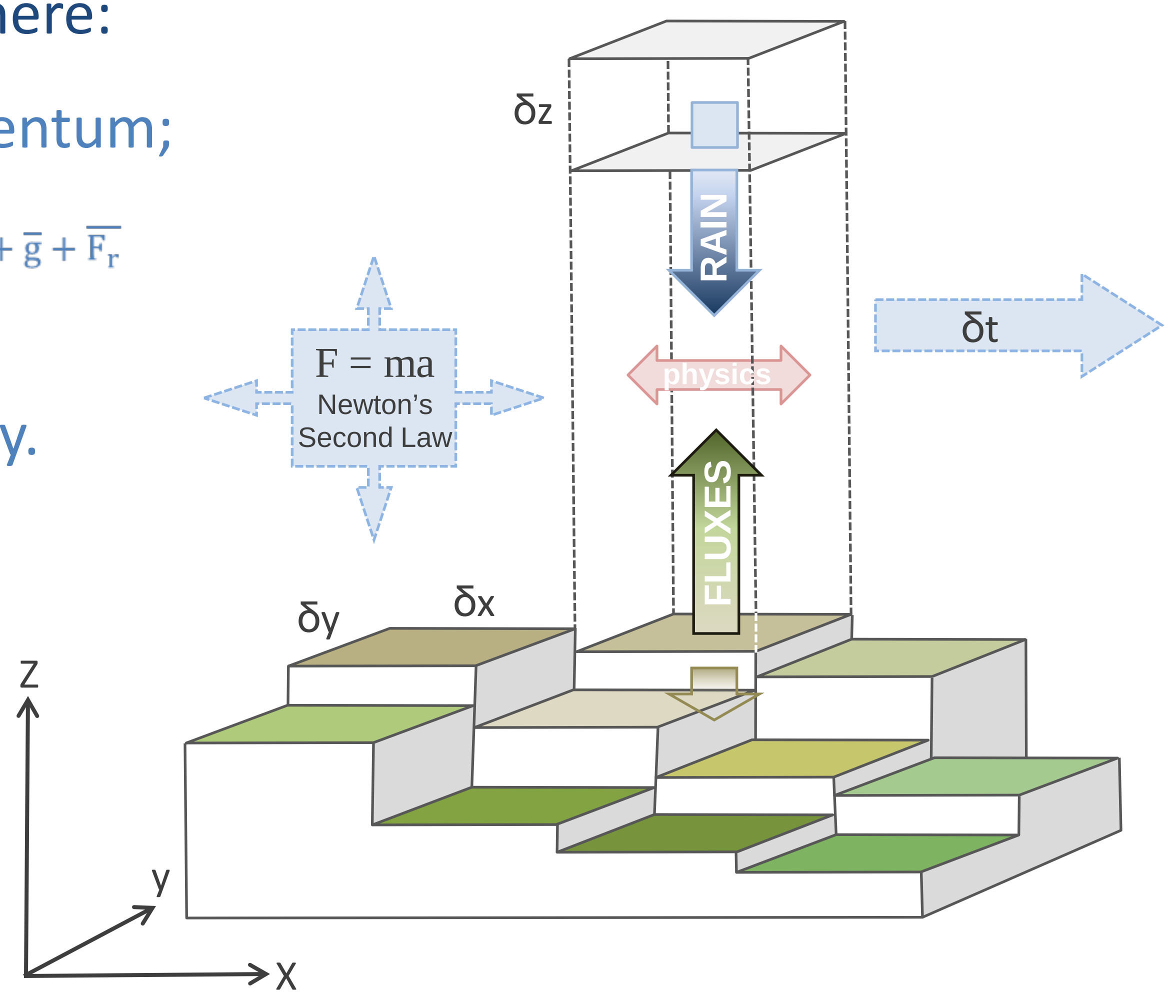
Meinshausen, M., S. J. Smith, K. V. Calvin, J. S. Daniel, M. L. T. Kainuma, J.-F. Lamarque, K. Matsumoto, S. A. Montzka, S. C. B. Raper, K. Riahi, A. M. Thomson, G. J. M. Velders and D. van Vuuren (2011). "The RCP Greenhouse Gas Concentrations and their Extension from 1765 to 2300." Climatic Change (Special Issue), DOI: 10.1007/s10584-011-0156-z. http://www.pik-potsdam.de/~mmalte/rcps/

Modelling of the Atmosphere:

- Conservation of momentum;

$$\overline{F} = m\overline{a} = m\frac{\partial \overline{U}}{\partial t} = -2\overline{\Omega}\times\overline{U} - \frac{1}{\rho}\overline{\nabla}p + \overline{g} + \overline{F_r}$$

- Conservation of mass;
- Conservation of energy.



Models are computer programmes developed to “solve” the atmospheric equations.

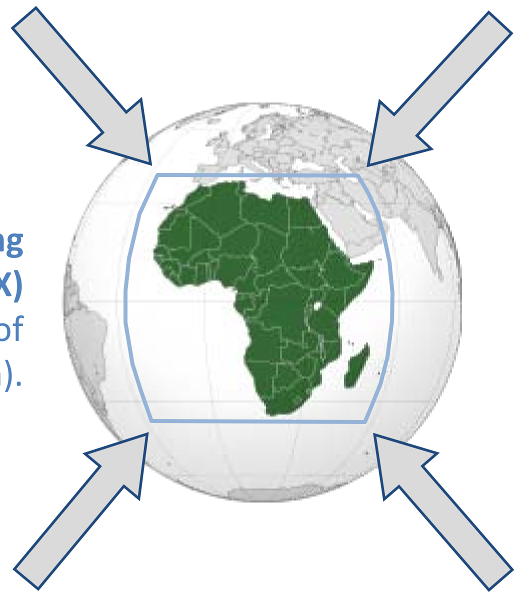
EXPERIMENTAL DESIGN

Results from an ensemble of four European based ocean-atmosphere Coupled Global Circulation Models (CGCMs), which were accommodated with the IPCC AR5, were considered for generating historical and future climate projections.

HadGEM2-ES ocean-atmosphere CGCM
United Kingdom (UK) Hadley Centre
(Caesar et al., 2013);

EC-EARTH ocean-atmosphere CGCM
EC-Earth consortium, coordinated by the Royal Netherlands Meteorological Institute (KNMI)
(Hazeleger et al., 2012);

COoRdinated Downscaling EXperiment (CORDEX)
Grid resolution of
44º x 0.44º (≈50km x 50km).

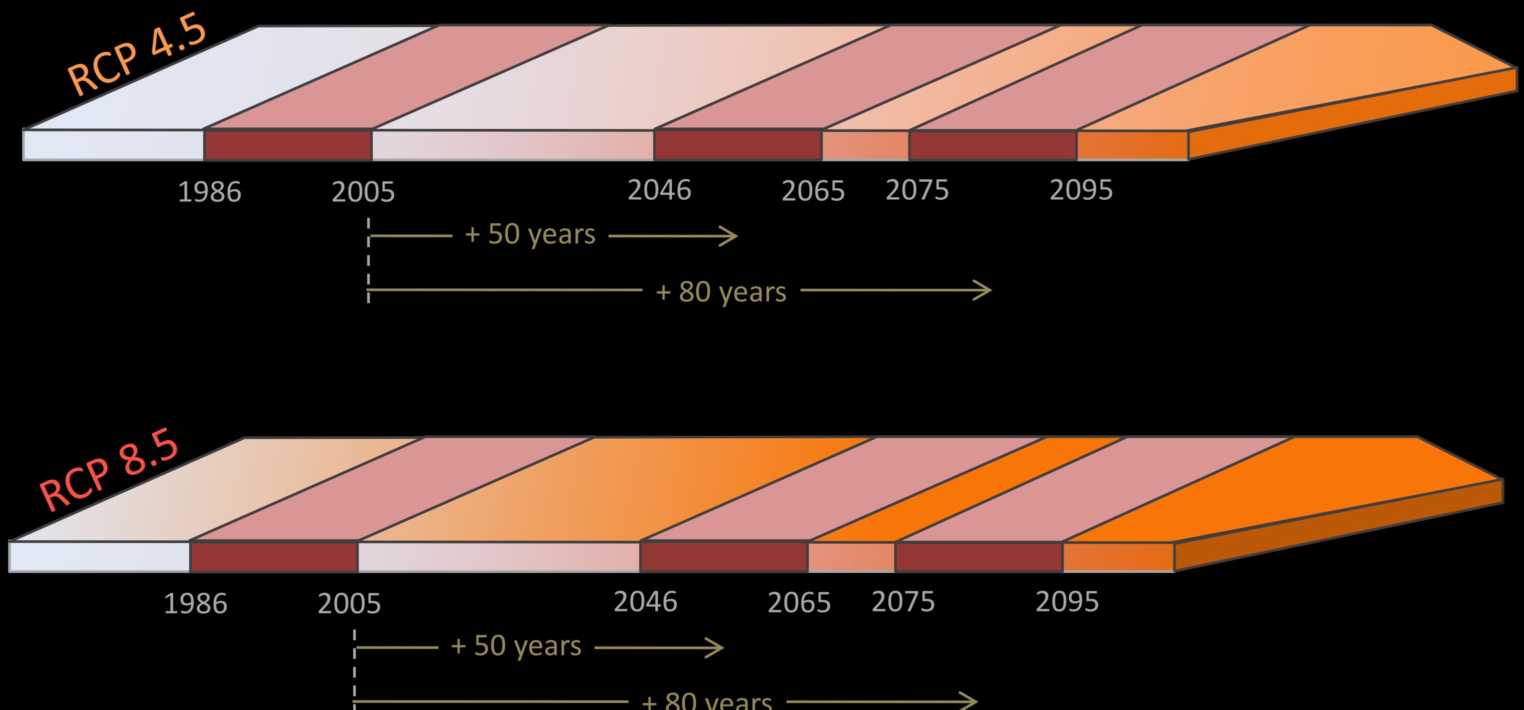


Dynamical downscaling: The four ocean-atmosphere CGCMs provided lateral boundary input to the COnsortium for Small-scale MOdeling-climate mode (COSMO) (version 4.8) model of the Climate Limited-area Modelling (CLM) community, known as the **COSMO-CLM 4.8** or **CCLM 4.8** Regional Climate Model.

CNRM-CM5 ocean-atmosphere CGCM
National Centre for Meteorological Research (CNRM), Climate Modelling and Global Change team, France - Meteo France
(Voldoire et al., 2011)

MPI-ESM-LR ocean-atmosphere CGCM
Max-Planck-Institut für Meteorologie
(Giorgetta et.al., 2013).

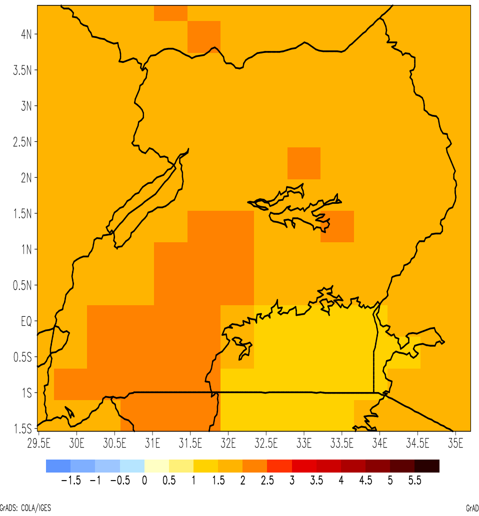
2 x 150-year simulations, each with a different CO_2 concentration pathway, were completed by each one of the four models.
20-year periods (historical, +50 and +80 years from present) of averaged temperature and rainfall were considered for analyses.

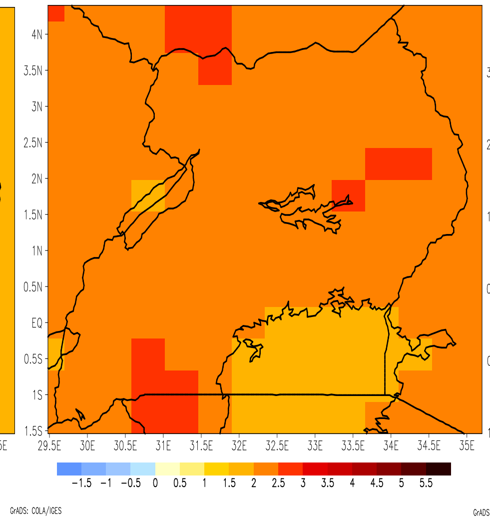


Projected change of the MEDIAN

RCP 4.5: Annual temperature change (ºC) relative to 1985-2005

2046 – 2065 (+50 years)	2076 – 2095 (+80 years)





RCP 4.5: Annual rainfall change (mm/month) relative to 1985-2005

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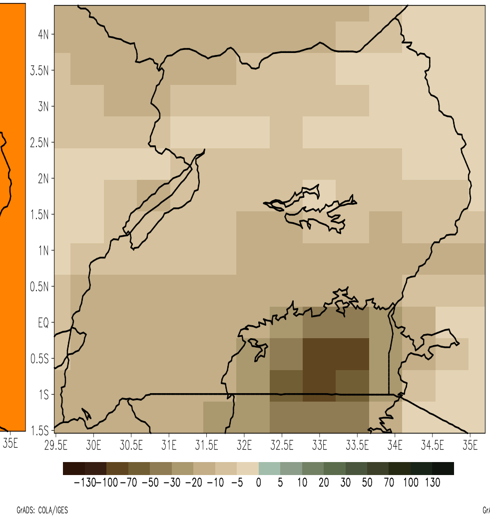

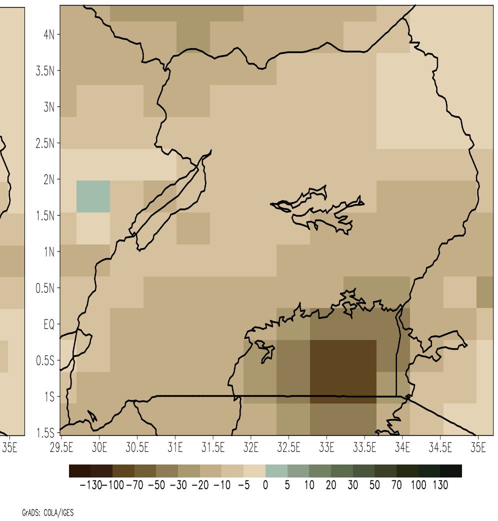

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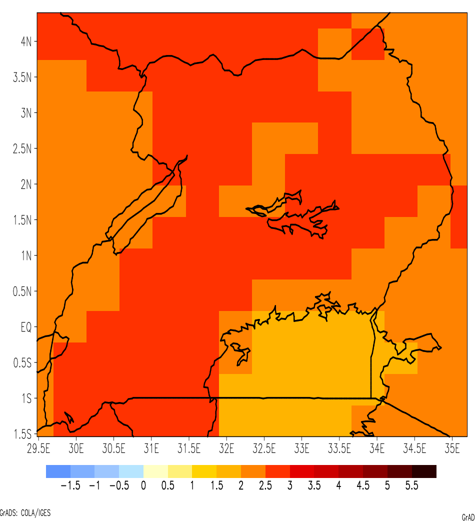

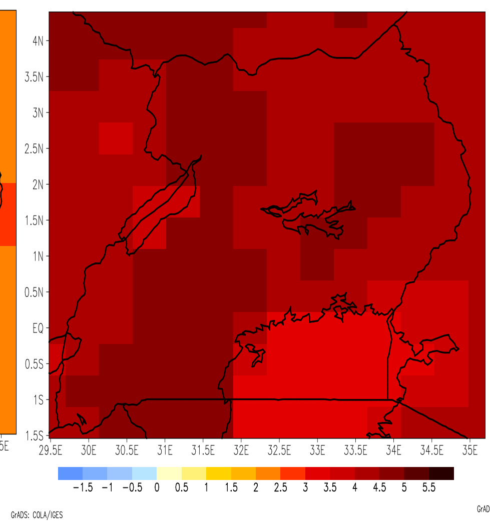

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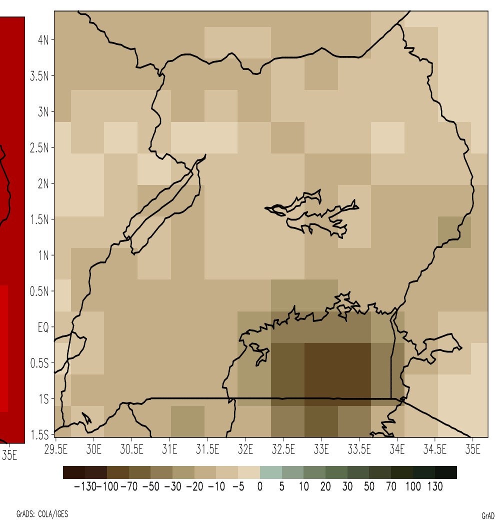
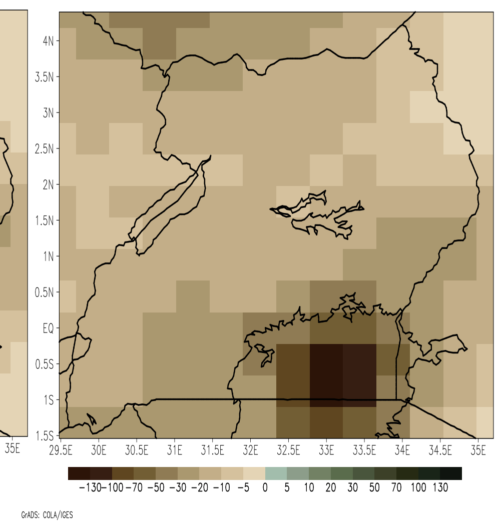
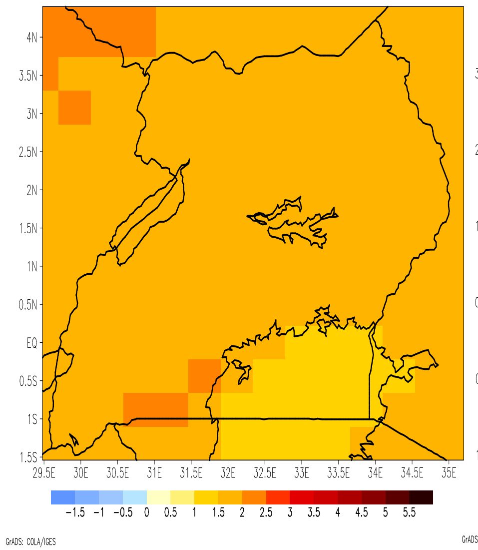


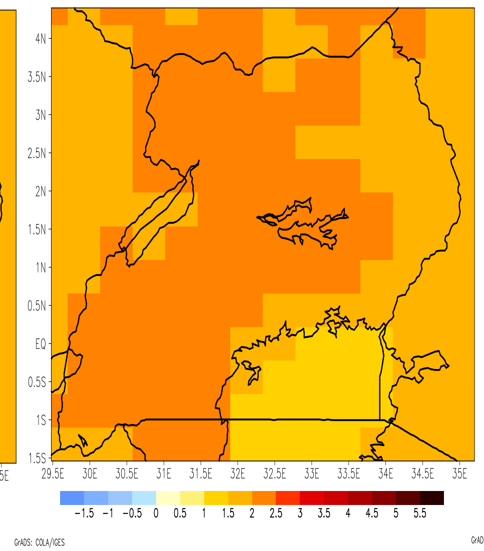


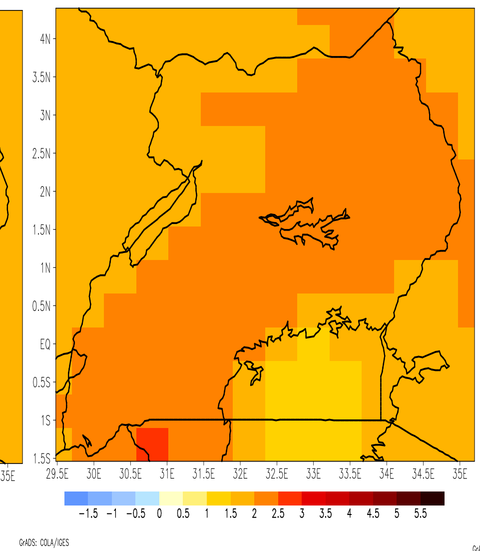
Projected change of the MEDIAN – RCP4.5

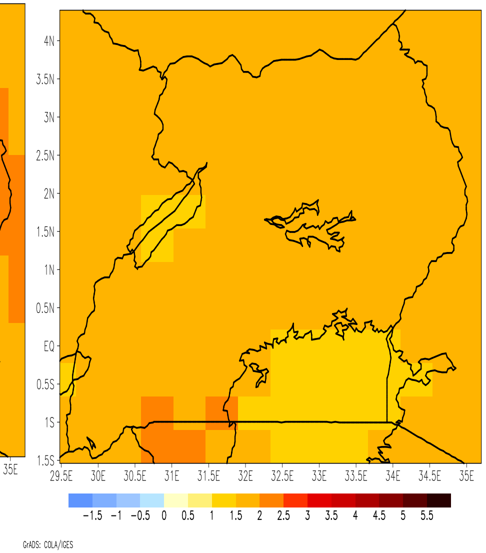
Seasonal temperature change (ºC) for 2046 – 2065 (+50 years) - relative to 1985-2005

DJF	MAM	JJA	SON



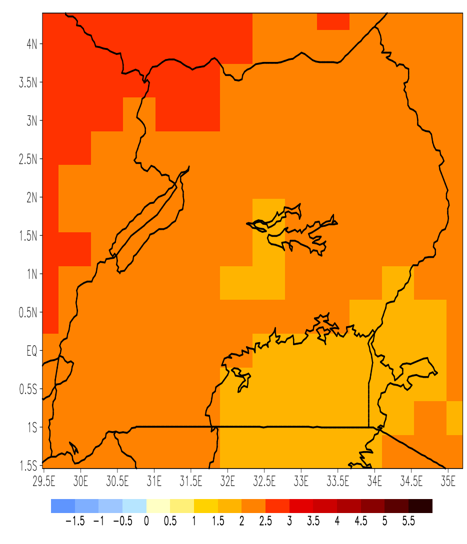


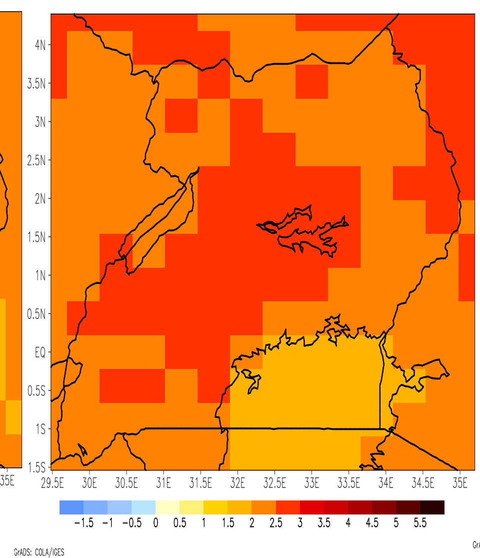


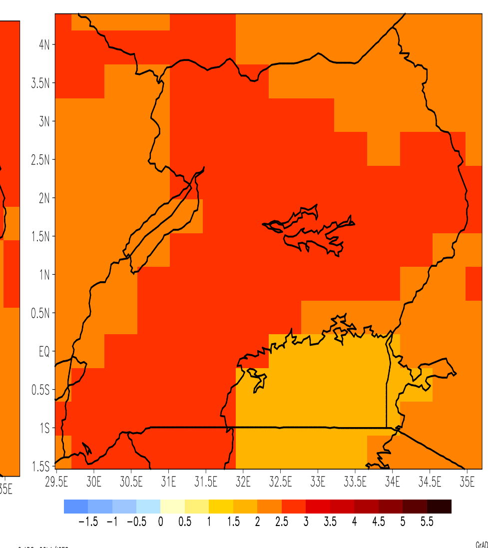


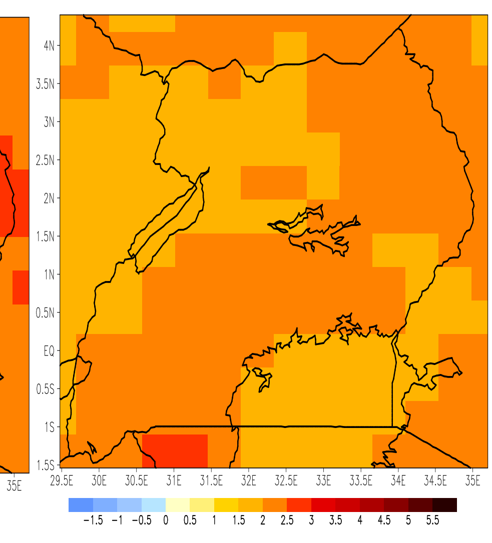
Seasonal temperature change (ºC) for 2076 – 2095 (+80 years) - relative to 1985-2005

DJF	MAM	JJA	SON





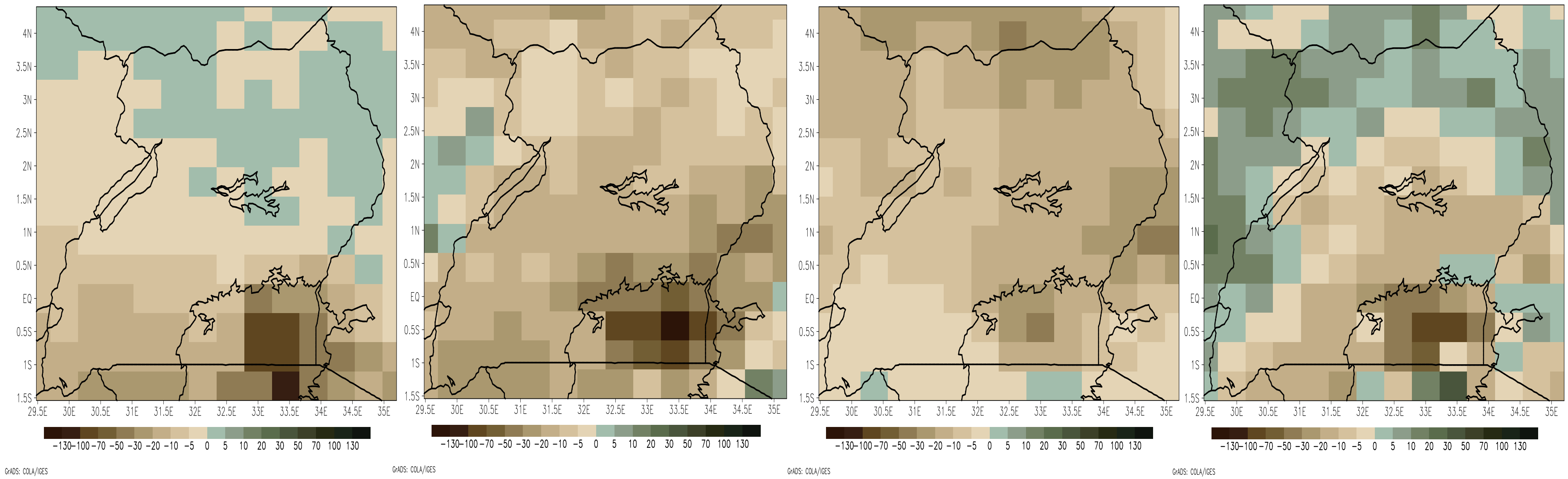




Projected change of the MEDIAN – RCP4.5

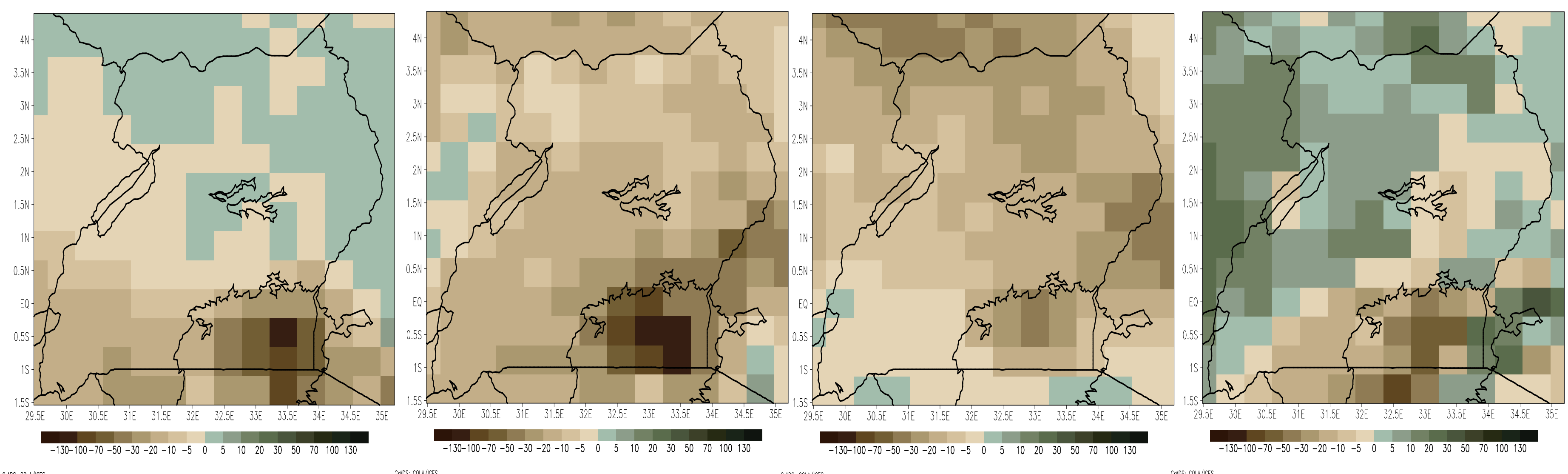
Seasonal rainfall change (mm/month) for 2046 – 2065 (+50 years) - relative to 1985-2005

DJF	MAM	JJA	SON



Seasonal rainfall change (mm/month) for 2076 – 2095 (+80 years) - relative to 1985-2005

DJF	MAM	JJA	SON



Projected change of the MEDIAN – RCP8.5

Seasonal temperature change (ºC) for 2046 – 2065 (+50 years) - relative to 1985-2005

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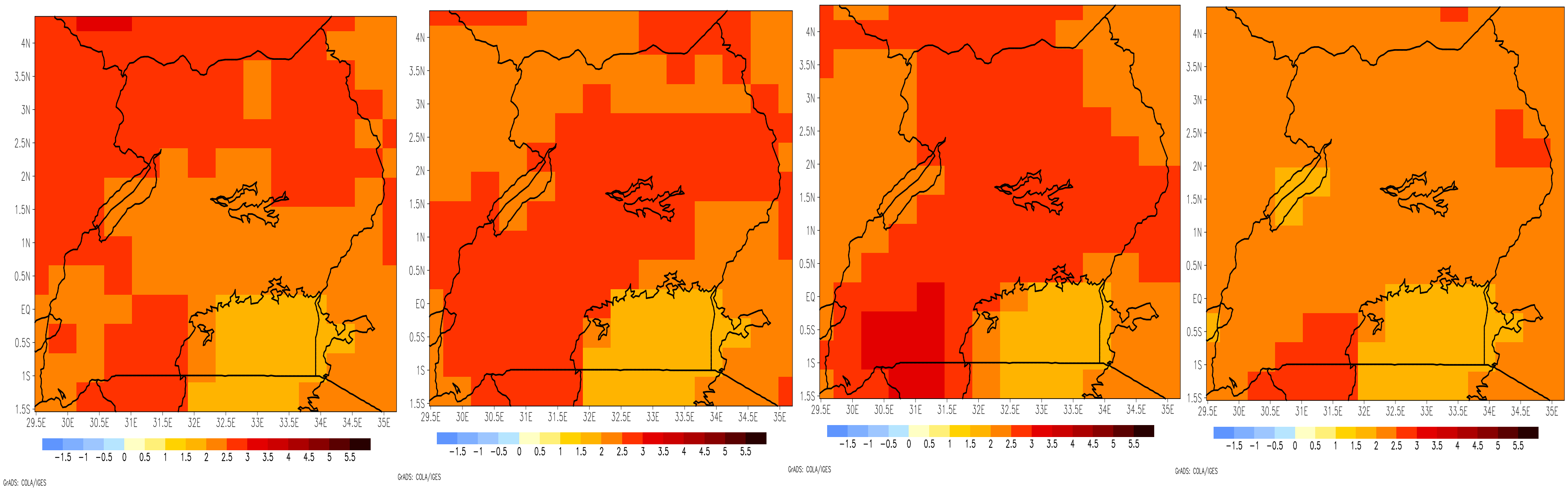
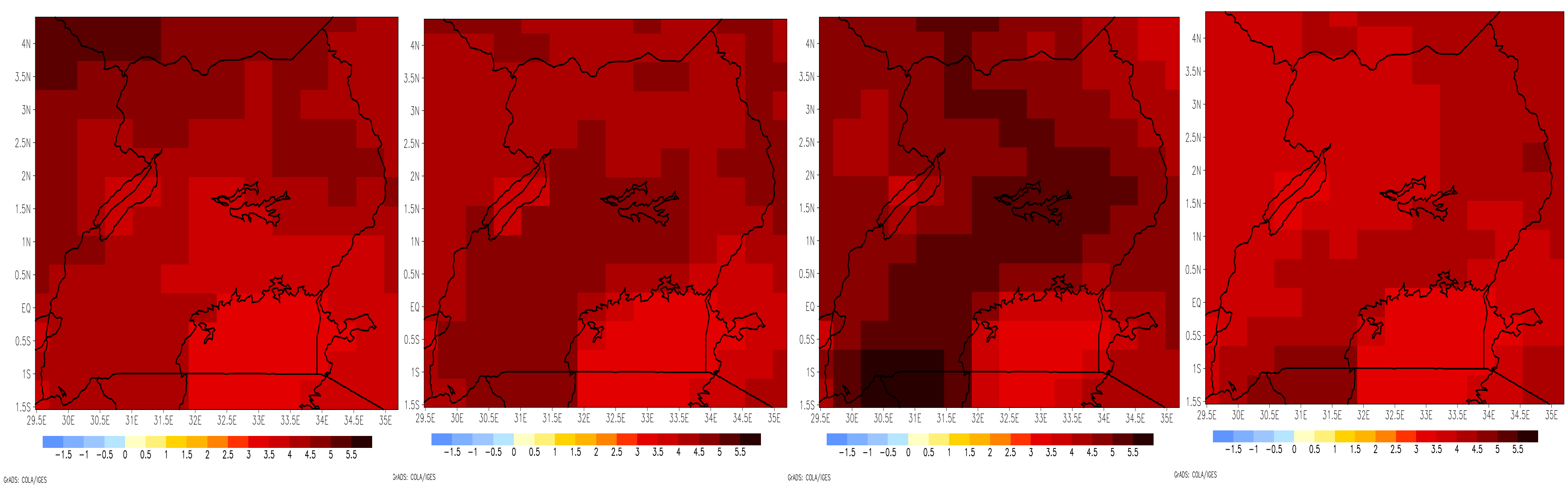


Seasonal temperature change (ºC) for 2076 – 2095 (+80 years) - relative to 1985-2005

DJF	MAM	JJA	SON



Projected change of the MEDIAN – RCP8.5

Seasonal rainfall change (mm/month) for 2046 – 2065 (+50 years) - relative to 1985-2005

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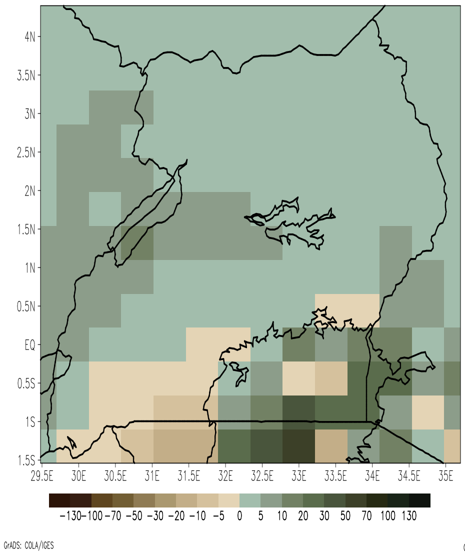

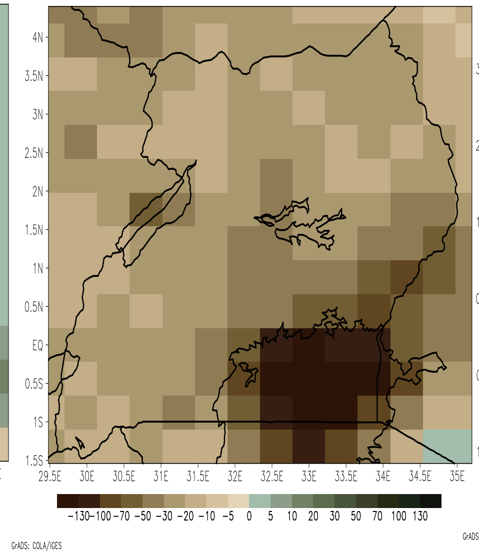

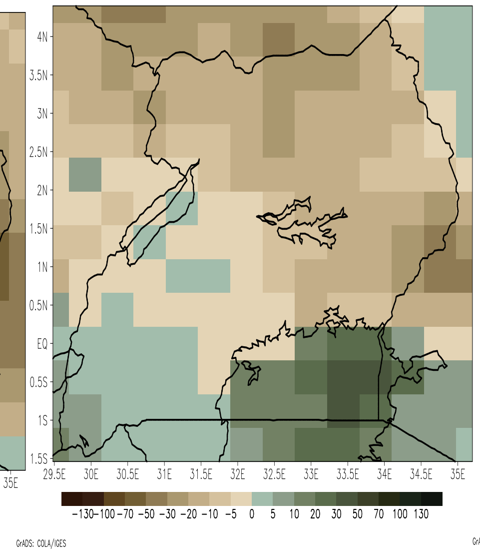

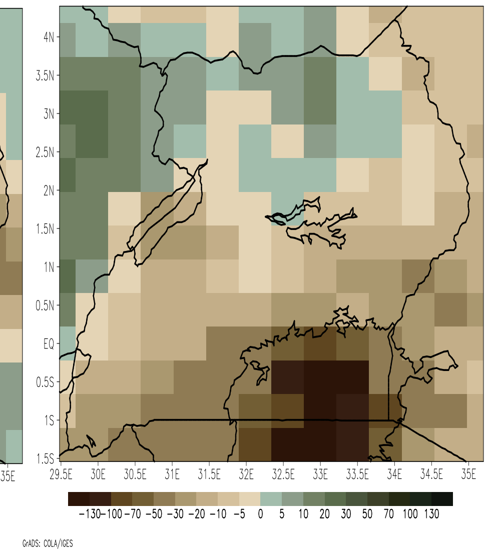

Seasonal rainfall change (mm/month) for 2076 – 2095 (+80 years) - relative to 1985-2005

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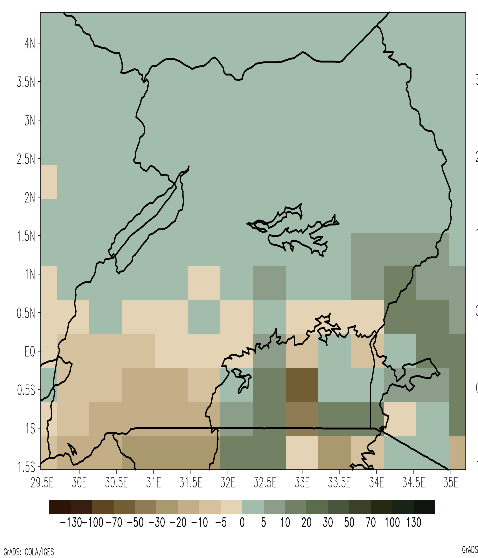
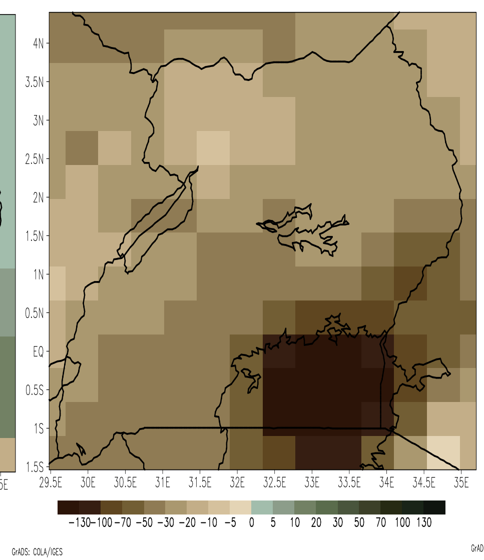
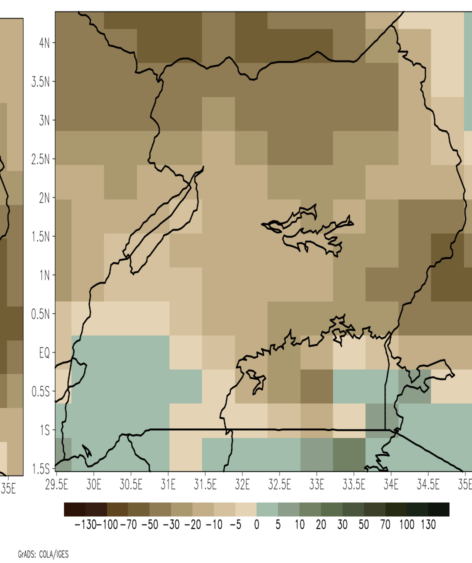
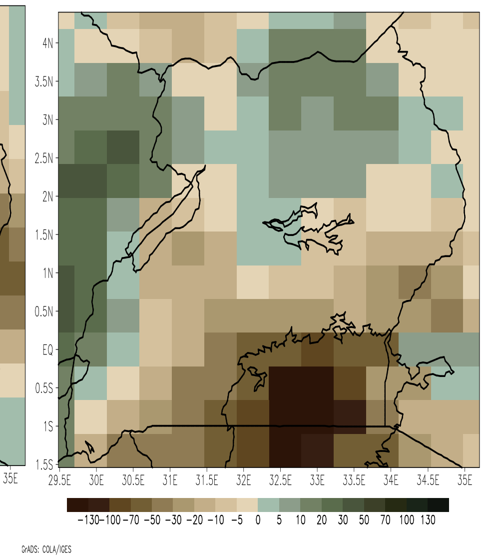




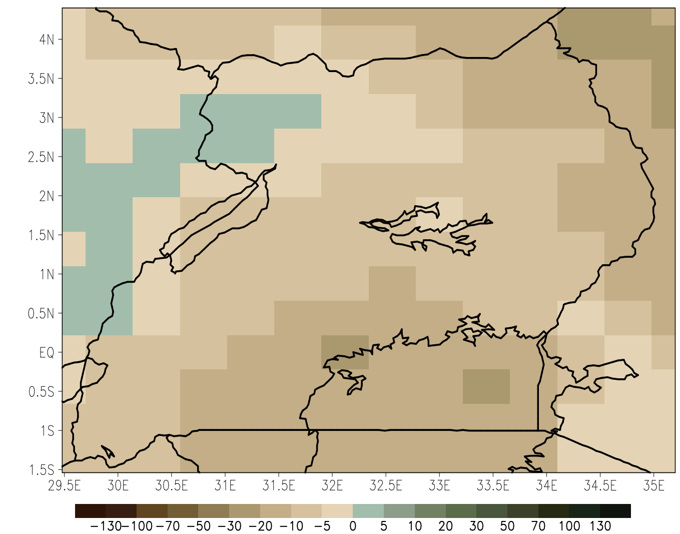




Projected percentage (%) change

RCP 4.5: Annual rainfall change (mm/month)

2046 – 2065 (+50 years)



GrADS: COLA/IGES

RCP 4.5: Annual rainfall change (mm/month)

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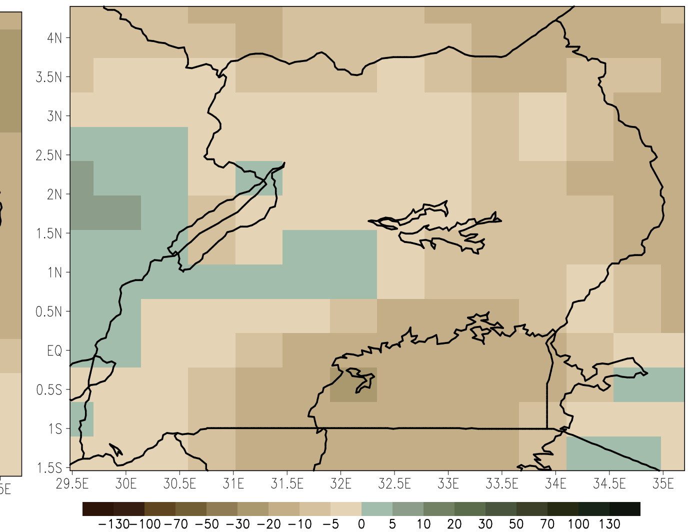

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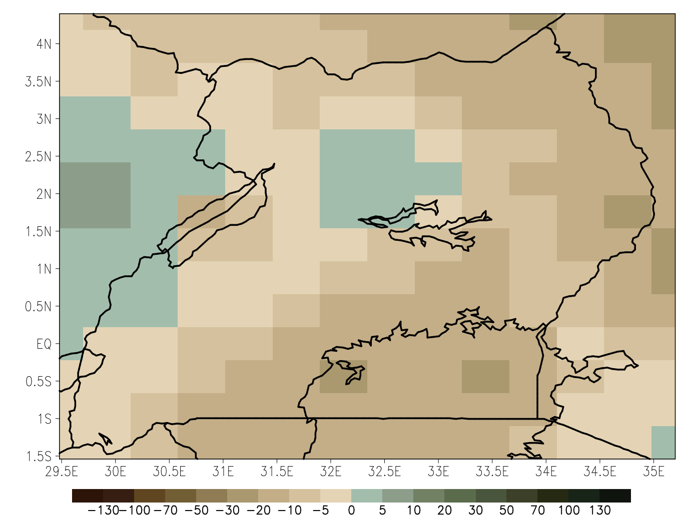

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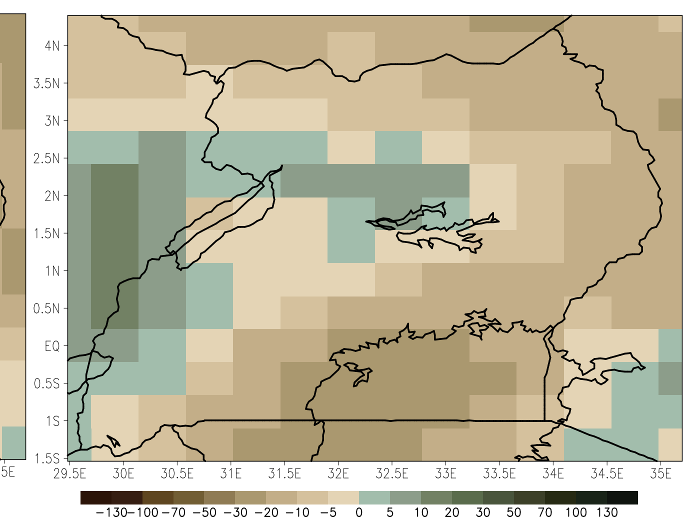
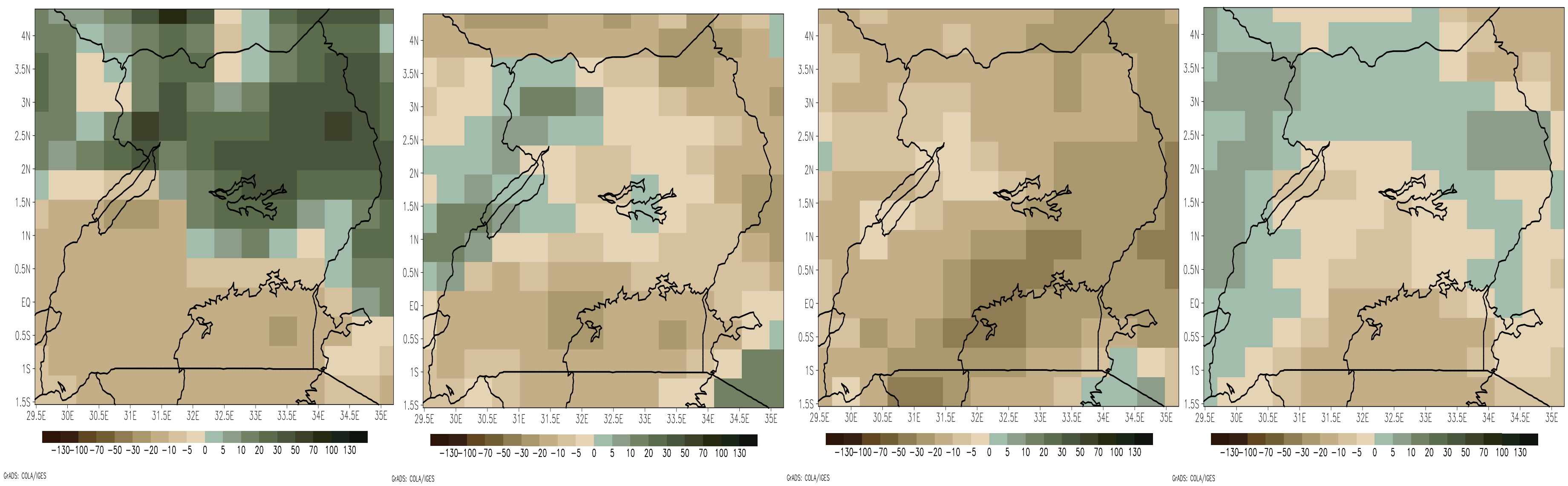


GrADS: COLA/IGES

Projected percentage (%) change – RCP4.5

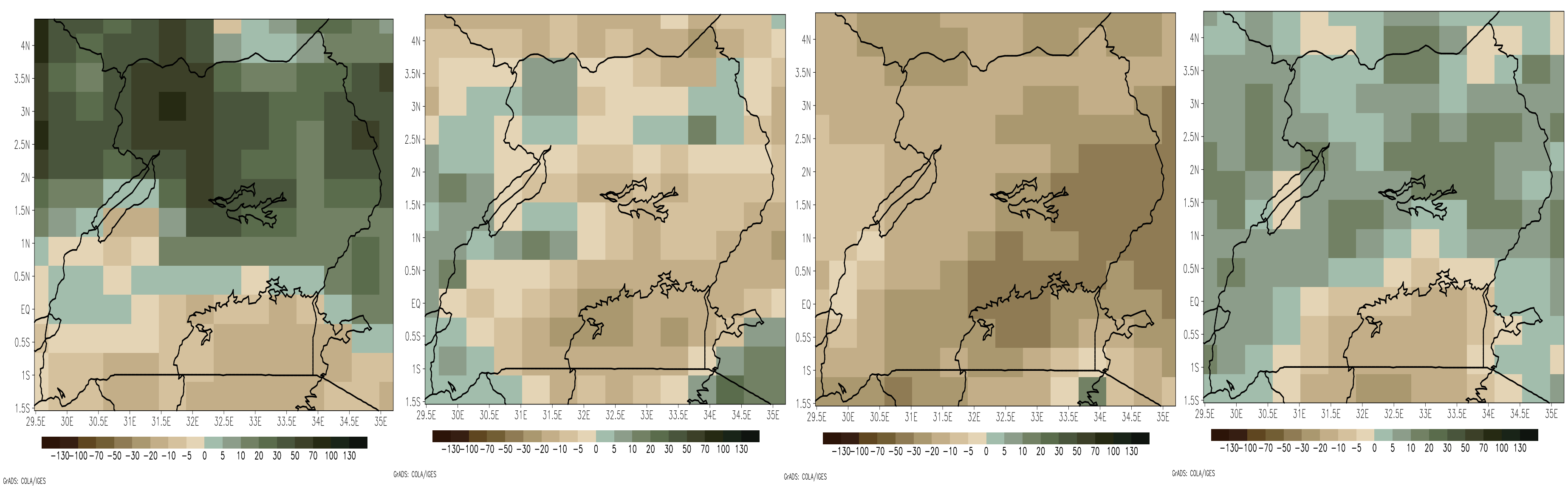
Seasonal rainfall change (mm/month) for 2046 – 2065 (+50 years) - relative to 1985-2005

DJF	MAM	JJA	SON



Seasonal rainfall change (mm/month) for 2076 – 2095 (+80 years) - relative to 1985-2005

DJF	MAM	JJA	SON



Projected percentage (%) change – RCP8.5

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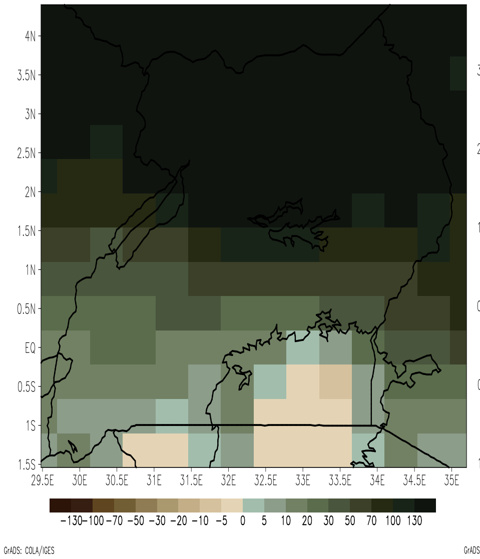
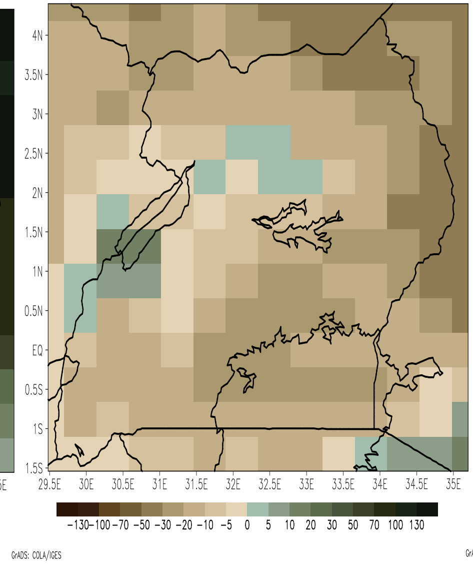
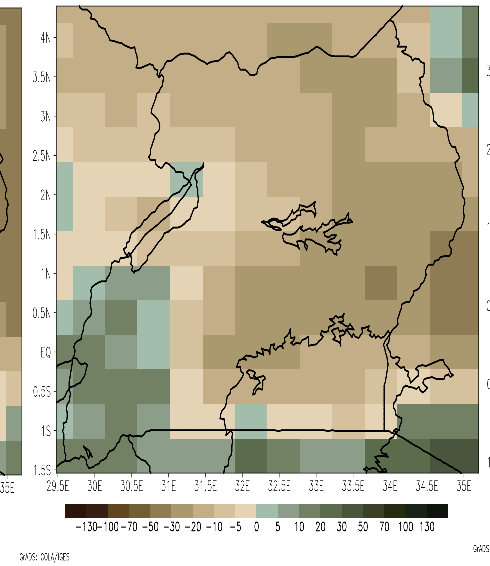
DJF



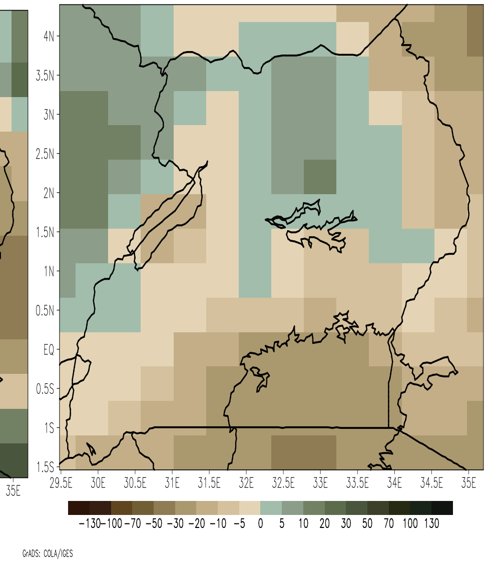
MAM



JJA

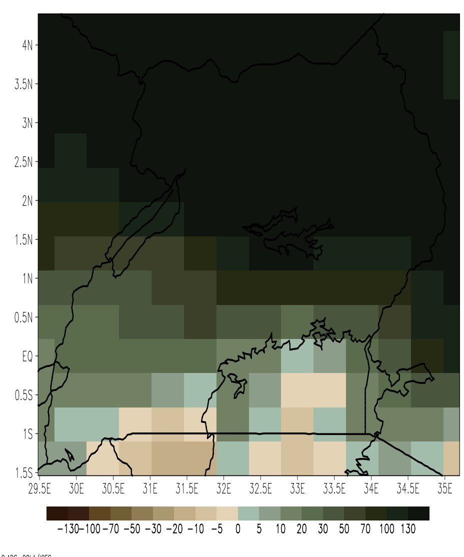


SON

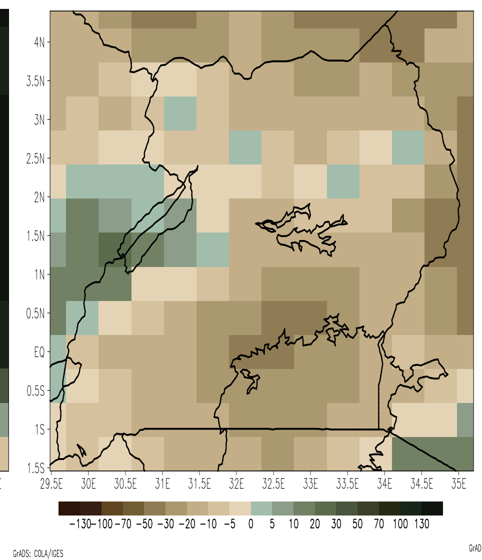


Seasonal rainfall change (mm/month) for 2076 – 2095 (+80 years) - relative to 1985-2005

DJF



MAM



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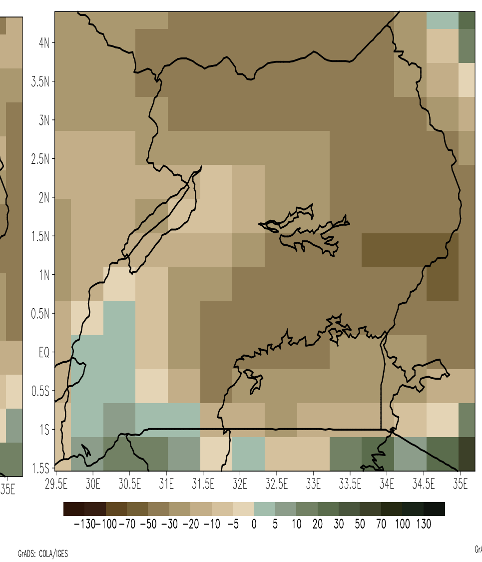

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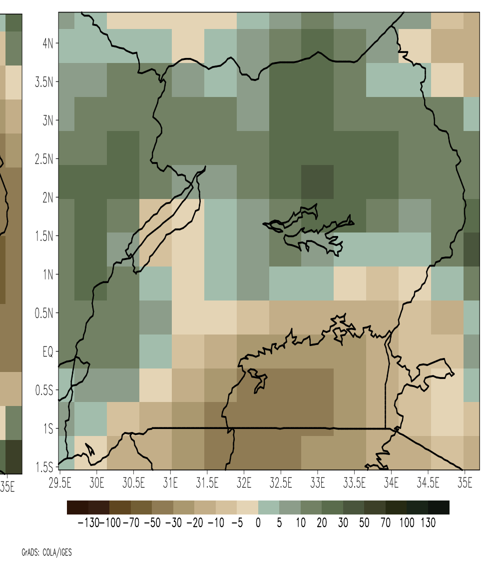
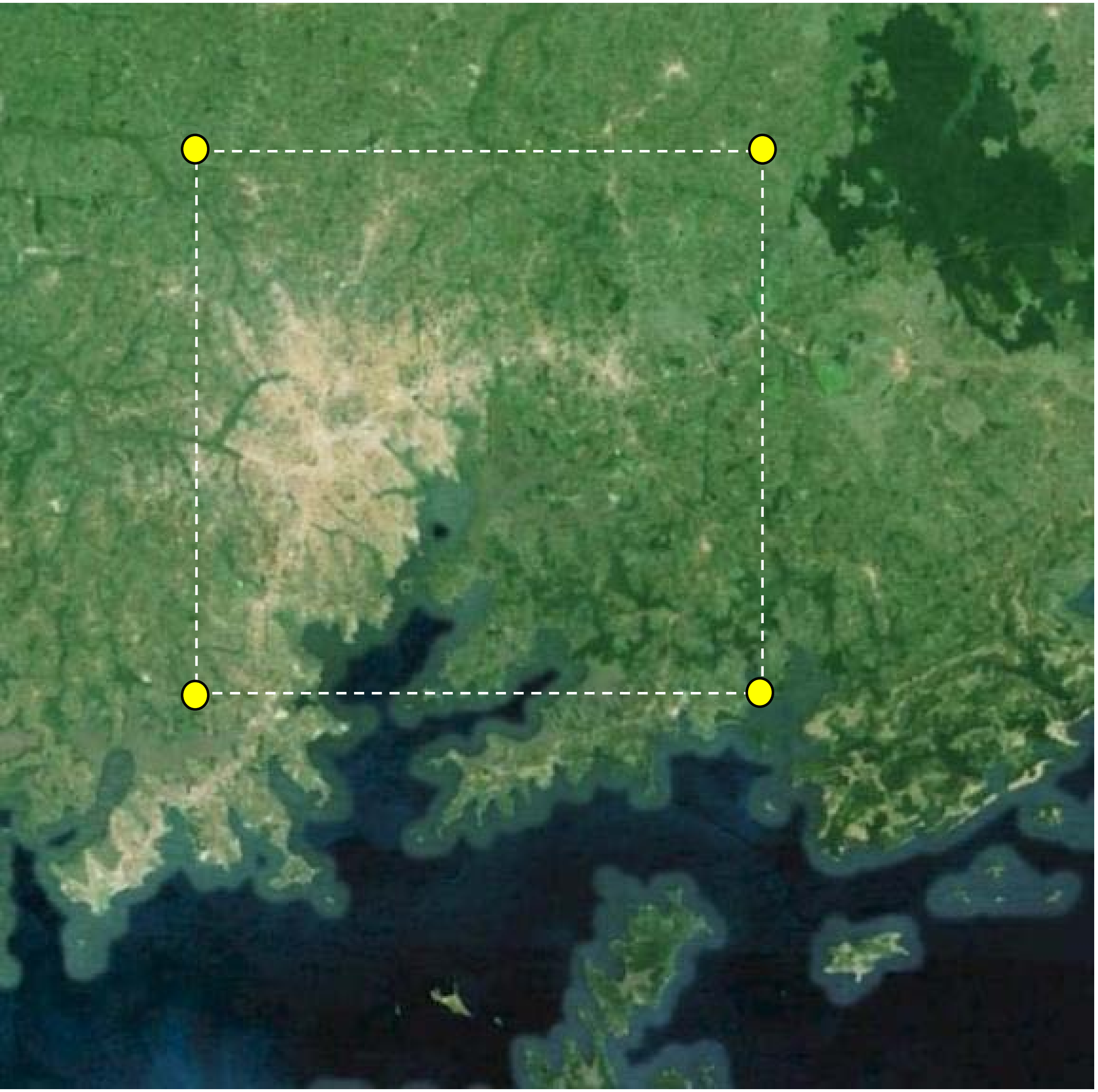
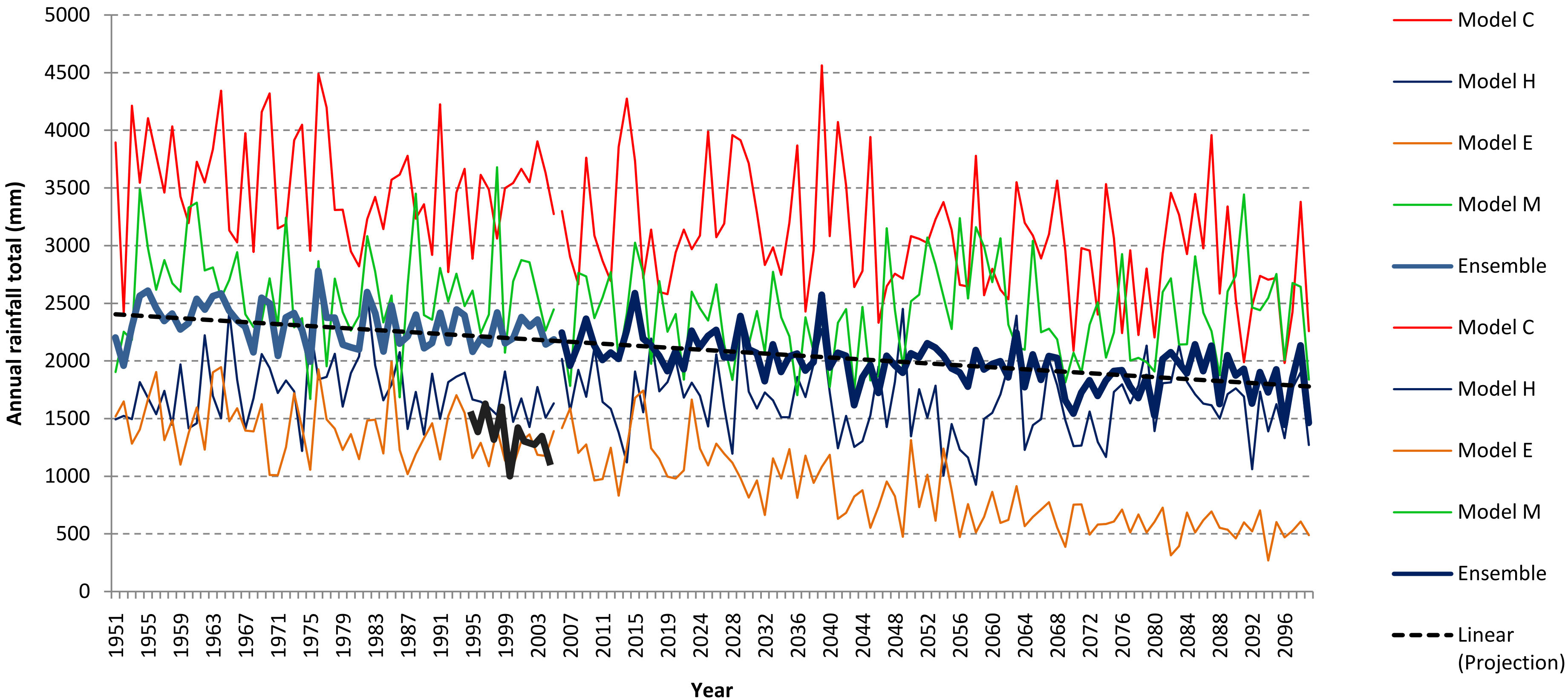


Dynamical *and statistical* downscaling for KAMPALA



The Kampala, Uganda domain (dashed square: 32.56ºE – 33.00ºE ; 0.0ºN – 0.44ºN) with the position of the four model grid points nearest to the metro pole. The average of rainfall and near-surface temperature values at these grid points were regarded as representative for Kampala, from where **STATISTICAL DOWNSCALING** will be performed.

Dynamical *and statistical* downscaling for KAMPALA



Kampala (Uganda) **annual rainfall totals** (mm) for the moderate **RCP 8.5** greenhouse gas concentration pathway as simulated over the historical period **1951** to **2005**, and projected for the period **2006** to **2099** by the CCLM 4.8 Regional Climate Model (RCM) forced across its lateral boundaries by the 1) CNRM-CM5(red thin line), 2) HadGEM2-ES (thin blue line), 3) EC-EARTH (orange thin line) and 4) MPI-ESM-LR. The ensemble mean between these CGCMs are indicated by thick blue lines, and the linear trend in the ensemble projection is indicated by a thick dashed line.

Development and Knowledge sharing workshop: Makerere University, 18 – 20 August 2014

Delegates who attended the Climate Change Development and Knowledge sharing workshop that took place earlier this week at Makerere University

Thank you

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