Using the Community Earth System Model in African Great Lakes Watersheds to inform Regional Stakeholders and Conservation Planners

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African Great Lakes Conference

CONSERVATION STRATEGY FOR THE GREAT LAKES REGION OF EAST AND CENTRAL AFRICA

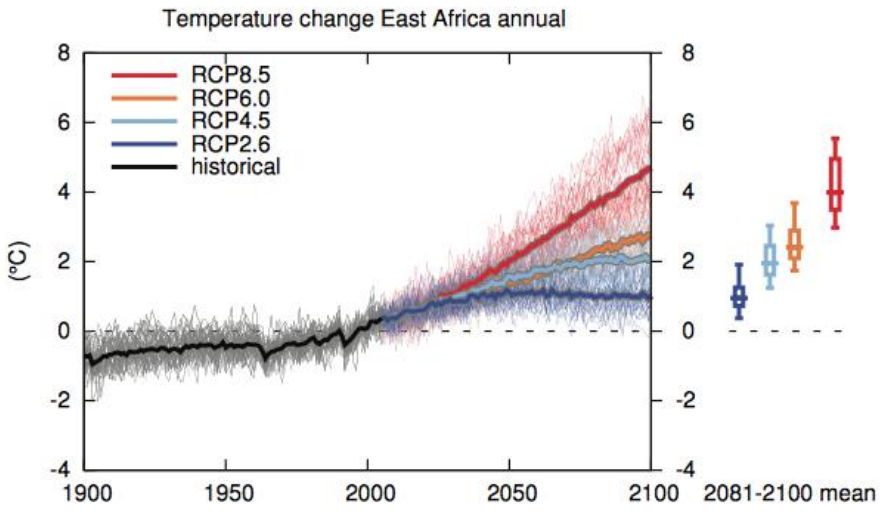
BirdLife International & MacArthur Foundation (2012)

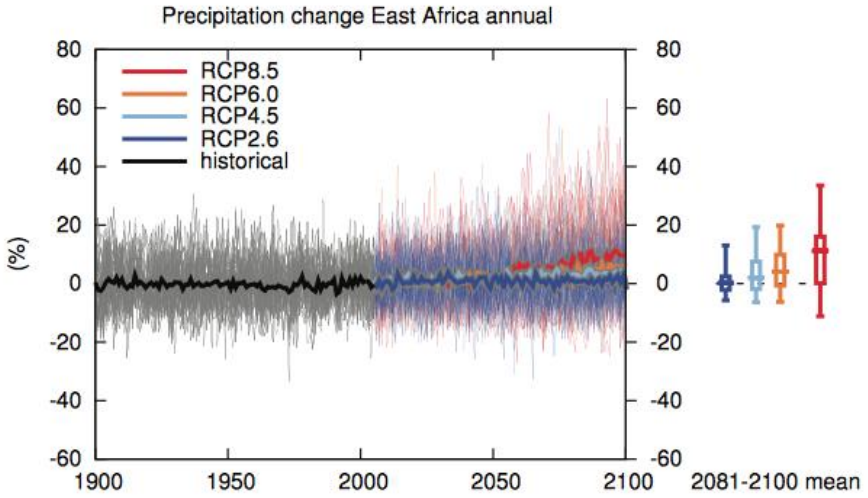
Actions needed on climate change for biodiversity conservation and the services biodiversity provides to humanity across the Great Lakes Region.

- ♦ Integrate climate change in all forms of planning.
- ♦ Perform lake-basin scale climate change assessments.
- ♦ Understand the direct impacts climate change has on biodiversity and the biophysical environment
- ♦ Understand the indirect responses from human action.
- ♦ Understand the response of other threats to climate change.
- ♦ Integrate monitoring into planning and vulnerability assessments.
- ♦ Test different adaptation solutions.
- ♦ Undertake 'no regrets' actions now.

Ch. 5, Seimon et al.)

IPCC Multi-model Projections for East Africa

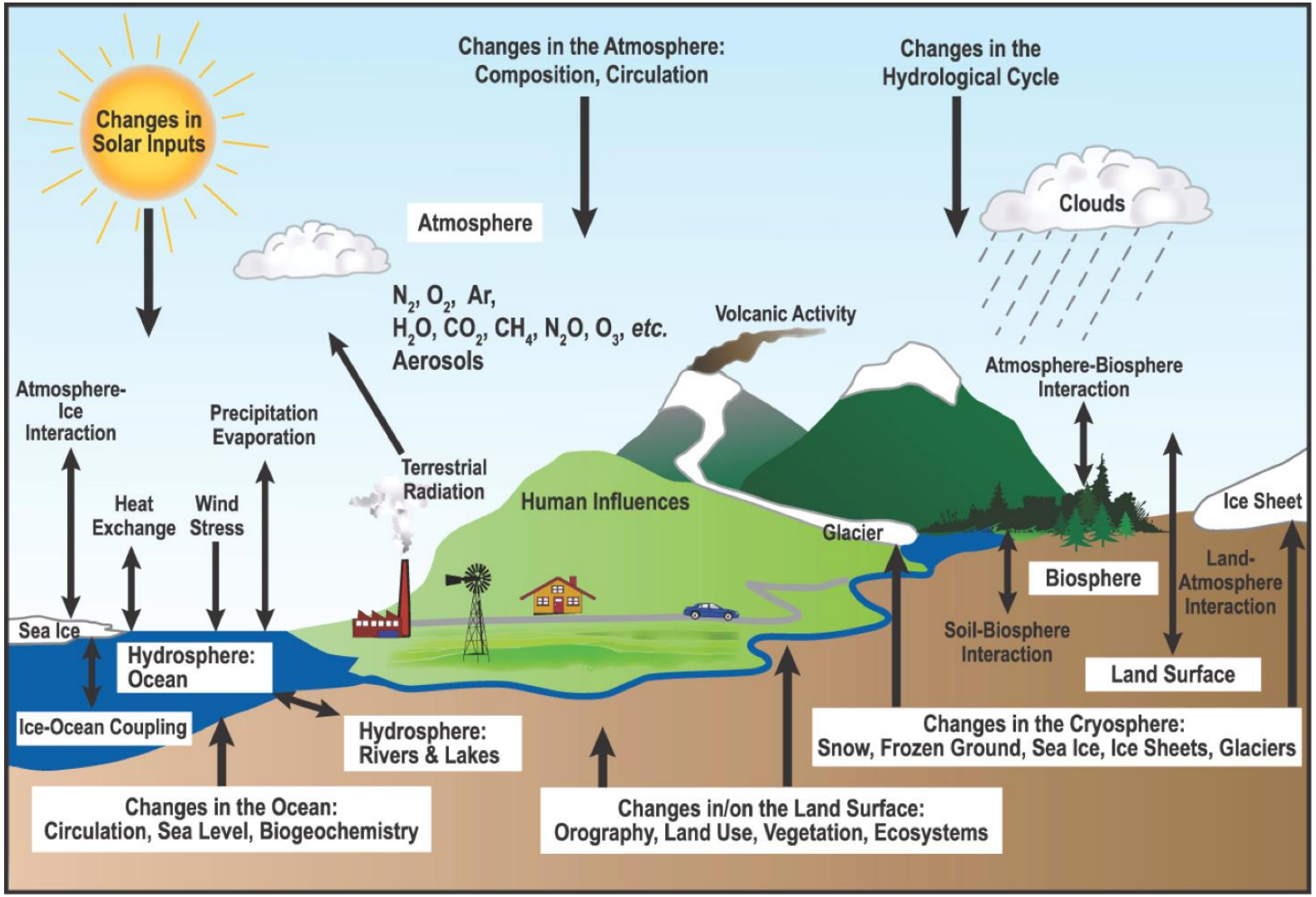




How do we translate such information into environmental outcomes?

What is the climate change information that stakeholders actually need?

Earth System processes & feedbacks that govern climatic conditions



Source: NCAR CESM project

CESM Approach to Modeling Historical and Future Human and Earth Systems

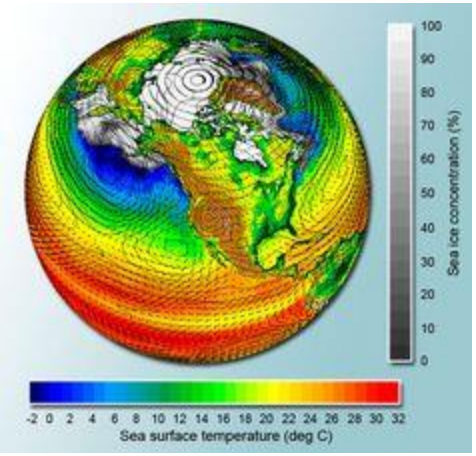
NCAR's Global Human and Earth System Modeling tools show how humans change the Earth System through emissions of greenhouse gases and aerosols, and from changes in surface processes through land use and land cover change.

<u>Great Lakes Project Interest</u>: Can these global models be used regionally with higher spatial resolution and improved local understanding to evaluate how human activity and climate change are impacting the natural and human systems of the African Rift Valley?

If so, how can they be best utilized to inform Conservation and Resource Management through the region?

NCAR Global Human and Earth System Modeling

Community Earth System Model (CESM)



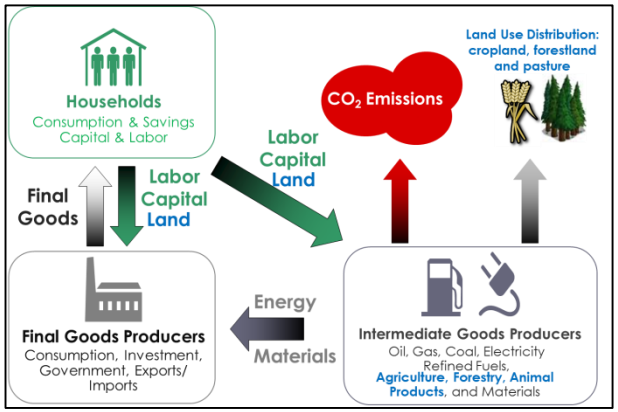
Historical or Future Climate Scenarios (RCPs)

Historical or Future Socio Economic Scenarios (SSPs)

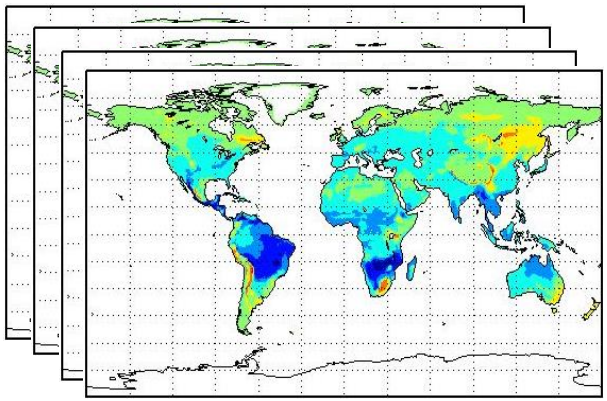
Population, GDP, Energy mix (Annual)

Emissions: CO_2, CH_4, N_2O, Aerosols

Integrated Assessment Model (iPETS / GCAM)



Climate (30 mins): Temp. Precip. Sea Ice

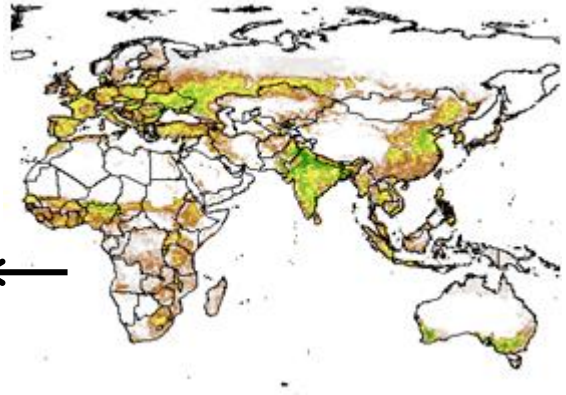


Modeled Impacts: Heating / Cooling, Carbon, Water, Wood, Food, Biofuel

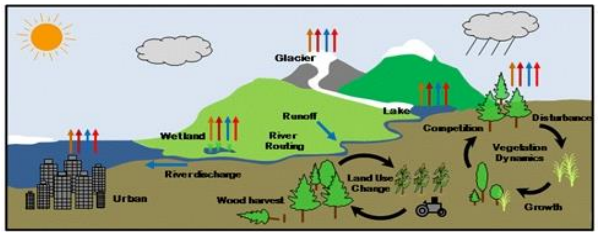
Analysis Tools for: Climate, Water, Crops, Ecosystems

Land use: Crop, Forestry, Conservation, Carbon, Urban

Historical Data/Downscale Models



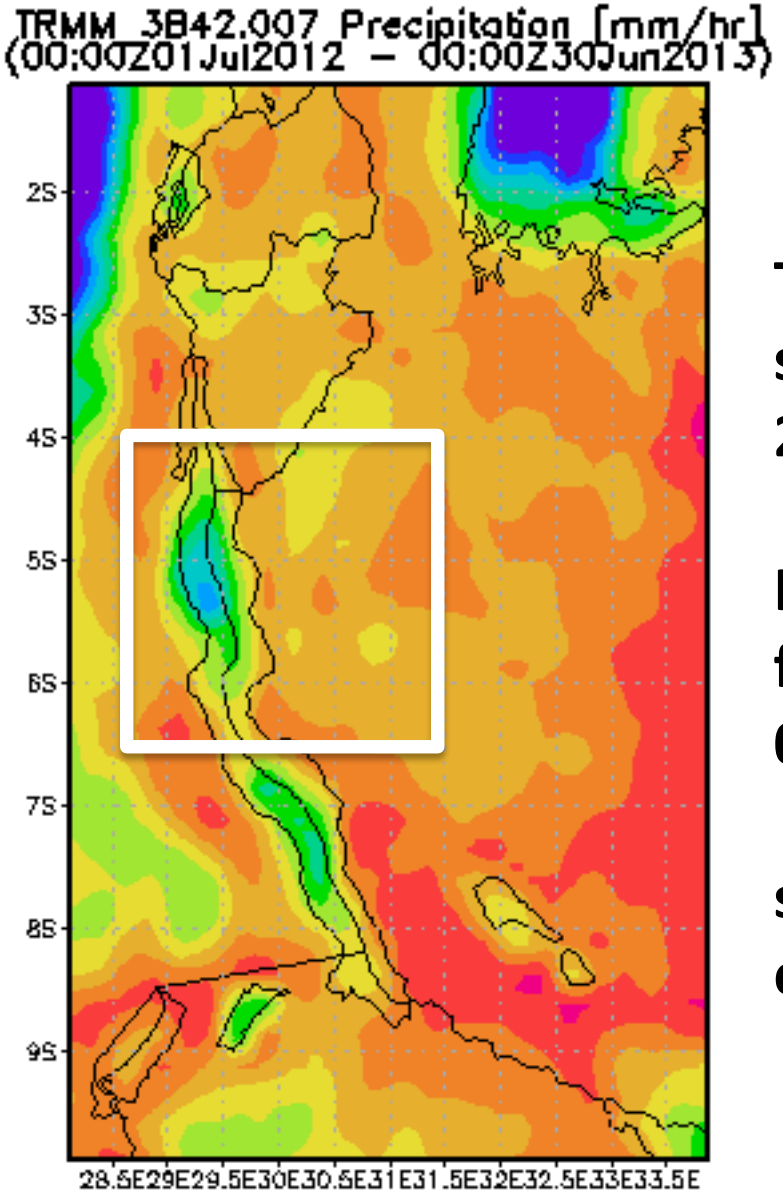
Community Land Model (CLM)



Land Surface (30 mins): Hydrology, Carbon, Crops, Ecosystem Dynamics, Fire

Improvements in Model Resolution

Tanganyika basin annual rainfall



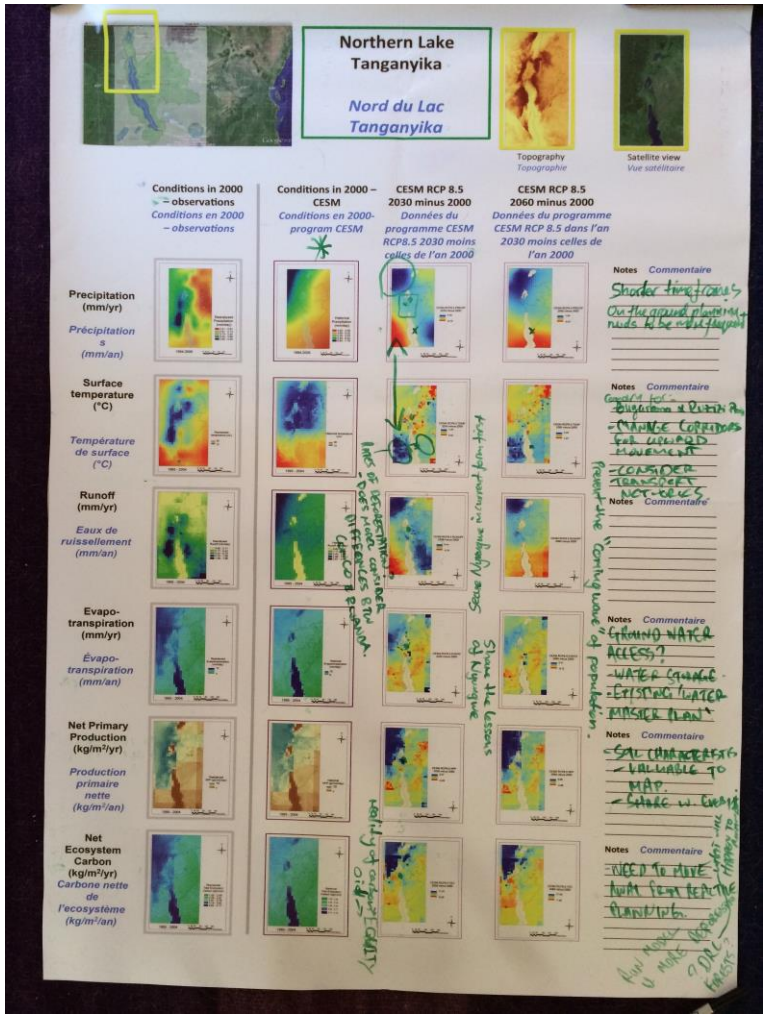
Typical GCM grid cell size 10 years ago: 2.5° x 2.5°

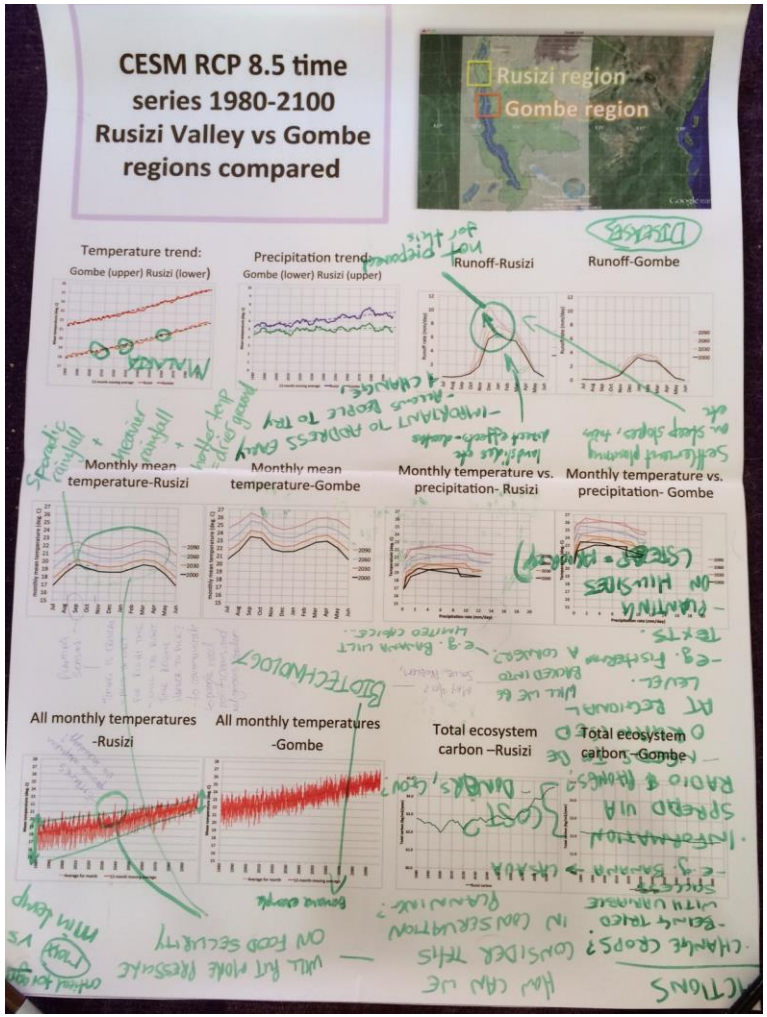
In specialized CESM runs for GLR region: 0.1°x 0.1°

same region now contains 756 grid cells

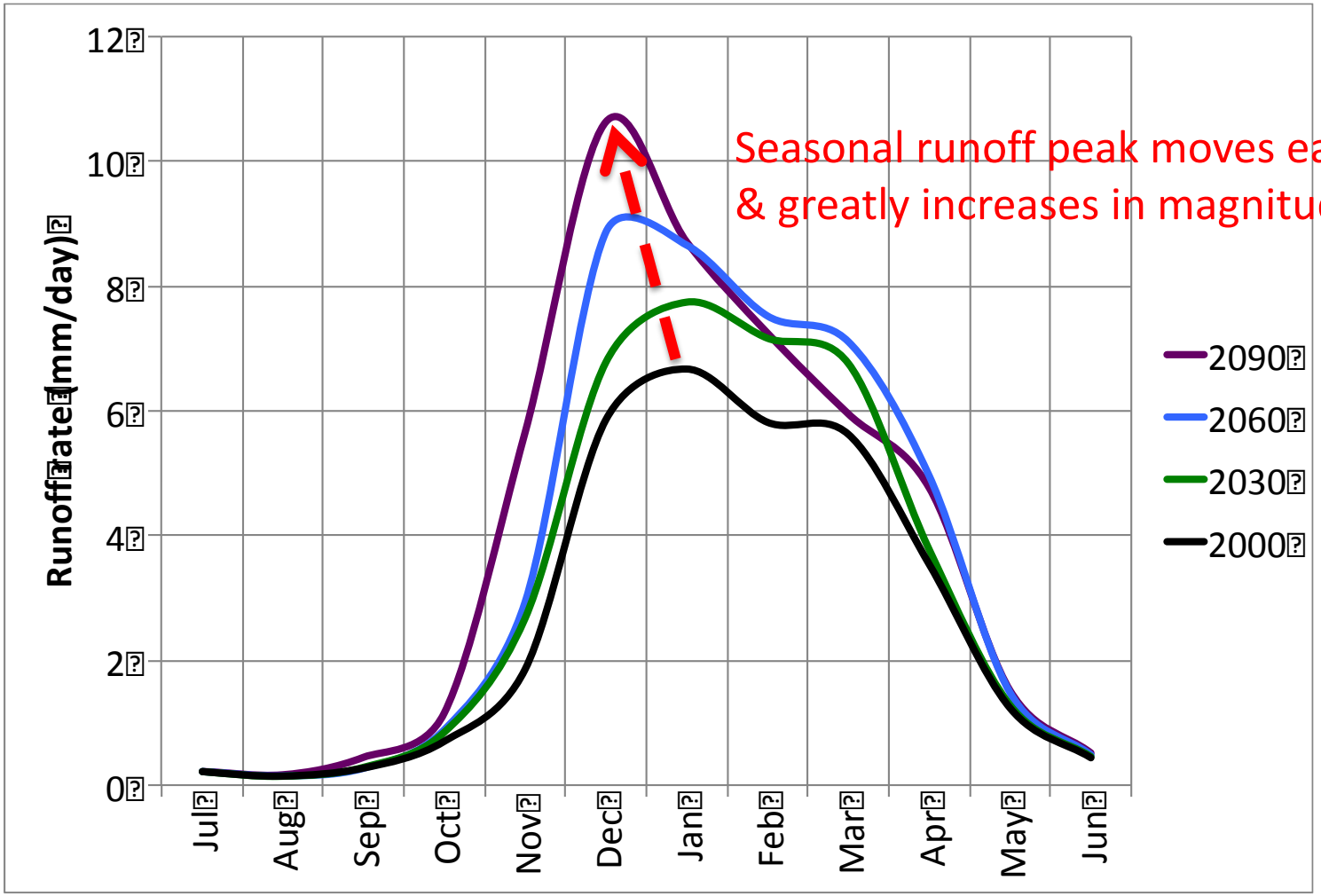
MacArthur project partners workshop Gisenyi, Rwanda, Sept 2014

Partners Workshop – Sept 2014



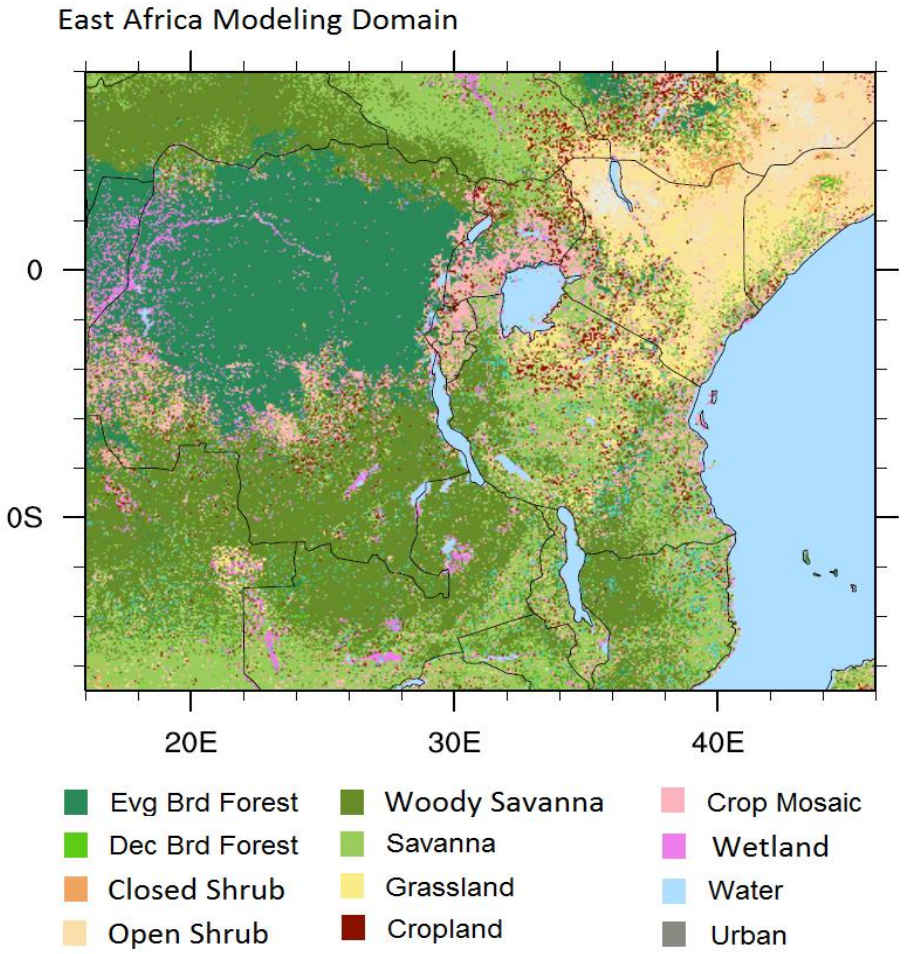


CESM RCP8.5: **Hydrological Runoff** changes in the Lake Kivu-Rusizi region



Community Earth System Modeling of High-Stress Climatic Conditions

- High-resolution fully coupled simulations 0.25°
- Contrast recent past (1979-2012) with late-century prediction (2070-2099)
- RCP 8.5 (business as usual, high warming)



What is heat stress?

US NWS Classification	Apparent Temperature Range (°C)	US NWS Classified "Effect on Body"
Caution	27–32	Fatigue possible with prolonged exposure and/or physical activity
Extreme caution	32–39	Heat stroke, heat cramps, or heat exhaustion possible with prolonged exposure and/or physical activity
Danger	39–51	Heat cramps or heat exhaustion likely, and heat stroke possible with prolonged exposure and/or physical activity
Extreme Danger	51	Heat stroke highly likely

Apparent Temperature
- relative humidity (RH) , Temp (T) , wind speed (WS)

(Garland et al., 2015)

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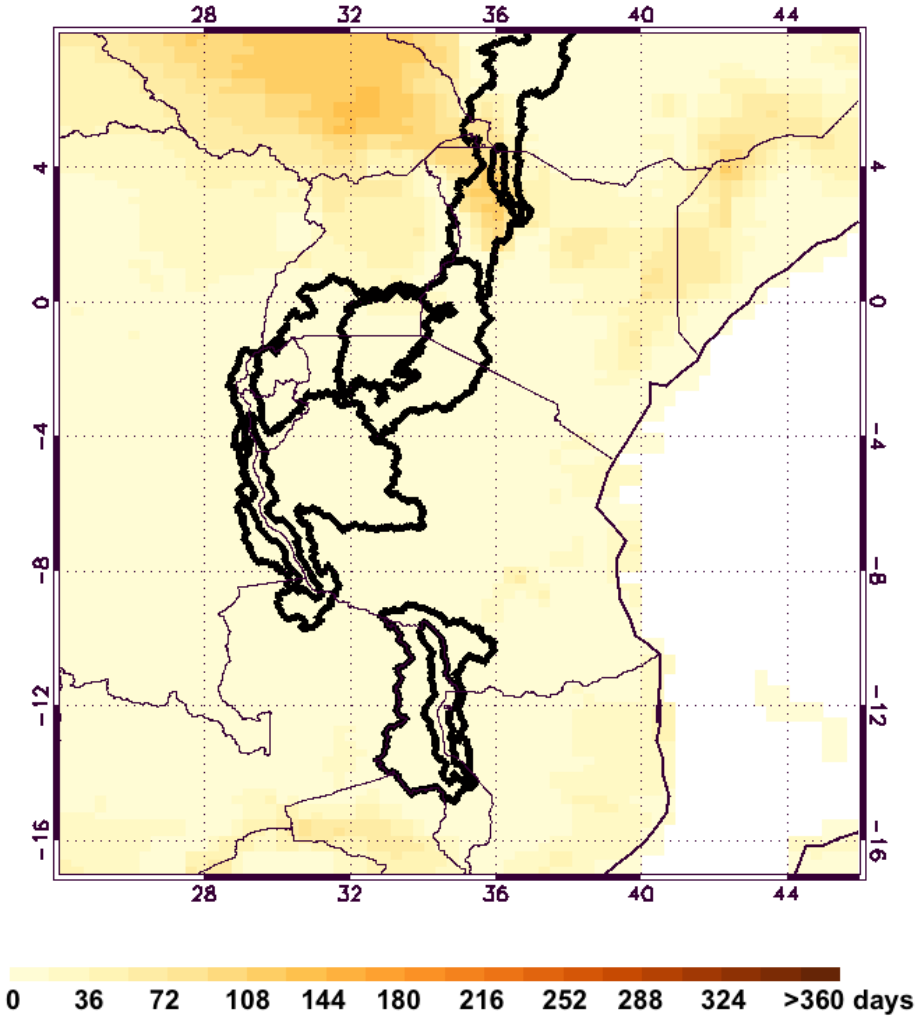
Annual extreme heat stress (days AT > 39°C)

1979-2012



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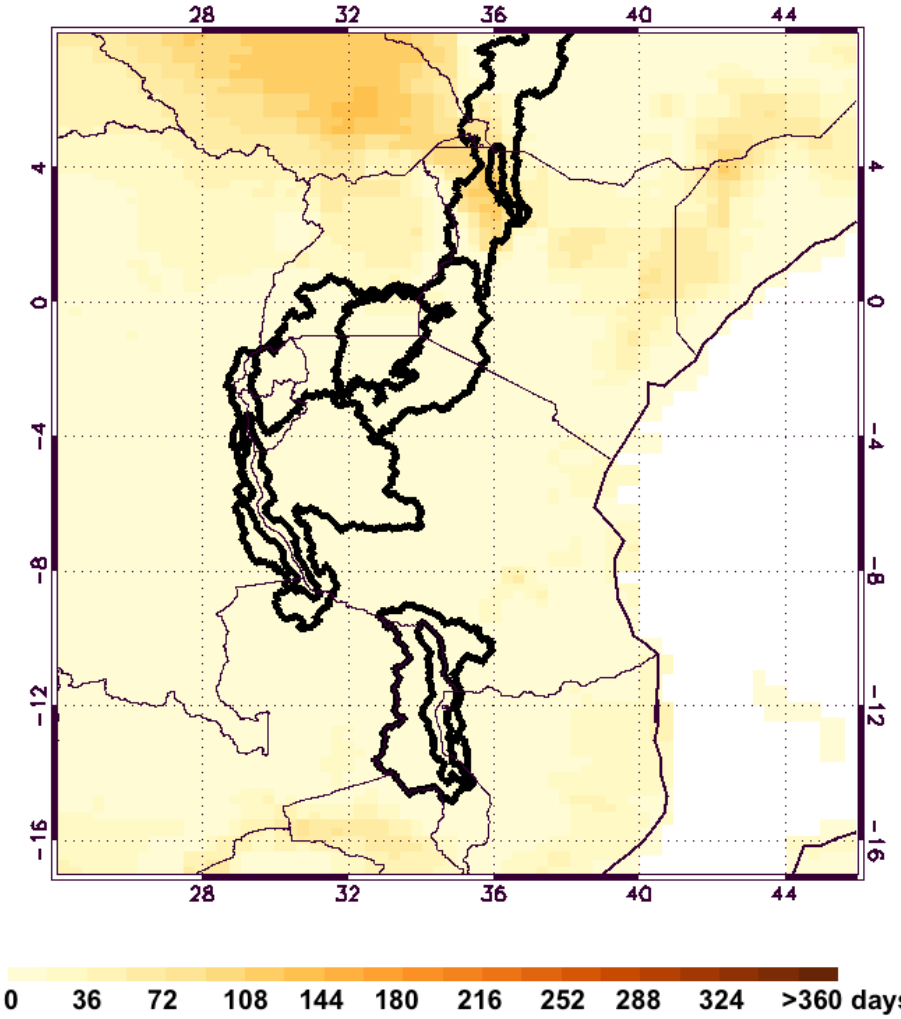
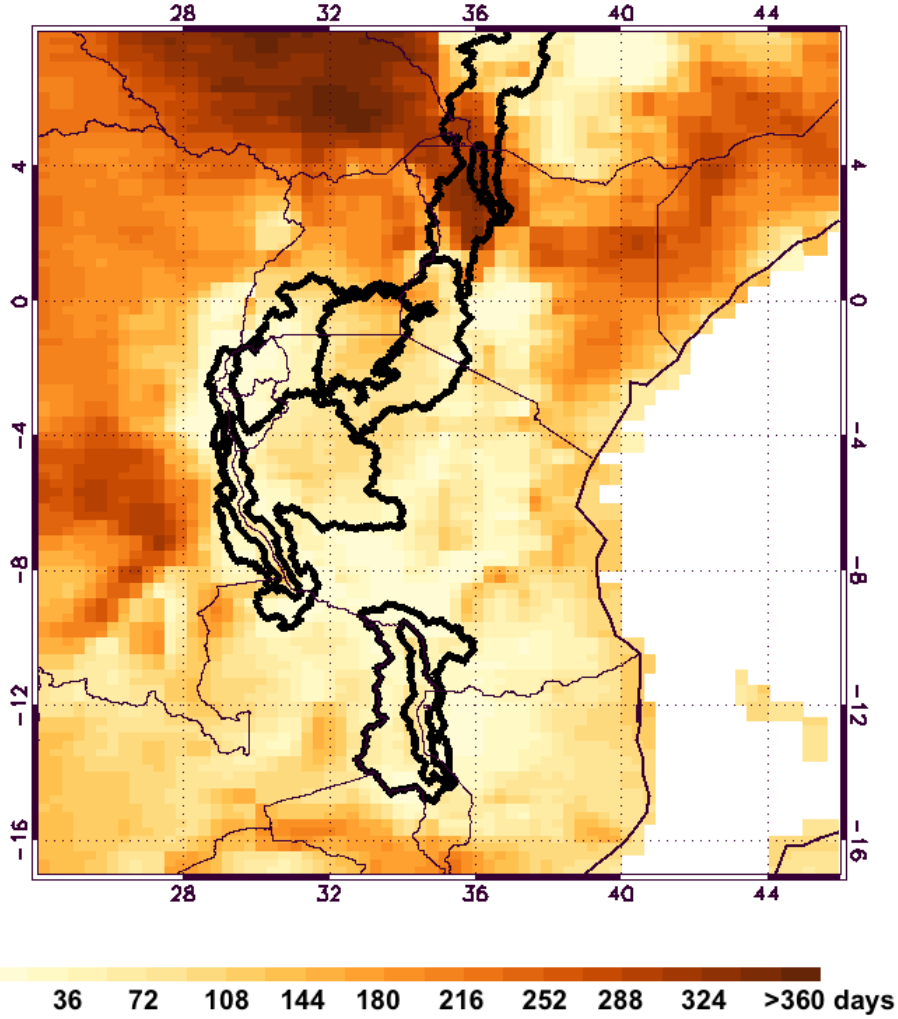


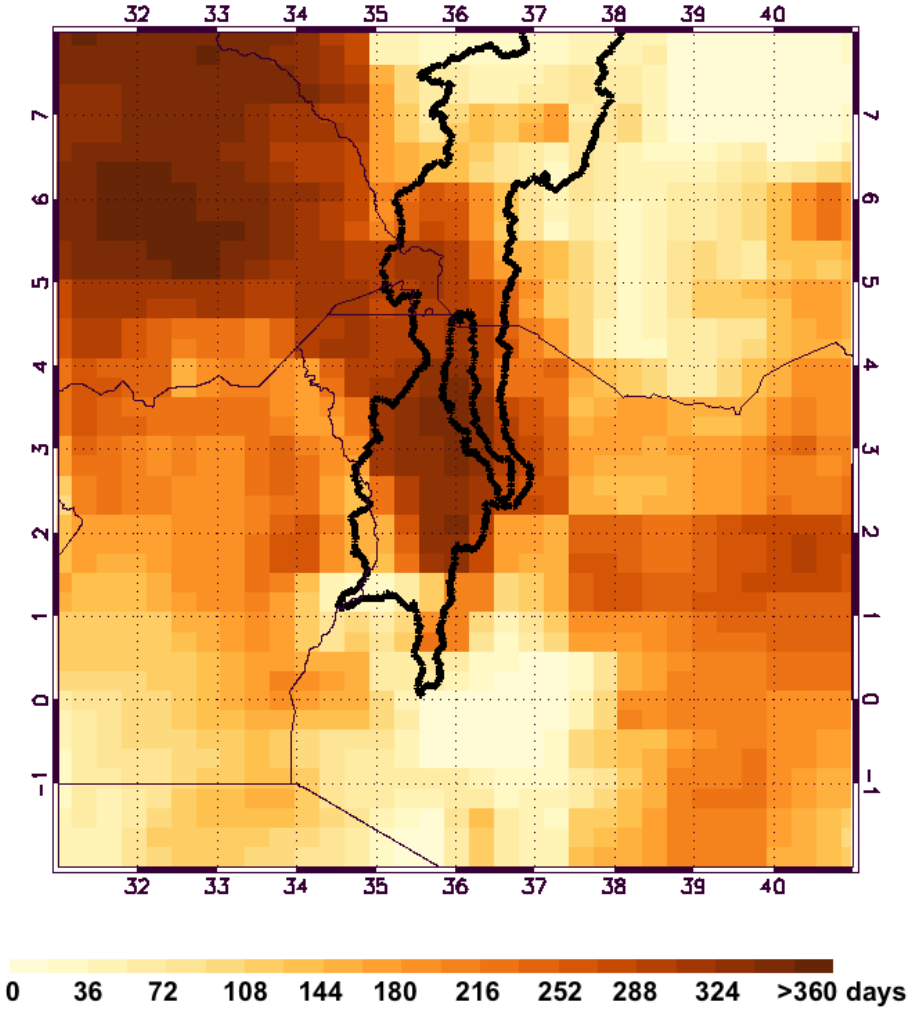
2070-2099



Annual extreme heat stress (days AT > 39°C)

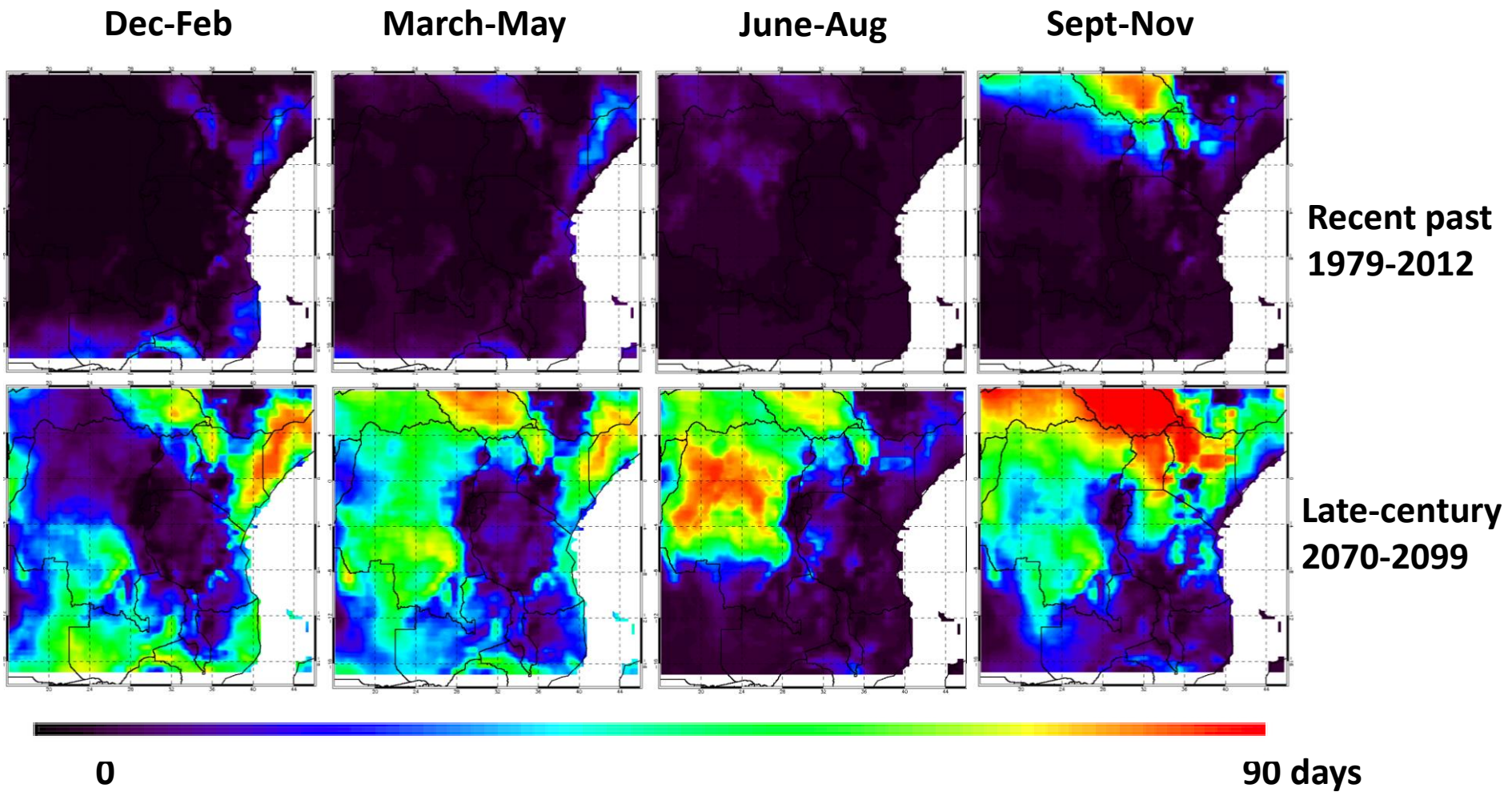
Lake Turkana Basin

2070-99



Seasonal extreme heat stress

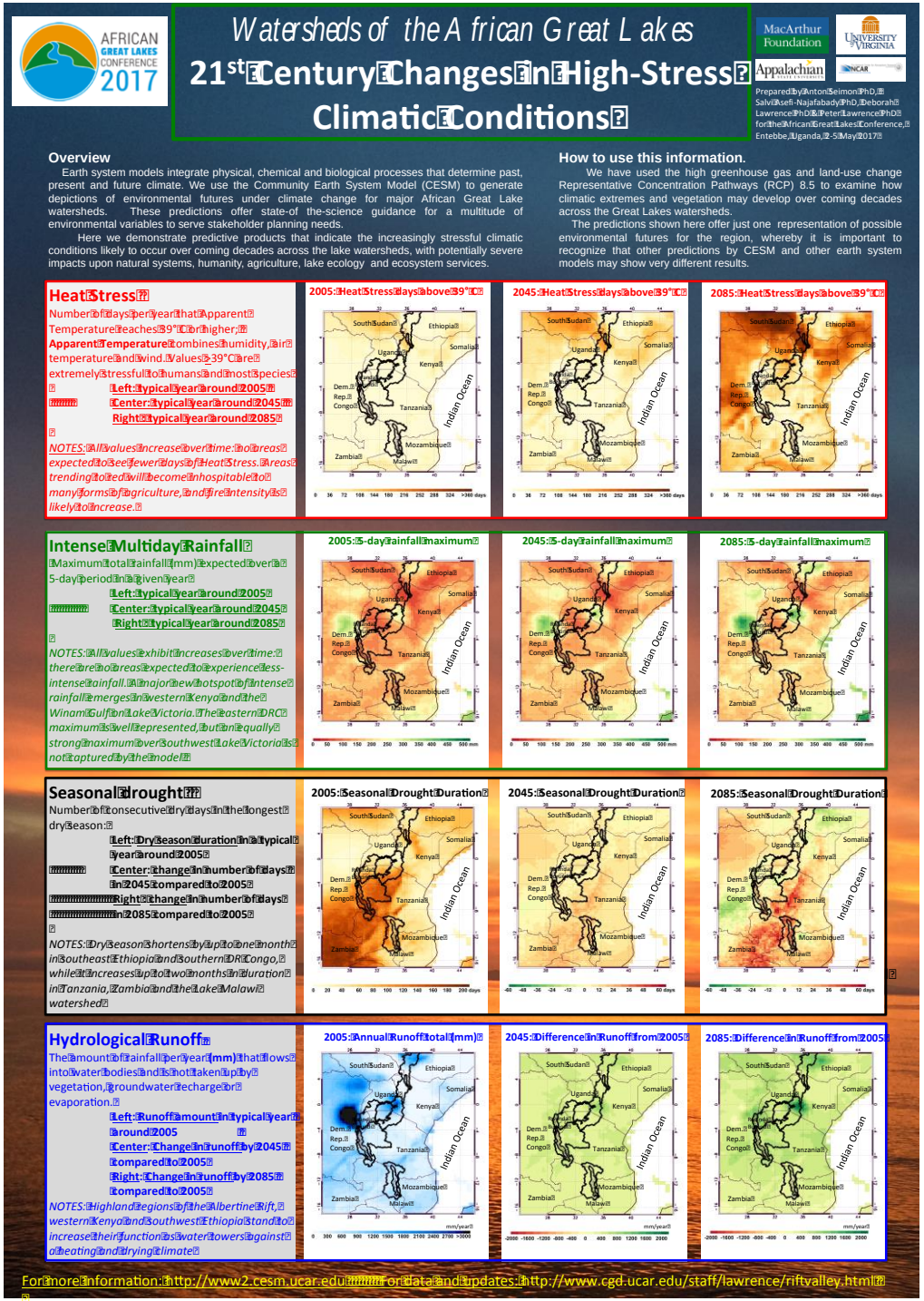
(days AT>39°C)



Poster on high stress climatic conditions

Copies available for you to take home!

Other CESM products to be placed online as they become available, can also be emailed directly to stakeholders.



How to use this information

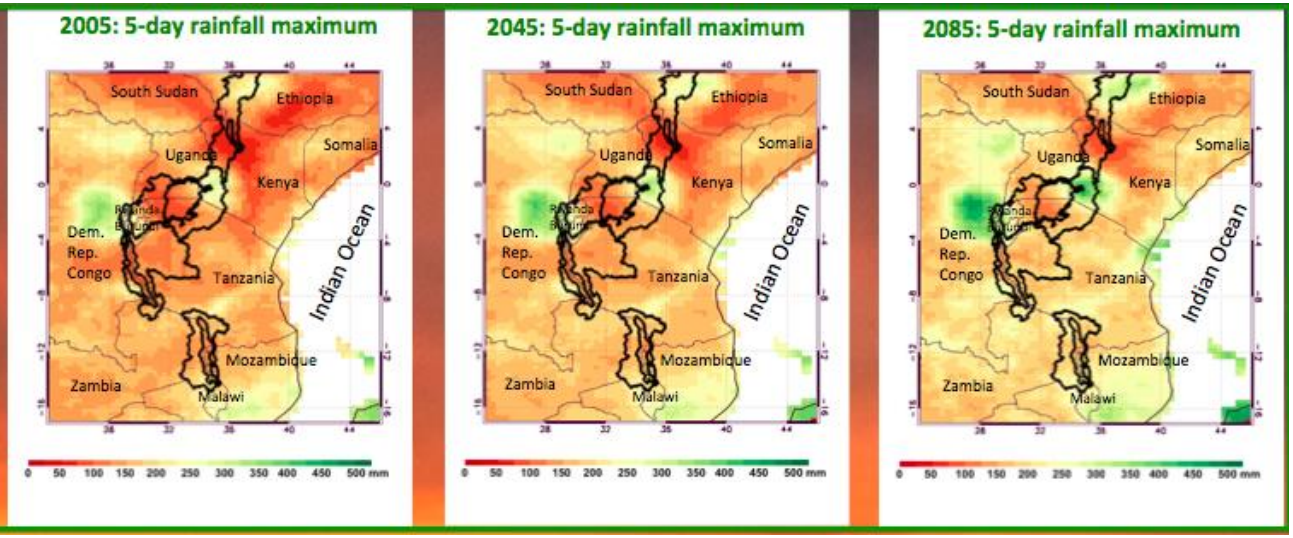
The predictions shown on the poster offer just one representation of possible environmental futures for the region, whereby it is important to recognize that other predictions by CESM and other earth system models may show very different results.

Intense Multiday Rainfall

Maximum total rainfall (mm) expected over a 5-day period in a given year

Left: typical year around 2005
Center: typical year around 2045
Right : typical year around 2085

NOTES: All values exhibit increases over time: there are no areas expected to experience less-intense rainfall. A major new hotspot of intense rainfall emerges in western Kenya and the Winam Gulf on Lake Victoria. The eastern DRC maximum is well represented, but an equally strong maximum over southwest Lake Victoria is not captured by the model

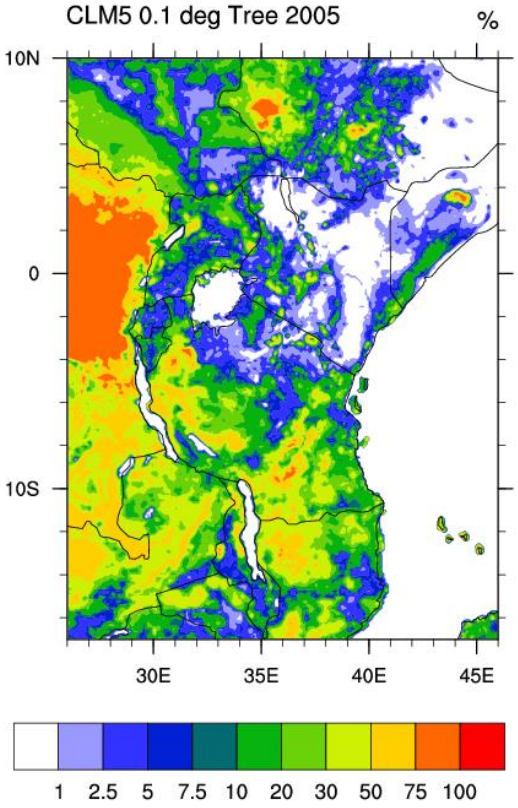


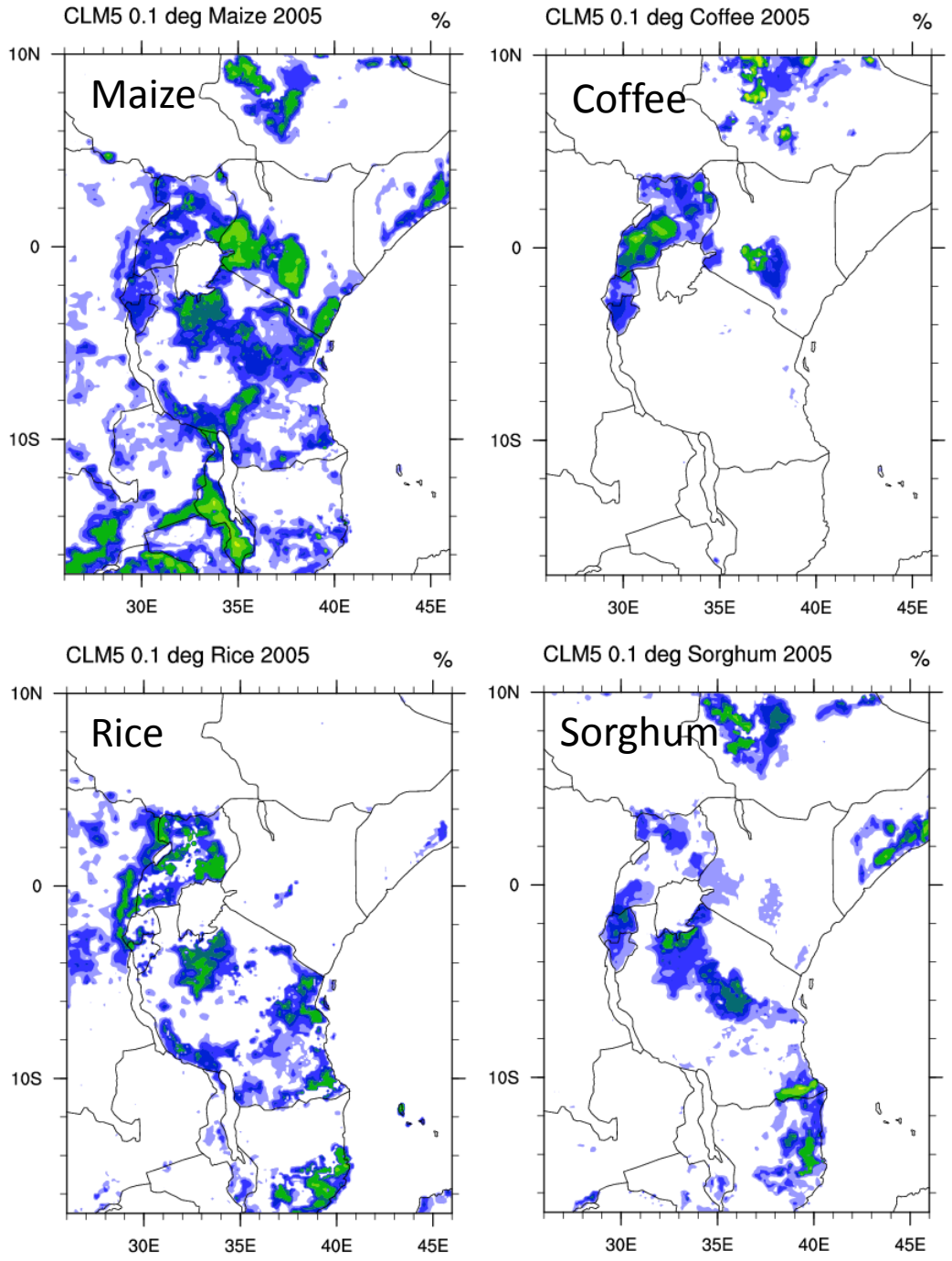
CLM5 CMIP6 – New Land Surface Descriptions

Global Land Model (GLM): annual time series dynamics of agriculture and forests through changes in 12 land units at 27 km spatial resolution.

- Primary Forest
- Secondary Forest
- Crop C3 Annual
- Crop C3 Nitrogen Fixing
- Crop C4 Perennial
- Grazing Rangeland
- Primary Non Forest
- Secondary Non Forest
- Crop C3 Perennial
- Crop C4 Annual
- Grazing Pasture
- Urban

Land management detailed for Crops and Forests through annual crop specific Nitrogen Fertilizer and Irrigation, and five Wood Harvest classes





Percent coverage by crop types in 2005; can be predicted by CESM-CLM for each crop in the future

32 crop types currently considered

Current work - CESM East Africa Rift Valley Modeling Strategy

Understand how Natural and Human Systems have been, or potentially will be, impacted by:

1. **Climate, through changes in:**
   - **Temperature** that impacts vegetation directly through photosynthesis responses, and agriculture through flowering and grain fill, as well as people through heat stress and disease.
   - **Precipitation** that impacts surface hydrology and through that vegetation and agriculture through water availability, and streams and and lakes through changes in runoff.
   - **Relative humidity and wind speed** that impact potential evaporation, the vapor pressure deficit response of vegetation, and fire ignition, intensity and spread.

2. **Atmospheric CO_2 concentration through changes in:**
   - **Photosynthesis** through carbon availability, with higher CO_2 resulting in higher productivity.
   - **Water use efficiency**, with less water loss for the same carbon uptake.

Current work - CESM East Africa Rift Valley Modeling Strategy

3. Land Cover Change:

- **Deforestation** for agricultural expansion of crops and pastures.
- **Wood harvest** for timber production along with other forest disturbance.
- **Conservation and afforestation** for carbon storage and biodiversity protection.
- **Biofuel production** from forests and crops.

4. Land Use Management:

- **Changes in crop production** resulting from cropping area, fertilizer application, irrigation use and crop selection.
- **Changes in carbon storage** in response to crop practices.
- **Changes in water availability** in streams and lakes through irrigation withdrawal and water management.

East African Rift Valley Shared Socioeconomic Selection

Table 1. Summary of assumptions about demographic factors for five SSPs. Country groupings for factors affecting population growth outcomes (fertility, mortality, migration) are made according to current fertility and income conditions [17], while groupings for urbanization assumptions are made according to current income alone [18].

	SSP1 Sustainability	SSP2 Middle of the road	SSP3 Regional rivalry	SSP4 Inequality	SSP5 Fossil-fueled development
Population Growth					
High fertility	Low	Medium	High	High	Low
Other low fertility	Low	Medium	High	Medium low	Low
Rich low fertility	Medium	Medium	Low	Medium low	High
Urbanization level					
High income	Fast	Central	Slow	Central	Fast
Medium income	Fast	Central	Slow	Fast	Fast
Low income	Fast	Central	Slow	Fast	Fast
Spatial pattern	Concentrated	Historical patterns	Mixed	Mixed	Sprawl

East African Rift Valley Shared Socioeconomic Pathways (SSP)

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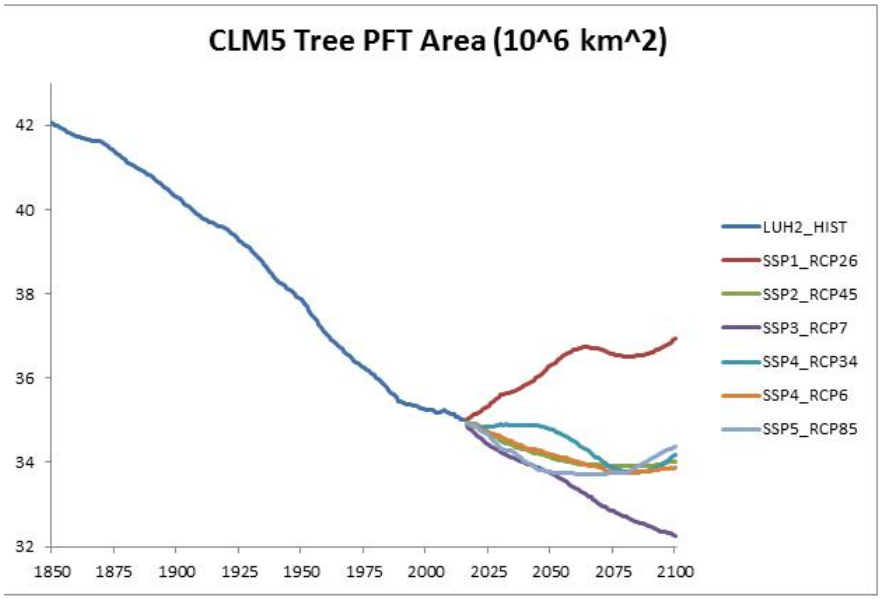
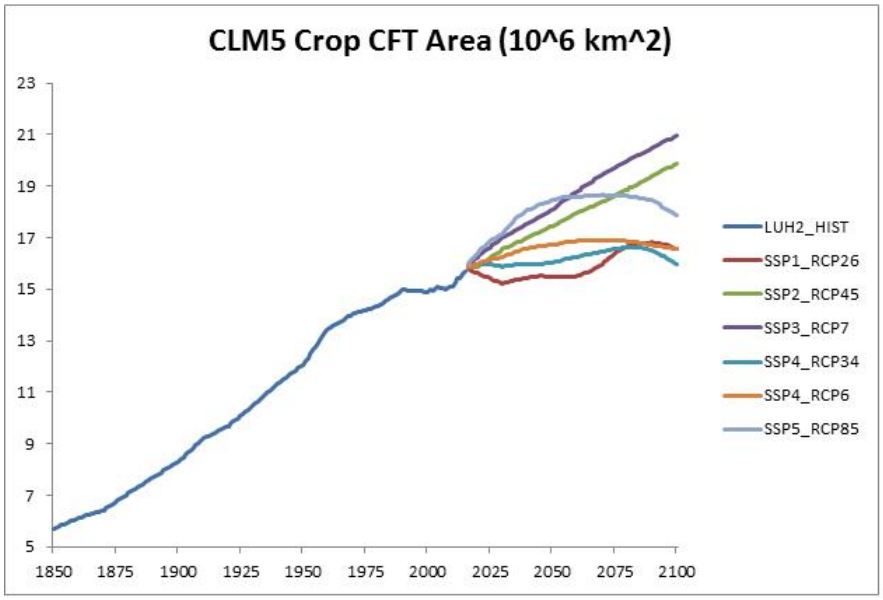
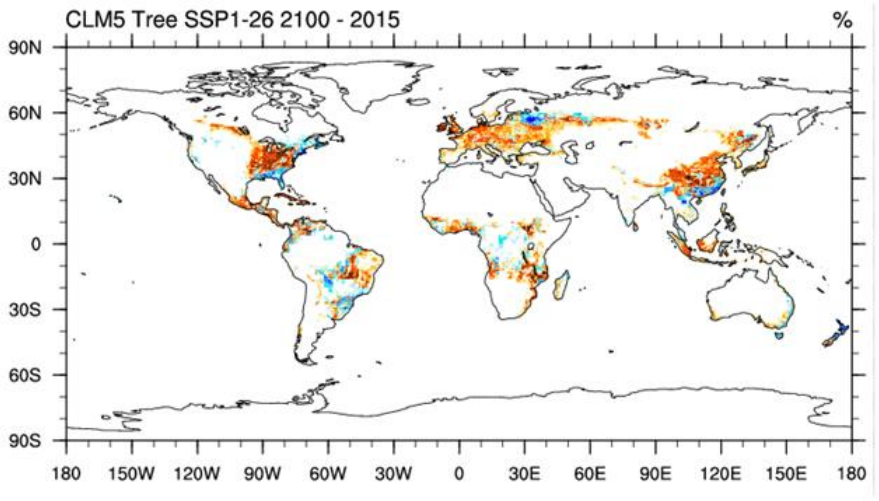
SSP1
Path to sustainability:
"optimistic"

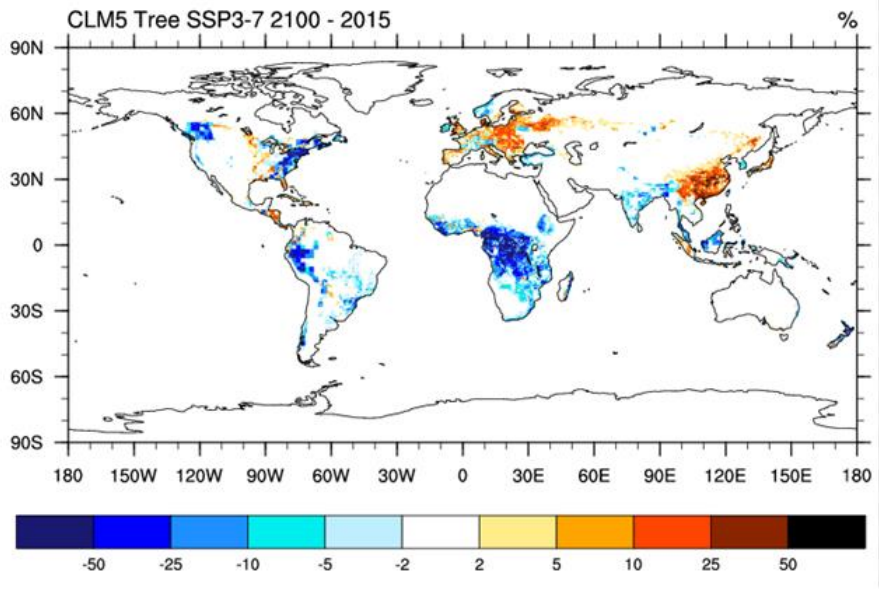
SSP3
Business as usual
"pessimistic"

SSP1 & SSP3– Tree cover change

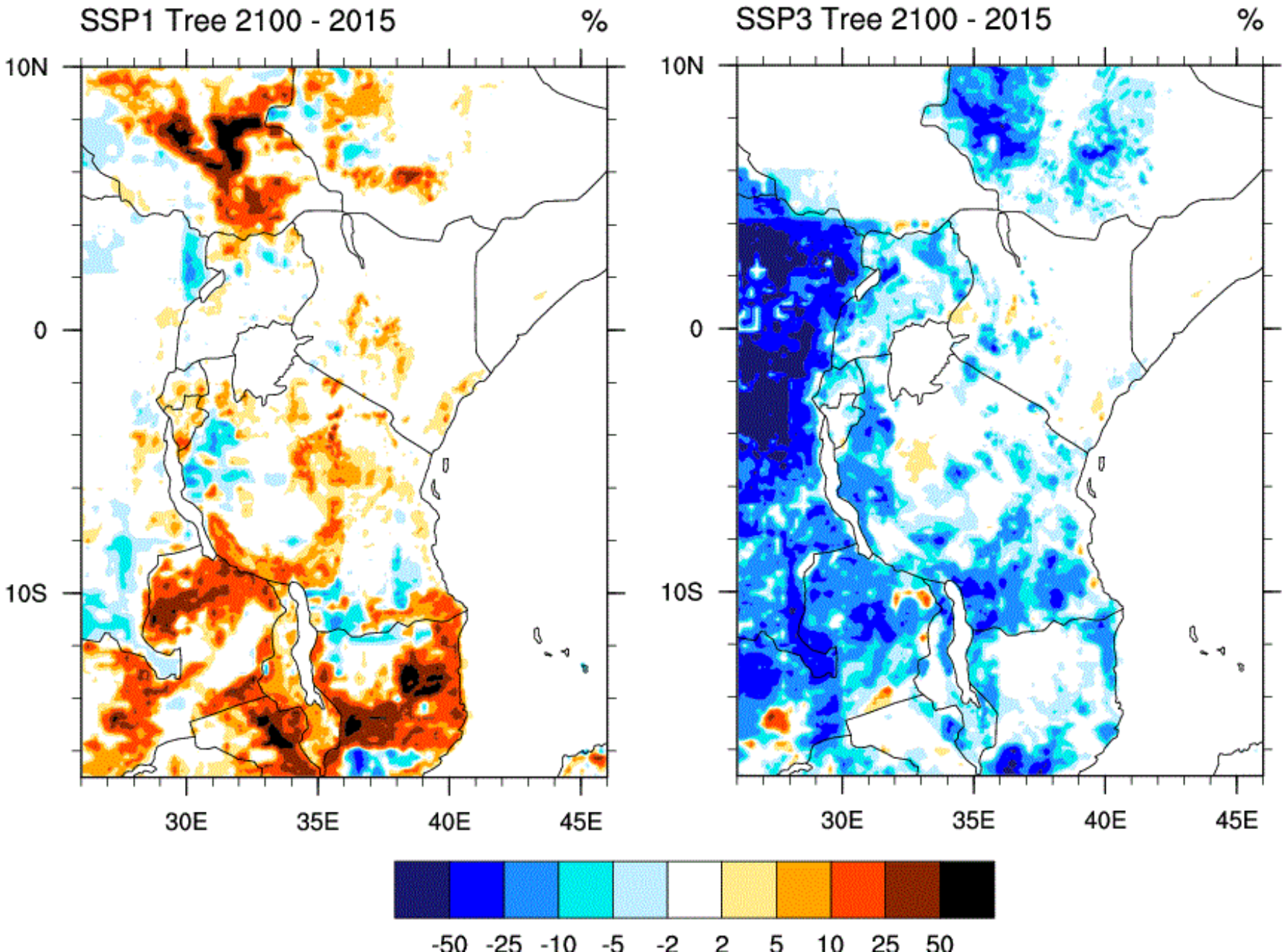








Great Lakes Region SSP1 & SSP3– Tree cover change



Current work - Creating a diverse set of environmental predictions

Compare how Natural and Managed systems respond:

- under changing CO_2 and climate
- with and without Land Use and Land Cover Change
- for the Historical and two different Future Climate Scenarios

Specific CESM model runs:

1. 1850 spin up of carbon cycle at 0.1 degrees from global 1850 simulation.

2a. Historical 1850 - 2015 simulation with ramping CO_2 and climate.
2b. Historical 1850 - 2015 simulation with no Land Use Land Cover Change

3a. SSP1 Land Use with RCP4.5 atmospheric conditions 2016 - 2100
3b. SSP3 Land Use with RCP4.5 atmospheric conditions 2016 - 2100
3c. No Land Use (2015 vegetation distribution) with RCP4.5 atm 2016 - 2100

4a. SSP1 Land Use with RCP8.5 atmospheric conditions 2016 - 2100
4b. SSP3 Land Use with RCP8.5 atmospheric conditions 2016 - 2100
4c. No Land User (2015 veg no wood harvest) with RCP 8.5 atm 2016 – 2100.

These outputs will be available to all, can be used to inform decision making