

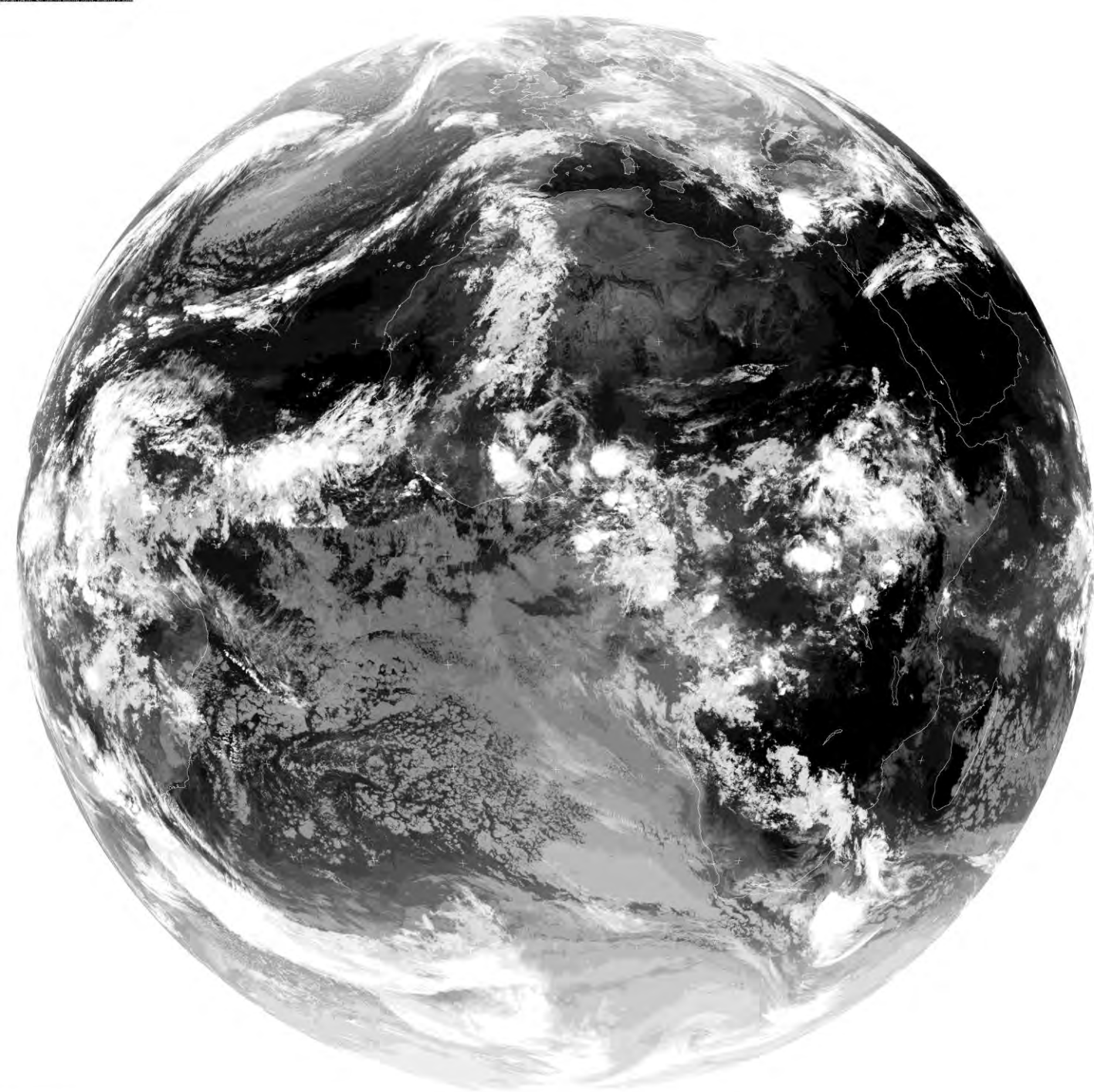
# The global change challenge: a regional perspective

Francois Engelbrecht and Emma Archer van Garderen

CSIR Natural Resources and the Environment

Climate Studies, Modelling and Environmental Health





How will global change impact on the southern African region?

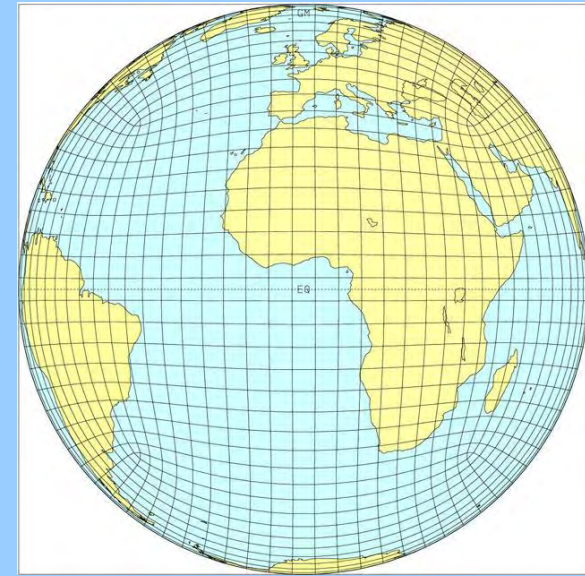
How vulnerable is southern Africa to regional climate change?

MSG IR image;  
9.8-11.8  $\mu\text{m}$ ;  
2012-10-08 20:00  
SAST

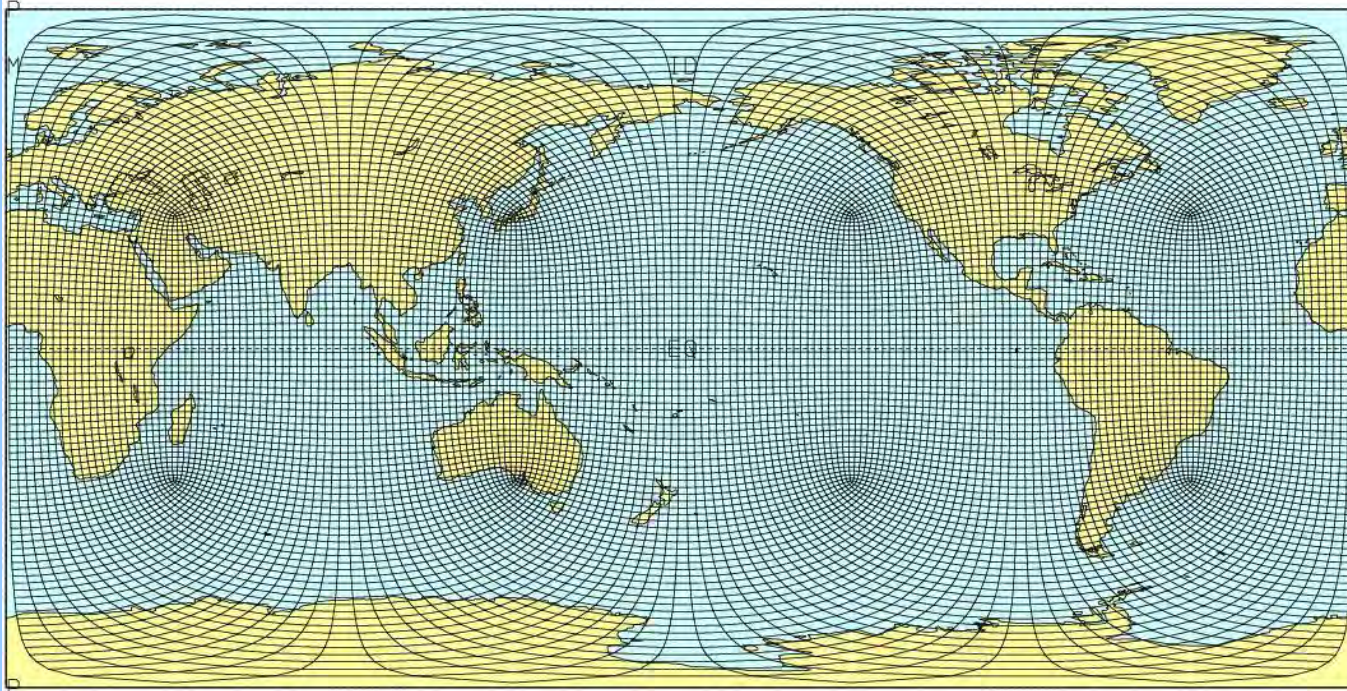
**CSIR**  
*our future through science*

# Climate Modelling at the CSIR NRE

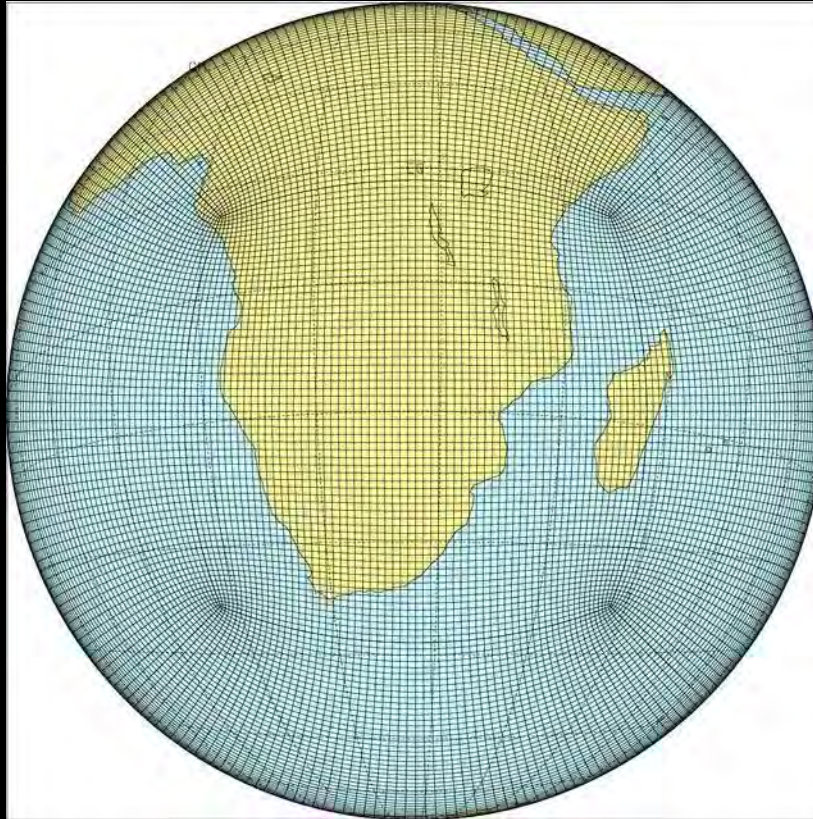
- NWP and RCM capacity build around the conformal-cubic atmospheric model (CCAM) of the CSIRO
- A cube-based global model; semi-Lagrangian semi-implicit solution of the primitive equations
- Includes a wide range of physical parameterizations
- Developed by the CSIRO Marine and Atmospheric Research (McGregor, 2005)
- Runs in quasi-uniform or in stretched grid mode
- Multi-scale climate modelling.



Quasi-uniform C48 grid with resolution about 210 km



# Regional climate modelling over Africa using CCAM



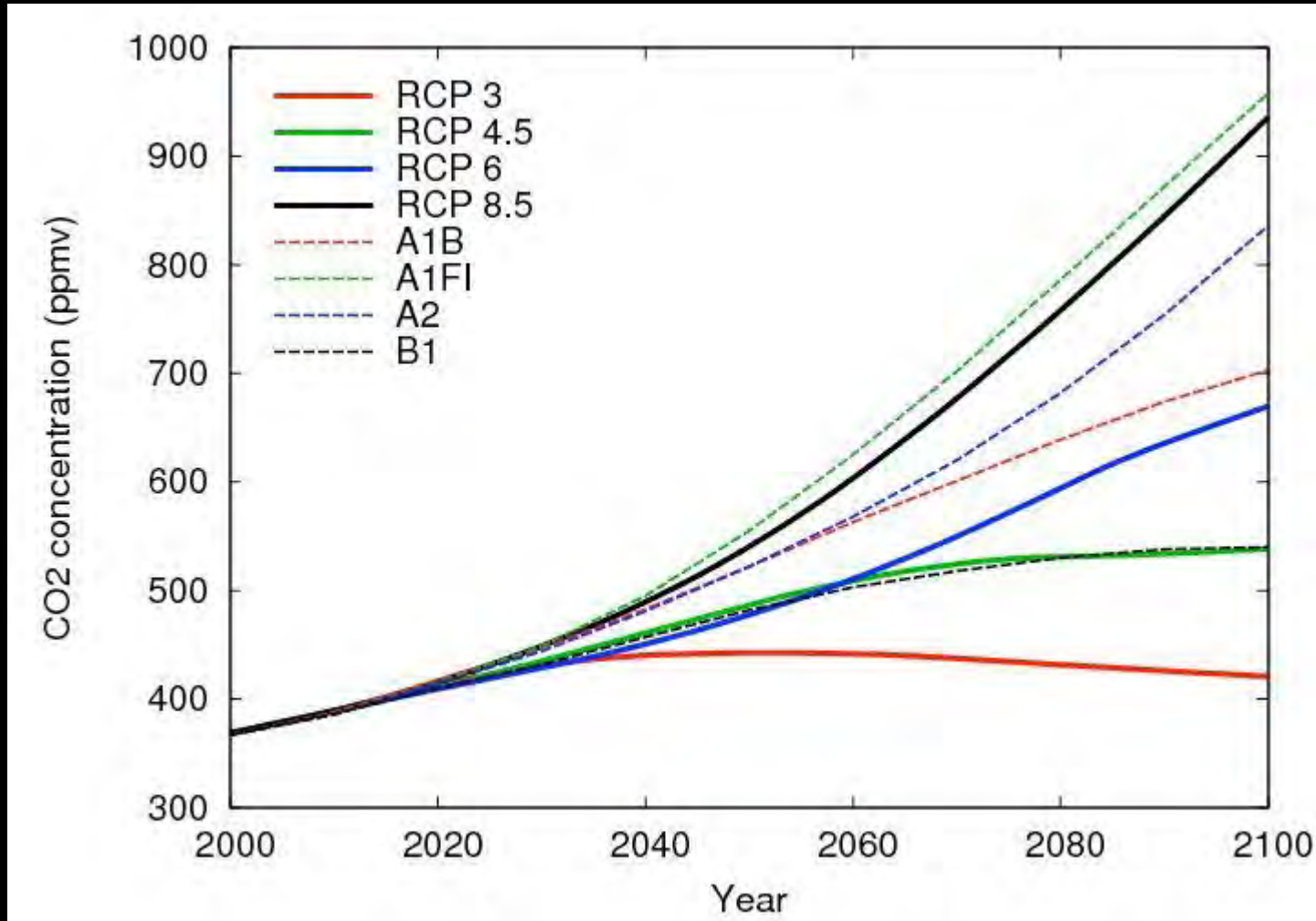
C64 stretched-grid with resolution about 60 km over southern Africa

CCAM applied in stretched-grid mode

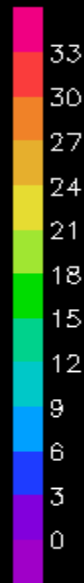
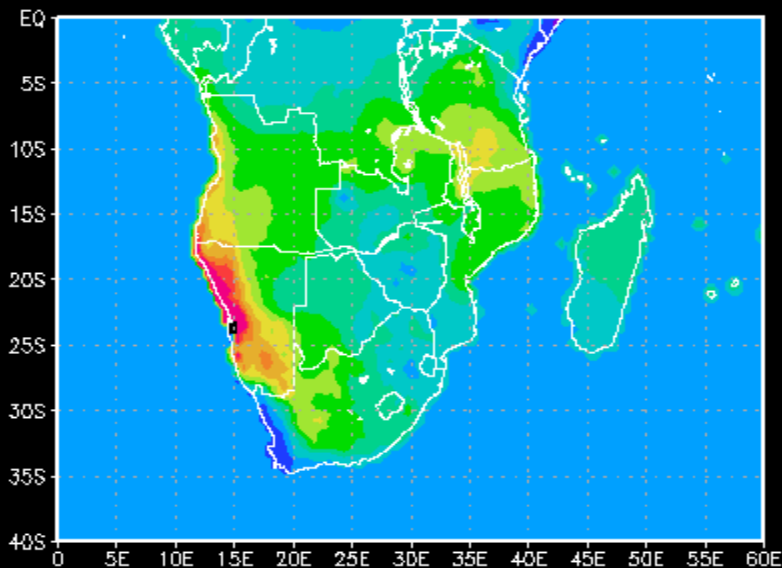
Modest stretching provides a resolution of about 60 km over southern Africa; decreases to about 4 degrees in the far-field

Options for spectral nudging, gridpoint nudging or no nudging from the host model (atmospheric fields)

# Emission Scenarios and Representative Concentration Pathways



CRU MAR Rainfall %



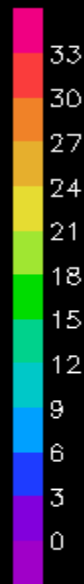
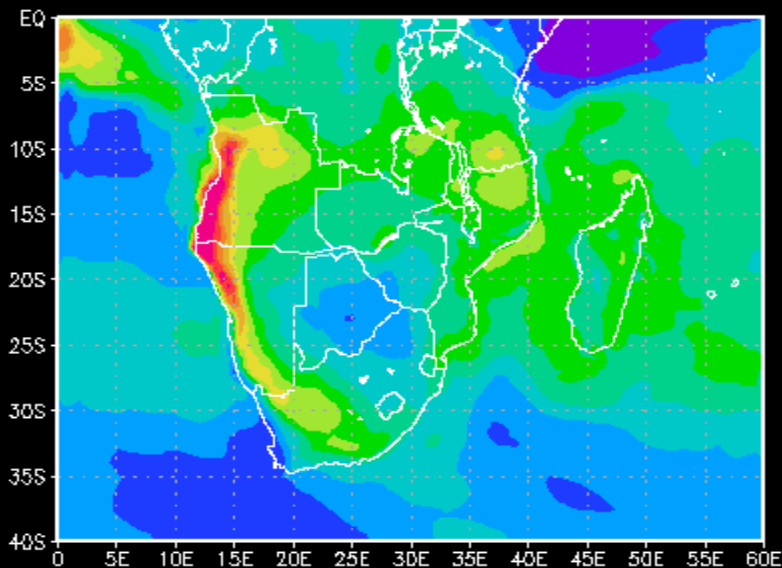
# CCAM applied as regional/global climate model - verification

Climatological means, intra-annual cycle in rainfall and circulation [Engelbrecht et al. (2009) *IJC*; Engelbrecht et al. (2011) *Water SA*]

Closed-low tracks and extreme rainfall events, tropical cyclone landfall [Engelbrecht et al. (2012) *IJC*; Malherbe et al. (2012) *Clim Dynamics*]

Inter-annual variability in AMIP-style runs [Landman et al. (2010); WRC Report; Engelbrecht et al. (2011) *Water SA*]

CCAM MAR RAINFALL %

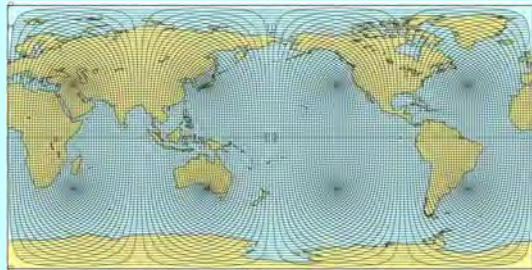


**CSIR**

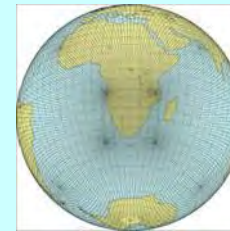
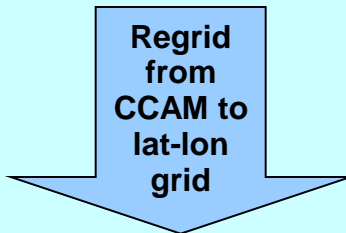
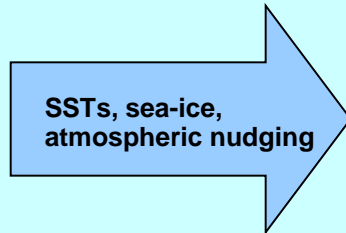
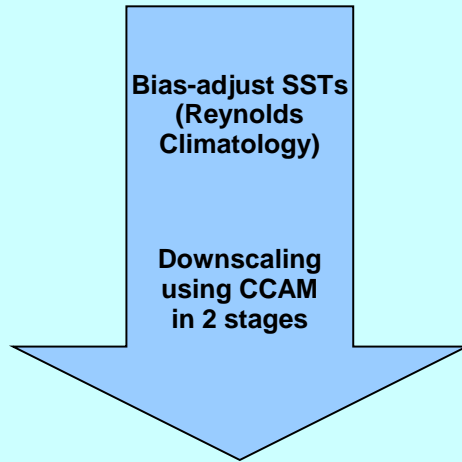
our future through science

# 6 CGCMs (SSTs and sea-ice) of AR4 – A2 SRES; 1961-2100

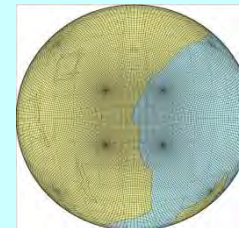
## Regional Climate Modelling Flow of Events: new CSIR ensemble of projections



Global simulations, quasi-uniform resolution (~ 200 km)



Regional stretched-grid simulations (~ 60 km resolution)

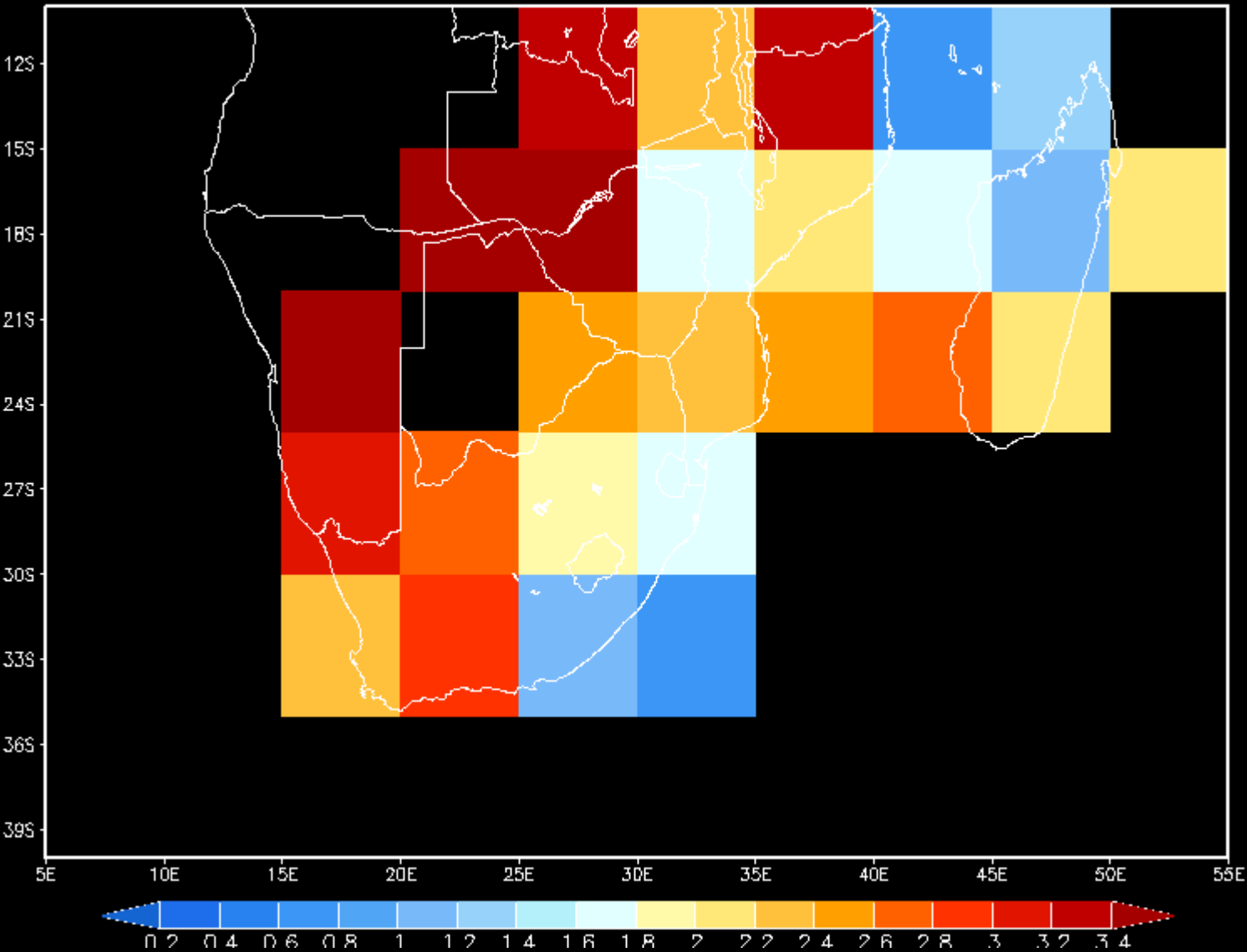


Very high-resolution simulations over areas of interest (~ 8 km resolution).

Climate Dynamics + Application Modelling/Studies

**CSIR**  
**CHPC**

CRUTEMP3v trend annual ave temp 1961–2010



## CRUTEMP3v linear temperature trend 1961- 2010

Strong warming  
has occurred  
over the  
western+central  
parts of southern  
Africa

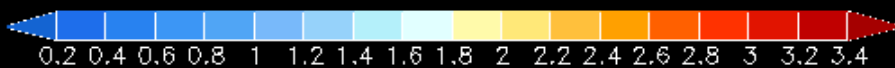
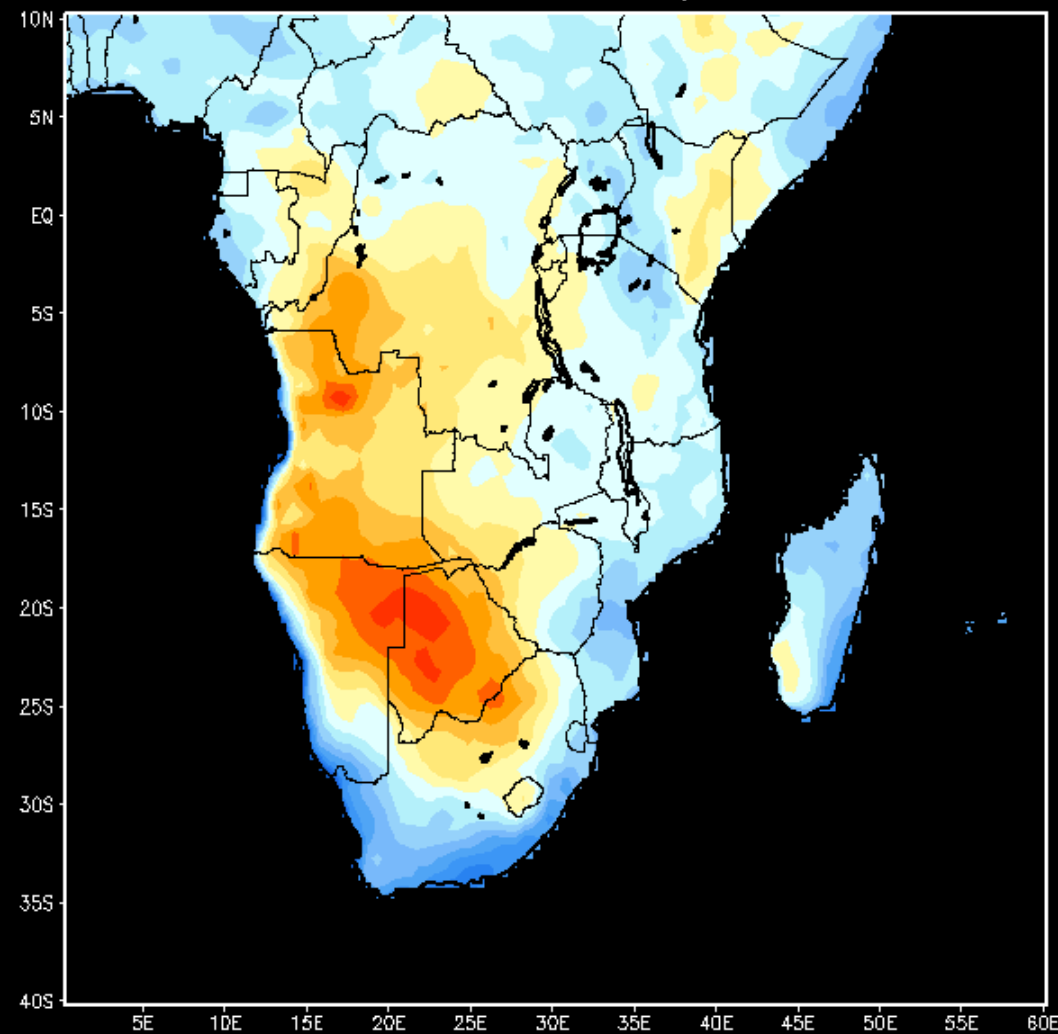
Warming more  
moderate along  
the coastal areas



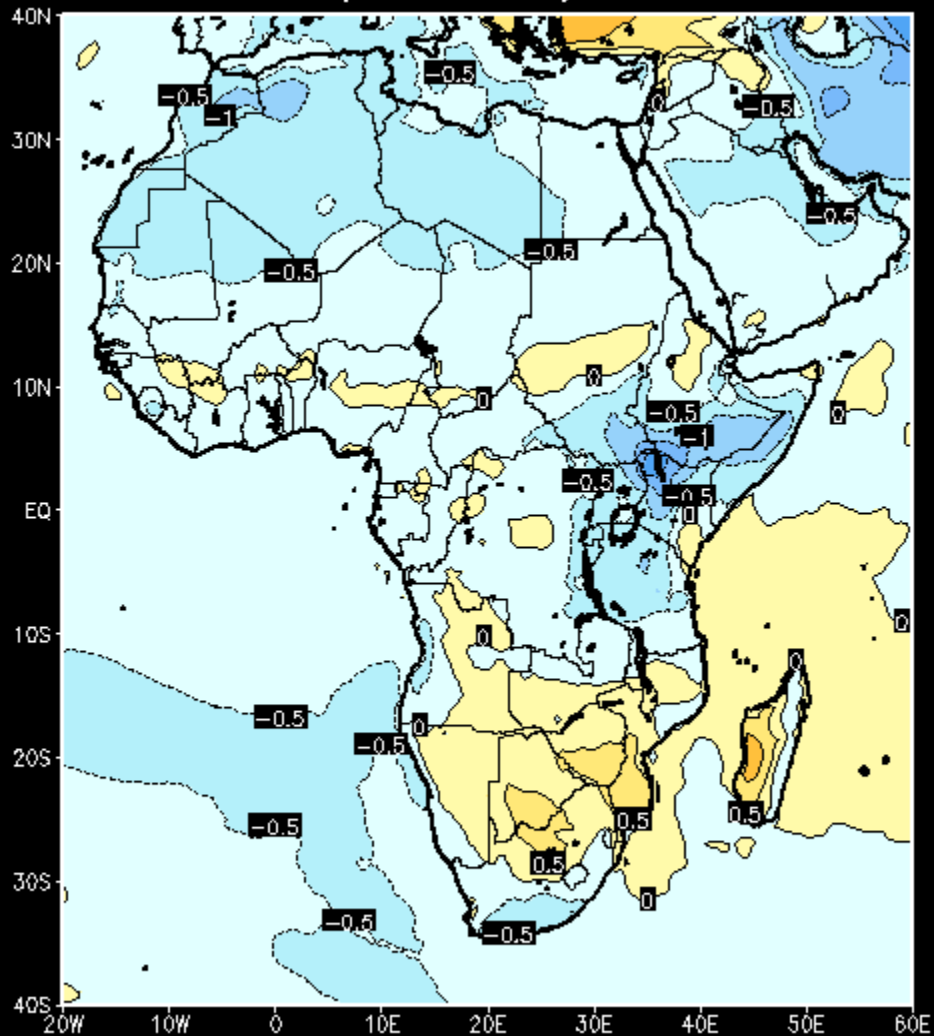
# CCAM-HADCM3 simulated linear temperature trend 1961-2009

Pattern correlation =  
0.574

UKMO trend Ann ave temp 1961-2009

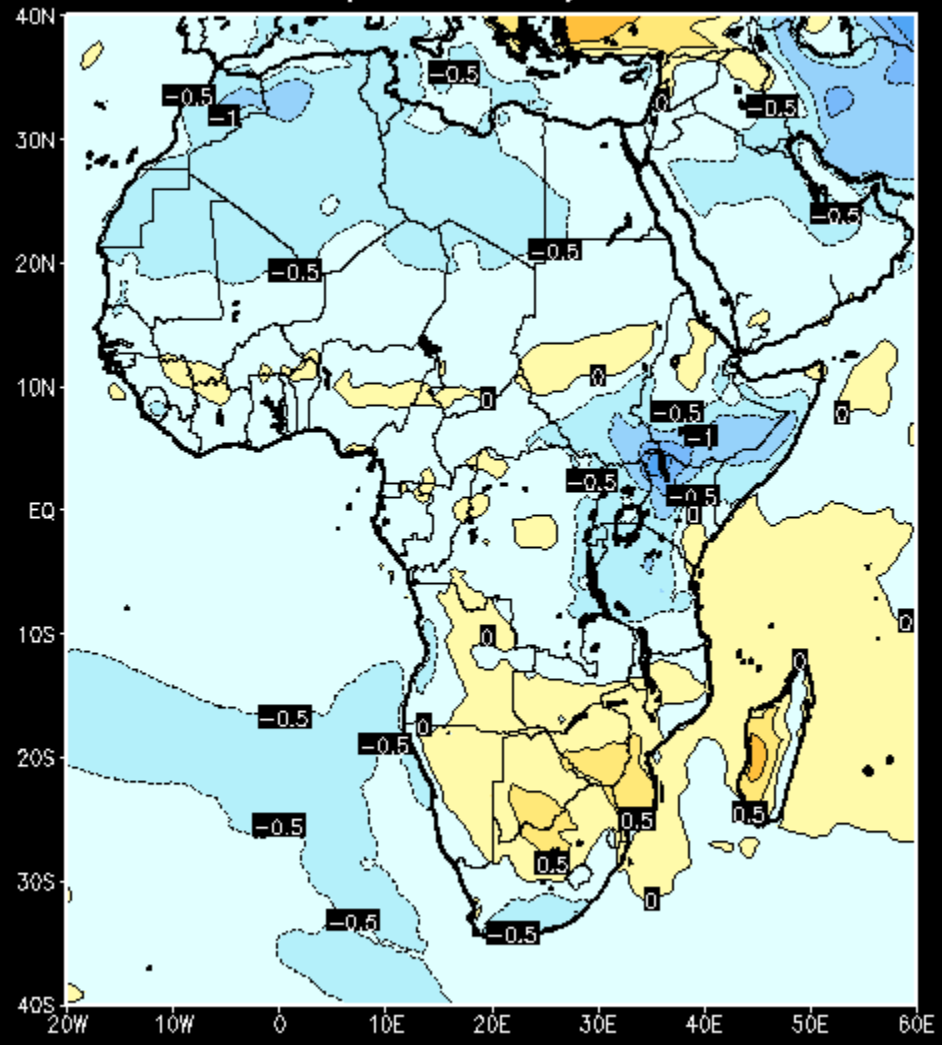


## Temp anomaly 1961

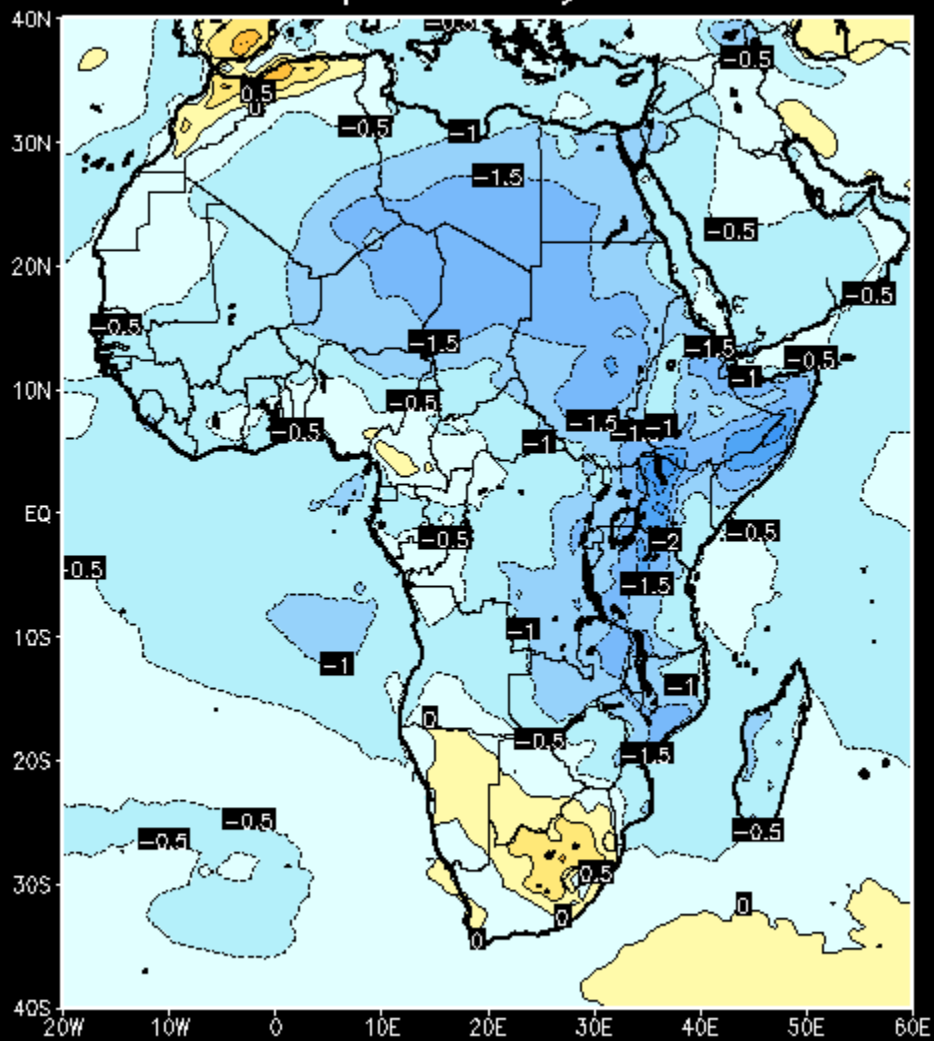


Simulated  
annual  
temperature  
anomalies  
relative to the  
1961-1990  
climatological  
average

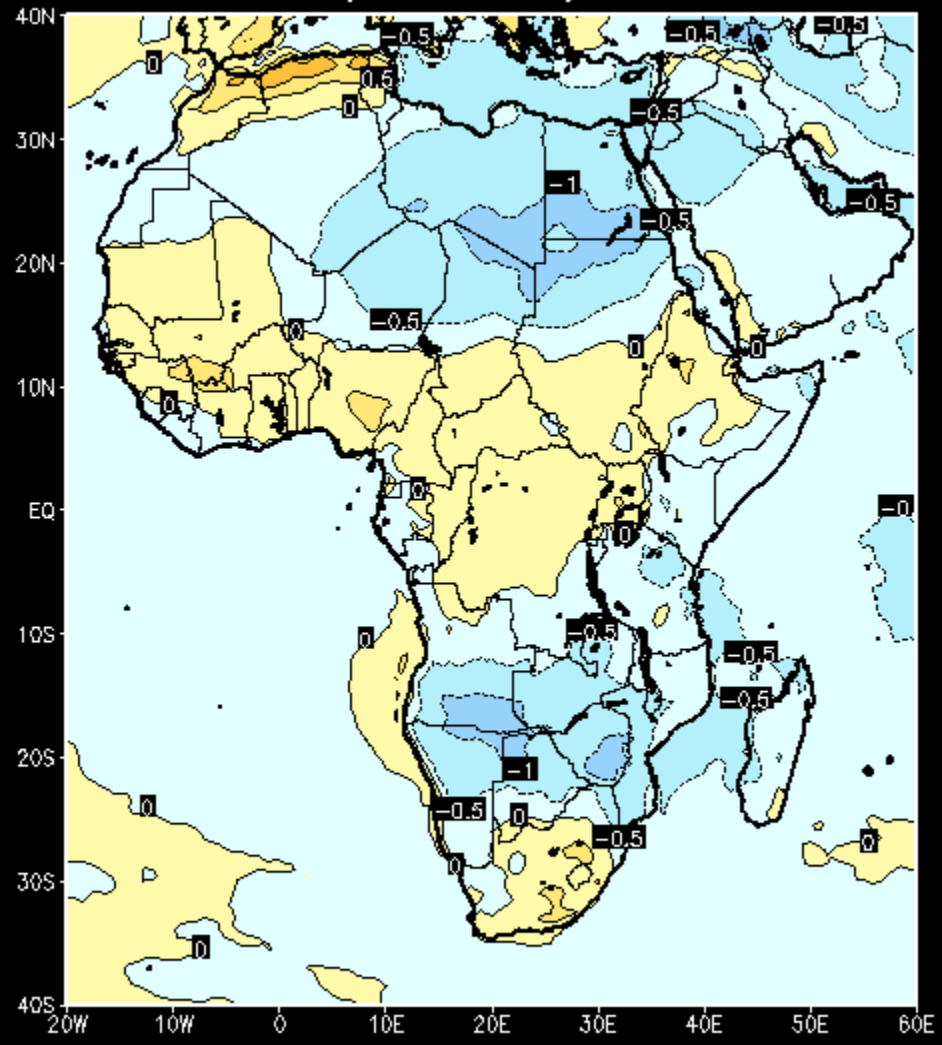
# Temp anomaly 1961



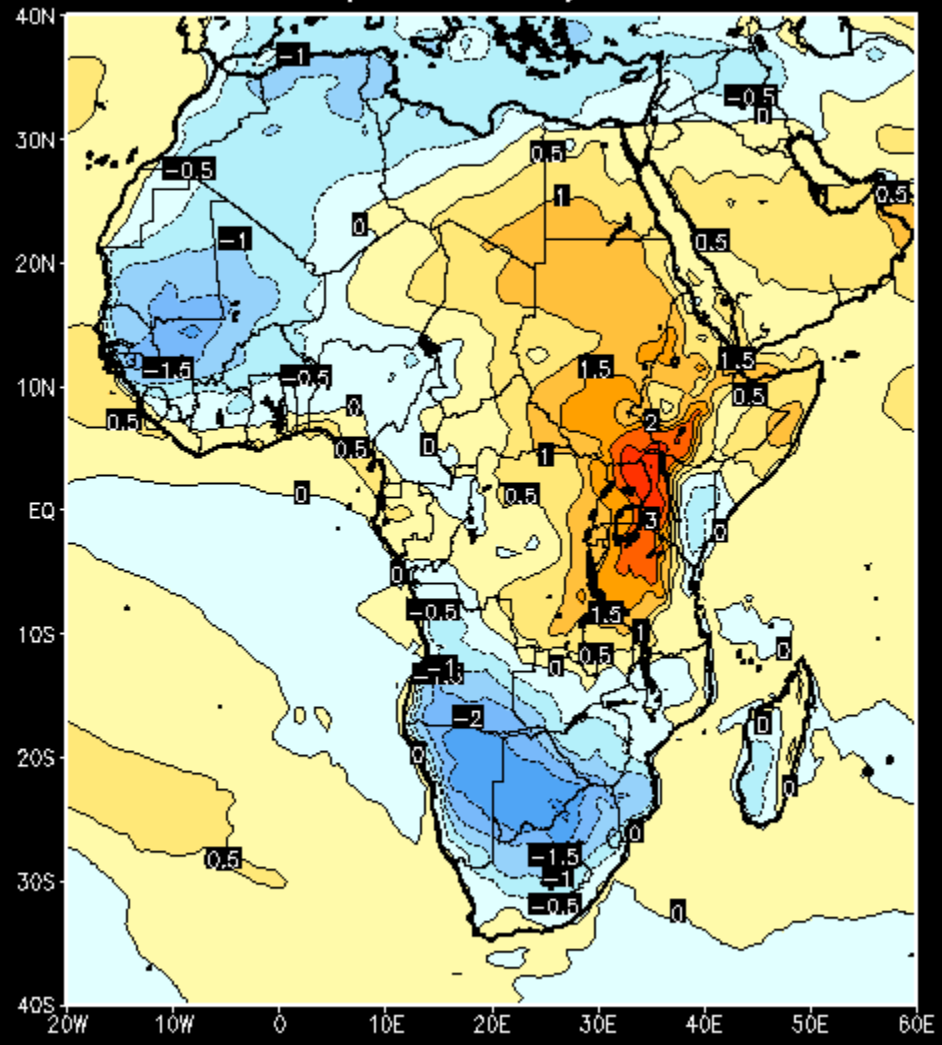
# Temp anomaly 1962



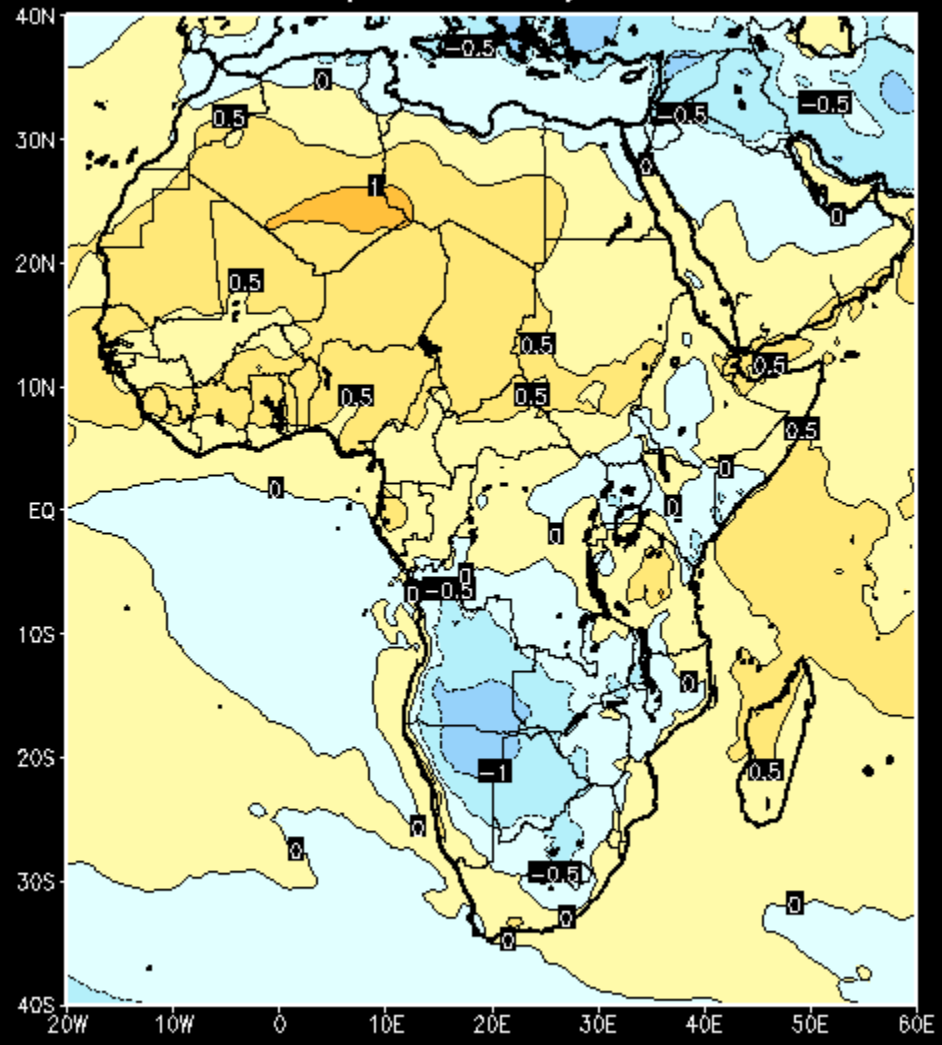
# Temp anomaly 1963



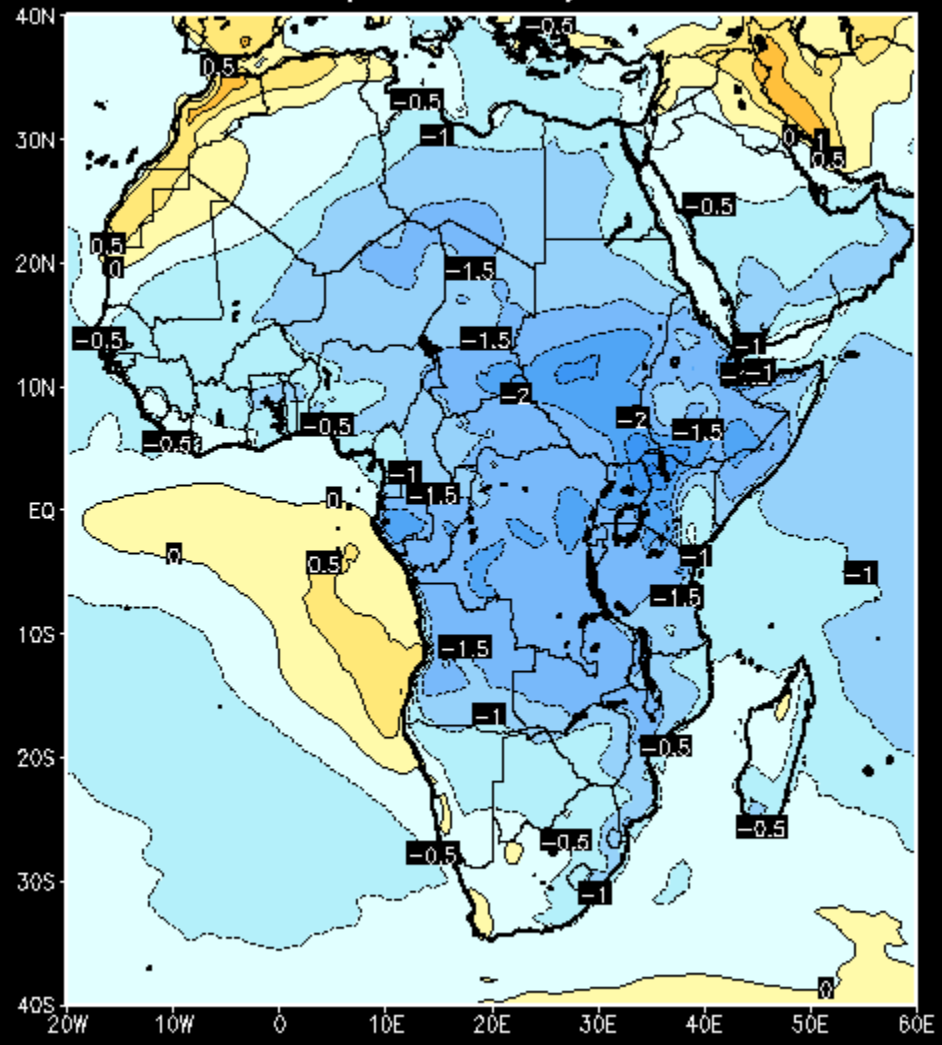
# Temp anomaly 1964



# Temp anomaly 1965

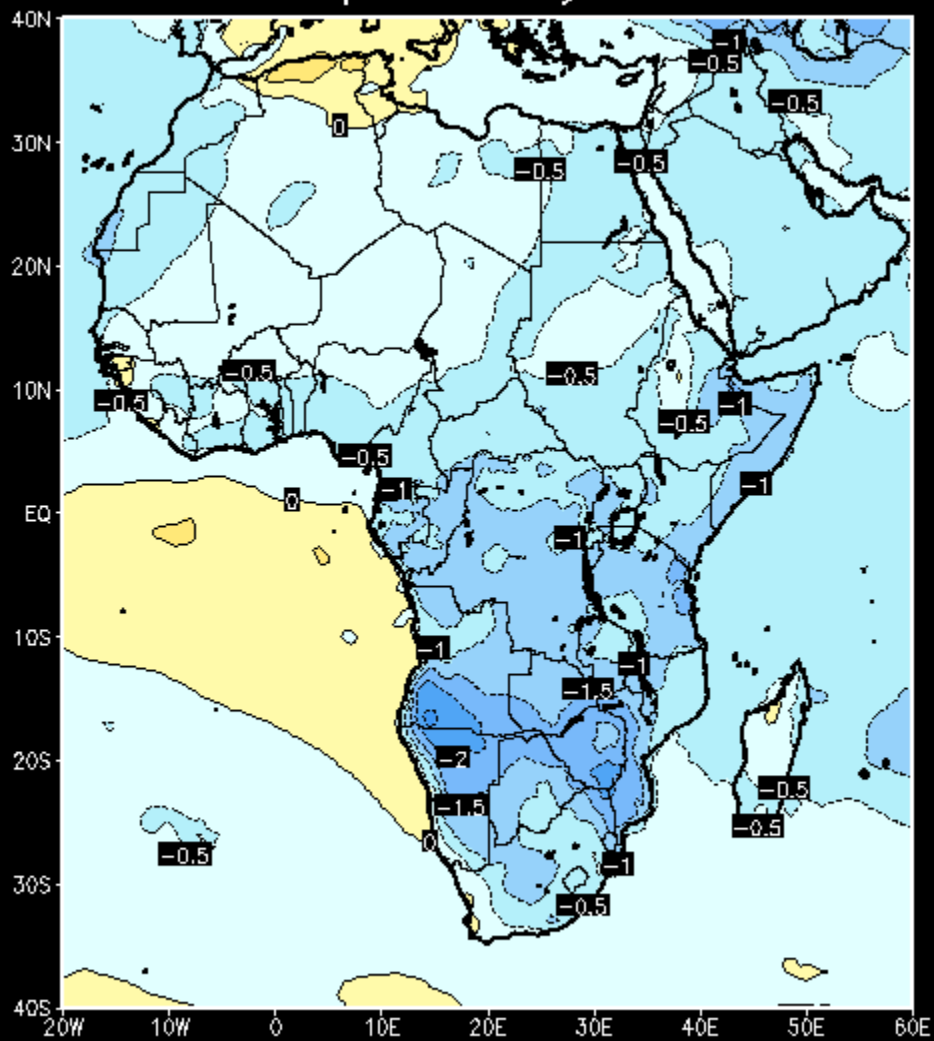


# Temp anomaly 1966

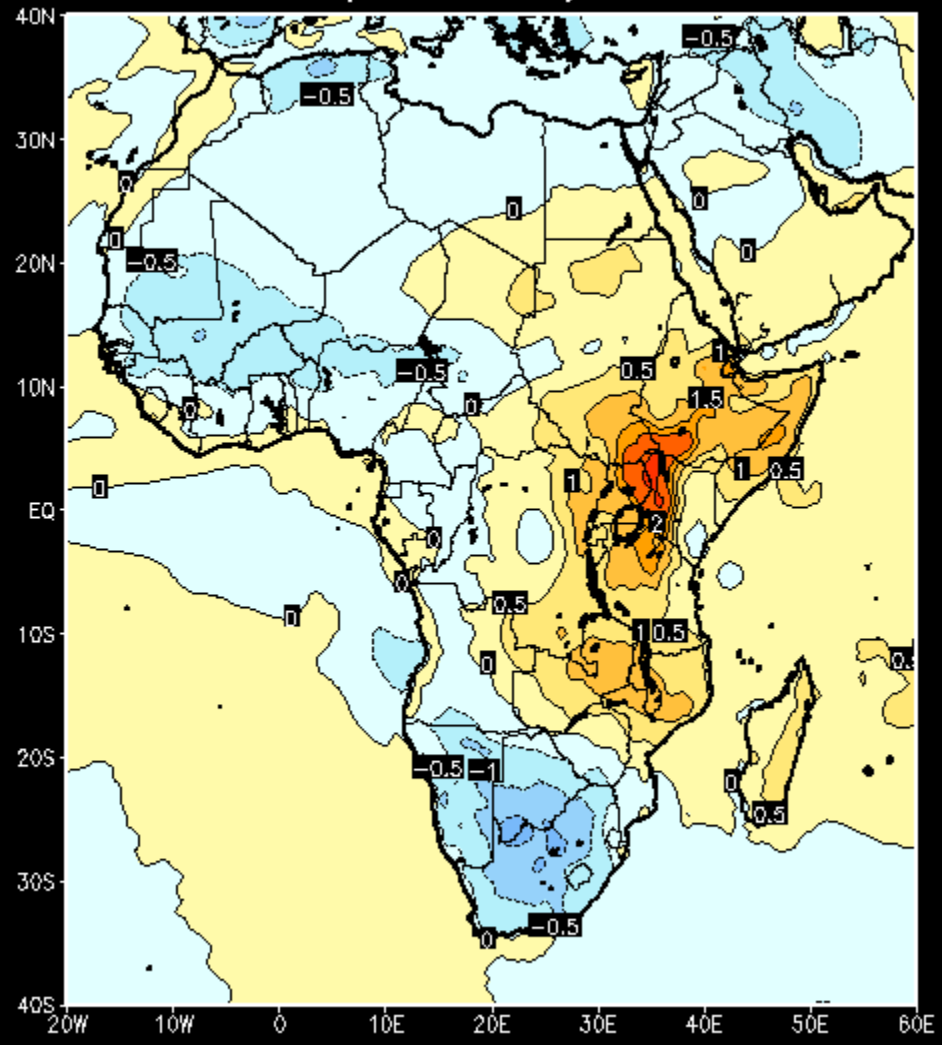




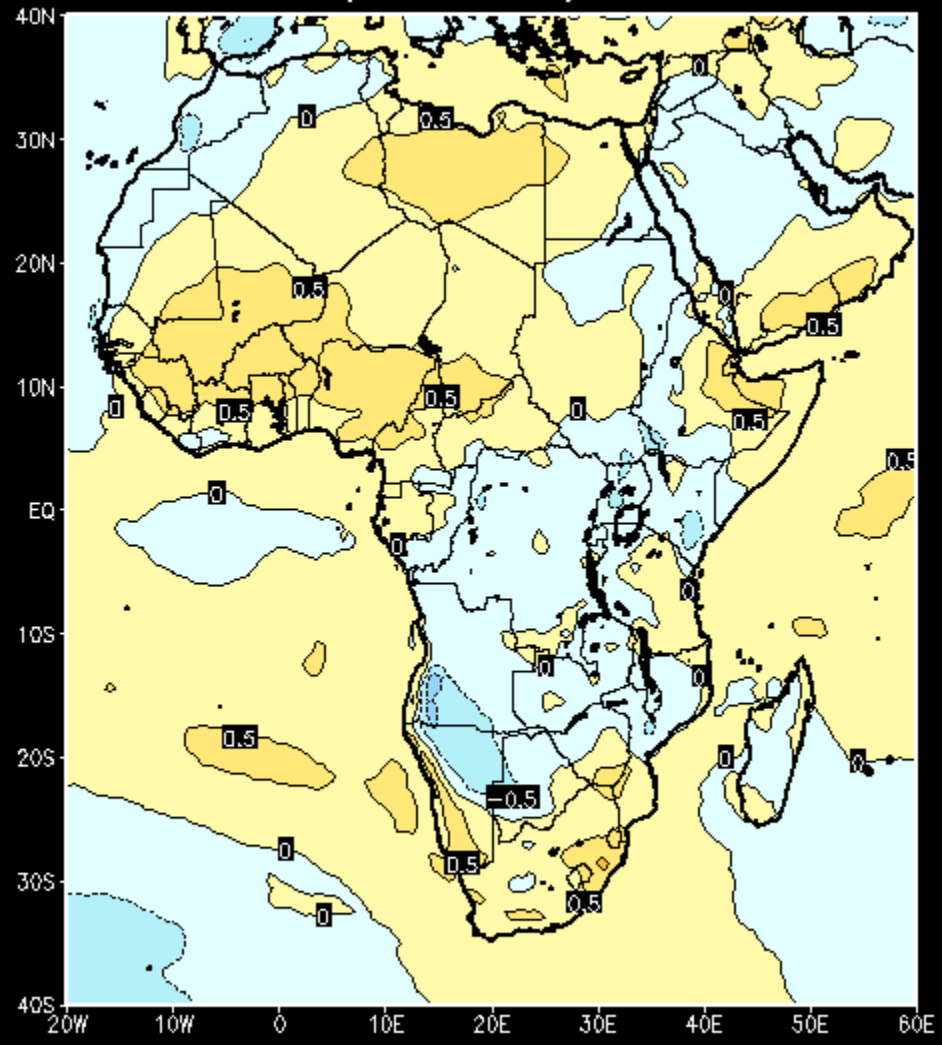
# Temp anomaly 1967



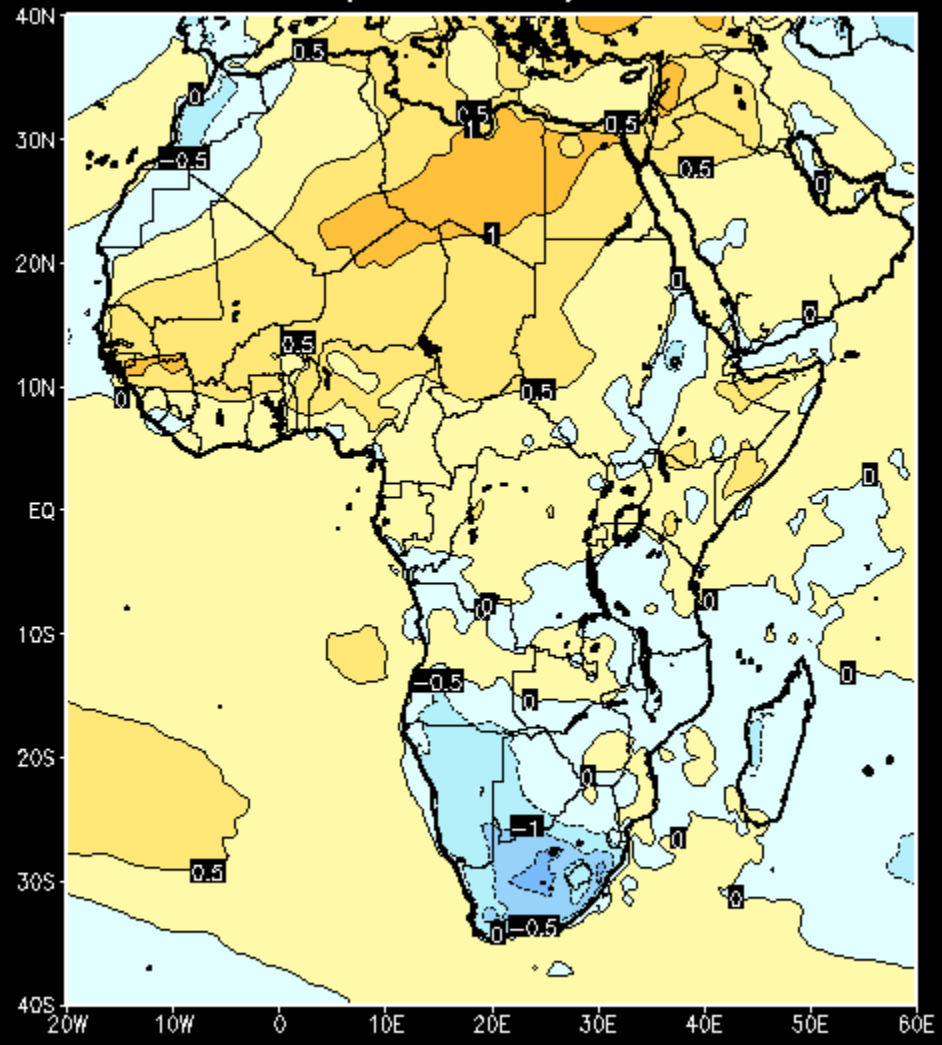
# Temp anomaly 1968



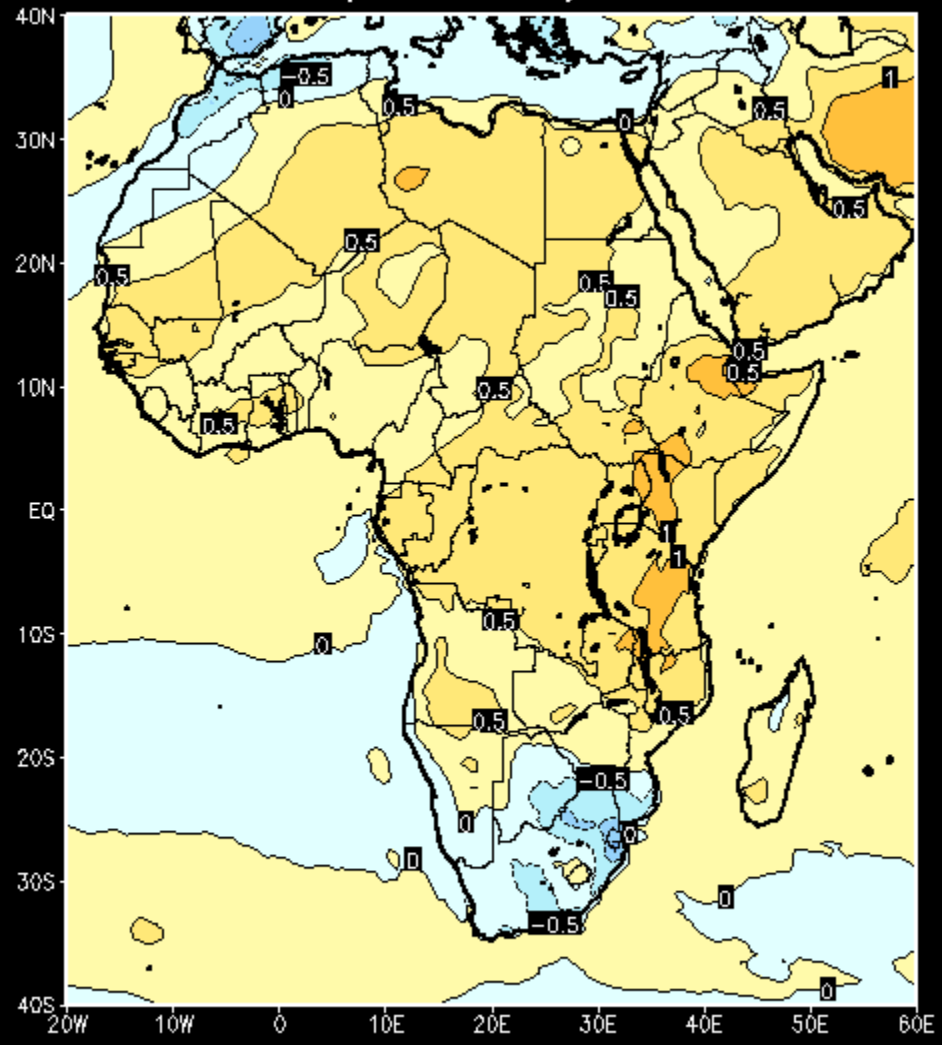
# Temp anomaly 1969



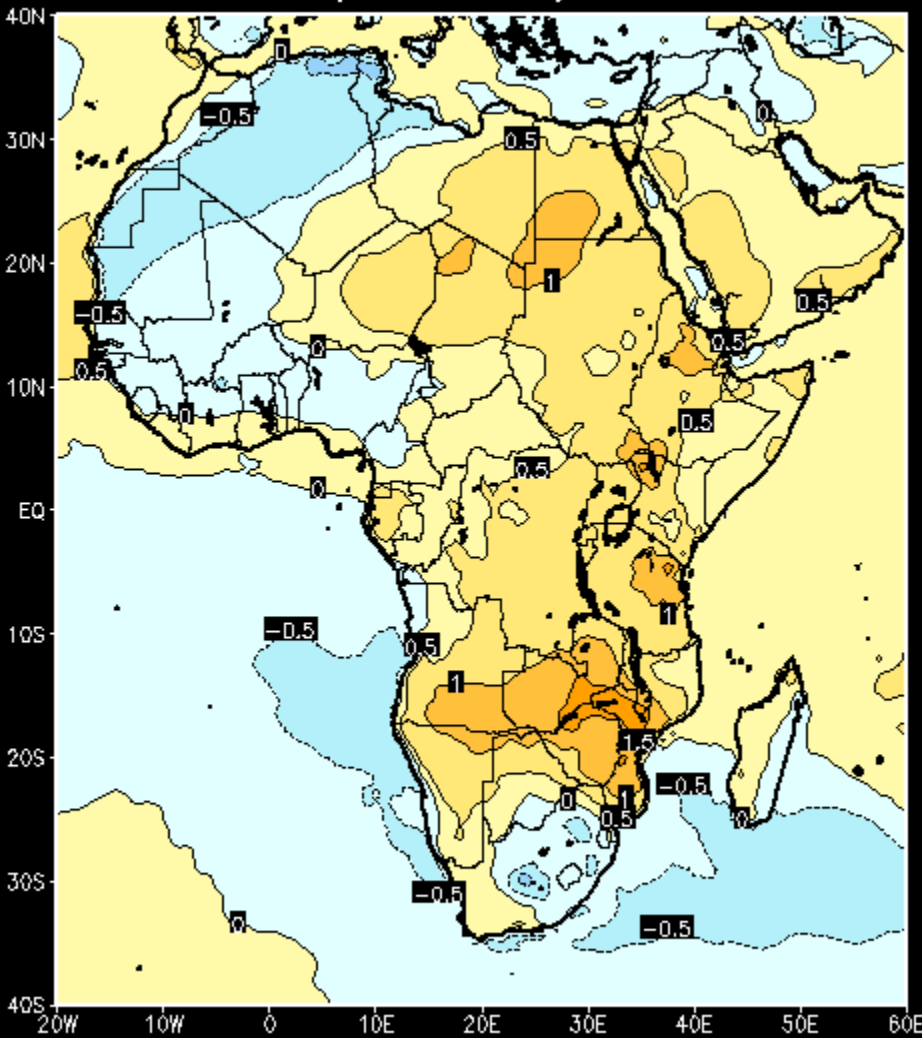
# Temp anomaly 1970



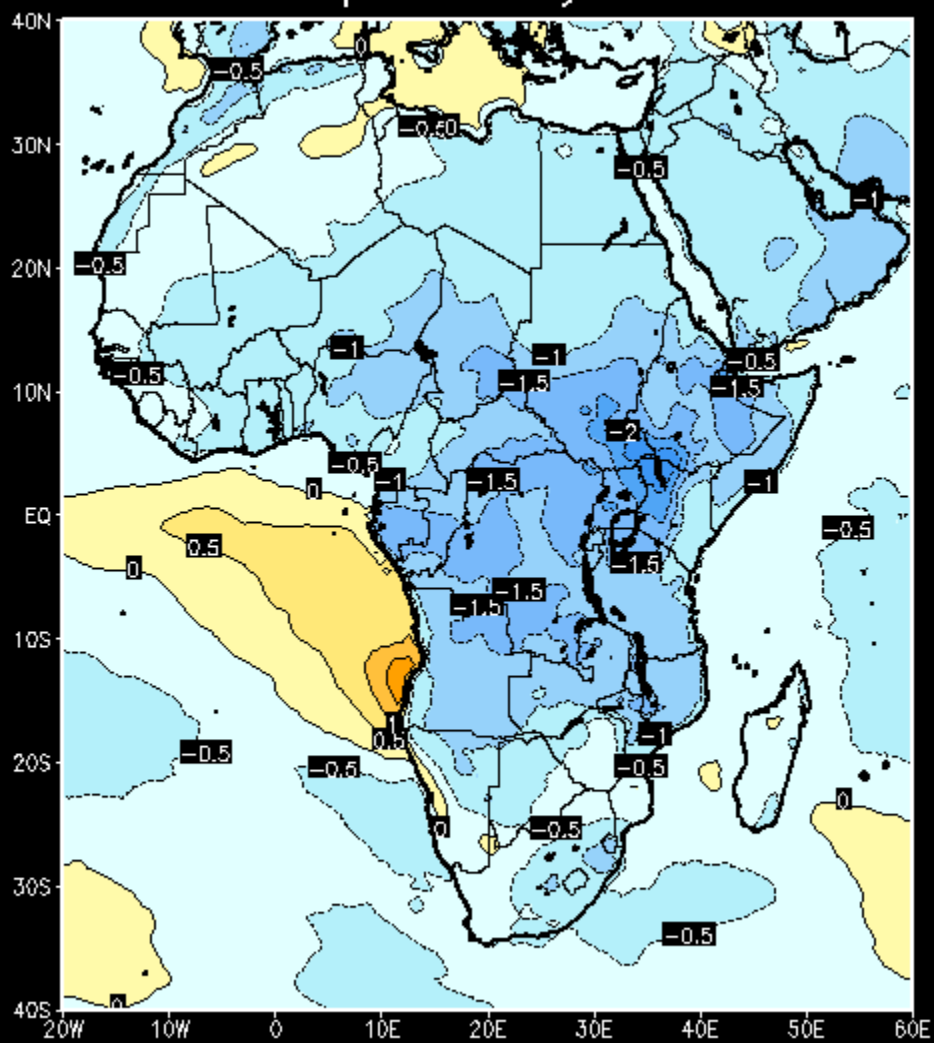
# Temp anomaly 1971



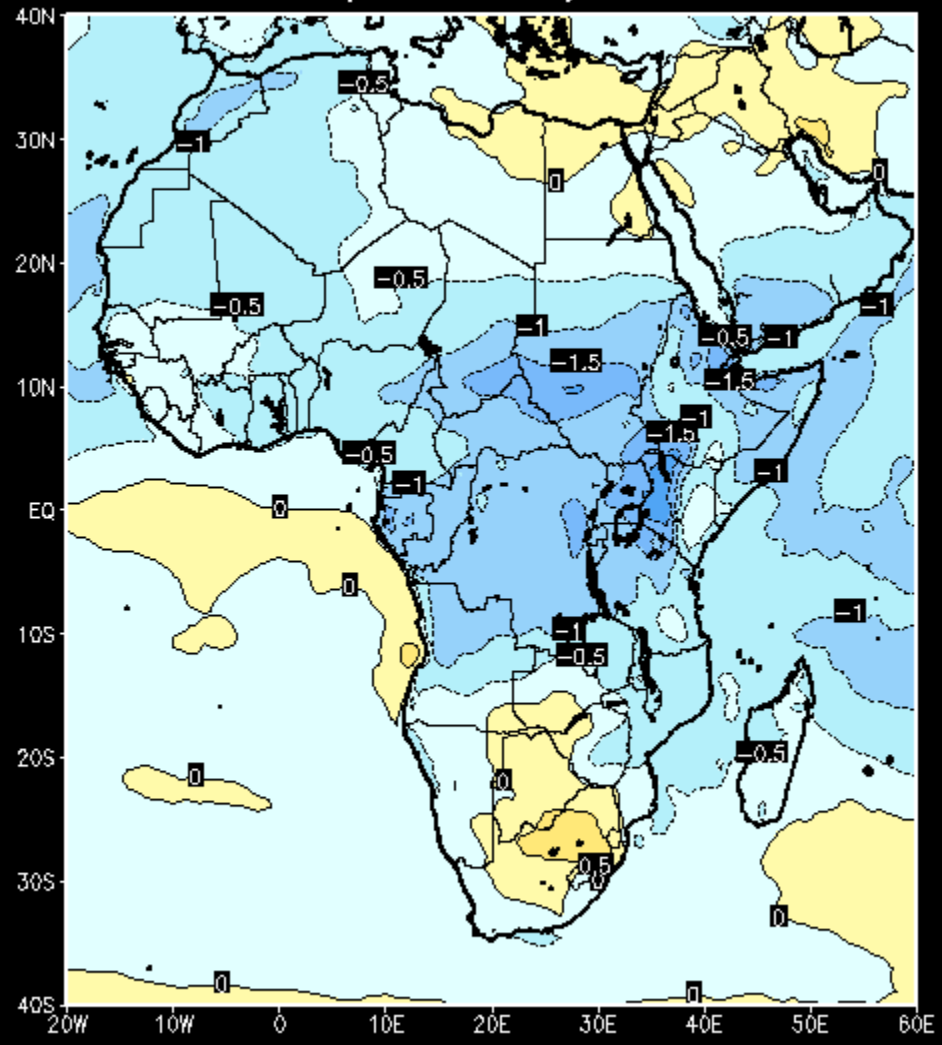
# Temp anomaly 1972



# Temp anomaly 1973

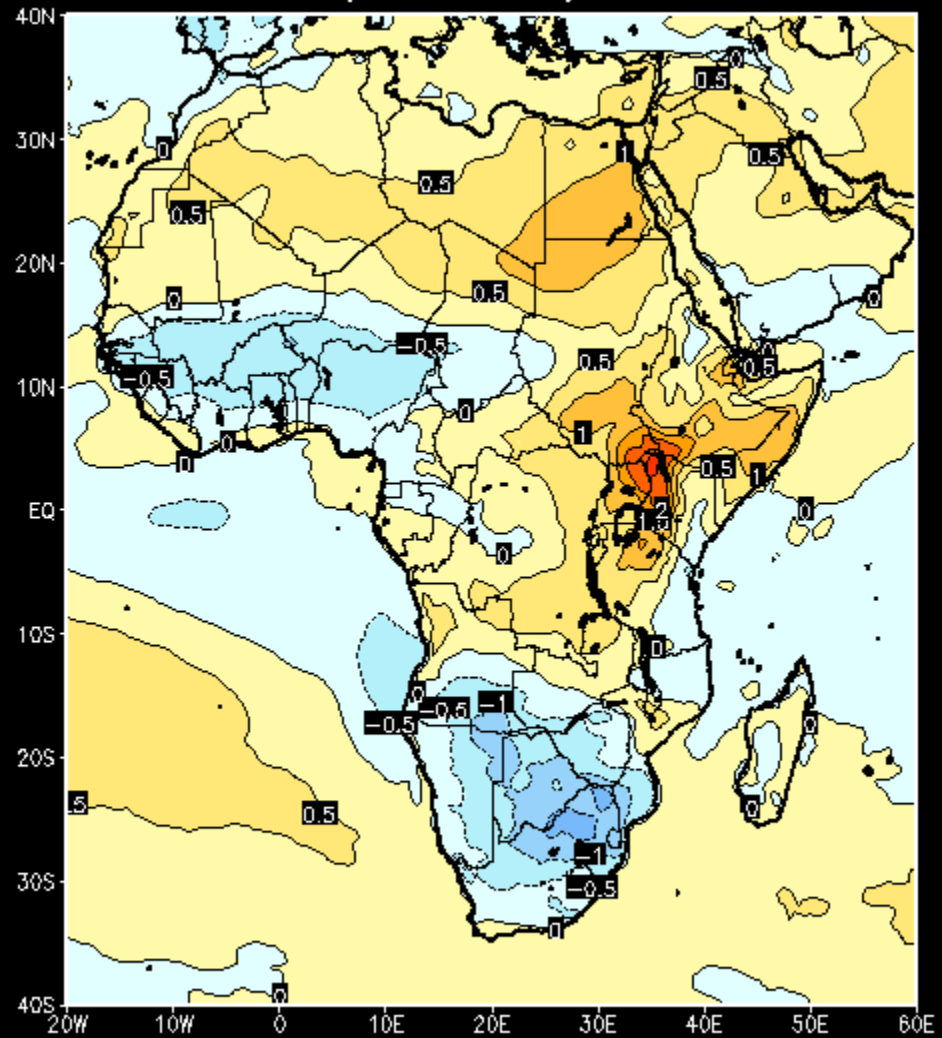


# Temp anomaly 1974

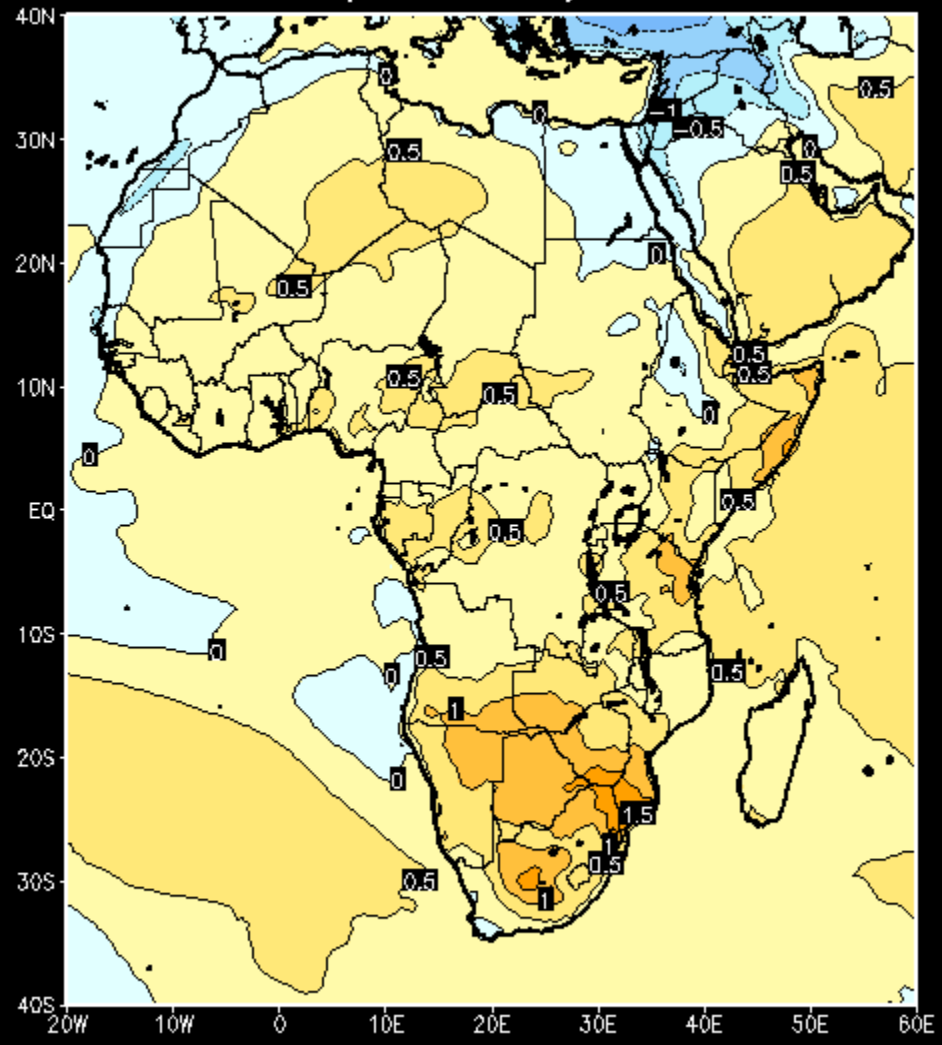




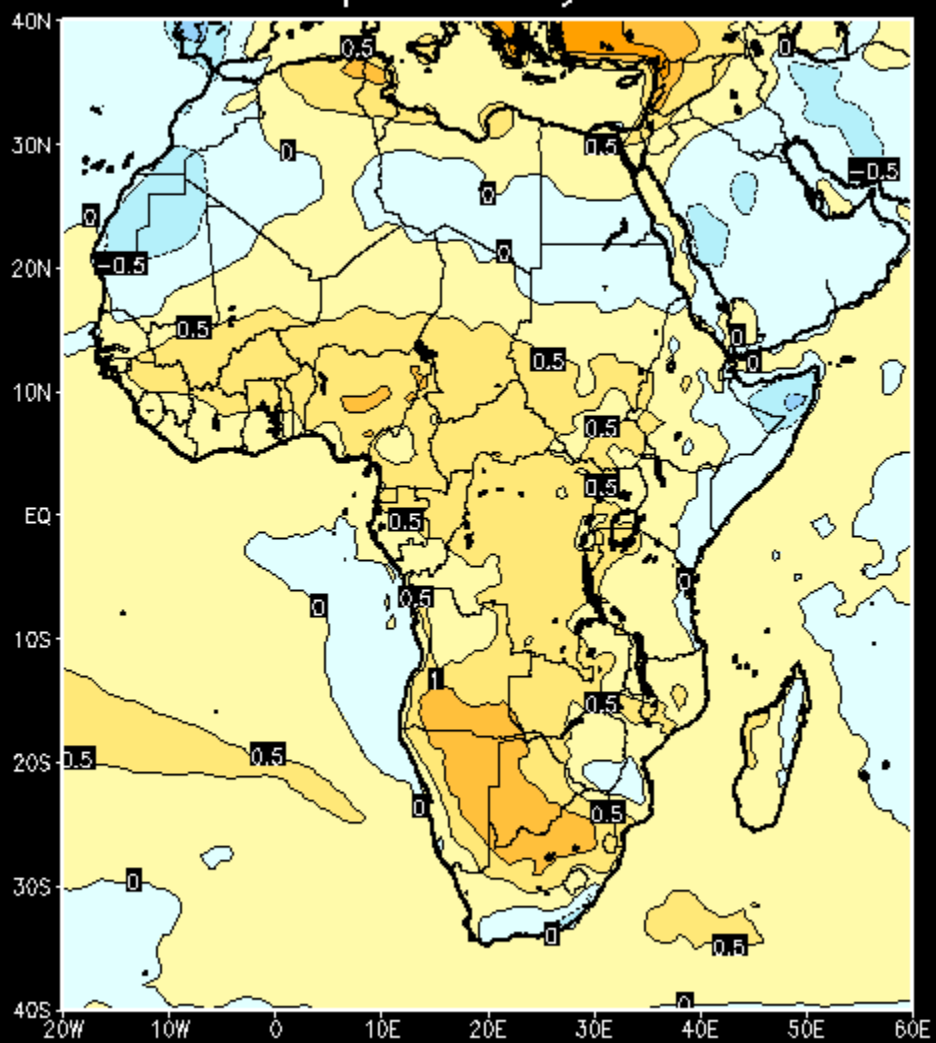
# Temp anomaly 1975



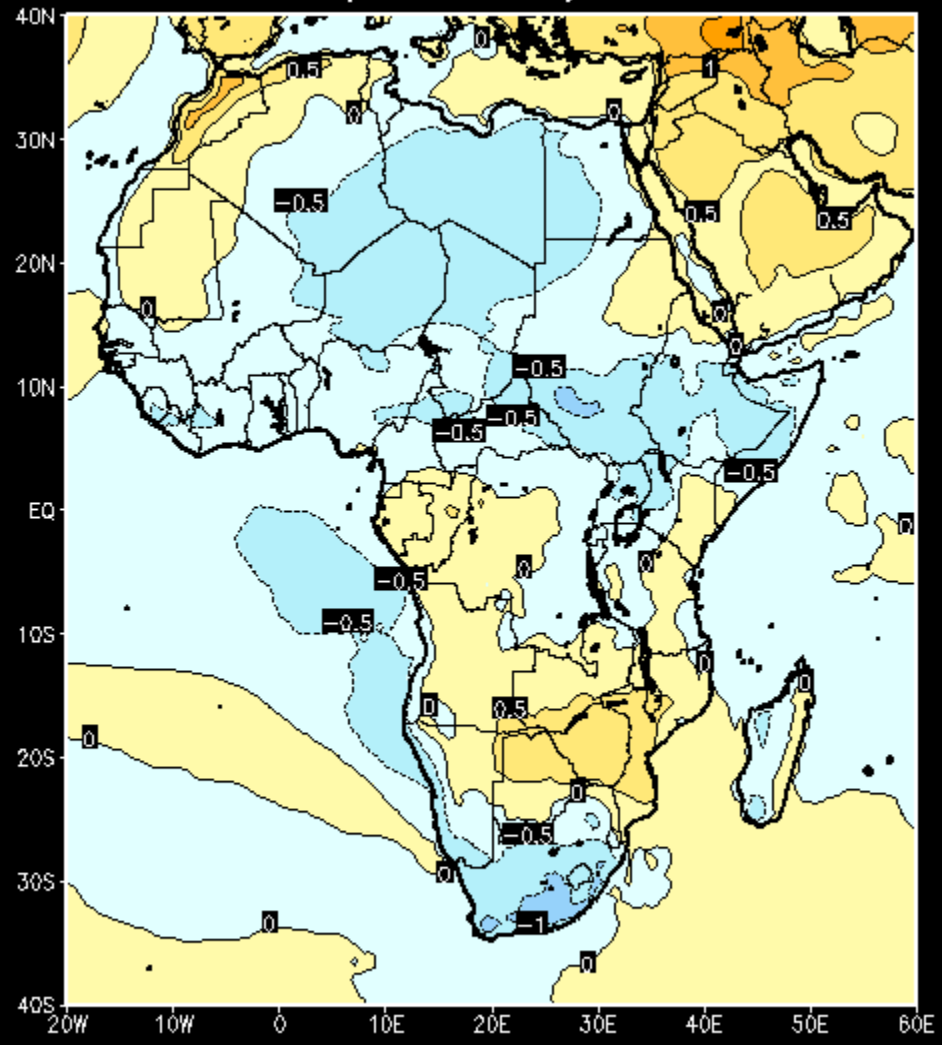
# Temp anomaly 1976



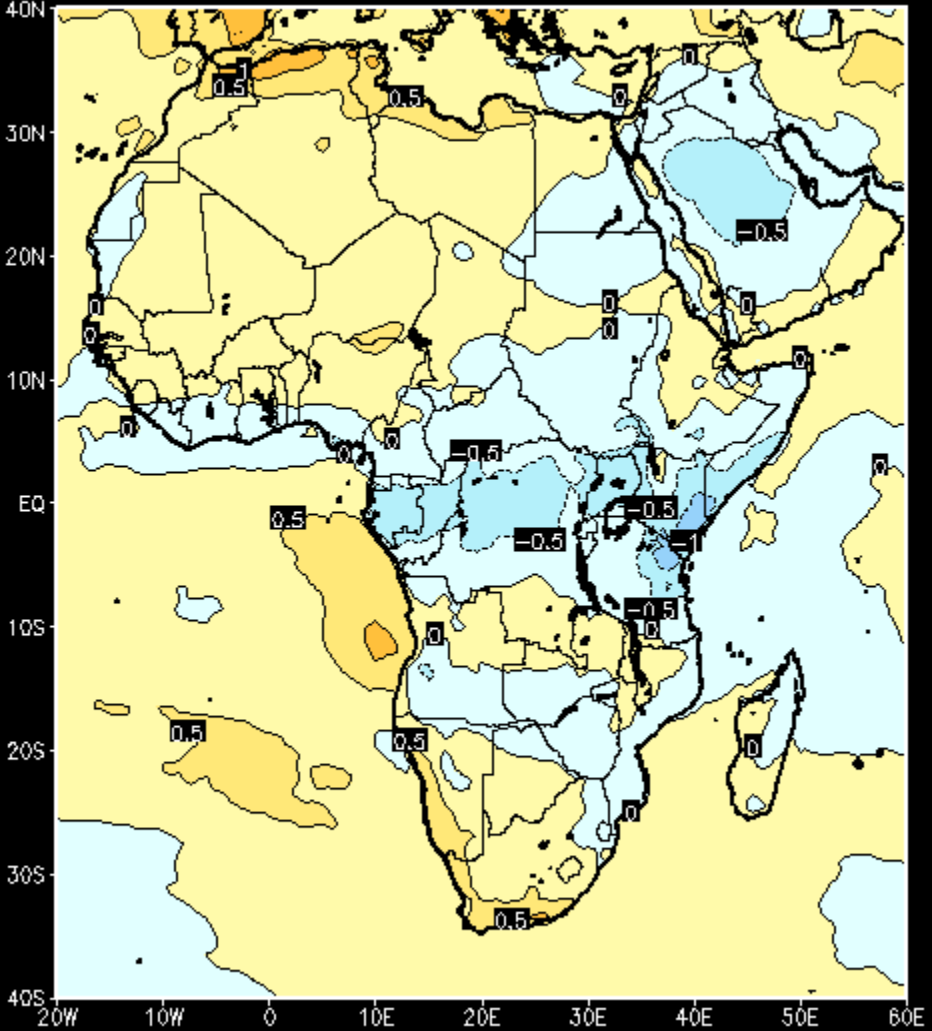
# Temp anomaly 1977



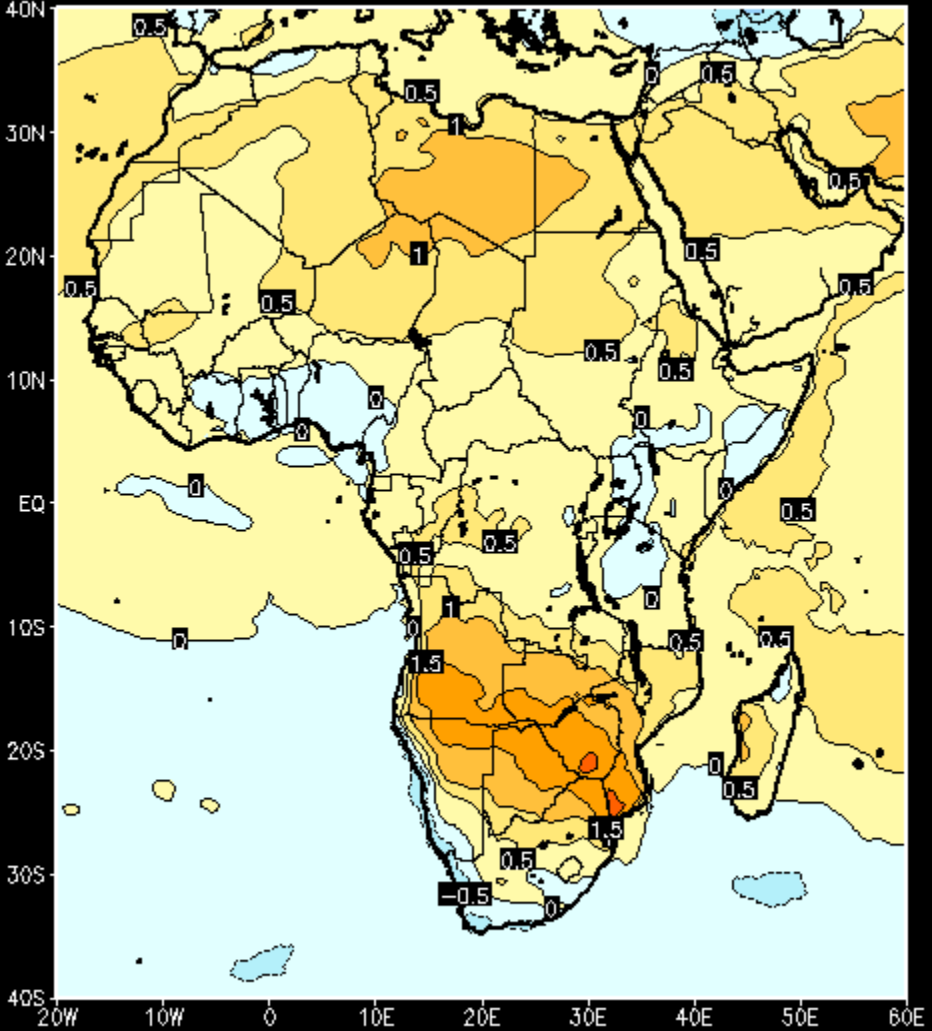
# Temp anomaly 1978



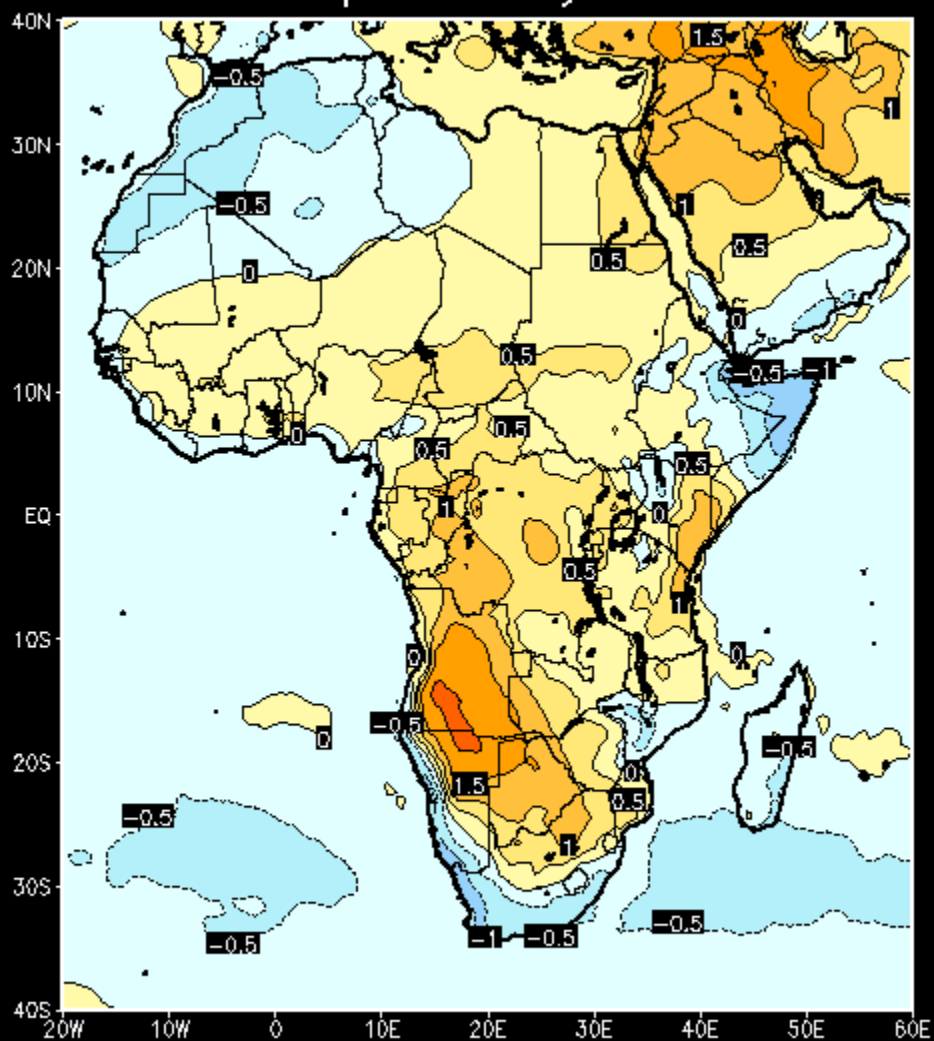
# Temp anomaly 1979



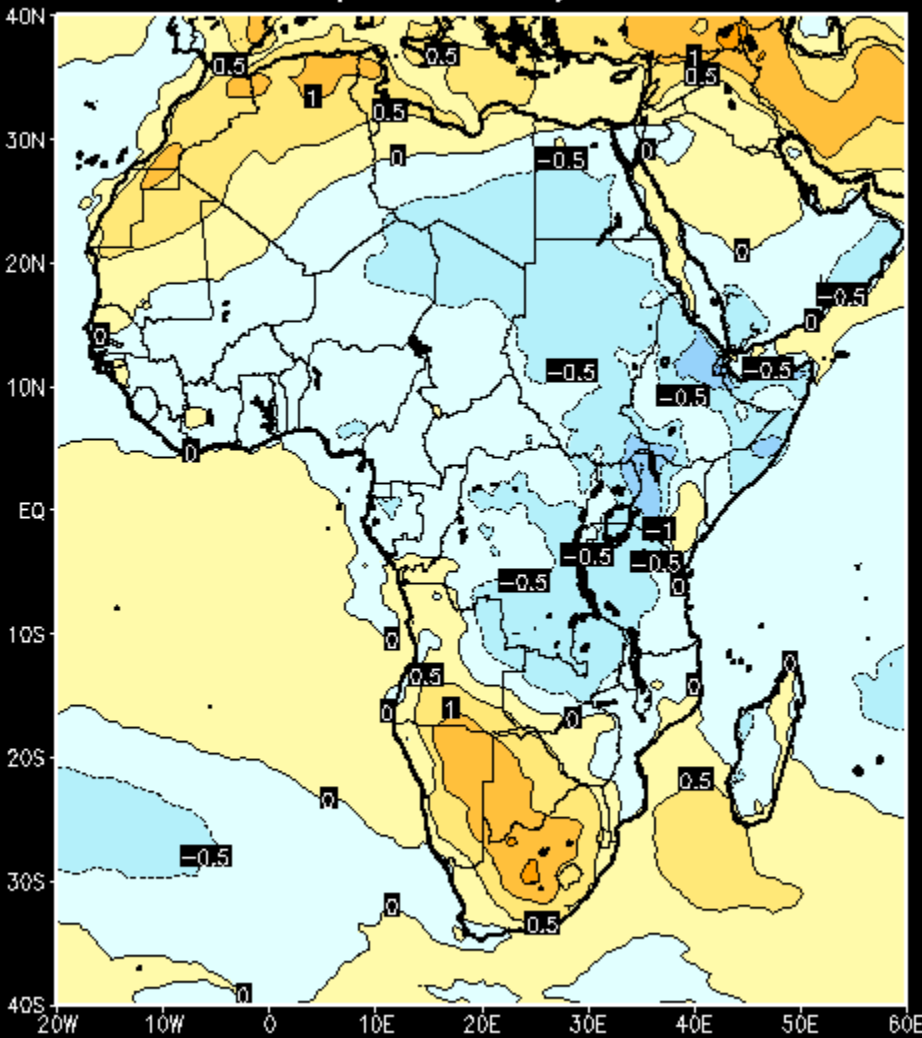
# Temp anomaly 1980



# Temp anomaly 1981

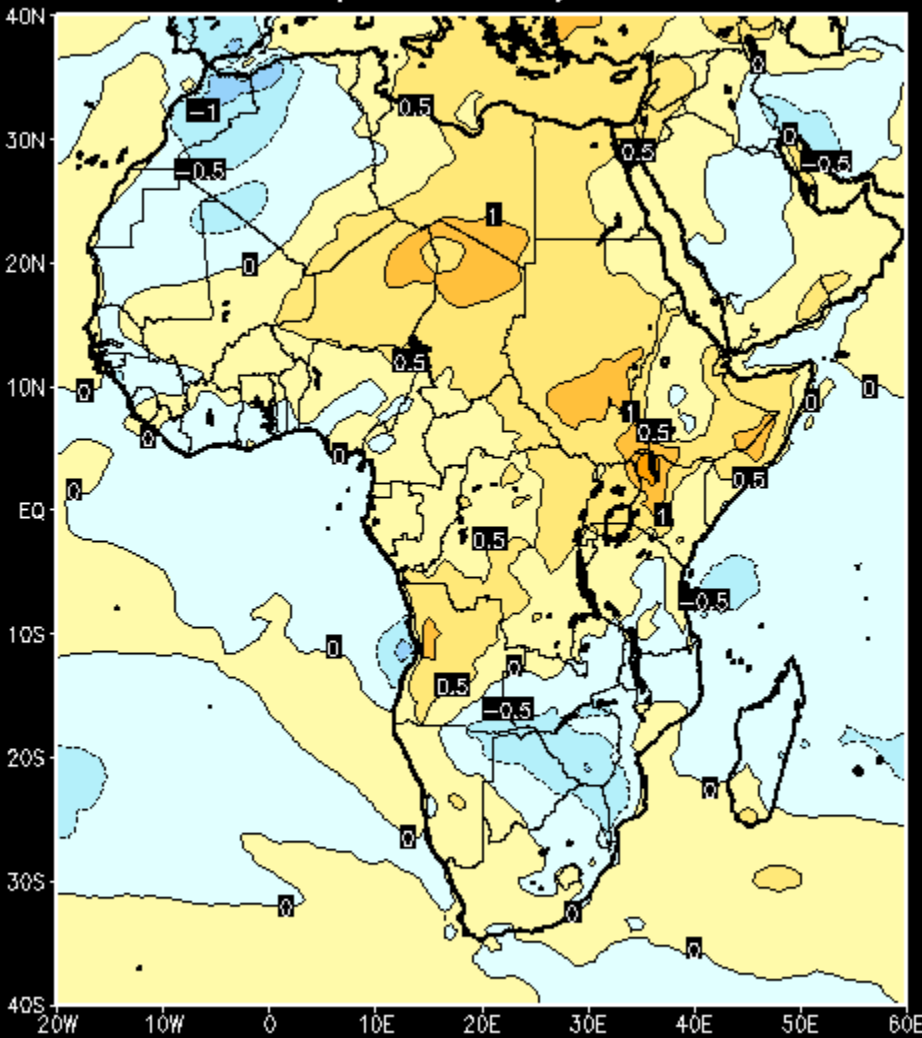


# Temp anomaly 1982

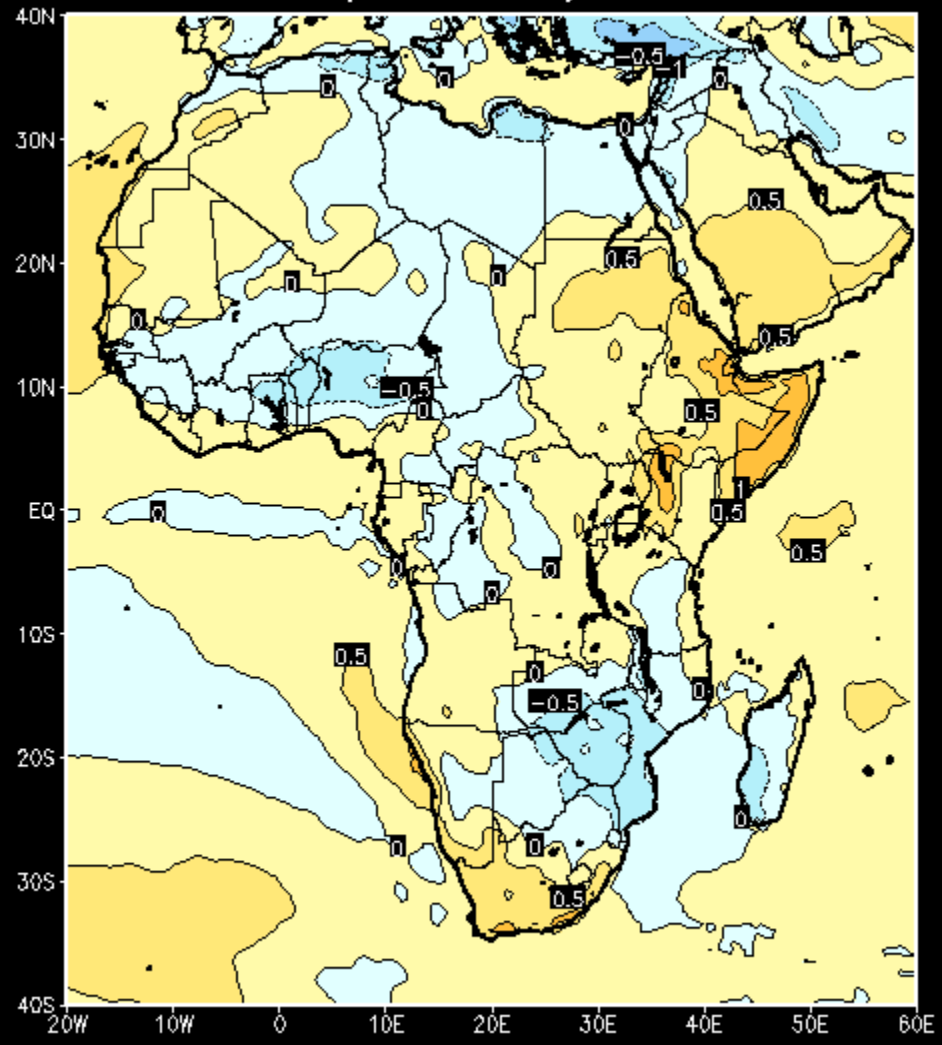




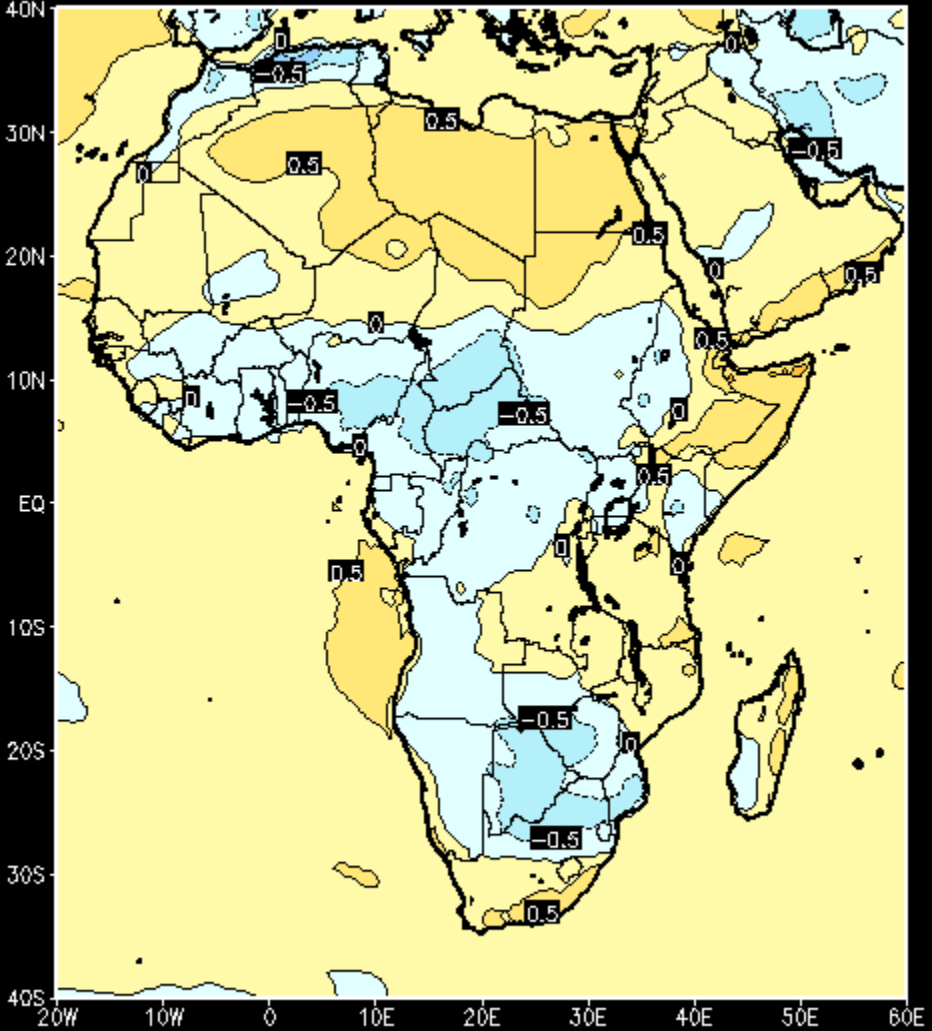
# Temp anomaly 1983



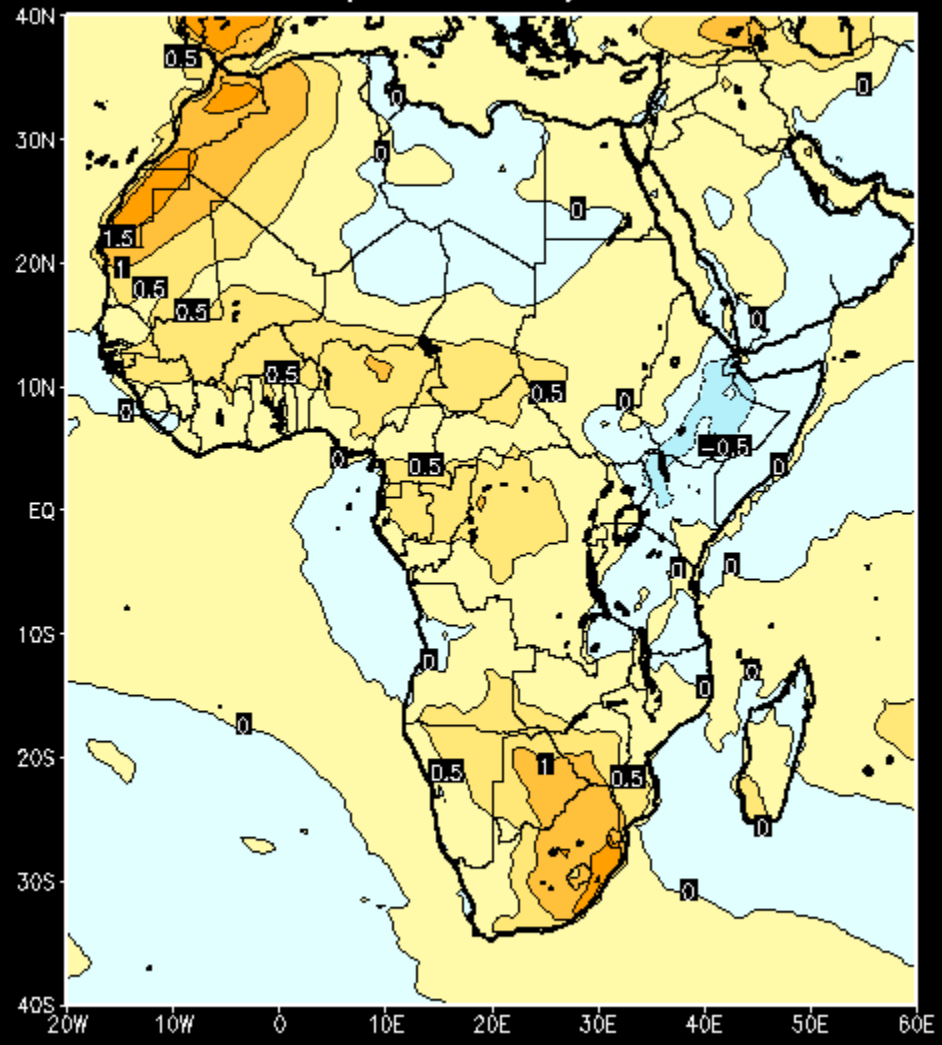
# Temp anomaly 1984



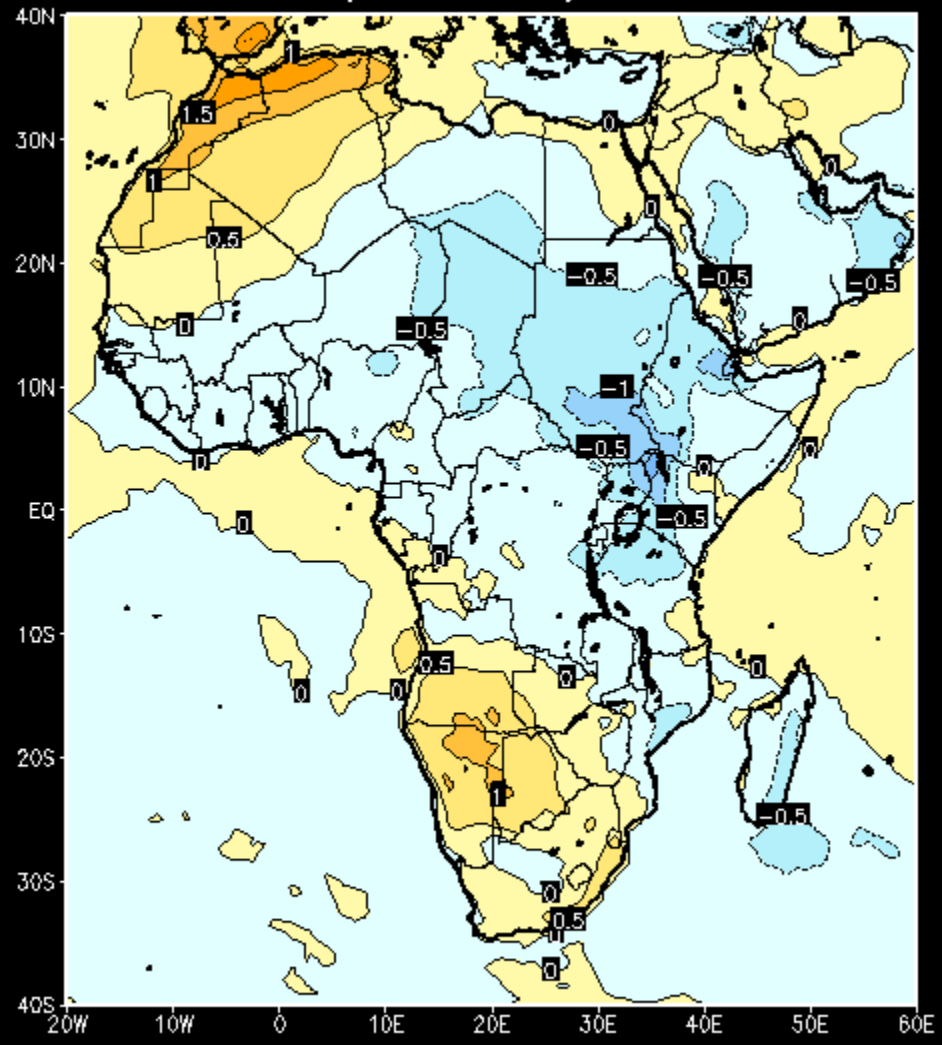
# Temp anomaly 1985



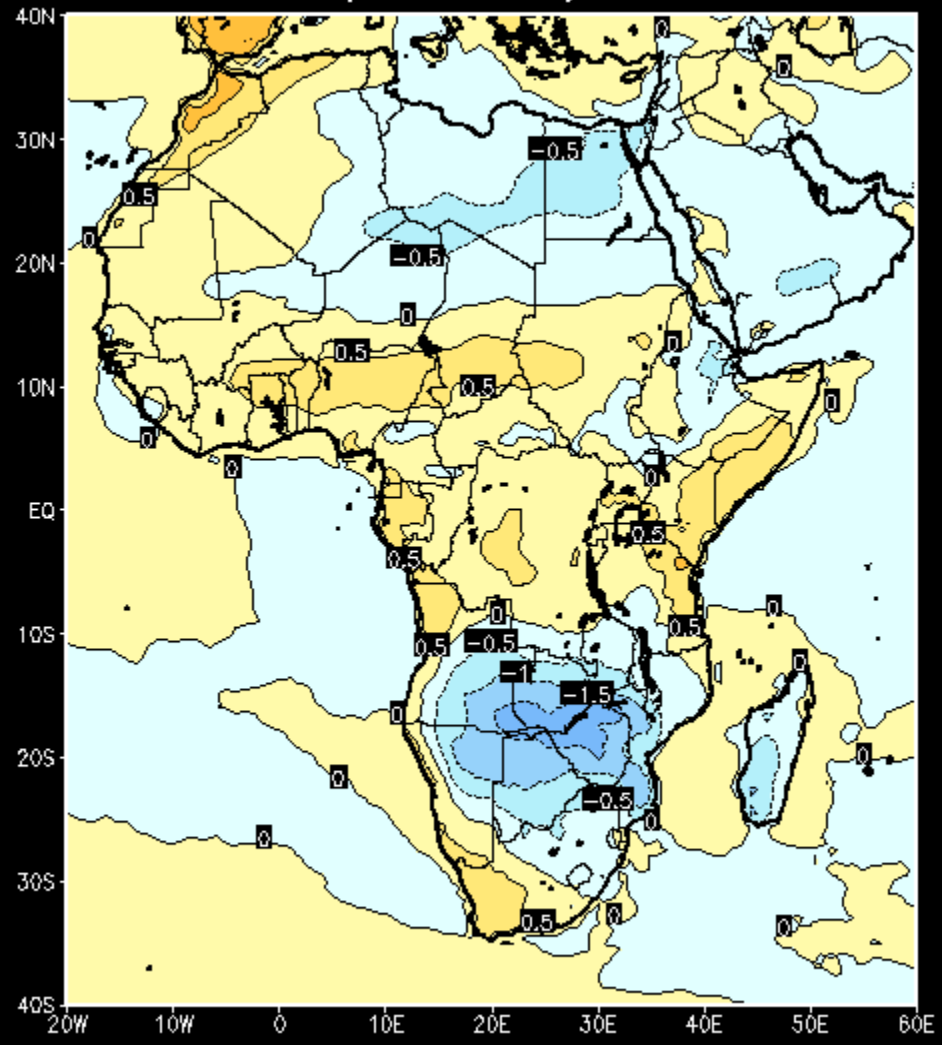
# Temp anomaly 1986



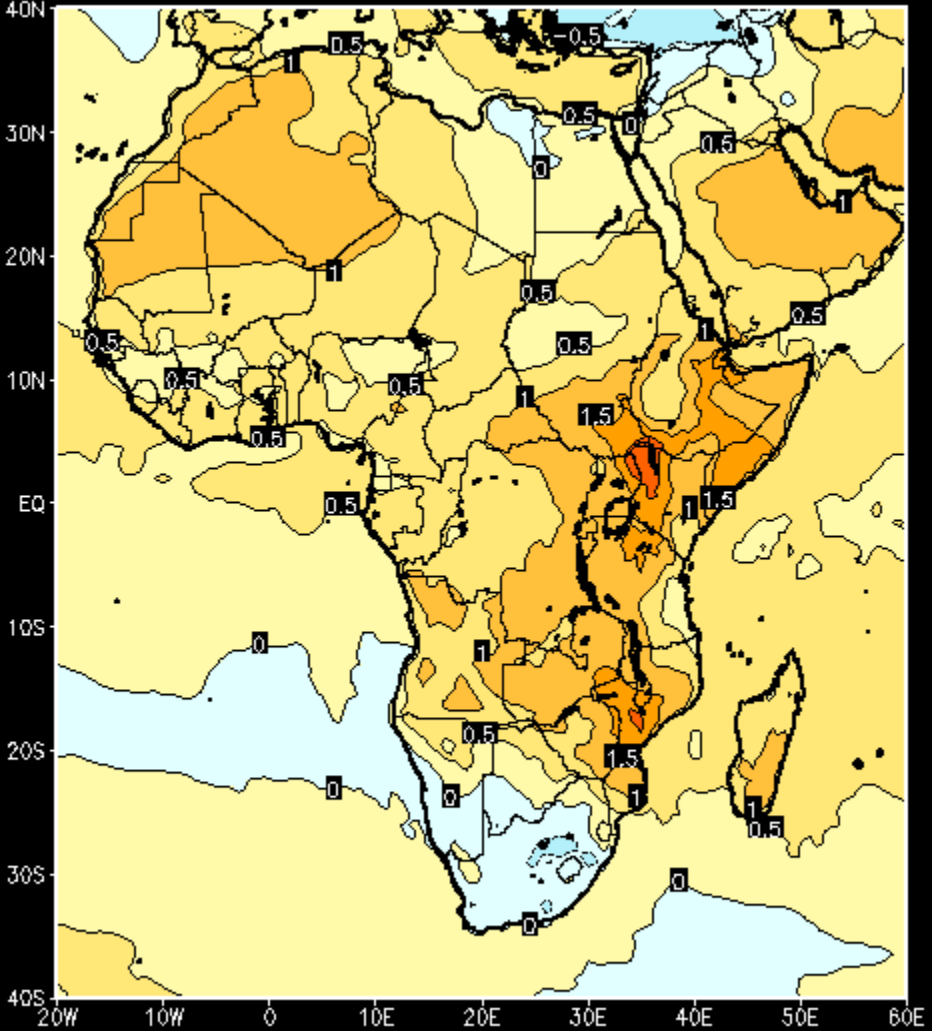
# Temp anomaly 1987



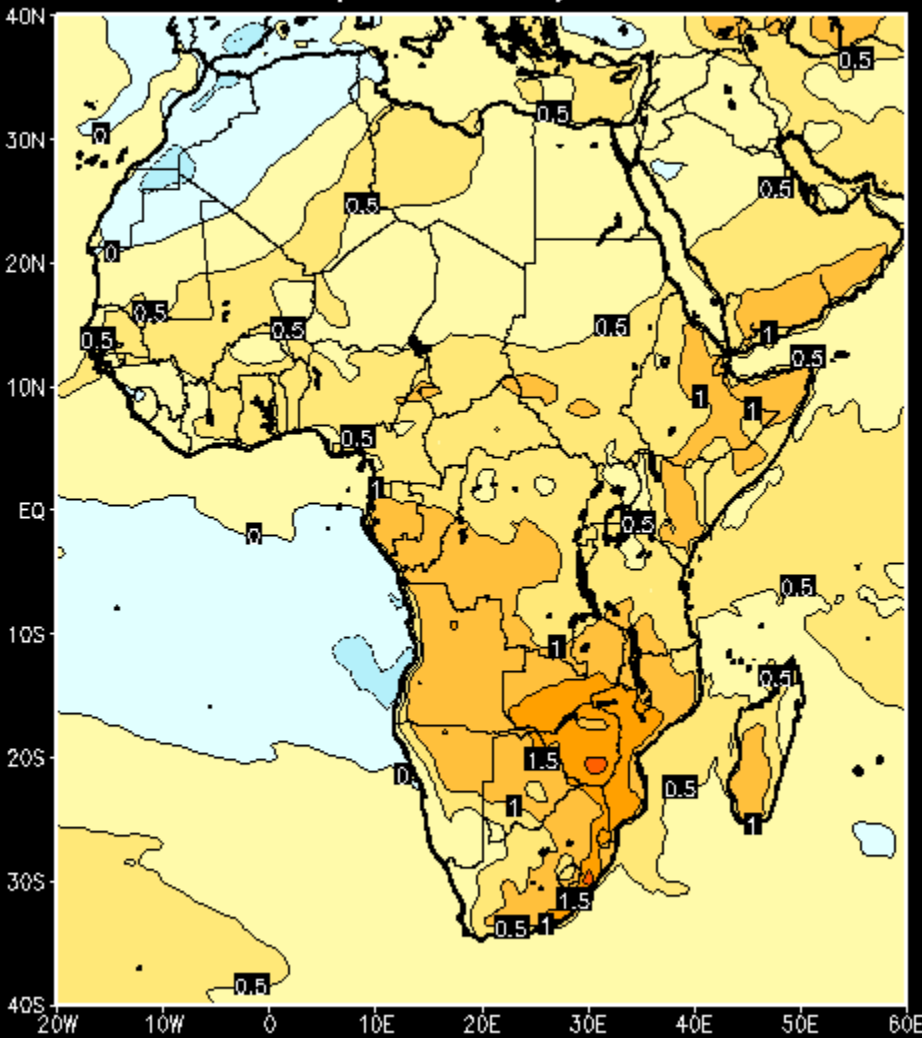
# Temp anomaly 1988



# Temp anomaly 1989

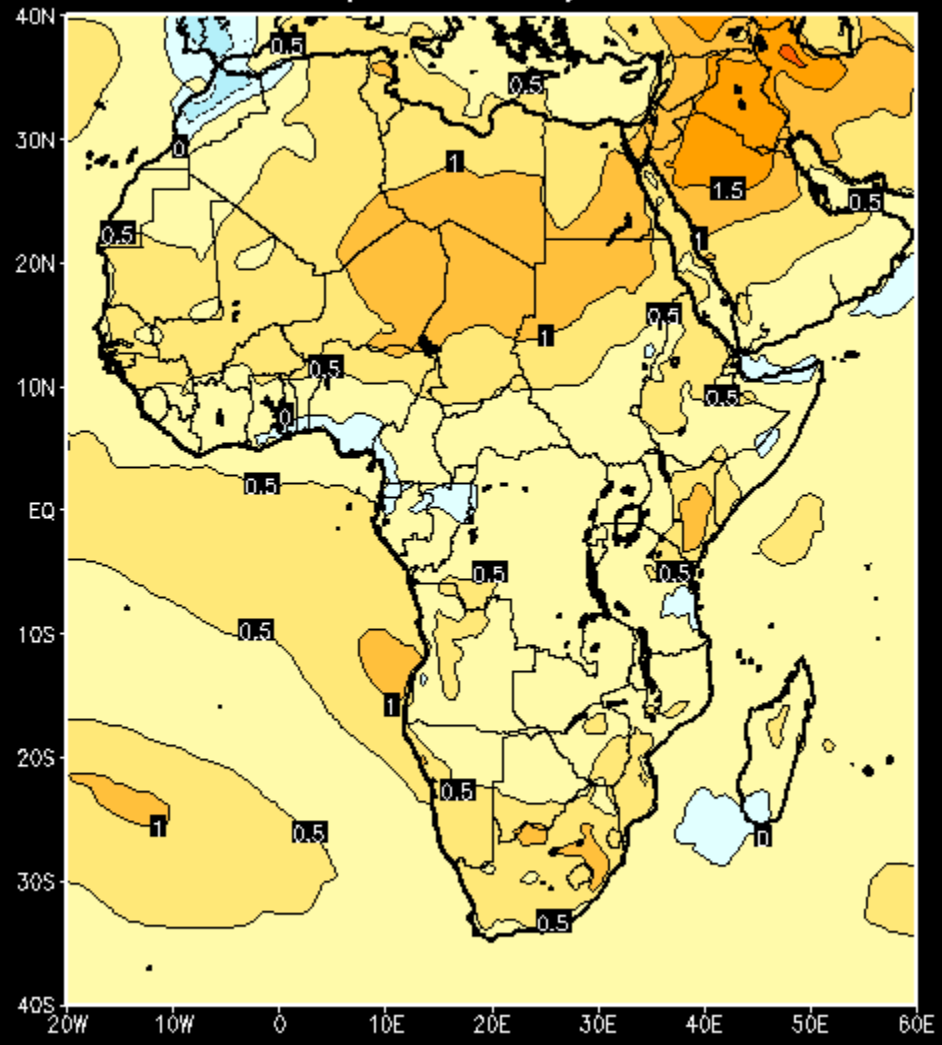


# Temp anomaly 1990

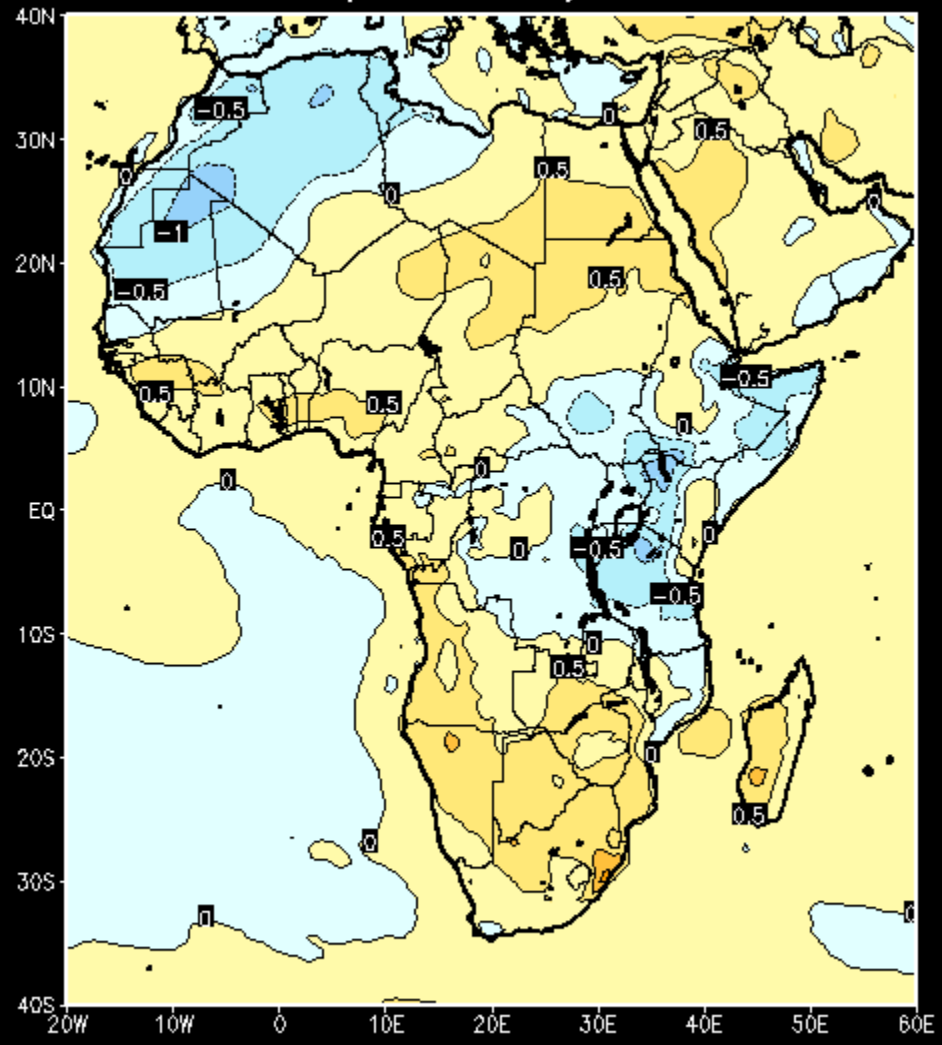




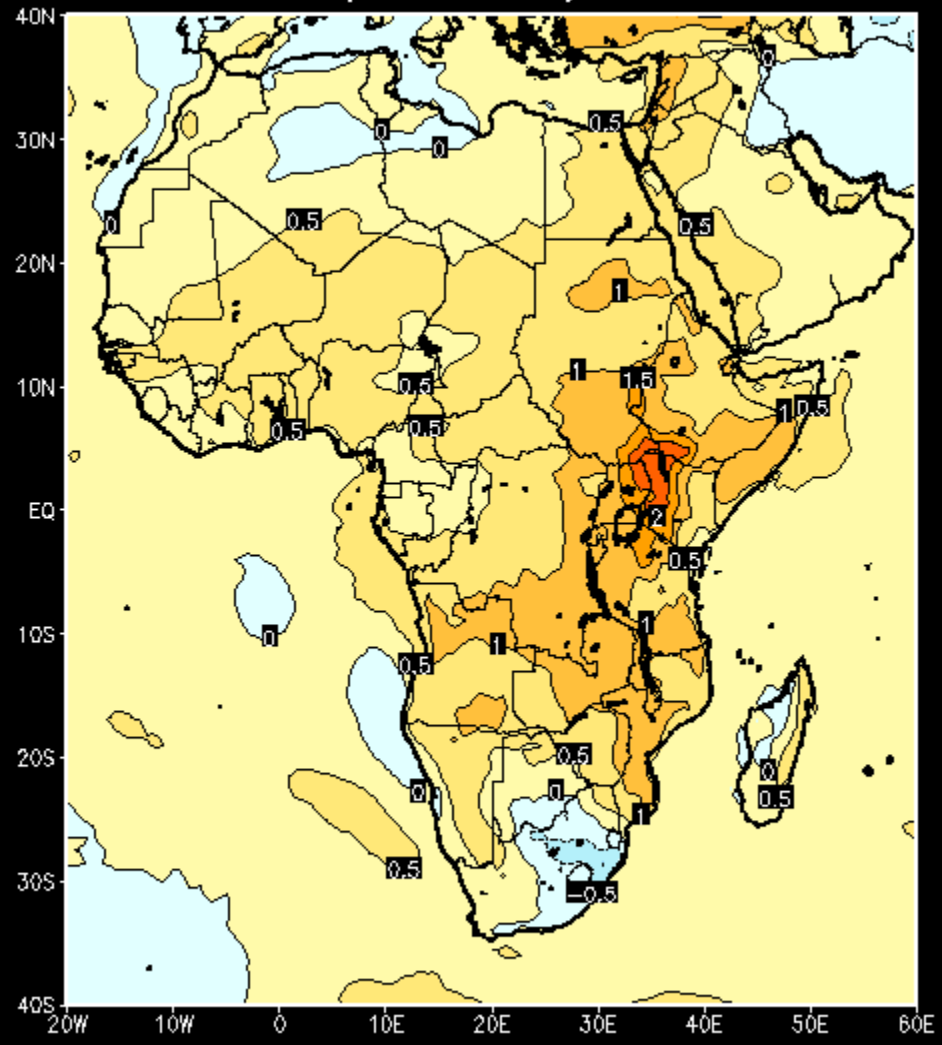
# Temp anomaly 1991



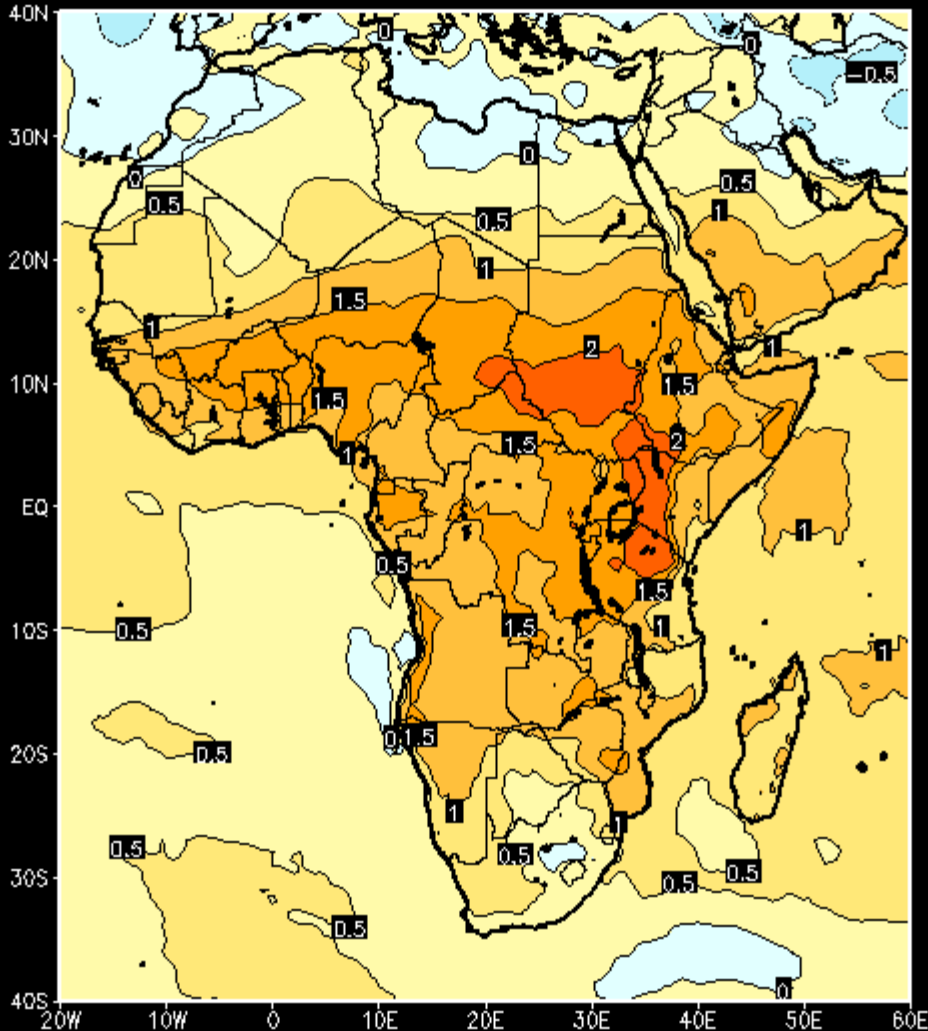
# Temp anomaly 1992



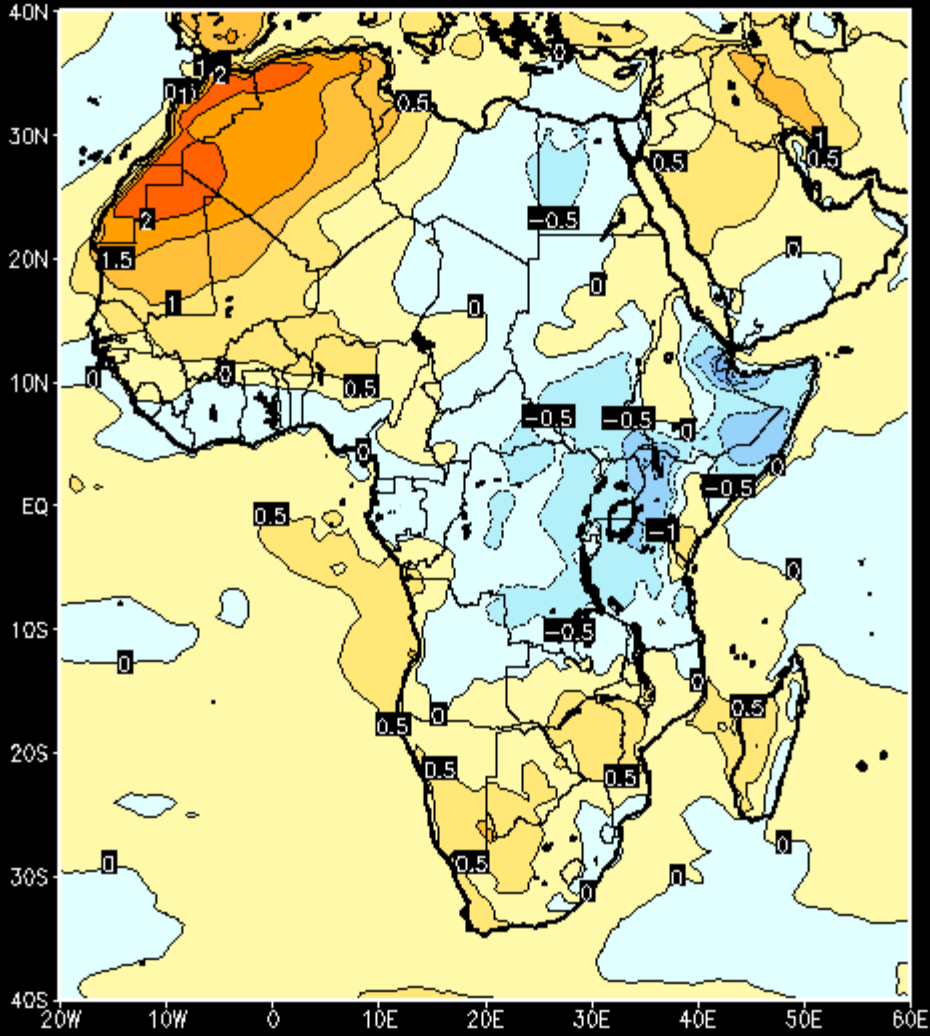
# Temp anomaly 1993



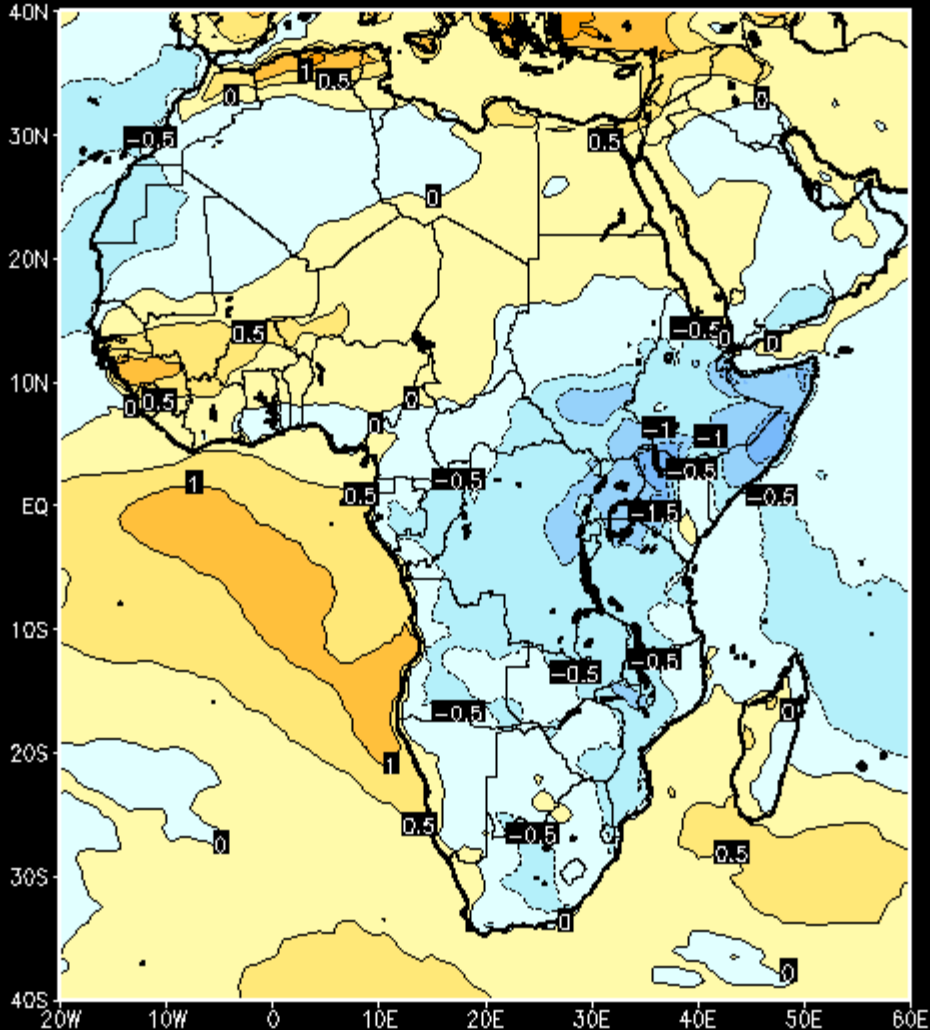
# Temp anomaly 1994



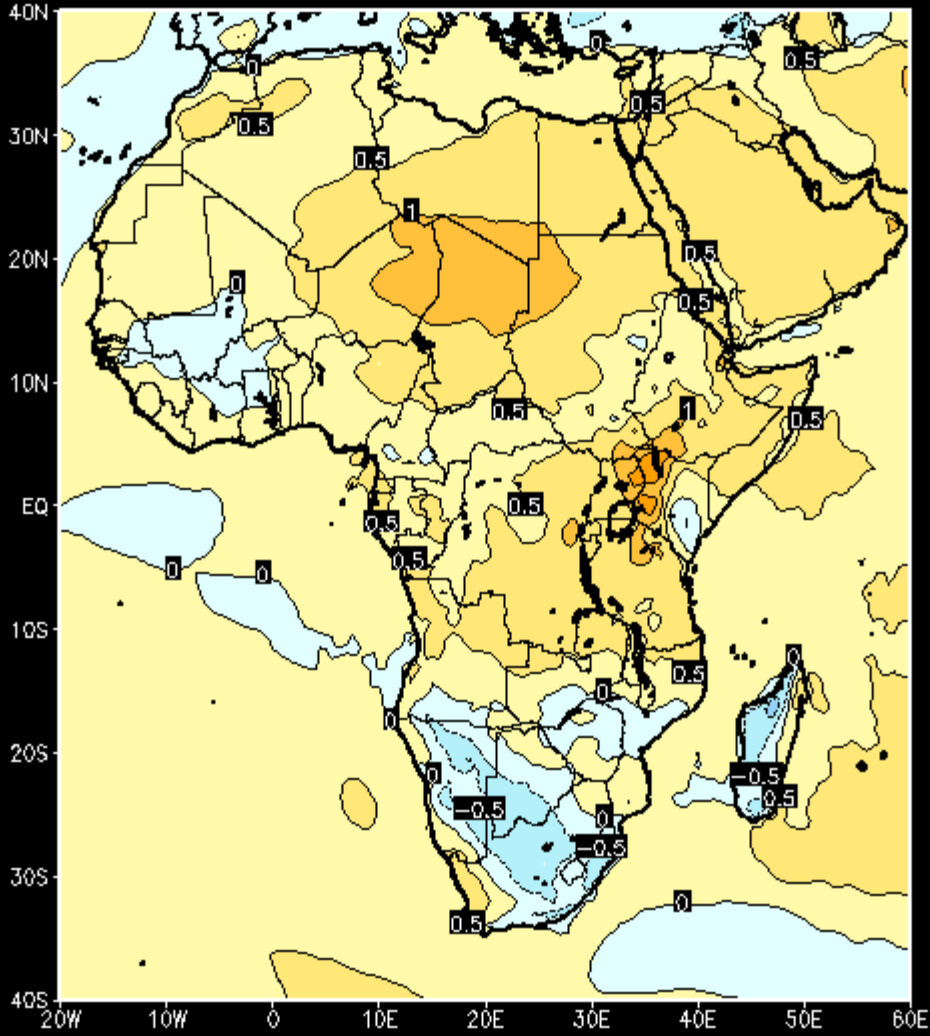
# Temp anomaly 1995



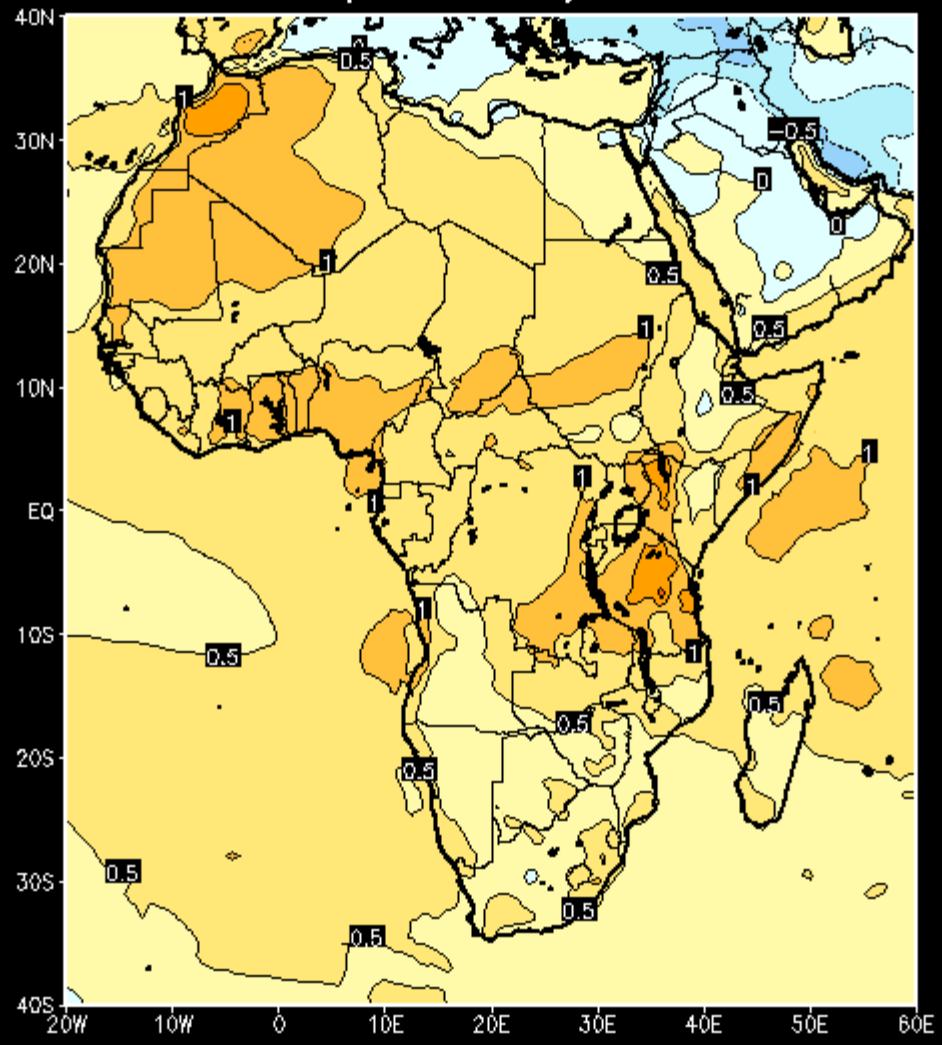
# Temp anomaly 1996



# Temp anomaly 1997

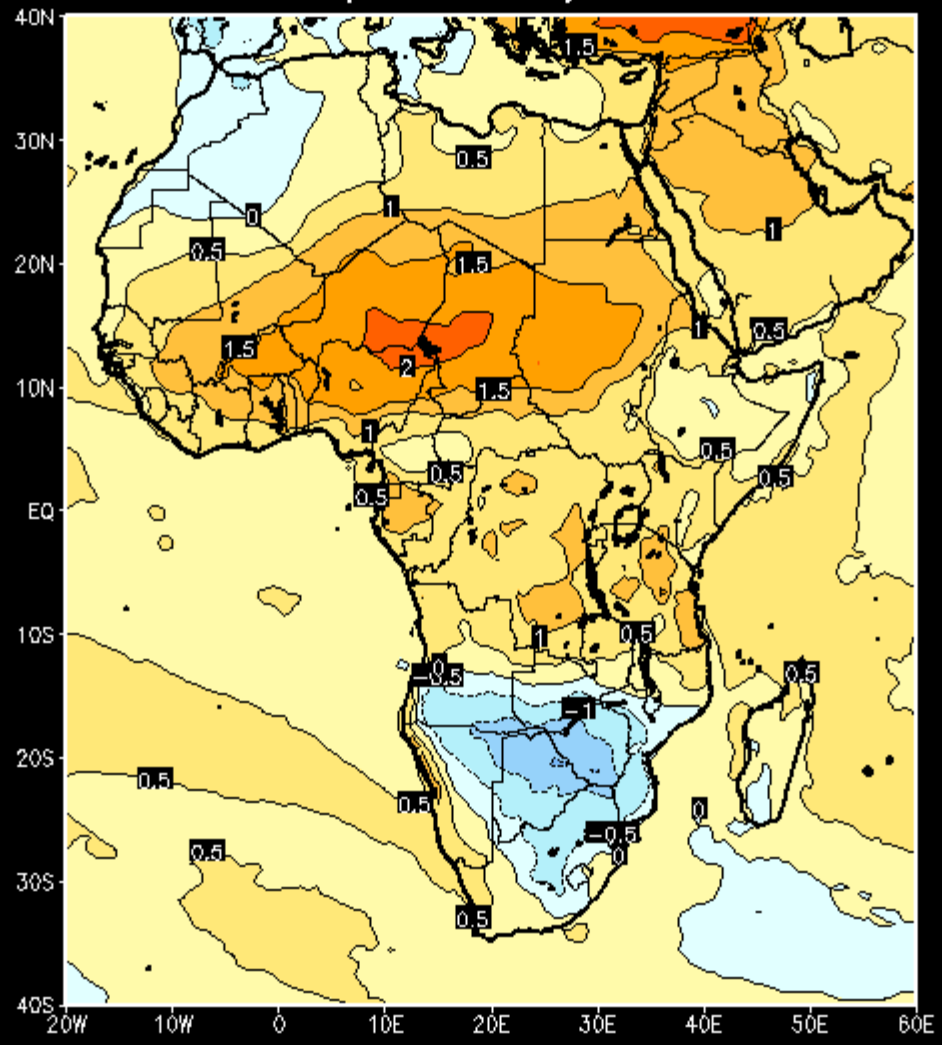


# Temp anomaly 1998

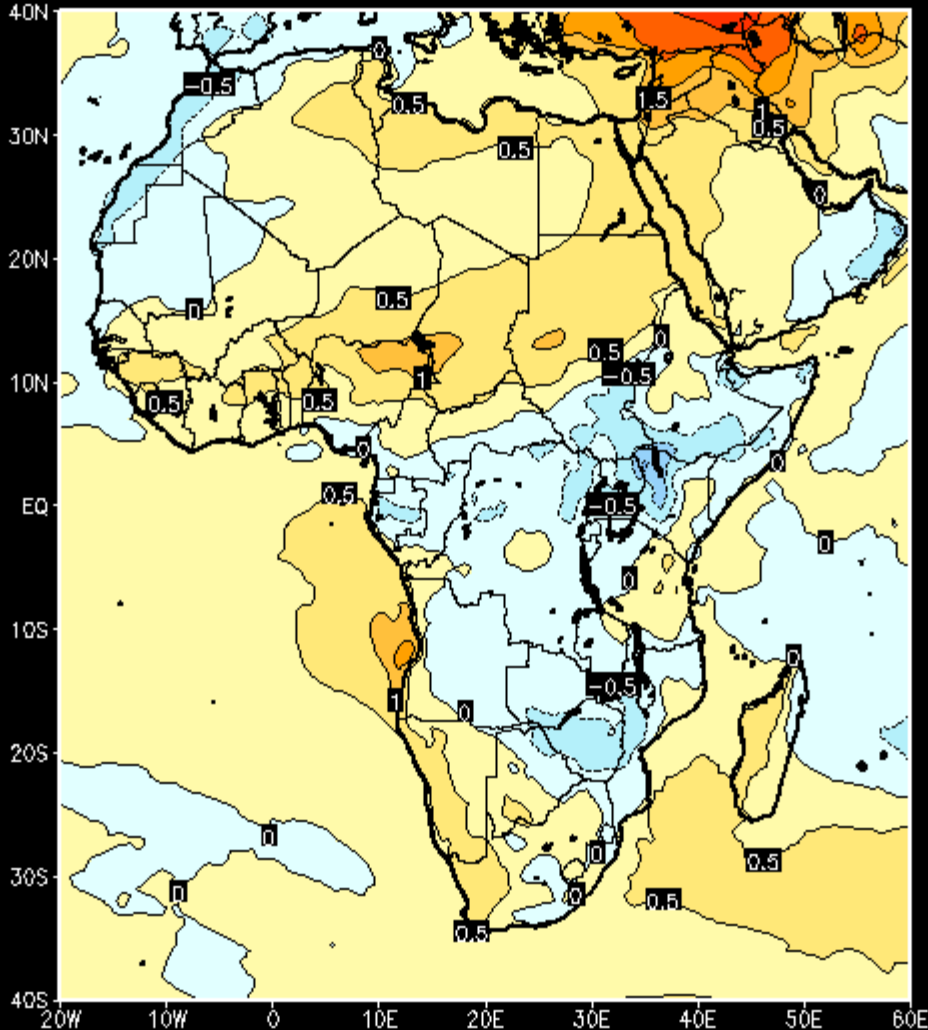




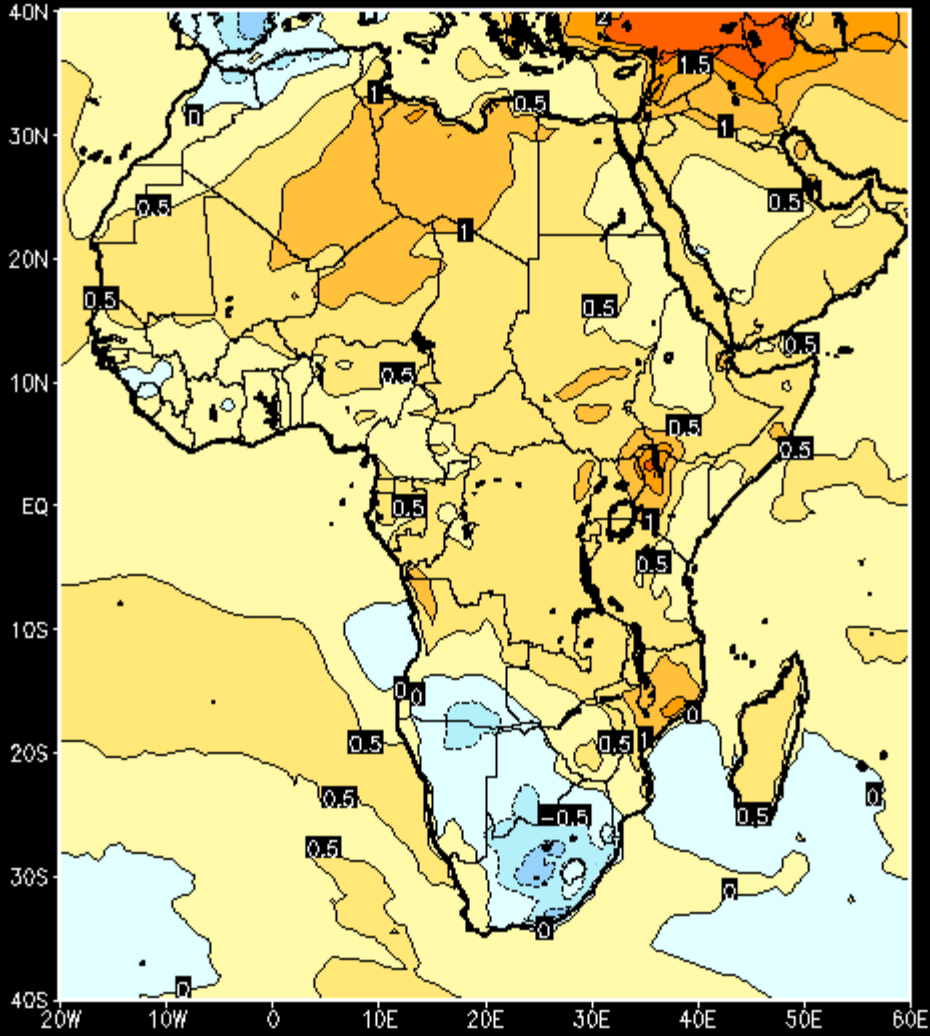
# Temp anomaly 1999



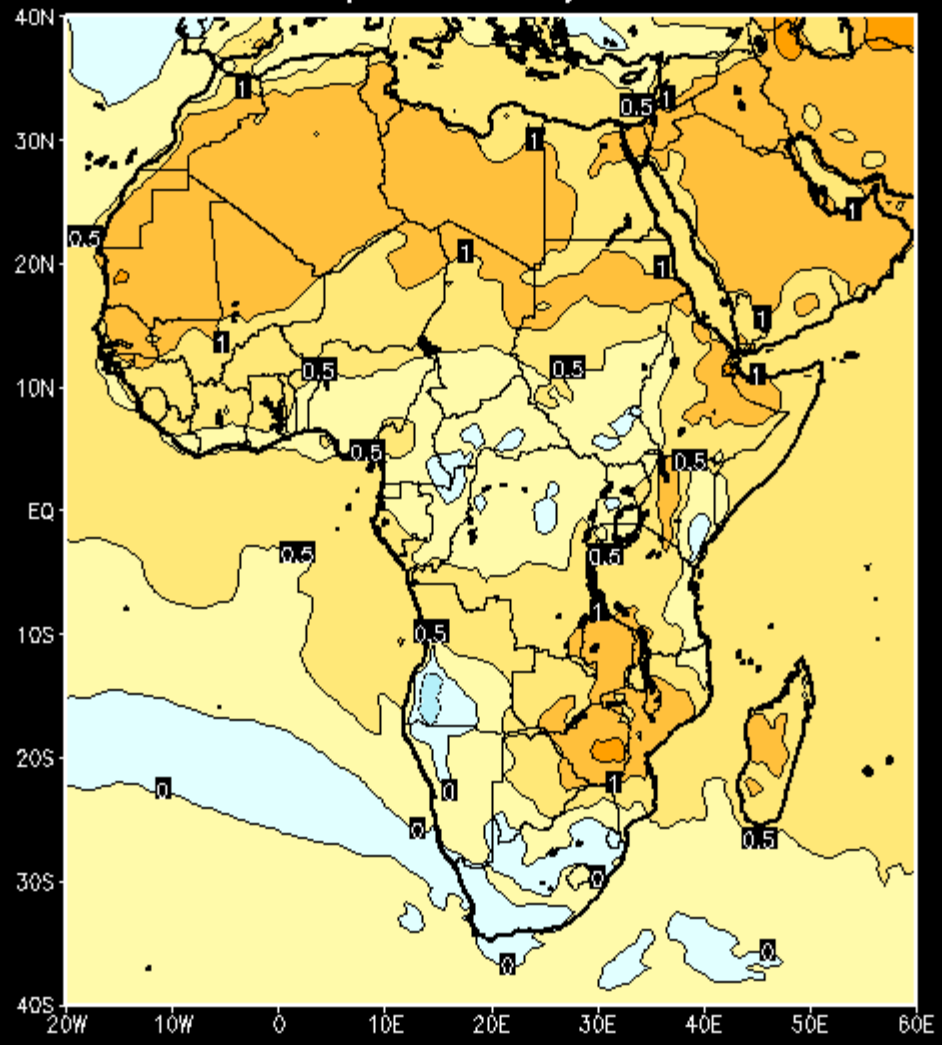
# Temp anomaly 2000



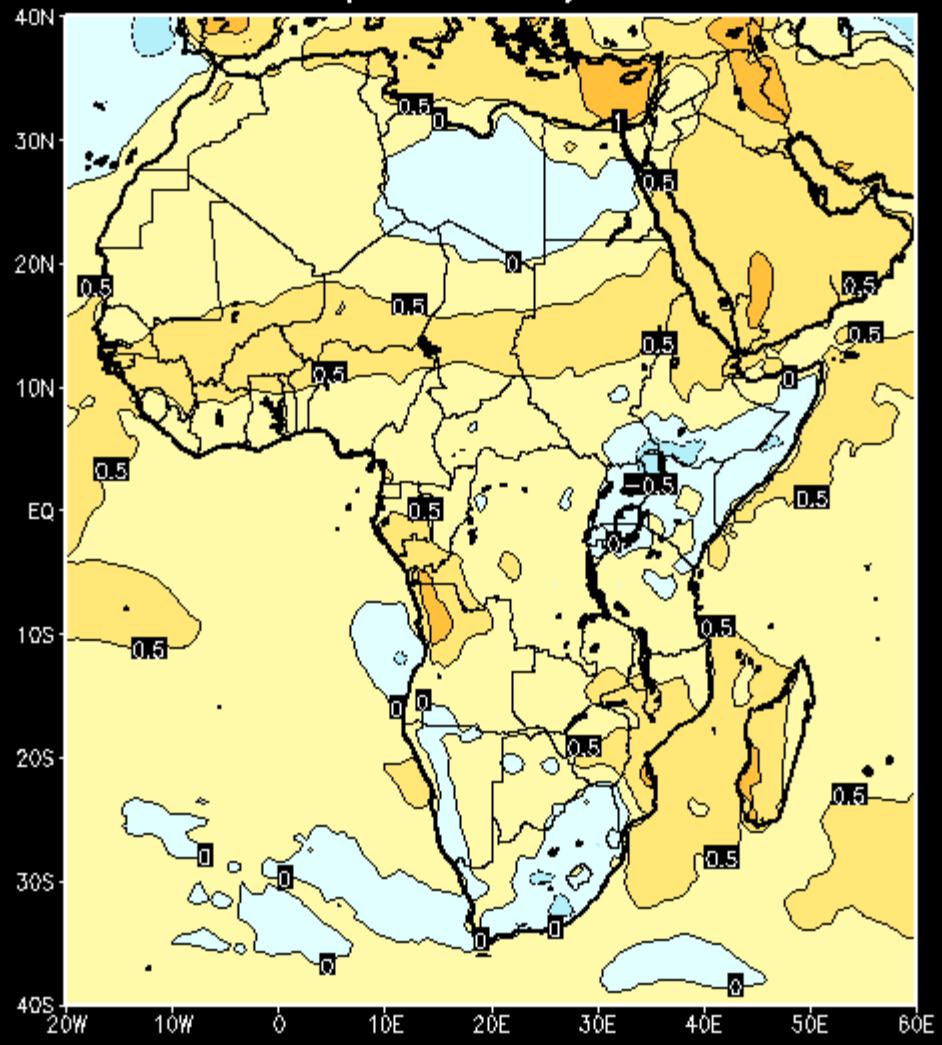
# Temp anomaly 2001



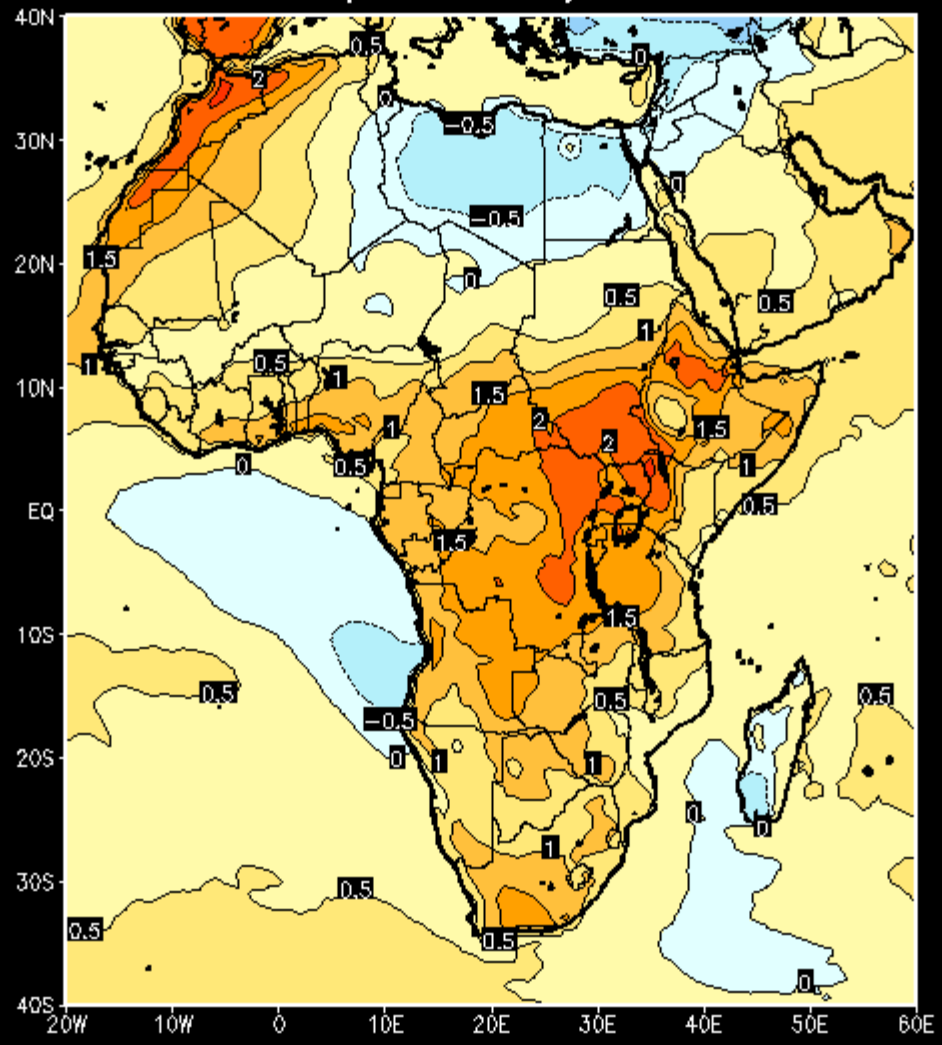
# Temp anomaly 2002



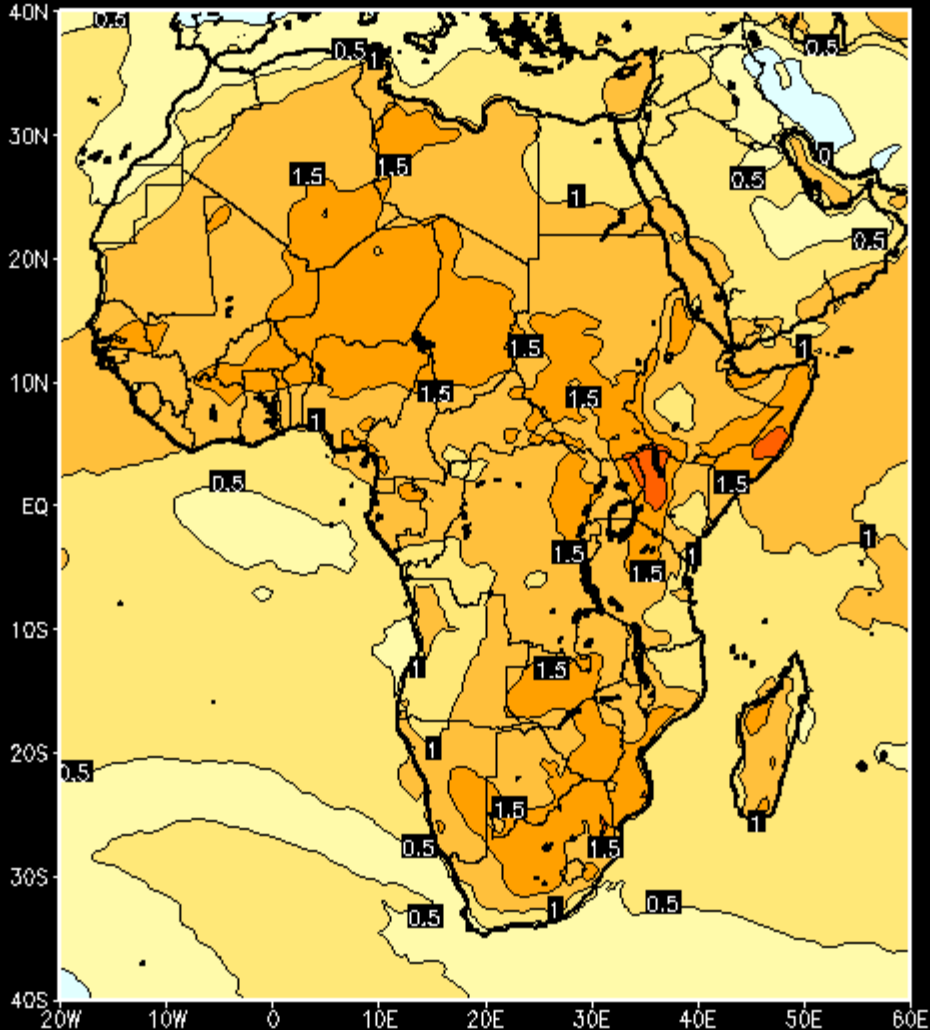
# Temp anomaly 2003



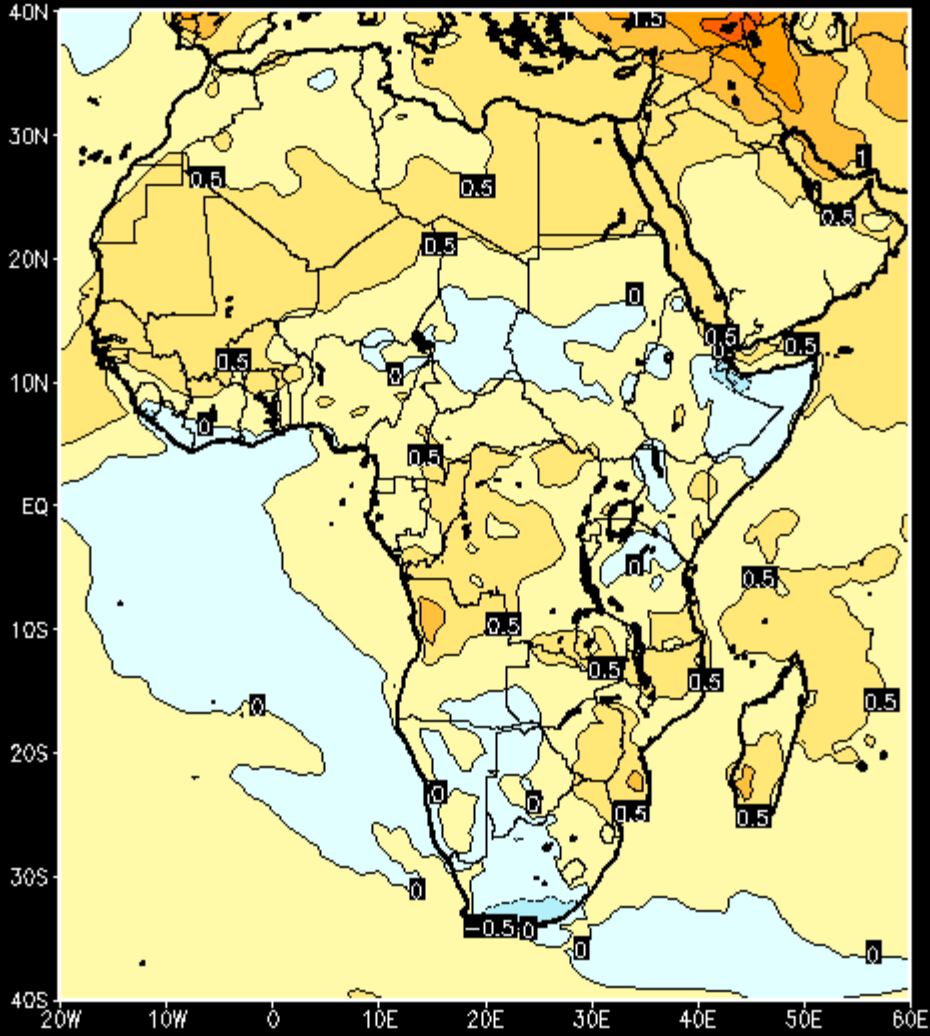
# Temp anomaly 2004



# Temp anomaly 2005

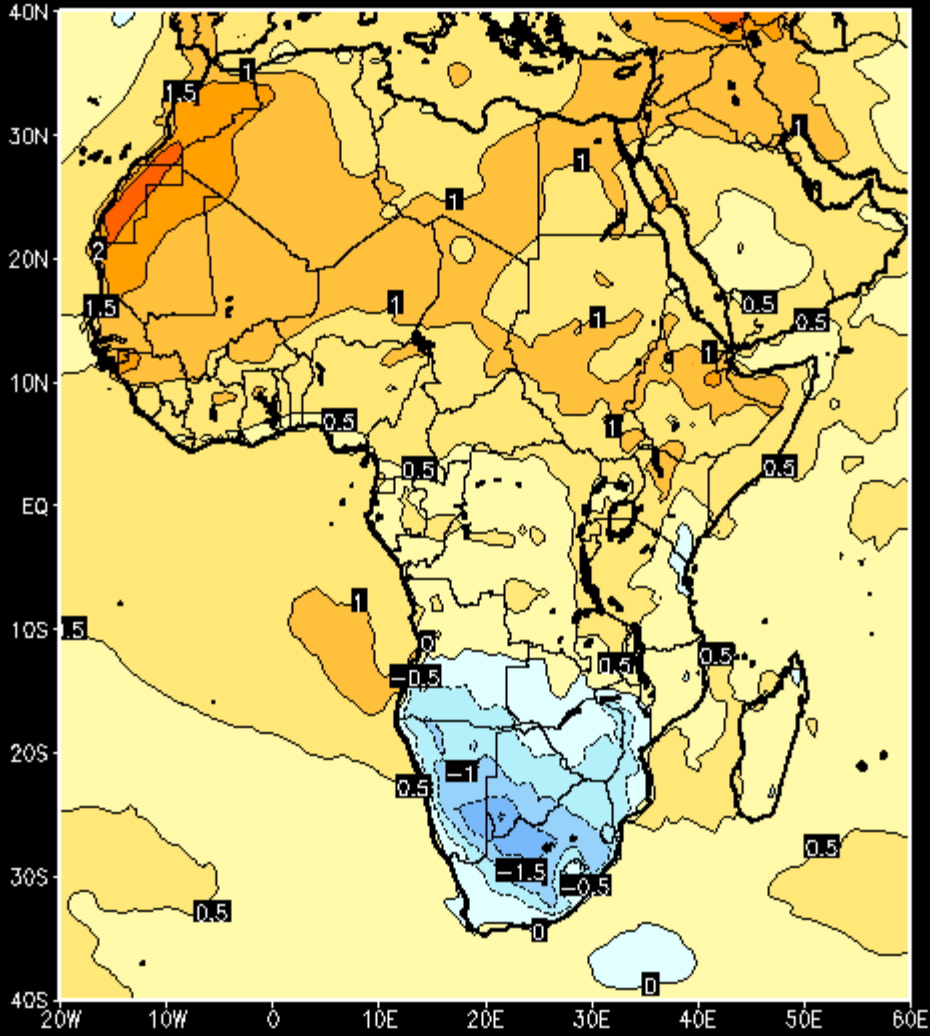


# Temp anomaly 2006

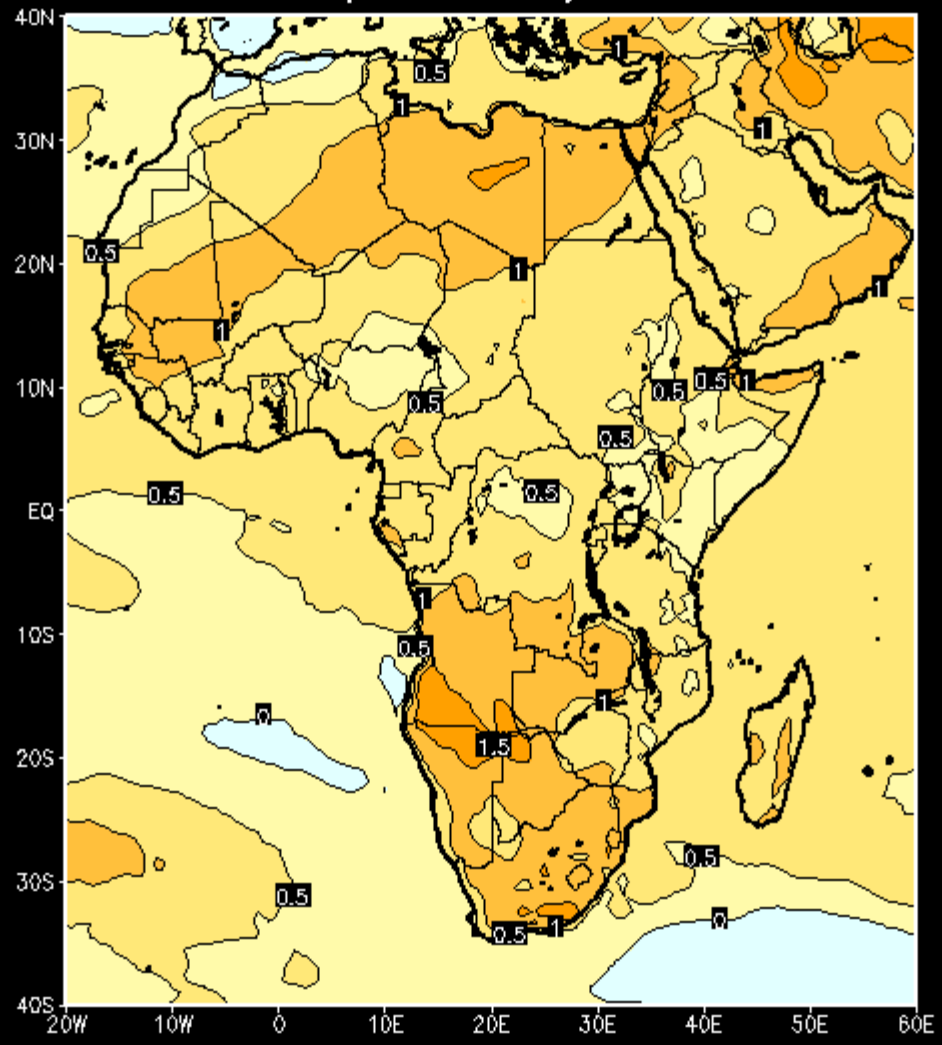




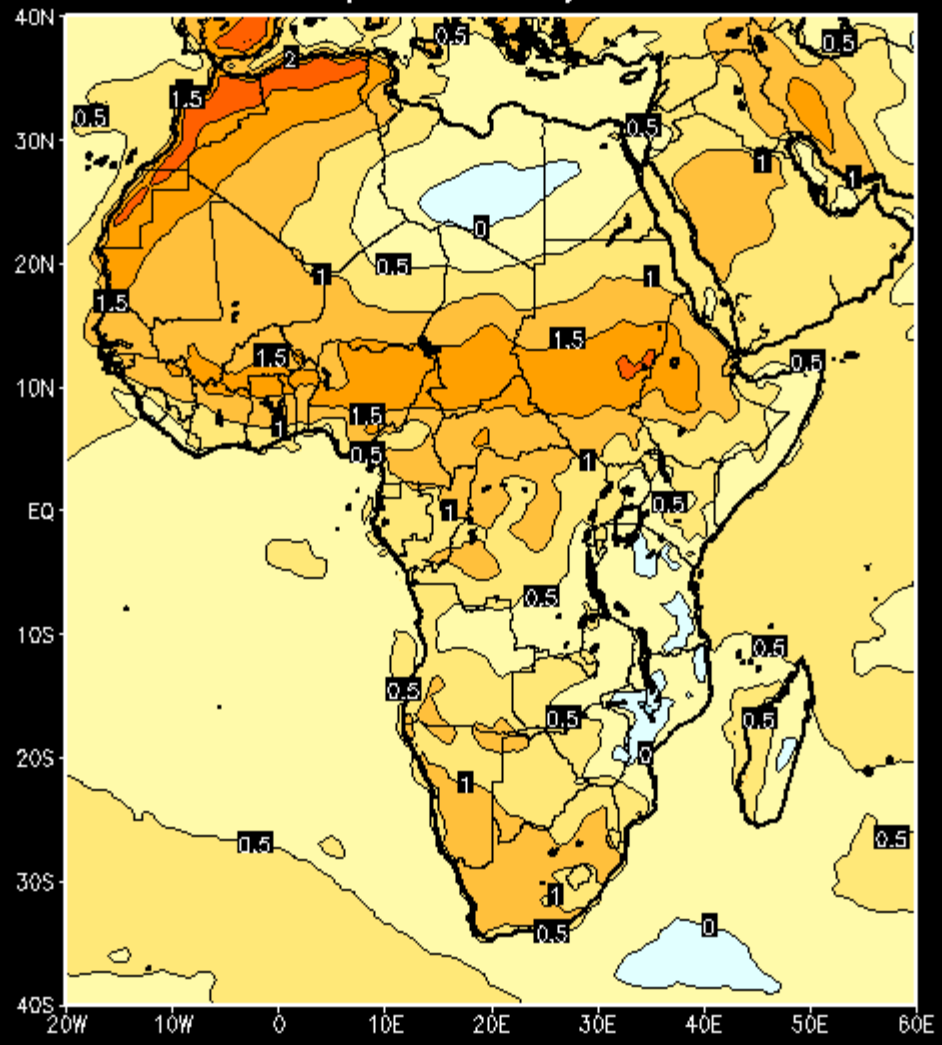
# Temp anomaly 2007



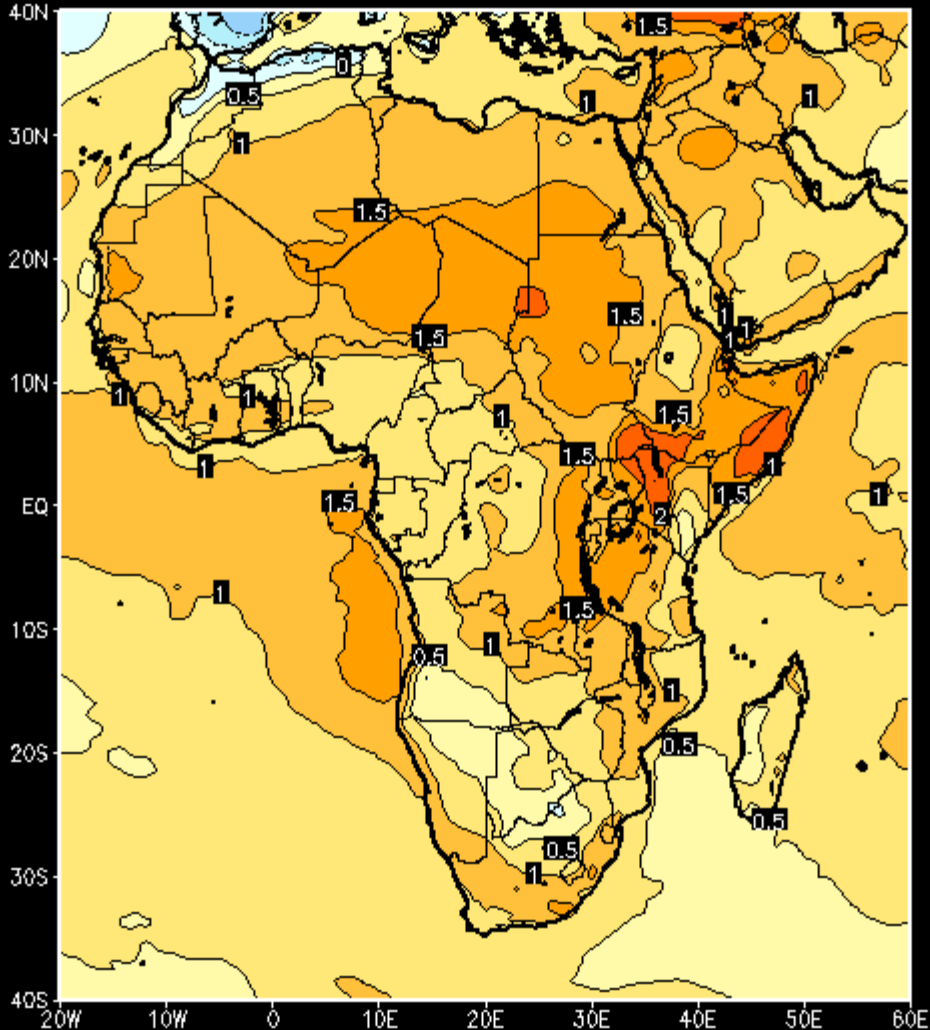
# Temp anomaly 2008



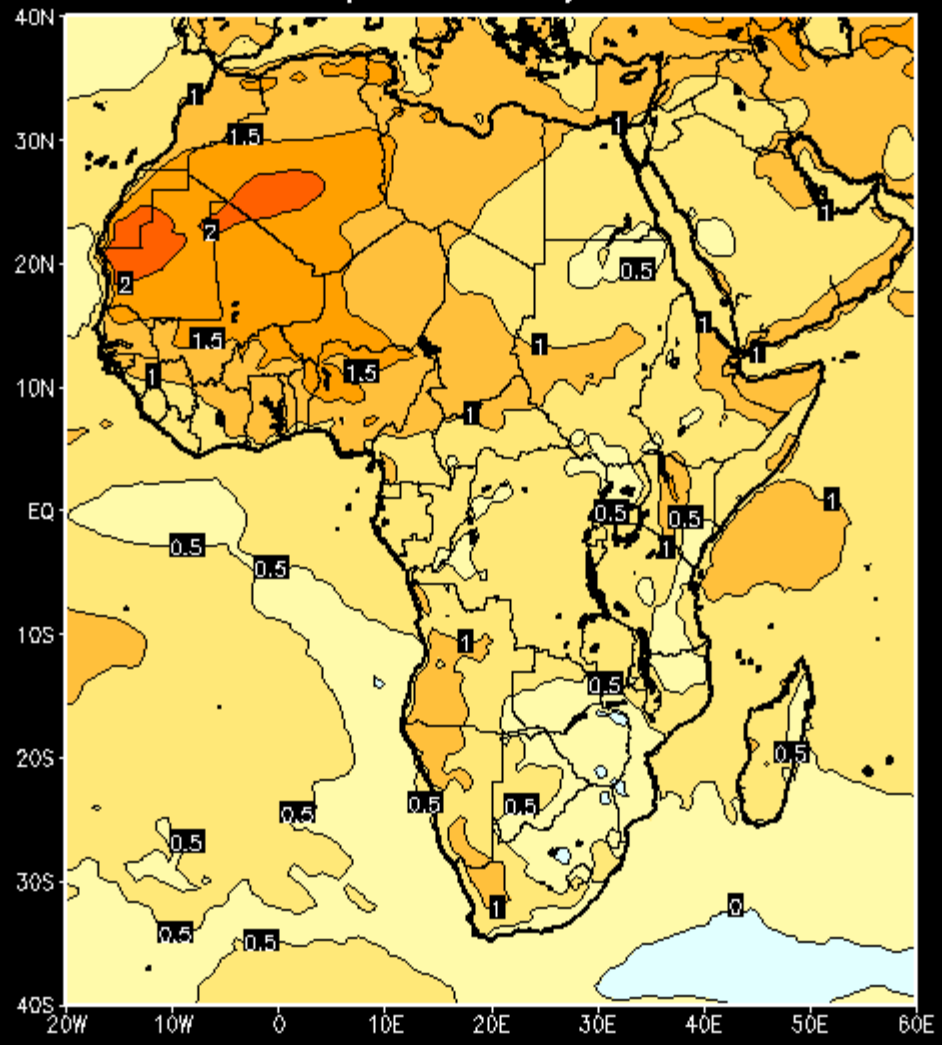
# Temp anomaly 2009



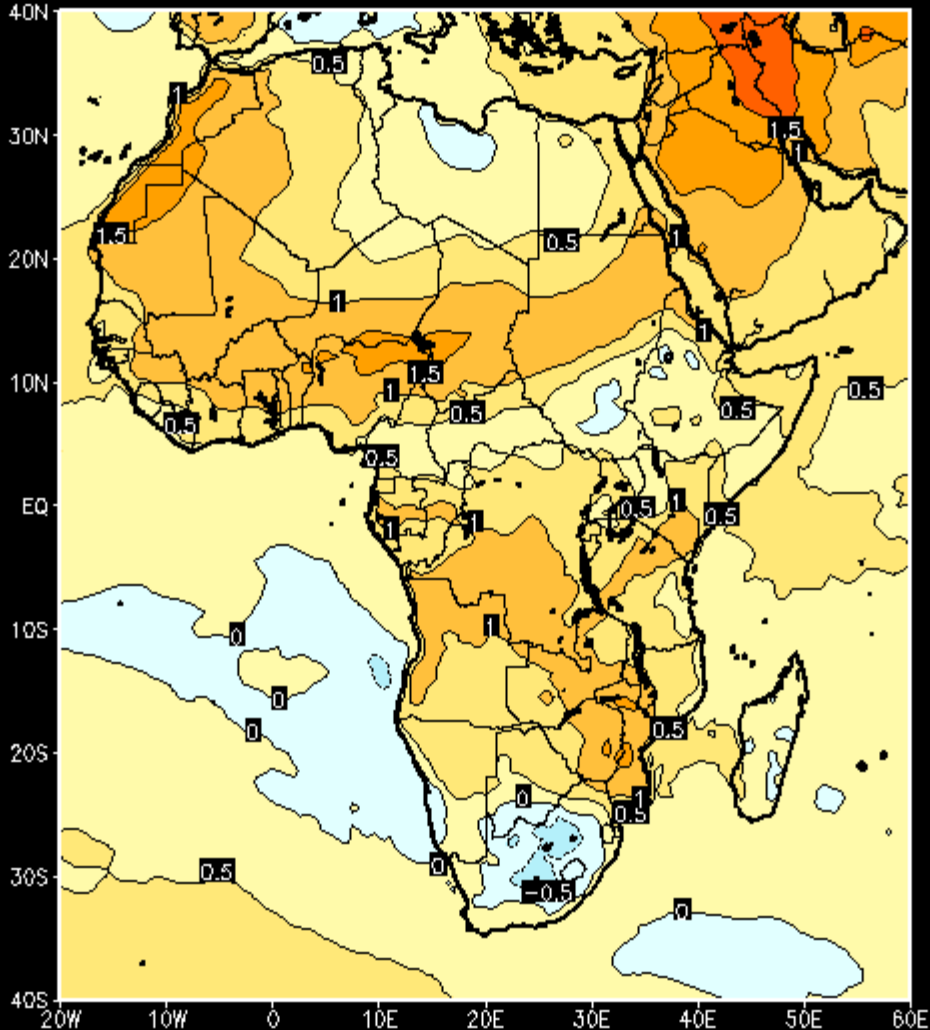
# Temp anomaly 2010



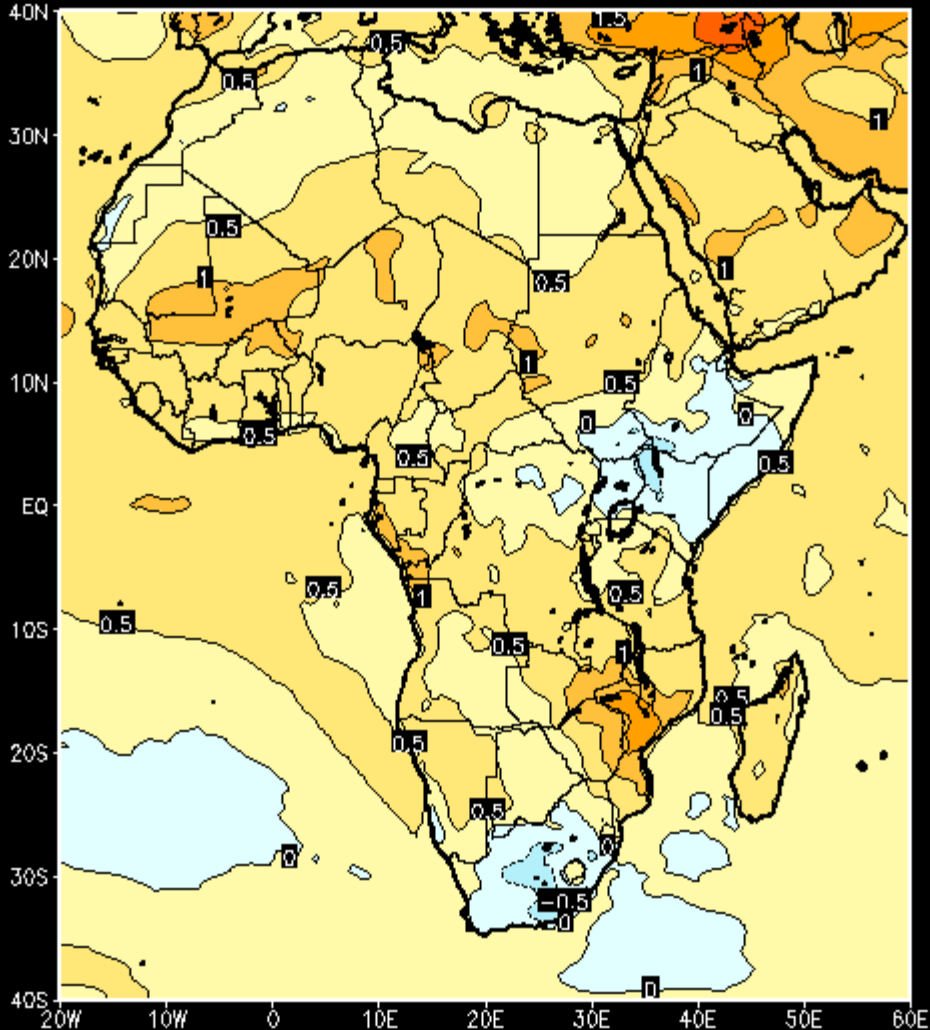
# Temp anomaly 2011



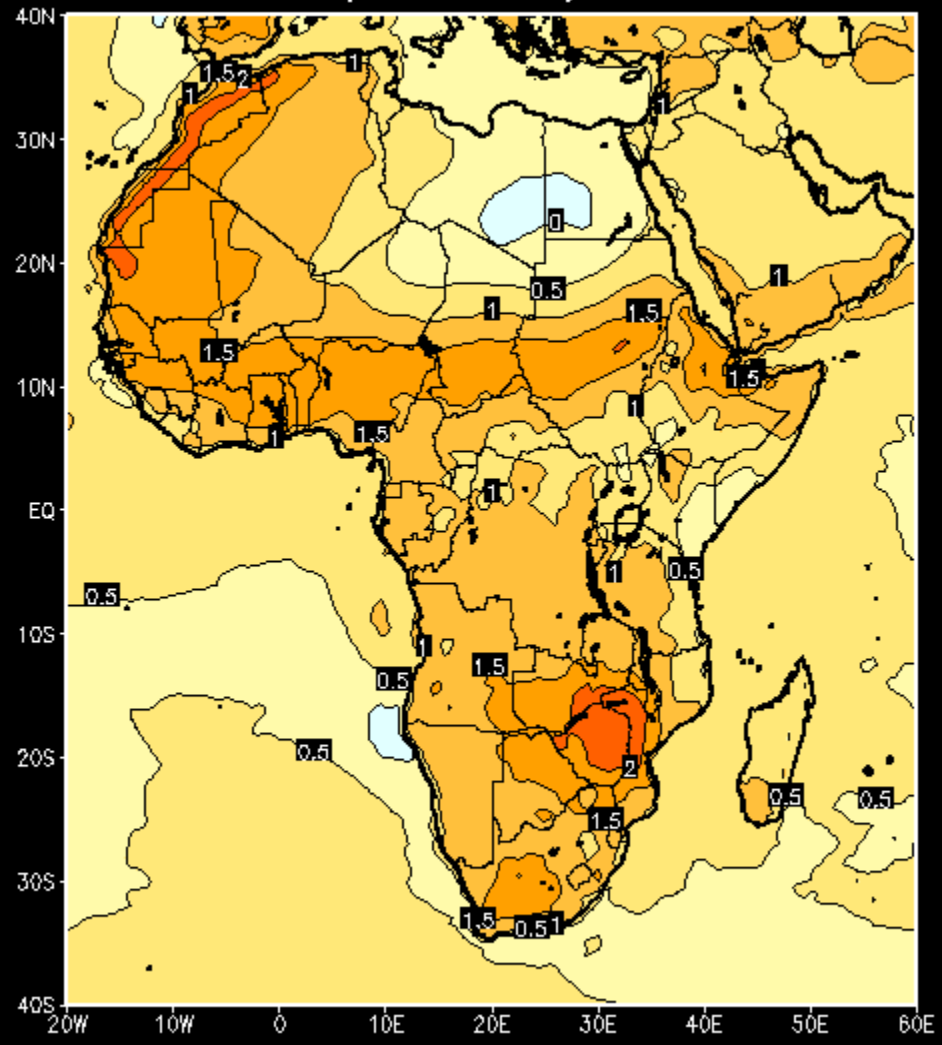
# Temp anomaly 2012



# Temp anomaly 2013

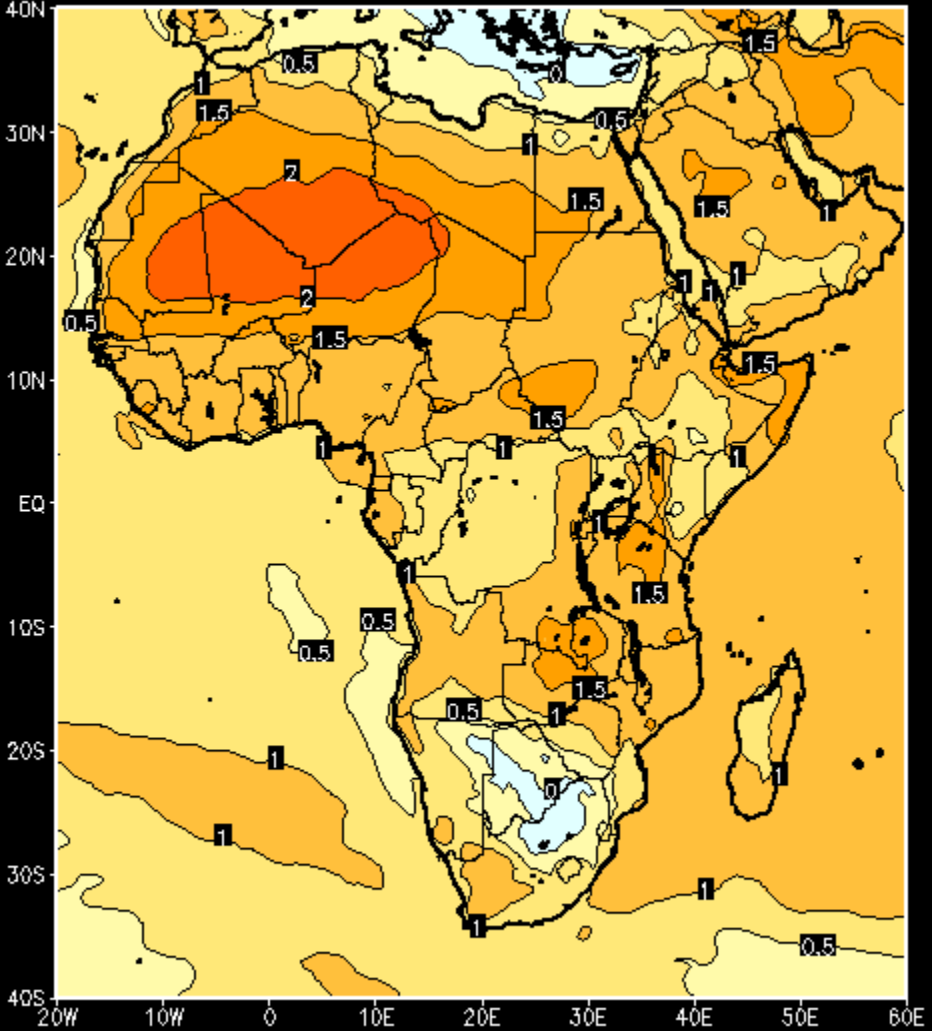


# Temp anomaly 2014

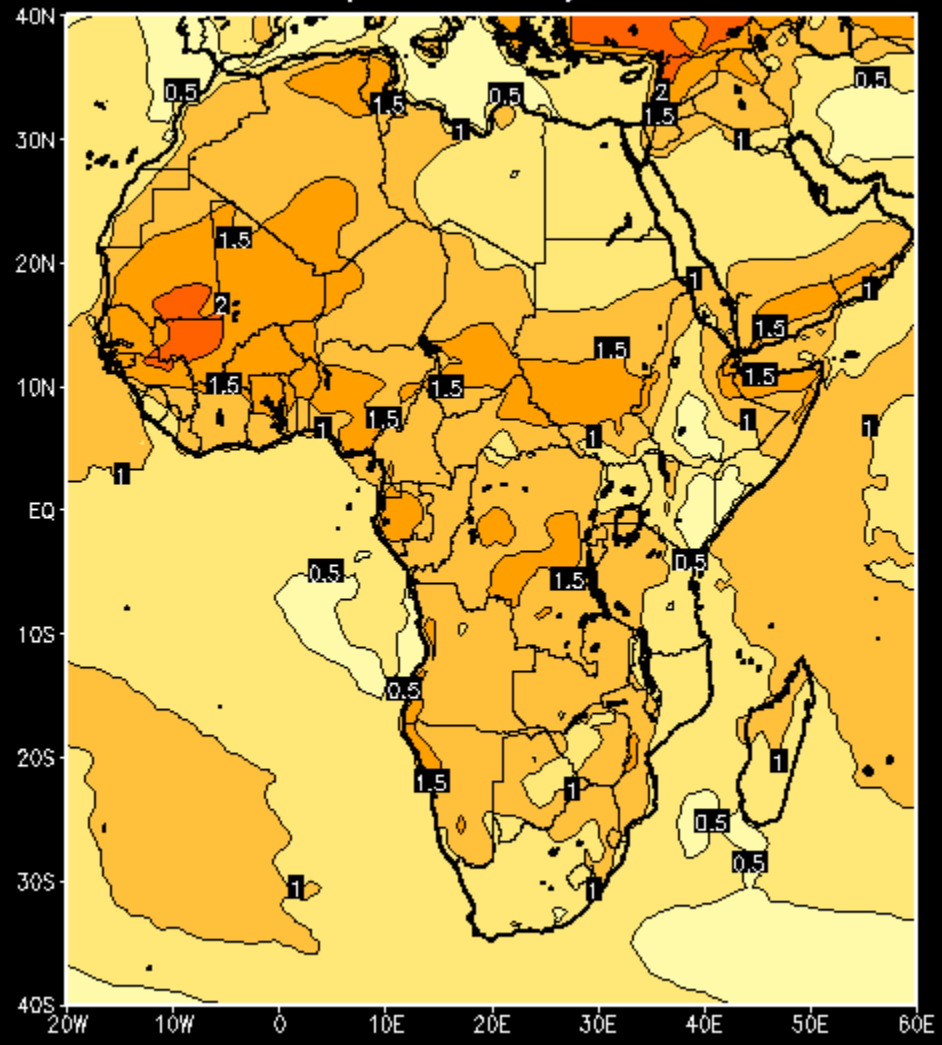




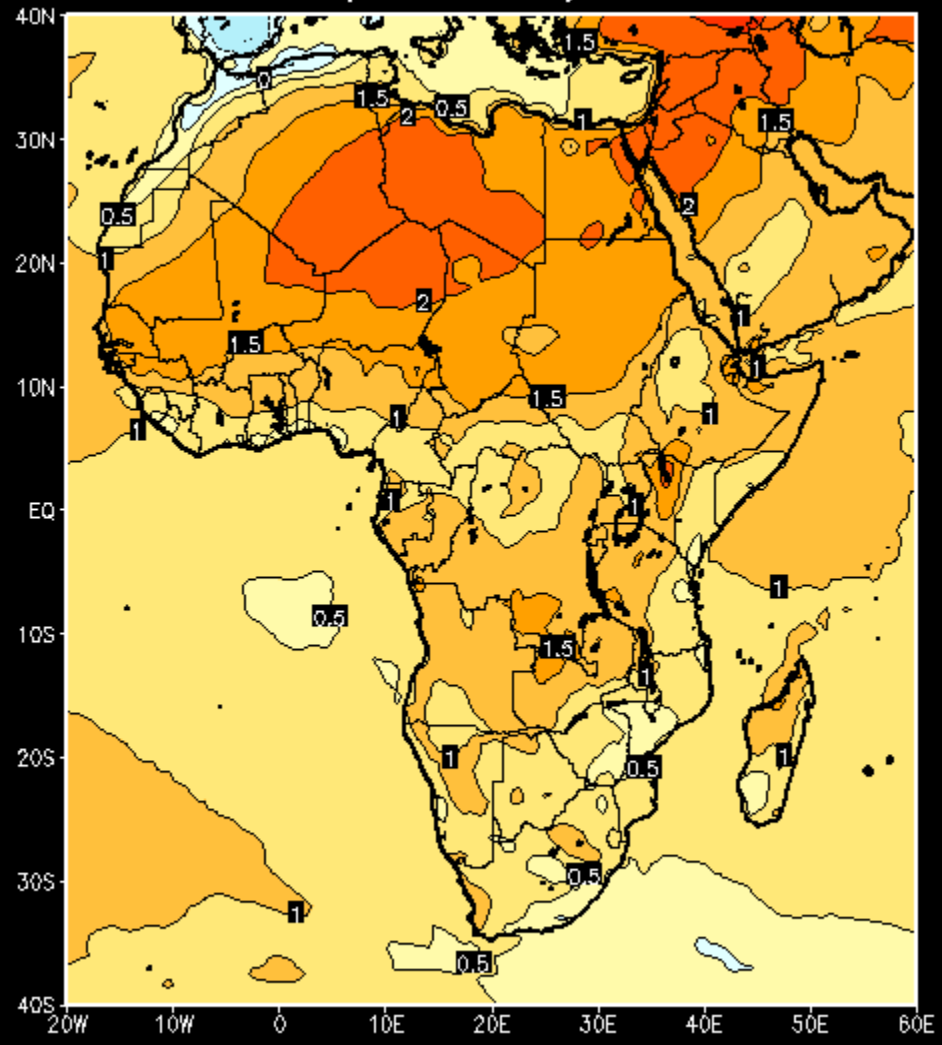
# Temp anomaly 2015



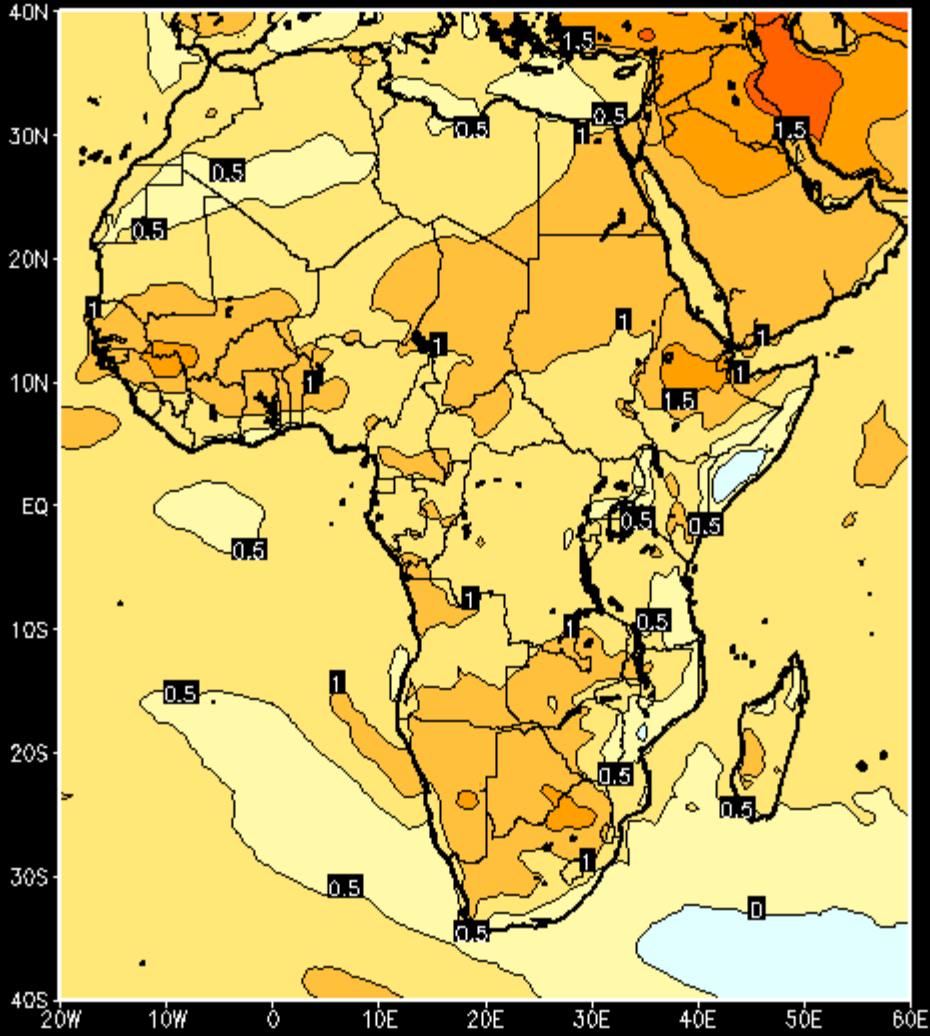
# Temp anomaly 2016



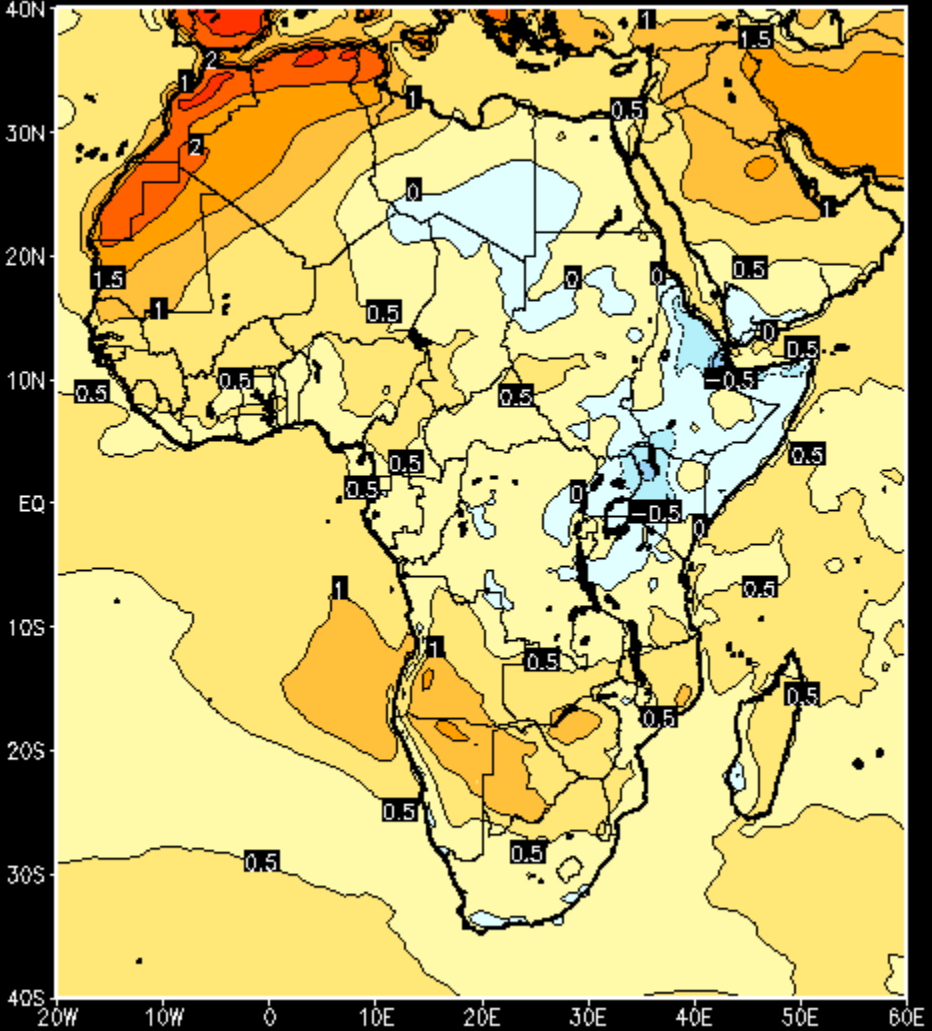
# Temp anomaly 2017



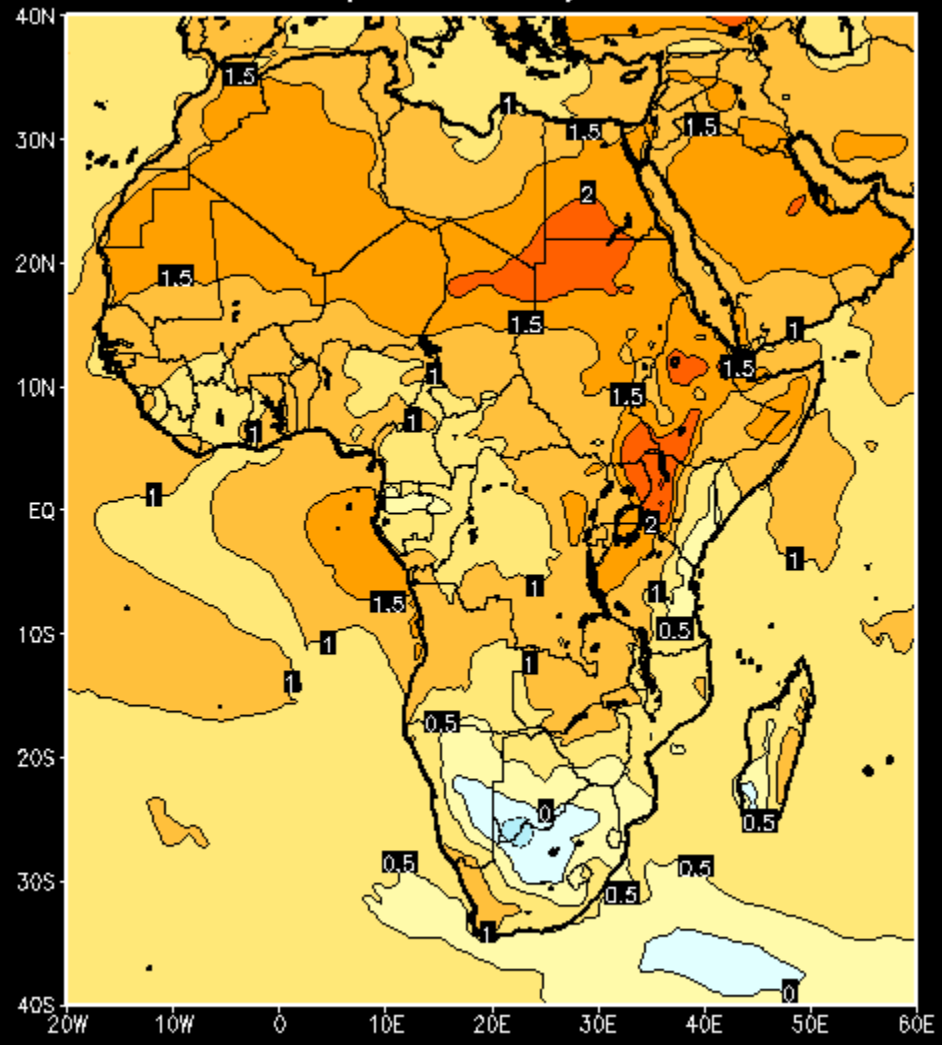
# Temp anomaly 2018



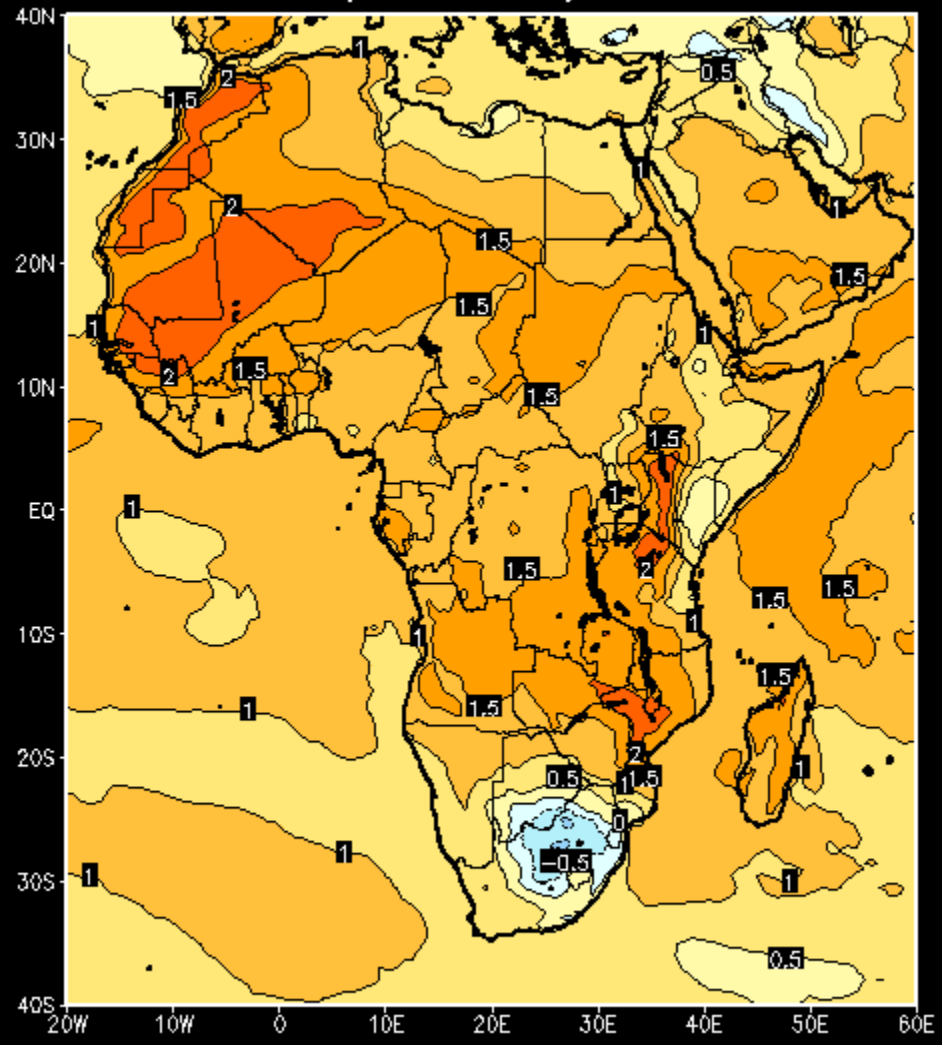
# Temp anomaly 2019



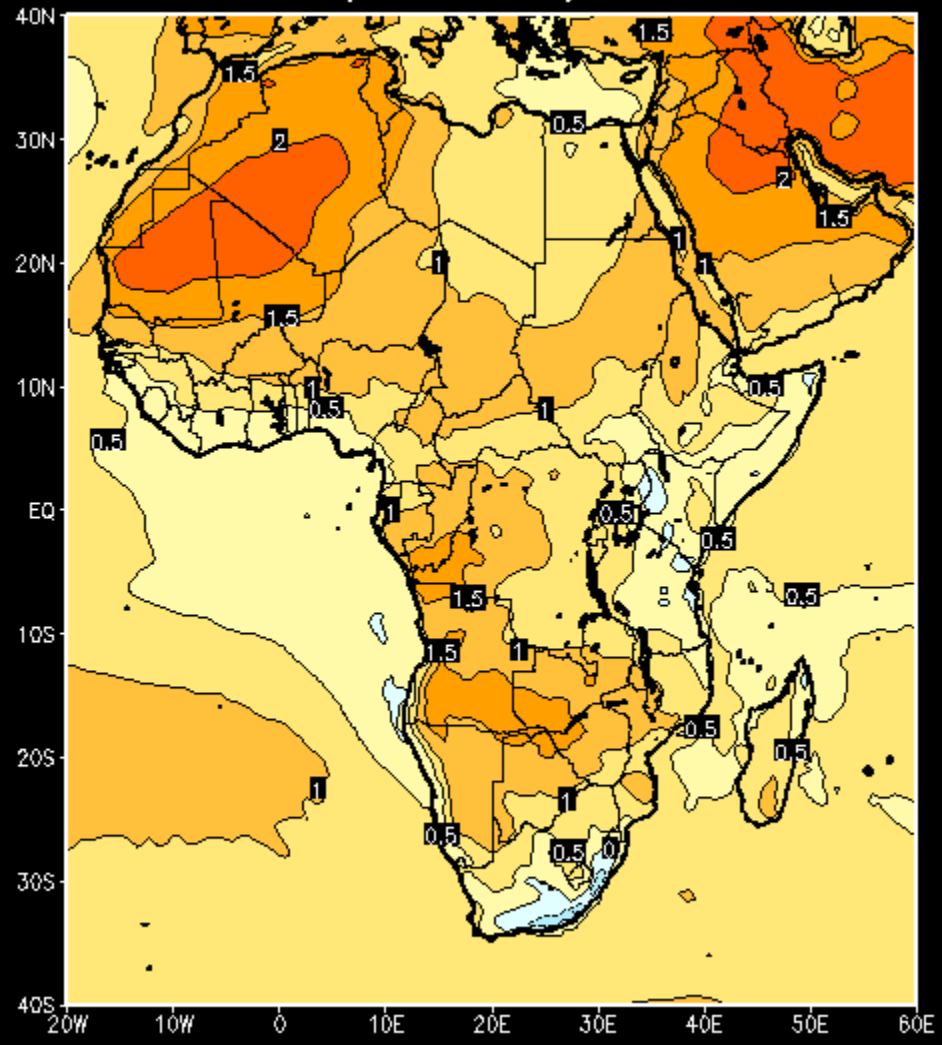
# Temp anomaly 2020



# Temp anomaly 2021

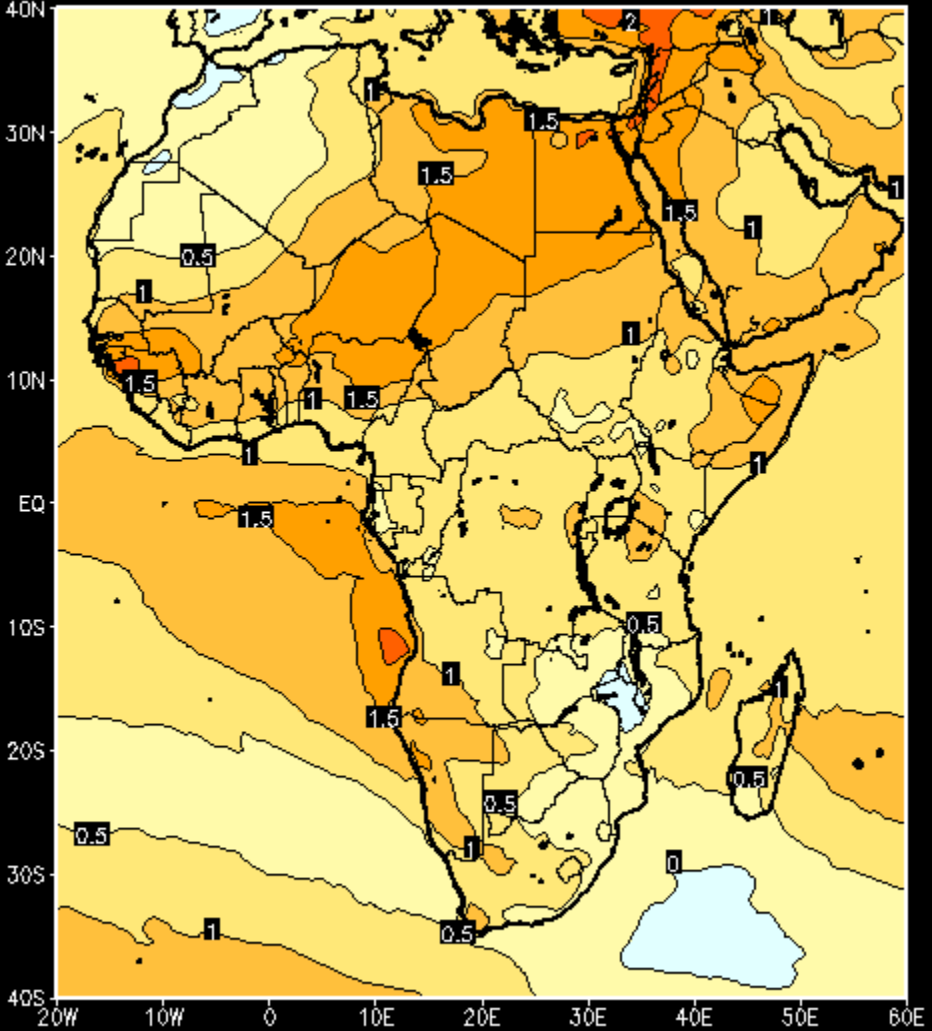


# Temp anomaly 2022

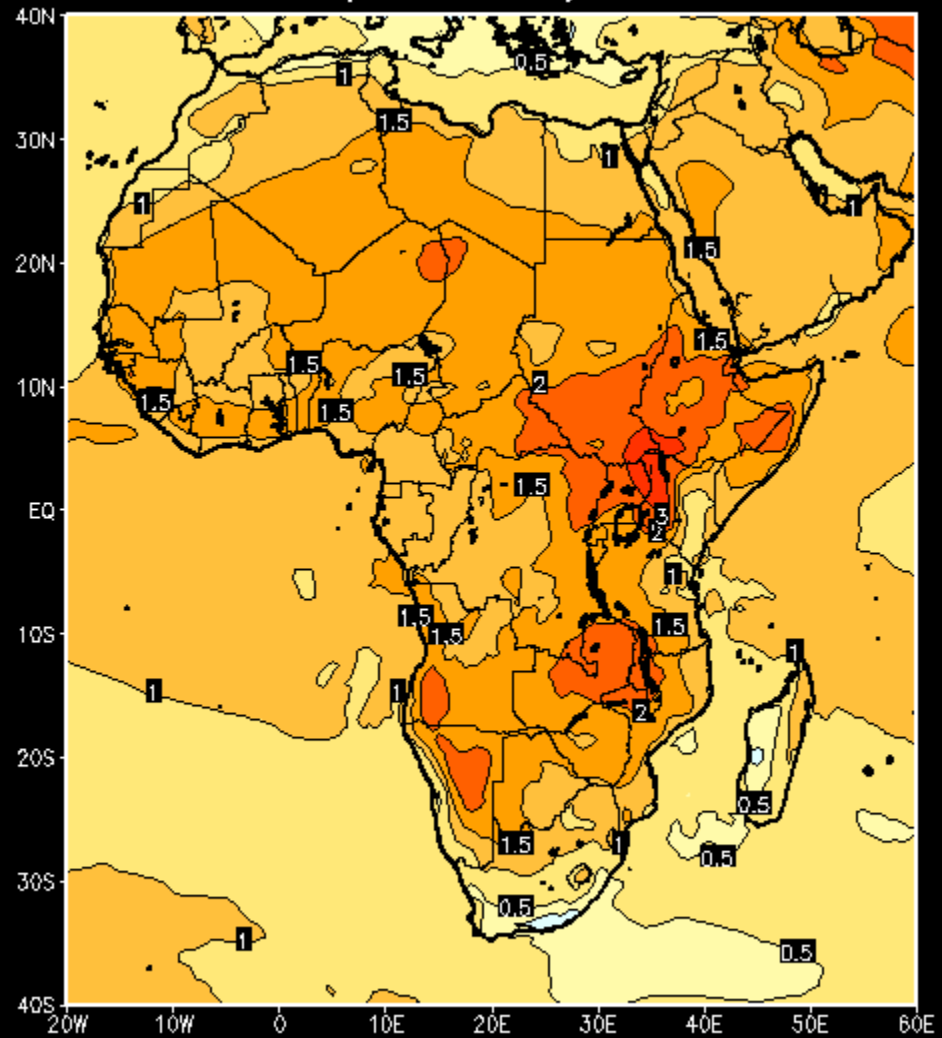




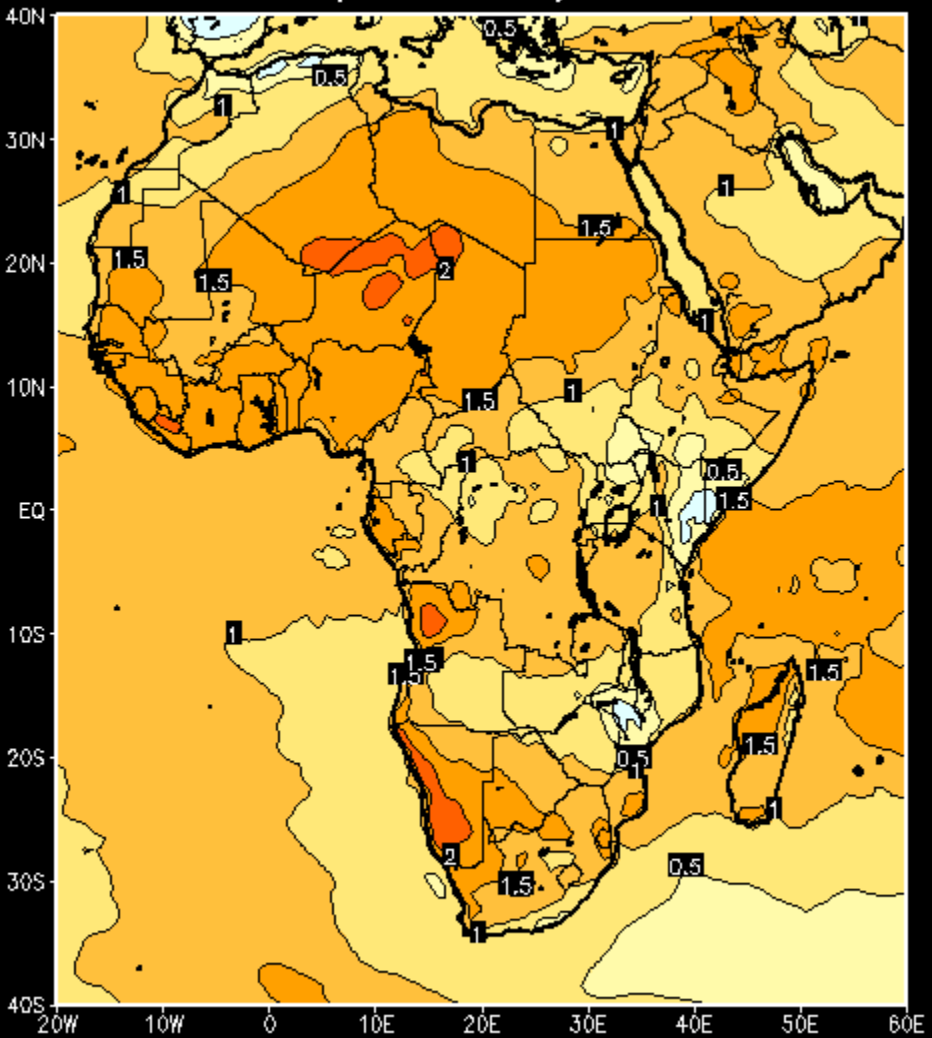
# Temp anomaly 2023



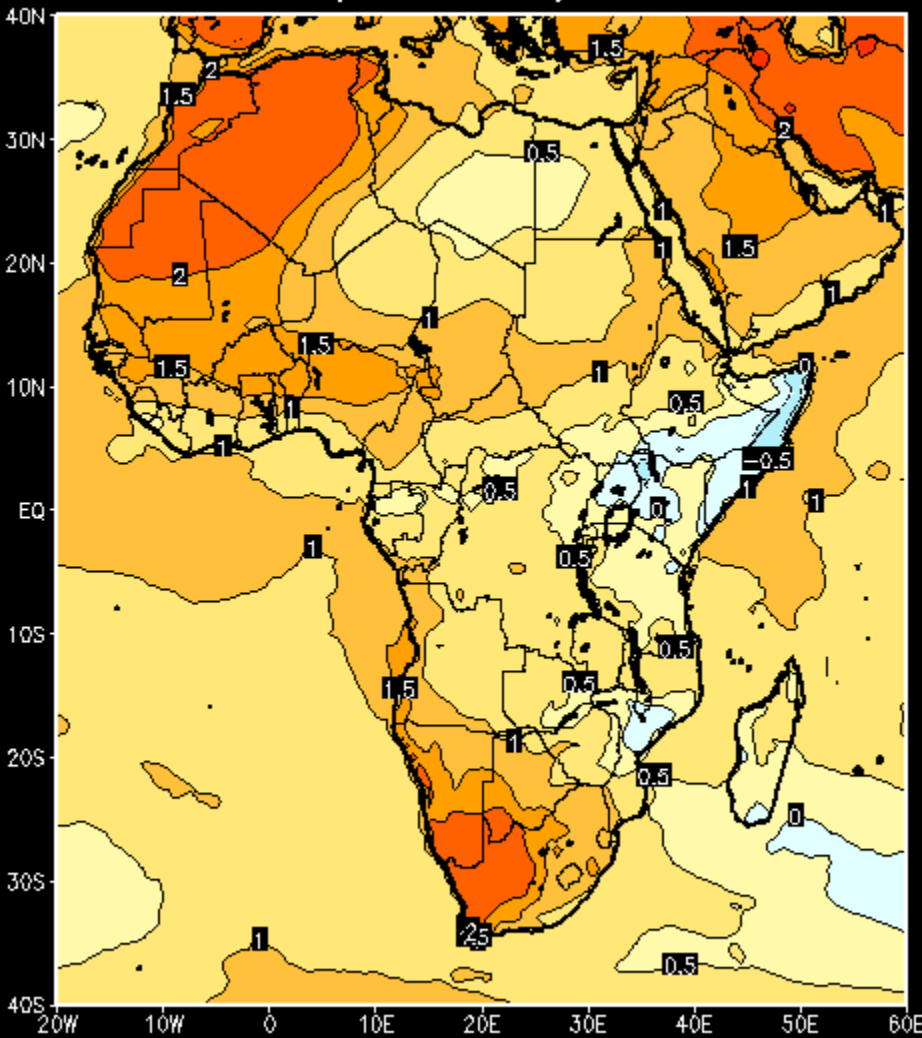
# Temp anomaly 2024



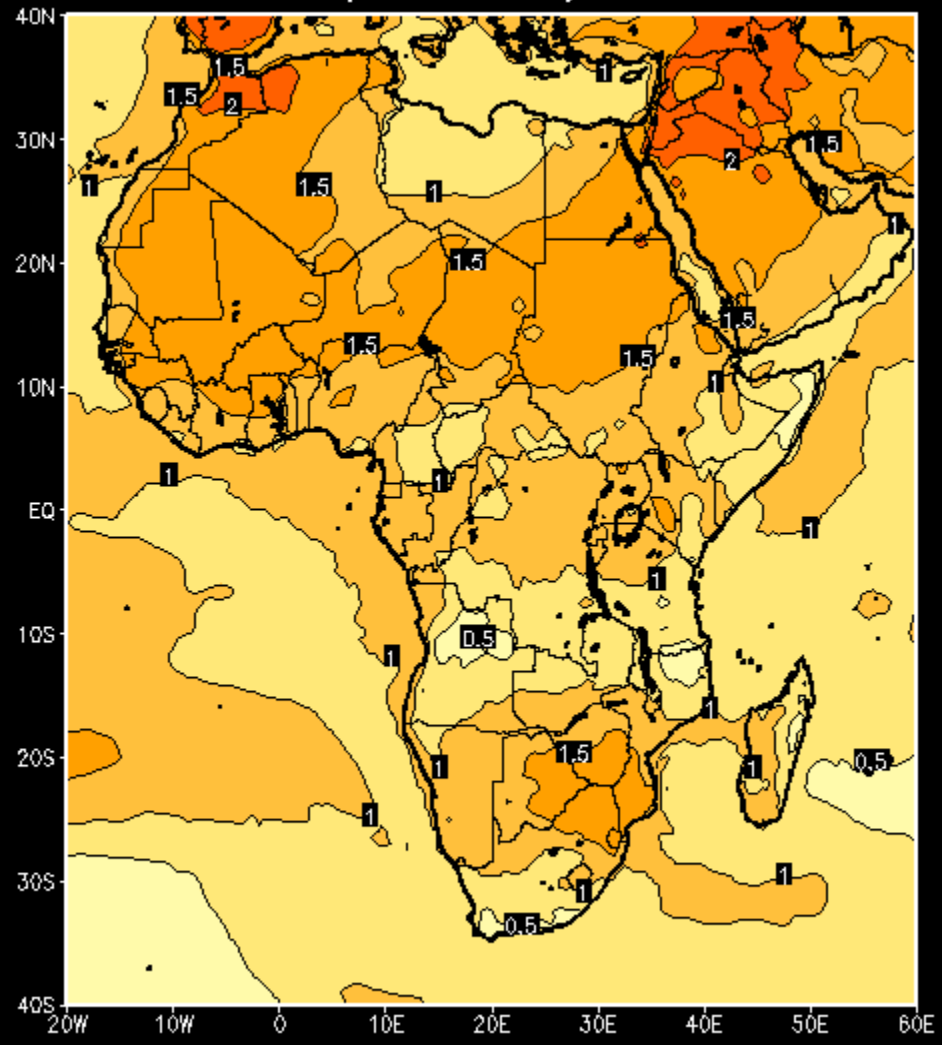
# Temp anomaly 2025



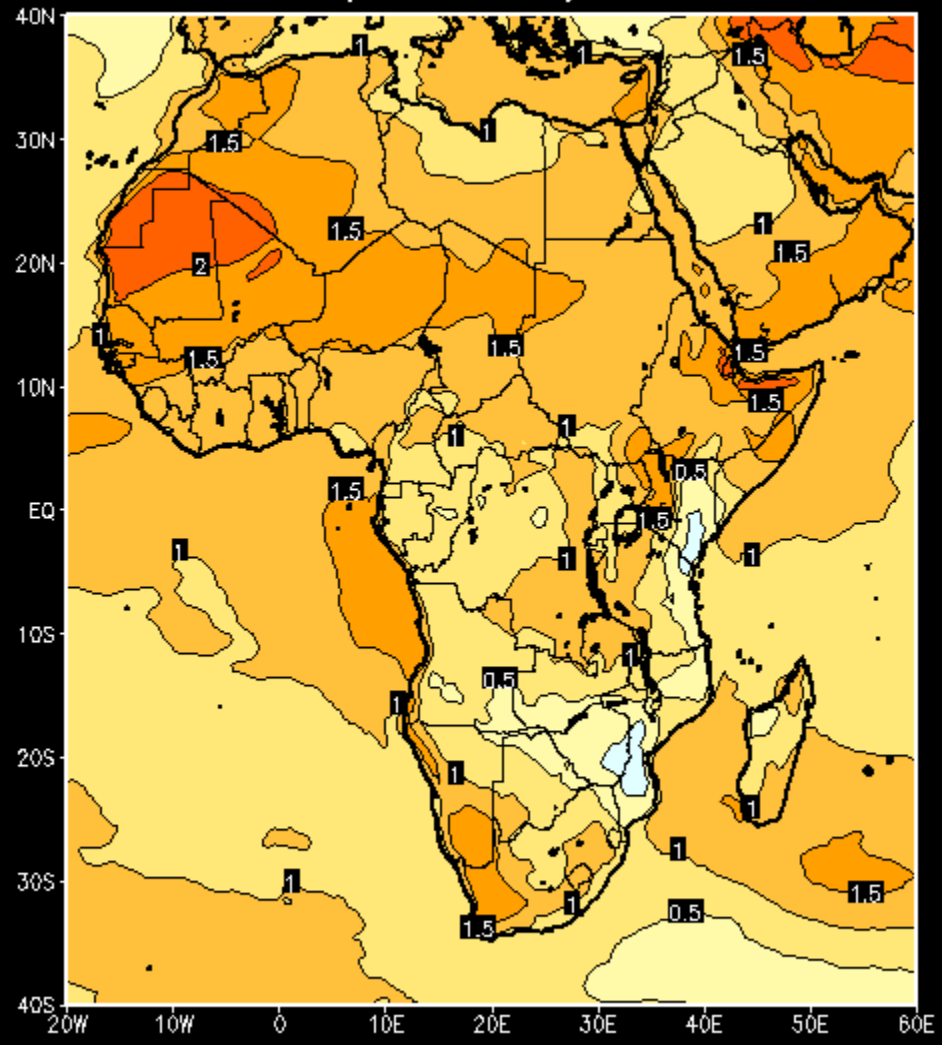
# Temp anomaly 2026



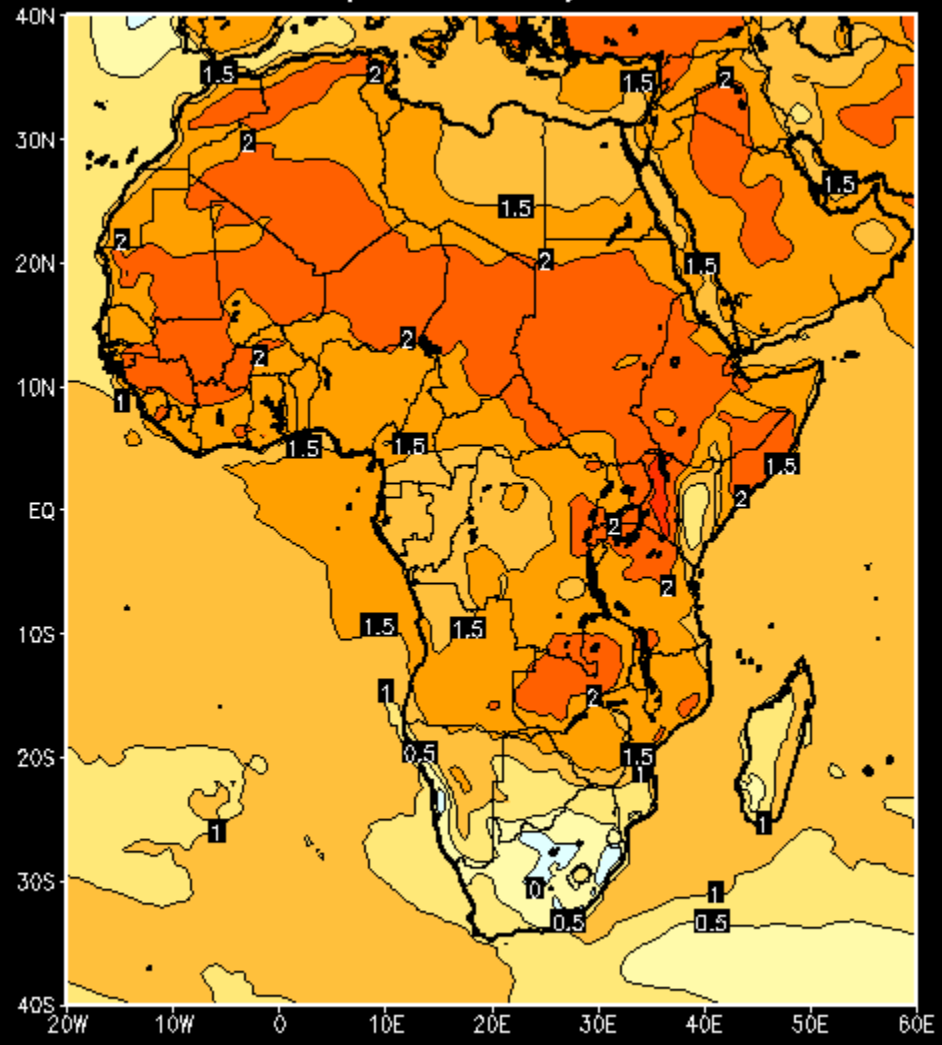
# Temp anomaly 2027



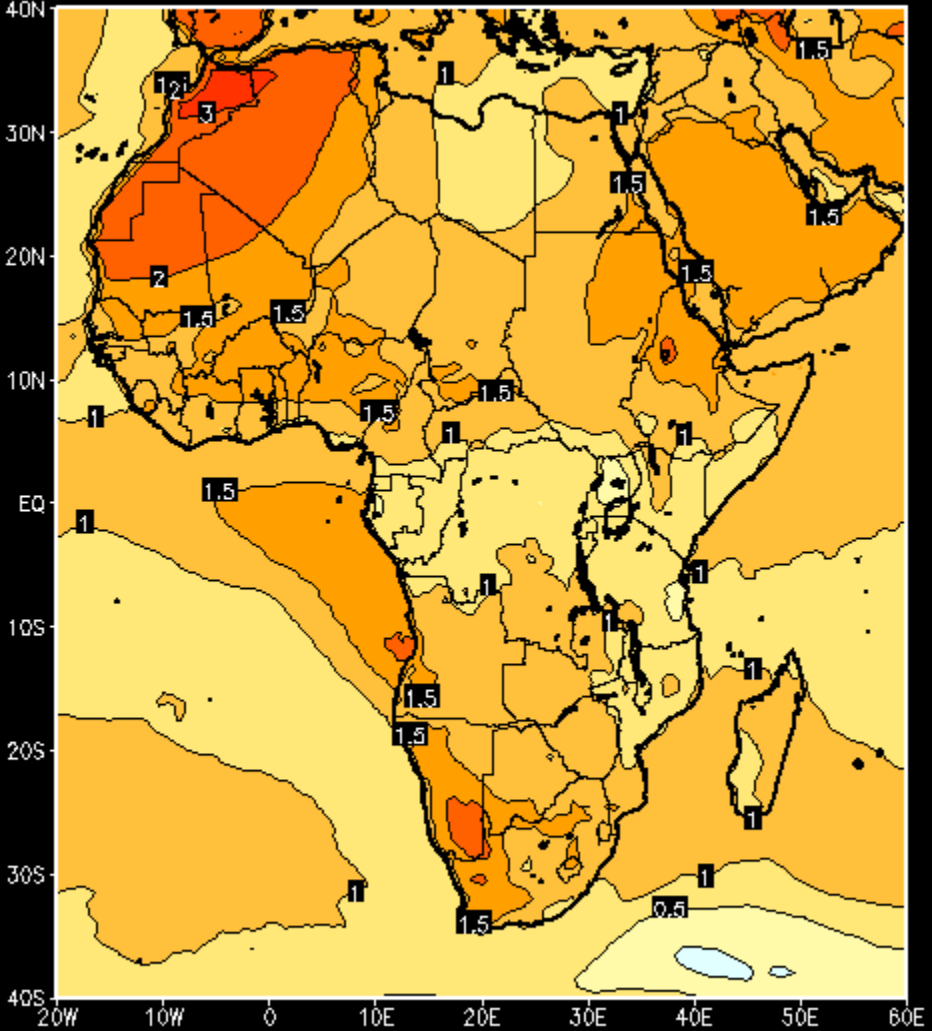
# Temp anomaly 2028



# Temp anomaly 2029

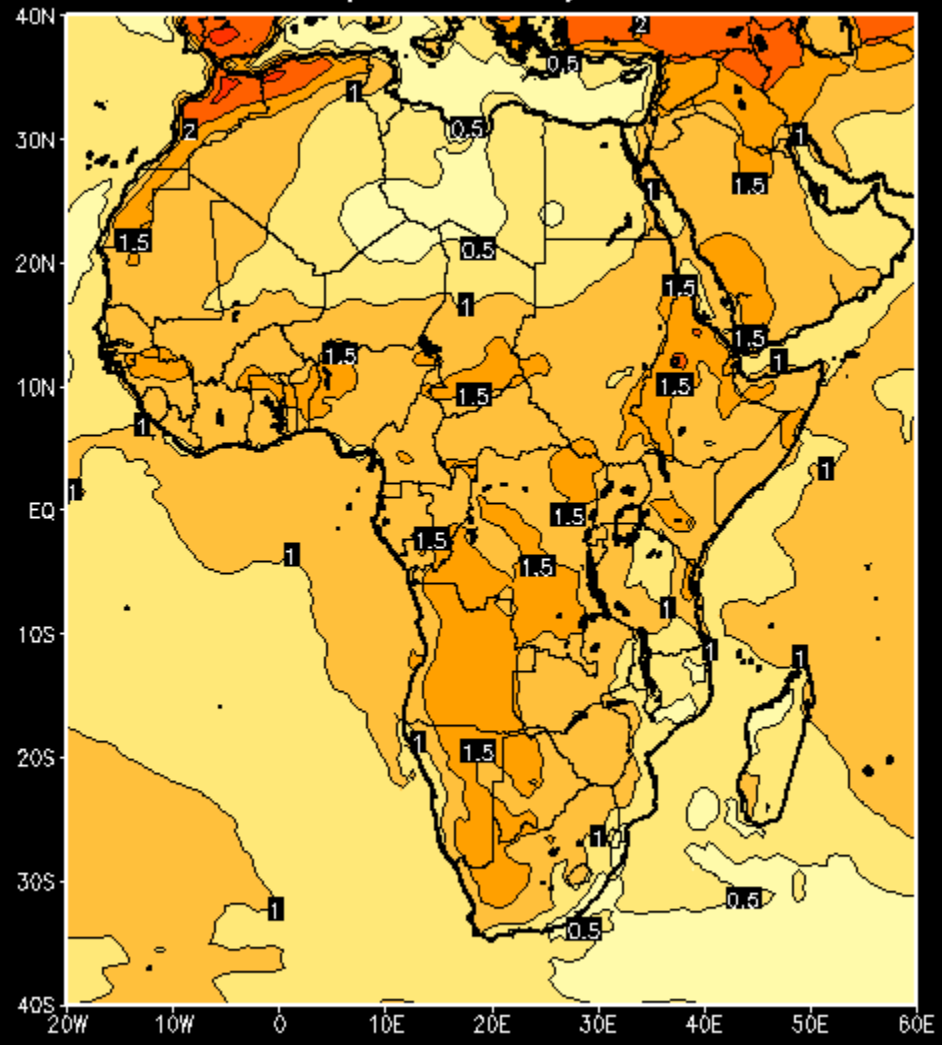


# Temp anomaly 2030

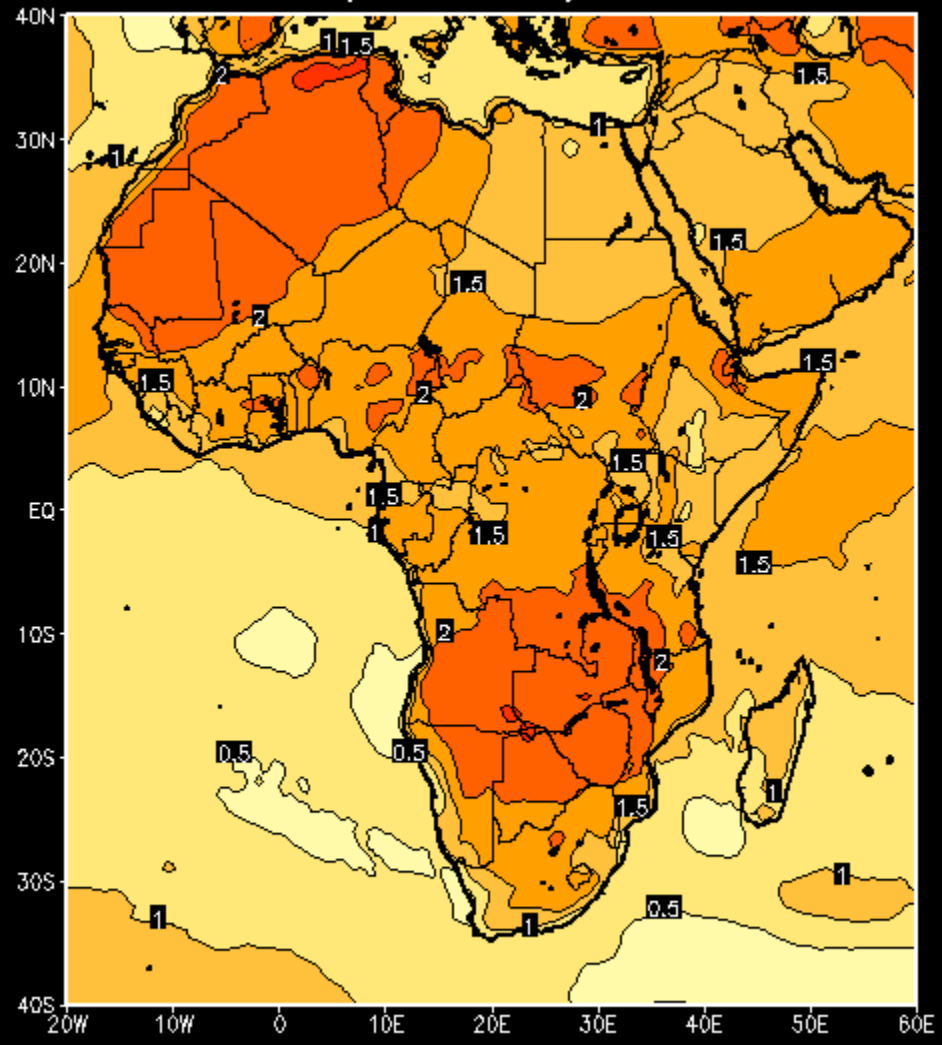




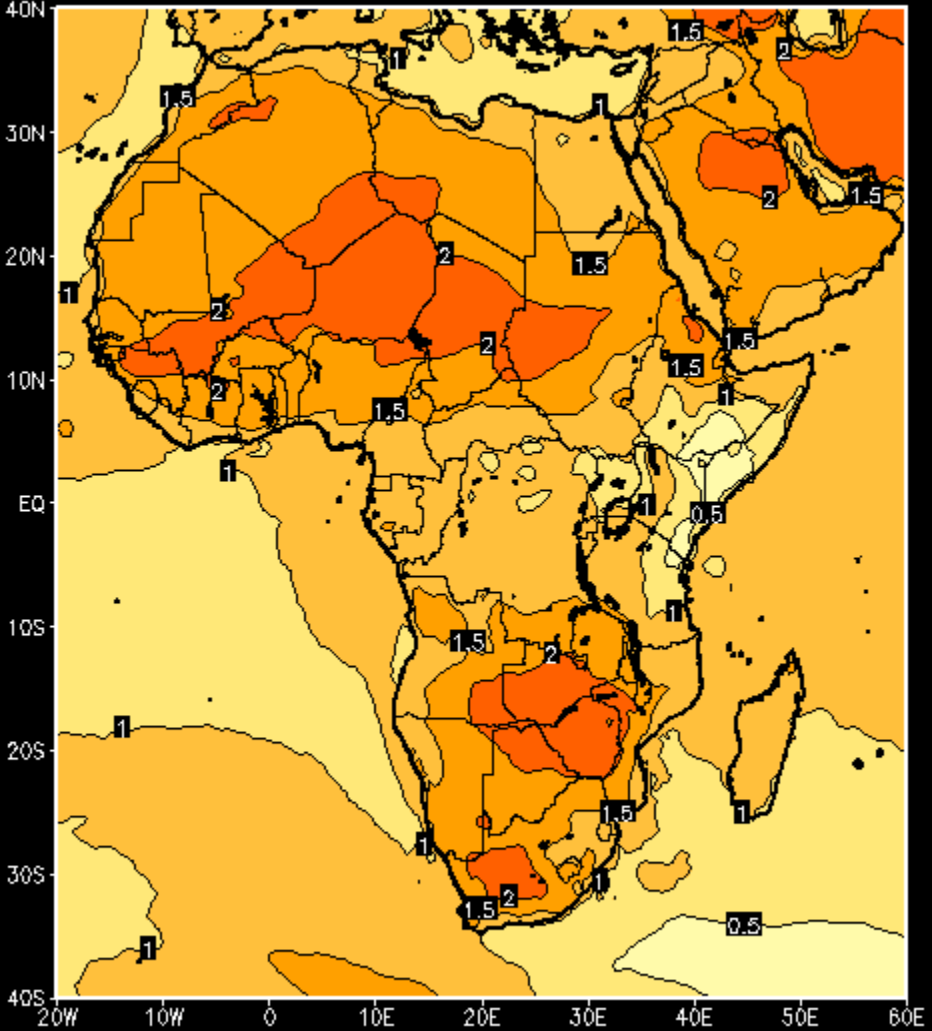
# Temp anomaly 2031



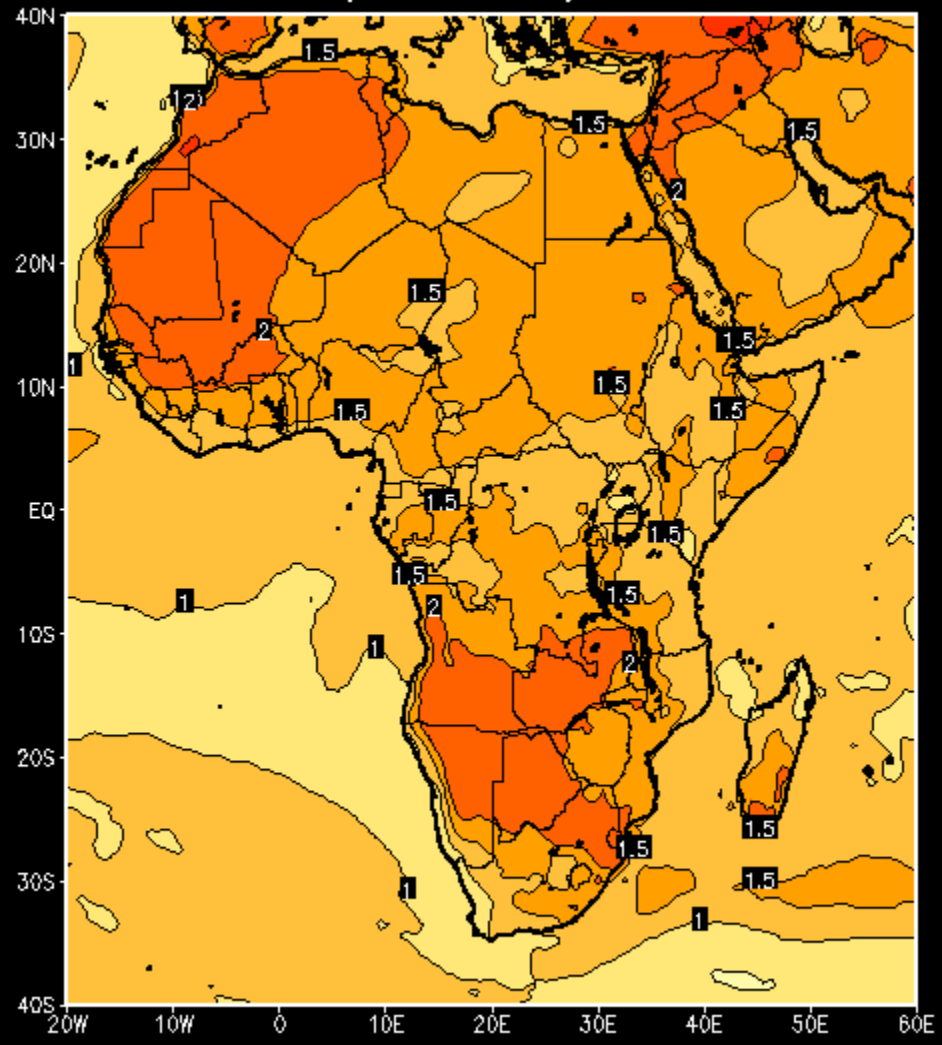
# Temp anomaly 2032



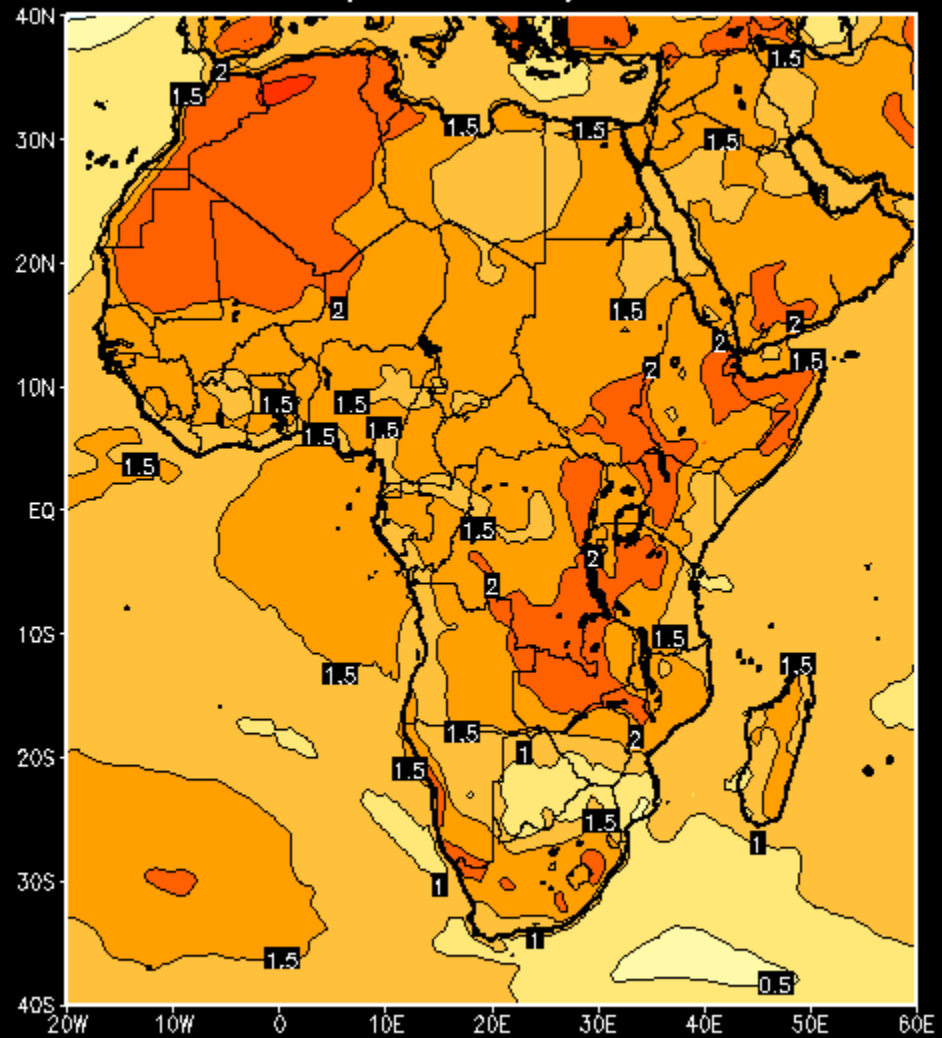
# Temp anomaly 2033



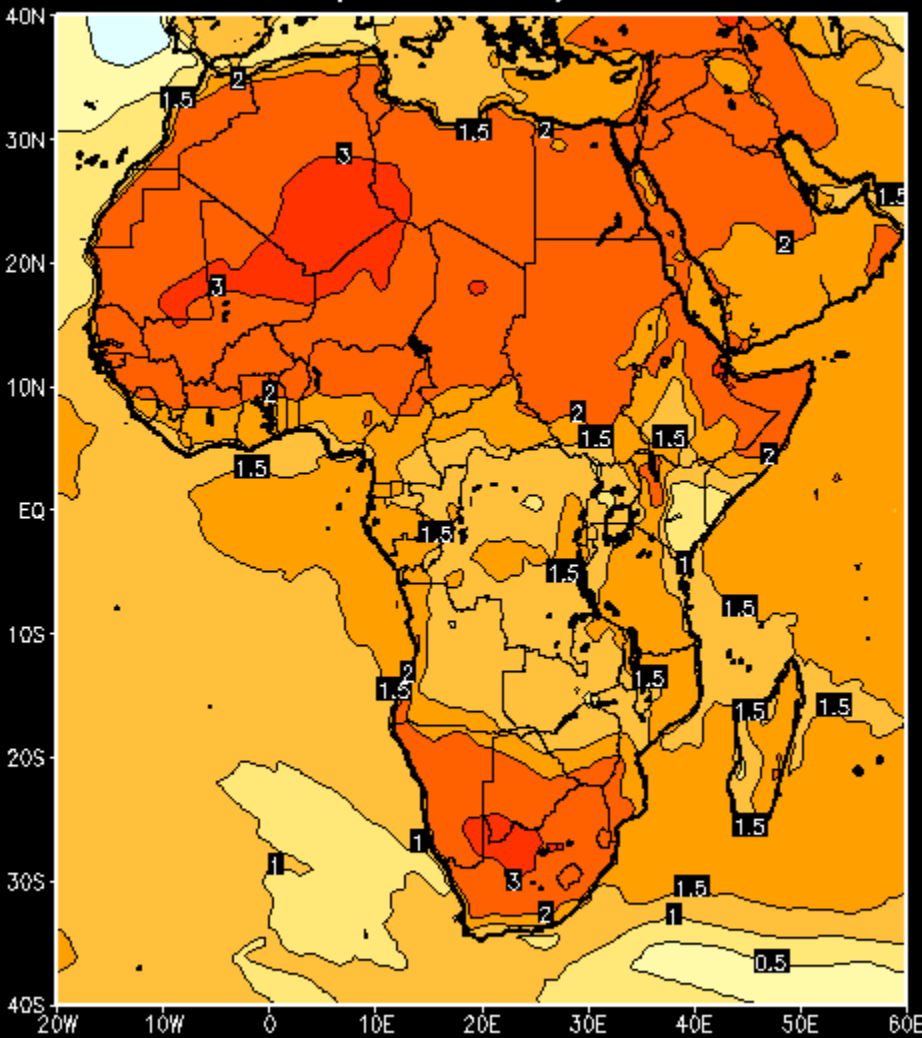
# Temp anomaly 2034



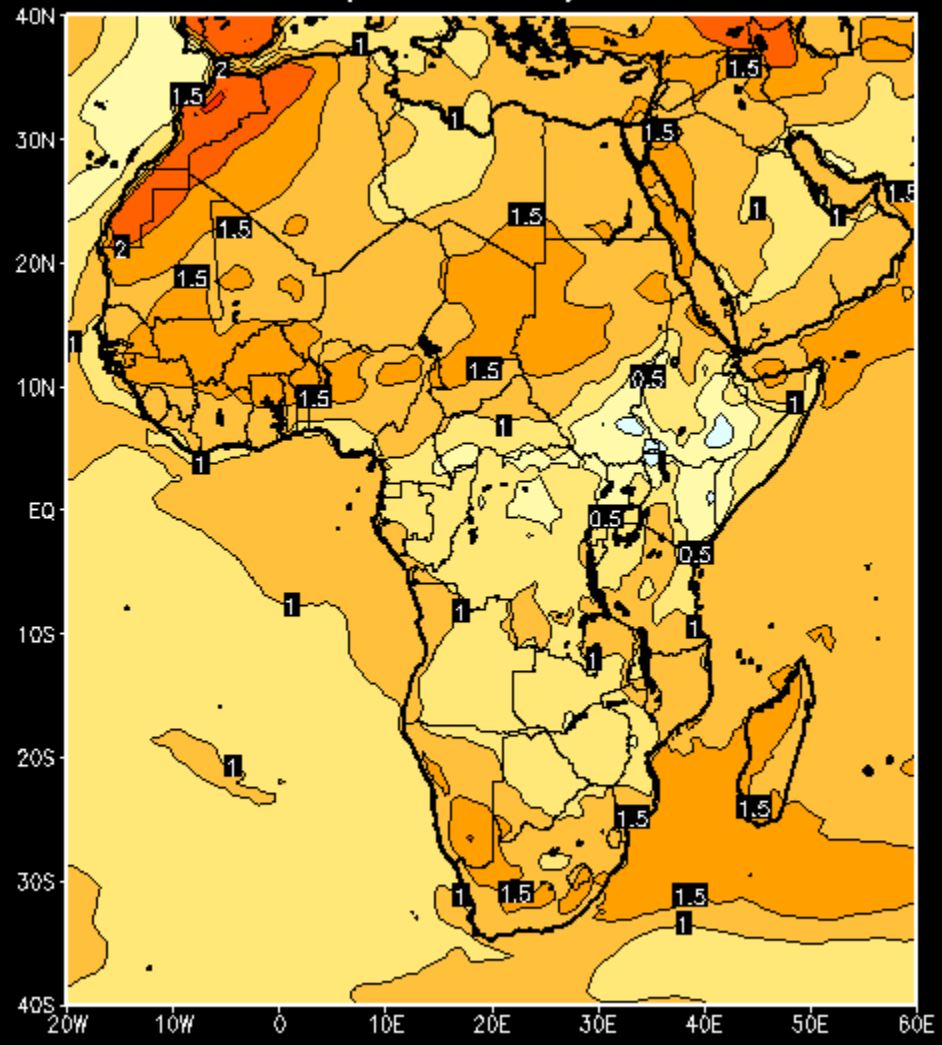
# Temp anomaly 2035



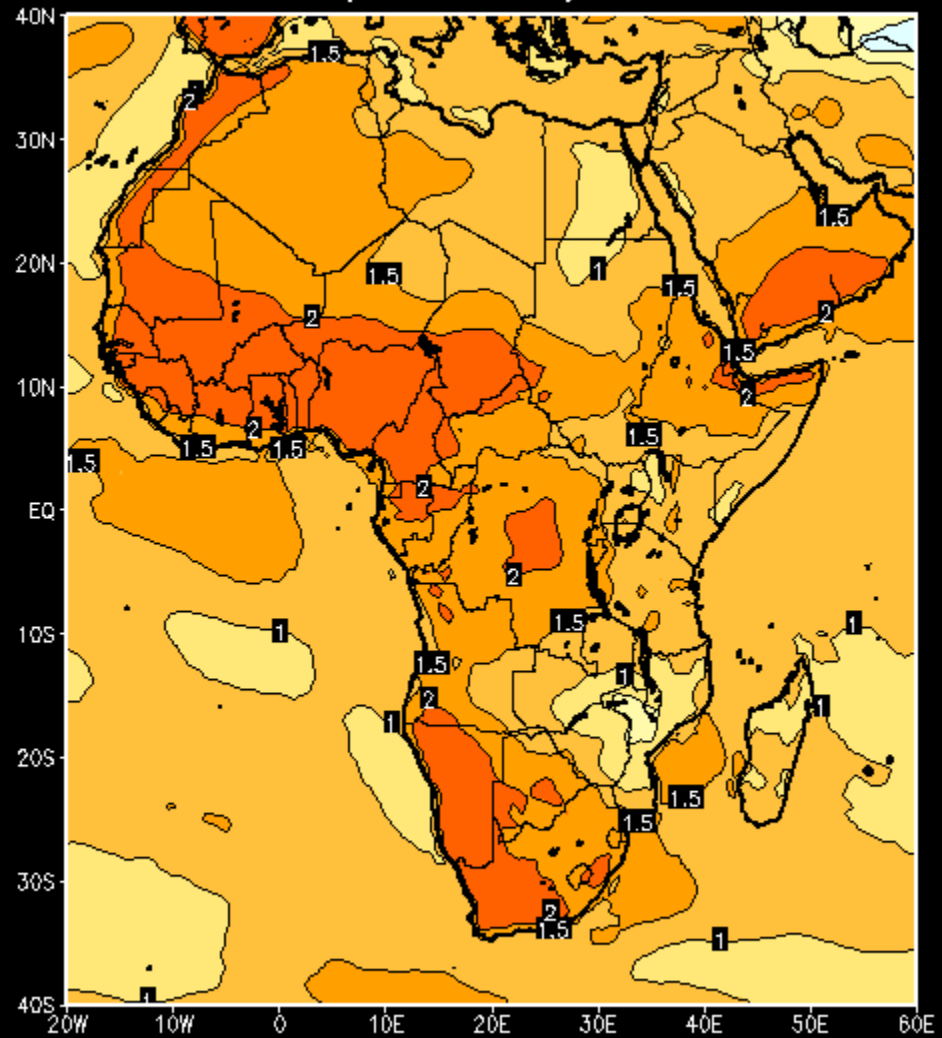
# Temp anomaly 2036



# Temp anomaly 2037

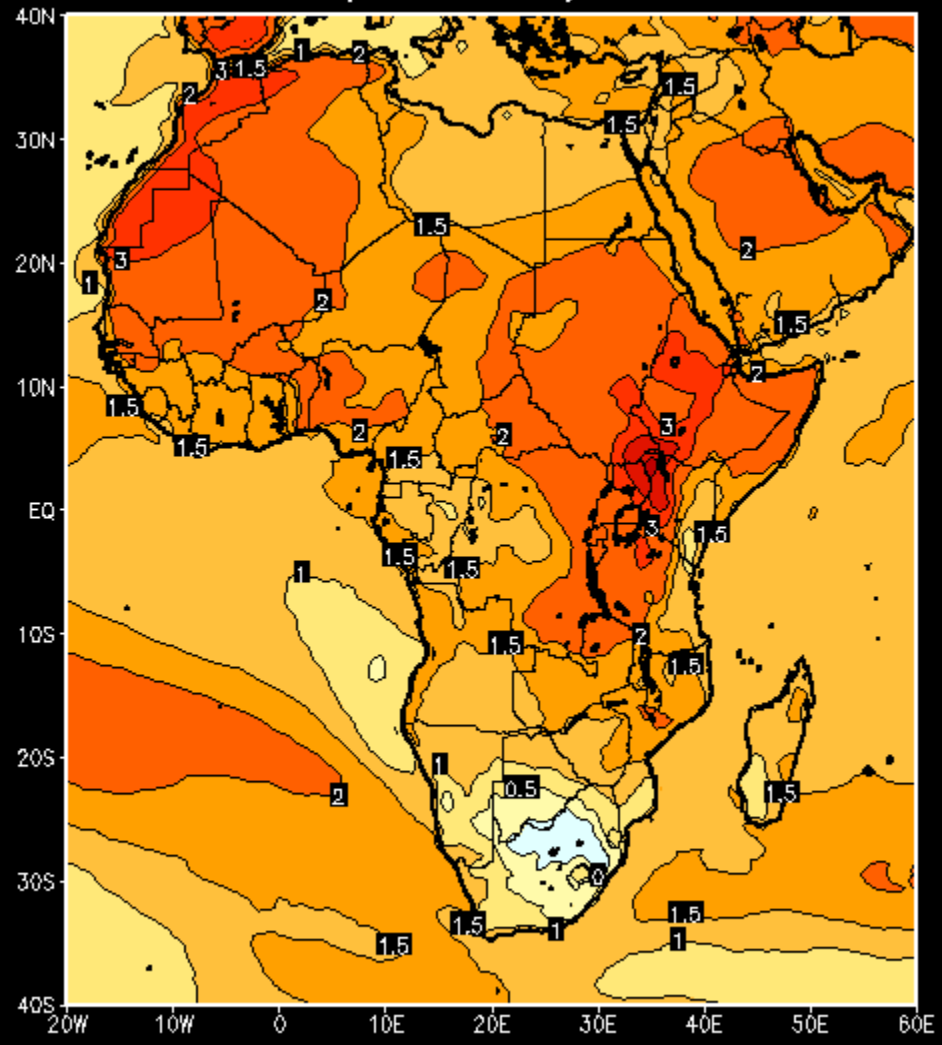


# Temp anomaly 2038

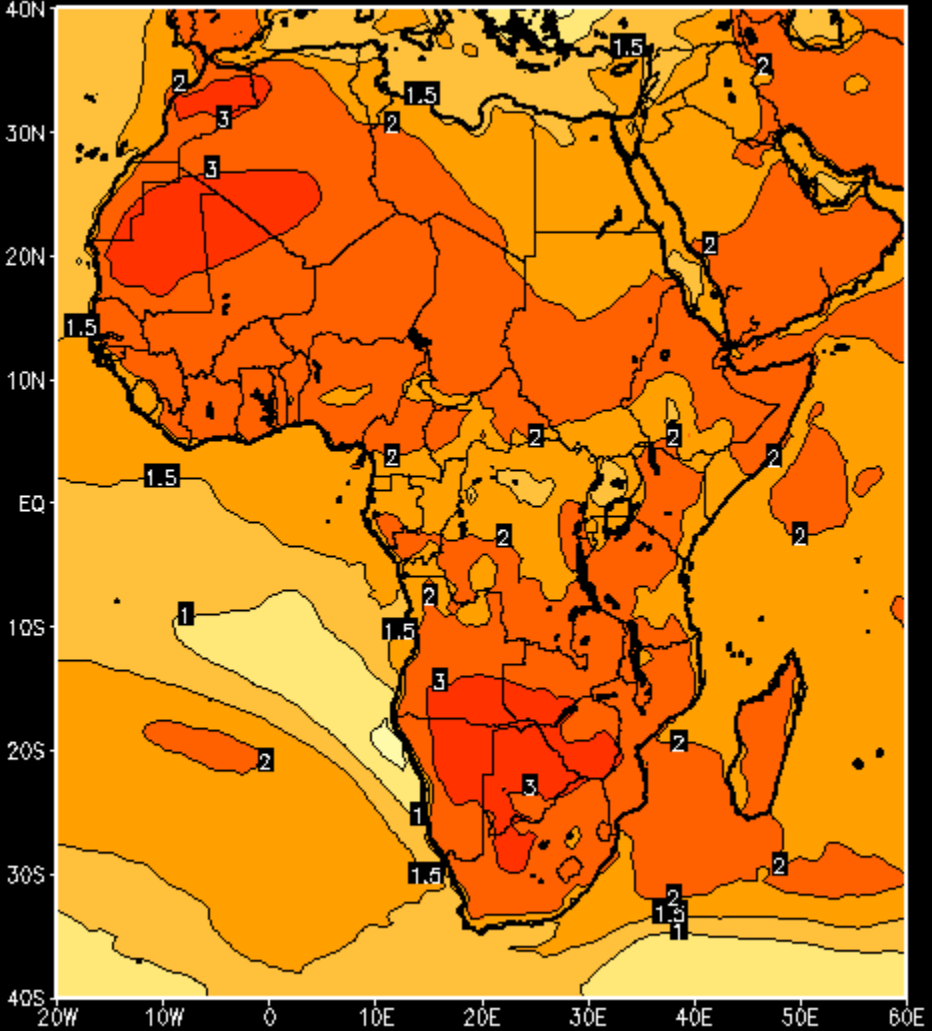




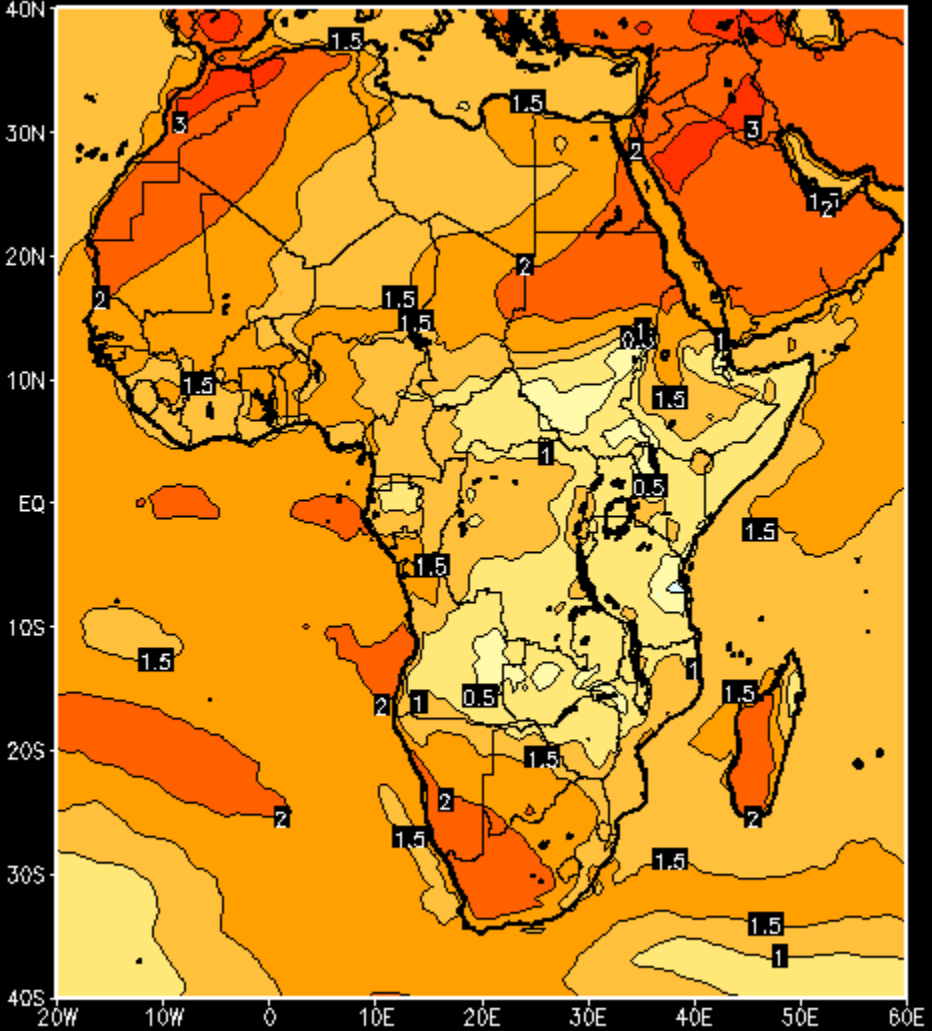
# Temp anomaly 2039



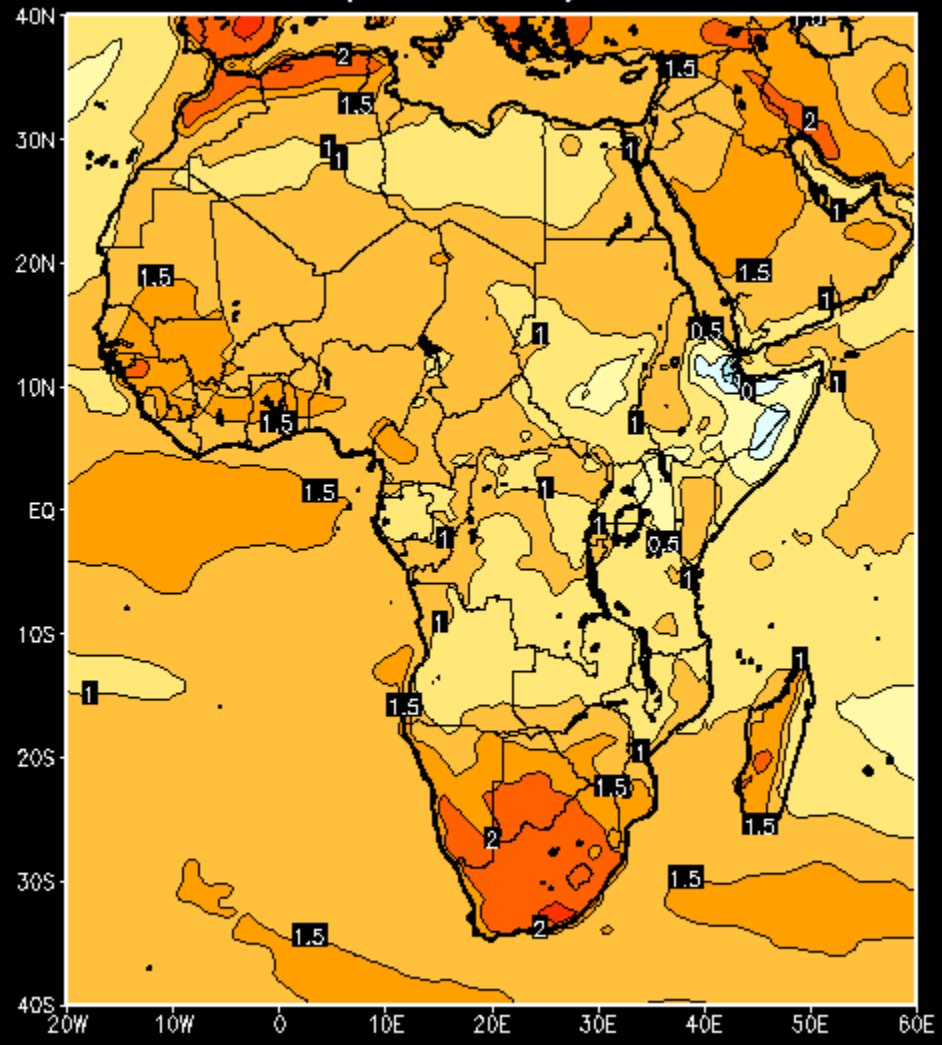
# Temp anomaly 2040



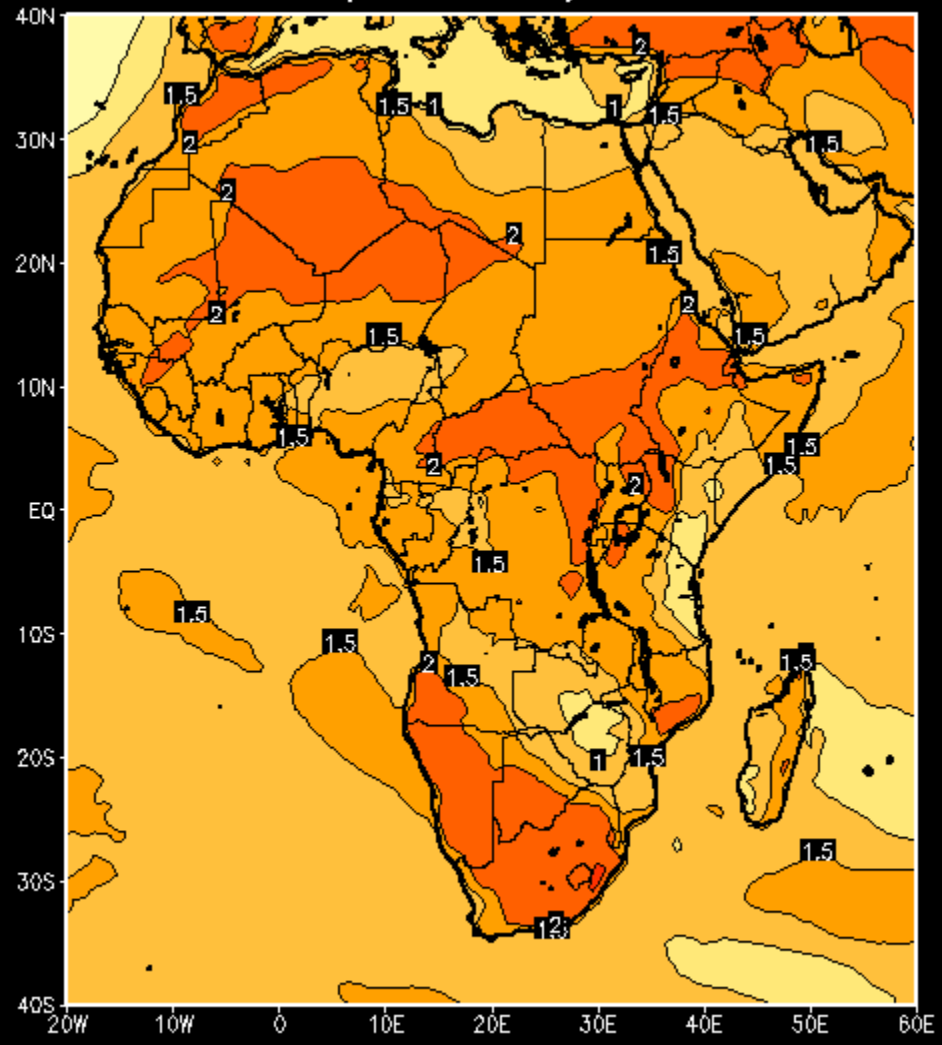
# Temp anomaly 2041



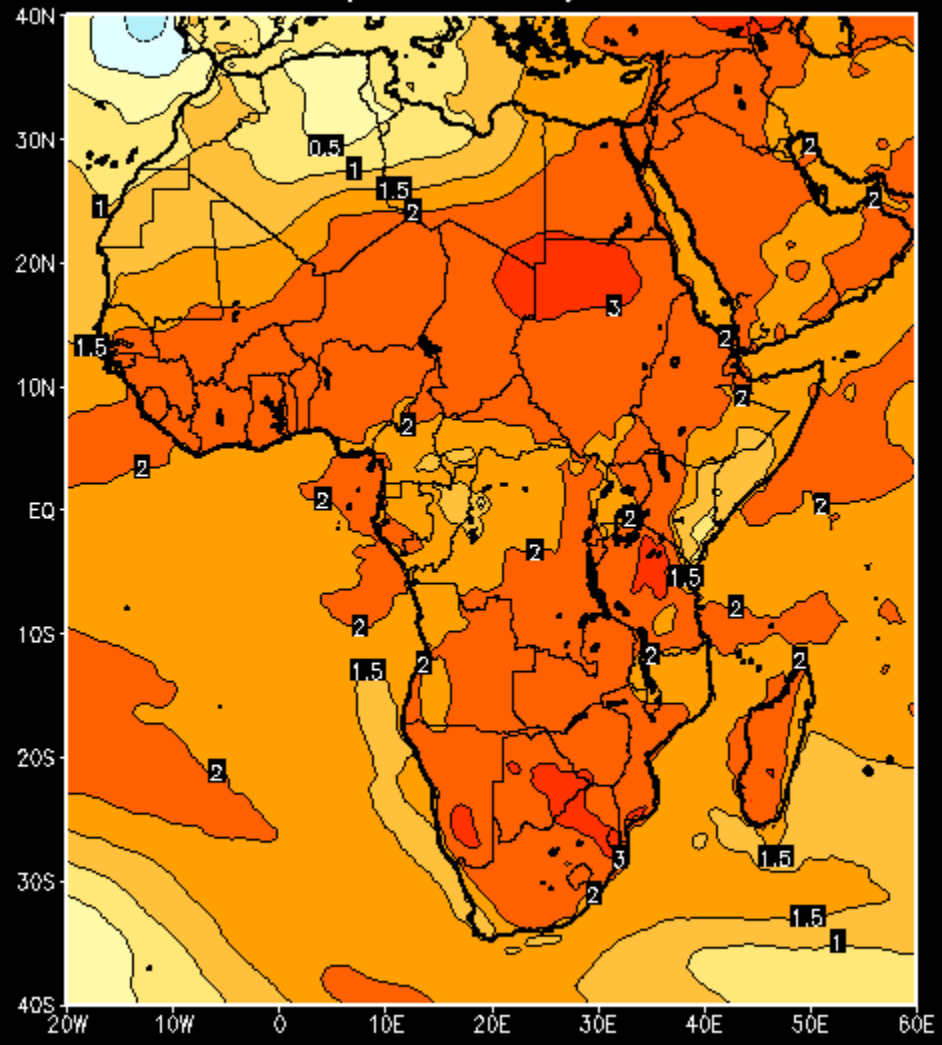
# Temp anomaly 2042



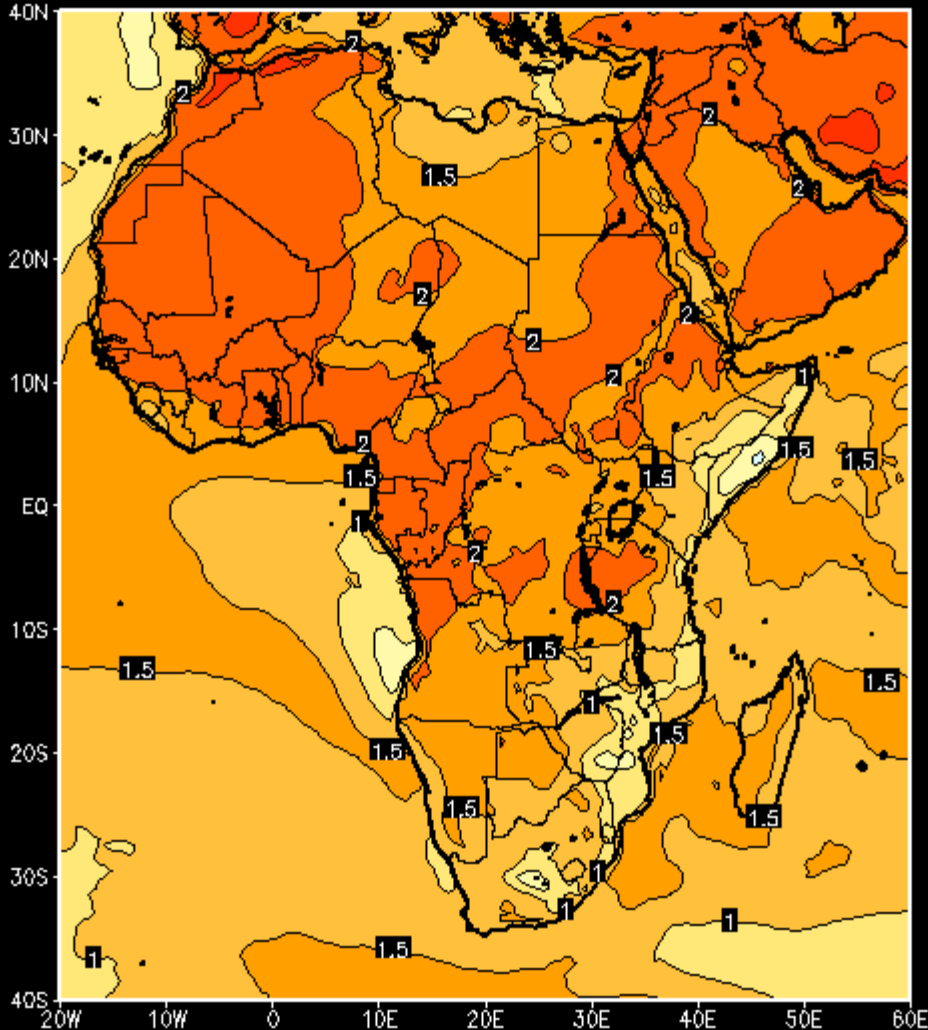
# Temp anomaly 2043



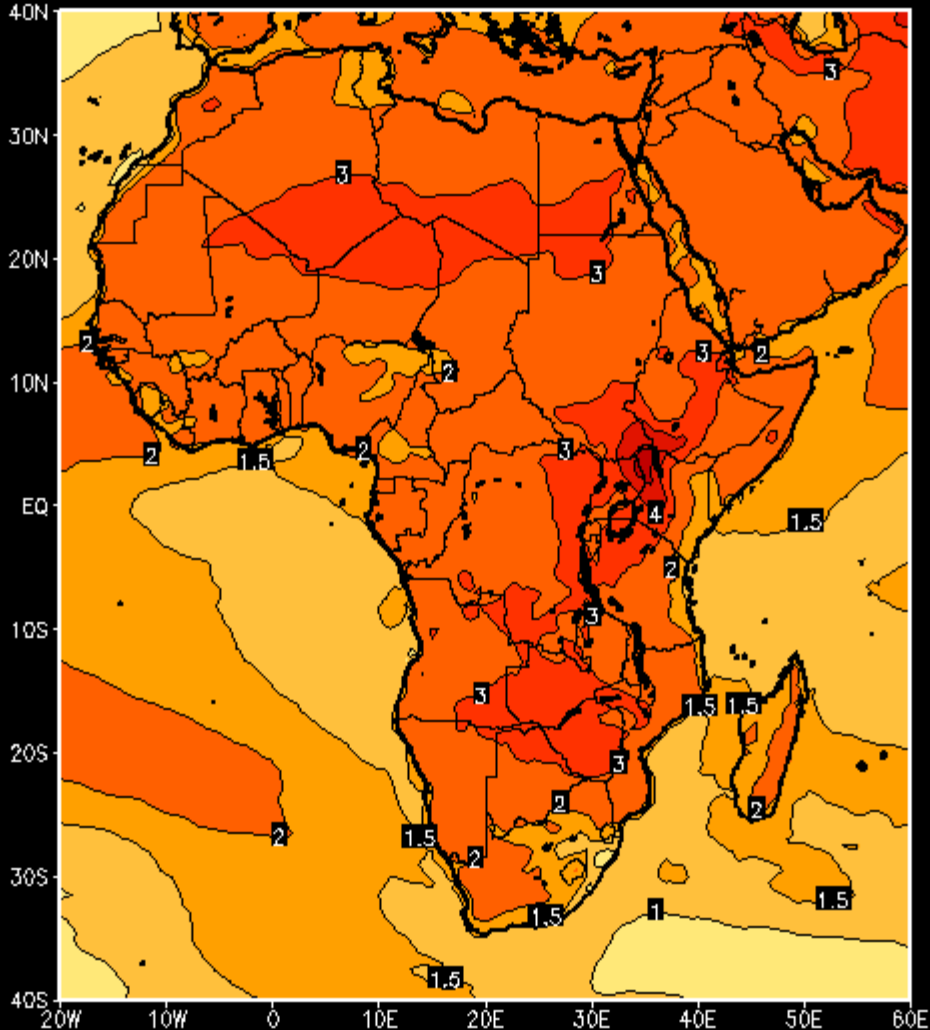
# Temp anomaly 2044



# Temp anomaly 2045

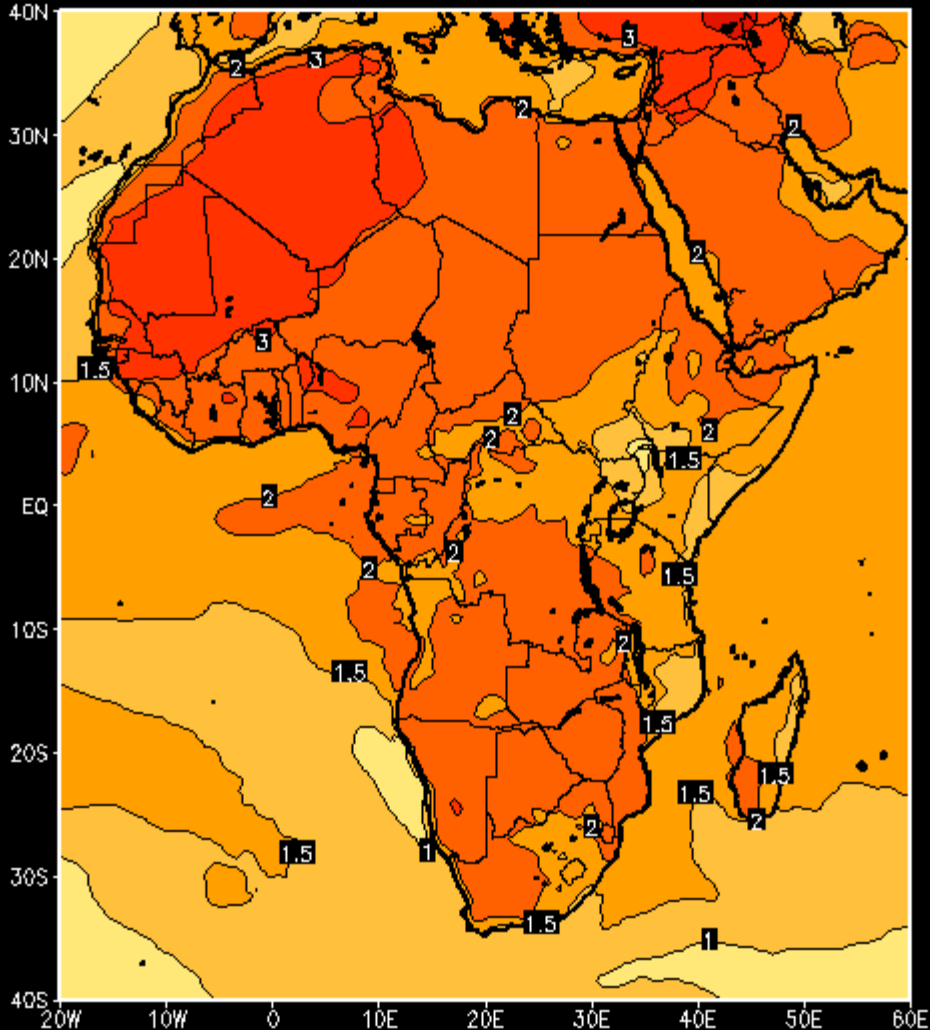


# Temp anomaly 2046

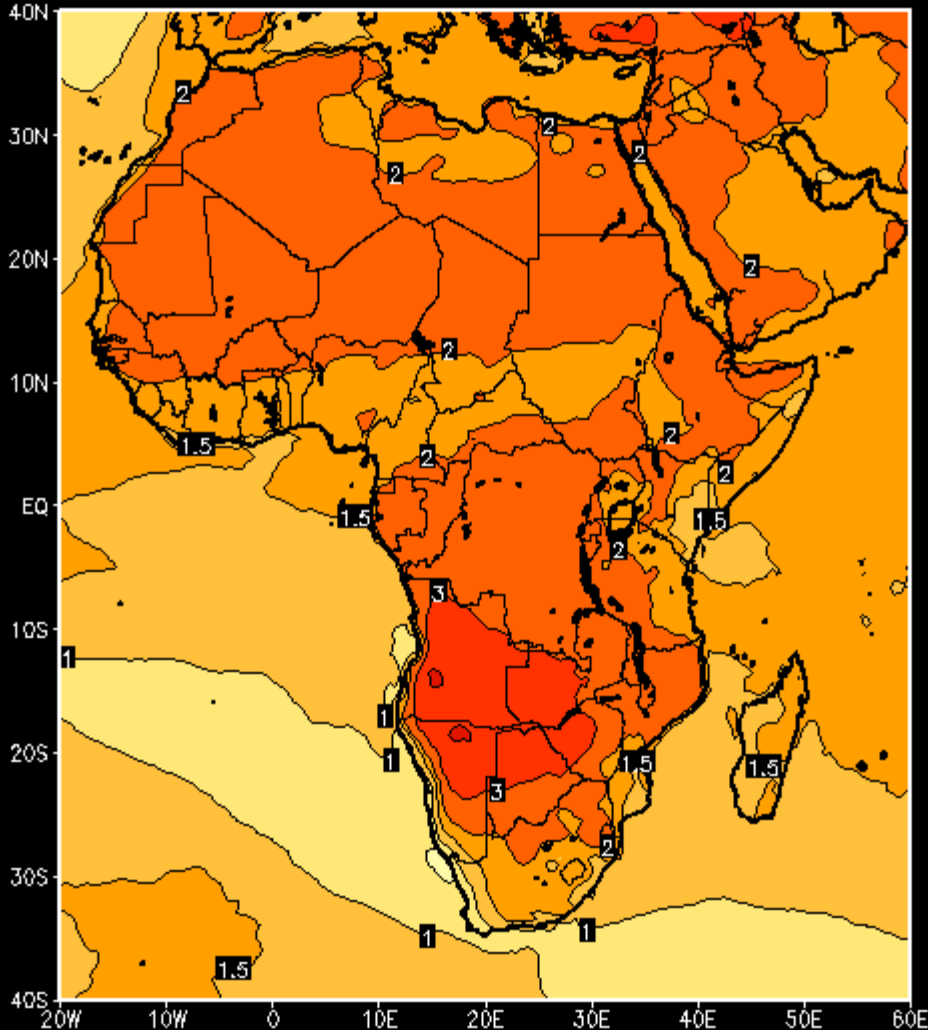




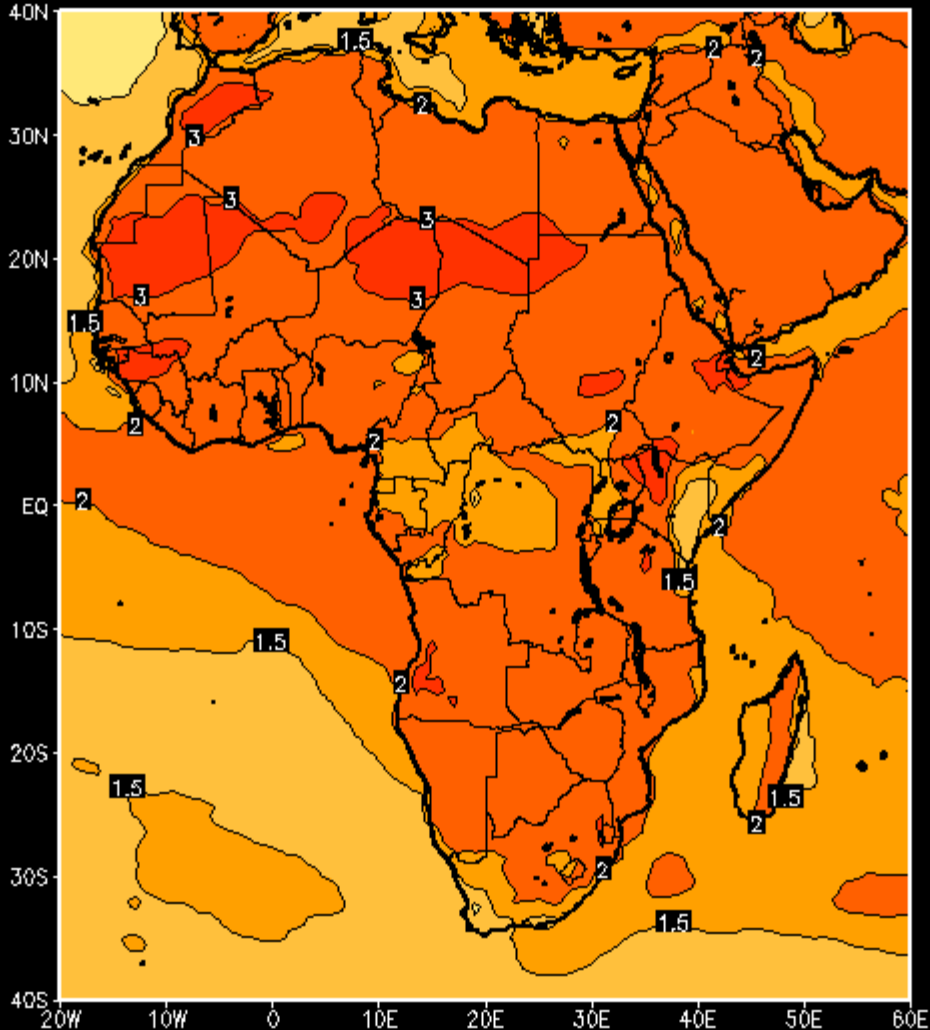
# Temp anomaly 2047



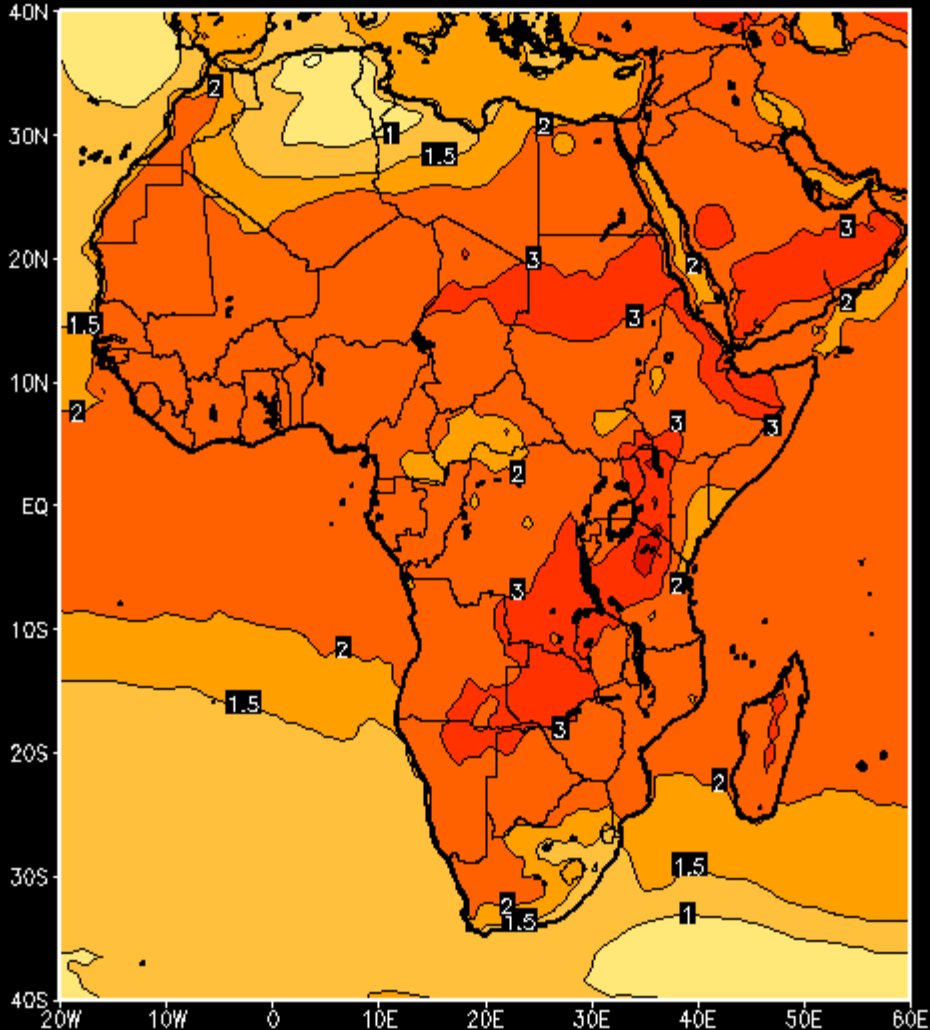
# Temp anomaly 2048



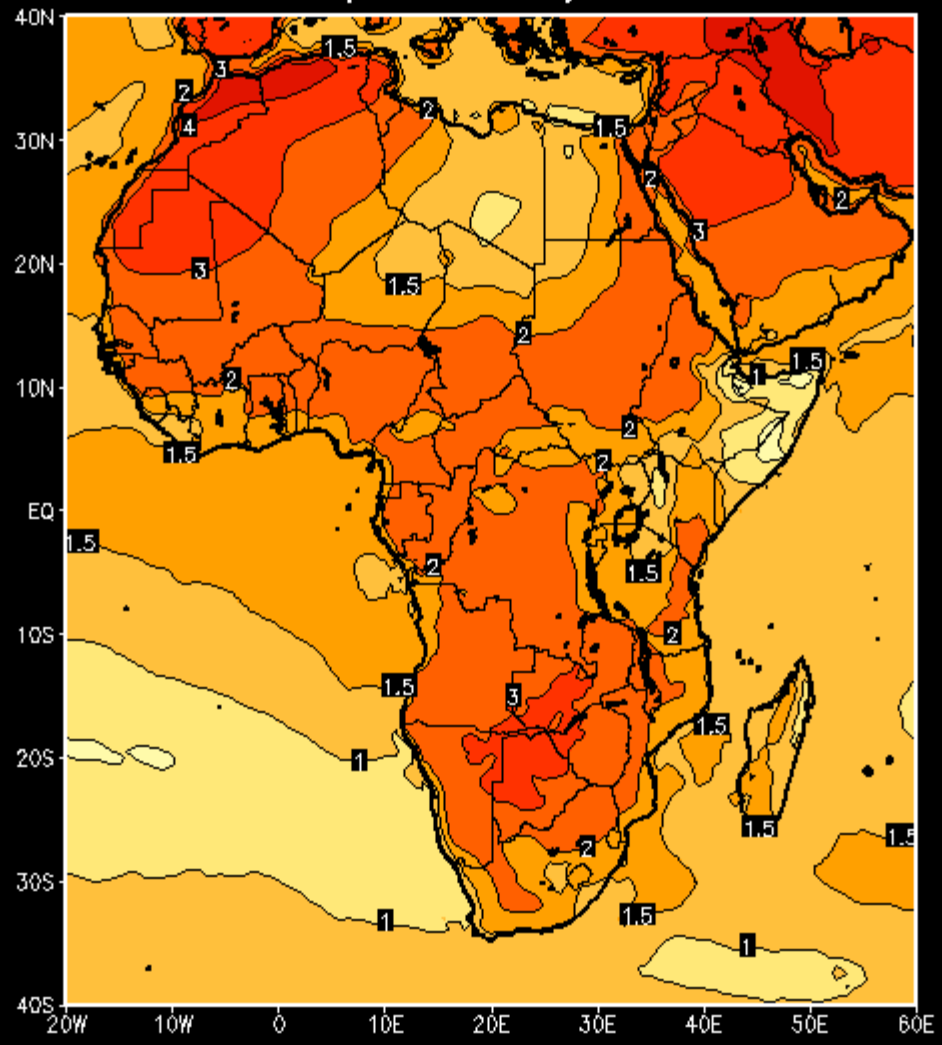
# Temp anomaly 2049



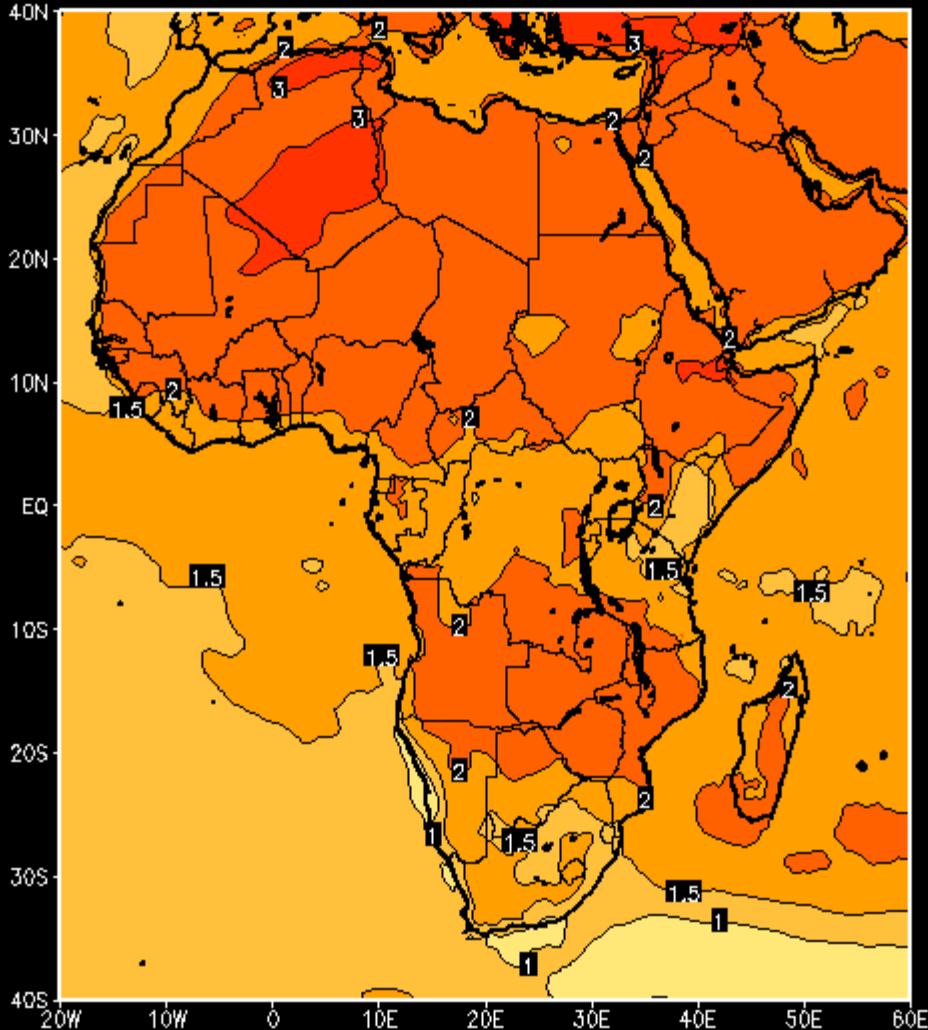
# Temp anomaly 2050



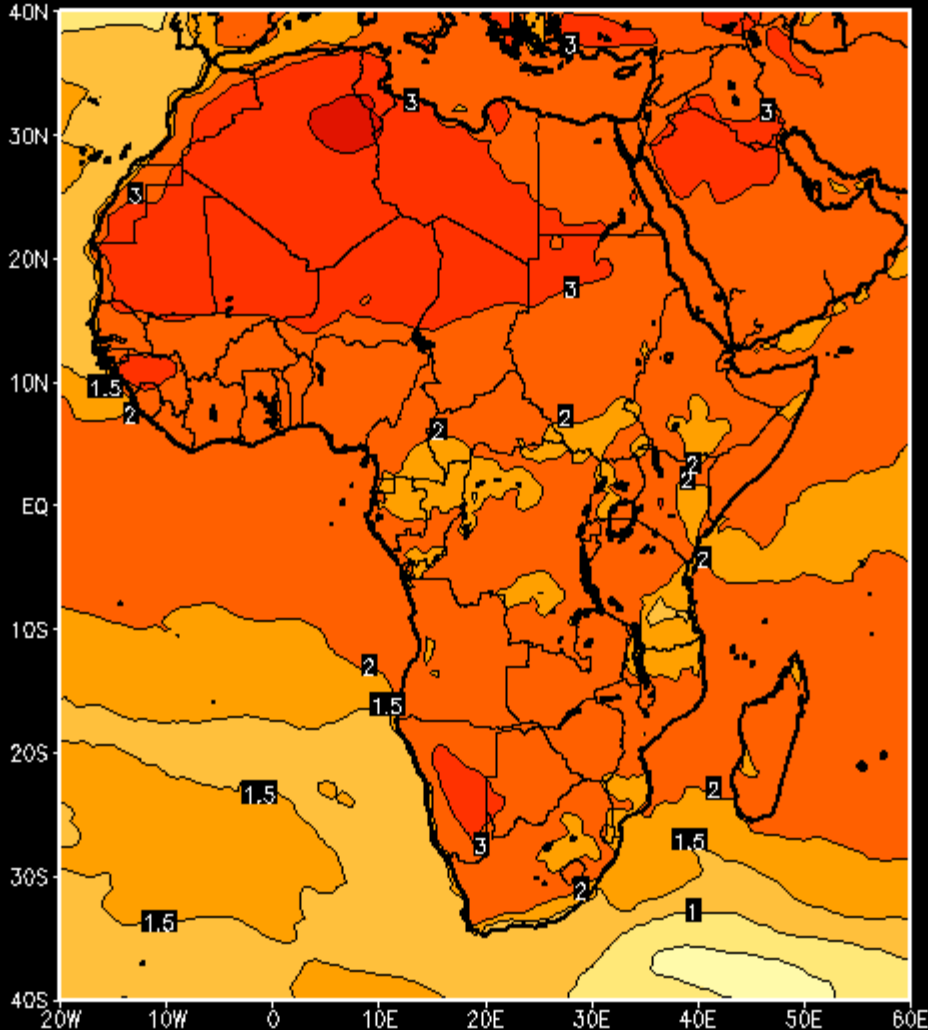
# Temp anomaly 2051



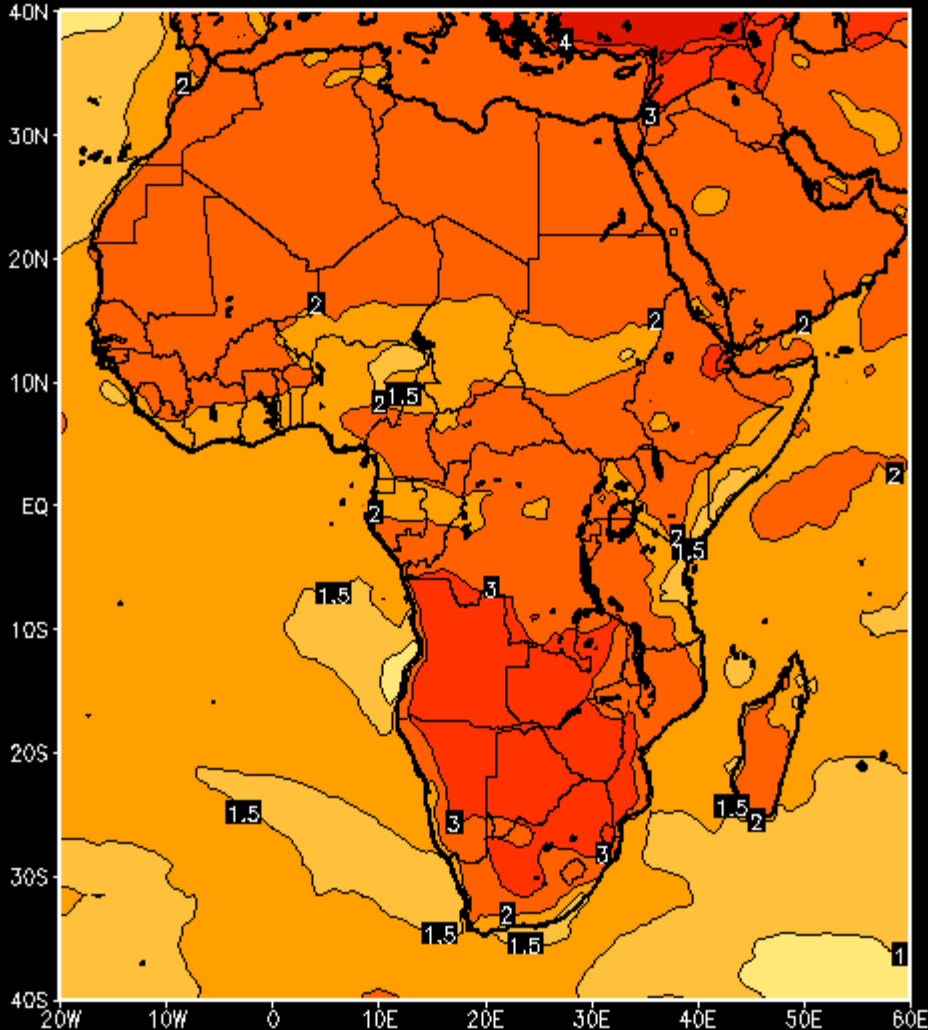
# Temp anomaly 2052



# Temp anomaly 2053

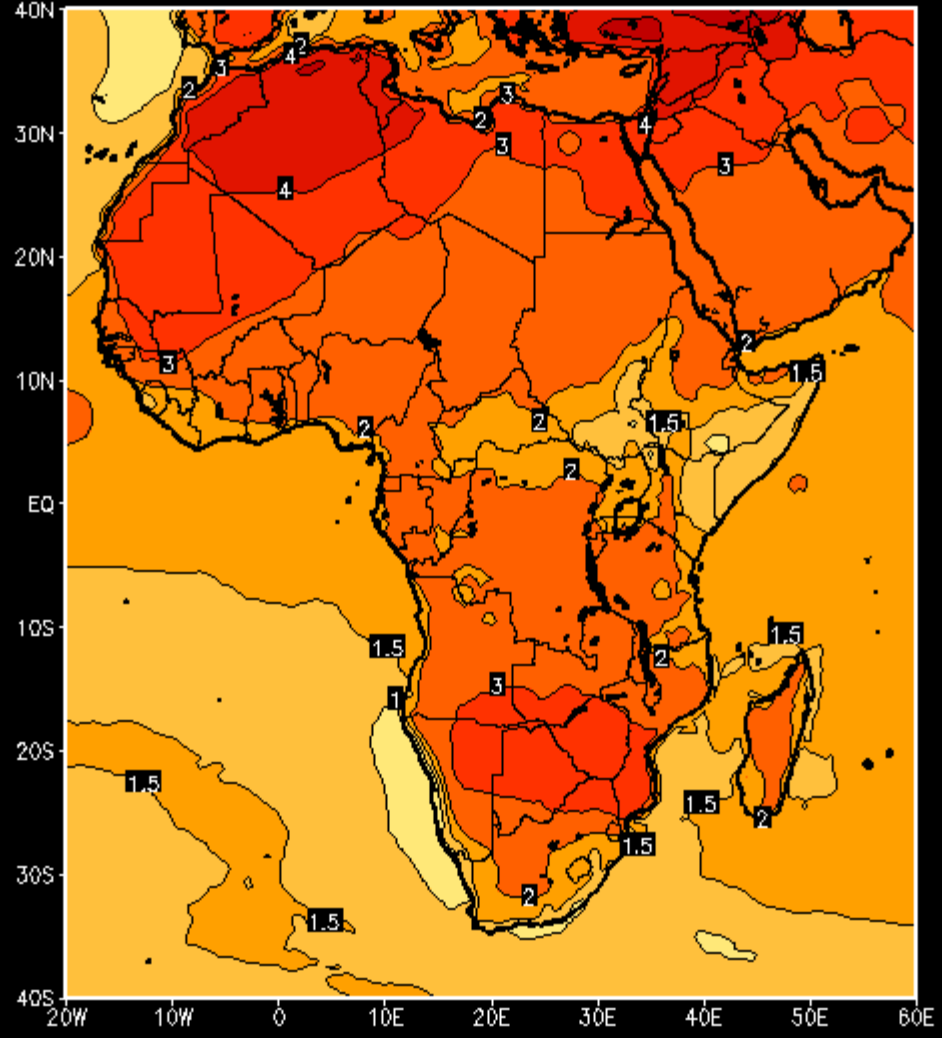


# Temp anomaly 2054

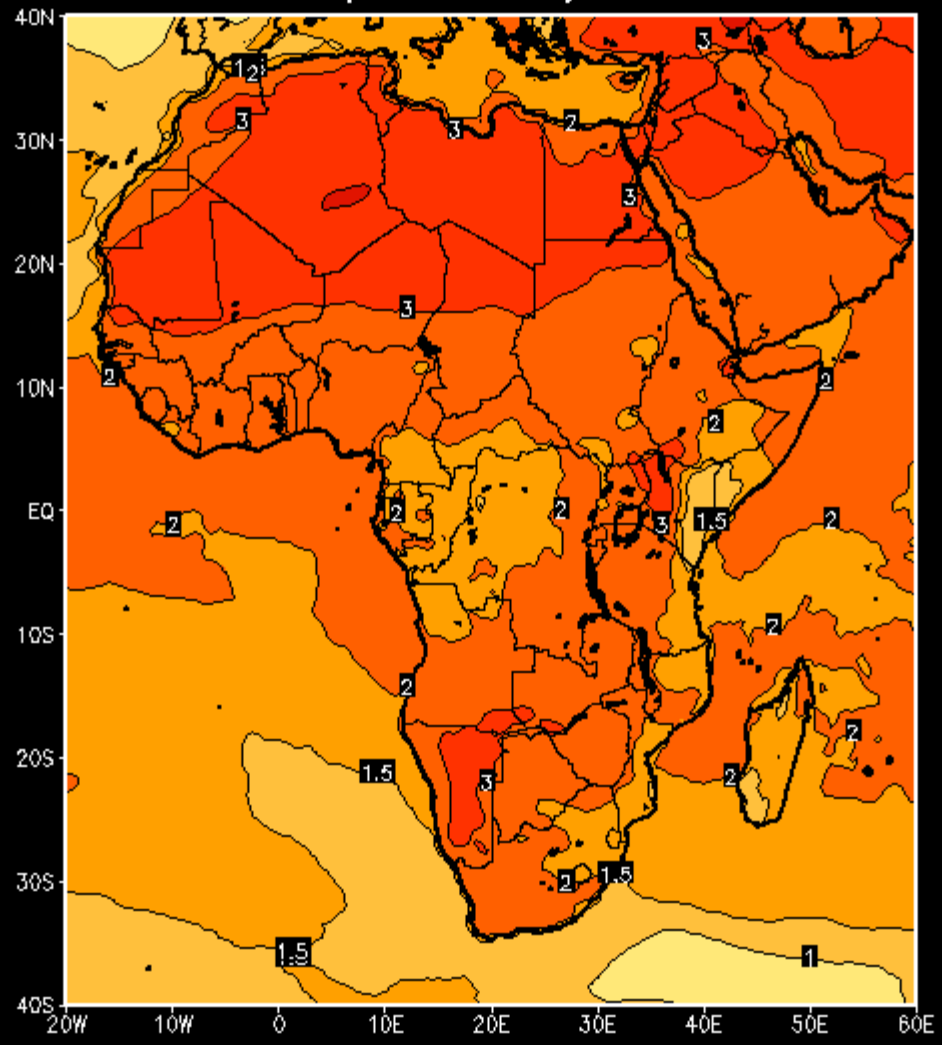




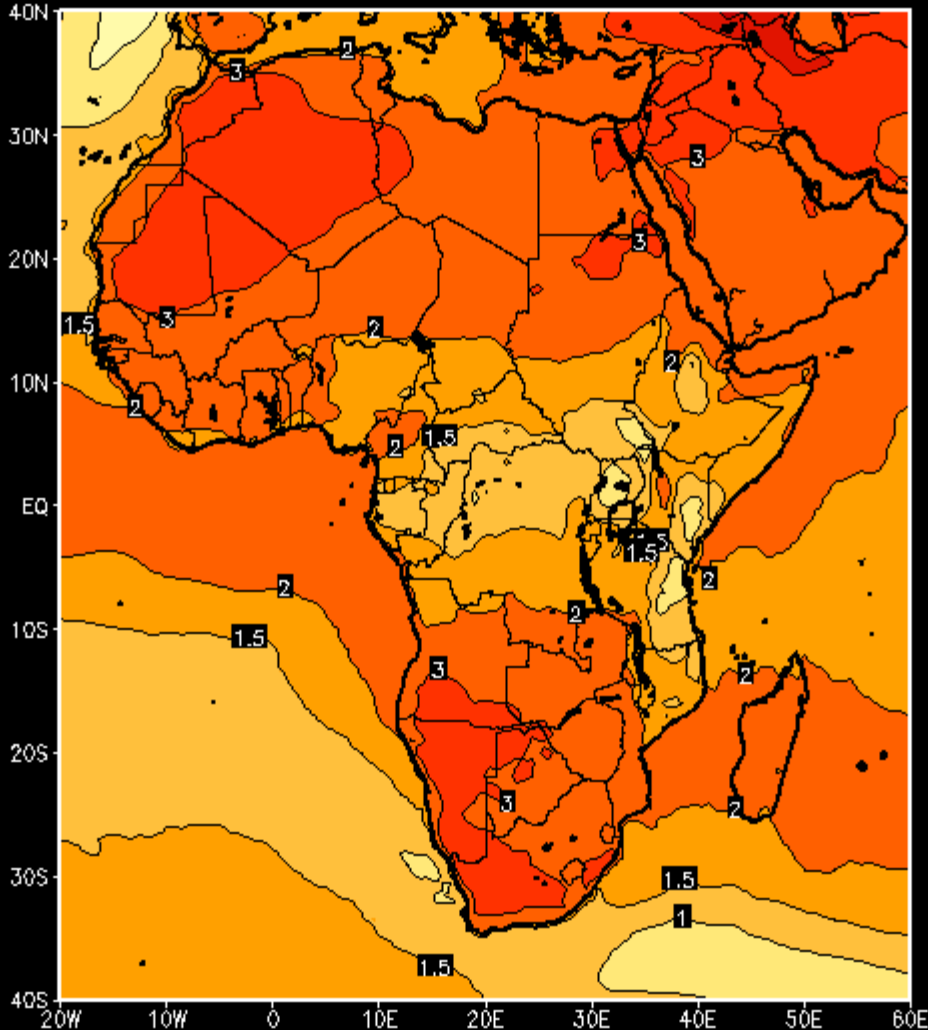
# Temp anomaly 2055



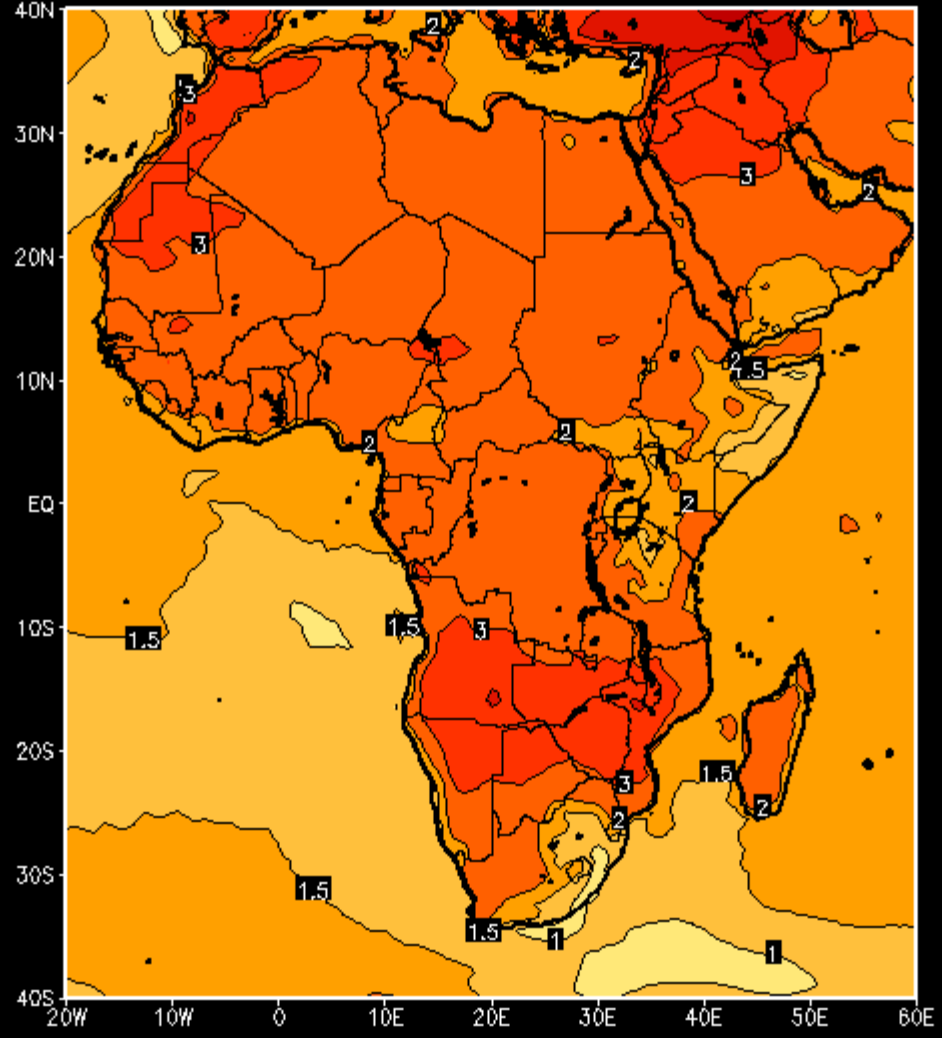
# Temp anomaly 2056



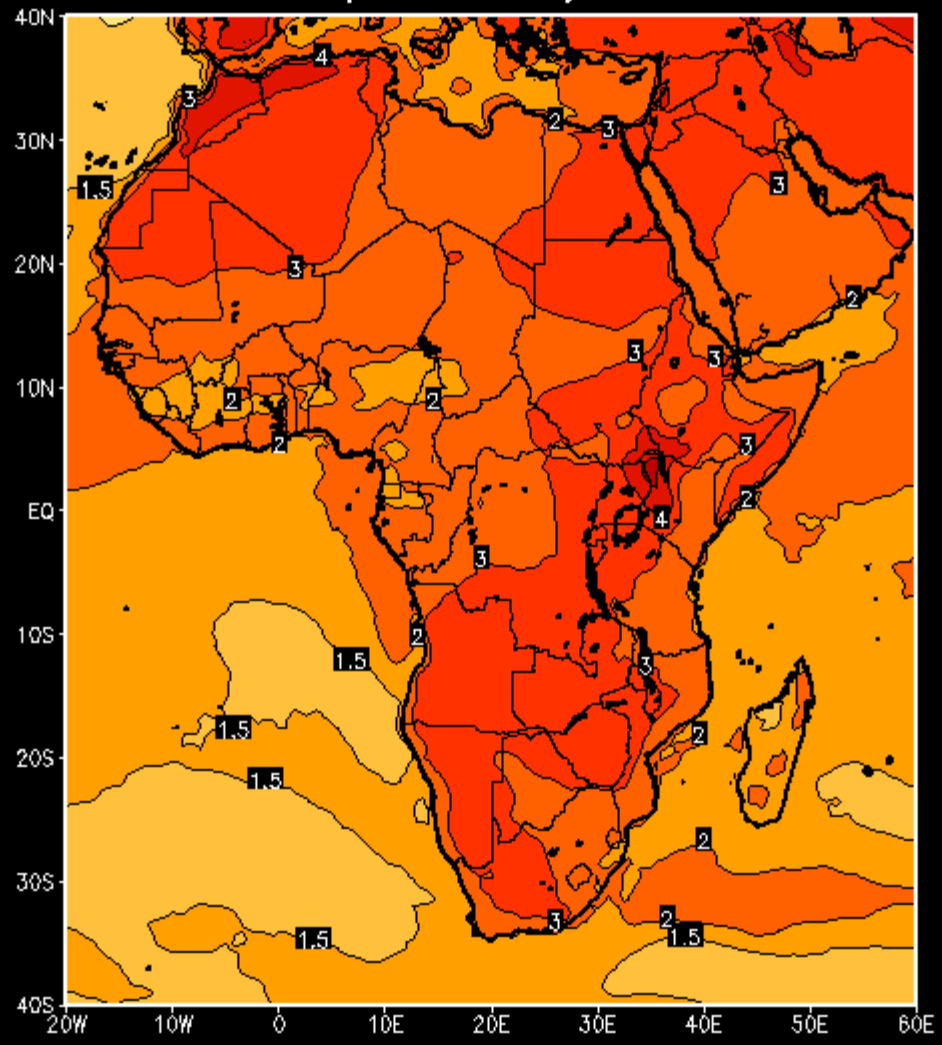
# Temp anomaly 2057



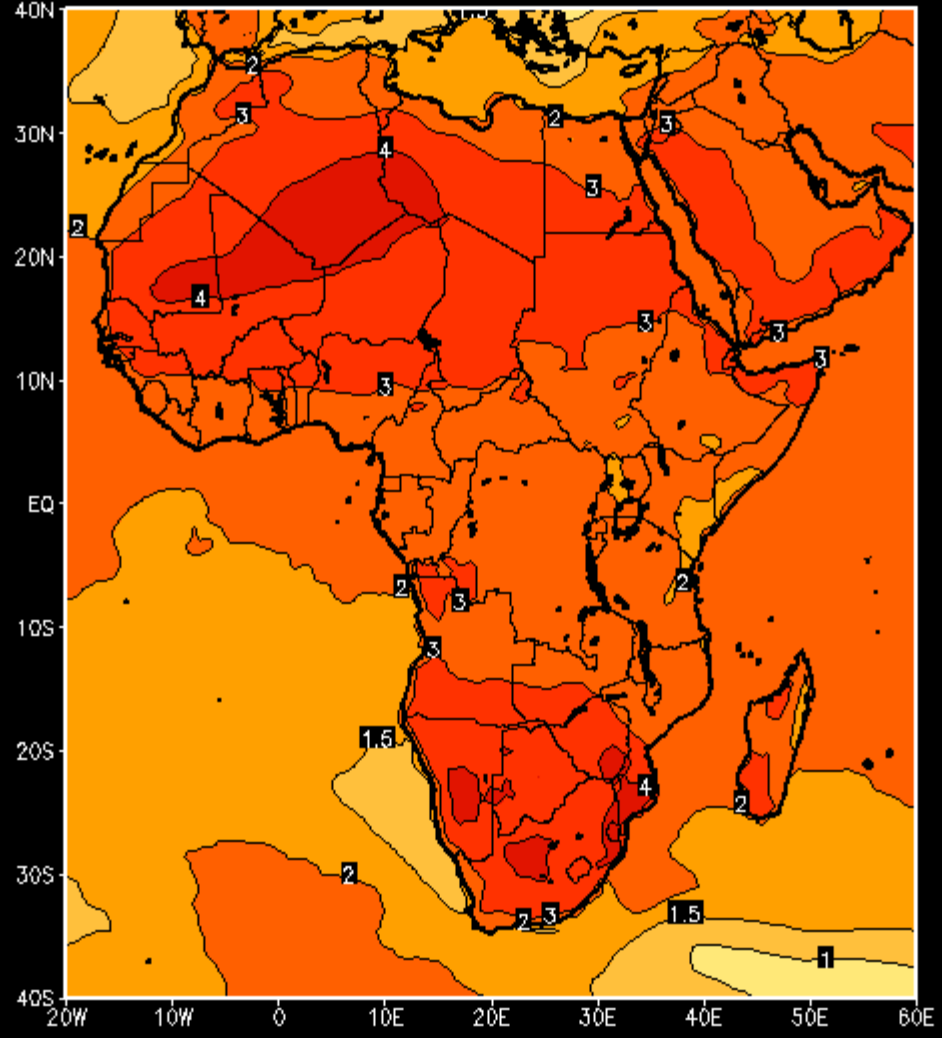
# Temp anomaly 2058



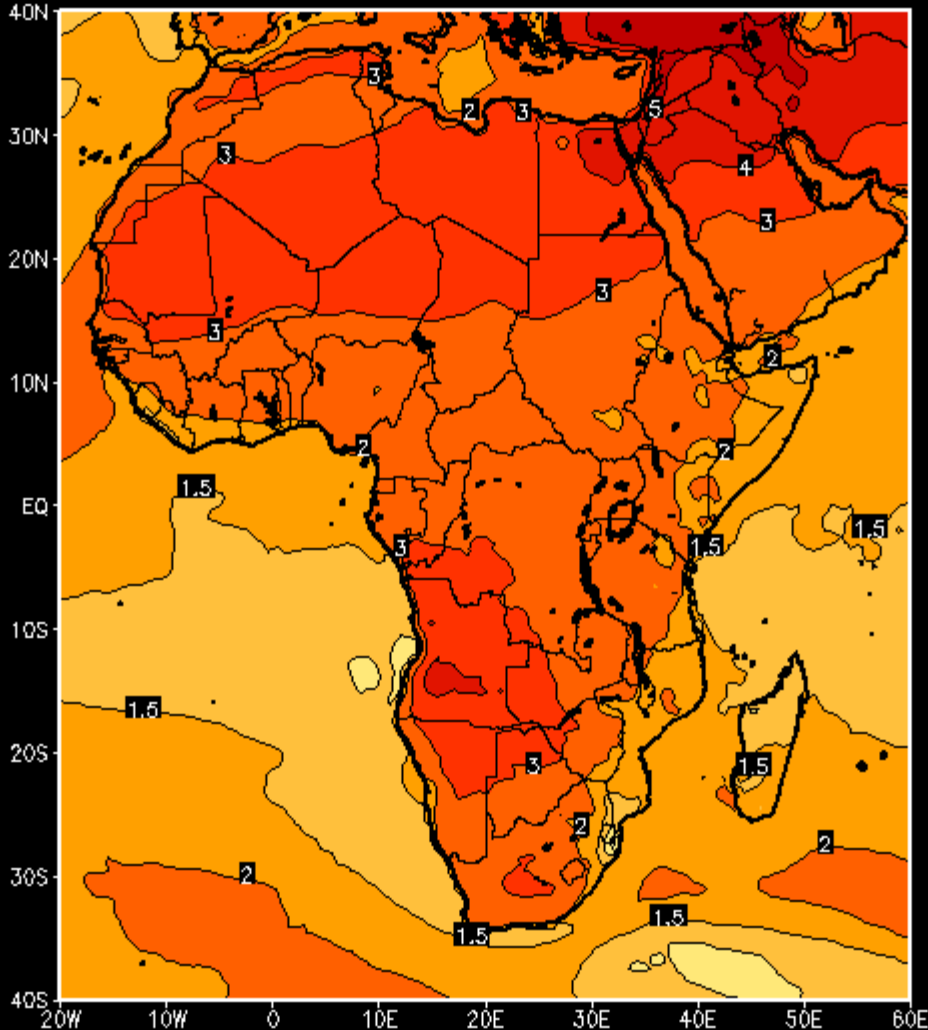
# Temp anomaly 2059



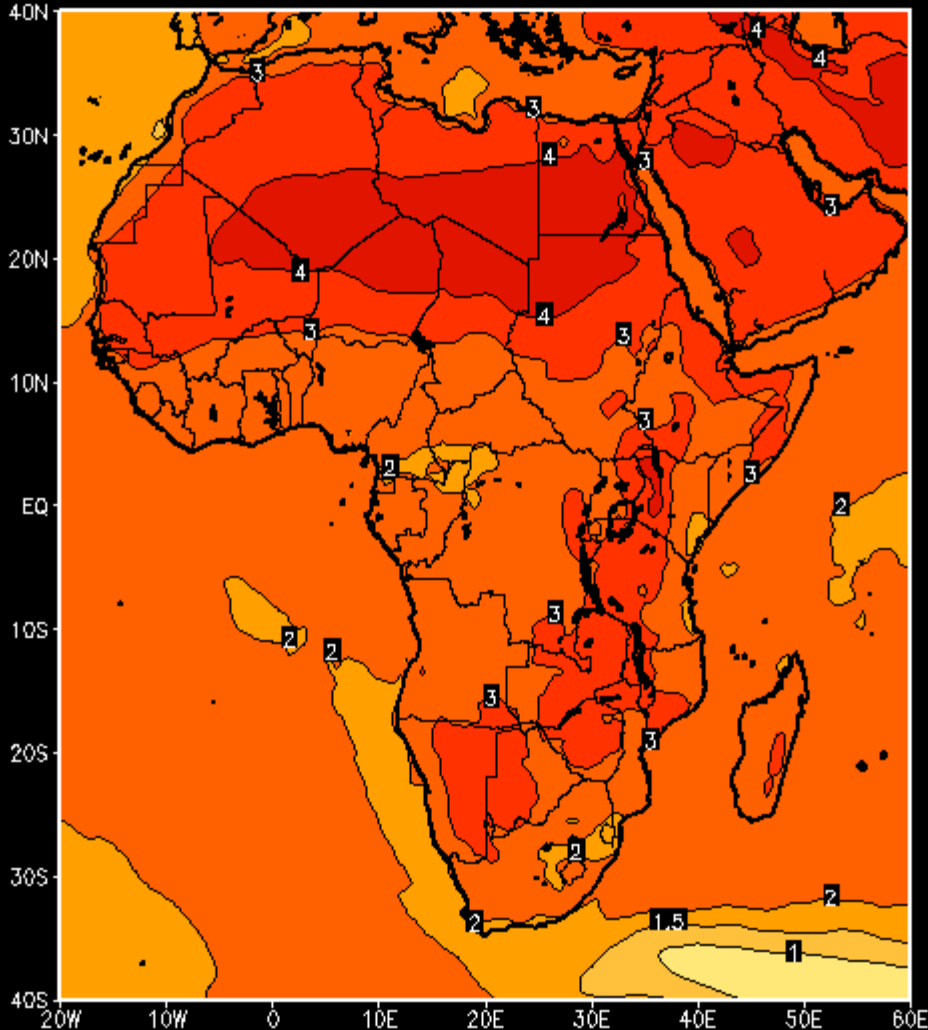
# Temp anomaly 2060



# Temp anomaly 2061

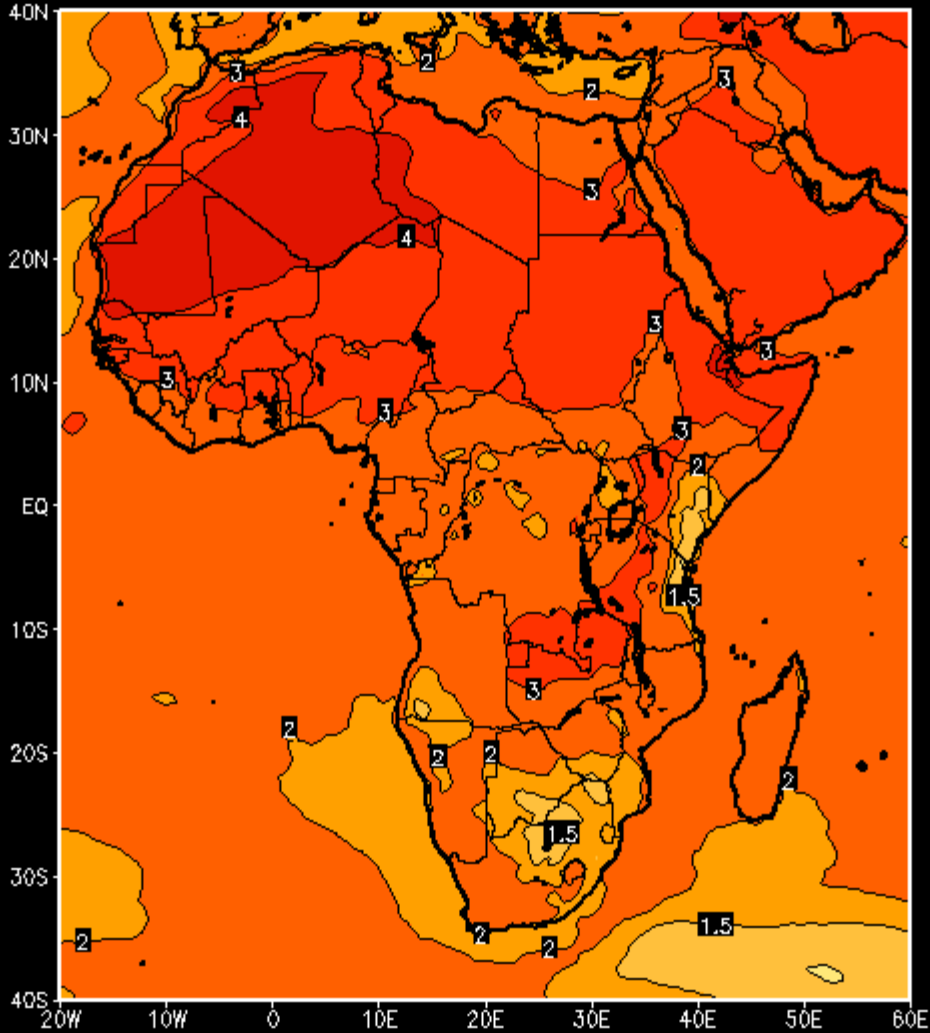


# Temp anomaly 2062

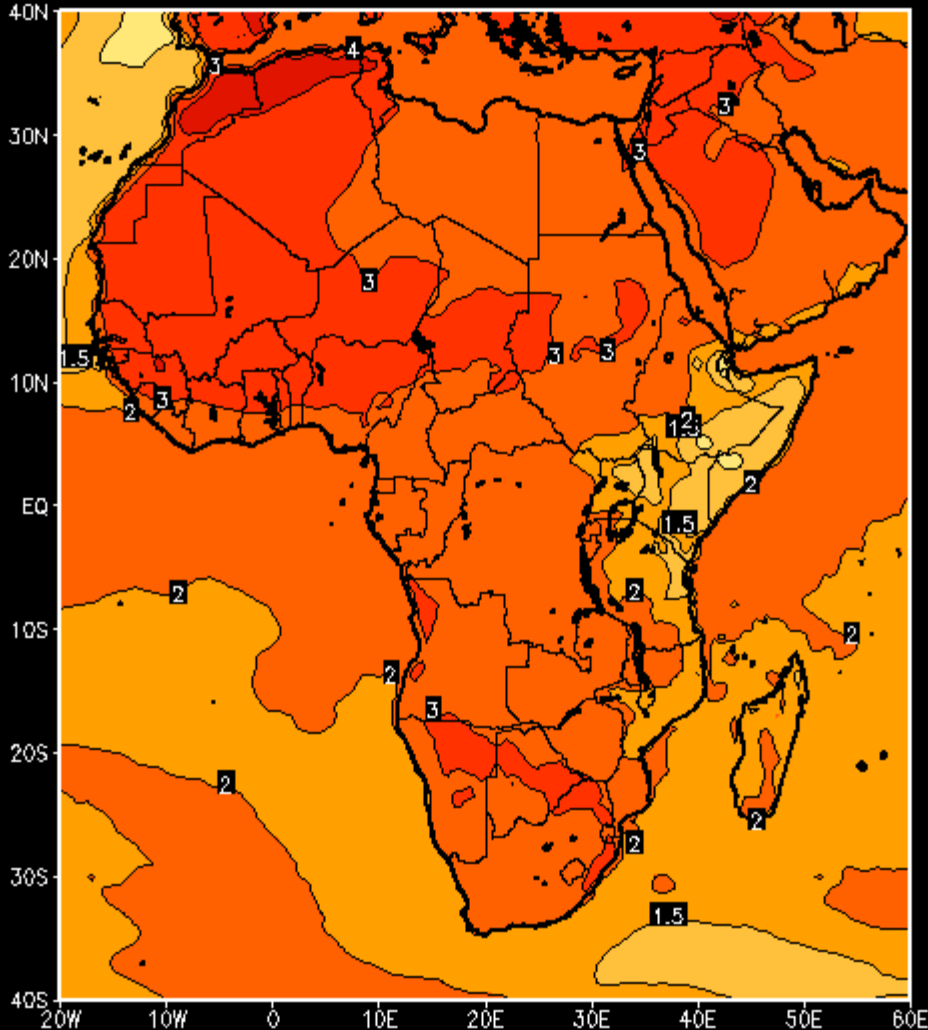




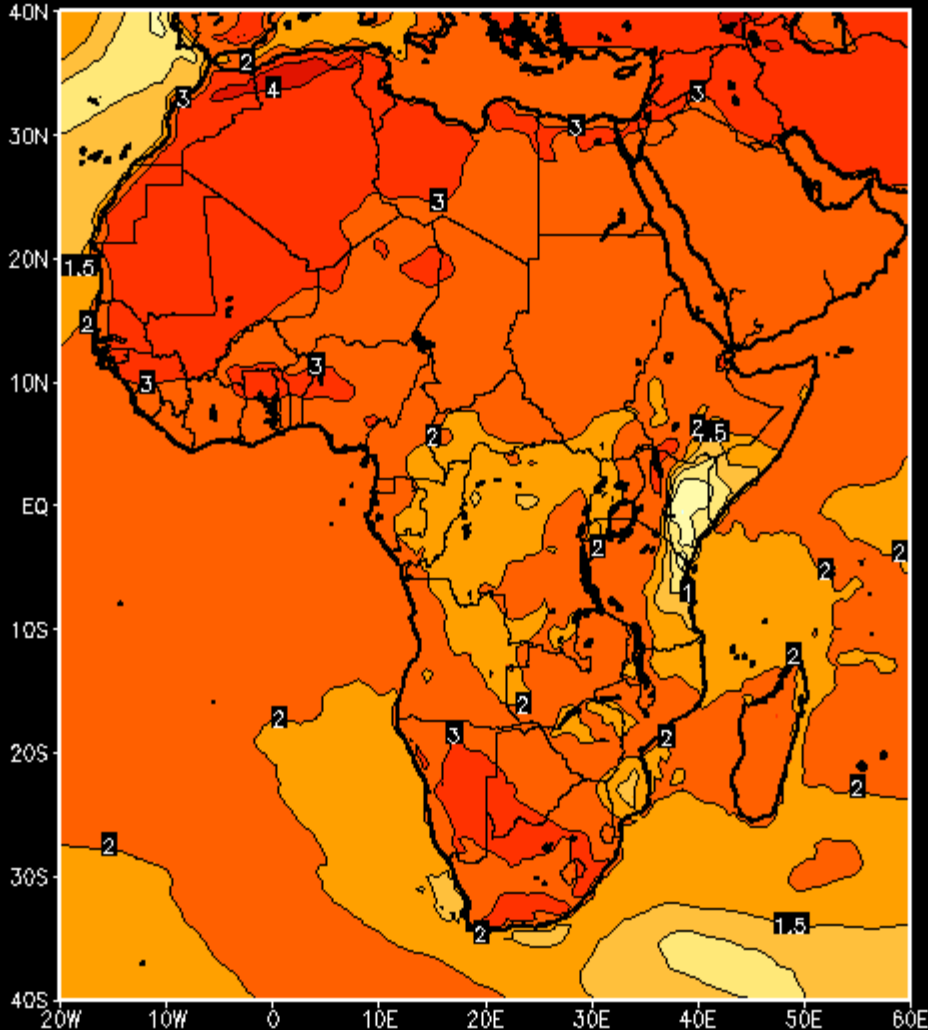
# Temp anomaly 2063



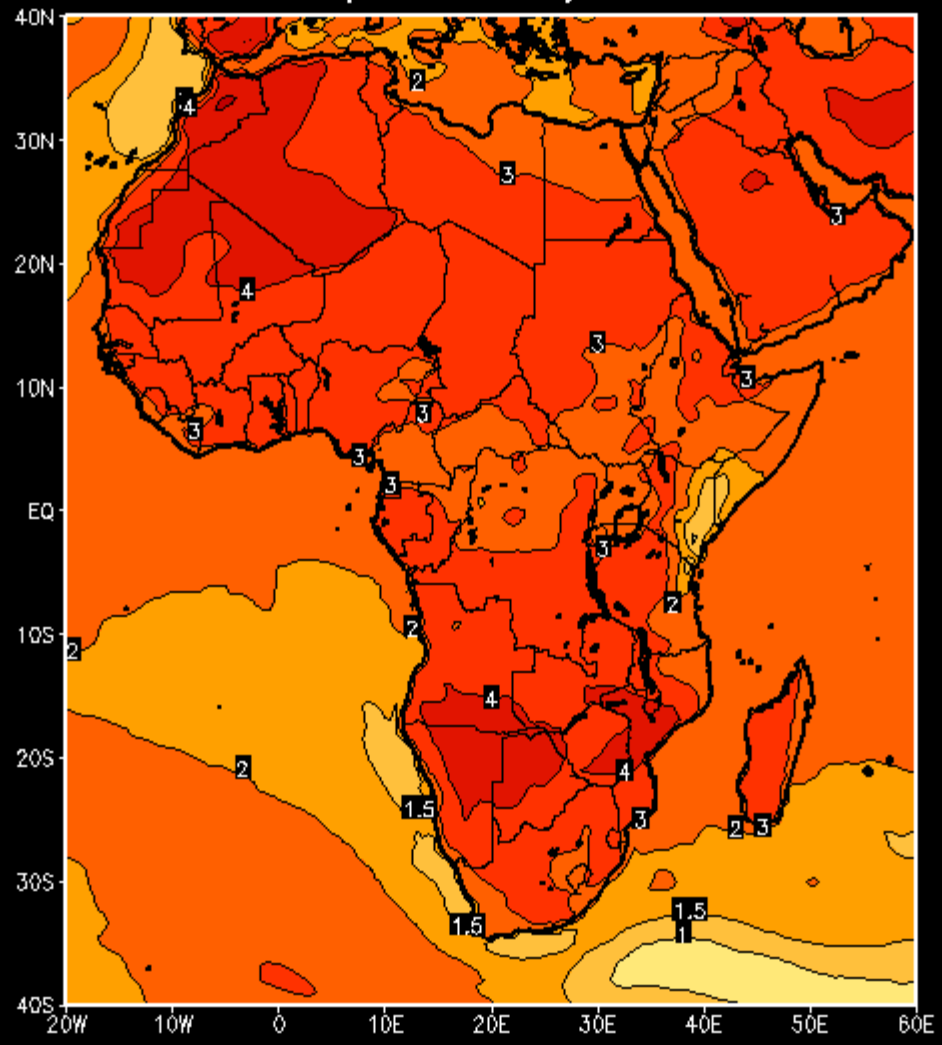
# Temp anomaly 2064



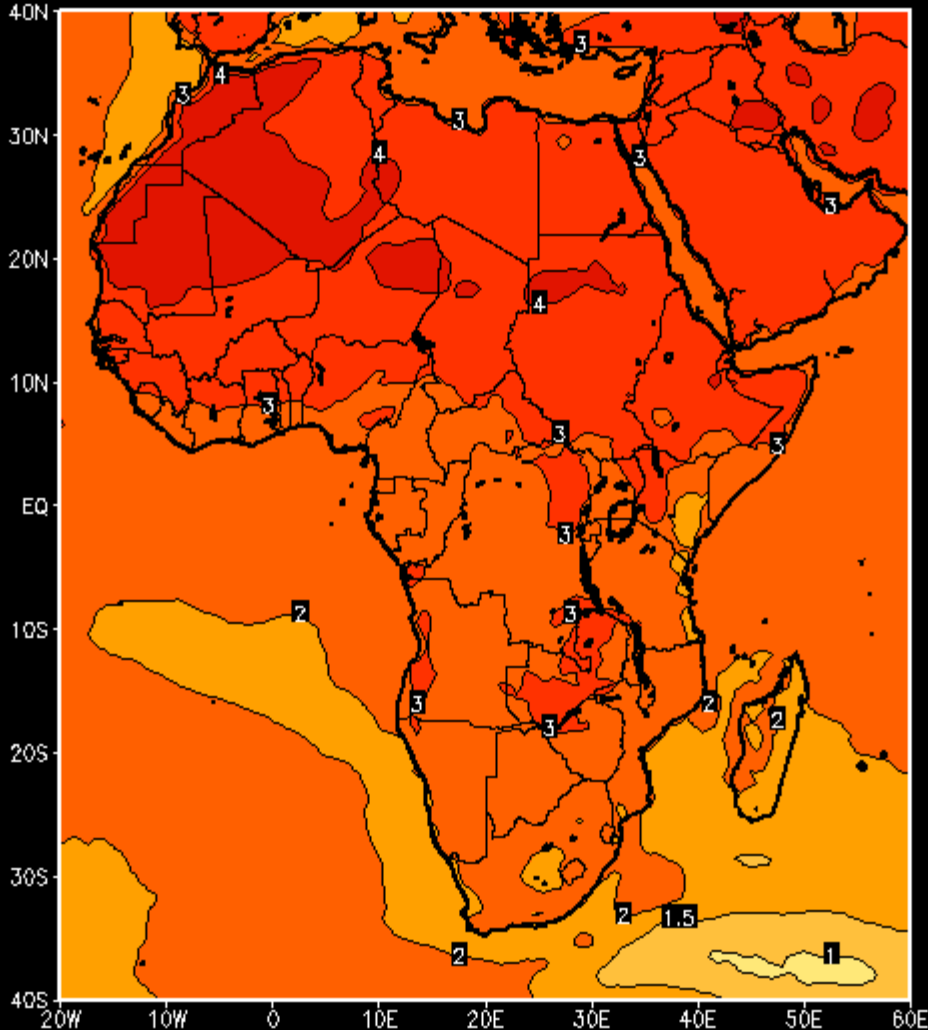
# Temp anomaly 2065



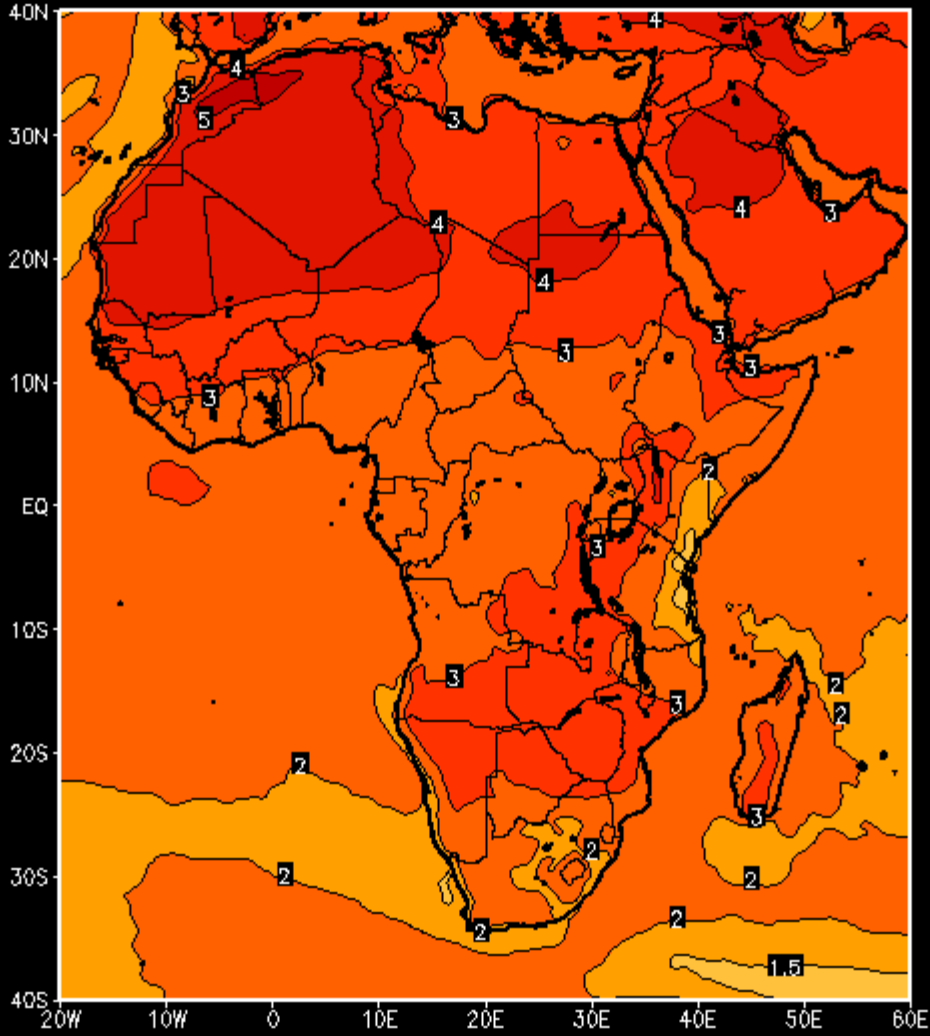
# Temp anomaly 2066



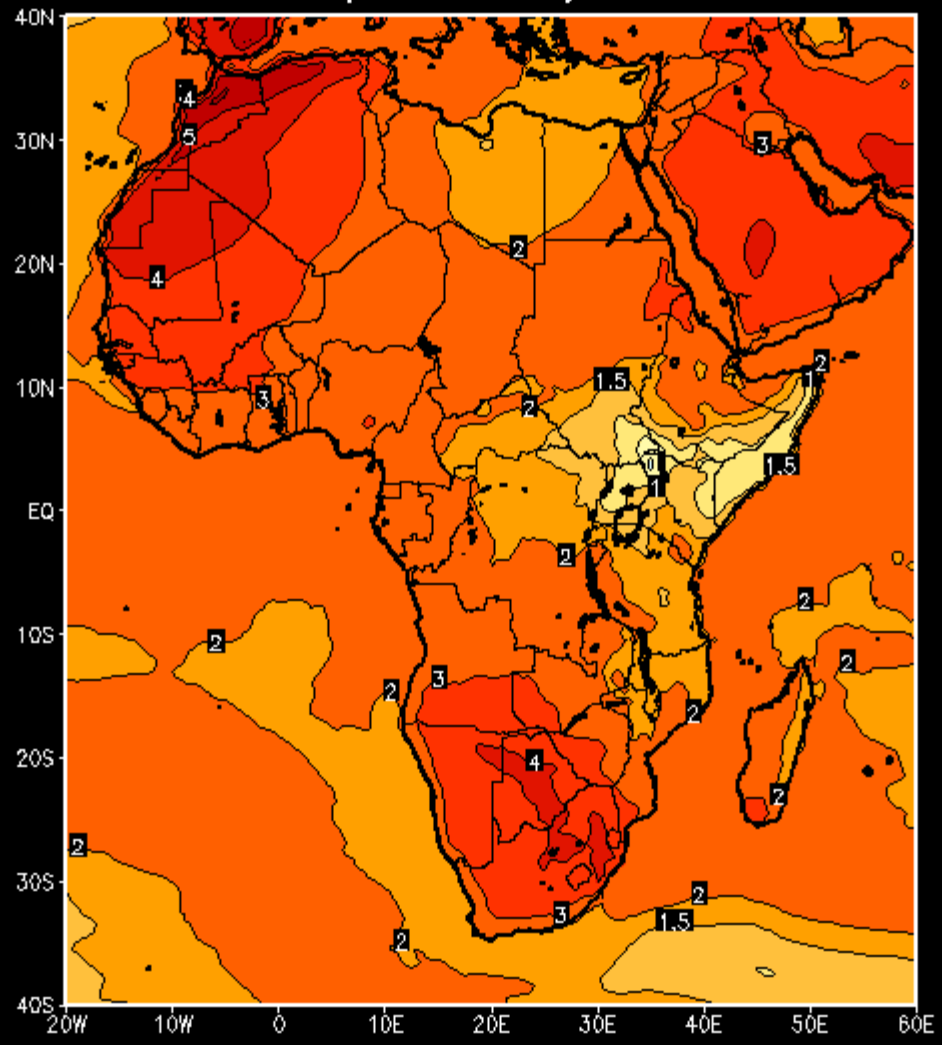
# Temp anomaly 2067



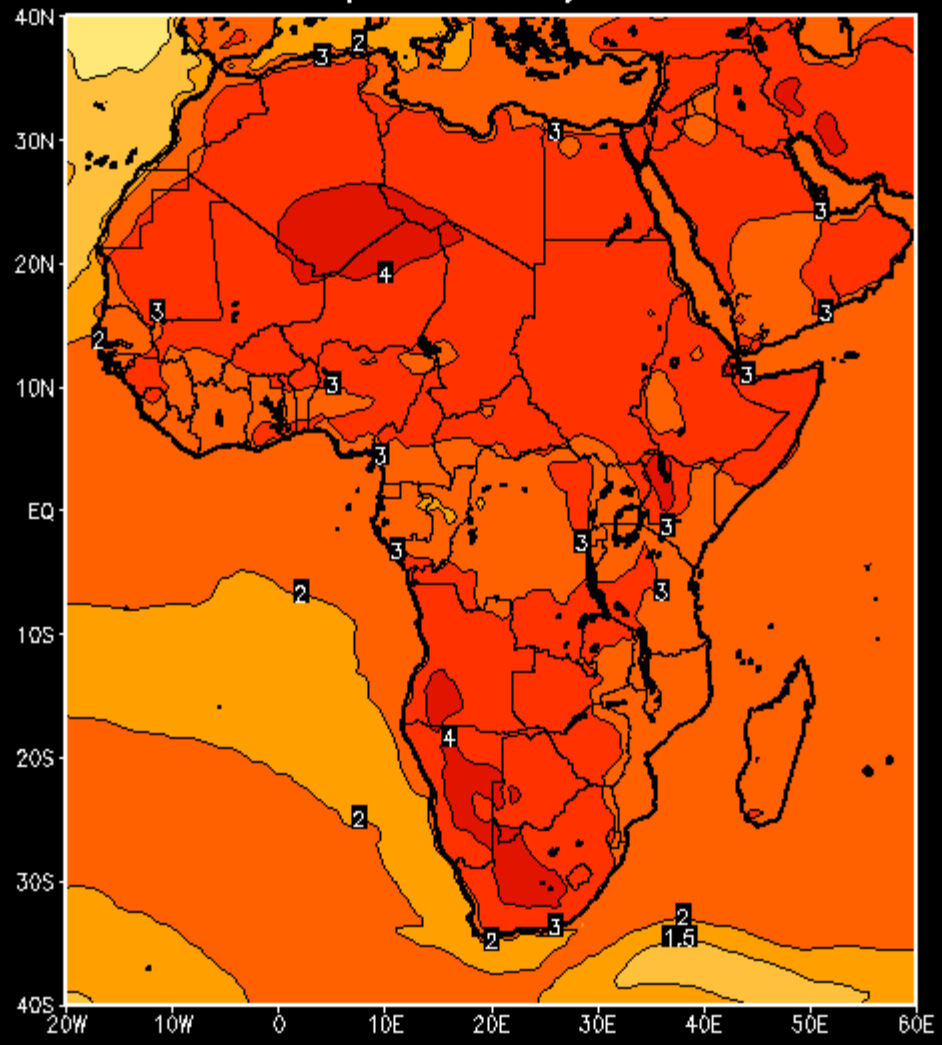
# Temp anomaly 2068



# Temp anomaly 2069

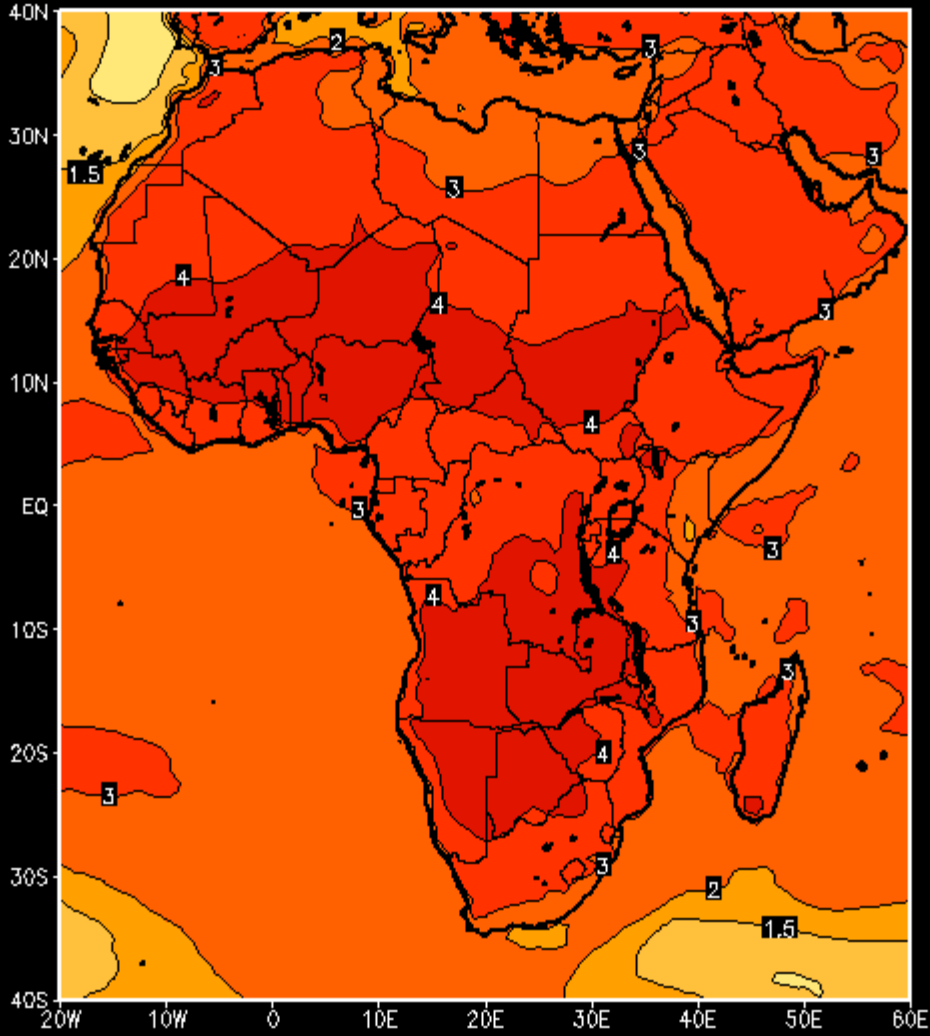


# Temp anomaly 2070

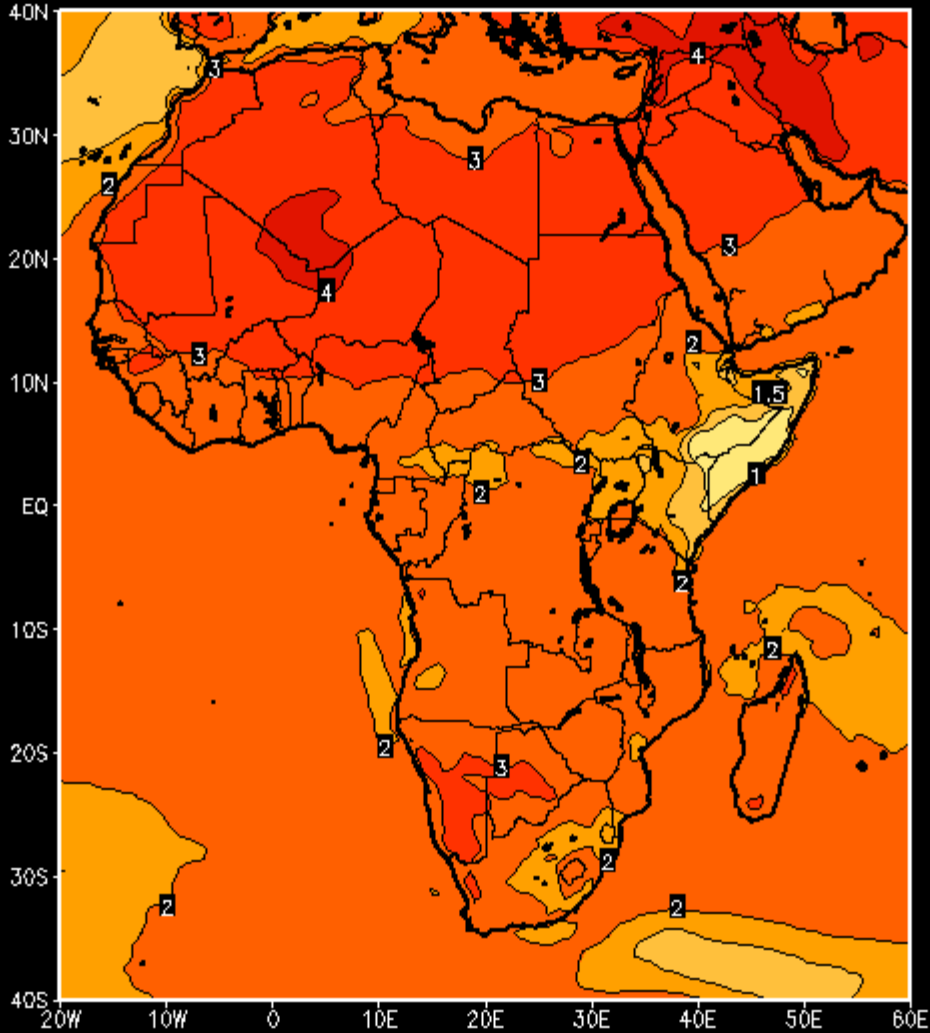




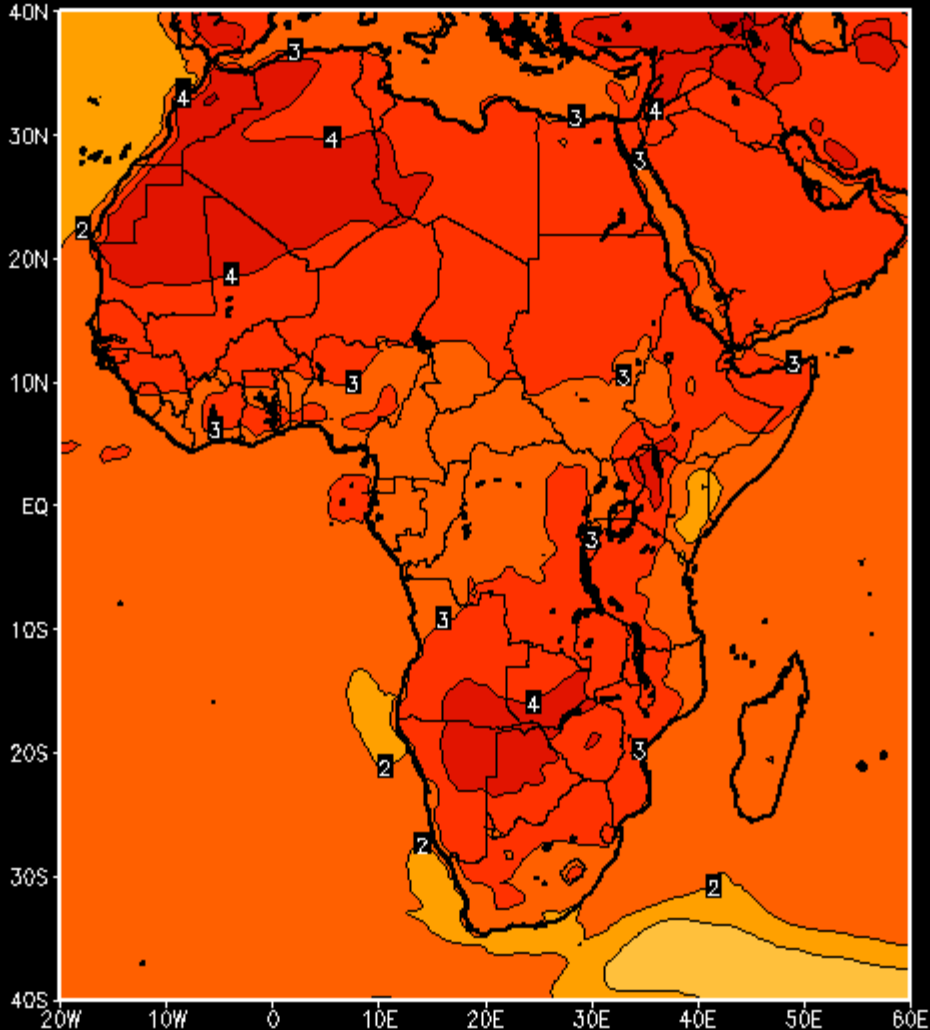
# Temp anomaly 2071



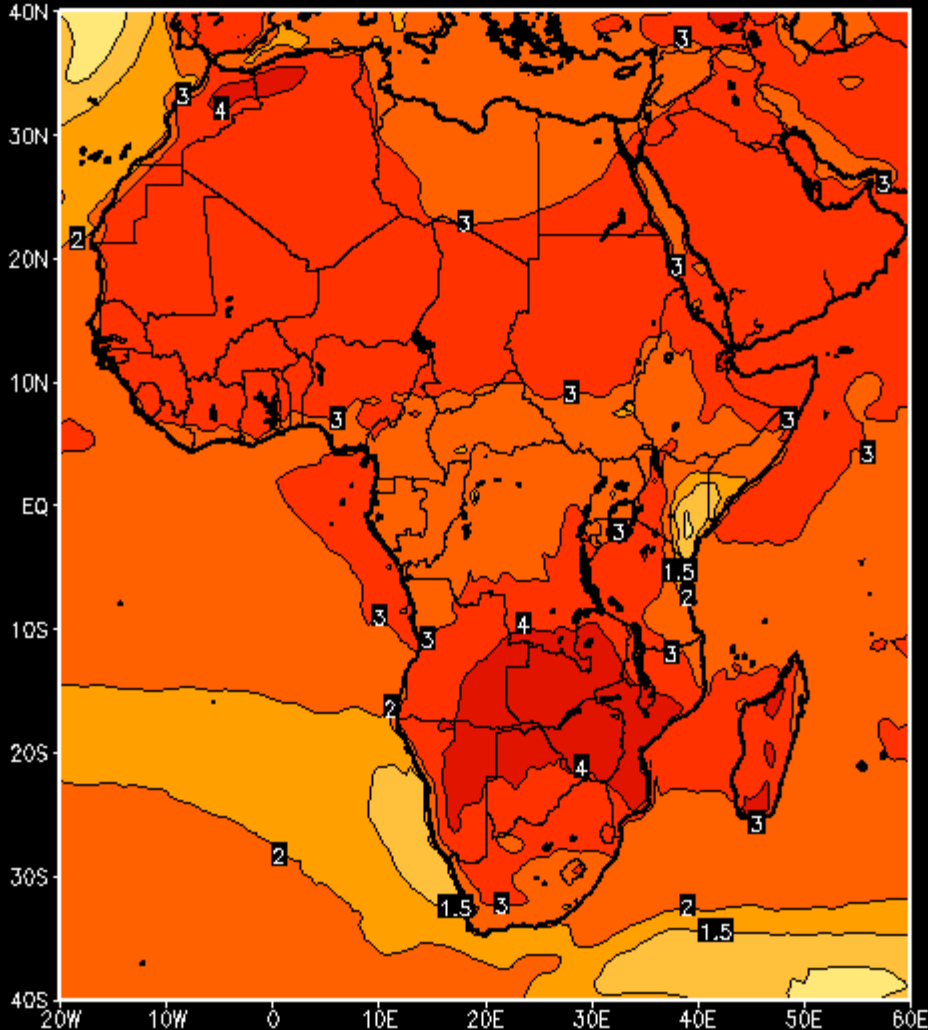
# Temp anomaly 2072



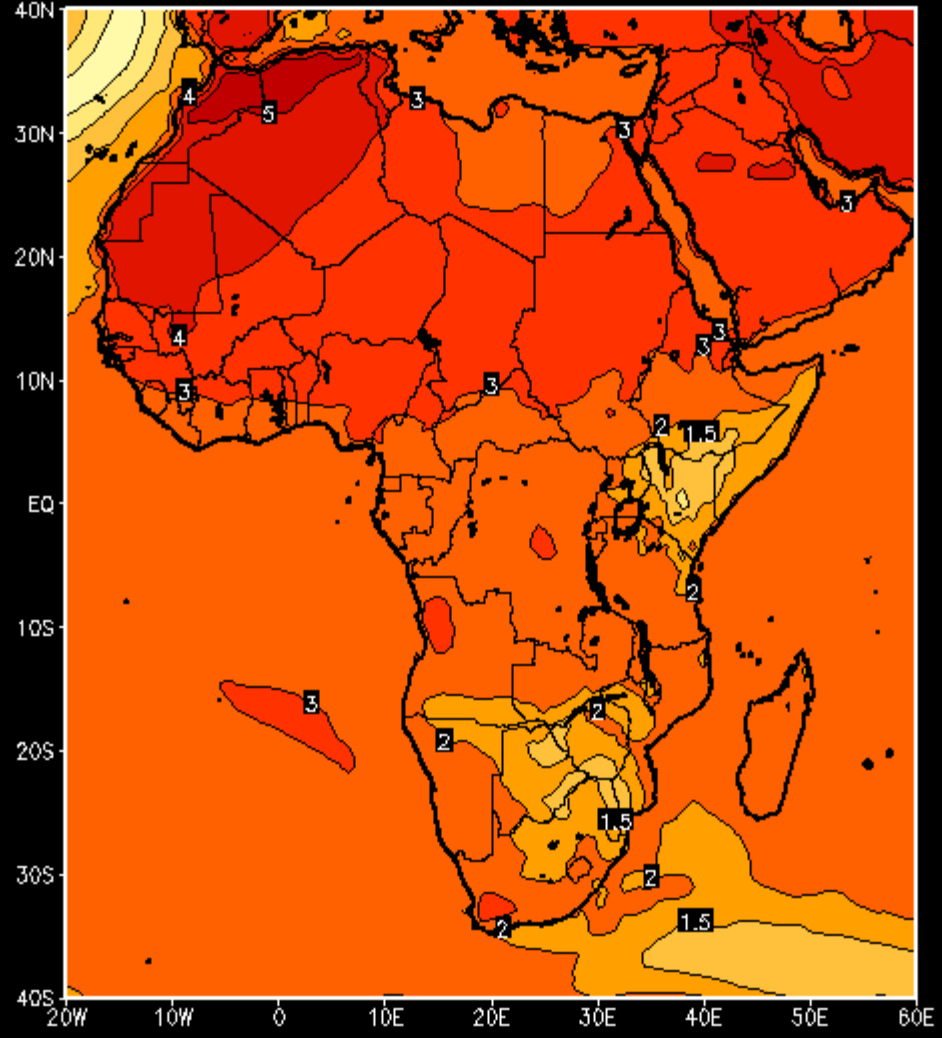
# Temp anomaly 2073



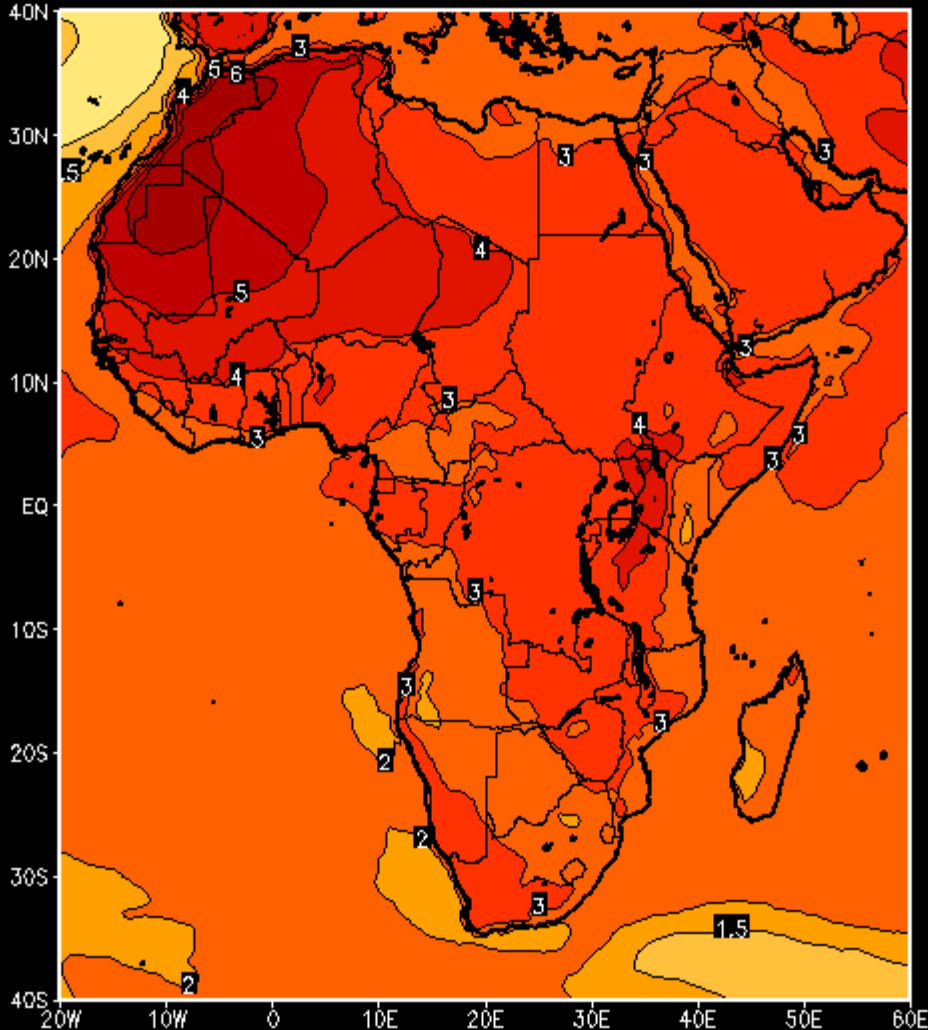
# Temp anomaly 2074



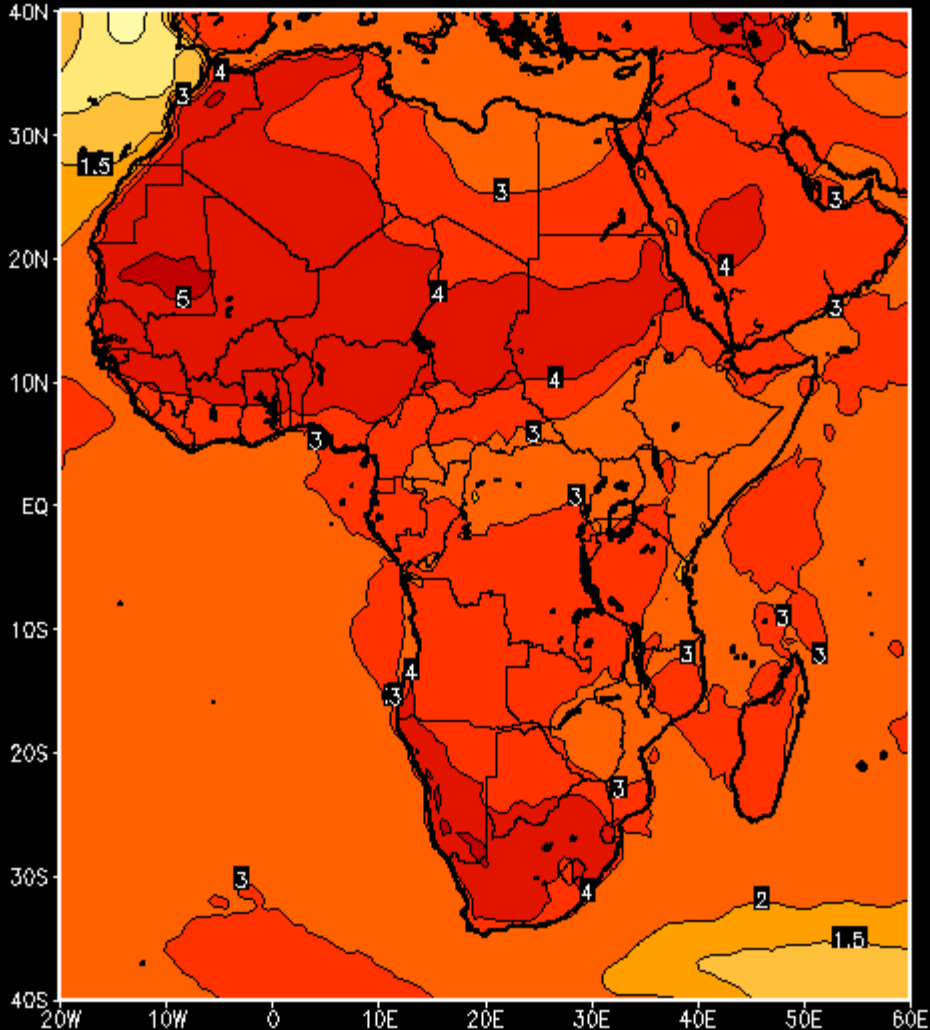
# Temp anomaly 2075



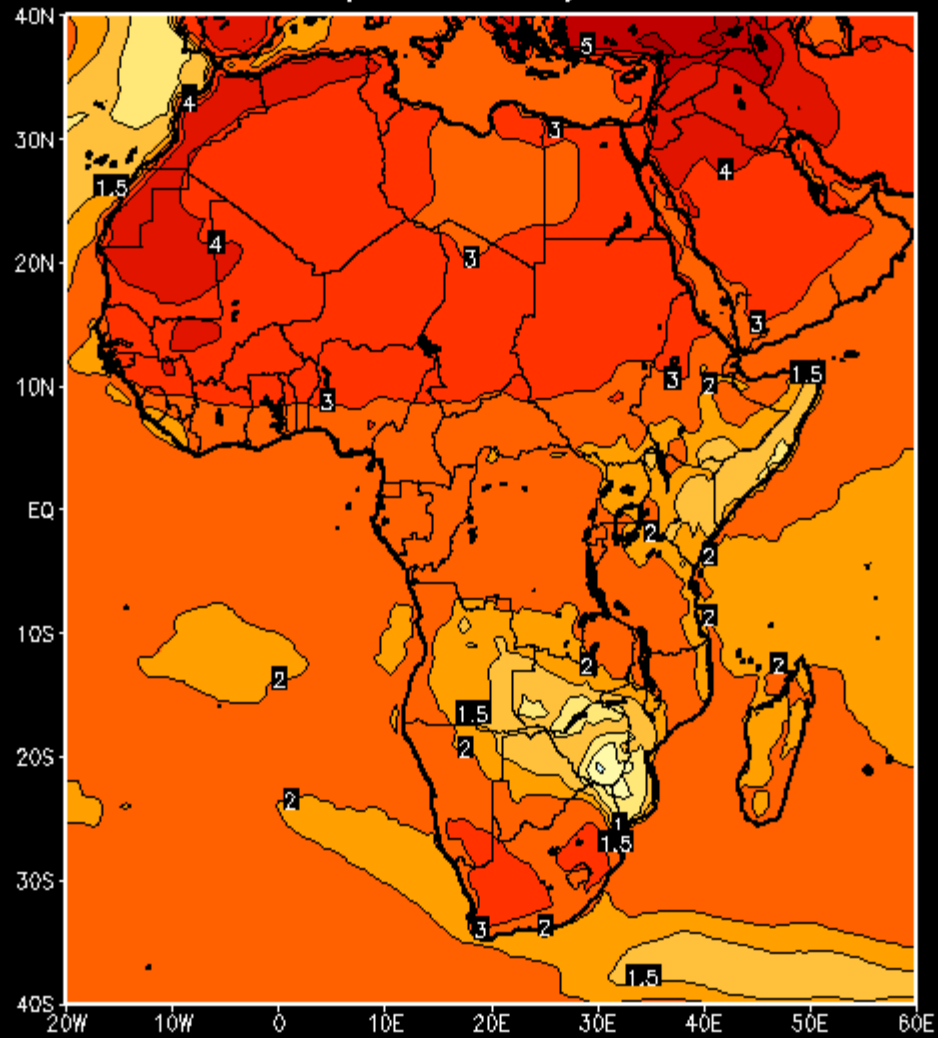
# Temp anomaly 2076



# Temp anomaly 2077

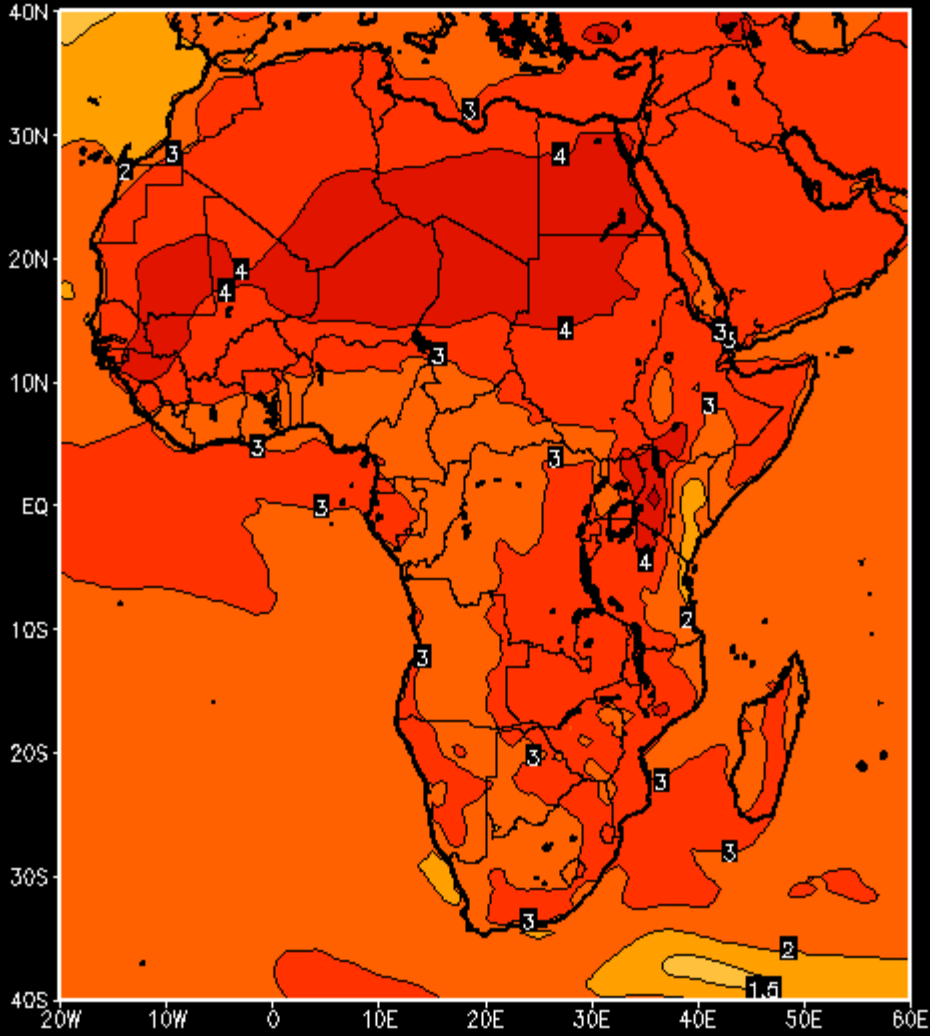


# Temp anomaly 2078

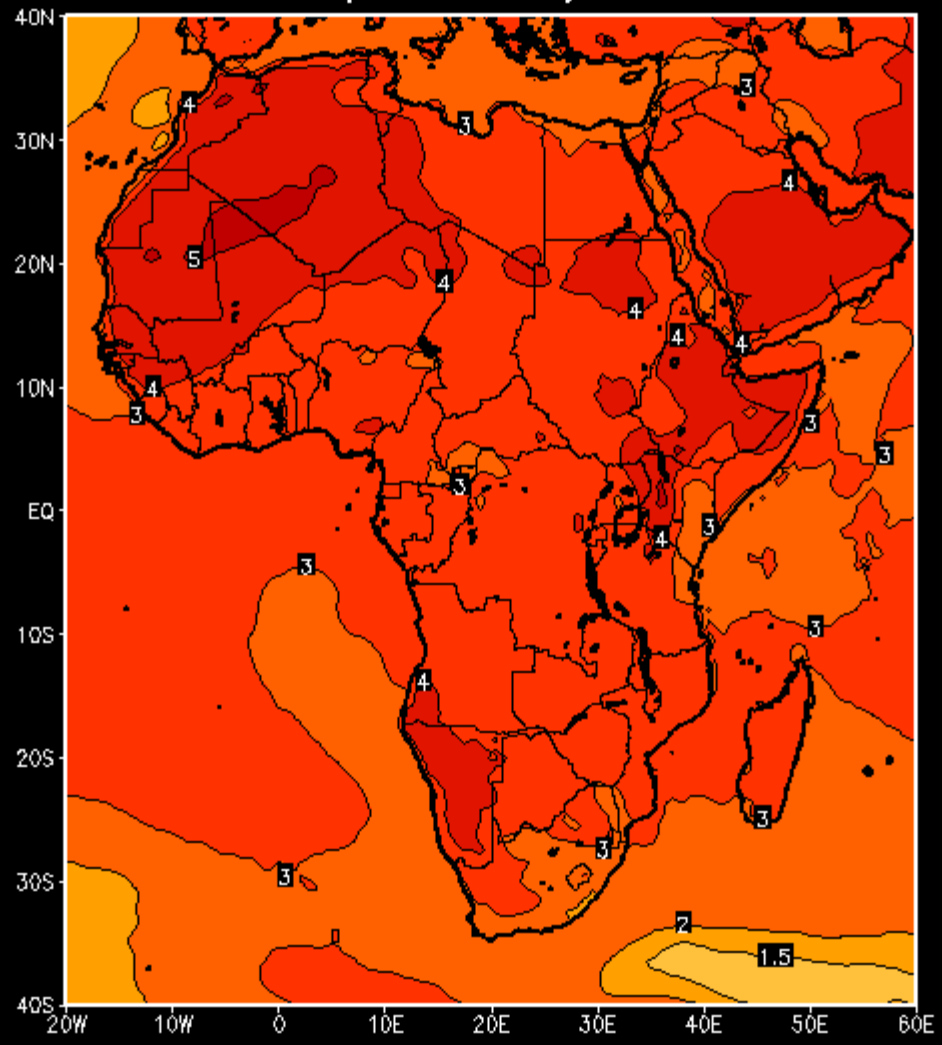




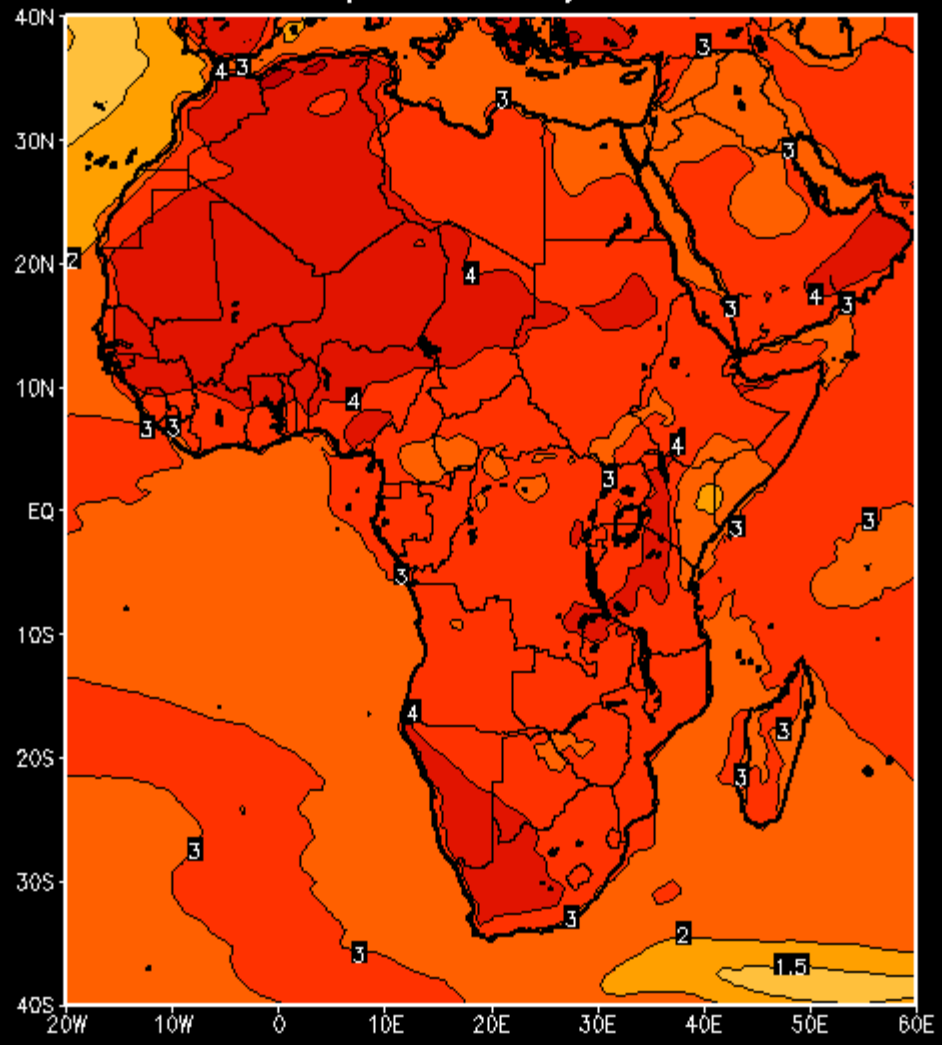
# Temp anomaly 2079



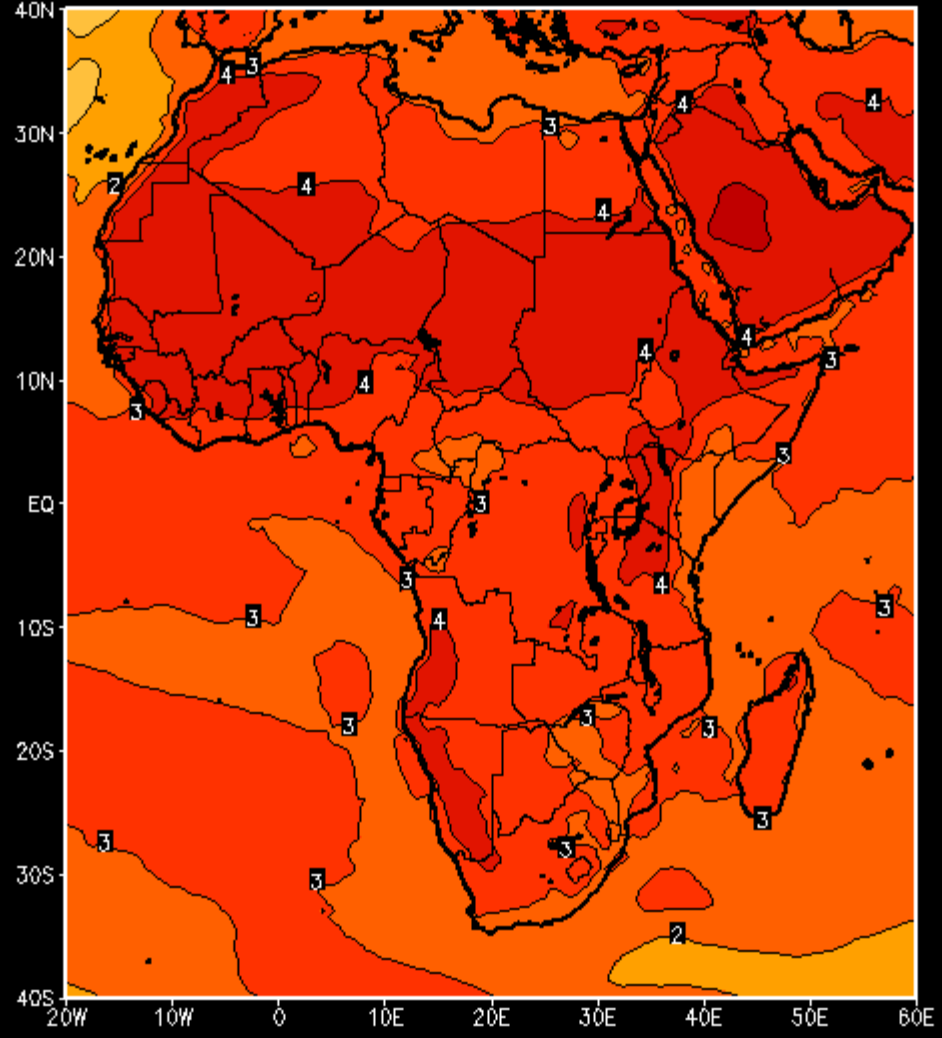
# Temp anomaly 2080



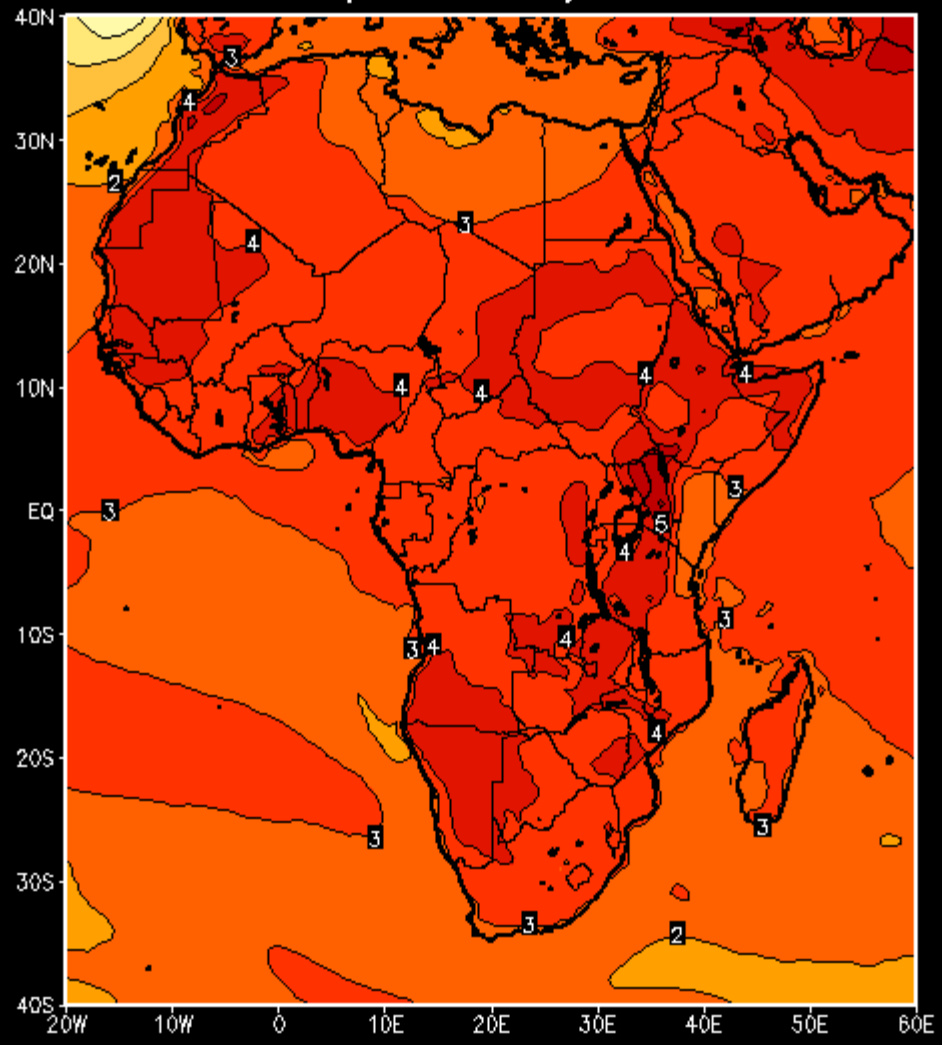
# Temp anomaly 2081



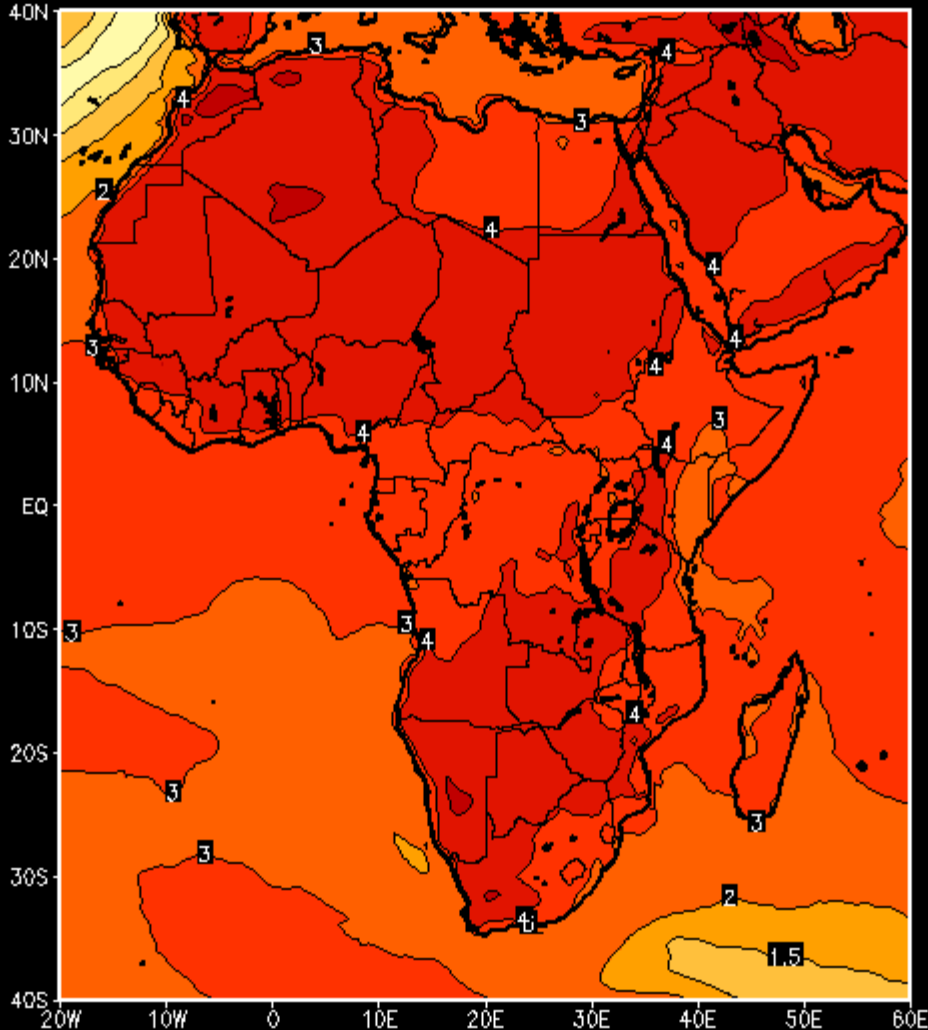
# Temp anomaly 2082



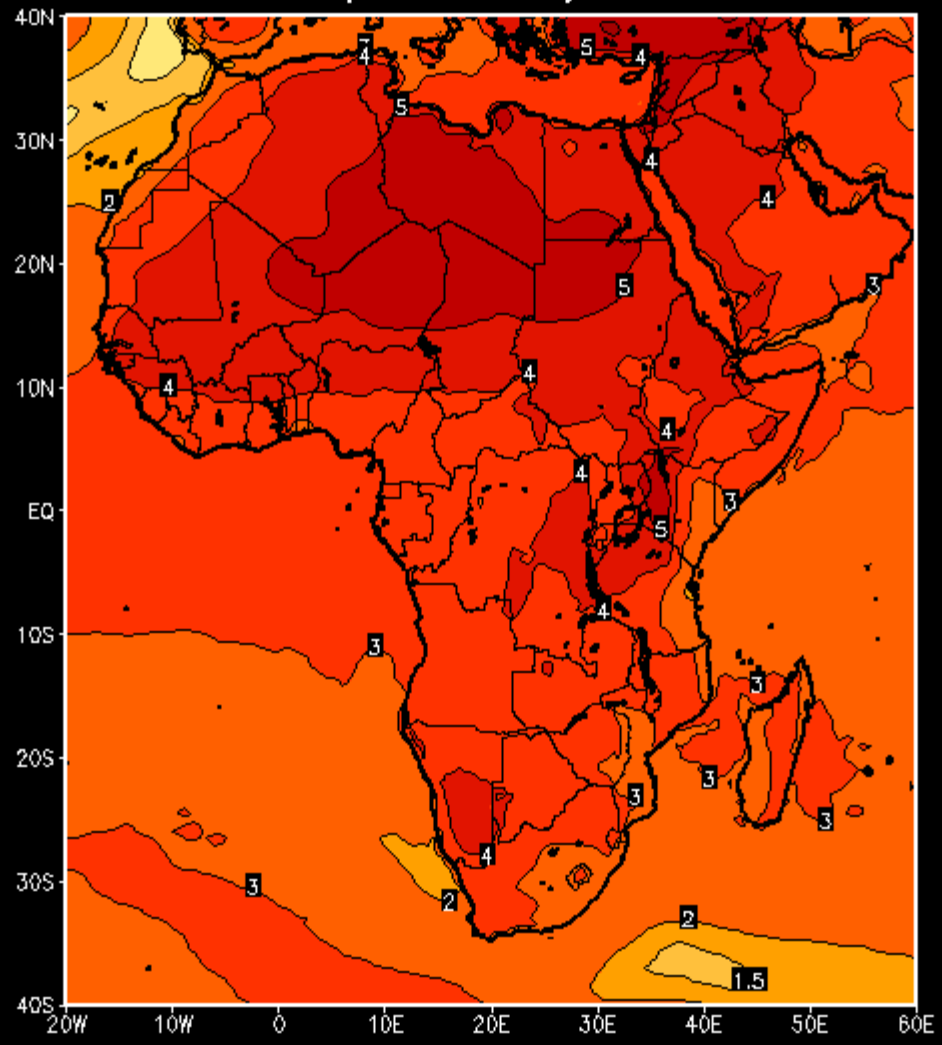
# Temp anomaly 2083



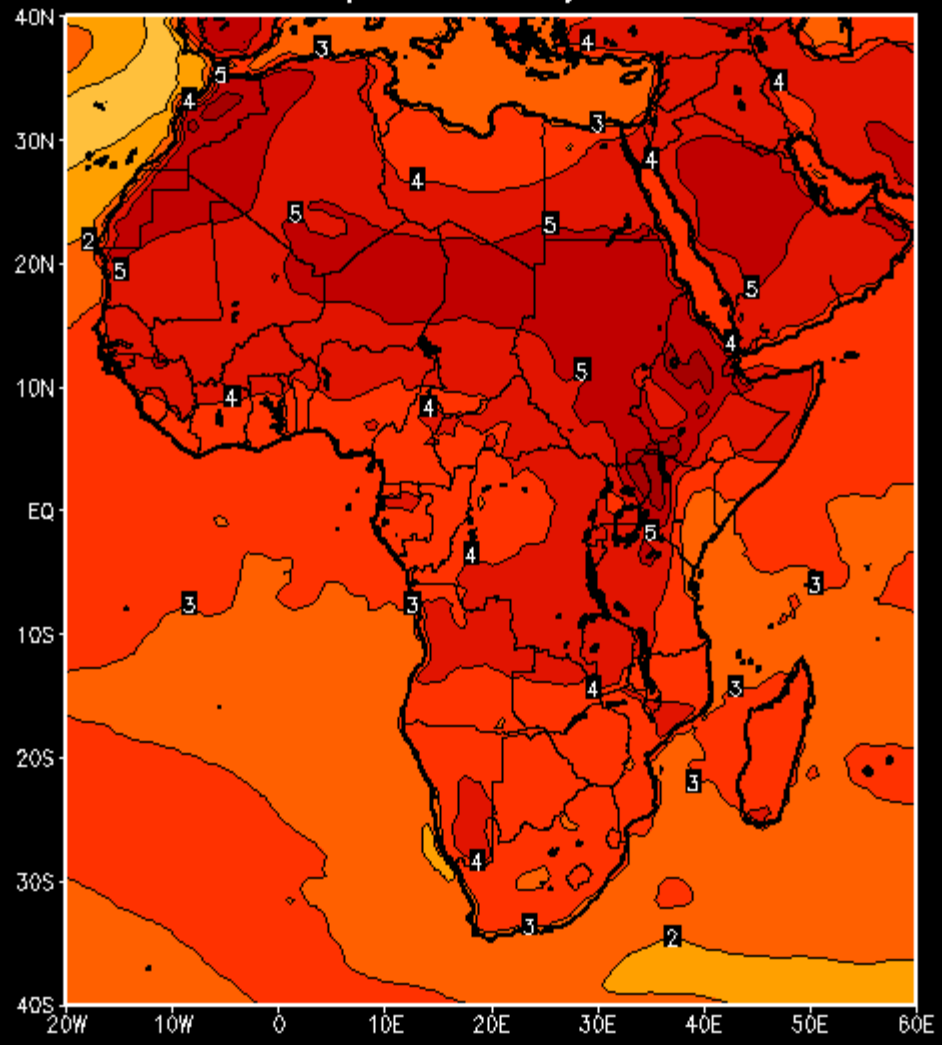
# Temp anomaly 2084



# Temp anomaly 2085

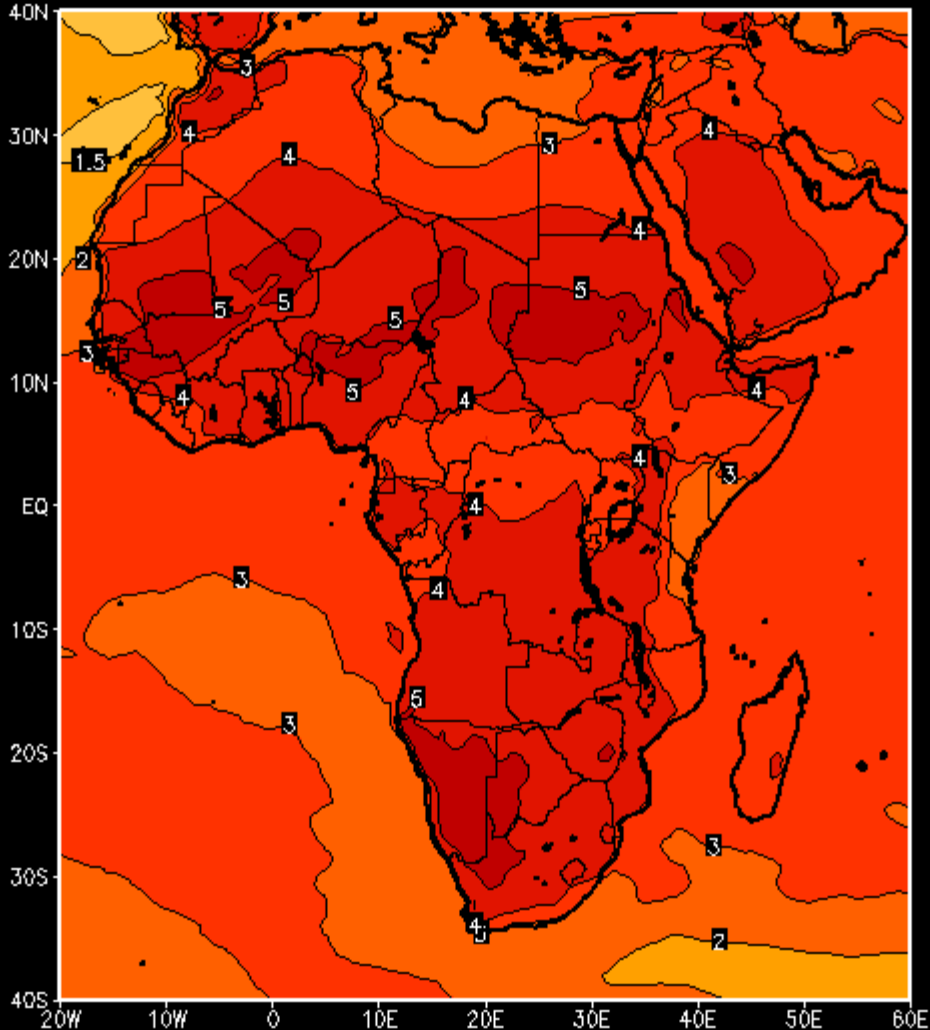


# Temp anomaly 2086

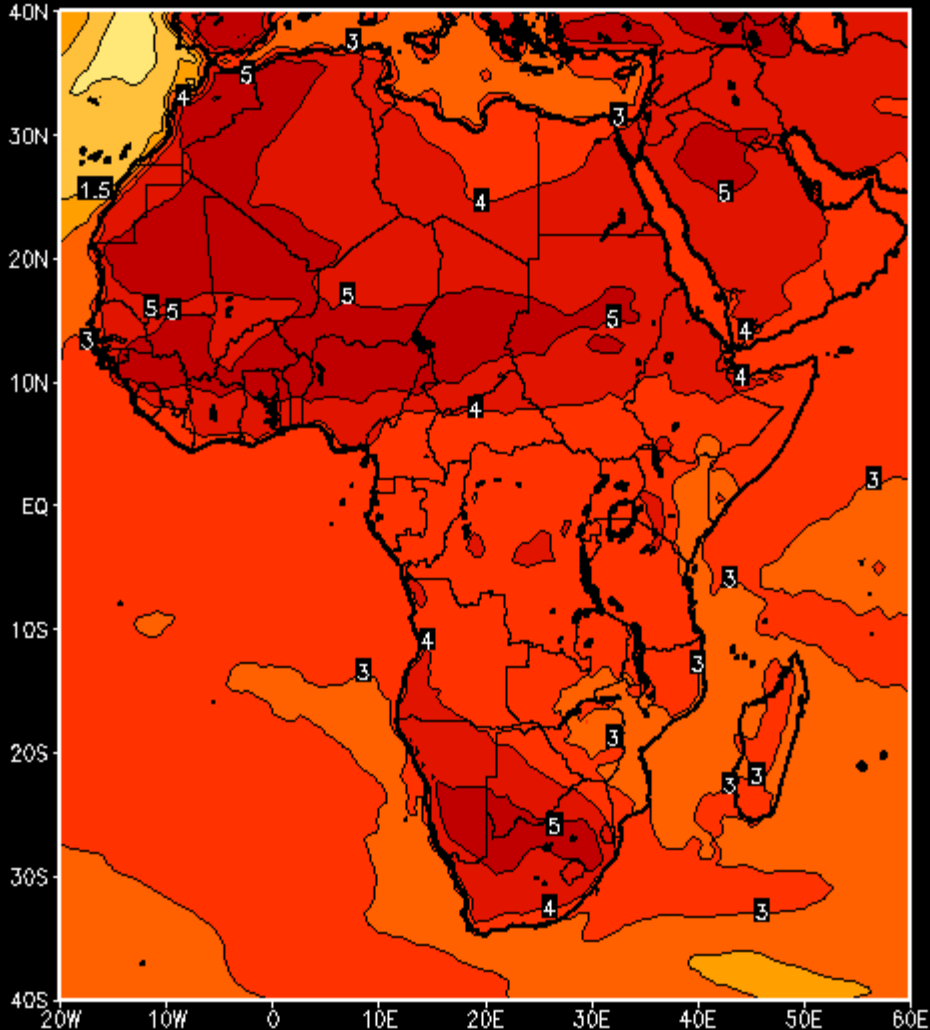




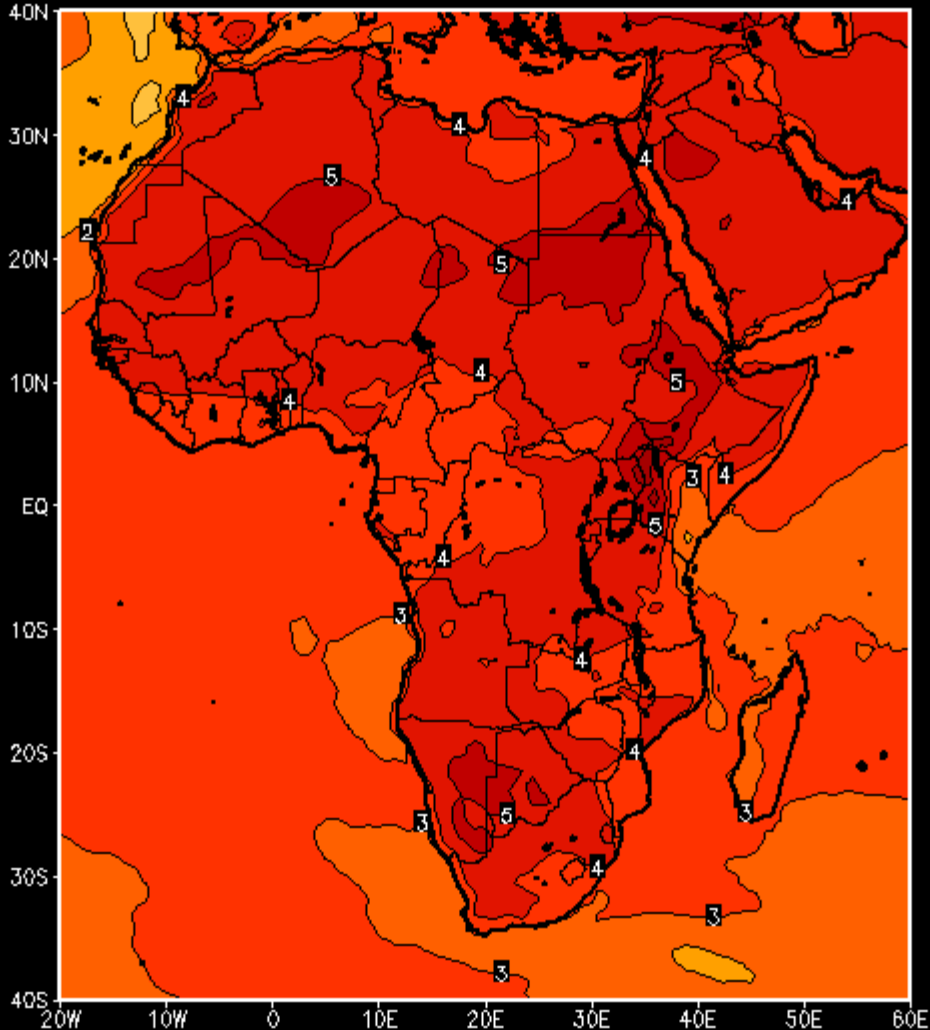
# Temp anomaly 2087



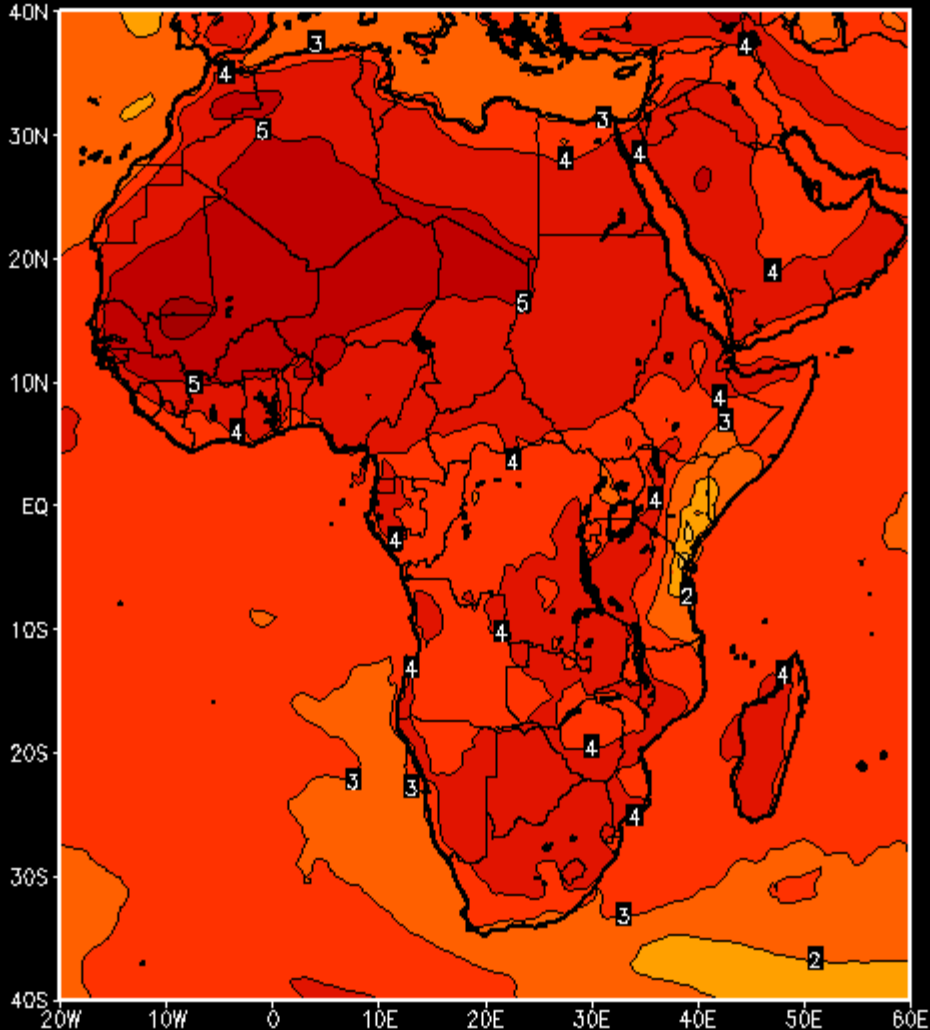
# Temp anomaly 2088



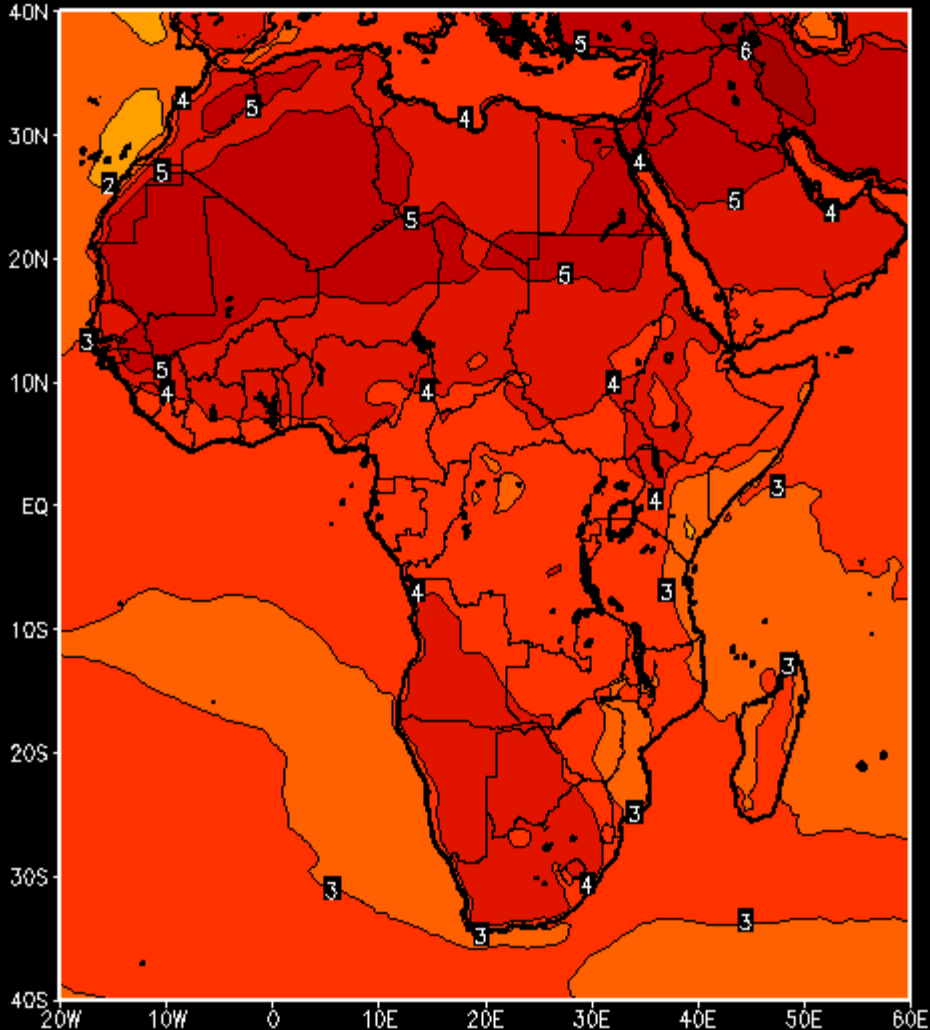
# Temp anomaly 2089



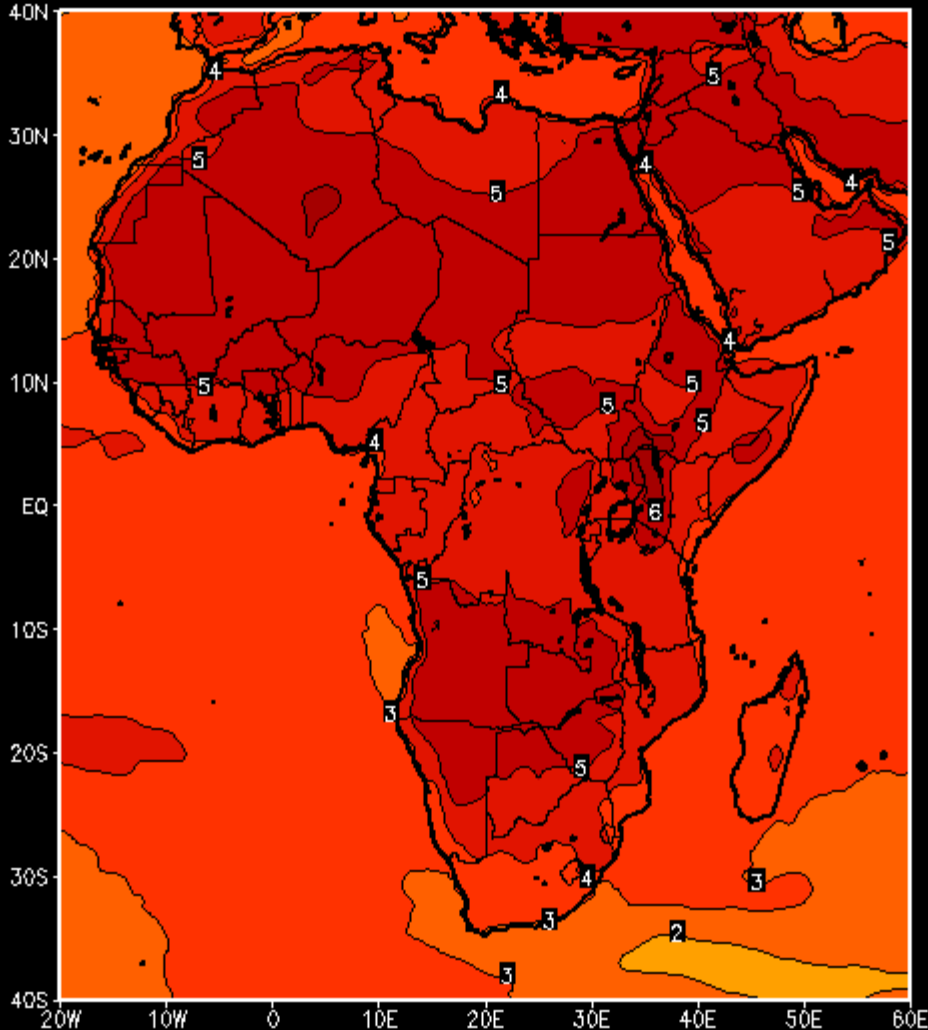
# Temp anomaly 2090



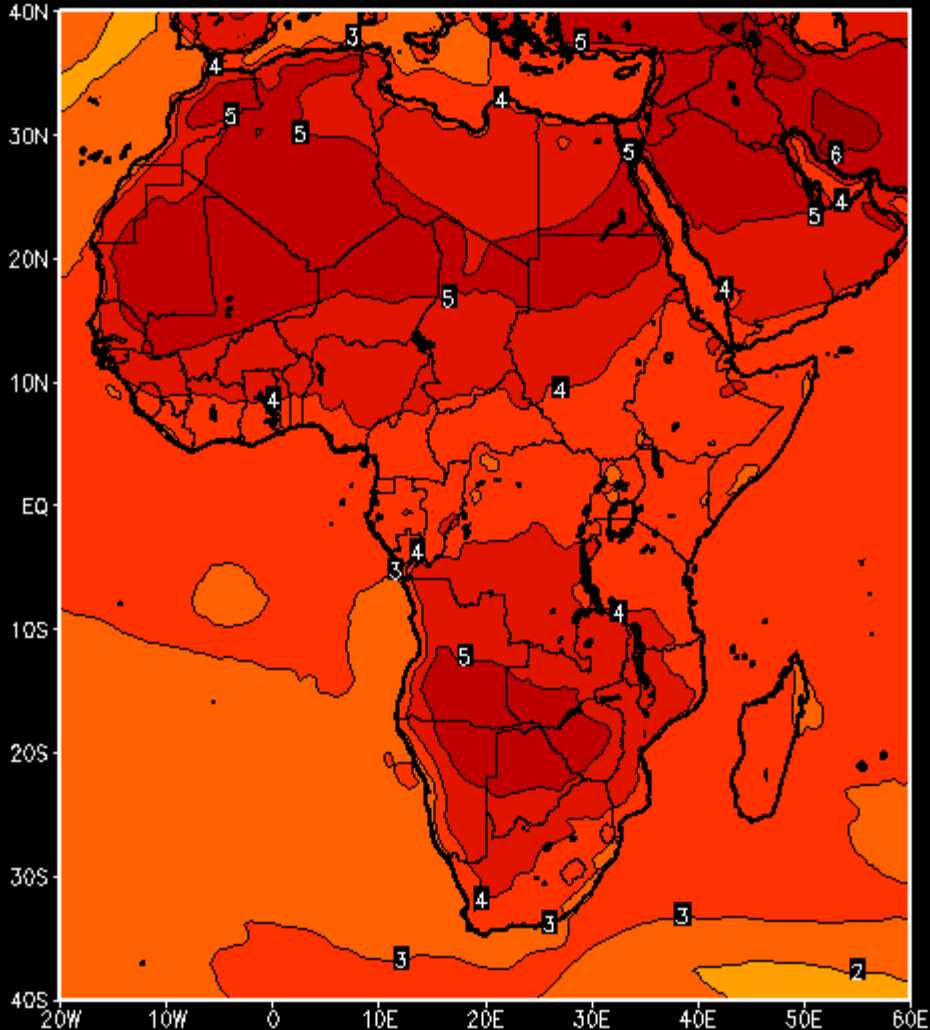
# Temp anomaly 2091



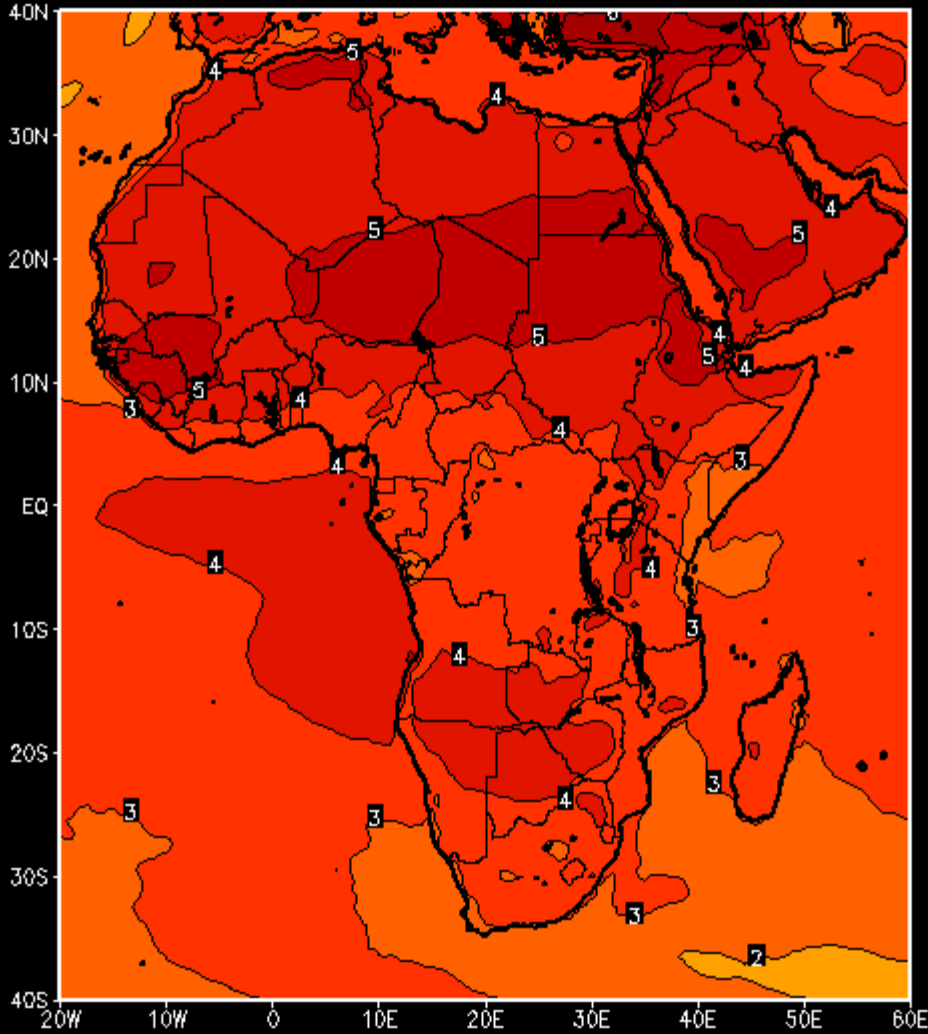
# Temp anomaly 2092



# Temp anomaly 2093

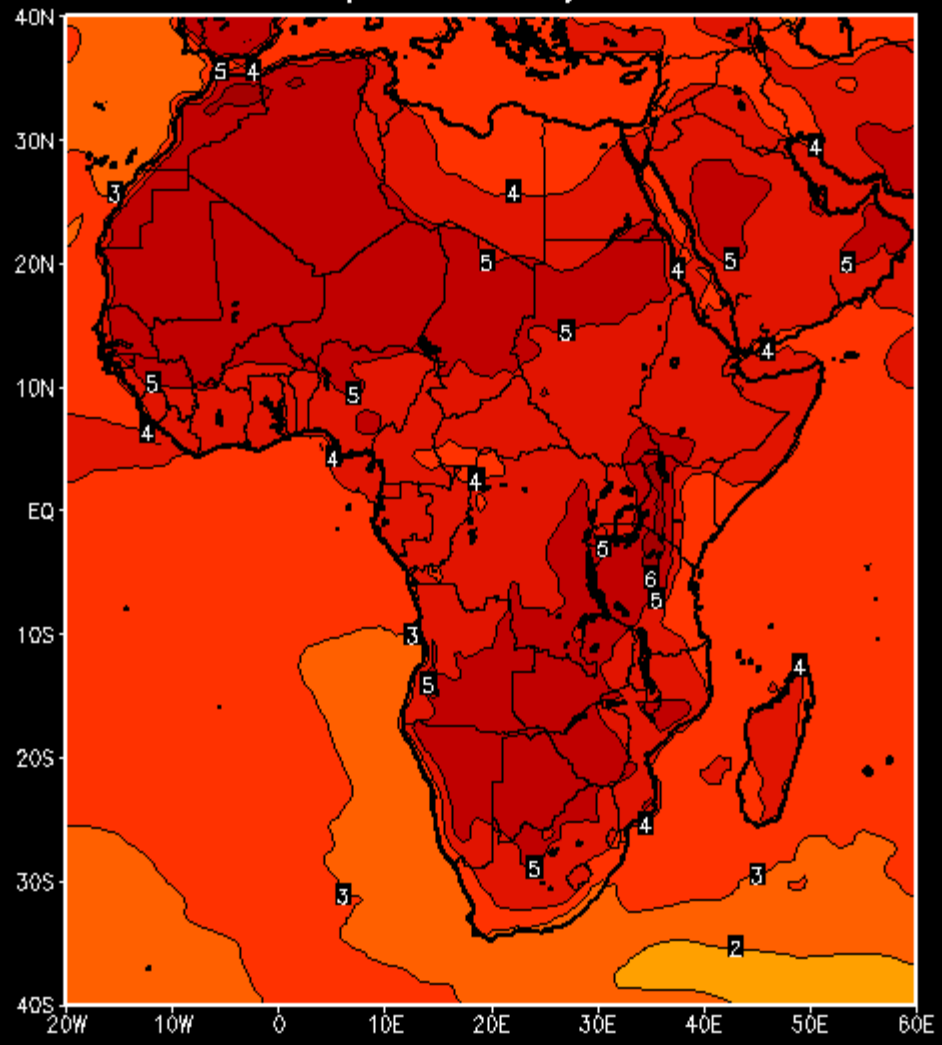


# Temp anomaly 2094

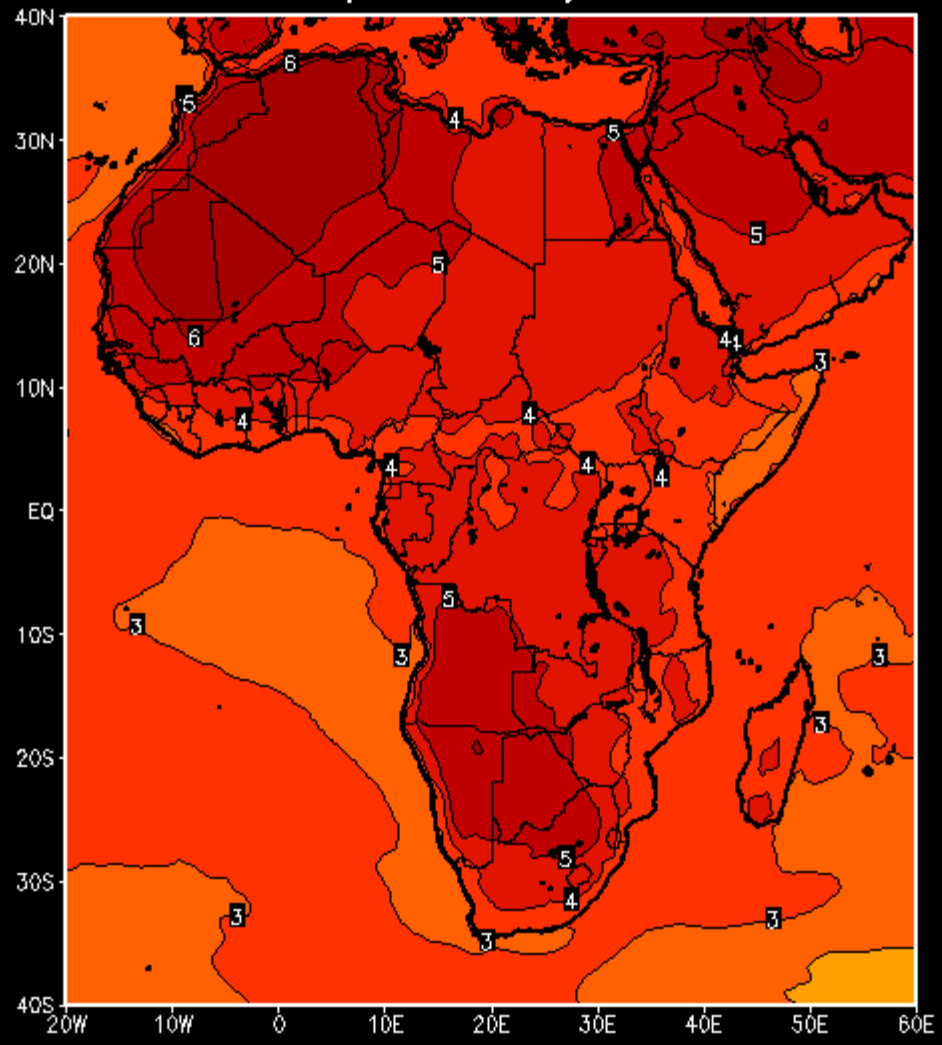




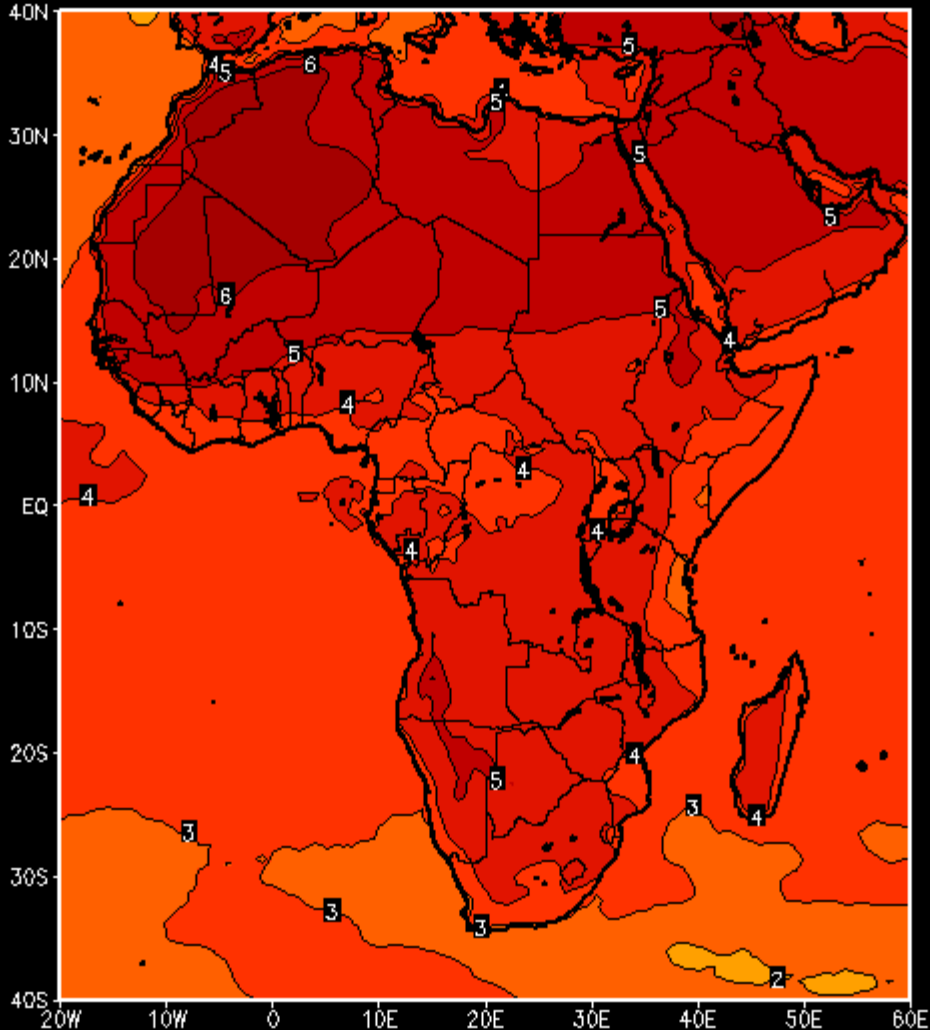
# Temp anomaly 2095



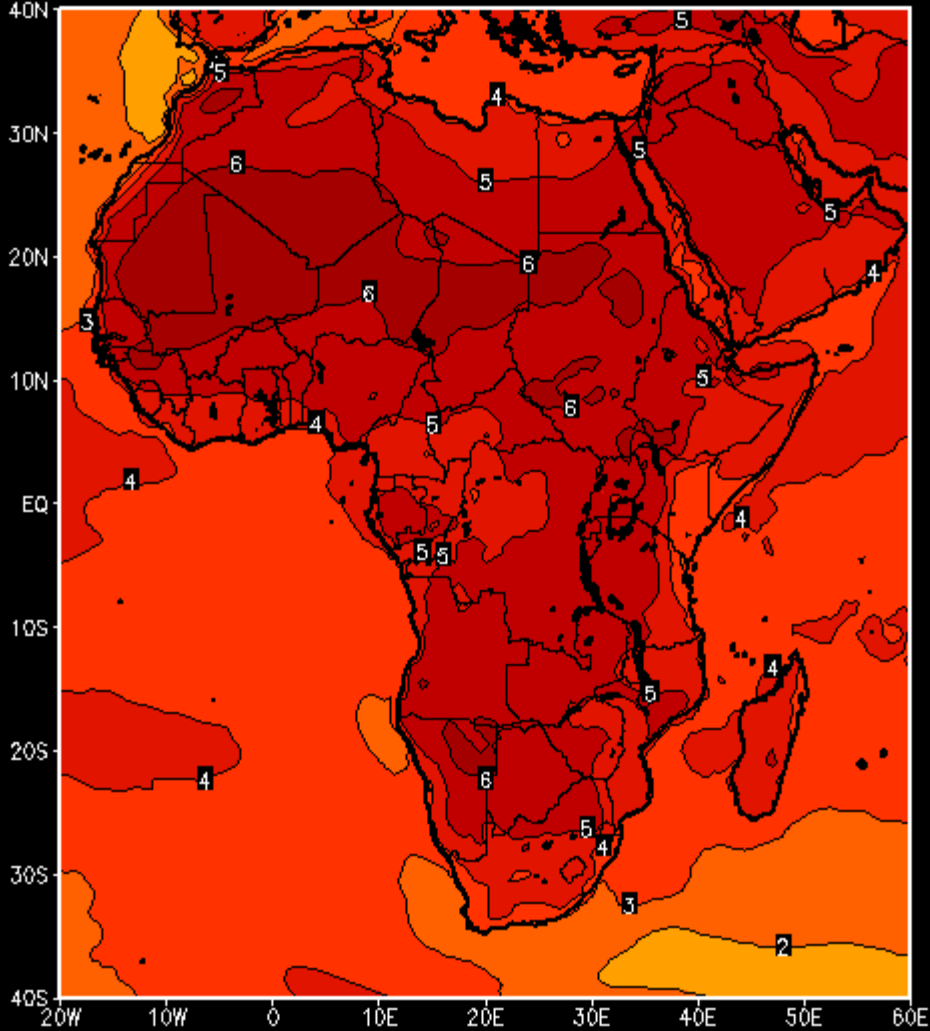
# Temp anomaly 2096



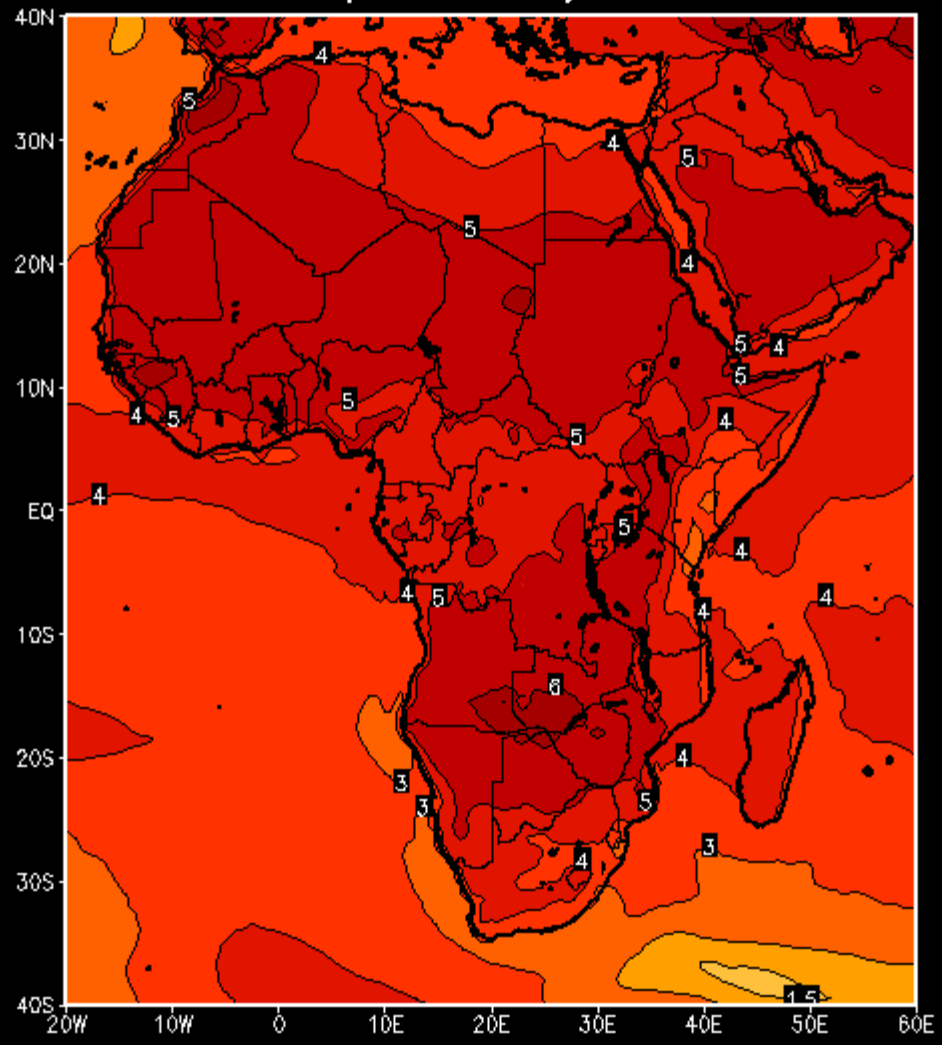
# Temp anomaly 2097



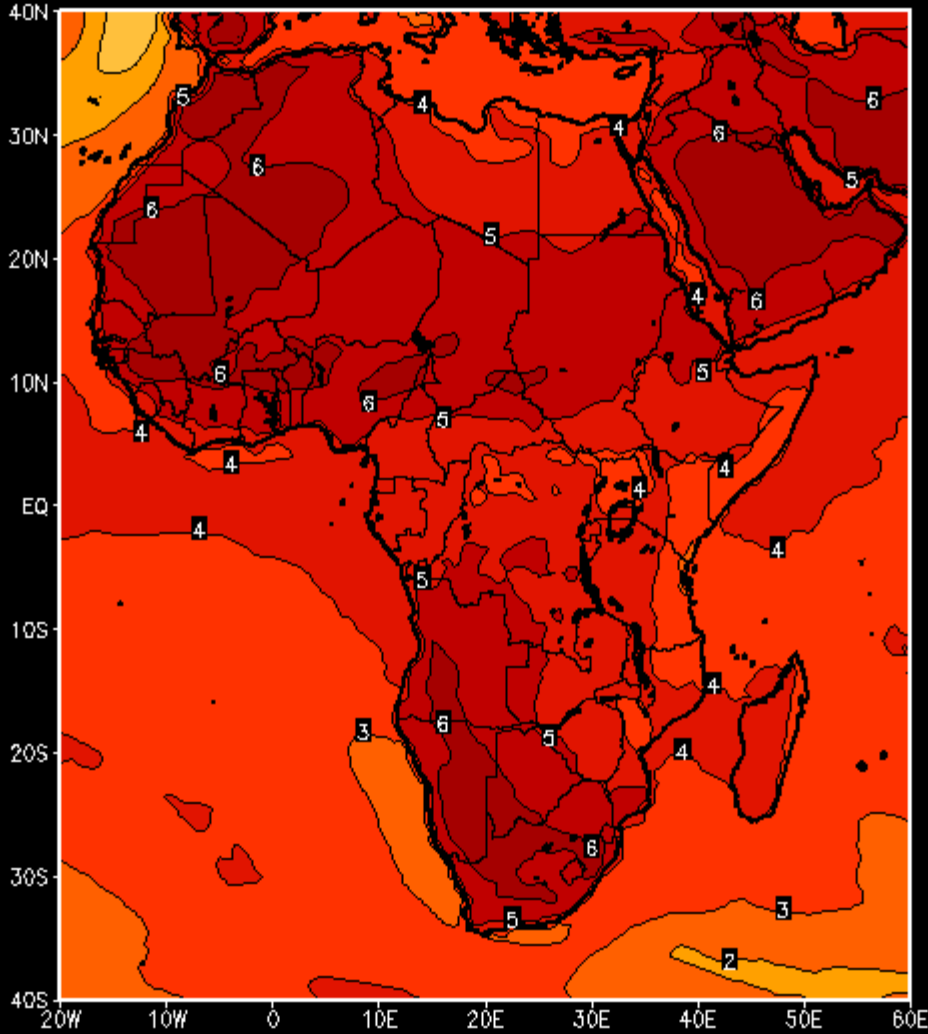
# Temp anomaly 2098



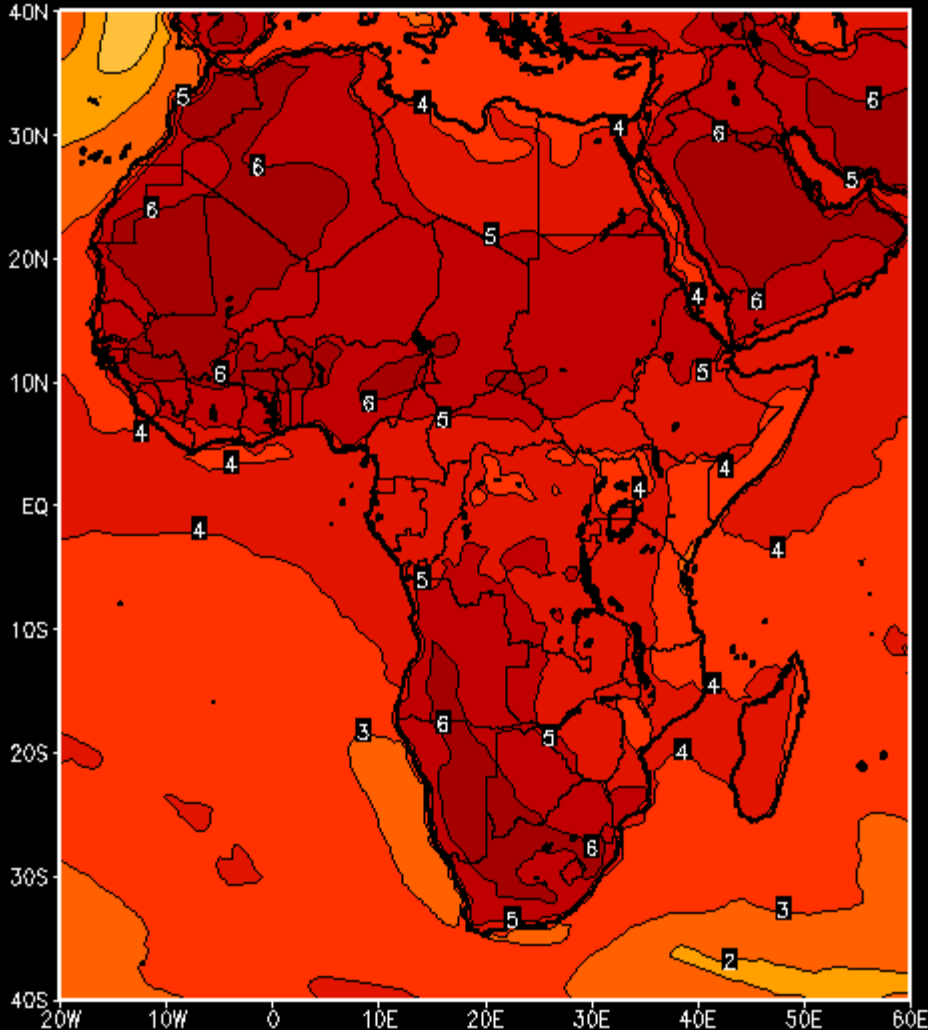
# Temp anomaly 2099

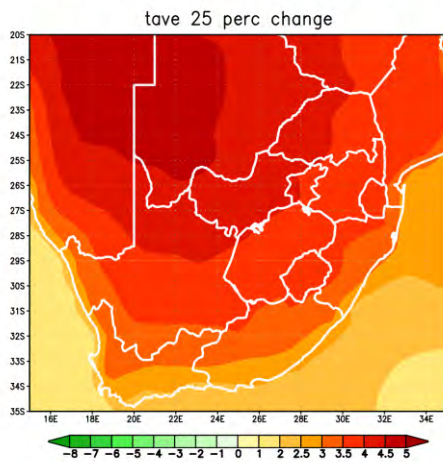
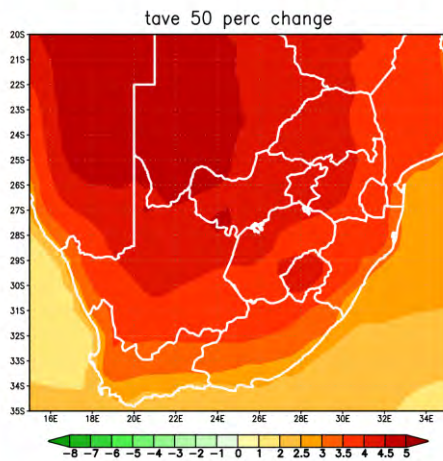
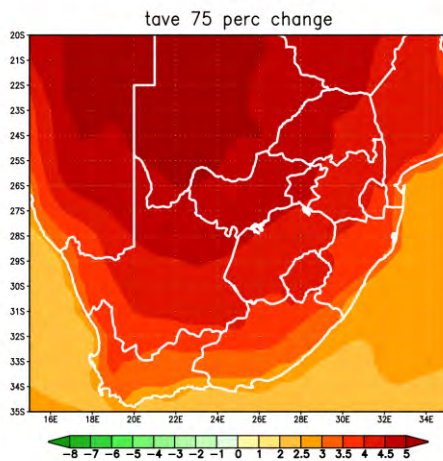


# Temp anomaly 2100



# Temp anomaly 2100





# Regional model ensemble: projected change in annual average temperature for 2071-2100 vs 1961-1990

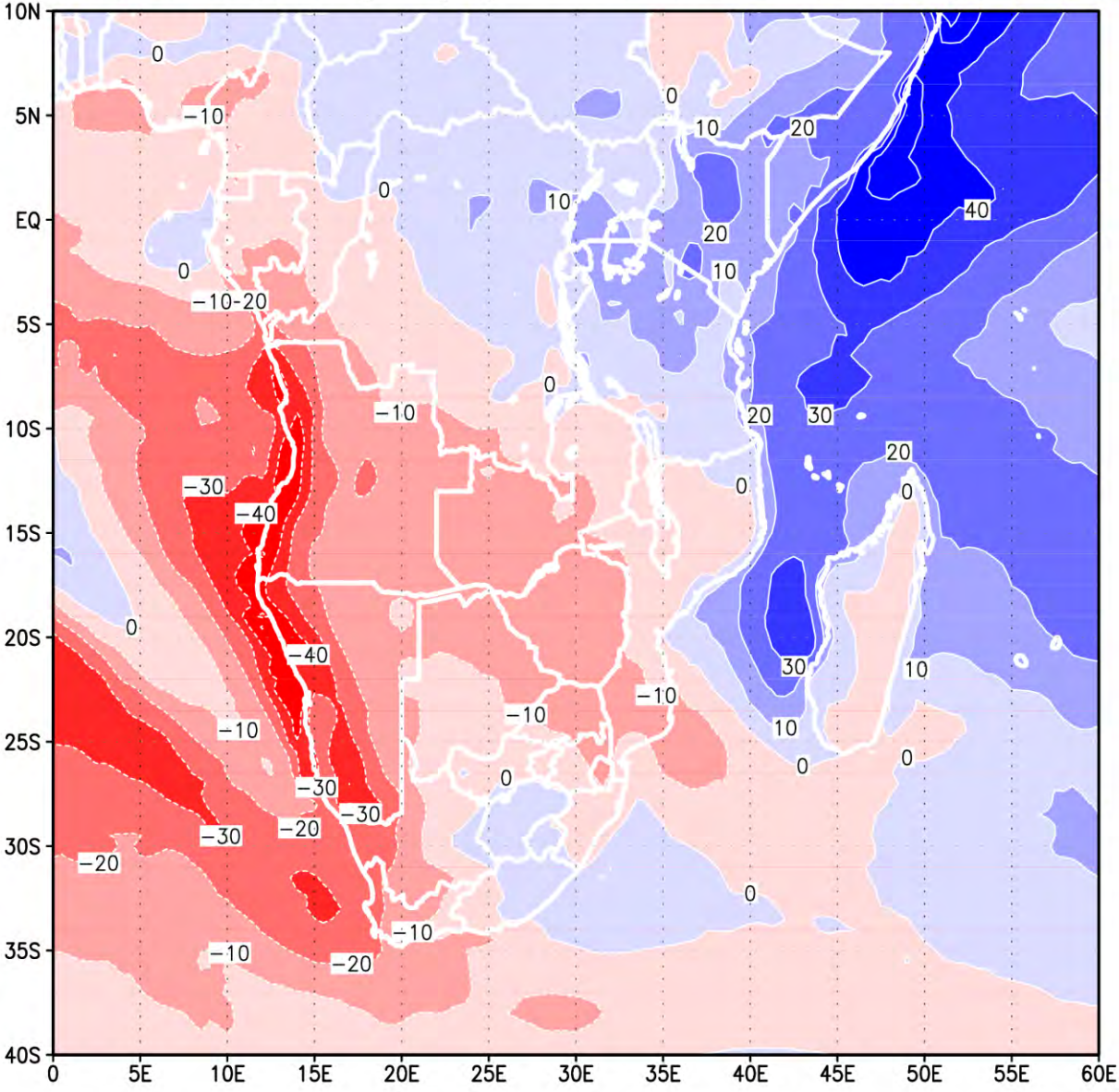
Under the A2 emission scenario, temperature increases of 3 to 6 degrees C are projected for the southern African interior, for the period 2071-2100 relative to 1961-1990

Temperatures over the interior regions of South Africa are projected to rise at twice the global rate of temperature increase

Drastic increases in extreme temperature events to impact on crop yield, livestock, biodiversity and energy demand



CCAM rnd change (%) 2071–2100 vs 1961–1990



**RCM ens-ave  
projected  
change in annual  
rainfall (%) for  
2071-2100 vs  
1961-1990**

Southern Africa  
projected to become  
generally drier

East Africa  
projected to become  
generally wetter

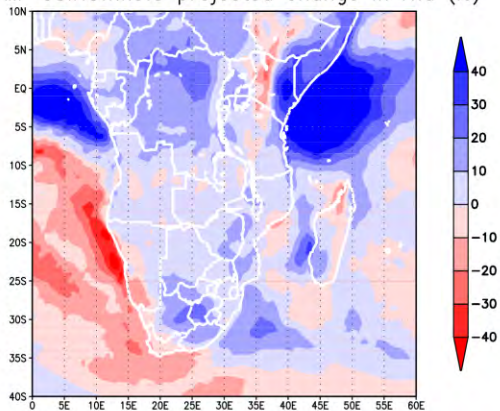


# RCM ensemble: projected change in annual rainfall (%) for 2071-2100 vs 1961-1990

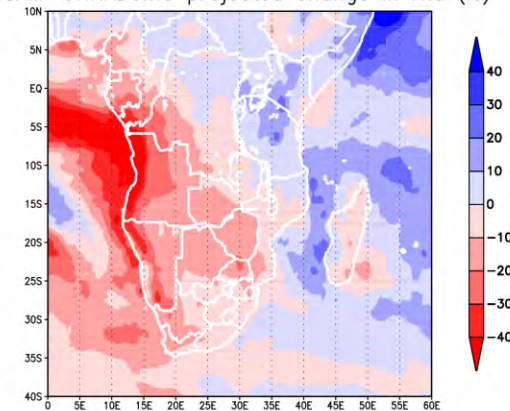
Most models project a  
generally drier  
southern Africa, but  
wetter East Africa

Thunderstorm related  
rainfall signal over  
central South Africa

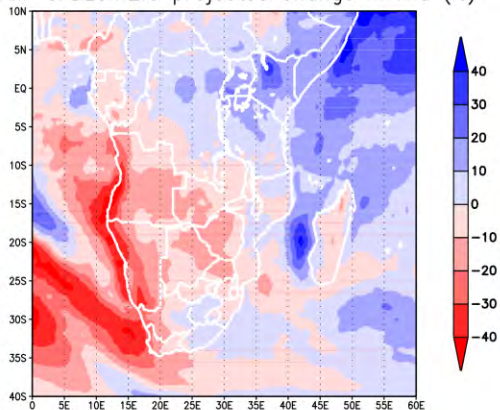
CCAM-CSIROmk3.5 projected change in rnd (%)



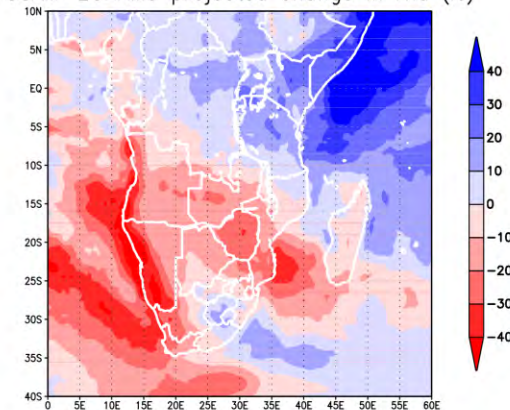
CCAM-UKHADcm3 projected change in rnd (%)



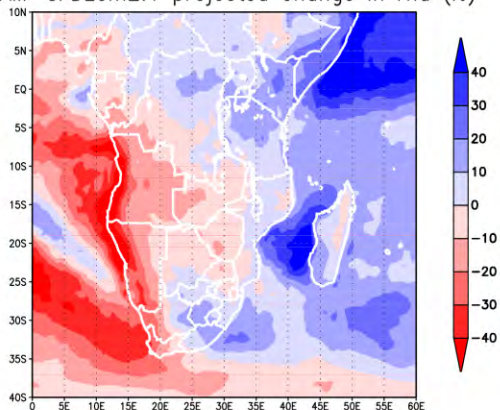
CCAM-GFDLcm2.0 projected change in rnd (%)



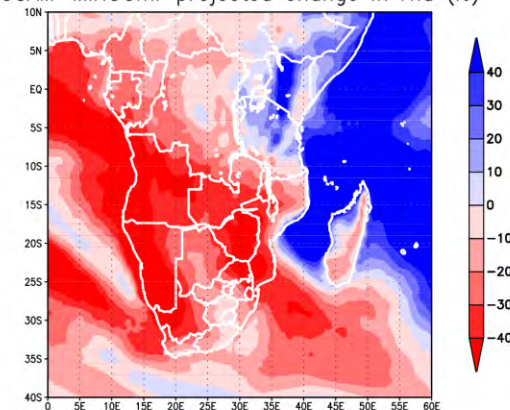
CCAM-ECHAM5 projected change in rnd (%)



CCAM-GFDLcm2.1 projected change in rnd (%)



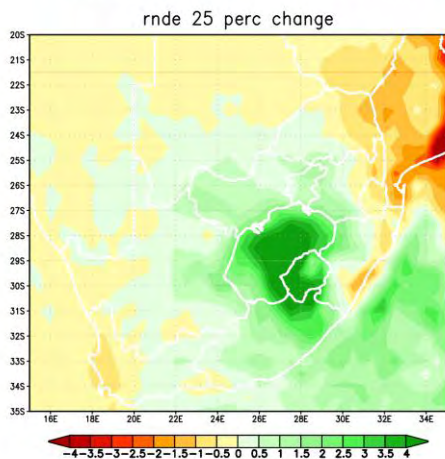
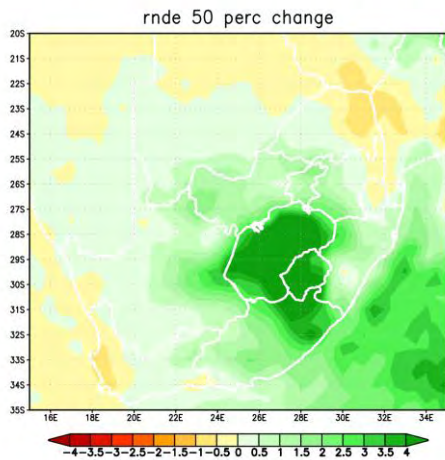
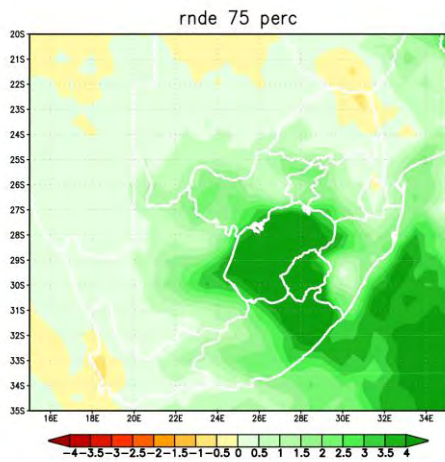
CCAM-MIROCmr projected change in rnd (%)



# Regional climate model ensemble: projected change in the number of extreme rainfall events for 2071-2100 vs 1961-1990

A general increase in the frequency of occurrence of extreme rainfall events (20 mm of rain falling within 24 hours over and area of 50 km x 50 km) is projected for South Africa

Most models project a generally drier South Africa, despite the projected increase in extreme rainfall events



A grayscale satellite image showing a tropical cyclone over the southern part of Africa. The cyclone is characterized by a bright, dense central core surrounded by a well-defined eye wall and a spiral of cloud bands extending outwards. The landmass of southern Africa is visible on the left side of the frame, appearing in dark tones. The surrounding ocean is also visible, with some scattered cloud clusters.

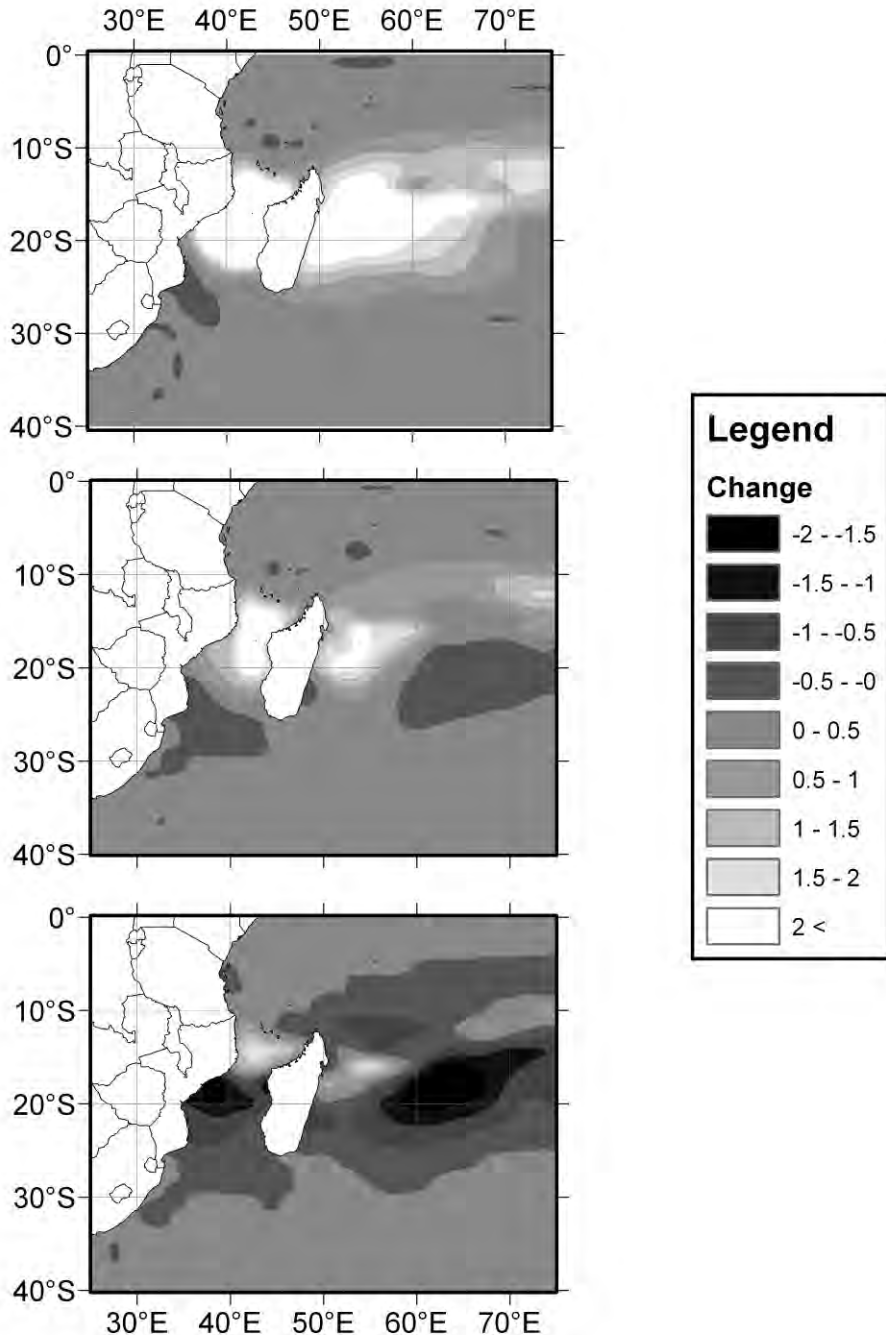
**Climate Change and  
Tropical Cyclones+Lows  
over southern Africa**

**MSG IR image**

# Climate Change and Tropical Cyclones+Lows

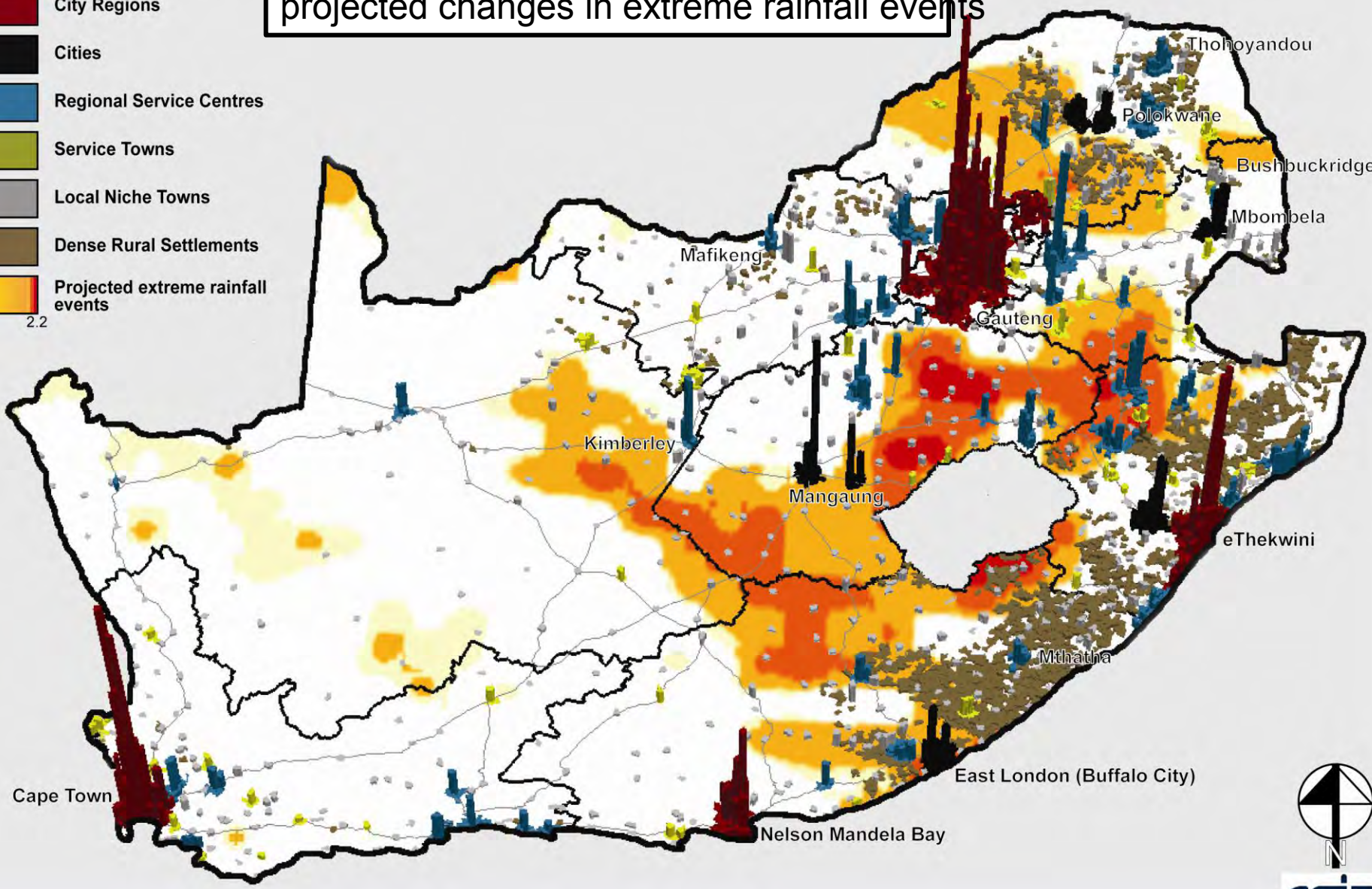
Model projected change in tropical cyclone and tropical low frequencies over the southwestern IO and southern Africa, for 2071-2100 relative to 1961-1990.

Malherbe et al. (2012)

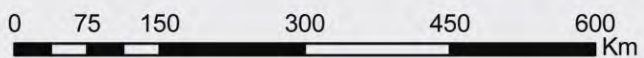


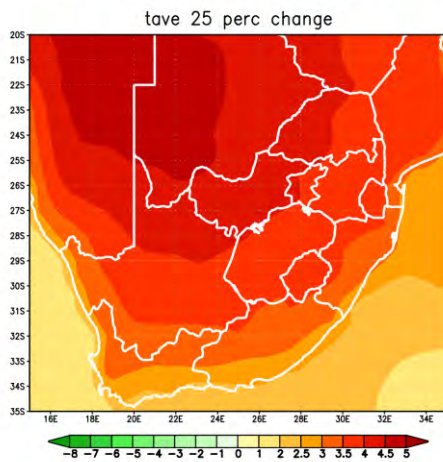
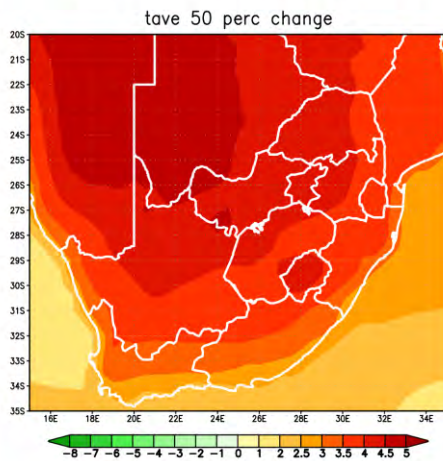
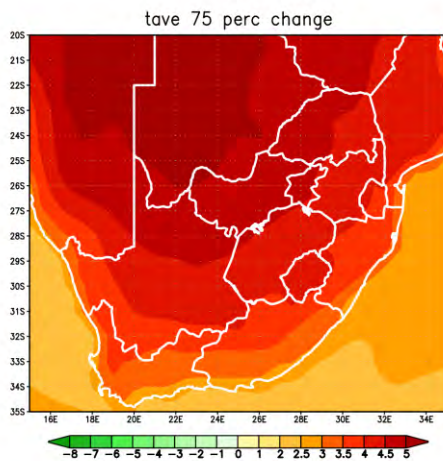
## EXAMPLE : Settlements vulnerability to projected changes in extreme rainfall events

(Height indicates population size)



Data sources: SA Settlements typology. Developed by the CSIR for SACN, 2009. Updated by CSIR for The Presidency, 2011 and based on CSIR mesoframe, 2011. Projected change in frequency of extreme rainfall events(> 20mm rain in 24h for 2011-2040) – CSM&EH.





# Conclusions: Drastic climate change over southern Africa in a +2 degree world

Constraining the global temperature increase to 2 °C may not be a solution for southern Africa's climate change problems

Drastic increases in surface temperatures likely to impact on crop yield and local hydrology (through increased evaporation)

Only slight changes in rainfall totals are projected, however, uncertainty surrounds the “direction” of change

The message of an increase in the frequency of occurrence of extreme rainfall events is robust

**CSIR is involved in and climate change adaptation and impact research across many different sectors**

