Modeling/Calibration/Generated Scenarios in East Africa

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- Climate Models and Climate System
- Operational Modeling
- Climate Projections and Scenario Modeling

What is a climate model?

“ a mathematical representation of the climate system, solved numerically on a computer”

```
! IF (ISOLIR.EQ.IP_SOLAR) THEN
DO L=1, N_PROFILE
SOURCE_GROUND_FREE(L)=(ALBEDO_SURFACE_DIR(L)
& -ALBEDO_SURFACE_DIFF(L))
& *(FLUX_DIRECT(L, N_LAYER)
& -FLUX_DIRECT_GROUND_CLOUD(L))
SOURCE_GROUND_CLOUD(L)=(ALBEDO_SURFACE_DIR(L) & -
ALBEDO_SURFACE_DIFF(L))
& *FLUX_DIRECT_GROUND_CLOUD(L)
ENDDO
ELSE
DO L=1, N_PROFILE
SOURCE_GROUND_FREE(L)
& =CLOUD_OVERLAP(L, N_LAYER, IP_CLOVLP_BFF)
& *SOURCE_GROUND(L)
SOURCE_GROUND_CLOUD(L)
& =CLOUD_OVERLAP(L, N_LAYER, IP_CLOVLP_BCF)
& *SOURCE_GROUND(L)
ENDDO
ENDIF
```

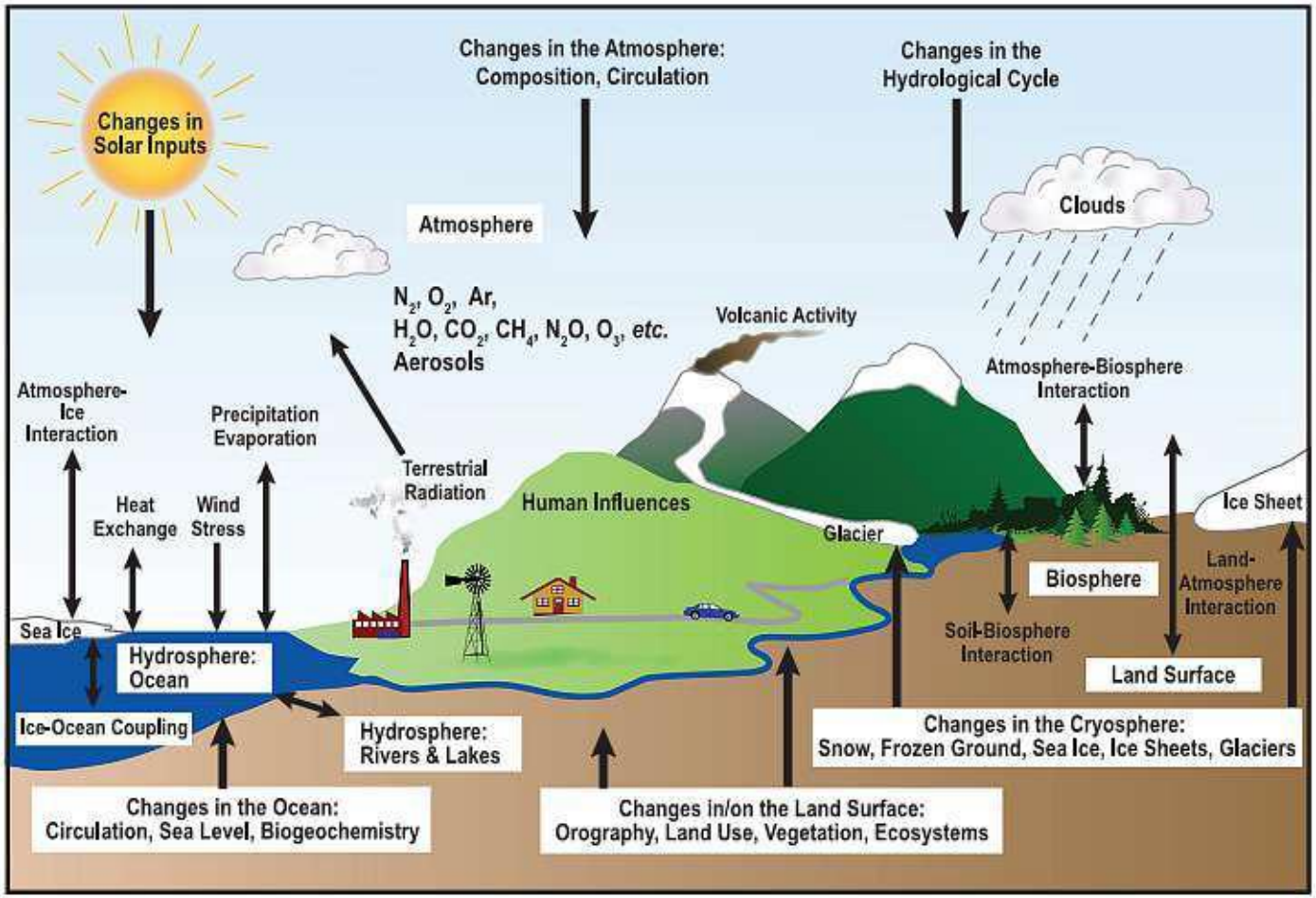
Hierarchy of climate models

More complex

Less complex

Earth System Models	➢Include all physics. ➢Simulate (nearly) all components of the earth system. ➢ Hugely expensive - no ensembles. ➢Carry out ‘snapshots’ or short transients.
Complex General Circulation Models (GCMs).	➢As ESMs, but do not simulate all components of the earth system, usually atmos, ocean, (veg). ➢Still too slow to carry out long transient simulations, but can be used for ensembles.
Earth-system Models of Intermediate Complexity (EMICs).	➢Include some physics. ➢Include all components of earth-system. ➢Can carry out long transient simulations and snaphots.
Conceptual Models	➢Include a few or no processes. ➢Can aid understanding.

Earth System Model/GCM



Factors that change the climate

Forcing agents

- Greenhouse Gases (CO2, CH4, N2O, O3, CFCs)
- Aerosols (SO4, Carbon, Nitrate, Dut etc)
- Land Use and Land Cover
- Solar
- Volcano
- etc

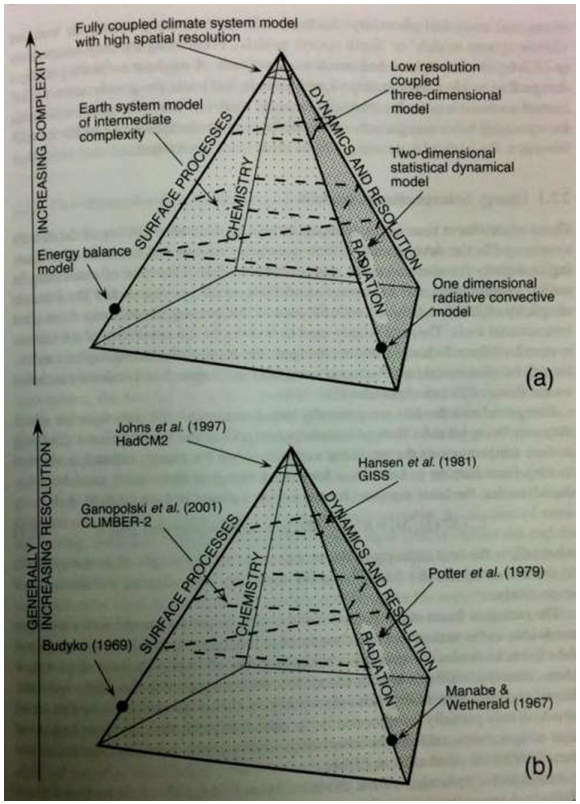
Sources/Actors:

People, Industry, Agriculture, Urbanization, Vehicles, Disaster etc.

(Source: IPCC 2013)

Understand Climate Models (5-Components)

1. **Solar Radiation** *(absorbed by the atmosphere and Sea*)
2. **Dynamics** *(e.g. movement of energy/heat and mass by winds)*
3. **Surface processes** *(effects of ice, snow, vegetation, albedo, moisture interchanges)*

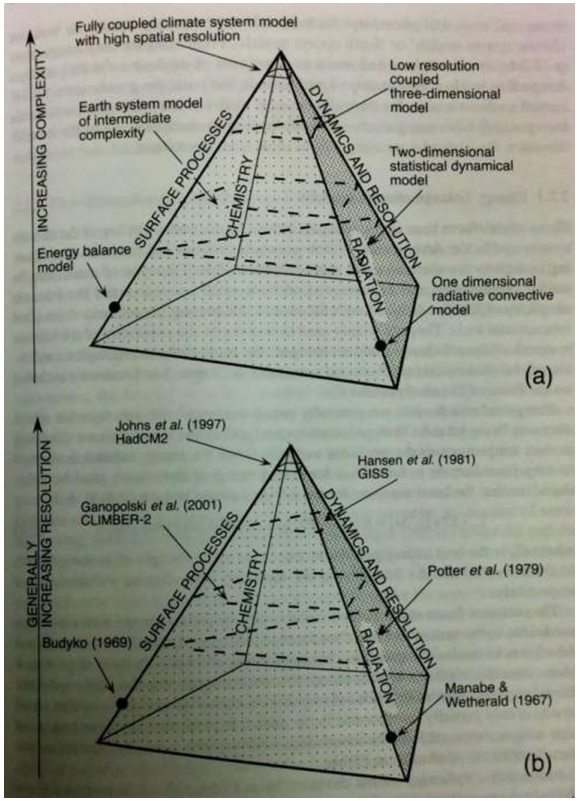


(Source: McGuffie and Henderson-Sellers, 2005)

Understand Climate Models (5-Components)

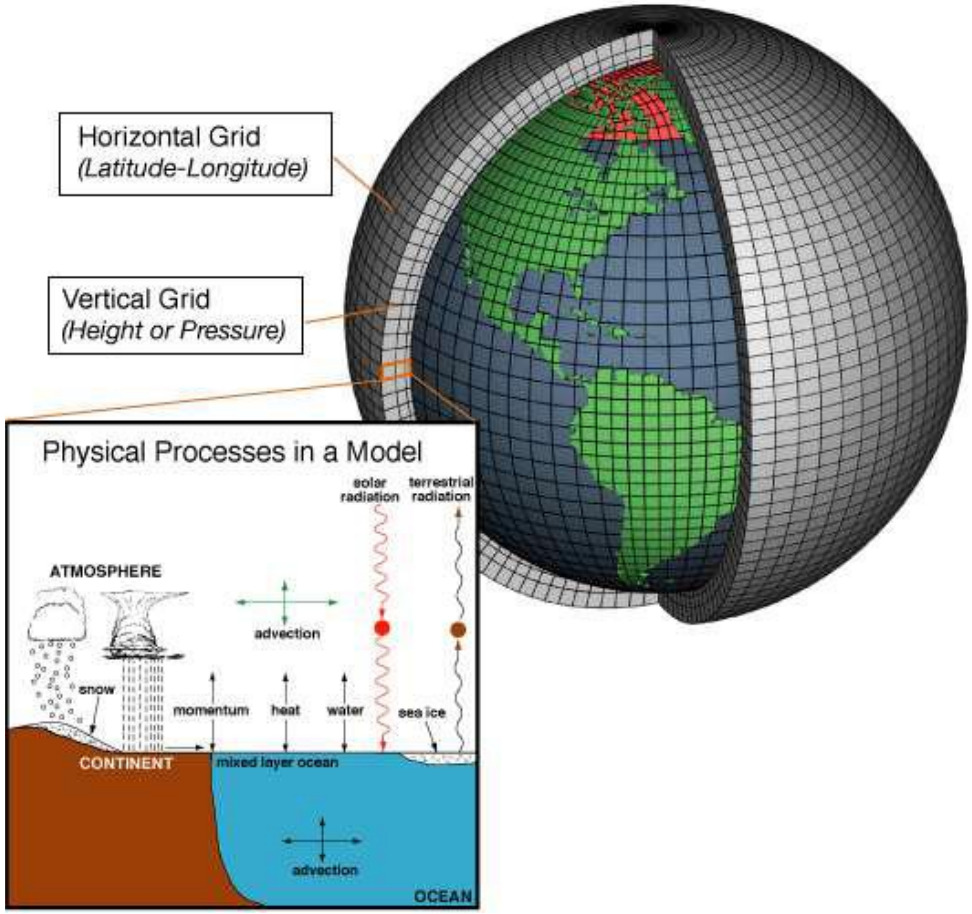
4. Chemistry *(Chemical composition of atmosphere and interactions, e.g. CO2 exchanges between sea, land and atmosphere)*

5. Resolution in both time and space *(the timestep of the model and horizontal & vertical scales resolved)- Model setup & programming language platform*



(Source: McGuffie and Henderson-Sellers, 2005)

Global Climate Models (GCMs)



- Mathematical model of the general circulation of the atmosphere and ocean
- Based on the *Navier-Stokes* equations on a rotating sphere with thermodynamic terms for various energy sources (radiation, latent heat)

GCMs

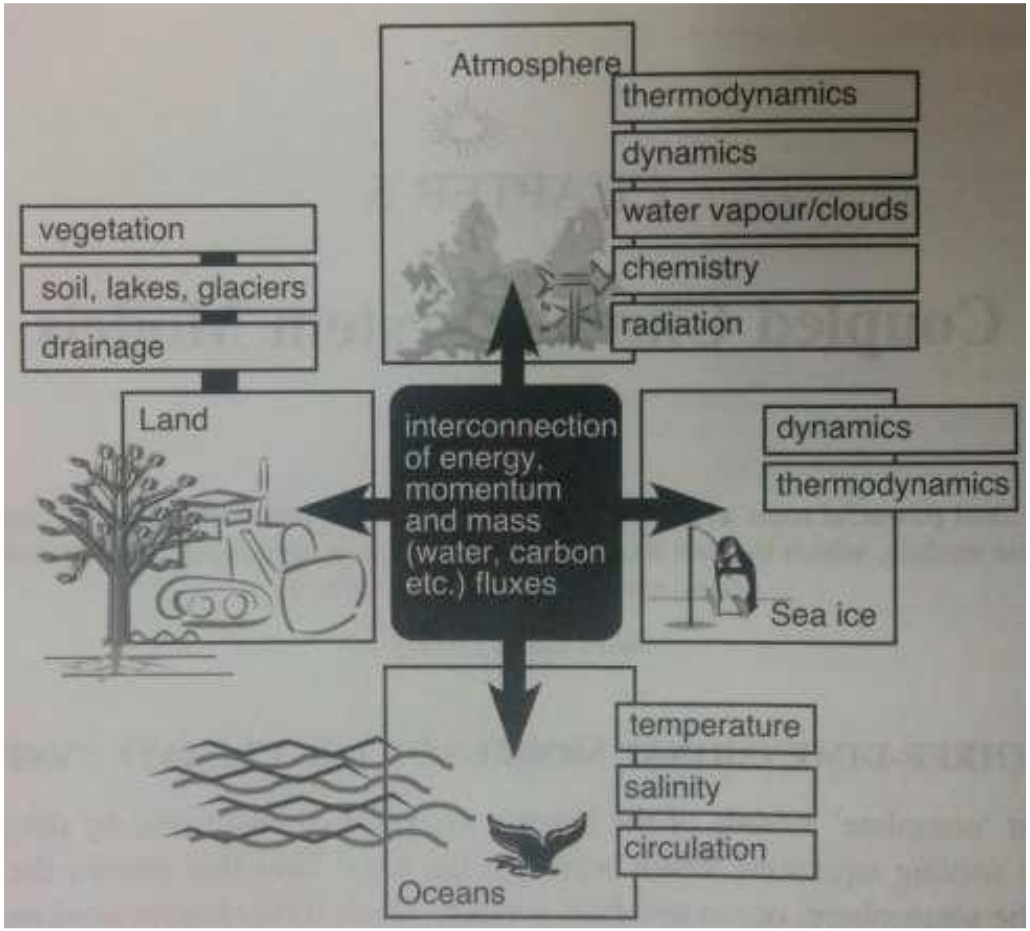
Fundamental Four-laws considered:

1. **Conservation of Energy** (1st law of thermodynamics i.e. input energy=increase in internal energy + work done)
2. **Conservation of Momentum** (Newton's second law of motion i.e. F – ma)
3. **Conservation of mass** (continuity equation)
4. **Ideal gas law** (an approximation to the equation of state-atmosphere only i.e. *PV ∞ Absolute temperature x density)*

Types of GCMs

1. AGCM (Atmospheric GCM); atmosphere and impose SSTs
2. OGCM (Ocean GCM); Global se patterns
3. AOGCM (atmosphere and Ocean GCM or CGCM)

Coupled atmosphere-ocean models (e.g. CCSM4, HadCM3, GFDL)



Key take on Climate Modeling

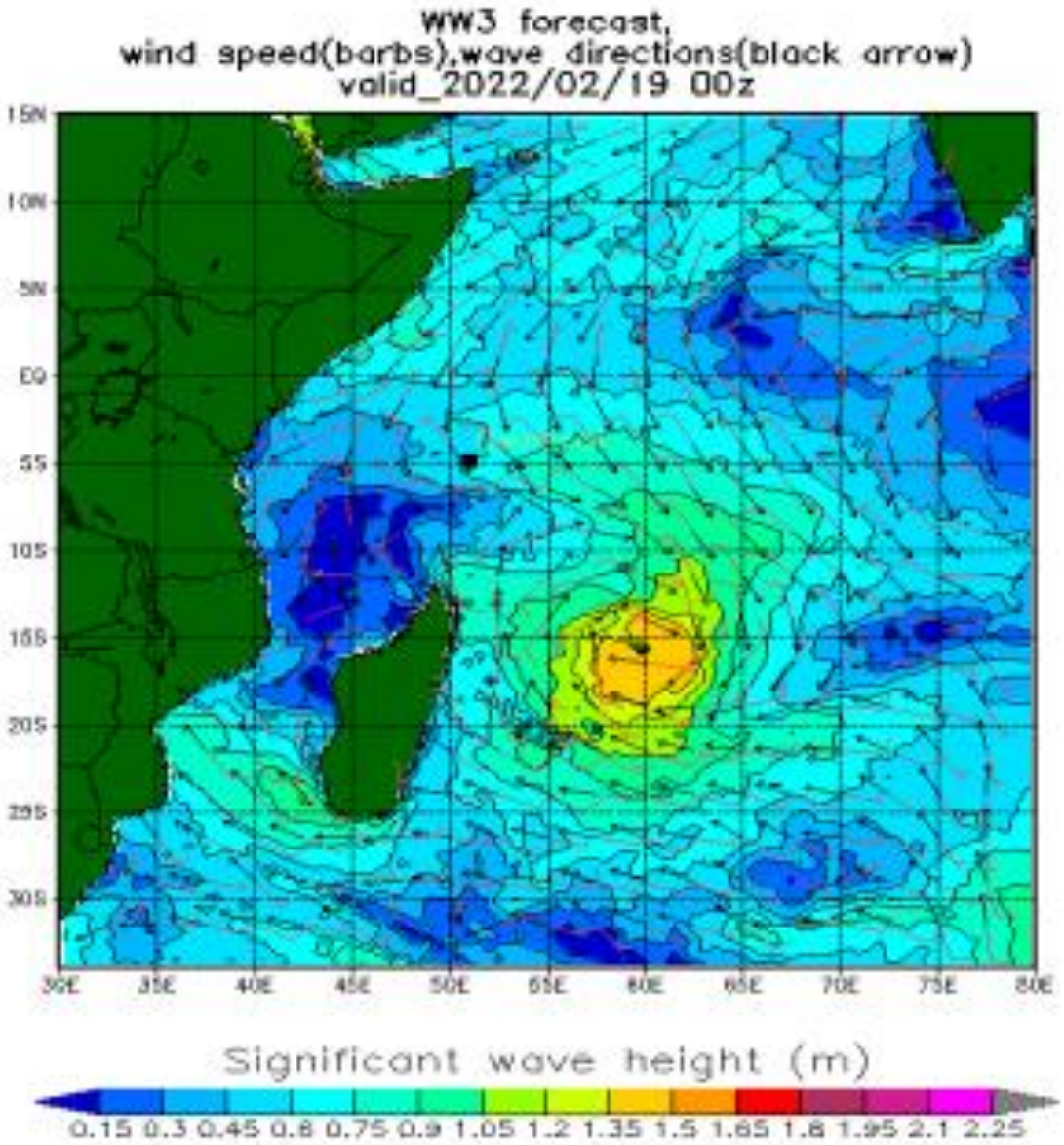
- Provides means to understand how the climate has changed in the past and may change in the future
- Require some of the largest supercomputers in the world to generate the projections
- Climate models are constantly being updated (new physical processes, biogeochemical cycles etc.)

Operational Modeling

- Operationally most agencies in EA runs atmospheric NWP model (WRF) and Ocean model, Wave Watch III (WW3)
- The WRF-ARW uses initials and boundary conditions (IC&BC) from Global Forecast System (GFS) models (for short and medium range runs) and Climate Forecast System (CFS) global model (for long range forecast)
- Wave Watch III (WW3) model runs for short and medium range forecasts and get IC&BC from GFS model

Operational Modeling

- Resolution; Varies depending of the nesting chosen e.g 25km, 12km, 4km
- Due to lack of buoy network, most common verification method used is the satellite approach.
- EOVs modeled are winds and waves


WW3 forecast,
wind speed(barbs),wave directions(black arrow)
valid_2022/02/19 00z
15N
10N
5N
EQ
5S
10S
15S
20S
25S
30S
30E
35E
40E
45E
50E
55E
60E
65E
70E
75E
80E
Significant wave height (m)
0.15 0.3 0.45 0.6 0.75 0.9 1.05 1.2 1.35 1.5 1.65 1.8 1.95 2.1 2.25

Projections and Scenario Modeling

Data Sources for GCMs

https://www.ipcc-data.org/sim/gcm_monthly/AR5/CMIP5-Experiments.html

https://climexp.knmi.nl/start.cgi

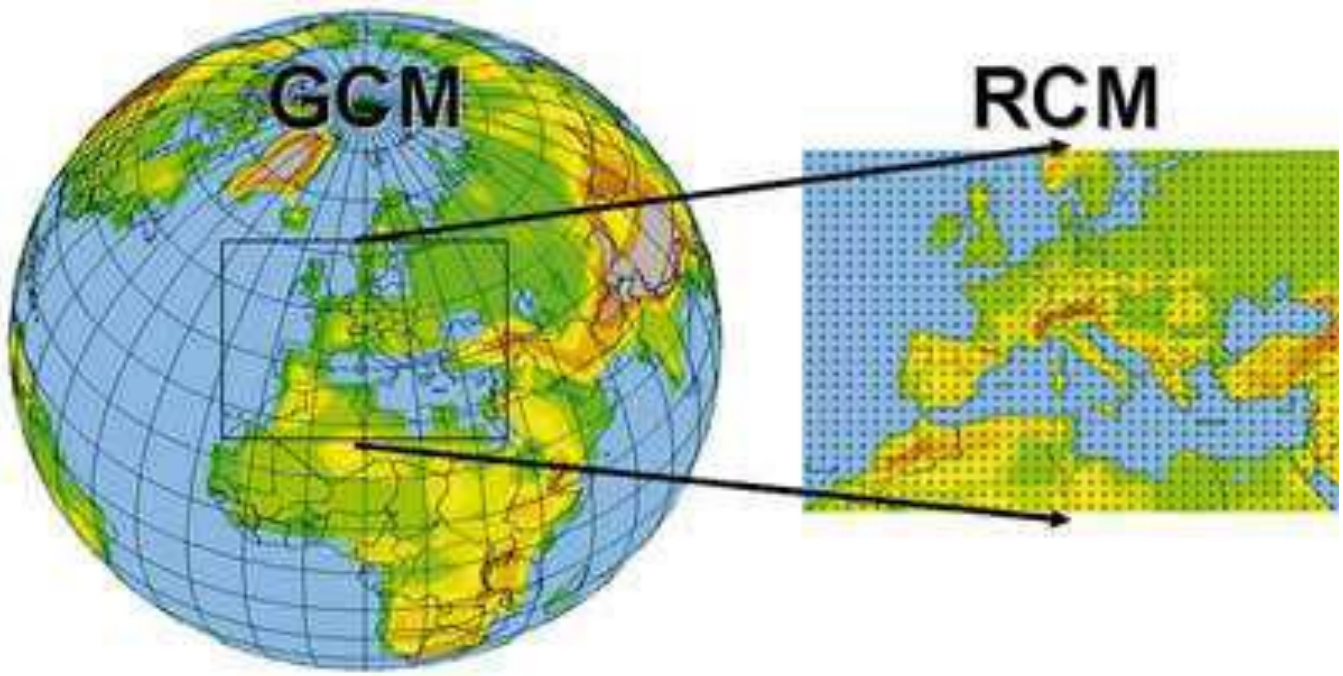
https://climexp.knmi.nl/start.cgi

https://esgf-node.llnl.gov/search/cmip6/

Downscaling: Regional Climate Models

- Numerical climate prediction model forced by specified lateral and ocean conditions from a GCM
- Set of techniques that allows fine scale information to be derived from GCM output
- Smaller scale climate results from an interaction between global climate and local physiographic details
- Climate impacts community needs high-resolution climate change scenarios to assess vulnerability and possible adaptation strategies
- Regional projections lack the regional scale detail due to coarse spatial resolution.

Downscaling: Regional Climate Models



NOTE: *RCM used to achieve high-resolution climate data from coarsely resolved GCMs*

CORDEX- Coordinated Regional Climate Downscaling Experiment

Vision:

To advance and coordinate the science and application of regional climate downscaling through global partnerships

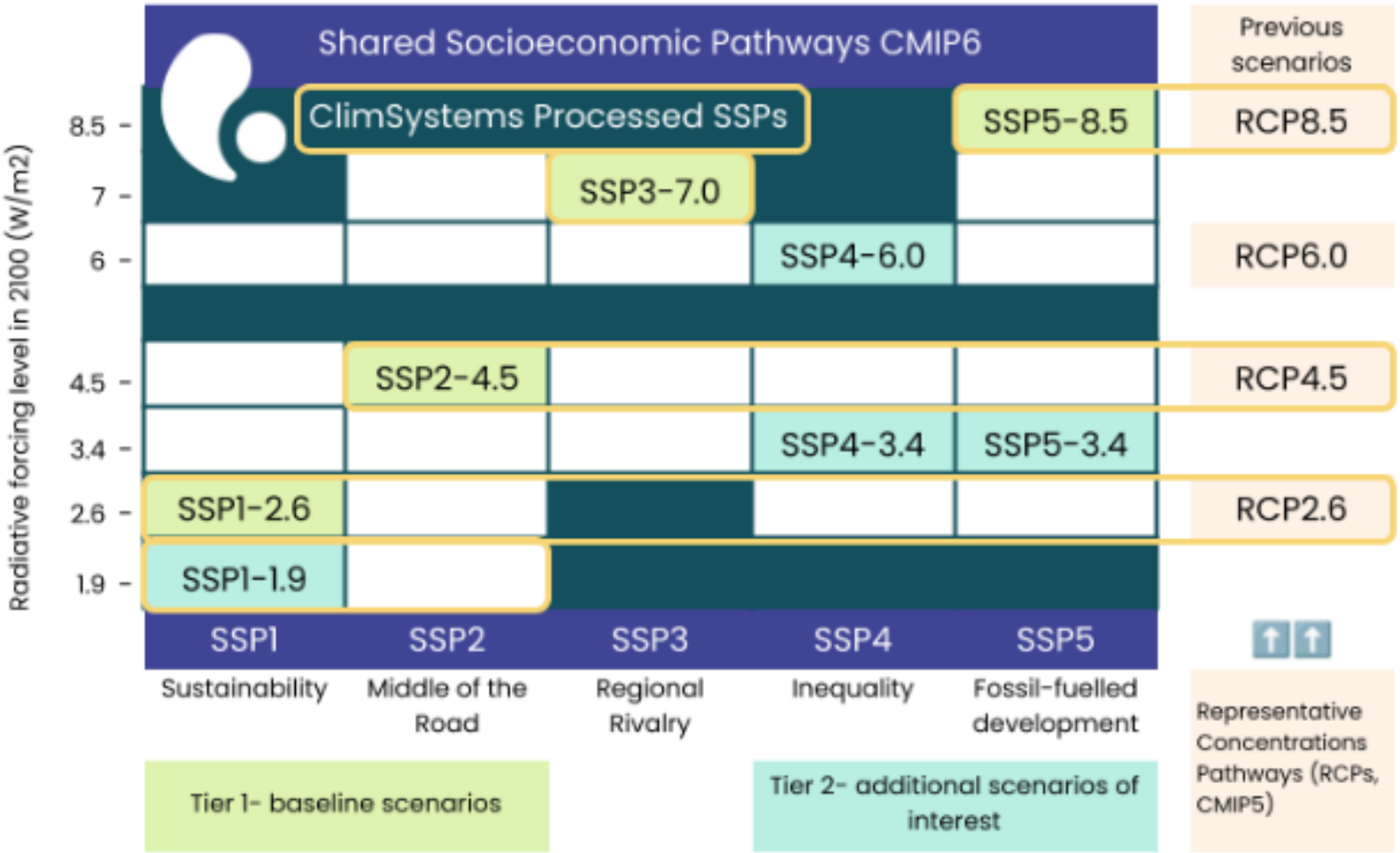
CORDEX goals:

1. Better understand relevant regional/local climate phenomena, their variability and changes, through downscaling
2. Evaluate and improve regional climate downscaling models and techniques
3. To produce coordinated sets of regional downscaled projections worldwide
4. Foster communication and knowledge exchange with users of regional climate information

Projection Scenarios

- A climate projection scenario combines future narratives of socio-economic drivers, like greenhouse gas emissions, with climate models that simulate the resulting physical changes in the Earth's system.
- RCPs are greenhouse gas (GHG) concentration pathways focusing on atmospheric concentrations and radiative forcing, while SSPs are broader socio-economic storylines of future development, including land use and societal choices.

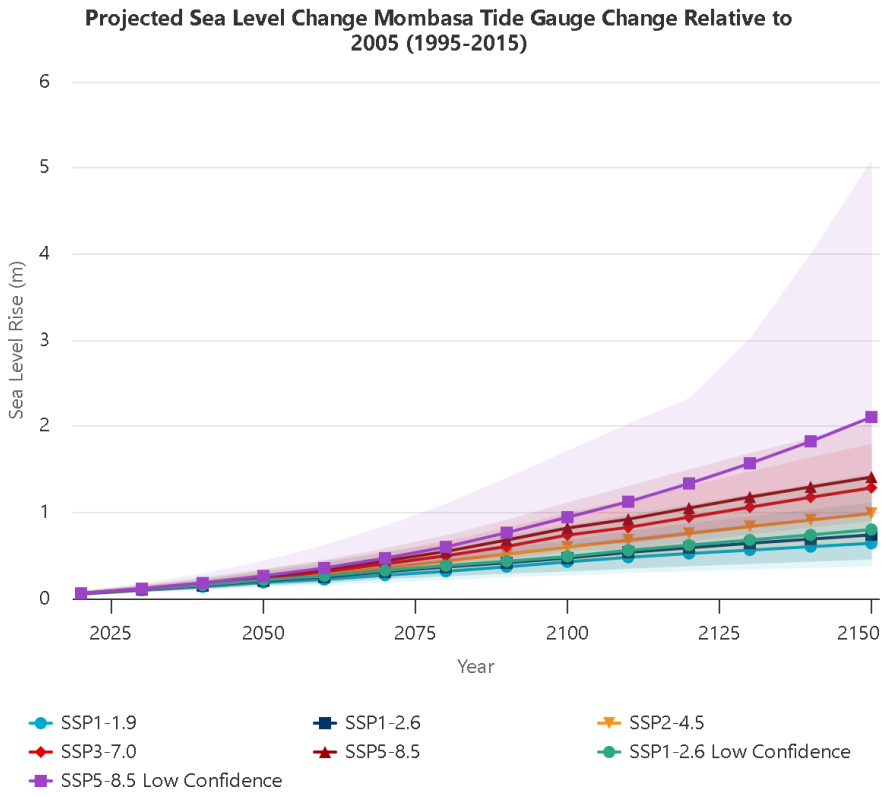
SSPs and RCPs

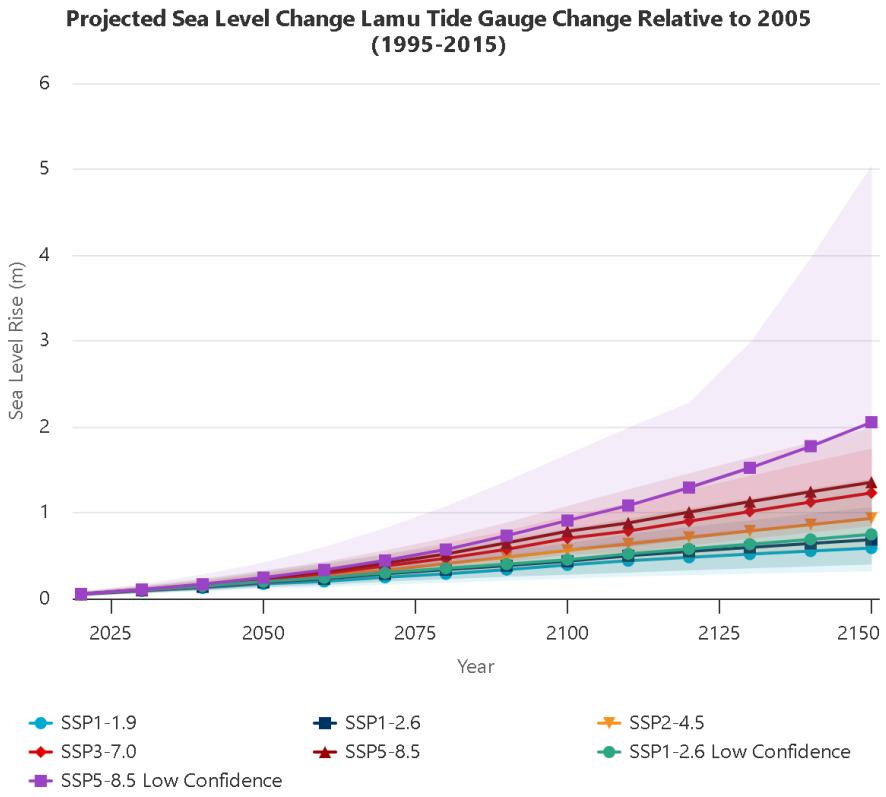


AR6: Shared Socio Economic Pathways (SSP)

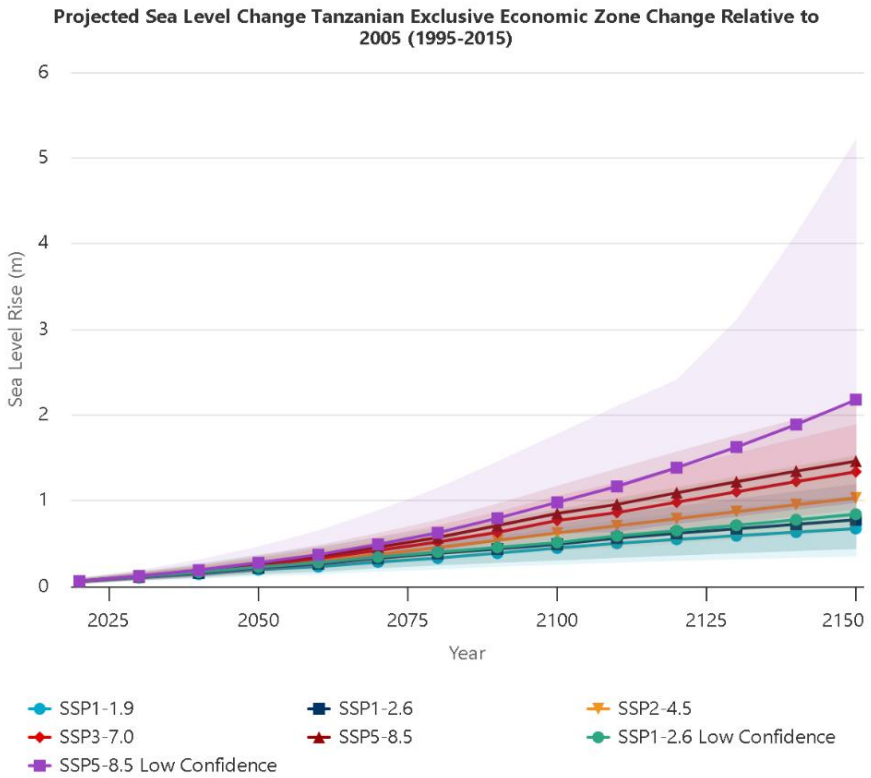
- New scenarios to explore how the world might change over the rest of 21st Century
- Examine how global society, demographics and economics might change
- Collectively known as the "*Shared Socioeconomic Pathways (SSPS)*"
- Involved an international team of climate scientists
- Five pathways that the world could take

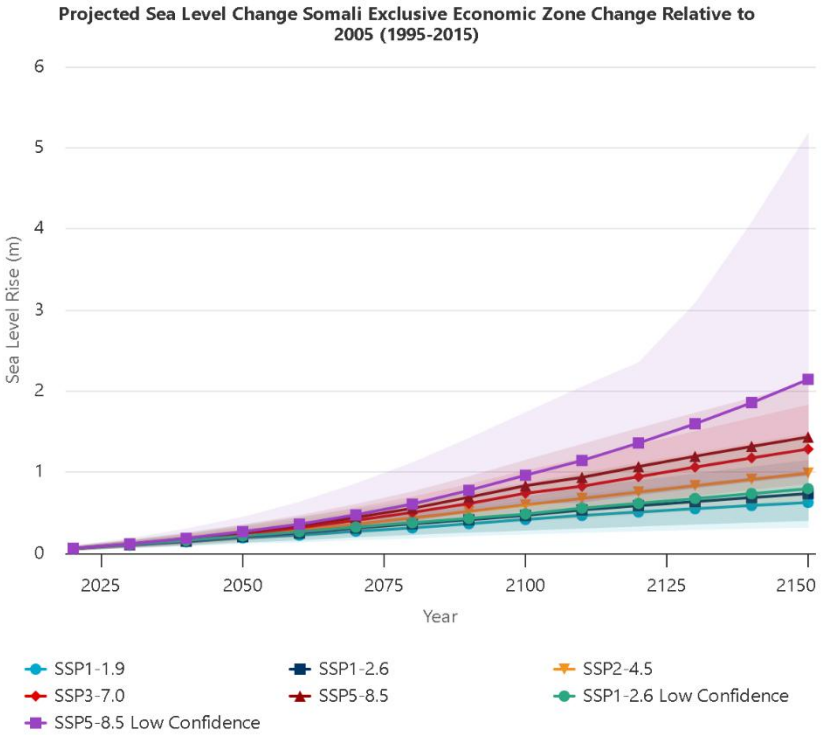
Examples of SSP Scenarios for Mombasa and Lamu





Examples of SSP Scenarios for Tanzania and Somalia EEZ





Thanks