# Limitations and uncertainties of climate change models and projections: Implications for advancing process of climate change adaptation planning.

Formulating NAPs for an integrated, risk-informed climate response

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Zewdu Eshetu (PhD)
Addis Ababa University

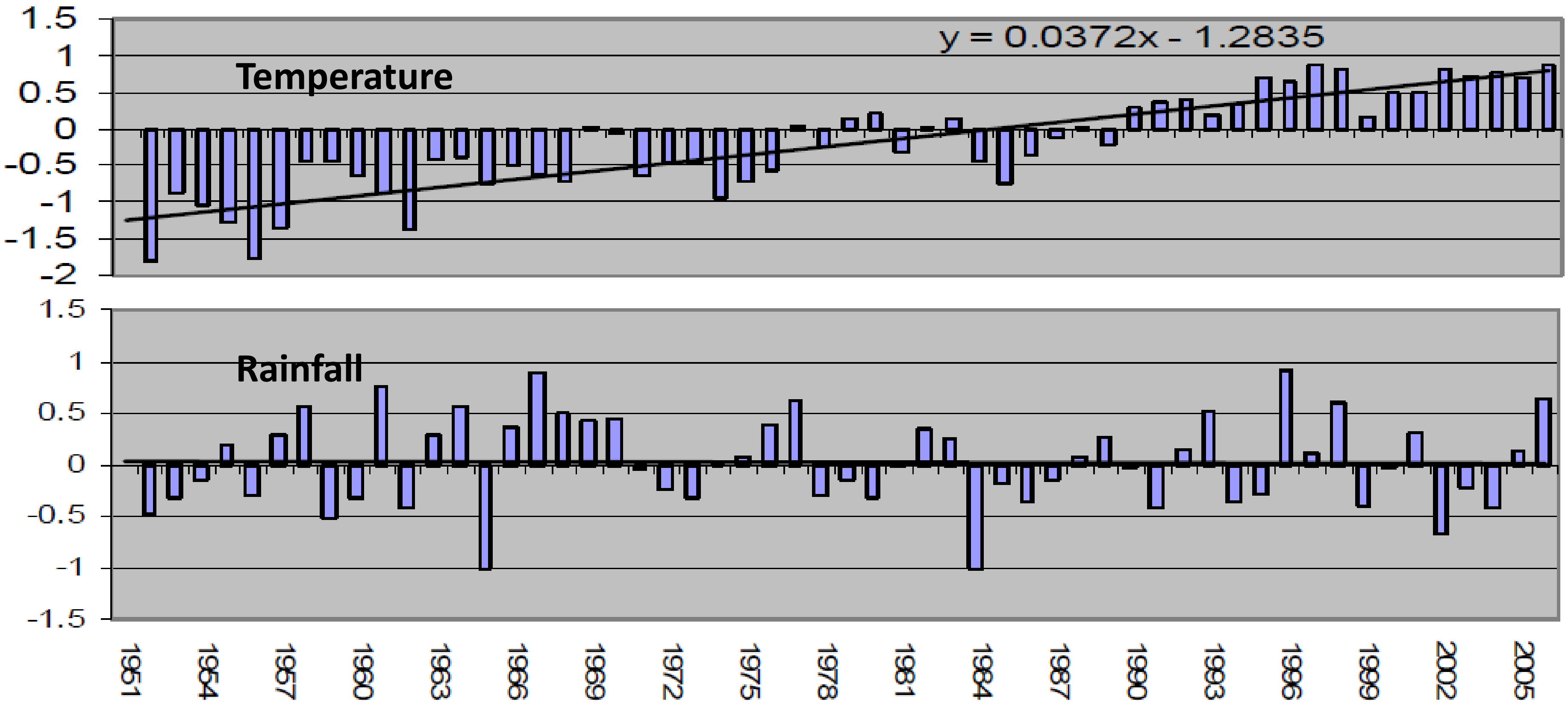
# Key entry questions

- Why LDCs/you need to develop/formulate NAPs?
- Which sectors are highly relevant for NAP implementation(Ethiopia's case)?
- Sources of data and information for adaptation planning?
- How it is vertically and horizontally coordinated and integrated?
- What is your view on the contribution of NAPs to global climate change agenda?
- What practical and actionable guidance are needed to incorporate national development projects into your NAP processes?
- What kinds of projections and climate models are used in climate change adaptation planning and project development?
- How the projections and models are certain, what are possible sources of uncertainties?
- What are key limitations in using climate models?
- Which national institutions are the likely best to serve as center for down scaling?
- What are the pros and cons of building the national capacities to do downscaling or using Hadley Centre or some regional initiative?

# Eth-NAPs: Rationale ? …

Straightforward reasons:

- ❑ highly vulnerable to extreme climate events induced by climate change

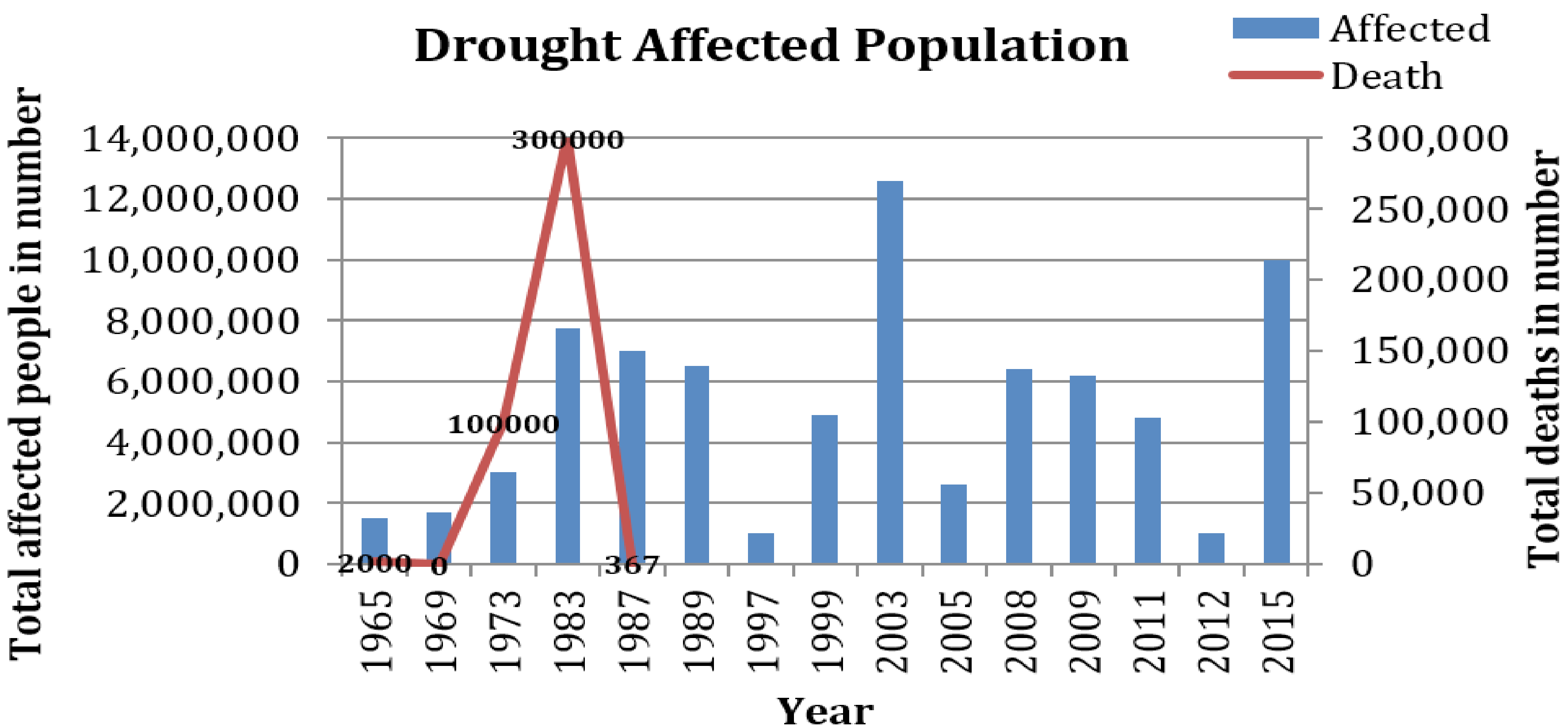



*Year to Year Variability of Temperature and rainfall over Ethiopia (NAPA 2007)*

# Eth-NAPs: Rationale ? …

<u>Straightforward reasons:</u>

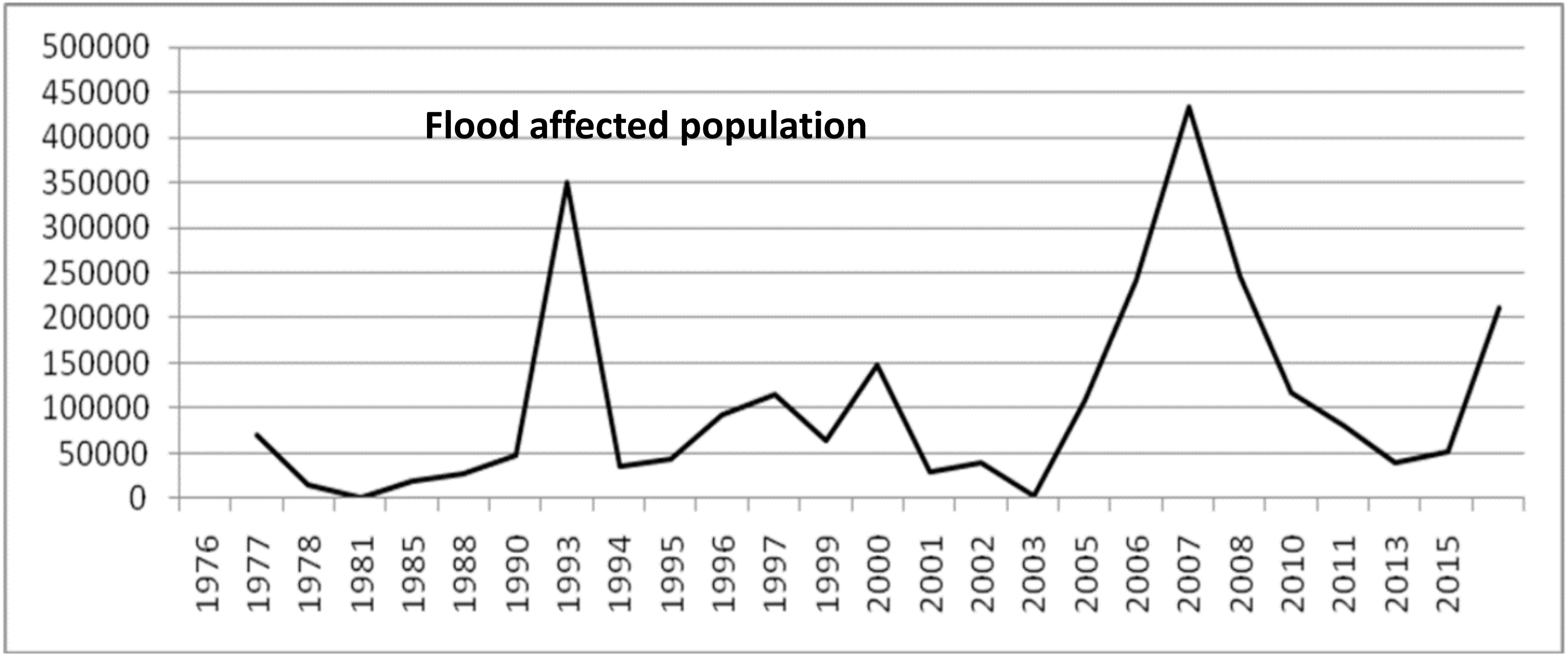
- ❑ highly vulnerable to recurrent drought events



# Eth-NAPs: Rationale ? ...

<u>Straightforward reasons:</u>

- ❑ highly vulnerable to frequent floods induced by erratic rainfall pattern

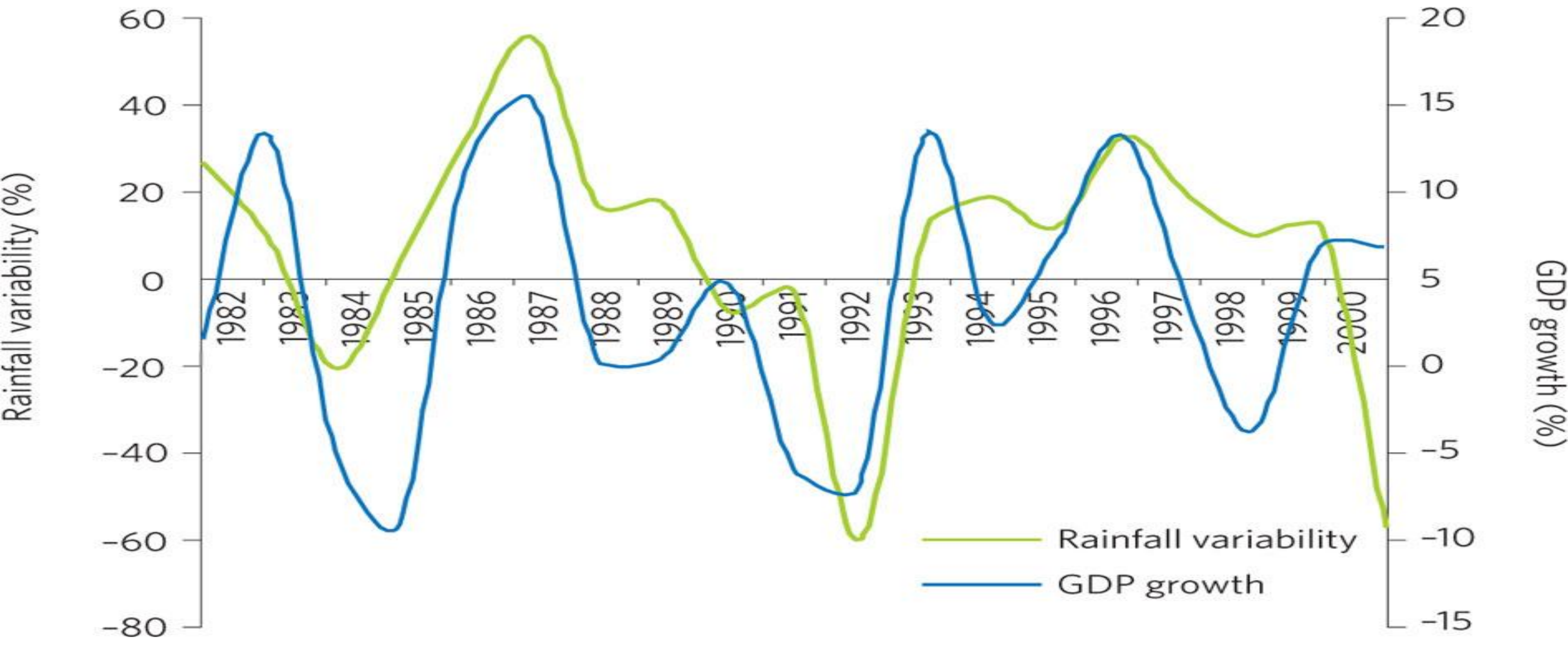



Number of Population Affected by Flood in Ethiopia

# Eth-NAPs: Rationale ? …

Straightforward reasons:

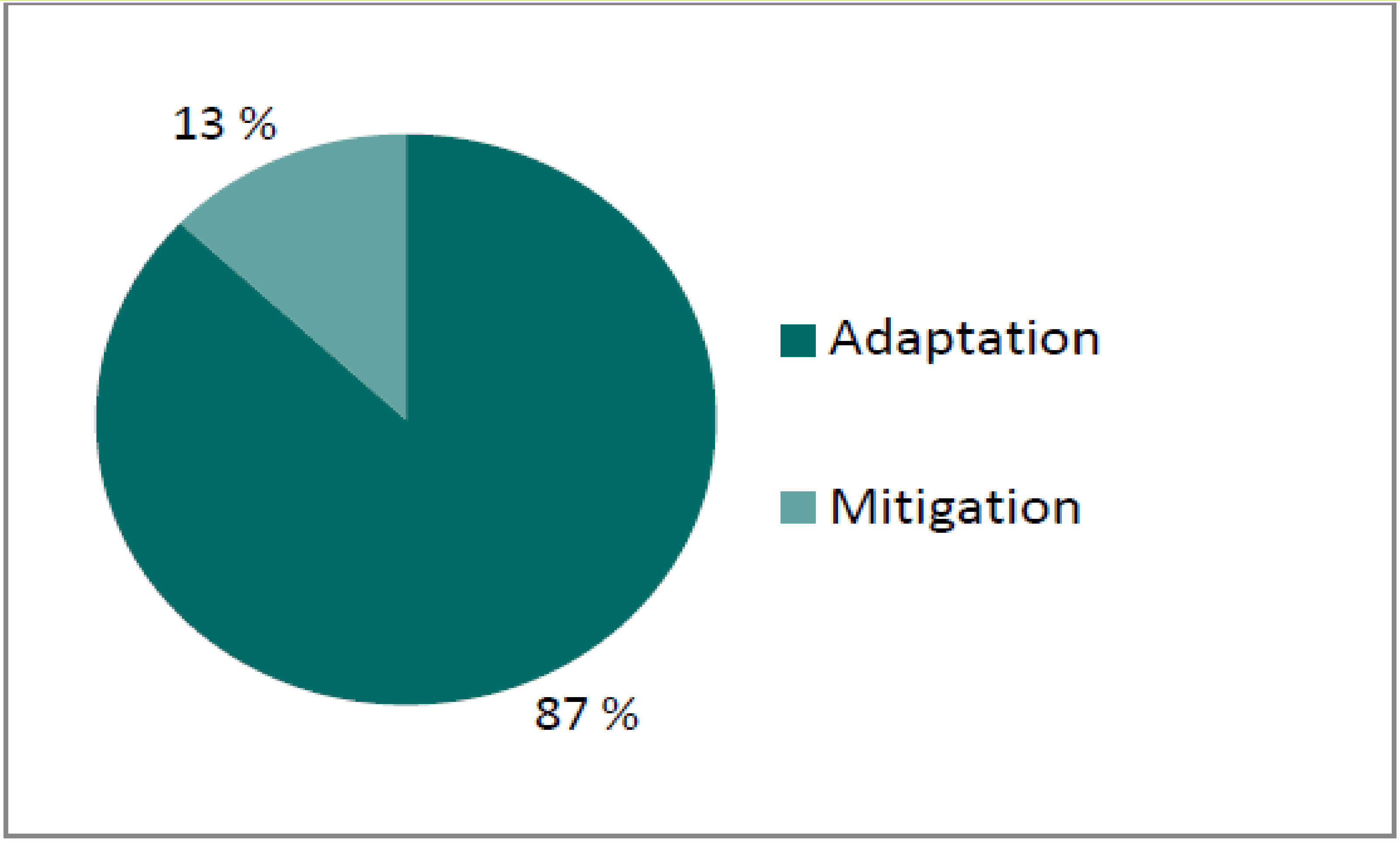
Agriculture GDP is highly related to rainfall variability (Anna Petherick, 2012)



# Eth-NAPs: Rationale ? …

Straightforward reasons:

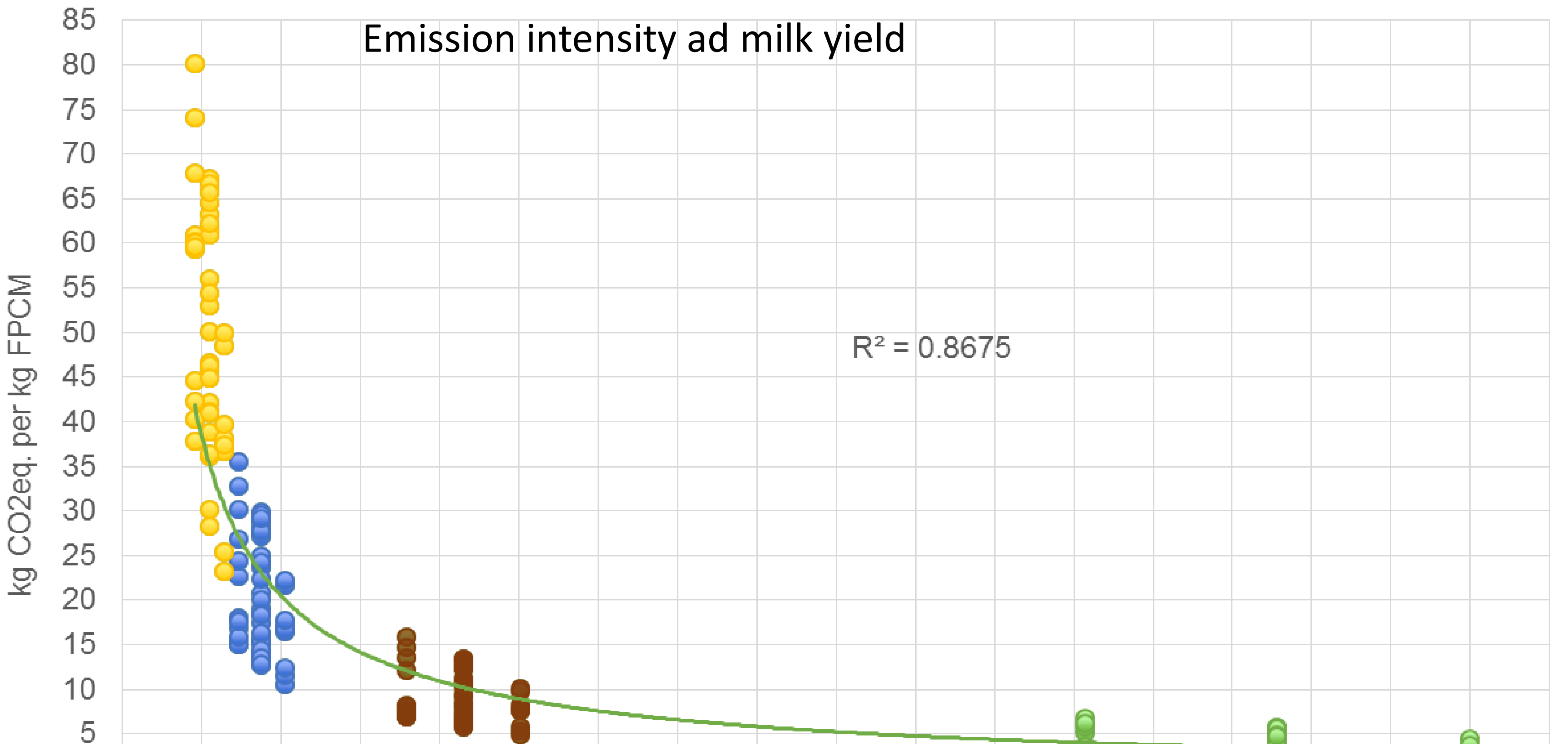
- Climate change expenditure takes about 2% GDP (Neil et al 2014)



# Eth-NAPs: Rationale ? …

## Straightforward reasons:

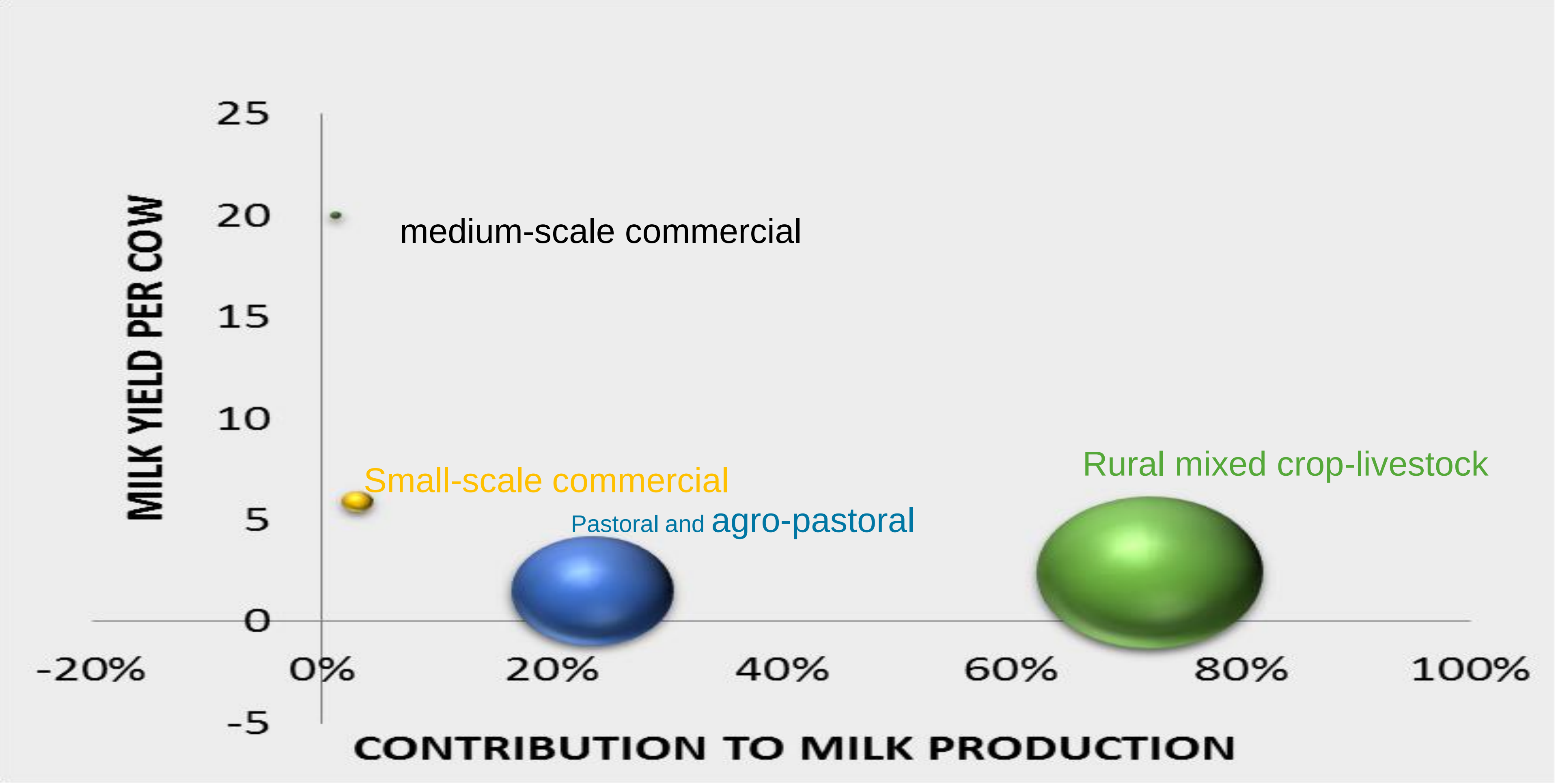
- Major GHG emissions are from livestock (42%) and deforestation (37%), and need substantial improvement in livestock and forest management efficiency .



# Eth-NAPs: Rationale ? ...

## Straightforward reasons:

- ❑ Four production sectors need substantial improvement in production efficiency .



# Eth-NAPS Goal?

Goal:

- To reduce vulnerability to the adverse impacts of climate change by building adaptive capacity and resilience through integration of climate change adaptation options with long-term national development pathway, including climate risk reduction/management

Key Implementing sectors:

Agriculture, forestry, health, transport, power, industry, water and urban, because they are highly vulnerable to climate induced adverse impacts,

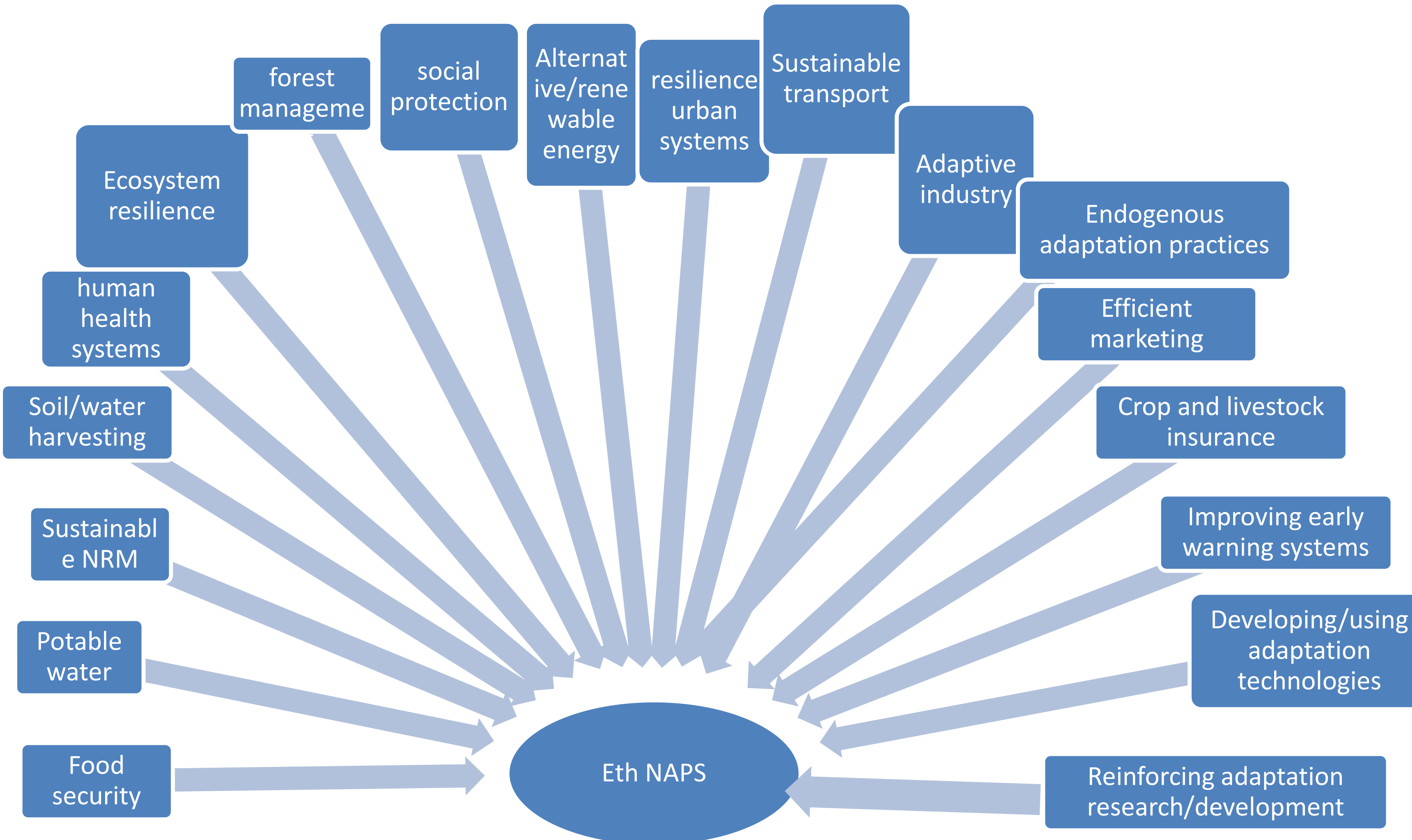
# Eth-NAPS Goal? …

Strategic priorities:

- ❑ Mainstreaming climate change adaptation into development policies, plans and strategies (CRGE, GTP, INDC,
- ❑ Building long-term capacities of institutional structures involved in NAP-ETH
- ❑ Implementing effective and sustainable funding mechanisms
- ❑ Advancing adaptation research and development in the area of climate change adaptation including research and academic institutions
- ❑ Improving the knowledge management system for NAP-ETH including climate service delivery insititions

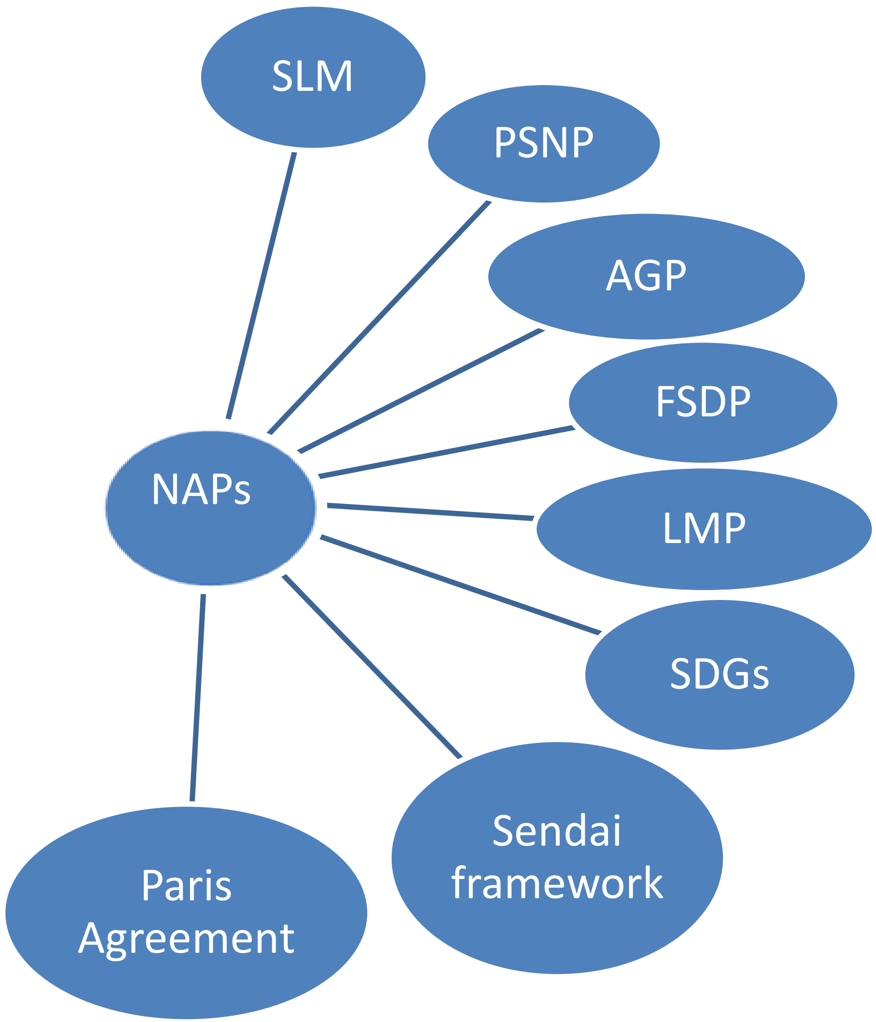
# Eth-NAPS Goal? …

## 18 Adaptation options:



# Eth-NAPS Goal? …

Aligned with national projects and international initiatives

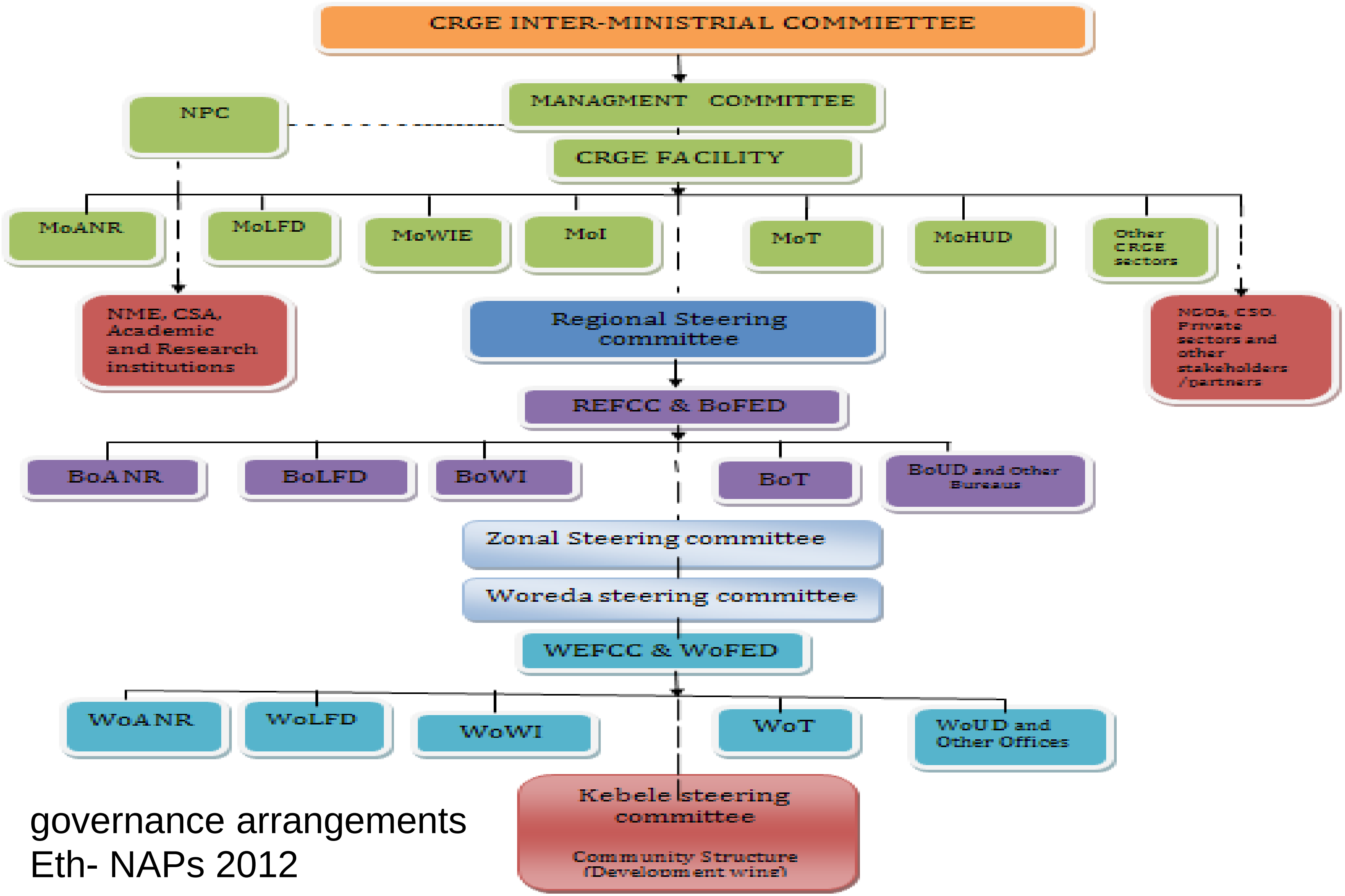


# Data/information for adaptation planning

Possible sources:

- ❑ Multiple sets of national senses data on socioeconomic aspects: from Central statistic/national planning offices
- ❑ Specialized sector based data/information: sectorial line ministries or offices e.g MoA, MoWIE, MEFCC, NDRMC etc.
- ❑ Real time data and station based climate data set: from NMA
- ❑ from published and unpublished research and academic papers, project reports on historical data: from academic and research institutes, journals etc.
- ❑ Expert views

# Vertical coordination and integration.

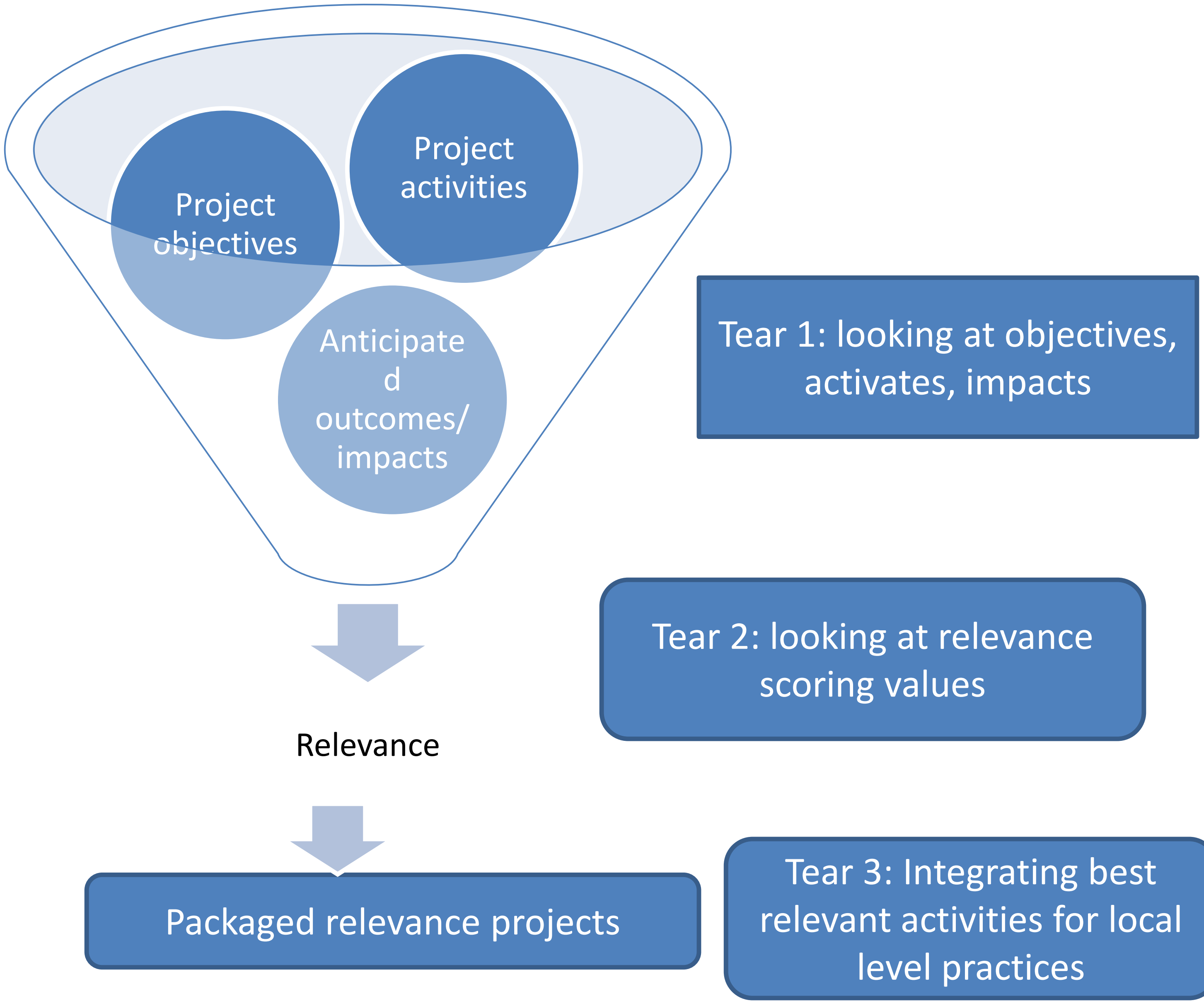



governance arrangements
Eth- NAPs 2012

# Practical and actionable guidance to incorporate sectoral projects to NAPs processes

- Each sector has multiple national and local projects of national and local significance with funding from multiple agencies,
- There are duplication and fragmentation of activities, budget and human resources
- There is a need of packaging the various projects based on their level of climate smartness in relation to the management and use of carbon, nitrogen, energy, weather, water, food and nutrition and climate knowledge,
- Those projects with objectives and activities that have high relevance values of climate smartness are packaged during NAPs planning process for integrated implementation by kebele NAPs committee.

# Iterative processes of packaging projects



# Kinds of projections and climate models used in climate change adaptation planning and project development

- There are so many climate models and there are roughly thirty research groups that have developed their own global circulation models.
- While the basic structure of these models is comparable, they all differ in their details, incredibly complicated;
- Different models make different portrays of the vertical structure of the atmosphere is subdivided.
- Different models also have different portrayals of elements of the climate system that are more challenging to model, such as the treatment of clouds, aerosols, or the carbon cycle etc.
- All must portray the physical interactions between the atmosphere, the oceans, land surfaces, and sea ice,
- All climate models incorporate human activity in the form of greenhouse gas emissions for projecting future climate change and economic activity resulting in greenhouse gas emissions by adopting a set of standardized greenhouse gas concentration scenarios (Representative Concentration Pathways, or RCPs),
- The four RCPs are GHG concentrations emitted in the years to come and are labelled after a possible range of radiative forcing values in the year 2100 (i.e., 2.6, 4.5, 6.0, and 8.5 $W/m^2$, respectively).

# Few examples of climate models

| Climate Model | Description |
|---|---|
| **Coupled Model Intercomparison Project (CMIP)** | help compare the different models and improve our understanding of the climate system |
| **General Circulation Models/ Global Climate Models (GCMs)** | are a class of computer-driven models for understanding climate and projecting climate change |
| **Regional climate model (RCM)** | numerical climate prediction model forced by specified lateral and ocean conditions from a general circulation model (GCM) or observation-based dataset that simulates atmospheric and land surface processes, while accounting for high-resolution topographic |
| **Hydrologic model** | is a simplification of a real-world system (e.g., surface water, soil water, wetland, groundwater, estuary) that aids in understanding, predicting, and managing water resources. Both the flow and quality of water are commonly studied using hydrologic models. |
| **Community Earth System Model (CESM)** | Fully coupled numerical simulation of the Earth system ( atmospheric, ocean, ice, land surface, carbon cycle, and other components. It provides state-of-art simulations of the Earth's past, present, and future |
| **The Climate Forecast System or coupled forecast system (CFS)** | medium to long range numerical weather prediction and a climate model run by the National Centers for Environmental Prediction (NCEP) to bridge weather and climate timescales |
| **Atmospheric dispersion modeling** | Is the mathematical simulation of how air pollutants disperse in the ambient atmosphere . It is performed with computer programs that solve the mathematical equations and algorithms which simulate the pollutant dispersion |
| **Biosphere model,** | In climate science, is used to model the biosphere of Earth, and can be coupled with atmospheric general circulation models (GCMs) for modelling the entire climate system. |
| **Chemical transport model (CTM)** | computer numerical model which typically simulates atmospheric chemistry and may give air pollution forecasting. |
| **ECHAM (European Centre Hamburg Model (global climate model)** | a general circulation model (GCM) developed by the Max Planck Institute for Meteorology, by modifying global forecast models to be used for climate research. |

# What we are doing with models?

- **Forecast-** an expected outcome based on established patterns (physical, technological, economic, social etc) and is for the near-future - in climate terms forecasts can be made up to the level of seasons

- **Prediction-** an estimate of the way a system will react in the future, for example at a seasonal level. Predictions use the state of variables in the current system (for example sea-surface temperatures) to estimate the evolution of the system in the near-future.

- **Projection-** Looks at the response of the climate system to scenarios of changes in emissions, aerosols and radiative forcing. Projections depend on the assumptions underlying the scenario and model used, which may or may not occur, so are only possible futures as they are subject to uncertainty.

# Models are working with downscaling methods

GCMs used for climate projections are typically run at spatial resolutions of 150 - 200 km and are limited in their ability to resolve important sub-grid scale features of the earth such as convection clouds and topography; as a result, GCM based projections may not be robust for local impact studies,

**Downscaling** methods are developed to obtain local-scale weather and climate, particularly at the surface level, from regional-scale atmospheric variables that are provided by GCMs.

**Downscaling techniques:**

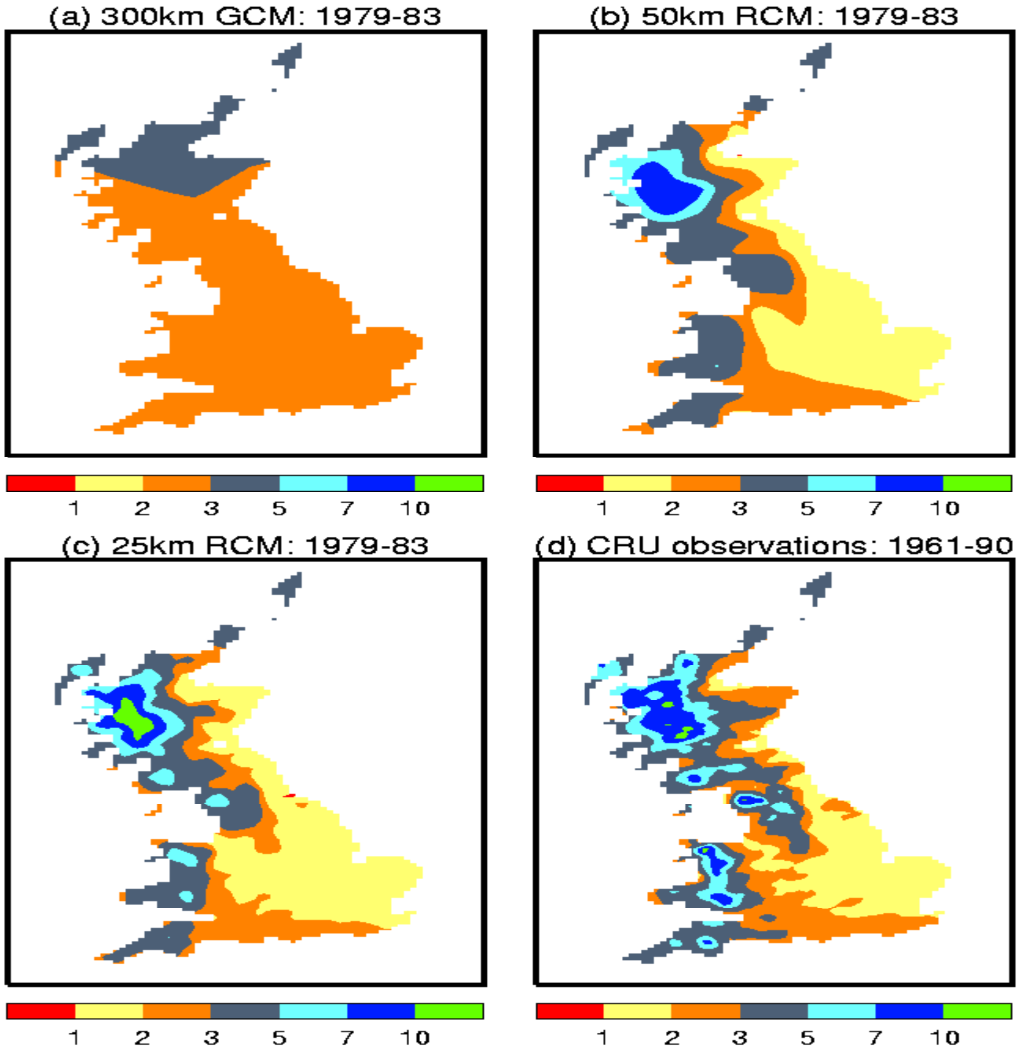
**Dynamical downscaling**: Output from the GCM is used to drive a regional, numerical model in higher spatial resolution to simulate local conditions in greater detail.

**Statistical downscaling**: A statistical relationship is established from observations between large scale variables (like atmospheric surface pressure) and a local variable (like the wind speed at a particular site); The relationship is then used on the GCM data to obtain the local variables from the GCM output.

# Winter precipitation over Britain

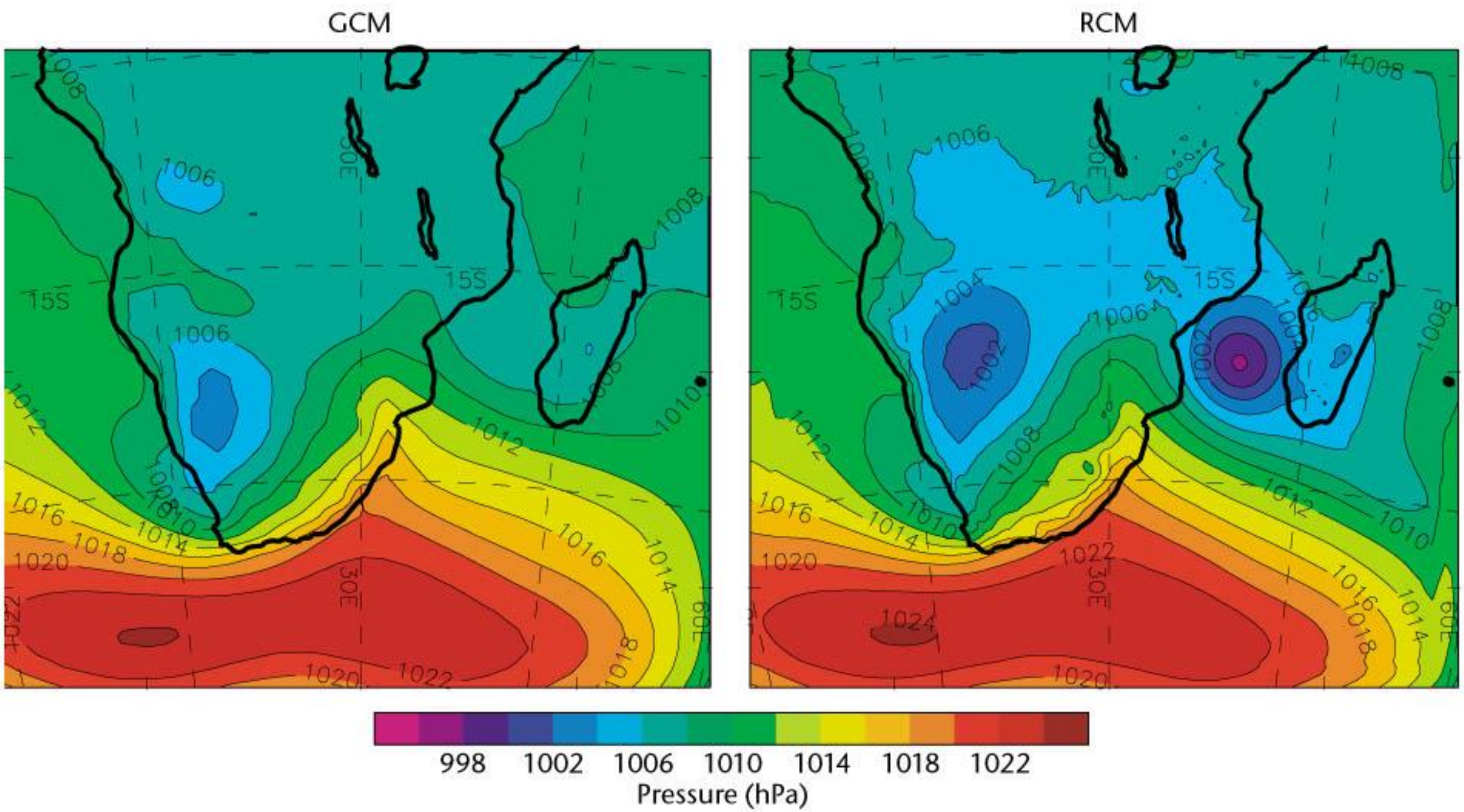
**300km Global Model**

**50km Regional Model**

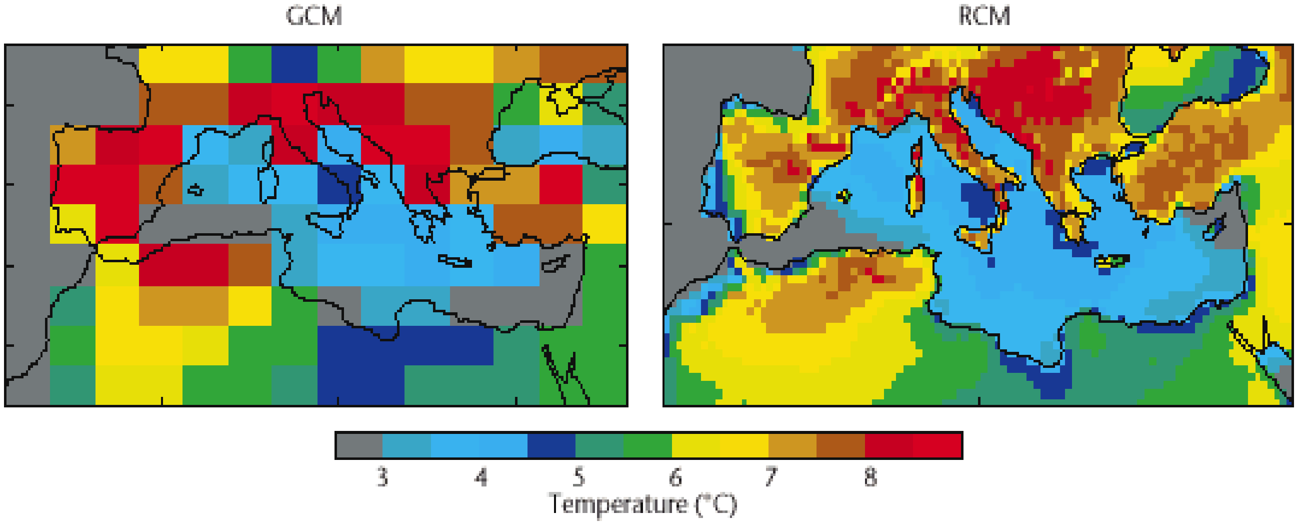



**25km Regional Model**

**Observed 10km**


GCM
RCM
998
1002
1006
1010
1014
1018
1022
Pressure (hPa)

# Represent smaller islands




Projected changes in summer surface air temperature between present day and the end of the 21st century.

# Models are working with emission scenarios (SRES)

- Climate models still fail to take into account all the detailed aspects of clouds/water vapor and GHG that cause two antagonist effects on the ground temperature (cooling effect, heat trapping, reflexive for sun rays, preventing incoming solar radiation etc).

- The state of the future climate (e.g. 2100) not only depends on the amount of GHG already emitted but also on the amount that will be emitted till 2100.

  - IPCC has published a voluminous book describing the 40 scenarios used, that are grouped in 4 main scenarios: A1, A2, B1, B2)

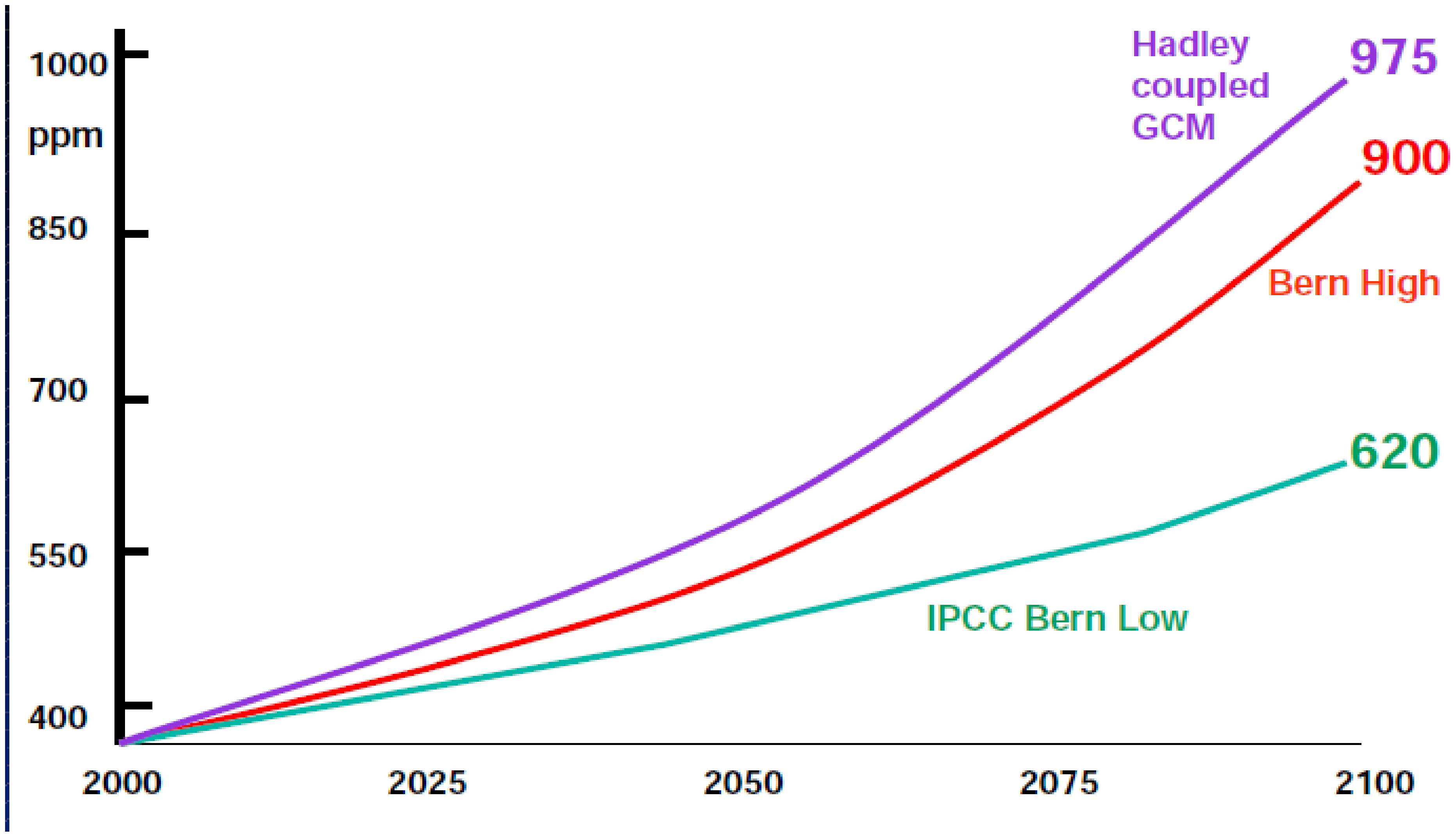
# GHG emission scenarios

| Scenarios | Hypothesis |
|---|---|
| **A1** | • economic growth is fast, and the world population reaches 9 billion people in 2050 then decreases thereafter<br>• new and efficient technologies are quickly spreading,<br>• the income per capita and the way of life converge between regions<br>• social and cultural interactions increase heavily (which means that the cultural models are the same for everyone, roughly), |
| **A1F1** | • average energy consumption per capita in the world rises to 7,8 ton of oil equivalent in 2100<br>• the world fossil fuel consumption rises to 30 billion ton of oil equivalent |
| **A1T1** | • average energy consumption per capita in the world rises to 4,2 ton of oil equivalent in 2100.<br>• world fossil fuel consumption rises to 13 billion tone of oil equivalent in 2050 (50% more than today) |

# GHG emission scenarios …

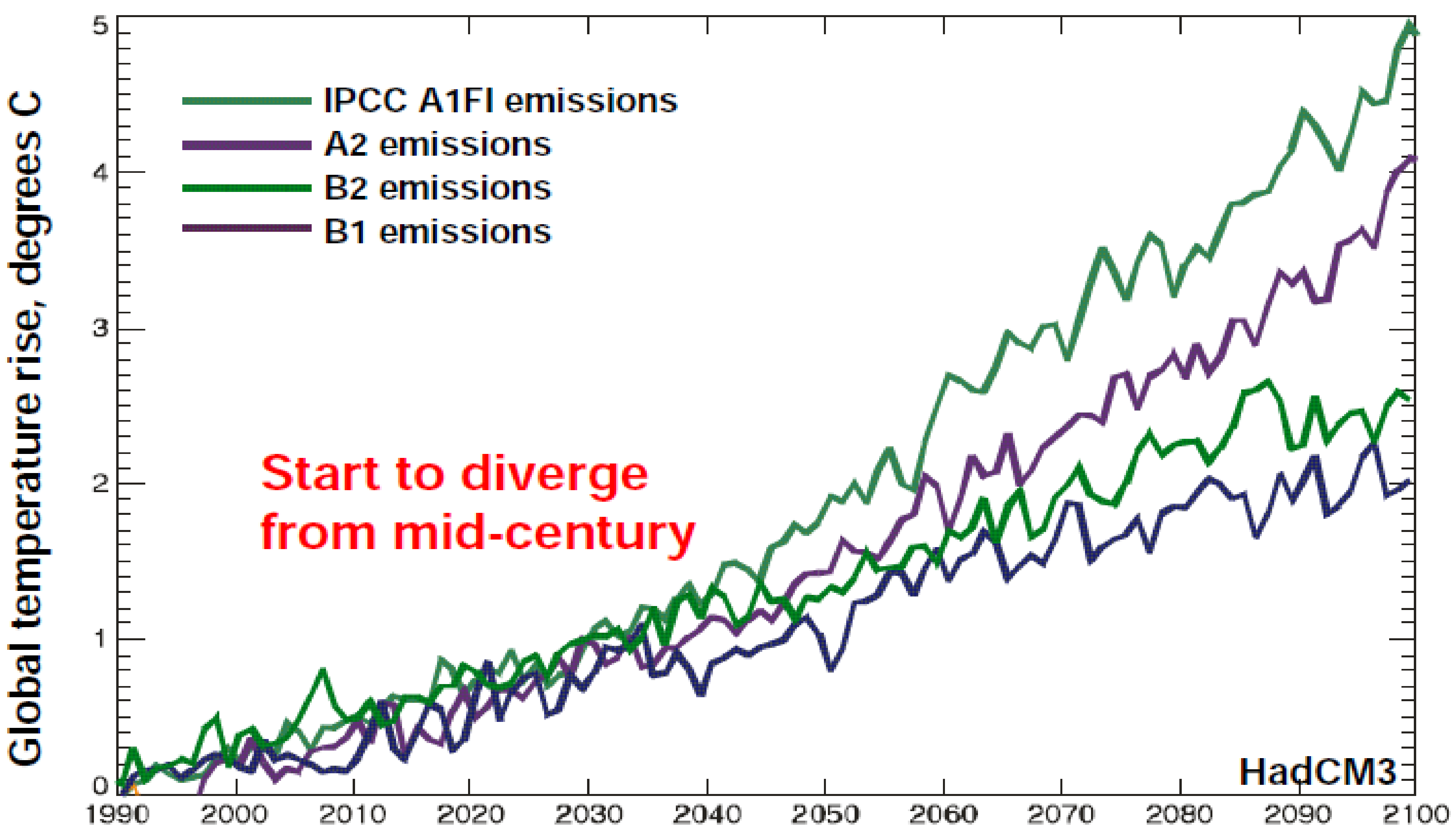
| Scenarios | Hypothesis |
|---|---|
| **A2** | • the world evolves in a very heterogeneous way,<br>• the world population reaches 15 billion people in 2100, and rising,<br>• economic growth and the spreading of new efficient technologies are very different depending on the region of the world,<br>• the average energy consumption per capita in the world rises to 3,1 toe in 2100.<br>world fossil fuel consumption rises to 30 Btoe in 2100, 4 times more than today |
| **B1** | • the world population reaches almost 9 billion people in 2050 then decreases,<br>• the economy is dominated by services and information technologies, new efficient technologies spread very quickly and are massively used, |
| **B1T** | • the average energy consumption per capita in the world rises to 2,4 toe in 2100. That’s 1,5 times the present value,<br>• the world fossil fuel consumption rises to 12 Btoe in 2050, 30% more than today |
| **B2** | • the world population reaches more than 10 billion people in 2100, and rising<br>• the economy becomes more and more local<br>• the dispersion between individual incomes is lower to what it is for A2, but higher to what it is for A1,<br>• the developing and spreading of new efficient technologies is uneven and goes slower than for B1 or A1.<br>• the average energy consumption per capita in the world rises to 2,9 toe in 2100.<br>• the world fossil fuel consumption rises to 18 Btoe in 2050, which is 2,5 times more than today, |

# Uncertainty in $CO_2$ concentration



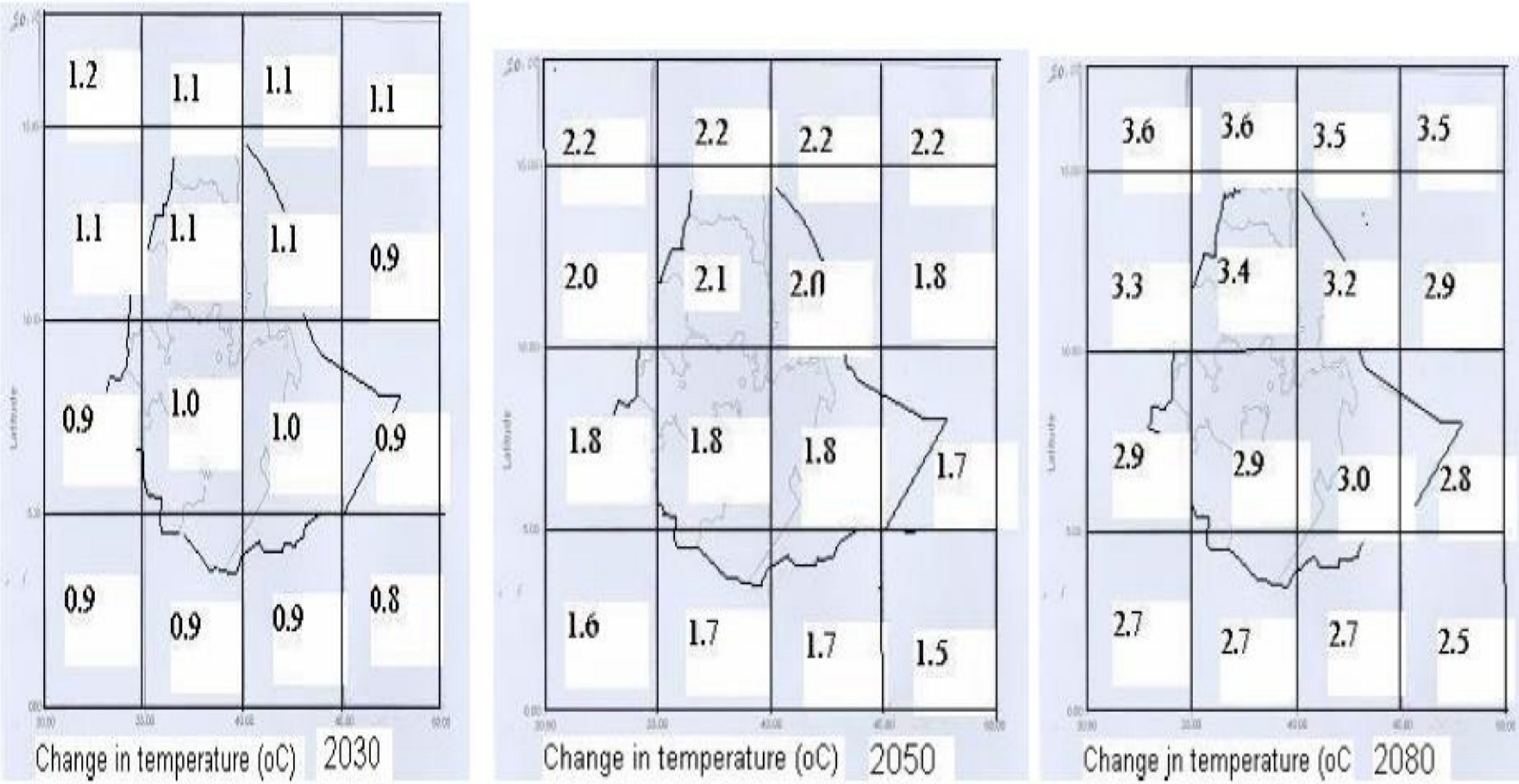

**Hadley Centre for Climate Prediction and Research**

# Global temperature rises



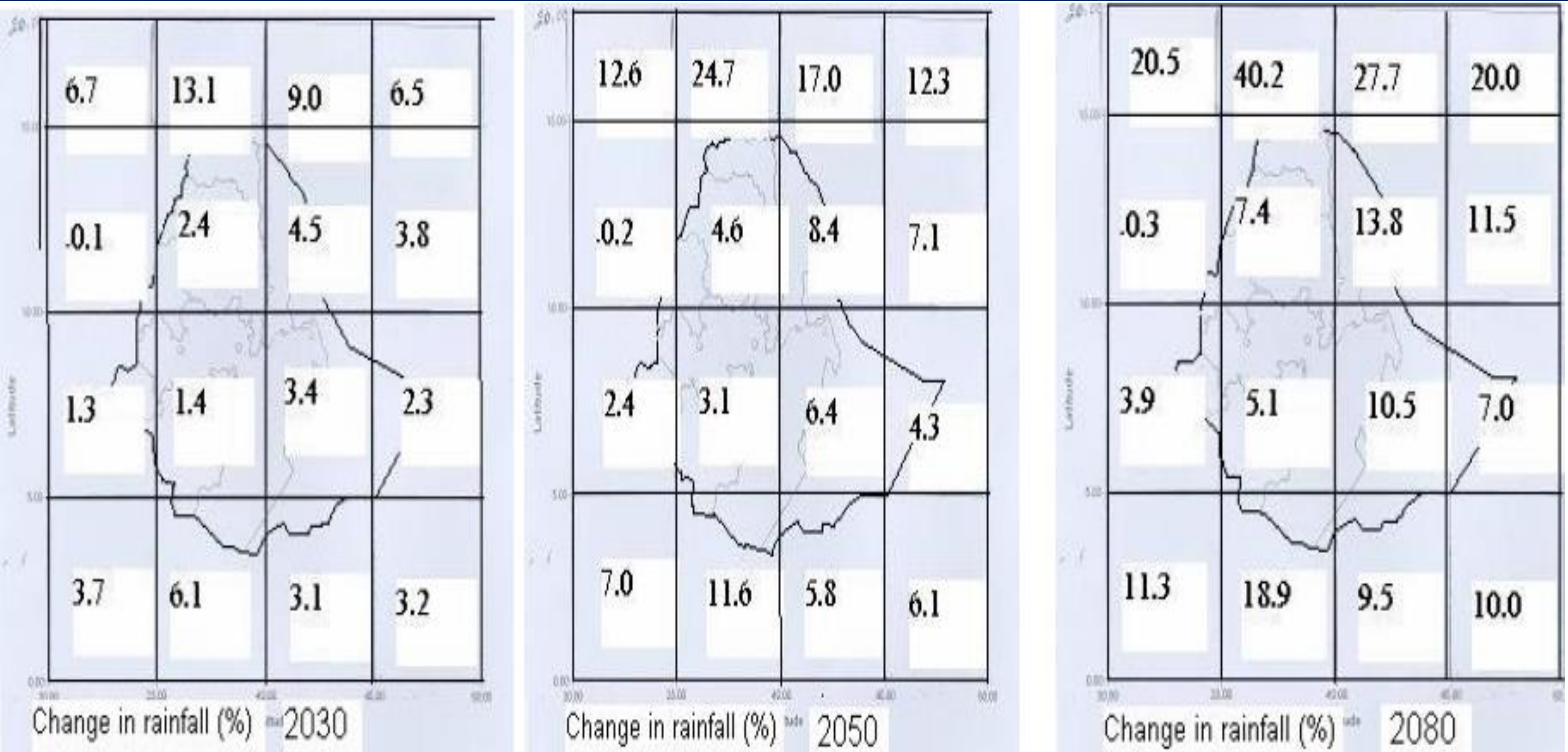

Hadley Centre for Climate Prediction and Research

# Changes in temperature (ºC) relative to 1961-1990 over Ethiopia (NAPA 2007)



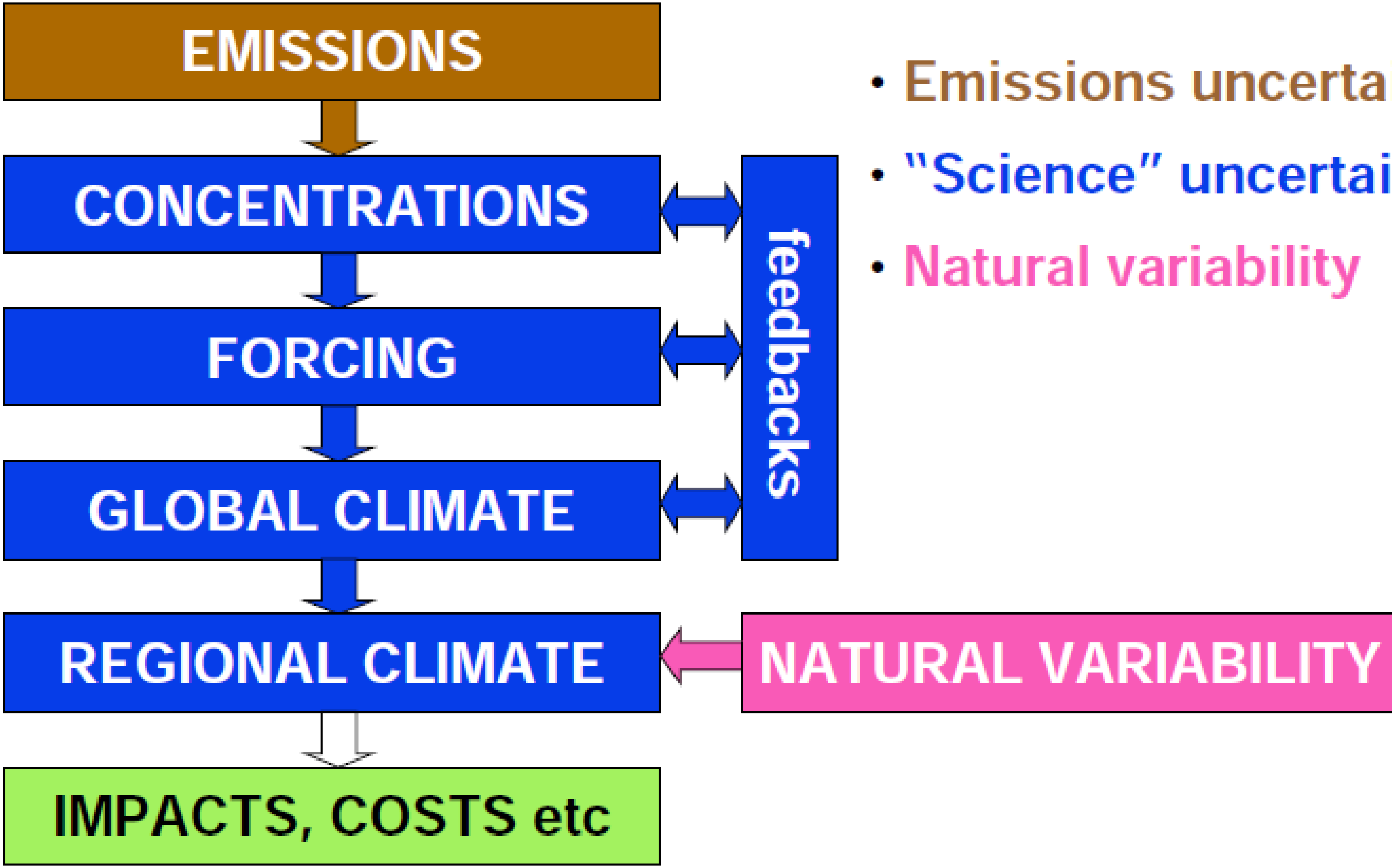

Composite (average of 19 GCMs) change in temperature (oC) relative to 1961-1990 normal for A1B emission scenario.

# Changes in rainfall (%) relative to 1961-1990 over Ethiopia (NAPA 2007)




Composite (average of 19 GCMs) change in temperature (oC) relative to 1961-1990 normal for A1B emission scenario.

# Possible sources uncertainties




- Emissions uncertainty
- "Science" uncertainty
- Natural variability

Geoff Jenkins (2002)

# Limitations of models in climate prediction

Anthony Lupo and (USA) and William Kininmonth (Australia) in their review article on "Global Climate Models and Their Limitations, 2013" presents the following limitations of using models in climate prediction:

- Model prediction techniques introduce biases of varying magnitude into model Projections;
- Several of important chemical and biological processes that influence climate over long time periods are either missing or inadequately represented in today's state-of-the-art climate models,
- Low-resolution models fail to capture many important phenomena of regional and lesser scales (such as clouds); and downscaling to higher-resolution models introduces boundary interactions that can contaminate the modelling area and propagate error,
- Many GCMs fail to account properly for certain "multiplier effects" that may significantly amplify the initial impacts of various biospheric processes (e.g., . absolute variations associated with some solar-related phenomena)

- Major imperfections in the models prevent proper simulation of important elements of the climate system, including pressure, wind, clouds, temperature, precipitation, ocean currents, sea ice, permafrost, etc.
  - Large differences between model predictions and observations frequently exist when comparing these elements or features.
  - In some cases computer models fail to simulate even the correct sign of the observed parameters.

**Thanks for your time**

**Don't just learn . . .**

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