Climate Basics

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AIM for Scale
AI Weather Training

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Content

I. Basic concepts: weather, climate and climate change

II. Factors determining climate of a location

III. Climate Variability

IV. Climate data vs climate information

V. Climate Forecast

VI. Climate change

I. Introduction: Basic Concepts

1.1. Weather and Climate

What is the difference between Weather and Climate?

Somebody explains …

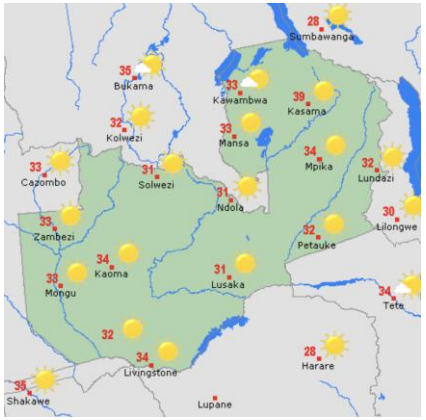
"climate is what you expect and weather is what you get“

Andrew Herbertson

1. Weather and Climate

Weather

- State of the atmosphere at a given time and place with regard to temperature, air pressure , wind, humidity, cloudiness, and precipitation.
- The term *weather* is restricted to conditions over short periods of time:
- Whatever is happening outdoors in a given place at a given time
- Can change a lot within a very short time
- Is what we hear about on the television news every night



Weather and Climate

Climate

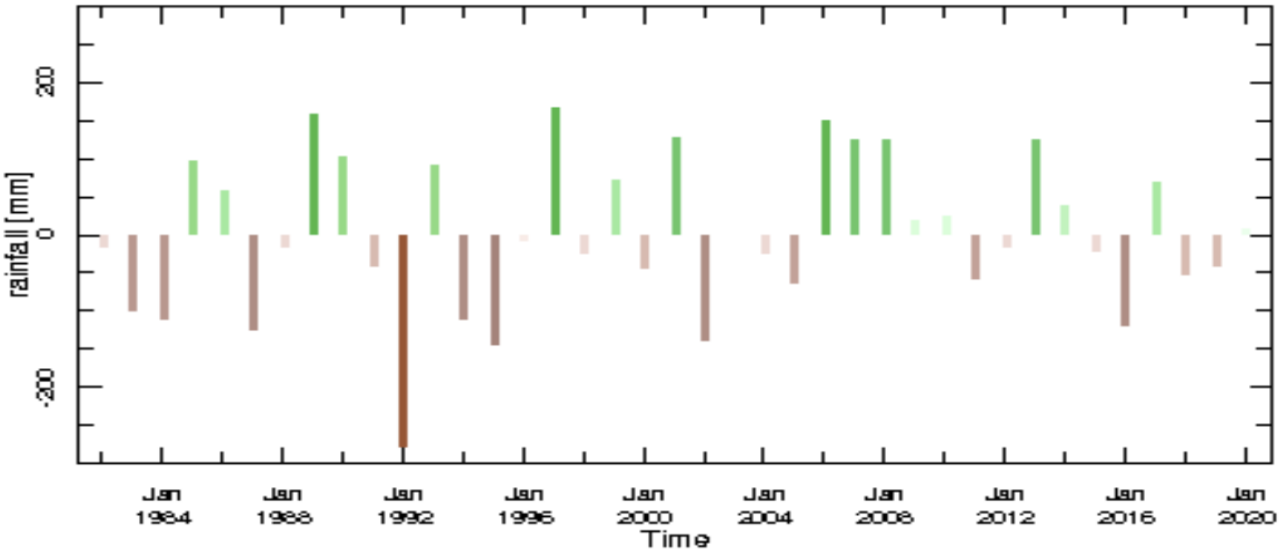
- **Encompasses the total experience of weather at any place over a longer period of time, including year-to-year variations,**
- **Average condition of the atmosphere near the earth's surface over a long period of time:**
  - **Seasons (e.g. dry vs rainy season),**
  - **Statistics of extreme weather events (e.g. tornadoes and floods)**
- **Climate tells us what it's usually like in the place where you live**

Weather and Climate

Climate Variability

Climate variability is defined as differences from the average state of the climate, or climatology, across temporal and spatial scales.

According to the WMO, **climate variability** refers to “deviations of climate over a given period of time (e.g., a month, season, year, or even decade) when compared to long-term statistics for the same calendar period.



Seasonal rainfall anomalies for Dec-Feb

Questions?

Basic concepts

Weather, Climate, Climate Change

Quiz

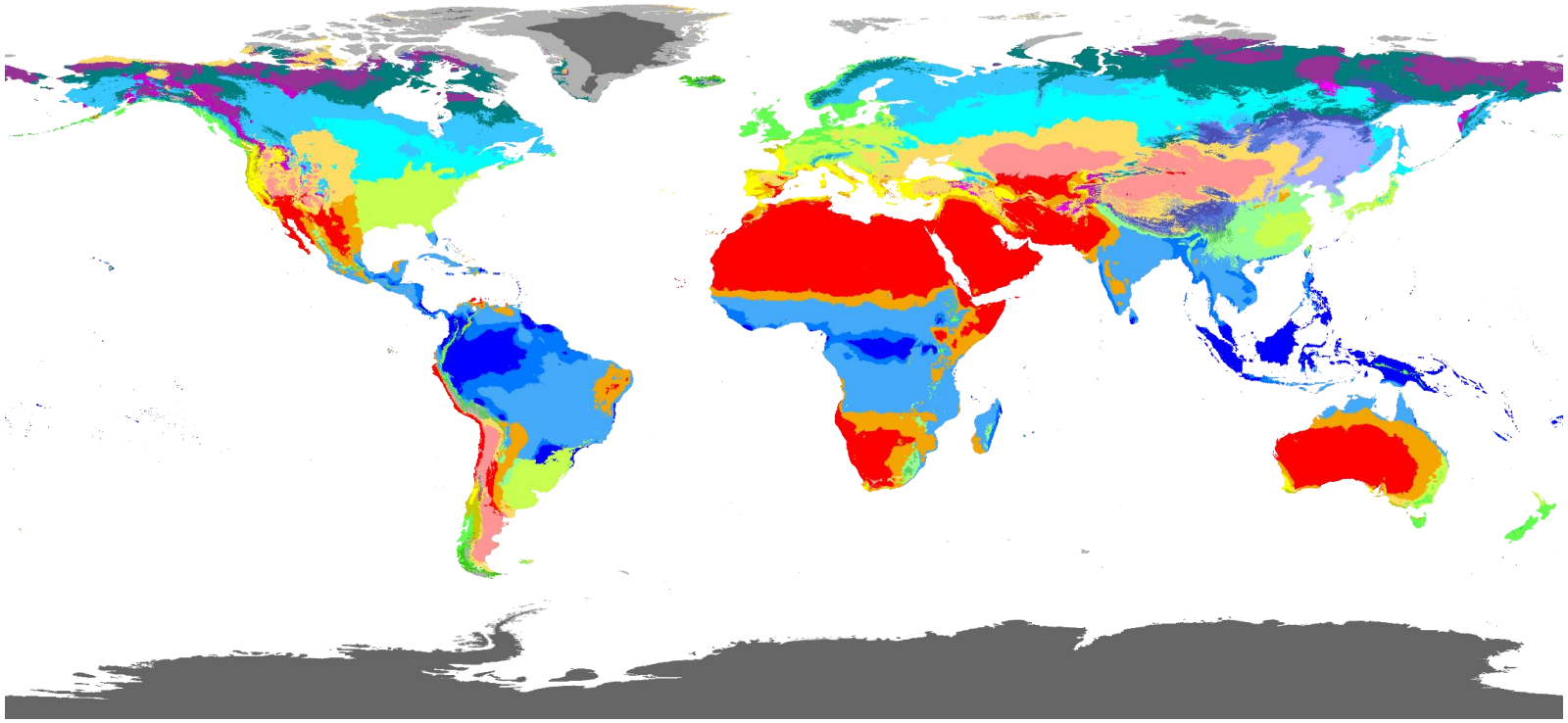
Which of the statements below relates to weather, climate or climate change?

1. On August 7th 2020 it rained 124mm in Lusaka
2. Flooding is more and more frequent in Addis Ababa
3. The rainfall recorded in Dakar on August 7th 2020 was the third largest daily amount on the record
4. The frequency of daily rainfall exceeding 100mm in Nairobi has been steadily increasing over past 50 years

II. Factors determining climate of a location

1. Describing the climate of a location

Spatial variation



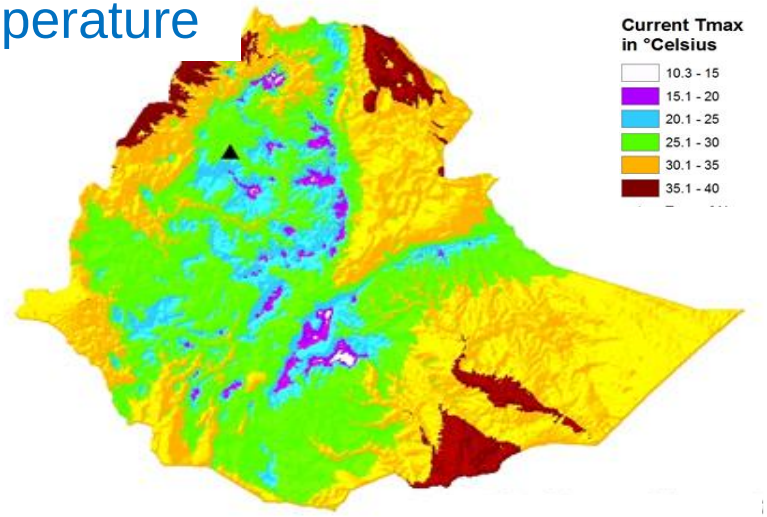
Global Köppen-Geiger climate classification

Describing the climate of a location

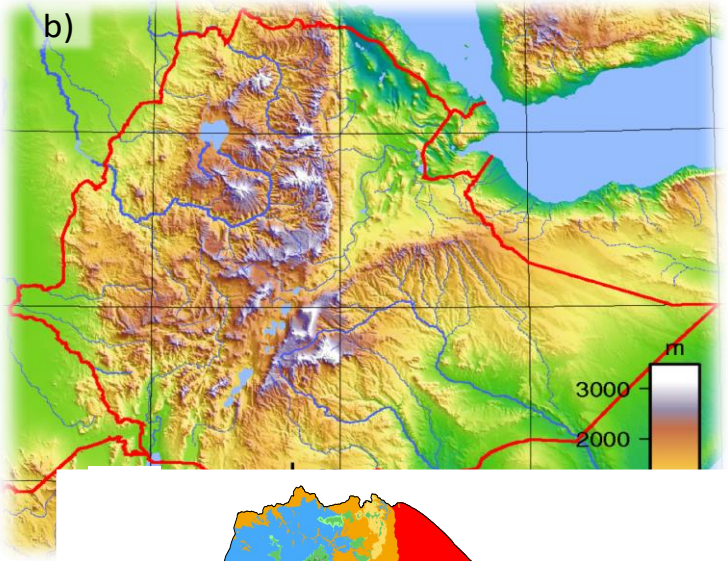
Spatial variation

Spatial variation: Ethiopia example

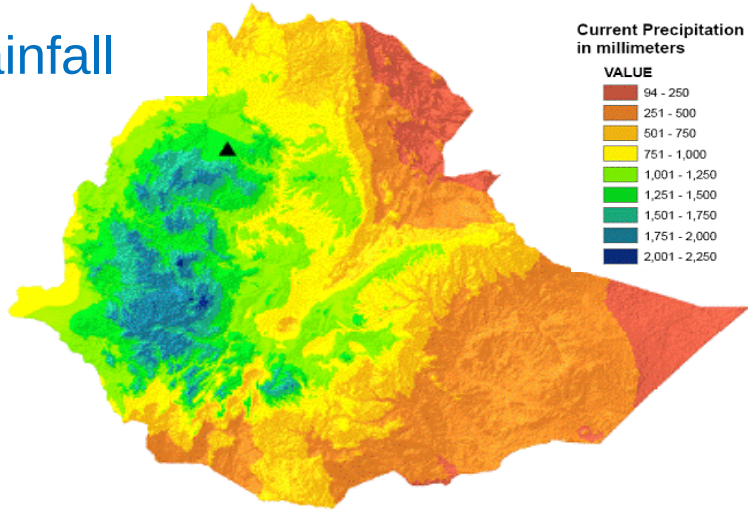
Temperature

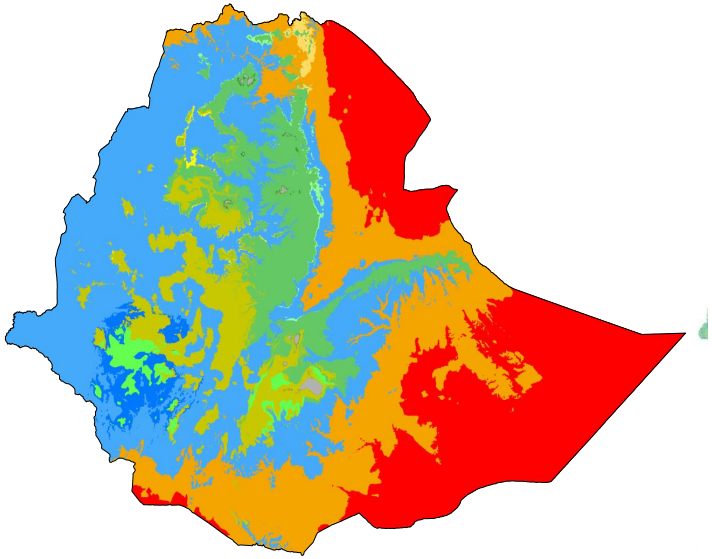


Topography



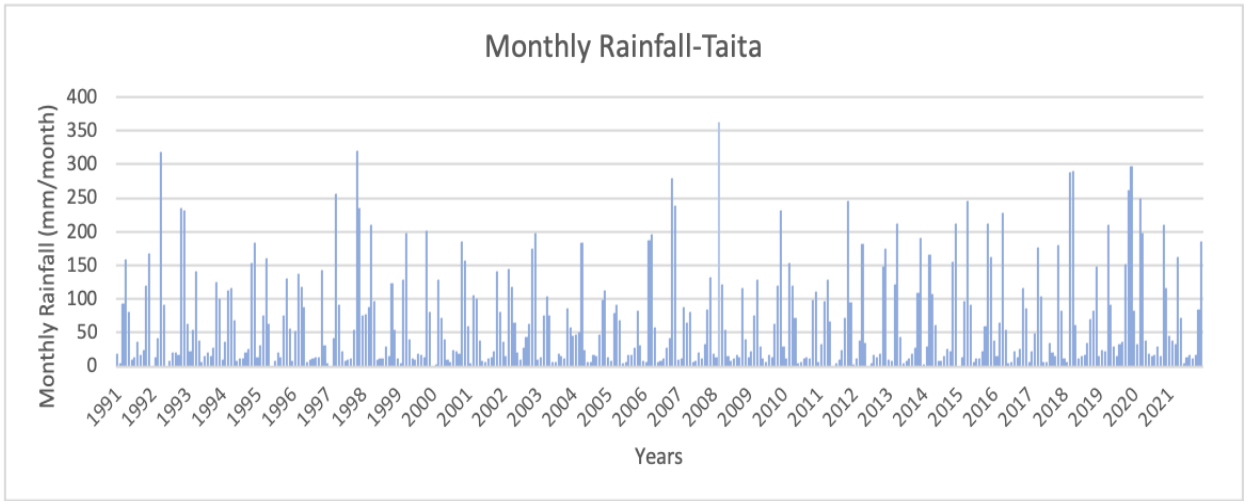
Rainfall

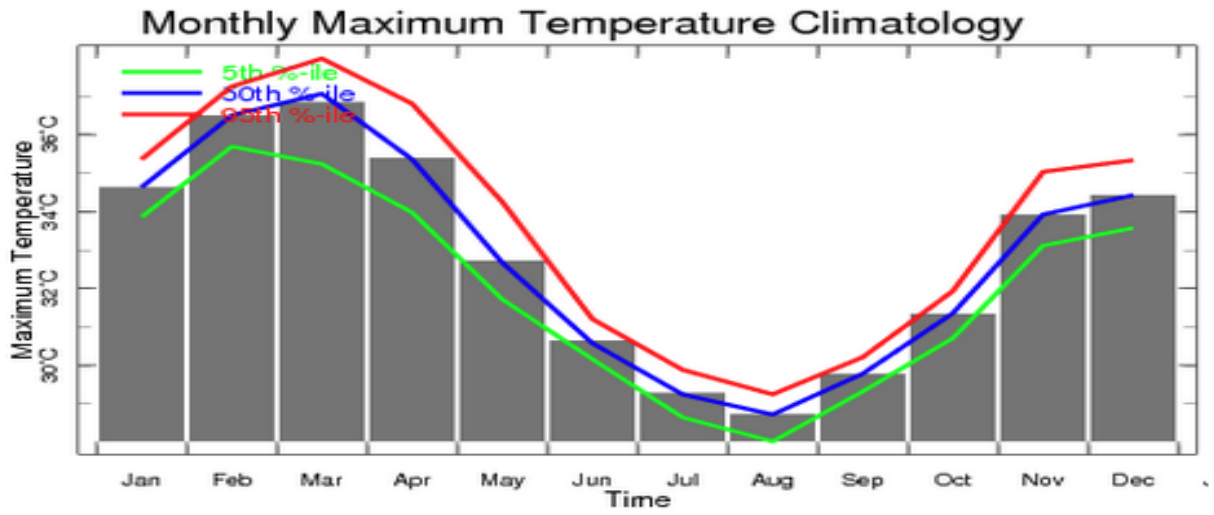




Describing the climate of a location

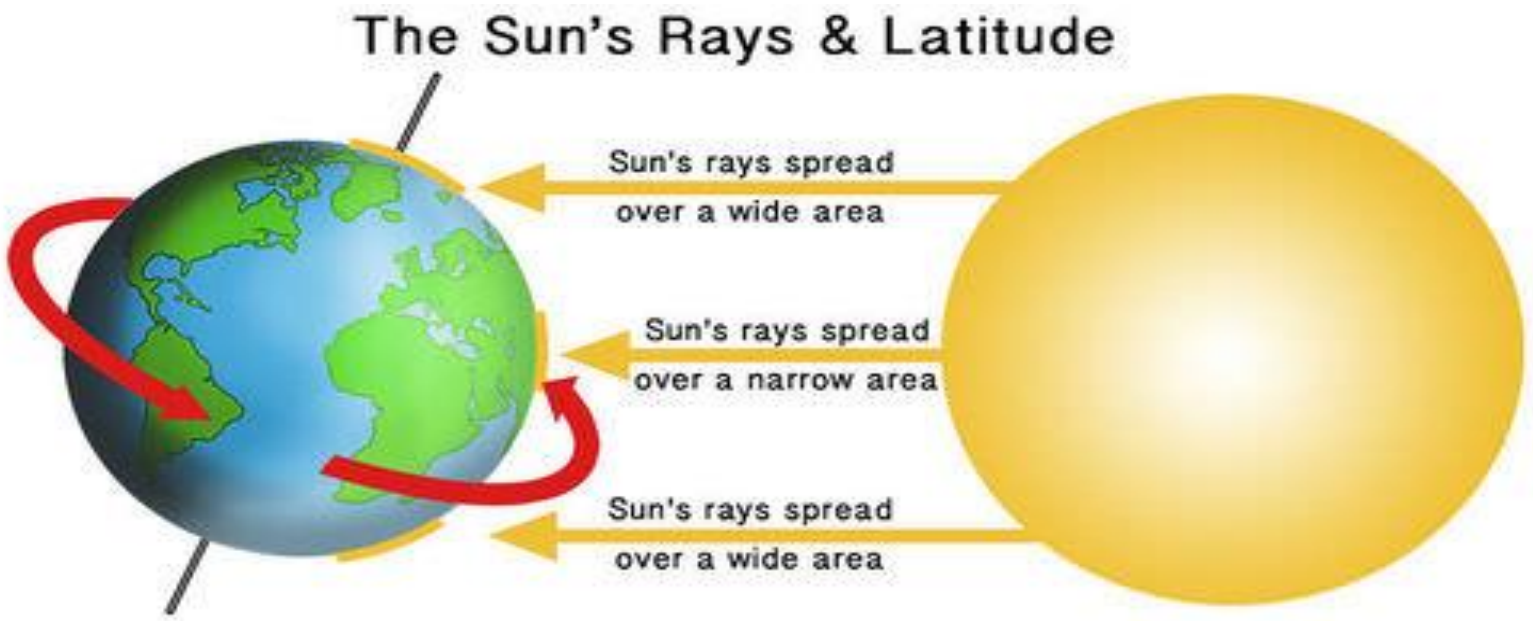
Temporal variation: Nigeria example





2. Global factors

i. Energy balance



More energy/m^2 at the equator than in polar regions

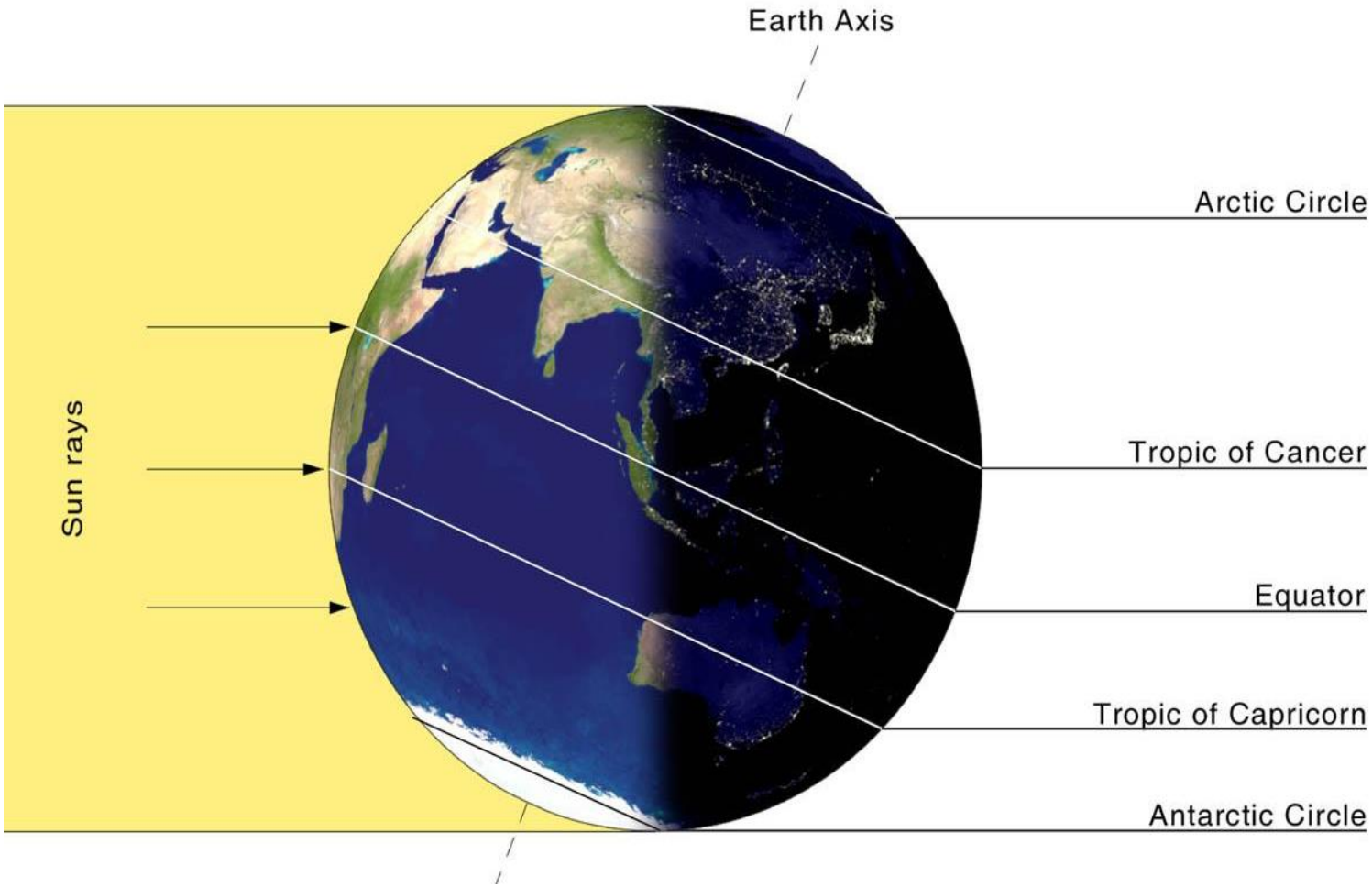
- **Temperature differences**
- **Atmosphere and Oceans redistribute the energy**

Role of the Latitude

https://flexbooks.ck12.org/cbook/ck-12-middle-school-earth-science-flexbook-2.0/section/10.13/primary/lesson/solar-energy-and-latitude-ms-es/

Global Factors

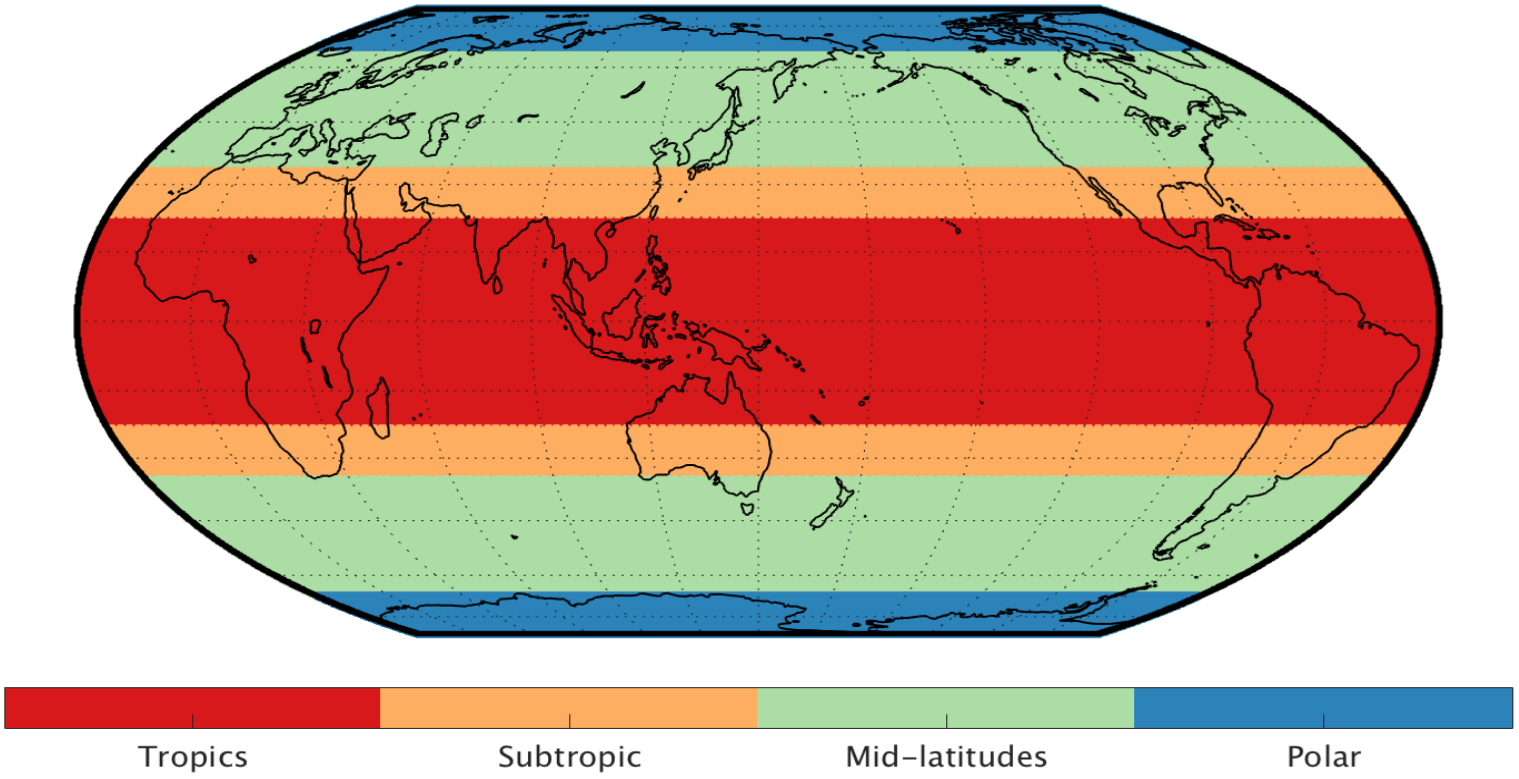
i. Energy balance



Global Factors

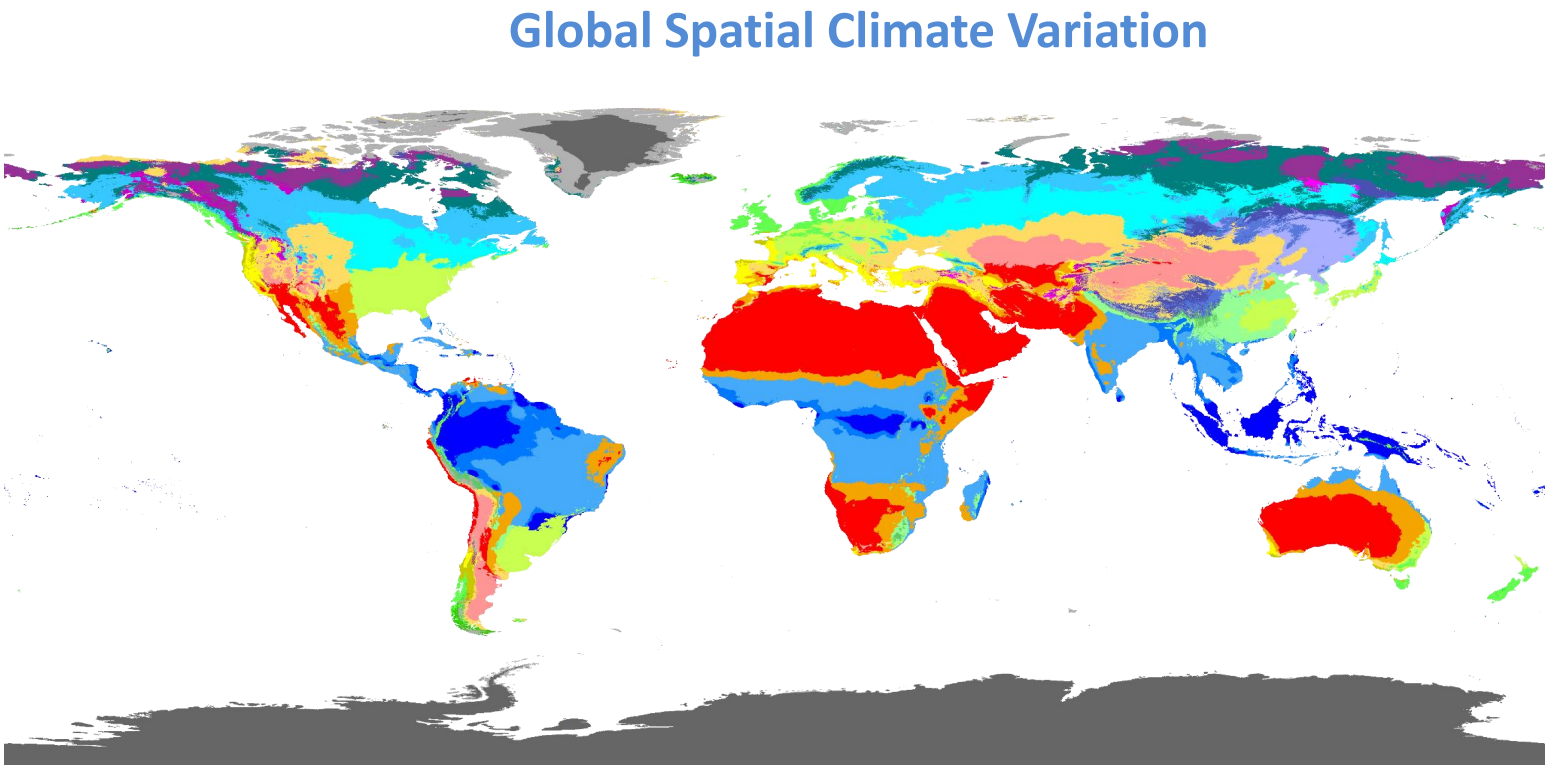
Energy balance

Global Climate zones



Global Factors

Energy balance

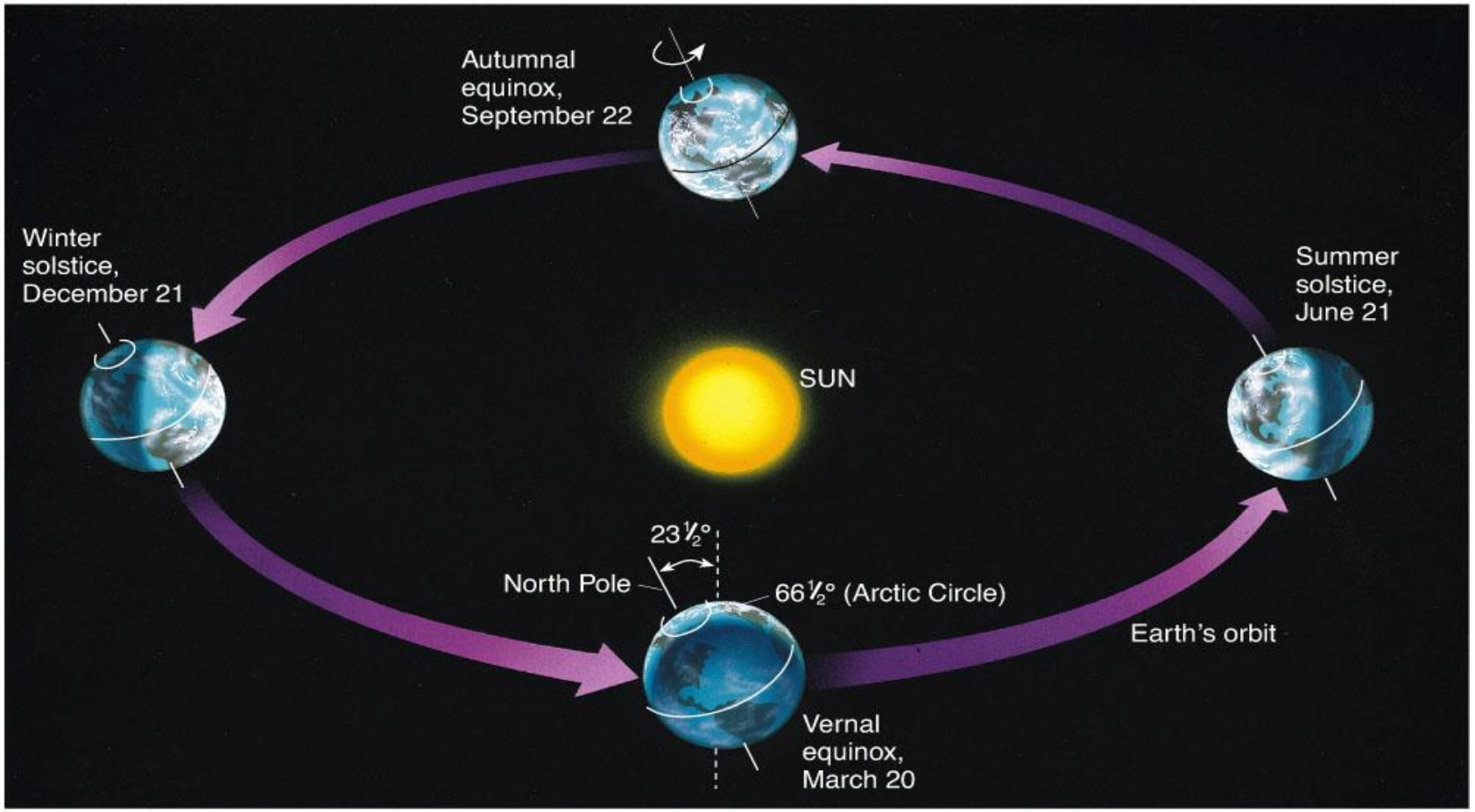


Global Köppen-Geiger climate classification

Source: Beck, H.E., Zimmermann, N. E., McVicar, T. R., Vergopolan, N., Berg, A., & Wood, E. F.,

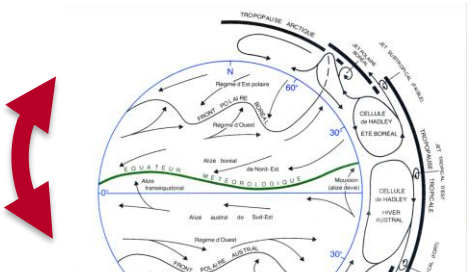
Global Factors

ii. Earth's rotation around the sun and seasonality



Global Factors

Seasonality



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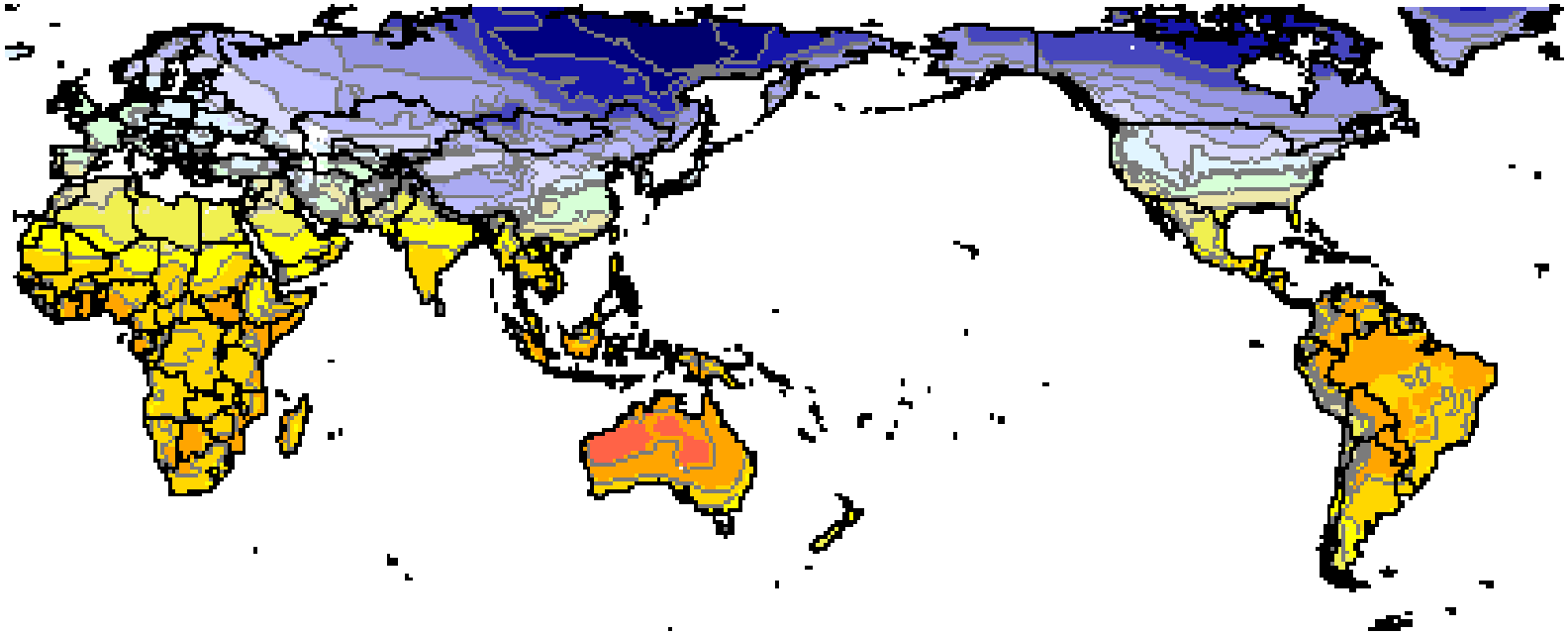
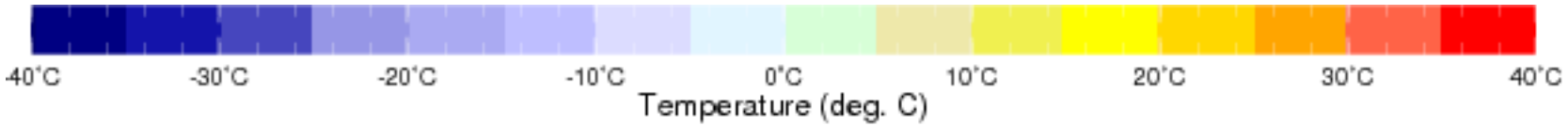
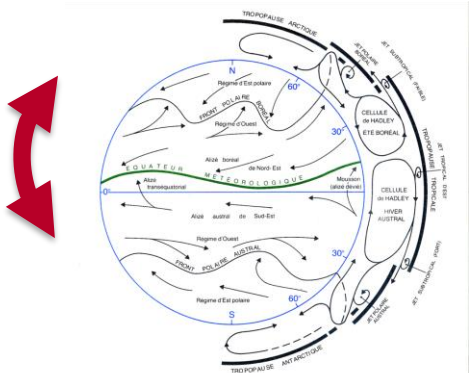




Global Factors

Seasonality



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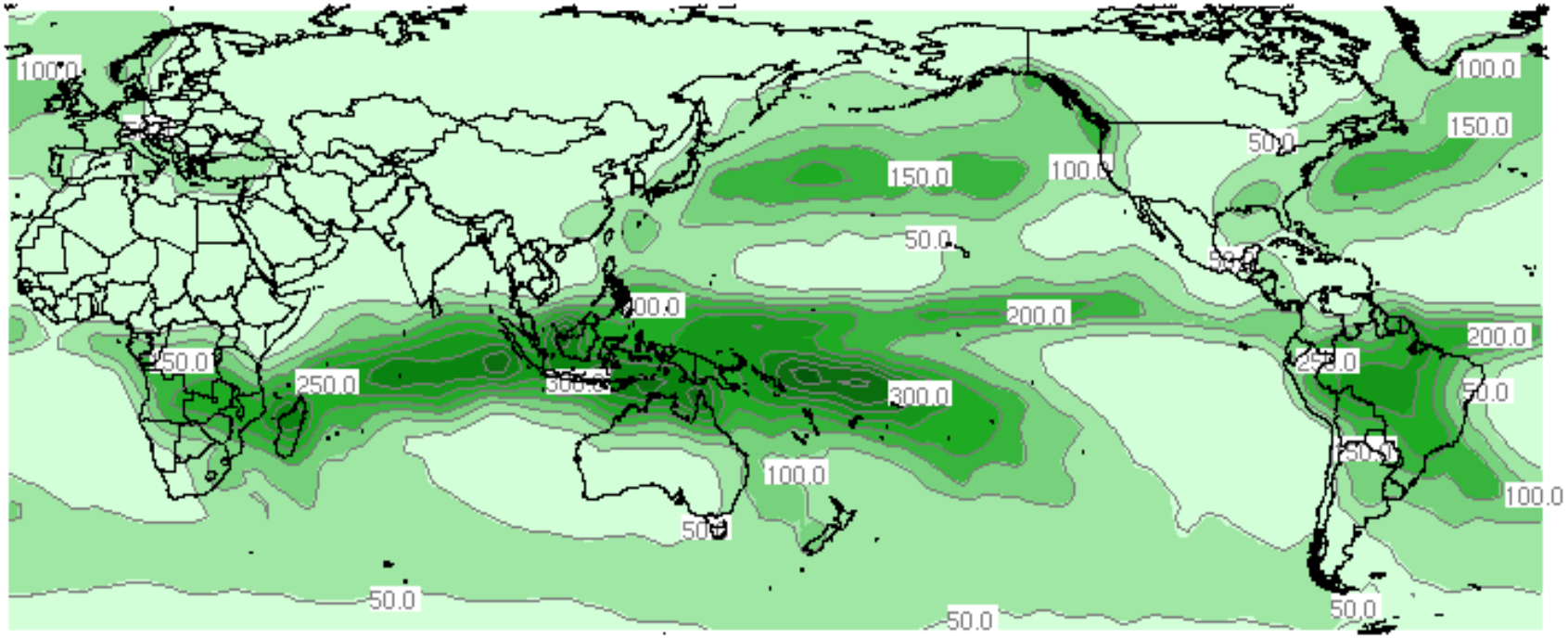
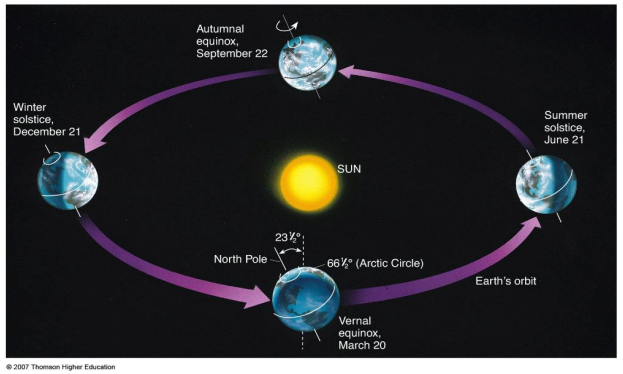
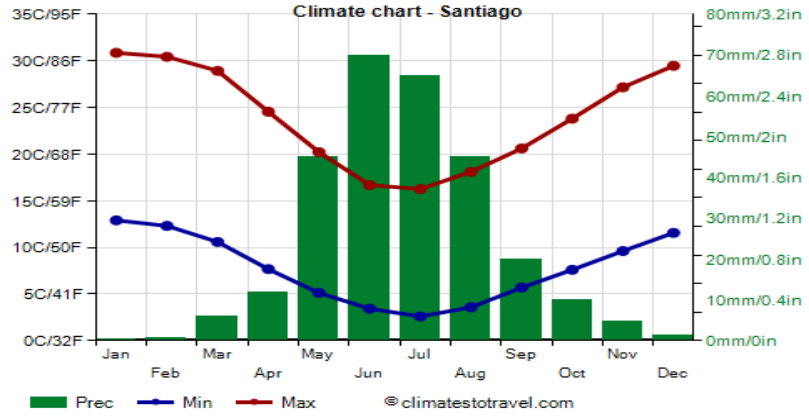
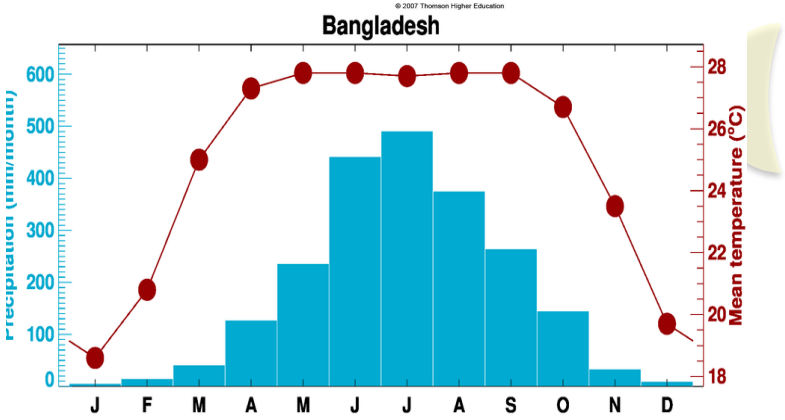


Global Factors

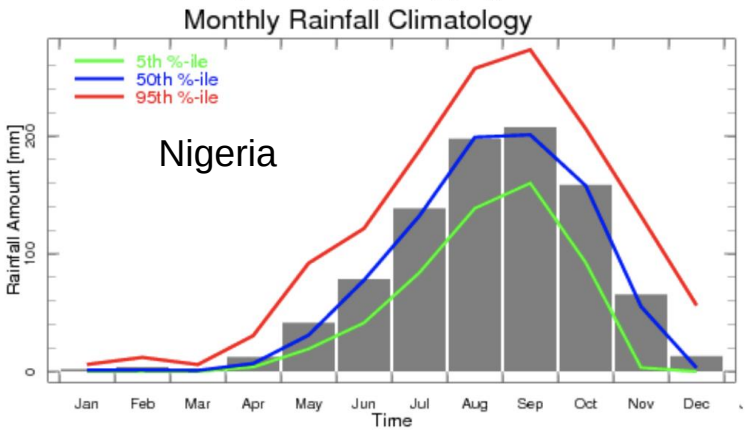
Seasonality examples

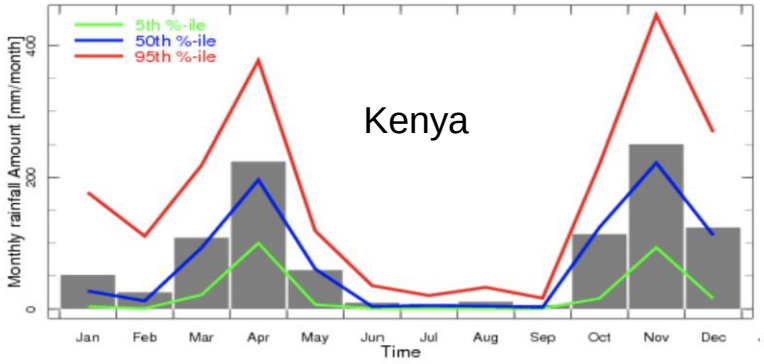






Observations for **Abuja Municipal, Abuja, Nigeria**

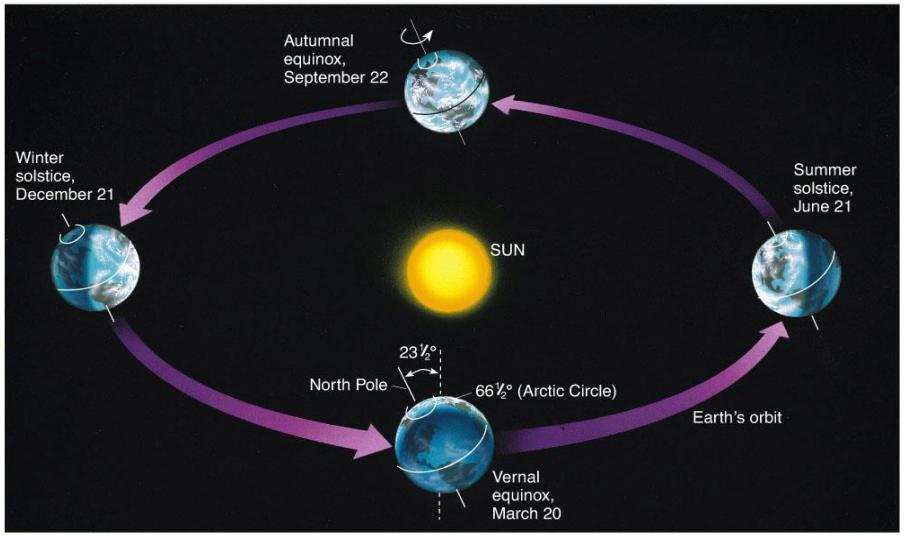


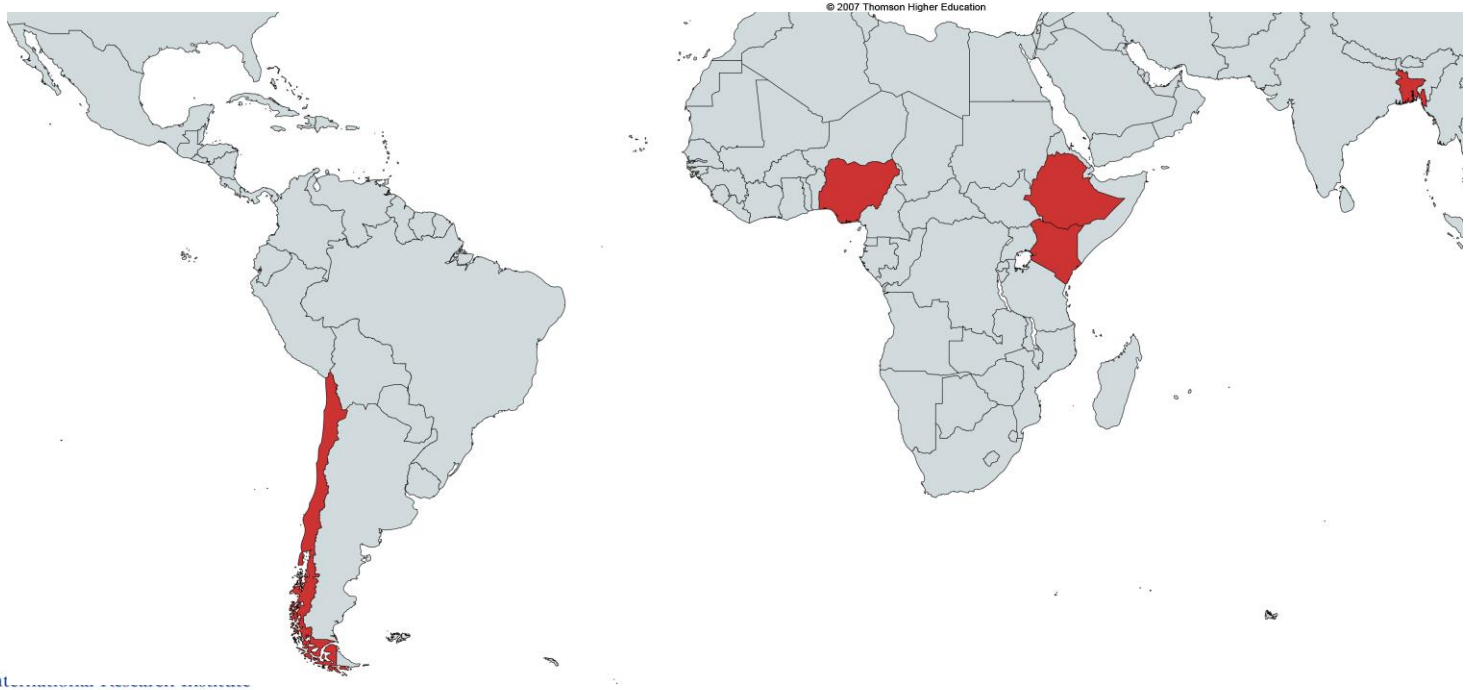


Factors determining climate of a location

Global Factors

Seasonality

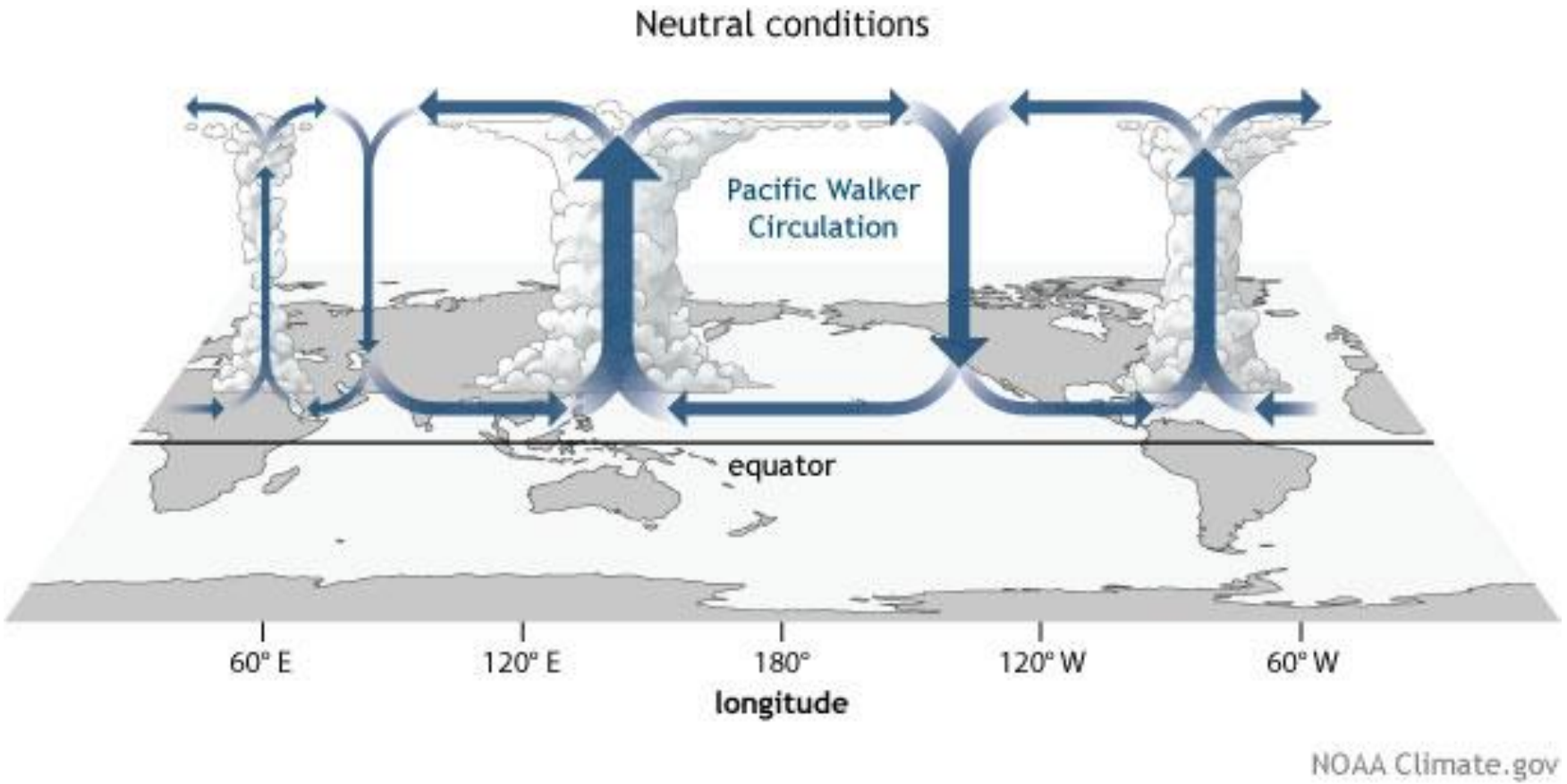




Global Factors

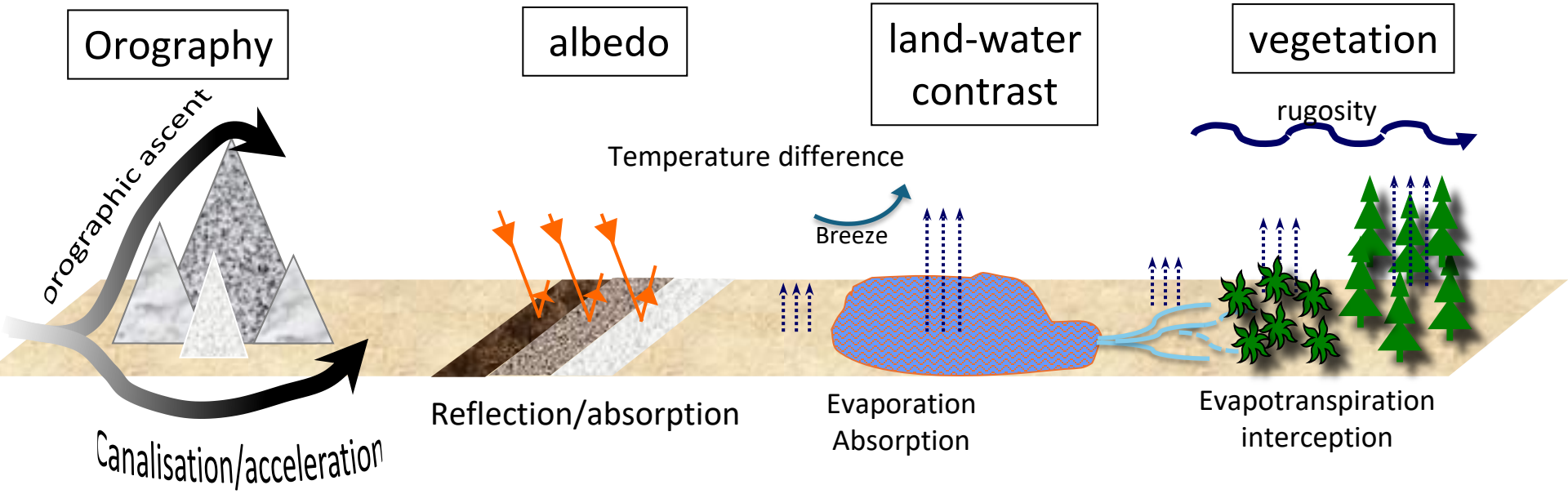
iii. Sea-land distribution

➢ Zonal circulations



Role of the Longitude

3. Local factors



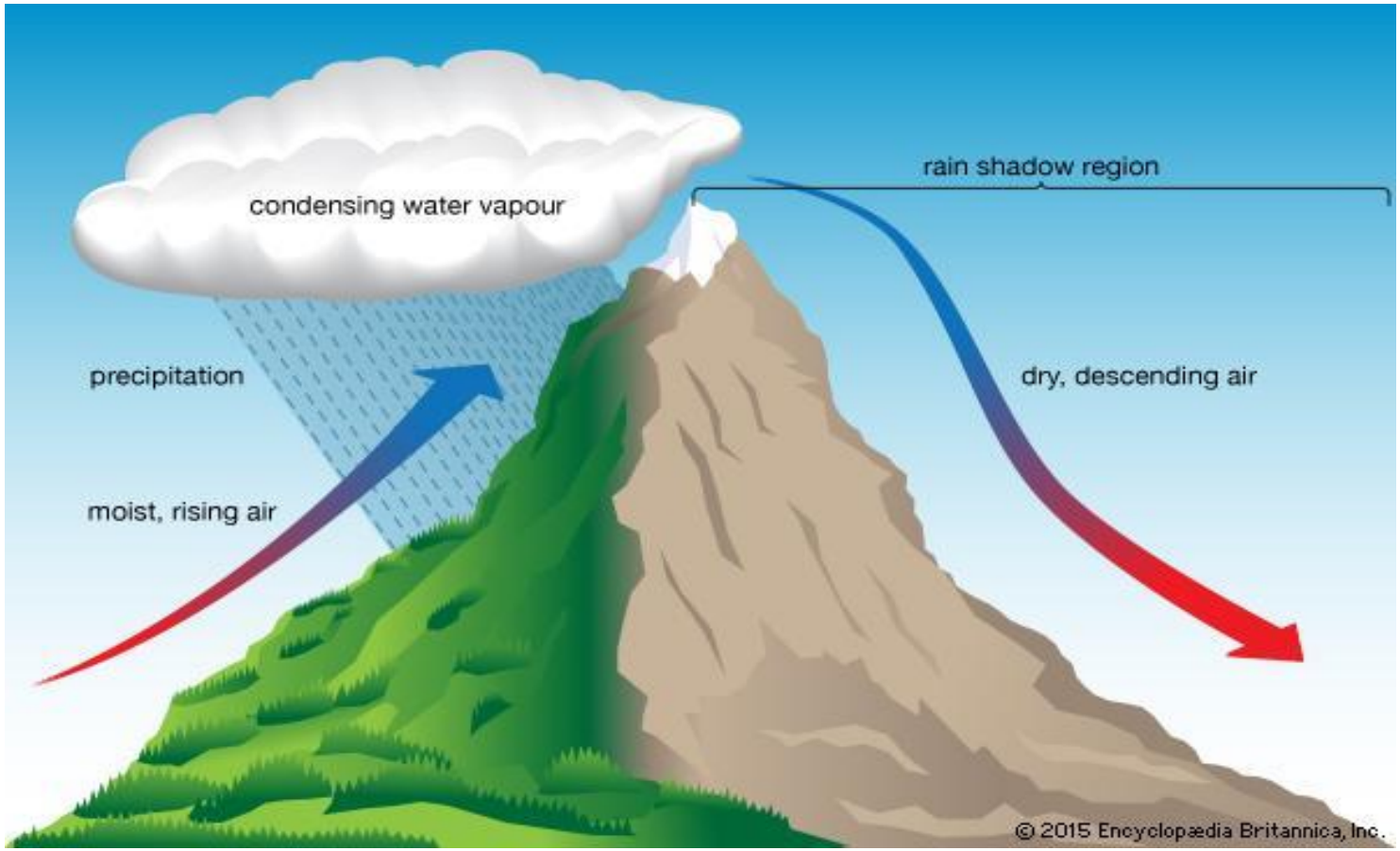
Which of these factors are the most important in Ethiopia?

Local factors

Oroography

Orographic rainfall (mountains)

Mountains have a pronounced impact on local climate, also known as an orographic effect,



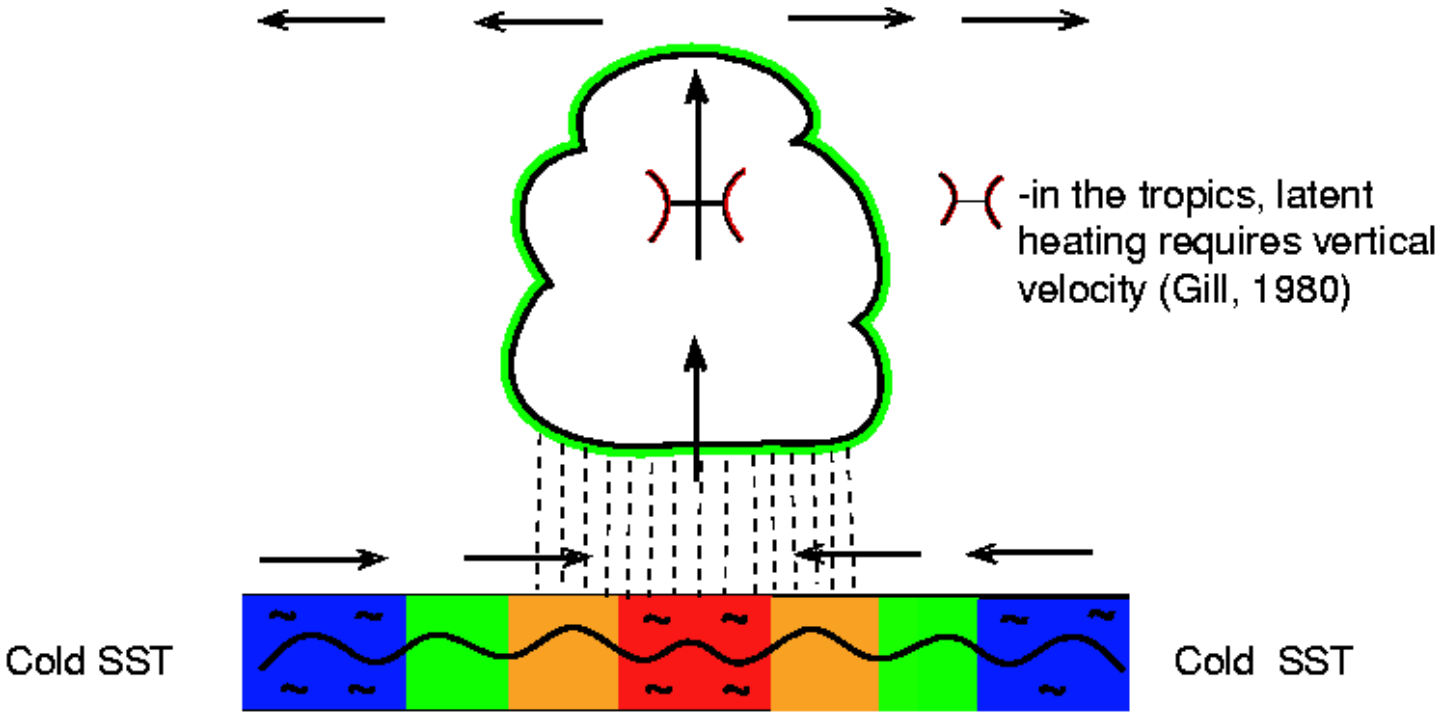
Questions?

III. Climate Variability

Climate variability

Interannual variability

1. The role of Sea Surface Temperatures



Interannual variability

2. El Nino-Southern Oscillation (ENSO)

- It is an oceanic and atmospheric phenomenon;
- El Niño represents the oceanic component (although it describes just the warm phase ;
- Southern Oscillation represents the atmospheric component
- **El Niño** event is characterized by an abnormally warm sea-surface in the eastern and central equatorial Pacific Ocean
- **La Niña** refers to conditions in the eastern equatorial Pacific that are cooler than normal

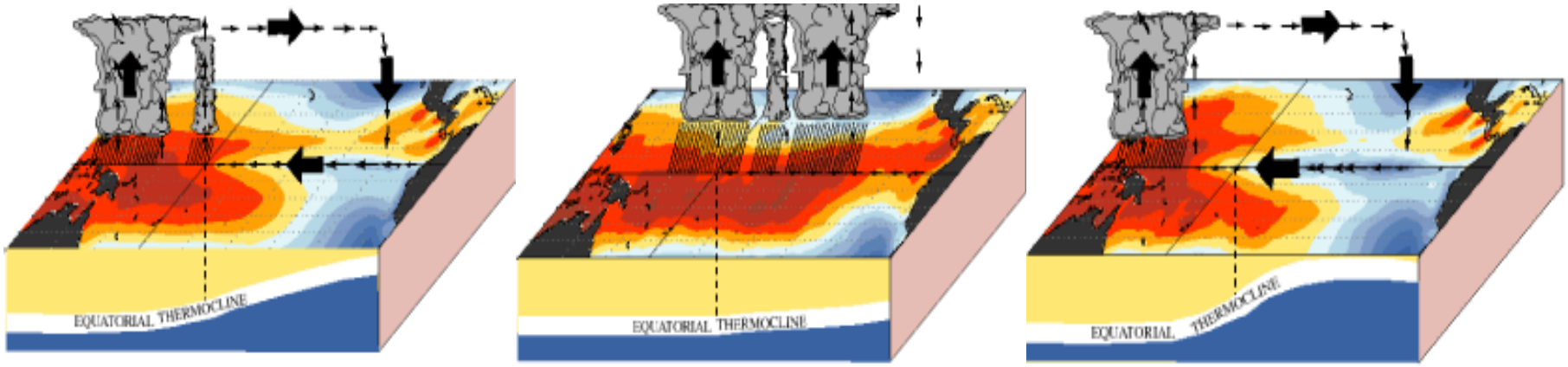
Interannual variability

El Nino-Southern Oscillation (ENSO)

a) Neutral conditions

b) El Niño conditions

c) La Niña conditions

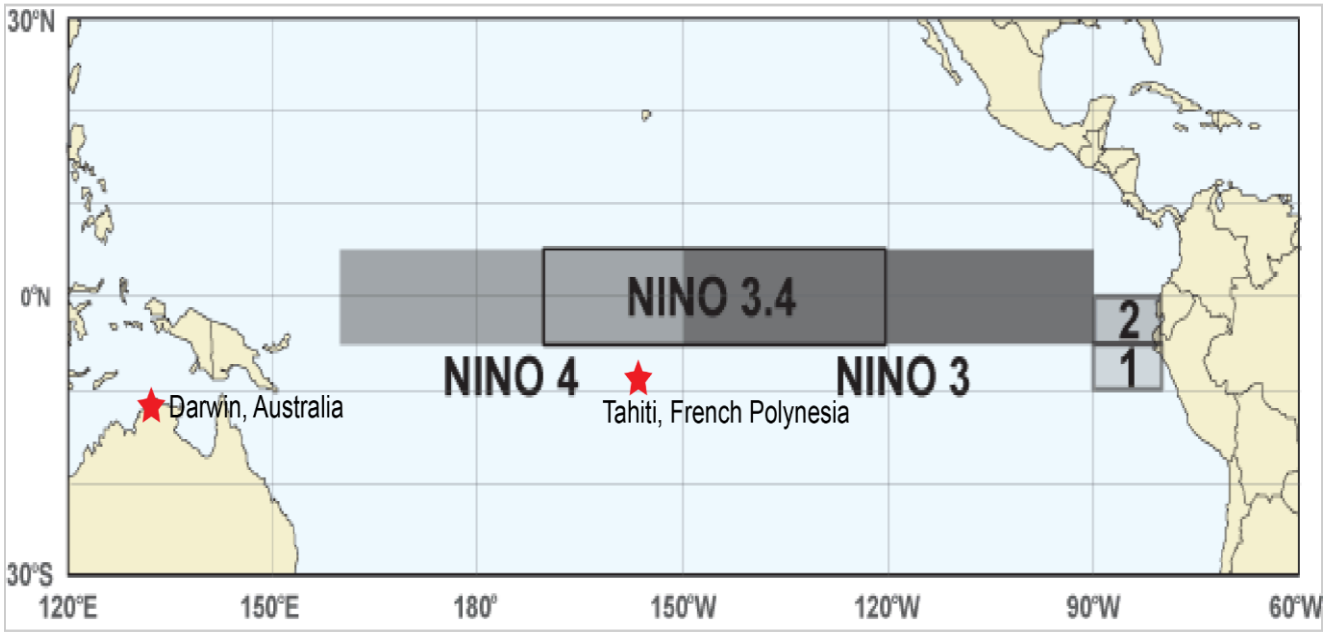


Schematic representation Neutral, El Niño, and La Niña conditions in Equatorial Pacific

Interannual variability

Measuring El Nino-Southern Oscillation (ENSO)

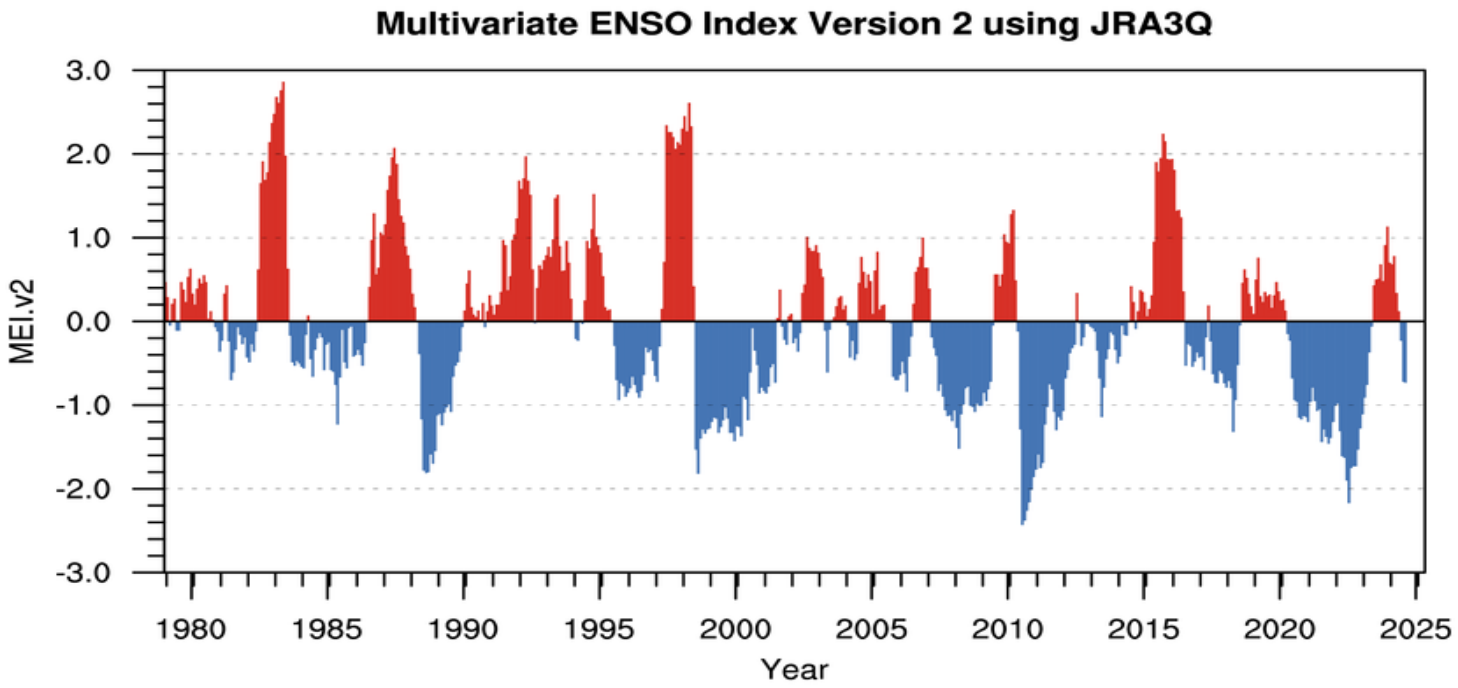
The strength of an El Niño event is characterized by how much the sea-surface temperatures in the central-eastern part of the equatorial Pacific Ocean heat up or cool down.



Pacific Ocean regions used to monitor ENSO

Interannual variability

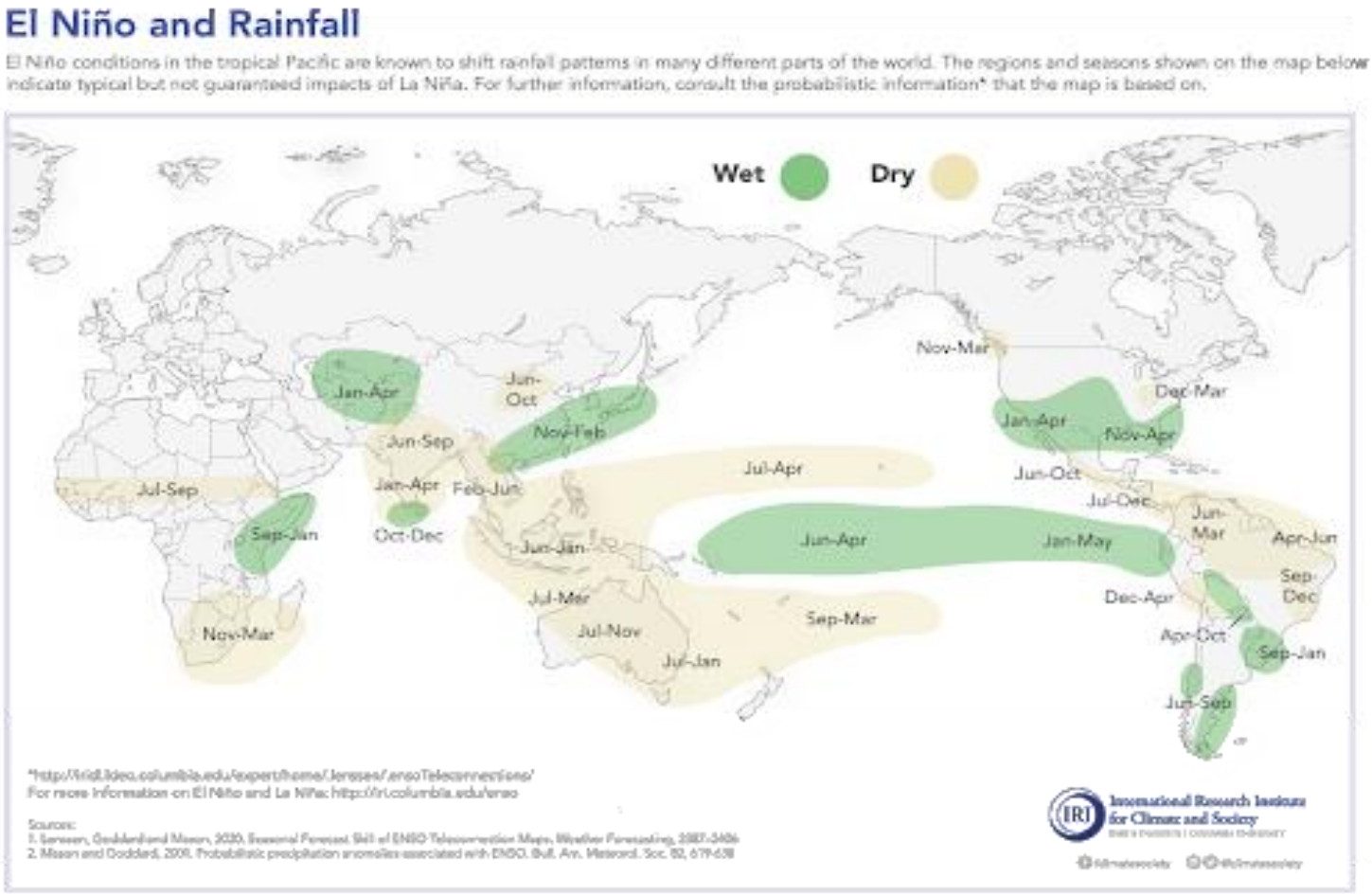
Measuring ENSO



Time series of the El Niño-Southern Oscillation based on the Oceanic Niño Index

Interannual variability

What are the impacts of ENOS?



Questions?

IV. Climate data, climate information, and climate analysis

1. Data vs information

Data

A collection of values/measurements of the variable of interest
(temperature, air pressure, wind, humidity, cloudiness, precip. etc.)

- array of values ☛ usually not very useful for non-specialists

Information

Analyzed/ Interpreted data with a specific goal/focus

- value added to the raw data!
- same data yield to different information depending on the interest

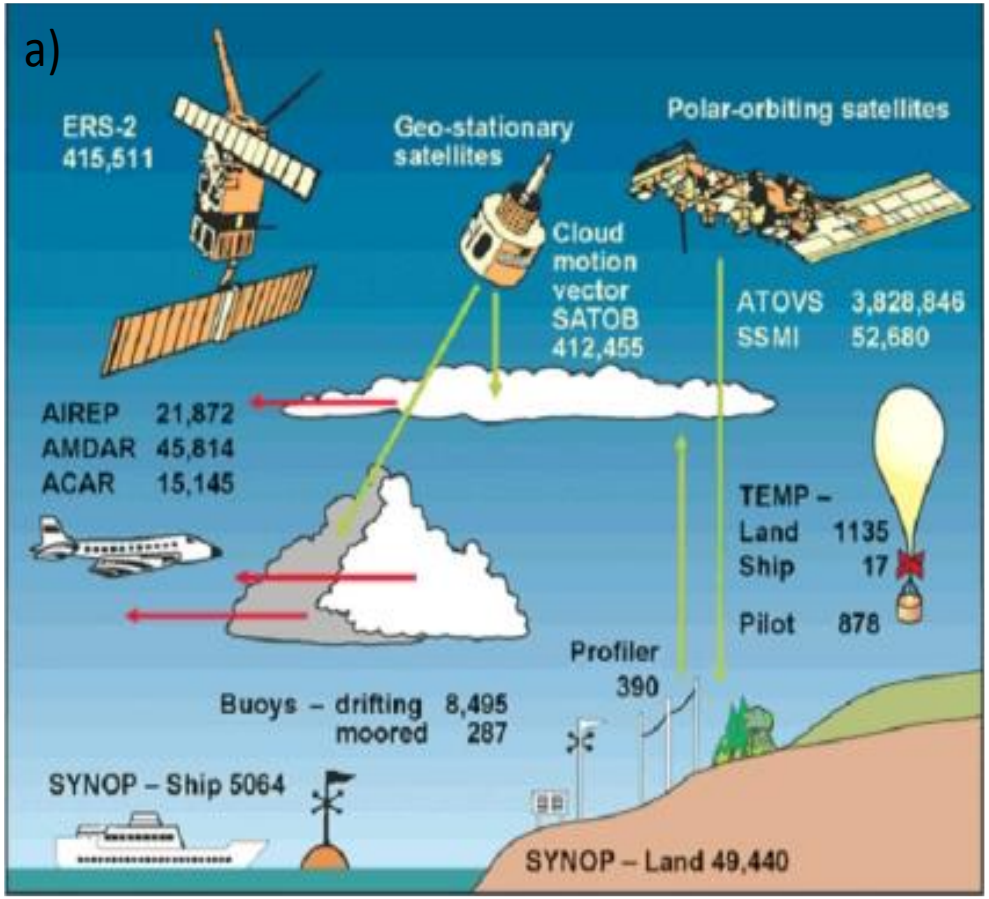
e.g. frequency of extreme precipitation (above a certain threshold)
vs. mean seasonal cycle of precipitation (rainy vs dry season),
both extracted from the same daily precipitation records…

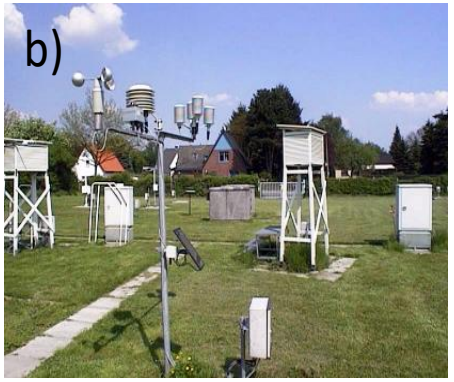
- methods of information extraction adapted to the problem/demand

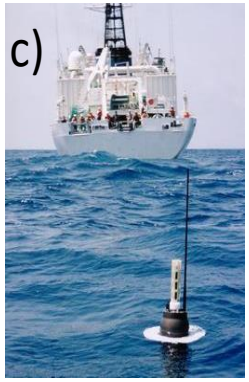
☛ important to formulate a well defined objective when asking for information;

2. Sources of climate data

- Routine meteorological surface/near surface observations
- Aircraft/radar upper atmosphere
- Ship/buoy ocean observations
- Satellite observations



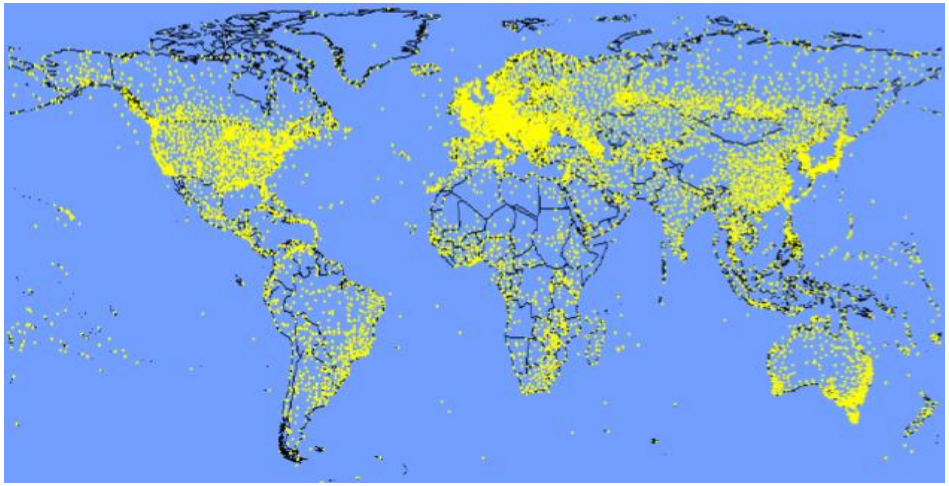




3. Climate data types

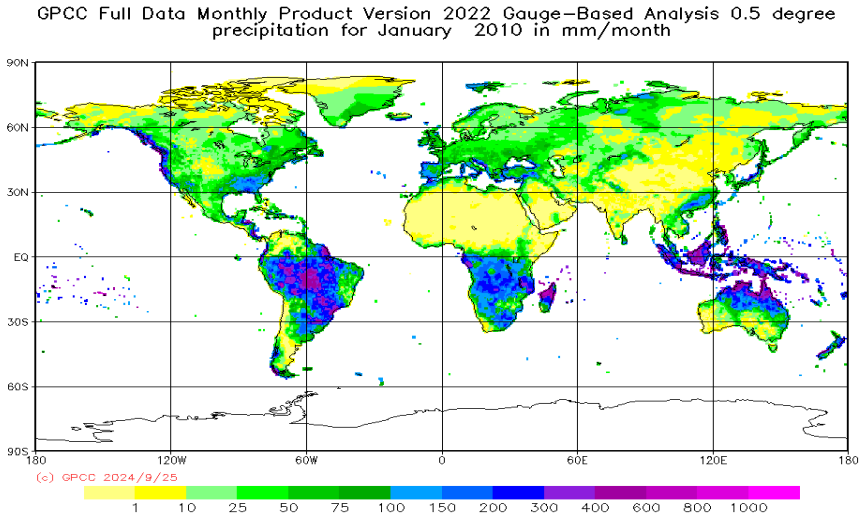
Station data

- Collected through meteorological stations around the world
- Localized – represent local conditions
- Sparse spatial coverage in some areas



Gridded/interpolated data

- Interpolation from scatted point observation to regularly spaced grid
- Provide data where there are no observations

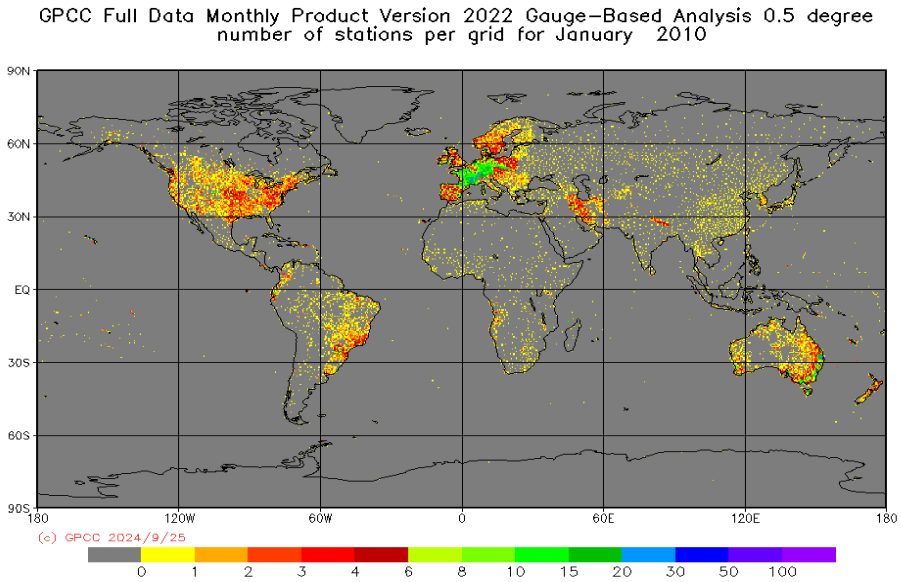


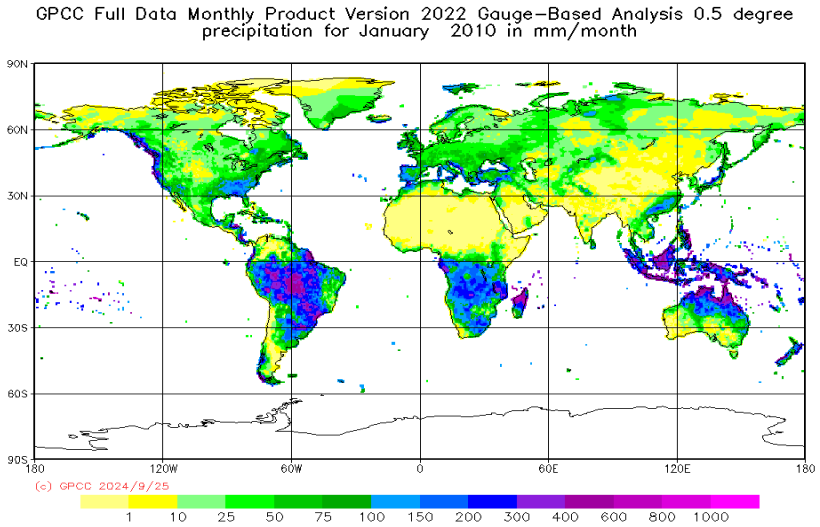
https://kunden.dwd.de/GPCC/Visualizer

3. Climate data types

Gridded/interpolated data

Impact of station data availability





Gridded/interpolated data

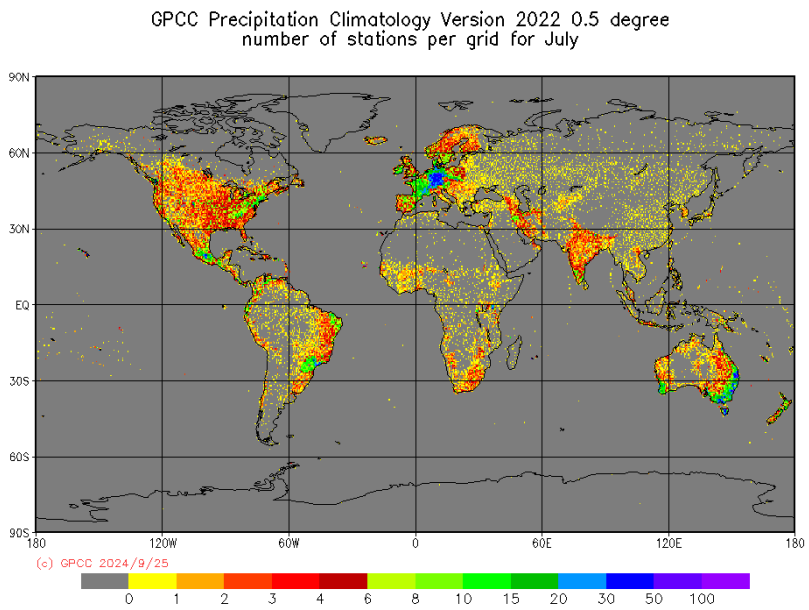
- ☛ How well do they represent local conditions in places with no stations?

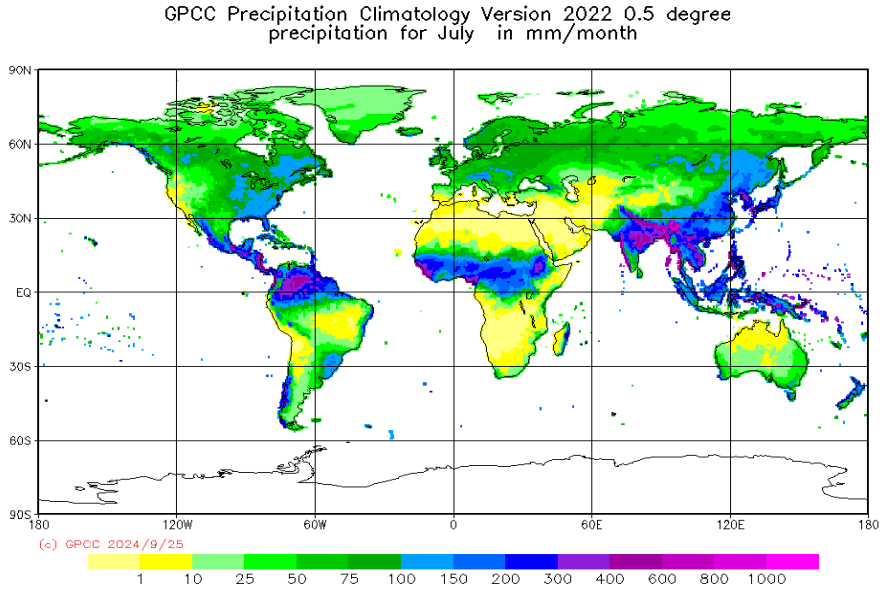
https://kunden.dwd.de/GPCC/Visualizer

3. Climate data types

Gridded/interpolated data

Impact of station data availability





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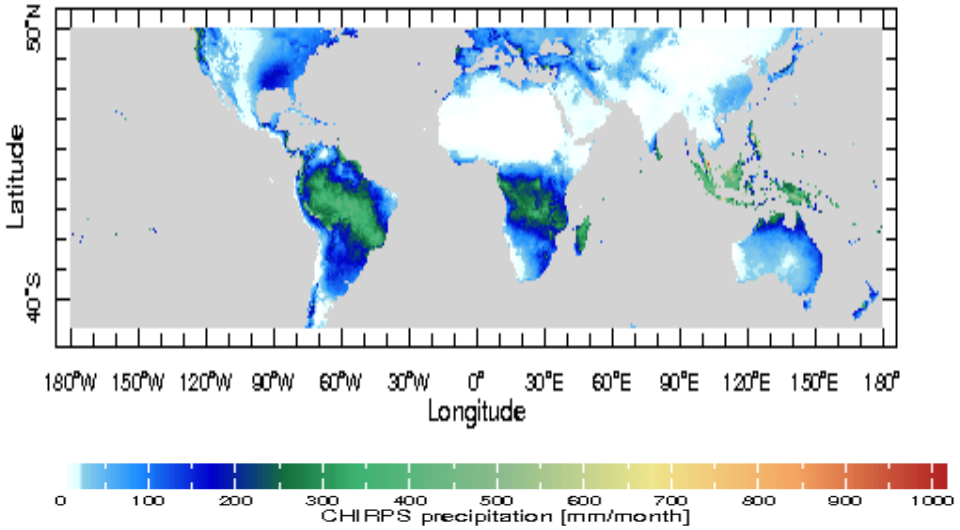
Data types

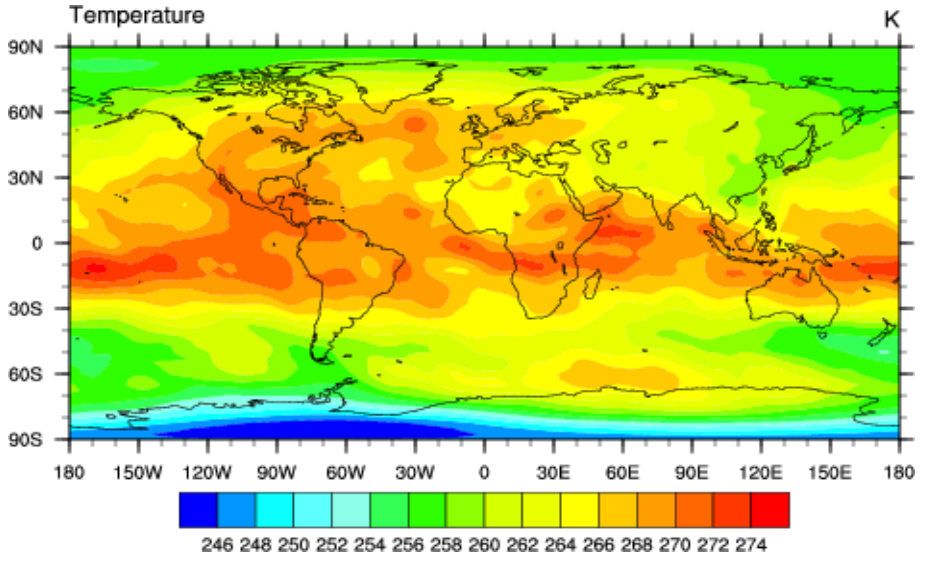
Satellite data

- Estimated from satellite observations
- The most widely used satellite data is rainfall
- High-resolution data (4km and above)



Climate model data

- Reanalysis – physics-based interpolation from observations (historical)
- General Circulation Models or Regional Models – numerical representation of climate based on knowledge of physics – used for forecasting (weather, seasonal, climate change)



4. Types of climate information

Types of climate information based on time horizon/decision type

1.Historical information

- Inform on mean climate, trends, climate statistics (extreme events etc.)
- Basis for planning and optimizing investments, current climate vulnerability

2.Real time/Monitoring/Early Warning Systems

- Current observations, short term forecasts (weather)
- Everyday decisions, monitoring of floods, droughts, food security, disease…

➥ Disaster management

3.Forecasts/projections

- Weather (medium range), season, climate change…
- To help operational risk management, contingency planning

Questions?

V. Weather and Climate Forecast

Timescales of weather and climate information

Sources of predictability

We can make forecasts at different timescales because there are different reasons why the predictions can work:

- *days*: current weather/observation
- *months*: sea-surface temperatures
- *years*: sub-surface ocean temperatures
- *decades*: atmospheric composition

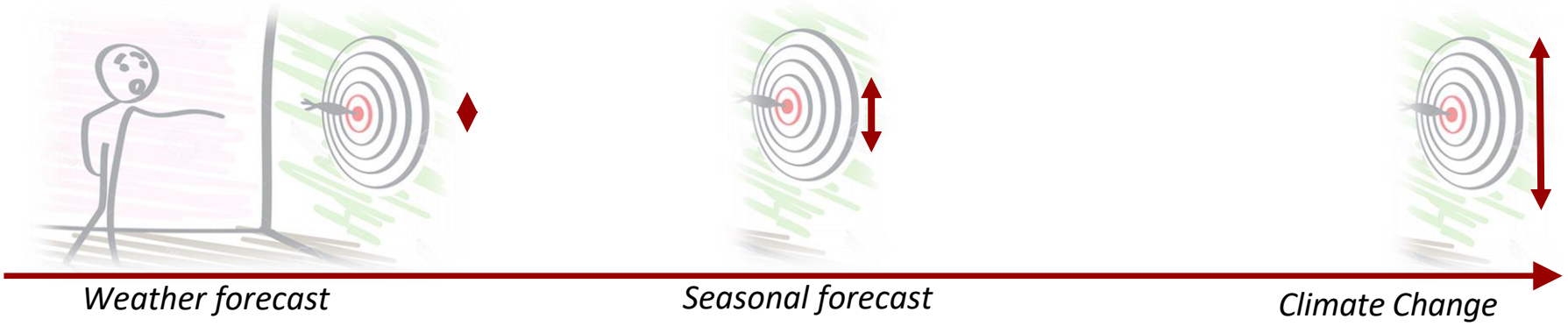
Concept of uncertainity in forecasts

Can I forecast the arrival point of the dart?

We know the physical laws that drive the motion of the dart, so what defines its arrival point?

- Conditions at the departure point
- Conditions along its trajectory

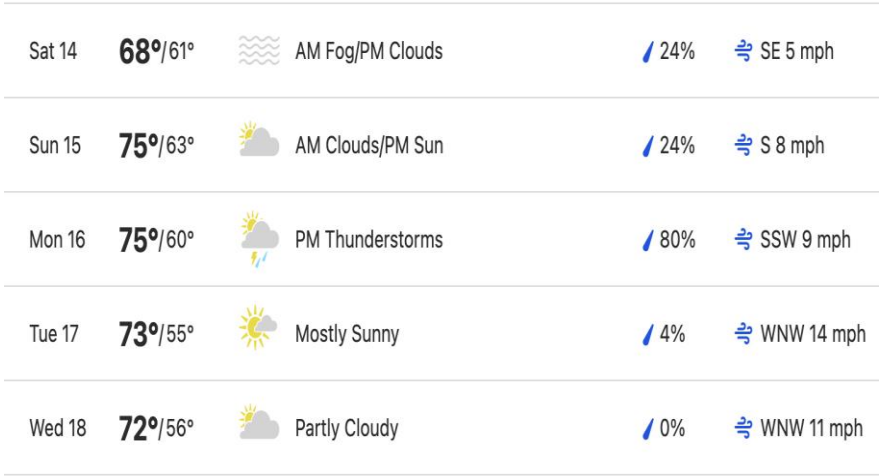
- The farther the target the bigger the uncertainty



Weather Forecast

What do we need to know to make a good prediction?

- The current state (*initial conditions*)
- How the current state will evolve



Sat 14	68°/61°	AM Fog/PM Clouds	24%	SE 5 mph
Sun 15	75°/63°	AM Clouds/PM Sun	24%	S 8 mph
Mon 16	75°/60°	PM Thunderstorms	80%	SSW 9 mph
Tue 17	73°/55°	Mostly Sunny	4%	WNW 14 mph
Wed 18	72°/56°	Partly Cloudy	0%	WNW 11 mph

So there are two sources of **uncertainty**:

- The current state
- How the current state will evolve

Weather Forecast

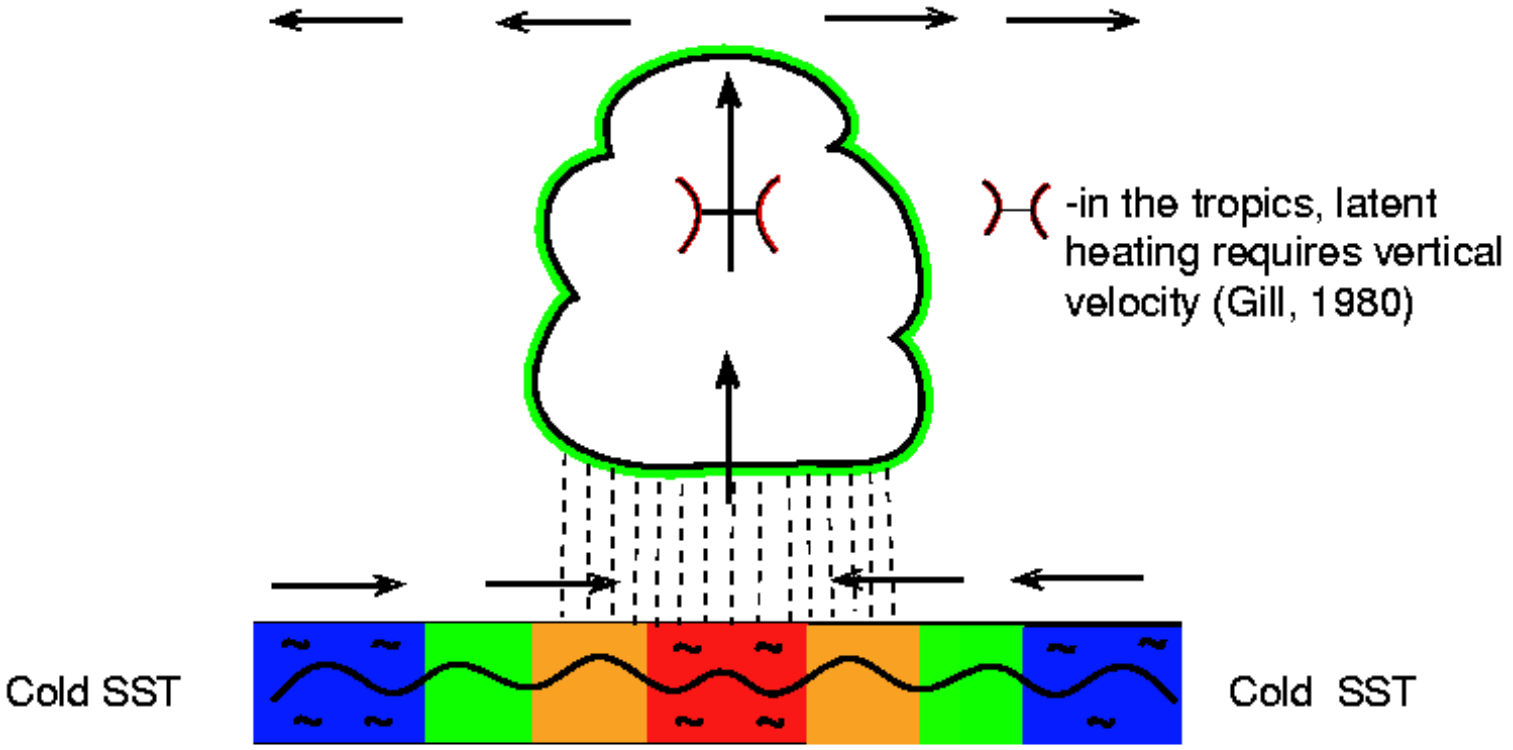
Different types of forecasts

- Deterministic forecast
- Probability forecast
- Interval forecast
- Category forecast

Climate prediction

- Predictions of weather-related variables further into the future than about two weeks;
- Aims to make broader, more general predictive statements of the characteristics of atmospheric conditions over a longer period of time with a longer lead time;
- Focuses more on larger drivers of long-term atmospheric behavior, such as changes in how the ocean and atmosphere interact.
- Provide helpful insights into possible changes in the frequency and intensity of different types of weather over the coming few weeks and months, allowing for early preparedness.

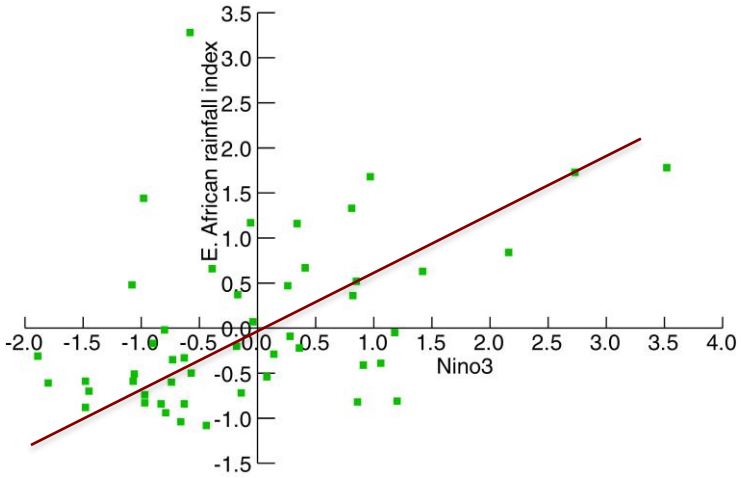
Rationale for seasonal forecast



Main methods

- Statistical Methods
  - ☛ Identification of statistical relationships between variables in the past

Ex. Relationship between a rainfall index in E Africa and Nino3.4



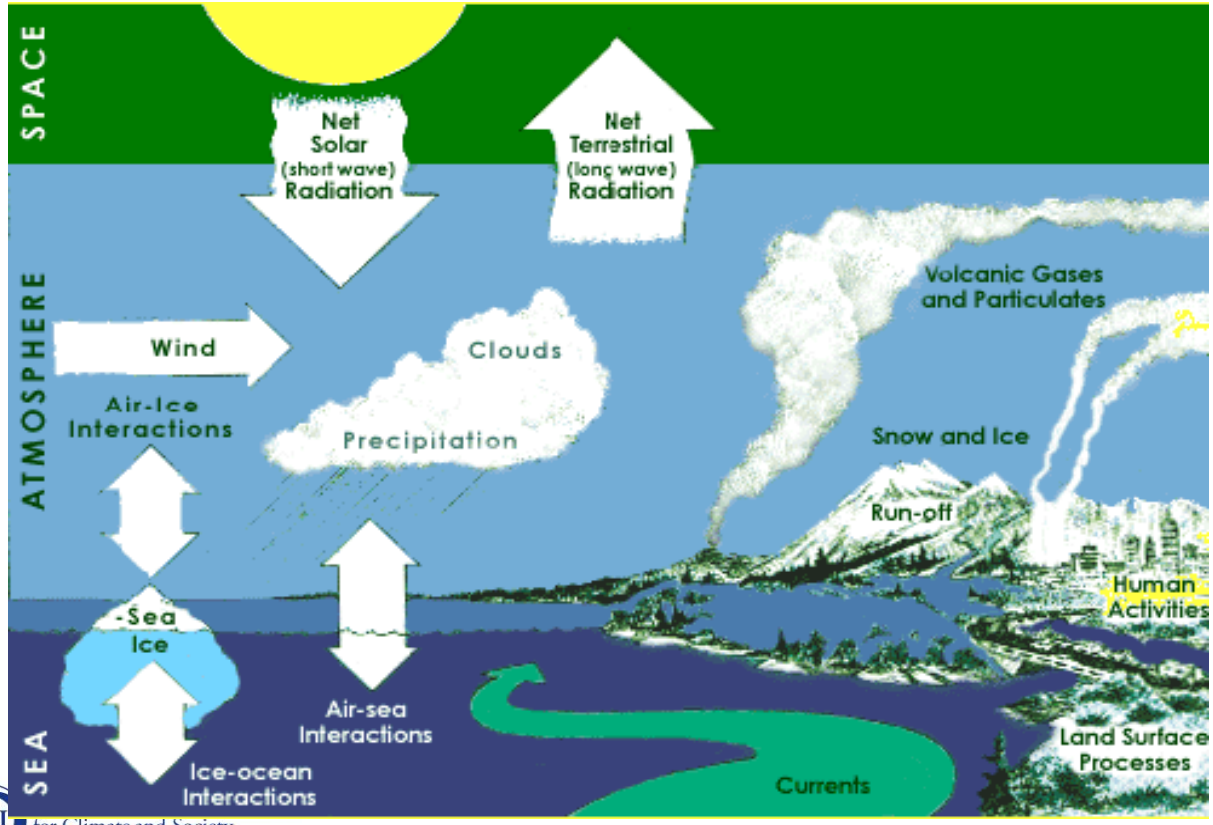
Ex. 3 SST indices used to forecast JAS rainfall in the Sahel *(multiple linear regression)*

The set of predictors and relationships based on the past
There are instabilities in the teleconnections and interactions

Main methods

- Dynamical Methods
  - Numerical Models of Climate System **G**eneral **C**irculation **M**odels (GCM)

Attempt to quantitatively represent all the processes in the climate system

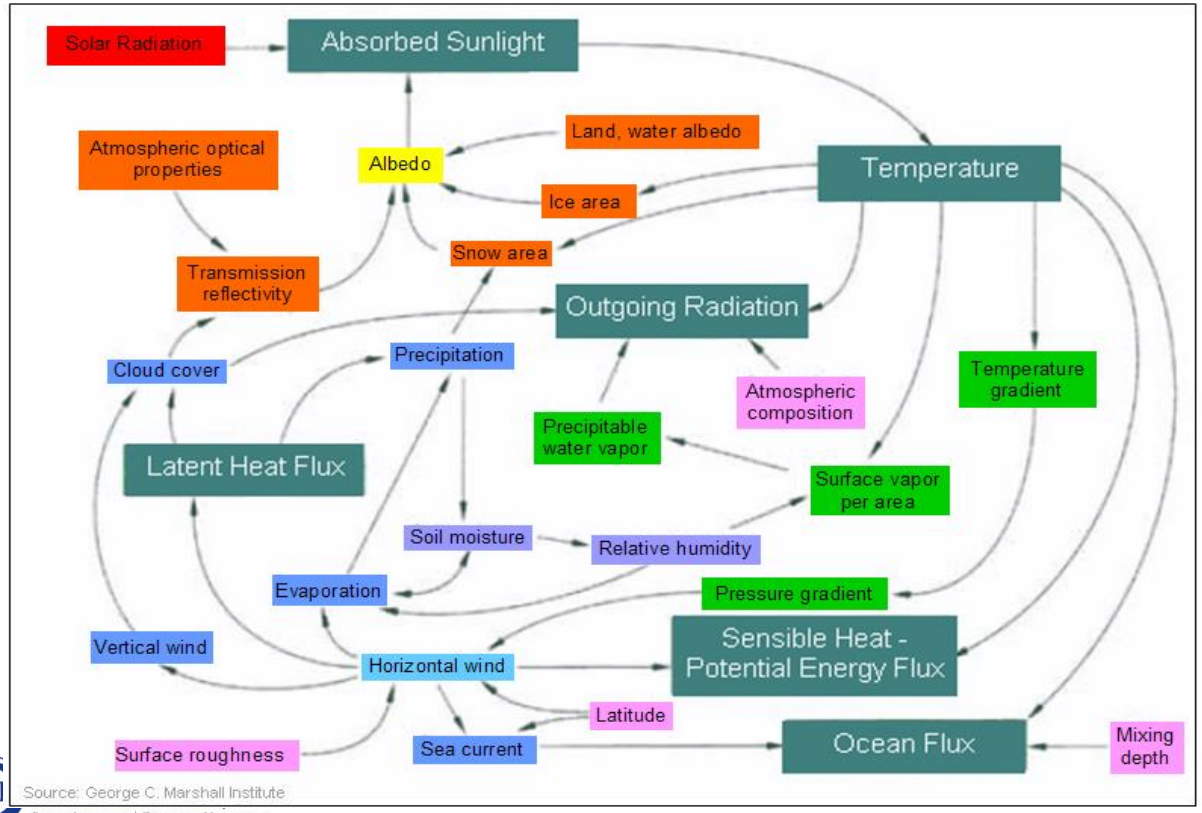


- Numerical Models
- Based on well known physical equations
- Spatio-temporal discretization's: the quantities are computed for a 3D box with a given time step

Main methods

- Dynamical Methods
  - ☛ Numerical Models of Climate System **G**eneral **C**irculation **M**odels (GCM)

Attempt to quantitatively represent all the processes in the climate system

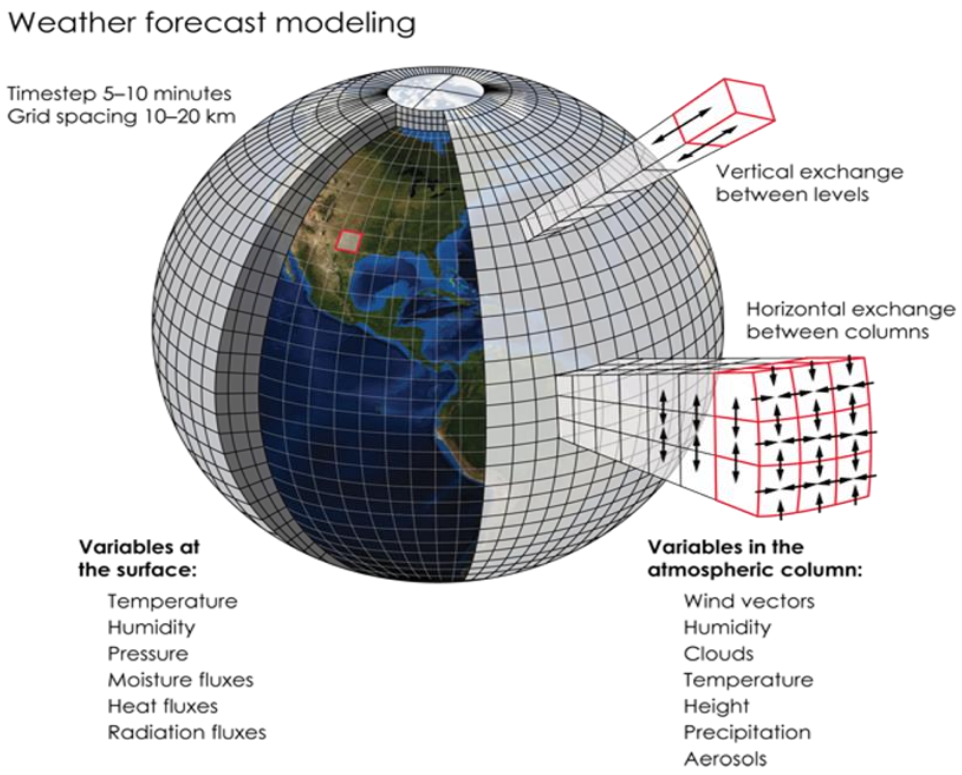


Example of processes and interactions

Climate prediction: main methods

- Dynamical Methods
  - Numerical Models of Climate System **G**eneral **C**irculation **M**odels (GCM)

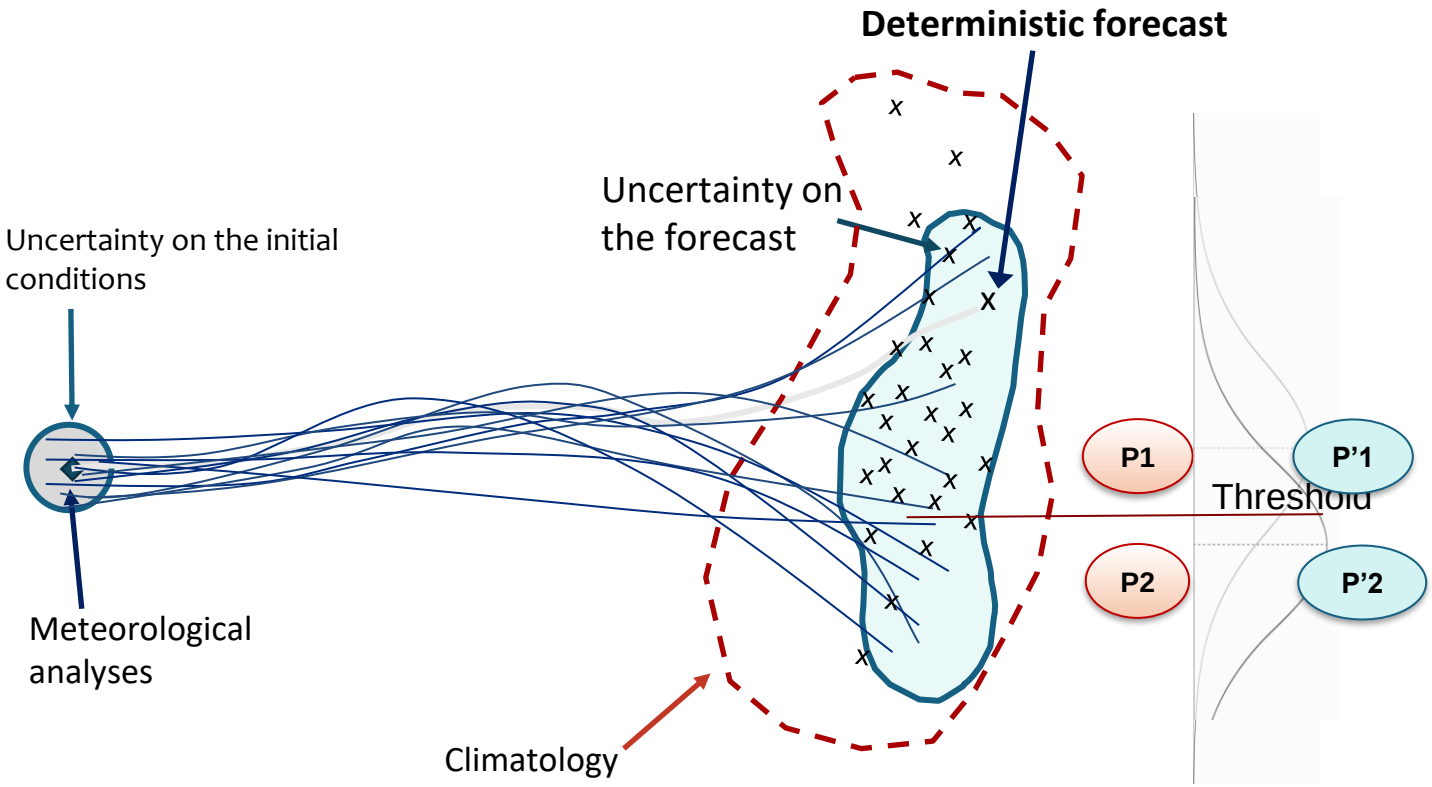
Attempt to quantitatively represent all the processes in the climate system



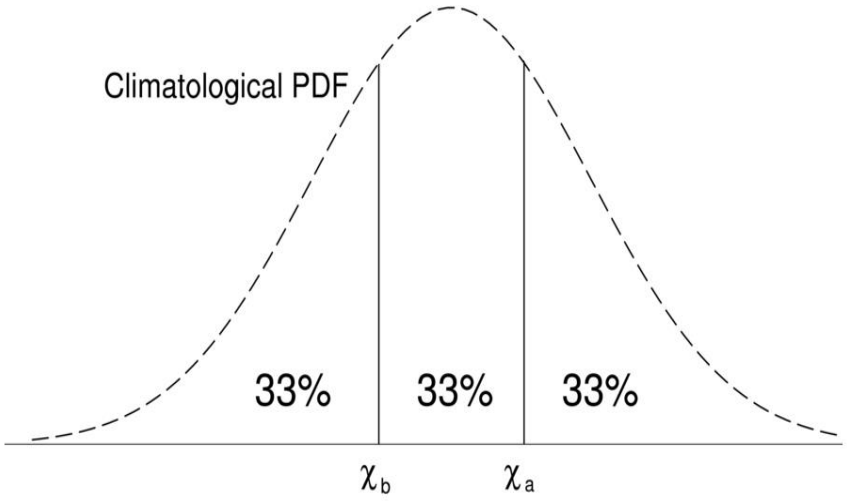
- Constraints on computing resources = constraints on the resolution
  - Typical GCM resolution for climate purposes: 250x250km
  - Time step: 15min
- Sources of Errors:
  - Scale of numerous phenomena smaller than model grid scale (ex. clouds)
  - Models of different subsystems (ex. atmosphere, ocean) developed separately, assuming the other component perfectly known/represented

Uncertainty

We deal with uncertainty by communicating the levels of confidence in our forecast



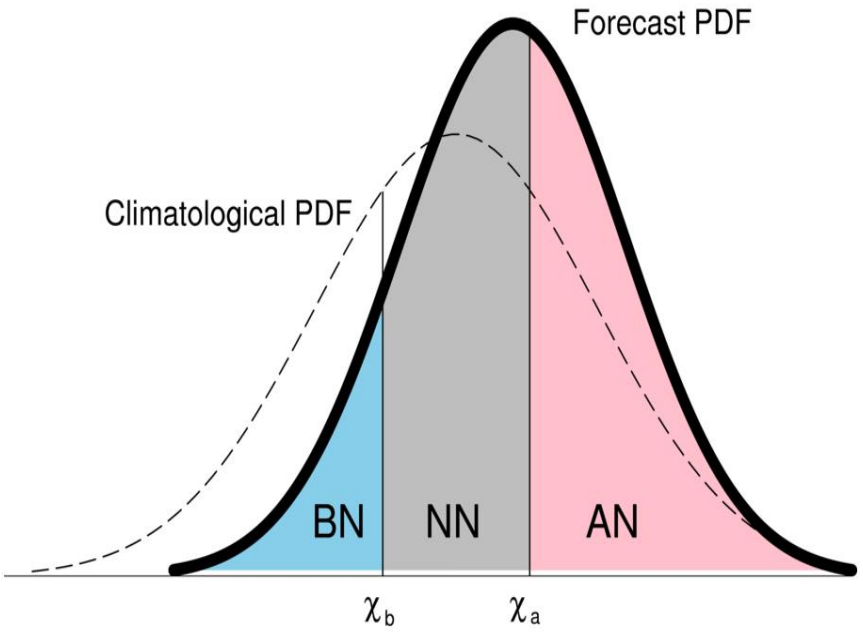
Uncertainty and forecast presentation



The upper tercile: $\chi_a = \mu + 0.43\sigma$

The lower tercile: $\chi_b = \mu - 0.43\sigma$

where μ and σ are the mean and standard deviation of the hindcast sample, respectively



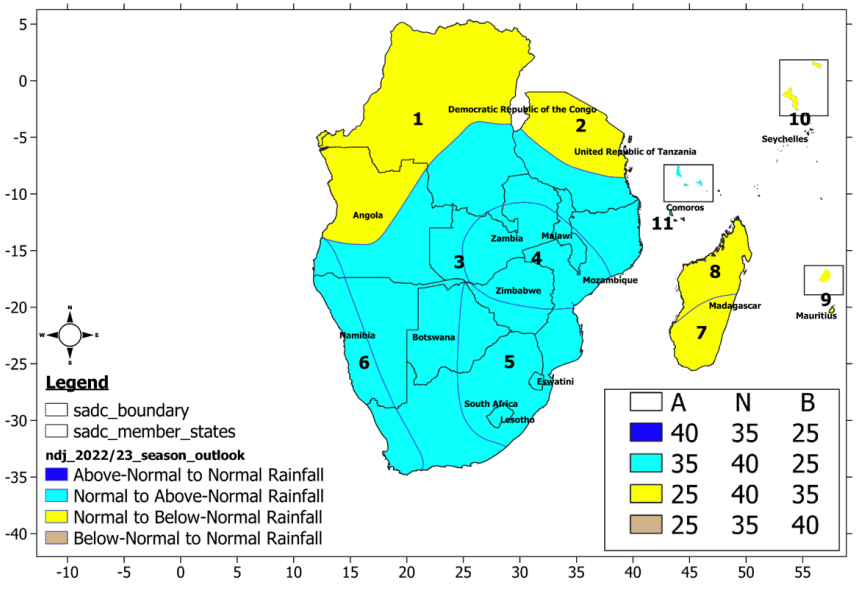
AN: probability for above normal condition

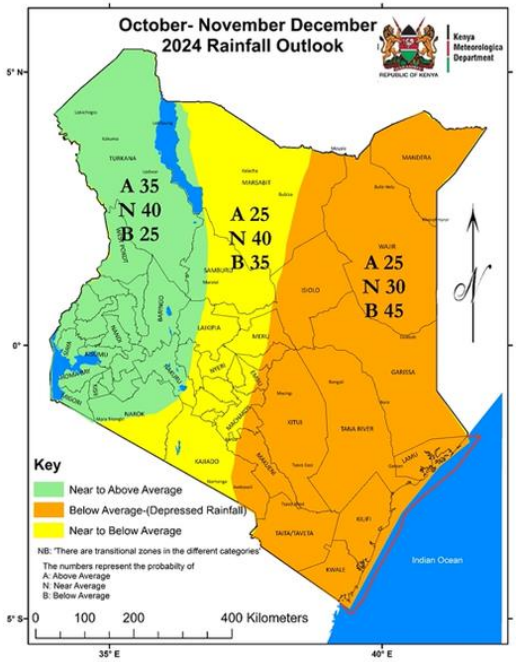
NN: probability for near normal condition

BN: probability for below normal condition

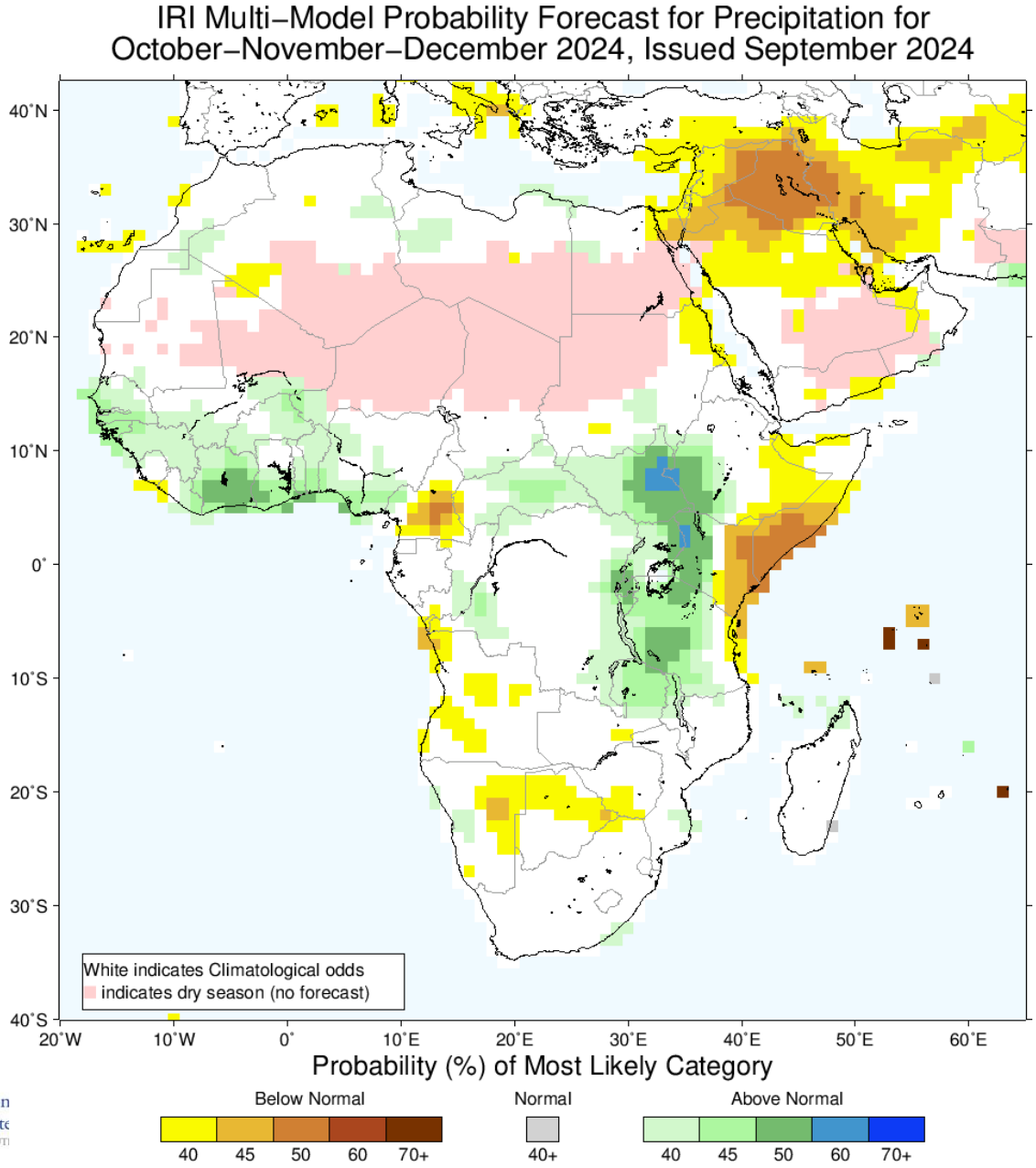
Very high probability of above normal rainfall

Presentation





Presentation-→global forecast



IRI International Institute for Climate and Earth

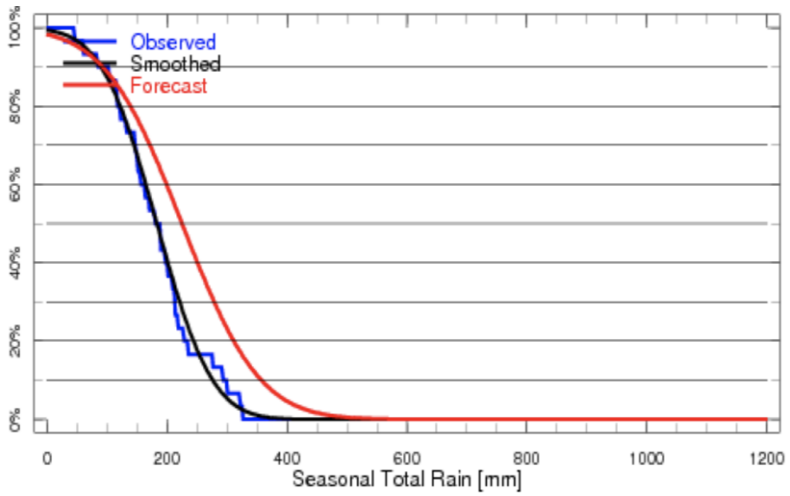
Presentation (flexible)

Forecast for **[36.75E-37E, 0.25N-0.5N]** located in or near **Laikipia North, Laikipia, KE2013A23102**

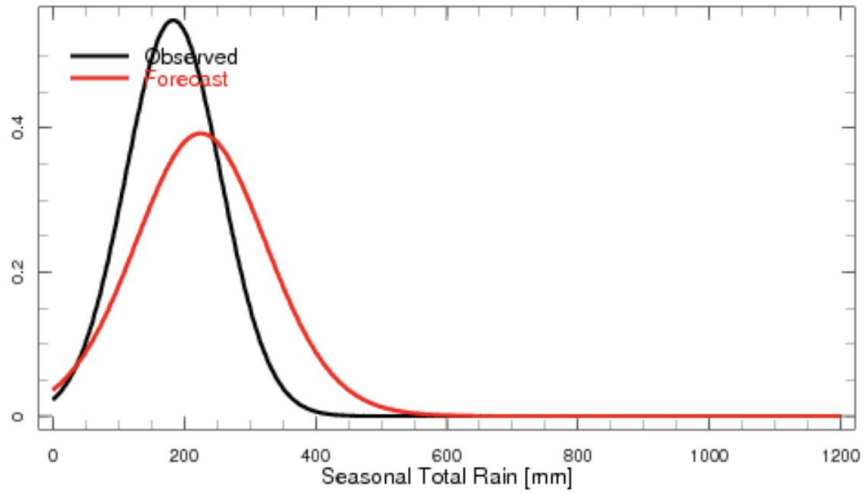
Precipitation Forecast for

Target Date	Issue Date
Mar-May 2020	**Feb 2020**

Probability of Exceedance



Probability Distribution



Questions?

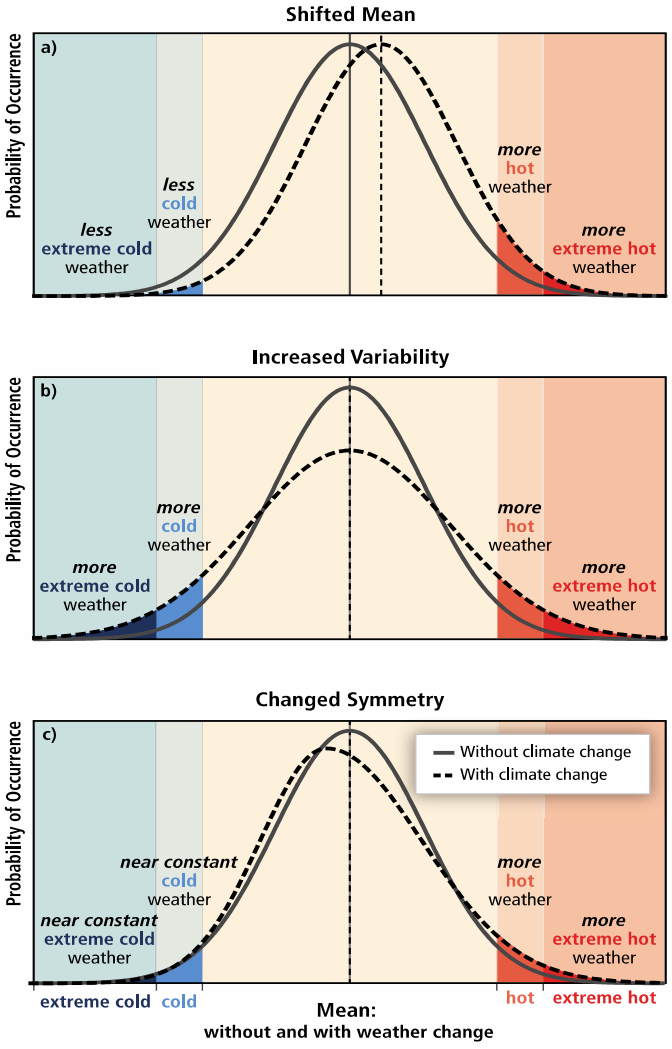
VI. Climate Change

Climate Change

1. Definition

Changes in the characteristics of climate over very long periods of time.

- Variation in global or regional climates over time.
- Reflects changes over time in all the characteristics of climate
- Occurs on scales ranging from decades to millions of years.



Climate Change

Climate change vs. global warming

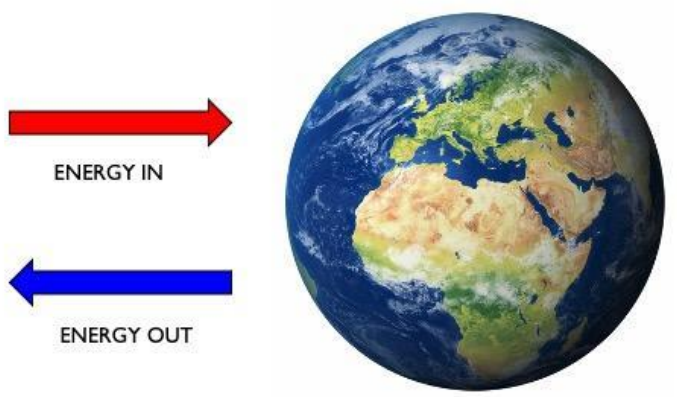
Climate change refers to anything that results in a different climate across the planet, which includes, long-term, average global temperatures or precipitations(decrease or increase)

Global warming refers only to a rise in global temperatures. In other words, **global warming is one of the possible features of climate change**.

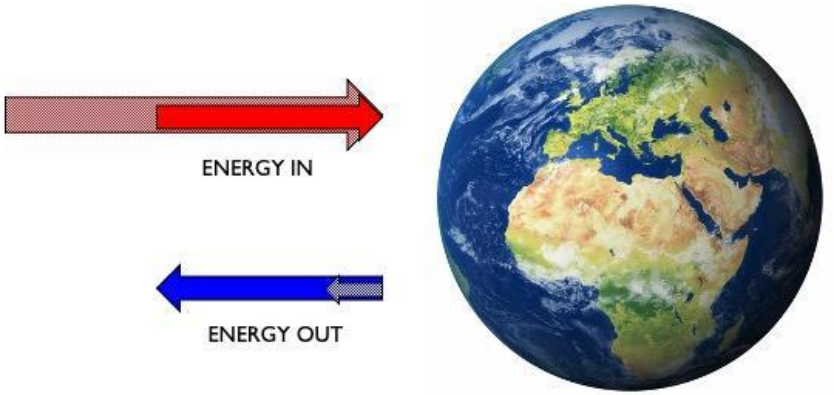
Climate Change

2. What is the cause?

Climate change occurs when the energy entering the earth system does not equal the energy exiting the earth system



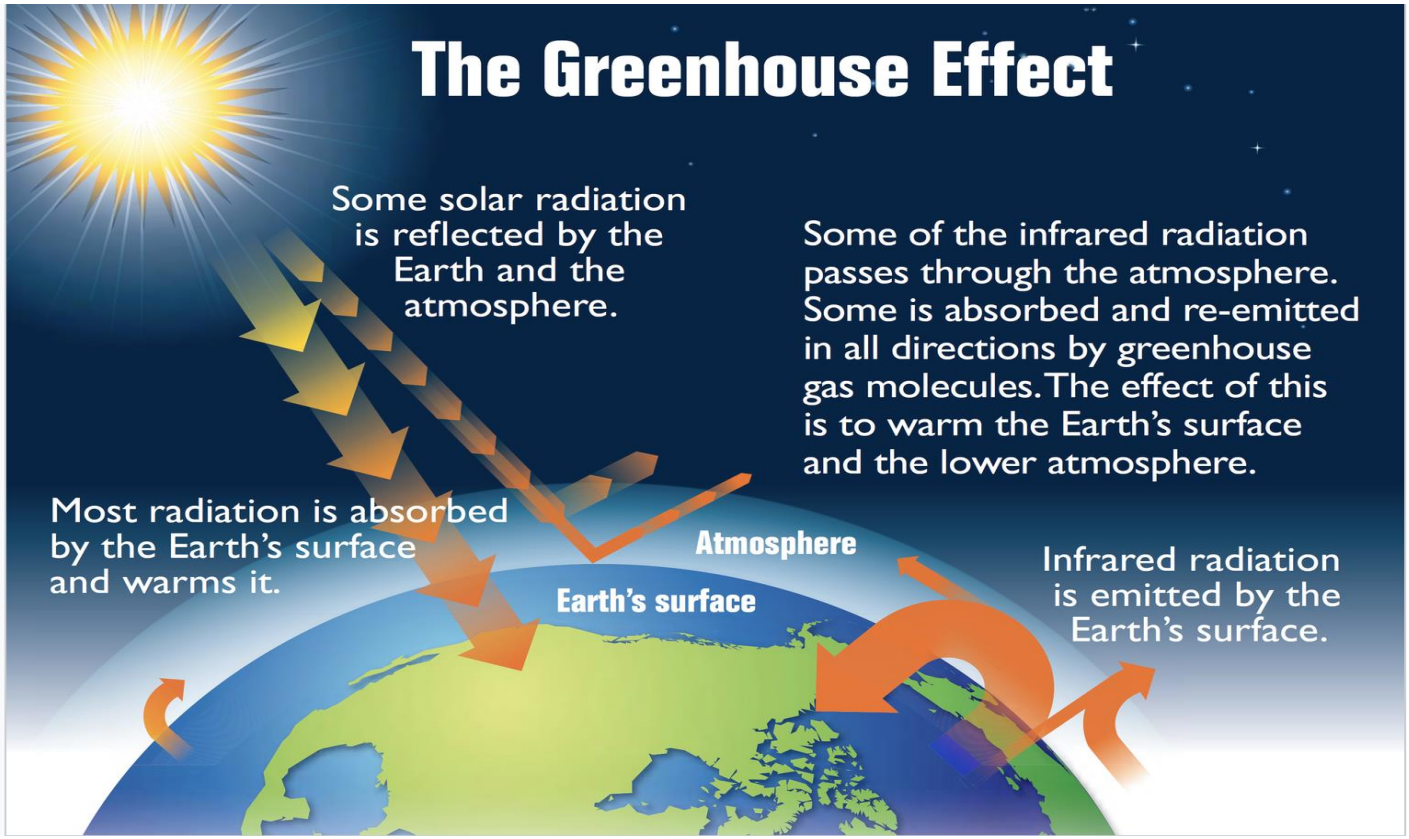
This energy imbalance occurs due to either **more energy** coming in, or **less energy** going out



Source: Courtesy of Lisa Goddard (2021), IRI.

Climate Change

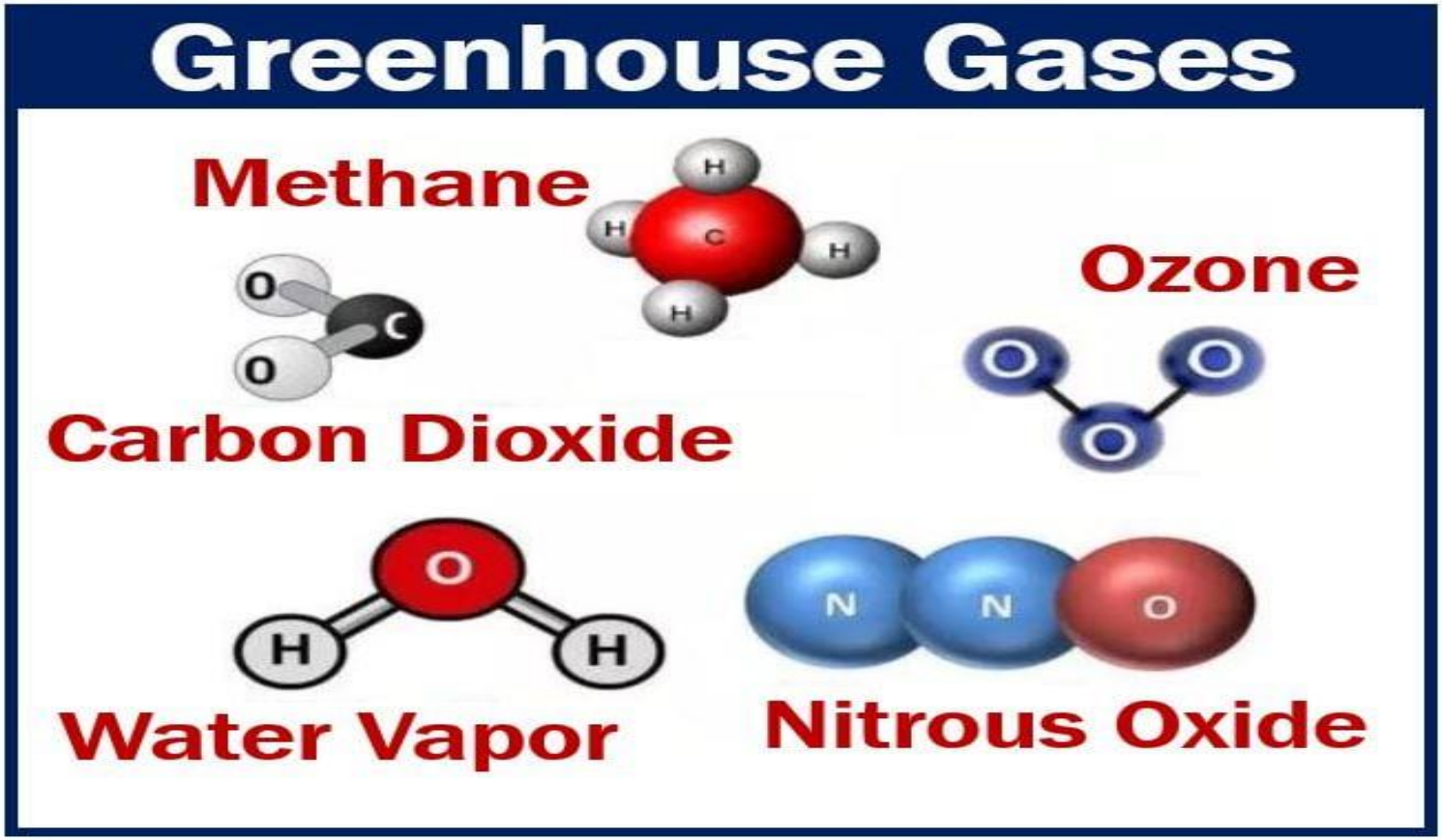
Cause: the green house effect



https://energyeducation.ca/encyclopedia/Greenhouse_effect

Climate Change

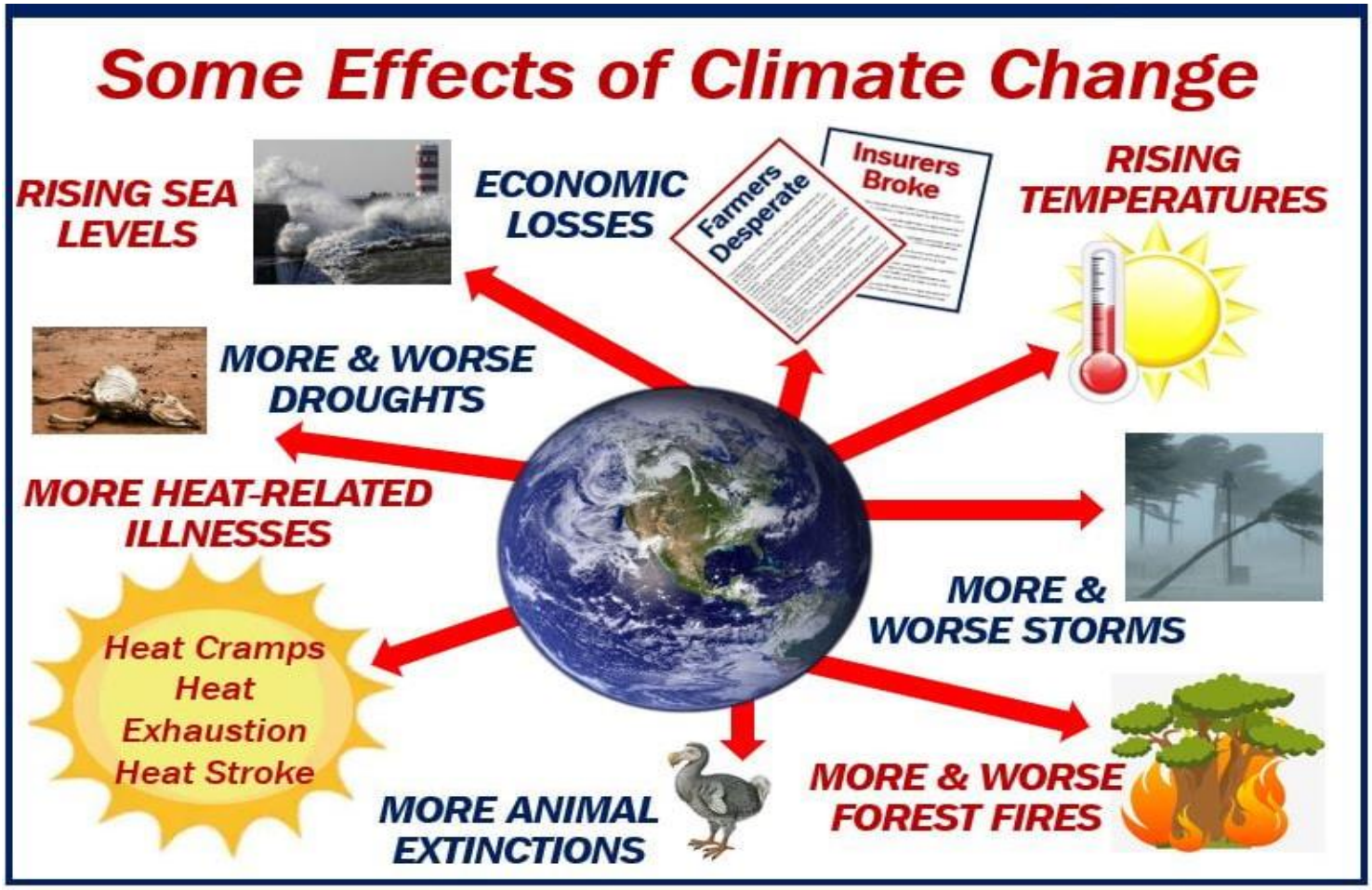
Cause: green house gases



https://marketbusinessnews.com/financial-glossary/climate-change/

Climate Change

3. Impact



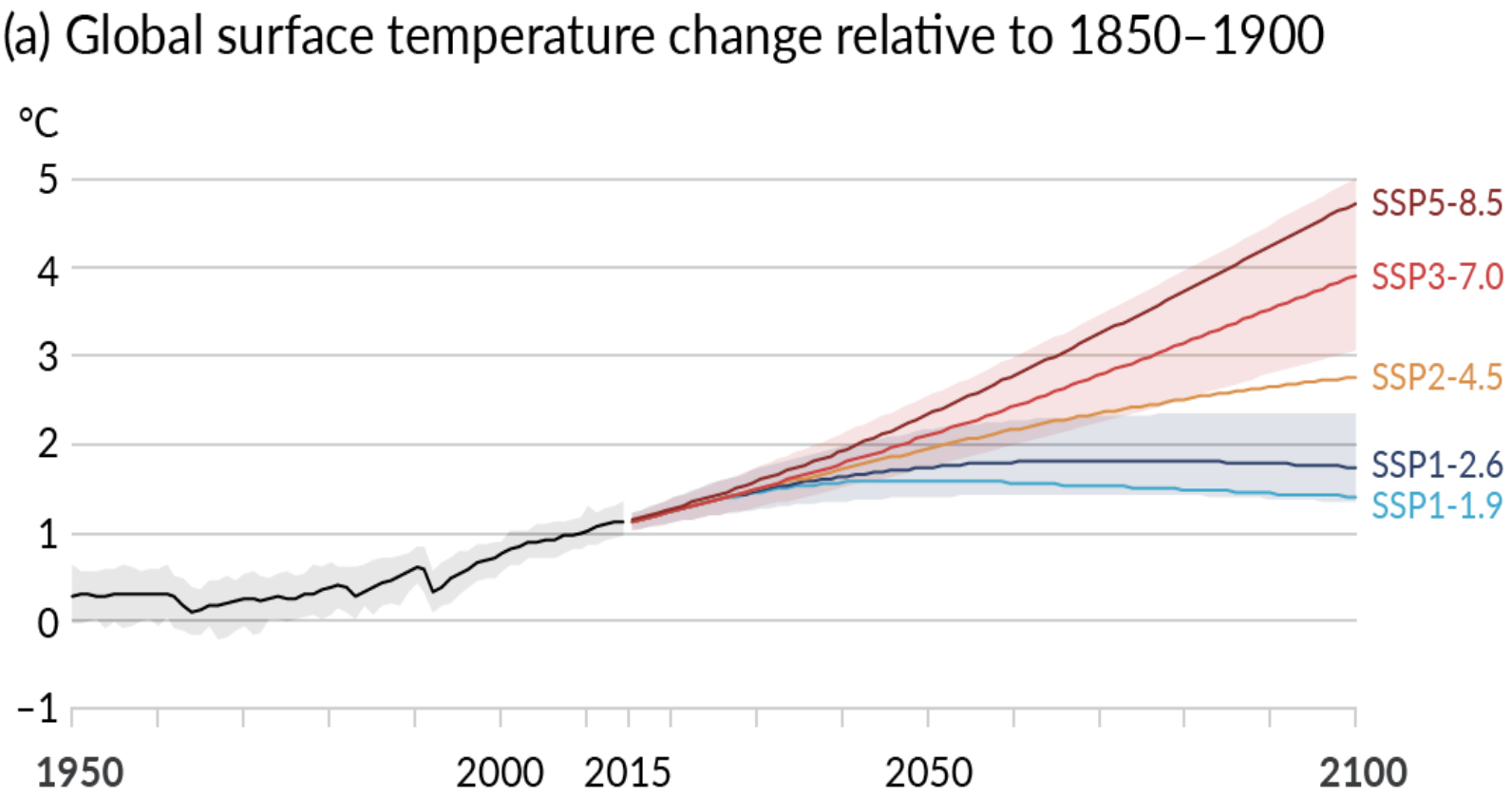
https://marketbusinessnews.com/financial-glossary/climate-change/

Climate change projection

- Simulations of Earth's climate for future decades (typically until 2100) based on assumed **'scenarios**' for the concentrations of greenhouse gases, aerosols, and other atmospheric constituents that affect the planet's radiative balance.
- Use General Circulation Models
- Tested by simulating climate observed over past 100 years

Climate Change Projections

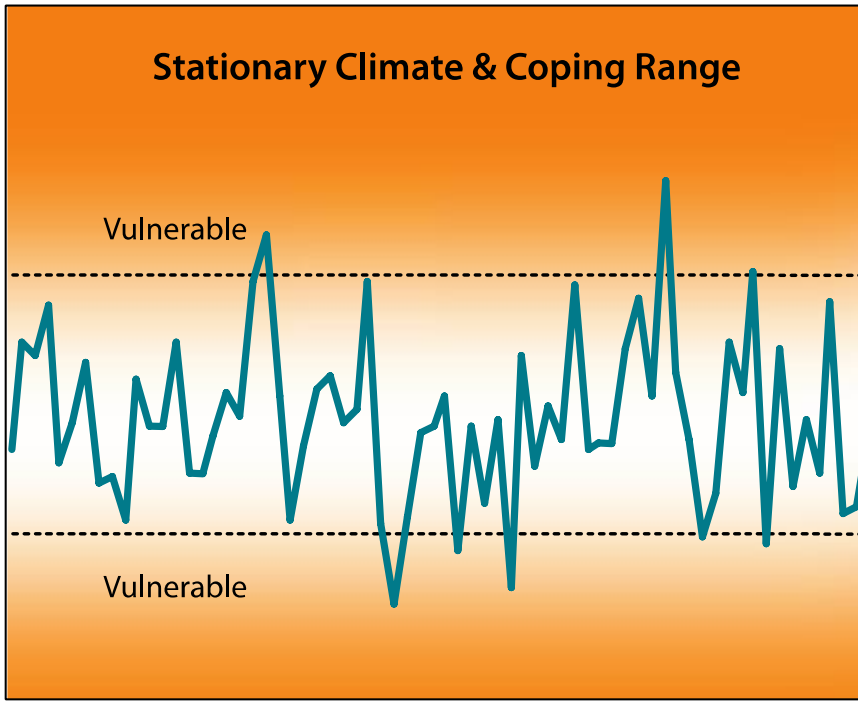
Scenarios (Shared Socioeconomic Pathways (SSPs))



Observed and simulated global surface temperature change relative to the 1850-1900 mean temperature for the different SSP emissions scenarios, IPCC, AR6

Climate Change

5. Climate Variability vs Climate Change



Source: Lu, 2007, adapted from Carter et al. 2007.

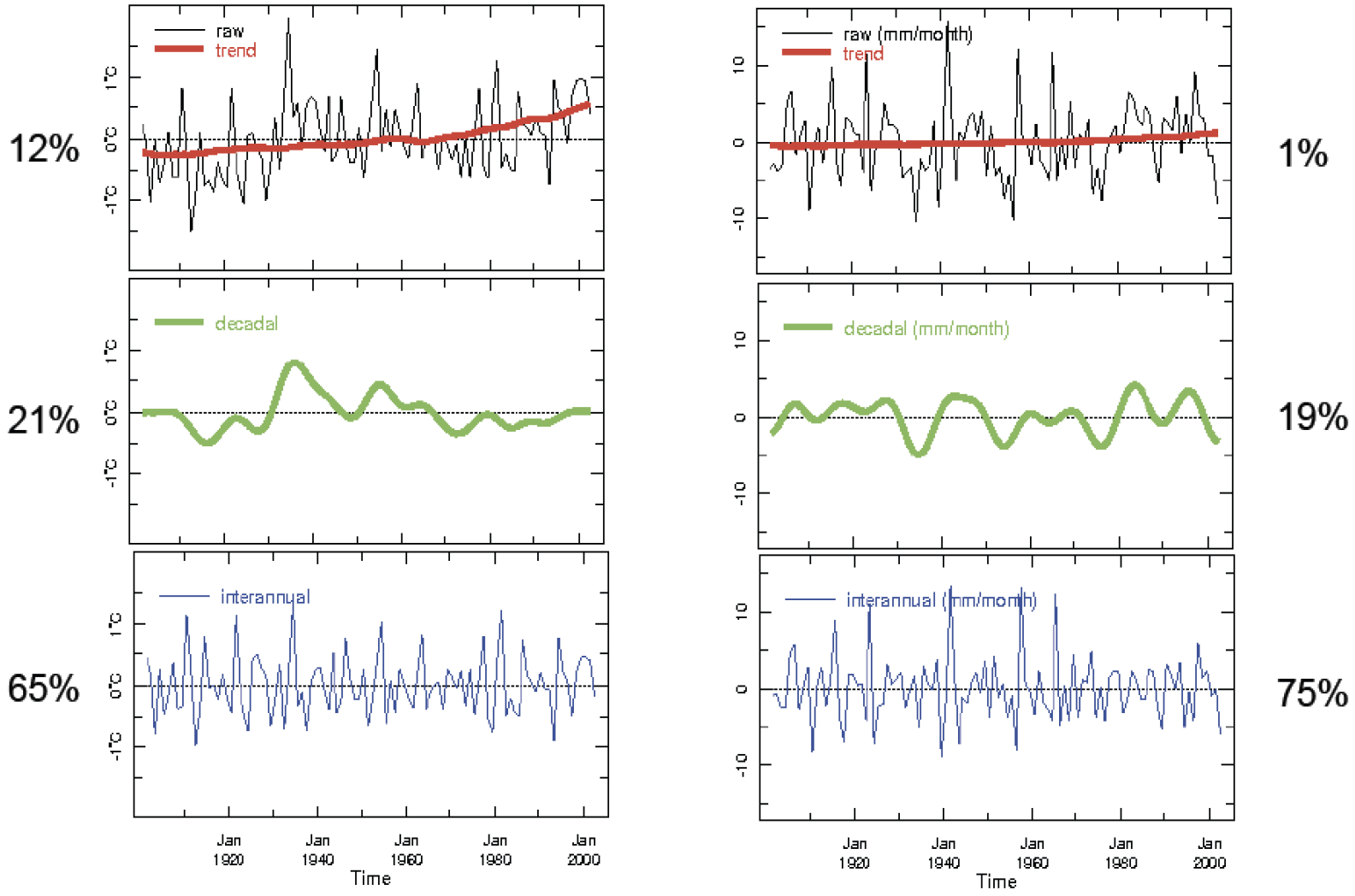
Climate Change **is more than change in average**

Variability vs Change

Temperature

Observations for Colorado, USA - DJF

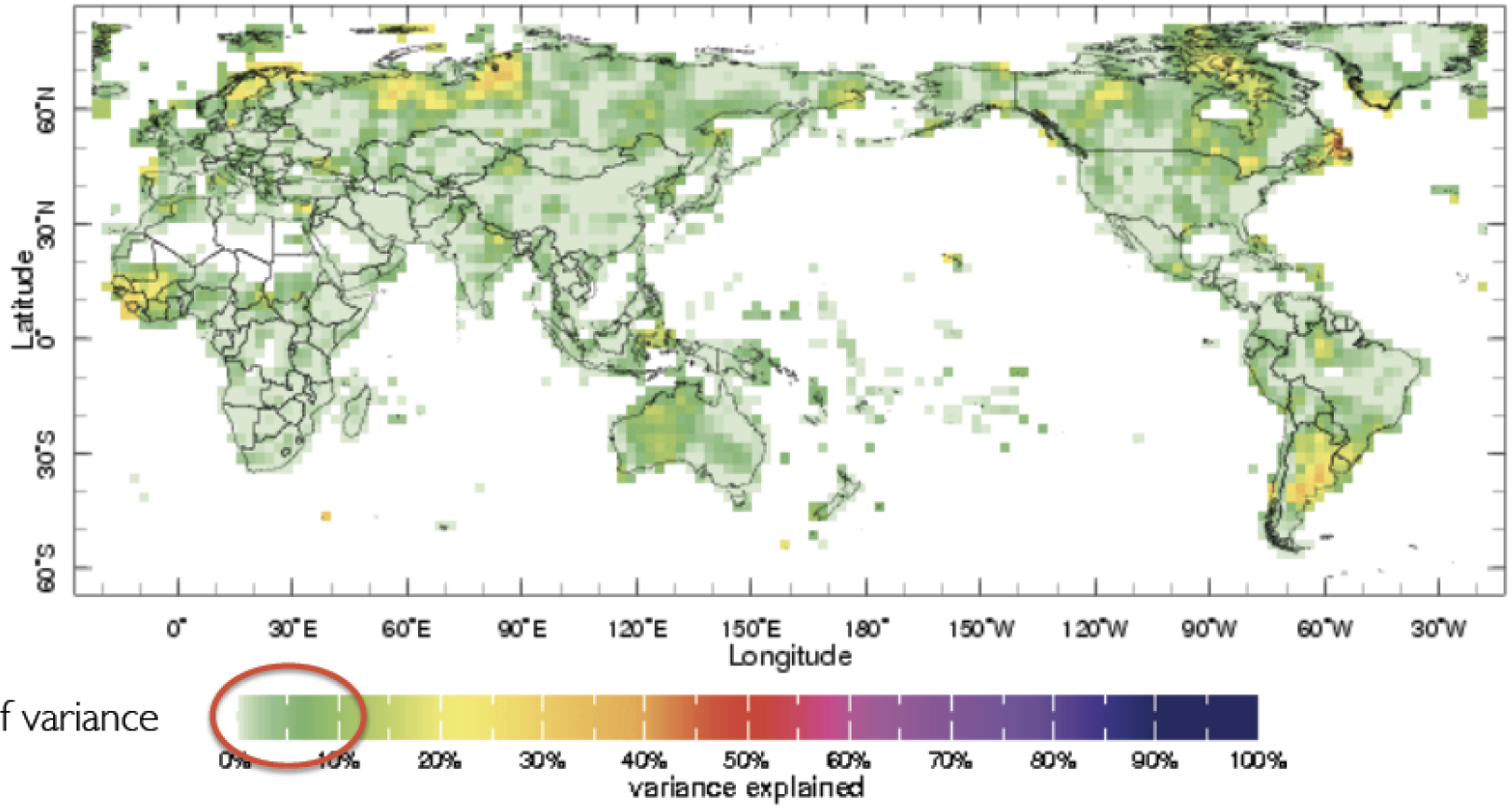
Precipitation



Variability vs Change

Precipitation Trends

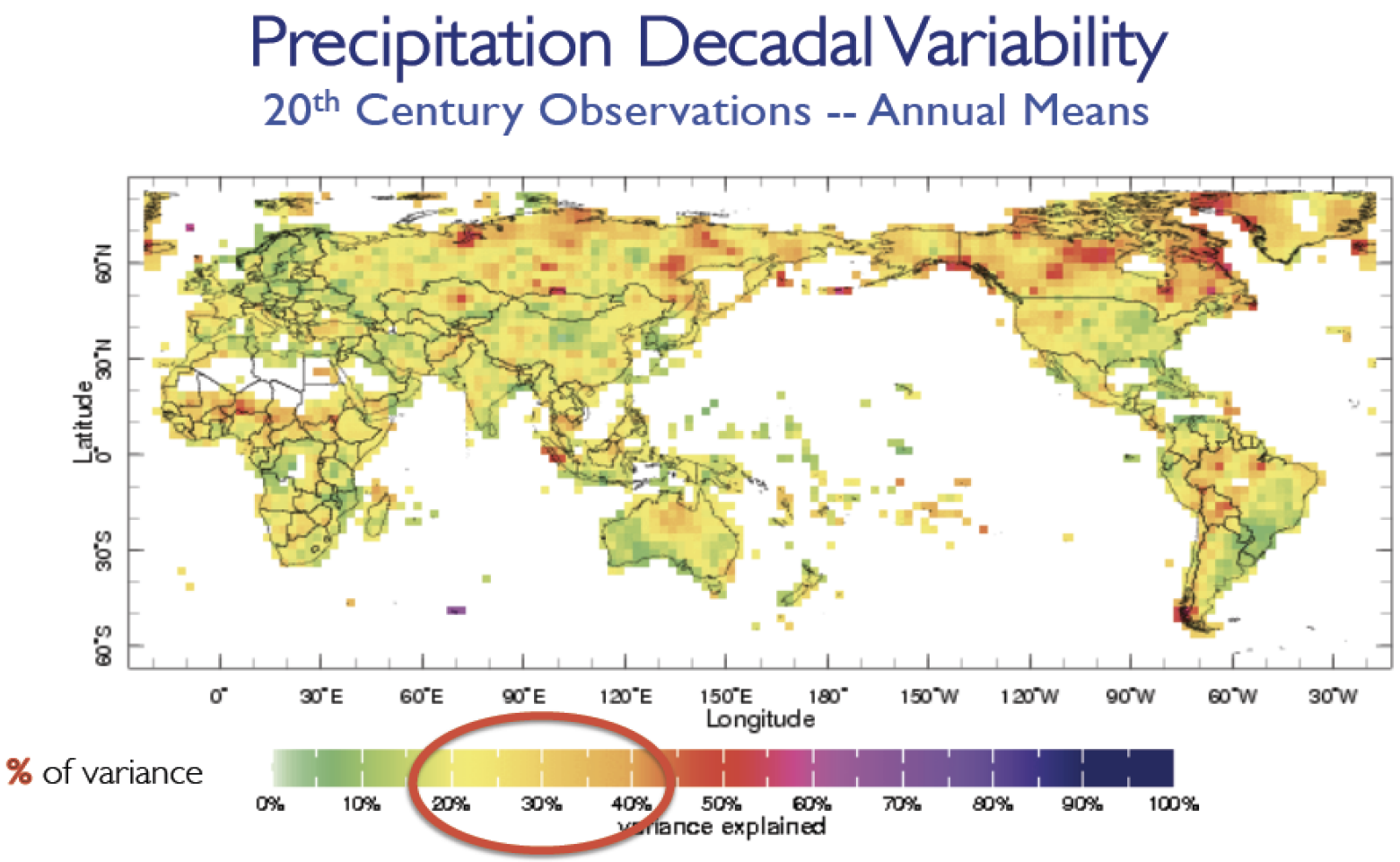
20th Century Observations -- Annual Means



% of variance

http://iridl.ldeo.columbia.edu/maproom/Global/Time_Scales/

Variability vs Change



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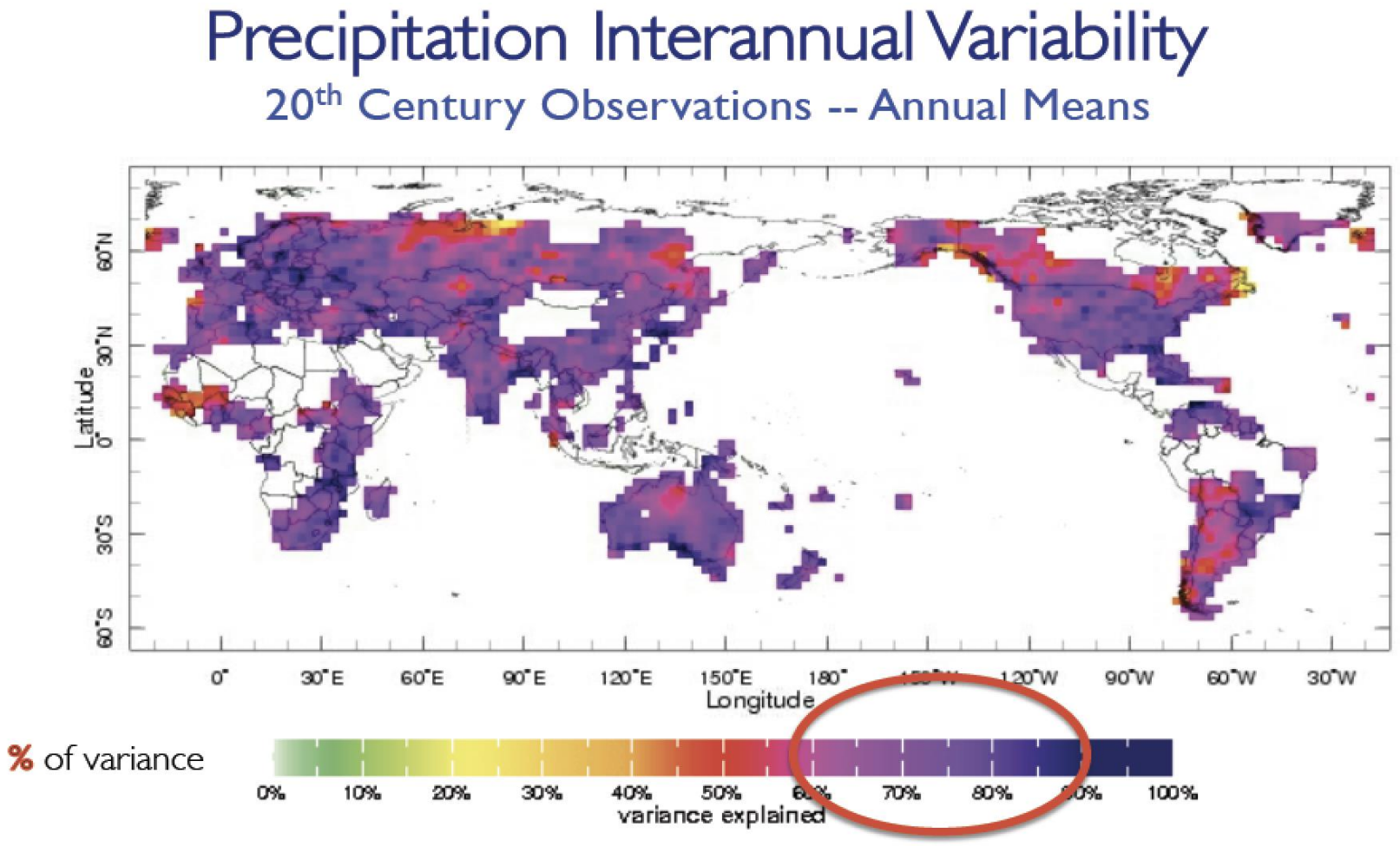
Variability vs Change



http://iridl.ldeo.columbia.edu/maproom/Global/Time_Scales/

Questions?

Thank you !

Email : info@aimforscale.org
Web : www.aimforscale.org

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