United Nations Framework Convention on Climate Change

CGE HANDS-ON TRAINING WORKSHOP FOR VULNERABILITY AND ADAPTATION ASSESSMENT

Climate change scenarios

Outline

- Climate change overview
- Observed climate data
- Why we use scenarios?
- Approach to scenario development
- Climate models
  a) Global Climate Models (GCMs)
  b) Downscaling techniques
- Climate model tools
- Projections for Africa, Asia, and Latin America

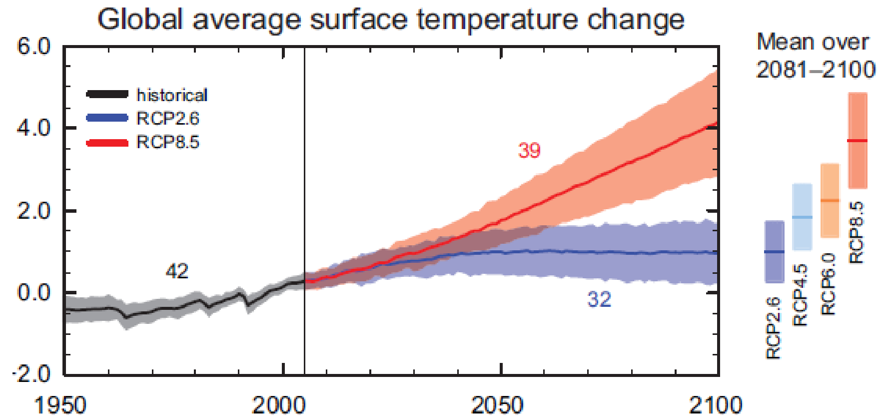
Climate change overview

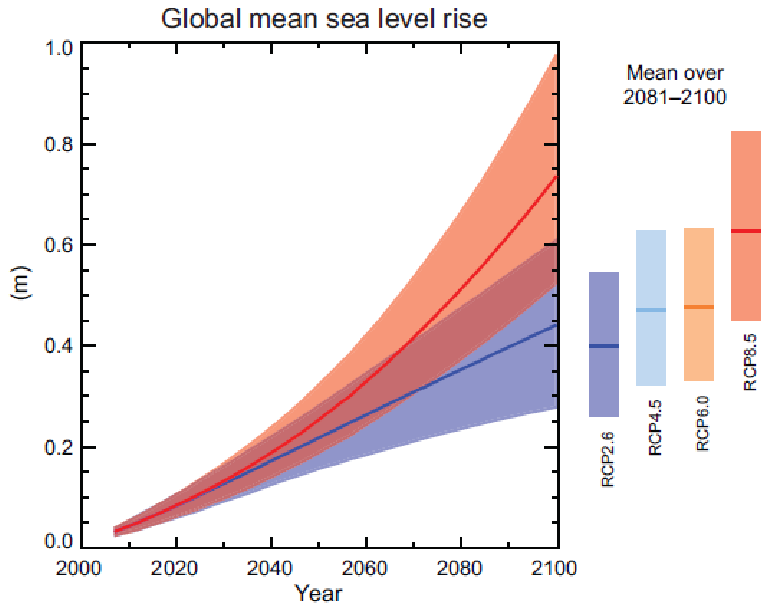
Change in climate is unequivocal

- Rising temperatures over 20th century
- Rising sea levels
- More intense precipitation in many locations
- Changes in precipitation
- Extremely likely that human influence is dominant cause of warming since mid-20th century

Climate change in the 21st century

- More warming is highly likely – 1 to 5°C
- Sea level rise (SLR) 0.26 to 0.98 meters
  a) Could be up to 2 meters
- Increased precipitation in high latitudes, equatorial Pacific, and some mid-latitudes
- Less precipitation in many mid- and low latitudes
- More intense precipitation is likely





Key bottom line

- We know the climate is going to continue changing
- We know the direction of change for some key variables
  a) We cannot forecast the magnitude of change
- For other variables even the direction of change is not certain

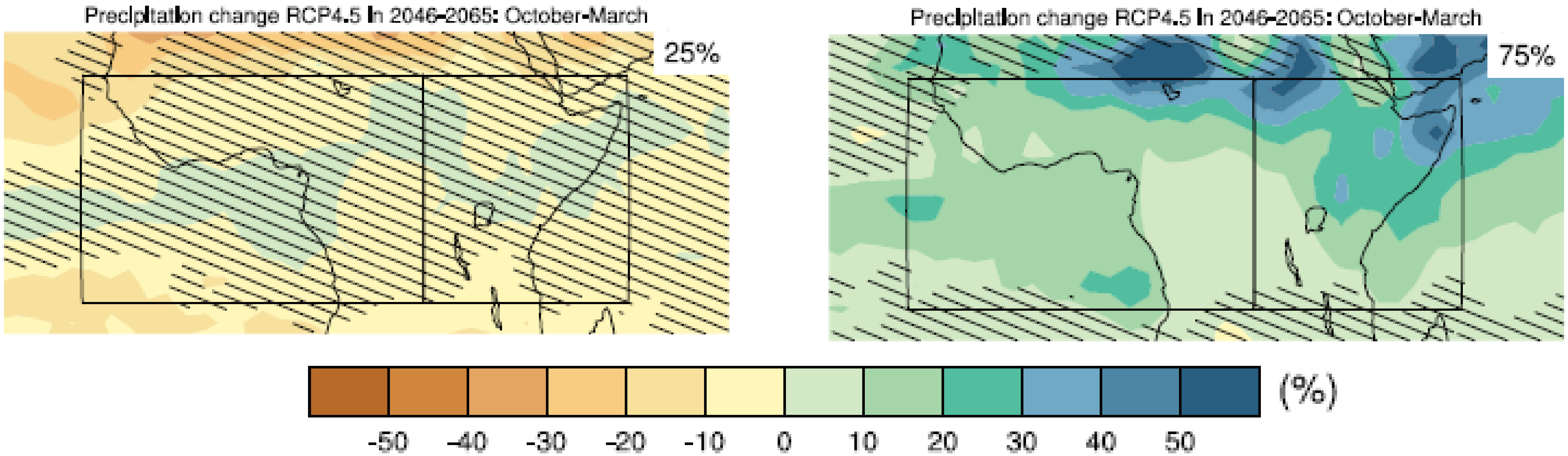
Key sources of uncertainty

1. Emissions of greenhouse gases (GHGs)
   a) RCPs 2.6 to 8.5

2. Climate sensitivity
   a) How much does average global temperature rise with doubling of CO_2 levels
      - Likely range: 1.5 to 4.5°C
        - 2/3 probability
      - Very likely range 1 to 6°C
        - 90% probability

Key sources of uncertainty (cont.)

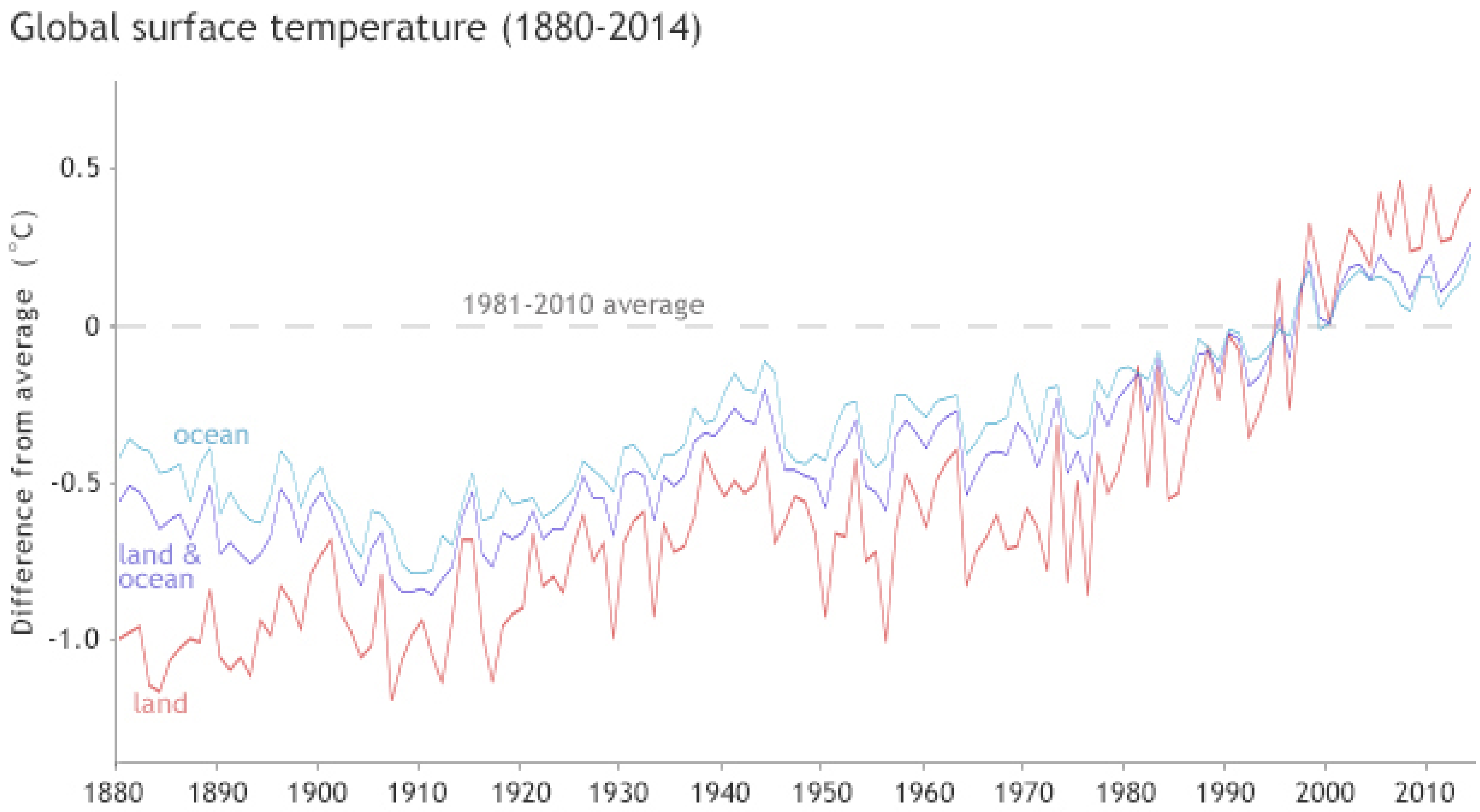
3. Regional pattern of change
   a) Particularly important for precipitation
      - Figure shows difference in precipitation projections between 25th and 75th percentiles



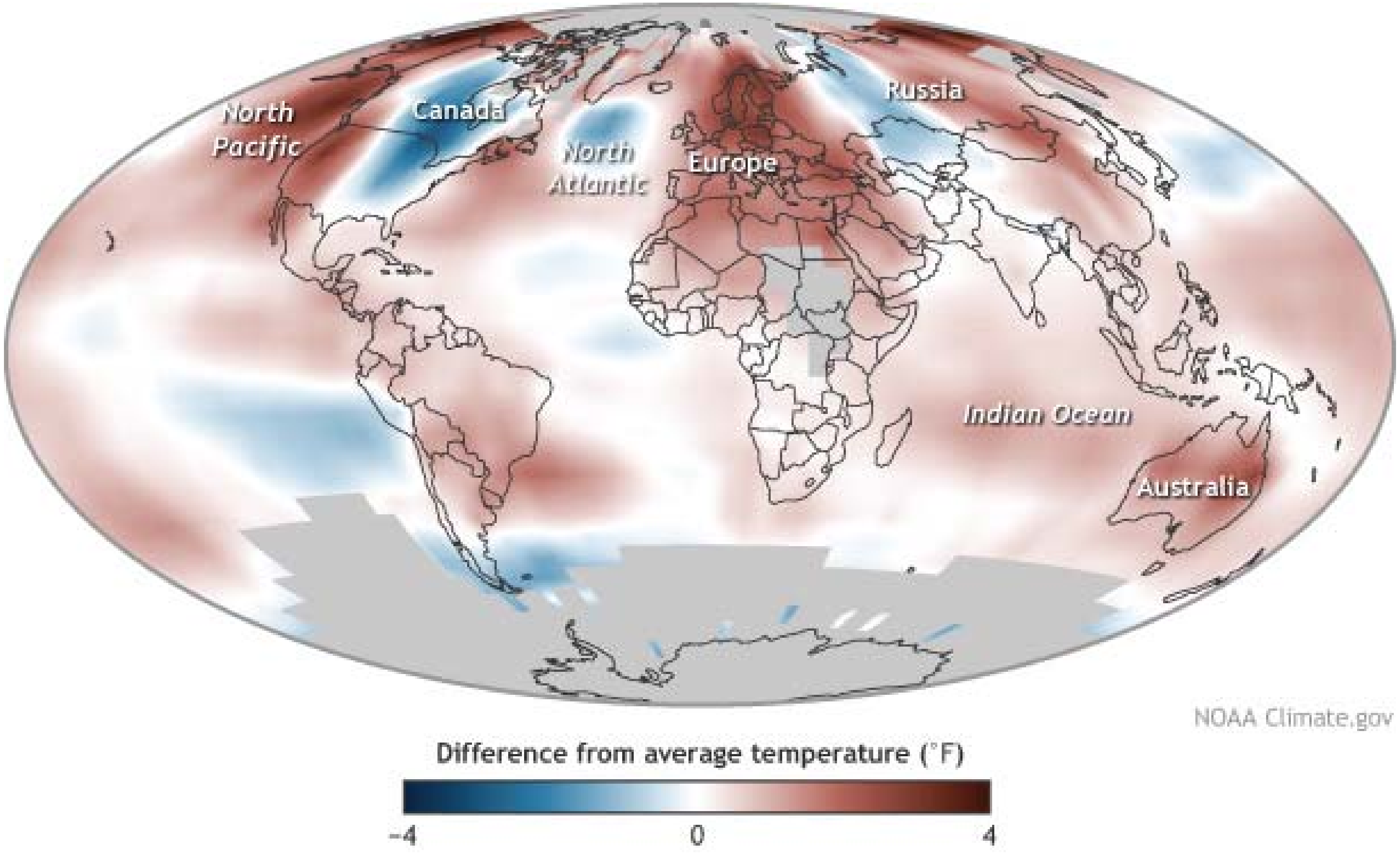
Source: IPCC, 2013

4. Climate variability, e.g., ENSO

A reminder of climate variability – long term trends



A reminder of climate variability – 2014 temperatures



Why do we use climate change scenarios?

- We create climate change scenarios to capture some of the uncertainty about future climate change
  a) Particularly at a regional and local level

Common fallacies

- Climate change will be monotonic
  a) Hiatus (?)

- Climate change will be gradual

- Climate variability will not change
  a) Is potential for more extremes

Baseline climate data

Specification of the baseline climate

- Baseline climate data helps to identify key characteristics of the current climate regime (such as seasonality, trends and variability, extreme events and local weather phenomena)

- There are several questions that need to be answered to define the baseline climate:
  a) Which baseline period should be selected?
     - WMO 30-year is typical
     - Longer periods useful for extreme climate
  b) What data sources are available?

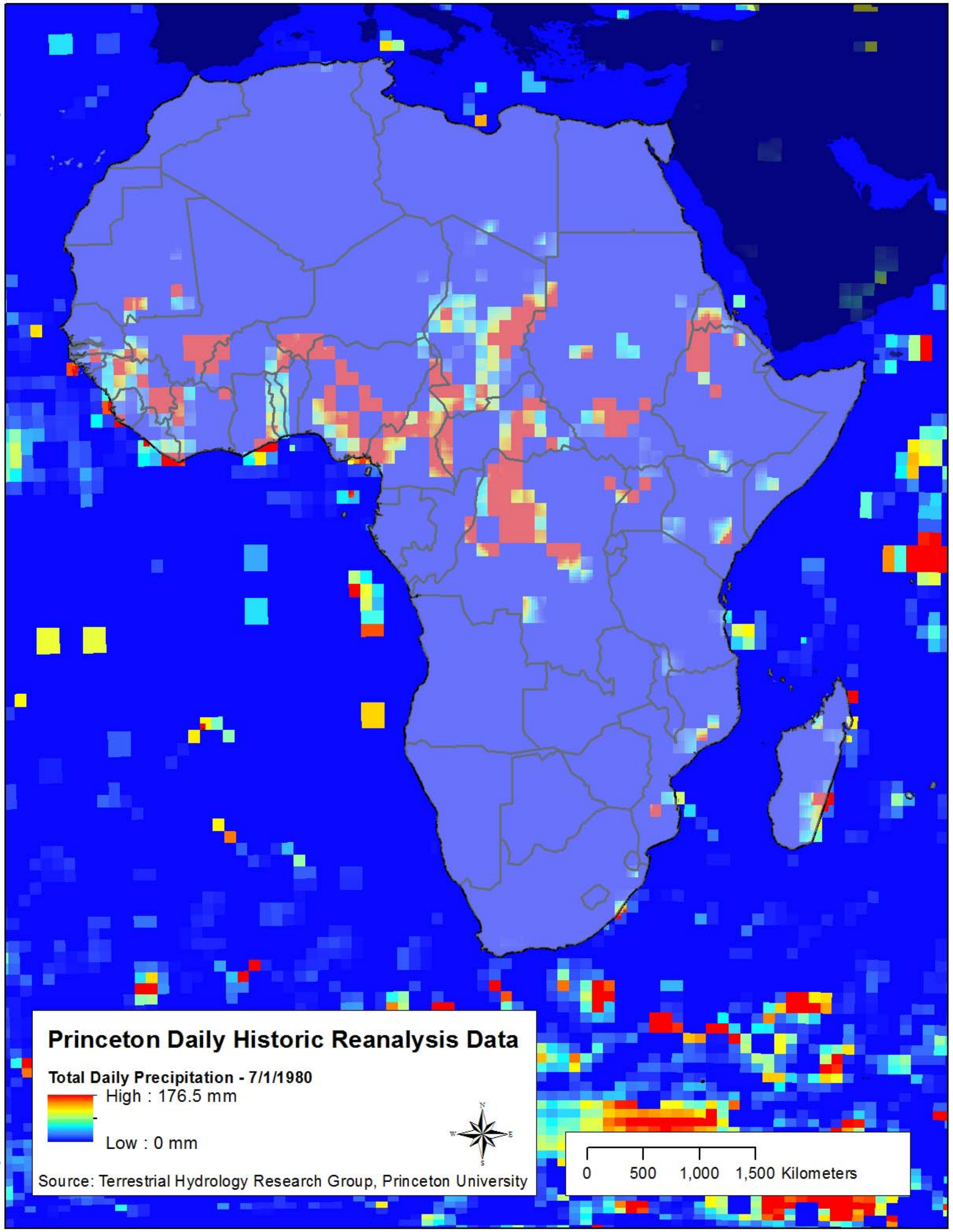
Identification of key data sources

- Key data sources available to define baseline climate include:
  - a) National meteorological agencies archives
  - b) Global data sets
  - c) Weather generators
  - d) Reanalysis data
  - e) Outputs from GCM control simulations
  - f) Bias corrected spatially disaggregated data

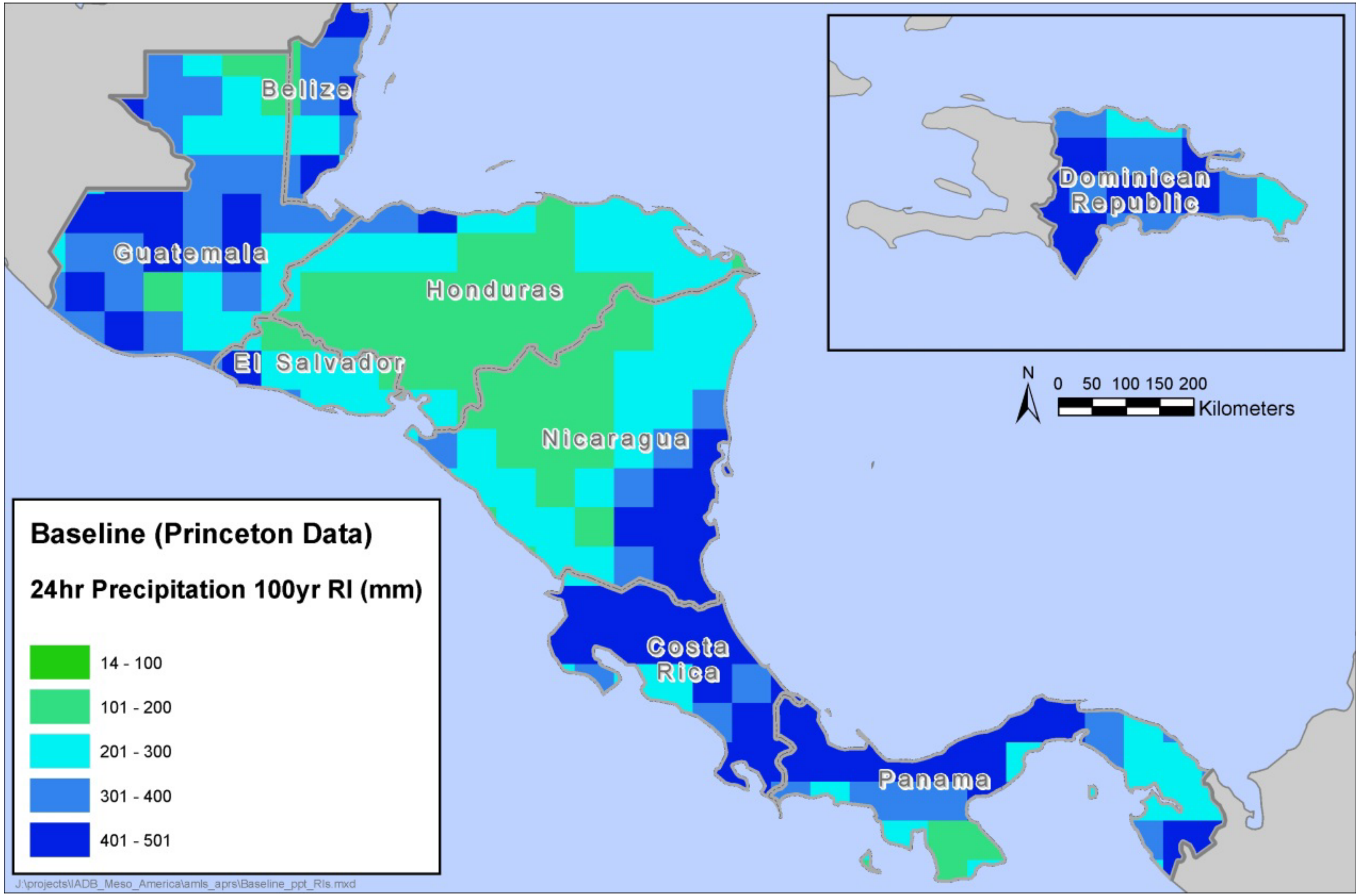
Some climate data sources

- IPCC Data Distribution Center
  http://www.ipcc-data.org/
- International Research Institute for Climate and Society
  http://iridl.ldeo.columbia.edu/docfind/databrief/?sem=iridl%3ADCAtmosphere
- Tyndall Centre for Climate Change Research
  http://www.cru.uea.ac.uk/cru/data/hrg/
- U.S. National Climate Data Center daily data
  http://89.218.85.187/SOURCES/.NOAA/.NCDC/.GDCN/
- TRMM satellite data on precipitation
  http://disc.sci.gsfc.nasa.gov/TRMM
- Princeton Terrestrial Hydrology Research Group
  http://hydrology.princeton.edu/data.pgf.php

Princeton data set



TRMM data set



Climate change scenarios

Why use climate change scenarios?

- We are unsure exactly how regional climate will change
- Scenarios are plausible combinations of variables, consistent with what we know about human-induced climate change
- Think of them as the projection of a model, contingent upon the GHG emissions scenarios
- Estimates of regional change by models differ substantially, consequently, individual model estimates should be treated more as a scenario
- Scenarios help us to understand climate change impacts and determine key vulnerabilities
- They can also be used to evaluate and identify adaptation strategies

What are climate change scenarios?

- Climate change scenarios are tools to:
  a) Help envision how regional climates may change with increased GHG concentrations
  b) To understand and evaluate how sensitive systems may be affected by human-induced climate change in the hope for policy-relevant information about expected changes and guidance for appropriate mitigation and adaptation measures

- It is critical to keep in mind that climate change scenarios are not a prediction nor forecast of future climate change
  a) They can be wrong

Characteristics climate change scenarios should have

1. Consistent with global projections of climate change

2. Physically plausible

3. Applicable for use in V&A
   a) Sufficient variables
   b) Sufficient spatial and temporal resolution

4. ***Representative of plausible range of climate change***

5. Accessible
   a) Be able to obtain, apply, and interpret scenario data

Climate models

Climate models

- Models are mathematical representations of the climate system

- A model that incorporates the principles of **physics, chemistry and biology into a mathematical model of climate**, e.g., GCM or regional climate model (RCM; limited area model)

- Such a model has to estimate what happens to temperature, precipitation, humidity, wind speed and direction, clouds, ice and other variables all around the globe over time

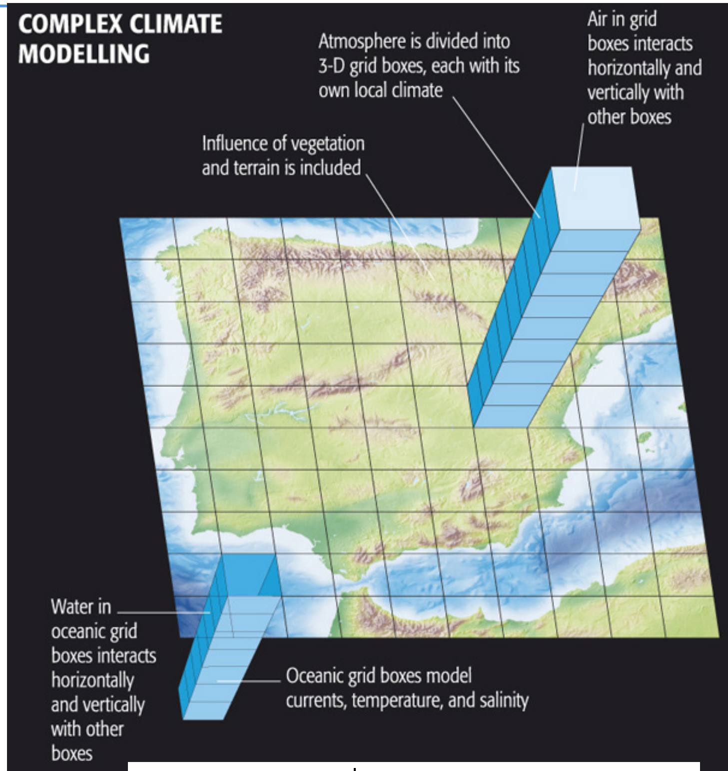
- They can be run with different forcings, e.g., higher GHG concentrations.

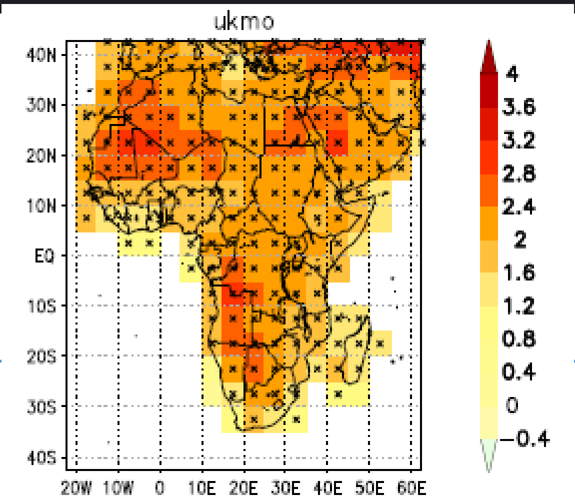
- Models are the only way to capture the complexities of increased GHG concentrations

GCMs

- Pros
  a) Can represent the spatial details of future climate conditions for all variables
  b) Can maintain internal consistency

- Cons
  a) Relatively low spatial resolution
     - Is getting better
  b) May not accurately represent climate parameters
     - Is getting better





Downscaling from GCMs

- Downscaling is a way to obtain higher spatial resolution output based on GCMs

- Options include:

  a) Combine low-resolution monthly GCM output with high-resolution observations

  b) Use statistical downscaling

  c) Dynamical: use RCMs

Key limitations of downscaling

- While can better represent regional and local climate
- Downscaling does not correct errors of GCMs
- Downscaling will not reduce uncertainty across GCMs

"Simple downscaling": Combine monthly GCM output with observations

- An approach that has been used in many studies

- Typically, one adds the (low resolution) average monthly change from a GCM to an observed (high resolution) present-day "baseline" climate:
  a) 30 year averages should be used, if possible, e.g., 1961–1990 or 1981–2010:
     - Make sure the baseline from the GCM (i.e., the period from which changes are measured) is consistent with the choice of observational baseline

- This method can provide daily data at the resolution of weather observation stations

- Assumes uniform changes within a GCM grid box and over a month:
  a) No change in spatial, daily/weekly, or interannual variability

Statistical downscaling

- Statistical downscaling is a mathematical procedure that relates changes at the large spatial scale that GCMs simulate to a much finer scale:

    a) For example, a statistical relationship can be created between variables simulated by GCMs such as air, sea surface temperature (SST), and precipitation at the GCM scale (predictors) with temperature and precipitation at a particular location (predictands)

- There is a direct statistical relationship with SST indices (or other physically established predictor indices)

- Statistical downscaling from numerical model output is widely used in climate change downscaling from daily GCM fields "perfect prognosis" assumption

Statistical downscaling (cont.)

- Is most appropriate for:

  a) Subgrid scales (small islands, point processes, etc.)
  b) Complex/heterogeneous environments
  c) Extreme events
  d) Exotic predictands
  e) Transient change/ensembles Is not appropriate for data-poor regions
  f) Where relationships between predictors and predictands may change

- Statistical downscaling is much easier to apply than regional climate modeling

Statistical downscaling (cont.)

- Statistical downscaling assumes that the relationship between the predictors and the predictands remains the same
- Those relationships could change
- In such cases, using RCMs may be more appropriate

Bias correction

- Bias correction uses quantiles to adjust GCM simulation of current climate to observations
  a) Can be done at high resolution, e.g., 1/8th degree
  b) Can capture climate variance
  c) Quite useful when current climate has low absolute values
     - E.g., precipitation in arid or semi-arid climates

- Bias correction does not estimate how change in climate varies within GCM grid box

- NASA NEX has global BCSD to 25 km

RCMs

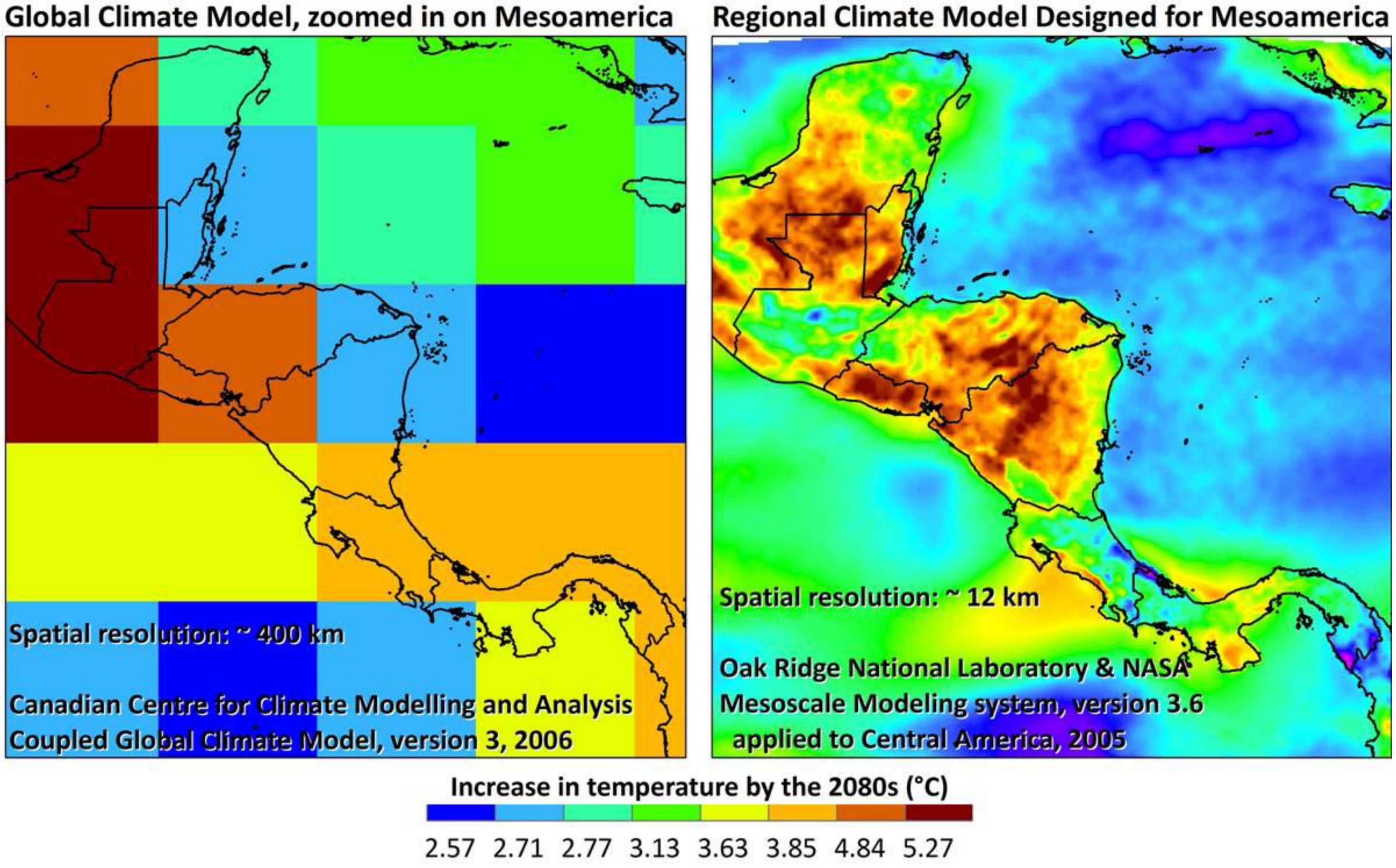
- These are high resolution models that are "nested" within GCMs:
  a) A common grid resolution is 36–50 km:
     - Some have much higher resolution
  b) RCMs are often run at continental scale with boundary conditions from GCMs

- They give much higher resolution output than GCMs
  a) Hence, much greater sensitivity to smaller scale factors such as mountains, water bodies
  b) Good to investigate higher order climate variability

RCM limitations

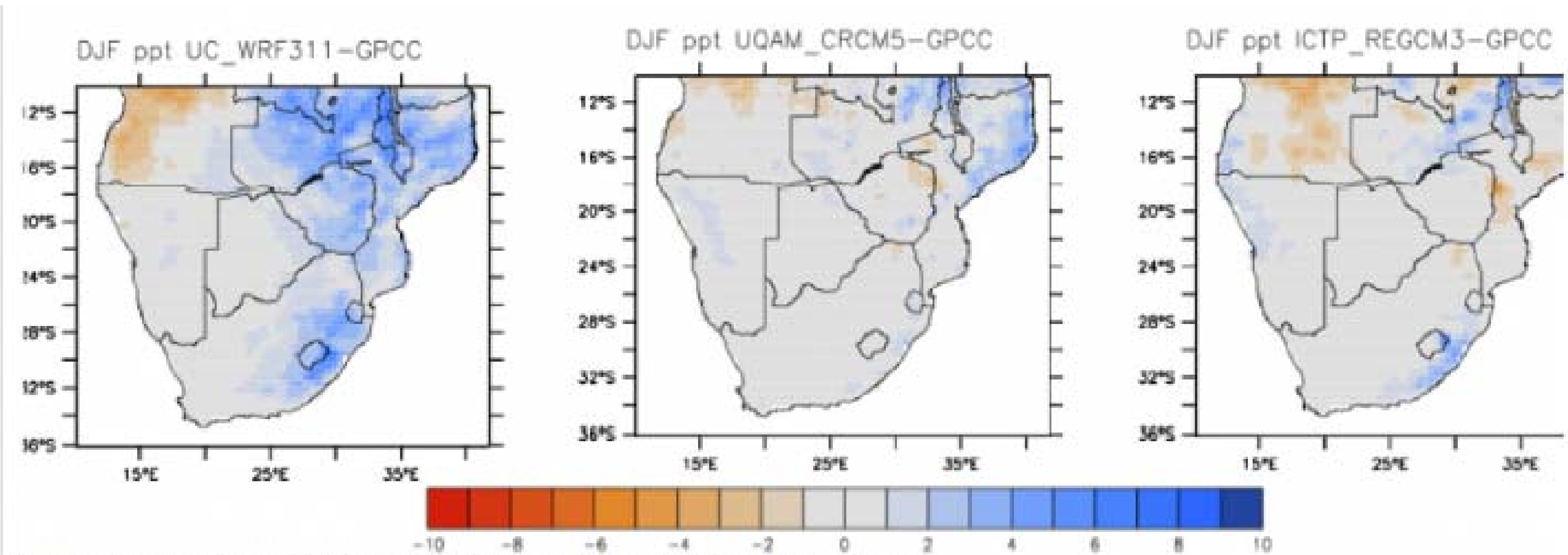
- Can correct for some, but not all, errors in GCMs
- Typically applied to one GCM or only a few GCMs
- In many applications, just run for a simulated decade, e.g., 2040s
- Still need to parameterize many processes
- May need further downscaling or bias correction for some applications
- Needs diagnostics based on known weather and climate features
- RCM evaluation limited by (observations) data availability

RCMs



Global Climate Model, zoomed in on Mesoamerica
Regional Climate Model Designed for Mesoamerica
Spatial resolution: ~ 400 km
Canadian Centre for Climate Modelling and Analysis
Coupled Global Climate Model, version 3, 2006
Spatial resolution: ~ 12 km
Oak Ridge National Laboratory & NASA
Mesoscale Modeling system, version 3.6
applied to Central America, 2005
Increase in temperature by the 2080s (°C)
2.57 2.71 2.77 3.13 3.63 3.85 4.84 5.27

RCMs in Africa



(http://www.csag.uct.ac.za/wp-content/uploads/2012/06/SmAf.pptbias1.png)

Extremes

- Intensity of storms sensitive to model resolution
- Higher resolution improves intensity of precipitation
- Higher resolution improves intensity location

By now you may be confused…

- So many choices, what to do?

- First, let us remember the basics:
  a) Scenarios are essentially educational tools to help:
     - See ranges of potential climate change
     - Provide tools for better understanding the sensitivities of affected systems

- So, we need to select scenarios that enable us to meet these goals

Selected methods and tools

- MAGICC/SCENGEN
- SimCLIM
- PRECIS
- SDSM (Statistical Downscaling Model)
- ClimateWizard
- KNMI Climate Explorer

Tools for assessing regional model output

- Normalized GCM results allow comparison of the relative regional changes
- Can analyze the degree to which models agree about change in direction and relative magnitude:
  a) A measure of GCM uncertainty

Normalizing GCM output

- Expresses regional change relative to an increase of 1°C in global mean temperature (GMT):
  a) This is a way to avoid high-sensitivity models dominating results
  b) It allows us to compare GCM output based on relative regional change
  c) Let us select emissions scenarios and climate sensitivity

- Normalized temperature change = $\Delta T_{RGCM}/\Delta T_{GMTGCM}$

- Normalized precipitation change = $\Delta P_{RGCM}/\Delta T_{GMTGCM}$

Pattern scaling

- Is a technique for estimating change in regional climate using normalized patterns of change and changes in GMT

- Pattern scaled temperature change:
  a) $\Delta T_{R\Delta GMT} = (\Delta T_{RGCM}/\Delta T_{GMTGCM}) \times \Delta GMT$

- Pattern scaled precipitation:
  a) $\Delta P_{R\Delta GMT} = (\Delta P_{RGCM}/\Delta T_{GMTGCM}) \times \Delta GMT$ 3

Scenario selection

How to select scenarios

- Use one or several of the methods and tools to assess the range of temperature or precipitation changes

- Models can be selected based on:

  a) How well they simulate current climate
     - SCENGEN has a routine for CMIP3 models

  b) How well they representing a broad range of conditions

Selecting GCMs

- Some factors to consider in selecting GCMs

  a) Age of the model run:
     - More recent runs tend to be better, but there are some exceptions

  b) Model resolution:
     - Higher resolution tends to be better

  c) Model accuracy in simulating current climate:
     - MAGICC/SCENGEN has a routine

Selecting GCMs II

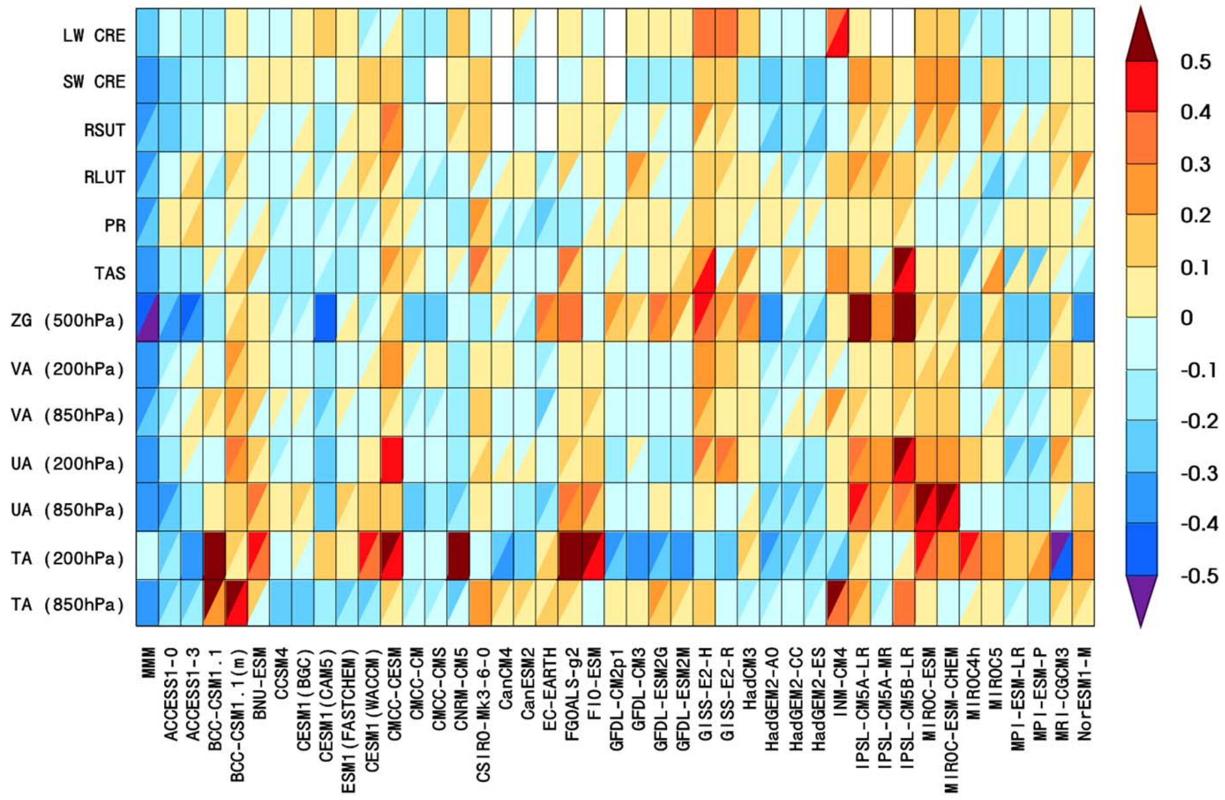


Figure 9.7 | Relative error measures of CMIP5 model performance, based on the global seasonal-cycle climatology (1980–2005) computed from the historical experiments. Rows and columns represent individual variables and models, respectively. The error measure is a space–time root-mean-square error (RMSE), which, treating each variable separately, is portrayed as a relative error by normalizing the result by the median error of all model results (Gleckler et al., 2008). For example, a value of 0.20 indicates that a model's RMSE is 20% larger than the median CMIP5 error for that variable, whereas a value of –0.20 means the error is 20% smaller than the median error. No colour (white) indicates that model results are currently unavailable. A diagonal split of a grid square shows the relative error with respect to both the default reference data set (upper left triangle) and the alternate (lower right triangle). The relative errors are calculated independently for the default and alternate data sets. All reference data used in the diagram are summarized in Table 9.3.

Scenarios for extreme events

- Difficult to obtain from any of these sources

- Options:
  a) Use long historical or paleoclimate records
  b) Incrementally change historical extremes:
     - Try to be consistent with transient GCMs
  c) These methods are primarily useful for sensitivity studies
  d) Use daily data

Future of climate change scenarios

- Observed (baseline) data sets should be improved

- Climate science is improving
  a) Will improve science in models

- With increased computing power, model resolution is improving
  a) GCMs are already at 1° (~ 100 km)
  b) RCMs – some are being run at a few km resolution

- Don't expect consensus on climate sensitivity or regional patterns of change

Brief review on climate change scenarios

- We mainly used climate model output as basis for climate change scenarios
- All scenarios derive from GCMs
  a) Simple downscaling uses GCMs directly by combining average projections with observations
  b) GCMs have low resolution, but resolution is increasing
  c) Tools such as Climate Wizard, MAGICC/SCENGEN and SimCLIM can help organize GCM output
- Downscaling estimates climate change within GCM grid boxes
  a) RCMs are higher resolution climate models
     - Projections are “dynamic”
  b) Statistical downscaling uses mathematical relationship with GCM output
     - Preferable for very small spatial scales, extremes or exotic variables
- Bias correction provides high resolution output but does not estimate how climate change varies within GCM grid boxes

Final thoughts

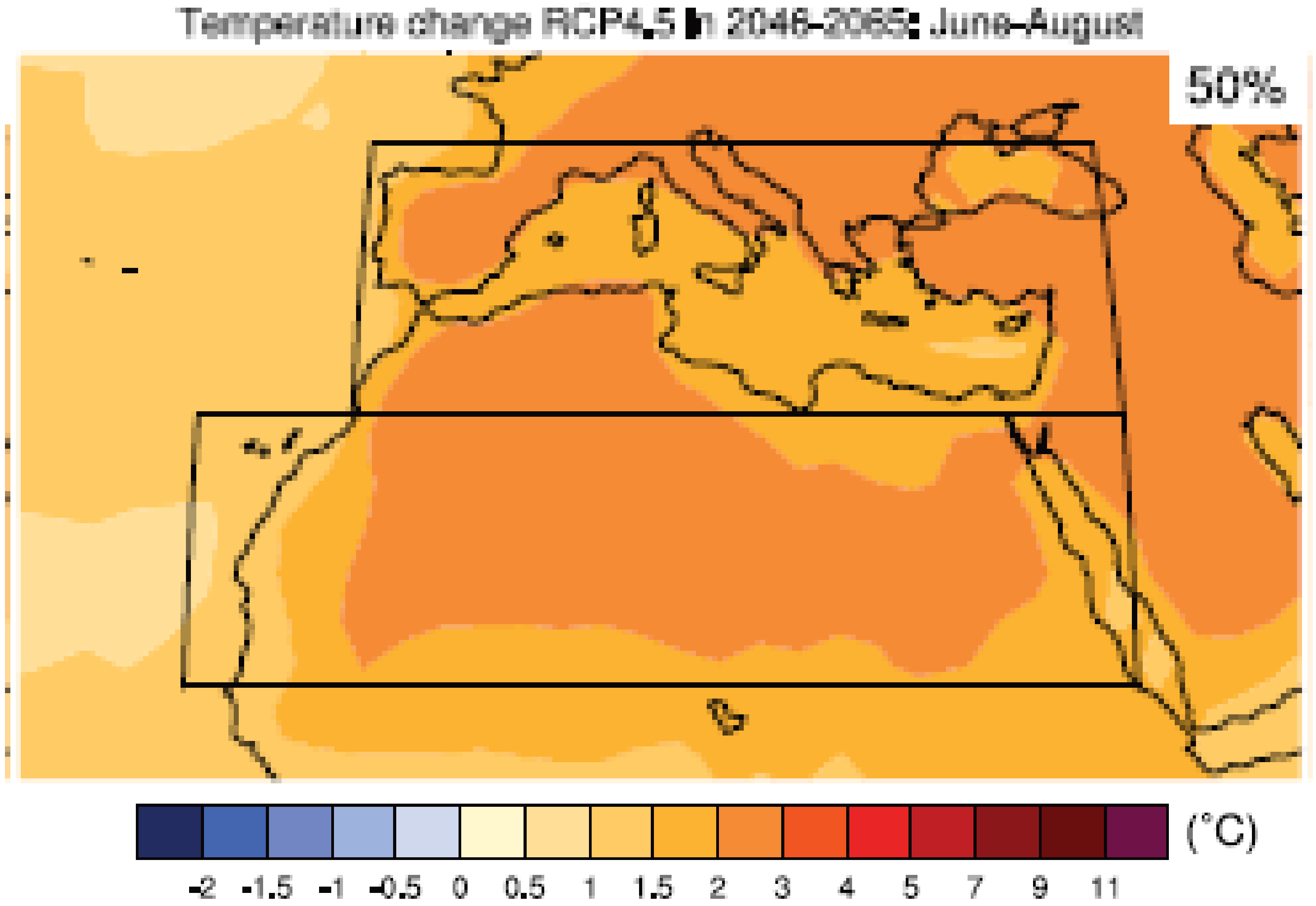
- Remember that individual scenarios are not predictions of future regional climate change

- If used properly, they can help us understand and portray:
  a) What is known about how regional climates may change
  b) Uncertainties about regional climate change
  c) The potential consequences

REGIONAL CLIMATE PROJECTIONS FROM IPCC AR5

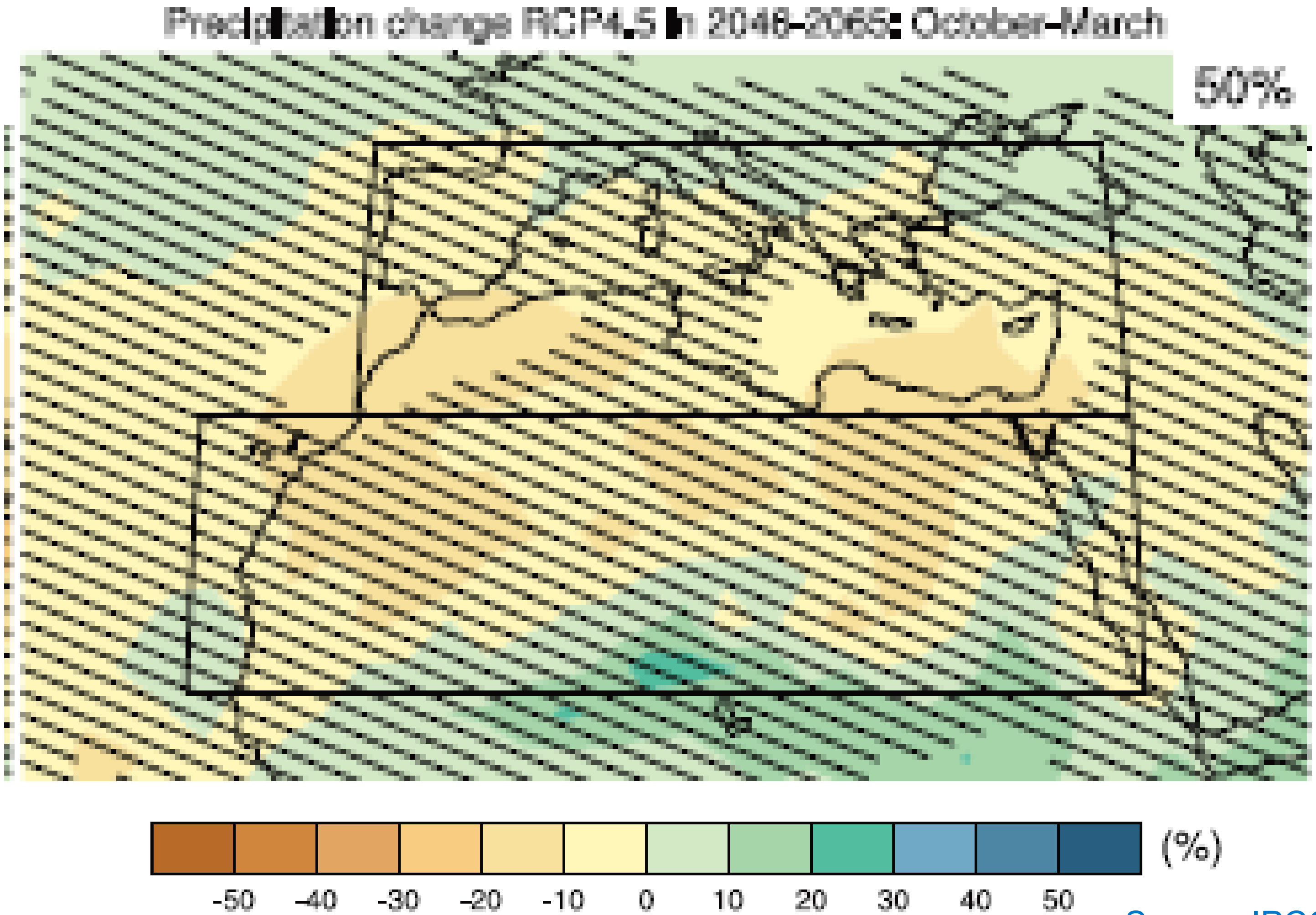
Projections for Africa

North Africa temperature rise: Jun–Aug 2046–2065



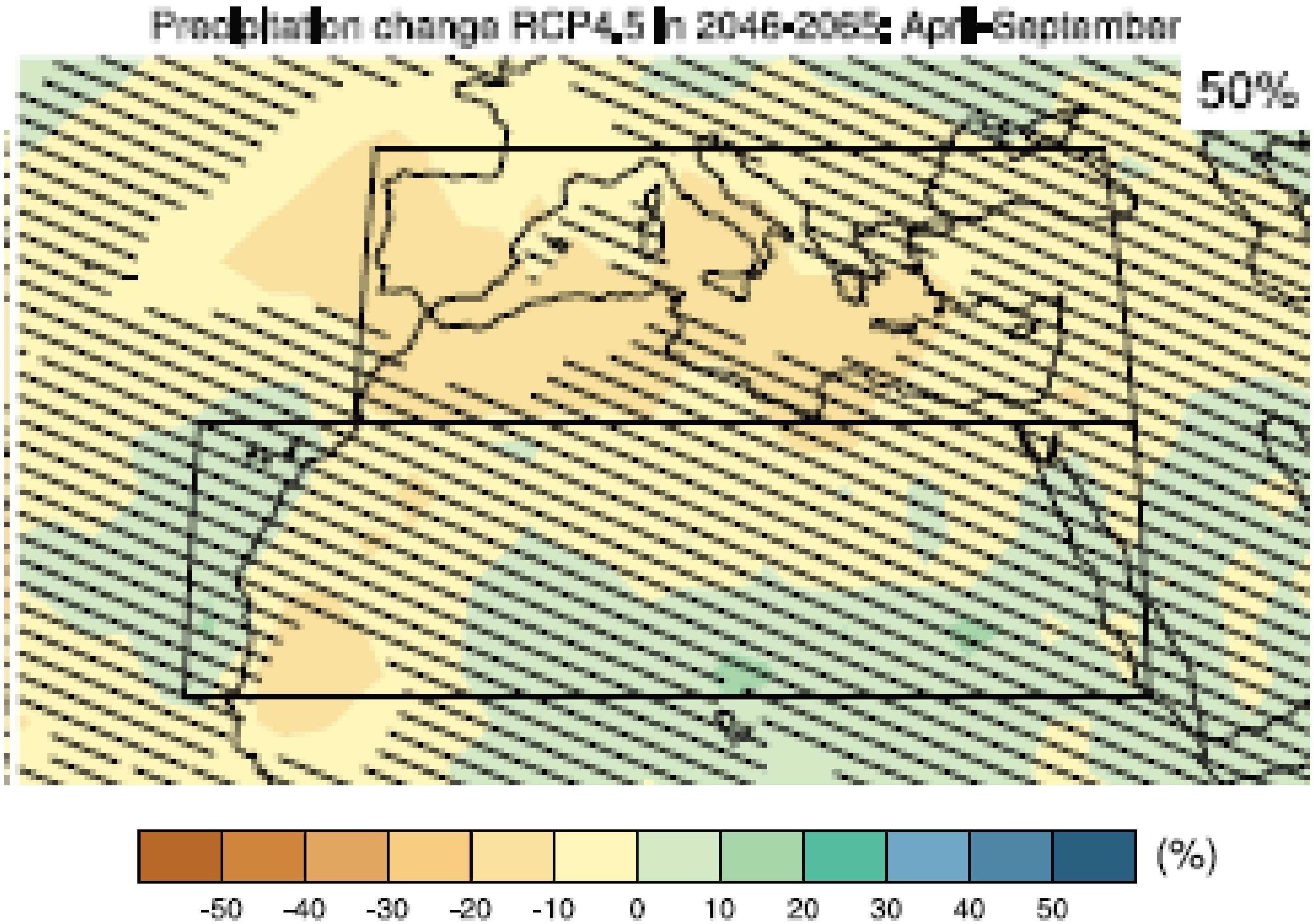
Source: IPCC, 2013

North Africa precipitation change: Oct–Mar 2046–2065



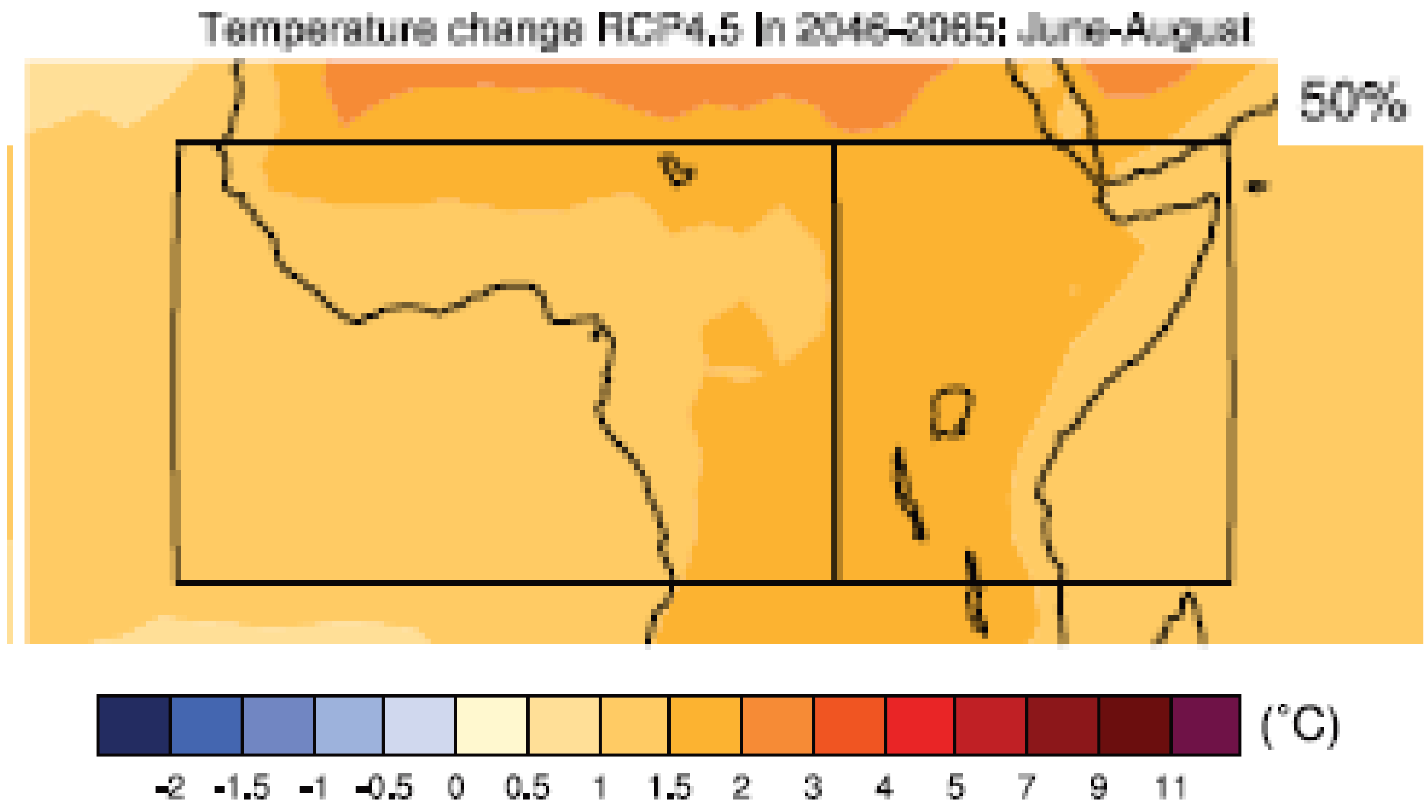
Source: IPCC, 2013

North Africa precipitation change: Apr–Sept 2046–2065



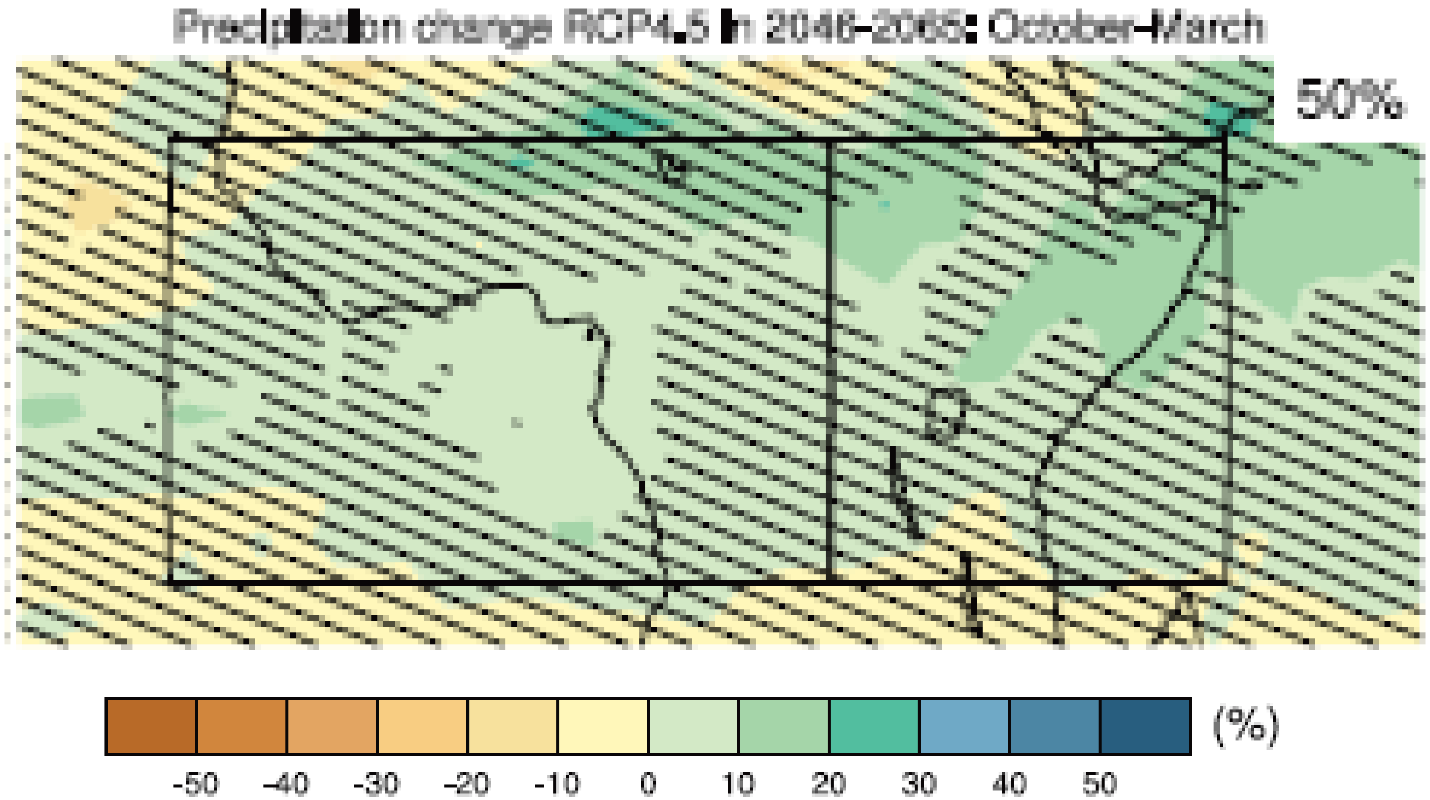
Source: IPCC, 2013

Central Africa temperature rise: Jun–Aug 2046–2065



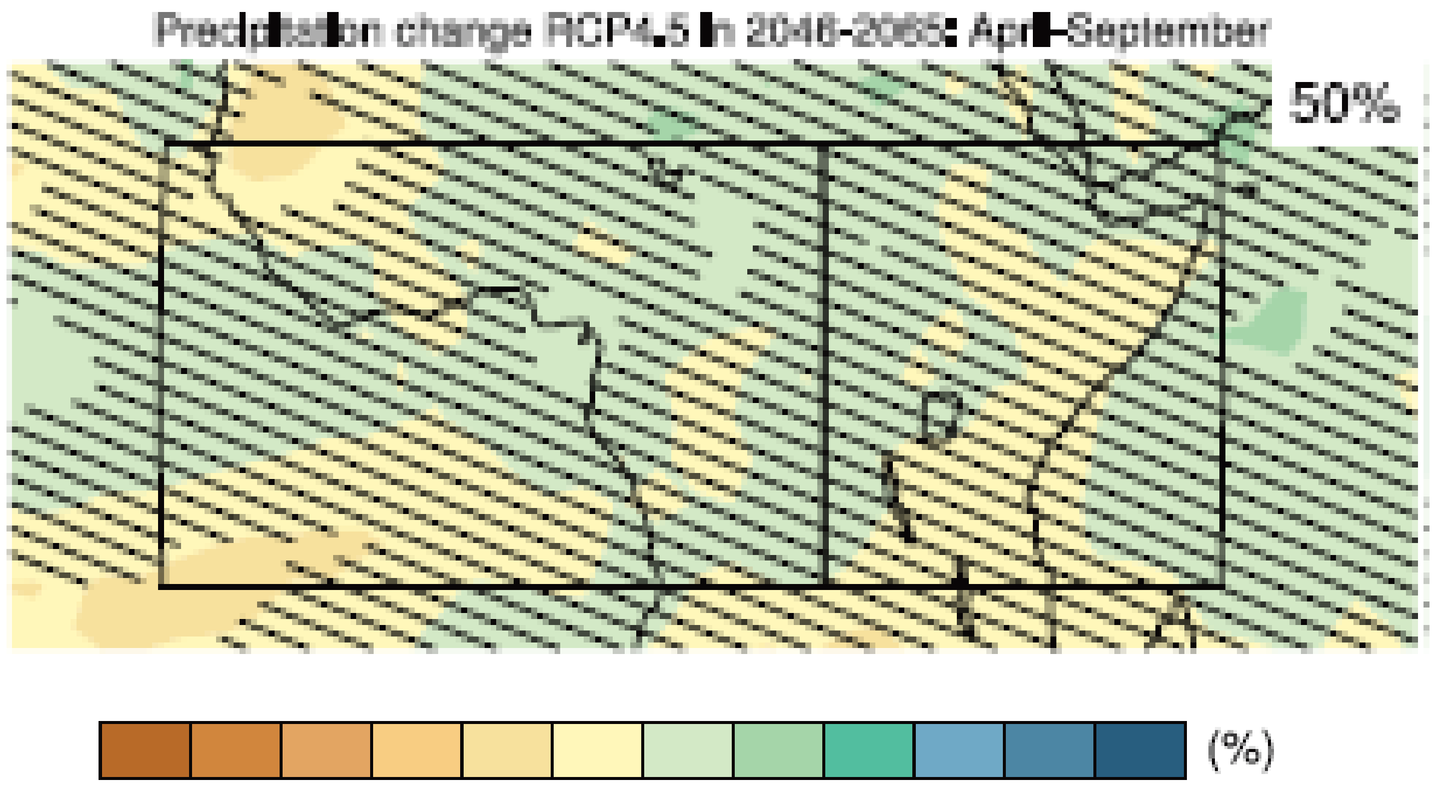
Source: IPCC, 2013

Central Africa precipitation change: Oct–Mar 2046–2065



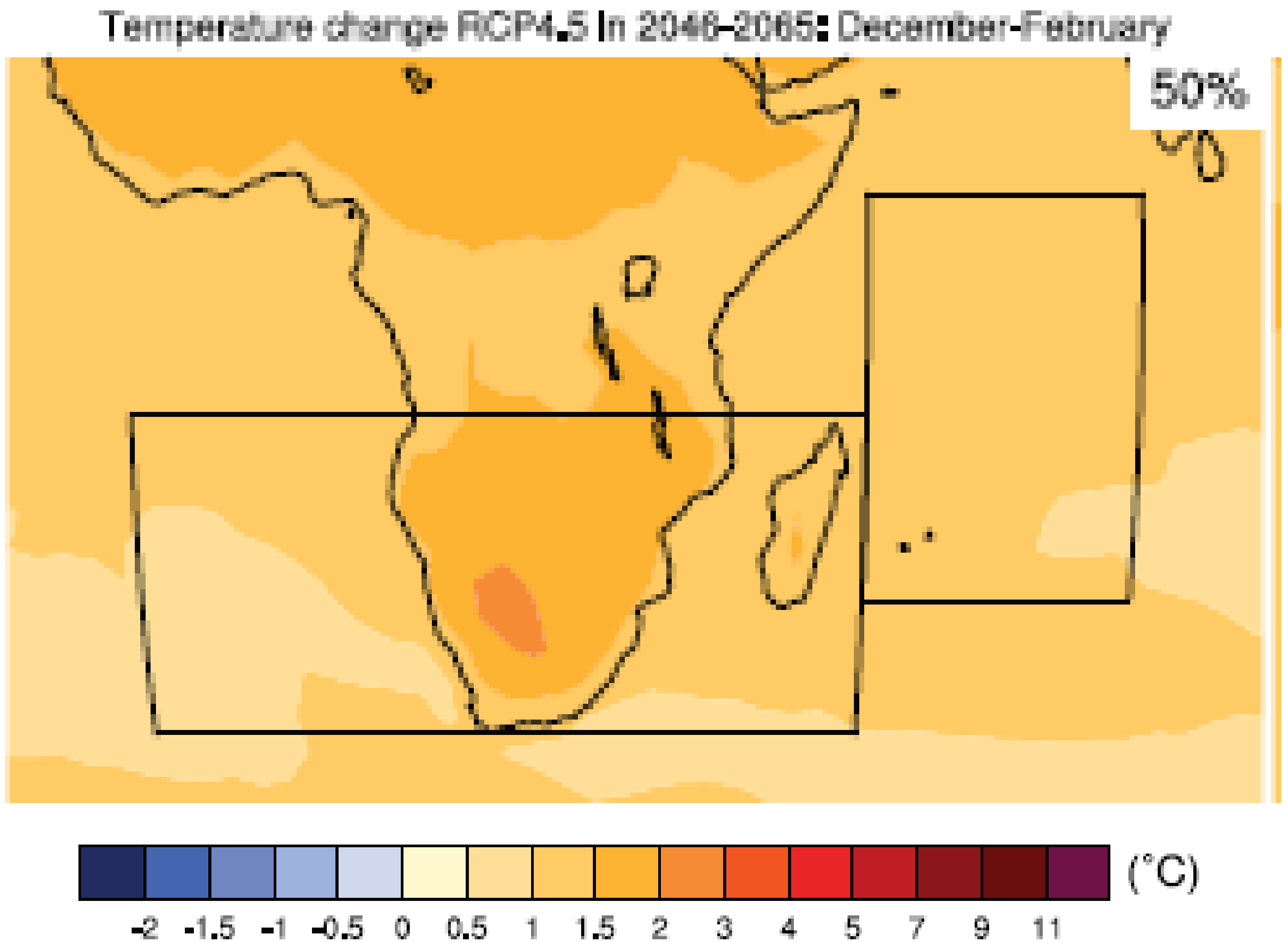
Source: IPCC, 2013

Central Africa precipitation change: Apr–Sept 2046–2065



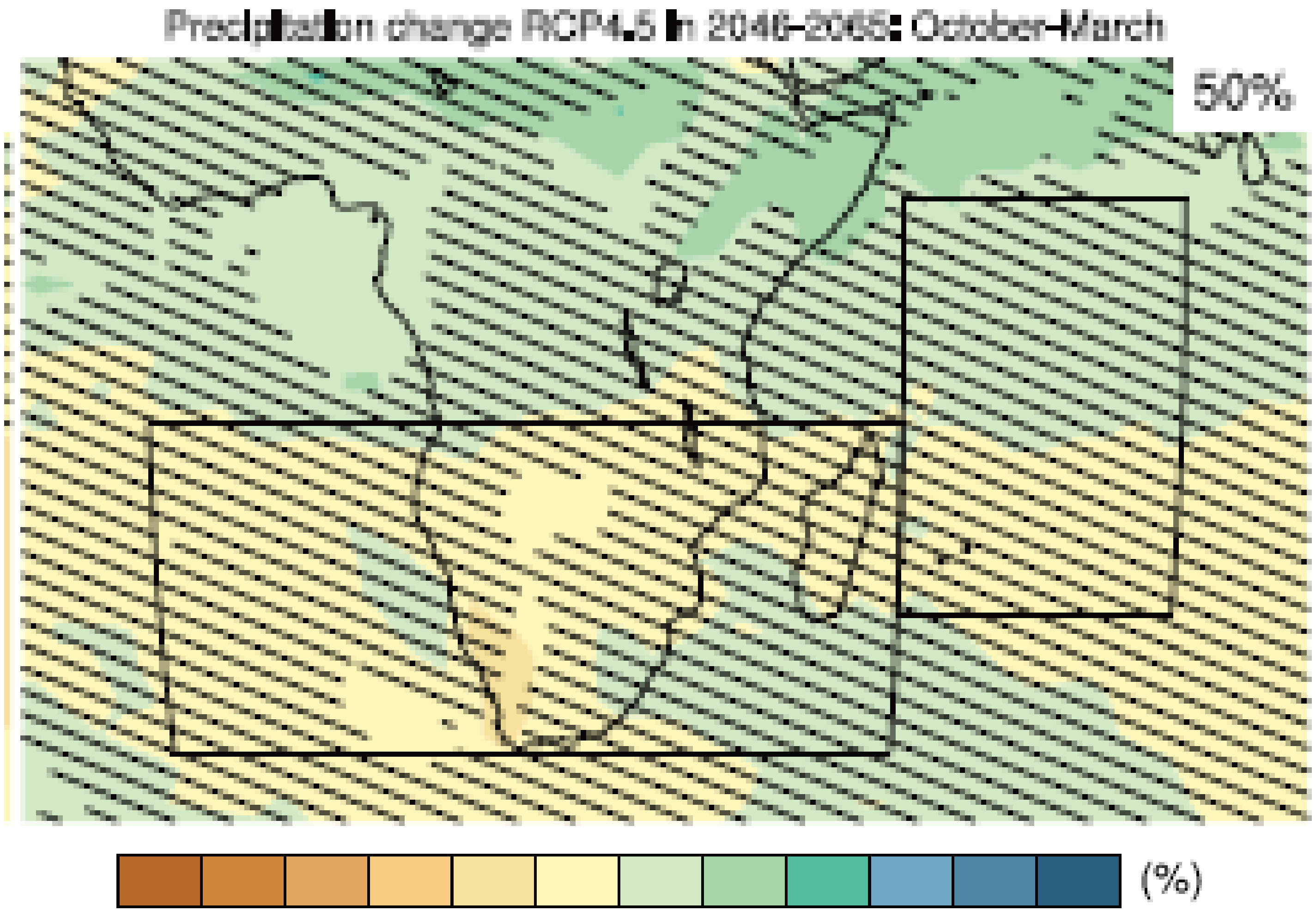
Source: IPCC, 2013

South Africa temperature rise: Dec–Feb 2046–2065



Source: IPCC, 2013

South Africa precipitation change: Oct–Mar 2046–2065



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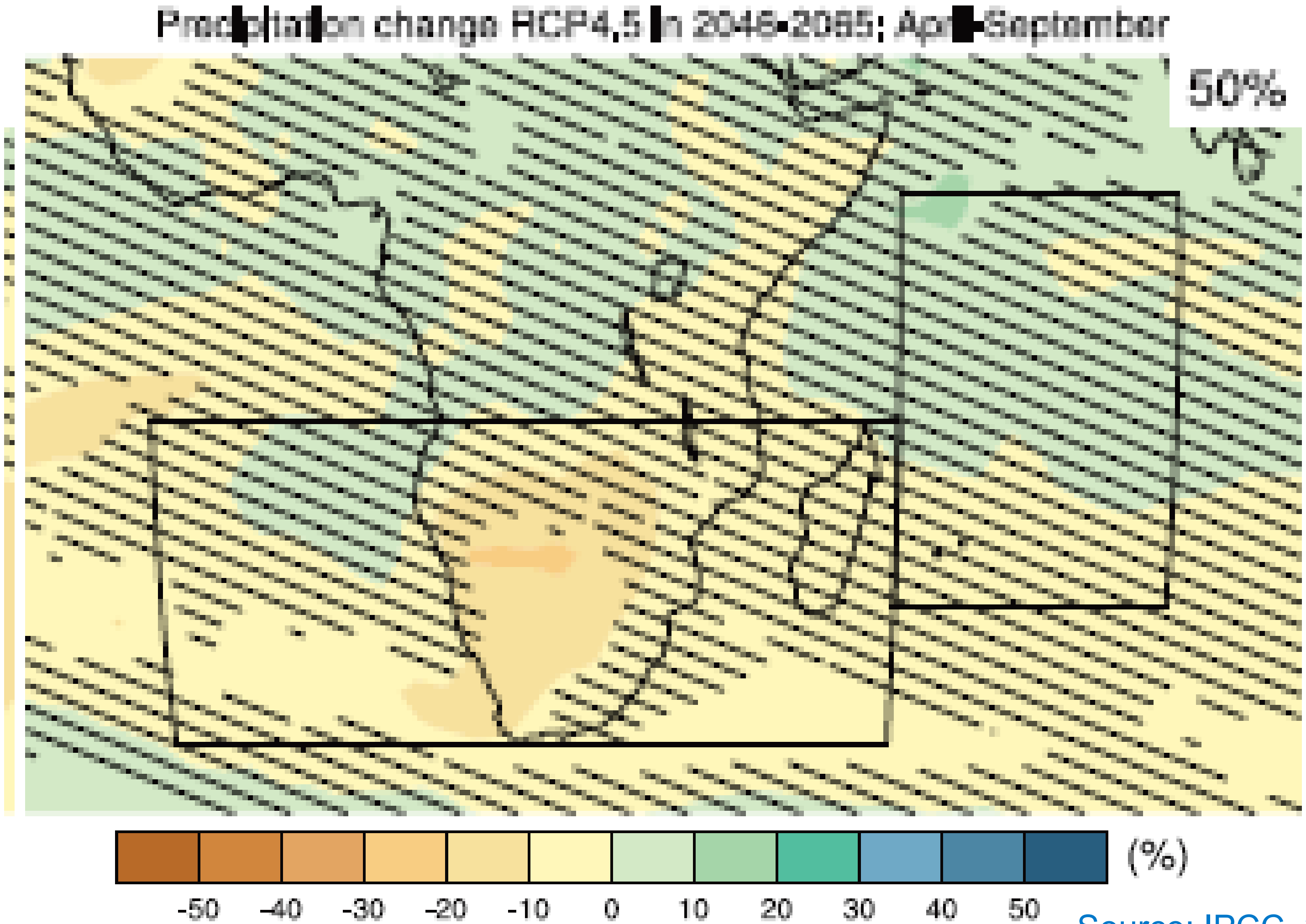
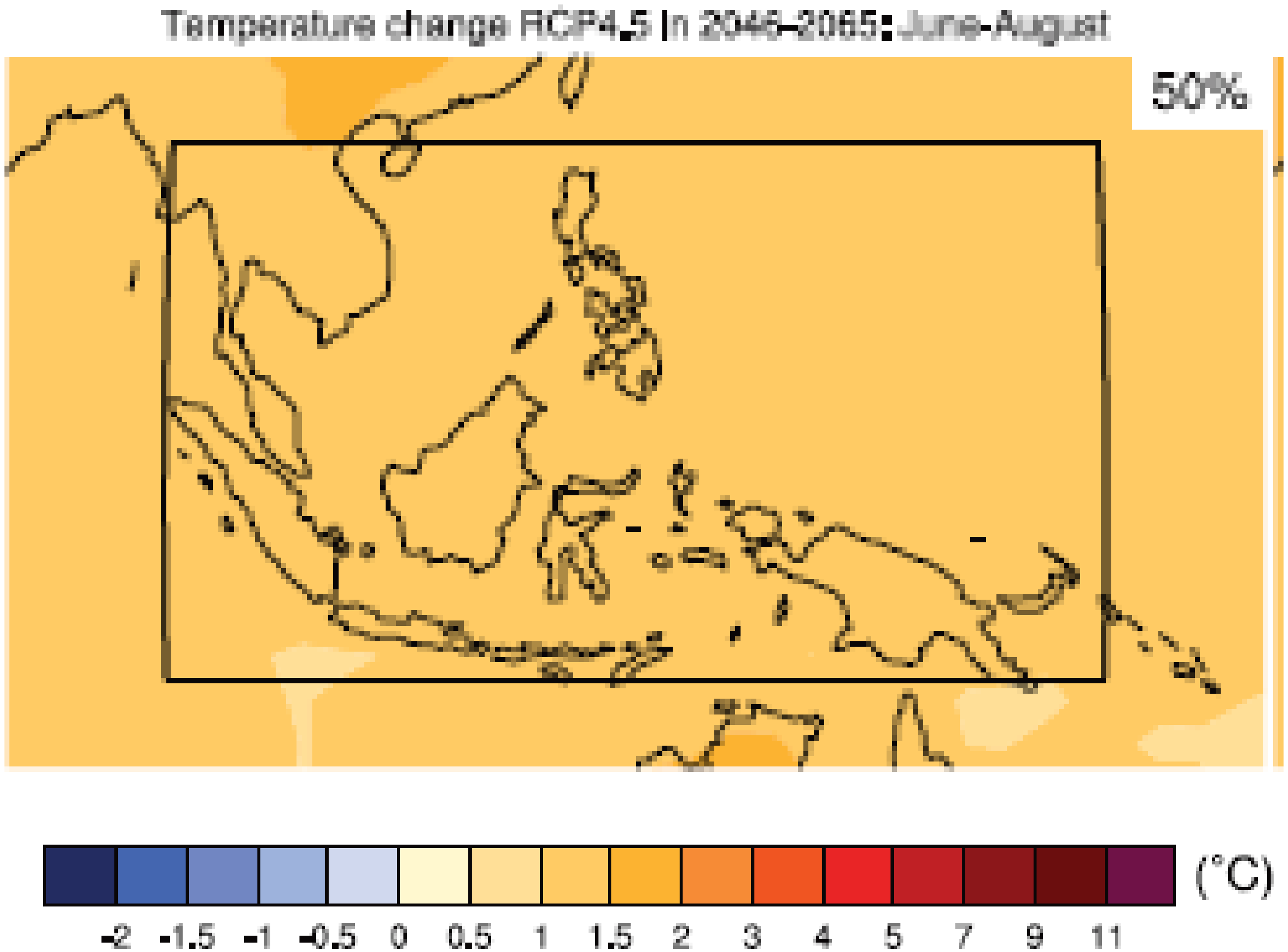


Source: IPCC, 2013

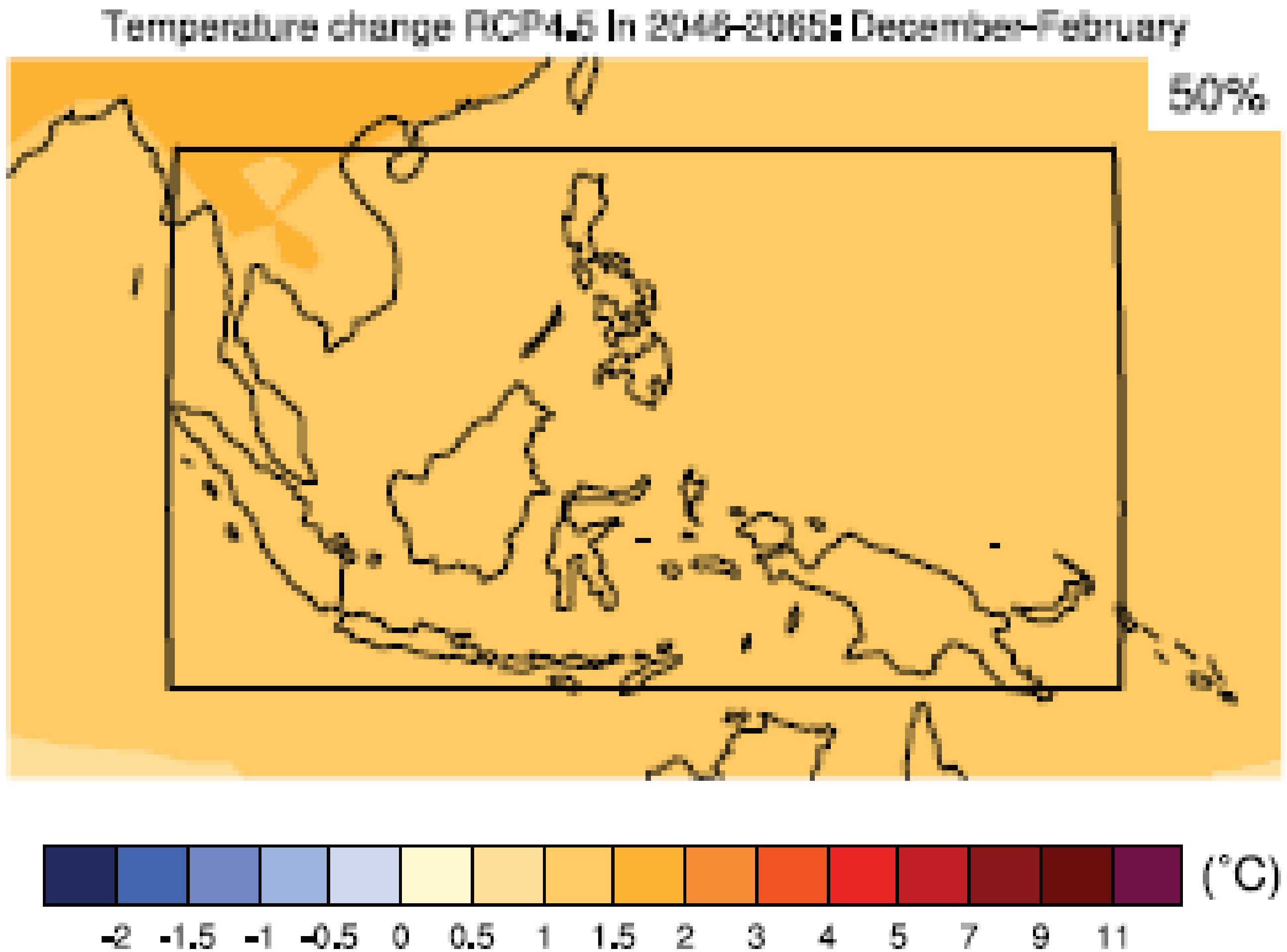
Projections for Asia

SE Asia/Pacific temperature rise: Jun–Aug 2046–2065



Source: IPCC, 2013

SE Asia/Pacific temperature rise: Dec–Feb 2046–2065



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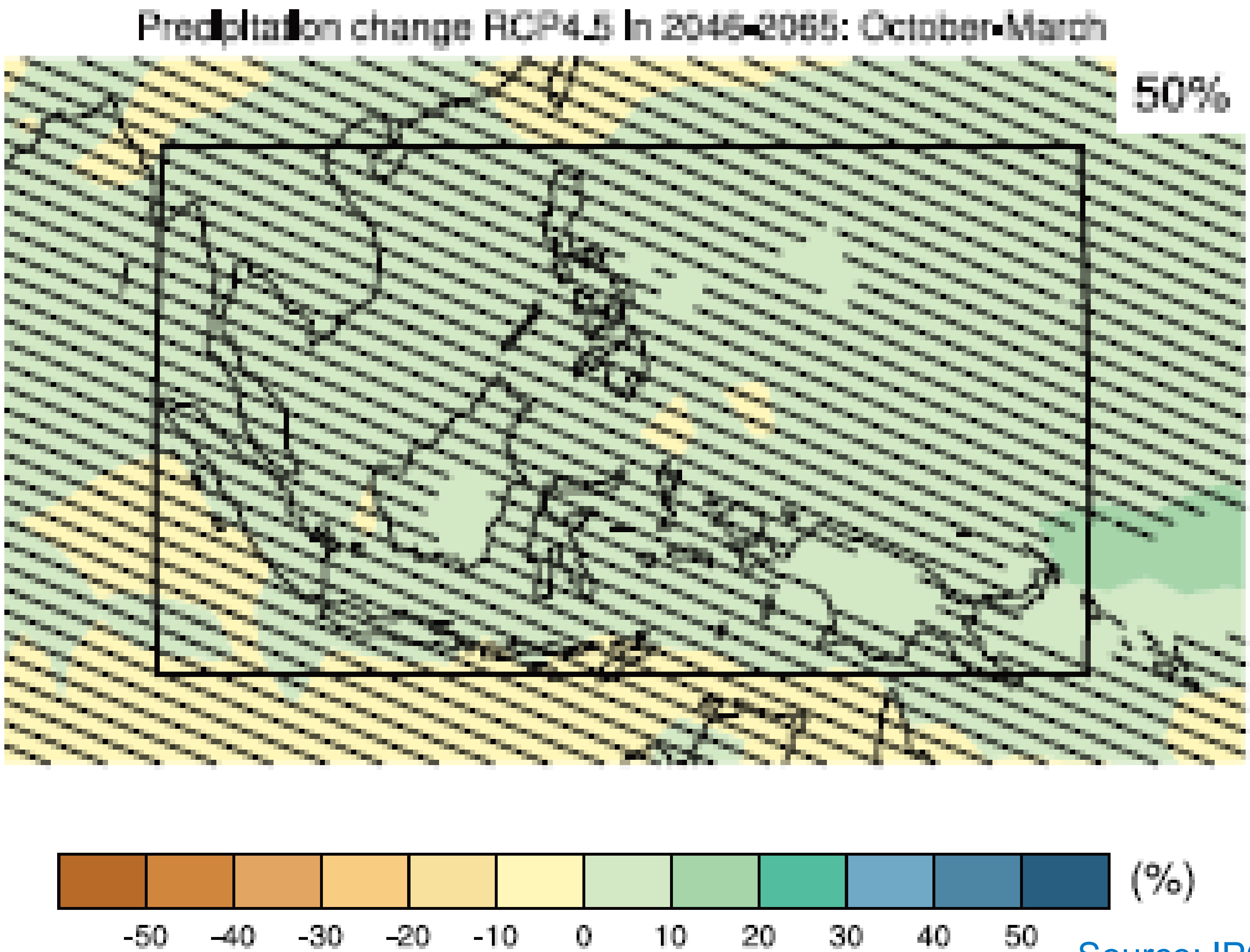

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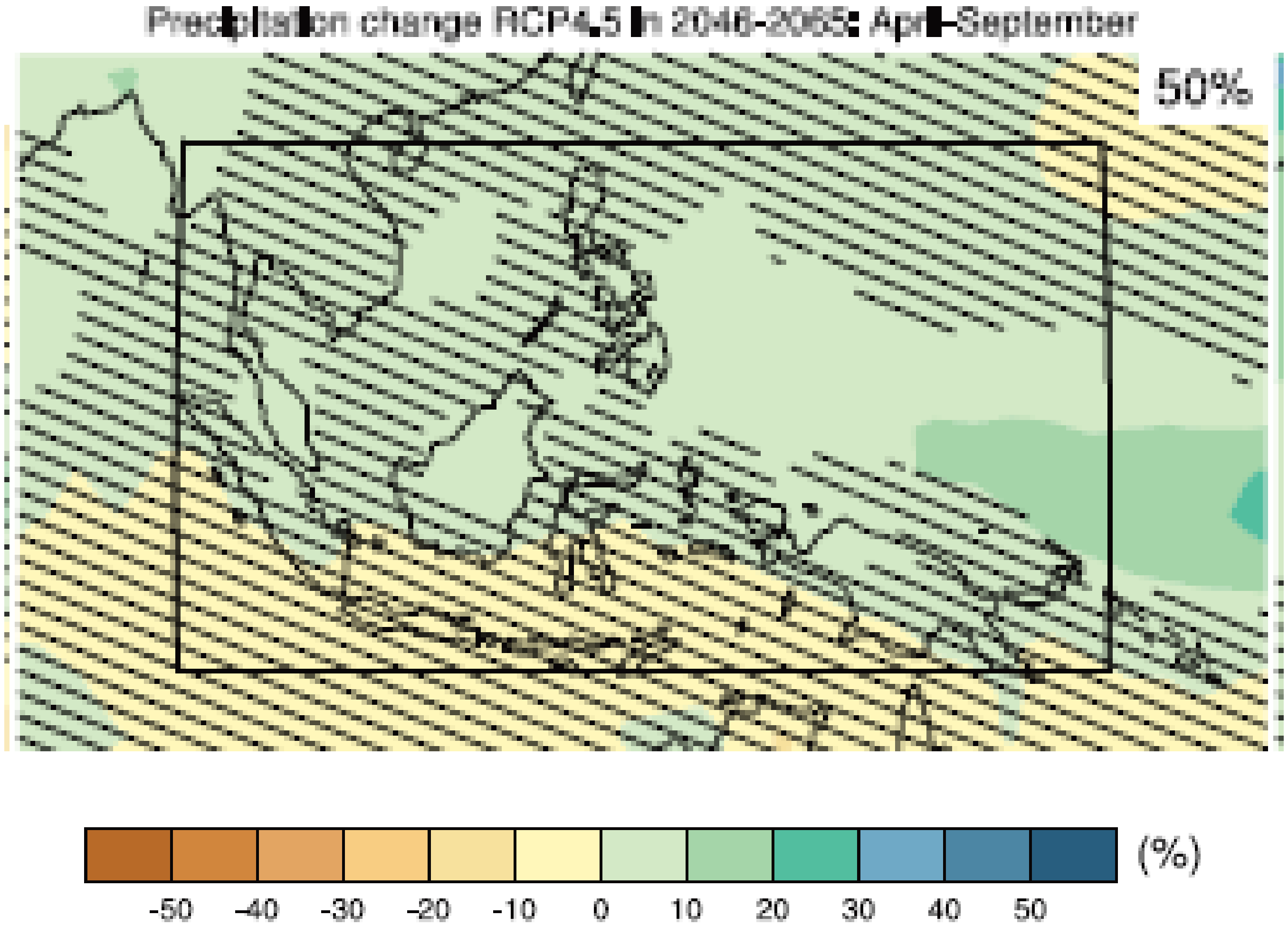
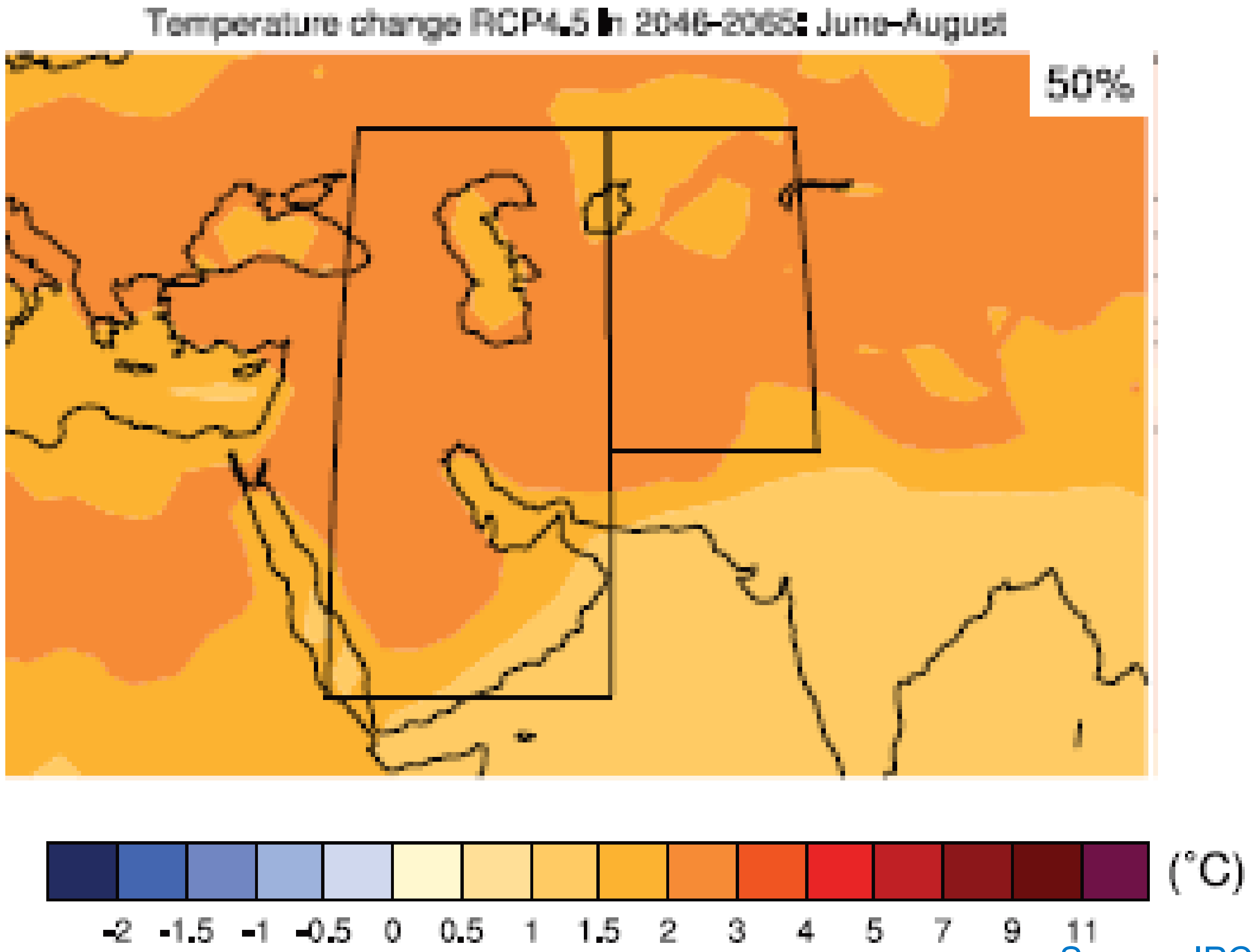


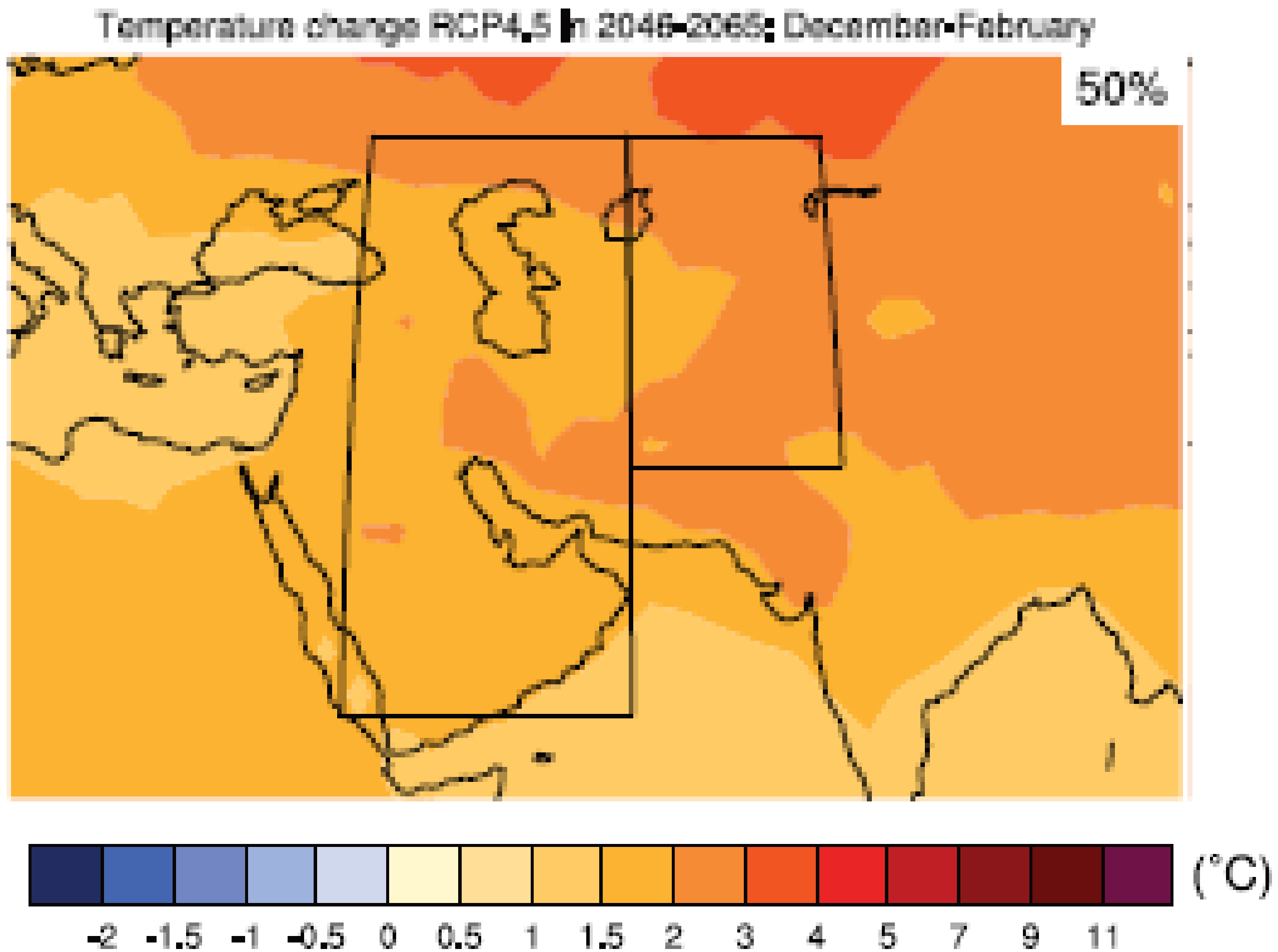
Source: IPCC, 2013

SW/South Asia temperature rise: Jun–Aug 2046–2065



Source: IPCC, 2013

SW/South Asia temperature rise: Dec–Feb 2046–2065



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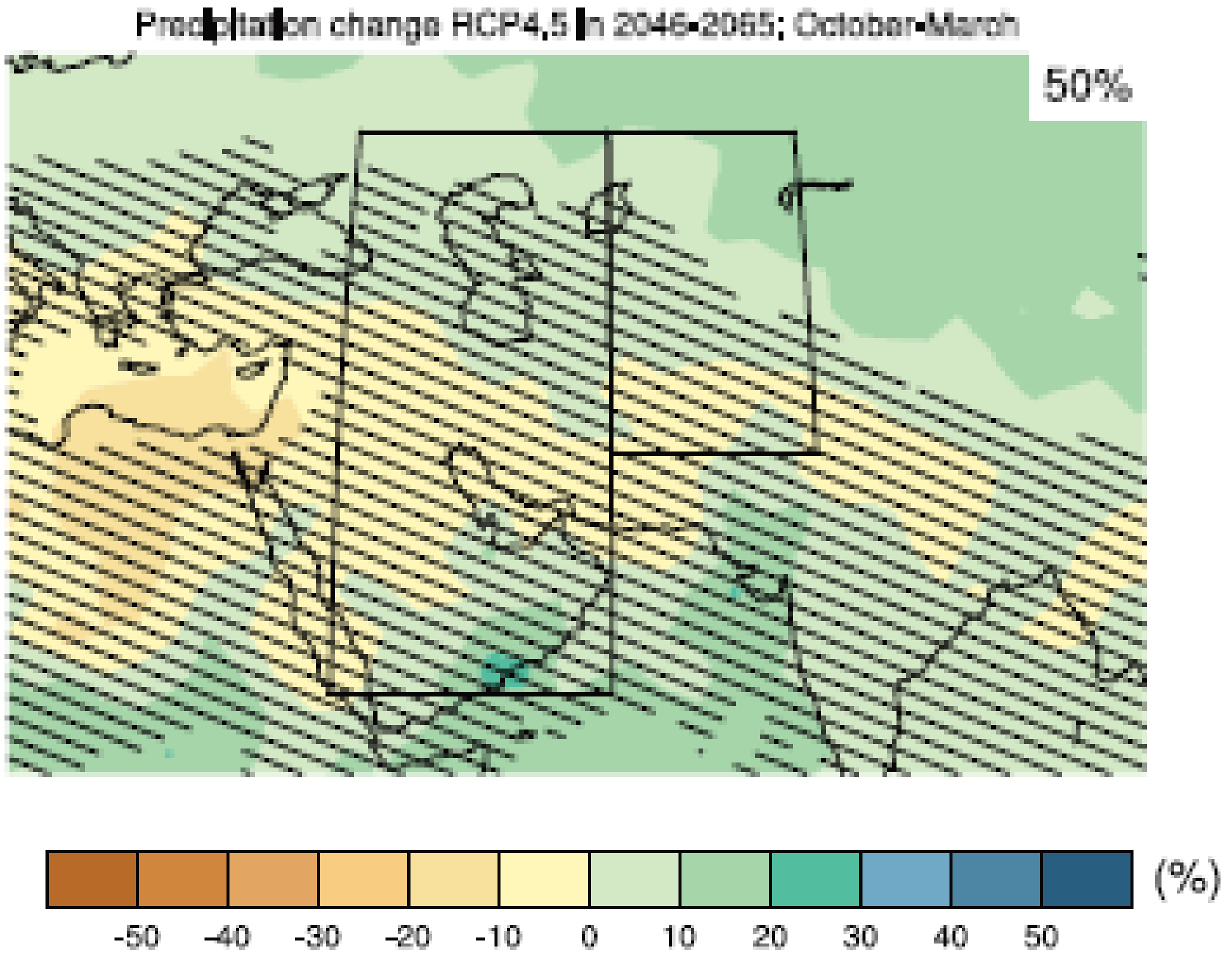

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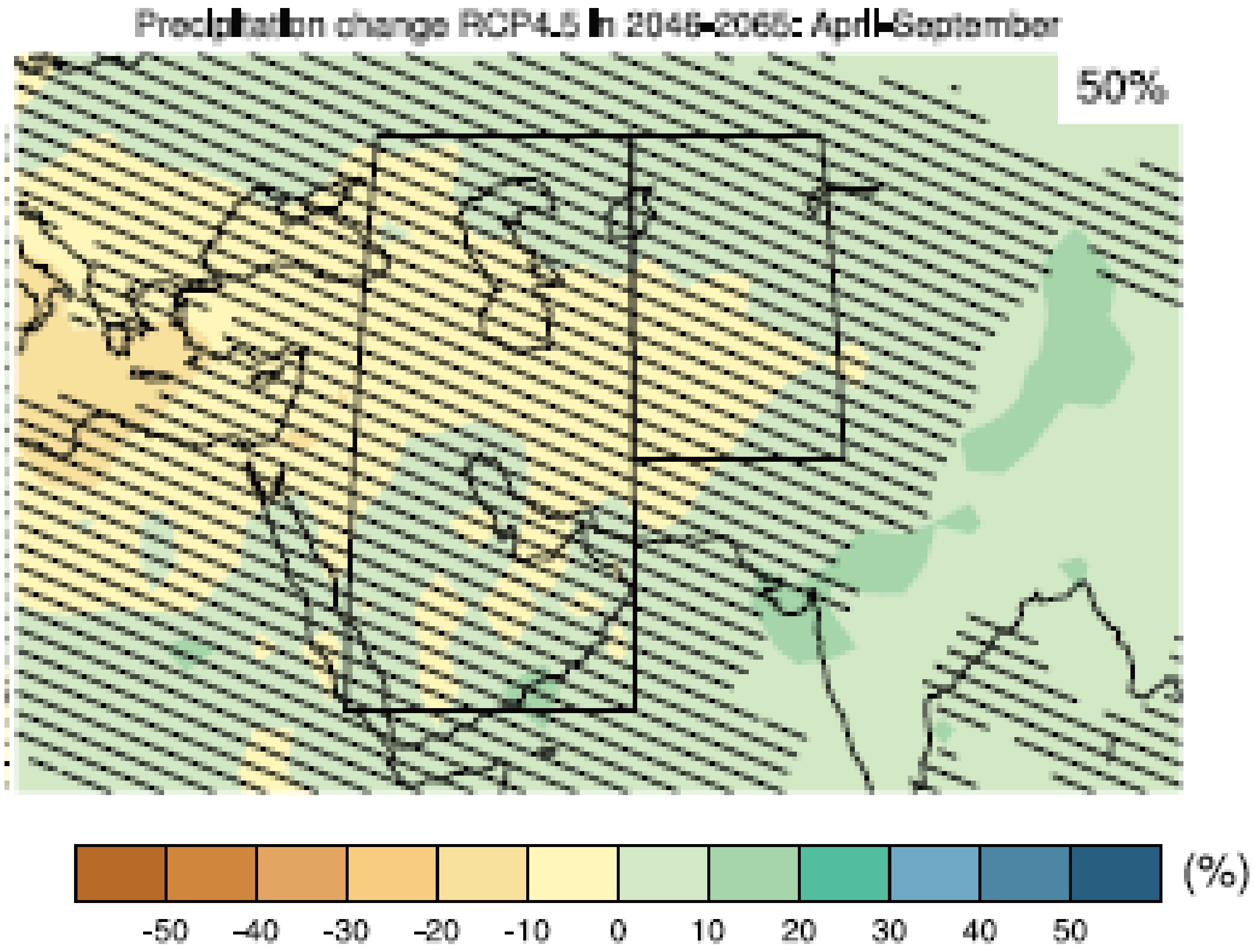
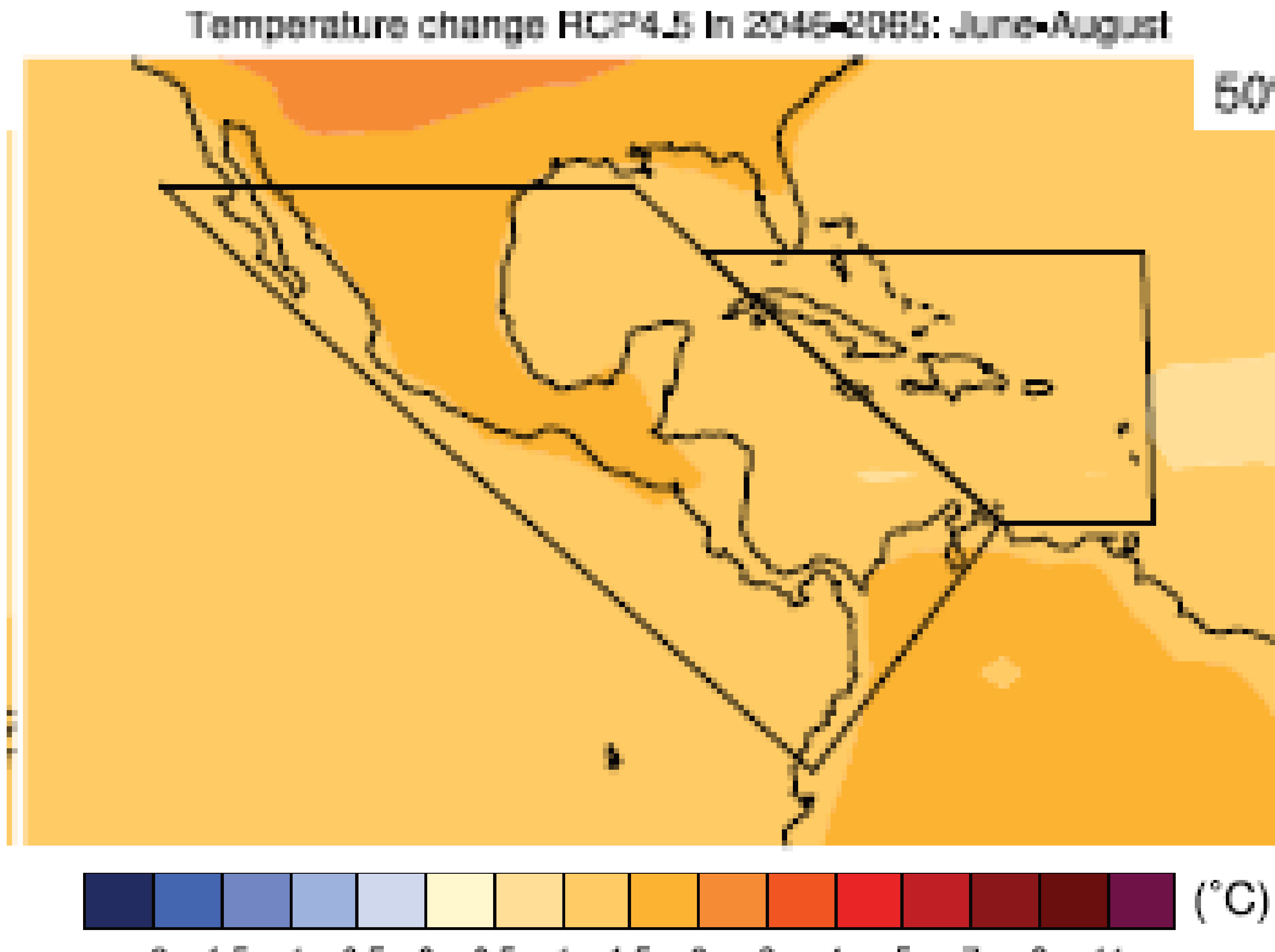
SW/South Asia precipitation change: Apr–Sept 2046–2065



Source: IPCC, 2013

Projections for Latin America and the Caribbean

Caribbean temperature rise: Jun–Aug 2046–2065



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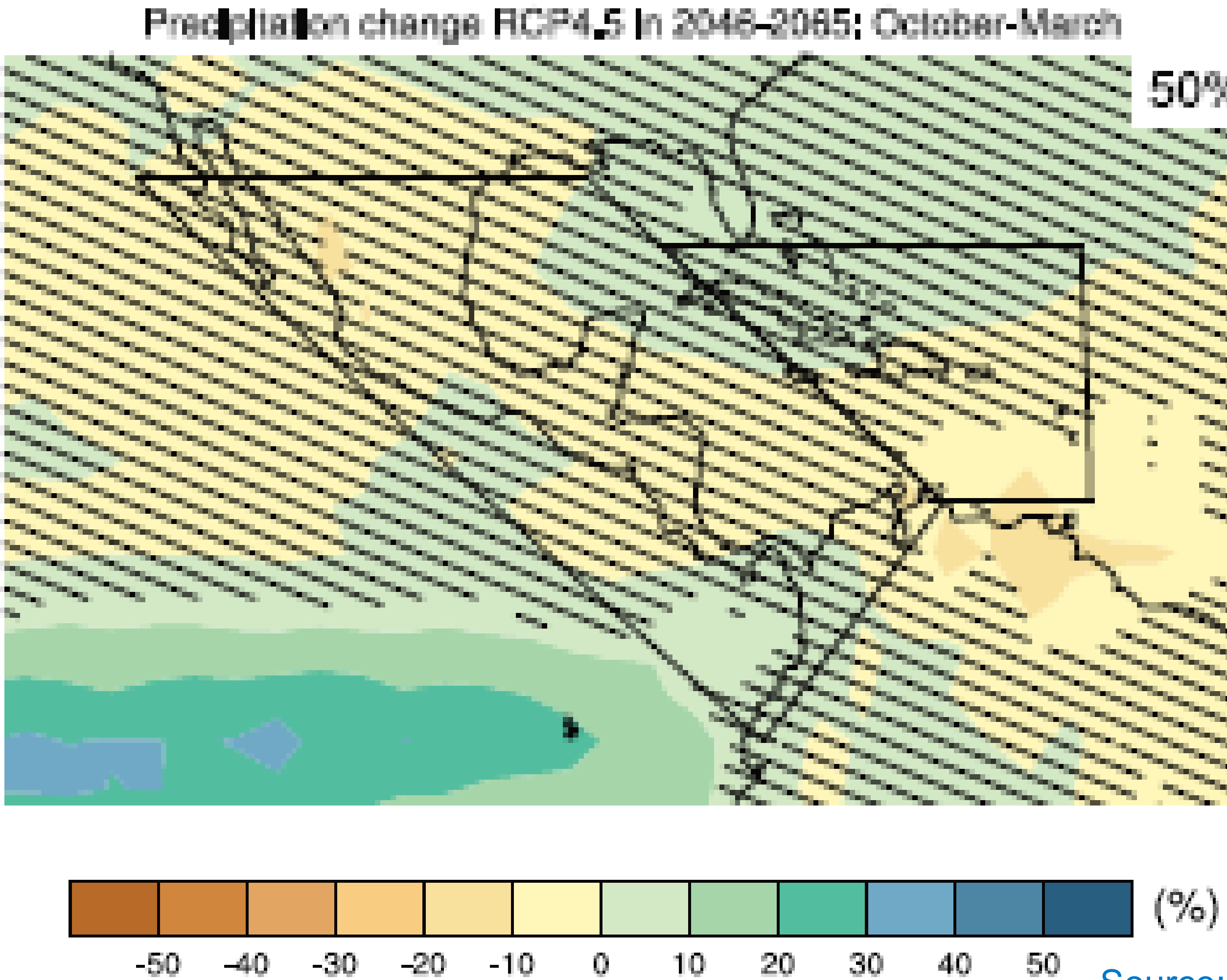
Caribbean precipitation change: Oct–Mar 2046–2065



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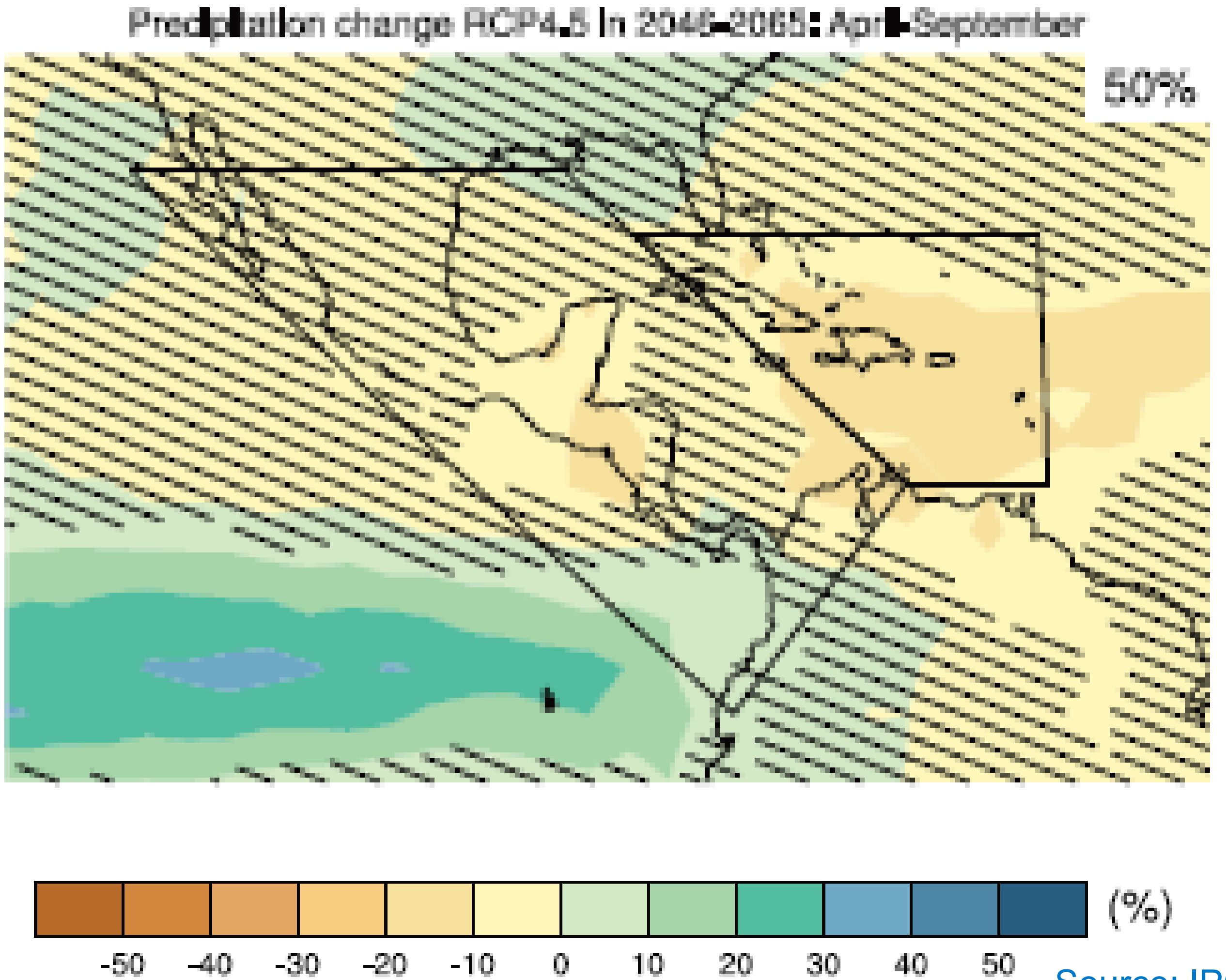
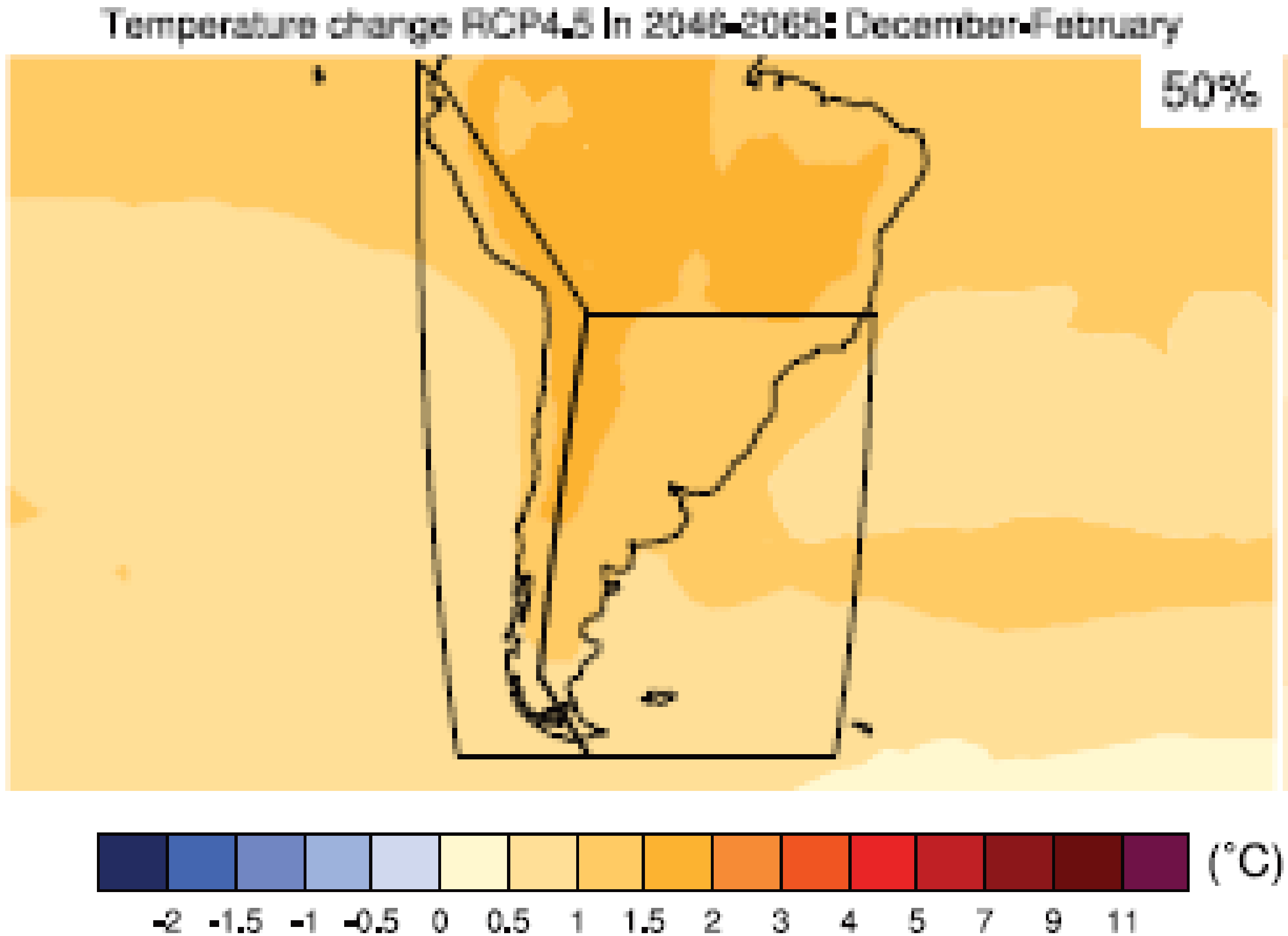


Source: IPCC, 2013

South America temperature rise: Dec–Feb 2046–2065



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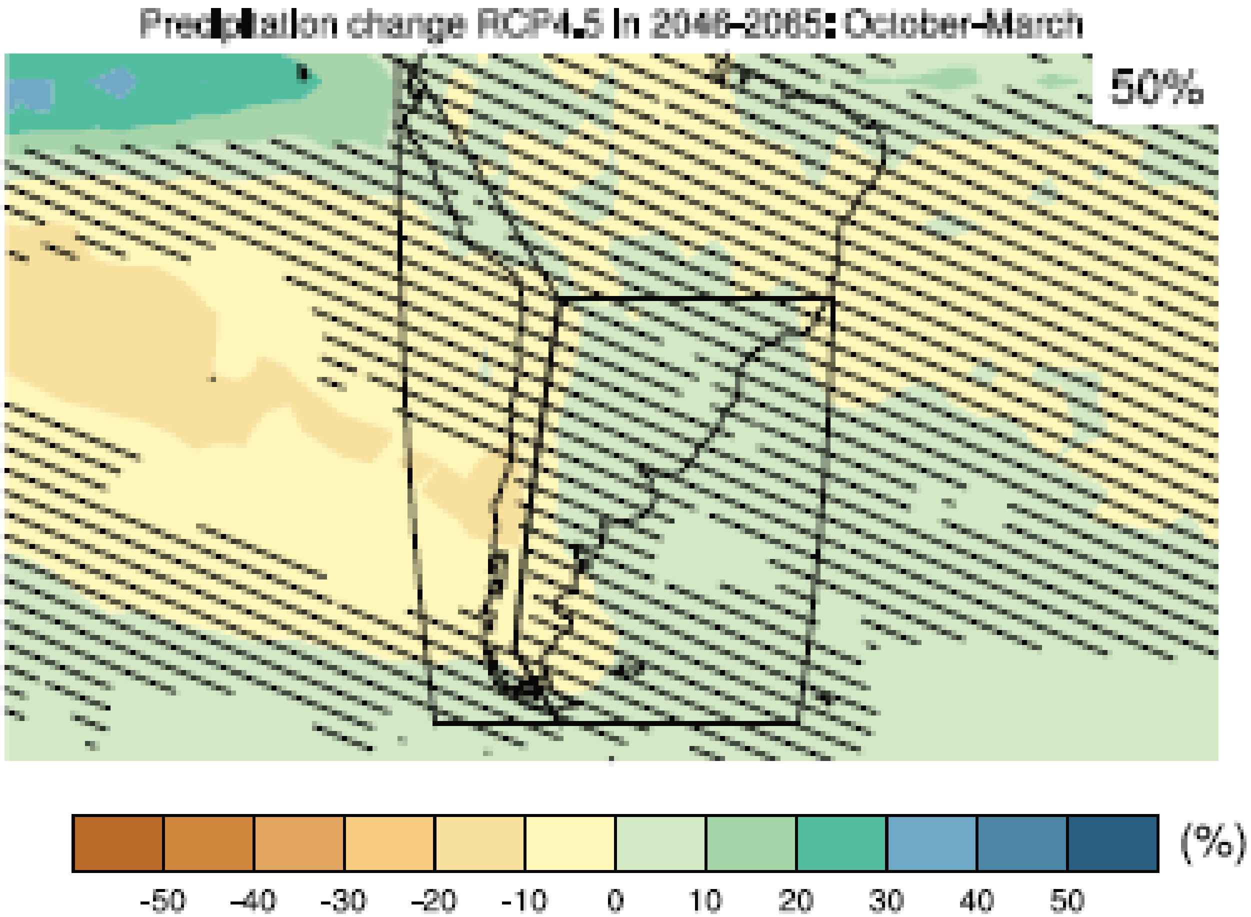
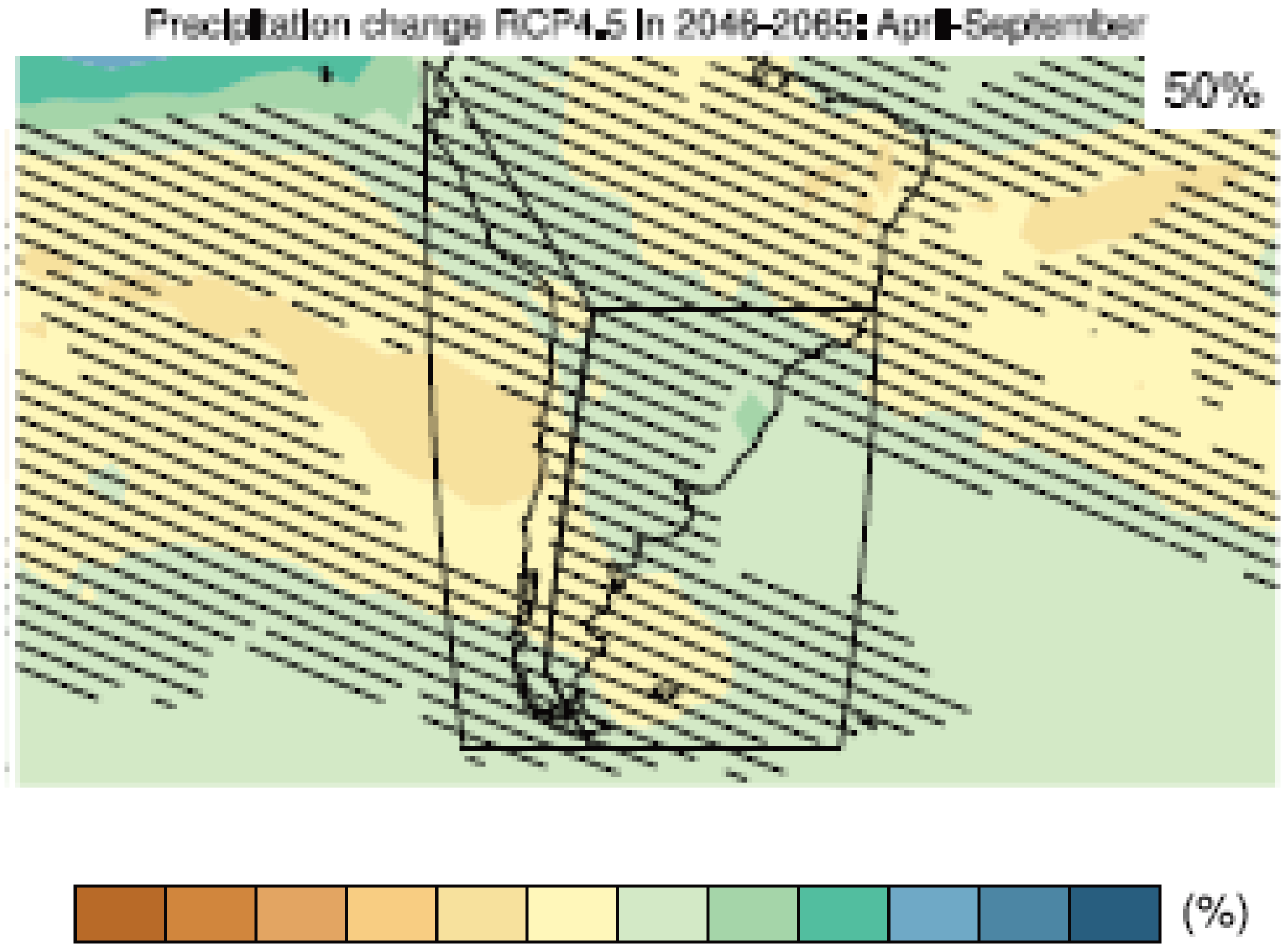
South America precipitation change: Oct–Mar 2046–2065



Source: IPCC, 2013

South America precipitation change: Apr–Sept 2046–2065



Source: IPCC, 2013

Thank you