Protected Areas Resilient to Climate Change, PARCC West Africa

2015

PARCC Project Training Manual

Module 2. Climate data and scenarios

ENGLISH

Met Office Hadley Centre

2015

The United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) is the specialist biodiversity assessment centre of the United Nations Environment Programme (UNEP), the world's foremost intergovernmental environmental organisation. The Centre has been in operation for over 30 years, combining scientific research with practical policy advice.

UNEP WCMC

PARCC Project Training Manual, prepared by UNEP-WCMC and all PARCC project technical partners (Met Office Hadley centre, IUCN Species Programme, BirdLife International, Durham University, and DICE University of Kent), with funding from Global Environment Facility (GEF) via UNEP.

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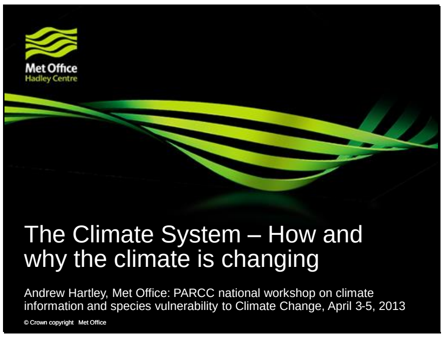
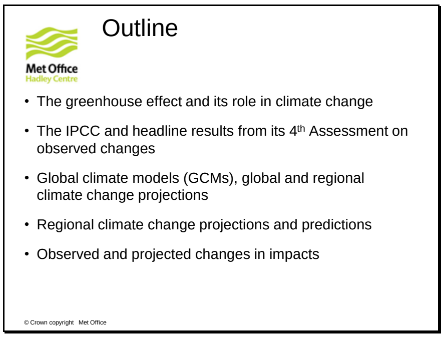
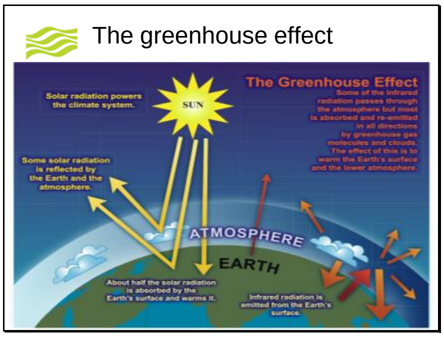
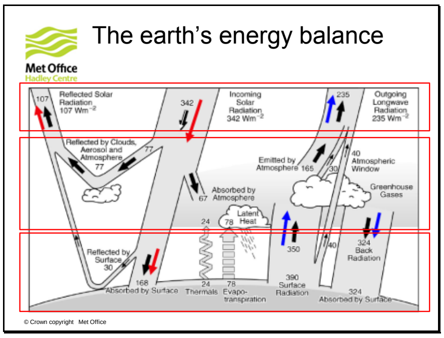
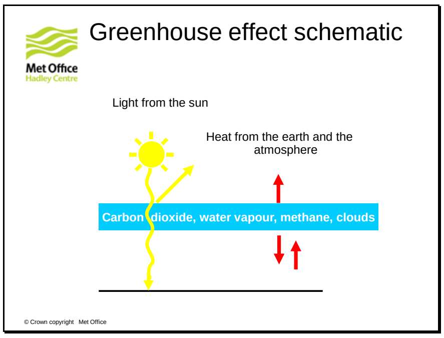
Chapter 1. The Climate System – How and why the climate is changing











The greenhouse effect is essential

If the sun only heated the earth then the temperature of the earth would be about -18° C (about the temperature of your freezer at home)

Carbon dioxide, water vapour, methane and other greenhouse gases in the atmosphere trap some of this heat

Because the atmosphere traps some of this heat it warms the earth so most of it is above freezing and able to sustain life

The main cause of current climate change is an enhancement of the greenhouse effect

Since people have started to use coal and oil for energy for factories, heating and transport they have increased the amount of carbon dioxide by about one-third

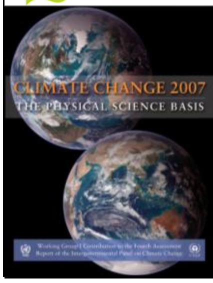
The number of people in the world has increased which has needed more farming which has increased the amount of methane in the atmosphere

Because this has made the atmosphere warmer there is now more water vapour in the atmosphere

Other causes of climate change include emission of aerosols, land-use change – and natural factors such as orbital changes and volcanoes

The IPCC and headline results from its 4th Assessment

IPCC (Intergovernmental Panel on Climate Change) 4th Assessment

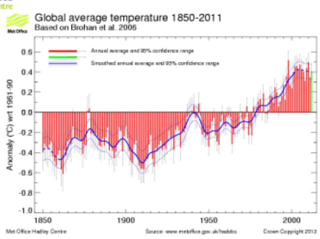


- IPCC 4th Assessment 2004 – 2007
- 152 Authors
- ~450 contributors
- ~600 expert reviewers
- 30,000+ review comments

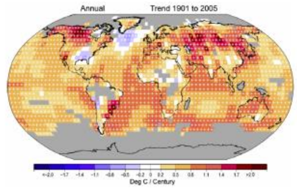
Contents

- Summary for Policymakers – **agreed by all governments**
- Technical Summary
- 11 Chapters + FAQ
- ~5000 literature references
- ~1000 pages

The world has warmed



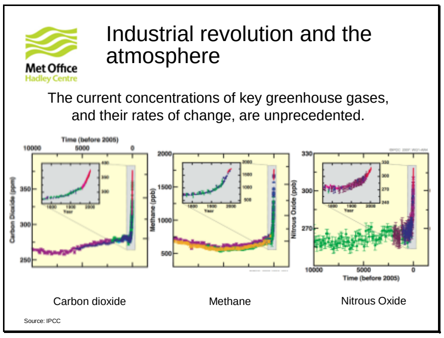
The world has warmed

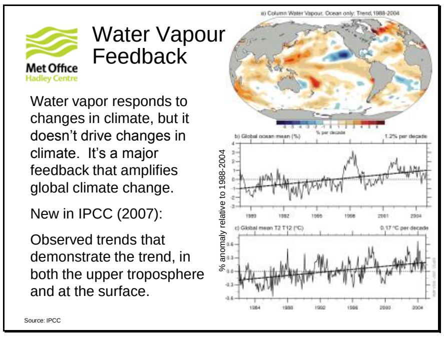


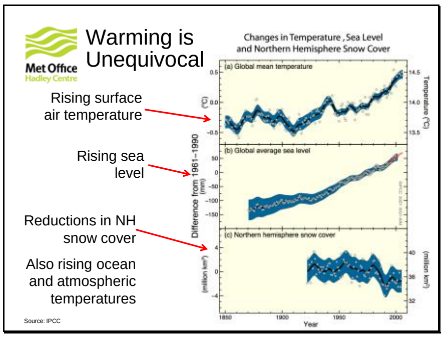
Globally averaged, the planet is about 0.75° C warmer than it was in 1860, based upon dozens of high-quality long records using thermometers worldwide, including land and ocean.

Eleven of the last 12 years are among 12 warmest since 1850 in the global average.

Source: IPCC


Industrial revolution and the atmosphere
Met Office
Hadley Centre
The current concentrations of key greenhouse gases, and their rates of change, are unprecedented.
Carbon dioxide
Methane
Nitrous Oxide
Source: IPCC


Water Vapour Feedback
Met Office
Hadley Centre
Water vapor responds to changes in climate, but it doesn't drive changes in climate. It's a major feedback that amplifies global climate change.
New in IPCC (2007):
Observed trends that demonstrate the trend, in both the upper troposphere and at the surface.
Source: IPCC


Warming is Unequivocal
Met Office
Hadley Centre
Changes in Temperature, Sea Level and Northern Hemisphere Snow Cover
Rising surface air temperature
Rising sea level
Reductions in NH snow cover
Also rising ocean and atmospheric temperatures
Source: IPCC


Met Office
Hadley Centre
Global climate models (GCMs), global and regional climate change projections
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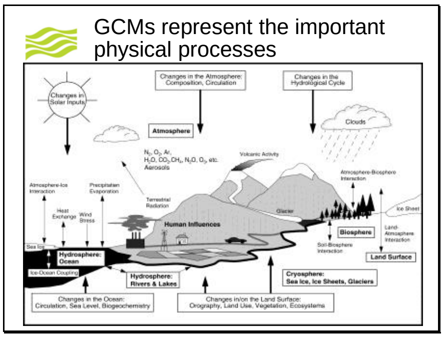
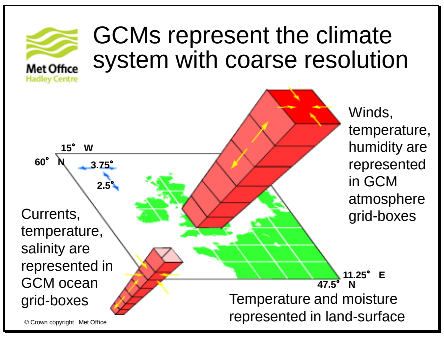

GCMs represent the important physical processes


GCMs represent the climate system with coarse resolution
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Hadley Centre
Winds, temperature, humidity are represented in GCM atmosphere grid-boxes
Currents, temperature, salinity are represented in GCM ocean grid-boxes
Temperature and moisture represented in land-surface
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GCMs and predicting regional climate change

~ 20 modelling centres around the world have built and run GCMs for understanding and predicting climate change

Modelling experiments are organised by the Coupled Modelling Intercomparison Project (CMIP)

Models run under the third CMIP (CMIP3) were widely used and assessed in the IPCC AR4

Currently, models run for CMIP5 are being analysed and assessed as part of IPCC AR5

Using GCMs to understand the drivers of the warming

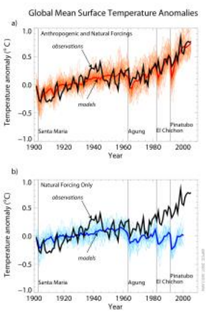
- Are observed changes consistent with

☑ expected responses to forcings

☒ with alternative explanations

Most of the observed increase in globally averaged temperatures since 1950s due to the observed increase in anthropogenic greenhouse gases

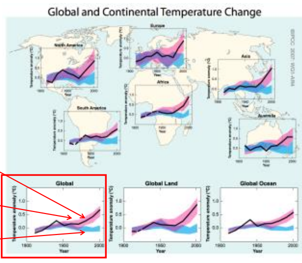
Applying global models with natural and observed forcings is key to this understanding



Source: IPCC

Understanding and attributing regional climate change

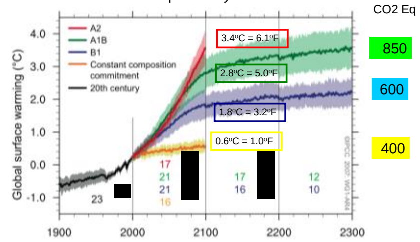
Anthropogenic warming is discernible on all inhabited continents



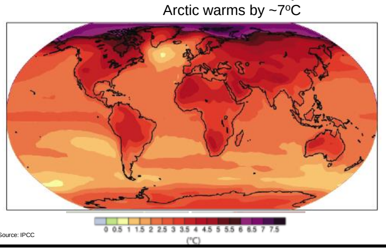
Source: IPCC

What will and what may happen

Warming will increase if GHG increase. If GHG were fixed at current levels, 0.6° C more warming would be expected by 2100.

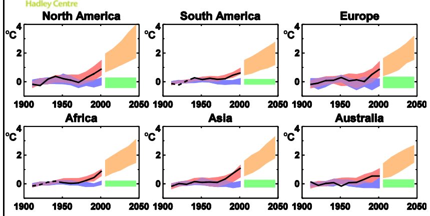


With A1B emissions (typical "business as usual") the average of CMIP3 global climate model projections has:
Global mean warming 2.8°C by 2090-2099;
Much of land area warms by ~3.5°C
Arctic warms by ~7°C



Source: IPCC

How unusual would this be regionally? Observed, simulated and future temperature ranges with human and natural forcings



Significant "predicted" regional temperatures rises in which we have confidence given the models' responses to observed forcing

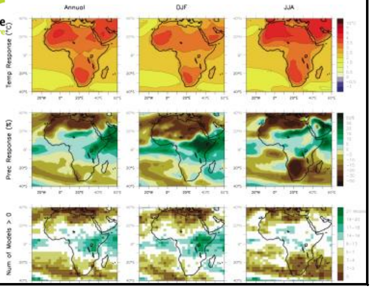
IPCC summary of temperature and rainfall changes from CMIP3 models

Met Office Hadley Centre

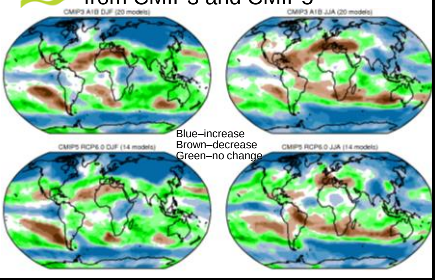
ΔT

ΔP

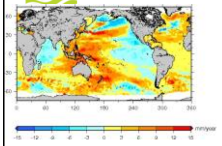
|ΔP| agree-ment

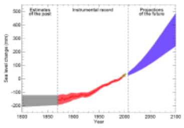


Projected changes in precipitation from CMIP3 and CMIP5



Sea level rise in a warmer world





Observations of sea level rise from satellites, 1993-2003.

The global average SLR for the 20th century was about 17cm, mostly from expansion of the warming oceans with contributions from glacier melt (Alaska, Patagonia, Europe….).

Future changes just from these processes could be up to 0.5 m by 2100, and up to 1m within about 2-3 centuries, depending on how much GHGs are emitted.

Other processes such as loss of major ice sheets could increase these changes

Source: IPCC

Regional climate predictions and projections

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Statements we have confidence in:

Seasonal temperature will increase in all regions – models respond as we would expect to observed forcings

Seasonal precipitation will change in many regions – confident statements can be made where the dominant processes are driven by warming

Sea-levels will rise in all regions – global average range from observations and process understanding, regional range due to model-dependent variability in patterns

Regional climate scenarios

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Available regional climate scenarios include clear predictions (temperature, sea-level rise) and projections where we have less confidence (precipitation, tropical storms)

Thus some clear basis for decision-making but this needs to be done using information with different levels of confidence

Most information is derived from global climate models (GCMs) which do not provide sufficient detail at the country level

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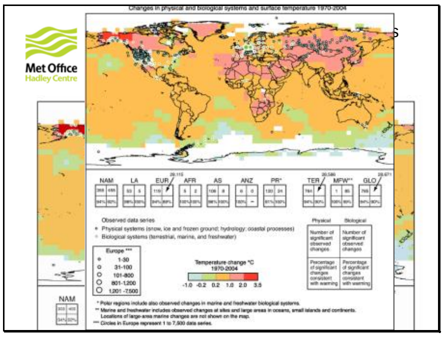
Observed and projected changes in impacts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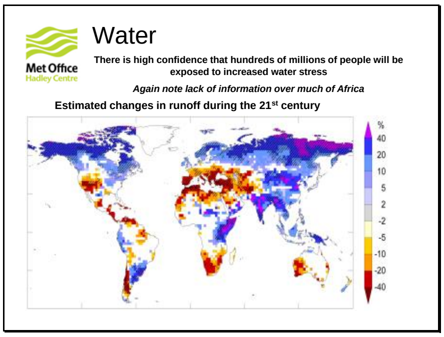
Changes in physical and biological systems and surface temperature 1970-2004
NAM
LA
EUR
AFR
AS
ANZ
PR*
TER
MFW**
GLO
Observed data series
Physical
Biological
Europe ***
Temperature change °C
1970-2004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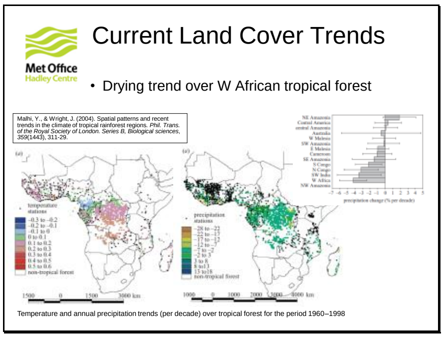
Water
There is high confidence that hundreds of millions of people will be exposed to increased water stress
Again note lack of information over much of Africa
Estimated changes in runoff during the 21st century
%
40
20
10
5
2
-2
-5
-10
-20
-40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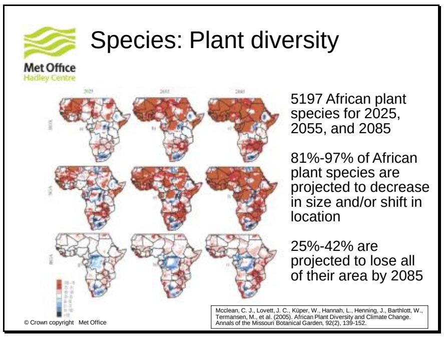
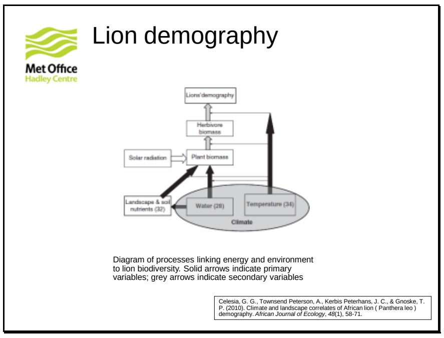
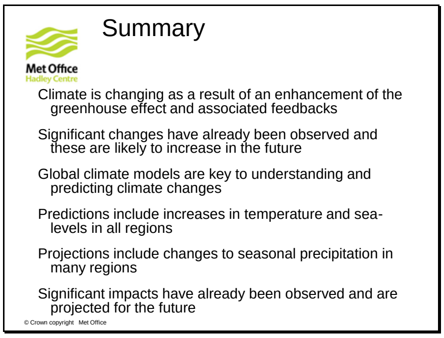
Current Land Cover Trends
• Drying trend over W African tropical forest
Malhi, Y., & Wright, J. (2004). Spatial patterns and recent trends in the climate of tropical rainforest regions. Phil. Trans. of the Royal Society of London. Series B, Biological sciences, 359(1443), 311-29.
Temperature and annual precipitation trends (per decade) over tropical forest for the period 1960–1998


Met Office
Hadley Centre
Species: Plant diversity
5197 African plant species for 2025, 2055, and 2085
81%-97% of African plant species are projected to decrease in size and/or shift in location
25%-42% are projected to lose all of their area by 2085
© Crown copyright Met Office
Mcclean, C. J., Lovett, J. C., Küper, W., Hannah, L., Henning, J., Barthlott, W., Termansen, M., et al. (2005). African Plant Diversity and Climate Change. Annals of the Missouri Botanical Garden, 92(2), 139-152.


Met Office
Hadley Centre
Lion demography
Lions' demography
Herbivore biomass
Solar radiation
Plant biomass
Landscape & soil nutrients (32)
Water (28)
Temperature (34)
Climate
Diagram of processes linking energy and environment to lion biodiversity. Solid arrows indicate primary variables; grey arrows indicate secondary variables
Celesia, G. G., Townsend Peterson, A., Kerbis Peterhans, J. C., & Gnoske, T. P. (2010). Climate and landscape correlates of African lion (Panthera leo) demography. African Journal of Ecology, 48(1), 58-71.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Summary
Climate is changing as a result of an enhancement of the greenhouse effect and associated feedbacks
Significant changes have already been observed and these are likely to increase in the future
Global climate models are key to understanding and predicting climate changes
Predictions include increases in temperature and sea-levels in all regions
Projections include changes to seasonal precipitation in many regions
Significant impacts have already been observed and are projected for the future
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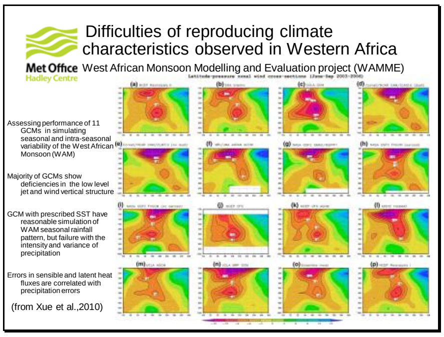
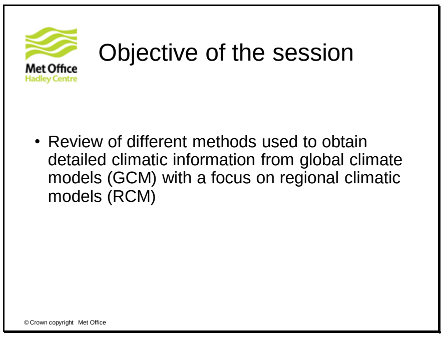
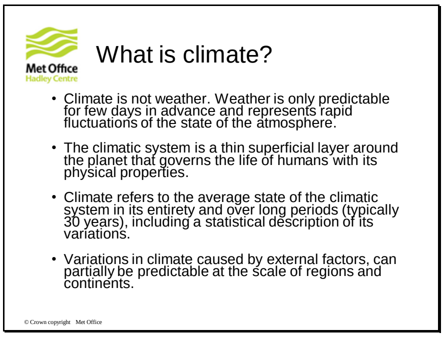
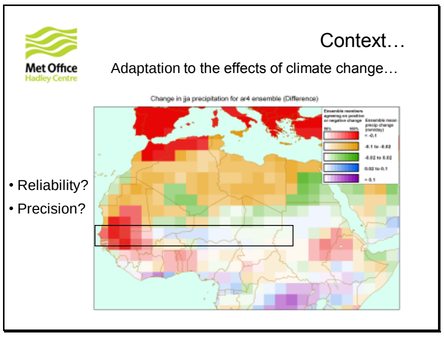
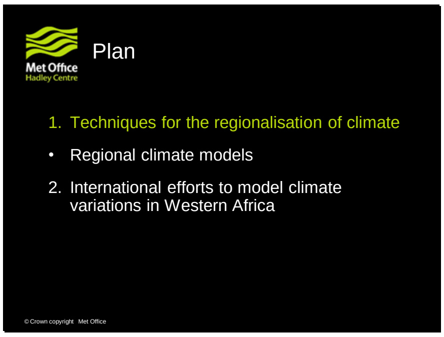
Chapter 2. Modelling regional climate











Techniques for the regionalisation of climate?

- These techniques allow to extract precise information from outputs of GCMs.
- The climate of a region results from interactions of global climate and local physiographic characteristics.
- Impact evaluators need regional climatic details for vulnerability studies and to define adaptation.
- The projections of OAGCM lack regional details because of the coarse spatial resolution
- Down-scaling with regard to evaluations of climate change is different from down-scaling seasonal climate predictions.

Statistical and empirical techniques

From historic data :

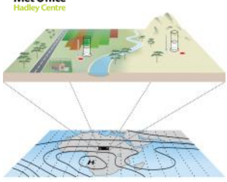
Local variable = Φ (large-scale variable(s))

From ÒAGCM outputs :

Local predicted variable = Φ (large-scale variable)

Φ is applied to the results of GCM to obtain a future local variable

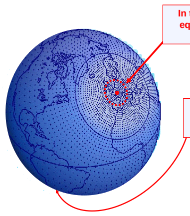
Proceed from global to local climate...



Local / Regional: spatial scale required for climate impact studies.

Continental: scale at which the outputs of Global Circulation Models (GCM) are reliable.

Caracteristics of the elastic grid of AGCM



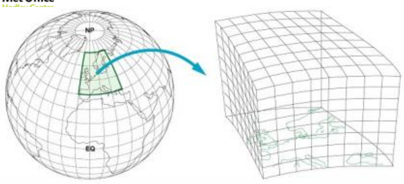
In this place, the spatial resolution is equivalent to one grid cell of roughly 30km.

The spatial resolution is progressively relaxed with a deplacement towards the antipods (close to New Zealand).

Classification

- Statistical
  - Climate generators
  - Transfer functions
  - Climate typology
- Dynamic
  - High resolution and variable resolution of AGCM
  - Regional climate models
- Statistical/Dynamic

Regional Climate Models



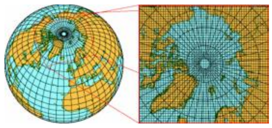
Regional atmospheric modelling : nested in a general circulation model

Criteria of relevance of the techniques for the regionalisation of climate

- Coherence at the regional level with global projections
- Physical plausibility and realism
- Adequacy of information for impact evaluation
- Representativeness of future climatic changes
- Accessibility for the utilisation in impact studies

Regional Climate Models

- Cover only a limited portion of the planet.
- Like GCMs, incorporate a detailed representation of the atmosphere, continental surfaces and and can simulate the evolution of weather (and of climate).



Relevance of techniques for the regionalisation

Method	Strength	Weaknesses
Statistical	• High resolution • Little computing power required for the calculations	• depends on an empirical relation derived from present climate • depends on long and high quality chronological series • few variables are available • not easily transposed
AGCM high–resolution	• High (very high) resolution • Can present extremes	• depends on the surface conditions of the coupled ocean–atmosphere model • expensive in terms of computing power • parameterise sub–grid cell processes
Regional models	• Physical base • Multiple variables • RCM : easily transposable	• depends on the conditions of the lateral boundaries • conditions at the surface limits • absence of bidirectional imbrication • parameterise different scales

Physical parameterisation

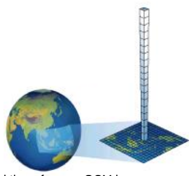
In climatic models, this terms refers to the technique of representing processes that cannot be explicitly resolved at the scale of the spatial or temporal resolution of the model (that means sub-grid cell scale processes), by relations between the area or average influence of the process at the grid-cell scale and the large-scale circulation.

Plan

1. Techniques for the regionalisation of climate
   - Regional Climate Models
2. International efforts to model climate variations in Western Africa

Uni-directional imbrication

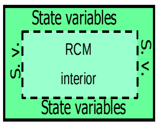
- A RCM is a limited aera model (LAM), similar to those used to forecast weather (NWP)
- RCM are forced from the lateral boundaries by GCM outputs or analytical data. . .



- The deviations between a RCM and the reference GCM have a tendency to be more important towards the surface and the middle of the domain.

Conditions at the lateral boundaries

- Method of relaxation (PRECIS,RegCM)
  - Forcing at the large scale with a lateral buffer
- Spectral imbrication(CRCM)
- Large sale forcing of the components with low wave numbers
- Important questions
  - The resolution of spatial reference data
  - Update frequency of the reference data



Evaluate the accuracy with which the projecting system reproduces the current climate

- **Model system = GCM + RCM**
- **Question1. Are there incoherences in the model system?**
  - Amongst the parts of the system
  - Among a part of the system and "reality"
- **Question 2. If yes, why?**
  - Systematic biais of the model (errors in the physical concepts underlying the model)
  - Spatial sampling problems (differences in the resolution of the model and observations)
  - Mistake in the observations (problems with the grid, problems link to instruments)

Conditions at the oceanic surface boundary

Two methods to obtain the oceanic surface temperature (OST) and ice thickness :

- Use a coupled OAGCM
  - ➢ Necessitates a high-quality simulation of the OST and sea ice in the model.
- Use observations
  - ➢ For the simulation of the observed climate.
  - ➢ In the case of the simulation of future climates, the observed values with noted changes of the OST and the ice produced by a coupled GCM simulation

Types of validation

- These techniques can be applied to four types of validation :
  - 1) GCM vs. observations
  - 2) RCM derived from a GCM vs. GCM
  - 3) RCM derived from a GCM vs. observations
  - 4) RCM derived from observations vs. observations
- The level of validation depends on the experimental design. For example :
  - Sensitivity or process analysis based on observed boundary conditions 4)
  - Climatic changes: 2) and 3), maybe 1)

Validation of the climate model

- The validation of the model is **ESSENTIAL** :
  - ➢ A simulation could be made in areas where the performance has never been tested.
  - ➢ Allows to familiarise one-self with the characteristics of the model
  - ➢ It is an indicator of the level of credibility of the RCM outputs and for the best way to make use of the results.

1) Measure the realism of a GCM

- ➢ Compare what is comparable
  - The GCM is onle applicable at the maximum spatial resolution of its grid (large)
  - Aggregate or interpolate the GCM output or observations
- ➢ Annual output of GCM cannot be compared individually with annual observations
  - The atmospheric response to the modelled external forcing is not guaranteed to correspond to the real atmosphere (example : OST, CO_2).

2) Evaluate the coherence between RCM and GCM

RCM ← coherence → GCM
realism
Observations

- Question : At which point does the RCM becomes contradictory to the GCM
  - Very important in the context of climate change
- Necessity of including the interannual variability in the comparisson
  - In certains years , the important of the boundary forcing is higher than in others : minimum of three years to include all interannual variability
- Examine the seasons separately to confirm the behaviour under generally different forcing regimes

4) Derived experiences from the re-analysis

MCR ← coherence
realism
Observations

- The BCs *"quasi-observational"* allow an alternative validation of RCM, by testing the capacity of the model in the absence of large-scale errors inherent to GCM
- The BC are those of a GCM of the only atmosphere which is limited to observations by satellites, sondes, terrestrial stations, ships , buoys etc. Les CLs sont celles d'un MCG de la seule atmosphère qui se limite aux observations de satellites, de sondes, de stations terrestres, de navires, de bouées, etc.
- The RCM is forced by reproductions of reality at both the external (example: temperatures observed at the ocean surface: OST) and internal level (Bcs quasi-observed)
  - Given the possibility of comparisons between RCM and periods of observations or particular events.

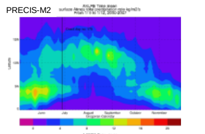
3) Evaluate to which extent the RCM reflects the current climate

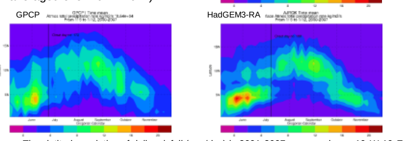
MCR ← coherence → MCG
realism
realism
Observations

- Compare what is comparable
  - A RCM is reliable uniquely at the spatial resolution of its grid (fine
  - Necessity to aggregate or interpolate the GCM output or observations
- Annual output of GCM cannot be compared individually with annual observations (for the same reasons that apply to GCM)
- The errors are a combination of the three sources :
  - 1) Physical errors in the GCM that affect the boundary conditions (BC)
  - 2) Errors of coherence between RCM and GCM
  - 3) Physical errors in the RCM

Intraseasonal variability of precipitation (onset)

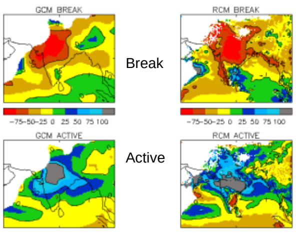
Definition of Onset: Date at which the main precipitation area migrates north of 10 N (using temporally smoothed data averaged over 10 W-10 E)



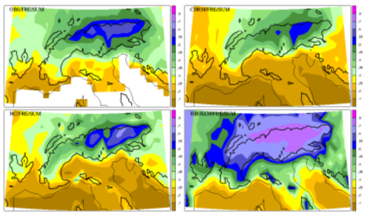


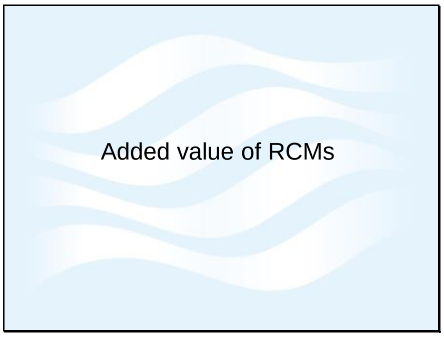
Time-latitude evolution of daily rainfall (mm/day) in 2001-2007, averaged over 10 W-10 E

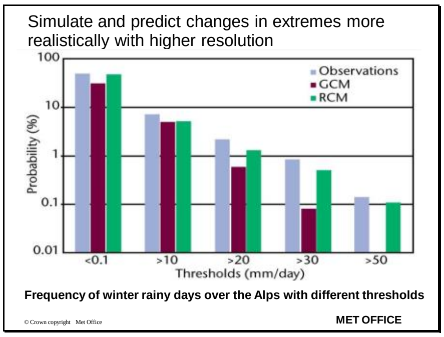
Intra-seasonal variability of the Indian Monsoon active phase/secession of precipitation

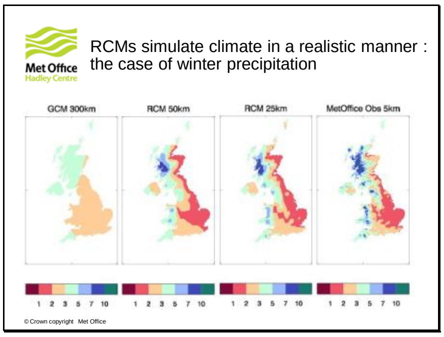


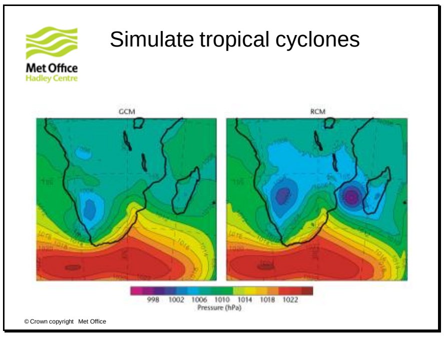
Frequency of rainy days for 3 RCMs over the Alpes, in summer, compared to observations

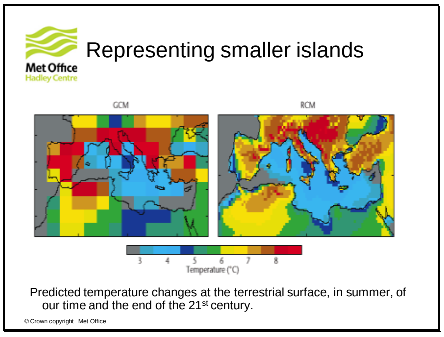


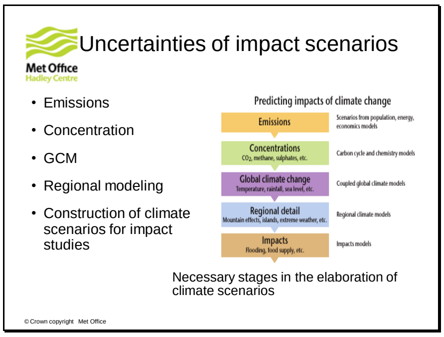

Added value of RCMs

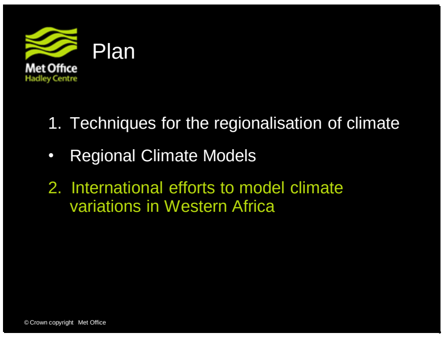

Simulate and predict changes in extremes more realistically with higher resolution
Probability (%)
100
10
1
0.1
0.01
Observations
GCM
RCM
<0.1
>10
>20
>30
>50
Thresholds (mm/day)
Frequency of winter rainy days over the Alps with different thresholds
MET OFFICE

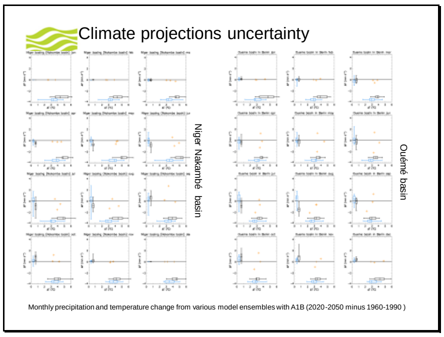

Met Office
Hadley Centre
RCMs simulate climate in a realistic manner : the case of winter precipitation
GCM 300km
RCM 50km
RCM 25km
MetOffice Obs 5km
1 2 3 5 7 10
© Crown copyright Met Office

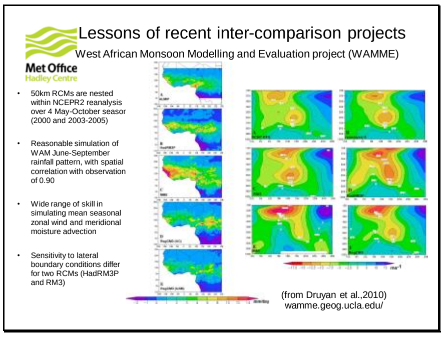

Met Office
Hadley Centre
Simulate tropical cyclones
GCM
RCM
998 1002 1006 1010 1014 1018 1022
Pressure (hPa)
© Crown copyright Met Office

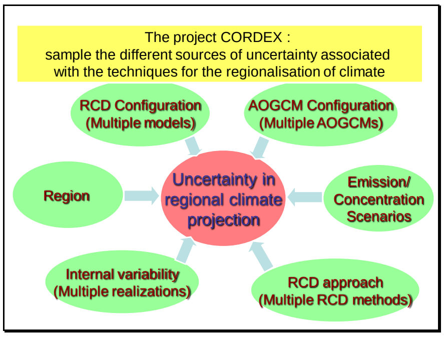

Met Office
Hadley Centre
Representing smaller islands
GCM
RCM
3 4 5 6 7 8
Temperature (°C)
Predicted temperature changes at the terrestrial surface, in summer, of our time and the end of the 21st century.
© Crown copyright Met Office

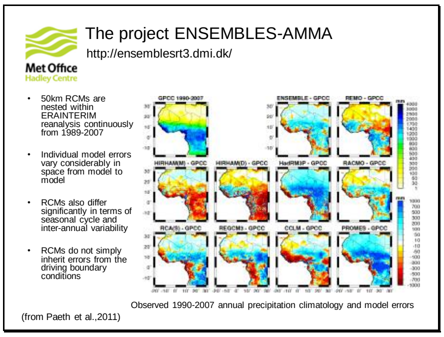

Met Office
Hadley Centre
Uncertainties of impact scenarios
• Emissions
• Concentration
• GCM
• Regional modeling
• Construction of climate scenarios for impact studies
Predicting impacts of climate change
Emissions
Concentrations
Global climate change
Regional detail
Impacts
Necessary stages in the elaboration of climate scenarios
© Crown copyright Met Office

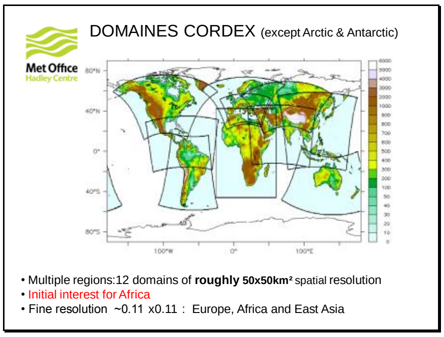

Plan
1. Techniques for the regionalisation of climate
• Regional Climate Models
2. International efforts to model climate variations in Western Africa
© Crown copyright Met Office

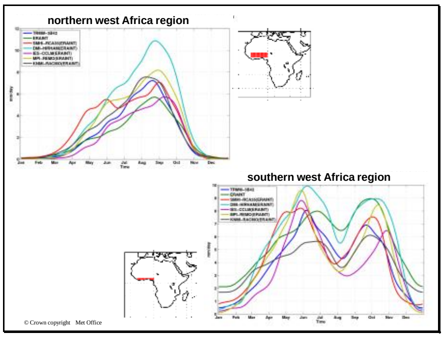

Climate projections uncertainty
Niger Nakambé basin
Ouémé basin
Monthly precipitation and temperature change from various model ensembles with A1B (2020-2050 minus 1960-1990)


Lessons of recent inter-comparison projects
West African Monsoon Modelling and Evaluation project (WAMME)
• 50km RCMs are nested within NCEPR2 reanalysis over 4 May-October season (2000 and 2003-2005)
• Reasonable simulation of WAM June-September rainfall pattern, with spatial correlation with observation of 0.90
• Wide range of skill in simulating mean seasonal zonal wind and meridional moisture advection
• Sensitivity to lateral boundary conditions differ for two RCMs (HadRM3P and RM3)
(from Druyan et al.,2010)
wamme.geog.ucla.edu/


The project CORDEX :
sample the different sources of uncertainty associated with the techniques for the regionalisation of climate
RCD Configuration (Multiple models)
AOGCM Configuration (Multiple AOGCMs)
Region
Uncertainty in regional climate projection
Emission/ Concentration Scenarios
Internal variability (Multiple realizations)
RCD approach (Multiple RCD methods)


The project ENSEMBLES-AMMA
http://ensemblesrt3.dmi.dk/
• 50km RCMs are nested within ERAINTERIM reanalysis continuously from 1989-2007
• Individual model errors vary considerably in space from model to model
• RCMs also differ significantly in terms of seasonal cycle and inter-annual variability
• RCMs do not simply inherit errors from the driving boundary conditions
GPCC 1990-2007
ENSEMBLE - GPCC
REMO - GPCC
HIRHAM(M) - GPCC
HIRHAM(D) - GPCC
HadRM3P - GPCC
RACMO - GPCC
RCA(S) - GPCC
REGCM3 - GPCC
CCLM - GPCC
PROMES - GPCC
Observed 1990-2007 annual precipitation climatology and model errors
(from Paeth et al.,2011)

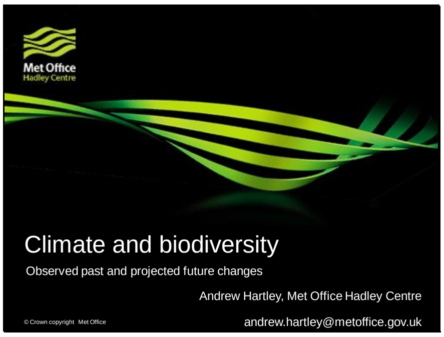

DOMAINES CORDEX (except Arctic & Antarctic)
• Multiple regions:12 domains of roughly 50x50km² spatial resolution
• Initial interest for Africa
• Fine resolution ~0.11 x0.11 : Europe, Africa and East Asia

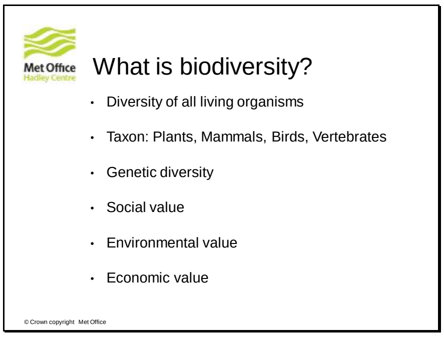


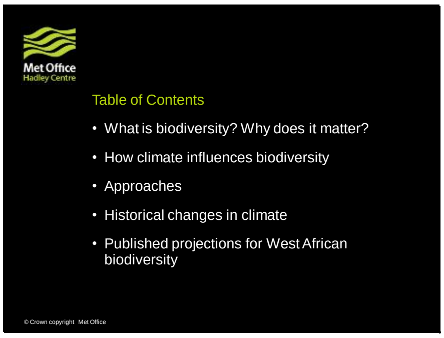
Conclusions

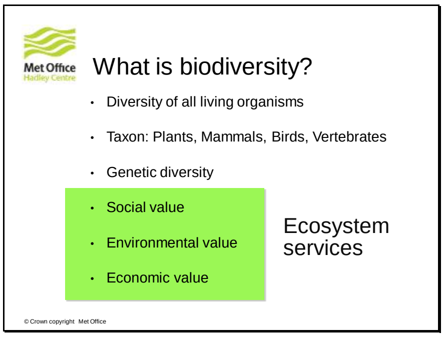
- The techniques for the regionalisation of climate are used to extract fine-scale climatic informations from GCM projections
- Multiple methods for the regionalisation of climate exist and have mixed advantages (and disadvantages)
- The regional climate model is a tool based on physical and mathematical principles , and is easily accessible to generate climate scenarios of fine-scale spatial resolution.
- Only dynamic methods of prediction of climate changes are capable of providing realistic and coherent climate scenarios.
- The choice of method for the regionalisation of climate adds adegree of uncertainty on top of the evaluation of the effect of climat change on the environment and society.

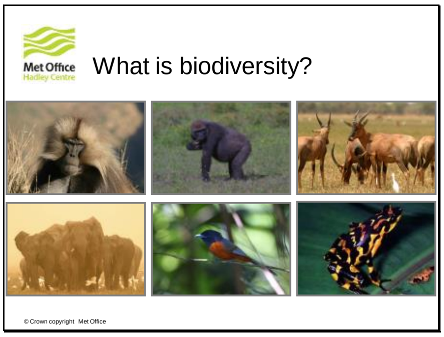
Chapter 3. Climate and biodiversity: Observed past and projected future changes

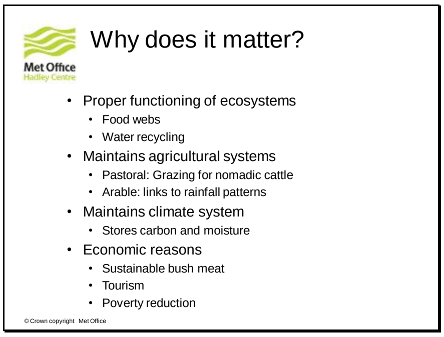












How does climate influence biodiversity?

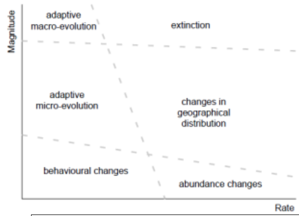
How does weather/climate influence biodiversity?

Growth	Expanding climatic niches Reproduction Dispersion CO_2 fertilisation More efficient water use
Decline	Shifting climatic niche Invasive species Extreme events – drought, floods Alters dependence between species Large scale ecosystem change

How does weather/climate influence biodiversity?

Growth	
Decline	

Magnitude and rate of Climate Change



Huntley, B., et al. (2010). Beyond bioclimatic envelopes: dynamic species' range and abundance modelling in the context of climatic change. Ecography, (33), 621-626.

How does weather/climate influence biodiversity?

Growth	Expanding climatic niches Reproduction Dispersion CO_2 fertilisation More efficient water use
Decline	

Exercise

- What species occur in your country?
- What are the benefits of biodiversity in your country?
- How might these species depend on or affect the climate?

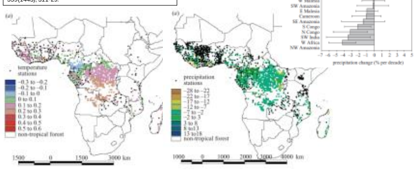
Historical changes in biodiversity

Has the climate influenced biodiversity in the past?

Current Land Cover Trends

- Drying trend over W African tropical forest

Malhi, Y., & Wright, J. (2004). Spatial patterns and recent trends in the climate of tropical rainforest regions. *Phil. Trans. of the Royal Society of London. Series B, Biological sciences*, 359(1443), 311-29.



Temperature and annual precipitation trends (per decade) over tropical forest for the period 1960–1998

Evidence of change

- In Northern Hemisphere, northern and upper elevation boundaries moved, on average, 6.1 km per decade northward or 6.1 m per decade upward ($P < 0.02$) (Parmesan & Yohe 2003).
- Phenological responses give estimates of advancement of 2.3 days per decade across all species (Parmesan & Yohe 2003)
- 5.1 days per decade for those species showing substantive change (Root et al. 2003).

Lion demography

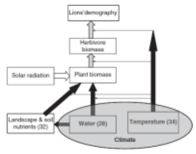


Diagram of processes linking energy and environment to lion biodiversity. Solid arrows indicate primary variables; grey arrows indicate secondary variables

Celesia, G. G., Townsend Peterson, A., Kerbis Peterhans, J. C., & Gnoske, T. P. (2010). Climate and landscape correlates of African lion (Panthera leo) demography. *African Journal of Ecology*, 48(1), 58-71.

Changes in phenology

- Temperate regions (esp. Europe and N. America) have robust long term records
- Butterfly populations sensitive to spring temperatures
- Japan cherry blossom records (Menzel & Dose, 2005):
  - 1400-1900 no significant trend
  - statistically significant change point early 1900s
  - steady advancement since 1952
- April-August temperatures explain 84% of the variation in European grape harvest

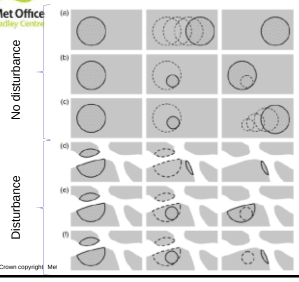
Approaches

How to relate biodiversity to climate

Approaches

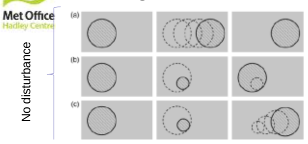
- Bioclimatic Envelope Models (aka Niche Models; Species Distribution Models)
- Extremes / thresholds that maybe relevant to ecosystems
- Dynamic Global Vegetation Models

Shifting bioclimatic niches



Hof *et al.* 2011

Shifting bioclimatic niches



Hof *et al.* 2011

What's missing?

- Climate variability – decadal / inter-annual / seasonal
- Dispersal ability
- Population dynamics – interaction / competition
- Adaptive capacity – mechanistic responses
- Response to elevated CO_2
- Non-climatic factors
- Disturbance
- Species – area curve assumptions

Bioclimatic Envelope Models

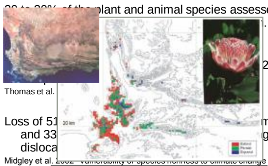
plant and animal species assessed so far

2050 in

Thomas et al.

Loss of 51 ... me area, and 33 ... ge disloca

Midgley et al. ... in a biodivers

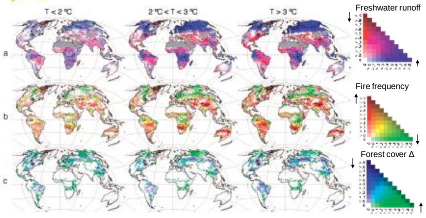


Protea lacticolor, a species endemic to the South African Cape Floristic Region. Source: Hannah, *et al.* 2005. BioScience, 55(3)

Approaches

- Bioclimatic Envelope Models (aka Niche Models; Species Distribution Models)
- Extremes and thresholds that maybe relevant to ecosystems
- Dynamic Global Vegetation Models

Extremes and thresholds

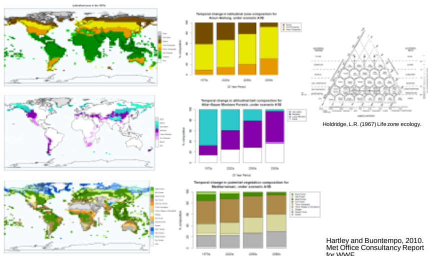


Scholze, *et al.* 2006. A climate-change risk analysis for world ecosystems. PNAS 103:13116-20.

Approaches

- Bioclimatic Envelope Models (aka Niche Models; Species Distribution Models)
- Extremes / thresholds that maybe relevant to ecosystems
- Dynamic Global Vegetation Models

Extremes and thresholds

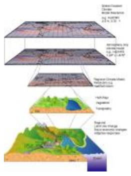


Holdridge, L.R. (1967) Life zone ecology.

Hartley and Buontempo, 2010. Met Office Consultancy Report for WWF

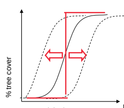
Dynamic Global Vegetation Models

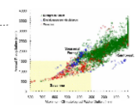
- Interactions between atmosphere and land surface
- Competition between plant functional types
- Cox et al. 2004 "Amazonian forest dieback under climate-carbon cycle projections"
  - atmosphere-land interactions
  - simple competition between plant functional types
  - Possible drying trend in parts of Amazon



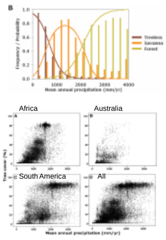
What's missing?

- Sensitivity to threshold exceedance?
- Mechanistic responses – will species adapt?
- Micro-climate inertia, or rapid change due to fire?
- Hysteresis



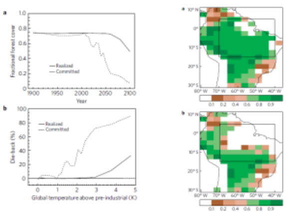


Malhi *et al*, 2009. Exploring the likelihood and mechanism of a climate-change-induced dieback of the Amazon rainforest. PNAS, 2009



Hirota *et al*, 2011. Global Resilience of tropical forest and savannah to critical transitions. Science, 334

Dynamic Global Vegetation Models



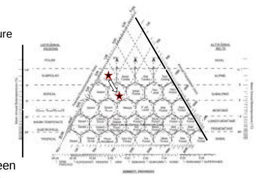
Jones *et al.* 2009. Committed terrestrial ecosystem changes due to climate change. Nature Geoscience, 2(7)

What's missing?

- Intended to characterise land-atmosphere interactions
- Limited number of PFTs
- Validate poorly against land cover observations
- Difficult to communicate uncertainties to non-specialists

Large Scale Terrestrial Ecosystems: Holdridge Life Zones

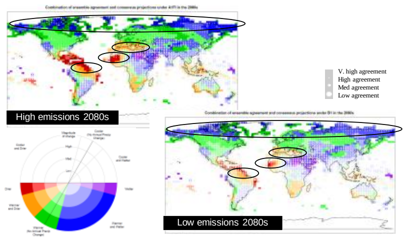
- Combination of:
  - Biotemperature – average growing season temperature
  - Annual precipitation
- Can be used to classify
  - Latitudinal zones
  - Altitudinal zones
  - Potential vegetation
- Magnitude of change between present and future climates



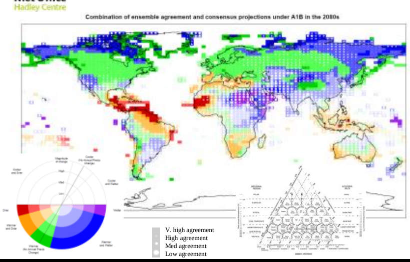
Projections for W African biodiversity

How might climate impact on biodiversity in the future?

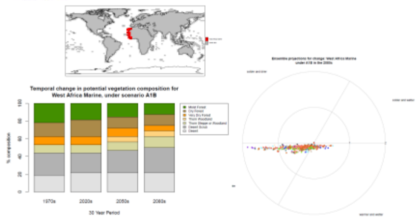
Large Scale Terrestrial Ecosystems

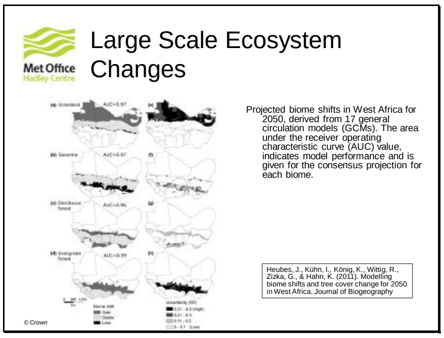


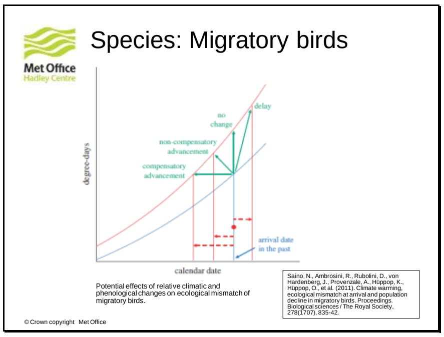
Large Scale Terrestrial Ecosystems



Large Scale Ecosystem Changes




Met Office
Hadley Centre
Large Scale Ecosystem Changes
Projected biome shifts in West Africa for 2050, derived from 17 general circulation models (GCMs). The area under the receiver operating characteristic curve (AUC) value, indicates model performance and is given for the consensus projection for each biome.
Heubes, J., Kühn, I., König, K., Wittig, R., Zizka, G., & Hahn, K. (2011). Modelling biome shifts and tree cover change for 2050 in West Africa. Journal of Biogeography
© Crown


Met Office
Hadley Centre
Species: Migratory birds
delay
no change
non-compensatory advancement
compensatory advancement
degree-days
arrival date in the past
calendar date
Potential effects of relative climatic and phenological changes on ecological mismatch of migratory birds.
Saino, N., Ambrosini, R., Rubolini, D., von Hardenberg, J., Provenzale, A., Hüppop, K., Hüppop, O., et al. (2011). Climate warming, ecological mismatch at arrival and population decline in migratory birds. Proceedings. Biological sciences / The Royal Society, 278(1707), 835-42.
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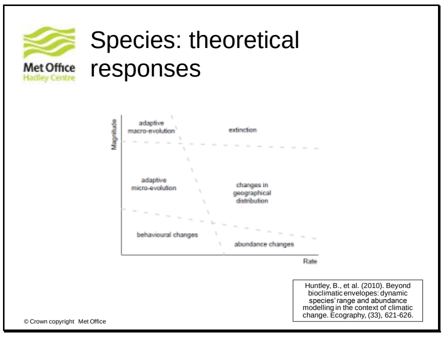
Met Office
Hadley Centre
Species: theoretical responses
Magnitude
adaptive macro-evolution
extinction
adaptive micro-evolution
changes in geographical distribution
behavioural changes
abundance changes
Rate
Huntley, B., et al. (2010). Beyond bioclimatic envelopes: dynamic species' range and abundance modelling in the context of climatic change. Ecography, (33), 621-626.
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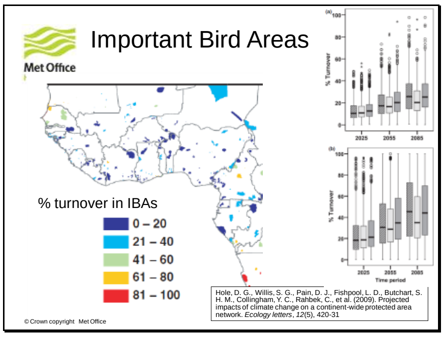
Met Office
Important Bird Areas
% turnover in IBAs
0 – 20
21 – 40
41 – 60
61 – 80
81 – 100
% Turnover
2025
2055
2085
Time period
Hole, D. G., Willis, S. G., Pain, D. J., Fishpool, L. D., Butchart, S. H. M., Collingham, Y. C., Rahbek, C., et al. (2009). Projected impacts of climate change on a continent-wide protected area network. Ecology letters, 12(5), 420-31
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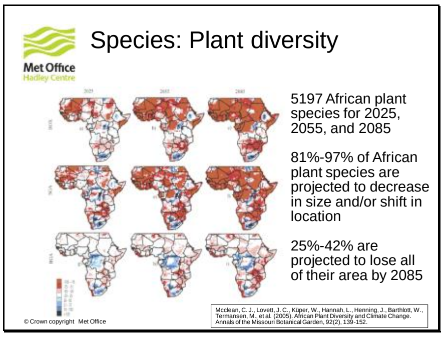
Met Office
Hadley Centre
Species: Plant diversity
5197 African plant species for 2025, 2055, and 2085
81%-97% of African plant species are projected to decrease in size and/or shift in location
25%-42% are projected to lose all of their area by 2085
Mcclean, C. J., Lovett, J. C., Küper, W., Hannah, L., Henning, J., Barthlott, W., Termansen, M., et al. (2005). African Plant Diversity and Climate Change. Annals of the Missouri Botanical Garden, 92(2), 139-152.
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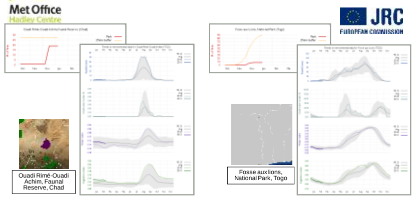
Any questions?

Climate and biodiversity

Integrating climate science into adaptation actions

Monitoring and early warning



Lessons learnt from earth observation, monitoring. Seasonal forecasting

The Assessment of African Protected Areas (2007) Hartley, A., Nelson, A., Mayaux, P. and Grégoire, J-M. JRC Scientific and Technical Reports. Office for Official Publications of the European Communities, Luxembourg, EUR 22780 EN. http://bioval.jrc.ec.europa.eu/APAAT/

How to support adaptation to climate change

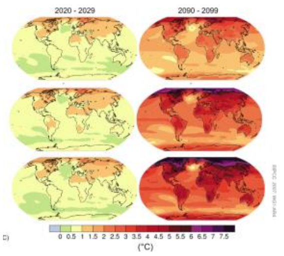
- Understand:
  - Existing climate-related vulnerabilities
  - Climatic extremes and why they occur
  - How species ranges may shift in response to climate change
- Monitoring, early warning and seasonal forecasting
- Climate projections and uncertainties
- Support land use planning

Climate Projections: IPCC 4th Report

B1

A1B

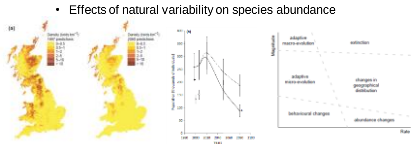
A2



Change relative to 1980-1999 global mean temperature

Understand: Better biodiversity data

- Improved understanding of
  - Drivers of species' and ecosystems' sensitivity to change
  - Effects of natural variability on species abundance



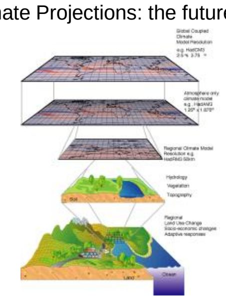
GLMs to model breeding densities of 4 bird species as a function of climate and land use

e.g. Eurasian Curlew, *Numenius arquata*

Renwick, *et al.* (2011). Modelling changes in species' abundance in response to projected climate change. Diversity and Distributions

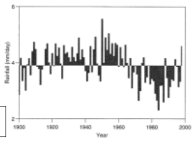
Huntley, B., et al. (2010). Beyond bioclimatic envelopes: dynamic species' range and abundance modelling in the context of climatic change. Ecography, (33), 621-626.

Climate Projections: the future

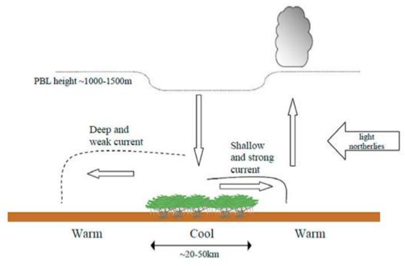


Land use planning

- 70-90% of Sahelian and Sudanian precipitation from Mesoscale Convective Systems (MCS)
- African Monsoon Multidisciplinary Analysis (AMMA)
- MCS initiation related to:
  - Soil moisture gradients
  - Land surface – forest-cropland mix



Observed Sahel rainfall (mm per day) during 20th Century (Hulme 1992)



Garcia-Carreras, L., *et al* (2010). Impact of mesoscale vegetation heterogeneities on the dynamical and thermodynamic properties of the planetary boundary layer. Journal of Geophysical Research, 115

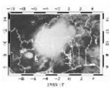
Land use planning

Mesoscale Convective System 11th – 13th June 2006

Nested regional prediction system: 9km and 3km

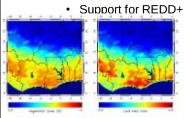
Soil-Veg-Atmos transfer model

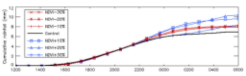
7 credible variations in veg cover



11th June 2006

- Support land use planning
  - Impacts of land cover change on regional weather patterns
  - Experiments to support long term land use plans
  - Support for REDD+





Lauwaet, *et al.* 2010. Impact of veg changes on a mesoscale convective system. Meterol Atmos Phys, 107

Climate Change Adaptation Strategies

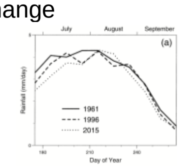
- Recent advice for IBA adaptation (Hole et al, 2011)
- 5 potential scenarios of emigration / colonization / persistence

Category	Emigrating	Colonizing	Persisting
High persistence	Low	Low	High
Increasing specialisation	High	Low	Low
High turnover	High	High	Low
Increasing value	Low	High	High
Increasing diversification	Intermediate	Intermediate	Intermediate

Land use change

SALU land use model

	1961	1996	2015
Fuelwood	72	40	35
Pasture	14	16	17
Cropland	5	14	22
Fallow	9	16	15
Unused	0	13	11

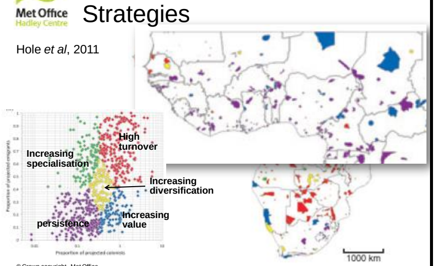


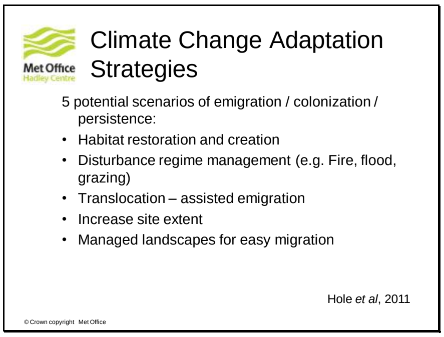
- Increase in cropland from 5 to 22%
- 8.7% reduction in wet season rainfall (2015 – 1961)
- Due to delayed onset of wet season in July
- SST patterns more likely to explain Sahelian drought, but …
- Sensitivity of rainfall to albedo suggests ecosystem dynamics may prolong externally forced drought

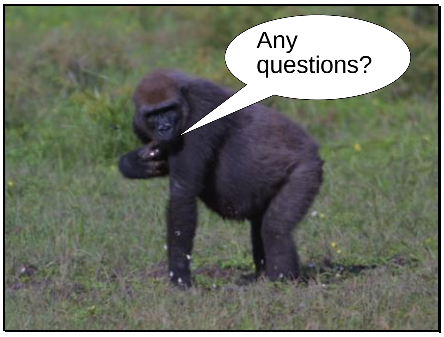
Taylor, C. M., Lambin, E. F., Stephenne, N., Harding, R. J., & Essery, R. L. H. (2002). The Influence of Land Use Change on Climate in the Sahel. Journal of Climate, 15(24), 3615-3629

Climate Change Adaptation Strategies

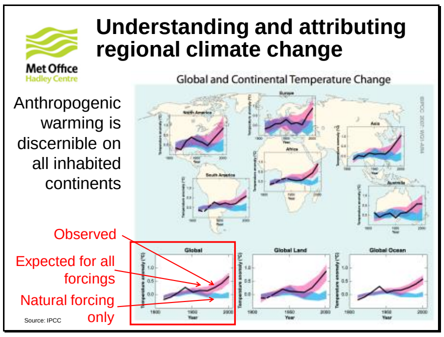
Hole *et al*, 2011

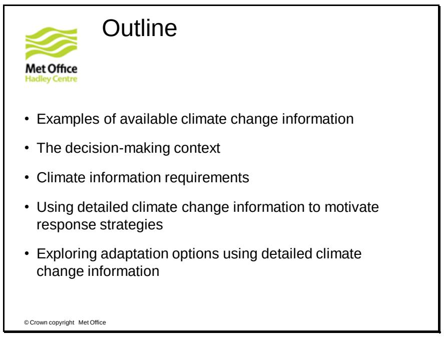


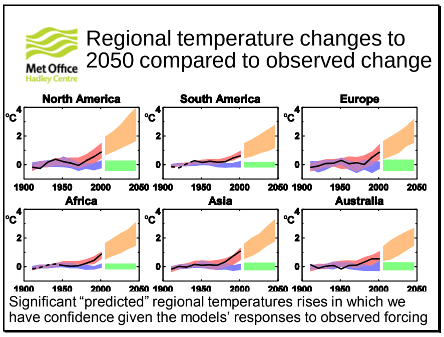

Met Office
Hadley Centre
Climate Change Adaptation Strategies
5 potential scenarios of emigration / colonization / persistence:
• Habitat restoration and creation
• Disturbance regime management (e.g. Fire, flood, grazing)
• Translocation – assisted emigration
• Increase site extent
• Managed landscapes for easy migration
Hole *et al*, 2011
© Crown copyright Met Office

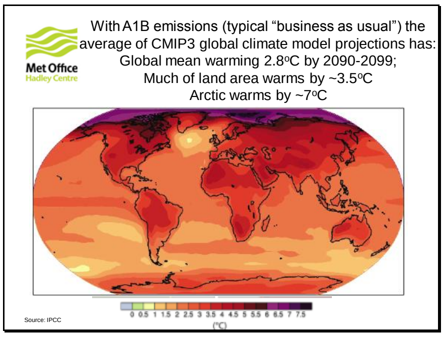

Any questions?

Chapter 4. Application of climate information for assessing adaptation

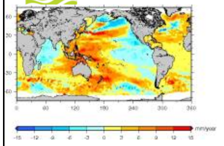


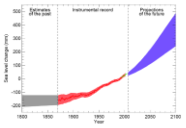






Sea-level rise in a warmer world





Observations of sea level rise from satellites, 1993-2003.

The global average SLR for the 20th century was about 17cm, mostly from expansion of the warming oceans with contributions from glacier melt (Alaska, Patagonia, Europe….).

Future changes just from these processes could be up to 0.5 m by 2100, and up to 1m within about 2-3 centuries, depending on how much GHGs are emitted.

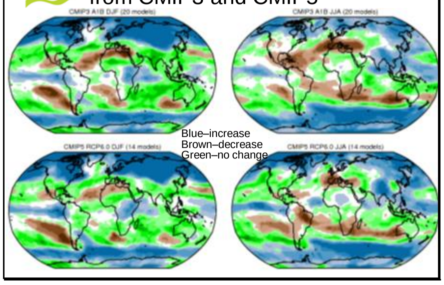
Other processes such as loss of major ice sheets could increase these changes

Source: IPCC

Drivers of changes in natural and human systems

- Identifying climate change as a potential threat (or opportunity) motivates the examination of the sensitivity of systems to climate (change)
- *(Note that this can often lead to the realisation that systems are vulnerable to climate variability and would benefit from the application of climate information, e.g. such as seasonal forecasts)*
- Systems are generally sensitive to a range of non-climate drivers and their importance relative to the climate drivers needs to be assessed

Projected changes in precipitation from CMIP3 and CMIP5



Other drivers and barriers to action

- Decision-making can be constrained by practical considerations such as time-scales which require decisions to be taken with far from ideal information
- This implies that both clear statements of the limitations of information are important as well as the willingness to engage in decision-making using incomplete or poor information
- Barriers can include the structure of institutional frameworks and inappropriate communication channels

The decision-making context

Climate information requirements

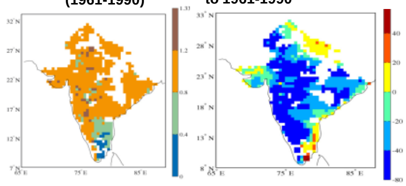
Impacts and adaptation assessment information needs are broad and often detailed

Applications for climate information are diverse, for example:

- Management of transport infrastructure
- Hydrology/hydraulic modelling for urban flood prediction
- Defining drought indices for climate change impacts on crops
- Storm-surge modelling for coastal protection

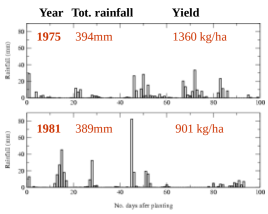
The information requirements for these applications be very different and as will the quality of the available climate data

Change in ground-nut yields over India



Crop studied sensitive to temperatures above 28ºC – thus daily maximum temperature required in modelling yields as well as precipitation, humidity, solar radiation etc

Understanding characteristics of rainfall information for predicting crop yields



- Seasonal rainfall totals for the two years are similar
- Total yield in 1975 is 50% higher than 1981
- Implies important to capture timing of rainfall within the season (as relevant to crop development)

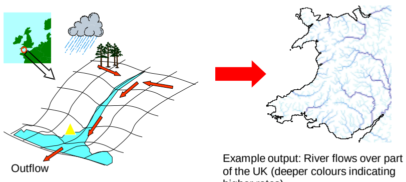
Implications for information needed when assessing climate impacts

- Multiple climate variables are often needed
- Information can be required at high temporal and spatial resolution
  - Temporal details can involve the daily timescale to capture maxima/minima and sub-seasonal variability
  - Fine spatial details are often needed to be able to realistically represent the physical system being studied
- Thresholds of some of the climate variables can be important

Applying a 1km grid-based river flow model over the UK

- 1km resolution required to represent UK rivers
- Requires hourly precipitation and daily potential evaporation

Precipitation disaggregated from 25km RCM grid using statistical relationship derived from 1km observed rainfall

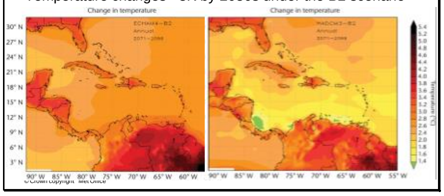


Example output: River flows over part of the UK (deeper colours indicating higher rates)

Using detailed climate change information to motivate response strategies

Large temperature changes expected over land areas

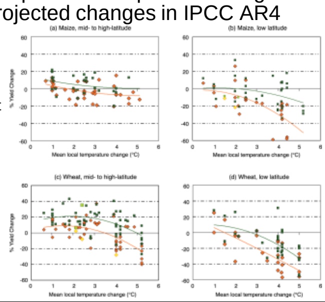
- High resolution modelling delivers consistent message on large warming over land even with different sea temperature changes
- Temperature changes >3K by 2080s under the B2 scenario



Response of crops to the range of projected changes in IPCC AR4

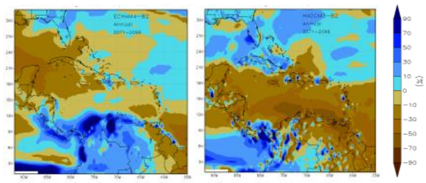
General signal of little change or increases at high lat. and decreases at low lat. (with and without CO_2 effect)

One possible response thus to change global crop distributions



The message on precipitation change is less clear

- Precipitation changes of up to +/- 20% by 2080s under the B2 scenario



Exploring adaptation options using detailed climate change information

Impact on Caribbean crops of a 2ºC temperature rise

Crop	Temperature Change (ºC)	% Change in Precipitation	Yield (kg/ha)	Change in Yield
Rice	0	0	3356	
	+2	+20	3014	-10%
	+2	-20	2888	-14%
Beans	0	0	1354	
	+2	+20	1164	-14%
	+2	-20	1093	-19%
Maize	0	0	4511	
	+2	+20	3737	-22%
	+2	-20	3759	-17%

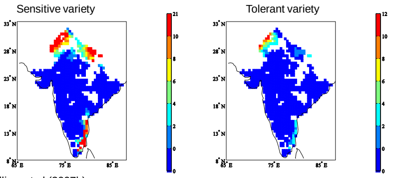
Examples of assessing adaptation options

1) Adapting agriculture to climate change
   a) How climate will change?
   b) What is the impact on the crops?
   c) Do suitable options for adaptation exist

2) Adapting infrastructure to climate change
   - How climate will change?
   - Can the infrastructure cope with the changes?
   - If not what options are available?

Genotypic adaptation to high temperature stress

- Hadley Centre PRECIS model, A2 (high emission) scenario 2071-2100
- Impact of climate scenario on number of years when greater than than 50% crop failure for temperature sensitive and tolerant variety



Challinor et al (2007b)

Summary

Seasonal temperature and sea-levels will increase in all regions and seasonal precipitation will change in many regions

Clear basis for decision-making but need to work with information with different levels of confidence

More detailed information is often required, is sometimes available or can be generated

This allows assessment of impacts and adaptation options and thus can motivate response strategies

Assessing adaptive capacity using crop-climate ensembles: India

180,000+ crop simulations, using ensemble climate changes and the resulting crop responses

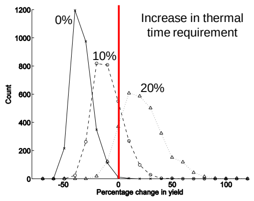
Simulations suggest:

30% increase in thermal time requirement may be needed

Field studies suggest:

14 to 40% increase available within current germplasm

=> some capacity for adaptation

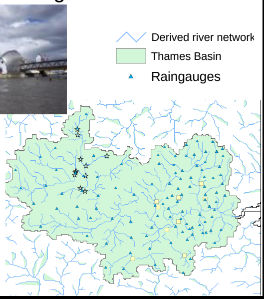


Challinor et al. (2009a)

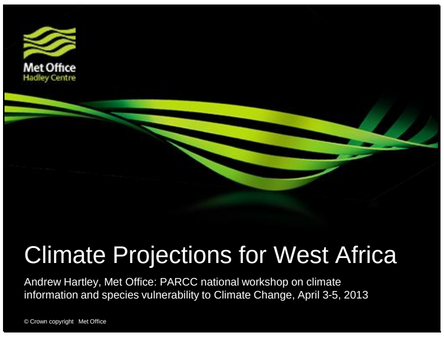
Questions and discussion

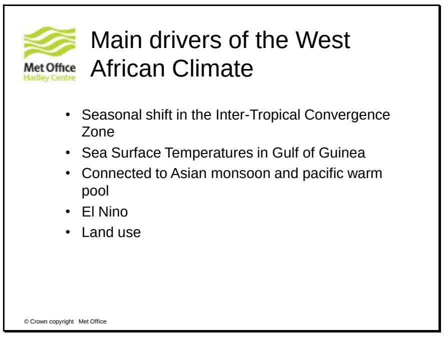
Climate-proofing the Thames barrier

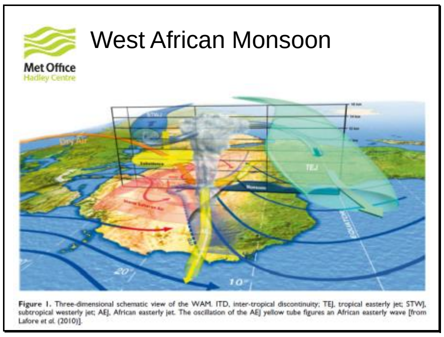
Hadley Centre, POL, CEH assessed future London flood risk
- Peak flows by 2080 may increase by 40%
- Maximum estuary water levels may rise by 2.7m by 2080
- Current protection sufficient to 2030, then review decision

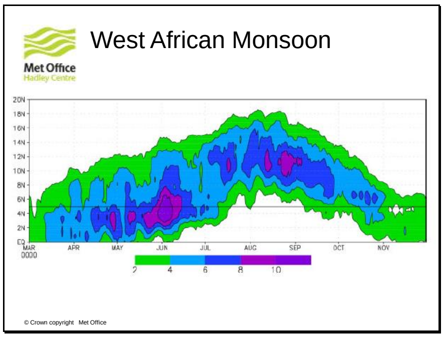


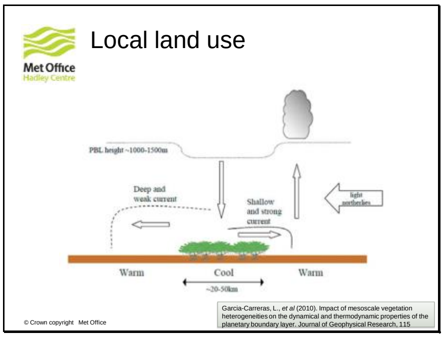
Chapter 5. Climate projection for West Africa

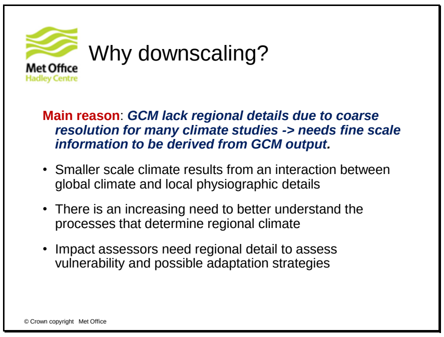









Local land use
Met Office
Hadley Centre
PBL height ~1000-1500m
Deep and weak current
Shallow and strong current
light northerlies
Warm
Cool
Warm
~20-50km
Garcia-Carreras, L., et al (2010). Impact of mesoscale vegetation heterogeneities on the dynamical and thermodynamic properties of the planetary boundary layer. Journal of Geophysical Research, 115
© Crown copyright Met Office


Why downscaling?
Met Office
Hadley Centre
Main reason: GCM lack regional details due to coarse resolution for many climate studies -> needs fine scale information to be derived from GCM output.
• Smaller scale climate results from an interaction between global climate and local physiographic details
• There is an increasing need to better understand the processes that determine regional climate
• Impact assessors need regional detail to assess vulnerability and possible adaptation strategies
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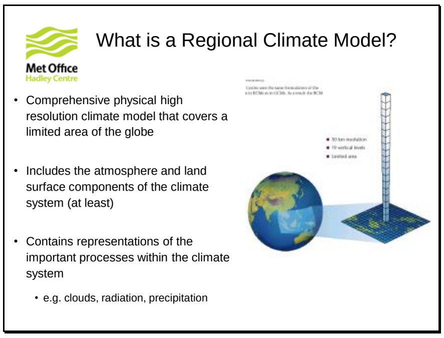
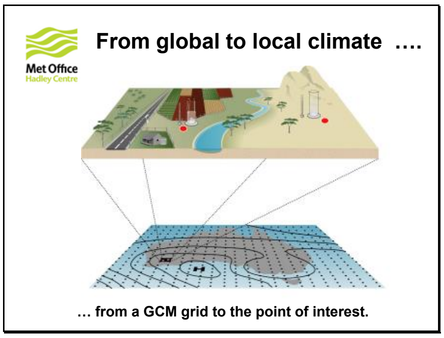
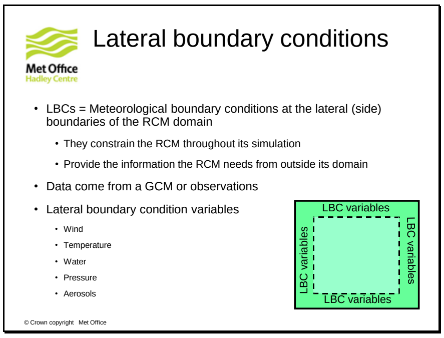
Met Office
Hadley Centre
Regional Downscaling
© Crown copyright Met Office


What is a Regional Climate Model?
Met Office
Hadley Centre
• Comprehensive physical high resolution climate model that covers a limited area of the globe
• Includes the atmosphere and land surface components of the climate system (at least)
• Contains representations of the important processes within the climate system
• e.g. clouds, radiation, precipitation


From global to local climate ….
Met Office
Hadley Centre
… from a GCM grid to the point of interest.


Lateral boundary conditions
Met Office
Hadley Centre
• LBCs = Meteorological boundary conditions at the lateral (side) boundaries of the RCM domain
• They constrain the RCM throughout its simulation
• Provide the information the RCM needs from outside its domain
• Data come from a GCM or observations
• Lateral boundary condition variables
• Wind
• Temperature
• Water
• Pressure
• Aerosols
LBC variables
LBC variables
LBC variables
LBC variables
© Crown copyright Met Office


Met Office
Hadley Centre
Added value of RCMs
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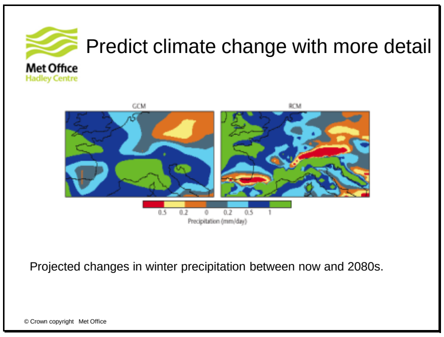
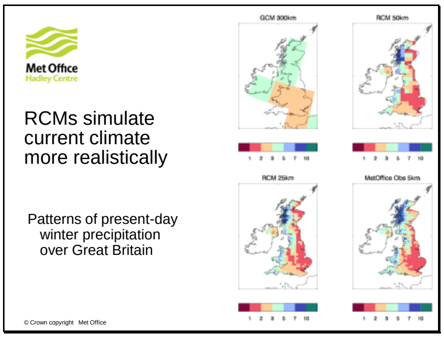
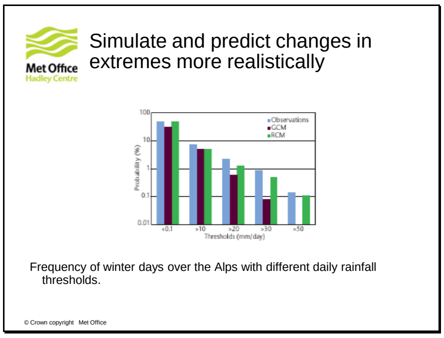

Met Office
Hadley Centre
Predict climate change with more detail
GCM
RCM
Precipitation (mm/day)
Projected changes in winter precipitation between now and 2080s.
© Crown copyright Met Office


Met Office
Hadley Centre
RCMs simulate current climate more realistically
Patterns of present-day winter precipitation over Great Britain
GCM 300km
RCM 50km
RCM 25km
MetOffice Obs 5km
© Crown copyright Met Office


Met Office
Hadley Centre
Simulate and predict changes in extremes more realistically
Observations
GCM
RCM
Thresholds (mm/day)
Frequency of winter days over the Alps with different daily rainfall thresholds.
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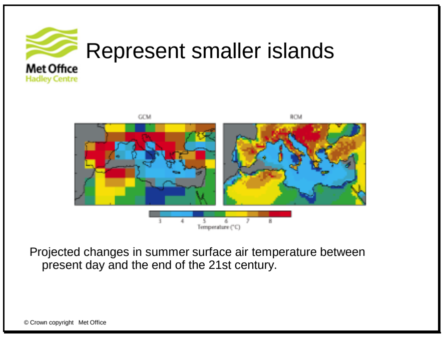
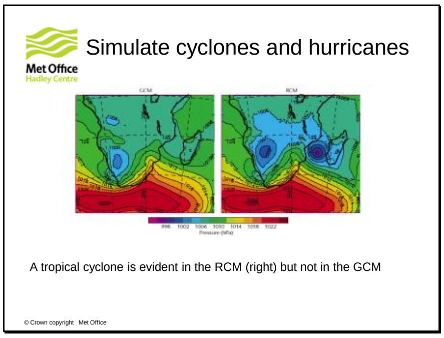

Met Office
Hadley Centre
Represent smaller islands
GCM
RCM
Temperature (°C)
Projected changes in summer surface air temperature between present day and the end of the 21st century.
© Crown copyright Met Office


Met Office
Hadley Centre
Simulate cyclones and hurricanes
GCM
RCM
A tropical cyclone is evident in the RCM (right) but not in the GCM
© Crown copyright Met Office


Met Office
Hadley Centre
Africa RCM
The modeling process
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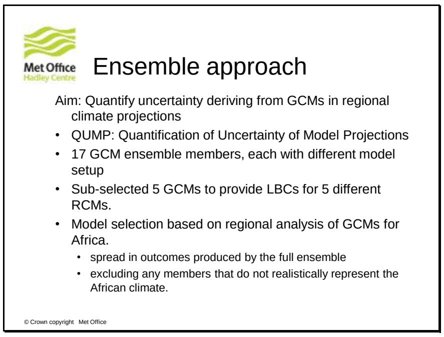
Met Office
Hadley Centre
Ensemble approach
Aim: Quantify uncertainty deriving from GCMs in regional climate projections
• QUMP: Quantification of Uncertainty of Model Projections
• 17 GCM ensemble members, each with different model setup
• Sub-selected 5 GCMs to provide LBCs for 5 different RCMs.
• Model selection based on regional analysis of GCMs for Africa.
• spread in outcomes produced by the full ensemble
• excluding any members that do not realistically represent the African climate.
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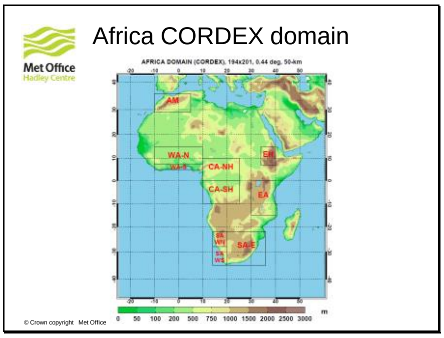
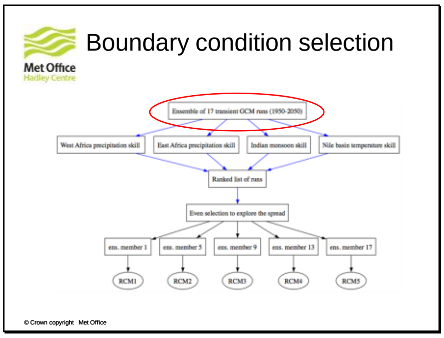

Met Office
Hadley Centre
Africa CORDEX domain
AFRICA DOMAIN (CORDEX), 194x201, 0.44 deg, 50-km
AM
WA-N
CA-NH
CA-SH
EA
SA-E
0 50 100 200 500 750 1000 1500 2000 2500 3000
m
© Crown copyright Met Office


Met Office
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Boundary condition selection
Ensemble of 17 transient GCM runs (1950-2050)
West Africa precipitation skill
East Africa precipitation skill
Indian monsoon skill
Nile basin temperature skill
Ranked list of runs
Even selection to explore the spread
ens. member 1
ens. member 5
ens. member 9
ens. member 13
ens. member 17
RCM1
RCM2
RCM3
RCM4
RCM5
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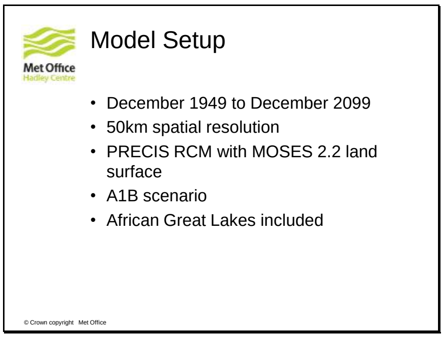
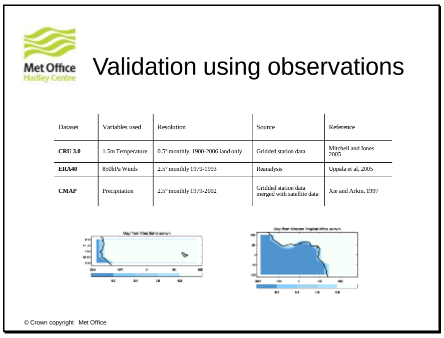
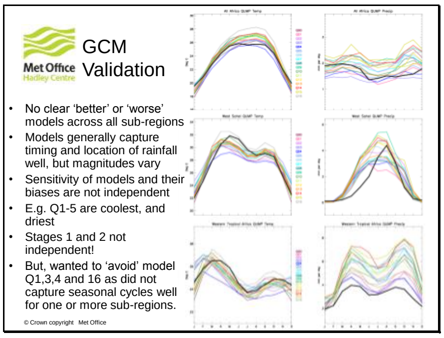
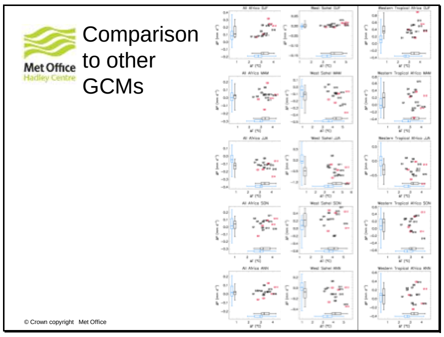
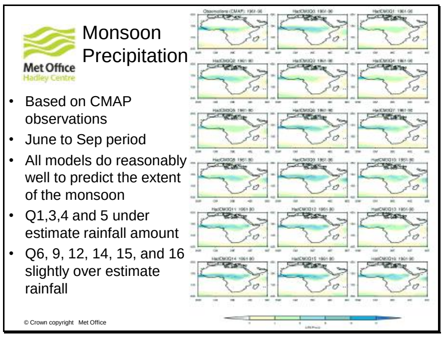

Met Office
Hadley Centre
Model Setup
• December 1949 to December 2099
• 50km spatial resolution
• PRECIS RCM with MOSES 2.2 land surface
• A1B scenario
• African Great Lakes included
© Crown copyright Met Office


Met Office
Hadley Centre
Validation using observations
Dataset
Variables used
Resolution
Source
Reference
CRU 3.0
1.5m Temperature
0.5° monthly, 1900-2006 land only
Gridded station data
Mitchell and Jones 2005
ERA40
850hPa Winds
2.5° monthly 1979-1993
Reanalysis
Uppala et al, 2005
CMAP
Precipitation
2.5° monthly 1979-2002
Gridded station data merged with satellite data
Xie and Arkin, 1997
© Crown copyright Met Office


GCM Validation
No clear 'better' or 'worse' models across all sub-regions
Models generally capture timing and location of rainfall well, but magnitudes vary
Sensitivity of models and their biases are not independent
E.g. Q1-5 are coolest, and driest
Stages 1 and 2 not independent!
But, wanted to 'avoid' model Q1,3,4 and 16 as did not capture seasonal cycles well for one or more sub-regions.
© Crown copyright Met Office


Comparison to other GCMs
© Crown copyright Met Office


Monsoon Precipitation
Based on CMAP observations
June to Sep period
All models do reasonably well to predict the extent of the monsoon
Q1,3,4 and 5 under estimate rainfall amount
Q6, 9, 12, 14, 15, and 16 slightly over estimate rainfall
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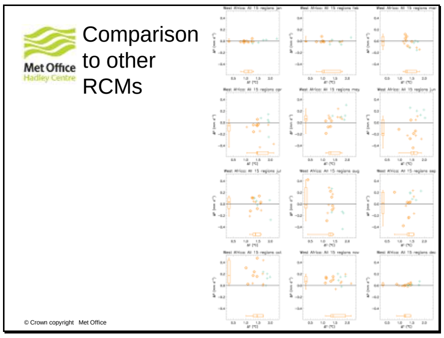
Comparison to other RCMs
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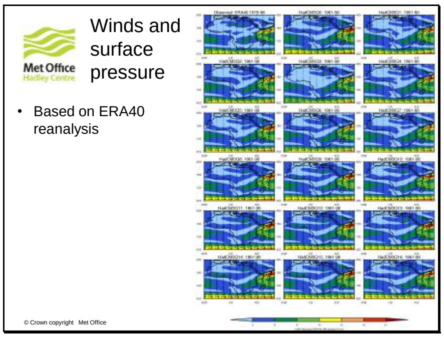
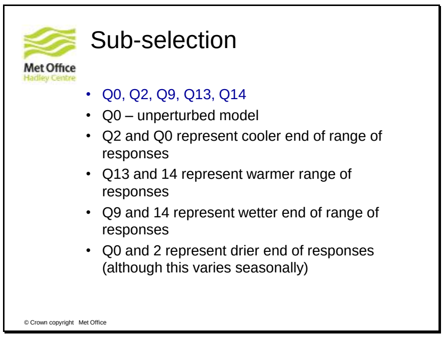

Winds and surface pressure
Based on ERA40 reanalysis
© Crown copyright Met Office


Sub-selection
Q0, Q2, Q9, Q13, Q14
Q0 – unperturbed model
Q2 and Q0 represent cooler end of range of responses
Q13 and 14 represent warmer range of responses
Q9 and 14 represent wetter end of range of responses
Q0 and 2 represent drier end of responses (although this varies seasonally)
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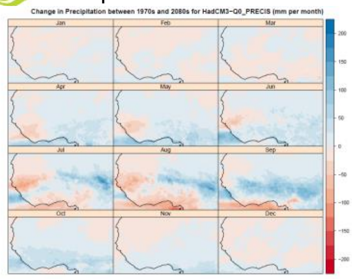
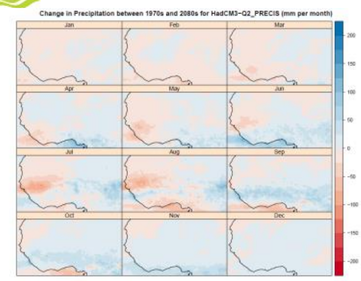
Main points

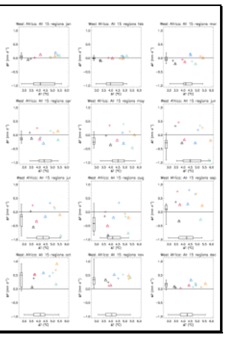
- **Large scale geographical distribution** of the temperature and precipitation of the African climate are captured
- The sample captures **full range of outcomes** produced by the QUMP ensemble and the **annual variation** for as many of the sub-regions as possible.
- Q0 and Q2 represent the **cooler end of the range** of future projections and Q13 and Q14 **represent the warmer** end of the range to provide the spread in temperature.
- **No particular model consistently** shows the largest change in precipitation for both regions throughout the year.
- Q14 **represents the wetter end of the range** in future projections for Western Tropical Africa during December, January and February (DJF) but not during June, July, August (JJA) and annually in West Sahel it is actually the driest model.
- Overall, the analysis suggests that Q0 captures the **drier end of the range** of future projections and Q9 captures the **wetter end of the range**.

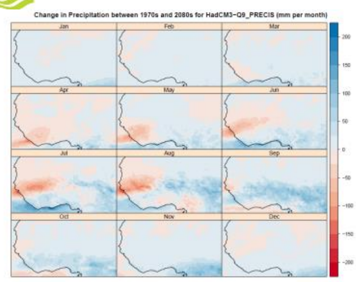
Precipitation

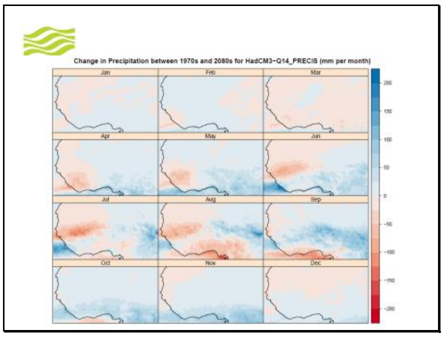


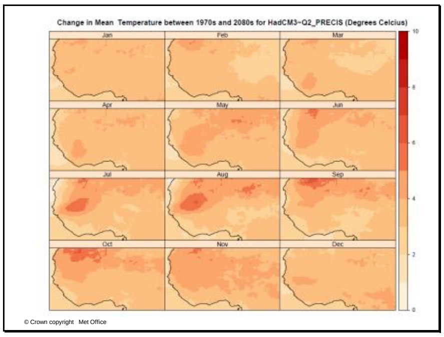
Key results for West Africa








Change in Precipitation between 1970s and 2080s for HadCM3-Q14_PRECIS (mm per month)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Change in Mean Temperature between 1970s and 2080s for HadCM3-Q2_PRECIS (Degrees Celcius)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
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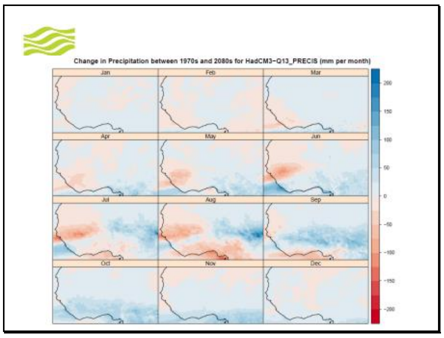
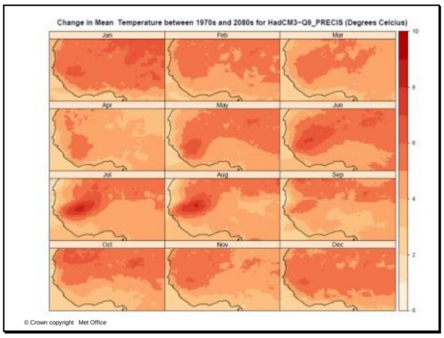

Change in Precipitation between 1970s and 2080s for HadCM3-Q13_PRECIS (mm per month)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Change in Mean Temperature between 1970s and 2080s for HadCM3-Q9_PRECIS (Degrees Celcius)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
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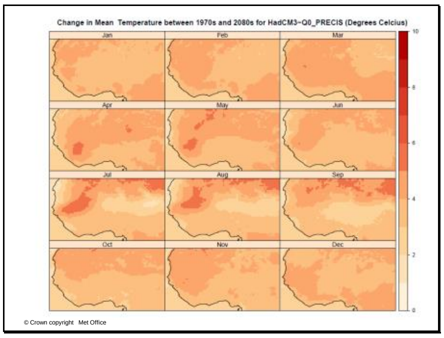
Change in Mean Temperature between 1970s and 2080s for HadCM3-Q0_PRECIS (Degrees Celcius)
Jan
Feb
Mar
Apr
May
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Jul
Aug
Sep
Oct
Nov
Dec
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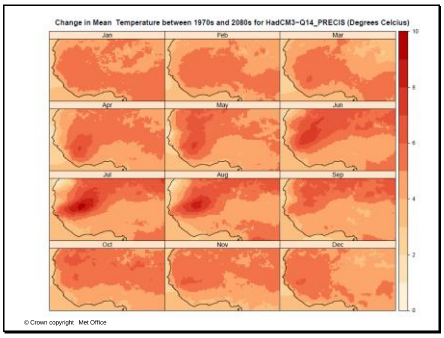
Change in Mean Temperature between 1970s and 2080s for HadCM3-Q14_PRECIS (Degrees Celcius)
Jan
Feb
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May
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Jul
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Oct
Nov
Dec
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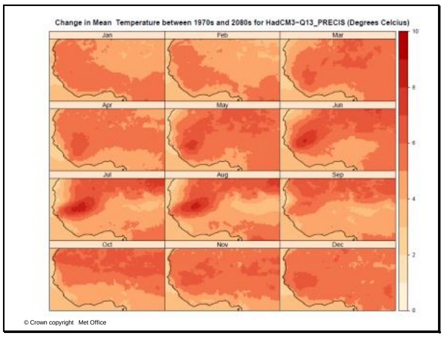
Change in Mean Temperature between 1970s and 2080s for HadCM3-Q13_PRECIS (Degrees Celcius)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
10
8
6
4
2
0
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Practical Session
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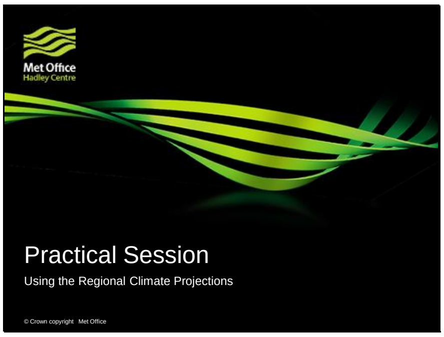
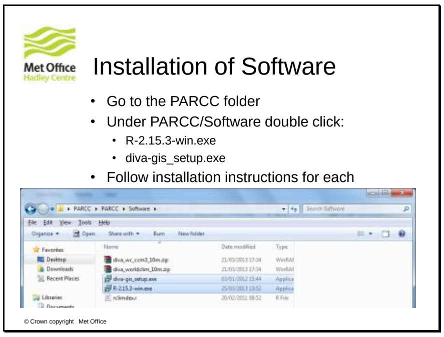
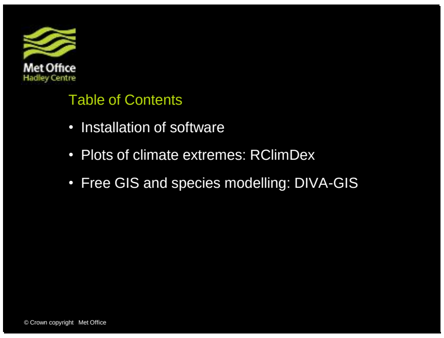
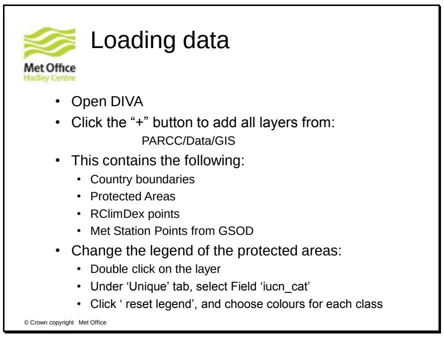
Chapter 6. Practical Session: Using the regional climate projections









Add Labels

- Select layer 'rclimdex_points'
- Go to Layer -> Add Labels
- Choose Field 'name'
- Set appropriate font
- Click 'OK' then 'Close'

RClimDex – What is it?

A user friendly interface to compute indices of climate extremes

Computes all 28 core indices recommended by the World Climate Research Programme for Climate Change Detection Monitoring and Indices

Additionally other temperature and precipitation indices with user defined thresholds

Add baseline climate data

- Source: WorldClim climatic means for each month averaged over 1950-2000 at approx. 0.17 degree
- Go to Tools -> Options
- Click folder, and navigate to PARCC\Data\BaselineClimate\
- From dropdown select 'worldclim_10m'
- Click 'OK'
- Go to Data -> Climate -> Map
- Match settings on right ->
- Choose file, then click 'Apply'

Analysis of extremes

- Wide range of space and time scales
  - From very small scale (precip) to large scale (droughts)
  - Extremes(GCM) ≠ Extremes(RCM) ≠ Extremes(Observed)
- Definitions?
  - High impact events
  - Unprecedented events (in the available record)
  - Rare events (long return periods)
  - Exceedence of a relatively low threshold (indices, such as 10th percentile of daily temperature or 95th percentile of daily precipitation amounts)
  - Persistence of weather conditions (droughts)
  - Climatic extremes (e.g. extreme seasons)

Climate Extreme Indices

RClimDex

CCl/CLIVAR/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI)

from ETCCDI:

- Definition of 28 core extreme indices
- Organization of regional workshop
- WMO-guide on extremes, 2009, targeted at NMHSs around the world

http://www.wmo.int/datastat/documents/WCDMP_72_TD_1500_en_1_1.pdf

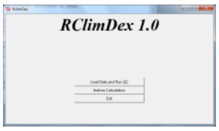
Running RClimDex

- Make a note of the full path to your PARCC folder
  - E.g. C:/Users/precis/Desktop/PARCC/PARCC
- Open R
- Change directory to PARCC/Software

```
>setwd("C:/Users/precis/Desktop/PARCC/PARCC/Software")
```

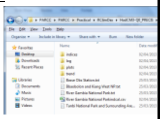
- Run the script

```
> source("rclimdex.r")
```



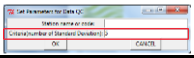
What has RClimDex done?

- Check back in the directory:
  - "PARCC/Practical/RClimDex/HadCM3-Q0_PRECIS"
- RClimDex created new directories
- Check "log" directory
- What does this contain?



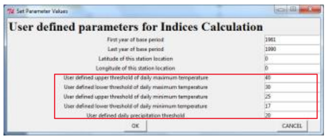
Loading data

- Click "Load Data and Run QC"
- Navigate to:
  PARCC\Practical\RClimDex\HadCM3-Q0_PRECIS
- Load "River Gambia National Park.txt". This is the daily RCM data (1949-2099) extracted for the area surrounding River Gambia National Park
- Click OK
- Under "Set Parameters for Data QC", change to 5 standard deviations



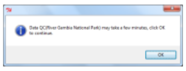
Indices Calculation

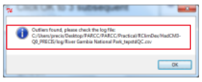
- Data is now loaded into memory
- Click "Indices Calculation", and enter the following settings



Loading data

- Click OK to 3 subsequent messages
- These are alerts for the detection of outliers in station observations
- Check "PARCC/Practical/RClimDex/HadCM3-Q0_PRECIS/log/River Gambia National Park_tepstdQC.csv"
- These events are excluded from the analysis



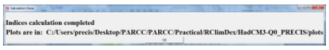


Indices Calculation

- Next, keep all variables checked, and click OK

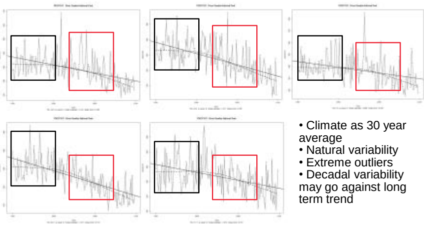
Indices Calculation

- After several minutes, a completion message will appear



- Check the "plots" folder
- Use the handout to identify variables
- Which variables could be useful to species in your country?

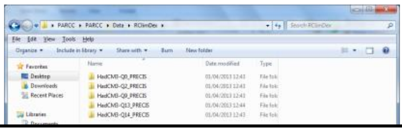
Comparing plots



- Climate as 30 year average
- Natural variability
- Extreme outliers
- Decadal variability may go against long term trend

Next steps

- Review thresholds
- Consider other ensemble members and other locations
- All indices have been calculated. Check ...



Quiz Questions!

Tip: if using Windows 7, the search function is very good! When in the directory PARCC/Data/RClimDex , try searching for "river gambia PRCPTOT jpg"

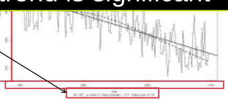
1. In River Gambia National Park, how would you describe the projections for change in total precipitation for the climate of the:
   a. 2040s?
   b. 2080s?
2. In Bbaobolon and Kiang West, look at maximum number of consecutive wet days (CWD) between 1950-2000. For each ensemble member:
   a. What is the average number of CWD?
   b. What is the range?
3. For Q0, which park has no significant trend in Daily Temperature Range?
4. Which other ensemble members have no trend in DTR for that park?

Interpretation

- Pay attention to scales on y-axis
- Years between 1950-2100 on x-axis

CAUTION!
If the p-value is > 0.05 we cannot be confident that the trend is significant

p-value < 0.05 means that there is a significant relationship between the trend and the data points



regression (best fit)

Loess smoothing

Quiz Answers!

1. In River Gambia National Park, how would you describe the projections for change in total precipitation for the climate of the:
   a. 2040s? Slight decrease, although most ensemble members show little change outside of natural variability
   b. 2080s? Significant decreases in all models of approximately 100m per year
2. In Bbaobolon and Kiang West, look at maximum number of consecutive wet days (CWD) between 1950-2000. For each ensemble member:
   a. What is the average number of CWD? 11, 11, 9, 9, 9
   b. What is the range? 6-34, 3-22, 4-20, 5-18, 5-14
3. For Q0, which park has no significant trend in Daily Temperature Range? Tanbi NP
4. Which other ensemble members have no trend for that park? All of them (Q0, Q2, Q9, Q13, Q14)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Thank you!
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