GEUS

Special session

Climate models: Uncertainties effects and adaptation

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Climate change adaptation strategies: Water management options under high uncertainty - A Danish example

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Outline

- Uncertainty terminology and concepts
  - Definition
  - Characterisation of uncertainty
    - Level
    - Nature
    - Source
- Uncertainty in climate change impacts and adaptation – the uncertainty cascade
- Adaptation strategies to handle uncertainty – 5 key messages

What is uncertainty – IPCC Glossary

(Bates et al., 2008, Climate change and Water. IPCC Technical Paper VI)

An expression of the degree to which a value (e.g., the future state of the *climate system*) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain *projections* of human behaviour. Uncertainty can therefore be represented by quantitative measures, for example, a range of values calculated by various models, or by qualitative statements, for example, reflecting the judgement of a team of experts.

What is it?

Where does it come from?

How can it be characterised?

What is uncertainty?

- typical definition in water resources (Klauer and Brown, 2003)

Definition (Uncertainty): *A person is uncertain if s/he lacks confidence about the specific outcomes of an event. Reasons for this lack of confidence might include a judgement of the information as incomplete, blurred, inaccurate or potentially false.*

Uncertainty is a property (state of confidence) of the decision maker rather than a property (state of perfection) of the total body of available knowledge ➔ subjectivity is an important aspect of how we define uncertainty

Example: A person may be uncertain about the exact value of a river discharge value due to uncertainties related to instruments used for measurements, representativeness of measurements, method of transforming measurements (of often secondary variables) to discharge. Two different persons may have different perceptions of the magnitude of this uncertainty.

Uncertainty is not a province of probability theory – it must be seen in a much broader perspective

Nature of uncertainty

Epistemic uncertainty

- uncertainty due to imperfect knowledge

➔ *reducible by more data and knowledge*

Ontological uncertainty

(Other names: aleatory or stochastic uncertainty)

- uncertainty due to inherent variability, e.g. climate variability

➔ *non-reducible*

Ambiguity

- uncertainty due to multiple knowledge frames among stakeholders

➔ *reducible by more dialogue and knowledge sharing*

Level of uncertainty

Statistical uncertainty

- All outcomes known
- All probabilities known

Scenario uncertainty

- Range of outcomes of plausible futures (not all known)
- No probabilities known

Qualitative uncertainty

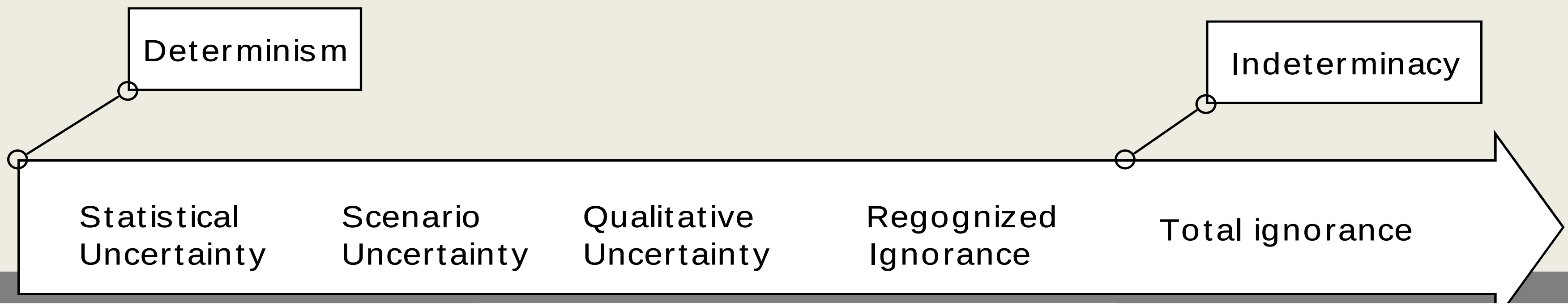
- Not all outcomes necessarily known
- Cannot be described statistically

Ignorance

- We are aware that there is something we do not know

Total ignorance (=epistemic arrogance)

- We do not know that there is something we do not know



Sources of uncertainty in Water Resources Management

Data
- physical, chemical, biological, etc.
- scale problems (temporal and spatial)

Model
- bugs in model code
- numerical solution (approximations)
- parameter values
- model structure (process equations, hydrogeological conceptual model)

Context – boundary conditions
- future climate
- legislation, regulatory conditions, etc.

Framing of problem
- multiple knowledge frames among decision makers and stakeholders

Uncertainty Matrix

- Mapping of uncertainty characteristics

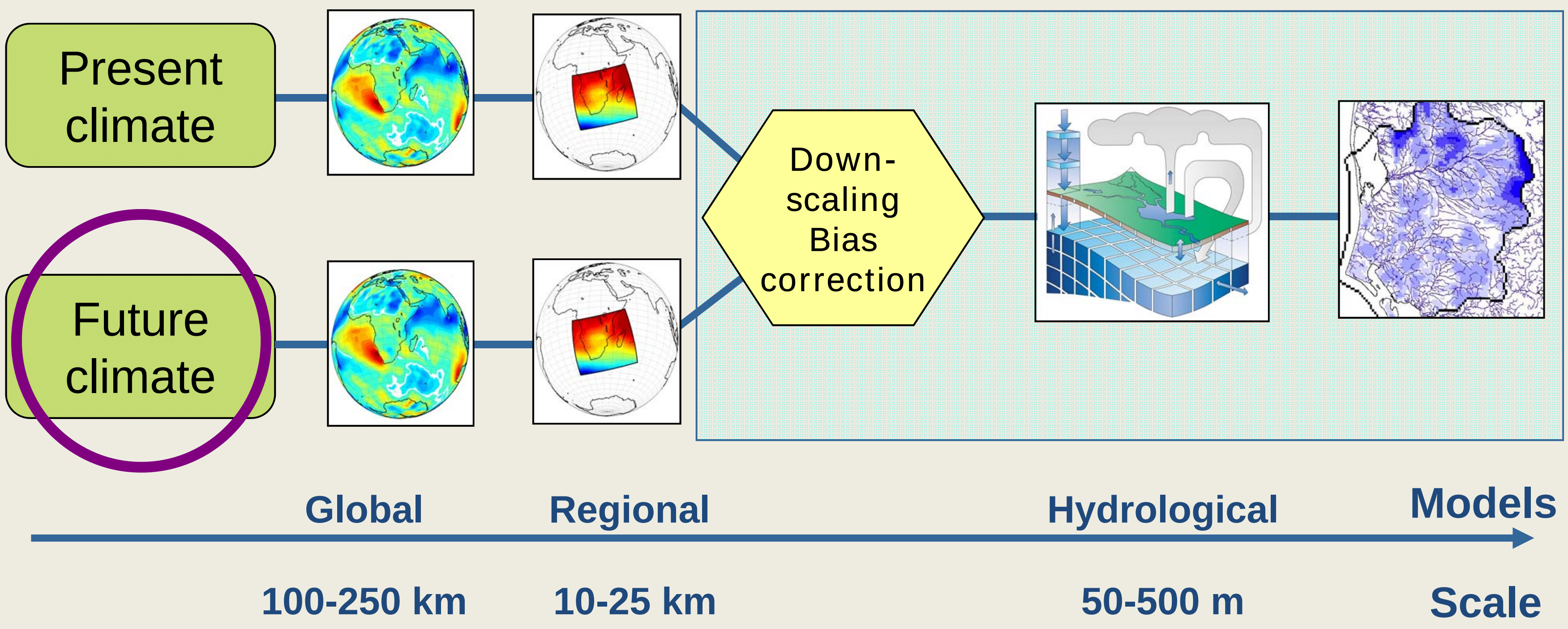
Source of uncertainty		**Level (type) of uncertainty**				**Nature**		
		Statistical uncertainty	Scenario uncertainty	Qualitative uncertainty	Ignorance	Epistemic uncertainty	Ontological uncertainty	Ambiguity
Inputs	System data							
	Driving forces							
Model	Model structure							
	Technical							
	Parameters							
Context (boundary conditions)	Future climate							
	Regulatory conditions							
Framing	Multiple knowledge frames							

Adapted from Walker et al. (2003)

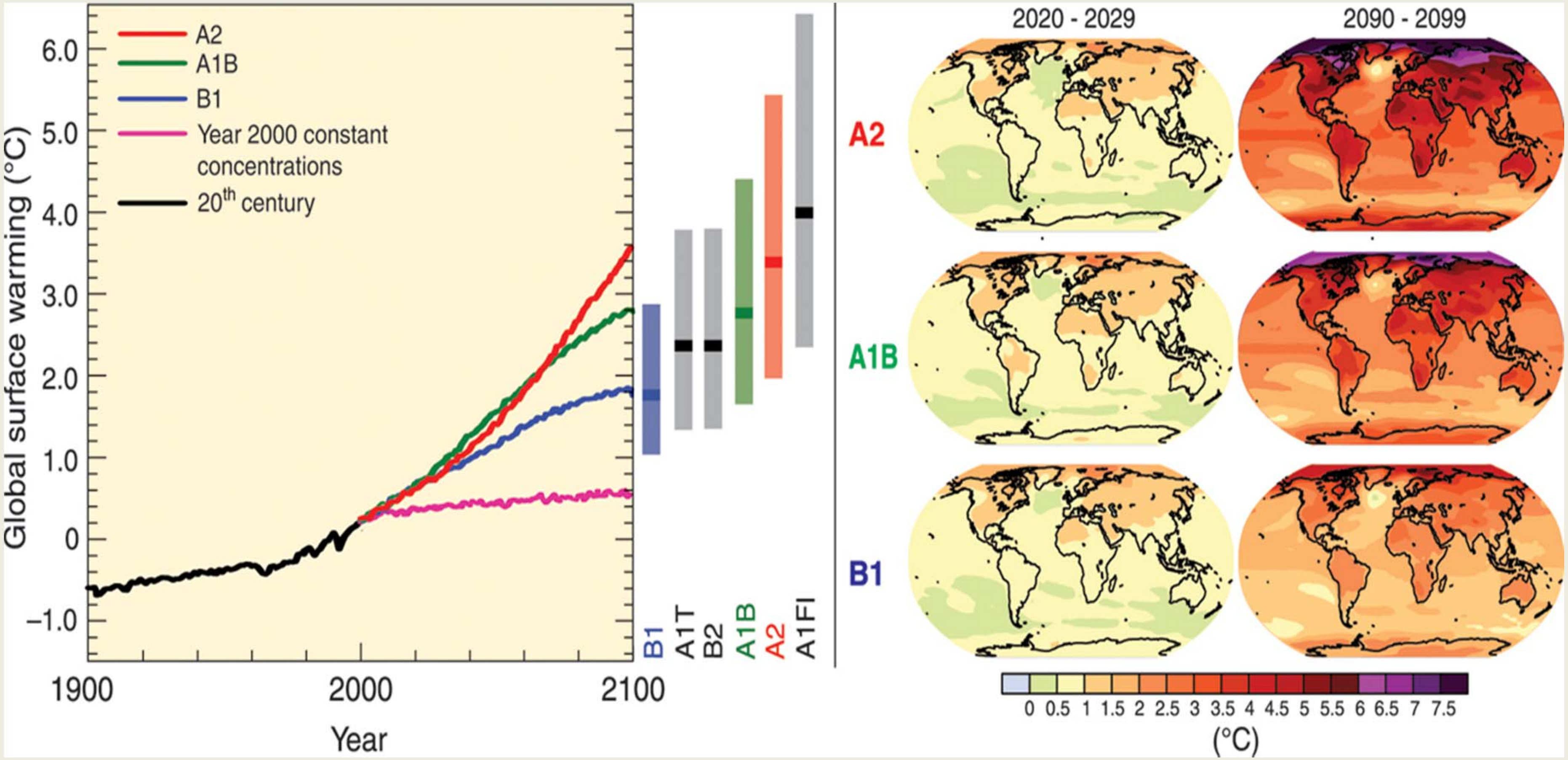
Climate change impacts on hydrology

The cascade of uncertainties

- Emission scenarios



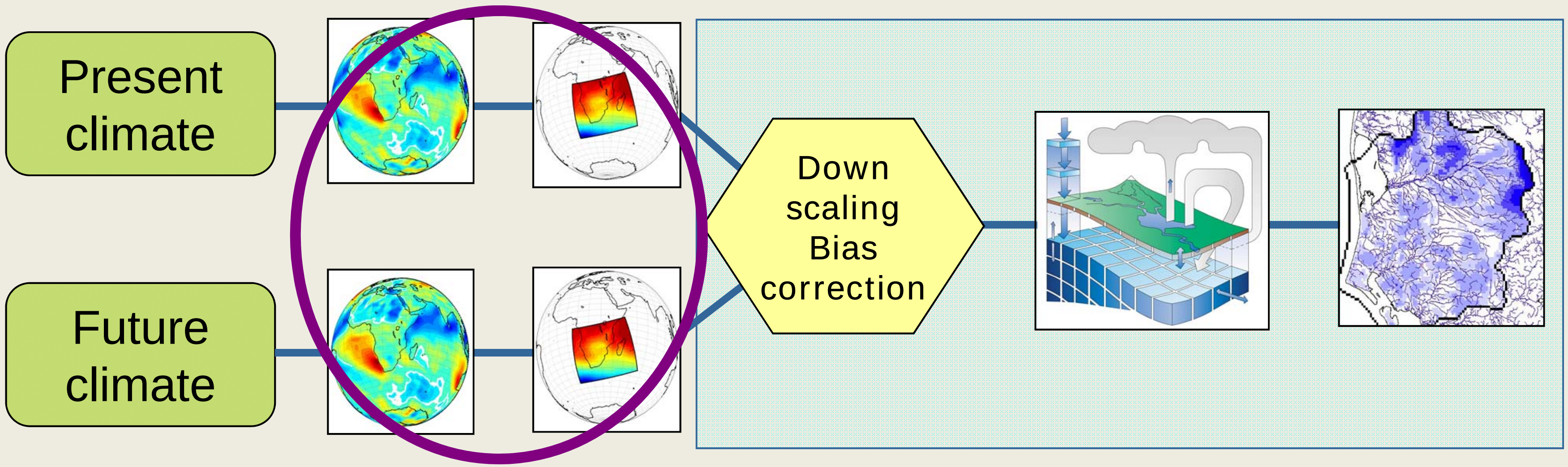
IPCC Greenhouse Gas Emission Scenarios



Climate change impacts on hydrology

The chain of uncertainties

- Emission scenarios
- Climate models (GCM + RCM)

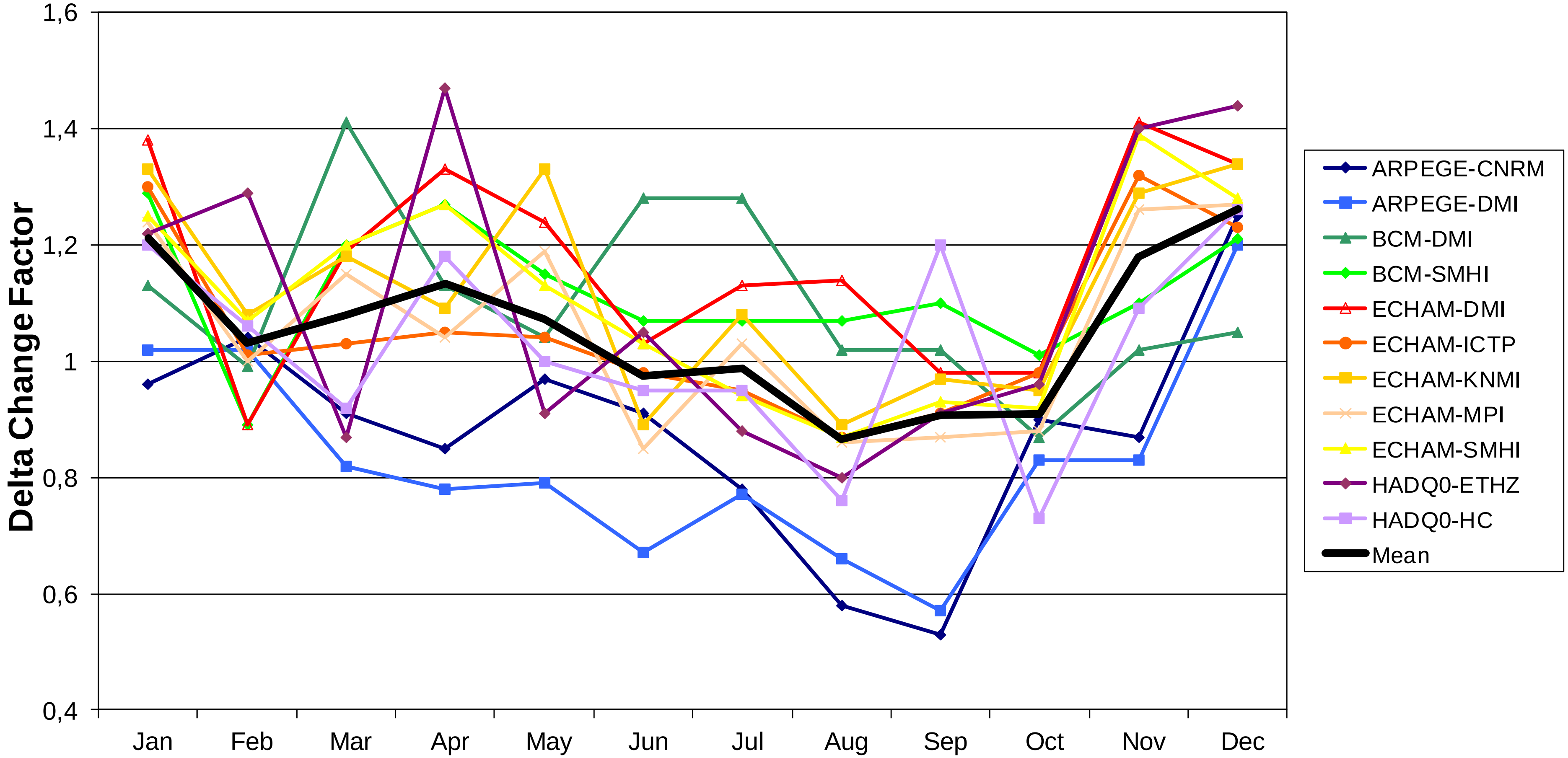


Global | Regional | Hydrological | Models

100-250 km | 10-25 km | 50-500 m | Scale

Uncertainties on climate models' projections

- Delta change factors on precipitation 2071-2100



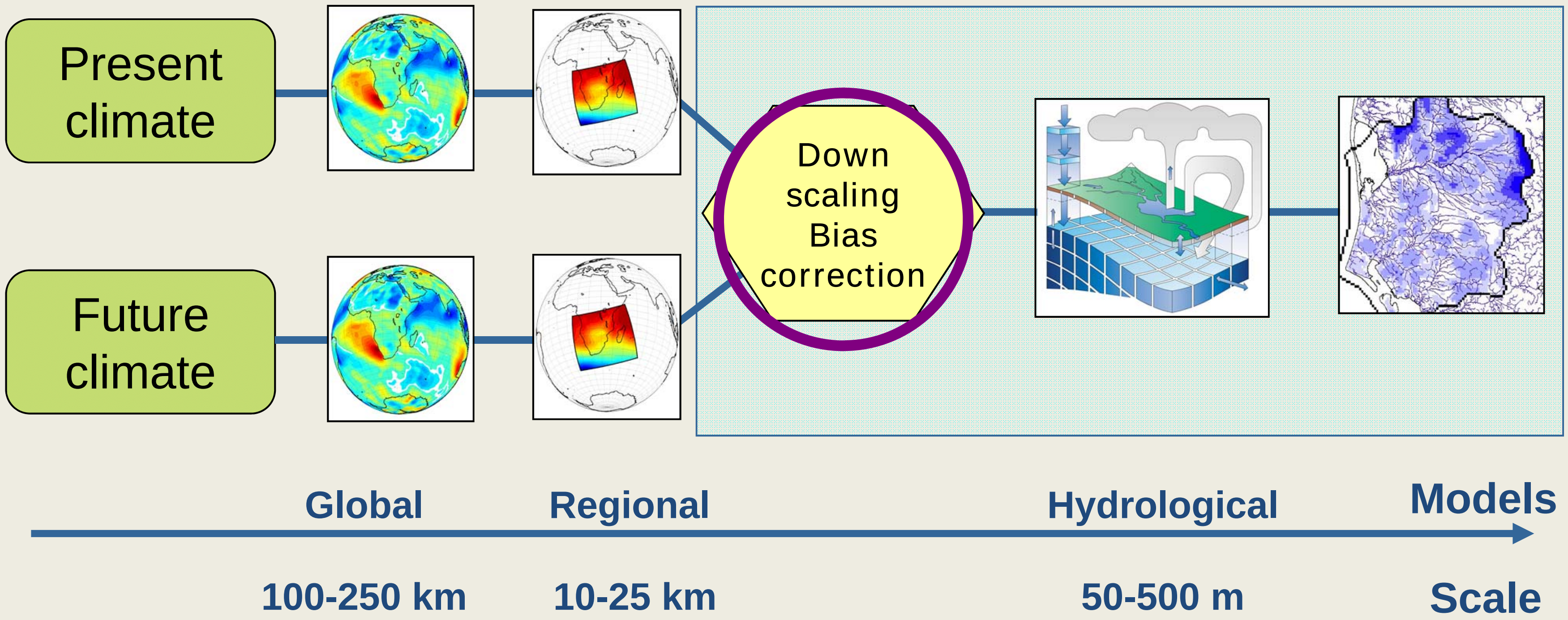
Lauren P Seaby
PhD project www.hyacints.dk
Preliminary results

Data from 11 climate models in the ENSEMBLES project (A1B)

Climate change impacts on hydrology

The chain of uncertainties

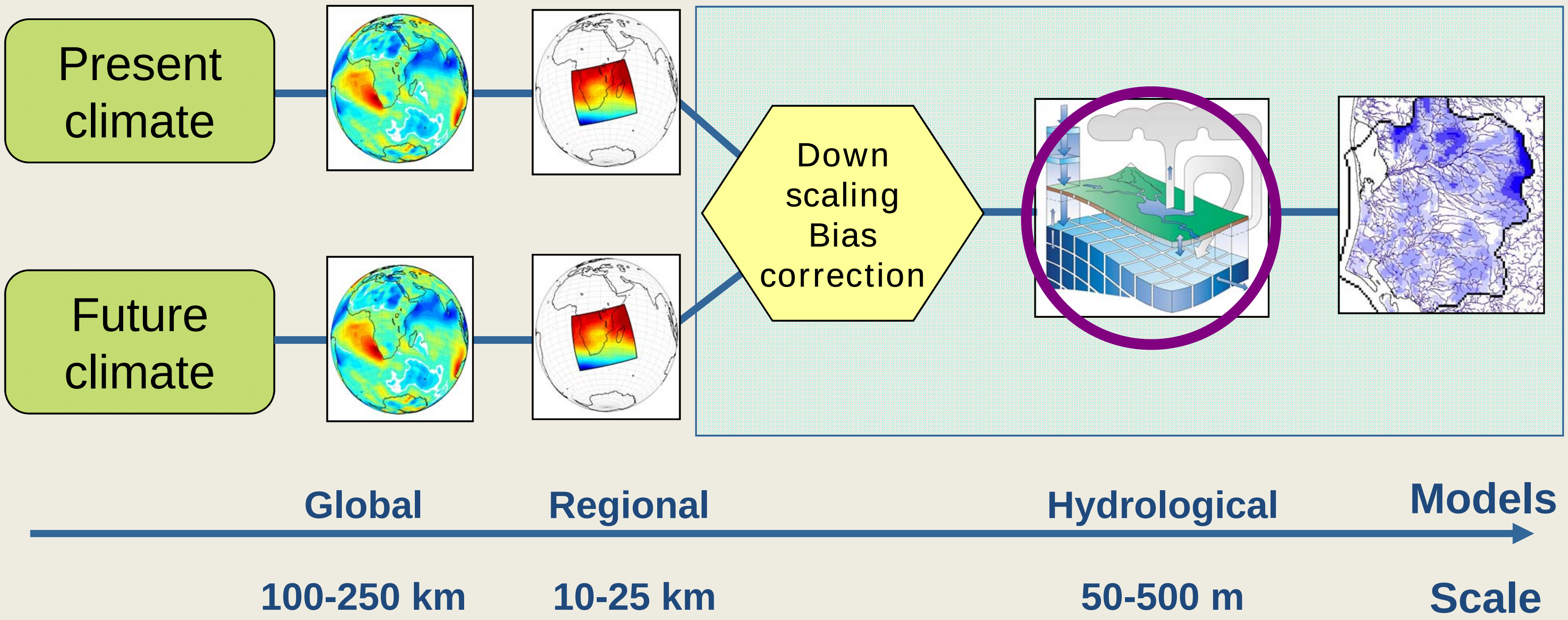
- Emission scenarios
- Climate models (GCM + RCM)
- Downscaling / bias correction

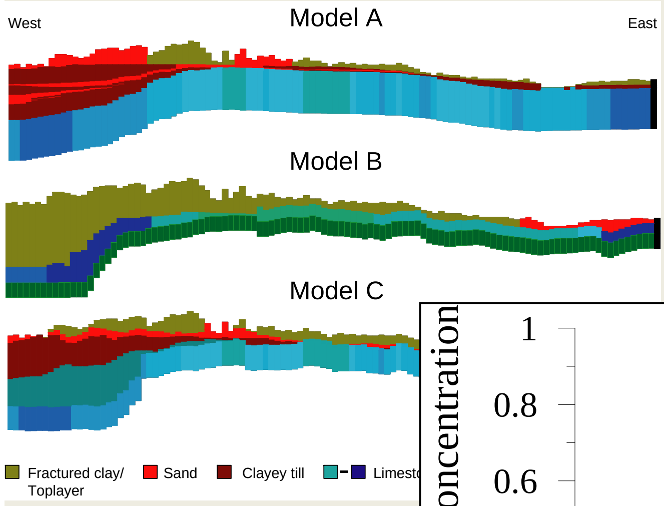


Climate change impacts on hydrology

The chain of uncertainties

- Emission scenarios
- Climate models (GCM + RCM)
- Downscaling / bias correction
- Hydrological model (geology, process equations, parameter values, input data)

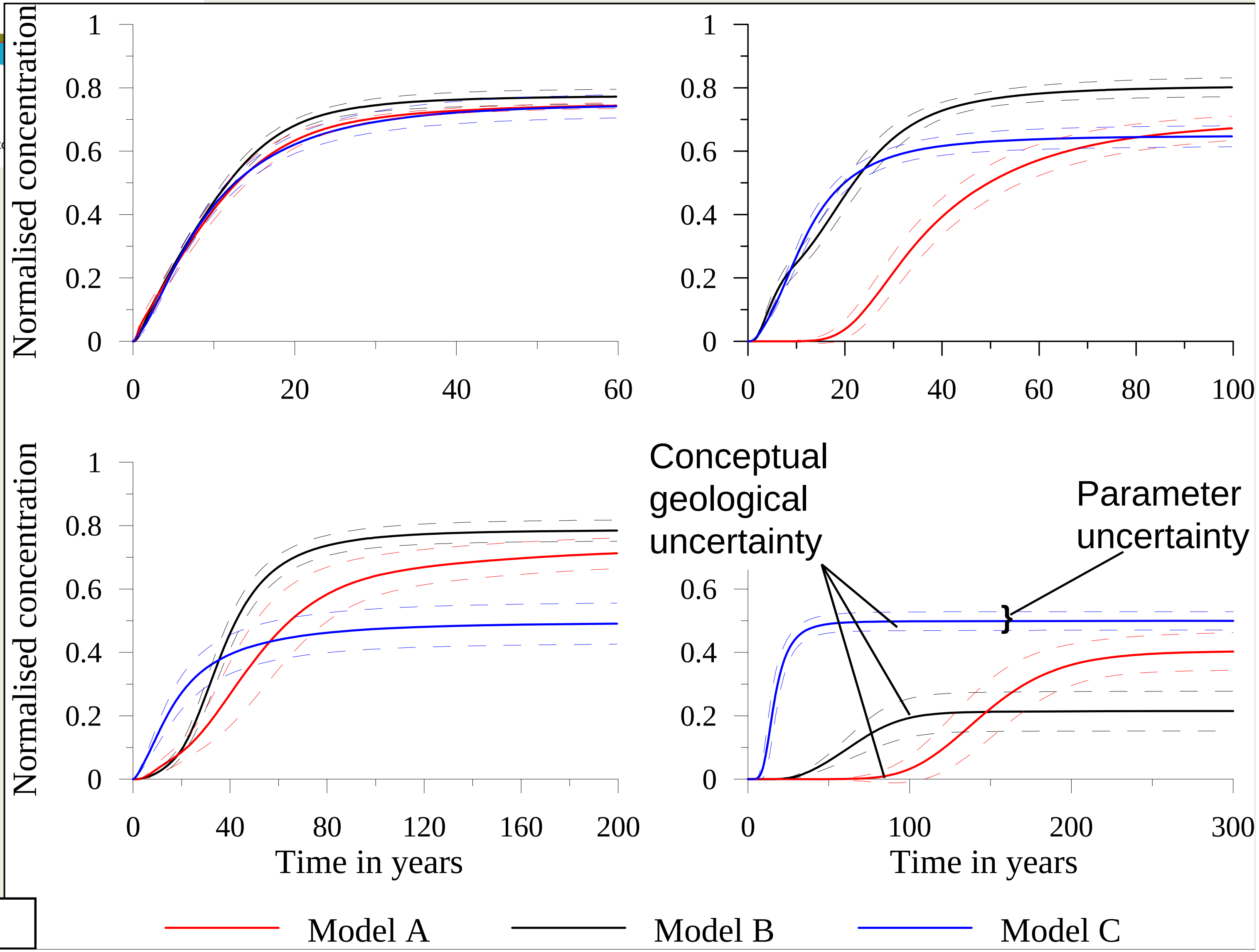




Uncertainty on parameters versus conceptual geological model

- Effects on flow paths/breakthrough curves

Simulated breakthrough in 4 abstraction wells

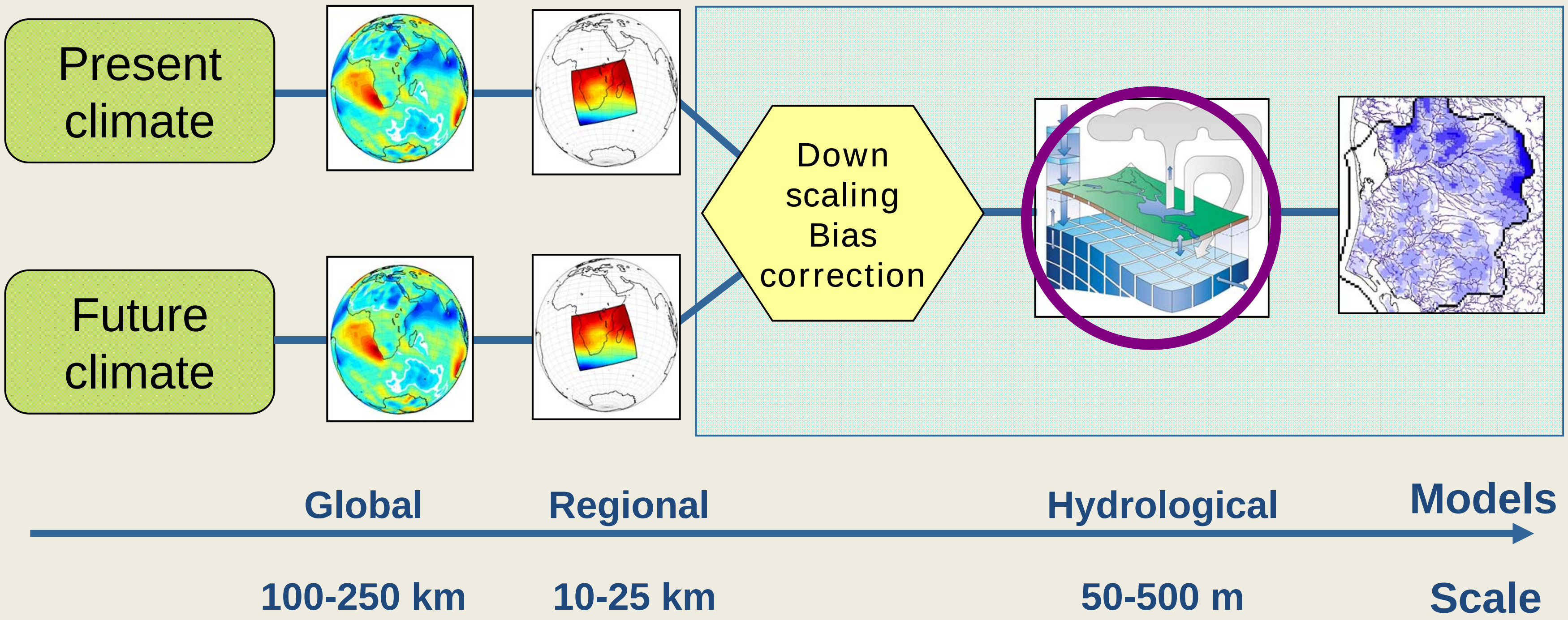


Højberg and Refsgaard (2005)

Climate change impacts on hydrology

The chain of uncertainties

- Emission scenarios
- Climate models (GCM + RCM)
- Downscaling / bias correction
- Hydrological model (geology, process equations, parameter values, input data)
- Natural variability of climate system

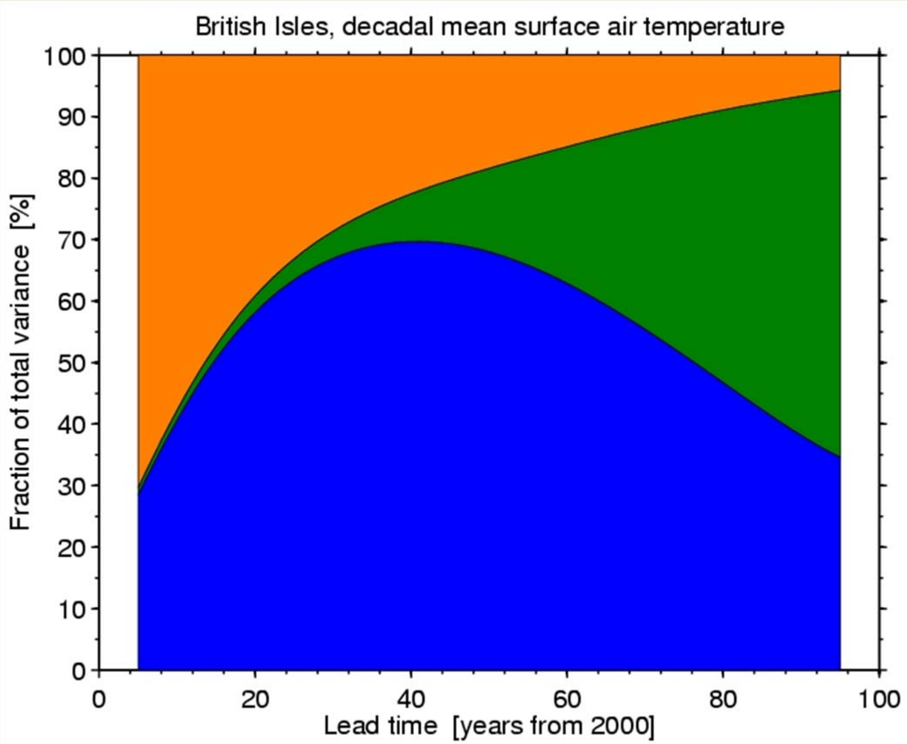


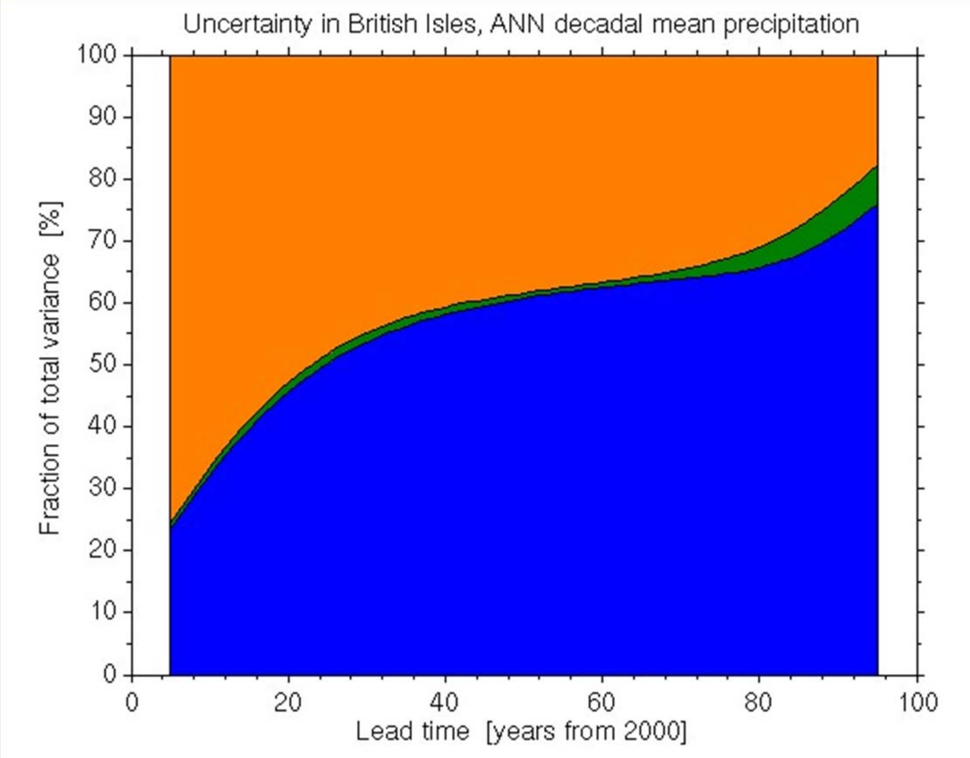
Natural climate variability

Relative importance of different sources of uncertainty

(Hawkins and Sutton, 2009 & 2010)

UK - 10 years mean temperature and precipitation





Blue: Uncertainty due to climate models (GCMs)

Green: Uncertainty due to GHG emission scenarios

Orange : Uncertainty due to internal (natural) variability

Uncertainty in climate change adaptation

- *General mapping*

Steps in climate change adaptation analyses (chain in uncertainty cascade)		**Sources of uncertainty**						**Nature of uncertainty**		
		Input data	Model			Context	Multiple know-ledge frames	Ambi-guity	Epistemic uncer-tainty (reducible)	Ontologic al uncer-tainty (ir-reducible)
			Parame-ter values	Model techni-cal aspects	Model struc-ture					
Greenhouse gas emissions						XX	XXX	XXX	XX	
Socio-economic scenarios		XX			XX	XX	XXX	XXX	XX	
Future climate (Climate models)	GCMs			XX	XXX				XXX	
	RCMs			XX	XXX				XXX	
	Initial conditions/natural variability	XX								XXX
Downscaling/statistical correction			XXX		XX				XX	XX
Water system impacts (Hydro-ecological models)		X	XXX	X	XXX	XX	X	X	XXX	X
Socio-economic impacts (Socio-economic tools)		XX			XX	XX	XXX	XXX	XX	
Adaptation measures		XX	XXX	X	XXX	XX	XXX	XXX	XXX	XX

Refsgaard et al (submitted)
CRES www.cres-centre.dk

Uncertainty in climate change adaptation

- *water infrastructure in rural areas, Denmark*

Climate change impact					Adaptation			
Type of problem	**Consequence**	**Risk level**	**Dominating uncertainty**		**Option**	**Cost level**	**Additional uncertainty**	
			Source	Nature			Source	Nature
Water supply. Changes in groundwater recharge or acceptable influence on streamflow in critical low flow periods	Change in how much groundwater can be abstracted in a sustainable manner due to either problems in aquifer or low flow conditions in stream.	High	Climate models + hydro-ecological model parameters + structure (geology)	Epistemic	Relocation of groundwater abstraction – influencing also the protection zones (item below) *(structural)*	Med	Same as for impacts	
					Changes in objectives and risk willingness *(non-structural)*	Low	Multiple frames	Ambiguity
Water supply. Changes in wellfield capture zones	The selected areas for groundwater proctection will be the wrong area.	Med	CHG emissions + climate models + hydro-ecological model parameters + structure (geology)	Epistemic	Increase protection areas to account for worst case *(structural)*	High	Same as for impacts	
					Changes in strategy, increased risk to protect wrong area *(non-structural)*	Low	Multiple frames	Ambiguity
Inundations of roads	Road traffic interrupted	Med	CHG emissions + climate model structure	Epistemic+ Ontological	New design to avoid inundation *(structural)*	High	Same as for impacts	
					Close roads + warning in critical periods *(non-structural)*	Low	Multiple frames	Ambiguity
Undermining of road foundation due to increased groundwater table	Roads deteriorate	Med	Climate models + hydro-ecological model parameters and structure (geology)	Epistemic	New designs to accept high groundwater table *(structural)*	High	Same as for impacts	
					New designs to avoid high groundwater table *(structural)*	High		
					Drainage or pumping scheme to keep groundwater table low *(structural)*	Low		

Refsgaard et al (submitted)
CRES www.cres-centre.dk

Key message 1

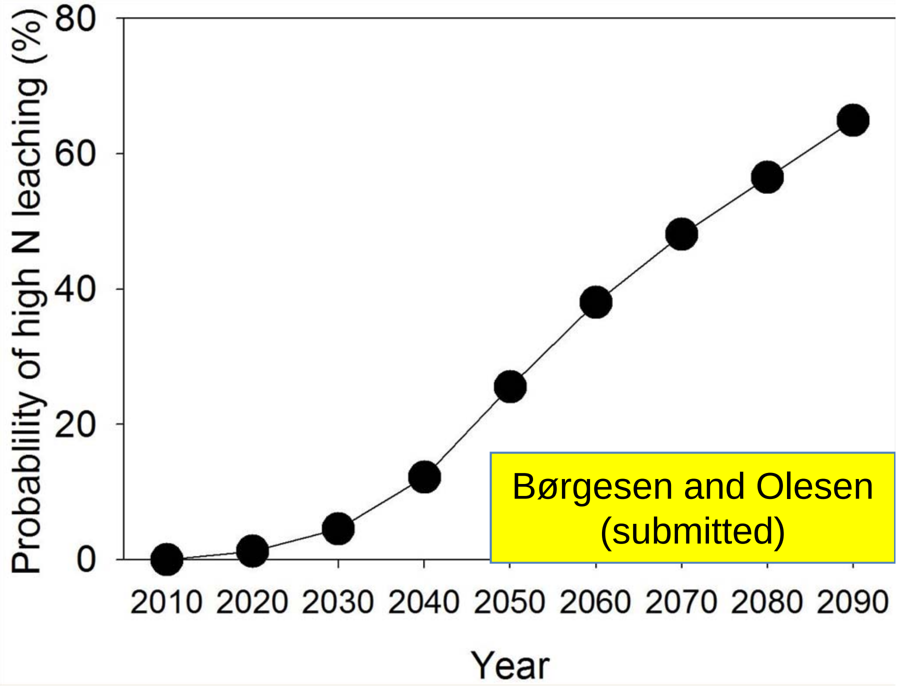
Climate change adaptation decisions needed in spite of large uncertainties - Already today, we often have sufficient knowledge to make decisions on climate change adaptations

Example 1 – urban drainage

- Design rainfall expected to increase 30% until 2100 (confidence interval 5% - 75%)
- Construction of new drainage systems: Marginal cost of 50% extra capacity ➔ only 10% extra cost
- Increase design level for construction of new built drainage systems

Example 2 – agriculture/freshwater ecosystems

- Increase of nutrient load in future climate
- Probability of average N leaching from winter wheat exceeding 70 kg/ha ➔ Critical threshold will be passed



Key message 2

Assess adaptation now as a basis for optimal timing

Example – future water supply

- Drinking water pumped from aquifers typically 50-100 years old
- Groundwater protection policy
  - Groundwater mapping, 2600 million DKK (2000 – 2015)
  - Groundwater protection, specific measures within well field capture zones to be implemented by water companies
- Climate change may change location of well field capture zones ➔ risk to protect the wrong areas
- Include climate uncertainties in assessment of well field capture zones and design action plans that are robust towards climate uncertainty.

Key message 3

Adaptation assessments should include cross-sectoral synergies

Example – Agriculture abnd freshwater ecology (negative synergy example)

- Increased winter precipitation and earlier start of agricultural field work in spring ➔ inundation problems in some (low lying) fields
- An adaptation option to improve field drainage
  - Positive for agricultural production
  - Risks of N and P loss to the aquatic environment

Key message 4

Risk willingness differs among individuals and stakeholders

Example – agriculture and freshwater ecology

- Decisions on adaption measures to ensure good ecological status will include stakeholders (agriculture, environment) with different interests and different perceptions of what constitutes the most important problem
  - Ambiguity often more important than uncertainty on climate
  - Reduction of ambiguity (e.g. by dialogue and stakeholder involvement processes) need not await that (epistemic) climate induced uncertainty is reduced

Key message 5

Risk strategies should not be based on status quo attitudes to risk acceptance

Example – inundation of roads

- Standard for road designs today: roads should never be inundated (but we accept closure of roads due to snow and closure of bridges when there are heavy winds)
- Future climate: Large uncertainty on inundations due to combinations of extreme rainfall, increased groundwater tables
  - If precautionary principle used for design of roads lasting 100 years (e.g. motorways)
    - the construction costs will be very high
    - High probability for overdesign (loss of money)
  - Alternative strategy: accept that roads are inundated at some (seldom) intervals + supplement with real-time warning systems

Strategies to handle uncertainty in climate change adaptation

- Strategy depends on nature of uncertainty
  - Epistemic: reducible by more knowledge
  - Ambiguity: reducible by dialogue and knowledge sharing
  - Ontological: non-reducible ➔ live with it
- Large uncertainties should not postpone actions
  - Some times the uncertainty has no importance for the decision
  - Planning (assess adaptation options) should be made now – as a basis for optimal timing of measures
- Adaptation assessments should include cross-sectoral synergies
- Risk perception differs among individuals and stakeholders
- Risk strategies should not be based on status quo attitudes to risk acceptance

Conclusions

Terminology

- Be aware of ambiguities in terminology used by others – and be specific defining the terminology you use

Uncertainty in climate change

- Climate change predictions involves large uncertainties
- Uncertainty sources → cascade of uncertainties
- Adaptations to climate change → additional uncertainties, ambiguity important

Uncertainty is no excuse to postpone actions on climate change adaptation

- But the adaptation strategies and actions should take the uncertainties into account