GEUS

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The role of uncertainty in climate change adaptation – examples from the water sector in Denmark

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Outline

- IDA (Danish Society of Engineers) climate change adaptation strategy for Denmark
  - Guiding principles
  - Implementation principles
  - Example of adaptation options from water sector
- Uncertainty framework (MITI paper)
  - The uncertainty cascade
  - Characterisation of uncertainty
    - Level
    - Nature
    - Source
- Strategies for coping with uncertainty
  - System control
  - System resilience

Background

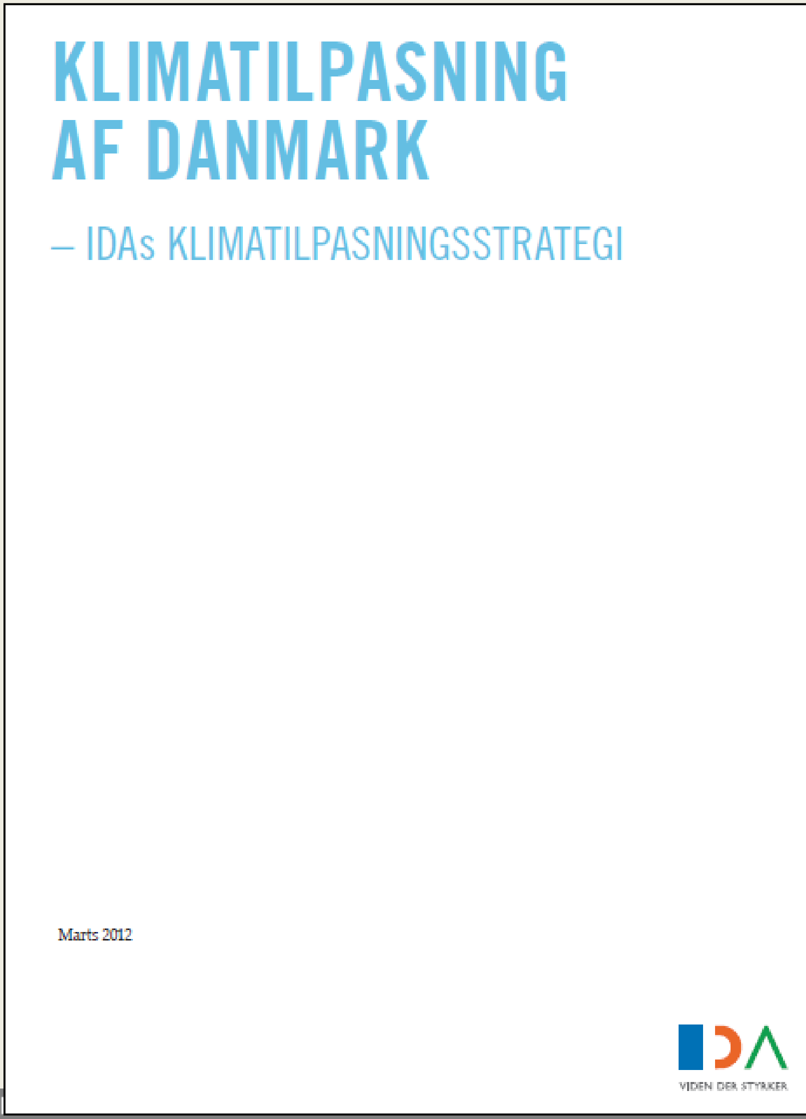
- Climate change adaptation strategies in Denmark

- National strategy (Government, 2008)
  - ”Ad hoc” adaptation
  - No requirement for government agencies or municipalities to prepare climate change adaptation strategies ➔ no co-ordination possible
  - Top down – no stakeholder involvement
  - Uncertainties not addressed
- A variety of local initiatives
  - Climate change impacts not integrated into WFD River Basin Action Plans
  - Some municipalities have developed their strategies (e.g. Copenhagen)
  - Some government agencies started to consider climate change adaptation in specific projects (e.g. Road Agency)

The Danish Society of Engineers (IDA)

- A knowledge based strategy for climate change adaptation of Denmark
- March 2012
- Authored by a group of scientists and professionals/practitioners

http://ipaper.ipapercms.dk/IDA/Politik/Klimatilpasning/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IDA climate change adaptation strategy for Denmark

Guiding principles

- Climate change risk assessment **must** be performed
- **Uncertainties** in climate change impacts and in effects of adaptation measures must be taken into account. Very large uncertainties ➔ look for robust solutions
- **Stakeholder involvement** crucial. Both for problem identification and for assessing possible adaptation measures
- **Cross-sectoral** impacts needs to be analysed. Look both for positive and negative synergetic effects
- Prepare **contingency plans to cope with extreme events**
  - Infrastructure to protect against consequences of extremes (structural)
  - Actions to reduce impacts of extremes, e.g. real-time forecasting, warning and control (non-structural)

IDA climate change adaptation strategy for Denmark

Implementation principles

- Climate change adaptation must be integrated in existing planning processes (Water Framework Directive, Groundwater Directive; Habitate Directive, physical planning of rural and urban areas, etc.)
- Not a one-off master plan, but rolling planning with updated information on climate change impacts for each planning cycle
- Develop competences within climate change adaptation which can also form a basis for export of Danish services to other countries
  - Create home market demand for sophisticated, integrated solutions
  - Research, innovation and demonstration projects to develop and test new technologies

IDA climate change adaptation strategy for Denmark

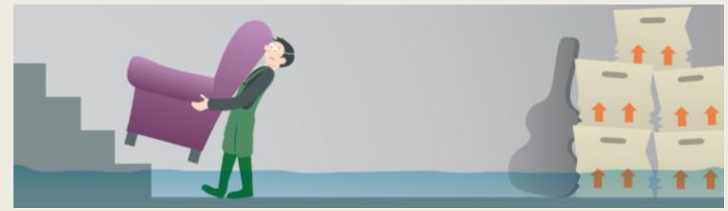
Sectors – climate change impacts and adaptation options

- Water in rural areas

- Ocean and coastal areas

- Water in urban areas

- Buildings



- Transport

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Water in rural areas

Climate change impact - threats
Change in groundwater level/flooding/water logged areas
Drought and water scarcity
Deterioration of groundwater quality – threat against water supply
Deterioration of freshwater ecosystems

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Water in rural areas

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Adaptation options	Effect of adaptation option	Comments
Improved retention of water in the catchment	Moderation of streamflow hydrograph; increased biodiversity, increased groundwater recharge	Possibly loss of agricultural production
More effective draining and pumping of areas with shallow groundwater	Improved possibilities for effective agriculture	Increased maximum flows of water and solute; less wetlands; less biodiversity, reduced groundwater recharge
Real-time forecasting	Possibility for targetted warning and mitigation plans	

The largest challenge → uncertainty

- Changes in monthly precipitation over Denmark to 2071-2100

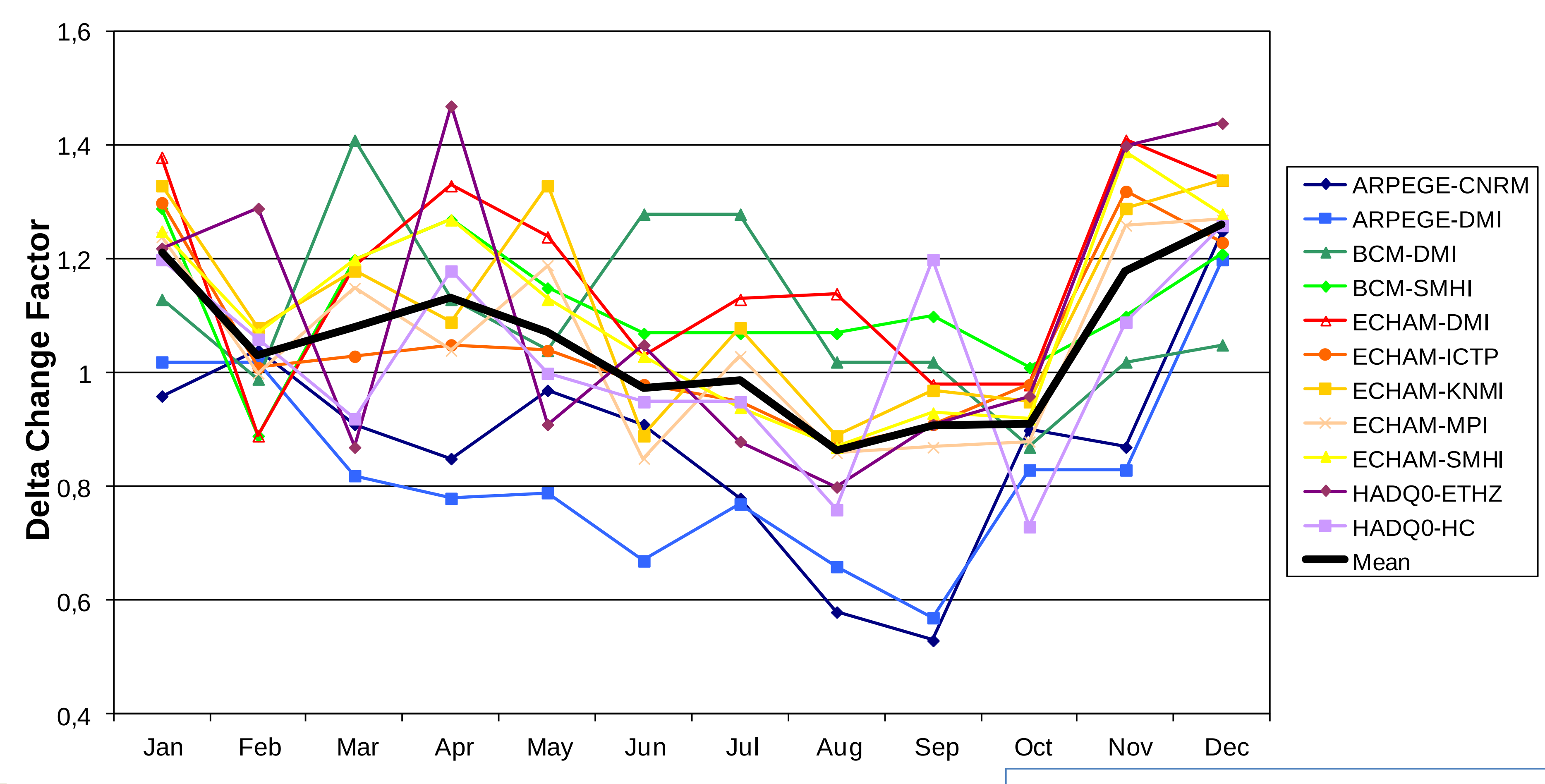
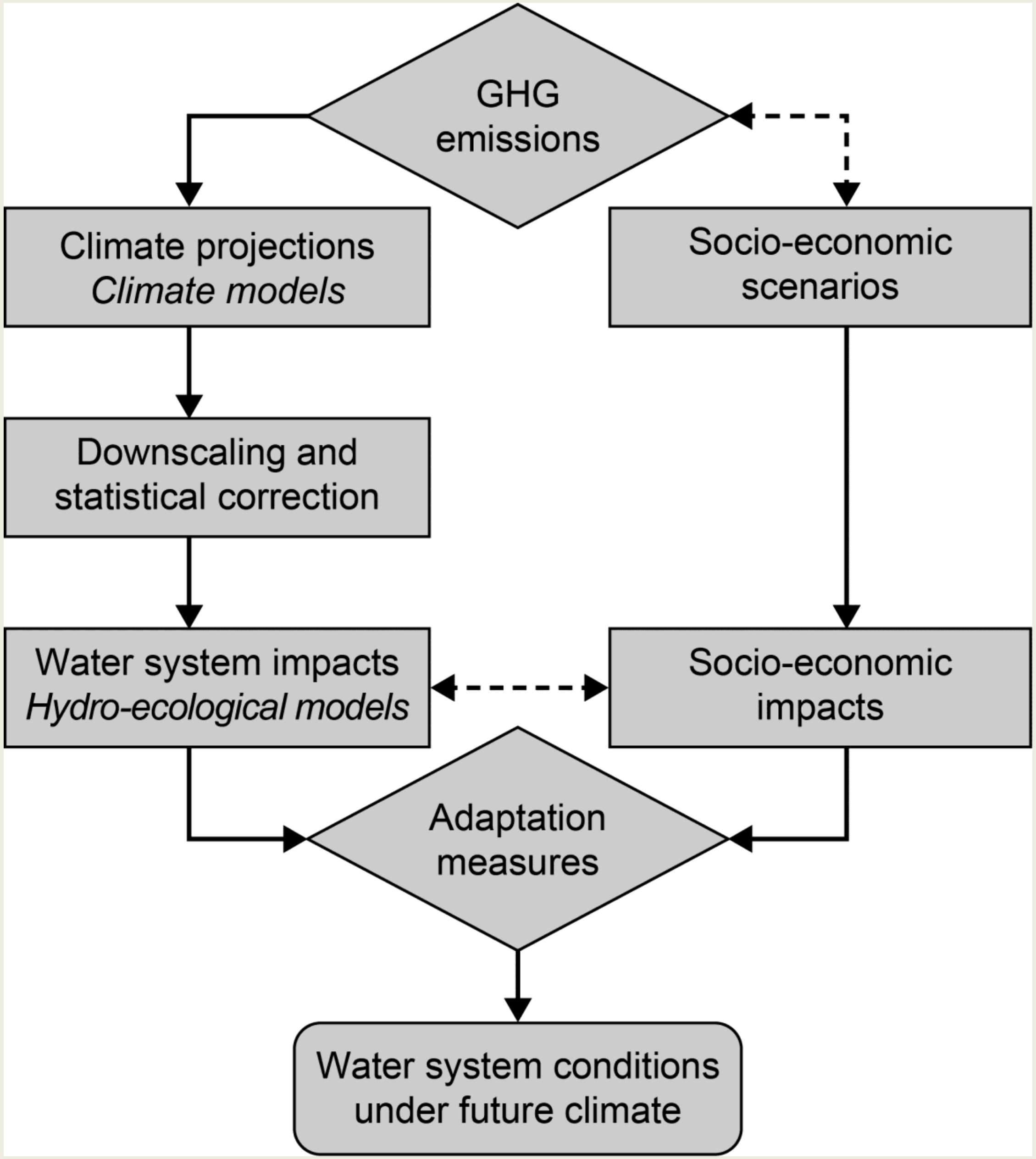


Figure: Lauren P Seaby, GEUS PhD project www.hyacints.dk

Data from 11 GCM/RCM models from the ENSEMBLES project (A1B)

The uncertainty cascade



Nature of uncertainty

Epistemic uncertainty

- uncertainty due to imperfect knowledge

➔ *reducible by more data and knowledge*

Aleatory uncertainty

(Other names: unpredictability, 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

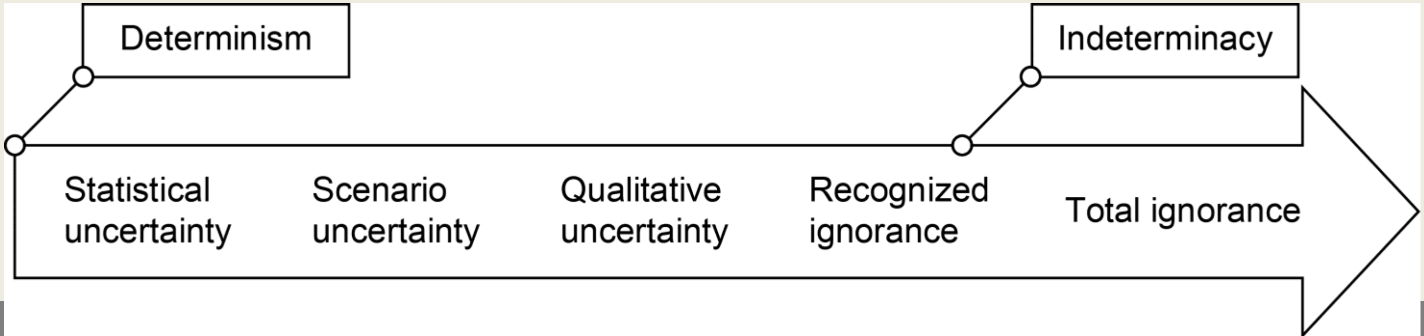
Statistical uncertainty
- All outcomes known
- All probabilities known

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	Aleatory 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)

Strategies for coping with uncertainty in climate change adaptation

System control

- Stable, predictable system (small uncertainty)
- Control of key variables, reduce uncertainty (e.g. construct dike)
- Strength: performs well under controlled (foreseen) conditions
- Weakness: reduced system performance in unforeseen events (potential for system collapse in case storm > dike design)

Building of system resilience

- Complex, unpredictable system (large uncertainty)
- Improve system flexibility. For instance activate multiple measures in case of storm > dike, e.g. controlled inundation of certain areas, real-time warning, contingency plans. Requires active stakeholder involvement (social learning)
- Strength: more flexible for situations with large uncertainty and big chances to face new, unforeseen situations

➔ **Need for a combination of the two strategies**

System control - resilience

Example – inundation and road design for a future climate

System control – design infrastructure to avoid inundation

- Today: roads should never be inundated (but we accept closure of roads due to snow and closure of bridges due to 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)

Building resilience

- Accept that roads are inundated at some (seldom) intervals
- Supplement with real-time warning systems
- Supplement with controlled inundation of other areas

Conclusions

IDA climate change adaptation strategy

- Climate change risk assessment must be performed
- Uncertainty
- Stakeholder involvement
- Cross-sectoral integration
- Contingency plans for handling of extreme events
- Implementation in existing planning cycles

Uncertainty framework

- Characterisation of uncertainty according to
    - Nature (epistemic, aleatory, ambiguity)
    - Level of uncertainty (statistical, scenario, qualitative, ignorance)
    - Source of uncertainty (data, models, context, multiple knowledge frames)

Coping with uncertainty in climate change adaptation

- Climate change adaptation not just a matter of changing factors in design formula ➔ need for a completely new planning paradigm
- Need to build more resilience instead of system control

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– and further information

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ORIGINAL ARTICLE

The role of uncertainty in climate change adaptation strategies—A Danish water management example

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Abstract We propose a generic framework to characterize climate change adaptation uncertainty according to three dimensions: level, source and nature. Our framework is

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