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Global and regional climate models fail to predict the impact of climate change on water availability in the Zambezi basin, southern Africa

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Global and regional climate models fail to predict the impact of climate change on water availability in the Zambezi basin, southern Africa

Outline

1. Introduction

Literature review

2. Rainfall
3. Stream flow
4. Sectoral impacts: agriculture, economic, ecosystems

Interpretation

5. Uncertainty
6. Alternative approaches
7. Conclusions

1. Introduction

Awareness that the future is uncertain

Climate change is on many people's mind

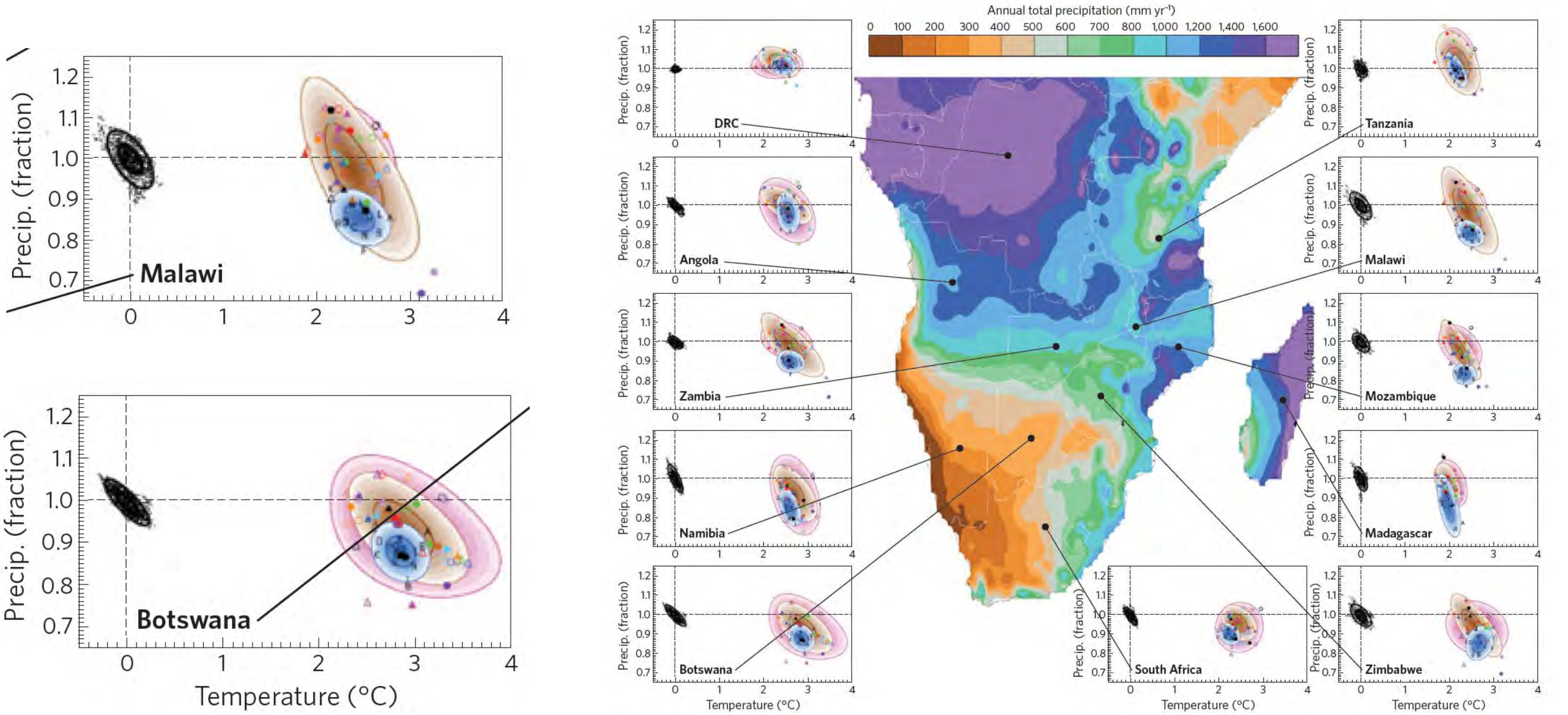
WWF:

What will be the impact of climate change on the livelihoods and the ecosystems of the Zambezi?

Let's try to get the answer from the literature:

– 40 papers published since 2010

2. Current knowledge on climate change in Zambezi - rainfall



Average annual total precipitation (1961–1990) and multimodel ensembles of projected changes in national average annual precipitation (as a fraction of 1961–1990 mean) and national average annual mean temperature (°C change from 1961–1990 mean).

Source: Conway et al. (2015)

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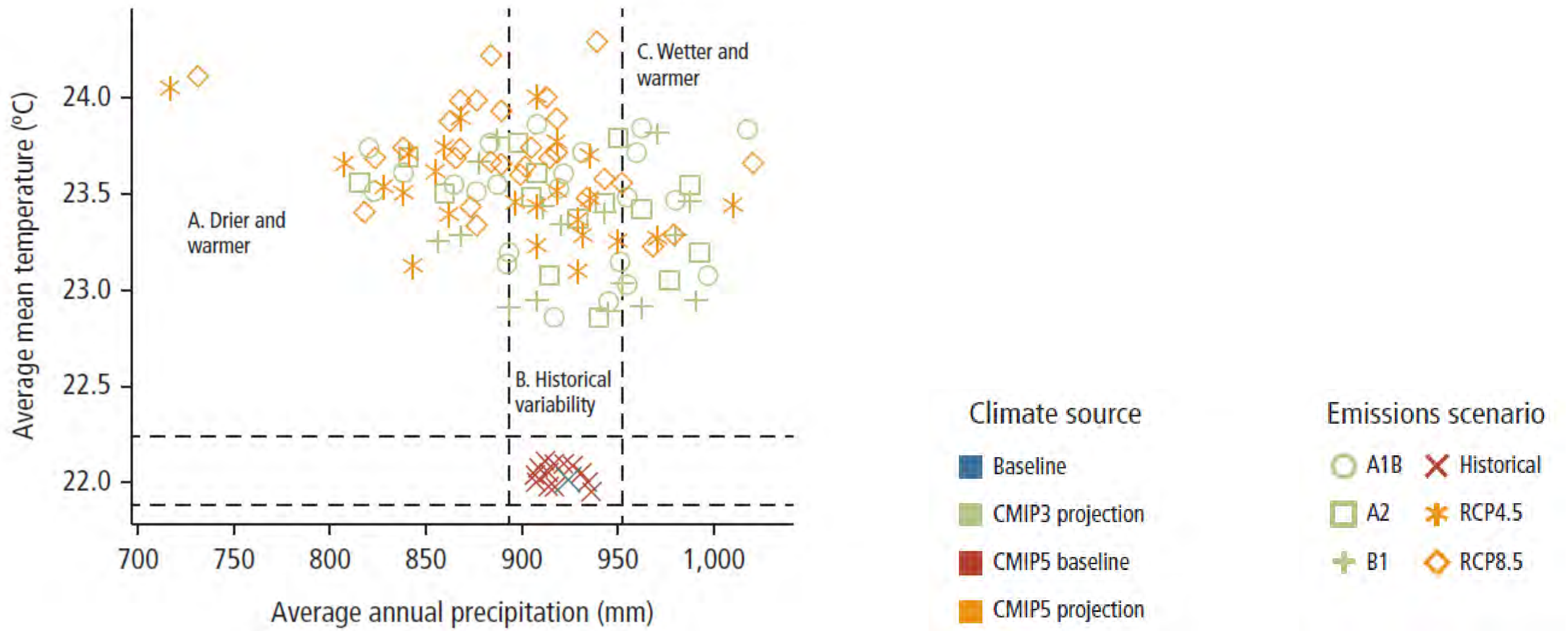
2. Current knowledge on climate change in Zambezi - rainfall

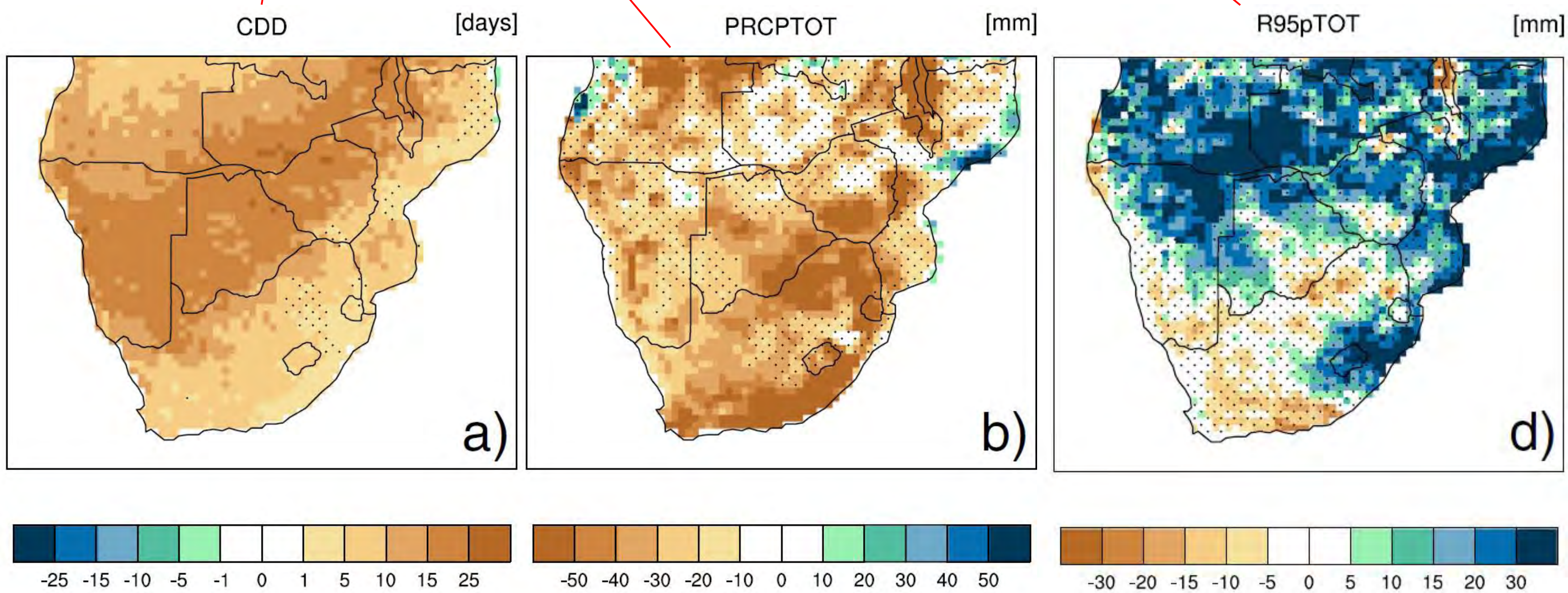


Climate futures in 2050 for the Zambezi basin

Source: World Bank, 2015

2. Current knowledge on climate change in Zambezi - rainfall

- max. number of consecutive dry days [CDD] will *increase*
- annual total precipitation [PRCPTOT] will *decrease*
- number of very wet days [R95pTOT] will *increase*



Projected multi-model mean changes in moderate extreme events for the period of 2069–2098 under RCP4.5 emission scenario, relative to the reference period 1976–2005

Stippling indicates grid points with changes that are not significant (5 % significance level using t-test)   Source: Pinto et al. (2015)

2. Current knowledge on climate change in Zambezi - rainfall

Lack of consensus among scientists

"the [GCM and RCM] models are able to capture the observed climatological spatial patterns of the extreme precipitation [in Southern Africa]"

Source: Pinto et al., 2015

"Downscaled GCMs cannot reproduce important historical rainfall characteristics, such as such as number of raindays and wet-dry sequences [in the uMngeni catchment in South Africa]"

Source: Kusangaya et al., 2016

3. Current knowledge on climate change in Zambezi - streamflow

Seven recent hydrological studies papers attempt to assess climate change impact on streamflow (hence blue water)

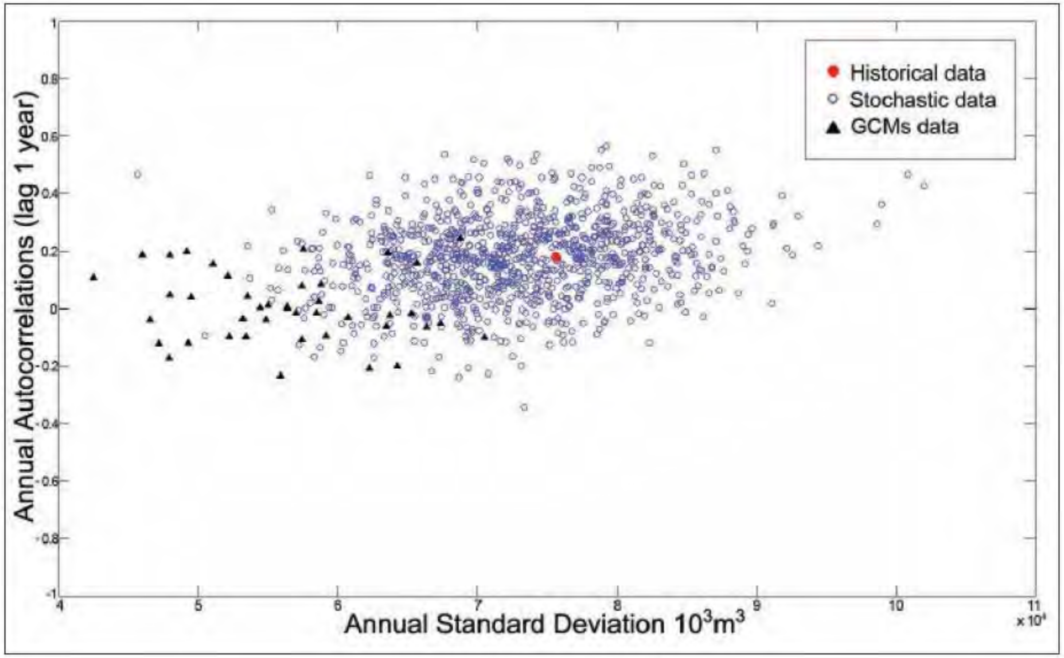
Some conclusions:

- all use relatively old scenarios; none are based on the RCPs;
- all are based on GCMs and thus have a very coarse spatial resolution; downscaling of *P* to finer spatial resolutions is simplistic
- all except one (Ngongondo et al., 2013) use monthly time-step, which makes it difficult to account for the hydrological impact of expected change in rainfall

Thus, existing studies cannot achieve what they are supposed to do!

3. Current knowledge on climate change in Zambezi - streamflow

Downscaled GCMs cannot reproduce variability in stream flow



Variability statistics of bias-corrected, statistically downscaled historical GCM, 30-year simulations (triangles) and resampled historical 30-year annual streamflow (circles) for a region of the northeast United States.
The actual historical value is indicated by the red dot.

Source: Brown and Wilby, 2012

4. Current knowledge on climate change in Zambezi - sectoral impact

Agricultural impact

The few papers that specifically look into the impacts of climate change on agriculture are empirically thin.

Rosenzweig et al. (2014) provide global data on the impact of climate change on crop yields, which Conway et al. (2015) use to conclude that:

> “The simulated maize yield averaged across southern Africa decreases by 15.7 ± 16.3% (rain fed) and 8.3 ± 20.4% (irrigated) by the 2080s relative to the 2000s.
> [...]
> Average crop water use decreases, resulting in a 5.9 ± 20.7% increase in estimated crop water productivity”

Source: Conway et al., 2015: 841

4. Current knowledge on climate change in Zambezi - sectoral impact

Socio-economic impact

The special issue of *Climatic Change* 130 (1) entitled
"Climate change and the Zambezi River Valley"
would ideally answer the WWF question:

"GDP loss in 2050 due to climate change in Mozambique of 3.1%:
- agricultural output will decline by 4% (affecting GDP by -0.4%)
- damage to roads reduces GDP by 2%
- to hydropower by 0.3 %, and
- cyclones by 0.4%."

"GDP losses of less than five percent by about 2050 imply a growth delay of less than two years. … Viewed through this optic, climate change does not appear to exert a large influence at least out to 2050."

Source: Arndt and Thurlow (2015)

4. Current knowledge on climate change in Zambezi - sectoral impact

Ecological impact

No papers were found that are concerned with the impact of climate change on the ecology in the Zambezi basin.

5. Uncertainty

Can climate models correctly forecast future (blue) water availability?

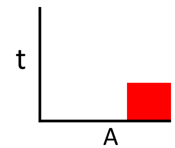
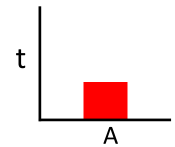
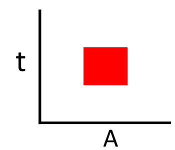
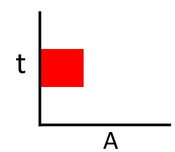
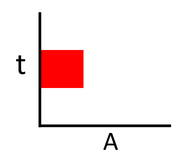
"The traditional approach uses ensembles of climate model simulations, statistical bias correction, downscaling to the spatial and temporal scales relevant to decision-makers, and then translation into quantities of interest.

The veracity of this approach cannot be tested, and it faces in-principle challenges."

Source: Hazeleger et al, 2015, p. 107

5. Uncertainty

Can climate models correctly forecast future (blue) water availability?

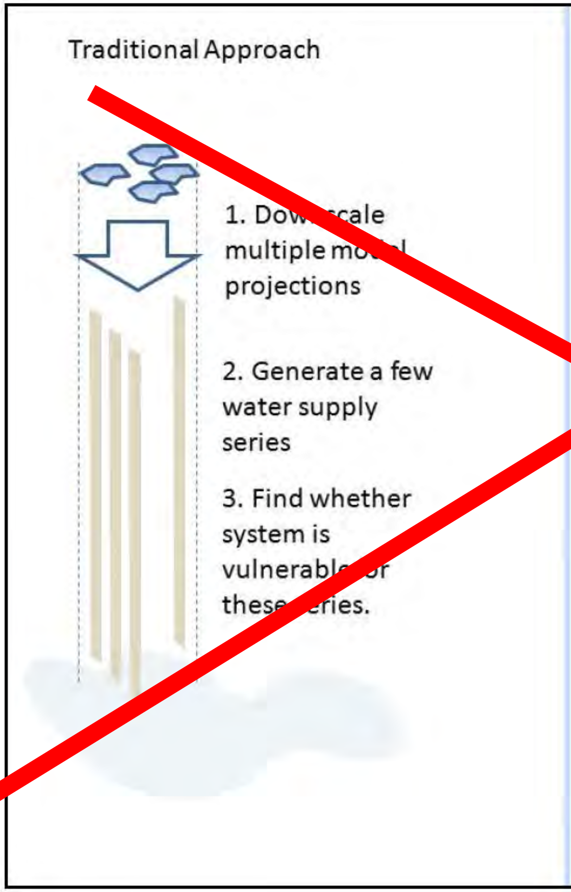
		Resolution	Spatial (A)	Temporal (t)
Available data	GCM		10^4-10^5 km^2	hours/days
	RCM		10^4-10^5 km^2	hours
Required data	T (temp)		10^1 km^2	days
	P (rain)		10^{-2}-10^0 km^2	days
	Q (flow)		10^{-2}-10^0 km^2	days

5. Uncertainty

Perhaps the only valid conclusion that may be drawn is:

With the current state of knowledge and techniques
it is impossible to generate data at the required spatial resolution
to be able to predict future green and blue water availability
in so far as they influence livelihoods
with any degree of precision

5. Uncertainty



The traditional MCDT model:

Model the entire climate system,
Correct for biases,
Downscale to the scales of interest
Translate into terms suitable for application

Source: Hazeleger et al., 2015

Picture: Casey Brown, "Decision-scaling for Robust Planning and Policy under Climate Uncertainty." World Resources Report, Washington DC; http://www.worldresourcesreport.org

5. Uncertainty

So we have to do things differently!

- Tales of future weather
- Decision-scaling
- Dynamic Adaptive Policy Pathways

6. Alternative approaches that can better deal with uncertainty

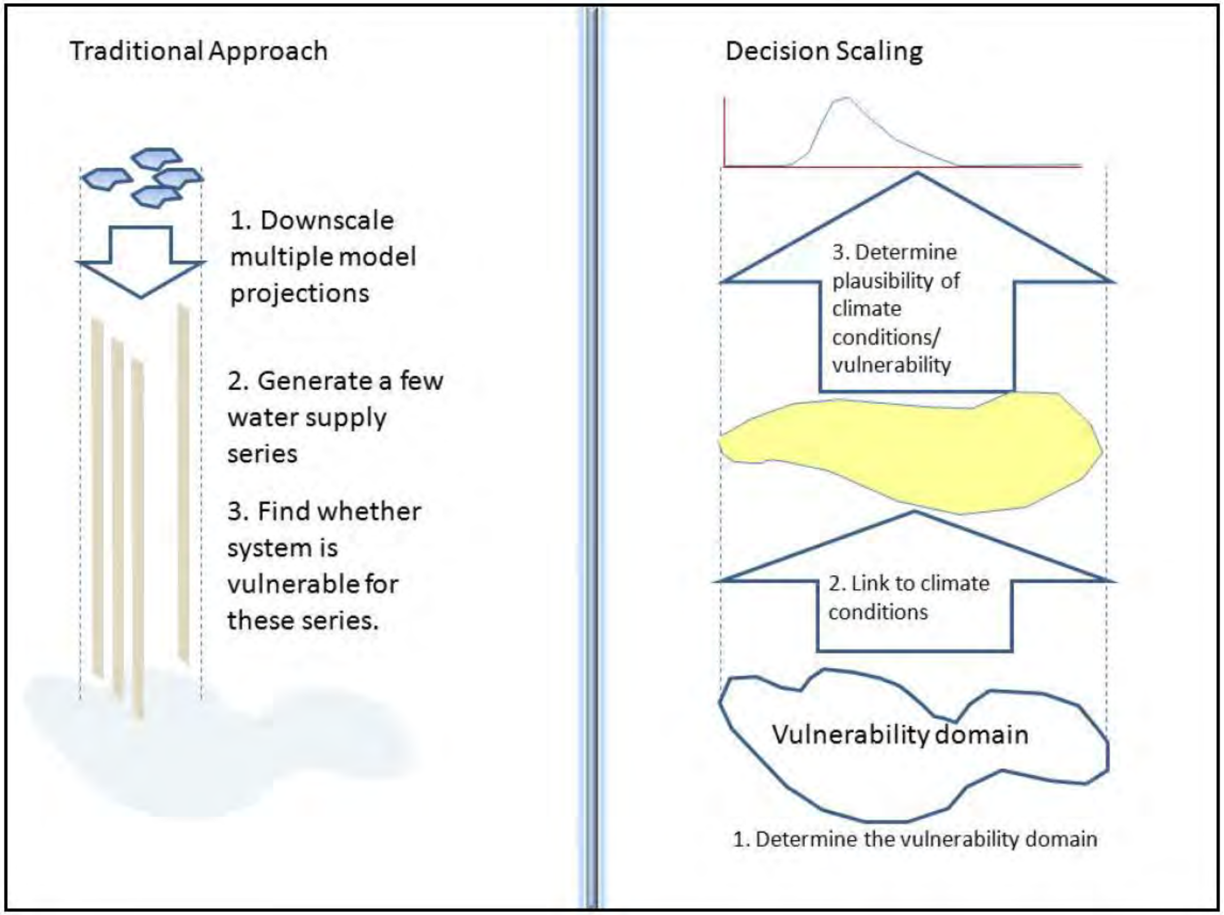
Tales of future weather (Hazeleger et al. 2015)

- Develop storylines of realistic synoptic weather events [~1000 km scale]
- Link these to past weather analogues and everyday experiences of people
- Analogue weather events are put into the context of the vulnerability of society to extremes
- Having analogues allows these to be considered in much greater detail
- Then synoptic weather patterns in a future climate setting are developed, e.g. using traditional (calibrated) climate models,
  while using GCMs and RCMs to generate plausible background/boundary conditions consistent with larger-scale changes in the climate system.
- The Tales approach avoids a naive realist interpretation of climate model simulations as forecasts, by focusing on individual meteorological events.

6. Alternative approaches that can better deal with uncertainty

Decision scaling (Brown et al., 2012)

The question is not
"what will the future climate be?" which is very difficult with an infinite number of possibilities,
but rather
"is the climate that favors action A more or less likely than the climate that favors action B?"



Source: Casey Brown, "Decision-scaling for Robust Planning and Policy under Climate Uncertainty." World Resources Report, Washington DC. See http://www.worldresourcesreport.org

6. Alternative approaches that can better deal with uncertainty

Decision scaling (Brown et al., 2012)

Step 1. Bottom-Up Analysis: Identification of key concerns and decision thresholds.

- Stakeholders identify climate conditions that have caused problems historically or that are otherwise of concern and/or require a particular decision to be taken.

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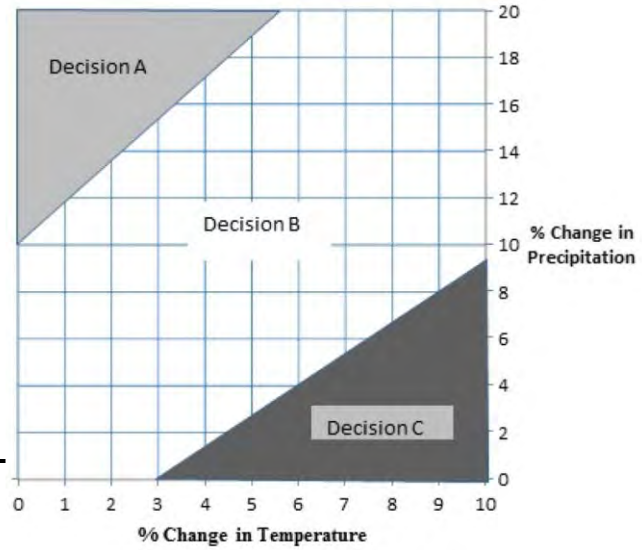
Step 2. Model the response to changing climate conditions.



6. Alternative approaches that can better deal with uncertainty

Decision scaling (Brown et al., 2012)

Step 1. Bottom-Up Analysis: Identification of key concerns and decision thresholds.

- Stakeholders identify climate conditions that have caused problems historically or that are otherwise of concern and/or require a particular decision to be taken.

Step 2. Model the response to changing climate conditions.

Step 3. Estimate relative probability of changing climate conditions.

- This may involve the use of projections from GCMs, or stochastic simulations from historical data or paleoclimatological data, or narrative assessments of future climate based on local and regional knowledge.

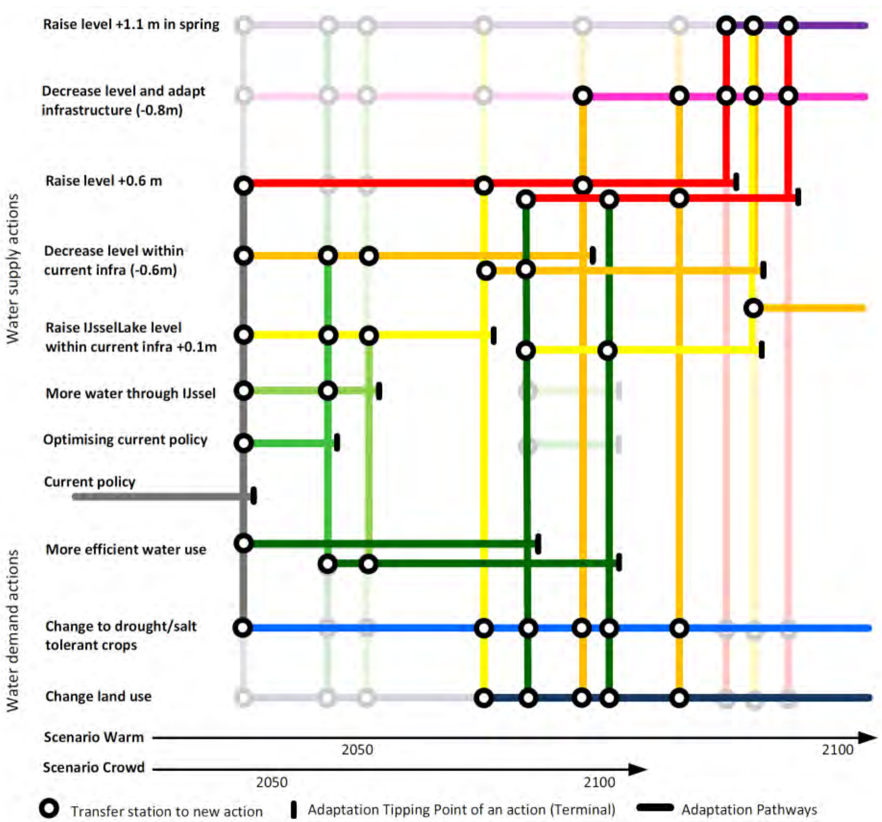
6. Alternative approaches that can better deal with uncertainty

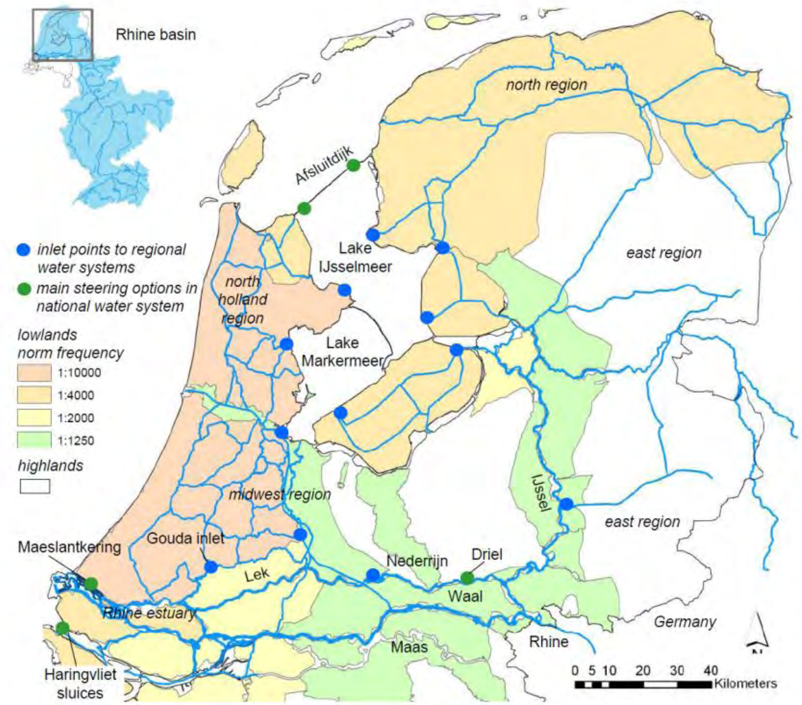
Dynamic adaptive policy pathways (Haasnoot et al., 2013)

- Develop alternative development scenarios for a water system (which include possible economic, population and climate futures)
- Identify possible actions, and their sell-by dates
- Identify feasible pathways
- Select preferred pathways
    - Postpone expensive interventions as much as possible
    - Implement no-regret actions first
- Monitor & learn

6. Alternative approaches that can better deal with uncertainty

Dynamic adaptive policy pathways





Source: Haasnoot et al., 2013

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7. Conclusions

- Concerns for the impact of climate change on society are real and legitimate
- We need to prepare water-dependent systems for future climate change

  (we should have prepared them to cope with current climate variability)
- We should invert the conventional approach – bottom up:
- Start with the water-dependent system at hand, and not with future climate
- Analyse vulnerability to current climate extremes and future climate change
- Engage stakeholders and their local knowledge of past climate events
- Focus on decisions that can make water systems resilient to extremes
- Start implementing no-regrets NOW!

Start implementing no-regrets NOW !

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