Detection and prediction of uncertain climate thresholds: Challenges and research needs

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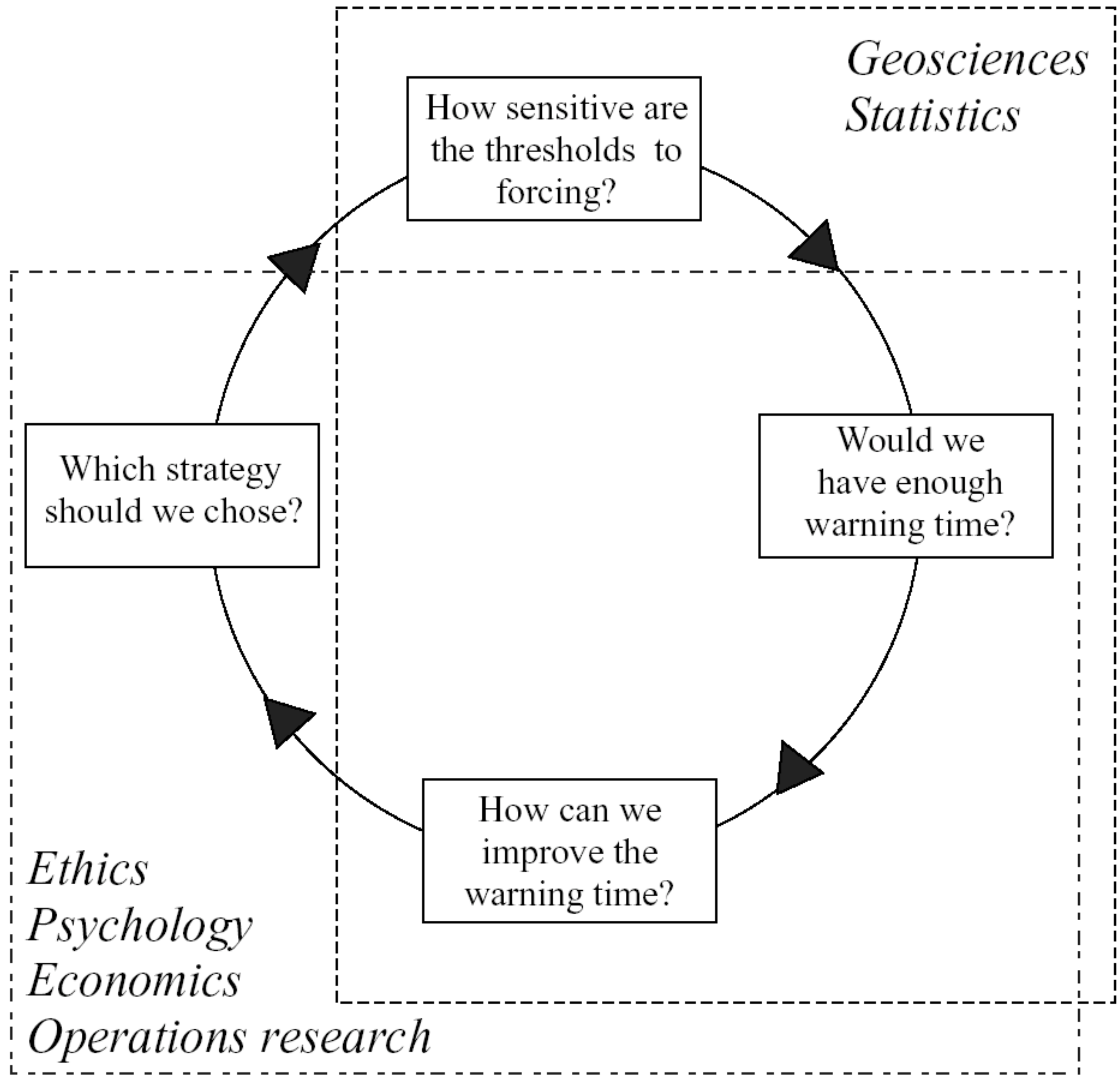
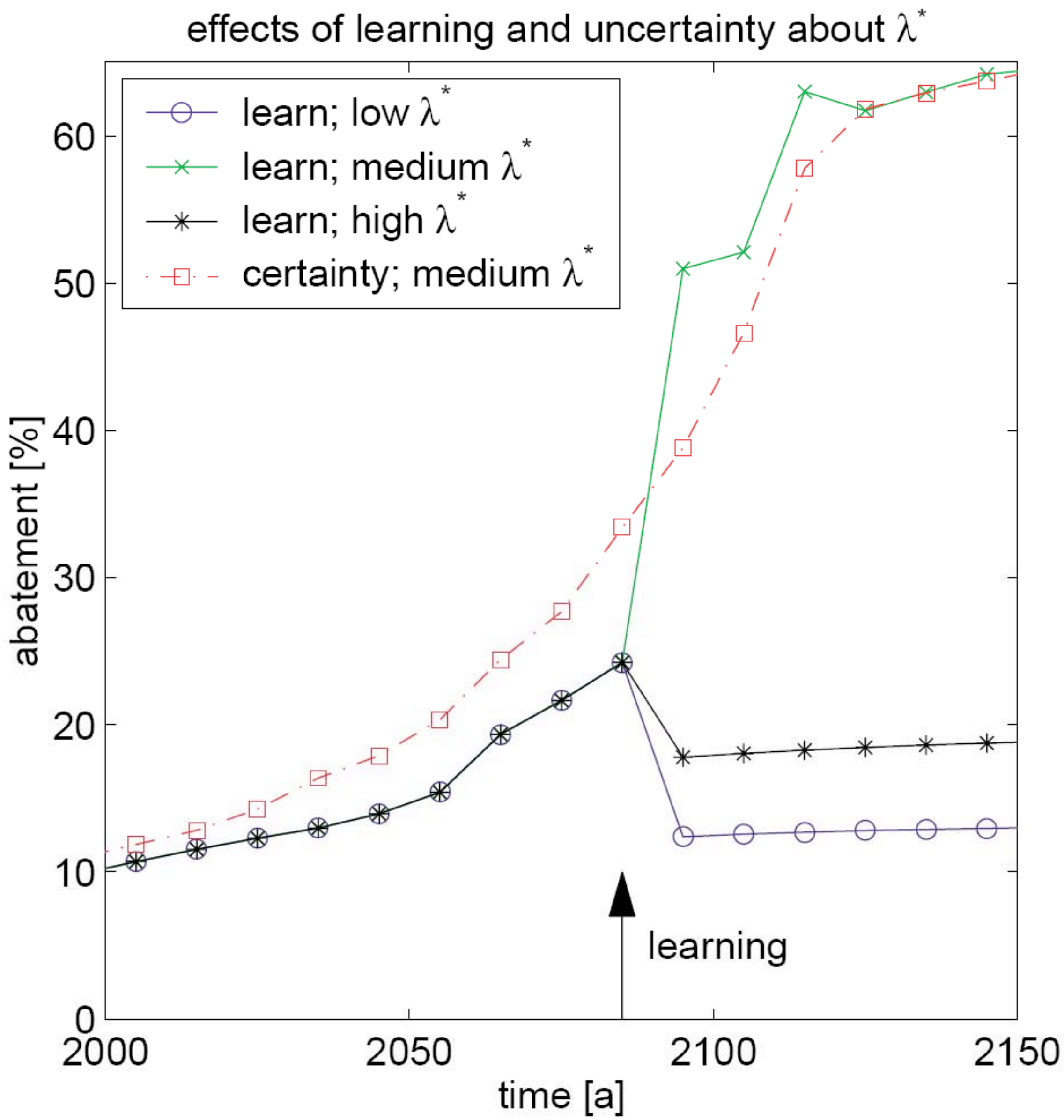
Designing a sound strategy in the face of uncertain climate thresholds requires:

(i) Fundamental advance in the disciplines; and

(ii) A solid integration across disciplines.



Reducing the uncertainty about future climate thresholds can improve climate policies



Considered objective: optimal control with a potential MOC collapse under uncertainty and learning.

Keller *et al* (2004)

Five Challenges

i. Detection might occur *after* the threshold has been triggered.

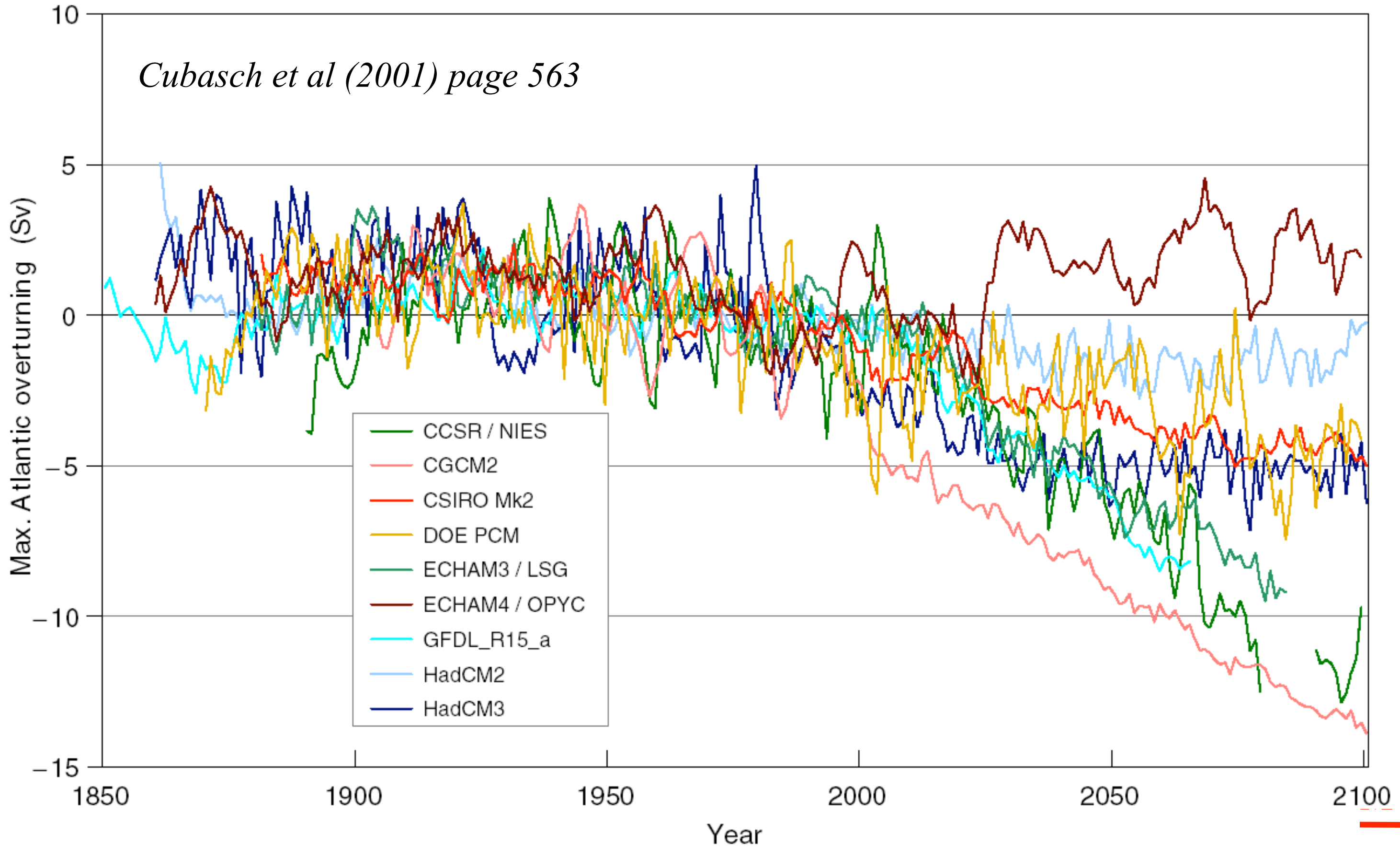
ii. Future detection and prediction are random variables.

iii. Detection requires so far unknown information about the nature of the unforced variability.

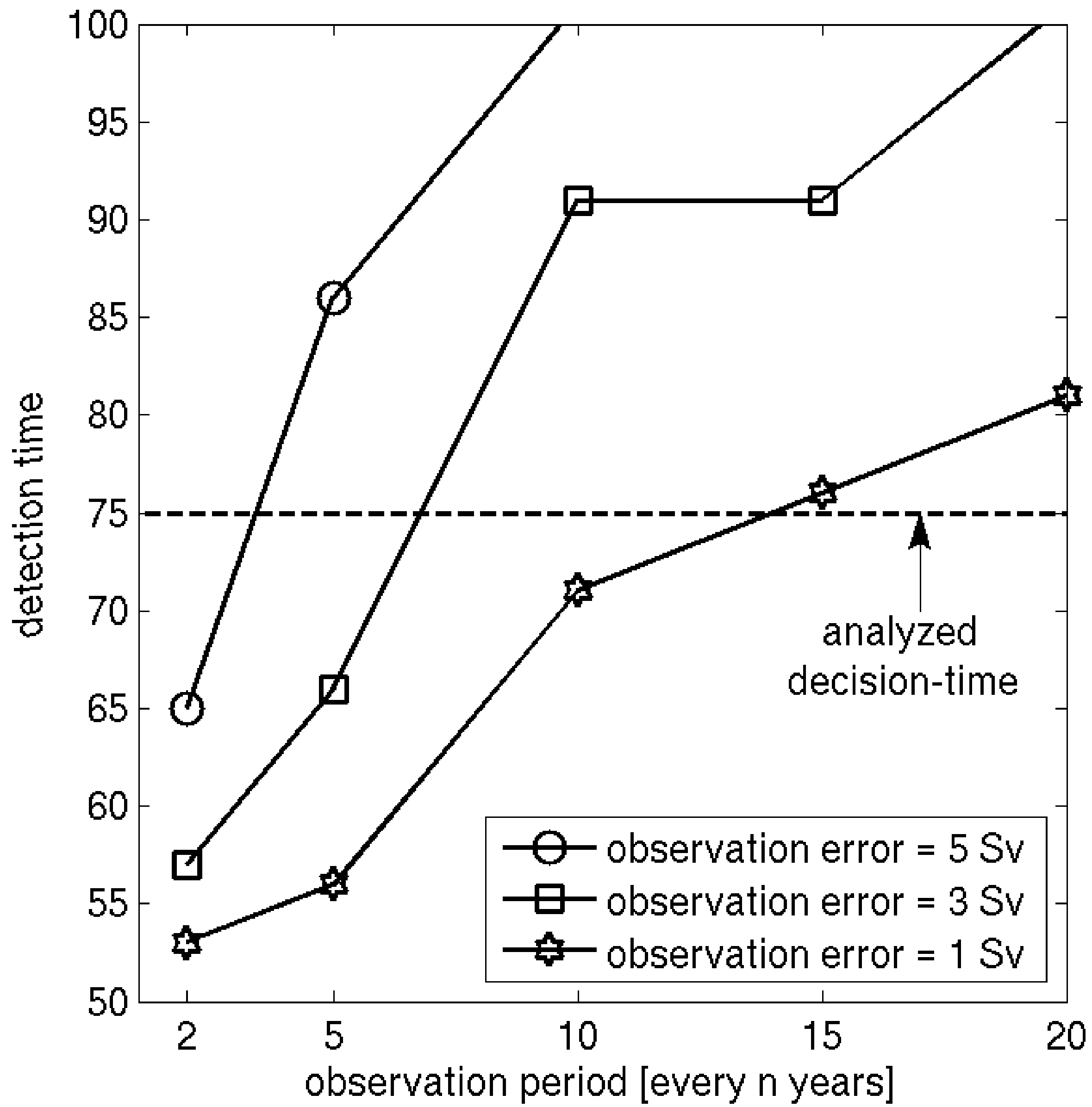
iv. Current decision-analyses of climate thresholds are likely based on overconfident parameter estimates.

v. *Prediction*, not just detection is required for many decision-making frameworks.

(i) Detection might occur *after* the threshold has been triggered.



Not all MOC observation systems may deliver actionable warning signs before decisions have to be made.



Some of the caveats:

- A single MOC model
- Simplistic forcing
- Shown are *median* detection times (discussed later)

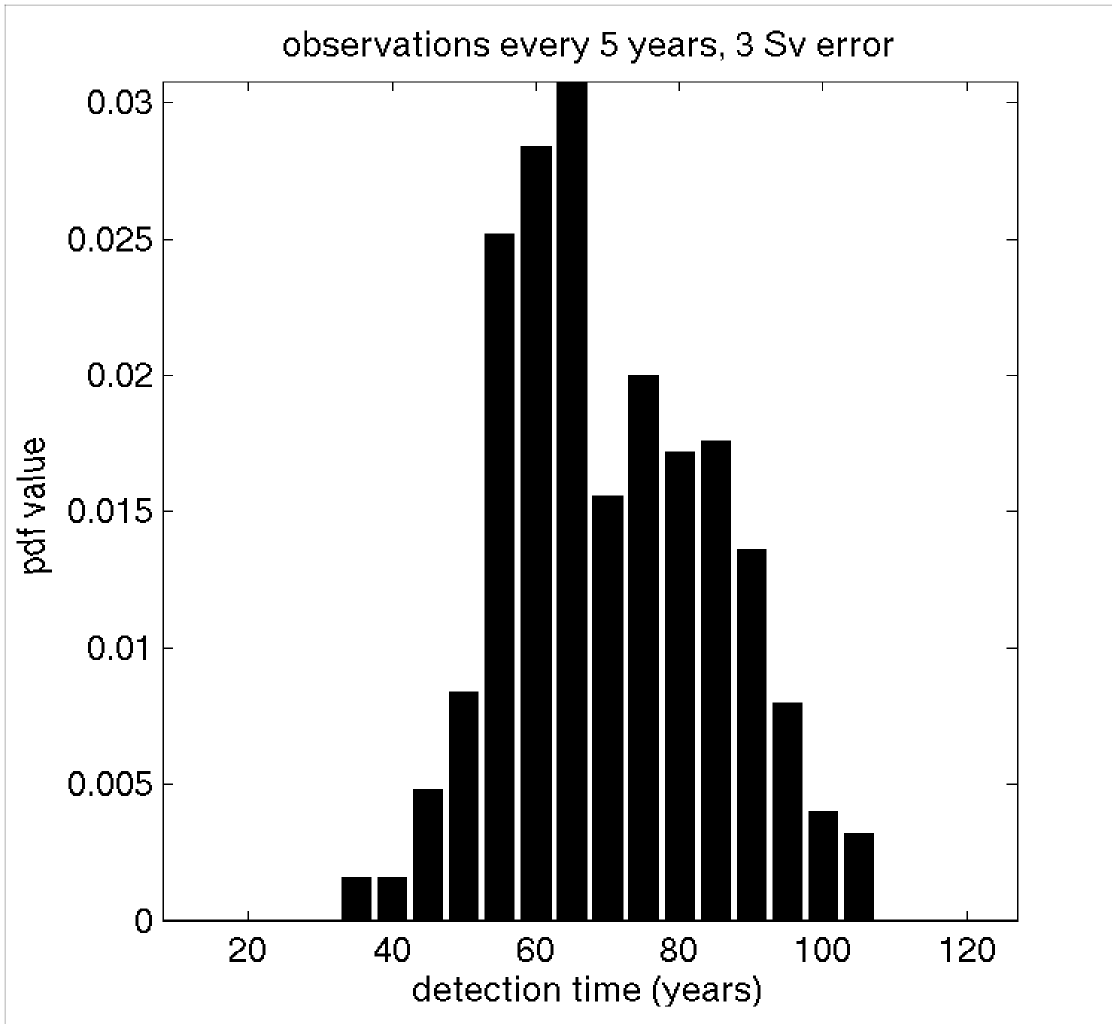
Keller et al (2005)

(ii) Future detection is a random variable.

- Do decision-makers prefer robust or reliable decision-making over expected utility maximization?

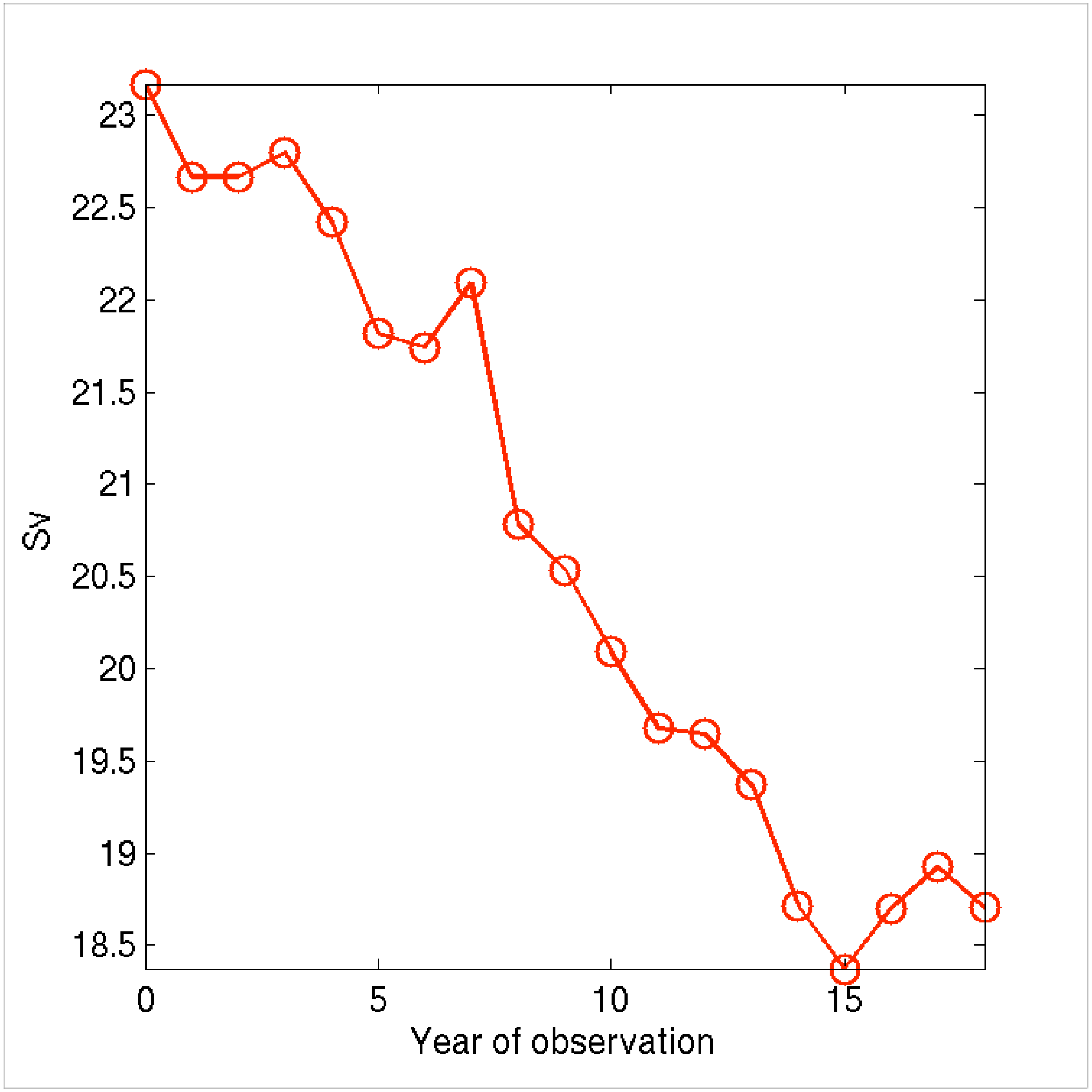
- For what reliability or degree of risk-aversion should one design the system?

- If detection based on the pure MOC is so difficult, are there additional sources of information that one could use?



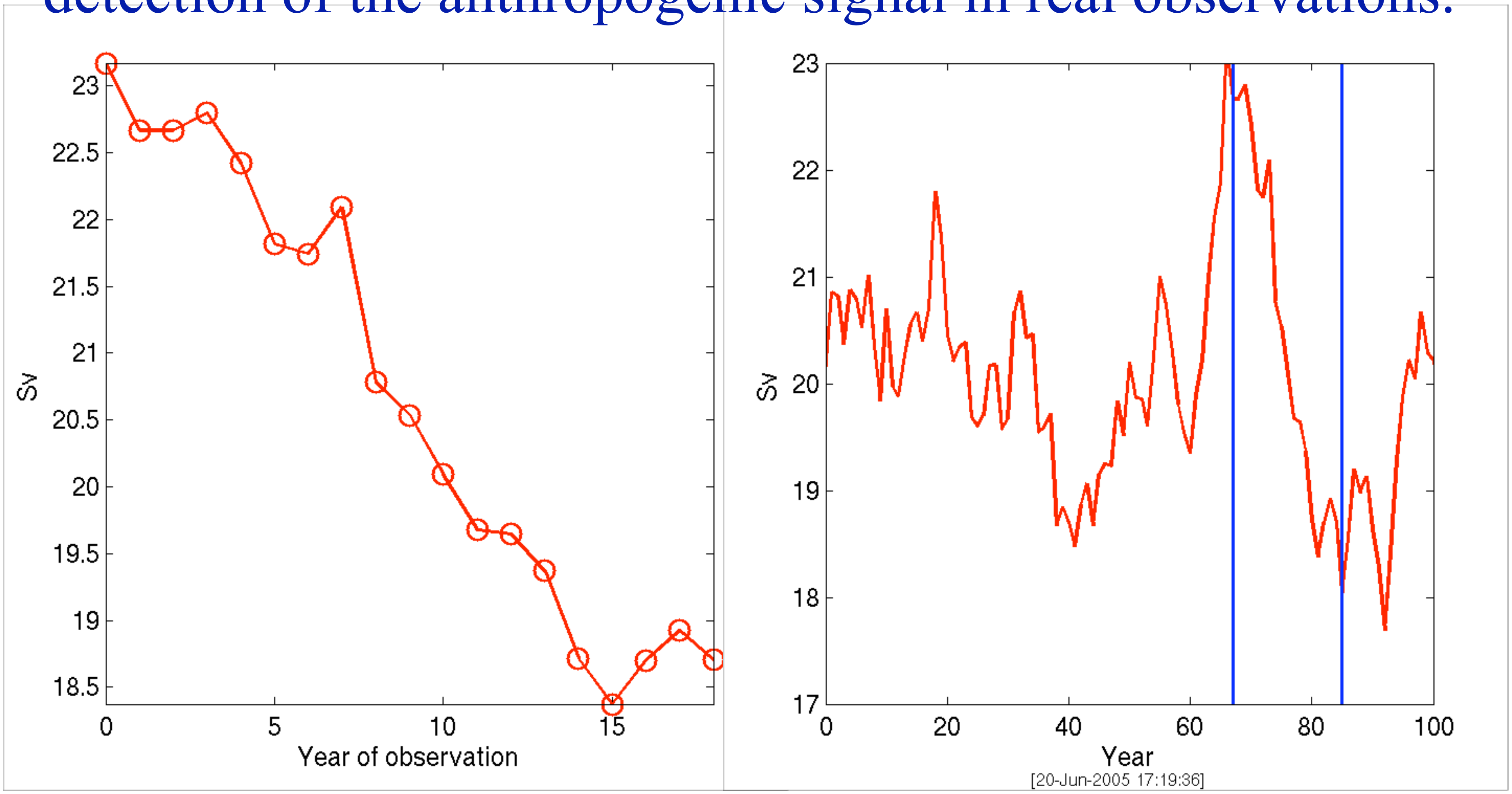
cf. Keller et al (2005)

(iii) Detection requires so far unknown information about the nature of the unforced variability.



Example time series (artificially produced without any observation error): What would one conclude if this were the information from an implemented MOC observation system?

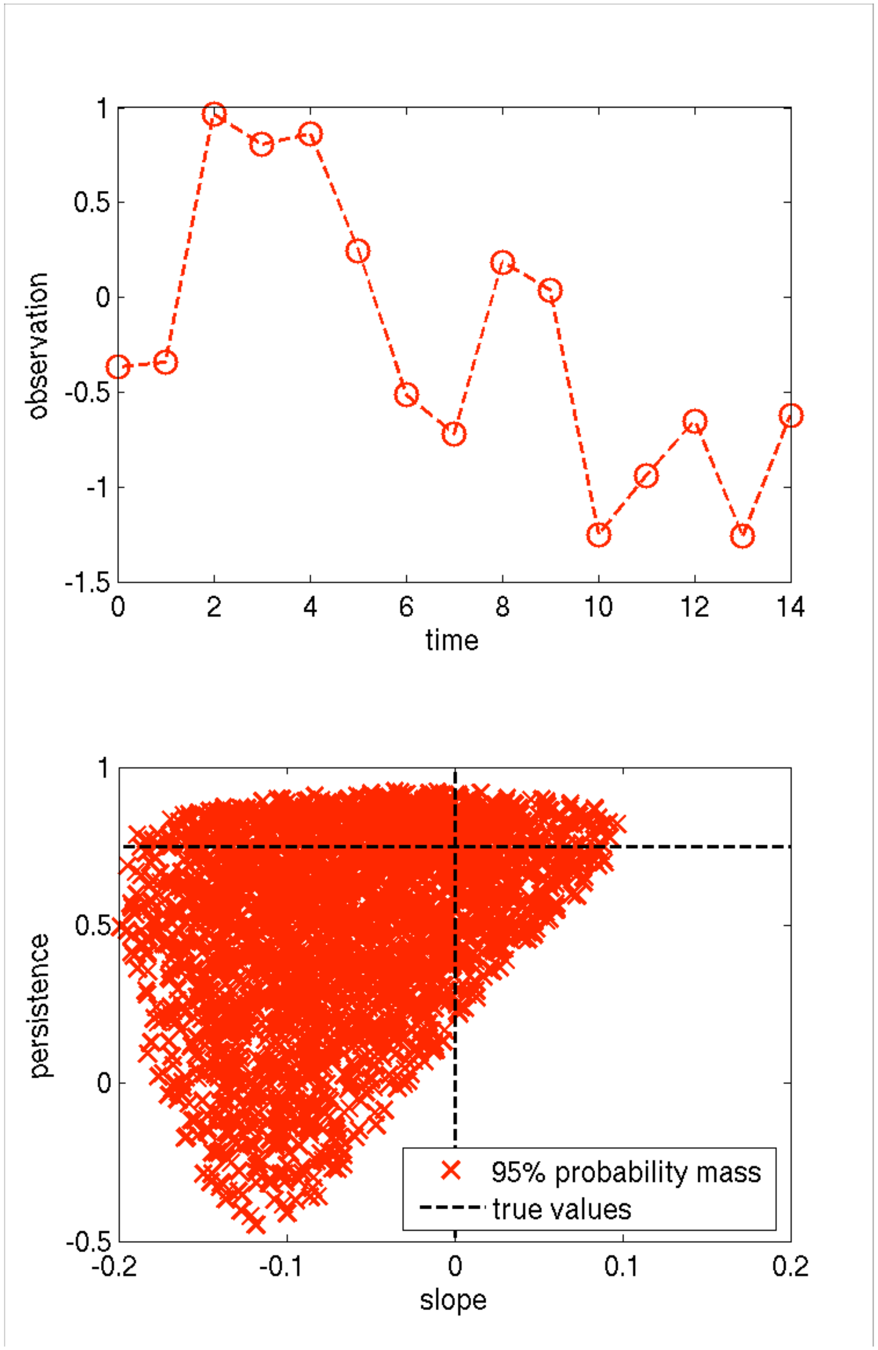
The - so far - mostly unknown internal variability of the unforced system poses nontrivial challenges for the detection of the anthropogenic signal in real observations.



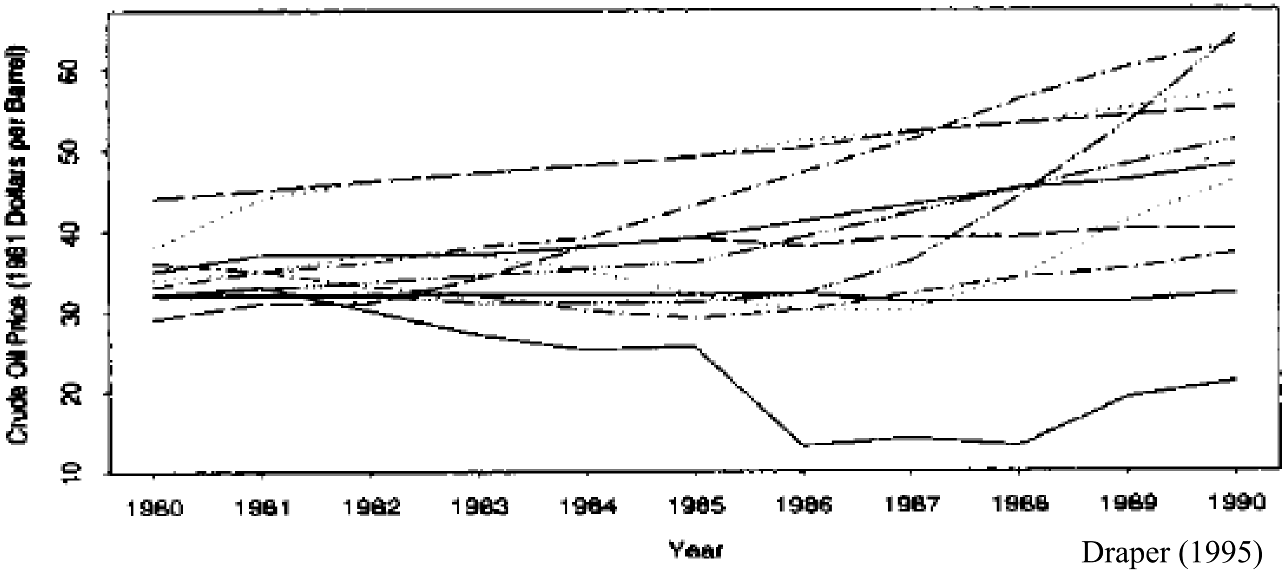
Sample time series from last slide:
a sub-sample of a stationary time series
(right panel)

Full time series.
Note the autoregressive properties

Neglecting the potential persistence in the observed time series can lead to overconfident and wrong conclusions.



(iv) Current decision-analyses of climate thresholds are potentially based on overconfident parameter estimates.



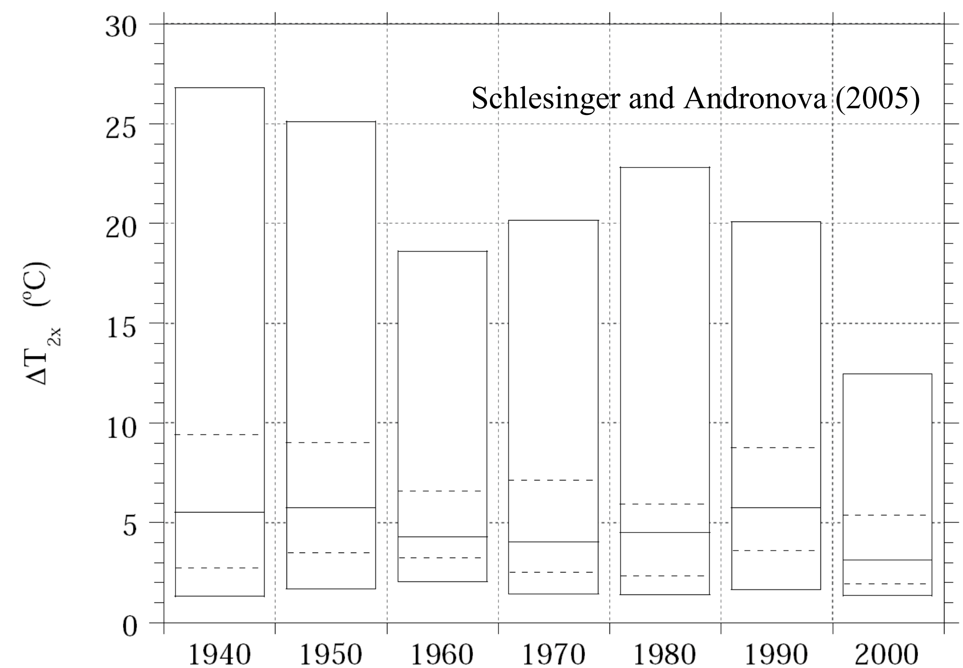
Draper (1995)

Fig. 1. Forecasts of the price of oil by each of the 10 EMF models under the reference scenario, 1980–90: the lower full curve is the actual price

Does this overconfidence also apply to model predictions relevant to climate thresholds?

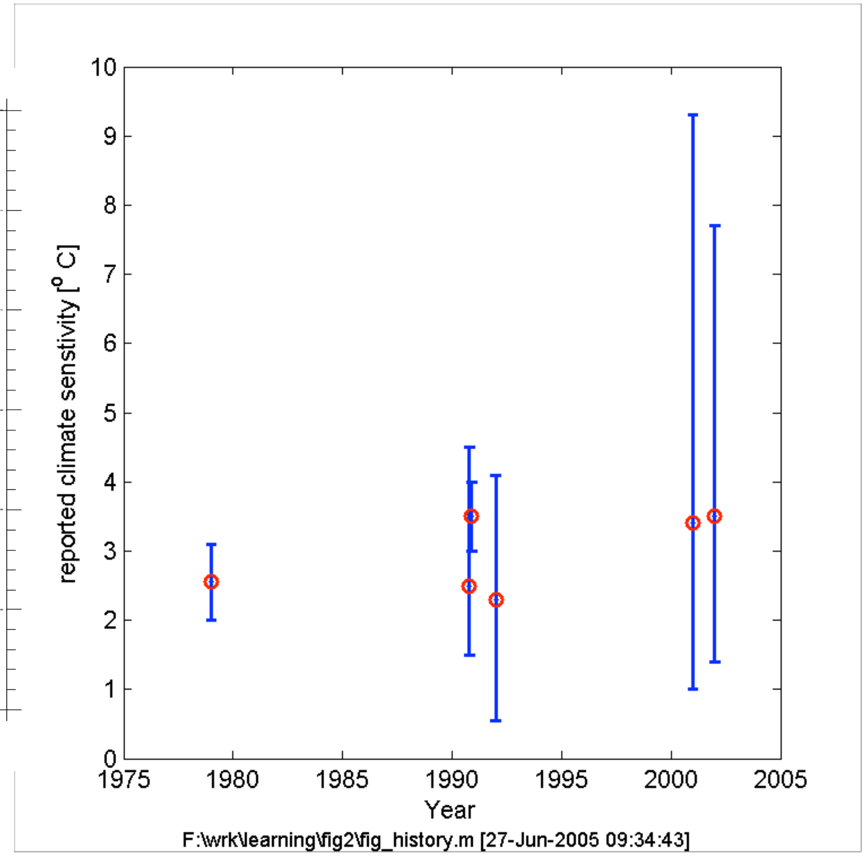
….Current decision-analyses of climate thresholds are potentially based on overconfident parameter estimates.

The typical result of generally decreasing uncertainty over time.



Statistical analysis using a single model structure.

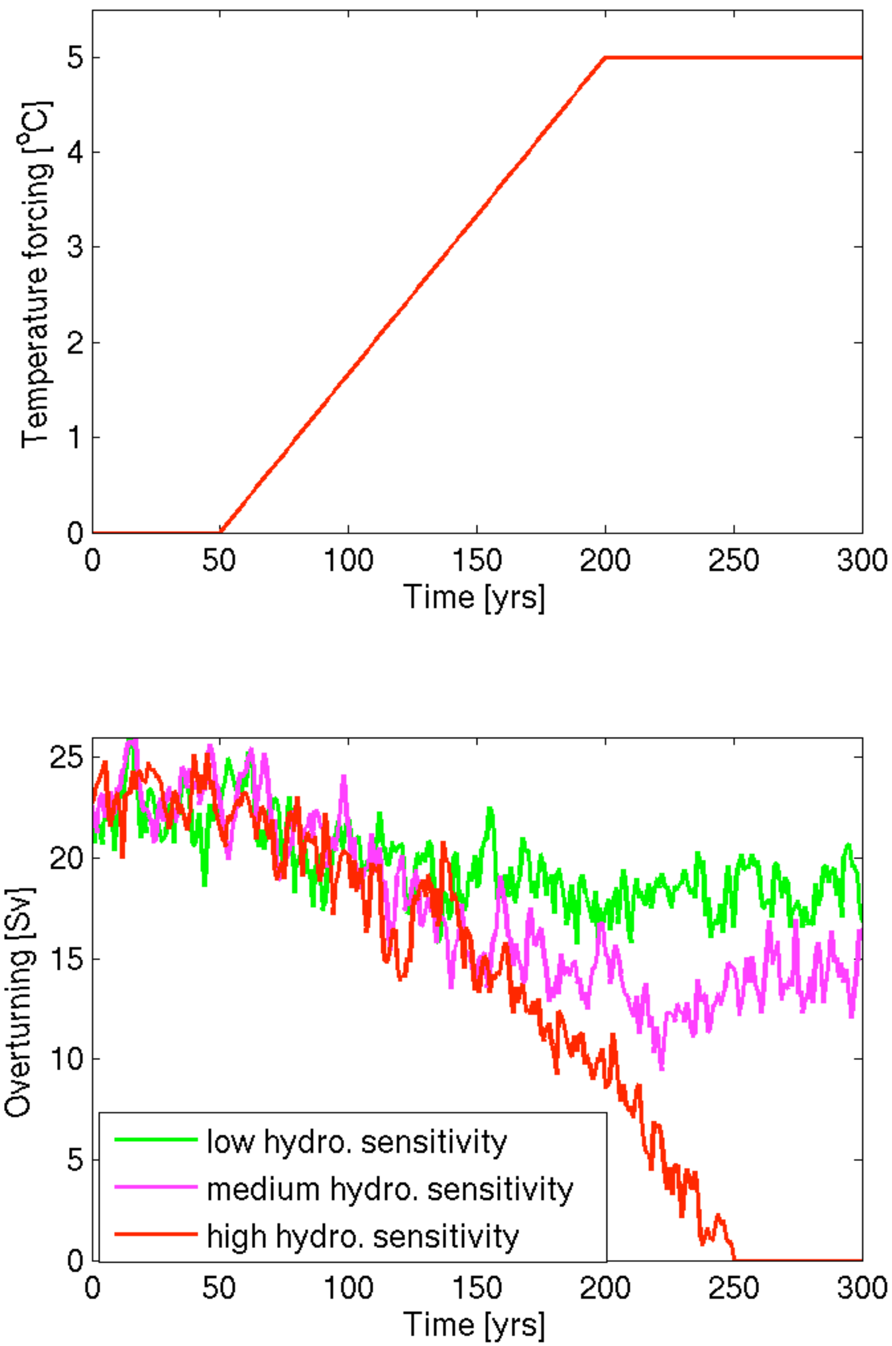
Contrasted with the observed development of historical estimates.



Observed development, based on literature review.

(iv) *Prediction*, not just detection is required for many decision-making frameworks.

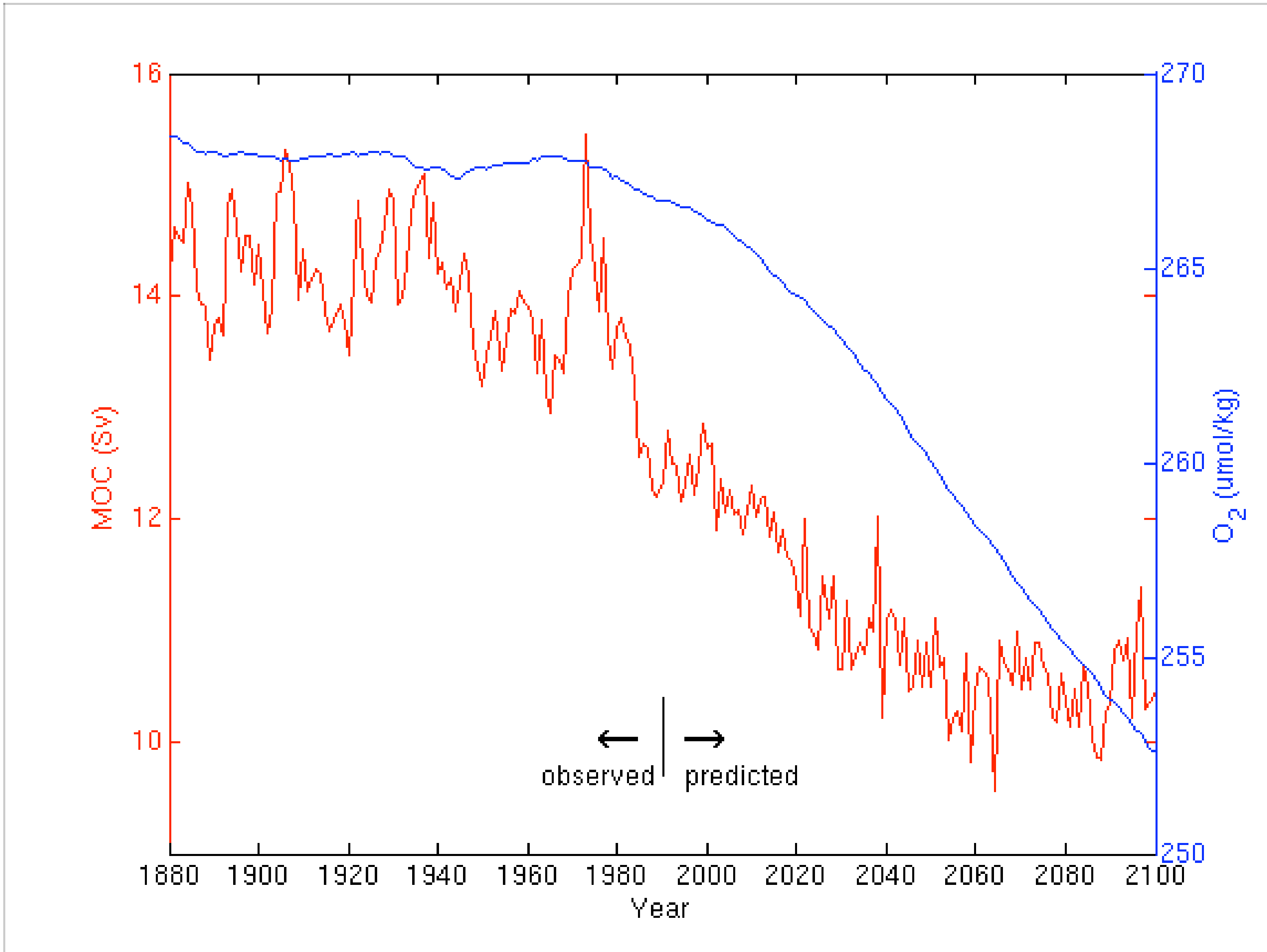
Ocean observation systems designed for early detection of MOC changes are likely insufficient for early prediction of a future MOC collapse.



Modified simple box-model from Zickfeld et al (2004)

One possible approach to the detection and prediction problem

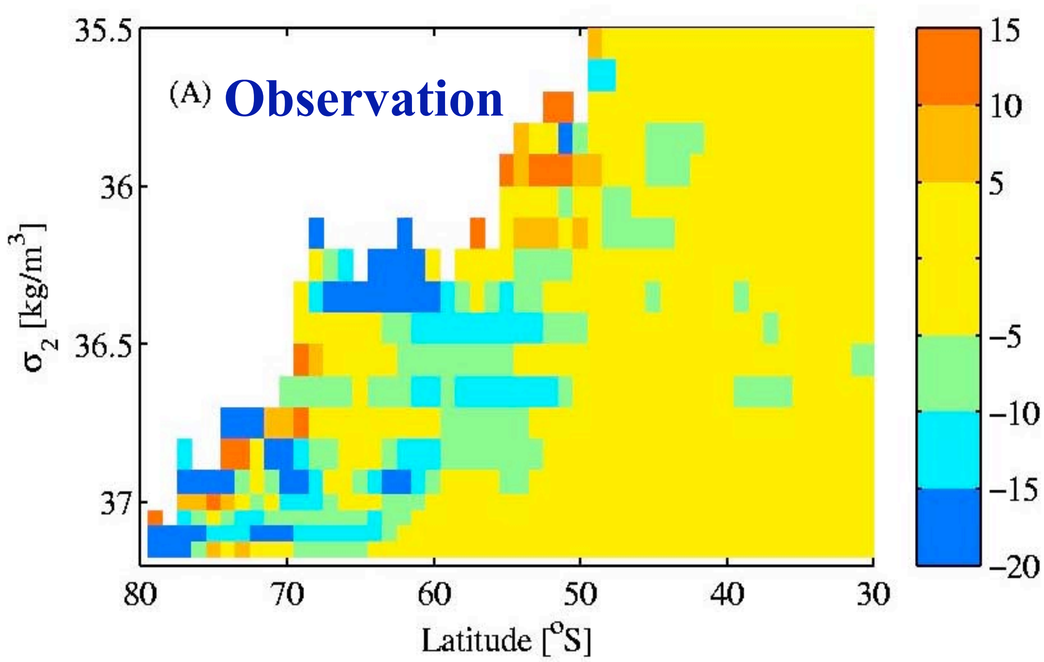
Hydrographic tracers may show a larger signal to noise ratio than reconstructed flows



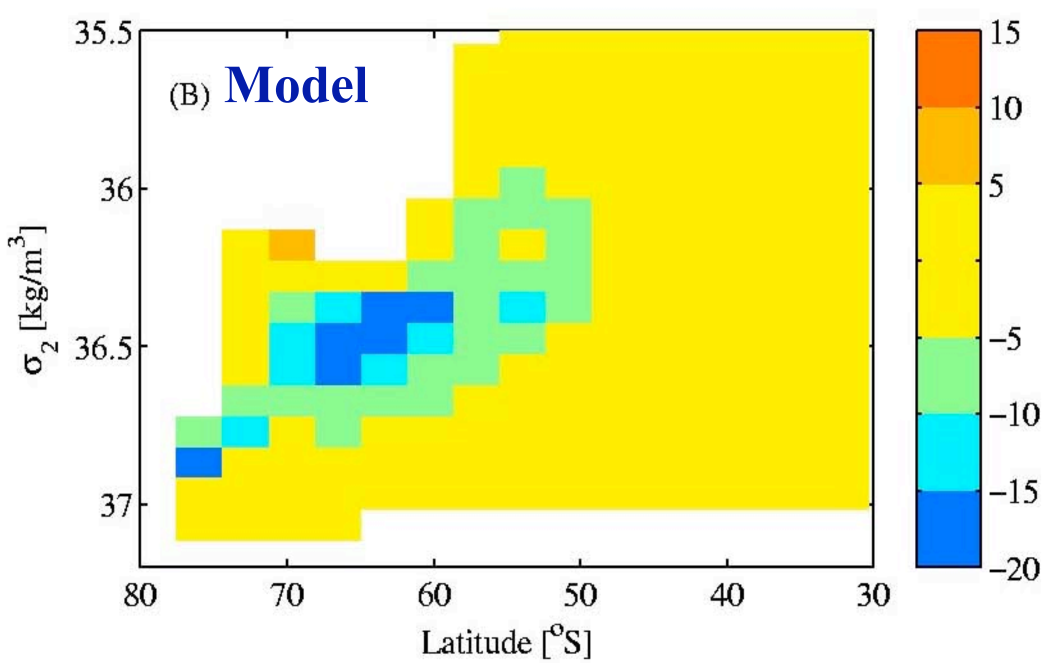
Brennan and Keller (in prep)

Model simulations from Matear *et al* (2000).

Historic observations in the oceans may contain detectable and significant fingerprints of MOC changes, which reduce the current uncertainty about future MOC responses.



- Observed and modeled oxygen trends estimated from roughly 80, 00 oxygen observations. Database: (Conkright et al, 2002)
- Model “hindcast” from Matear et al (2000).



Keller and Min (in prep)

Five Challenges - Revisited

i. Detection might occur *after* the threshold has been triggered.
   How can we improve detection systems?

ii. Future detection and prediction are random variables.
   For what reliability should one design observation systems?

iii. Detection requires so far unknown information about the nature of the unforced variability.
   How can we estimate the internal variability *and* the trends from modern observations?

iv. Current decision-analyses of climate thresholds are likely based on overconfident parameter estimates.
   How can we assess and correct for overconfidence?

v. *Prediction*, not just detection is required for many decision-making frameworks.
   Does a system designed to inform detection also perform well for the prediction tasks?

Key Questions

- What climate thresholds could be triggered by anthropogenic greenhouse gas emissions and where are they located?
- What is the unforced variability of the system at the relevant resolution?
- How does the likelihood of crossing the thresholds change along a business-as-usual strategy?
- How overconfident are current predictions of the coupled natural-human system and how does this bias decision-analyses?
- What would be the socio-economic impacts of
  - crossing the thresholds and
  - avoiding to cross the threshold?
- What observation systems would yield actionable early warning signs early enough to allow for effective mitigation measures?

Dedicated to
David Bradford
† February 2005