Modeling Climate Change

Uncertainty with imprecise probabilities

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Thanks

1st International Workshop on Integrated Climate Models

An interdisciplinary assessment of climate impacts and policies

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Outline

- Classical intertemporal risk analysis
- Ignorance, uncertainty and imprecise probabilities
- (Futures studies and global warming 2100)

Questions: anytime

Risk vs. uncertainty

Classical since Knight (1921), Keynes...

- Risk: well founded probabilities
- No probabilities: Ambiguity, Deep/epistemic/hard uncertainty

1. Classical intertemporal risk analysis.

Classical risk analysis

- 1.1 Expected utility
- 1.2 Stochastic dynamic programming
- 1.3 Modeling the climate risk

1.1 Where to park the ice-cream truck?

- Expected profit $\Pi(a, s)$ is:

		Location a			
Weather s		α	β	γ	δ
Hot	$\mathbf{H}$	10	6	11	8
Cold	$\mathbf{C}$	2	4	0	3

Classwork

Assume $p(H) = p(C) = 0.5$
consider the isoelastic utility function:

$$U(\Pi) = \frac{\Pi^{1-r}}{1-r}$$

1/ Which optimal choice corresponds to $r = 0$?
2/ Predict intuitively which optimal choice corresponds to $r = -1$ and $r = 1.5$.
3/ Give a value for r such that the optimal choice is δ.

1.2 Expected value of information

- In the sequel I assume $U(\Pi) = \Pi$
- E denotes the expected value with respect to probability p

$$E\Pi(a, s) = p(H)\Pi(a, H) + p(C)\Pi(a, C)$$

What is the Expected profit?

Classwork

What is the expected profit if the decision maker has an enveloppe containing a perfect prediction about s ?

		Location a			
Weather s		α	β	γ	δ
Hot	$\mathbf{H}$	10	6	11	8
Cold	$\mathbf{C}$	2	4	0	3

What is the Expected Value of Perfect Information (EVPI)?

Value of future information (EVFI)

For climatic change, EVPI is irrelevant,
we must use the value of *future* information.

Closing options todays destroys EVFI.

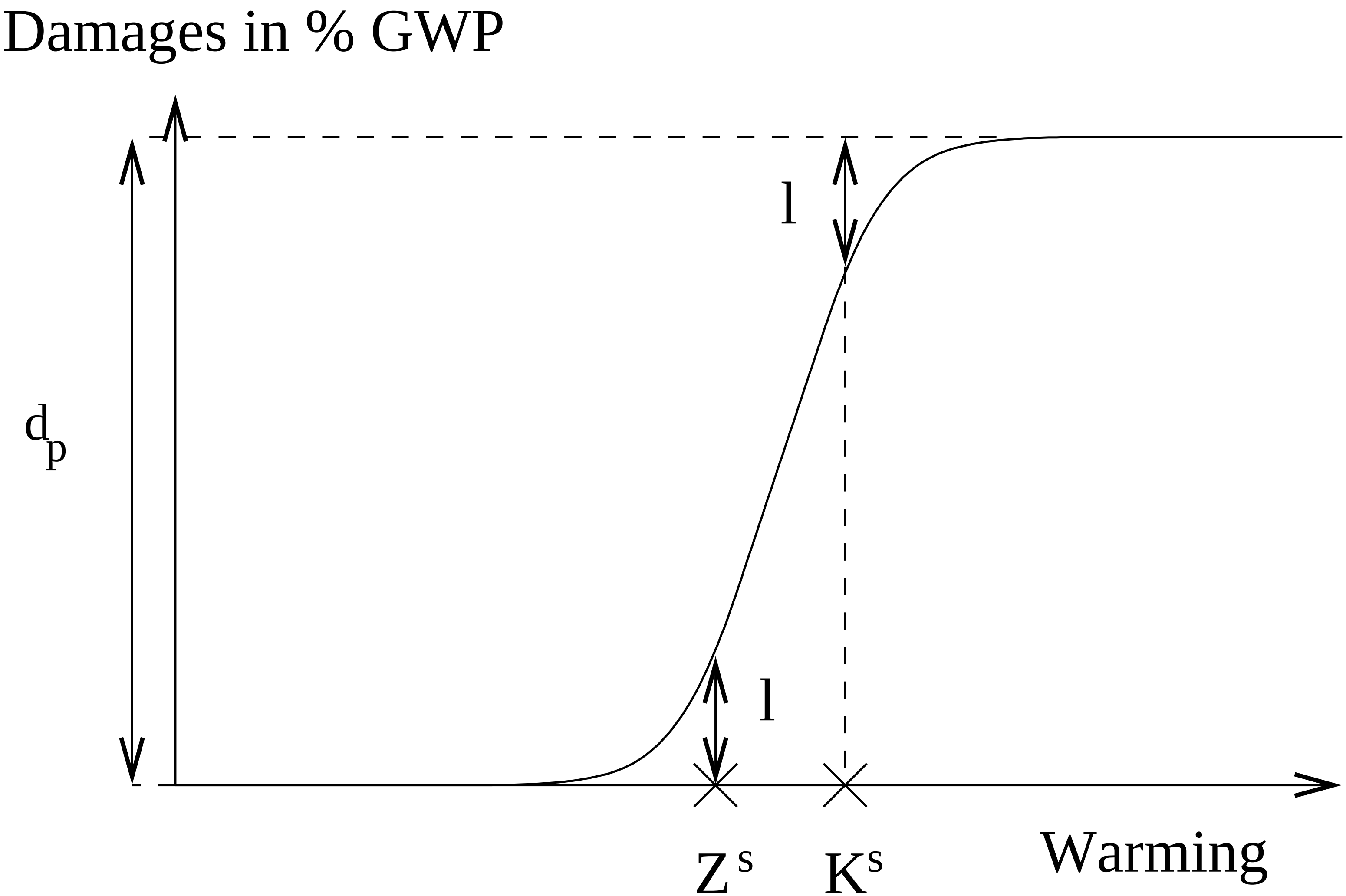
1.3 Modeling the climate risk

Message:
Nonlinearity in climate impact significantly adds to the risk.

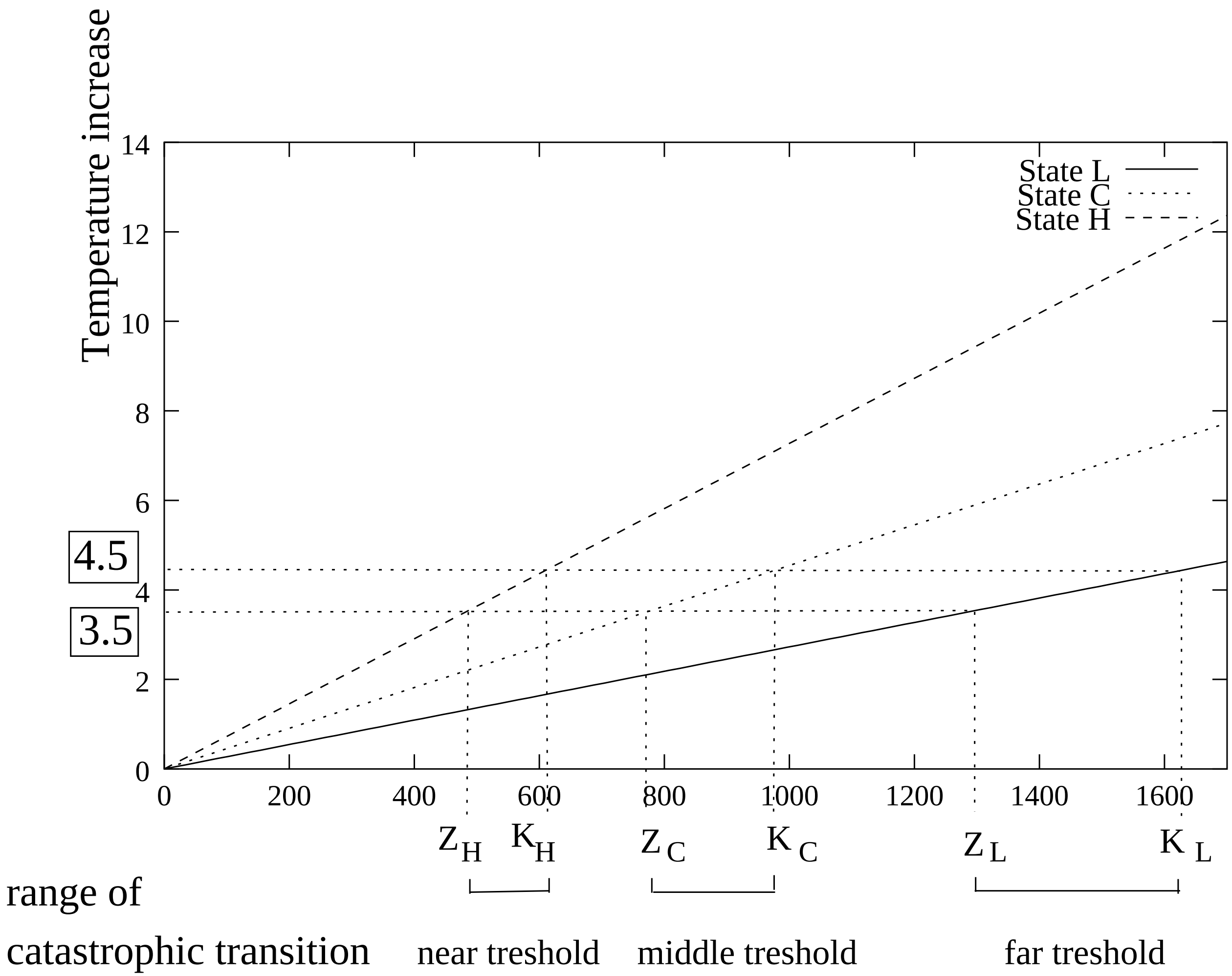
Reviewing an integrated climate model:

$$\max_a E\Pi(a,s) = -\sum_{2000}^{2200} \frac{C(a) + D(a,s)}{(1+d)^{t-t_0}}$$

The nonlinear function $t(\Delta T, s)$



Where are the tresholds ?



Steps of the analysis

Cf. Nordhaus (1994) Managing the global commons

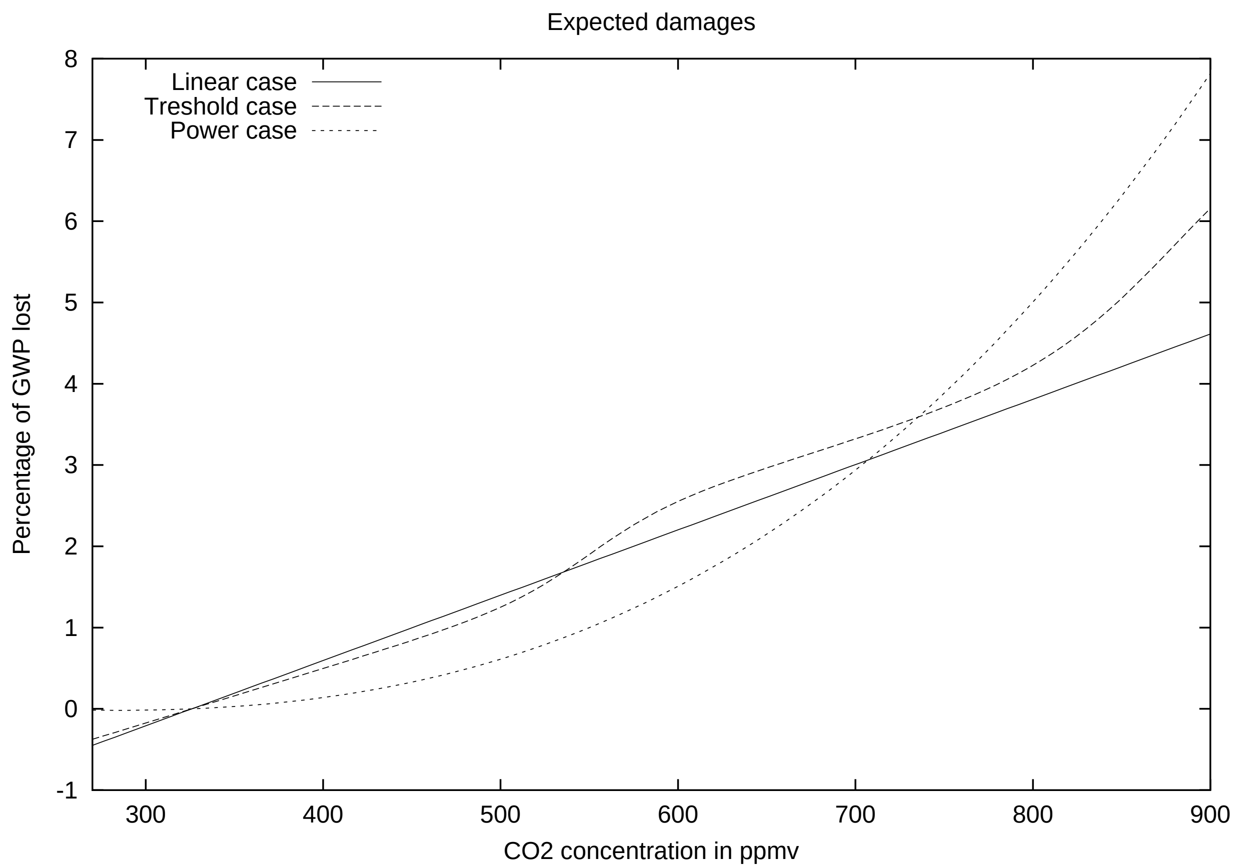
- Central case
- Sensitivity analysis
- Scenarios
- Dynamic programming

Comparing damage curves shapes

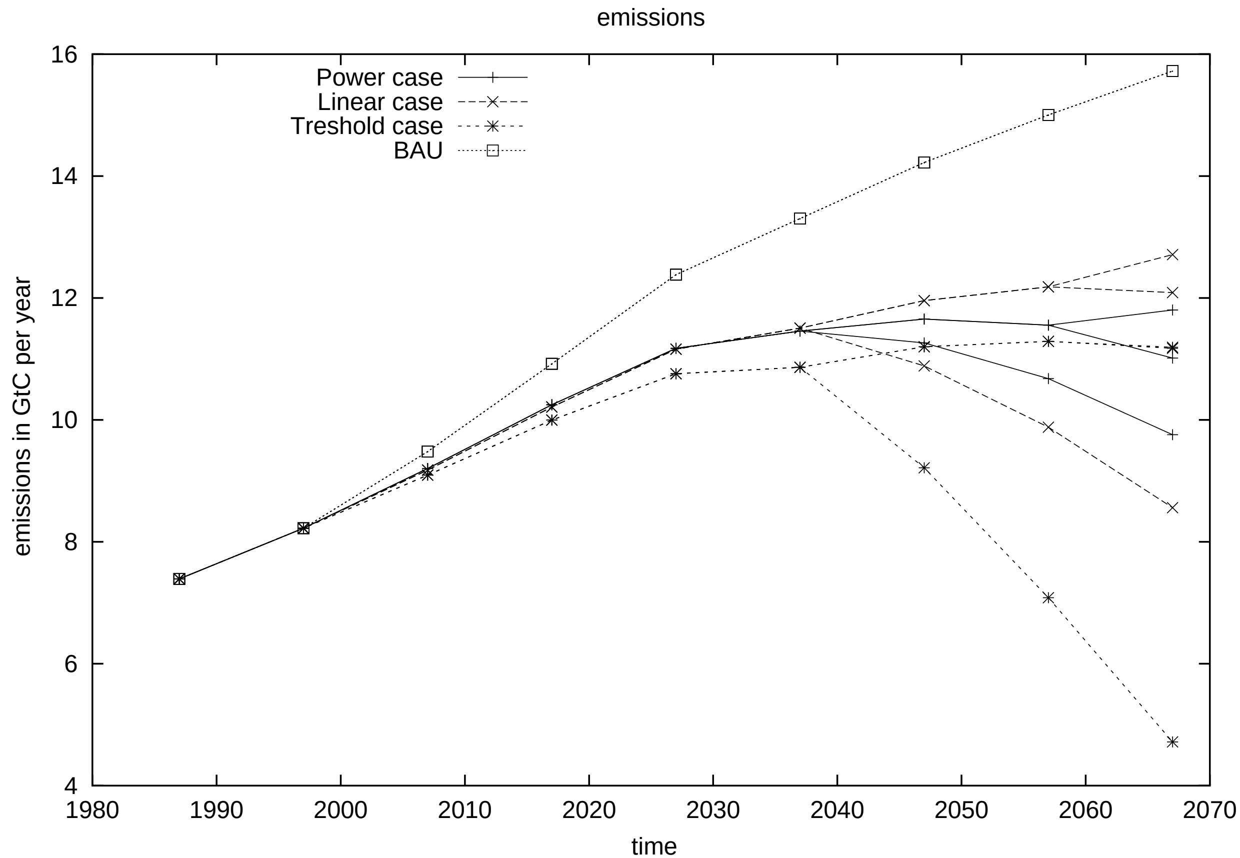
Assuming a $\Delta T = f(a)$ climate module.
I compare a linear, power and treshold stochastic damage functions:

$$\begin{aligned} D(a,s) &= \tilde{s}\Delta T \\ D(a,s) &= b\Delta T^{\tilde{s}} \\ D(a,s) &= b\Delta T + t(\Delta T, \tilde{s}) \end{aligned}$$

Expected damages are comparable



Optimal strategies



Conclusion

Expected utility + dynamic programming $\longrightarrow$ precaution
but
where do the probabilities come from?

Discussion on part 1.

2. Ignorance and uncertainty.

Levels of ignorance

Simplified from Smithson (1988) Ignorance and uncertainty

- Risk
- Uncertainty (+ Ambiguity)
- Error (+ Surprises, Unk. Unk.)
- Ignorance (+ Taboo, active ignorance)

Outline

Ignorance and uncertainty

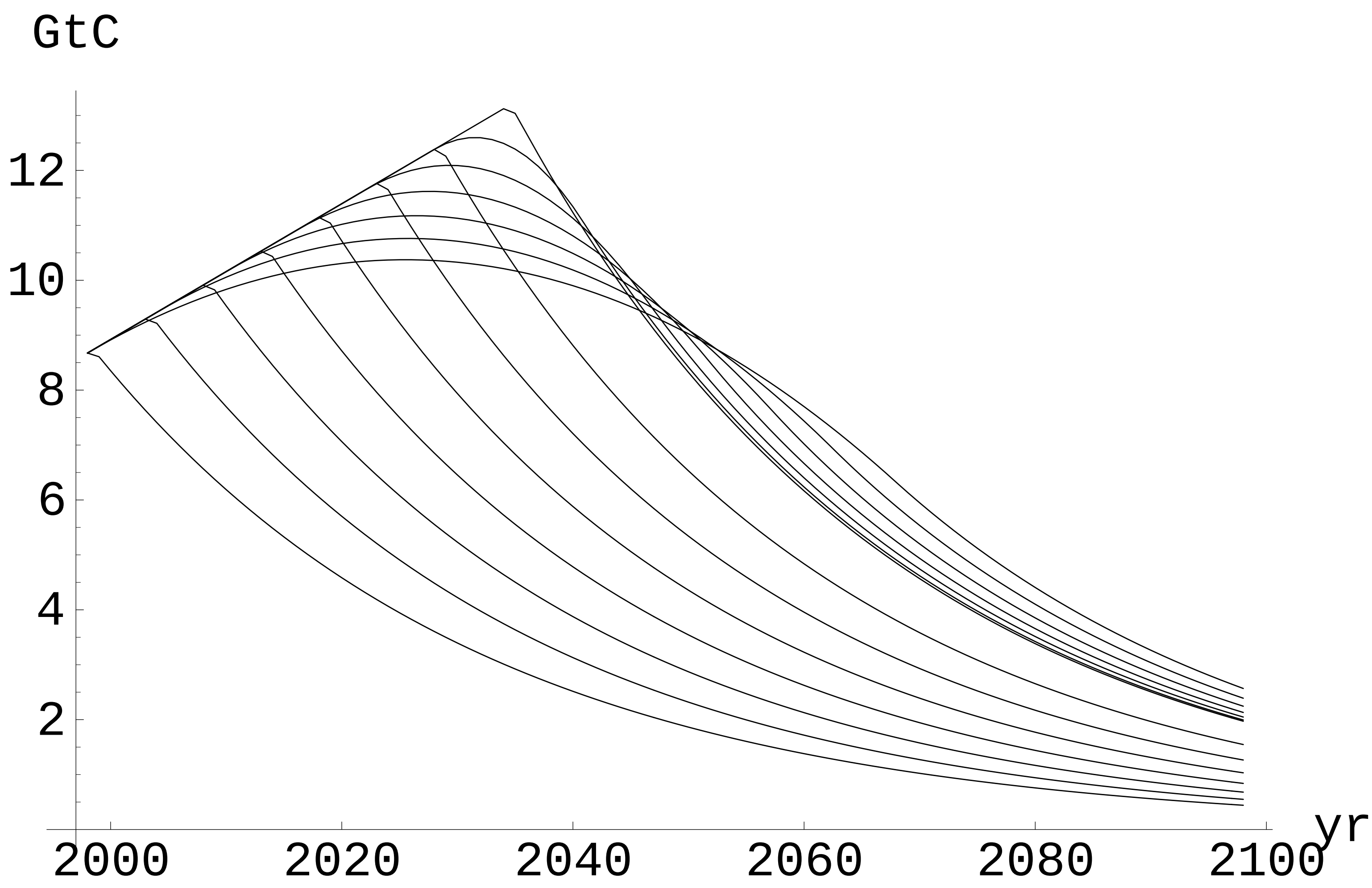
- Constraint-based methods
- Imprecise probabilities
- Communicating the impacts uncertainty

2.1 Constraint based methods

Action a is acceptable if and only if:
the trajectory it leads to lies within acceptability constraints.

Example: CO_2 emissions contrained by a 550 ppmv ceiling

Viable C emissions profiles



Take-home on viability

- Familly of acceptable actions
- Not any arbitrary curve inside the enveloppe is acceptable
- The upper enveloppe is not acceptable

2.2 At which gate to park the food truck?

- Expected profit Π is:

		Location			
Winning team		α	β	γ	δ
Home	$\mathbf{H}$	10	6	11	8
Visitors	$\mathbf{V}$	2	4	0	3

- Home team won 5, lost 2 in last 9 matches, NO TIES

Imprecise Dirichlet Model

Information: Home team won 5, lost 2 out of —including the next unknown— 10 matches:

(1) $$\frac{5}{10} \leq p(\mathbf{H}) \leq 1 - \frac{2}{10}$$

$\mathcal{C}$= [0.5, 0.8] is called a credal set

Precautionary comparison (Walley 1991)

Location α is preferred to location β because

The expected profit is larger in α than in β
for all credible probabilities:

$$\alpha \succ \beta \overset{def}{\Leftrightarrow} \text{for all } p \in \mathcal{C},\ \mathsf{E}_p(\Pi(\alpha, s)) > \mathsf{E}_p(\Pi(\beta, s))$$

Classwork

Compare α with δ.
Compare α with γ.

		Location			
Winning team		α	β	γ	δ
Home	$\mathbf{H}$	10	6	11	8
Visitors	$\mathbf{V}$	2	4	0	3

(2) $$0.5 \leq p(\mathbf{H}) \leq 0.8$$

A partial ordering

$$\alpha \succ \beta, \gamma \succ \beta, \delta \succ \beta, \alpha \succ \delta$$

There is a familly of maximal actions, but not all actions can be compared.

Classwork

Would the driver be ready to pay 5 for the location α?
What is its maximum willingness to pay for α?
If the driver had a firm reservation for α, would he be ready to give it up for 9?
What is its minimum willingness to accept?

3.3 Uncertainty about climate impacts

- So far a linear probability scale
- Imprecise probability suggests a 2 dimensional possibility/necessity vocabulary
- And a vocabulary about experts agreement

Conclusion on Part 2

- Non Expected Utility lead to more than one 'best policy'
- Another form of precaution
- Dynamic programing: on the research agenda

Discussion on part 2.

Reception

Adriatico Guesthouse Bar

Wednesday, October 1st, 20.00 hour

3. Assessing Global Warming 2100

Outline

Assessing climate change impacts

- Uncertainty and futures studies
- Upper probabilities on ΔT_{2100}
- Scenarios

3.1 SRES controversy

Schneider (2002) Can we estimate the likelihood of climatic change in 2100?

Intergovernmental Panel on Climate Change emissions scenarios have no probabilities.

The upper bound is +5.8 degree C in 2100.

The usual problematic gap

A recurring controversy of Futures research:

- Forecasts have probabilities
- Scenarios do not have a quantitative likelihood

Use upper probability as possibility!

$$p \in [0, \overline{p}]$$

- Necessity (lower probability) is 0
- Possibility $\overline{p}$ can be < 1 for irrealistic futures
- Use imprecise probabilities for decision making
- Use Shackle (1952) Logic of surprise combination rules

3.2 Assessing $\overline{p}$(global warming 2100)

Rationally subjective, based on published literature.

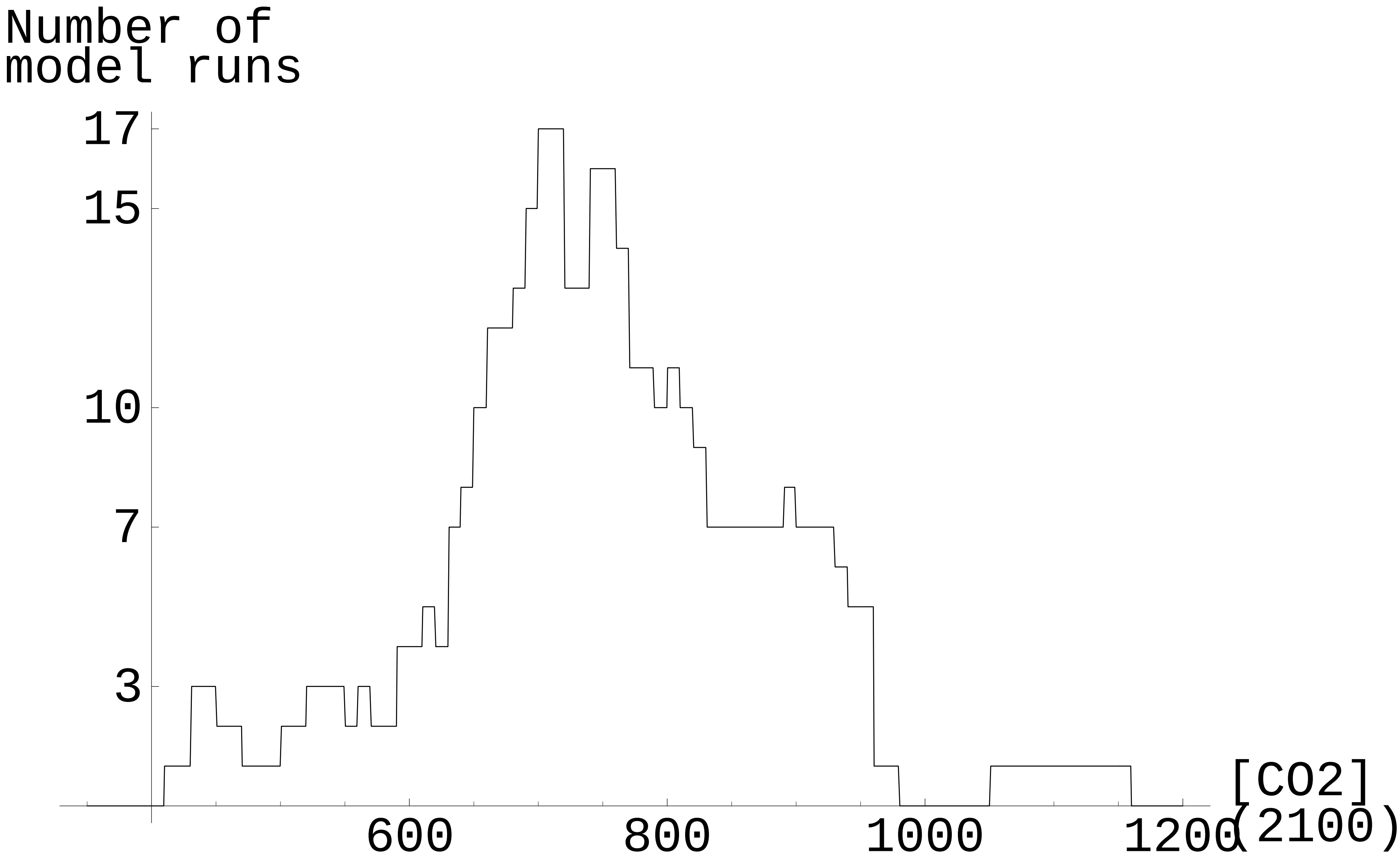
Warming 2100 = CO_2 concentration excess $\times$ $\frac{1}{3}$climate sensitivity

Summarizing model results on [CO_2]

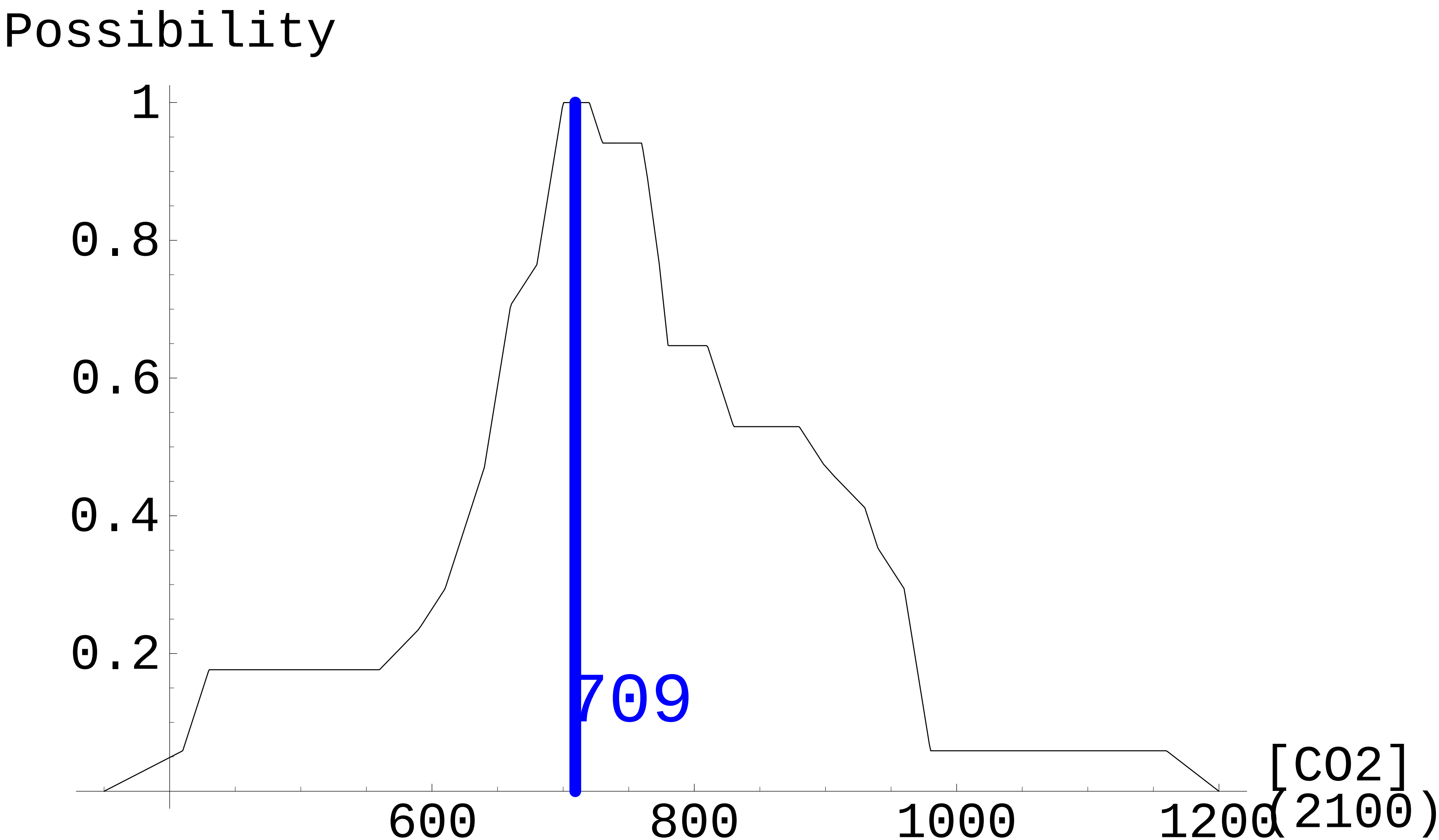
- M: Atmospheric carbon dioxide concentration in 2100
- Source: All 56 'no-intervention' records in SRES database*
- The possibility of M is proportional to the number of models predicting concentration 5% close to M

* Made publicly available thanks to Tsuneyuki Morita, Social & Environmental Systems Division, National Institute for Environmental Studies, Tsukuba Japan

Histogram of available results



Possibility of CO_2 concentration in 2100

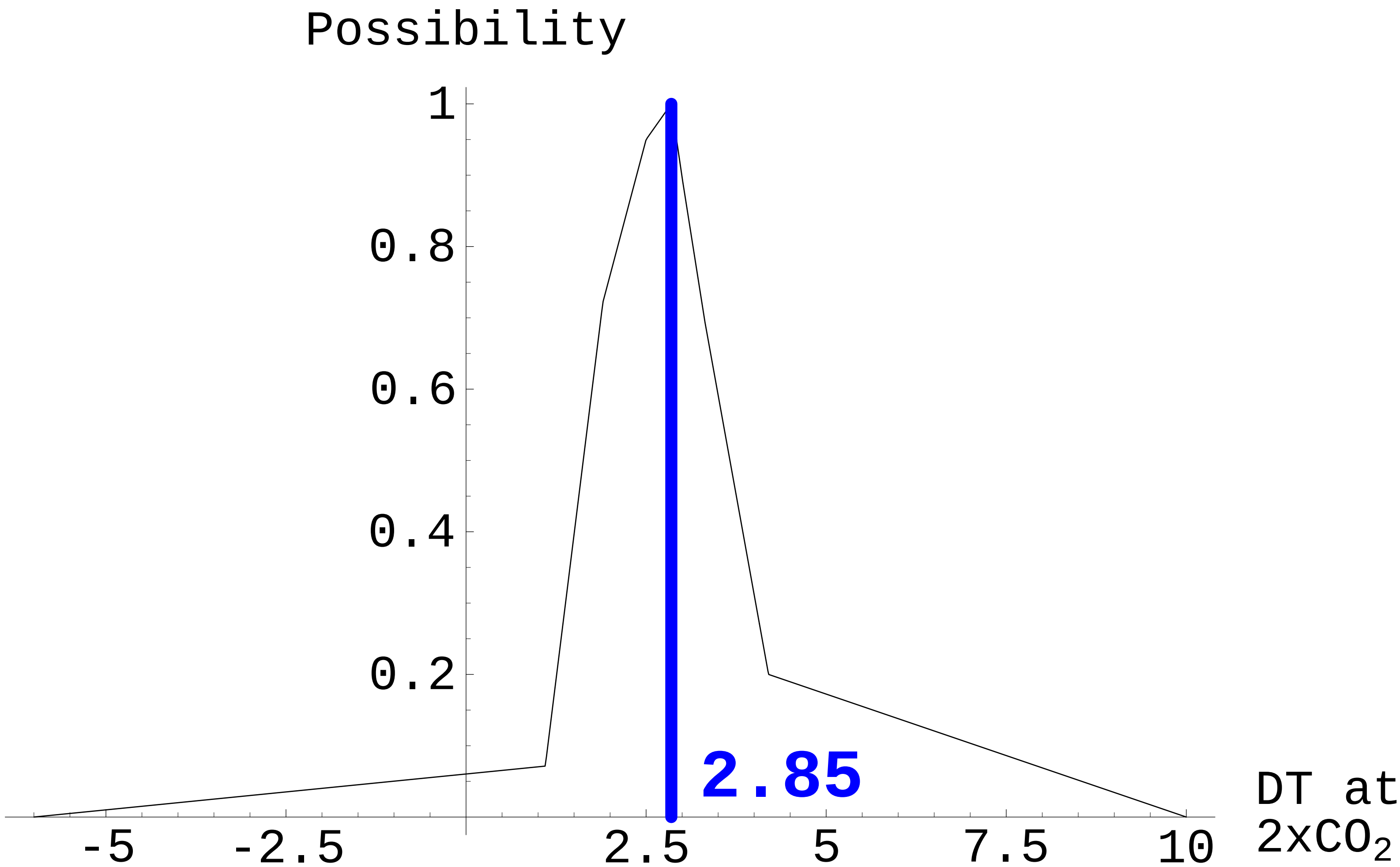


Experts judgment on climate sensitivity

- ΔT(2$\times$$CO_2$): Equilibrium global warming for a doubling of pre-industrial CO_2 concentration
- 16 experts elicitation survey by Keith-Morgan

1. Transform elicited probabilities into possibility
2. Discount experts pretending to know better (standard deviation lower than peer average/2).
3. Fusion without the independence assumption (hyper-cautious conjunction)

Subjective assessment of $\Delta T(2\times CO_2)$

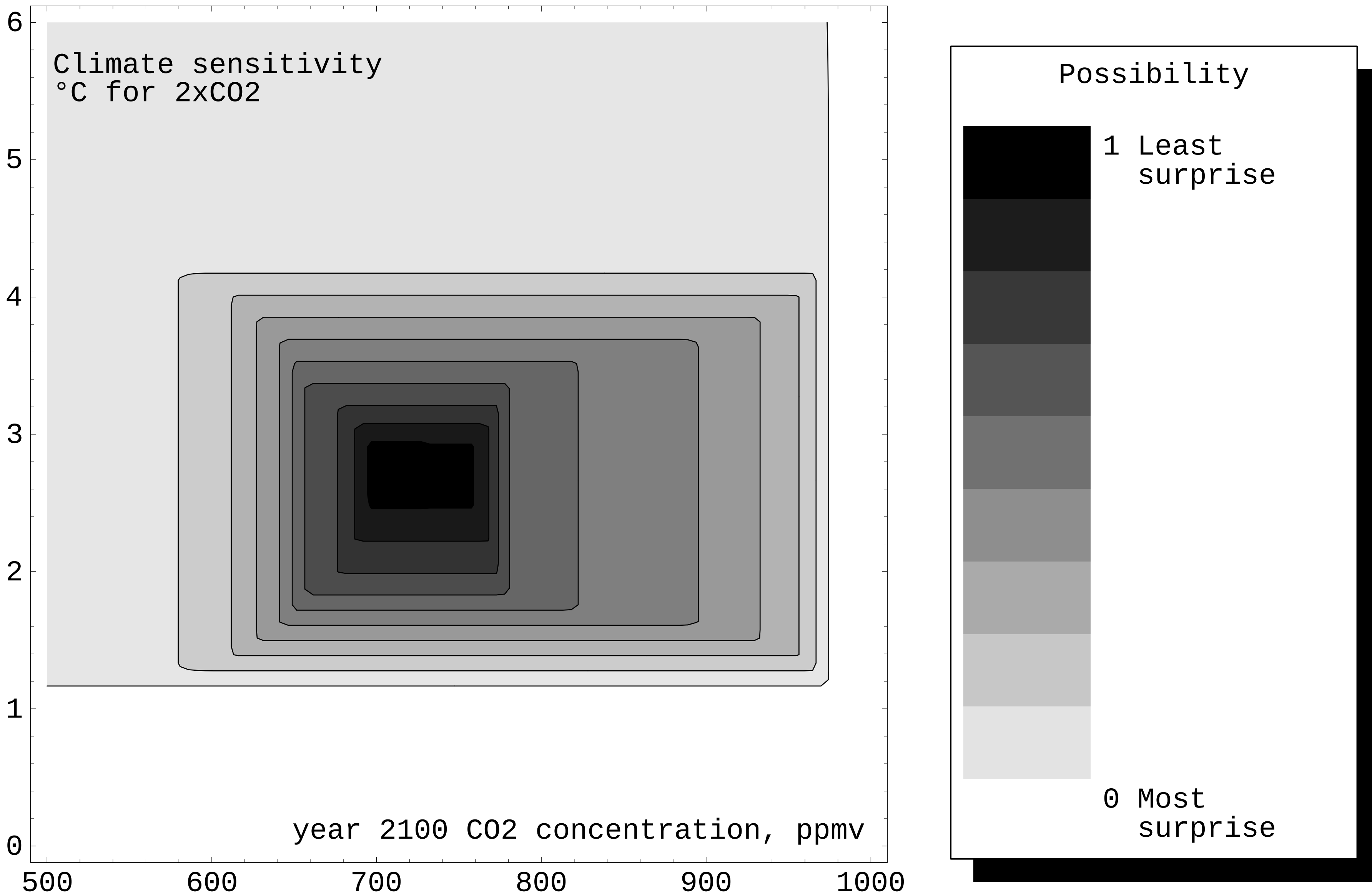


Combining rules

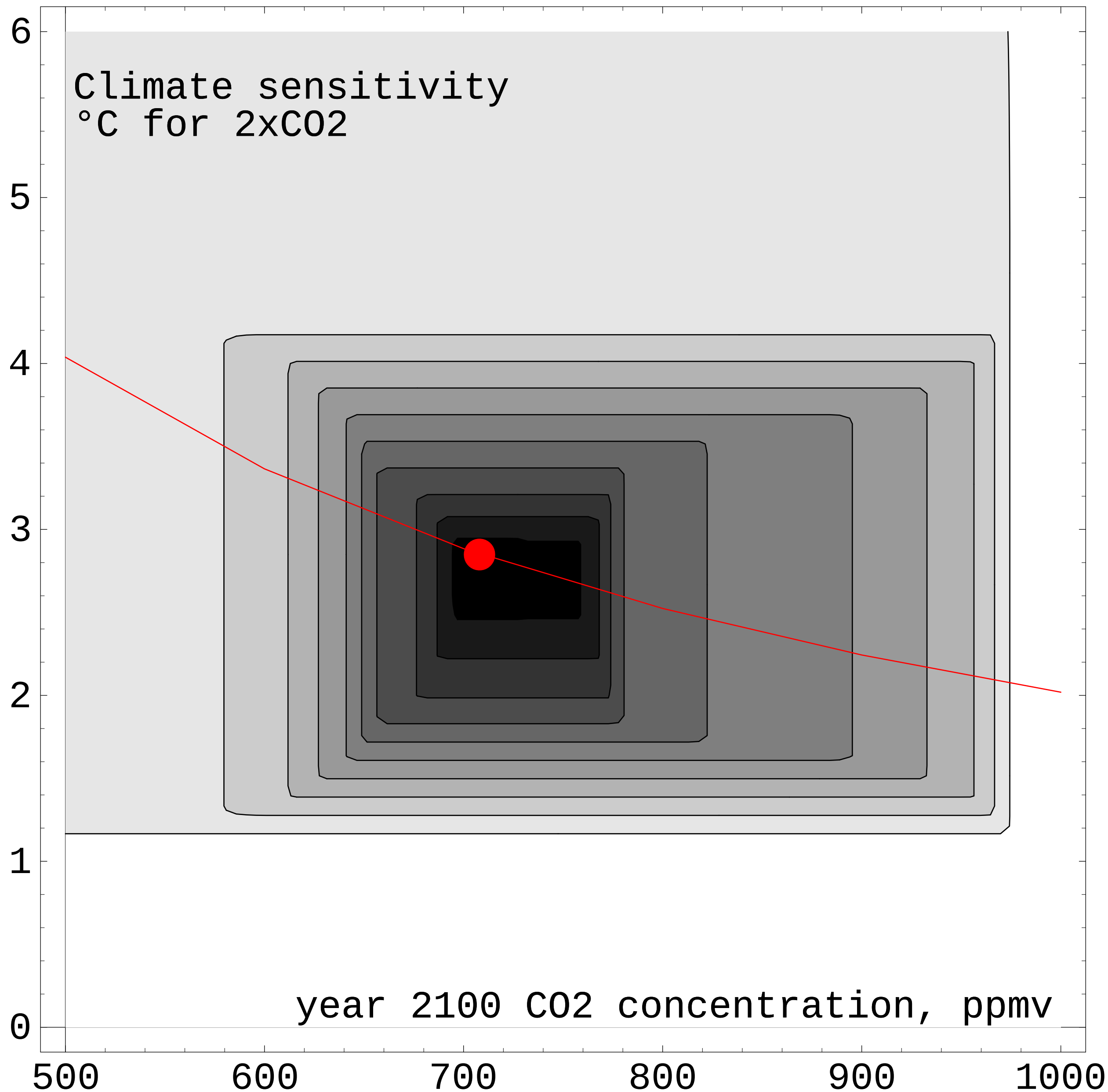
Assuming no interaction,

- Conjunction: The joint possibility of ([CO_2],ΔT(2$\times$$CO_2$)) is the minimum of the possibilities of each component.
- Disjunction: The possibility of ' A OR B ' is the maximum of the possibilities of each component.

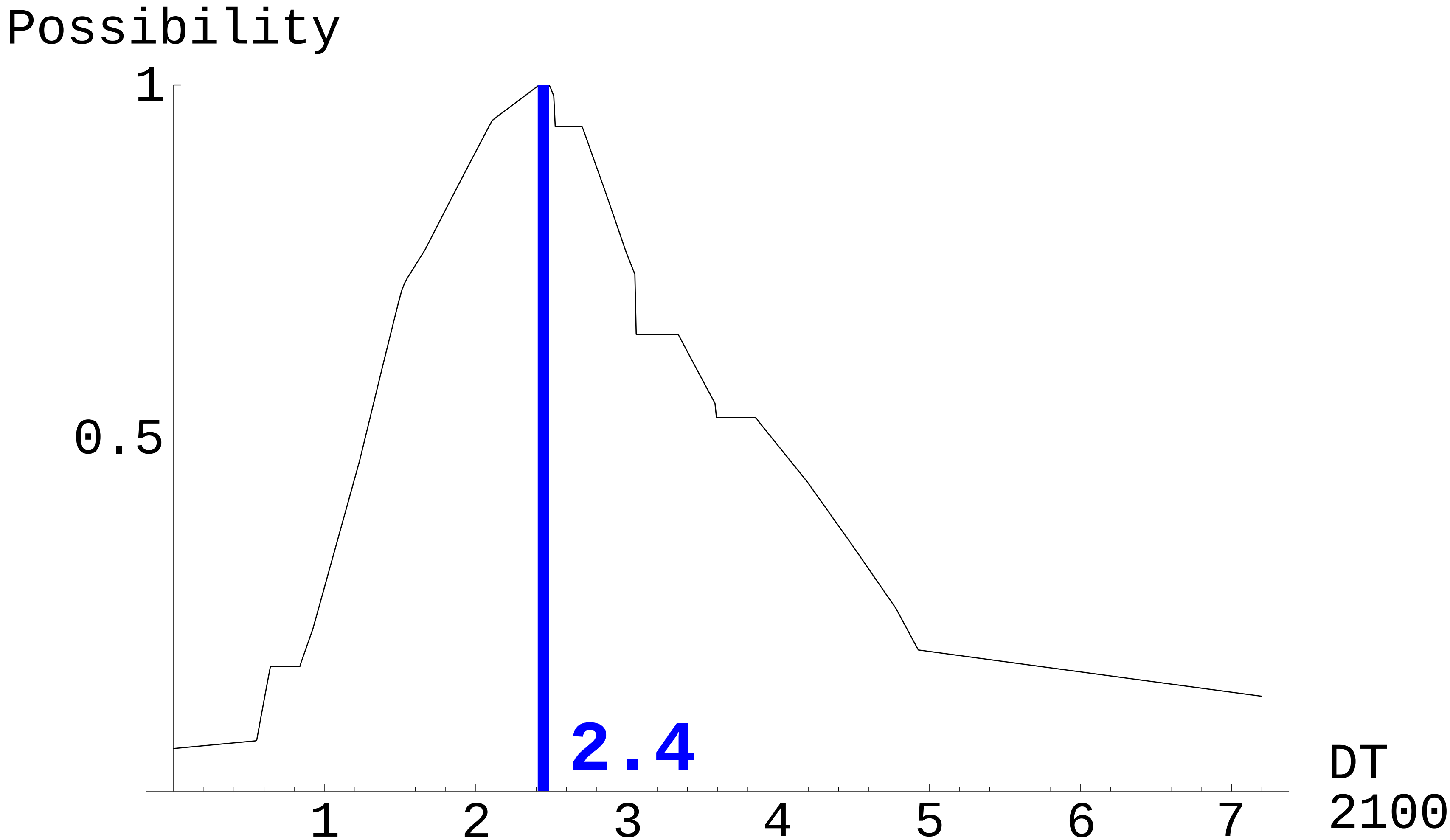
The joint possibility distribution



The possibility of 2.4° C warming

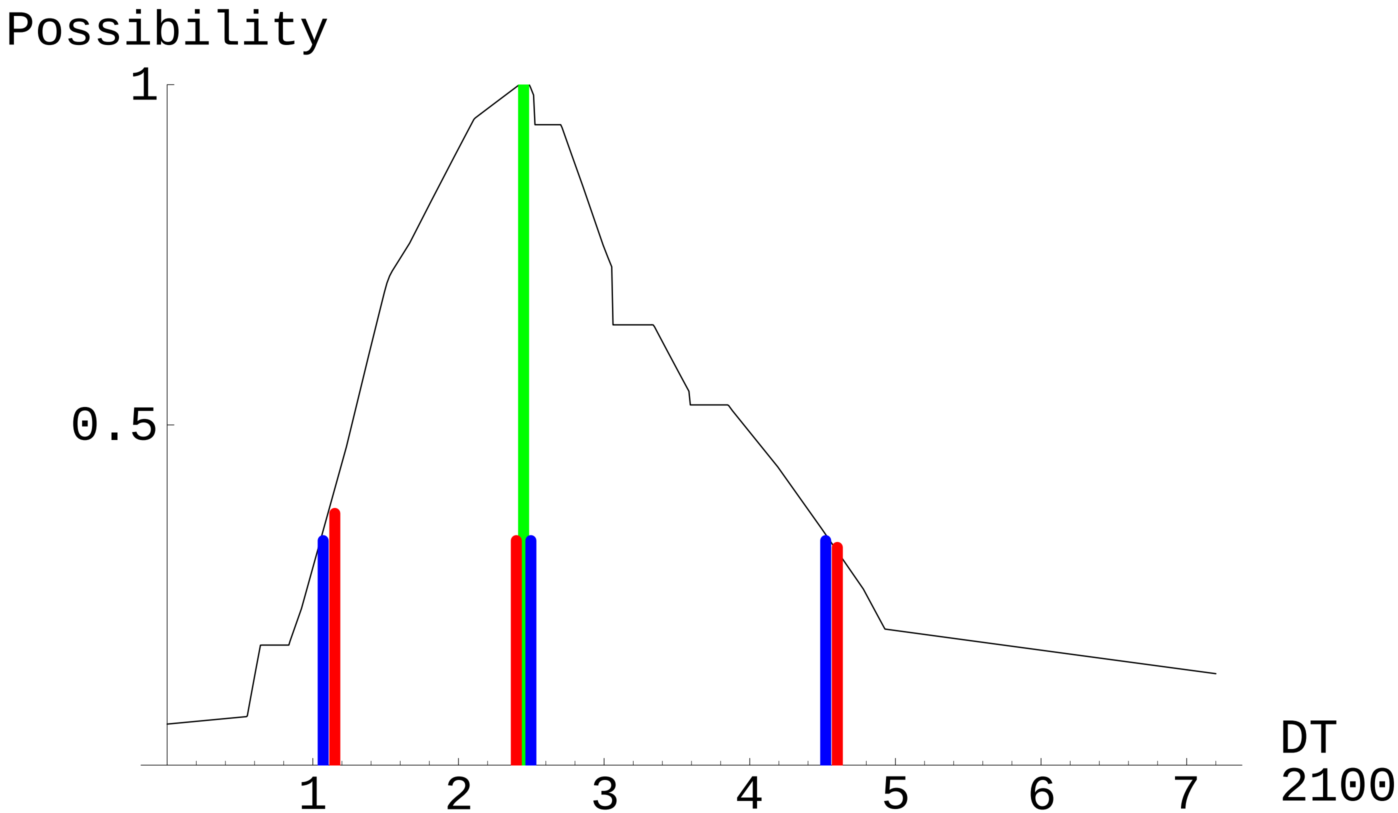


Global warming 2100 possibility



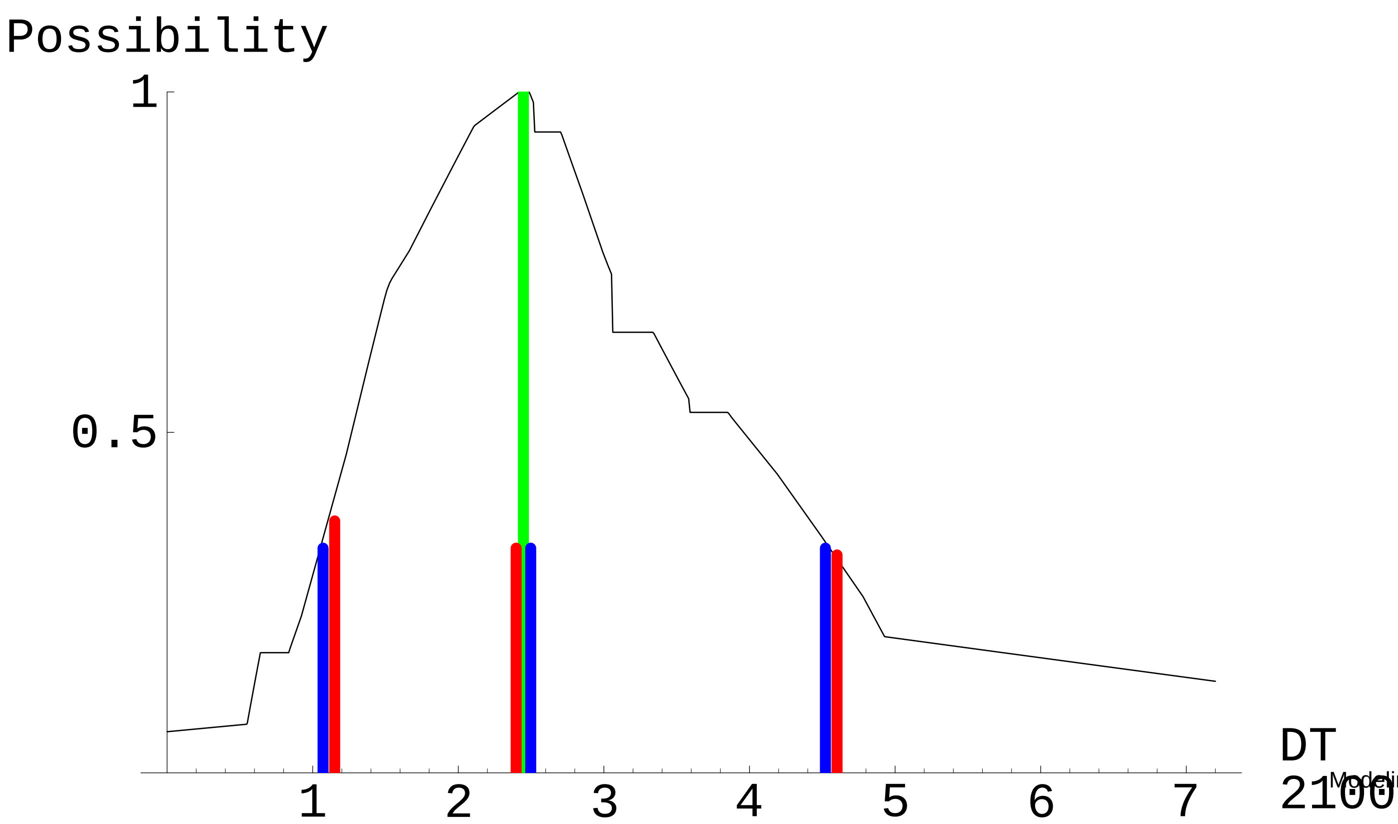
3.3 Picking focal futures

Remember the credal set interpretation



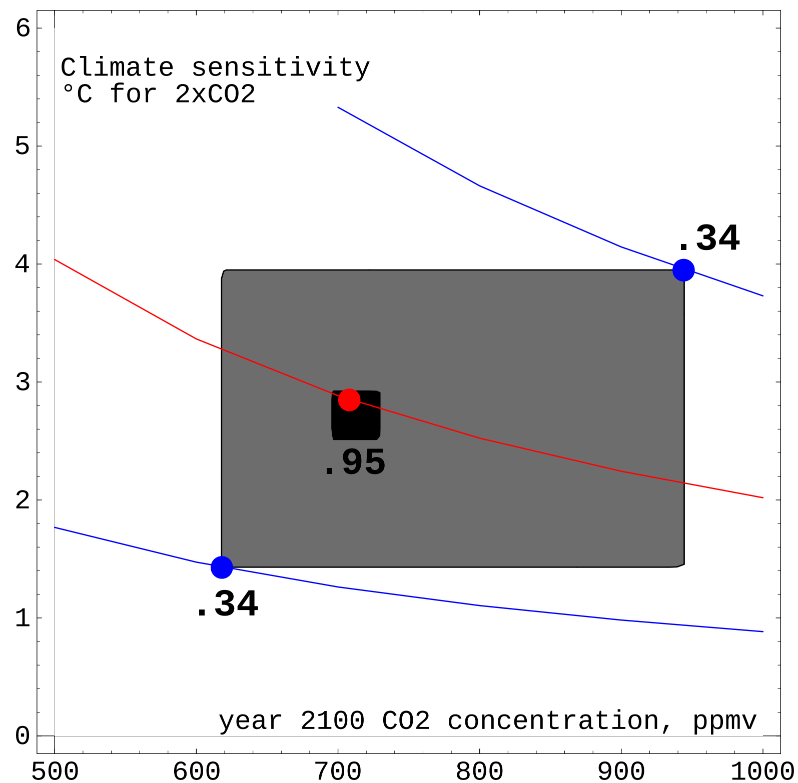
Properties of the focal futures

- Include the most likely
- None is preferred
- Widely contrasted

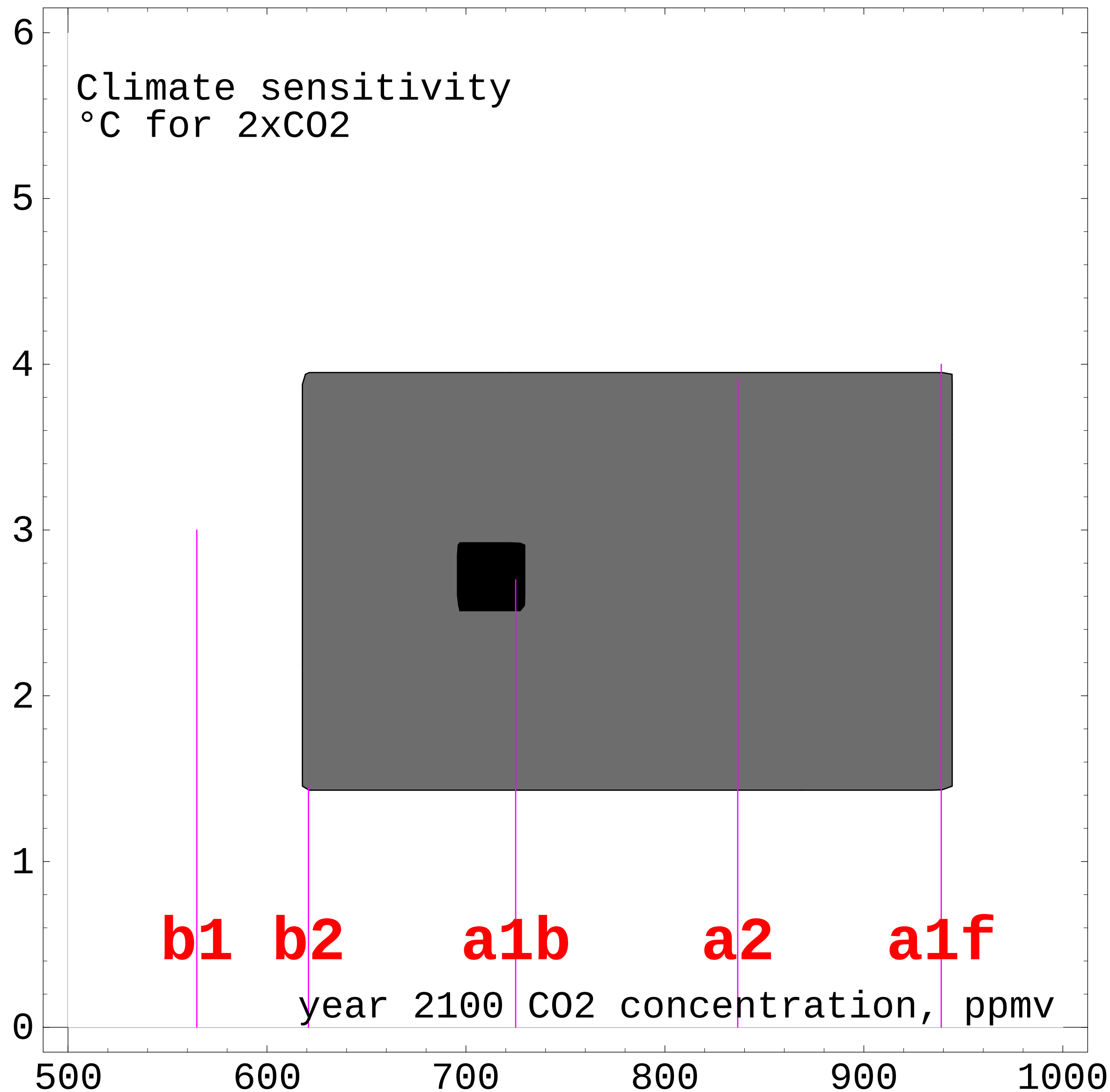


Results: Global warming futures

	π	$[CO_2]$ ppmv	Sensitivity °C/$_{2\times CO_2}$	Warming °C
Baseline	1	709	2.85	2.4
Low	0.34	618	1.43	1.1
High	0.34	944	3.95	4.5



Relation with IPCC scenarios



Possibility of IPCC scenarios

	π	$[CO_2]$ ppmv	Climate Sensitivity $^\circ C/_{2\times CO_2}$	Global Warming $^\circ C$
A1b	1	720	2.7	2.4
A2	0.36	840	3.9	4.0
B2	0.36	620	1.4	1.1
B1	0.18	560	3.0	2.0

General discussion