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Impact of climate change on deterioration and lifecycle costs of flexible pavements

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narc Nottingham Asphalt Research Consortium

SCI where science meets business

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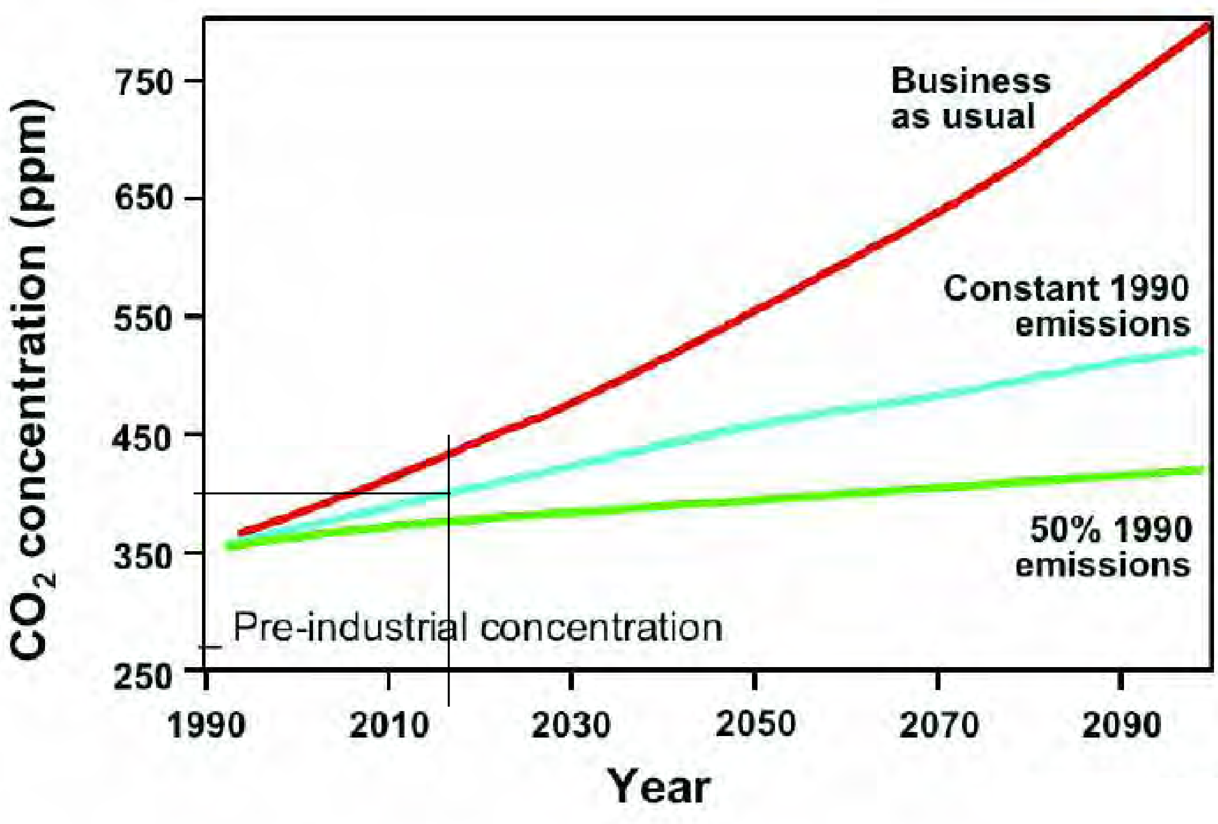
What is Climate Change ?

CO_2 is increasing

CO_2 Concentration



CO_2 and other 'greenhouse gases' (GHG) are increasing in the atmosphere

This figure shows CO_2 concentrations with time for three scenarios.

If we are to continue 'business as usual' CO_2 concentrations will increase dramatically.

Source: IPCC, Intergovernmental Panel on Climate Change http://www.ipcc.ch

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What will the impact be ?

- The rise of CO_2 so far has been associated with a global rise in temperature of almost 1°C.
- Further increase in CO_2, and the effect of previous increases in CO_2, seem certain to cause a further increase in global temperature.
- But the magnitude of this rise, and its effect on local climate change are much less certain.
- Extremes are anticipated, but when, where and how much are ?impossible to predict

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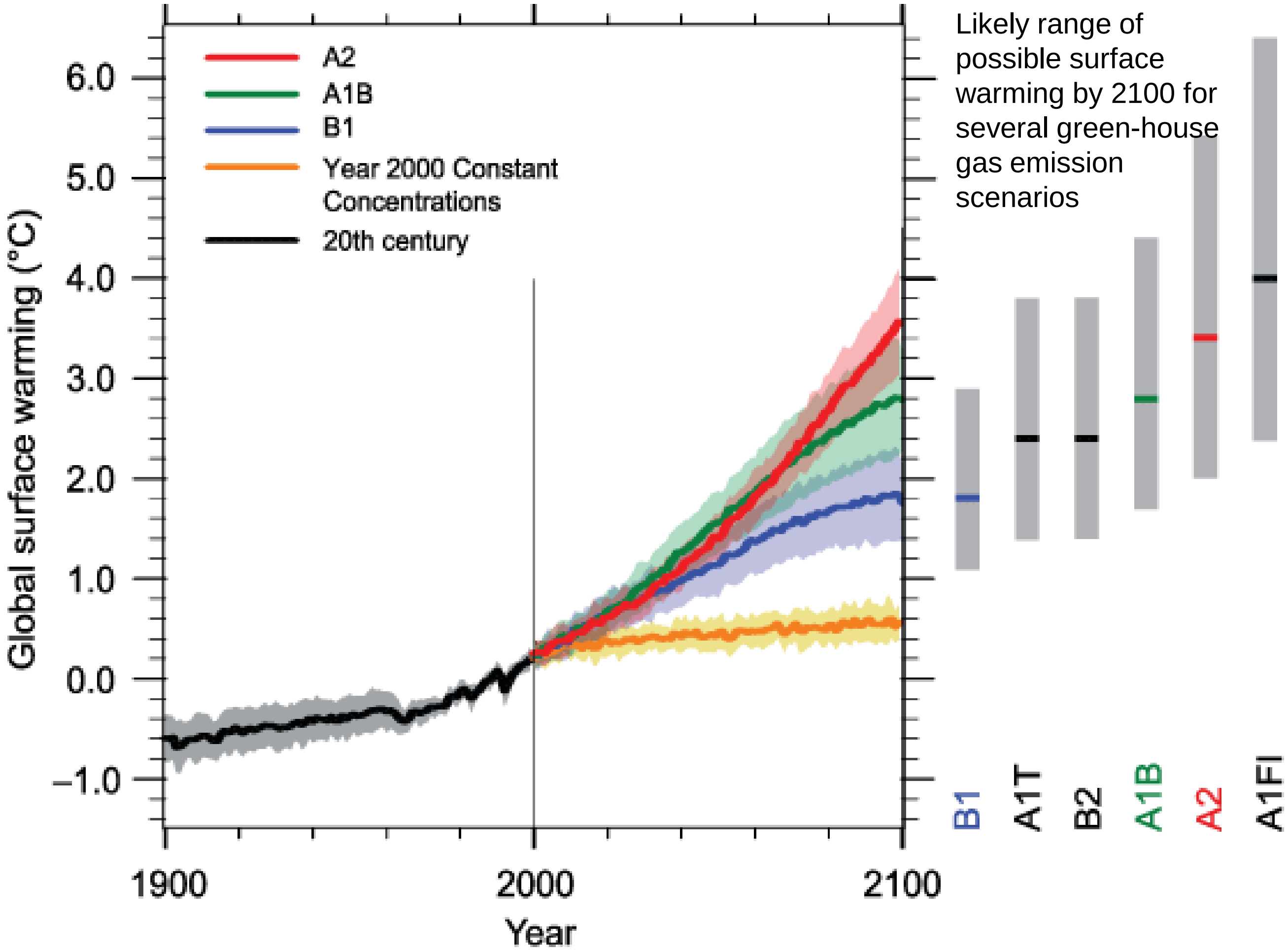
Global Climate Change



Variations in global temperature: 1900 to 2100 (relative to 1980-1999)

Uncertainty depends on

- assumptions of future green-house gas emission
- the theoretical model employed.

Source: IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [*Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)*]. Cambridge University Press, 18pp.

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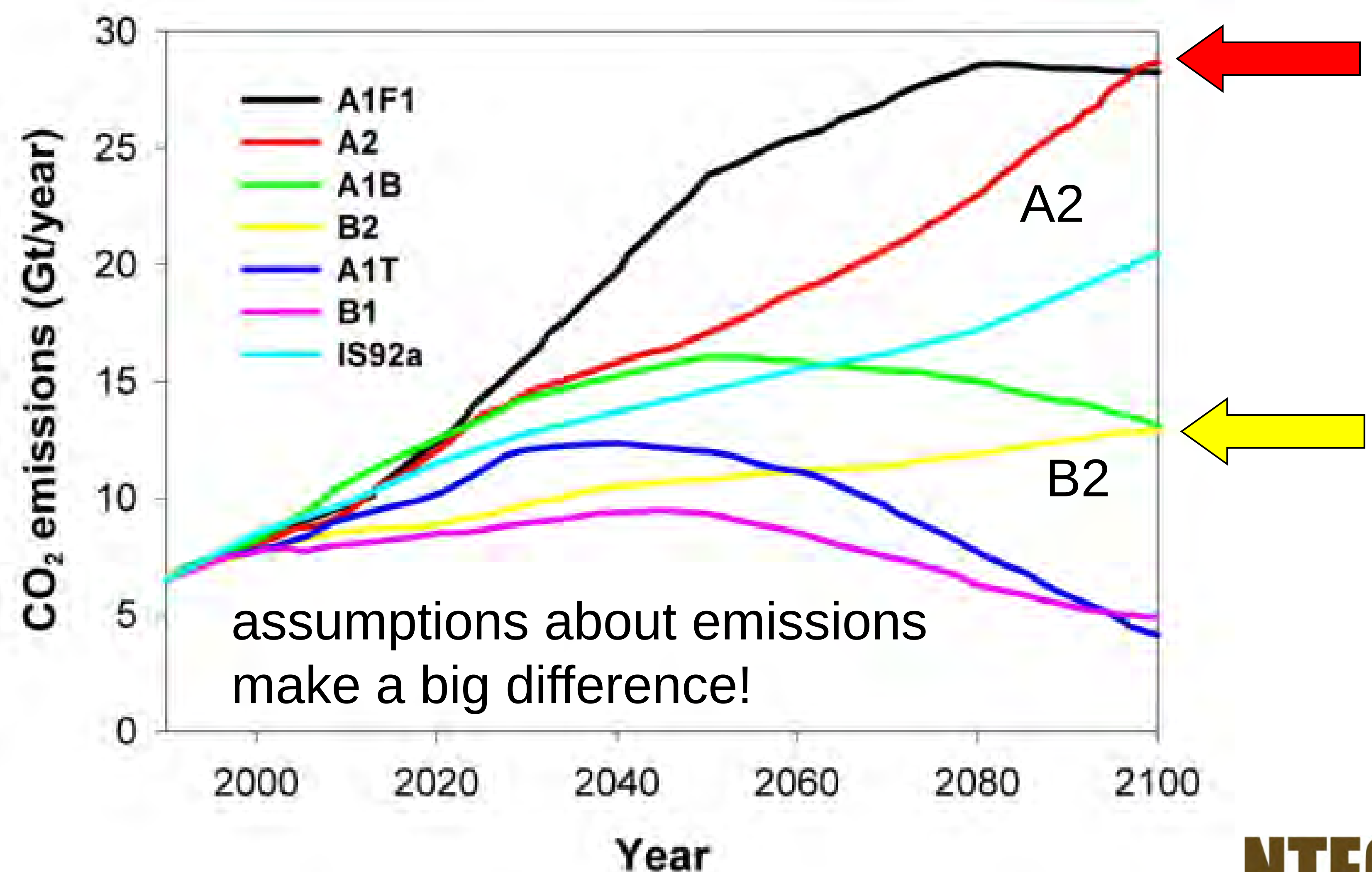
A2 & B2


30
25
20
15
10
5
0
CO_2 emissions (Gt/year)
2000
2020
2040
2060
2080
2100
Year
A1F1
A2
A1B
B2
A1T
B1
IS92a
A2
B2
assumptions about emissions
make a big difference!

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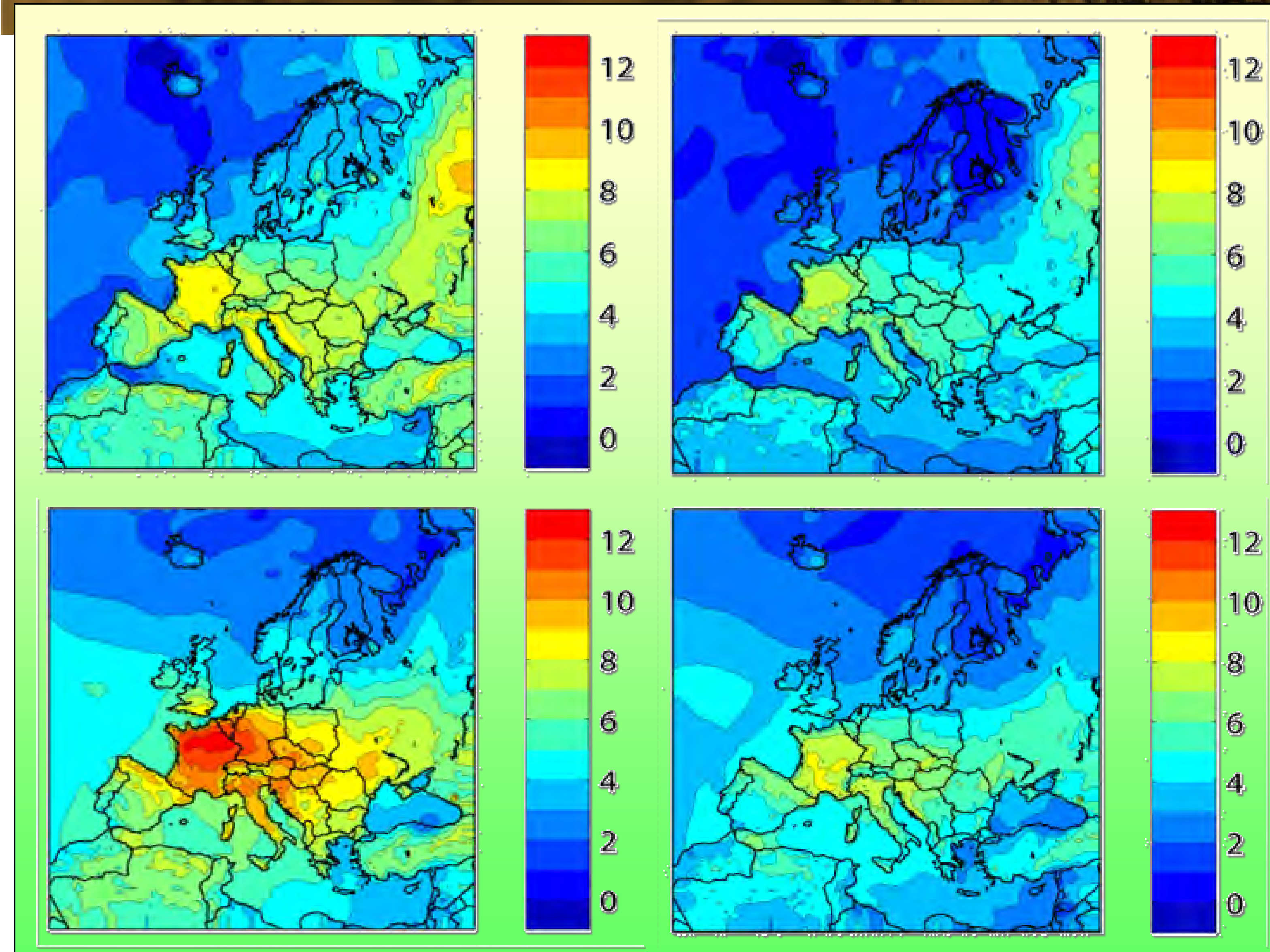
Sensitivity to scenario & model



Mean change in annual max. temp. (° C)

1	2
3	4

1=HadleyA2

2=HadleyB2

3=MPI-A2

4=MPI-B2

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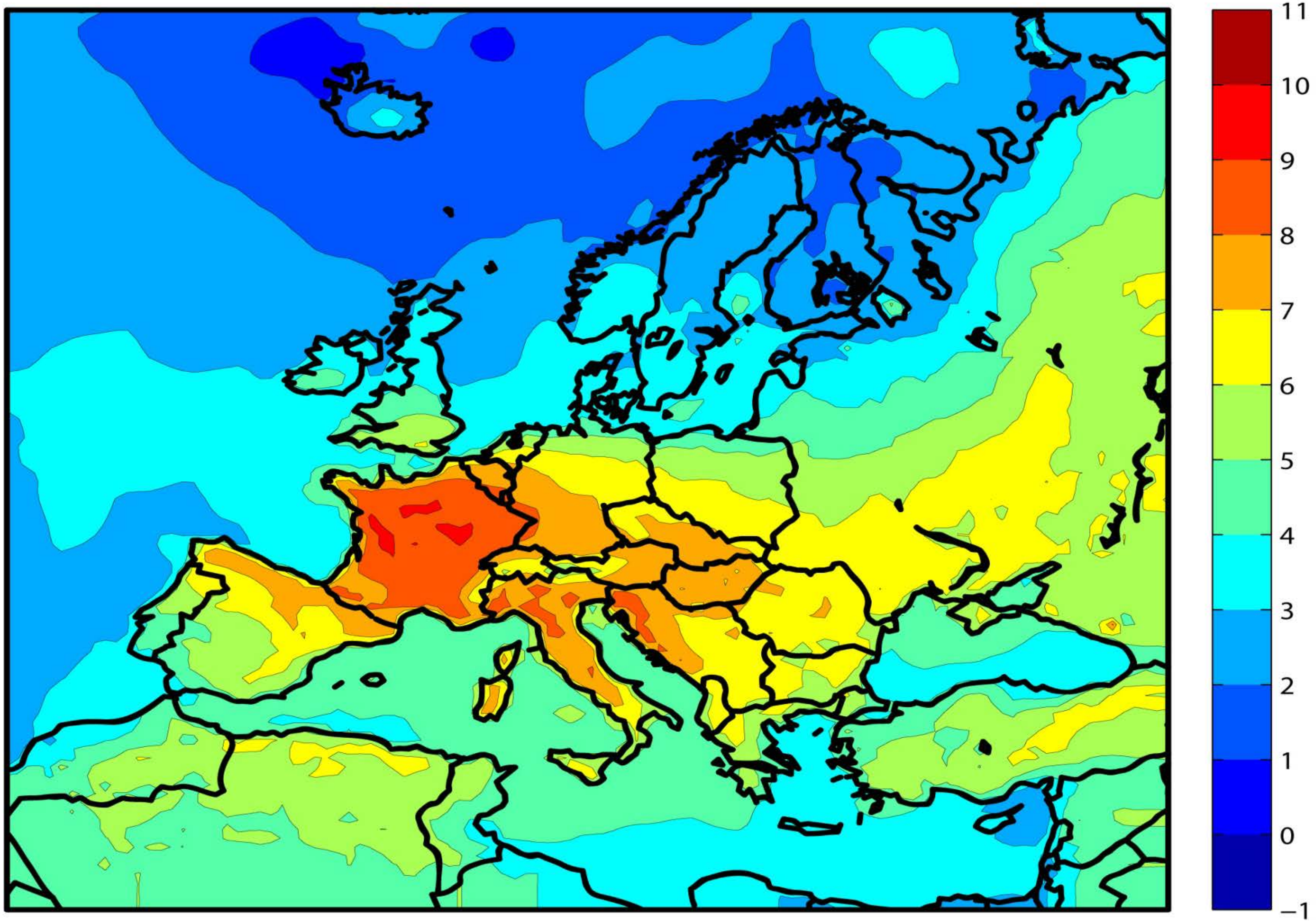
Mean change in annual max. temp. (°C)



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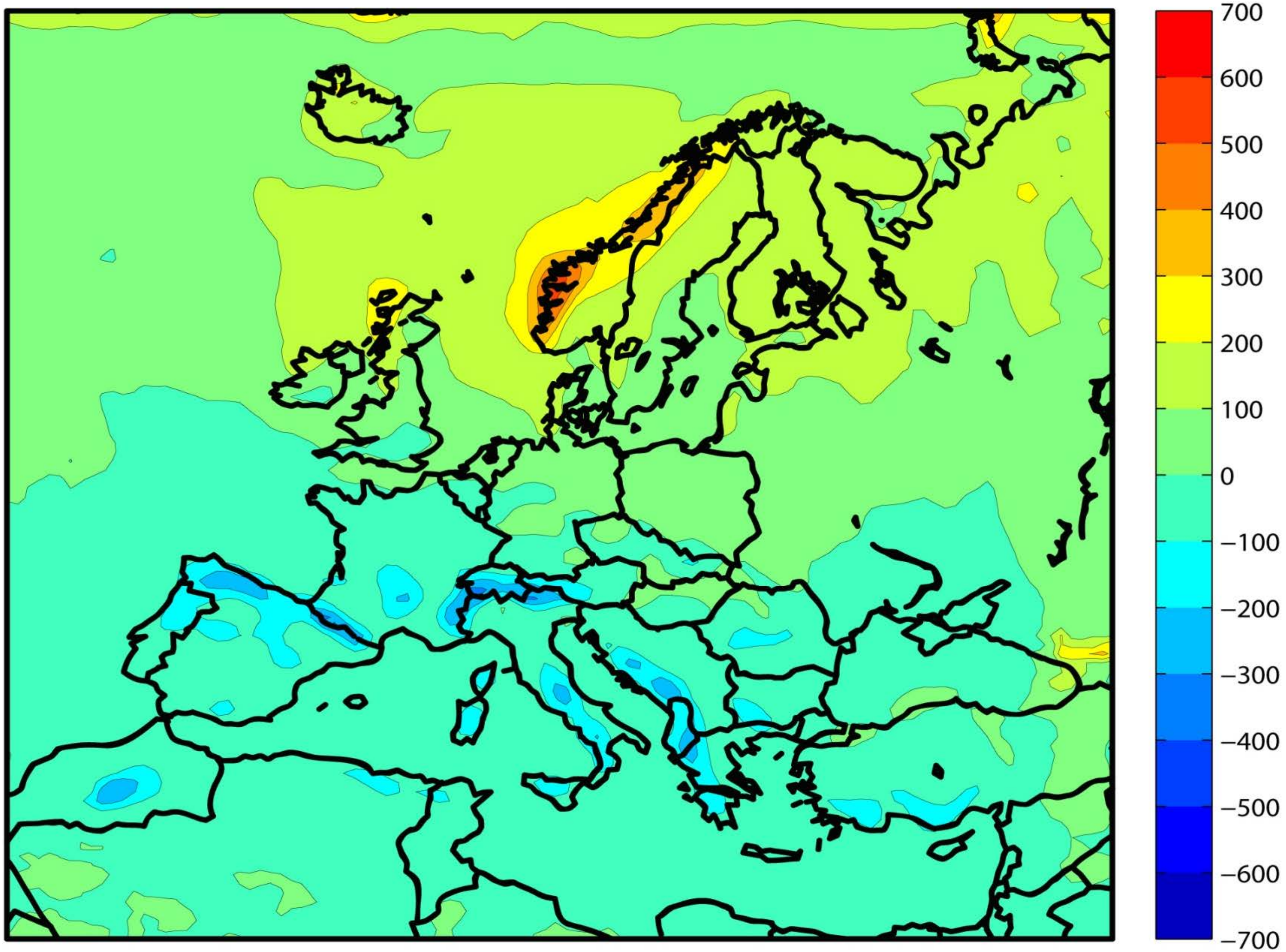
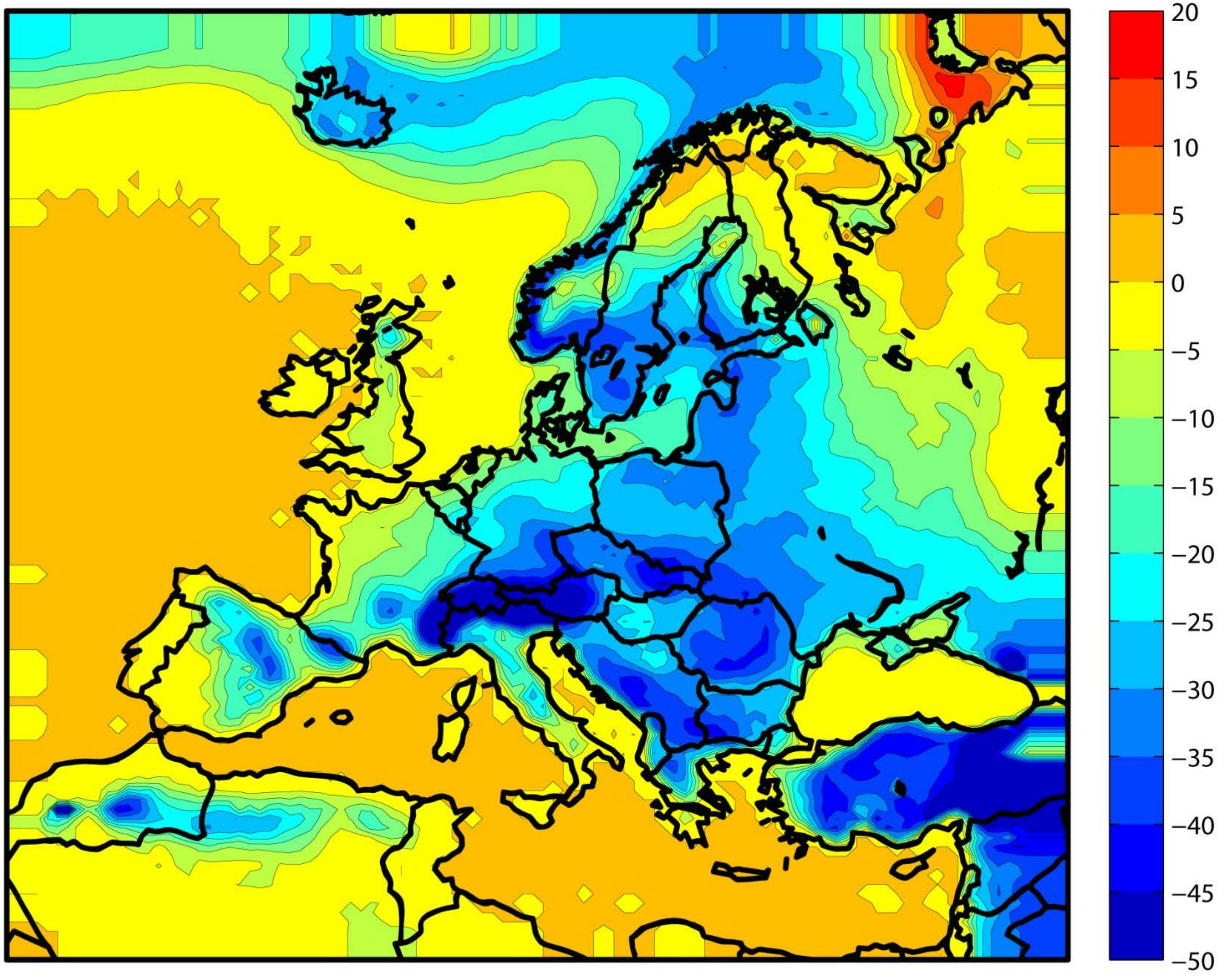
Mean change in Precipitation (mm)



Change in no. of 0°C crossings



Summary - Key Climate Changes

- Temperature Rise
  - Hotter summers (France, S. Germany, S. Czech Republic, S. Slovakia)
  - Shorter frozen period in winter (Far North)
  - Intermittent (or no) freezing (Nordic & Baltic Region)
- Greater Precipitation
  - Scotland, Nordic & Baltic Region, N. Poland, Alps
- Heavier Precipitation
  - All regions
- Sea level rise & more regular flooding of low points

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What about extremes?

- Climate models don't predict weather!
- So very difficult / impossible to predict changes in weather
- But generally agreed that extremes will be more extreme
  - No more rain (except in Scotland), but heavier when it does rain
  - Average temperature rise small, but summer peaks may be hotter and winter colds may be colder

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How might pavements be affected ?

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Higher peak temperatures

- Good for the subgrade & aggregate
  - More evaporation
  - Dryer
- Challenging for asphalt
  - Rutting
  - Cracking

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Structural Impacts

(asphaltic pavements)

- Top-down cracking
- Rutting
- Asphalt aging
- Roughness
- Bottom-up cracking
- Thermal cracking

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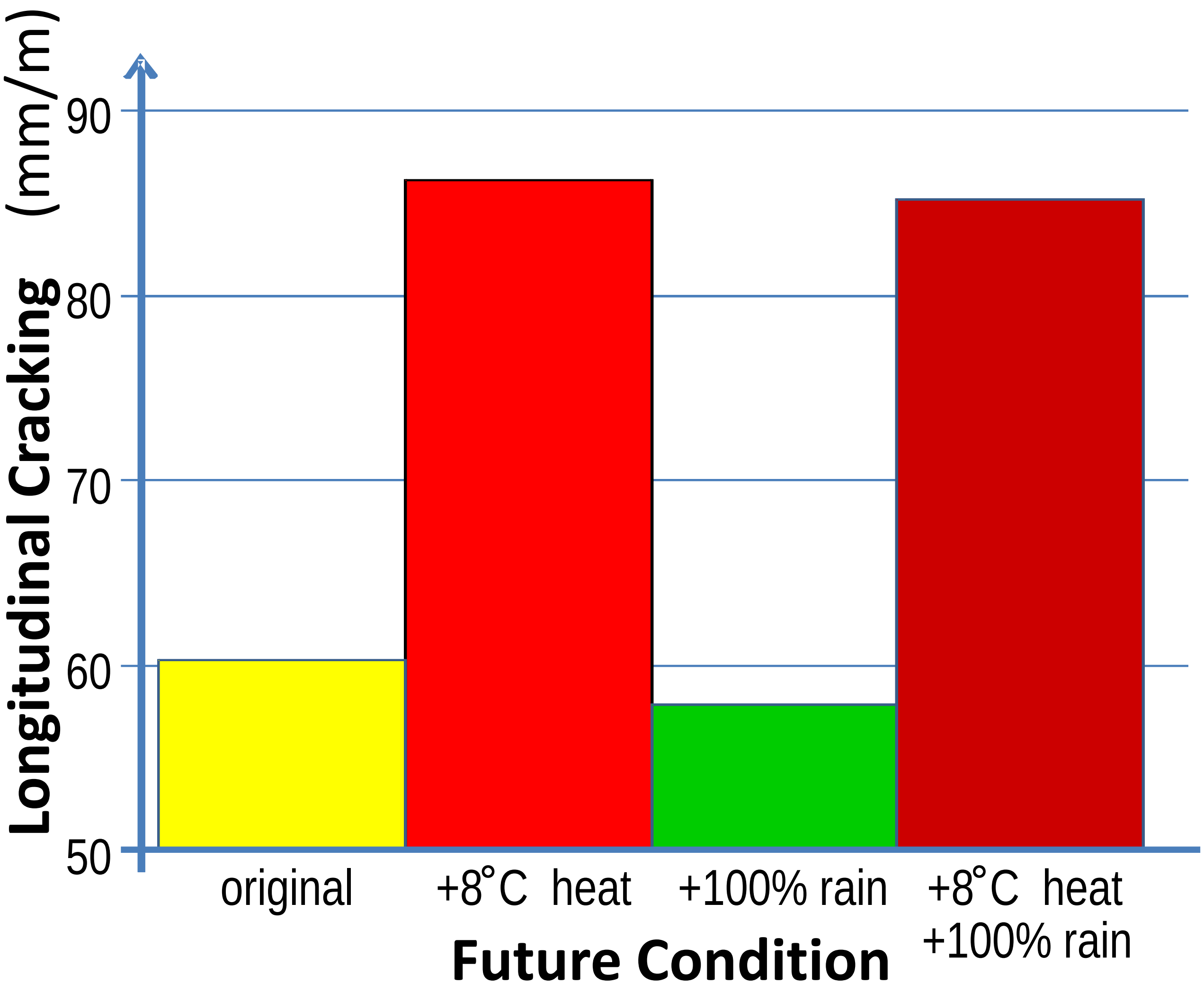
Top down cracking



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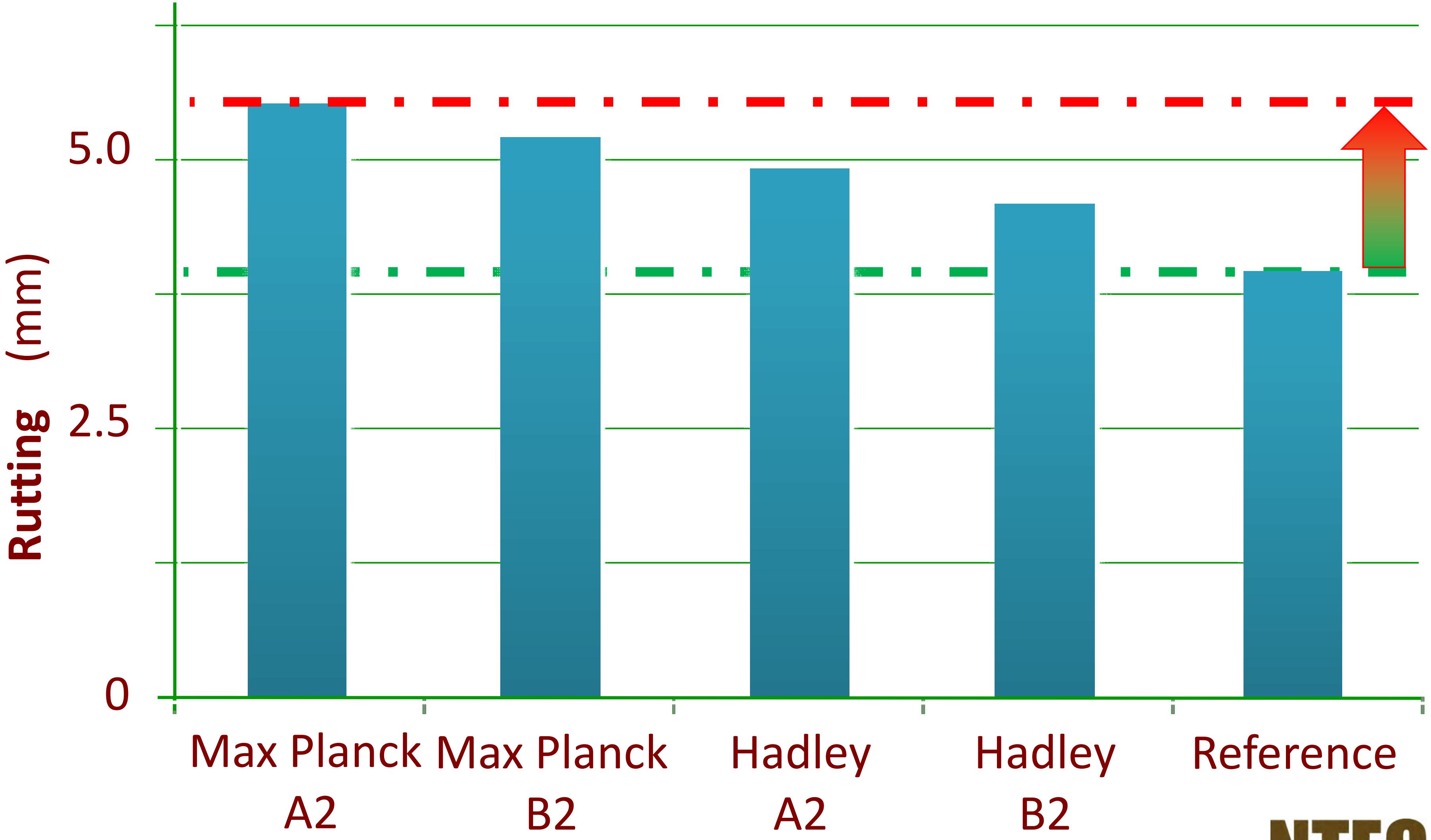
Increased Rutting



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Wetter Surfaces

- During & after rain
- Stripping set to increase
- More opportunity for water to enter pavement structures if cracks exist
- Porous asphalt surfaces have potential, but may need attention for use in heavier storms
  - Outlets ?
  - Greater attention to sealing underneath ?

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Poor drainage will lead to softened subgrades & pavement distress

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Sub-surface drains will need extra capacity and maintenance

courtesy Antero Nousiainen

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Critical exception

- Flooding will become more common
  - At low points
  - By the sea
- Higher water table
- Considerable loss of stiff support

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Implications for Deterioration, Maintenance & Life Cycle Cost

(*pavement structure only*)

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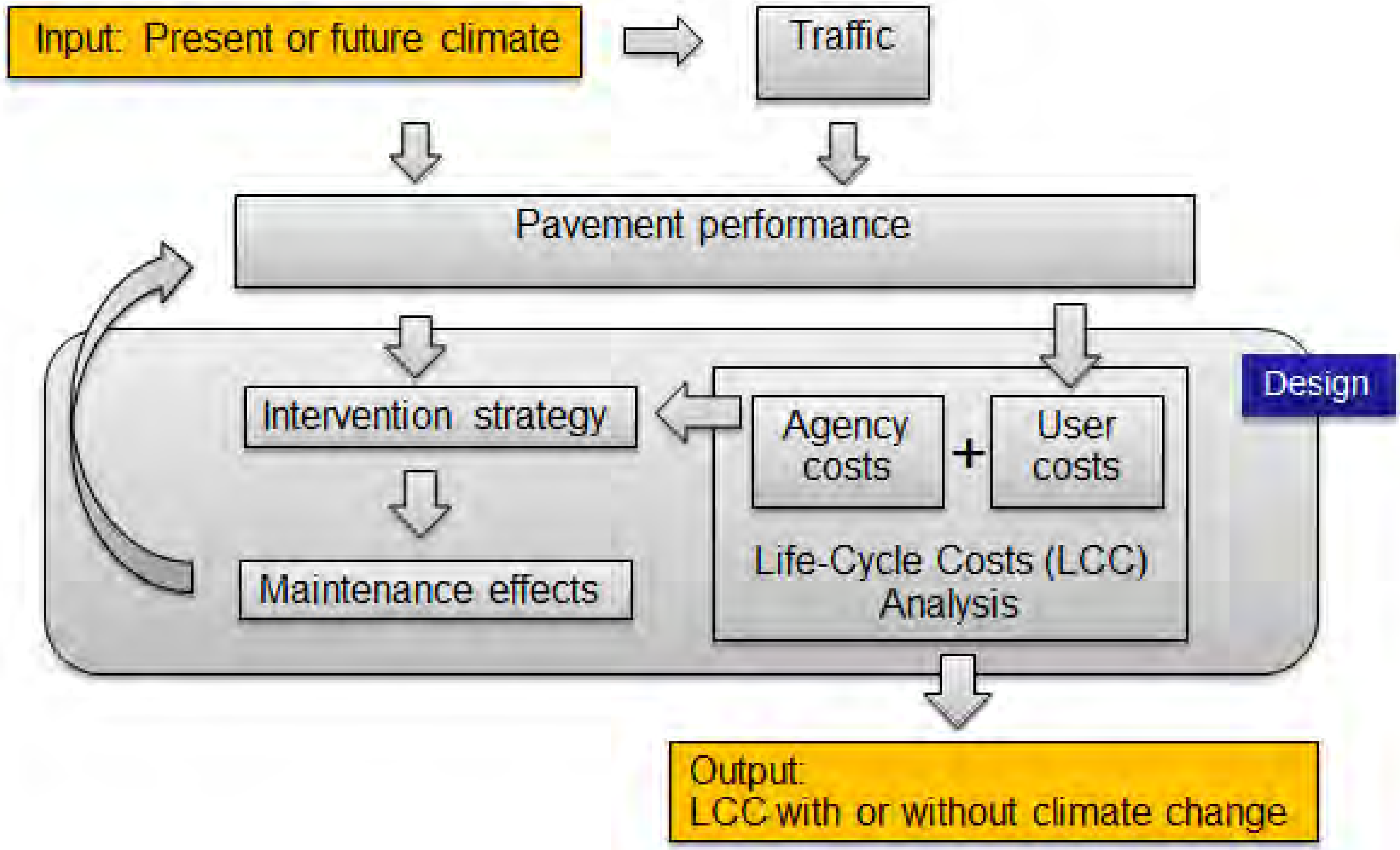
How can we predict impact?

- Use standard LCCA with changing inputs



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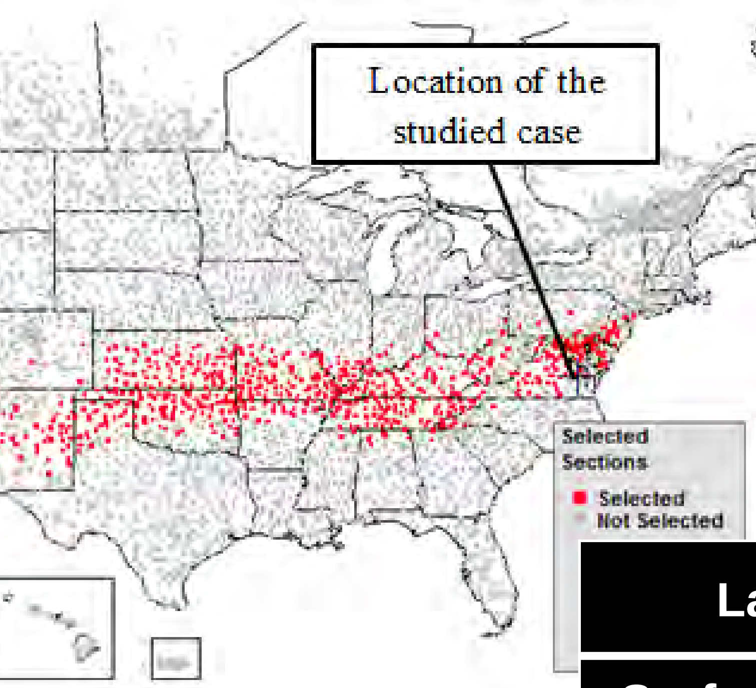
Case study (Virginia, USA)



AADT = 380 000
10% commercial veh.
Length = 100km

Layers	Material	Binder	Thickness (mm)
Surface course	12.5mm SM	PG 70-22	50
Bituminous base course	25mm Base	PG 64-22	63
Bituminous base course	25mm Base	PG 64-22	75
Granular Base	-	-	125
Sub-base	Clay-silt, MP	-	150
Subgrade	Clay-silt, MP	-	-

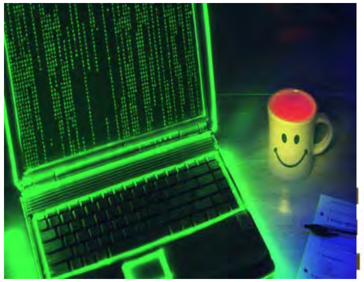
Projected Temperature Change

Projection year and emission scenarios		Increase of Annual Average Temperature 2000s – 2050s (°C)
2050	A1FI	2.02
	A1B	1.72
	B1	1.26

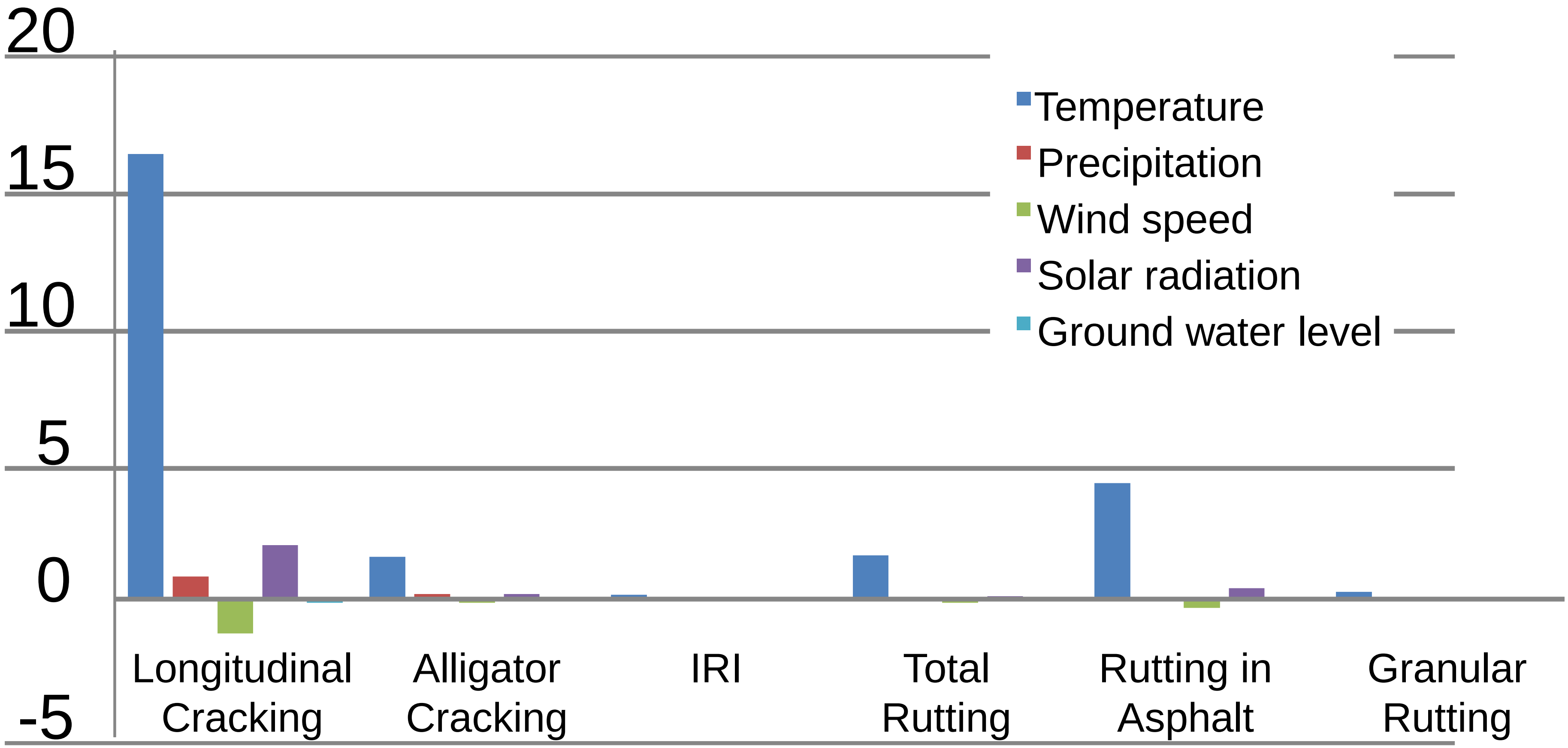
A1FI

A1B

B1



Sensitivity analysis (+5%) for all climatic factors



Similar to findings for European Study Earlier

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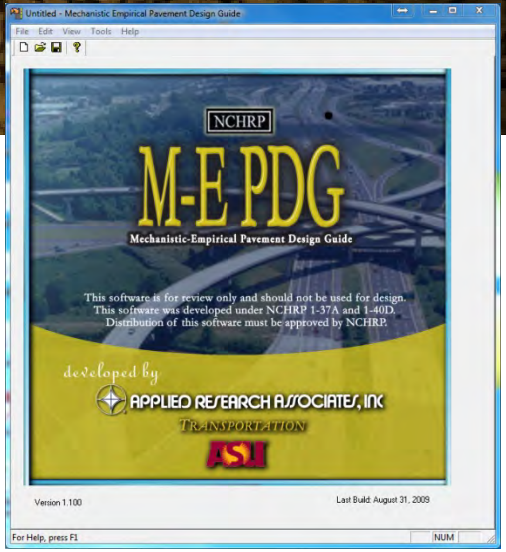
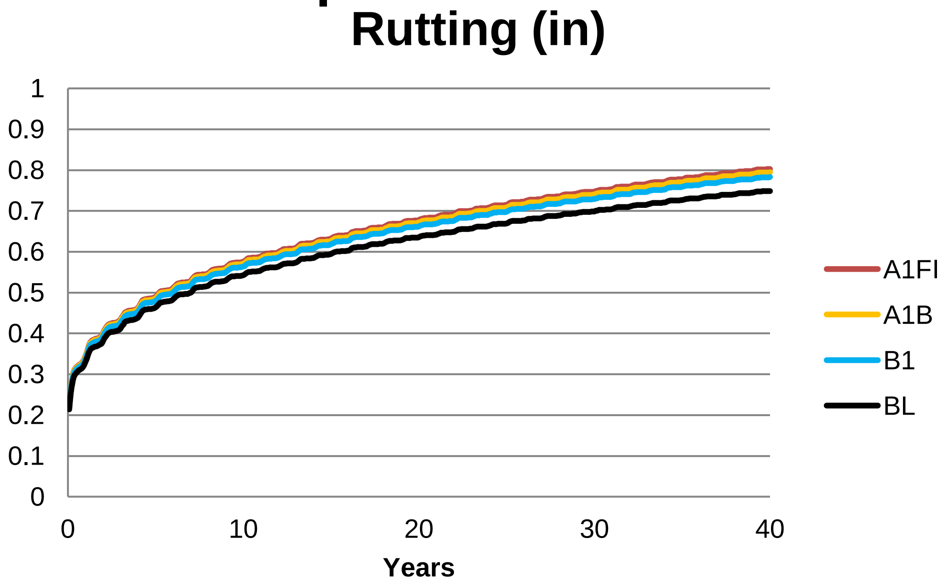
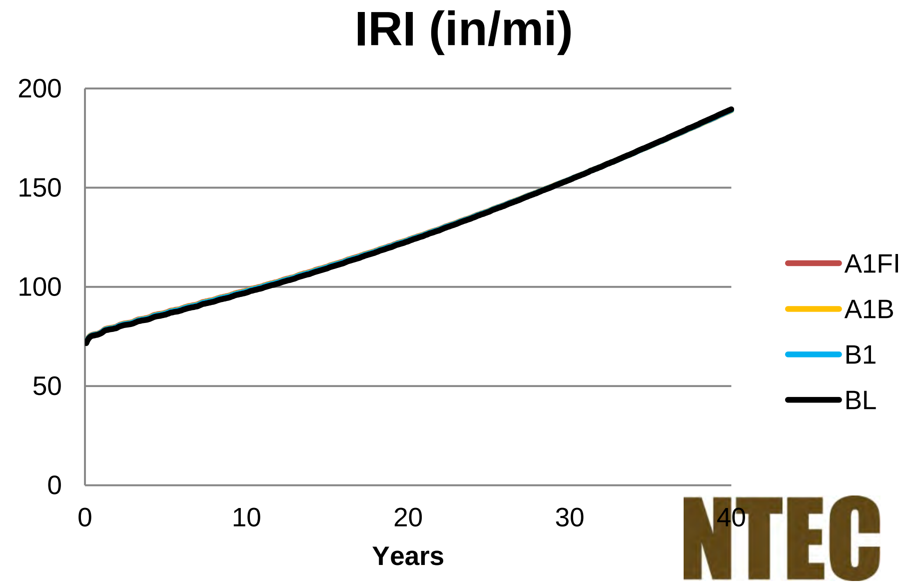
Pavement performance modelling

- Used US Mechanistic-Empirical Design Guide (AASHTO)



- Response without structural maintenance:





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Maintenance Effects Modelling

- Maintenance data from three frequently maintained districts in Virginia, USA
  - 735 records used
- Related performance (IRI, rutting, etc.) to maintenance operation
- Investigated maintenance type
  - Thin overlay (Op1)
  - Overlay + intermediate layer (Op2)
  - Inlay (Op3)
- Agency costs established

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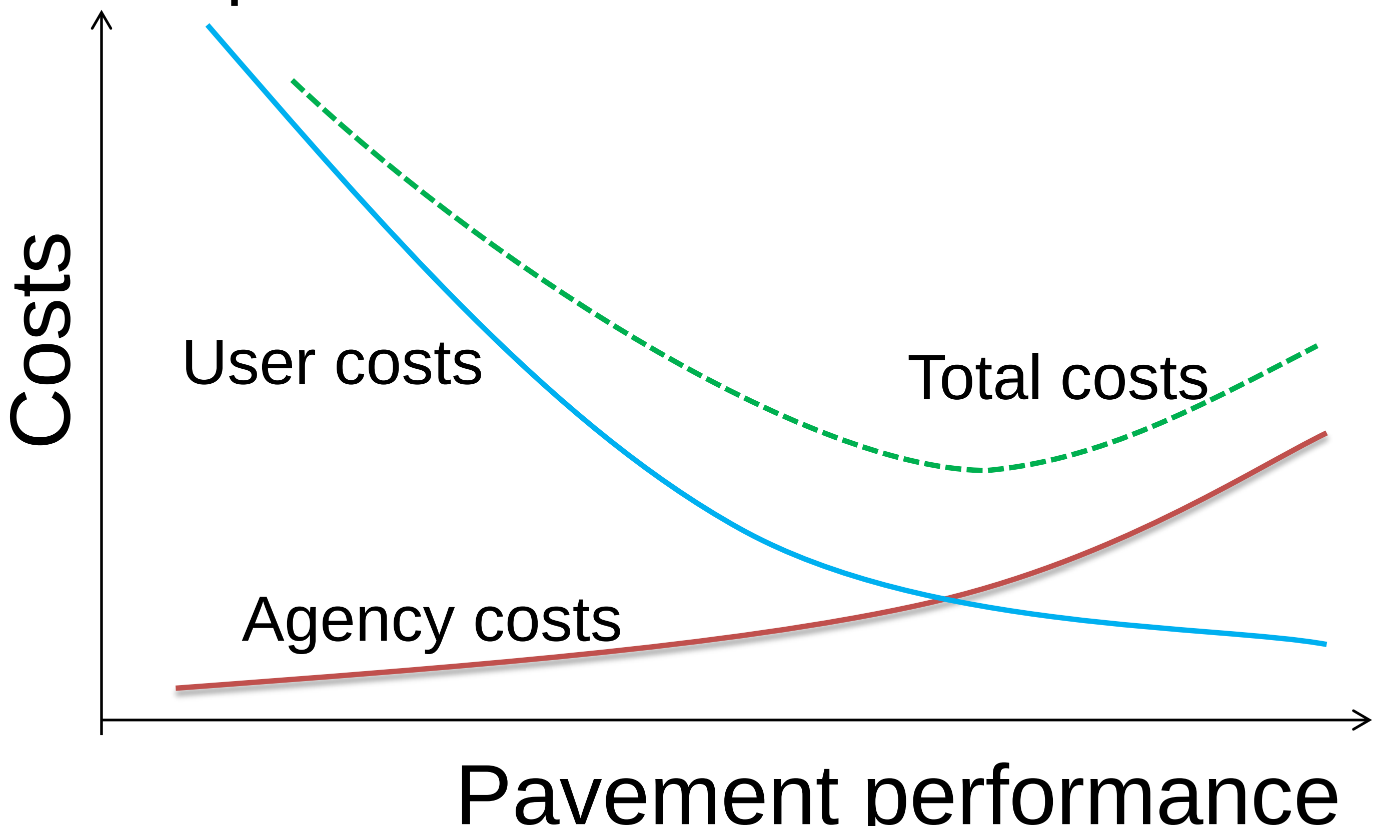
LCCA

- Agency costs (maintenance costs)
- Road user costs (Veh. Op. costs)
- Optimise maintenance to minimize costs



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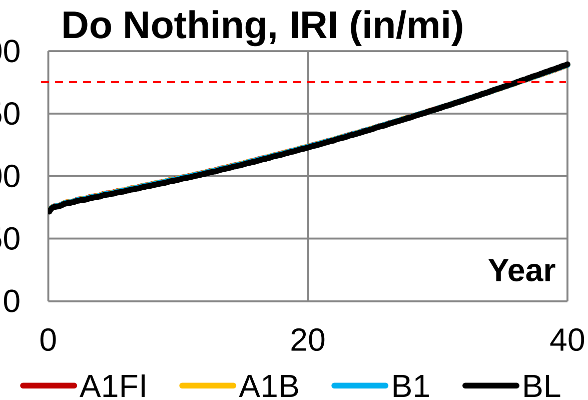
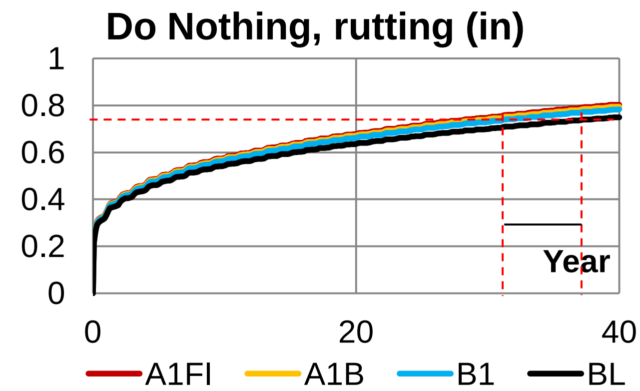
Uncertainty “warning”

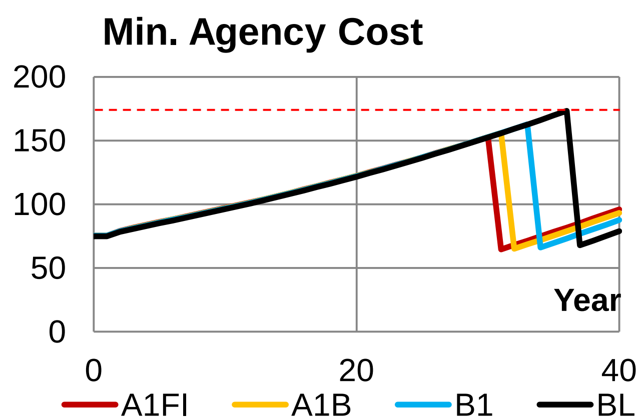
Uncertainty is a major reason why LCAs routinely come to contradictory conclusions

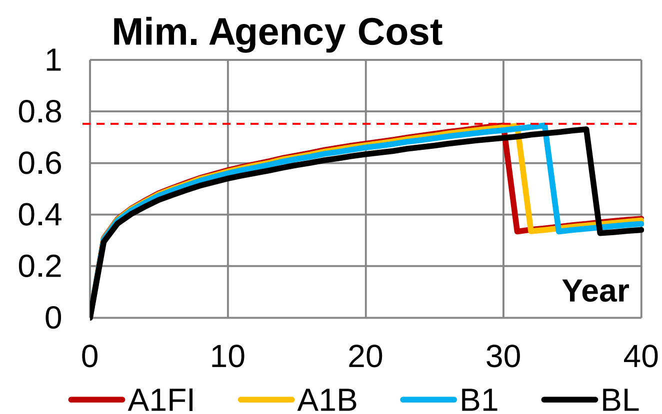
The differences between alternatives are easily outweighed by the variability in the environmental factors

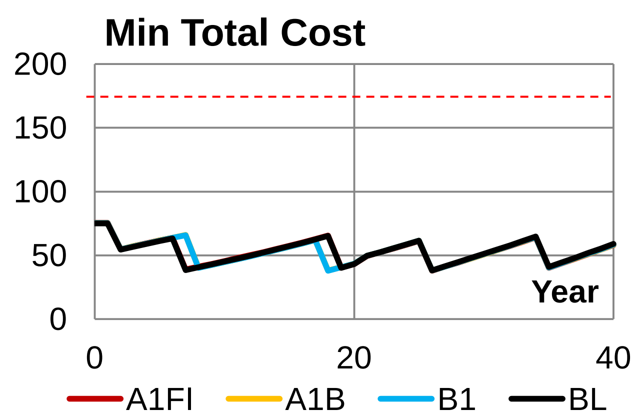
Results

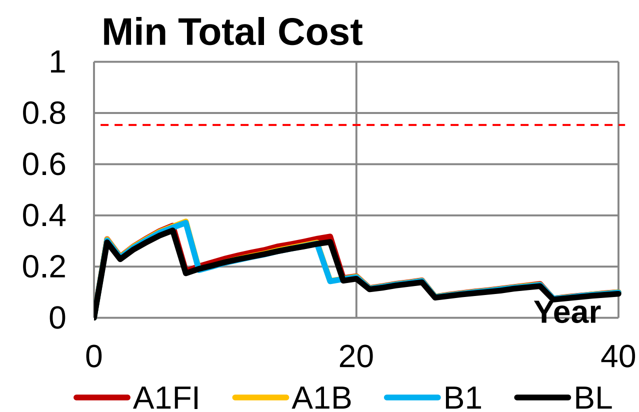

Do Nothing, IRI (in/mi)
200
150
100
50
0
Year
0
20
40
A1FI
A1B
B1
BL


Do Nothing, rutting (in)
1
0.8
0.6
0.4
0.2
0
Year
0
20
40
A1FI
A1B
B1
BL

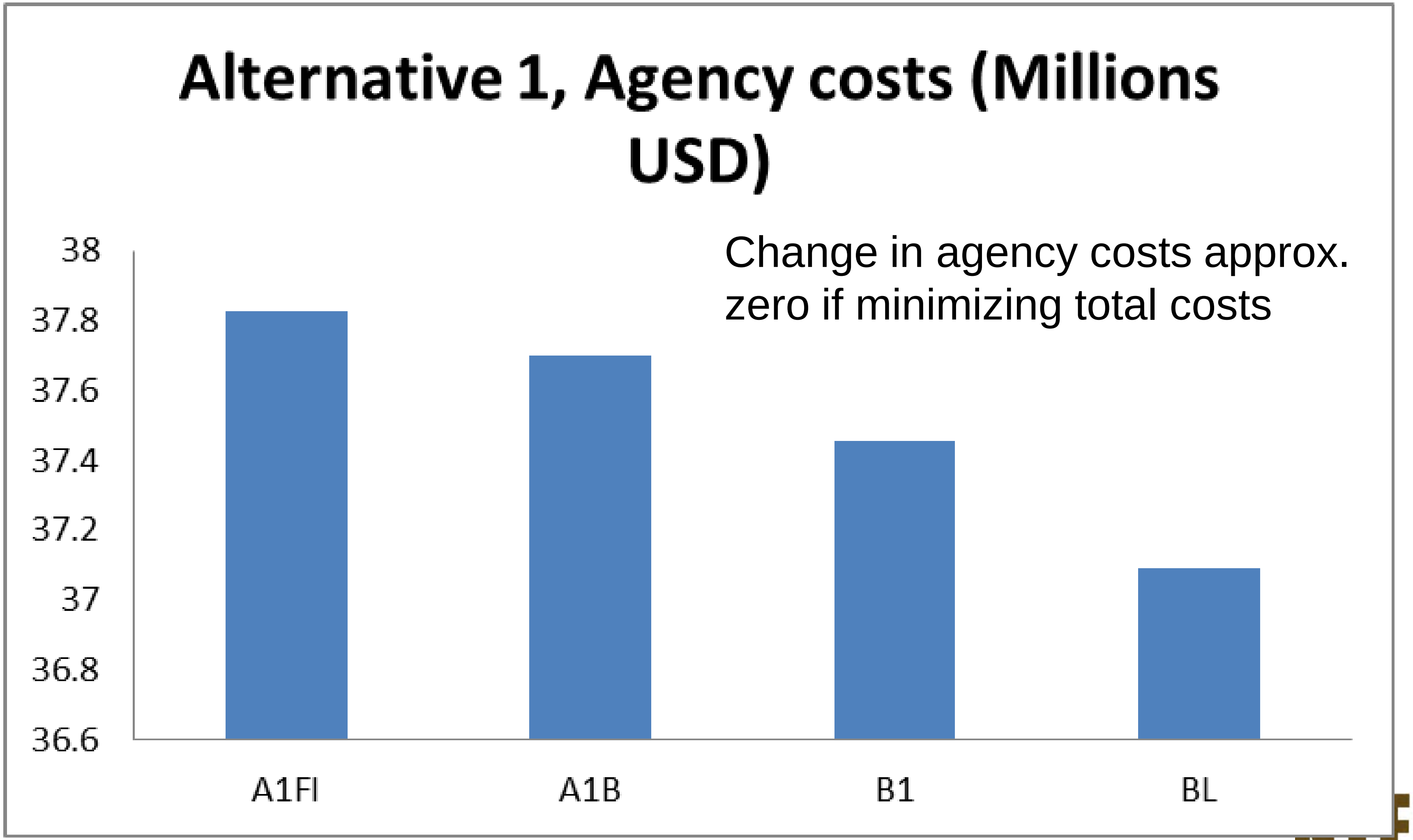

Min. Agency Cost
200
150
100
50
0
Year
0
20
40
A1FI
A1B
B1
BL


Mim. Agency Cost
1
0.8
0.6
0.4
0.2
0
Year
0
10
20
30
40
A1FI
A1B
B1
BL

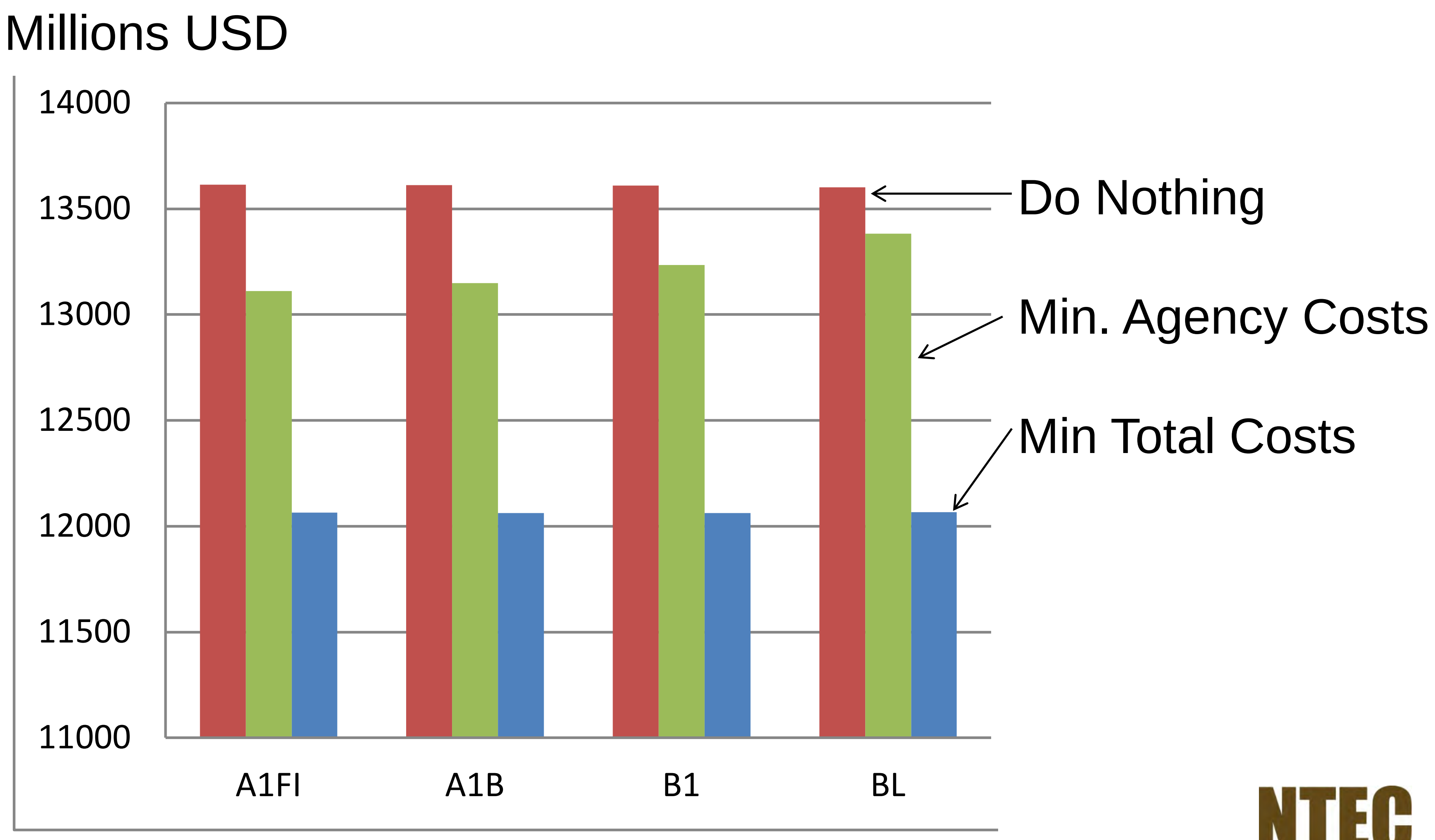

Min Total Cost
200
150
100
50
0
Year
0
20
40
A1FI
A1B
B1
BL


Min Total Cost
1
0.8
0.6
0.4
0.2
0
Year
0
20
40
A1FI
A1B
B1
BL

Minimized agency costs + 1.5% due to climate



LCC – Agency+User



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Tentative conclusions

- Overall Climate Change effects:
  - Hotter asphalt surfacing
    - Greater top-down cracking
    - Greater rutting
    - Greater roughness
  - But effects on LCC small
    - Can probably ignore
- Extreme Climate Change effects:
  - Unpredictable but widespread:
    - Hot & Cold extremes
    - Hot extremes
  - Predictable because localised:
    - Flooding
  - Effects on LCC probably moderate for any non-flooding segment
    - Will need an increased contingency fund

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What to do?

- Update design standards for new climatic conditions
  - Regarding temperature & rainfall
- Raise road levels at low spots / amend drainage
- Monitor condition & distress vs. climate experienced
- Include different (but probably not novel) materials at next reconstruction.
- and note:
  - User & funder demands will change more than climate
  - Demographic changes will impose greater changes
- Problematic: important but not urgent

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Thank you