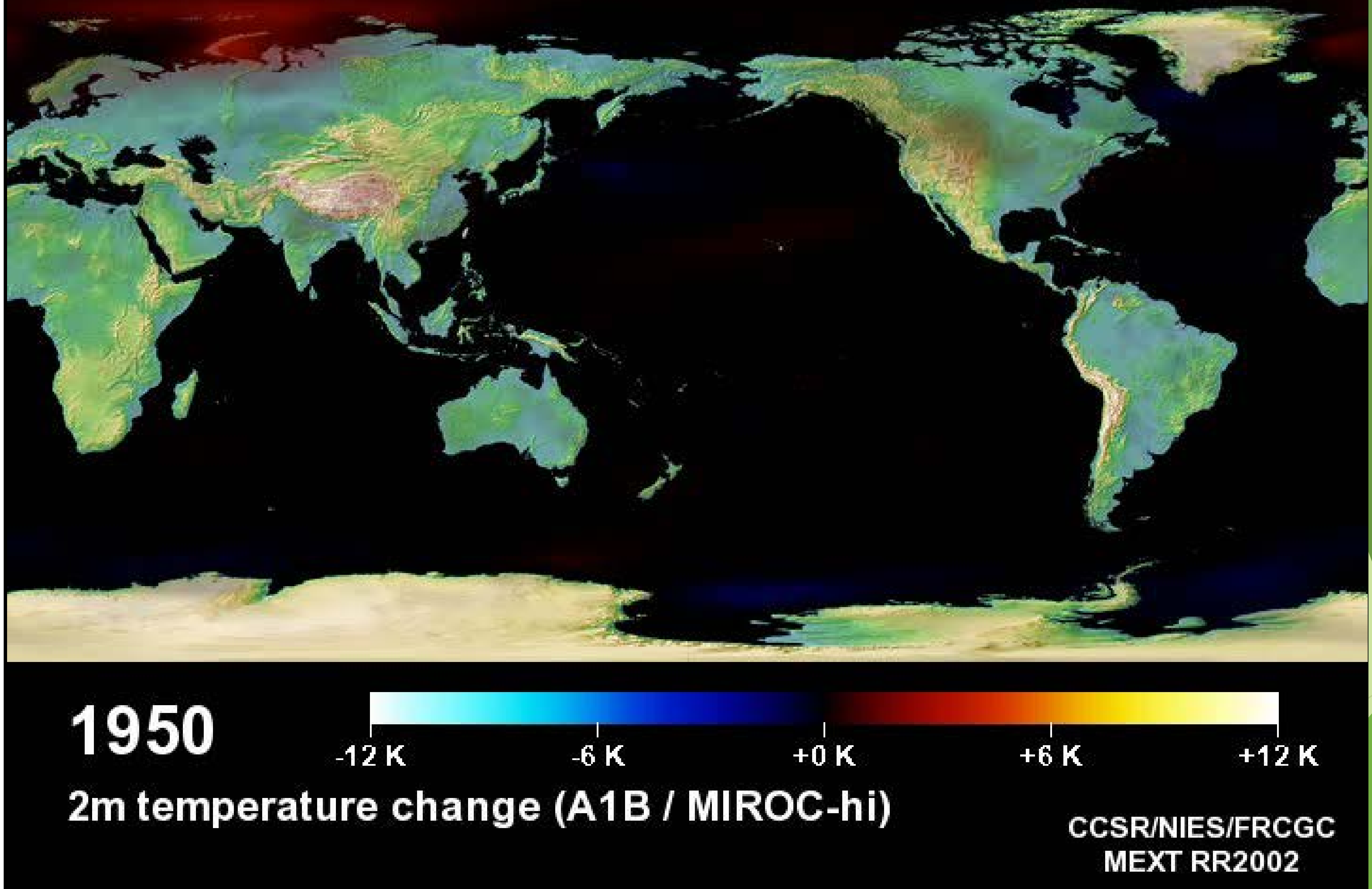
From climate change to emission scenarios

The Bad News and the Good News

The Bad News

Climate impacts and positive feedback



Computeranimation: Earth Simulator, Japan


2012

Models project substantial warming in temperature extremes by the end of the 21st century. increase by about 1°C to 3°C by the mid-21st century and by about 2°C to 5°C by the late 21st century, depending on the region and emissions scenario

It is *likely* that the frequency of heavy precipitation or the proportion of total rainfall from heavy falls will increase in the 21st century over many areas of the globe.

This is particularly the case in the high latitudes and tropical regions, and in winter in the northern mid-latitudes. Heavy rainfalls associated with tropical cyclones are *likely* to increase with continued warming.

There is ***medium confidence*** that, in some regions, increases in heavy precipitation will occur despite projected decreases in total precipitation

There is *medium confidence* that there will be a reduction in the number of extra tropical cyclones averaged over each hemisphere.
While there is ***low confidence*** in the detailed geographical projections of extra tropical cyclone activity


There is *medium confidence* that droughts will intensify in the 21st century in some seasons and areas, due to reduced precipitation and/or increased evapotranspiration.

This applies to regions including southern Europe and the Mediterranean region, central Europe, central North America, Central America and Mexico, northeast Brazil, and southern Africa. Elsewhere there is overall *low confidence* because of inconsistent projections of drought changes (dependent both on model and dryness index). Definitional issues, lack of observational data, and the inability of models to include all the factors that influence droughts preclude stronger confidence than *medium* in drought projections.

Projected precipitation and temperature changes imply possible changes in floods, although overall there is *low confidence* in projections of changes in fluvial floods. Confidence is *low* due to *limited evidence* and because the causes of regional changes are complex, although there are exceptions to this statement.

There is ***medium confidence*** (based on physical reasoning) that projected increases in heavy rainfall would contribute to increases in local flooding in some catchments or regions.

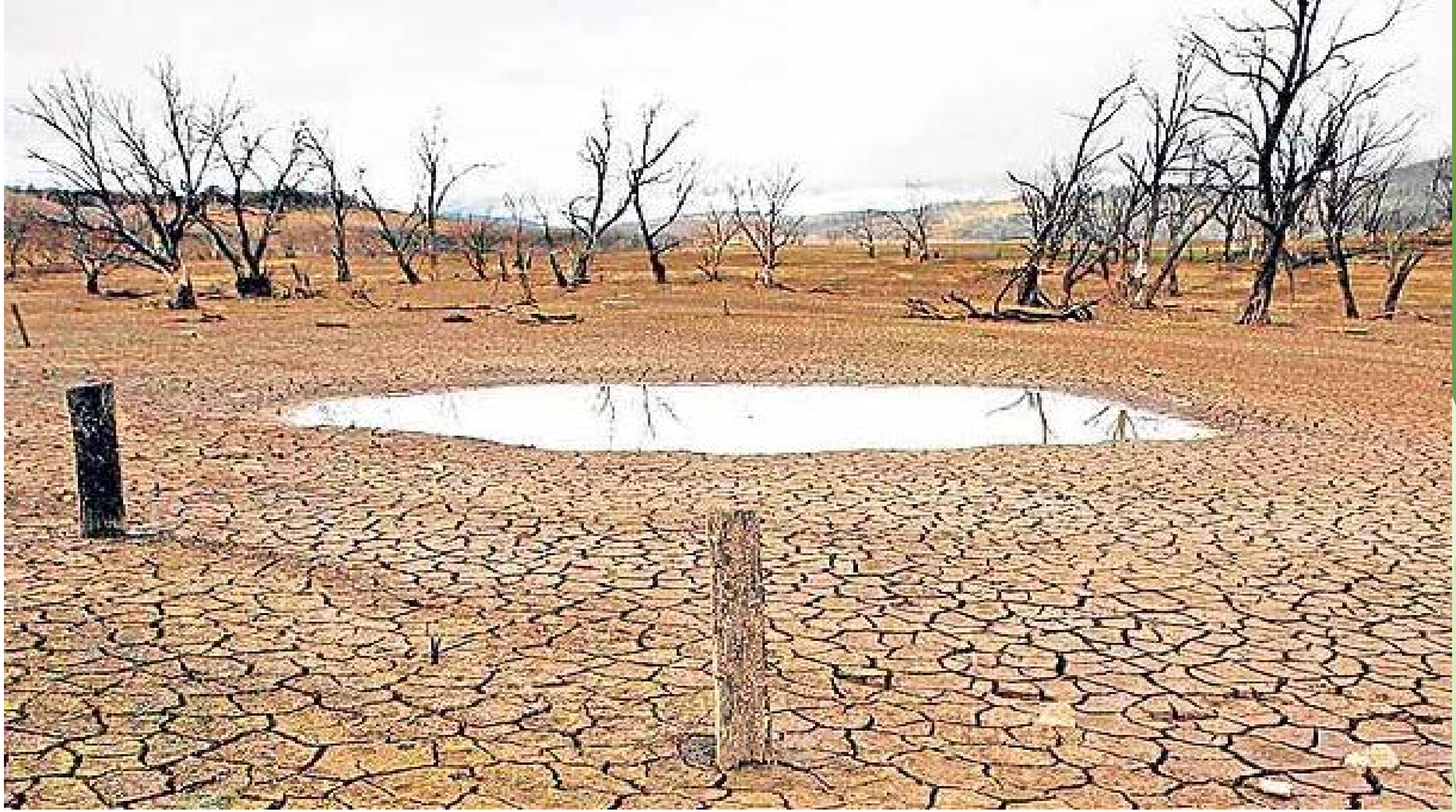
It is *very likely* that mean sea level rise will contribute to upward trends in extreme coastal high water levels in the future.

There is ***high confidence*** that locations currently experiencing adverse impacts such as coastal erosion and inundation will continue to do so in the future due to increasing sea levels, all other contributing factors being equal.

The ***very likely*** contribution of mean sea level rise to increased extreme coastal high water levels, coupled with the ***likely* increase** in tropical cyclone maximum wind speed, is a specific issue for tropical small island states.

There is *high confidence* that changes in heat waves, glacial retreat, and/or permafrost degradation will affect high mountain phenomena such as slope instabilities, movements of mass, and glacial lake outburst floods.

There is also ***high confidence*** that changes in heavy precipitation will affect landslides in some regions

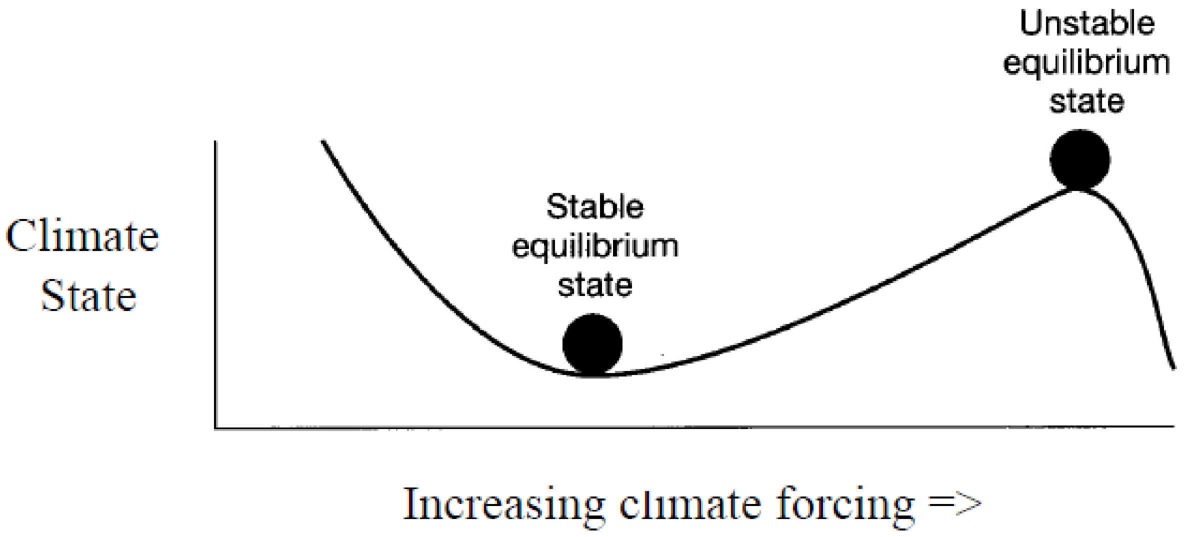


There is *low confidence* in projections of changes in large-scale patterns of natural climate variability.

Confidence is *low* in projections of changes in monsoons (rainfall, circulation) because there is little consensus in climate models regarding the sign of future change in the monsoons. Model projections of changes in El Niño–Southern Oscillation variability and the frequency of El Niño episodes are not consistent, and so there is ***low confidence*** in projections of changes in this phenomenon.

EUROPE AND MEDITERRANEAN	
Temp. max	High confidence: Likely increase in WD and likely decrease in CD in most of the region. Some regional and temporal variations in significance of trends. Likely strongest and most significant trends in the Iberian Peninsula and Southern France (Medium confidence: Smaller or less significant trends in S.E. Europe and Italy due to change point in trends at the end of the 1970s / beginning of 1980s; sometimes linked with changes in sign of trends; strongest WD increase since
Temp.min	High confidence: Likely increase in WN and likely decrease in CN in most of the region. Some regional variations in significance of trends. Very likely overall increase in WN and very likely overall decrease in CN in S.W. Europe and W. Mediterranean; likely strongest signals in Spain and Southern France. Likely overall tendency for increase in WN and likely overall tendency for decrease in CN in S.E. Europe and E. Mediterranean
Heat Waves/Warm Spells	High confidence: Likely overall increase in HW in summer (JJA). Significant increase in max HW duration since 1880 in Iberian Peninsula and west Central Europe in JJA. Significant increase in max HW duration in Tuscany (Italy). Significant increase in HW indices in Turkey and to a smaller extent in S.E. Europe and Turkey in JJA. Less significant signal in HW indices in S.E. Europe due to presence of change point in trends.
Heavy Precipitation	Low confidence: Inconsistent trends within domain and across studies. Medium confidence: Overall increase in dryness (SMA, PDSI, CDD), but partial dependence on index and time period.
Dryness	Medium confidence: Overall increase in dryness (SMA, PDSI, CDD), but partial dependence on index and time period.

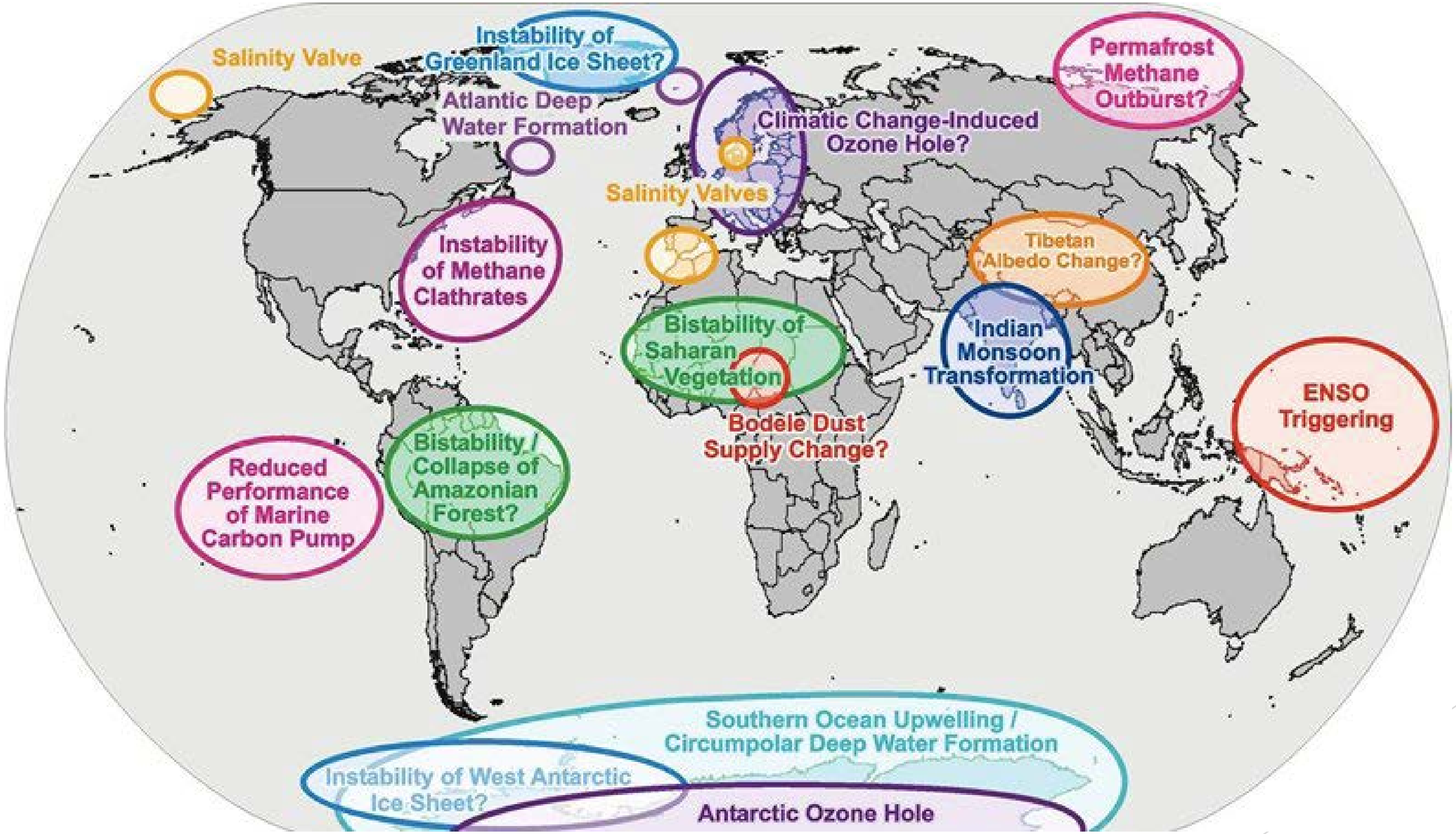
What is a climate treshold?



modified from Kump *et al* (2003)

- A negative feedback switches to a positive feedback loop
- Potentially several basins of attraction
- Changes can occur abruptly
- Hysteresis response: The system does not return to the original state after the forcing is removed (over a relevant time period).

Potential turning points



Example 1:

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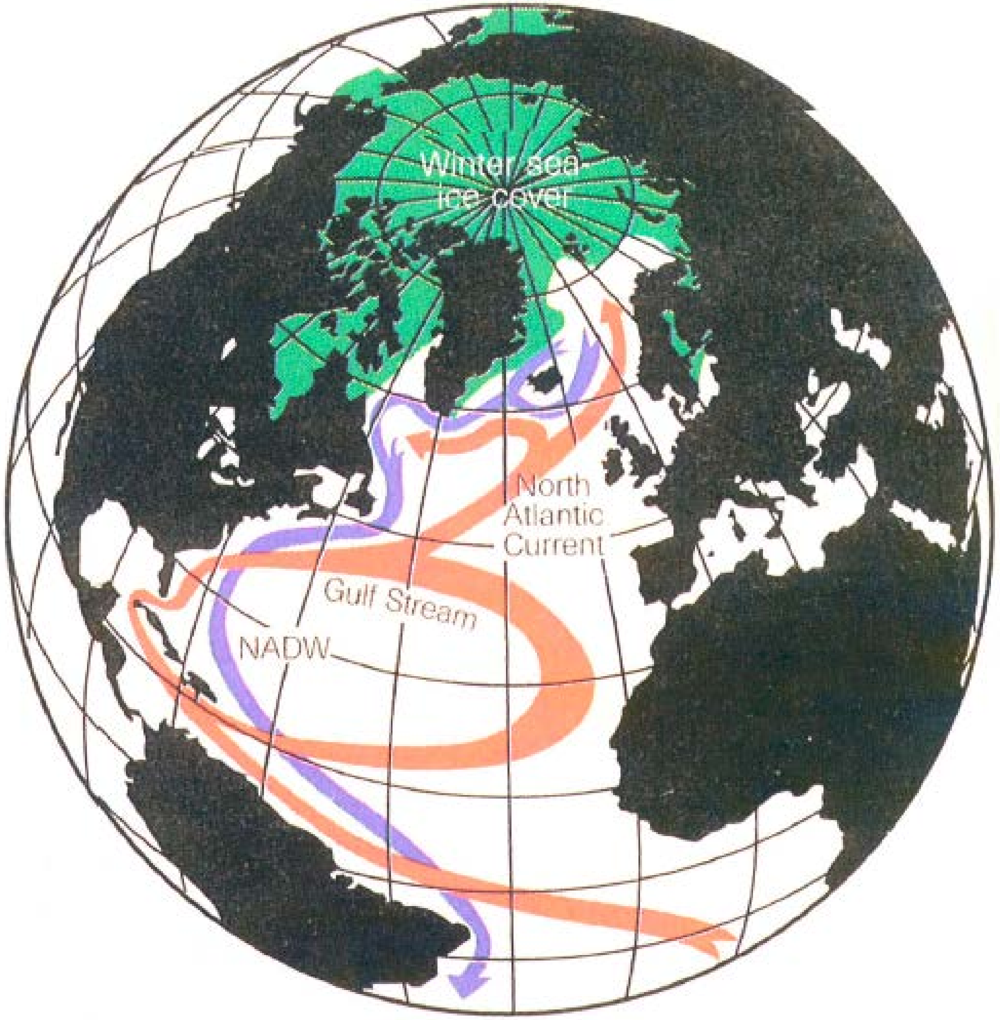
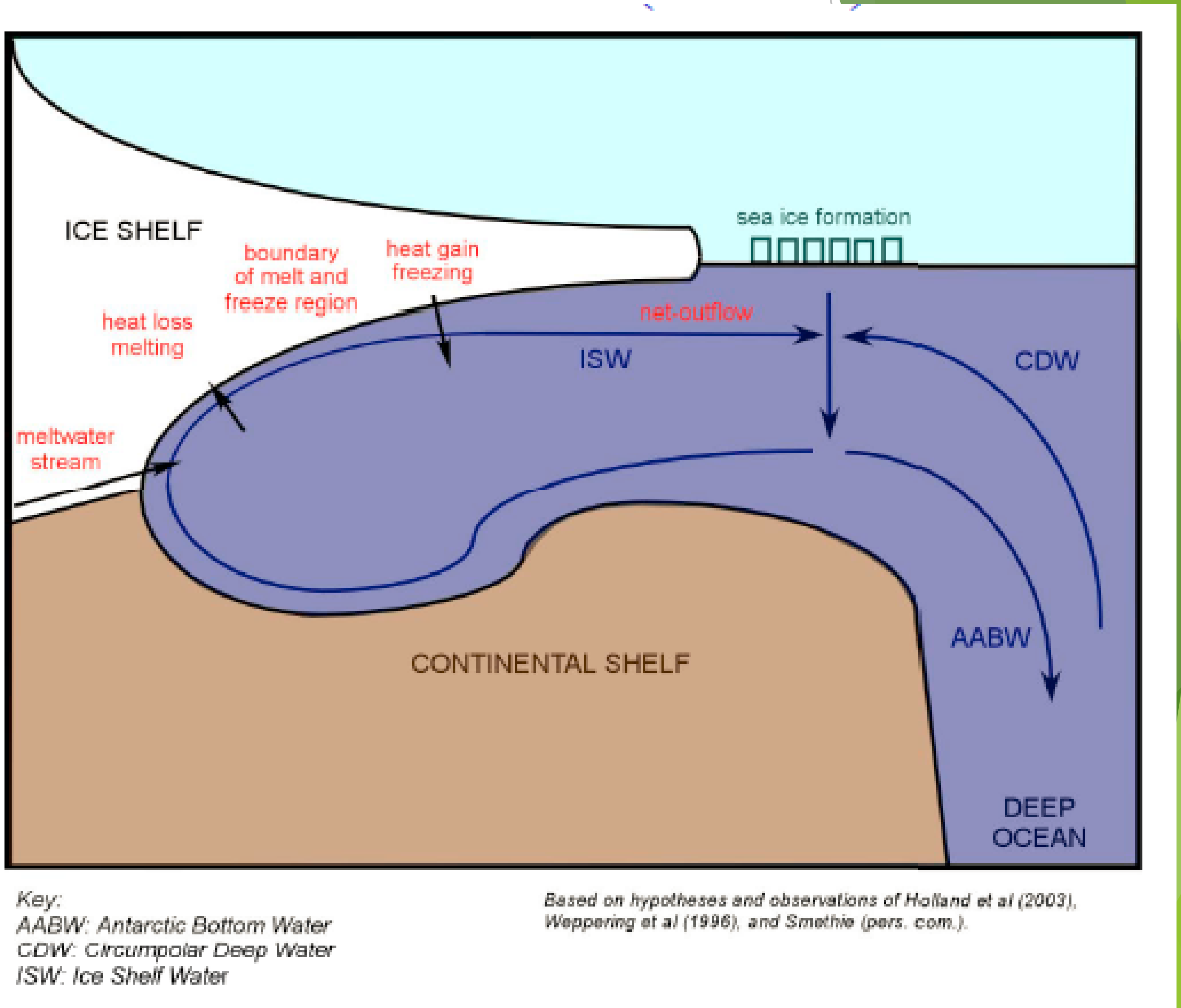
The North Atlantic Meridional verturning Circulation (MOC) may collapse in a threshold response



Rahmstorf (1997)

Example 2:

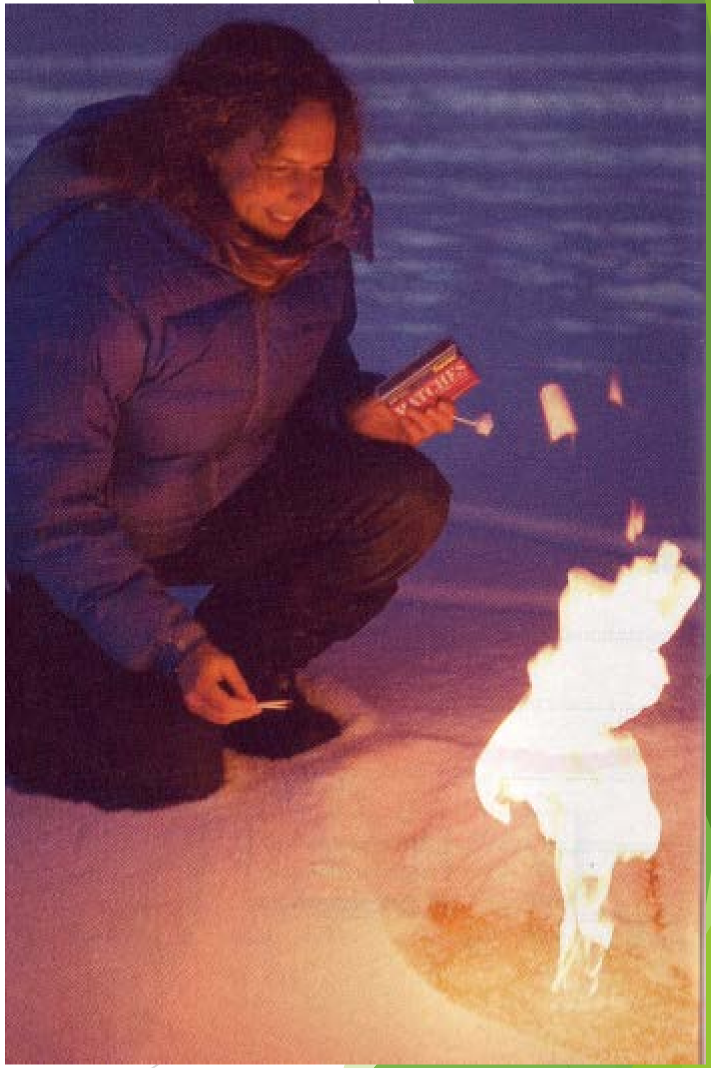
- The WAIS may disintegrate in response to anthropogenic greenhouse gas emissions (*cf.* Oppenheimer 1998).
- An anthropogenic warming of 2.5 oC has been interpreted as a WAIS climate limit.
- The consequences of a WAIS collapse *could* include a global sea level rise of around 6 meters and a disruption of global oceanic circulation patterns.



Two possible positive feedbacks:
- slip rate up -> bottom temperature up -> slip rate up
- temp. up -> melting rate up -> height down -> temp. up

Example 3

- It is estimated that the west Siberian bog alone contains some 70 billion tonnes of methane, a quarter of all the methane stored on the land surface of the world. This is equivalent to emitting 1.7 trillion tons of CO_2, which is more greenhouse gas than has been emitted by humans in the past 200 years
- Warming triggers the release of methane with the melting of permafrost

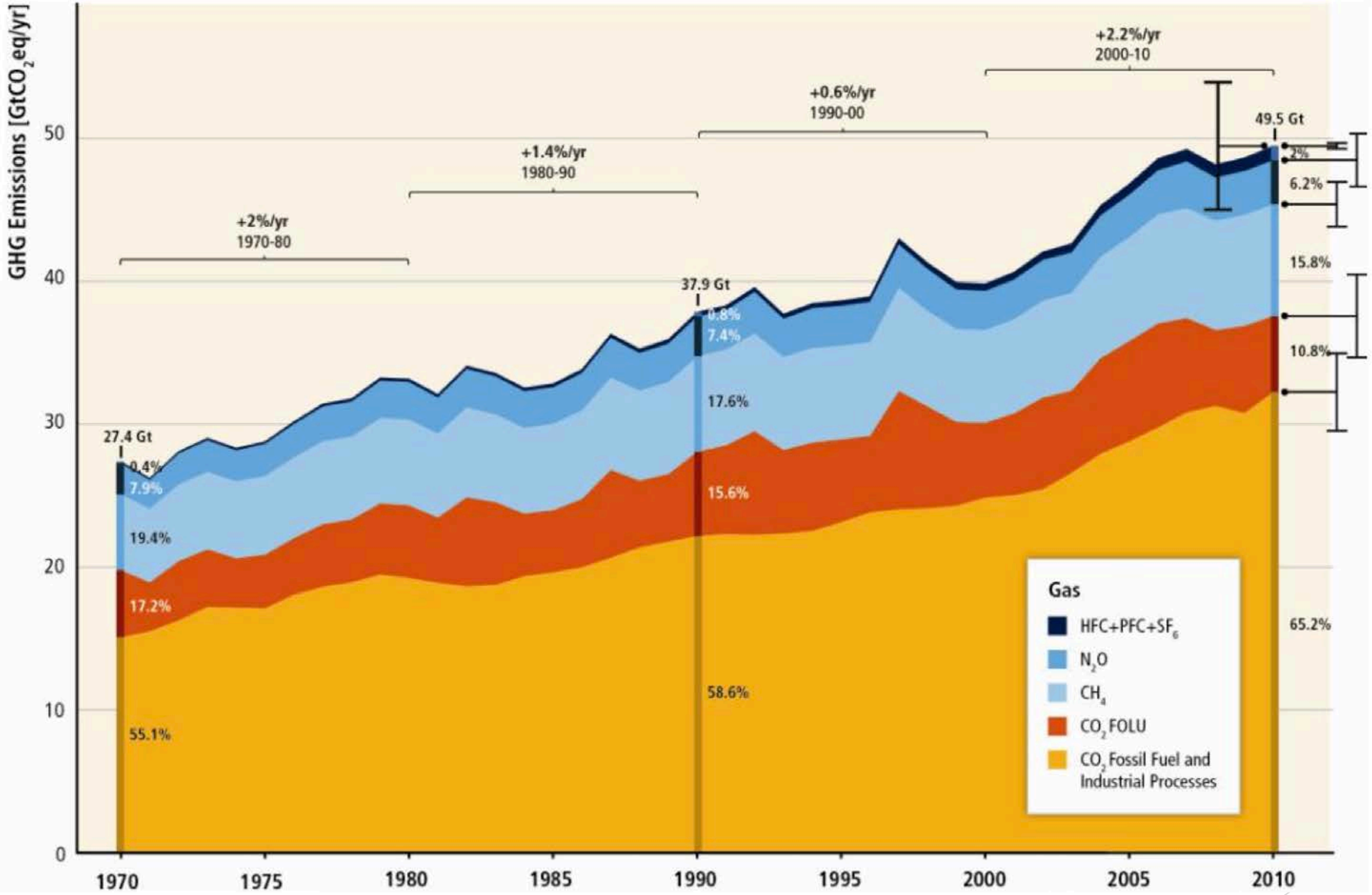


Emission reduction

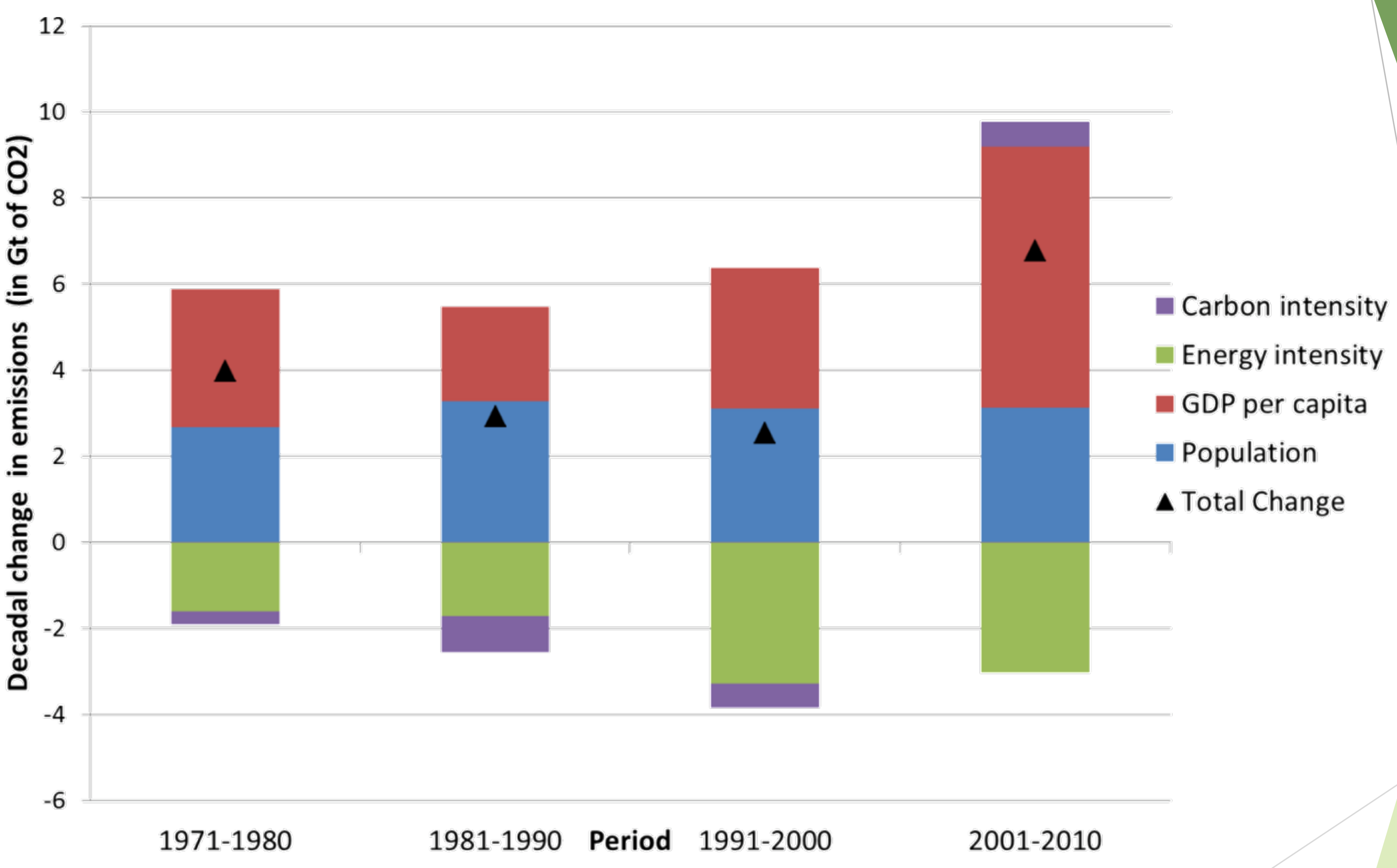
The Good News?

TOP Results – IPCC AR5

- 2°C (even 1.5°C) still possible
- Mitigation is affordable! (0.04-0.14% loss in annual GDP growth (BAU=1.6-3.0% growth))
- Delay makes mitigation more costly, less likely to succeed and leaves less options
- Large scale changes in global energy system needed; especially electricity
- Climate change is a global commons problem and requires international cooperation, include considerations of equitable effort-sharing, but also effective national and subnational policy implementation



GHG Emissions [$GtCO_2eq/yr$]
+2%/yr
1970-80
+1.4%/yr
1980-90
+0.6%/yr
1990-00
+2.2%/yr
2000-10
27.4 Gt
0.4%
7.9%
19.4%
17.2%
55.1%
37.9 Gt
0.8%
7.4%
17.6%
15.6%
58.6%
49.5 Gt
2%
6.2%
15.8%
10.8%
65.2%
Gas
$HFC+PFC+SF_6$
N_2O
CH_4
CO_2 FOLU
CO_2 Fossil Fuel and Industrial Processes
0
10
20
30
40
50
1970
1975
1980
1985
1990
1995
2000
2005
2010



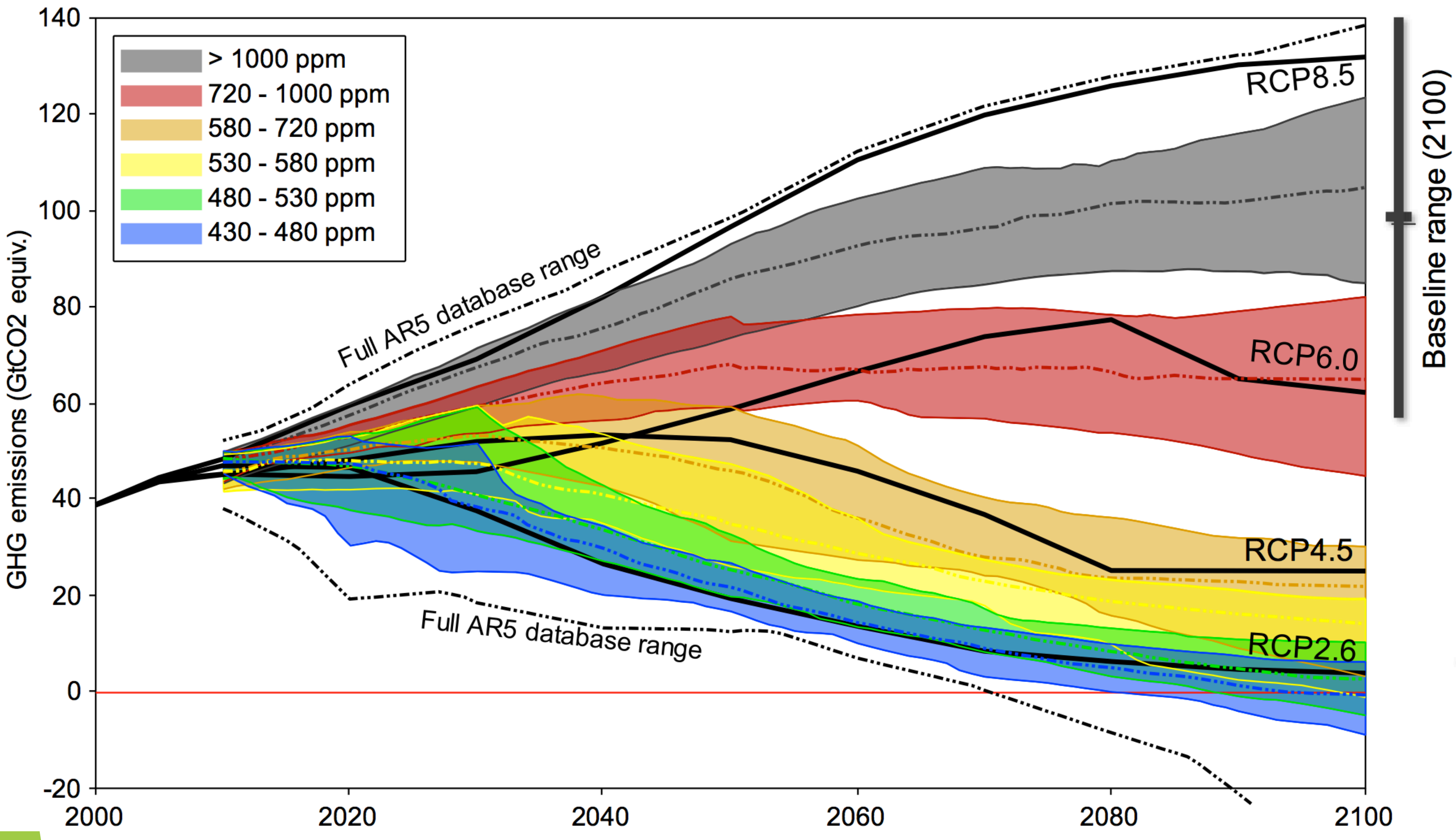
12
10
8
6
4
2
0
-2
-4
-6
Decadal change in emissions (in Gt of CO2)
1971-1980
1981-1990
Period
1991-2000
2001-2010
Carbon intensity
Energy intensity
GDP per capita
Population
Total Change

Past Emissions

- Last decade +2.2% p.a.; higher than any decade since 1970
- Population and economic growth main drivers; with population relatively constant and economy increasing markedly
  - can be counteracted by reducing carbon intensity (decarbonization of energy) and energy intensity (efficiency) of economy
  - Without dedicated mitigation will continue driving emissions up (BAU: 750-1300+ ppm CO2e in 2100)
- Whichever way you slice it (2010 vs 1990-2010 vs 1750-2010, incl vs excl LULUCF, consumption-based vs production based):
  ten countries responsible for roughly 70% of emissions
- Per-capita emissions differ widely: 1.4t median LIC vs 13t median HIC

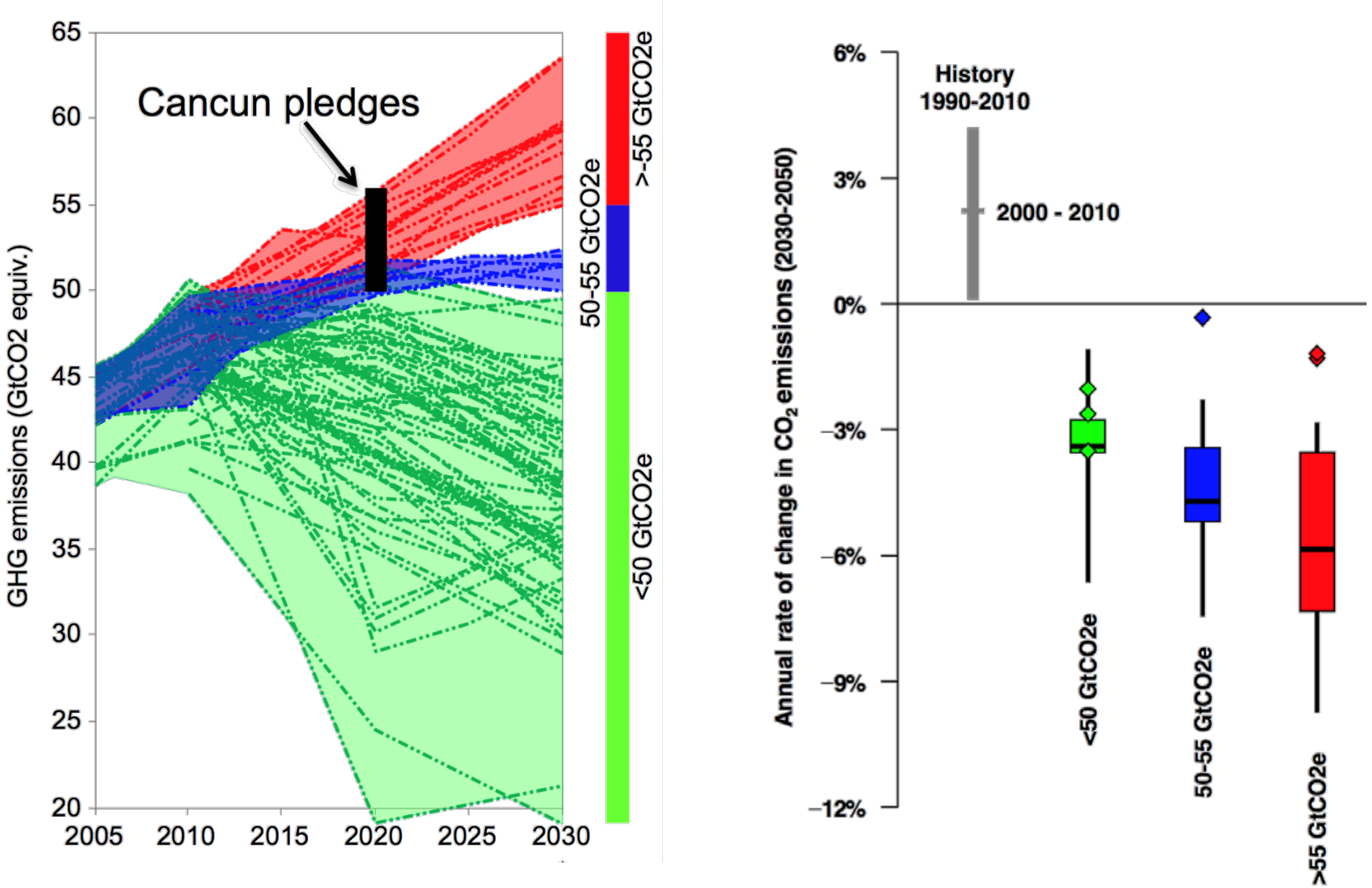
Table SPM.1: Key characteristics of the scenarios collected and assessed for WG3 AR5. For all parameters, the 10th to 90th percentile of the scenarios is shown[1]. [Table 6.3]

CO_2eq Conc in 2100 (ppm CO_2eq)	*Representative Concentration Pathways (RCPs)*		*CO_2 emission budget[2] ($GtCO_2$)*		*CO_2eq emissions in 2050 relative to 2010 (%)*	*Temperature change (relative to 1850-1870)[3,4]*			
			2011-2050	*2011-2100*		*2100 Temperature (degrees C)[5]*	*Probability of staying below 1.5 degrees C (%)*	*Probability of staying below 2 degrees C (%)*	*Probability of staying below 2.5 degrees C (%)*
<430		*Only limited number of studies from individual research groups*							
430 – 480	RCP 2.6	Total range	550-1270	630-1180	31-65	1.5-1.8 (1.2-2.3)	Less likely than not	Likely	Very likely
480 - 530		No exceedance of 530 ppm CO_2eq	900-1220	1020-1280	43-60	1.8-1.9 (1.4-2.4)	Unlikely	More likely than not	Likely
		Exceedance of 530 ppm CO_2eq	1190-1620	990-1550	51-119	1.9-2.2 (1.5-2.9)	Very unlikely	More unlikely than not	More likely than not
530 – 580		No exceedance of 580 ppm CO_2eq	1110-1600	1220-2130	52-98	2.1-2.3 (1.7-2.9)	Very unlikely	More unlikely than not	Likely
		Exceedance of 580 ppm CO_2eq	1510-1790	1160-1970	98-123	2.2-2.3 (1.7-2.9)	Extremely unlikely	Unlikely	More likely than not
580 – 650	RCP 4.5	Total range	1260-1640	1880-2430	68-139	2.3-2.7 (1.8-3.4)	Extremely unlikely	Unlikely	About as likely as not
650 – 720		Total range	1320-1720	2620-3320	103-131	2.6-2.9 (2.1-3.6)	Exceptionally unlikely	Very unlikely	Unlikely
720 – 1000	RCP 6.0	Total range	1600-1930	3620-4990	128-168	3.1-3.7 (2.5-4.7)	Exceptionally unlikely	Extremely unlikely	Unlikely to very unlikely
>1000	RCP 8.5	Total range	1840-2320	5350-6950	165-220	4.1-4.8 (3.3-6.3)	Exceptionally unlikely	Exceptionally unlikely	Exceptionally unlikely



> 1000 ppm
720 - 1000 ppm
580 - 720 ppm
530 - 580 ppm
480 - 530 ppm
430 - 480 ppm
GHG emissions (GtCO2 equiv.)
140
120
100
80
60
40
20
0
-20
2000
2020
2040
2060
2080
2100
Full AR5 database range
Full AR5 database range
RCP8.5
RCP6.0
RCP4.5
RCP2.6
Baseline range (2100)

Delay to mitigation



Delay in mitigation

- Delay reduces options, increases challenge, increases costs; delay scenarios
  - more often need CDR
  - require higher rates of low carbon energy deployment
  - need much higher rates of annual decline in 2030-2050
- Cancun/Copenhagen pledges
  - higher emissions levels than lowest-cost 2°Cmax scenarios
  - consistent with 550-650ppm (=2.2-2.7°C) scenarios

Cross cutting policy issues

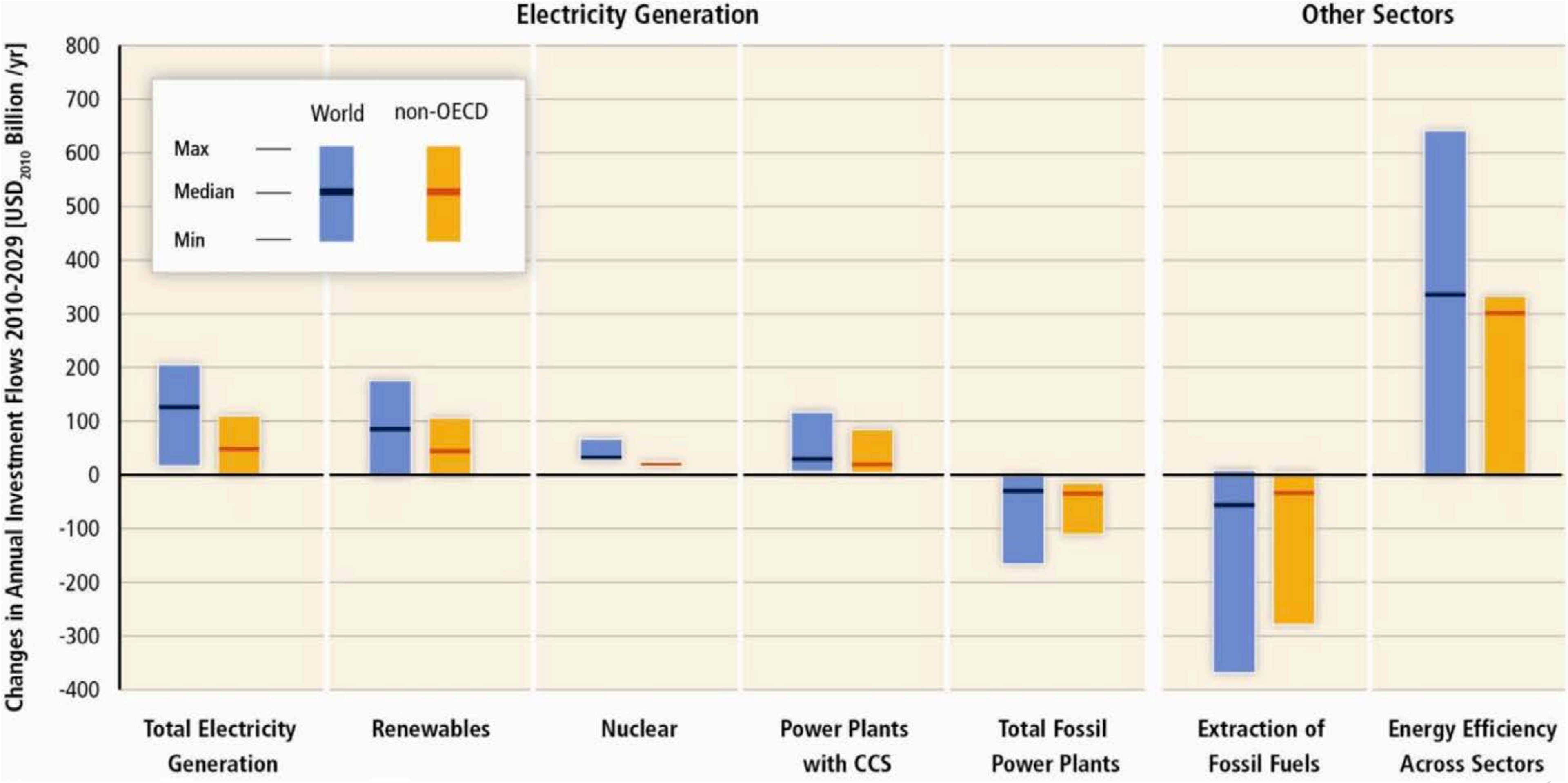
- w/o mitigation all sectors up, except LULUCF
- Highlights lock-in effect of infrastructure
  - Compounded by lifetime of infrastructure, investment cost, Δ emissions to alternative
  - positive and negative lock-in possible
- Systemic and cross-sectoral more effective than sector-by-sector policies
- Energy Efficiency makes supply side transformation easier!
  - reduces required pace of low carbon supply deployment, avoids lock-in, maximizes co-benefits, increases cost effectiveness of transformation
- Co-Benefits! (can increase political support, reduce cost…)

Costs

- High uncertainty re costs
  - Estimate of 0.04-0.14% (median 0.06%) in reduction of GDP growth (BAU GDP growth=1.6-3.0% p.a.) for 450ppm scenarios (= “likely” 2°Cmax)
  - With compounding equals 1-4% (1.7%) by 2030, 2-6% (3.4%) by 2050 and 3-11% (4.8%) by 2100 (BAU=300-900%)
- Redirection of investment vs “cost”
- Substantial co-benefits
  - E.g. reduction of cost of energy security and air quality objectives
    - National energy security/self-sufficiency, less exposure to price volatility and supply disruptions
    - Public health benefits re air quality
  - Reduction of climate impact costs
- Low (or negative) social cost of revenue-generating mitigation policies

Divestment/Investment

- Transformation to low-carbon economy requires new investment pattern; for low carbon scenarios
  - $30bn/yr divestment from fossil extraction and combustion (2010-2029)
  - $147bn/yr *additional* investment in low carbon electricity
  - several $100bn/yr in efficiency in transport, buildings, industry
  - (comparison: annual investment in energy=$1.2tn)



Electricity Generation
Other Sectors
Changes in Annual Investment Flows 2010-2029 [USD2010 Billion /yr]
800
700
600
500
400
300
200
100
0
-100
-200
-300
-400
World
non-OECD
Max
Median
Min
Total Electricity Generation
Renewables
Nuclear
Power Plants with CCS
Total Fossil Power Plants
Extraction of Fossil Fuels
Energy Efficiency Across Sectors

Energy Supply

- Energy supply sector largest and increasing (via coal and demand) GHG contributor
- Decarbonization of electricity generation is faster than other sectors (building, transport, industry)
  - Rapid reduction of coal (with limited near time natural gas replacement)
- RE much advanced since AR4, but still in need of support in many places (support includes carbon pricing)
- Natural gas only near-term replacement of coal if fugitive emissions from extraction and supply in check and used in combined cycle or combined heat and power plants
  - NG below current levels in 2050 and lower still after
- CCS not yet demonstrated; BECCS combines risks and uncertainties of CCS with risks and adverse effects of biofuels

Transport

- projected rapid growth (pass+freight) to outweigh mitigation measures w/o decarbonization and efficiency + comprehensive mitigation policy framework
  - Technical, behavioral, modal-shift, urban planning can reduce final energy demand in 2050 by 40% below BAU
- Infrastructure lock-in limits options in OECD countries; avoid lock-in in urban growth areas
- Co-benefits: access, mobility, safety, cost and time savings, reduced travel demand

Buildings/Cities (1)

- Buildings=34% final energy use; 18% GHGs
- Significant lock-in risk (or opportunity) due to lifetime of buildings and related infrastructure, incld urban planning
- Very low energy buildings possible; smart urban planning
- Building retrofit=key mitigation strategy!
  - and stringent building codes for new buildings

Buildings/Cities (2)

- Urbanization=megatrend; urban population to double by 2050
- 2/3 of future cities not built yet → next two decades = window of opportunity for positive lock-in
- Cities are taking action (mainly EE)
  - Lack of focus on urban sprawl, transit etc

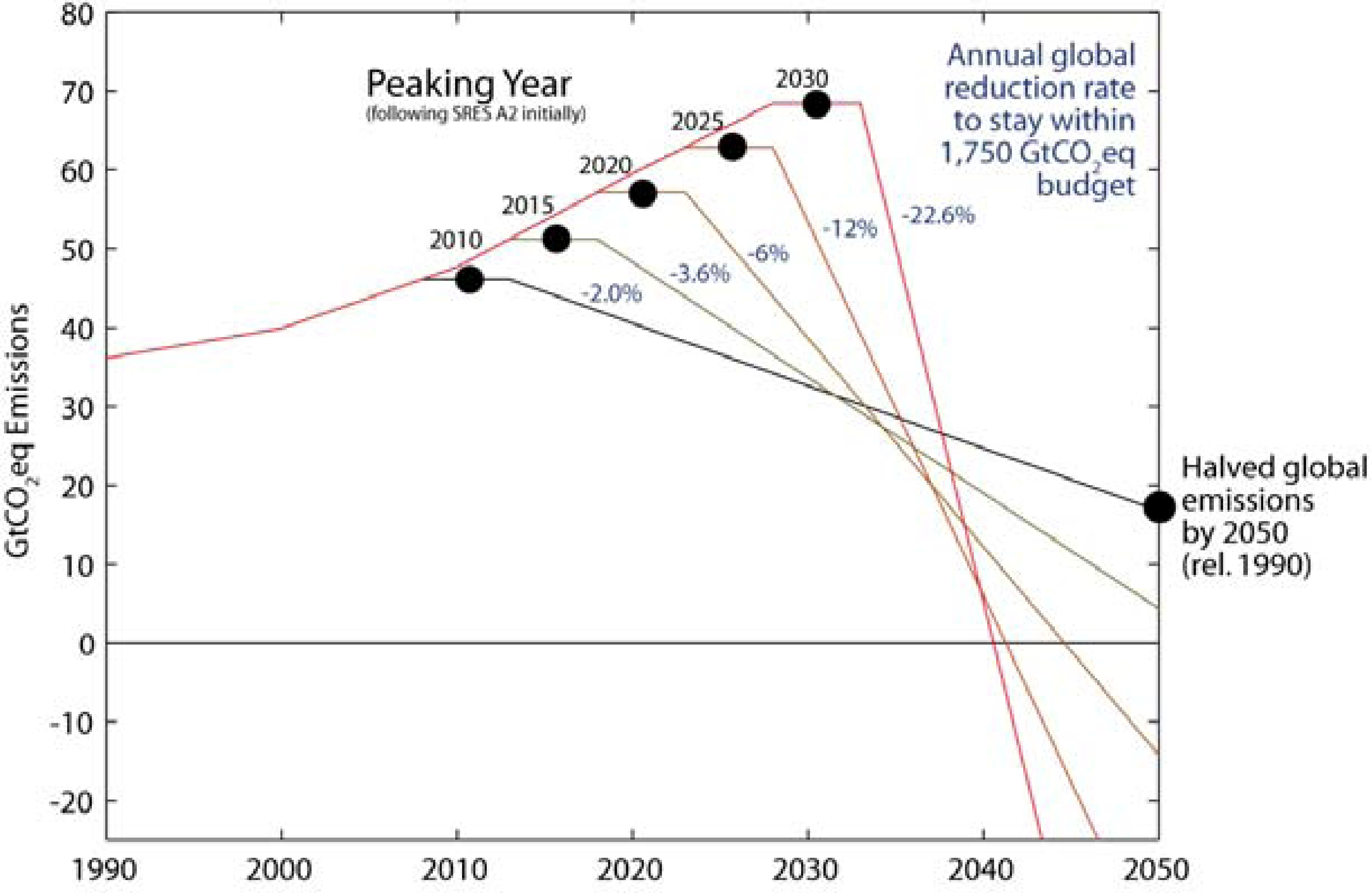
AFOLU

- AFOLU sector down; BAU= -50%(2010) by 2050; net negative later in C21
- Best mitigation strategy in AFOLU=reduce deforestation

Mitigation Policy (2)

- Cap and trade systems
  - Too early to call success or failure; new designs promise increased acceptability of more stringent caps
- Carbon taxes
  - shown to decouple GDP and GHG
  - in Europe, fuel taxes resulted in -50% reductions in transport sector
  - have been used to reduce other taxes; lowering overall social costs
- Reduction of Fossil Fuel subsidies can achieve significant emission reduction at negative cost

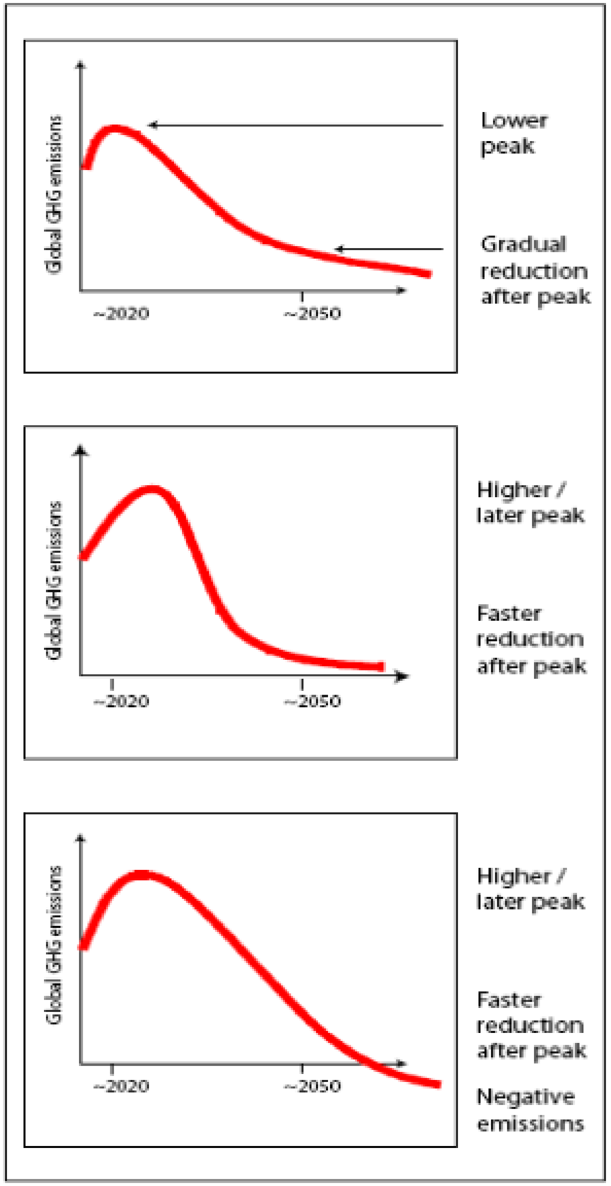
Delay in peaking of emissions



Cumulative emissions matter

1. Meeting a temperature target depends largely on *cumulative* emissions

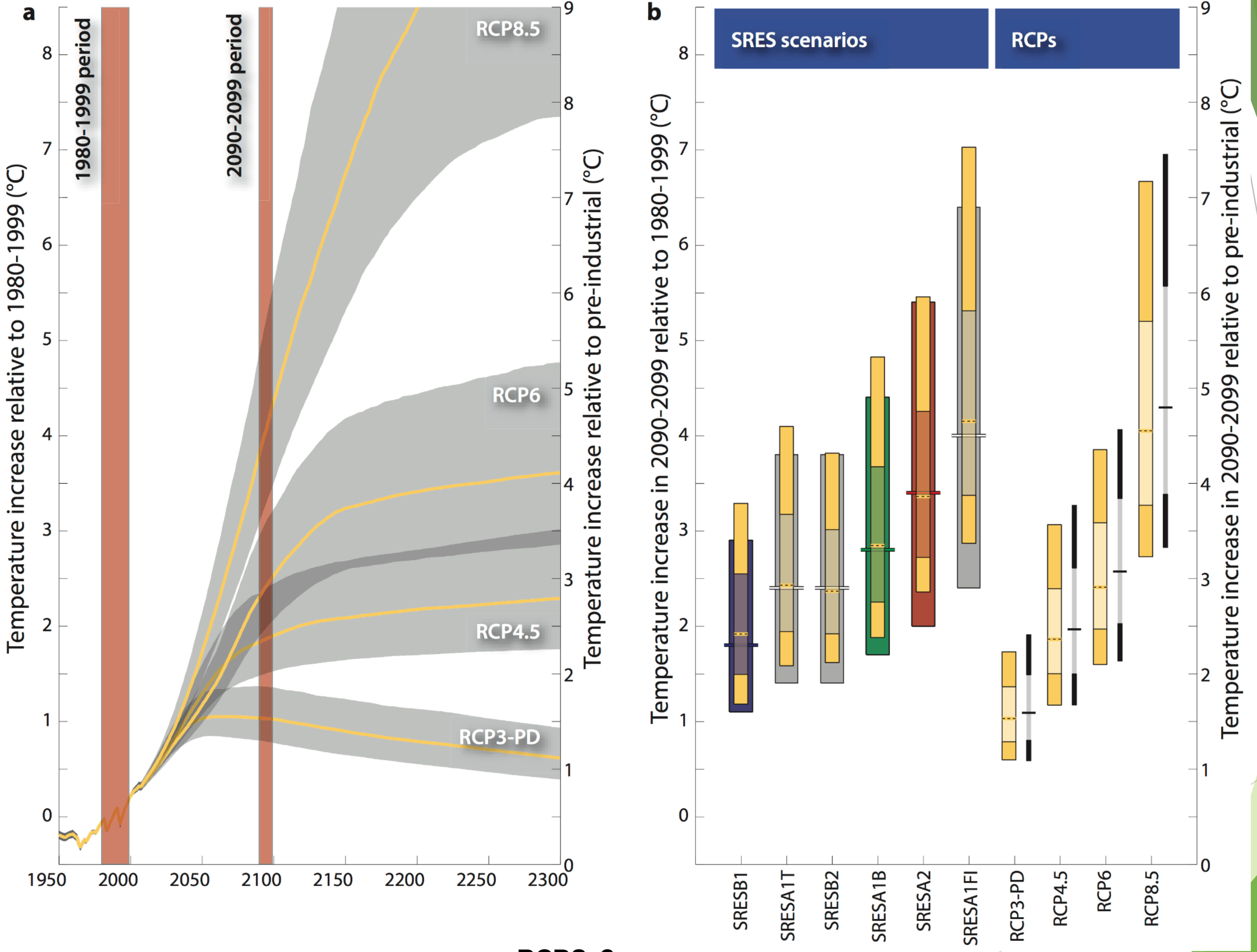
2. Different pathways of annual emissions can lead to same cumulative emissions



Conclusion

- We have a serious problem which require action
- Action is not easy, but possible
  - --- but profound conversation of the way we live is needed
  - Full decarbonisation by 2070
- Due to the magnitude of change needed, it is paramount importance to have planning, in order to minimise costs and reduce lock-in

Thank you for your attention!



RCP2.6

Source: IPCC AR5 Wg1 Fig 12.40, p. 1116