OVERSHOOT PATHWAYS TO CO2 CONCENTRATION STABILIZATION

[Formerly 'THE EFFECT OF CARBON-CYCLE CLIMATE FEEDBACKS ON THE EMISSIONS REQUIREMENTS FOR CO_2 STABILIZATION']

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SUMMARY

- Description of revised carbon cycle model
- Production of new stabilization profiles accounting for climate feedbacks
- Emissions requirements to follow new profiles
- Quantification of the effect of climate feedbacks on these requirements
- Alternative pathways to concentration stabilization

BACKGROUND:

(1) The first CO_2 stabilization profiles that attempted to account realistically for economic constraints were the WRE profiles (Wigley, Richels and Edmonds, *Nature* **379**, 240–243, 1996).

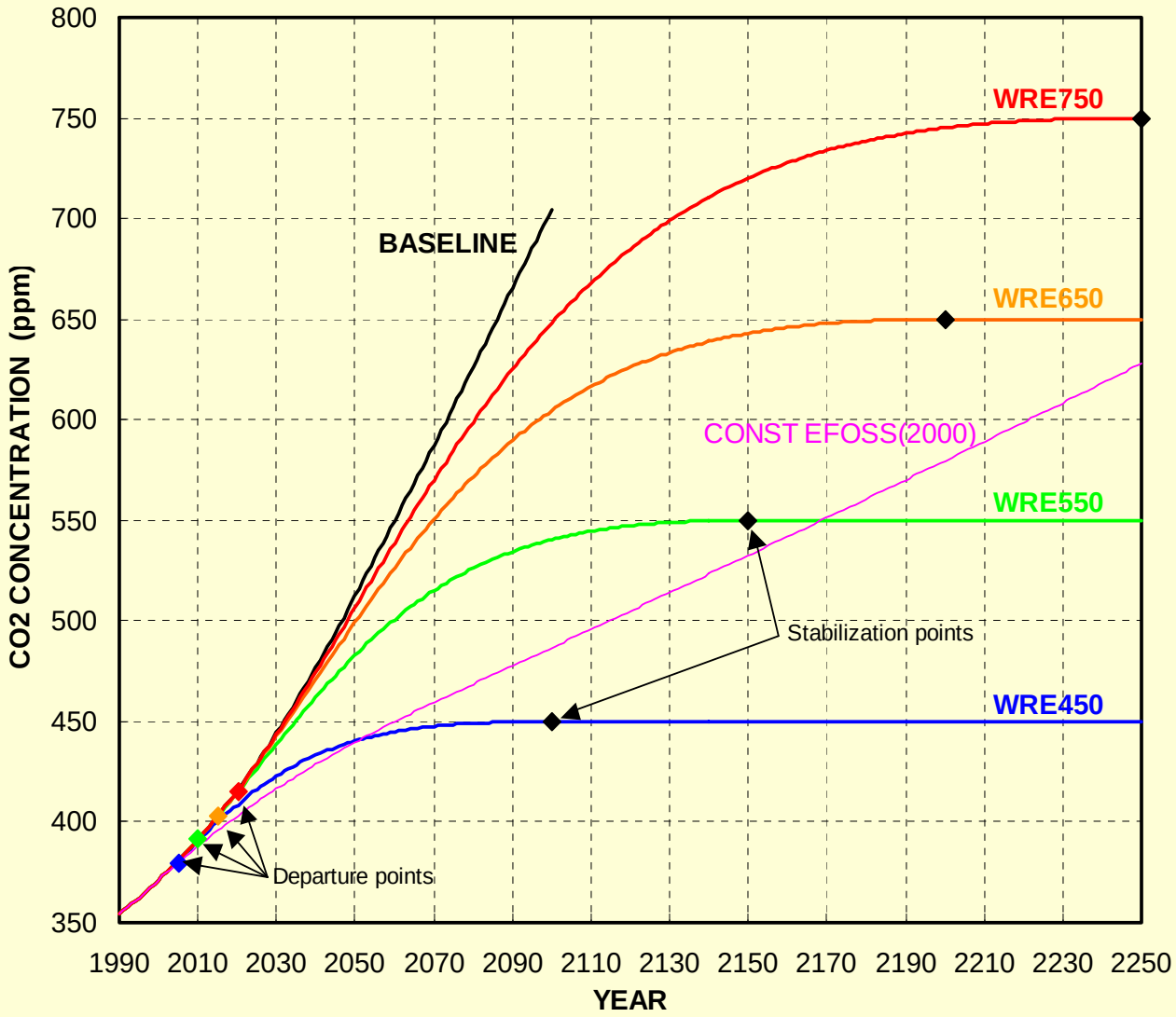
(2) These profiles assumed that concentrations could, initially, only depart slowly from a baseline, no-climate-policy scenario.

(3) They also assumed that the date for the beginning of a significant departure was later for higher stabilization targets.

(4) Emissions requirements were determined using an inverse carbon cycle model.

(5) The original carbon cycle was calibrated to reflect the state of the science in 1995/6, and did not account for climate-related feedbacks on the carbon cycle.

ORIGINAL (WRE) STABILIZATION PROFILES



REVISED CARBON-CYCLE MODEL

QUESTION: How does the revised MAGICC carbon cycle model compare with the other two models used in the IPCC TAR?

Table 1: Comparison of climate feedbacks: 2100 concentrations (ppm) for the IS92a emissions scenario.

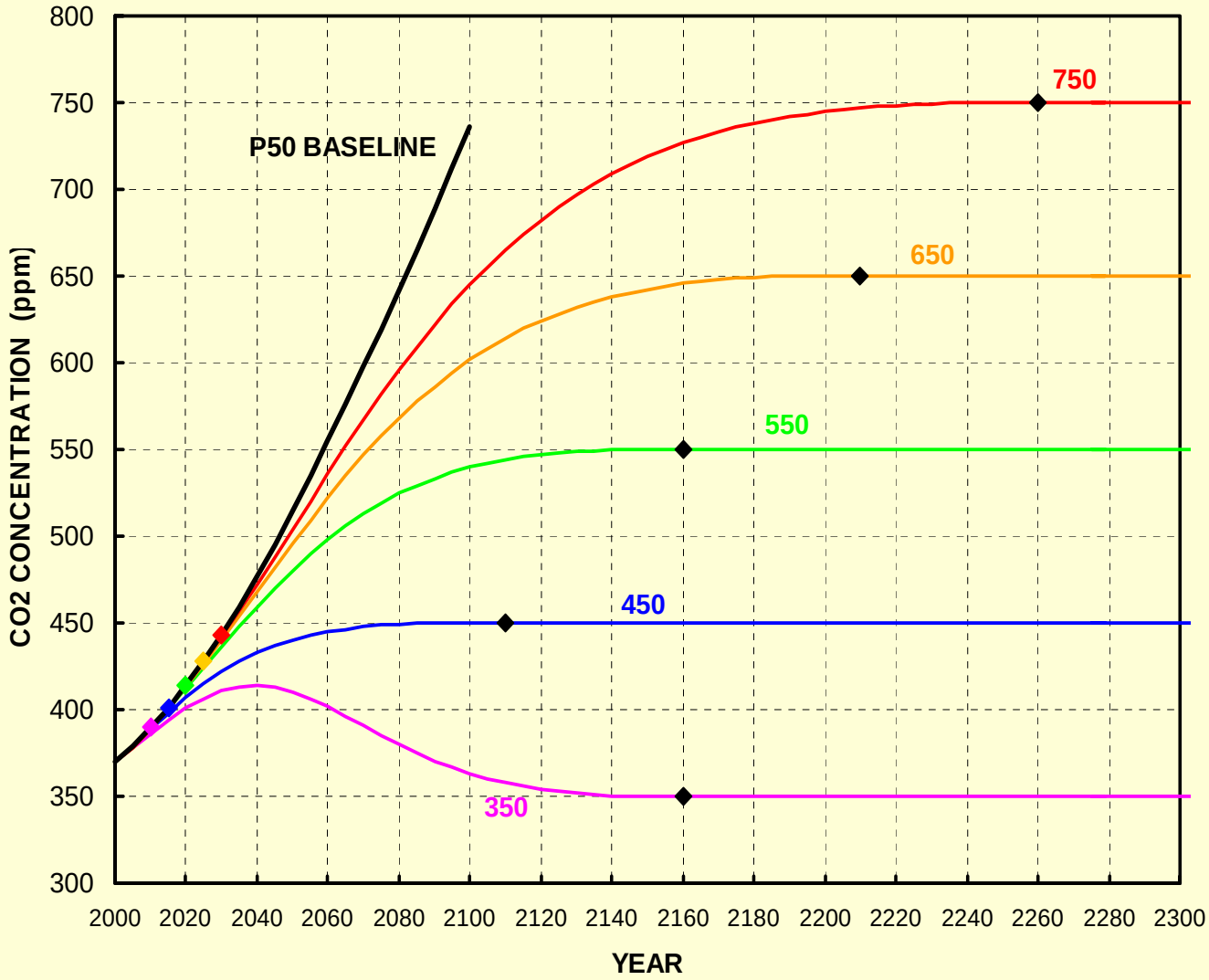
MODEL	No climate feedbacks	With climate feedbacks	Increase due to climate feedbacks
Bern	651	706	55
ISAM	682	723	41
MAGICC	675	715	40

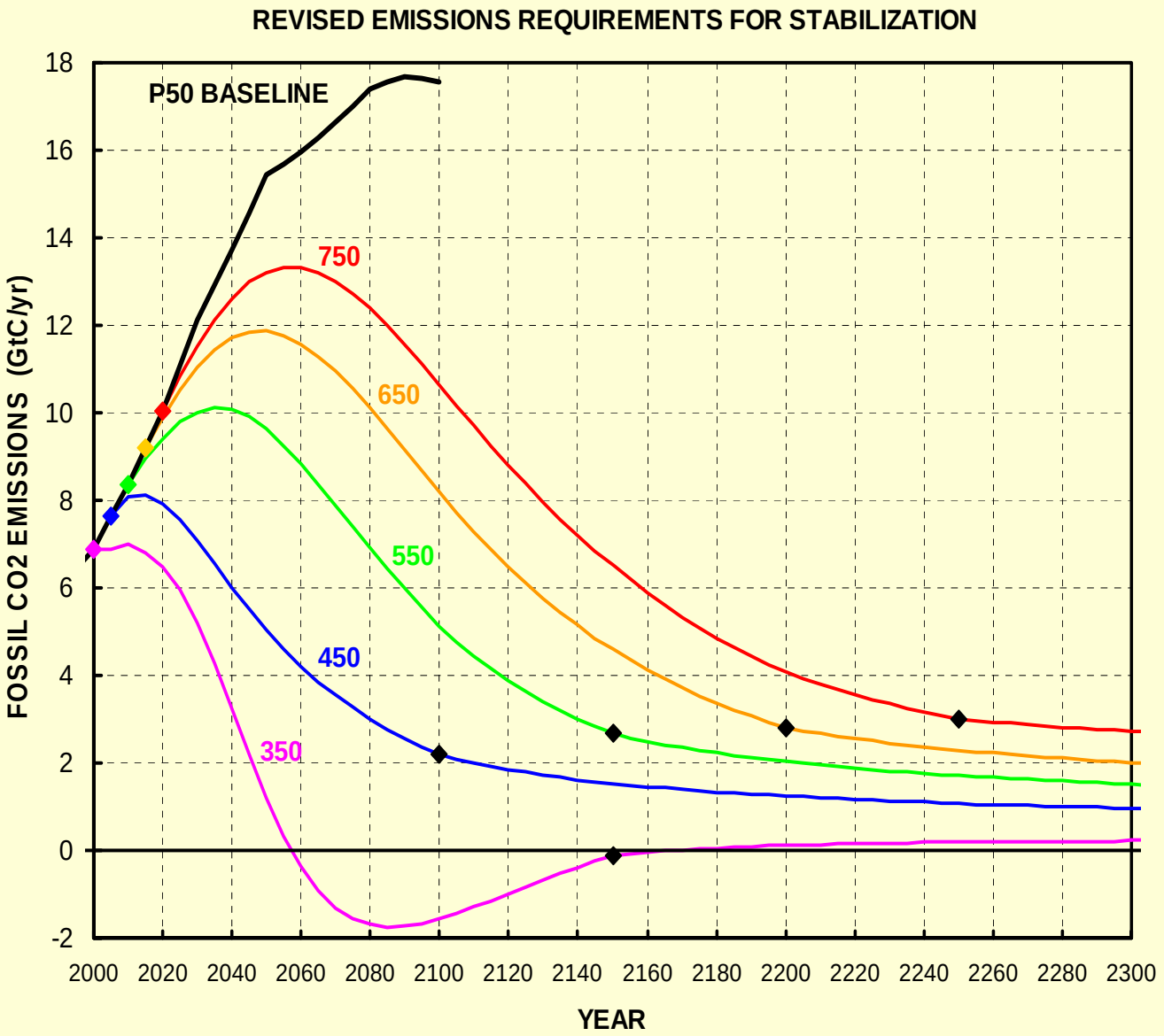
CONSTRUCTING NEW STABILIZATION PROFILES

Changes are required because …..

- there are new baseline no-policy scenarios,
- there are improved carbon cycle models, and
- these models now account for climate feedbacks on the carbon cycle.

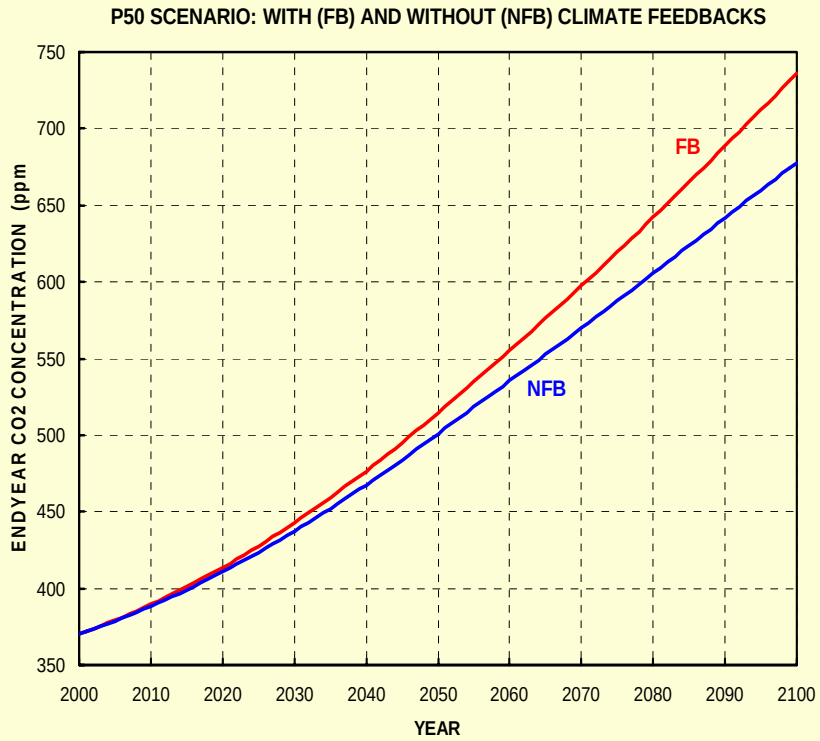
SUMMARY OF NEW CONCENTRATION PROFILES




REVISED EMISSIONS REQUIREMENTS FOR STABILIZATION
P50 BASELINE
750
650
550
450
350
FOSSIL CO2 EMISSIONS (GtC/yr)
18
16
14
12
10
8
6
4
2
0
-2
2000
2020
2040
2060
2080
2100
2120
2140
2160
2180
2200
2220
2240
2260
2280
2300
YEAR

QUANTIFYING THE CLIMATE FEEDBACK INFLUENCE

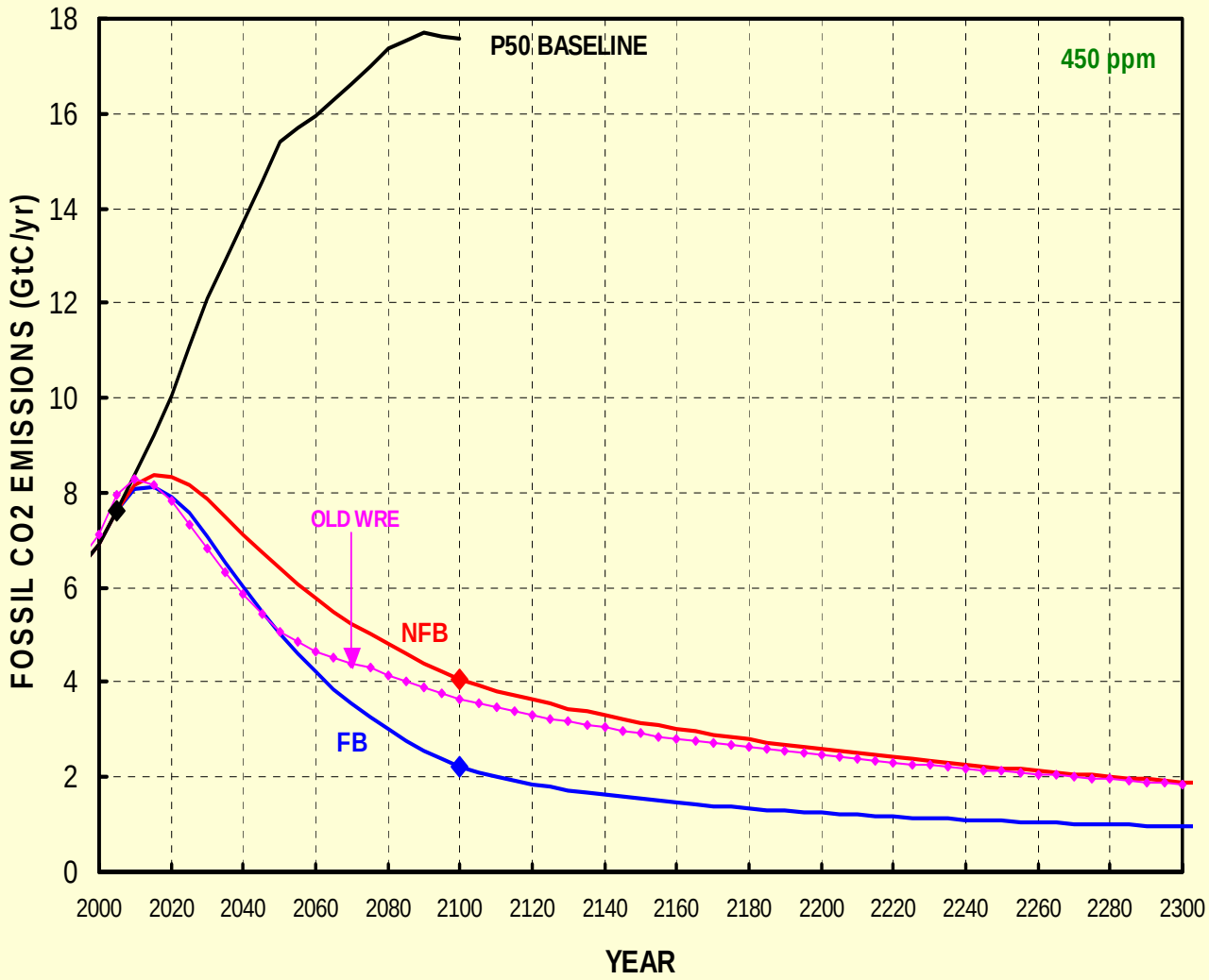
Climate feedbacks lead to higher concentrations for any given emissions scenario ⟶



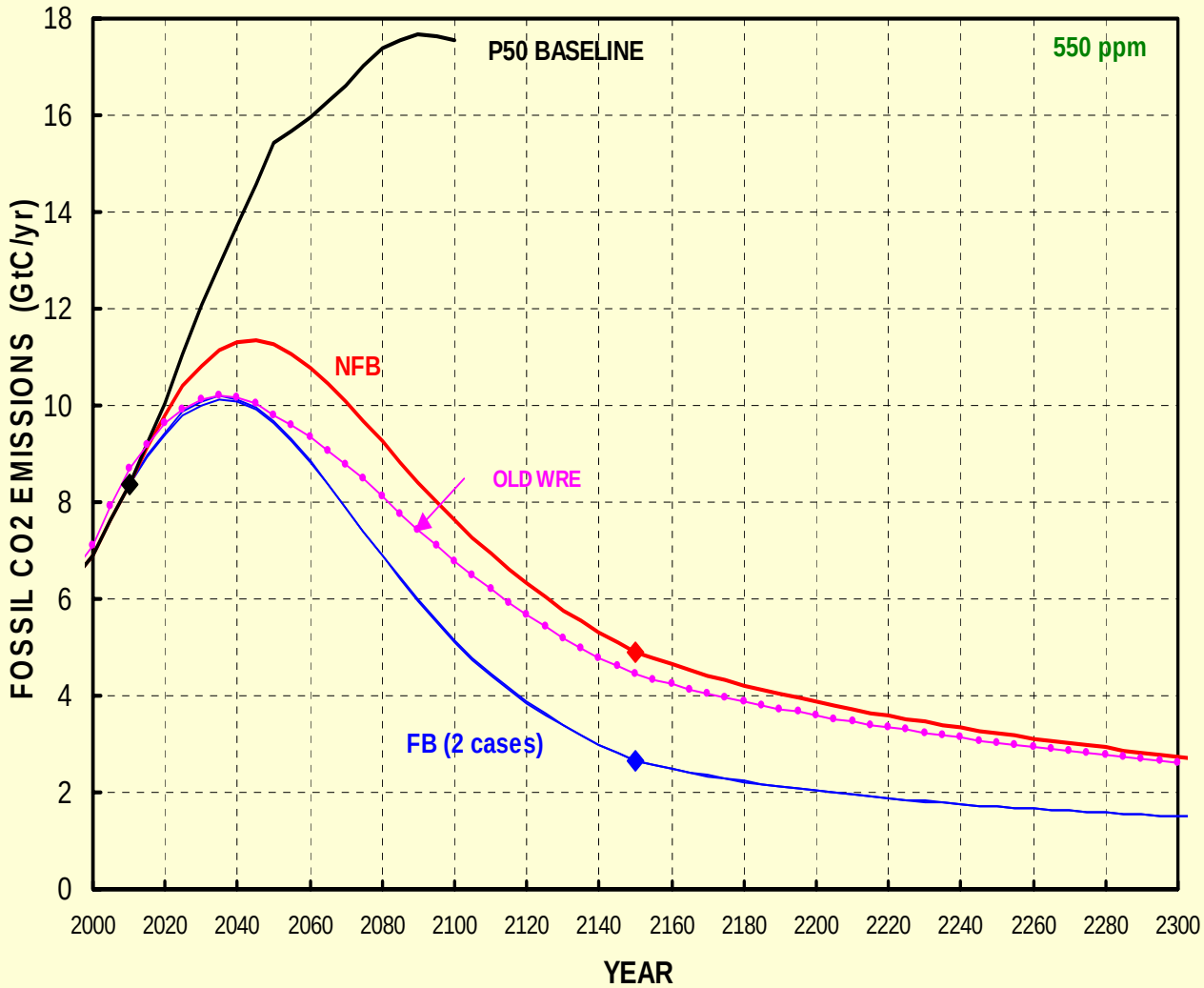
….. hence …..

For a given concentration profile, climate feedbacks lead to lower emissions requirements

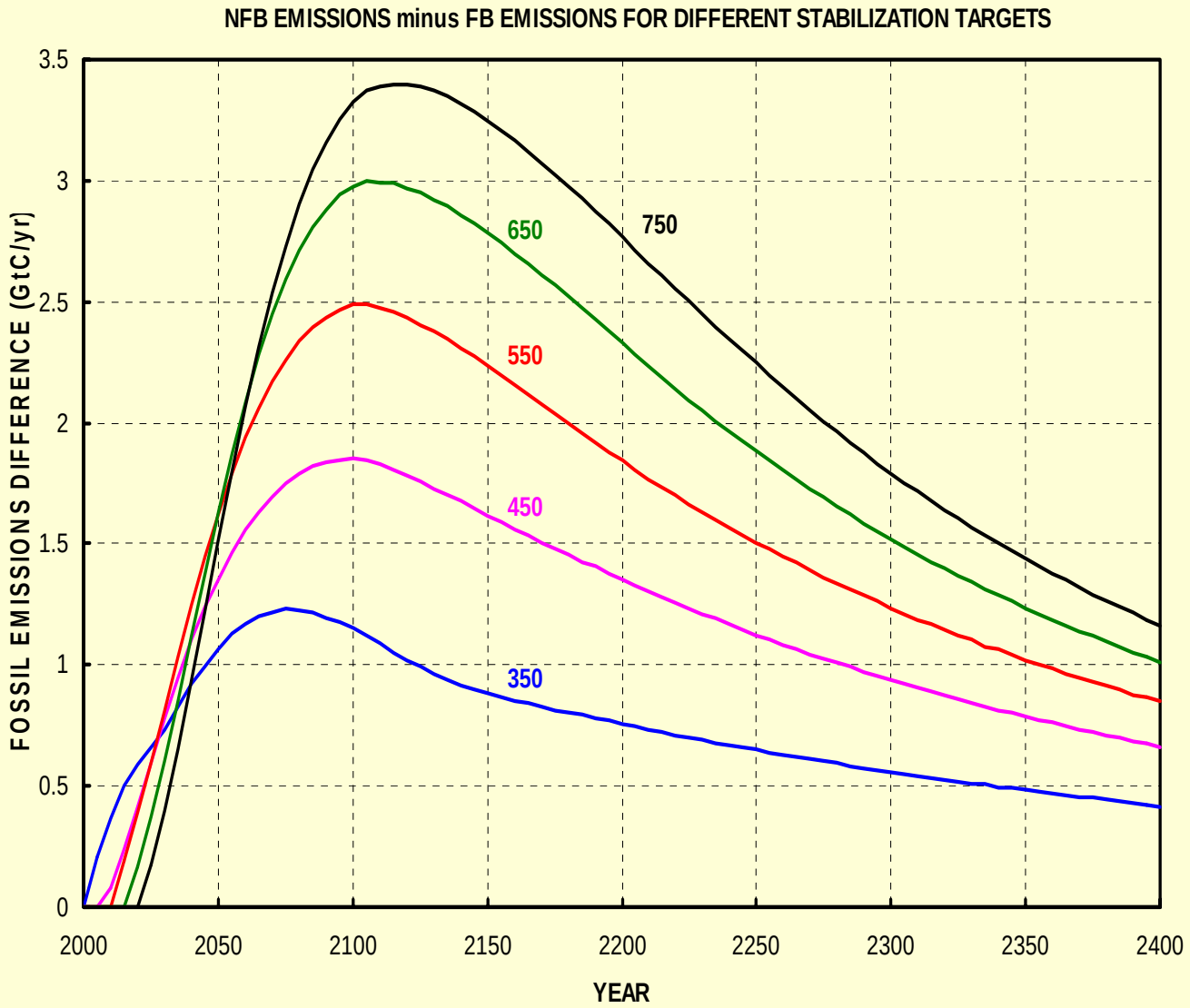
EFFECT OF CLIMATE FEEDBACKS ON EMISSIONS (WRE450)



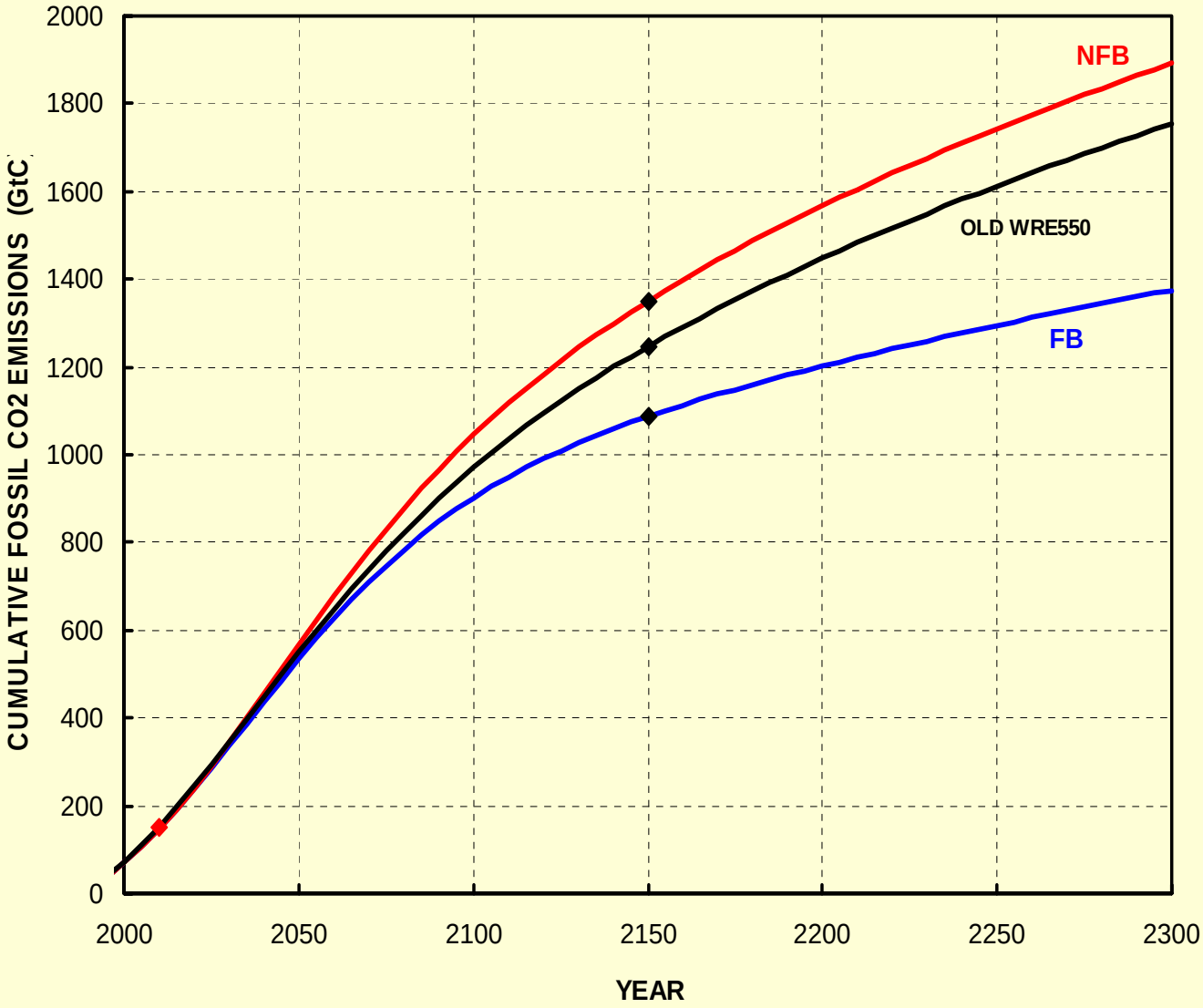
EFFECT OF CLIMATE FEEDBACKS ON EMISSIONS (WRE550)

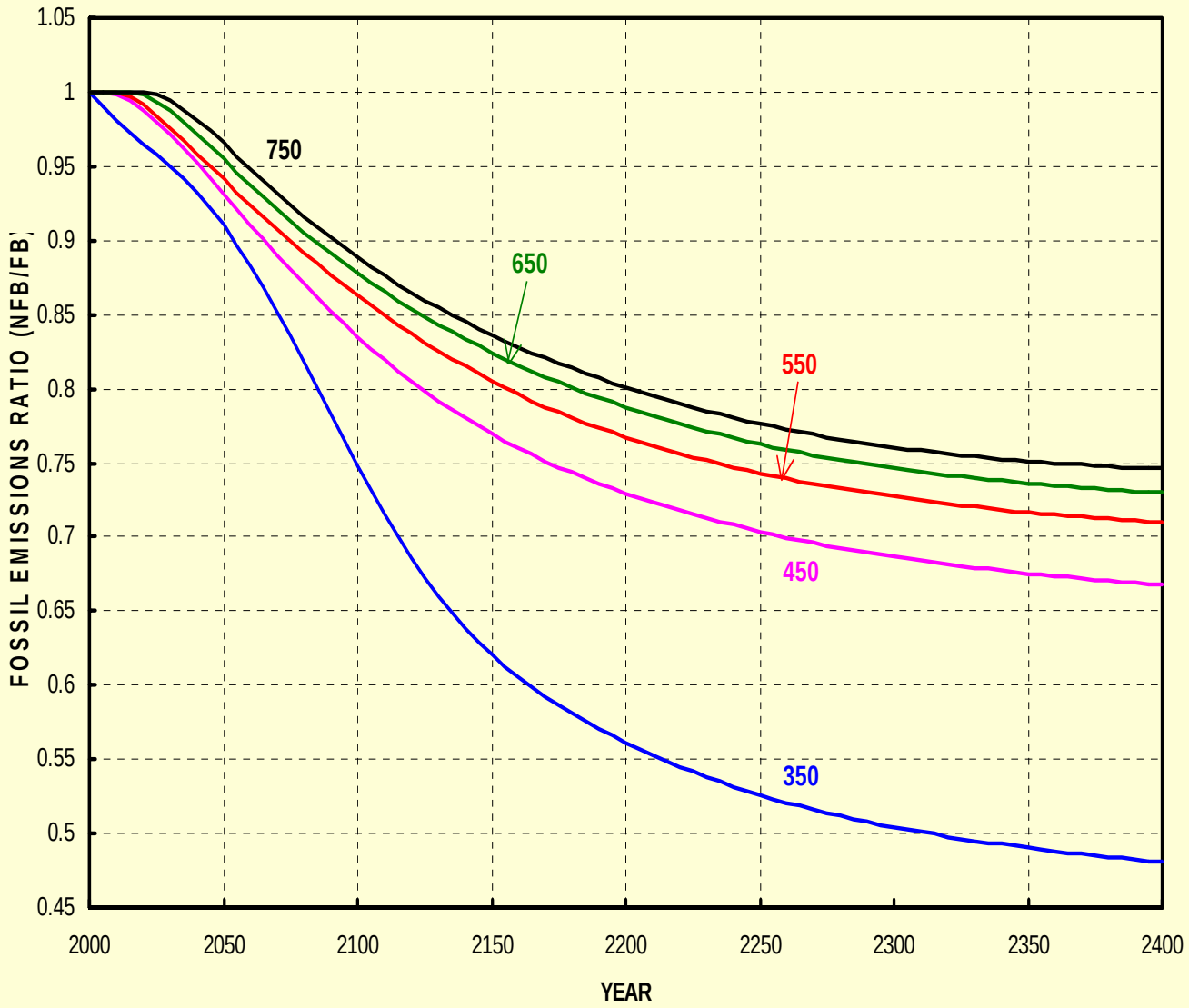


SUMMARY OF FEEDBACK EFFECT



EFFECT OF CLIMATE FEEDBACKS ON CUMULATIVE CO2 EMISSIONS

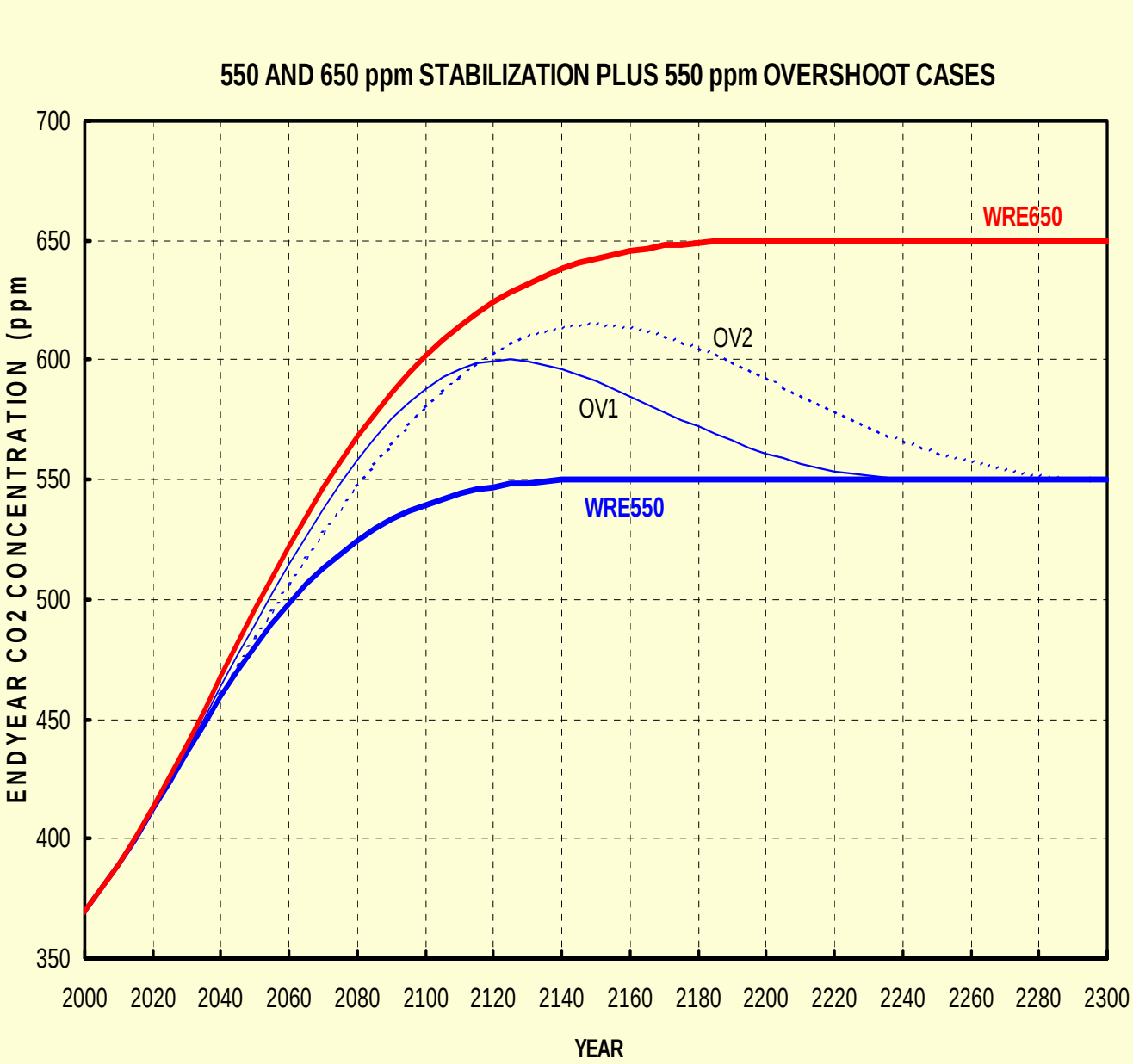

EFFECT OF CLIMATE FEEDBACKS ON CUMULATIVE EMISSIONS (550ppm)
CUMULATIVE FOSSIL CO2 EMISSIONS (GtC)
YEAR
NFB
OLD WRE550
FB
2000
1800
1600
1400
1200
1000
800
600
400
200
0
2000
2050
2100
2150
2200
2250
2300

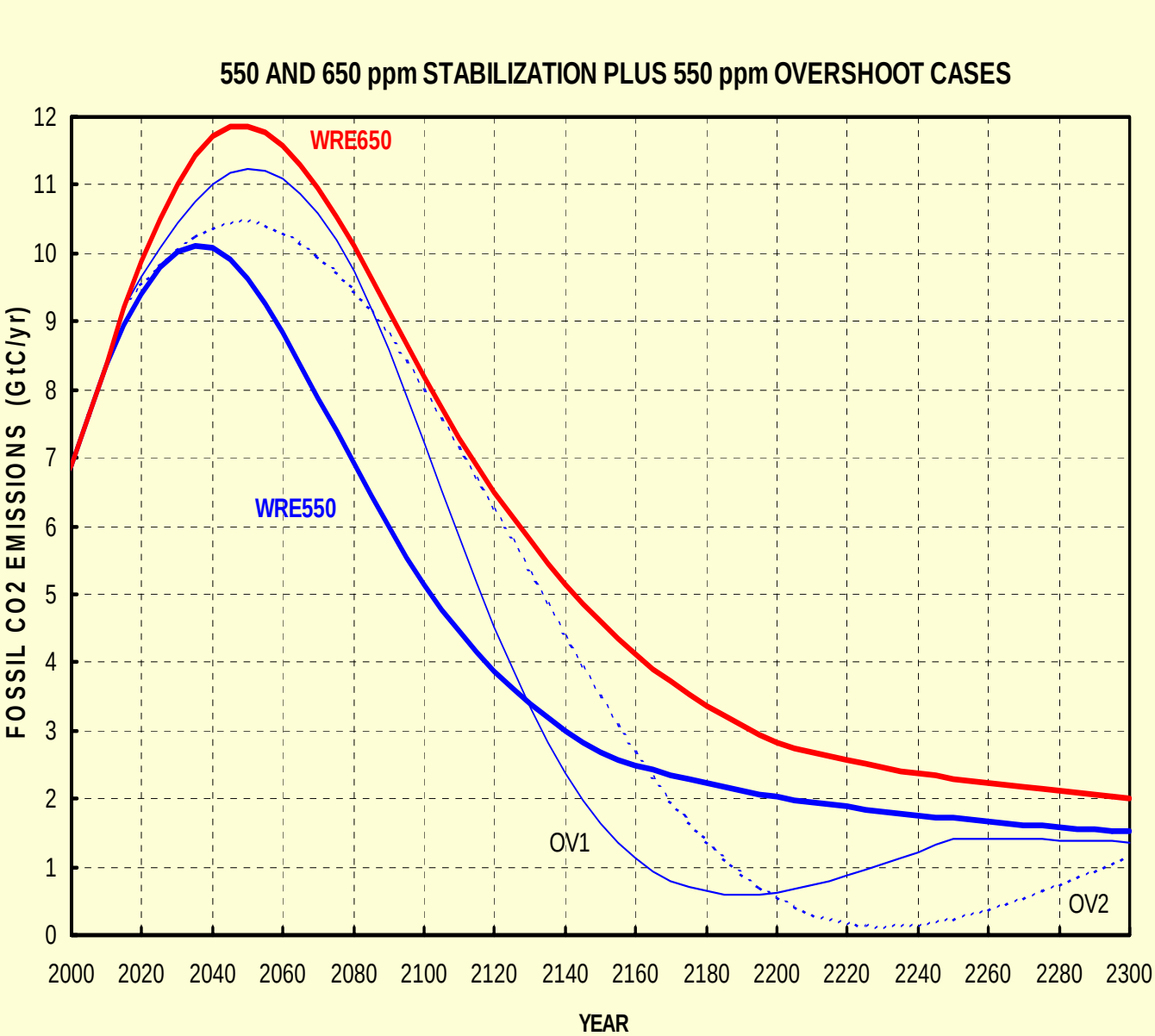

RATIO NFB/FB CUMULATIVE EMISSIONS : DIFFERENT STABILIZATION TARGETS
FOSSIL EMISSIONS RATIO (NFB/FB)
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
2000
2050
2100
2150
2200
2250
2300
2350
2400
YEAR
750
650
550
450
350

ALTERNATIVE PATHWAYS TO STABILIZATION : OVERSHOOT POSSIBILITIES

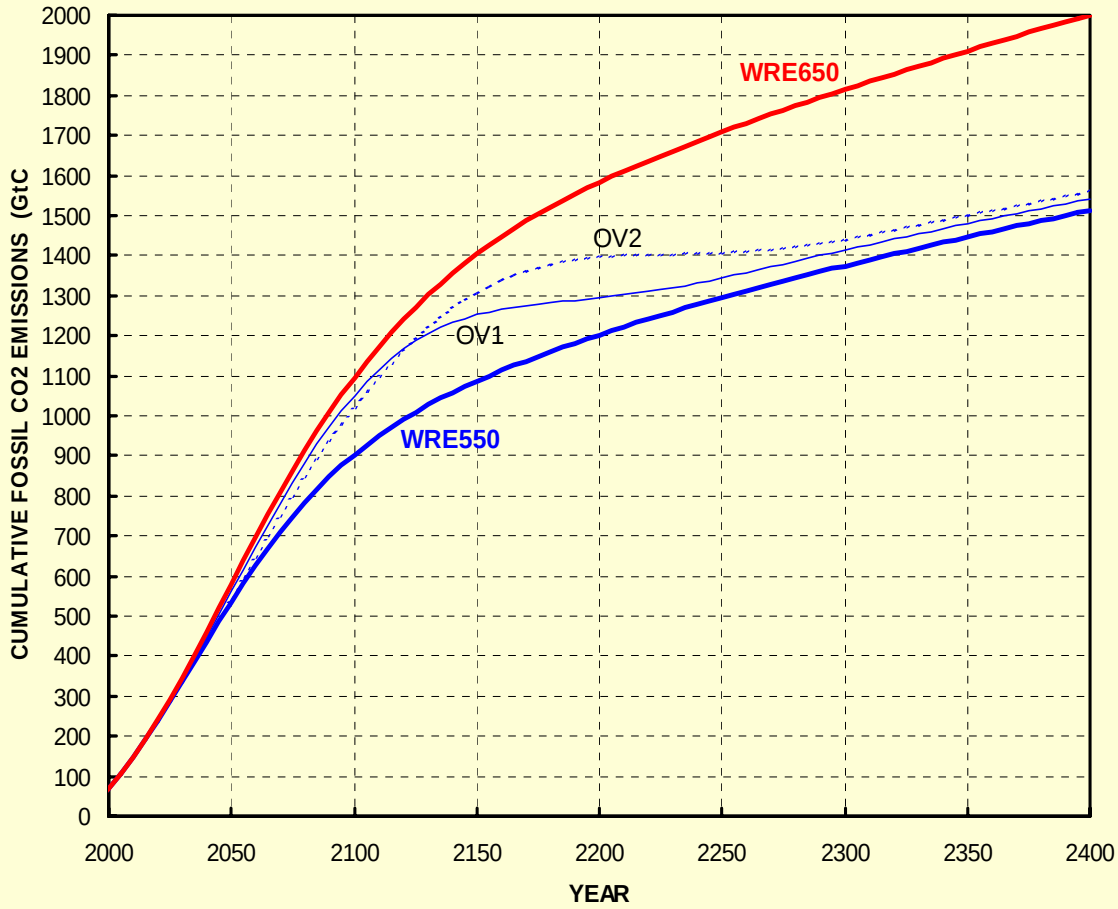
- Except for the 350 ppm stabilization case, all WRE profiles assume monotonic increases in concentration.

- What if we allow the profile to go above the stabilization level and then decline?


550 AND 650 ppm STABILIZATION PLUS 550 ppm OVERSHOOT CASES
ENDYEAR CO2 CONCENTRATION (ppm
700
650
600
550
500
450
400
350
2000
2020
2040
2060
2080
2100
2120
2140
2160
2180
2200
2220
2240
2260
2280
2300
YEAR
WRE650
OV2
OV1
WRE550

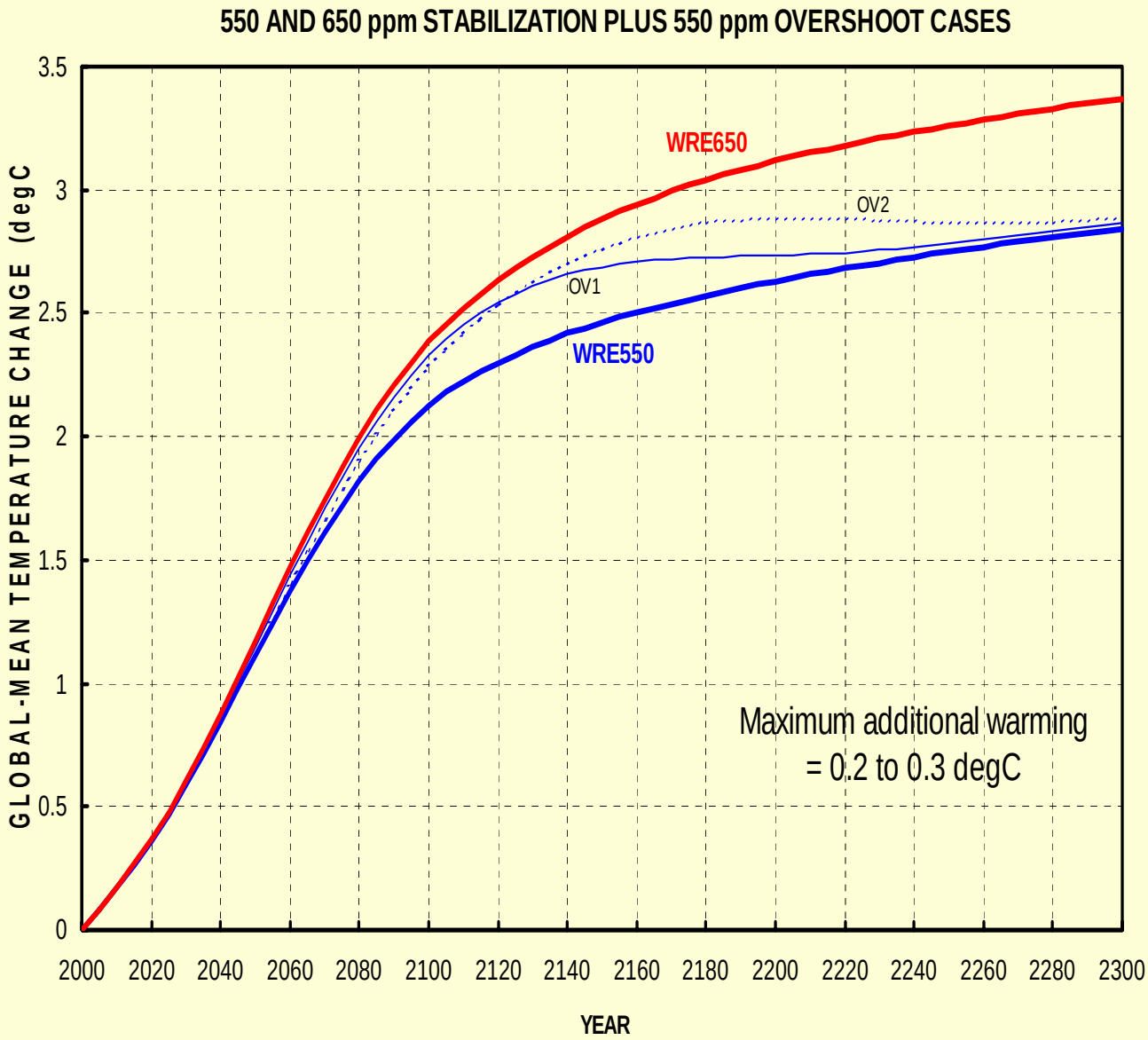

550 AND 650 ppm STABILIZATION PLUS 550 ppm OVERSHOOT CASES
FOSSIL CO2 EMISSIONS (GtC/yr)
YEAR
WRE650
WRE550
OV1
OV2
0
1
2
3
4
5
6
7
8
9
10
11
12
2000
2020
2040
2060
2080
2100
2120
2140
2160
2180
2200
2220
2240
2260
2280
2300

CUMULATIVE EMISSIONS

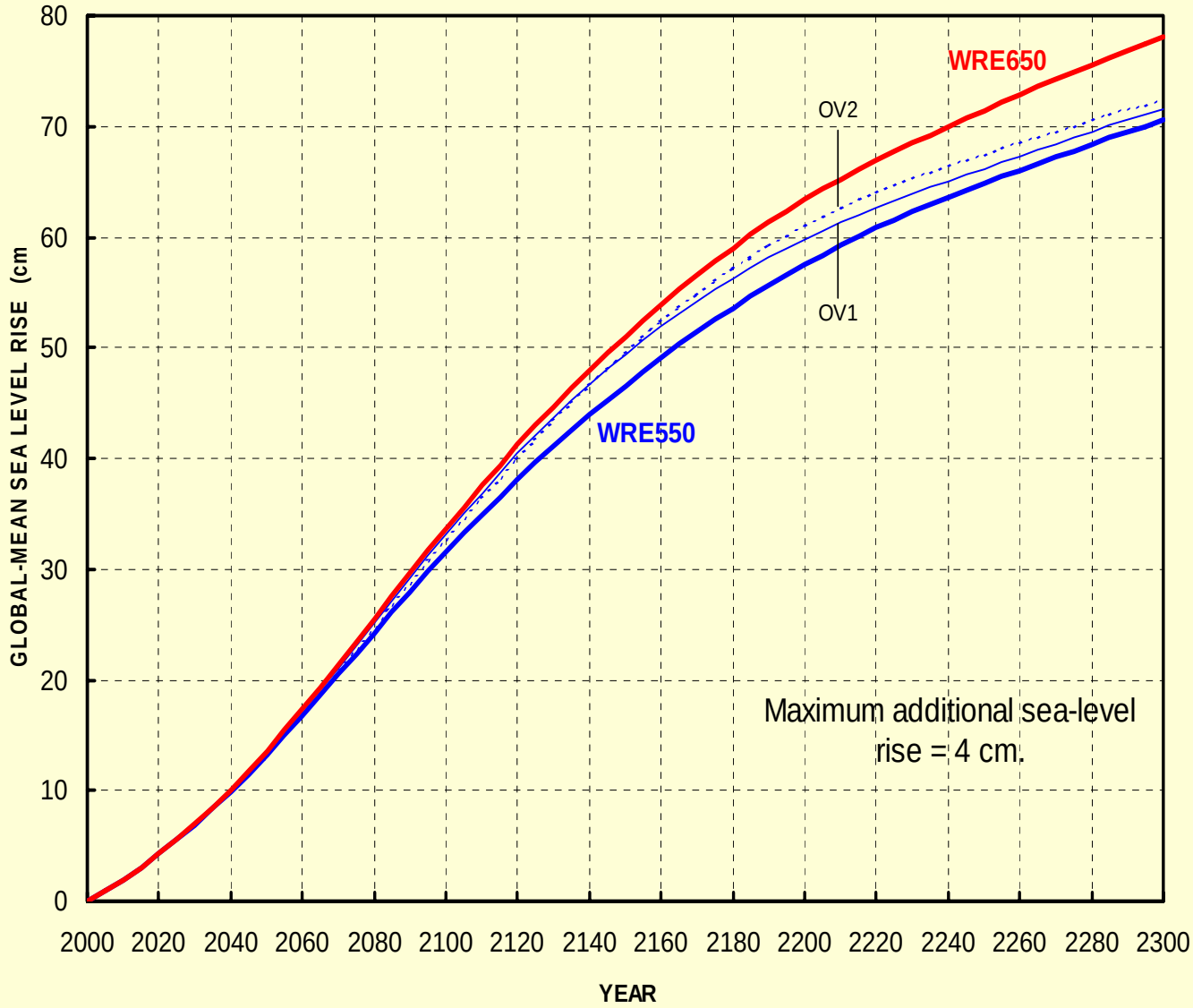


Overshoot cases allow more emissions for 100+ years, but have very similar asymptotic cumulative emissions. In general, total allowed emissions depends on the stabilization level, but not on the path to stabilization.

TEMPERATURE AND SEA LEVEL CONSEQUENCES OF OVERSHOOT PROFILES


550 AND 650 ppm STABILIZATION PLUS 550 ppm OVERSHOOT CASES
GLOBAL-MEAN TEMPERATURE CHANGE (degC
3.5
3
2.5
2
1.5
1
0.5
0
2000
2020
2040
2060
2080
2100
2120
2140
2160
2180
2200
2220
2240
2260
2280
2300
YEAR
WRE650
OV2
OV1
WRE550
Maximum additional warming
= 0.2 to 0.3 degC

550 AND 650 ppm STABILIZATION PLUS 550 ppm OVERSHOOT CASES

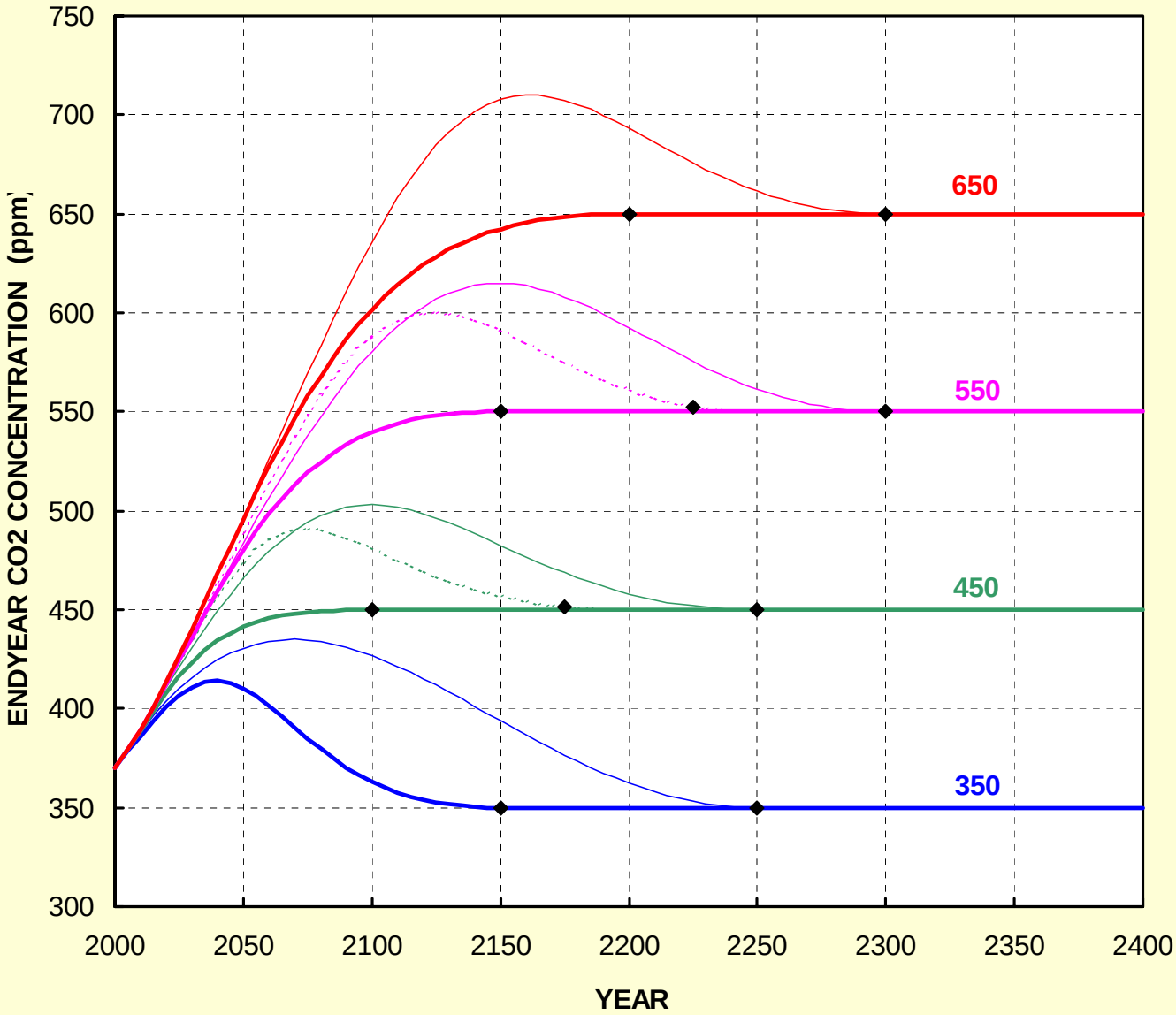


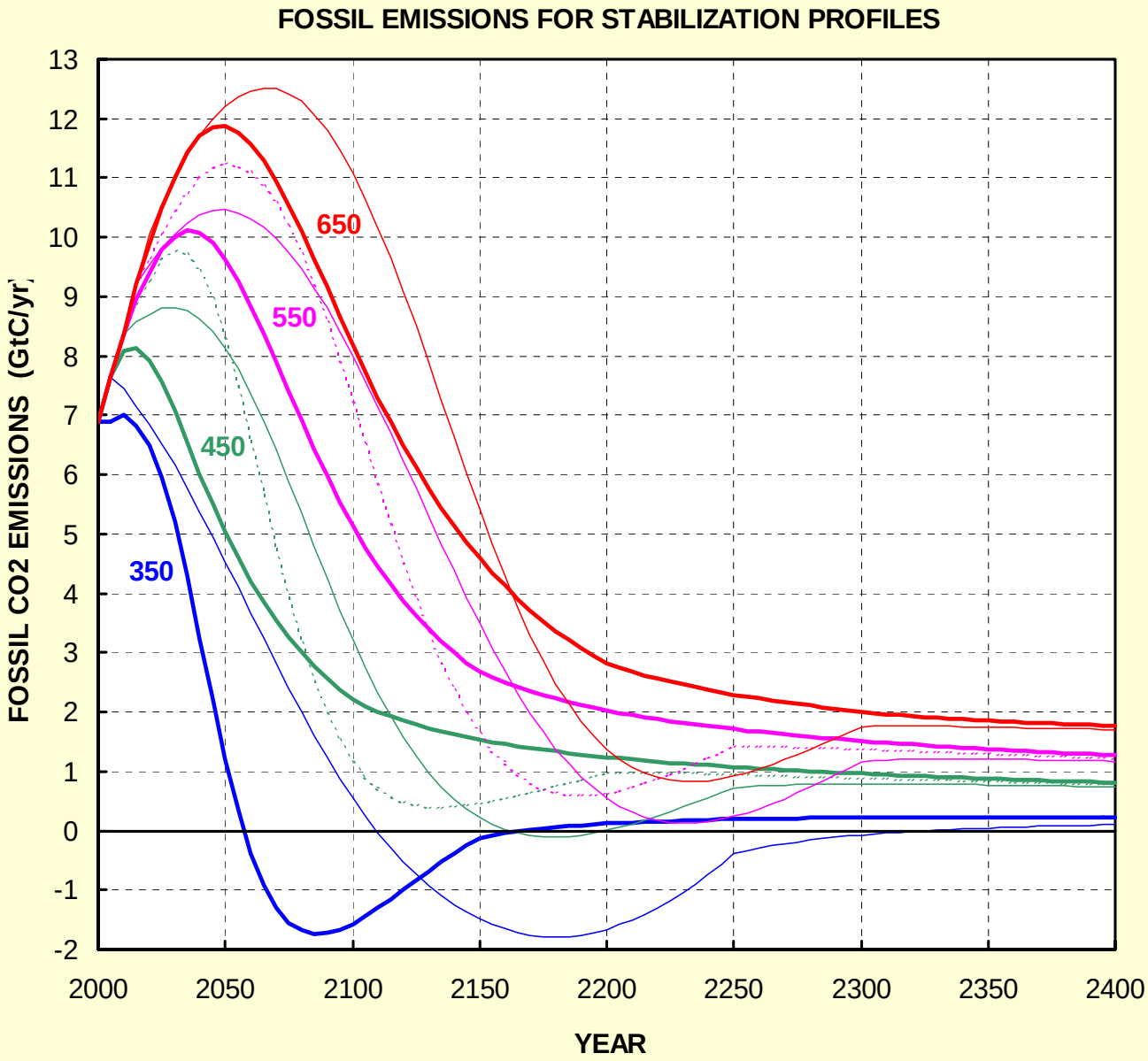
SUMMARY OF OVERSHOOT RESULTS FOR DIFFERENT STABILIZATION LEVELS

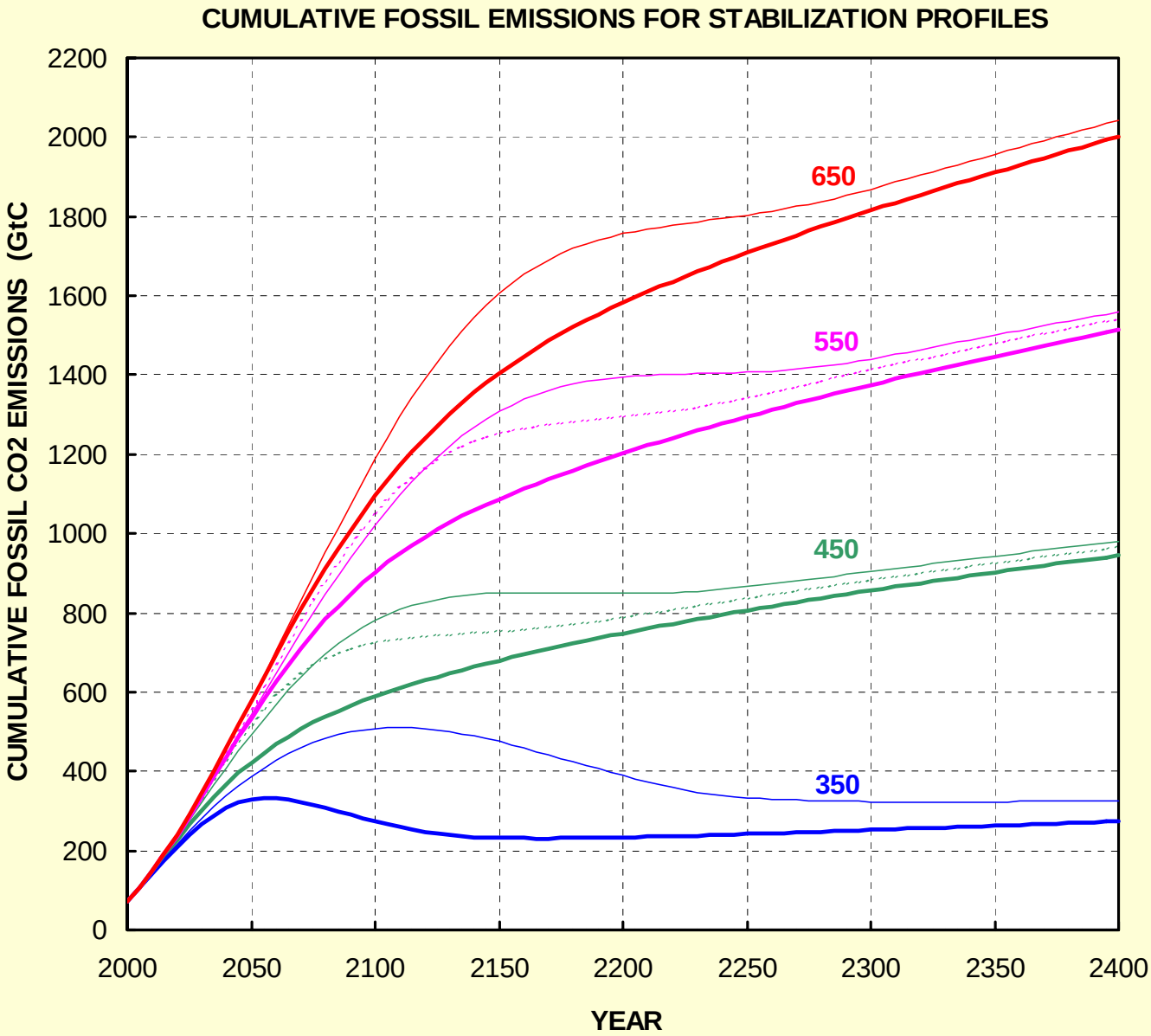
350, 450, 550 & 650 ppm

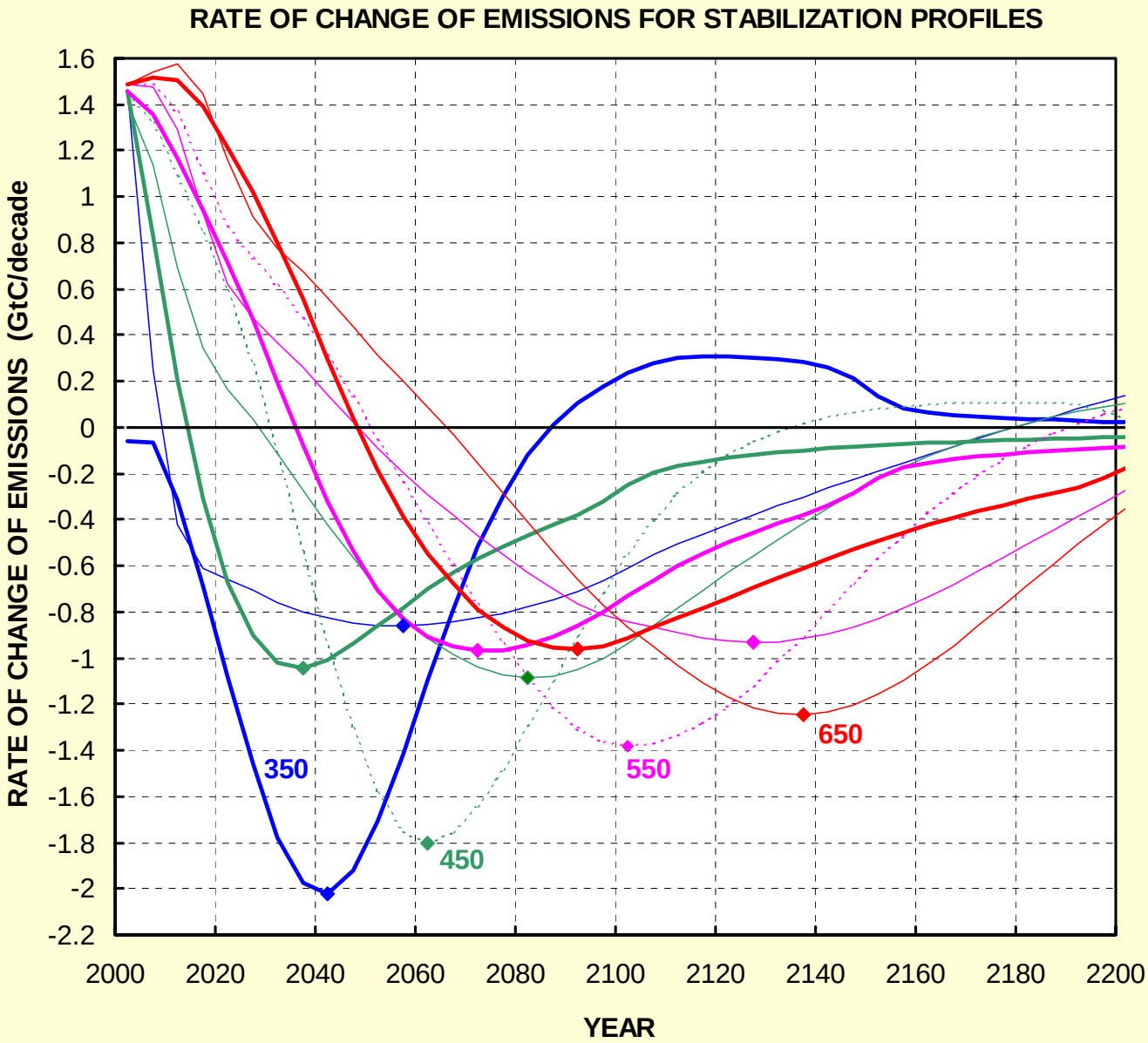
CONCENTRATION PROFILES, FOSSIL CO2 EMISSIONS, CUMULATIVE FOSSIL CO2 EMISSIONS, GLOBAL-MEAN TEMPERATURE & SEA LEVEL RISE (out to 2400)

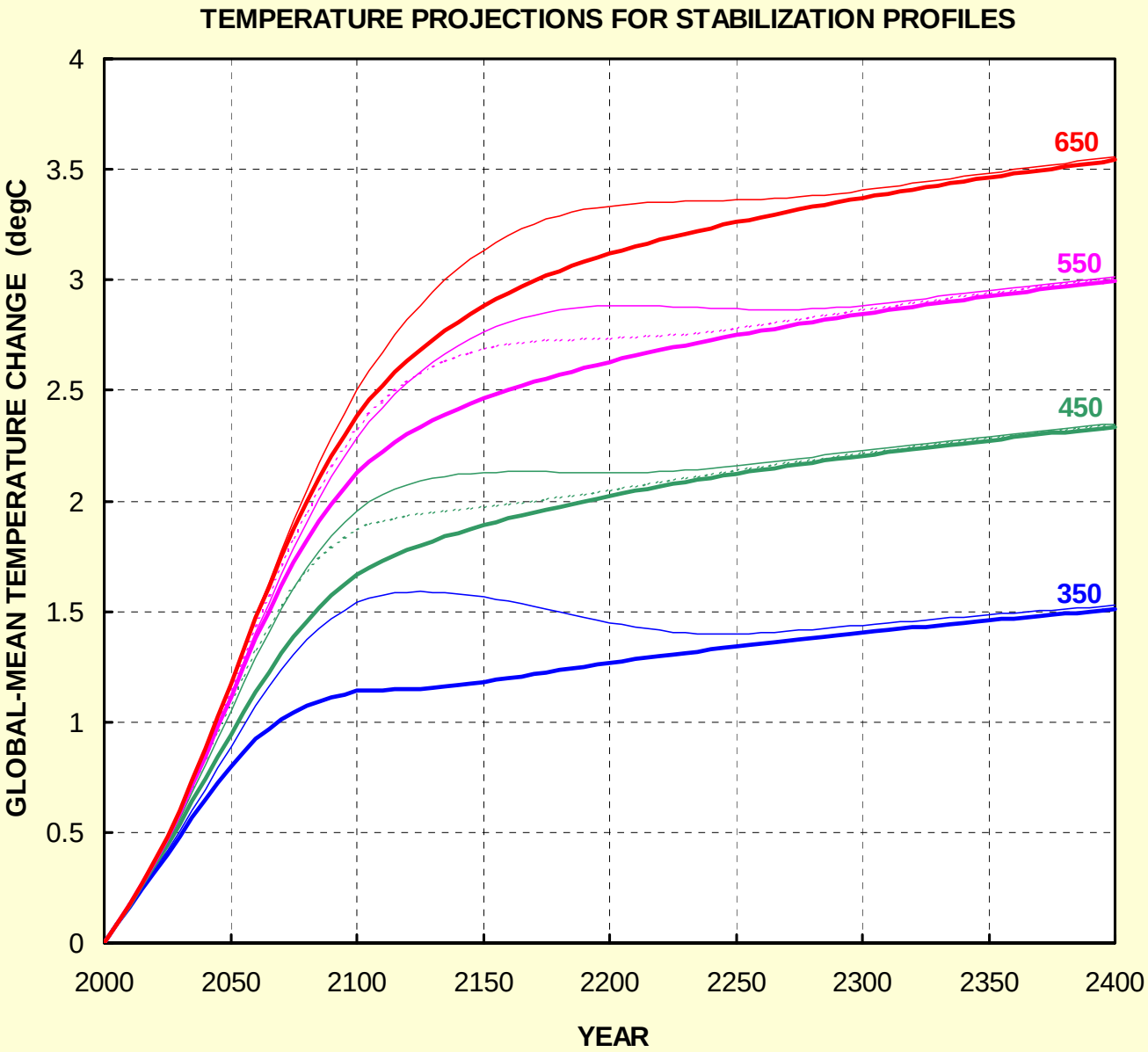
CONCENTRATION PROJECTIONS FOR STABILIZATION PROFILES

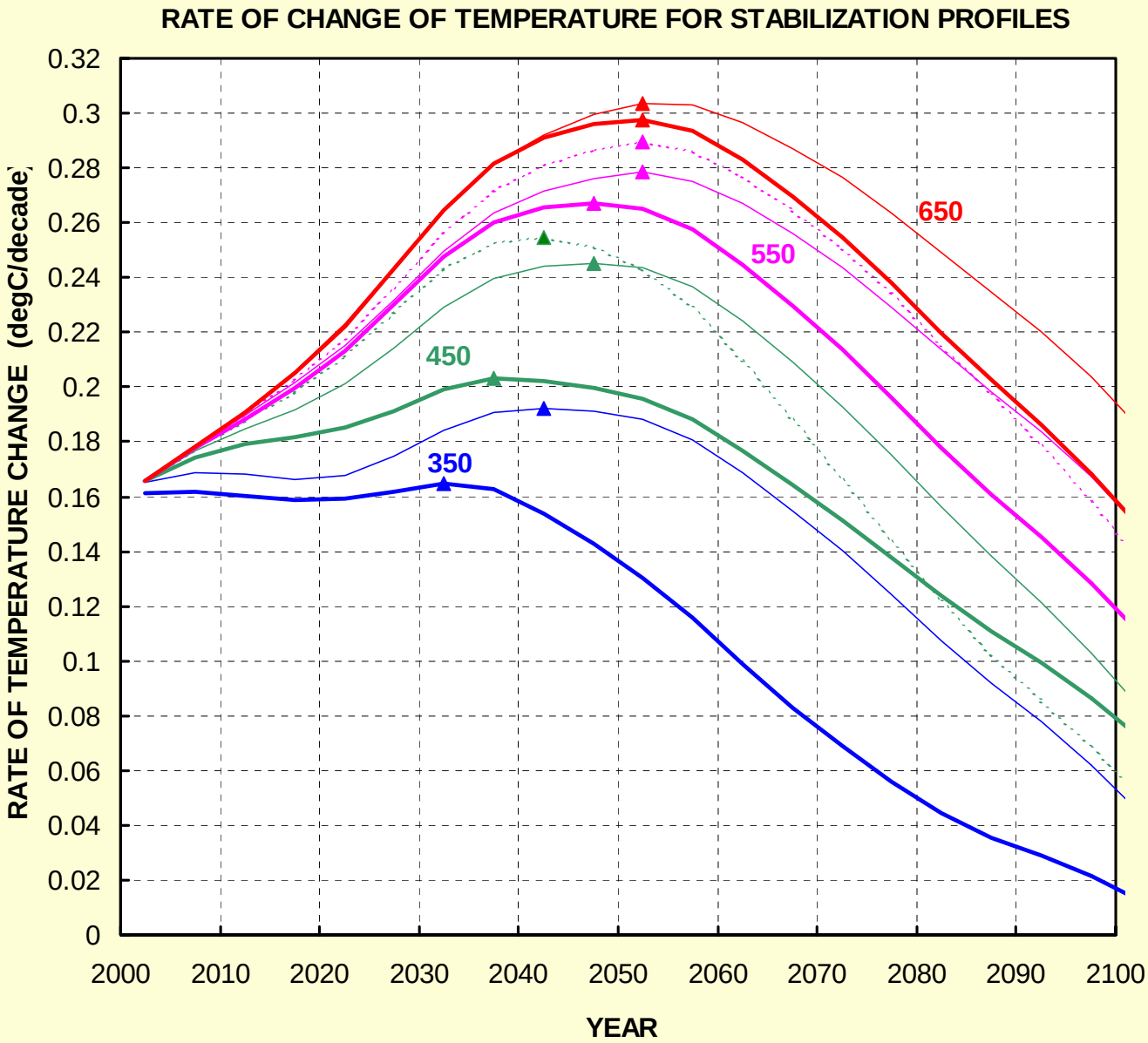


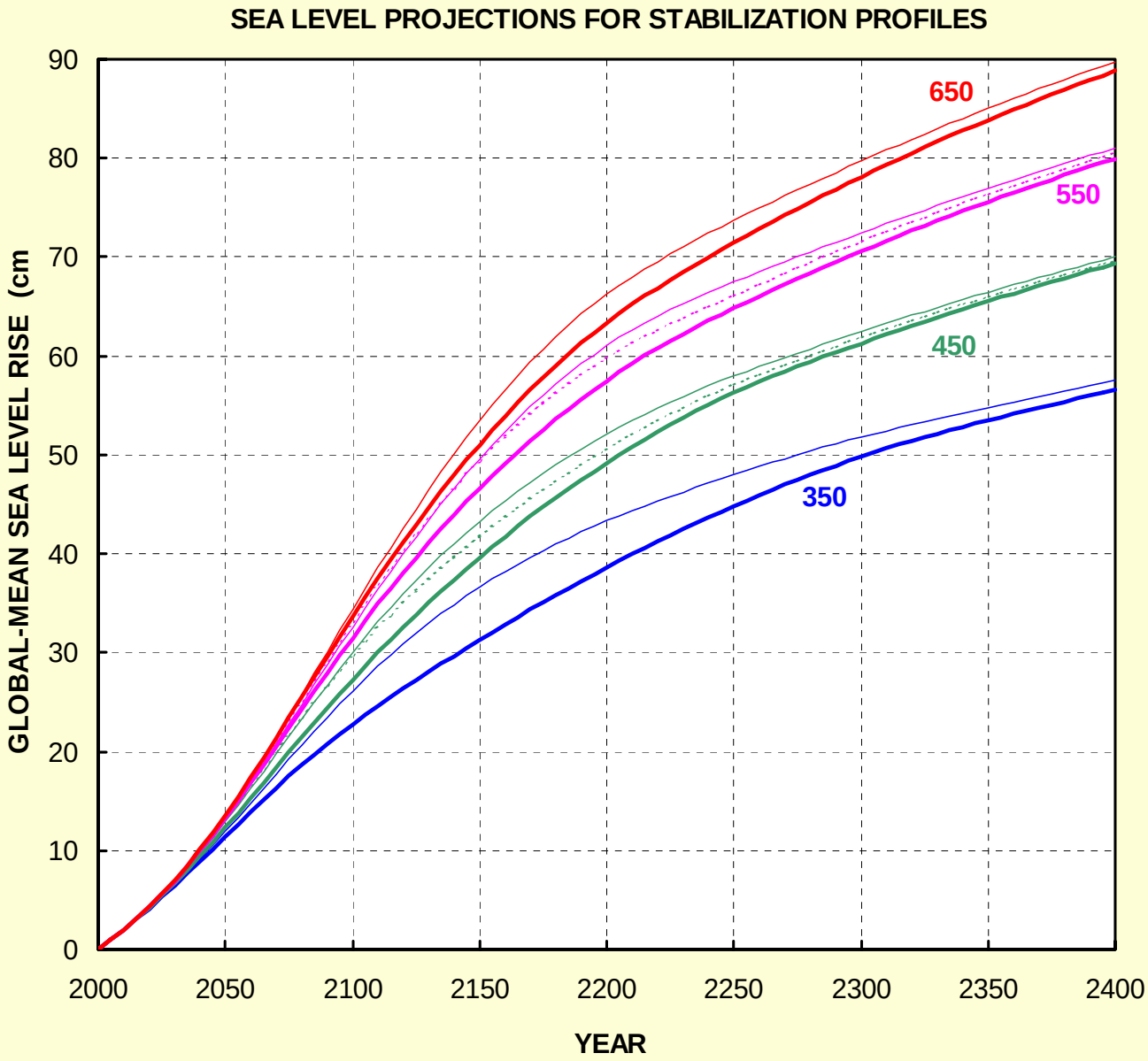

FOSSIL EMISSIONS FOR STABILIZATION PROFILES
FOSSIL CO2 EMISSIONS (GtC/yr)
YEAR
650
550
450
350
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
2000
2050
2100
2150
2200
2250
2300
2350
2400


CUMULATIVE FOSSIL EMISSIONS FOR STABILIZATION PROFILES
CUMULATIVE FOSSIL CO2 EMISSIONS (GtC
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
650
550
450
350
2000
2050
2100
2150
2200
2250
2300
2350
2400
YEAR


RATE OF CHANGE OF EMISSIONS FOR STABILIZATION PROFILES
RATE OF CHANGE OF EMISSIONS (GtC/decade
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2
-2.2
2000
2020
2040
2060
2080
2100
2120
2140
2160
2180
2200
YEAR
350
450
550
650


TEMPERATURE PROJECTIONS FOR STABILIZATION PROFILES
GLOBAL-MEAN TEMPERATURE CHANGE (degC
YEAR
650
550
450
350
0
0.5
1
1.5
2
2.5
3
3.5
4
2000
2050
2100
2150
2200
2250
2300
2350
2400


RATE OF CHANGE OF TEMPERATURE FOR STABILIZATION PROFILES
RATE OF TEMPERATURE CHANGE (degC/decade)
0.32
0.3
0.28
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
YEAR
650
550
450
350


SEA LEVEL PROJECTIONS FOR STABILIZATION PROFILES
GLOBAL-MEAN SEA LEVEL RISE (cm
YEAR
650
550
450
350
0
10
20
30
40
50
60
70
80
90
2000
2050
2100
2150
2200
2250
2300
2350
2400

CONCLUSIONS

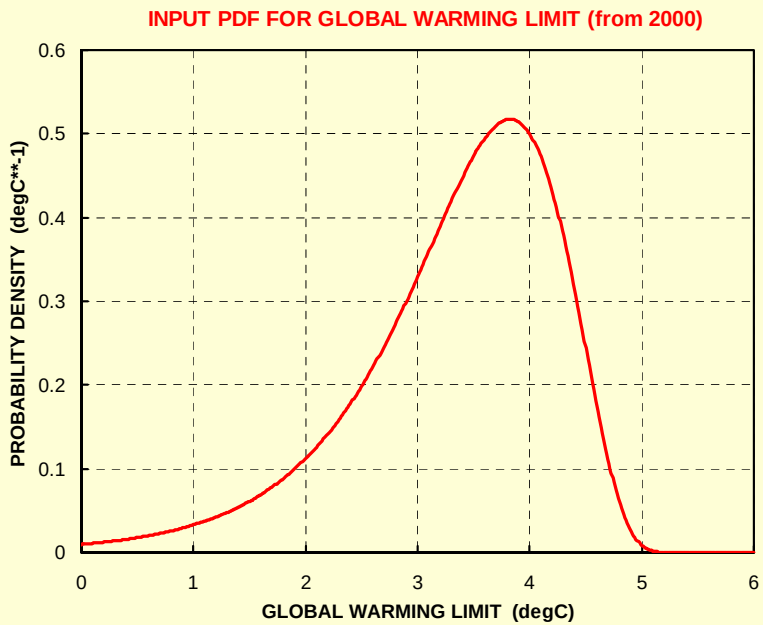
- For a given emissions scenario, climate feedbacks lead to concentration increases 10-20% larger than without feedbacks (even larger with some models!)
- Climate feedbacks lead to substantially lower emissions requirements to meet any given stabilization target
- The percentage reduction in cumulative emissions is larger for lower stabilization targets
- Overshoot pathways …..
  - delay the time when emissions must begin to decrease by about 10 years
  - can be constructed to both delay and not increase $(dE/dt)_{max}$
  - allow much larger near-term (100+ years) cumulative emissions
  - lead to small increases in the magnitude of future climate and sea-level change, and small increases in the rates of change
- It seems likely that overshoot pathways would reduce mitigation costs much more than they would increase climate-change damages – unless there are nonlinearities that lead to much larger damages if thresholds are passed

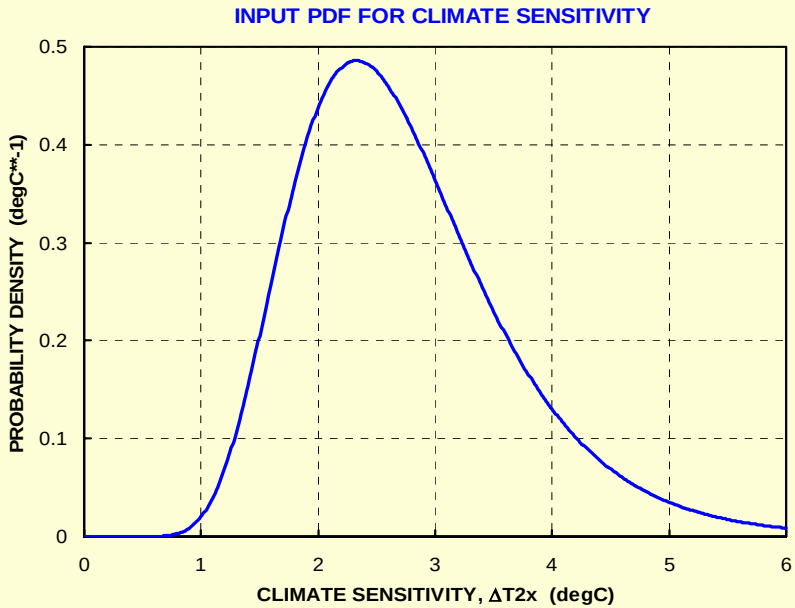
ADDITIONAL MATERIAL ON CHOOSING A STBILIZATION TARGET

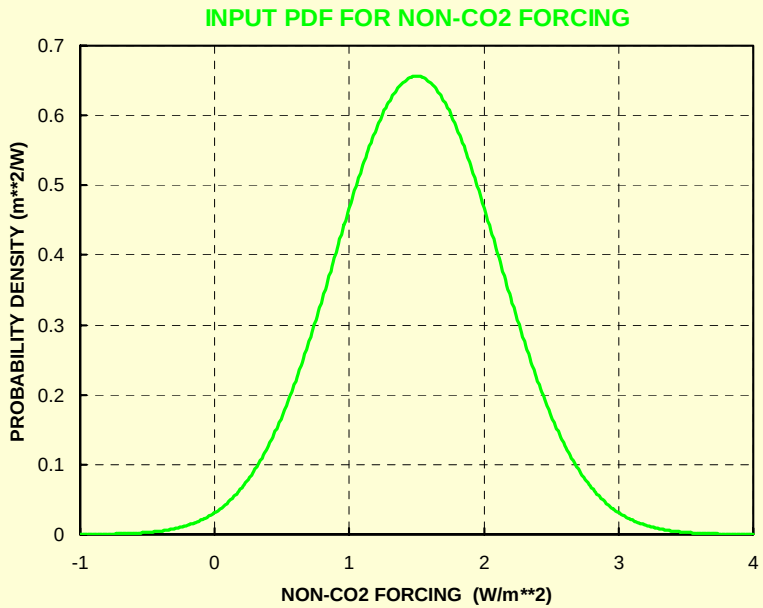
WHAT SHOULD THE STABILIZATION TARGET BE?

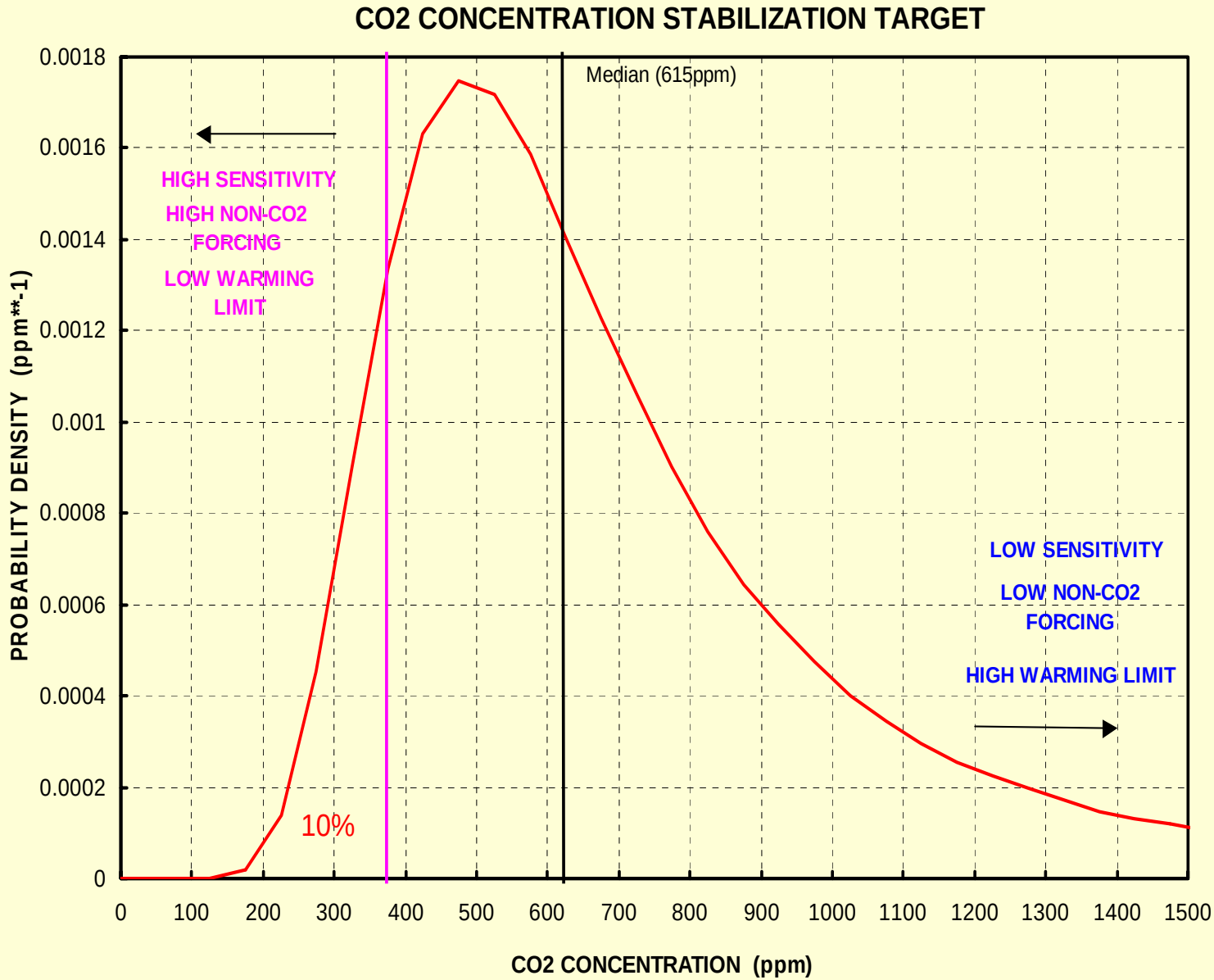
(What does ‘dangerous interference’ mean?)

INPUT PDFs : CO2 STABILIZATION CONCENTRATION IS CONTROLLED BY WARMING LIMIT, CLIMATE SENSITIVITY AND NON-CO2 FORCING








CO2 CONCENTRATION STABILIZATION TARGET
PROBABILITY DENSITY (ppm**-1)
0.0018
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
Median (615ppm)
HIGH SENSITIVITY
HIGH NON-CO2
FORCING
LOW WARMING
LIMIT
LOW SENSITIVITY
LOW NON-CO2
FORCING
HIGH WARMING LIMIT
10%
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
CO2 CONCENTRATION (ppm)

CONCLUSION

- The CO_2 stabilization target depends on what is judged to be ‘dangerous interference’, the climate sensitivity, and forcing from non-CO_2 sources.

- There is a probability of around 10% that the target could be below the current level.