Re-examination of the emission paths considering uncertainty of the climate sensitivity

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New target of EU and the difficulty in achieving the target

2015.2.25 Nikkei newspaper says:

EU fixed the new long term target such that GHG emission should be reduced by 60% when compared with the level in 2010.

Difficulty in achieving the above target

present emission: developing c. 6 vs. advanced c.4

Following the above target requires developing c. to reduce their emission by half by 2050, even if advanced c. reduce their emission by 80%.

According to OECD forecast: energy demand of developing c. will be doubled by 2050

→ How do we fill this gap?

2 ℃ target and overshoot scenarios

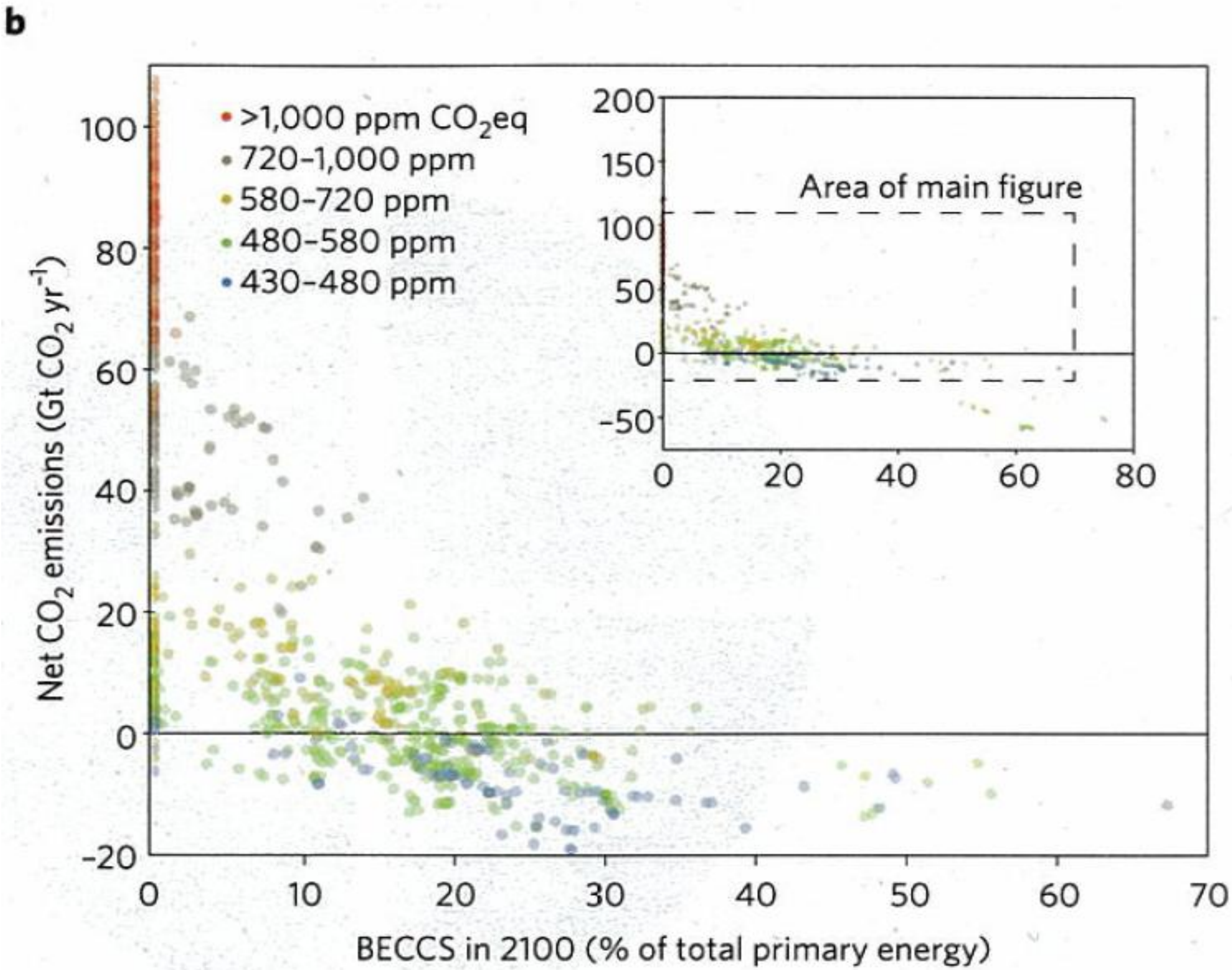
Scenarios of IPCC AR-5 WG3 for 2℃ target

2100: 653 scenarios of 480～720ppm

235 scenarios : negative CO2 emission before 2100 (see the next figure)

negative CO2 emission: afforestation
BECCS

the issue: whether the negative emission as above will be able to be realized



Source: Fuss,S.et al, Nature Climate Change .October 2014p.851

Measures for negative emission of CO_2
- Capture of CO_2 in the air and its storage-

1. Afforestation: storage of CO_2 in forests

2.BECCS(BioEnergy Carbon Capture and Storage)

grasses—harvesting —burning
—capture of CO_2—storage in underground

(Notice that trees are not utilized for BECCS, as trees store CO_2 within themselves. Cutting trees for CCS is meaningless for CO_2 capture from the air.)

Areas required for afforestation and BECCS

1. Base data of CO_2 absorption (Whittaker et al.)
   temperate forest: 18.3 ton CO_2/ha/year
   temperate grass field: 8.4 ton CO_2/ha/year
2. CO_2 to be absorbed
   3Gton CO_2 /year (most frequently used in the IPCC scenarios : 1/10 of annual global emission)
3. Areas required for absorption of CO_2
   temperate forest: 170 Mha/year (¼ of Australia)
   BECCS : 380 Mha/year (½ of Australia)
   ･･･too large in practice
   (Present global deforestation is several Mha, much less than the above number)

How can we do then?

The above discussions tell how difficult to achieve 2℃ target. How shall we do then?

Idea 1: Adoption of higher temperature rise as the target (already mentioned in the same seminar of last year)

Idea 2: Re-examination of science of climate change

→ the issue of climate sensitivity

The proposal by J.Curry in Wall Street Journal in Oct 13, 2014

1. The climate sensitivity evaluated by climate models seems too high. Our evaluation indicated much lower climate sensitivity.
2. We are not outlier. There have been published more than a dozen of papers of similar character.
3. <u>Lower climate sensitivity indicates that we have more time for decarbonization of the economy than expected in the past</u>.

* J.Curry: Professor of Georgia Inst. of technology, President of Climate Forecast Applications Network.

Climate sensitivity

ECS(equilibrium climate sensitivity)

The final value of rise in global temperature when CO_2 concentration in the air doubles

TCR(transient climate response)

rise in temperature when CO_2 concentration doubles with the speed of 1% per year

Methods for evaluating climate sensitivity

1. Evaluation by climate models (AOGCM)

$2 \times CO_2$→model run →final value of global temp.rise =ECS

2. Evaluation from paleoclimate data

3. Evaluation by energy balance model and observation data

$$ECS = F_{CO2 \times 2} \frac{\Delta T}{\Delta F - \Delta Q} \quad (1)$$

ECS:Equilibrium Climate Sensitivity

F: radiative forcing ΔQ: energy to the ocean

ΔT: temperature change

In the past the method 1 has been utilized almost solely, but number of papers based upon the method 3 has remarkably increased recently.

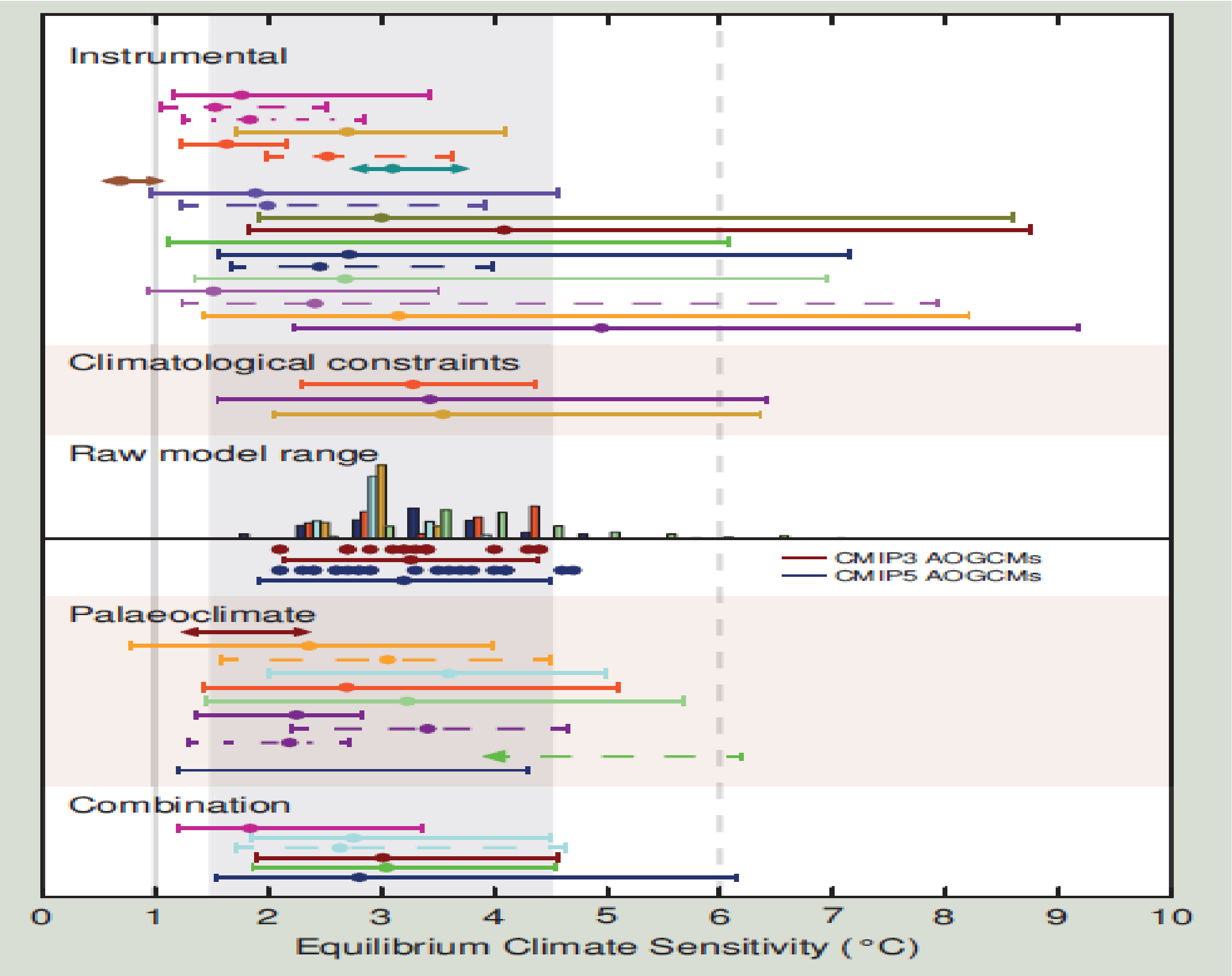


FIG. : IPCC AR-5   Evaluation of ECS by various methods
Source: IPCC AR-5 WG1,TS,TFE6,Fig.1

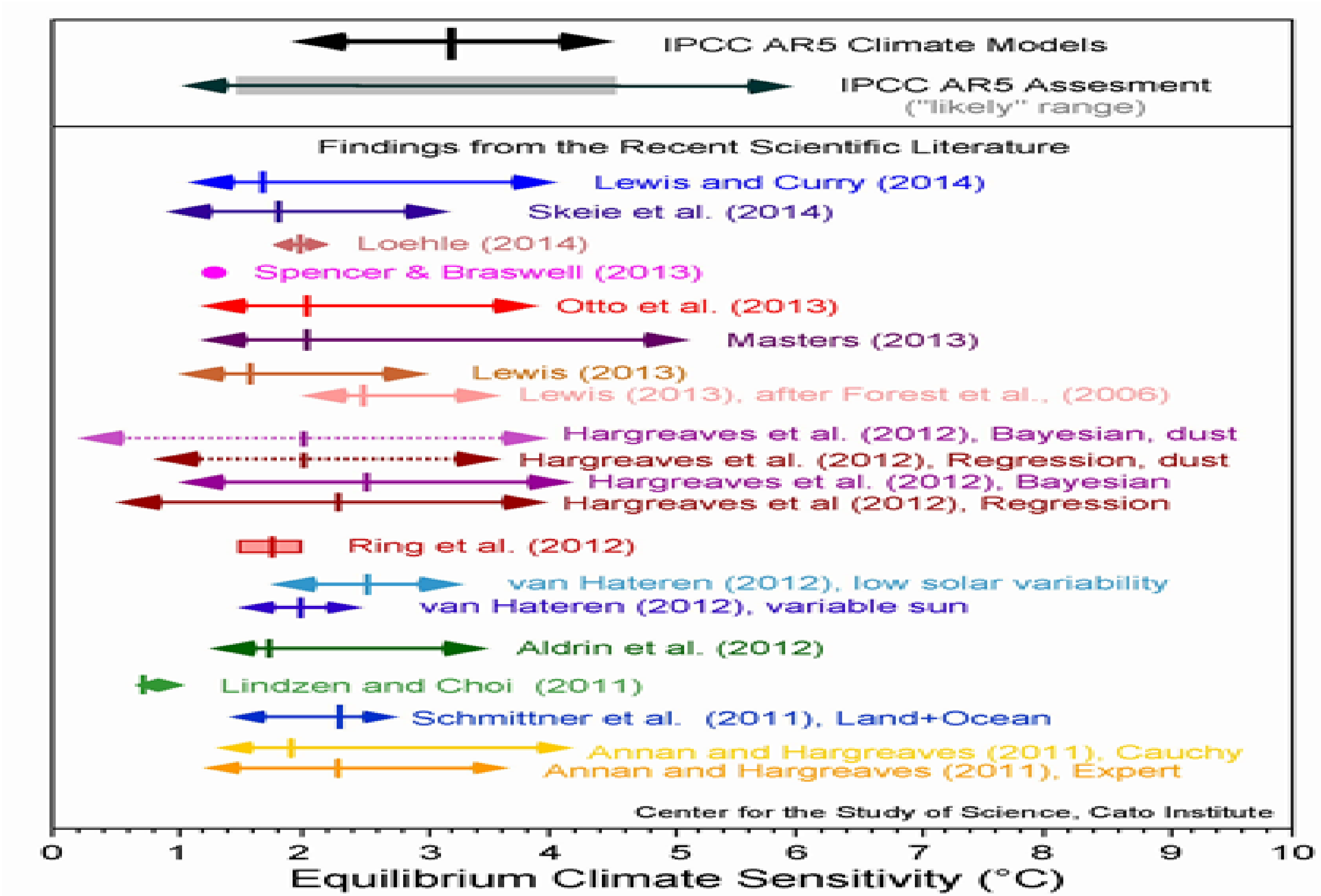
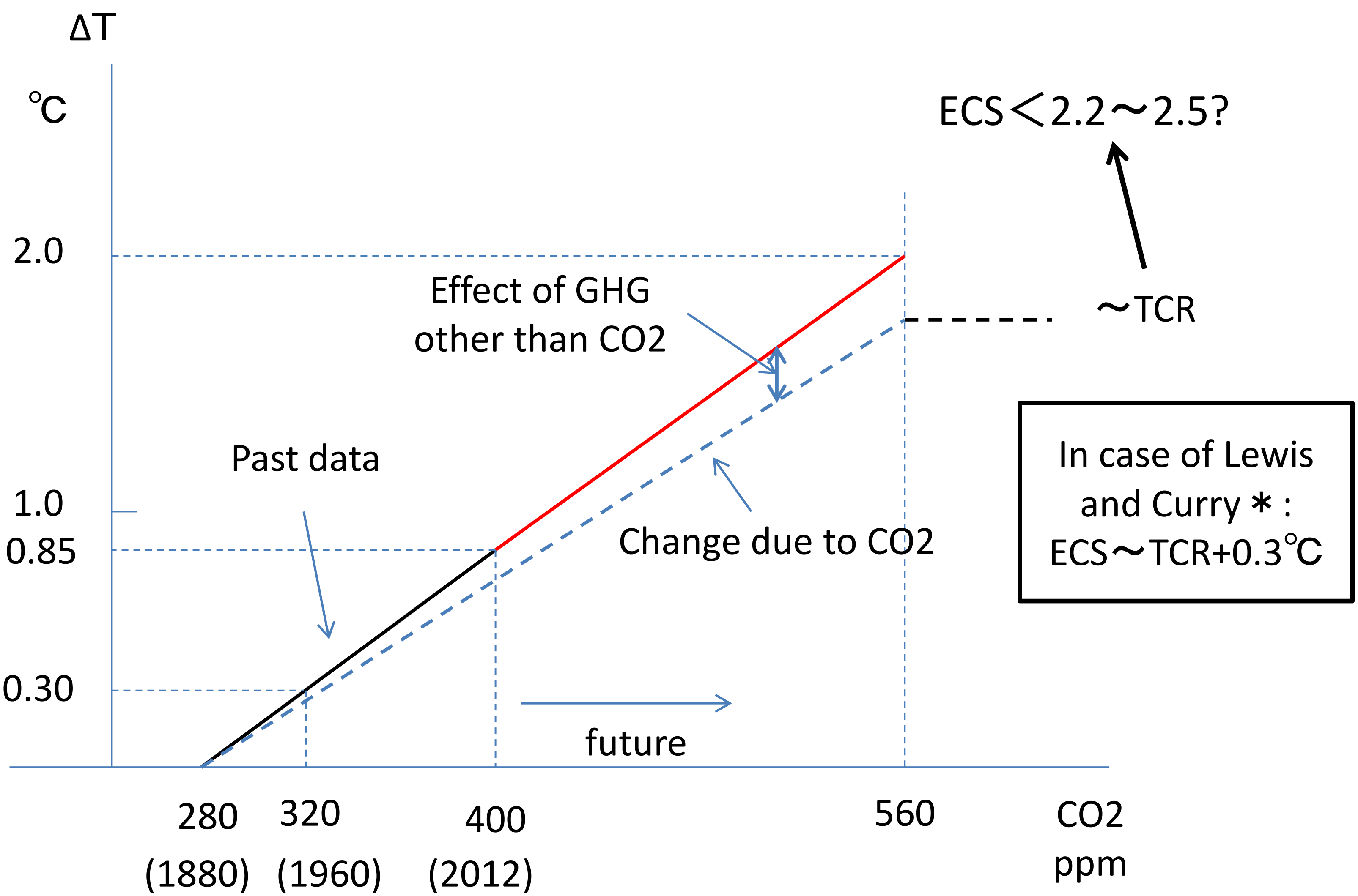


Fig. Recent results mainly by use of energy balance models
Source: Michaels,P.J.et al,2014.9

Estimation results: ECS

	band estimates (likely)	best estimate
IPCC AR4 AR5	2.0 ~ 4.5 K 1.5 ~ 4.5 K	3.0 K cannot be **determined**
Average of median 1)IPCC AR5 WG,TS Fig.1 2)Michaels,P.J.etal,2014.9		Average Instrumental 2.6 K Climate model 3.2 K mostly observation data 2.0K

Fig. A simple estimation of ECS
—The basis of energy balance method?—



＊Lewis,N.&J.A.Curry,Climate Dynamics,Springer,Sept.2014

Climate sensitivity in IPCC AR-5

１．WG1

The temperature rise vs. cumulative CO2 emission curve has been made by climate models of which ECS are relatively high. The change in lower limit of band estimate of ECS was then not utilized in the evaluation of the relation between the temperature rise and cumulative CO2 emission.

２．WG3

１）**<u>RCP's climate model are MAGICC in which ECS of 3 degrees has been utilized.</u>**

２）**Most of other models quoted in WG3 report utilized the best estimate of AR4 which is 3 K .**

Change in ECS in the following investigation

1. The lower limit of band estimate of ECS was lowered by 0.5℃.

２. While the best estimate of ECS evaluated from climate models is 3℃, the average of medians of ECS evaluated by energy balance models is
2.0〜2.6℃.

３. From IPCC 1st report to 3rd report, ECS was thought
to be 1.5〜4.5℃, and the best estimate is 2.5℃*.

*IPCC 2nd report, WG1,p.34,1995,Cambridge Univ.Press

⇒ Set the best estimate of ECS to be 2.5℃,
and evaluate its impacts on emissions.

Point 1. How much is the rest of cumulative emission of CO_2
for 2℃ target (how much easier than when ECS=3℃?)
2. Changes in realizability of emission path (marginal cost, etc.)

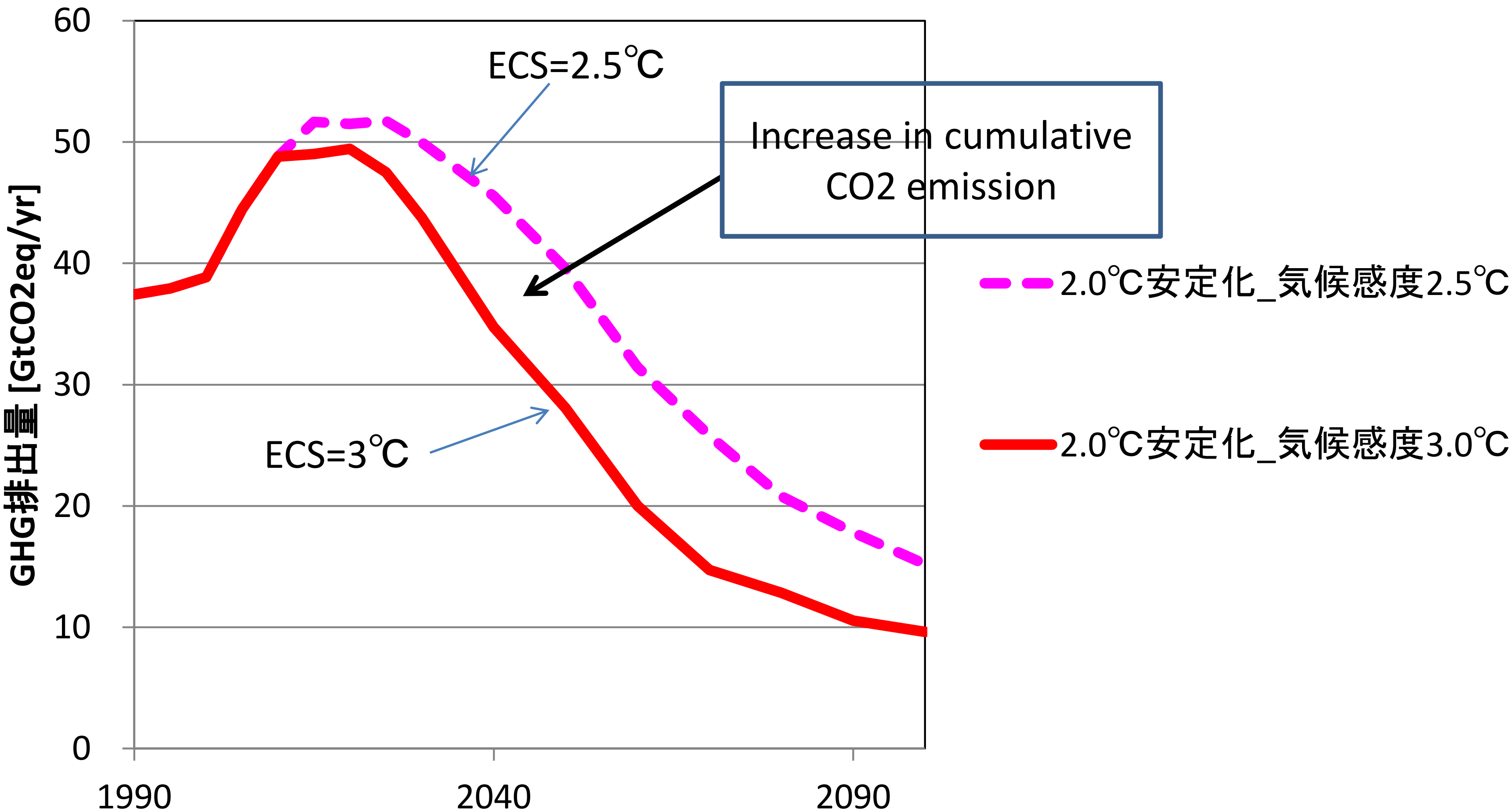


Fig. Global GHG emission
-2℃target case -

Fig. Rise in global temperature and cumulative CO2 emission

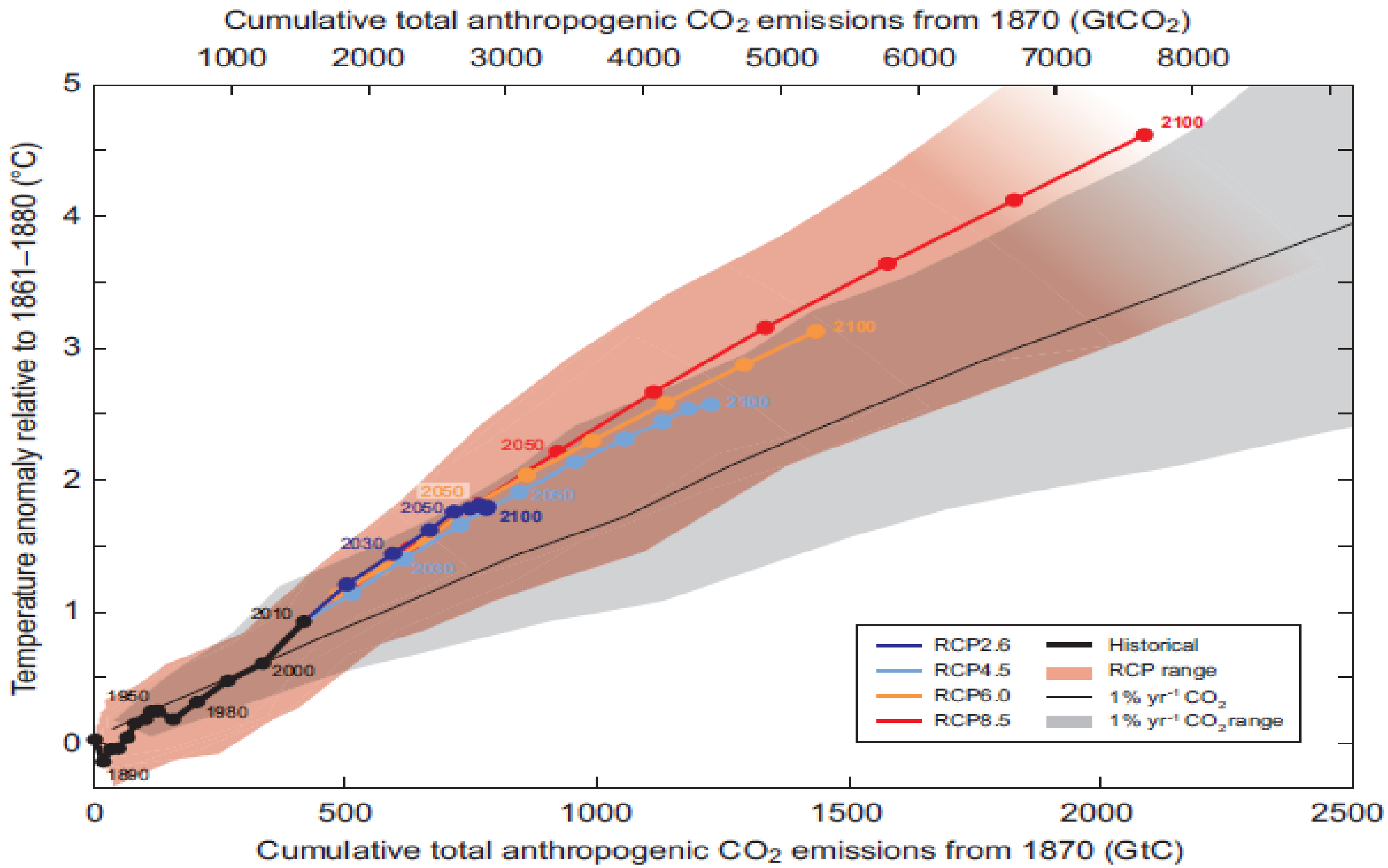
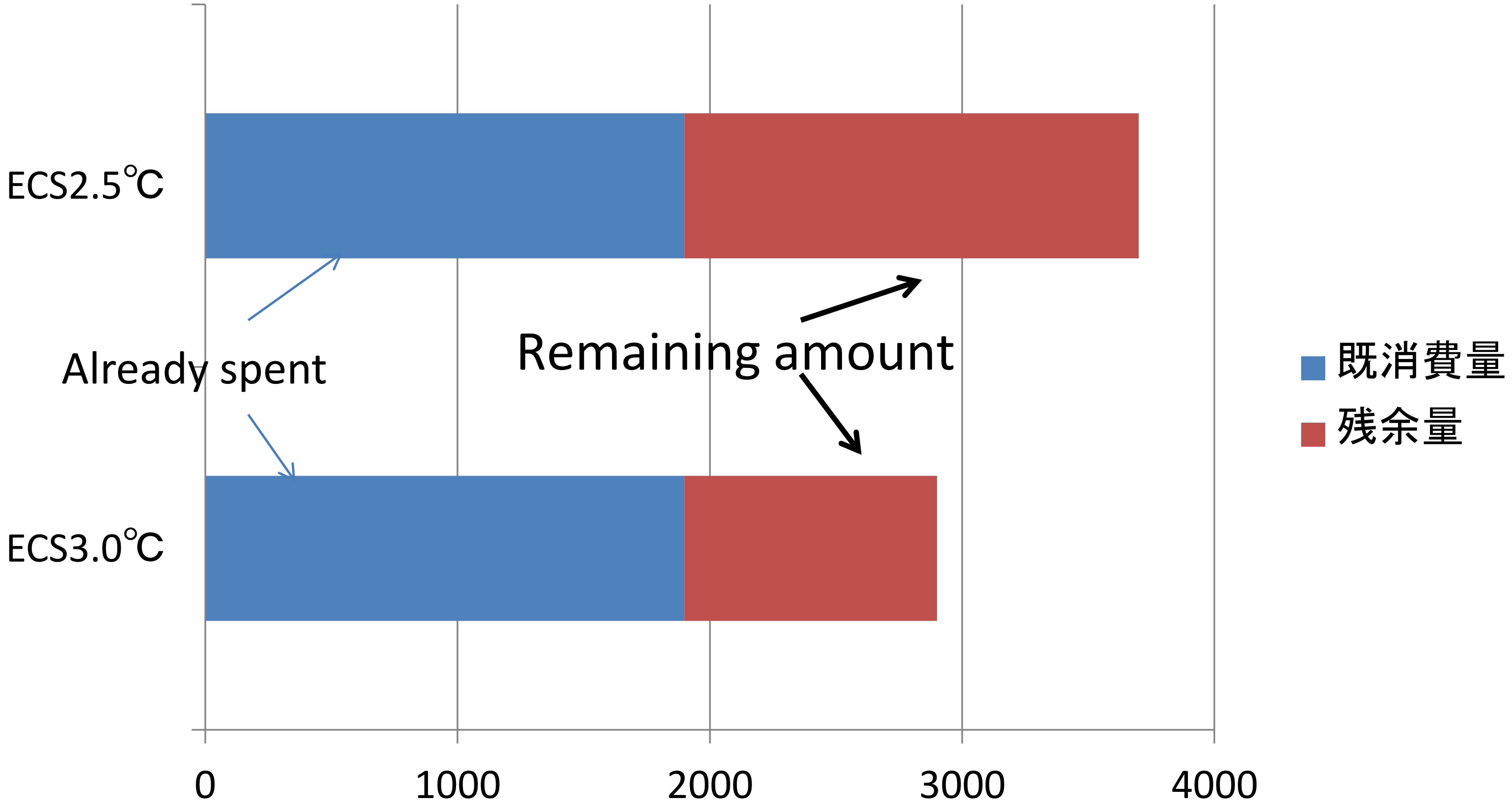


Figure SPM.10 | Global mean surface temperature increase as a function of cumulative total global CO_2 emissions from various lines of evidence. Multi-model results from a hierarchy of climate-carbon cycle models for each RCP until 2100 are shown with coloured lines and decadal means (dots). Some decadal means are labeled for clarity (e.g., 2050 indicating the decade 2040−2049). Model results over the historical period (1860 to 2010) are indicated in black. The coloured plume illustrates the multi-model spread over the four RCP scenarios and fades with the decreasing number of available models in RCP8.5. The multi-model mean and range simulated by CMIP5 models, forced by a CO_2 increase of 1% per year (1% yr^{-1} CO_2 simulations), is given by the thin black line and grey area. For a specific amount of cumulative CO_2 emissions, the 1% per year CO_2 simulations exhibit lower warming than those driven by RCPs, which include additional non-CO_2 forcings. Temperature values are given relative to the 1861−1880 base period, emissions relative to 1870. Decadal averages are connected by straight lines. For further technical details see the Technical Summary Supplementary Material. {Figure 12.45; TS TFE.8, Figure 1}

Source: IPCC AR5 WG1, SPM, 2013

Remaining cumulative CO2 emission - for 2℃ rise -



Note: Achieving probability of 66%

Changes in emissionable amount of CO_2 when ECS changes from ３℃ to２．５℃

１．Remaining cumulative emissionable CO_2

ECS ３℃　　1,000Gt CO_2 (>66%probability）

remaining time

＝remaining amount/annual emission～３０y

ECS 2.5℃　　1,800Gt CO_2

remaining time ～　６０y (almost twice)

２．Improvement in realizability of emission paths（to be shown)

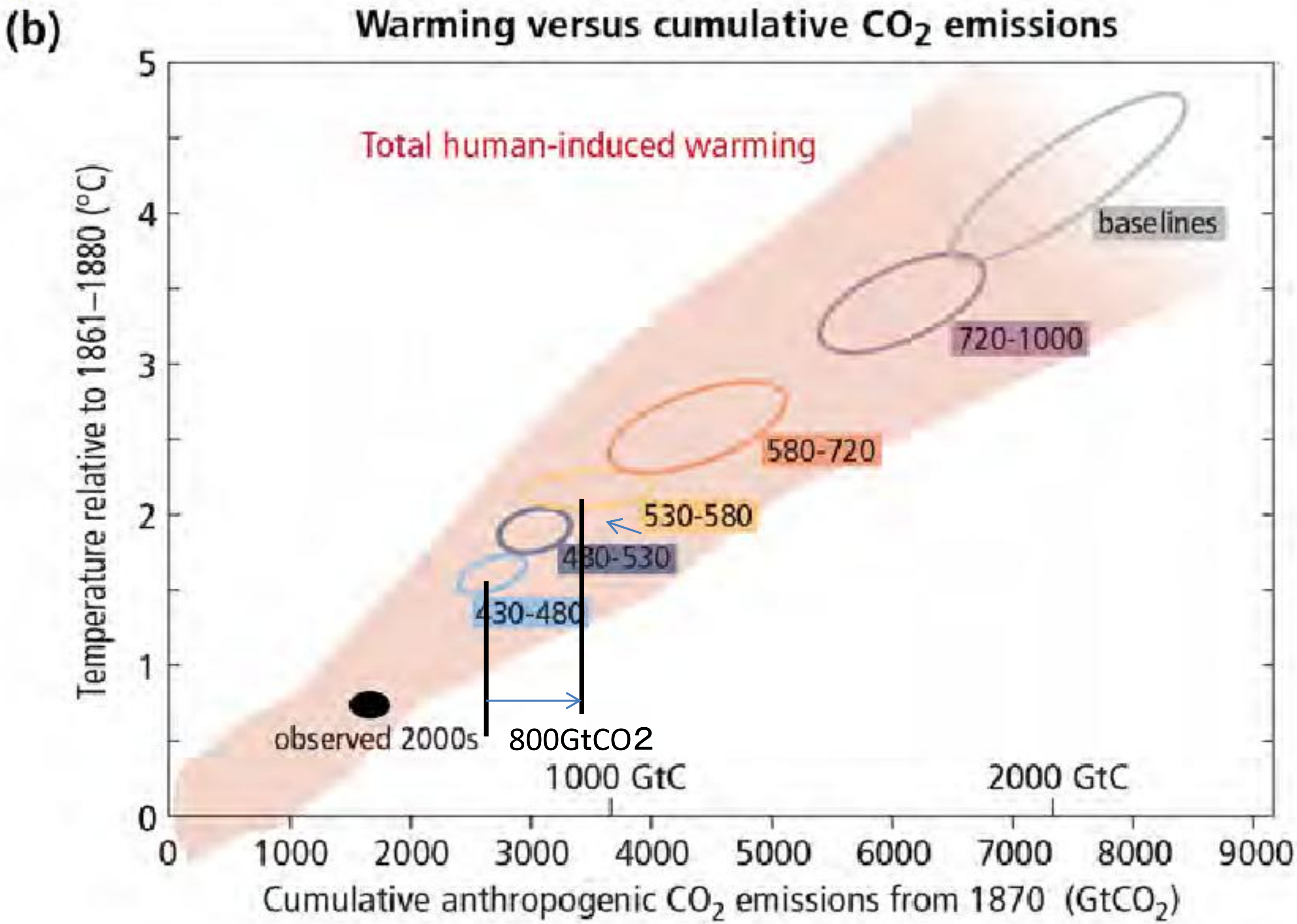


Fig. Rise in temp. and cumulative CO2 emission
Source: IPCC AR-5 Synthesis Rep. FIg.SPM.5 (b)

Change in ECS ～ Change in target rise in temperature

1. ECS 3℃→2.5℃

Increase in remaining cumulative CO_2 emission is almost the same as in the case of

ECS 3℃ and

the target of rise in temp. of <u>2.5℃</u>

(final CO_2 concentration 530～580ppm)

2. The above means that lowering in ECS is almost equal to rise in the temperature target.

Changes in emission paths when ECS=3.0℃→2.5℃

１. World

What change will happen in marginal cost of GHG reduction？

２. Various regions

If Developed countries (monotonous reduction)

China.India.Brazil（peaking in 2030）

Other developing c.（peaking in 2050）

what will be emission paths and marginal costs?

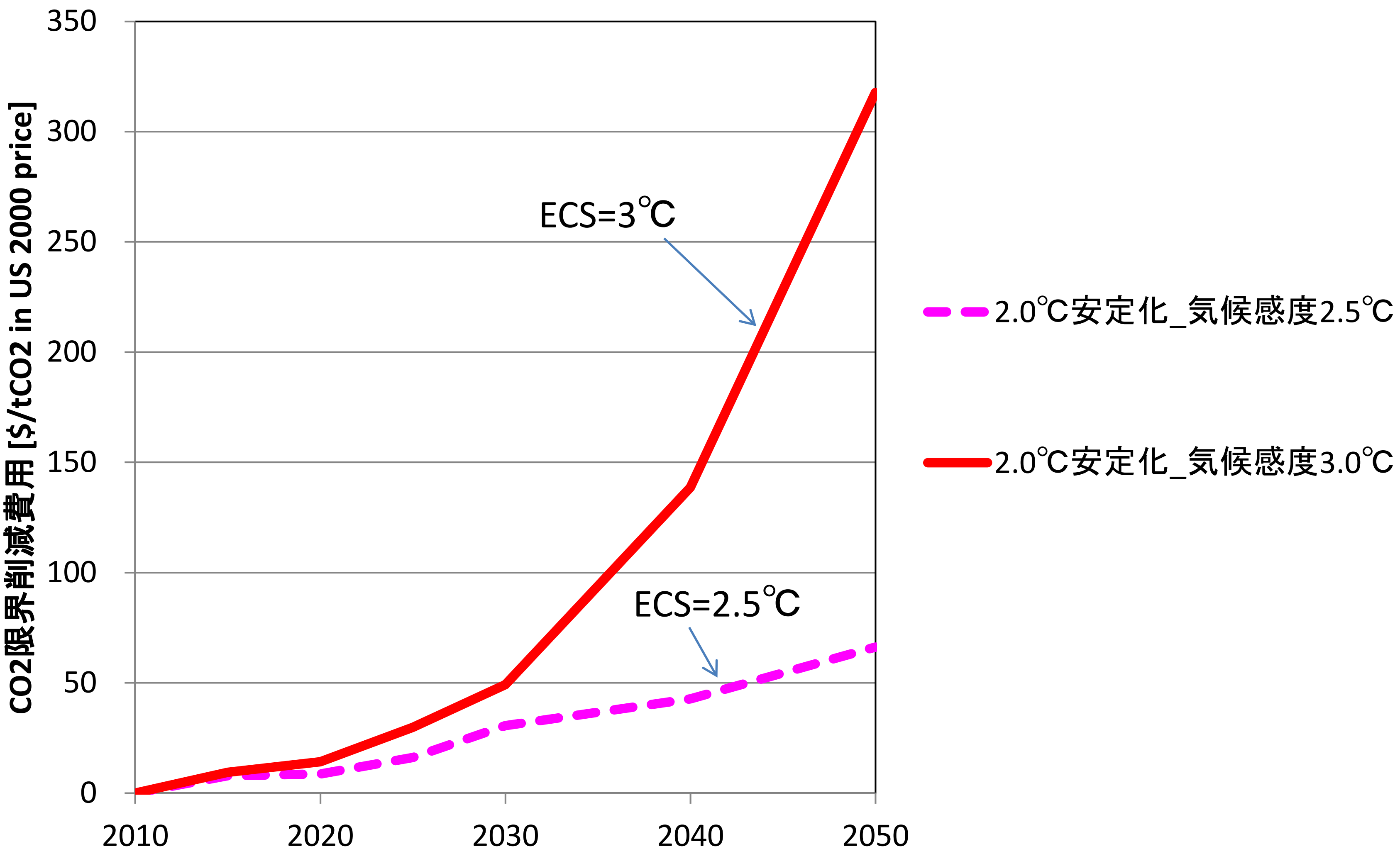
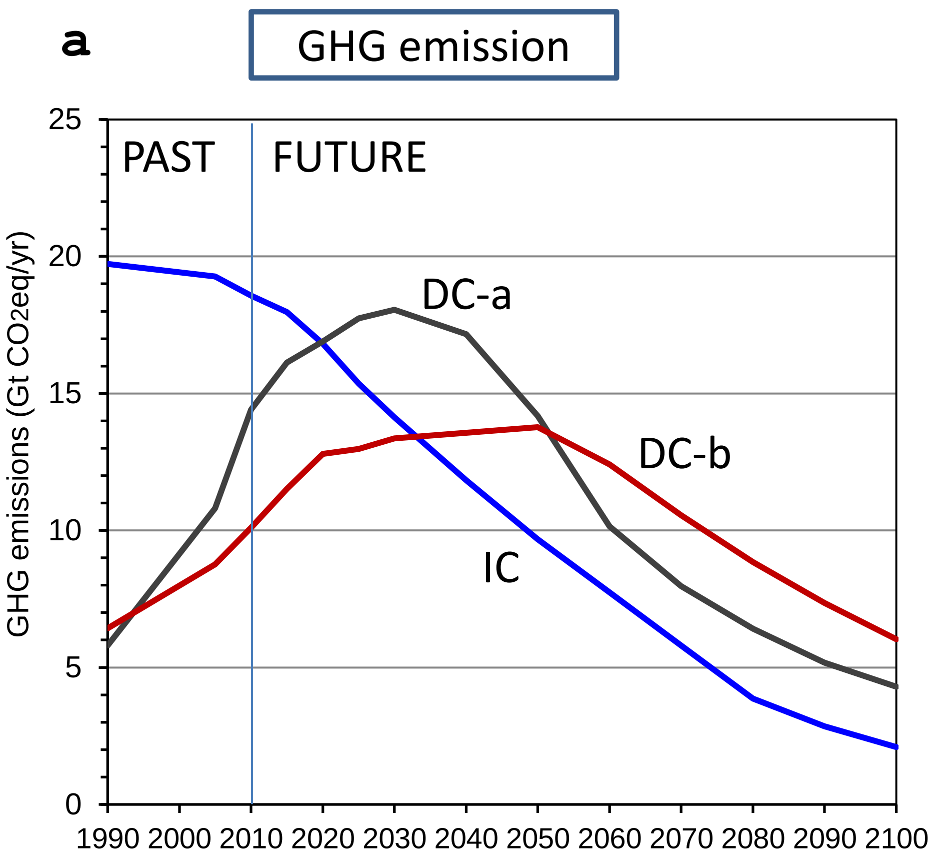


Fig. Marginal cost of GHG reduction
—in case of globally monotonous action —



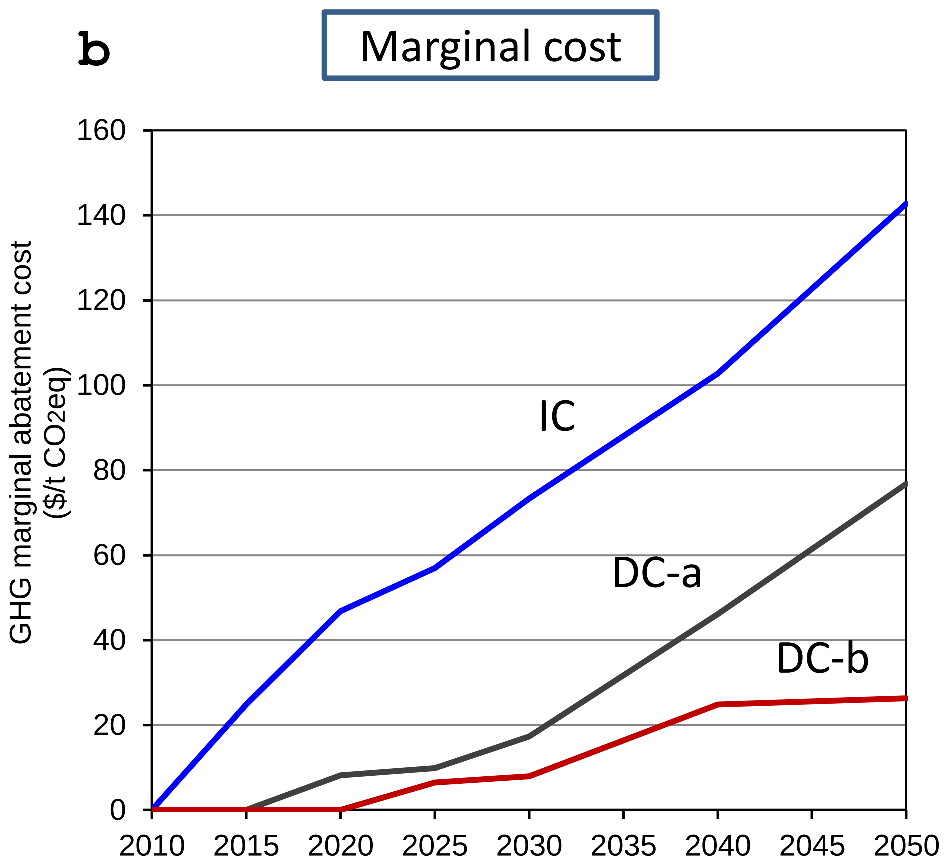


Fig. Region oriented approach: 2℃ target, ECS =2.5 ℃

IC：developed countries

DC－a：China.India.Brazil （peaking 2030)

DC－b: Other developing countries （peaking 2050)

GHG emissions of the world and developed countries in 2050 - 2 degree target -

Base year: present	world	developed countries
Climate sensitivity = 3 ℃	50% reduction	80% reduction
Climate sensitivity = 2.5℃	the same as present value	50% reduction

Summary

1. It is hard to achieve 2℃ target by measures including CO_2 absorption.
   It is recommended to consider more practical strategy.
2. There is a possibility that the climate sensitivity is lower than the value evaluated in the past. With that climate sensitivity we may realize more realistic strategy for climate change.
3. Lowering of ECS by o.5 ℃ has the following large effects on emission.
   1) For the same target of the global temperature rise
      remaining cumulative CO_2 amount will be almost doubled.
   2) The marginal costs of GHG reduction of all over the world
      will be largely reduced .

Therefore we earnestly recommend to do efforts for reducing as much uncertainties of climate sensitivity as possible.