

April 22, 2015

Interpretation of IPCC AR5 Scenarios under better understanding of climate sensitivity assessments, and the implications of INDCs in terms of 2 °C target

**Systems Analysis Group
Research Institute of Innovative Technology
for the Earth (RITE)**

Contact to:

E-mail: sysinfo@rite.or.jp



Introduction

- ◆ Several countries including the U.S., EU have submitted their INDCs (Intended Nationally Determined Contributions) by the end of March, 2015.
- ◆ There are discussions on the emission gap between the expected global emissions by the INDCs and a political target, “2 °C target”, in which the global mean temperature change should be below 2 °C increase relative to preindustrial level.
- ◆ Under the important discussions for the global emission reductions beyond 2020, it is important to understand that the scientific knowledge require the emission pathways for the 2 °C target appropriately. The incorrect understandings of the scientific knowledge will mislead the climate change negotiations toward COP21 and the collapse.
- ◆ This paper summarized the scientific knowledge on climate sensitivity with uncertainties in the IPCC AR5, and evaluated the allowable cumulative emissions, CO₂ concentration levels, and emission pathways.
- ◆ In addition, the expected global emission by the INDCs submitted by the end of March was estimated, and was compared with the emission pathways for the 2 °C target with the uncertainty of climate sensitivity.

Also refer to:

- Keigo Akimoto, Discussion paper providing to the advisory committee for the INDCs, December 5, 2014 (in Japanese)
- http://www.meti.go.jp/committee/sankoushin/sangyougijutsu/chikyu_kankyo/yakusoku_souan_wg/pdf/003_s02_00.pdf
- Mitsutsune Yamaguchi & Yoichi Kaya, Nikkei-Keizai-kyoshitsu, Nikkei Newspaper, April 3, 2015 (in Japanese)

History of climate sensitivity judgment by IPCC and the sensitivity employed in the scenario assessments of the IPCC WG3 AR5

	Equilibrium climate sensitivity Likely range (“best estimate” or “most likely value”)
Before IPCC WG1 AR4	1.5–4.5°C (2.5°C)
IPCC WG1 AR4	2.0–4.5°C (3.0°C)
Global mean temperature estimations for the long-term scenarios in the IPCC WG3 AR4 (employing MAGICC)	No estimates with probability (3.0°C)
IPCC WG1 AR5	1.5–4.5°C (no consensus)
Global mean temperature estimations for the long-term scenarios in the IPCC WG3 AR5 (employing MAGICC)	2.0–4.5°C (3.0°C) [Based on the AR4]

[The related descriptions of the SPM of WG1 AR5]

Likely in the range 1.5 °C to 4.5 °C (high confidence)

Extremely unlikely less than 1 °C (high confidence)

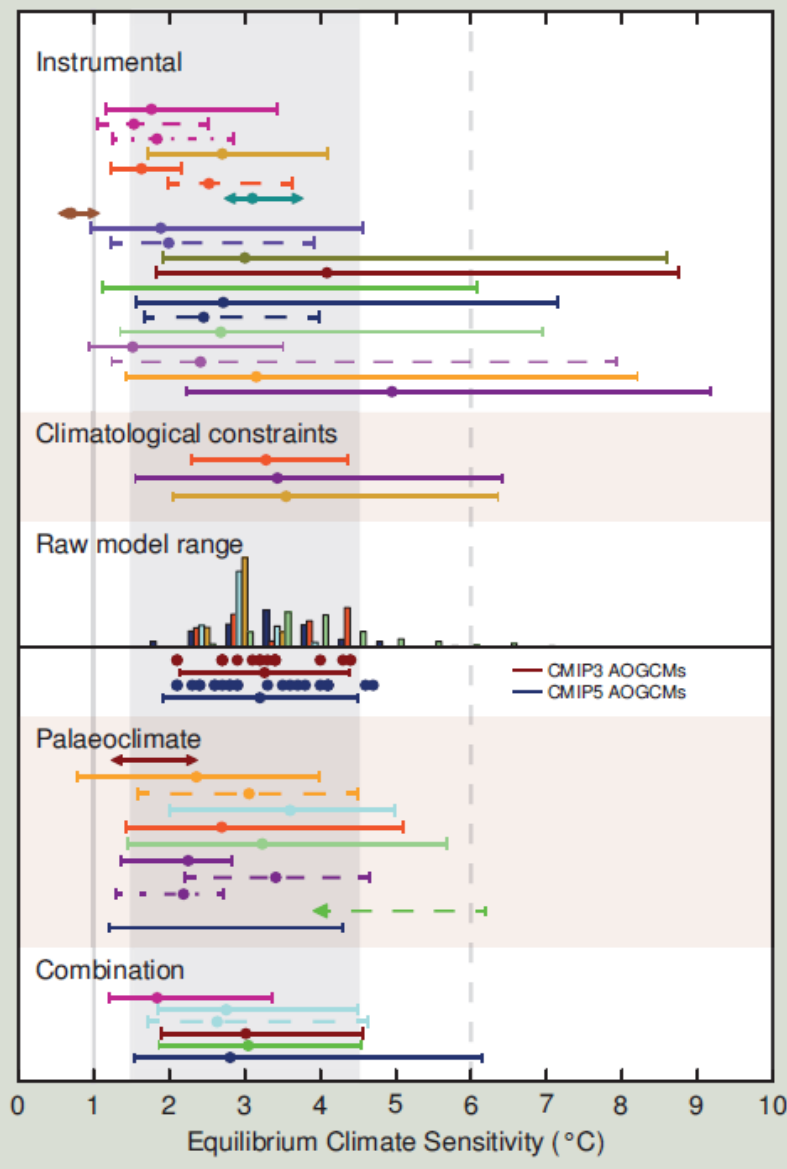
Very unlikely greater than 6 °C (medium confidence)

No best estimate for equilibrium climate sensitivity can now be given because of a lack of agreement on values across assessed lines of evidence and studies.

- ◆ The equilibrium climate sensitivity, which corresponds to global mean temperature increase in equilibrium when GHG concentration is doubles, is still greatly uncertain.
- ◆ AR5 WG1 judged the likely range of climate sensitivity to be 1.5–4.5 °C, in which the bottom range was changed to a smaller number than that in the AR4, based not only on CIMP5 (AOGCM) results but also other study results.
- ◆ However, AR5 WG3 adopted the climate sensitivity of AR4, which has the likely range of 2.0–4.5 °C with the best estimate of 3.0 °C, for temperature rise estimates of long-term emission scenarios.

Equilibrium climate sensitivity estimates and the IPCC WG1 expert judgment

[Evaluations in the IPCC WG1 AR5]



[A sample estimate after IPCC WG1 AR5]

- Lewis and Curry (2014):

1.25–2.45 °C [17–83% (66%) range];

1.05–4.05 °C [5–95% (90%) range];

best estimate : 1.64 °C

Estimates from AOGCMs

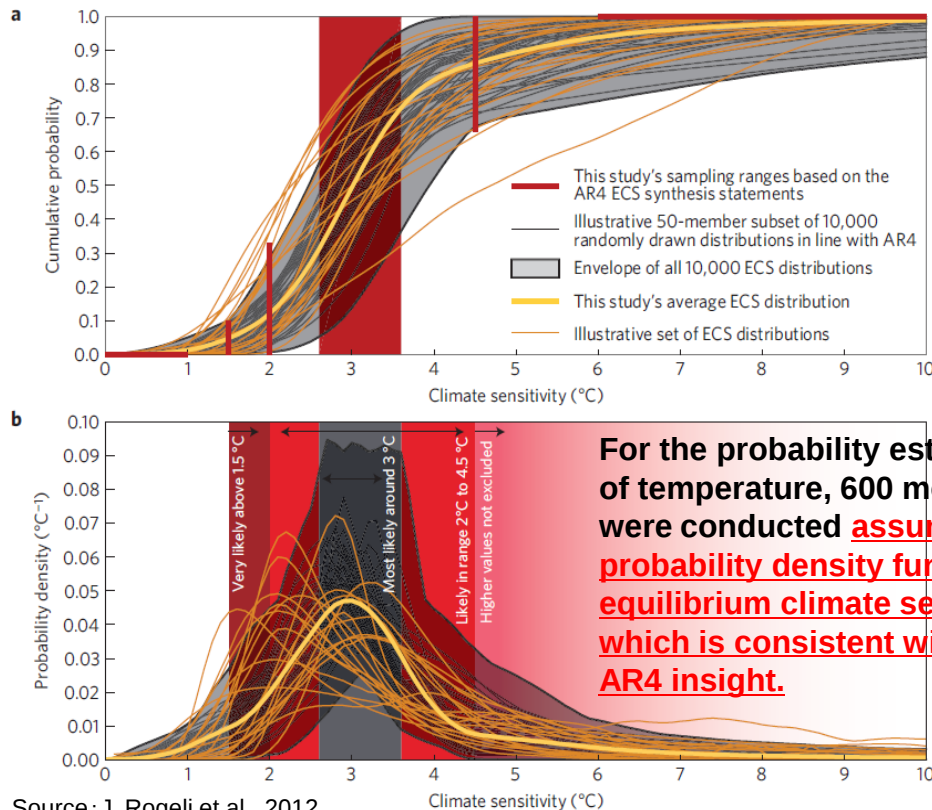
The model comparison project CMIP5: 2.0–4.5°C
with the mean value of 3.2 °C

(CMIP3 (for AR4):, 2.1–4.4°C; mean: 3.2 °C)

- ◆ The expert judgment of the AR5 WG1 was 1.5–4.5°C considering broad studies including instrumental and palaeoclimate studies. The lower boundary is smaller than that of the AR4 and the estimates of CMIP5.

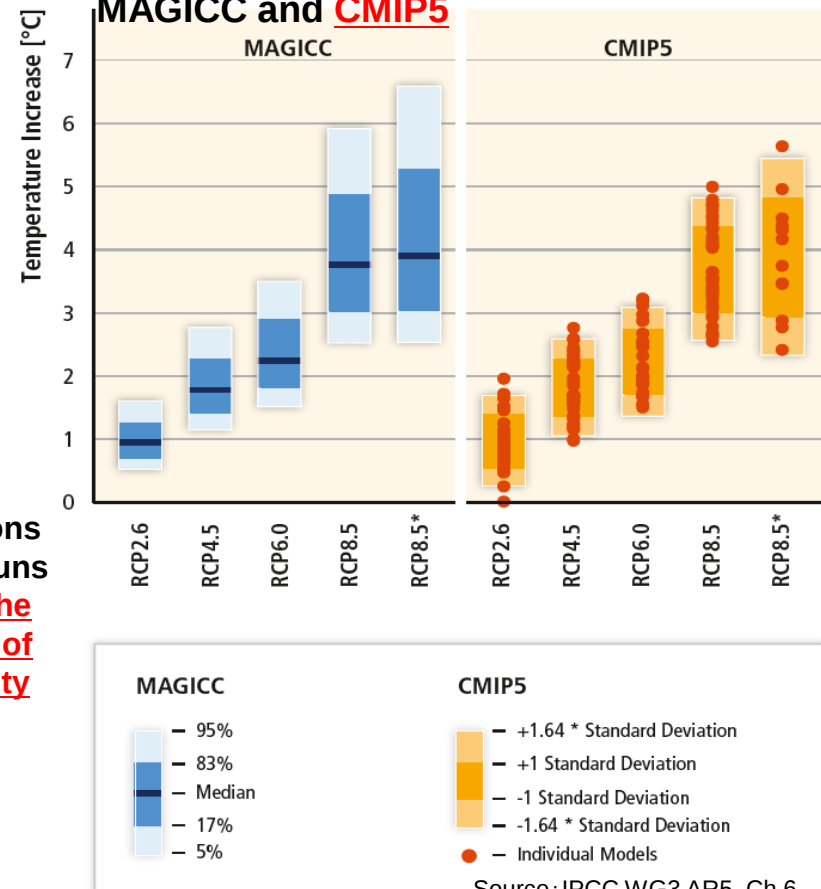
The climate sensitivity of MAGICC model which was employed for the temperature change estimations in the long-term scenarios of IPCC WG3 AR5

WG3 AR5 employed a simple climate change model MAGICC for the temperature estimates for long-term scenarios.



Source: J. Rogelj et al., 2012

The AR5 checked the differences between MAGICC and **CMIP5**

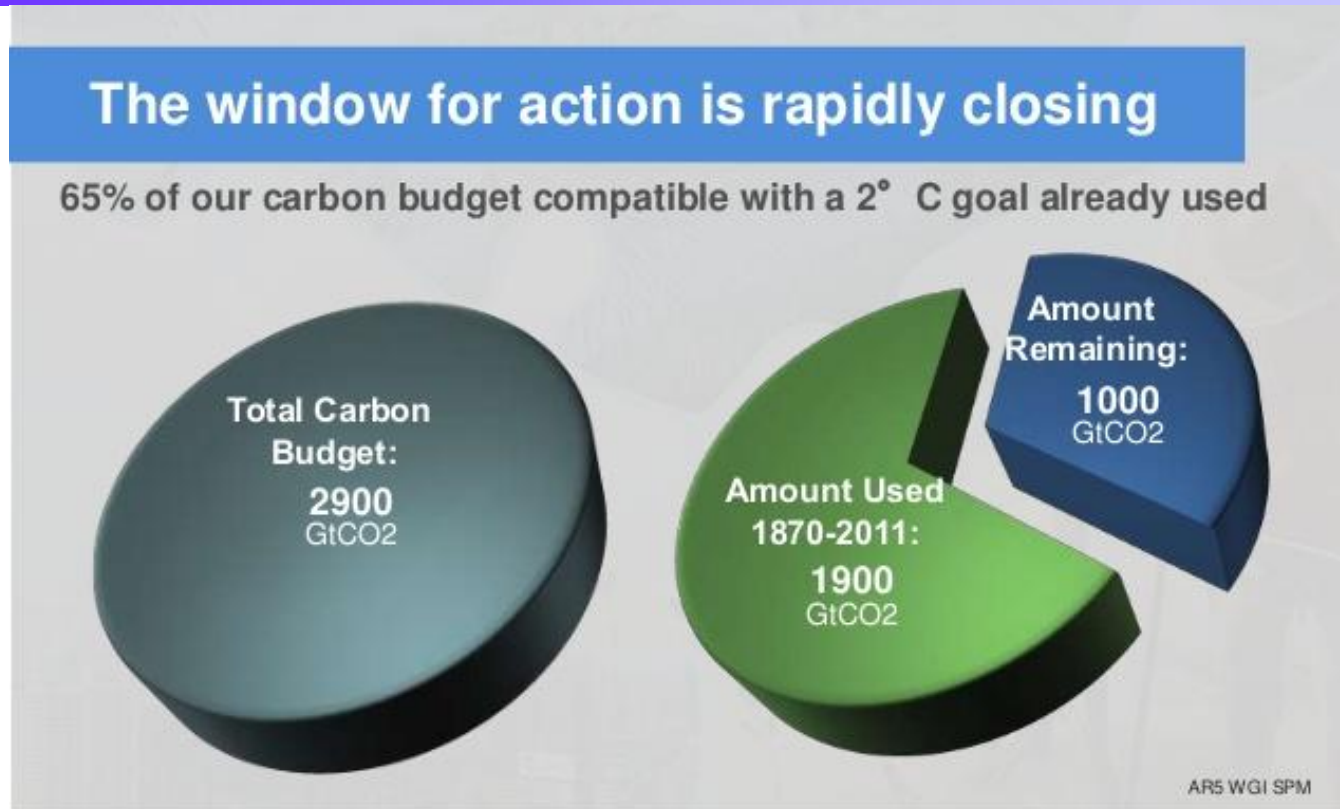


- ◆ WG3 AR5 employed the climate sensitivity of AR4 (likely range: 2.0–4.5 $^{\circ}\text{C}$, best estimate: 3.0 $^{\circ}\text{C}$) for estimating the temperature of long-term scenarios. This is almost consistent with the CMIP5 results but is inconsistent with the new judgment of WG1 AR5 considering other studies.
- ◆ Therefore, when the latest judgment for climate sensitivity of WG1 AR5 is employed, the temperature rise estimates of WG3 scenarios can be smaller than those shown in the WG3 AR5.

Points should be recognized (1)

- ◆ IPCC WG1 AR5 judged the likely range of climate sensitivity to be 1.5–4.5°C, in which the bottom range was changed to a smaller number than that in the AR4 (the likely range of 2.0–4.5°C; the best estimate of 3.0°C).
- ◆ However, the calculations of global mean temperature change for long-term scenarios in the WG3 AR5 adopted the climate sensitivity of AR4.
- ◆ The calculations of global mean temperature change for long-term scenarios in the WG3 AR4 adopted the "best estimate" or "most likely value" of climate sensitivity of 3.0°C. This also means that the achieving probability of temperature targets were adopted to be >50% (not adopting >66%).

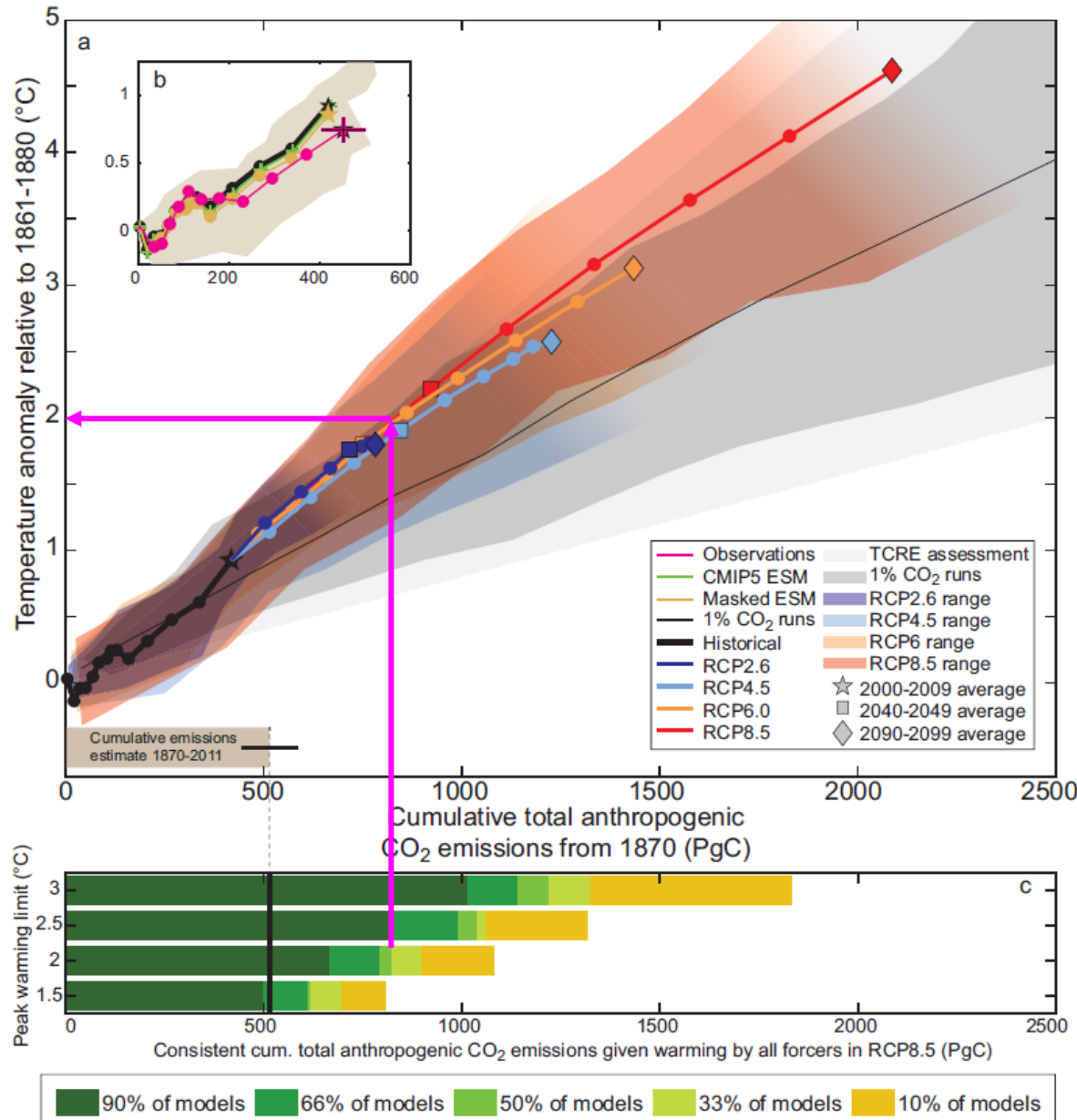
The IPCC “official” explanation for the allowable cumulative emissions for 2°C target



IPCC AR5 Synthesis Report

This presentation slide indicates that it is required to be limit of 2900 GtCO₂ of cumulative emissions in order to achieve +2 °C target, and that the rest of allowable emissions is only 1000 GtCO₂ because 1900 GtCO₂ has been already emitted by 2011. This explanation is conducted by the IPCC bureaus, but the IPCC reports do not provide such a simple outcome (will be discussed in the following slides).

The relationship between cumulative emissions and global mean temperature change (1/2)



This figure is estimated by the CMIP5 models (the equilibrium climate sensitivity of CMIP5: 2–4.5 °C; mean: 3.2 °C)

The solid lines in the figure show the average value of CMIP5 for RCPs, which means the results in the case of >50%.

>33% ⇒ 900 GtC (3300 GtCO₂)
【1500 GtCO₂】

>50% ⇒ 820 GtC (3010 GtCO₂)
【1300 GtCO₂】

>66% ⇒ 790 GtC (2900 GtCO₂)
【1000 GtCO₂】

(The numbers in 【】 show the allowable cumulative emissions after 2011.)

The discussions for the allowable global emissions beyond 2020 based on the rest of the budget of 1000 GtCO₂ are misleading.

Source) IPCC WG1 AR5, TS, TFE.8, Figure 1

Points should be recognized (2)

- ◆ IPCC bureaus make the presentation that the rest of allowable cumulative emissions is about 1000 GtCO₂ to achieve the 2°C target. However, the number is calculated by the AOGCMs that the range of climate sensitivity is 2.0–4.5°C and the mean value is 3.0°C which is consistent with those of AR4 (but not with the AR5) and in the case of achieving probability of the 2°C target of >66%.
- ◆ As pointed out in the (1), the climate sensitivity in the AR5 was changed to be lower than that in the AR4 considering the other types of estimates than AOGCMs.
- ◆ In addition, the figures in the IPCC AR5 for the relationship between cumulative emissions and temperature changes employed the case mainly of >50% probability.

The allowable cumulative emissions expected when the climate sensitivity is lower by 0.5 °C

Estimates based on CMIP5:
2–4.5°C (mean: 3.2°C)

Cumulative CO ₂ emissions from 1870 in GtCO ₂									
Net anthropogenic warming ^a	<1.5°C			<2°C			<3°C		
Fraction of simulations meeting goal ^b	66%	50%	33%	66%	50%	33%	66%	50%	33%
Complex models, RCP scenarios only ^c	2250	2250	2550	2900	3000	3300	4200	4500	4850
Simple model, WGIII scenarios ^d	No data	2300 to 2350	2400 to 2950	2550 to 3150	2900 to 3200	2950 to 3800	n.a. ^e	4150 to 5750	5250 to 6000
Cumulative CO ₂ emissions from 2011 in GtCO ₂									
Complex models, RCP scenarios only ^c	400	550	850	1000	1300	1500	2400	2800	3250
Simple model, WGIII scenarios ^d	No data	550 to 600	600 to 1150	750 to 1400	1150 to 1400	1150 to 2050	n.a. ^e	2350 to 4000	3500 to 4250
Total fossil carbon available in 2011 ^f : 3670 to 7100 GtCO ₂ (reserves) and 31300 to 50050 GtCO ₂ (resources)									

IPCC Synthesis report, Table 2.2

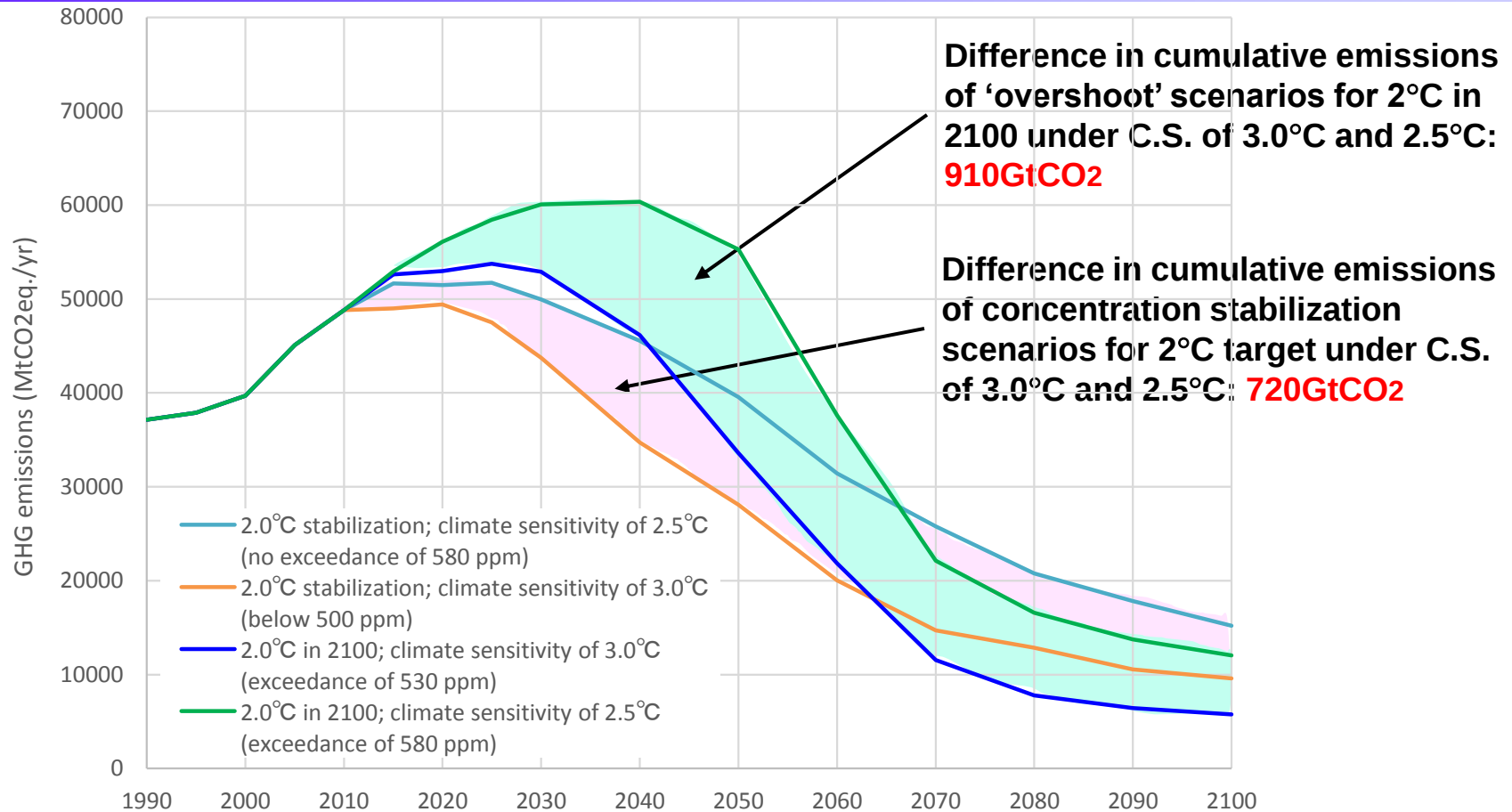
The difference is 750 Gt for the temperature difference of 0.5 °C.

Estimates by
MAGICC:
2.0–4.5°C
(median: 3.0°C)

Note: The ranges in the table are generated by differences in non-CO₂ GHG emission scenarios.

Although there are differences between temperature estimate and equilibrium climate sensitivity, a rough estimation can be conducted: 1300-550=750 GtCO₂. According to this estimate, the rest of the allowable cumulative emission will be about **2000 GtCO₂ even for the 2 °C target**, when the achieving probability of **50%> and the climate sensitivity of 2.5 °C are employed**. (This is consistent with the cumulative emissions of 530-580 ppm scenarios provided by the IPCC WG3 AR5.)

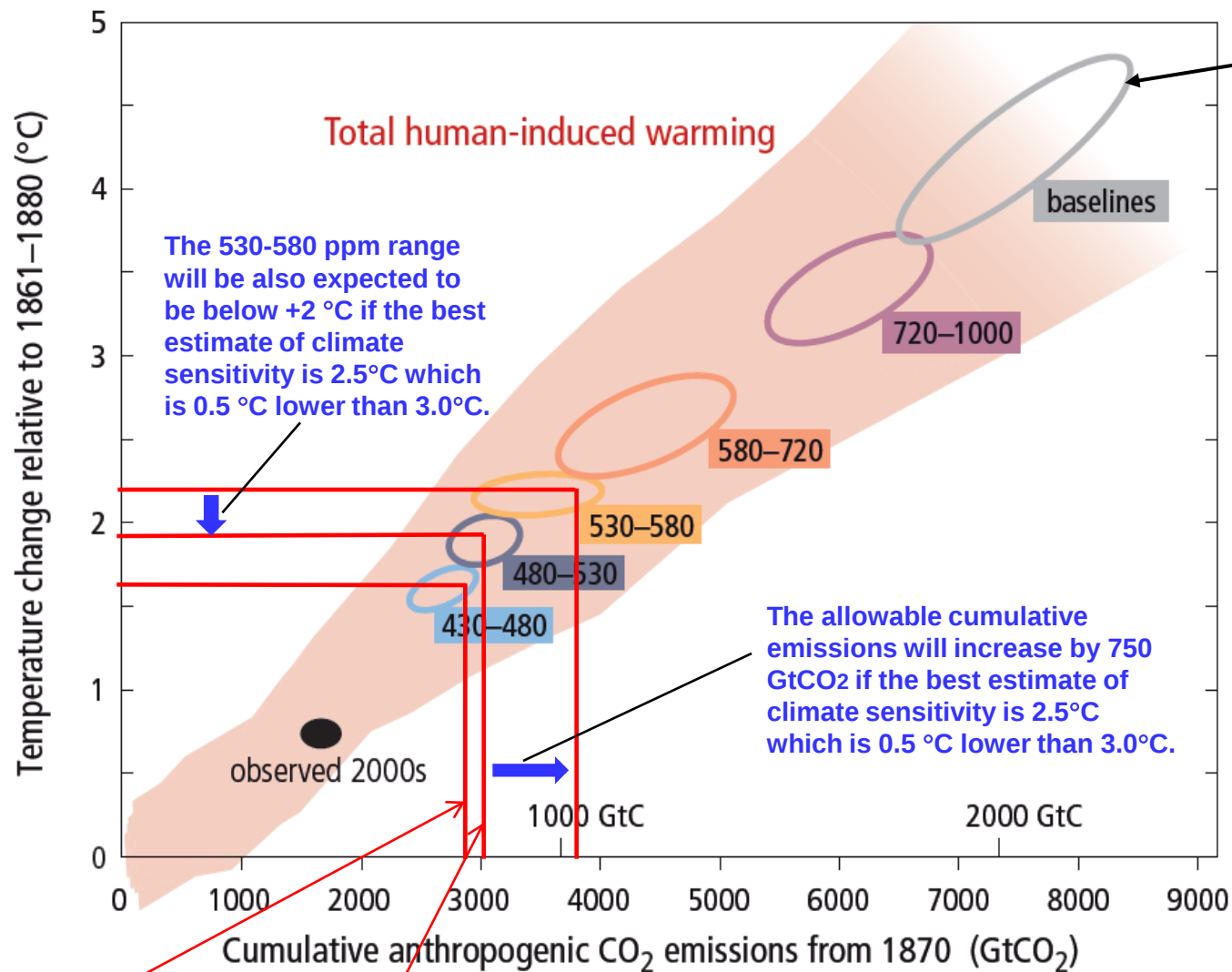
Differences in the allowable cumulative emissions to 2100 for 2 °C target between the two climate sensitivity of 3.0 and 2.5 °C



Note: GHG emissions are positive in the figure but CO₂ emissions in the second half of this century are negative for the 2 °C target under the climate sensitivity of 3 °C.
Source: estimated by RITE

The previous slide indicates that the allowable cumulative emissions of about **750 GtCO₂** increase if the climate sensitivity is changed from 3.0 °C to 2.5 °C, according to the IPCC estimates (The figure and table which is estimated based on the CIMP5 results). In addition, according to the emission pathways by RITE and MAGICC model estimates, the allowable cumulative emissions will be about **720–910 GtCO₂**. The two different kinds of estimations are almost consistent with each other.

Relationship between cumulative emissions and CO₂ concentration and temperature change



Ellipses show the relationship between the cumulative emissions and CO₂ concentration and the expected temperature change by the median estimates (>50% probability) of MAGICC with the most likely value of climate sensitivity of 3.0 °C.

The 2900 GtCO₂ corresponds to 430-480 ppm, and 2°C with >66% probability.

The 3000 GtCO₂ corresponds to 480-530 ppm, and 2°C with >50% probability.

Source: modified by RITE based on Figure SPM.5 of the Synthesis Report of IPCC AR5

Probabilities to achieve 2°C target and the global emission allowance in 2050

Long-term scenarios summarized by IPCC WG3 AR5

Estimated by a simple climate
change model MAGICC

Equilibrium climate sensitivity is based on that of the AR4 (the likely range: 2.0–4.5 °C, best estimate: 3.0 °C)

Likelihood of
staying below 2°C

CO2eq concentration in 2100 (ppm CO2eq)	Subcategories	RCP	CO2eq emissions in 2050 relative to 2010	2100 temperature (°C, relative to 1850-1900)	Probability of exceeding the target temperatures		
					1.5°C	2.0°C	3.0°C
<430	Only a limited number of individual model studies have explored levels below 430 ppm CO2eq						
450 (430-480)	—	RCP2.6	-72~-41%	1.5~1.7°C (1.0~2.8)	49-86%	12-37%	1-3%
500 (480-530)	Exceedance of 530 ppm CO2eq		-57~-42%	1.7~1.9°C (1.2~2.9)	80-87%	32-40%	3-4%
	Exceedance of 530 ppm CO2eq		-55~-25%	1.8~2.0°C (1.2~3.3)	88-96%	39-61%	4-10%
550 (530-580)	No exceedance of 580 ppm CO2eq		-47~-19%	2.0~2.2°C (1.4~3.6)	93-95%	54-70%	8-13%
	Exceedance of 580 ppm CO2eq		-16~+7%	2.1~2.3°C (1.4~3.6)	95-99%	66-84%	8-19%
(580-650)	—	RCP4.5	-38~+24%	2.3~2.6°C (1.5~4.2)	96-100%	74-93%	14-35%
(650-720)	—		-11~+17%	2.6~2.9°C (1.8~4.5)	99-100%	88-95%	26-43%
(720-1000)	—	RCP6.0	+18~+54%	3.1~3.7°C (2.1~5.8)	100-100%	97-100%	55-83%
>1000	—	RCP8.5	+52~+95%	4.1~4.8°C (2.8~7.8)	100-100%	100-100%	92-98%

>66% (the C.S. is derived from the CMIP5)

>50% (the C.S. is derived from the CMIP5)

Probably, >66% (the C.S. is derived from the WG1's latest insight: 1.5–4.5 °C)

Probably, >50% (the C.S. is derived from the WG1's latest insight: 1.5–4.5 °C)

Note: IPCC AR4 only shows the temperature estimates of the best estimate which is almost consistent with the achievability of >50%.

- For the 2 °C target with the likelihood of >66%, the global emission in 2100 should be reduced by 72–42%, but with the likelihood of >50% (which is consistent with the AR4 estimates using the best estimate of climate sensitivity) the emission should be reduced by >25%.
- The temperatures and the likelihoods were estimated by MAGICC in which the climate sensitivity was employed based on the AR4 insight (2.0–4.5 °C, best estimate: 3.0 °C). When the latest insight of WG1 AR5 (1.5–4.5 °C) is employed, the 530-580 ppm category scenarios also meet the 2 C target with >50% likelihood. In this case, the global emissions in 2050 are -72 to +7% relative to 2010.

Points should be recognized (3)

- ◆ The allowable cumulative emissions for achieving the 2°C target will increase by 750 GtCO₂ if the best estimate of climate sensitivity is 2.5°C which is 0.5°C lower than 3.0°C.
- ◆ Based on the estimations, the rest of the allowable cumulative emissions for achieving the 2°C target will be around 2000 GtCO₂, which is almost double compared with 1000 GtCO₂ which is explained by the IPCC bureaus.
- ◆ The concentration of 530–580 ppm CO₂eq. also expect to achieve the 2°C target with probability of >50%.
- ◆ The corresponding global GHG emissions in 2050 are -47–+7% relative to 2010. Some people interpret that the IPCC reports concluded the 2°C target = 430–480 ppm CO₂eq.= -72–-41% in 2050 relative to 2010. However, this is not necessarily correct, and rather the IPCC reports should be interpreted in the above for the precise understandings.

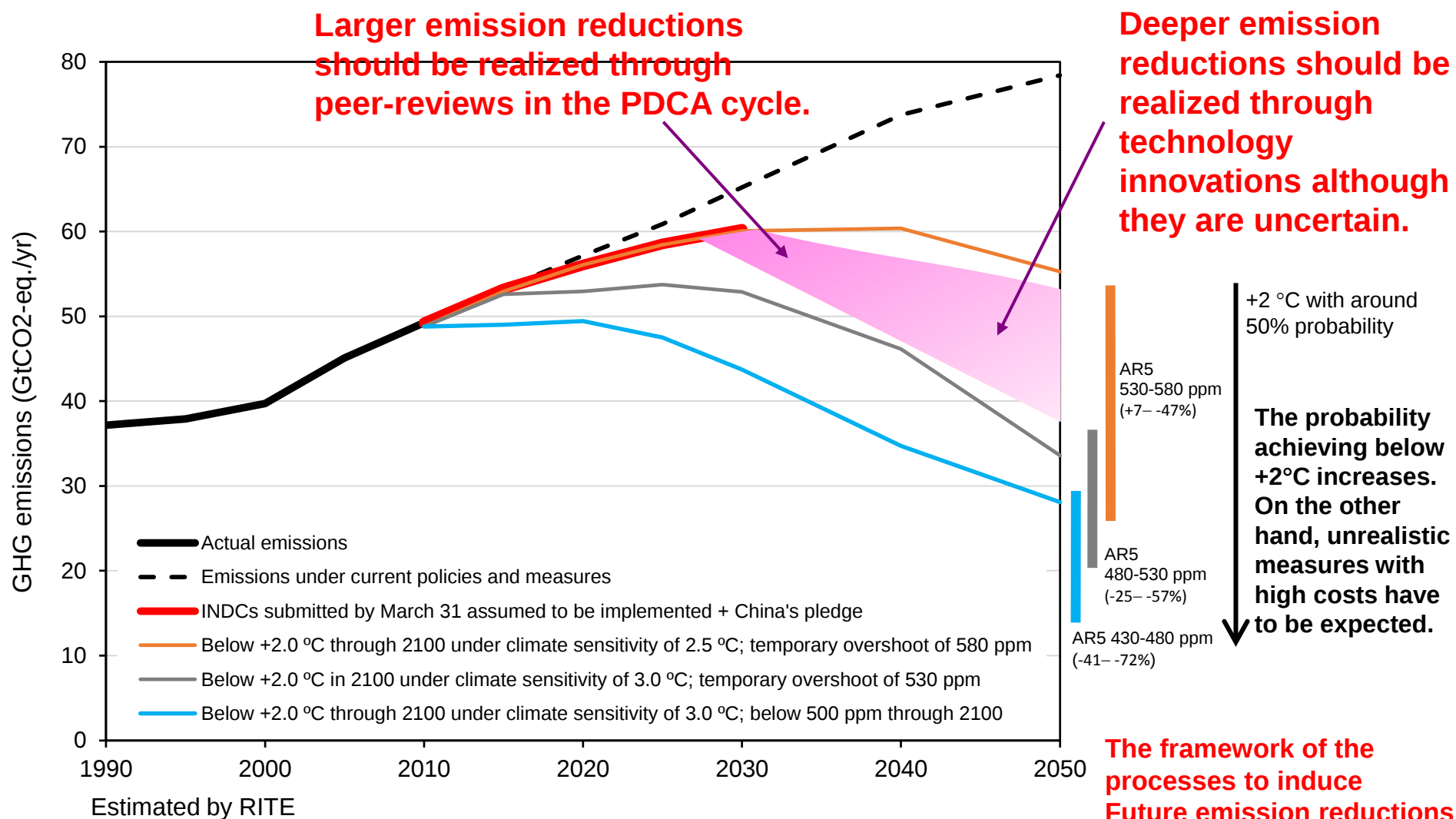
Evaluated INDCs

(The submitted countries by the end of March 2015 and China)

	INDCs (in the end of March 2015)	Supplementary explanations on the evaluations in this study
United States	26–28% reduction in GHG by 2025 relative to 2005	17% reduction in GHG by 2020 relative to 2005; 37–38% reduction in GHG by 2030 relative to 2005, which is assumed by using a linear interpolation between 2025 and 2050 targets of 80% reduction
EU28	40% reduction in GHG by 2030 relative to 1990	24% reduction in GHG by 2020 relative to 1990 (Reference scenario 2013 in “EU energy, transport and GHG emissions trends to 2050”)
Norway	40% reduction in GHG by 2030 relative to 1990	30–40% reduction in GHG by 2020 relative to 1990
Switzerland	50% reduction in GHG by 2030 relative to 1990 (By 2025, 35% reduction in GHG relative to 1990 is anticipated.)	20–30% reduction in GHG by 2020 relative to 1990
Russia	25–30% reduction in GHG by 2030 relative to 1990	15–25% reduction in GHG by 2020 relative to 1990
Mexico	25–40% reduction in GHG + black carbon by 2030 compared to BaU levels (22–36% reduction in GHG by 2030 compared to BaU levels)	A net emissions peak starting from 2026
China	No submission (However, China expressed net emissions peak starting from 2030.)	40–45% reduction in CO ₂ intensity per unit of GDP by 2020 relative to 2005; GHG emission in 2030 is assumed to be 15.0–16.5 GtCO ₂ eq.

Note) Gabon submitted her INDC by the end of March 2015, but this study does not evaluate her INDC.

The relationship between climate sensitivity and global emission pathways for 2°C target, and outlook of INDCs



There are large gaps between the expected global emission under current INDCs and the emission pathway to 2°C target under climate sensitivity of 3.0°C. However, the INDCs are consistent with 2°C target if climate sensitivity is 2.5°C.

The framework of the processes to induce Future emission reductions are more important than the levels of INDCs decided in COP21.

Conclusion

- ◆ **Climate sensitivity has still large uncertainty. Equilibrium climate sensitivity was changed to 1.5–4.5 °C in the AR5 from 2.0–4.5 °C with 3.0 °C of best estimate in the AR4.**
- ◆ **However, the temperature rise estimates for the WG3 long-term scenarios were estimated based on the AR4 insight on the climate sensitivity. Therefore, the temperatures will be smaller than those shown in the WG3 AR5 when the climate sensitivity based on the AR5 is employed.**
- ◆ **The estimates of the allowable cumulative emissions for 2 °C target provided by IPCC are based on the CMIP5 results, whose the climate sensitivity evaluations correspond to those of AR4. When the new judgment of the climate sensitivity of AR5 is employed, the allowable cumulative emissions are also much bigger.**
- ◆ **Even when the long-term target of 2 °C persists, it is not necessarily correct that the remaining allowable cumulative emission is 1000GtCO₂ and the global emission in 2050 is required to reduce by 40 to 70% relative to 2010. These numbers change greatly when the climate sensitivity is changed just by 0.5 °C. Therefore, the numbers should be taken flexibly to avoid the deadlock of the negotiations toward COP21. The acceptance of flexibility is considered more scientific.**
- ◆ **The expected global emission from the INDCs submitted by the end of March 2015 and the pledge of China has large gaps from the emission pathways for 2 °C under the climate sensitivity of 3 °C, but they are almost within the allowable pathway for 2 °C target under the sensitivity of 2.5 °C.**