Shiogama et al. Emergent constraints on future precipitation changes. *Nature*, 602, 612–616 (2022)

Observational constraints on the uncertainties of the future precipitation change projections

Hideo Shiogama[1], Masahiro Watanabe[2], Hyungjun Kim[3,4,5] & Nagio Hirota[1]

[1]Earth System Division, National Institute for Environmental Studies, Tsukuba, Japan

[2]Atmosphere and Ocean Research Institute, University of Tokyo, Kashiwa, Japan

[3]Moon Soul Graduate School of Future Strategy, KAIST, Daejeon, Korea

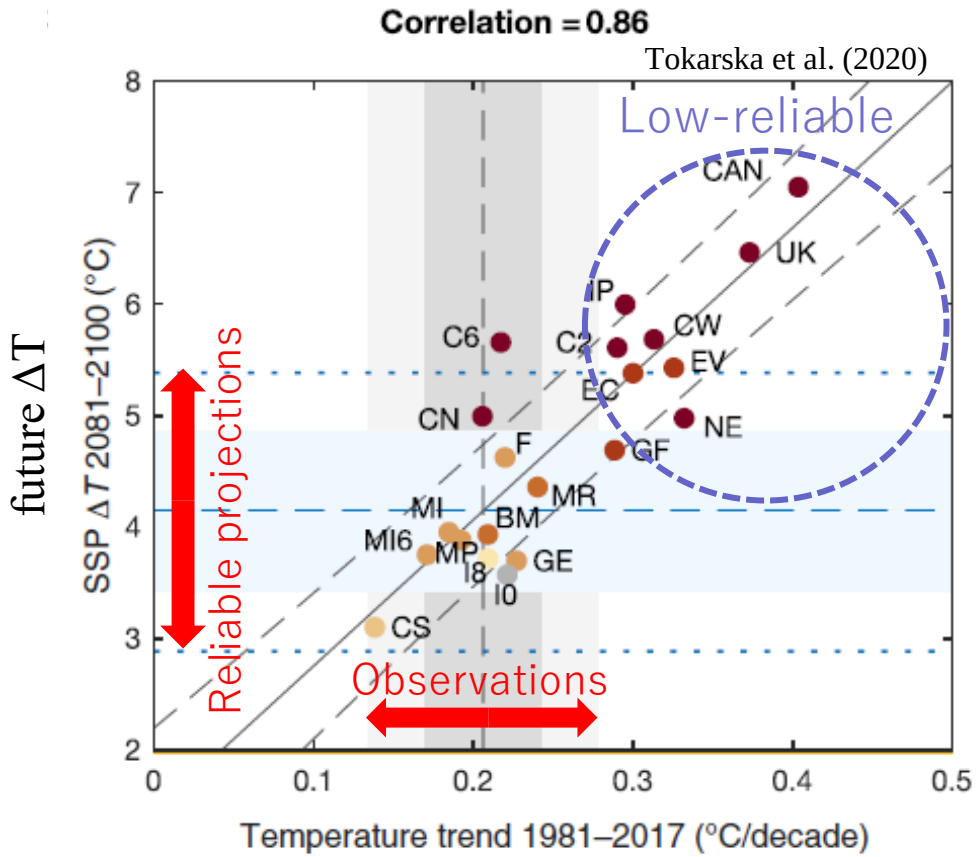
[4]Dept. of Civil and Environmental Engineering, KAIST, Daejeon, Korea

[5]Institute of Industrial Science, University of Tokyo, Tokyo, Japan

Emergent constraints (ECs) of global mean temperature changes (ΔT)

- Emergent constraints (ECs) are promising approaches to constrain discrepancies of climate change projections between ESMs.

- If we can find a significant relationship between observable past metrics and future changes of ESMs (emergent relationship), there is a possibility to constrain the uncertainty range of future projection.
- If some ESMs are inconsistent with observations, we can consider that their future projections are less reliable.
- By applying "smaller weights for less reliable models", we can reduce the uncertainty range of the future projections.
- There are a lot of EC studies of global mean temperature changes (ΔT).
- By contrast, no studies have successfully proposed ECs of the global mean precipitation change (ΔP) .
- Long-term (e.g. 1850-2014) historical trends of P is largely affected by aerosols, while future ΔP is mainly caused by the GHG increases. Because there are differences in the external forcing factors between the future and past, it is difficult to propose ECs of ΔP.

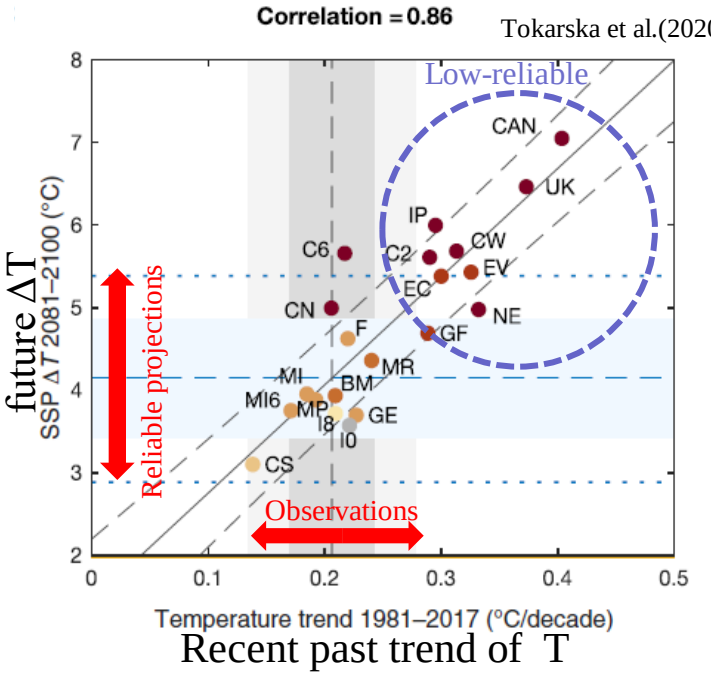


future ΔT

Recent past trend of T

Introduction: our idea of EC of ΔP

- Tokarska et al. (2020) suggested that the upper bound of future ΔT can be lowered by using the T trend for the recent decades after 1980.
- The global anthropogenic aerosol emissions were nearly constant during the recent decades after 1980, because the aerosol emissions increased in China and India while decreased in Europe, US and Japan.
- The influence of the constant aerosol forcing is small in the *recent trends* of T.
- Because both the recent T trends and the future ΔT are mainly driven by greenhouse gas increases, there is a significant positive correlation between the two.



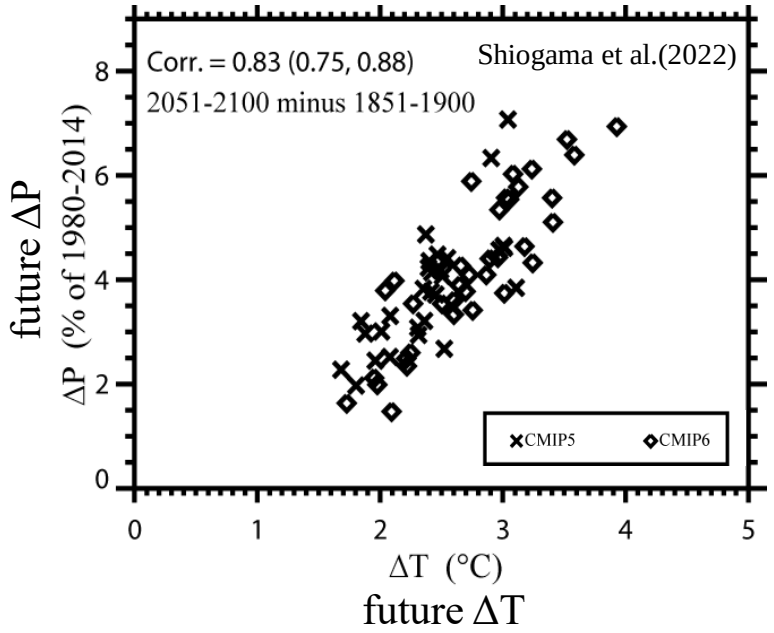
Tokarska et al.(2020)

Recent past trend of T

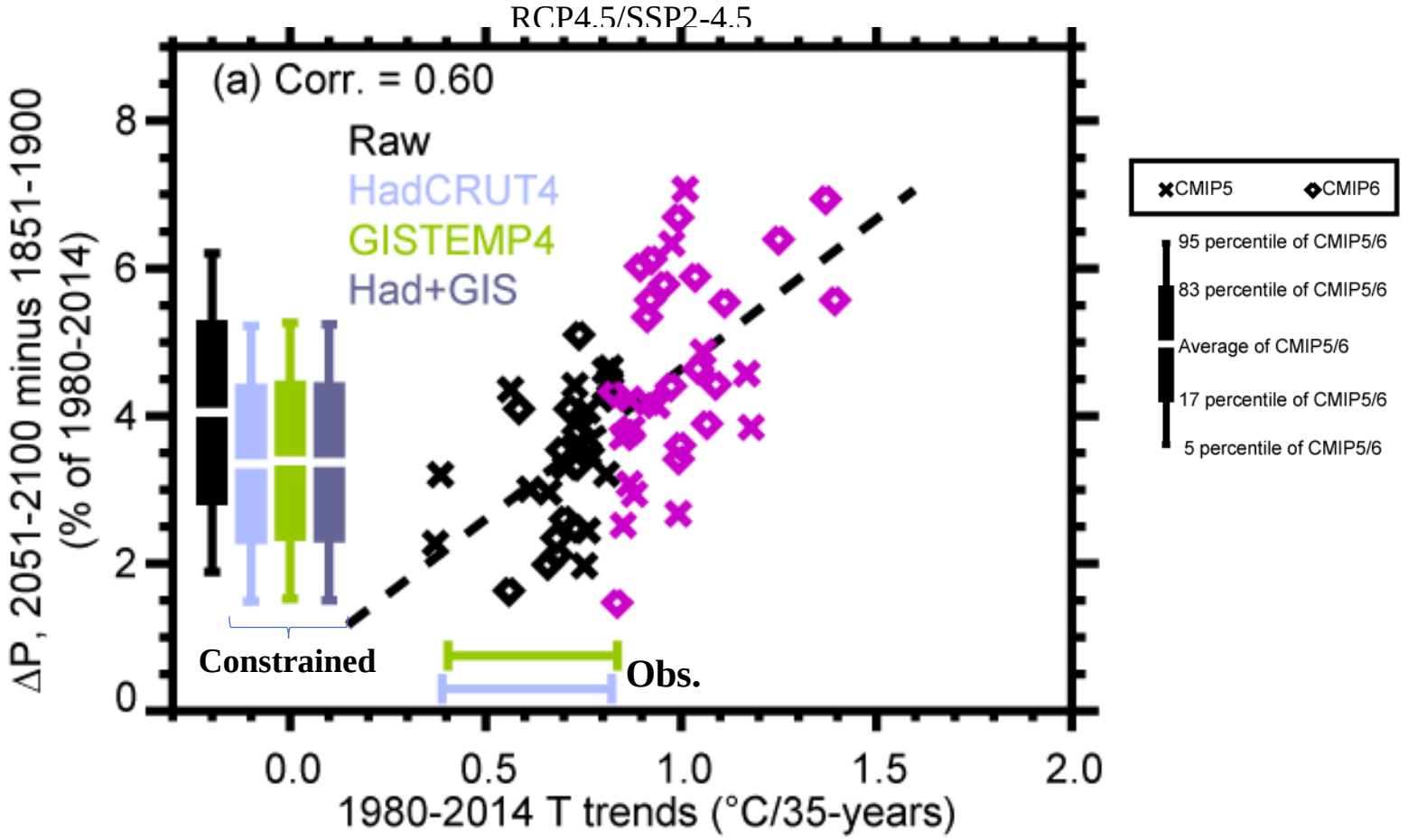
We extend this idea of Tokarska et al. (2020) to EC of ΔP.

[Idea 1] Future ΔP are well related to future ΔT in the CMIP5/6 ensembles. Can we constrain future ΔP by using the recent T trends?

[Idea 2] The influence of the constant aerosol forcing would be small on the *recent past trends* of P. Can we constrain future ΔP by using the recent P trends?

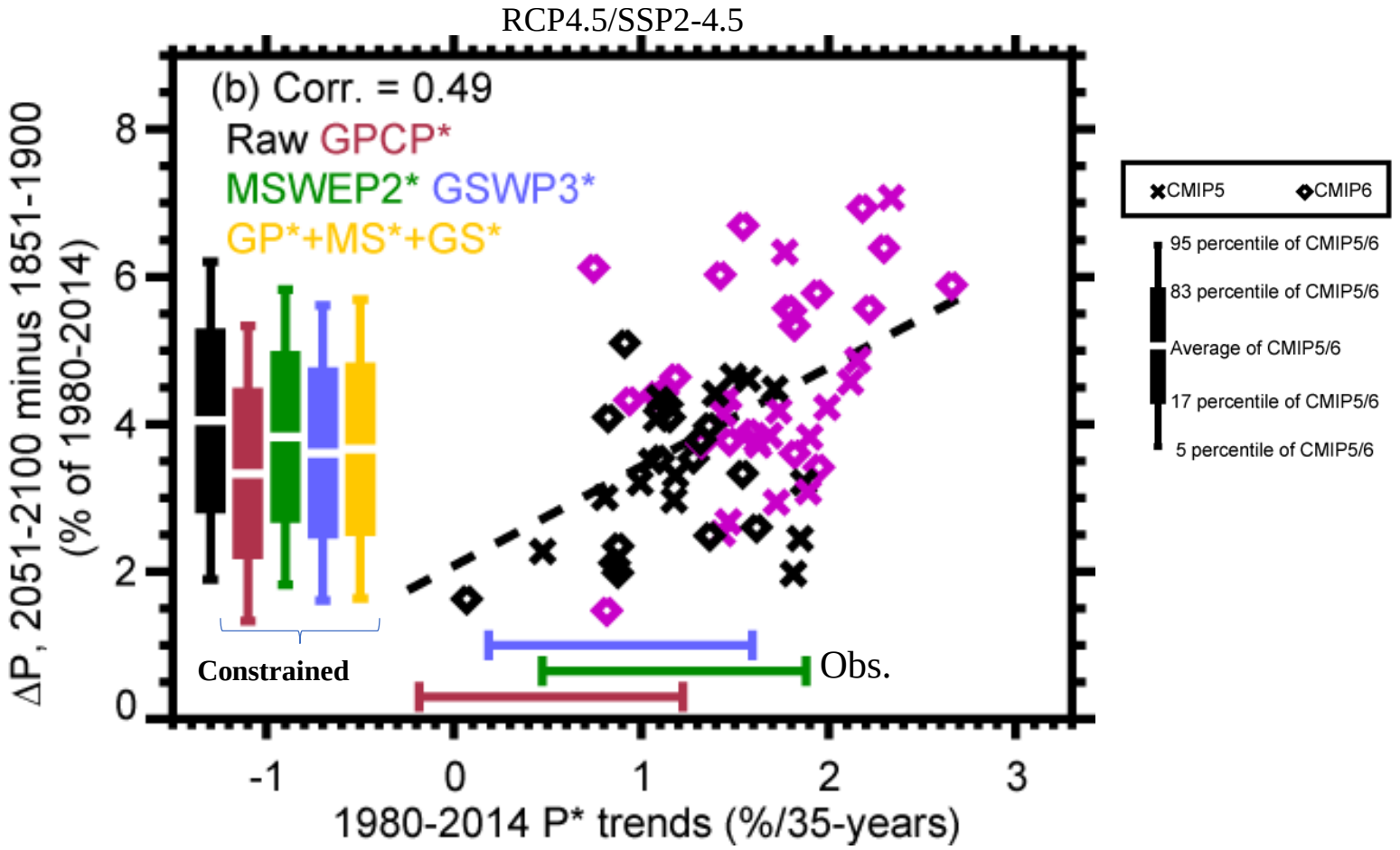


EC on future ΔP by using the recent past trends of T



- Significant correlation between the future ΔP and the recent past T trends.
- ESMs with larger warming in the recent past tend to simulate greater ΔP in the future.
- Some ESMs overestimate the recent past T trends.
- We can lower the upper bound of the future ΔP.

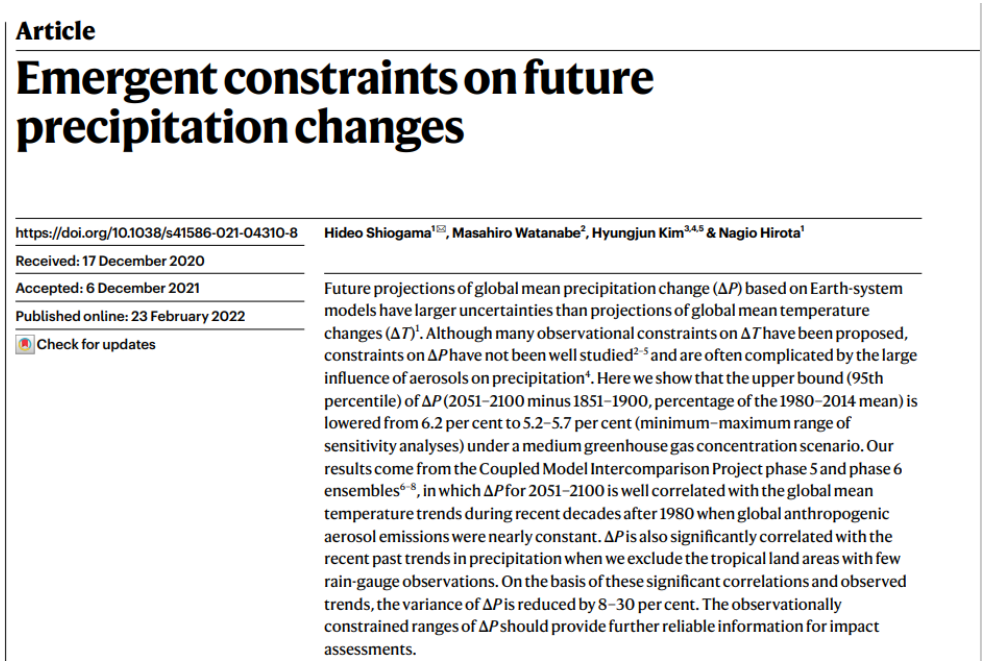
EC on future ΔP by using the recent past trends of P*



- P* indicates precipitation averaged over the world but excluding some tropical land regions with few rain gauge observations.
- Significant correlation between the future ΔP and the recent past P* trends.
- ESMs with larger trends of P* in the recent past tend to simulate greater ΔP in the future.
- We can lower the upper bound of the future ΔP.

Summary

- We are the first to succeed in observationally constraining the uncertainty in the global mean precipitation changes up to the end of the 21st century by reducing the confounding influence of anthropogenic aerosols in our analysis.
- The upper end of the ΔP in the CMIP5/6 ESMs is lowered from 6.2% in the raw CMIP5/CMIP6 ESMs to 5.2-5.7% under the medium greenhouse gas concentration scenario.
- The variance of the future ΔP is reduced by 8-30%.
- The observationally constrained ranges of ΔP should provide further reliable information for impact assessments.



Article

Emergent constraints on future precipitation changes

https://doi.org/10.1038/s41586-021-04310-8
Received: 17 December 2020
Accepted: 6 December 2021
Published online: 23 February 2022
Check for updates

Hideo Shiogama[1]✉, Masahiro Watanabe[2], Hyungjun Kim[3,4,5] & Nagio Hirota[1]

Future projections of global mean precipitation change (Δ*P*) based on Earth-system models have larger uncertainties than projections of global mean temperature changes (Δ*T*)[1]. Although many observational constraints on Δ*T* have been proposed, constraints on Δ*P* have not been well studied[2–5] and are often complicated by the large influence of aerosols on precipitation[4]. Here we show that the upper bound (95th percentile) of Δ*P* (2051–2100 minus 1851–1900, percentage of the 1980–2014 mean) is lowered from 6.2 per cent to 5.2–5.7 per cent (minimum–maximum range of sensitivity analyses) under a medium greenhouse gas concentration scenario. Our results come from the Coupled Model Intercomparison Project phase 5 and phase 6 ensembles[6–8], in which Δ*P* for 2051–2100 is well correlated with the global mean temperature trends during recent decades after 1980 when global anthropogenic aerosol emissions were nearly constant. Δ*P* is also significantly correlated with the recent past trends in precipitation when we exclude the tropical land areas with few rain-gauge observations. On the basis of these significant correlations and observed trends, the variance of Δ*P* is reduced by 8–30 per cent. The observationally constrained ranges of Δ*P* should provide further reliable information for impact assessments.

Shiogama et al. Emergent constraints on future precipitation changes. *Nature*, 602, 612–616 (2022)