Time dependence of climate sensitivity

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Short Summary

Many models show a change in climate sensitivity between the first 20 years (early period) and the succeeding years (late period) in abrupt forcing experiments. Here we investigate the role of the Eastern Pacific (EP) region on climate sensitivity in CMIP5 and CMIP6.

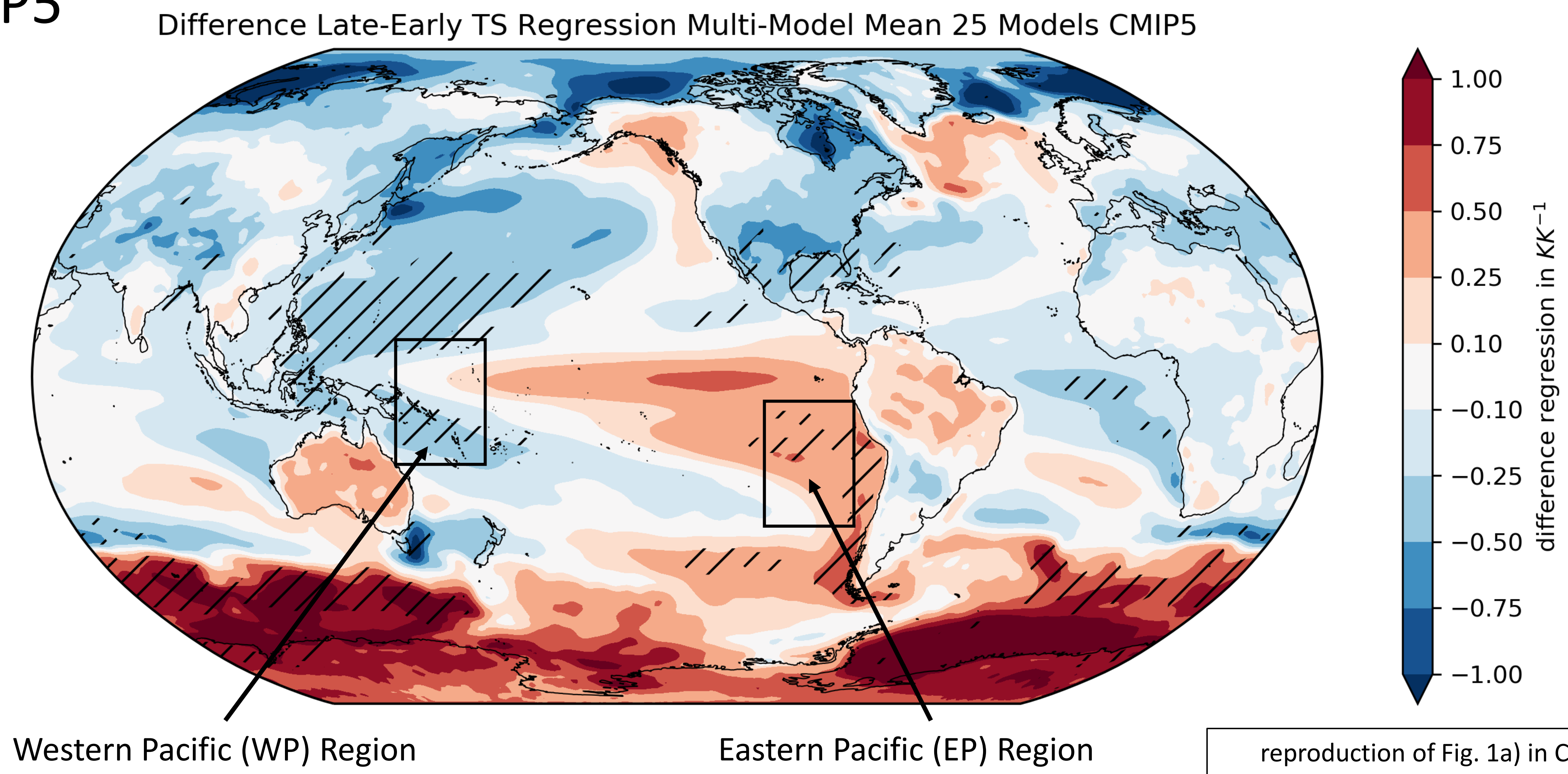
General Points

- model experiments from CMIP5 & 6:
  - abrupt4xCO2 (150 years)
  - piControl (150 years corresponding to the abrupt4xCO2 run)

- convention:
  - early period: years 1-20
  - late period: years 21-150

- number of models available with the required data:
  - CMIP5: 25
  - CMIP6: 22

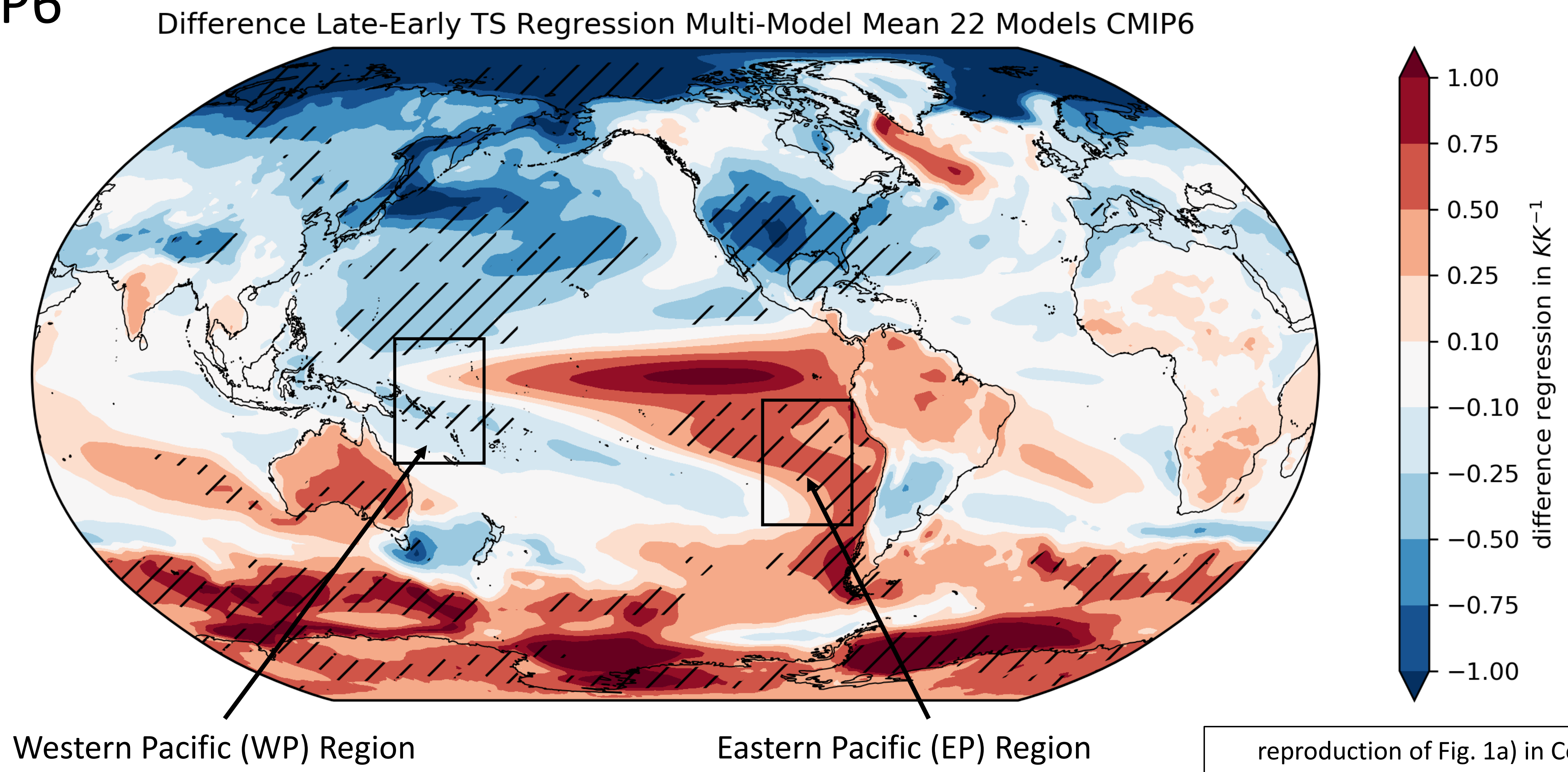
CMIP5



reproduction of Fig. 1a) in Ceppi and Gregory (2017) with more CMIP5 members

- red: the surface temperature rises more strongly in the late than in the early period compared to the global mean
- blue: the surface temperature rises more strongly in the early than in the late period compared to the global mean
- hatching: multi-model mean absolute anomaly > 1 standard deviation across all models

CMIP6



reproduction of Fig. 1a) in Ceppi and Gregory (2017) with CMIP6 members

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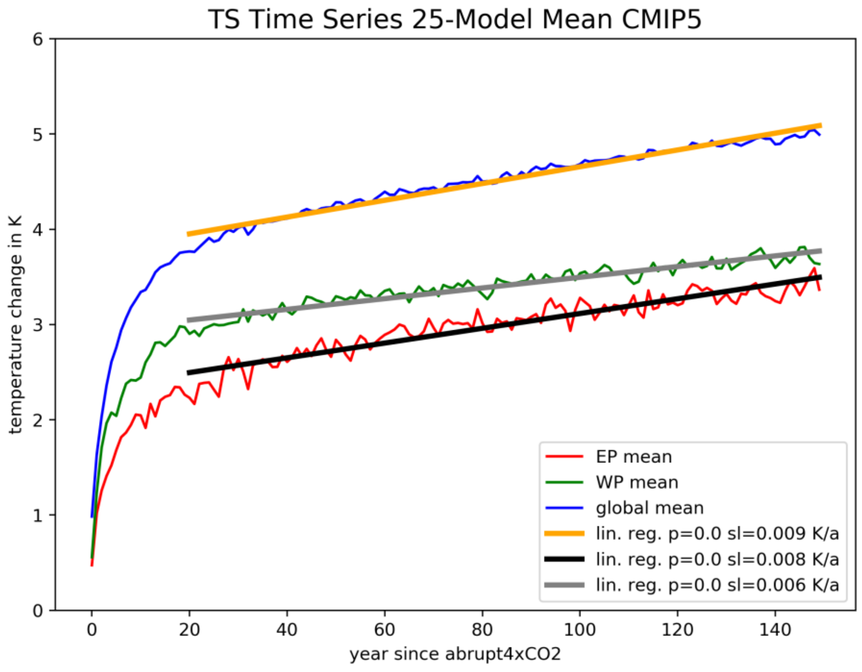
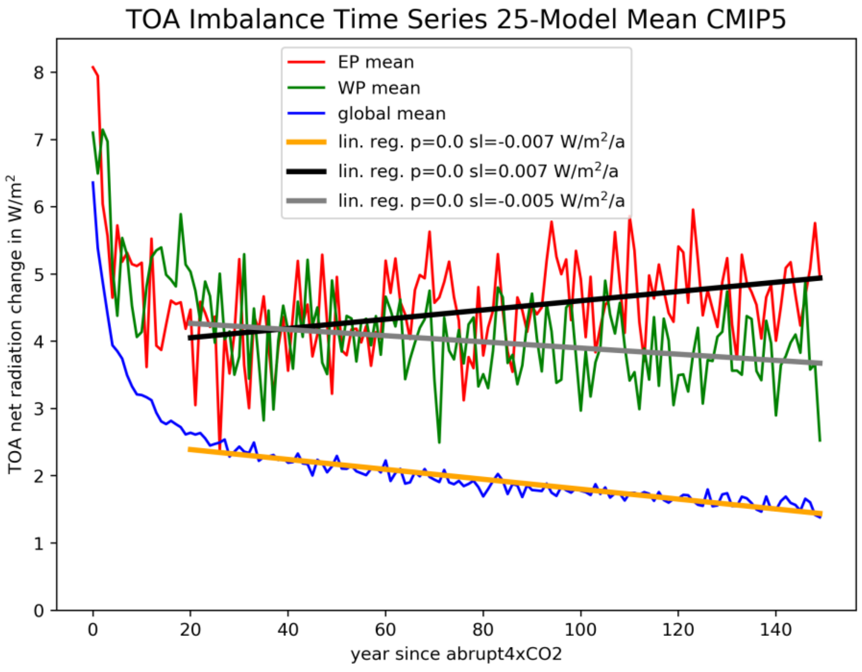
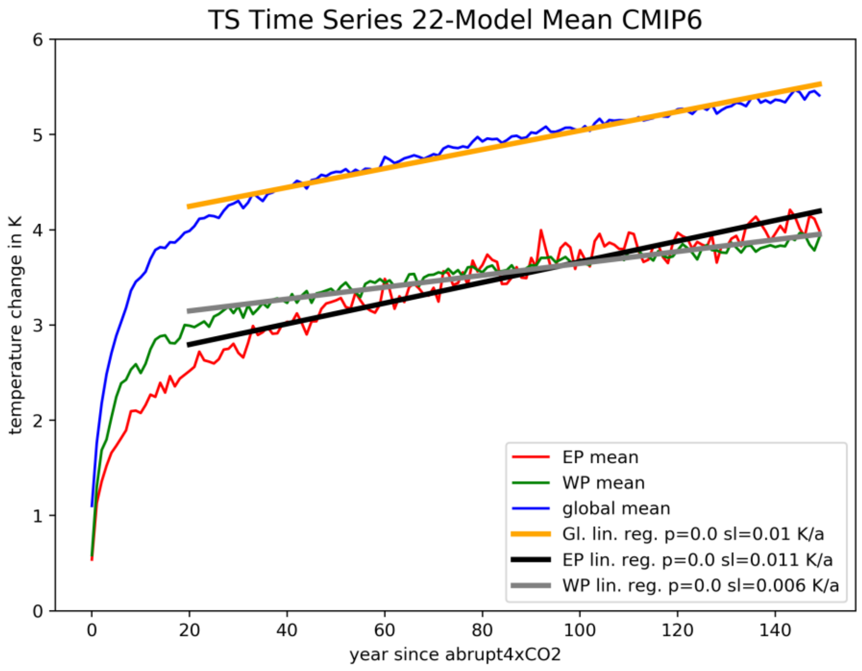
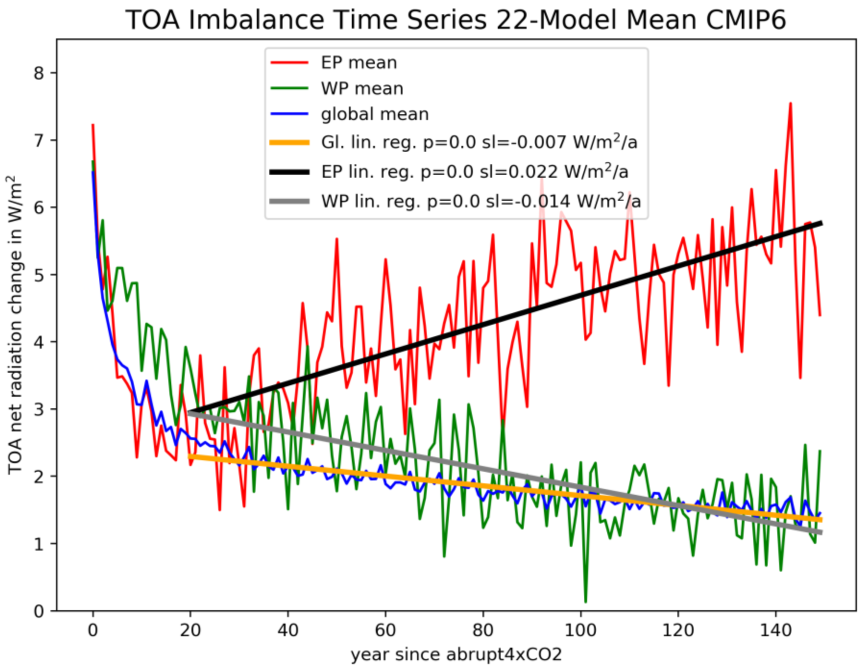
Methodolgy for the two previous figures

- from Ceppi and Gregory (2017)
- divide the 150-year model experiment into an early (years 1-20) and a late (years 21-150) period
- for both periods regress the local surface temperature anomalies (annual means) onto the global mean annual mean surface temperature
- subtract the slope of the regression of the early period from that of the late period

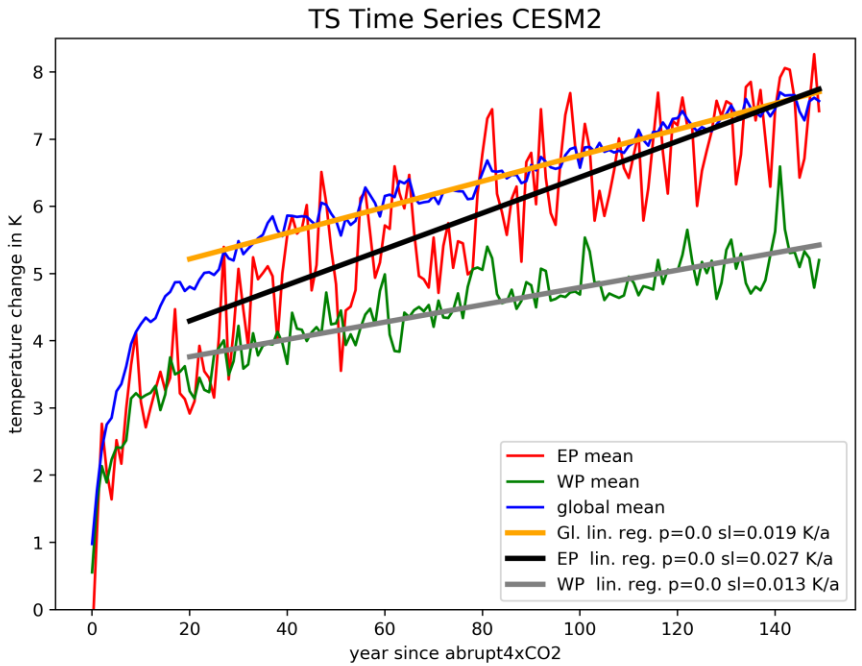


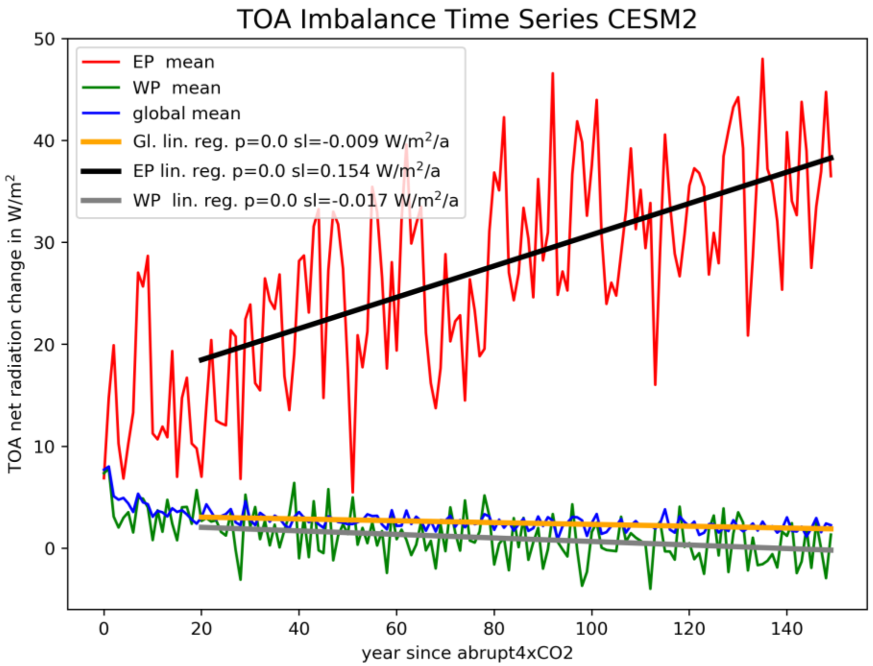


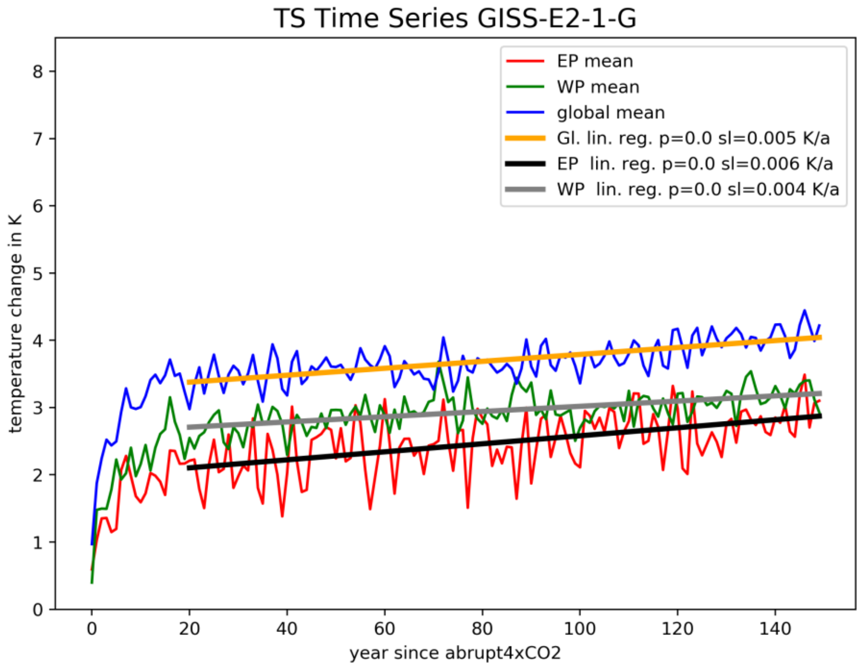


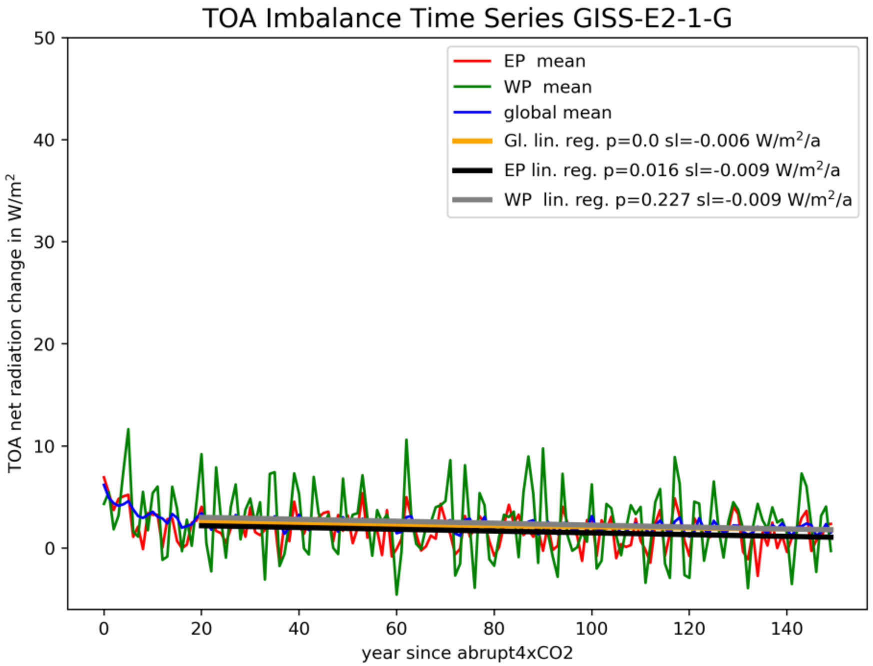


- surface temperature and top-of-atmosphere (TOA) radiative imbalance mean values for EP and WP regions
- for comparison: the global mean values
- depicted values correspond to abrupt4xCO2 minus piControl
- globally and WP region: **decrease** of TOA imbalance
- EP region: **increase** of TOA imbalance
- → stronger increase for the CMIP6 mean than for CMIP5 mean







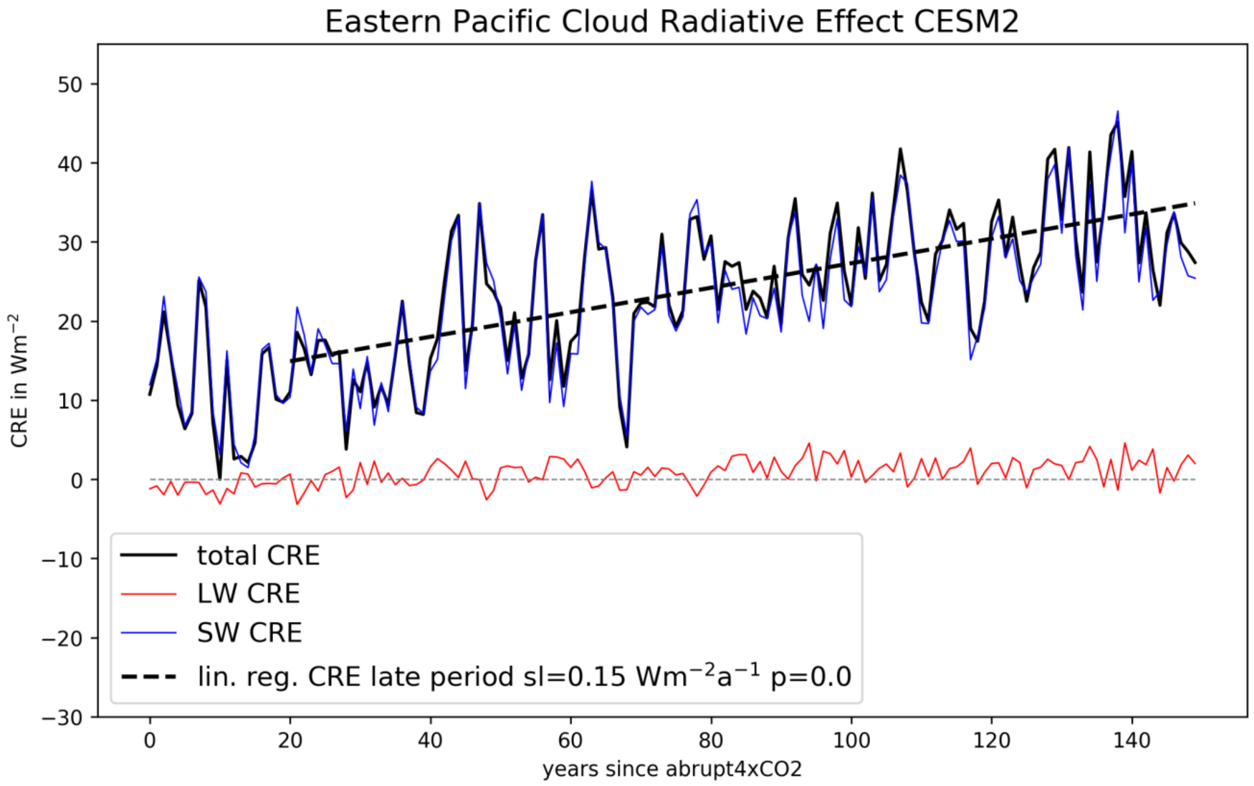


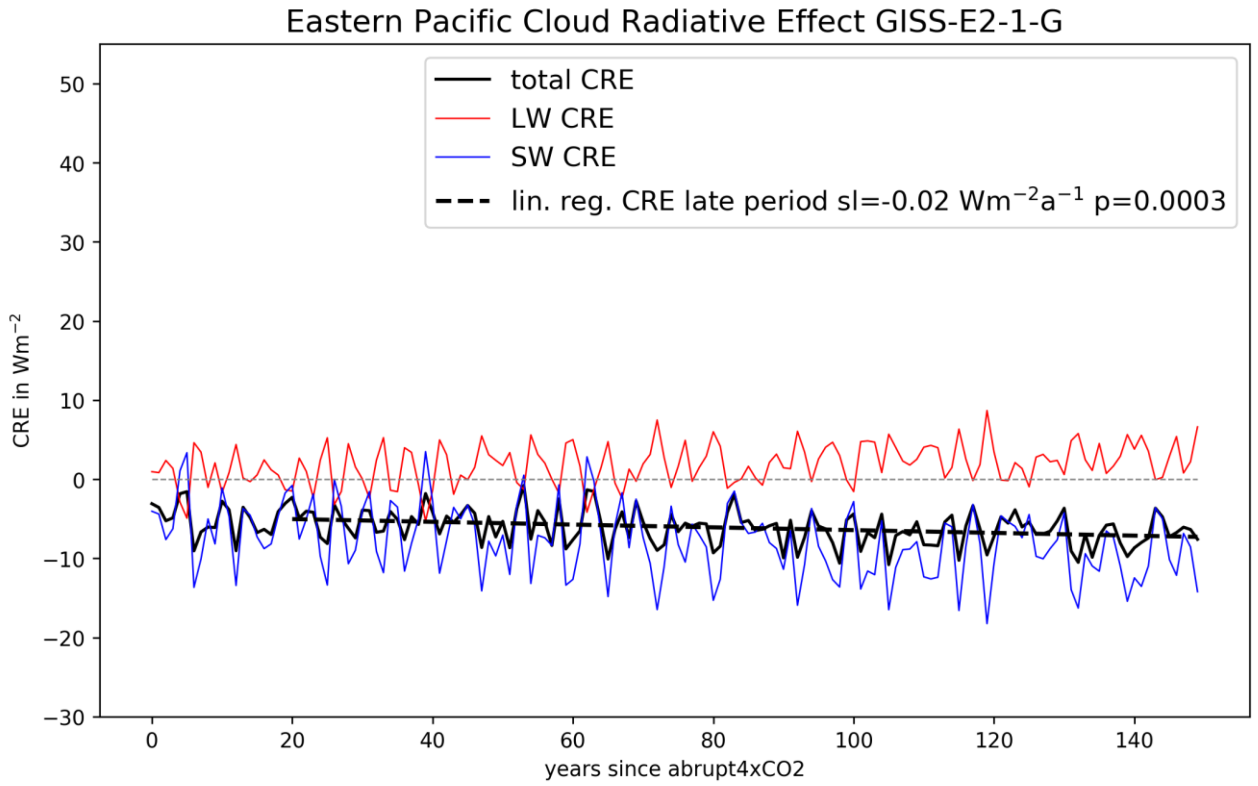
- same as the previous slide but for two of the most distinctly different models: CESM2 and GISS-E2-1-G
- **note the different y-axis scale on the right hand side compared to the previous slide → CESM2 is a considerable outlier and impacts the CMIP6 mean significantly**

- climate sensitivity estimates (abrupt4xCO2, 150 years):
  - CESM2: 10.38 K
  - GISS-E2-1-G: 5.37 K

- climate sensitivity change early to late period:
  - CESM2: +4.92 K
  - GISS-E2-1-G: -0.07 K

(climate sensitivity estimates from Gregory et al. (2004) method)





- cloud radiative effect (CRE) annual mean EP region mean for CESM2 and GISS-E2-1-G
- long-wave (LW) CRE very similar for both models
- short-wave (SW) CRE markedly different: strongly positive in CESM2; negative in GISS-E2-1-G

- → a reduction in low clouds in CESM2 seems to lead to the increase in TOA imbalance in the EP region
- → this might be a contributing factor to the strong change in climate sensitivity in CESM2
- → in GISS-E2-1-G the inverse seems to be happening, although less pronounced

References

- Ceppi, P. and J. M. Gregory (2017): Relationship of tropospheric stability to climate sensitivity and Earth‘s observed radiation budget. In: Proceedings of the National Academy of Sciences 114: 13126-13131. doi: 10.1073/pnas.1714308114

- Gregory, J. M. et al. (2004): A new method for diagnosing radiative forcing and climate sensitivity. In: Geophysical Research Letters 31, L03205. doi: 10.1029/2003GL018747