Twentieth Century Warming Rates in CMIP3, CMIP5, and Large Ensemble Climate Simulations – Spatial and Temporal Variability, Differences and their Attribution

(Relevance for recent ‘hiatus’/’no hiatus’)

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Objectives

① Are there significant differences between CMIP3 and CMIP5 for 20th century warming rates?

② If so, can we attribute it to climate processes, pre-industrial control state, model improvements etc.

③ Role of internal variability using NCAR large ensemble climate simulations and its comparison with CMIP5

④ What does it say about recent 'hiatus'/'no hiatus'?

What if I already know all the answers?

① Are there significant differences between CMIP3 and CMIP5 for 20th century warming rates?
② If so, can we attribute it to climate processes, pre-industrial control state, model improvements etc.

An alternative hypothesis for the differences between CMIP3 and CMIP5

③ Role of internal variability using NCAR large ensemble climate simulations and its comparison with CMIP5

A cleaner comparison on the role of internal variability using new model data that was not available during AR5

④ What does it says about recent 'hiatus'/'no hiatus'?

A persuasive demonstration of recent 'hiatus'/'no hiatus'

Data and Methods

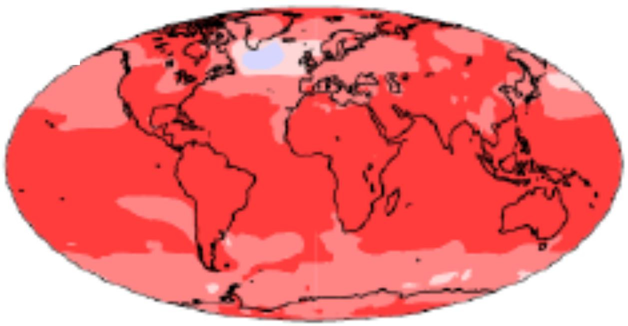
- Climate Models: 22 CMIP3 models (66 ensemble), 41 CMIP5 models (138 ensemble), NCAR CESM Large ensemble (30 members)
- All forcings historical simulations are extended to 2015 using SRES-A1B and RCP8.5 climate projections, respectively.
- Three global temperature observations – HadCRUT4, NOAA-MLOST, and GISSTEMP
- Non-parametric method for trends estimation [*Kumar et al.*, 2009; 2013]

$$\beta = median\left[\frac{x_j - x_i}{j - i}\right] \quad \text{for all } i < j$$

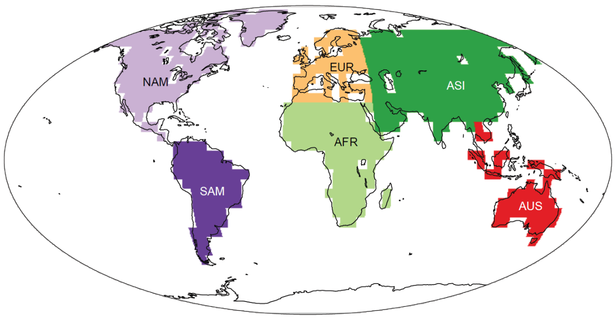
- One model One Vote Policy [*Jones et al.*, 2013]

Scales of Analysis

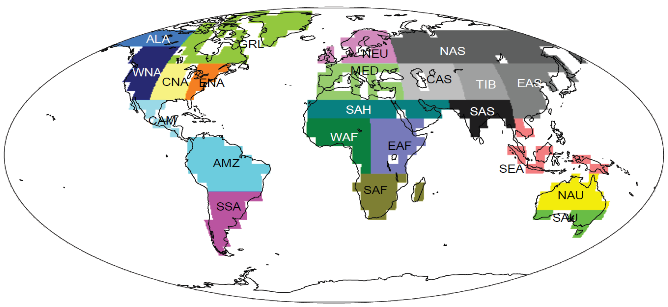
1. Global scales (land + oceans), land only, and ocean only



2. Continental Scales

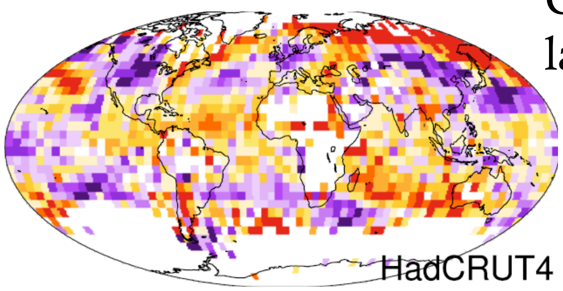


3. Regional scales

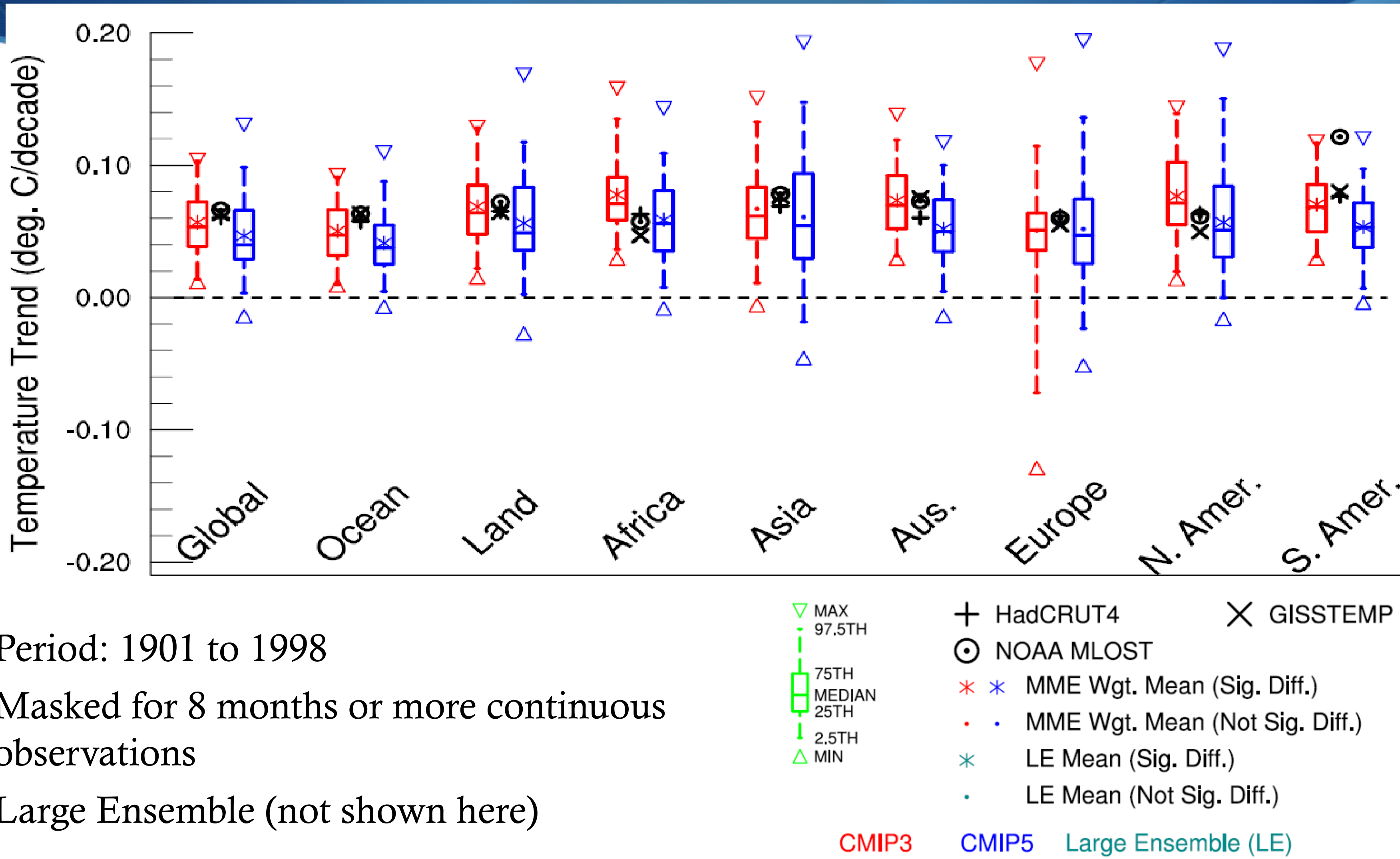


4. Local scales

Only for land



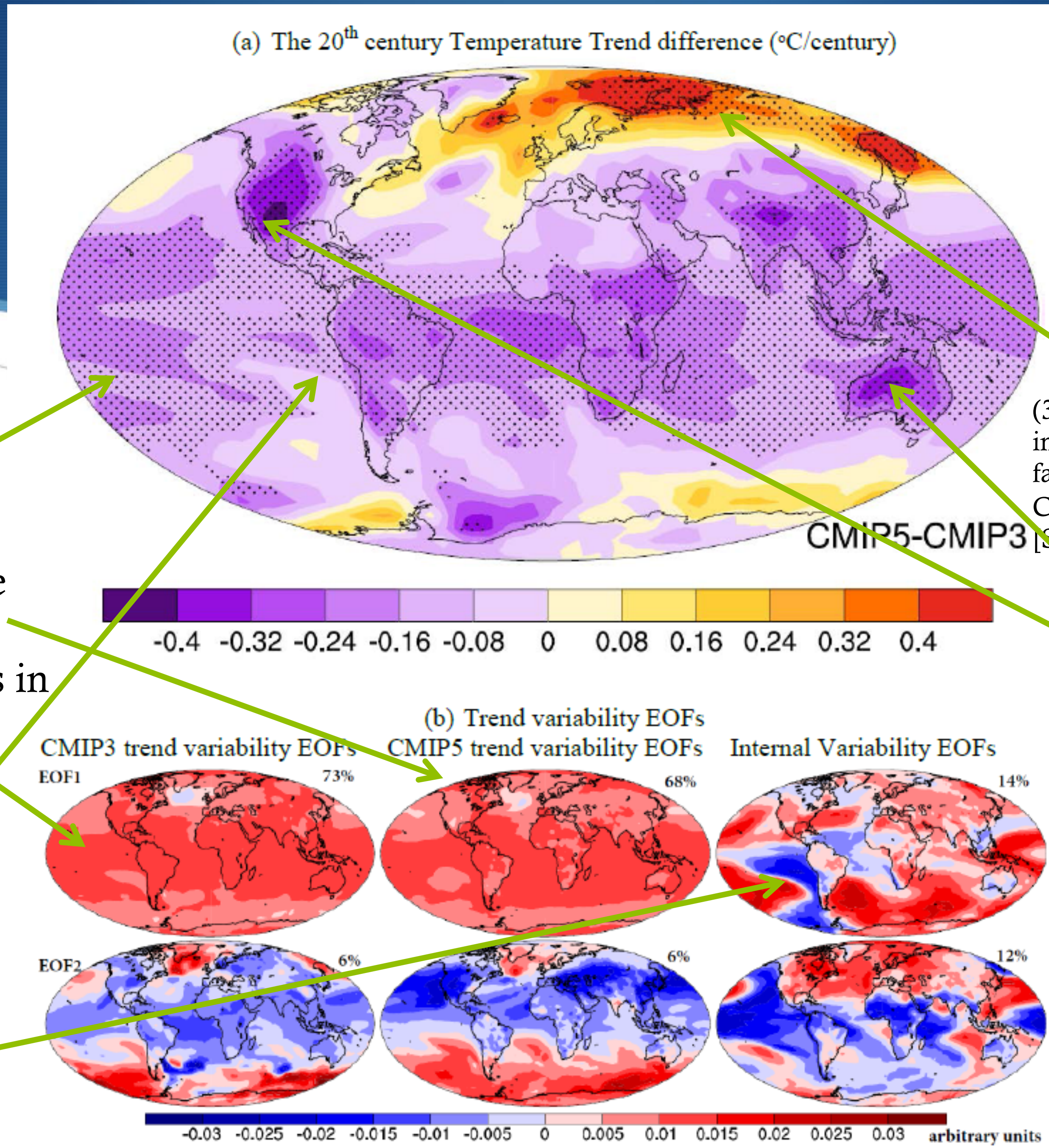
The 20th century Temperature Trends



Period: 1901 to 1998

Masked for 8 months or more continuous observations

Large Ensemble (not shown here)



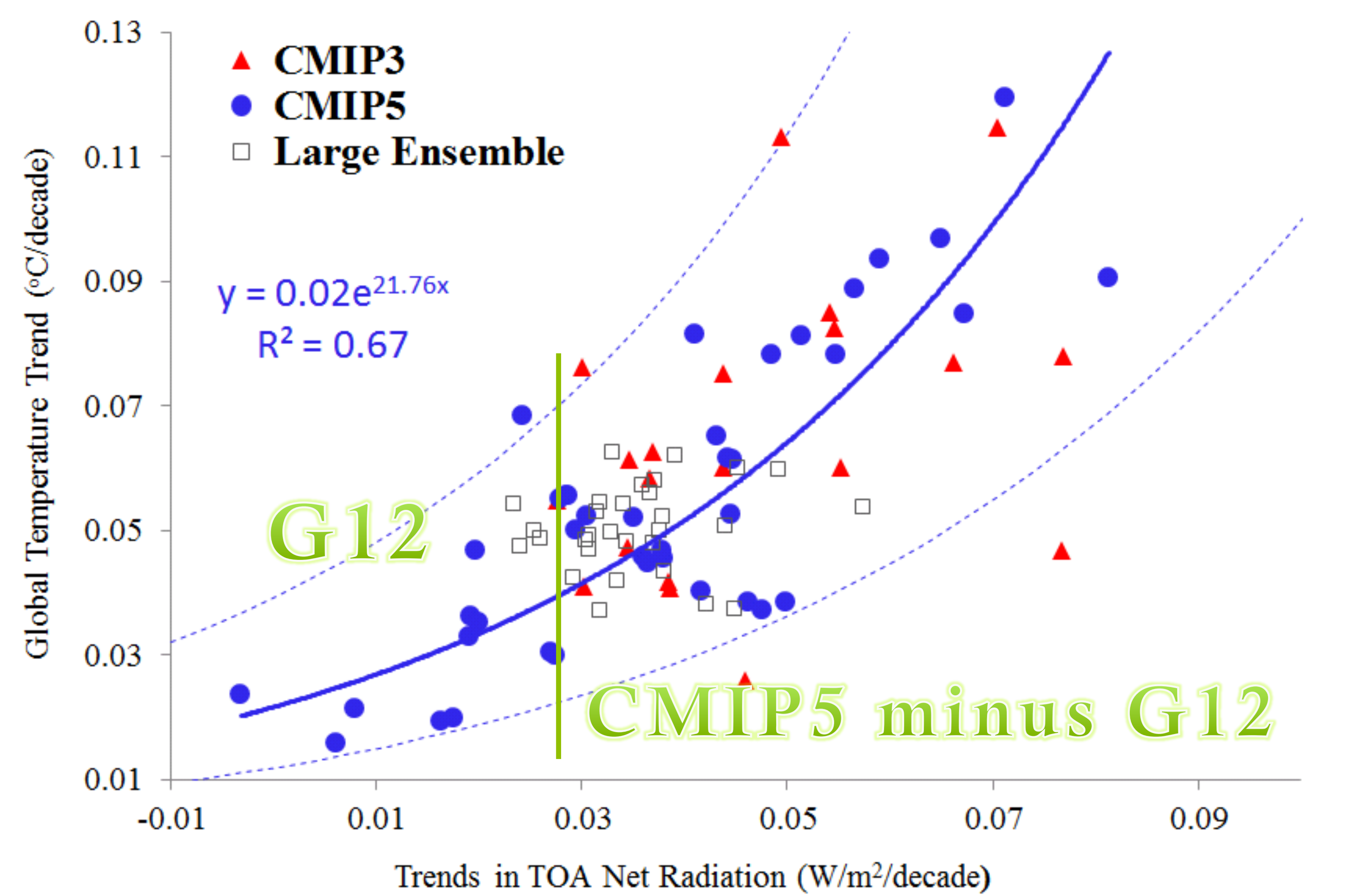
(1) Significant differences in the tropics (similar spatial pattern as in EOF1)

(2) This is not internal variability

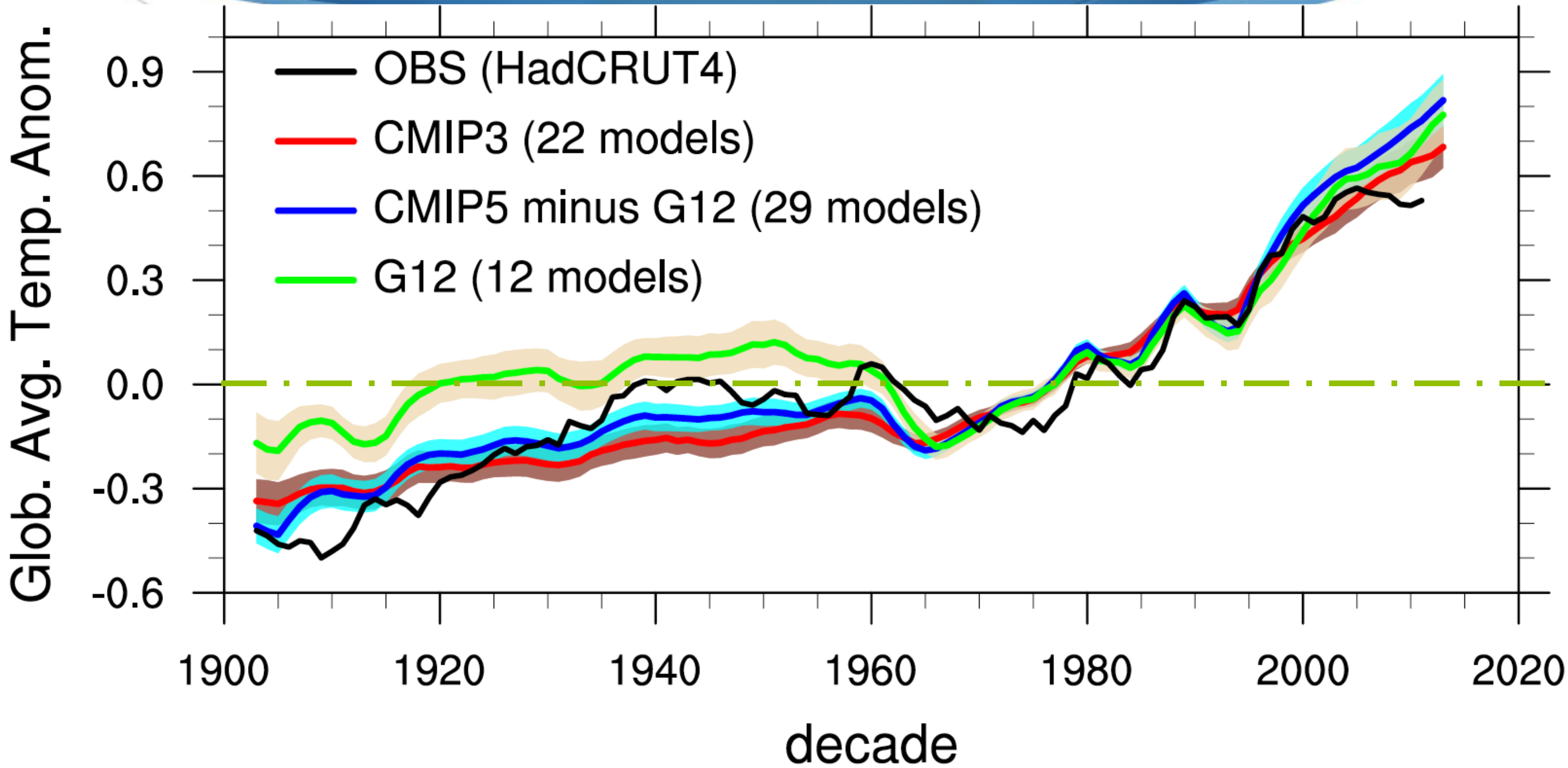
(3) Thinner sea ice initializations and faster melting in CMIP5 than CMIP3 [Stroeve et al., 2013]

(4) Greater cooling in drier areas, may be related to dust aerosols [*Huang et al.*, 2014]

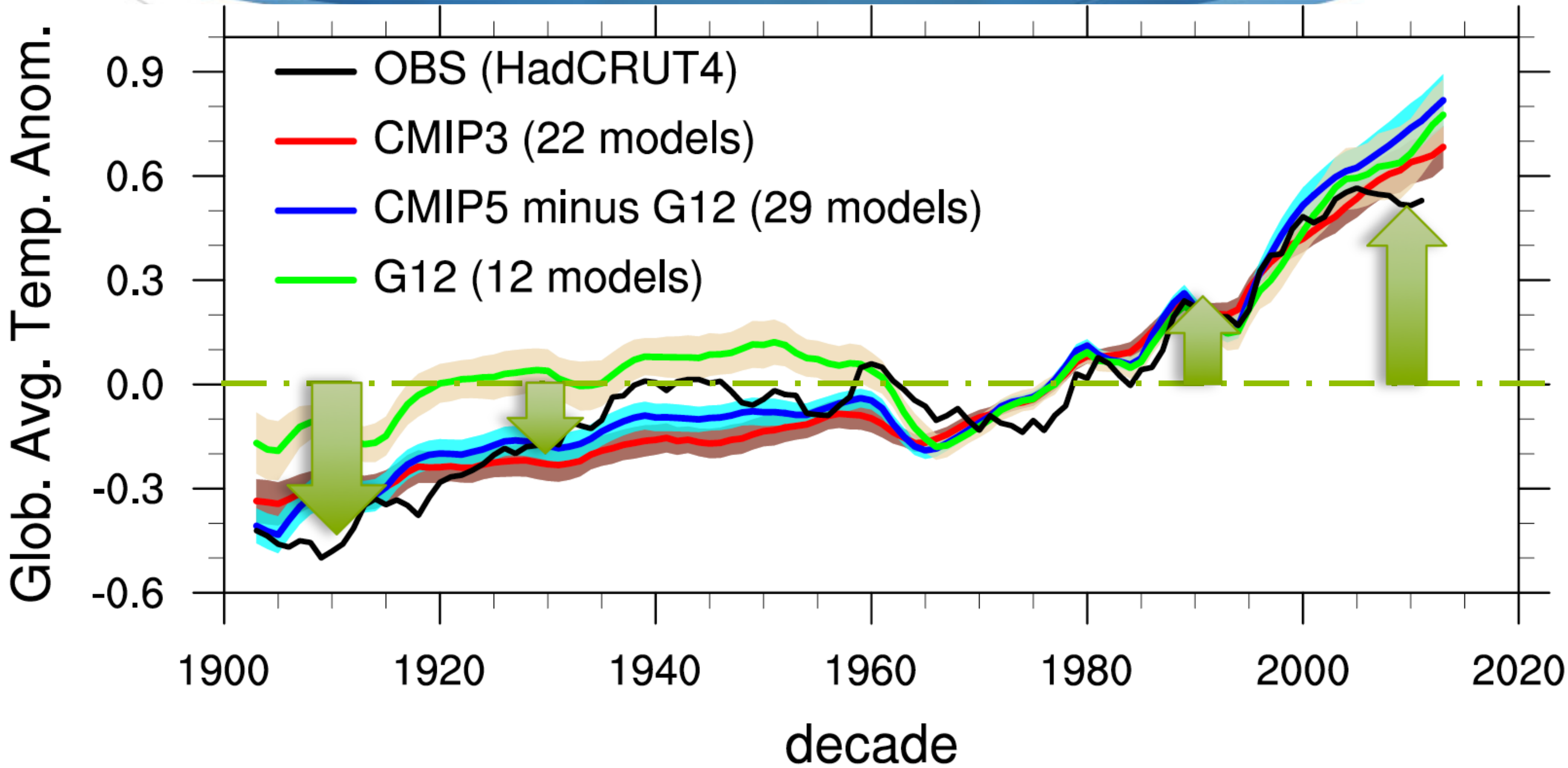
Attribution of the difference in long-term trends



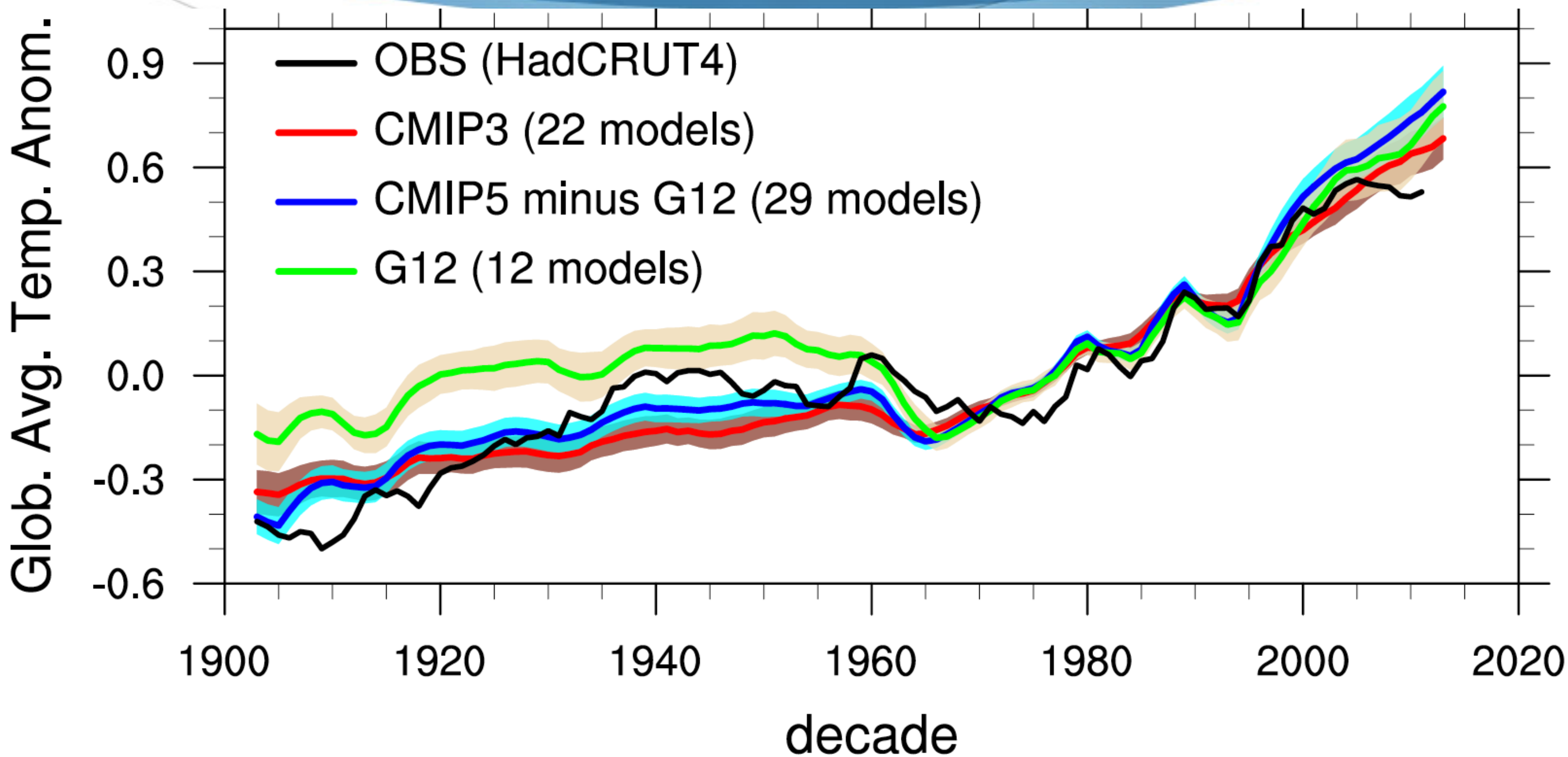
Global Average Temperature Anomaly (base: 1961 to 1990)



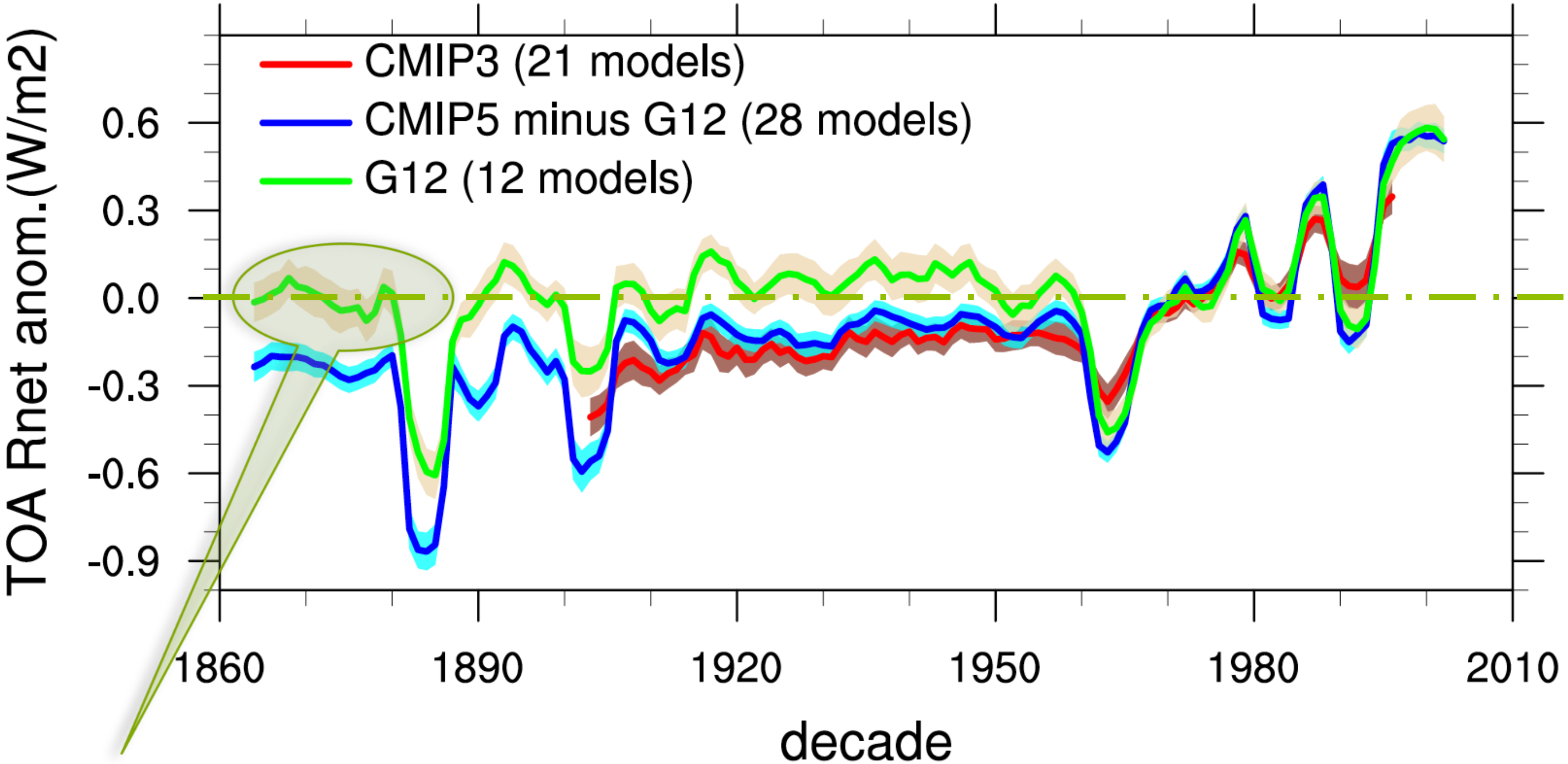
1. There has been NO 'hiatus'



2. Systematic differences between G12 and CMIP3/CMIP5 models

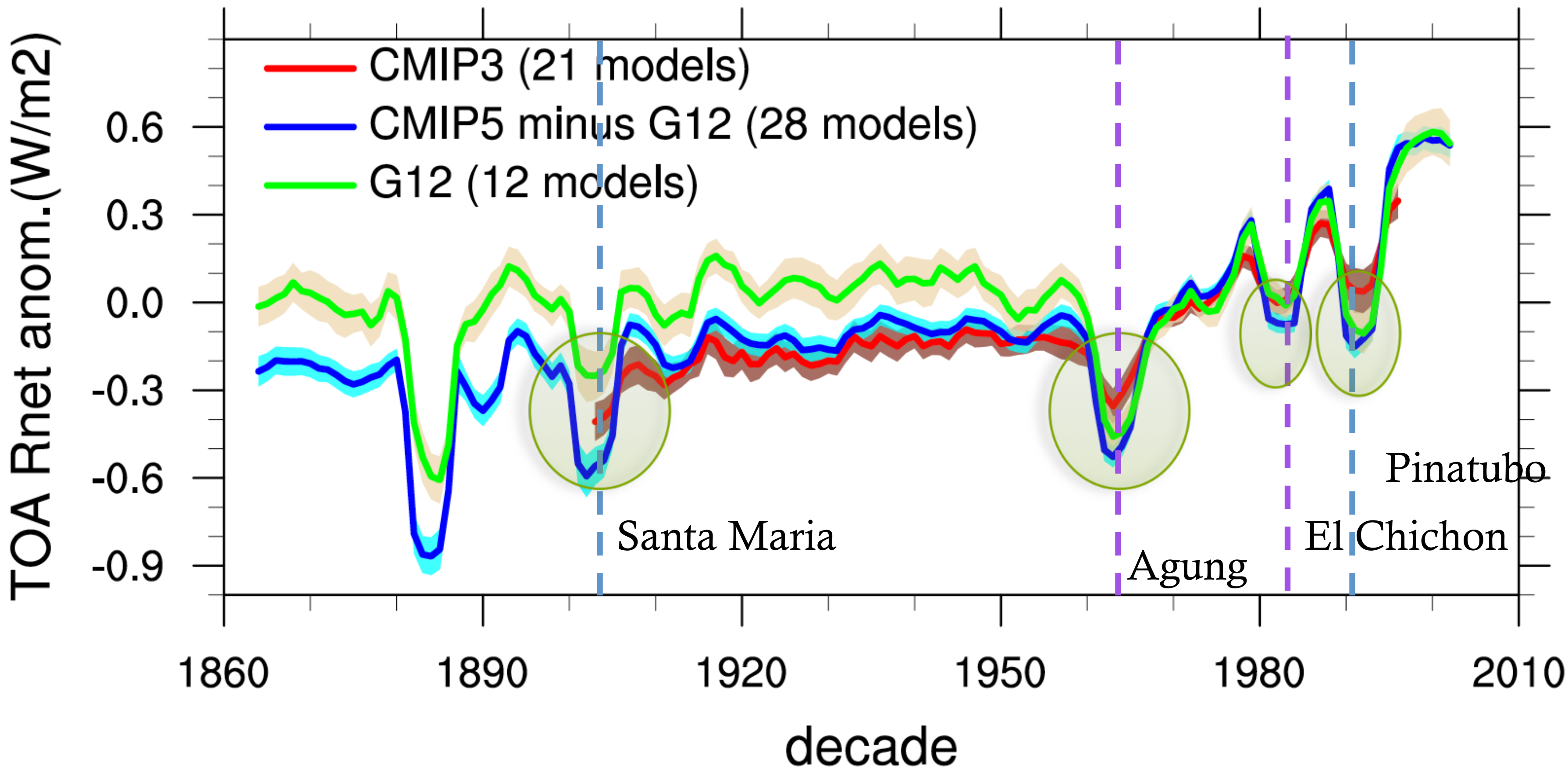


Top of the Atmosphere Net Radiation Anomaly



TOA balance **<u>but with respect to 1961-1990 climatology</u>**

Top of the Atmosphere Net Radiation Anomaly



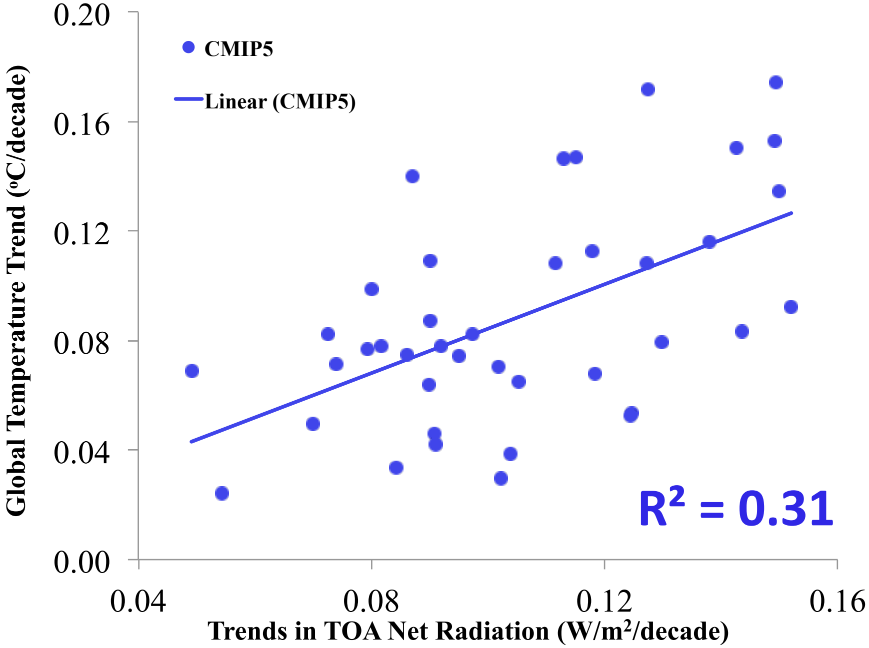
A higher reflectance in CMIP5 than CMIP3 during volcanic eruptions

No systematic difference between G12 and CMIP3/CMIP5 for incoming solar (not shown)

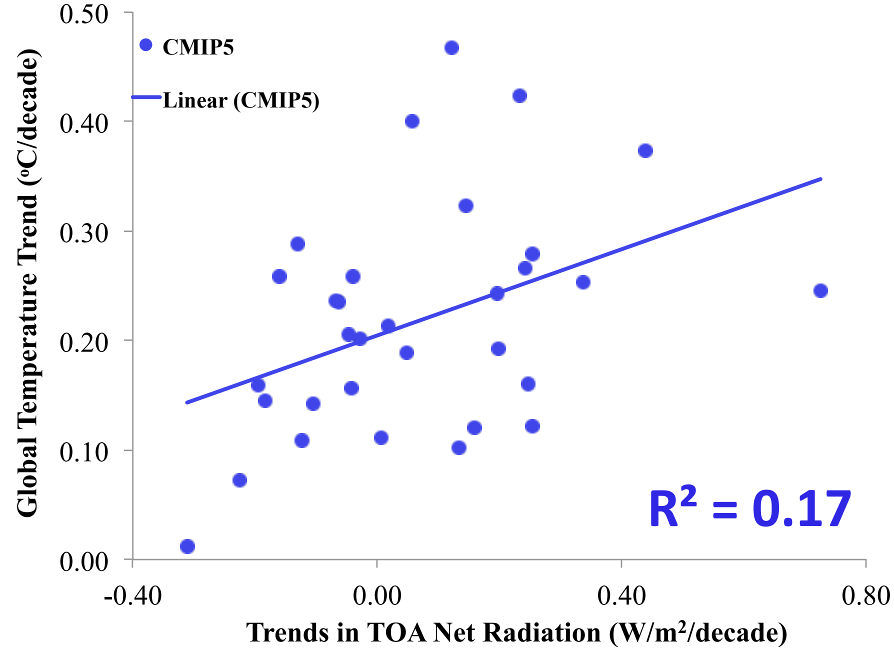
Summary of Part 1 [long-term historical trends]

1. There are significant differences between between CMIP3, and CMIP5 for long-term 20th century temperature trends (1901 to 1998)
2. The multi-model mean global average temperature trends are: 0.57±0.07 °C/century (in CMIP3), 0.47±0.06 (CMIP5); 0.60 (HadCRUT4), 0.66 (NOAA MLOST), and 0.64 (GISSTEMP).
3. The spatial pattern of the difference closely matches with well mixed greenhouse gas or aerosol forcing responses.
4. Most differences is attributable to G12 groups of CMIP5 models that have considerably smaller net TOA radiative forcing trends (significant differences goes away after removing these 12 models (not shown))
5. **Alternative hypothesis**: G12 models contributed most to the difference between CMIP3, and CMIP5, and this may be related to pre-industrial control state.

Shorter term trends (50 years and 15 years)



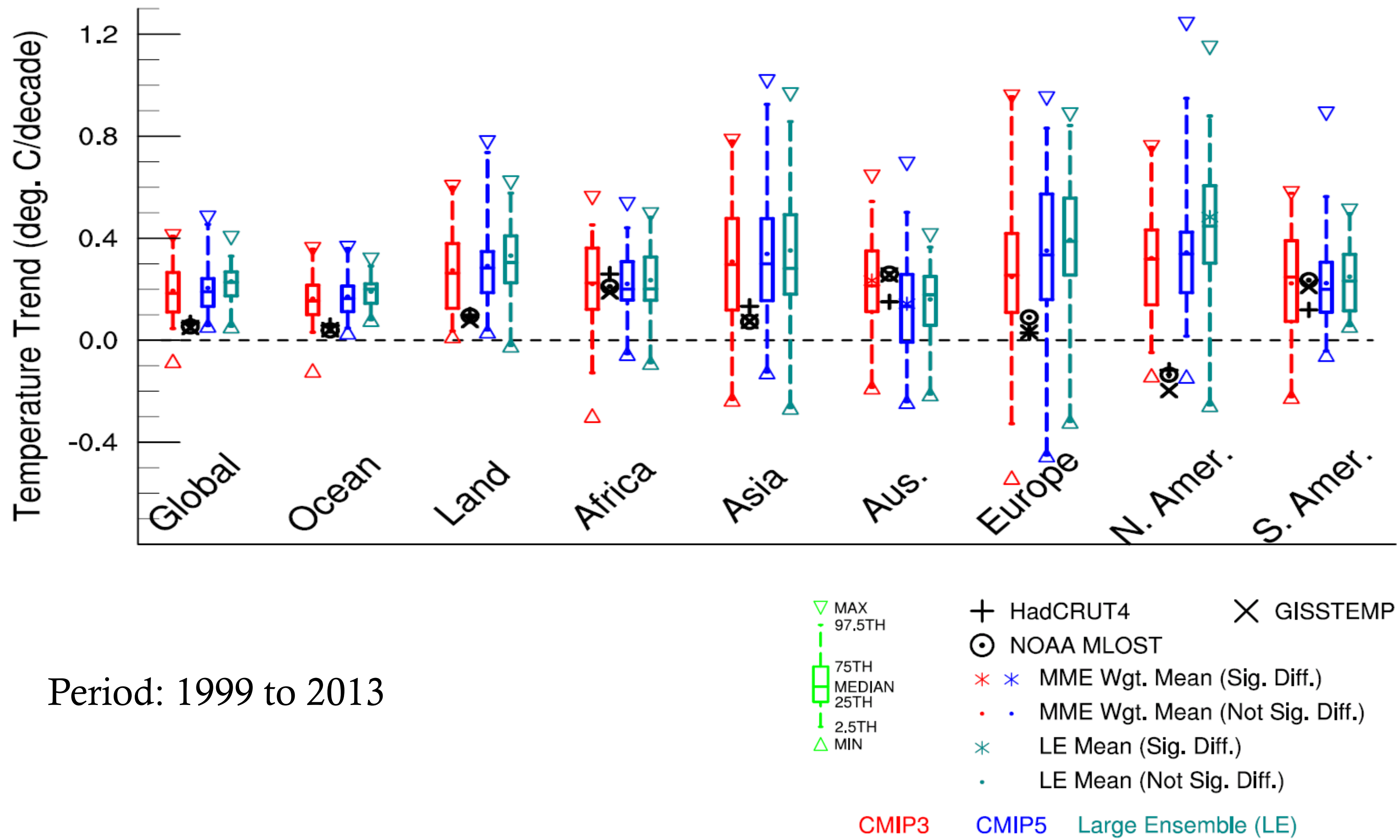
Period: 1950 to 1998



Period: 1999 to 2013

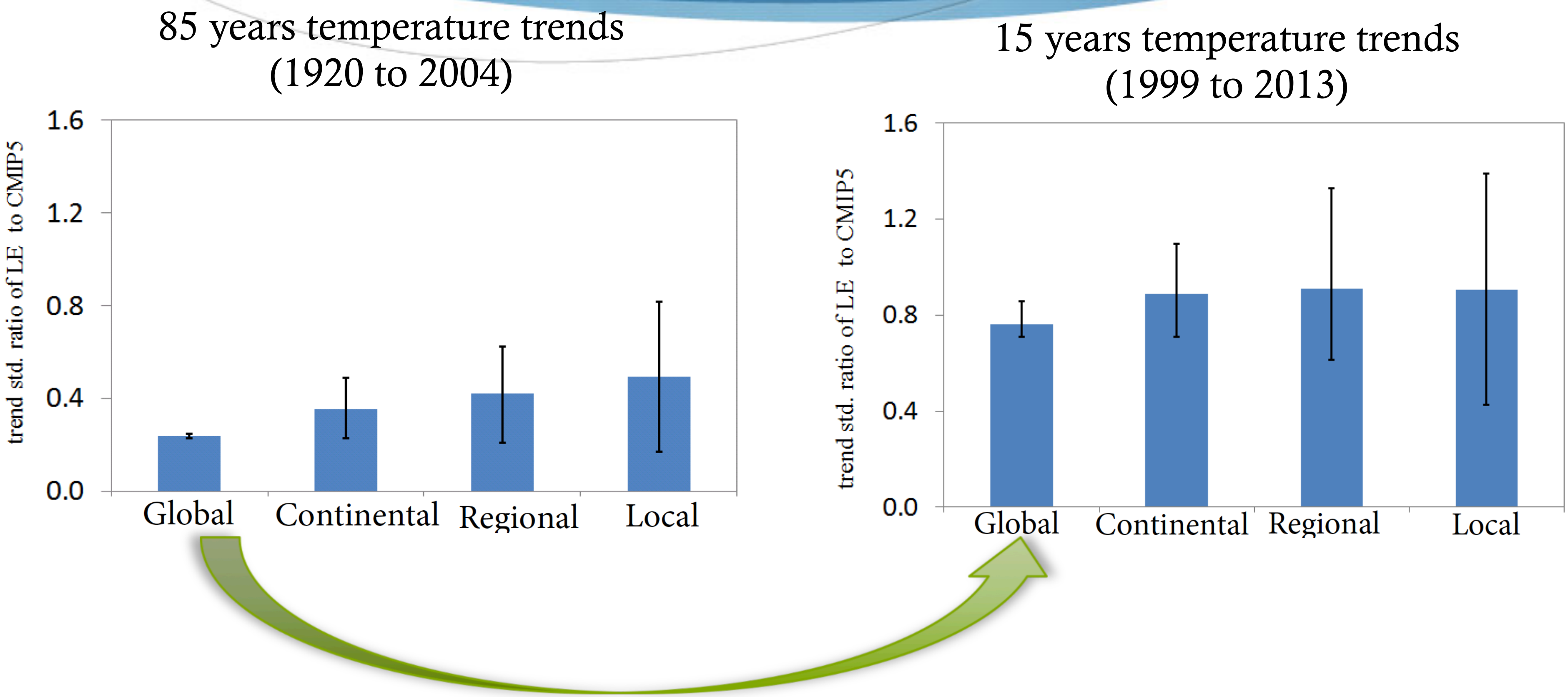
Diminishing role of external forgings in explaining shorter terms global average temperature trends

Recent 'hiatus'/'no hiatus' trends



Period: 1999 to 2013

Role of internal variability as seen using NCAR CESM Large Ensemble



Ratio of LE/CMIP5 temperature trends standard deviations

Summary of Part 2

1. TOA net radiation trends explains 67% variance in long-term global average temperature trends spread in CMIP5 simulations. The explained variance reduces to 31%, and 17% for 50-year, and 15-year trends, respectively.

2. NCAR CESM Large Ensemble simulations allows us to quantify role of internal viability in a cleaner way.

3. Role of internal variability increase from 24±1% for 85-year temperature trends to 76±7% for 15-year temperature trends at global scales.

4. At regional scales, internal variability plays a major role even at longer time scales. Role of internal variability increases from 42±21% for 85-year temperature trends to 91±36% for 15-year temperature trends.

Answers

① Are there significant differences between CMIP3 and CMIP5 for 20th century warming rates?
Answer: Yes, No, It depends whether G12 are included or not

② If so, can we attribute it to climate processes, initializations, model improvements etc.
Answer: An alternative hypothesis for the differences between CMIP3 and CMIP5, may be related to pre-industrial control state.

③ Role of internal variability using NCAR large ensemble climate simulations and its comparison with CMIP5
Answer: A cleaner comparison on the role of internal variability. Caveat: Only one model.

④ What does it say about recent 'hiatus'/'no hiatus'?
Answer: A manifestation of internal variability

Acknowledgments

- WCRP CMIP Projects for providing Climate Model outputs
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