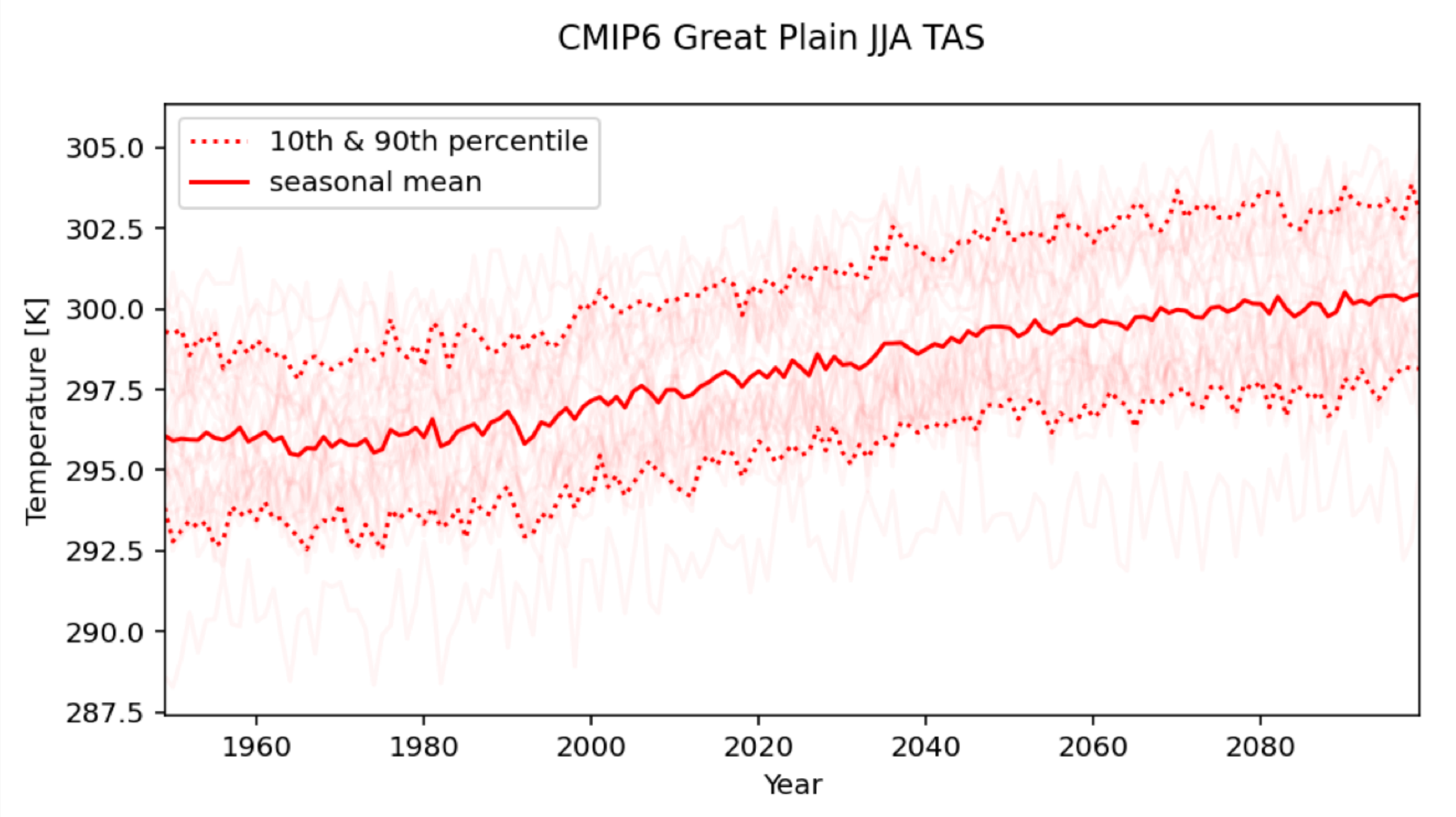
Applications of GCMs: Community Earth System Model (CESM)

What contributes to the intermodel spread?



Three major sources of uncertainties:

- ~~External forcing~~
- Internal variability
- Model structural differences

What is the relative contribution of internal variability vs. model structural differences?

Time series of the surface air temperature over the US Great Plain from 1949-2099 from 26 CMIP6 models (thin lines), their ensemble mean (thick line) and the 10-90% percentile (thick dashed lines). Figure credit: Seung Uk Kim.

CESM Large Ensemble Project (CESM-LE)

- The CESM Large Ensemble Project is intended for advancing understanding of internal climate variability and climate change.
- With a small number of ensemble simulations, it is difficult, or even impossible, to disentangle model error and internal climate variability.
- CESM-LE has 30 ensemble members, and each member is continuously integrated from 1920 to 2100. The ensemble members are initialized by perturbing the atmospheric initial condition at the round-off level.
    - Ensemble members 2–30 were all started on 1 January 1920
    - Historical forcing from 1920-2005
    - RCP8.5 from 2006-2100
- It includes high-frequency output (daily, 6-hourly) for selected time periods.

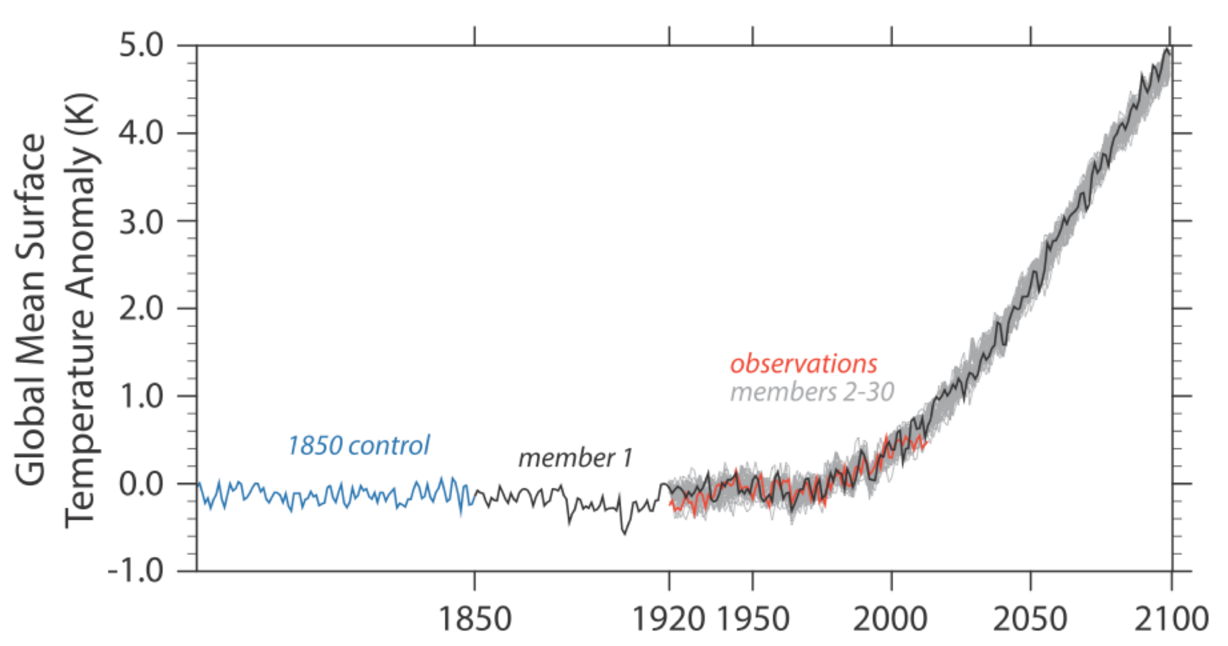


Fig. 2. Global surface temperature anomaly (1961–90 base period) for the 1850 control, individual ensemble members, and observations (HadCRUT4; Morice et al. 2012).

CESM Large Ensemble Project: model configuration

CESM LE consists of coupled atmosphere, ocean, land, and sea ice component models at approximately 1° horizontal resolution in all model components.

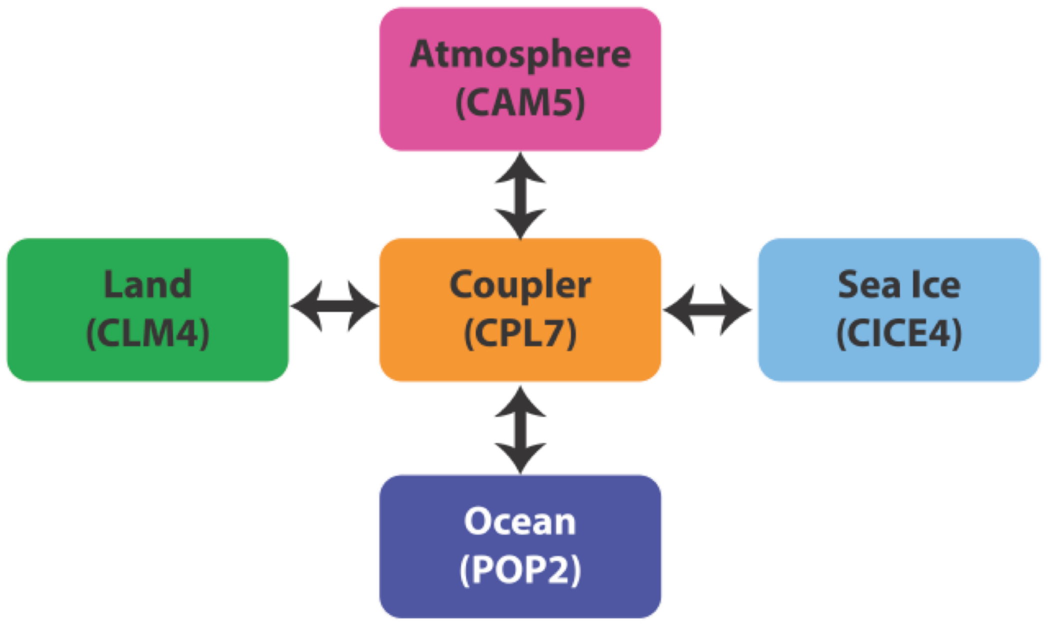


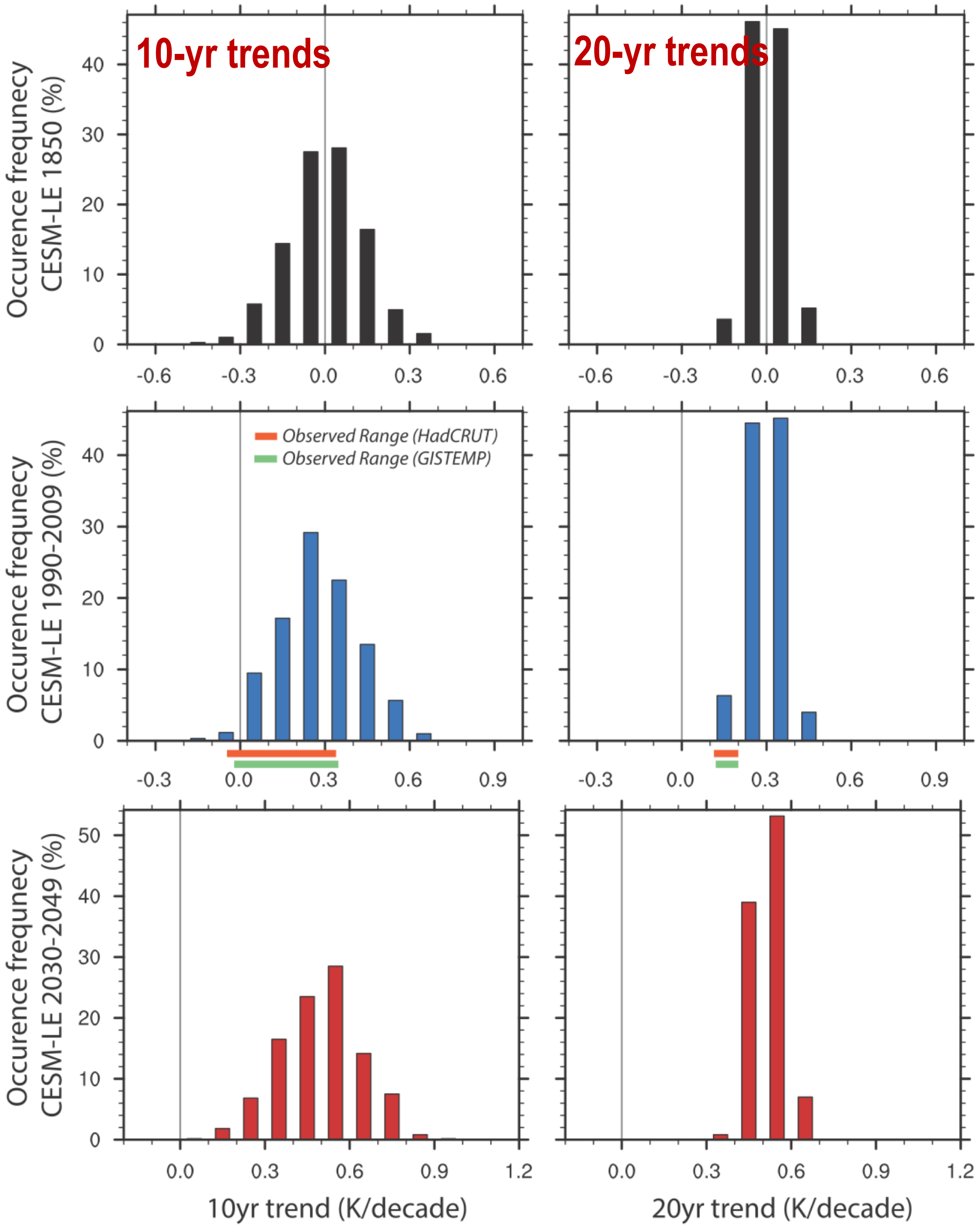
FIG. 1. CESM1(CAM5) component models and coupling (Hurrell et al. 2013). All components were run at ~1° horizontal resolution. CESM1(CAM5) consists of coupled atmosphere (CAM5, 30 vertical levels), ocean [Parallel Ocean Program, version 2 (POP), 60 vertical levels], land [Community Land Model, version 4 (CLM4)], and sea ice [Los Alamos Sea Ice Model (CICE)] component models.

Illustrative Examples: Global Warming “Hiatus”

CESM-LE can be used to explore the question how modes of internal climate variability and external forcing jointly affect global warming trends and what mechanisms are involved. Global warming hiatus: or a global warming slowdown, is a period of relatively little change in globally averaged surface temperatures

What do we learn from the figure on the right?

1) 10-year trends have a larger spread – more strongly modulated by internal variability
2) Cooling trends become increasingly unlikely in future.
3) global-mean surface air temperatures can show no trend or even slight cooling in the presence of long-term warming due to the modulation by internal variability.



Histograms of 10- and 20-yr trends in global surface air temperature for the 1850 control (black), starting from 1990 to 2009 (blue) and starting from 2030 to 2049 (red). Observed trend minimum–maximum ranges calculated from two different data sources are shown in red and green bars in the second row. (Fig. 3 from Kay et al. 2015 © American Meteorological Society. Used with permission)

Regional Trends: internal variability and external forcing

- *How are the individual ensemble members compared to the ensemble mean?*
- *How is the ensemble mean compared to the observation?*
- *How should we use observations to validate model projections (or predictions)?*

- The magnitude and sign of regional trends vary strongly among ensemble members because of the internal climate variability.
- The ensemble mean differs from individual ensemble members or the observations because the internal variability is smoothed out or reduced in the ensemble mean.
- The observations represent one possible response of the climate system to external forcing in the presence of internal climate variability.
- If the model is skillful and the ensemble size is large enough, the observed trend should fall within the ensemble envelope.

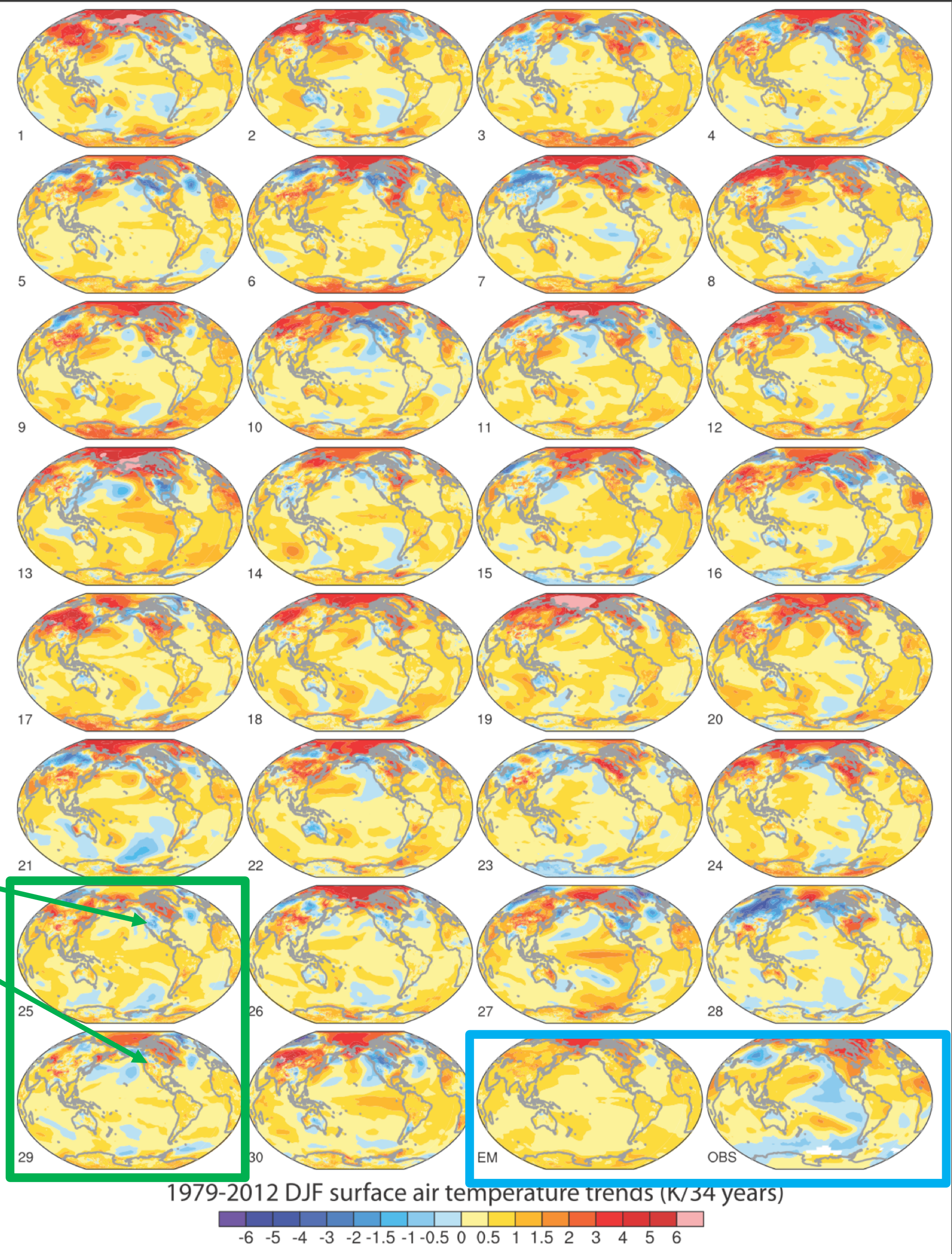
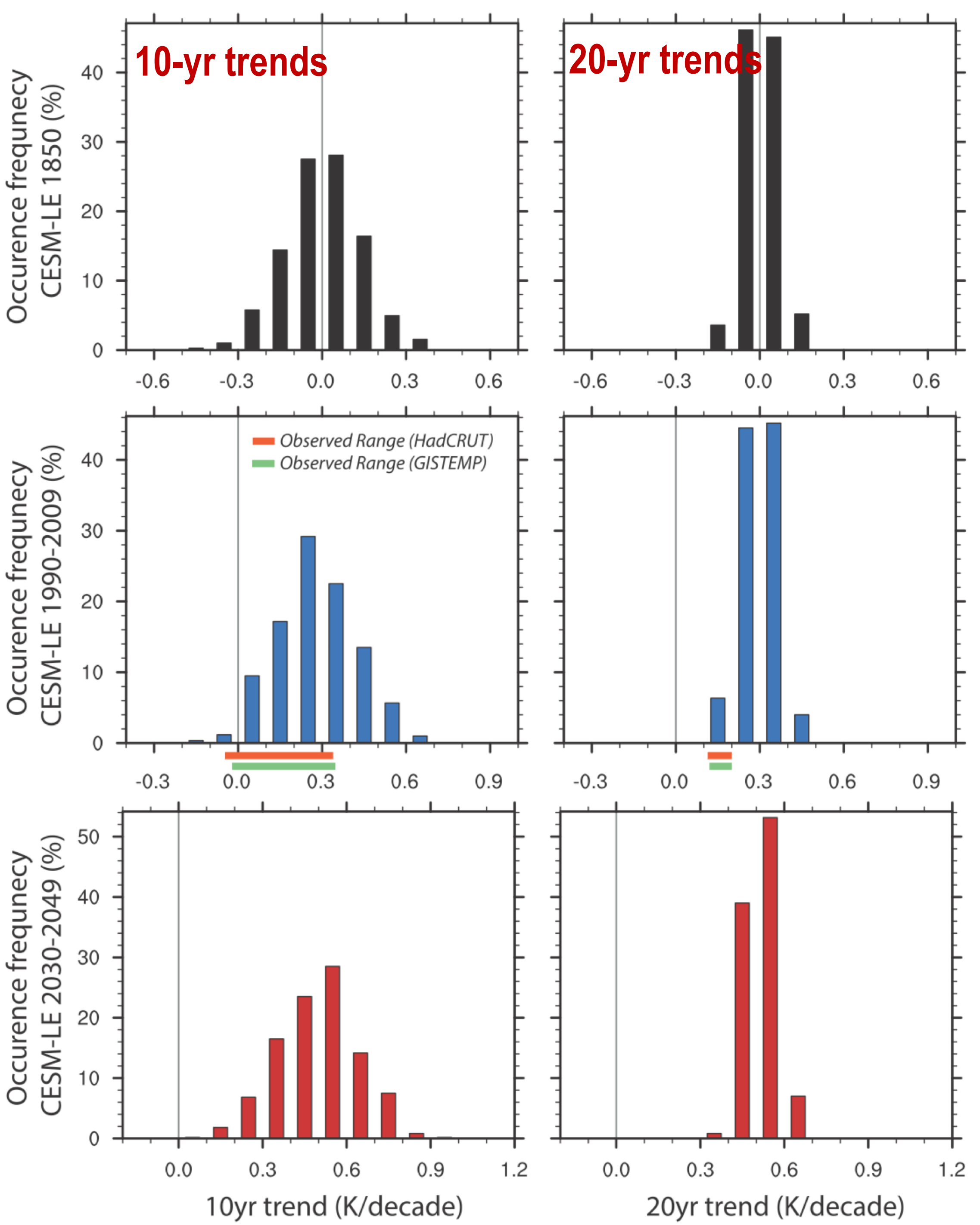


Fig. 4. Global maps of historical (1979–2012) boreal winter (DJF) surface air temperature trends for each of the 30 individual CESM-LE members, the CESM-LE ensemble mean (denoted EM), and observations (denoted OBS based on GISTEMP; Hansen et al. 2010).

Illustrative Examples: Global Warming "Hiatus"

In this example, the observed trends are enclosed by the model ensemble spread, so the model does a reasonable job in representing the real climate system.



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