Emerging Changes in Arctic Longwave Radiation

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Motivation

- Two decades of satellite observations capture changes in Arctic outgoing longwave radiation (OLR) associated with sea ice loss and surface warming.
- Global Climate Model Large Ensembles allow us to predict when observed OLR changes driven by anthropogenic emissions will emerge from internal climate variability.

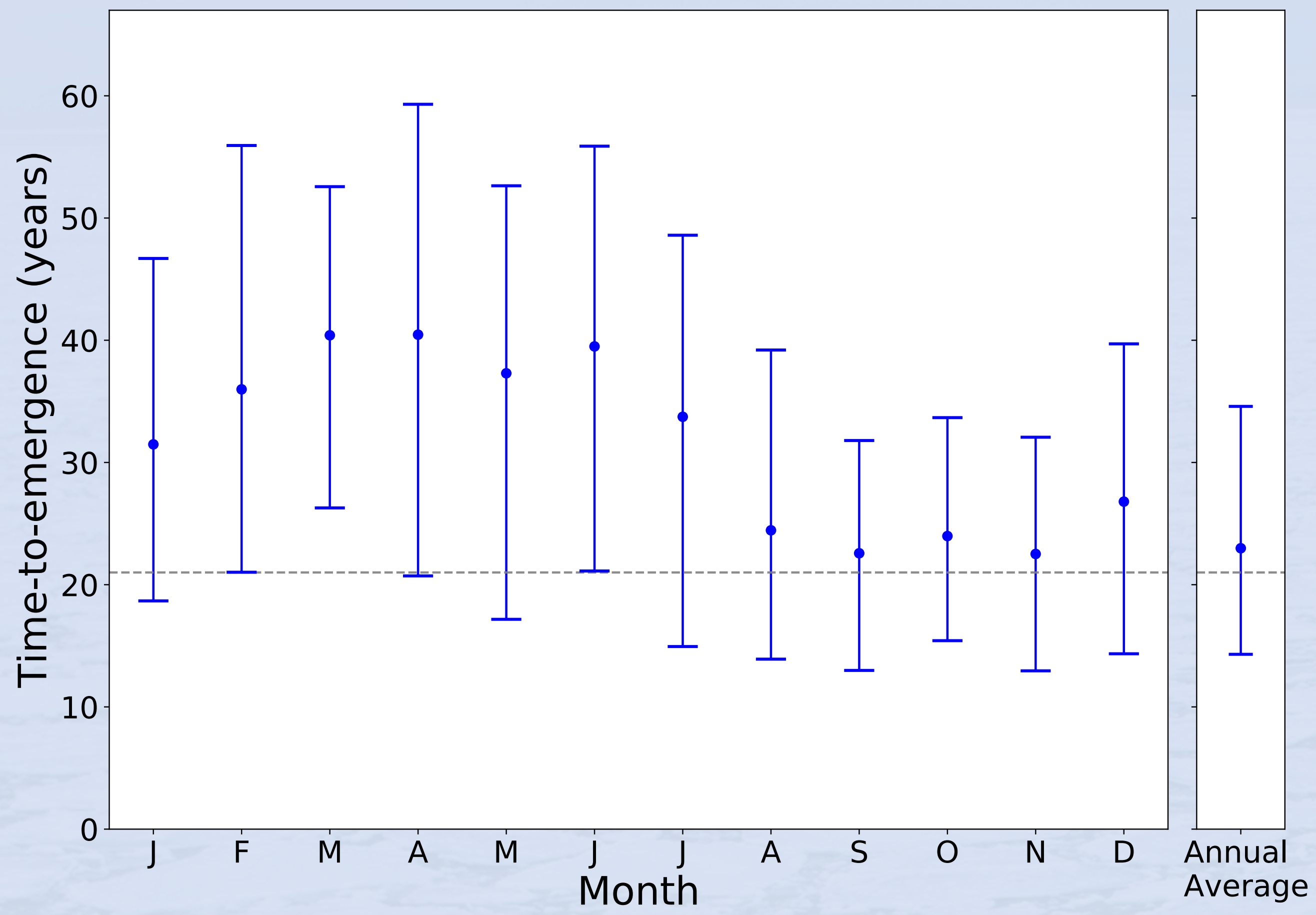

Figure 1: Monthly and annual time-to-emergence of top-of-atmosphere all-sky Arctic OLR for members of the CESM1 Large Ensemble (CESM1-LE) for time series beginning in 2001. Error bars span a bootstrapped 95% confidence interval on estimated time-to-emergence. The dashed grey line indicates the 22-year CERES observational record.

Key Points

- Fall OLR changes emerge before Spring OLR changes on average, but internal variability creates irreducible uncertainty (Fig. 1).
- Larger forced change and smaller internal variability in the Fall relative to Spring cause seasonal contrasts in time-to-emergence (Fig 2). Shortwave absorption during the melt season controls the size of the seasonal contrast (Figs 4-5).
- Rapid warming in the Arctic is generally paired with large internal variability, preventing Arctic warming from emerging earlier than the rest of the globe.

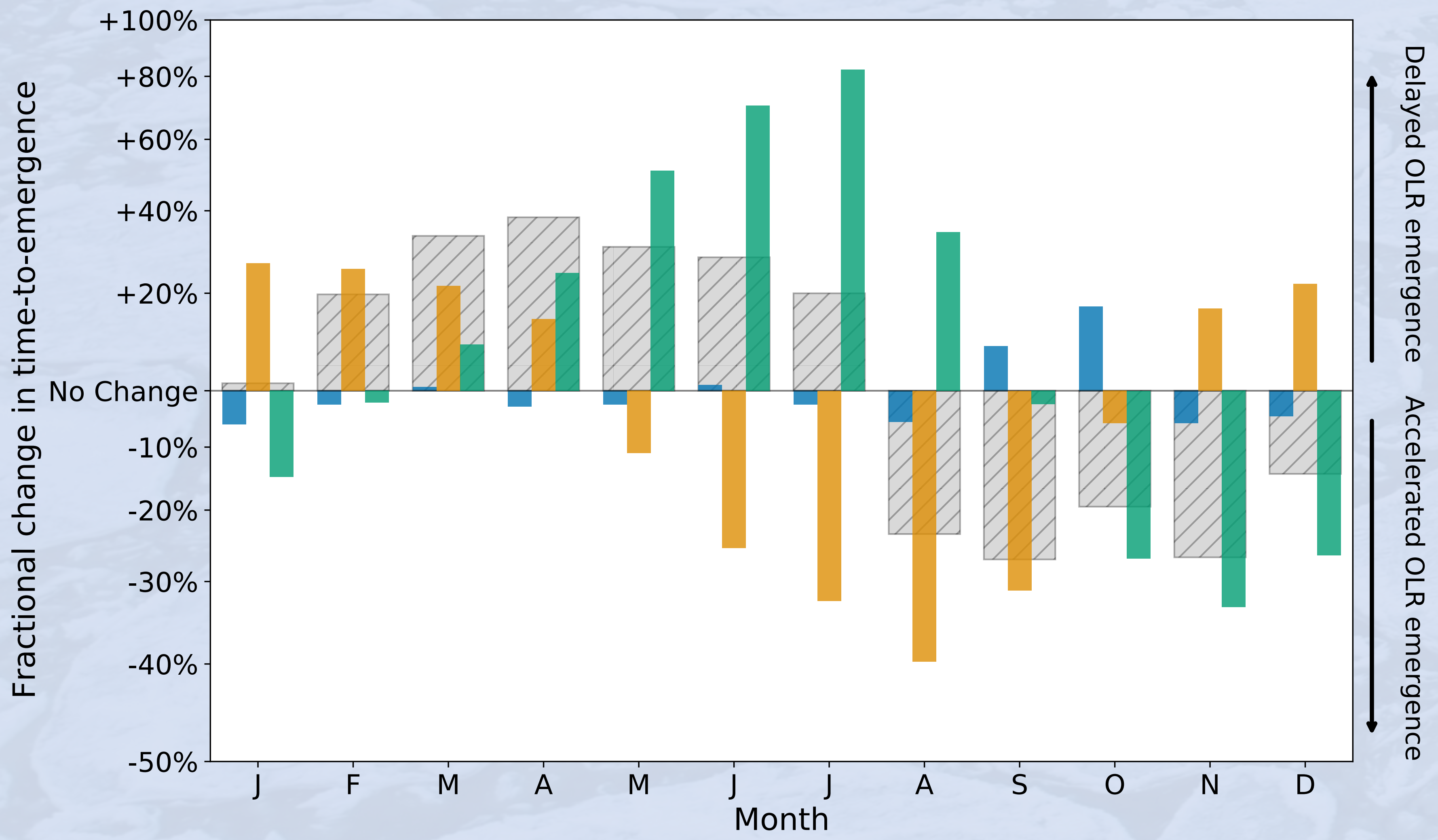

Figure 2: Monthly differences in time-to-emergence (grey) decomposed into contributions from correlation time (blue), standard deviation (orange), and trend (green). Values are calculated using years 400-2200 of the CESM1 1850 pre-industrial control simulation.

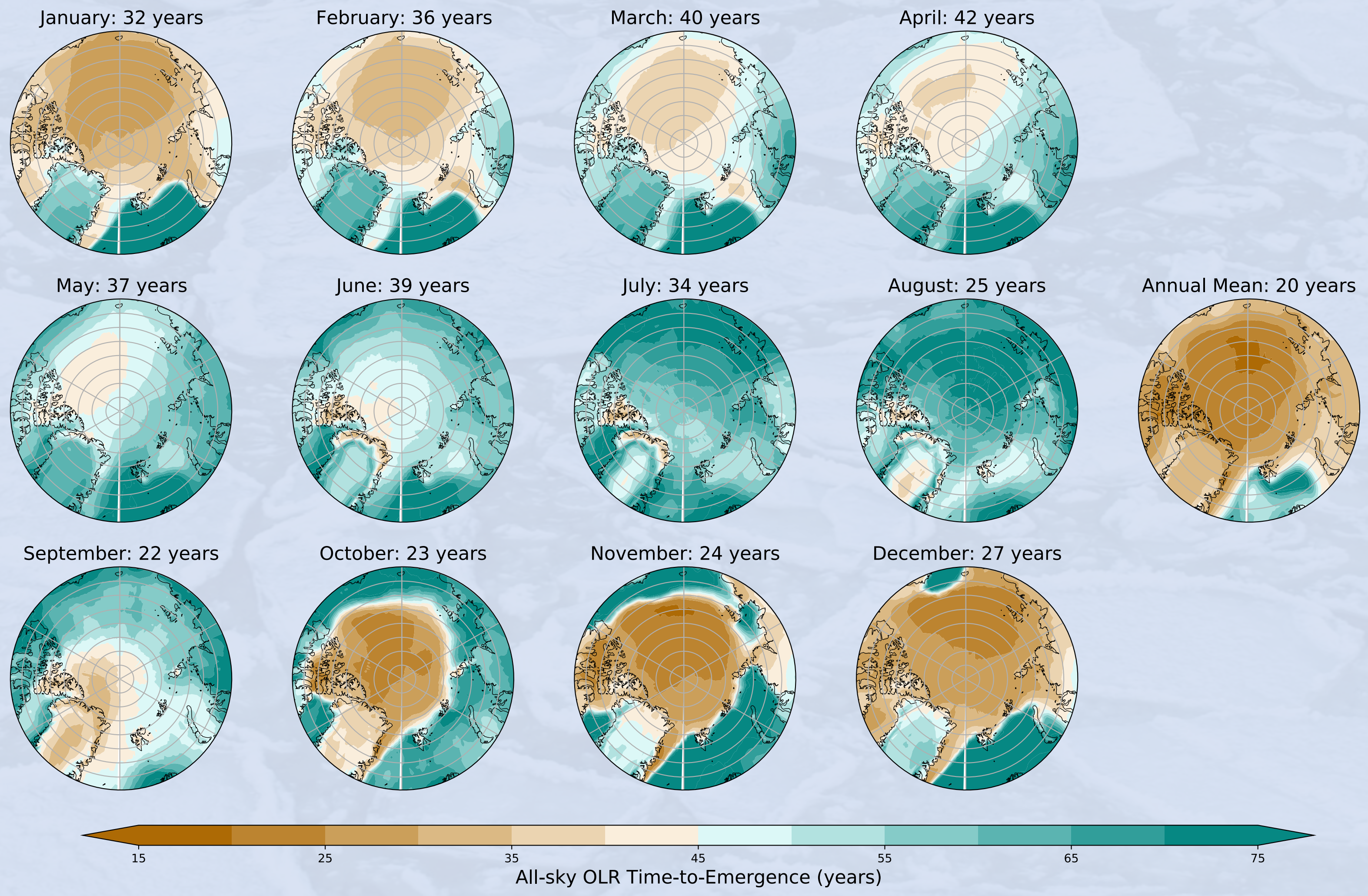

Figure 3: Spatial maps of the monthly and annual mean time-to-emergence of all-sky OLR. Panels show the CESM1-LE ensemble mean time-to-emergence. The time-to-emergence of the area-weighted Arctic (70°–90°N) average OLR from Fig. 1 is reported in the title of each plot.

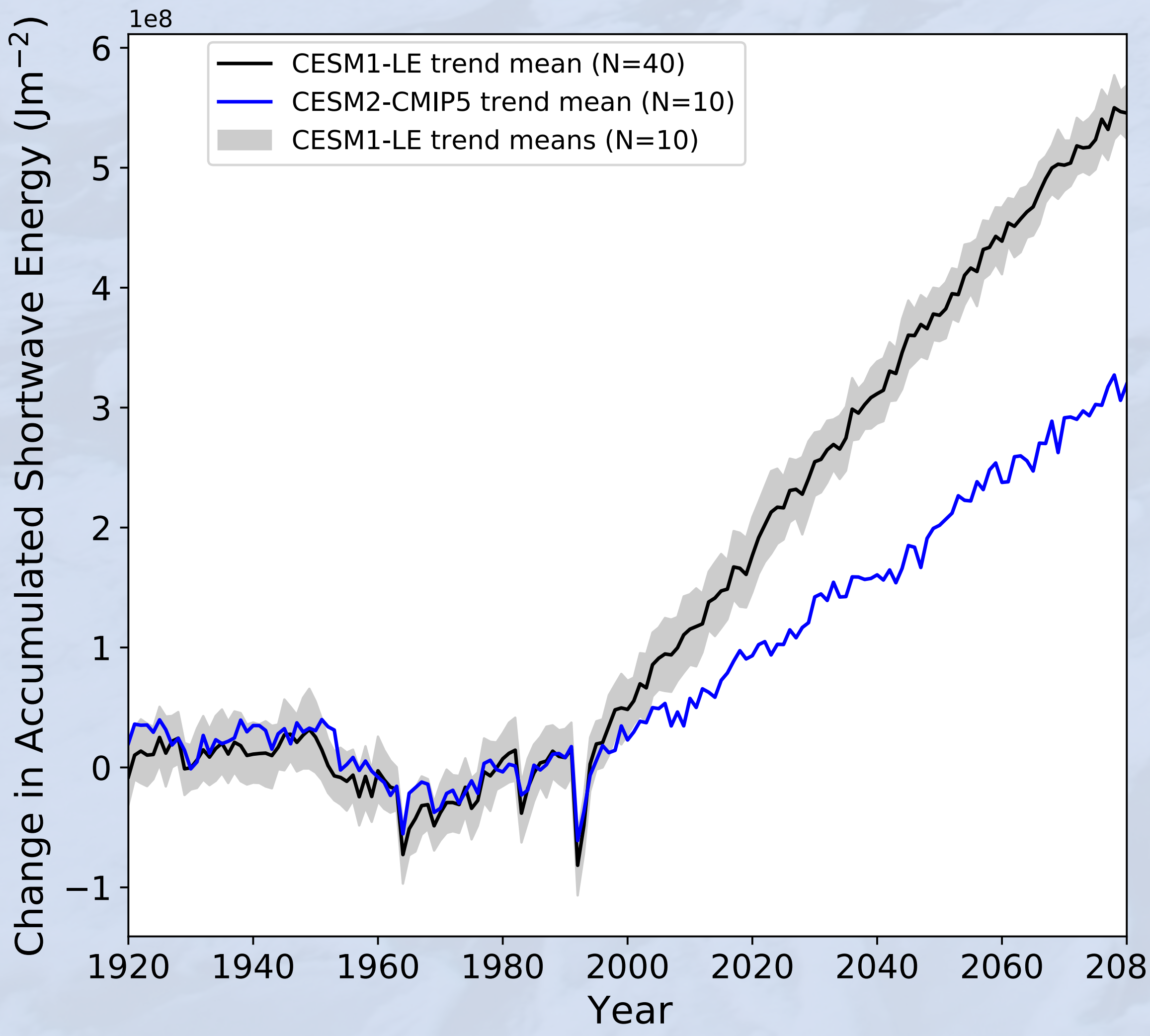

Figure 4: Change in shortwave radiation absorbed over the melt season (March - September) in CESM2 simulations with CMIP5 forcing (blue) and the CESM1-LE (gray). Change in absorbed shortwave radiation is calculated relative to a pre-industrial control. CESM2-CMIP5 data is from Holland et al..

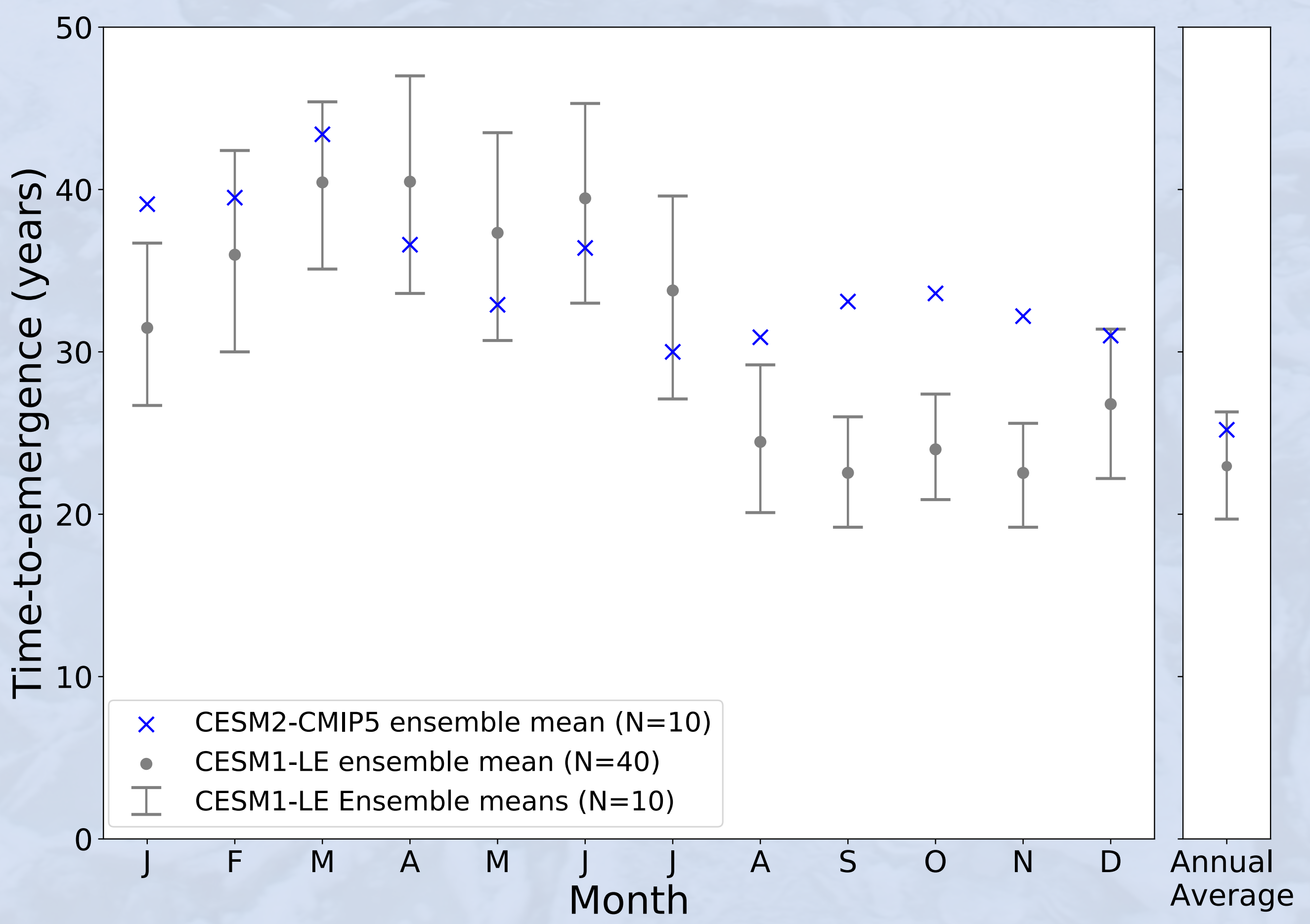

Figure 5: Monthly and annual time-to-emergence of top-of-atmosphere all-sky Arctic OLR in CESM2 simulations with CMIP5 forcing (blue) compared to the CESM1-LE (gray). Bootstrapping is used to compare the different sizes of the two climate model ensembles. CESM2-CMIP5 data is from Holland et al..

Future Work

Use spectral OLR observations from NASA AIRS to identify where in the infrared spectrum changes emerge first and isolate the responsible climate processes.

Funding:
This work is supported by the NASA PREFIRE mission Award Number 849K995 and NASA FINESST Grant Number 80NSSC22K1

References:

Holland, M., et al. (under review).
Kay, J., et al. (2015). doi:10.1175/BAMS-D-13-00255.1
Shaw, J.K. and J.E. Kay (2023). doi: 10.1175/JCLI-D-23-0020.1.