An Intercomparison of Interdecadal Variability and Climate Shifts In Reanalysis Datasets And Climate Model Simulations

Houk Paek
School for Engineering of Matter, Transport, and Energy, Arizona State University, Tempe, Arizona

Huei-Ping Huang
School for Engineering of Matter, Transport, and Energy, Arizona State University, Tempe, Arizona

Using globally integrated atmospheric angular momentum (AAM) as a climate index, the decadal-to-interdecadal variability and the 1976 climate shift event are compared among six reanalysis datasets, including NCEP Reanalysis I and II, 20CR, ERA-40, ERA-Interim, and JRA-25. It is found that the decadal-to-interdecadal variability, extracted by band-pass filtering, is very similar among all of those datasets for the second half of the 20th century. The timing and magnitude of the 1976 shift are also consistent across all datasets. The more noticeable discrepancies are in the long-term mean and the long-term trend. After removing these slowest components, the time series of the band-pass-filtered AAM in 20CR is almost indistinguishable from those in other datasets. This is remarkable since the low-frequency variability of AAM is known to largely reflect the fluctuation of upper-tropospheric zonal jets whereas the 20CR data were constructed by assimilating only surface observations. The long-term mean of global AAM in 20CR is smaller than that in other reanalysis datasets. This reflects the fact that there is no Quasi-biennial Oscillation in 20CR; The absence of QBO left a perpetual easterly state in the equatorial upper troposphere and lower stratosphere, corresponding to a lower level of AAM.

After establishing our confidence in the reanalysis datasets, they are used as observation to cross validate the decadal-to-interdecadal variability in centennial climate model simulations in CMIP3 and CMIP5. Among the 23 models in CMIP3, it is found that three quarters of them simulated a decadal (7-12 yr band) variance that is indistinguishable from observation at 95% significance level. On the other hand, almost all CMIP3 models underestimate the interdecadal (15-30 yr) variance.

In order to compare the 1976-like climate shift events in observation and climate model simulations, two criteria were developed to detect and quantify the shifts in the AAM time series. The first is based on the level of statistical significance of the hypothesis that a shift in the mean occurs between the pre-shift and post-shift epochs. The second is based on the degree of fit when matching the time series of AAM by a step function. Confirming the validity of the criteria, the 1976/77 event is found to stand out when they are applied to the AAM time series of the 20CR dataset. These criteria are then tested on the historical and pre-industrial runs in CMIP3. It is found that an interdecadal shift in AAM with a magnitude comparable to the observed 1976/77 event rarely happens in the pre-industrial runs and the historical runs. A similar analysis on the interdecadal variability and climate shifts in CMIP5 is underway pending the complete release of the dataset. Nevertheless, a preliminary analysis of a subset of the CMIP5 models indicates that the behavior of CMIP5 simulations does not deviate significantly from CMIP3.

Corresponding Author:

Name: Houk Paek
Organization: School for Engineering of Matter, Transport, and Energy
Arizona State University
Address: PO Box 876106
Tempe, AZ 85287-6106
USA