Long-term variations of circulation in East Asian summer during the past half century

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Summary

- Observed surface air temperature data in East Asian summer show cooling/leveling-off trends during the past half century, which are cooler than other seasons and other regions (**Fig. 1** and **Fig. 2**).
- Consistent with these surface trends, 500hPa height and 850hPa temperature in reanalysis data show decreased trends over the mid-latitudes of the North Pacific, including East Asia (**Fig. 3 left**).
- Blocking frequency over the Far East show increased trend (**Fig. 4**).
- AMIP simulations by a 60km mesh MRI-AGCM reproduce these observed trends in general (**Fig. 3 right**), suggesting the observed trends are strongly attributed to prescribed historical forcing, such as SST and greenhouse gases.
- Extra-tropical factors, such as cooling over the North Pacific due to the Pacific decadal oscillation (PDO) and land warming over eastern Siberia caused by global warming may be partly responsible for the observed East Asian cooling/leveling-off trends. (**Fig. 5**).

1. Introduction

In previous studies, it has been reported that surface air temperature (SAT) shows cooling trends in summer in some regions of East Asia (Yu and Zhou 2007), in contrast to general warming trends in the world. For further understanding of these observed trends, we investigate long-term data including surface observation data and atmospheric reanalysis data during the past half century (1958-2009).

To investigate possible causes of the observed trends, we conducted numerical simulations using atmospheric general circulation model (MRI-AGCM), prescribed by historical forcing.

2. Observed SAT trends

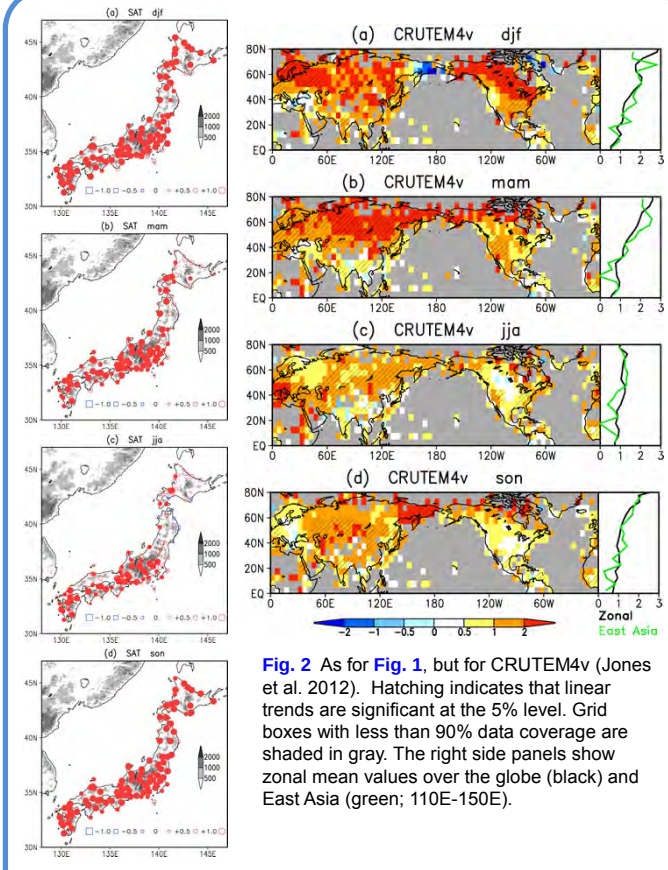

Fig. 2 As for **Fig. 1**, but for CRUTEM4v (Jones et al. 2012). Hatching indicates that linear trends are significant at the 5% level. Grid boxes with less than 90% data coverage are shaded in gray. The right side panels show zonal mean values over the globe (black) and East Asia (green; 110E-150E).

Fig. 1 Surface air temperature (SAT) linear trends (℃ per 50 years) at observation sites in Japan for 1958-2009 in (a) DJF, (b) MAM, (c) JJA, and (d) SON. Filled circles/squares indicate that linear trends are significant at the 5% level. Shadings show topography height (m).

3. Observed and simulated circulation trends

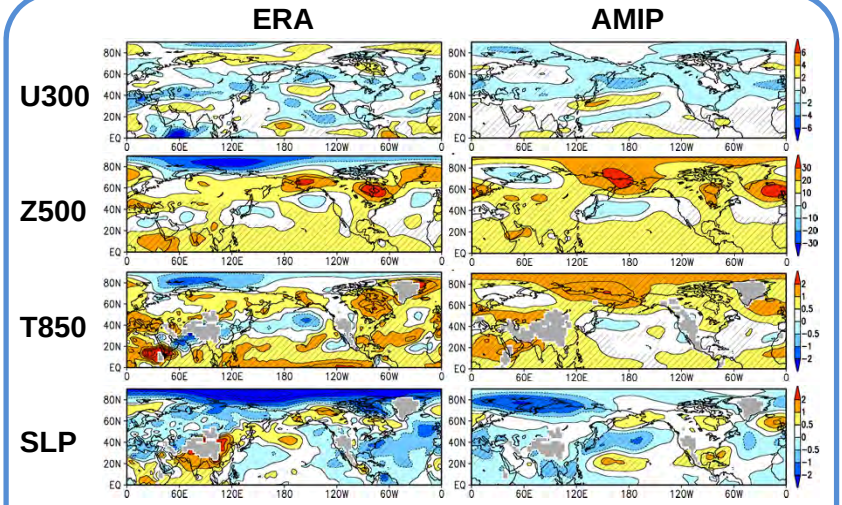

Fig. 3 Linear trends (per 50 years) in JJA for 1958-2009 for 300hPa zonal wind (m/s), 500hPa height (m), 850hPa temperature (degree), and sea level pressure (hPa). The left (right) panels are based on the ERA40 and the ERA-Interim (AMIP simulations). Hatching indicates that linear trends are significant at the 5% level.

ERA-40 (Uppala et al. 2005) for 1958–1978 and ERA-Interim (Dee et al. 2011) for 1979–2009 are used for the calculation after removing systematic bias between the two datasets for the overlapped period 1979-2001 (**Fig. 3 left**).

AGCM simulations forced by historical forcing, such as SST, greenhouse gases, and aerosols (i.e. AMIP simulations) are conducted using the 60km mesh MRI-AGCM (Mizuta et al. 2012) with 3 members for the period. (**Fig. 3 right**).

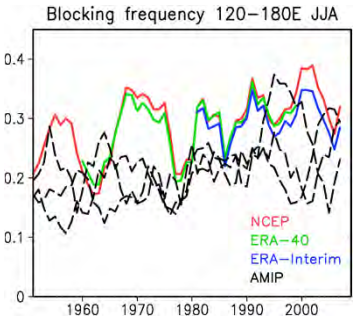

Fig. 4 Time series of the blocking frequencies (5 years running mean) in JJA over the Far East (120E-180E).

Long-term variation of blocking frequencies over the Far East are examined based on a blocking index utilizing daily 500hPa heights (D'Andrea et al. 1998).

$$\begin{cases} \mathrm{GHGS} = \dfrac{Z(\phi_0) - Z(\phi_s)}{\phi_0 - \phi_s}, \\ \mathrm{GHGN} = \dfrac{Z(\phi_n) - Z(\phi_0)}{\phi_n - \phi_0}, \end{cases} \quad \text{where} \quad \begin{cases} \phi_s = 77.5°\mathrm{N} \pm \Delta, \\ \phi_0 = 60.0°\mathrm{N} \pm \Delta, \\ \phi_n = 40.0°\mathrm{N} \pm \Delta, \end{cases} \quad \Delta = 0°, 2.5°, 5.0°,$$

$$\begin{cases} \mathrm{GHGS} > 0, \\ \mathrm{GHGN} < -5\ \mathrm{m/deg\ lat.} \end{cases}$$

A specific longitude on a specific day is defined as blocked if the above conditions are satisfied (for at least one value of Δ). The Far East sector is then defined as being blocked if 10 degree or more adjacent longitudes within 120E-180E are consecutively blocked.

4. Discussion

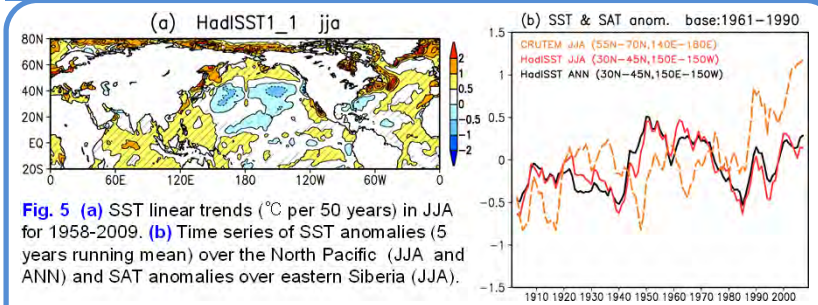

Fig. 5 **(a)** SST linear trends (℃ per 50 years) in JJA for 1958-2009. **(b)** Time series of SST anomalies (5 years running mean) over the North Pacific (JJA and ANN) and SAT anomalies over eastern Siberia (JJA).

Our results suggest that the observed cooling/leveling-off trends in East Asian summer are strongly attributed to historical prescribed forcing, such as SST and greenhouse gases. Cooling over the North Pacific due to the Pacific decadal oscillation (PDO) may be partly responsible for the East Asian summer trends. In addition, land warming over eastern Siberia caused by global warming may affect the East Asian summer trends by enhancing blocking occurrence as a result of weakening of the meridional temperature gradient over the northern North Pacific.

The relative importance of these extra-tropical factors and tropical factors to the East Asian summer trends will be examined in our continuing work.