



Up-to-date (1900-2009) rapid warming over Japan: an assessment of urban contamination

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The present study considers the total amount of surface warming over Japan through analyzing the annual mean surface air temperature of 60 reliable synoptic stations that have records of 1870s onwards. The spatial pattern of up-to-date (1900-2009) observed warming over Japan depends significantly on size of population rather on latitude/longitude, indicates the existence of urban contamination in the long term trend. The urban contamination is extensively estimated selecting different sets of the rural stations based on mean city population, satellite imagery and JMA recommended rural sets as well as land/sea warming contrasts simulated from IPCC-AR4 climate models. The trends of 53 out of 60 (~89%) stations reported here have trend-to-noise ratios greater than 1.96 and regarded as statistically significant at 95% level. We also included 95% uncertainty intervals (as \pm) in all regionally average long-term trends. The regionally averaged mean annual temperature within Japan has increased by $1.75 \pm 0.12^\circ\text{C}$ (noticeably higher than other countries); the surrounding oceans ($25 - 50^\circ\text{N}$ and $120 - 150^\circ\text{E}$) have warmed by $0.96 \pm 0.07^\circ\text{C}$ in the last 11 decades during the period of 1900-2009. The 9 highly populated cities (Sapporo, Tokyo, Yokohama, Kyoto, Osaka, Nagoya, Hiroshima, Kobe, and Fukuoka) show an increasing trend of $2.40 \pm 0.15^\circ\text{C}$. All sets of data exhibited relatively high rural warming despite of significant contamination of urban warming ($0.10^\circ\text{C}/\text{decades}$) due to influence of metropolitan cities and $0.04^\circ\text{C}/\text{decade}$ due to rapidly growing sub urban cities.

Current generation of AR4 climate models reproduce observed Cobe SST quite well and to some extend the observed rural warming but none of the climate model reproduce the observed centennial scale rapid surface air temperature trend over Japan mostly arising from urban contamination. The residual part of warming between observed and model simulated land surface air temperature enable us to determine indirectly the extent of urban contamination over Japan.

Key words: Rural warming, population, urbanization effect, land/sea warming contrast