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The mechanism of summer heatwaves over eastern Siberia and its linkage to
atmospheric and oceanic variability in the western North Pacific
(東シベリアにおける熱波のメカニズムおよび北西太平洋の大気海洋変動との関係)

Summer heatwaves have become increasingly frequent and intense worldwide with the progression of global warming. These rapid increases have also been observed in high-latitude regions, including eastern Siberia, a region underlain by carbon-rich permafrost. Summer heatwaves over eastern Siberia exert significant adverse impacts on the local ecosystems and have a potential role in amplifying global warming. Compared to densely populated regions such as Europe and East Asia, summer heatwaves over eastern Siberia have received limited attention from climate scientists. Moreover, earlier research suggests that these heatwaves are linked to weather variability in East Asia, with potential implications for sea surface temperature variability in the western North Pacific (WNP). However, the processes underlying this linkage remain unclear. Addressing these research gaps, this dissertation aims to elucidate the mechanism of summer heatwaves over eastern Siberia and examine its linkage to atmospheric and oceanic variability in the WNP.

This study compares the atmospheric circulation patterns and mechanisms associated with heatwaves over northeastern Siberia (NES) in July and August. While the frequency of NES heatwaves significantly increases during these two months, their interannual variations are out of phase. Regression analysis reveals clear wave train features along northern Eurasia associated with NES heatwaves in July. Empirical Orthogonal Function analysis further confirms that the British–Okhotsk Corridor pattern primarily regulates NES heatwaves in this month. However, this teleconnection is less clear in August because the Rossby waveguide effect is weaker in August than in July. In contrast, NES heatwaves in August are associated with a meridional atmospheric circulation pattern extending from the Arctic to the WNP. An Arctic low-pressure anomaly facilitates the formation of NES heatwaves through the propagation of Rossby wave, as supported by the linear baroclinic model experiment. Additionally, the heatwave-related high-pressure anomaly over the NES in August may influence weather and sea surface temperature variability in the WNP.

The impacts of NES heatwave-related atmospheric circulation patterns on weather and sea surface temperature variability in the WNP are further examined. The results show a strong linkage between August heatwaves over the NES and subsequent sea surface temperature cooling in the WNP, which primarily arises from an anomalous dipole pressure pattern over the NES and WNP. Anomalous high

pressure over the NES leads to clear sky and enhanced insolation, promoting heatwave formation. Conversely, anomalous low pressure over the WNP leads to cloudy sky and reduced insolation. Furthermore, anomalous northeasterly winds from the Bering Sea enhance the release of latent heat flux from the ocean surface. These processes lead to surface heat loss in the WNP and subsequent sea surface temperature cooling. The shallow mixed layer depth in the WNP during the warm season makes sea surface temperature more responsive to the heat loss, contributing to the uniqueness of this linkage.

The impacts of global warming on summer heatwaves over the NES are further explored by comparing large ensemble historical simulation and non-warming simulation datasets. The results indicate that, while external forcings have contributed to the observed recent increase in heatwaves, internal atmospheric variability remains a key factor on a yearly basis. Event attribution analysis of major observed heatwave periods reveals that global warming has increased the occurrence probability of such extreme periods. An additional analysis of the dominant modes of summer heatwaves over northern Eurasia identifies three primary patterns: a pattern with a single positive anomaly centered over western Siberia, which seems driven by the external forcings and sea surface temperature warming, and the other two patterns exhibiting tripolar distribution across northern Eurasia, which are predominantly regulated by internal atmospheric variability.

The findings of this study offer valuable insights into the characteristics and mechanisms of summer heatwaves over eastern Siberia. These enhanced understandings can help inform strategies to address associated challenges, such as the monitoring of wildfires and permafrost thawing, thereby contributing to the protection of the ecosystems in eastern Siberia. Furthermore, the study underscores the role of atmospheric forcing from eastern Siberia as a potential precursor for predicting weather and sea surface temperature variability in the WNP. These results deepen our understanding of the regional climate system and provide important implications for the conservation of regional marine ecosystems.