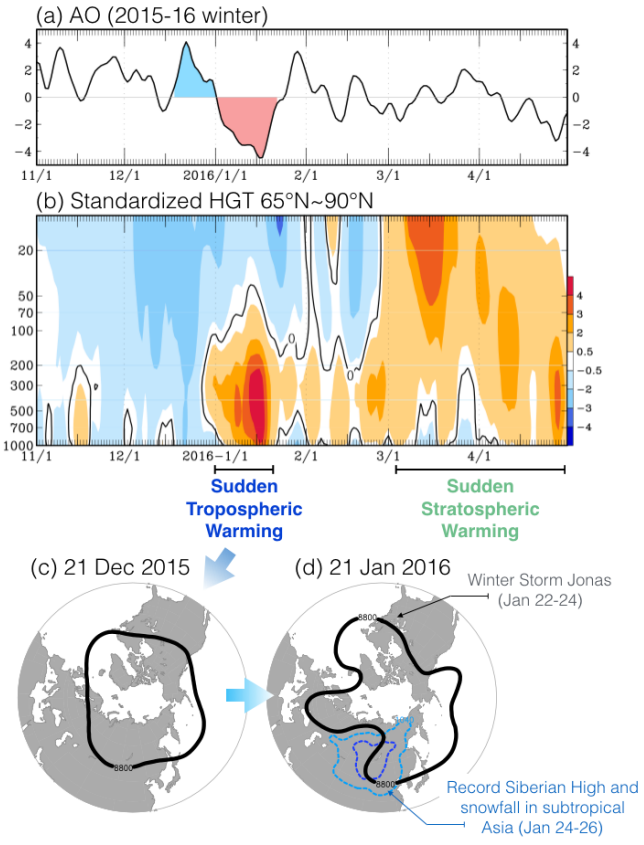
The tropospheric route of rapid Arctic warming events: 2016 and trend

From late December 2015 through January 2016, the Arctic region underwent a sudden and remarkable warming episode. The Arctic Oscillation (AO) index responded with a rapid phase reversal from positive to negative exceeding 2 standard deviations (σ) within merely 20 days (Figure 1a). As shown by the vertical profile of standardized geopotential height over the Arctic region (Figure 1b; averaged north of 65°N), the troposphere expanded rapidly during mid-January 2016; this incident is referred herein as the rapid tropospheric warming (RTW). The upper tropospheric circulation transitioned from a circular pattern in late December (Figure 1c) to high-amplitude stationary waves in late January (Figure 1d), accompanied by extreme weather events worldwide, such as the record flooding in U.K. and Ireland in early January, Winter Storm Jonas that "rivals biggest East Coast snowstorms on record" in late January, and record snowfalls and cold weather in East Asia including 84 hyperthermia casualties and severe agricultural damages in Taiwan, which followed an unprecedented strength in the buildup of the Siberian high (Figure 1d). This RTW event corresponded with the record warmth and record low sea ice content (SIC) in the Arctic that continued through April.

Following the RTW episode, a classic sudden stratospheric warming (SSW) event took place during March-April (Figure 1b) accompanied by a mild AO phase reversal (Figure 1a). Previous studies have suggested that SSW is a precursor to AO phase change through the downward propagation of the stratospheric polar vortex variation, though this notion does not apply to the RTW case and its associated AO phase reversal. The record RTW event and the subsequent occurrence of SSW during early 2016, along with the RTW's associated severe cold-weather damages in East Asia, is intriguing in the context of the two different types of Arctic warming. This RTW event also suggests that the AO phase reversal does not necessarily require a stratospheric precursor and this presents a challenge in subseasonal climate prediction.



By tracking the RTW and SSW events and separating their trends, it was found that only the RTW events have increased and with an accelerated change after the 1990s. The SSW events have remained relatively unchanged without any significant trend. In the presentation, the methods and approaches used in identifying and validating the RTW vs. SSW events are discussed. A set of forced experiments using ECHAM5 model is presented. CFS forecast revealed challenge in capturing the Siberian high and temperature responses to the RTW event.