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Recent Slow Melt of Arctic Summer Sea Ice Due to Tropical Pacific SST Changes

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1. Introduction

In this study, we aim to understand the influence of tropical Pacific sea surface temperature (SST) changes on Arctic sea-ice decline in September. Arctic sea ice has shown accelerated melting from the early 2000's to the early 2010's and a slowing down thereafter (Swart *et al.* 2015). However, this slowdown is not expected with a steadily increasing rate of greenhouse gas emissions over this period. Our analysis of observational and model evidence shows that the recent slowdown of summer sea ice loss reflects a continuous anthropogenically forced melting enhanced and then masked by interdecadal variability of Arctic atmospheric circulation. This variation is driven by teleconnections originating from SST changes in the eastern-central tropical Pacific via a Rossby wave train propagating into the Arctic. This teleconnection, which we refer to as the "PARC", or Pacific-Arctic teleconnection, has contributed to abrupt warming and Arctic sea ice loss from 2007 to 2012, followed by a much slower decline in recent years, resulting in the slowdown appearance. Given the importance of this process in driving the Arctic climate on low–frequency time scales, accurate representation and prediction of the PARC mode in climate models is critical for future projections of the Arctic climate.

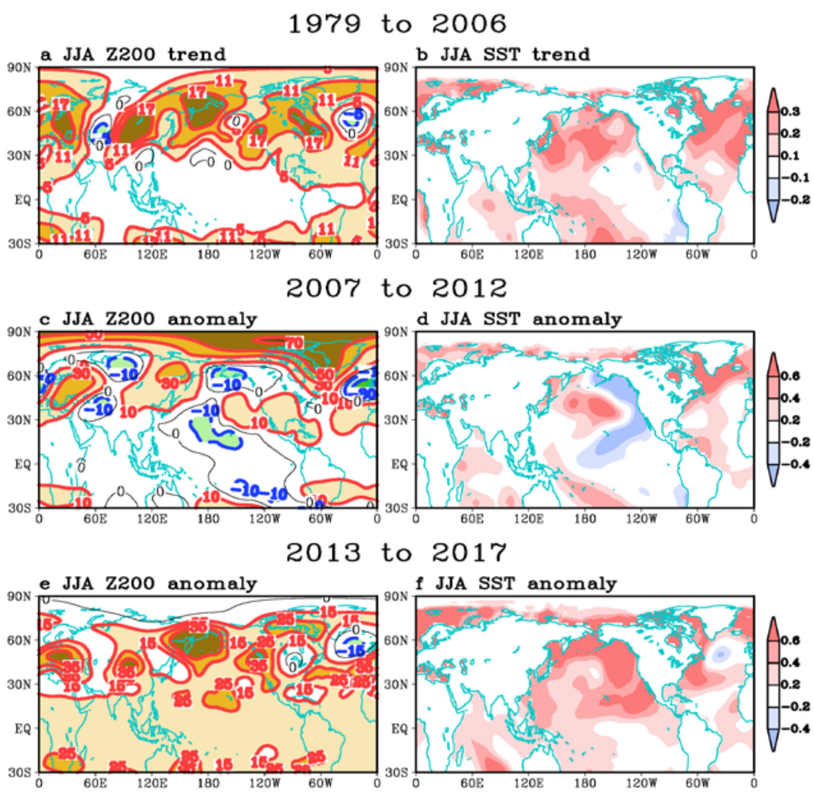

Fig. 1 1979-2006 linear trend in (a) ERA-Interim JJA 200hPa geopotential height and (b) ERSSTv4 JJA sea surface temperatures. (c) and (d) are the same as (a) and (b) but for 2007-2012 anomaly from 1979-2017 mean. (e) and (f) are the same as (c) and (d) but for 2013 to 2017 anomaly.

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2. The observed Pacific-Arctic teleconnection

We first examined all linear trends longer than 10 years in the total September Arctic sea ice index and found two prominent trends: a period of the fastest melting from 2001 to 2012 and the only near-zero trend from 2007 to 2017. These two periods overlap from 2007 to 2012. Thus, to focus on this period and its role in the slowdown, we divided our analysis into three epochs: the linear trend from 1979 to 2006 and the anomalies from 2007 to 2012 and 2013 to 2017 (Fig. 1). The linear trend from 1979 to 2006 does not show a strong change in the eastern Pacific or in the Arctic. However, from 2007 to 2012 there is cooling in the eastern tropical Pacific that generates high pressure in the Arctic troposphere through Rossby wave propagation. The barotropic high pressure structure then leads to adiabatic descent of air, that warms and moistens the lower Arctic troposphere, increasing emission of longwave radiation and contributing to enhanced sea ice melt (Ding *et al.* 2014, 2017). Between 2012 and 2013, eastern-central Pacific SST switched to a warm phase, leading to a cooling effect in the Arctic and masking of CO_2-driven melting.

The PARC is the leading internal mode obtained through Maximum Covariance Analysis (also called Singular Value Decomposition) using a covariance matrix between detrended June-July-August (JJA) SST from 30°S to 30°N and 200 hPa geopotential height from 60°N to 90°N. The PARC links changes in eastern tropical Pacific SST to abrupt changes in geopotential height, temperature, and sea ice in the Arctic through a poleward propagating Rossby wave train. The PARC shows a peak between 2007 and 2012, coinciding with the most rapid period of September sea ice decline.

3. Model experiment

We utilize a pacemaker experiment to test the ability of tropical Pacific sea surface temperatures to drive Rossby wave propagation from the eastern-central Pacific to the Arctic during the enhanced melting period from 2007 to 2012. For this, we use the ECHAM4.6 general circulation model (GCM) coupled with a simple thermodynamic sea ice-ocean model. Since our model uses only a simple thermodynamic model, we focus primarily on the influence of tropical Pacific SST on Arctic circulation. The sensitivity simulation was driven by the observed SSTs in the eastern central Pacific (30°S to 30°N) averaged from 2007 to 2012 and run for 40 years with the first 10 years considered spin up. With this method, each year can be considered an individual realization and the 30-year average as an ensemble mean. The control simulation was driven by observed climatological SSTs (12-month annual cycle) everywhere and run for 40 years. The difference between the 30-year average of the sensitivity and control runs shows SST changes in the eastern-central Pacific can generate Rossby wave propagation to the Arctic from 2007 to 2012 with a high pressure center near Greenland similar to that seen in observations (Fig. 2).

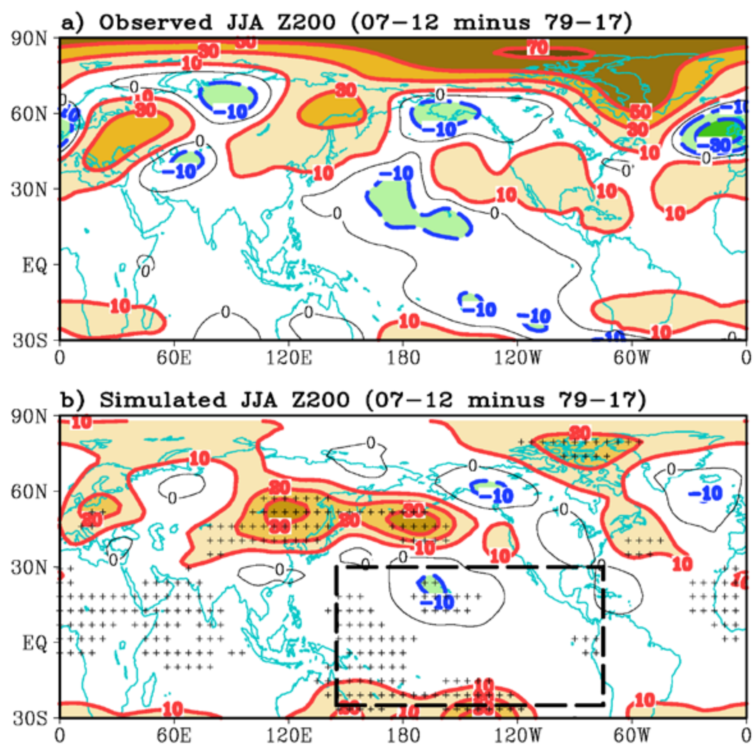

Fig. 2 a) Observed JJA 200hPa geopotential height anomaly (unit: m) for 2007-2012 against the 1979-2017 mean. (b) Same as (a) but for the model response from the sensitivity experiment described in the text. The dashed, black box (145°E-285°E, 25°S-30°N) indicates the region where observed SSTs were prescribed to force the model. Stippling in (b) indicates statistically significant differences at the 95% confidence level by the two-sample *t*-test.

4. Conclusions

Our observational analysis in combination with the results from the pacemaker experiment suggest an eastern-central Pacific-Arctic teleconnection (PARC) is partially responsible for the recent slowdown appearance in the decline of September Arctic sea ice. Through changes in Arctic circulation, the PARC is able to strengthen or mask the effects of CO_2-driven atmospheric warming in the Arctic. This is most clearly seen from 2007 to 2012 as cooling in the eastern-central Pacific led to Rossby wave propagation to high latitudes, high pressure near Greenland and in the Arctic and decreased September sea ice cover. A shift from the strengthening phase (2007-2012) to a masking phase (2013-2017) gives the appearance of a slowdown in September Arctic sea-ice decline.

References

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