Does the Arctic Amplification peak this decade?

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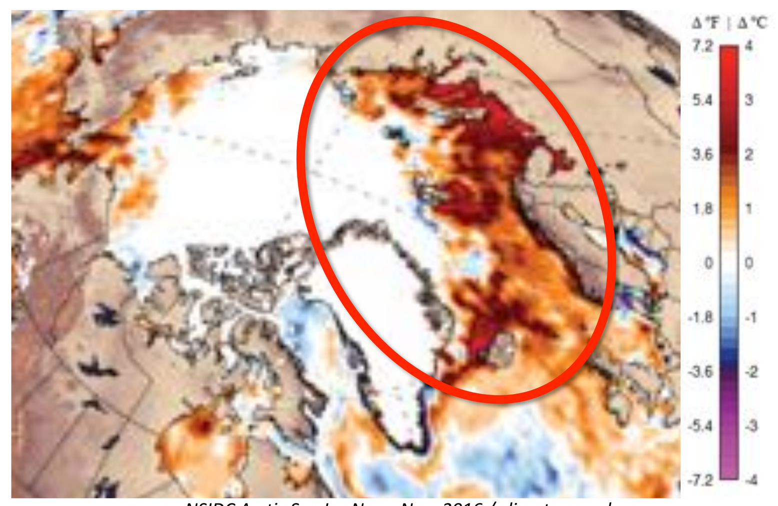
The heat is on

SST anomaly on Oct 25, 2016, NASA OISST V2



The Arctic region warms rapidly accompanied by shrinking sea ice coverage. Last autumn unusual high SST hindered sea ice regrowth which lead to record low sea ice area and volume this past winter.

What is Arctic Amplification?

In the Arctic (here defined as area >70˚N) surface air temperature (SAT) rises faster than the global mean under increasing greenhouse gas concentrations (*see Figure 1*). While this Arctic Amplification is present throughout the troposphere we focus on the strong surface effect[1].

What causes it?

Several processes are involved:

- albedo contrast between ice and ocean
- seasonal heat storage in ocean and exchange with atmosphere (moderated by sea ice)
- year-to-year memory in sea ice thickness
- temperature and radiation (lapse rate and Planck) feedbacks
- change in cloud type and coverage
- snow cover and vegetation change on land
- heat and water vapor advection from subpolar region

Note, as sea ice vanishes, its effectiveness in Arctic amplification decreases.

Models

This study is based on CMIP5 simulations including the following climate models: ACCESS1-0, ACCESS1-3, BNU-ESM, CCSM4, CESM1-BGC, CESM1-CAM5, EC-EARTH, HadGEM2-AO, HadGEM2-CC, HadGEM2-ES, MIROC-ESM-CHEM, MIROC5, MIROC-ESM, MPI-ESM-LR, MPI-ESM-MR, which have been verified by different metrics to best simulate the present sea ice decline[2,3]. We include runs of the historical and RCP8.5 scenarios.

1 Arctic and global warming

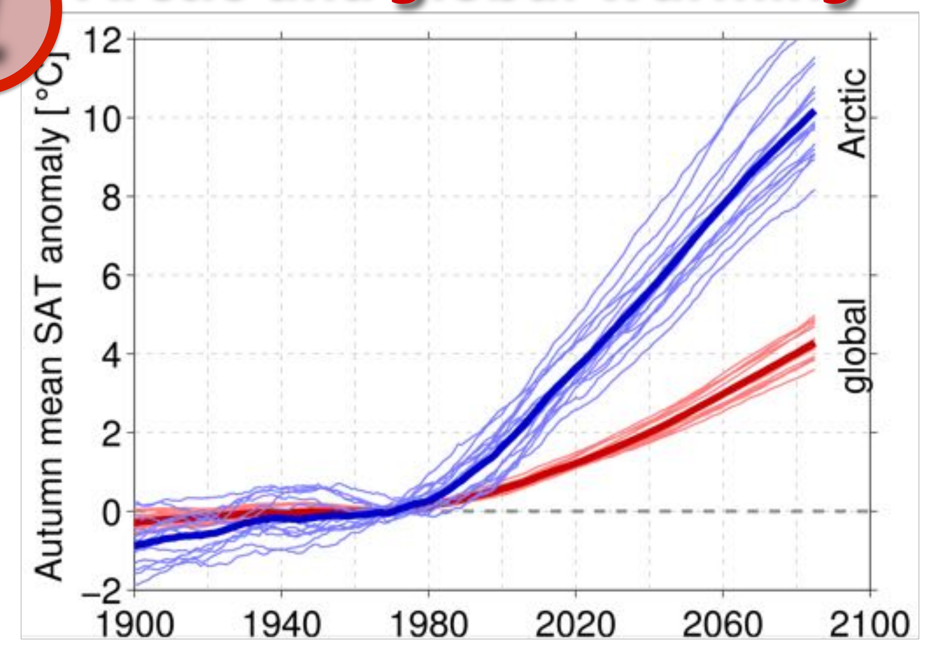


Figure 1: Autumn (September to November) Arctic mean (blue) and global mean SAT anomalies (red) referenced to 1960–1980 mean and smoothed by a 30-year boxcar filter.

Year-to-year change in temperature and sea ice

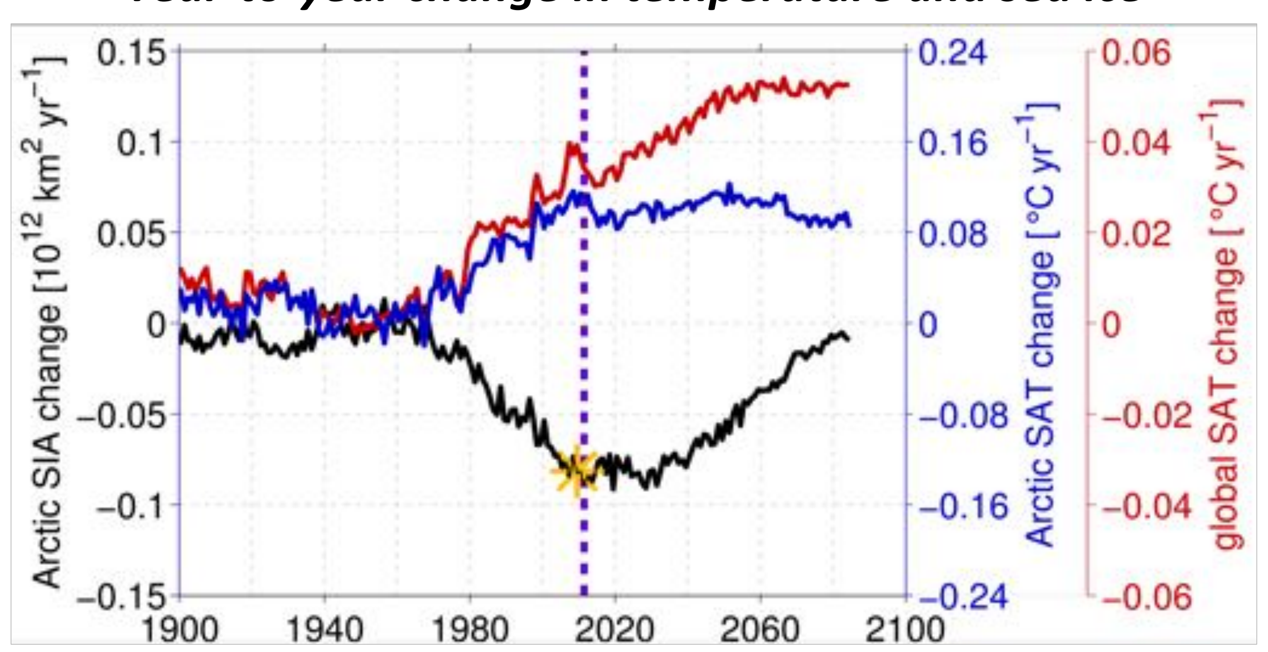


Figure 2: Rates of SAT and sea ice area (SIA) change based on the 30-year boxcar filter smoothed multi-model mean time series shown in Figures 1 and 3 above and below. For the yellow star and purple dashed line markers see 2 and 3 respectively.

2 Sea ice area decline

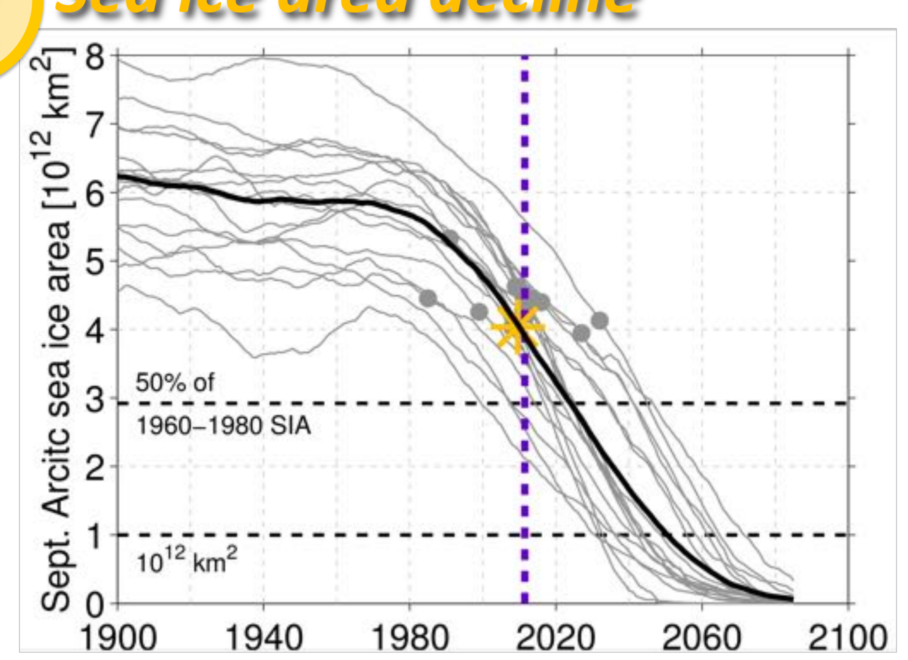


Figure 3: Arctic September mean sea ice area from CMIP5 models (gray lines) and the multi-model mean (black line). Circles mark the year in which each model run passes through *Se* = 1 (see Fig. 6 on right). The vertical purple dashed line marks the multi-model mean peak year of sea ice related feedbacks and is explained under 3.

3 Peak in coincident sea ice and SAT year-to-year change

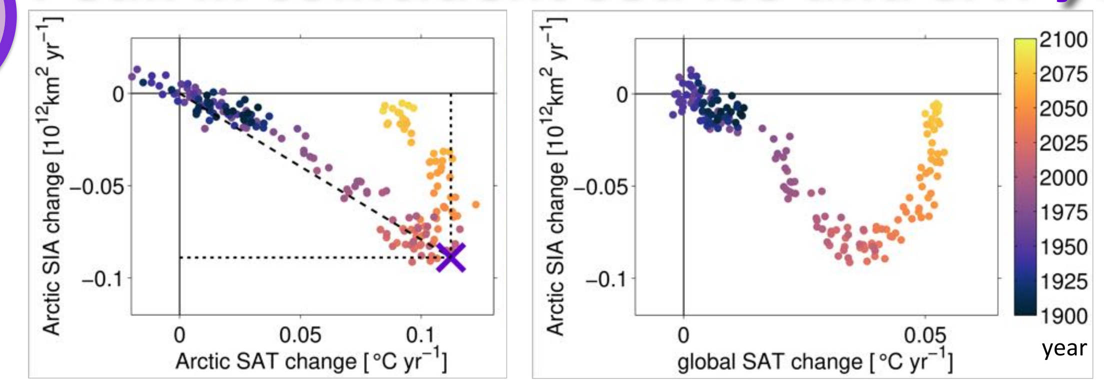


Figure 4: Peak in coincident sea ice retreat and Arctic SAT warming (indicated by purple 'x' in left panel). This year is marked by a dashed purple line in Figures 2, 3 & 5. Color-filled circles depict year-to-year changes of Arctic September mean sea ice area and autumn mean SAT. Right panel shows the same but for global autumn mean SAT. Here, the 30-year boxcar filter smoothed multi-model means of Figure 2 are shown.

The CMIP5 model ensemble* projects ***autumn mean Arctic Amplification to peak in the 2010s***

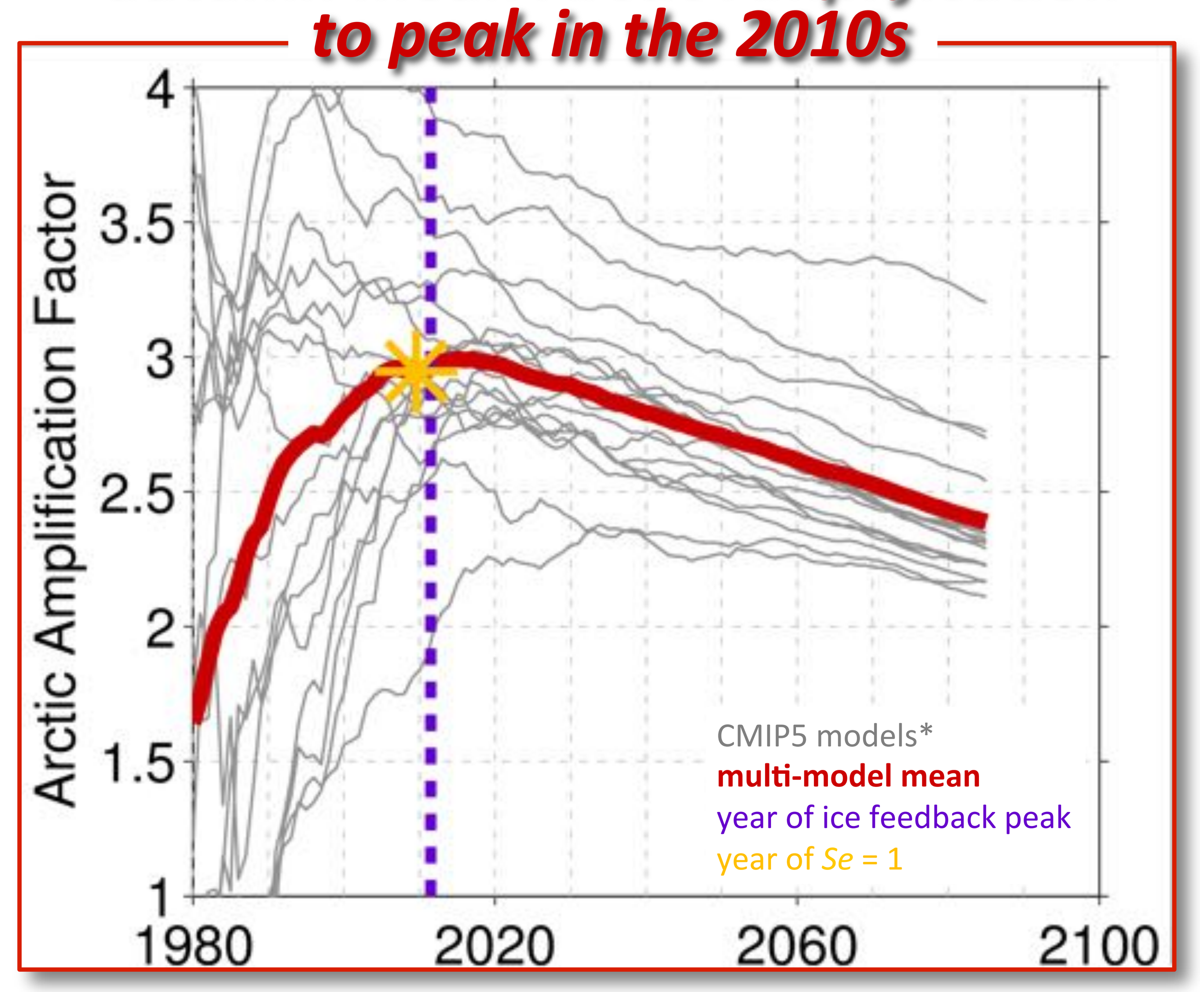


Figure 5: Time series of the autumn mean surface Arctic Amplification factor defined as the ratio of Arctic to global SAT anomalies as shown in Figure 1.
*Models included in the ensemble are listed in the box on the bottom left.

The northern hemisphere sea ice system has entered the seasonal regime

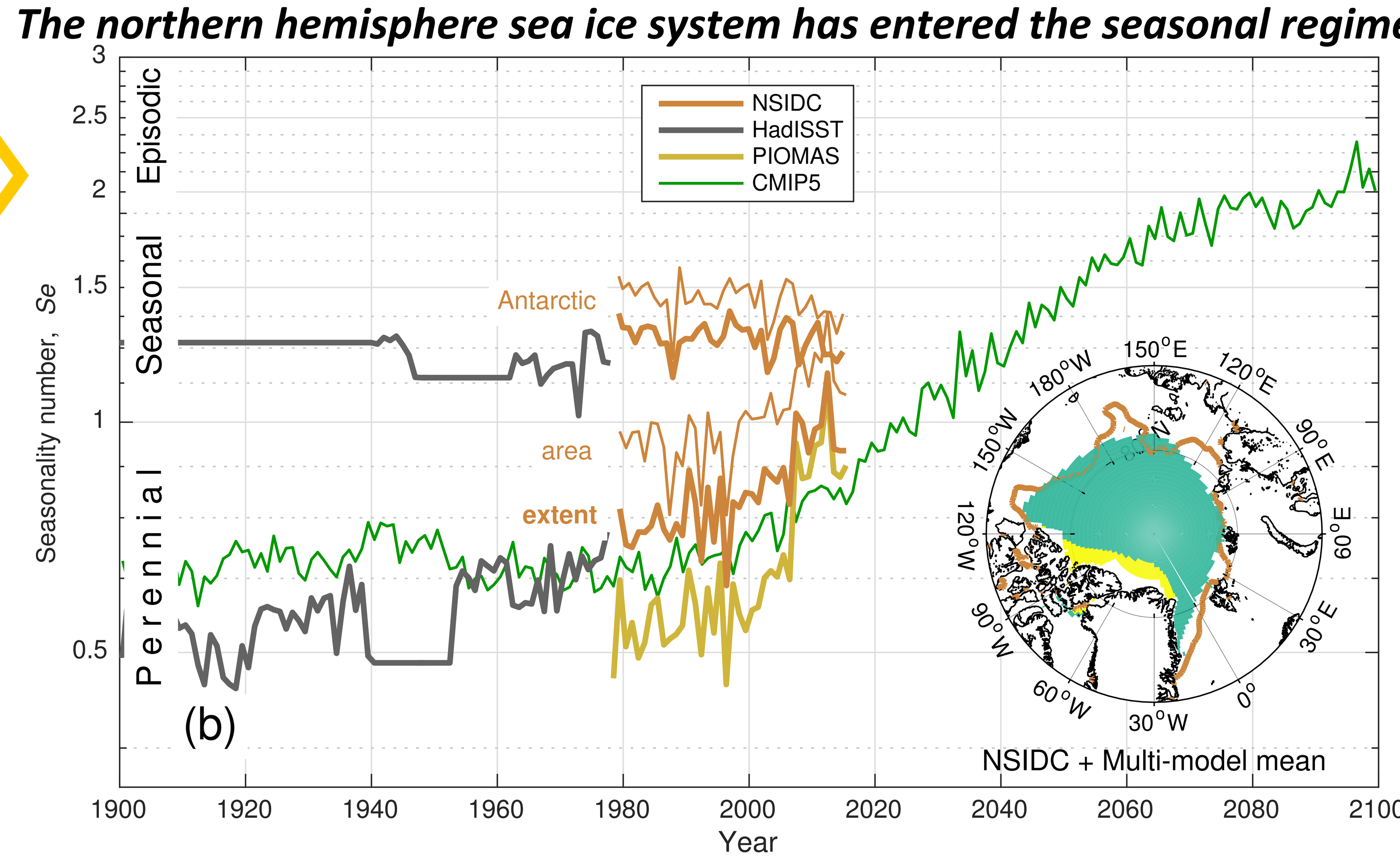


Figure 6: Increasing seasonality of Arctic sea ice extent and area: We define the seasonality number *Se* as

$$Se(T) = (t_2 - t_1)\frac{|x(t_2) - x(t_1)|}{\int_{t_1}^{t_2} x(t')\,dt'}$$

the ratio of seasonal range to annual mean sea ice extent/area[4]. Seasonality numbers presented are from NSIDC satellite data[5] (Arctic and Antarctic) as well as PIOMAS[6] Arctic hindcast w/assimilation for the observational period, HadISST[7] (Arctic & Antarctic) prior to 1978, and the CMIP5 multi-model Arctic mean for 1900-2100 (historical + RCP8.5).

Conclusions

- Surface Arctic Amplification peaks under continuous global warming.
- For autumn months this peak occurs in the 2010s but later in 2060-2080 for the winter season according to model projections under the CMIP5 RCP8.5 climate scenario.
- The autumn peak coincides with the Arctic sea ice cover entering the seasonal regime …
- and a maximum in effectiveness of sea ice in associated feedback mechanisms, such as the ice-albedo feedback.
- The seasonality number[4] is thus a more meaningful measure of the changing Artic than the 10^6 km^2 sea ice extent threshold often cited in the literature to identify and ice-free Arctic.

4 Peak in Arctic Amplification shifts from 2010s in early autumn to 2080s in winter

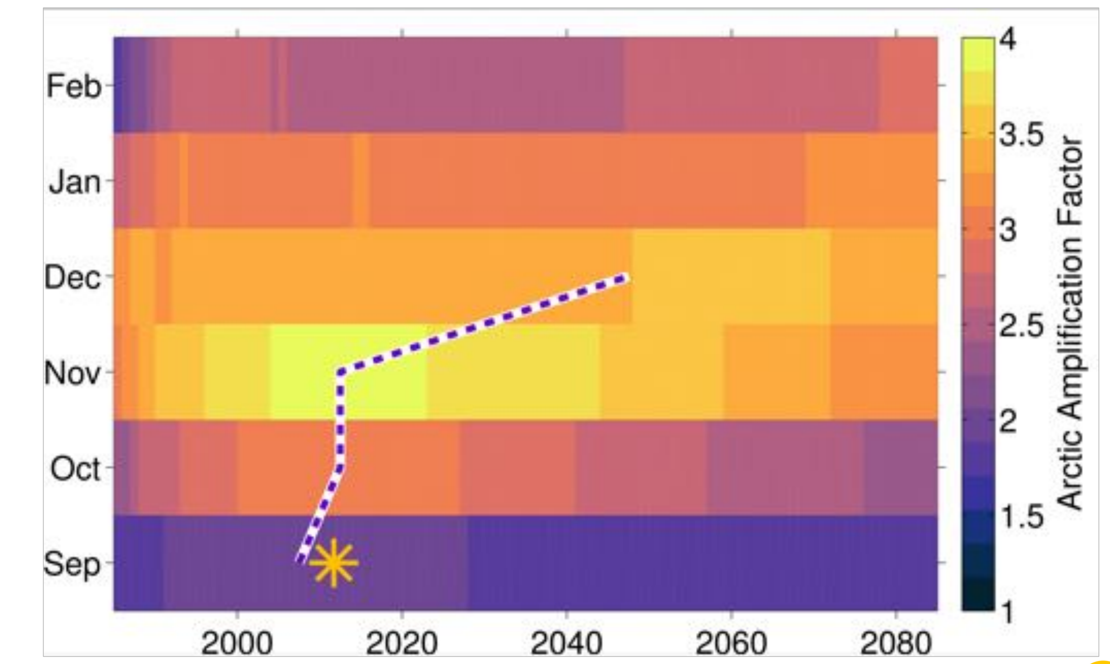


Figure 7: Time series of multi-model mean Arctic Amplification factors by month from early autumn to mid-winter. Clearly, Artic Amplification is strongest in November. A progression of the peak in each month from 2008 for September to the late 21[st] century for February can be seen.

For the yellow star and purple dashed line markers see 2 and 3 respectively. Here, the peak in SAT and SIA changes is calculated for each month. From mid-winter to spring sea ice retreat becomes less dominant and Arctic Amplification is driven by other processes preventing a meaningful computation of this metric.

References

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