Science and Technology Infusion Climate Bulletin
NOAA's National Weather Service
43rd NOAA Annual Climate Diagnostics and Prediction Workshop
Santa Barbara, CA, 23-25 October 2018

How Well Do Climate Models Simulate the Internal Variability in Arctic Air-Sea Ice Trend?

Pengfei Zhang[1, 2] and Qinghua Ding[2]
[1]*University of California, Los Angeles, California*
[2]*University of California, Santa Barbara, California*

1. Introduction

It has been found with high confidence that human-induced climate warming drove the Arctic sea ice decline over recent several decades (IPCC 2013). It is very likely that the summer Arctic will be nearly sea ice free around 2040 based on model projections (Overland and Wang 2013). However, climate models are significantly underestimate the observed sea ice melting rate (*Stroeve et al.* 2012). This underestimation largely limits the confidence of the future projection of the sea ice change in climate models.

Recent studies revealed that both natural variability and anthropogenic warming modulate Arctic sea ice decline (Kay *et al.* 2011; Day *et al.* 2012; Swart *et al.* 2015). Especially, the significant contribution of atmospheric internal variability has been emphasized (Ogi and Wallace 2012; Ding *et al.* 2017). It found that the variability of minimum Arctic sea ice in September is highly related to JJA surface anticyclonic circulation anomalies (Ogi and Wallace 2012), which have vertical coherent structure from the surface to the upper troposphere (Ding *et al.* 2017). This atmospheric internal variability, in consort with warming directly induced by the external anthropogenic radiation forcing, contributes to the sea ice decline in recent decades (Ding *et al*. 2014). However, it is still unclear that if this internal air-sea ice linkage can be well represented in climate models.

2. Evaluation of model simulation

In this study we evaluated the role of internal air-sea ice linkage in the simulation of sea ice trend in the forced run of 27 Coupled Model Intercomparison Project 5 (CMIP5) models and Large Ensemble (LENS) project output using the CAM5-BGC/CESM model (The Community Earth System Model with Community Atmosphere Model 5.0 as its atmospheric component uses active biogeochemistry). The results show that the observed tropospheric circulation pattern centered over northern Greenland is biased shifted to Chukchi Sea and the neighboring Arctic Ocean in climate models, which impact the sea ice export out of Arctic Ocean via kinematic effect. Second, the air-sea ice linkage induced by the internal variability can be simulated by CAM5-BGC/CESM. This internal variability significantly contributes to the large spread of sea ice melting rates in forced climate model simulations. Stream function reasonably presents the internal circulation changes in the context of anthropogenic warming. Third, the underestimation of sea ice decline in the ensemble mean of model simulation is due to the atmospheric internal variability induced sea ice decline is mostly averaged out in the mean (see Fig. 1). The model simulations with an observation-like anticyclonic trend and anthropogenic forcing could reproduce a realistic sea ice decline.

3. Concluding remarks

Our results suggest that the model performance in Arctic atmospheric circulation needs improvement to advance the simulation of the internal air-sea ice linkage. The contribution of internal variability to sea ice melting cannot be neglected when we estimate the future amount of Arctic sea ice loss. A model with a well-represented internal variability, such as CESM-CAM5-BGC, is the precondition to get a reasonable projection of Arctic sea ice change.

Correspondence to: Pengfei Zhang, University of California, Los Angeles, CA 90095, and University of California, Santa Barbara, CA 93106; E-mail: zpengfei@ucsb.edu

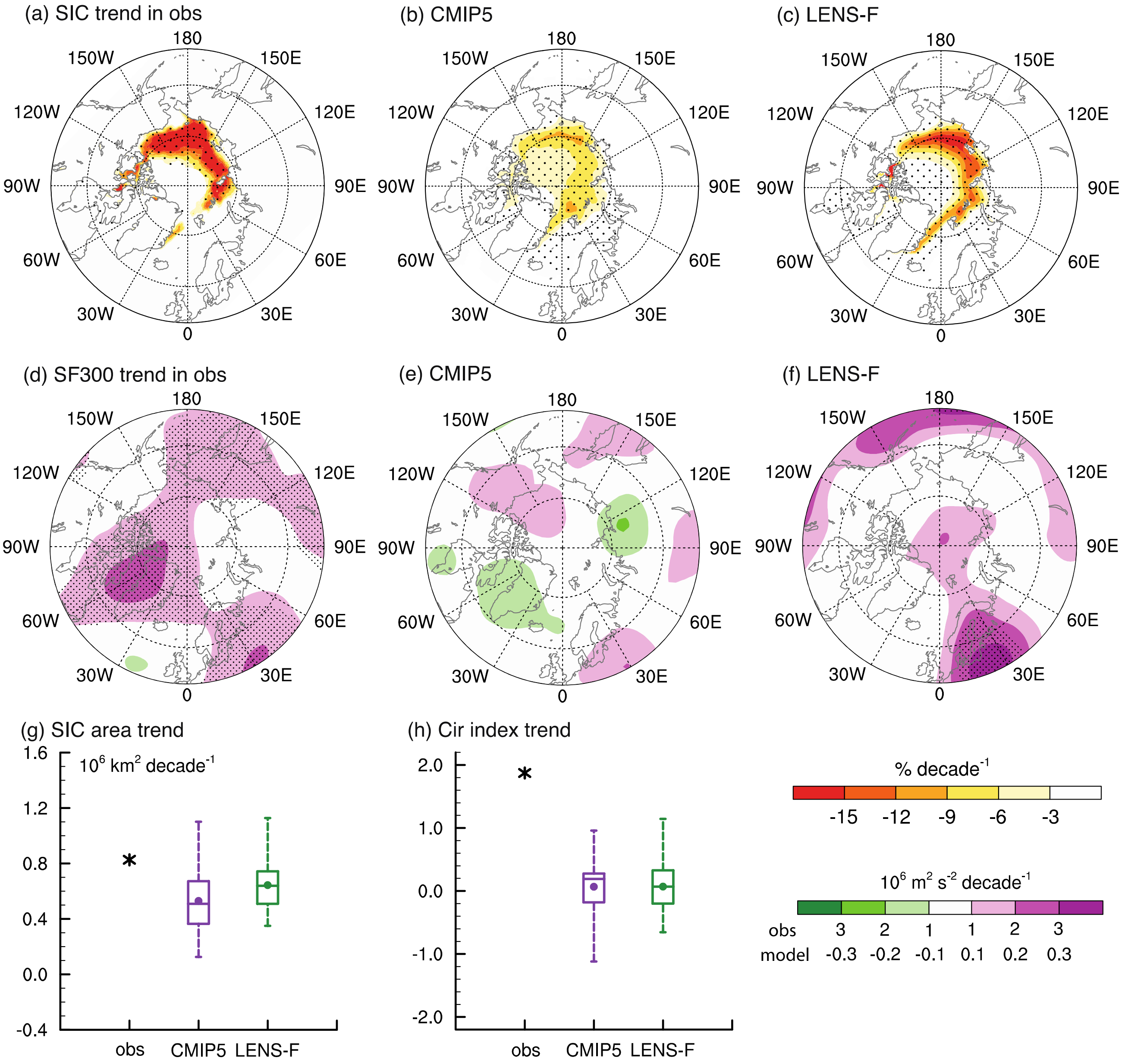

Fig. 1 (a-c) Arctic September sea ice trend (% per decade) in 1979-2016 in observation (a), CMIP5 (b) and LENS-F (c). (d-f) Same as the (a-c) but for the 300hPa stream function (units: 10^6 m^2 s^{-2} per decade. It is noted that the interval for observation is the ten times of that in model ensembles). (g) box plot of the trend of sea ice area (million km^2 per decade) in observation (black star), CMIP5 27 models (purple box) and LENS-F 40 runs (green box). The box values from bottom to top are the minimum, first quartile, median, third quartile and maximum of the CMIP5 27 model runs and LENS-F 40 runs, respectively. The dots denote the ensemble mean of CMIP5 and LENS-F, respectively. (h) Same as (g) but for the 300hPa stream function. The values in (g) were reversed to emphasize the sea ice loss.

References

Day, J. J., and Coauthors, 2012: Sources of multi-decadal variability in Arctic sea ice extent. *Environ. Res. Lett.*, **7**, 0340111, doi:10.1088/1748-9326/7/3/034011

Ding, Q., and Coauthors, 2014: Tropical forcing of the recent rapid Arctic warming in northeastern Canada and Greenland, *Nature*, **509**, 209-212, doi:10.1038/nature13260.

Ding, Q., and Coauthors, 2017: Influence of high-latitude atmospheric circulation changes on summertime Arctic sea ice. *Nat. Clim. Change*, **7**, 289–295, doi:10.1038/nclimate3241.

IPCC, 2013: *Climate Change 2013: The Physical Science Basis.* Cambridge University Press, 1535 pp.

Kay, J. E., and Coauthors, 2011: Inter-annual to multi-decadal Arctic sea ice extent trends in a warming world. *Geophys. Res. Lett.*, **38**, L15708, doi:10.1029/2011GL048008.

Ogi, M., and J. M. Wallace, 2012: The role of summer surface wind anomalies in the summer Arctic sea ice extent in 2010 and 2011. *Geophys. Res. Lett.*, **39**, L09704, doi:10.1029/2012GL051330.

Overland, J. E., and M. Wang, 2013: When will the summer Arctic be nearly sea ice free? *Geophys. Res. Lett.*, **40**, 2097-2101, doi:10.1002/grl.50316.

Stroeve, J. C., and Coauthors, 2012: Trends in Arctic sea ice extent from CMIP5, CMIP3 and observations, *Geophys. Res. Lett.*, **39**, L16502, doi:10.1029/2012GL052676

Swart, N. C., and Coauthors, 2015: Influence of internal variability on Arctic sea-ice trends, *Nat. Clim. Change*, 5, 86–89, doi:10.1038/nclimate2483.