An Evaluation of Forecast Performance for North Atlantic Oscillation Onsets

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1. Introduction

- The North Atlantic Oscillation (NAO) is a dominant, low-frequency atmospheric dipole mode in the Northern Hemisphere during wintertime, which has great influences on weather and climate in North America and Eurasia (Walker and Bliss, 1932; Hurrell, 1995; Woollings et al., 2008; Diao et al., 2015).
- Many studies have investigated the NAO and its climatic effects from a perspective of monthly mean or seasonal mean (Thompson and Wallace, 2000; Thompson et al., 2000; Zuo et al., 2016; Whan and Zwiers, 2017). Furthermore, Feldstein (2003) showed that the intrinsic time scale of the NAO is approximate 2 weeks.
- NAO events are often related with extreme weather in the Northern Hemisphere during wintertime, it is necessary to investigate the forecast performance for the onset of NAO events..

2. Data and method

- The reanalysis data used in this paper are the daily SLP from NCEP/NCAR. The spatial resolution is 2.5° ×2.5° , and the time period is from 01 January 1958 to 31 December 2015 (Kalnay et al., 1996; Kistler et al., 2001).
- TIGGE data include daily weather forecasting products from 10 global centers (Park et al., 2008; Swinbank et al., 2016), and daily operational forecasts of SLP from ECMWF, NCEP, JMA and CMA are used in this investigation.
- NAO index (NAOI) is defined as the difference in normalized sea level pressure regionally that is zonally averaged over the Atlantic sector (i.e., longitudes from 80° W to 30° E between a mid-latitude (35° N) and a high-latitude (65° N)).
- If the NAOI is greater than 1.0 standard deviation for 3 or more consecutive days, an NAO event is identified. 22 NAO+ events and 9 NAO- events are selected for evaluation during the wintertime from 2006/07 to 2014/15.
- The skillful forecast time is defined as the longest day that the NAO onset could be forecasted. Products with different forecast time are tested and the longest day which is able to meet the condition is defined as the skillful forecast time.

3. Results

3.1 Evaluation for control forecast

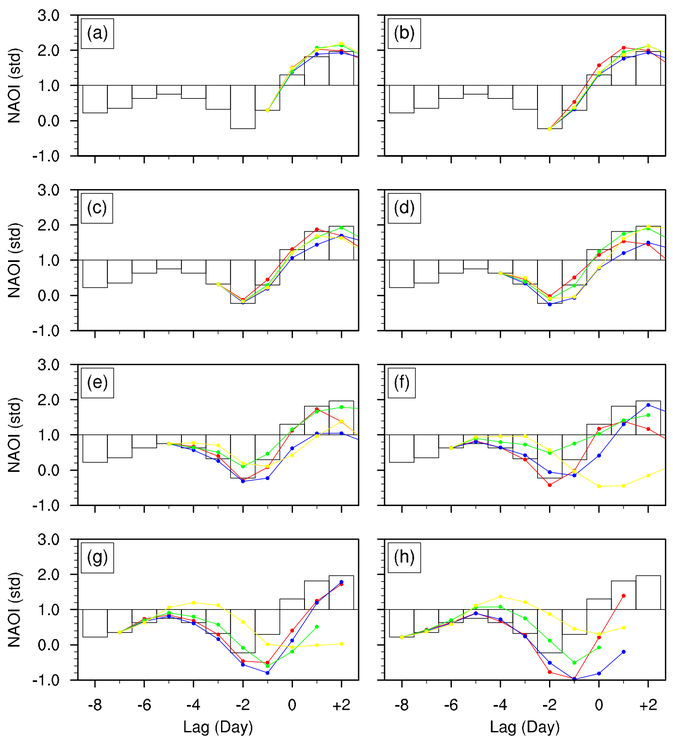

Fig. 1 Schematics of the NAO+ event onset forecast times. (a)-(h) represent forecast times that are 1-8 days in advance, subsequently. The vertical axis is the normalized NAOI, and the histogram represents the reanalysis index. Red, blue, green and yellow lines represent the forecast indexes from the ECMWF, NCEP, JMA and CMA, respectively. Lag 0 corresponds to the NAO+ event onset, which is on 5 December 2007.

The 4 centers chosen have the ability to forecast NAO event onsets several days in advance. However, the skillful forecast time is short (the average is 3-5 days).

The forecasted NAOI can trace the NAO+ onset with a leading time of 7 or 8 days, but the predicted circulation pattern is dissimilar to the reanalysis, which confirms that for NAO+ event onsets, skillful forecast could only be made several days (approximate 3-4 days on average) in advance.

The proportion of failures among the NAO- event onset predictions is higher than that for the NAO+ events, which indicates that NAO- events are more difficult to predict.

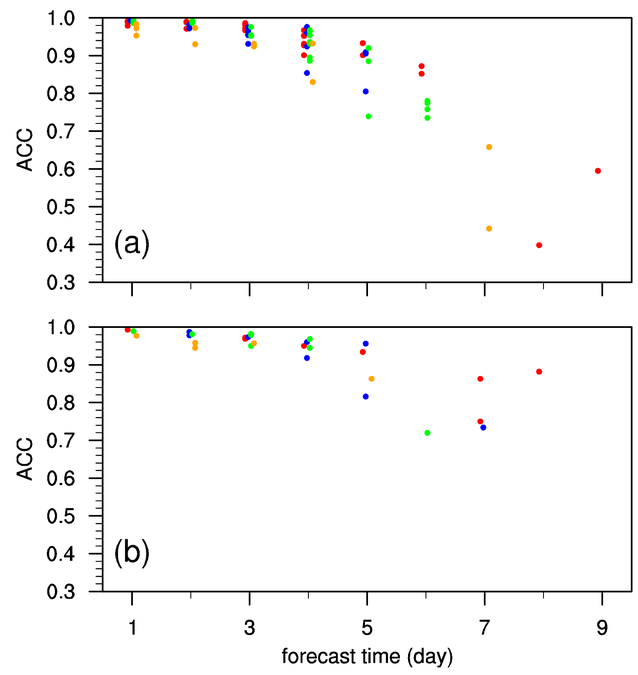

Fig. 2 The ACC of the SLP anomalies in the North Atlantic sector between the reanalysis and the products from 4 centers with their respective forecast times for 22 NAO+ events (a) and 9 NAO- events (b). The x-axis represents the forecast time (unit: day) and the y-axis represents ACC. Red, blue, green and yellow dots represent forecasts from the ECMWF, NCEP, JMA and CMA, respectively.

3.2 Evaluation for ensemble mean forecast

Tab.1 Comparison of the NAO event onset forecasts among the 4 centers

		ECMWF	NCEP	JMA	CMA
NAO+ success ratio	ctrl	22/22	17/18	22/22	13/13
	ens-mean	22/22	17/18	22/22	13/13
NAO+ skillful forecast time	ctrl	3.82	3.18	3.77	3.08
	ens-mean	3.86	3.35	3.27	2.77
NAO- success ratio	ctrl	9/9	8/8	8/9	5/7
	ens-mean	9/9	7/8	9/9	5/7
NAO- skillful forecast time	ctrl	4.56	4.00	3.25	2.60
	ens-mean	4.33	3.29	3.11	2.60

Ensemble mean can produce a more accurate circulation pattern in the North Atlantic sector compared with control forecast with the same leading time.

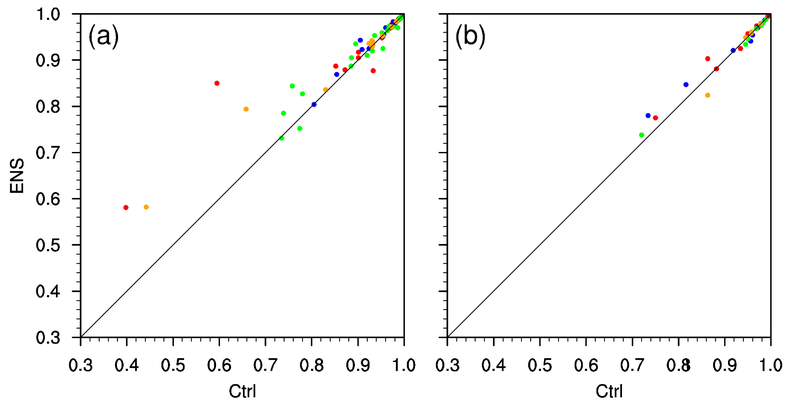

Fig. 3 A comparison of ACC values derived from the control forecasts and the ensemble mean forecasts for (a) the onset of NAO+ events and (b) the onset of NAO- events.

Tab.2 As in Tab.1, but for the NAO events with a threshold of 0.6 std

		ECMWF	NCEP	JMA	CMA
NAO+ success ratio	ctrl	30/30	25/25	33/33	21/21
	ens-mean	30/30	24/25	33/33	18/20
NAO+ skillful forecast time	ctrl	3.87	3.28	3.45	2.43
	ens-mean	4.03	3.29	3.24	2.55
NAO- success ratio	ctrl	19/20	17/18	17/20	13/15
	ens-mean	19/20	17/18	17/20	13/15
NAO- skillful forecast time	ctrl	3.47	3.47	4.00	3.23
	ens-mean	3.63	3.23	3.24	3.08

4. Summary

- For the individual onset of an NAO event, operational weather forecasts can predict it 3 to 5 days in advance. On average, ECMWF has a skillful forecast time of 3.82 days for NAO+ onset and 4.56 days for NAO- onset by control forecast, which is the longest among the 4 centers, followed by NCEP and JMA, and then CMA.
- From our investigation, the failure proportion for the NAO- event onsets prediction is higher than that of NAO+ onsets, regardless of whether control forecast or ensemble forecast is used. This may indicate that the onset of NAO- events is comparatively more difficult to forecast.
- When compared with the control forecast, the ensemble forecasts do not improve the skillful forecast time for the onset of NAO events. However, the ensemble mean can produce a more accurate circulation pattern in the North Atlantic sector compared with control forecast with the same leading time.