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Can Eurasia Experience a Cold Winter under a Third-Year La Niña in 2022/23?

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ABSTRACT

The Northern Hemisphere (NH) often experiences frequent cold air outbreaks and heavy snowfalls during La Niña winters. In 2022, a third-year La Niña event has exceeded both the oceanic and atmospheric thresholds since spring and is predicted to reach its mature phase in December 2022. Under such a significant global climate signal, whether the Eurasian Continent will experience a tough cold winter should not be assumed, despite the direct influence of mid- to high-latitude, large-scale atmospheric circulations upon frequent Eurasian cold extremes, whose teleconnection physically operates by favoring Arctic air invasions into Eurasia as a consequence of the reduction of the meridional background temperature gradient in the NH. In the 2022/23 winter, as indicated by the seasonal predictions from various climate models and statistical approaches developed at the Institute of Atmospheric Physics, abnormal warming will very likely cover most parts of Europe under the control of the North Atlantic Oscillation and the anomalous anticyclone near the Ural Mountains, despite the cooling effects of La Niña. At the same time, the possibility of frequent cold conditions in mid-latitude Asia is also recognized for this upcoming winter, in accordance with the tendency for cold air invasions to be triggered by the synergistic effect of a warm Arctic and a cold tropical Pacific on the hemispheric scale. However, how the future climate will evolve in the 2022/23 winter is still subject to some uncertainty, mostly in terms of unpredictable internal atmospheric variability. Consequently, the status of the mid- to high-latitude atmospheric circulation should be timely updated by medium-term numerical weather forecasts and sub-seasonal-to-seasonal prediction for the necessary date information and early warnings.

Key words: Eurasian climate, seasonal forecast, La Niña, winter cold climate

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The winter climate in Eurasia is of great concern, considering the dense population and economic activities therein. In

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the context of global warming, the frequent occurrence of extremely cold weather in mid-latitudes has been widely examined (Johnson et al., 2018; Rudeva and Simmonds, 2021) and is also highly controversial (Blackport et al., 2022; Cohen et al., 2022). On the seasonal scale, oceanic conditions, including La Niña (Ding et al., 2017) and Arctic sea ice (Wu et al., 2017c; Cohen et al., 2020; Ding and Wu, 2021), can significantly affect the wintertime weather and climate of Eurasia (e.g., Komatsu et al., 2022; Zheng et al., 2022a). Atmospheric processes such as the North Atlantic Oscillation (NAO; Yao and Luo, 2014; Li et al., 2022a), East Asian winter monsoon (He and Wang, 2013; Chen et al., 2014; Wang and Chen, 2014; Wang and Lu, 2017), and blocking (Xu et al., 2022; Yao et al., 2022; Zhuo et al., 2022), also have important effects on the Eurasian climate in winter. The synergistic influence of multiple atmospheric and oceanic factors on Eurasian weather and climate has been subject to increasing uncertainty by many studies (e.g., Chen et al., 2013; Mu et al., 2022; Yao et al., 2022; Zhang et al., 2022b), indicating a complex and challenging task for short-term climate prediction (Zheng et al., 2022b).

In June 2022, Jones (2022) and Fang et al. (2022) suggested that a "triple-dip" La Niña was more likely to occur this winter. Most recently, the World Meteorological Organization updated its El Niño-Southern Oscillation (ENSO) predictions (https://public.wmo.int/en/our-mandate/climate/el-ni%C3%B1ola-ni%C3%B1a-update), showing that this probability has further increased. In a third-year La Niña scenario, how the 2022/23 winter weather and climate over the Eurasian Continent respond to such a significant global climate signal and whether the Eurasian Continent will experience a cold winter or not poses an urgent question for seasonal climate prediction.

A third-year La Niña is predicted for the 2022/23 winter

Compared with El Niño, the complexity of La Niña is more reflected in time than space (Zhang et al., 2022a). For example, 16 La Niñas have occurred from 1980 to the present, 13 have lasted for at least two years, and the 1998–2001 La Niña was a three-year event (Fang et al., 2022). Recently, 2021–22 has been officially identified as a La Niña year, which makes 2020–22 a two-year La Niña event (Li et al., 2022b). Furthermore, this La Niña did not quickly decay after its peak, which persists as a weak/moderate La Niña and even recently rebounded in the autumn of 2022. According to the latest Climate Prediction Center and International Research Institute for Climate and Society (CPC/IRI) ENSO Outlook issued in October 2022 (http://iri.columbia.edu/climate/ENSO/currentinfo/update.html), there is a 75% chance of La Niña during the 2022–23 winter (December-February), with a 54% chance for ENSO-neutral conditions in February-April 2023.

Five climate models (Table 1) developed at the Institute of Atmospheric Physics (IAP), Chinese Academy of Sciences predict the following evolution of the 2022/23 La Niña event, including two coupled general circulation models (CGCMs; NZC PSM and FGOALS-f2), two intermediate coupled models (ICMs; IAP ENSO EPS and LASG-NFSV) and one statistical model (SAM; FU_IAP_ASCSM). The five prediction systems have the capability of making the ENSO prediction with a lead time of up to six months (Table 1). Their corresponding predictions starting from October 2022 are shown in Fig. 1. It can be seen that there are slight differences among the five predictions, in which all results call for a La Niña advisory, suggesting that there is almost a 100% chance that La Niña will persist through the 2022/23 winter, with a potential transition to ENSO-neutral conditions during spring 2023. To sum up the most recent predictions by the IAP and IRI, it seems that another three-year La Niña (2020–23) will emerge, the first since 1998–2001. However, it is important to note that La Niña is not the only factor that will drive the global and regional climate patterns in the 2022/23 winter. The effects of a La Niña event on the climates of the Eurasian Continent can vary on a yearly timescale in addition to other factors, as we have demonstrated in this report.

Table 1. ENSO prediction systems used in this report.

System	Specialized Techniques for ENSO Prediction
NZC PSM	Global ocean potential temperature and salinity anomalies are imported into the initial oceanic conditions from CFSR data (Sun and Ahn, 2015).
FGOALS-f2	Sub-seasonal to Decadal (S2D) seamless prediction for ENSO (Bao et al., 2019; Li et al., 2021).
IAP ENSO EPS	An air-sea coupled data assimilation system is developed to minimize the initial atmospheric/oceanic errors by assimilating available atmosphere and ocean observations simultaneously into the system (Zheng and Zhu, 2010). A stochastic error model is further designed to account for the temporal evolution of the forecasted uncertainties and embedded within the system to randomly perturb the modeled physical fields (Zheng and Zhu, 2016).
LASG-NFSV	A nonlinear forcing singular vector data assimilation (NFSV-DA) technique for neutralizing the combined effects of model and initial errors (Tao et al., 2020; Duan et al., 2022).
FU_IAP_ASCSM	The model is for realistic ENSO prediction as constructed based on the GODAS reanalysis datasets during 1980–2020 (Fang et al., 2022), in which the linear regression equation is based on four physically oriented variables, including the zonal mean and zonal gradient of thermocline depth anomalies in the equatorial Pacific, the mean zonal/meridional wind stress anomalies in the western/eastern equatorial Pacific (Fang and Zheng, 2021).

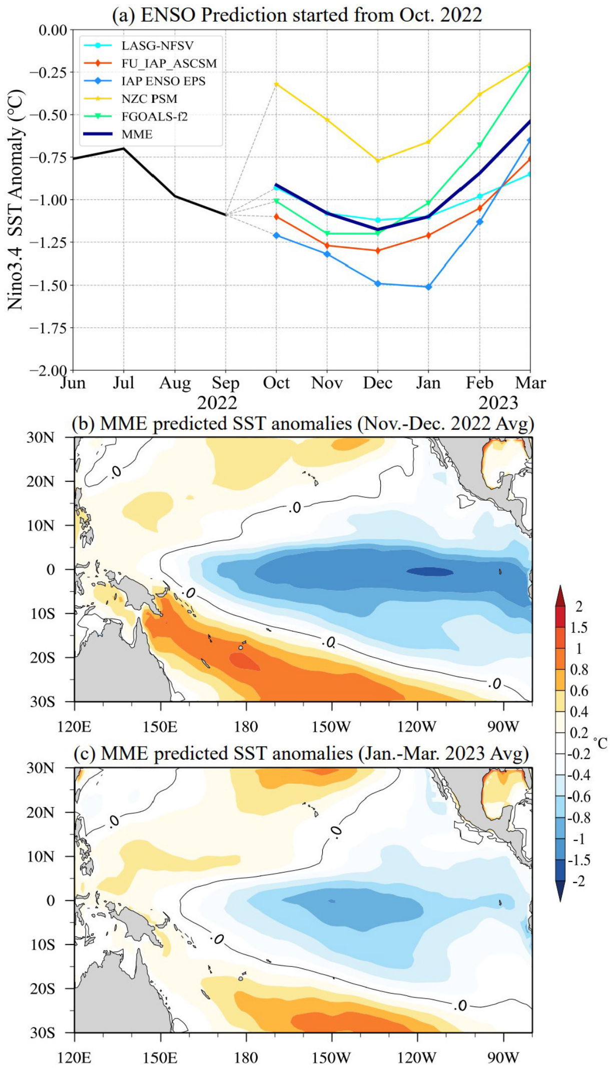

Fig. 1. (a) six-month prediction of Niño-3.4 index from September 2022 initial conditions by five statistical or physical climate models in IAP. (b) MME predicted SST anomalies (°C) as averaged from November to December in 2022. (c) Same as in (b), but for the averaged result of Jan. –Mar. 2023.

Predictions of the Eurasian temperature and precipitation from seasonal prediction systems

Four independent seasonal predictions based on four different state-of-the-art coupled general circulation models were conducted at IAP. Through the adaptation of various data assimilation methods and datasets, these models were routinely initialized by assimilating oceanic and/or atmospheric data from observational or reanalysis data (Table 2). Seasonal predictions for the surface air temperature (SAT) and precipitation anomalies were carried out by using the ensemble approach, and the multi-model ensemble mean (MME) prediction was calculated using the ensemble mean of individual models.

To reduce the initial shocks and model drifts prone to occur during the integrations of predictions, the prediction anomalies were calculated relative to the average of hindcasts from 2002–2021. The predictive skill of the MME prediction for land precipitation and SAT anomalies in boreal winter has been evaluated using the hindcasts of the past 20 years to show that the MME prediction has a higher prediction skill than that of individual models because the MME approach can greatly increase the signal-to-noise ratio, thus increasing the predictive skill, as reported in previous studies (DelSole et al., 2014; Kumar et al., 2016; Barnston et al., 2019).

For the SAT, the Eurasian Continent is predicted to be generally covered by warm anomalies, except for India and Southeast Asia in the tropics and Central Siberia in the high latitudes (Fig. 2a). The warm anomalies are thought to be caused by the superposition of internal variability and an anthropogenic warming trend, with the latter contribution being far smaller

Table 2. Seasonal prediction experiments used in this report.

Model	Member size	Assimilated observational/reanalysis data	Reference
CAS-ESM-c	7	OISST, EN4, AVISO SLA	Lin et al. (2019); Zheng et al. (2022c)
NZC-PSM	12	FNL, CFSR, CFSR	Ma and Wang (2014); Sun and Ahn (2015)
FGOALS-f2	60	CRA40, FNL/GFS, OSTIA	Bao et al.(2019); Li et al.(2021)
FGOALS-f3_L	20	EN4, HadISST	Wu et al. (2018)

than the former for the anomalies relative to the climatology of the past 20 years. Over the entire Eurasian Continent, Europe has the strongest warm anomalies, with intensities exceeding 1°C. The warming anomalies are mainly caused by the positive phase of the NAO internally generated in the climate system, despite the cooling effects of La Niña. The NAO is the opposite surface pressure oscillation between the high latitudes of the North Atlantic and the central North Atlantic, and a positive (negative) NAO can cause warm (cold) anomalies over Europe (Barnston and Livezey, 1987; Hurrell, 1995; Hurrell et al., 2003; Yao and Luo, 2014). As shown by the MME seasonal prediction, the NAO is in a weak positive phase, with its normalized index being 0.23. However, it is worth noting that the prediction for NAO has a large uncertainty, for the model predictive skill for NAO is low (the correlation between hindcasts and observations is only 0.11).

Based on the analysis of historical observations and due to the ENSO diversity and the limit of sample size, the relationship between winter SAT in East Asia and ENSO is weak (e.g., Wu et al., 2006; Wang et al., 2010; Li et al., 2022a), and La Niña exudes a complicated performance in affecting the East Asian SAT in winter, whereby La Niña tends to cause warm anomalies in Northeast China and North China but does not significantly contribute to the winter SAT in other areas of China (figure not shown). As confirmed by the MME seasonal prediction, East Asia has weak warm anomalies with magnitudes of about 0.5°C in the winter of 2022/23. Moreover, cold anomalies over India and Southeast Asia in the winter of 2022/23 might be caused by the remote forcing of La Niña and the basin-wide cold sea surface temperature (SST) anomalies in the tropical Indian Ocean. The cold SST anomalies in the equatorial central-eastern Pacific can suppress local convection and thus cause cold anomalies in the troposphere, noting that basin-wide cold SST anomalies in the tropical Indian Ocean are responses to remote forcing from La Niña and the negative Indian Ocean dipole mode in the preceding fall, which also impacts surrounding areas.

In these seasonal prediction systems, the predictive skill for land precipitation is much lower than that for SAT. The most pronounced feature in the MME seasonal prediction for the winter of 2022/23 is the negative precipitation anomalies over Southeast China and positive precipitation anomalies over Southeast Asia (Fig. 2b). The precipitation anomalies are associated with northeasterly wind anomalies along the northwestern flank of a low-level anomalous cyclone over the tropical western North Pacific. The anomalous cyclone is a response to La Niña forcing and is maintained by the "wind-induced moist enthalpy advection" and "wind-evaporation-SST feedback" mechanisms (Wang et al., 2000; Li et al., 2017; Wu et al., 2017a, b; Zheng et al., 2020).

Interpretations from a dynamical and statistical perspective

In seasonal climate predictions, the atmospheric anomalies associated with slowly varying atmospheric boundaries are usually regarded as potentially predictable, and the remaining component is climate noise and the primary source of uncertainties. As such, any interpretation of the possible status of the upcoming winter two months in advance depends on the nature of the climate variable itself and the capability of the prediction systems to capture the predictable component of climate variables. For the wintertime Eurasian SAT, the leading mode of its interannual variability explains approximately 45% of the total variance and is closely tied to the Arctic Oscillation (AO, Wang et al., 2019), a dynamical pattern that can arise purely from internal atmospheric processes. Although the interannual variation of AO can be associated with certain atmospheric external forcing, its chaotic nature limits the potential predictability of SAT. This interpretation is confirmed by the low prediction skill of SAT over mid- and high-latitude Eurasia in the latest fifth-generation seasonal forecast system of the European Centre for Medium-Range Weather Forecasts (SEAS5, Fan et al., 2020). Nevertheless, by pinpointing the external atmospheric forcing crucial to the predictable components of SAT and incorporating the information with well-designed dynamical and statistical schemes, the prediction skill of SAT can be visibly improved in certain regions, especially in the mid-high-latitudes of Eurasia (Fan et al., 2020).

The ENSO-like SST pattern, Arctic sea ice, and Eurasian snow cover are leading external atmospheric forcings for the interannual variability of the wintertime Eurasian SAT (Fan et al., 2020). There is a high possibility that the "triple-dip" La Niña will continue into the upcoming winter (Fang et al., 2022), which facilitates a below-normal SAT over most of Eurasia according to the composite of previous similar events. Meanwhile, the Arctic sea ice extent this autumn is slightly higher than the 2011–2020 average and much lower than the 1981–2010 climatology, especially in the areas extending from the Barents Sea to the East Siberian Sea. The reduction of Arctic sea ice, in conjunction with the persistence of La Niña, builds a

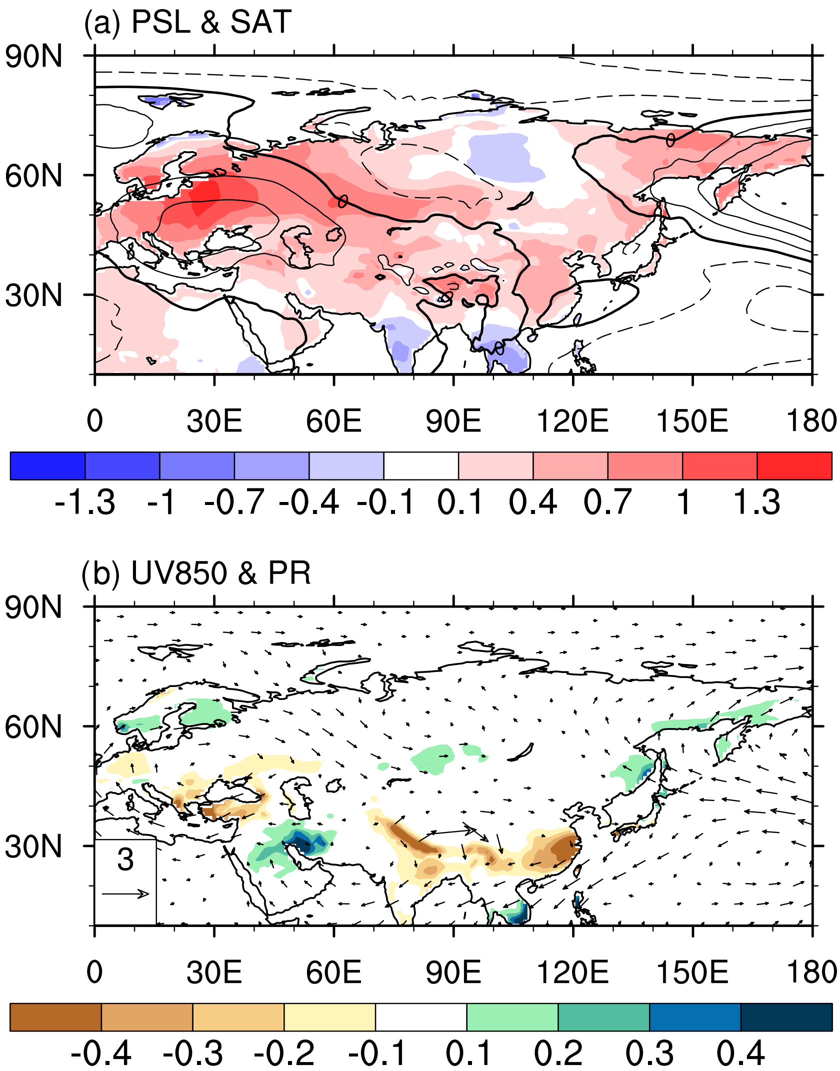

Fig. 2. MME seasonal forecast for the winter of 2022. (a) Sea level pressure (contour, units: Pa) and land surface air temperature anomalies (shading, units: °C). (b) 850 hPa wind (vector, units: m s^{-1}) and precipitation anomalies (shading, units: mm d^{-1}).

weak meridional temperature gradient on a hemispheric scale (Luo et al., 2019). These configurations facilitate the frequent occurrence and prolonged maintenance of wintertime Ural blocking (Yao et al., 2017, 2022) and increase the possibility of strong temperature drops and extreme cold weather over Eurasia. The MME of predictions initialized from 1 October by SEAS5 suggests widespread warm anomalies over Eurasia for the upcoming winter. Using the calibration scheme that incorporates the above and several other atmospheric external forcings (Fan et al., 2020), the reconstructed prediction indicates large-scale cold anomalies over Eurasia to the south of approximately 55ºN. Although the reconstructed prediction is rejected in many regions south of approximately 40ºN according to the prediction skill in hindcasts (Fan et al., 2020), this calibration implies a possibility of cold conditions in mid-latitude Eurasia in this upcoming winter by considering the external atmospheric forcings alone. Considering the internal atmospheric variability, which is unpredictable at this point, the possibility of cold conditions in mid-latitude Eurasia may increase further.

Conclusions and discussion

Winter climate in Eurasia is influenced by internal atmospheric variability, external forcing, and other factors (Bueh and Nakamura, 2007; Tyrlis et al., 2019; Mu et al., 2022; Yao et al., 2022; Zheng et al., 2022a). The MME seasonal predictions and the statistical forecasts at IAP both show a consistent result that abnormal warming will cover most parts of Europe under the control of NAO and anomalous anticyclone near the Ural Mountains. Meanwhile, there will be anticyclonic anomalies near 40°–50°E, which implies the presence of an anomalous high to the west of the Ural Mountains. This feature is tied to anomalous northerlies and westerlies prevailing over northern China, thus favoring cold air activities affecting the northern part of China in the upcoming winter (Bueh et al., 2022). Moreover, the previous (Fang et al., 2022) and recent ENSO predictions by IAP also suggest a third-year La Niña event in the winter of 2022/23, which will be the third three-year La Niña event since 1950, indicating a possible weakening of the meridional temperature gradient in the middle and high latitudes of Eurasia that tend to favor East Asian cold waves for the winter of 2022/23 (Tao, 1957, 1959; Qiu and Wang, 1983; Yao et al., 2022). From the decadal timescale perspective, Li et al. (2022a) predicted that the wintertime East Asian SAT will continue to fluctuate downward until 2025, implying an increased likelihood for extreme cold events to occur this coming winter in East Asia. In addition, as global warming raises the risk of extreme weather in the upcoming winter and the probability of strong cold air activities over Eurasia in winter increases, governments and the public alike should pay particular attention to medium-range weather forecasts and weather alerts to mitigate possible weather-related disasters.

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