Supplementary Information

ENSO phase transition enables prediction of winter North Atlantic Oscillation one year ahead

Kiwook Kim[a], Myong-In Lee[a,*], Adam A. Scaife[b,c], and Doug M. Smith[b]

[a] Department of Civil, Urban, Earth and Environmental Engineering, Ulsan National Institute of Science and Technology, Ulsan, South Korea

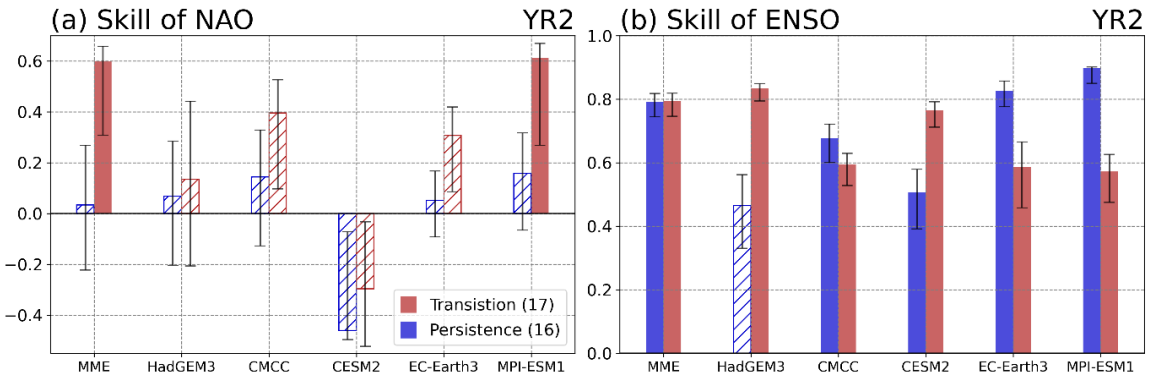
[b] Met Office Hadley Centre, Exeter, United Kingdom

[c] Department of Mathematics and Statistics, University of Exeter, Exeter, United Kingdom

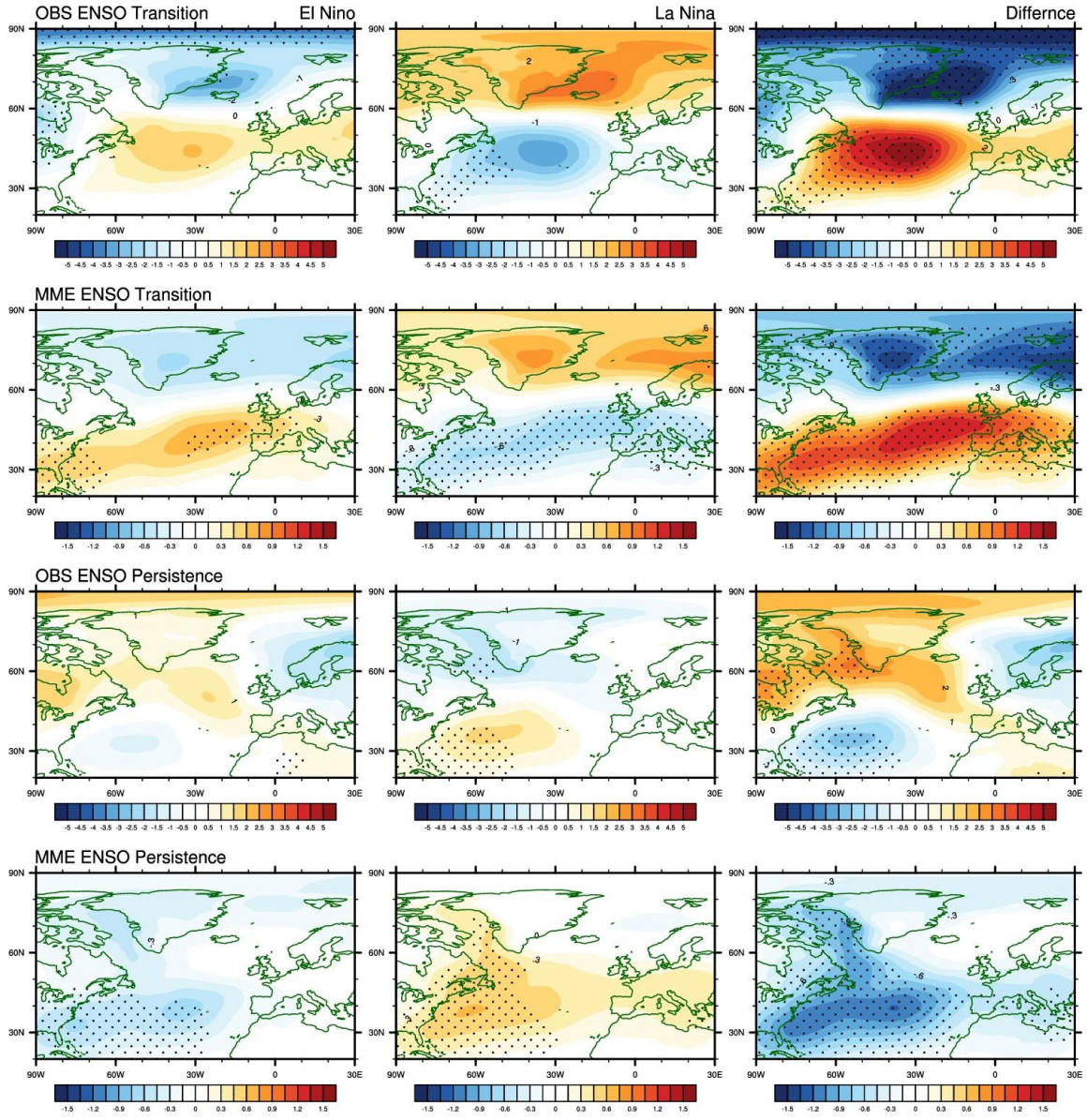
[*]Corresponding author.

E-mail addresses: milee@unist.ac.kr

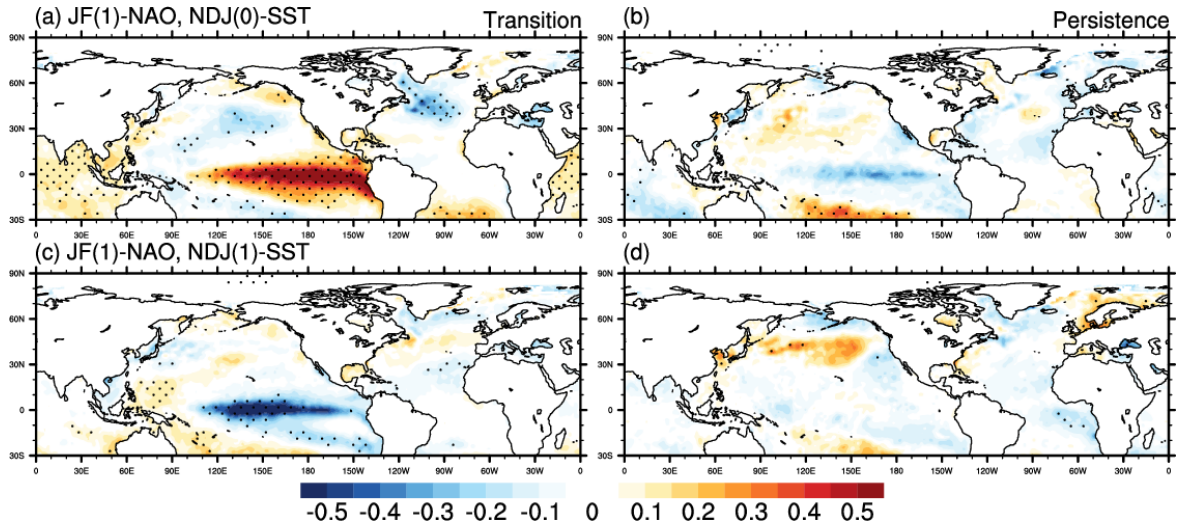
Supplementary Figures



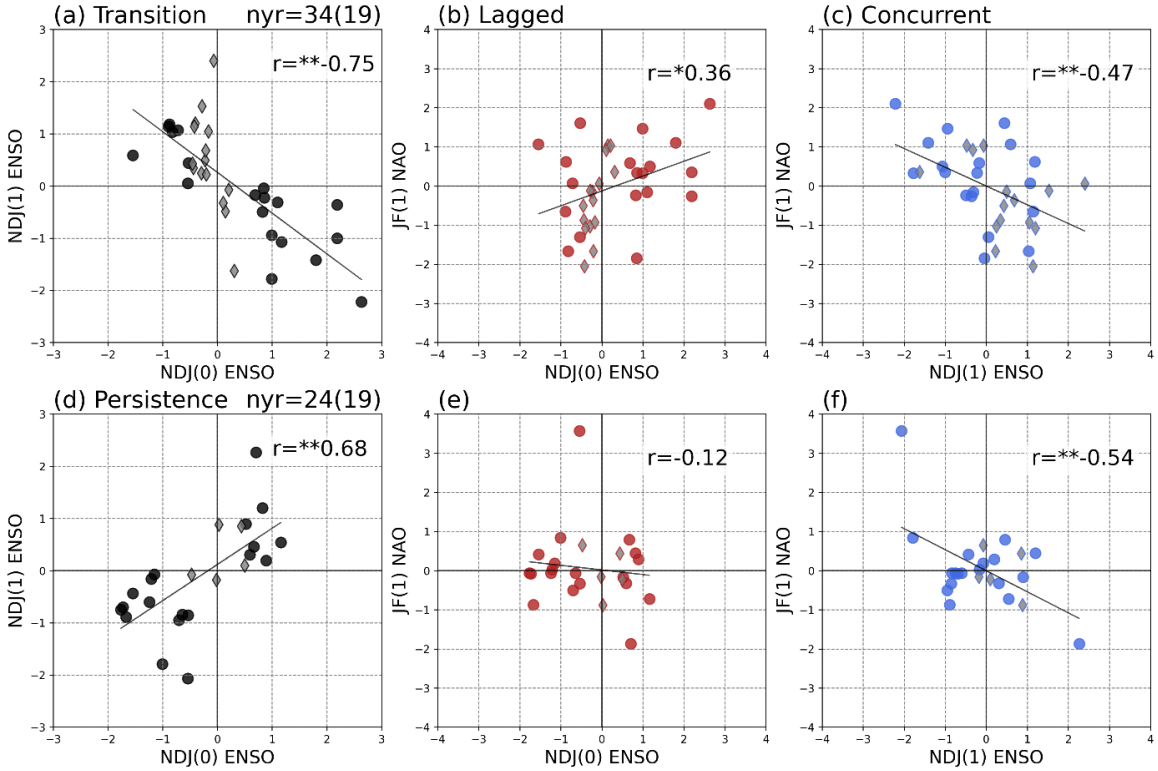
Supplementary Fig. 1: (a) Prediction skill of JF(1)-mean NAO index in ENSO persistence (blue bar) and transition years (red bar) and **(b)** NDJ(1)-mean ENSO index initialized YR2. Skills that are not statistically significant are indicated by hatched bars at the confidence level 95% (under the gray dashed lines). The error bars in each model indicate the 10th and 90th percentiles using the bootstrapping ensembles for 1,000 times in each period.



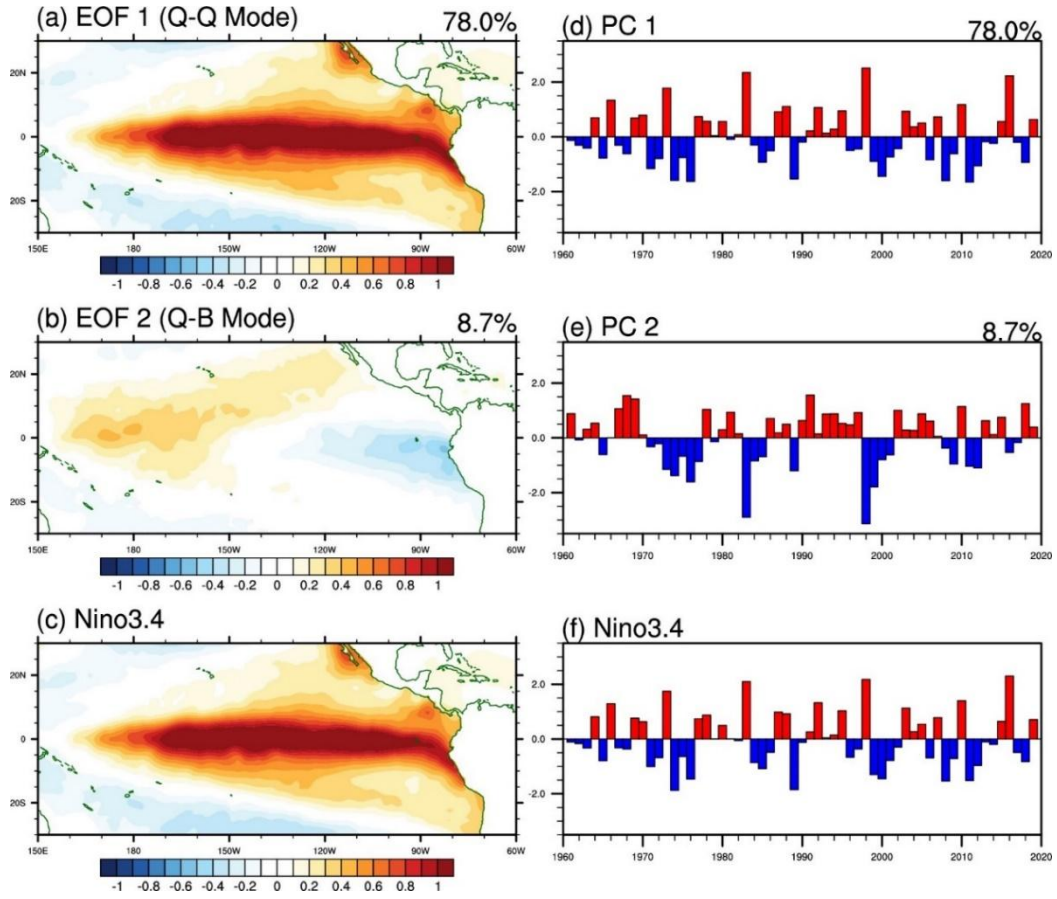
Supplementary Fig. 2: The average SLP anomaly in the years of El Niño and La Niña occurrence, including the results shown in **Fig. 2**.



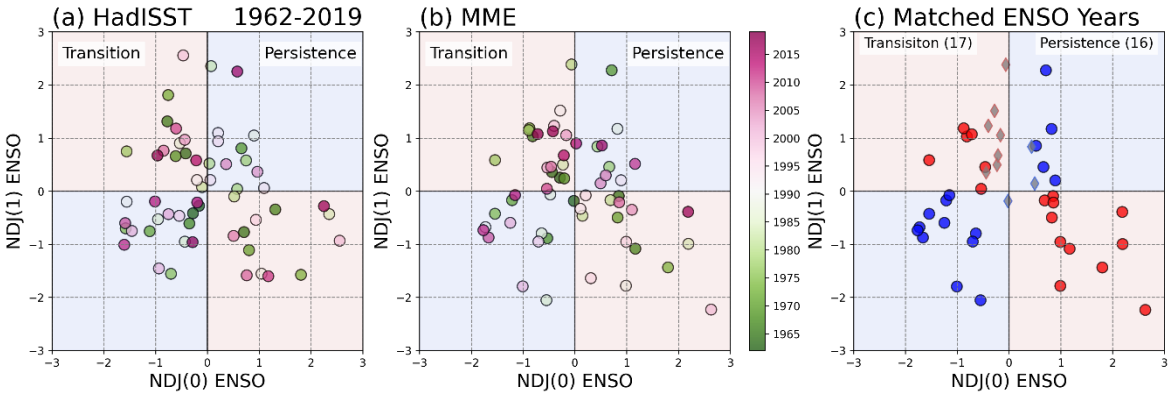
Supplementary Fig. 3: Observational NDJ(0)-mean SST anomaly regressed onto the JF(1)-mean NAO index in **(a)** ENSO transition year, **(b)** persistence year. **(c), (d)** in NDJ(1)-mean SST anomaly. The dotted area indicated statistical significance at the 95% confidence level.



Supplementary Fig. 4: The same method of **Fig. 3** in model world of MME using the bootstrapping ensembles for 1,000 times.



Supplementary Fig. 5: (a), (b) Observational two leading EOF modes of NDJ SST anomalies and **(c)** spatial SST pattern with Niño3.4 index. **(d)-(f)** Time series of PC 1, PC 2, Niño3.4 index.



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40 **Supplementary Fig. 6: (a)** Observational scatter plot of the NDJ(0)-mean ENSO index (x-axis) and NDJ(1)-
41 mean ENSO index (y-axis) after 1-year in 1962-2019. **(b)** The ensemble-mean ENSO index predicted in the MME
42 using the same method (YR1 in x-axis, YR2 in y-axis). The shading indicates the year. **(c)** The scatter plot of
43 MME for composite years with the same characteristics of ENSO indices 1-year after observation and MME.
44 Diamonds represent cases were weak ENSO transition and persistence previous years. The red box is ENSO
45 transition, and the blue box is ENSO persistence. Predicted ENSO index on MME using the bootstrapping
46 ensembles for 1,000 times.

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Supplementary Tables

Supplementary Table. 1: Summary of the decadal climate prediction systems

Forecasting center	Forecasting System	Hindcast	Model (atm, ocn, land, and ice, aero, chem)	Resolution	Ensemble cycle
Met Office, UK	HadGEM3-GC3.1[1]	1960-2018	HadGEM3-GA7.1, JULES-GL7.1, NEMO-GO6.0, CICE-GSI8, UKCA-GLOMAP	N216, L75	10 members on 1st day of November in each year
CMCC, Italy	CMCC-CM2-SR5[2]	1960-2018	CAM5.3, CLM4.5, NEMO3.6, CICE4.0, MAM3	0.9 x 1.25, L30	20 members on 1st day of November in each year
EC Earth Consortium	EC-Earth3[3]	1960-2018	IFS cy36r4, HTESSEL, NEMO3.6, LIM3	T255, L91	10 members on 1st day of November in each year
MPI-M, Germany	MPI-ESM1-2-HR[4]	1960-2018	ECHAM6.3, JSBACH3.20, MPIOM1.63, HAMOCC6	T127, L95	10 members on 1st day of November in each year
NCAR, USA	CESM2[5]	1970-2019	CAM6.0, CLM5, POP2, CICE5, MARBL	0.9 x 1.25, L30	20 members on 1st day of Nov, Feb, May, Aug in each year

Supplementary Table. 2: Summary of the CMIP6 Models

Number	CMIP ID	Modeling Group	Reference
1	ACCESS-CM2	Commonwealth Scientific and Industrial Research Organization	Bi et al. (2013)[6]
2	ACCESS-ESM1-5		Law et al. (2017)[7]
3	AWI-CM-1-1-MR	Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research	Semmler et al. (2020)[8]
4	AWI-ESM-1-1-LR		Shi et al. (2020)[9]
5	BCC-CSM2-MR	Beijing Climate Center, China Meteorological Administration	Wu et al. (2019)[10]
6	BCC-ESM1		Wu et al. (2020)[11]
7	CanESM5	Canadian Centre for Climate Modelling and Analysis	Swart et al. (2019)[12]
8	CAMS-CSM1-0	Chinese Academy of Meteorological Sciences	Rong et al. (2019)[13]
9	CESM2	National Center for Atmospheric Research	Lauritzen et al. (2018)[14]
10	CESM2-FV2		Danabasoglu (2019a)[15]
11	CESM2-WACCM		Danabasoglu (2019b)[16]
12	CESM2-WACCM-FV2		Danabasoglu (2019c)[17]
13	CMCC-CM2-HR4	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Scoccimarro et al. (2020)[18]
14	CMCC-CM2-SR5		Cherchi et al. (2019)[19]
15	CMCC-ESM2		Lovato et al. (2022)[20]
16	FGOALS-g3	Chinese Academy of Sciences	Li et al. (2020)[21]
17	FIO-ESM-2-0	First Institute of Oceanography, Qingdao National Laboratory for Marine Science and Technology	Bao et al. (2020)[22]
18	GISS-E2-1-G	NASA Goddard Institute for Space Studies	Kelly et al. (2020)[23]

19	GISS-E2-1-G-CC		NASA/GISS (2019a)[24]
20	GISS-E2-1-H		NASA/GISS (2019b)[25]
21	HadGEM3-GC31-LL	Met Office Hadley Centre	Andrews et al. (2019)[26]
22	HadGEM3-GC31-MM		
23	MIROC6	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute, National Institute for Environmental Studies and RIKEN Center for Computational Science	Tatebe et al. (2019)[27]
24	MIROC-ES2L		Hajima et al. (2020)[28]
25	MPI-ESM-1-2-HAM	HAMMOZ-Consortium	Neubauer et al. (2019)[29]
26	MPI-ESM1-2-HR	Max Planck Institute for Meteorology	Gutjahr et al. (2019)[4]
27	MPI-ESM1-2-LR		Mauritsen et al. (2019)[30]
28	MRI-ESM2-0	Meteorological Research Institute	Yukimoto et al. (2019)[31]
29	NESM3	Nanjing University of Information Science and Technology	Cao et al. (2018)[32]
30	SAM0-UNICON	Seoul National University	Park et al. (2019)[33]
31	TaiESM1	Research Center for Environmental Changes, Academia Sinica	Lee et al. (2020)[34]
32	UKESM1-0-LL	Met Office Hadley Centre	Sellar et al. (2019)[35]

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