Supplementary Materials

for

Sources of Subseasonal Predictability of Atmospheric Rivers

Wei Zhang[1,2]*; Baoqiang Xiang[3,4]; Kai-Chih Tseng[1,5]; Nathaniel C. Johnson[3];

Lucas Harris[3]; Tom Delworth[3]; Ben Kirtman[2,6,7]

[1] Program in Atmospheric and Oceanic Sciences, Princeton University, Princeton, NJ 08540, USA.

[2] Rosenstiel School of Marine, Atmospheric, and Earth Science, University of Miami, Miami, FL 33149, USA.

[3] NOAA/Geophysical Fluid Dynamics Laboratory, Princeton, NJ 08540, USA.

[4] Cooperative Programs for the Advancement of Earth System Science, University Corporation for Atmospheric Research, Boulder, CO 80301, USA.

[5] Department of Atmospheric Science, National Taiwan University, Taipei, 106319, Taiwan.

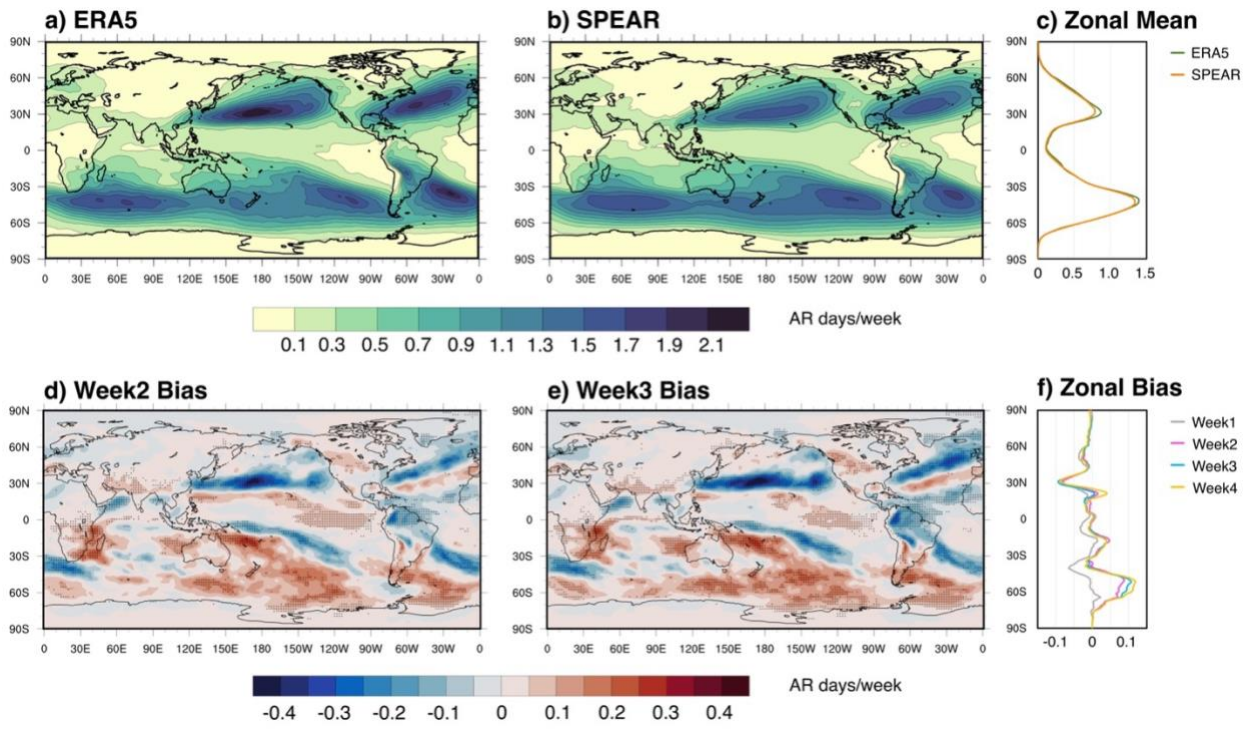
[6] The Cooperative Institute for Marine and Atmospheric Studies, Miami, FL 33149, USA.

[7] Frost Institute for Data Science and Computing, Coral Gables, FL 33146, USA.

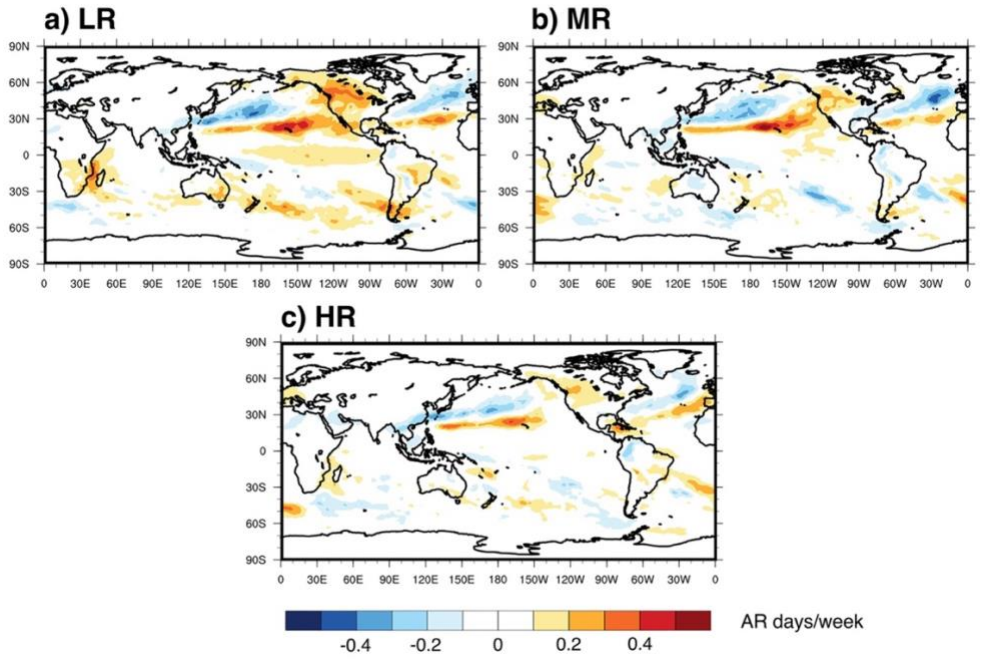
*Corresponding author: Wei Zhang, Program in Atmospheric and Oceanic Sciences, Princeton University, 201 Forrestal Road, Princeton, NJ 08540. Email: wei.zhang@earth.miami.edu

This file includes:

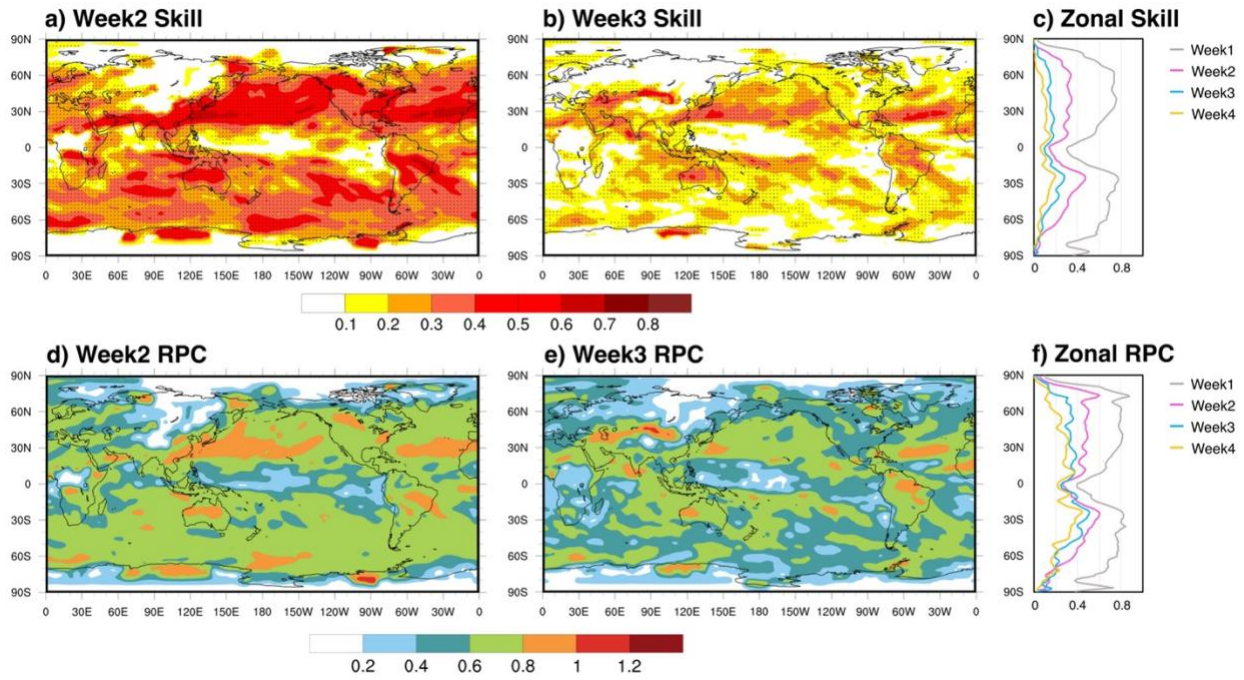
-Supplementary Figures 1-7



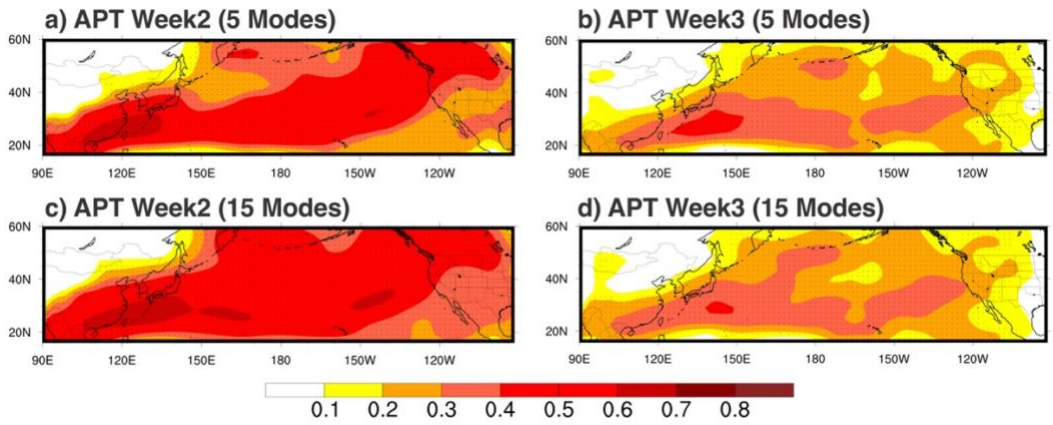
Supplementary Fig. S1 | Global climatology and bias of wintertime AR frequency (AR days/week) based on the ERA5 reanalysis and SPEAR model hindcasts. a. ERA5 AR climatology. **b.** SPEAR AR climatology for week-1. **c.** Comparison of zonal mean AR climatology between ERA5 and SPEAR. **d.** Bias for week-2 hindcasts. **e.** Bias for week-3 hindcasts. The stippling indicates that the model bias is significant at 5% level considering the effective sample size. **f.** Zonal mean bias for week-1 to week-4. Bias is computed as the difference between SPEAR and ERA5 reanalysis.



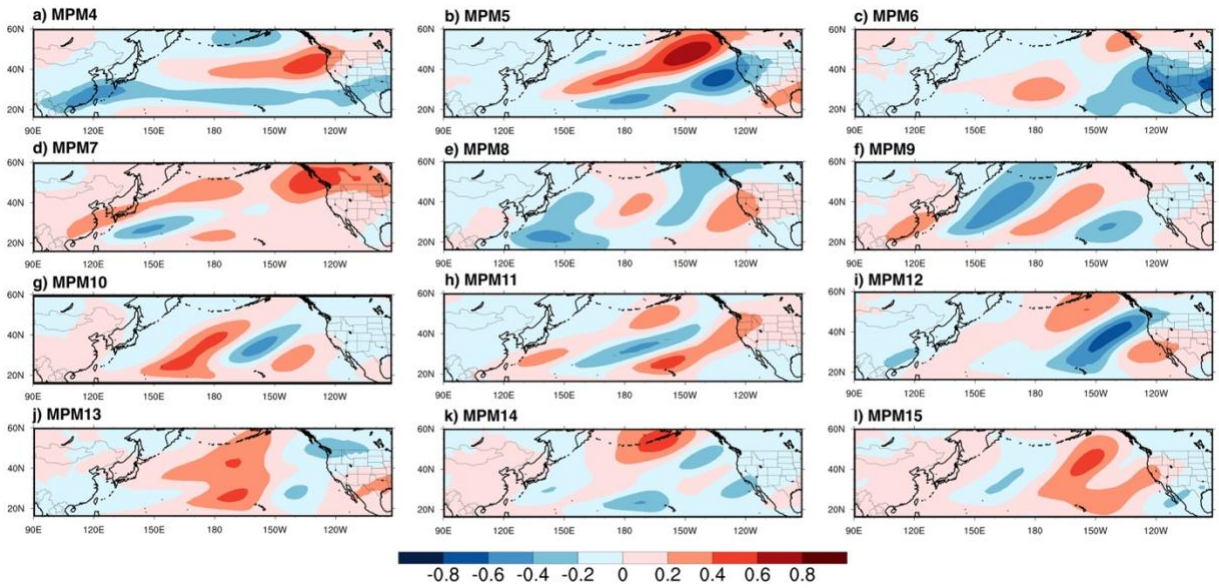
Supplementary Fig. S2 | Bias of weekly mean AR frequency (days/week) in three sets of control experiments with different atmospheric resolutions. a. Low-resolution Experiment (LR: 1° grid). **b.** Medium-resolution Experiment (MR: 0.5° grid). **c.** High-resolution Experiment (HR: 0.25° grid). The bias is computed as the difference of week-1 AR climatology between SPEAR model simulation and ERA5 reanalysis.



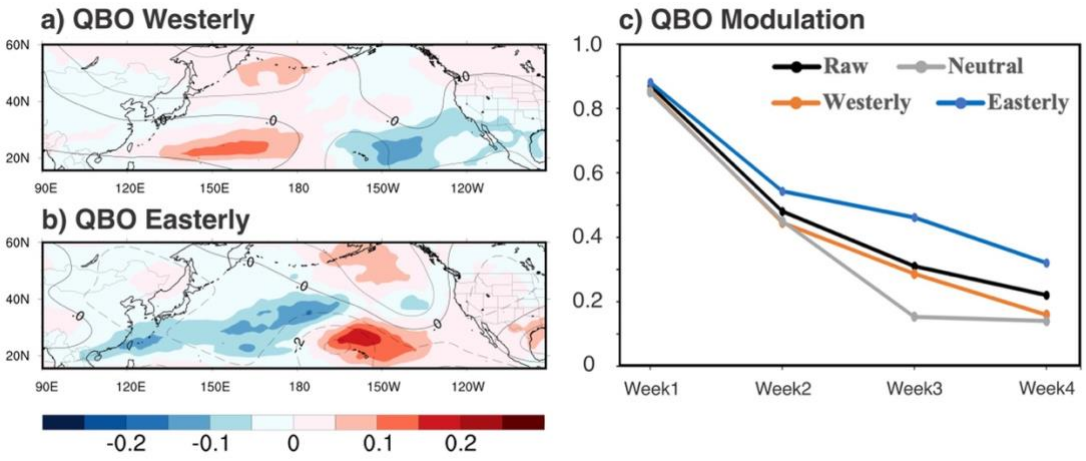
Supplementary Fig. S3 | Global subseasonal forecast correlation of wintertime AR frequency in the SPEAR model. a. ACC for week-2 lead time. **b.** ACC for week-3 lead time. The stippling denotes the region with correlation skill significant at 5% level considering the effective sample size. **c.** Zonal mean ACC from week-1 to week-4. **d.** RPC for week-2 lead time. **e.** RPC for week-3 lead time. **f.** Zonal mean RPC values from week-1 to week-4.



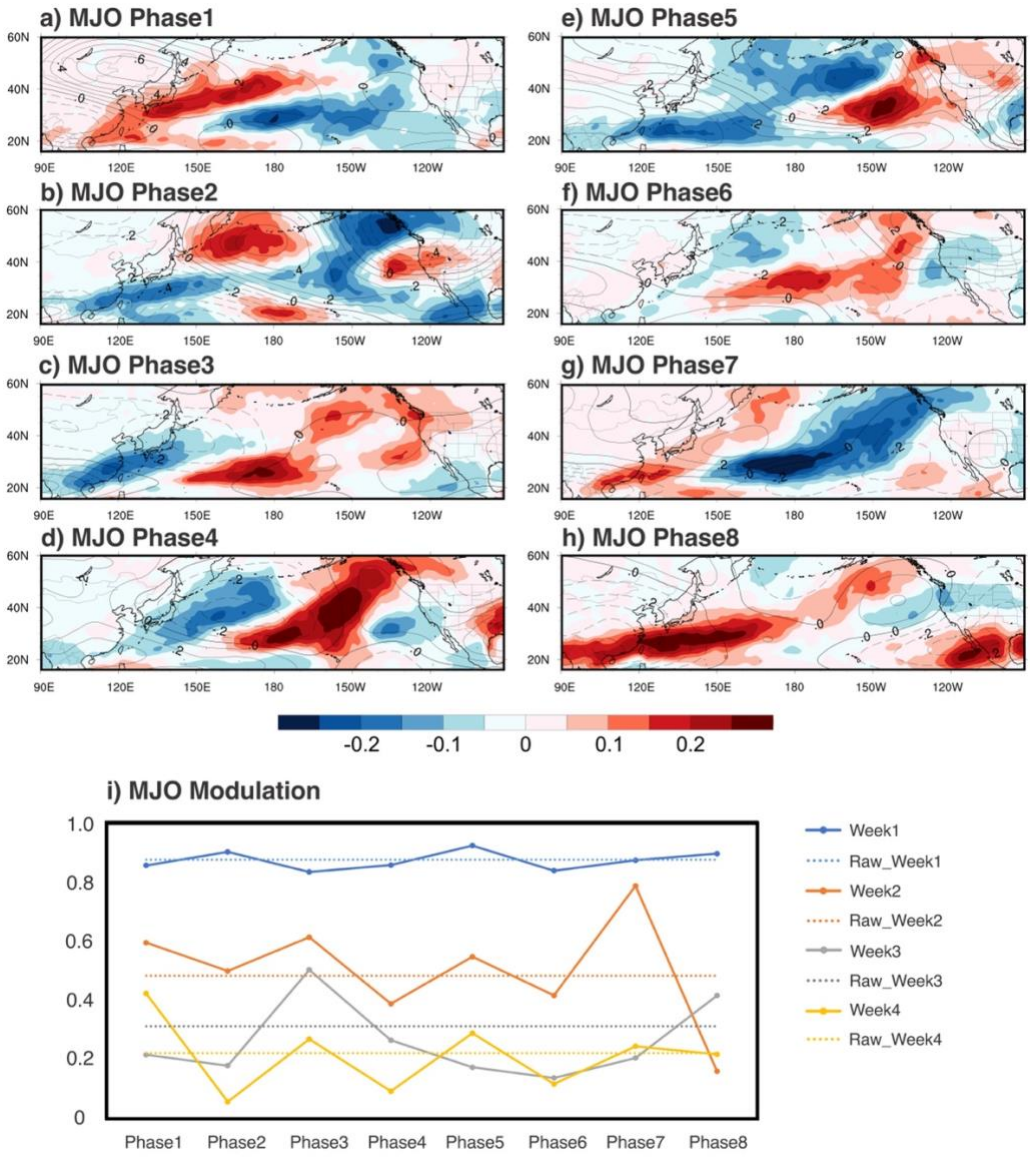
Supplementary Fig. S4 | APT-reconstructed forecast correlation of wintertime ARs. a. Week-2 with the first five MPMs, **b.** Week-3 with the first five MPMs, **c.** Week-2 with the first fifteen MPMs, and **d.** Week-3 with the first fifteen MPMs.



Supplementary Fig. S5 | The spatial patterns of the MPM4-15 for wintertime AR activity (week-3) over the North Pacific sector.



Supplementary Fig. S6 | The composite winter AR occurrence anomalies in week-3 during westerly and easterly QBO, and the modulation of QBO phases on subseasonal prediction skill of ARs over western U.S. a. QBO westerly**, b.** QBO easterly**.** The contour in each panel indicates the composite of the 500hPa geopotential height anomalies. **c.** Composite prediction skill of wintertime AR occurrence anomalies from week-1 to week-4 over the western U.S. (30°-50°N, 115°-130°W) based on the SPEAR during westerly (orange curve), easterly (blue curve), and neutral (grey curve) phases of QBO. The black curve indicates raw correlation skill over the western U.S. considering the whole period during 2000-2019.



Supplementary Fig. S7 | The composite winter AR occurrence anomalies in week-3 during eight phases of MJO, and the modulation of MJO phases on subseasonal prediction skill of ARs over western U.S. a-h. Phase 1-8 patterns of MJO. The contour in each panel indicates the composite of the 500hPa geopotential height anomalies. **i.** Composite prediction skill of wintertime AR occurrence anomalies from week-1 to week-4 over the western U.S. during eight MJO phases. The four horizonal dashed lines indicate raw correlation skill over the western U.S. for week-1 to week-4, respectively, considering the whole period during 2000-2019.