Prediction of the MJO and Related Teleconnections

Prediction of the MJO

- A statistical model: Jiang et al. (2008)
- Dynamical prediction of the MJO and Teleconnections in subseasonal forecasting systems: Vitart (2017)
- Factors affecting the MJO prediction skill

Statistical Prediction of the MJO
(Jiang et al. 2008)

- Based on the time series of the MJO RMM1 and RMM2 indices, a linear lag-regression model is constructed

$$X(t_0 + \tau) = \beta_1 \mathrm{PC}_1(t_0) + \beta_2 \mathrm{PC}_2(t_0),$$

where t is the forecast initialization time and tao is the forecast lead; PC1 and PC2 are time series of the leading pair of EOFs of the combined fields of OLR and zonal winds at 850 and 200 hPa (i.e., RMM1 and RMM2), β1 and β2 are the lag-regression parameters of PC1 and PC2.

X is the predictand at a particular grid point. The predictand can be different field variables, such as OLR, u850, and u200

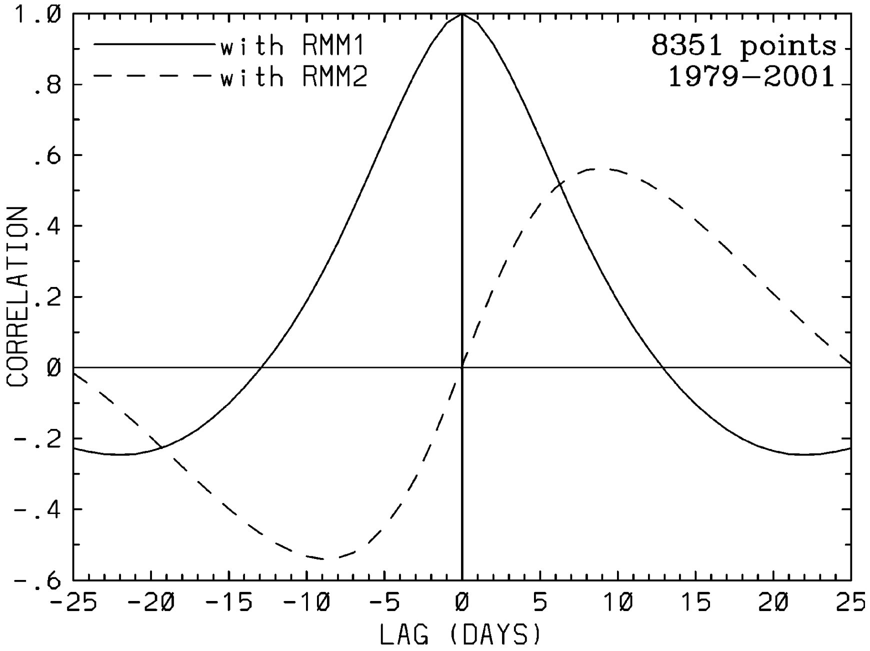

FIG. 6. Lag correlations between RMM1 and itself, and with RMM2 for all seasons.

Figure from Wheeler and Hendon (2004).

Statistical Prediction of the MJO (cont'd): Hindcast of OLR (15S-15N)

Obs **5d** **10d** **15d**

Jun/04
May/04
Apr/04
Mar/04
Feb/04
Jan/04
Dec/03
Nov/03

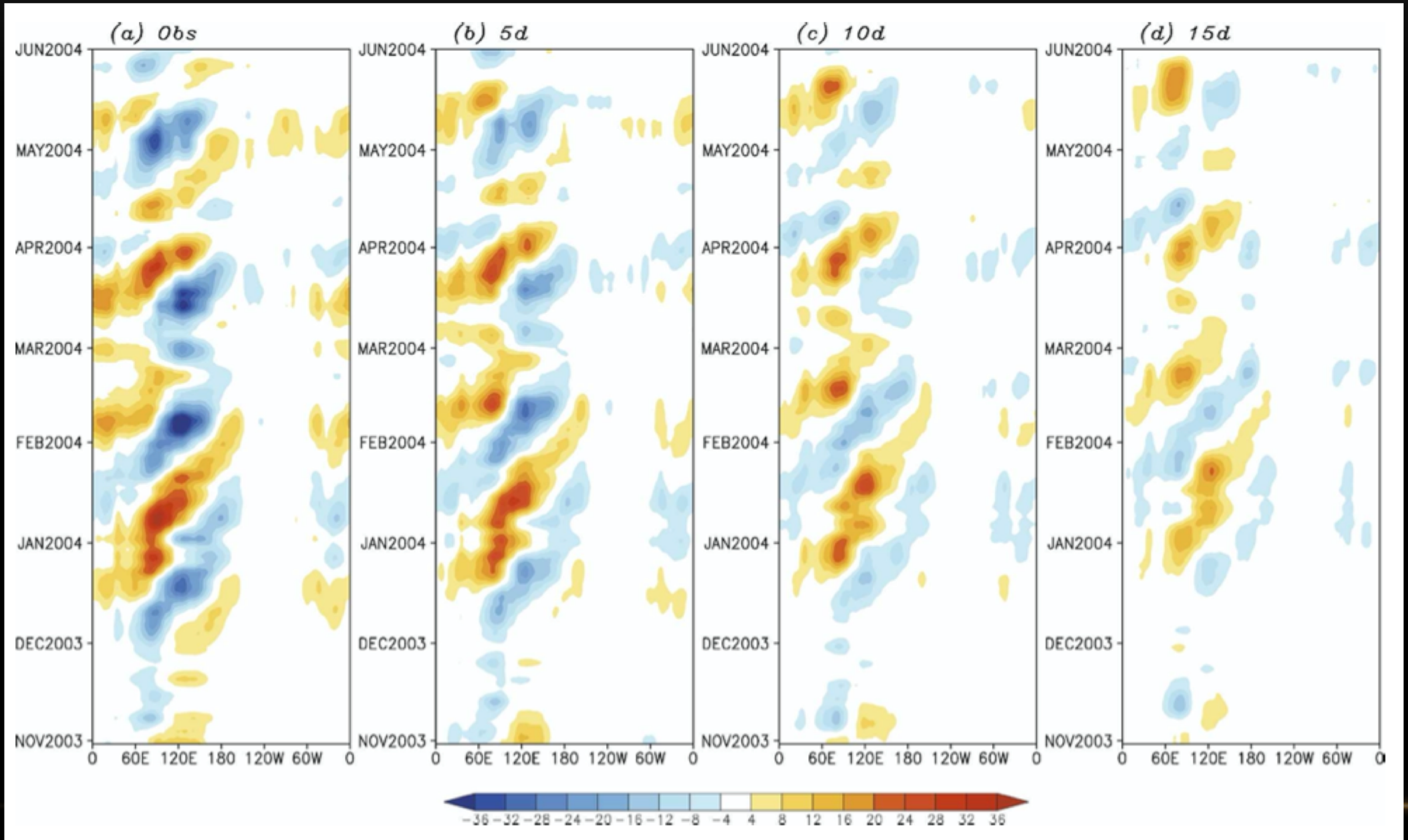

FIG. 16. Hovmöller diagram of OLR (averaged over 10°S–10°N) during 2003/04 winter by the (a) observed EOF-filtered field and forecasts at the lead time of (b) 5, (c) 10, and (d) 15 days (W m^{-2}).

Several major eastward-propagating MJO events during this winter season are very well predicted, although the amplitudes of predicted OLR decreases with an increase of forecast lead times.

Statistical Prediction of the MJO (cont'd): Pattern Corr. btw the Predicted and Observed OLR

- Solid lines represented the prediction skill by the statistical model, circles for winter and triangles for summer, and the dashed lines represent the skill by persistence forecasts.
- The forecast model exhibits superior skill over the persistence forecasts for both winter and summer predictions. The predictive skill for the MJOs during winter is higher than that during summer

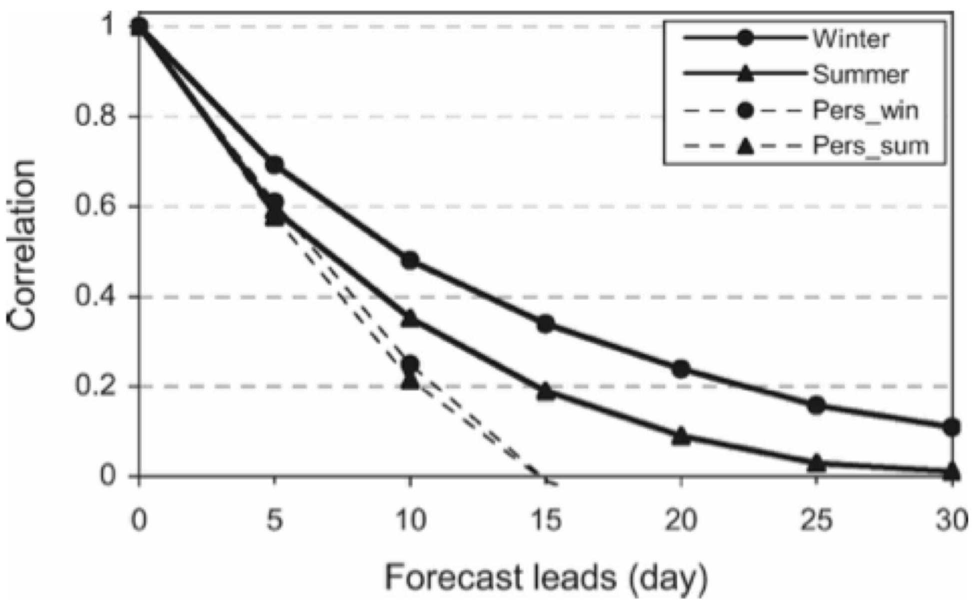

FIG. 4. Pattern correlation of OLR over global tropics between predicted and observed EOF-filtered OLR perturbation patterns for boreal winter (solid line with circles) and summer (solid line with triangles) predictions. The observed EOF-filtered OLR perturbation patterns are reconstructed based on the simultaneous regression relationship between OLR and two leading PCs of combined EOFs. Dashed lines denote the predictive skill obtained by persistence for winter (circles) and summer (triangles) predictions.

MJO Prediction in the S2S Database
Vitart (2017)

- The S2S database includes near-real-time ensemble forecasts and reforecasts up to 60 days from 11 operational centers:
  - Australian Bureau of Meteorology (BoM), China Meteorological Administration (CMA), European Centre for Medium-Range Weather Forecasts (ECMWF), Environment and Climate Change Canada (ECCC), the Italian Institute of Atmospheric Sciences and Climate (CNR-ISAC), Hydrometeorological Centre of Russia (HMCR), Japan Meteorological Agency (JMA), Korea Meteorological Administration (KMA), Meteo-France/Centre National de Recherche Meteorologiques (CNRM), US National Centers for Environmental Prediction (NCEP) and the United Kingdom Met Office (UKMO).
- Some reforecasts are computed all at once prior to operational implementation, while others are produced progressively "on the fly" (i.e., using different model versions).

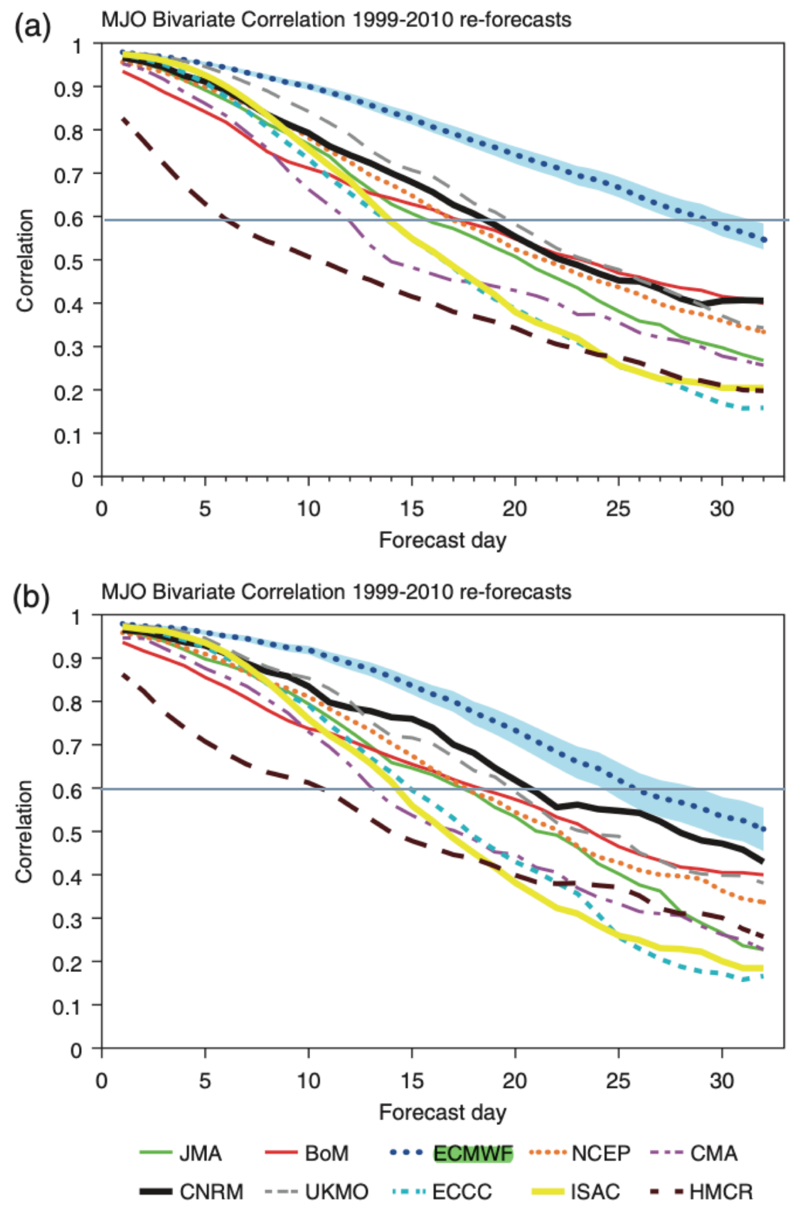

Figure 1. Evolution of the MJO bivariate correlation between the model ensemble means and ERA-Interim as a function of lead time for ten S2S models. The MJO bivariate correlations have been calculated over the period 1999 – 2010 for (a) all the seasons and (b) extended winters (December – March). The shaded area represents the 95% level of confidence computed from a 10 000 bootstrap re-sampling procedure. [Colour figure can be viewed at wileyonlinelibrary.com].

MJO Prediction in the S2S Database (cont'd): Bivariate Correlations

The bivariate anomaly correlation coefficient (ACC) can be calculated as

$$\mathrm{ACC}(\tau) = \frac{\sum_{t=1}^{N} [a_1(t) b_1(t,\tau) + a_2(t) b_2(t,\tau)]}{\sqrt{\sum_{t=1}^{N} [a_1^2(t) + a_2^2(t)]} \sqrt{\sum_{t=1}^{N} [b_1^2(t,\tau) + b_2^2(t,\tau)]}},$$

where a1 and a2 are the observed RMM1 and RMM2 at time t,
and b1 and b2 are the predicted RMM1 and RMM2 for the time t with a lead time of tao days. N is the number of predictions

- The prediction skill varies strongly from model to model.
- ECMWF performs the best.

Vitart 2017

MJO Prediction in the S2S Database (cont'd): Bivariate Correlations

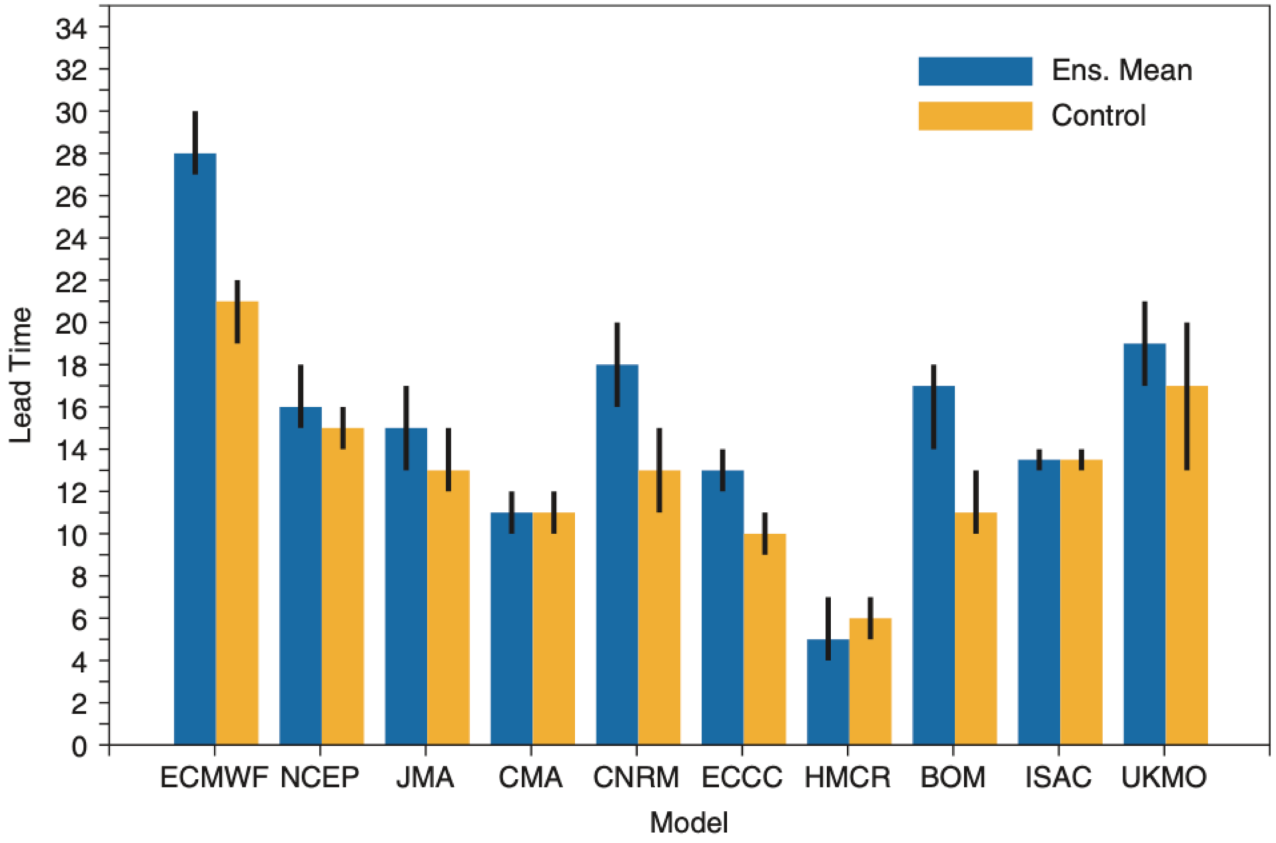

Figure 2. Forecast lead time (in days) when the MJO bivariate correlation between the model ensemble means and control run reaches 0.6. The vertical black bars represent the 95% level of confidence computed from a 10 000 bootstrap re-sampling procedure. [Colour figure can be viewed at wileyonlinelibrary.com].

- In nearly all models the ensemble mean performs better than a single ensemble member. The ECMWF model performs the best.

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MJO Prediction in the S2S Database (cont'd): Composites of H500 After a Strong MJO

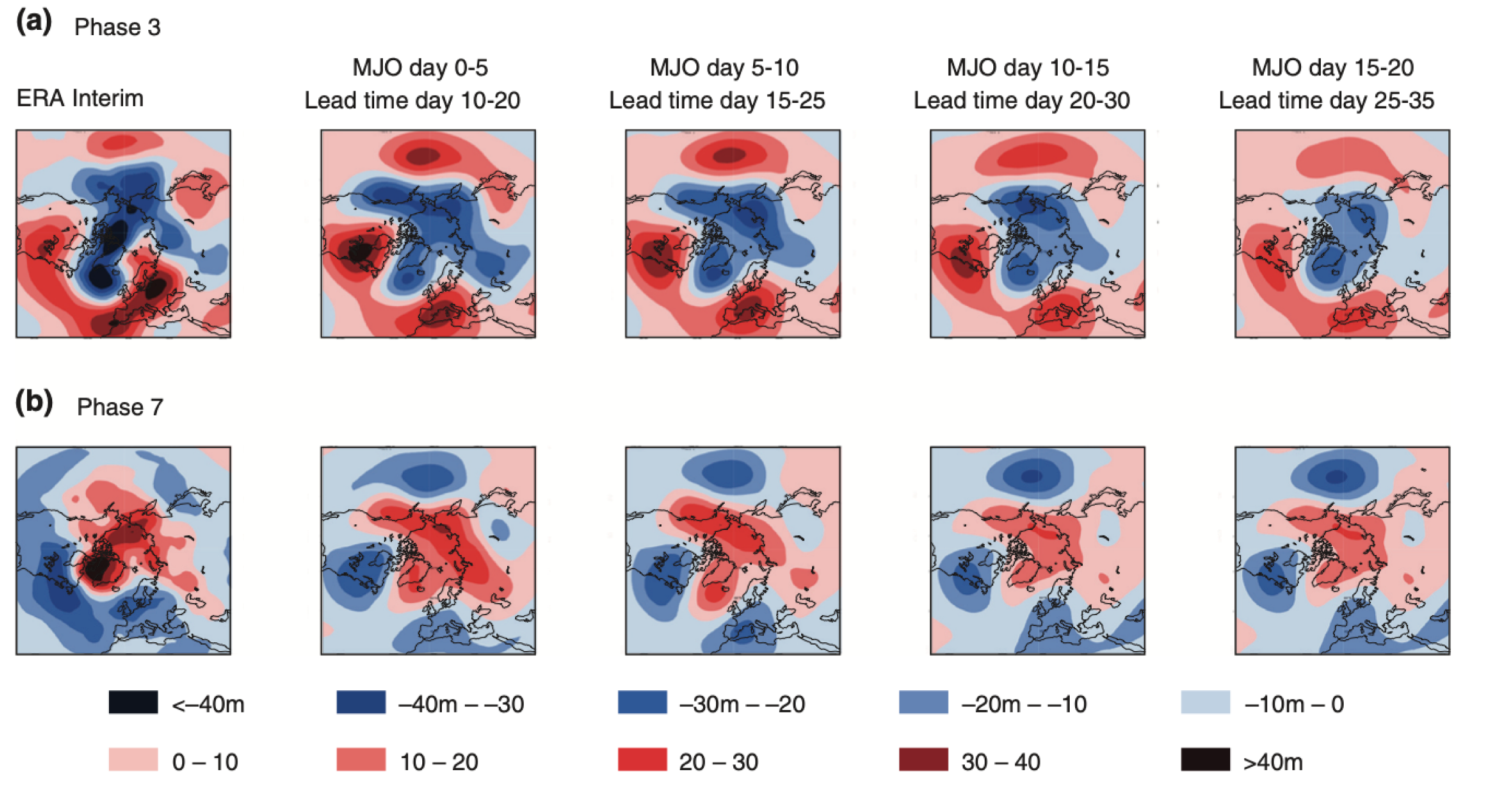

Figure 10. Composites of 500 hPa geopotential height anomalies 11 – 15 days (third pentad) after a strong MJO (amplitude larger than 1) in (a) Phase 3 or (b) Phase 7 in ERA-Interim (left panels) and in the ECMWF reforecasts for various lead times. For instance, the second column shows the teleconnections associated with MJO events present in the first 5 days of the reforecasts, which represents a lead time for 500 hPa geopotential height anomalies between 10 and 20 days.

- The figure shows the MJO teleconnection predicted by the ECMWF model in terms of H500 11 – 15 days after a strong MJO in (a) Phase 3 or (b) Phase 7.
- The spatial patterns of the MJO teleconnection is well captured in the reforecasts following Phase 3, but the amplitude weakens with lead times.
- Following phase 7, the teleconnection is characterized by the NAO-, indicating the link between the MJO and NAO. The model shows less skill in capturing the MJO teleconnection following Phase 7.

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MJO prediction skill is sensitive to the MJO strength

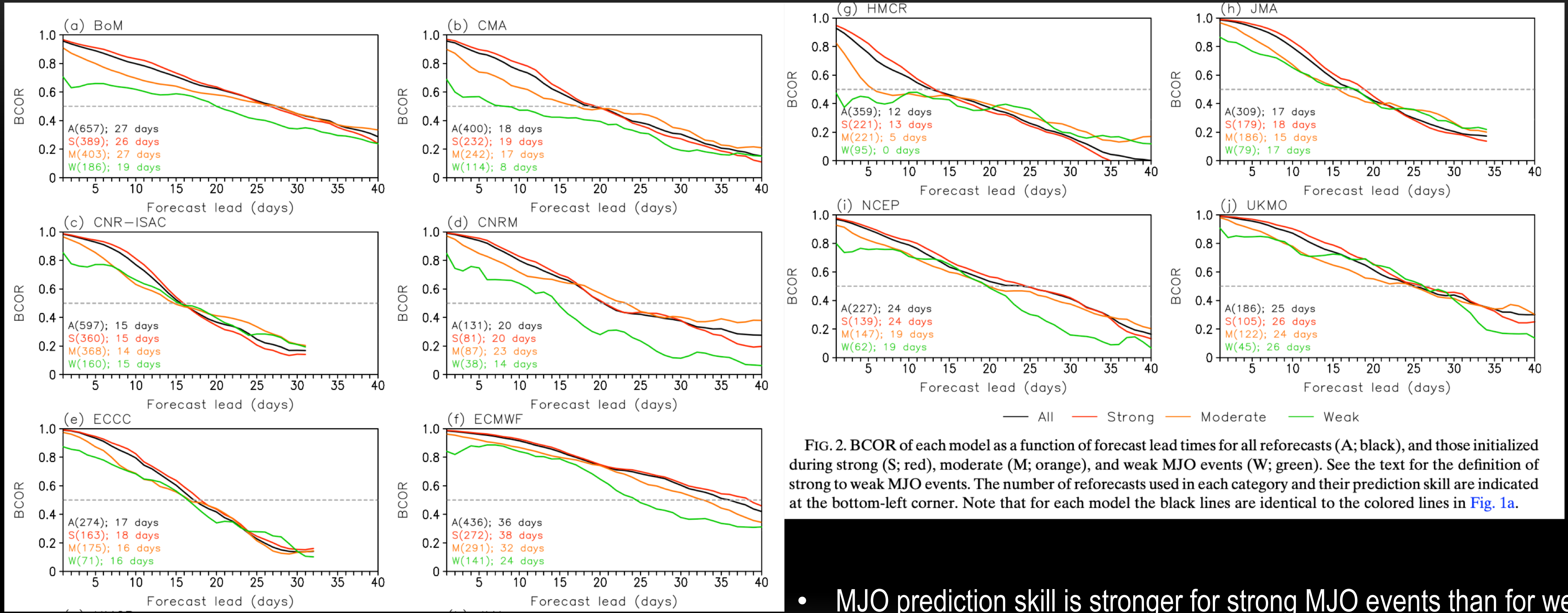

FIG. 2. BCOR of each model as a function of forecast lead times for all reforecasts (A; black), and those initialized during strong (S; red), moderate (M; orange), and weak MJO events (W; green). See the text for the definition of strong to weak MJO events. The number of reforecasts used in each category and their prediction skill are indicated at the bottom-left corner. Note that for each model the black lines are identical to the colored lines in Fig. 1a.

Black: All MJO	Red: strong MJO
Orange: moderate MJO	Green: weak MJO

- MJO prediction skill is stronger for strong MJO events than for weak MJO phase.
- ECMWF is among the best models. The ACC remains above 0.5 up to 35 days for all MJO events.
- Note that a correlation coefficient of 0.5 indicates that only 25% of the observed variances can be explained by the prediction.

MJO prediction skill is sensitive to the MJO phases

- The pattern correlation of U200 between forecasts and observation for different MJO phases and at different lead times.
- MJO prediction is often lower during the MJO initiation phase (phase 1 or 2) and during the phase when the MJO moves across the Maritime Continent (phase 5)

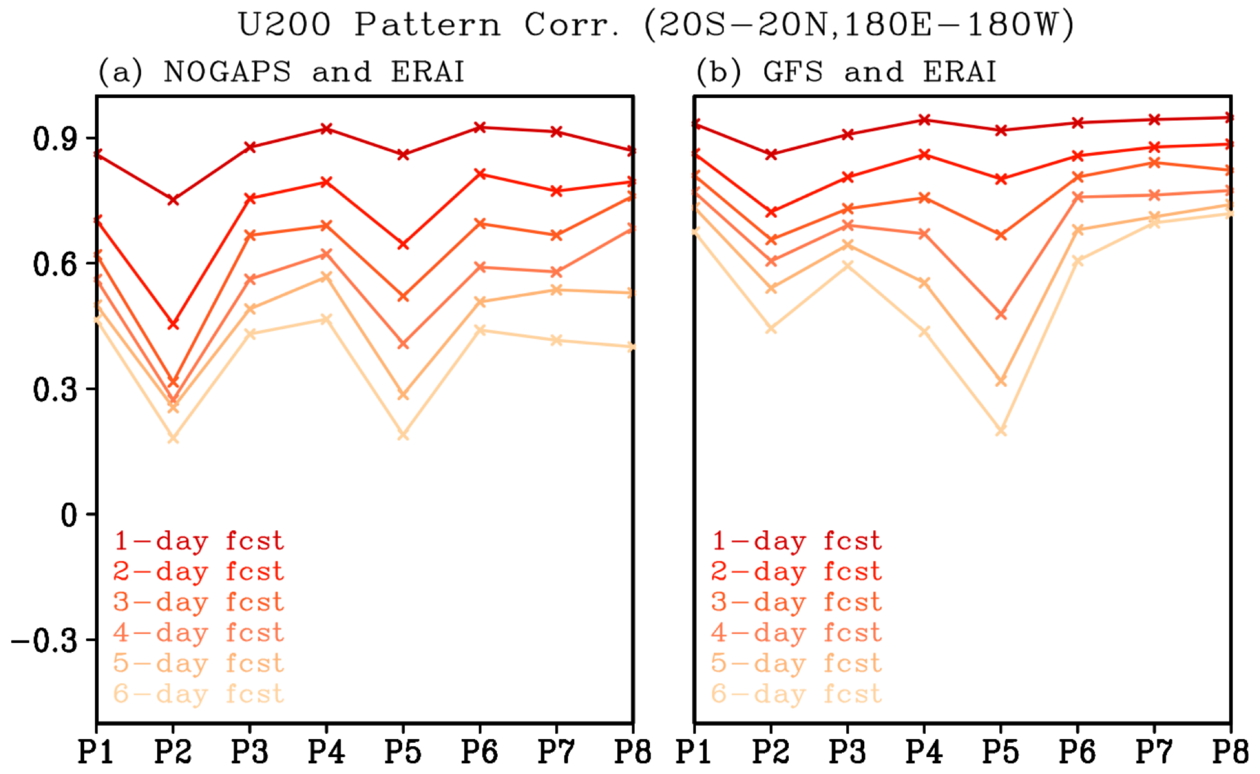

FIG. 14. Spatial pattern correlations of tropical (20°S–20°N, 180°–180°) zonal winds at 200 hPa between forecasts from: (a) the NOGAPS and ERAI and (b) GFS and ERAI for eight MJO phases (WH04), using all available data in boreal summer during 2008–11. The red lines of decreasing thicknesses show the correlations for 1- to 6-day forecasts.

References

- Jiang, X., Waliser, D. E., Wheeler, M. C., Jones, C., Lee, M., & Schubert, S. D. (2008). Assessing the Skill of an All-Season Statistical Forecast Model for the Madden–Julian Oscillation, *Monthly Weather Review*, *136*(6), 1940-1956.
- Vitart, Frédéric, 2017, "Madden-Julian Oscillation prediction and teleconnections in the S2S database" Quarterly Journal of the Royal Meteorological Society Vol. 143, No. 706, pp 2210, 00359009
- NOAA CPC Dynamical Model MJO Forecasts: http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/clivar_wh.shtml#for