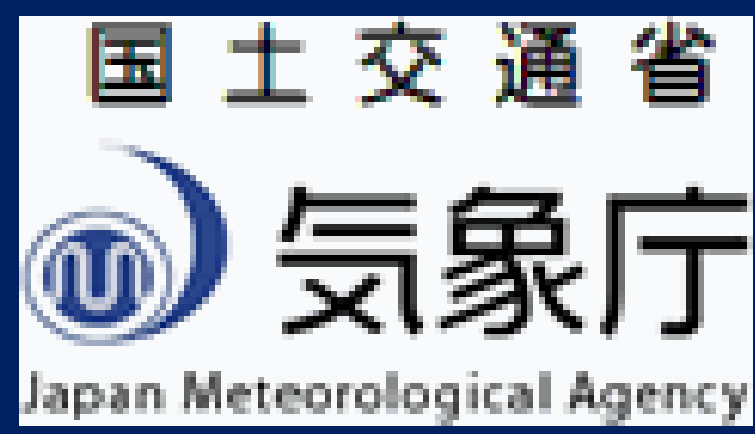


Predictability of extreme weather events for sub-seasonal to seasonal forecasts using JMA's prediction systems

Shingo Ito, Hiroyuki Watanabe, Kazuto Takemura, Shuhei Maeda
Japan Meteorological Agency



1. Introduction

- ✓ The Japan Meteorological Agency (JMA) plans to provide early warning forecasts for extreme events by 2030, and is currently conducting multifaceted investigation to identify the conditions and phenomena causing extreme weather events, which have high predictability of JMA's Global Ensemble Prediction System (GEPS) for sub-seasonal forecasts and Coupled Prediction System Version 3 (JMA/MRI-CPS3) for sub-seasonal to seasonal forecasts.
- ✓ This study introduces the three phenomena and conditions; stratospheric sudden warming (SSW), meandering of the summertime Asian jet relation, the pattern that the model predicts well on winter.

2. Data

- ✓ Forecast Data of JMA's prediction systems : see table 1
- ✓ Analysis Data : JRA-3Q (Kosaka et al., 2024), 1.25 degree and 45 levels.

Table 1 : JMA/MRI-CPS3 and GEPS configuration

	JMA/MRI-CPS3 (Hirahara et al., 2023)	GEPS
Atmospheric Model	JMA-GSM TL319L100 (~55 km)	JMA-GSM TQ479 (~27 km) up to 18days TQ319 (~40 km) after 18days
Ensemble size	Operation: 5 members / day Rerecast: 10 members / month	Operation: 50 / initial date Rerecast: 13 / initial date

3. The effect to Predictability of SSW on Mar 2018

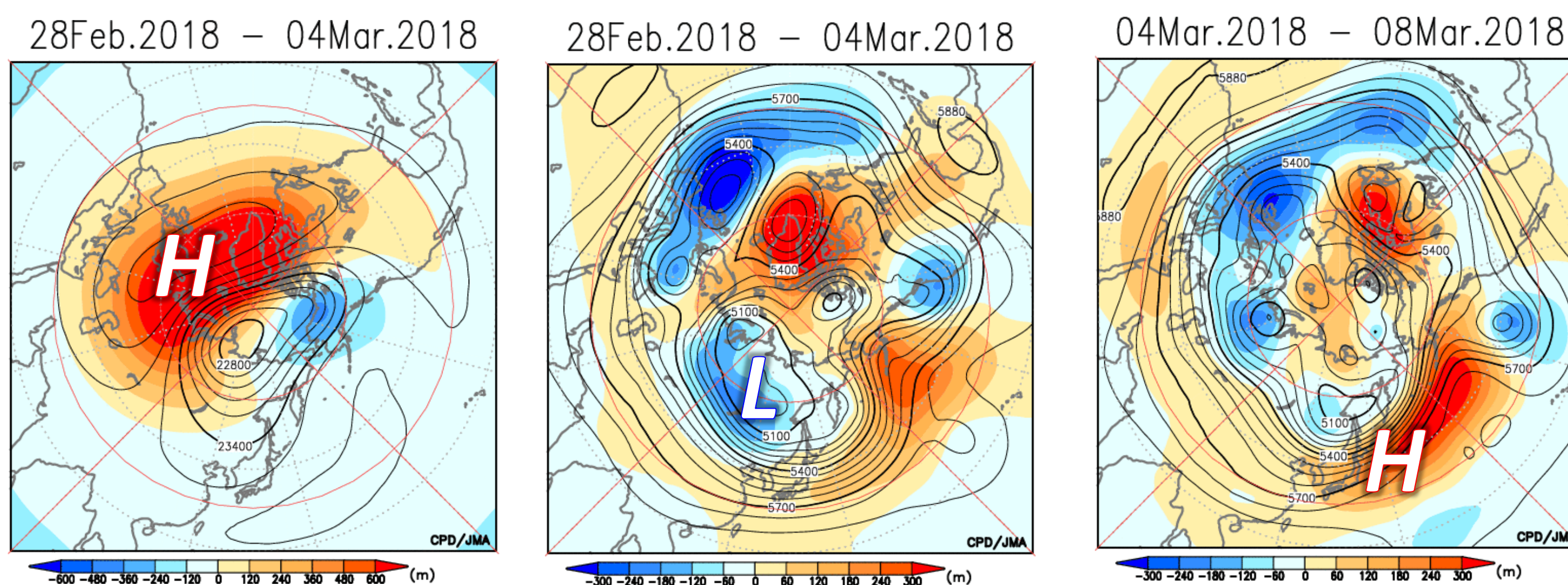


Fig 1 : Geopotential height(contour) and anomalies(shade) at 30-hPa averaged from 28 Feb. to 04 Mar.(left) , at 500-hPa averaged from 28 Feb. to 04 Mar.(centre), from 4 Mar. to 8 Mar.(right).

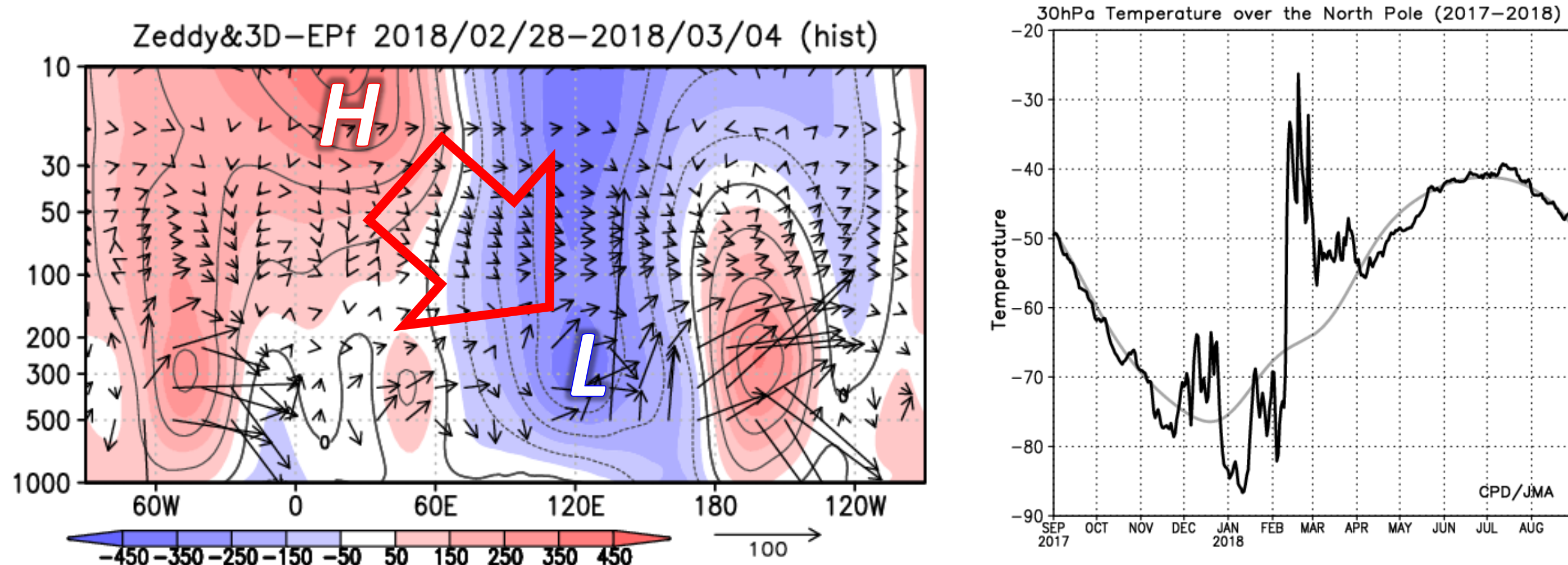


Fig 2 : The difference of the geopotential height from zonal mean(contour, shade) and the wave activity flux(Plumb, 1985)(left). The 30-hPa temperature over the North Pole (right).

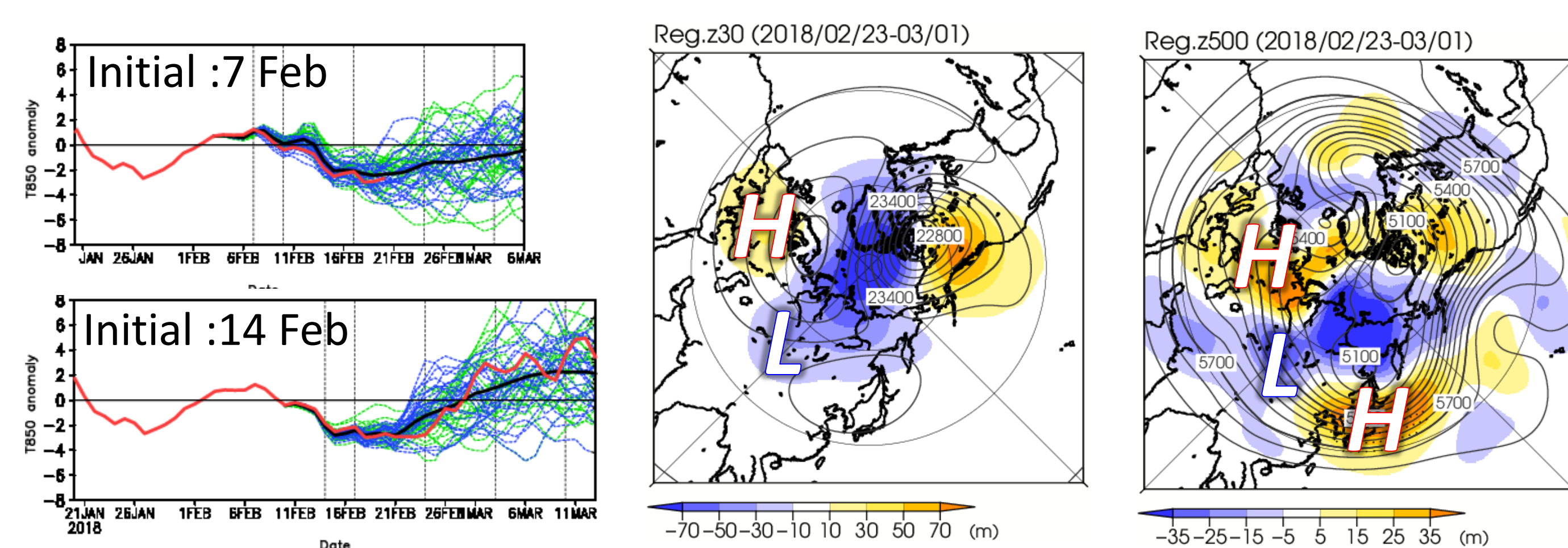


Fig 3 : The 850-hPa temperature forecast for northern Japan started from 7 Feb.(left upper), 14 Feb.(left bottom) by GEPS. Lagged regression analysis of 30-hPa (centre) and 500-hPa (right) geopotential heights averaged from 23 Feb. to 01 Mar. on the 500-hPa geopotential height averaged over the region (30N-50N, 120E-120W) for the period from 1 Mar. to 7 Mar., using the ensemble member of the GEPS rerecasts starting from 15 Feb. 2018.

- ✓ A SSW occurred in early Feb. 2018, leading to a split in the polar vortex. By early Mar. 2018, a prominent ridge at 30-hPa was positioned over Europe. Wave propagation from the stratosphere into the troposphere resulted in a significant ridge forming east of Japan, leading to extremely high temperatures in Japan.
- ✓ These high temperatures were not predicted starting from 7 Feb, when SSW had not yet occurred, but were predicted starting from 14 Feb., after the SSW had occurred.
- ✓ The lagged regression analysis using ensemble members indicates that the ridge east of Japan is related to the 30-hPa geopotential height. This result suggests that understanding the mechanism of the SSW could make our forecasts more reliable.
- ✓ Similar results were obtained in Mar. 2023.

4. Prediction Skill of the Asian Jet Variability in JMA/MRI-CPS3 Seasonal Forecast July to August.

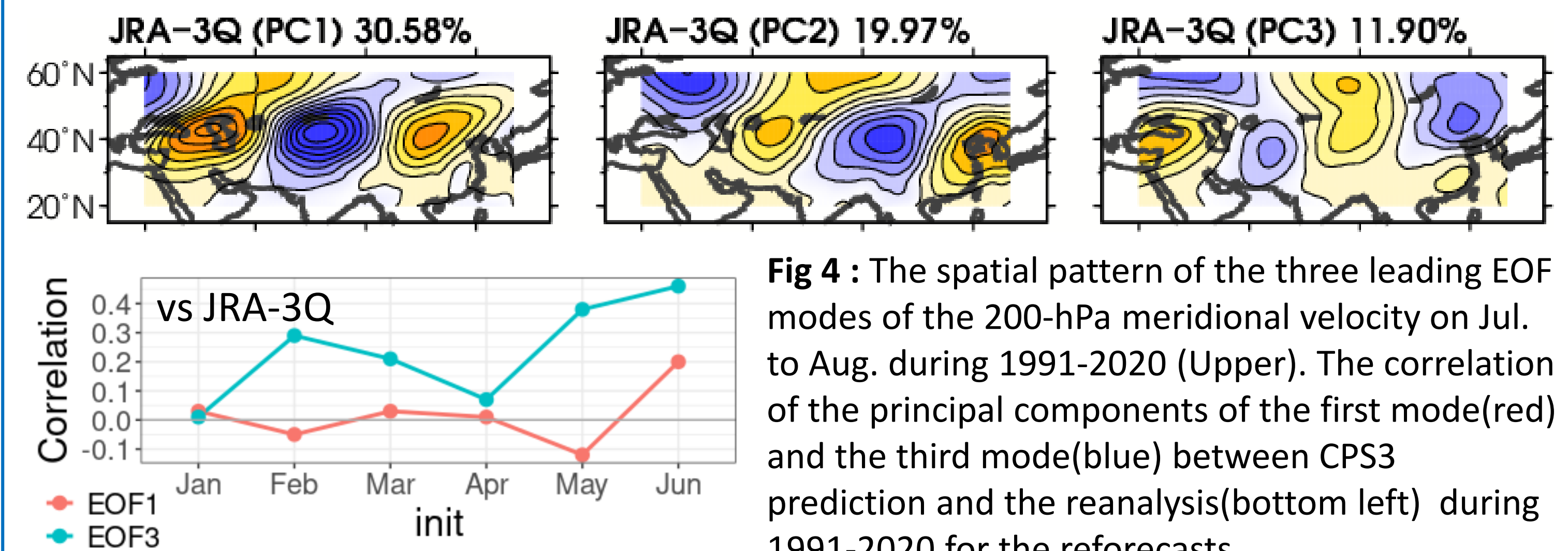


Fig 4 : The spatial pattern of the three leading EOF modes of the 200-hPa meridional velocity on Jul. to Aug. during 1991-2020 (Upper). The correlation of the principal components of the first mode (red) and the third mode (blue) between CPS3 prediction and the reanalysis (bottom left) during 1991-2020 for the rerecasts.

- ✓ Takemura et al.(2023) suggested that the Rossby wave breaking near Japan during JA is underestimated in JMA/MRI-CPS3. To investigate the cause of this underestimation, the prediction skill of the Asian jet variability is examined.
- ✓ Conducted EOF analysis of the upper-tropospheric meridional velocity to investigate the predictability of the Asian jet over Eurasia.
- ✓ Prediction accuracy was found to be minimal for the first and second modes, but the third mode showed some degree of predictability.
- ✓ Identified a link connection between the third mode and ENSO; discovered that, despite our previous beliefs about the difficulty of predicting waves along the Asian jet, there are indeed predictable modes.

5. Phenomena with High Predictive Accuracy in Winter and Their Application to Forecasting

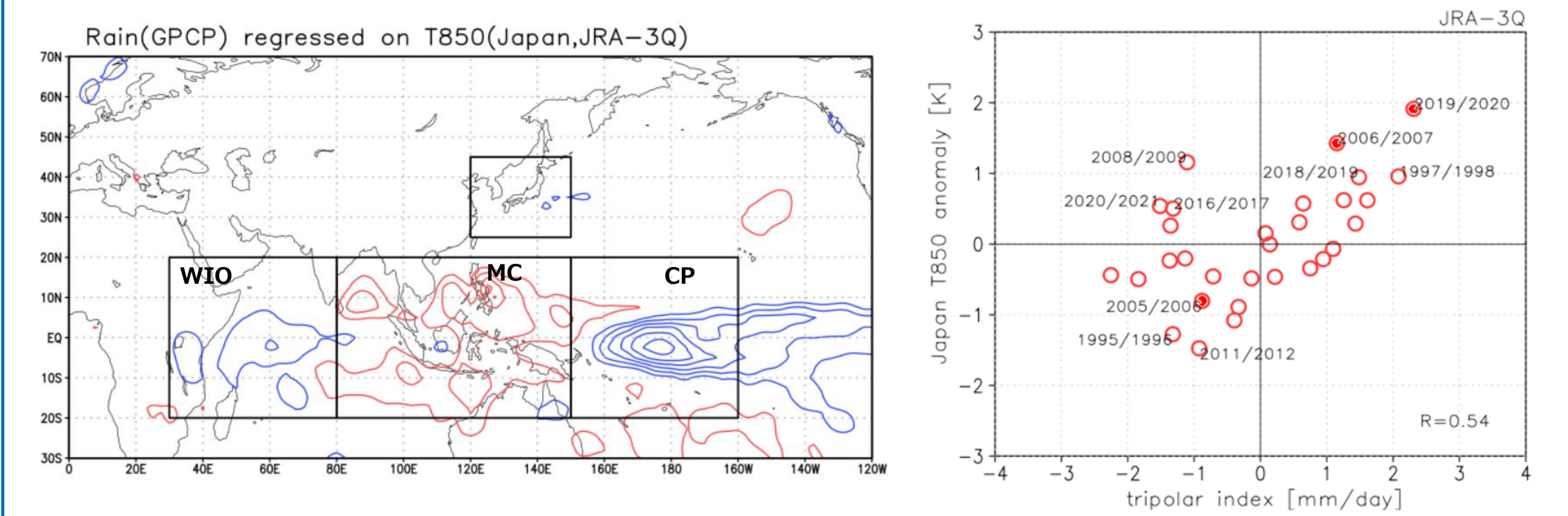


Fig 5 : (Left) Rainfall regressed on 850-hPa temperatures averaged over Japan (black square area) in DJF from 1991/92 to 2020/21. The blue line is positive and the red line is negative. (Right) The relationship between the 850-hPa temperature averaged over Japan and index defined as $\frac{\text{rain}_{(WIO)} + \text{rain}_{(CP)} - 2\text{rain}_{(MC)}}{2}$ (Kuramochi et al., 2021).

- ✓ The rainfall distribution regressed on the 850-hPa temperature averaged over Japan shows a tripolar pattern; the western Indian ocean and the central Pacific are active convection, while the Maritime Continent is inactive convection.
- ✓ The positive correlation between the index and the 850-hPa temperature averaged over Japan is clear, the correlation coefficient is 0.54.
- ✓ The predictability of the index by JMA/MRI-CPS3 is significantly high, with a correlation coefficient of 0.91 between the forecast and the reanalysis. This pattern could be significant signal for forecasts.
- ✓ A clear manifestation of this pattern was predicted in the winter season forecast published in September 2023, leading to the announcement of a high probability of the forecast.

6. Summary

- ✓ It is found to have the potential to identify phenomena and conditions with high predictability, even if the overall predictability of the data is not high.
- ✓ Prediction from the day when the SSW has occurred could have more predictability than normal.
- ✓ In the Asian jet over Eurasia, the third EOF mode of the upper-tropospheric meridional velocity related to ENSO has more predictability than the first and second EOF modes.
- ✓ The model system could have strength in predicting of specific phenomena. It is found that JMA/MRI-CPS3 has high predictability for the structure such as tripolar of rain from Indo ocean to Pacific ocean. The structure is strongly related to the temperature around Japan.
- ✓ These results could make our forecasts more confident, leading us to provide a higher probability forecast.

Reference
 • Hirahara, S., Y. Kubo, T. Yoshida, T. Komori, J. Chiba, T. Takakura, T. Kanehama, R. Sekiguchi, K. Ochi, H. Sugimoto, Y. Adachi, I. Ishikawa, and Y. Fujii, 2023: Japan Meteorological Agency/Meteorological Research Institute Coupled Prediction System version 3 (JMA/MRI-CPS3). *J. Meteor. Soc. Japan*, **101**, 149-169.
 • Kosaka, Y., S. Kobayashi, Y. Harada, C. Kobayashi, H. Naoe, K. Yoshimoto, M. Harada, N. Goto, J. Chiba, K. Miyaoka, R. Sekiguchi, M. Deushi, H. Kamahori, T. Nakaegawa, T. Y. Tanaka, T. Tokuhito, Y. Sato, Y. Matsushita, and K. Onogi, 2024: The JRA-3Q reanalysis. *J. Meteor. Soc. Japan*, 102.
 • Kuramochi M. and H. Ueda, 2023: Two types of wintertime teleconnection patterns over the western North Pacific associated with regionally different heating anomalies. *J. Meteor. Soc. Japan*, 101, 21-37.
 • Takemura, K., Maeda, S., Yamada, K., Mukougawa, H., & Naoe, H. 2023: Improved predictability of summertime Rossby wave breaking frequency near Japan in JMA/MRI-CPS3 seasonal forecasts. *Weather and Forecasting*, 38(6), 999-1010.
 • Plumb, R. A., 1985: On the three dimensional propagation of stationary waves. *J. Atmos. Sci.*, **42**, 217-229.