The 2019 New Year Stratospheric Sudden Warming and Its Predictions in 11 S2S Models

Jian Rao[1,2,*], Chaim Garfinkel[1], Haishan Chen[2], Ian White[1]

1. Hebrew University of Jerusalem, Israel
2. Nanjing University of Information Science and Technology, China

*E-mail: raojian@nuist.edu.cn or jian.rao@mail.huji.ac.il

Motivations

An SSW was observed to occur on 31 December 2018 - January 2019, which is still not widely reported:

(1) What are the general favorable conditions for this SSW event from a perspective of statistics?
(2) To what extent can the onset and duration of this SSW be forecasted in multiple S2S models?

Data and Methods

- Daily NCEP/NCAR reanalysis (Kalnay et al. 1996)
- Real-time multivariate Madden-Julian Oscillation (MJO) series (Wheeler and Hendon, 2004)
- Monthly mean time-series for the ENSO index derived from the extended reconstructed sea surface temperature version 5 (ERSSTv5) (Huang et al., 2017)
- Quasi biennial oscillation (QBO) data series (FREIE UNIVERSITÄT BERLIN)
- 11-year solar cycle indexed by the 10.7cm solar flux (NOAA)
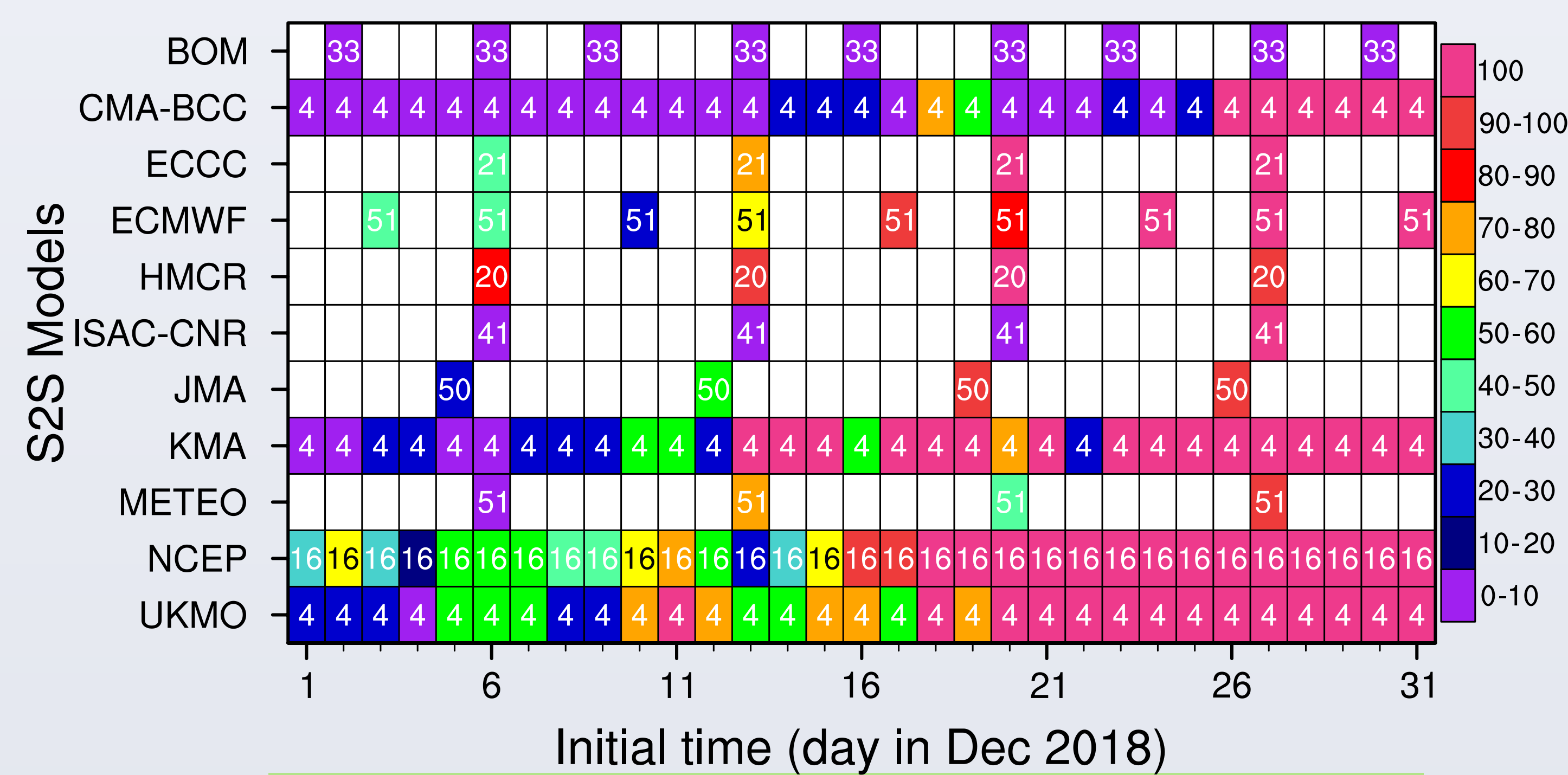- 11 sub-seasonal to seasonal (S2S) models in Fig. 1

Fig. 1 SSW Hit ratio for each available initializations from each models (color fillings) and the number of all members for each initialization (no initialization in white space).
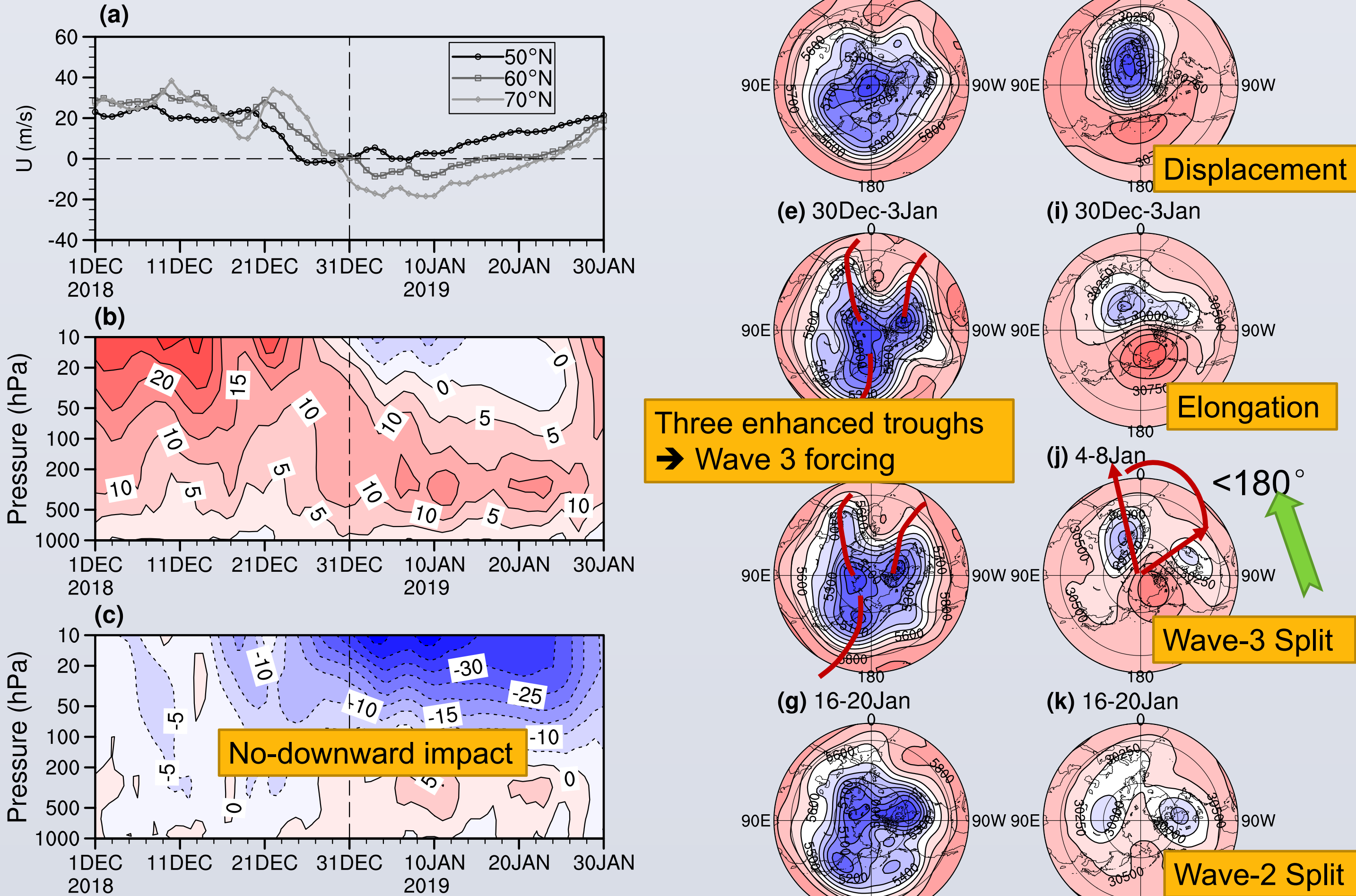
Observations

Fig. 2 (a, b) Zonal-mean zonal winds and their anomalies and (c) their anomalies. (d–g) Synoptic maps of 500-hPa heights. (h–k) Synoptic maps of 10-hPa heights.

Three enhanced troughs → Wave 3 forcing

Displacement
Elongation
Wave-3 Split
Wave-2 Split

No-downward impact

The 2019 SSW happened during favorable conditions:
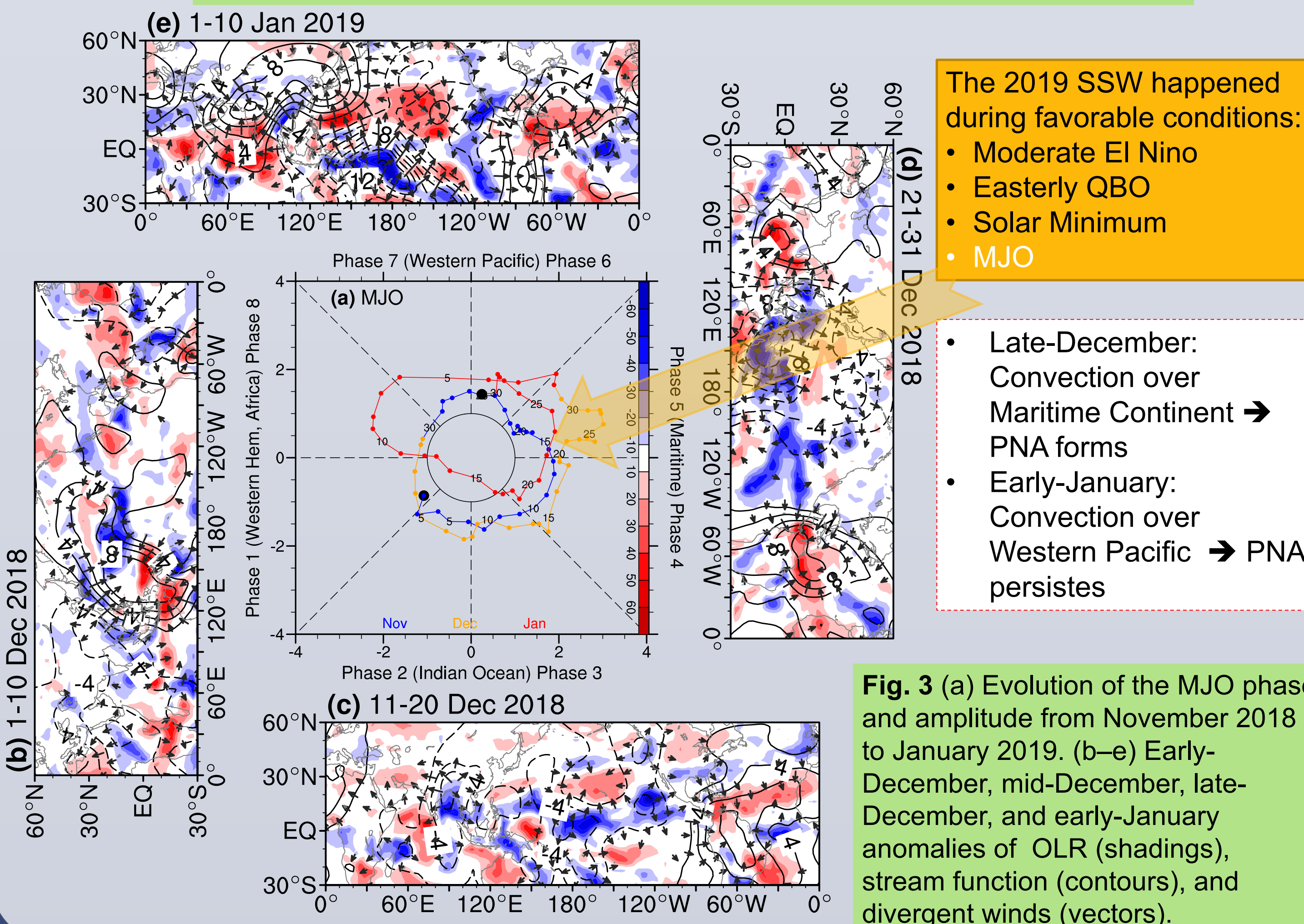- Moderate El Nino
- Easterly QBO
- Solar Minimum
- MJO

Fig. 3 (a) Evolution of the MJO phase and amplitude from November 2018 to January 2019. (b–e) Early-December, mid-December, late-December, and early-January anomalies of OLR (shadings), stream function (contours), and divergent winds (vectors).

- Late-December: Convection over Maritime Continent → PNA forms
- Early-January: Convection over Western Pacific → PNA persistes
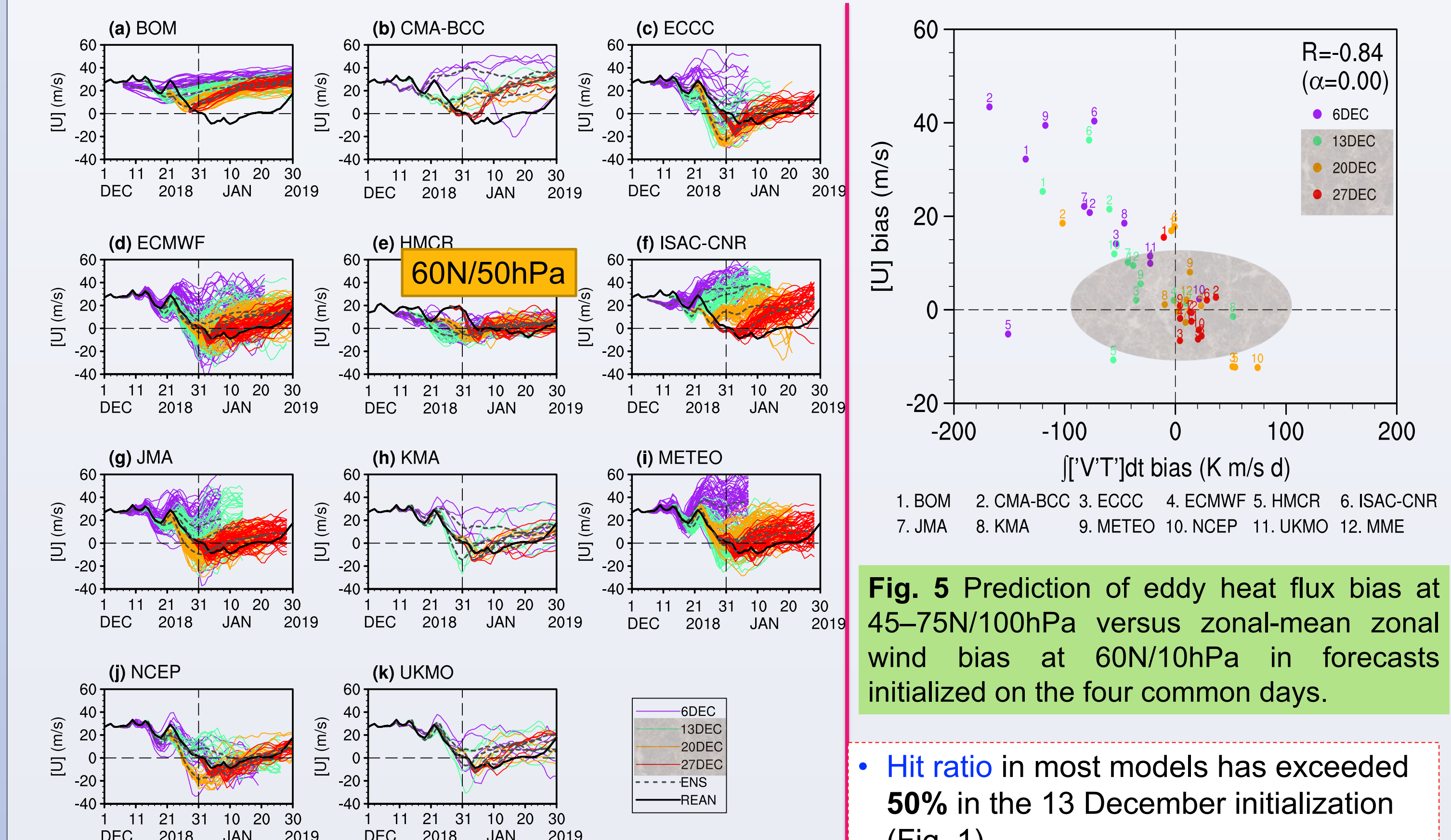
Prediction of the 2019 SSW in 11 S2S models

Fig. 4 Prediction of zonal-mean zonal wind at 60N/10hPa in forecasts initialized on the four common days (the zonal-mean zonal wind at 60N/50hPa is shown for HMCR).
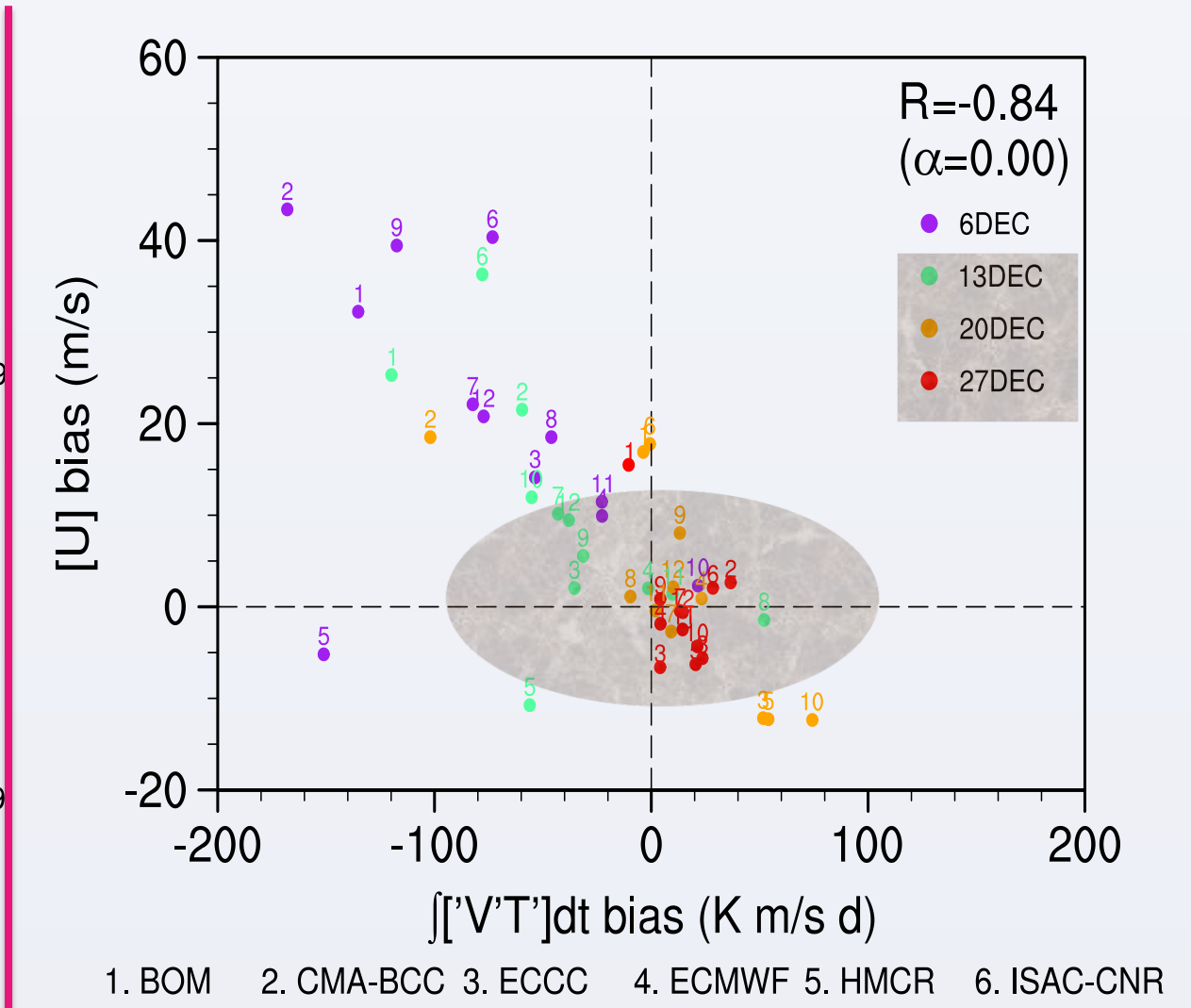

Fig. 5 Prediction of eddy heat flux bias at 45–75N/100hPa versus zonal-mean zonal wind bias at 60N/10hPa in forecasts initialized on the four common days.

1. BOM   2. CMA-BCC   3. ECCC   4. ECMWF   5. HMCR   6. ISAC-CNR   7. JMA   8. KMA   9. METEO   10. NCEP   11. UKMO   12. MME

- **Hit ratio** in most models has exceeded **50%** in the 13 December initialization (Fig. 1)
- **Low skill** models: BoM, CMA-BCC, ISAC-CNR (Figs. 4 and 5)
- **High skill** models: ECMWF, NCEP, UKMO (Figs. 4 and 5)
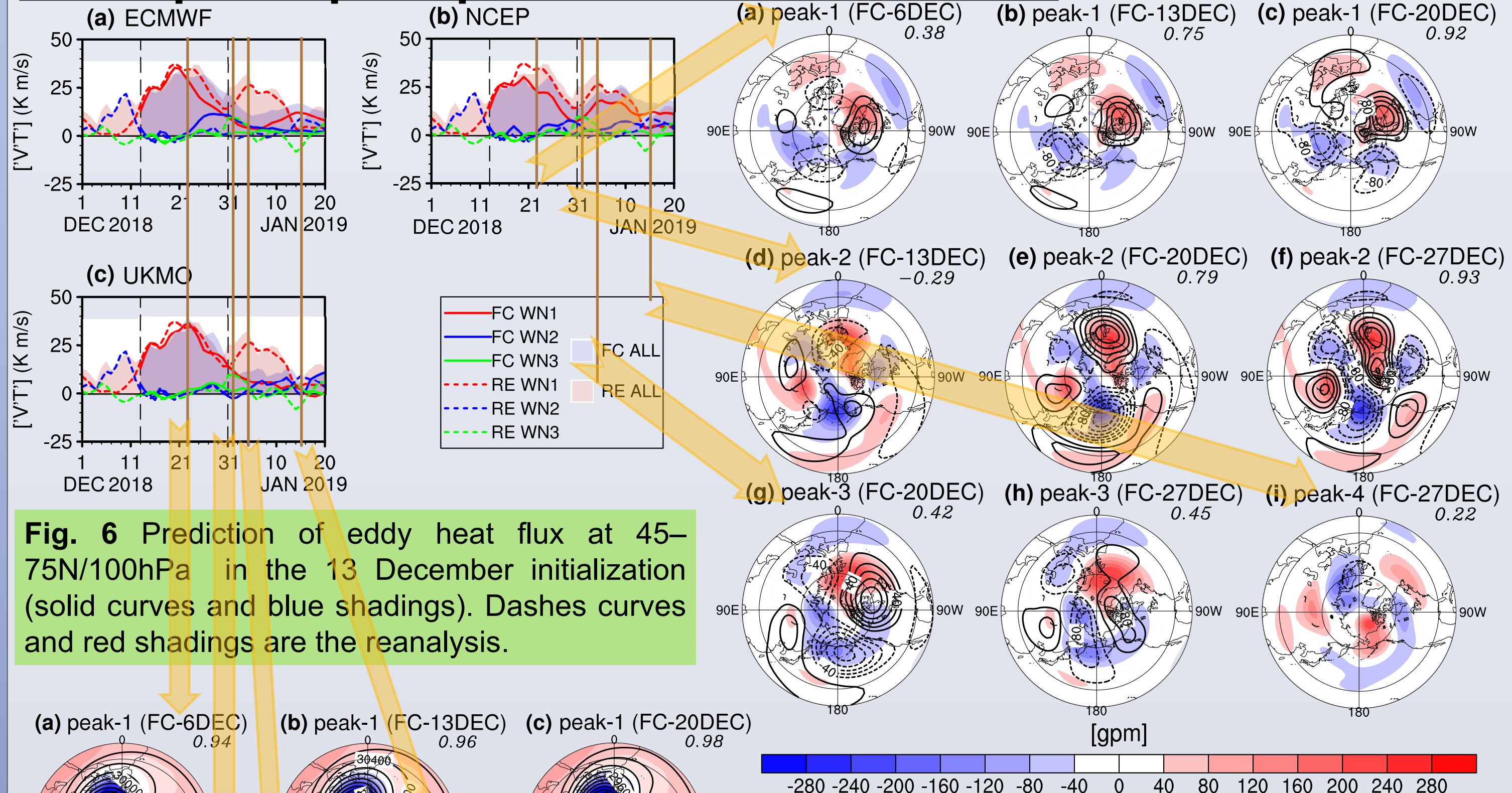
Four special peak periods for the 2019 SSW

Fig. 6 Prediction of eddy heat flux at 45–75N/100hPa in the 13 December initialization (solid curves and blue shadings). Dashes curves and red shadings are the reanalysis.
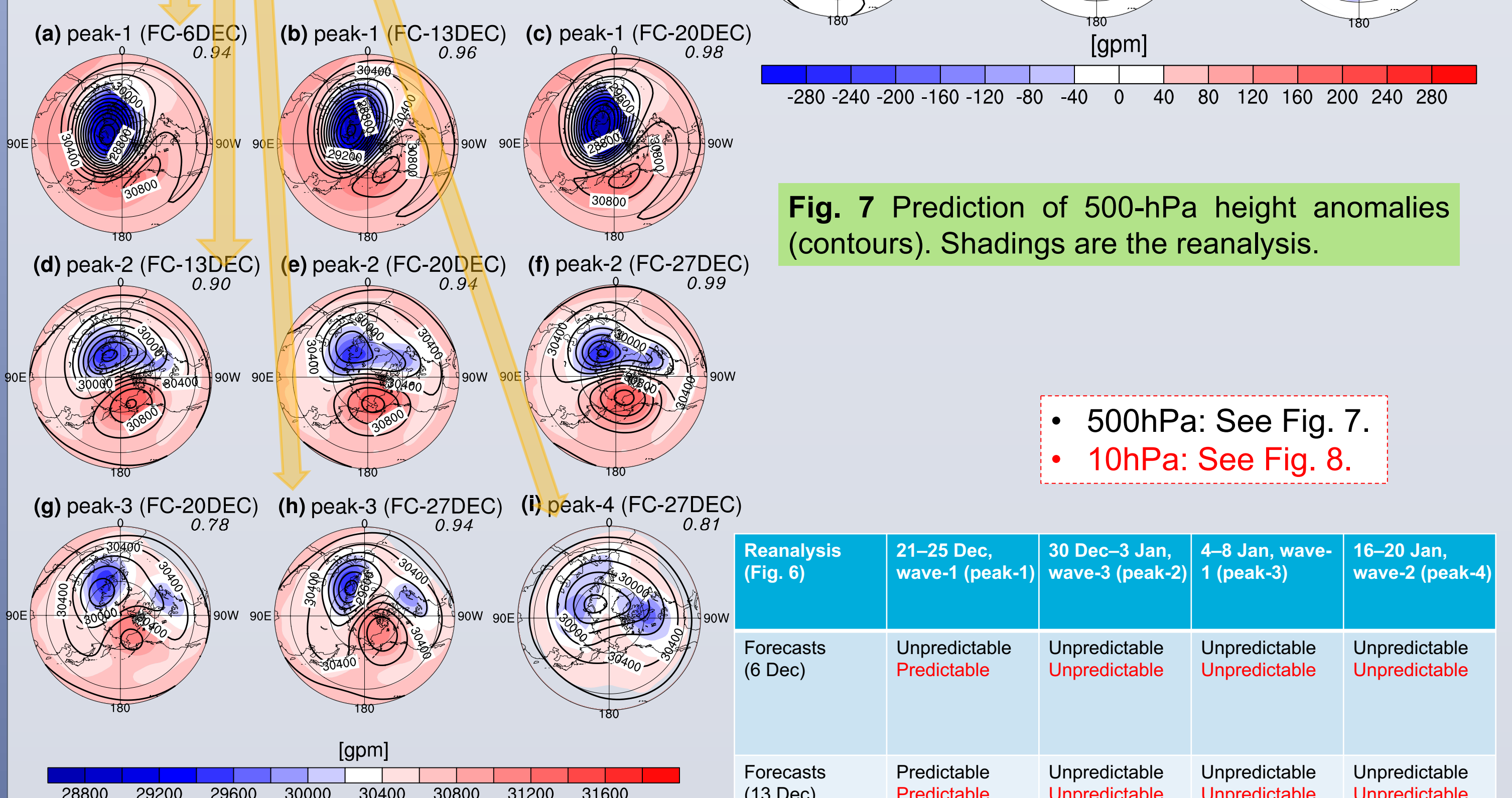

Fig. 7 Prediction of 500-hPa height anomalies (contours). Shadings are the reanalysis.

- 500hPa: See Fig. 7.
- 10hPa: See Fig. 8.

Fig. 8 Prediction of 10-hPa heights (contours). Shadings are the reanalysis.

Reanalysis (Fig. 6)	21–25 Dec, wave-1 (peak-1)	30 Dec–3 Jan, wave-3 (peak-2)	4–8 Jan, wave-1 (peak-3)	16–20 Jan, wave-2 (peak-4)
Forecasts (6 Dec)	Unpredictable / Predictable	Unpredictable / Unpredictable	Unpredictable / Unpredictable	Unpredictable / Unpredictable
Forecasts (13 Dec)	Predictable / Predictable	Unpredictable / Unpredictable	Unpredictable / Unpredictable	Unpredictable / Unpredictable
Forecasts (20 Dec)	Predictable / Predictable	Predictable / Predictable	Unpredictable / Unpredictable	Unpredictable / Unpredictable
Forecasts (27 Dec)	—	Predictable / Predictable	Unpredictable / Unpredictable	Unpredictable / Unpredictable

Summary

- This mixed-type (displacement followed by elongation and split) SSW event occurred under moderate El Niño, the easterly QBO phase together with solar minimum, and MJO phases 4–6. Nearly all of these external forcings are preferable for an SSW.
- The predictability of this SSW onset is beyond 18 days in most S2S models, longer than the average predictive limit in existing literature.
- The splitting of the stratospheric polar vortex and its persistence after the SSW onset, explained by the alternate wave-3 and wave-2 pulses, are difficult to forecast in S2S models.

Reference: Rao, J., Chaim I. Garfinkel, H. Chen, and Ian P. White, 2019: The 2019 New Year Stratospheric Sudden Warming and Its Real-Time Predictions in Multiple S2S Models. J. Geophys. Res. Atmos., 124, doi:10.1029/2019JD030826.