Predicting the Downward and Surface Influence of the February 2018 and January 2019 Sudden Stratospheric Warming events in S2S Models

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Motivations

Only two major sudden stratospheric warming (SSW) event occurred since the initiation of the sub-seasonal to seasonal (S2S) prediction program:

(1) What controls the magnitude of the downward impact of SSWs on the surface from a statistical perspective? **(2)** What is the difference between the two SSWs in term of their intensity, type, and the skill at which they can be forecasted?

Data and Methods

- Daily NCEP/NCAR reanalysis and 11 S2S models in Figs. 1a, 1b
- MWO SSW onset criterion ($[U]_{60N/10hPa}$): **11 February 2018 and 1 January 2019**
- SSW hit ratio (HR) = $\frac{\text{Number of forecast members that forecast the SSW (}\pm\text{2-day error is allowed)}}{\text{Total number of the ensemble members for this initialization}}$
- Anomaly correlation, $ACC(t)=\frac{\sum_{i=1}^{n} w(i)[T_{FC}(i,t)-\overline{T_{FC}(t)}][T_{NNR}(i,t)-\overline{T_{NNR}(t)}]}{\sqrt{\sum_{i=1}^{n} w(i)[T_{FC}(i,t)-\overline{T_{FC}(t)}]^2}\sqrt{\sum_{i=1}^{n} w(i)[T_{NNR}(i,t)-\overline{T_{NNR}(t)}]^2}}$, $\overline{T(t)}=\frac{\sum_{i=1}^{n} w(i)T(i,t)}{\sum_{i=1}^{n} w(i)}$

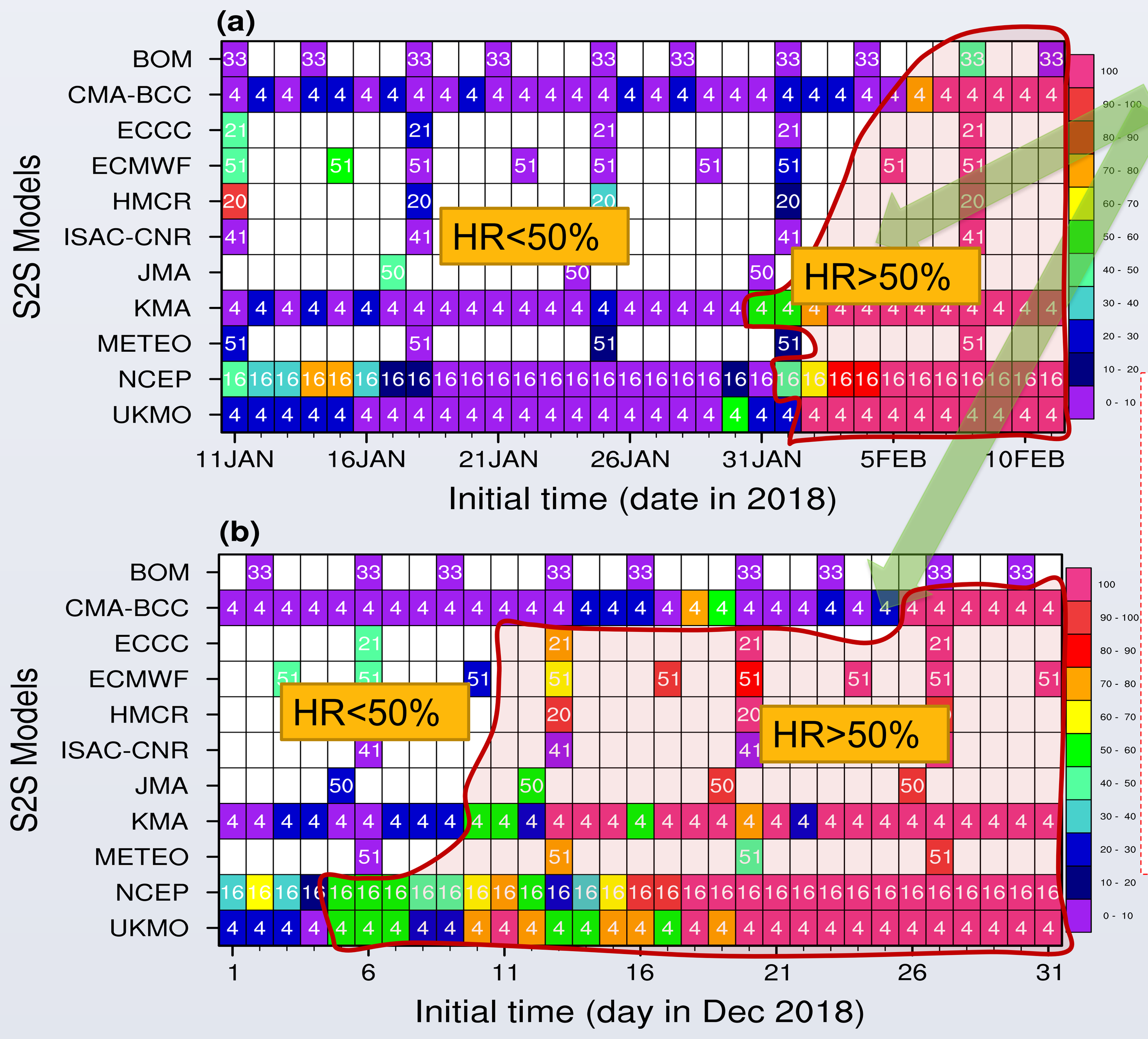


Fig. 1 (a, b) SSW hit ratio for each available initializations from each models (color fillings) and the number of all members for each initialization (no initialization in white space) for the two SSWs.

Compare the two SSWs' predictability:

- The 2019 SSW is more predictable than the 2018 SSW
- Low skill models for both SSWs: BoM, CMA-BCC, ISAC-CNR
- High skill models for both SSWs: ECMWF, NCEP, UKMO

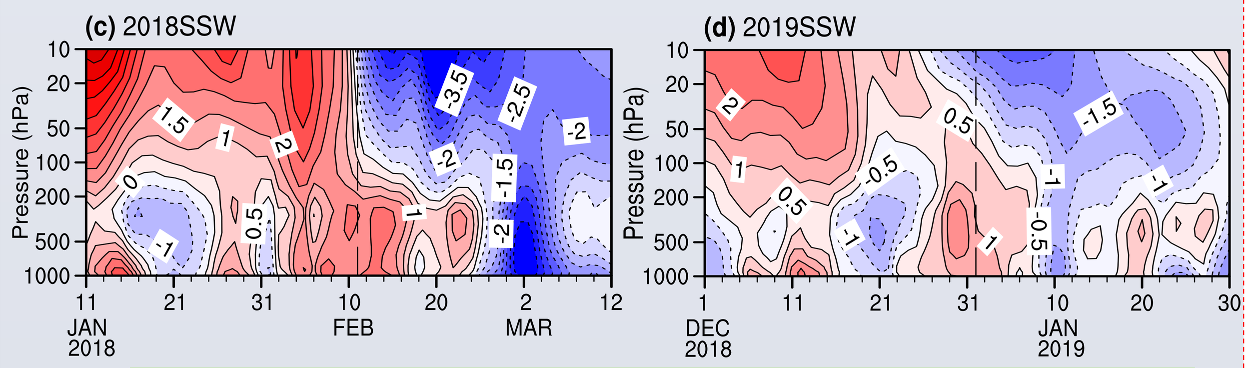


Fig. 1 (c, d) NAM evolutions from 1000–10hPa in the reanalysis during the two SSWs, respectively.

Compare the two SSWs' downward propagation:

- The 2018 SSW shows a strong downward propagation, whereas the 2019 SSW shows a less downward propagation.
- The tropospheric negative NAM following the 2018 SSW is much stronger than the 2019 SSW.

Predictability of lower stratospheric response to SSW events

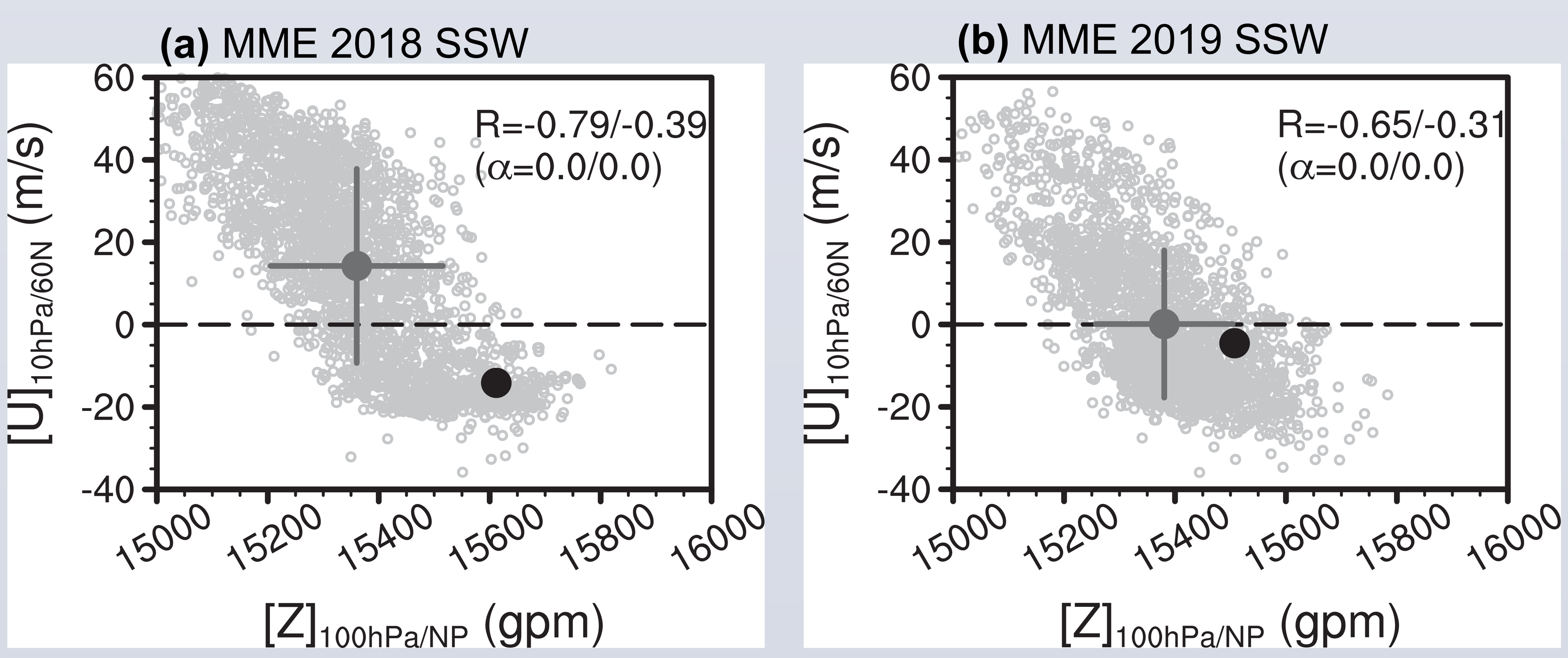


Fig. 2 Scatterplot of the zonal mean zonal wind at 60°N/10hPa (ordinates) on days 0–5 versus the area-averaged polar (65–90°N) geopotential height at 100hPa (abscissas) on days 0–15 from all ensemble members of all initializations in all models.

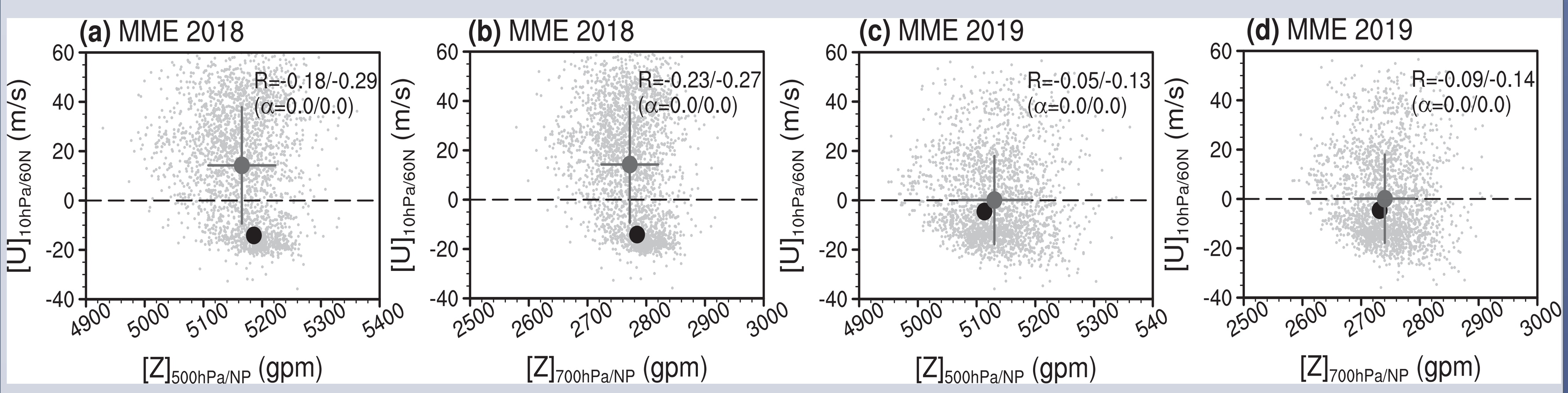


Fig. 3 Scatterplot of the zonal mean zonal wind at 60°N/10hPa (ordinates) on days 0–5 versus the area-averaged polar (65–90°N) geopotential height at 500hPa or 700hPa (abscissas) on days 6–20.

- Based on the MME, $[U]_{10hPa/60N}$ at the beginning of SSWs is negatively (positively) correlated with the polar cap height (NAM) at 100hPa in the following weeks (Fig. 2).
- Such a significant correlation becomes weaker between $[U]_{10hPa/60N}$ and $NAM_{500hPa/NP}$ or $NAM_{700hPa/NP}$ than between $[U]_{10hPa/60N}$ and $NAM_{100hPa/NP}$ (Fig. 3).
- In probabilistic sense, a strong SSW (e.g., February 2018 SSW) tends to propagate downward more easily than a weak SSW (e.g. January 2019 SSW) (Fig. 4).

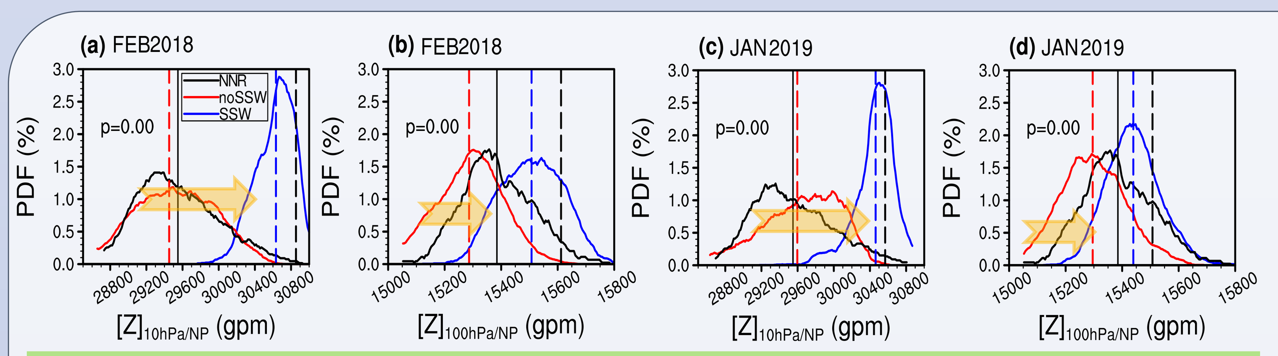


Fig. 4 PDF distribution of the polar cap height at 10hPa on days 0–5 and at 100hPa on days 0–15. Red/Blue curves are SSW-hit/-missed forecasts, and black curves are reanalysis climatological PDF.

Relative to SSW-missed forecasts and climate, possibility of high polar cap height (or low NAM) increases in SSW-hit forecasts.

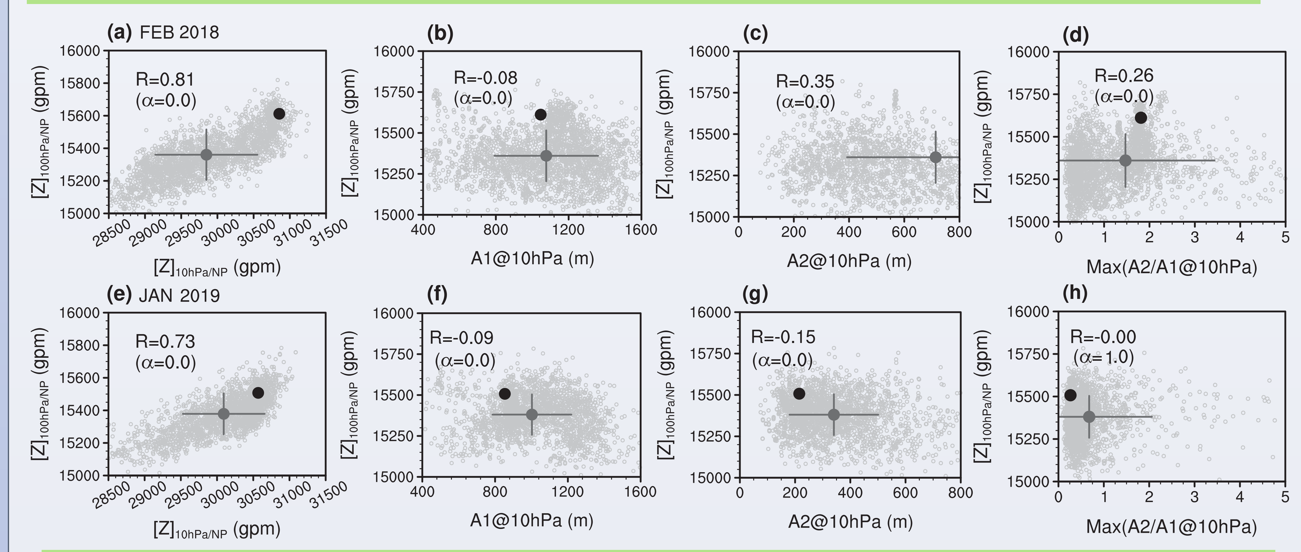
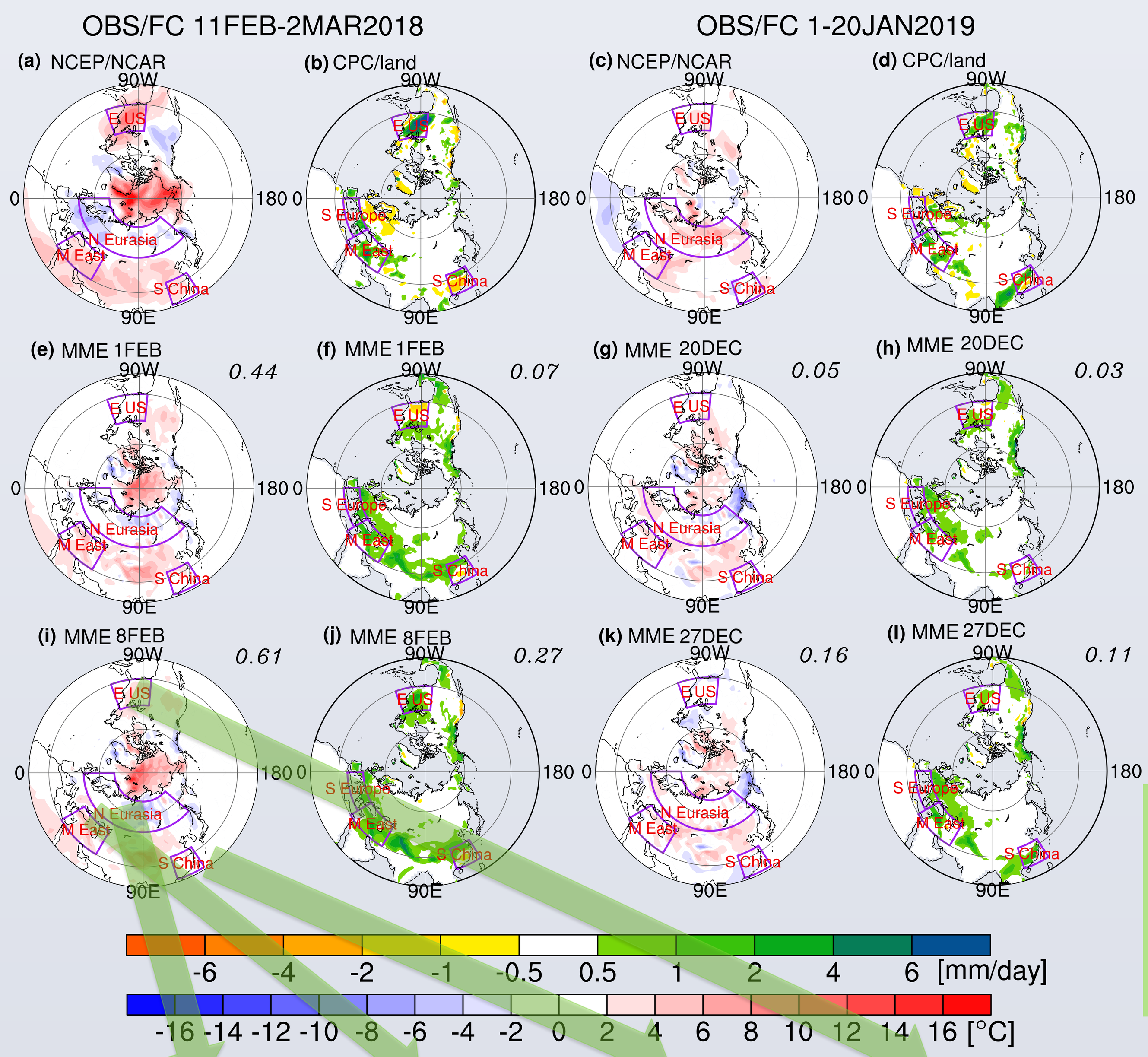


Fig. 5 What determines the lower-level response to SSW event at 10hPa, the SSW intensity or wave-1/wave-2 amplitude?

Compare the SSW intensity, wave-1, wave-2:

- SSW intensity is more important for the lower-level response.
- The wave-1 and wave-2 coordinates are more scattered and more unorganized.

Predicting surface impact of downward propagating SSWs



- Forecast skill of SSWs ≠ forecast skill of near surface temperature and rainfall.
- Only downward propagating SSWs might help to enhance the predictability of surface.
- Rainfall is more difficult to forecast than 2-m temperature for (non-)downward propagating SSWs.

Fig. 6 Spatial pattern of the near-surface air temperature anomalies and land precipitation anomalies on days 0–20 for the two SSWs:

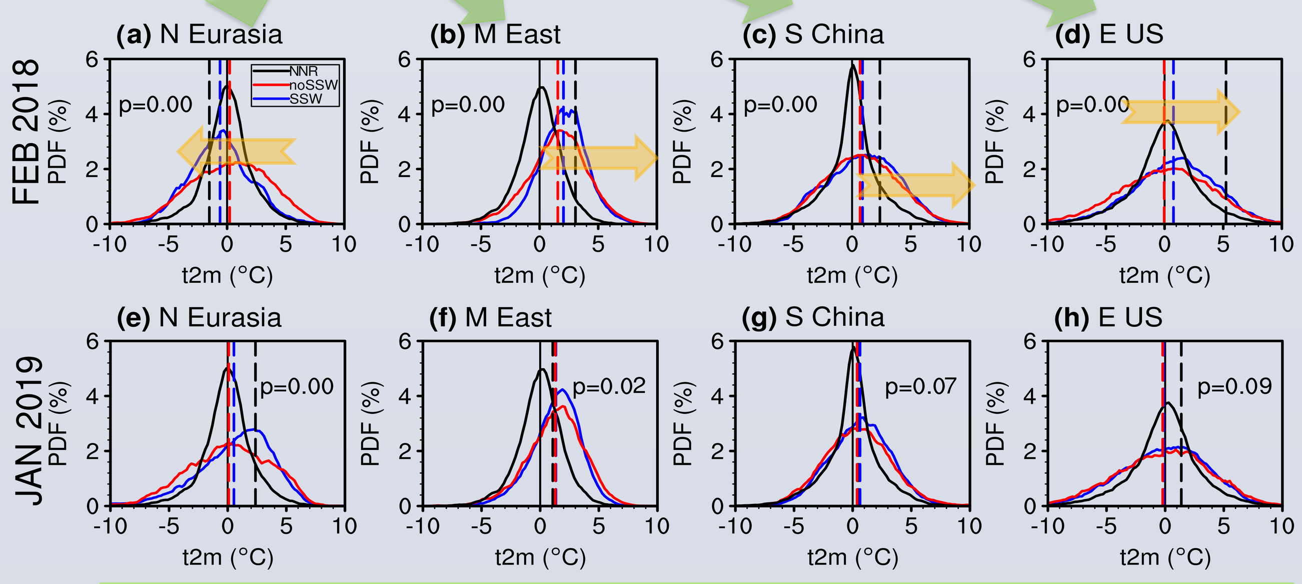


Fig. 7 Probabilistic forecasts of 2-m temperature anomalies in four regions

- For the February 2018 downward propagating SSW, the cold anomalies in North Eurasia and warm anomalies in Middle East, South China, and East US can be forecasted in MME, although underestimated (Fig. 7).
- The warm anomalies in North Eurasia for the 2019 SSW is unpredictable in deterministic and probabilistic sense.
- Rainfall is more difficult to forecast in some regions. The positive rainfall anomalies in Southern Europe and East US for the 2018 SSW can be well forecasted (Fig. 8).

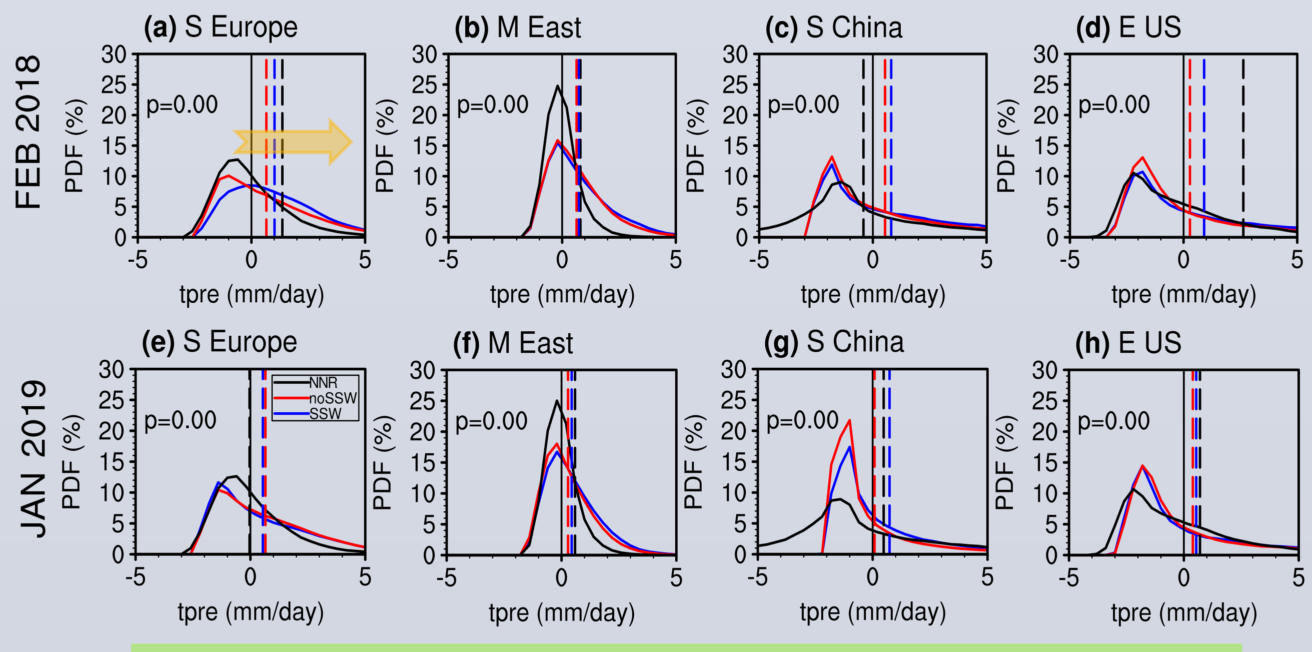


Fig. 8 Probabilistic forecasts of rainfall anomalies in four regions

Summary

- The strength of the SSW is more important to determine the magnitude of the downward impact than the dominant wavenumber.
- The T2m in North Eurasia, Middle East, South China and Eastern US is more difficult to forecast for the non-downward propagating 2019 SSW.
- The rainfall anomalies in some regions are poorly forecasted both in a deterministic and probabilistic sense for (non-)downward propagating SSWs.

Reference: Rao, J., Chaim I. Garfinkel, and Ian P. White, 2019: Predicting the Downward and Surface Influence of the February 2018 and January 2019 Sudden Stratospheric Warming events in Subseasonal to Seasonal (S2S) Models, submitted to J. Geophys. Res. Atmos.