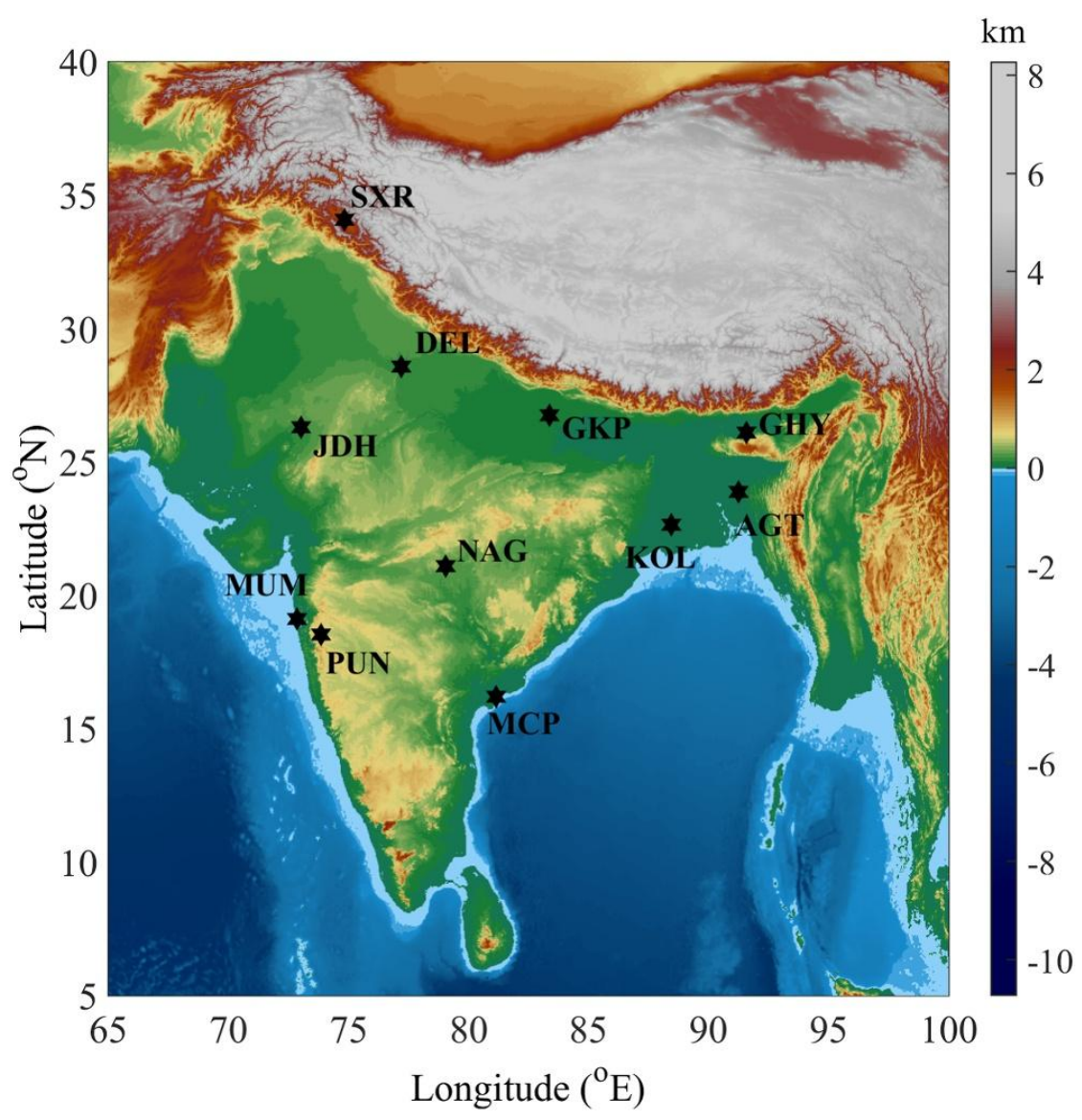




Why does bias assessment matter in reanalyses datasets?

Reanalyses bridge gaps between sparse observations and are widely used for monsoon research and forecasting, model initialization, boundary forcing, and diagnostic analyses. Temperature, humidity and wind control monsoon circulation, moisture transport and convection. Errors in them affect the diagnosis of monsoon convection, mesoscale organization, and upper-tropospheric divergence. *Mean biases alone do not reveal all errors in their vertical structure.*

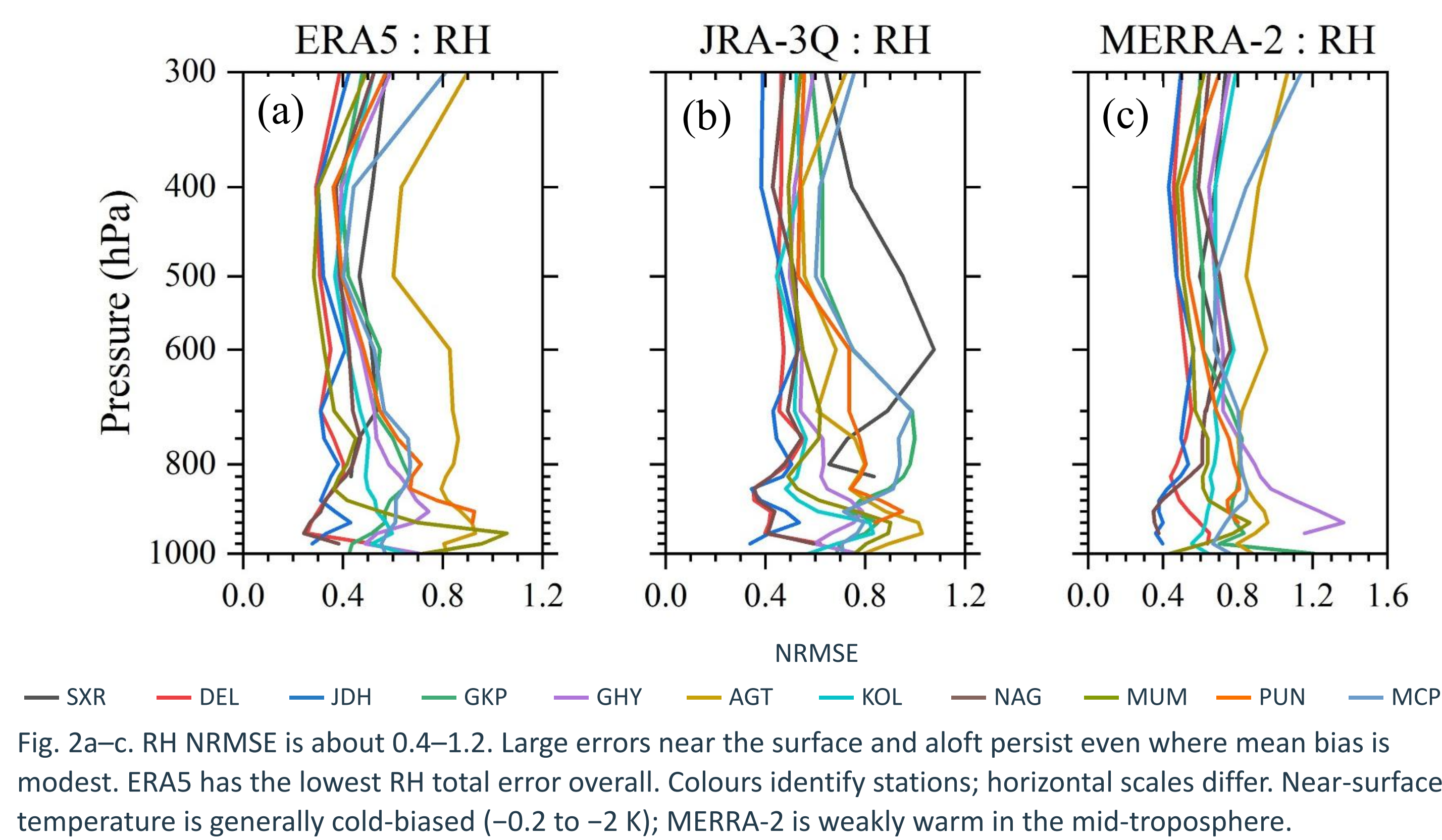
Research question

Are reanalysis errors mainly correctable mean offsets, or mismatches in observed variability and timing?

Methodology

- RS41 versus ERA5, JRA-3Q and MERRA-2. Temperature and wind: lower troposphere to 100 hPa; relative humidity (RH): to 300 hPa.
- Exact launch-time matching; bilinear horizontal interpolation; radiosondes interpolated to standard pressure levels. Mean bias = reanalysis – radiosonde
- Koh et al. (2012): total error (NRMSE) separated into mean-offset and residual pattern components (NPE). Errors are normalised by pooled observed/reanalysis variability.
- Observed regimes: all profiles, lower quintile (Q20) and upper quintile (Q80) for extremes.

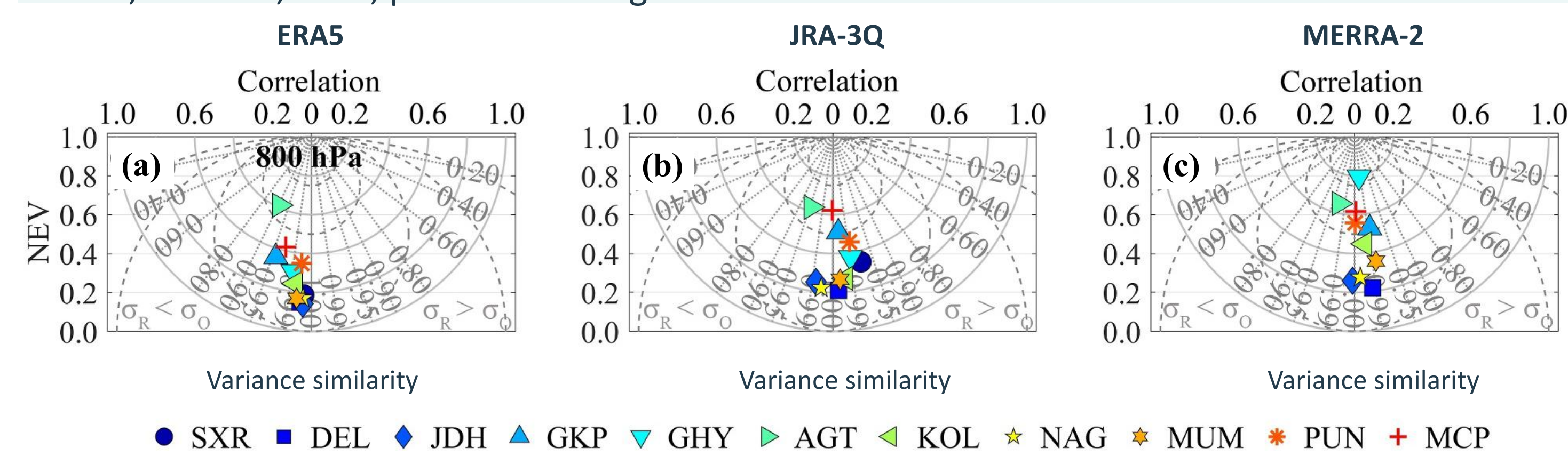
01 Humidity has the largest total error



02 Pattern error dominates the total error budget

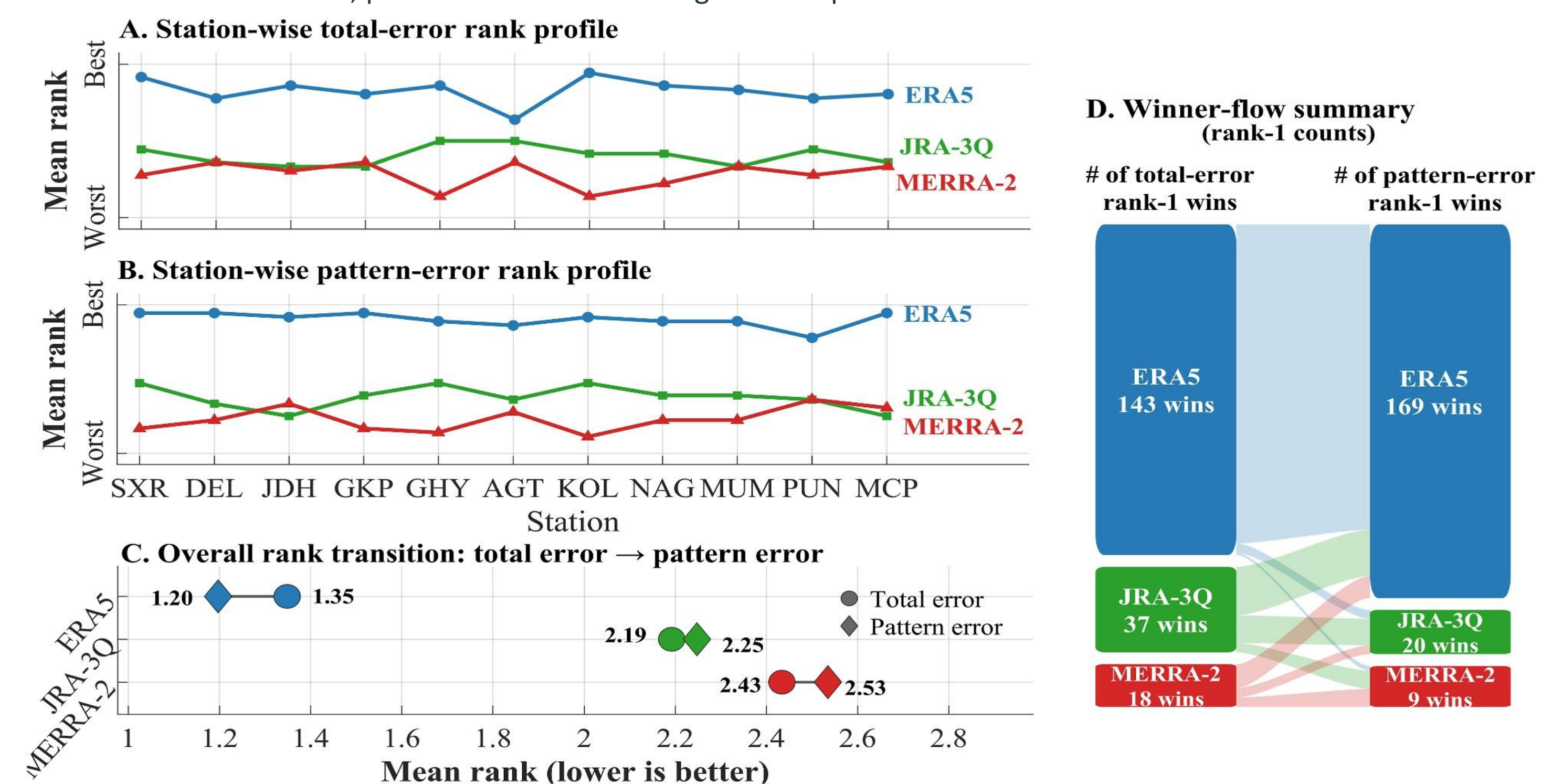
≈88% of valid comparisons are pattern-error dominated

Pattern error commonly contributes around 80% of total squared error; its share varies across station, variable, level, product and regime.

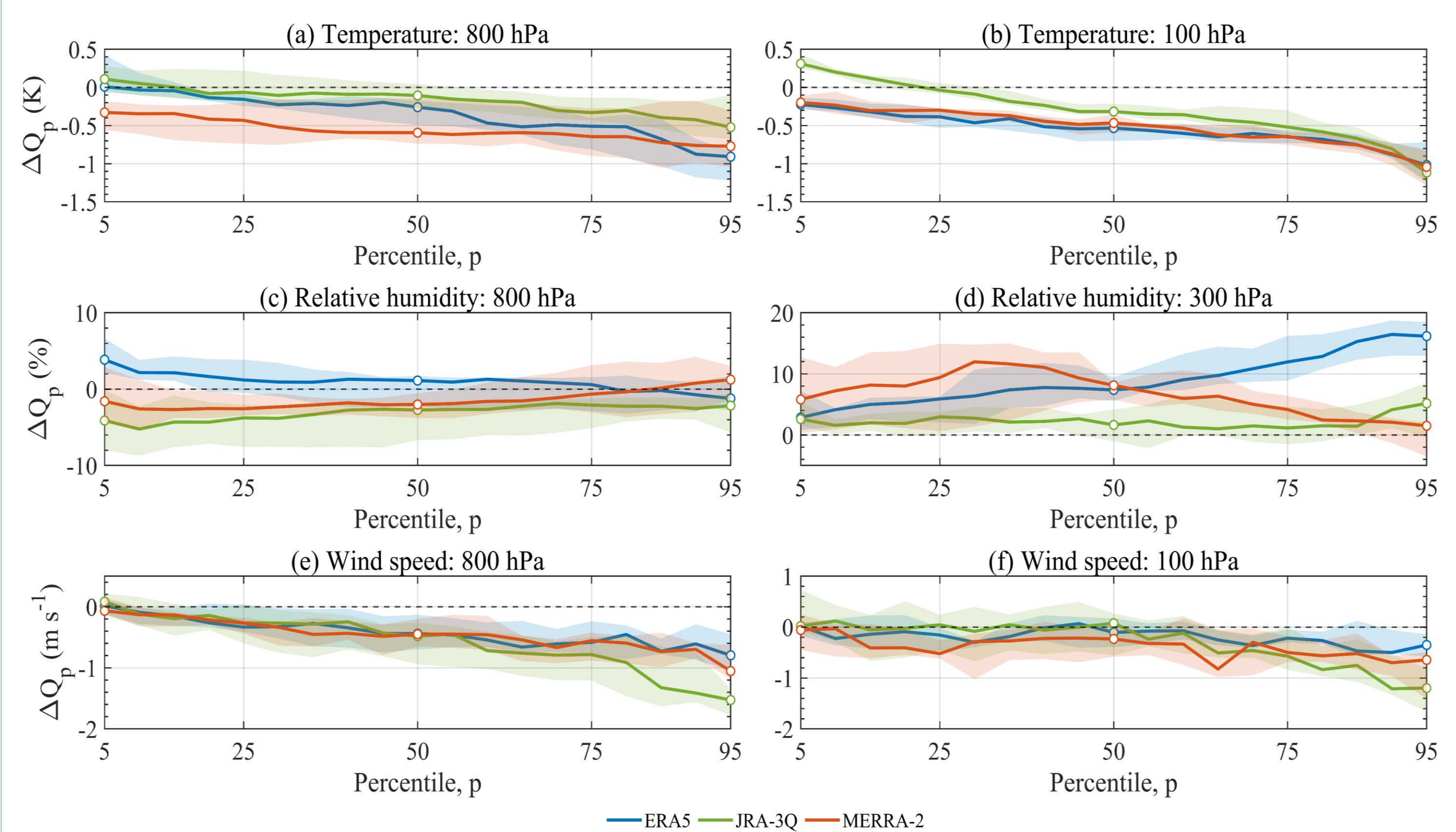


03 ERA5 ranks first most often among other reanalyses

Fig. 4. Station-wise mean ranks (a,b), overall mean-rank transition (c), and rank-1 winner flow (d). Lower rank is better. ERA5 leads overall; performance remains diagnostic-dependent.

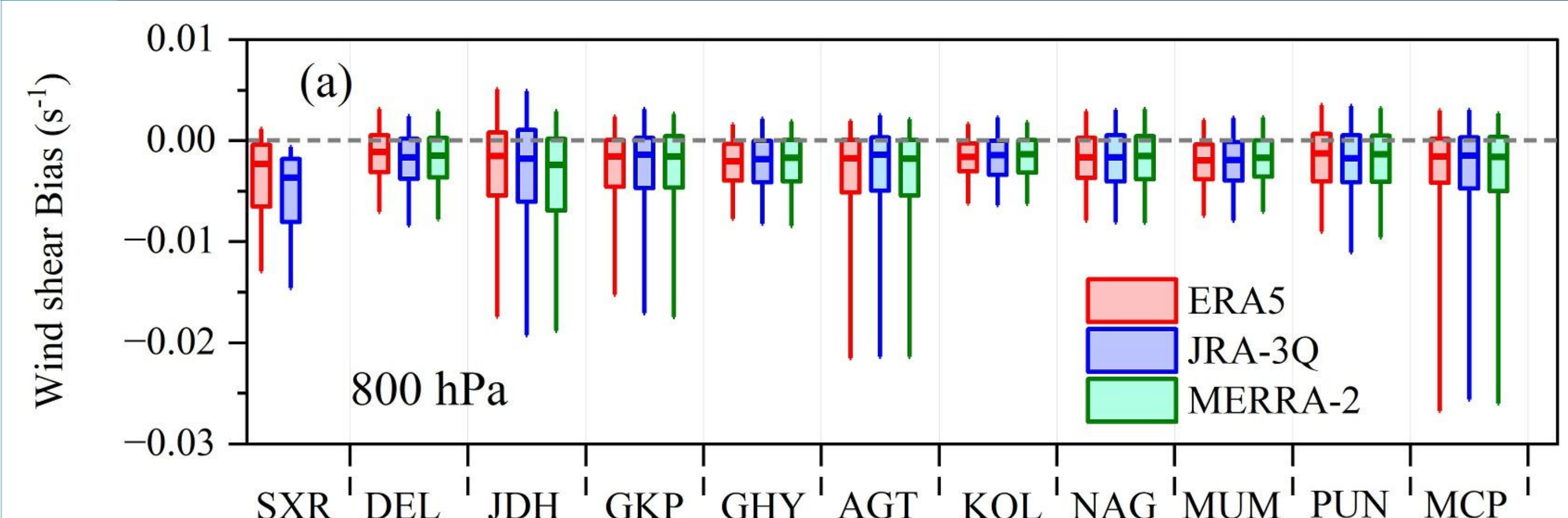


04 Warm and strong-wind extremes are misrepresented



- Warm-temperature and strong-wind extremes are systematically underestimated. RH distributional errors are more product- and altitude-dependent.

05 Biases in wind shear and stability can affect monsoon diagnostics



Median shear bias: $-(1.6-1.8) \times 10^{-3} \text{ s}^{-1}$

- Low-level shear bias is negative in about 73–75% of samples, indicating smoother vertical wind structure in reanalyses.

Static stability: biases reverse with height

Level	Median N ² bias (s ^{–2})
800 hPa	$+(3-8) \times 10^{-6}$
100 hPa	$-(2-7) \times 10^{-6}$

- Low-level vertical wind shear is systematically underestimated across all three reanalyses. Static stability is slightly overestimated in the lower troposphere and underestimated near the tropopause. Shear and stability errors may alter inferred environments for organized convection, monsoon depressions and upper troposphere–lower stratosphere (UTLS) coupling.

Take-home messages

1 Mean offsets are only part of the error. Bias correction alone cannot recover observed variability and timing.

2 Pattern error is the largest error component in about 88% of valid comparisons and commonly contributes around 80% of the total squared error.

3 Humidity variability remains the largest uncertainty. Temperature, RH and wind extremes are generally misrepresented.

