

A spread-versus-error framework to reliably quantify the potential for sub-seasonal windows of forecast opportunity

Reduction in ensemble spread = window of forecast opportunity?

Philip Rupp¹, Jonas Spaeth^{1,2} and Thomas Birner^{1,3}

¹ Meteorological Institute Munich, LMU, Germany, ² ECMWF, Bonn, Germany, ³ DLR Institute of Atmospheric Physics, Oberpfaffenhofen, Germany
Contact: thomas.birner@lmu.de

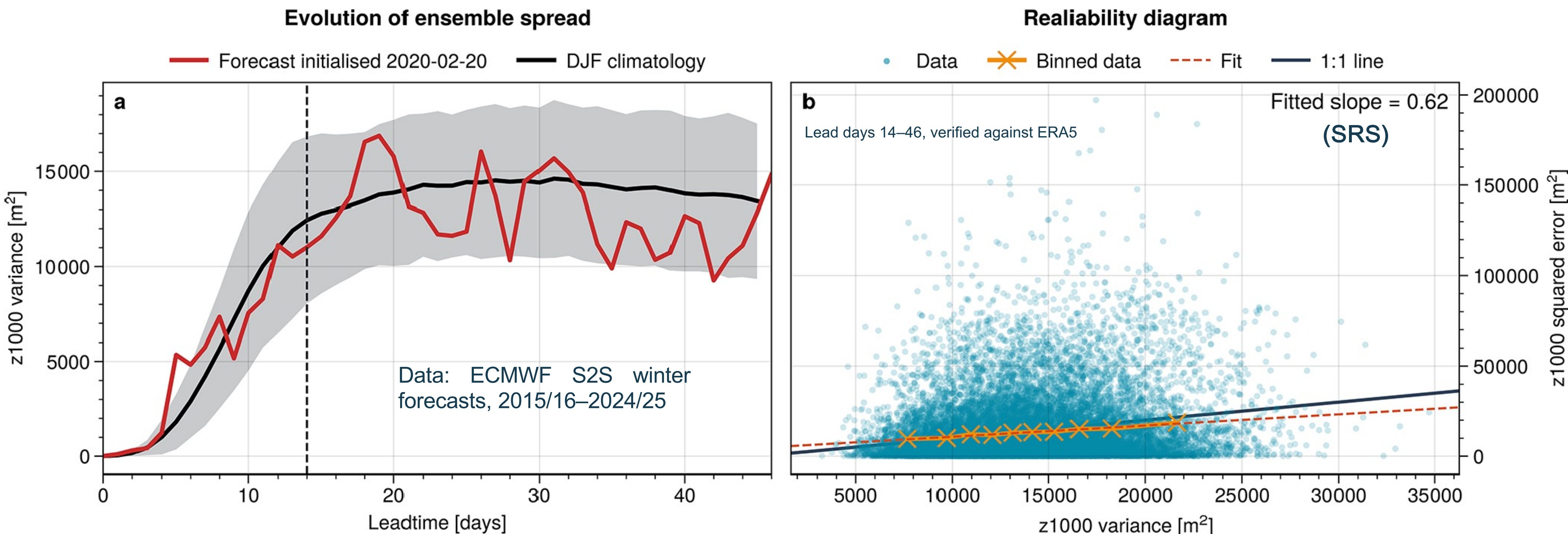


—Rupp et al. (2026)

1 Quantifying reliability: spread-reliability slope (SRS)

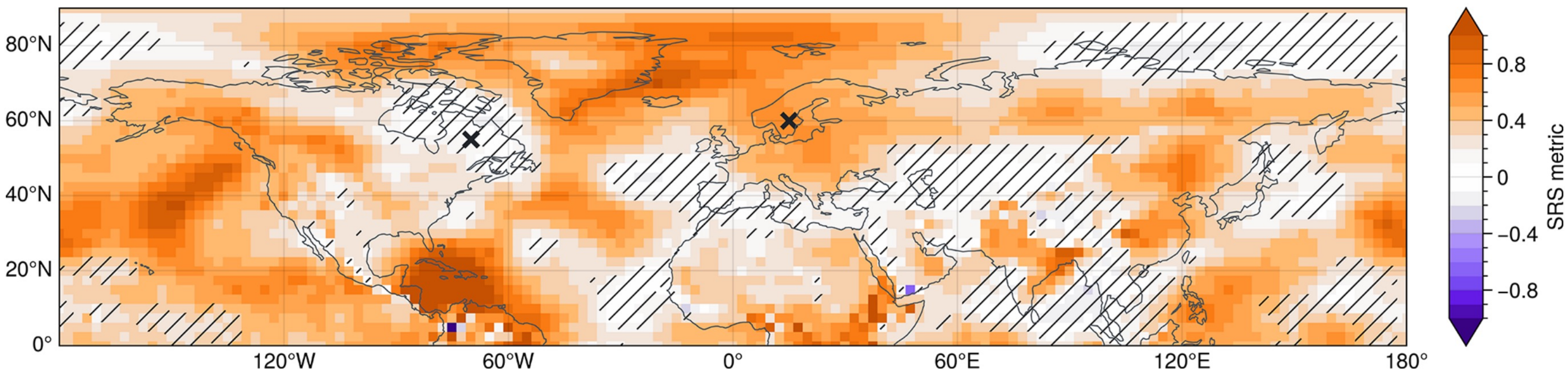
Reliability: to what extent do variations in ensemble spread represent variations in forecast error? Obtain slope of linear fit of spread-error relation = SRS, illustrated below for example grid point in northern Europe (60°N, 15°E).

SRS = 1: ideal slope → reliable quantification of uncertainty variations
SRS ≈ 0: unreliable spread-error relation
(spread variations dominated by sampling)



Sampling noise in small ensembles flattens spread-reliability slope (SRS). Strong physical variability between forecast cases helps distinguish genuine uncertainty changes from that noise.

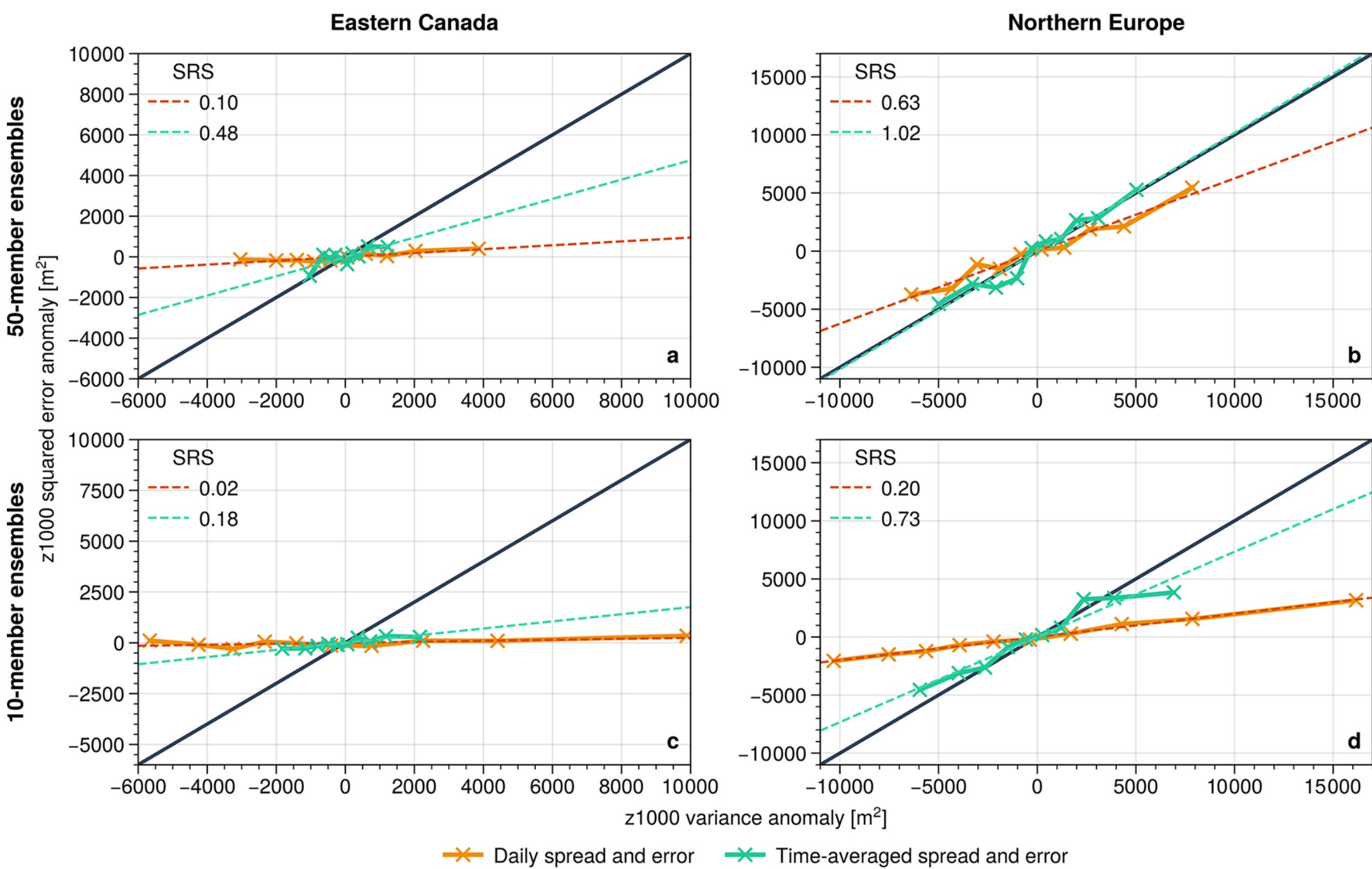
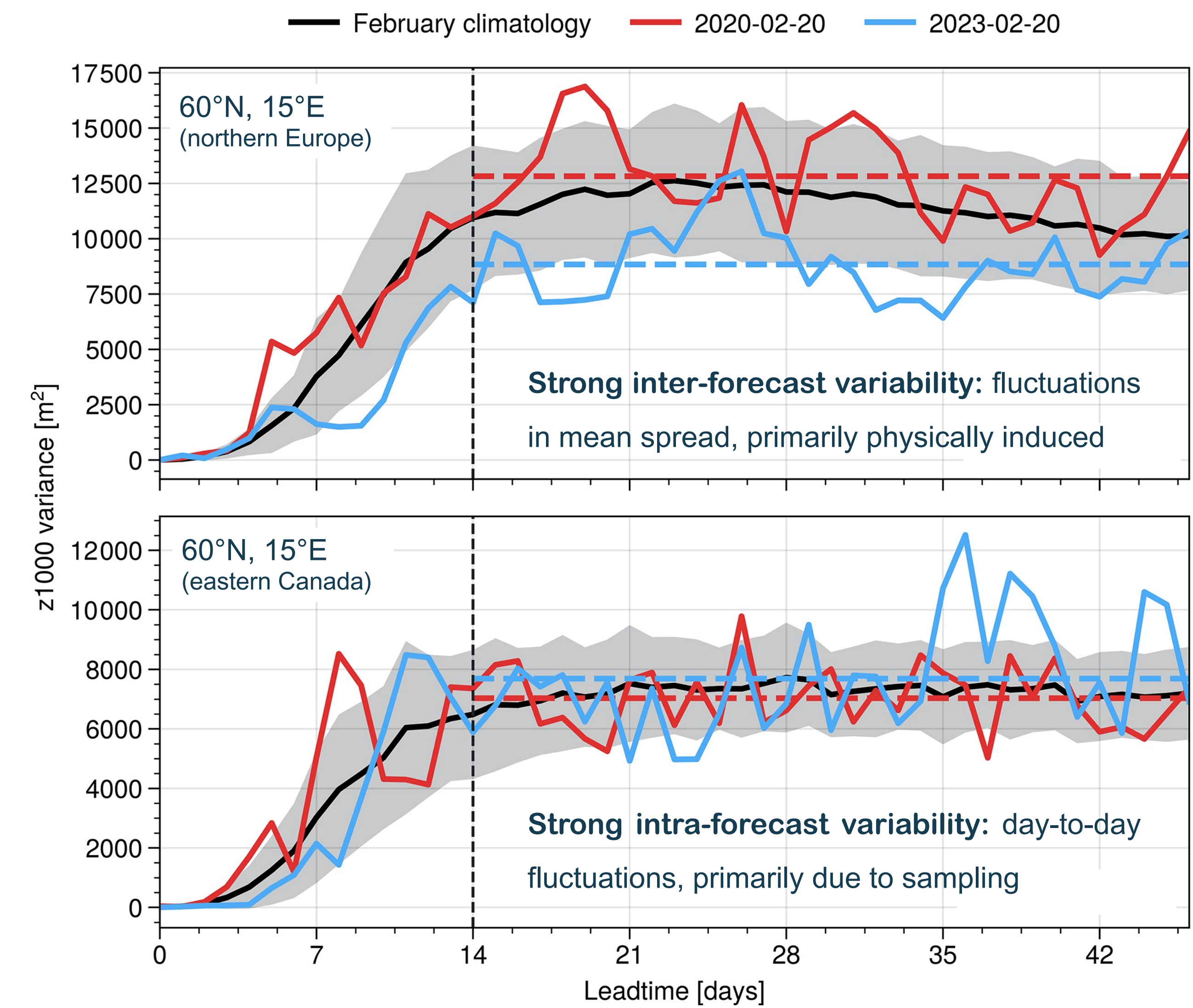
2 Where are spread-error relations reliable?



SRS for 50-member ensembles. Hatching: slope not significantly different from zero at 99% confidence. Qualitatively similar morphology for 100-member ensemble.

3 Physical variability versus sampling variability

4 Leveraging daily sampling to improve reliability



→ temporal averaging of intra-forecast variability improves SRS, even in 10-member ensembles

→ reliability (SRS close to 1) requires high inter-over-intra variability ratio