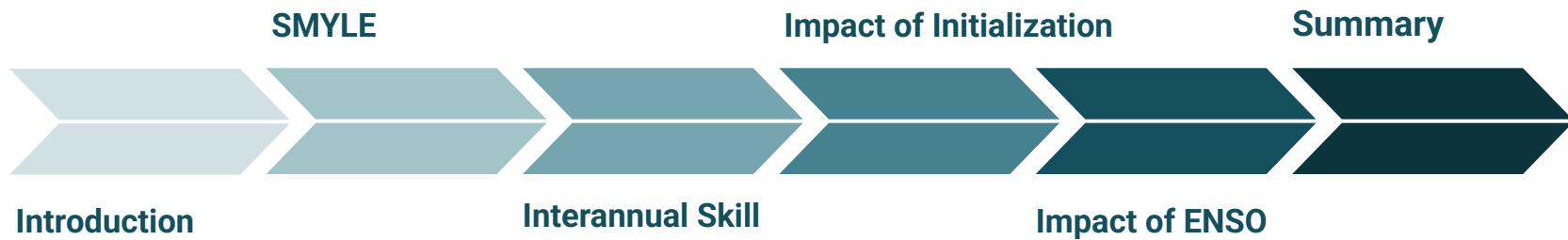


Predictability of Temperature Extremes in Multi-Annual Forecasts

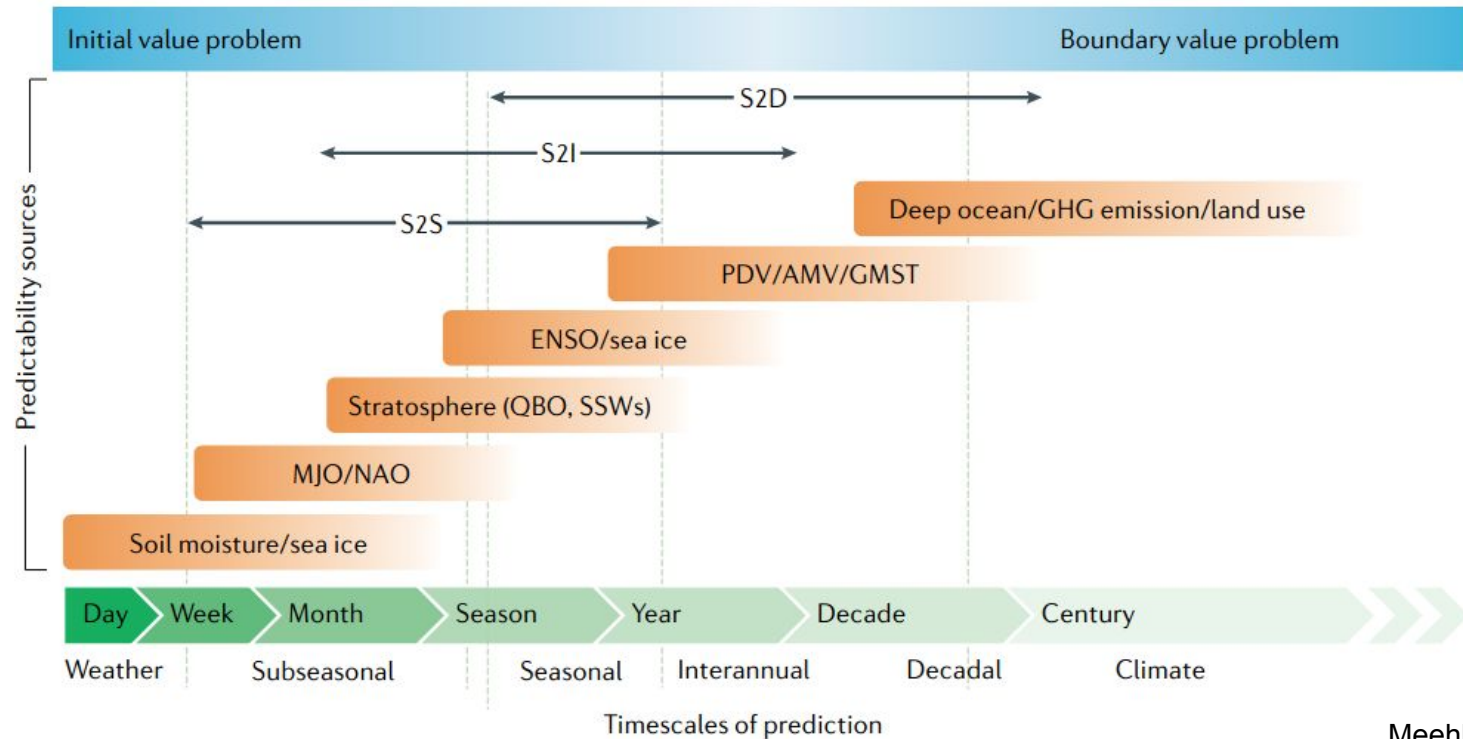
Eirini Tsartsali, Stephen Yeager, Panos Athanasiadis,
Silvio Gualdi, Stefano Tibaldi



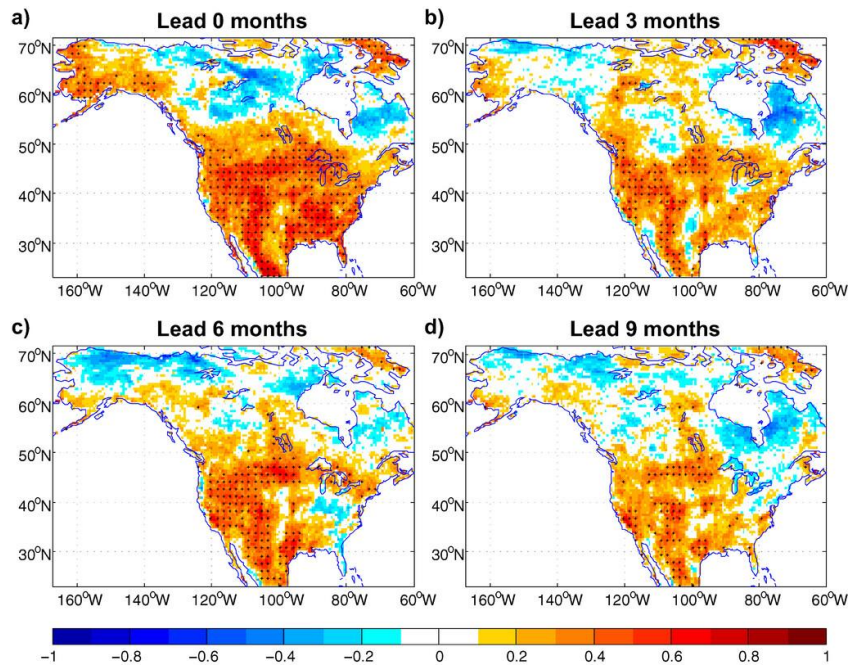
Outline



Timescales of Predictions

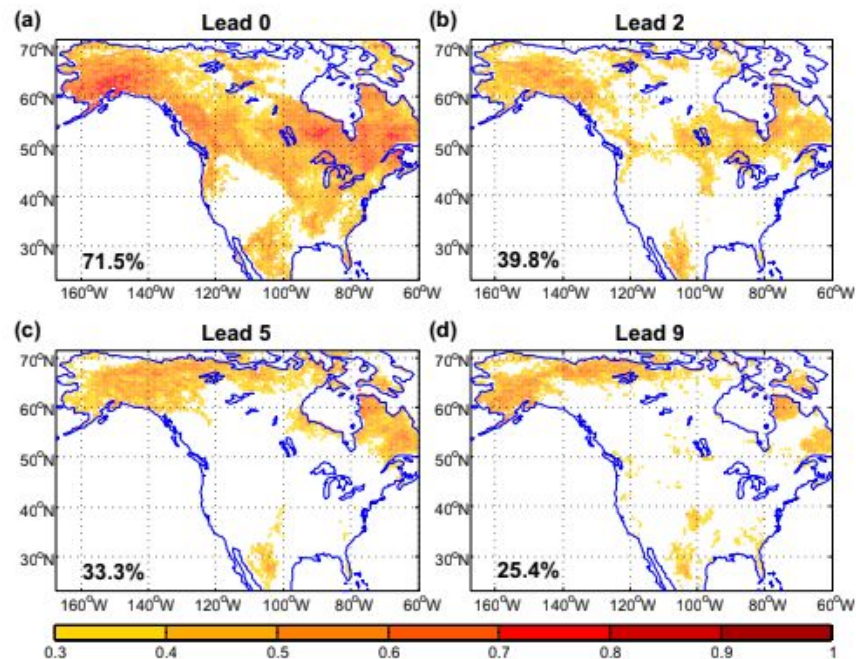


Heat extremes skill in GFDL SPEAR



Jia et al., 2022

Cold extremes skill in GFDL SPEAR



Jia et al., 2023

Seasonal-to-Multiyear Large Ensemble (SMYLE)

CESM2-SMYLE

- Components:
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- 20-member

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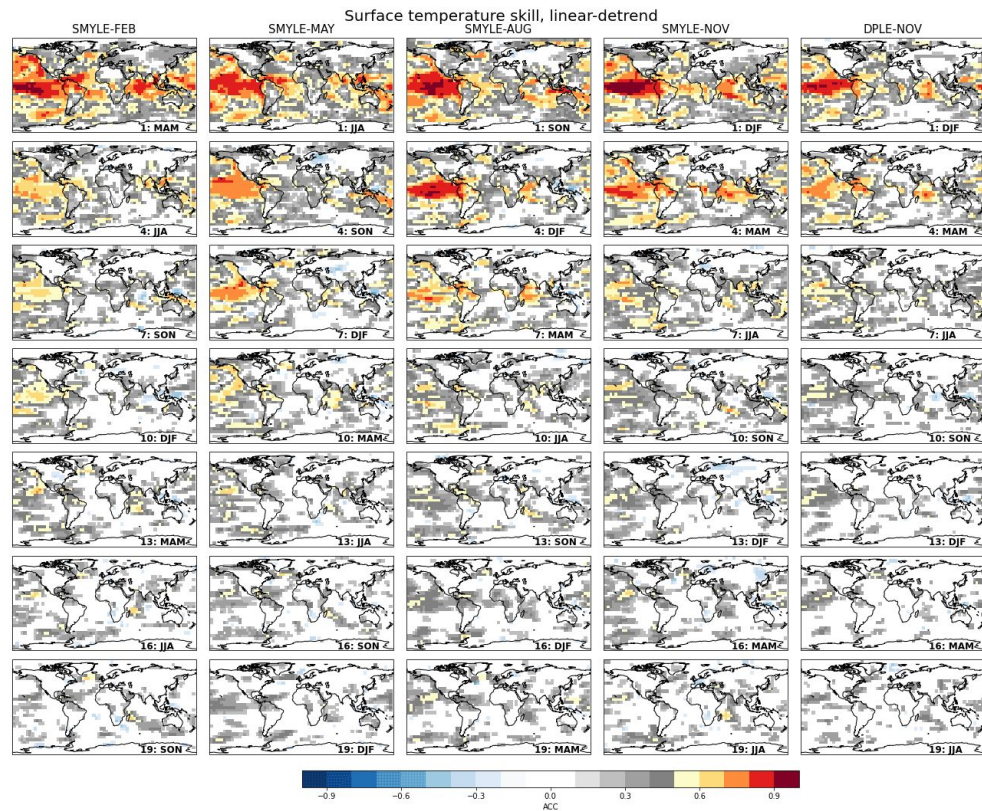
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Define Temperature Extremes

An episode of 3 or more consecutive days when the **maximum** (**minimum**) temperature anomaly is **exceeding** (**subceeding**) the **90th** (**10th**) percentile.

Reference period: 1972-2019

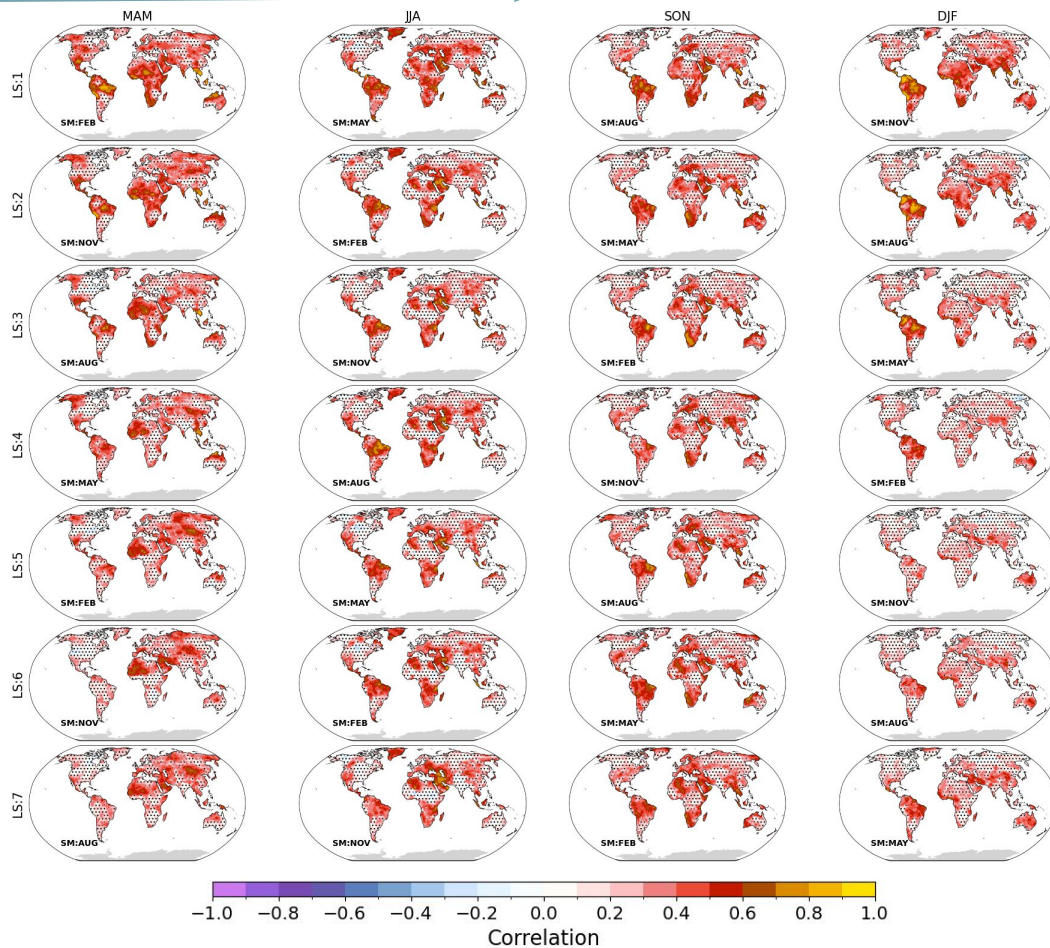
Metric: Number of days in episodes

Focus on Warm Extremes

Anomaly Correlation Coefficient (ACC)

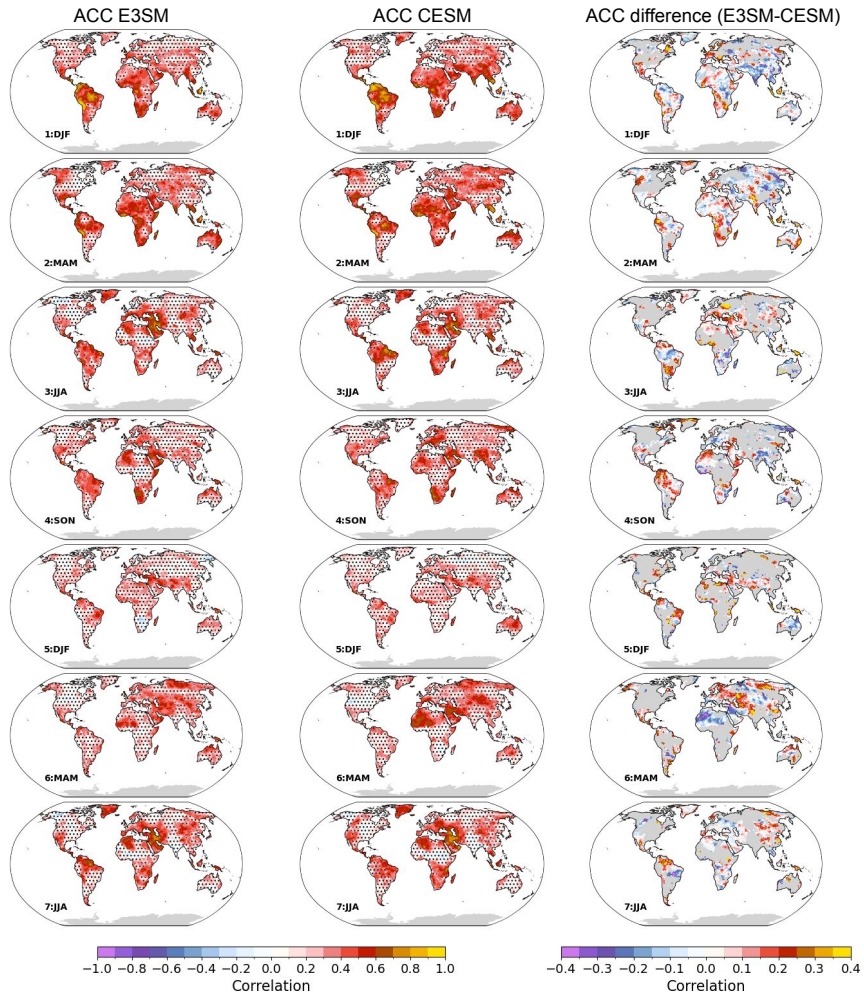
Target Forecasted Month

Lead Season



Verification Dataset:
Berkeley Earth Surface Temperatures
(BEST)
Verification Period: 1970–2021

Model Intercomparison



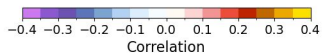
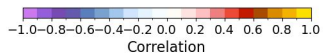
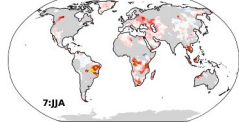
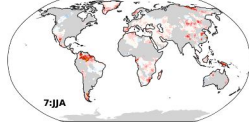
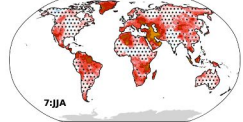
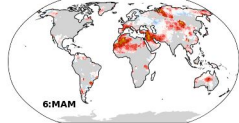
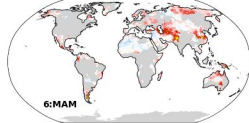
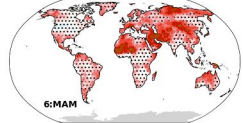
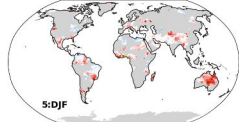
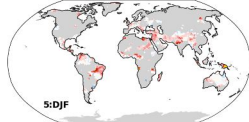
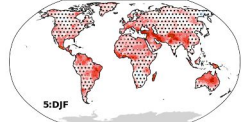
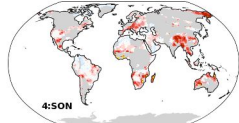
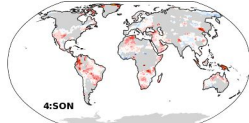
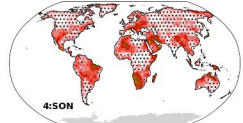
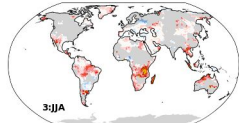
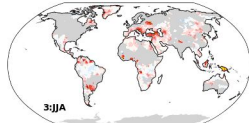
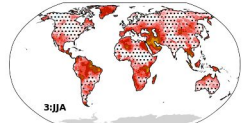
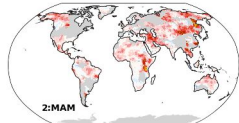
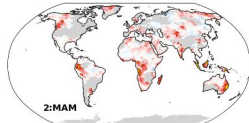
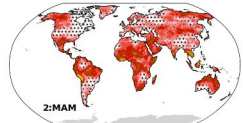
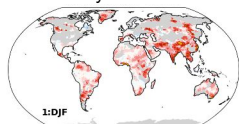
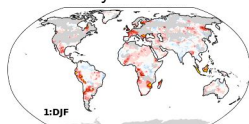
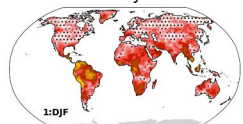
Multi-System Skill

ACC Difference

Multi-System

Multi-System-CESM

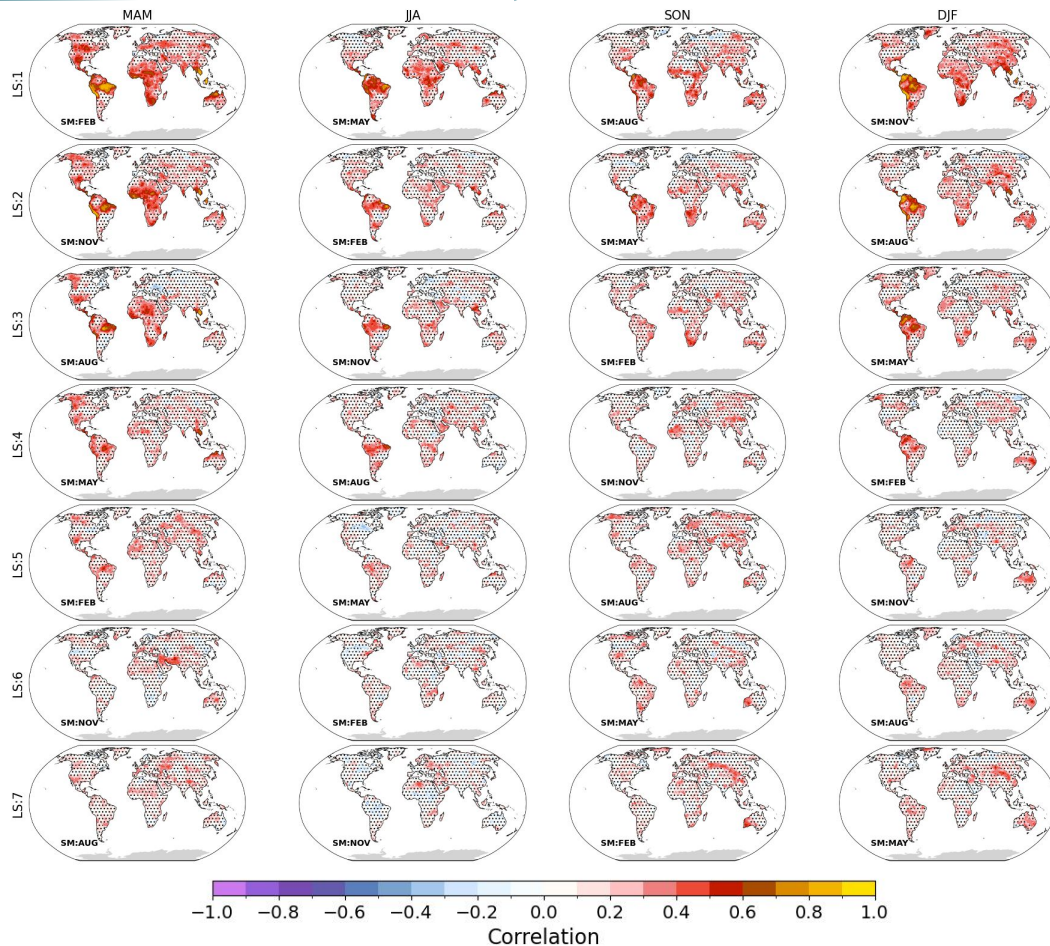
Multi-System-E3SM



Impact of Initialization

Target Forecasted Month

Lead Season



Residuals ACC (Smith et al., 2019):
Regress out the ensemble mean of the uninitialized simulations from both the hindcasts and the verification dataset and recompute the ACC.

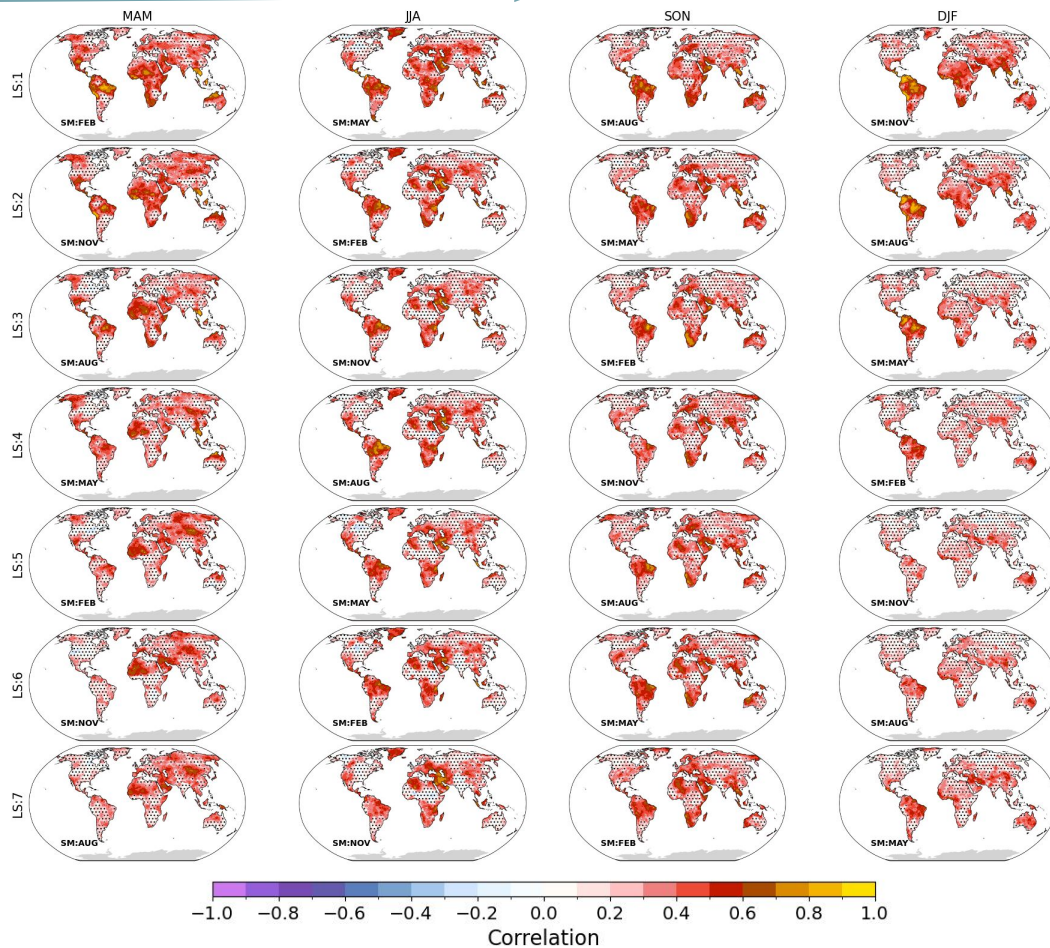
Uninitialized Simulations:
CESM2 Large Ensemble (CESM2-LE)
50 members

Verification Dataset:
Berkeley Earth Surface Temperatures (BEST)
Verification Period: 1970–2021

Anomaly Correlation Coefficient (ACC)

Target Forecasted Month

Lead Season

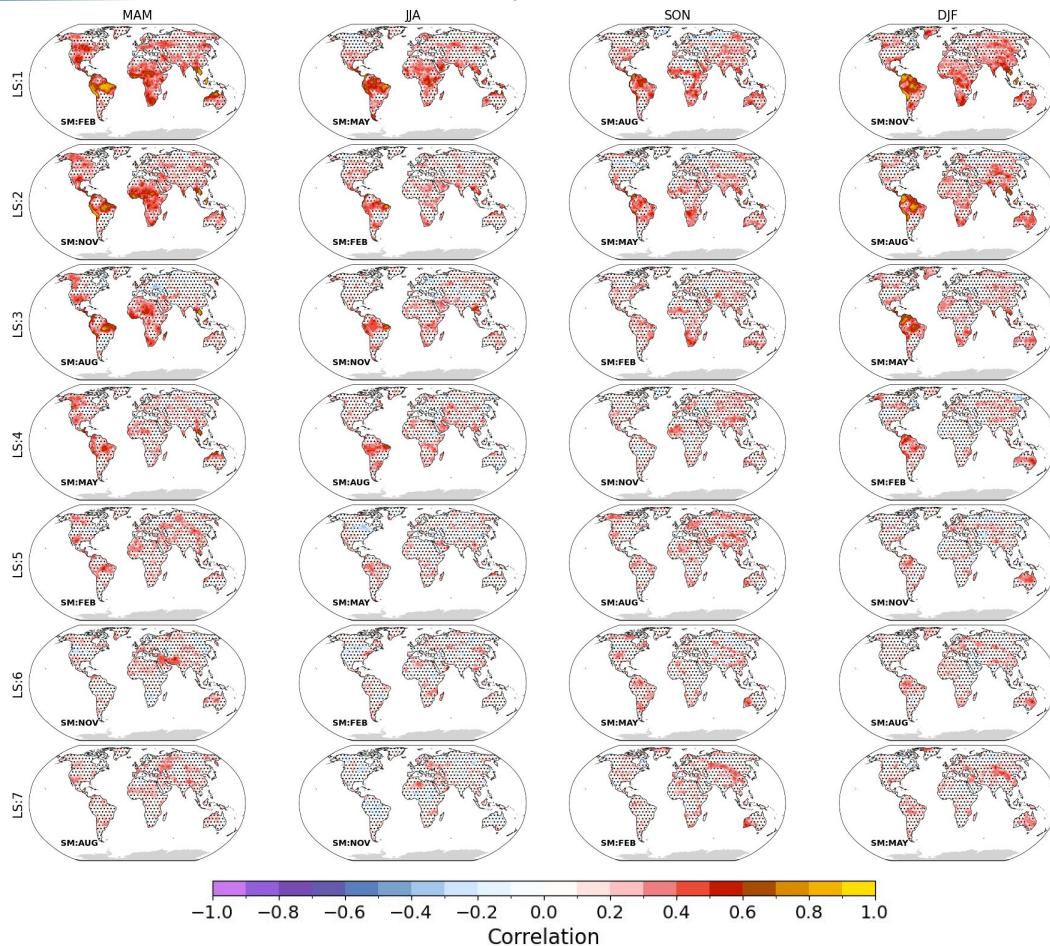


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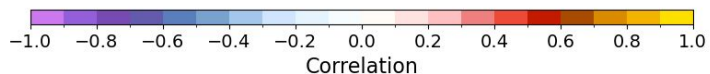
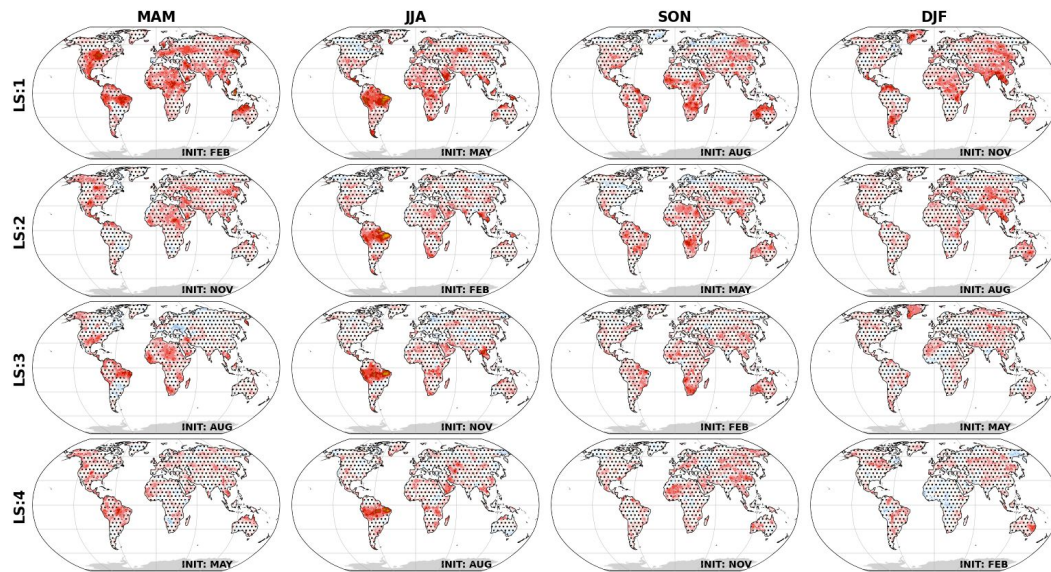
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Is this ENSO-related skill?

Target Forecasted Month →

Lead Season ↓



Skill (ACC) after removing also the ENSO signal:

the ensemble mean NINO3.4 signal has been regressed out from the residual variability using a linear or logistic function.

Verification Dataset:

Berkeley Earth Surface Temperatures (BEST)

Verification Period: 1970–2021

- High skill for the number of days belonging to episodes is found until forecast season 7, decreasing with lead time.
- The two systems exhibit similar skill (mapping and dependence on forecast time).
- The multi-system predictions generally outperform each individual system.
- For some regions and calendar seasons significant added skill from initialization is found up to forecast season 4.
- Most of the remaining skill is found to stem from ENSO.

References

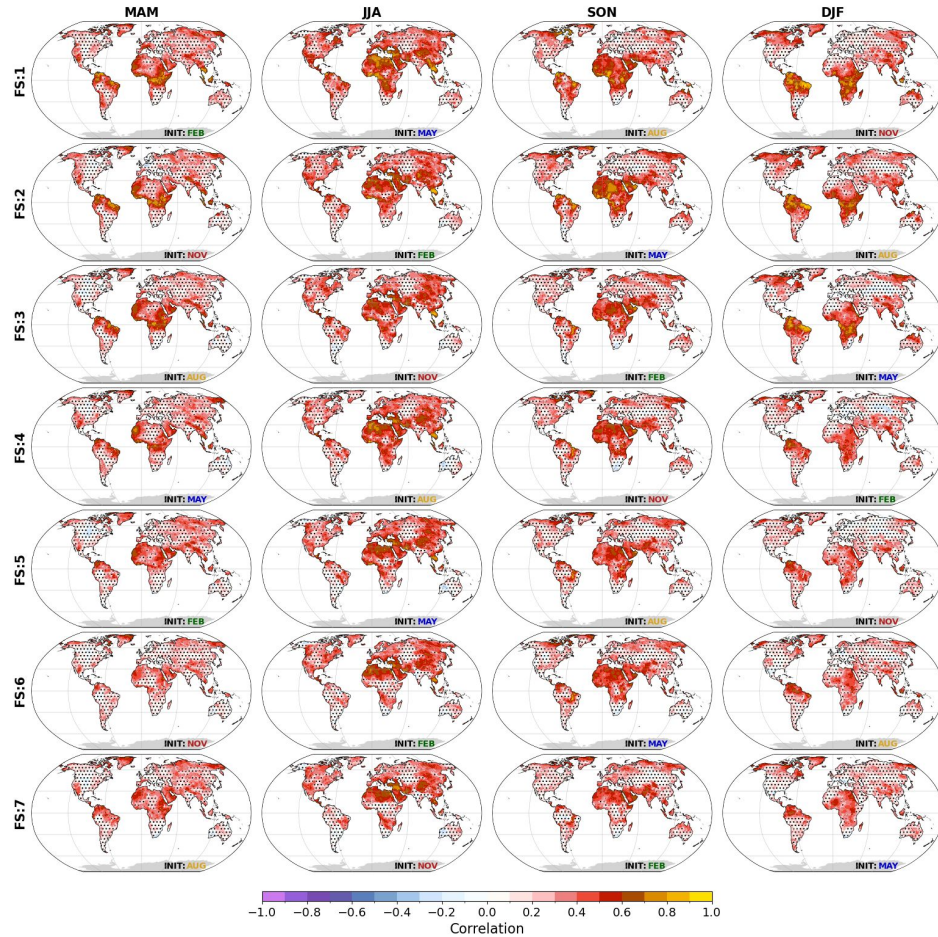
- Jia, L., Delworth, T. L., Kapnick, S., Yang, X., Johnson, N. C., Cooke, W., Lu, F., Harrison, M., Rosati, A., Zeng, F. et al. (2022). Skillful seasonal prediction of north american summertime heat extremes, *Journal of Climate* 35(13): 4331–4345.
- Jia, L., Delworth, T. L., Yang, X., Cooke, W., Johnson, N. C., McHugh, C. and Lu, F. (2023). Seasonal prediction of north american wintertime cold extremes in the gfdl spear forecast system, *Climate Dynamics* 61(3): 1769–1781.
- Meehl, G. A., Richter, J. H., Teng, H., Capotondi, A., Cobb, K., Doblas-Reyes, F., Donat, M. G., England, M. H., Fyfe, J. C., Han, W. et al. (2021). Initialized earth system prediction from subseasonal to decadal timescales, *Nature Reviews Earth & Environment* 2(5): 340–357.
- Smith, D., Eade, R., Scaife, A., Caron, L.-P., Danabasoglu, G., DelSole, T., Delworth, T., Doblas-Reyes, F., Dunstone, N., Hermanson, L. et al. (2019). Robust skill of decadal climate predictions, *Npj Climate and Atmospheric Science* 2(1): 13.
- Yeager, S. G., Rosenbloom, N., Glanville, A. A., Wu, X., Simpson, I., Li, H., Molina, M. J., Krumhardt, K., Mogen, S., Lindsay, K., Lombardozzi, D., Wieder, W., Kim, W. M., Richter, J. H., Long, M., Danabasoglu, G., Bailey, D., Holland, M., Lovenduski, N., Strand, W. G. and King, T. (2022). The seasonal-to-multiyear large ensemble (smyle) prediction system using the community earth system model version 2, *Geoscientific Model Development* 15(16): 6451–6493.

Thank you for your attention!

Anomaly Correlation Coefficient (ACC)

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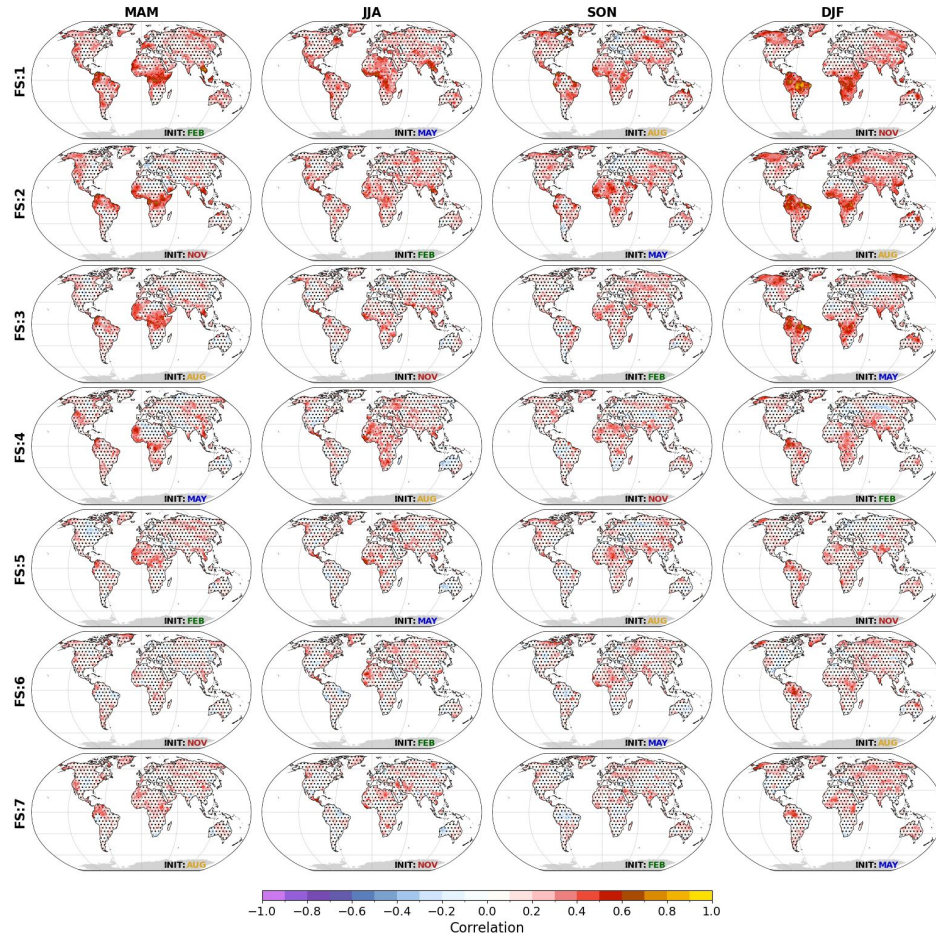
Lead Season



Impact of Initialization

Target Forecasted Month

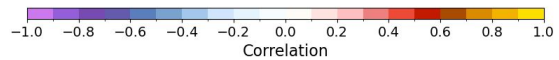
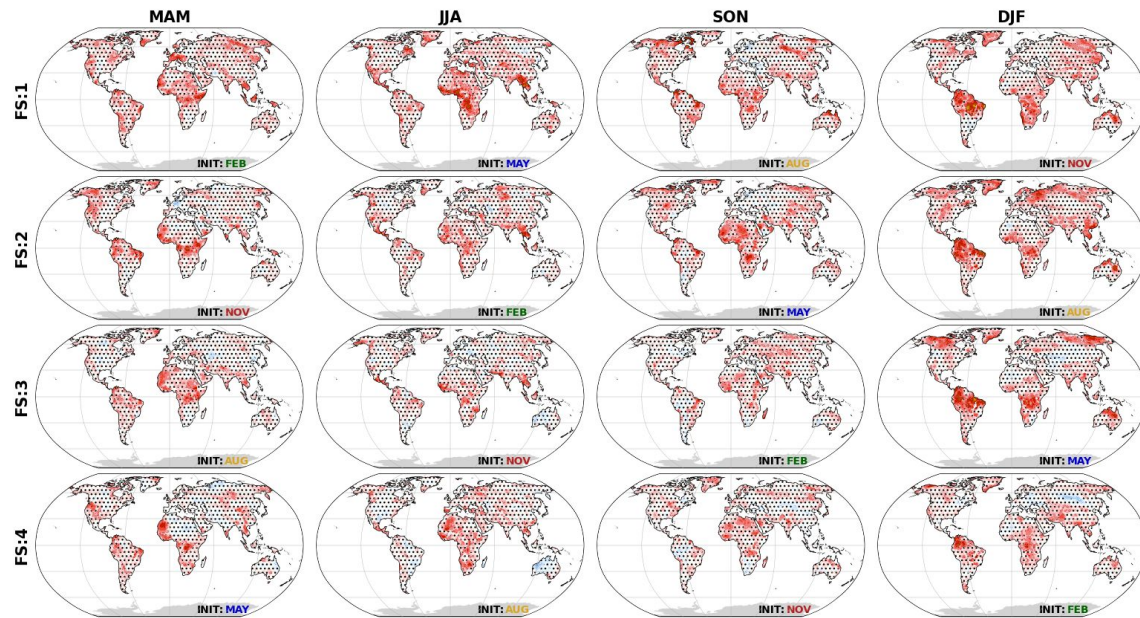
Lead Season



Impact of ENSO

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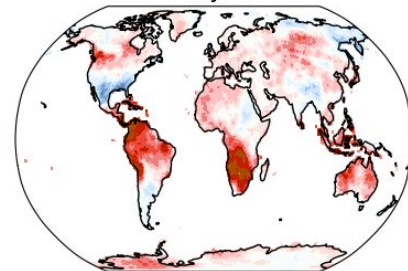
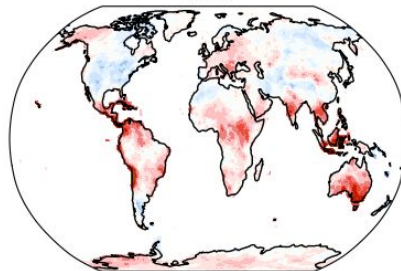
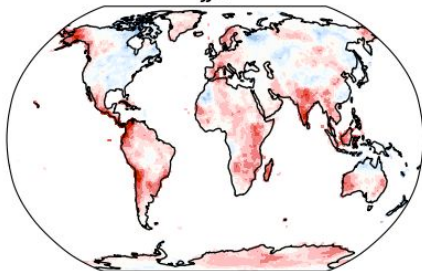
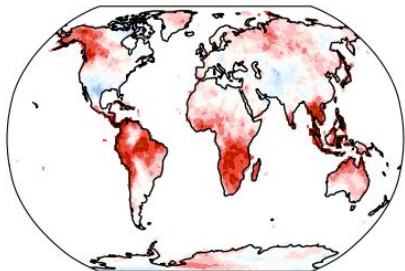
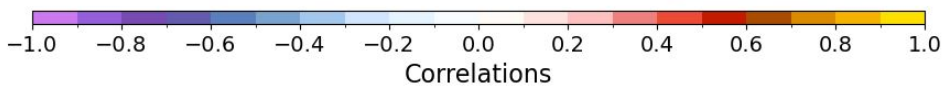
NINO3.4 - Days in Episodes Correlation

MAM

JJA

SON

DJF



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