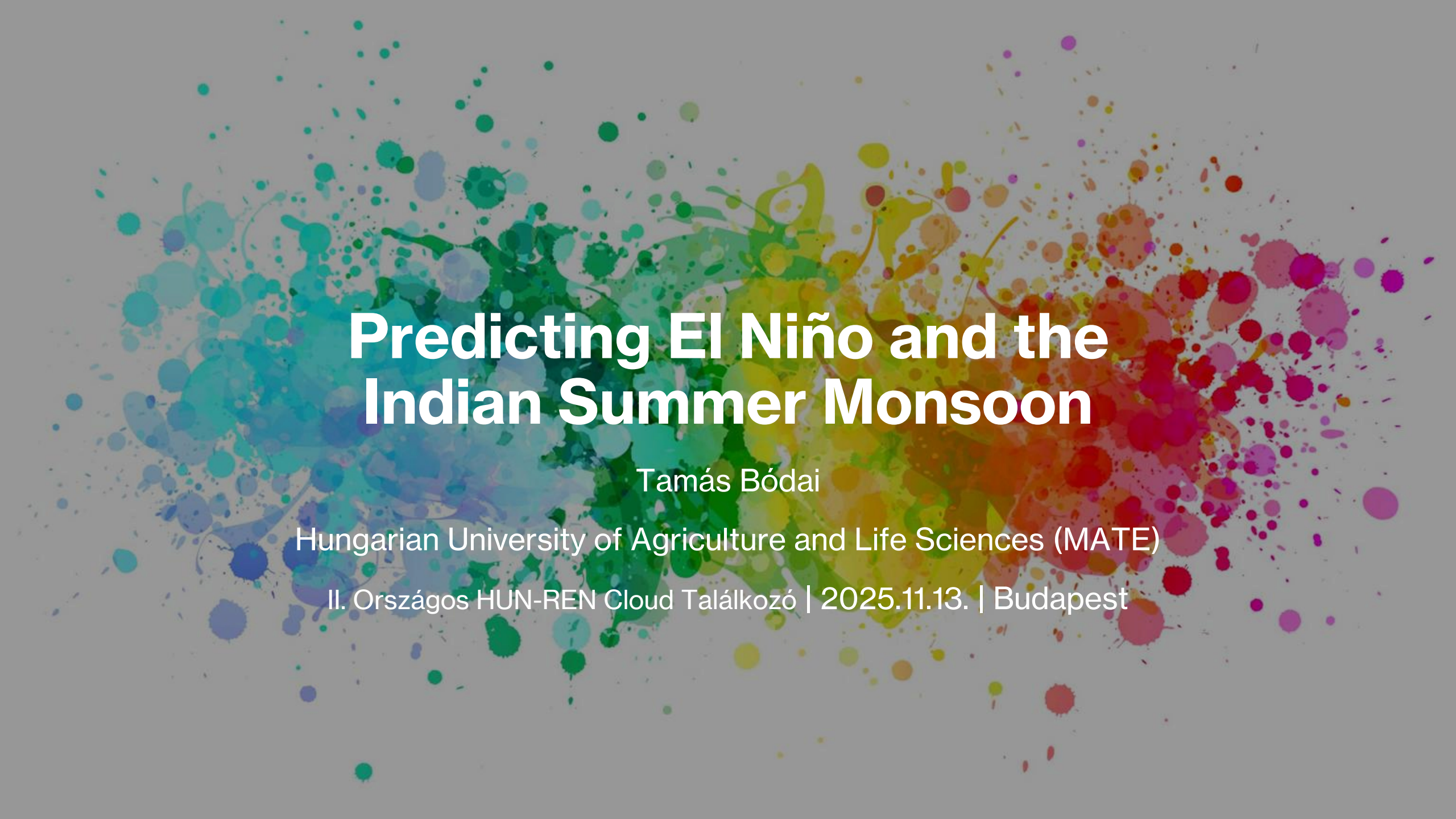




Predicting El Niño and the Indian Summer Monsoon

Tamás Bódai

Hungarian University of Agriculture and Life Sciences (MATE)

II. Országos HUN-REN Cloud Találkozó | 2025.11.13. | Budapest

Acknowledgement

My visit at the **Bjerknes Centre for Climate Research**, Bergen, Norway was funded by a research mobility stipend of the *Hungarian University of Agriculture and Life Sciences* (MATE) in the framework of the **Pannónia Scholarship** programme. I was also supported by the University's **Research Excellence Programme** (KKP).



BIG THANKS, MATE!

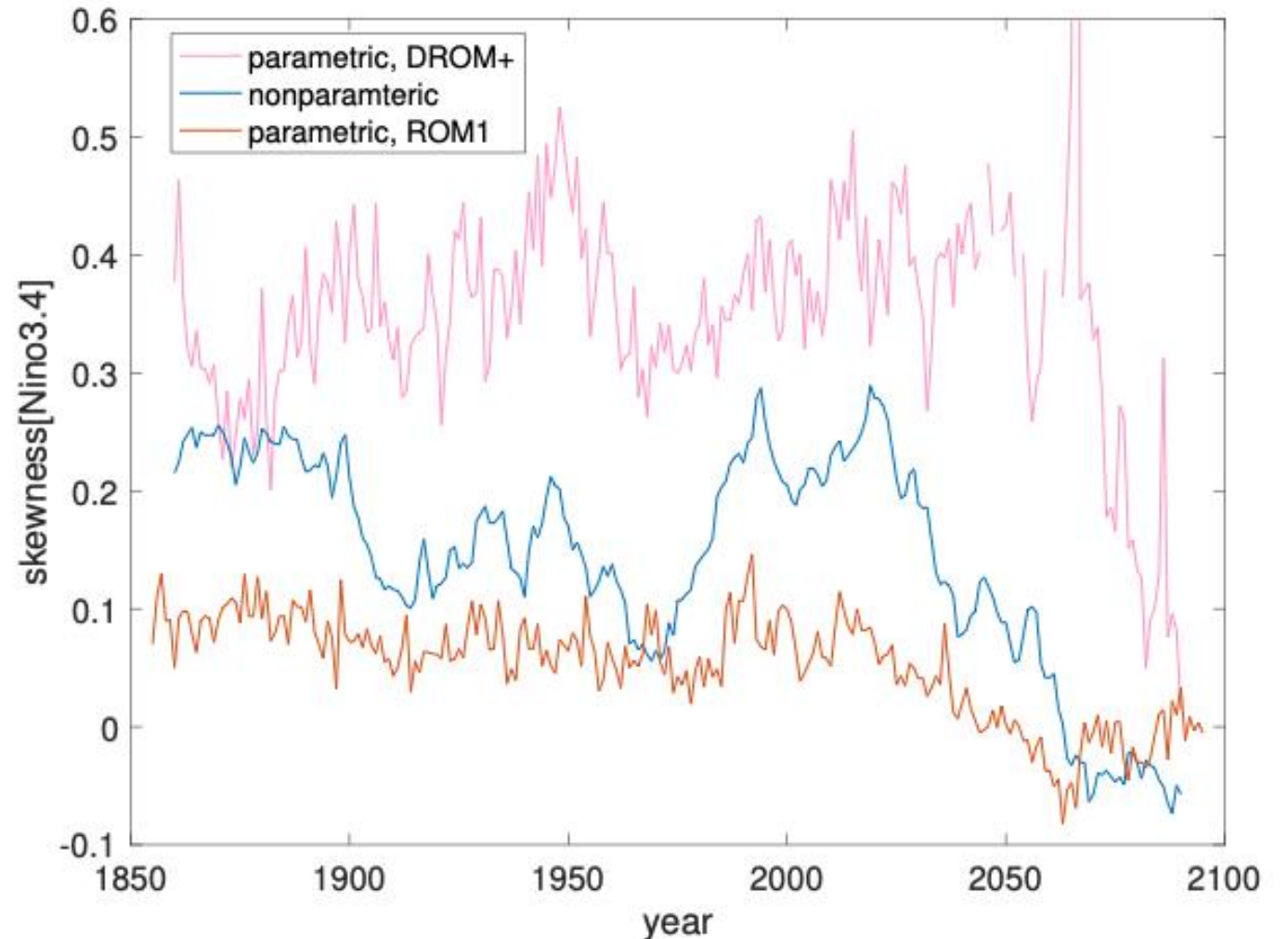
Motivation: a study of the **forced change** of ENSO skewness (asymmetry)

Model: CESMv2

Initial condition Large
Ensemble data: CESM2-LE
(Rodgers et al. ESD 2021)

ROM1 underestimates
CESM2 skewness

CESM2 underrepresents true
ENSO skewness



Recharge Oscillation Models (ROMs)

ROM1

$$\frac{dT}{dt} = (a_{1,TT} + A \cos(\Omega t - \Phi))T + a_{1,Th}h + a_{2,TT}T^2 + \sqrt{2D_T}(1 + bT)\xi_T, \quad (1a)$$

$$\frac{dh}{dt} = a_{1,hT}T + a_{1,hh}h + \sqrt{2D_h}\xi_h, \quad (1b)$$

DROM+ ($i = 1, 2$) $d = 1, \dots, D$

$$\frac{dx_i}{dt} = a_i^j x_j + f_{il}(x_j, t; \hat{c}_i^l) + \sigma_i^\xi (1 + b_i x_i) \xi_i(t), \quad (2)$$

$$x_{i(n+1)} \approx \boxed{a_i^{jd} x_{j(n-d)}} + f_{il}(x_{jn}; c_i^l) + \sqrt{2D_i \Delta t} (1 + b_i x_{in}) \xi_{in}, \quad (3)$$

XROM ($i = 1, \dots, 10$) $\xi_i(t)$ are **red** noise ($d = 0$)

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Article | Published: 26 June 2024

Explainable El Niño predictability from climate mode interactions

[Sen Zhao](#), [Fei-Fei Jin](#) , [Malte F. Stuecker](#), [Philip R. Thompson](#), [Jong-Seong Kug](#), [Michael J. McPhaden](#),
[Mark A. Cane](#), [Andrew T. Wittenberg](#) & [Wenju Cai](#)

[Nature](#) **630**, 891–898 (2024) | [Cite this article](#)

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Standing on the shoulders of Goliath.

“Climate mode interaction” = Teleconnection

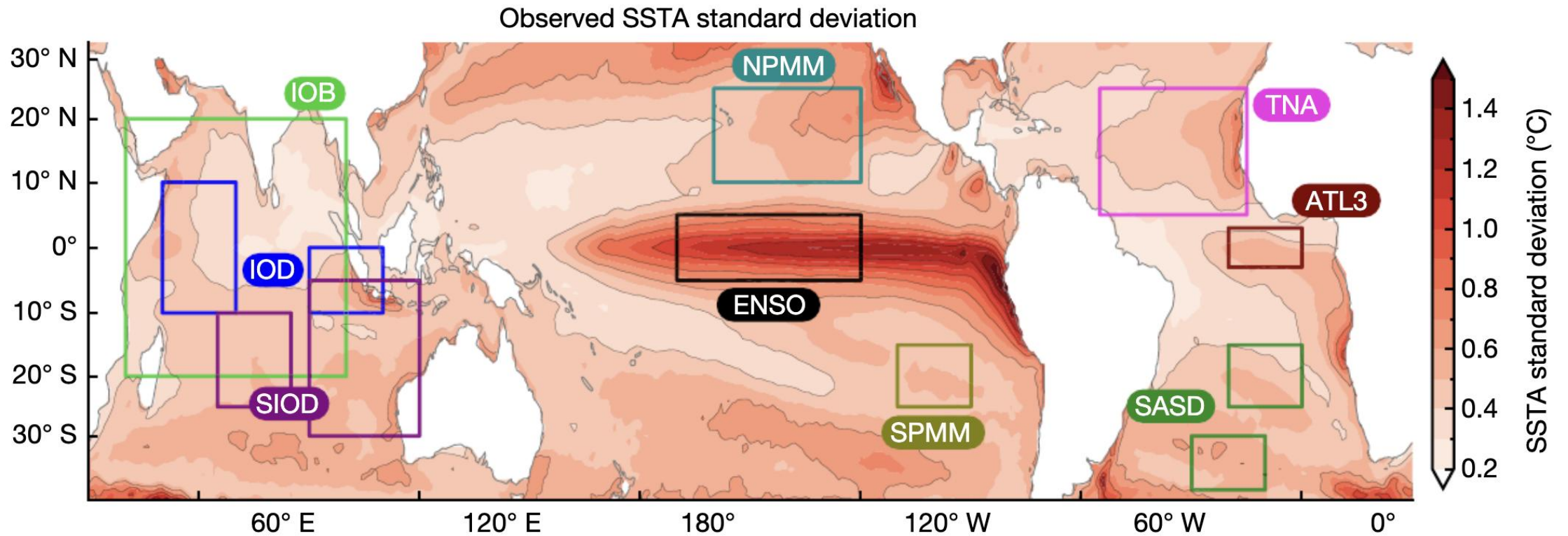


Fig. 1a of [\(Zhao et al. Nature 2024\)](#)

Zhao et al. (Nature 2024) vs Ham et al. (Nature 2019)

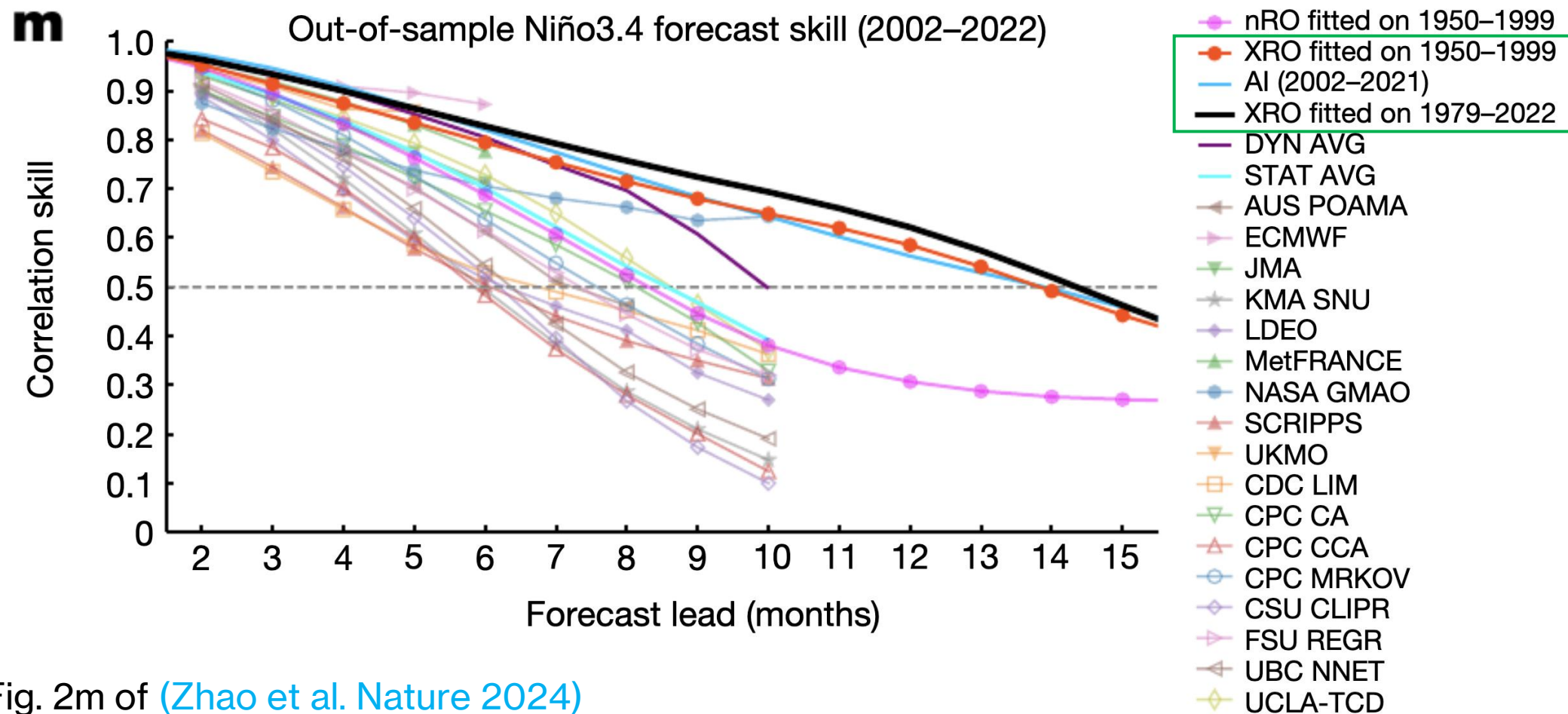


Fig. 2m of (Zhao et al. Nature 2024)

Article | [Open access](#) | Published: 22 July 2025

Enhanced El Niño predictability from climate mode interactions

[Tamás Bódai](#) 

[npj Climate and Atmospheric Science](#) **8**, Article number: 278 (2025) | [Cite this article](#)

781 Accesses | [Metrics](#)

Recap: Slight (3) changes XROM -> XDROM+

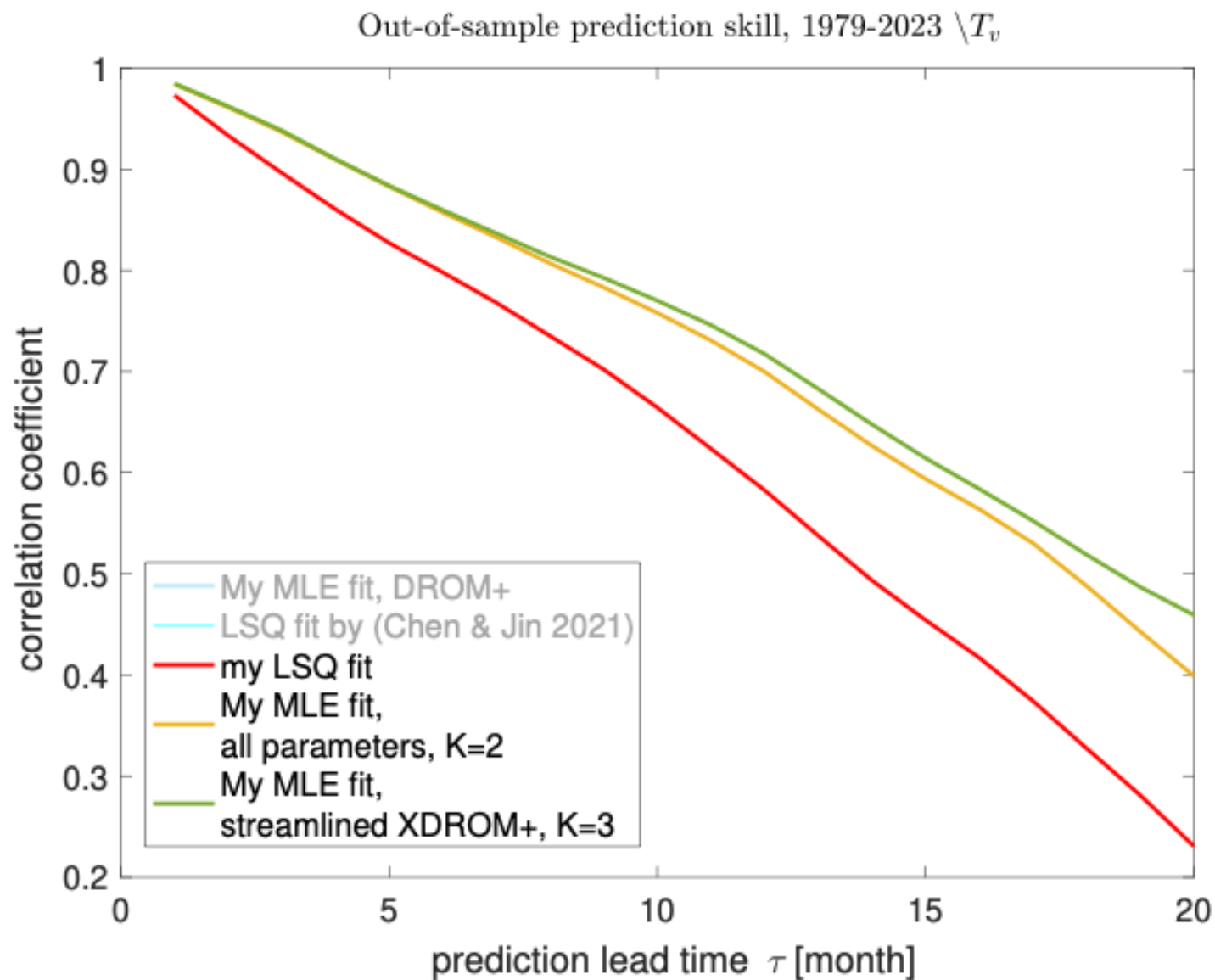
1. D: delay variables instead of red noise, to correctly represent [coarse-graining](#)
2. +: Add [state-dependence](#) for the noise in the first eq. ($i = 1$)
3. +: Add seasonal modulation of both the (a) additive noise magnitude and the (b) (multiplicative) state dependent noise magnitude.

Further coarse-graining: XDROM+ -> DROM+: $i = 1, \dots, l, l = 10 \rightarrow 2$

Wait! Can this improve [forecast skill](#) if we have a large enough (but not too large) memory, D ?

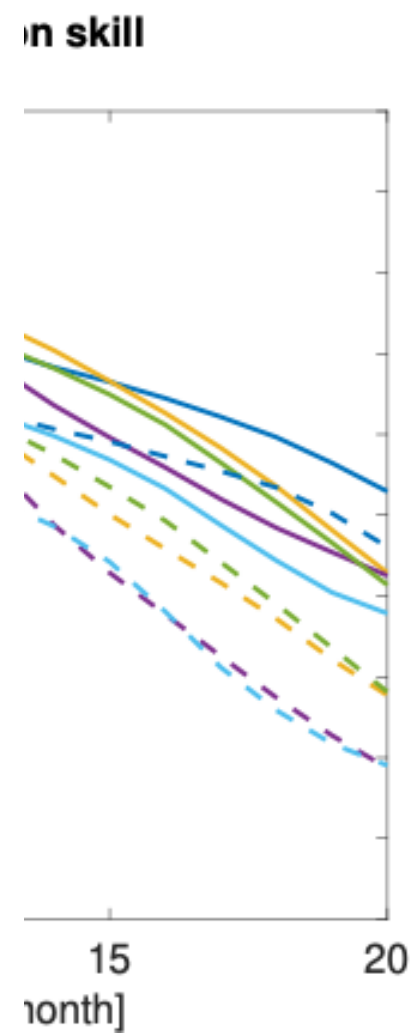
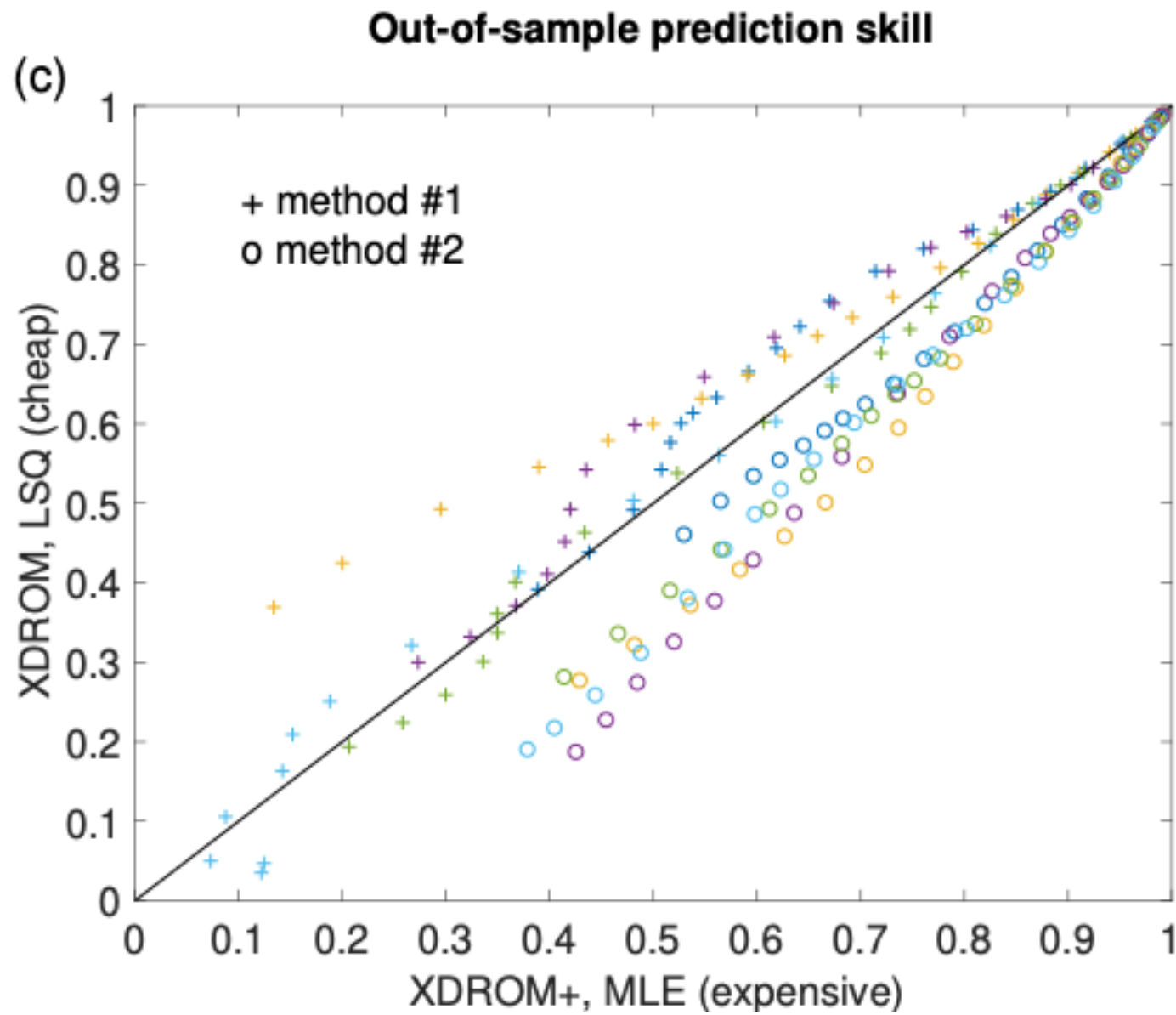
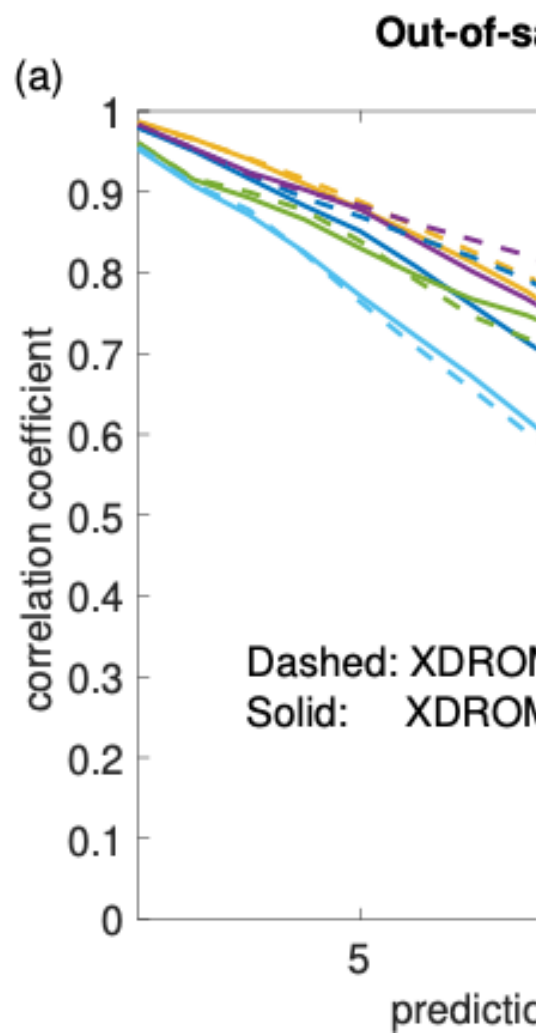


Oh!



The overfitting is
“BENIGN”. (Bartlett
et al. PNAS 2020)

Have no doubt!



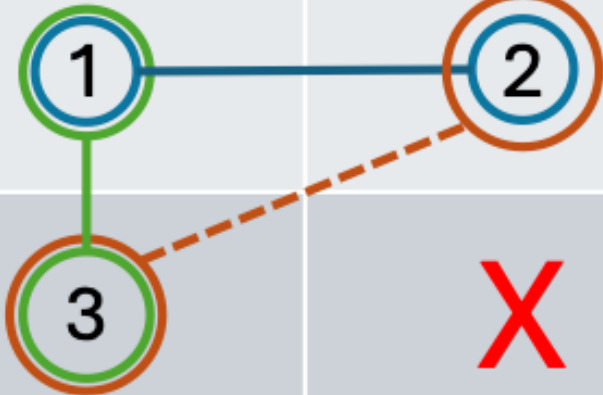
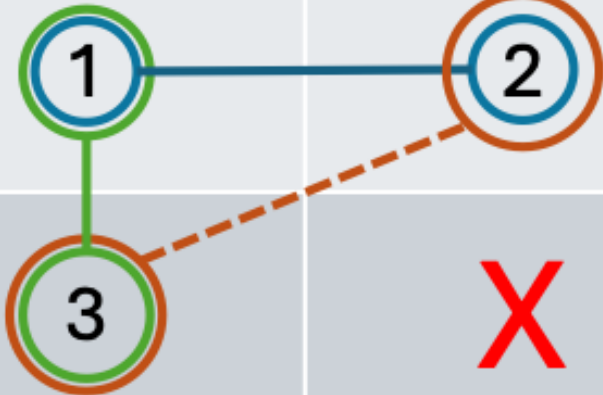
Incredibly Lucky!



**We DO have 46 years of
reliable satellite data!**



Rank of skills for (valid) scenarios

THREE Comparisons		Model	
		XDROM	XDROM+
Fitting method	MLE		
	LSQ		X

Altogether 3
comparisons of 2
scenarios wrt.

skill:

-- C1

– C2

– C3

- C3 implies: **MLE is better** than LSQ
- C2 implies: there is **no** ENSO noise state dependence
- Note: these two inferences can be made also by C1 & C2

ENSO MYTH

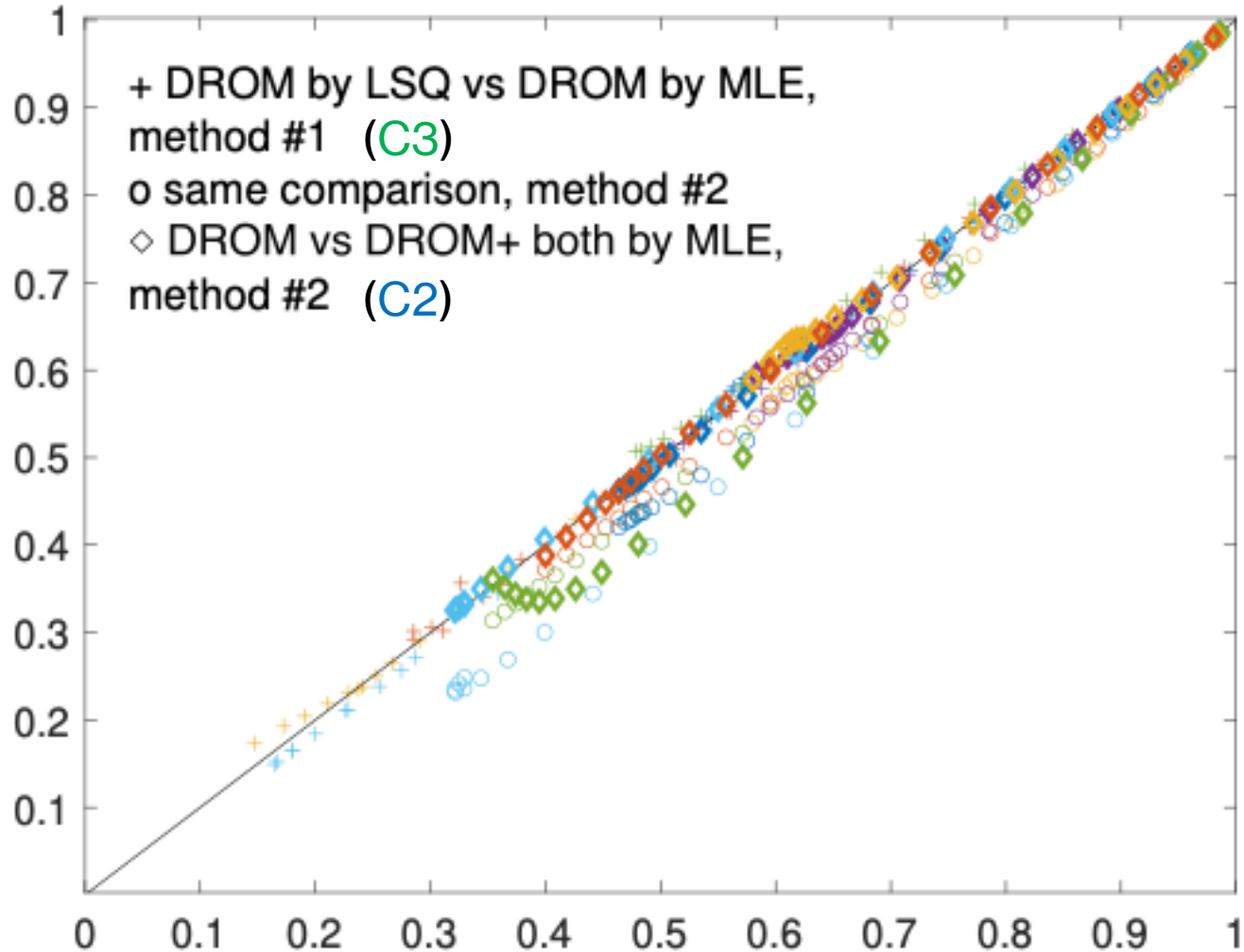
- C3 implies: **MLE is better** than LSQ
- C2 implies: there is **no** ENSO noise state dependence
- Note: these two inferences can be made also by C1 & C2

ENSO WITH
BUSINESS

Really? Wait! How about CGCMs?

Out-of-sample prediction skill

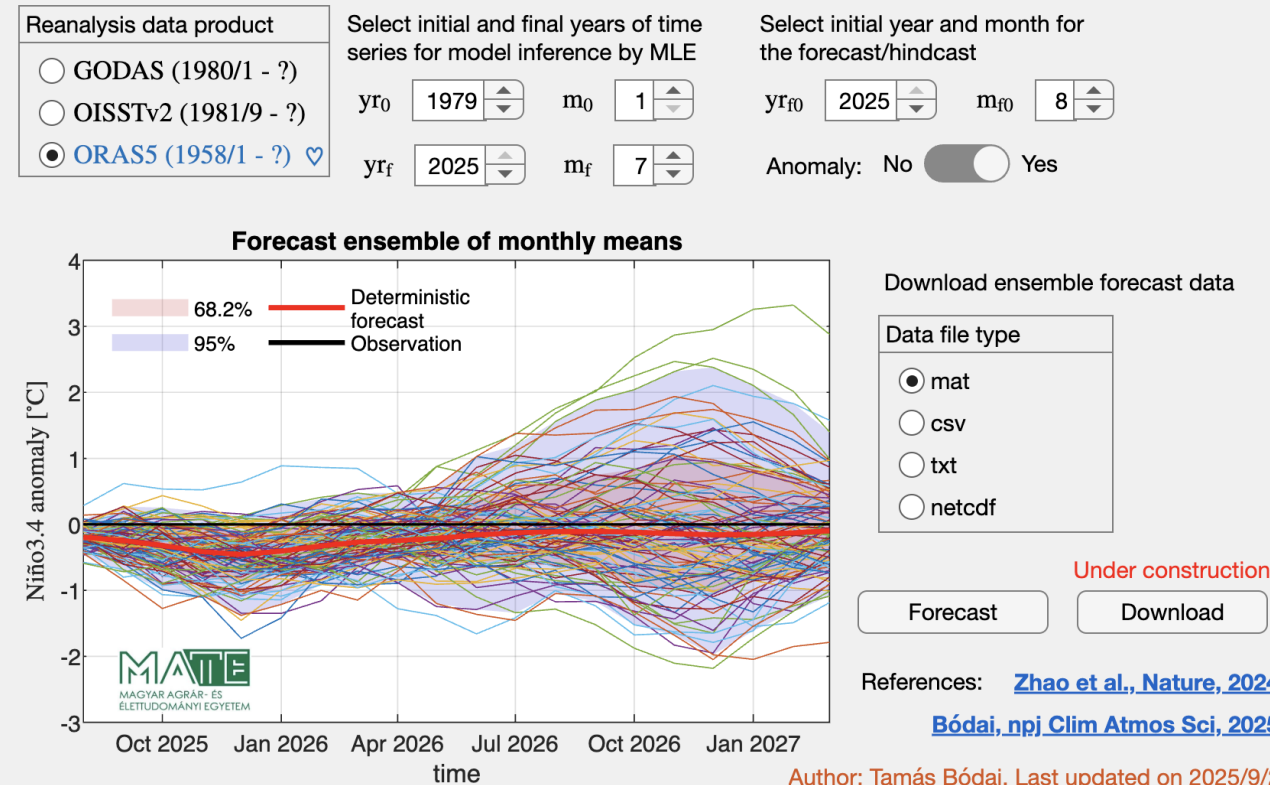
Using 6 member
of the CESM2-L



My operational ENSO forecast service

- A Matlab web app:
<http://bodaimatlab.zapto.org:9988/>
 - Susceptible to: power cuts; laziness; high demand (nahh! get over yourself!).
- Check out the service by Sen Zhao:
<https://senzhaonetlifyapp/climate/xro/>
 - (But only if mine is unavailable.)

Data-driven seasonal forecast for the Niño3.4 index based on the XDROM+ model



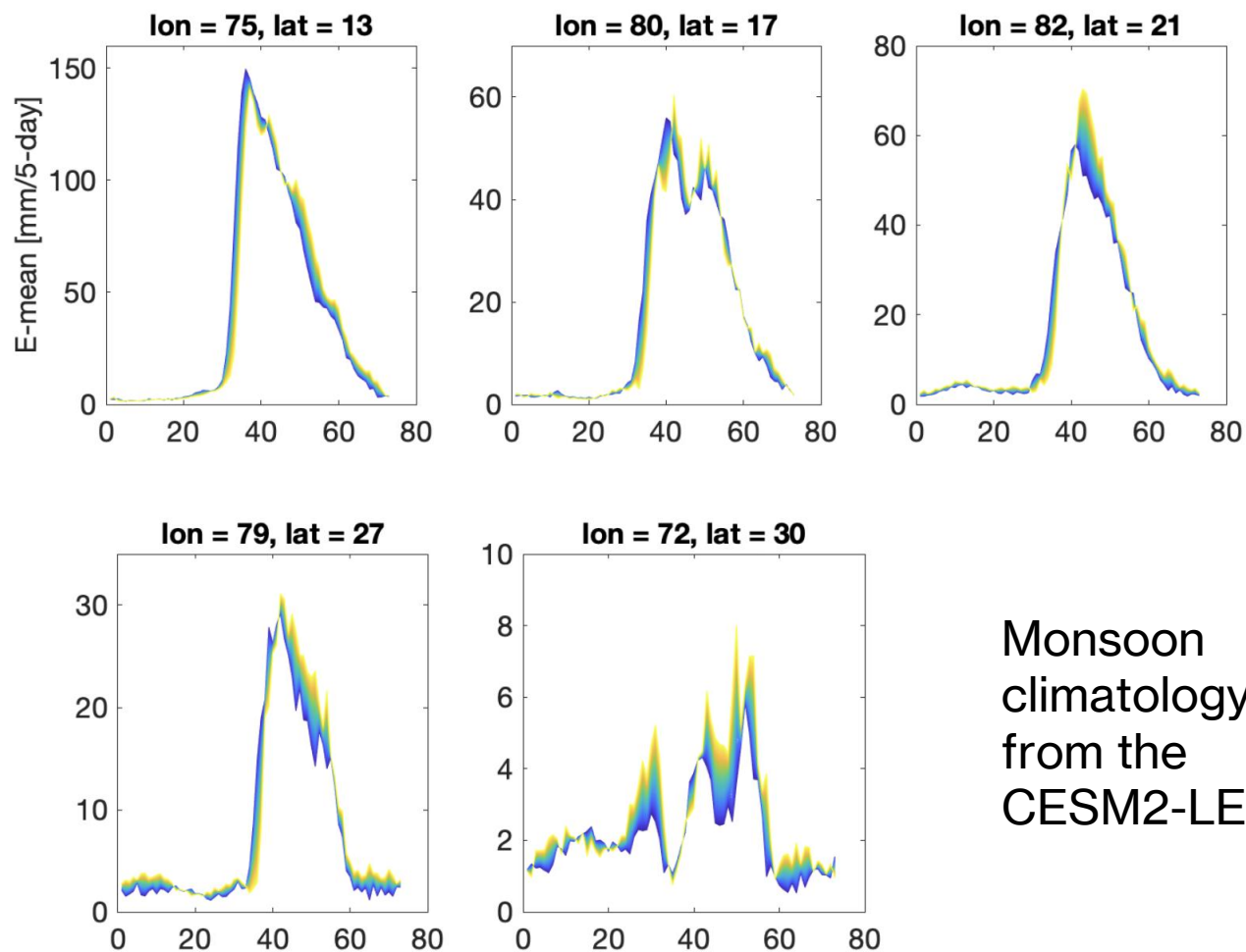
What I've been doing in Bergen

- Developing a forecast service for the [Indian summer monsoon](#).
 - Go regional / local!
- Forecasting monthly means, with a couple of months lead time.
- Backbone is the XDROM+.
 - I.e., it is a cheap skate data-driven forecast system, riding on the backs of expensive data acquisition missions, reanalysis products (CHIRPS, ORA5S).
 - We can have any seasonal / “extended range” forecast skill thanks only to the thermal inertia of the ocean.

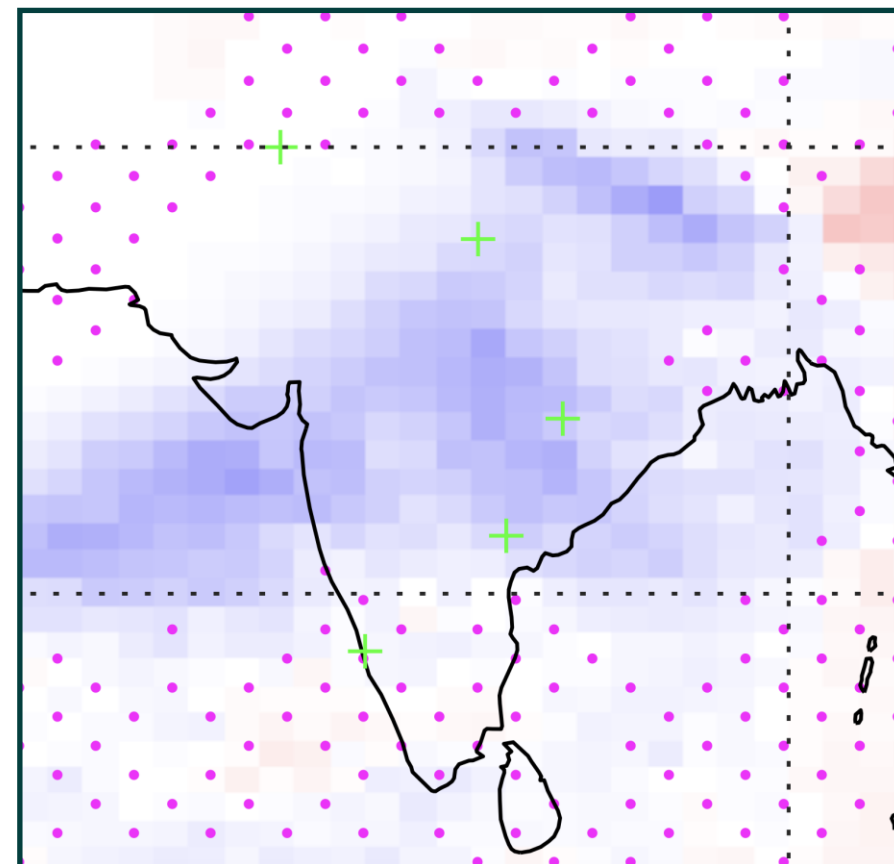


**Okay, but
can you show
us
something?**

Nice. Glad you had a good time! Any diagrams, though?

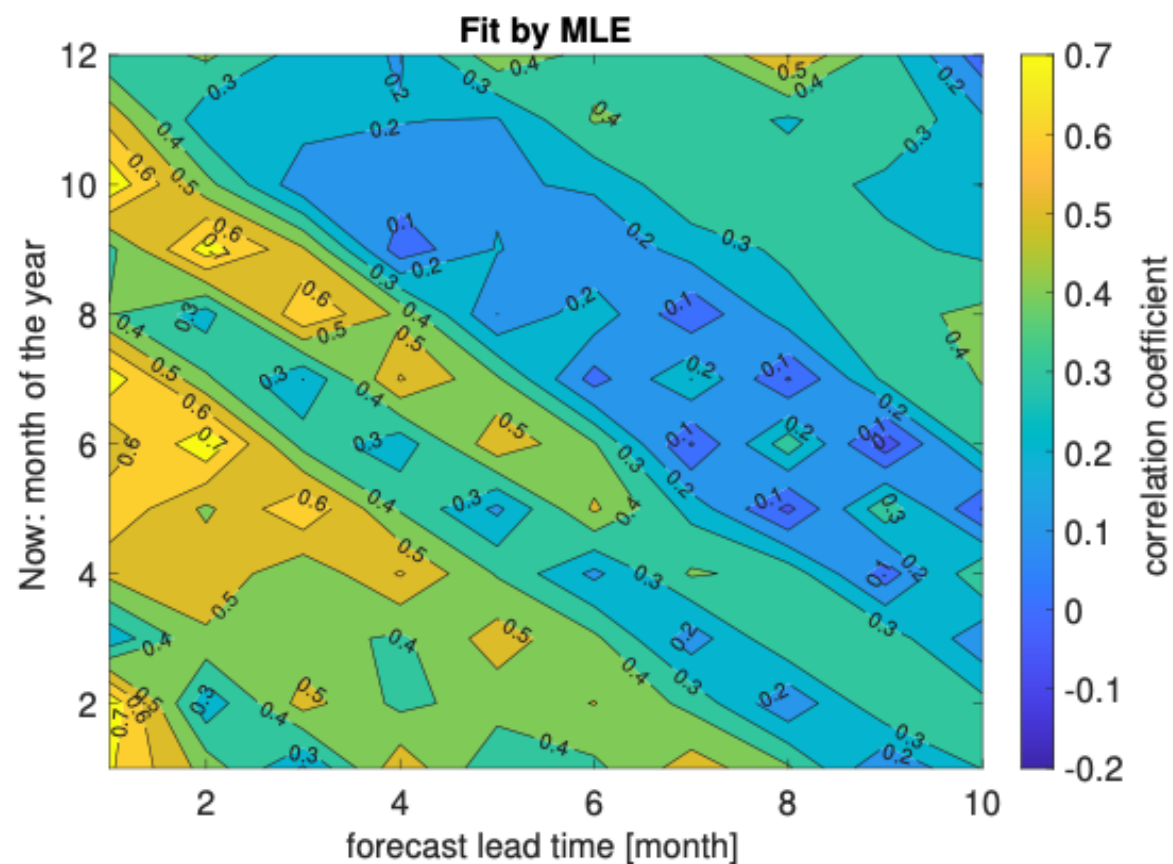
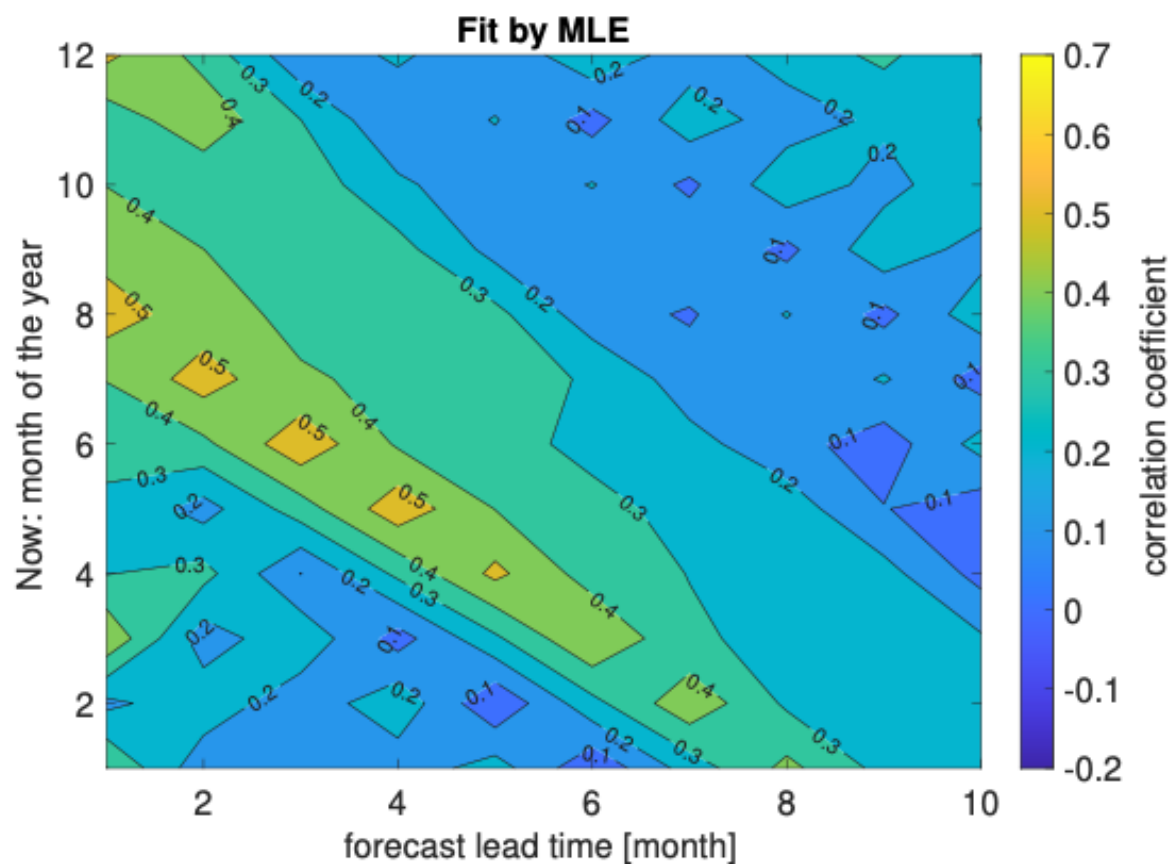


Monsoon
climatology
from the
CESM2-LE

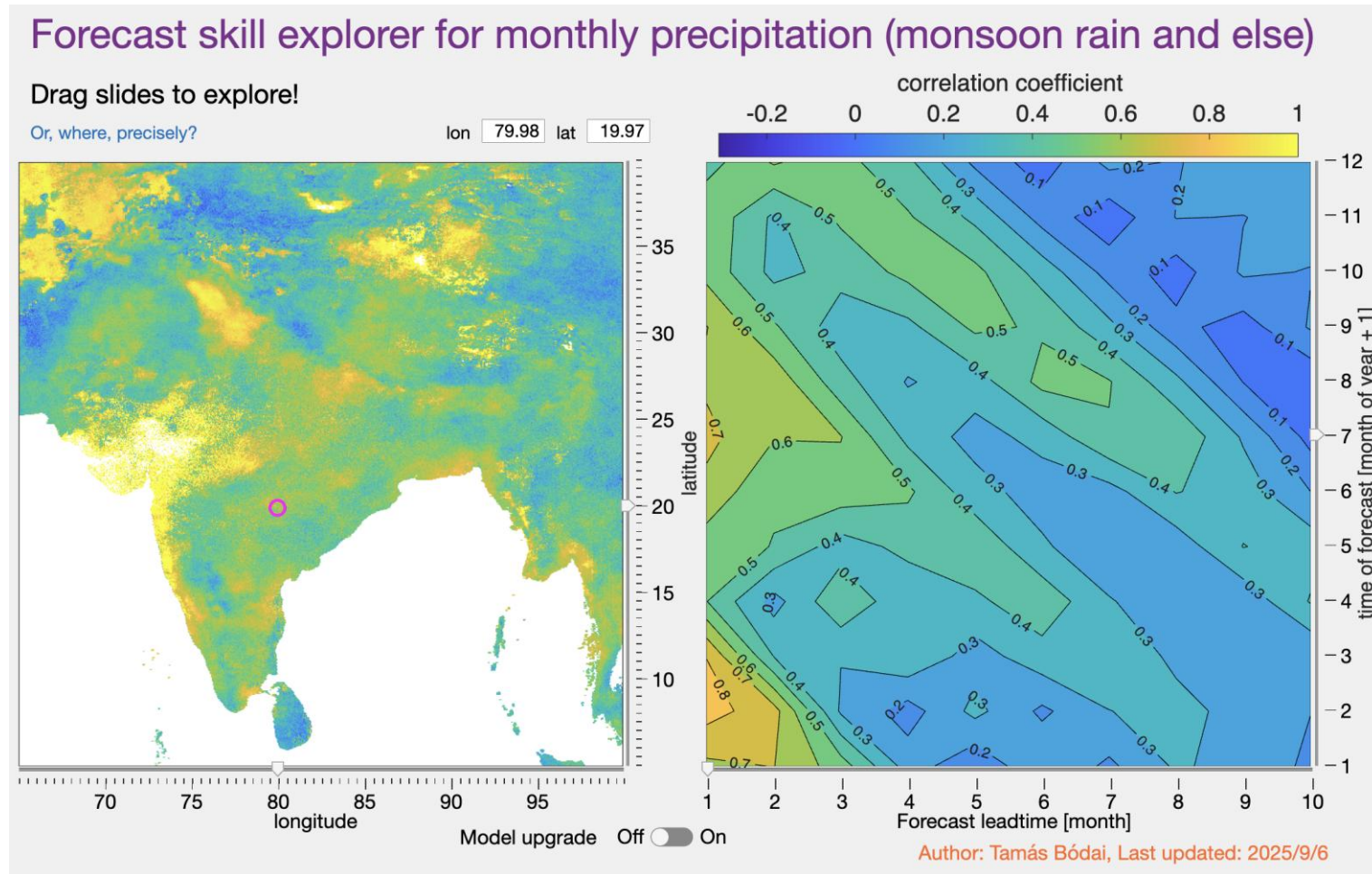


I think you have had these figures for a long time...

- Guilty as charged!
- But...



Dude, you have to submit a **report** about your trip!
No-one will care how much you worked if you don't
have something to show for!



Comparison

[Home](#) > [Climate Dynamics](#) > Article

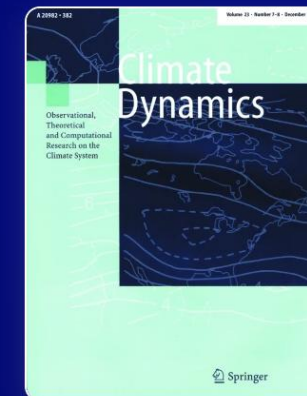
Skill of Indian summer monsoon rainfall prediction in multiple seasonal prediction systems

Published: 19 September 2018

Volume 52, pages 5291–5301, (2019) [Cite this article](#)

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[Shipra Jain](#) ✉, [Adam A. Scaife](#) & [Ashis K. Mitra](#)

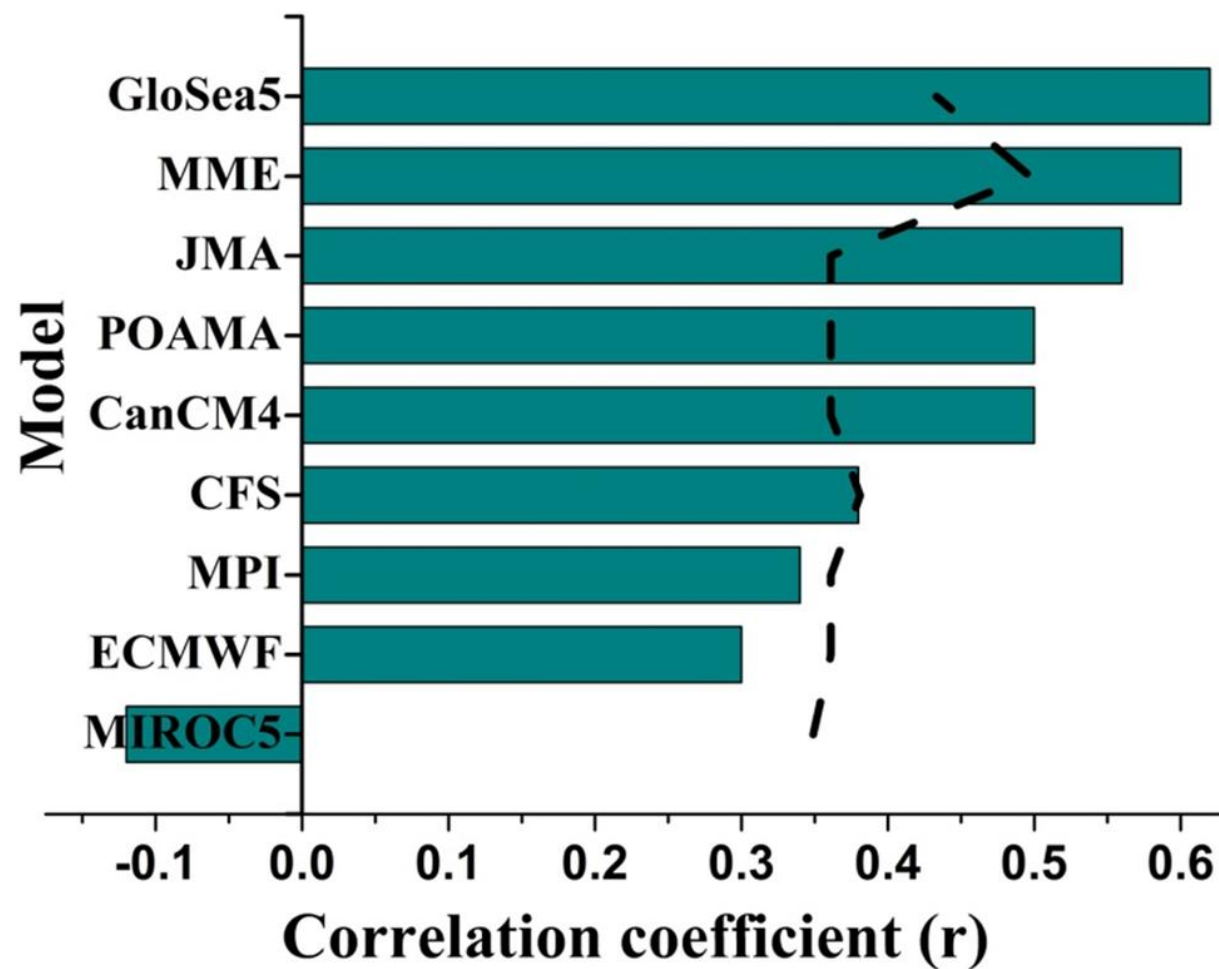
📄 1564 Accesses 📄 47 Citations [Explore all metrics](#) →

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Avoid common mistakes on your manuscript.

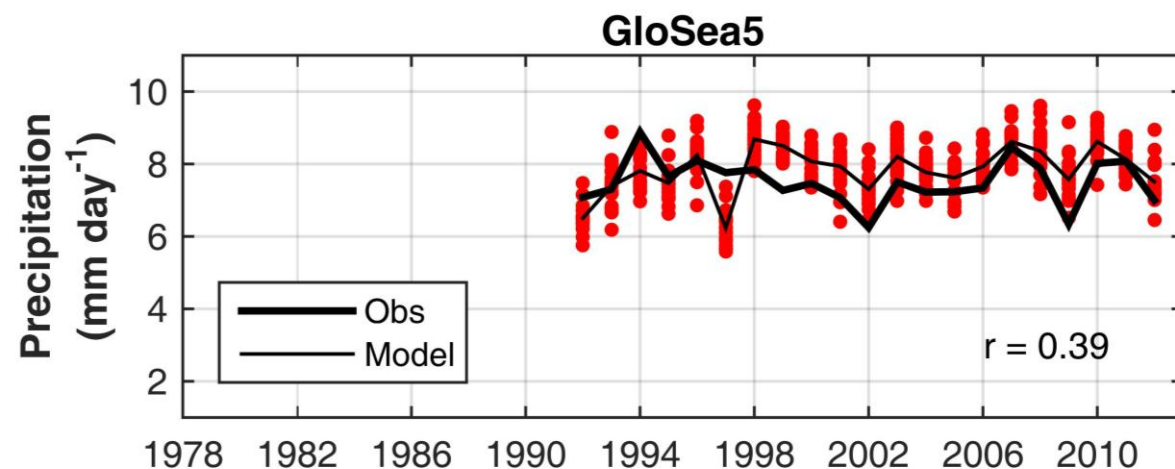
Comparison for forecasting JJA rain on 1 May

In a box (rain over ocean included)



Over land only

Just one model



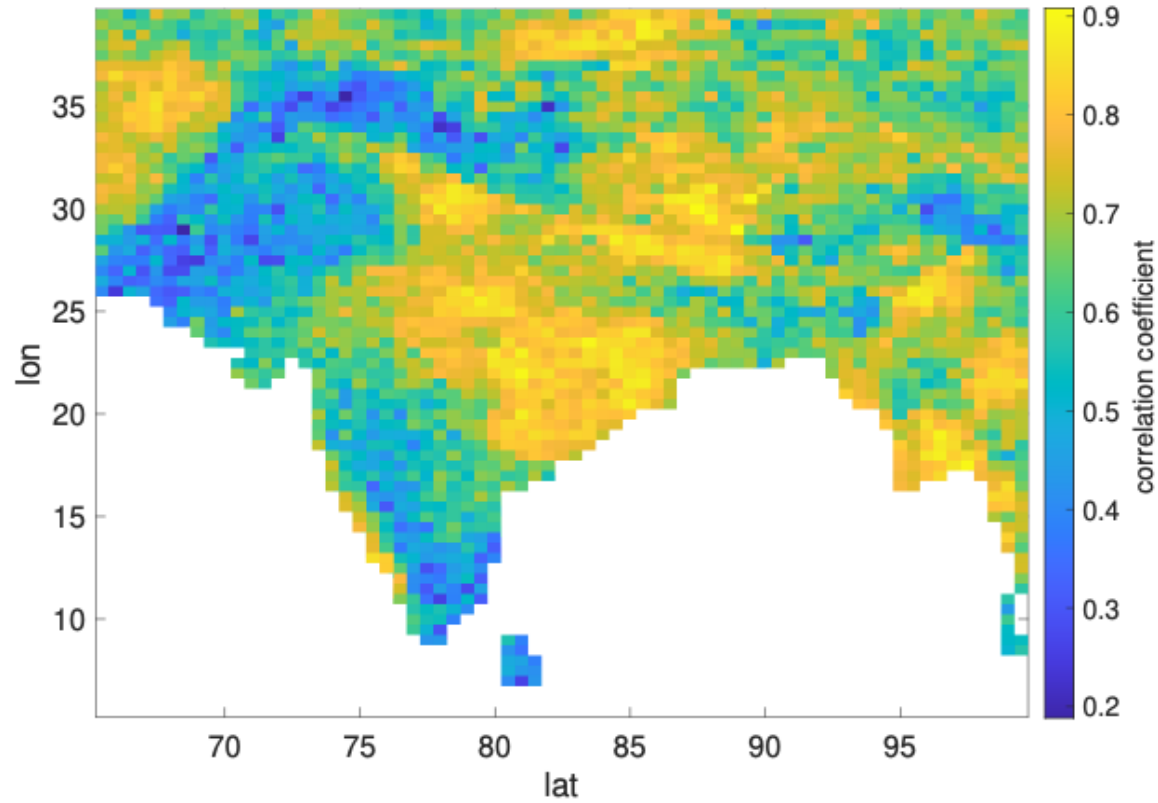
For my model: $r = 0.837$

Sample r is calculated over years 1992-2007

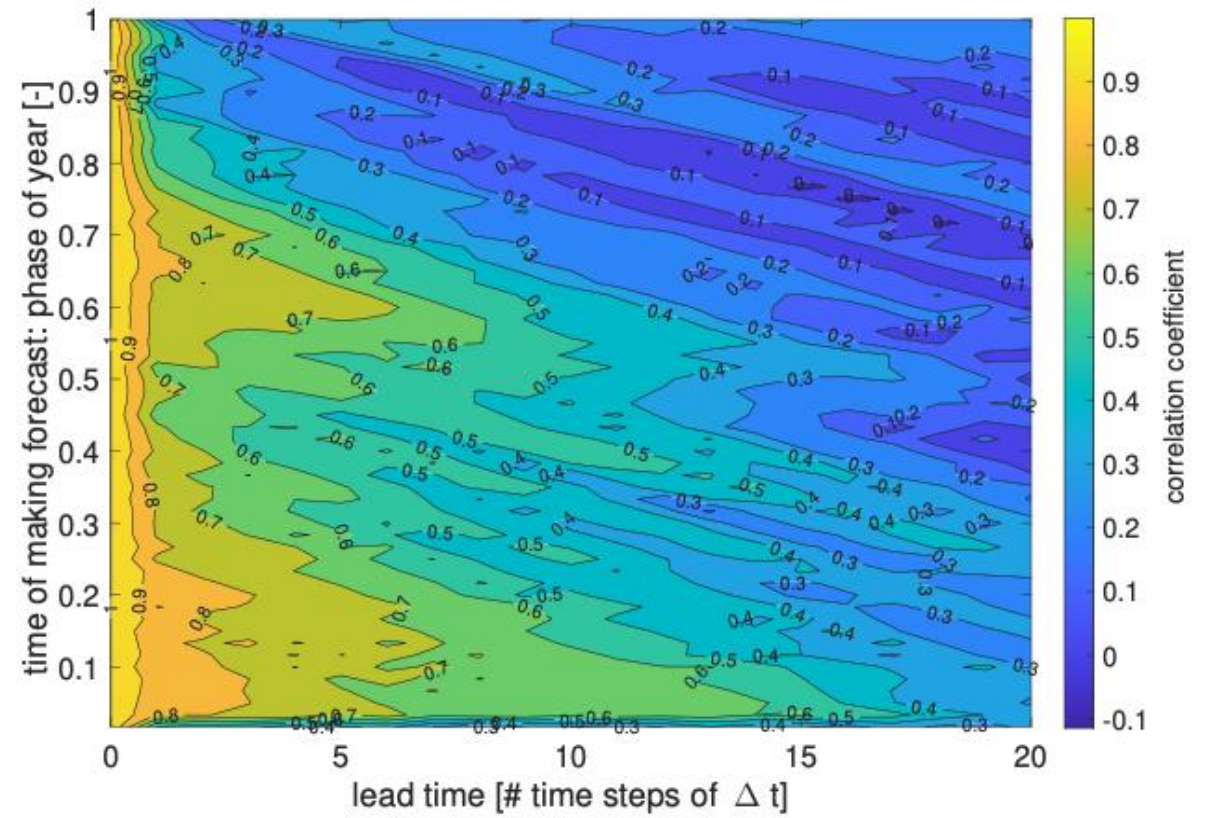
For the full data period (1981-2022): $r = 0.711$

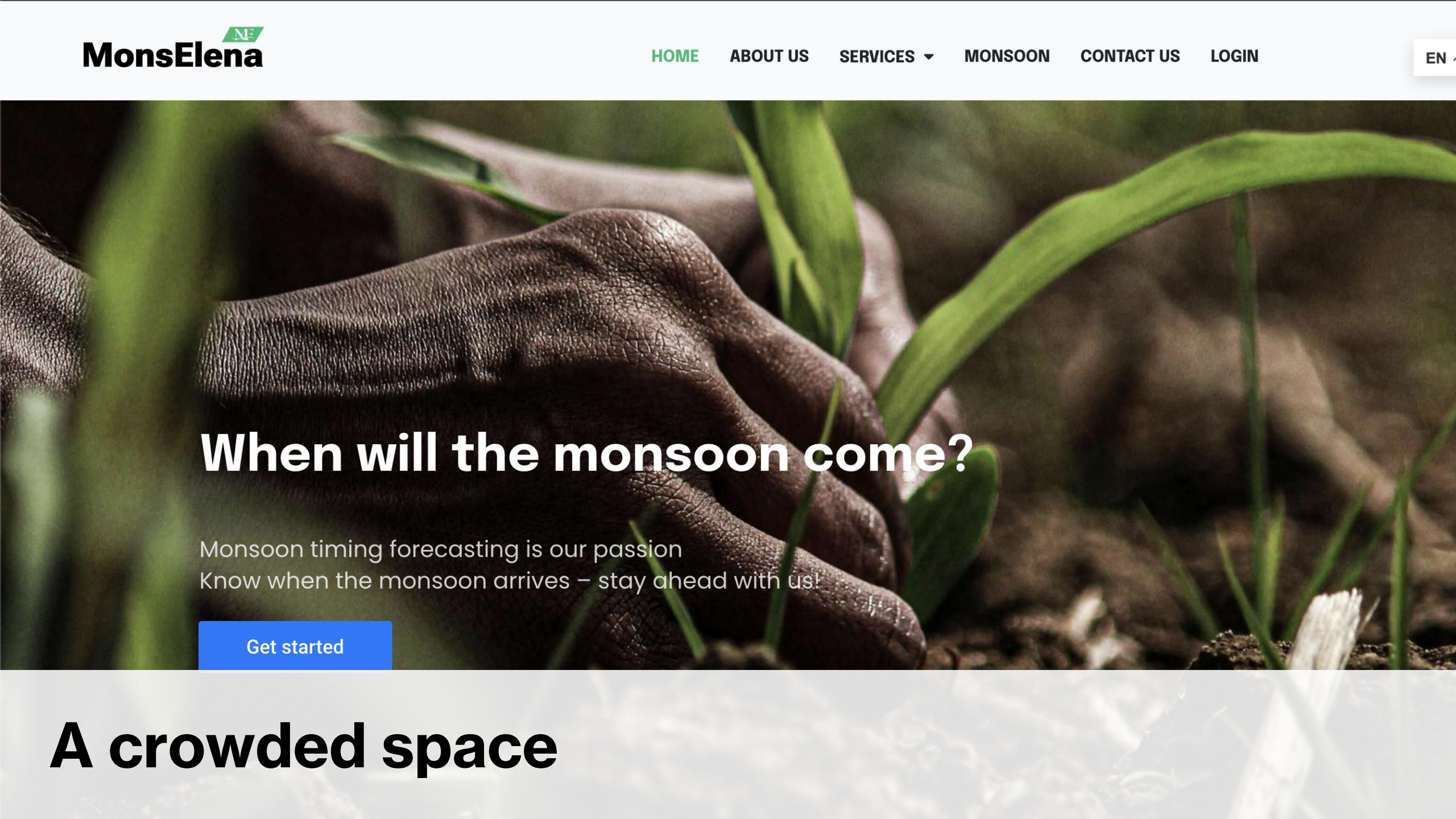
Treat also pentads!

Lead time: 2 pentads



Location: middle of box



A close-up photograph of a person's hand, with dark skin, planting a small green seedling into the soil. The hand is positioned in the center-left of the frame, with fingers gently holding the plant. The background is a blurred field of similar green plants, suggesting a farm or agricultural setting. The lighting is natural, highlighting the texture of the skin and the vibrant green of the leaves.

When will the monsoon come?

Monsoon timing forecasting is our passion
Know when the monsoon arrives – stay ahead with us!

[Get started](#)

A crowded space

A crowded space

Campus news

AI revolutionizes weather prediction to help farmers in India

Co-developed by UC Berkeley's William Boos, an artificial intelligence-based weather model delivered a timely prediction of a stalled monsoon this season, helping farmers decide when to plant their crops.

By [Robert Sanders](#)



India's Ministry of Agriculture and Farmer Welfare delivered regular forecasts via cellphone to some 38 million farmers across northeastern India at the start of the 2025 summer monsoon season. For the first time, these forecasts provided up to four weeks' advance notice of the start of the continuous rainy season, allowing the farmers to better time the planting of crops with the onset of the rains.

And it's going
to be
even more
crowded

Scientists Must Join Forces to Solve Forecasting's Predictability Desert

To strengthen societal resilience to worsening natural hazards, siloed Earth system science communities must collaborate to understand conditions that favor skillful subseasonal-to-seasonal forecasts.

By **Jadwiga H. Richter** and **Everette Joseph** 17 October 2025



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an expert!

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to speak to
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Earth and
space science.

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LECTURE



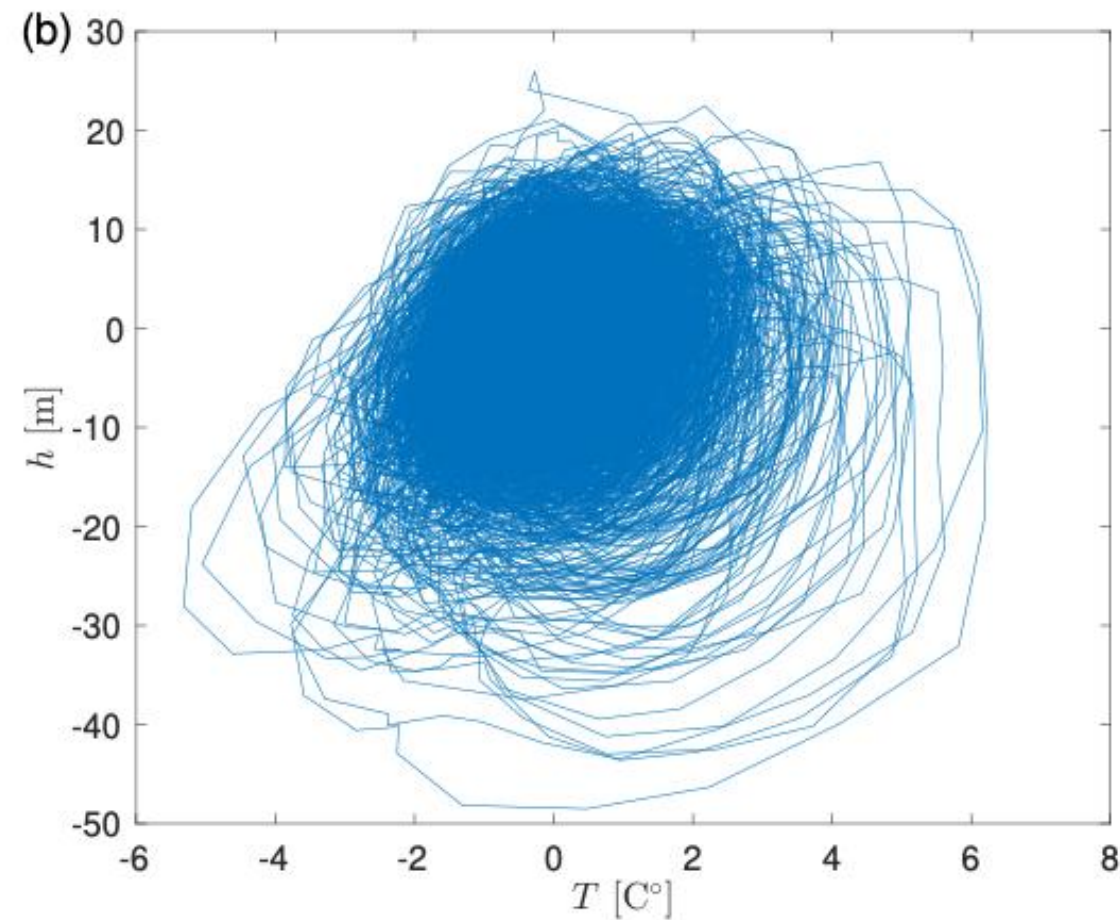
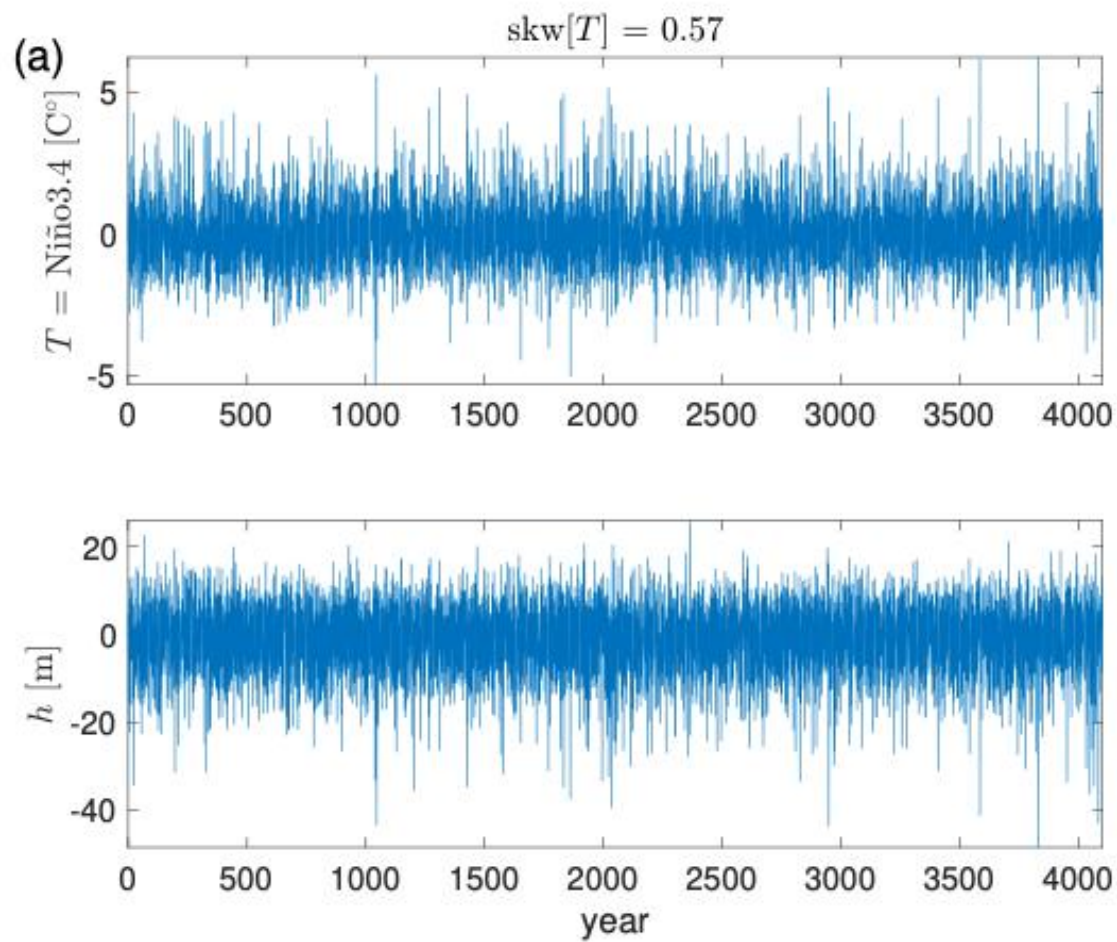
Thank You!
Takk!

Köszönöm!

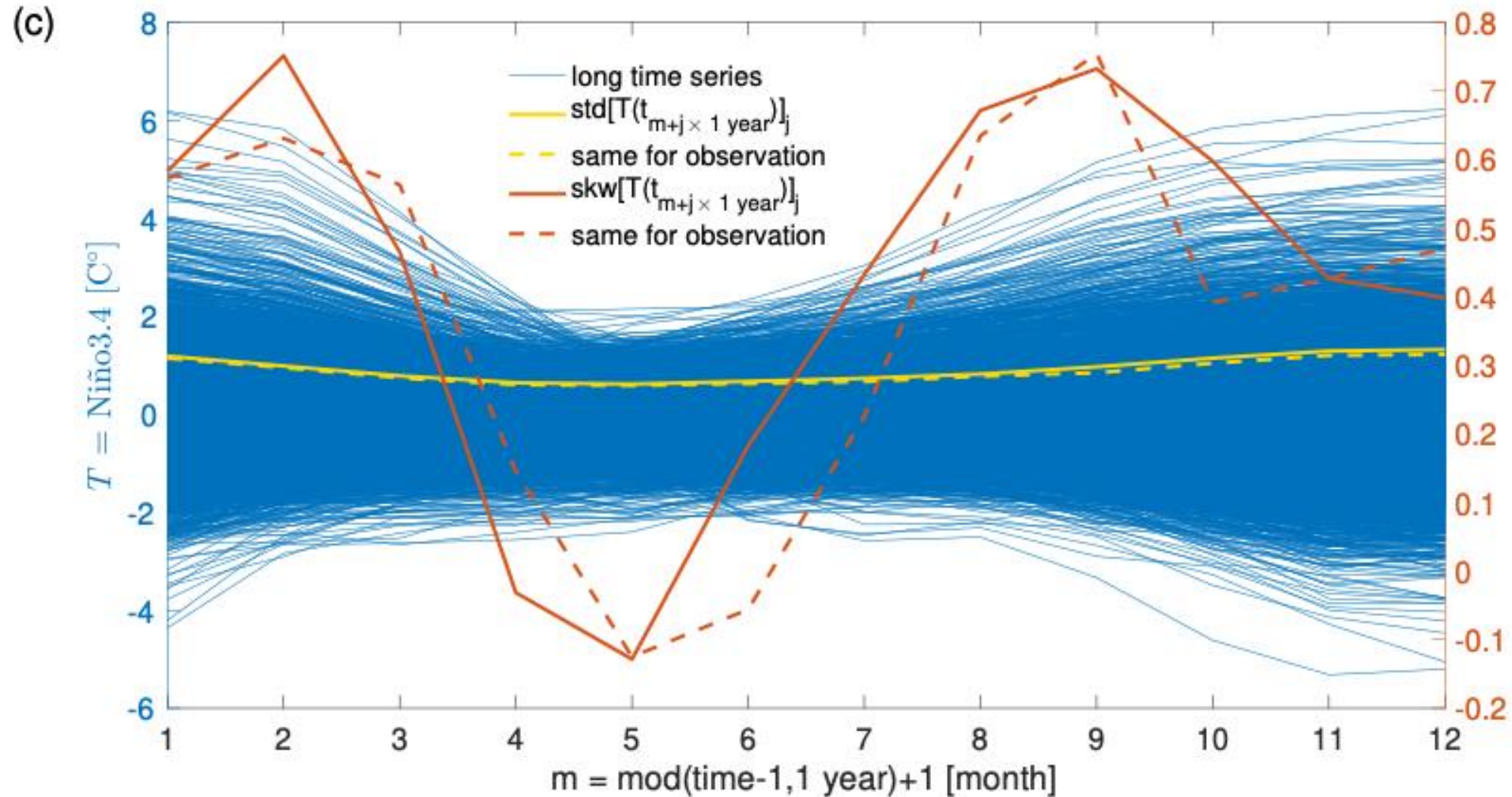
Feel free to find me on LinkedIn 



Authenticity of the X(D)ROM(+)



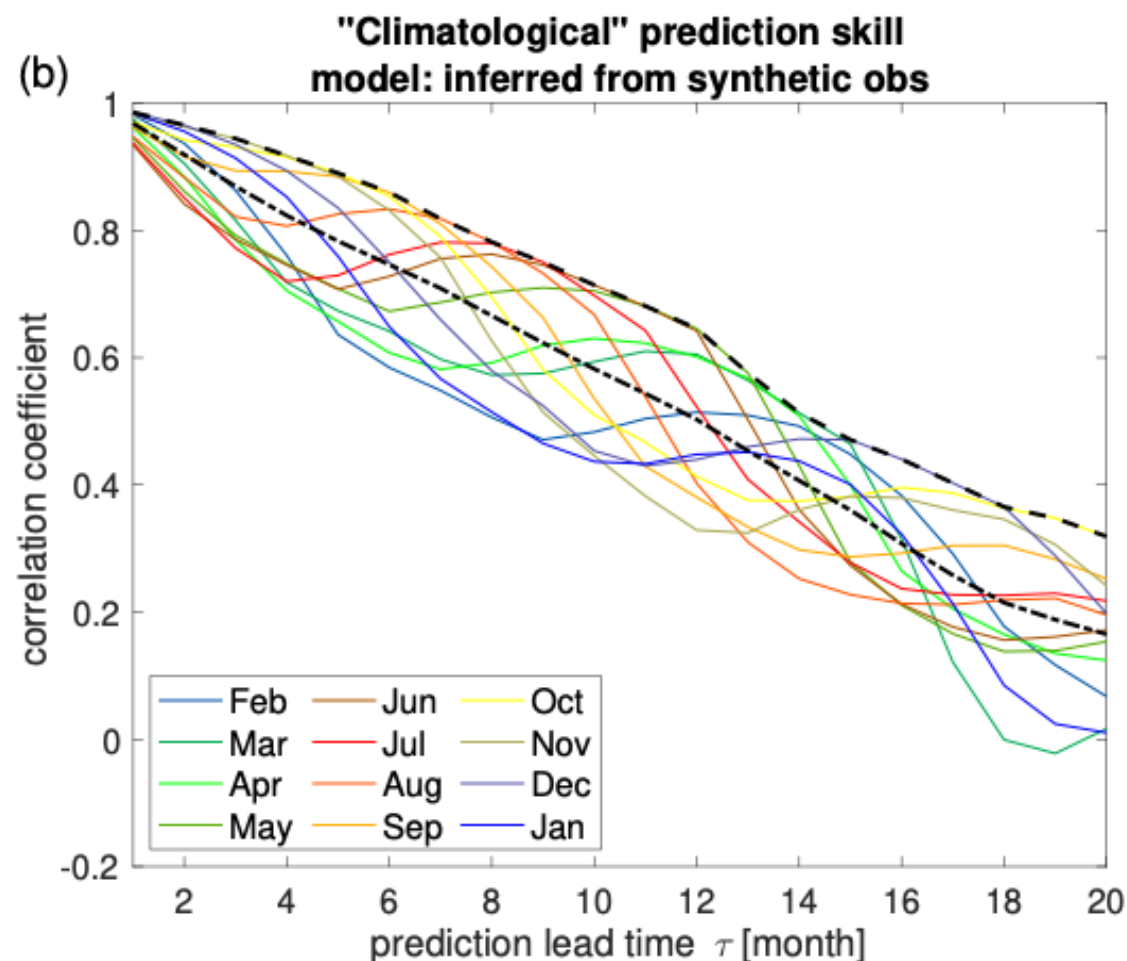
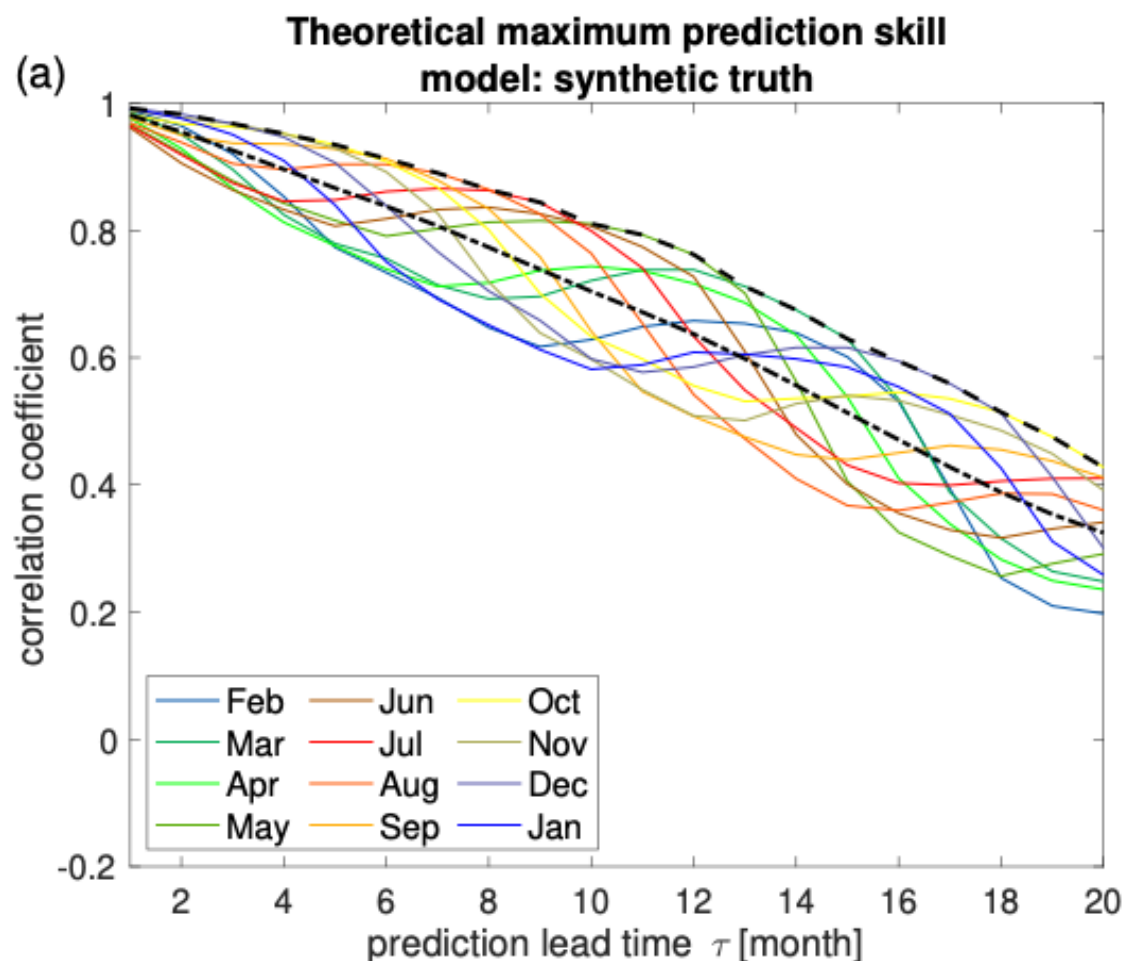
Authenticity of the X(D)ROM(+)



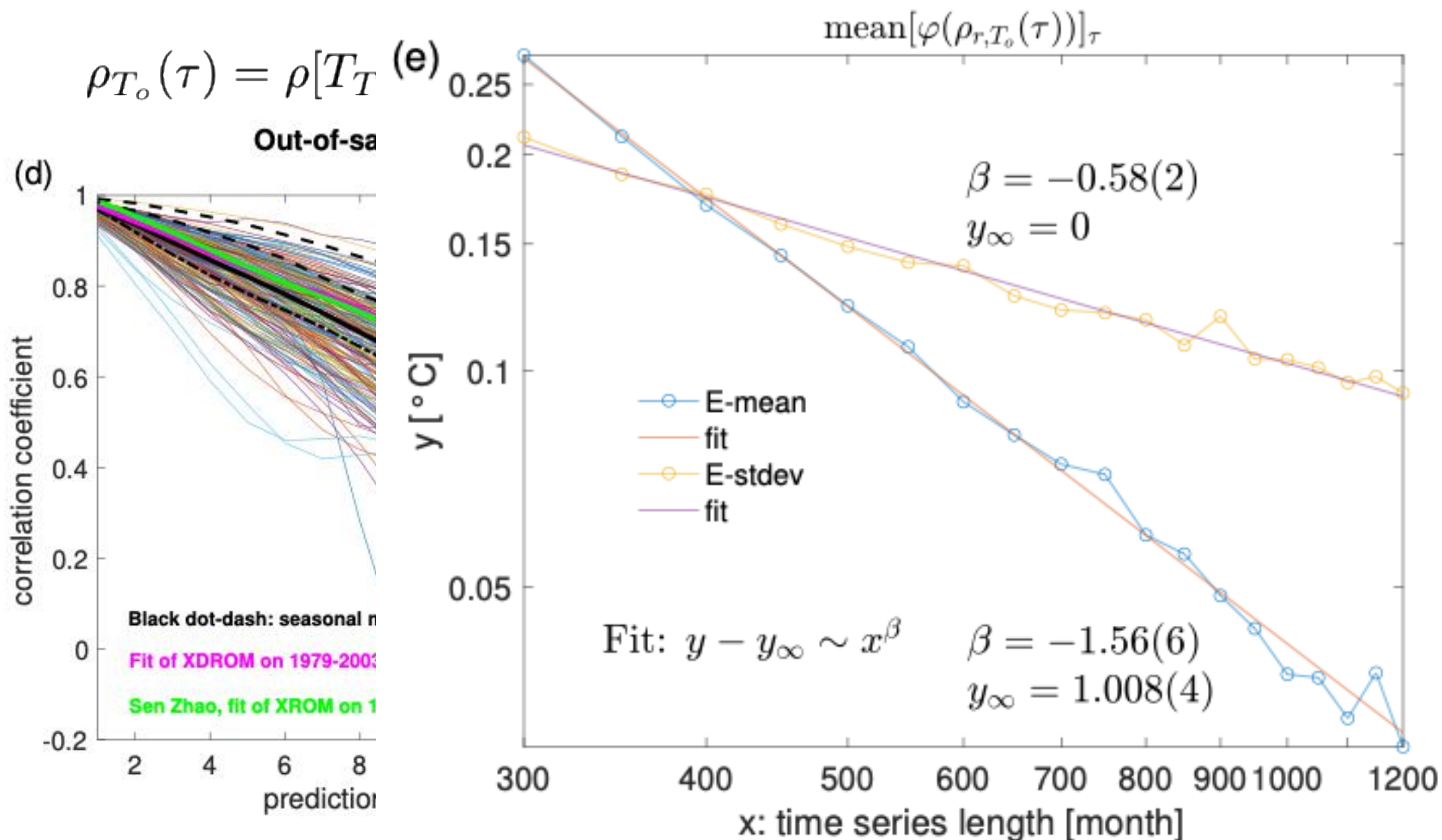
Theoretical maximum and climatological skill

$$\rho_{max}(\tau) = \rho[T_{r,p}(t_t + \tau), T_{r,t}(t_t + \tau)]_r$$

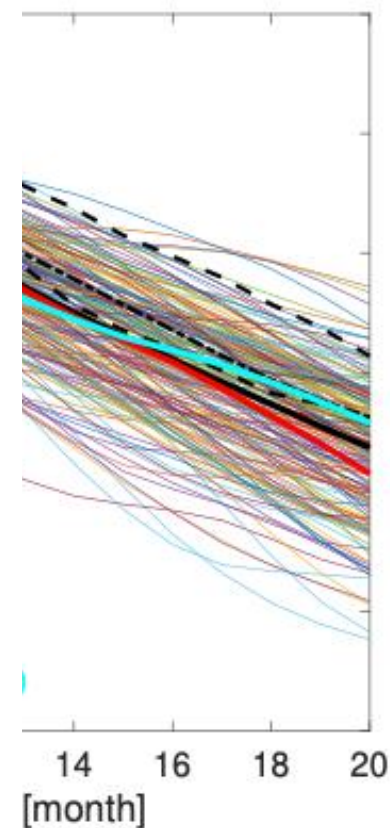
$$\rho_{T_t,max}(\tau) = \rho[T_{r,T_t,p}(t_t + \tau), T_{r,t}(t_t + \tau)]_r$$



Apparent skill



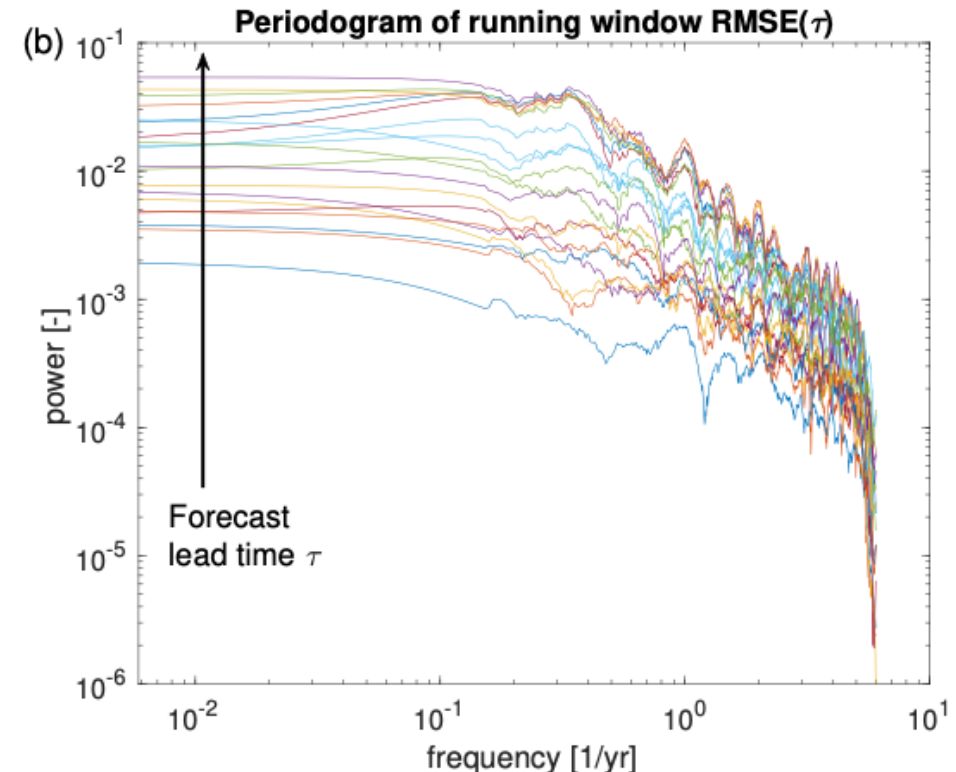
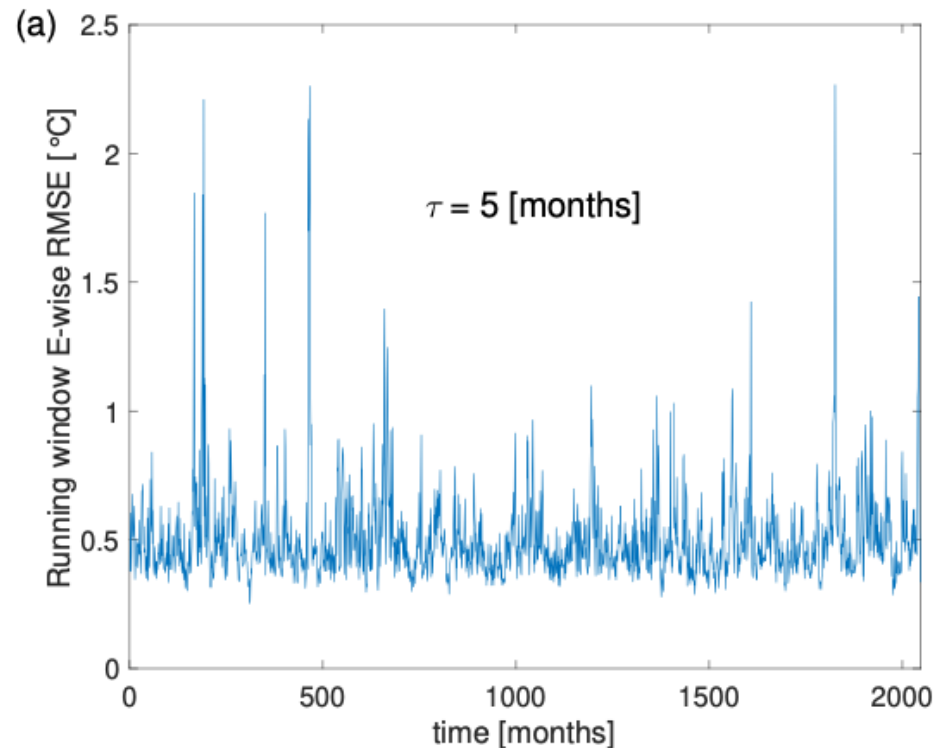
tion skill



True skill

- It cannot be a correlation coefficient
- Rather an ensemble-wise RMSE:

$$\text{REMSE}_{T_o}(\tau) = \text{RMSE}[T_{r,T_o,p}(t_f + \tau), T_{r,t}(t_f + \tau)]_r, \quad t_f = \max[T_o]$$



The apparent skill is not indicative of the true skill...

...as the true skill has hardly any persistence. Also:

