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Seamless climate information for the next few months to multiple years: merging of seasonal and decadal predictions, and their comparison to multi-annual predictions

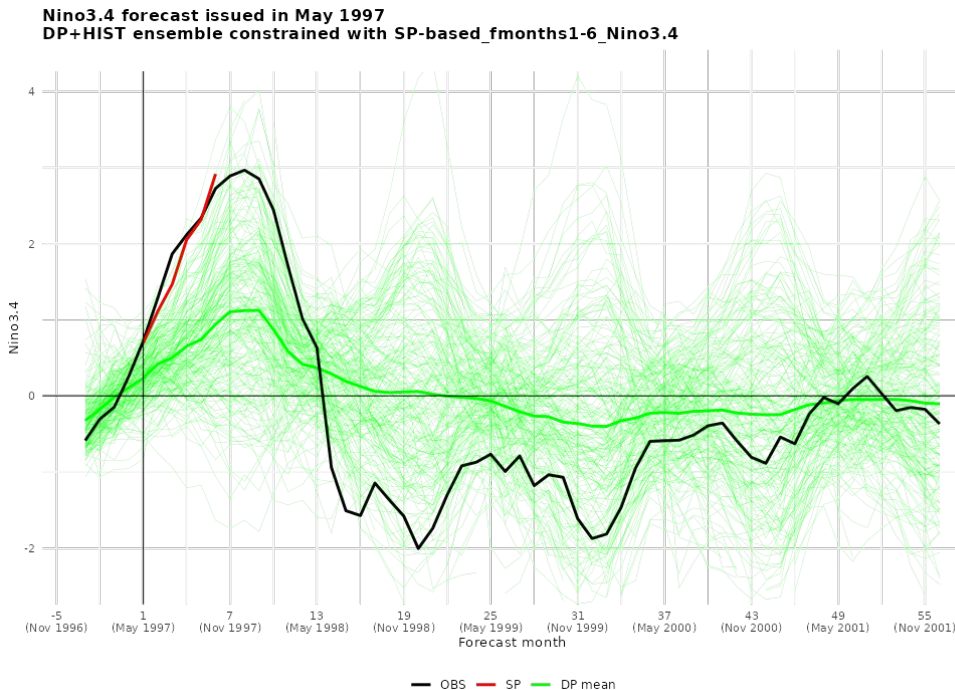
Carlos Delgado-Torres, Markus G. Donat, Núria Pérez-Zanón, Verónica Torralba, Roberto Bilbao, Pierre-Antoine Bretonnière, Margarida Samsó-Cabré, Albert Soret, and Francisco J. Doblas-Reyes

**UPCLIV Workshop
Bologna, November 2025**

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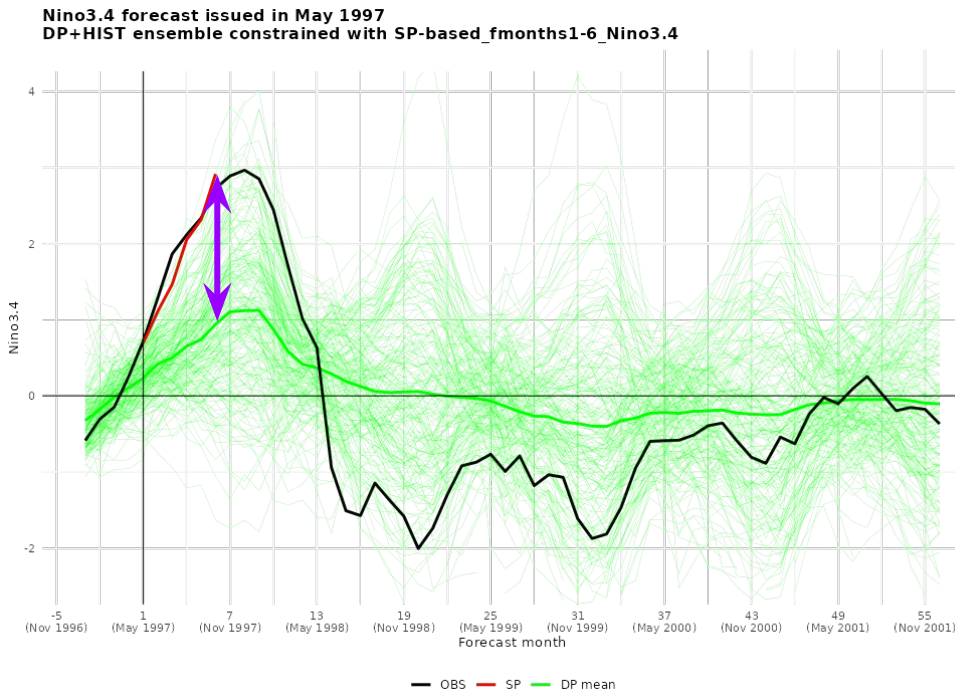
Motivation

- Need for climate information that spans **multiple timescales**. Shifting from seasonal forecasts (used during the first few months) to decadal forecasts (for subsequent years) **introduces inconsistencies**
- By combining seasonal and decadal forecast, we could:
 - Improve **forecast quality** (by transferring short-term predictability into longer time scales)
 - Increase **forecast consistency** at seasonal and decadal timescales (by avoiding “jumps” when switching from one horizon to the other)



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Data

Climate predictions

Time scale	Forecast months	Total members	N	Forecast system	Ensemble members
Seasonal	1-6	25	1	SEAS5	1-25
Multiannual	1-24	70	1	CMCC-CM2-SR5-i5	r1-10i5p1f1
			2	EC-Earth3-i5	r1-20i5p1f1
			3	EC-Earth3-HR	r1-15i1p1f1
			4	ECMWF	1-25
Decadal	1-60	197	1	BCC-CSM2-MR	r1-8i1p1f1
			2	CanESM5	r1-20i1p2f1
			3	CESM1-1-CAM5-CMIP5	1-40
			4	CMCC-CM2-SR5-i1	r1-10i1p1f1
			5	CNRM-ESM2-1	r1-10i1p1f2
			6	EC-Earth3-i1	r1-10i1p1f1
			7	EC-Earth3-i2	r6-10i2p1f1
			8	EC-Earth3-i4	r1-10i4p1f1
			9	FGOALS-f3-L	r1-3i1p1f1
			10	HadGEM3-GC3.1-MM	r1-10i1p1f2
			11	IPSL-CM6A-LR	r1-10i1p1f1
			12	MIROC6	r1-10i1p1f1
			13	MPI-ESM1-2-HR	r6-10i1p1f1
			14	MPI-ESM1-2-LR	r1-16i1p1f1
			15	MRI-ESM2-0	r1-10i1p1f1
			16	NorCPM1-i1	r1-10i1p1f1
			17	NorCPM1-i2	r1-10i2p1f1

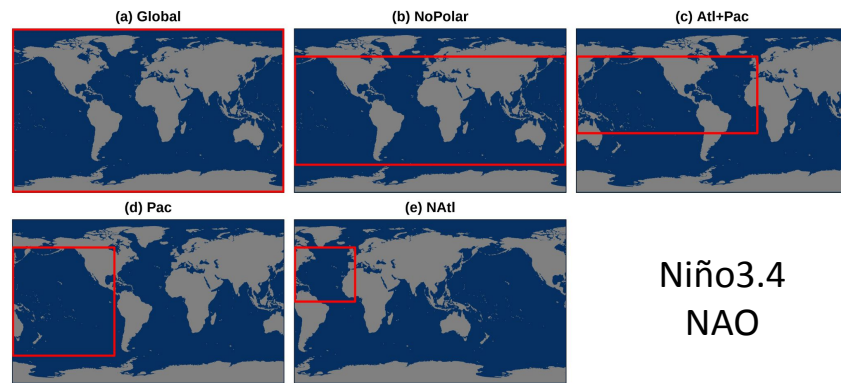
Data

Climate projections (hist+ssp245)

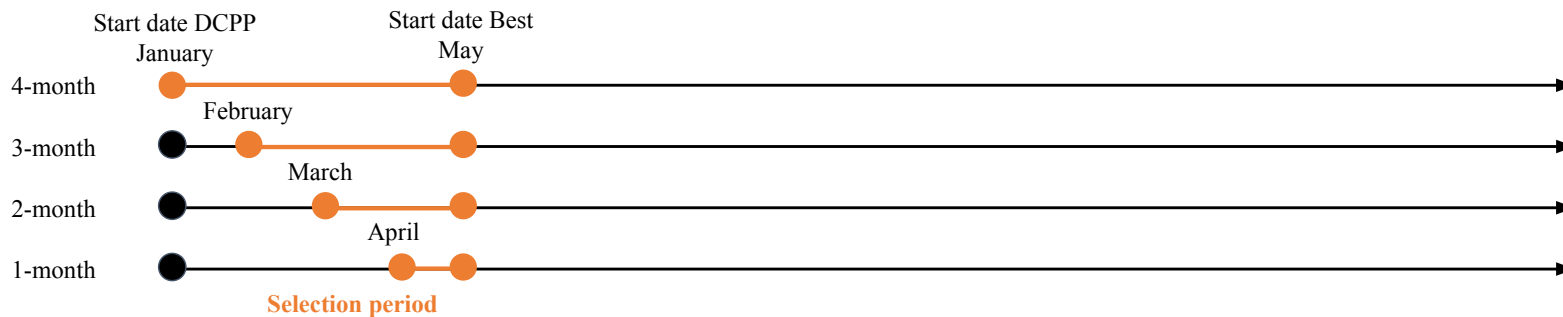
Total members	N	Climate model	Ensemble members	N	Climate model	Ensemble members
264	1	ACCESS-CM2	r1-5ilp1fl	17	FGOALS-g3	r4ilp1fl
	2	ACCESS-ESM1-5	r1-12ilp1fl	18	FIO-ESM-2-0	r1-3ilp1fl
	3	BCC-CSM2-MR	r1ilp1fl	19	GISS-E2-1-G	r1-10ilp1f2
	4	CAMS-CSM1-0	r1-2ilp1fl	20	HadGEM3-GC3.1-LL	r1ilp1f3
	5	CAS-ESM2-0	r(1,3)ilp1fl	21	INM-CM5-0	r1ilp1fl
	6	CESM1-1-CAM5-CMIP5	1-40	22	IPSL-CM6A-LR	r(1:-6,10-11,14,22,25) ilp1fl
	7	CESM2-WACCM	r1-3ilp1fl	23	KIOST-ESM	r1ilp1fl
	8	CMCC-CM2-SR5	r1ilp1fl	24	MIROC-ES2L	r1-30ilp1f2
	9	CMCC-ESM2	r1ilp1fl	25	MIROC6	r1-50ilp1fl
	10	CNRM-CM6-1-HR	r1ilp1f2	26	MPI-ESM1-2-HR	r1-2ilp1fl
	11	CNRM-CM6-1	r1-6ilp1f2	27	MPI-ESM1-2-LR	r1-10ilp1fl
	12	CNRM-ESM2-1	r1-10ilp1f2	28	MRI-ESM2-0	r1-5ilp1fl
	13	CanESM5-CanOE	r1-3ilp2f1	29	NESM3	r1-2ilp1fl
	14	CanESM5	r1-25ilp2f1	30	NorESM2-LM	r1-3ilp1fl
	15	EC-Earth3	r(2,7,10,12,14,16-25) ilp1fl	31	NorESM2-MM	r1ilp1fl
	16	FGOALS-f3-L	r1ilp1fl	32	UKESM1-0-LL	r(1-4,8)ilp1f2

Methods

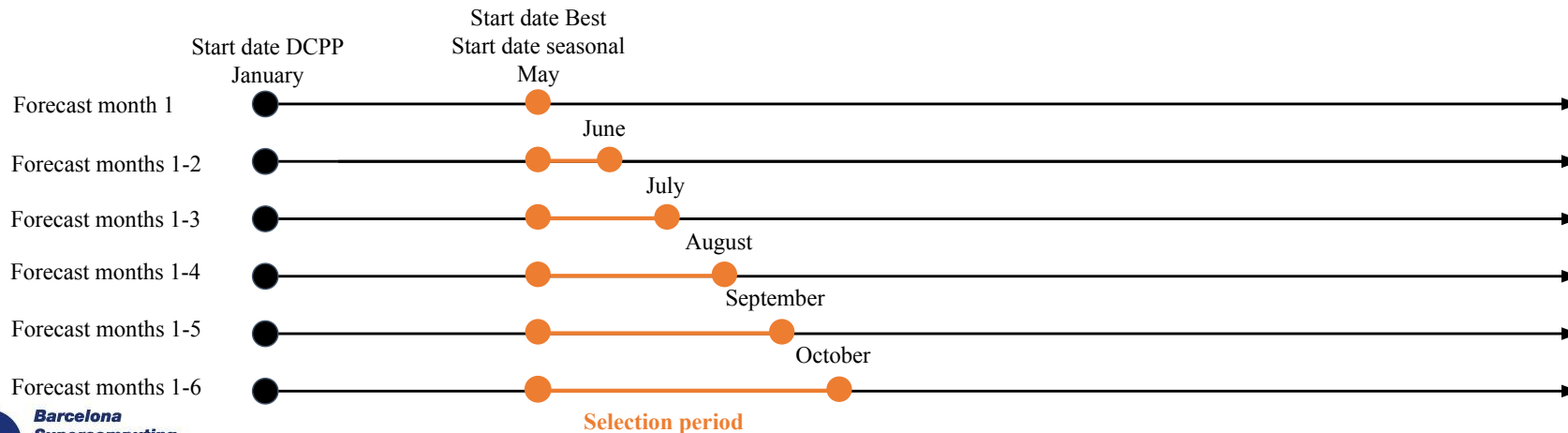
- Selecting the **best 30 members** from
 - decadal predictions (197 members from 17 models)
 - climate projections (264 members from 32 models)
- The selection is based on
 - **recent observations** (1-4 months)
 - **seasonal predictions** (SEAS5; forecast months 1-6)
- It can be **updated at any time of the year** (with updated observations or seasonal predictions)
- All members are bias-adjusted to have the correct mean and variance
- Tested different constraints based on
 - variables: sea surface temperature, sea level pressure, Niño3.4 or NAO
 - metrics: ACC, centered-RMSE, uncentered-RMSE
 - regions: Global, NoPolar, Atl+Pac, Pac, NATl
- With all combinations:
 - 128 OBS-based constraints
 - 192 SP-based constraints



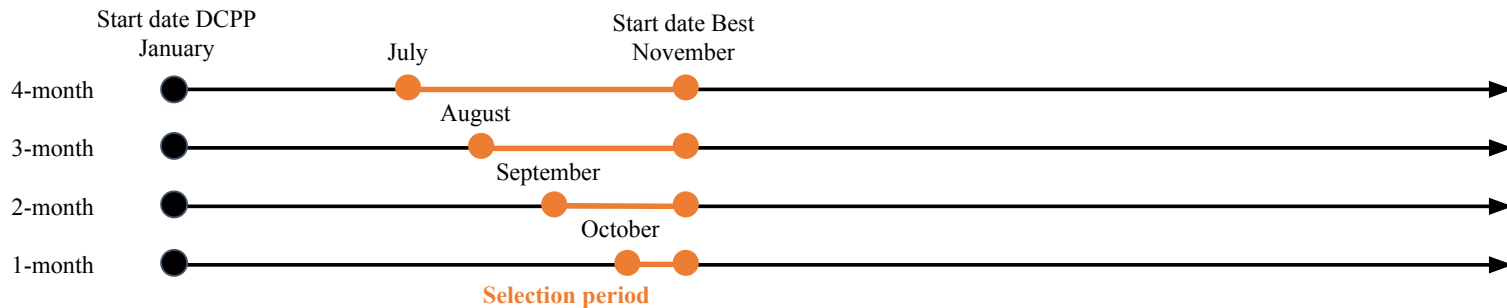
Based on recent observations



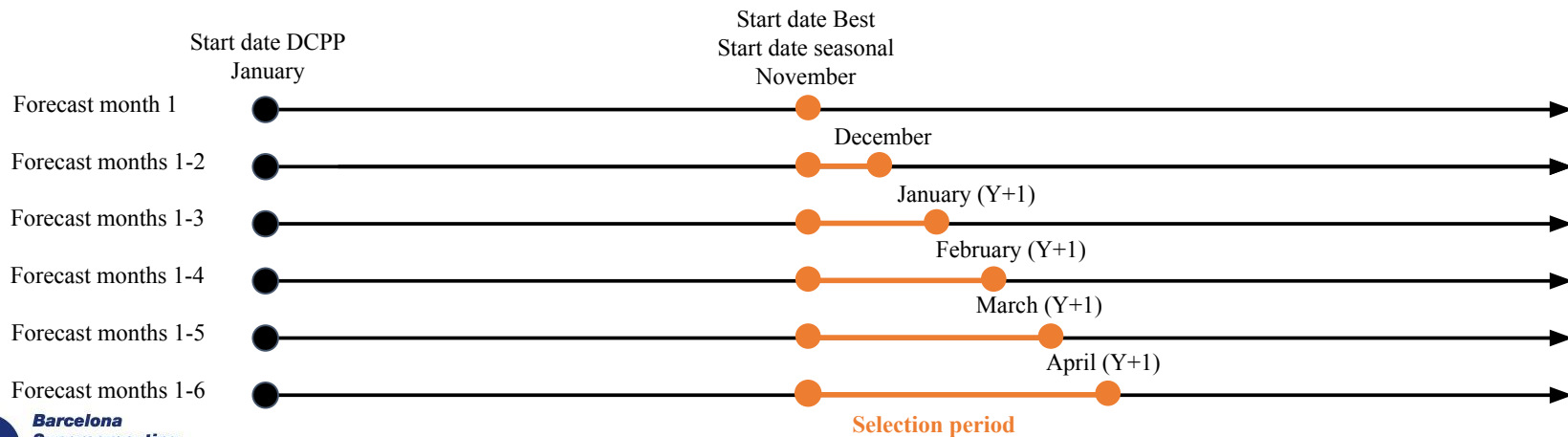
Based on seasonal predictions



Based on recent observations



Based on seasonal predictions



Initialised multi-annual predictions

Start date multi-annual
May

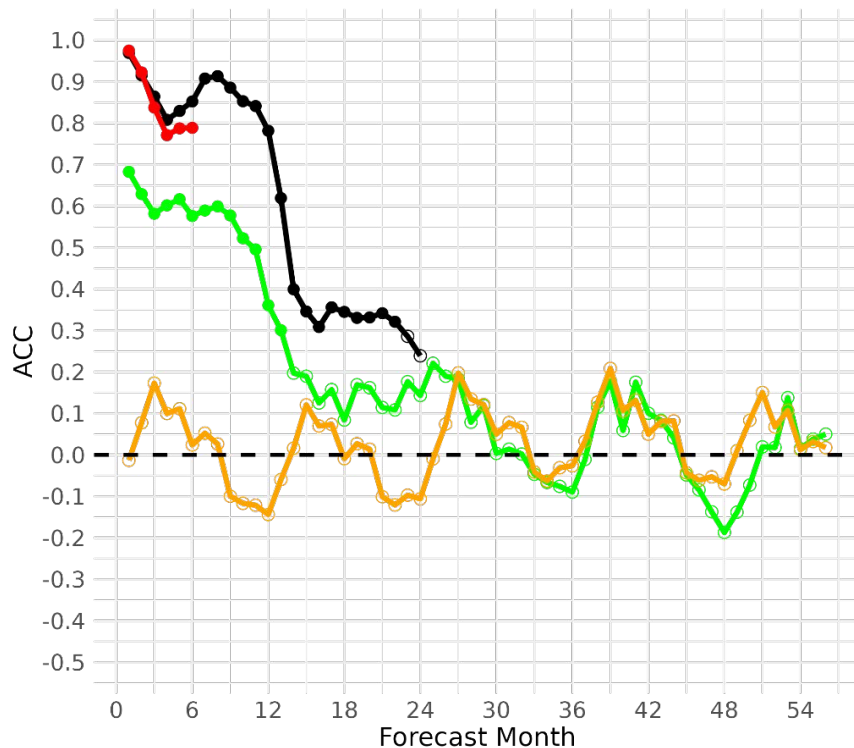


Start date multi-annual
Nov

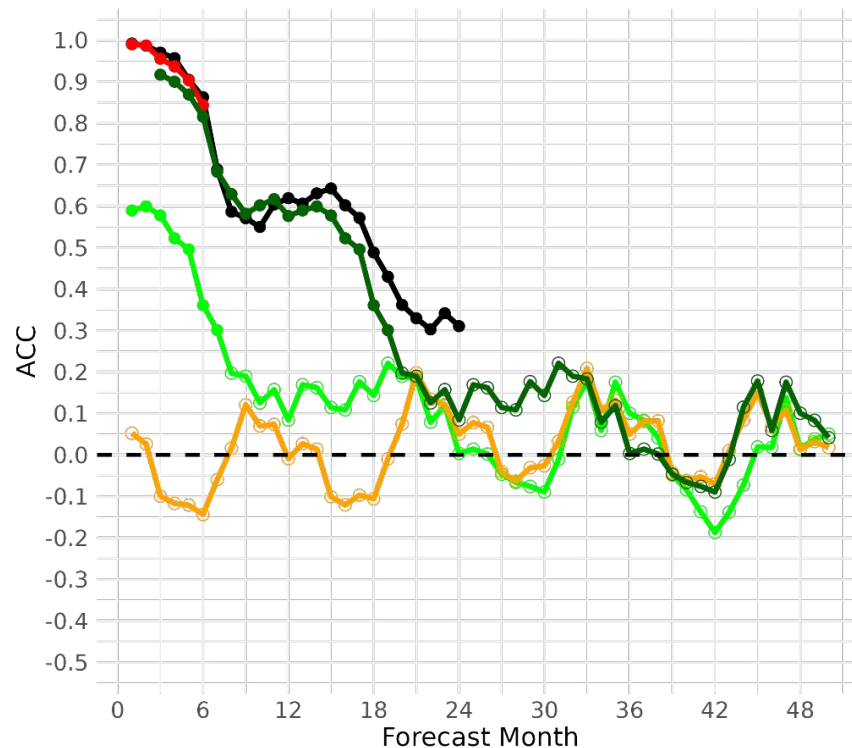


Skill for Niño3.4

(a) May initialisation



(b) November initialisation

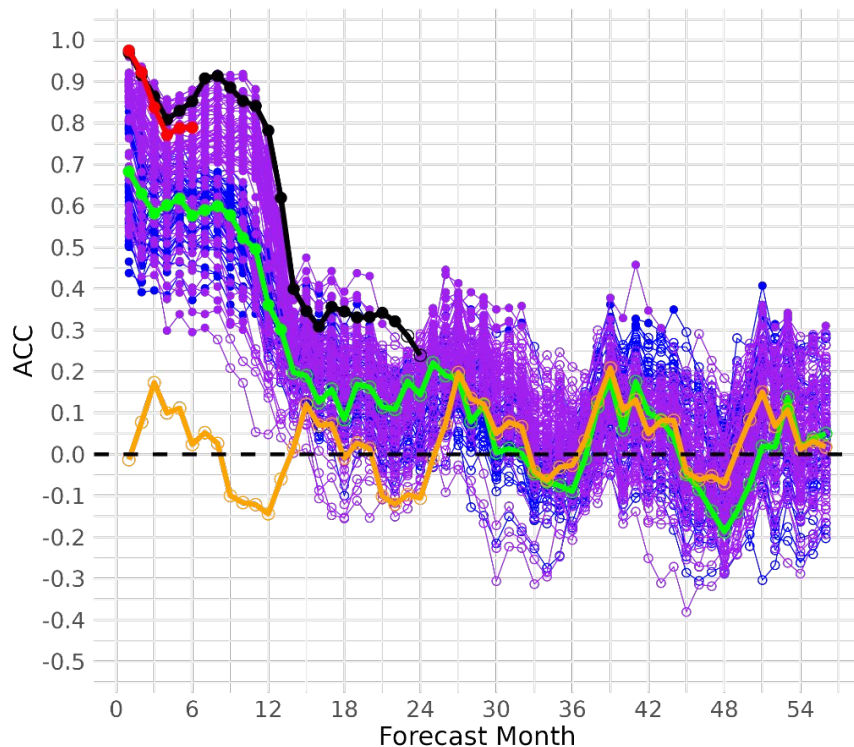


DP HIST MP SP

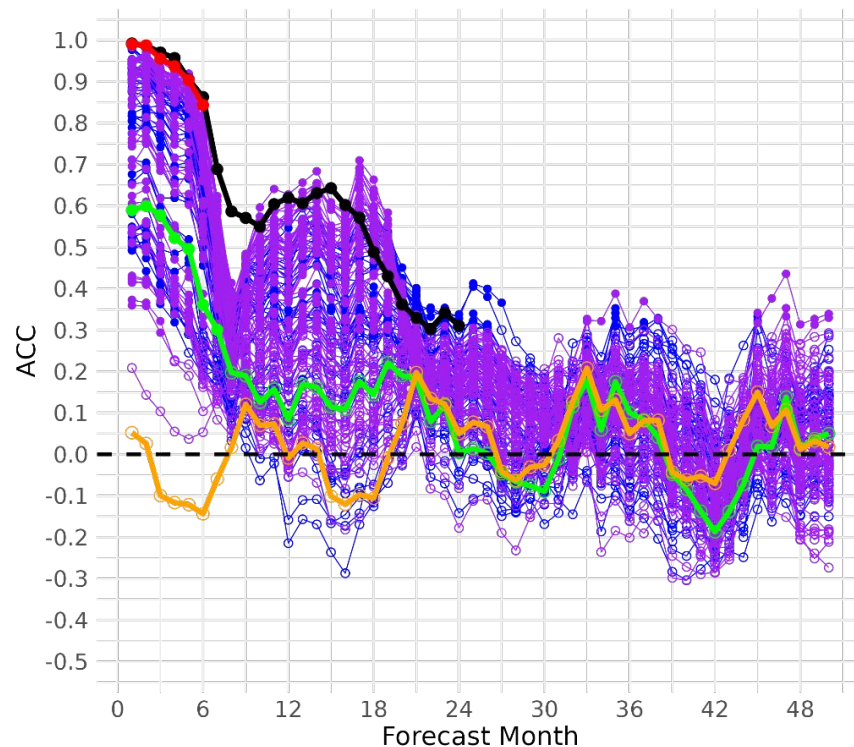
DP DP* HIST MP SP

Skill for Niño3.4

(a) May initialisation

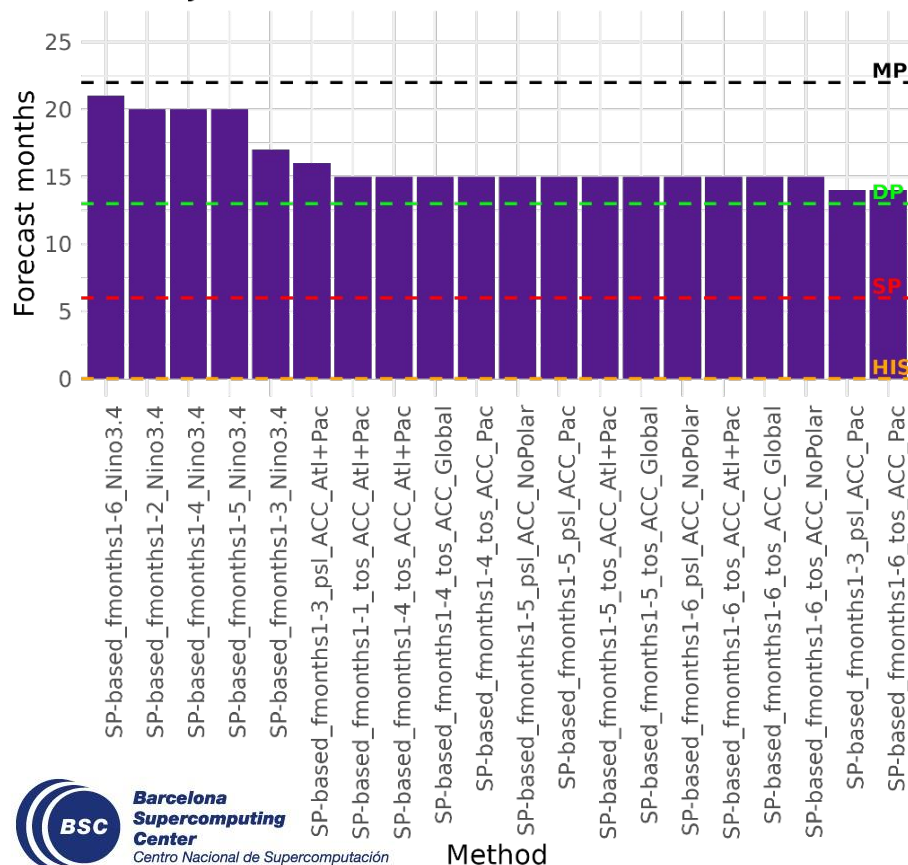


(b) November initialisation

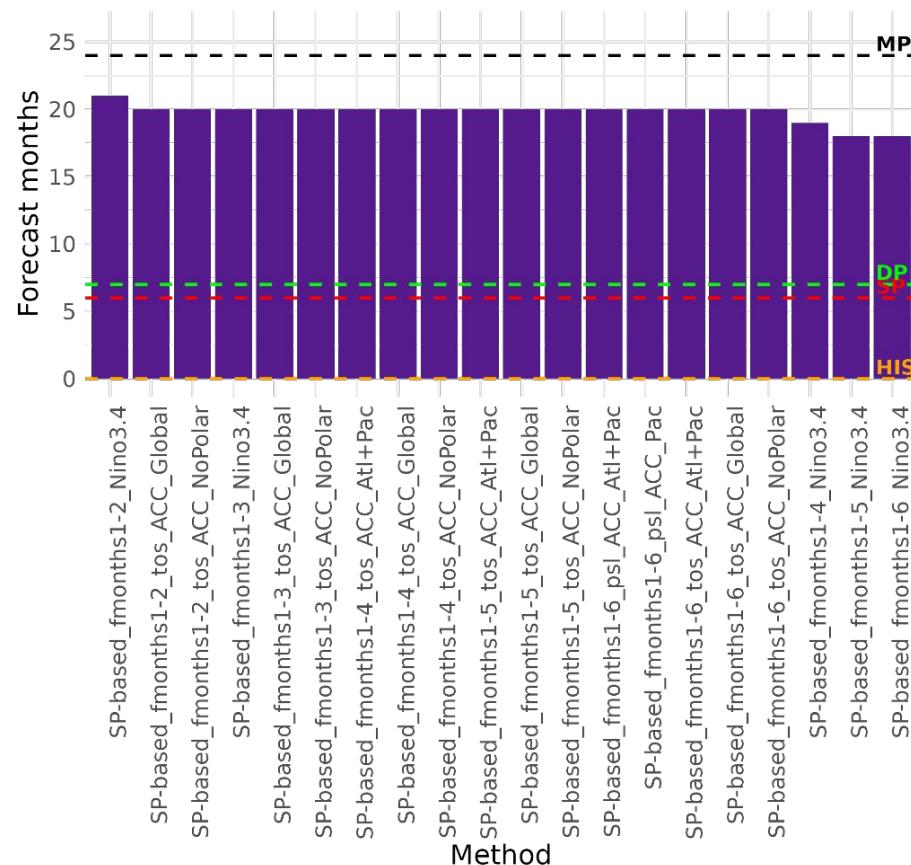


Top methods for Niño3.4

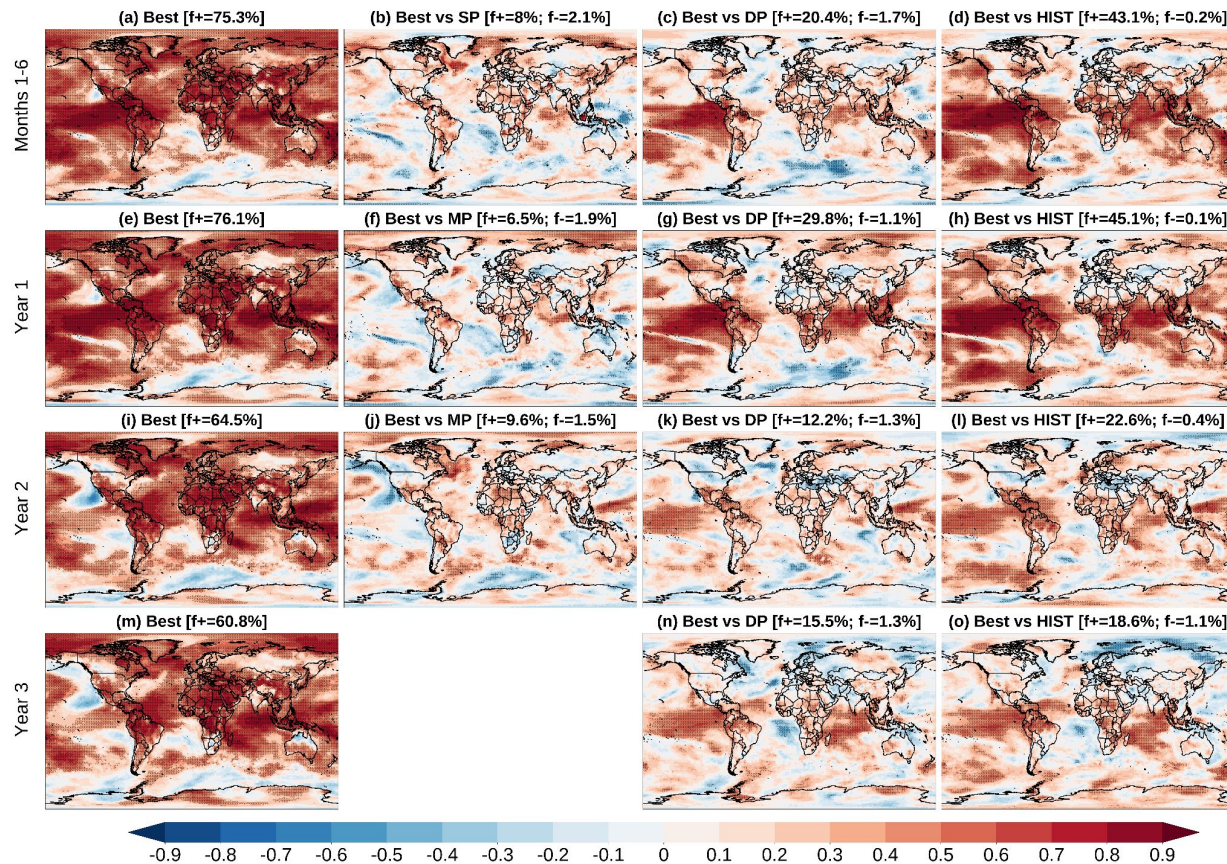
(a) May initialisation



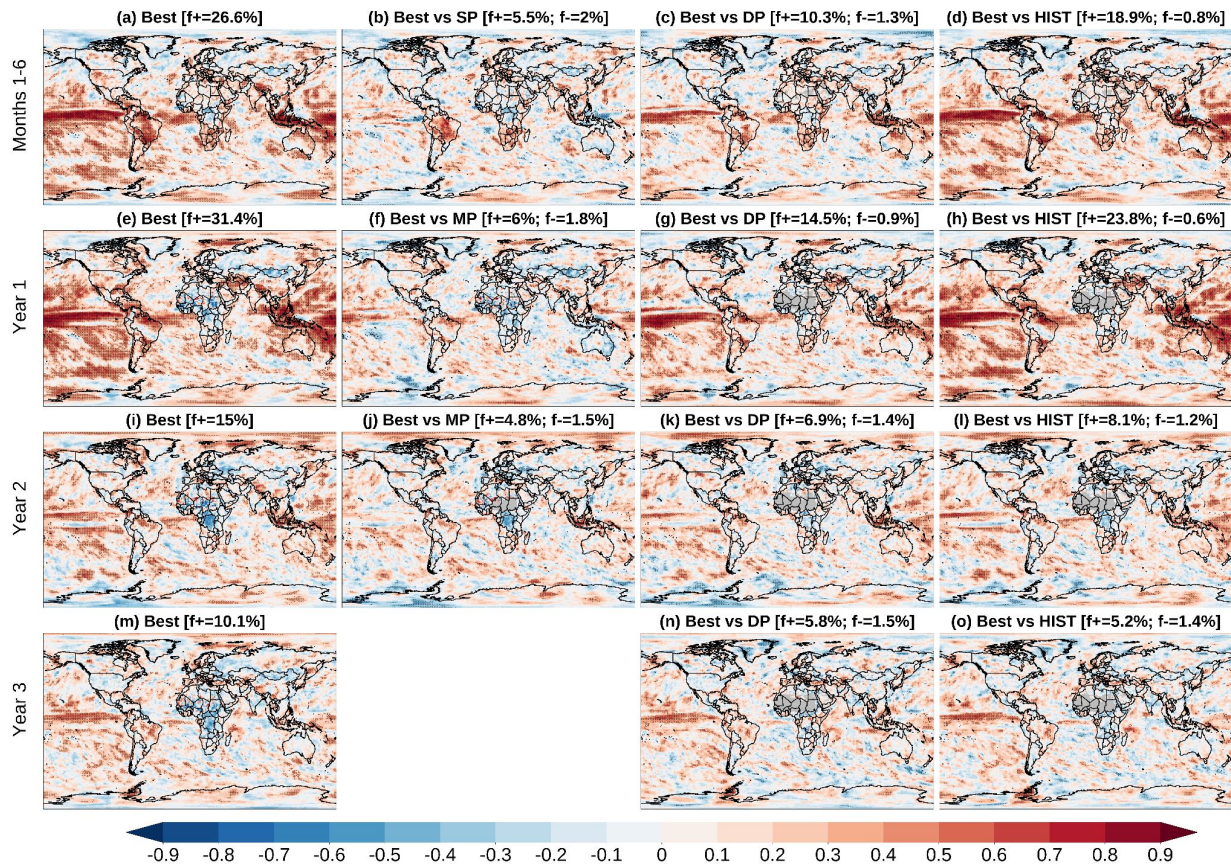
(b) November initialisation



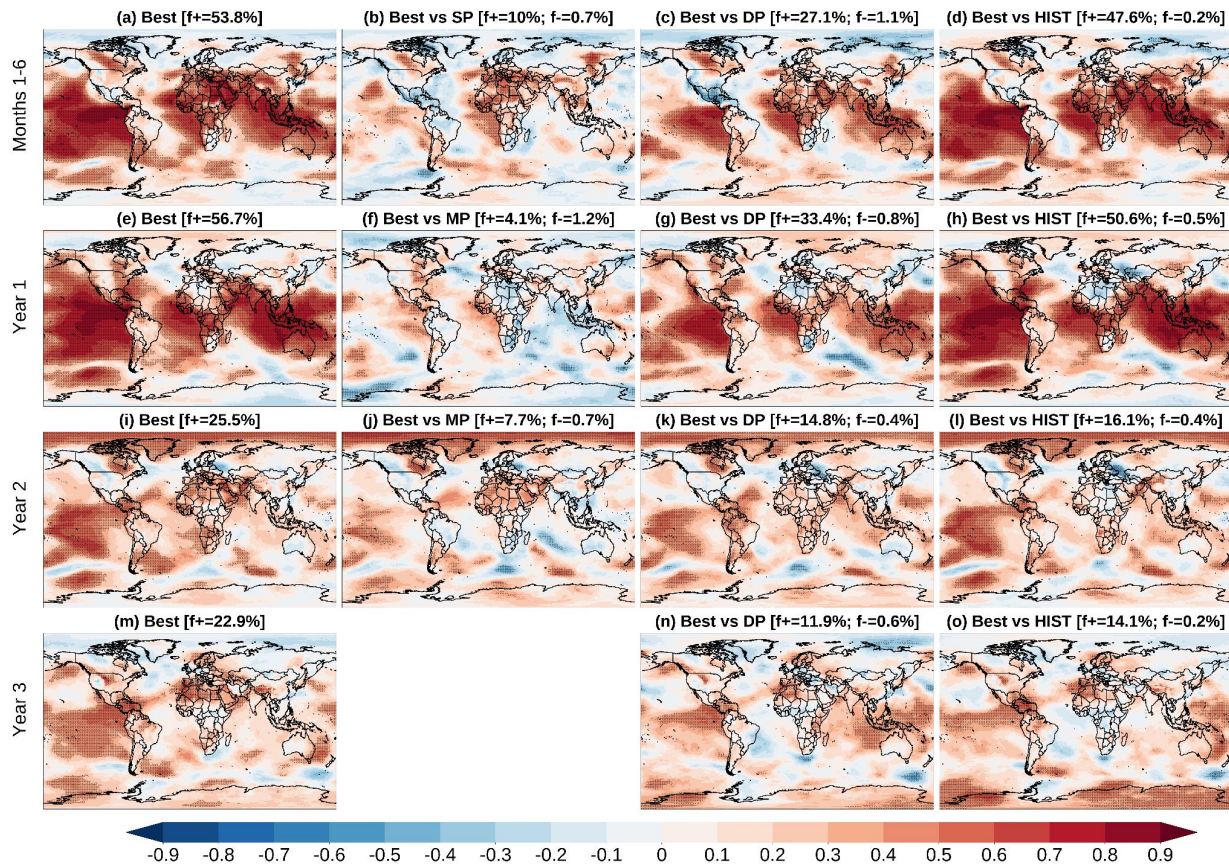
Skill for near-surface air temperature (May init)



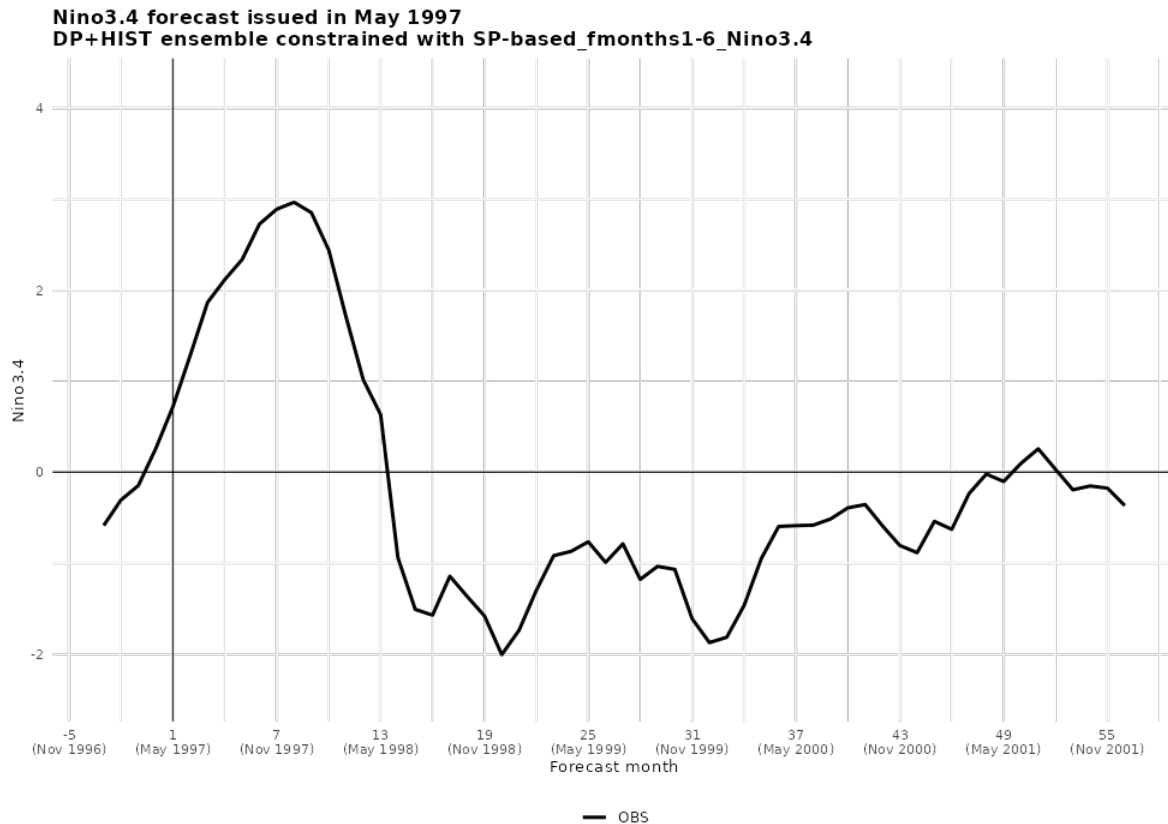
Skill for precipitation (May init)



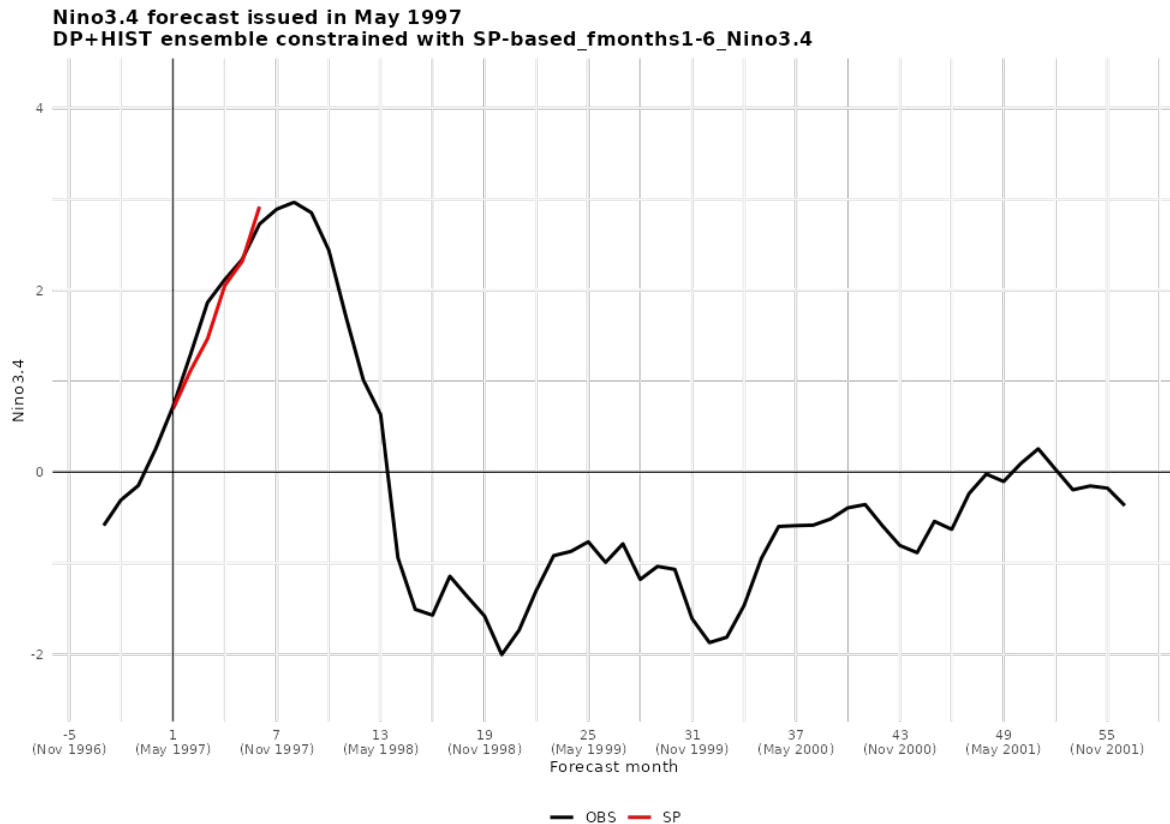
Skill for sea level pressure (May init)



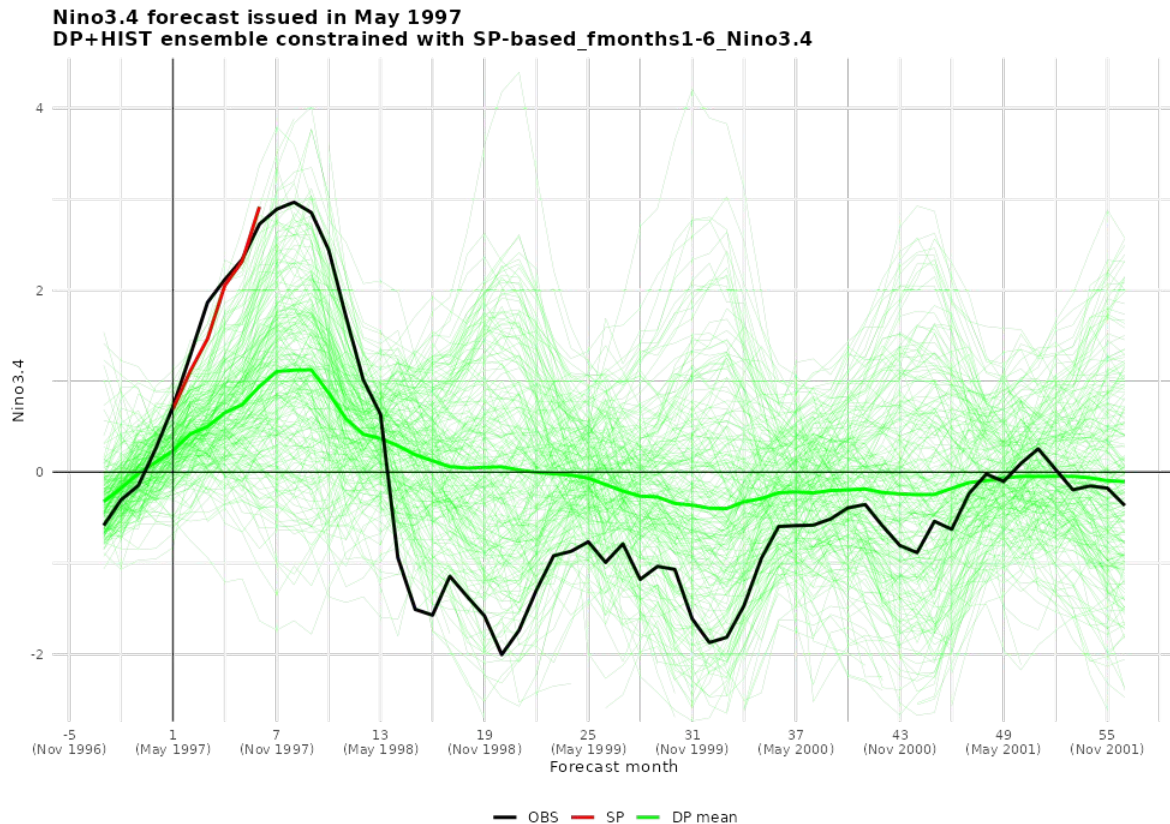
Seamless ENSO forecast (May 1997)



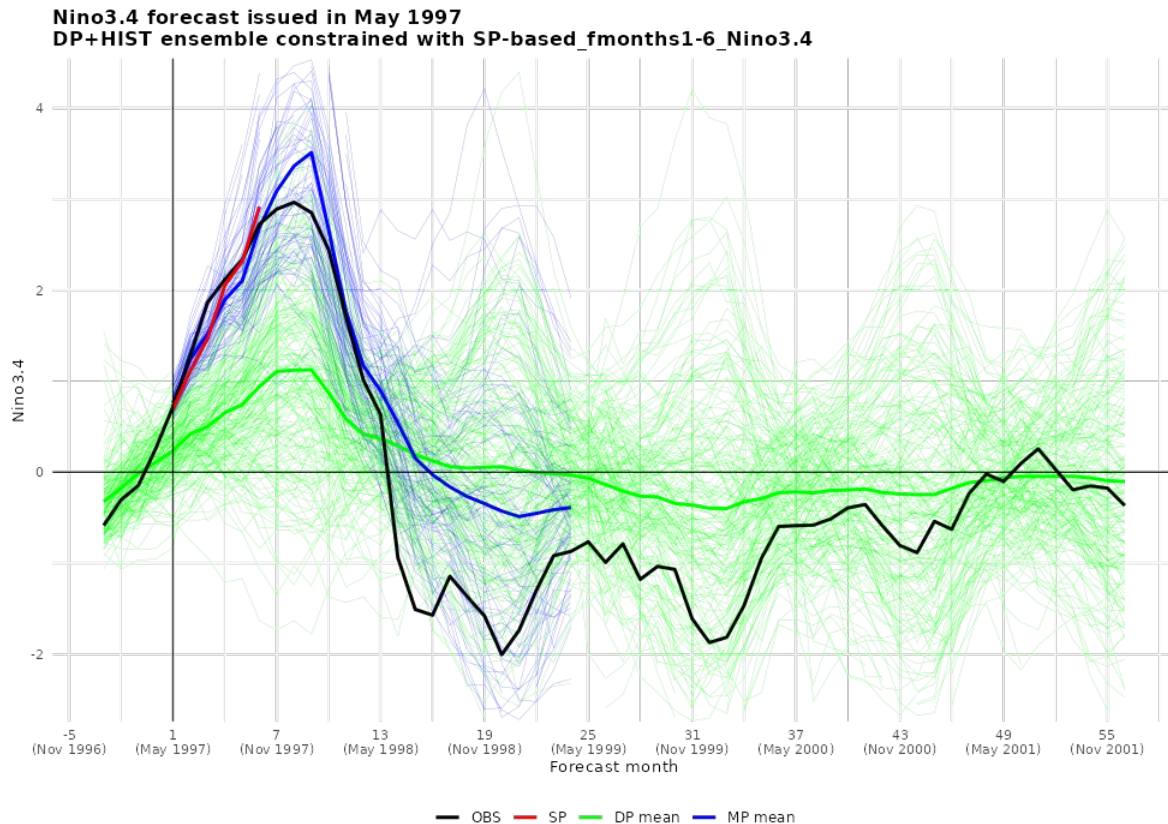
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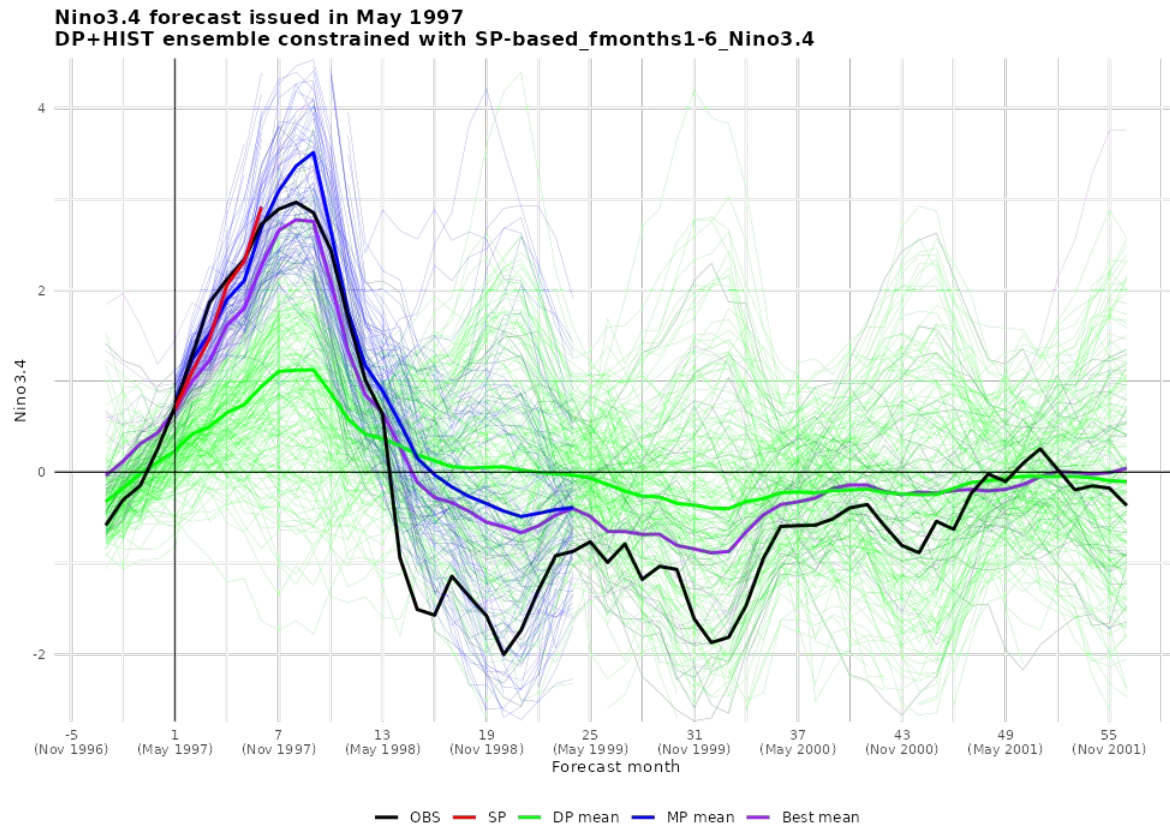
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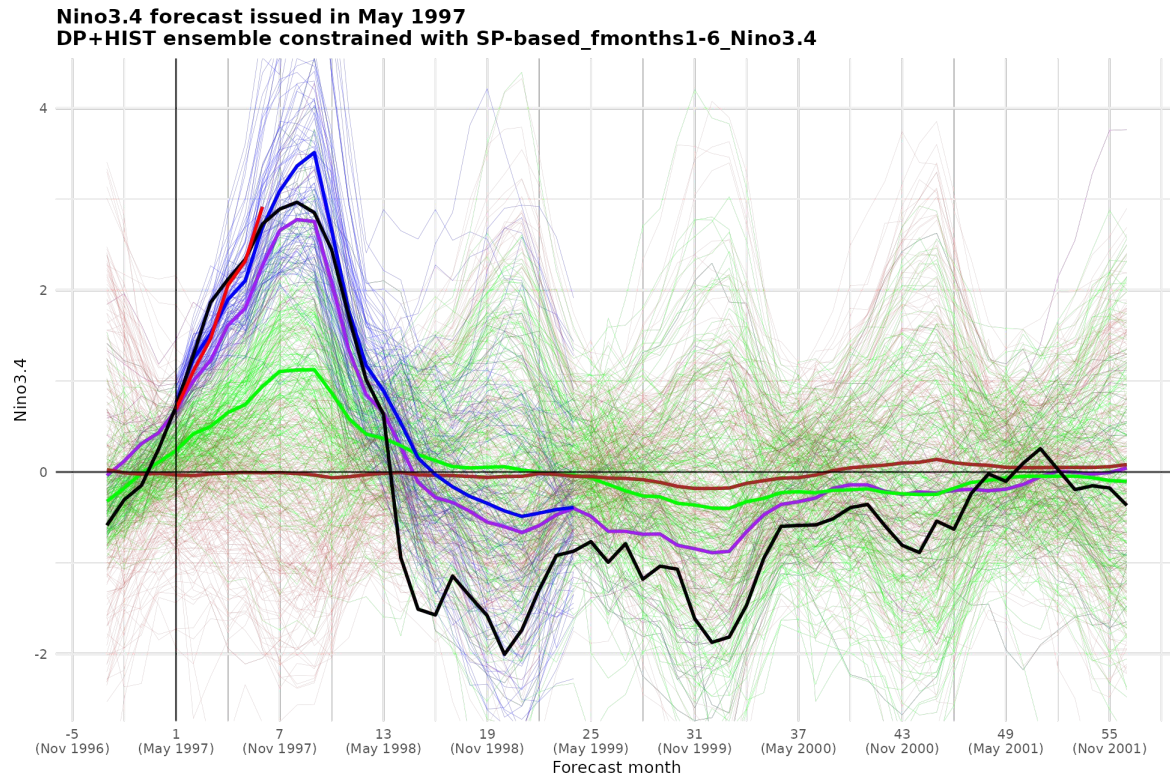
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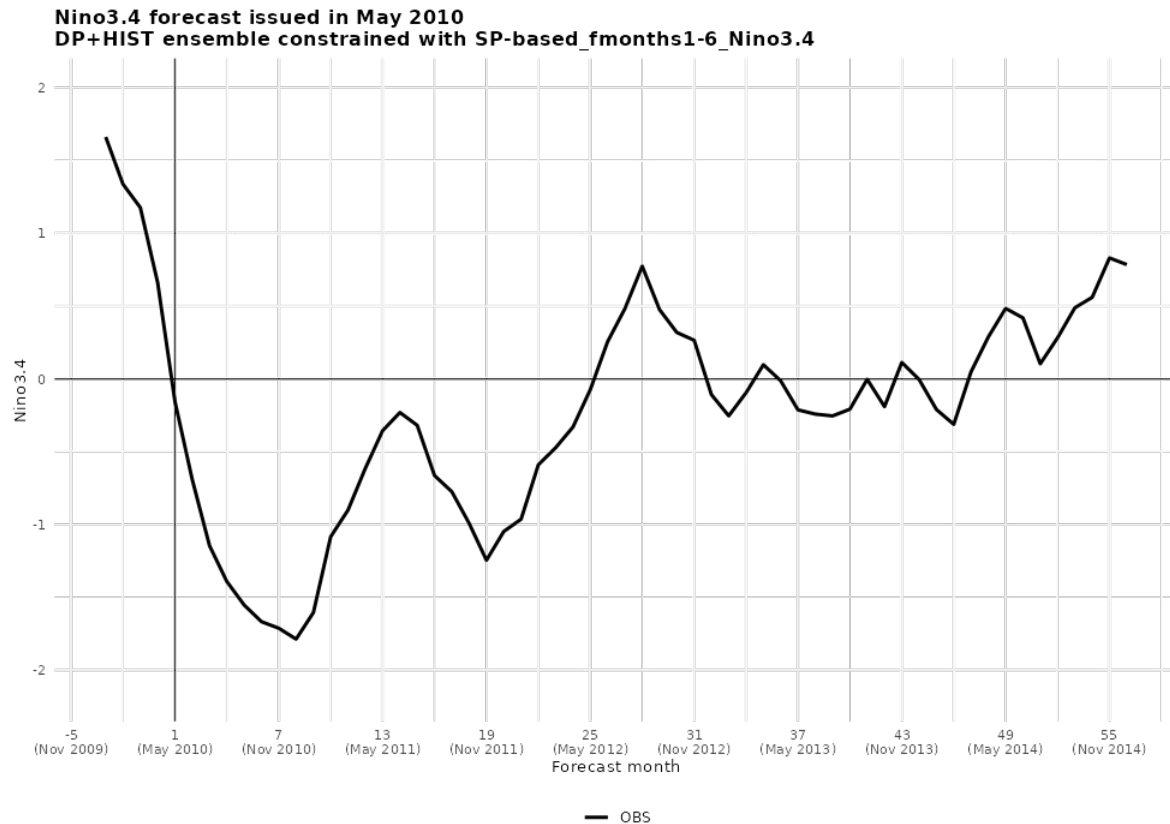
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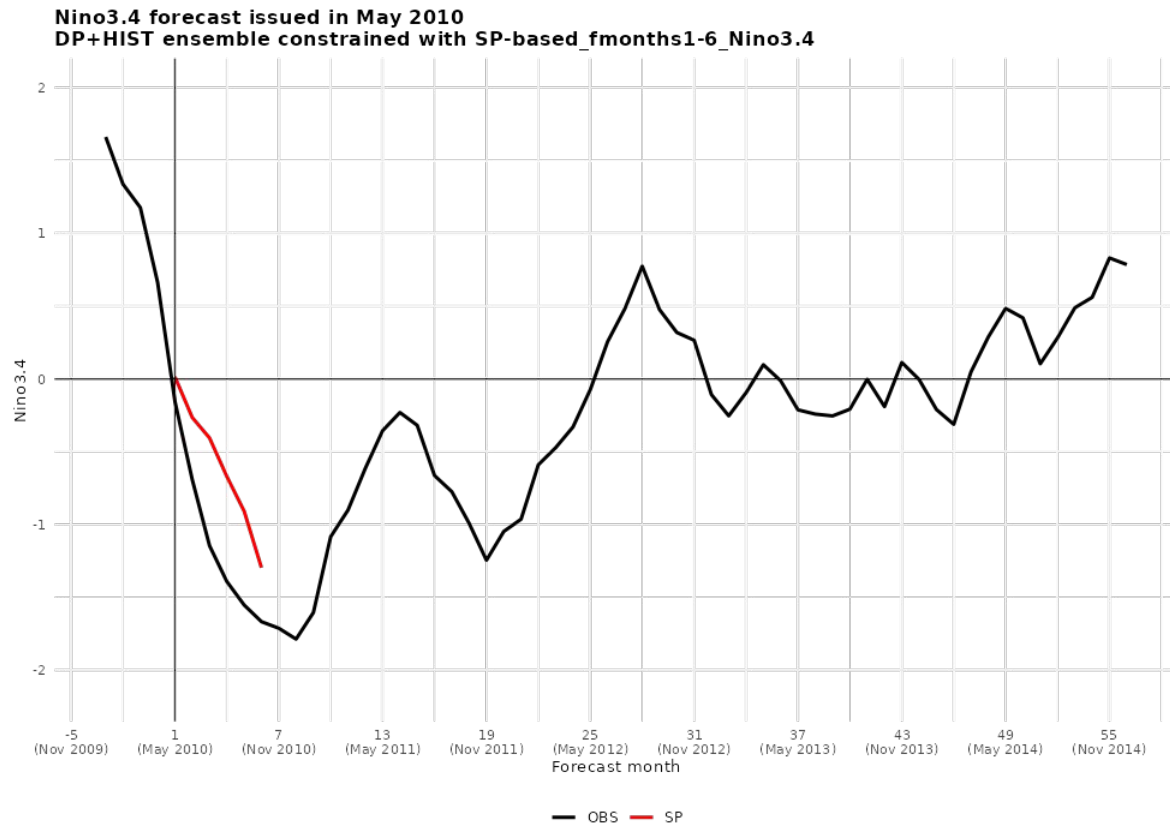
Seamless ENSO forecast (May 1997)



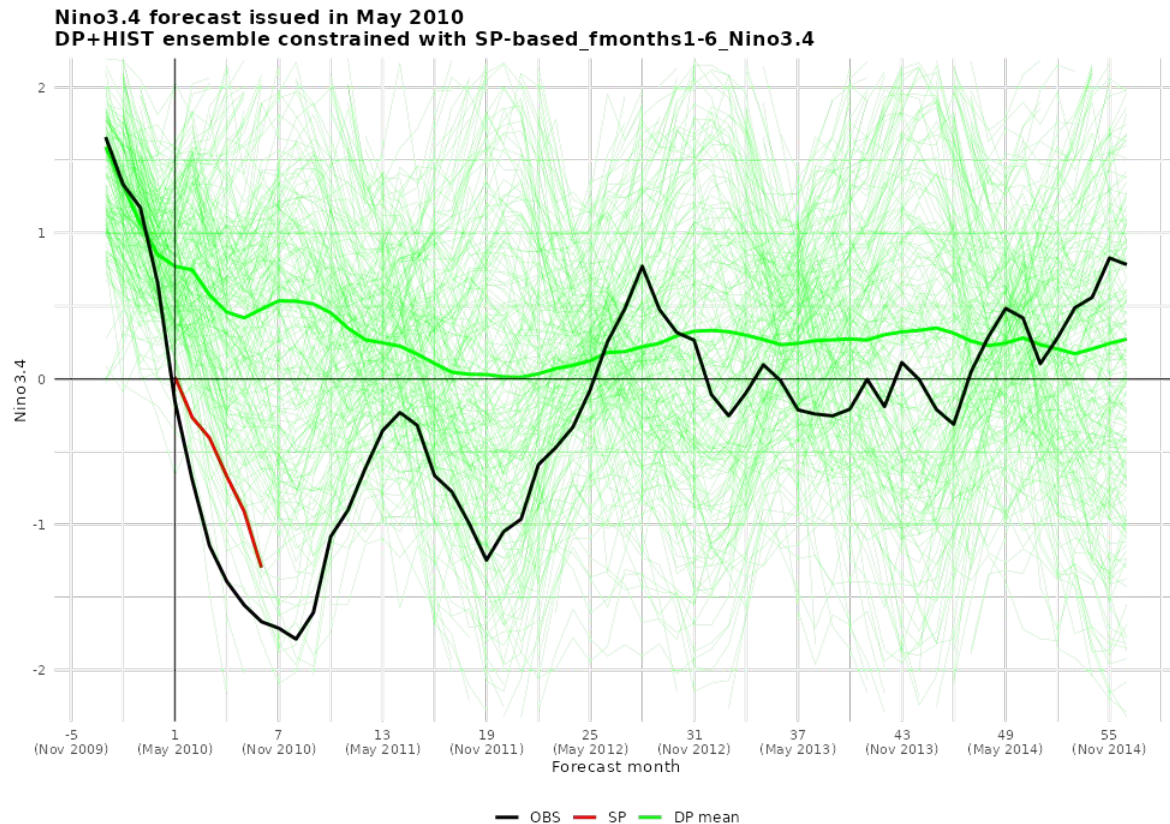
Seamless ENSO forecast (May 2010)



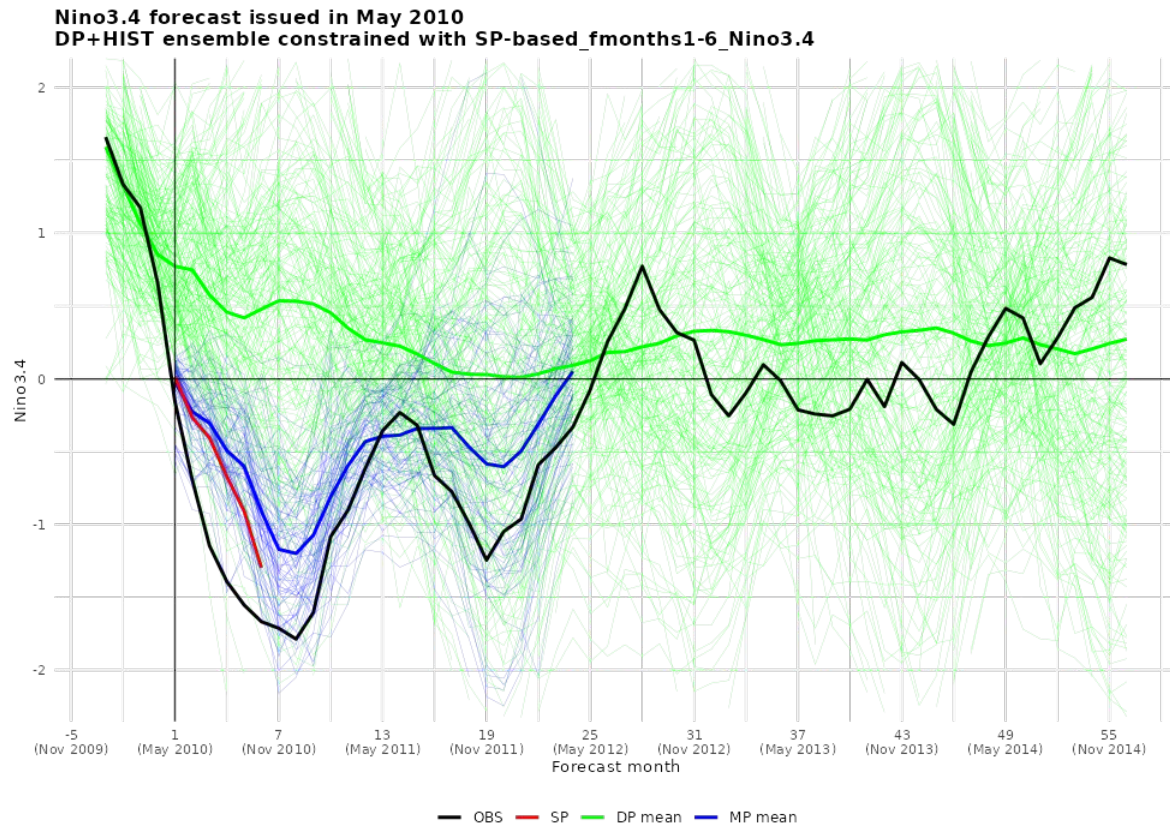
Seamless ENSO forecast (May 2010)



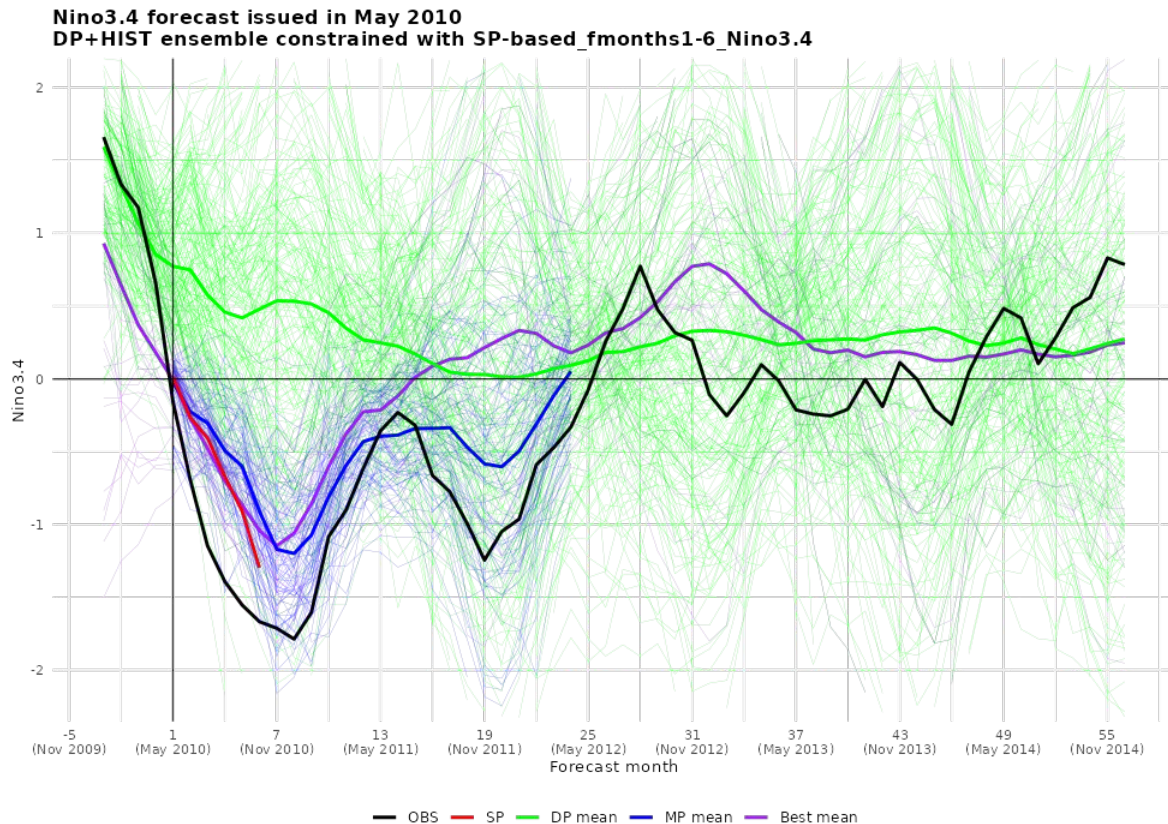
Seamless ENSO forecast (May 2010)



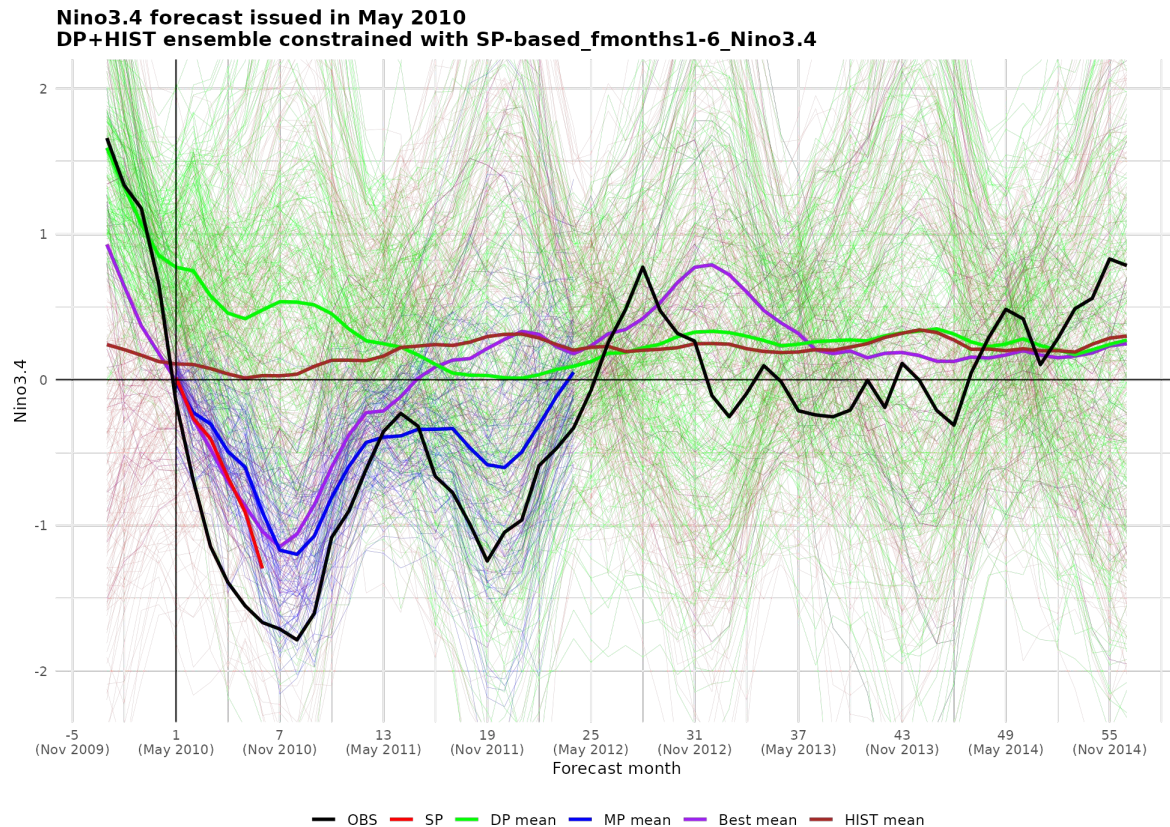
Seamless ENSO forecast (May 2010)



Seamless ENSO forecast (May 2010)



Seamless ENSO forecast (May 2010)



Conclusions

- **SP-based constraints** show higher skill than OBS-based constraints
- Initialised **MP represents the upper bound of skill** achievable by the constraining approaches
- MP are not typically produced in real-time, so **constraining approaches offer a cheap alternative** (with slightly lower skill) for operational forecasts
- **Selecting only DP members provides the highest skill** (compared to selecting HIST or DP+HIST members). However, DP availability is lower in real-time, requiring the inclusion of HIST members
→ **trade-off between forecast skill and operational feasibility**
- During the overlapping period, constrained predictions are as skillful as SP, which suggests that the **constrained predictions can be used since the beginning of the forecast period** (using SP to select the best members)
- Constraining approaches **not only improve skill, but also ensures consistency** during the transition between timescales
- The **method can be optimised** for specific variables and regions



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the European Union

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PID2022-140673OA-I00.

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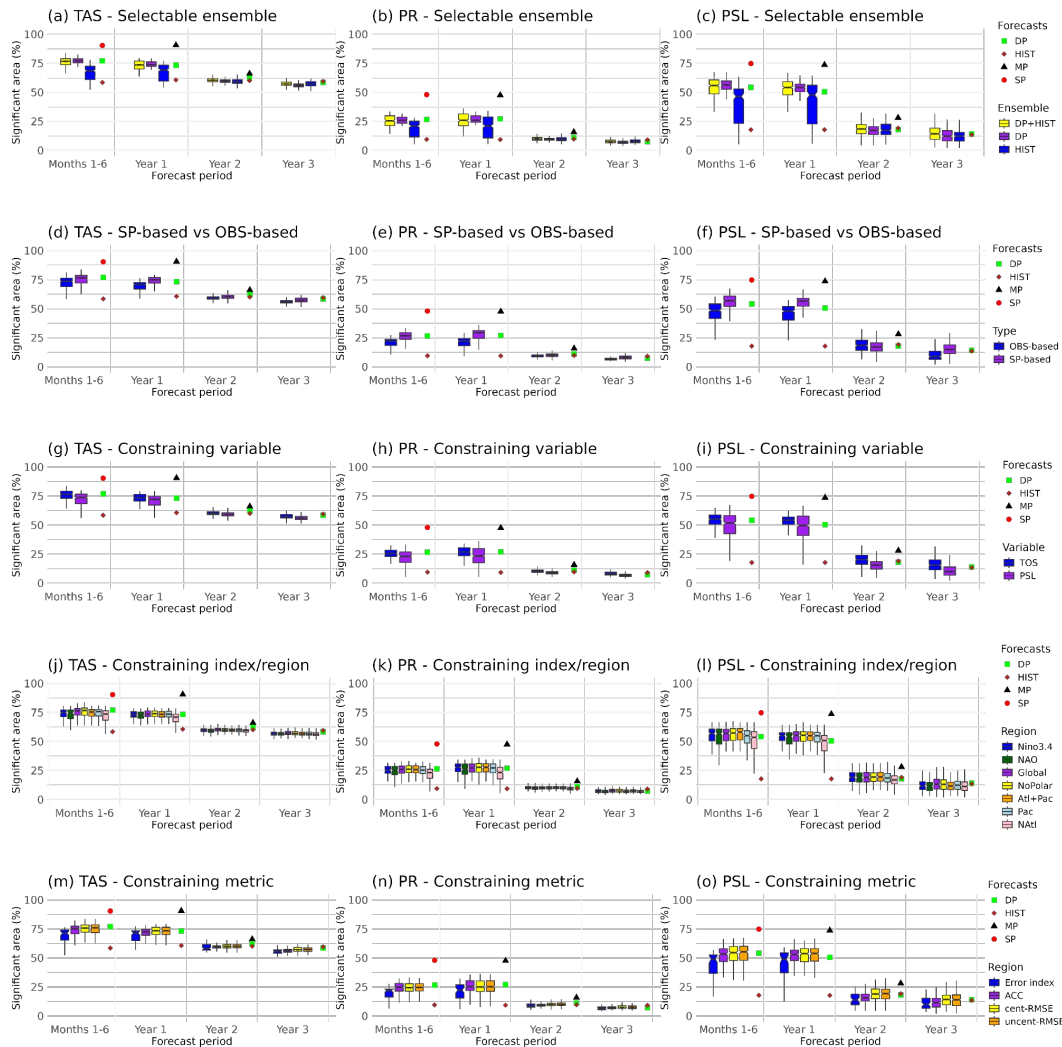


Thank you!

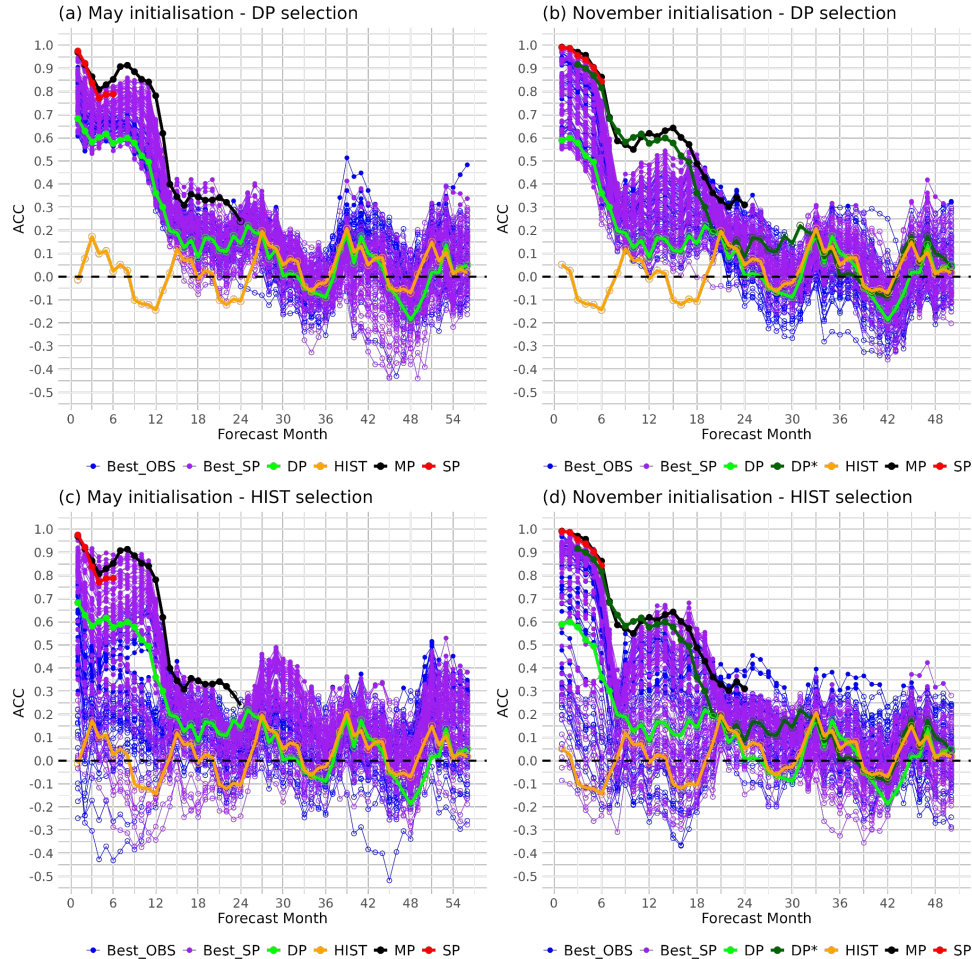
Delgado-Torres, C., Donat, M. G., Pérez-Zanón, N., Torralba, V., Bilbao, R., Bretonnière, P.-A., Samsó-Cabré, M., Soret, A., and Doblas-Reyes, F. J.: Seamless climate information for the next months to multiple years: merging of seasonal and decadal predictions, and their comparison to multi-annual predictions, EGUsphere [preprint], <https://doi.org/10.5194/egusphere-2025-3674>, 2025.

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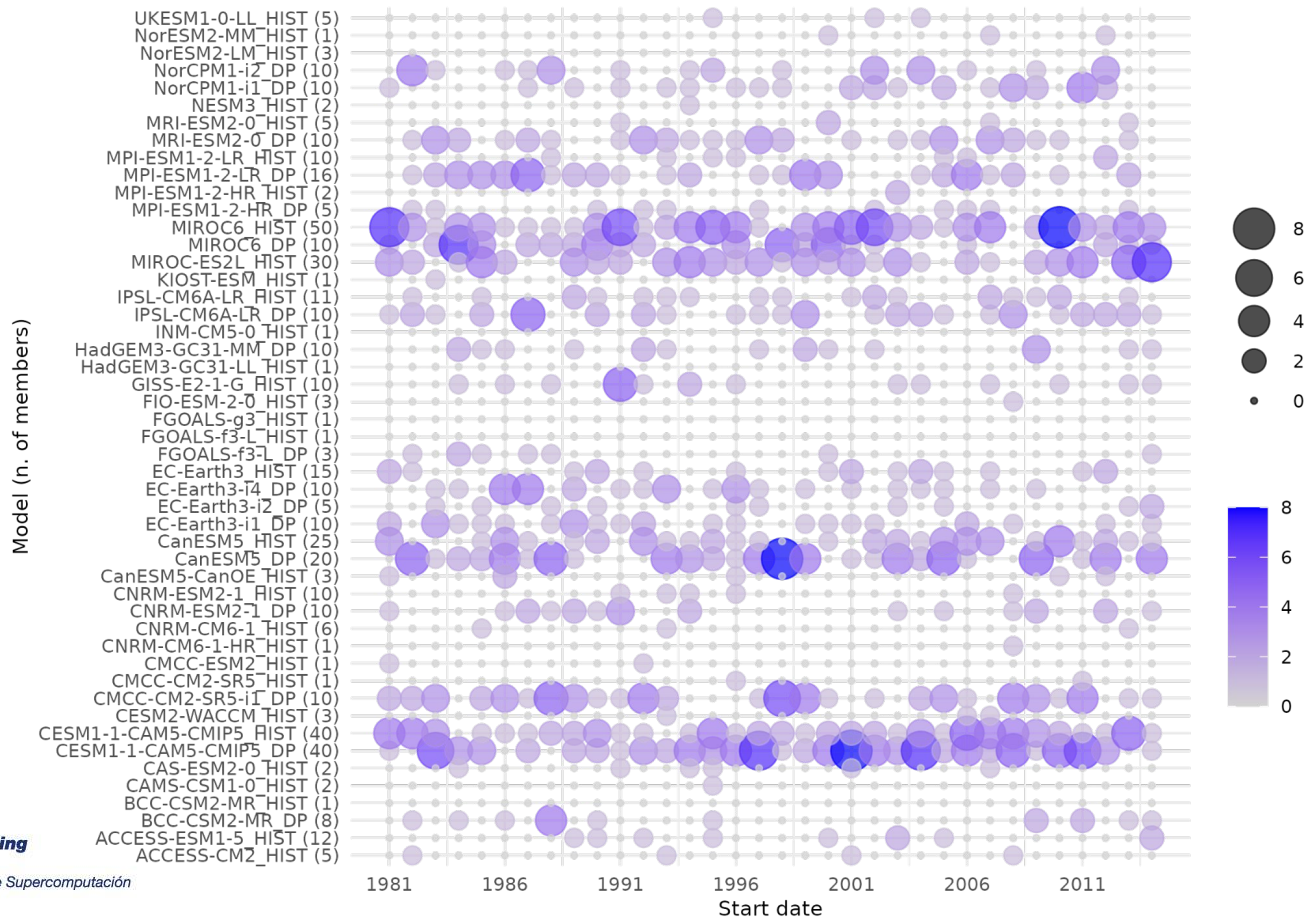
Sensitivity analysis to different constraining options



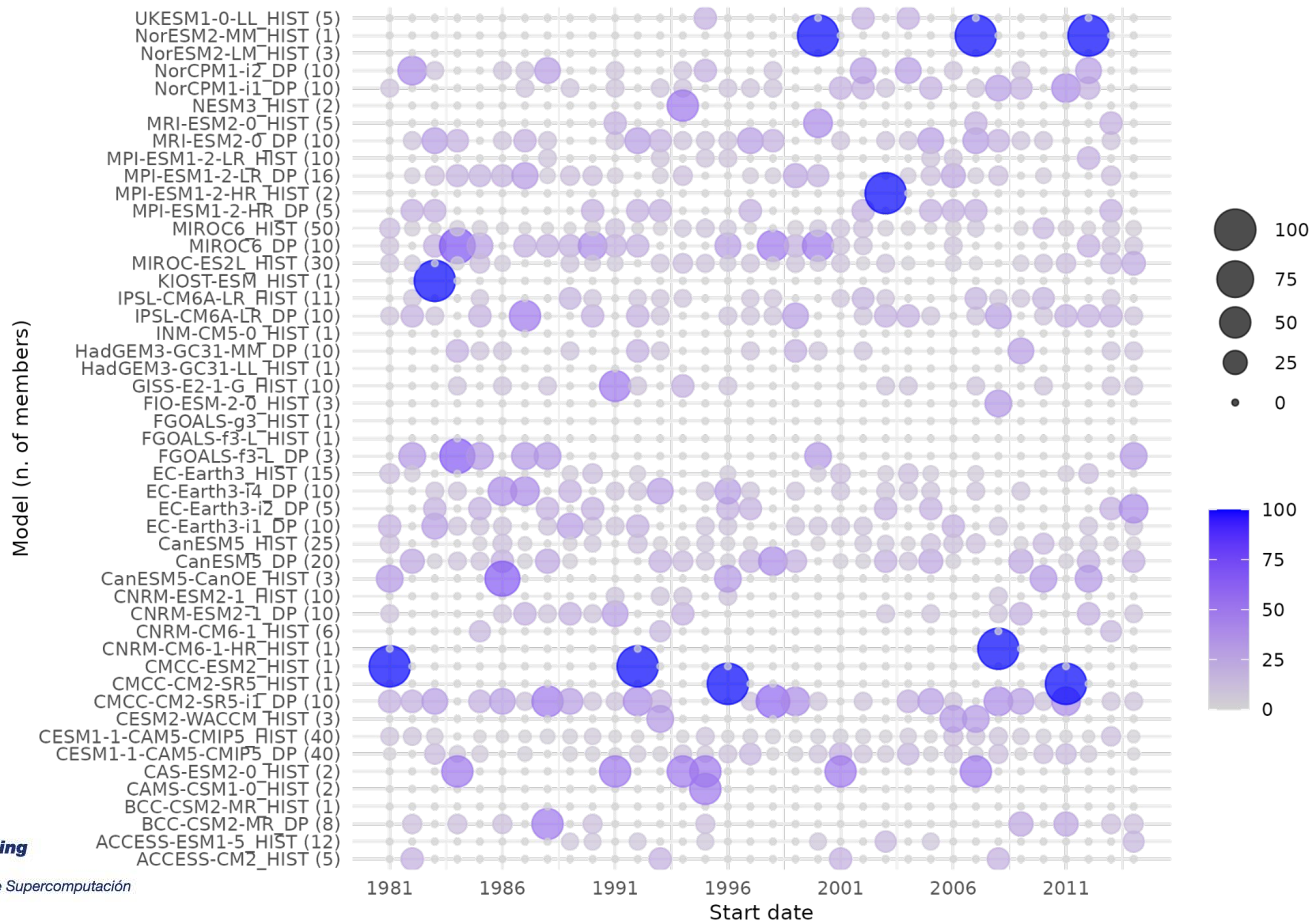
DP vs HIST selection



Number of selected members

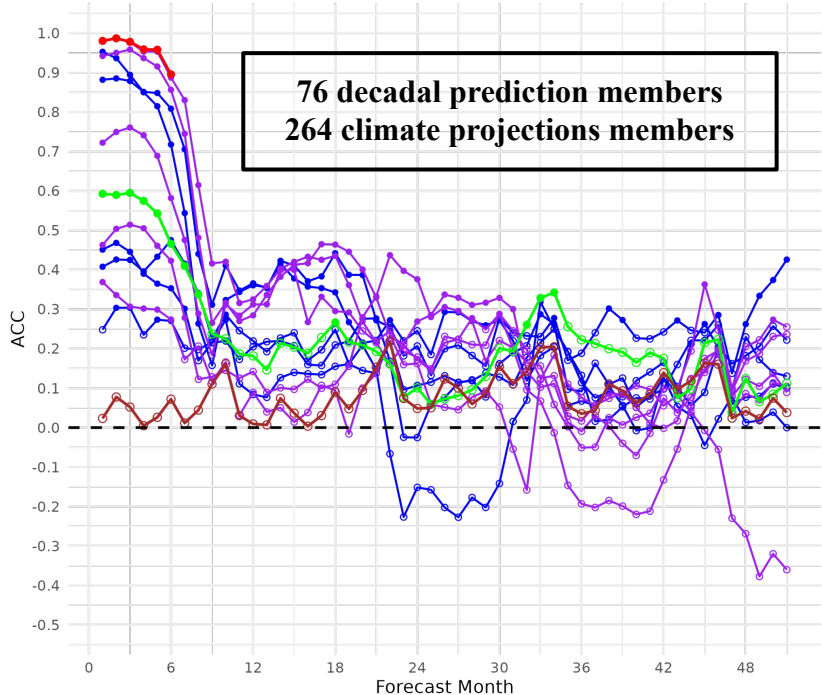


Percentage of selected members

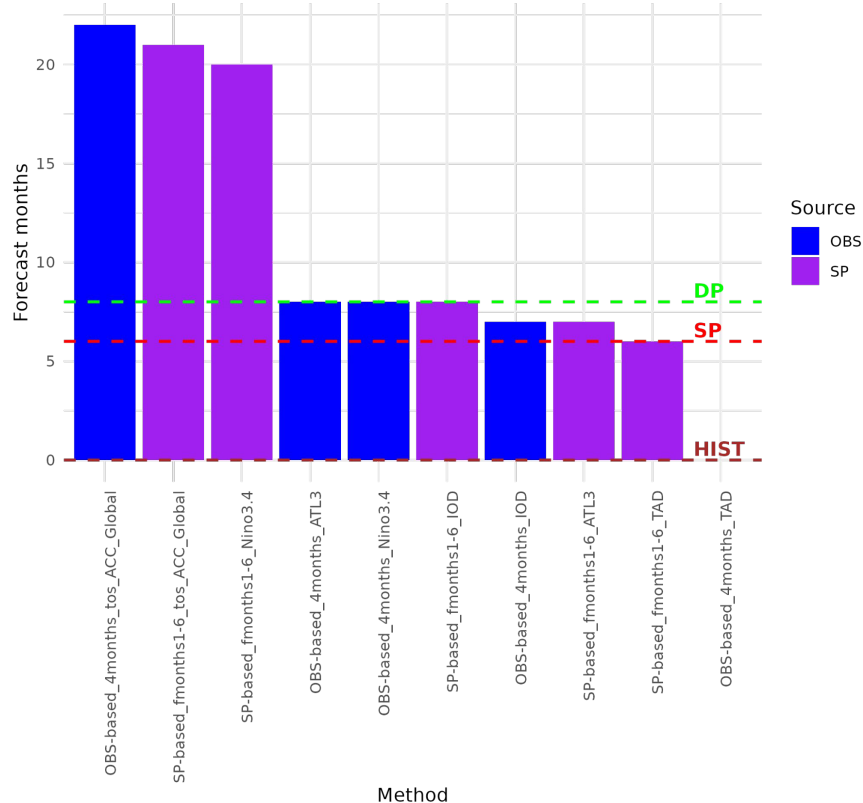


“Real-time” seamless forecast (Oct 2025)

ACC for Nino3.4; constrained with spatial ACC
Start month: 10; Period: full; Moving months: 1



Top methods by consecutive positive significance
ACC for Nino3.4; Start month: 10; Period: full; Moving months: 1

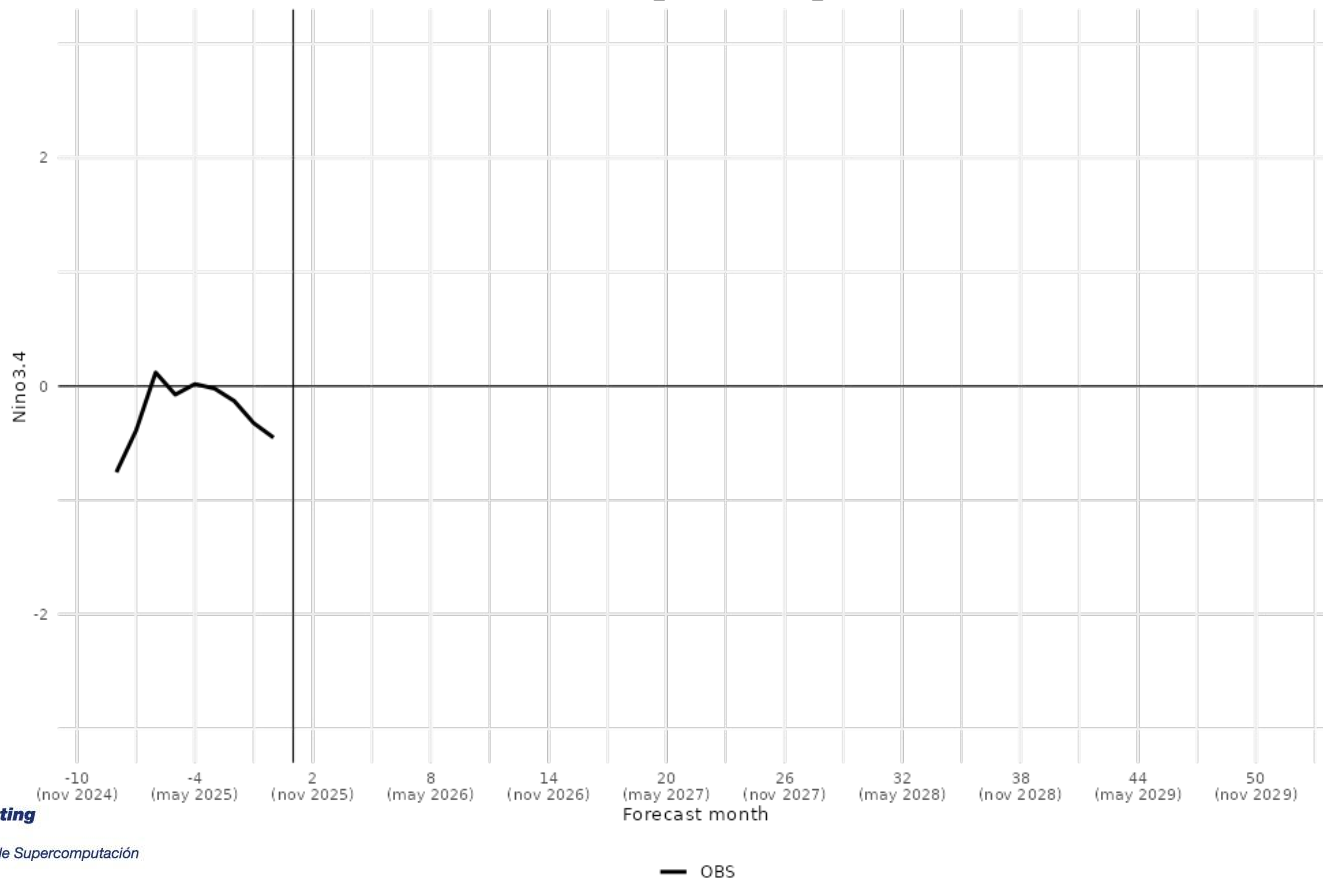


Ensemble: Best_OBS Best_SP DP HIST SP Significant: TRUE FA

“Real-time” seamless forecast (Oct 2025)

Nino3.4 forecast issued in October 2025

DP+HIST ensemble constrained with SP-based_fmmonths1-6_Nino3.4



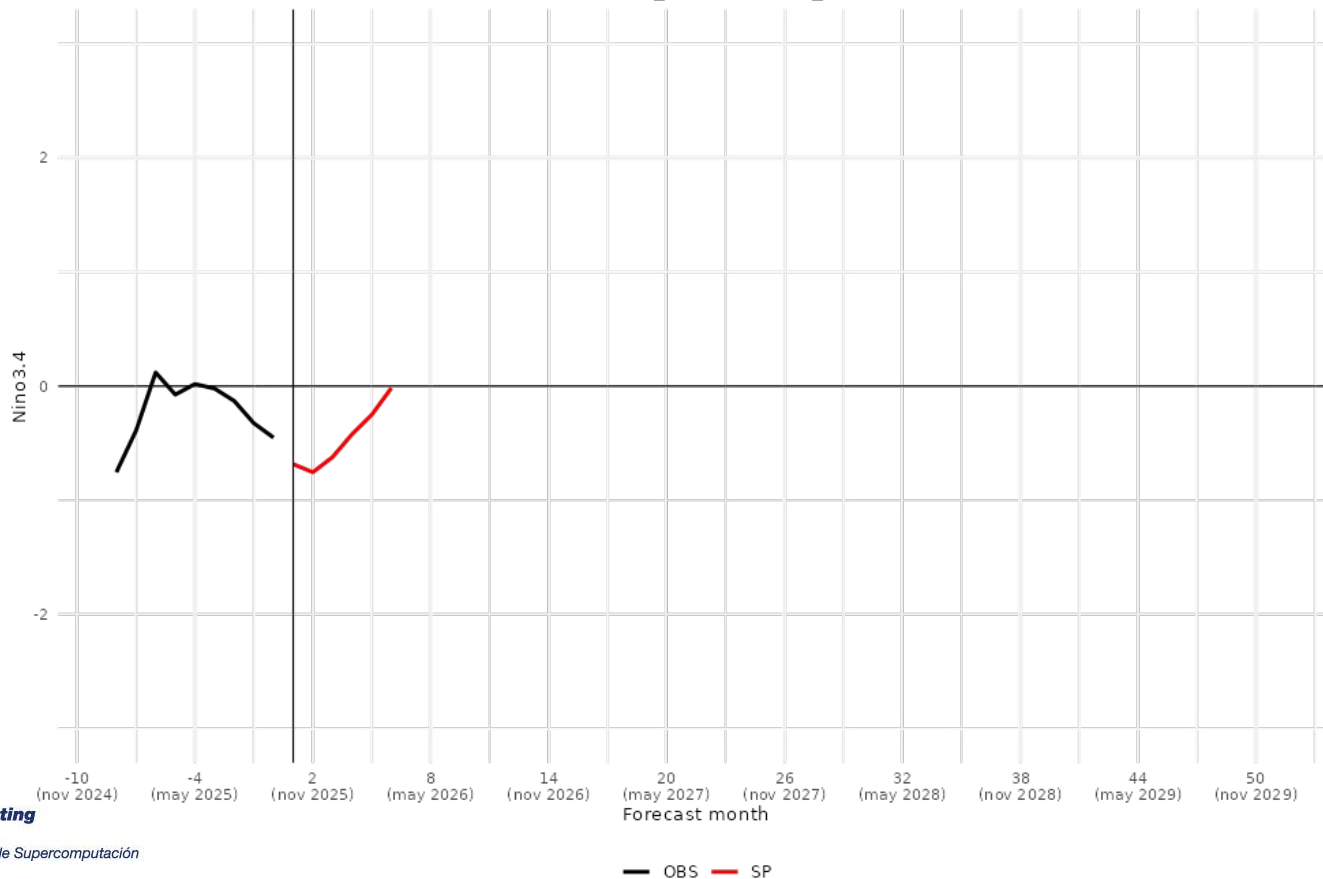
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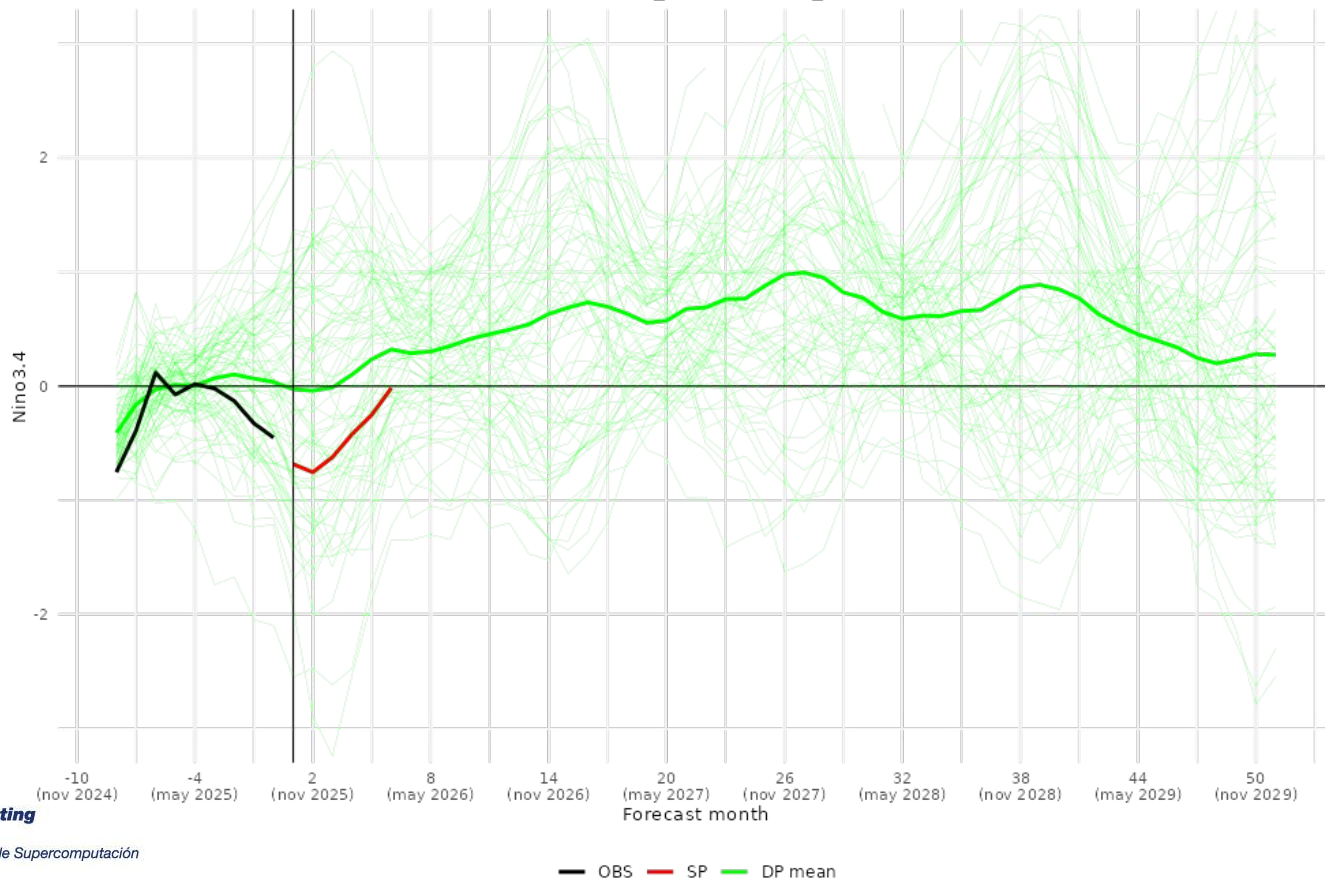
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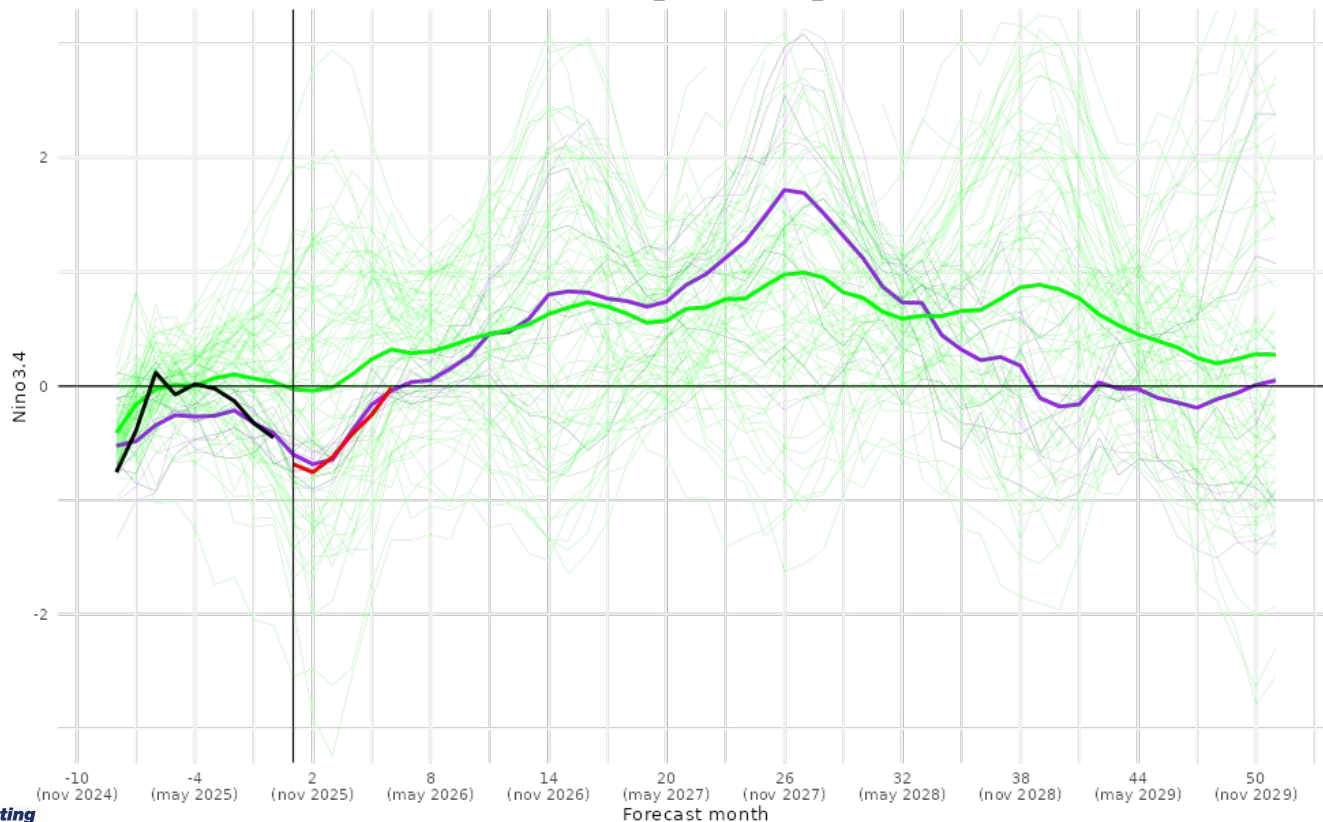
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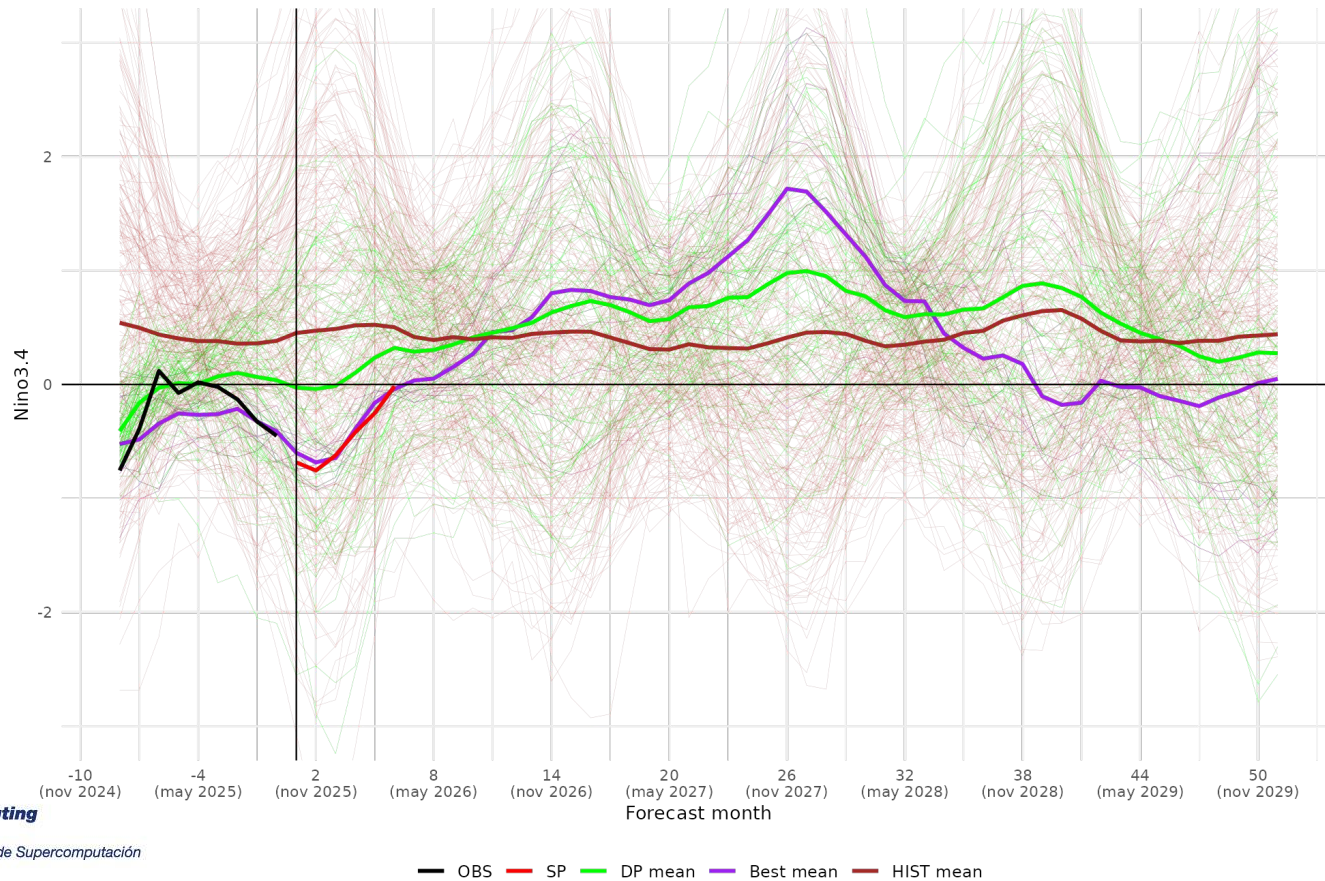
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— OBS — SP — DP mean — Best mean

“Real-time” seamless forecast (Oct 2025)

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