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Centro Nacional de Supercomputación



Seamless climate information from months to multiple years: constraining decadal predictions with seasonal predictions and past observations, and their comparison to multi-annual predictions

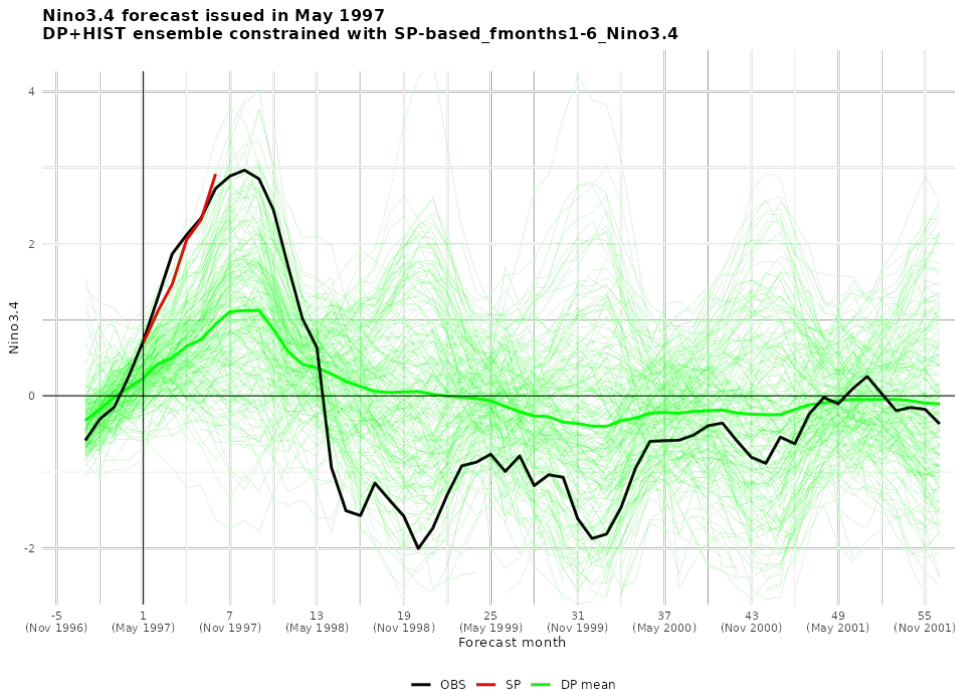
Carlos Delgado-Torres, Markus G. Donat, Núria Pérez-Zanón, Verónica Torralba, Roberto Bilbao, Pierre-Antoine Bretonnière, Margarida Samsó-Cabré, Albert Soret, and Francisco J. Doblas-Reyes

**S2S2D Conference
Reading, September 2026**

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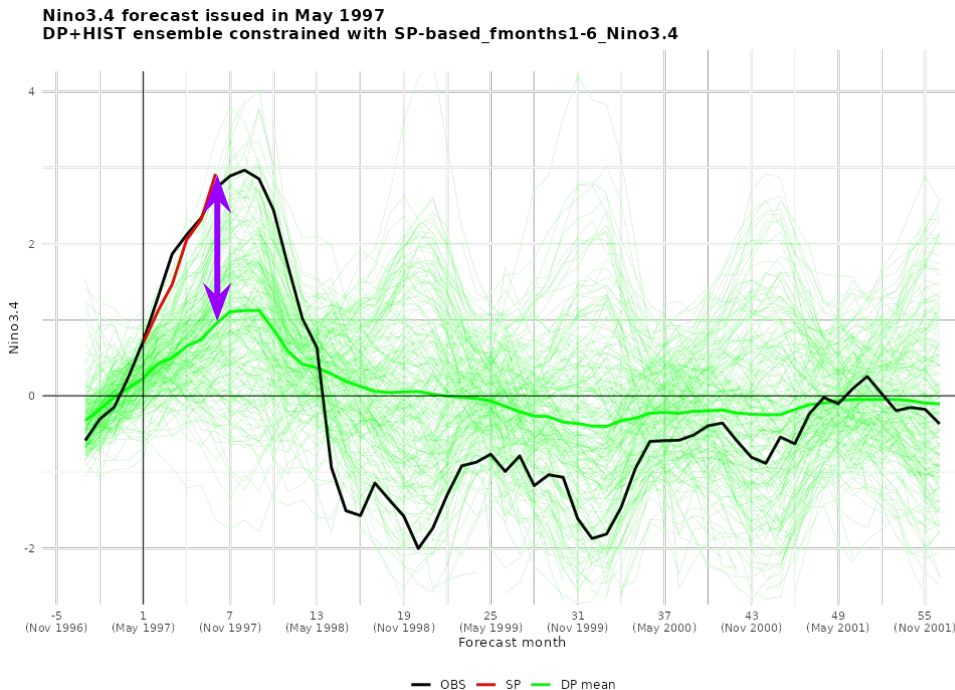
Motivation

- 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

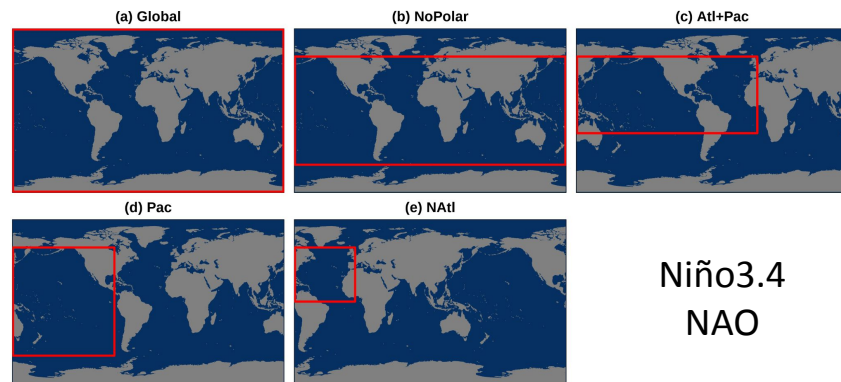
Data

Climate projections (hist+ssp245)

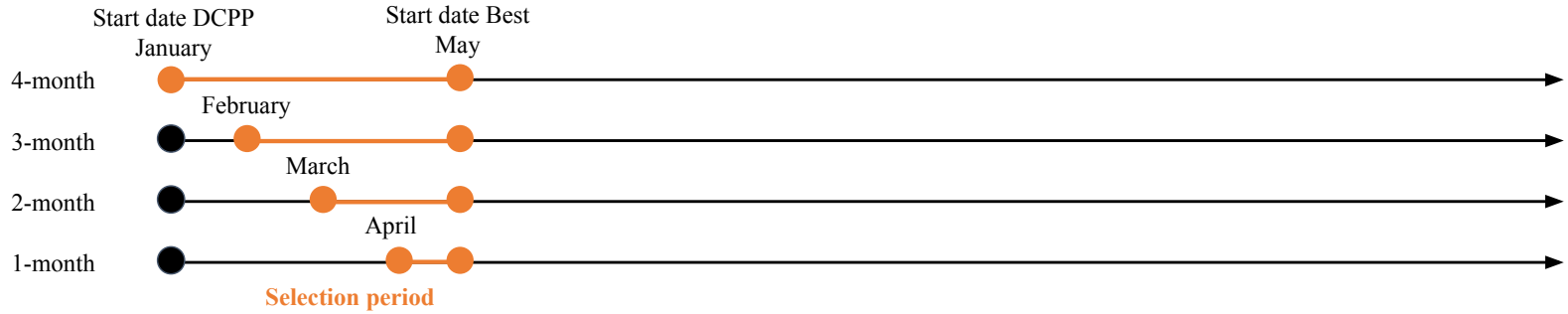
Total members	N	Climate model	Ensemble members	N	Climate model	Ensemble members
264	1	ACCESS-CM2	r1-5ilp1fl	17	FGOALS-g3	r4ilp1fl
	2	ACCESS-ESM1-5	r1-12ilp1fl	18	FIO-ESM-2-0	r1-3ilp1fl
	3	BCC-CSM2-MR	r1ilp1fl	19	GISS-E2-1-G	r1-10ilp1f2
	4	CAMS-CSM1-0	r1-2ilp1fl	20	HadGEM3-GC3.1-LL	r1ilp1f3
	5	CAS-ESM2-0	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

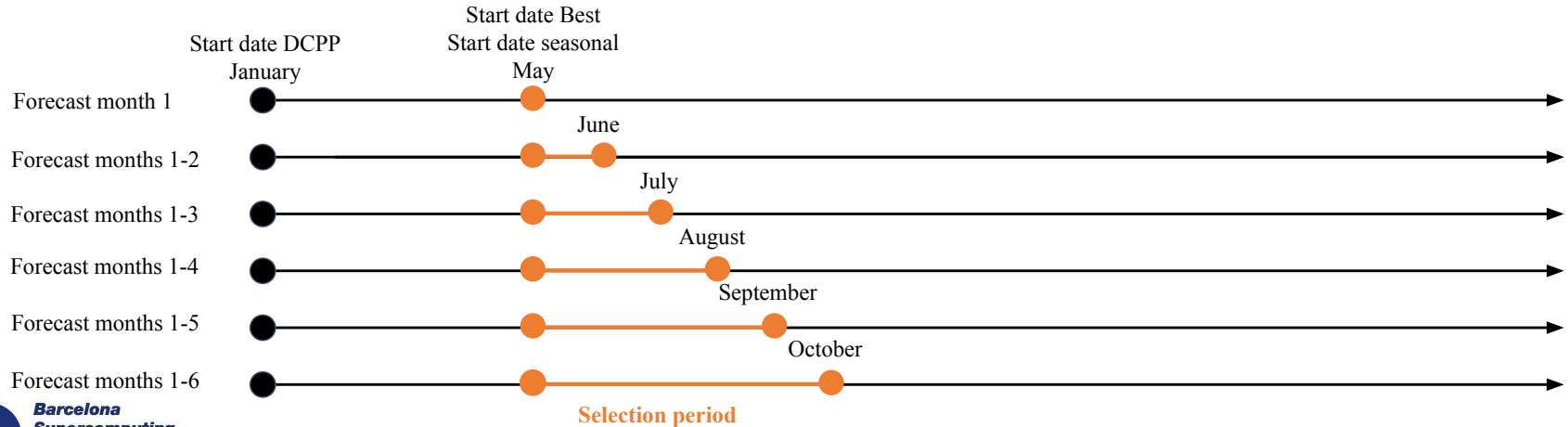
- Selecting the **best 30 members** from
 - decadal predictions (197 members from 17 models)
 - climate projections (264 members from 32 models)
- The selection is based on
 - **recent observations** (1-4 months)
 - **seasonal predictions** (SEAS5; forecast months 1-6)
- It can be **updated at any time 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



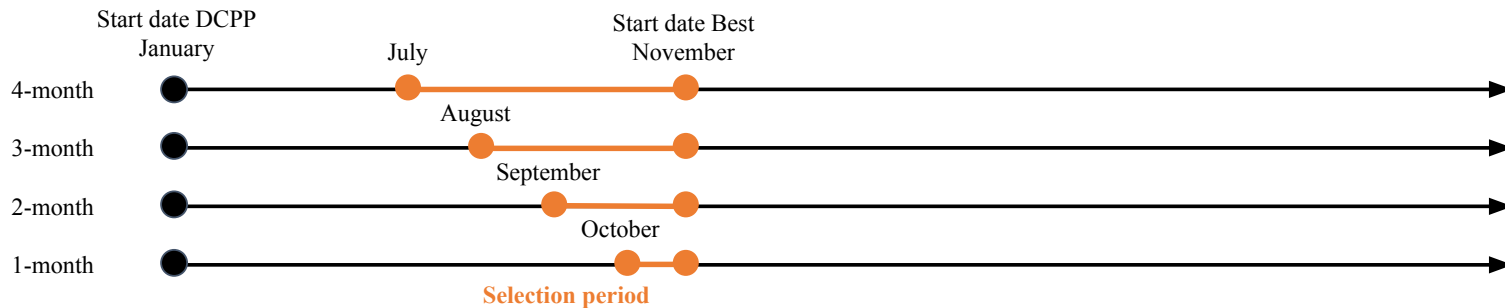
Based on recent observations (May)



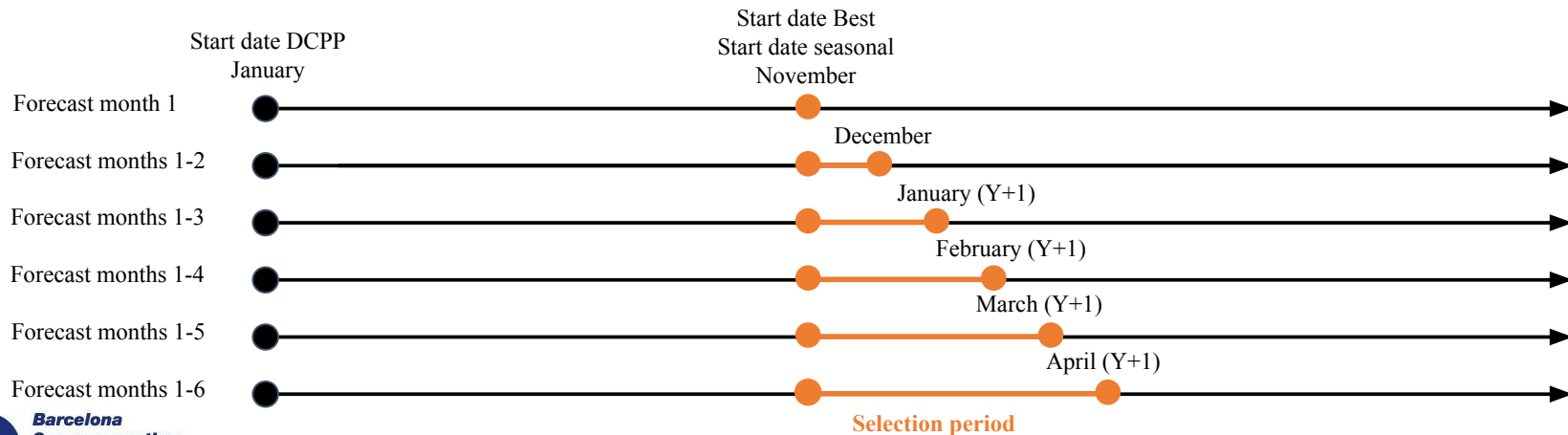
Based on seasonal predictions (May)



Based on recent observations (November)



Based on seasonal predictions (November)



Initialised multi-annual predictions

Start date multi-annual
May

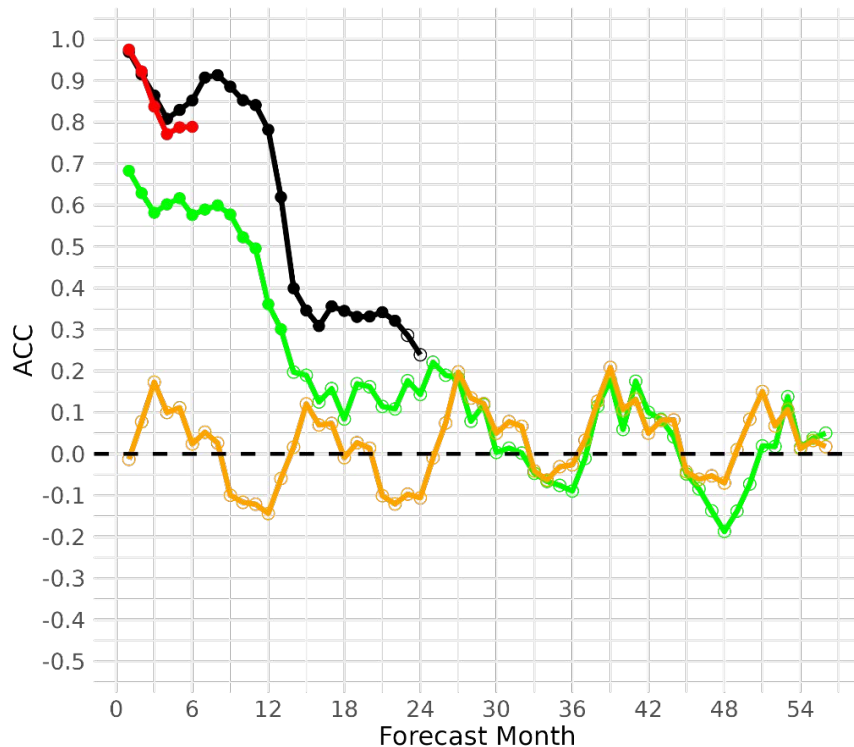


Start date multi-annual
Nov

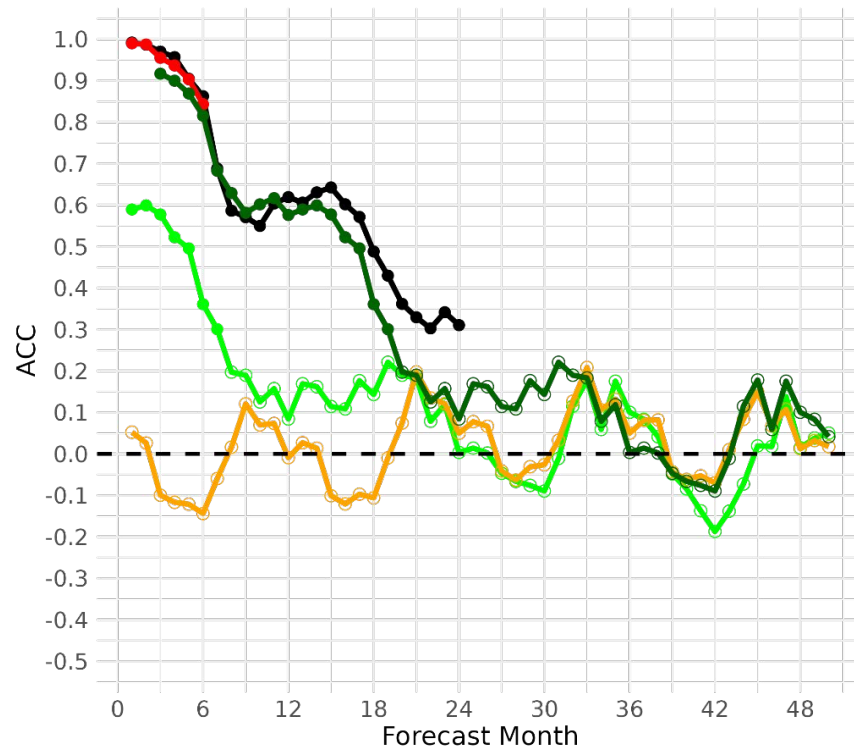


Skill for Niño3.4

(a) May initialisation



(b) November initialisation

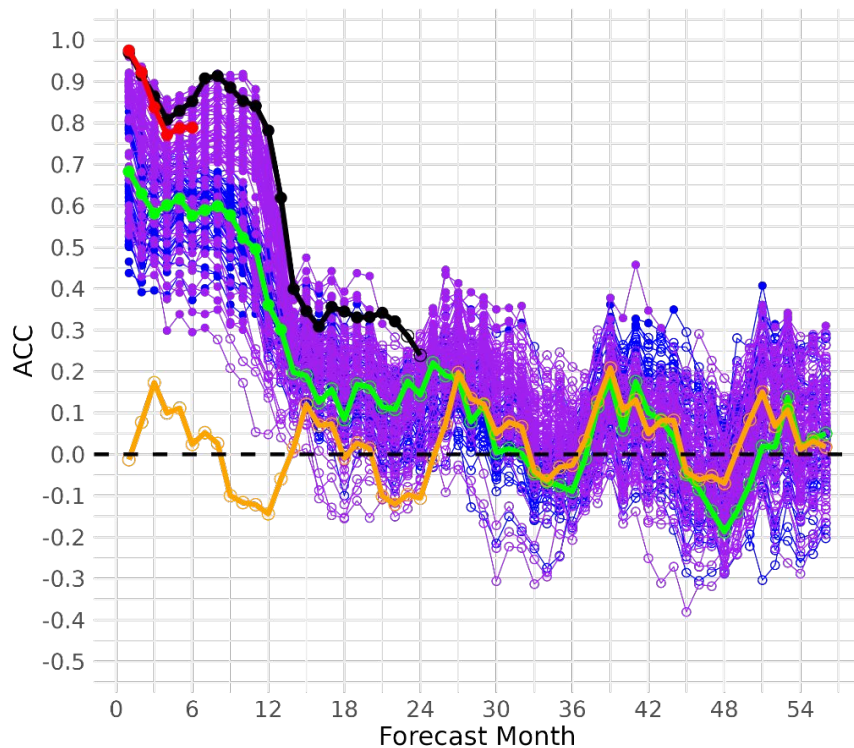


DP HIST MP SP

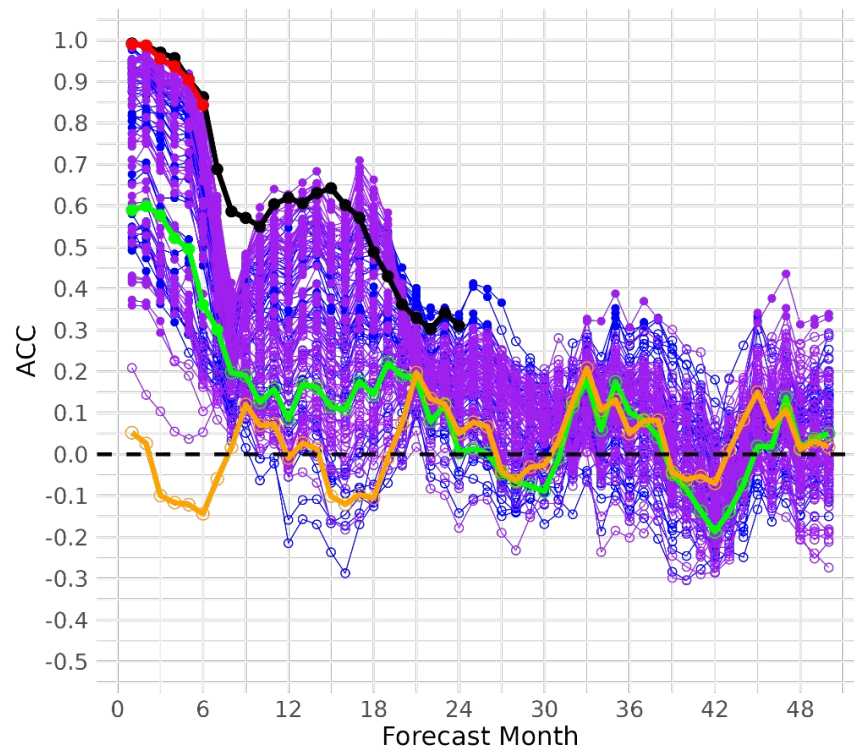
DP DP* HIST MP SP

Skill for Niño3.4

(a) May initialisation

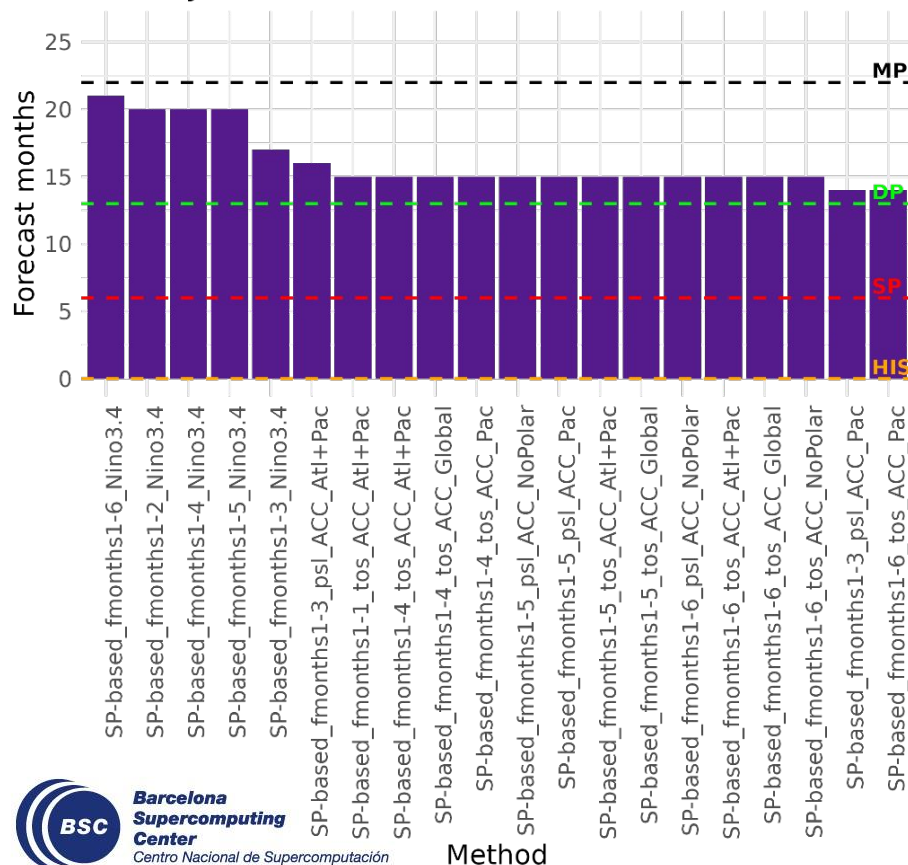


(b) November initialisation

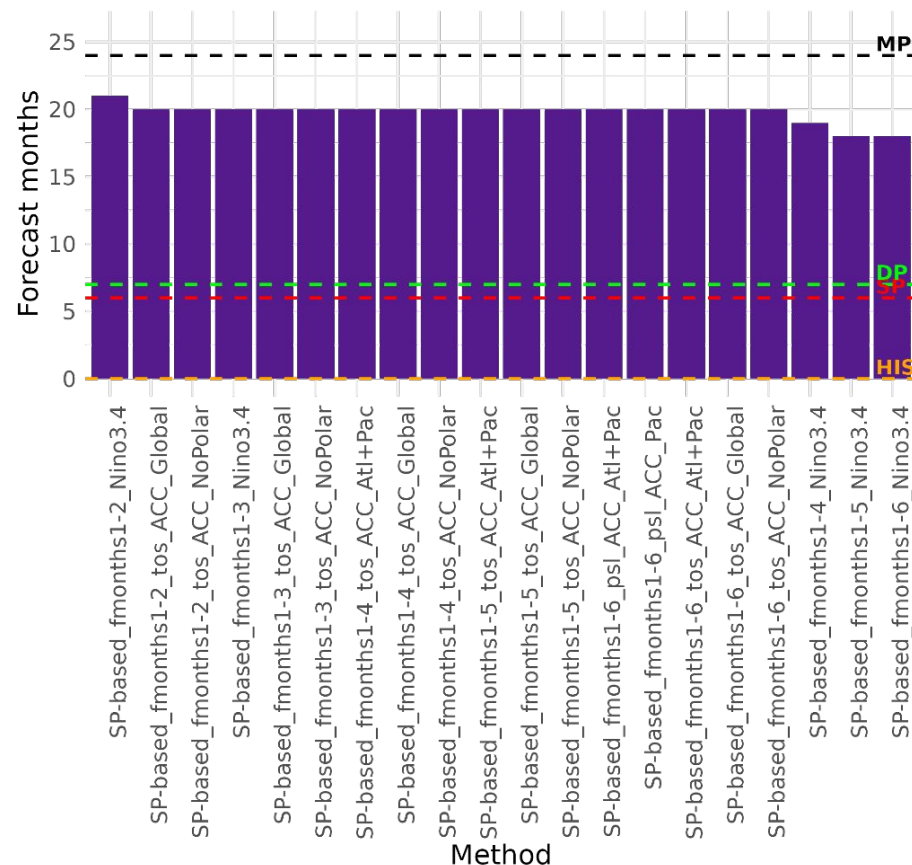


Top methods for Niño3.4

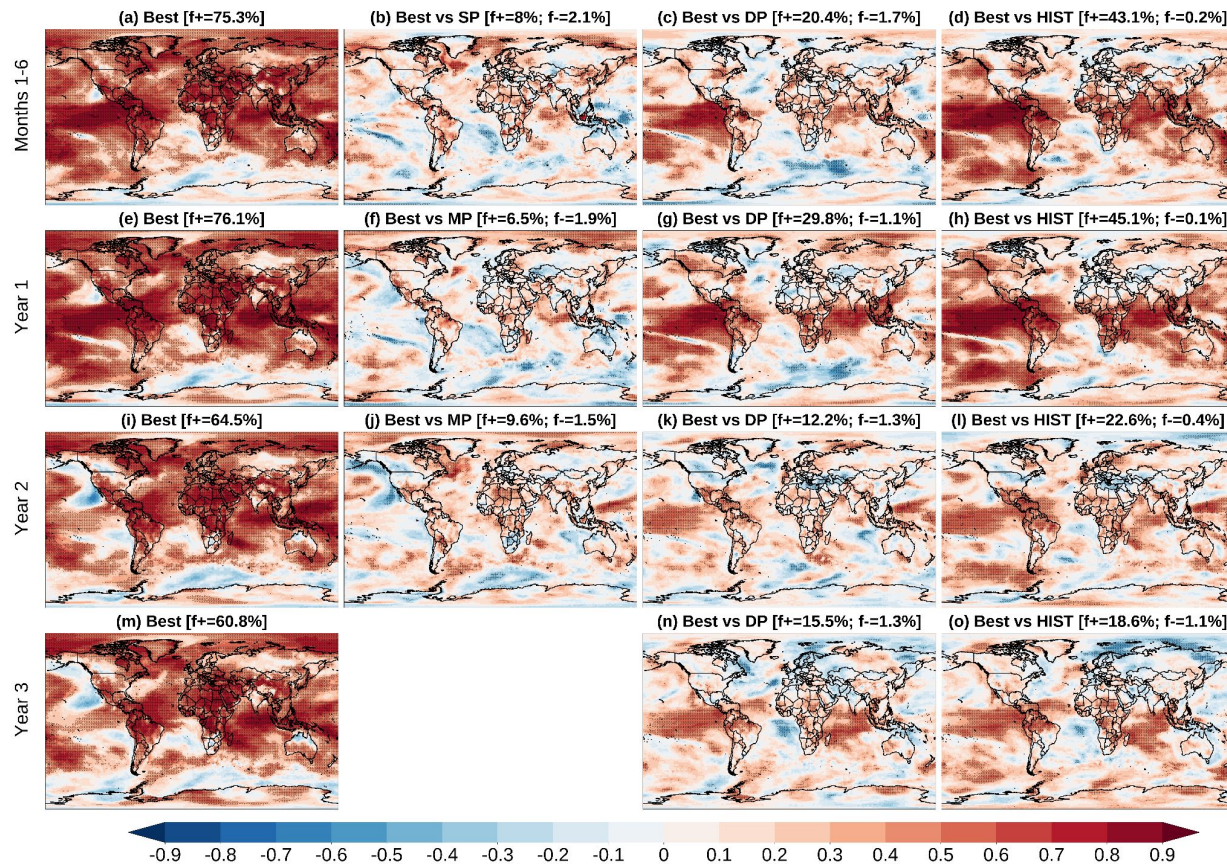
(a) May initialisation



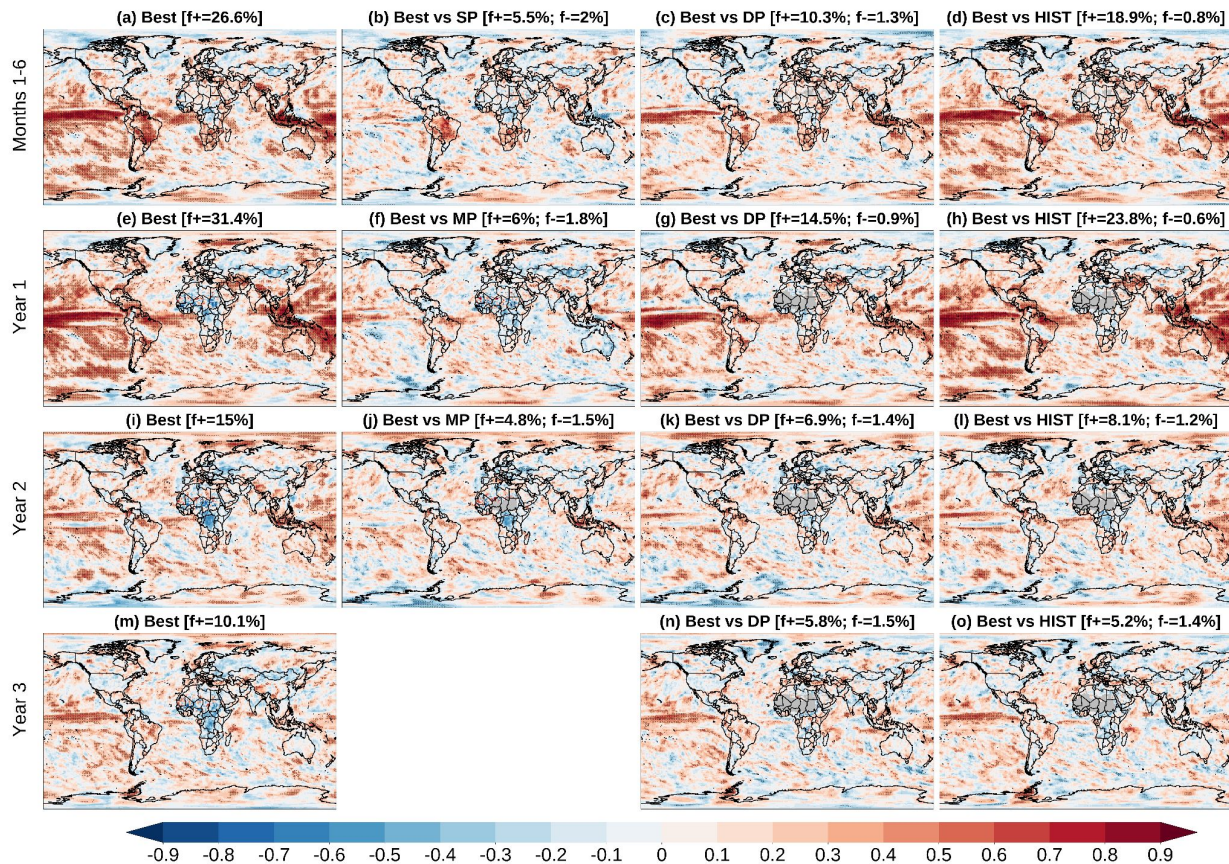
(b) November initialisation



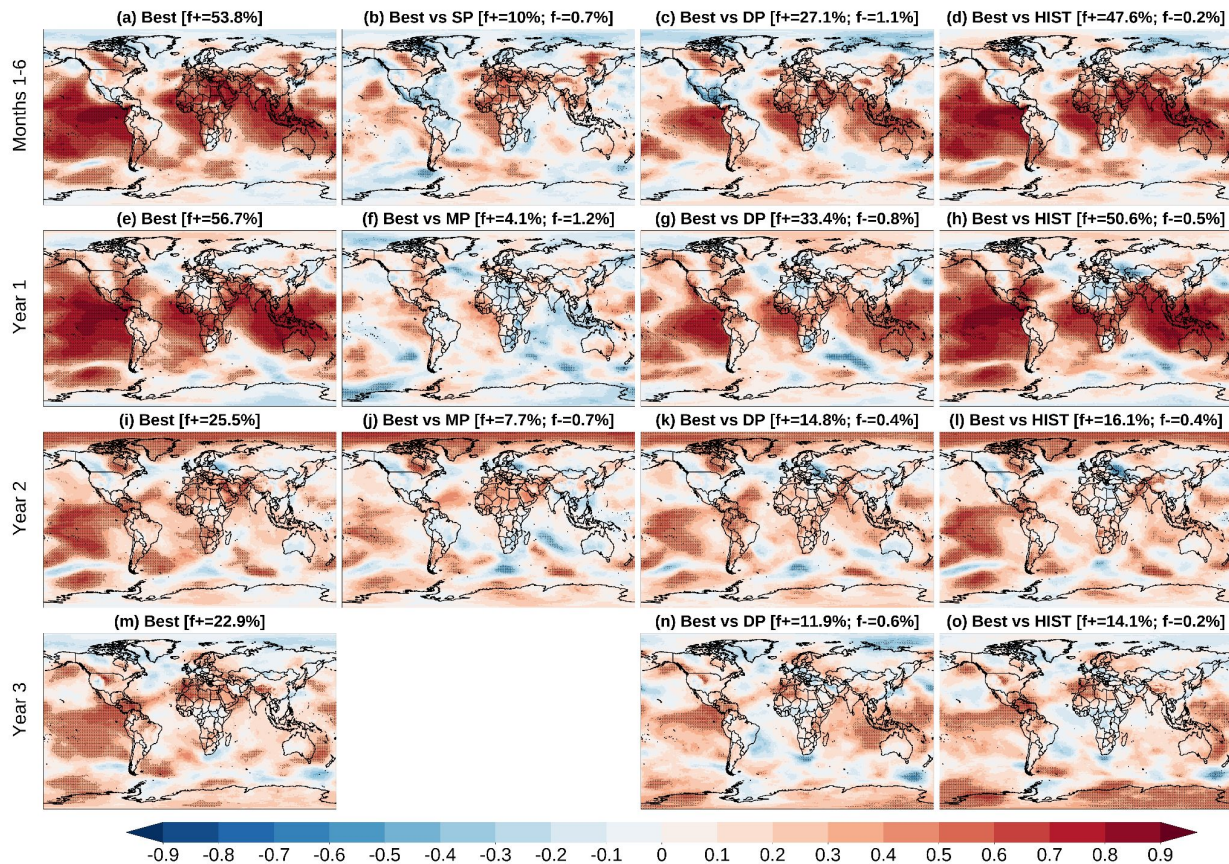
Skill for near-surface air temperature (May init)



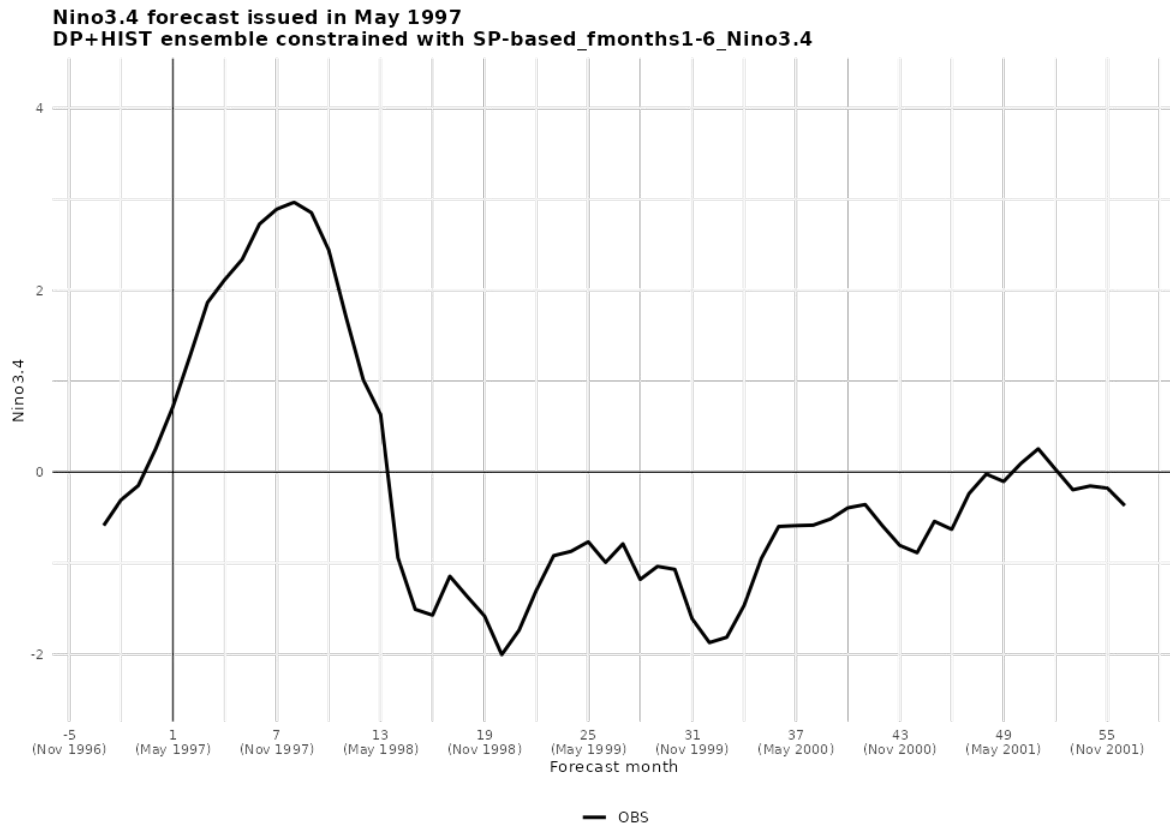
Skill for precipitation (May init)



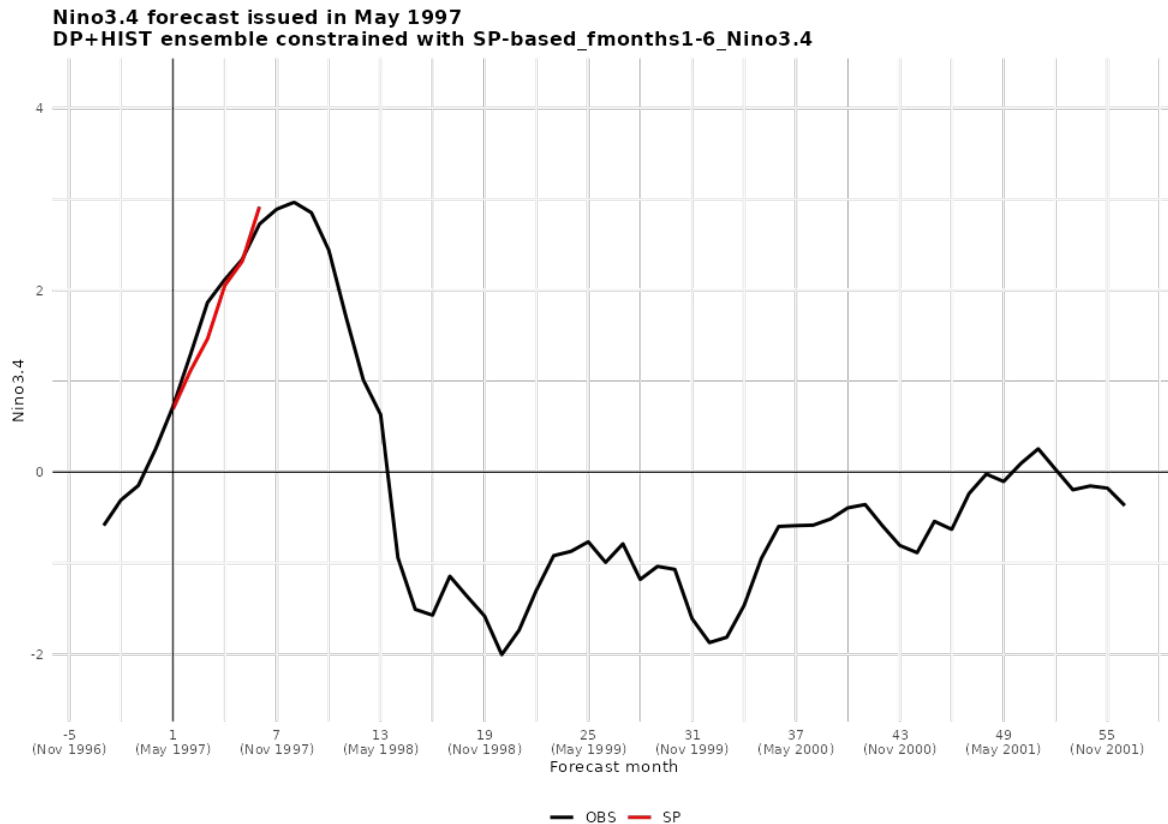
Skill for sea level pressure (May init)



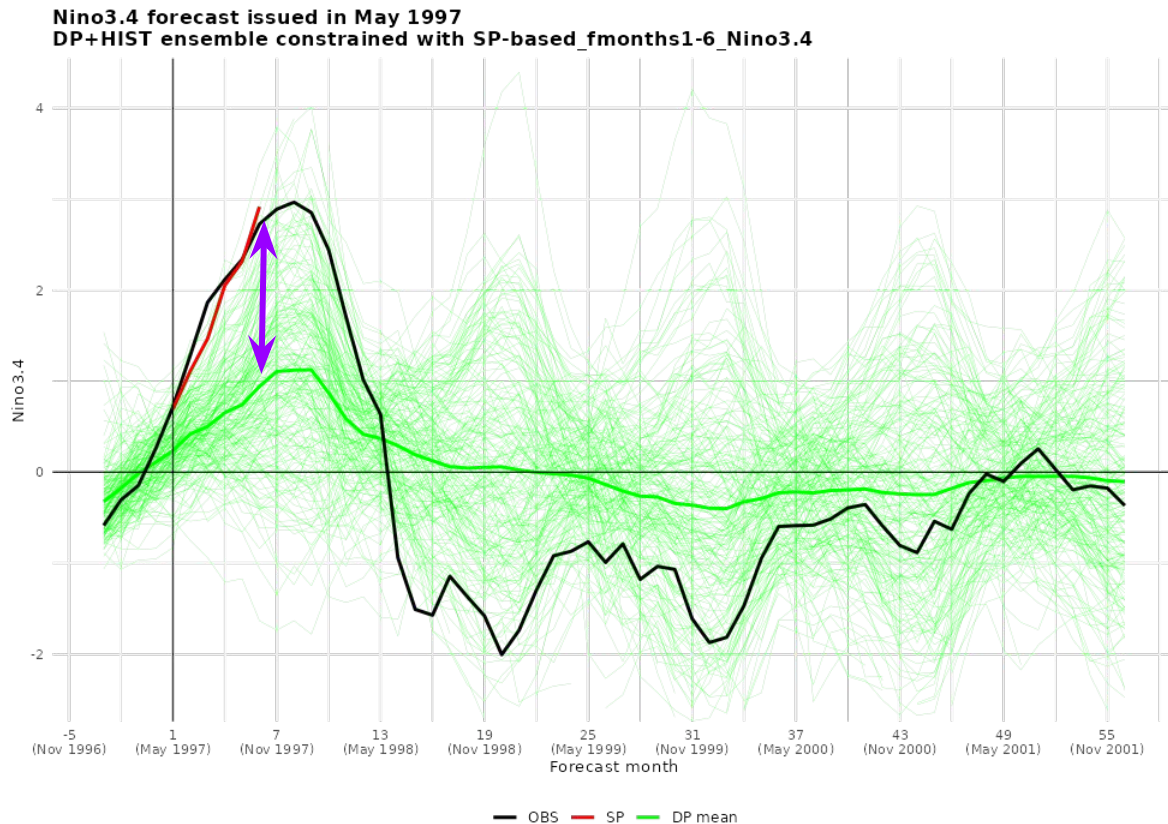
Seamless ENSO forecast (May 1997)



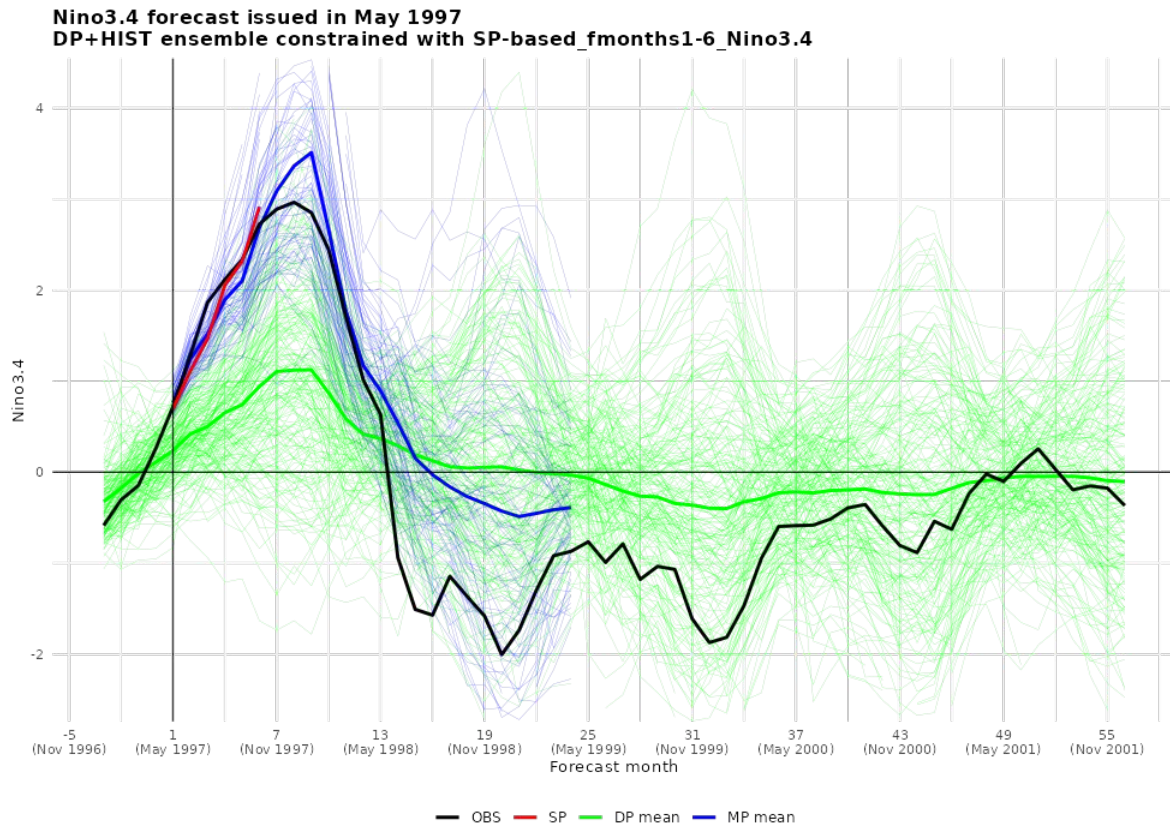
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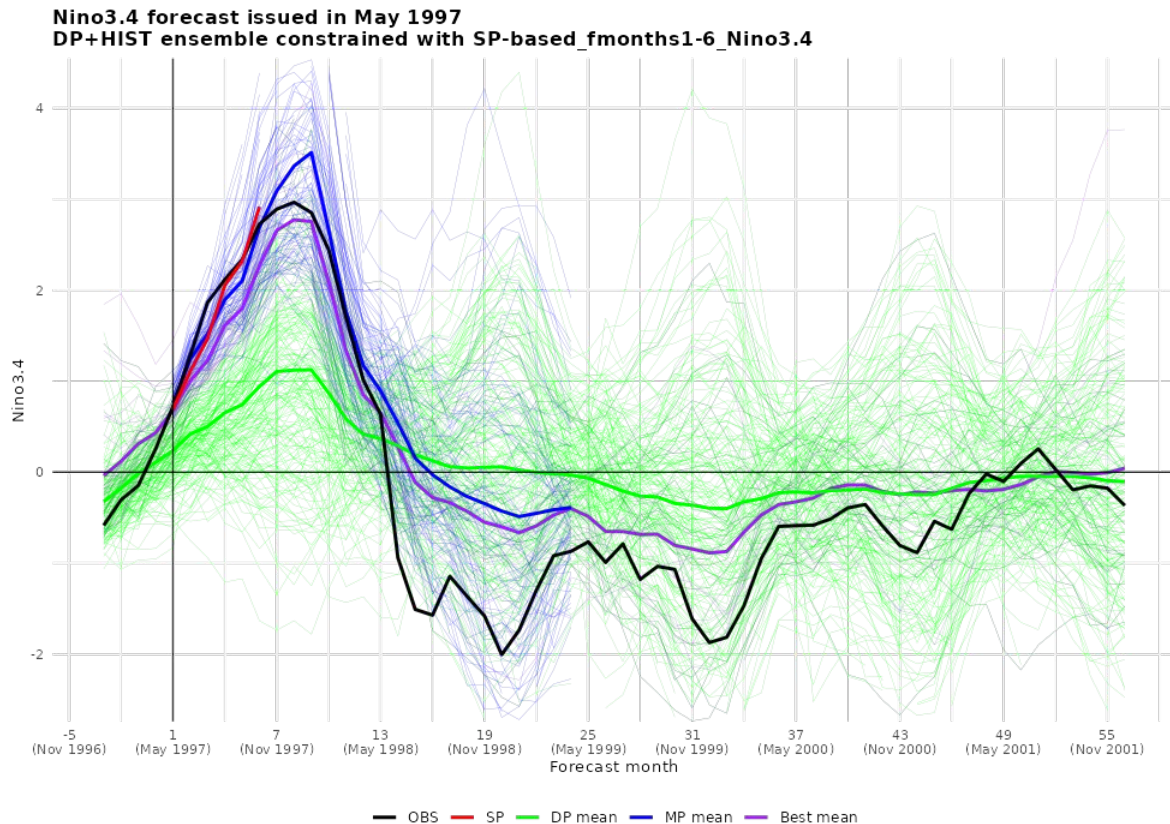
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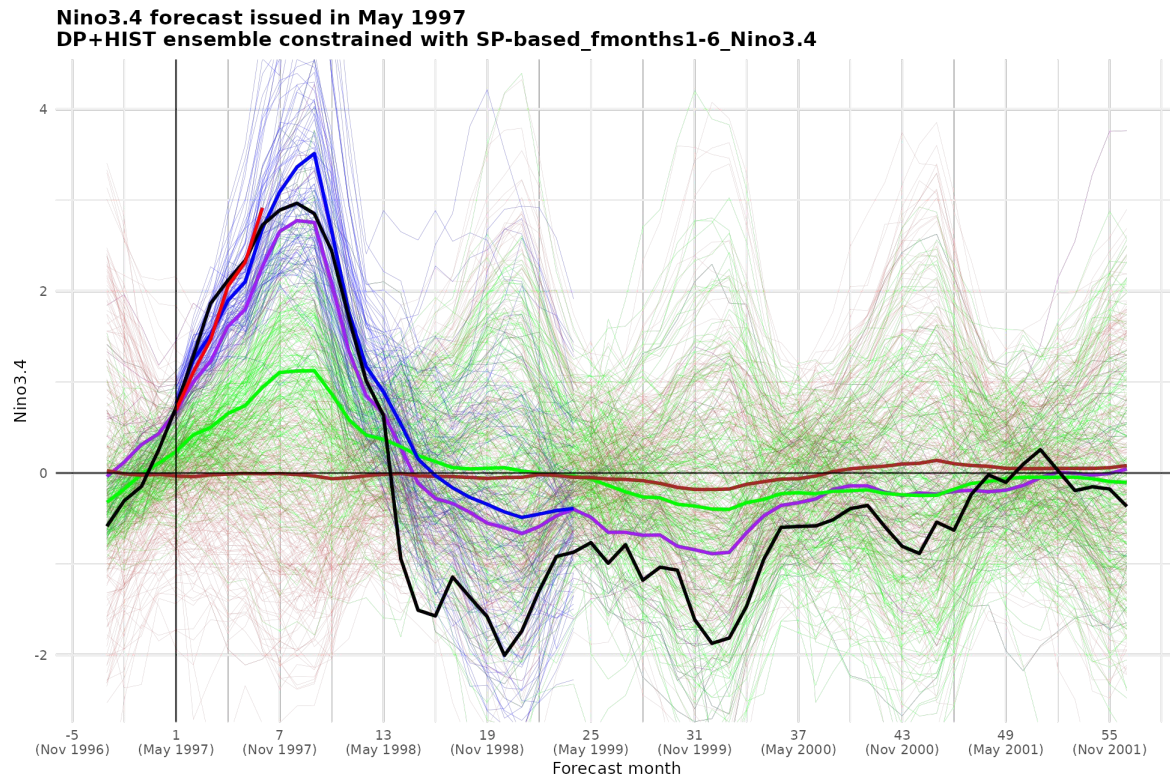
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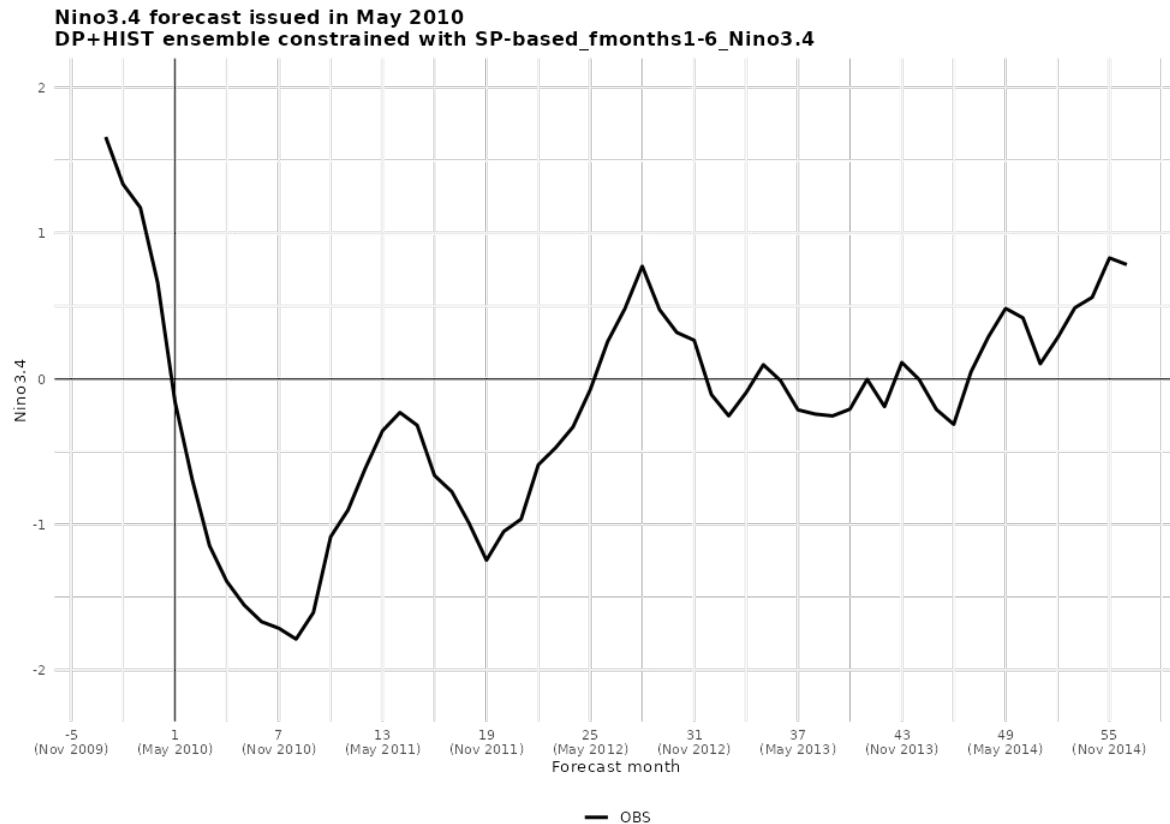
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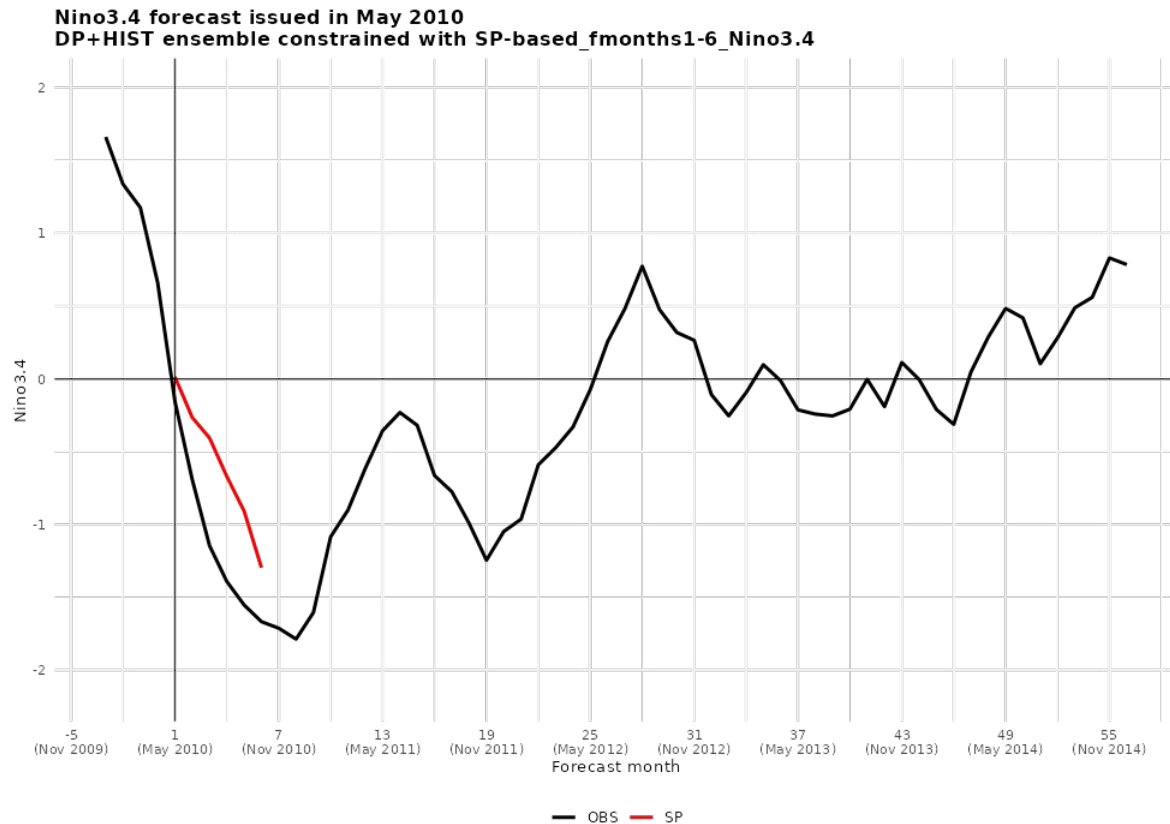
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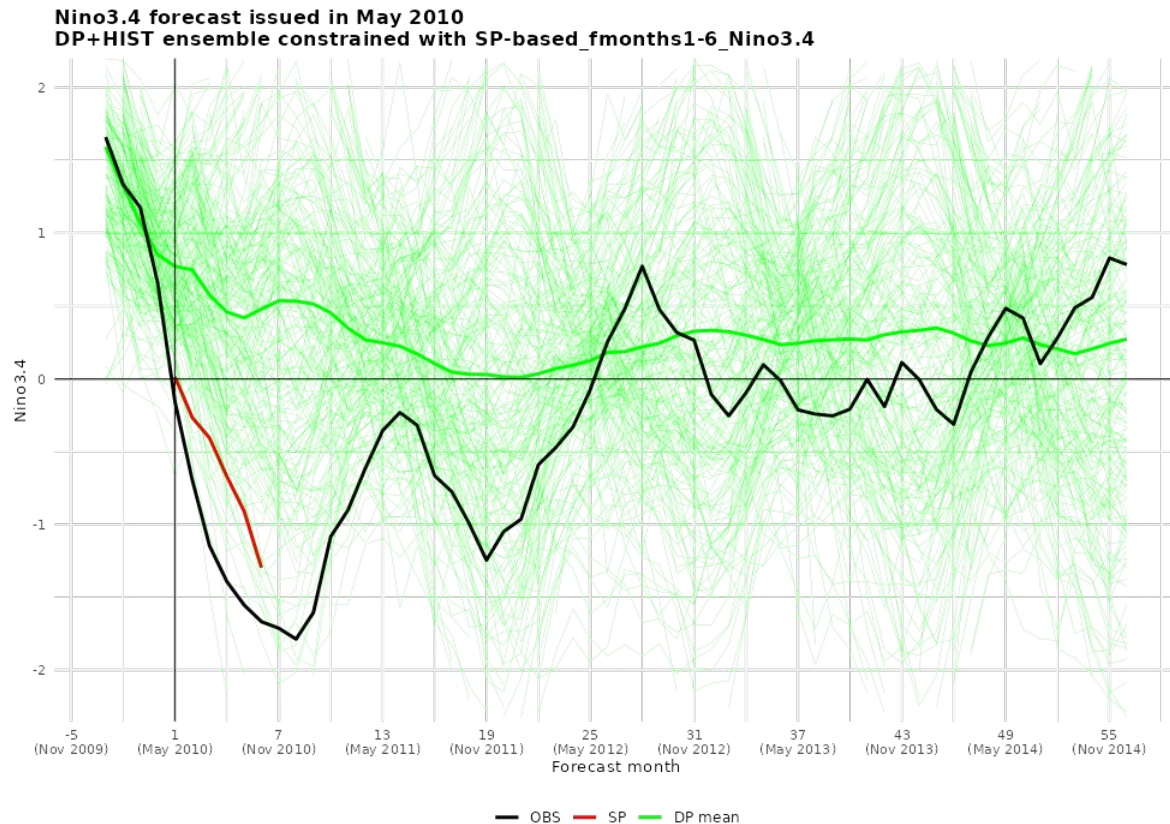
Seamless ENSO forecast (May 2010)



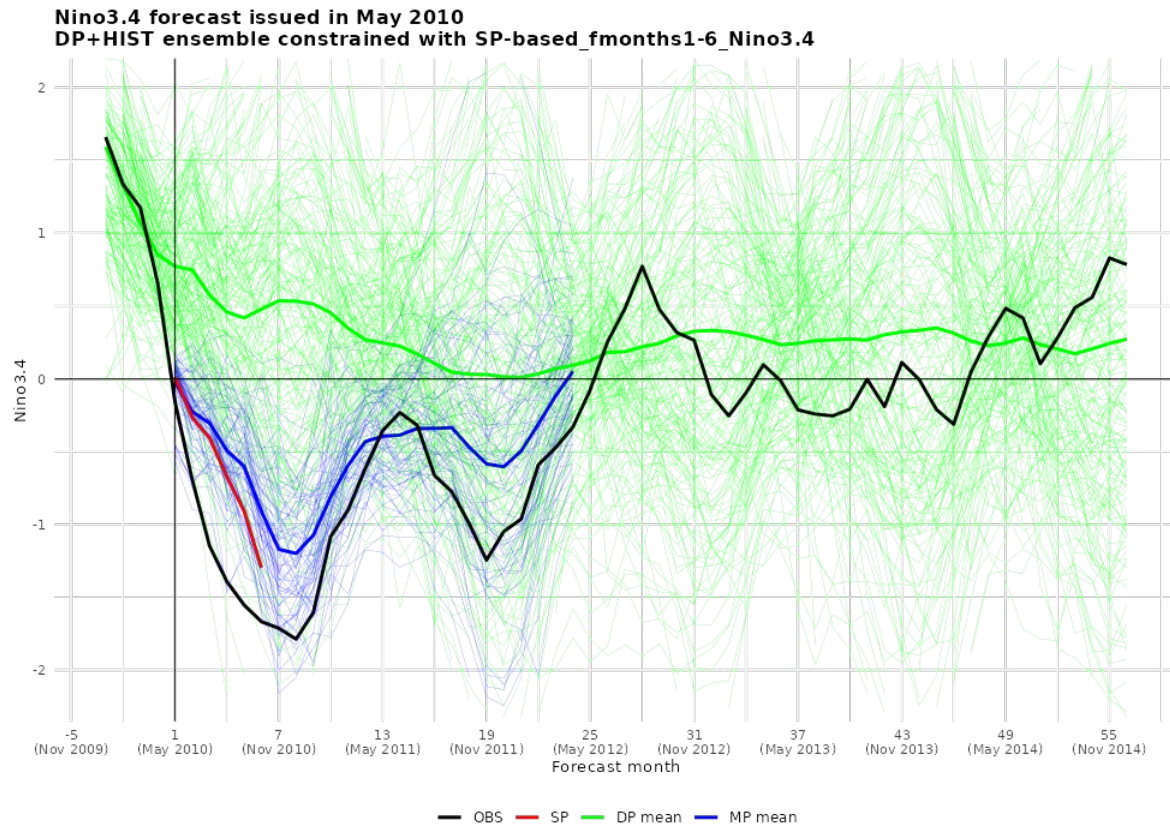
Seamless ENSO forecast (May 2010)



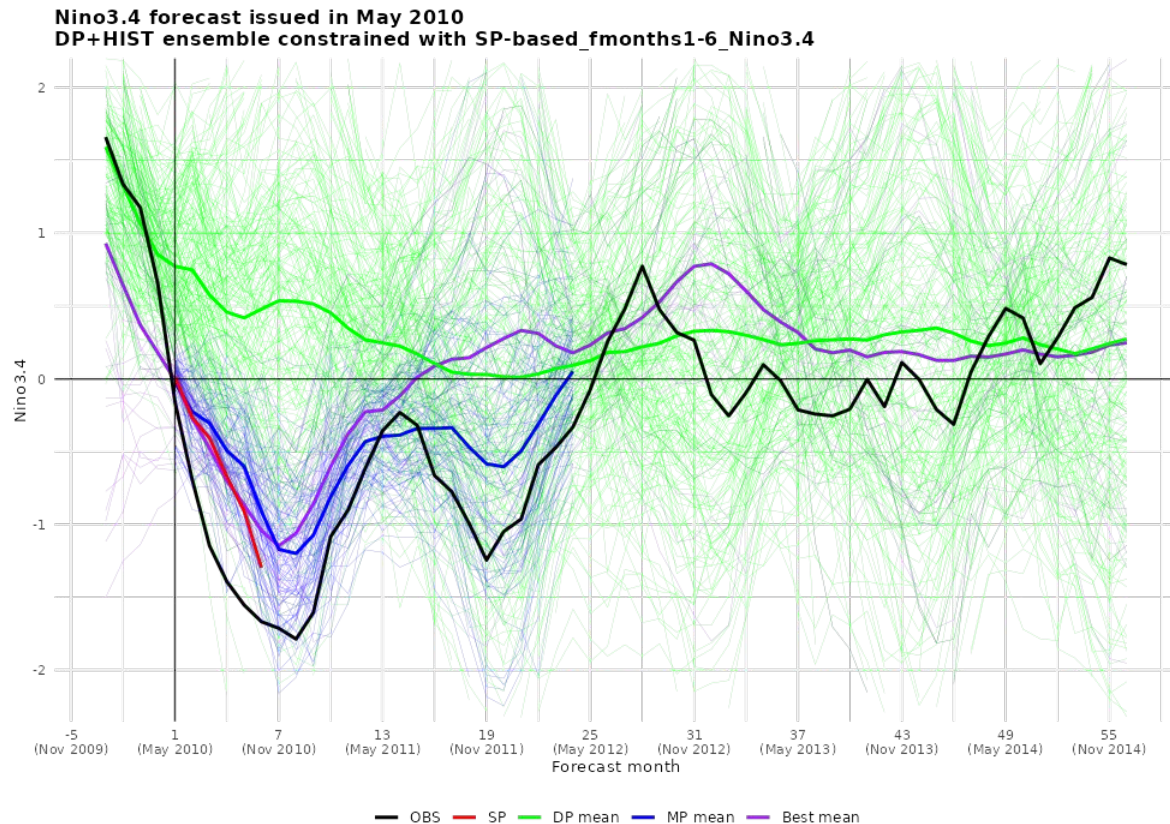
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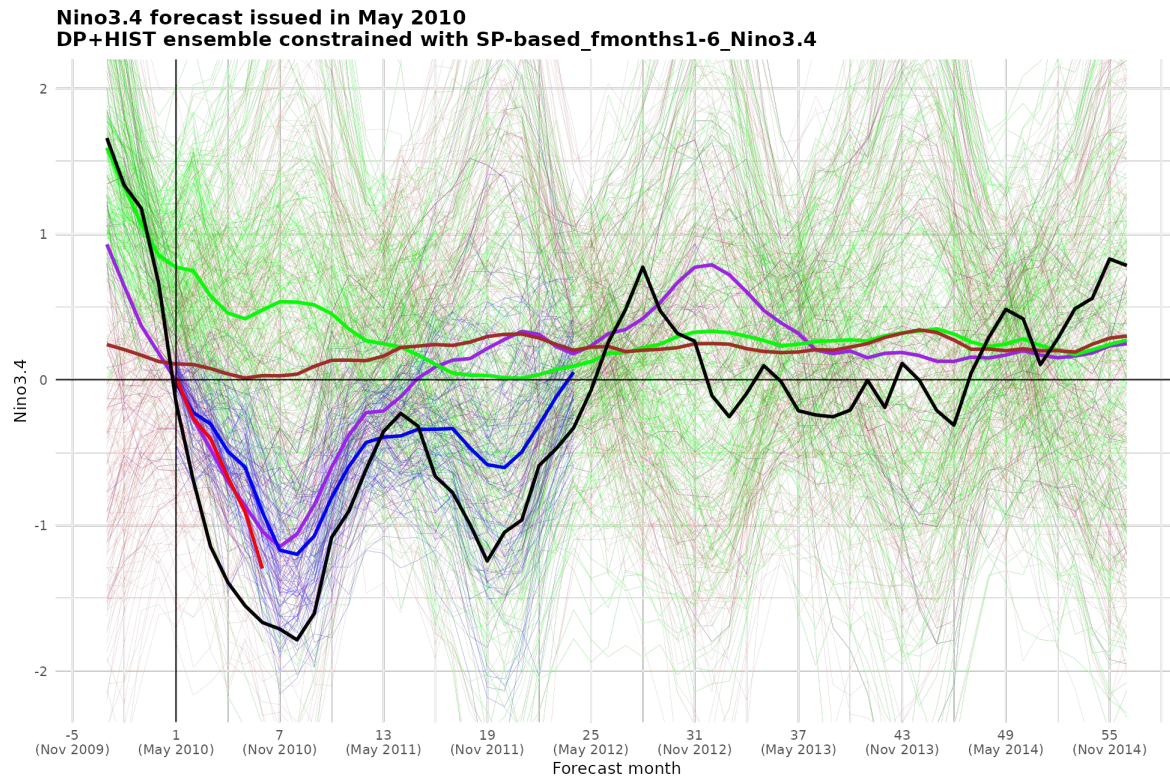
Seamless ENSO forecast (May 2010)



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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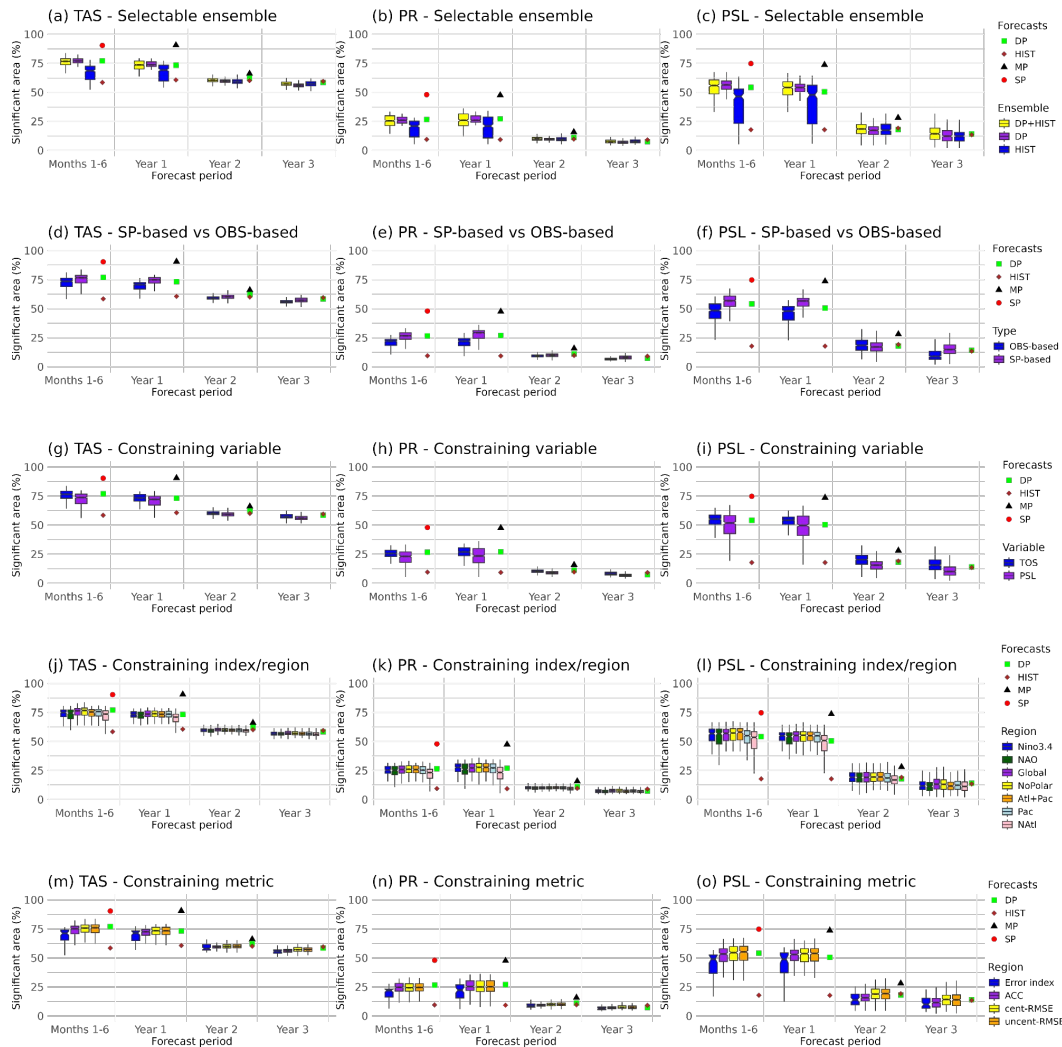
Thank you!

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 from months to multiple years: constraining decadal predictions with seasonal predictions and past observations, and their comparison to multi-annual predictions, *Earth Syst. Dynam.*, 17, 41–56, <https://doi.org/10.5194/esd-17-41-2026>, 2026.

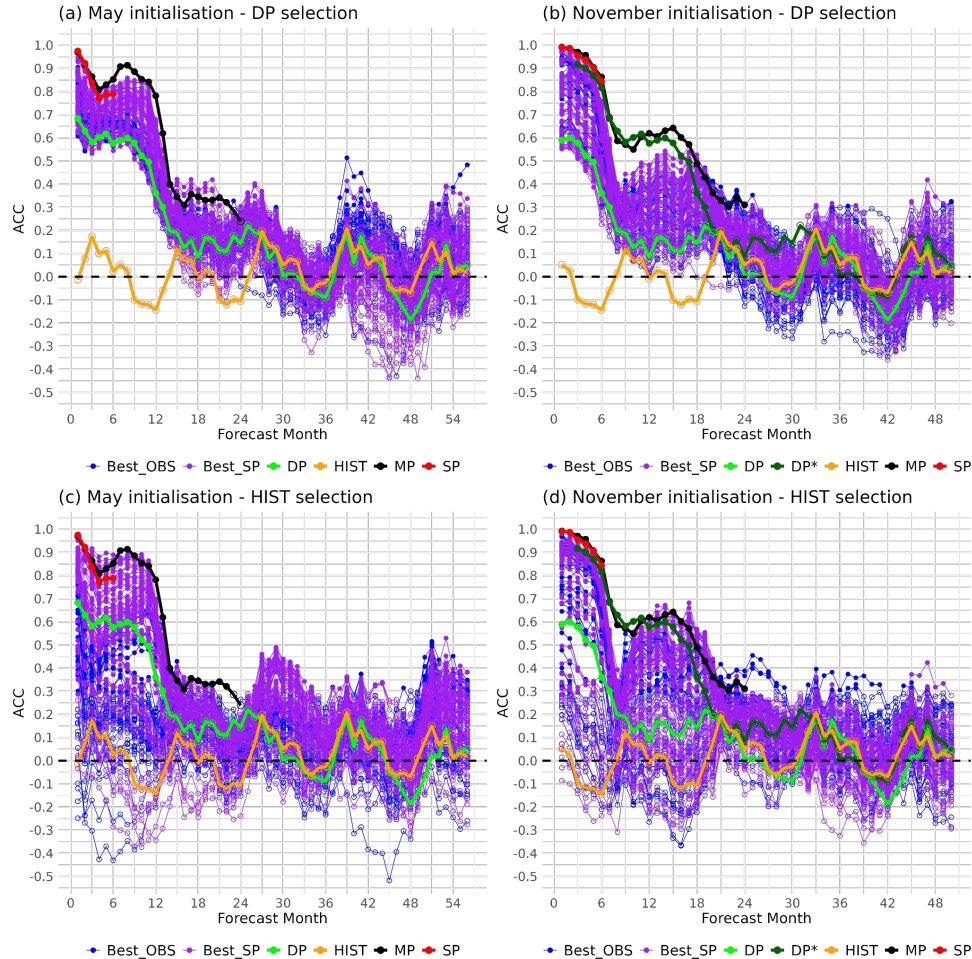
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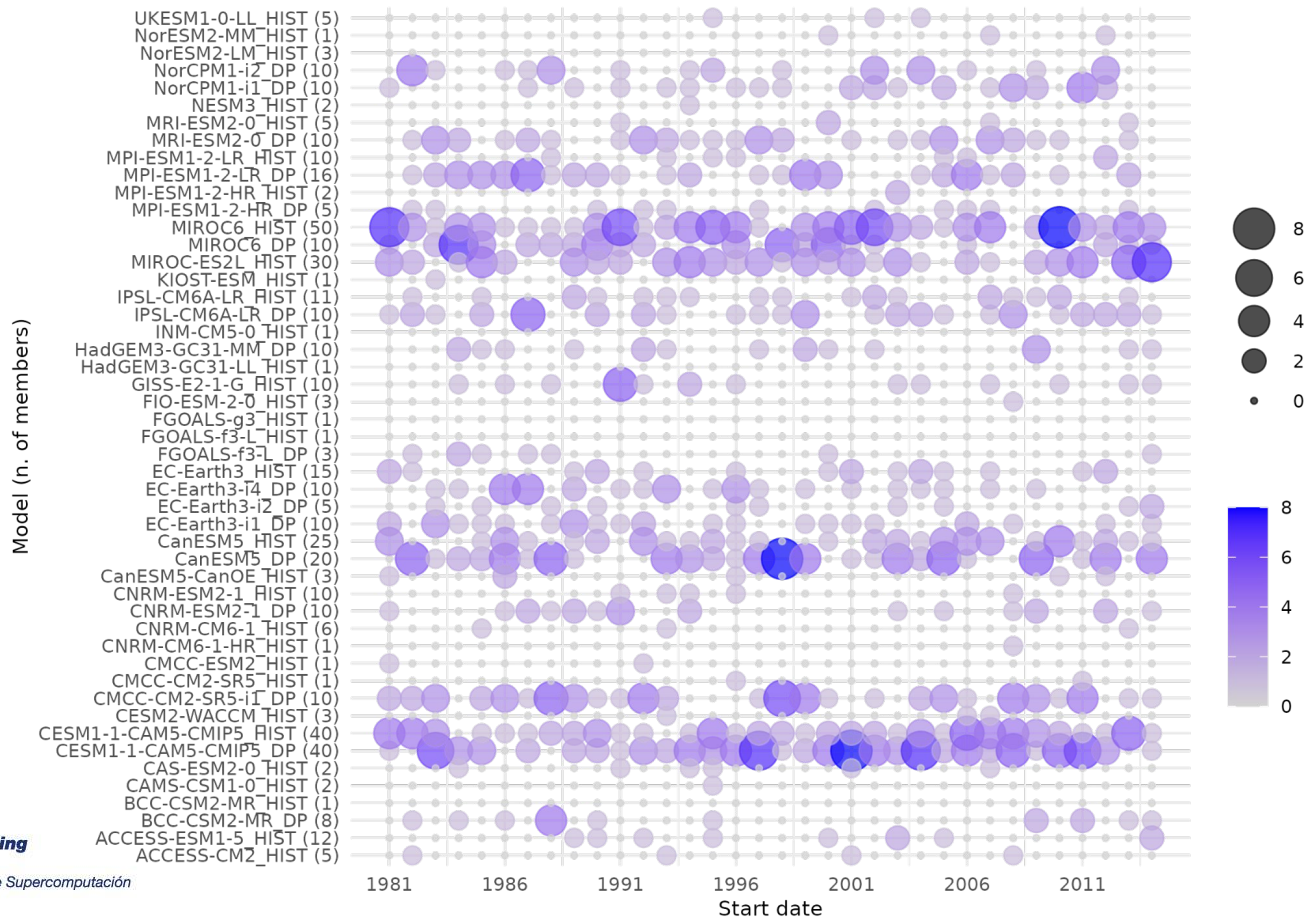
Sensitivity analysis to different constraining options



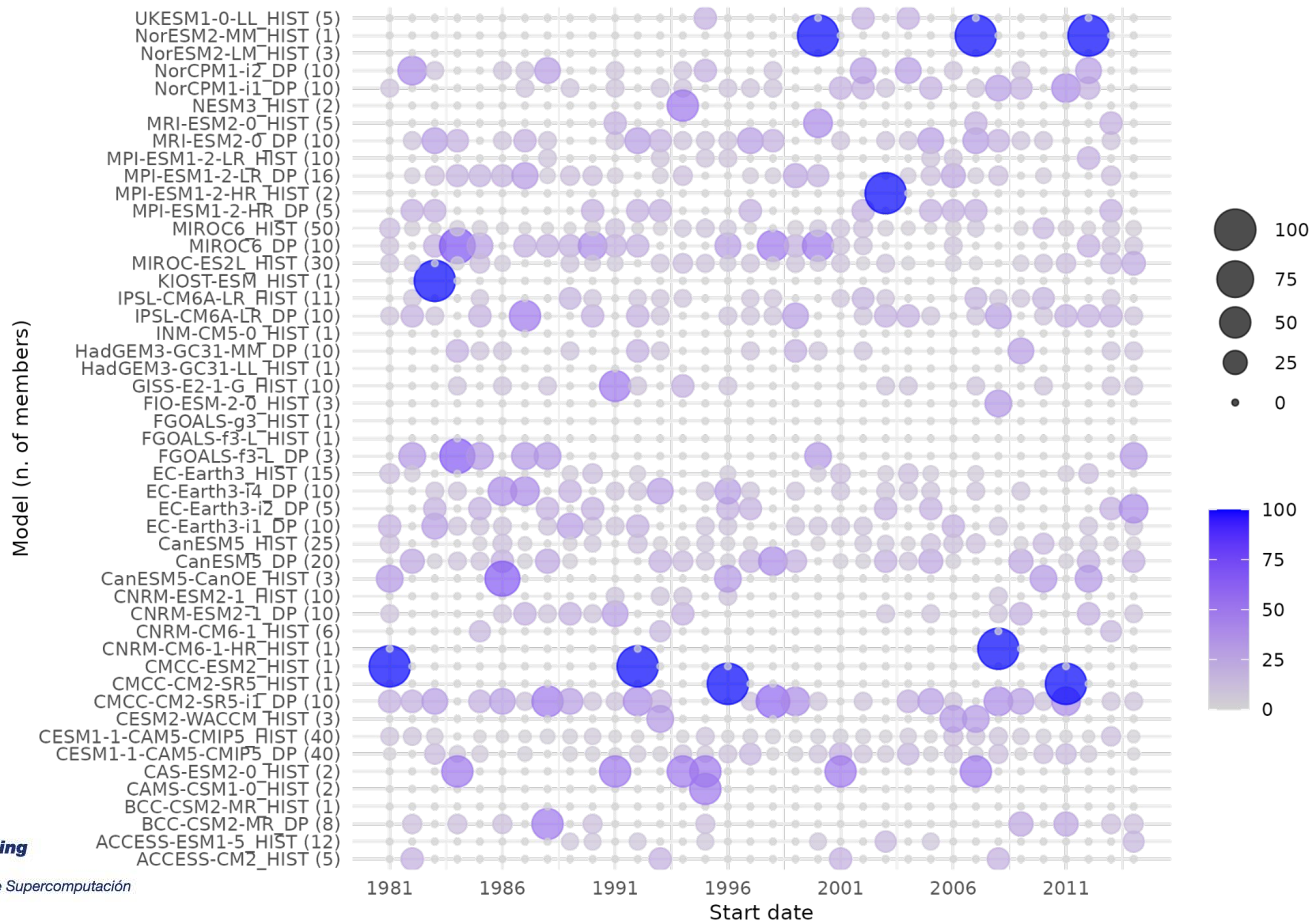
DP vs HIST selection



Number of selected members

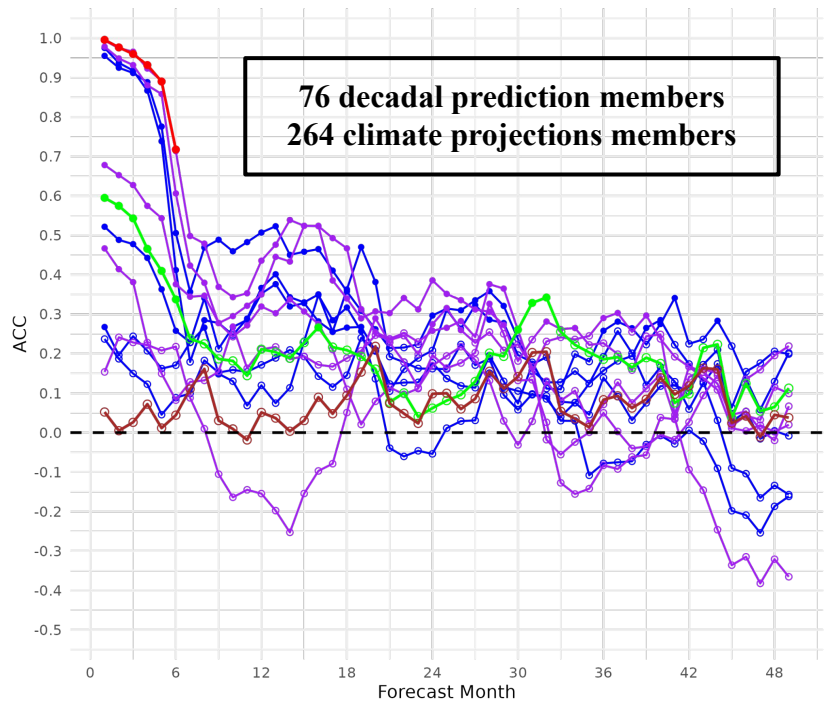


Percentage of selected members

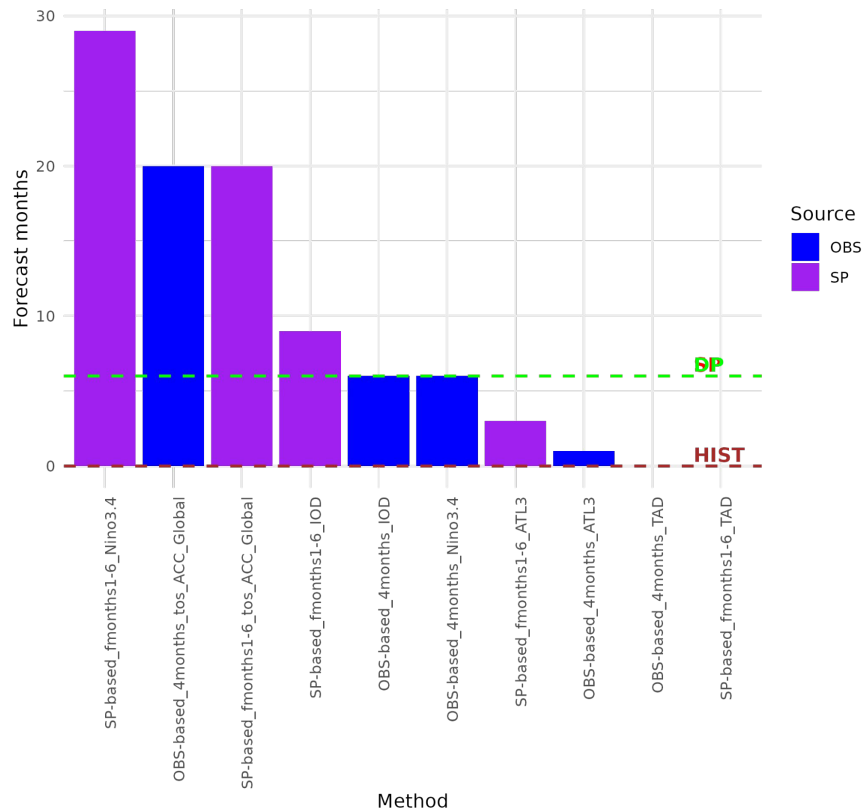


“Real-time” seamless forecast skill (Dec)

ACC for Nino3.4; constrained with spatial ACC
Start month: 12; Period: full; Moving months: 1



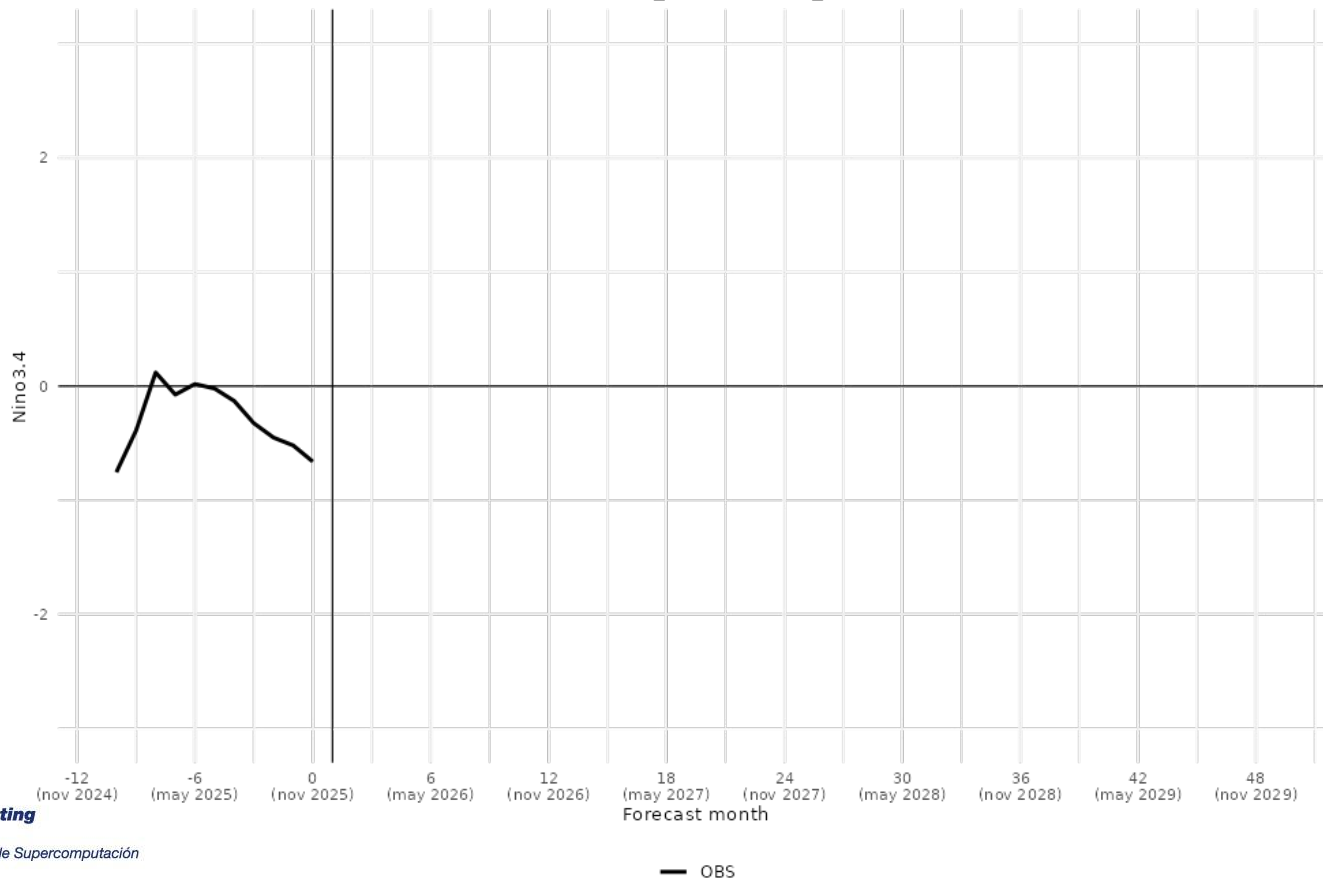
Top methods by consecutive positive significance
ACC for Nino3.4; Start month: 12; Period: full; Moving months: 1



“Real-time” seamless forecast (Dec 2025)

Nino3.4 forecast issued in December 2025

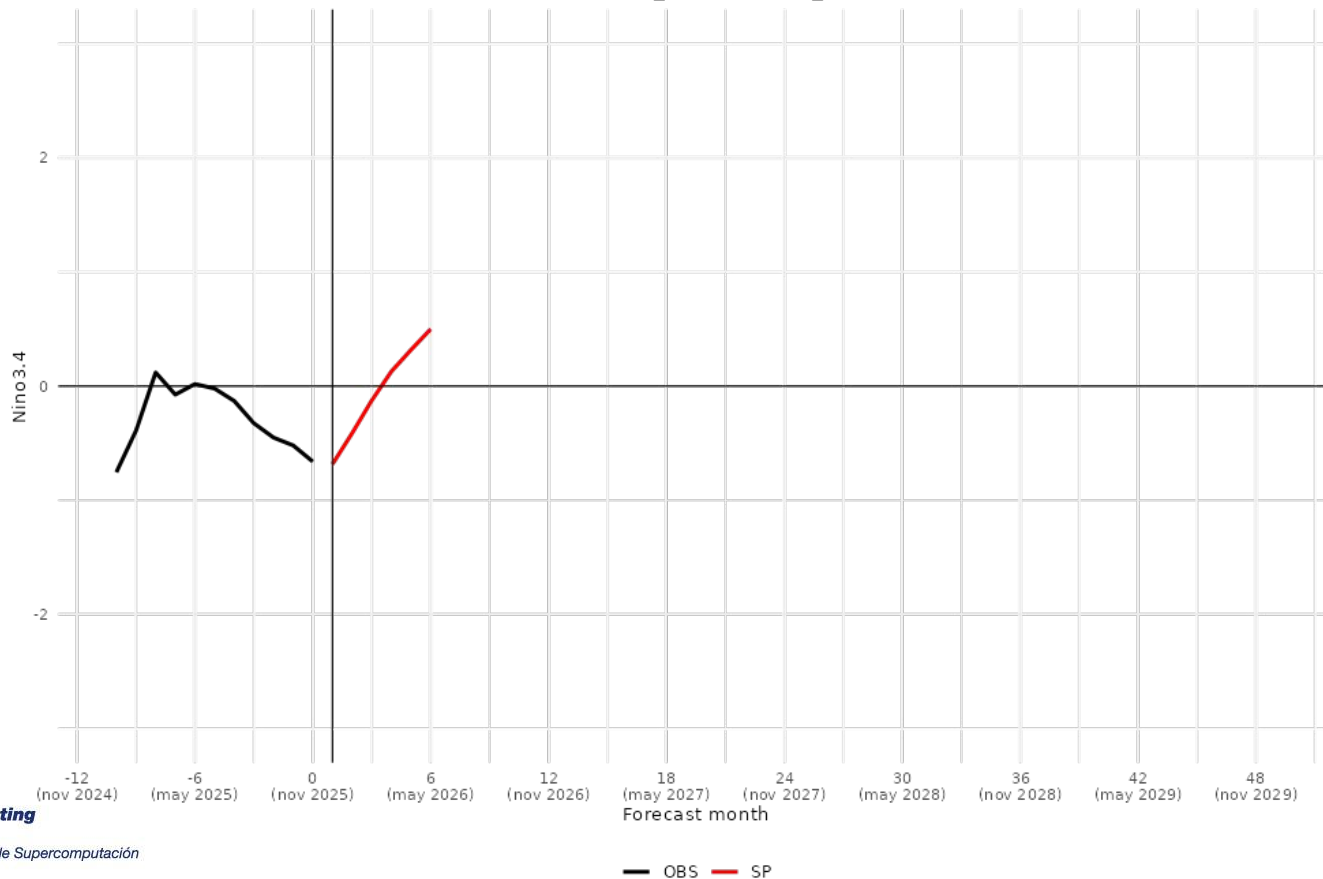
DP+HIST ensemble constrained with SP-based_fmonths1-6_Nino3.4



“Real-time” seamless forecast (Dec 2025)

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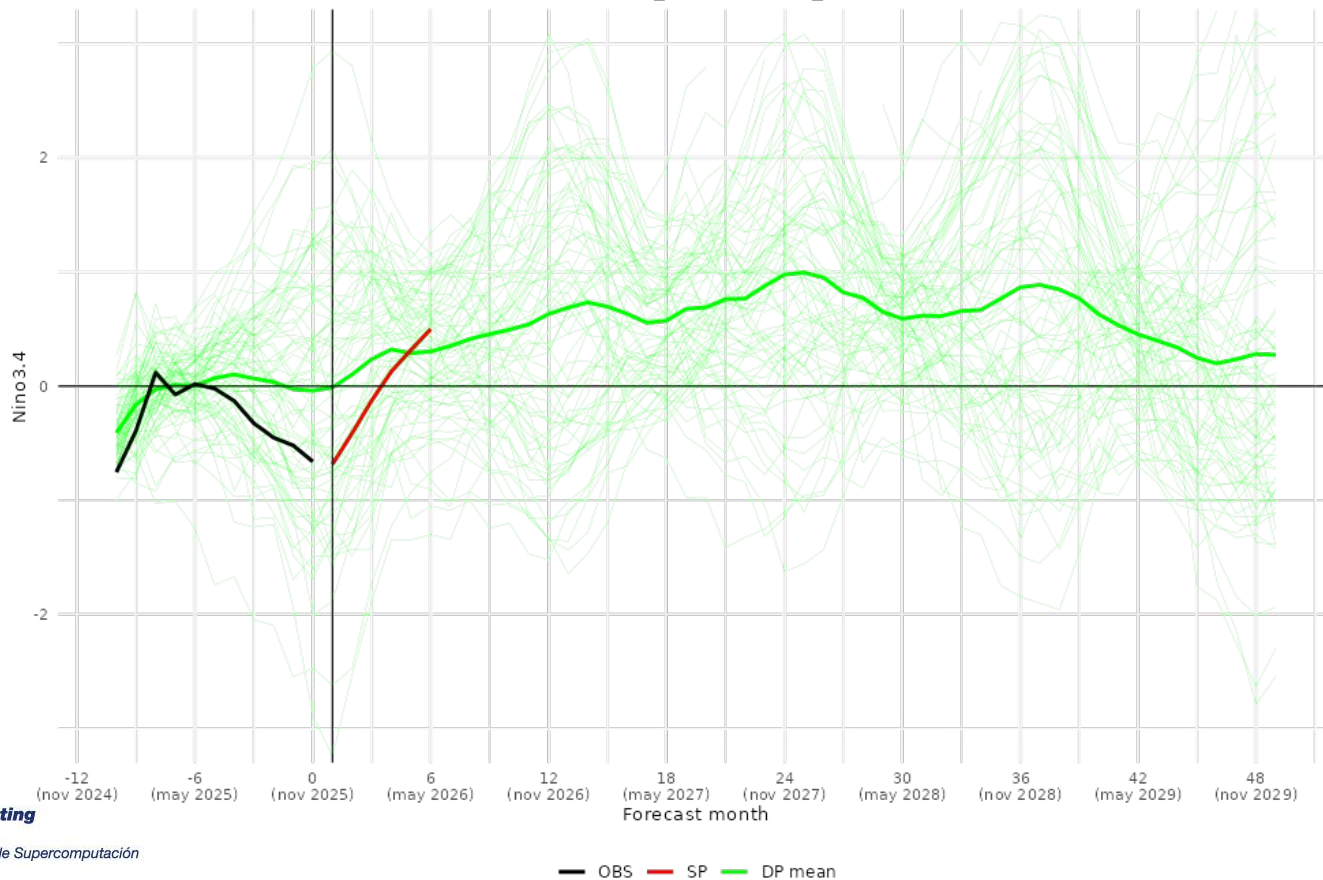
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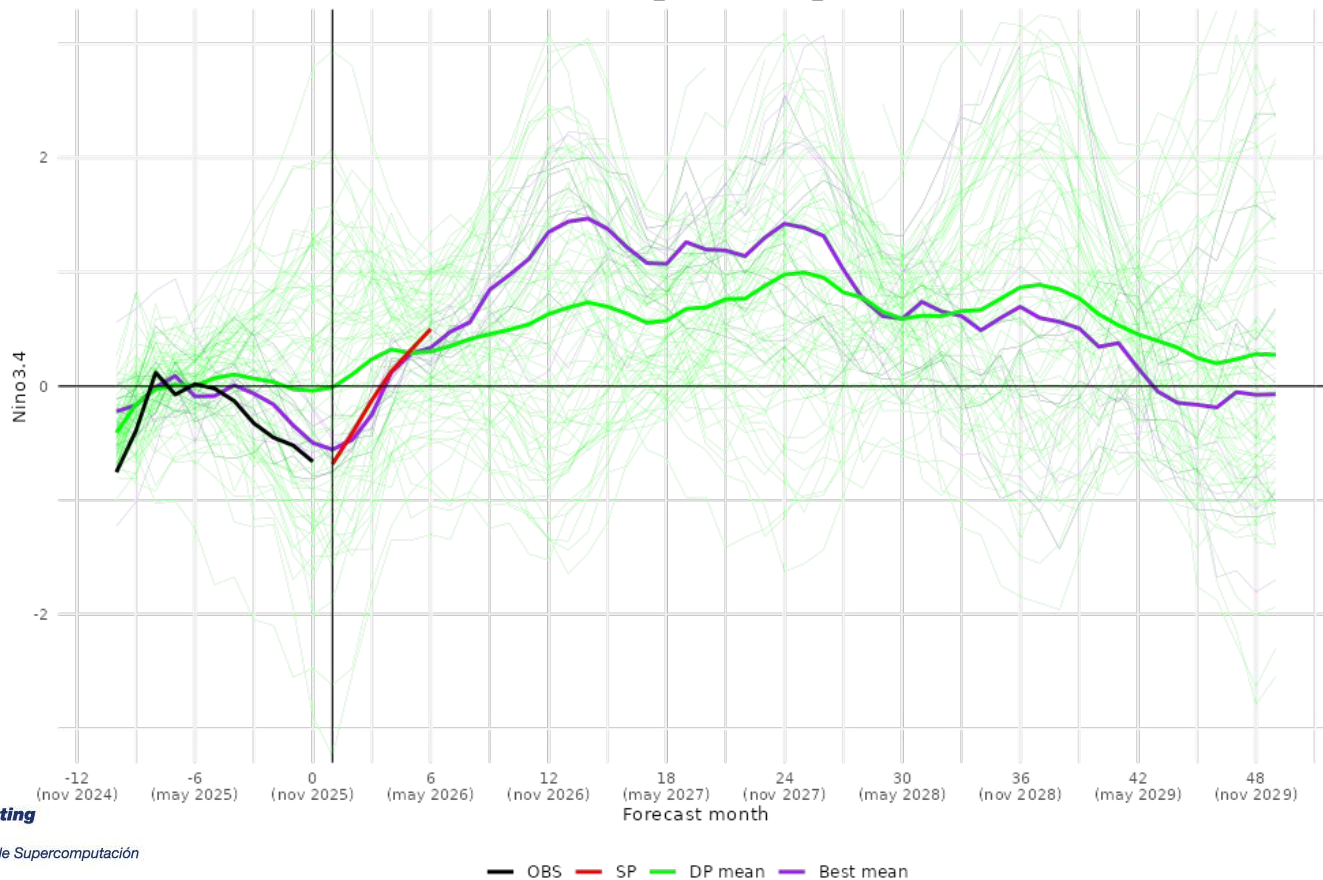
DP+HIST ensemble constrained with SP-based_fmmonths1-6_Nino3.4



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