



Servicio  
Meteorológico  
Nacional  
Argentina

# Verification of numerical forecasts over Argentina

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# Introduction

- In January 2020 the National Meteorological Service of Argentina (SMN) began running an operational forecasting system based on the WRF model
- This has been a long awaited moment in the SMN, where the WRF had been used for research purposes and operationally in a simple setting.
- This was in part possible through the acquisition of a powerful fully-dedicated HPC cluster

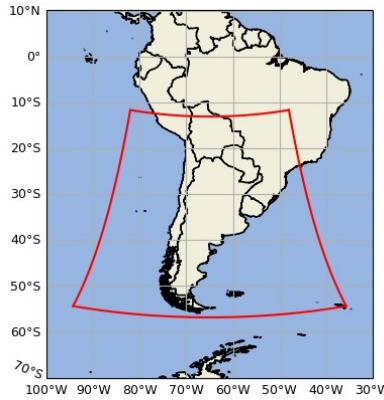
# Introduction

- There are several reasons why a country, region or institution may want to run a regional model (foster local science, autonomy, full control of data etc.)
- In all cases, the expectation is that such forecasts should be at least partially better than their driving global models
- In what follows we will show verification results from the SMN forecasting system in comparison with the driving data.

# Operational NWP System (SAP.SMN) since 2020

## Main configuration

- WRF numerical model version 4.0
- 4 km horizontal resolution
- 1200 x 1250 model grid points and 45 vertical levels
- Hourly forecasts outputs
- Initialized 4 times a day (00Z, 06Z, 12Z, 18Z)
- ICs and BCs from the GFS/GEFS model



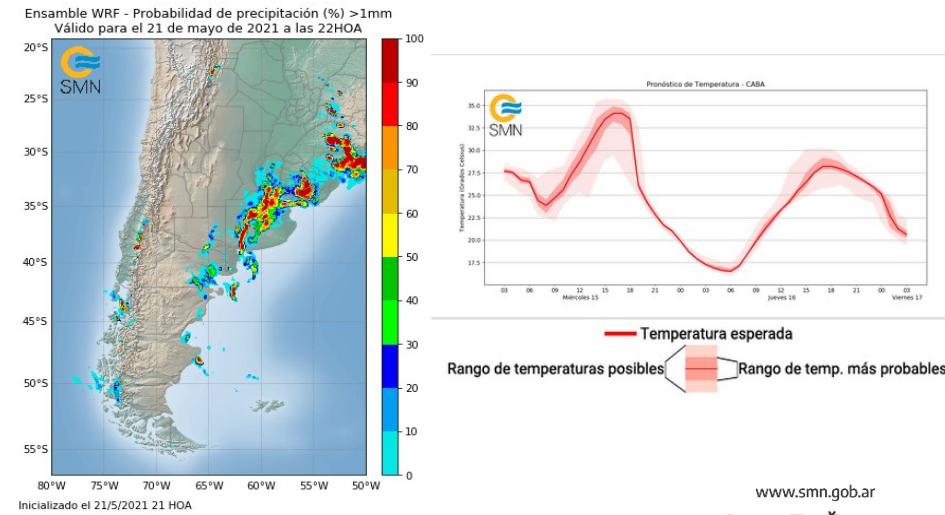
<https://registry.opendata.aws/smn-ar-wrf-dataset/>

## Deterministic forecast (SAP.SMN-DET)

- Forecast lead time: 72 hours

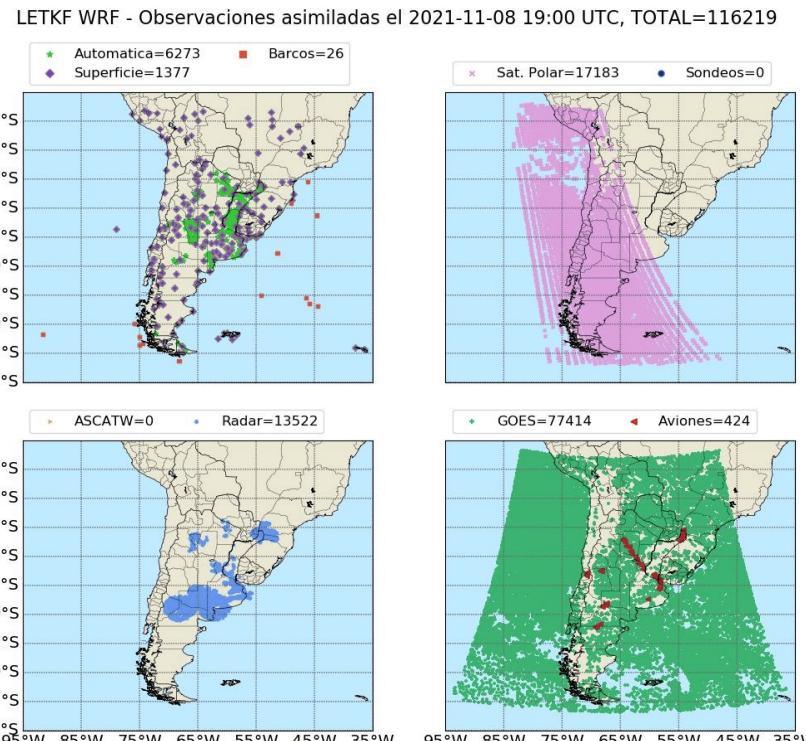
## Ensemble forecast (SAP.SMN-ENS)

- Forecast lead time: 48 hours
- 20-member multi-physics ensemble combining PBL (MYJ, SH, YSU) and 1-moment MP schemes (WSM6, LIN)



# Data Assimilation System (experimental 2023)

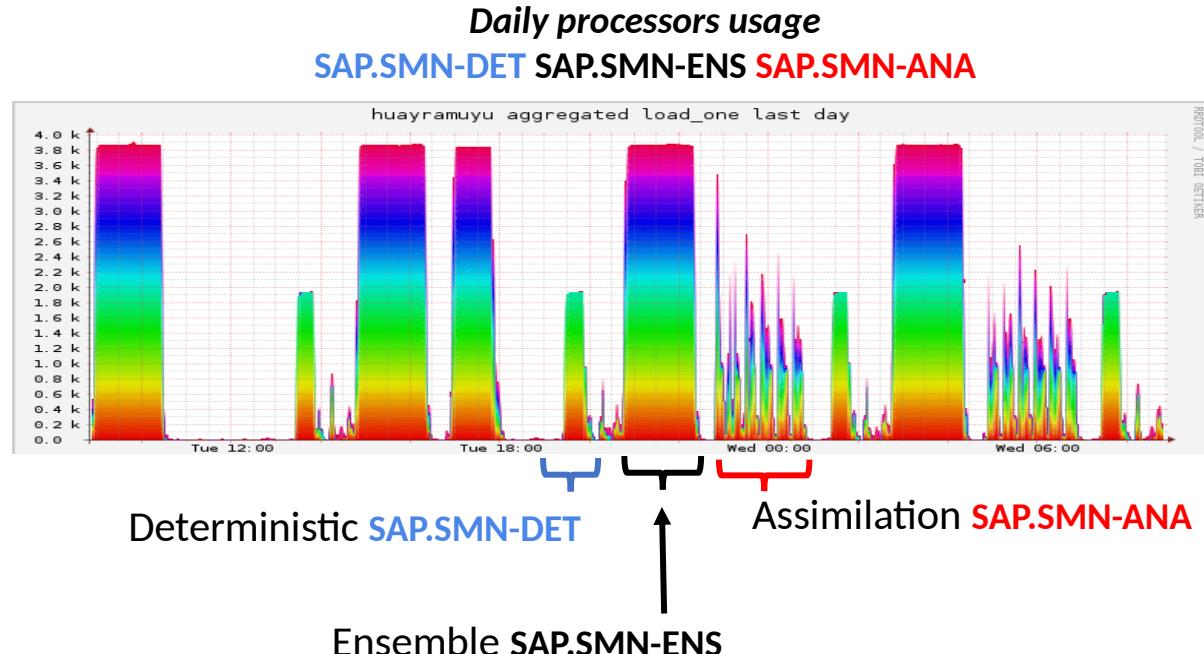
Data source	Assimilated variables
Conventional SWS	PSFC, T, U, V, HR
Automatic SWS (private +AWOS)	PSFC, T, U, V, HR
Ships, buoys	PNMM, T, U, V, HR
Soundings	T, U, V, HR
Aircraft (AMDAR, AA)	T, U, V
Aqua (AIRS)	T, Q
Metop-B (ASCAT)	U, V
GOES-16	U, V
C-band Radar	Z



- 4D-LETKF method coupled with the WRF model (10-min slots) (Fortran implementation from Miyoshi T., Ruiz J.)
- Hourly analysis with 4 km horizontal resolution
- 40 multi-physics ensemble members
- Real-time data flux and associated scripts

# HPC Resources at the NMS (since 2020)

- 370 Teraflops
- 4096 processors, 870 Tb storage
- Acquisition 2019 (CyT ALERTA government project)



# Selected Data

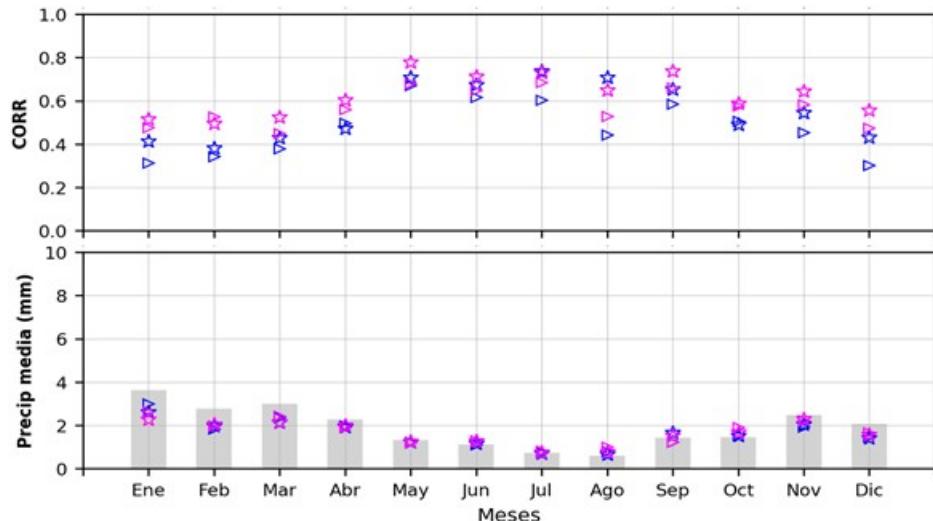
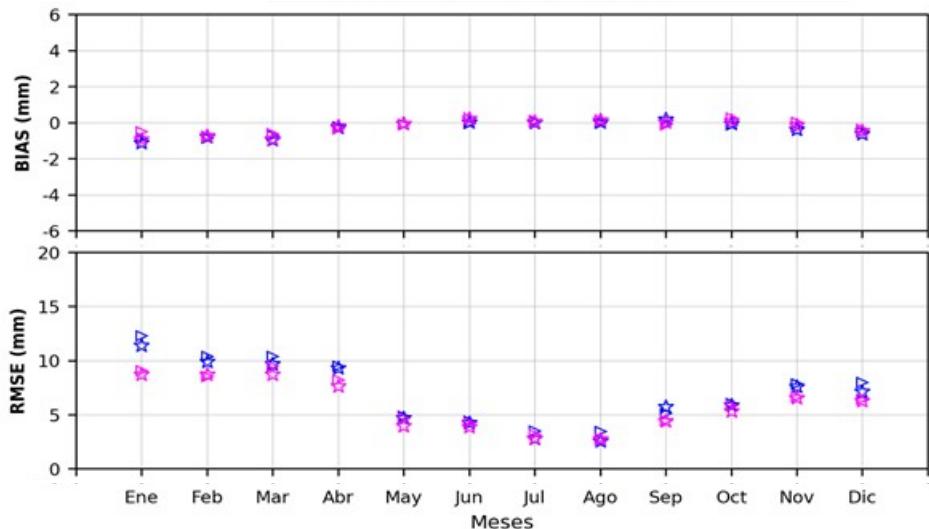
- Verification period: 2020-2022
- Observations: 101 surface stations
- Hourly deterministic forecasts: 1-hour precipitation, minimum and maximum daily temperature (nearest neighbor interpolation)
- Models: WRF and GFS
- Cycle: 06UTC



# Deterministic run verification

# Deterministic 24-h precipitation

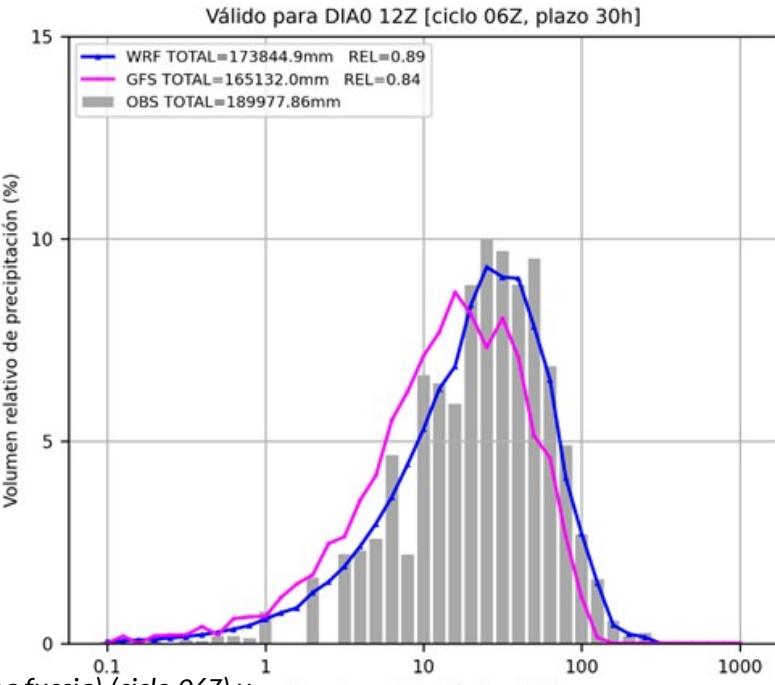
☆ WRF plazo 30h    ▲ GFS plazo 30h    ■ PP24obs  
▷ WRF plazo 54h    ▷ GFS plazo 54h



For WRF and GFS, cycle 06Z

# Deterministic 24-h precipitation

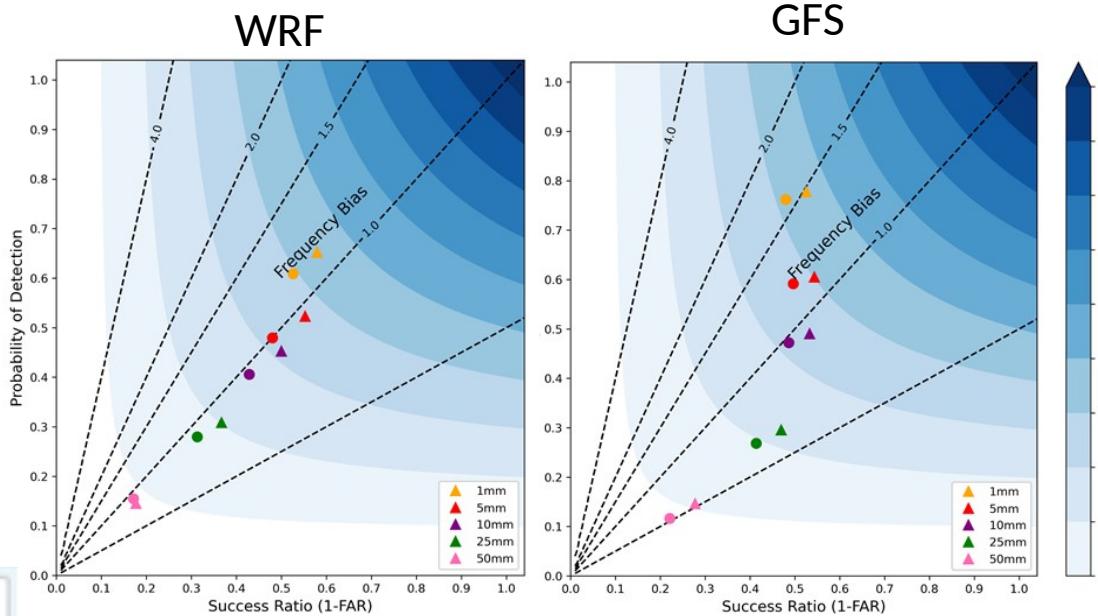
- Grey bars indicate total observed precipitation rate volume in the verification period.
- Both models WRF and GFS underestimate the total amount of rainfall volume for day0 and day+1 lead times.
- WRF has a better correspondence to observed distribution. GFS shows a bias towards the lighter values of precipitation.



**Figura 4:** PDFs volumétricas de PP24 para el modelo WRF (línea azul) y GFS (línea fucsia) (ciclo 06Z) y distribución del volumen de precipitación de las observaciones (barras grises) válidas para el día 0 (izq.) y para el día+1 (der.) (ciclo 06Z). En el cuadro se indican los valores totales de precipitación observada y pronosticada considerando el total de estaciones y la relación entre el total pronosticado respecto al observado.

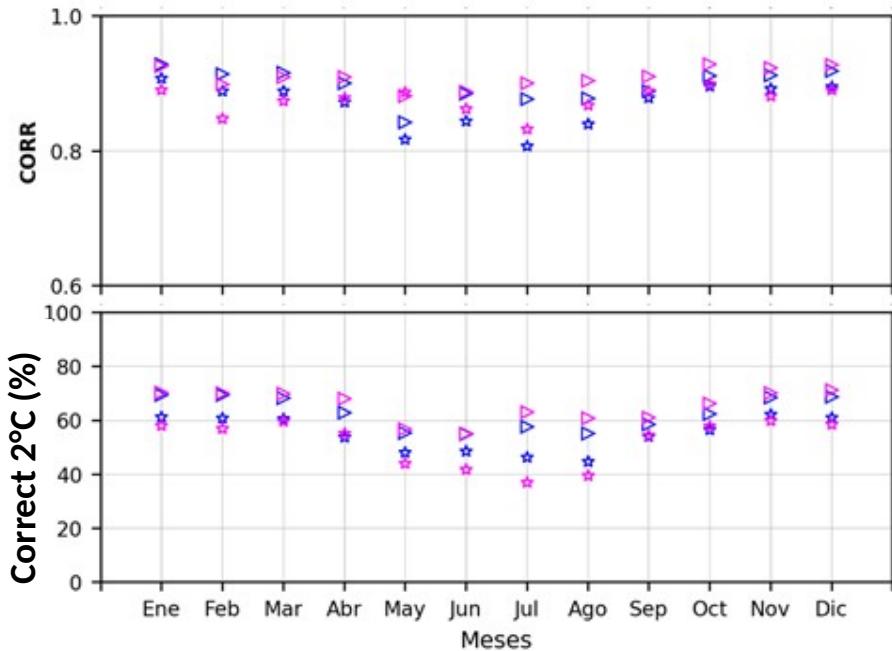
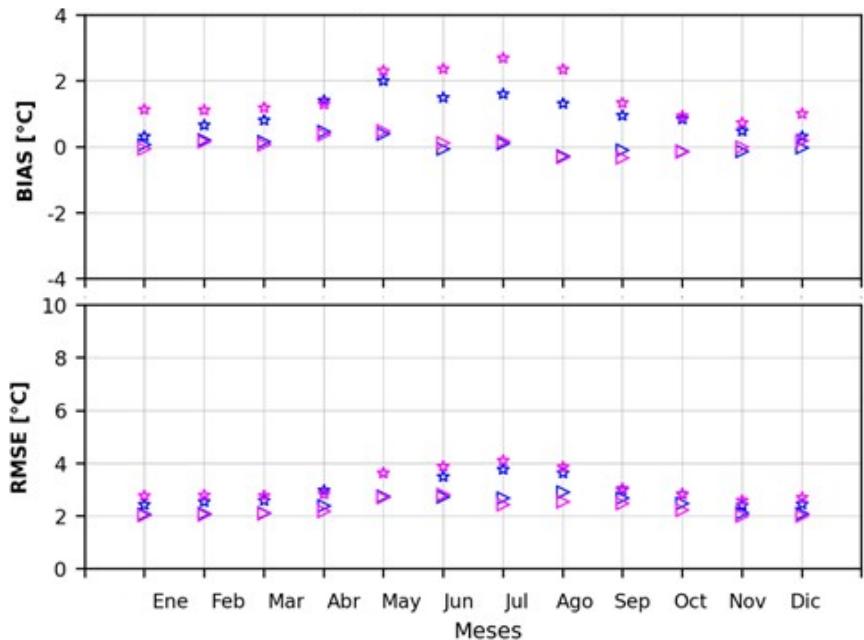
# Deterministic 24-h precipitation

- Performance diagram
- WRF shows better performance in terms of FBIAS.
- Better skill for lower precipitation rates
- Better skill for shorter-term forecast



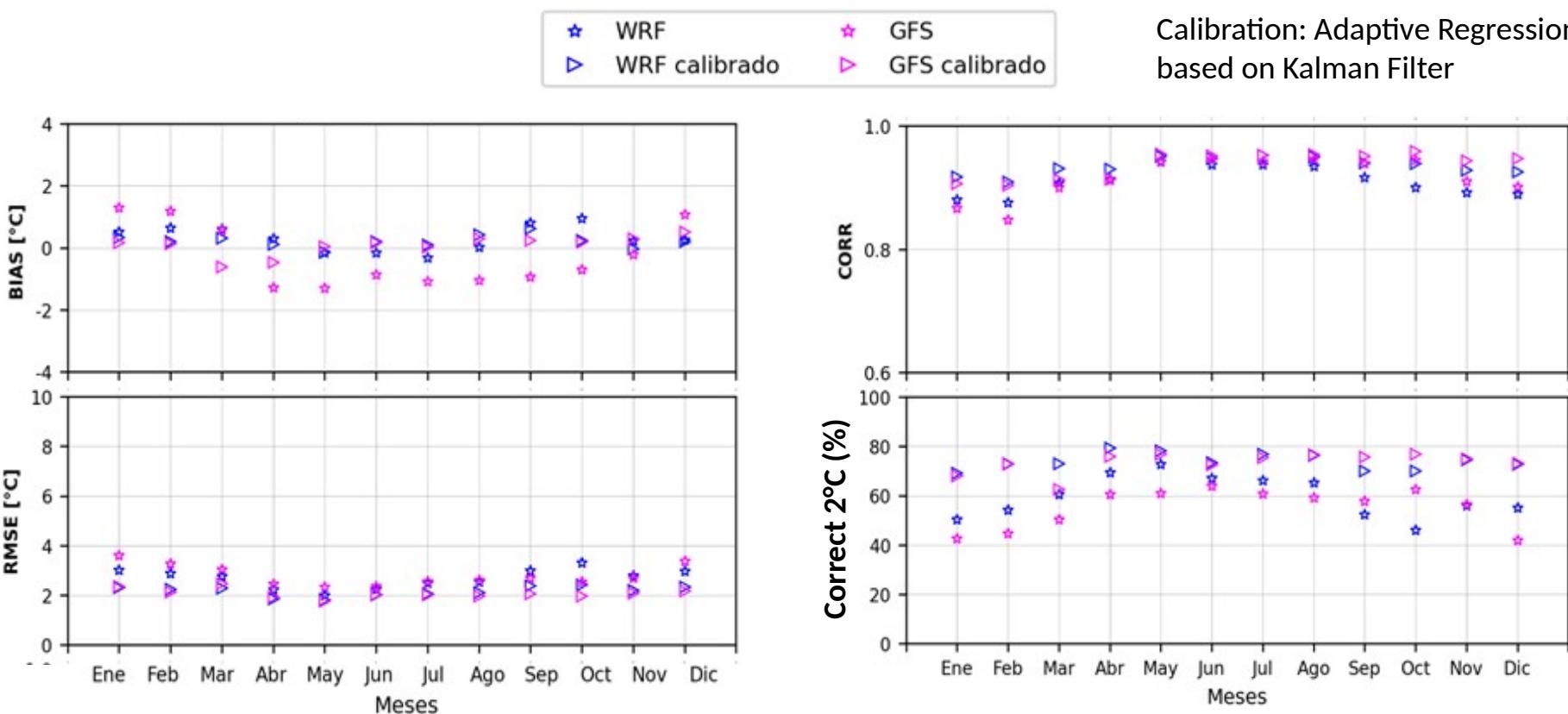
30-h forecast (triangles)  
54-h forecast (circles)

# Deterministic 24-h Tmin



Calibration: Adaptive Regression  
based on Kalman Filter

# Deterministic 24-h Tmax

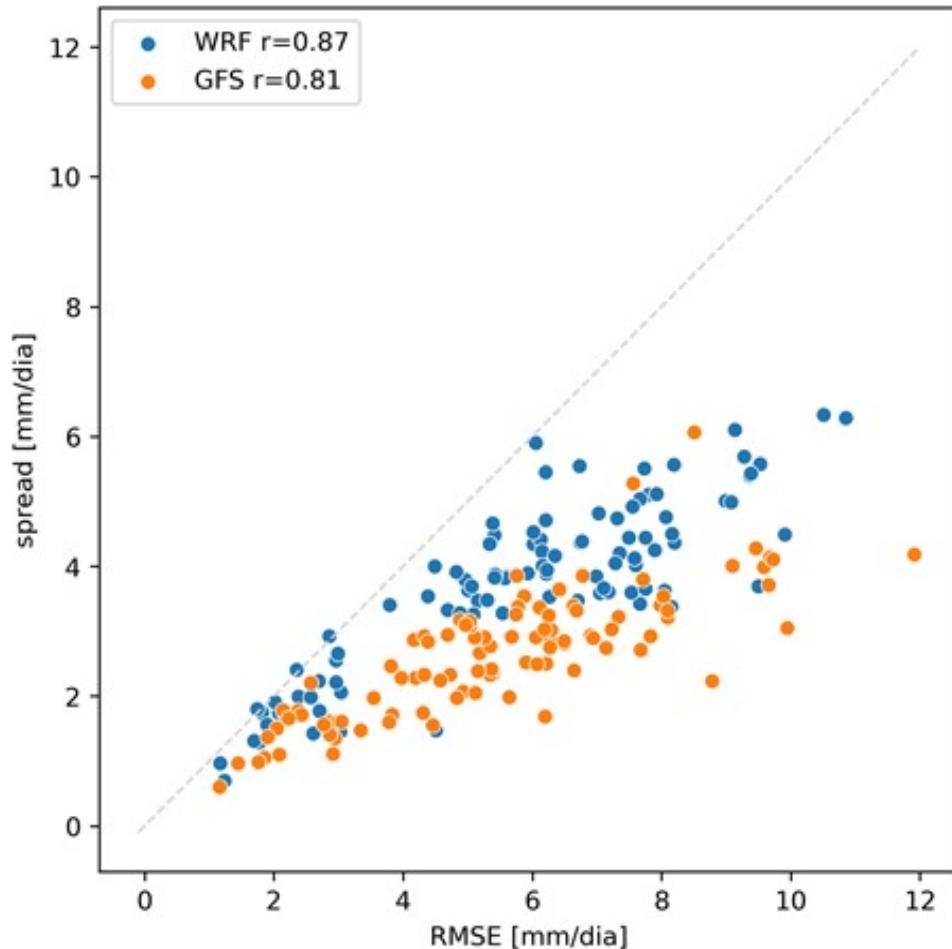


Calibration: Adaptive Regression  
based on Kalman Filter

# Ensemble verification

# Ensemble 24-h precipitation

- Relationship between ensemble mean RMSE and spread shows a better correspondence for WRF than for GFS

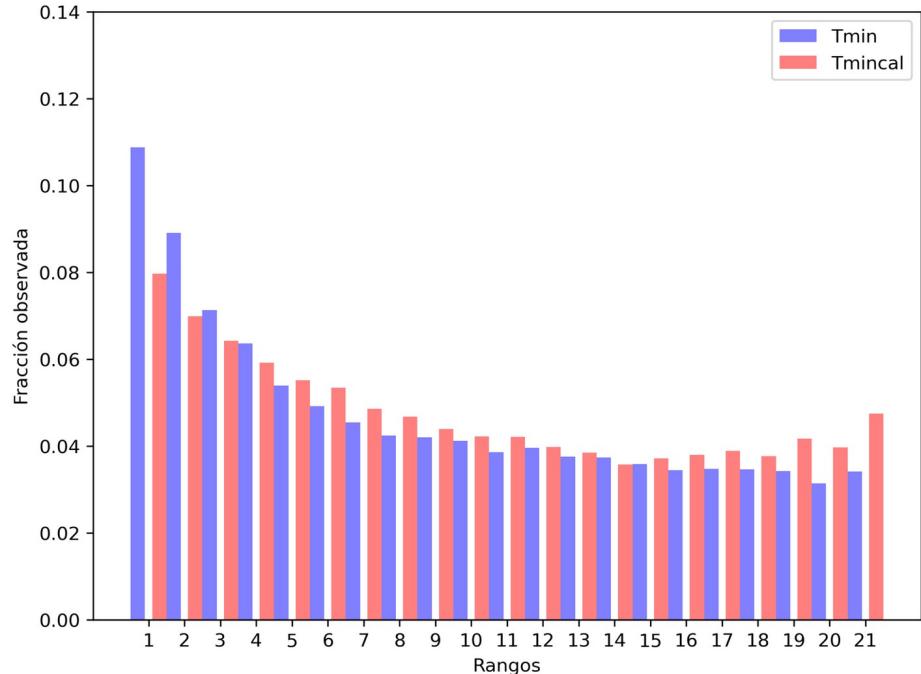


# Ensemble 24-h Tmin and Tmax

WRF.ENS: Tmin vs. obs [ANUAL 2020-2022]

Ciclo 06Z [válido para DIA+1 entre 00 y 12Z]

Histograma de rangos normalizado: la suma de los intervalos es 1, valores > 0.01

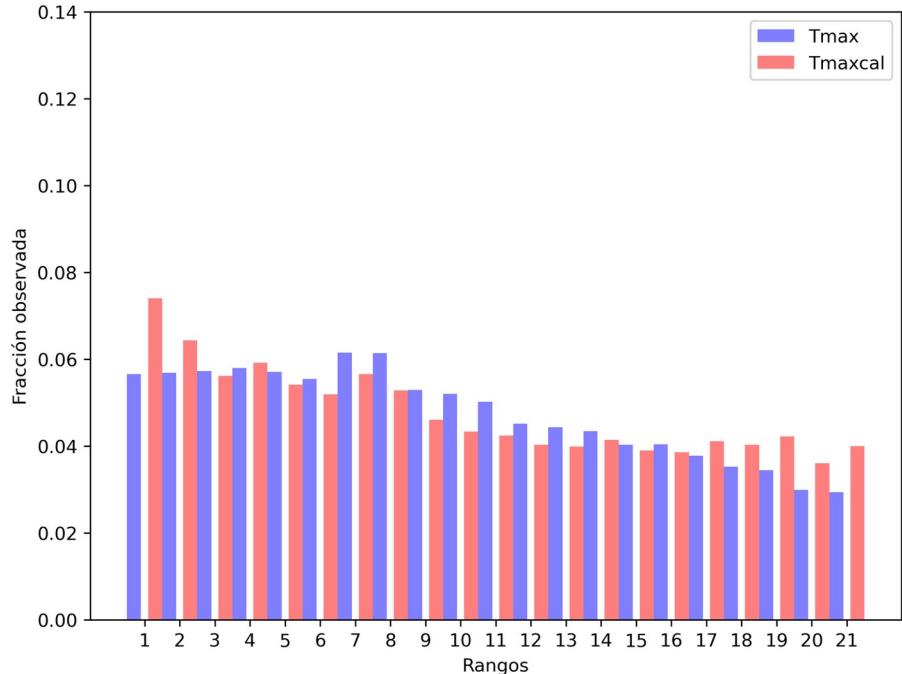


Rank histogram for Tmin  
Under-dispersive ensemble

WRF.ENS: Tmax vs. obs [ANUAL 2020-2022]

Ciclo 06Z [válido para DIA+1 entre 12 y 00Z]

Histograma de rangos normalizado: la suma de los intervalos es 1, valores > 0.01



Rank histogram for Tmax:

# Conclusions

- The verification of the SAP.SMN in their deterministic and ensamble runs are comparable to the GEFS
- As expected improvements are found mostly in small scale precipitation
- Preliminary results indicate that the inclusion of assimilation further improves results
- Calibration is applied now to surface temperature, wind intensity, and precipitation
- Future directions include:
  - Testing of the MPAS and evaluating a future transition to this model
  - Follow MONAN progress and examine lines of possible interactions



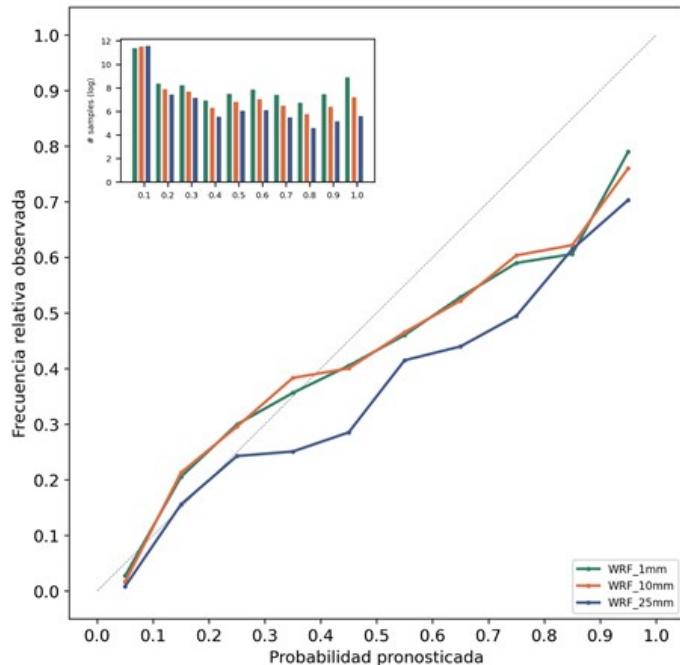
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[www.smn.gob.ar](http://www.smn.gob.ar)



# Ensemble 24-h precipitation



- WRF overestimates events greater than 25mm and for 1mm and 10mm thresholds, it shows an underestimation for low probabilities.
- A not very smooth curve implies the limited sample size

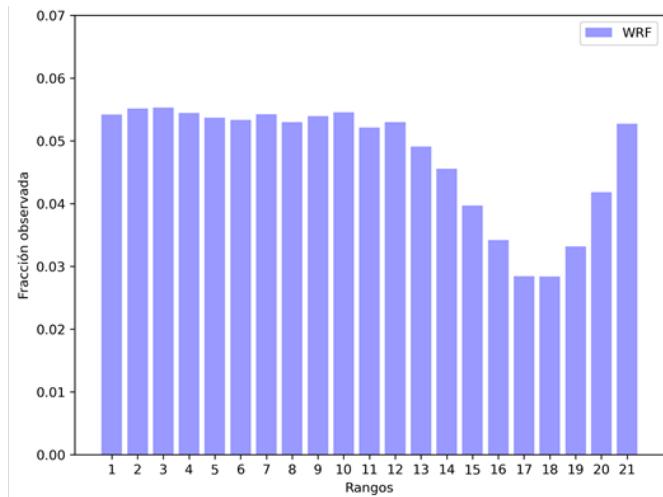
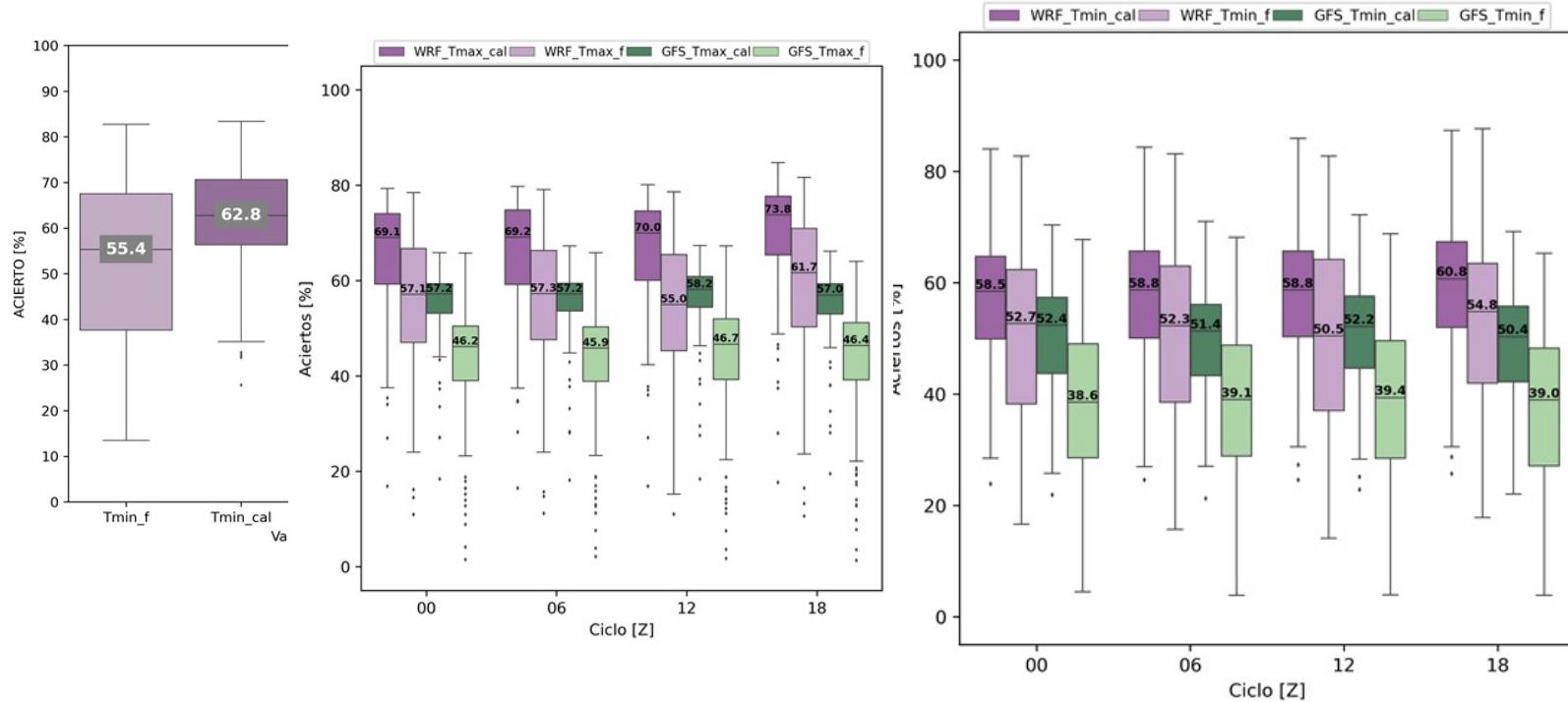


Figura 14: Histograma de rangos para la PP24 (izq.) normalizado tal que la suma de los rangos es 1. Se consideraron valores de PP24 superiores a 0.01mm y diagrama de confiabilidad (der.) para los umbrales 1, 10 y 25mm (ciclo 06Z, plazo t+30h).

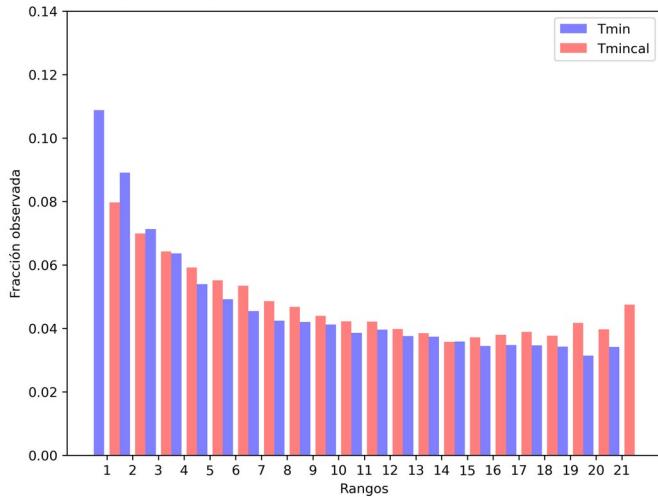
# Ensemble 24-h Tmin and Tmax



**Figura 15:** Boxplots del porcentaje de acierto de las Tmin y Tmáx calibradas y sin calibrar computado con las medias del ensamble. El valor indicado dentro de la caja corresponde a la mediana de la distribución (ciclo 06Z, día+1).

# Ensemble 24-h Tmin and Tmax

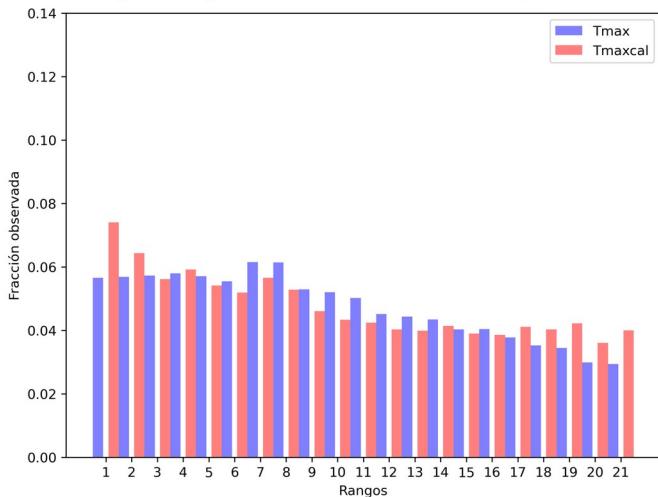
WRF.ENS: Tmin vs. obs [ANUAL 2020-2022]  
Ciclo 06Z [válido para DIA+1 entre 00 y 12Z]  
Histograma de rangos normalizado: la suma de los intervalos es 1, valores > 0.01



Tmin: although spread is low (U-shaped), calibration improves positive bias of variance

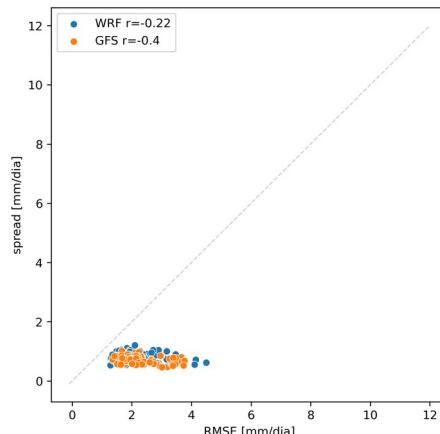
Under-dispersive ensemble

WRF.ENS: Tmax vs. obs [ANUAL 2020-2022]  
Ciclo 06Z [válido para DIA+1 entre 12 y 00Z]  
Histograma de rangos normalizado: la suma de los intervalos es 1, valores > 0.01

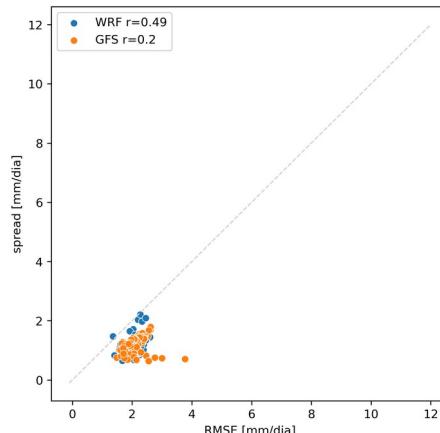


Tmax: observation variability (uncertainty) is better represented by the forecast spread a little better than for Tmin

Tmin.cal vs. obs [ANUAL 2020-2022]  
Ciclo 06Z [válido para DIA+1 entre 00 y 12Z]  
101 estaciones



Tmax.cal vs. obs [ANUAL 2020-2022]  
Ciclo 06Z [válido para DIA+1 entre 12 y 00Z]  
101 estaciones

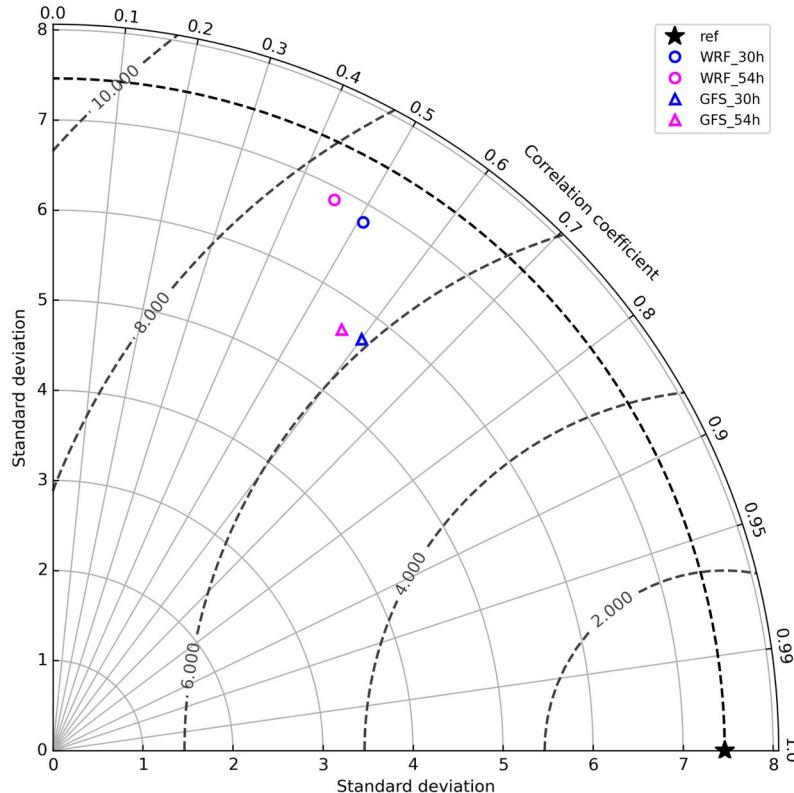


# Deterministic 24-h precipitation

WRF.DET: PP24 vs. obs [ANUAL 2020-2022]

Ciclo 06Z

Diagrama de Taylor

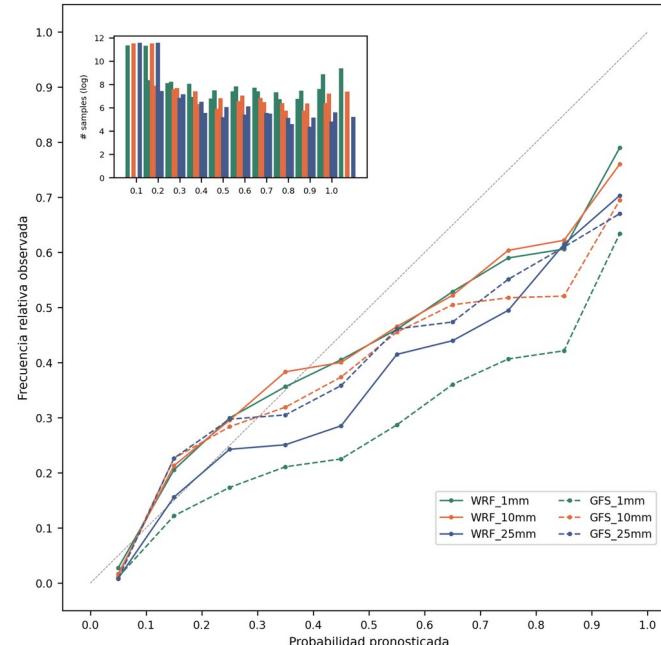


# Ensemble 24-h precipitation

WRF.ENS: PP24 vs. obs [ANUAL 2020-2022]

Ciclo 06Z plazo 30h

Diagrama de confiabilidad



# Ensemble 24-h Tmin and Tmax

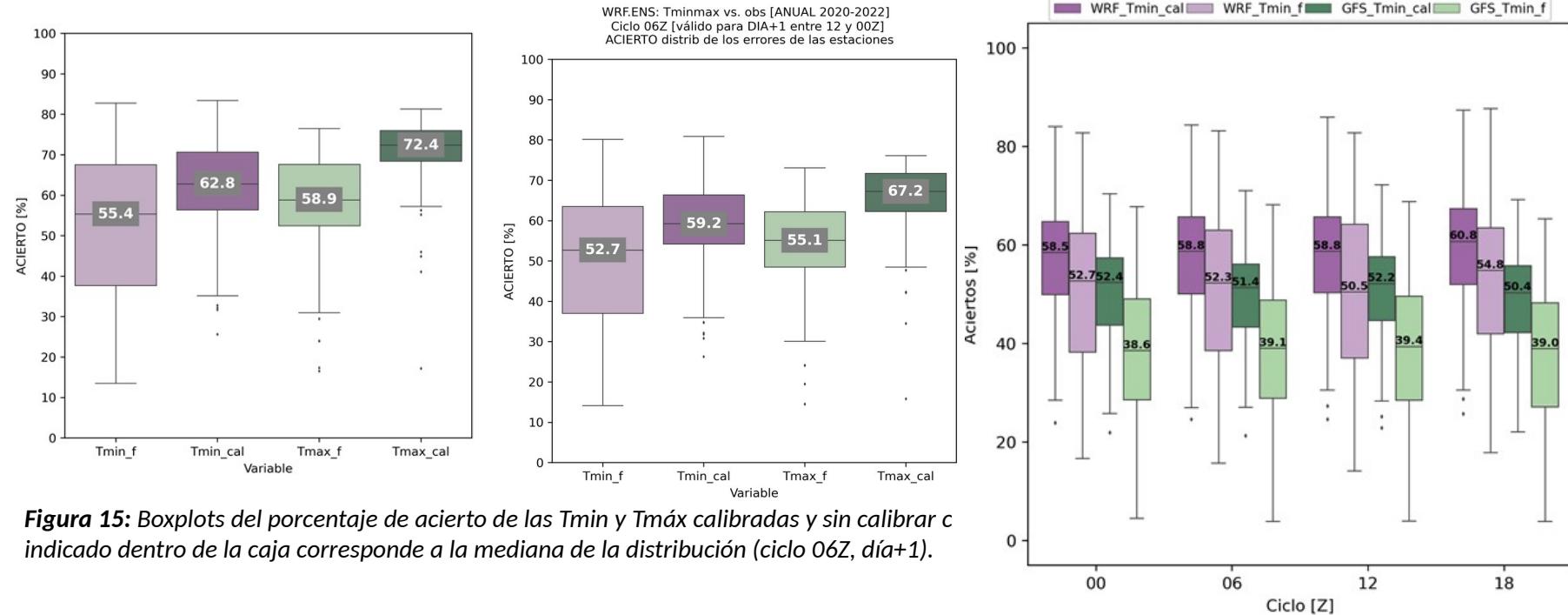


Figura 15: Boxplots del porcentaje de acierto de las Tmin y Tmáx calibradas y sin calibrar c indicado dentro de la caja corresponde a la mediana de la distribución (ciclo 06Z, día+1).

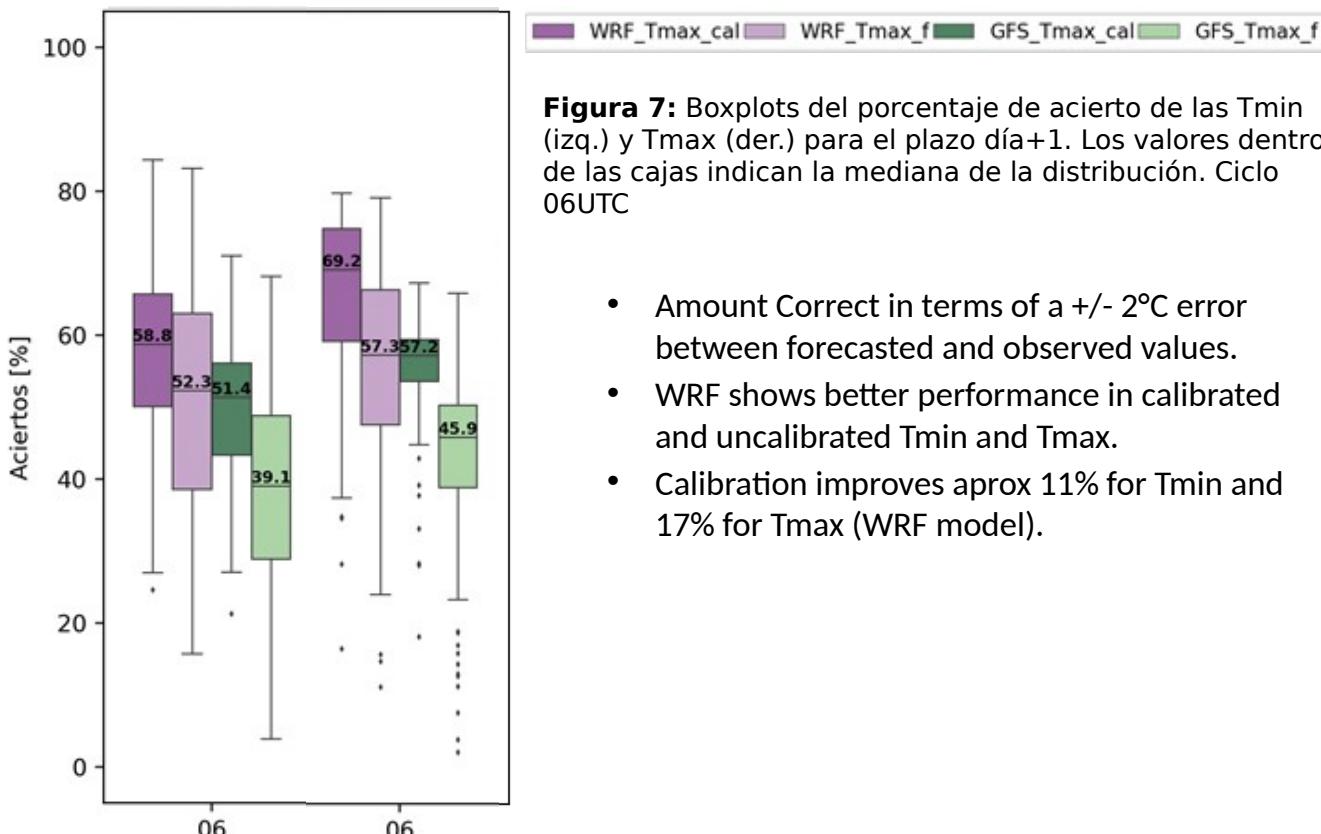
# Operational NWP System (SAP.SMN) since 2020

20-member ensemble configuration					
Microphysics	Member number - PBL				
<b>WSM6</b>	001-MYJ	002-MYJ	003-MYJ	004-SH	005-SH
	006-SH	007-YSU	008-YSU	009-YSU	010-MYJ
<b>LIN</b>	011-MYJ	012-MYJ	013-MYJ	014-SH	015-SH
	016-SH	017-YSU	018-YSU	019-YSU	020-YSU

Mellor-Yamada-Janjic (MYJ), Shin-Hong (SH), Yonsei University (YSU), (WSM6) microphysics scheme ([Hong and Lim 2006](#)), Lin scheme ([Lin et al. 1983](#));

**Tabla I:** Combinación de las configuraciones físicas de los miembros del SAP.SMN-ENS

# Deterministic 24-h Tmin and Tmax



**Figura 7:** Boxplots del porcentaje de acierto de las Tmin (izq.) y Tmax (der.) para el plazo día+1. Los valores dentro de las cajas indican la mediana de la distribución. Ciclo 06UTC

- Amount Correct in terms of a +/- 2°C error between forecasted and observed values.
- WRF shows better performance in calibrated and uncalibrated Tmin and Tmax.
- Calibration improves approx 11% for Tmin and 17% for Tmax (WRF model).

# The SMN regional forecasting system (SAP.SMN)

WRF (ARW) 4.0

20 members

4km resolution (det and ens)

45 levels (top at 10hPa)

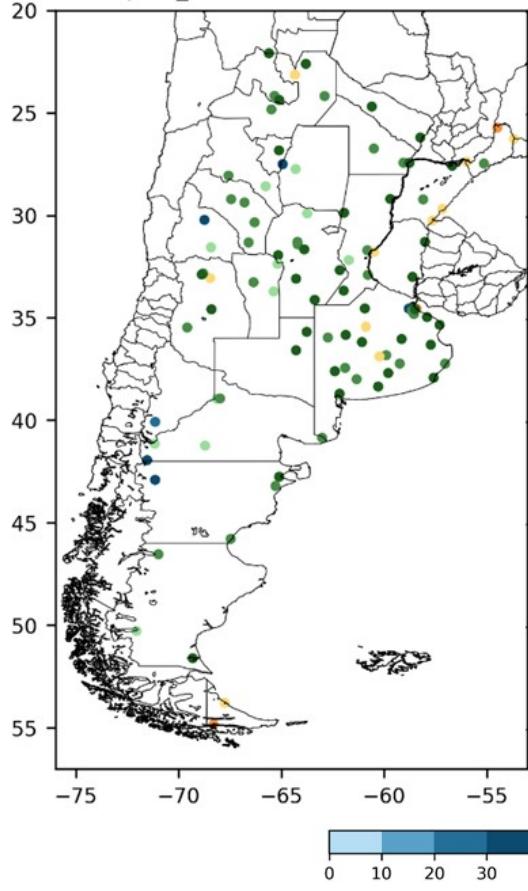
4 daily cycles

IC and BC from GFS



Figura 1: Dominio WRF con proyección Conforme de Lambert

WRF Tmin\_cal  
porc\_acierto TOT PAIS=59.03



WRF Tmax\_cal  
porc\_acierto TOT PAIS=68.71

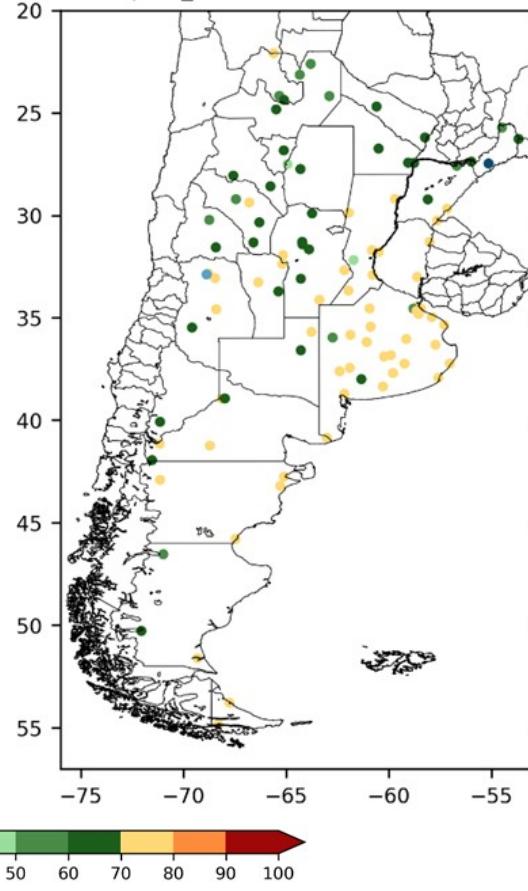
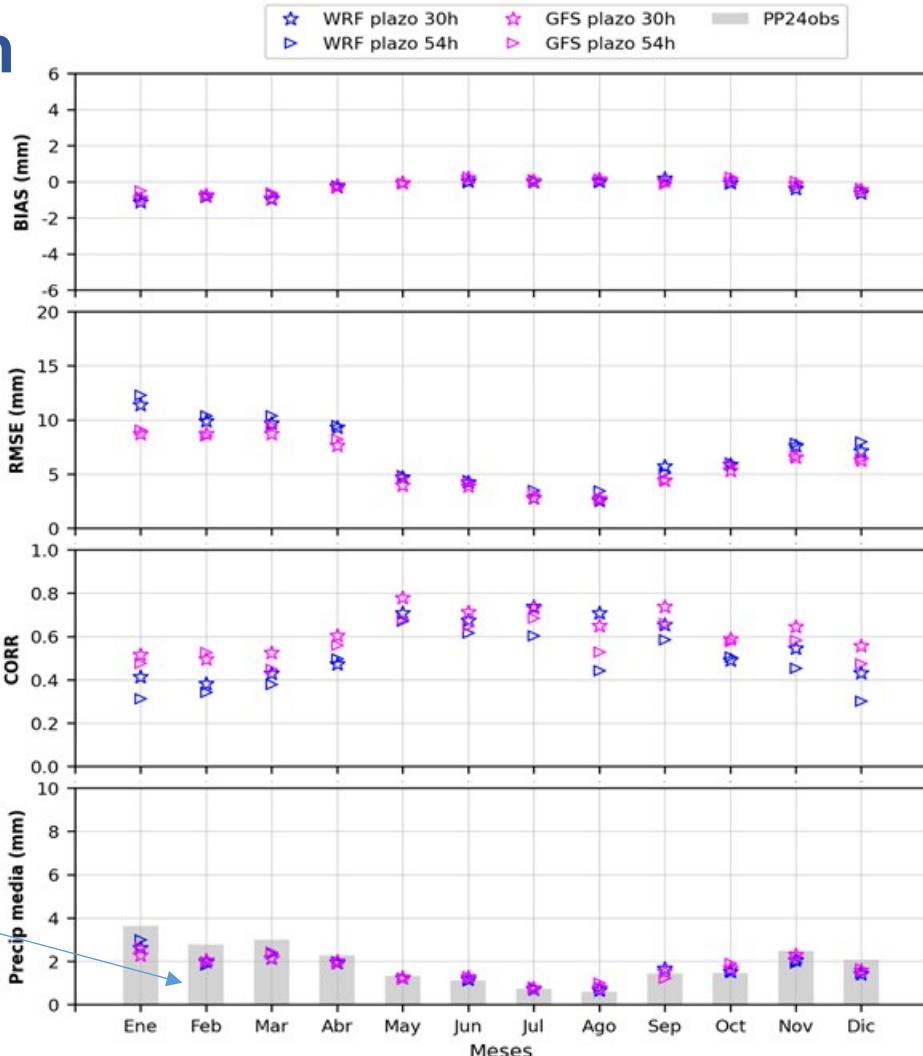


Figura 8: Mapas de porcentaje de acierto para el día+1 de la temperatura mínima calibrada (izq.) y máxima calibrada (der.) ( ciclo 1962-2012). En el título se indica el valor del porcentaje de acierto medio para el total de estaciones

# Deterministic 24-h precipitation

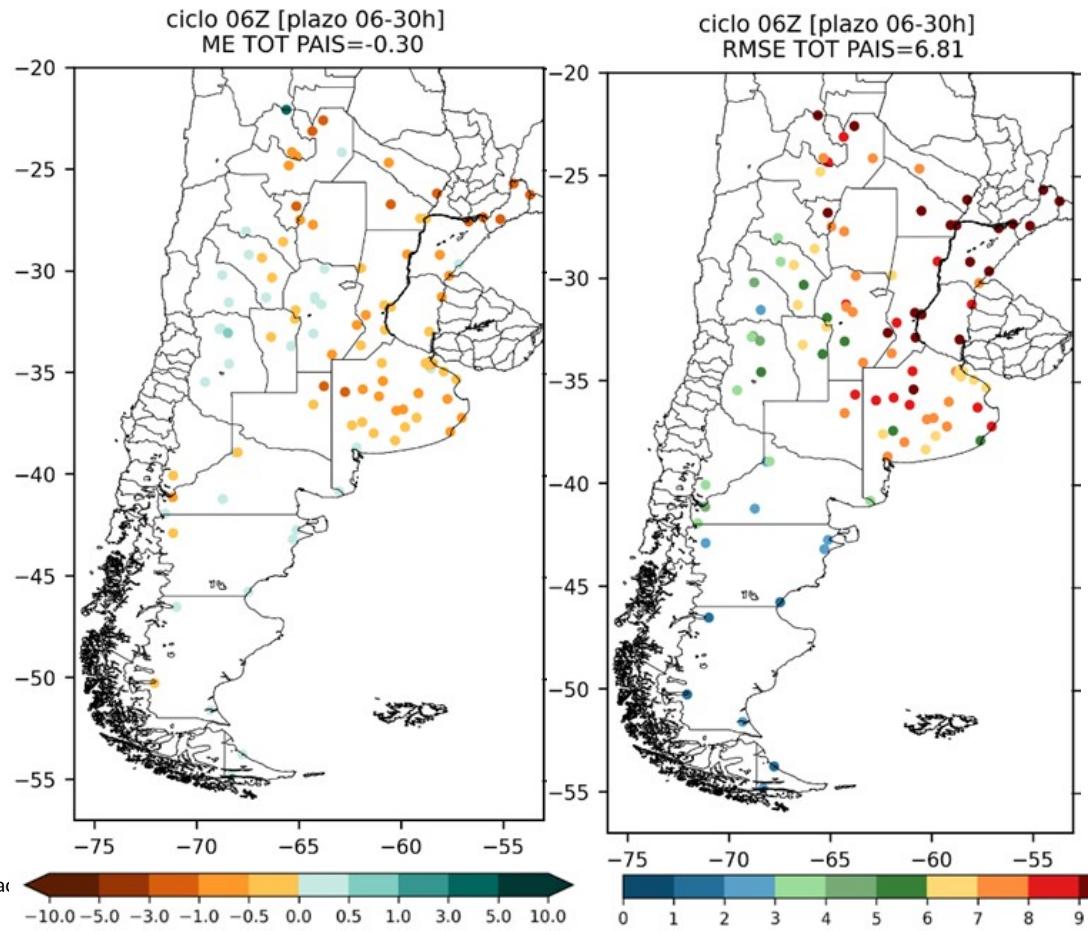
For WRF and GFS, cycle 06Z

Observations



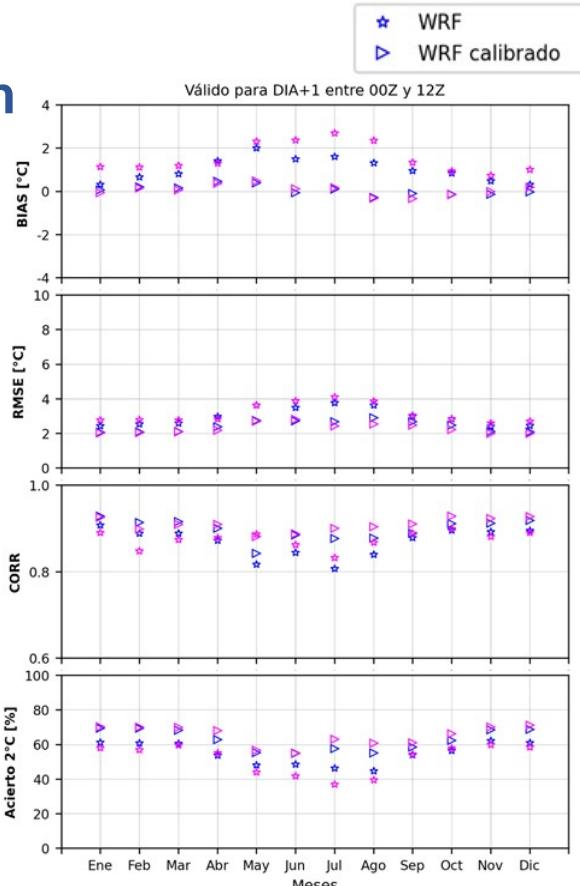
# Deterministic 24-h precipitation

**Figura 3:** Mapas de BIAS de WRF (izq.) y RMSE de WRF (der.) de la precipitación diaria (ciclo 06Z, plazo 30h). Los valores en el título indican el promedio sobre el total de las estaciones sobre el periodo de verificación.

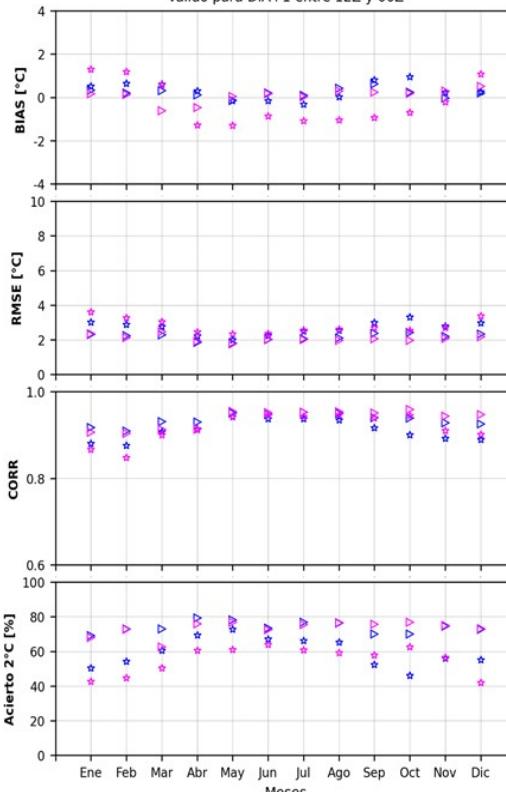


# Deterministic 24-h Tmin and Tmax

Tmin



Válido para DIA+1 entre 12Z y 00Z



Tmax

**Figura 6:** Evolución anual del BIAS, RMSE, el coeficiente de correlación lineal y el porcentaje de acierto para Tmín (izq.) y Tmáx (der.) calibradas y sin calibrar (ciclo 06Z, plazo día+1)  
Todo las estaciones de sup junto, los 3 años.

# **Taken from** Avaliação dos Candidatos ao Núcleo Dinâmico do Componente Atmosférico (MONAN-ATM):

- A proposta do Model for Ocean-laNd-Atmosphere predictioN (MONAN) representa um novo paradigma de foco e organização para o avanço efetivo da qualidade, confiabilidade e prazo de previsibilidade dos produtos numéricos de previsão de tempo, clima e ambiente do Brasil.