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CopERnIcus climate change Service Evolution - CERISE

Comprehensive Assessment of Seasonal Forecasts Across Multiple Models and Model Versions

Núria Pérez-Zanón, Nadia Milders, Carlos Delgado-Torres, Victòria Agudetse, Ángel G. Muñoz, and Francisco Doblas-Reyes

11th of September 2025

EMS Annual Meeting

Ljubljana & online | 7–12 September 2025

ECMWF · Norwegian Meteorological Institute · SMHI · Deutscher Wetterdienst (DWD) Wetter und Klima aus einer Hand · cmcc Centro Euro-Mediterraneo sui Cambiamenti Climatici · BSC Barcelona Supercomputing Center Centro Nacional de Supercomputación · METEO FRANCE · The Danish Meteorological Institute · Estellus · IPMA · NILU · Met Office

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CERISE

The three most important reasons to verify forecasts are:

★ to monitor forecast quality - how accurate are the forecasts and are they improving over time?

★ to improve forecast quality - the first step toward getting better is discovering what you're doing wrong.

★ to compare the quality of different forecast systems - to what extent does one forecast system give better forecasts than another, and in what ways is that system better?

https://www.cawcr.gov.au/projects/verification/#Why_verify

\+ To inform users about the quality of the climate products

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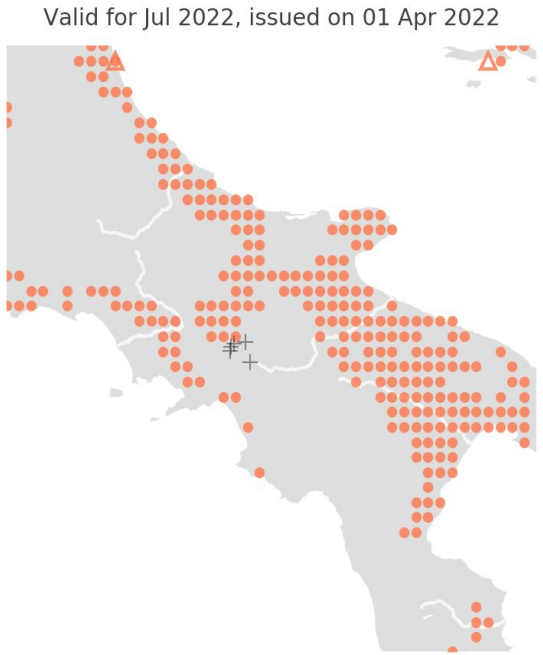
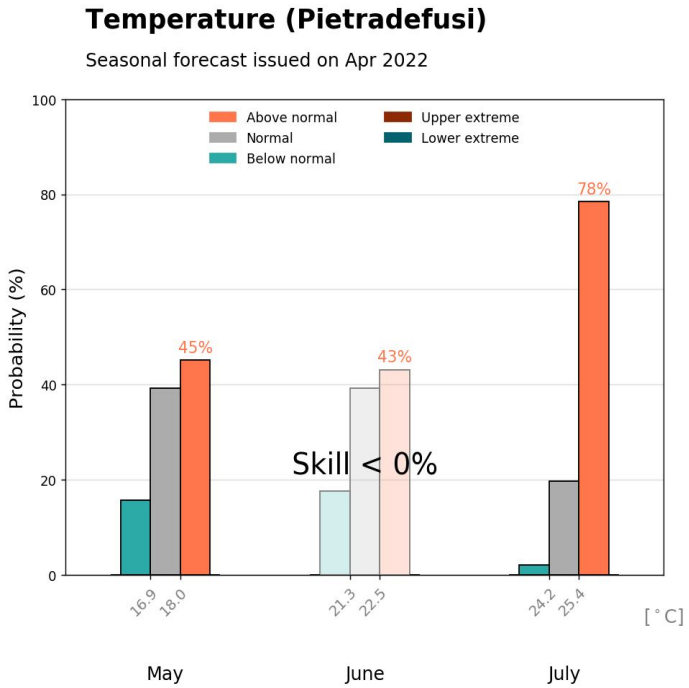
CERISE

VitiGEOSS climate forecast service developed for the vineyard management is an example on applying forecast verification to inform users

Mask applied during operational service





Pérez-Zanón et al., 2024 doi:10.1016/j.cliser.2024.100513

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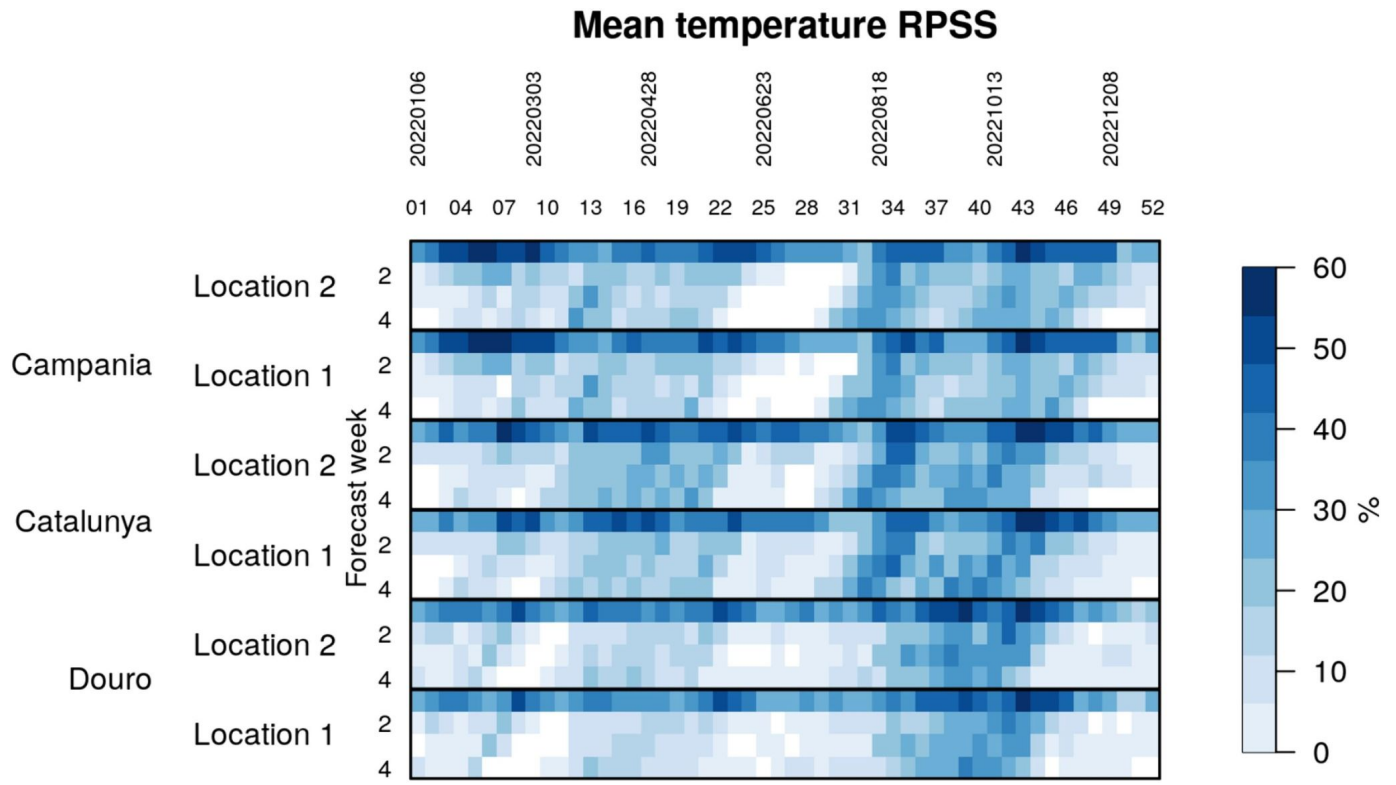
VitiGEOSS climate forecast service developed for the vineyard management is an example on applying forecast verification to inform users

Overall expectation along the year



Pérez-Zanón et al., 2024 doi:10.1016/j.cliser.2024.100513

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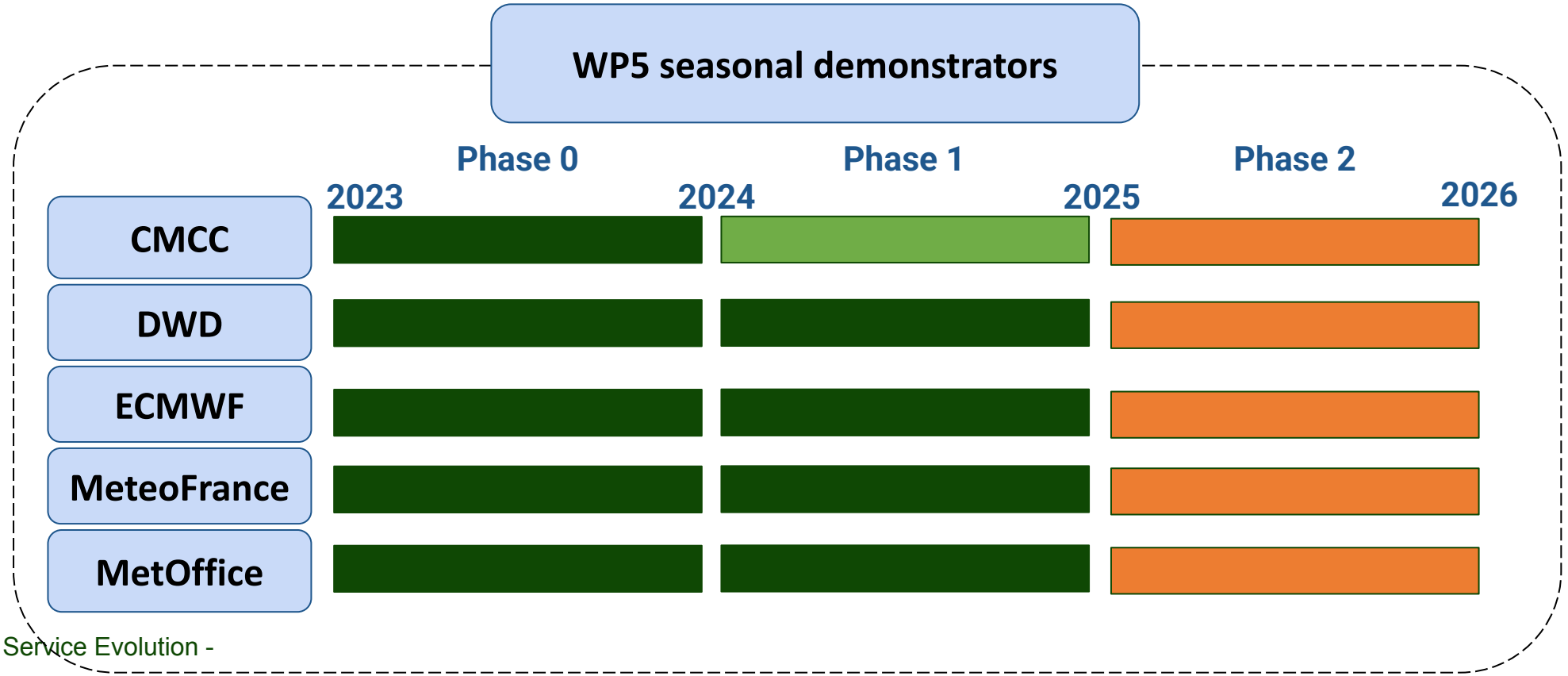
CERISE

CERISE aims to **support the long-term evolution** of the C3S for :

➔ regional and global climate **reanalysis** and

➔ multi-system **seasonal prediction**,

towards an Earth system approach, with a **focus on land-atmosphere coupling**.



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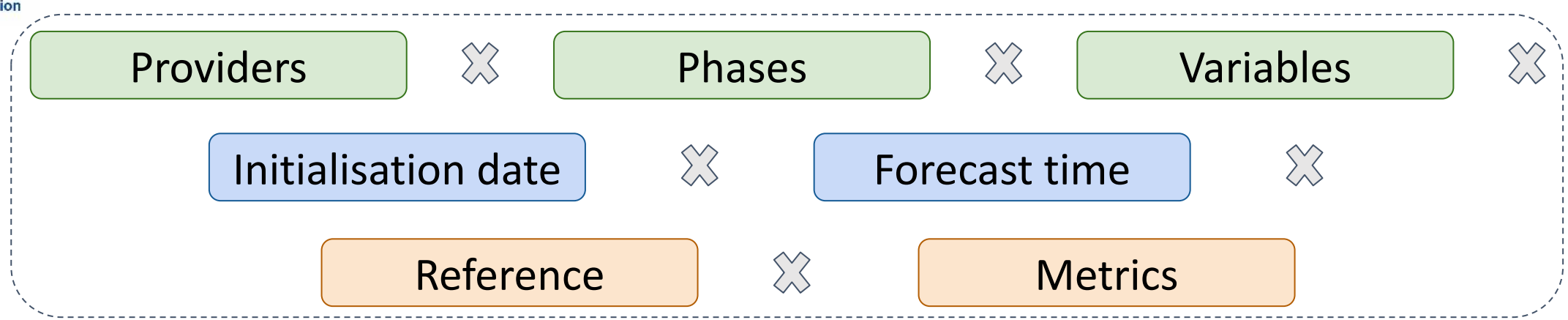

Phase 0 = 5 x 1 x 9 x 12 x 6 x 1 x 7 = 68040

Phase 1 and 2 = 5 x 2 x 9 x 4 x 4 x 1 x 7 = 10080

= 78120

Only in Task 5.3, we are expecting ~ 80000 maps

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SUbseasoNal to decadal climate forecaSt post-processing and assEssment suiTe

Pérez-Zanón, N., Agudetse, V., Palma, L., Ho, A.-C., Delgado-Torres, C., Milders, N., Duzenli, E., Llabrés-Brustenga, A., de Paula Kinoshita, B., Bretonnière, P.-A., and G. Muñoz, Á.: SUNSET: SUbseasoNal to decadal climate forecast post-processIng and asSEssmenT suite, EMS Annual Meeting 2024, Barcelona, Spain, 1–6 Sep 2024, EMS2024-361, https://doi.org/10.5194/ems2024-361, 2024.

> Post-processing climate forecast (e.g. climate indices)

> Assessment of climate forecast

> Visualization

Manubens et al., 2018 doi:10.1016/j.envsoft.2018.01.018; Pérez-Zanón et al. 2022 doi:10.5194/GMD-15-6115-2022; Pérez-Zanón et al., 2023 https://doi.org/10.1016/j.cliser.2023.100393

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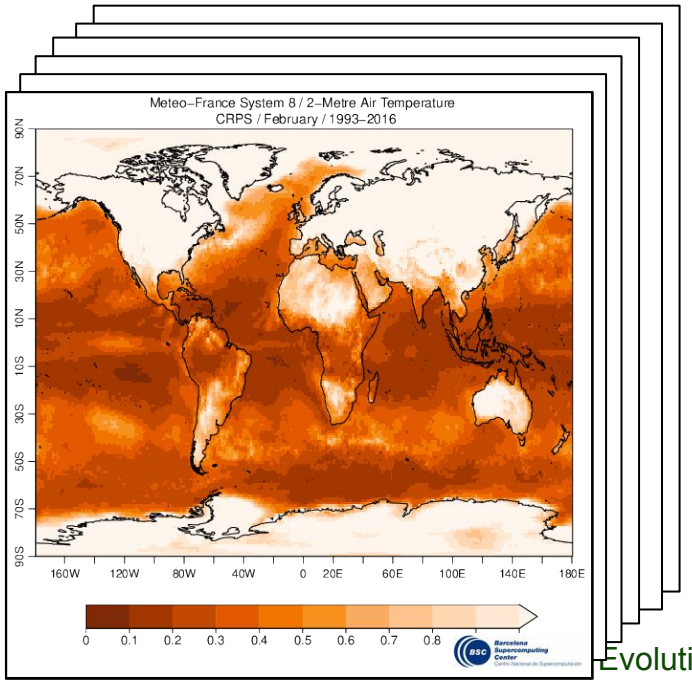
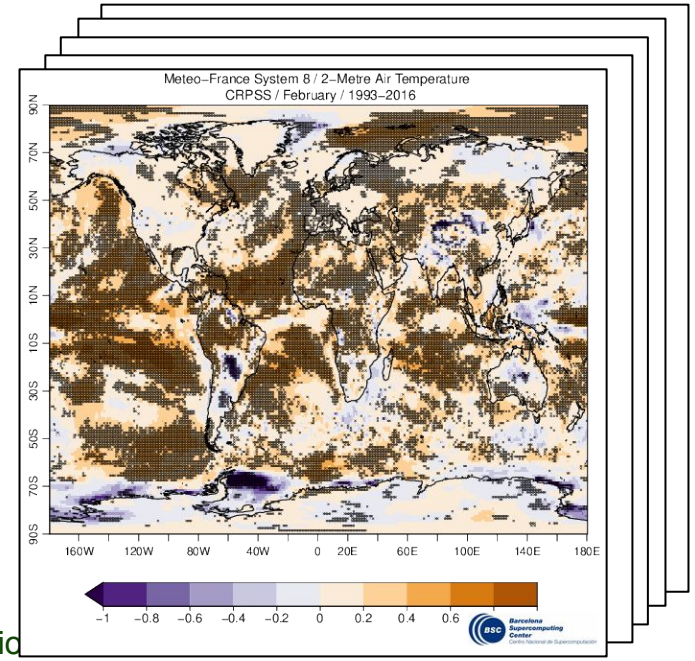
Consider the evaluation of 1 variable, for 1 phase 0 demonstrator, we will obtain 504 maps for all 5 metrics that characterise different forecast features.

Are we able to summarise them?

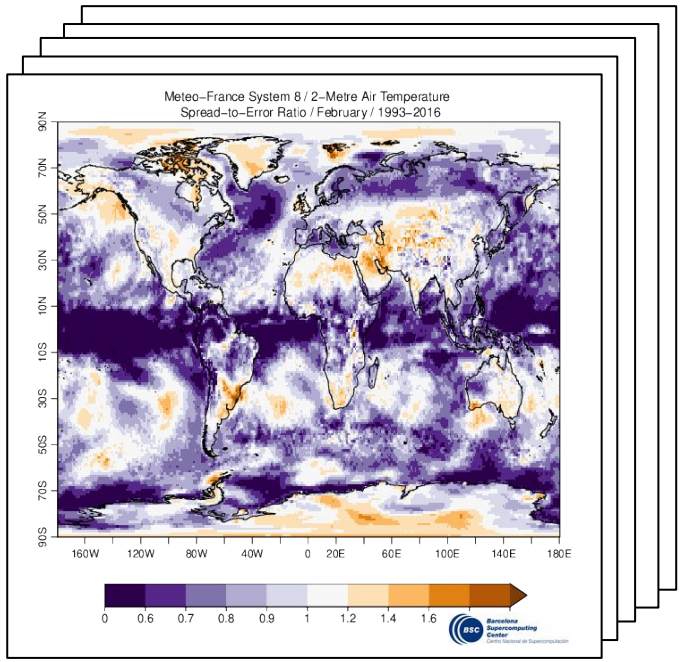
Mean bias



CRPSS



Spread-to-error ratio



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CERISE

Get a summary of the metrics for each forecast system and variable: **Scorecards**

Mean bias →systematic error (over- or under-estimation)
Correlation →association (linear relationship with observations)
RPSS / CRPSS → accuracy + resolution + reliability
Spread-to-error ratio → reliability

2-metre air temperature of Meteo-France System 8

(Ref: ERA5 1993-2016)

Mean bias (K)

Region	Forecast Month	Start date: Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Extra-tropical NH	1	-0.20	-0.40	-0.29	0.02	0.62	1.21	1.31	1.01	0.59	0.53	0.62	0.20
	2	-0.42	-0.41	-0.04	0.63	1.40	1.72	1.42	0.77	0.54	0.63	0.27	-0.22
	3	-0.48	-0.16	0.58	1.38	1.90	1.77	1.07	0.67	0.70	0.33	-0.23	-0.47
	4	-0.17	0.49	1.34	1.89	1.93	1.35	0.87	0.73	0.38	-0.17	-0.47	-0.54
	5	0.44	1.25	1.86	1.93	1.50	1.11	0.90	0.38	-0.15	-0.46	-0.56	-0.24
	6	1.21	1.80	1.91	1.52	1.27	1.13	0.49	-0.16	-0.46	-0.56	-0.30	0.41
Tropics	1	0.56	0.55	0.59	0.59	0.57	0.61	0.62	0.58	0.53	0.53	0.51	0.52
	2	0.62	0.62	0.63	0.62	0.68	0.69	0.65	0.56	0.53	0.54	0.55	0.63
	3	0.68	0.63	0.63	0.70	0.72	0.68	0.61	0.54	0.53	0.57	0.67	0.68
	4	0.67	0.61	0.67	0.73	0.69	0.64	0.58	0.54	0.56	0.69	0.70	0.71
	5	0.64	0.64	0.69	0.71	0.65	0.58	0.55	0.56	0.67	0.70	0.73	0.70
	6	0.67	0.66	0.67	0.67	0.59	0.55	0.57	0.68	0.68	0.73	0.72	0.65
Extra-tropical SH	1	0.43	0.31	0.15	-0.07	-0.37	-0.57	-0.54	-0.63	-0.51	-0.25	-0.09	0.14
	2	0.65	0.33	0.10	-0.25	-0.58	-0.63	-0.75	-0.60	-0.29	-0.06	0.40	0.76
	3	0.55	0.32	-0.05	-0.41	-0.63	-0.87	-0.72	-0.36	-0.11	0.43	0.97	0.85
	4	0.55	0.20	-0.22	-0.44	-0.85	-0.79	-0.44	-0.16	0.36	0.98	1.03	0.72
	5	0.46	0.04	-0.29	-0.71	-0.78	-0.50	-0.25	0.32	0.92	1.04	0.88	0.74
	6	0.32	-0.04	-0.56	-0.69	-0.50	-0.32	0.22	0.89	1.01	0.89	0.89	0.66

Correlation

Region	Forecast Month	Start date: Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Extra-tropical NH	1	0.49	0.55	0.58	0.47	0.46	0.44	0.44	0.52	0.47	0.43	0.43	0.49
	2	0.27	0.38	0.32	0.29	0.26	0.29	0.34	0.33	0.28	0.24	0.25	0.29
	3	0.25	0.32	0.29	0.23	0.27	0.28	0.33	0.25	0.25	0.18	0.25	0.25
	4	0.24	0.26	0.22	0.25	0.29	0.27	0.23	0.23	0.26	0.22	0.25	0.28
	5	0.30	0.24	0.25	0.23	0.28	0.23	0.21	0.25	0.21	0.23	0.26	0.20
	6	0.25	0.24	0.24	0.25	0.27	0.18	0.18	0.20	0.22	0.24	0.20	0.22
Tropics	1	0.68	0.71	0.73	0.70	0.67	0.65	0.65	0.65	0.65	0.66	0.60	0.66
	2	0.59	0.59	0.62	0.57	0.57	0.56	0.56	0.57	0.59	0.52	0.53	0.57
	3	0.53	0.57	0.52	0.51	0.52	0.50	0.53	0.53	0.50	0.51	0.52	0.55
	4	0.52	0.49	0.46	0.48	0.47	0.48	0.51	0.47	0.50	0.50	0.51	0.53
	5	0.46	0.43	0.43	0.44	0.46	0.48	0.45	0.47	0.50	0.51	0.49	0.52
	6	0.40	0.41	0.41	0.43	0.46	0.42	0.44	0.47	0.50	0.49	0.47	0.43
Extra-tropical SH	1	0.51	0.54	0.57	0.49	0.46	0.40	0.45	0.45	0.44	0.50	0.45	0.52
	2	0.39	0.38	0.36	0.26	0.28	0.28	0.24	0.29	0.36	0.33	0.32	0.37
	3	0.31	0.31	0.28	0.17	0.26	0.21	0.26	0.31	0.29	0.29	0.30	0.30
	4	0.26	0.24	0.21	0.20	0.18	0.21	0.27	0.24	0.27	0.26	0.24	0.30
	5	0.20	0.22	0.20	0.14	0.20	0.25	0.24	0.22	0.25	0.22	0.20	0.24
	6	0.14	0.17	0.18	0.21	0.23	0.24	0.22	0.23	0.21	0.23	0.22	0.19

RPSS

Region	Forecast Month	Start date: Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Extra-tropical NH	1	0.12	0.18	0.21	0.11	0.12	0.11	0.09	0.16	0.12	0.10	0.10	0.12
	2	0.02	0.08	0.03	0.04	0.03	0.04	0.06	0.06	0.03	-0.01	0.00	0.04
	3	0.01	0.04	0.04	0.01	0.02	0.04	0.06	0.02	-0.01	-0.02	0.02	0.02
	4	0.01	0.03	0.01	0.02	0.04	0.04	0.02	0.00	0.02	0.02	0.02	0.03
	5	0.04	0.01	0.01	0.01	0.03	0.03	-0.01	0.01	0.02	0.02	0.02	0.00
	6	0.02	0.01	0.01	0.02	0.03	-0.02	-0.01	0.01	0.02	0.02	-0.01	0.00
Tropics	1	0.28	0.30	0.31	0.26	0.25	0.25	0.22	0.22	0.23	0.24	0.19	0.28
	2	0.20	0.19	0.20	0.18	0.19	0.16	0.15	0.17	0.19	0.16	0.18	0.20
	3	0.15	0.17	0.13	0.13	0.12	0.09	0.13	0.15	0.14	0.16	0.16	0.18
	4	0.13	0.12	0.09	0.09	0.07	0.09	0.13	0.13	0.16	0.16	0.16	0.16
	5	0.09	0.08	0.05	0.04	0.07	0.10	0.10	0.13	0.15	0.16	0.13	0.15
	6	0.06	0.04	0.02	0.04	0.08	0.08	0.10	0.13	0.16	0.14	0.12	0.09
Extra-tropical SH	1	0.11	0.16	0.19	0.12	0.08	0.06	0.09	0.07	0.08	0.12	0.10	0.13
	2	0.06	0.06	0.05	-0.01	-0.01	0.00	-0.03	0.00	0.04	0.02	0.00	0.04
	3	0.03	0.02	-0.01	-0.07	-0.02	-0.04	-0.01	0.01	0.01	0.00	0.01	0.01
	4	0.00	-0.02	-0.04	-0.04	-0.05	-0.04	-0.02	-0.02	0.00	0.00	-0.02	0.02
	5	-0.04	-0.01	-0.04	-0.08	-0.04	-0.02	0.00	-0.03	0.00	-0.02	-0.02	-0.01
	6	-0.06	-0.05	-0.05	-0.04	-0.03	0.01	-0.02	-0.01	-0.02	0.00	-0.01	-0.05

CRPSS

Region	Forecast Month	Start date: Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Extra-tropical NH	1	0.10	0.15	0.17	0.10	0.08	-0.08	-0.03	0.11	0.09	0.08	0.07	0.10
	2	0.02	0.07	0.03	0.02	-0.12	-0.06	0.02	0.04	0.03	0.00	-0.01	0.03
	3	0.01	0.04	0.02	-0.14	-0.08	0.00	0.04	0.02	0.01	-0.01	0.00	0.02
	4	0.00	0.00	-0.15	-0.09	0.00	0.02	0.02	0.01	0.01	0.01	0.01	0.03
	5	0.01	-0.15	-0.11	-0.02	0.03	0.02	0.00	0.01	0.01	0.02	0.01	0.00
	6	-0.14	-0.11	-0.02	0.01	0.03	-0.01	-0.01	0.01	0.02	0.02	-0.02	-0.02
Tropics	1	0.22	0.26	0.28	0.24	0.20	0.17	0.15	0.16	0.17	0.18	0.10	0.20
	2	0.17	0.16	0.18	0.14	0.12	0.09	0.08	0.11	0.14	0.09	0.09	0.15
	3	0.12	0.14	0.09	0.07	0.06	0.01	0.06	0.10	0.09	0.10	0.11	0.15
	4	0.10	0.07	0.04	0.03	0.00	0.01	0.07	0.07	0.11	0.13	0.12	0.13
	5	0.05	0.03	0.00	-0.02	0.00	0.03	0.03	0.09	0.12	0.13	0.10	0.11
	6	0.02	0.00	-0.02	-0.03	0.02	0.01	0.05	0.10	0.13	0.12	0.08	0.04
Extra-tropical SH	1	-0.16	0.12	0.16	0.11	0.07	0.05	0.08	0.07	0.07	0.10	0.03	-0.12
	2	0.03	0.04	0.04	-0.02	-0.01	0.00	-0.04	-0.01	0.03	-0.02	-0.25	-0.15
	3	0.02	0.02	-0.01	-0.06	-0.01	-0.05	-0.02	-0.01	-0.03	-0.23	-0.14	-0.01
	4	0.00	-0.02	-0.03	-0.03	-0.06	-0.04	-0.04	-0.06	-0.21	-0.15	-0.03	0.01
	5	-0.04	-0.02	-0.02	-0.07	-0.04	-0.04	-0.06	-0.27	-0.15	-0.04	-0.02	-0.01
	6	-0.06	-0.04	-0.04	-0.04	-0.04	-0.04	-0.24	-0.18	-0.04	-0.01	0.00	-0.04

Spread-to-error ratio

Region	Forecast Month	Start date: Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Extra-tropical NH	1	0.96	0.95	0.93	0.92	1.02	1.09	1.06	1.08	1.03	0.91	0.85	0.93
	2	0.97	0.98	0.97	1.04	1.17	1.17	1.12	1.10	0.95	0.87	0.93	1.02
	3	0.97	0.99	1.07	1.17	1.19	1.12	1.11	0.96	0.89	0.93	1.03	1.00
	4	1.00	1.07	1.17	1.18	1.12	1.11	0.97	0.88	0.94	1.04	0.99	1.00
	5	1.09	1.20	1.17	1.12	1.09	0.98	0.88	0.94	1.02	0.98	0.99	0.99
	6	1.20	1.18	1.11	1.09	0.98	0.87	0.92	1.03	0.99	0.98	0.98	1.07
Tropics	1	0.82	0.81	0.81	0.85	0.78	0.75	0.74	0.73	0.77	0.80	0.77	0.83
	2	0.91	0.91	0.96	0.90	0.89	0.85	0.85	0.88	0.94	0.94	0.91	0.95
	3	0.95	0.99	0.92	0.93	0.90	0.86	0.90	0.95	0.99	0.98	0.95	0.96
	4	1.01	0.95	0.93	0.92	0.88	0.90	0.97	1.02	1.01	1.02	0.95	1.00
	5	0.97	0.95	0.91	0.89	0.91	0.96	1.01	1.02	1.03	0.99	0.99	1.05
	6	0.97	0.93	0.90	0.91	0.96	1.01	1.00	1.03	1.00	1.02	1.02	0.98
Extra-tropical SH	1	0.93	0.91	0.87	0.86	0.86	0.87	0.85	0.85	0.82	0.90	0.88	0.88
	2	1.01	0.93	0.87	0.87	0.92	0.87	0.87	0.85	0.94	0.92	0.96	1.02
	3	0.94	0.89	0.88	0.89	0.89	0.89	0.88	0.97	0.96	0.98	1.08	0.99
	4	0.88	0.87	0.90	0.88	0.91	0.91	0.98	0.96	1.04	1.09	1.01	0.95
	5	0.85	0.90	0.88	0.90	0.93	1.00	1.00	1.03	1.13	1.01	0.93	0.86
	6	0.87	0.86	0.91	0.92	1.01	1.03	1.06	1.12	1.03	0.96	0.87	0.85

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CERISE

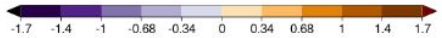
Near-Surface Air Temperature. Region: Spain (Interpolation = to system, Aggregation level = skill, Cross-validation = anomalies & terciles & crps_clim)

(Ref: ERA5 1993-2016)

Mean bias (K)

Start date

Forecast month	System	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	ECMWF SEAS5	-0.95	-0.93	-1.68	-0.77	-0.77	-0.40	-0.13	-0.11	-0.11	-1.19	-0.64	-1.13
	CMCC-SPS3.5	-0.34	-0.27	-0.88	-0.21	-0.17	0.39	0.88	0.59	0.40	-0.47	0.14	-0.43
	DWD GCFS 2.1	-0.08	0.07	-0.67	-0.26	-0.51	-0.21	0.13	0.66	0.97	-0.08	0.29	-0.26
	NCEP CFSv2	-0.69	-0.60	-1.33	-0.85	-0.74	-0.55	-0.33	-0.52	-0.23	-0.96	-0.45	-0.69
	Multimodel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	ECMWF SEAS5	-0.87	-1.48	-1.20	-0.94	-0.51	0.01	-0.09	0.11	-0.91	-0.70	-0.95	-1.20
	CMCC-SPS3.5	-0.29	-0.84	-0.31	-0.33	-0.09	0.57	0.39	0.23	-0.77	-0.12	-0.22	-0.51
	DWD GCFS 2.1	0.23	-0.33	-0.16	-0.12	0.08	0.52	0.67	1.30	0.11	0.35	0.31	0.03
	NCEP CFSv2	-0.78	-1.59	-1.38	-1.14	-0.89	-0.45	-0.79	-0.54	-1.15	-0.62	-0.66	-0.82
	Multimodel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	ECMWF SEAS5	-1.55	-1.31	-1.20	-0.76	0.01	-0.04	0.16	-0.81	-0.48	-0.72	-0.97	-0.98
	CMCC-SPS3.5	-0.94	-0.30	-0.55	-0.41	0.29	0.26	0.24	-0.82	-0.15	-0.20	-0.45	-0.45
	DWD GCFS 2.1	-0.34	-0.21	-0.32	0.19	0.87	1.04	1.47	0.39	0.59	0.45	0.15	0.32
	NCEP CFSv2	-1.65	-1.44	-1.47	-1.46	-0.54	-0.64	-0.34	-1.06	-0.64	-0.85	-0.91	-0.91
	Multimodel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	ECMWF SEAS5	-1.17	-1.26	-0.96	-0.16	-0.14	0.16	-0.87	-0.42	-0.55	-0.92	-0.77	-1.59
	CMCC-SPS3.5	-0.28	-0.60	-0.59	0.15	0.07	0.14	-0.77	-0.20	-0.10	-0.37	-0.36	-0.95
	DWD GCFS 2.1	-0.30	-0.37	0.16	0.97	1.23	1.65	0.27	0.61	0.63	0.19	0.45	-0.29
	NCEP CFSv2	-1.54	-1.54	-1.73	-0.87	-0.66	-0.24	-1.06	-0.61	-0.89	-1.06	-1.00	-1.77
	Multimodel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	ECMWF SEAS5	-1.32	-0.99	-0.38	-0.22	0.10	-0.92	-0.42	-0.55	-0.71	-0.77	-1.42	-1.29
	CMCC-SPS3.5	-0.62	-0.65	0.02	-0.10	0.06	-0.85	-0.19	-0.21	-0.33	-0.34	-0.86	-0.45
	DWD GCFS 2.1	-0.43	0.02	0.97	1.31	1.78	0.31	0.47	0.59	0.43	0.50	-0.13	-0.28
	NCEP CFSv2	-1.69	-1.84	-1.17	-0.96	-0.32	-1.07	-0.60	-0.97	-1.04	-1.08	-1.90	-1.66
	Multimodel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	ECMWF SEAS5	-1.07	-0.47	-0.41	-0.05	-0.98	-0.54	-0.49	-0.72	-0.61	-1.39	-1.24	-1.33
	CMCC-SPS3.5	-0.88	-0.10	-0.30	-0.14	-0.97	-0.28	-0.20	-0.40	-0.32	-0.92	-0.44	-0.77
	DWD GCFS 2.1	-0.05	0.89	1.25	1.71	0.45	0.62	0.60	0.38	0.58	-0.15	-0.27	-0.43
	NCEP CFSv2	-1.92	-1.34	-1.24	-0.61	-1.08	-0.63	-0.89	-1.20	-1.14	-1.91	-1.69	-1.87
	Multimodel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00



Correlation

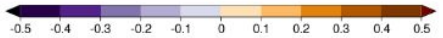
Start date

Forecast month	System	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	ECMWF SEAS5	0.75	0.79	0.51	0.57	0.62	0.67	0.75	0.68	0.65	0.67	0.67	0.48
	CMCC-SPS3.5	0.55	0.76	0.49	0.56	0.60	0.57	0.60	0.58	0.45	0.58	0.65	0.50
	DWD GCFS 2.1	0.47	0.61	0.44	0.42	0.39	0.42	0.54	0.46	0.44	0.49	0.24	0.35
	NCEP CFSv2	0.60	0.59	0.23	0.51	0.52	0.44	0.47	0.38	0.58	0.51	0.38	0.33
	Multimodel	0.65	0.78	0.49	0.60	0.62	0.63	0.69	0.66	0.58	0.60	0.54	0.48
2	ECMWF SEAS5	0.21	-0.10	0.12	0.23	0.14	0.32	0.18	0.28	0.24	0.33	0.23	0.45
	CMCC-SPS3.5	0.21	-0.03	0.16	0.14	0.07	0.33	0.21	0.28	0.20	0.21	0.20	0.30
	DWD GCFS 2.1	0.15	-0.03	0.16	0.21	0.15	0.09	0.19	0.44	0.23	0.06	0.12	0.20
	NCEP CFSv2	0.11	0.10	-0.10	-0.01	0.14	0.20	0.14	0.19	-0.03	0.10	0.20	0.30
	Multimodel	0.22	-0.03	0.12	0.20	0.16	0.29	0.22	0.39	0.24	0.21	0.23	0.35
3	ECMWF SEAS5	-0.23	0.03	-0.14	0.17	0.12	0.20	0.32	0.06	0.23	0.15	0.06	0.28
	CMCC-SPS3.5	-0.08	-0.08	0.05	0.21	0.32	0.21	0.04	0.11	0.31	0.00	0.26	0.22
	DWD GCFS 2.1	-0.11	-0.10	0.04	0.07	-0.01	0.14	0.33	0.12	0.00	-0.04	0.45	-0.02
	NCEP CFSv2	-0.12	0.02	-0.14	0.07	0.19	0.21	0.34	0.16	0.11	0.08	0.16	0.10
	Multimodel	-0.17	-0.06	-0.04	0.16	0.18	0.22	0.30	0.13	0.22	0.05	0.31	0.18
4	ECMWF SEAS5	0.07	-0.09	0.04	0.10	0.06	0.35	0.16	0.30	0.15	0.24	0.04	0.02
	CMCC-SPS3.5	0.13	0.14	0.12	0.16	0.30	0.23	0.18	0.16	0.00	0.23	0.32	-0.21
	DWD GCFS 2.1	0.13	-0.09	0.14	-0.06	0.08	0.45	0.11	0.16	0.06	0.11	0.23	-0.19
	NCEP CFSv2	0.18	0.01	-0.03	0.08	0.23	0.20	0.21	-0.08	0.10	0.19	-0.03	-0.05
	Multimodel	0.17	-0.01	0.12	0.06	0.20	0.37	0.20	0.19	0.10	0.24	0.19	-0.15
5	ECMWF SEAS5	-0.09	0.05	0.19	0.14	0.37	0.37	0.24	0.18	0.23	0.04	-0.02	-0.04
	CMCC-SPS3.5	0.05	0.00	-0.07	0.26	0.39	0.28	0.25	0.04	0.12	0.26	-0.14	0.06
	DWD GCFS 2.1	-0.09	0.11	-0.06	0.15	0.47	0.10	-0.11	0.08	0.25	-0.09	0.00	0.08
	NCEP CFSv2	-0.01	0.11	0.06	0.20	0.27	0.25	0.10	0.15	0.28	0.04	-0.20	-0.18
	Multimodel	-0.05	0.08	0.01	0.23	0.46	0.32	0.15	0.14	0.27	0.09	-0.12	-0.01
6	ECMWF SEAS5	0.19	0.11	-0.05	0.23	0.10	0.23	-0.03	0.13	0.08	0.09	0.33	-0.16
	CMCC-SPS3.5	0.14	0.16	-0.05	0.36	0.19	0.28	0.02	0.00	0.32	-0.18	-0.03	-0.02
	DWD GCFS 2.1	0.03	0.15	-0.03	0.32	0.15	0.34	-0.03	0.26	0.11	0.02	0.10	-0.06
	NCEP CFSv2	0.09	0.20	0.02	0.39	0.20	-0.12	0.12	0.39	0.14	-0.24	0.06	-0.17
	Multimodel	0.14	0.18	-0.05	0.42	0.21	0.28	0.03	0.27	0.21	-0.13	0.15	-0.12

RPSS

Start date

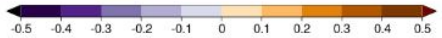
Forecast month	System	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	ECMWF SEAS5	0.34	0.46	0.15	0.14	0.25	0.25	0.35	0.20	0.24	0.26	0.29	0.09
	CMCC-SPS3.5	0.09	0.39	0.11	0.18	0.26	0.17	0.19	0.13	0.08	0.15	0.27	0.15
	DWD GCFS 2.1	0.03	0.21	-0.09	-0.08	-0.03	-0.12	-0.02	-0.07	-0.05	-0.12	-0.29	-0.13
	NCEP CFSv2	0.19	0.18	-0.02	0.13	0.14	0.11	0.12	0.05	0.18	0.11	0.08	0.03
	Multimodel	0.24	0.43	0.13	0.21	0.27	0.23	0.27	0.20	0.21	0.18	0.20	0.14
2	ECMWF SEAS5	-0.02	-0.15	-0.02	0.03	-0.05	0.03	-0.06	0.04	-0.03	0.06	-0.02	0.10
	CMCC-SPS3.5	-0.01	-0.10	0.01	0.00	-0.07	0.05	-0.02	0.04	0.01	0.00	0.02	0.05
	DWD GCFS 2.1	-0.07	-0.14	-0.02	-0.02	-0.08	-0.11	-0.07	0.09	-0.02	-0.07	-0.11	-0.06
	NCEP CFSv2	-0.07	-0.04	-0.12	-0.06	-0.07	-0.01	-0.07	-0.03	-0.10	-0.07	-0.02	0.02
	Multimodel	0.01	-0.07	0.01	0.03	-0.02	0.05	0.00	0.08	0.01	0.02	0.01	0.07
3	ECMWF SEAS5	-0.20	-0.06	-0.13	-0.04	-0.06	-0.04	0.02	-0.08	0.05	-0.02	-0.07	0.00
	CMCC-SPS3.5	-0.09	-0.06	-0.01	0.00	0.05	-0.01	-0.07	-0.03	0.06	-0.06	0.01	0.00
	DWD GCFS 2.1	-0.06	-0.13	-0.07	-0.11	-0.13	-0.07	0.02	-0.07	-0.08	-0.12	0.10	-0.09
	NCEP CFSv2	-0.14	-0.07	-0.12	-0.06	-0.02	-0.07	0.03	-0.03	-0.04	-0.14	-0.08	0.00
	Multimodel	-0.08	-0.05	-0.04	-0.01	0.01	0.00	0.03	-0.02	0.03	-0.05	0.04	0.02
4	ECMWF SEAS5	-0.07	-0.12	-0.10	-0.06	-0.09	0.02	-0.09	0.06	-0.01	0.01	-0.05	-0.09
	CMCC-SPS3.5	0.00	0.00	-0.02	-0.04	0.02	-0.02	-0.04	0.02	-0.07	0.00	0.05	-0.12
	DWD GCFS 2.1	0.00	-0.17	-0.05	-0.16	-0.10	0.08	-0.06	-0.01	-0.06	-0.03	0.01	-0.11
	NCEP CFSv2	-0.05	-0.10	-0.07	-0.03	-0.04	-0.03	-0.03	-0.13	-0.06	-0.08	-0.14	-0.13
	Multimodel	0.01	-0.05	-0.02	-0.04	0.00	0.05	-0.03	0.02	-0.02	0.02	0.02	-0.08
5	ECMWF SEAS5	-0.15	-0.05	-0.01	-0.04	0.04	0.08	0.03	0.03	0.00	-0.04	-0.06	-0.09
	CMCC-SPS3.5	-0.02	-0.06	-0.08	0.04	0.04	0.02	0.02	-0.07	-0.01	-0.01	-0.07	-0.02
	DWD GCFS 2.1	-0.13	-0.04	-0.16	-0.05	0.09	-0.07	-0.09	-0.04	0.01	-0.11	-0.02	-0.05
	NCEP CFSv2	-0.12	-0.05	-0.06	-0.02	0.01	0.02	-0.04	-0.02	-0.01	-0.12	-0.15	-0.16
	Multimodel	-0.06	-0.02	-0.04	0.03	0.08	0.04	0.02	0.00	0.03	-0.03	-0.04	-0.03
6	ECMWF SEAS5	0.01	-0.05	-0.11	-0.03	-0.06	0.02	-0.10	-0.05	-0.04	-0.02	0.05	-0.18
	CMCC-SPS3.5	-0.01	-0.01	-0.06	0.04	0.00	0.03	-0.05	-0.06	0.04	-0.10	-0.04	-0.04
	DWD GCFS 2.1	-0.05	-0.05	-0.12	0.01	-0.03	0.05	-0.09	0.02	-0.05	-0.05	-0.04	-0.08
	NCEP CFSv2	-0.06	0.01	-0.05	0.07	-0.03	-0.17	-0.02	0.03	-0.06	-0.16	-0.06	-0.20
	Multimodel	0.01	0.01	-0.05	0.06	0.00	0.04	-0.03	0.02	0.01	-0.04	0.01	-0.08



CRPSS

Start date

Forecast month	System	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	ECMWF SEAS5	0.35	0.40	0.11	0.17	0.22	0.25	0.35	0.27	0.24	0.30	0.30	0.13
	CMCC-SPS3.5	0.13	0.37	0.07	0.14	0.19	0.18	0.23	0.21	0.10	0.21	0.28	0.18
	DWD GCFS 2.1	0.02	0.15	-0.26	-0.07	-0.01	-0.10	0.05	0.01	-0.05	-0.05	-0.24	-0.09
	NCEP CFSv2	0.19	0.22	-0.04	0.15	0.16	0.14	0.15	0.10	0.19	0.17	0.12	0.08
	Multimodel	0.27	0.39	0.09	0.22	0.25	0.25	0.31	0.27	0.22	0.24	0.23	0.18
2	ECMWF SEAS5	0.06	-0.13	0.02	0.07	-0.02	0.07	0.00	0.08	0.06	0.10	0.04	0.13
	CMCC-SPS3.5	0.06	-0.10	0.04	0.00	-0.02	0.09	0.02	0.08	0.07	0.04	0.07	0.10
	DWD GCFS 2.1	0.02	-0.15	-0.02	0.01	-0.04	-0.07	-0.03	0.13	0.05	-0.02	-0.02	0.02
	NCEP CFSv2	0.01	-0.06	-0.08	-0.03	-0.01	0.03	-0.01	0.01	-0.02	0.00	0.02	0.07
	Multimodel	0.08	-0.06	0.05	0.06	0.03	0.09	0.05	0.12	0.08	0.07	0.08	0.12
3	ECMWF SEAS5	-0.16	-0.01	-0.07	-0.01	0.00	0.02	0.08	0.01	0.08	0.03	0.00	0.09
	CMCC-SPS3.5	-0.12	-0.04	0.00	0.02	0.09	0.04	0.00	0.04	0.09	0.02	0.08	0.07
	DWD GCFS 2.1	-0.09	-0.09	-0.02	-0.09	-0.09	-0.02	0.08	0.02	0.00	-0.04	0.15	-0.01
	NCEP CFSv2	-0.15	-0.03	-0.06	-0.01	0.03	0.01	0.08	0.04	0.02	-0.07	-0.01	0.03
	Multimodel	-0.08	0.00	0.01	0.02	0.06	0.06	0.09	0.06	0.08	0.03	0.11	0.08
4	ECMWF SEAS5	0.00	-0.06	-0.06	0.00	-0.04	0.08	0.02	0.09	0.04	0.05	0.01	-0.09
	CMCC-SPS3.5	0.00	0.01	-0.01	0.02	0.07	0.06	0.04	0.07	0.02	0.07	0.08	-0.11
	DWD GCFS 2.1	0.00	-0.10	-0.03	-0.13	-0.05	0.12	0.03	0.05	0.01	0.03	0.07	-0.12
	NCEP CFSv2	-0.01	-0.03	0.01	0.00	0.03	0.04	0.05	-0.04	0.00	-0.03	-0.04	-0.13
	Multimodel	0.04	0.00	0.02	0.02	0.05	0.11	0.06	0.08	0.05	0.08	0.07	-0.06
5	ECMWF SEAS5	-0.08	-0.02	0.03	0.02	0.09	0.12	0.08	0.07	0.06	0.03	-0.05	-0.04
	CMCC-SPS3.5	0.00	-0.03	-0.02	0.06	0.11	0.09	0.07	0.02	0.05	0.06	-0.08	-0.01
	DWD GCFS 2.1	-0.07	-0.03	-0.13	-0.02	0.13	0.01	-0.02	0.01	0.08	-0.03	-0.06	-0.01
	NCEP CFSv2	-0.04	0.02	0.00	0.03	0.06	0.08	0.02	0.00	0.01	-0.03	-0.19	-0.10
	Multimodel	0.00	0.02	0.01	0.07	0.14	0.10	0.07	0.06	0.09	0.04	-0.05	0.01
6	ECMWF SEAS5	0.02	0.01	-0.04	0.04	0.03	0.06	-0.01	0.01	0.03	-0.01	0.08	-0.08
	CMCC-SPS3.5	0.00	0.03	-0.03	0.10	0.06	0.08	0.03	0.03	0.09	-0.11	-0.02	0.00
	DWD GCFS 2.1	-0.03	-0.02	-0.09	0.07	0.03	0.10	-0.03	0.07	0.03	-0.05	-0.03	-0.04
	NCEP CFSv2	0.00	0.05	0.00	0.11	0.05	-0.07	0.00	0.07	0.00	-0.19	-0.02	-0.11
	Multimodel	0.04	0.06	0.00	0.12	0.08	0.09	0.04	0.08	0.08	-0.04	0.04	-0.01



Spread-to-error ratio

Start date

Forecast month	System	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	ECMWF SEAS5	1.21	0.99	1.01	1.08	1.01	1.15	1.07	1.04	1.00	0.93	1.04	0.88
	CMCC-SPS3.5	0.95	1.10	1.17	1.26	1.21	1.21	1.05	1.07	0.92	0.90	1.01	1.01
	DWD GCFS 2.1	0.62	0.55	0.62	0.63	0.61	0.56	0.58	0.63	0.63	0.53	0.46	0.58
	NCEP CFSv2	1.31	1.04	1.25	1.32	1.15	1.14	1.02	1.08	1.28	1.05	1.16	1.23
	Multimodel	1.19	1.18	1.20	1.33	1.25	1.28	1.20	1.24	1.14	0.99	1.04	1.07
2	ECMWF SEAS5	0.88	1.07	1.21	1.18	1.17	1.05	1.00	1.08	0.95	1.07	1.13	1.27
	CMCC-SPS3.5	0.91	1.29	1.38	1.27	1.22	1.16	1.12	1.13	0.93	0.92	1.02	1.09
	DWD GCFS 2.1	0.84	1.11	1.27	1.18	1.07	0.90	1.03	1.26	1.00	0.92	0.98	1.00
	NCEP CFSv2	0.91	1.27	1.14	1.05	1.01	0.95	0.97	1.06	0.92	1.12	1.24	1.26
	Multimodel	0.92	1.25	1.34	1.25	1.21	1.10	1.12	1.21	0.99	1.02	1.13	1.19
3	ECMWF SEAS5	1.05	1.10	1.05	1.27	0.99	1.06	1.14	0.92	1.09	1.13	1.08	0.97
	CMCC-SPS3.5	1.29	1.33	1.29	1.31	1.20	1.21	1.06	0.91	0.98	0.94	1.07	0.94
	DWD GCFS 2.1	1.22	1.17	1.14	1.15	0.92	1.01	1.18	1.03	0.97	1.02	1.24	0.84
	NCEP CFSv2	1.18	1.10	1.00	1.00	0.98	0.98	1.09	0.95	1.05	1.23	1.22	0.91
	Multimodel	1.25	1.24	1.18	1.26	1.09	1.14	1.16	0.97	1.04	1.08	1.20	0.95
4	ECMWF SEAS5	1.15	1.05	1.20	1.03	1.01	1.21	0.97	1.06	1.11	1.26	0.92	1.21
	CMCC-SPS3.5	1.43	1.33	1.31	1.16	1.26	1.11	0.90	0.93	0.90	1.09	0.99	1.31
	DWD GCFS 2.1	1.30	1.07	1.21	0.98	1.04	1.30	1.03	1.11	1.07	1.17	0.91	1.24
	NCEP CFSv2	1.27	1.02	1.02	0.95	0.99	1.04	0.96	1.04	1.27	1.31	0.97	1.16
	Multimodel	1.37	1.19	1.27	1.09	1.15	1.21	0.98	1.05	1.09	1.25	0.98	1.30
5	ECMWF SEAS5	1.03	1.21	1.09	1.07	1.18	1.01	1.04	1.13	1.23	0.94	1.25	1.17
	CMCC-SPS3.5	1.31	1.26	1.13	1.24	1.21	0.95	0.89	0.93	1.07	0.96	1.31	1.35
	DWD GCFS 2.1	1.14	1.24	1.02	1.10	1.32	1.06	1.02	1.19	1.24	0.87	1.34	1.28
	NCEP CFSv2	1.03	1.05	0.98	1.01	1.07	0.98	1.07	1.30	1.34	0.96	1.09	1.08
	Multimodel	1.19	1.26	1.12	1.18	1.25	1.03	1.02	1.14	1.24	0.95	1.30	1.30
6	ECMWF SEAS5	1.34	1.08	1.03	1.13	0.99	1.02	1.04	1.18	0.96	1.28	1.34	1.08
	CMCC-SPS3.5	1.30	1.18	1.16	1.18	0.90	0.91	0.97	1.02	0.97	1.29	1.37	1.25
	DWD GCFS 2.1	1.25	1.11	1.08	1.26	1.07	1.12	1.15	1.21	0.96	1.34	1.36	1.15
	NCEP CFSv2	1.09	1.09	0.99	1.17	0.97	0.95	1.27	1.52	1.03	1.17	1.15	0.95
	Multimodel	1.31	1.17	1.13	1.24	1.00	1.04	1.12	1.24	1.00	1.33	1.38	1.17

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How to fill an scorecard?

It depends on the product that we provide to the user:

a) If we provide the average over a region, a time series needs to be verified
b) If we provide a gridded forecast over a region, all grid points need to be verified

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2-metre air temperature of Meteo-France System 8

(Ref: ERA5 1993-2016)

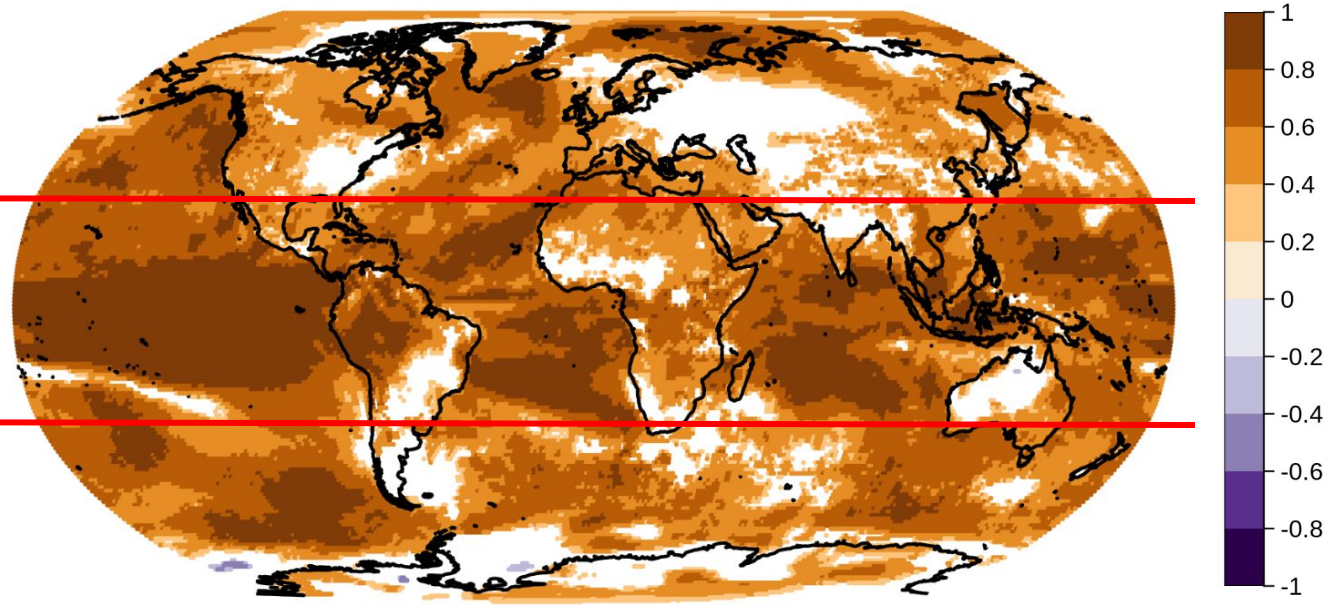
Correlation

Start date

Region	Forecast Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Extra-tropical NH	1	0.49	0.55	0.58	0.47	0.46	0.44	0.44	0.52	0.47	0.43	0.43	0.49
	2	0.27	0.38	0.32	0.29	0.26	0.29	0.34	0.33	0.28	0.24	0.25	0.29
	3	0.25	0.32	0.29	0.23	0.27	0.28	0.33	0.25	0.25	0.18	0.25	0.25
	4	0.24	0.26	0.22	0.25	0.29	0.27	0.23	0.23	0.26	0.22	0.25	0.28
	5	0.30	0.24	0.25	0.23	0.28	0.23	0.21	0.25	0.21	0.23	0.26	0.20
	6	0.25	0.24	0.24	0.25	0.27	0.18	0.18	0.20	0.22	0.24	0.20	0.22
Tropics	1	0.68	0.71	0.73	0.70	0.67	0.65	0.65	0.65	0.65	0.66	0.60	0.66
	2	0.59	0.59	0.62	0.57	0.57	0.56	0.56	0.57	0.59	0.52	0.53	0.57
	3	0.53	0.57	0.52	0.51	0.52	0.50	0.53	0.53	0.50	0.51	0.52	0.55
	4	0.52	0.49	0.46	0.48	0.47	0.48	0.51	0.47	0.50	0.50	0.51	0.53
	5	0.46	0.43	0.43	0.44	0.46	0.48	0.45	0.47	0.50	0.51	0.49	0.52
	6	0.40	0.41	0.41	0.43	0.46	0.42	0.44	0.47	0.50	0.49	0.47	0.43
Extra-tropical SH	1	0.51	0.54	0.57	0.49	0.46	0.40	0.45	0.45	0.44	0.50	0.45	0.52
	2	0.39	0.38	0.36	0.26	0.28	0.28	0.24	0.29	0.36	0.33	0.32	0.37
	3	0.31	0.31	0.28	0.17	0.26	0.21	0.26	0.31	0.29	0.29	0.30	0.30
	4	0.26	0.24	0.21	0.20	0.18	0.21	0.27	0.24	0.27	0.26	0.24	0.30
	5	0.20	0.22	0.20	0.14	0.20	0.25	0.24	0.22	0.25	0.22	0.20	0.24
	6	0.14	0.17	0.18	0.21	0.23	0.24	0.22	0.23	0.21	0.23	0.22	0.19

-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1

Meteo-France System 8 / 2-Metre Air Temperature
Ensemble Mean Correlation / January / 1993-2016



Nominal start date: 1st of January
Forecast month: 01
Reference: ERA5
alpha = 0.05

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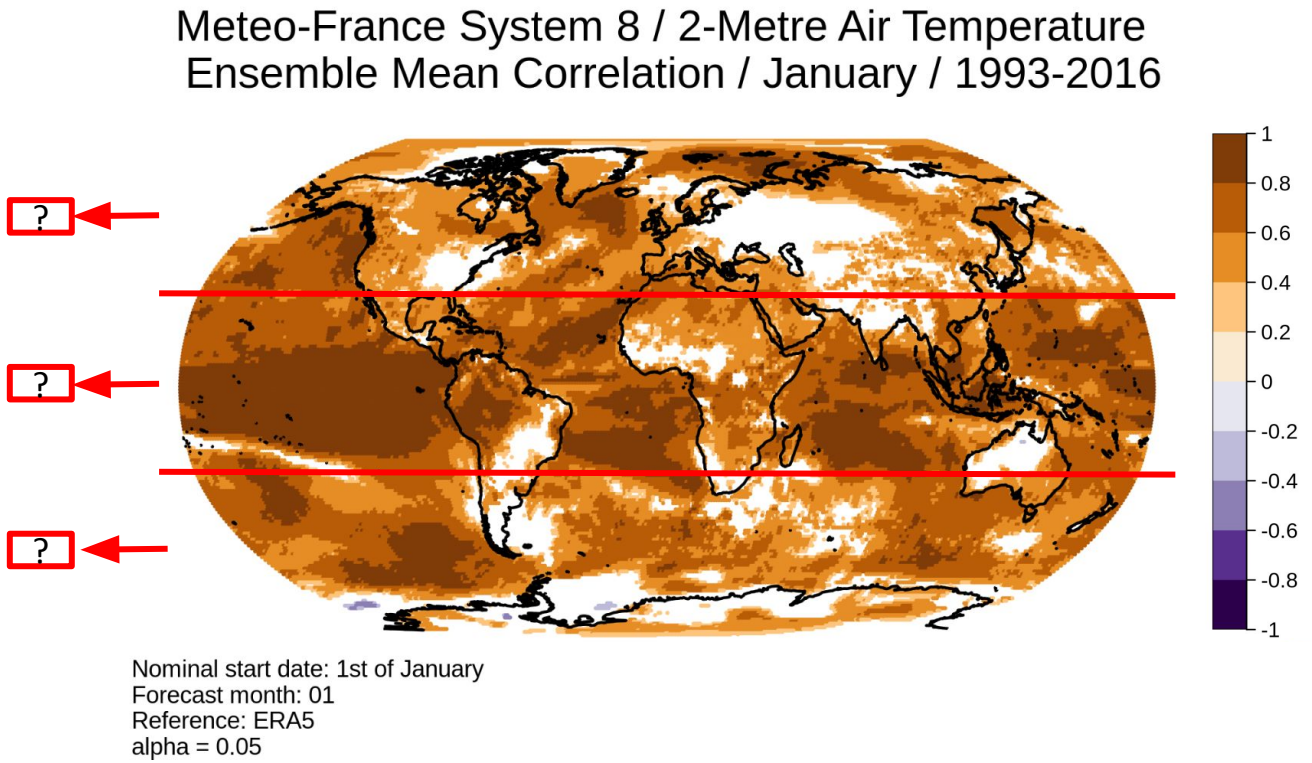
How to fill each scorecard cell?

Averaging correlations for each region is not mathematically correct.

Alternative:

1. compute the standard deviation and covariance at each grid point,
2. compute the weighted mean of the variance and covariance for the region
3. compute the correlation



On-going development

$$Correlation = \frac{Cov\,(x, y)}{\sigma x * \sigma y}$$

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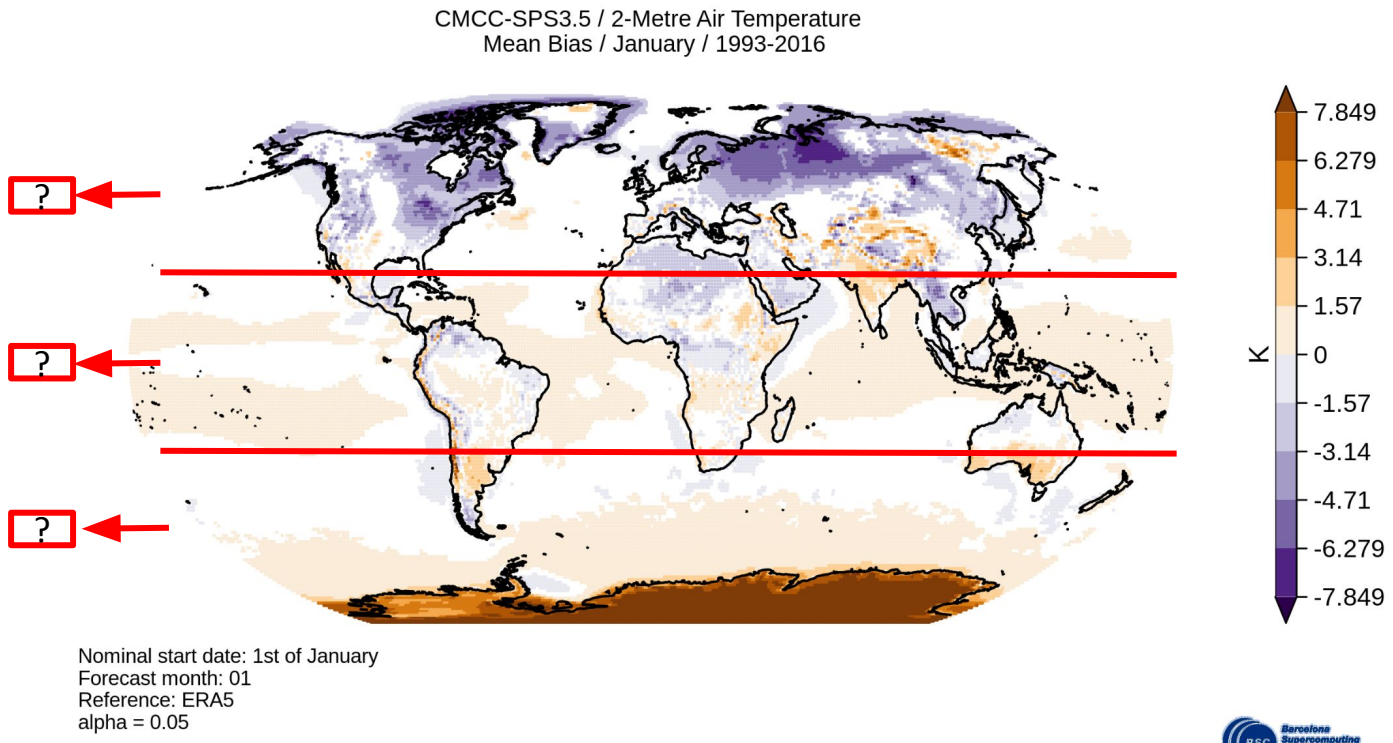
How to highlight a result that is statistically significant?

For mean bias, we could use the **Welch's t-test** that considers the variance of observations and ensemble mean in the region

$$t = \frac{\Delta\overline{X}}{s_{\Delta\bar{X}}} = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{s^2_{\bar{X}_1} + s^2_{\bar{X}_2}}},$$

$$s_{\bar{X}_i} = \frac{s_i}{\sqrt{N_i}},$$



On-going development

https://earth.bsc.es/gitlab/es/s2dv/-/blob/master/R/Bias.R

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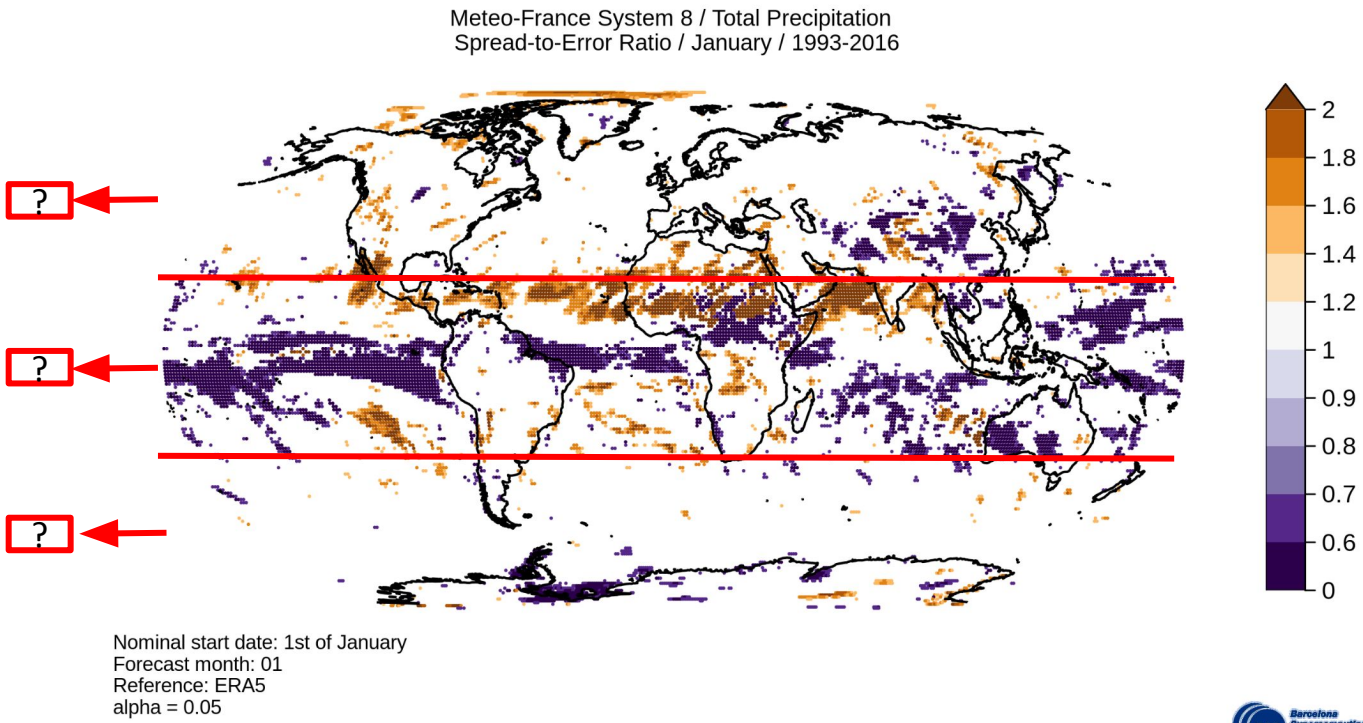
CERISE

How to highlight a result that is statistically significant?

How to know if the spread-to-error ratio over a region is significantly different from 1?



On-going development

Funded by the European Union

Coordinated by ECMWF

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Thank you!

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