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Barcelona Supercomputing Center Centro Nacional de Supercomputación

The Bone and The Marrow: Some Suggestions for the Future of Climate Prediction

### **Francisco Doblas-Reyes**

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### **Outline: a collection of thoughts**

Understanding the title:

- the bone and the marrow as a set of key elements for life
- chill to the marrow/to the bone

What we can do:

- with what we have
- with what climate change colleagues are doing
- with what other domains are doing





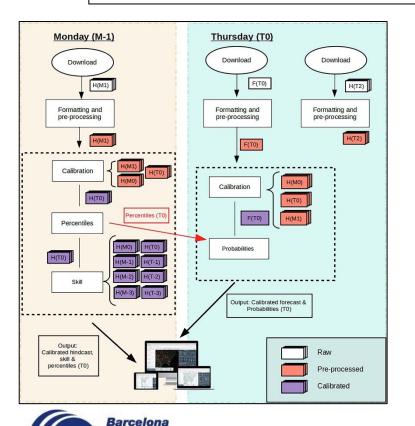
# Some of what else we can do with what we have: Transparency, standards, guidance, user engagement



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### **Non-trivial climatology definitions**

ECMWF-Ext-Ens 2016 Period: 1996-2015 Month: April Reference: ERA Int Variable: 2-m temperature



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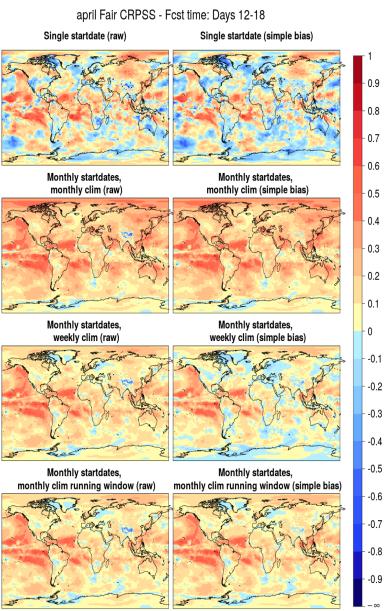
Weekly: too noisy

Monthly: good skill, but suspiciously high ...

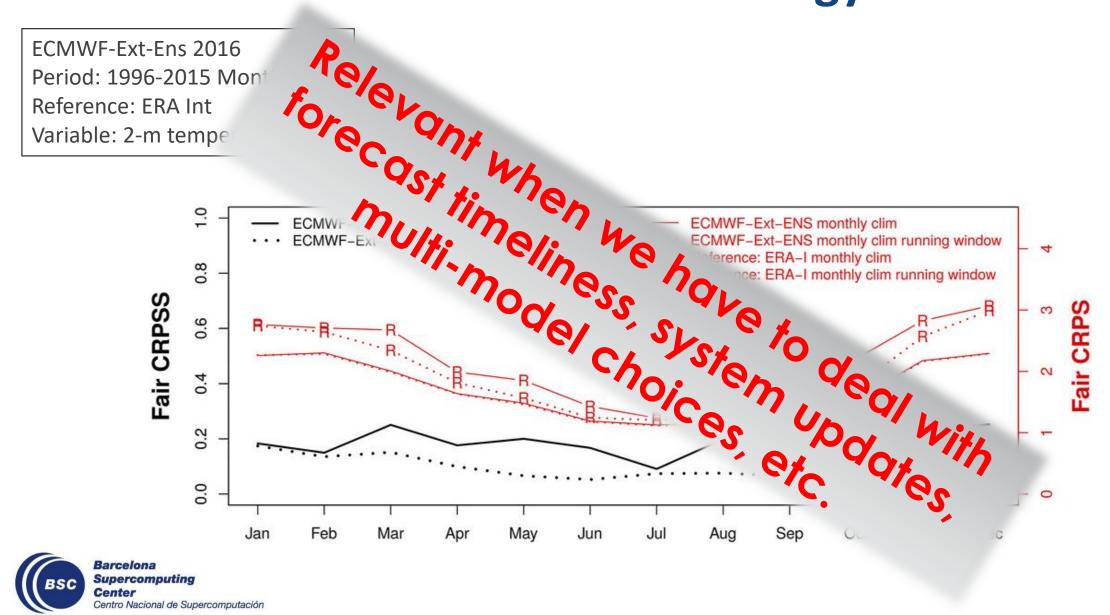
Monthly running window, but weekly for the bias adjustment: lower skill , and too noisy for the adjustment



Manrique-Suñén et al. (2020, MWR; 2023, CliSer)



### What for? Non-trivial climatology definitions



Manrique-Suñén et al. (2020, MWR)

### Systematic forecast quality assessment

Near-Surface Air Temperature of CMCC System 35 (cross-validation = false, skill aggregation)

(Ref: ERA5 1993-2016)						M	ean l	oias (	K)									(	Corre	latio	n										RP	SS					
(Ref: ERA5 1993-2016)							Start	date											Start	date											Start	date					
Region	Forecast month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	1	0.18	0.23	0.31	0.30	0.24	0.17	0.16	0.16	0.22	0.23	0.23	0.18	0.74	0.78	0.76	0.75	0.71	0.73	0.70	0.71	0.73	0.72	0.70	0.72	0.35	0.39	0.35	0.32	0.31	0.34	0.30	0.31	0.32	0.31	0.29	0.33
	2	0.18	0.29	0.30	0.26	0.13	0.11	0.11	0.17	0.20	0.18	0.15	0.15	0.61	0.62	0.63	0.59	0.57	0.59	0.59	0.58	0.60	0.56	0.57	0.60	0.23	0.23	0.22	0.21	0.20	0.19	0.20	0.20	0.22	0.19	0.22	0.23
	3	0.26	0.28	0.23	0.13	0.06	0.02	0.10	0.09	0.10	0.08	0.12	0.16	0.56	0.59	0.54	0.52	0.53	0.52	0.53	0.56	0.53	0.53	0.54	0.57	0.17	0.20	0.17	0.17	0.15	0.14	0.15	0.18	0.18	0.19	0.19	0.20
Tropics	4	0.27	0.20	0.10	0.04	-0.04	-0.02	-0.01	-0.02	0.00	0.06	0.15	0.25	0.55	0.51	0.49	0.50	0.48	0.48	0.52	0.50	0.52	0.53	0.55	0.52	0.16	0.15	0.12	0.14	0.10	0.11	0.15	0.15	0.18	0.19	0.19	0.15
	5	0.20	0.08	0.01	-0.07	-0.11	-0.14	-0.11	-0.11	0.00	0.09	0.24	0.28	0.48	0.47	0.47	0.45	0.46	0.47	0.47	0.49	0.51	0.52	0.50	0.52	0.11	0.11	0.11	0.09	0.09	0.11	0.13	0.15	0.17	0.18	0.15	0.15
	6	0.10	-0.01	-0.11	-0.15	-0.24	-0.23	-0.18	-0.11	0.02	0.18	0.27	0.22	0.41	0.45	0.44	0.42	0.46	0.43	0.48	0.49	0.52	0.49	0.50	0.45	0.07	0.09	0.08	0.07	0.10	0.10	0.14	0.16	0.17	0.14	0.14	0.10
	1	-1.22	-1.15	-1.20	-1.12	-0.62	-0.21	0.23	0.15	-0.06	-0.20	-0.48	-1.03	0.61	0.66	0.67	0.63	0.61	0.61	0.57	0.59	0.56	0.57	0.60	0.62	0.21	0.28	0.29	0.24	0.24	0.24	0.19	0.20	0.18	0.18	0.21	0.22
	2	-0.79	-0.82	-1.05	-0.99	-0.79	-0.10	-0.01	-0.28	-0.25	-0.35	-0.71	-0.91	0.30	0.38	0.34	0.32	0.31	0.34	0.36	0.38	0.25	0.25	0.32	0.37	0.04	0.08	0.06	0.07	0.06	0.06	0.06	0.09	0.03	0.01	0.05	0.08
	3	-0.86	-1.11	-1.07	-1.06	-0.47	-0.19	-0.19	-0.28	-0.23	-0.59	-0.95	-0.86	0.29	0.32	0.28	0.27	0.28	0.35	0.34	0.27	0.19	0.24	0.24	0.29	0.04	0.05	0.05	0.05	0.04	0.06	0.06	0.04	0.00	0.02	0.04	0.05
Extra-tropical NH	4	-1.27	-1.16	-1.24	-0.74	-0.52	-0.28	-0.04	-0.11	-0.51	-0.91	-0.92	-1.00	0.28	0.27	0.28	0.25	0.29	0.31	0.28	0.21	0.18	0.22	0.24	0.26	0.03	0.04	0.04	0.03	0.04	0.05	0.04	0.00	0.00	0.02	0.03	0.03
	5	-1.26	-1.31	-0.92	-0.78	-0.63	-0.07	0.15	-0.37	-0.90	-0.92	-1.08	-1.38	0.25	0.24	0.23	0.26	0.31	0.28	0.21	0.21	0.20	0.19	0.21	0.24	0.02	0.03	0.02	0.03	0.05	0.05	0.00	0.01	0.03	0.00	0.01	0.02
	6	-1.40	-1.05	-0.99	-0.88	-0.56	0.19	-0.20	-0.80	-0.90	-1.06	-1.48	-1.36	0.24	0.24	0.25	0.26	0.26	0.21	0.19	0.21	0.20	0.25	0.24	0.23	0.02	0.01	0.02	0.03	0.03	0.00	0.01	0.03	0.01	0.03	0.02	0.02
	1	0.07	-0.04	-0.17	-0.24	-0.17	-0.10	0.03	0.00	-0.01	0.03	0.08	0.10	0.68	0.72	0.70	0.68	0.66	0.66	0.64	0.65	0.64	0.66	0.65	0.67	0.29	0.33	0.31	0.27	0.26	0.27	0.24	0.25	0.25	0.26	0.25	0.28
	2	0.07	-0.07	-0.22	-0.29	-0.31	-0.09	-0.07	-0.09	0.00	0.08	0.15	0.17	0.49	0.51	0.49	0.45	0.43	0.46	0.45	0.46	0.46	0.43	0.46	0.51	0.15	0.16	0.14	0.13	0.12	0.12	0.12	0.13	0.13	0.11	0.14	0.16
	3	-0.03	-0.19	-0.30	-0.40	-0.24	-0.19	-0.13	-0.08	0.05	0.13	0.12	0.06	0.45	0.45	0.41	0.38	0.40	0.41	0.41	0.43	0.39	0.41	0.43	0.45	0.11	0.12	0.10	0.09	0.09	0.08	0.09	0.11	0.10	0.11	0.12	0.13
Extra-tropical SH	4	-0.13	-0.27	-0.44	-0.34	-0.35	-0.24	-0.10	0.01	0.10	0.10	0.03	-0.04	0.42	0.39	0.37	0.37	0.36	0.37	0.41	0.37	0.38	0.40	0.41	0.41	0.10	0.08	0.07	0.07	0.06	0.07	0.09	0.08	0.10	0.11	0.11	0.10
	5	-0.18	-0.40	-0.39	-0.44	-0.41	-0.19	0.01	0.07	0.06	0.00	-0.08	-0.12	0.35	0.35	0.35	0.34	0.35	0.38	0.36	0.36	0.38	0.38	0.38	0.39	0.06	0.06	0.06	0.05	0.05	0.07	0.07	0.08	0.10	0.09	0.08	0.08
	6	-0.30	-0.37	-0.50	-0.50	-0.39	-0.06	0.06	0.02	-0.04	-0.10	-0.16	-0.14	0.31	0.33	0.33	0.32	0.36	0.33	0.35	0.37	0.37	0.38	0.37	0.34	0.04	0.04	0.04	0.04	0.05	0.05	0.07	0.09	0.09	0.08	0.08	0.06





N. Milders (BSC)

### Systematic forecast quality assessment

Near-Surface Air Temperature of ECMWF System 5 (cross-validation = false, skill aggregation)

	itear ourrade ra	Temperature of Lowith System 5 (closs-valuation - raise, ski	aggregation					
		Mean bias (K)	Correlation	RPSS	CRPSS			
	(Ref: ERA5 1993-2016)	Start date	Start date	Start date	Start date			
	Region	Forecast month Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec	Jan Feb Mar Aor May Jun Jul Aug Sep Oct Nov Dec	Jan Feb Mar Aor May Jun Jul Aun Sep Oct Nov Dec	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec			
		1 -0.20 -0.21 -0.16 -0.15 -0.11 -0.16 -0.18 -0.18 -0.16 -0.16 -0.21 -0.23	0.81 0.86 0.83 0.83 0.80 0.80 0.78 0.80 0.79 0.79 0.78 0.79	0.45 0.51 0.46 0.44 0.43 0.43 0.41 0.42 0.41 0.42 0.41 0.43	0.40 0.47 0.43 0.41 0.38 0.37 0.35 0.38 0.36 0.37 0.35 0.38			
		2 -0.24 -0.20 -0.16 -0.09 -0.10 -0.14 -0.14 -0.15 -0.17 -0.19 -0.24 -0.24	0.66 0.67 0.68 0.63 0.62 0.63 0.65 0.63 0.65 0.59 0.62 0.63	0.28 0.29 0.28 0.26 0.26 0.25 0.27 0.25 0.27 0.23 0.27 0.27	0.24 0.25 0.25 0.21 0.20 0.19 0.22 0.20 0.22 0.17 0.22 0.22			
		3 -0.19 -0.18 -0.11 -0.07 -0.09 -0.12 -0.13 -0.18 -0.18 -0.22 -0.22 -0.25	0.60 0.63 0.58 0.56 0.58 0.58 0.59 0.61 0.56 0.55 0.59 0.61	0.22 0.24 0.20 0.20 0.20 0.20 0.21 0.23 0.20 0.22 0.24 0.23	0.18 0.20 0.15 0.14 0.15 0.15 0.15 0.18 0.14 0.16 0.19 0.19			
	Tropics			0.20 0.18 0.17 0.18 0.16 0.17 0.20 0.19 0.19 0.19 0.22 0.18				
				0.15 0.15 0.15 0.13 0.15 0.17 0.16 0.18 0.20 0.18 0.18 0.17				
			and a second	0.11 0.13 0.11 0.13 0.15 0.15 0.15 0.18 0.19 0.15 0.17 0.13				
				0.28 0.38 0.40 0.34 0.30 0.29 0.27 0.30 0.25 0.27 0.29 0.28				
		2 -0.45 -0.20 -0.23 -0.24 -0.18 -0.11 -0.11 0.10 0.22 0.05 -0.37 -0.55 3 -0.32 -0.34 -0.38 -0.37 -0.25 -0.20 0.04 0.27 0.32 -0.09 -0.49 -0.43	And a second		0.00 0.05 0.03 0.02 0.00 0.02 0.05 0.04 0.01 -0.02 -0.01 0.02			
	Extra-tropical NH	3 0.12 -0.34 -0.38 -0.37 0.25 -0.20 0.04 0.27 0.32 -0.09 -0.49 -0.43 4 -0.39 -0.46 -0.51 -0.42 +0.34 -0.11 0.17 0.31 0.06 -0.36 -0.42 -0.35			0.00 0.01 0.00 -0.02 -0.02 0.02 0.03 -0.01 -0.01 -0.02 -0.04 0.00			
	Extra-tropical HH	5 -0.50 -0.58 -0.54 -0.48 +0.22 -0.06 -0.21 0.11 -0.20 -0.39 -0.36 -0.41	and the second	server to dee environmental server states consistent and the server server servers	-0.04 -0.02 -0.04 -0.04 0.01 -0.01 -0.03 -0.03 -0.03 -0.03 -0.02 -0.04			
				0.01 0.03 0.00 0.02 0.02 0.02 0.00 0.01 0.03 0.01 0.01 0.00				
	96 - O		the state of the s	0.38 0.44 0.41 0.38 0.36 0.35 0.33 0.35 0.34 0.35 0.36 0.36				
		2 -0.16 -0.06 -0.07 -0.10 -0.14 -0.09 -0.10 -0.05 -0.02 -0.11 -0.22 -0.23	0.52 0.55 0.54 0.48 0.46 0.49 0.51 0.50 0.50 0.46 0.47 0.52	0.18 0.20 0.18 0.16 0.15 0.16 0.18 0.16 0.17 0.14 0.16 0.18	0.14 0.16 0.14 0.11 0.10 0.11 0.13 0.11 0.13 0.09 0.11 0.12			
		3 -0.04 -0.05 -0.10 -0.15 -0.13 -0.13 -0.06 -0.02 -0.05 -0.16 -0.22 -0.15	0.47 0.49 0.43 0.40 0.43 0.44 0.45 0.45 0.42 0.42 0.44 0.47	0.14 0.15 0.12 0.11 0.12 0.12 0.13 0.13 0.12 0.13 0.14 0.15	0.10 0.11 0.07 0.06 0.07 0.07 0.08 0.09 0.07 0.08 0.09 0.10			
	Extra-tropical SH	4 -0.02 -0.09 -0.17 -0.15 -0.17 -0.10 -0.05 -0.07 -0.14 -0.20 -0.15 -0.05	0.45 0.41 0.39 0.40 0.40 0.40 0.45 0.40 0.41 0.40 0.44 0.43	0.12 0.10 0.09 0.09 0.09 0.09 0.12 0.11 0.11 0.11 0.13 0.11	0.08 0.06 0.04 0.05 0.04 0.04 0.08 0.06 0.07 0.06 0.09 0.07			
		5 -0.07 -0.16 -0.17 -0.19 -0.14 -0.11 -0.10 -0.15 -0.17 -0.15 -0.05 -0.02	AND A REAL PROPERTY A REAL PROPERTY AND A REAL	The second s	0.03 0.03 0.03 0.02 0.04 0.04 0.04 0.05 0.06 0.05 0.06 0.05			
		6 -0.15 -0.18 -0.21 -0.16 -0.14 -0.15 -0.17 -0.18 -0.13 -0.05 -0.02 -0.06	0.34 0.39 0.36 0.37 <mark>0.40</mark> 0.38 0.36 0.39 0.39 0.38 0.40 0.34	0.06 0.08 0.06 0.07 0.09 0.09 0.08 0.10 0.10 0.08 0.09 0.06	0.01 0.03 0.02 0.02 0.04 0.04 0.04 0.05 0.06 0.04 0.05 0.01			
	Near-Surface Al	r remperature of ECMWF System 5 (cross-validation = true, skill	aggregation)					
				2222	00000			
Impact of cross-	<i>l</i> alida <sup>.</sup>	Mean bias (K)	Correlation	RPSS	CRPSS			
	anda	Start date	Start date	Start date	Start date			
	Region	Forecast month Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec	<b>Start date</b> Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec		Start date Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec			
		Forecast month Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec		Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec			
		Forecast month      Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec        1      -0.20      -0.21      -0.16      -0.15      -0.11      -0.16      -0.18      -0.18      -0.18      -0.16      -0.21      0.221	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec 0.81 0.86 0.83 0.83 0.80 0.80 0.78 0.80 0.79 0.79 0.79 0.78	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec 0.40 0.47 0.43 0.41 0.38 0.37 0.35 0.38 0.36 0.37 0.35 0.38			
		Image: Start Gate      Start Gate        Start Gate      Start Gate        Instanting      Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec        1      -0.20      -0.21      -0.16      -0.15      -0.11      -0.16      -0.18      -0.18      -0.16      -0.16      -0.21      0.221        2      -0.24      -0.20      -0.16      -0.09      -0.10      -0.14      -0.14      -0.15      -0.17      -0.24      -0.24	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec 0.81 0.86 0.83 0.83 0.80 0.80 0.78 0.80 0.79 0.79 0.78 0.74 0.66 0.67 0.68 0.63 0.62 0.63 0.65 0.63 0.65 0.59 0.62 0.63	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec 0.45 0.51 0.46 0.44 0.42 0.43 0.40 0.41 0.41 0.41 0.40 0.42	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec 0.40 0.47 0.43 0.41 0.38 0.37 0.35 0.36 0.36 0.37 0.35 0.38 0.24 0.25 0.25 0.21 0.20 0.19 0.22 0.20 0.22 0.17 0.32 0.22			
		Porecasti monthi      Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec        1      -0.20      -0.21      -0.16      -0.15      -0.11      -0.16      -0.18      -0.18      -0.18      -0.16      -0.16      -0.21      -0.22        2      -0.24      -0.20      -0.16      -0.01      -0.14      -0.14      -0.15      -0.17      -0.21      -0.24        3      -0.19      -0.11      -0.07      -0.09      -0.12      -0.13      -0.18      -0.18      -0.18      -0.18      -0.18      -0.18      -0.18      -0.11      -0.24	Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec        0.81      0.86      0.82      0.80      0.80      0.76      0.80      0.79      0.78      0.70      0.78      0.70      0.78      0.70      0.78      0.70      0.78      0.70      0.78      0.70      0.78      0.70      0.78      0.70      0.78      0.70      0.78      0.70      0.78      0.70      0.78      0.70      0.78      0.70      0.78      0.70      0.78      0.70      0.78      0.70      0.78      0.70      0.78      0.70      0.78      0.78      0.70      0.78	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec 0.45 0.51 0.46 0.44 0.42 0.43 0.40 0.41 0.41 0.41 0.40 0.42 0.27 0.28 0.27 0.25 0.25 0.24 0.27 0.24 0.27 0.23 0.26 0.27	Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec        0.40      0.47      0.43      0.41      0.39      0.37      0.30      0.38      0.36      0.37      0.39      0.38      0.36      0.37      0.39      0.38      0.38      0.36      0.37      0.39      0.38      0.38      0.36      0.37      0.39      0.38      0.38      0.32      0.37      0.32			
	Region	Start Gate      Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec        1      -0.20      -0.21      -0.16      -0.15      -0.11      -0.16      -0.15      -0.11      -0.16      -0.16      -0.21      -0.23        2      -0.24      -0.26      -0.16      -0.05      -0.11      -0.14      -0.15      -0.16      -0.21      -0.23        3      -0.19      -0.18      -0.11      -0.07      -0.09      -0.12      -0.22	Jan      Feb      Mar      Apr      May      Jun      Jun      Aug      Sep      Oct      Nov      Dec        0.61      0.68      0.63      0.63      0.60      0.70	Jan      Feb      Mar      Apr      May      Jan      Jul      Aug      Sep      Oct      Nov      Dec        0.45      0.51      0.46      0.44      0.42      0.43      0.40      0.41      0.41      0.41      0.40      0.42      0.42      0.27      0.24      0.24      0.24      0.24      0.24      0.24      0.24      0.24      0.24      0.24      0.24      0.24      0.24      0.24      0.24      0.24      0.24      0.24	Jan      Feb      Mar      Apr      May      Jun      Jun      Aug      Sep      Oct      Nov      Dec        0.40      0.47      0.43      0.41      0.38      0.37      0.35      0.38      0.36      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.35      0.15			
	Region	Forecast month      Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec        1      -0.20      -0.21      -0.16      -0.15      -0.16      -0.18      -0.18      -0.18      -0.16      -0.16      -0.21      -0.23      -0.21        2      -0.24      -0.20      -0.21      -0.16      -0.01      -0.16      -0.17      -0.16      -0.21      -0.24        3      -0.19      -0.18      -0.16      -0.17      -0.16      -0.21      -0.24        4      -0.20      -0.21      -0.16      -0.07      -0.08      -0.18      -0.16      -0.17      -0.16      -0.21      -0.24        5      -0.19      -0.15      -0.06      -0.06      -0.16      -0.16      -0.22 <td>Jan      Feb      Mar      Apr      May      Jun      Jun      Aug      Sep      Oct      Nov      Dec        0.81      0.86      0.40      0.80      0.78      0.78      0.79</td> <td>Jan      Feb      Mar      Apr      May      Jan      Jal      Aug      Sep      Oct      Nov      Dec        0.45      0.46      0.44      0.42      0.40      0.40      0.41      0.41      0.40      0.42        0.27      0.28      0.27      0.28      0.27      0.24      0.27      0.24      0.27      0.24      0.24      0.27      0.24      0.27      0.24</td> <td>Jan      Feb      Mar      Apr      May      Jun      Jun      Aug      Sep      Oct      Nov      Dec        0.40      0.47      0.43      0.41      0.38      0.37      0.35      0.38      0.30      0.37      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.31      0.10      0.15      0.18      0.15      0.13      0.11      0.15      0.13      0.14      0.15      0.13      0.14      0.11      0.15      0.13      0.14      0.15      0.14      0.15      0.14      0.15      0.17</td>	Jan      Feb      Mar      Apr      May      Jun      Jun      Aug      Sep      Oct      Nov      Dec        0.81      0.86      0.40      0.80      0.78      0.78      0.79	Jan      Feb      Mar      Apr      May      Jan      Jal      Aug      Sep      Oct      Nov      Dec        0.45      0.46      0.44      0.42      0.40      0.40      0.41      0.41      0.40      0.42        0.27      0.28      0.27      0.28      0.27      0.24      0.27      0.24      0.27      0.24      0.24      0.27      0.24      0.27      0.24	Jan      Feb      Mar      Apr      May      Jun      Jun      Aug      Sep      Oct      Nov      Dec        0.40      0.47      0.43      0.41      0.38      0.37      0.35      0.38      0.30      0.37      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.31      0.10      0.15      0.18      0.15      0.13      0.11      0.15      0.13      0.14      0.15      0.13      0.14      0.11      0.15      0.13      0.14      0.15      0.14      0.15      0.14      0.15      0.17			
	Region	Forecast month      Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec        1      -0.20      -0.21      -0.16      -0.15      -0.11      -0.16      -0.18      -0.18      -0.18      -0.16      -0.16      -0.21      -0.22      -0.22      -0.22      -0.22      -0.22      -0.22      -0.22      -0.22      -0.22      -0.22      -0.22      -0.22      -0.22      -0.22      -0.22      -0.22      -0.22      -0.22      -0.24 <td< td=""><td>Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec        0.81      0.86      0.80      0.80      0.78      0.80      0.79      0.78      0.79      0.79      0.78      0.79      0.79      0.79      0.78      0.79      0.79      0.79      0.79      0.49</td><td>Jan      Feb      Mar      Apr      May      Jan      Jan      Aug      Sep      Oct      Nov      Dec        0.45      0.51      0.46      0.44      0.42      0.43      0.40      0.41      0.41      0.40      0.42        0.27      0.28      0.27      0.24      0.27      0.24      0.27      0.24      0.24      0.27      0.24      0.27      0.24</td><td>Jan      Feb      Mar      Apr      May      Jun      Jun      Aug      Sep      Oct      Nov      Dec        0.40      0.47      0.43      0.41      0.58      0.37      0.35      0.38      0.36      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.30      0.31      0.31      0.31      0.31      0.15      0.18      0.18      0.15      0.18      0.15      0.14      0.15      0.14      0.11      0.15      0.14      0.15      0.14      0.15      0.14      0.15</td></td<>	Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec        0.81      0.86      0.80      0.80      0.78      0.80      0.79      0.78      0.79      0.79      0.78      0.79      0.79      0.79      0.78      0.79      0.79      0.79      0.79      0.49	Jan      Feb      Mar      Apr      May      Jan      Jan      Aug      Sep      Oct      Nov      Dec        0.45      0.51      0.46      0.44      0.42      0.43      0.40      0.41      0.41      0.40      0.42        0.27      0.28      0.27      0.24      0.27      0.24      0.27      0.24      0.24      0.27      0.24      0.27      0.24	Jan      Feb      Mar      Apr      May      Jun      Jun      Aug      Sep      Oct      Nov      Dec        0.40      0.47      0.43      0.41      0.58      0.37      0.35      0.38      0.36      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.35      0.38      0.37      0.30      0.31      0.31      0.31      0.31      0.15      0.18      0.18      0.15      0.18      0.15      0.14      0.15      0.14      0.11      0.15      0.14      0.15      0.14      0.15      0.14      0.15			
	Region	Forecasti fmonthi      Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Decision        1      -0.20      -0.21      -0.16      -0.15      -0.11      -0.16      -0.18      -0.18      -0.18      -0.16      -0.12      -0.22        2      -0.24      -0.20      -0.16      -0.07      -0.09      -0.12      -0.18      -0.18      -0.16      -0.21      -0.23      -0.24 <td< td=""><td>Feb      Mar      Apr      May      Jun      Jun      Aug      Sep      Oct      No      Dec        0.10      0.46      0.43      0.43      0.40</td><td>Jan      Feb      Mar      Apr      May      Jan      Jal      Apr      Easy      Dec      Dec      Dec        0.45      0.45      0.44      0.42      0.43      0.40      0.41      0.41      0.40      0.42        0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.29      0.24      0.27      0.28      0.29      0.24      0.27      0.28      0.29      0.24      0.27      0.28      0.29      0.24      0.27      0.28      0.29      0.21      0.24      0.27      0.28      0.29      0.21      0.23      0.20      0.21      0.12      0.16</td><td>And      And      And      And      And      And      Sep      Oct      Nov      Dec        0.40      0.47      0.43      0.47      0.36      0.36      0.36      0.37      0.30      0.37      0.30      0.38      0.37      0.30      0.37      0.30      0.38      0.37      0.30      0.37      0.30      0.38      0.37      0.30      0.37      0.30      0.38      0.37      0.30      0.37      0.30      0.38      0.37      0.30      0.32      0.37      0.30      0.38      0.37      0.30      0.32      0.32      0.32      0.37      0.30      0.38      0.37      0.30      0.32      0.32      0.32      0.32      0.32      0.32      0.32      0.32      0.32      0.31      0.30      0.31</td></td<>	Feb      Mar      Apr      May      Jun      Jun      Aug      Sep      Oct      No      Dec        0.10      0.46      0.43      0.43      0.40	Jan      Feb      Mar      Apr      May      Jan      Jal      Apr      Easy      Dec      Dec      Dec        0.45      0.45      0.44      0.42      0.43      0.40      0.41      0.41      0.40      0.42        0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.29      0.24      0.27      0.28      0.29      0.24      0.27      0.28      0.29      0.24      0.27      0.28      0.29      0.24      0.27      0.28      0.29      0.21      0.24      0.27      0.28      0.29      0.21      0.23      0.20      0.21      0.12      0.16	And      And      And      And      And      And      Sep      Oct      Nov      Dec        0.40      0.47      0.43      0.47      0.36      0.36      0.36      0.37      0.30      0.37      0.30      0.38      0.37      0.30      0.37      0.30      0.38      0.37      0.30      0.37      0.30      0.38      0.37      0.30      0.37      0.30      0.38      0.37      0.30      0.37      0.30      0.38      0.37      0.30      0.32      0.37      0.30      0.38      0.37      0.30      0.32      0.32      0.32      0.37      0.30      0.38      0.37      0.30      0.32      0.32      0.32      0.32      0.32      0.32      0.32      0.32      0.32      0.31      0.30      0.31			
	Region	Forecasti monthi      Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Decession        1      -0.20      -0.21      -0.16      -0.15      -0.11      -0.16      -0.18      -0.12      -0.24      -0.22      -0.22      -0.22      -0.22      -0.22      -0.22      -0.22      -0.22      -0.22      -0.22      -0.22      -0.22      -0.22	Feb      Mar      Apr      May      Jun      Jun      Jung      Sep      Oct      Nov      Dec        0.10      0.46      0.43      0.43      0.40	Jan      Feb      Mar      Apr      Mar      Jan      Jal      Aug      Epp      Oct      Nov      Dec        0.43      0.44      0.44      0.42      0.42      0.41      0.41      0.41      0.40      0.42      0.27      0.28      0.28      0.27      0.28      0.29      0.28	And      Apr			
	Region	Statistical	Path      Mar      Apr      May      Jun      Jun      Jung      Apr      Apr      May      Jung      Apr      Apr      Apr      Jung      Jung      Apr      Apr      Apr      Apr      Jung      Jung      Apr      Apr      Apr      Jung      Jung      Apr      Apr      Apr      Jung      Jung      Apr	Jan      Feb      Mar      Apr      May      Jan      Jul      Aug      Eqp      Oct      Nov      Dec        0.45      0.46      0.44      0.42      0.43      0.40      0.41      0.41      0.40      0.42      0.42      0.41      0.41      0.40      0.42      0.42      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.29      0.29      0.21      0.22      0.20      0.21      0.22      0.21      0.20      0.21      0.20      0.21      0.20      0.21      0.20      0.21      0.21      0.20      0.11      0.10      0.15      0.15      0.15      0.15      0.17      0.13      0.11      0.15      0.15      0.15      0.15      0.17      0.10      0.10      0.12      0.12      0.12      0.12      0.12      0.10      0.10      0.10      0.10      0.10	Jan      Feb      Mar      Apr      Mar      Jan      Jan      Aug      Sep      Oct      Nov      Deteccccccccccccccccccccccccccccccccccc			
	Region Tropics	and      fead      May      May <th>Image      Image      <th< th=""><th>Jan      Feb      Mar      Apr      May      Jan      Jul      Aug      Epp      Oct      Nov      Dec        0.45      0.46      0.44      0.42      0.43      0.40      0.41      0.41      0.41      0.40      0.42</th><th>Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Deteccccccccccccccccccccccccccccccccccc</th></th<></th>	Image      Image <th< th=""><th>Jan      Feb      Mar      Apr      May      Jan      Jul      Aug      Epp      Oct      Nov      Dec        0.45      0.46      0.44      0.42      0.43      0.40      0.41      0.41      0.41      0.40      0.42</th><th>Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Deteccccccccccccccccccccccccccccccccccc</th></th<>	Jan      Feb      Mar      Apr      May      Jan      Jul      Aug      Epp      Oct      Nov      Dec        0.45      0.46      0.44      0.42      0.43      0.40      0.41      0.41      0.41      0.40      0.42	Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Deteccccccccccccccccccccccccccccccccccc			
	Region Tropics	Image: Second	Image      Image <th< th=""><th>Jan      Feb      Mar      Apr      May      Jan      Jal      Aug      Sep      Oct      Nov      Dect        0.45      0.46      0.44      0.42      0.43      0.40      0.41      0.41      0.41      0.40      0.42      0.41      0.41      0.41      0.41</th><th>Jan      Feb      Mar      Apr      May      Jun      Jun      Aug      Sep      Oct      Nov      Des        0.40      0.47      0.43      0.41      0.42      0.42      0.42      0.42      0.43      0.41      0.40      0.40      0.43      0.41      0.40</th></th<>	Jan      Feb      Mar      Apr      May      Jan      Jal      Aug      Sep      Oct      Nov      Dect        0.45      0.46      0.44      0.42      0.43      0.40      0.41      0.41      0.41      0.40      0.42      0.41      0.41      0.41      0.41	Jan      Feb      Mar      Apr      May      Jun      Jun      Aug      Sep      Oct      Nov      Des        0.40      0.47      0.43      0.41      0.42      0.42      0.42      0.42      0.43      0.41      0.40      0.40      0.43      0.41      0.40			
	Region Tropics	Image: Second	And      And <td>Jan      Feb      Mar      Apr      May      Jan      Jan      Aug      Sep      Oct      Nov      Dec        0.45      0.41      0.44      0.42      0.43      0.40      0.41      0.41      0.41      0.40      0.42        0.27      0.28      0.27      0.24      0.27      0.24      0.27      0.24      0.27      0.24      0.27      0.24      0.27      0.24      0.27      0.24      0.27      0.24      0.27      0.24      0.24      0.27      0.24      0.27      0.24      0.27      0.24      0.27      0.24      0.27      0.24      0.28      0.24</td> <td>Jan      Feb      Mar      Apr      May      Jun      Jun      Aug      Sep      Oct      Nov      Des        0.40      0.47      0.43      0.41      0.42      0.42      0.42      0.42      0.43      0.41      0.40      0.40      0.43      0.41      0.40</td>	Jan      Feb      Mar      Apr      May      Jan      Jan      Aug      Sep      Oct      Nov      Dec        0.45      0.41      0.44      0.42      0.43      0.40      0.41      0.41      0.41      0.40      0.42        0.27      0.28      0.27      0.24      0.27      0.24      0.27      0.24      0.27      0.24      0.27      0.24      0.27      0.24      0.27      0.24      0.27      0.24      0.27      0.24      0.24      0.27      0.24      0.27      0.24      0.27      0.24      0.27      0.24      0.27      0.24      0.28      0.24	Jan      Feb      Mar      Apr      May      Jun      Jun      Aug      Sep      Oct      Nov      Des        0.40      0.47      0.43      0.41      0.42      0.42      0.42      0.42      0.43      0.41      0.40      0.40      0.43      0.41      0.40			
	Region Tropics	Forecasti Formati      Jan      Feb      Mar      Map      Map      Map      Jun      Map      Sup	Nor      Apr      May      Jun      Jun      Jung      Apr      Apr      Apr      Apr      Jung      Apr      Apr      Apr      Apr      Jung      Apr      Apr<	Jan      Feb      Mar      Apr      Mar      Jan      Jal      Apr      Apr <td>Jan      Feb      Mar      Apr      Mar      Jan      Jan      Mar      Sep      Oct      Nov      Dec        0.40      0.41      0.41      0.42      0.25      0.26      0.26      0.27      0.28      0.28      0.27      0.28      0.28      0.27      0.28      0.28      0.27      0.28      0.20      0.22      0.27      0.22      0.22      0.27      0.22      0.22      0.21      0.20      0.11      0.10      0.10      0.11      0.10      0.11      0.10      0.11      0.10      0.11      0.10      0.11      0.10      0.11      0.10      0.11      0.10      0.11      0.11      0.10      0.10      0.10</td>	Jan      Feb      Mar      Apr      Mar      Jan      Jan      Mar      Sep      Oct      Nov      Dec        0.40      0.41      0.41      0.42      0.25      0.26      0.26      0.27      0.28      0.28      0.27      0.28      0.28      0.27      0.28      0.28      0.27      0.28      0.20      0.22      0.27      0.22      0.22      0.27      0.22      0.22      0.21      0.20      0.11      0.10      0.10      0.11      0.10      0.11      0.10      0.11      0.10      0.11      0.10      0.11      0.10      0.11      0.10      0.11      0.10      0.11      0.11      0.10      0.10      0.10			
	Region Tropics	Image: Second	No.      No. <td>Jan      Feb      Mar      Apr      Mar      Jan      Jal      Apr      Apr<td>Jan      Feb      Apr      Apr      Jan      Jan      Apr      Apr</td></td>	Jan      Feb      Mar      Apr      Mar      Jan      Jal      Apr      Apr <td>Jan      Feb      Apr      Apr      Jan      Jan      Apr      Apr</td>	Jan      Feb      Apr      Apr      Jan      Jan      Apr			
	Region Tropics Extra-tropical NH	Processiti Froncessiti 2      Jan      Feb      May      May      May      Jan      May      Sep      Oct      Nov      Decision        1      -020      -021      -016      -015      -011      -016      -018      -018      -016      -016      -012      -023      -023      -023      -024      -023      -024	Image      Image <th< td=""><td>Jan      Feb      Mar      Apr      May      Jan      Jan      Aug      Epp      Oct      Nov      Dect        0.45      0.40      0.44      0.42      0.43      0.40      0.41      0.41      0.41      0.40      0.42      0.44      0.41</td><td>Jan      Feb      Mar      Apr      May      Jan      Jan      Aug      Sep      O.C      Nov      Dec        0.40      0.47      0.43      0.41      0.42      0.42      0.43      0.41      0.40      0.43      0.41      0.40      0.43      0.41      0.42      0.42      0.40      0.41      0.42      0.40      0.41      0.42      0.40      0.41      0.42      0.40      0.41      0.42      0.40      0.41</td></th<>	Jan      Feb      Mar      Apr      May      Jan      Jan      Aug      Epp      Oct      Nov      Dect        0.45      0.40      0.44      0.42      0.43      0.40      0.41      0.41      0.41      0.40      0.42      0.44      0.41	Jan      Feb      Mar      Apr      May      Jan      Jan      Aug      Sep      O.C      Nov      Dec        0.40      0.47      0.43      0.41      0.42      0.42      0.43      0.41      0.40      0.43      0.41      0.40      0.43      0.41      0.42      0.42      0.40      0.41      0.42      0.40      0.41      0.42      0.40      0.41      0.42      0.40      0.41      0.42      0.40      0.41			
	Region Tropics Extra-tropical NH	Processiti Froncessiti 2      Jan      Feb      May      May      May      Jan      May      Sep      Oct      Nov      Decision        1      -020      -021      -016      -015      -011      -016      -018      -018      -016      -016      -012      -023      -023      -023      -024      -023      -024	Image      Image <th< th=""><th>Jan      Feb      Mar      App      May      Jan      Jan      Aug      Exp      Oct      Nov      Dect        0.45      0.51      0.46      0.44      0.42      0.43      0.40      0.41      0.41      0.41      0.40      0.42      0.42      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.20      0.21      0.22      0.21      0.23      0.20      0.21      0.22      0.21      0.22      0.21      0.21      0.22      0.21      0.23      0.20      0.21      0.22      0.21      0.20      0.21      0.20      0.21      0.21      0.20      0.21</th><th>Jan      Feb      Mar      Apr      May      Jan      Jan      Aug      Sep      O.C      Nov      Dec        0.40      0.47      0.43      0.41      0.42      0.42      0.43      0.41      0.40      0.43      0.41      0.40      0.43      0.41      0.42      0.42      0.40      0.41      0.42      0.40      0.41      0.42      0.40      0.41      0.42      0.40      0.41      0.42      0.40      0.41</th></th<>	Jan      Feb      Mar      App      May      Jan      Jan      Aug      Exp      Oct      Nov      Dect        0.45      0.51      0.46      0.44      0.42      0.43      0.40      0.41      0.41      0.41      0.40      0.42      0.42      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.20      0.21      0.22      0.21      0.23      0.20      0.21      0.22      0.21      0.22      0.21      0.21      0.22      0.21      0.23      0.20      0.21      0.22      0.21      0.20      0.21      0.20      0.21      0.21      0.20      0.21	Jan      Feb      Mar      Apr      May      Jan      Jan      Aug      Sep      O.C      Nov      Dec        0.40      0.47      0.43      0.41      0.42      0.42      0.43      0.41      0.40      0.43      0.41      0.40      0.43      0.41      0.42      0.42      0.40      0.41      0.42      0.40      0.41      0.42      0.40      0.41      0.42      0.40      0.41      0.42      0.40      0.41			
Barcelona	Region Tropics Extra-tropical NH	Processiti Froncessiti 2      Jan      Feb      May      May      May      Jan      May      Sep      Oct      Nov      Decision        1      -020      -021      -016      -015      -011      -016      -018      -018      -016      -016      -012      -023      -023      -023      -024      -023      -024	Image      Image <th< th=""><th>Jan      Feb      Mar      Apr      May      Jan      Jan      Aug      Epp      Oct      Nov      Dect        0.45      0.40      0.44      0.42      0.43      0.40      0.41      0.41      0.41      0.40      0.42      0.44      0.41</th><th>Jan      Feb      Mar      Apr      May      Jan      Jan      Aug      Sep      O.C      Nov      Dec        0.40      0.47      0.43      0.41      0.42      0.42      0.43      0.41      0.40      0.43      0.41      0.40      0.43      0.41      0.42      0.42      0.40      0.41      0.42      0.40      0.41      0.42      0.40      0.41      0.42      0.40      0.41      0.42      0.40      0.41</th></th<>	Jan      Feb      Mar      Apr      May      Jan      Jan      Aug      Epp      Oct      Nov      Dect        0.45      0.40      0.44      0.42      0.43      0.40      0.41      0.41      0.41      0.40      0.42      0.44      0.41	Jan      Feb      Mar      Apr      May      Jan      Jan      Aug      Sep      O.C      Nov      Dec        0.40      0.47      0.43      0.41      0.42      0.42      0.43      0.41      0.40      0.43      0.41      0.40      0.43      0.41      0.42      0.42      0.40      0.41      0.42      0.40      0.41      0.42      0.40      0.41      0.42      0.40      0.41      0.42      0.40      0.41			
Barcelona	Region Tropics Extra-tropical NH Extra-tropical SH	month      Jan      Feb      Ma      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec        1      -0.20      -0.21      -0.15      -0.11      -0.12      -0.12      -0.12      -0.21      -0.22      -0.21      -0.21      -0.21      -0.21      -0.22      -0.22      -0.22      -0.21      -0.21      -0.21 <td>Path      Mar      Apr      May      Jun      Jun      Apr      Apr      May      Jun      Jun      Apr      Apr      Apr      Apr      Jun      Jun      Jun      Apr      Apr      Apr      Apr      Jun      Jun      Jun      Apr      Apr<td>Jan      Feb      Mar      Apr      May      Jan      Jal      Aug      Epp      Oct      Nov      Dec        0.45      0.46      0.44      0.42      0.42      0.41      0.41      0.41      0.41      0.41      0.41      0.41      0.41      0.41      0.42      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.20      0.21      0.24      0.27      0.28      0.20      0.20      0.21      0.22      0.20      0.21      0.23      0.20      0.21      0.23      0.20      0.21      0.23      0.20      0.21      0.23      0.20      0.21      0.23      0.20      0.21      0.21      0.21      0.21      0.23      0.20      0.21      0.21      0.21      0.21      0.23      0.20      0.21      0.21      0.21      0.21      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22</td><td>Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec        0.40      0.41      0.41      0.42      0.27      0.32      0.28      0.27      0.32      0.28      0.27      0.32      0.28      0.27      0.32      0.28      0.27      0.32      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.21      0.20      0.10      0.15      0.18      0.14      0.15      0.18      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.10      0.11</td></td>	Path      Mar      Apr      May      Jun      Jun      Apr      Apr      May      Jun      Jun      Apr      Apr      Apr      Apr      Jun      Jun      Jun      Apr      Apr      Apr      Apr      Jun      Jun      Jun      Apr      Apr <td>Jan      Feb      Mar      Apr      May      Jan      Jal      Aug      Epp      Oct      Nov      Dec        0.45      0.46      0.44      0.42      0.42      0.41      0.41      0.41      0.41      0.41      0.41      0.41      0.41      0.41      0.42      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.20      0.21      0.24      0.27      0.28      0.20      0.20      0.21      0.22      0.20      0.21      0.23      0.20      0.21      0.23      0.20      0.21      0.23      0.20      0.21      0.23      0.20      0.21      0.23      0.20      0.21      0.21      0.21      0.21      0.23      0.20      0.21      0.21      0.21      0.21      0.23      0.20      0.21      0.21      0.21      0.21      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22</td> <td>Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec        0.40      0.41      0.41      0.42      0.27      0.32      0.28      0.27      0.32      0.28      0.27      0.32      0.28      0.27      0.32      0.28      0.27      0.32      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.21      0.20      0.10      0.15      0.18      0.14      0.15      0.18      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.10      0.11</td>	Jan      Feb      Mar      Apr      May      Jan      Jal      Aug      Epp      Oct      Nov      Dec        0.45      0.46      0.44      0.42      0.42      0.41      0.41      0.41      0.41      0.41      0.41      0.41      0.41      0.41      0.42      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.20      0.21      0.24      0.27      0.28      0.20      0.20      0.21      0.22      0.20      0.21      0.23      0.20      0.21      0.23      0.20      0.21      0.23      0.20      0.21      0.23      0.20      0.21      0.23      0.20      0.21      0.21      0.21      0.21      0.23      0.20      0.21      0.21      0.21      0.21      0.23      0.20      0.21      0.21      0.21      0.21      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22	Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec        0.40      0.41      0.41      0.42      0.27      0.32      0.28      0.27      0.32      0.28      0.27      0.32      0.28      0.27      0.32      0.28      0.27      0.32      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.21      0.20      0.10      0.15      0.18      0.14      0.15      0.18      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.10      0.11			
Barcelona Supercomput	Region Tropics Extra-tropical NH Extra-tropical SH	Processiti Froncessiti 2      Jan      Feb      May      May      May      Jan      May      Sep      Oct      Nov      Decision        1      -020      -021      -016      -015      -011      -016      -018      -018      -016      -016      -012      -023      -023      -023      -024      -023      -024	Image      Image <th< td=""><td>Jan      Feb      Mar      Apr      May      Jan      Jan      Aug      Epp      Oct      Nov      Dect        0.45      0.40      0.44      0.42      0.43      0.40      0.41      0.41      0.41      0.40      0.42      0.44      0.41</td><td>Jan      Feb      Mar      Apr      May      Jan      Jan      Aug      Sep      O.C      Nov      Dec        0.40      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.44      0.45      0.44      0.45      0.44      0.45      0.44      0.45      0.44      0.45</td></th<>	Jan      Feb      Mar      Apr      May      Jan      Jan      Aug      Epp      Oct      Nov      Dect        0.45      0.40      0.44      0.42      0.43      0.40      0.41      0.41      0.41      0.40      0.42      0.44      0.41	Jan      Feb      Mar      Apr      May      Jan      Jan      Aug      Sep      O.C      Nov      Dec        0.40      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.43      0.44      0.44      0.45      0.44      0.45      0.44      0.45      0.44      0.45      0.44      0.45			
Barcelona	Region Tropics Extra-tropical NH Extra-tropical SH	Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec        1      -0.20      -0.21      -0.16      -0.15      -0.11      -0.16      -0.15      -0.11      -0.16      -0.16      -0.17      -0.16      -0.17      -0.16      -0.17      -0.16      -0.17      -0.16      -0.17      -0.16      -0.17      -0.16      -0.22      -0.2	Path      Mar      Apr      May      Jun      Jun      Apr      Apr      May      Jun      Jun      Apr      Apr      Apr      Apr      Jun      Jun      Jun      Apr      Apr      Apr      Apr      Jun      Jun      Jun      Apr      Apr <td>Jan      Feb      Mar      Apr      May      Jan      Jal      Aug      Epp      Oct      Nov      Dec        0.45      0.46      0.44      0.42      0.42      0.41      0.41      0.41      0.41      0.41      0.41      0.41      0.41      0.41      0.42      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.20      0.21      0.24      0.27      0.28      0.20      0.20      0.21      0.22      0.20      0.21      0.23      0.20      0.21      0.23      0.20      0.21      0.23      0.20      0.21      0.23      0.20      0.21      0.23      0.20      0.21      0.21      0.21      0.21      0.23      0.20      0.21      0.21      0.21      0.21      0.23      0.20      0.21      0.21      0.21      0.21      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22</td> <td>Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec        0.40      0.41      0.41      0.42      0.27      0.32      0.28      0.27      0.32      0.28      0.27      0.32      0.28      0.27      0.32      0.28      0.27      0.32      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.21      0.20      0.10      0.15      0.18      0.14      0.15      0.18      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.10      0.11</td>	Jan      Feb      Mar      Apr      May      Jan      Jal      Aug      Epp      Oct      Nov      Dec        0.45      0.46      0.44      0.42      0.42      0.41      0.41      0.41      0.41      0.41      0.41      0.41      0.41      0.41      0.42      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.27      0.28      0.20      0.21      0.24      0.27      0.28      0.20      0.20      0.21      0.22      0.20      0.21      0.23      0.20      0.21      0.23      0.20      0.21      0.23      0.20      0.21      0.23      0.20      0.21      0.23      0.20      0.21      0.21      0.21      0.21      0.23      0.20      0.21      0.21      0.21      0.21      0.23      0.20      0.21      0.21      0.21      0.21      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22	Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec        0.40      0.41      0.41      0.42      0.27      0.32      0.28      0.27      0.32      0.28      0.27      0.32      0.28      0.27      0.32      0.28      0.27      0.32      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.22      0.21      0.20      0.10      0.15      0.18      0.14      0.15      0.18      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.13      0.14      0.15      0.10      0.11			

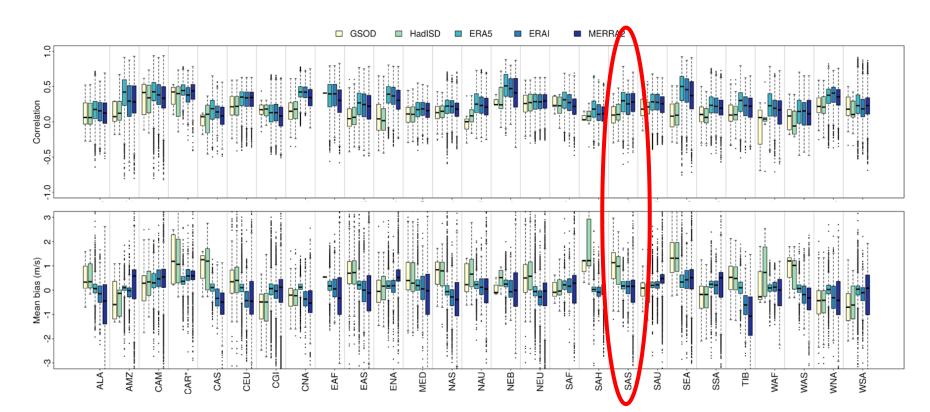
N. Milders (BSC)

### Beware of the observational uncertainty

Verification with two ground-based observational datasets and three reanalyses. The use of both types of datasets is very informative for wind energy users as they use them for the development of impact models and the long-term resource assessments.

"Failing to account for the effects of observation error when deciding between two forecasting systems could lead to the wrong choice and a high opportunity cost" (Ferro, 2017)



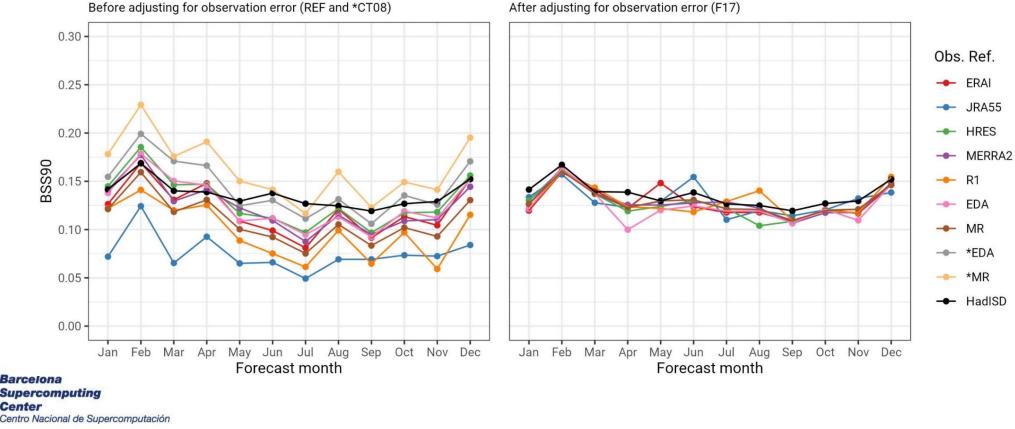




### **Observational uncertainty**

Verification against several reanalysis-based references gives different results. Adjustment of the observational references to in-situ observations (HadISD) shows that this uncertainty can be reduced. 10 m wind speed, BSS90 for zero-month lead one-month forecasts from ECMWF S5 (1981-2017).

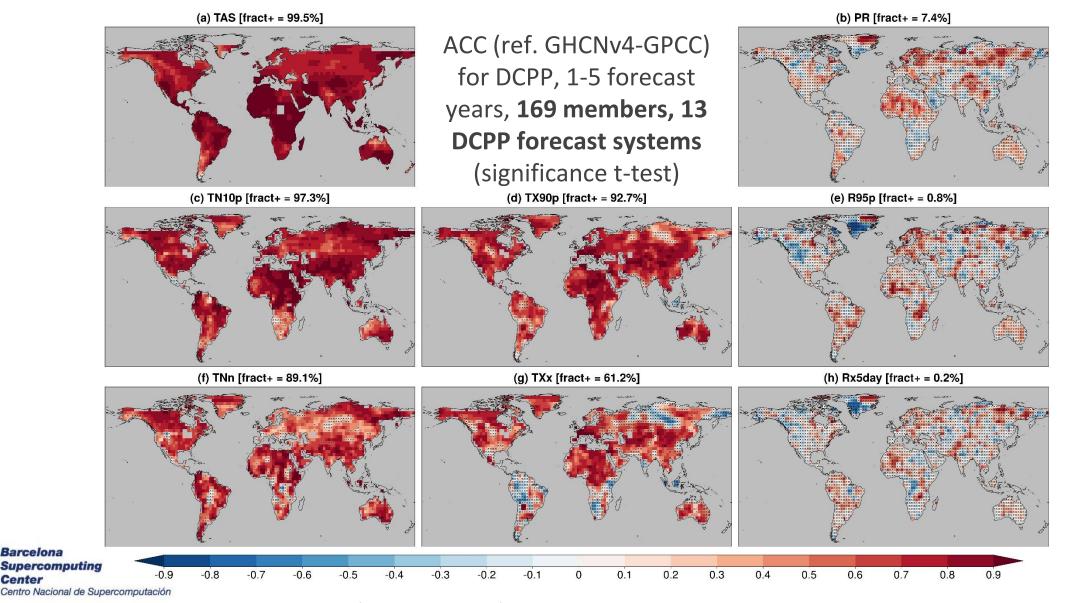
"Failing to account for the effects of observation error when deciding between two forecasting systems could lead to the wrong choice and a high opportunity cost" (Ferro, 2017)



After adjusting for observation error (F17)

Ramon et al. (in preparation)

### **Building multi-model systems**



Delgado-Torres et al. (2022, J. Climate)

Barcelona

Center

### **Building multi-model systems**

(a) TAS [fract+ = 95.9%]

(c) TN10p [fract+ = 84.1%]

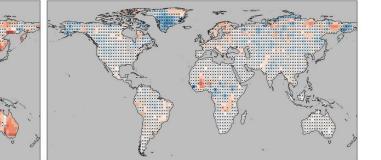
Center

RPSS (3 cat.; BEST-REGEN) for DCPP, 1.5 forecast years, 169 members, 13 **DCPP forecast systems** (significance random walk)

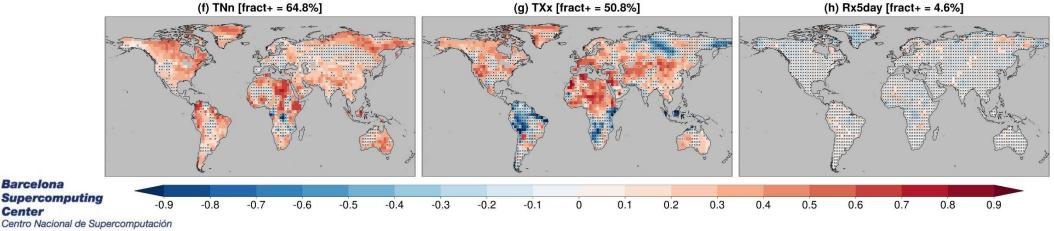
(d) TX90p [fract+ = 81.7%]

(b) PR [fract+ = 4.2%]

(e) R95p [fract+ = 9.2%]



(h) Rx5day [fract+ = 4.6%]

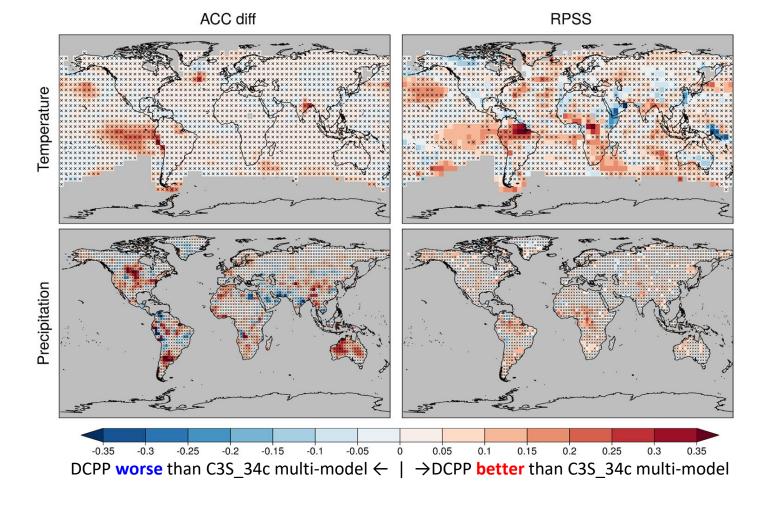




### **Building multi-model systems**

Systematic assessment of the multi-model decadal prediction forecast quality helps illustrating, among other things, the importance of a large enough operational multi-model.

Comparison between a research (DCPP, **169 members, 13 forecast systems**) and an operational (C3S\_34c, **40 members, 4 forecast systems**, CMCC-CM2-SR5, EC-Earth3-i1, HadGEM3-GC3.1-MM and MPI-ESM1.2-HR).

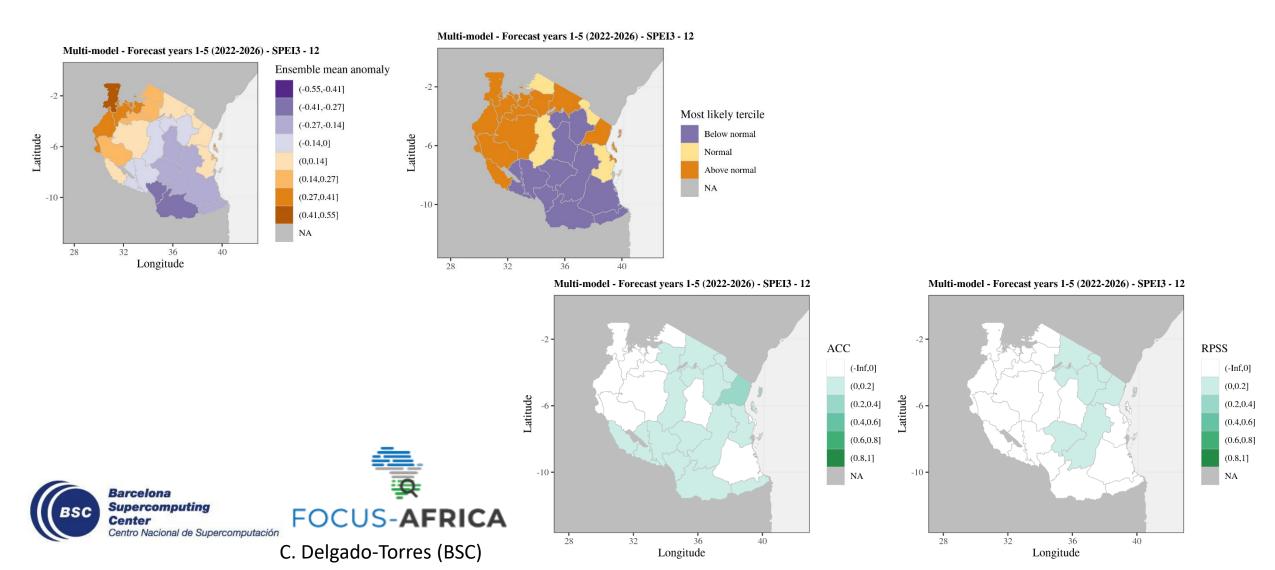




Delgado-Torres et al. (2022, J. Climate)

### Where to from here? User requirements

Downscaled SPEI3 (October to December) multi-model (three models) predictions for 2022-2026 over Tanzania to support agricultural decisions for maize. ERA5Land used as reference.



### Lessons from research in user engagement

- Better links, collaboration and knowledge sharing among the increasing, and currently fragmented, community of practice. The current supply-driven approach is more likely to improve climate data, but not necessarily to contribute to better informed decisions. Direct interaction would allow identifying improvement areas and emerging user needs (role for climate services).
- Better interaction between providers and users and more effort to build local competences.
- Improving usefulness and usability of the products and moving towards demand-driven (instead of demand-relevant):
  - enhancing credibility with a more transparent appr of the corresponding climate services
  - enhancing salience by improving the skill, user inte
  - enhancing legitimacy by creating independent qua including the different stakeholders involved in the
- Find a space for those forecast intermediaries (nat been using subjective methods, consider a balance objective forecasts.

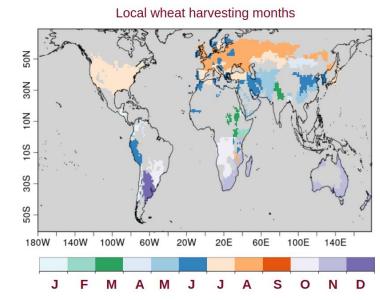




Findlater et al. (2021, NCC), Bojovic et al. (2022, Clim. Change)

### **Forecasts for crop yield**

WMO recognised global producing centres of decadal predictions contribute with the definition of standards for decadal predictions data and products, while C3S promotes the evaluation of the European multi-model and the illustration of the decadal prediction use in, among other sectors, the agricultural sector using indicators.

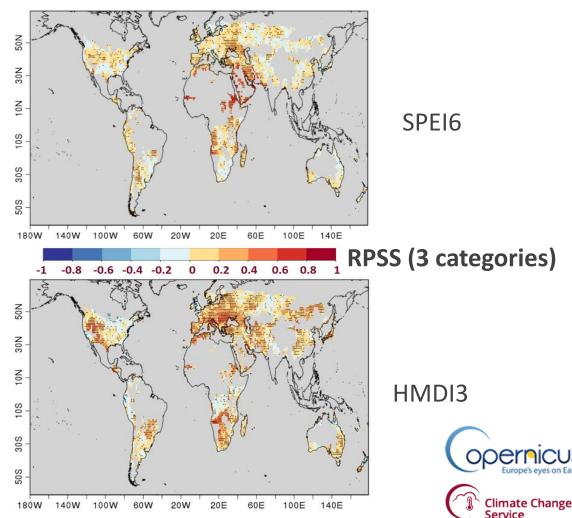


Indicators:

- Drought: Standardized Precipitation
  Evapotranspiration Index (SPEI6)
- Heat stress: Heat Magnitude Day Index (HMDI3)



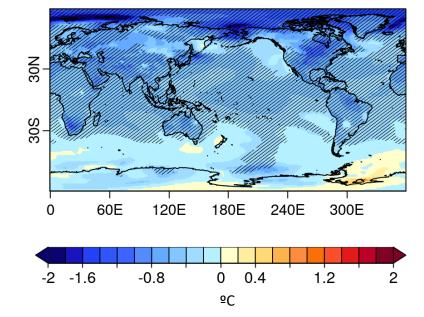
Solaraju-Murali et al. (2021, NPJ Climate)



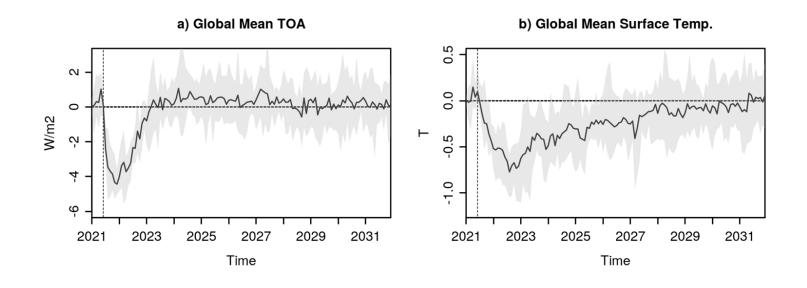
### **Volcanic influence**

Results from the Decadal Prediction Volcanic Response Readiness Exercise (VolRes-RE).

A 2xEl Chichón eruption is set in April 2022 for the decadal forecast started in late 2021 and the difference with respect to DCPP-A made.



#### TAS YR2-5







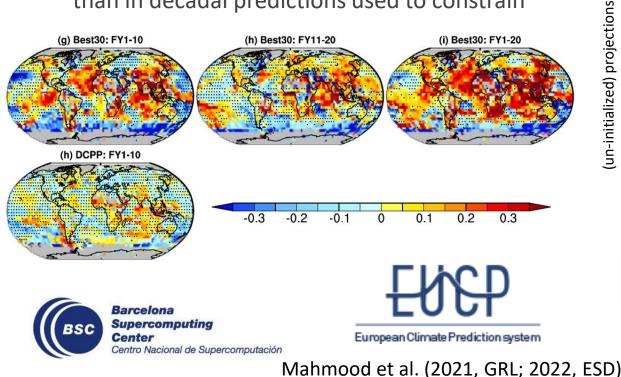
# Some of what we can do with what happens around us: Seamless information, more realistic models, carbon cycle

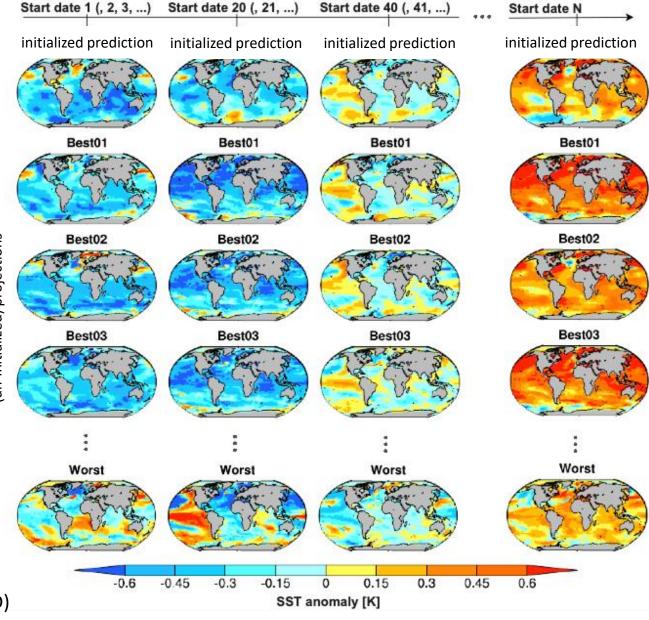


**Barcelona Supercomputing Center** Centro Nacional de Supercomputación

### **Near-term seamless climate information**

- Projections: **223 members** from 35 models Decadal predictions: **93 members** from 9 models Sub-selecting the 30 projections members in closest agreement with the predictions over years 1-9
  - → There is substantial multi-decadal predictability by aligning internal variability
  - → Skill in constrained projections can be larger than in decadal predictions used to constrain

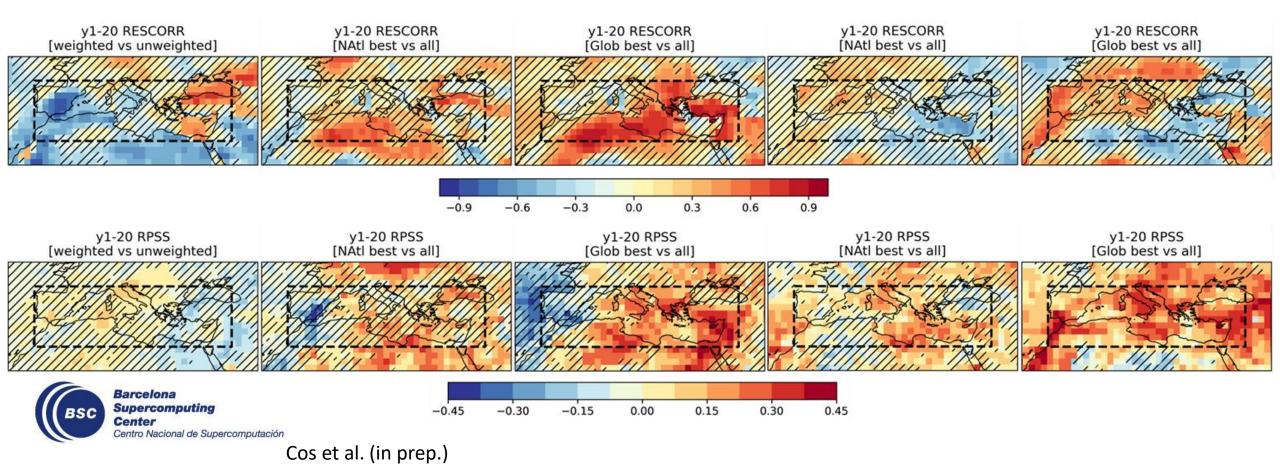




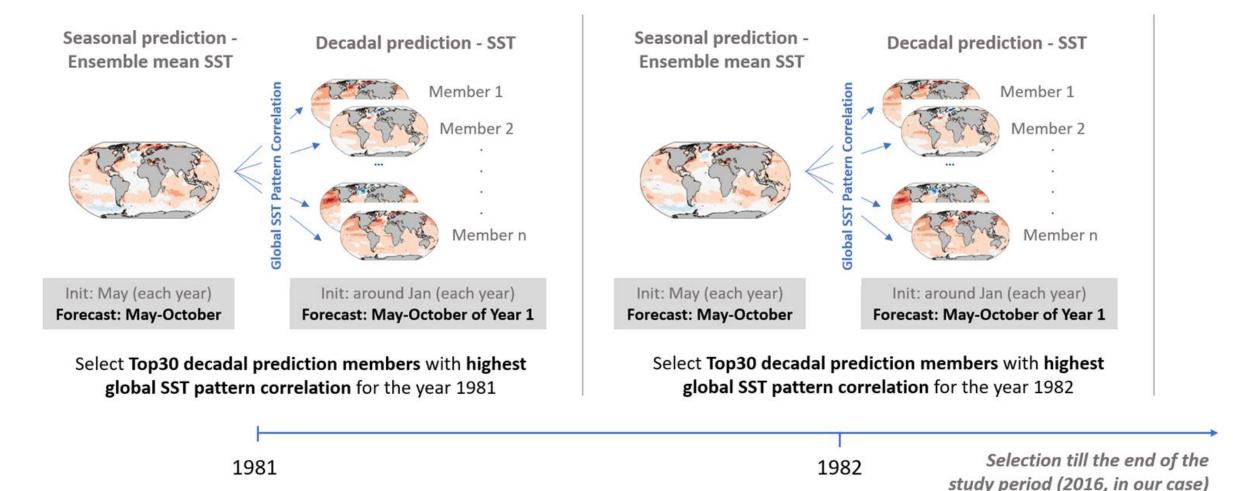
### **Near-term seamless climate information**

Skill of 20-year projections using five constraining methods over the period 1970-2000

- Heterogeneity between methods
- It's fundamental to evaluate the constraining methods before claiming improvements in regional climate projections



## Merging seasonal and decadal predictions

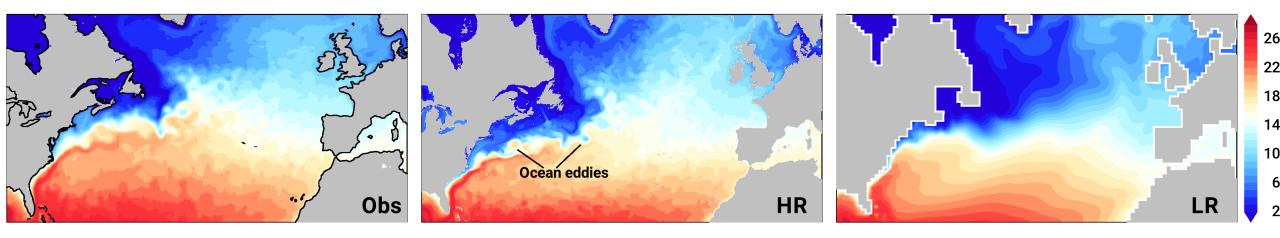


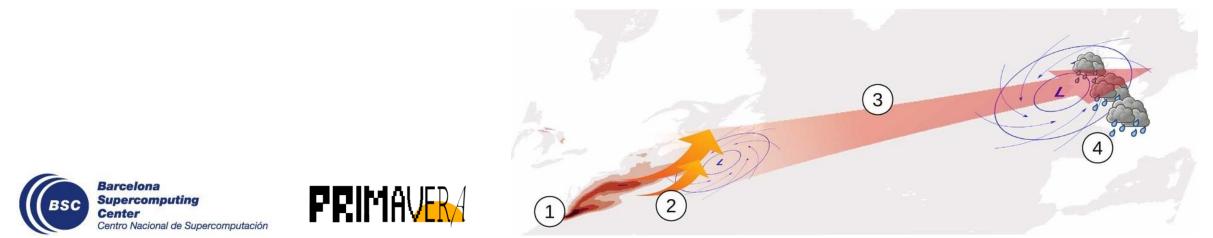


Solaraju Murali (BSC)

### New generation of climate models: resolution

Eddy-rich, storm-resolving models (10-km or higher resolution) simulate a decrease in SST biases over the North Atlantic (right) and a northward shift in the Gulf Stream over the XXI Century that leads to rainfall increases in Europe (left), not found with traditional low-resolution models.



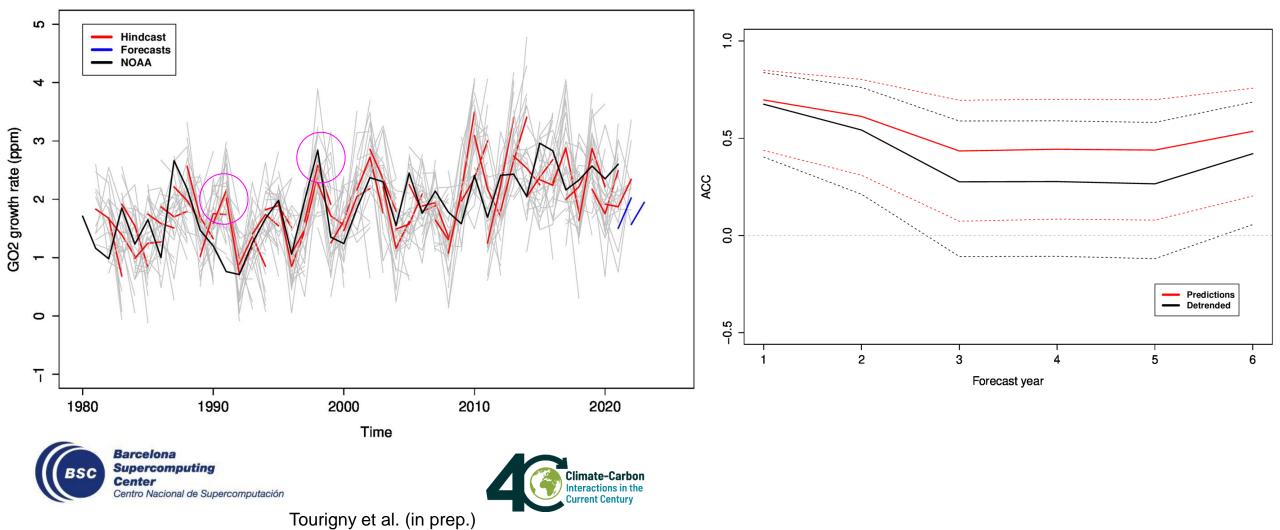


Moreno-Chamarro et al. (2021, ERL)

### **Carbon cycle predictions**

Global atmospheric CO2 growth rate predictions from EC-Earth3-CC. Initial conditions are obtained from off-line simulations.

There is skill up to two years. It then decreases mainly due to the land-atmosphere flux.



# What gives the chill: Lack of interactivity, emergence of AI-based solutions



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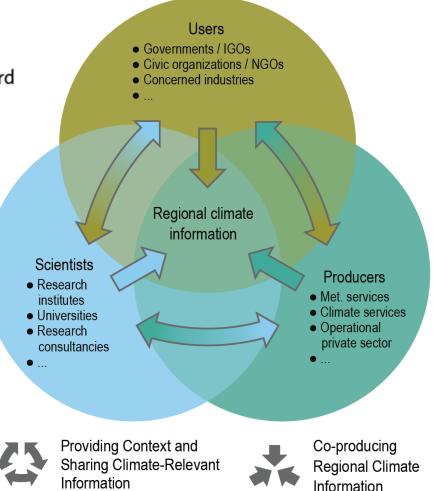
### Actors and values in climate information

### The value of values in climate science

To date, values are not widely acknowledged or discussed within physical climate science. Yet, effective management of values in physical climate science is required for the benefit of both science and society.

Karoliina Pulkkinen, Sabine Undorf, Frida Bender, Per Wikman-Svahn, Francisco Doblas-Reyes, Clare Flynn, Gabriele C. Hegerl, Aiden Jönsson, Gah-Kai Leung, Joe Roussos, Theodore G. Shepherd and Erica Thompson

> This can only work if the user is offered true interactivity with the data sources.

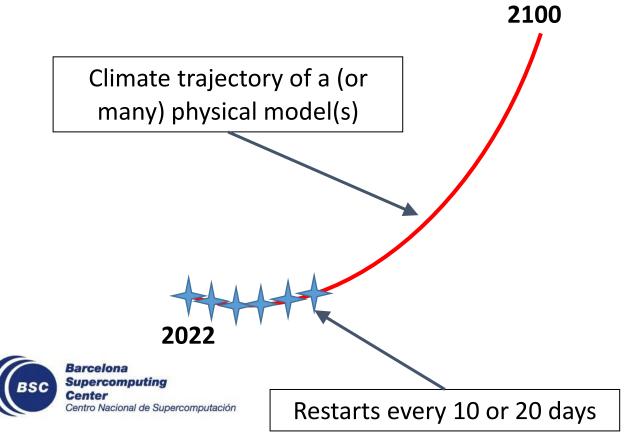




AR6 WGI Figure 10.2

### **Tethering: A necessary condition for interactivity**

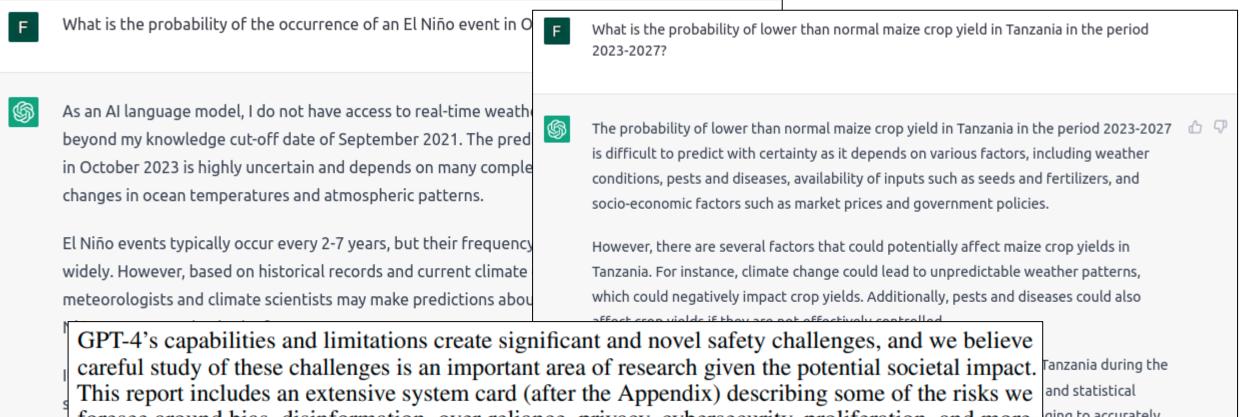
One of the ML-based weather forecast models (e.g., FourCastNet) could be trained on the trajectories of a (preferably several) process-based climate model (with high-frequency output). The tethering concept allows, using the climate model restarts, to recreate almost instantly (in inference mode as an interpolation between restarts) the model output requested by any user leading for true interactivity.



- The ML-based model can provide downscaled (super-resolution), targeted (user indicators), and bias adjusted data with large ensembles (if uncertainty handling is trustworthy).
- The physical model is a guarantee that there is a possibility to generate wildcards, i.e., unprecedented events plausible in a changing climate.

## **User interface to climate information**

### How long before a generative chatbot will be trained with the latest forecast information?



foresee around bias, disinformation, over-reliance, privacy, cybersecurity, proliferation, and more. ging to accurately It also describes interventions we made to mitigate potential harms from the deployment of GPT-4, ce them. including adversarial testing with domain experts, and a model-assisted safety pipeline.

countries are



particularly vulnerable to crop failure and food insecurity, and efforts to support sustainable agricultural practices and increase resilience to climate change are essential to ensure food security and livelihoods.

## A collection of thoughts

Understanding the title:

- the bone and the marrow as a set of key elements for life
- chill to the marrow/to the bone

What we can do

- with what we have
- with what climate change colleagues are doing
- with what other domains are doing







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