Assessment of Noah-MP Land Surface Model for parameterization schemes selection across the Iberian Peninsula

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Introduction: Importance of soil parameterization

Bellucci et al. (2015):

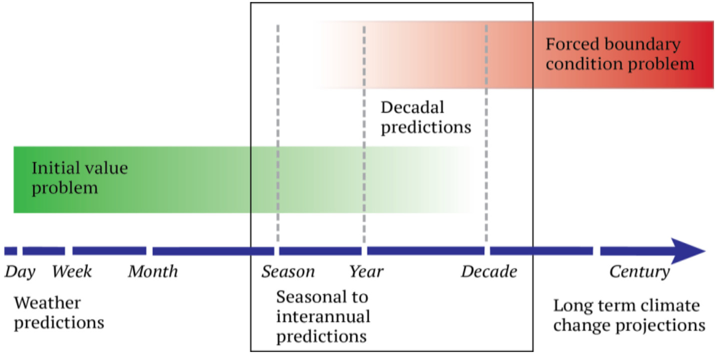
- Transitional climate zones with strong land-atmosphere coupling.

Breil et al. (2019):

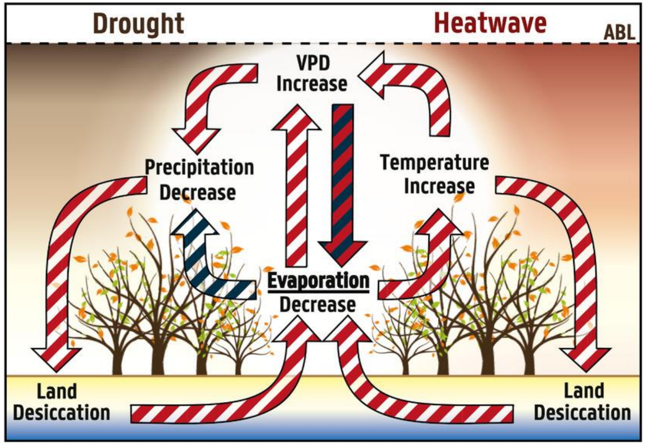
- Improves the predictive capacity of climate models on a decadal scale.

Miralles et al. (2014):

- Feedback mechanisms: extremes and effects of climate change (prediction of droughts and heat waves).



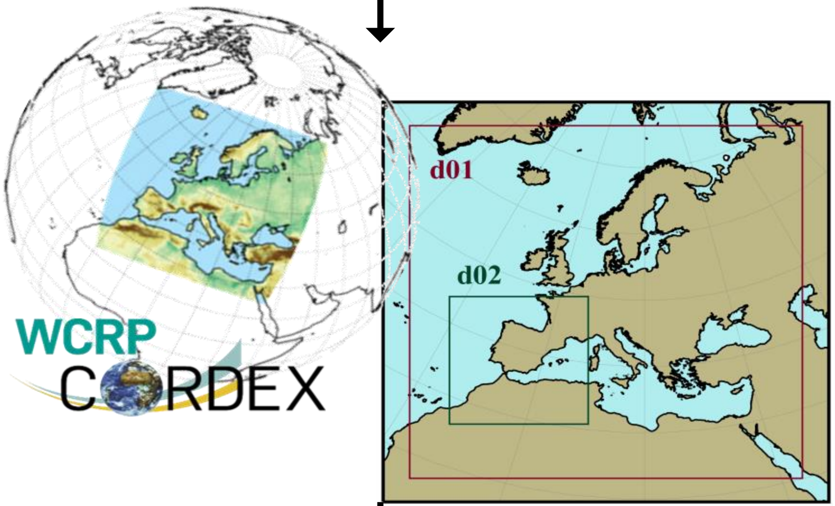
Kirtman, B., et al. (2013)



Miralles, D., et al. (2019)

Data and methodology: WRF model configuration

ERA5



TASMAX: temperatura máxima

TASMIN: temperatura mínima

PR: precipitación

- Nested domains:
  - d01: EUROCORDEX, ~50Km
  - d02: Iberian Peninsula ~10Km
- Parameterization schemes (Argüeso et al., 2011; García-Valdecasas Ojeda et al., 2017, 2020):
  - Microphysics: WSM3C
  - Cumulus clouds: BMJ
  - Short/long wave radiation: CAM 3
  - Surface layer physics: MM5 similarity.
  - Planetary boundary layer: ACM2
- 30 years of spin up (Hu et al., 2023)

Data and methodology: Noah-MP and choice of experiments

Variable physical meaning/definition	New name	Original name
Namelist		
options for dynamic vegetation	OptDynamicVeg	OPT_DVEG
options for canopy stomatal resistance	OptStomataResistance	OPT_CRS
options for soil moisture factor for stomatal resistance	OptSoilWaterTranspiration	OPT_BTR
options for surface runoff	OptRunoffSurface	OPT_RUNSRF
options for subsurface runoff	OptRunoffSubsurface	OPT_RUNSUB
options for surface layer drag coeff	OptSurfaceDrag	OPT_SFC
options for supercooled liquid water (or ice fraction)	OptSoilSupercoolWater	OPT_FRZ
options for frozen soil permeability	OptSoilPermeabilityFrozen	OPT_INF
options for canopy radiation transfer	OptCanopyRadiationTransfer	OPT_RAD
options for ground snow surface albedo	OptSnowAlbedo	OPT_ALB
options for partitioning precipitation into rainfall & snowfall	OptRainSnowPartition	OPT_SNF
options for lower boundary condition of soil temperature	OptSoilTemperatureBottom	OPT_TBOT
options for snow/soil temperature time scheme (only layer 1)	OptSnowSoilTempTime	OPT_STC
options for surface resistent to evaporation/sublimation	OptGroundResistanceEvap	OPT_RSF

Default →

Common references and basic combinations

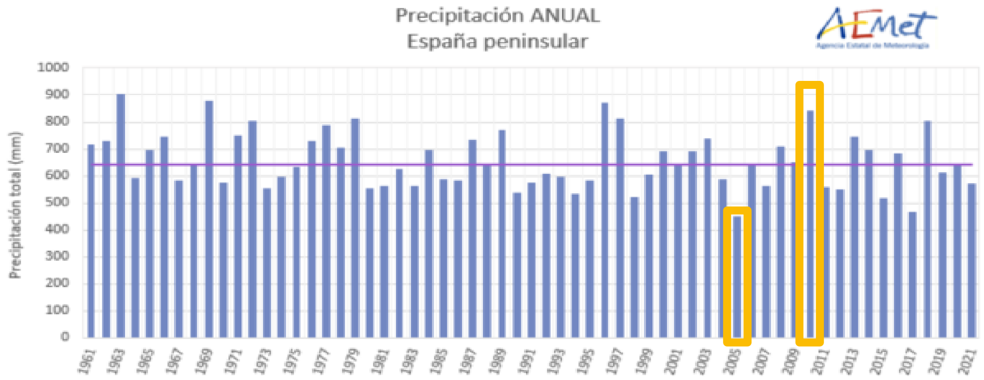
Exp	dveg	crs	sfc	btr	run	frz	inf	rad	alb	tbot	stc	rsf
0	4	1	1	1	3	1	1	3	2	2	1	1
1	2	1	1	1	1	1	1	1	1	1	1	1
2	3	1	1	1	1	1	1	1	1	1	1	1
3	2	2	1	1	1	1	1	1	1	1	1	1
4	2	1	1	2	1	1	1	1	1	1	1	1
5	2	1	2	1	1	1	1	1	1	1	1	1
6	2	1	1	1	1	1	1	2	1	1	1	1
7	2	1	1	1	1	1	1	3	1	1	1	1
8	2	1	1	1	1	1	1	1	2	1	1	1
9	2	1	1	1	4	1	1	1	1	1	1	1
10	2	1	1	1	1	2	1	1	1	1	1	1
11	2	1	1	3	1	1	1	1	1	1	1	1

Data and methodology: Noah-MP and choice of experiments

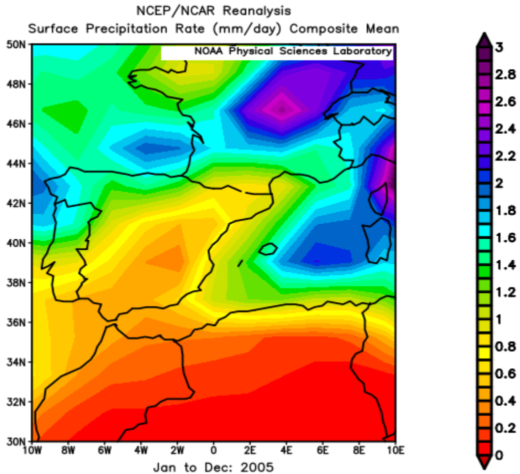
Variable physical meaning/definition	New name	Original name
Namelist		
options for dynamic vegetation	OptDynamicVeg	OPT_DVEG
options for canopy stomatal resistance	OptStomataResistance	OPT_CRS
options for soil moisture factor for stomatal resistance	OptSoilWaterTranspiration	OPT_BTR
options for surface runoff	OptRunoffSurface	OPT_RUNSRF
options for subsurface runoff	OptRunoffSubsurface	OPT_RUNSUB
options for surface layer drag coeff	OptSurfaceDrag	OPT_SFC
options for supercooled liquid water (or ice fraction)	OptSoilSupercoolWater	OPT_FRZ
options for frozen soil permeability	OptSoilPermeabilityFrozen	OPT_INF
options for canopy radiation transfer	OptCanopyRadiationTransfer	OPT_RAD
options for ground snow surface albedo	OptSnowAlbedo	OPT_ALB
options for partitioning precipitation into rainfall & snowfall	OptRainSnowPartition	OPT_SNF
options for lower boundary condition of soil temperature	OptSoilTemperatureBottom	OPT_TBOT
options for snow/soil temperature time scheme (only layer 1)	OptSnowSoilTempTime	OPT_STC
options for surface resistent to evaporation/sublimation	OptGroundResistanceEvap	OPT_RSF

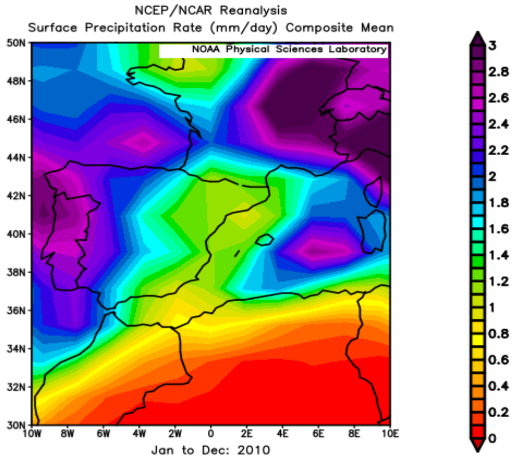
Dry scenario	12	5	1	1	1	1	1	1	1	1	1	1	1
	13	5	1	1	1	1	1	1	1	1	1	1	3
	14	5	1	1	2	1	1	2	1	1	1	1	1
	15	5	1	1	2	1	1	2	1	1	1	1	3
	16	5	1	1	2	4	1	2	1	1	1	1	3
	17	5	2	1	2	4	2	2	1	1	1	1	3
Wet scenario	18	2	1	2	1	1	1	1	2	2	2	1	1
	19	2	1	1	2	1	1	1	1	1	2	1	1
	20	2	1	1	3	1	1	1	1	2	1	1	1
	21	2	1	1	3	1	1	1	3	2	1	1	1
	22	2	1	1	3	1	1	1	3	2	2	1	1
	23	5	1	1	2	1	1	1	3	2	2	1	1
	24	1	1	1	1	1	1	1	1	1	1	1	1
	25	2	1	1	3	3	1	1	3	2	2	1	1
	26	2	1	1	3	3	1	1	3	2	1	1	1
	27	2	1	1	3	3	1	1	1	2	1	1	1
Combination	28	5	2	1	3	1	2	1	3	2	1	1	1

Data and methodology: Year selection



Annual accumulated precipitation in peninsular Spain.
Source: AEMET





Precipitation rate (mm/day) for 2005 (left) and for 2010 (right).
Data: NCEP/NCAR 40-year reanalysis (Kalnay et al. 1996)

Data and methodology: Selection of parameterization schemes

Sensitivity

Evaluation Metrics: Chang, M. et al. (2019)

Statistical formulae used for the analyses of the option combinations.

Statistical Metrics	Equation[1]
Mean Bias Error(MBE)	$\frac{\sum_{i=1}^{n}(M_i - O_i)}{n}$
Standard Deviation(SD)	$\left\lvert 1 - \frac{\sqrt{\frac{\sum_{i=1}^{n}(M_i - \overline{M})^2}{n-1}}}{\sqrt{\frac{\sum_{i=1}^{n}(O_i - \overline{O})^2}{n-1}}} \right\rvert$
Correlation Coefficient(COR)	$\frac{n\sum_{i=1}^{n}(O_i M_i) - (\sum_{i=1}^{n} O_i \sum_{i=1}^{n} M_i)}{\sqrt{[n\sum_{i=1}^{n} O_i^2 - (\sum_{i=1}^{n} O_i)^2][n\sum_{i=1}^{n} M_i^2 - (\sum_{i=1}^{n} M_i)^2]}}$
Normalized Mean Error(NME)	$\frac{\sum_{i=1}^{n} \lvert M_i - O_i \rvert}{\sum_{i=1}^{n} \lvert \overline{O} - O_i \rvert}$
5% Statistical Measure[2] (%5)	$\lvert M_5 - O_5 \rvert$
95% Statistical Measure[2] (%95)	$\lvert M_{95} - O_{95} \rvert$

[1] M represents the model values and O the observed values.

[2] M_5, O_5: value at 5% of distribution of M, O respectively, M_{95}, O_{95}: value at 95% of distribution of M, O respectively.

↓

Ranking

Spatial analysis

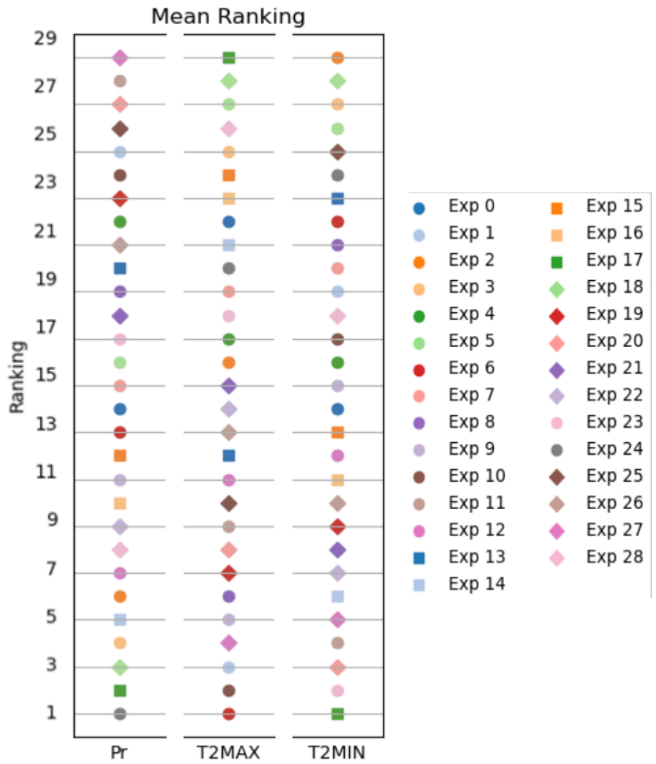
Application of the Student t Test with α = 0.05 between the WRF and AEMET experiments

$$\text{Prueba T de Muestras Independientes} = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{s^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

donde

$$s^2 = \frac{\sum_{i=1}^{n_1}(x_i - \overline{x}_1)^2 + \sum_{j=1}^{n_2}(x_j - \overline{x}_2)^2}{n_1 + n_2 - 2}$$

Results: sensitivity



Ranking for pr, Tmin and Tmax taking into account the correlation, standard deviation, MBE, NME, p5 and p95 with respect to AEMET

Proposed experiments

Default → (Exp 0)

Common references and basic combinations (Exp 1–11)

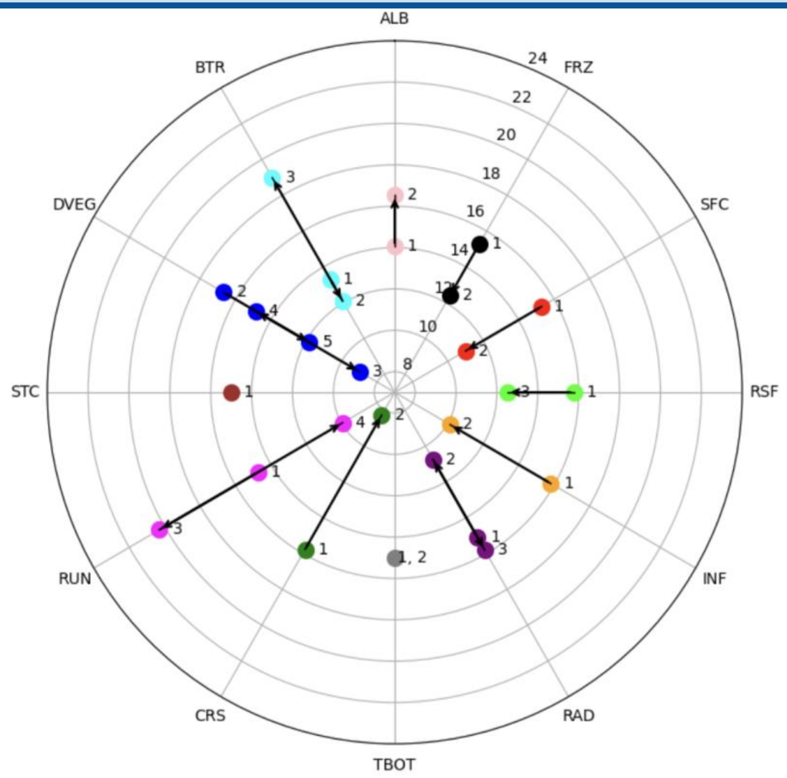
Dry scenario (Exp 12–17)

Wet scenario (Exp 18–27)

Combination → (Exp 28)

Exp	dveg	crs	sfc	btr	run	frz	inf	rad	alb	tbot	stc	rsf
0	4	1	1	1	3	1	1	3	2	2	1	1
1	2	1	1	1	1	1	1	1	1	1	1	1
2	3	1	1	1	1	1	1	1	1	1	1	1
3	2	2	1	1	1	1	1	1	1	1	1	1
4	2	1	1	2	1	1	1	1	1	1	1	1
5	2	1	2	1	1	1	1	1	1	1	1	1
6	2	1	1	1	1	1	1	2	1	1	1	1
7	2	1	1	1	1	1	1	3	1	1	1	1
8	2	1	1	1	1	1	1	1	2	1	1	1
9	2	1	1	1	4	1	1	1	1	1	1	1
10	2	1	1	1	1	2	1	1	1	1	1	1
11	2	1	1	3	1	1	1	1	1	1	1	1
12	5	1	1	1	1	1	1	1	1	1	1	1
13	5	1	1	1	1	1	1	1	1	1	1	3
14	5	1	1	2	1	1	2	1	1	1	1	1
15	5	1	1	2	1	1	2	1	1	1	1	3
16	5	1	1	2	4	1	2	1	1	1	1	3
17	5	2	1	2	4	2	2	1	1	1	1	3
18	2	1	2	1	1	1	1	2	2	2	1	1
19	2	1	1	2	1	1	1	1	1	2	1	1
20	2	1	1	3	1	1	1	1	2	1	1	1
21	2	1	1	3	1	1	1	3	2	1	1	1
22	2	1	1	3	1	1	1	3	2	2	1	1
23	5	1	1	2	1	1	1	3	2	2	1	1
24	1	1	1	1	1	1	1	1	1	1	1	1
25	2	1	1	3	3	1	1	3	2	2	1	1
26	2	1	1	3	3	1	1	3	2	1	1	1
27	2	1	1	3	3	1	1	1	2	1	1	1
28	5	2	1	3	1	2	1	3	2	1	1	1

Results: Precipitation sensitivity

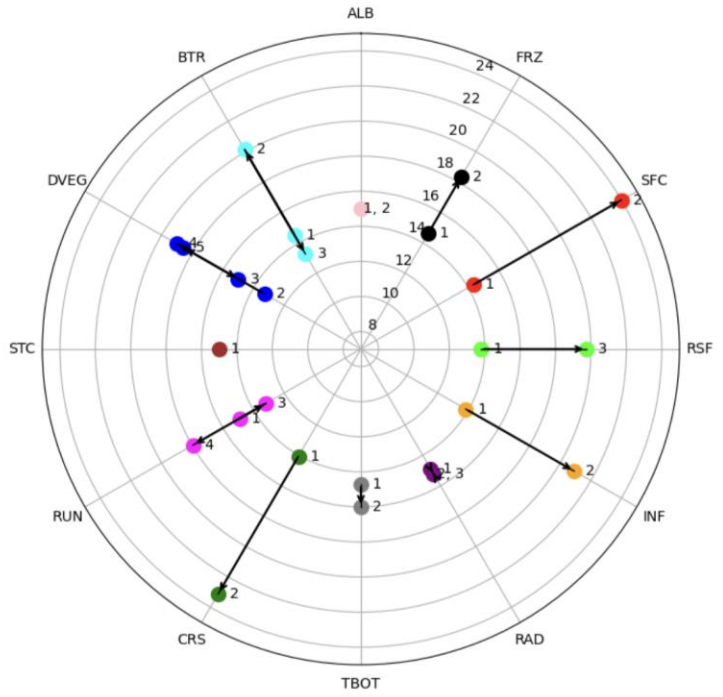


Sensitivity analysis based on the ranking of experiments of the different parameters of the Noah-MP configuration for precipitation

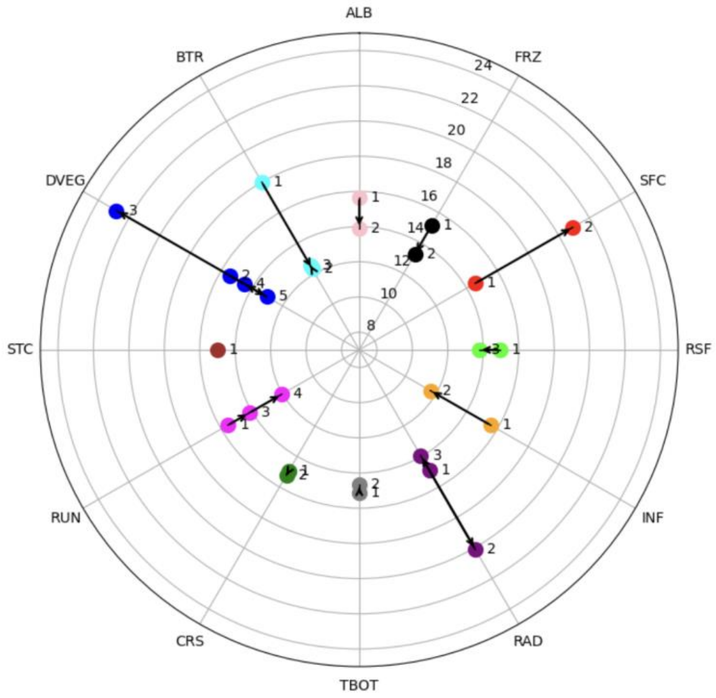
Exp	dveg	crs	sfc	btr	run	frz	inf	rad	alb	tbot	stc	rsf
0	4	1	1	1	3	1	1	3	2	2	1	1
1	2	1	1	1	1	1	1	1	1	1	1	1
2	3	1	1	1	1	1	1	1	1	1	1	1
3	2	2	1	1	1	1	1	1	1	1	1	1
4	2	1	1	2	1	1	1	1	1	1	1	1
5	2	1	2	1	1	1	1	1	1	1	1	1
6	2	1	1	1	1	1	1	2	1	1	1	1
7	2	1	1	1	1	1	1	3	1	1	1	1
8	2	1	1	1	1	1	1	1	2	1	1	1
9	2	1	1	1	4	1	1	1	1	1	1	1
10	2	1	1	1	1	2	1	1	1	1	1	1
11	2	1	1	3	1	1	1	1	1	1	1	1
12	5	1	1	1	1	1	1	1	1	1	1	1
13	5	1	1	1	1	1	1	1	1	1	1	3
14	5	1	1	2	1	1	2	1	1	1	1	1
15	5	1	1	2	1	1	2	1	1	1	1	3
16	5	1	1	2	4	1	2	1	1	1	1	3
17	5	2	1	2	4	2	2	1	1	1	1	3
18	2	1	2	1	1	1	1	2	2	2	1	1
19	2	1	1	2	1	1	1	1	1	2	1	1
20	2	1	1	3	1	1	1	1	2	1	1	1
21	2	1	1	3	1	1	1	3	2	1	1	1
22	2	1	1	3	1	1	1	3	2	2	1	1
23	5	1	1	2	1	1	1	3	2	2	1	1
24	1	1	1	1	1	1	1	1	1	1	1	1
25	2	1	1	3	3	1	1	3	2	2	1	1
26	2	1	1	3	3	1	1	3	2	1	1	1
27	2	1	1	3	3	1	1	1	2	1	1	1
28	5	2	1	3	1	2	1	3	2	1	1	1

Results: Maximum and minimum temperature sensitivity

T. max

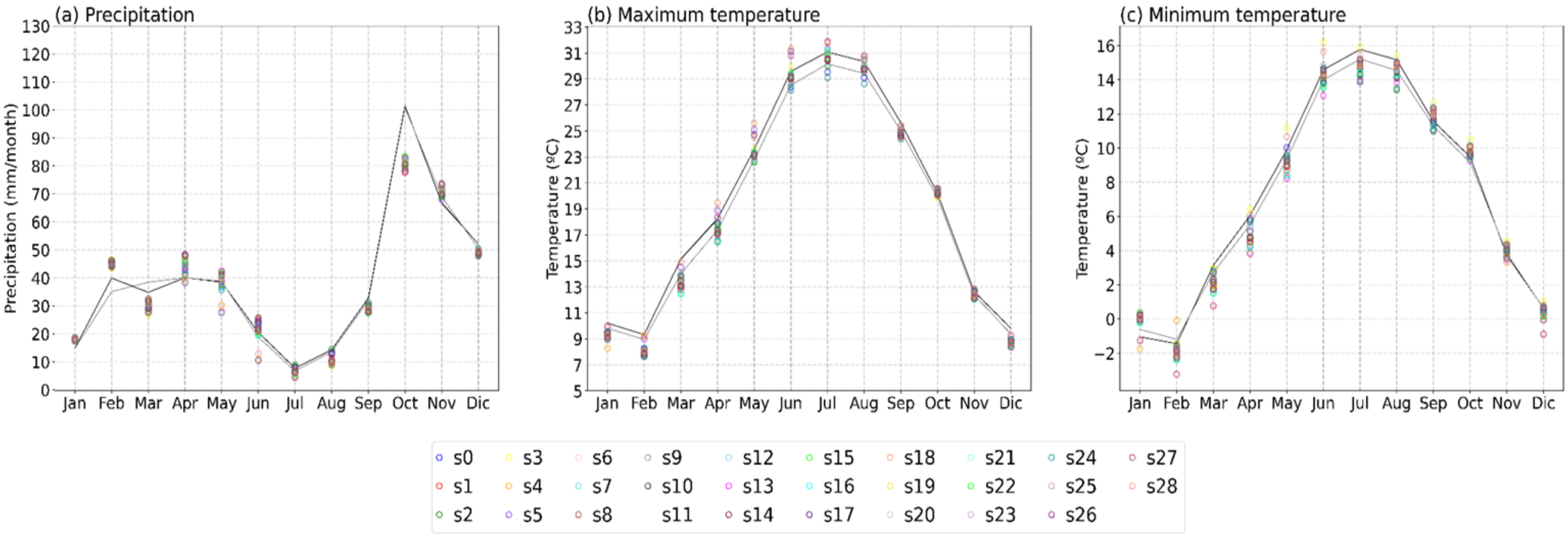


T. min



Sensitivity analysis based on the ranking of experiments of the different parameters of the Noah-MP configuration for maximum temperature and minimum temperature.

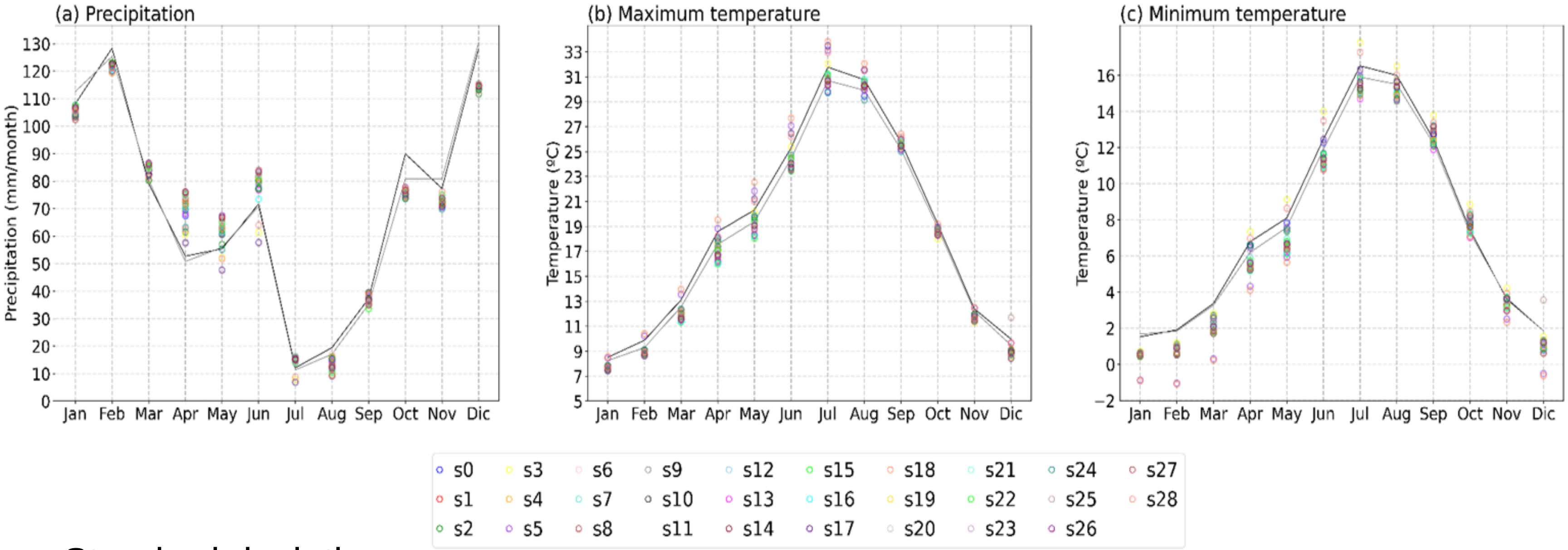
Results: Annual cycle - 2005



Standard deviations:

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
pr	0.14	1.31	2.00	14.60	2.79	3.19	1.40	0.86	2.17	1.01	0.94	2.84	0.29	0.68	3.77	2.75	4.52	14.16	3.01	1.96	1.55	3.68	4.42	2.47	1.14	1.74	2.21	1.00	12.30
tmax	0.76	0.66	0.69	0.75	0.73	0.08	0.68	0.68	0.67	0.63	0.67	0.81	0.79	0.87	0.75	0.90	0.84	0.27	0.40	0.76	0.80	0.74	0.75	0.64	0.88	0.83	0.80	0.87	0.11
tmin	0.07	0.43	0.34	0.69	0.28	0.86	0.53	0.13	0.43	0.42	0.45	0.38	0.47	0.85	0.41	0.78	0.77	0.36	0.96	0.33	0.38	0.04	0.06	0.06	0.36	0.09	0.07	0.41	0.32

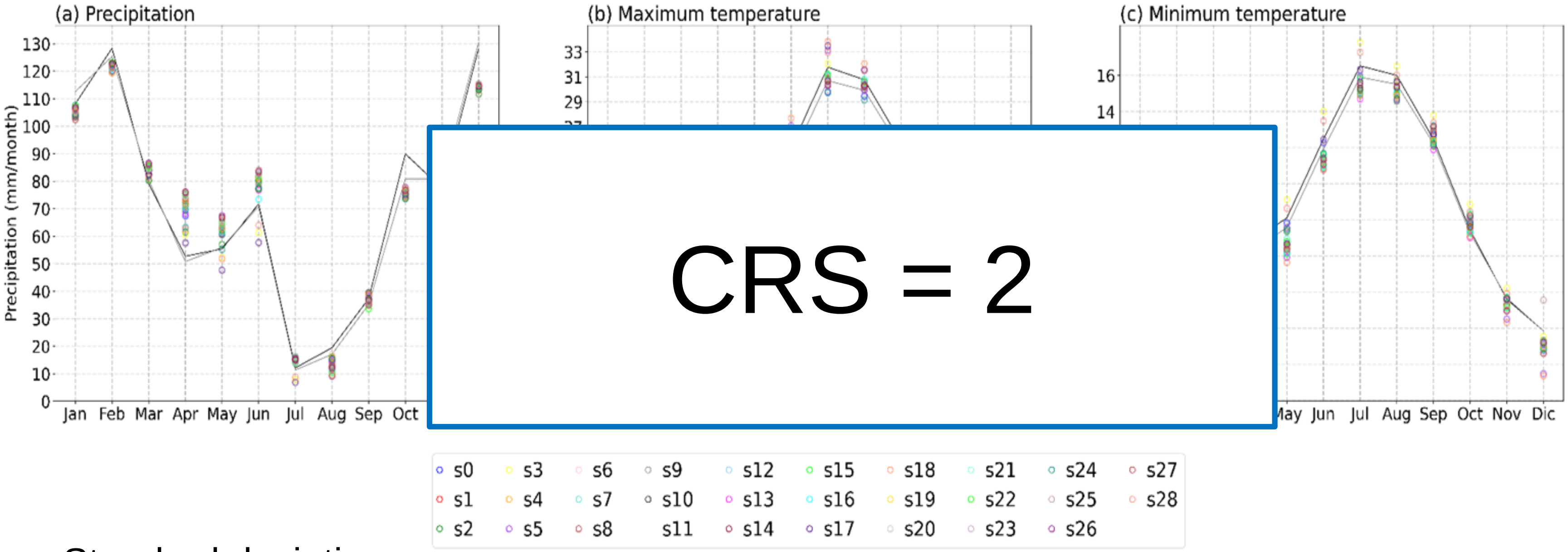
Results: Annual cycle - 2010



Standard deviations:

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
pr	1.88	3.34	0.21	11.46	0.54	2.06	3.01	2.38	2.09	2.11	3.44	1.66	1.83	1.90	0.38	0.43	1.19	12.98	0.77	3.34	1.55	1.06	0.04	0.28	1.41	3.14	2.50	3.89	9.40
tmax	1.00	0.78	0.73	0.70	0.82	0.51	0.78	0.74	0.77	0.66	0.78	0.91	1.09	1.26	1.08	1.20	1.09	0.19	0.90	0.78	0.91	0.83	0.83	0.93	0.93	0.80	1.02	1.11	0.15
tmin	0.35	0.95	0.63	0.50	0.81	1.67	1.04	0.62	0.94	0.90	0.96	0.89	0.94	1.23	0.87	1.13	1.09	0.38	1.87	0.95	0.88	0.52	0.53	0.39	0.62	0.42	0.61	0.99	0.14

Results: Annual cycle - 2010



CRS = 2

Standard deviations:

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
pr	1.88	3.34	0.21	11.46	0.54	2.06	3.01	2.38	2.09	2.11	3.44	1.66	1.83	1.90	0.38	0.43	1.19	12.98	0.77	3.34	1.55	1.06	0.04	0.28	1.41	3.14	2.50	3.89	9.40
tmax	1.00	0.78	0.73	0.70	0.82	0.51	0.78	0.74	0.77	0.66	0.78	0.91	1.09	1.26	1.08	1.20	1.09	0.19	0.90	0.78	0.91	0.83	0.83	0.93	0.93	0.80	1.02	1.11	0.15
tmin	0.35	0.95	0.63	0.50	0.81	1.67	1.04	0.62	0.94	0.90	0.96	0.89	0.94	1.23	0.87	1.13	1.09	0.38	1.87	0.95	0.88	0.52	0.53	0.39	0.62	0.42	0.61	0.99	0.14

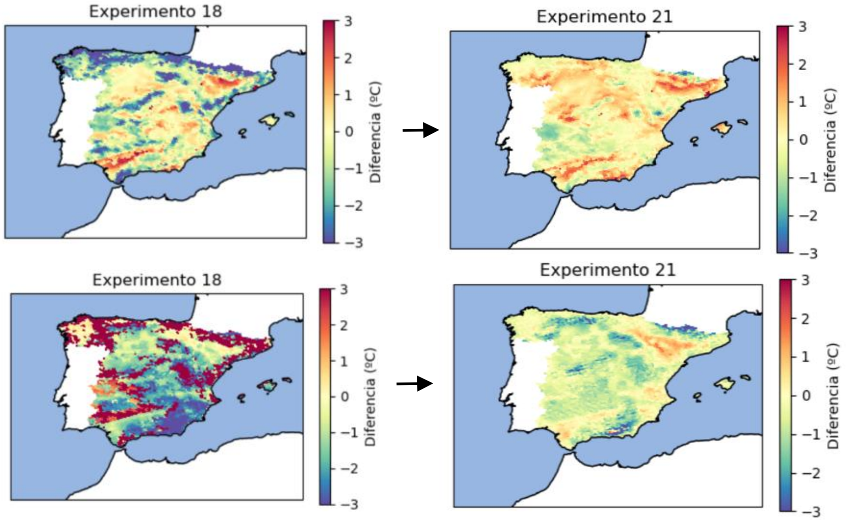
Results: Spatial and temporal analysis

OptSurfaceDrag options for surface layer drag/exchange coefficient	1*	Monin-Obukhov (M-O) Similarity Theory (Brutsaert, 1982)
	2	original Noah (Chen et al. 1997)

Temperatures: big improvement over Noah-LSM

T. min:

T. max:



Annual average differences (Model - AEMET)

Exp	dveg	crs	sfc	btr	run	frz	inf	rad	alb	tbot	stc	rsf
0	4	1	1	1	3	1	1	3	2	2	1	1
1	2	1	1	1	1	1	1	1	1	1	1	1
2	3	1	1	1	1	1	1	1	1	1	1	1
3	2	2	1	1	1	1	1	1	1	1	1	1
4	2	1	1	2	1	1	1	1	1	1	1	1
5	2	1	2	1	1	1	1	1	1	1	1	1
6	2	1	1	1	1	1	1	2	1	1	1	1
7	2	1	1	1	1	1	1	3	1	1	1	1
8	2	1	1	1	1	1	1	1	2	1	1	1
9	2	1	1	1	4	1	1	1	1	1	1	1
10	2	1	1	1	1	2	1	1	1	1	1	1
11	2	1	1	3	1	1	1	1	1	1	1	1
12	5	1	1	1	1	1	1	1	1	1	1	1
13	5	1	1	1	1	1	1	1	1	1	1	3
14	5	1	1	2	1	1	2	1	1	1	1	1
15	5	1	1	2	1	1	2	1	1	1	1	3
16	5	1	1	2	4	1	2	1	1	1	1	3
17	5	2	1	2	4	2	2	1	1	1	1	3
18	2	1	2	1	1	1	1	2	2	2	1	1
19	2	1	1	2	1	1	1	1	1	2	1	1
20	2	1	1	3	1	1	1	1	2	1	1	1
21	2	1	1	3	1	1	1	3	2	1	1	1
22	2	1	1	3	1	1	1	3	2	2	1	1
23	5	1	1	2	1	1	1	3	2	2	1	1
24	1	1	1	1	1	1	1	1	1	1	1	1
25	2	1	1	3	3	1	1	3	2	2	1	1
26	2	1	1	3	3	1	1	3	2	1	1	1
27	2	1	1	3	3	1	1	1	2	1	1	1
28	5	2	1	3	1	2	1	3	2	1	1	1

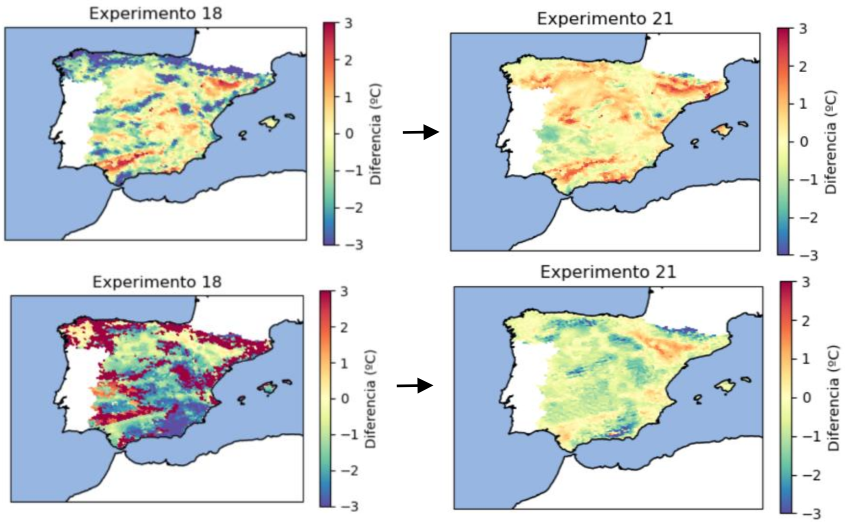
Results: Spatial and temporal analysis

OptSurfaceDrag options for surface layer drag/exchange coefficient	1*	Monin-Obukhov (M-O) Similarity Theory (Brutsaert, 1982)
	2	original Noah (Chen et al. 1997)

Temperatures: big improvement over Noah-LSM

T. min:

T. max:



Annual average differences (Model - AEMET)

Percentage of area with non-significant differences

Experiment	T2MAX		T2MIN	
	2005	2010	2005	2010
0	83,48	76,60	78,39	80,71
1	86,92	85,98	80,73	54,28
2	86,94	87,53	78,76	69,62
3	83,85	89,11	52,33	66,04
4	87,12	84,98	82,71	63,60
5	27,96	45,80	58,60	30,74
6	85,94	85,60	78,62	48,73
7	86,86	87,73	79,94	70,80
8	86,75	86,14	80,63	54,95
9	87,45	89,81	80,81	57,64
10	87,10	86,18	80,43	53,73
11	85,80	82,05	82,85	58,88
12	77,40	69,32	79,74	55,89
13	81,22	60,88	63,30	38,45
14	80,59	71,01	80,57	59,61
15	77,46	65,35	67,51	44,11
16	78,43	71,31	68,04	45,88
17	90,97	95,50	76,95	78,96
18	27,96	49,18	56,30	23,26
19	86,43	85,98	82,54	54,28
20	86,04	82,24	83,17	58,80
21	86,45	85,19	81,08	76,87
22	85,94	85,37	80,81	76,85
23	83,60	78,70	79,71	81,59
24	78,58	79,59	78,86	70,93
25	84,05	85,19	81,83	77,38
26	84,70	76,54	81,81	73,55
27	83,46	71,76	82,50	52,15
28	89,83	94,59	68,71	81,91

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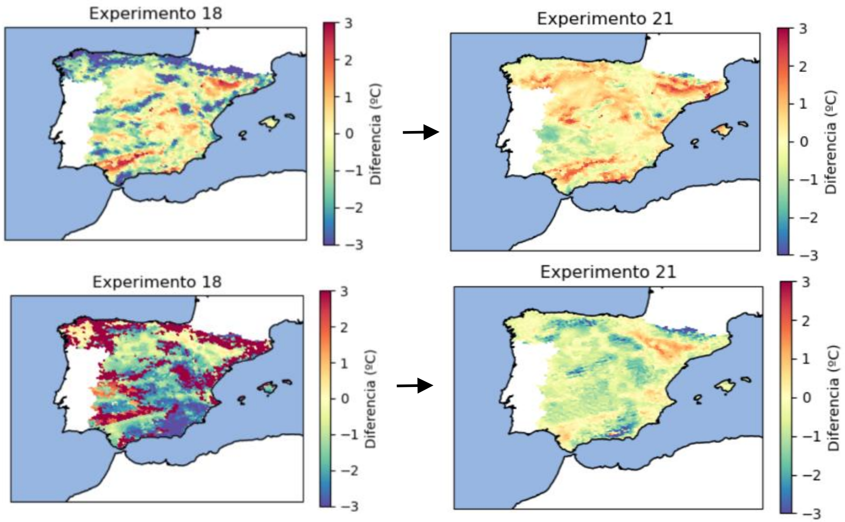

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Conclusions

- Exp 5 and Exp18 (options for surface layer drag/exchange coefficient)
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  - Options for canopy stomatal resistance: Ball-Berry scheme < Jarvis scheme

	dveg	crs	sfc	btr	run	frz	inf	rad	alb	tbot	stc	rsf
16	5	1	1	2	4	1	2	1	1	1	1	3
17	5	2	1	2	4	2	2	1	1	1	1	3

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- Exp 22 < Exp 21: (options for soil temperature lower limit conditions)
  zero heat flux from bottom > TemperatureSoilBottom read from a file (original Noah)
- Exp 25 ~ Exp 22 (Runoff and Groundwater Option): No improvement from original

	dveg	crs	sfc	btr	run	frz	inf	rad	alb	tbot	stc	rsf
20	2	1	1	3	1	1	1	1	2	1	1	1
21	2	1	1	3	1	1	1	3	2	1	1	1
22	2	1	1	3	1	1	1	3	2	2	1	1
25	2	1	1	3	3	1	1	3	2	2	1	1

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25	2	1	1	3	3	1	1	3	2	2	1	1

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