



Supplement of

Calibrating the GAMIL3-1° climate model using a derivative-free optimization method

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1 **Supplementary S1: The DFO-LS algorithm settings**

```
2 "dfols":{
3   "sigma": true,
4   "sigma_comment": "If True use constraint weights",
5   "μ": 0.01,
6   "μ_comment": "The inverse weighting given to the constraint -- it
7   gets wt 1/(2μ). If Null then no constraint should be applied",
8   "growing.ndirs_initial": null,
9   "growing.ndirs_initial_comment": "the number of perturbations on
10  first iteration. If not specified then will make Nparm perturbbtions",
11  "rhobeg": 0.18,
12  "rhobeg_comment": "Radius of parameter trust region at start",
13  "rhoend": 0.1,
14  "rhoend_comment": "Radius of parameter trust region for termination
15  (for our purpose this is in normalised parameters)",
16  "maxfun": 50,
17  "maxfun_comment": "Maximum number of model evaluations to be done.
18  Default is 0(1000). reduced to 50 so have data to do a mid-point look
19  at ",
20  "scaling_within_bounds": true,
21  "scaling_within_bounds_comment": "Scale internally so all in range 0
22  to 1",
23  "raise_error":null,
24  "raise_error_comment":"If True then allow optimise function to raise
25  error rather than DFOLS. Default is false",
26  "trap_two_evals":true,
27  "trap_two_evals_comment":"If true then if dfols generates two
28  evaluations (which is should not) then the last one will be ignored.
29  Default value is False.",
30  "namedSettings": {
31    "logging.save_poisedness": true,
32    "logging.save_poisedness_comment": "whether or not to calculate
33    geometry statistics as part of diagnostic information",
34    "init.random_initial_directions": false,
35    "init.random_initial_directions_comment": "If true perturb in
36    random directions. If false perturb along co-ordinate axis. Set false
37    when provisional running on.",
38    "init.run_in_parallel": false,
39    "init.run_in_parallel_comment": "Run initial cases in parallel.
40    Set false when provisional running",
41    "noise.additive_noise_level": 21.0,
42    "noise.additive_noise_level_comment": "Estimate of noise in cost
43    function. Used in termination -- nb cost fn is sum of squares **not**
```

```

44 sum of squares/nObs. ",
45     "logging.save_diagnostic_info": true,
46     "logging.save_diagnostic_info_comment": "Save logging info",
47     "logging.save_xk": true,
48     "logging.save_xk_comment": "Save the full vector of trial values
49 ",
50     "noise.quit_on_noise_level": true,
51     "noise.quit_on_noise_level_comment": "quit/restart if all trial
52 evaluations are within noise level of last iteration",
53     "general.check_objfun_for_overflow": false,
54     "general.check_objfun_for_overflow_comment": "Presumably check
55 that function behaves itself",
56     "slow.history_for_slow": 2,
57     "slow.history_for_slow_comment": "No of past successful
58 iterations to look at to decide if slow or not",
59     "slow.thresh_for_slow": 0.1,
60     "slow.thresh_for_slow_comment": "Log cost function change for
61 slow convergence",
62     "slow.max_slow_iters": 5,
63     "slow.max_slow_iters_comment": "The number of iterations (once
64 slow determined) to decide making slow progress",
65     "restarts.use_restarts": true,
66     "restarts.use_restarts_comment": "Restart when slow convergence
67 or too noisy. ",
68     "restarts.use_soft_restarts": true,
69     "restarts.use_soft_restarts_comment": "Use soft restart -- reuse
70 some existing points when restarting",
71     "restarts.soft.num_geom_steps": 3,
72     "restarts.soft.num_geom_steps_comment": "How many extra runs to
73 be done when restarting",
74     "restarts.increase_npt": false,
75     "restarts.increase_npt_comment": "Increase number of points when
76 restarting",
77     "restarts.increase_npt_amt_comment": "Number of points to
78 increase by in restarts.increase_npt set when restarting",
79     "restarts.max_unsuccessful_restarts": 100,
80     "restarts.max_unsuccessful_restarts_comment": "Number of
81 consecutive restarts allowed when no progress made",
82     "restarts.hard.increase_ndirs_initial_amt": 1,
83     "restarts.hard.increase_ndirs_initial_amt_comment": "How many
84 points to increase by when doing hard restart (not using any
85 existing pts)",
86     "restarts.max_npt": null,
87     "restarts.max_npt_comment": "Maximum number of points/model evals

```

```

88   in each restart",
89       "tr_radius.gamma_dec": 0.8,
90       "tr_radius.alpha1": 0.9,
91       "tr_radius.alpha2": 0.95
92   },
93       "namedSettings_comment": "Settings for named parameters that get
94   passed into dfols via user_params"
95

```

96 **Table S1:** Comparison of the default parameter set with three optimized sets from the 10-parameter
97 experiments, based on the closest cost function values.

	c0_conv	rhcrit	caplmt	alfa	ke	c0	cmftau	rhminl	rhminh	dthdpmn
Default	1.00e-3	0.85	70.00	0.20	9.0e-6	5.0e-5	4800.00	0.95	0.50	-0.08
Optimized	1.40e-3	0.83	34.40	0.25	6.4e-6	3.0e-5	4931.40	0.97	0.56	-0.09
Experiment1	1.06e-3	0.83	22.49	0.25	6.0e-6	3.0e-5	5916.36	0.98	0.61	-0.09
Experiment2	1.17e-3	0.84	44.28	0.14	7.6e-6	3.6e-5	3252.07	0.96	0.51	-0.09

98

99 **Table S2:** Initial values of the 10 parameters for the default and the three sensitivity cases.

	c0_conv	rhcrit	caplmt	alfa	ke	c0	cmftau	rhminl	rhminh	dthdpmn
Default	1.00e-3	0.85	70.00	0.20	9.0e-6	5.0e-5	4800.00	0.95	0.50	-0.08
Random1	3.48e-3	0.79	134.29	0.05	4.3e-6	1.5e-4	14212.74	0.91	0.95	-0.11
Random2	3.63e-4	0.77	131.30	0.06	2.7e-6	1.8e-4	3801.59	0.90	0.62	-0.13
Random3	5.00e-3	0.95	200.00	0.60	1.5e-5	2.0e-4	14400.00	0.99	0.99	-0.05

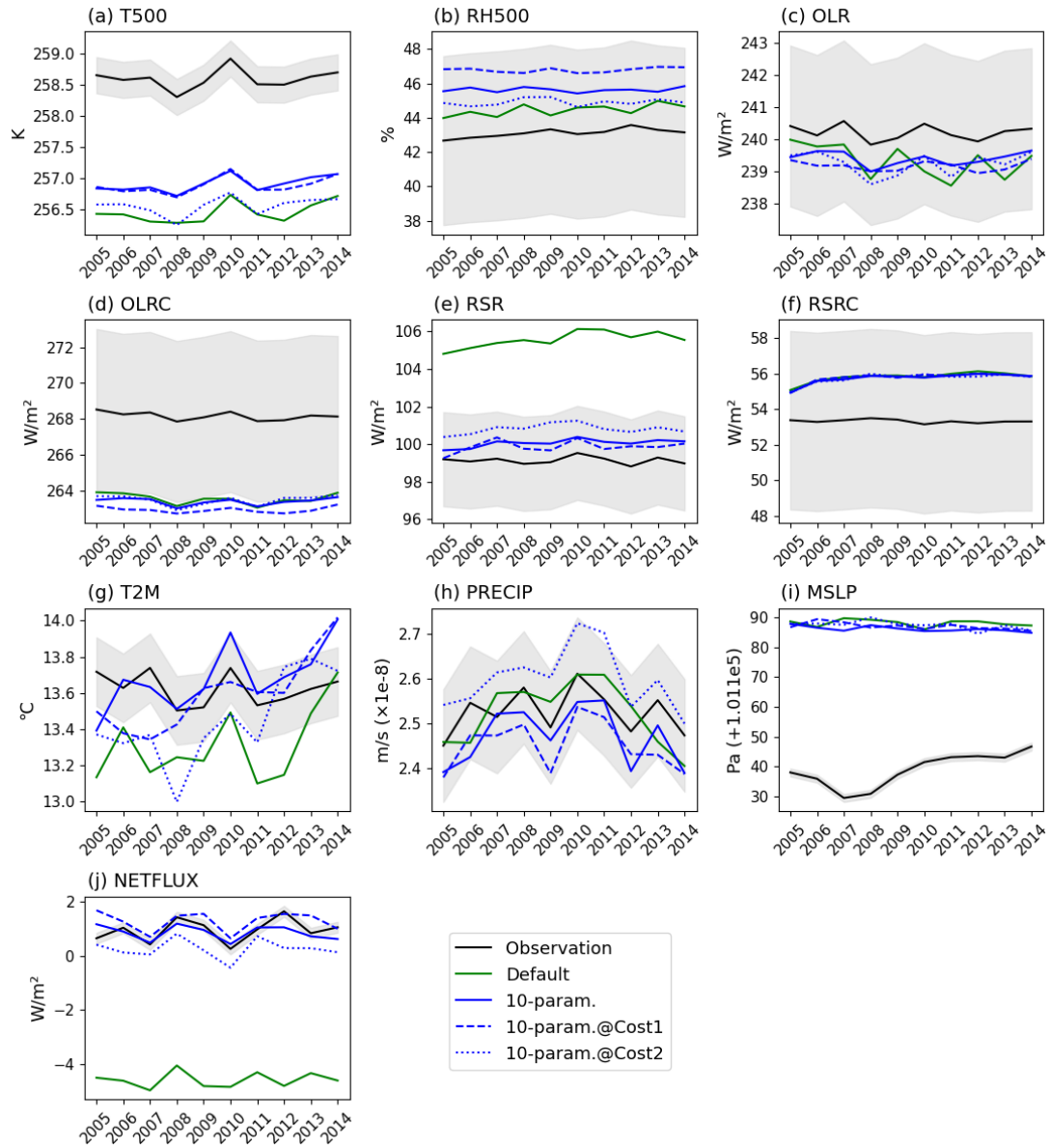
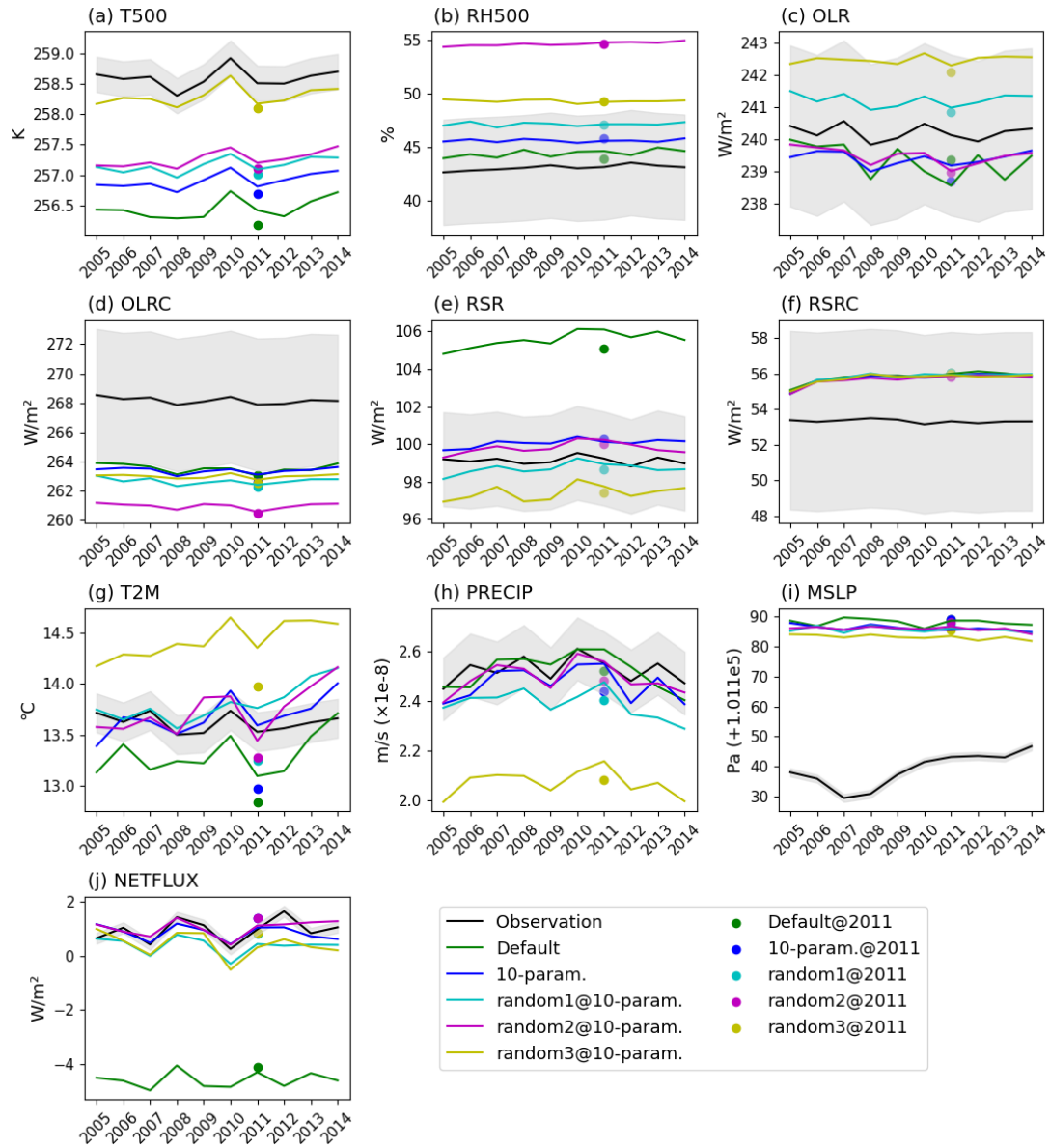


Figure S1. Same as Fig. 4, but showing the results of two additional experiments (represented by dashed lines) with cost function values closest to the minimum in the 10-parameter case.

S2



104

105 **Figure S2.** Same as Fig. 4, but for experiments with different initial parameter sets.

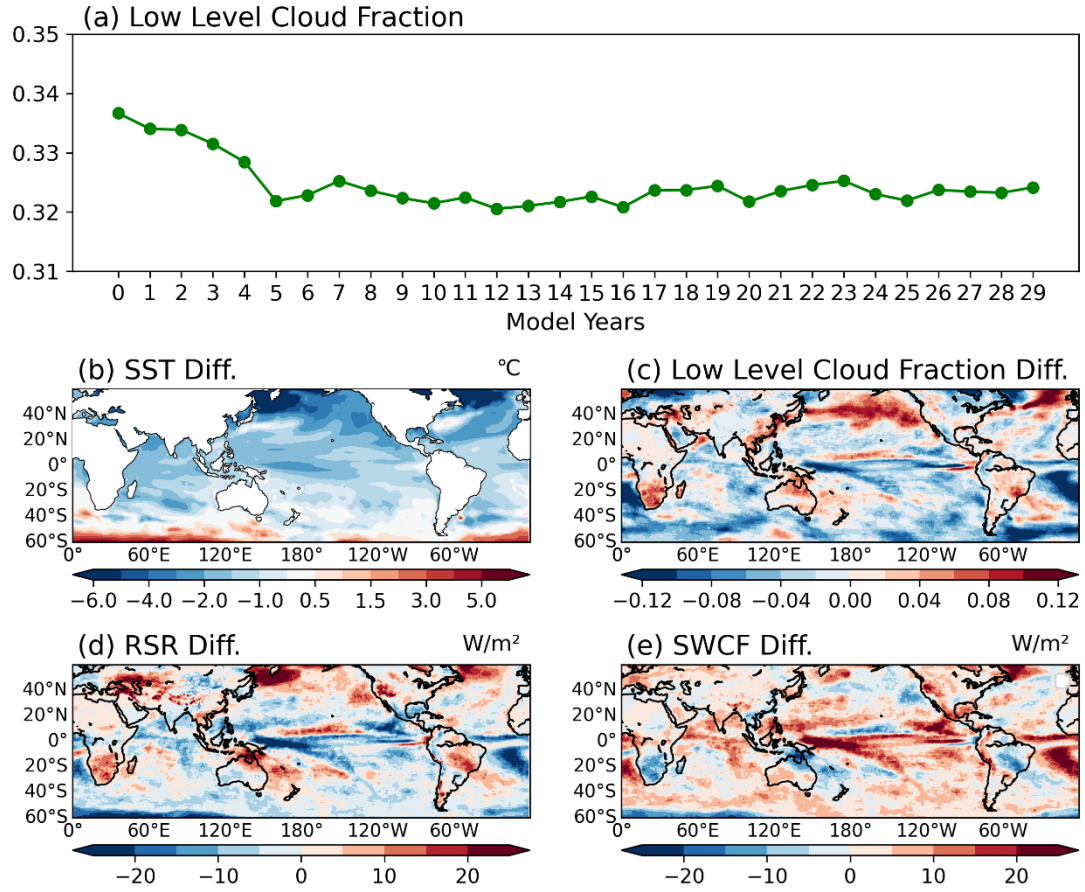


Figure S3. Panel (a) shows the 30-year time series of low-level cloud fraction over the mid- to low-latitude region (60°S–60°N) in the default case. Panels (b)–(e) display the differences between year 6 and year 1 in the piControl run for the default case, including SST (b), low-level cloud fraction (c), RSR (d), and shortwave cloud forcing (SWCF; e).

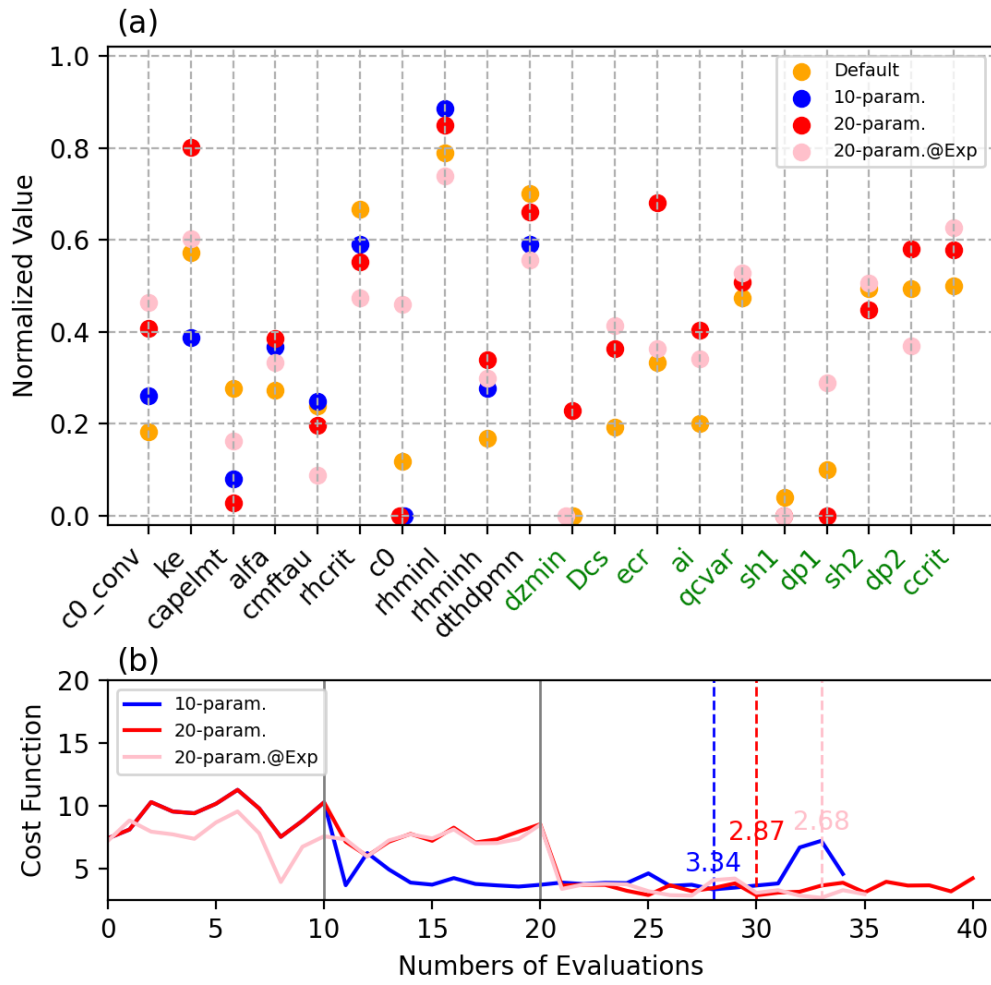


Figure S4. Same as Fig. 3, but adds the optimized 20-parameter case with independent initial perturbations applied to all parameters (shown as pink dots and lines; labeled “20-param.@Exp”).

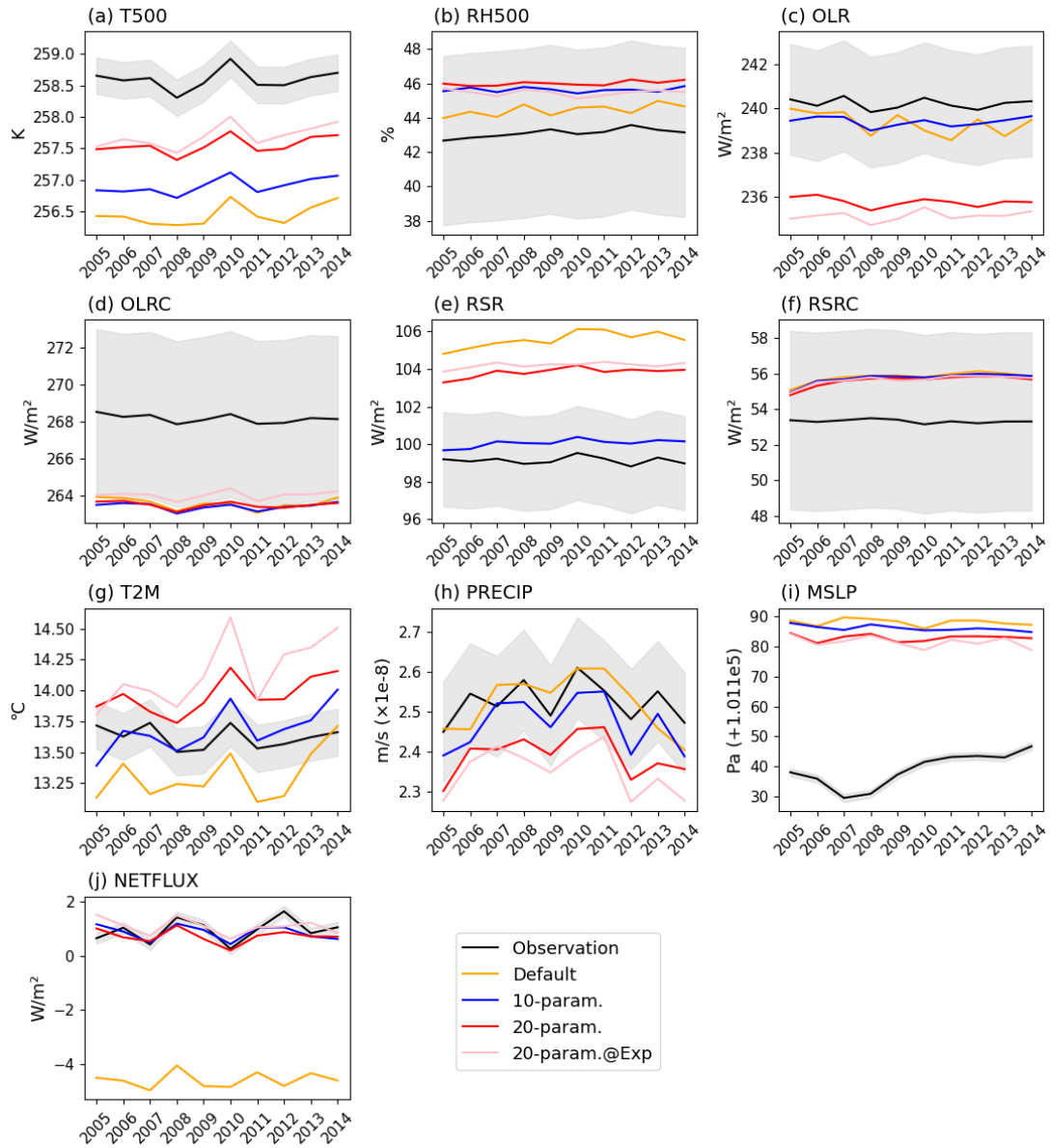


Figure S5. Same as Fig. 5, but adds the optimized 20-parameter case with independent initial perturbations applied to all parameters (shown as pink lines; labeled “20-param.@Exp”).

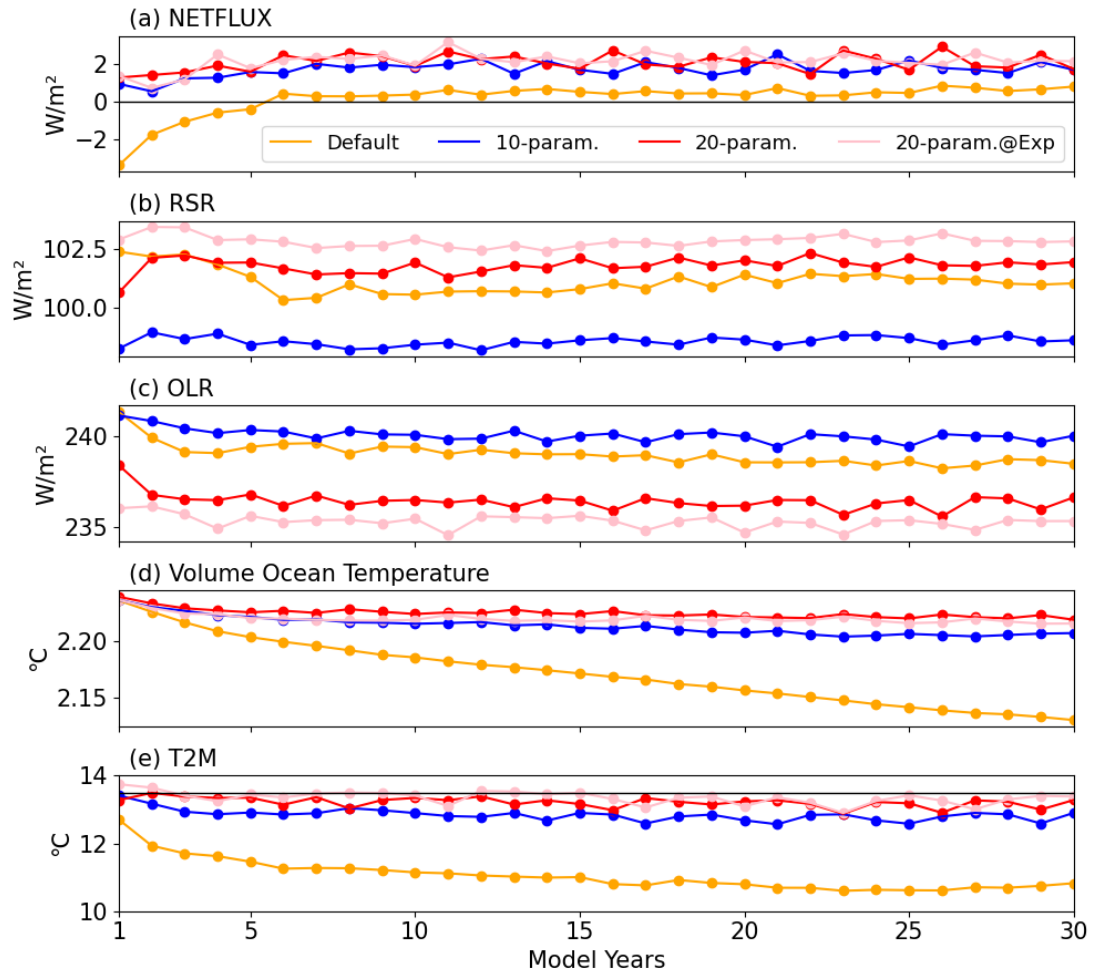


Figure S6. Same as Fig. 10, but adds the optimized 20-parameter case with independent initial perturbations applied to all parameters (shown in pink lines; labeled “20-param.@Exp”).