SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year	2015
Project Title:	EC-EARTH: developing a European Earth System model based on ECMWF modelling systems
Computer Project Account:	SPNLTUNE
Principal Investigator(s):	Dr. Ralf Döscher
Affiliation:	Rossby Centre, SMHI
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Dr. Souhail Bousetta
Start date of the project:	2015
Expected end date:	2017

Computer resources allocated/used for the current year and the previous one
(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)			25000000	6516046
Data storage capacity	(Gbytes)			70000	?

Summary of project objectives
(10 lines max)

The integration, testing and tuning of these components in EC-Earth 3 are representing a major effort in the development of the model in the framework of this project. During the first phase, the main objective was to test and tune the atmosphere-standalone model based on the IFS cyc 36 and EC-Earth-specific modifications in climate model. This work was done in the expected standard resolution, which is planned for most applications in the upcoming CMIP6 project. The goal was to reduce biases and at the same time maintain a stable model suitable also for forthcoming coupled applications. This version is also the base for an ESM setup, which is expected to be released later during 2015.

Summary of problems encountered (if any)

(20 lines max)

We did not experience major technical problems with the computing environment. Challenges exist concerning the EC-Earth tuning. Those are addressed in the summary of results.

Summary of results of the current year (from July of previous year to June of current year)

This section should comprise 1 to 8 pages and can be replaced by a short summary plus an existing scientific report on the project

Here we give a short summary and attach a report.

We investigated the sensitivity of the EC-Earth radiative fields and performance indexes (PIs) to 12 different parameters that affects convection, entrainment rates, precipitation, and other various water-cycle-related features. Tuning experiments were carried out in atmosphere-standalone mode. We were successfully able to reduce the net top-of-the-atmosphere (TOA) long wave (LW) and short wave (SW) fluxes, and this can be achieved in different ways. Most efficient tuning buttons are RPRCON (controls the rate of conversion of cloud water to rain) and RVICE (regulates fall speed of ice particles), since they operate on high cloud cover. Supplementary tuning is likely needed for optimal results once the model will be run in coupled mode.

List of publications/reports from the project with complete references

We are listing selected publications based on earlier phases of the SPNLTUNE project.

Davini P.,von Hardenberg J., Filippi, L., Provenzale A. (2014). Impact of Greenland orography on the Atlantic Meridional Overturning Circulation. *Geophysical Research Letters.* Article in Press.

Palazzi, E., von Hardenberg, J., Terzago, S., Provenzale, A. (2014). Precipitation in the Karakoram-Himalaya: a CMIP5 view. *Climate Dynamics*, 25 p. Article in Press. doi: 10.1007/s00382-014-2341-z

Van Noije, T.P.C., Le Sager, P., Segers, A.J., van Velthoven, P.F.J., Krol, M.C., Hazeleger, W., Williams, A.G., and Chambers, C.D., 2014. Simulation of tropospheric chemistry and aerosols with the climate model EC-Earth, Geosci. Model Dev., 7, 2435-2475, doi:10.5194/gmd-7-2435-2014.

Weiss, M., Miller, P., van den Hurk, B., van Noije, T., Stefanescu, S., Haarsma, R., van Ulft, L.H., Hazeleger, W., Le Sager, P., Smith B., and Schurgers, G., 2014. Contribution of dynamic vegetation phenology to decadal climate predictability, J. Climate, doi:10.1175/JCLI-D-13-00684.1.

Summary of plans for the continuation of the project

(10 lines max)

By the end of June 2015, the first version of the coupled climate model Ec-Earth 3.2 beta will be released, which will be subject to further coupling. Based on the atmosphere-standalone results of the previous project year, a coupled tuning effort is planned. The expected result is a new climate model able to simulate recent climate and its variability reasonably well and at the same time resembles observed integrative constraints, such as the surface and TOA energy balances. The central judgement of the new climate model will be based on Reichler and Kim climate model performance index. Initially the tuning and testing effort will continue to focus on standard resolution. Later, tuning will be extended to high resolution versions and ESM configurations.

24 june 2015

SPNLTUNE: Summary of results of the current year

covering July 2014 year to June 2015

Paolo Davini, Jost von Hardenberg and Ralf Döscher

The EC-Earth consortium is switching the version of the ocean model from NEMO 3.3.1 to NEMO 3.6. This is an ongoing effort and in the meantime the work in SPNLTUNE focused on the tuning of the atmospheric model, IFS cy36r4 for climate applications. We investigated the sensitivity of the EC-Earth radiative fields and performance indexes (PIs) to 12 different parameters that affects convection, entrainment rates, precipitation, and other various water-cycle-related features. We performed AMIP runs (6 years each) where we changed only one parameter at a time, exploring increasing and decreasing values. This was done with standard climatological SSTs and with perennial present day forcing.

The tuning parameters are located in the model routines `sucumf.F90` and `sucldp.F90` (with the exception of `RALBSEAD`). Some of them are standard tuning buttons, others are newly addressed after consultation with ECMWF experts (Richard Forbes). They are listed here below:

1. ***ENTRORG** : it controls the organized entrainment in deep convection*
2. ***RPRCON** : it controls the rate of conversion of cloud water to rain*
3. ***DETRPEN** : it controls the detrainment rate in penetrative convection*
4. ***ENTRDD** : it controls the average entrainment rate for downdrafts*
5. ***RMFDEPS** : it controls the fractional massflux for downdrafts*
6. ***RVICE** : it regulates fall speed of ice particles*
7. ***RLCRITSNOW** : it affects the critical autoconversion threshold for snow in large scale precipitation*
8. ***RSNOWLIN2** : it is the snow autoconversion constant in large scale precipitation.*
9. ***RLCRIT** : it is the critical autoconversion threshold for rain (actually we found out that is not used by code)*
10. ***RTAUMEL** : it controls the relaxation time that affects the melting of falling solid particles for large scale precipitation*
11. ***RALBSEAD** : it controls the albedo for diffusive radiation over the ocean*
12. ***COND-LIMITER** : it is a code modification suggested by Richard Forbes at ECWMF that affects the vertical humidity distribution.*

We evaluated years 2 to 6 of the simulation with the EC-mean analysis package and we assessed the different sensitivities of the parameterization against a number of parameters. An example of the tests performed is shown in *Fig. 1*, where the sensitivity of the net TOA flux to the above mentioned parameters is reported.

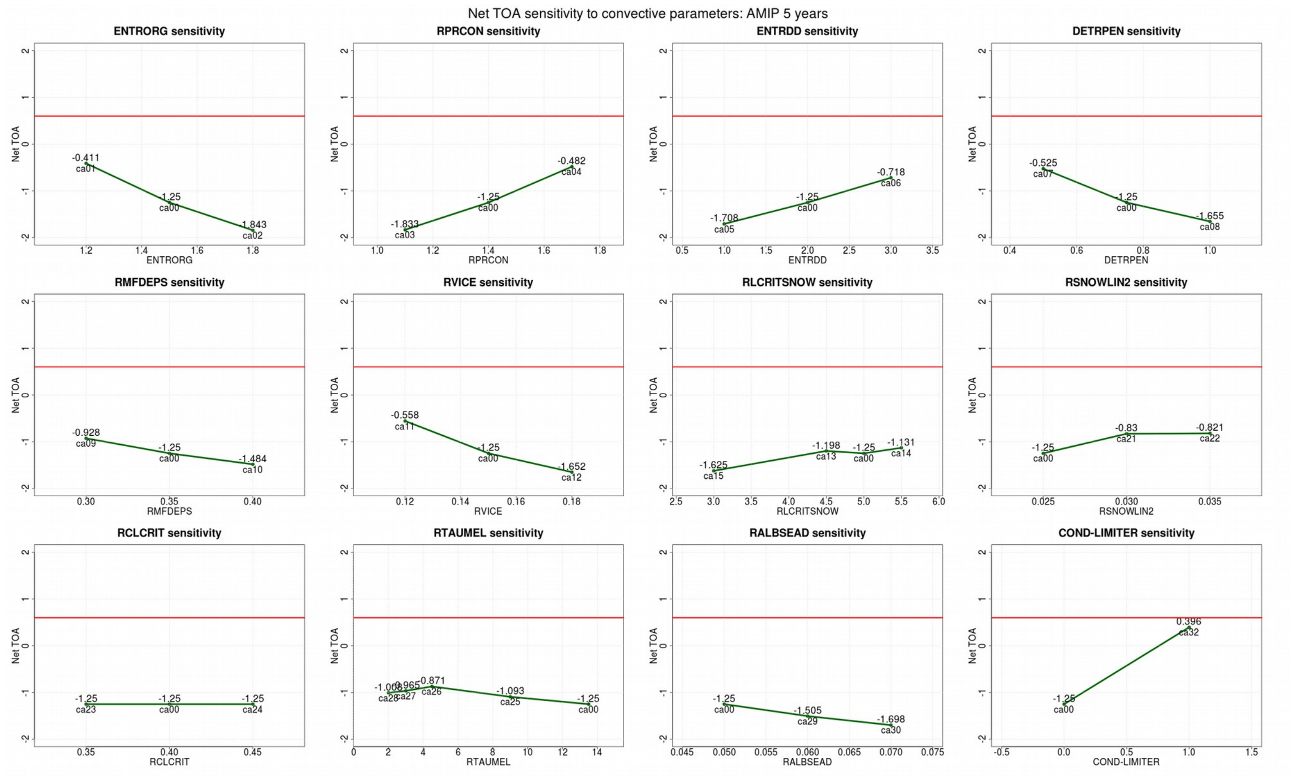

Fig. 1: Sensitivity of the net TOA flux to 12 parameters

After this first group of sensitivity experiments, we combined parameter variations in order to improve the representation of the main radiative fluxes. We aimed at improving 3 main issues:

- The standard EC-Earth 3.1 has an unrealisticly high net TOA shortwave and longwave fluxes (about 243 W/m^2 vs. observed of about 240 W/m^2). Those need to be reduced to acceptable values.
- LW cloud forcing shows unrealistic low values (about 24 W/m^2 vs. observed about 26 W/m^2).
- The standard EC-Earth 3.1 shows a too low net surface flux. At present day, the flux is estimated about 0.6 W/m^2. Here we tried to increase the radiation reaching the surface to a similar value.

The goal is to obtain improvements while keeping parameter values within their established ranges.

Results are shown in Fig 2 and 3. Fig. 2 shows the sensitivity of different radiative fluxes (TOA LW and SW fluxes, cloud forcing) and other mean fields (t2m, precip, P-E, cloud cover) testing different parameters combinations. Fig. 3 shows the same in terms of Reichler and Kim (2008) performance indices (PI). The information in Fig. 2 is more relevant for judging the tuning results while Fig. 3 is documenting progress towards an optimal configuration in a more fomalized way.

The green shading in Fig. 2 shows the range of acceptable values derived from scientific literature. Red lines are the “realistic” values from literature, mainly derived from Trenberth et al. (2009). The parameter combination cac8 (“Cy40-like”) is a configuration adopted from the IFS cycle 40.

We were successfully able to reduce the net TOA LW and SW fluxes, and this can be achieved in different ways. Most efficient tuning buttons are RPRCON and RVICE, since they operate on high cloud cover.

The situation is more complex when trying to detect the optimal outcome for net surface flux. Theoretically the net surface flux should be computed as the sum of the net shortwave, net longwave, sensible heat and latent heat flux plus the contribution of snowmelt. In this framework, the best configuration achievable is the one reported in `cac8 (“Cy40-like”)`.

When applying this configuration to the coupled models atmosphere in EC-Earth 3.1, we get a negative net surface flux of about -0.9 W/m^2, which is likely associated with a heat generation in the ocean or by the coupling procedure of about 0.9 W/m^2. This is unsatisfying but we decide not to address the issue at this point, because major upgrades in the ocean model and the coupling procedure are expected between the current and the first version for CMIP6, EC-Earth 3.2 beta. For the time being, if continuing tuning for a coupled atmosphere in the EC-Earth 3.1 framework, parameter configurations allowing a negative surface flux would be the recommended configuration. Cac7 would be such a configuration. Interestingly, both `cac7` and `cac8` shows an overall reduction of the Pis.

To conclude, the atmosphere-standalone tuning is giving valuable information as a base line even for forthcoming tuning of a coupled model. Supplementary sensitivity runs will be needed to further optize parameter combinations with respect to surface heat fluxes. This will be expecially necessary because of major changes in the upcoming ocean model version NEMO 3.6. In any case, the sensitivity of those tuning parameters will hardly change (since they are all IFS elements). We should be able to obtain rapidly a tuned atmosphere once a first coupled model version EC-Earth 3.2beta will be released.

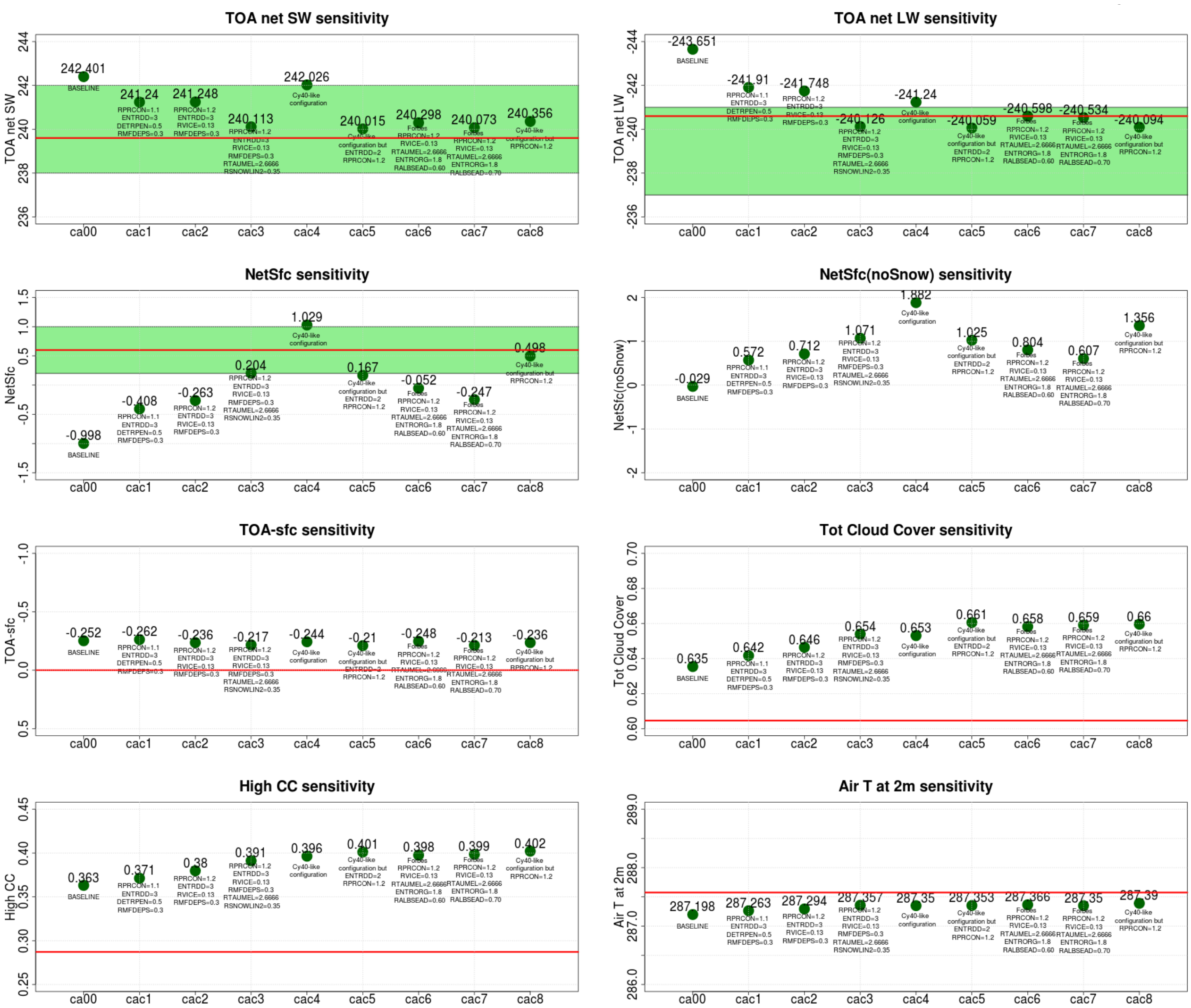

Fig. 2a: Sensitivity of different radiative fluxes (TOA LW and SW fluxes, cloud forcing) and other mean fields (t2m, precip, P-E, cloud cover) testing different parameters combinations.

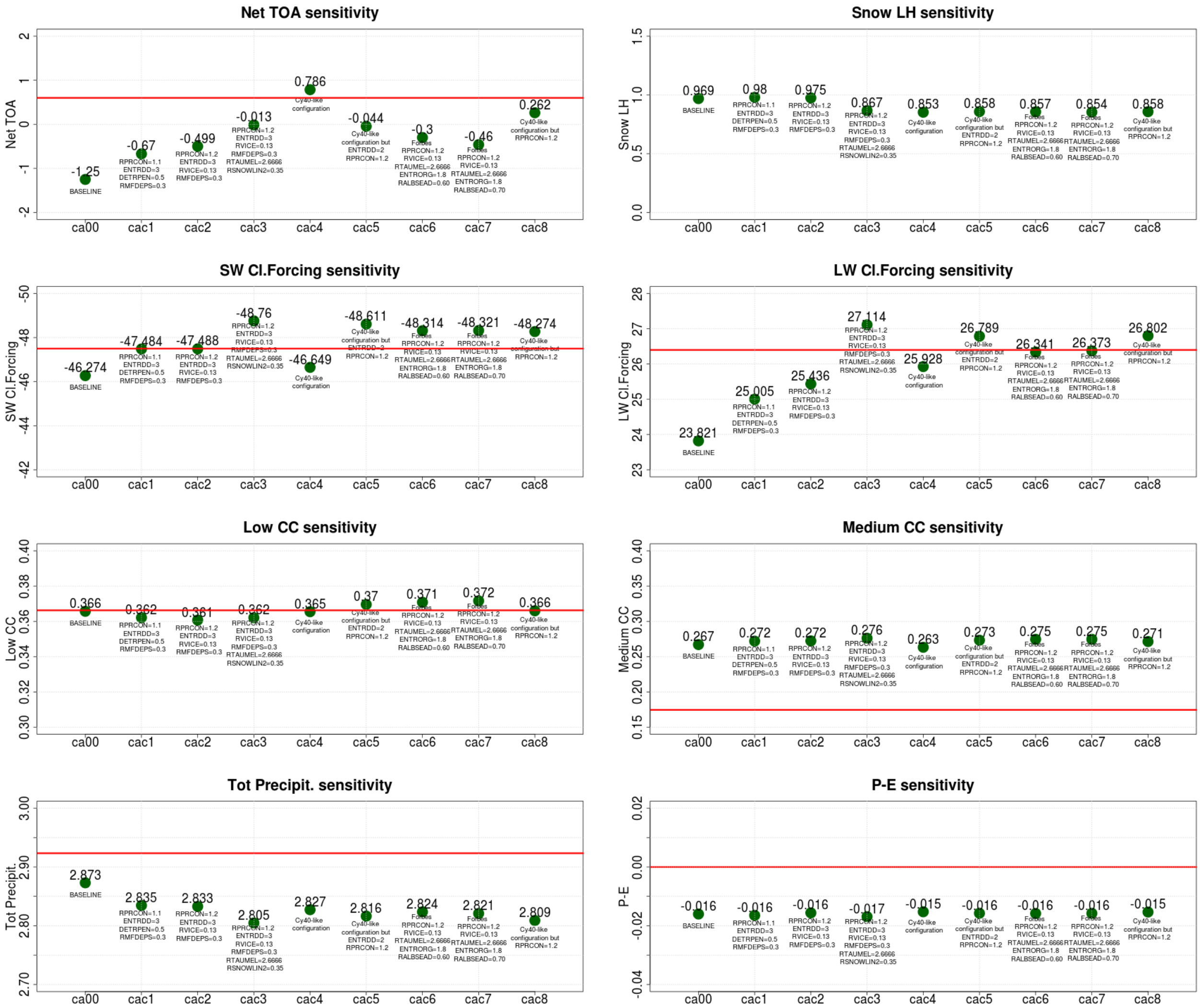

Fig. 2b: Sensitivity of different radiative fluxes (TOA LW and SW fluxes, cloud forcing) and other mean fields (t2m, precip, P-E, cloud cover) testing different parameters combinations.

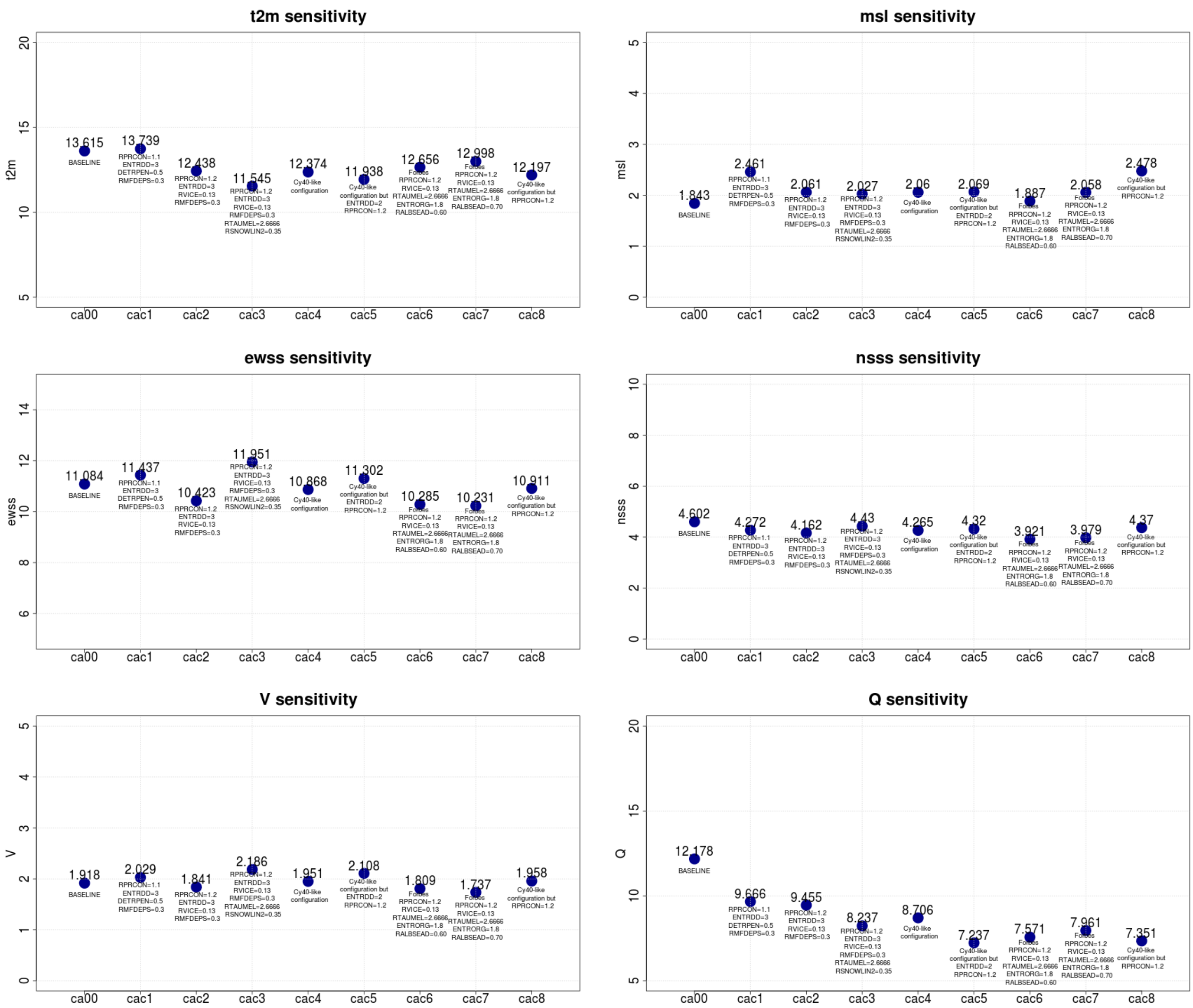

Fig. 3a: Sensitivity of different radiative fluxes mean fields testing different parameters combinations in terms of Reichler and Kim (2008) performance indices (PI).

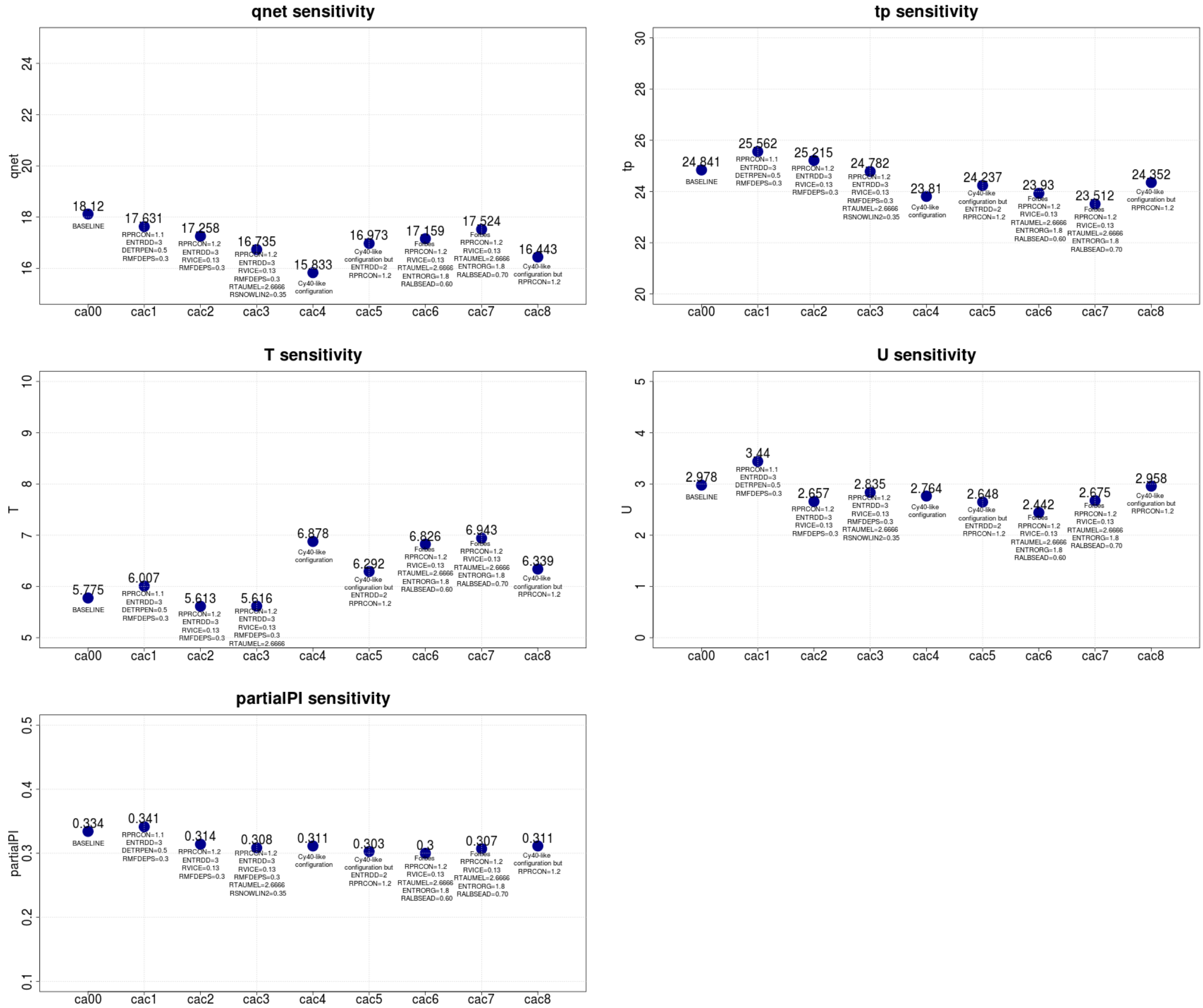

Fig. 3b: Sensitivity of different radiative fluxes mean fields testing different parameters combinations in terms of Reichler and Kim (2008) performance indices (PI).