Priority Project T^2RC^2:

Tuning the new radiation scheme

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Overview

- Priority Project "Testing and Tuning of Revised Cloud Radiation Coupling" (T^2RC^2) aims at development of the new cloud-radiation coupling scheme in the COSMO model (COSMO-cloudrad). The new scheme includes revised sub-grid scale clouds effect on radiation, detailed optical properties for liquid and frozen particles of different sizes, more accurate representation of aerosol effects on cloud microphysics, etc.

- From algorithmical point of view, the new scheme contains many cloud-radiation dependencies which contribution is described by about thirty parameters. Besides, different options are activated using ten logical switches. This makes the tuning of the scheme a difficult problem. The idealized COSMO framework was previously used to determine the parameters having particularly high influence on the radiative fluxes in the model (Khain et al., 2016).

- Here we utilize an "objective" parameters tuning (Voudouri et al., 2017; Khain et al., 2017) via comparison of real model forecasts against global radiation from CM-SAF satellite data (Müller et al., 2015) and surface stations.

- The experiments were performed for several month during 2016 over COSMO-DE domain. We present parameters values of four subversions of COSMO-cloudrad, which optimize the global radiation over Germany.

Calibrated versions and parameters

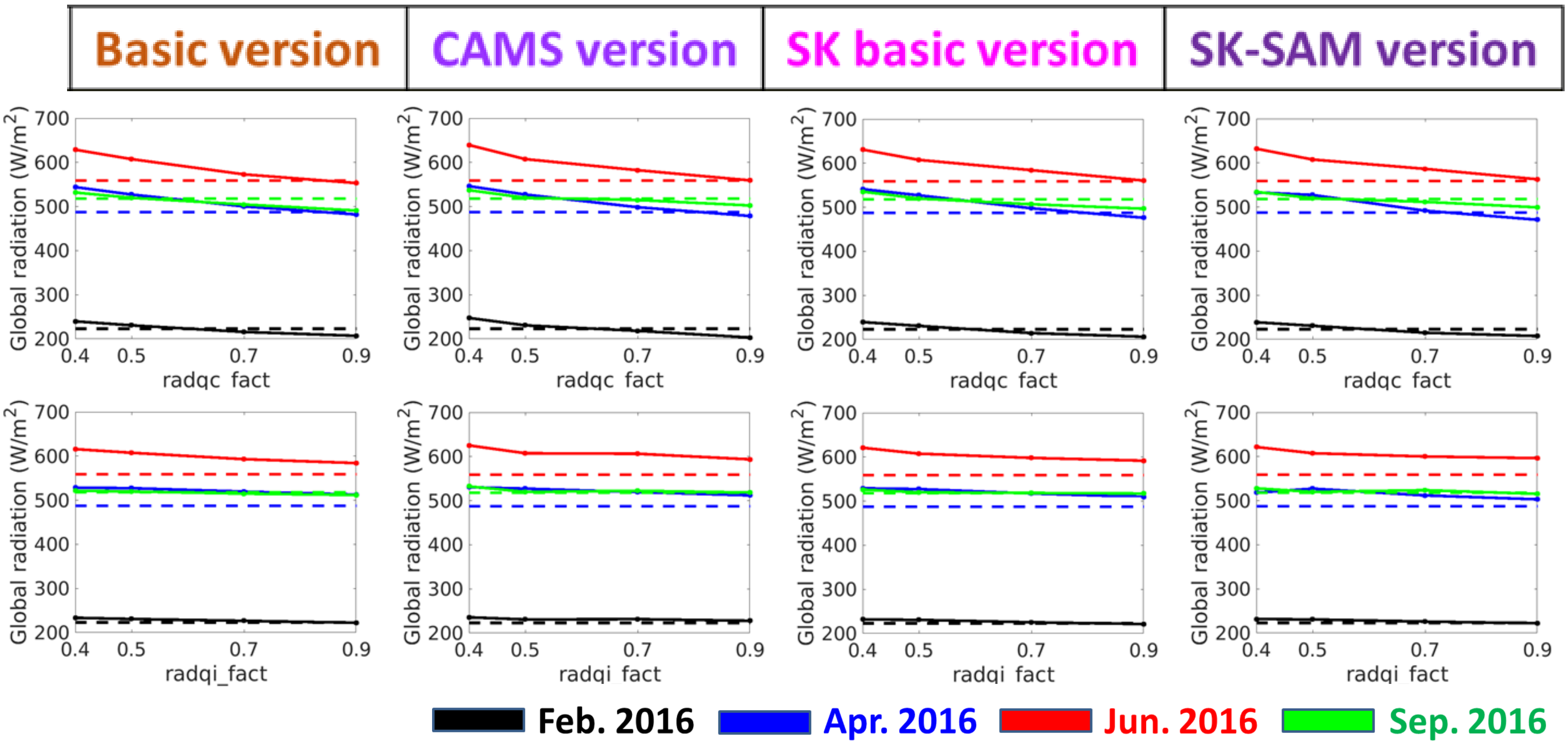
- *COSMO-DE 2.8km 5.1 <u>four</u> "cloudrad" versions, driven by ICON-EU analyses.*
- *For each version several continuous parameters are tuned - cyan in table*

Key switches (yellow) | Tuned continuous parameters (cyan) | **Calibrated versions**

Parameter meaning	Parameter	Basic version	CAMS version	SK basic version	SK-SAM version
Tegen/CAMS CCN	itype_aerosol	2	4	2	2
Use Segal Khain parametrization for the droplets number concentration	icloud_num_type_rad	1	1	2	2
Use constant SGS droplets effective radius	luse_reff_ini_c_as_reffc_sgs	TRUE	TRUE	FALSE	FALSE
Use adiabatic profiles for droplets microphysics in convective SGS clouds	luse_qc_adiab_for_reffc_sgs	FALSE	FALSE	FALSE	TRUE
LWC reduction due to SGS variability	radqcfact [0.4 0.5 0.9]	X	X	X	X
IWC reduction due to SGS variability	radqifact [0.4 0.5 0.9]	X	X	X	X
SGS droplets effective radius	reff_ini_c [3 5 20]$\cdot 10^{-6}$	X	X		
SGS LWC scale factor	qvsatfact_sgscl_rad [0.005 0.01 0.02]	X	X	X	X
Droplets number concentration for radiation	cloud_num_rad [0.5 2 5]$\cdot 10^{8}$	X	X		
SGS droplets effective radius scale of adiabatic profile	reff_avg_fact [0.5 0.9 1]				X
SGS droplets concentration scale of adiabatic profile (clouds dilution)	qnc_avg_fact [0.1 0.38 1]				X

For every version and every parameter (X in table above) the averaged modeled (solid) global radiation for 12Z is plotted against the parameter value (keeping the other parameters default) and is compared to the averaged observed value (dashed).

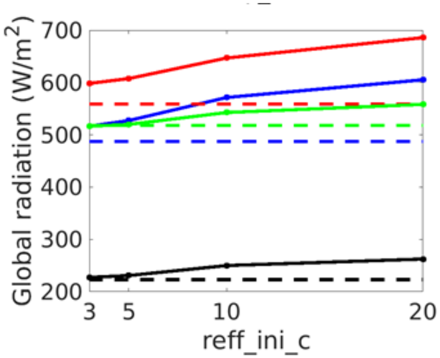
Global radiation sensitivity – radqcfact,radqifact

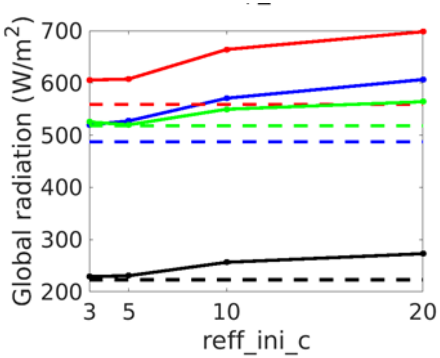


- The global radiation is the lowest in February and the highest in June (obvious).
- Larger <u>radqcfact</u> (strongly) reduces the global radiation (increases GS and SGS LWC).
- <u>radqifact</u> has weaker effect (cloud ice).

Global radiation sensitivity – reff_ini_c

Basic version	CAMS version	SK basic version	SK-SAM version



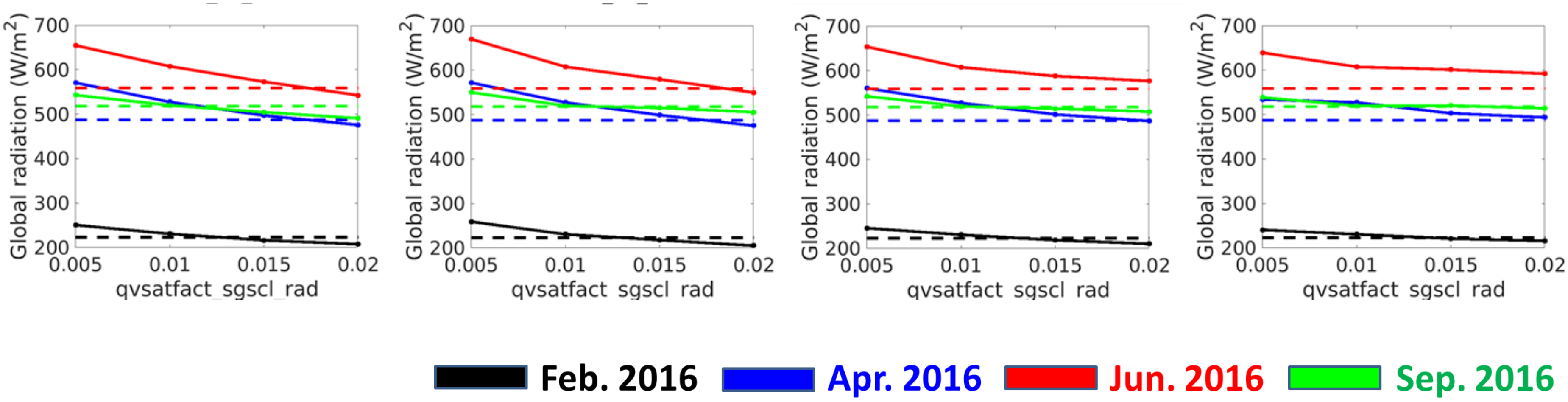


Feb. 2016 **Apr. 2016** **Jun. 2016** **Sep. 2016**

- **Larger <u>reff_ini_c</u> (strongly) increases the global radiation (larger droplets).**

Global radiation sensitivity – qvsatfact_sgscl_rad

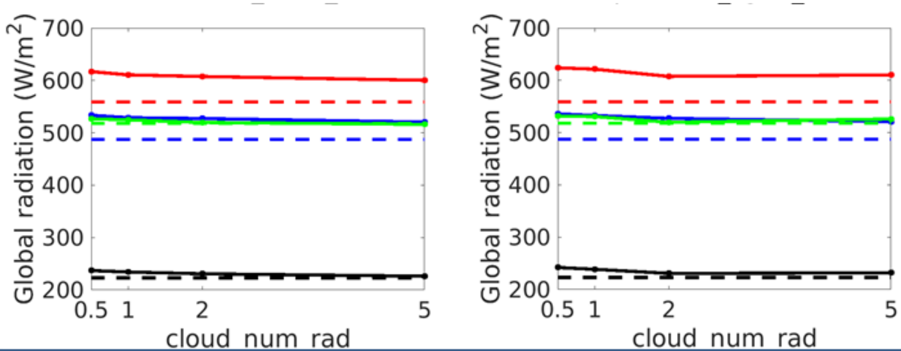
Basic version	CAMS version	SK basic version	SK-SAM version



- **Larger <u>qvsatfact_sgscl_rad</u> (strongly) reduces the global radiation (larger SGS LWC).**

Global radiation sensitivity – cloud_num_rad

Basic version	CAMS version	SK basic version	SK-SAM version

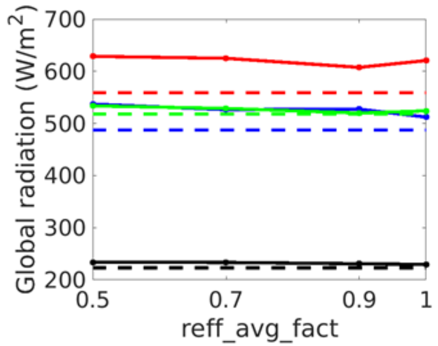


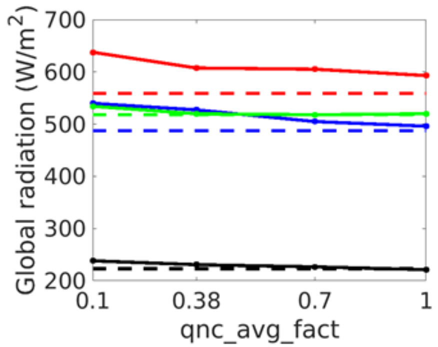
Feb. 2016 Apr. 2016 Jun. 2016 Sep. 2016

- **Larger <u>cloud_num_rad</u> (slightly) reduces the global radiation (higher droplets concentration).**

Global radiation sensitivity – reff_avg_fact,qnc_avg_fact

Basic version	CAMS version	SK basic version	SK-SAM version





Feb. 2016 Apr. 2016 Jun. 2016 Sep. 2016

- **reff_avg_fact has uncertain effect. Larger value increases the size of droplets in SGS cumulus (more transparent) but increases also their LWC (less transparent).**
- **Larger qnc_avg_fact (slightly) reduces the global radiation (lower dilution→ larger SGS LWC in cumulus). Significant in convective seasons (April and June).**

Calibration Method

Meta-Model

- ***First, several parameters combinations are chosen according to specific design (Voudouri et al. 2017). For each combination, COSMO runs are performed for February, April, June and September 2016.***
- ***For every hour at every grid point, the forecast of global radiation is then interpolated in parameters space using 2^{nd} order polynomial (with interaction terms).***
- ***These interpolations yield a "guess" for the global radiation for any chosen parameters combination (Meta-Model).***

Optimization

- ***The parameters space is then sampled by large number of parameter combinations. For each combination the Meta-Model is verified against CM-SAF hourly global radiation at 5km resolution or against surface stations data.***
- ***The seek of the optimal parameters combination is performed by convergence algorithm (Khain et al. 2017).***
- ***Finally the parameters combination which yields the optimal Meta-Model guess is defined.***

Calibration Method

A. Choosing "tunable" cases

The parameters are related to radiation transfer through clouds.

Therefore we focus on grid points/hours where both model runs and observations had similar cloud cover >0.

B. Obtaining optimal parameters for these cases

C. Obtaining estimated improvement over ALL the cases using these parameters

Calibration Method

A. Choosing "tunable" cases

The parameters are related to radiation transfer through clouds.

Therefore we focus on grid points/hours where both model runs and observations had similar cloud cover >0.

- Cloudy conditions: Observations < 0.9*clear sky
- The models also cloudy: ratio of models with < 0.9*clear sky is > 0.7
- The models are not very far from observations: at least 2 models from each of the sides of the observations

Results

A. Choosing "tunable" cases

The parameters are related to radiation transfer through clouds.

Therefore we focus on grid points/hours where both model runs and observations had similar cloud cover >0.

B. Obtaining optimal parameters for these cases

C. Obtaining estimated improvement over ALL the cases using these parameters

Optimal parameters - CMSAF

	Basic	CAMS	SK basic	SK-SAM
radqcfact	0.739	0.497	0.471	0.483
	0.474	0.5	0.478	0.515
	0.528	0.5	0.475	0.478
	0.61	0.52	0.471	0.496
radqifact	0.506	0.488	0.493	0.482
	0.485	0.488	0.484	0.859
	0.484	0.494	0.495	0.486
	0.493	0.497	0.506	0.489
reff_ini_c ($*10^{-6}$)	6.458	5.714		
	5.971	5.635		
	5.409	5.415		
	5.265	5.484		
qvsatfact_sgscl_rad	0.008	0.013	0.017	0.016
	0.014	0.012	0.017	0.01
	0.011	0.011	0.016	0.017
	0.009	0.011	0.017	0.01
cloud_num_rad ($*10^{8}$)	1.591	1.089		
	1.273	1.063		
	1.082	1.079		
	1.186	1.011		
reff_avg_fact				0.932
				0.93
				0.941
				0.933
qnc_avg_fact				0.325
				0.404
				0.35
				0.823

Optimal parameters - RADSFC

	Basic	CAMS	SK basic	SK-SAM	
radqcfact	0.7	0.598	0.479	0.724	Feb. 2016
	0.471	0.478	0.479	0.735	Apr. 2016
	0.735	0.471	0.485	0.517	Jun. 2016
	0.476	0.534	0.474	0.507	Sep. 2016
radqifact	0.532	0.506	0.485	0.479	Feb. 2016
	0.493	0.508	0.477	0.489	Apr. 2016
	0.497	0.483	0.868	0.5	Jun. 2016
	0.482	0.528	0.515	0.479	Sep. 2016
reff_ini_c ($*10^{-6}$)	6.257	5.512			Feb. 2016
	6.08	5.695			Apr. 2016
	6.084	5.545			Jun. 2016
	6.667	5.56			Sep. 2016
qvsatfact_sgscl_rad	0.008	0.009	0.017	0.008	Feb. 2016
	0.015	0.015	0.017	0.009	Apr. 2016
	0.009	0.014	0.016	0.015	Jun. 2016
	0.017	0.009	0.018	0.01	Sep. 2016
cloud_num_rad ($*10^{8}$)	1.211	0.979			Feb. 2016
	1.36	1.211			Apr. 2016
	1.422	1.228			Jun. 2016
	1.518	1.087			Sep. 2016
reff_avg_fact				0.937	Feb. 2016
				0.913	Apr. 2016
				0.916	Jun. 2016
				0.931	Sep. 2016
qnc_avg_fact				0.372	Feb. 2016
				0.384	Apr. 2016
				0.331	Jun. 2016
				0.838	Sep. 2016

Entire period (4 month)

Optimal parameters - CMSAF

	Basic	CAMS	SK basic	SK-SAM
radqcfact	0.52	0.497	0.471	0.478
radqifact	0.482	0.492	0.489	0.483
reff_ini_c (*10^{-6})	5.432	5.491		
qvsatfact_sgscl_rad	0.011	0.012	0.016	0.017
cloud_num_rad (*10^{8})	1.089	1.058		
reff_avg_fact				0.934
qnc_avg_fact				0.352

Optimal parameters - RADSFC

	Basic	CAMS	SK basic	SK-SAM
radqcfact	0.712	0.475	0.483	0.493
radqifact	0.498	0.489	0.501	0.496
reff_ini_c (*10^{-6})	5.955	5.618		
qvsatfact_sgscl_rad	0.009	0.014	0.017	0.018
cloud_num_rad (*10^{8})	1.317	1.191		
reff_avg_fact				0.926
qnc_avg_fact				0.369

Results

A. Choosing "tunable" cases

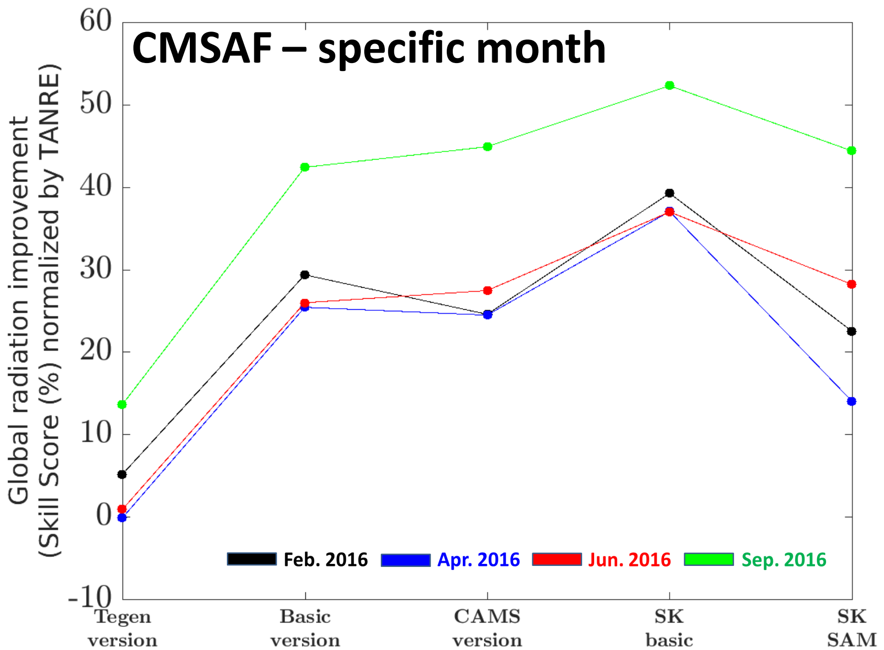
The parameters are related to radiation transfer through clouds.

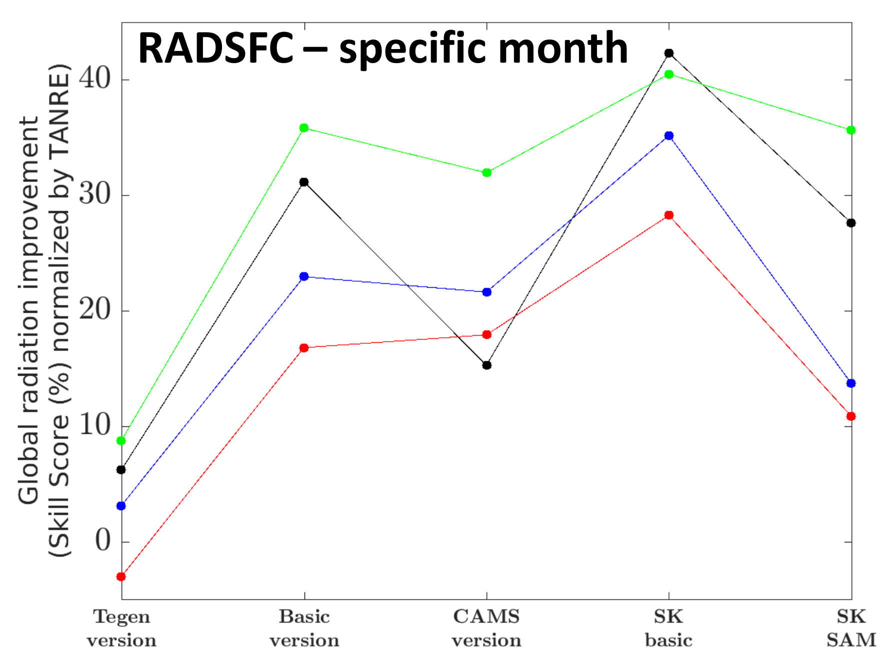
Therefore we focus on grid points/hours where both model runs and observations had similar cloud cover >0.

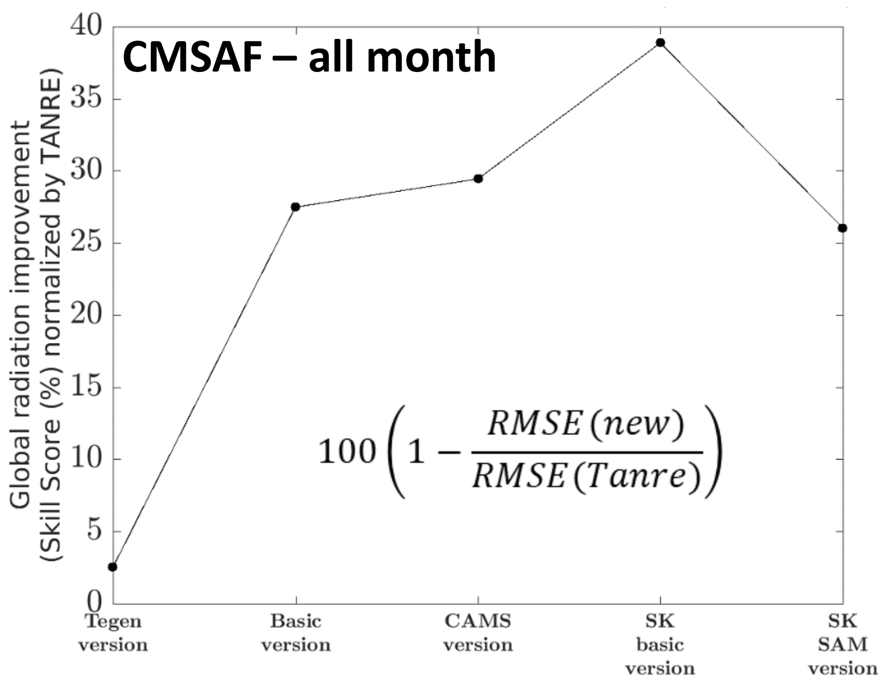
B. Obtaining optimal parameters for these cases

C. Obtaining estimated improvement over ALL the cases using these parameters

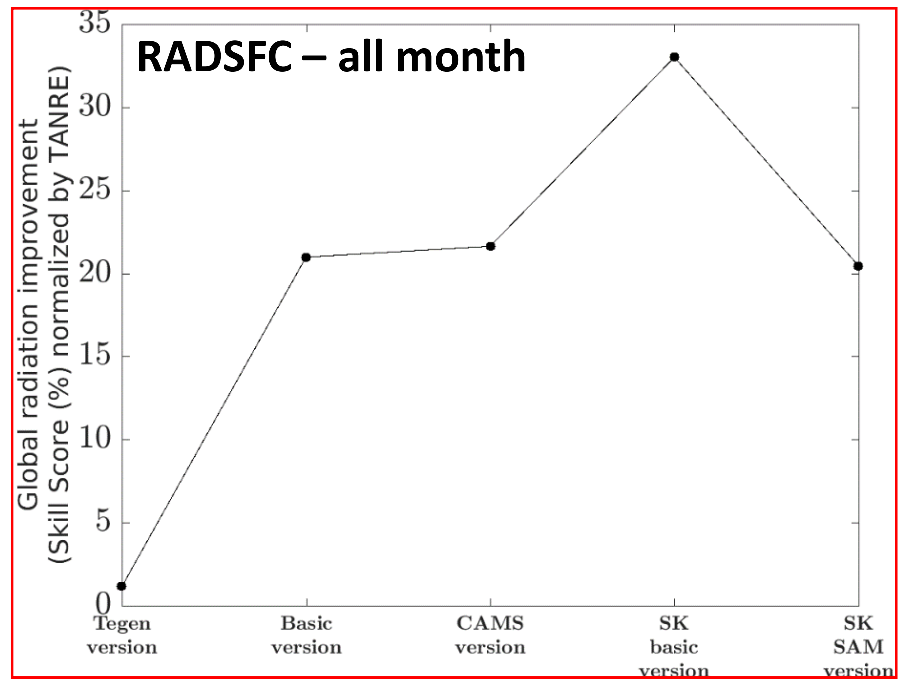
Improvement for “tunable” cases only



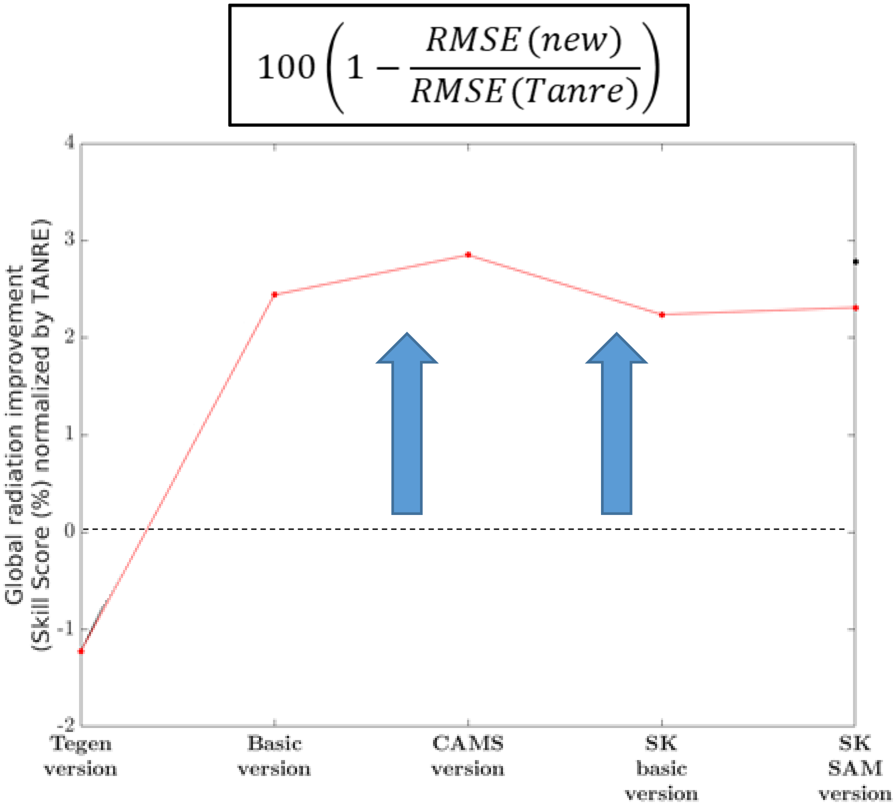


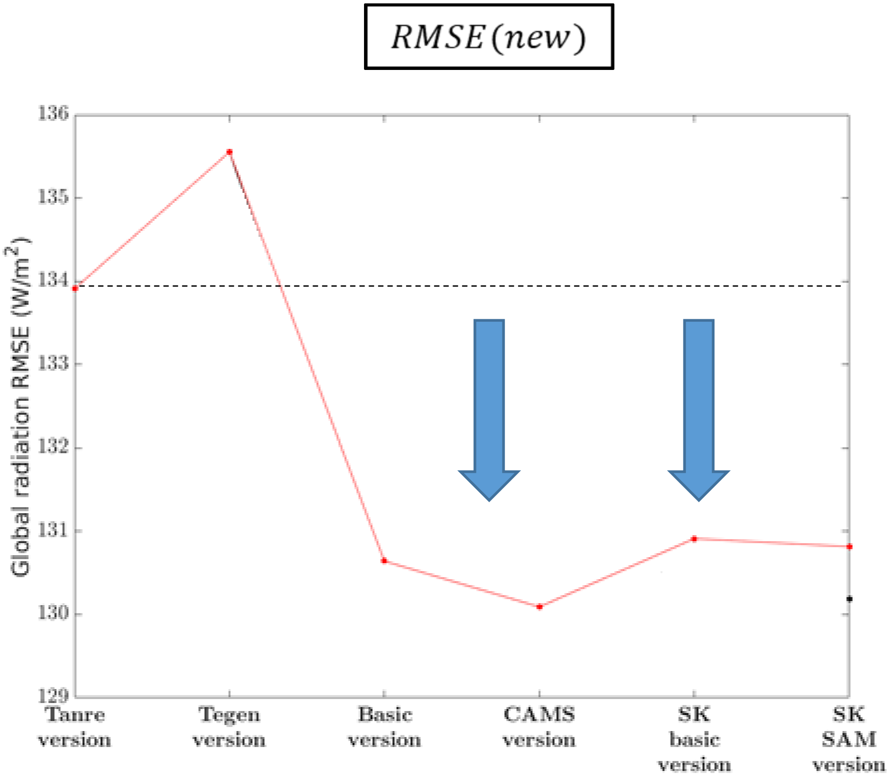


$$100\left(1-\frac{RMSE\,(new)}{RMSE\,(Tanre)}\right)$$



Improvement for all the cases





Conclusions

Thanks!

Additional slides …

Improvement for all the cases

Improvement for all the cases using optimal parameters