Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

C2SM
Center for Climate Systems Modeling

Towards systematic calibration of comprehensive climate models:

“Exploring perturbed physics ensembles for regional climate modelling”

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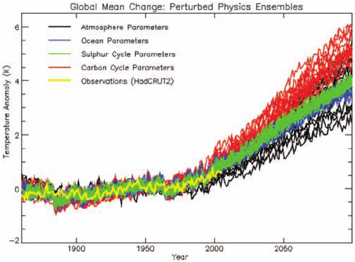
Outline

1. Introduction
   - Motivation
   - Project
2. Results
   - Model, Data and Ensembles
   - Annual Cycle
   - Sensitive Parameters
   - Equilibrium Timescale
   - Scoring Ensembles
3. Conclusions

Motivation - Model Uncertainties

- Assessment using ensembles of simulations. Multi-model ensembles (MME) (CMIP, Meehl 2007) and/or **Perturbed physics ensembles (PPE)** (climate*prediction*.net, Allen 1999)
- Parameter uncertainty is relevant (Murphy et al. 2004, Stainforth et al. 2005)
- Work mainly based on GCMs and NWP
- For RCMs little work has been done with a PPE approach (deElia 2008, Lynn 2009, Suklitsch 2010, UKCIP). MME: PRUDENCE → ENSEMBLES → **CORDEX**



HadCM3,ENSEMBLES (2010)

Motivation - Calibration

- **Calibration**: Narrow probability distributions of model parameters using observations.
- Calibration for low resolution models common (Price et al. 2005, Jones et al. 2005)
- Correlation of observed model behavior with projection signal unfortunately low (Knutti 2010).
- **RCMs are under a much stronger test than GCMs when driven by re-analysis. Optimal for calibration.**
- Scoring metrics are a constant debate in climate research (Gleckler et al. 2009)

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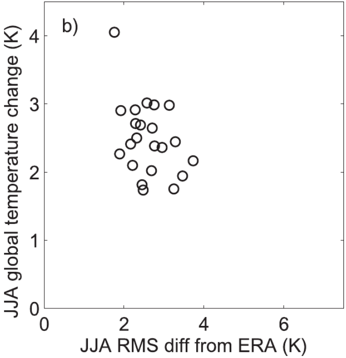


Knutti et al (2010)

Overarching Tasks

Error Model

- Target variables
- Spatial and temporal averages
- Apply scores
- Robustness

PPE

- **Parameter uncertainty**
- Structural errors
- **Timescales**
- **Sensitive parameters**

Scenario

- CORDEX simulations
- Climate change signals
- Bias assumptions
- Correlation of scores

Calibration

- Methods
- Improve model statistics
- Narrow parameter uncertainty
- Parameter interrelations

Ensembles, Variables and Observations

CCLM Ensembles

Name	Purpose	Sim.	Resolution	Period.
LONG	PPE for optimal setup CORDEX	38	0.44°	1990-2000
SHORT	PPE sampling parameter sensitivity	106	0.44°	1990-1990
IV	Sample internal variability (Rösch 2008)	4	0.44°	1958-2001

Observations

Name	Variables	Resolution	Period.
E-OBS III	T_2M[1], PR[2], TMAX, TMIN	0.22°	1950-2009
ISCCP FD	CLCT[3], TOA fluxes	2.5°	1983 - 2008
CRU TS2.1	CLCT, T_2M, PR	0.5°	1901 - 2002
ERA-Interim	several	1.5°	1989 - 2010
Willmott-Matsura	T_2M, PR	0.5°	1900 - 2006

[1] T_2M: 2m Temperature. [2] PR: Precipitation. [3] CLCT: Total Cloud Cover

Perturbed model parameters

Turbulence

tkesmot	[0,0.15*,0.5,1,1.5]
wichfakt	[0,0.15*,0.3,0.5,1]
securi	[0.1,0.85*,0.9]
tkhmin	[0,1*,2]
tkmmin	[0,1*,2]
turb_len	[100,500*,1000]
a_heat	[0.1,0.5,0.74*]
a_mom	[0.5,0.8,0.92*]
d_heat	[12,15,10.1*]
d_mom	[12,15,16.6*]
c_diff	[0.01,0.2*,10]

Convection

rmfdeps	[0.2,0.35*,0.5]
rcucov	[0.01,0.05*,0.5]
rtau	[0.5,1*,1.5]
rprcon	[1.5,1,15*,20,150]e-3
entrsc	[0.0001,0.001]
entrpen	[0.0004,0.0008*,0.0012]
entrmid	[0.0004,0.008*,0.0012]
entrscv	[0.001,0.003*,0.01]

Land Surface

rlam_heat	[0.1,3*,5,10]
rat_sea	[1,10*,50,100]
rat_can	[0,1*,10]
rat_lam	[0.1,1*,10]
c_sea	[1,1.5*,10]
c_soil	[0,1*,10]
c_lnd	[1,2*,10]
z0m_dia	[0.001,0.1*,10]
patlen	[10,100,500*,1000]
e_surf	[0.1,1.5*,10]
crsmin	[50,200,300*]

Microphysics

cloud_num	[5e7,5e8*,1e9]
qi0	[0,0.01*]
zxstar	[.33,2.6*,7.25]e-09
zv0s	[10,15*,30]

* default value

Radiation

uc1	[0.2,0.5*,0.8]
q_crit	[1,4*,7,10]
clc_diag	[0.2,0.5*,0.8]
hincrad	[0.5,0.75,1*]
conv_clc	[0.7,1*,1.3]

Logical

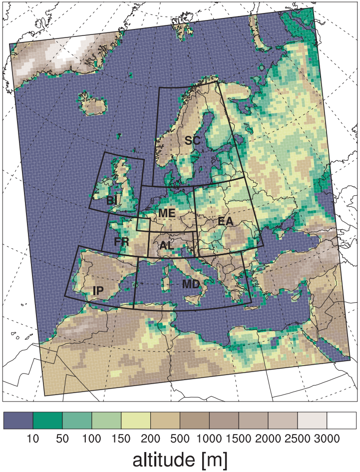
iconv_type	[Tiedkte,IFS]
lsso	[TRUE,FALSE]
ltrans_prec	[TRUE,FALSE]
lprogprec	[TRUE,FALSE]
itype_gscp	[no ice (2) , ice (3)]
l2tls	[LF,RK]
lexpcor	[TRUE,FALSE]

External

AER_X	[Tegen,Tanre,Aerocom]
LAI	[ISLSCPII,GLC2000]
ROOTDP	[ISLSCPII,GLC2000]
PLCOV	[ISLSCPII,GLC2000]

Model Setup

Domain and Topography COSMO-CLM



CCLM 4.8.10
Grid: 0.44° Δ x=$\sim$ 50 km
Leap Frog, dt=240s
ERA-40 boundary data
(updating every 6h)

Basic setting: COSMO EU.
IFS Convection Scheme (Brockhaus et al. 2010)

Results

A: Does the parameter uncertainty encompass observations?

- Important for calibration
- Consider internal variability and observational error

B: Which are the sensitive parameters?

- Identify important calibration parameters.

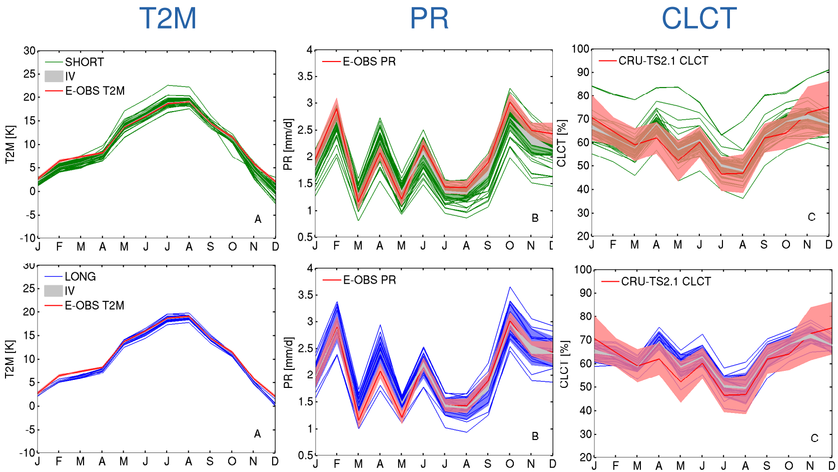
C: Is one year enough?

- RCM expensive to run. Calibration needs many simulations.

D: How can we score PPE ensembles?

- Comparison of different score metrics

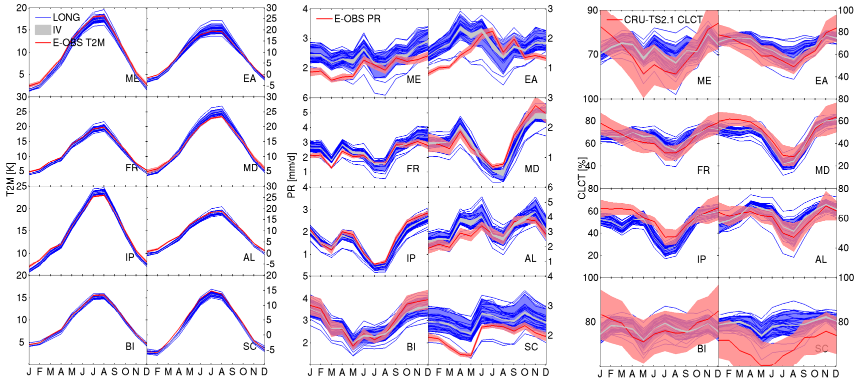
A: Annual Cycle



σ_{iv} Internal Variability σ_{ens} Parameter σ_{err} Observational

A: Annual Cycle

T2M | PR | CLCT

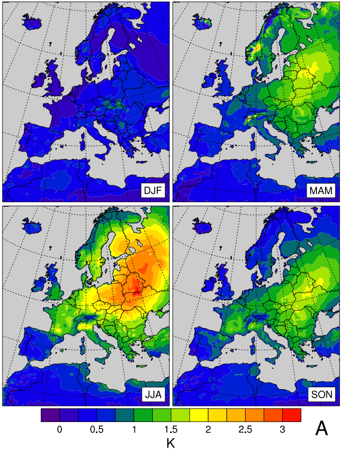


Internal Variability | Parameter Uncertainty | Observational Uncertainty

Ensemble spread encompasses observations at regional level.

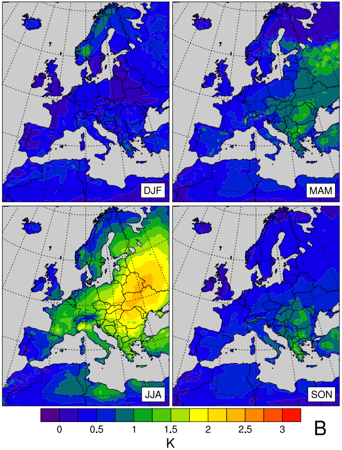
A: Extremes

Spread of 90th percentile of T2M



A

Spread of 50th percentile of T2M



B

Extremes are more sensitive than median statistics

B: Sensitive Parameters

Performance Score

$$PS = exp\left(-0.5\frac{1}{mn}\sum_t^n\sum_i^m\left(\frac{m_{t,i}-o_{t,i}}{\sigma_{o_i}+\sigma_{IV_{t,i}}+\sigma_{err_{t,i}}}\right)^2\right)$$

Multivariate performance analysis considering different sources of uncertainty. Extended climate prediction index (CPI) Murphy 2004.

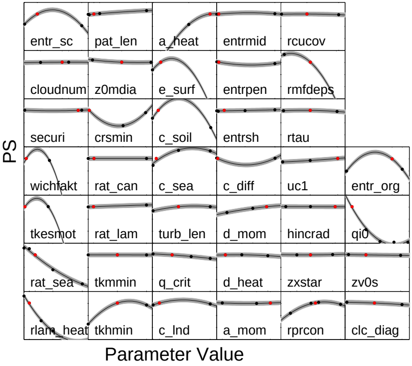
m=model output, o=observations, σ_o=natural variability of observations, σ_{IV}=internal variability of CCLM, σ_{err}=uncertainty of observations, ΔPS=max. change of performance.

Parameter sensitivity

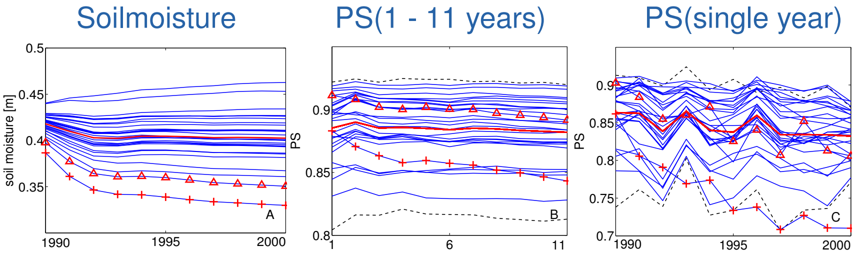
Parameter	Δ PS		
a_heat	0.256	clc_diag	0.010
e_surf	0.188	c_lnd	0.008
rmfdeps	0.162	entrsh	0.008
rlam_heat	0.158	rat_lam	0.007
qi0	0.148	entrpen	0.007
rat_sea	0.121	entrmid	0.007
tkhmin	0.088	c_diff	0.006
c_soil	0.072	securi	0.005
crsmin	0.063	d_heat	0.005
rprcon	0.053	rtau	0.005
entr_sc	0.048	zv0s	0.005
c_sea	0.046	rcucov	0.003
pat_len	0.028	cloudnum	0.002
a_mom	0.024	tkmmin	0.002
d_mom	0.024	zxstar	0.002
turb_len	0.020	hincrad	0.002
z0mdia	0.016	rat_can	0.000

B: Sensitive Parameters (2)

- Many parameters unsensitive
- Effect of RCM(IV) small, no multiple realisation necessary
- Only few simuations lead to improvemnts (e.g. rlam_heat,rmfdeps,c_sea)
- Entrainment coefficients also sensitive in IFS, as *climateprediction.net* and QUMP (Rougier,2009)

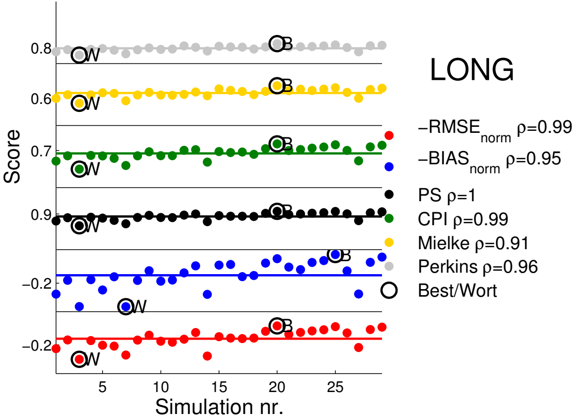


C: Is one year enough? Equilibrium timescale



- Perturbations to the physics affect soil moisture equilibrium
- Performance is robust after one year already
- Selection of time slice has some effects on the ranking

D: Comparison of alternative scores.



- All scores correlate strongly with PS
- Same best and worst simulations
- Choice of model variables and temporal means has a stronger effect

Conclusions

- Parameter induced spread encompasses usually the observations.
- Internal variability of the RCM alone plays minor role.
- Observational uncertainty can be very high for Cloud Cover.
- Optimal simulation length about 3 years.
- Ranking stable after one year.
- PS score robust in comparison to other scores.
- PPE mainly affect the bias terms.
- Parameters for calibration identified. Only a few parameters are important.

Thank you! Questions?

Soil moisture initialization

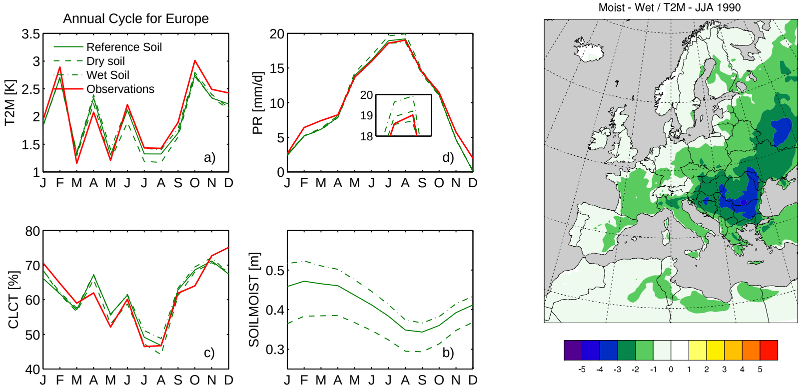
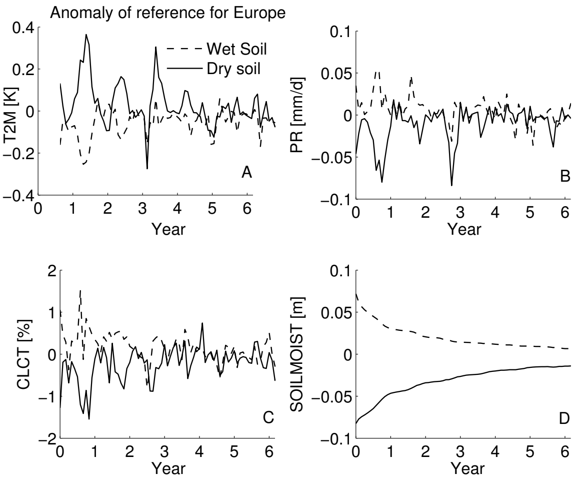
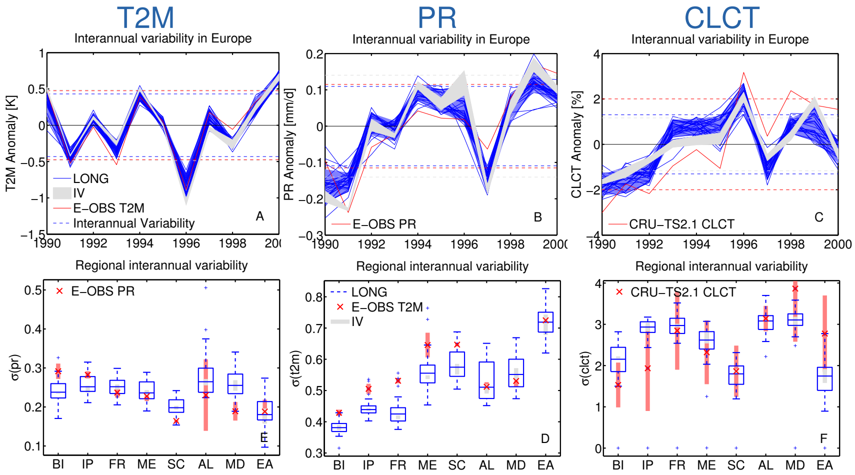


Figure: Experiment with ± 30% initialized soilmoisture in October 1989.

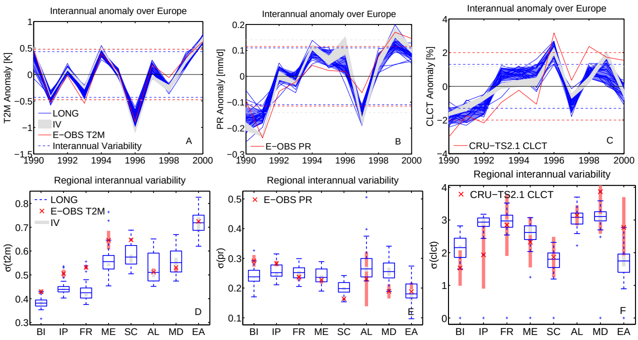
Soil moisture initialization (2)



A: Interannual Variability

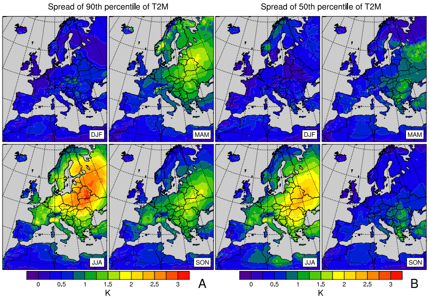


Interannual Variability



- Interannual signal correlates well with observations
- **Interannual variability lies within the PPE range** also at regional basis.
- Uncertainty of interannual variability due to observations large PR (AL), CLCT (all)
- IV also small for interannual variability

Uncertainty of extremes



- Spread of extreme quantaties large for T2M and PR (similar as MME spread and climate signal)
- Strong contribution to the spread is a change in the median.
- But additional spreading of the distribution tails (EA) and also some narrowing (SC).
- Spread largest in summer
- Eastern europe is highly sensitive to physical perturbations (Outflow, **Soilmoisture...**)

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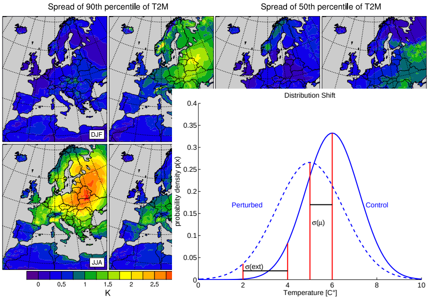

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