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NWP model forecast skill optimization via closure parameter variations

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Motivation

- **All model changes require re-tuning**
  - For instance, implementation of a new physics scheme
- **Currenty a manual task**
  - Hard to show improved skill by model improvements
  - Delays in operational implementations
- **Algorithmic model tuning to support decision making**

Time-scales in model parameter estimation

- **Hours - tangent-linear (TL) range**
- **Days - beyond TL, within deterministic predictability (DP)**
- **Weeks-Months-Years – beyond DP, fully chaotic**

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  Filtering applications (e.g. EKF with state augmentation)

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  Deterministic or ensemble prediction

- **Weeks-Months-Years – beyond DP, fully chaotic**

  Seasonal-to-decadal climate simulation

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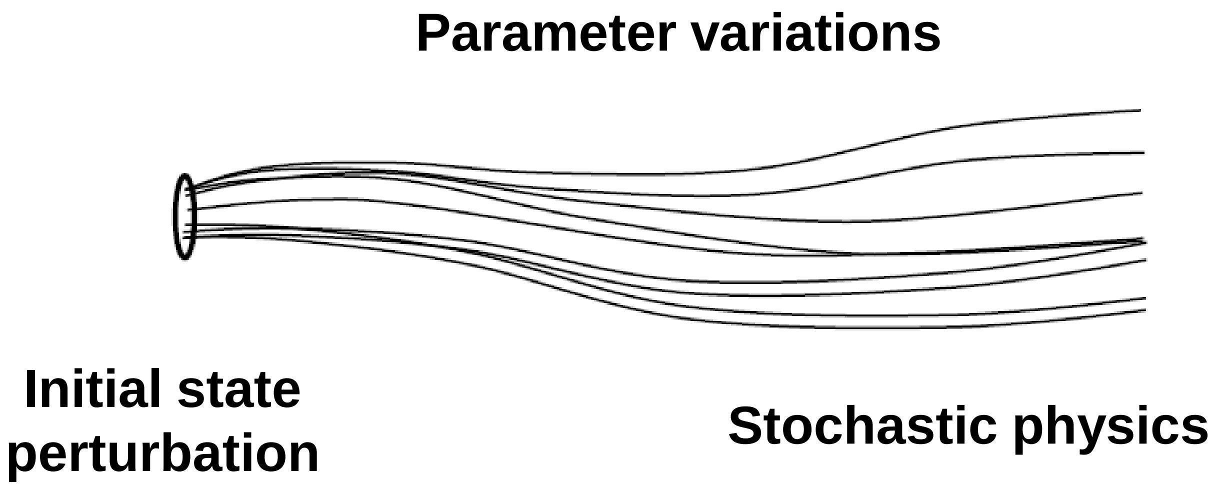
EPS: Aim to estimate the forecast uncertainty



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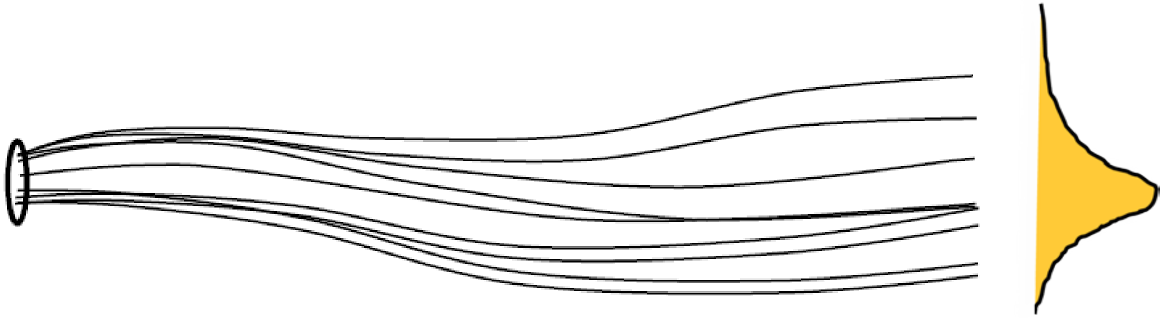
EPS: Aim to estimate the forecast uncertainty



A priori, all ensemble members are equally likely

EPS: Aim to estimate the forecast uncertainty

Verifying observations + cost function evaluation

A posteriori, some ensemble members appear more likely than others

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EPPES = EPS + parameter estimation

<u>The EPPES concept</u>:

ASSUME background uncertainty in the model parameters θ

$$\theta \sim N(\mu, \Sigma)$$

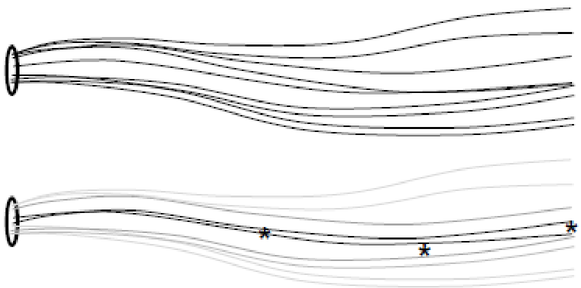
SAMPLE parameters θ from this distribution

EVALUATE a cost function based on forecast skill

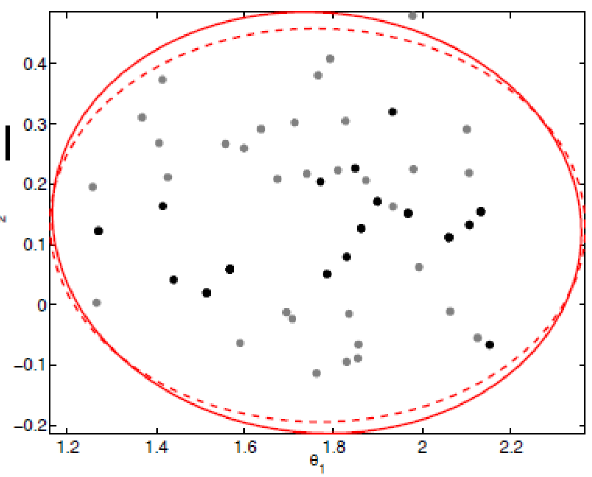
WEIGHT parameters according to their likelihood

UPDATE distribution parameters μ and Σ sequentially

State space



Parameter space

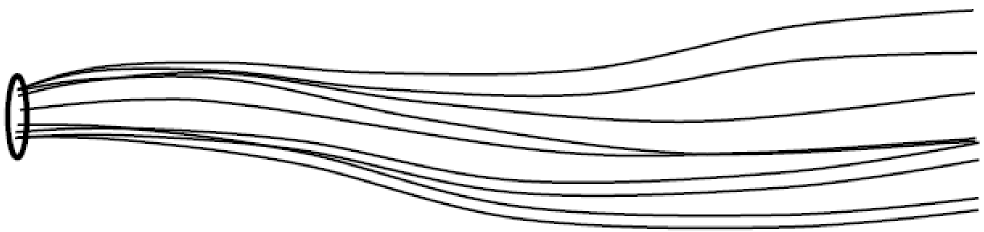


EPPES = EPS + parameter estimation

The EPPES concept:

Systematic effect

Parameter variations



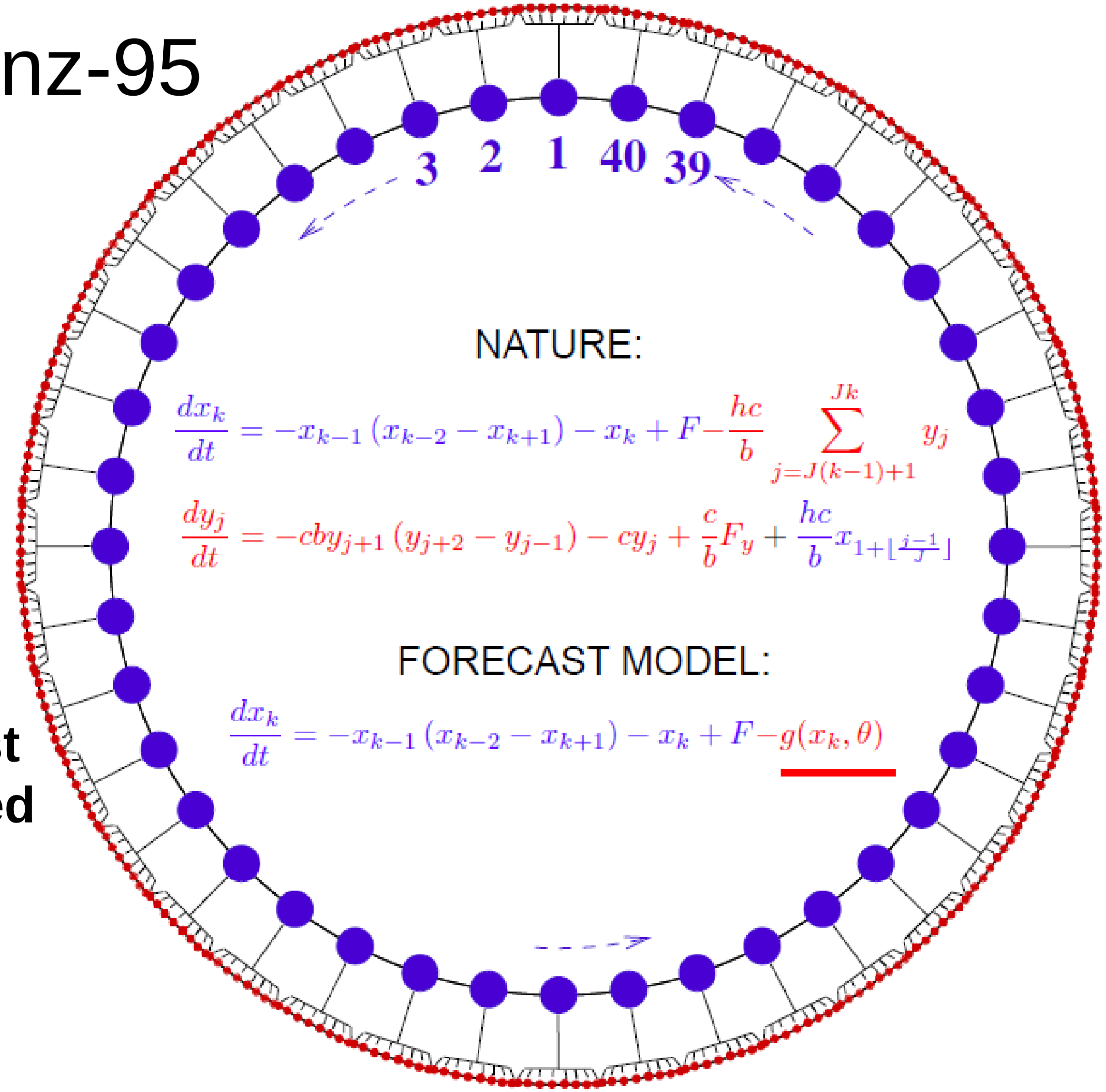
Initial state perturbation

Stochastic physics

Stochastic effects

Stochastic Lorenz-95

- **40 slow variables**
- **320 fast variables**



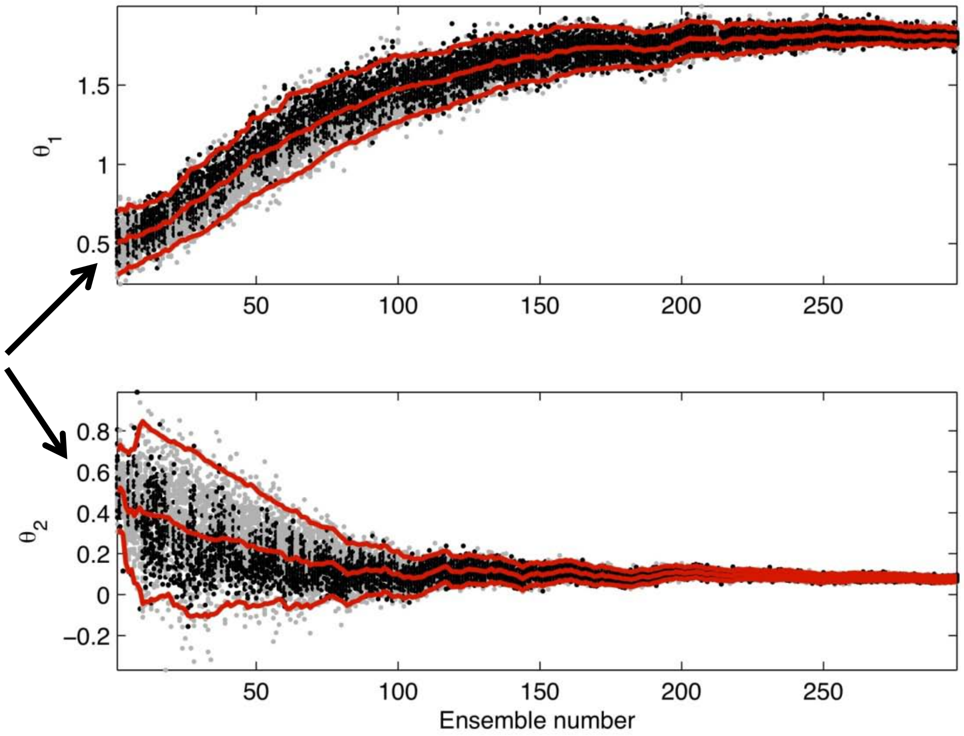
The net effect of the fast valiables is parameterized

$$g\left(x_k;\theta\right) = \theta_1 + \theta_2 x_k$$

Wilks (2005, QJRMS); Leutbecher (2010, ECMWF Lectures)

Evolution of parameters θ_1 and θ_2

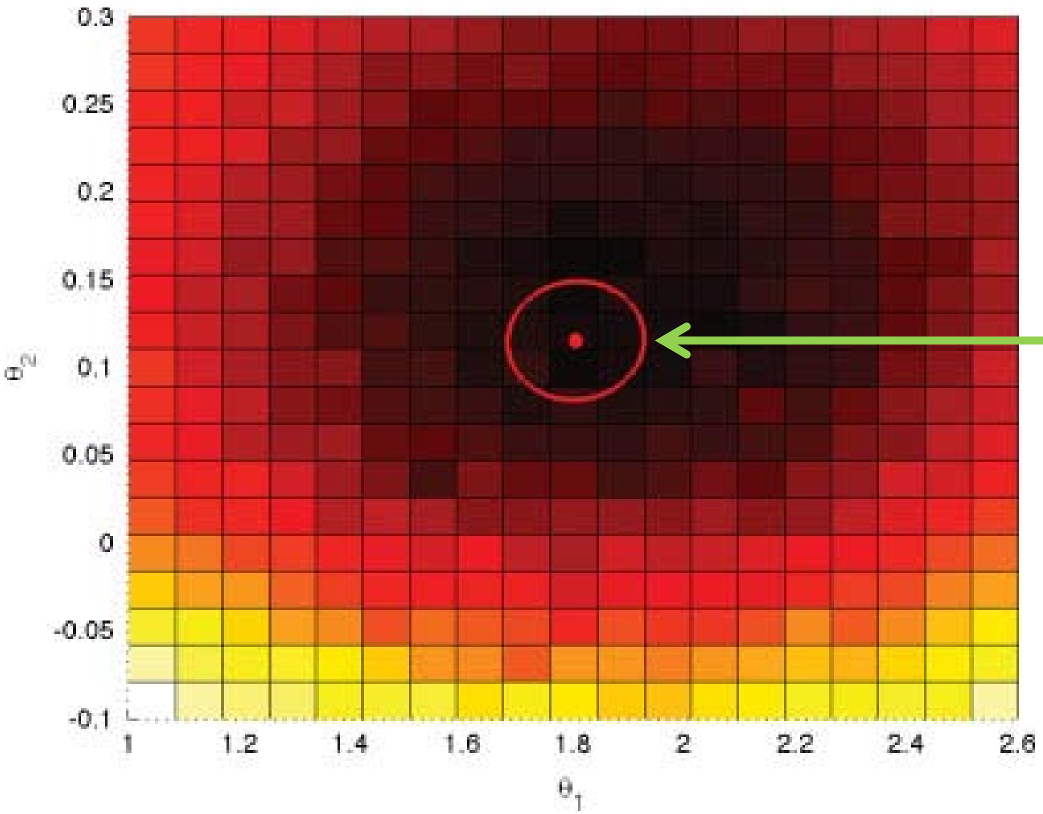
Badly selected initial values



Small uncertainty in the final values

300 sequential ensembles
50 members in each ensemble
Cost function: ”6 day” forecast skill

"6 day" forecast skill vs. parameter values



Background uncertainty of the final values

$$\theta \sim N(\mu, \Sigma)$$

Dark colours = high forecast skill
Note: initial parameter values outside the plot

ECHAM5 T42L31 climate model in ”EPS mode”

- **Control + 50 members with variations in 4 parameters**
- **Initial states + perturbations from the ECMWF EPS**
- **Twice daily 10 day forecats January - March 2011**
- **Thus: 2 × 90 × 51 = 9180 sample points**

Cost function (3 and 10 day forecast skill)

$$J(\theta) = \frac{5}{2}\sum_{A}\left(z_f^{72}(\theta) - z_a\right)^2 dA + \sum_{A}\left(z_f^{240}(\theta) - z_a\right)^2 dA,$$

Parameters (clouds and precipitation)

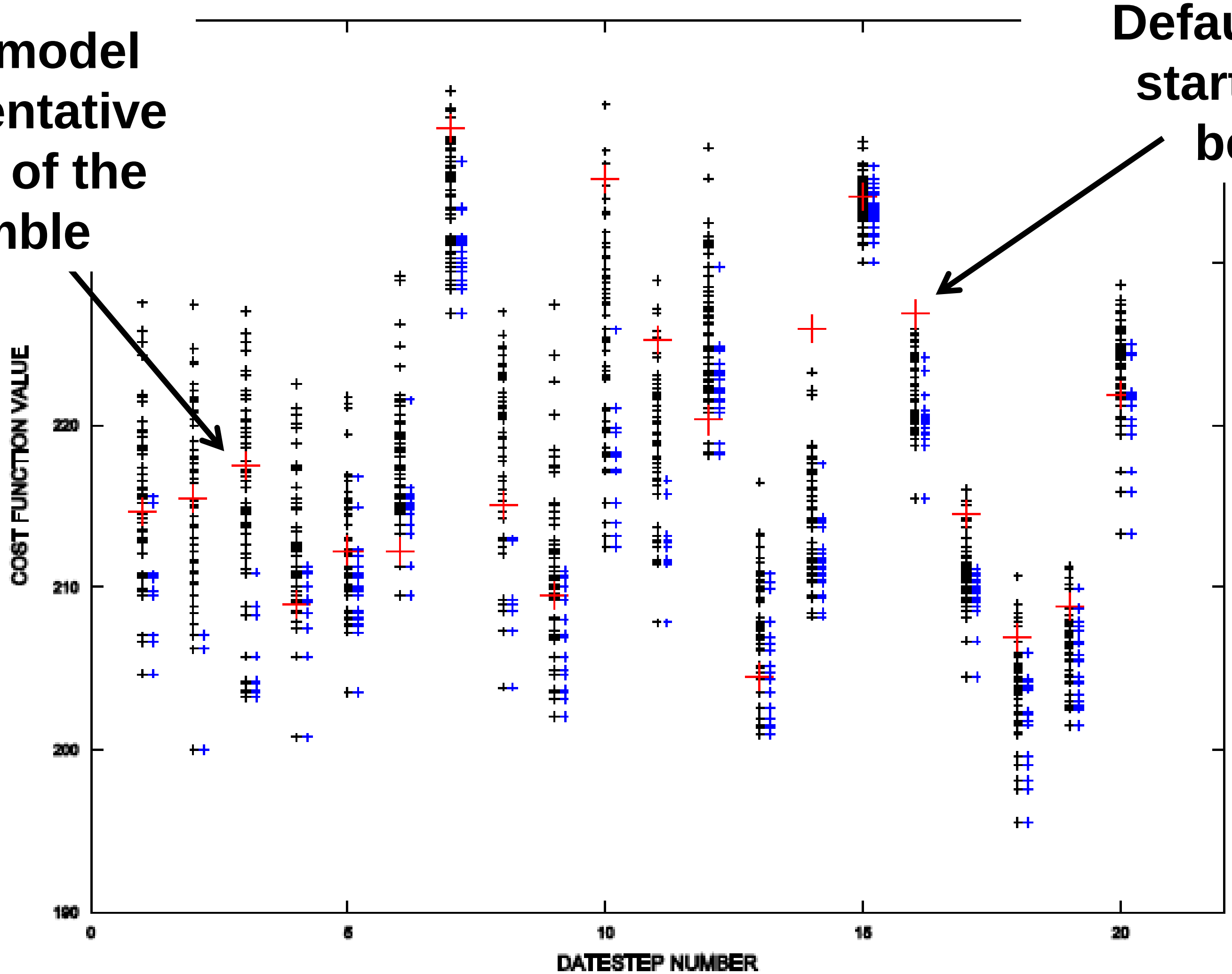
Parameter	Description
CAULOC	A parameter influencing the accretion of cloud droplets by precipitation (rain formation in stratiform clouds)
CMFCTOP	Relative cloud mass flux at the level above non-buoyancy (in cumulus mass flux scheme)
CPRCON	A coefficient for determining conversion from cloud water to rain (in convective clouds)
ENTRSCV	Entrainment rate for shallow convection

Järvinen et al. (2010) Estimation of ECHAM5 climate model closure parameters with adaptive MCMC. *Atmos. Chem. Phys*., **10**, 9993-10002.

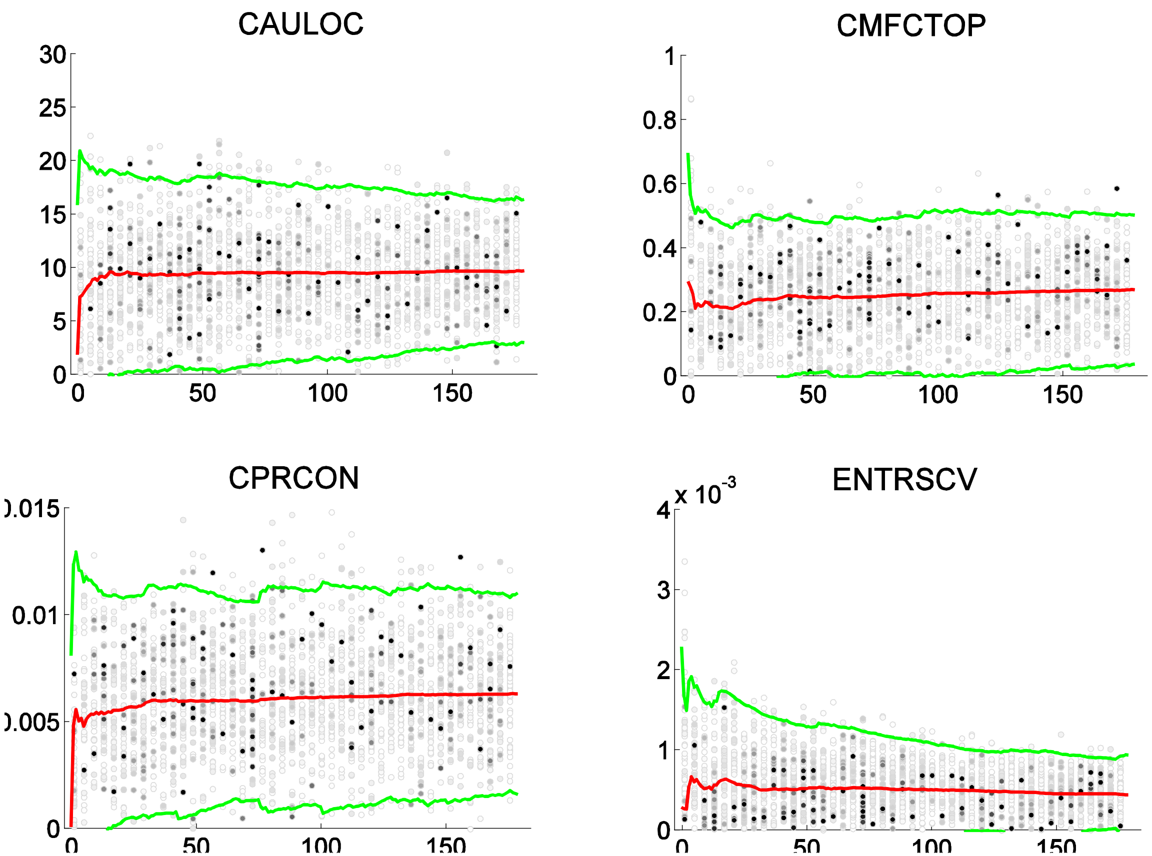
Cost function values in the first 20 ensembles

Default model a representative member of the ensemble

Default model starts to lag behind



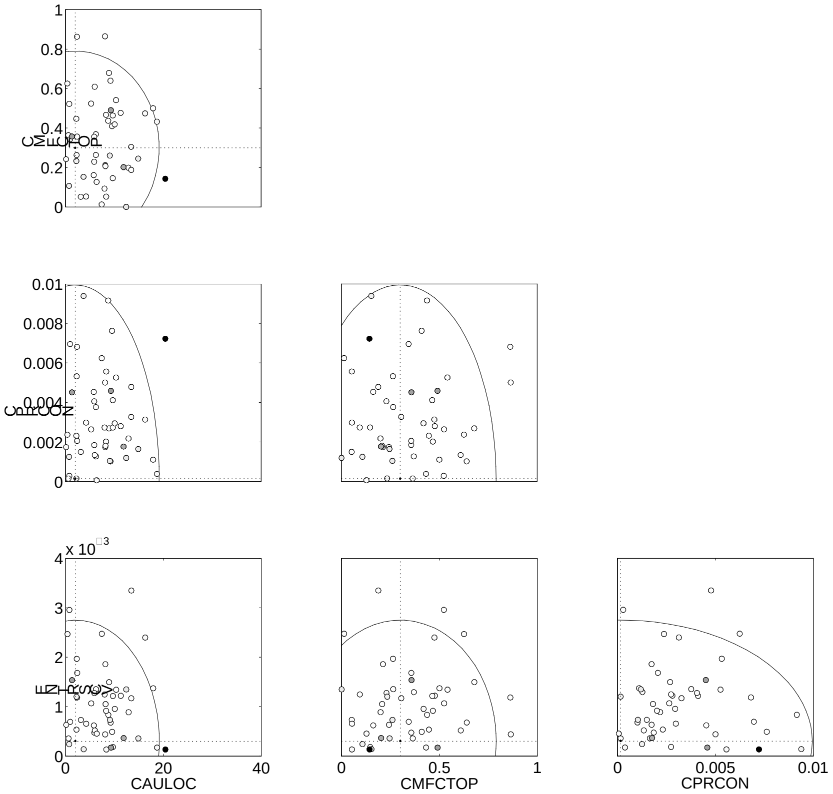
Parameter evolution in 180 consecutive ensembles



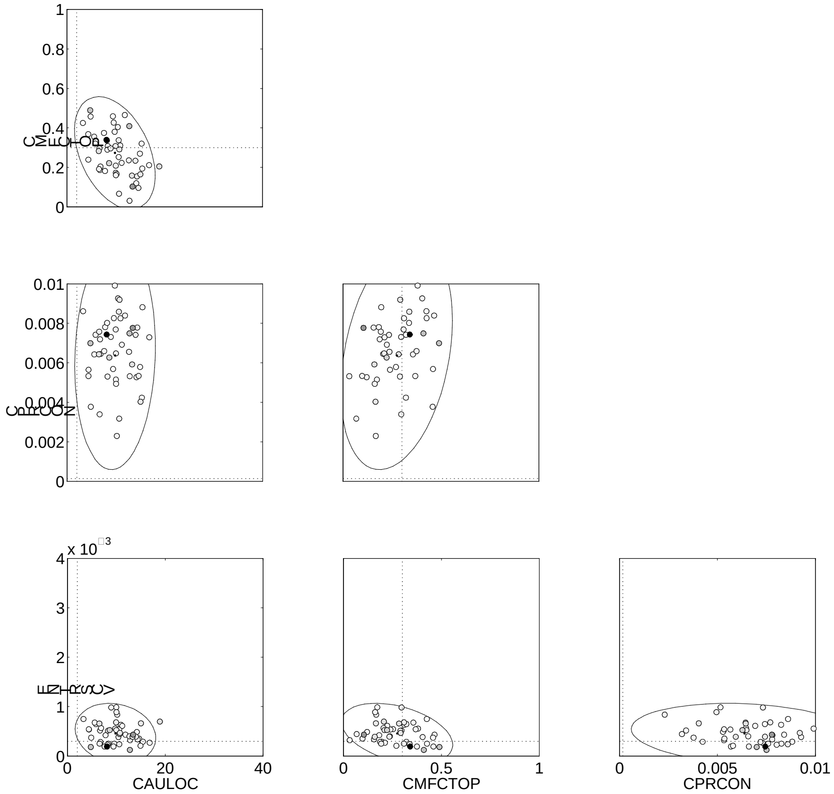
Proposed (grey) and re-sampled (black) parameter distribution mean value μ (red) and $\mu \pm 2\times$standard deviation (green) only every fourth ensemble is plotted.

Pair-wise parameter uncertainties

As specified intially



As estimated (180 steps)



Validation of the 500 hPa height forecast skill

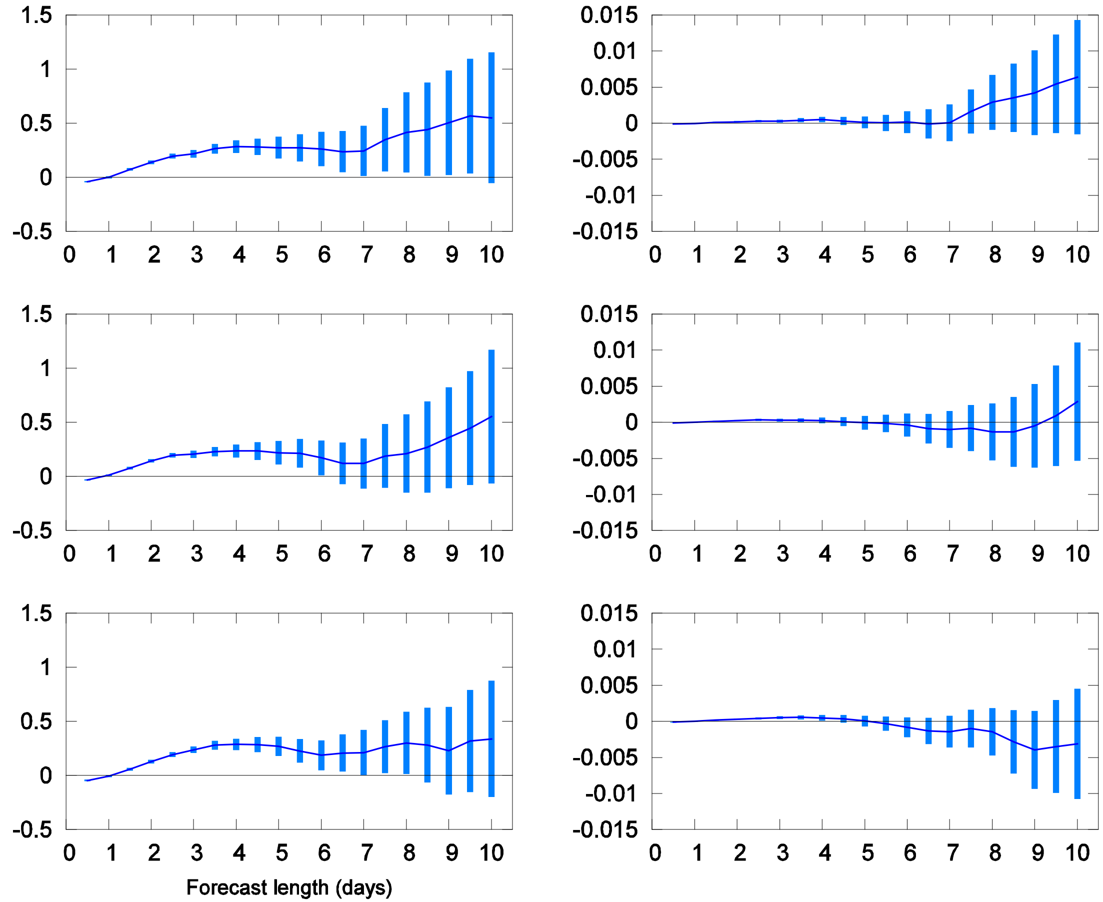
(skill difference OPT vs. DEF; above zero, good for OPT)

RMSE | **ACC**

"Training" sample (Jan-Mar 2011)

Independent sample (April 2011)

Independent sample (Jan-Mar 2010)



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Validation of model climate

Time-latitude cross-section

Blue/red colour implies bias w.r.t. CERES and ISCCP data

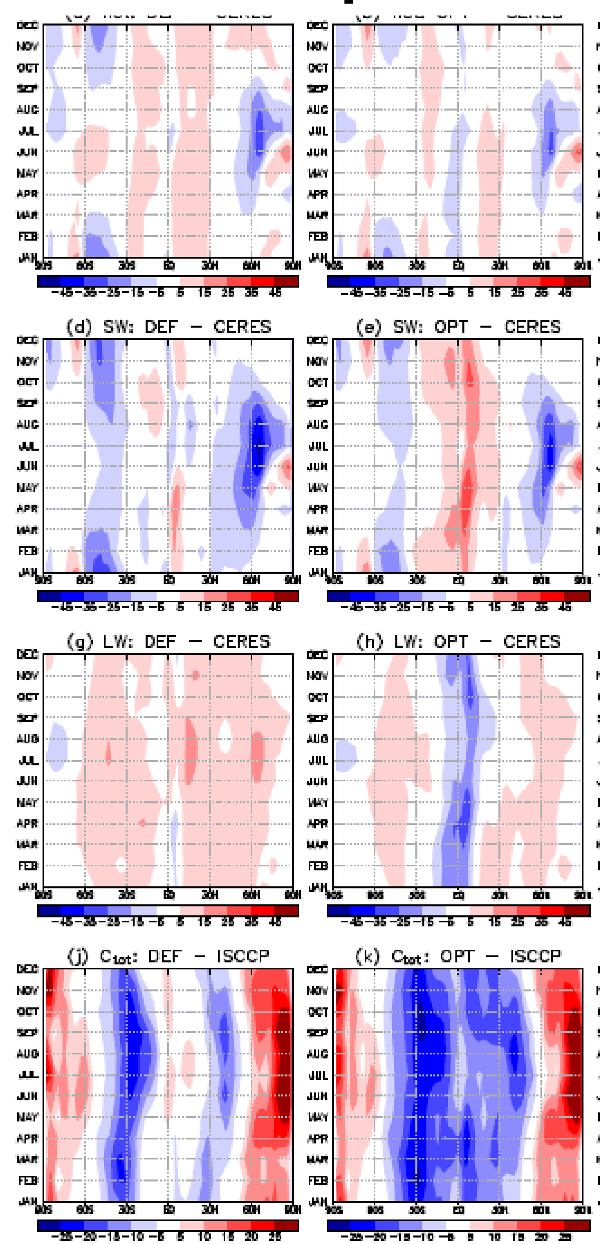
Default **Optimized**

Net ToA flux

SW ToA

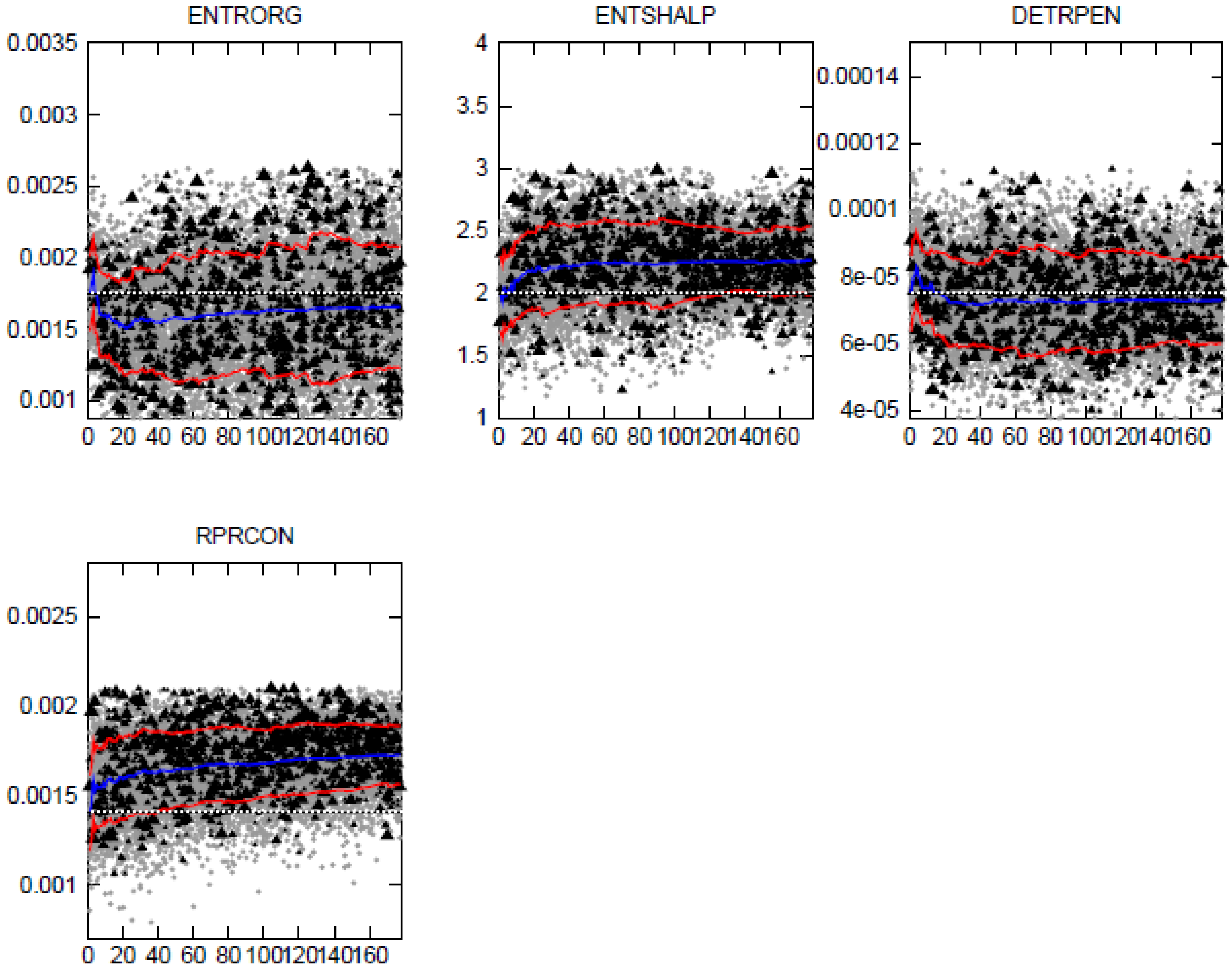
LW ToA

Cloud TOT



ECMWF Integrated Forecasting System

- **Implemented to the IFS CY37R3 by Pirkka Ollinaho, together with Peter Bechtold and Martin Leutbecher**
- **Initial experimentation very encouraging**


ENTRORG
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DETRPEN
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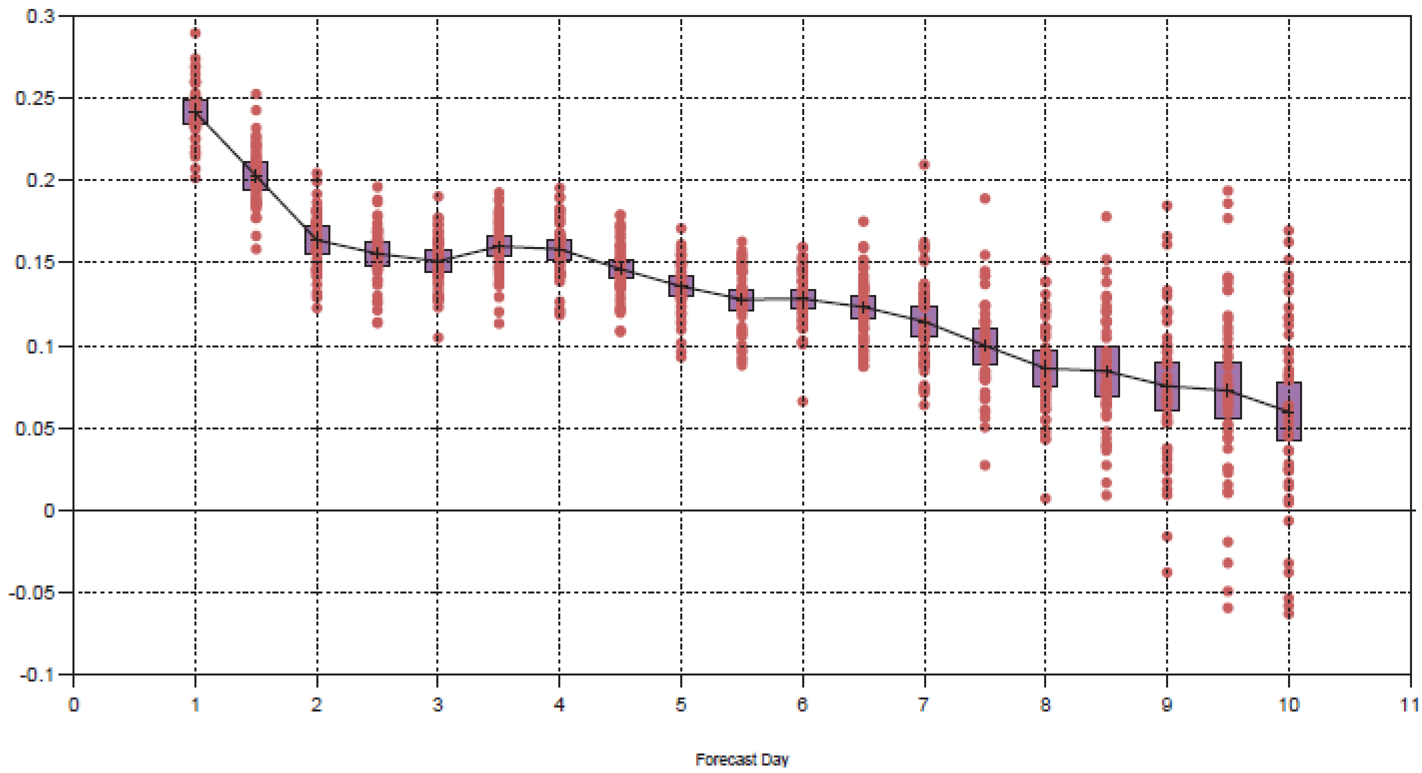
8e-05
6e-05
4e-05
0 20 40 60 80 100120140160
RPRCON
0.0025
0.002
0.0015
0.001
0 20 40 60 80 100120140160

500 geopotential height (IFS CY38R1 T159L60)
Mean error, tropics
Confidence 95%, population 45
Summer 2011



Conclusions and open questions

- **EPPES seems a robust method**
- **It is easy to implement to existing EPS systems**
- **It does not add computing cost (on top of EPS)**
- **It can be used as a support tool in decisions making**

- **How to select model parameters and the cost function?**
- **How to scale/weight multi-criteria cost function?**
- **How to maintain the proper calibration of EPS?**

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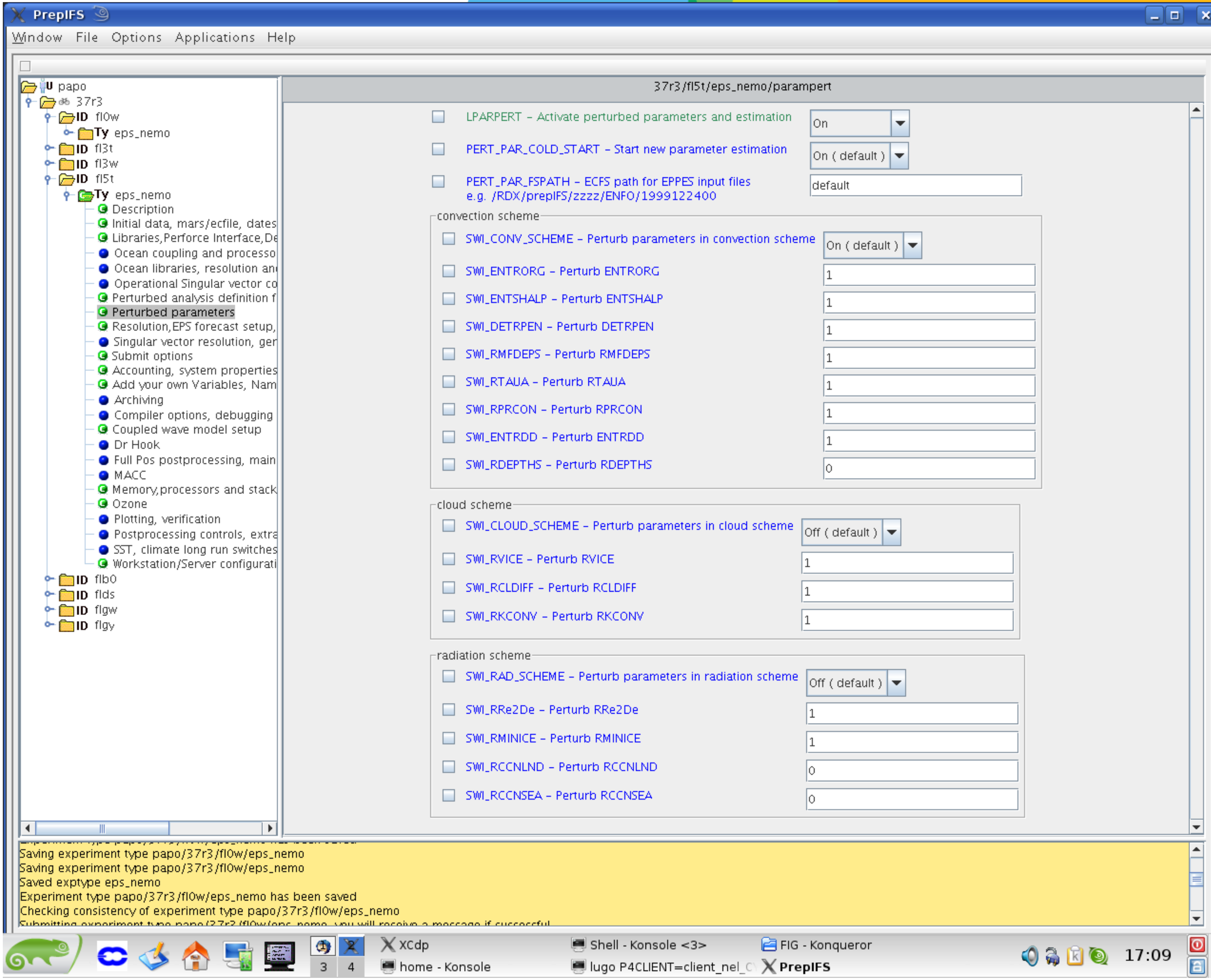
References:

Järvinen, H, Laine, M, Solonen, A and H Haario, 2011: Ensemble prediction and parameter estimation system: the concept. *Q. J. R. Meteorol. Soc.*, Early view, doi:10.1002/qj.923.

Laine, M, Solonen, A, Haario, H and H Järvinen, 2011: Ensemble prediction and parameter estimation system: the method. *Q. J. R. Meteorol. Soc.*, Early view, doi:10.1002/qj.922.

Ollinaho, P, Järvinen, H, Laine, M, Solonen, A and H Haario, 2012: NWP model forecast skill optimization via closure parameter variations. *Q. J. R. Meteorol. Soc.* (in review).


PrepIFS
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Description
Initial data, mars/ecfile, dates
Libraries,Perforce Interface,De
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Coupled wave model setup
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Ozone
Plotting, verification
Postprocessing controls, extra
SST, climate long run switches
Workstation/Server configurati
flb0
flds
flgw
flgy
37r3/fl5t/eps_nemo/parampert
LPARPERT – Activate perturbed parameters and estimation
On
PERT_PAR_COLD_START – Start new parameter estimation
On (default)
PERT_PAR_FSPATH – ECFS path for EPPES input files
e.g. /RDX/prepIFS/zzzz/ENFO/1999122400
default
convection scheme
SWI_CONV_SCHEME – Perturb parameters in convection scheme
On (default)
SWI_ENTRORG – Perturb ENTRORG
1
SWI_ENTSHALP – Perturb ENTSHALP
1
SWI_DETRPEN – Perturb DETRPEN
1
SWI_RMFDEPS – Perturb RMFDEPS
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SWI_RTAUA – Perturb RTAUA
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SWI_RPRCON – Perturb RPRCON
1
SWI_ENTRDD – Perturb ENTRDD
1
SWI_RDEPTHS – Perturb RDEPTHS
0
cloud scheme
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Off (default)
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1
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1
SWI_RKCONV – Perturb RKCONV
1
radiation scheme
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1
SWI_RMINICE – Perturb RMINICE
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SWI_RCCNLND – Perturb RCCNLND
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SWI_RCCNSEA – Perturb RCCNSEA
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Saving experiment type papo/37r3/fl0w/eps_nemo
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FIG - Konqueror
PrepIFS
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