Probabilistic assessment of regional climate change by ensemble dressing

2008 Joint Statistical Meetings
August 3rd 2008, Denver, CO

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Outline

Ensembles of global and regional climate simulations

Focus

Climate change signals from ensembles of global and regional climate models

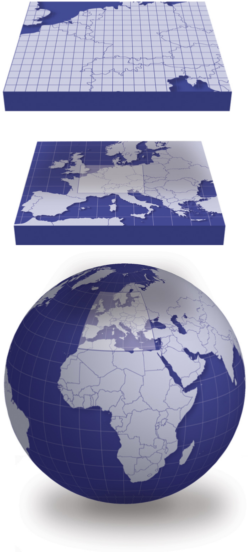
Regional climate model (CLM 4.2)

- Horizontal resolution: 7 km (Germany)
- Additional nesting: 50 km (Europe)

Global forcing ⇝ ensembles

General circulation models (IPCC AR4)

- ECHAM5-MPI/OM
- ECHO-G
- CCSM3.1



Outline

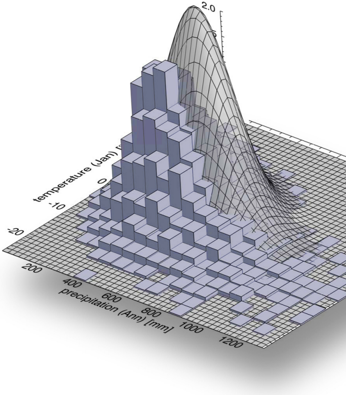
Making sense of ensemble simulations

Problem
Climate change signal with different sources of uncertainty

Question
How to translate ensembles into probabilistic information?

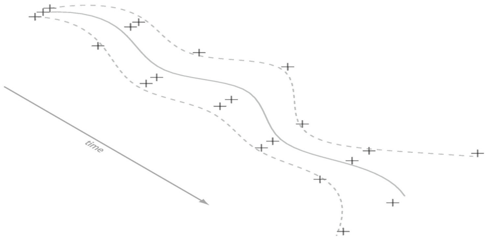
Outline

1. Ensemble post-processing in NWP and CC
2. Multivariate ensemble dressing
3. Application to ECHO-G simulations



Ensemble post-processing

Statistical post-processing of ensemble simulations



Notations

Ensemble simulations $j = 1, \ldots, n_{ens}$

Y	observations (y_i) / prediction (y)
$\vec{X} = (X_1, \ldots, X_{n_{ens}})^T$	ensemble members ($x_{ij}, \vec{x}$)

Ensemble prediction

...as conditional probability density $[Y|\vec{X}, \vec{\theta}]$ or $f_{ens}(y|\vec{x})$

Related approaches

Statistical post-processing of ensemble simulations

Regression methods

GDF: Gaussian DF interpretation

NGR: Non-homogeneous Gaussian regression

Ensemble dressing methods

SKD: Standard kernel dressing

GED: Gaussian ensemble dressing

AKD: Affine kernel dressing

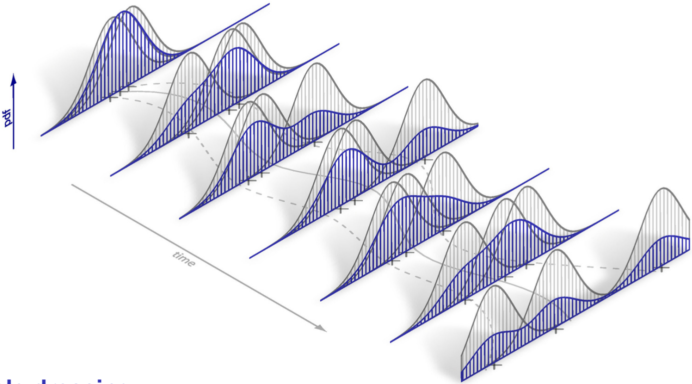
BMA: Bayesian model averaging

Bayesian approaches

Hierarchical Bayesian modeling, MCMC, . . .

Ensemble dressing

. . . e.g. standard kernel ensemble dressing



Ensemble dressing

Define a probability density (kernel) around each ensemble member X_j and average the resulting distributions

Ensemble dressing methods

Kernel dressing and Bayesian model averaging

Standard kernel dressing (SKD)

$$f_{ens}^{(SKD)}(y|\vec{x}) = \frac{1}{n_{ens}} \sum_{n_{ens}}^{j=1} f_K\left(\frac{y-(a\cdot x_j+\omega)}{\sigma_D}\right)$$

...with kernel f_K, scaling a, offset ω, and dressing variance σ_D

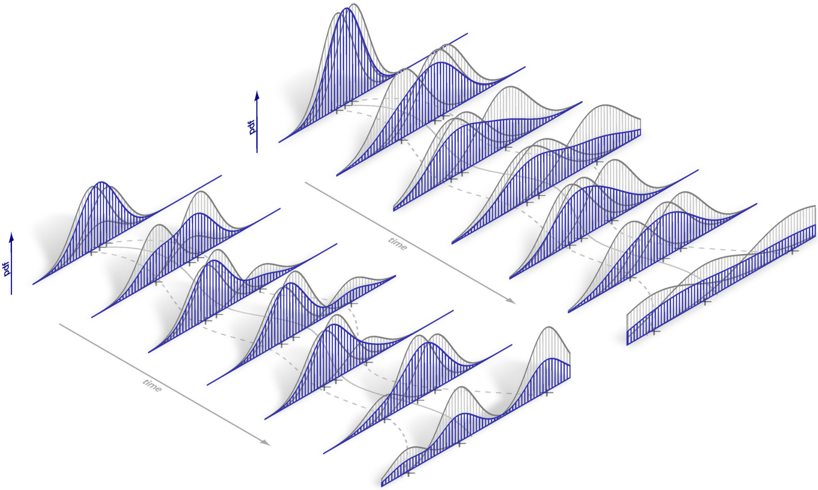
Bayesian model averaging (BMA)

$$f_{ens}^{(BMA)}(y|\vec{x}) = \frac{1}{n_{ens}} \sum_{n_{ens}}^{j=1} w_j \cdot f_K\left(\frac{y-(a\cdot x_j+\omega)}{\sigma_D}\right)$$

...is similar to SKD, but introduces weights w_j, the probability that X_j the best member

Ensemble dressing methods

Kernel dressing and Bayesian model averaging



Bayesian model averaging (left) and Affine kernel dressing (right)

Ensemble dressing methods

Different application w.r.t. NWP or CC

Standard kernel dressing (SKD)

- Dressing variance typically given by average error the best member
- Assume indistinguishable simulations

Bayesian model averaging (BMA)

- Estimate weights via Bayes factors or EM-algorithm
- Follows the idea of supporting the best member

Bröcker *et al.*, (2008): “Ensembles are merely a source of information rather than a possible scenario of reality”

Multivariate extension

A multivariate extension to Gaussian ensemble dressing

Multivariate extension

Multi-dimensional random vectors $\vec{Y}$ and $\vec{X}_j$ (e.g. space-time) with dressing (co)variance Σ_D

$$f_{ens}^{(mvt)}(\vec{y}|\vec{x}_1, \ldots, \vec{x}_{n_{ens}}) = \frac{1}{n_{ens}} \sum_{n_{ens}}^{j=1} f_K\left((\vec{y} - \vec{x}_j)^T \Sigma_D^{-1} (\vec{y} - \vec{x}_j)\right)$$

Note: $\vec{X}_j \sim \mathcal{N}(\ldots)$ but $\vec{Y} \nsim \mathcal{N}(\ldots)$

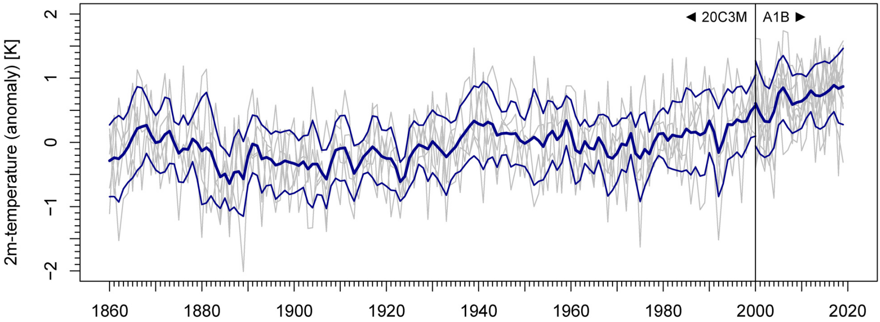
Practical application

. . . of multivariate Gaussian ensemble dressing

ECHO-G simulations

Ensemble members (T_{2m}, annual mean in 48°N–55°N and 5°E–15°E):

5	×	1860–2000	20C3M scenario
9	×	2000–2019	SRES A1B scenario

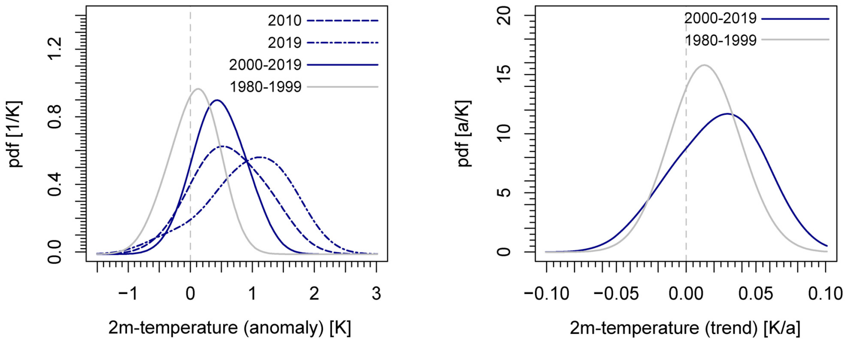


Trend estimation

. . . of multivariate Gaussian ensemble dressing

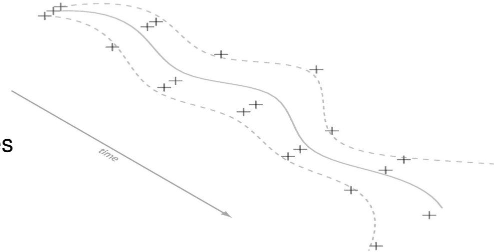
Trend estimation

- Estimate Σ_D from 20C3M-simulations
- Derive marginal distributions for mean and trend



Summary and Outlook

Future plans for application and development



Conclusions

- Conceptually different approaches to ensemble post-precessing
- Multivariate extension

Development

- Apply to CLM simulations
- Multivariate non-Gaussian kernel functions
- Bayesian framework

Acknowledgments. This work is part of the PArK project which is supported by the Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg (LUBW). The authors would also like to credit the contributors of the R project.

Navigation

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