



HAL
open science

Narrowing Uncertainties of Climate Projections using Data-driven Methods: the AMOC Case Study

Pierre Tandeo, Pierre Le Bras, Florian Sévellec, Pierre Ailliot, Juan Ruiz

► To cite this version:

Pierre Tandeo, Pierre Le Bras, Florian Sévellec, Pierre Ailliot, Juan Ruiz. Narrowing Uncertainties of Climate Projections using Data-driven Methods: the AMOC Case Study. NHM 2023: 6th International Workshop on Nonhydrostatic Models, Aug 2023, Sapporo, Japan. pp.1-13. hal-04193133

HAL Id: hal-04193133

<https://imt-atlantique.hal.science/hal-04193133v1>

Submitted on 4 Sep 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License



INSTITUT
UNIVERSITAIRE
EUROPÉEN
DE LA MER



Narrowing Uncertainties of Climate Projections using Data-driven Methods

The AMOC case study

Pierre Tandeo¹, Pierre Le Bras^{1,2}, Florian Sévellec², Pierre Ailliot³, and Juan Ruiz⁴

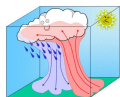
¹ Lab-STICC, IMT Atlantique, FRANCE

² Laboratoire d'Océanographie Physique et Spatiale, IUEM, FRANCE

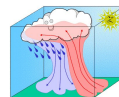
³ Laboratoire de Mathématiques de Bretagne Atlantique, UBO, FRANCE

⁴ Centro de Investigaciones del Mar y la Atmósfera, Univ. Buenos Aires, ARGENTINA

The 6th International Workshop on Nonhydrostatic Models (NHM-WS 2023)



31 August - 2 September 2023



Hokkaido University Conference Hall, Sapporo, Japan

Context: Atlantic Meridional Overturning Circulation (AMOC)

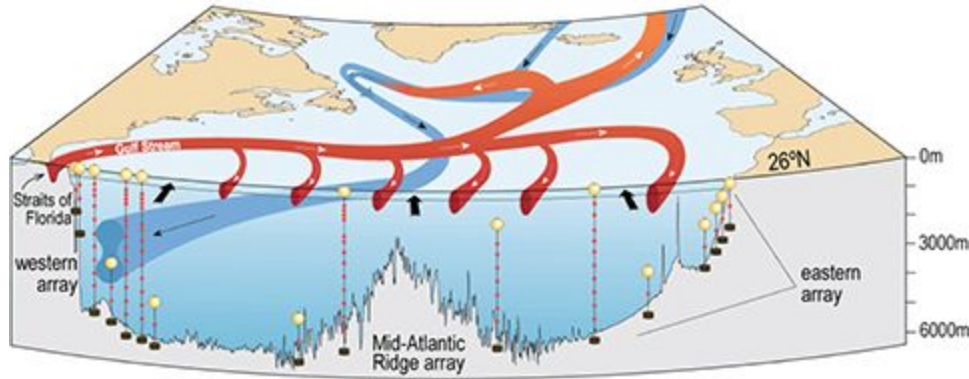


Fig.1: Schematic of AMOC
<http://www.noc.soton.ac.uk/rapidmoc/>

[Source:

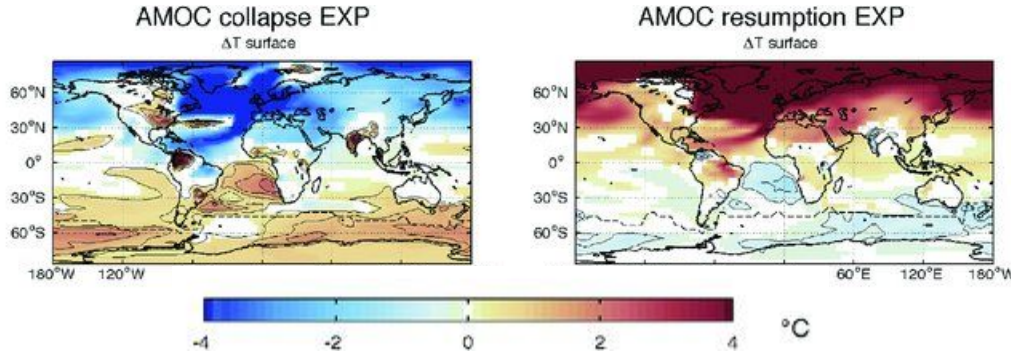


Fig.2: Experiences of AMOC collapse/resumption and influence on surface temperature anomalies
[Source: *Pedro et al., 2018*]

AMOC

- Circulation in the Atlantic ocean
 - Shallow warm water northward**
 - Deep cold water southward**
- Influence on climate of Atlantic regions
- Essential to monitor its evolution

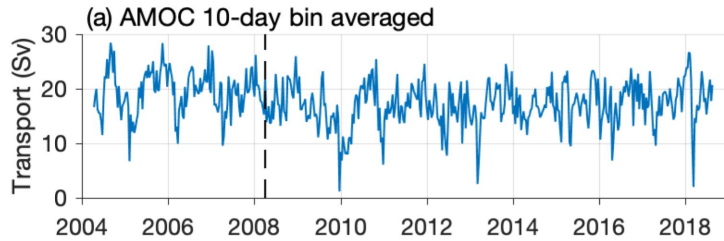


Fig.1: AMOC observations from RAPID/MOCHA system
[Source: Moat et al., 2020]

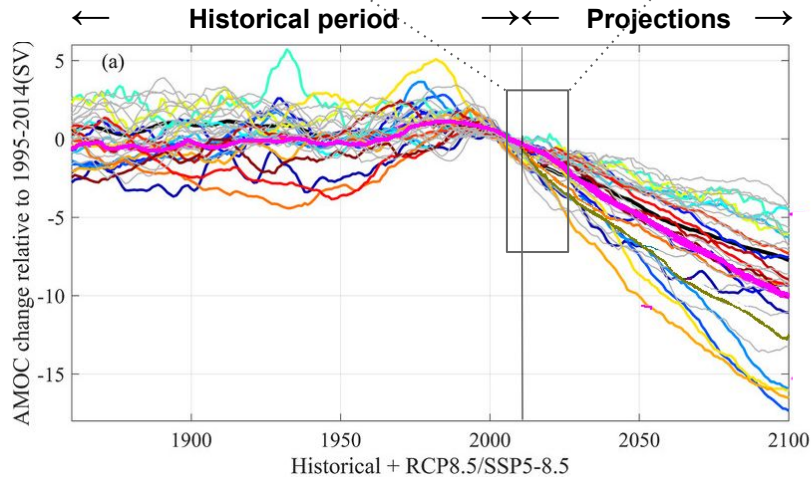


Fig.2: AMOC anomalies from different models (SSP5-8.5 in CMIP5-6)
[Source: Lyu and Church, 2020]

Observations:

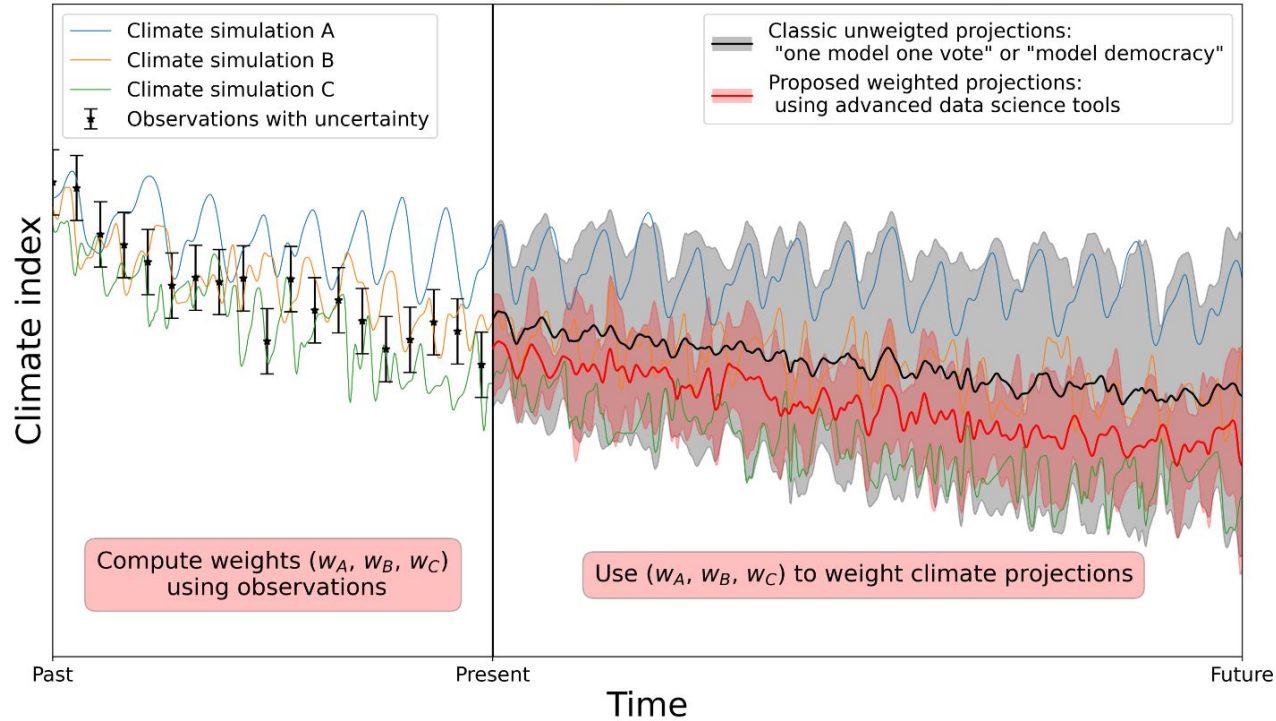
- Seasonal and interannual variability
- Hard to measure, lot of noise

CMIP Model projections:

- **Models predict severe decrease of the AMOC**
- **Wide spread** (model uncertainty)

How to improve accuracy
and reliability of AMOC projections?

Aim of this study: compute weights to constraint climate projections



State of the art

- Model democracy (same weights)
- Questionable (e.g., Knutti et al., 2019)

Our goal

- Weight the projections
- Using available simulations and observations
- Reduce the uncertainty

Proposed methodology: combination of data assimilation and machine learning

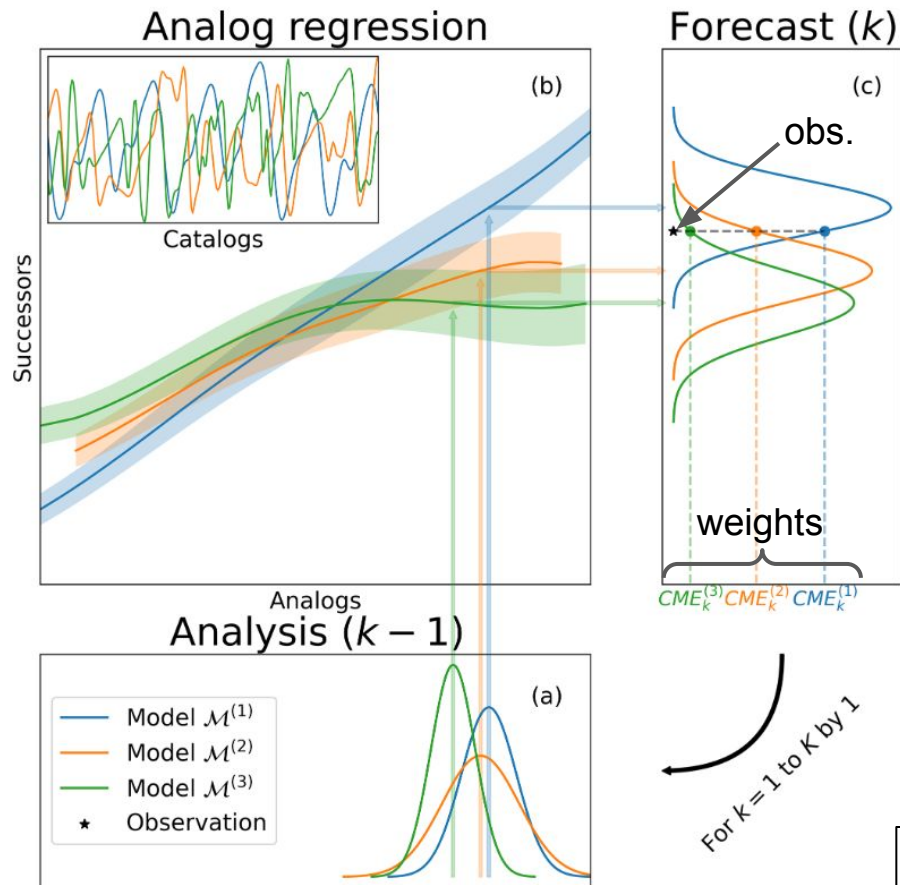


Fig.1: Scheme of the methodology
[Source: Ruiz et al., 2022]

Step (a): Data assimilation

- start from an accurate initial condition
- Ensemble Kalman filter (EnKF)

Step (b): Data-driven forecast

- make forecasts without equations
- analog method

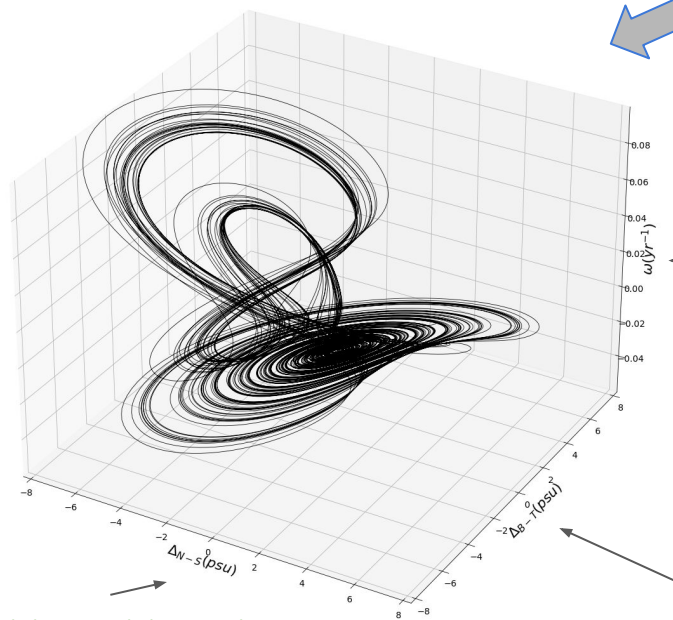
Step (c): Weighting procedure

- compute observation-forecast distance
- contextual model evidence (CME)

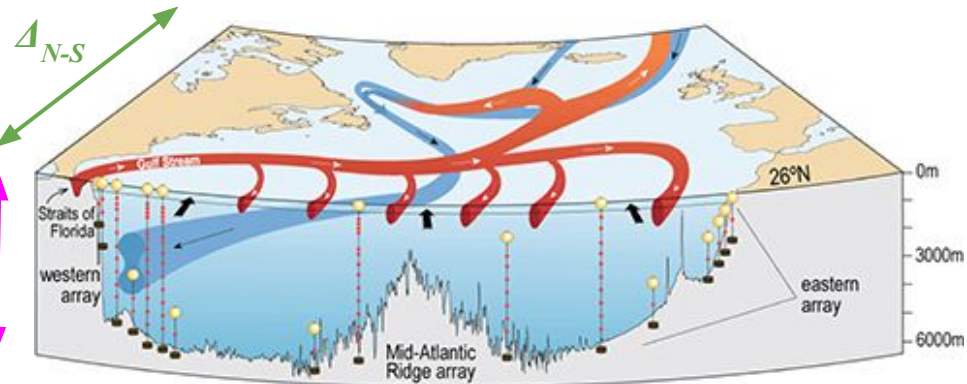
Ruiz, J., Ailliot, P., Chau, T. T. T., Le Bras, P., Monbet, V., Sévellec, F., & Tandeo, P. (2022). Analog data assimilation for the selection of suitable general circulation models. *Geoscientific Model Development*, 15(18), 7203-7220.

3-variable AMOC chaotic model

(Sévellec and Fedorov, 2014)



Δ_{B-T} : Stratified salinity



ω
overturning strength

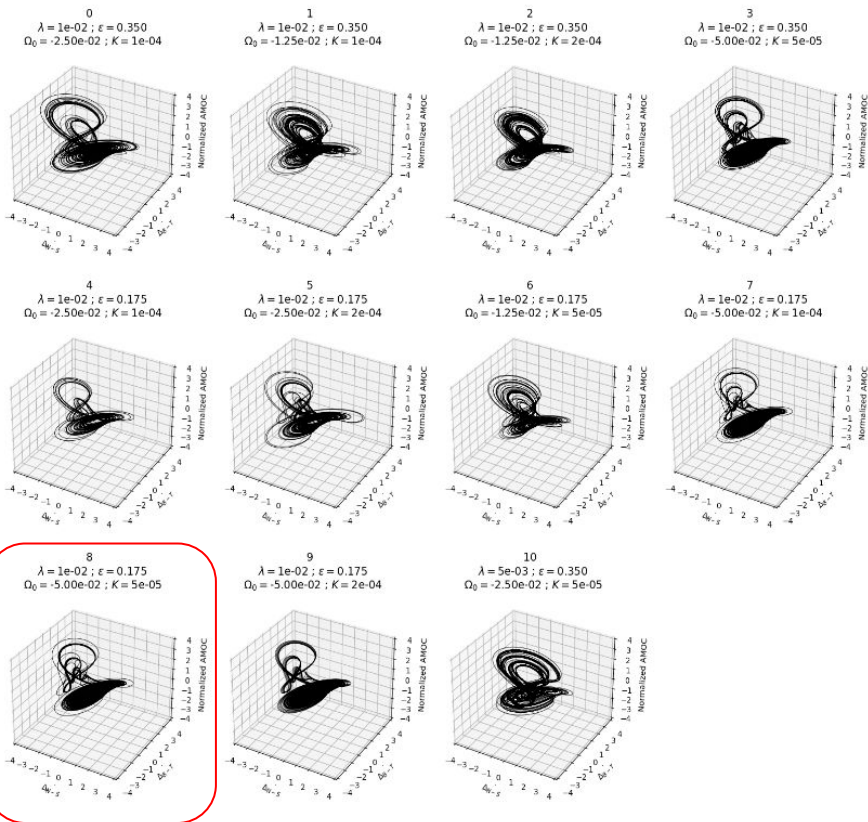
$$\frac{d\omega}{dt} = -\lambda\omega - \epsilon\beta S_{NS},$$

$$\frac{dS_{BT}}{dt} = (\Omega_0 + \omega) S_{NS} - K S_{BT} + \frac{F_0 S_0}{h},$$

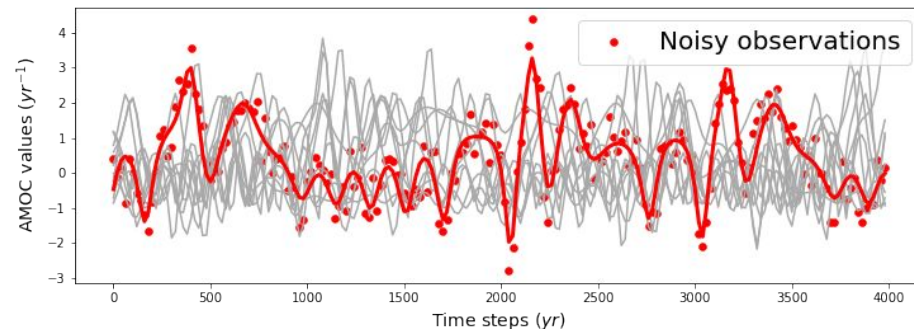
$$\frac{dS_{NS}}{dt} = -(\Omega_0 + \omega) S_{NS} - K S_{NS}$$

Δ_{N-S} : Meridional salinity gradient

Experimental set up: generation of different versions of the idealized AMOC model

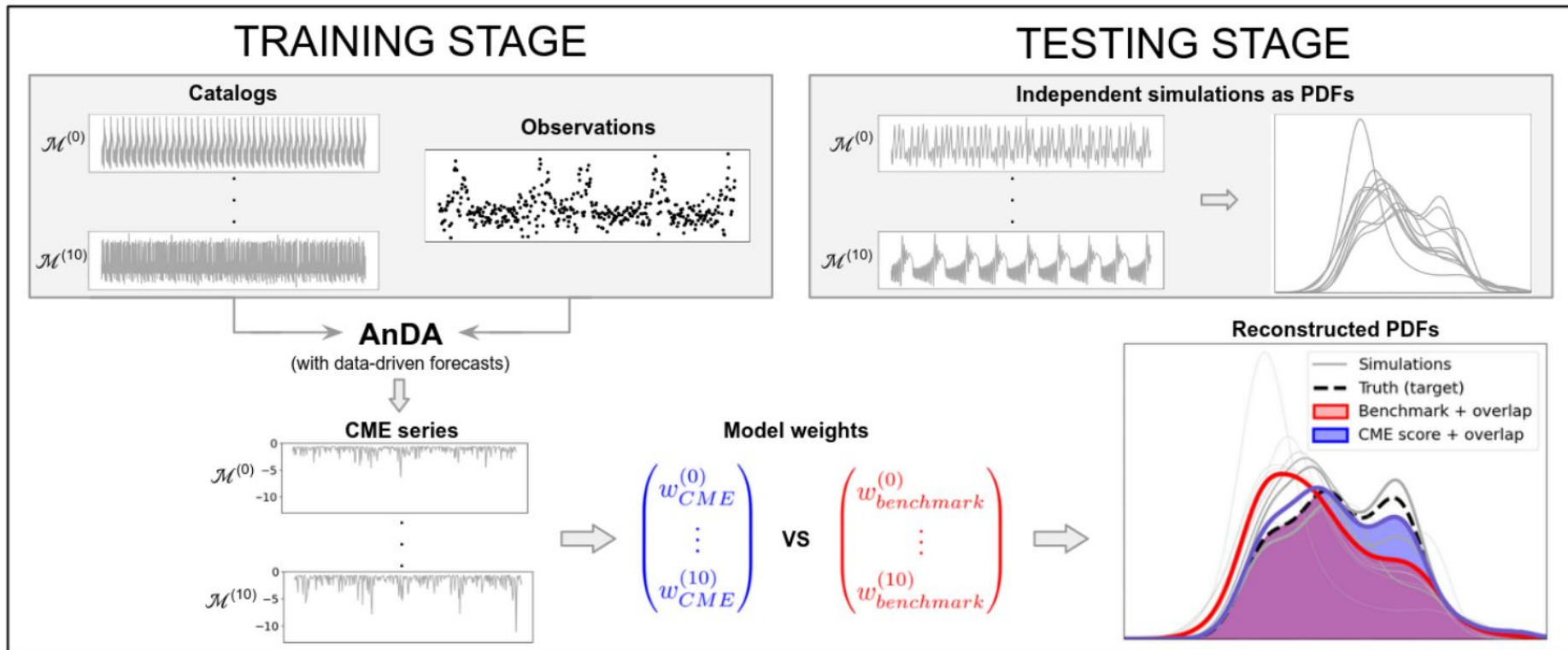


- 11 perturbed-parameter versions
- Leave-One-Out strategy
- Mimic 10 climate simulations and **1 observation**



Schematic of the Leave-One-Out strategy

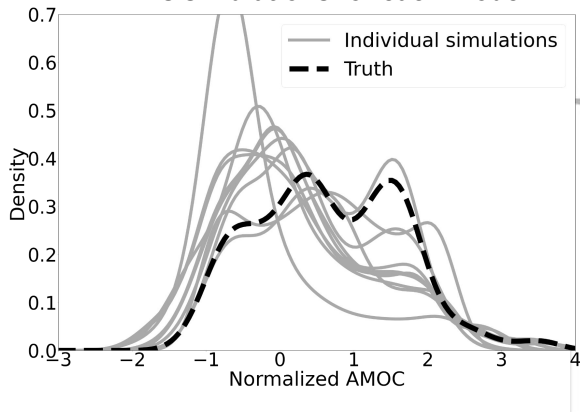
- Compute 10 weights
- Approximate observation distribution



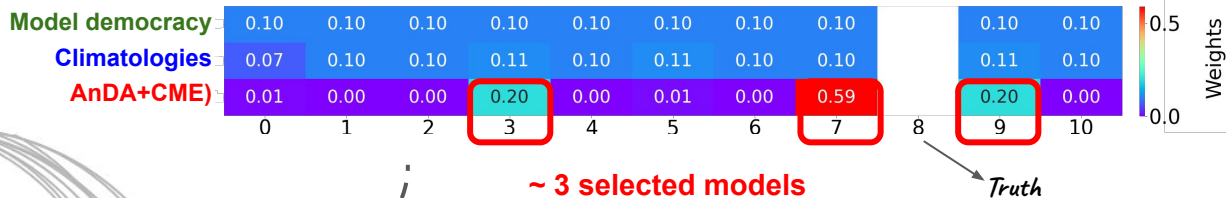
Application results for one experiment: applying the weights to reconstruct the truth

→ Out-of-training simulations

PDFs simulations for each model

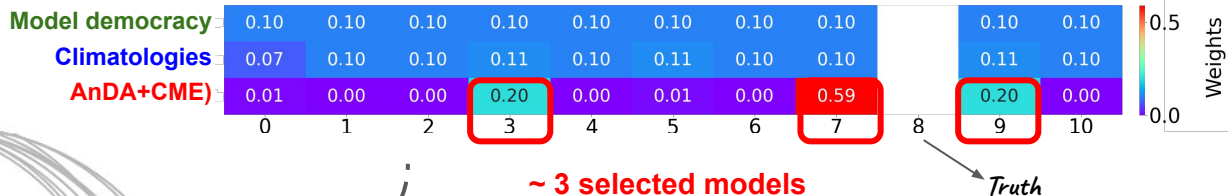
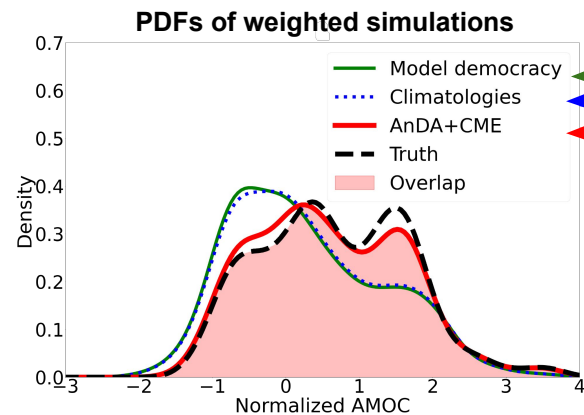
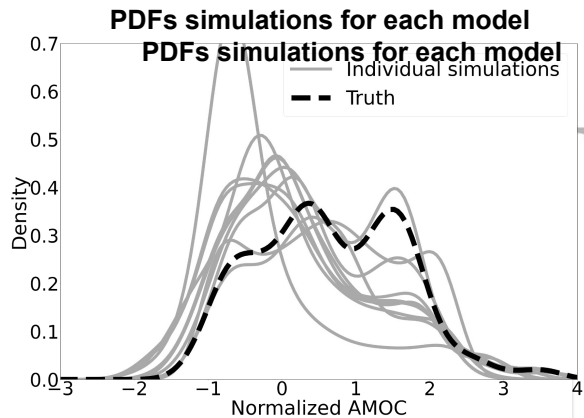


Attributed weights to each model



Application results for one experiment: applying the weights to reconstruct the truth

→ Out-of-training simulations



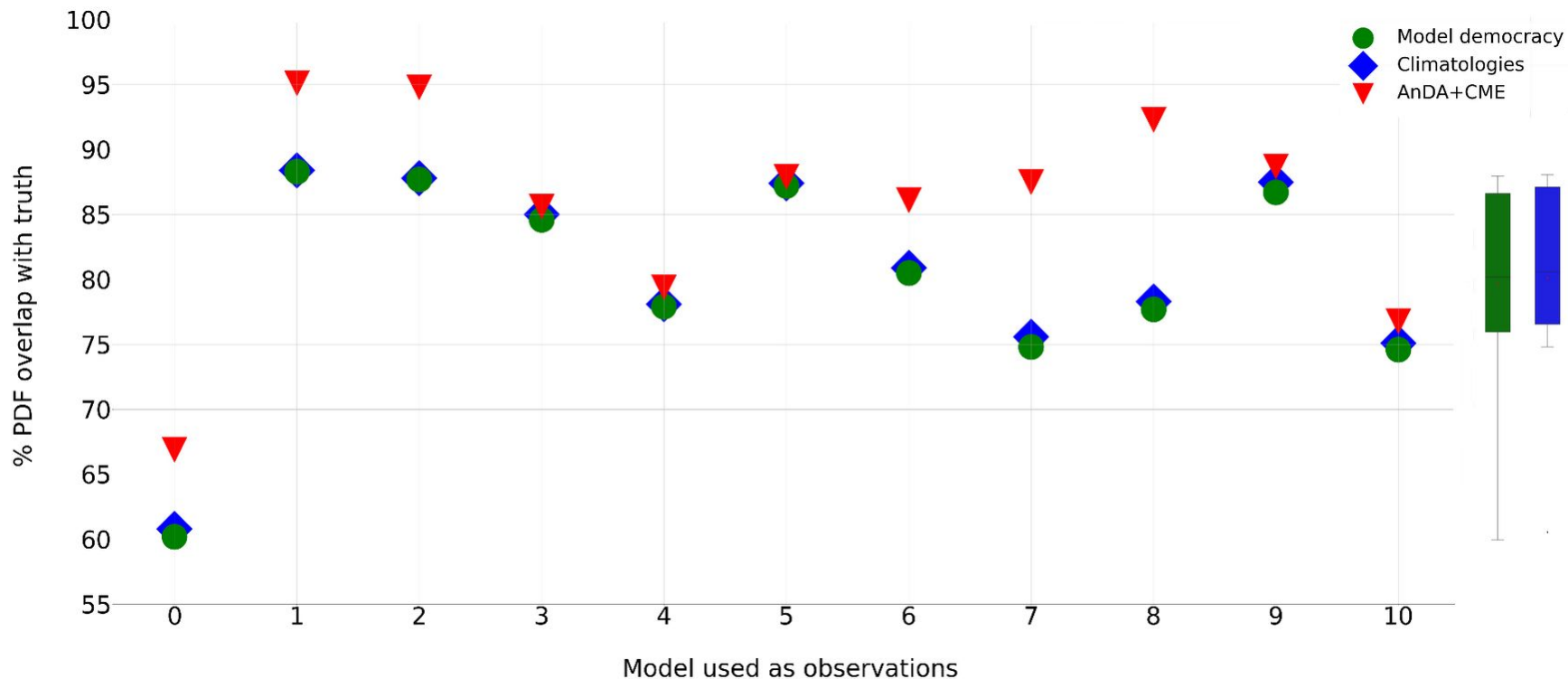
Weighting

Results: reconstruction skillness

% PDFs overlap	One experiment
Model democracy	77.6
Climatologies	78.3 (+0.7)
AnDA+CME	92.3 (+14.7)

AnDA with CME outperforms model democracy

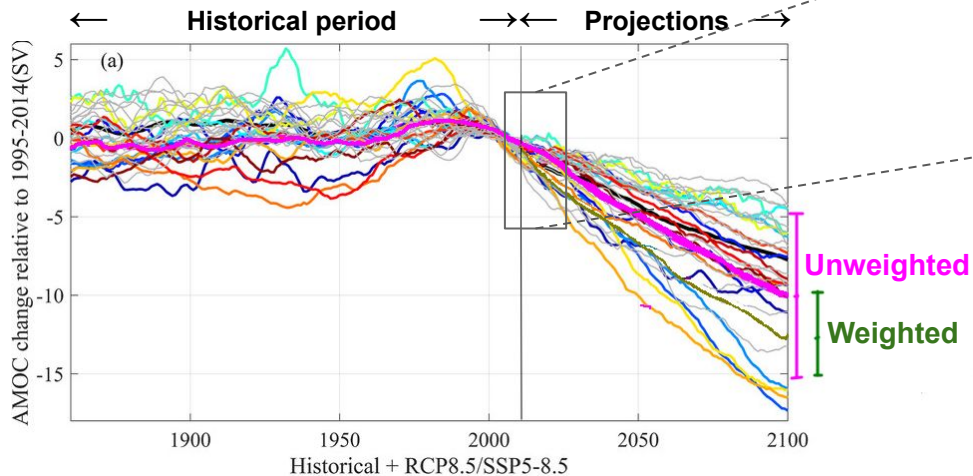
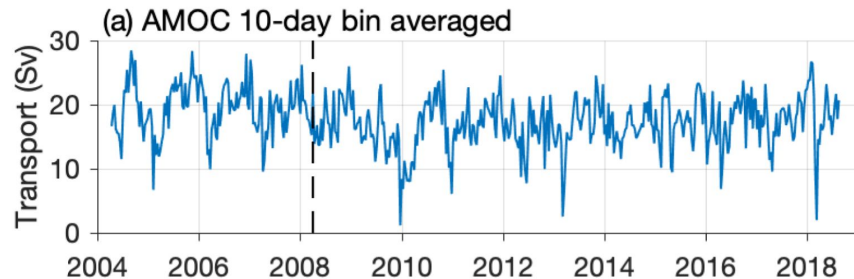
LOO results: % PDF overlap between each weighted PDF and the true one



AnDA with CME performs at least as good as model democracy

Conclusion & perspectives

- **Weight climate simulations using noisy observations**
- **Data-driven approach (no need to run climate models)**
- **Combination of Data Assimilation & Machine Learning**
- **Application to synthetic data of the AMOC**
- **The proposed method outperforms “model democracy”**



Article


Articles / Volume 15, Issue 18 / GMD, 15, 7203–7220, 2022

Search

<https://doi.org/10.5194/gmd-15-7203-2022>
 © Author(s) 2022. This work is distributed under the Creative Commons Attribution 4.0 License.

Methods for assessment of models | 

Analog data assimilation for the selection of suitable general circulation models

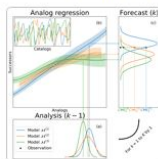
Juan Ruiz , Pierre Ailliot, Thi Tuyet Trang Chau, Pierre Le Bras, Valérie Monbet, Florian Sévellec, and Pierre Tandeo

Abstract

Data assimilation is a relevant framework to merge a dynamical model with noisy observations. When various models are in competition, the question is to find the model that best matches the observations. This matching can be measured by using the model evidence, defined by the likelihood of the observations given the model. This study explores the performance of model selection based on model evidence computed using data-driven data assimilation, where dynamical models are emulated using machine learning methods. In this work, the methodology is tested with the three-variable Lorenz model and with an intermediate complexity atmospheric general circulation model (a.k.a. the SPEEDY model). Numerical experiments show that the data-driven implementation of the model selection algorithm performs as well as the one that uses the dynamical model. The technique is able to select the best model among a set of possible models and also to characterize the spatiotemporal variability of the model sensitivity. Moreover, the technique is able to detect differences among models in terms of local dynamics in both time and space which are not reflected in the first two moments of the climatological probability distribution. This suggests the implementation of this technique using available long-term observations and model simulations.

 
[Article](#) | [Assets](#) | [Peer review](#) | [Metrics](#) | [Related articles](#)

26 Sep 2022



Download

- ▶ Article (6128 KB)
- ▶ Full-text XML
- ▶ BibTeX
- ▶ EndNote

Short summary

We present a new approach to validate numerical simulations of the current climate. The method...
 ▶ Read more

Share



Similar articles

-  ModE-Sim – a medium-sized atmospheric... Hand et al.
-  MESMAR v1: a new regional coupled climate... Storto et al.

ありがとうございます!
 arigato gozaimasu!

Contact:

<https://tandeo.wordpress.com/>
pierre.tandeo@imt-atlantique.fr