b
UNIVERSITÄT
BERN

OESCHGER CENTRE
CLIMATE CHANGE RESEARCH

The PALAEO-RA project

Combining an intermediate-size AGCM ensemble with historical observations and proxies to create a new dataset of the past 600 years of climate history

Stefan Brönnimann, Ralf Hand, Jörg Franke, Veronika Valler, and Andrey Martynov

Institute of Geography (Climatology Dpt.) & Oeschger Centre for Climate Change Research

2020-05-08, #shareEGU20

European Research Council
Established by the European Commission

UNIVERSITÄT
BERN

OESCHGER CENTRE
CLIMATE CHANGE RESEARCH

Motivation & Overview

UNIVERSITÄT BERN
OESCHGER CENTRE CLIMATE CHANGE RESEARCH

In PALAEO-RA we combine an ensemble of model simulations with historical simulations to create a new, global, monthly, physically consistent, 3-dimensional data set for the climate of the past 600 years:

Understanding the climate of the past is crucial to improve the knowledge about the underlying processes and, consequently, to improve climate predictions

To reach this aim, we can use:

Motivation & Overview

UNIVERSITÄT BERN
OESCHGER CENTRE
CLIMATE CHANGE RESEARCH

In PALAEO-RA we combine an ensemble of model simulations with historical simulations to create a new, global, monthly, physically consistent, 3-dimensional data set for the climate of the past 600 years:

Understanding the climate of the past is crucial to improve the knowledge about the underlying processes and, consequently, to improve climate predictions

To reach this aim, we can use:

Historical Observations,…

Motivation & Overview

In PALAEO-RA we combine an ensemble of model simulations with historical simulations to create a new, global, monthly, physically consistent, 3-dimensional data set for the climate of the past 600 years:

Understanding the climate of the past is crucial to improve the knowledge about the underlying processes and, consequently, to improve climate predictions

To reach this aim, we can use:

Historical Observations,…

☺ They represent „real“ states of the climate system at a certain time.

Motivation & Overview

In PALAEO-RA we combine an ensemble of model simulations with historical simulations to create a new, global, monthly, physically consistent, 3-dimensional data set for the climate of the past 600 years:

Understanding the climate of the past is crucial to improve the knowledge about the underlying processes and, consequently, to improve climate predictions

To reach this aim, we can use:

Historical Observations,…

☺ They represent „real" states of the climate system at a certain time.

☹ But they suffer from uncertainties and being temporarly and spatially sparse.

Motivation & Overview

In PALAEO-RA we combine an ensemble of model simulations with historical simulations to create a new, global, monthly, physically consistent, 3-dimensional data set for the climate of the past 600 years:

Understanding the climate of the past is crucial to improve the knowledge about the underlying processes and, consequently, to improve climate predictions

To reach this aim, we can use:

Historical Observations,…

☺ They represent „real“ states of the climate system at a certain time.

☹ But they suffer from uncertainties and being temporarly and spatially sparse.

or

Climate Models,…

Motivation & Overview

In PALAEO-RA we combine an ensemble of model simulations with historical simulations to create a new, global, monthly, physically consistent, 3-dimensional data set for the climate of the past 600 years:

Understanding the climate of the past is crucial to improve the knowledge about the underlying processes and, consequently, to improve climate predictions

To reach this aim, we can use:

Historical Observations,…

☺ They represent „real" states of the climate system at a certain time.

☹ But they suffer from uncertainties and being temporarly and spatially sparse.

or

Climate Models,…

☺ They are a useful tool to understand physical processes in the climate system.

Motivation & Overview

UNIVERSITÄT BERN
OESCHGER CENTRE CLIMATE CHANGE RESEARCH

In PALAEO-RA we combine an ensemble of model simulations with historical simulations to create a new, global, monthly, physically consistent, 3-dimensional data set for the climate of the past 600 years:

Understanding the climate of the past is crucial to improve the knowledge about the underlying processes and, consequently, to improve climate predictions

To reach this aim, we can use:

Historical Observations,...

☺ They represent „real“ states of the climate system at a certain time.

☹ But they suffer from uncertainties and being temporarly and spatially sparse.

or

Climate Models,...

☺ They are a useful tool to understand physical processes in the climate system.

☹ But individual simulations only represent a „possible state“ of the climate system, rather than „reality“.

Motivation & Overview

b
UNIVERSITÄT
BERN

OESCHGER CENTRE
CLIMATE CHANGE RESEARCH

In PALAEO-RA we combine an ensemble of model simulations with historical simulations to create a new, global, monthly, physically consistent, 3-dimensional data set for the climate of the past 600 years:

Understanding the climate of the past is crucial to improve the knowledge about the underlying processes and, consequently, to improve climate predictions

To reach this aim, we can use:

Historical Observations,…

☺ They represent „real“ states of the climate system at a certain time.

☹ But they suffer from uncertainties and being temporarly and spatially sparse.

~~or~~ **and**

Climate Models,…

☺ They are a useful tool to understand physical processes in the climate system.

☹ But individual simulations only represent a „possible state“ of the climate system, rather than „reality“.

Data Assimilation,…

… allows to to combine informations from models and observations.

Motivation & Overview

In PALAEO-RA we combine an ensemble of model simulations with historical simulations to create a new, global, monthly, physically consistent, 3-dimensional data set for the climate of the past 600 years:

Understanding the climate of the past is crucial to improve the knowledge about the underlying processes and, consequently, to improve climate predictions

To reach this aim, we can use:

In PALEO-RA we use different kinds of observations to combine them into a comprehensive dataset for covering the past 600 years. See slide 4 for details on our observations!

Historical Observations,…

☺ They represent „real“ states of the climate system at a certain time.

☹ But they suffer from uncertainties and being temporarly and spatially sparse.

~~or~~ **and**

Climate Models,…

☺ They are a useful tool to understand physical processes in the climate system.

☹ But individual simulations only represent a „possible state“ of the climate system, rather than „reality“.

Data Assimilation,…

… allows to to combine informations from models and observations.

Motivation & Overview

UNIVERSITÄT BERN

OESCHGER CENTRE
CLIMATE CHANGE RESEARCH

In PALAEO-RA we combine an ensemble of model simulations with historical simulations to create a new, global, monthly, physically consistent, 3-dimensional data set for the climate of the past 600 years:

Understanding the climate of the past is crucial to improve the knowledge about the underlying processes and, consequently, to improve climate predictions

To reach this aim, we can use:

In PALEO-RA we use different kinds of observations to combine them into a comprehensive dataset for covering the past 600 years. See slide 4 for details on our observations!

Historical Observations,…

☺ They represent „real“ states of the climate system at a certain time.

☹ But they suffer from uncertainties and being temporarly and spatially sparse.

~~or~~ **and**

Climate Models,…

☺ They are a useful tool to understand physical processes in the climate system.

☹ But individual simulations only represent a „possible state“ of the climate system, rather than „reality“.

In PALEO-RA we use a 30+ member ensemble of simulations with an atmospheric general circulation model to represent the range of realistic atmospheric states under a transient forcing and to aquire informations about spatial correlations. See slides 5 & 6 for details on our simulations!

Data Assimilation,…

… allows to combine informations from models and observations.

Motivation & Overview

UNIVERSITÄT BERN

OESCHGER CENTRE CLIMATE CHANGE RESEARCH

In PALAEO-RA we combine an ensemble of model simulations with historical simulations to create a new, global, monthly, physically consistent, 3-dimensional data set for the climate of the past 600 years:

Understanding the climate of the past is crucial to improve the knowledge about the underlying processes and, consequently, to improve climate predictions

To reach this aim, we can use:

In PALEO-RA we use different kinds of observations to combine them into a comprehensive dataset for covering the past 600 years. See slide 4 for details on our observations!

Historical Observations,…

☺ They represent „real“ states of the climate system at a certain time.

☹ But they suffer from uncertainties and being temporarly and spatially sparse.

~~or~~ **and**

Climate Models,…

☺ They are a useful tool to understand physical processes in the climate system.

☹ But individual simulations only represent a „possible state“ of the climate system, rather than „reality“.

In PALEO-RA we use a 30+ member ensemble of simulations with an atmospheric general circulation model to represent the range of realistic atmospheric states under a transient forcing and to aquire informations about spatial correlations. See slides 5 & 6 for details on our simulations!

Data Assimilation,…

… allows to to combine informations from models and observations.

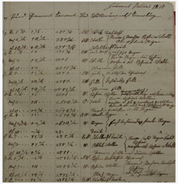
In PALEO-RA we will use Ensemble Kalman Fitting to combine the historical observations with the ensemble of model simulations. See slide 7 for details on our assimilation procedure!

The Observations

A comprehensive set of historical climate data

In PALAEO-RA we combine different types of data into one large database:

Historical data



© University of Bern

We will assimilate monthly resolved temperature, precipitations and sea level pressure data from existing existing as well as newly digitized early instrumental data and documentary data (e.g. cherry blossom and grape harvest dates) and complement them with newly digitized data.

Climate proxies

Arnoldius (Wikimedia commons)

Additionally we use annually resolved climate proxies, e.g. tree rings and corals.

The Model Set Up

Configuration of our experiments

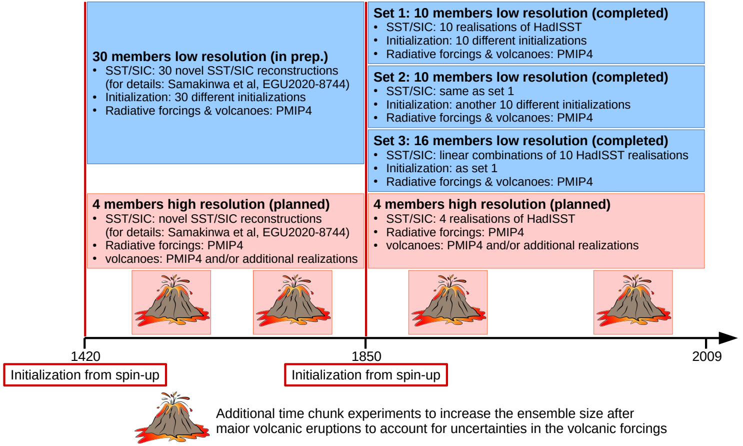
UNIVERSITÄT BERN
OESCHGER CENTRE
CLIMATE CHANGE RESEARCH

We will use an atmospheric general circulation model with prescribed SST and Sea Ice forcings.
ECHAM 6.3.05-LR horizontal resolution: T63 vertical resolution: L47
ECHAM 6.3.05-HR (to be used in a later project phase) horizontal resolution: T127 vertical resolution: L47
Configuration was choosen to be +/- consistent with the PMIP4 past 2k simulations, but...

- ... with prescribed ocean conditions (instead of a dynamically coupled ocean)
- ... without dynamic vegetation

The Ensemble

30+ members for the past 600 years



The simulations are supposed to represent the range of atmospheric states that is possible under given boundary conditions.

The Application: Ensemble Kalman Fitting

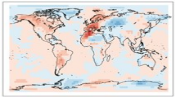
An offline approach for the serial assimilation of observations

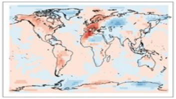
UNIVERSITÄT
BERN

OESCHGER CENTRE
CLIMATE CHANGE RESEARCH

Example for the assimilation of an observation in the mediterranean region

We start from the the **uncorrected ensemble mean**.





The Application: Ensemble Kalman Fitting

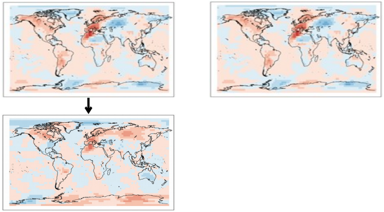
An offline approach for the serial assimilation of observations

UNIVERSITÄT BERN
OESCHGER CENTRE
CLIMATE CHANGE RESEARCH

Example for the assimilation of an observation in the mediterranean region

We start from the the **uncorrected ensemble mean**.

The **background error covariance matrix** was computed from the ensemble. It represents spatial correlations of the deviation from the ensemble mean in a distinct grid cell with the anomalies in all other grid cells.



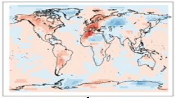
The Application: Ensemble Kalman Fitting

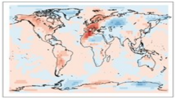
An offline approach for the serial assimilation of observations

UNIVERSITÄT BERN
OESCHGER CENTRE
CLIMATE CHANGE RESEARCH

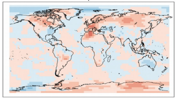
Example for the assimilation of an observation in the mediterranean region

We start from the the **uncorrected ensemble mean**.

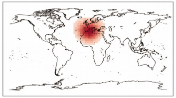




The **background error covariance matrix** was computed from the ensemble. It represents spatial correlations of the deviation from the ensemble mean in a distinct grid cell with the anomalies in all other grid cells.



To eliminate effects from spurious correlation with grid cells far away, we additionally apply a **localization matrix** that gives high weights to grid cells in the close neighbourhoud and zero weight to grid cells far away.



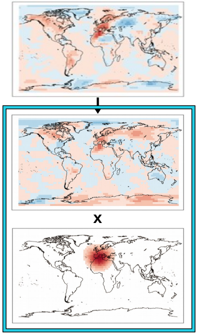
The Application: Ensemble Kalman Fitting

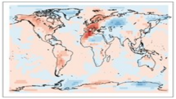
An offline approach for the serial assimilation of observations

UNIVERSITÄT BERN
OESCHGER CENTRE CLIMATE CHANGE RESEARCH

Example for the assimilation of an observation in the mediterranean region

We start from the the **uncorrected ensemble mean**.





The **background error covariance matrix** was computed from the ensemble. It represents spatial correlations of the deviation from the ensemble mean in a distinct grid cell with the anomalies in all other grid cells.

To eliminate effects from spurious correlation with grid cells far away, we additionally apply a **localization matrix** that gives high weights to grid cells in the close neighbourhoud and zero weight to grid cells far away.

The Application: Ensemble Kalman Fitting

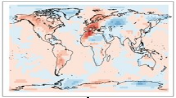
An offline approach for the serial assimilation of observations

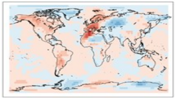
UNIVERSITÄT BERN

OESCHGER CENTRE CLIMATE CHANGE RESEARCH

Example for the assimilation of an observation in the mediterranean region

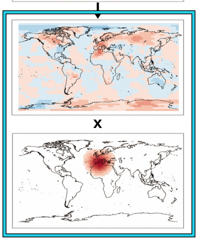
We start from the the **uncorrected ensemble mean**.

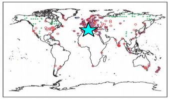




The **background error covariance matrix** was computed from the ensemble. It represents spatial correlations of the deviation from the ensemble mean in a distinct grid cell with the anomalies in all other grid cells.

To eliminate effects from spurious correlation with grid cells far away, we additionally apply a **localization matrix** that gives high weights to grid cells in the close neighbourhood and zero weight to grid cells far away.





We now assimilate the first **observation** (★) as part of an observation network (**o** **+**)

The Application: Ensemble Kalman Fitting

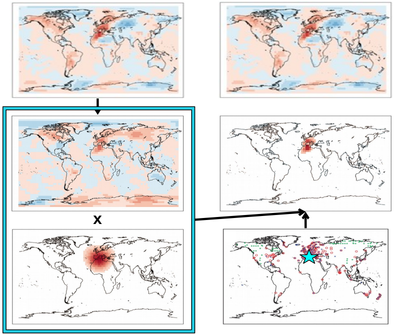
An offline approach for the serial assimilation of observations

Example for the assimilation of an observation in the mediterranean region

We start from the the **uncorrected ensemble mean**.

The **background error covariance matrix** was computed from the ensemble. It represents spatial correlations of the deviation from the ensemble mean in a distinct grid cell with the anomalies in all other grid cells.

To eliminate effects from spurious correlation with grid cells far away, we additionally apply a **localization matrix** that gives high weights to grid cells in the close neighbourhood and zero weight to grid cells far away.



Combining the observation error with the localized background error covariance matrix gives us the **Kalman gain** that is applied as a correction term to update the ensemble mean towards the observation.

We now assimilate the first **observation** (★) as part of an observation network (**o** **+**)

The Application: Ensemble Kalman Fitting

An offline approach for the serial assimilation of observations

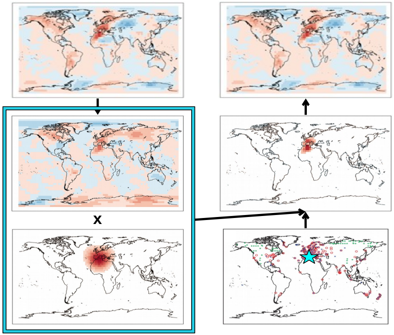
UNIVERSITÄT BERN
OESCHGER CENTRE
CLIMATE CHANGE RESEARCH

Example for the assimilation of an observation in the mediterranean region

We start from the the **uncorrected ensemble mean**.

The **background error covariance matrix** was computed from the ensemble. It represents spatial correlations of the deviation from the ensemble mean in a distinct grid cell with the anomalies in all other grid cells.

To eliminate effects from spurious correlation with grid cells far away, we additionally apply a **localization matrix** that gives high weights to grid cells in the close neighbourhood and zero weight to grid cells far away.



Adding the observation weighted by the Kalman gain then gives us the **updated ensemble**. Afterwards the whole procedure is repeated to update the anomalies of all ensemble members accordingly.

Combining the observation error with the localized background error covariance matrix gives us the **Kalman gain** that is applied as a correction term to update the ensemble mean towards the observation.

We now assimilate the first **observation** (★) as part of an observation network (**o** **+**)

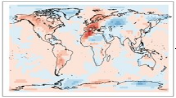
The Application: Ensemble Kalman Fitting

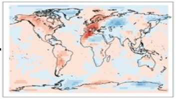
An offline approach for the serial assimilation of observations

UNIVERSITÄT BERN
OESCHGER CENTRE
CLIMATE CHANGE RESEARCH

Example for the assimilation of an observation in the mediterranean region

The **updated ensemble mean** then is the starting point for the assimilation of the next observation



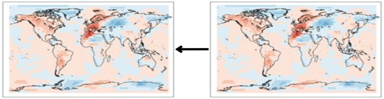


The Application: Ensemble Kalman Fitting

An offline approach for the serial assimilation of observations

Example for the assimilation of an observation in the mediterranean region

The **updated ensemble mean** then is the starting point for the assimilation of the next observation



We assimilate data twice per year. This is beyond the typical memory of the atmosphere. Thus, in contrast to the conventional use of Ensemble Kalman Filters, the assimilation can be done offline (i.e. after the ensemble simulations are finished), which makes the problem computationally feasible. For details on the method see Bhend. et al, 2012; doi:10.5194/cp-8-963-2012.

The Dataset
Accessibility

More information? Click here to visit the PALAEO-RA Website