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Improving decadal climate predictions by ocean ensemble dispersion filtering (EDF) and an efficient systematic evaluation framework (Freva)

Institute of Meteorology – Freie Universität Berlin

GERMANY



Talk @ BSC
Barcelona
30.05.2019

Agenda

Table

1. Introduction

2. Evaluation Platform

3. Prediction Technique

4. Summary

With regards to content



Introduction into **decadal prediction and MiKlip** and applied models as well as concepts/methods



Development of the evaluation platform **Freva** for Earth system models and decadal climate prediction

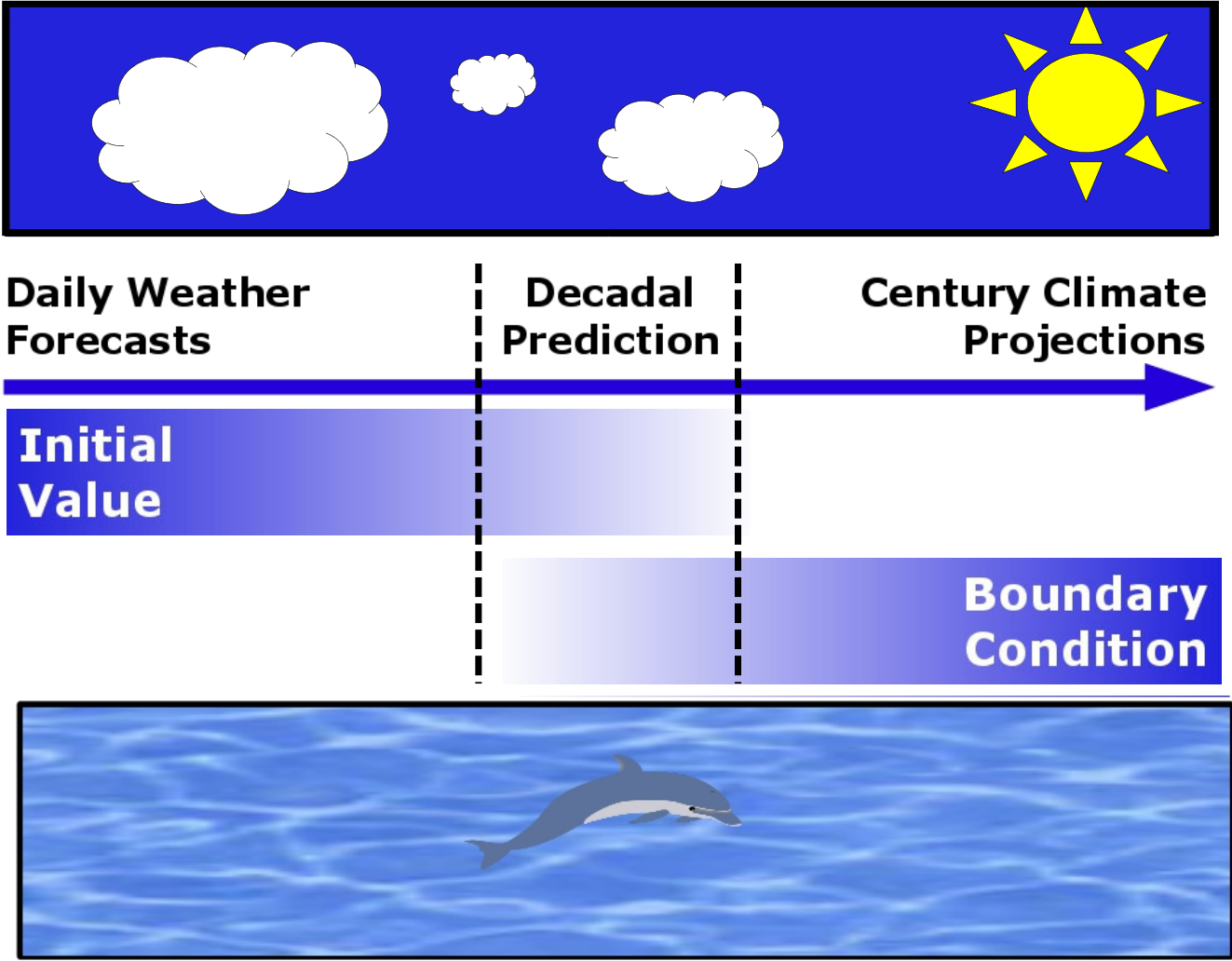


Development of the **Ensemble Dispersion Filter** for decadal climate prediction exploiting the ocean memory and the ensemble mean



Conclusion of the results and **summary**

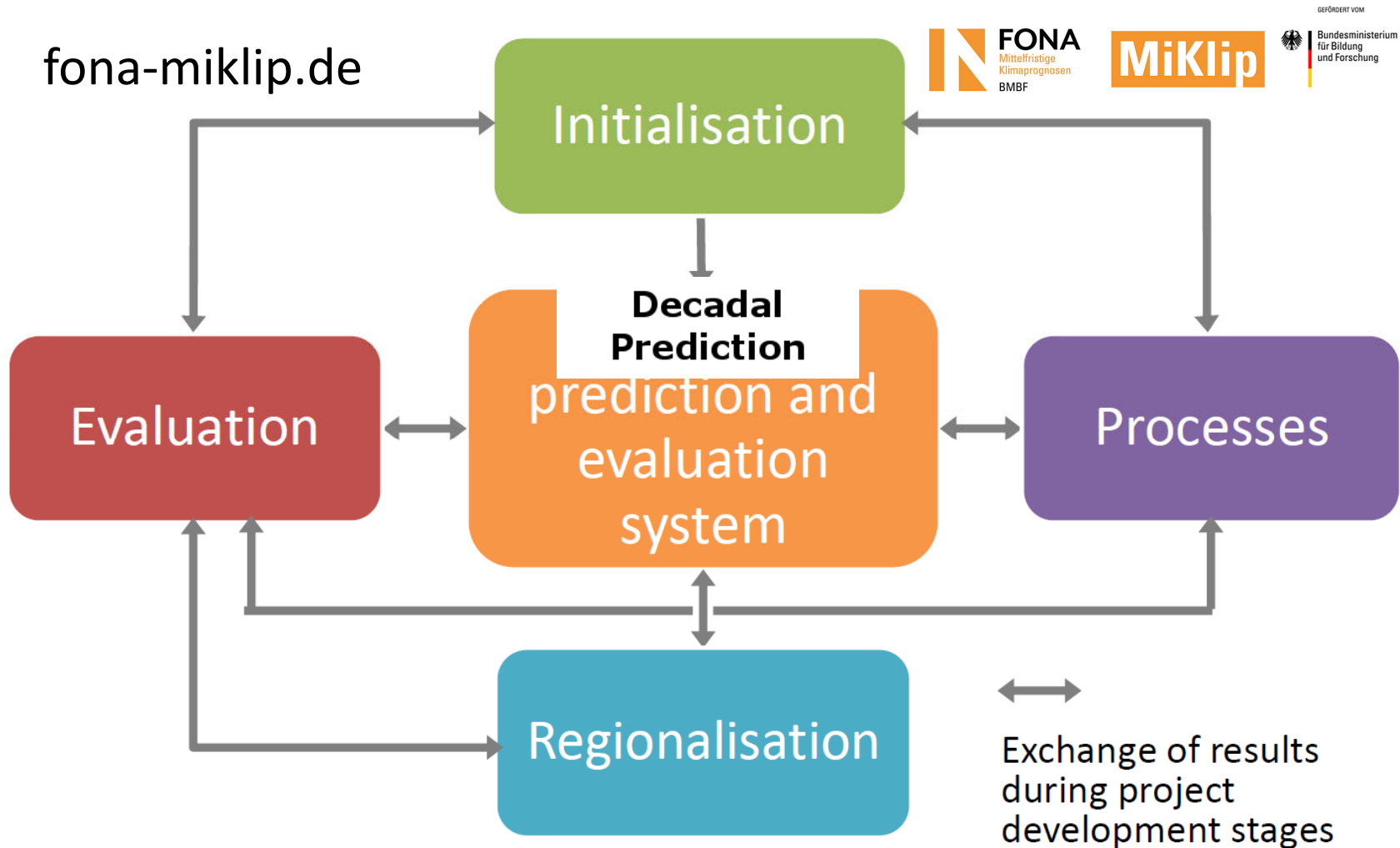
Introduction



Based on Meehl et al. 2009

Introduction

MiKlip project



Mittelfristige Klimaprognosen (MiKlip)

↔
Exchange of results during project development stages

Introduction

MiKlip project

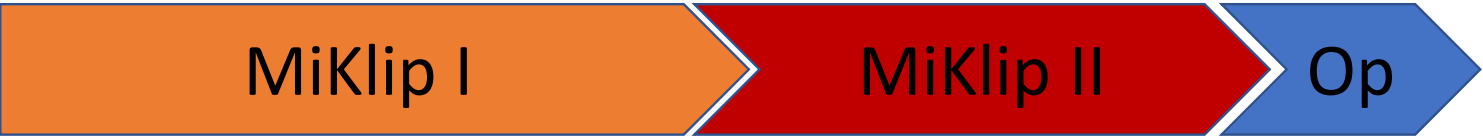
fona-miklip.de



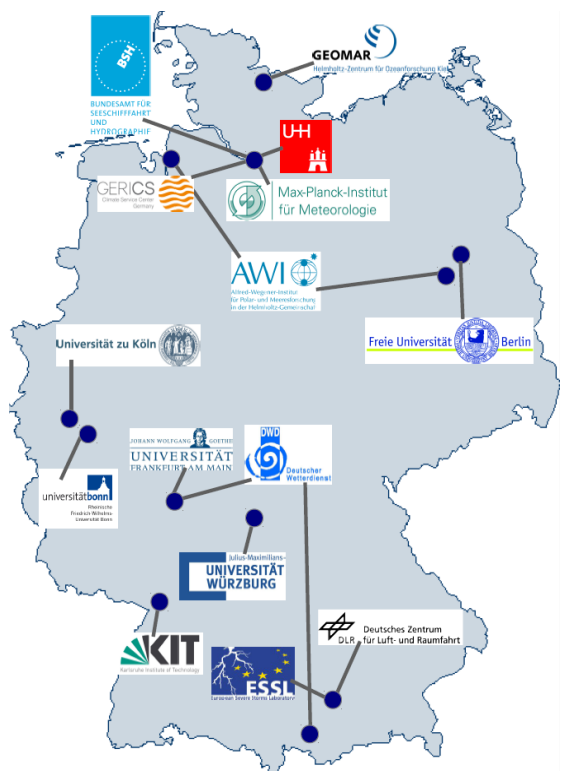
2011 -2015

2016 -2018

2019



1. Year	2. Year	3. Year	4. Year	5. Year	6. Year	7. Year	8. Year
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Introduction

MiKlip project

fona-miklip.de



The screenshot shows the website header with logos for FONA (Decadal Climate Prediction BMBF), MiKlip, and the Federal Ministry of Education and Research. A search bar is present with the text "Your search phrase". Below the header is a navigation bar with links: MIKLIP -, RESEARCH, DECADAL FORECAST -, SERVICE -, and a MIKLIP-CES button. A breadcrumb trail reads: "You are here: Home » Decadal Climate Prediction Sys... » Decadal forecast for 2019-2028".

Important information

Choose forecast

Decadal forecast

Yearly forecast

Select forecast model

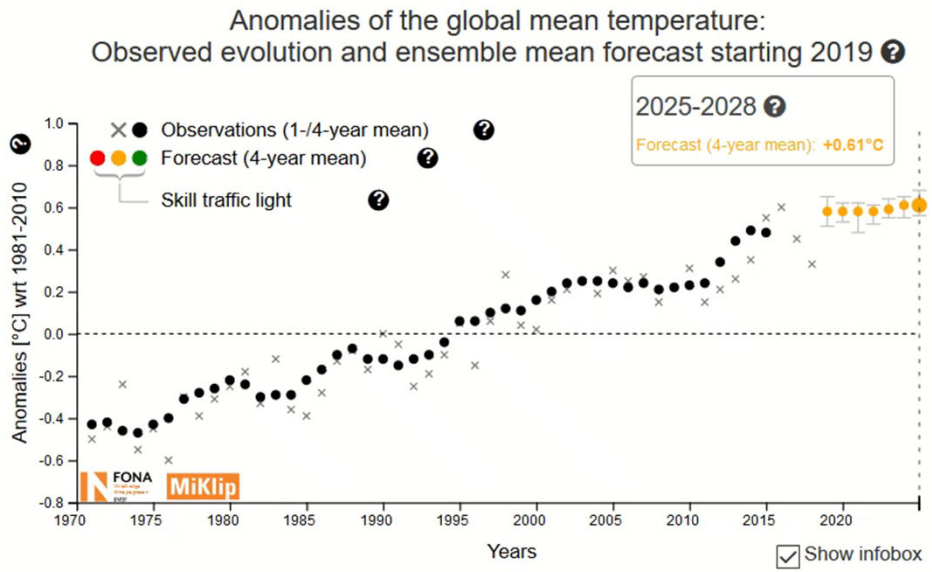
Global forecast model

Regional forecast model

Choose region

Global

Choose forecast time period (2025-2028)



Introduction

MiKlip Prediction System - Baseline1 -> MiKlip-REF

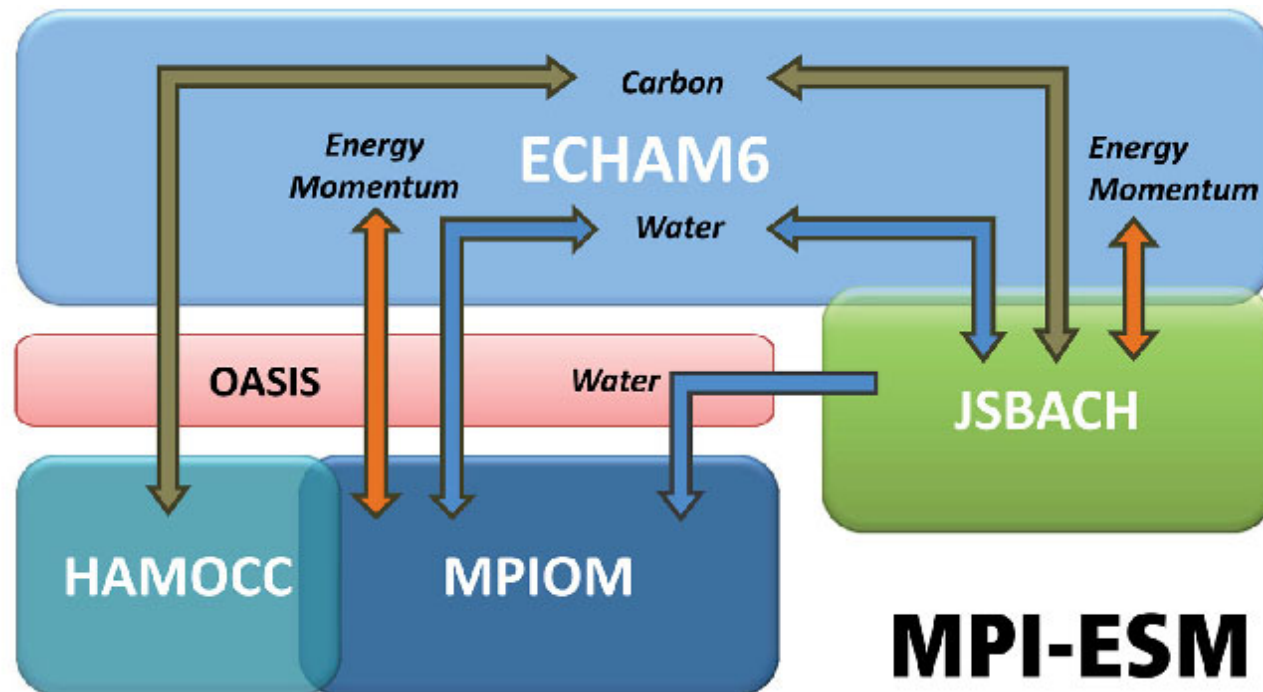
Max-Planck-Institute Earth System Model - Low Resolution

Atmosphere:  Resolution T63 (~1.8°) Level 49

Initialization: ERA-40/Interim Fullfield

Ocean:  Resolution 1.5° Level 40

Initialization: ORAS4 Anomaly

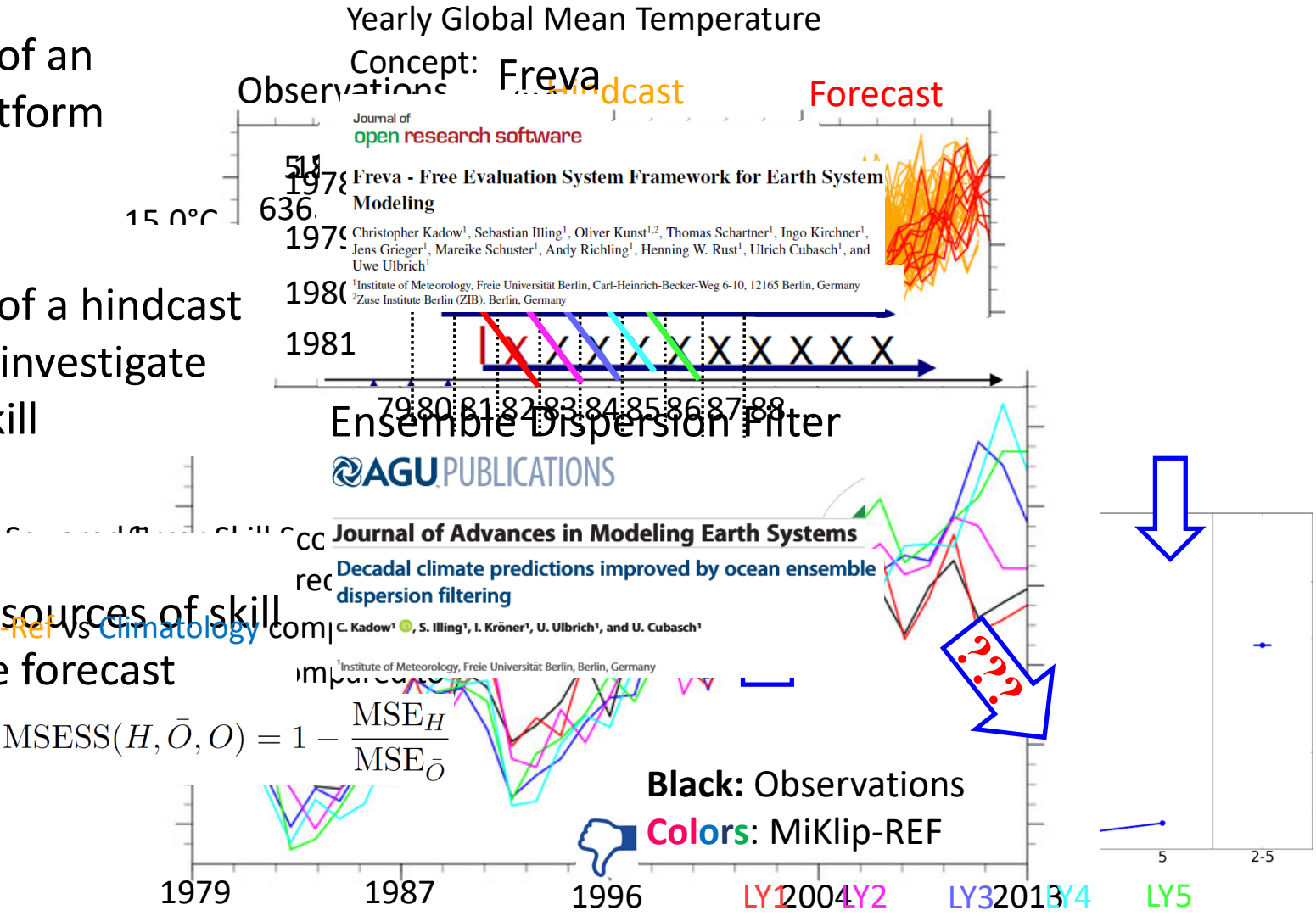


Introduction - Motivation

Development of an evaluation platform

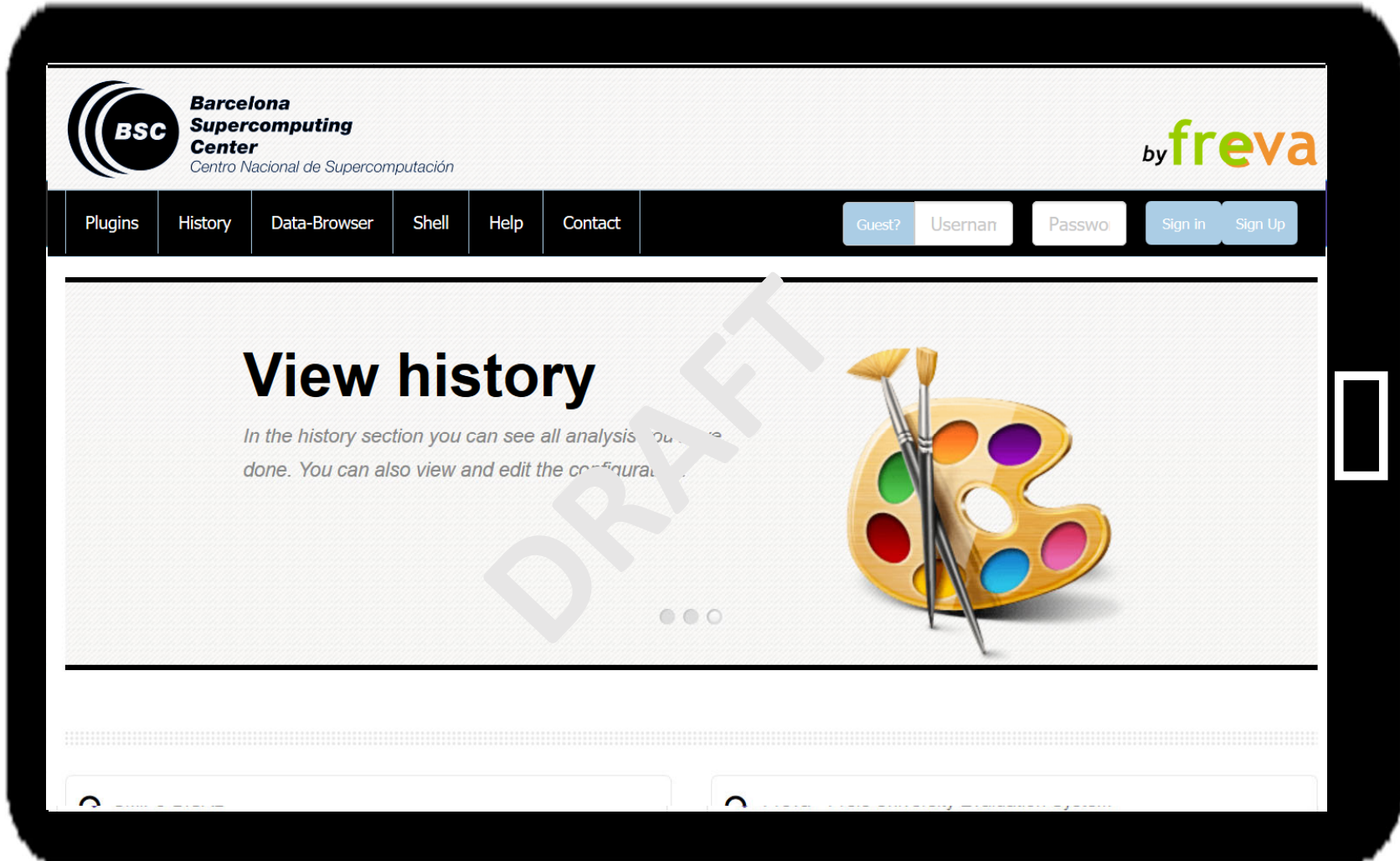
Development of a hindcast evaluation to investigate the forecast skill

Exploiting the sources of skill to improve the forecast

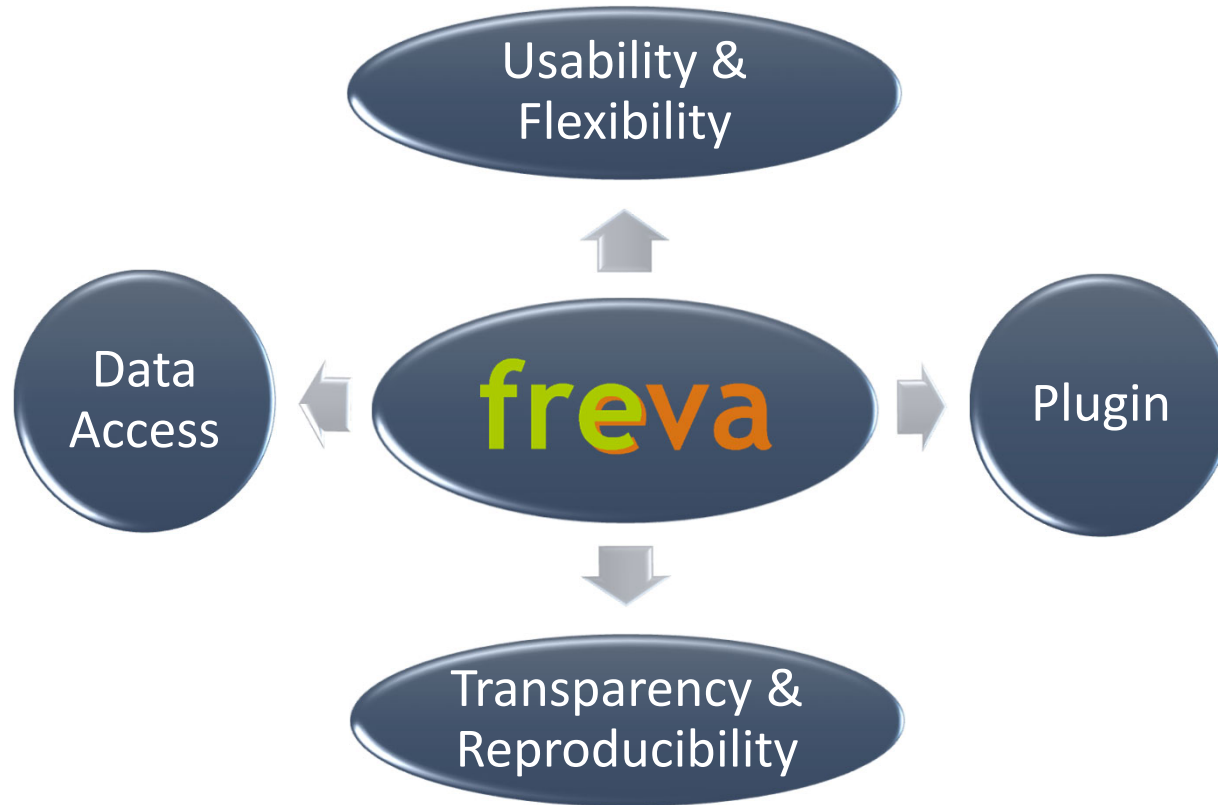


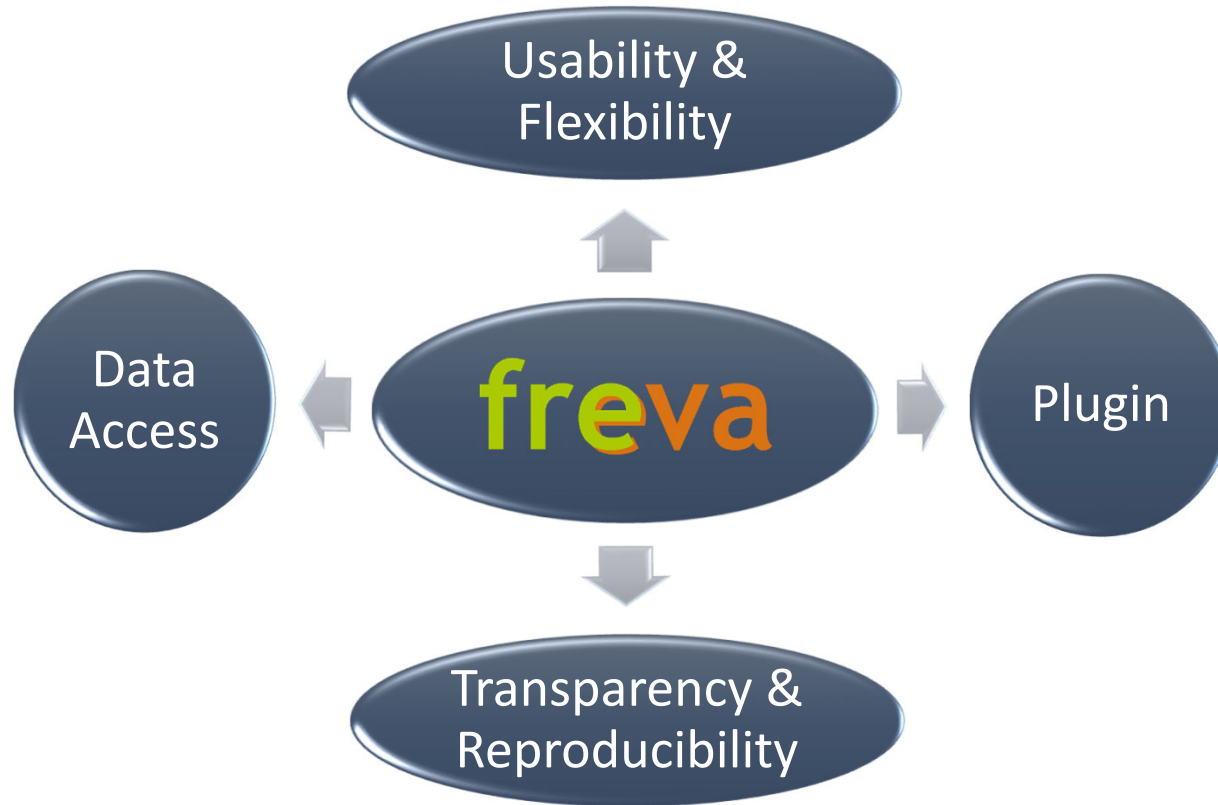
Evaluation Platform

website: www-miklip.dkrz.de | visitor-login: Click on **‘guest?’** -> Login



Freva - Free Evaluation System Framework






```
b324031@miklip2%  
b324031@miklip2%  
b324031@miklip2%  
b324031@miklip2%  
b324031@miklip2%  
b324031@miklip2%  
b324031@miklip2%  
b324031@miklip2%  
b324031@miklip2%  
b324031@miklip2%  
b324031@miklip2%  
b324031@miklip2% freva --plugin movieplotter lat  
lon='20,35,-95,-70' secperpic='0.1' title='Hurri  
cane Katrina' input=/work/bmx825/data4miklip/rea  
nalysis/reanalysis/ECMWF/IFS/ERAINT/6hr/atmos/ps  
l/rli1p1/psl_6hrPlev_reanalysis_ERAINT_rli1p1_20  
05010100-2005123118.nc seldate='2005-08-25,2005-  
08-31' cacheclear='True' resolution='800'
```

FONA
Decadal
Climate Prediction
BMBF

MiKlip

by **freva**

Forecast Hindcast Plugins History Result-Browser Data-Browser Help logout (b324031)

Start analyses

You can easily start all analysis in the evaluation system online. Just fill out the form a click "Run".

MiKlip - Decadal Prediction and Evaluation System

The German research project "MiKlip - Decadal Predictions" aims to develop a system for climate predictions for up to a decade ahead. The prediction system is based on the MPI-M Earth System Model (MPI-ESM) from the Max Planck Institute for Meteorology in Hamburg. Several research groups participate in the major project funded by the Federal Ministry of Education and Research in Germany (BMBF)

Usability &
Flexibility



Human Readability within the Data Standard

MiKlip (global) / CMOR

DIRECTORY:

project/product/institute/model/experiment/time_frequency/realm/variable/ensemble/

FILENAME:

variable_cmortable_model_experiment_ensemble_starttime-endtime.nc



EXAMPLE:

DIRECTORY:

miklip/output/MPI-M/MPI-ESM-LR/rcp45/mon/atmos/tas/r10i1p1/

FILENAME:

tas_Amon_MPI-ESM-LR_rcp45_r10i1p1_200601-210012.nc

Data-Browser

Decadals

? decadals cli
98

Specify the experiments you want to use. I.e. 1960,1965,1970,...,1995. Or you can write 1!

Variable

Select a variable

|

abs550aer

ageice

agessc

albisccp

arag

areacella

Institute1

Select a institute

```
lon:axis = "x" ;
lon:long_name = "longitude" ;
lon:standard_name = "longitude" ;
double lon_bnds(lon, bnds) ;
float pr(time, lat, lon) ;
pr:standard_name = "precipitation_flux" ;
pr:long_name = "Precipitation" ;
pr:comment = "at surface: includes both liquid and solid phases from
```

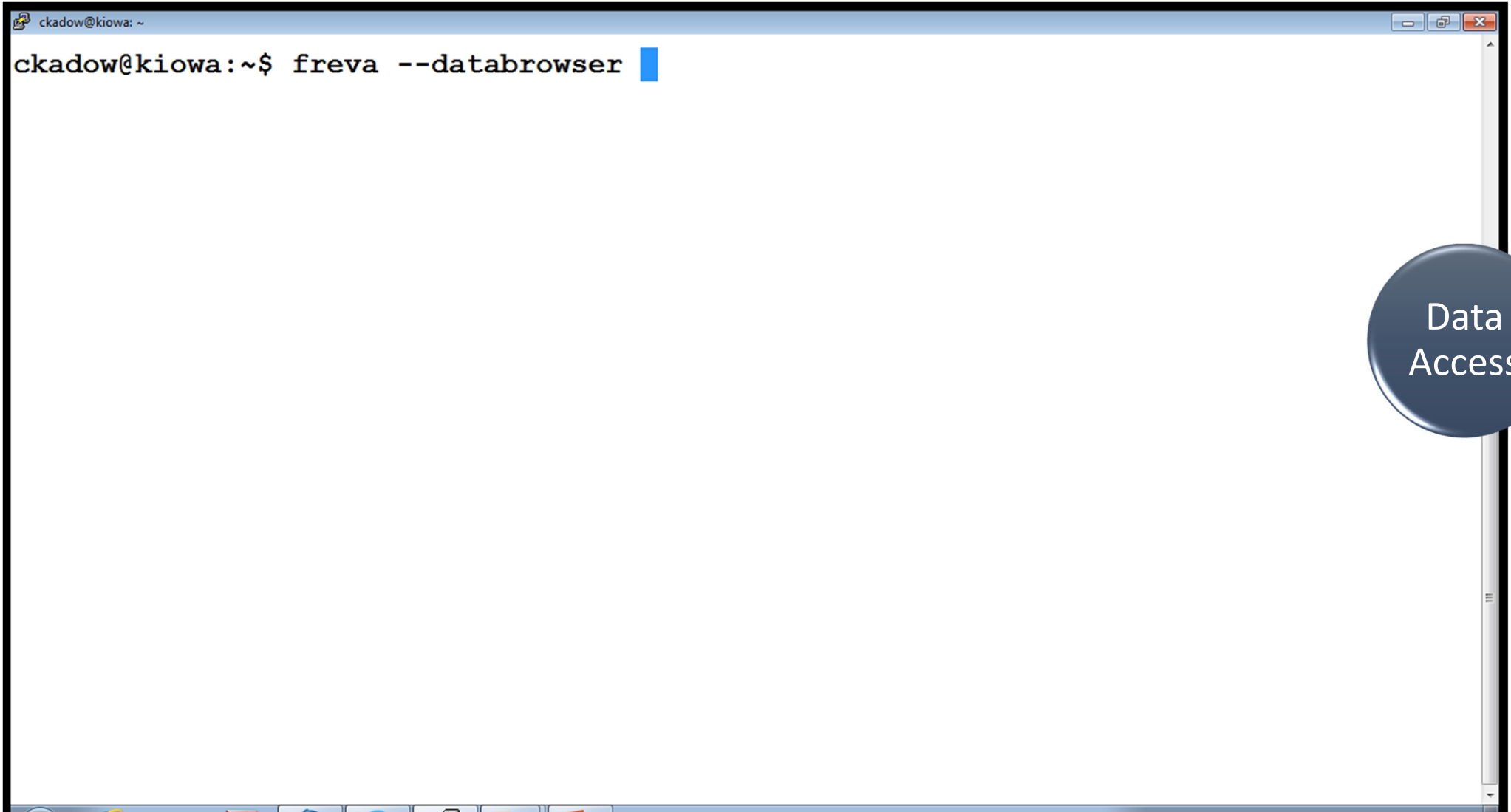
MiKlip uses **CMOR** & access several ESGF standards

SOLR Apache

- Indexing the different standards
- Host a **search tool** using CMOR options
- Support **developers** in process this data



Data-Browser in the Shell



```
ckadow@kiowa: ~  
ckadow@kiowa:~$ freva --databrowser
```

Data
Access

MySQL Database

- Every analysis is saved and can be rerun
- Can be shared among scientists



Transparency & Reproducibility

GIT Versioning

- Every tool and system version is saved to the analysis!

Additional Information

Analyze command:	<code>freva --plugin murcss model2='mpi-esm-lr' model1='mpi-esm-lr' bootstrap_number='500' variable='tas' observation_ensemble='' ensemblemembers2='r1i1p1,r2i1p1,r3i1p1' ensemblemembers1='r1i1p1,r2i1p1,r3i1p1' project1='baseline1' project2='baseline0' cache='/scratch/b324031/evaluation_system/cache/murcss/139343856755229' output_plots='/scratch/b324031/evaluation_system/plots/murcss' product2='output1' product1='output' significance='True' metrics='accuracy' experiment1='decs4e' experiment2='decadal' decadals='1960, 1961, 1962, 1963, 1964, 1965, 1966, 1967, 1968, 1969, 1970, 1971, 1972, 1973, 1974, 1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007' output_type='basic' institute1='mpi-m' institute2='mpi-m' observation='hadcrut3v' leadtimes='2-5' maskMissingValues='True' leadtimes_mode='yearly' output='/scratch/b324031/evaluation_system/output/murcss' cacheClear='True'</code>
Tool repository:	<code>/miklip/integration/repositories/goddard.git</code>
Tool internal version:	<code>972132d44a661ceb336c808575e7eed37d10344e</code>
System repository:	<code>/miklip/integration/repositories/evaluation_system.git/</code>
System internal version:	<code>76188e756fad20c95e80c300de6c49c031c1a501</code>

Featured Recommendations

Inspired by your browsing history



Transparency & Reproducibility

Saving CPU time, I/O and disk space!

The screenshot shows a web interface for a tool named "Maskmissingvalues". The interface includes several sections: "Maskmissingvalues" with radio buttons for "False" (selected) and "True"; "Cache" with a text input field containing "/usr/test_scratch/b324057/ev"; "Workdir"; "Cacheclear" with radio buttons for "False" (selected) and "True"; "Result grid" with a text input field; "Months" with a text input field; and "Caption" with a text input field. A modal dialog titled "Enter password" is overlaid on the interface. The dialog contains a text input field with masked characters, a message "To schedule the analysis you have to re-enter your password", and a message "This analysis has already be done by other users. Here you can view their results." Below these messages are five small thumbnail images of data grids, each with a caption: "Result #9010 by b324057", "Result #9005 by b324057", "Result #9002 by b324057", "Result #3988 by b324057", and "Result #3978 by b324057". At the bottom of the dialog are "Cancel" and "Submit analysis" buttons. On the right side of the main interface, there is a vertical list of similar thumbnail images, each with a caption "y b324057".



Transparency &
Reproducibility

The Admin Panel

Django-Verwaltung

, Christopher. Auf der Website anzeigen / Dokumentation / Abmelden

Start > History > Historys

history zur Änderung auswählen

history hinzufügen +

Suchen

2013 2014 2015 2016 2017 2018 2019

Aktion: ----- v Ausführen 0 von 1

<input type="checkbox"/>	ID	Timestamp	Tool	Link to model	Status name	Started from website
<input type="checkbox"/>	156076	13. Februar 2019 18:11	vadylight	Show Results	finished	⊖
<input type="checkbox"/>	156075	13. Februar 2019 17:48	vadylight	Show Results	finished	⊖
<input type="checkbox"/>	156074	13. Februar 2019 17:23	vadylight	Show Results	finished	⊖
<input type="checkbox"/>	156073	13. Februar 2019 17:20	cvprepare	Show Results	finished_no_output	⊖
<input type="checkbox"/>	156072	13. Februar 2019 16:56	cvprepare	Show Results	broken	⊖
<input type="checkbox"/>	156071	13. Februar 2019 16:01	murcss	Show Results	broken	⊕
<input type="checkbox"/>	156070	13. Februar 2019 15:42	murcss	Show Results	broken	⊕
<input type="checkbox"/>	156069	13. Februar 2019 15:27	vadylight	Show Results	finished	⊖
<input type="checkbox"/>	156068	13. Februar 2019 15:01	cvprepare	Show Results	finished_no_output	⊖
<input type="checkbox"/>	156067	13. Februar 2019 15:01	recalibration	Show Results	finished_no_output	⊖

INTEGRATION set up 3 tools to show

- MiKlip developers
 - **how2plugin** via different scripts
- MiKlip users
 - **how2use** the evaluation system

ADVANTAGES:

- No specific programming language requested
- No need to know all the code environments



```
fрева --plugin MoviePlotter input=/path/2/tas_Amon_MPI-ESM-LR_decadal2000_r1i1p1_2003.nc outputdir=.
```

```
from evaluation_system.api import plugin

class MoviePlotter(plugin.PluginAbstract):
    __short_description__ = "Plots 2D lon/lat movies in GIF format"
    __version__ = (0,0,1)
    __config_metadict__ = plugin.metadict(compact_creation=True,
        input=(None, dict(type=str, mandatory=True, help=' File to be plotted')),
        outputdir=(None, dict(type=str, mandatory=True, help='default output dir')))

    def runTool(self, config_dict=None):
        input = config_dict['input']
        outputdir=config_dict['outputdir']

    result= self.call('%s/movie_plotter.sh %s %s' % (self.getClassBaseDir(),input,outputdir))
```

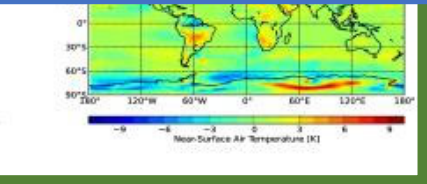
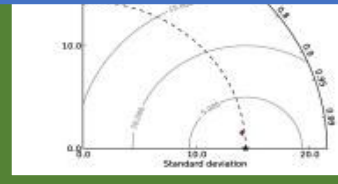
NCL

```
./movie_plotter.sh /path/2/INPUT /path/2/OUTPUT
```

C++



Python



Plugins

- Decadal Evaluation
- VADYcirc
- Post-Processing
- Supporting Plugins

Reliability Diagram of a MiKlip model version (B1) (RELDIAG)

Analysis from 21.10.14 21:12:23 c

Edit configuration

Share R

Configuration

Program's output

Notes (1)

#2189 Commentary

AWESOME !!!!

Results

STEPCLIM

Tool to estimate the annual frequency of lightning and convective hazards

Send email to MiKlip users

Select user to mail to

Wolfgl

Müller, Wolfgang (m222025)

Steinbrecht, Wolfgang (b380071)

Hey Wolfgang, check back with Stefan Siegert...

Send me a copy

One mail to all

Send



Freva Plugin output can be automatically part of the data base

Developers get a function from Freva for the plugin

```
if link2database:
    self.linkmydata(os.path.join(
        outputdir_org,'CMOR'))
```

Option in plugin:



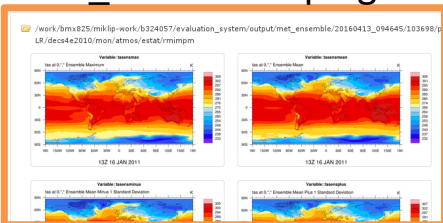
Link2database

False

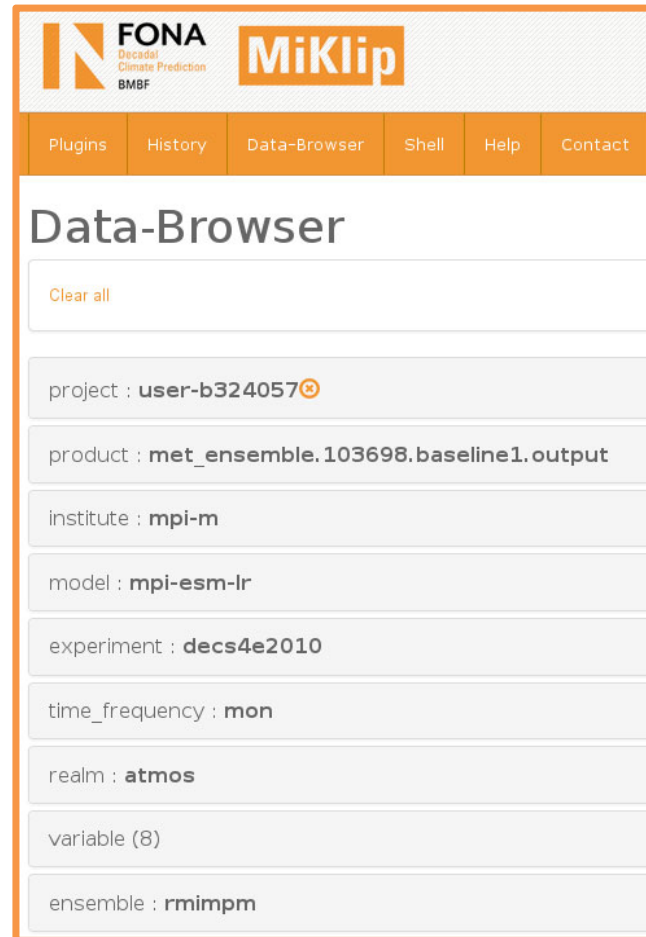
True

Set "True" for crawl and ingest the output

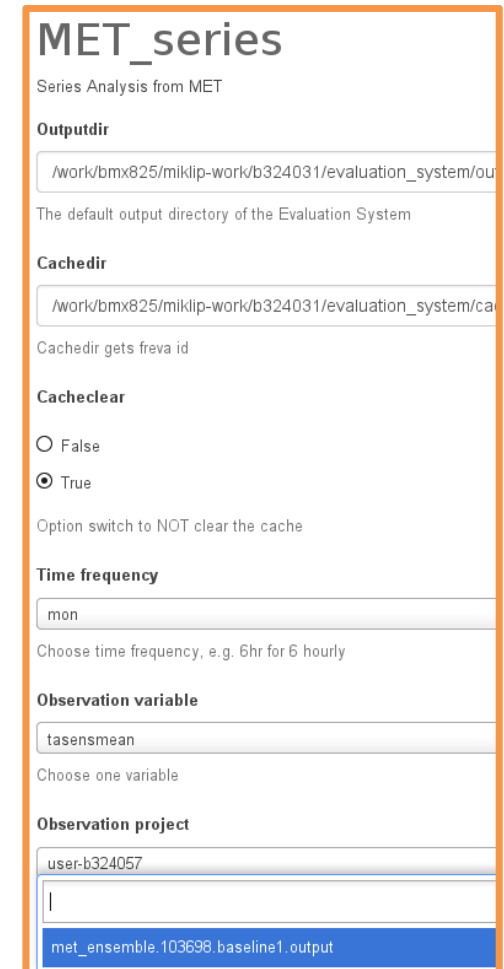
Preview output of the MET_ENSEMBLE plugin:



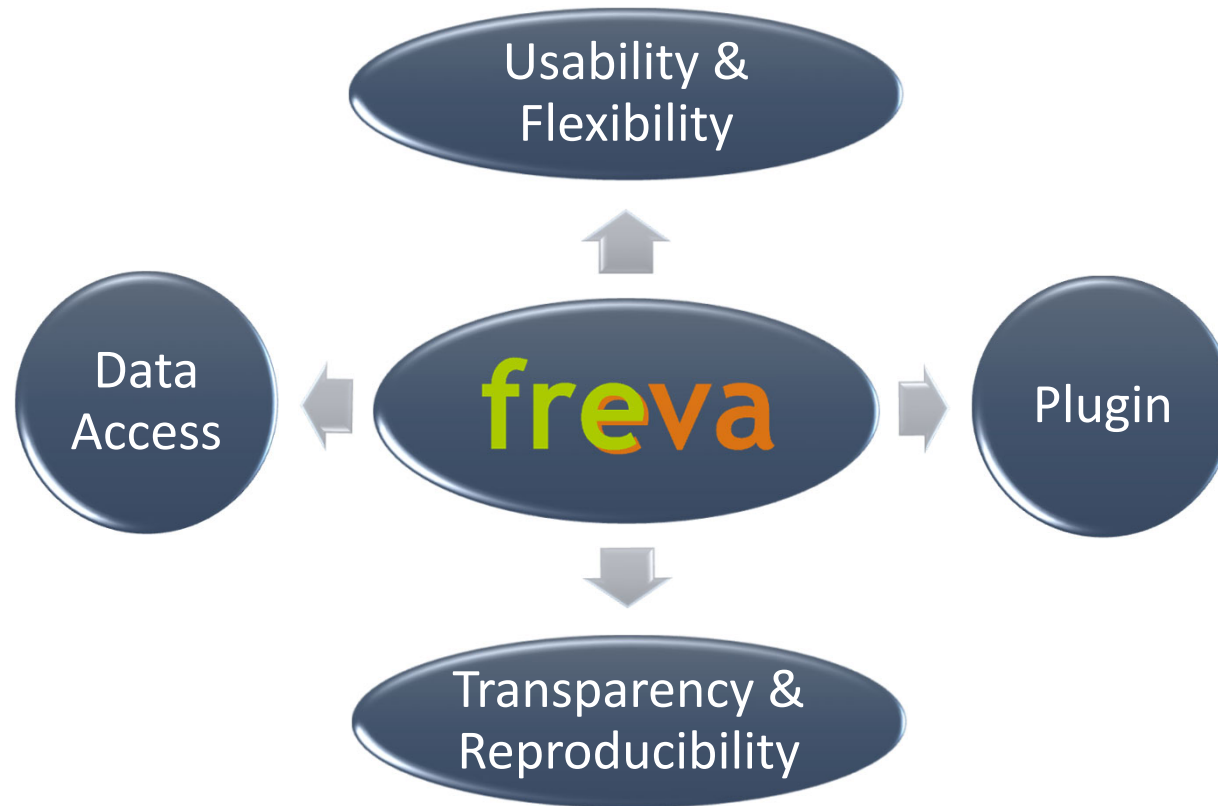
Result of the plugin now part of the users database



... and can be chosen as input for next plugin



A standardized data and application system for evaluation...



... of climate model forecasts, hindcasts and projections

Freva @ BSC?

s2dVerification @ Freva

Andy Richling (FUB)



DISCOVER BSC RESEARCH & DEVELOPMENT MARENOSTRUM TECH TRANSFER JOIN US EDUCATION NEWS

A screenshot of the Freva web application interface. The page title is 'View history'. Below the title, there is a descriptive paragraph: 'In the history section you can see all analysis you have done. You can also view and edit the configuration.' To the right of the text is an illustration of a yellow artist's palette with two paintbrushes. The interface includes a top navigation bar with the BSC logo and 'freva by' branding, a secondary navigation bar with links like 'Plugins', 'History', 'Data-Browser', 'Shell', 'Help', and 'Contact', and a user login area with buttons for 'Guest?', 'Usernam', 'Passwo', 'Sign in', and 'Sign Up'. A left sidebar contains navigation options such as '< Home', '< Research', and 'Software'. The background shows a blurred view of the application's main content area.

Summary of Evaluation Platform

Free Evaluation System Framework

- Standardized data & applications
- Usability & Flexibility
- Shared Knowledge approach
- Toolset for Verification Systems
- ... and Operational Systems

Application Potential

- Major Projects & Big Institutions

More Informations @ MiKlip

- fona-miklip.de

More Informations @ DKRZ

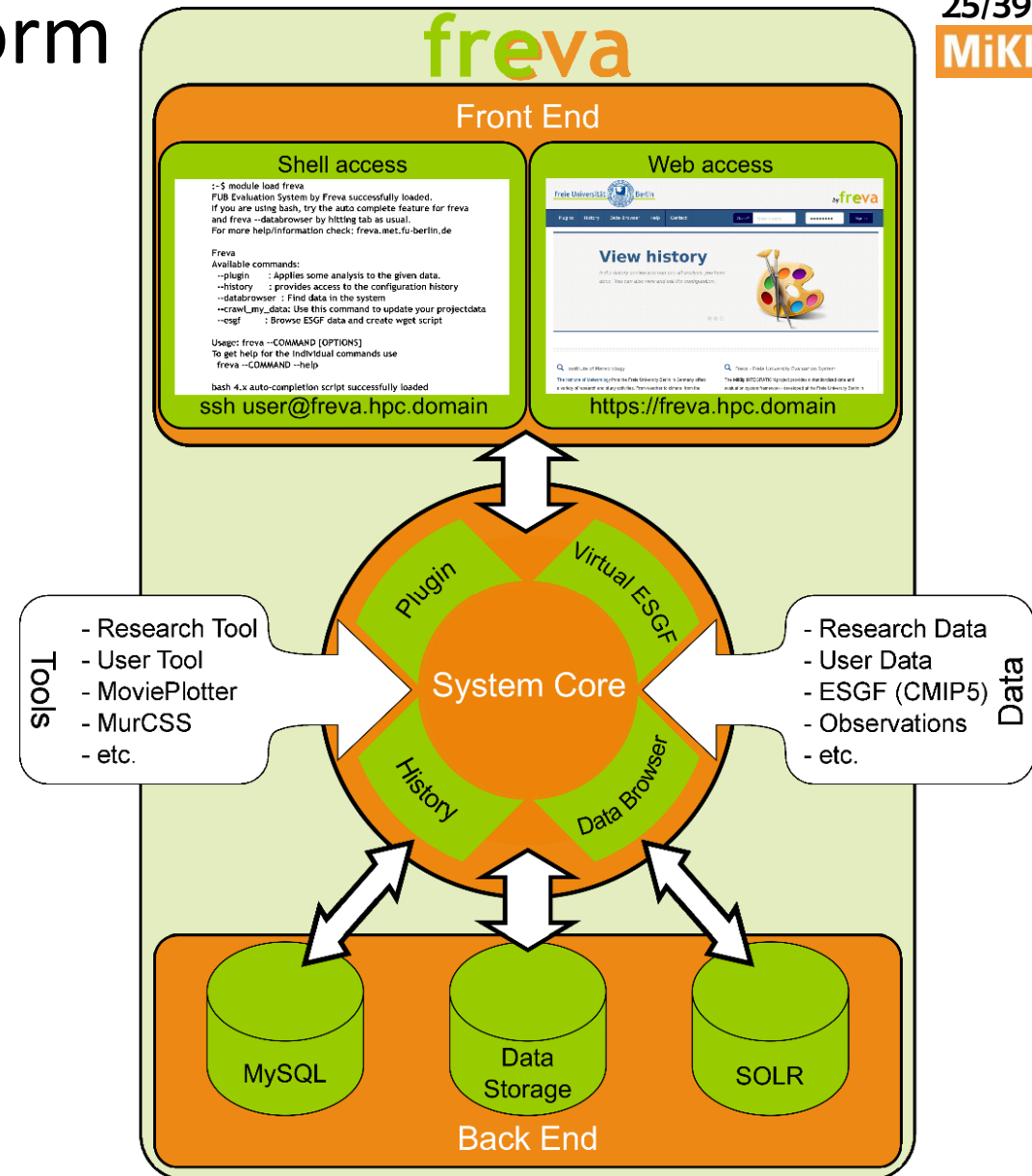
- www-miklip.dkrz.de

More Informations @ FU-Berlin

- freva.klimod.de

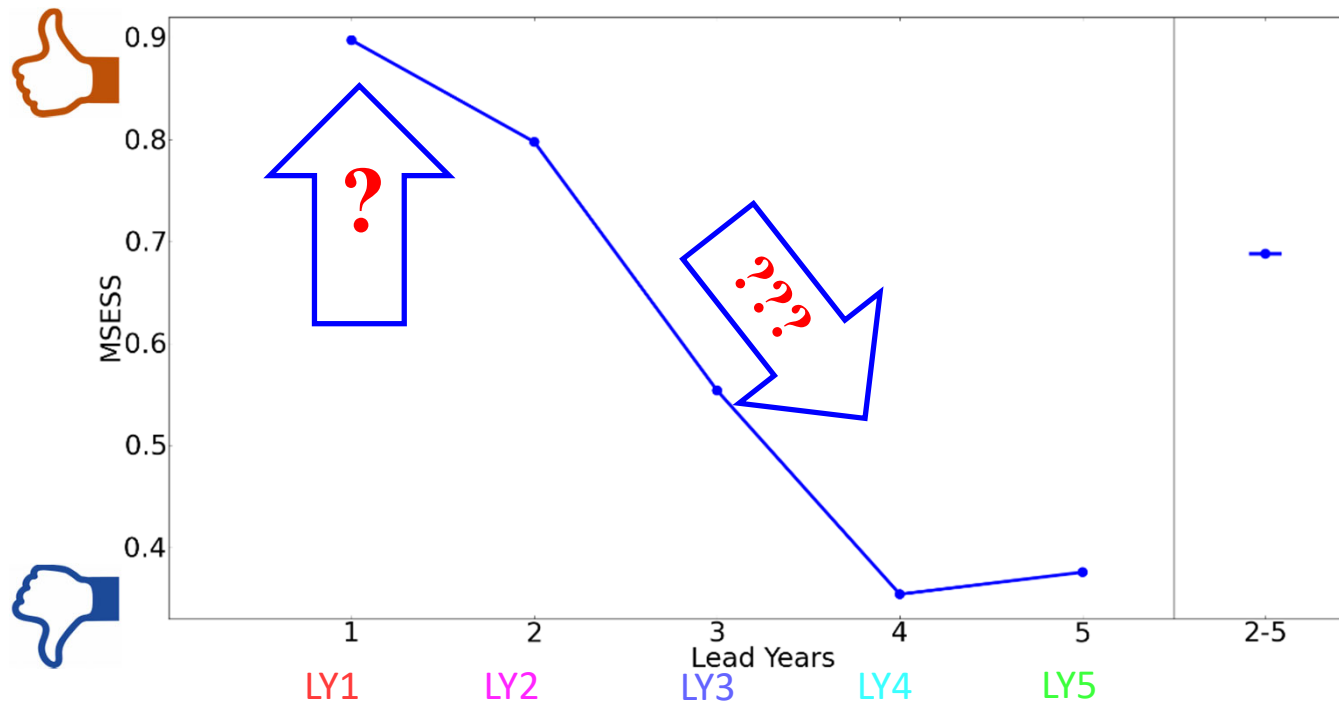
More Informations @ CMIP

- cmip-esmvaltool.dkrz.de



Prediction Technique

Exploiting the sources of skill to improve the forecast

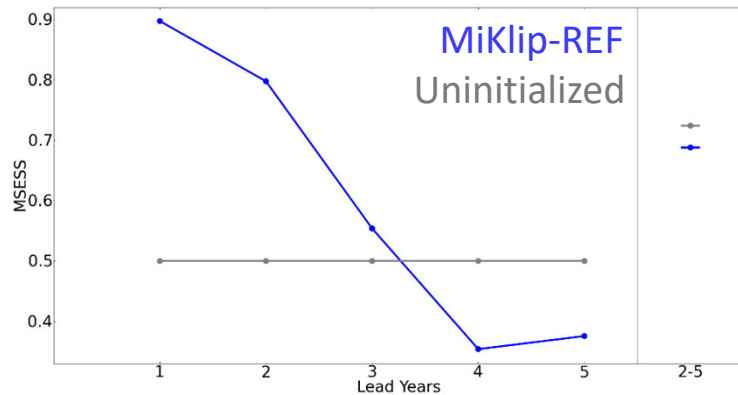


Prediction Technique

Ocean 2 Ensemble Climate Science Facts

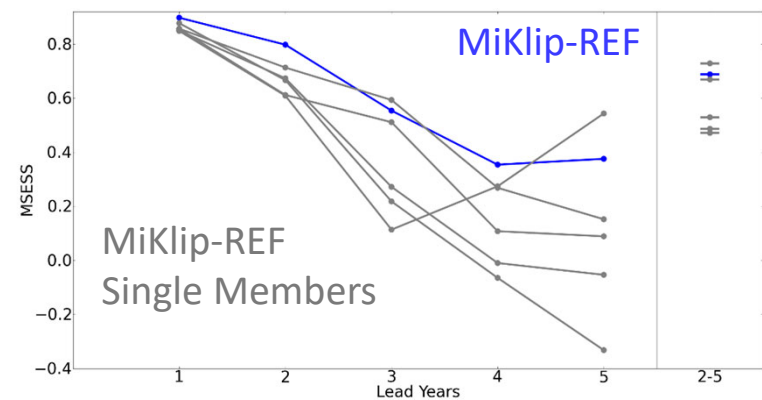
- large-scale mixing occurs on time scales from years to decades
- The ocean has a much larger heat capacity than the atmosphere
Vuille and Garreaud
- the ocean provides the important memory for climate variations

Trenberth



- ... the ensemble average is closer to the truth [...] due to non-linear filtering of errors ...
Kalnay, Hunt, Ott, Szunyogh
- ... skill of a [...] prediction based on the ensemble mean is shown to be always greater than that based on a single realization

Kumar and Hoerling



Prediction Technique

Ocean **THINK** Decadal Prediction **IE BOX** Ensemble

REPORT
Improved Surface Temperature Prediction for the Coming Decade from a Global Climate Model
Doug M. Smith*, Stephen Cusack, Andrew W. Colman, Chris K. Folland, Glen R. Harris, James M. Murphy

Letter | Published: 01 May 2008
Advancing decadal-scale climate prediction in the North Atlantic sector
N. S. Keenlyside, M. Latif, J. Jungclauss, L. Kornbluh & E. Roeckner

Initializing Decadal Climate Predictions with the GECCO Oceanic Synthesis: Effects on the North Atlantic
Holger Pohlmann* and Johann H. Jungclauss
Max-Planck-Institut für Meteorologie, Hamburg, Germany

Assimilation system **Ensemble Kalman Filter** Earth
Sebastian Brune, Lars Nerger, Johanna Baehr

X	O	X
X	O	X
O	X	O

Predicting Near-Term Changes in the Earth System: A Large Ensemble of Initialized Decadal Prediction Simulations
40 Member Hindcast Model
S. G. Yeager, G. Danabasoglu, H. A. Rosenbloom, W. Strand, S. C. Bates, G. A. Meehl, A. R. Karspeck, K. Lindsay, M. C. Long, and H. Teng
National Center for Atmospheric Research, Boulder, Colorado

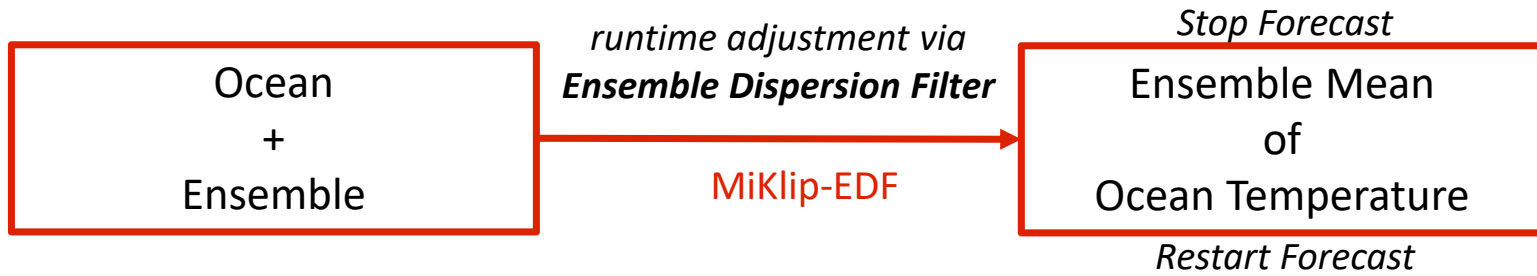
Ensemble size impact on the decadal predictive skill assessment
FRANK SIENZ*, WOLFGANG A. MÜLLER and HOLGER POHLMANN
Max-Planck-Institut für Meteorologie, Hamburg, Germany

Inherent Predictability, Requirements on the Ensemble Size, and Complementarity
Arun Kumar and Mingyue Chen
Climate Prediction Center, NOAA/NWS/NCEP, College Park, Maryland

Research Letter | Open Access |
Do seasonal-to-decadal climate predictions underestimate the predictability of the real world?
Rosie Eade, Doug Smith, Adam Scaife, Emily Wallace, Nick Dunstone, Leon Hermanson, Niall Robinson



Prediction Technique

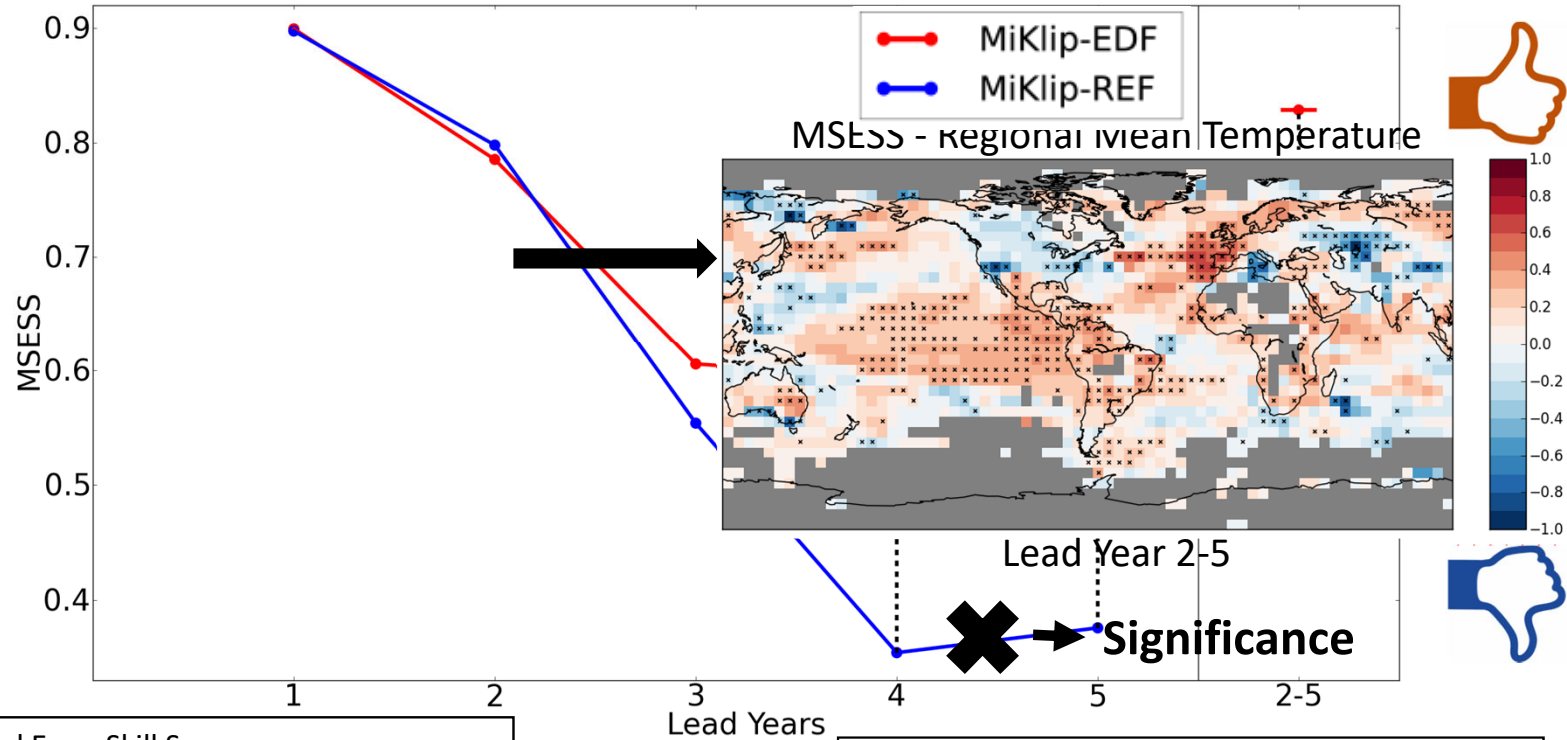


Prediction Technique

Question: Is the EDF system better? **Answer:** Ask Freva!

+ Deceleration of the loss of skill over lead years
+ Significant skill improvement in LY2-5

+ Strongest effect in the North Atlantic
+ Significant impact over Central Pacific



Mean Squared Error Skill Score
 Forecast vs Reference compared to Observations

 MiKlip-REF vs Climatology compared to HadCRUT4
 MiKlip-EDF vs Climatology compared to HadCRUT4

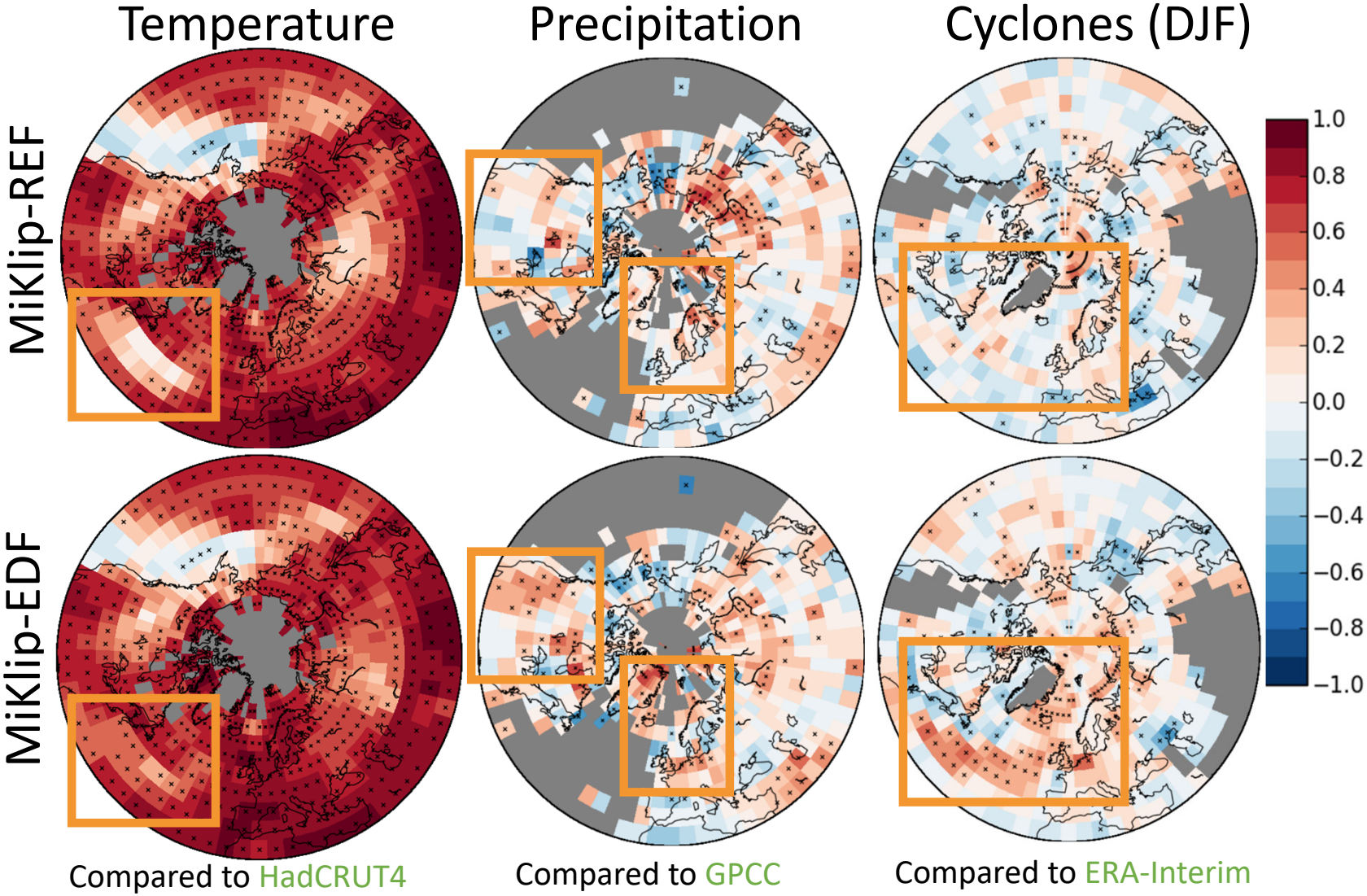
 MiKlip-EDF vs MiKlip-REF compared to HadCRUT4

Mean Squared Error Skill Score
 Forecast vs Reference compared to Observations

 MiKlip-EDF vs MiKlip-REF compared to HadCRUT4

Prediction Technique

Correlation LY2-5 - 1979 to 2013



Prediction Technique

- Does the EDF destroy the ensemble spread and the forecast reliability?
- Shouldn't the EDF effect be visible earlier? Why do we see the effect at first in LY4 and LY5?
- If the early positive development in the model is important, are specific regions critical for the forecast skill?
- Besides statistical measurements, do physical indices exist which explain why the skill could be better?
- Is the positive EDF effect „just“ an adjustment on the trend or really an improvement on the forecast of the variability?
- **What about full-field and/or seasonal predictions?**
- How good is the EDF vs more ensemble members or higher resolved models?
- Why is the EDF constructed like it is? Other variations possible?

• • •

Prediction Technique

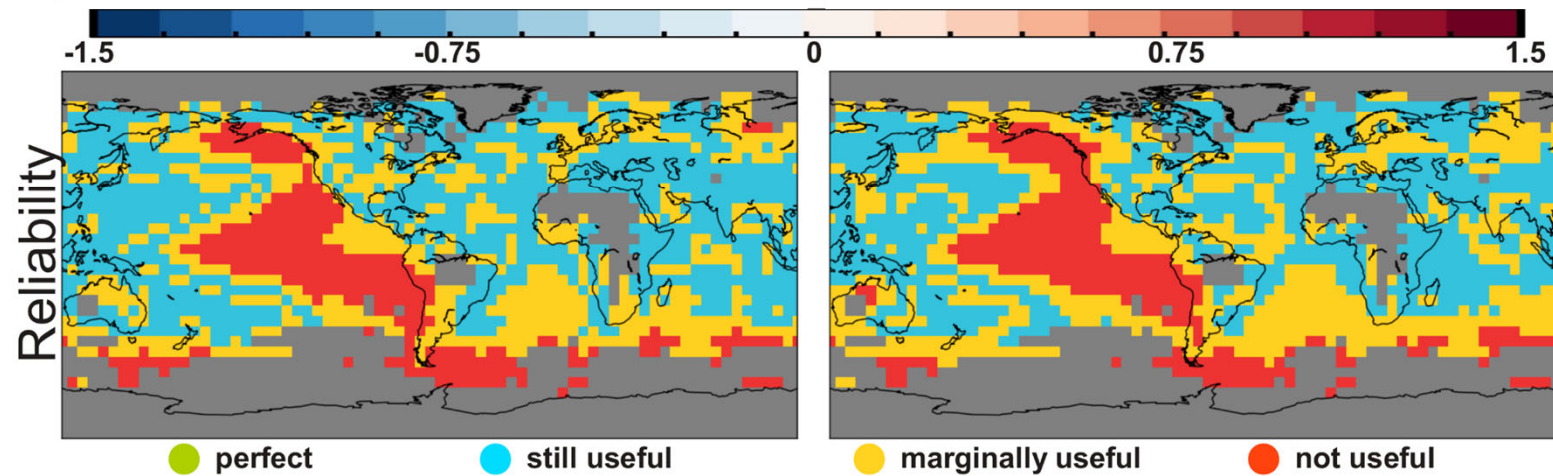
Spread and Reliability?

Ensemble Spread and Reliability – Near-Surface Air Temperature

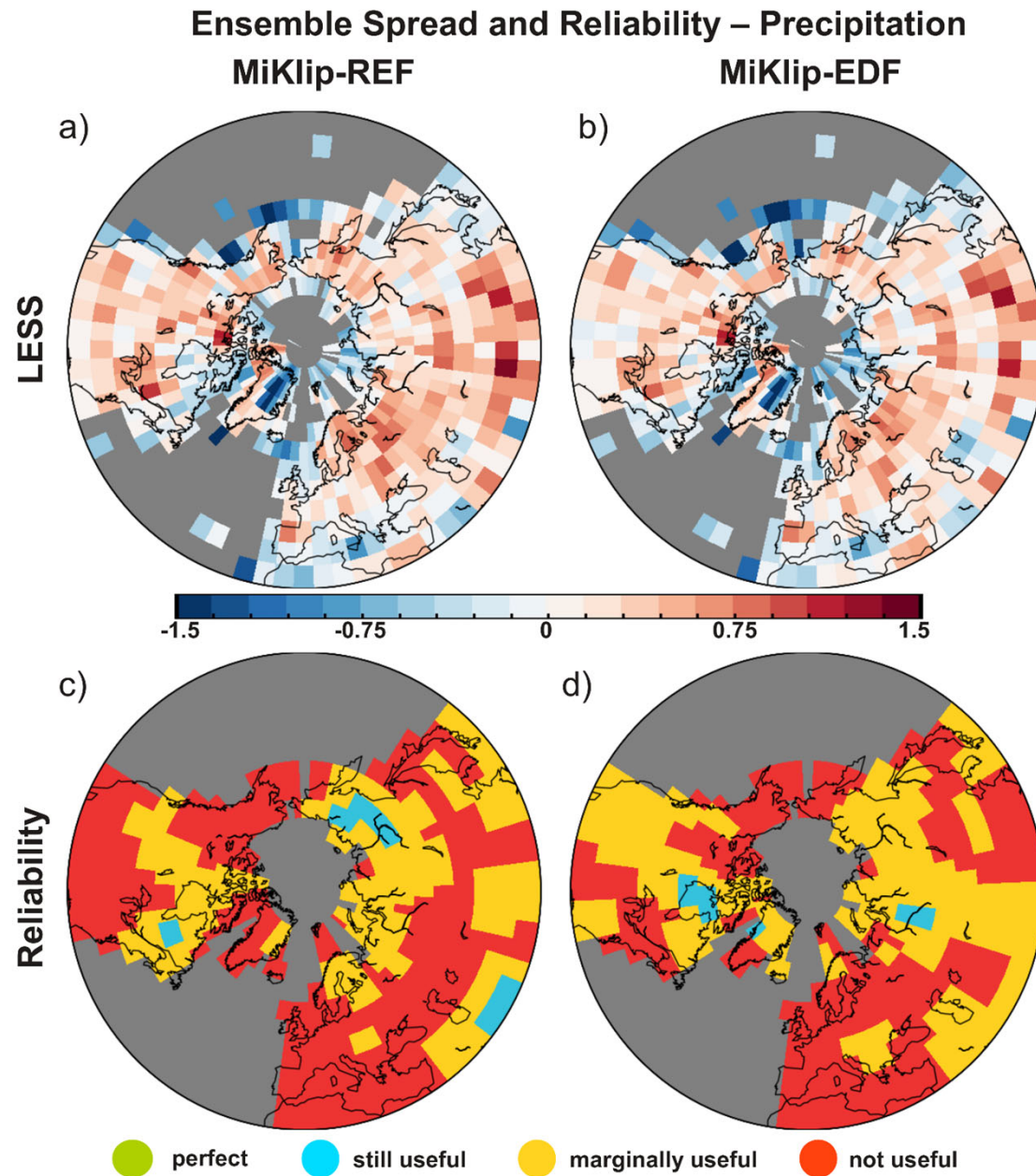
MiKlip-REF

MiKlip-EDF

LESS



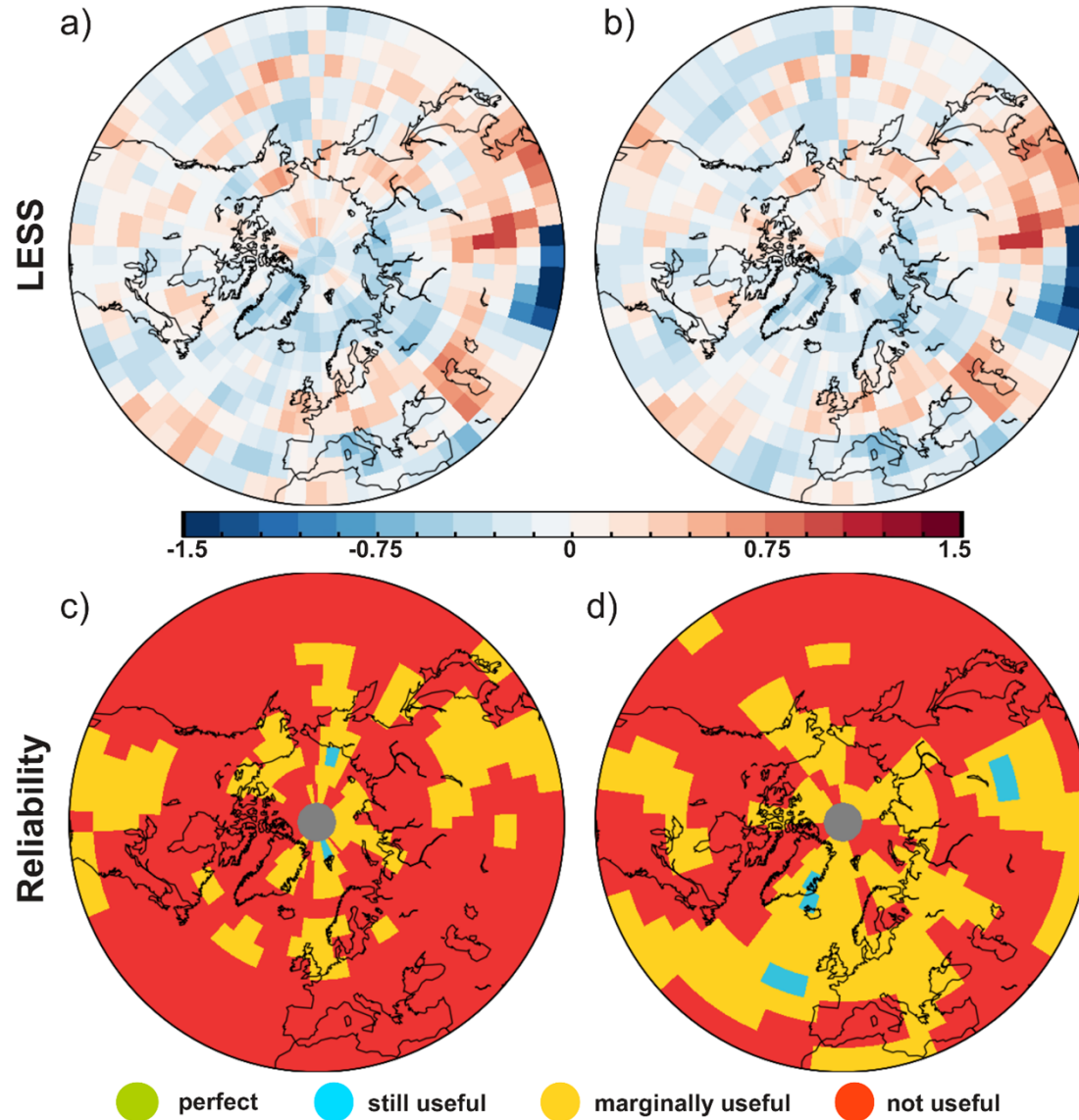
Prediction Technique



Spread and Reliability?

Prediction Technique

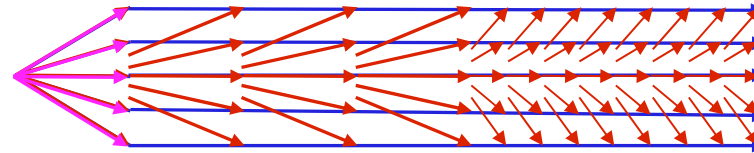
Ensemble Spread and Reliability – Cyclone Track Density
MiKlip-REF MiKlip-EDF



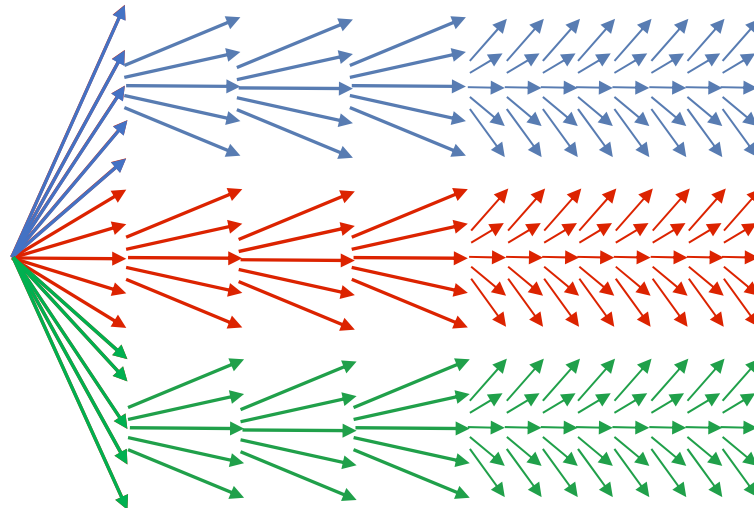
Spread and Reliability?

Experiment Setup to get „a“ spread back

decadal experiment
Raw and EDF



decadal experiment
15 Members EDF



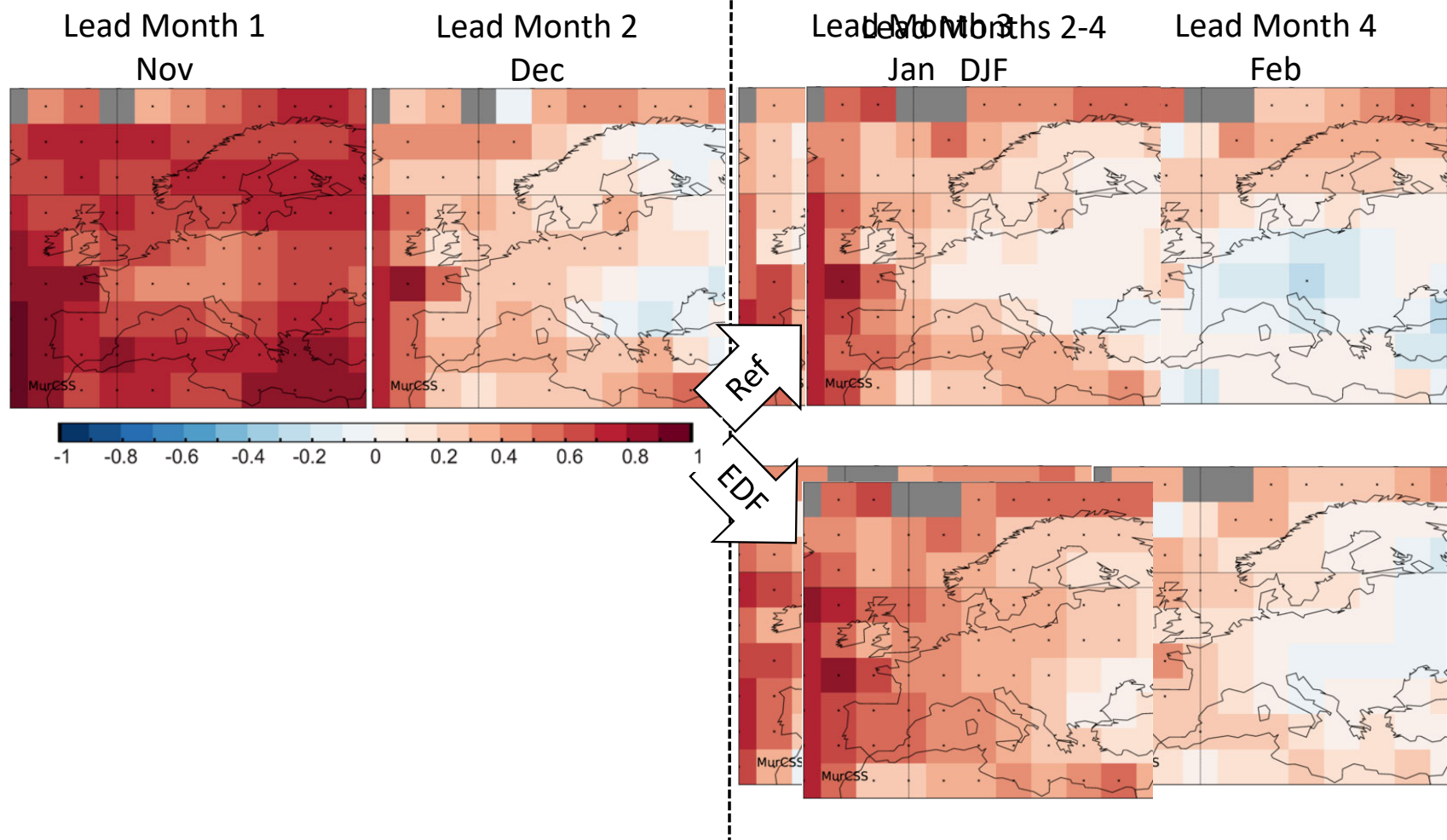
Prediction Technique

Seasonal Effect?

Decadal system starts in November to be synchronized with the Seasonal system

- New MiKlip Prediction system -

Check first Winter - Correlation



Summary of Prediction Technique

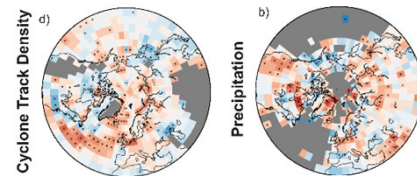
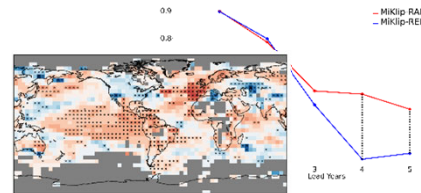
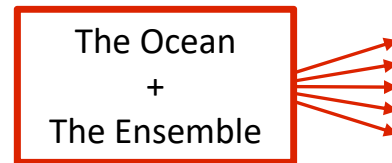
Question:

What is the main idea behind this novel approach?

Is the temperature forecast closer to the observations?

What about other important variables than temperature?

Answer:



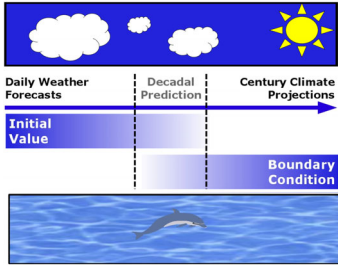
Using the **ensemble mean** (non-linear error filter) of the **ocean temperatures** (decadal memory) within a forecast, keeps the forecast on track

Yes, the prediction is better, due to deceleration of the loss of skill over lead years and a **significant skill improvement in LY2-5** (global and regional)

MiKlip-EDF shows large areas of significant **positive correlation** coefficients from precipitation and **winter cyclone track density**

Kadow, C., S. Illing, I. Kröner, U. Ulbrich, and U. Cubasch (2017), Decadal climate predictions improved by ocean ensemble dispersion filtering, J. Adv. Model. Earth Syst., 9, 1138–1149, doi:[10.1002/2016MS000787](https://doi.org/10.1002/2016MS000787)

Summary



Climate Science

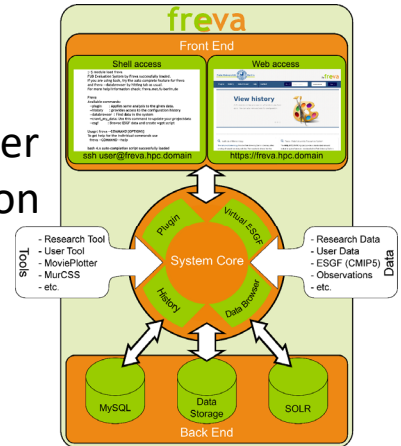


Decadal prediction has a lot of potential left, because of many scientific attributes: Initialization, green-house gases, couples atmosphere-ocean models, hindcast set-up, ensembles, lead year evaluation, etc.

Evaluation Platform



Earth system model evaluation framework (verification and developer system **Freva**) was developed for a common software and data interface on high performance computers.



Prediction Technique

New decadal prediction technique: **Ensemble Dispersion Filter**



What is the idea?
Is the prediction more accurate?



Exploiting the ensemble mean of the ocean temperatures keeps the evolution on track and **improves the prediction** (TAS, PR, CYC).



Intensify the cooperation between Barcelona/EUCP and Berlin/MiKlip in the field of climate prediction, evaluation, and Earth system modeling.

