Christopher Kadow

S. Illing, T. Schartner, I. Kröner, J. Grieger, A. Richling, O. Kunst, M. Schuster, I. Kirchner, H. Rust, U. Cubasch, and U. Ulbrich

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

Institute of Meteorology – Freie Universität Berlin

GERMANY

Freie Universität Berlin

FONA Decadal Climate Prediction BMBF

MiKlip

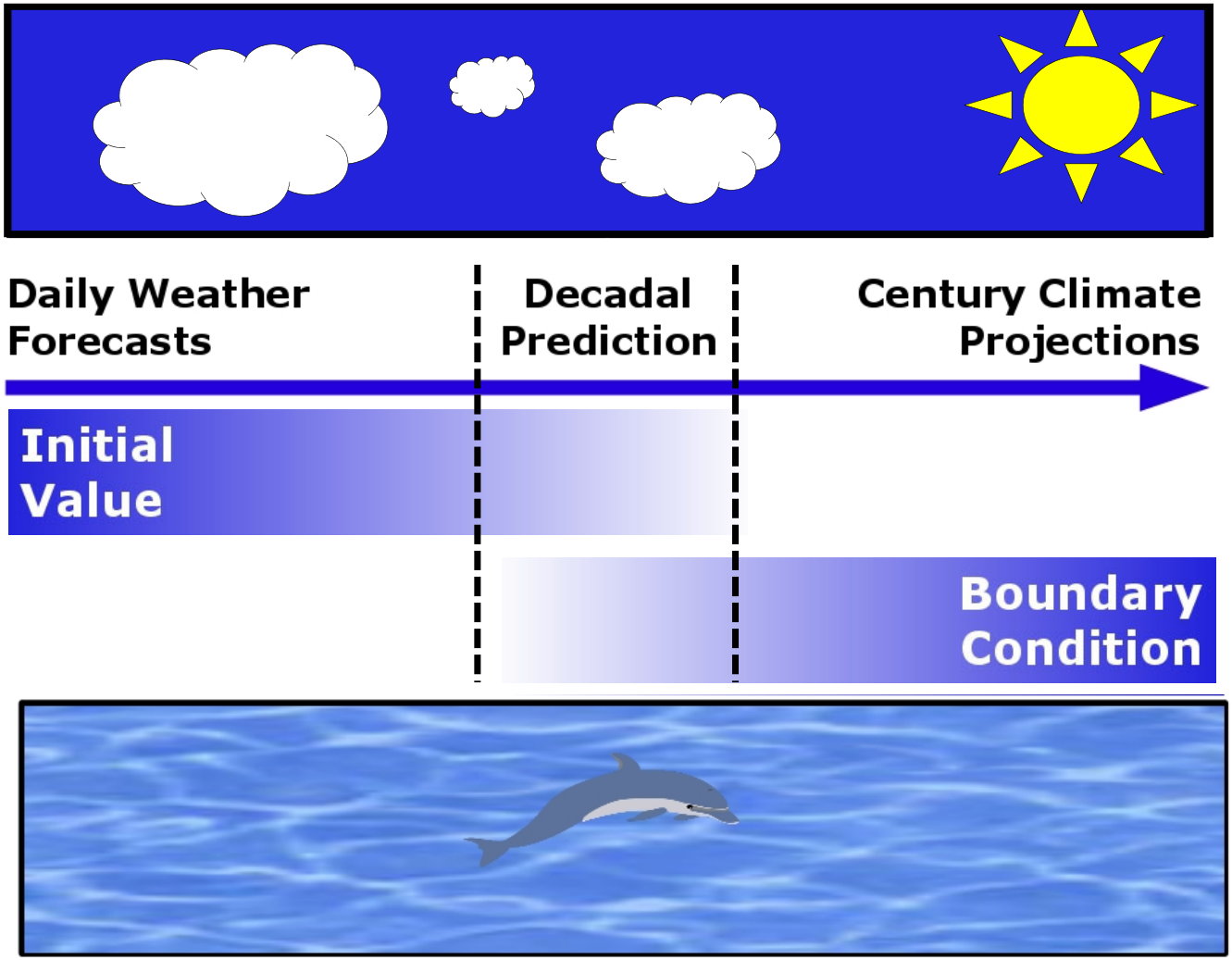
SPONSORED BY THE Federal Ministry of Education and Research

Talk @ BSC Barcelona 30.05.2019

Agenda

Table	With regards to content
1. Introduction	Introduction into **decadal prediction and MiKlip** and applied models as well as concepts/methods
2. Evaluation Platform	Development of the evaluation platform **Freva** for Earth system models and decadal climate prediction
3. Prediction Technique	Development of the **Ensemble Dispersion Filter** for decadal climate prediction exploiting the ocean memory and the ensemble mean
4. Summary	Conclusion of the results and **summary**

Introduction

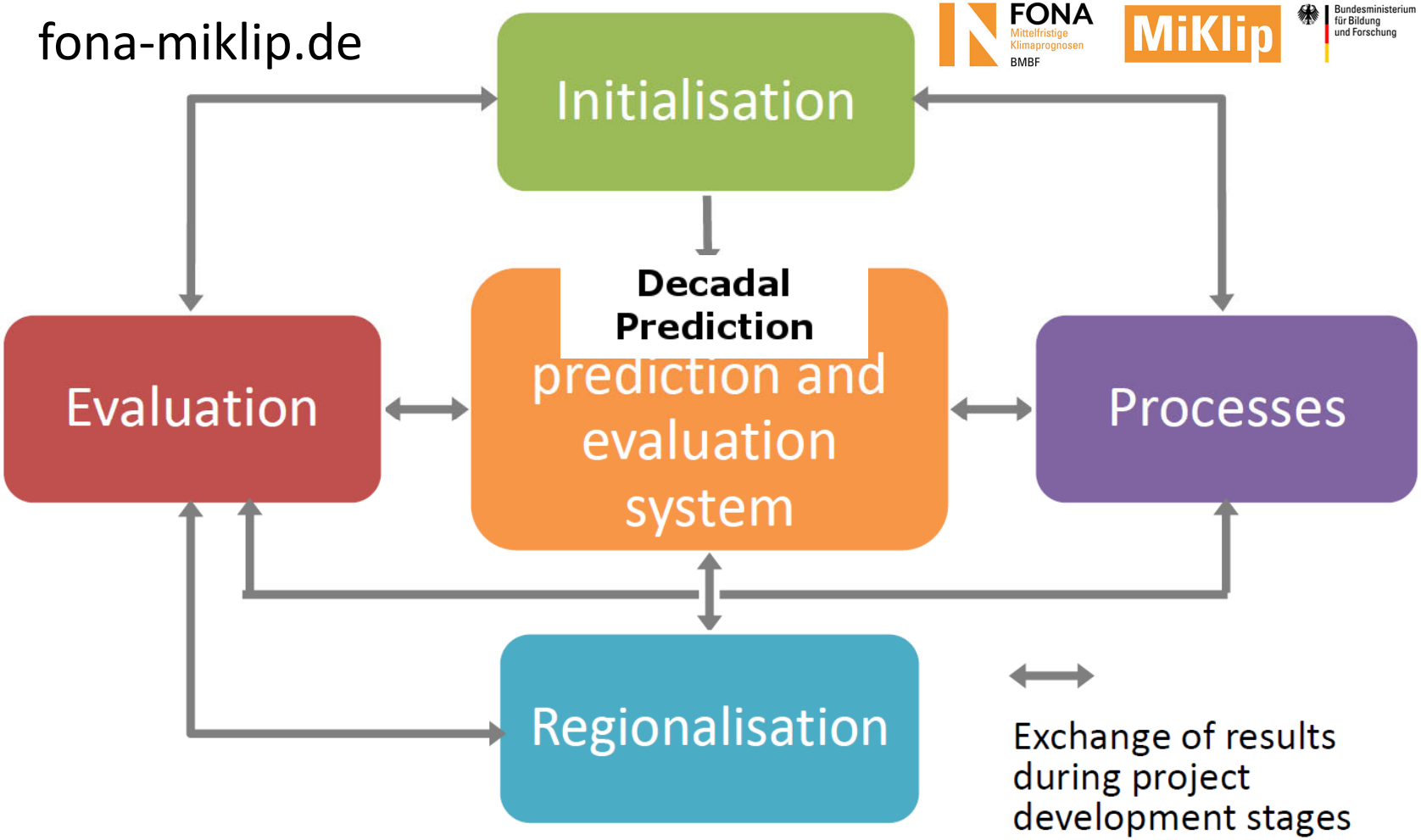


Based on Meehl et al. 2009

Introduction

MiKlip project

fona-miklip.de



Mittelfristige Klimaprognosen (MiKlip)

Introduction

MiKlip project

fona-miklip.de

FONA Mittelfristige Klimaprognosen BMBF

MiKlip

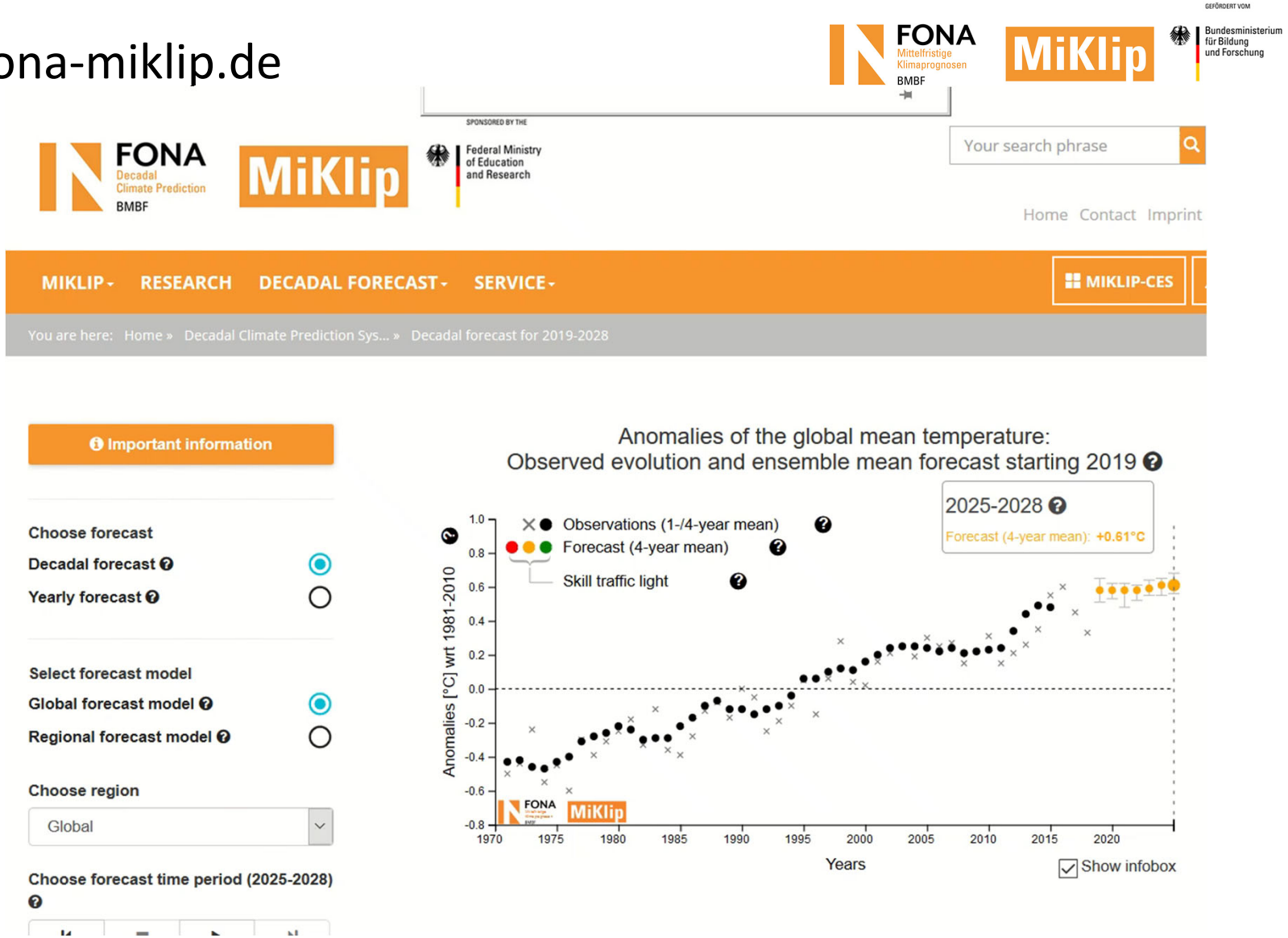
Gefördert vom Bundesministerium für Bildung und Forschung

2011 -2015				2016 -2018			2019
MiKlip I				MiKlip II			Op
1. Year	2. Year	3. Year	4. Year	5. Year	6. Year	7. Year	8. Year

Introduction

MiKlip project

fona-miklip.de



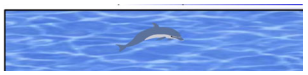
Introduction

MiKlip Prediction System - Baseline1 -> MiKlip-REF

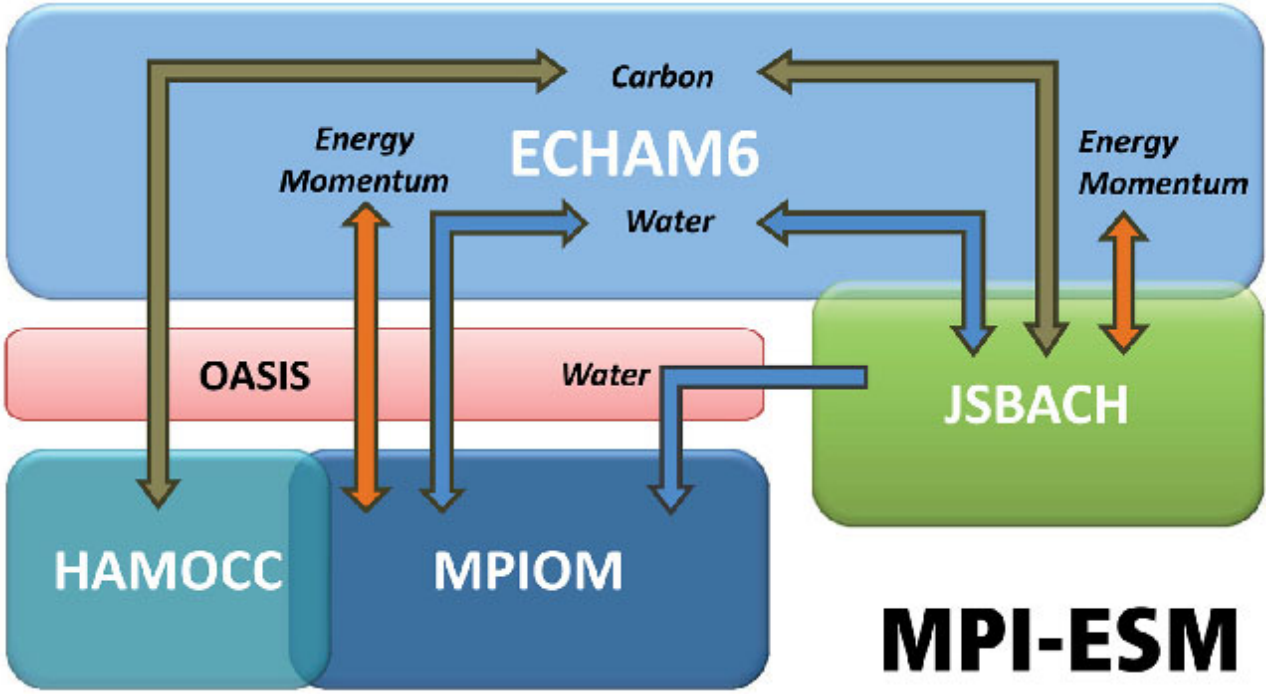
Max-Planck-Institute Earth System Model - Low Resolution

Atmosphere:  Resolution T63 (~1.8°) Level 49

Initialization: ERA-40/Interim Fullfield

Ocean:  Resolution 1.5° Level 40

Initialization: ORAS4 Anomaly

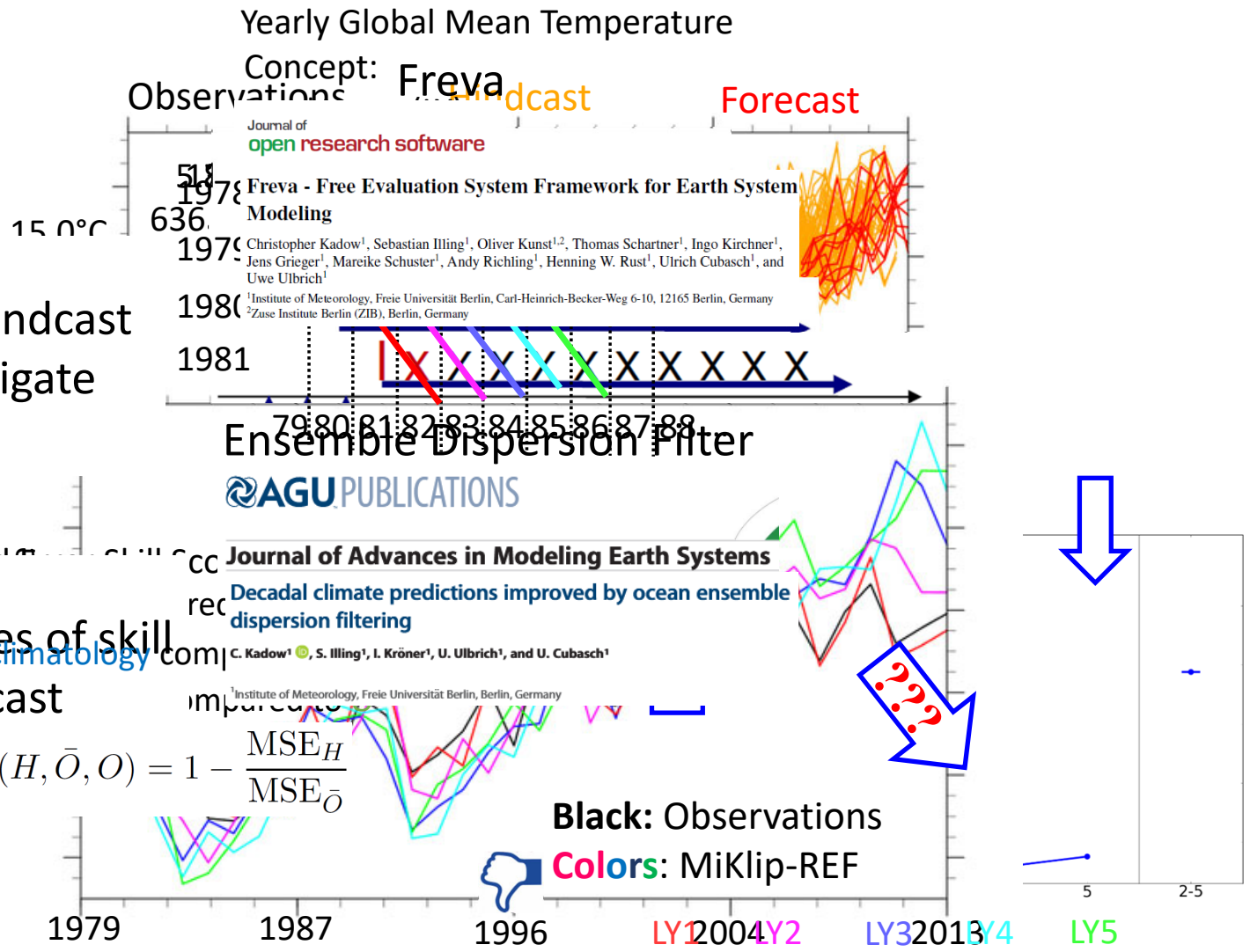


Introduction - Motivation

Development of an evaluation platform

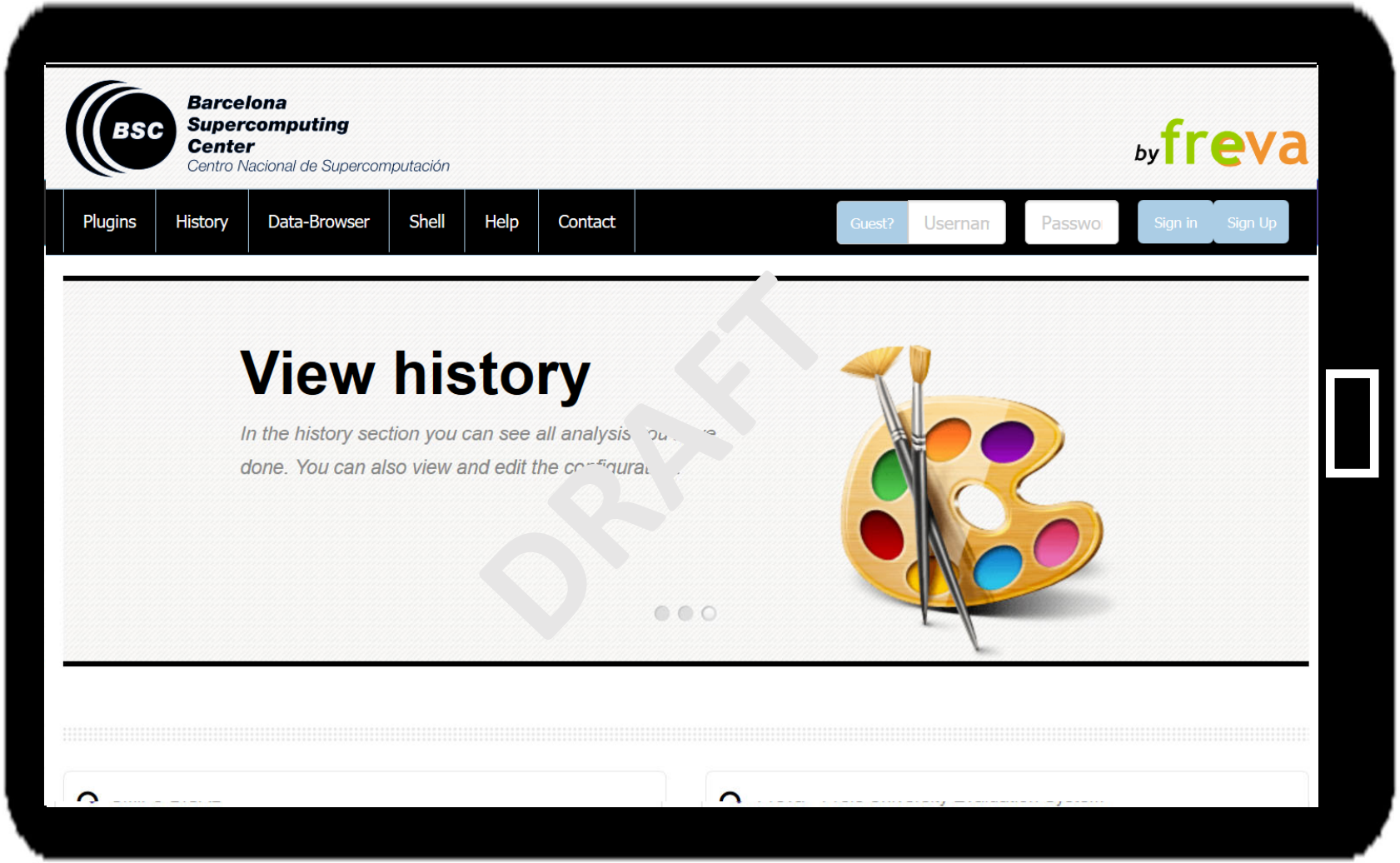
Development of a hindcast evaluation to investigate the forecast skill

Exploiting the sources of skill to improve the forecast

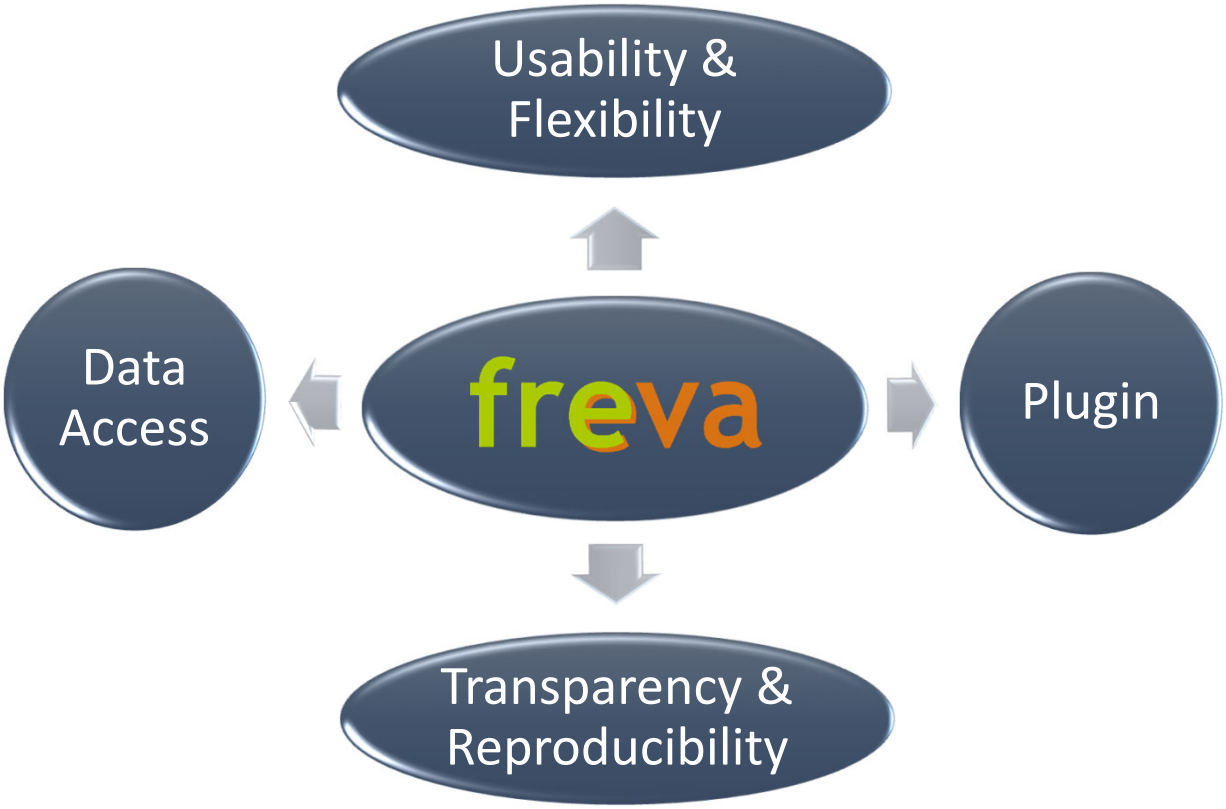


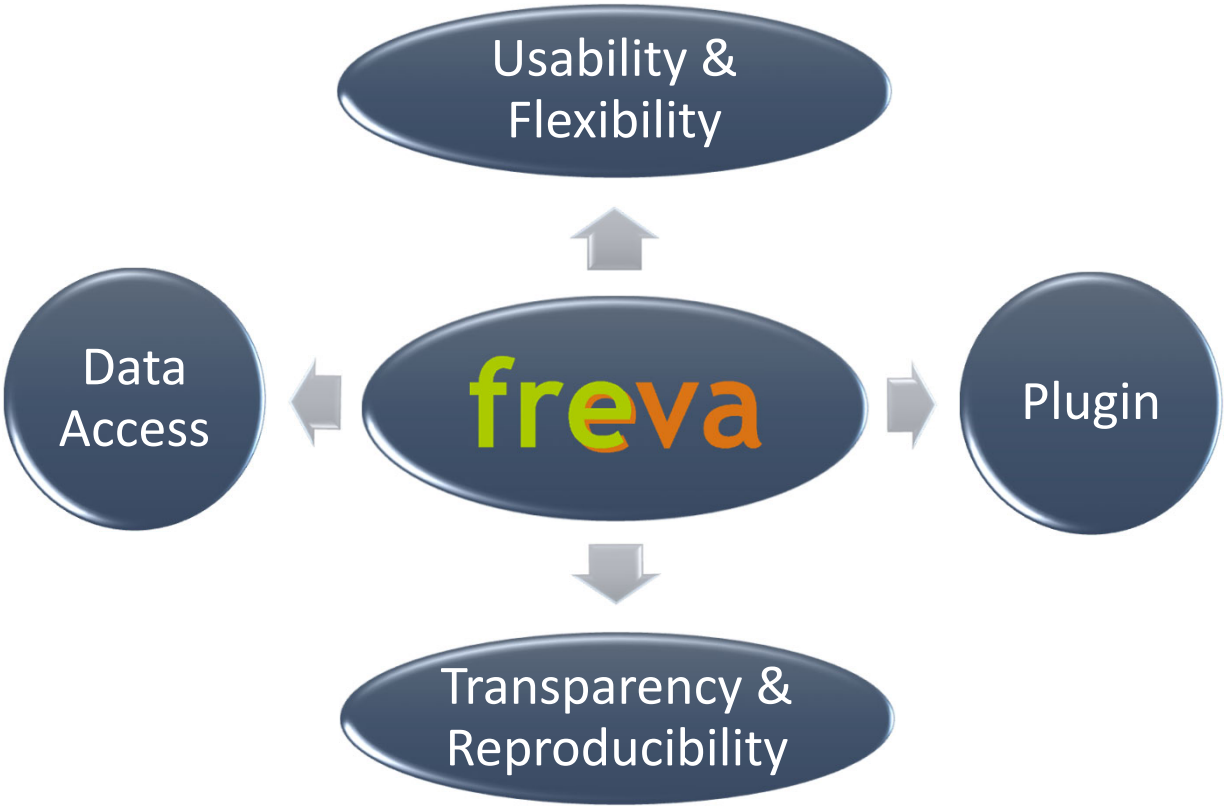
Evaluation Platform

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



Freva - Free Evaluation System Framework




Usability &
Flexibility
Data
Access
freva
Plugin
Transparency &
Reproducibility

```
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/r1i1p1/psl_6hrPlev_reanalysis_ERAINT_r1i1p1_20
05010100-2005123118.nc seldate='2005-08-25,2005-
08-31' cacheclear='True' resolution='800'
```

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

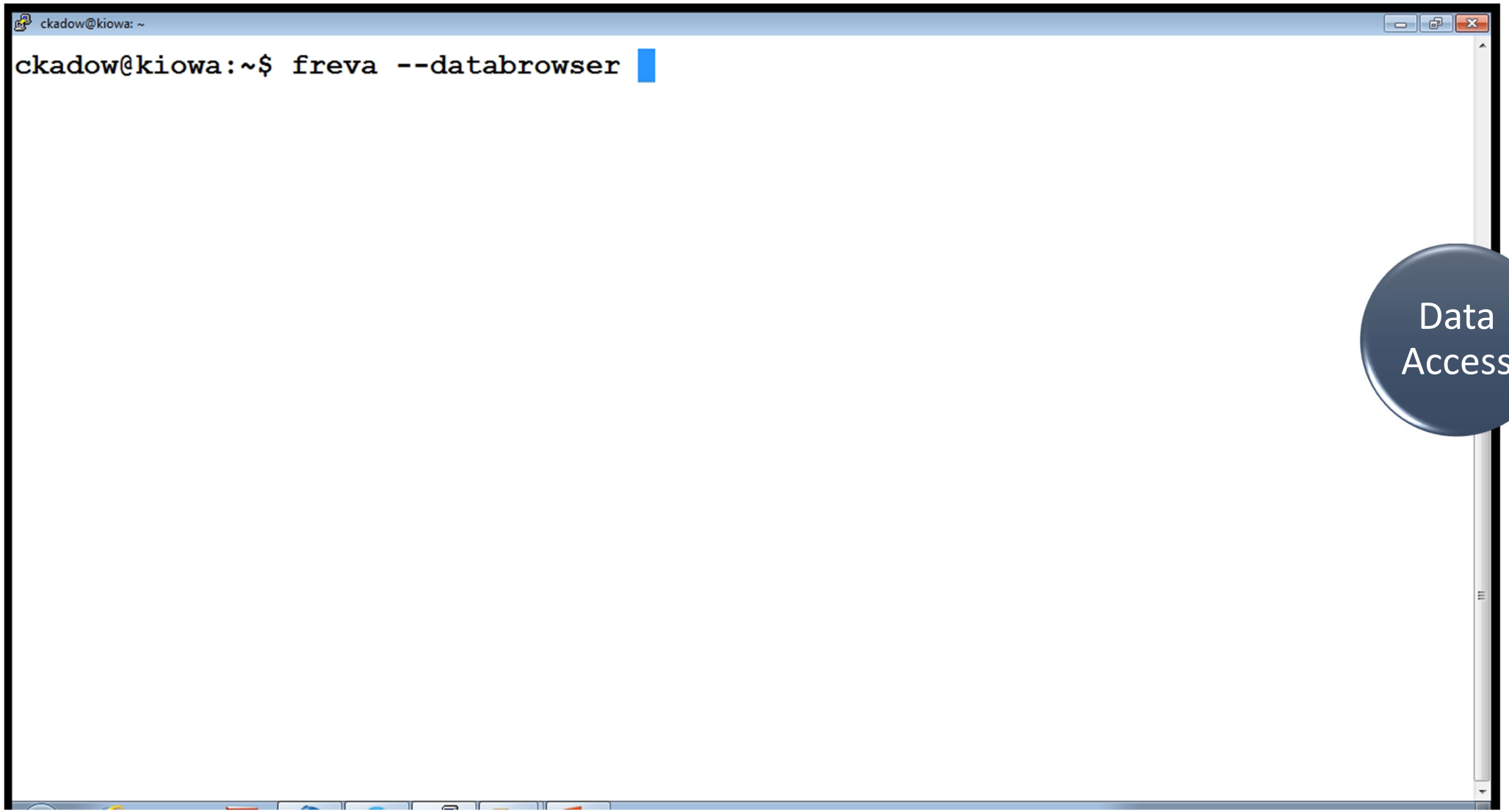
MiKlip uses **CMOR** & access several ESGF standards

SOLR Apache

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

Data Access

Data-Browser in the Shell



MySQL Database

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

GIT Versioning

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

Additional Information

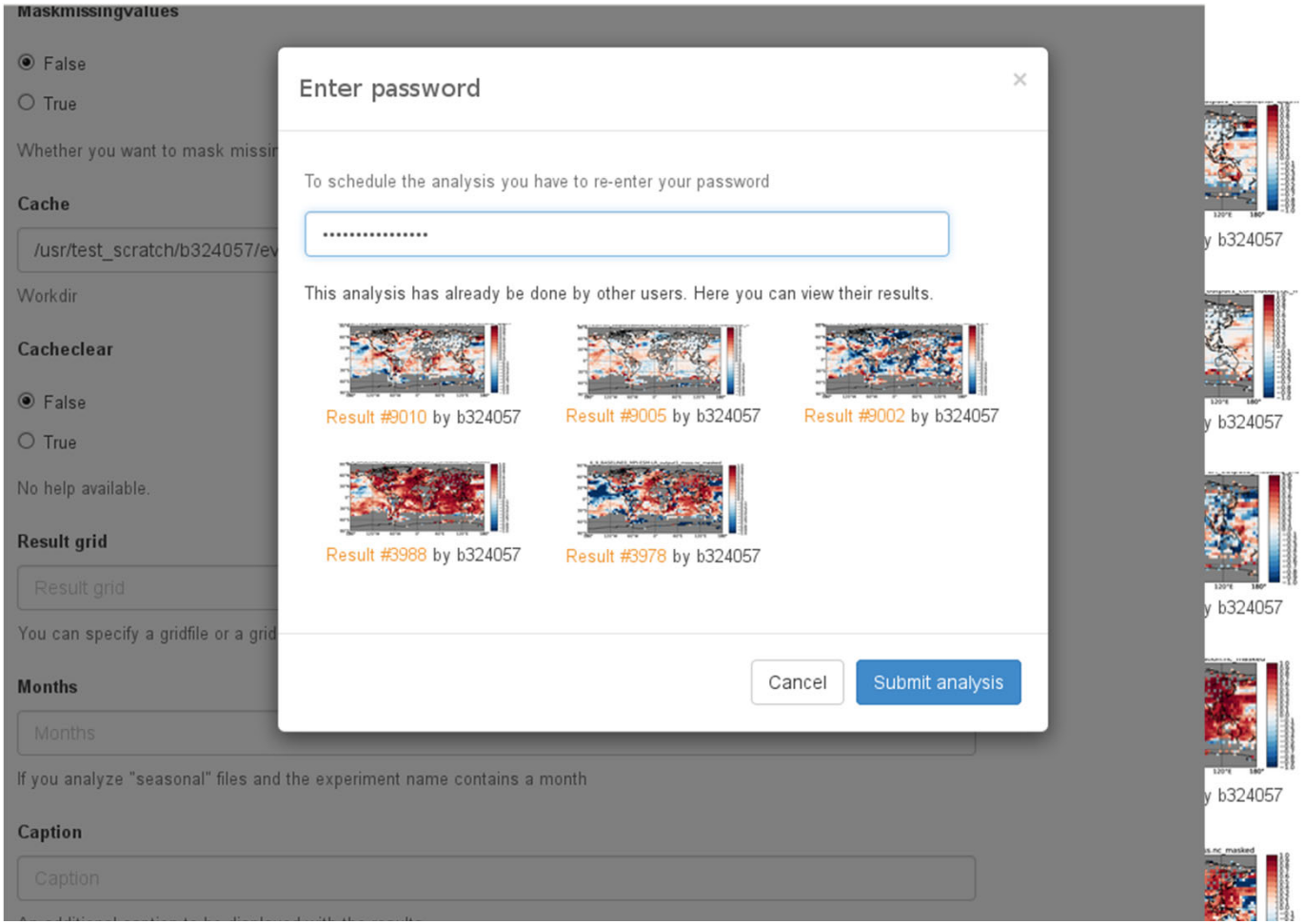
Analyze command:	freva --plugin murcss model2='mpi-esm-lr' model1='mpi-esm-lr' bootstrap_number='500' variable='tas' observation_ensemble='*' ensemblemembers2='r1i1p1,r2i1p1,r3i1p1' ensemblemembers1='r1i1p1,r2i1p1,r3i1p1' project1='baseline1' project2='baseline0' cache='/scratch/b324031/evaluation_system/cache/murcss/139343856755229' 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'
Tool repository:	/miklip/integration/repositories/goddard.git
Tool internal version:	972132d44a661ceb336c808575e7eed37d10344e
System repository:	/miklip/integration/repositories/evaluation_system.git/
System internal version:	76188e756fad20c95e80c300de6c49c031c1a501

Featured Recommendations

Inspired by your browsing history

Transparency & Reproducibility

Saving CPU time, I/O and disk space!



The Admin Panel

Transparency & Reproducibility

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: --------- Ausführen 0 von 1

ID	Timestamp	Tool	Link to model	Status name	Started from website
156076	13. Februar 2019 18:11	vadylight	Show Results	finished	⛔
156075	13. Februar 2019 17:48	vadylight	Show Results	finished	⛔
156074	13. Februar 2019 17:23	vadylight	Show Results	finished	⛔
156073	13. Februar 2019 17:20	cvprepare	Show Results	finished_no_output	⛔
156072	13. Februar 2019 16:56	cvprepare	Show Results	broken	⛔
156071	13. Februar 2019 16:01	murcss	Show Results	broken	✅
156070	13. Februar 2019 15:42	murcss	Show Results	broken	✅
156069	13. Februar 2019 15:27	vadylight	Show Results	finished	⛔
156068	13. Februar 2019 15:01	cvprepare	Show Results	finished_no_output	⛔
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

Plugin

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

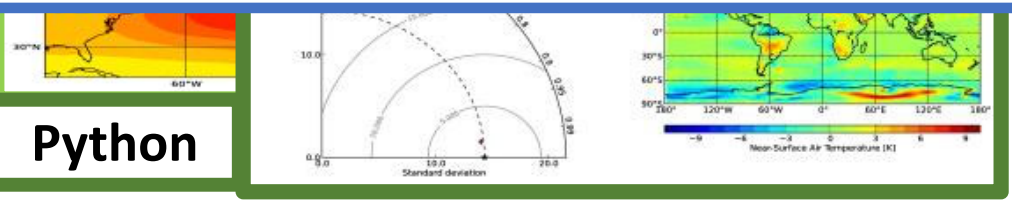
```
from evaluation_system.api import plugin

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

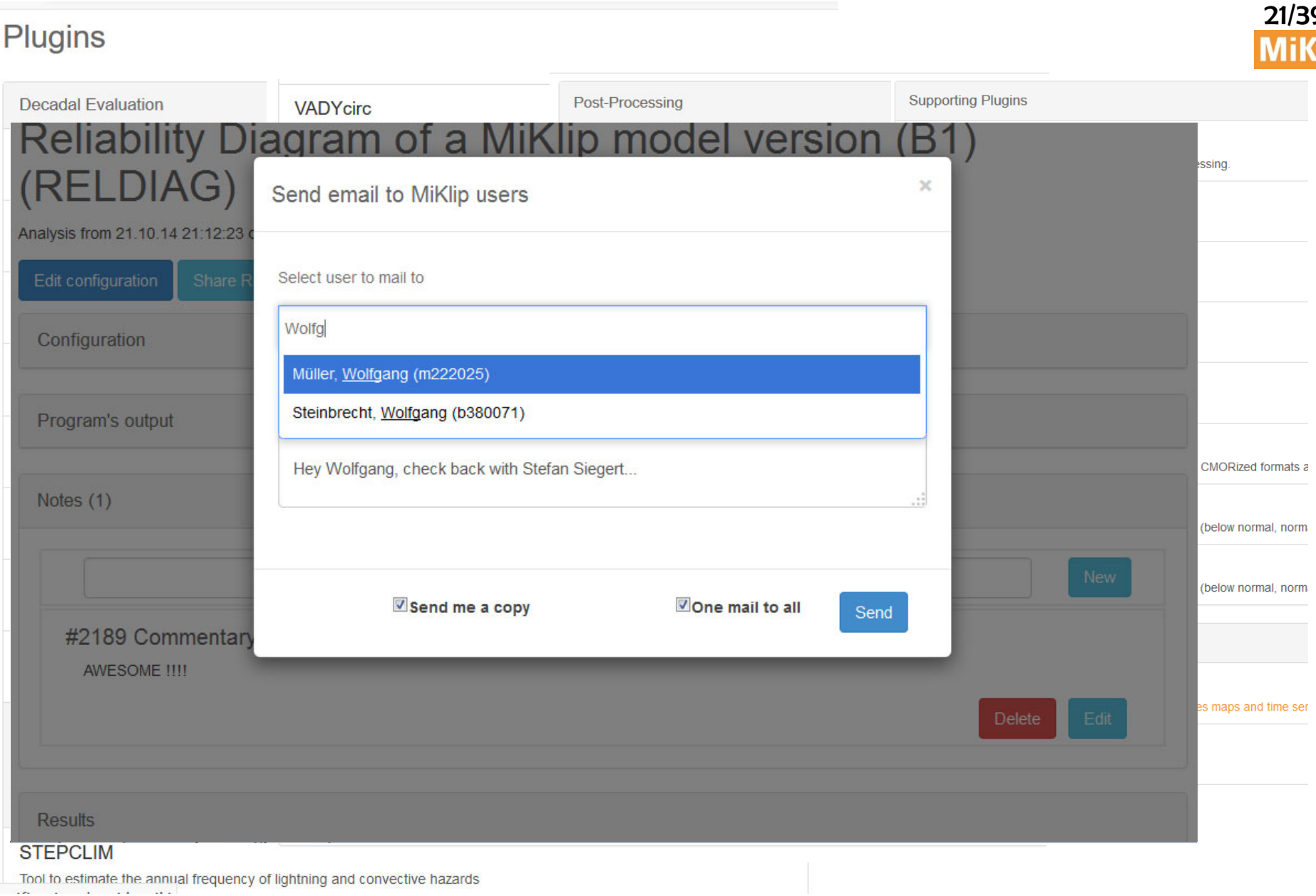
```
./movie_plotter.sh    /path/2/INPUT    /path/2/OUTPUT
```

C++

Python



Plugin


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
Edit configuration
Configuration
Program's output
Notes (1)
New
#2189 Commentary
AWESOME !!!!
Delete
Edit
Results
STEPCLIM
Tool to estimate the annual frequency of lightning and convective hazards
Send email to MiKlip users
Select user to mail to
Wolfg
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:

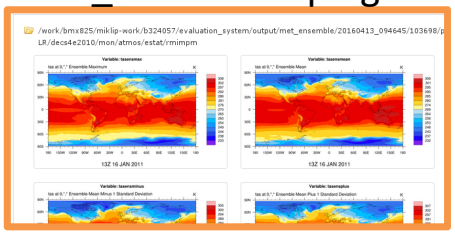
Link2database

○ False

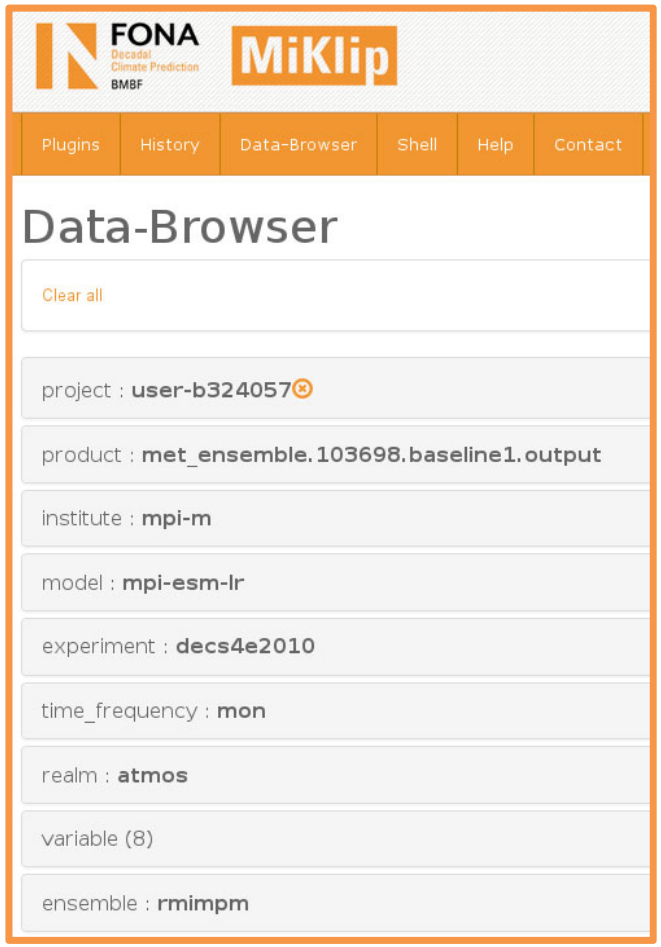
◉ True

Set "True" for crawl and ingest the output

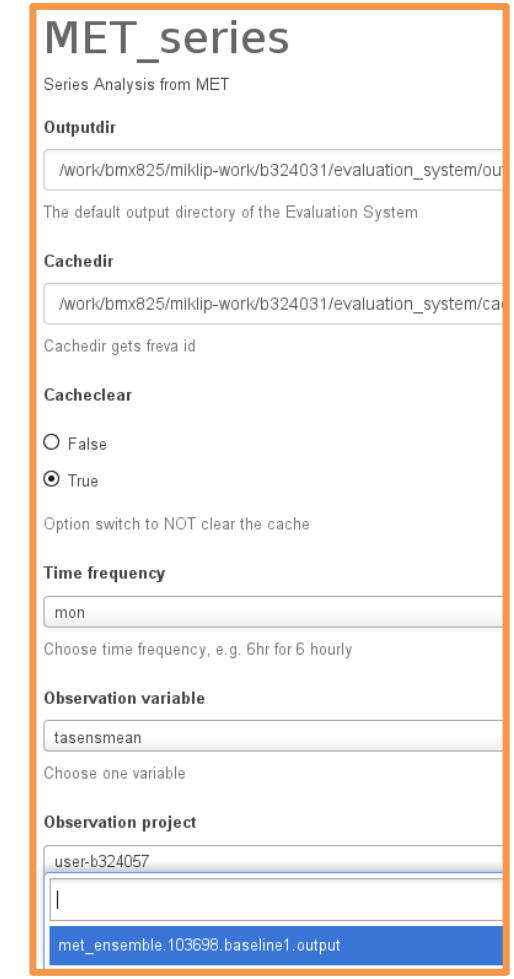
Preview output of the MET_ENSEMBLE plugin:



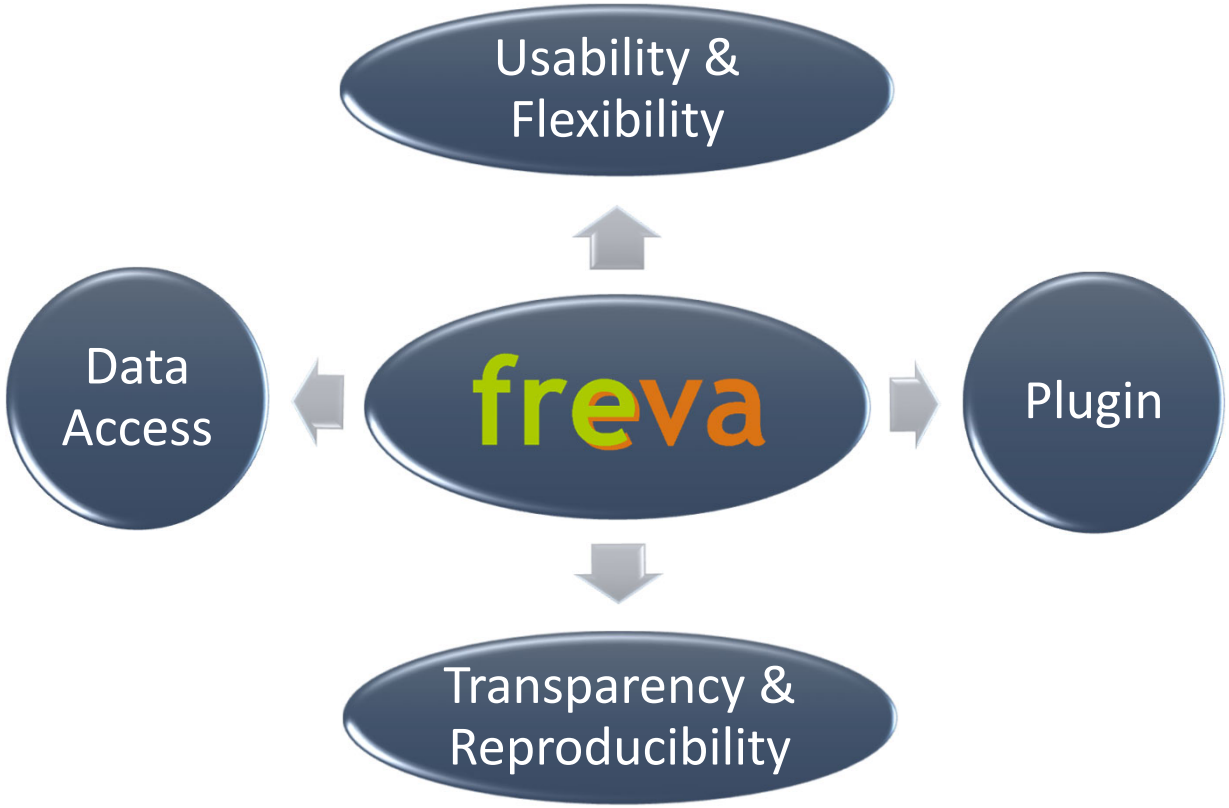
Result of the plugin now part of the users database



… and can be choosen as input for next plugin



A standardized data and application system for evaluation…

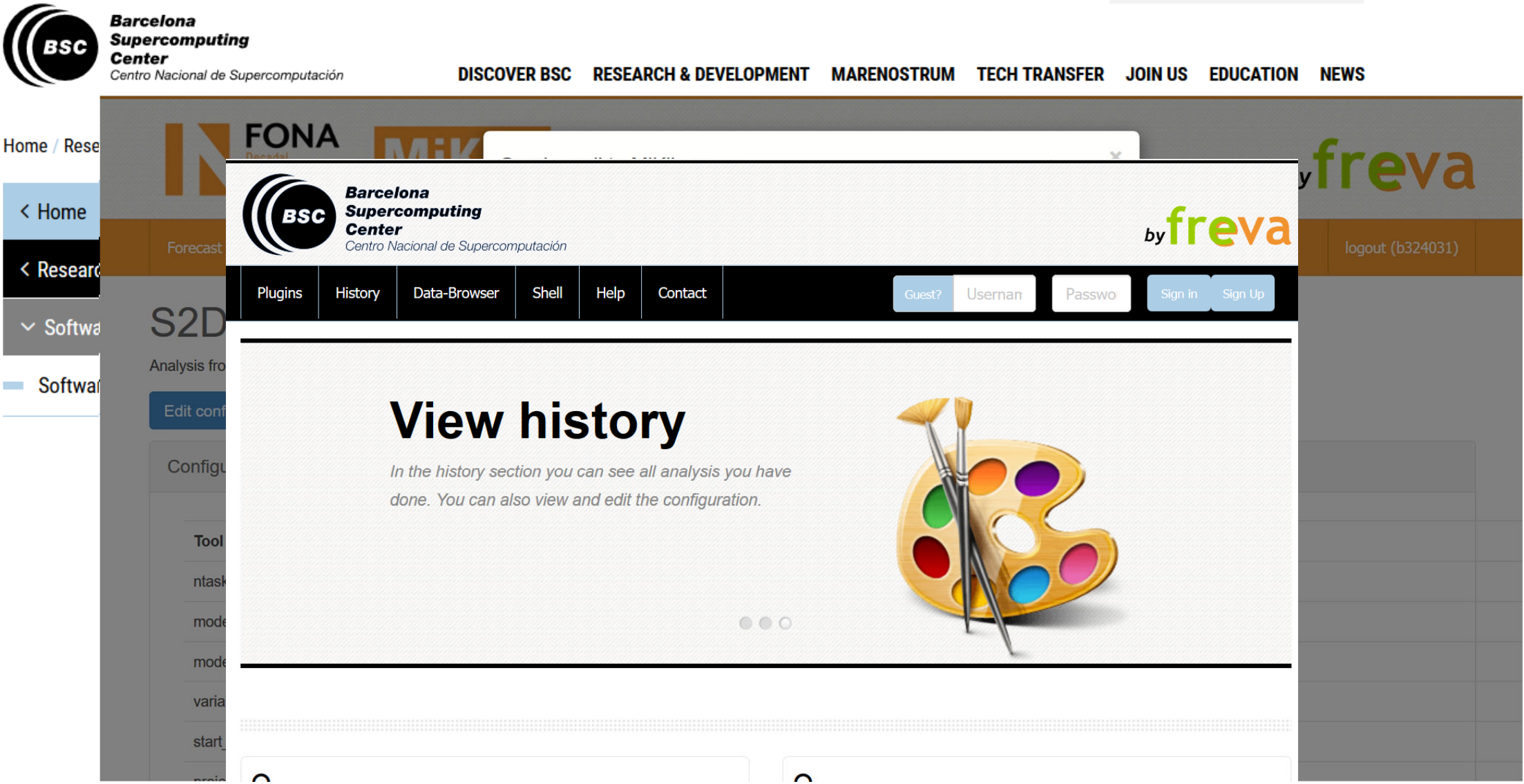


… of climate model forecasts, hindcasts and projections

Freva @ BSC?

s2dVerification @ Freva

Andy Richling (FUB)



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

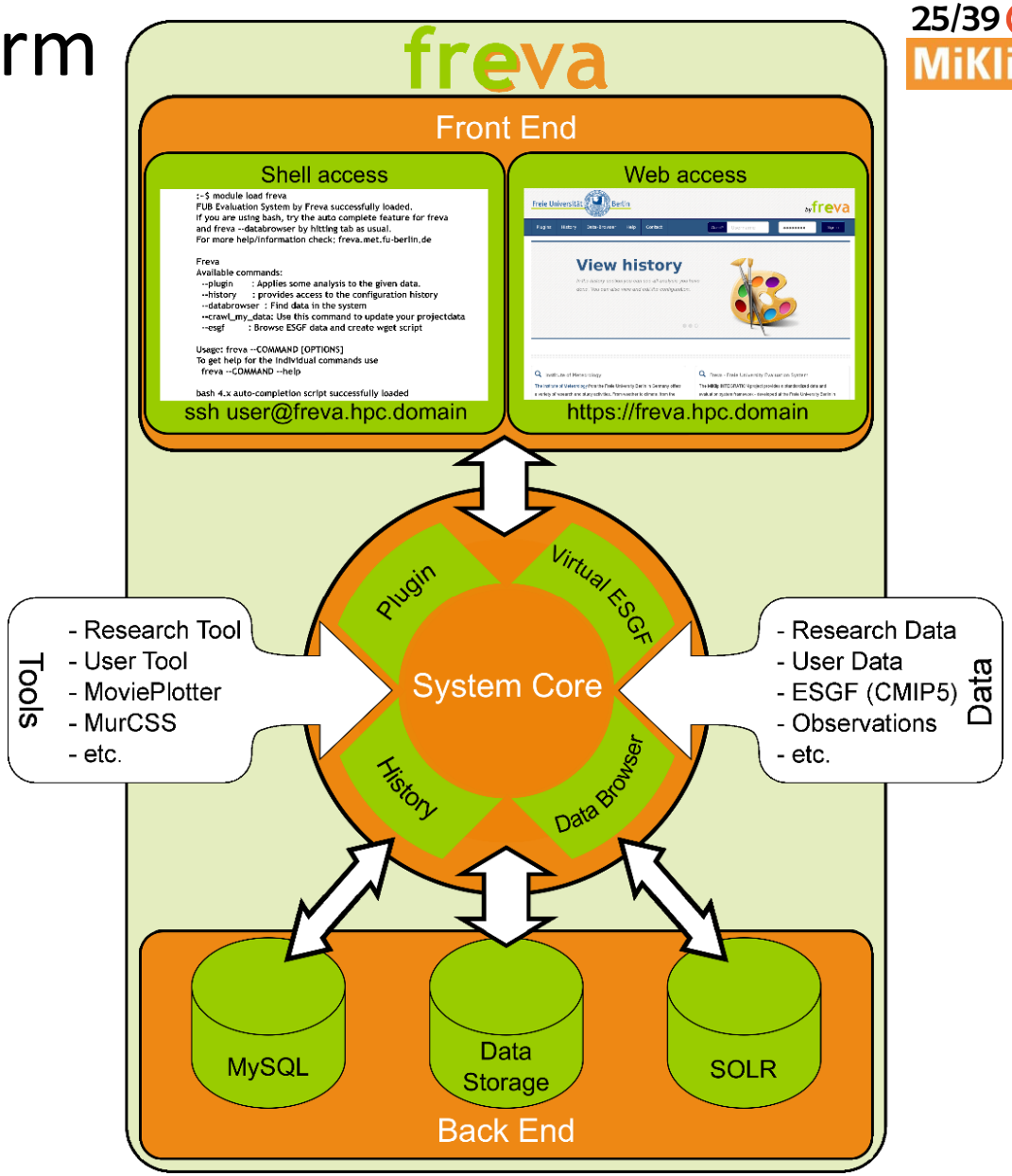
- *www-miklip.dkrz.de*

More Informations @ FU-Berlin

- *freva.klimod.de*

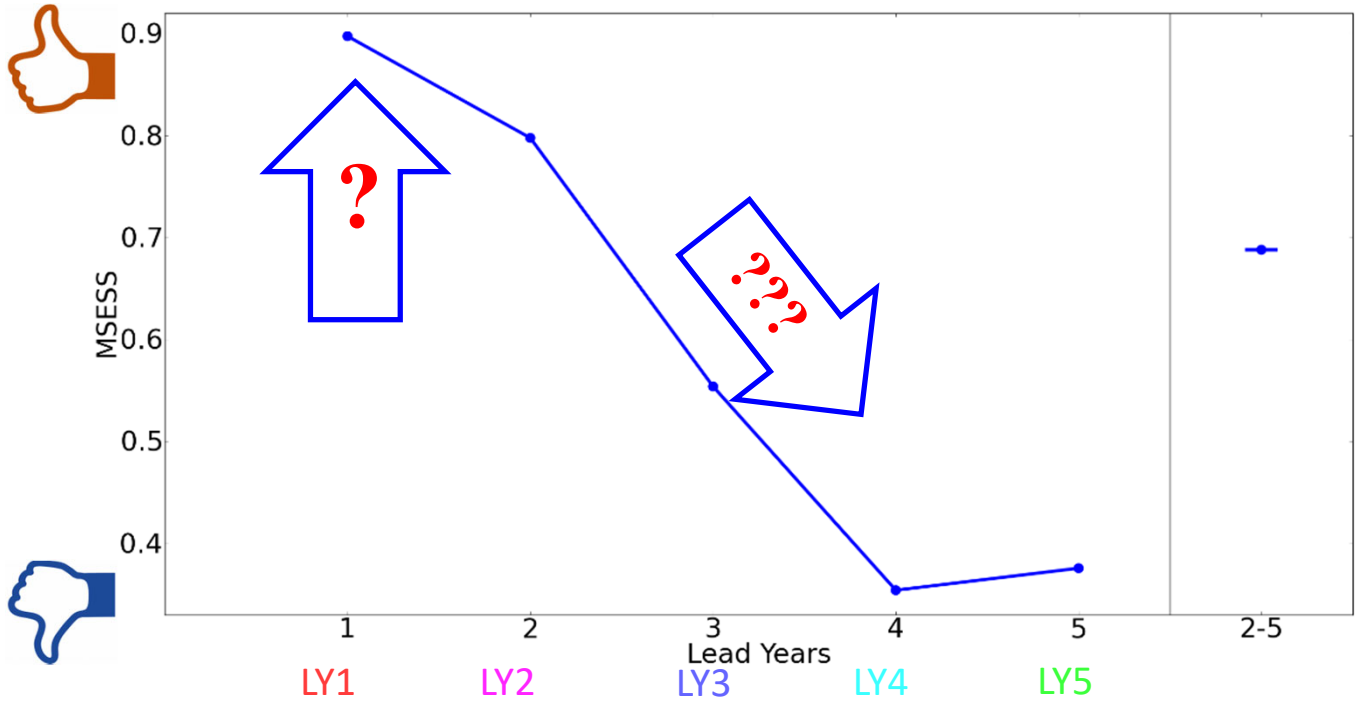
More Informations @ CMIP

- *cmip-esmvaltool.dkrz.de*



Prediction Technique

Exploiting the sources of skill to improve the forecast



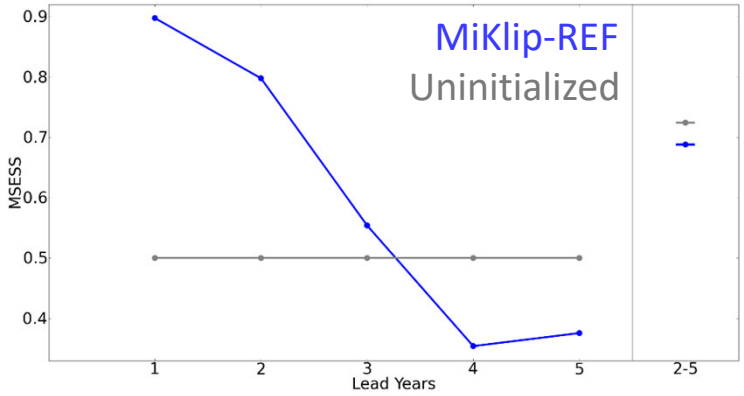
Prediction Technique

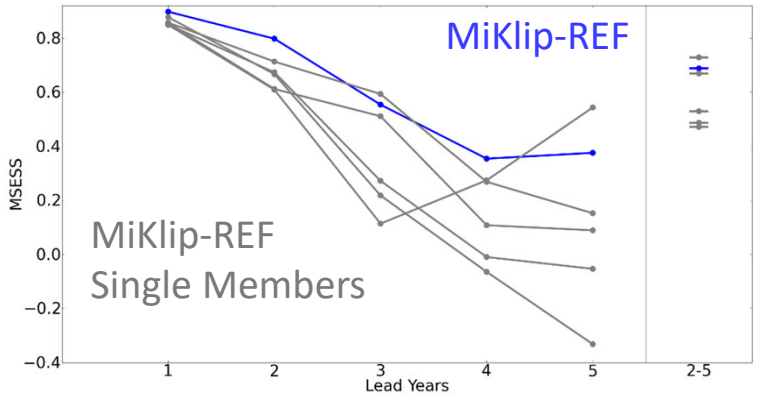
Ocean ^{2} Ensemble

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

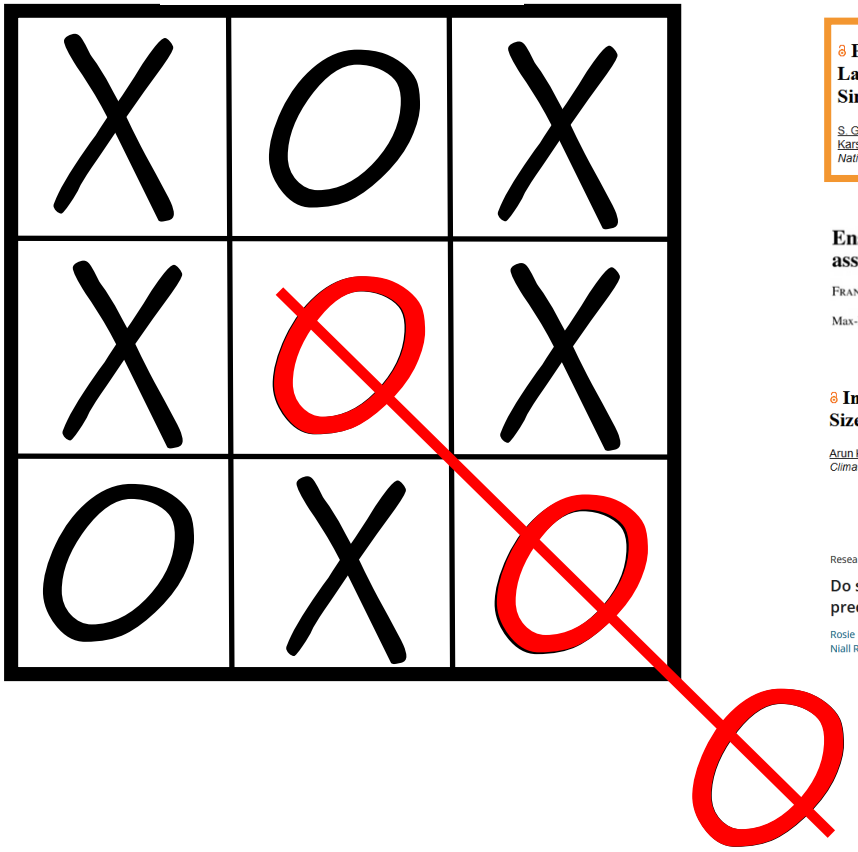




Prediction Technique

Ocean Ensemble

THINK Decadal Prediction IE BOX



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. Jungclaus, L. Kornblueh & E. Roeckner

Initializing Decadal Climate Predictions with the GECCO Oceanic Synthesis: Effects on the North Atlantic

Holger Pohlmann* and Johann H. Jungclaus
Max-Planck-Institut für Meteorologie, Hamburg, Germany

Assim… arth
syste… Ensemble Kalman Filter
Sebastian Brune, Lars Nerger, Johanna Baehr

...

Predicting Near-Term Changes in the Earth System: A Large … Simul… 40 Member Hindcast …Model

S. G. Yeager, G. Danabasoglu, N. 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 for Meteorology, 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

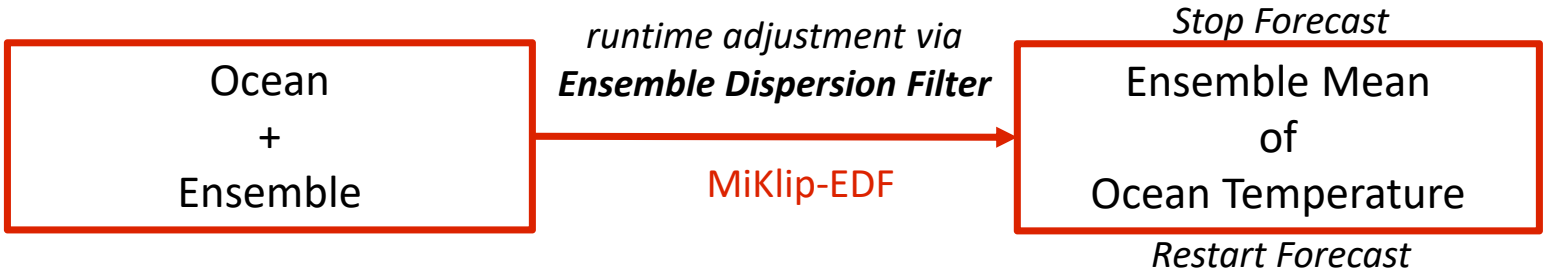
Research Letter | Open Access

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

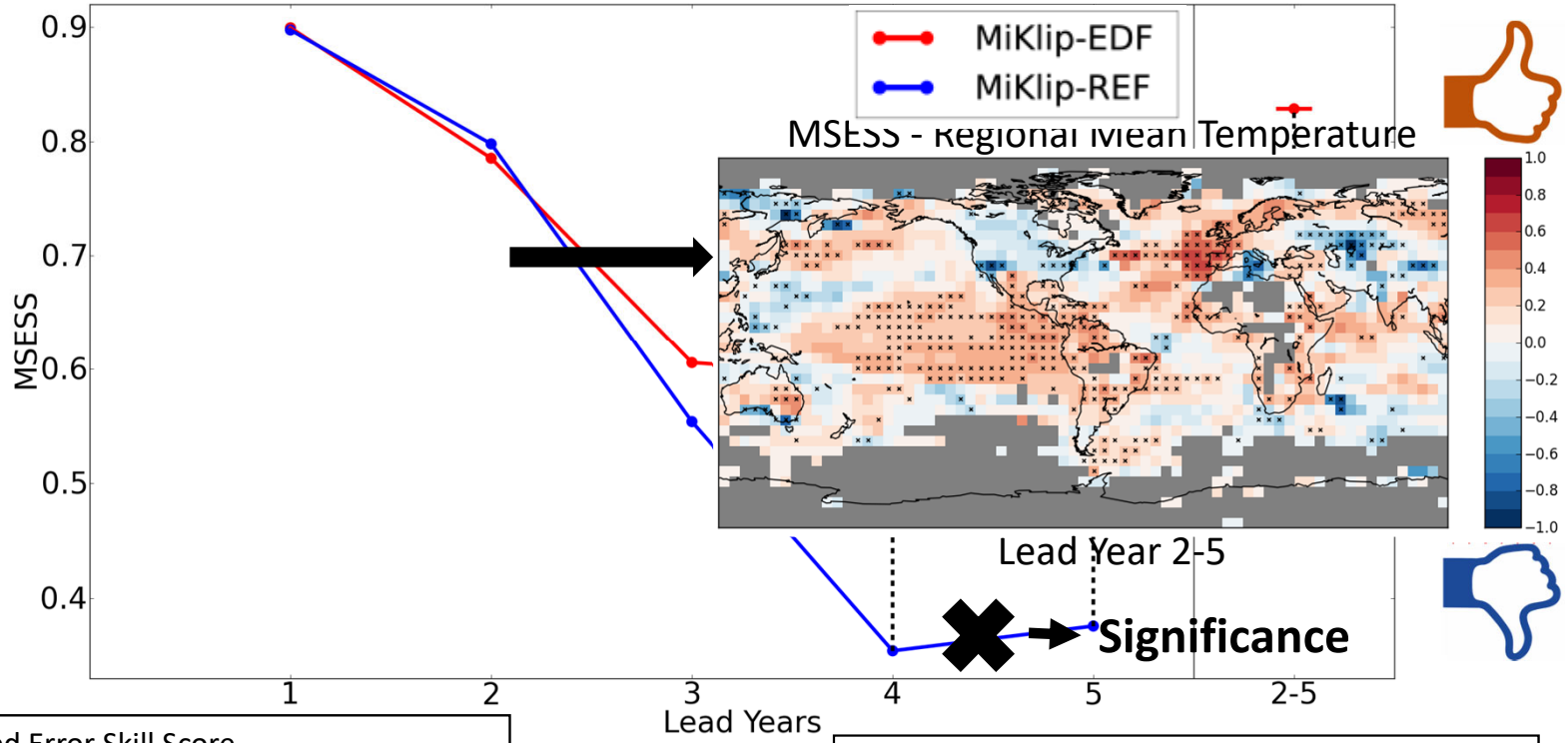


Prediction Technique

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
+ Large important impact over Central Pacific



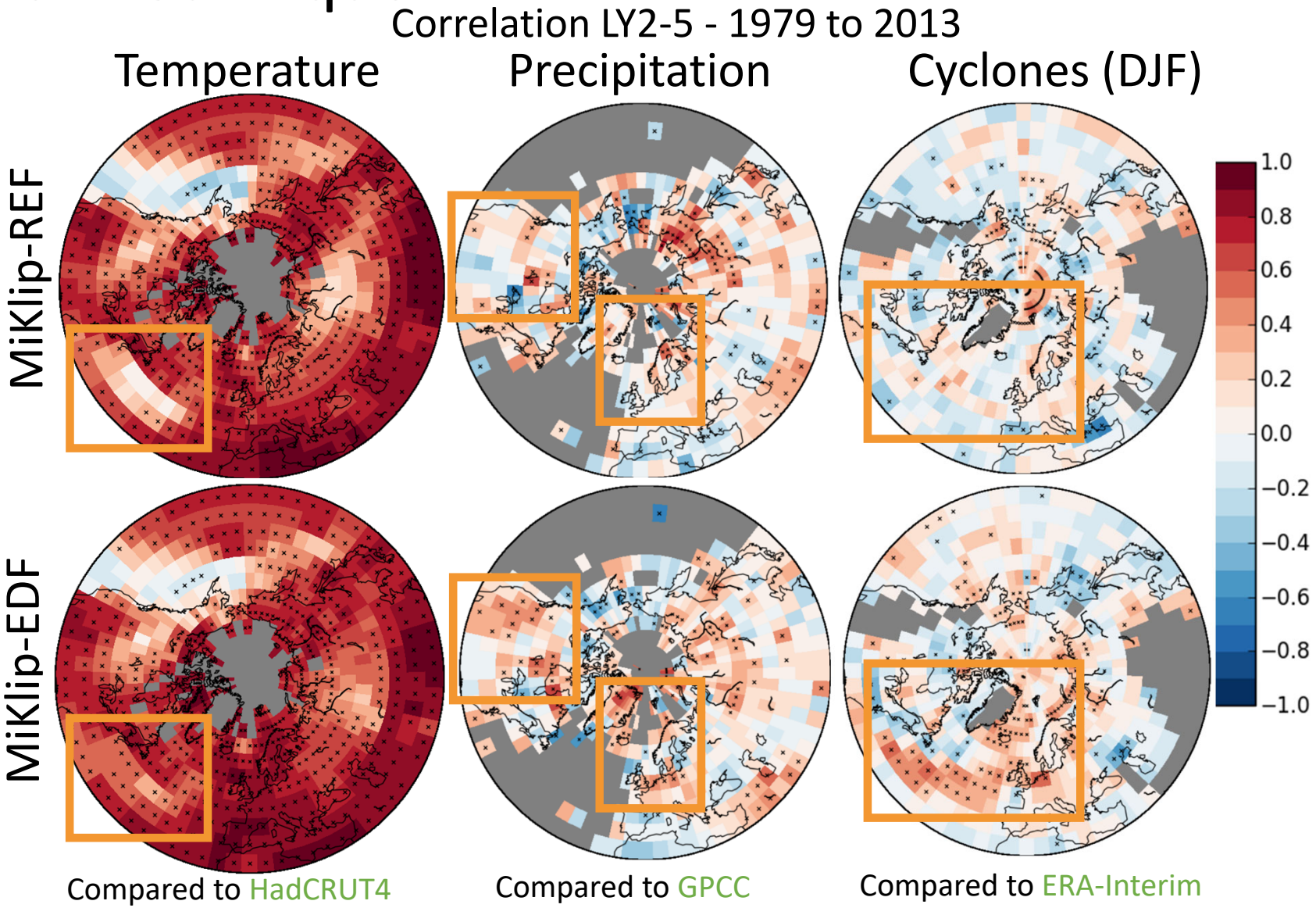
Mean Squared Error Skill Score
Forecast vs Reference compared to Observations

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



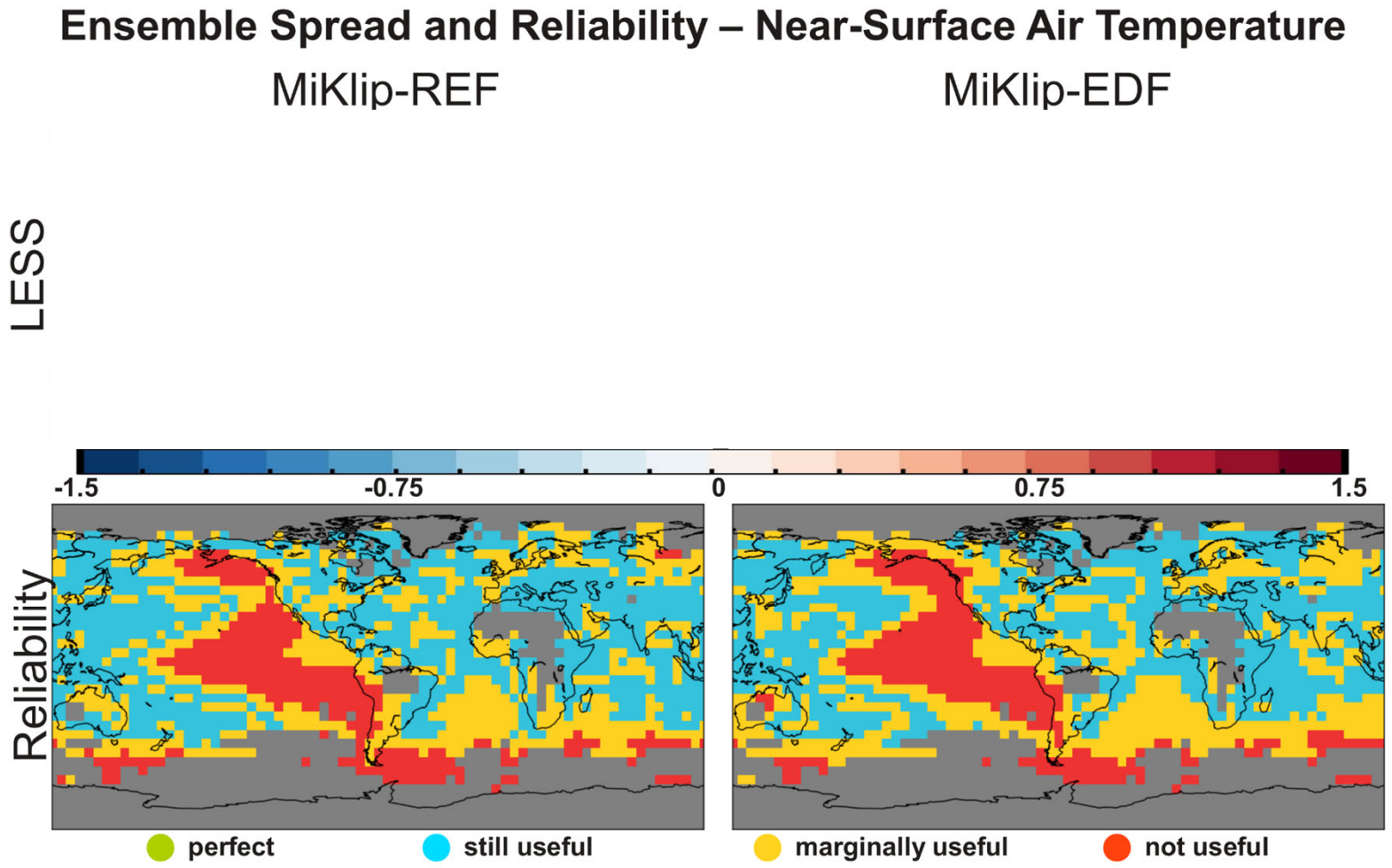
Prediction Technique

- 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?

...

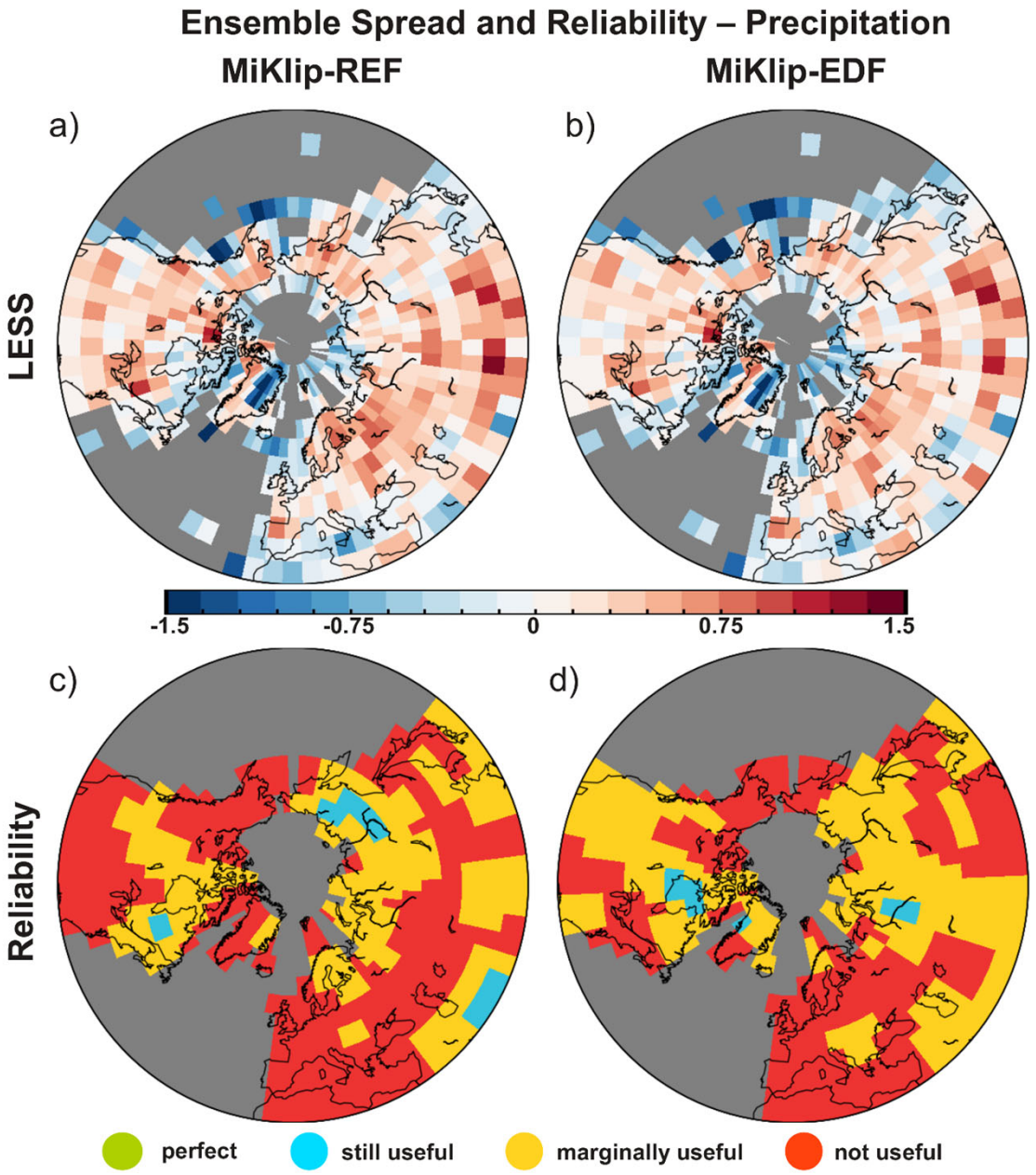
Prediction Technique

Spread and Reliability?

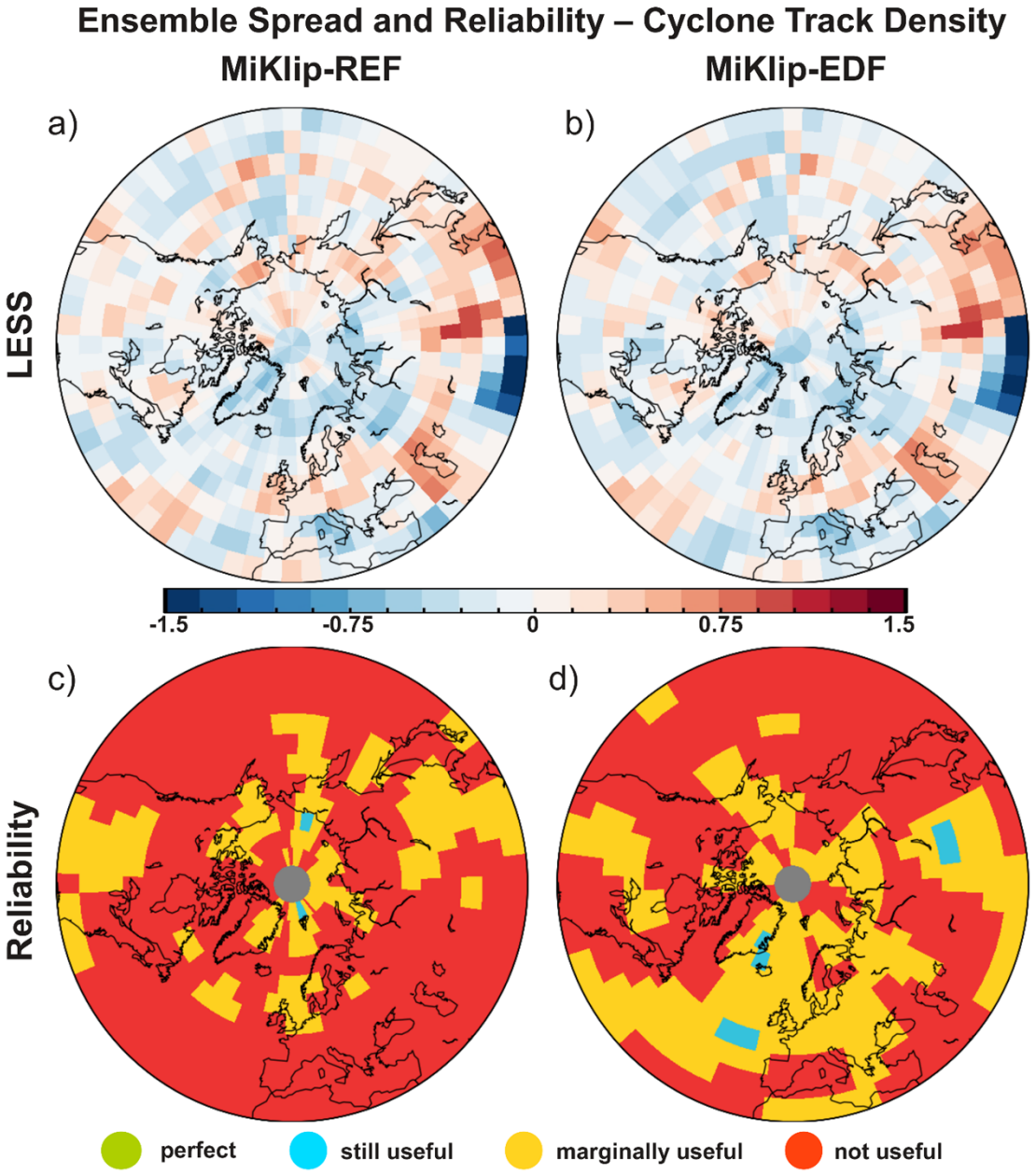


Prediction Technique

Spread and Reliability?



Prediction Technique



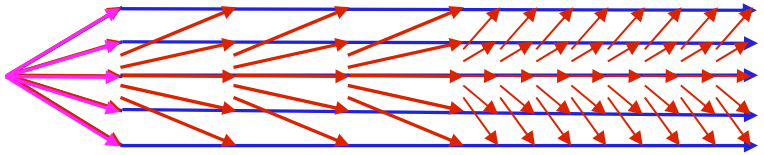
Spread and Reliability?

Prediction Technique

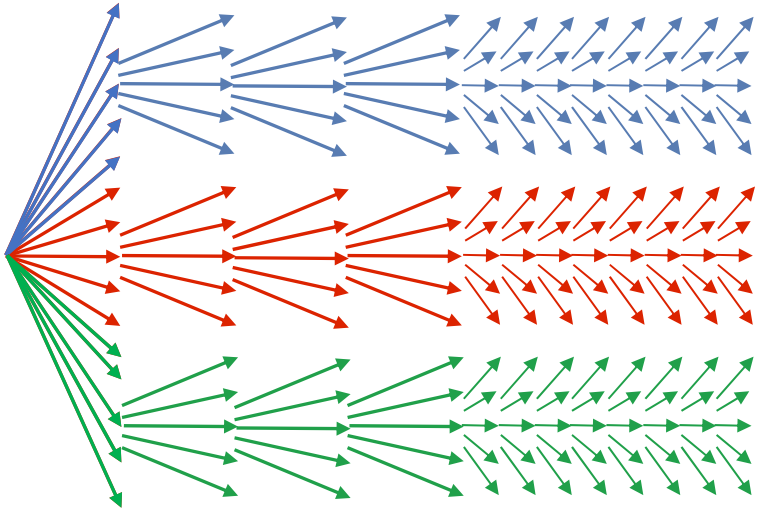
Spread and Reliability?

Experiment Setup to get „a“ spread back

decadal experiment
Raw and EDF



decadal experiment
15 Members EDF



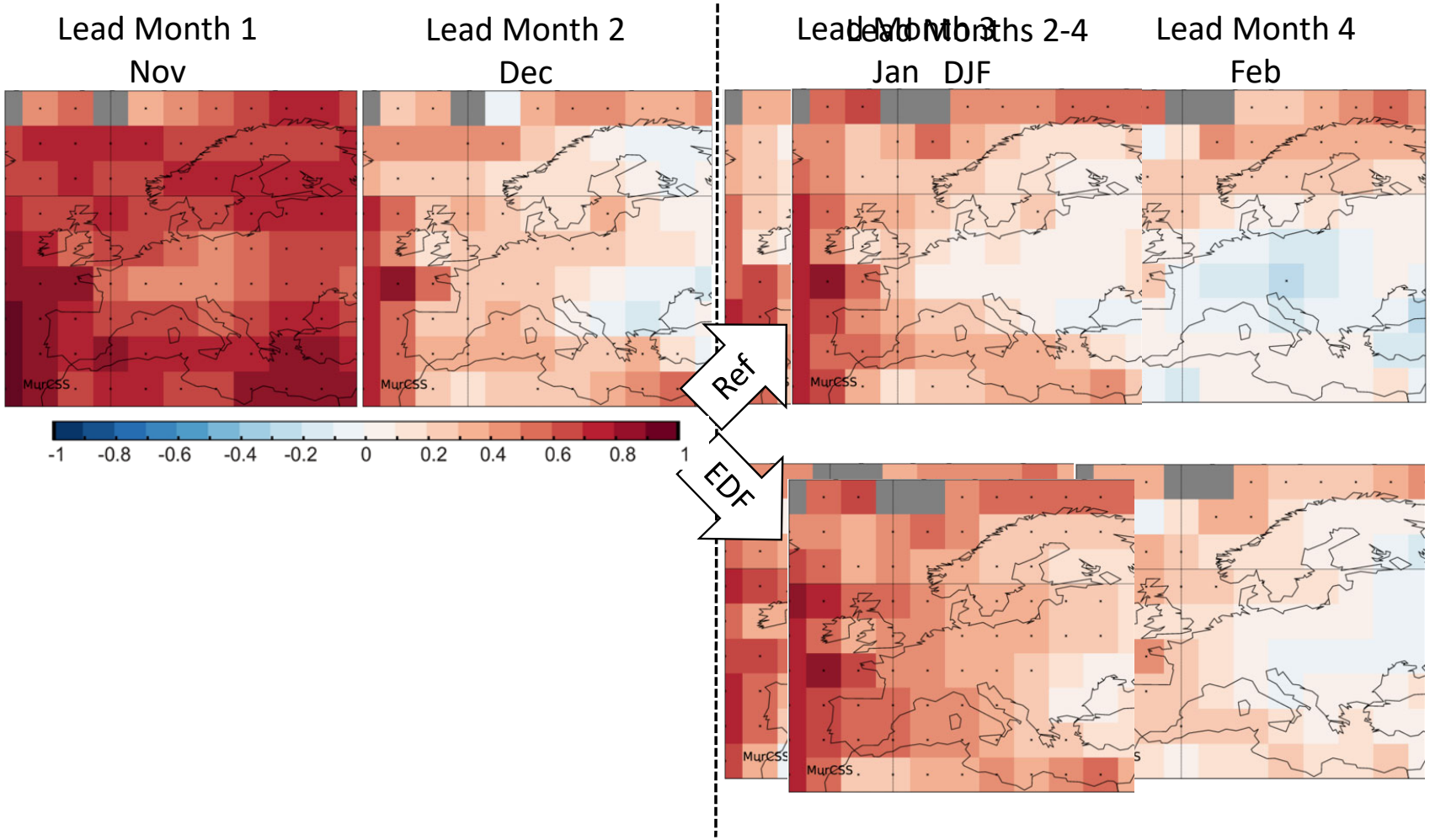
Prediction Technique

Seasonal Effect?

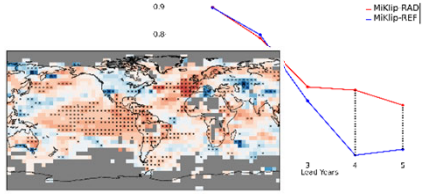
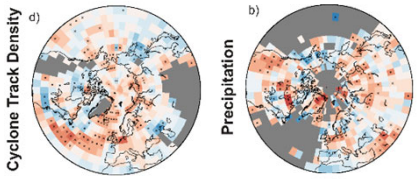
Decadal system starts in November to be synchronized with the Seasonal system

- New MiKlip Prediction system -

Check first Winter - Correlation

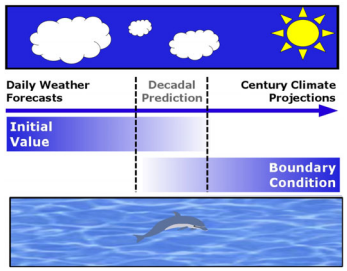


Summary of Prediction Technique

Question:	Answer:	
What is the main idea behind this novel approach?	The Ocean + The Ensemble	Using the **ensemble mean** (non-linear error filter) of the **ocean temperatures** (decadal memory) within a forecast, keeps the forecast on track
Is the temperature forecast closer to the observations?		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)
What about other important variables than temperature?		MiKlip-EDF shows large areas of significant **positive correlation** coeffients 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

Summary

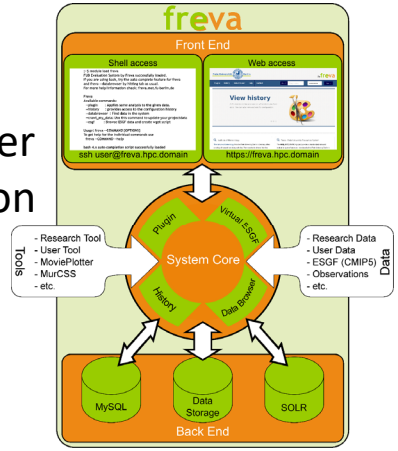


Climate Science

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.

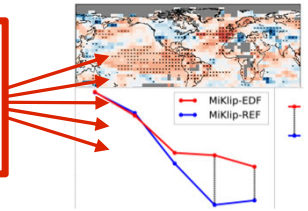


Prediction Technique

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

What is the idea? Is the prediction more accurate?

Ozean + Ensemble



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.