Climate SPHINX

High-resolution present-day and future climate simulations with an improved representation of small-scale variability

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*Climate **SPHINX** (Stochastic Physics High Resolution Experiments) **is a PRACE EU project which aims at investigating the sensitivity of climate simulations to model resolution and stochastic parameterizations**, and to determine if very high resolution is truly necessary to facilitate the simulation of the main features of climate variability.*

SPHINX is a project by **ISAC-CNR**, lead by Jost von Hardenberg, in collaboration with Oxford University (Tim Palmer and Antje Weisheimer group).

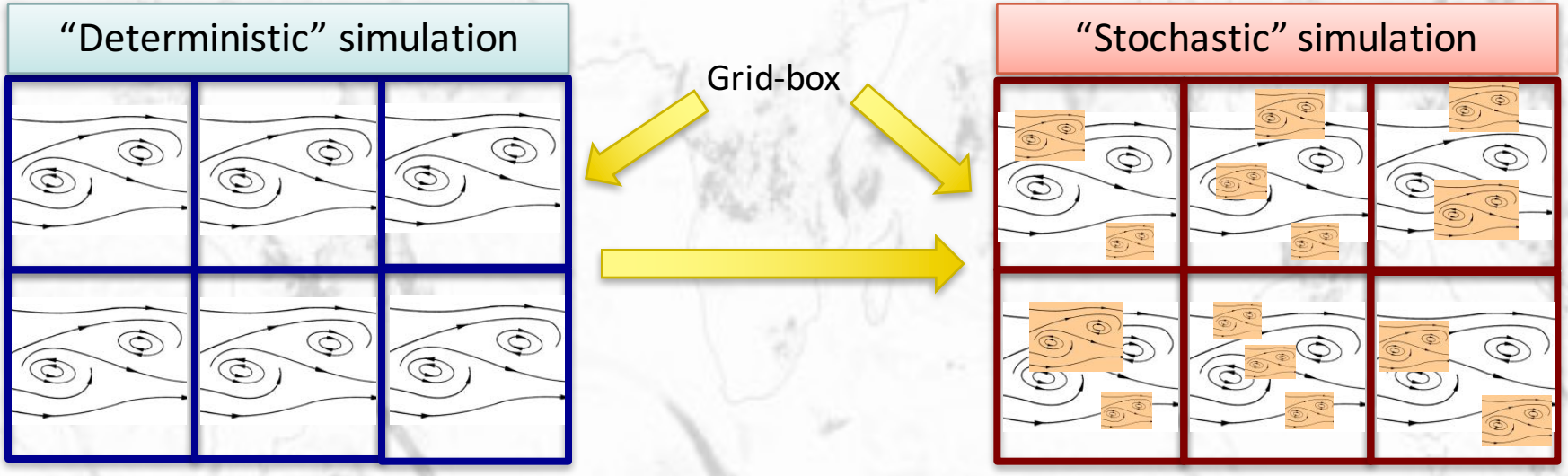
20 millions of core hours have been run on **Supermuc** @ LRZ Computing Center, Garching, Germany for a single-year PRACE project ended in **March 2016.**

EC-Earth Earth System Model **version 3.1** has been used.

WHAT IS STOCHASTIC PHYSICS?

Instead of explicitly resolving small-scale processes by increasing the resolution of climate models, a **computationally cheaper** alternative is to **use stochastic parameterization schemes** (Palmer 2012).

A stochastic scheme includes a **statistical representation of the small scales**, and hence is able to represent the impact of such small-scale processes on the resolved scale.



Practically, **Gaussian perturbations are applied on the 3D field tendencies**.

There is mounting evidence that stochastic parameterizations are beneficial for climate variability in GCM simulations (Dawson et al, 2012).

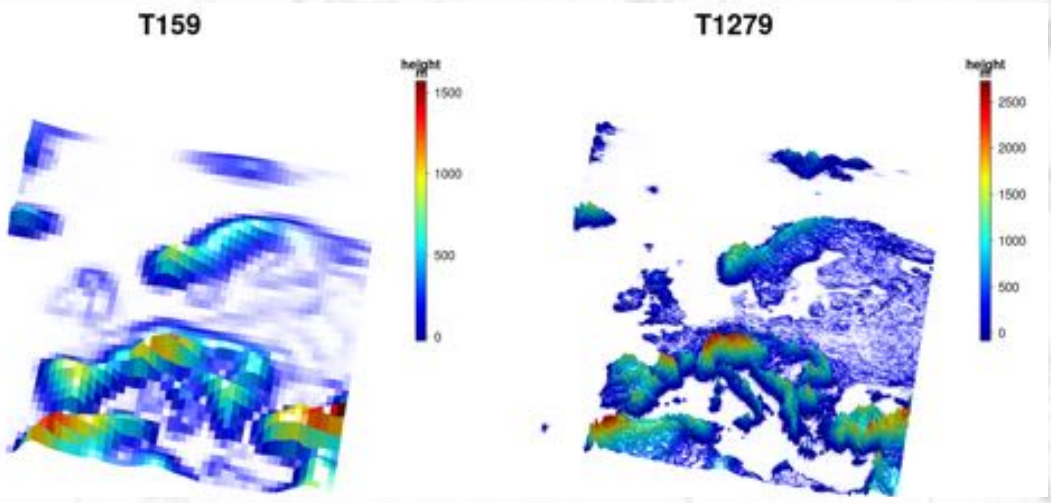
EXPERIMENTS & RESOLUTIONS

Atmospheric-only:
5 horizontal resolutions

Present day
1979-2008

Future Scenario
2039-2068 RCP85

Coupled: T255L91
1850-2100, historical + RCP8.5



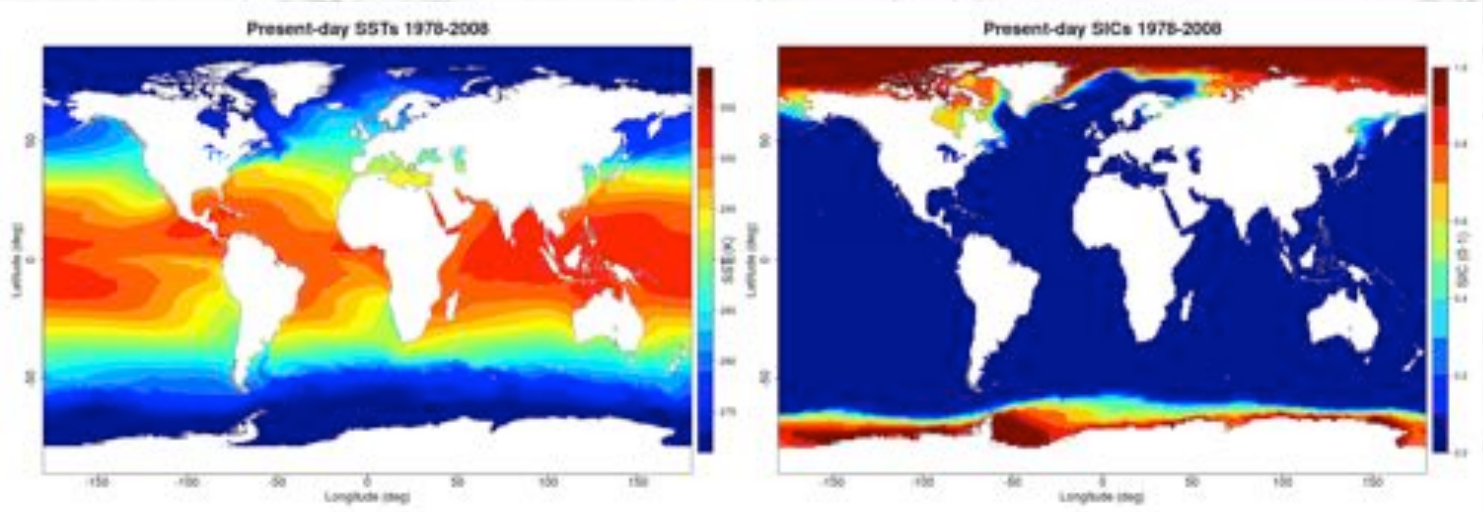
Tuning has been performed once only for T255L91 with no stochastic physics!

More than 110 simulations available!

T159L91 (125km): 10+10 ensemble members
T255L91 (80km): 10+10
T511L91 (40km): 5+5
T799L91 (25km): 3+3
T1279L91 (16km): 1+1

THE FORCING: PRESENT DAY

- New oceanic dataset: **HadISST 2.1.1** (Titchner et al., 2014; Kennedy et al, 2016)
- **Pentad-based daily 0.25x0.25 dataset for SST and and 1x1 for SIC.**
- ICs from ERAINTERIM 1979-01-01.
- 1979-2008: **Historical CMIP5 forcing for GHG.**
- Lake (not defined inland points): **ERAINTERIM 1-month lagged seasonal cycle** (Hersbach et al., 2015), ice when below zero. Coastal points (land-sea mask mismatch) are extrapolated.



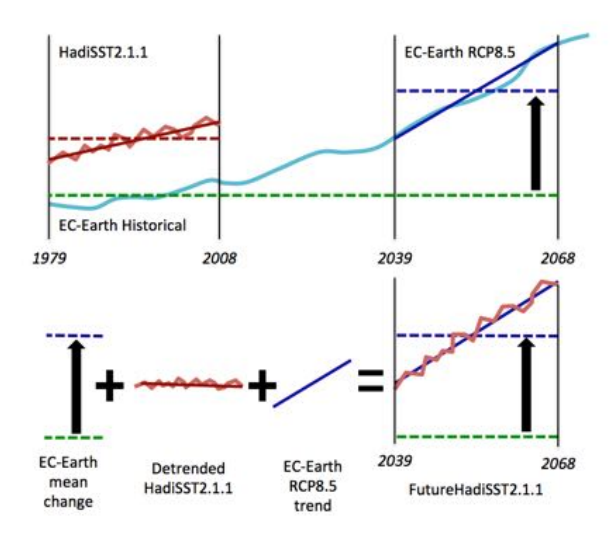
THE FORCING: FUTURE SCENARIO

- Future SSTs: **the new dataset has the same variability of HadISST2.1.1 and the mean field and values of EC-Earth ensemble mean.**

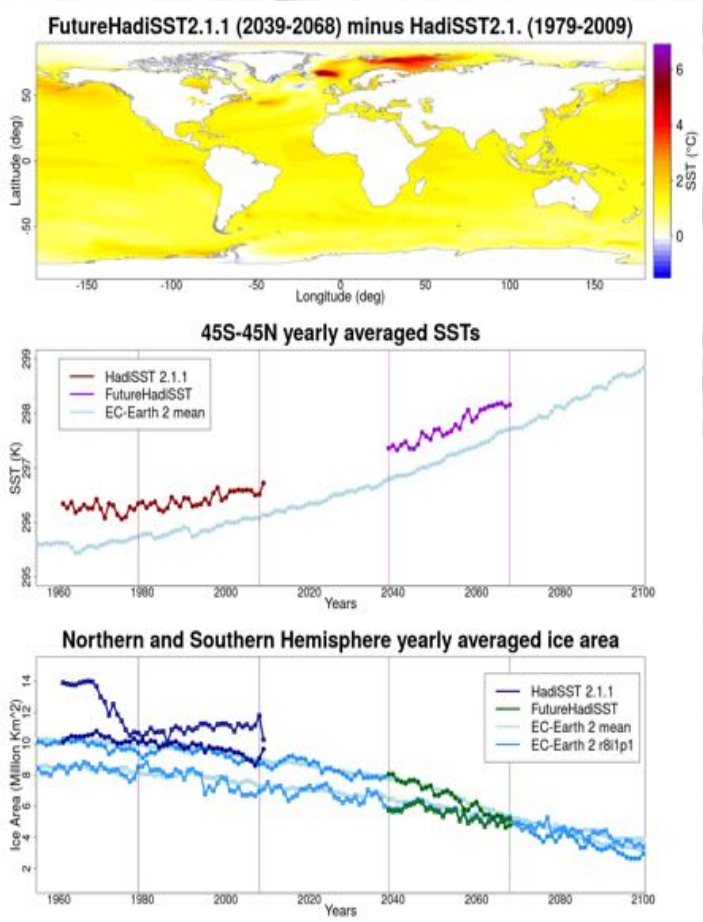
- EC-Earth 2 **CMIP5 ensemble mean for mean values and trend of SST**, and **daily variability is taken from HadiSST 2.1.1**.

- **2039-2068**: **RCP8.5 CMIP5.**

- For SICs, we pick one ensemble member of EC-Earth CMIP5 representative of the dataset (i.e. closer to ensemble mean).

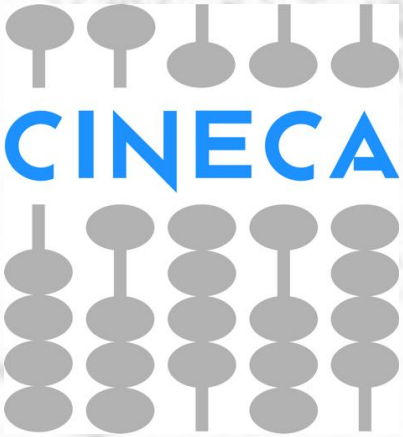


- **Bare-points due to retreat of sea-ice:** specific filling combining a linear interpolation and HadISST 2.1.1 variability.



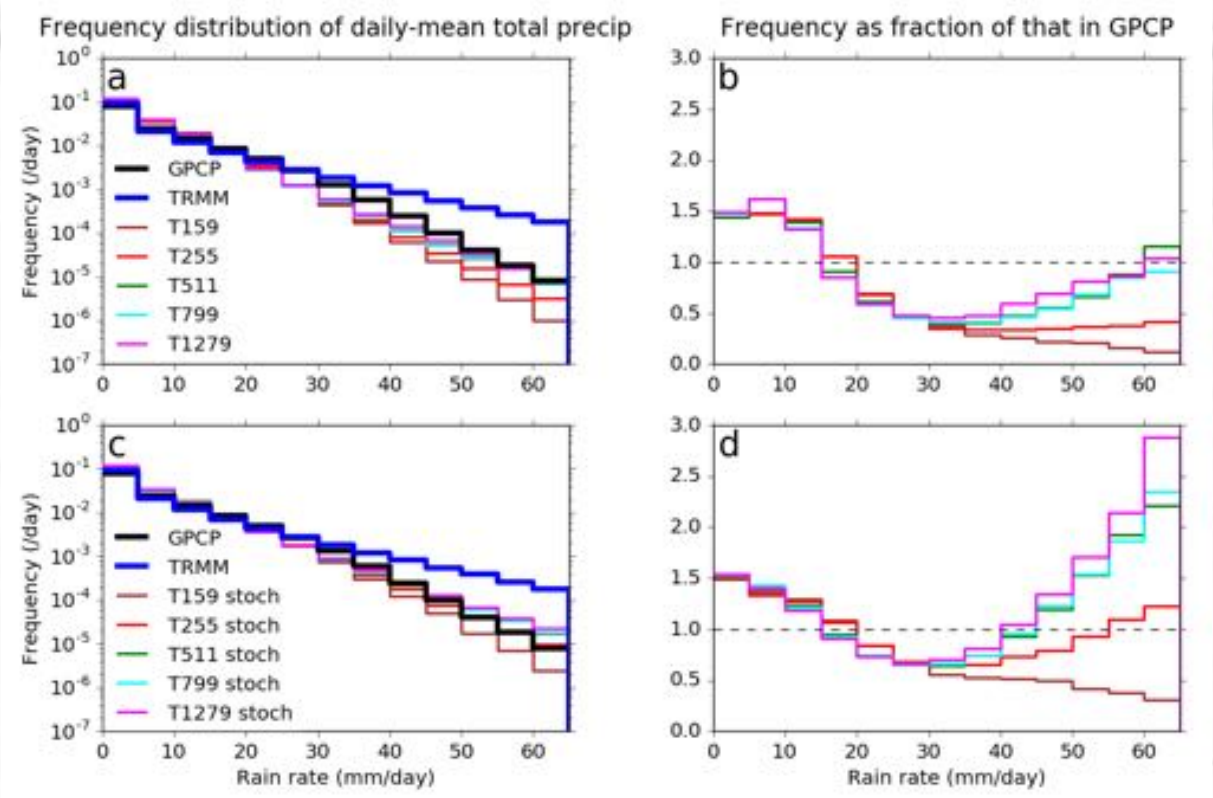
DATA AVALAIBILITY

- **DRES @ Cineca: EUDAT project to get operational a THREDDS server to share data**.
- **About 150 Tb of post-processed.**
- Different set of variables, CMOR-like. Monthly mean, synoptic monthly mean, daily, 6hrs and on some selected domain also 3hrs.
- **About 50 different fields.**
- 3D fields downgraded to T255 to save disk space.
- NetCDF4 Zip (HDF5) reduces significantly the amount of space needed.



RESULTS: TROPICAL PRECIPITATION

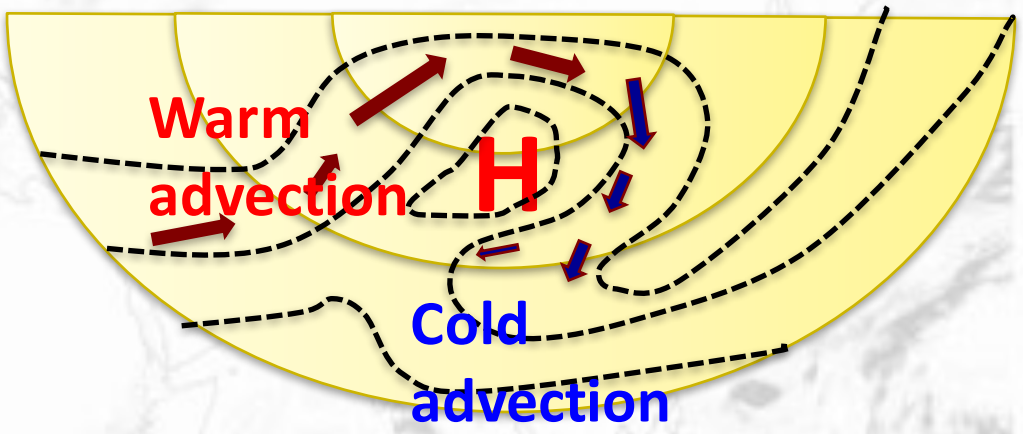
- One aspect of the **tropical variability** of particular interest is the **occurrence of heavy precipitation events**, which can result in flooding or reduce crop yields (IPCC, 2014).
- Estimated through the **frequency distribution of daily-mean precipitation rates** averaged over 2.5°x2.5° grid boxes **between 10°S-10°N** over the period 1998-2008



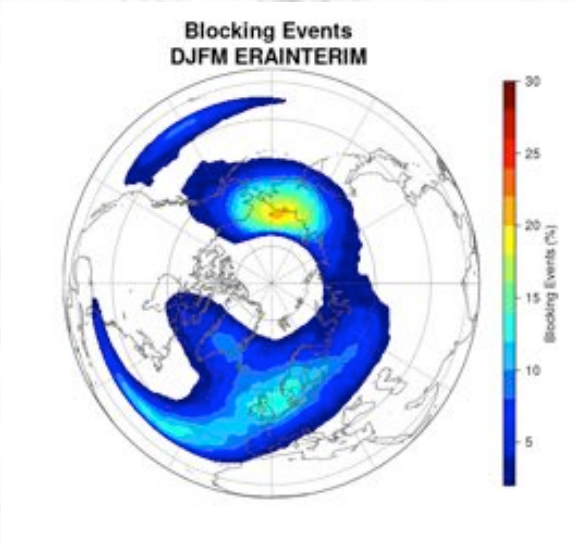
- In general, **underestimation of extreme rainfall events**
- **Increasing resolution leads to reduced bias**: however applying **stochastic parameterization improves the variability of low resolution models** (T159-T255).

RESULTS: BLOCKING

- Atmospheric blocking describes a mid-latitude weather pattern where a **quasi-stationary high-pressure system modifies the westerly flow**, "blocking" (or at least diverting) the eastward movement of the migratory cyclones **(Rex, 1950).**



- Blocking affects leading to **cold spells in winter (when it is more frequent) and heat waves in summer**.



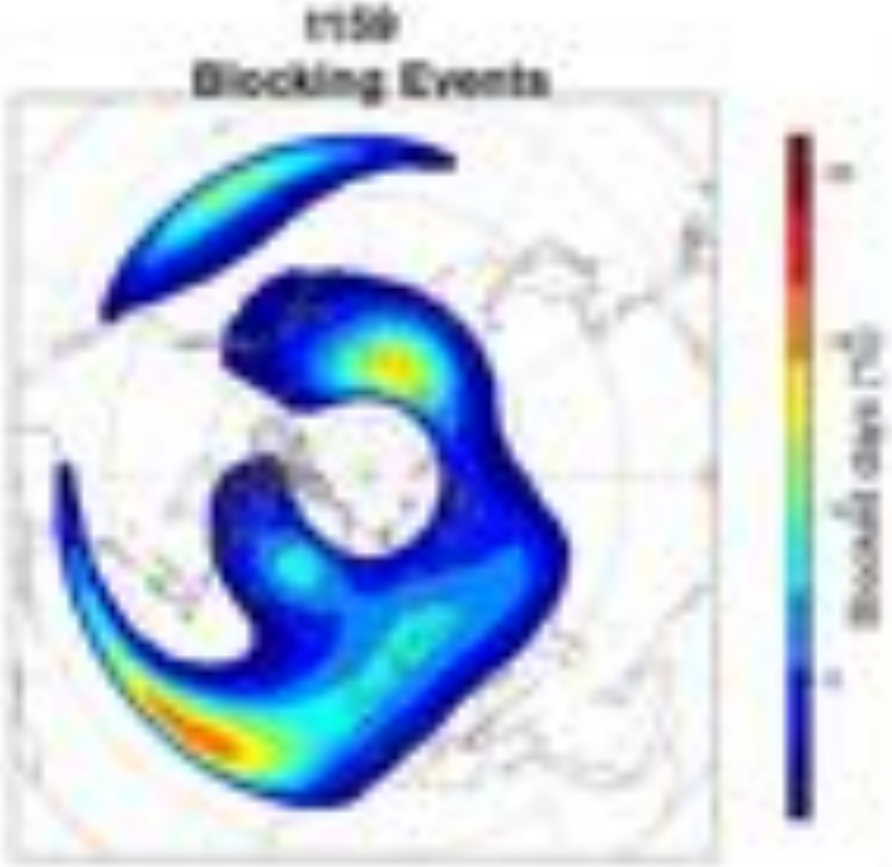
- Evaluation of winter (DJFM) **atmospheric blocking** using the 2D index extension of Tibaldi and Molteni (Davini et al 2012) in the present day (30 years).

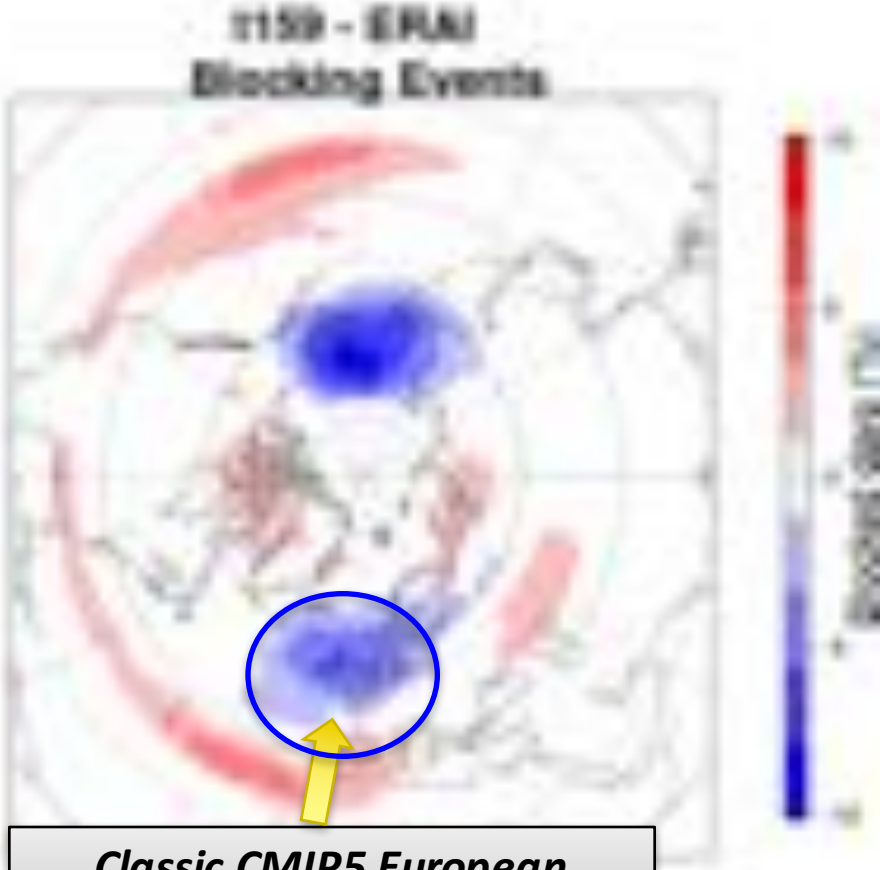
- Blocking over the **Pacific** and the **Atlantic**, at the exit of the jet stream.

- **Long-standing issue in GCMs**, large negative bias over Europe even in CMIP5 models.

RESULTS: BLOCKING

20 ensemble members, DJFM, 125 km resolution, present day

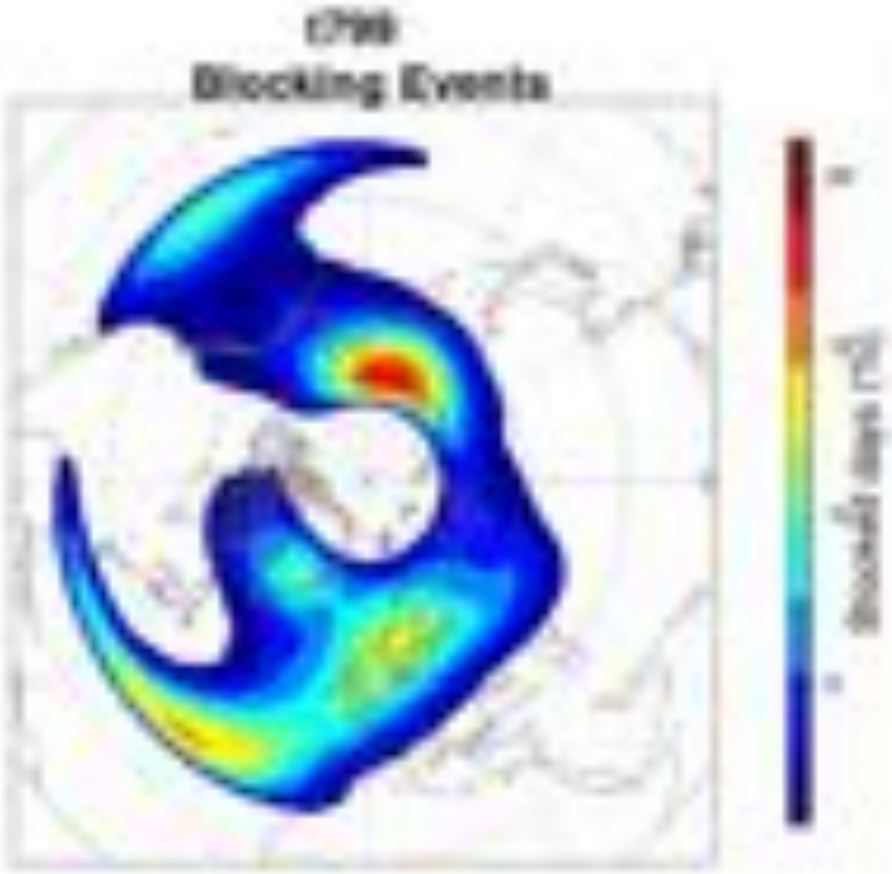


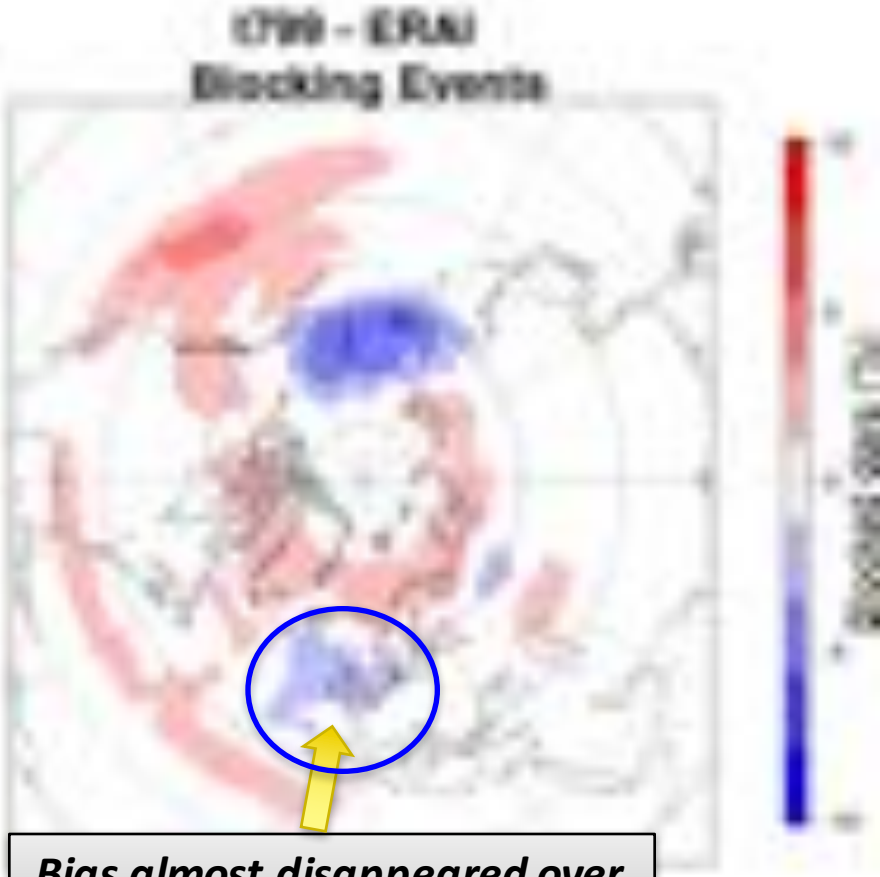


Classic CMIP5 European blocking bias

RESULTS: BLOCKING

6 ensemble members, DJFM, 25 km resolution, present day

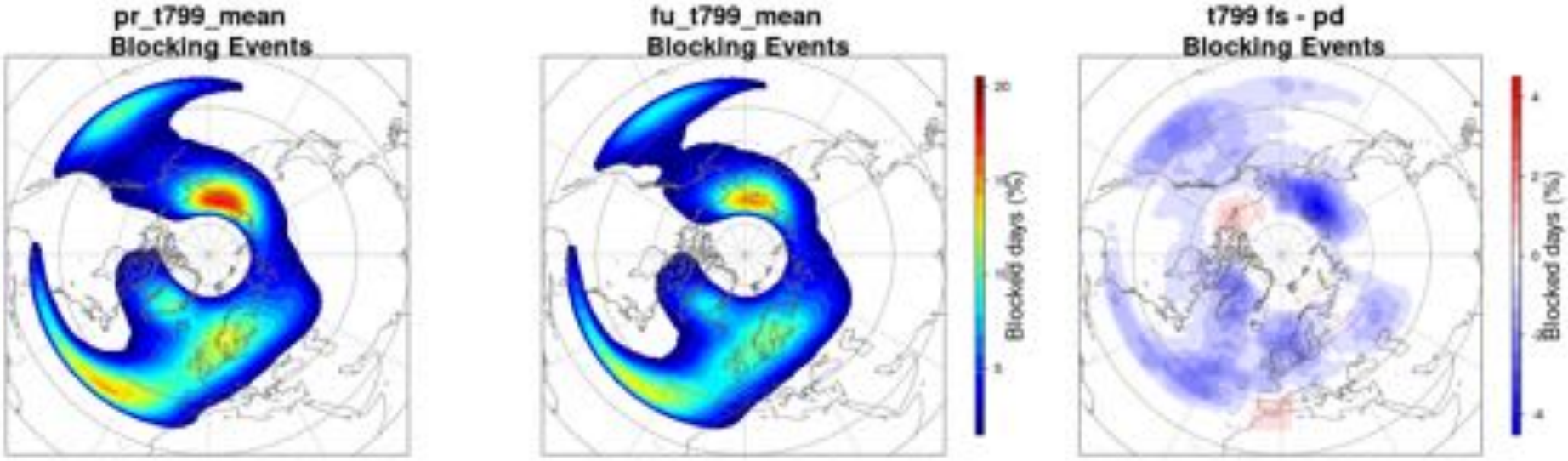




Bias almost disappeared over the Europe

RESULTS: FUTURE BLOCKING

6 ensemble members, DJFM, 25 km resolution, future vs. present day



EC-Earth 3.1 at T799 resolution is one of the best model for atmospheric blocking: **future climate simulations predict a large decrease of blocking activity** in every region of the globe.

Our "contribution" to the "waviness of the jet" debate for which the Arctic Amplification should lead to more frequent blocking and colder winters (Francis and Vavrus, 2012).

FINAL REMARKS

- **Climate SPHINX**: Large dataset to test horizontal resolution and parameterization of stochastic physics under both present day and future scenario.

- **150 Tb** of post-processed data for more than 110 simulations.

- **Data access via THREDDS server @ CINECA**, already operative!

- First results show **clear improvements in atmospheric blocking with increasing resolution and clear reduction of future blocking activity**.

- **Tropical variability is still underestimated**, but benefits are obtained with finer resolution and **applying stochastic physics at coarse resolution**.

THANK YOU FOR YOUR ATTENTION!

If you want to have a look at SPHINX data, you are welcome! Please let us know!

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