DESTINATION EARTH

CLIMATE DT: MODEL EVALUATION

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Consiglio Nazionale delle Ricerche

Funded by the European Union Destination Earth implemented by ECMWF esa EUMETSAT

HOW DO WE EVALUATE A CLIMATE MODEL?

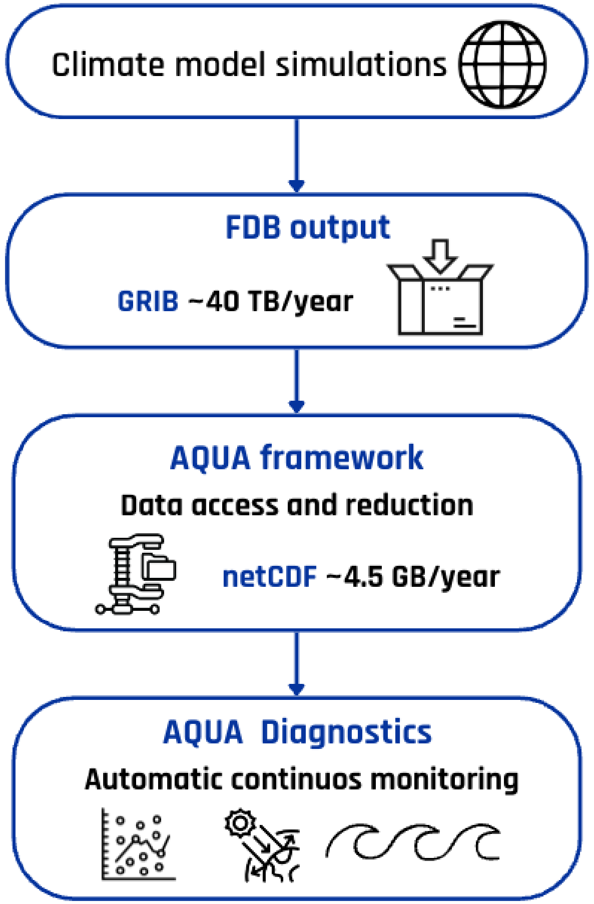
Climate model evaluation is a complicated job

Complex to operationalize, especially in the context of the **big-data challenges** of the ClimateDT: multiple players might be interested in **different aspects:**

- Local realistic phenomenon?
- Climate sensitivity?
- Mean climate?
- Large scale circulation?
- Temperature trends?
- Extremes?

This issues requires the introduction of **objective diagnostics and associated metrics** alongside **human interpretation**

A **selection of metrics** has been possible using **AQUA software,** which solves most of the technical problems!



CLIMATE MODEL SIMULATIONS

ICON

Experiment	Years	Atm Resolution	Oce Resolution
historical-1990	1990-2015 (running to 2020)	10 km	5 km
SSP3-7.0	2020-2035 (running to 2040)	5 km	5 km

IFS-NEMO

Experiment	Years	Atm Resolution	Oce Resolution
historical-1990	1990-2002	10 km	1/12 degree
SSP3-7.0	2020-2040	5 km	1/12 degree

PERFORMANCE INDICES (PI)

A useful and compact metrics are **Reichler and Kim (2008) Performance Indices (PI),** which build on the idea of providing a measure of the climate mean state of the model evaluating several 2D variables against observations

$$\sum \frac{\left(\text{Model climatology} - \text{Observation climatology}\right)^2}{\text{Observation variance}}$$

PIs can be **normalized** toward an "average" value which in our case is CMIP6 **model multi model mean**

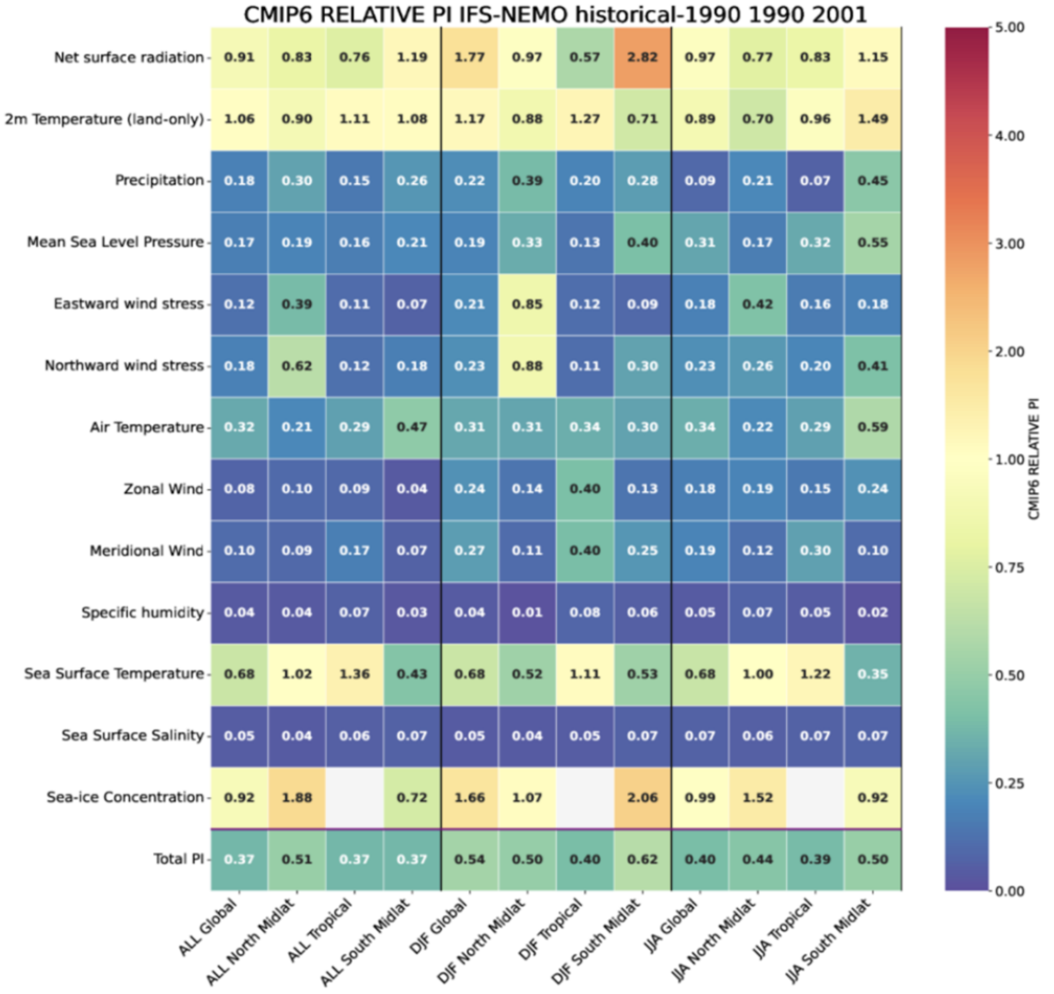
PI < 1: the model is doing a good job compared to CMIP6 models

PI > 1: the models is doing worse than the average of CMIP6 models

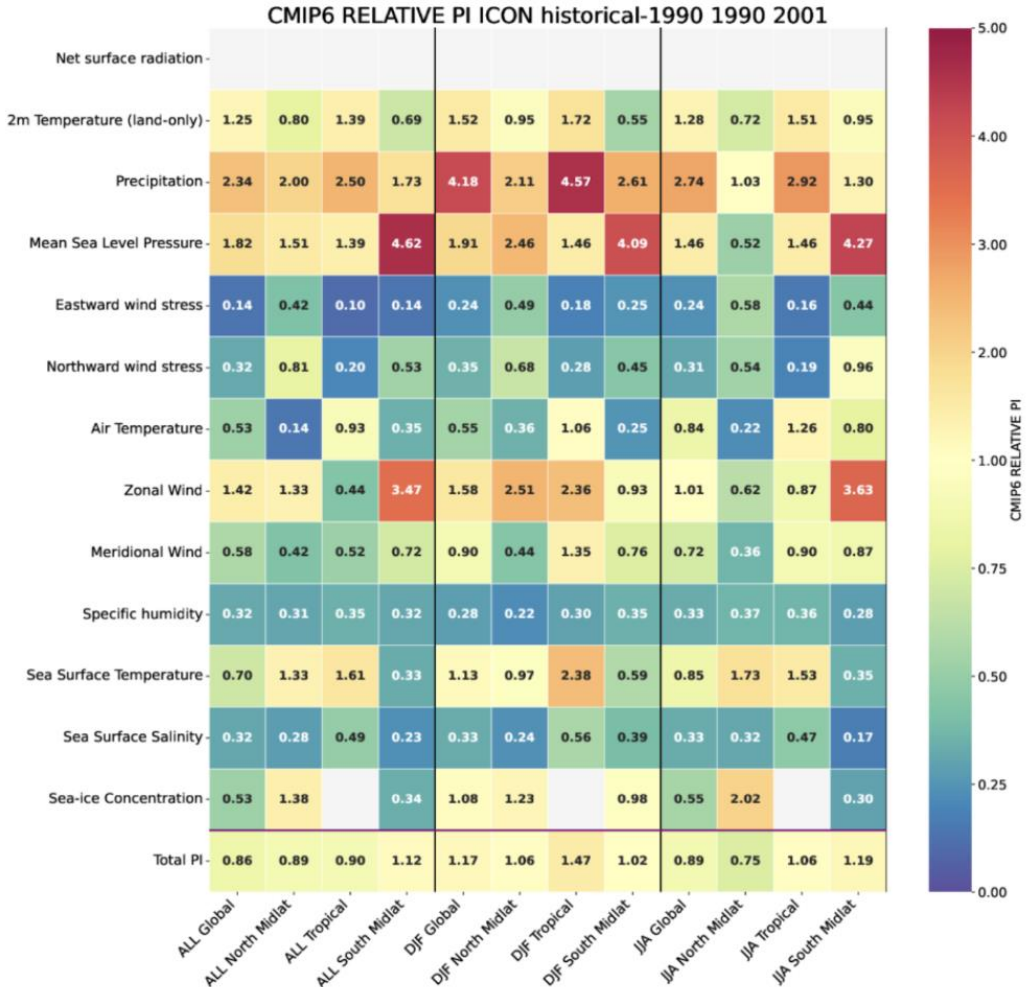
We run PI on the **ICON and IFS-NEMO historical run - not the scenarios!** - to provide a comprehensive assessment

We can compute **PIs for specific regions and seasons** or average them to have a "total PI" for each simulation

IFS-NEMO



ICON



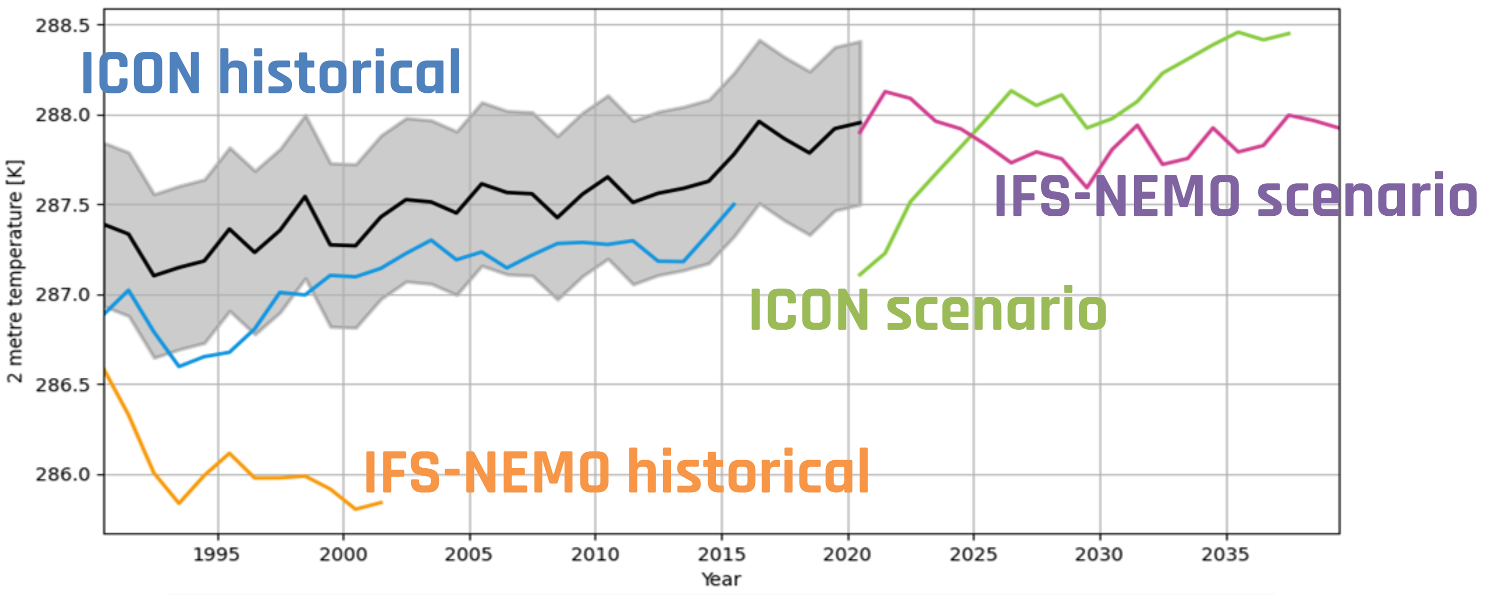
PI < 1 (green-blue colours): the model is doing a good job compared to CMIP6 models

PI > 1 (orange-red colours): the models is doing worse than the average of CMIP6 models

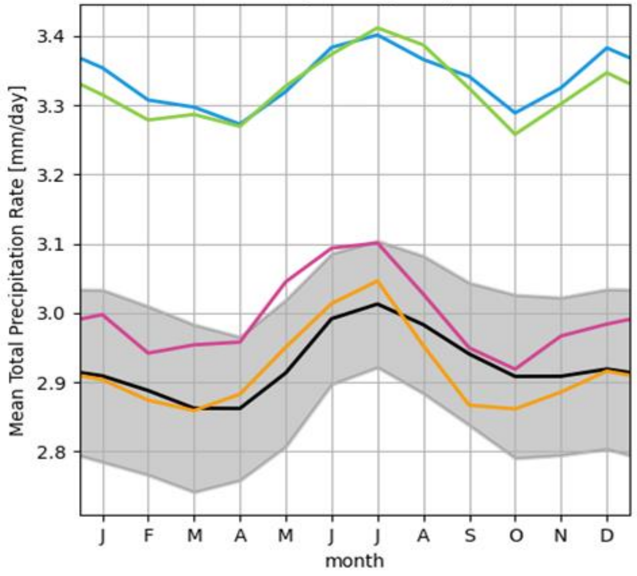
AN OVERALL VIEW

IFS-NEMO historical has an initialization adjustment which leads to a cold **temperature** bias; the same for the scenario that is not warming as expected

Globally averaged 2m temperature [K]



Seasonal cycle of precipitation rate [mm/day]



ICON is slightly colder than observations but shows a good warming rate in the historical, while the **scenario warms too quickly**. This is due to an excess of incoming radiative flux especially in the scenario

Seasonal cycle of **precipitation** is well captured by **IFS-NEMO** and overestimated in **ICON,** where it also clearly increase in the scenario

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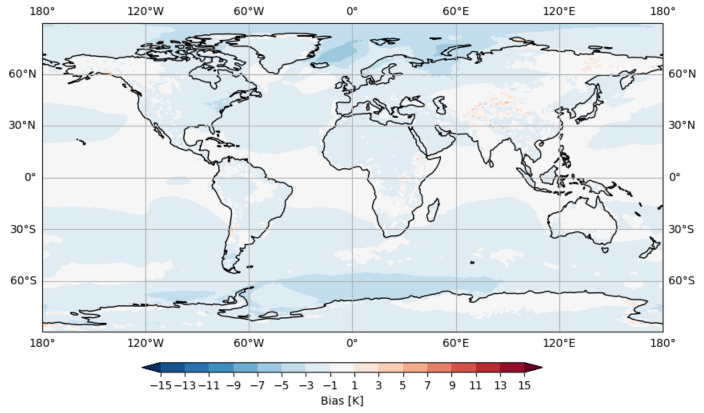
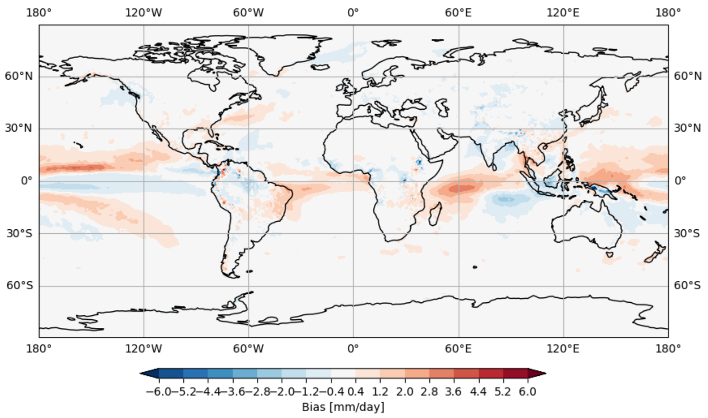
TEMPERATURE AND PRECIPITATION

IFS-NEMO

2m temperature [K]



precipitation rate [mm/day]

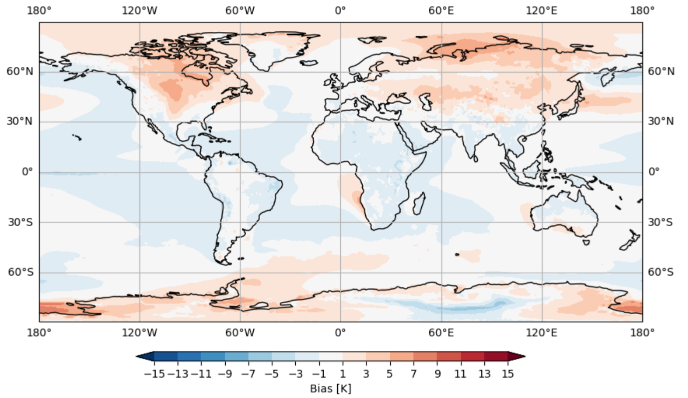


IFS-NEMO shows larger **negative temperature bias** in polar regions, likely linked to an overestimation of sea ice. Precipitation is reasonably represented

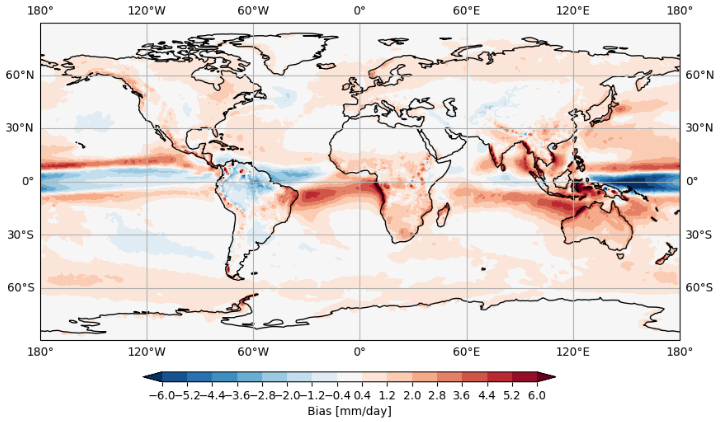
ICON conversely shows positive temperature bias in the polar latitudes and over continents, while **precipitation is overestimated** over the Indian and Atlantic ocean with traces of double ITCZ

ICON

2m temperature [K]

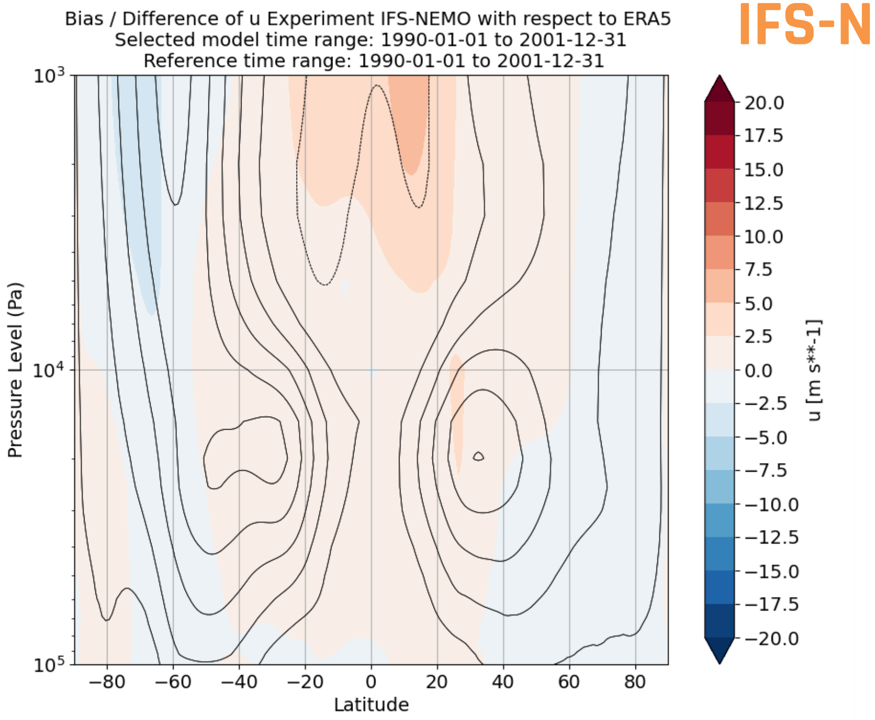


precipitation rate [mm/day]



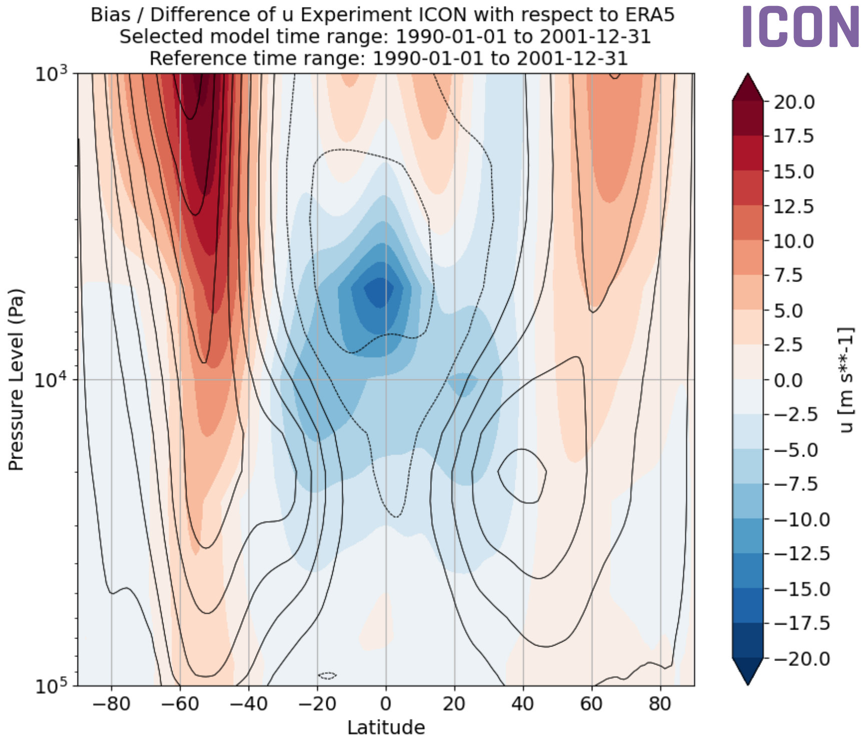
WIND PROFILES

IFS-NEMO



IFS-NEMO **zonal wind** vertical structure of the atmosphere is pretty good with moderate bias in the stratosphere (disclaimer: comparison against ERA5)

ICON

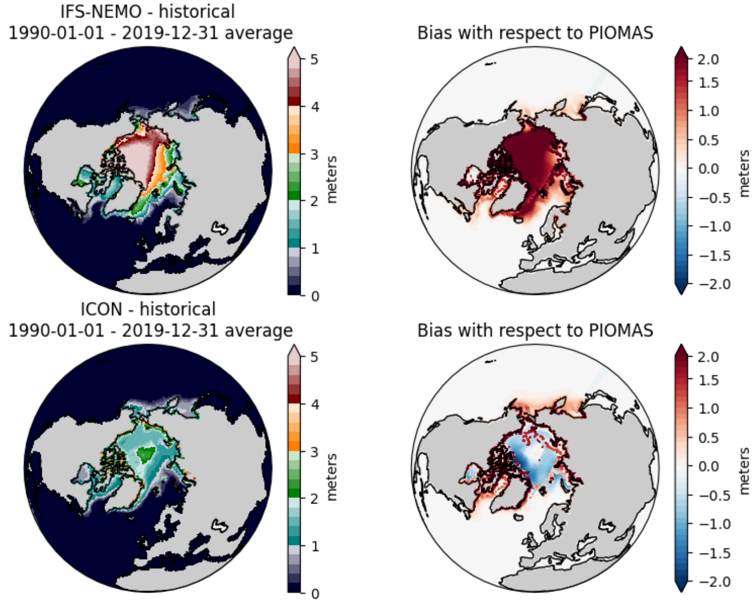


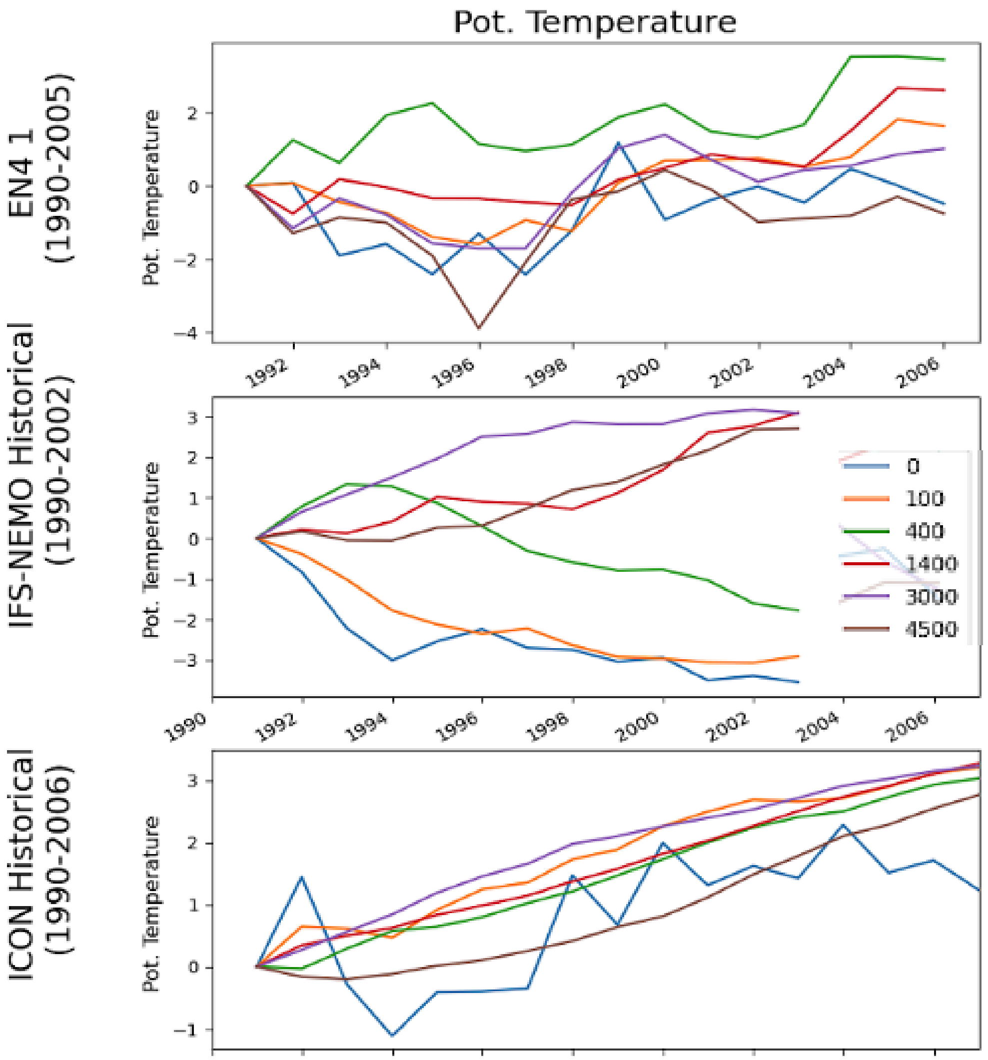
ICON has some issues in the **pressure level structure** in Southern Hemisphere, with overly westerly jet stream

STATE OF THE OCEAN

The **cold shock** we saw in the **IFS-NEMO** run is due to a negative drift in surface and mid-ocean temperature (i.e. not related to the Pinatubo forcing), likely **caused by the oceanic model not been at the equilibrium**. This is reflected by an **excess of sea ice** in Northern Hemisphere

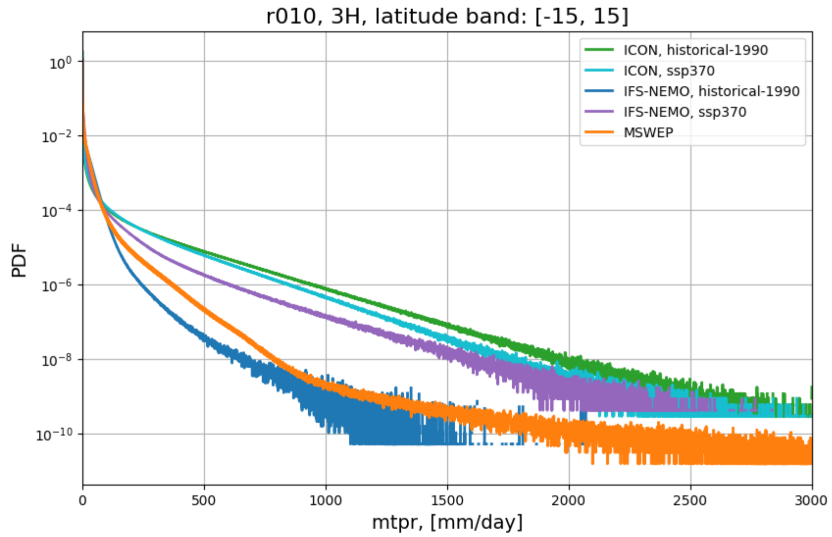
ICON conversely shows a clear **warming of all oceanic layers** as in observations, but this is likely **overestimated** suggesting a too large climate sensitivity



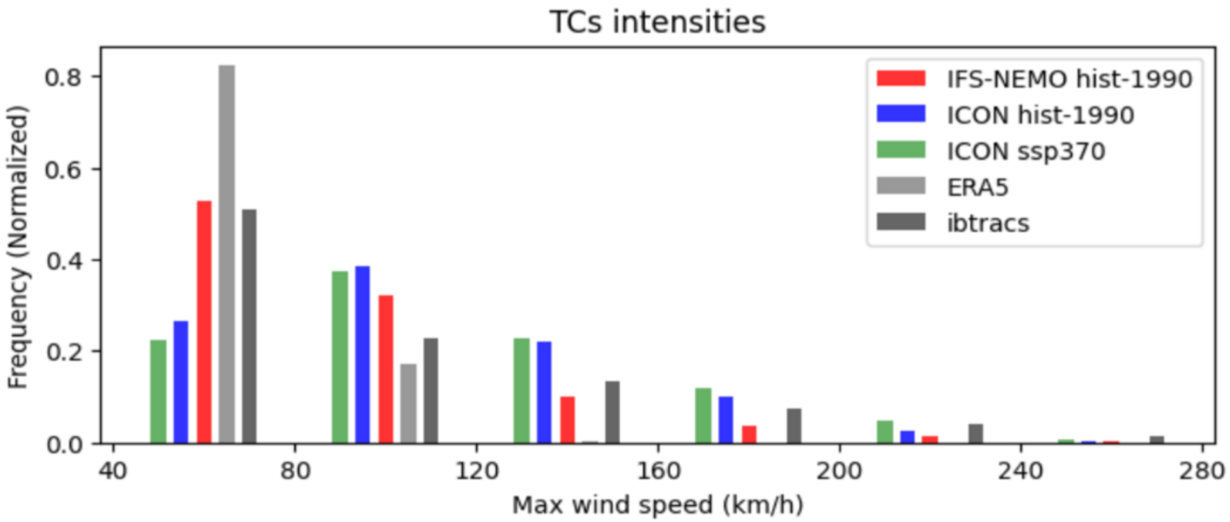


FRONTIER DIAGNOSTICS

ClimateDT provides also unprecedented high-resolution data to investigate features of climate which we are not used to assess in detail. The experimental set of "**frontier" diagnostics** is aiming at this task



ICON shows many strong **Tropical Cyclones** in both historical and scenario. Conversely **IFS-NEMO**, likely affected by the cold SST bias, underestimates the strongest one but correctly represent the weaker ones



All the models overestimate the upper tail of the **tropical precipitation distribution**, something unprecedented

Positive aspects

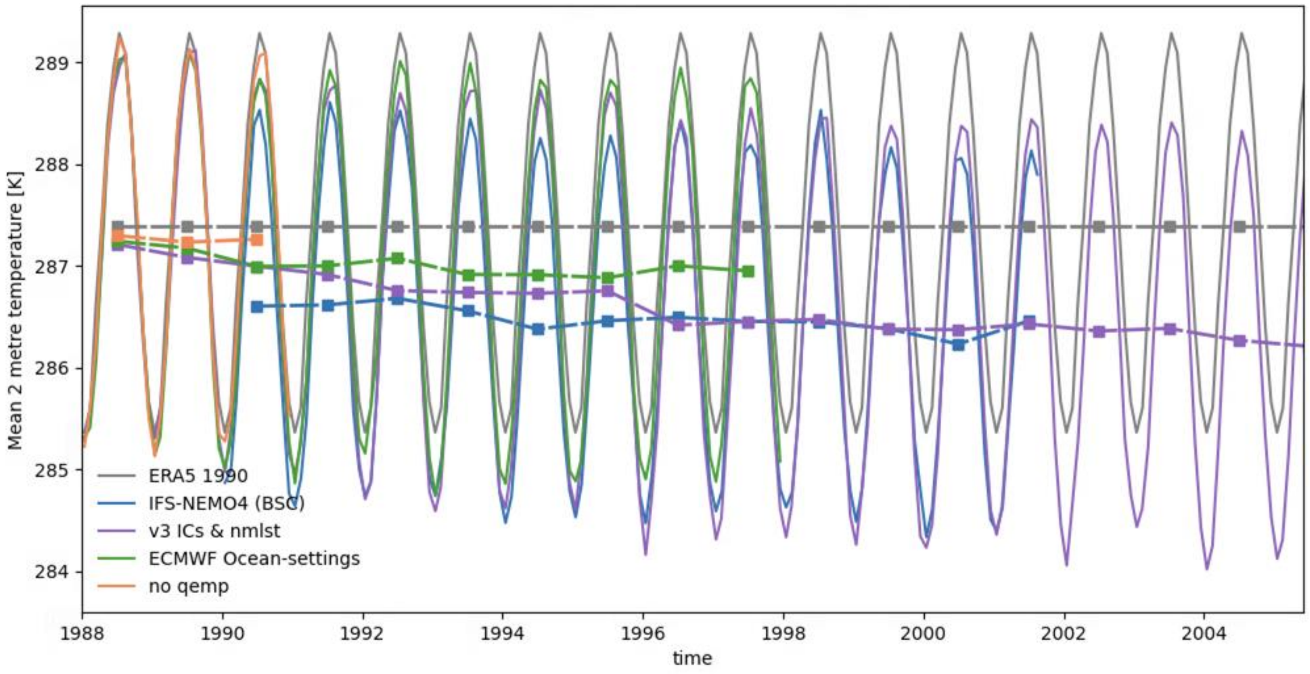
- **Very good mean climate** despite global surface temperature bias in IFS-NEMO
- High level of details in atmospheric and oceanic circulation in both models especially in IFS-NEMO
- On average both ICON and IFS-NEMO performance indices **better** than the **average of CMIP6** output

Things to be improved

- Too **cold global mean 2m-temperature** in historical and lack of warming in scenario (IFS-NEMO)
- Excessive precipitation in tropical areas (ICON)
- Wrong pressure patterns in Southern Hemisphere (ICON)
- Unclear if experiments have a realistic warming rate/climate sensitivity due to short experiments/limited ensemble

LOOKING FORWARD

- **Improve the quality of mean climate**
- Enhance and enlarge the diagnostics by going beyond the mean climate investigating also climate variability
- **Tuning** to correct the most evident temperature biases
- Develop a solid strategy for uncertainty quantification despite the few ensemble member available



IFS-NEMO tuning is already paying off: new runs (orange and green lines) massively reduced the cold bias and related initial cold shock (blue line) just by a better setup of the NEMO model