SPECIAL PROJECT PROGRESS REPORT

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All the following mandatory information
needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	2020
Project Title:	Innovative iNitialisation techniques for multi-annual ClImate PredIcTions (INCIPIT)
Computer Project Account:	spitvolp
Principal Investigator(s):	Danila Volpi
Affiliation:	Institute of Atmospheric Sciences and Climate, National Research Council (ISAC-CNR)
Name of ECMWF scientist(s) collaborating to the project (if applicable)	N/A
Start date of the project:	1/1/2019
Expected end date:	31/12/2020

Computer resources allocated/used for the current year and the previous one
(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	36 million	36.5 million	36 million	192000
Data storage capacity	(Gbytes)	50000	24740	50000	24740

Summary of project objectives (10 lines max)

The objective of this project is to test specific improvements to the standard anomaly initialisation technique to assess whether addressing some of the limitations detected in the technique has a positive impact on the skill of multi-annual predictions. The limitations to tackle are namely:
- the risk of introducing anomalies recorded in the observed data whose amplitude does not fit in the range of the internal variability generated by the model. This could result in the model erroneously predicting extreme events, such as an intense El Niño or a pause in the thermohaline circulation (first year experiment);
- the displacement between the geographical position where the model develops the variability modes, and the actual observed position of the modes, which could lead to a wrong propagation of the information coming from the observed state (second year experiment).

Summary of problems encountered (10 lines max)

The implementation of the second technique has been delayed by the analysis of the first experiment. In order to have the largest set of possible initial conditions from the model states, we are considering waiting for the completion of 10 extra historical simulations for which the restart files are saved for the initialisation month (November).

Summary of plans for the continuation of the project (10 lines max)

In parallel to the analysis of the first experiment, the implementation of the second initialisation method is in progress, namely the analog method. It consists of choosing a few modes to characterize the state of the system (e.g. AMOC, PDO, ocean heat content in some regions, pattern correlation of SST) and compute them with the reference data at the initialisation date. Then, create a pool of those modes from all the members and years available from the model historical simulations. The initial state will be the model state that minimizes the distance with the set of reference modes at the initialisation date.
We are also evaluating rearranging the computing resources of the year to enlarge the ensemble of the quantile matching experiment, in order to have more robust results.

List of publications/reports from the project with complete references

None yet.

Presentations in International conferences:

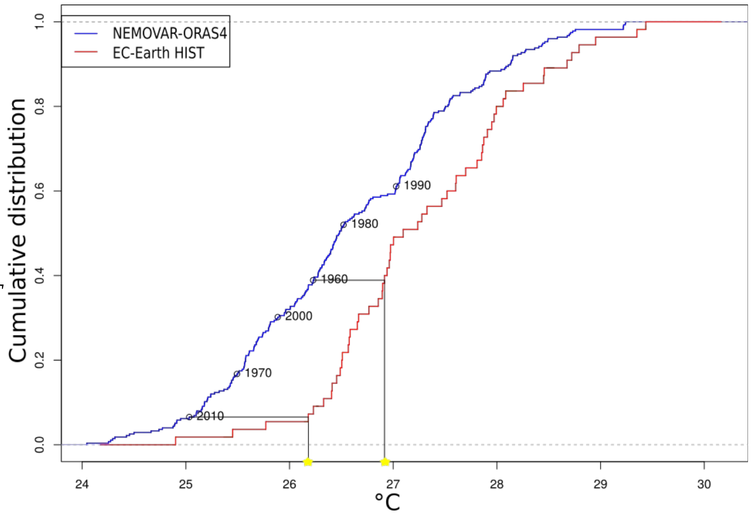
- Volpi D., Bilbao R., Corti S., Doblas-Reyes F., Guemas V., Meccia V. and Ortega P.: Preliminary results from a quantile matching initialised decadal hindcast, *EC-Earth Meeting*, 3rd-5th March 2020, teleconference, (oral presentation).
- Volpi D., Meccia V., Ortega P., Guemas V. and Corti S.: An innovative initialisation technique for decadal climate predictions, *Fall Meeting 2019, American Geosciences Union*, (poster presentation).

Summary of results

The first initialisation technique implemented in this project is the quantile matching, which allows the model to be on its attractor as oppose to the full field initialisation approach, and it reshapes the observed variability at the initialisation time to match the model variability. Such a scaling of the observed variability is designed to avoid the risk run in the standard anomaly initialisation technique of introducing anomalies recorded in the observations whose amplitude does not fit in the range of the internal variability generated by the model.

Figure 1 illustrates an example of the technique implementation for the sea surface temperature (SST) in the Niño 3.4 region. The cumulative distribution function of SST is shown respectively in red for a historical simulation of the model and in blue for the reference data (NEMOVAR-ORAS4). The black circles indicate the reference value at the initial date for the years specified. The model is initialised with the model value (marked by a yellow star in the figure) whose cumulative distribution function matches with the one of the reference value at the initialisation time. This has been computed for all the ocean variables at each grid point to generate a new initial state of the ocean, while the atmospheric component has been initialised with ERA40 and ERA-Interim reanalysis, and the sea ice component with a nudged simulation to NEMOVAR-ORAS4. The model used to produce the multi-annual hindcasts is EC-Earth 3.3.1 with standard resolution (ORCA1L75 configuration for NEMO and T255L159 resolution in IFS).

Figure 1. Cumulative distribution function of SST in the Niño 3.4 region. The function is defined as the probability that the SST takes a value smaller than the specific value of the function.



The experiment (hereafter referred to as QM for its initialisation technique) is composed by 6 ensemble members initialised every November from 1960 until 2014 (55 start dates) and run for 5 years. The ensemble is generated by 3D-temperature perturbations in the atmosphere, and computing the quantile matching in the ocean for the 5 different NEMOVAR-ORAS4 members, with the repetition of 1 member, to get 6 ocean states.
The QM experiment has been compared to the BSC contribution to DCPP (DCPP_BSC). The two experiments have identical atmosphere and sea ice initialisation, only the ocean initialisation differs: the DCPP_BSC is initialised with a full field nudged simulation to NEMOVAR-ORAS4.

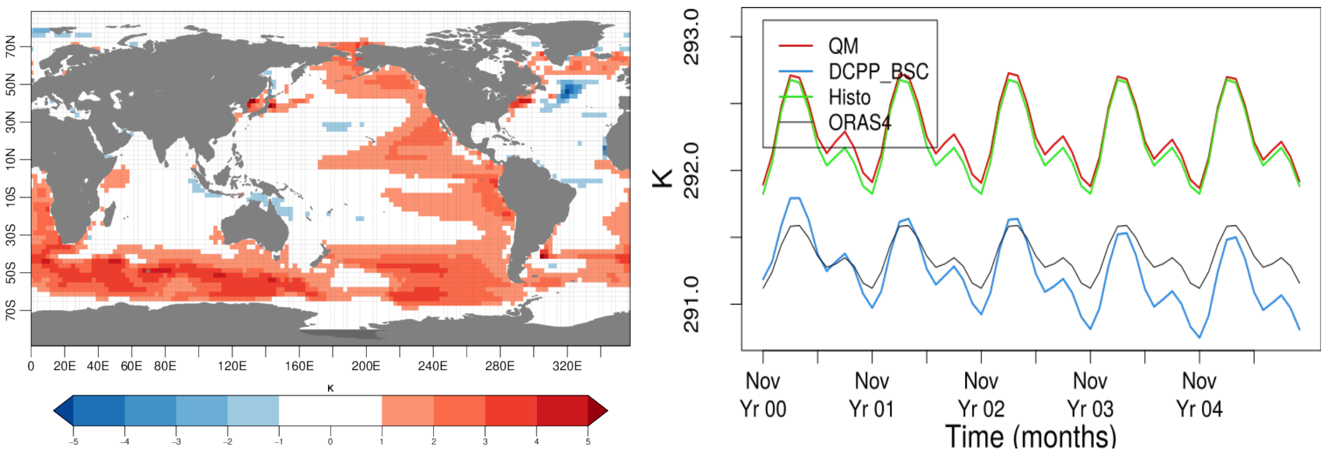


Figure 2. Left panel: Initial bias of the QM experiment for SST. Right panel: Global mean SST in red for the QM experiment, in blue for the DCPP_BSC experiment, in green for 15 historical simulations and in black for the reference data NEMOVAR-ORAS4.

One of the intrinsic characteristic of the QM experiment is that its initial state is close to the model attractor and therefore it is biased with respect to the observation, as shown in the left panel of Figure 2. The global mean SST (right panel of Figure 2) shows the behaviour of the different experiments: while the full field initialised experiment (blue line) starts close to the reference data and drifts away with forecast time, the QM experiment (red line) is close to the historical simulation during the whole forecast.

As a result of being on the model attractor, the QM experiment has a negligible drift in SST, as shown in Figure 3, while the DCPP_BSC experiment develops a larger drift with maxima over the 2 degrees.

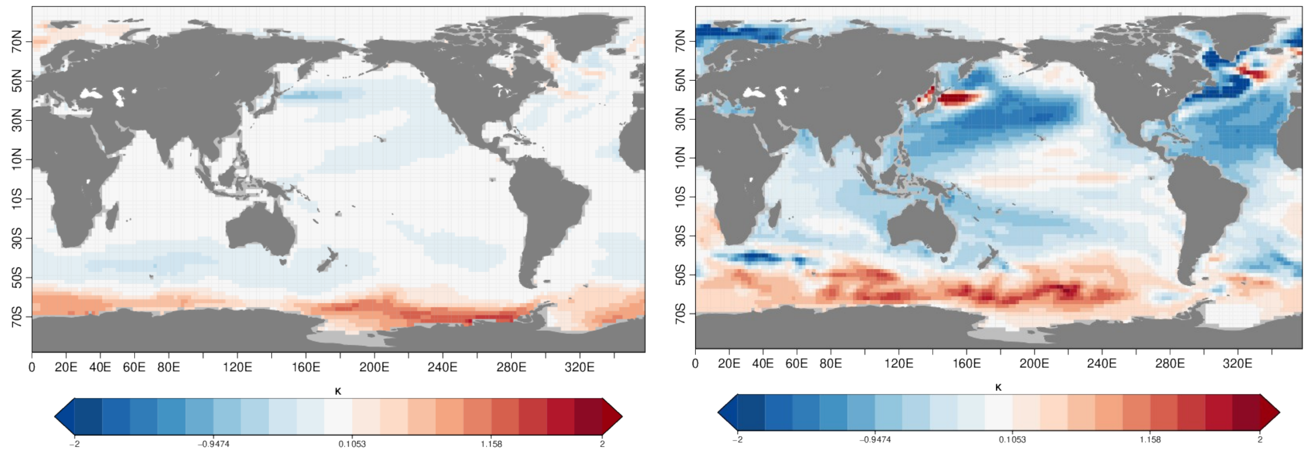


Figure 3. SST drift respectively of the QM experiment (left panel) and the DCPP_BSC experiment (right panel). The drift has been calculated as the difference between the fifth year and the first year annual mean SST climatology.

Figure 4 shows the SST correlation difference between the experiments for year 1 (first row) and years 1 to 5 (second row). During the first forecast year both initialised experiments show a general improvement with respect to the historical simulations in the North and Tropical Pacific, except

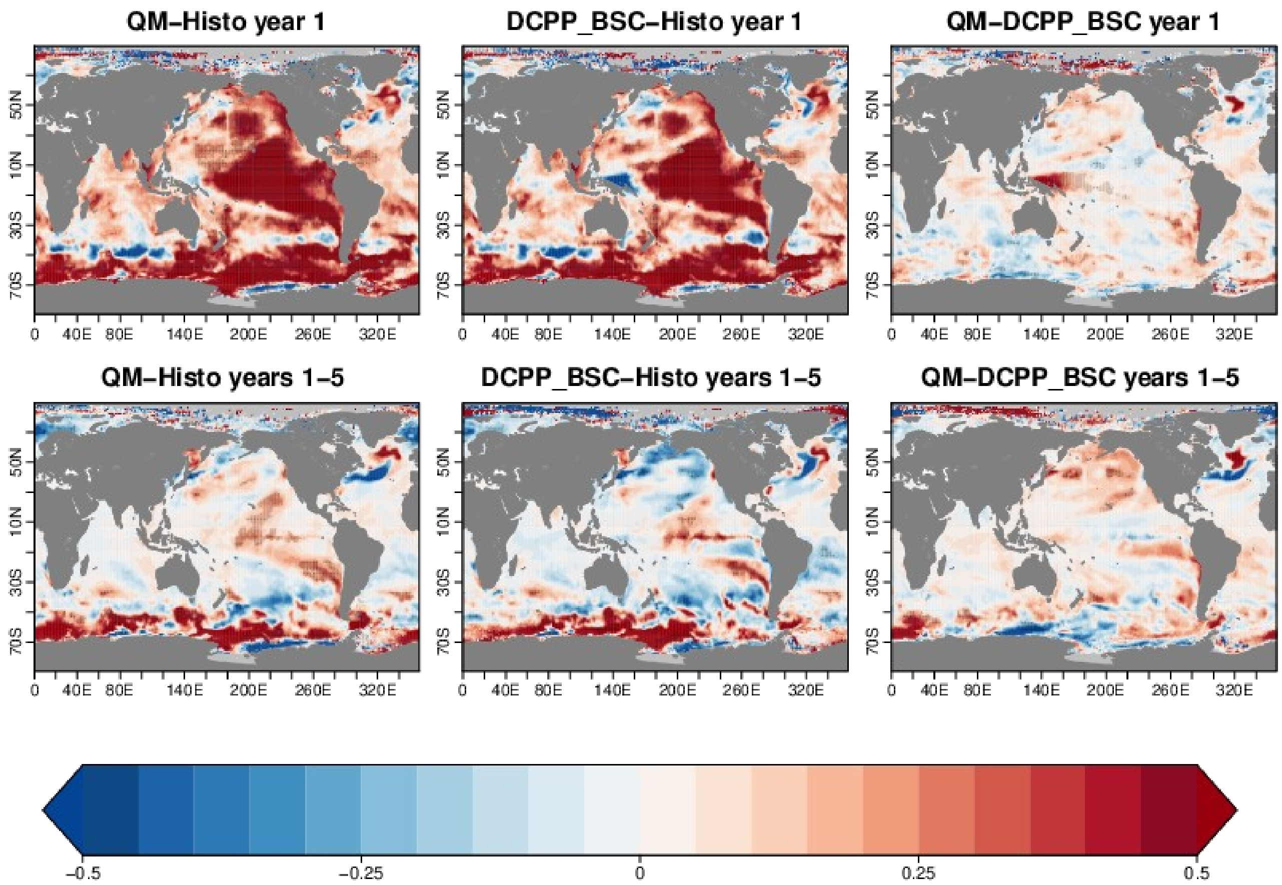


Figure 4. Sea surface temperature correlation difference respectively for the first year (first row) and for the years 1 to 5 (second row). The first column shows the correlation difference between the QM experiment and the historical simulations, the second column the difference between the full field initialised experiment (DCPP_BSC) and the historical simulations, while the third column shows the difference between the two initialised experiments, the QM and the DCPP_BSC. The correlation is calculated against HadISST data.

along the Philippines and Papua New Guinea coasts, where especially the DCPP_BSC experiment (first row, second column) degrades the skill of the prediction, as well as along the coast of Chile. Moreover the QM improves over the subpolar gyre region and partly degrades the skill along the Gulf Stream, with respect to both the historical simulations (first column) and the DCPP_BSC experiment (third column). The QM improvements in the North Pacific and in the subpolar gyre region persist during the whole forecast time (second row of Figure 4), although the Gulf Stream region is still degraded with respect of both the non-initialised (first column) and the other initialised experiment (third column).

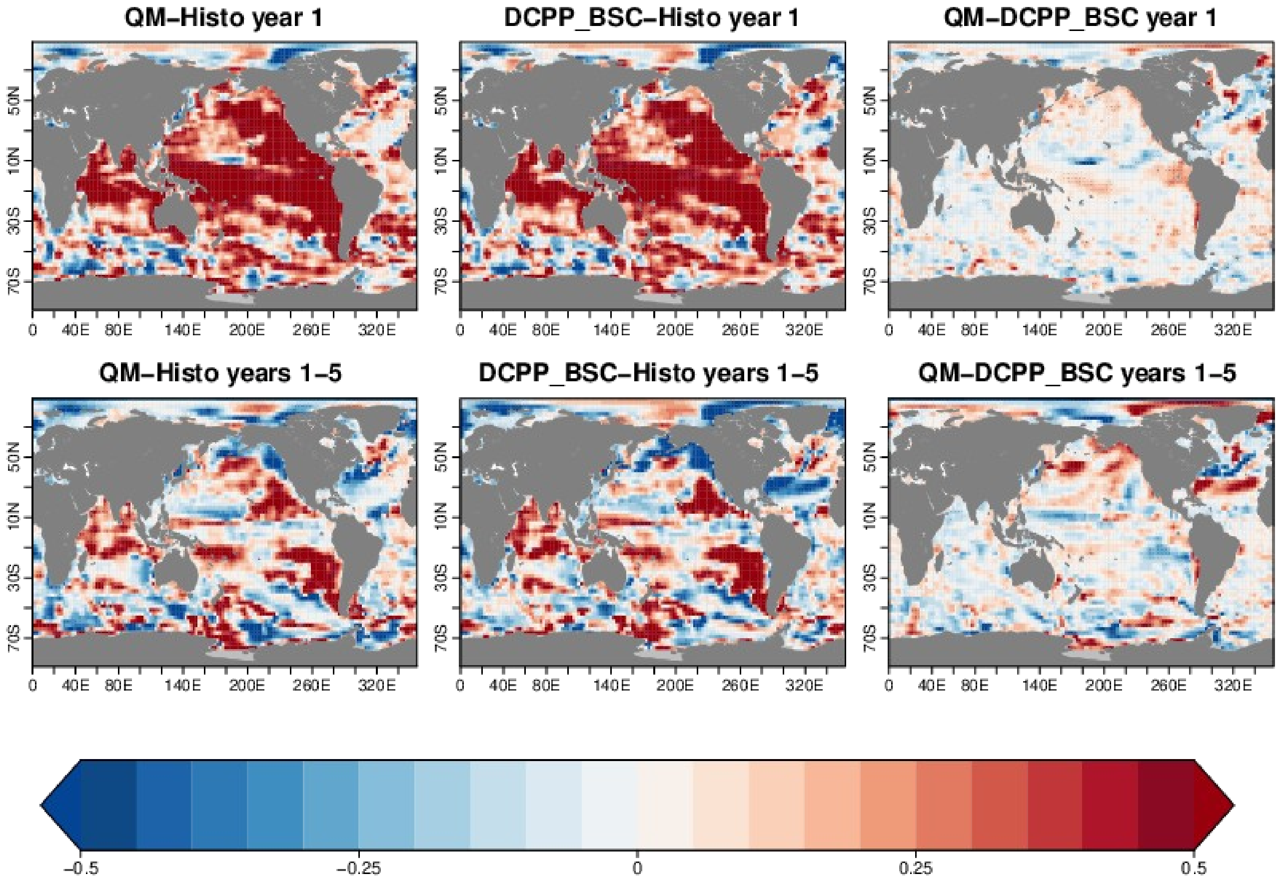


Figure 5. Ocean heat content in the top 300m correlation difference respectively for the first year (first row) and for the years 1 to 5 (second row). The first column shows the correlation difference between the QM experiment and the historical simulations, the second column the difference between the full field initialised experiment (DCPP_BSC) and the historical simulations, while the third column shows the difference between the two initialised experiments, the QM and the DCPP_BSC. The correlation is calculated against EN4 data.

Figure 5 is the analogous of Figure 4 for the ocean heat content in the top 300 m. Similarly to the results for SST, the main improvements of the QM with respect of both the historical simulations and the DCPP_BSC experiment (respectively first and third column) are in the North Pacific and in some regions of the North Atlantic.

Future analysis will involve the study of the convection, the AMOC, the subpolar gyre index to deepen the understanding of the effect of the QM initialisation in the North Atlantic, as well as the IPO and PDO indices to better understand the improvements in the North Pacific.