SPECIAL PROJECT PROGRESS REPORT

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

Reporting year …2022……

Project Title: Development of a 3-layer thermodynamic model of the upper ocean for studies on teleconnections from the tropical oceans

Computer Project Account: …SPITKUCH……

Principal Investigator(s): Fred Kucharski……

Affiliation: …The Abdus Salam ICTP, Strada Costiera 11, 34151 Trieste, Italy……

Name of ECMWF scientist(s) collaborating to the project (if applicable) …Franco Molteni……

Start date of the project: …1st January, 2020……

Expected end date: …31st Dec 2022……

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)	950000	N/A	950000	N/A
Data storage capacity	(Gbytes)	900	N/A	900	N/A

Summary of project objectives (10 lines max)

The proposed Special Project is planned in two phases. The first phase, which is expected to last one year and is covered by the 2020 proposal, will include:
a) re-tuning and testing the model in forced model with energy fluxes and PBL variables from ERA5;
b) testing the model in coupled mode with the SPEEDY AGCM and perform multi-decadal historical runs in both free and pacemaker mode;
c) coupling TOM3 to OpenIFS and test the coupled system on seasonal to multi-year (~5yr) scale.
At the end of this first phase, it is expected to have an 'optimal' set of model parameters which provide a suitably realistic representation of thermodynamically driven ocean variability.……
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Summary of problems encountered (10 lines max)

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

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…Points a) and b) of the objectives summary are competed now, next we will develop and test the sea-ice component of the TOM3 thermodynamic ocean model. Furthermore, a paper on the results obtained in multi-decadal runs with Version 42 of SPEEDY coupled to the TOM3 model will be prepared, to be submitted for peer review.
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List of publications/reports from the project with complete references

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…Not yet, but we are already working on them.
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Summary of results

If submitted **during the first project year**, please summarise the results achieved during the period from the project start to June of the current year. A few paragraphs might be sufficient. If submitted **during the second project year**, this summary should be more detailed and cover the period from the project start. The length, at most 8 pages, should reflect the complexity of the project. Alternatively, it could be replaced by a short summary plus an existing scientific report on the project attached to this document. If submitted **during**

the third project year, please summarise the results achieved during the period from July of the previous year to June of the current year. A few paragraphs might be sufficient.

Development of the TOM3 thermodynamic ocean model, and coupling to SPEEDY ver.42

TOM3 is a three-layer thermodynamic ocean model which describe the evolution of ocean heat content up to a depth of 300m. The two top layers represent the ocean mixed layer: the top layer has a fixed 10 m depth, the second layer extends to a depth variable between 30 and 60m. The mass of the top layer is divided between water and ice; the ice surface concentration and depth can be prescribed or evolved by the model. The temperature of the ice mass is also evolved thermodynamically, taking into account the energy required by freezing/melting.
In coupled mode, the TOM3 model gets solar and non-solar surface heat fluxes from the atmospheric model; in forced mode, a driver program provides surface fluxes from ERA-5 data. Thermodynamic ocean models require a forcing representing the convergence of heat from dynamical transport (Q-flux): this is computed by the driver, comparing temperature tendencies produced by TOM3 in the absence of Q-flux with climatological temperature tendencies from the WOA-09 ocean climatology.
The TOM3 model has been finalised, coupled to SPEEDY ver.42 and tested in a configuration with prescribed sea-ice mass. The Q-flux term computed from ERA-5 data can be modified to account for the SPEEDY bias in surface fluxes; also, a small time-dependent correction has been introduced to account for decadal-scale variations in vertical heat transport, due to climate change. Coupled experiment have been successfully run, covering a 71-year historical period from 1950 to 2020. For consistency with the TOM3 formulation, observed SST runs now use time-evolving sea-ice cover in addition to SST anomalies.

Fig. 1 shows the global heat content (upper 300 m) of SPEEDY-TOM3 compared to ORA-S4. The model reproduces the re-analysis upper ocean heat content surprisingly well. In a relaxation run, the zonal mean temperature change shows well known observed features, such as arctic applification (Fig. 2).
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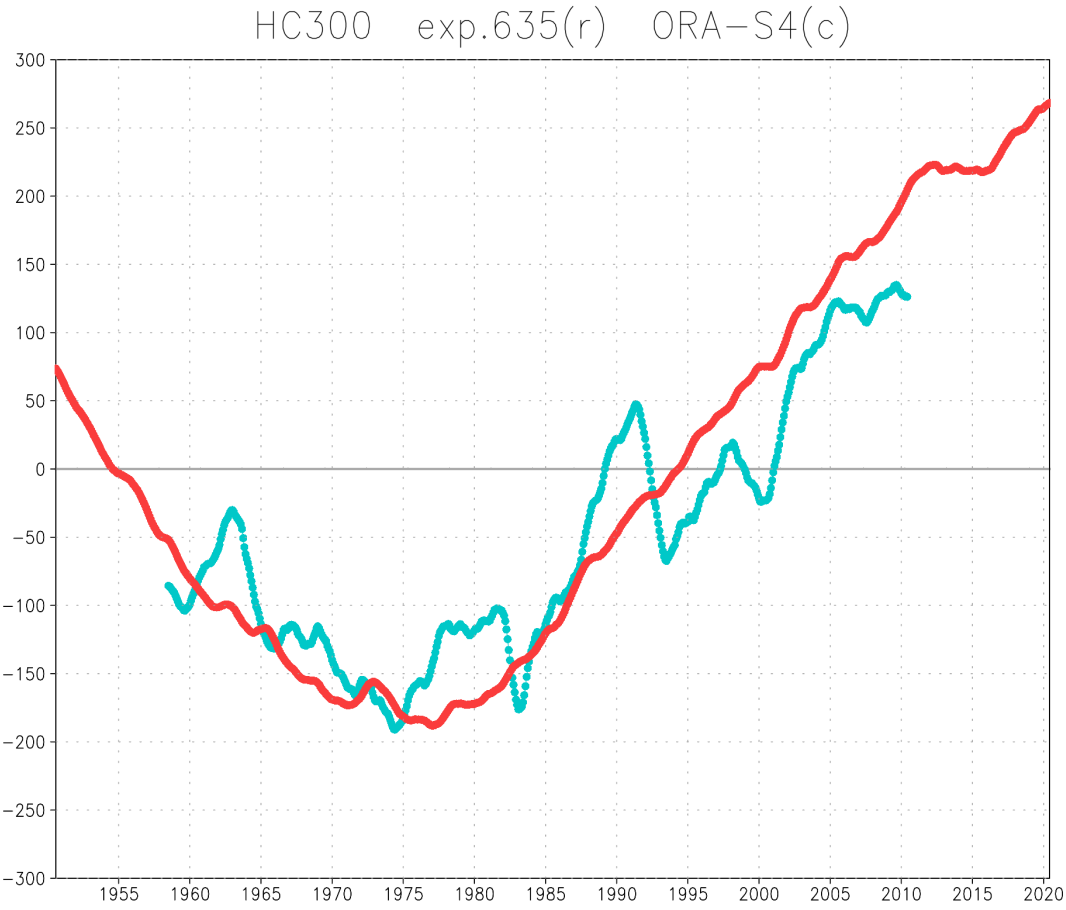

Figure 1: global upper 300 m heat content of SPEEDY-TOM3 (red) compared to ORA-S4 (blue). Units are MJ/m^2

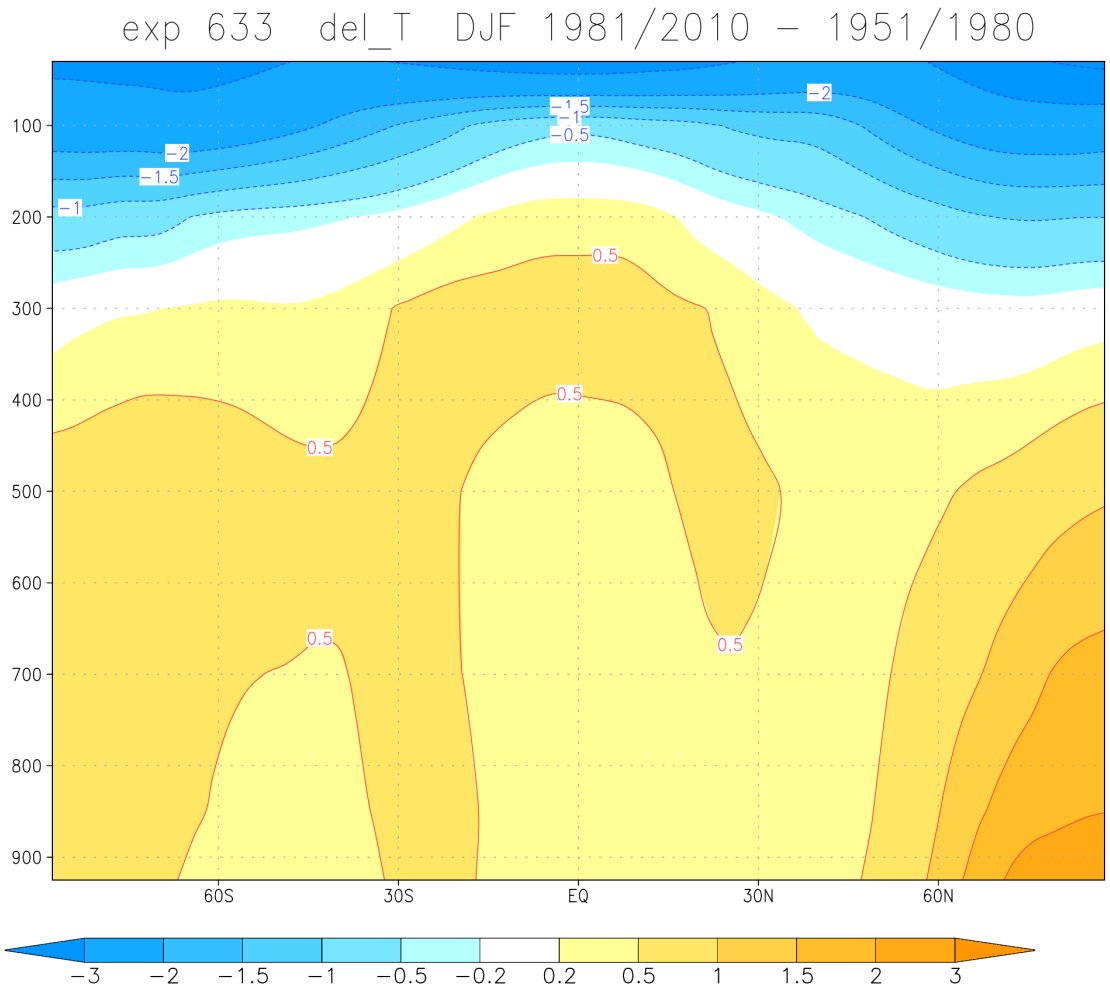

Figure 2: Temperature difference 1981/2010-1951/1980 in DJF in SST and sea-ice forced SPEEDY ver42 run. Units are K.