EMI R&D 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	…………2026…………………………………………………. ……
Project Title:	Hindcast experiments using the IFS 49r1 to investigate the impact of stratospheric ozone on predictability for the Horizon Europe project SOCLIM ……………………………………..……
Computer Project Account:	………speschio /esp1963………
Principal Investigator(s):	……Gabriel Chiodo……….…… ……………………………………………………………..……
Affiliation:	Instituto de Geociencias, Spanish National Research Council (IGEO-CSIC) ………..…… ……………………………………………………………..……
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Andreas Chrysanthou, Weiji Hu, Tim Stockdale, Inna Polichtchouk, Frederic Vitart, Daniela Domeisen, Felix Ploeger ……………………………………………………………..……
Start date of the project:	…01/2026………..……
Expected end date:	…12/2028……………..……

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)			2,880,000	596,606
Data storage capacity	(Gbytes)			16,820	

Summary of project objectives (10 lines max)

The project investigates how stratospheric ozone variability affects sub-seasonal to seasonal predictability in the IFS. In the first year of the project, we focus on hindcast experiments using different ozone configurations for four springs: 2011, 2018, 2020, and 2023. These are cases of special interest since they coincide with record low/high Arctic ozone and strong/weak stratospheric polar vortex. For these years, we will compare hindcast simulations with climatological ozone (1), observed ozone anomalies (2), the standard HLO scheme (3), and an updated hybrid linearized ozone (HLO) scheme to include the effects of heterogeneous chemistry (4). Each case will be run as a 30-member ensemble with 120-day integrations using the IFS cycle 49r1. Comparing the hindcasts with different ozone configurations will allow us to isolate the effects of ozone on forecast skill and more generally stratosphere-troposphere coupling. This project will assess the added value of interactive ozone over the standard approach of many S2S systems of using a prescribed climatological ozone. The project will also support broader activities on ozone and predictability, including APARC SNAP.

Summary of problems encountered (10 lines max)

The main difficulties encountered during the setup phase concerned the identification and adaptation of the appropriate model configuration for the experiments planned in Y1 of the special project; this was resolved by identifying the version C49r1.1 within the code repository. Initial testing of hindcast experiments of 2011 and 2022 was unsuccessful due to crashes, which were traced to a post-processing diagnostic task related to the calculation of atmospheric indices from the coupled forecast output rather than to a true failure ("ninotask"). Then, the preparation of the alternative ozone forcing for the Y1 experiments required additional work, as missing values in the SWOOSH dataset had to be interpolated, as the model otherwise crashes. In parallel, the higher computational cost of the 0.25-degree ocean configuration significantly increased the expense of early testing. To keep the computational cost close to our original request, we have decided to decrease the ocean resolution to 1-degree; this should not degrade the skill of the model in the metrics we are interested in (stratosphere-troposphere coupling). Finally, controlling the runs through ecflow required substantial debugging and training before the workflow became operational

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

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In the next phase, we will complete the simplified ozone hindcast experiments for the four target cases and extensively assess impacts on prediction skill. We will work on improving the HLO scheme, by adding new coefficients and heterogeneous chemistry term, to more properly represent polar ozone depletion. In Y2, we will then transition to full-chemistry experiments with the IFS-COMPO configuration, focusing on the strongest ozone-minimum years (2011 and 2020). The ability of the model to reforecst the dynamical conditions of these events and downward coupling will be compared across the different configurations. The results will be used to refine the experimental design and support the development of coordinated community protocols within the APARC/SNAP O3 protocol to be launched in late 2026. This work will also provide the basis for the analysis of chemistry-climate coupling and predictability that are essential for the ERC SOCLIM project.

List of publications/reports from the project with complete references

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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.

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We have successfully carried out hindcast experiments with the C49r1.1 version of IFS for the spring 2020 event, with February initializations and a fully coupled ocean configuration. This setup was designed to reproduce the exceptionally strong vortex and Arctic ozone depletion event described in Lawrence et al. (2020), which coincided with one of the most positive surface AO phases on record, along with pronounced surface anomalies such as warm conditions over Eurasia and dry anomalies over central Europe.

To assess the role of ozone representation, we tested the HLO scheme using ERA5-based initialization and compared it with alternative ozone forcings. In particular, we ran experiments with a zonal-mean monthly climatology derived from CMIP6, as well as simulations using ozone forcing based on the SWOOSH merged satellite composite dataset. All experiments were performed with three ensemble members.

Preliminary results for lower-stratospheric temperature (T100) indicate that the model reproduces the evolution reasonably well (to within the model spread across the three members) over the first three months, largely regardless of the ozone configuration (**Figure 1**). However, the simulations do not yet capture the observed magnitude of the ozone depletion itself, suggesting that the chemical signal remains largely underestimated in the current setup (**Figure 2**). We are currently extending the number of ensemble members to robustly assess the model skill, and we will explore the effects on the lifetime of the vortex and, in particular, stratosphere-troposphere coupling.

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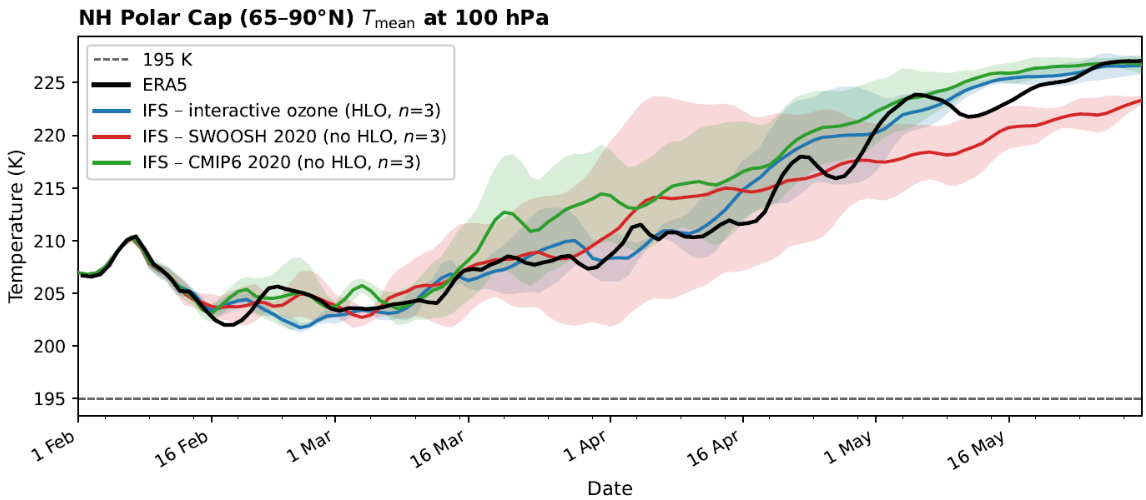
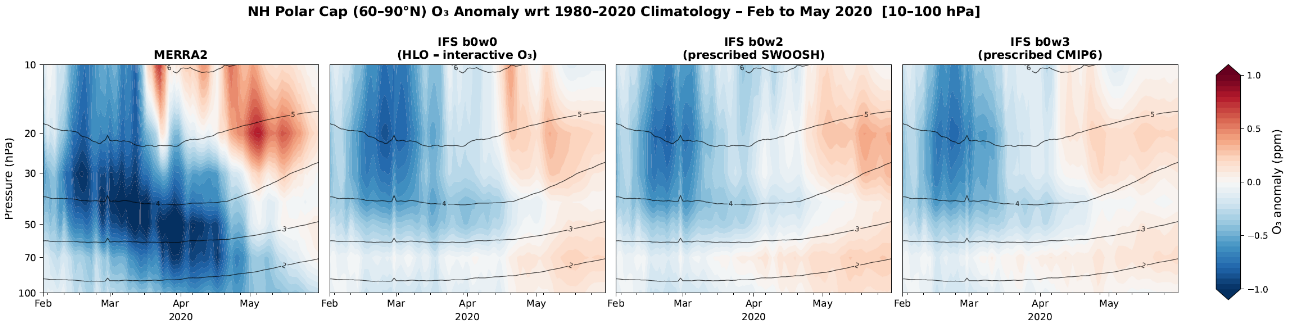


…Figure 1: Evolution of the NH polar cap zonal mean lower stratospheric temperature (100 hPa) in spring 2020 (black) and in the hindcast experiments performed with IFS cycle49.r1; in the ensemble with the HLO linearized ozone scheme (blue), in the ensemble using prescribed ozone values from SWOOSH (red) and using the CMIP6 ozone values (green). The shading shows the spread across the 3 realizations, using different initial conditions…



…Figure 2: Evolution as a function of height of the polar cap zonal mean ozone in spring 2020 in MERRA2 reanalysis (left), in the ensemble with HLO configuration (center-left), in the ensemble with prescribed SWOOSH (center-right) and CMIP6 ozone climatology (right)