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	2023
Project Title:	Investigating multi-decadal climate variations in seasonal forecasts: The role of aerosol and greenhouse gas forcings
Computer Project Account:	spgbwrig
Principal Investigator:	Mr. Matthew Wright Dr. Antje Weisheimer (ECMWF; University of Oxford) Prof. Tim Woollings (University of Oxford)
Affiliation:	University of Oxford
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Dr. Antje Weisheimer (ECMWF and University of Oxford) Dr. Tim Stockdale
Start date of the project:	January 2023
Expected end date:	December 2025

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)	N/A	N/A	23,600,000	10,380,000
Data storage capacity	(Gbytes)	N/A	N/A	83,840	~12,000

Summary of project objectives (10 lines max)

This project aims to build on the work of Weisheimer et al. (2017, 2022, 2023), to investigate multidecadal variations in seasonal hindcast skill throughout the twentieth century. The experiments run in this project will test hindcast skill's sensitivity to various sources of external forcing, initially focusing on aerosol loads and, later, greenhouse gas emissions. We will work closely with the CONFESS project team at ECMWF to run hindcasts with perturbed aerosol mass mixing ratios, focusing on comparing the low skill mid-century period to the high-skill recent period.

Summary of problems encountered (10 lines max)

Most issues so far have centred around getting used to modifying the IFS source code and branching and editing it to accept initial conditions from CERA-20C. Whilst a CY43R1 branch enabling this had been produced before in Perforce, so some changes that were required were known, new cycles had changed the source code such that some of these didn't work. Therefore, more in-depth coding and diagnoses of issues were required, with the support of ECMWF researchers. This meant that preparation of the model for the first set of experiments took longer than expected.

Further, the CONFESS aerosol dataset that we are using only goes back to 1970. Therefore, we have had to modify and develop our own aerosol dataset, when we thought we may be able to use CONFESS's for years before 1970.

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

We are on-track with the timeline presented in the initial proposal, in terms of experiments that will be completed this year. During the next few months, we will finalise the creation of an aerosol dataset (modifying CMIP6 aerosol mass mixing ratio data using CONFESS methodologies to create a time-varying aerosol dataset from 1900 onwards). We will then be able to run the remainder of the experiments scheduled for this project year. Once these have been completed, we will be able to analyse the results in full, including comparisons between the high, best guess and low aerosol loads during each period, and between the two periods. We will be able to make conclusions about how and why seasonal hindcast skill is sensitive to aerosol load.

List of publications/reports from the project with complete references

N/A yet – we are still running experiments and starting preliminary analysis of their outputs.

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.

In summary, so far this project has:

- Adapted the IFS to accept time-varying aerosol datasets, and initial conditions from CERA-20C, working with various ECMWF researchers.

- Developed and adapted aerosol datasets, using comparable methodologies to the CONFESS project, to enable experiments to be run with time-varying aerosol datasets early in the century.
- Run three experiments on cycle 48r1: November-start hindcasts from 1985-2010, with four-month lead times, with three different aerosol datasets (best guess, doubled and halved).
- Prepared three more experiments on cycle 48r1: November-start hindcasts from 1925-1950, with four-month lead times, with three different aerosol datasets (best guess, doubled and halved). These will be submitted imminently.
- Started very preliminary analysis of the results of the first few experiments.

See below for full descriptions:
Substantial results so far are limited, because most of this project year has been spent adapting the IFS seasonal forecasting system to be run earlier in the century (by changing source code so that the model accepts initial conditions from Coupled Reanalyses of the 20th century, CERA-20C). This involved changes mainly to the ifs-scripts branch of the bitbucket repository. In order to achieve these changes, we collaborated with several ECMWF researchers, including Tim Stockdale, Retish Senan and Stephanie Johnson. It is hoped that, once the experiments are completed and the results have been analysed, these changes will be tidied up and made into a centrally available IFS branch, which will enable other researchers to initialise the IFS from CERA-20C.

By default, aerosols are just prescribed through a monthly climatology, no matter the year the hindcast is initialised in. This means that natural and anthropogenic aerosols change seasonally (e.g., more black carbon during forest fire season), but not between years. For this project, we wanted to evolve aerosol loads based on the initialisation year (whilst maintaining the annual cycle). Therefore, new aerosol datasets have been developed and adapted, in order to change the aerosol forcing in the hindcasts. Working with the CONFESS team at ECMWF, we have merged the changes enabling CERA-20C initial conditions to be used with the IFS branch that accepts time-varying aerosol datasets. This means that experiments with time-varying aerosol datasets can be used to run experiments from 1900 onwards. CONFESS has developed a time-varying aerosol dataset that begins in 1970. For the recent runs, we are using this dataset. For the runs which are initialised before 1970, we have adapted CMIP6 data of aerosol mass mixing ratios, using similar methodology to the CONFESS project, to produce a similar time-varying aerosol dataset, which will be used for these experiments.

As of mid-June, we have completed three experiments. These use a configuration of IFS Cycle 48r1 at resolution TCo199, with 91 vertical levels, coupled to the NEMO ocean model version 3.4, at 1° resolution, with 42 vertical levels. Initial conditions were from CERA-20C and all three experiments had 21 ensemble members. Each experiment was a series of November-start hindcasts, run for four months. Each had a different aerosol forcing: one with 'best guess' aerosols taken from CONFESS's dataset, one with doubled aerosol forcing, and one with halved aerosol forcing.

Additionally, three more experiments are about to be submitted, as soon as the aerosol dataset is finalised for them. These are the same as above, but initialised in 1925-1950, using the aerosol dataset developed in this project.

Initial analysis of the first experiments has just begun. This has mainly been mapping and quantifying differences in the aerosol forcings between the experiments, and looking at the differences in large-scale atmospheric variables in the ensemble means between the experiments. For example, Figure 1 shows the difference in the time-averaged, ensemble mean total cloud cover between the highest and lowest aerosol forcing experiments. There are clearly regions of enhanced and reduced cloud cover. The reasons for these – and for differences in other variables – will be explored further in the coming months.

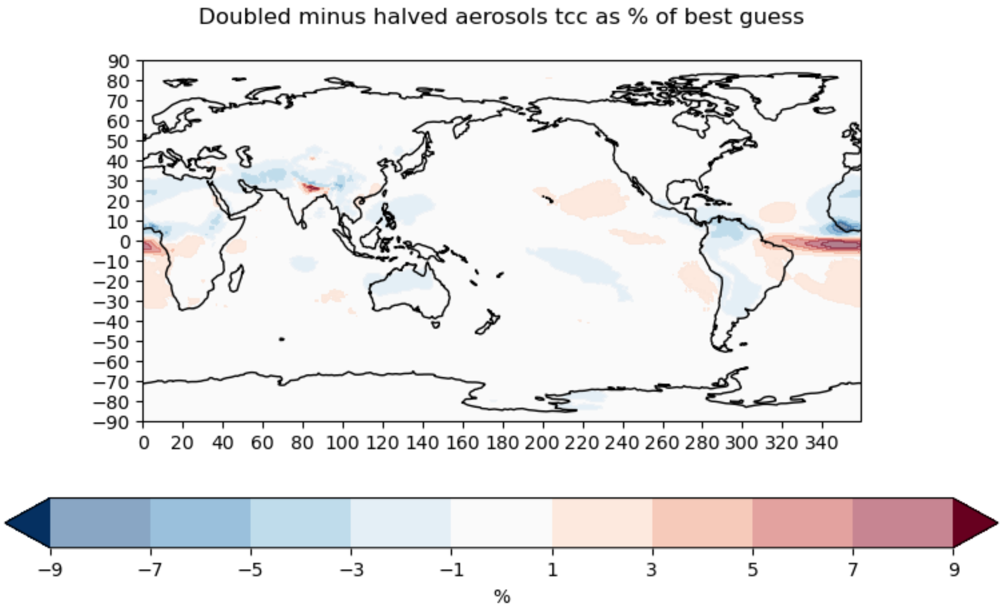

Figure 1: difference in total cloud cover, averaged 1985-2010, for the DJF season from November-start hindcasts. The difference is expressed as the difference between the cloud cover in the doubled aerosols experiment and the halved aerosols experiment, as a percentage of the best guess areosols experiment.