EMI R&D PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

Project Title:	Alternative schemes to accelerate seamless weather prediction
Computer Project Account:	spgbmong
Start Year - End Year :	2023 - 2025
Principal Investigator(s)	Beatriz Monge-Sanz
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Other Researchers (Name/Affiliation):	Antje Inness (ECMWF), Peter Dueben (ECMWF), Matthew Chantry (ECMWF), Noureddine Semane (ECMWF), Massimo Bonavita (ECMWF)

The following should cover the entire project duration.

Summary of project objectives

(10 lines max)

The new generation of Earth System Models (ESMs) required to answer pressing questions on weather extremes under climate change needs to be developed in ways that allow seamless prediction across a wide range of resolutions and timescales.

The role of stratospheric chemistry in ESMs and numerical weather prediction (NWP) is still an open question. Monge-Sanz et al. (2022) demonstrated the benefits of improving stratospheric ozone models for NWP at multiple timescales, from medium-range to seasonal and decadal. For this, they used a fast linear ozone model that superseded existing linear models as shown by Monge-Sanz et al. (2011). In this project we assessed the role of stratospheric key radiative species through ECMWF model experiments with different configurations and different approaches to incorporate the interaction between meteorological fields, radiation and stratospheric species.

Summary of problems encountered

(If you encountered any problems of a more technical nature, please describe them here.)

Not real problems but some technical aspects due to access permits, new systems and migration of data and branches required additional time. Support staff were very helpful.

Experience with the EMI R&D Project framework

(Please let us know about your experience with administrative aspects like the application procedure, progress reporting etc.)

Overall very positive experience with project application and reporting procedures.
Support staff also available if needed.

Summary of results

(This section should comprise up to 10 pages, reflecting the complexity and duration of the project, and can be replaced by a short summary plus an existing scientific report on the project.)

In this project we assessed the feasibility and performance of alternative fast approaches for stratospheric key radiative species that can be implemented in an ESM at low computational cost, while providing quality comparable to key chemical fields from widely used full-chemistry models. We also assessed the impact of Microwave Limb Sounder observations of atmospheric chemistry in IFS simulations.

Due to computational costs, full-chemistry descriptions for the stratosphere are still mainly reserved for coarser resolutions than operational numerical weather prediction (NWP) models require, and such full-chemistry descriptions are not yet affordable for multi-ensemble long-range weather simulations.

Offline simulations of the fast approaches we developed for stratospheric ozone showed feasibility and good agreement with corresponding fields from full-chemistry models. With these offline runs we were able to assess the performance of the fast approaches and also disentangle contribution from chemical and dynamical processes for different periods during the ERA-Interim reanalysis period. ERA-Interim was chosen for a more straightforward comparison with results from Monge-Sanz et al. (2022), and because ERA-Interim performance in the stratospheric region is still better than most reanalysis (SPARC 2022).

Results from our offline tests were analysed for different atmospheric regions and periods along a 30-year period, with particular attention to high latitudes. Ozone behaviour over high latitudes during the 1980-2010 period is particularly challenging and scientifically relevant because of the intensity and extension of spring ozone depletion, and because of the evolution of ozone depleting substances along the period considered. Our results showed the feasibility of these fast and ML approaches as alternatives to reproduce key stratospheric species with accuracy comparable to full-chemistry models, for cases and models where full-chemistry is not viable.

To assess the role of stratospheric ozone and the impact of Microwave Limb Sounder (MLS) observations of atmospheric chemistry, we performed IFS simulations with the latest cycle version 49r1, horizontal resolution T511 and full vertical resolution L137. These simulations covered NH recent winter/spring periods after 2020. We also assessed the role of stratospheric ozone with experiments using the CAMS model configuration. We have run several 3-month assimilation experiments in which the contribution of ozone datasets from key instruments like MLS to meteorological fields has been quantified.

In this project, we have thus identified the relevance of the Microwave Limb Sounder (MLS) O_3 dataset to be of potential benefit for improving meteorological fields in numerical weather prediction (NWP) system forecasts like those produced by ECMWF. The assimilation of this dataset causes differences in the mean temperature field of up to 0.2 K in forecast lead times between day 0 and day 5 (Figure 1). Complementary results have been obtained with MLS H_2O assimilated in 49r1 (Semane and Bonavita, 2025). This provides consistent proof of benefits that MLS observations of stratospheric species can bring to weather forecasting. Our results show the need for new observations that will continue to provide similar or improved information for key stratospheric species once the MLS instrument will be decommissioned. We are therefore showing the relevance that data provided by an instrument similar to the proposed ESA Earth Explorer 11 CAIRT candidate mission could have to improve NWP.

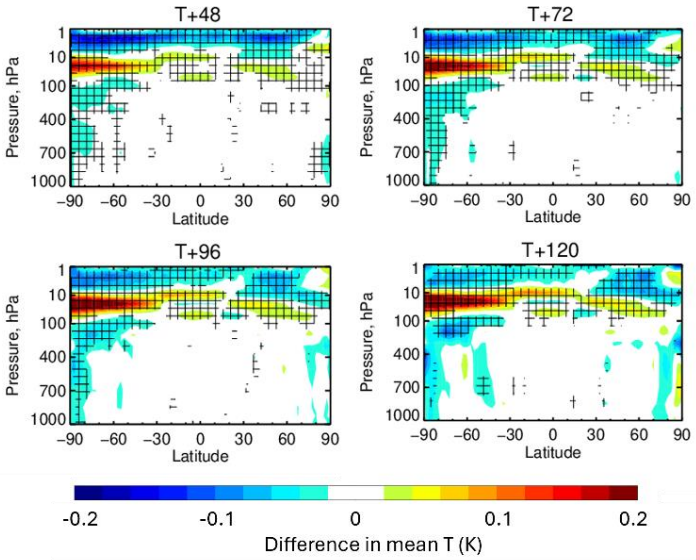

Figure 1. Cross sections for the change of mean Temperature (K) for forecast lead times from 48 to 120 h, for the period December 2020–March 2021, for two analysis experiments with and without MLS ozone. Hatched regions indicate where results are statistically significant to the 95% confidence interval. From Monge-Sanz et al. (*to submit to ACP*).

We have presented results related to this project at several international conferences and invited seminars, including an invited seminar at Imperial College 2023, talks at the 13th Atmospheric Limb Workshop 2025, the RMetS Annual Conference 2025 and EGU 2026, and a Solicited talk at the COSPAR 2026.

References:

Monge-Sanz, B. M., Bozzo, A., Byrne, N., Chipperfield, M. P., Diamantakis, M., Flemming, J., Gray, L. J., Hogan, R. J., Jones, L., Magnusson, L., Polichtchouk, I., Shepherd, T. G., Wedi, N., and Weisheimer, A.: A stratospheric prognostic ozone for seamless Earth System Models: performance, impacts and future, Atmos. Chem. Phys., https://doi.org/10.5194/acp-22-4277-2022, 2022.

Monge-Sanz, B. M., Chipperfield, M. P., Cariolle, D., and Feng, W.: Results from a new linear O_3 scheme with embedded heterogeneous chemistry compared with the parent full-chemistry 3-D CTM, Atmos. Chem. Phys., 11, 1227–1242, https://doi.org/10.5194/acp-11-1227-2011, 2011.

Semane, N., and Bonavita, M.: Reintroducing the analysis of humidity in the stratosphere, ECMWF Newsletter 183 - Spring 2025, 28-31, doi: 10.21957/ns41h80kl3, 2025.

SPARC, 2022: SPARC Reanalysis Intercomparison Project (S-RIP) Final Report. SPARC Report No. 10, WCRP-6/2021, doi: 10.17874/800dee57d13

List of publications/reports from the project with complete references

ESA, Report for Mission Selection: Earth Explorer 11 Candidate Mission CAIRT, European Space Agency, Noordwijk, The Netherlands, ESA-EOPSM-CAIR-RP-4797, 230pp, 2025

Monge-Sanz, B.M.: How stratospheric composition Limb observations improve weather model forecasts, 13th International Atmospheric Limb Workshop, Book of Abstracts, p54-55, 2025

Monge-Sanz, B., Inness, A., Errera, Q., and Sinnhuber, B.-M.: Stratospheric composition Limb observations to improve NWP forecasts and (re)analyses, EGU26-19175, https://doi.org/10.5194/egusphere-egu26-19175, 2026

Sinnhuber, B.-M., and Coauthors, Executive Summary of the ESA-CAIRT PerReC Activity, DOI: 10.5281/zenodo.18758615, 2026

Sinnhuber, B.-M., and Coauthors, The need for a new comprehensive view of the middle atmosphere – the potential of infrared limb imaging tomography, Bulletin of the American Meteorological Society (BAMS), accepted, 2026

Future plans

(Please let us know of any imminent plans regarding a continuation of this research activity, in particular if they are linked to another/new EMI R&D Project.)

A new EMI R&D project expanding on results obtained and developing new lines opened during this project has started in early 2026. This will also further strengthen collaboration with ECMWF researchers and expand international collaborations.