Decadal Prediction Volcanic Response Readiness Exercise (VolRes-RE)

A SPARC/DCPP initiative

William Merryfield[1], Reinel Sospedra-Alfonso[1], Matthew Toohey[2], Claudia Timmreck[3]

[1]Canadian Centre for Climate Modelling and Analysis, Environment and Climate Change Canada
[2]Department of Physics & Engineering Physics, University of Saskatchewan, Canada
[3]Max Planck Institute for Meteorology, Germany

Background

Real-time decadal predictions, such as those communicated by the WMO Lead Centre for Annual-to-Decadal Climate Prediction (LC-ADCP) that inform the WMO's Global Annual to Decadal Climate Update (Hermanson et al., 2022), are typically initialized once annually, late in the year preceding the year of issuance. Such predictions will not take into account the climatic impacts of any (essentially unpredictable) major volcanic eruption occurring after they are produced. Because such impacts can be substantial and last for multiple years, current predictions (for Year 1 and Years 1-5 as issued by the LC-ADCP) could largely be invalidated by such an event (Timmreck et al., 2016).

Acknowledging this possibility, the Decadal Climate Prediction Project (DCPP) panel of the WCRP prepared a set of Guidelines for updating climate forecasts following a sudden volcanic eruption (Müller & Smith, 2018). A key element is the proposed use of the Easy Volcanic Aerosol (EVA) idealized forcing generator (Toohey et al. 2016) to provide estimates of the stratospheric volcanic aerosol forcing in a form that can be incorporated into decadal prediction models. Given an input list of volcanic eruption attributes that can be determined rapidly from satellite observations (e.g from the SPARC/SSiRC VolRes activity), EVA provides time-, latitude-, and height-dependent forcings, consisting of aerosol extinction, single scattering albedo, and asymmetry factor, in wavelength bands that can straightforwardly be customized for CMIP6-contributing models (Zanchettin et al., 2016). EVA is also able to provide volcanic forcing inputs for pre-CMIP6 models that use simpler aerosol optical depth-based formulations after Sato et al. (1993; 2012).

Under VolRes-RE, centres that produced decadal forecasts for initial year 2022 are invited to respond in the manner outlined in the DCPP Guidelines to a hypothetical major volcanic eruption occurring in 2022 for which EVA-generated forcings are provided (details to be announced). This exercise will be described in a journal publication led by the organizers of VolRes-RE.

Motivation

It is currently not possible to predict the timing or impacts of a major volcanic eruption. The occurrence of an eruption having appreciable climate impacts will therefore require rapid response by the decadal prediction community if a revised prediction sufficiently timely to be useful is to be produced. Motivations for VolRes-RE are as follows:

- Although Guidelines for climate forecasts after sudden volcanic eruption have been developed (partly in response to the threat posed by eruptions of Mount Agung in 2017-2018), the communities involved in this response could achieve a higher state of readiness by carrying out the necessary procedures in advance. Such an exercise ensures that the necessary procedures will be "on the shelf", enabling a more rapid and organized response.

- By undertaking such an exercise, participants will confront any unanticipated issues not covered in the existing Guidelines.
- The experience gained may assist in streamlining the response procedures, e.g. by pointing toward a preference for one of the two response protocols described below.
- Results will highlight any major disagreements between prediction systems and motivate efforts to reconcile them.
- It has been more than 30 years since the 1991 eruption of Mount Pinatubo, the most recent eruption having major climatic impacts, and numerous additional years may pass before the next such event. Publishing an elaboration upon the current Guidelines and description of this exercise in the scientific literature will provide thorough, durable and discoverable documentation to inform the response to future events.

Description

VolRes-RE will test and compare both response protocols outlined in the current Guidelines:

Response Protocol 1: The forecast for 2022-2026 is repeated from the same initial date (e.g. 1 Nov 2021), but using EVA-generated volcanic forcings for the hypothetical 2022 eruption.

Response Protocol 2: A pair of forecasts is initialized no more than one month before the onset of the eruption (e.g. 1 Apr for a hypothetical eruption starting on 20 Apr). The first uses unperturbed stratospheric aerosol forcings, and the second includes the EVA-generated volcanic forcings for the hypothetical 2022 eruption.

Under Protocol 1 the operational response would be to replace the unperturbed 2022-2026 forecast with the perturbed version, whereas under Protocol 2 the unperturbed 2022-2026 forecast would be modified according to the differences between the perturbed and unperturbed forecasts initialized just before the eruption.

If a centre wishes to participate but has not already run an unperturbed 2022-2026 forecast, that forecast is requested also.

Data request

The modest VolRes-RE data request mirrors that provided annually by centres contributing to the WMO Lead Centre for Annual-to-Decadal Climate Prediction. For each of the three requested forecasts (one for Response Protocol 1 and two for Response Protocol 2), participants are requested to provide, in a similar manner as for existing LC-ADCP or DCPP Component B contributions,

- **Five-year predictions (2022-2026)**, although contributors may optionally provide predictions out to 10 years (2022-2031)
- **Same ensemble size as the unperturbed forecast** (minimum of 10 ensemble members)
- **Monthly mean fields** for each ensemble member and variable
- **Required variables:** near-surface (2 meter) air temperature (tas); precipitation flux (pr); air pressure at sea level (psl)

- **Additional variables (optional, if corresponding hind/forecast data already submitted to LC-ADCP or CMIP6 ESGF):** surface temperature (ts); sea ice area fraction, or concentration (siconc) including Arctic and Antarctic; Atlantic Meridional Overturning Circulation (AMOC) streamfunction
- **CF-compliant NetCDF format** is strongly preferred
- **Under the assumption that hindcast data is available from the LC-ADCP** (or the ESGF for additional CMIP6-contributing models) **no hindcast data is requested** unless needed to fill "holes" in the LC-ADCP or CMIP6 archives
- **If hindcast data is not available from the LC-ADCP or CMIP6 archive, or if a contributor otherwise prefers, then submissions may consist of bias corrected anomalies relative to the 1991-2020 base period currently used by the LC.** In this instance the unperturbed 2022-2026 forecast is requested also.

Further details including requested file naming conventions are provided in the Appendix below.

Timeline

Because VolRes-RE is targeted and limited in scope, a relatively rapid timeline is envisaged as follows.

Late August-early September 2022: this description circulated to prospective contributors and expressions of interest sought
Mid-September 2022: parameters of volcanic eruption and tool for generating model-specific volcanic forcings and associated technical advice made available
Mid-September-October 2022: volcanic forcings are incorporated into models, volcano-modified forecasts for the two response protocols are run (computationally equivalent to three real-time forecasts)
November-December 2022: data is collected from participating centres
January-June 2023: results analyzed and journal submission drafted

Planned outcomes

The primary outcome will be a journal submission (tentatively to *BAMS*) describing motivations for and results of VolRes-RE. This paper is intended to provide thorough and durable documentation and guidance for how the decadal prediction community should respond to a climatically significant volcanic eruption, and will highlight this issue to the larger scientific community. Writing will be led by VolRes-RE organizers, with all contributing participants invited to serve as coauthors.

References

Hermanson, L. et al. WMO global annual to decadal climate update: a prediction for 2021–25. *Bull. Am. Meteorol. Soc*. **103**, E1117–E1129 (2022).

Müller, W. A. & D. Smith. Guidelines for climate forecasts after sudden volcanic eruption. https://www.wcrp-climate.org/dcp-activities/dcp-cmip5-2 (2018).

Sato, M., J. E. Hansen, M. P. McCormick & J. B. Pollack. Stratospheric Aerosol Optical Depths, 1850–1990, *J. Geophys. Res*. **98**, 22987–22994 (1993).

Sato, M., et al. Stratospheric Aerosol Optical Thickness in the GISS Climate Model. Available at: http://data.giss.nasa.gov/modelforce/strataer/ (2012).

Timmreck, C., Pohlmann, H., Illing, S. & Kadow, C. The impact of stratospheric volcanic aerosol on decadal-scale climate predictions. *Geophys. Res. Lett.* **43**, 834–842 (2016).

Toohey, M., Stevens, B., Schmidt, H. & Timmreck, C. Easy volcanic aerosol (EVA v1.0): an idealized forcing generator for climate simulations. *Geosci. Model Dev*. **9**, 4049–4070 (2016).

Zanchettin, D. et al. The Model Intercomparison Project on the climatic response to Volcanic forcing (VolMIP): experimental design and forcing input data for CMIP6. *Geosci. Model Dev.* **9**, 2701–2719 (2016).

Appendix: Requested file standards for VolRes-RE contributions (adapted from file standards document for LC-ADCP 2022-2026 predictions)

General

We ask for separate netCDF files for each variable, containing full field monthly mean values. Ensemble members may either be provided in separate files, or all in one file, as indicated by the variant_label specifications below.

Filename

Filename should follow this pattern, which is similar to that used in CMIP6, e.g.

<variable_id>_Amon_<source_id>_<start_date>_<variant_label>.nc

for variables in the Amon MIP table.

Component of filename	Description	Allowed values
variable_id	CMIP6 variable ID	One of: tas, pr, psl
source_id	Source ID	Eg. DePreSys2
start_date	Date of start of forecast	yyyyMMdd, eg. 19801101
variant_label	CMIP6-style variant label*	Eg. r1i1p1f1 or a range r1-10i1p1f1

* r=realization (ensemble member), i=initialization method (usually same for all forecasts from a given system), p=physics version (usually same for all forecasts from a given system unless a perturbed physics ensemble is used), f=forcing version (1 for forecasts without 2022 volcano, 2 for forecasts with 2022 volcano)

As an example, for a system that initializes its decadal predictions on 1 Nov of each year, and Response Protocol 2 predictions initialized on 1 Apr 2022, files containing ensemble member 1 would follow these naming conventions:

1) Unperturbed 2022 forecast (presumed to already exist in which case no need to provide):

<variable_id>_Amon_<source_id>_20211101_r1i1p1f1.nc

2) Perturbed 2022 forecast under Response Protocol 1:

<variable_id>_Amon_<source_id>_20211101_r1i1p1f2.nc

3) Unperturbed 2022 forecast under Response Protocol 2:

<variable_id>_Amon_<source_id>_20220401_r1i1p1f1.nc

4) Perturbed forecast under Response Protocol 2:

<variable_id>_Amon_<source_id>_20220401_r1i1p1f2.nc

Dimensions

The variables should have three dimensions in this order: time, latitude, longitude.

time

Required attribute	Description	Allowed values
standard_name	Name of dimension	time
units	Units	[seconds/hours/days] since [year]-[month]-[day] [hour]:[minute]:[second] eg. days since 1960-01-01 00:00:00
calendar	Type of calendar	Any CF-compliant calendar name, eg. gregorian, 360_day, …

latitude and longitude

These dimensions should have two attributes: standard_name (latitude or longitude) and units (eg. degrees).

realization

This should be in all files, even those with only one member (in which case it will be a scalar coordinate). Minimum attributes: standard name (realization), units (1).

Variables

The variables submitted should be full field and have the units specified in the table below. As air_temperature is at 2m height, this should be indicated by the addition of a scalar coordinate (height: [2] with units = ‘m’).

Variable	CF label	Units	MIP Table	Priority
air_temperature	tas	K or degC	Amon	Required

precipitation_flux	pr	mm/day or kg m^{-2} s^{-1}	Amon	Required
air_pressure_at_sea_level	psl	hPa or Pa	Amon	Required
surface_temperature	ts	K or degC	Amon	Optional
sea_ice_area_fraction	siconc	%	SImon	Optional
Atlantic Meridional Overturning Circulation (AMOC) streamfunction	msftmz	Sv or kg s^{-1}	Omon	Optional

Global Attributes

There are no required global attributes, but these might be helpful: model, version, date_of_creation, grid, method, bias_correction_method (if applicable, e.g if anomalies are submitted and/or a trend correction is applied).