LATE REQUEST FOR A SPECIAL PROJECT 2015–2017

MEMBER STATE:	…UK…………………………………………………………………...…
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	……………………………………………………………………..……
Project Title:	…Quantifying the uncertainty in volcanic ash cloud forecasts ……………………..……

Would you accept support for 1 year only, if necessary?	YES X☐	NO ☐

Computer resources required for 2015-2017: (The project duration is limited to a maximum of 3 years, agreed at the beginning of the project. For late requests the project will start in the current year.)	**2015**	**2016**	**2017**
High Performance Computing Facility (units)	3,000,000		
Data storage capacity (total archive volume) (gigabytes)	9,000		

*An electronic copy of this form **must be sent** via e-mail to:* *special_projects@ecmwf.int*

Electronic copy of the form sent on (please specify date):

…29/06/15………………………

Continue overleaf

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide an annual progress report of the project's activities, etc.

Principal Investigator: …Helen Dacre………………………………………

Project Title: …Quantifying the uncertainty in volcanic ash cloud forecasts ……………………………………

Extended abstract

It is expected that Special Projects requesting large amounts of computing resources (500,000 SBU or more) should provide a more detailed abstract/project description (3-5 pages) including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used. The Scientific Advisory Committee and the Technical Advisory Committee review the scientific and technical aspects of each Special Project application. The review process takes into account the resources available, the quality of the scientific and technical proposals, the use of ECMWF software and data infrastructure, and their relevance to ECMWF's objectives. - Descriptions of all accepted projects will be published on the ECMWF website.

Quantifying the uncertainty in volcanic ash cloud forecasts

Abstract

In this special project application we request the use of ECMWF computing resources to run the ECMWF EPS for the period covering the eruption of the Eyjafjallajokull volcano in Iceland (April-May 2010). Output from the EPS will provide input for the UK Met Office's Volcanic Ash Transport and Dispersion (VATD) model, NAME, in order to produce an ensemble of volcanic ash forecasts. These volcanic ash forecasts will be quantitatively evaluated against satellite data in order to:

1. Quantify the uncertainty in volcanic ash forecasts due to uncertainty in the meteorological fields used to advect, disperse and remove ash particles from the atmosphere.
2. Determine how meteorological uncertainty compares to uncertainties in the volcanic eruption source parameters and internal VATD model parameters.
3. Evaluate how the performance of volcanic ash forecasts changes with forecast lead-time.

Introduction

Volcanic ash provides a significant hazard to aircraft by reducing visibility and causing both temporary engine failure and permanent engine damage (Casadevall, 1994). The presence of volcanic ash in the atmosphere can disrupt air traffic and result in large financial losses for the aviation industry. For example, the 2010 Eyjafjallajokull eruption closed European airspace for over 6 days, grounding over 95,000 flights and costing the airline industry over £1billion (Mazzocchi et al., 2010).

The decision to close airspace is to a large extent based on advice from the Volcanic Ash Advisory Centers (VAAC's). There are 9 VAAC's worldwide, covering different regions of the globe (Figure 1a). Each VAAC issues hazard maps (Figure 1b) of the predicted area covered by volcanic ash. These hazard maps are based on forecasts made using Volcanic Ash Transport and Dispersion (VATD) models. There can be large errors in these forecasts due to uncertainty in the input fields and approximations in the model itself (Mastin et al., 2009; Bursik et al., 2012). Current operational VATD models assume that both the input fields and the model are perfect. They therefore fail to represent the inherent uncertainty in the forecast which results in overconfidence in the model predictions and can lead to potentially incorrect decisions being made.

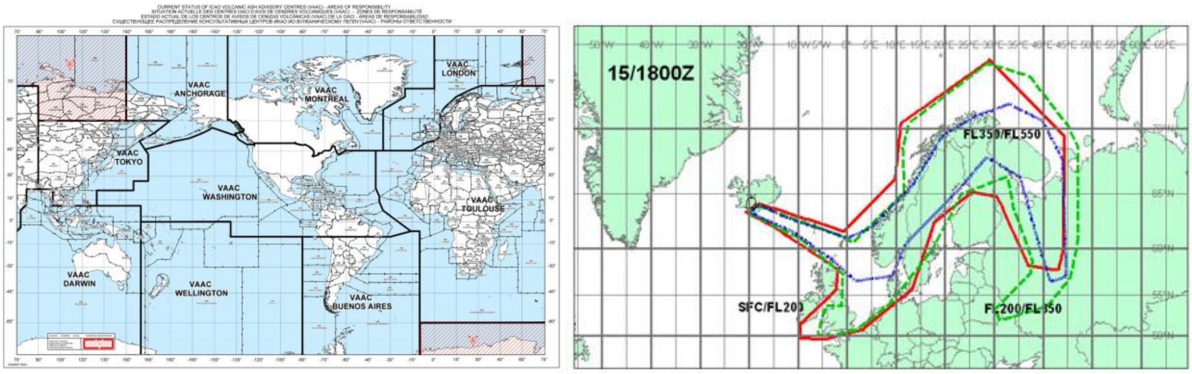
a  b

Figure 1: (a) Regions of the world covered by each of the VAAC's. (b) London VAAC volcanic ash graphic issued during the Eyjafjallajokull eruption in 2010. The forecast is valid at 18Z on April 15th 2010. The contours represent the outermost extent of the volcanic ash cloud as simulated by a VATD model (NAME) over 3 different levels; surface – flight level (FL)200 (20,000ft), FL200-FL350 (20,000ft – 35,000ft) and FL350-FL550 (35,000ft – 55,000ft).

Scientific Plan

There are several different methods of representing uncertainty in VATD modeling; (i) ensembles of different volcano eruption source parameters, (ii) ensembles of different VATD models, (iii) ensembles of different meteorological forecasts and (iv) a combination of one or more of the strategies above. Whilst progress has been made to represent both (i) and (ii), as yet no studies have been performed to represent the uncertainty in VATD model forecasts due to uncertainties in the meteorological forecast fields. Firstly this is because the observational data available needed to quantitatively assess the uncertainty in VATD models, over a wide range of spatial and temporal scales, has previously not been available and secondly because the data storage needed to archive the ensemble NWP model level data required as input to offline VATD models is prohibitive to perform on a routine basis.

Previous efforts to quantitatively evaluate the accuracy of volcanic ash forecasts have been limited by a severe lack of observational data. In general, studies have been restricted to either ground-based measurements at a small number of locations, for instance using vertically-pointing lidars, or in-situ measurements by aircraft flying through the ash cloud (e.g. Dacre et al., 2011). Both of these approaches suffer from a lack of spatial coverage. However, recent developments in satellite retrieval algorithms now mean that global datasets of volcanic ash properties, such as total column loading of ash and ash cloud height are available (e.g. Francis et al., 2012). These datasets have high temporal and spatial resolution and mean that, for the first time, a systematic evaluation of ash cloud concentration and vertical structure, two key components of the new VAAC guidelines, as well as ash cloud spatial extent can be performed. We have developed a verification methodology for dispersion forecasting, using these newly developed satellite datasets (Harvey and Dacre, 2015) and used this methodology to assess the uncertainty in both ensembles of different VATD models and ensembles of different volcanic eruption source parameters (Dacre et al. 2015).

In order to achieve our aim of quantifying the uncertainty in volcanic ash forecasts due to uncertainty in meteorological fields we will use ECMWF EPS data as input to the UK Met Office's VATD model and produce an ensemble of volcanic ash forecasts. To minimise the computational and data storage costs we have designed a set of simulations in which we use a reduced number of ensemble members (21 members), reduced forecast length (7-days), reduced temporal resolution (6-hourly), reduced number of vertical levels (25 levels) and reduced spatial domain (North Atlantic and European). This makes the project feasible both in terms of computing and data storage (see justification of computer resources below).

If significant improvements in volcanic ash forecasting are shown in this project, it will provide a major incentive for a larger international initiative to create operational ensemble forecast products. This would then allow Civil Aviation Authorities (CAA's) to make better use of volcanic ash forecasts in their decision-making.

Interest to the General Scientific Community

This project will be of interest to both the volcanic ash modeling community and the wider Lagrangian dispersion modeling community.

- As a result of the 2010 Eyjafjallajokull eruption 52 volcanologists, meteorologists and atmospheric dispersion modelers from 12 different countries met to discuss the needs of the VAACs and the ash dispersion modeling community. Recommendations were made for future VATD forecasting strategies to better characterize uncertainties (Bonadonna et al. 2011). It was concluded that ash forecasts would be more accurate if a range of probability values as opposed to absolute values of ash concentration and mass loading were produced. The results of this project will thus be of great interest to the volcanic ash modeling community (H. Webster, UK Met Office, pers. comm.)
- Following the 2011 AGU Chapman Conference on Advances in Lagrangian Modeling of the Atmosphere a white paper was written describing the input data requirements for Lagrangian dispersion models (Bowman et al. 2013). The paper concluded that the standard output products from current operational forecast models and reanalyses have characteristics that limit the accuracy of atmospheric trajectory and dispersion models. For example, due to storage constraints, model output is usually only provided on pressure coordinates. The methodology used in this project may provide a template for future routine archiving of forecast data for use by the Lagrangian dispersion modelling community (A. Jones, UK Met Office, pers. comm.)

Justification of Computer Resources and Technical Details

High Performance Computing

We will perform 7-day forecast runs with 21 ensemble members. It is estimated that a single 7-day forecast run with 21 ensemble members will require 35,000 SBUs. We will perform 60 simulations in total (14 April – 14 May 2010, from the 00UTC and 12 UTC start times). Thus we request 3 million SBUs to perform the simulations.

Data Storage

The post-processing will be performed using 6-hourly output data. 1 ensemble member storing 30 model level fields for 25 time steps (6-hourly data from T+0 to T+144) will require the following storage:

25 x 4 sh fields x 30 x 822360 bytes ~= 2.5 GBytes (T/U/V/W fields)
+ 25 x 3 gp fields x 30 x 1085640 bytes ~= 2.5 GBytes (Q/CLWC/CIWC fields)
+ 25 x 7 sh fields x 7 x 822360 bytes ~= 1 GBytes (PL fields)
+ 25 x 30 gp fields x 1 x 1085640 bytes ~= 1 GBytes (SFC fields)
(sh - spherical harmonic; gp - grid point).

Therefore the total storage needed per forecast per member is estimated to be 7 GBytes. Thus, to run 60 forecasts with 21 members, we will need about 9 TBytes (9,000 GBytes) of data storage.

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