REQUEST FOR A SPECIAL PROJECT 2015–2017

MEMBER STATE: Norway…………………………………………………………...…

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Project Title: FLEXPART transport simulations and inverse modelling of atmospheric components

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** NOFLEX_____________	
Starting year: (Each project will have a well defined duration, up to a maximum of 3 years, agreed at the beginning of the project.)	2015	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2015-2017: (The maximum project duration is 3 years, therefore a continuation project cannot request resources for 2017.)		**2015**	**2016**	**2017**
High Performance Computing Facility	(units)	50000	50000	
Data storage capacity (total archive volume)	(gigabytes)	150	150	

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):

……………26.06.2014……………

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.

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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.

Introduction

The Lagrangian particle dispersion model FLEXPART is run on ECMWF data to explore the transport and dispersion of various atmospheric constituents from greenhouse gases, radionuclides and aerosols like black carbon to volcanic ash released during eruptions. The model is used with various inversion techniques to infer emission estimates of many atmospheric compounds. This helps improving transport simulations of these substances and to understand their contribution and effects on the climate system.

In particular we focus on three subjects of inverse modelling where FLEXPART is used with ECMWF data:

1. Inverse modelling of methane in the northern high latitudes
2. Inverse modelling of radionuclides release rates during nuclear accidents
3. Inverse modelling of volcanic release rates during volcanic eruptions

Furthermore, atmospheric transport in historical climate and future climate scenarios is investigated from coupling of the NorESM model with FLEXPART. The historical part of the simulations will be compared to similar simulations performed using the FLEXPART model driven by ECMWF meteorological data. In addition, the transport of moisture towards Northern Europe within the NorESM climate model will be investigated for selected periods and for the historical periods, it will be compared to the transport of moisture obtained from ECMWF meteorological data. In both cases an established water source diagnostic based on the FLEXPART model will be used.

Model

FLEXPART is a Lagrangian particle dispersion model developed and updated within this working group (*Stohl et al., 1998; Stohl and Thomson, 1999; Stohl et al., 2005*) (see www.flexpart.eu) and used by at least 37 international research institutes. FLEXPART was validated with data from continental scale tracer experiments (*Stohl et al., 1998*) and was used previously to study the transport of BB emissions into the Arctic (*Stohl et al., 2006*), as well as the transport of anthropogenic emissions between continents (*Stohl et al., 2003*) and into the Arctic (*Eckhardt et al., 2007; Stohl et al. 2013*), FLEXPART can be driven with analyses from the European Centre for Medium-Range Weather Forecasts (ECMWF)

Application and model development

Inverse modelling of methane in the northern high latitudes

The Arctic is warming twice as faster than anywhere else on the globe. Rapid warming is driving a range of interacting physical and ecological changes in the region, such as the melting permafrost, and associated changes in terrestrial hydrology, lengthening of the snow-free season, and an increase in growing season length. In particular, melting permafrost and the warming of Arctic wetlands may act as a positive feedback on climate change through enhanced emissions of methane (CH_4), the second most important long-lived GHG. In addition to these emissions of CH_4, there are important anthropogenic sources in the Arctic, such as fugitive emissions from gas lines, and incomplete combustion of biomass and fossil fuels. There are still large uncertainties regarding the magnitude of the emissions, and for the wetland source, also of its variability. A recent inter-comparison of ecosystem model results of wetland CH_4 emissions, showed a large discrepancies, ±40% of the model mean, among the models, and greatly varying responses of the emissions to temperature.

To improve estimates of CH_4 emissions from natural (primarily wetland) and anthropogenic sources, and to provide a constraint on the sensitivity of the wetland emission to surface temperature, we will use inverse modelling. Inverse modelling uses concentration measurements in conjunction with a model of atmospheric transport to constrain the emissions in a statistically robust way. NILU has recently developed a Bayesian inversion framework, FLEXINVERT (*Thompson et al., 2014*), which uses transport modelled by the Lagrangian Particle Dispersion model, FLEXPART, driven with ECMWF wind fields. Using FLEXINVERT and observations from several long-term monitoring sites, we will estimate spatially and temporally resolved CH_4 emissions for the Arctic region. To constrain the anthropogenic versus natural emissions, we will use additional observations of ethane and the ratio of ^{13}C to ^{12}C in CH_4, referred to as $\delta^{13}C$. In addition, we will examine the influence of variability in precipitation, soil moisture and surface temperature on the optimized emissions.

Inverse modelling of radionuclides release rates during nuclear accidents

In a joint project with the Technischer Überwachungsverein (TÜV SÜD) and the Bundesamt für Strahlenschutz (BfS), NILU investigates the inverse modelling of radionuclide release rates during nuclear incidents using observations of gamma dose rates.

Severe accidents in nuclear power plants such as the historical accident in Chernobyl 1986 or the more recent disaster in the Fukushima Dai-ichi nuclear power plant in 2011 have drastic impacts on the population and environment. Observations and dispersion modelling of the released radionuclides help to assess the regional impact of such nuclear accidents. However, the true source term of the released radionuclides, which is used to model the dispersion of the radioactive plume, remains mostly uncertain.

The release rates of radionuclides at the accident site can be estimated using inverse modelling (e.g. *Stohl et al .2012*). The accuracy of the method depends amongst others on the resolution in time and space of the used observations. Radionuclide activity concentrations are observed on a relatively sparse grid and the temporal resolution of available data may be low within the order of hours or a day. Gamma dose rates, on the other hand, are observed routinely on a much denser grid and higher temporal resolution and provide therefore a wider basis for inverse modelling.

NILU develops a new inversion approach, which combines an atmospheric dispersion model and observations of radionuclide activity concentrations and gamma dose rates to obtain the source term of radionuclides. We use the Lagrangian particle dispersion model FLEXPART together with meteorological fields from the ECMWF to model the atmospheric transport of the released radionuclides.

The research project is set for 3 ¾ years and has been going on since 2013. It will continue until the end of 2015 and requires meteorological fields from the ECMWF until its completion.

Inverse modelling of volcanic release rates during volcanic eruptions

The Volcanic ash Strategic Initiative Team (VAST) project aims to improve the supporting services to the aviation community related to volcanic ash hazards. Within this project the FLEXPART model will be run and coupled with satellite observations of the volcanic clouds in order to estimate the so-called source term of the eruption. That is the ash release as a function of altitude and time, which is a crucial piece of information required to accurately simulate the fate of the ash injected into the atmosphere. With the source-term estimations, more accurate simulations of the dispersion of the ash cloud can be made, and together with accurate and timely satellite-based information, will provide an extended support to the existing volcanic ash avoidance centres (VAACs) for the issuing of volcanic ash alerts. The model simulations of the volcanic emission clouds will be based on ECMWF re-analysis data, and also compared to simulations driven with other meteorological data (e.g., NCEP GFS), and with simulations with other models (e.g., the NAME model operational at the UK Met Office / London VAAC). The model comparisons allow for an evaluation of the uncertainty related to the model predictions of the ash cloud transport. The project aims to develop a volcanic test database which include observation and modelling data for several historic eruptions, such as Eyjafjallajökull eruption. More information on the VAST project is available from *http://vast.nilu.no*, and relevant application studies of volcanic eruptions are found in *Stohl et al. (2011)*, *Kristiansen et al. (2012*) and *Moxnes et al (2014)* The project ends June 2015 and requires meteorological fields from the ECMWF until its completion.

Atmospheric transport in historical climate and future climate scenarios is studied from coupling of the NorESM model with FLEXPART

During the EarthClim project (http://folk.uib.no/ngfhd/EarthClim/Publications/publications.html) the Norwegian Earth System Model (NorESM, e.g. Bentsen et al. 2013) has been coupled with the FLEXPART Lagrangian stochastic particle model. This modelling system allows the study of Atmospheric transport characteristics in future climate scenarios, taking advantage of the unique diagnostic possibility offered by a fully Lagrangian approach. Daily based, 30 days backward in time, simulations have been performed for the years 1990 to 2070 for several measurement stations in the arctic and Antarctic. This allows investigating the variability of transport patterns to the Polar Regions in the future climate scenario. The historical part of these simulations will be compared during the EVA project (http://www.bjerknes.uib.no/pages.asp?kat=187&lang=2) to similar simulations performed using the FLEXPART model driven by ECMWF meteorological data. In addition, the transport of moisture towards Northern Europe within the NorESM climate model will be investigated for selected periods and for the historical periods, it will be compared to the transport of moisture obtained from ECMWF meteorological data. In both cases an established water source diagnostic (Stohl and James, 2004) based on the FLEXPART model will be used.

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