REQUEST FOR A SPECIAL PROJECT 2013–2015

MEMBER STATE: …FRANCE……………………………………………………………...
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Project Title: …Using Lyapunov covariant modes for atmospheric predictability……………………………………………………….……

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If this is a continuation of an existing project, please state the computer project account assigned previously.	**SPFRLAPE**_________________	
Starting year: (Each project will have a well defined duration, up to a maximum of 3 years, agreed at the beginning of the project.)	2012	
Would you accept support for 1 year only, if necessary?	YES ☐	NO ☒

Computer resources required for 2013-2015: (The maximum project duration is 3 years, therefore a continuation project cannot request resources for 2015.)	**2013**	**2014**	**2015**
High Performance Computing Facility (units)	10000	10000	
Data storage capacity (total archive volume) (gigabytes)	100	100	

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):
……10/04/2012……………………

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.

The scientific objective of this project is to make use of the Lyapunov covariant modes for atmospheric predictability. Until now, only singular vectors and bred vectors have been used for predictability studies of the atmosphere. The covariant modes are based on the ergodic theorem of Osseledec and are known since the work of Ruelle (1979) (see Eckman et Ruelle, 1985). They have been introduced in meteorology by Legras and Vautard (1996) then by Trevisan and Pancoti (1998). These modes describe the intrinsic instabilities in the vicinity of each trajectory in the phase space so that they are the more relevant to describe the error dynamics near a given prevision. Until now, these modes were only exploited in systems with a few degrees of freedom because we did not have a practical algorithm to compute them for large systems. However, this difficulty was recently removed and two algorithms have been proposed to compute the Lyapunov covariant modes (Ginelli et al., 2007 ; Wolfe et Samelson, 2007, 2008). These methods allow to determine a finite number of covariant modes (associated with exponents from the larger one to the smaller one).
The covariant modes are different from the singular vectors as they are intrinsic and do not depend on any norm. Moreover, they are conserved by the flow (a covariant mode at time t2 is the image of a covariant mode at time t1 integrating the perturbation along the linear tangent model), which is not the case for singular vectors. Finally, the localisation of these unstable structures is not affected by an arbitrary norm. Recent work (Pikovsky and Politi, 1998 ; Pazo et al., 2008 ; Romero-Bastida et al., 2010 ; Takeuchi et al., 2009) has shown that these modes are far better spatially and temporally localized than singular vectors. These piece of works have also shown that the covariant modes have a property of replication: the modes of higher order are a partial replication of modes of lower order which concentrate most of the information.
There are several implications for predictability:
1) The covariant modes describe the spatial structures of the instability of the atmospheric state without the drawback of the norm problem which is so important for singular vectors. We expect that these structures will be far better localized and present replication properties.
2) They allow to make use of the structure of slow modes, which have a growth rate close to 0 but are less susceptible to saturate and may carry the extended range predictability.
3) Using continuation on the unstable manifold, the covariant modes allow to study the nonlinear errors and, maybe, they would allow to make a link with bred vectors.
The methodology we follow will be to compute these covariant modes and study their properties in a hierarchy of models: from quasi-geostrophic ones (as in Gelaro et al 2002) to idealized general circulation models. We also expect to examine the extended range predictability within this framework.
During the first year of the project, we have begun the implementation of the computation of the modes and tested the accuracy of the method in a quasigeostrophic mode. We now plan to do an extensive analysis of these modes.

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