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Scientific and technical challenges of increasing horizontal resolution in atmospheric CO_2 inversion systems

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The gradual densification of CO_2 observation networks and CO_2 observation systems around the Earth, particularly from space, has increased the observational information available for data assimilation and atmospheric inverse modeling to all spatial scales. In particular, it makes it possible to infer surface fluxes of CO_2 over increasingly small regions.

This densification must be accompanied by a corresponding increase in the horizontal resolution of the transport models in which the observations are assimilated or which are inverted. In the latter application, the timescales involved extend over weeks, months or even years, and controlling computational speed despite increasing resolution is particularly critical. This challenge can be met by adapting transport models to new high-performance computing architectures and their new paradigms (multicore processors or accelerators based on graphics processing units). It deeply affects the structure of the codes, in particular the geometry of their mesh and the management of their inputs-outputs.

In this study, we redesign the offline transport model of the Laboratoire de Météorologie Dynamique (LMDz) Global Atmospheric General Circulation Model used in the Copernicus Atmosphere Monitoring Service inversion system (https://atmosphere.copernicus.eu/) in order to test such solutions.

First, we use a new dynamic core associated with an icosahedral-hexagonal spherical mesh, called DYNAMICO. DYNAMICO has a much better scalability than the current Cartesian grid of LMDz, while being efficiently vectorizable. Second, we use the parallel and asynchronous input-output management system called XIOS. XIOS helps damp performance losses associated with disk reads and writes.

The technical performances of the new version will be presented in the case of a regular mesh of 16,000 hexagons on the sphere, equivalent to a global resolution of about 180 km, and with 79 vertical layers, by comparison to the regular Cartesian grid. The scientific assessment is based on a large set of CO_2 observations from the ground, from airplanes and from surface remote sensing reference sites. Particular attention is paid to the skill at high latitudes where the new grid avoids

the singularity of the previous version at the pole, but at the cost of a coarser resolution.