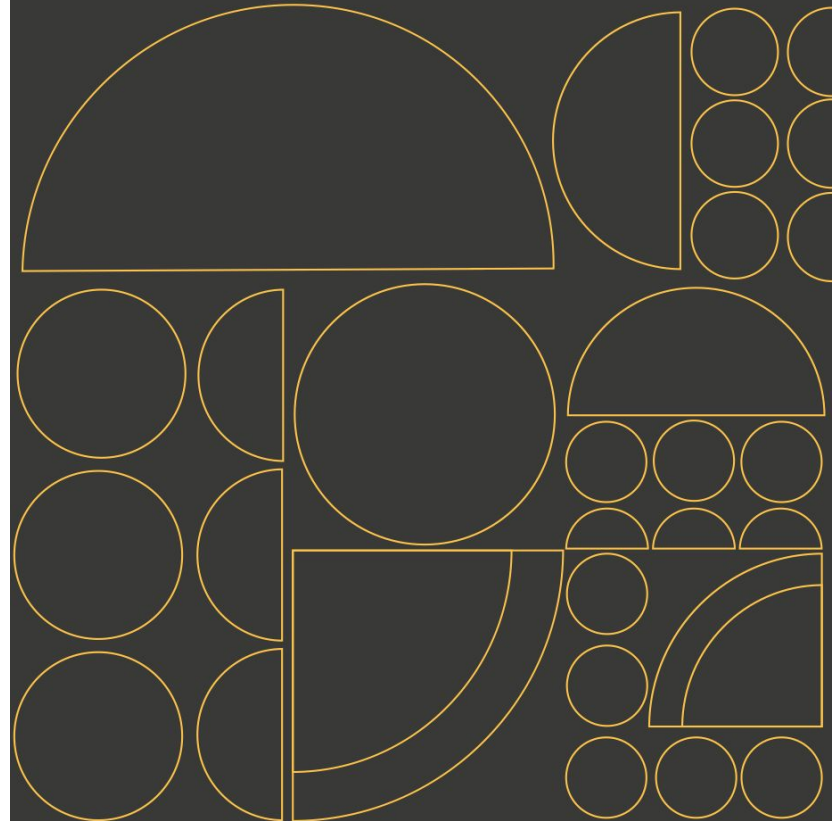


FALL3D

*A. Folch, H. Pascual, A. Guerrero & L. Mingari
Geociencias Barcelona (GEO3BCN - CSIC)*



Project funded by EuroHPC under the grant agreement No 101093038.





Developers:

A. Folch, A. Costa, G. Macedonio, L. Mingari, H. Pascual
(Geosciences Barcelona & INGV)



Description:

FALL3D is an open-source off-line Eulerian model for atmospheric passive transport and deposition of multiple atmospheric species, including volcanic ash and volcanic gases, mineral dust, and radionuclides.



Scientific area:

Earth and atmospheric sciences & Volcanology



Project role:

In ChEESE, FALL3D is used for modelling of volcanic clouds



Technical summary:

- MPI/OpenACC in Fortran 2008
- Based on a hierarchy of MPI communicators (ensemble runs)
- Parallel I/O in NetCDF-4



Target platforms:

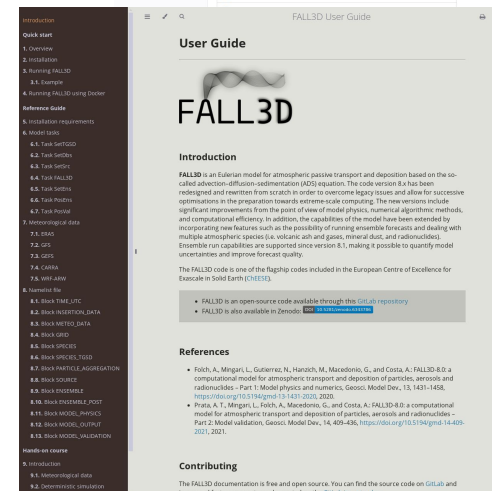
Leonardo, LUMI, MareNostrum V



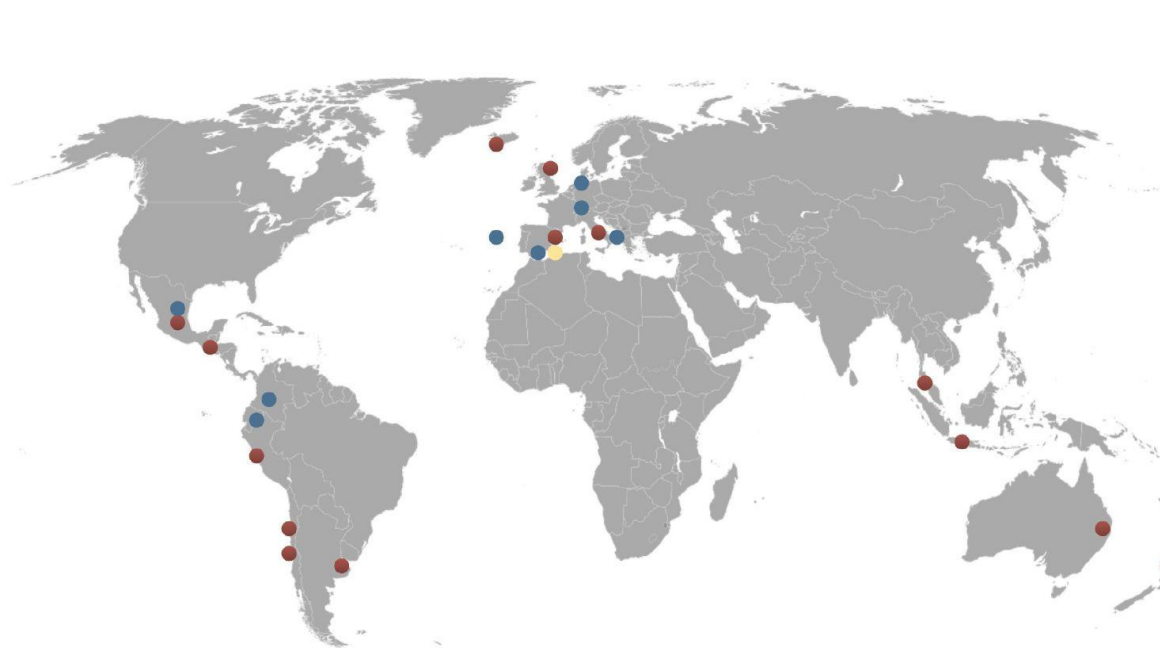
Repositories and online resources:

- Main repository: <https://gitlab.com/fall3d-suite>
- Main GP code: <https://gitlab.com/fall3d-suite/fall3d>
- GPU code
- Mini-app code
- Training material
- Documentation: <https://fall3d-suite.gitlab.io/fall3d/>
- Zenodo: <https://doi.org/10.5281/zenodo.6343786>

Name	Last commit	Last update
remove long lines in footer section	range added 2 weeks ago	
Example	range master	3 months ago
Manual	Added User Guide	10 months ago
Other	Remove prompt to user gpl	5 months ago
Source	remove long lines in footer	3 weeks ago
advent	Added configure files for	1 year ago
docs	Update running doc	3 months ago
net	Corrected configure as	2 years ago
ghgases	original ghgases	1 year ago
gpl-v2-pd	Use real latest	6 months ago
AUTHORS	gold badge	1 year ago
CHANGELOG	join is optional now	6 months ago
CITATION	Update CITATION	6 months ago
CITING	gold badge	1 year ago
CODE_OF_CONDUCT	New CONTRIBUTING	1 year ago
CONTRIBUTING	New CONTRIBUTING	1 year ago
LICENSE	Modified model_v2 for	4 years ago
Makelife	Corrected Makelife	1 year ago



FALL3D: relevant code users



Public institutes (operational): ●

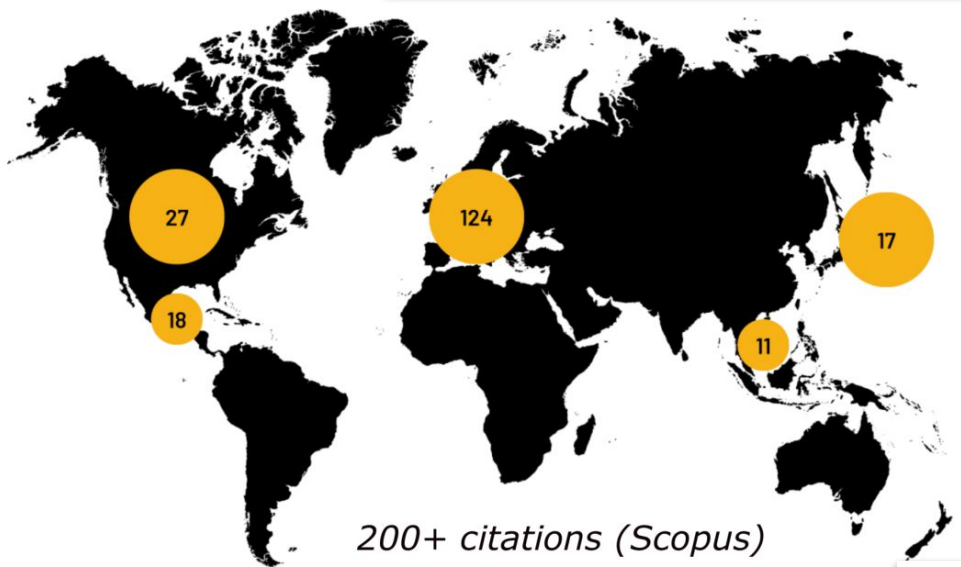
INGV (Italy)
CSIC (Spain)
IMO (Iceland)
BGS (UK)
SMN (Argentina)
IGP (Perú)
SERNAGEOMIN (Chile)
Dirección Meteorológica de Chile (Chile)
BMKG (Indonesia)
VAAC Buenos Aires (Argentina)
BSC (Spain)
GNS (New Zealand)
Bureau of Meteorology (Australia)
EOS (Singapore)
Cenapred (México)
INSIVUMEH (Guatemala)

Academic: ●

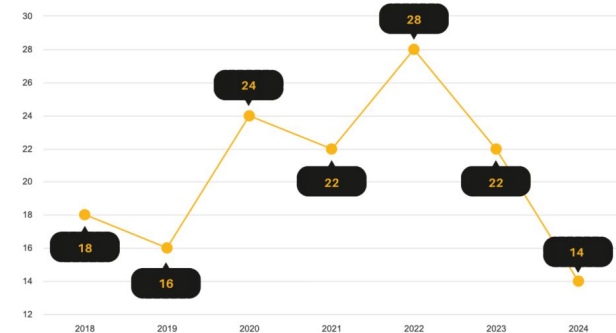
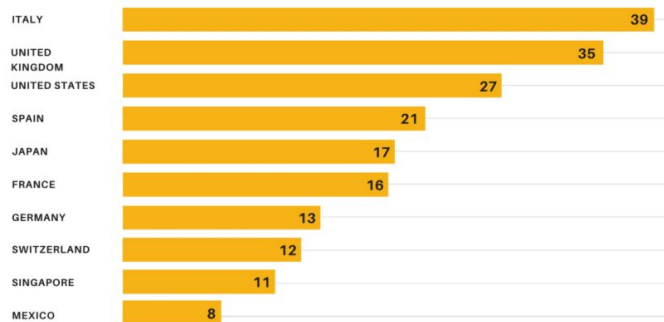
University of Geneva (Switzerland)
University of Bari (Italy)
University of Bremen (Germany)
University of Granada (Spain)
UNAM (México)
Univ. San Francisco de Quito (Ecuador)
Universidad de Nariño (Colombia)
University Azores (Portugal)

Private: ●

Mitiga Solutions (Spain)



200+ citations (Scopus)



FALL3D citations during both phases of ChEESE

CASTIEL's code of the Month

 **EuroCC_SpainRES**
@EuroCC_SpainRES

 Today's Code of the Month by @Cheese_CoE focused on the #codes FALL3D and OpenPDAC as they are able to #simulate different phenomena associated with explosive #volcaniceruptions.

#CASTIEL #EUROCC #centersofexcellence
pic.x.com/t2ggfvrhs3

11:57 AM · May 29, 2024

WP2 & WP3:

- ❑ 1st code audit with GPU version
- ❑ Code refactoring and development of a multiplatform code (merge GPU & CPU versions)
- ❑ 2nd code audit with the new code version
- ❑ Improve GPU scalability and overall portability
- ❑ Co-design with mini-app
- ❑ Intra-node communication efficiency
- ❑ Overall parallel IO efficiency
- ❑ CI/CD selected Euro HPC systems

WP5:

- ❑ Implement a mass-consistent meteorological downscaling
- ❑ Enable multiscale simulations
- ❑ SC5.1: The European tephra hazard map at a resolution of less than 10 km for European scale and 2 km at regional scale
- ❑ SC5.2: Volcanic gas dispersal at local scale: a reanalysis of the 2021 La Palma case at 1-2 km resolution making use of different observations available for tuning and verifying the model performance
- ❑ PD5: Ensemble-based volcanic dispersal at multiple scales

Baseline: v8.2



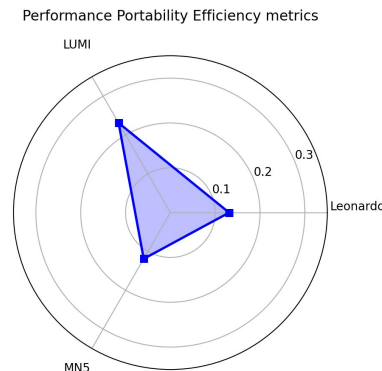
Current state: v9.0

- ❑ Code inherited from the 1st phase of ChEESE
- ❑ Multiple repositories (GPU & CPU)
- ❑ GPU code targeted to a single platform (Nvidia)
- ❑ Independent codes for CPU and GPU versions leading to duplicate development efforts and poor code quality
- ❑ Error-prone code, poor documentation
- ❑ Very difficult to extend the code, add new feature or physical parameterizations due to the extreme complex structure of the code

	Leonardo	MN5	LUMI
8.2	✓	✗	✗
9.0	✓	✓	✓

- ❑ Unified code in a single repository for multiple platforms (CPU+GPU):
Serial, Serial + ACC, MPI, MPI + ACC
- ❑ A single general repository
- ❑ Improved portability
- ❑ Improved code structure to make the code more maintainable
- ❑ More extensible and readable code with consistent coding style and conventions in order to decrease developer overhead over releases
- ❑ Better documentation
- ❑ Fraction of code accelerated: 40%

- Sacrificed performance for portability!
- Data transfers reduce the performance currently
- Still plenty of room for improvement



1st audit:

- ❑ Detected a inefficient use of device aware communications on initialization stage
- ❑ Highlighted some kernels to revise
- ❑ Pointed some suspicious MPI communications

Audit recommendations were considered in the development of the new version:

- Main issues were identified and fixed
- MPI communications were significantly reduced

Towards the 2nd audit:

- ❑ Energy efficiency, advisory, and correctness studies (second-level POP services)
- ❑ This audit aims to help the v9.0 development by enhancing its efficiency across all target platforms

Other tasks:

- ❑ Memory optimization: Reading of large meteorological datasets led to huge memory usage and overflows. It was fixed through an important refactoring of a pre-processing task
- ❑ CI/CD Pipeline using Docker Executor to automatically build, test and deploy to target platforms
- ❑ Different build systems were implemented to replace the Autotools (deprecated):

Comparison of build systems

	Autotools+Make	CMake	Meson+Ninja
Leonardo@CIN	GNU/NVHPC	GNU/NVHPC	GNU/NVHPC
MN5-ACC@BSC	Not working (dependency issues)	GNU/NVHPC	GNU/NVHPC
LUMI@CSC	Cray	Cray	Cray compiler not supported
Linux	GNU/NVHPC	GNU/NVHPC	GNU/NVHPC
MacOS	GNU	GNU	GNU

Legend

Not tested
Fetch the code
Compile code
Run test cases
Validate results

			x86 profiling status	HBM study	ARM porting	ARM profiling	SVE study	Optimisation status + comments
FALL3D	Mini-Fall3D CPU testing feedback		Done	Done	Done	In Progress	Not started	Not started

MiniFALL3D-CPU

- ☐ Preliminary study for characterising the mini-app
- ☐ Check if it's memory or compute bound
- ☐ Analysis of the main bottlenecks with Vtune
- ☐ Test of the HBM no sapphire rapids
- ☐ Environment:
 - X86 Intel Sapphire Rapids
 - Intel oneAPI 2024.0 ICC and Intel MPI 2021.0
 - Arch 64 Nvidia Grace
 - GNU 14.2 and Openmpi 4.1.6

Test run on Intel Sapphire Rapids (1 socket with 56c):

CPU time	CPU time per iteration	Compute bound	Memory bound	Vectorized
92 s	157 ms	30%	70%	No

- ☐ Profile with Vtune + compilation report
 - 85% CPU time in ads_solve_along_(x,y,z)
 - 60% of this time dedicated to the function called kt_rhs
 - kt_rhs is not vectorized

To take advantage of the SVE the mini-app should be vectorized

- ☐ HBM study
 - Using HBM on the SPR node improve results by 17%
 - CPU time: 78s CPU time per iteration: 135 ms

HBM improve performance as the mini-app is memory bound

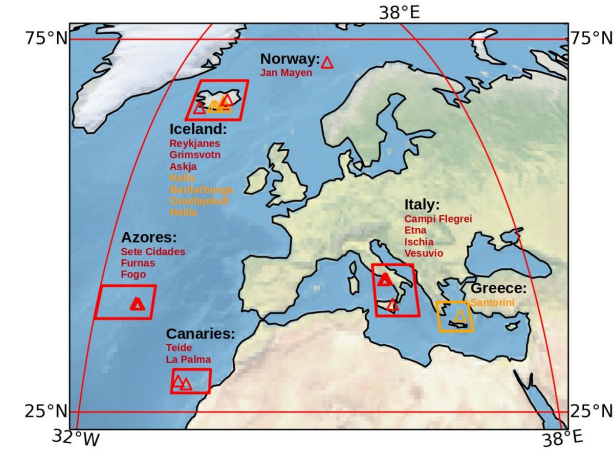
MiniFALL3D-GPU

Will be released soon! After the release of the multi-platform code (v9.0)

Towards the European tephra hazard model

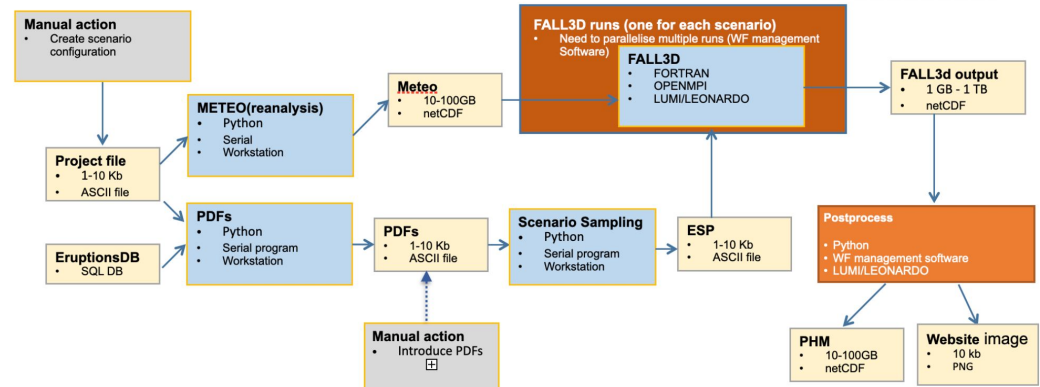
Simulation case 5.1 (WP-5)

- ❑ This simulation case aims at deriving the **first homogeneous multi-volcano probabilistic hazard model for volcanic tephra fallout and ash dispersal in Europe**
 - Local scale (2km): Identify in probabilistic terms those areas in the region more likely to receive tephra fallout
 - European scale (10km): A similar approach will be used to provide a European hazard model for airspace areas prone to be contaminated by hazardous concentrations at cruise Flight Level
- ❑ Extensible incrementally by adding further volcanoes
- ❑ The final datasets will be accessible through the Volcano Observations Thematic Core Service in EPOS for their usage and distribution
- ❑ EuroHPC proposal submitted on MN5-ACC for 37,000 node-h



Workflow

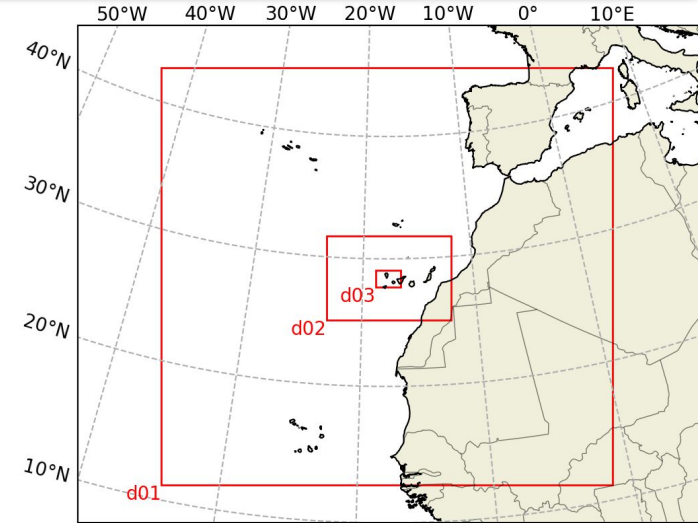
The workflow integrates historical meteorological data and an analysis of past volcanic activity to generate thousands of potential tephra dispersal scenarios



Volcanic dispersal at local scale: a reanalysis of the 2021 La Palma case

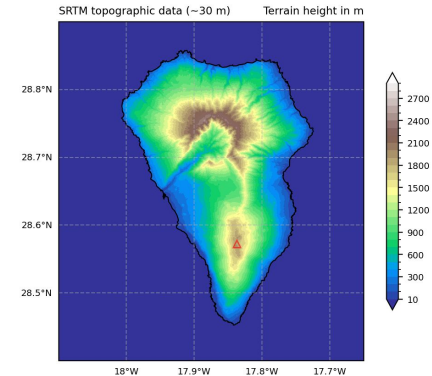
Simulation case 5.2 (WP-5)

- ❑ This simulation case aims at **simulating the volcanic gas dispersal at local scale and generate a reanalysis at 1-2 km resolutions of the 2021 eruption of Cumbre Vieja using a downscaling strategy capable of being efficiently applied in future small-scale events**
- ❑ Recent volcanic eruptions in Europe (La Palma in the Canaries and Fagradalsfjall in Iceland) characterized by sustained low-intensity gas (mainly SO₂) and ash emissions (several weeks) raised major concerns for public health as well as for environmental impact
- ❑ Volcanic events in small islands/peninsulas require simulations over very small spatial scales are challenging due to the presence of very complex terrain and the strong interaction between the atmosphere and the eruption dynamics
- ❑ The system comprises three main components:
 - FALL3D: Volcanic Ash Transport and Dispersion model
 - WRF-ARW: Numerical Weather Prediction model
 - MetPrep: Mass-Consistent Meteorological Downscaling model



MetPrep is a model-agnostic meteorological pre-processor for emergency applications of local pollutant dispersal which can ingest meteorological data from multiple sources and apply topographic corrections based on High-resolution DEM.

We are reaching the final stage of development and the model will be ready soon!



Volcanic dispersal at local scale: a reanalysis of the 2021 La Palma case

Simulation case 5.2 (WP-5)

List of 3-month simulations and required storage for the resulting dataset



Dataset	Total	File size per day	Time steps per file	Temporary	Format
ERA5 ⁺	0	390 GB	24	Yes	Grib
WRF-ARW (d01)	0.1 TB	466 MB	4	No	netCDF
WRF-ARW (d02)	0.72 TB	3.8 GB	24	No	netCDF
WRF-ARW (d03)	2.26 TB	12 GB	72	No	netCDF
MetPrep	1.2 TB	12 GB	72	No	netCDF
FALL3D	1 GB	11 MB	24	No	netCDF

Thanks!

