FLEXPART versions

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Outline

- Brief FLEXPART versions history (up to v9)
- FLEXPART forks, for different regional models, CTMs, GCMs and meto input
- FLEXPART development branches
- FLEXPART 10.3 current release candidate
- Current and future developments

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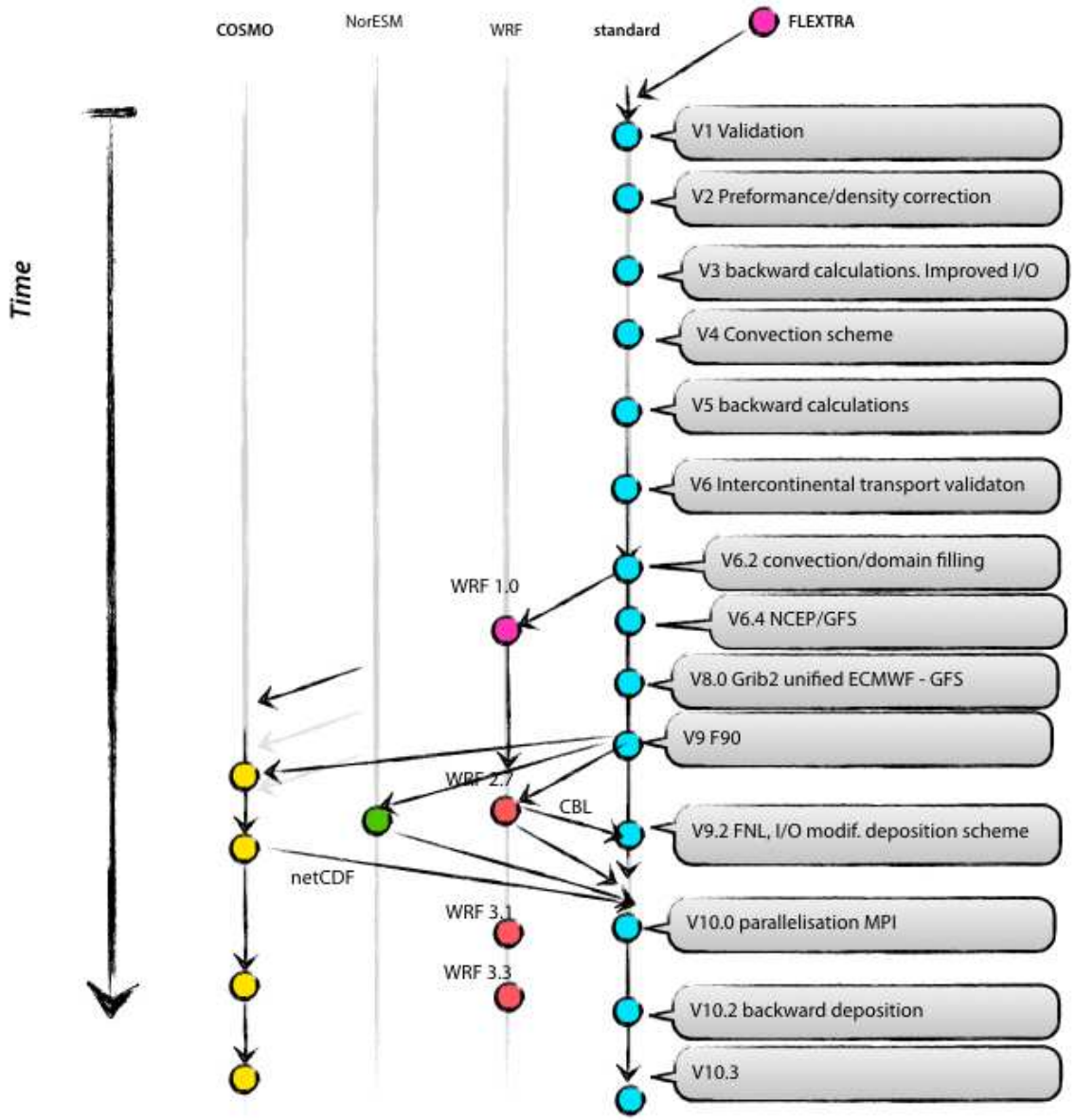
FLEXPART versions timeline



FLEXPART v1 and v2

- Further development of the trajectory model FLEXTRA
- Gridded output of concentrations of chemical species and radionuclides
- Meteorological input data based on ECMWF's specific GRIB-1 (Gridded Binary) format
- First applied in an extensive validation study using measurements from large scale tracer experiments
- Deposition module (v2)

FLEXPART v3 and v4

- Improvements in performance
- Subgrid scale terrain effects parametrization
- Output format (sparse matrix) optimized (3.1)
- Optional mixing ratio and particle positions output (3.1)
- PBL density correction (3.2)
- 1st convection scheme (3.2)
- Mass fluxes across grid cell faces (3.2)
- Convection scheme of Emanuel and Živković - Rothman (v4)

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FLEXPART v5 and v6

- Unit of the backward calculation was changed to seconds
- Validation during intercontinental air pollution transport studies 1990s, 2000s (v5)
- Corrections of the numerics in the convection scheme (v6.0)
- Domain-filling option
- Nested output

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FLEXPART v5 and v6

- Sources and receptors in both mass and mixing ratio units (v6.2)
- Use of NCEP GFS meteorological input data possible (v6.4)

FLEXPART v8

- v7 unreleased internal version
- Unified the code for ECMWF-IFS and NCEP-GFS input data (different makefiles)
- Fortran 90 constructs introduced in parts of the code
- Global land use inventory
- Gridded sensitivity to initial conditions in backward model runs

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FLEXPART v8 cont.

- Distinguished between in-cloud and below-cloud scavenging for washout
- One definition file per species
- Gravitational settling scheme for heavy particles

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FLEXPART v9

- Source code transformed to the Fortran 90 free-form format
- Option to produce output in compressed NetCDF 4 format
- Option to output surface gridded output only
- Wet deposition in-cloud and below-cloud

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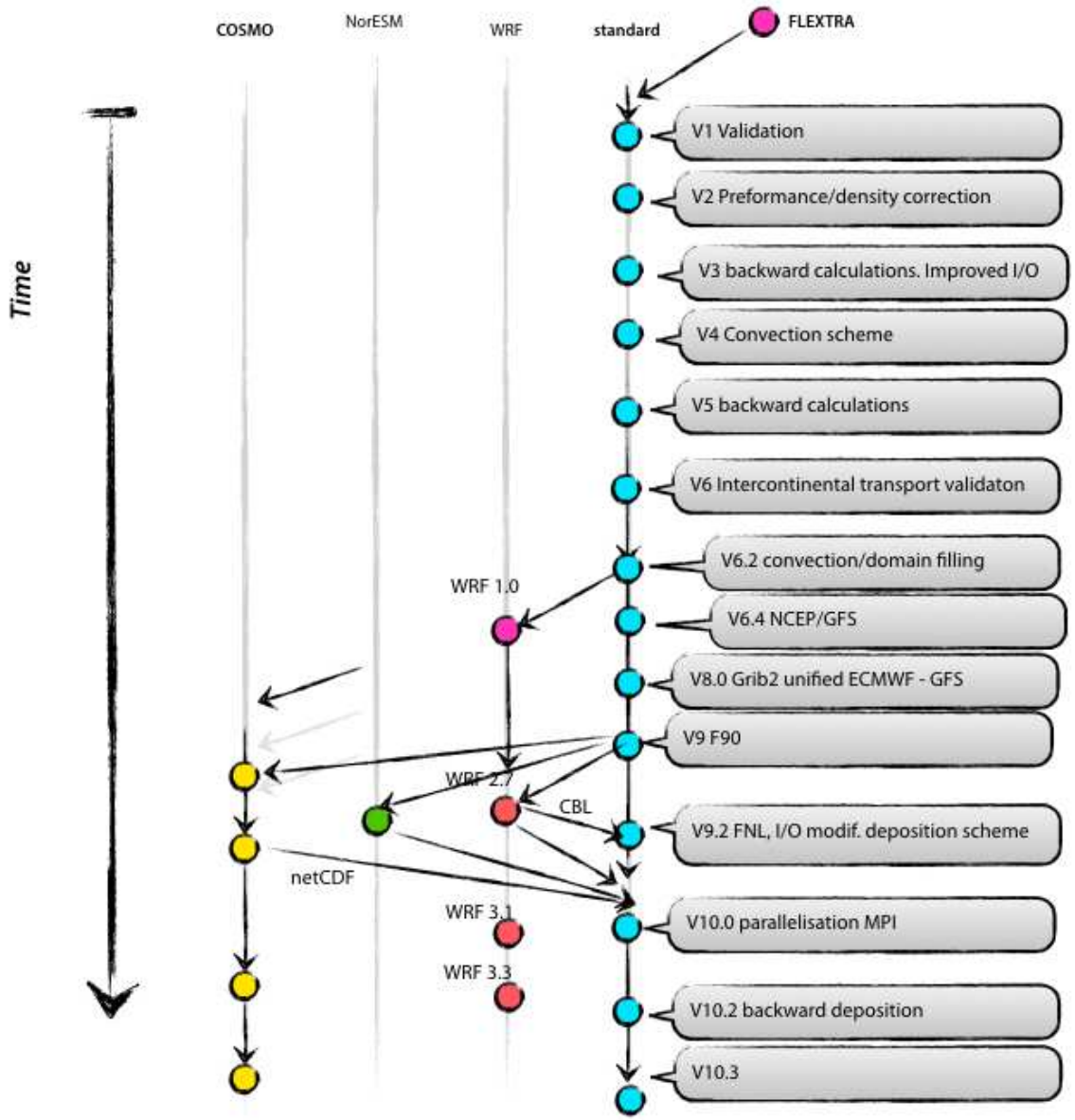
FLEXPART versions timeline



Some of the FLEXPART forks

- MM5, WRF–PILT (deprecated)
- WRF 3.3
- AROME
- FLEXPART-NorESM/CAM
- COSMO
- FLEXPART-CTM
- TRACZILLA
- FLEXCPP, Etc.

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FLEXPART-WRF

- Uses output from the Weather Research and Forecasting (WRF) mesoscale model.
- Originally developed at the Pacific Northwest National Laboratory, named PILT (PNNL Integrated Lagrangian Transport).
- New FLEXPART-WRF can use both instantaneous and time-averaged WRF output.
- Includes the skewed turbulence scheme, subsequently exported to the standard FLEXPART
- Output can either be binary or NetCDF format, both of which have efficient data compression.
- Parallelisation with Open-MP in shared memory and MPI in distributed memory.

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FLEXPART-NorESM/CAM

- Tailored to run with the meteorological output data generated by the CMIP5-version of NorESM1-M (the Norwegian Earth System Model)
- 1.89◦× 2.5◦horizontal resolution
- 26 vertical levels
- Based on FLEXPART V9
- the atmospheric component of NorESM1-M based on CAM4 (the Community Atmosphere Model).
- New routines to read meteorological fields,
- New post-processing routines to obtain the vertical velocity in the FLEXPART coordinate system

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FLEXPART-AROME

- The Applications of Research to Operations at Mesoscale (AROME) numerical weather prediction model is run operationally by Météo France at mesoscale. AROME forecasts for Europe exist at a resolution ranging from 0.5 to 2.5 km
- Based on FLEXPART-WRF, using AROME high-resolution (2.5×2.5 km^2)
- Simulates turbulent transport using the Thomson turbulent scheme (Thomson, 1987), already implemented by Lin et al. (2003) in the stochastic time-inverted Lagrangian transport (STILT) model.
- This method constrains mass transport between different turbulent regions to conserve mass locally for a passive well-mixed tracer.
- Turbulent kinetic energy profiles are taken directly from AROME model outputs.
- This ensures consistency between the turbulence in the meteorological fields calculated by the NWP model and turbulence computed in the offline Lagrangian transport model.
- Simulations using the Thompson scheme show better representation of the turbulent mixing between boundary layer air and free tropospheric air.

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FLEXPART COSMO

- In Europe several national weather services and research groups develop and operate the non-hydrostatic limited-area atmospheric model COSMO (Consortium for Small-scale Modeling).
- At MeteoSwiss COSMO is operationally run with data assimilation on two grids with approximately 7 × 7 km^2 and 2 × 2 km^2 horizontal resolution centered over Switzerland. This enables the study of atmospheric transport over complex terrain on a long-term basis.
- FLEXPART-COSMO coupled to COSMO output, supports output from multiple COSMO nests.
- Uses native vertical coordinate system used in COSMO and not, as in standard FLEXPART, in a terrain following z-system. This eliminates the need for an additional interpolation step.
- New flux de-accumulation scheme removes the need for pre-processing of input files.
- In addition to the Emanuel convection parameterisation, uses the Tiedtke scheme, as in COSMO.
- Possibility for offline nesting of FLEXPART-COSMO into a FLEXPART-ECMWF for backward simulations allows particles to leave the limited COSMO domain.
- The OpenMP shared-memory parallelisation allows for asynchronous reading of input data.

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TRACZILLA

- Fork from FLEXPART version 5 originally developed for studies of transport and mixing in the upper troposphere- lower stratosphere region.
- The modifications from FLEXPART advection scheme consists mainly in discarding the intermediate terrain following coordinate system and in performing a direct vertical interpolation of winds, linear in log-pressure, from hybrid levels.
- The vertical velocities are computed by the FLEXPART pre-processor using a mass conserving scheme in the hybrid ECMWF coordinates.
- Alternatively the vertical velocities can be computed from the rates of diabatic heating from ECMWF winds.
- Variable high atmosphere diffusivity.
- In addition to the re-analyses from ECMWF, the current version can use MERRA (Modern-Era Retrospective analysis for Research and Applications) from NASA and JRA-55 (the Japanese 55-year Reanalysis) from JMA.
- The parallelisation uses the OMP version of PGI.
- All arrays are allocated dynamically

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FLEXPART v10

- New skewed turbulence scheme (instead of Gaussian statistics in the convective ABL)
- Wet deposition scheme for aerosols revised: dependencies on aerosol size, precipitation type (rain or snow) and distinguishing between in-cloud and below-cloud scavenging
- Reading of 3D cloud water fields from meteorological input files

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FLEXPART v10

- Sensitivity of deposited quantities to sources in backward mode
- Chemical reactions with the hydroxyl radical (OH) made dependent on the temperature
- Parallelized using the Message Passing Interface (MPI)
- Code unified in single executable for both ECMWF and GFS input data

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FLEXPART v10

- Dust mobilization scheme
- Retrieval ECMWF data software modernized
- Testing environments

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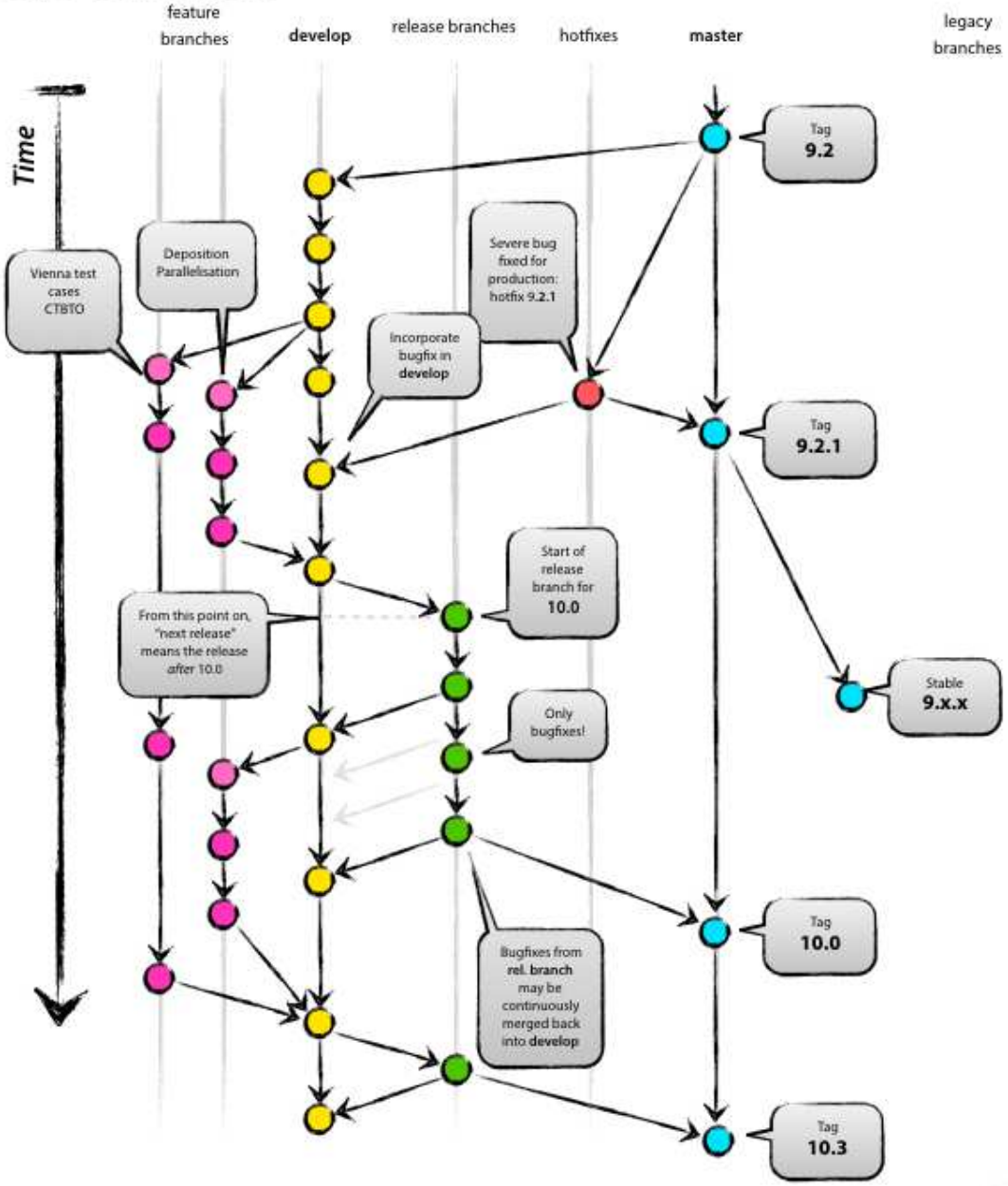
flexpart branch structure schematic



Based on template by Vincent Driessen
Original blog post: http://nvie.com/

FLEXPART main development branches (main version)

- master: stable version, last release
- dev: development version (integrated at NILU)
- hotfixes: only urgent bug fixes
- release-10: current release
- univie: contributions from U. Vienna
- ctbto: contributions from
- topical branches: GFS, input options, testing and integration...

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Current and future developments

- Integrate the ingestion of different meteorologies (e.g. regional models, climate/chemistry models, various reanalysis)
- Plume raise model
- Further development of the deposition scheme
- Increased support for chemical modeling
- Further development of the mixing scheme (e.g. turbulent intermittency)
- Further development of the testing protocols