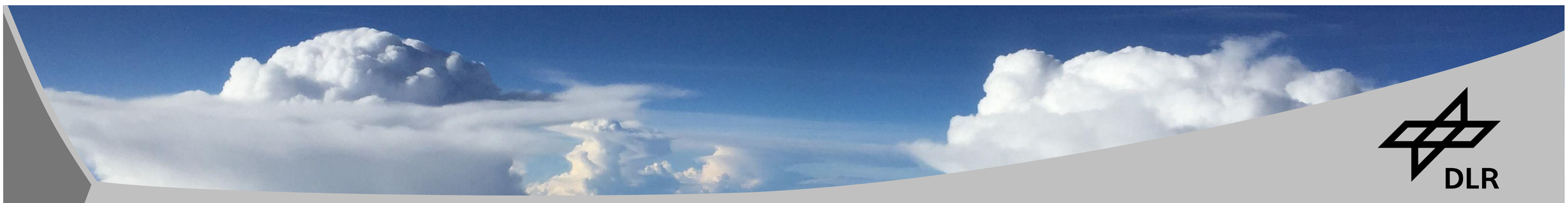

Lagrangian trajectories in high-resolution simulations of convective systems

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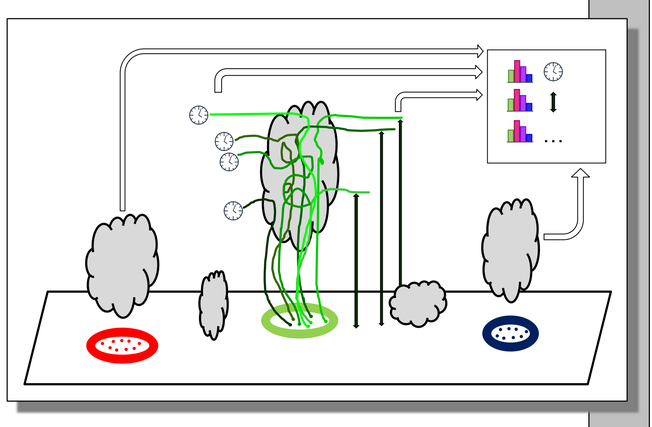
Introduction

The on-line trajectory tool LaMETTA is designed to work on highly parallelised systems, optimised for moderate inter-process communication and memory consumption. Due to the application on-line during the simulation, trajectory paths are calculated with the highest temporal resolution available. Trajectories can be started automatically in confined regions of interest.



In the HD(CP)² project LaMETTA is applied for life cycle studies of convective systems in high resolution simulations with the ICON (ICOsahedral Non-hydrostatic model system; Zängl et al., 2015).

LaMETTA: Lagrangian MESSy Tool for Trajectory Analysis

- Time integration scheme: Euler Forward or 4th order Runge-Kutta
- Interpolation of horizontal wind: Inverse distance weighting, 1, 4 or 13 stencil (cell value, direct neighbours, direct + indirect neighbours)
- Interpolation of vertical wind: linear
- Designed for low memory consumption and low inter-processor communication

MESSy: Modular Earth Submodel System

- Framework for a standardised, bottom-up implementation of Earth System Models (or parts of those) with flexible complexity
- Provides an infrastructure with generalised interfaces for the standardised control and interconnection (coupling) of "low-level ESM components"
- More information: https://www.messy-interface.org/; MESSy2: Jöckel et al., 2010; ICON-MESSy: Kern and Jöckel, 2016

Automatic trajectory seeding

The user can select a variable field and a threshold value for automatic trajectory seeding (via Fortran namelist). Massless particles are seeded every model timestep in grid cells where the value of the user selected variable field exceeds the threshold.

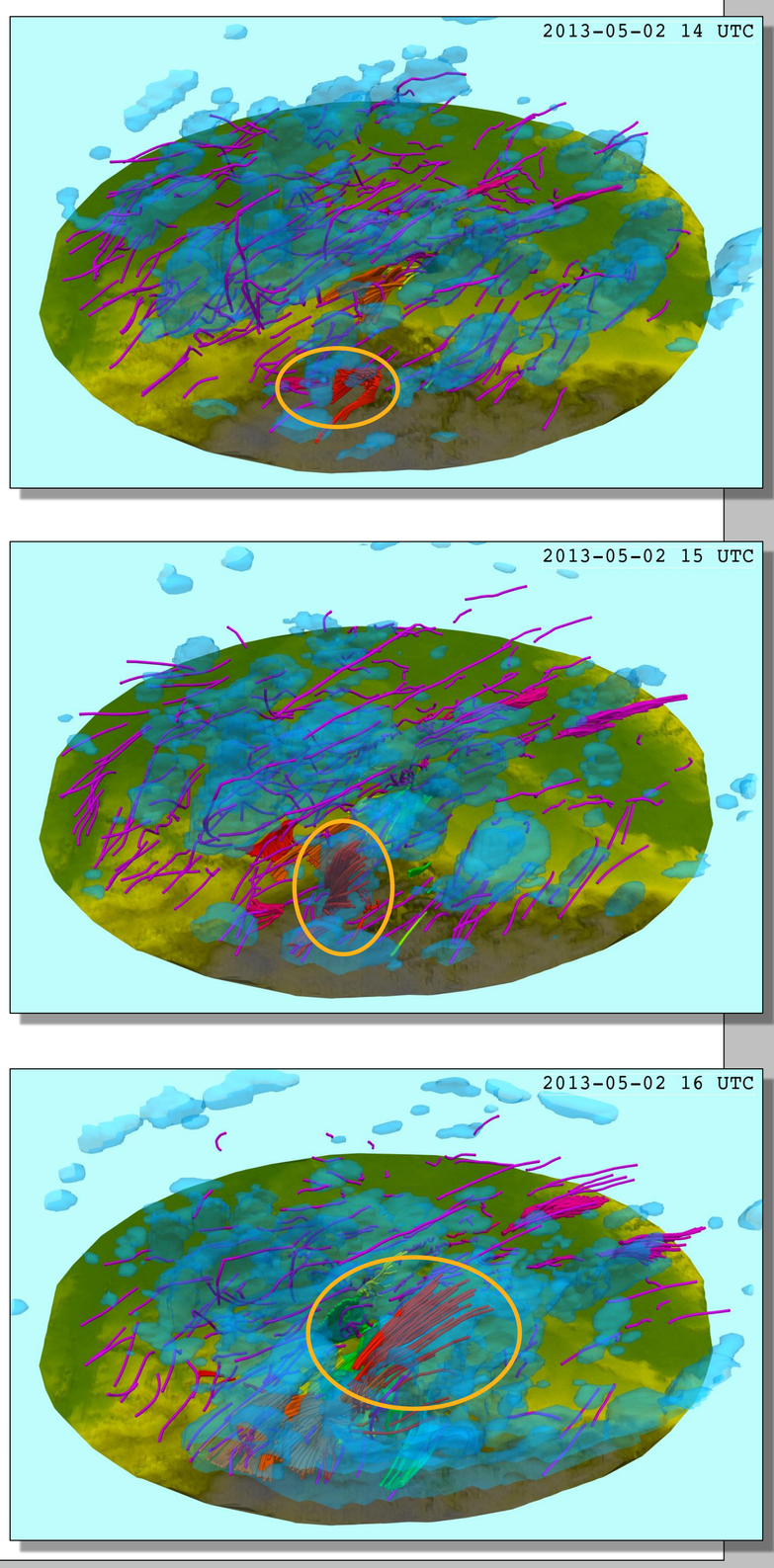
The Figures show three selected snapshots of a simulation with ICON-LEM in a limited area setup covering the region around Jülich in western Germany. **Model resolution is approx. 625 m, model timestep is 3 s**.

Light blue transparent contours represent clouds, solid lines show trajectory paths, coloured according to their starting time.

Trajectories are started at grid cell centres in the lowest model level, in regions where the **vertical wind exceeds 0.75 ms^{-1}**.

Trajectories in the high-lighted bundle are transported south-westward in the lower levels after their start. When they enter an updraft region, they are transported upward, entering the cloud.

The trajectories are transported north-eastward in the upper levels after their upward transport.



User defined trajectory seeding

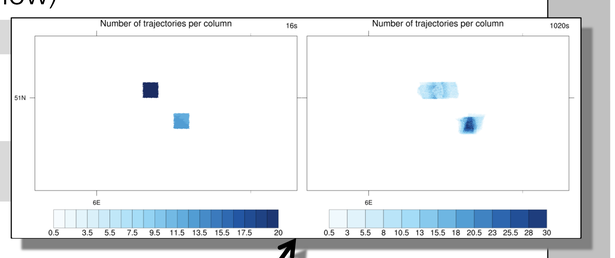
Available via Fortran namelist (lametta.nml)

- Domain filling at model start (example below)

```
init_position_mode = 0
```

- Automatic trajectory seeding with user defined threshold (example left)

```
seed_method = 'THRESHOLD'
init_trj = 'nh_state_prog', 'w', 0.75, 90, 1
```

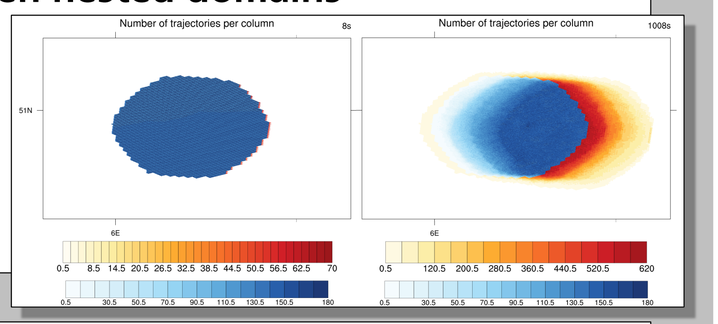


- User defined starting regions and timing

```
trj_reg(1) = '1', 6.3, 6.4, 51.0, 51.1, 300., 1000., 2
trj_reg(2) = '2', 6.5, 6.6, 50.8, 50.9, 300., 1000., 2
trj_timer(1) = '1', 4, 'seconds', "2013-04-25T00:00:00Z", "2013-04-25T00:00:04Z"
trj_timer_default = ' ', 16, 'seconds', "2013-04-25T00:00:08Z", "2013-04-25T00:00:32Z"
```

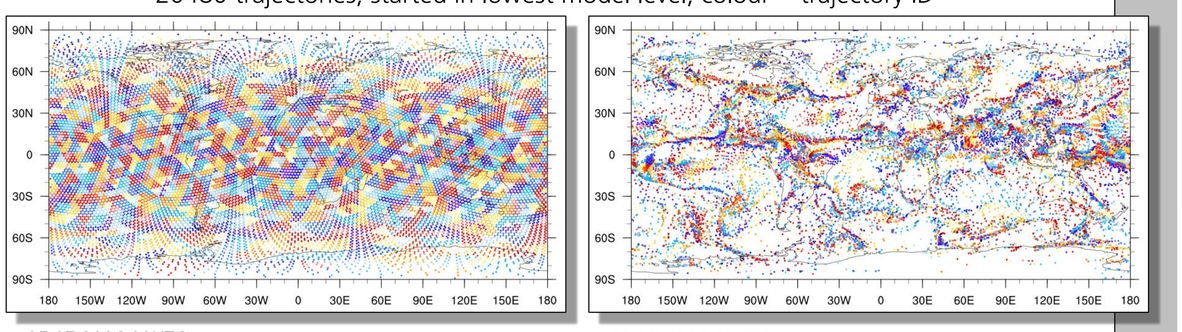
Trajectory transfer between nested domains

- Automatic transfer to the finest domain available at the current location
- Via MPI communication and a handshaking mechanism



LaMETTA in ICON-NWP (global)

20480 trajectories, started in lowest model level, colour = trajectory ID



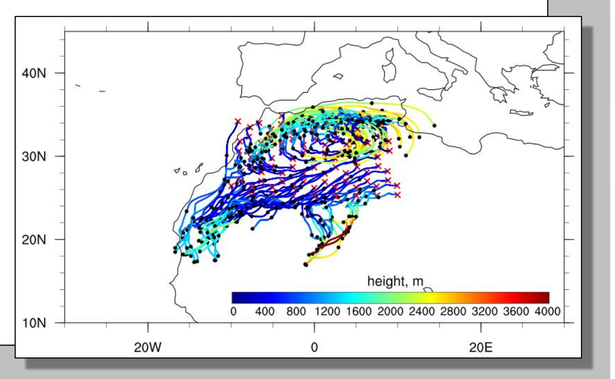
25.07.2006 00UTC

30.07.2006 00UTC

model resolution R2B04

model timestep 10 min

integration time 5 days



zoom over northern Africa, trajectories started 10W-10E, 25N-35N, in lowest level

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Outlook

The technical development of the on-line trajectory tool LaMETTA is finished, there is some work in progress w.r.t. code optimisation and enhancement of the module's I/O handling. Evaluation of trajectories calculated with LaMETTA is currently conducted, corresponding publications are in preparation.

Future work is the combination of on-line trajectories with advanced feature identification, as an enhanced diagnostic tool. Further developments will be in the direction of going from diagnostic applications to a Lagrangian transport scheme.

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